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Guidance on Integrated Urban Hydrometeorological, Climate and Environment Services

Volume II: Demonstration Cities

EDITORIAL NOTE

METEOTERM, the WMO terminology database, may be consulted at:
http://www.wmo.int/pages/prog/lsp/meteoterm_wmo_en.html.
Acronyms may also be found at: http://www.wmo.int/pages/themes/acronyms/index_en.html.

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EXECUTIVE SUMMARY FOR WMO MEMBERS

Guidance for Integrated Urban Hydrometeorological, Climate and Environment Services, Volume I: Concept and Methodology outlined the need for Integrated Urban Services (IUS) to support management and planning in cities. This Guidance Volume II: Demonstration Cities provides an overview of the demand for such services in WMO *Member* countries and examples of current IUS that were designed to meet a range of urban environmental challenges in a variety of administrative settings. A survey was conducted among WMO *Members* in 2018 and 87 responses were received. The purpose of the survey was to judge the level of service provision in different focal areas (weather, climate, hydrology and air quality), the extent to which users and providers collaborate, the operational status of urban services and the level of integration between the different service elements. Most of the responses reflected the perspective of the National Meteorological and Hydrological Services (NMHSs) rather than the country they represent. Half of the respondents indicated that they provide support for specific urban services, and in countries where these services are lacking, most are planning to initiate such services.

The common hazards that require IUS were identified as heavy rainfall, flooding, windstorms, tropical storms, heatwaves, thunderstorms and air pollution. Most respondents indicated that *Members* already provide warning or forecast services to a range of users and have communication systems that advise on hazard impact to users. However, while meteorological services to address the above requirements were considered “developed” by most respondents, those for hydrology and air quality are to a lesser degree. The survey demonstrated that there is a demand for developing IUS and most of the countries would like to learn from the experiences of the cities where such services are implemented.

This Guidance uses information gathered from 27 Demonstration Cities to provide examples of the types of IUS and their placement within distinct administrative frameworks. The details from these cities are abstracted to create a map that illustrates the level of integration along two dimensions: operational development (for example, hazard projections to actions) and; organizational partnerships (for example, weather to hydrology to insurance). The Demonstration Cities support the survey results in terms of the relative development of weather versus hydrological and air quality services. Examples of current IUS are dominated by applications for weather hazards linked with disaster management and health. According to the degree of integration, Demonstration Cities fall into two main categories: one group represents urban service production by adding value through provision of basic available data; the other represents more mature IUS that operationally deliver urban-specific services to a range of users - Paris, Hong Kong, Shanghai and Singapore illustrated the greatest combined integration.

Evidence from the Demonstration Cities indicates that:

- Good practice in IUS can be found within a variety of risk governance structures, but is most clearly visible in tightly integrated organizations embedded within a city-state government.
- With a few exceptions, urban requirements for weather and climate services are met by city authorities using national services provided by Members. However, examples show the benefits of tailoring this information to specific urban requirements.

- Cities have specific needs that are different from rural and national requirements. Examples show benefits where communities, city authorities and service providers work together in partnership to define the need and implement the services.
- Most IUS were developed to meet a particular need but, once created, they could be expanded for other requirements benefitting from information and data sharing and coordinated responses.
- Most countries have a variety of governmental and private sector organizations involved in delivering urban services, with hydrological services and air quality services typically provided by a combination of organizations other than weather services. It is also the case that service delivery is often separate from monitoring and prediction. The benefits of these organizations working in partnership are demonstrated. Open sharing of core (for example weather) and ancillary (for example land cover) data is essential for partnerships to deliver integrated services.
- Few weather services routinely engage social, economic and behavioural scientists in the design or delivery of their services. This type of engagement of multidisciplinary teams is more common in the provision of climate services with clear benefits. A growing number of countries and cities are providing online service portals that bring together urban and/or national services across multiple hazard areas from a variety of sources (typically governmental) to simplify delivery and provide easy access. This trend has several benefits for example, providing information and advice rapidly along with links to supporting agencies.

EXECUTIVE SUMMARY FOR CITY AUTHORITIES

Guidance for Integrated Urban Hydrometeorological, Climate and Environment Services, Volume I: Concept and Methodology outlined the need for Integrated Urban Services (IUS) to support management and planning in cities. This Guidance Volume II: Demonstration Cities provides an overview of the demand for such services in WMO *Member* countries and provides examples of current IUS that have designed to meet a range of urban environmental challenges in a variety of administrative settings. The information has been obtained from a survey of general weather, climate, hydrology and air quality services and detailed responses on selected Demonstration Cities that are currently using IUS. This survey was sent to the permanent representatives of all WMO Member States (192) in 2018 and 87 responses were received. The purpose of the survey was to gauge the level of service provision in each area, the extent to which users and providers collaborate and the status of urban services currently provided. Most of the responses reflected the perspective of the National Meteorological and Hydrological Services (NMHSs). About half of the respondents indicated that they have some type of specific urban services, and in countries where these services are lacking, most are planning to initiate such services.

The common hazards that require IUS were identified as heavy rainfall, flooding, windstorms, tropical storms, heatwaves, thunderstorms and air pollution. However, while meteorological services to support these needs were considered “developed” by most respondents, those for hydrology and air quality are to a lesser degree. Most respondents indicated that NMHSs already provide services to a range of users and have communication systems that connect hazard impact to users. These links provide a template for identifying and engaging with other urban users and their needs. The survey showed there is a demand for developing IUS and most wish to learn from the experiences of other cities.

This Guidance uses information gathered from 27 Demonstration Cities to provide examples of the types of IUS and their placement within distinct administrative frameworks. The details from these Demonstration Cities are abstracted to create a map that illustrates the level of integration along two dimensions: operational development (for example, hazard projections to actions) and; organizational partnerships (for example, weather to hydrology to insurance). The Demonstration Cities support the survey results in terms of the relative development of weather versus hydrological and air quality services. Examples of current IUS are dominated by applications for weather hazards linked with disaster management and health. According to the degree of integration, Demonstration Cities fall into two main categories: one group provides basic data and the other delivers city-specific tailored services to a range of users for managing and mitigating against risk from hazards.

Evidence from the Demonstration Cities indicates that:

- Good practice in IUS can be found within a variety of risk governance structures but is most clearly visible in cases where tightly integrated organizations were embedded within a city-state government such as Hong Kong, Shanghai and Singapore illustrated the greatest combined integration.
- With a few exceptions, urban requirements for weather and climate services are met by City Authorities using national services provided by Members. However, examples show the benefits of tailoring this information to specific urban requirements.

- Cities have specific needs that are different from rural and national requirements. Examples show the benefits that accrue where communities, City Authorities and service providers work together to define the needs, the services required to address these needs and co-design and implement the services.
- Most IUS were developed to meet a particular need but, once created, they can be expanded for other requirements to address multiple hazards and applications.
- Initially, cities should not target the development of very complex IUS. This Guidance presents examples of IUS at different levels of co-production between partners and completeness, so that cities can refer to simpler or more complex IUS.
- Experience shows that implementation of IUS are facilitated if cities are engaged in the collection of in situ observations, the establishment of IUS system, or in the experimental quantification of the potential benefits of an IUS within their domain of responsibility. This allows both better local knowledge (on the hazard/impacts) and appropriation of the IUS by the stakeholders and end users of the city.
- Local government should give full recognition to the "early warning" role of IUS and organize related government departments to establish disaster prevention and mitigation plans.
- Most countries have a variety of governmental and private sector organizations involved in delivering urban services, with hydrological services and air quality services typically provided by different organizations other than weather services. Service delivery is often separate from monitoring and prediction. The benefits of these organizations working in partnership are demonstrated in this Guidance. Open sharing of core (for example weather) and ancillary (for example land cover) data is essential for partnerships to deliver integrated services.
- Few weather services routinely engage social, economic and behavioural scientists in the design or delivery of their services. This type of engagement of multi-disciplinary teams is more common in the provision of climate services with clear benefits.
- A growing number of countries and cities are providing online service portals that bring together urban and/or national services across multiple hazard areas from a variety of sources (typically governmental) to simplify delivery and provide easy access. This trend has several benefits; for example, providing consistent information and rapid advice along with links to supporting agencies.

CHAPTER 1. INTRODUCTION

1.1 Challenges encountered in cities

More than half of the world's population now live in urban areas and by 2050, nearly 68% of the human race are predicted to be urban dwellers (https://population.un.org/wup/). The rapid urbanization in the past half a century has not only brought new immigrants into urban areas but has also converted natural landscapes into urban settings. Urban dwellers are the primary users of energy and resources and they contribute in a significant way to increasing atmospheric greenhouse gases (GHG) as well as to air pollution. These human activities have consequent impacts on human health and the environment. The frequency, intensity, and length of extreme weather events (such as flooding, storms, heatwaves, tropical cyclones) have increased and may likely increase in the twenty-first century due to climate change (IPCC, 2013). Most (90%) disasters affecting urban areas are of a hydrometeorological nature (Habitat-III, 2016). Cities are also responsible for generating up to 53-87% of the carbon dioxide (CO_2) and 37-49% of the greenhouse gas emissions that drive large-scale climate change. Thus, cities have an impact on climate change and vice versa. These two aspects need to be considered together. Further, a single extreme event can lead to a cascading or domino effect that generates new hazards and to a broad breakdown of a city's infrastructure (Figure 1.1). There is a critical need to consider the problem in a holistic manner with interactions of disaster risk reduction and climate change for urban areas (Grimmond et al., 2014; Baklanov et al., 2018).

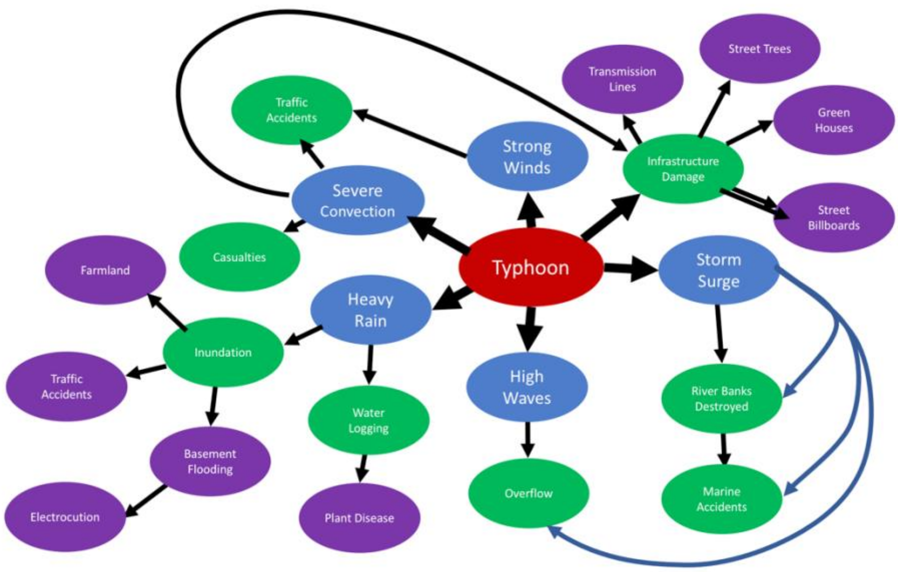

Figure 1.1. The Domino effect. An example of the cascading effects of a typhoon weather event with heavy rainfall leading to hydrological flooding, inundation and coastal erosion, strong winds leading to damaging waves, amongst others. This leads to the activation of emergency services for search and rescue, power outages, fires and even damage to nuclear power plants. Post-event impacts include disease, nuclear waste, urban fabric changes and even displaced peoples. Integrated Urban Services are required to provide consistent short-term emergency and long-term planning applications, efficiently and effectively.

Source: Paul Joe

1.2 WMO perspective

The United Nations Conference on Housing and Sustainable Urban Development in October 2016 adopted the New Urban Agenda (United Nations, 2017). Of the 17 UN Sustainable Development Goals (SDG), the 11th SDG focuses on urban resilience, climate and environment sustainability and disaster risk management (Figure 1.2). In response, WMO proposes a cross-cutting urban focus initiative through Integrated Urban Hydrometeorological, Climate and Environmental Services (IUS) for urban resilience and sustainable development. The main goal is to develop Urban Multi-Hazard Early Warning Systems, Integrated Urban GHG Information Systems (IG^3IS - urban), and climate services, with the focus on impact-based forecast and risk-based warnings. Integrated Urban Services is an emerging multidisciplinary holistic approach, where requirements are unformalized and research and development is still needed for refinement of the concept.

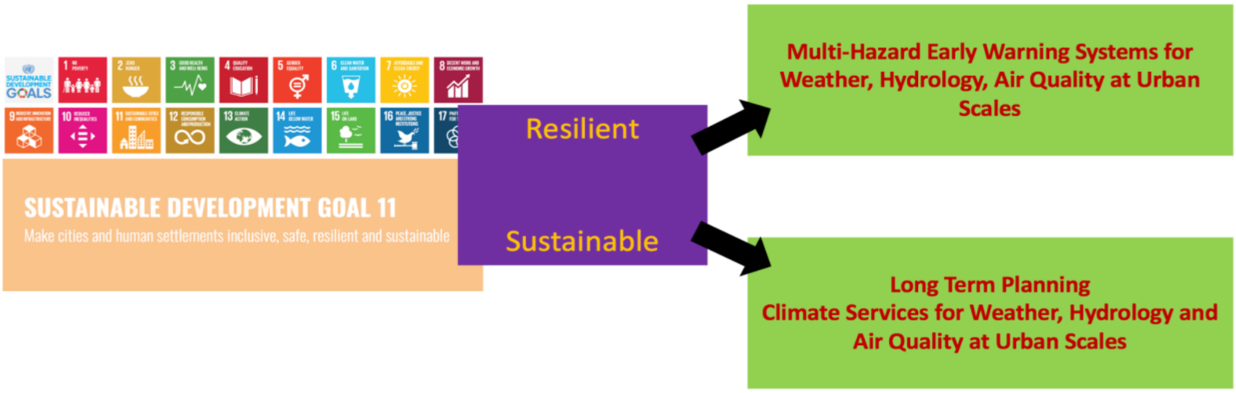

Figure 1.2. IUS concepts support UN Sustainable Development Goal Number 11. IUS support resilient and sustainable cities through multi-hazard early warning, through services to support emergency services and planning for the long-term impacts of disasters. Sustainability is supported through long term urban planning for climate change and support of adaptation and mitigation strategies.

Source: Paul Joe

WMO has provided assistance to Members for the increasing demands of urban areas to improve resilience to environmental, weather, climate and water-related hazards, increased frequency and severity of weather, water and climate extremes and impacts brought about by climate variability and change, through the following:

1) Resolution 68 of the seventeenth session of the World Meteorological Congress (WMO, 2015*a*): "Establishing a WMO cross-cutting urban focus".
2) Decision 15 of the sixty-eighth session of the Executive Council (WMO, 2016): "Implementation of WMO cross-cutting urban focus" and its Annex ("WMO cross-cutting urban focus: outline for implementation framework 2016-2019").
3) Decision 41 at the sixty-ninth session of the Executive Council (EC-69, 2017*b*) "Guidelines for the development of an integrated operational platform to meet urban service delivery needs".
4) Integrating air quality and urban issues into the WMO Strategic and Operating Plan 2020-2023.

5) Decision 7, of the seventh session of the Executive Council (WMO, 2018): "Integrated Urban Services", and Annexes 1 and 2 ("Guide for Integrated Urban Weather, Environment and Climate Services" and "Outline of Guidelines for the Development of an Integrated Operational Platform to Meet Urban Service Delivery Needs").

In response to Decision 41, WMO created a cross-sector multiprogramme international expert task team for the development of Guidance on Integrated Urban Hydrometeorological, Climate and Environmental Services, Volume I: Concept and Methodology (Box 1). In response to Decision 7, this report was prepared with examples from Demonstration Cities (Volume II).

Box 1. Integrated Urban Hydrometeorological, Climate and Environmental Services

The Integrated Urban Hydrometeorological, Climate and Environmental Services (IUS) includes a combination of dense observation networks, high-resolution forecasts, multi-hazard early warning systems, and climate services. The services should meet the special needs of cities as expressed by urban stakeholders and assist cities in setting and implementing mitigation and adaptation strategies that will enable them to build resilient, thriving sustainable cities that promote the New Urban Agenda of the United Nations.

The IUS focuses on improving and integrating the following main services and subsystems:

- Weather (especially high impact weather prediction at the urban scale).
- Climate (urban climate, climate extremes, sector specific climate indices, climate projections, climate risk management and adaptation).
- Hydrology and water related hazards (flash river floods, heavy precipitation, river water stage, inundation areas, storm tides, sea level rise, urban hydrology).
- Air quality (such as, urban air quality and larger-scale hazards affecting cities: long-range transport, duststorms, wildfires smog, anticyclonic and blocking driven air pollution episodes).

The IUS should consider seamless provision of services across all timescales: from historical records, monitoring current conditions, nowcasting (for very short term multi-hazards early warnings, for example, thunderstorms, flash floods, dispersion), short-term and medium-range forecasting for larger-scale phenomena (typhoons, extratropical storms), to long-term (sub-seasonal to seasonal and climate change) timescales at urban and sub-urban spatial scales for environmental and climate risk management, adaptation to climate change, mitigation strategy assessments, urban planning, decision-making mechanisms and effective communication routes.

Box 2. Urban services

Urban Services, in the traditional sense, and in the context of city management (by mayors and other city agencies), refers to aspects such as transportation, housing, water management, waste and wastewater management and snow clearance.

In this document, Integrated Urban Services refers to the provision by a WMO *Member* country of weather, climate, hydrology and air quality infrastructure (data, observations, predictions) that may be used to support traditional (and new) urban services. These services may be provided directly through *Member* operations, in cooperation with or indirectly through stakeholders or partners in public and private agencies.

Services include weather forecasts, related to thunderstorms, tropical cyclones, costal inundation, flooding, air quality, health-related stress as well as to climate services for building codes, zoning, planning and design.

Integrated Urban Services are inherently high resolution (Figure 1.3) and are provided at roughly the spatial scale of the urban footprint and smaller (Figure 1.4). However, they are highly dependent on the application, their requirements, local and regional factors. The urban domain is defined by local governments and may include nearby cities, the area and roads in-between, rural watersheds or catchments and location of industries in order to capture their impact. Urban planners may include surrounding areas as planning in major metropolitan area will impact housing, transportation and recreation in those areas.

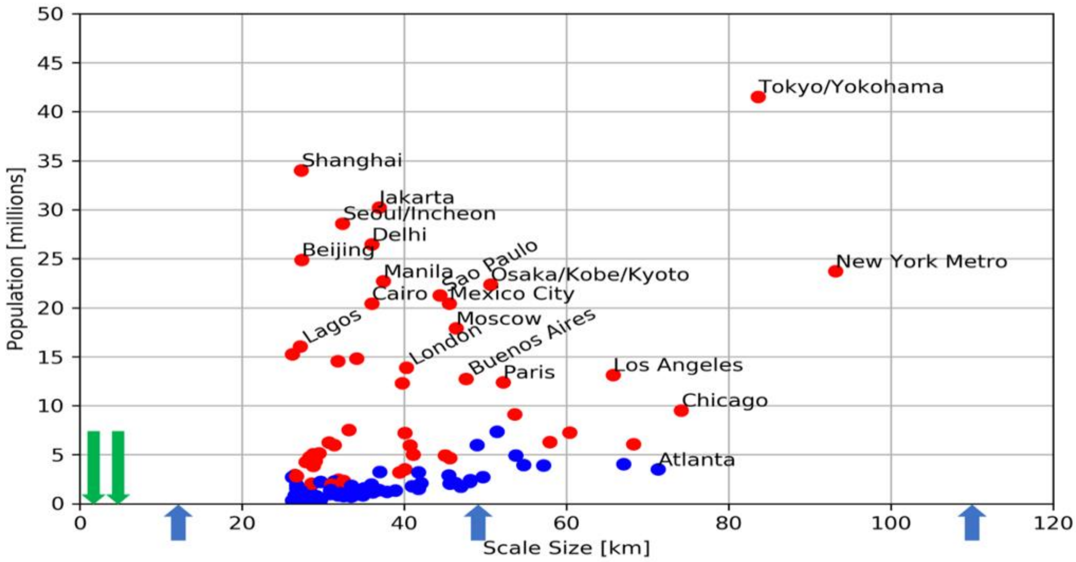

Figure 1.3. Population and spatial extent. The 150 most populated cities in 2008 (from cityMayors.com) are used to estimate characteristic size of a city (simple square root of the area) with population data for 2008 (blue) and 2018 (red). The spatial resolving capabilities (assuming five times grid resolution; Frelich and Sharman, 2008) of typical operational weather models (~2.5 km, 10 km and 30 km) used for local, global and seasonal predictions (blue arrows). Current and near future operational models can provide information at intra-urban scale resolutions. High resolution urban models (250 m, 1000 m, green arrows) are being developed in research and demonstrated in various projects (Annex 3, Toronto; Joe et al., 2018). This includes research into understanding and representation of dynamical, physical, chemical and hydrological urban processes (horizontally and vertically) and developing observation technologies to initialize, interpret and evaluate the models. High resolution weather models (~1 km) are used with climate change scenarios for long-term urban planning applications (Annex 3, Stockholm; Amorim et al., 2018).

Source: Paul Joe

Figure 1.4. Example of intra-urban IUS warning services for Toronto Pan and Parapan Games 2015. The domain of the image is about 100 km x100 km. IUS warnings (weather, air quality and heat stress) were provided to ensure public safety and security for venues (dots) with simultaneous events and large crowds. Normal public warning areas are shown (coloured blocks). The IUS venue warnings were provided to games organizers, emergency services and to health authorities only. They were given special training and support for interpretation of the tailored venue warnings as they may appear to contradict the public warnings.

Source: Paul Joe

The complete Guidance report will consist of 3 volumes:

Volume I: Concept and Methodology describes the concept and methodologies for the services integration (presented to and adopted by EC-70).

Volume II: Presents Good Practices of selected Demonstration Cities in order to improve the resilience and sustainability of urban areas to a great variety of natural and other hazards.

Volume III: Guidance for the Development of an Integrated Operational Platform to meet Urban Service Delivery needs" under development by Weather and Disaster Risk Reduction Services/Service Delivery Division.

Box 3. Terminology – service, integrated services, sectors

In this document, **service** refers to weather, climate, hydrology and air quality.

Integrated services means that the end user receives an appropriate product that takes into consideration two or more of weather, climate, hydrology and air quality. Integration can mean several things from: organizational integration, single access point for services or data, merging monitoring networks, coupled modelling, creating products from distinct systems or providing expertise at the service level.

These services may be delivered through different programmes or agencies within a Member country. An individual service may be delivered by different agencies. For effective urban service delivery, mandate and collaboration are the core jurisdictional and governance issues to resolve.

Also*,* urban services, are generally the mandate of, and, therefore delivered in partnership with, City Authorities (mayors, emergency services, health authorities, civil protection, amongst others). Social scientists, economists, regulatory agencies and policymakers may also play a role in the delivery of urban services.

Sector is used to generically describe service providers, City Authorities and others.

The generic term integration can refer to interaction and collaboration within a service (intra-service), among services (inter-service or cross-service) and among sectors (cross-sector or inter-sector). There may be different agencies or programmes within the City Authority or Others sector (for example, different water or health Authorities) that may benefit from integration (intra-sector).

It also means collaboration with City Authorities and other sectors.

High-resolution local area meteorological observations and modelling are two foundational elements for urban and sub-urban scale services (for example, city block scale) but large-scale phenomena (for example, tropical cyclones or synoptic storms) also affect cities.

Impact-based forecasts* describe the impact of a hazard, or multi-hazards, to an individual or a community at risk. It considers the hazard, the vulnerability and the exposure. For example, a hazard-based forecast could be "Severe thunderstorms are expected today with wind gusts exceeding 60 mph.", whereas an impact-based forecast would be "Extensive traffic delays in Kensington may occur due to the risk of large trees downing power lines and blocking roads as a result of severe thunderstorms."

Successful impact-based forecasting requires collaboration (integration) with others who have the additional necessary expertise, resources and knowledge (such as demographic data, crowdsourcing techniques, geographical information systems (GISs), interoperability, and third-party data integration and usage) to deliver impact services that NMHSs cannot do on their own. From the perspective of service users, this would include communities most vulnerable to disasters contributing to the information system.

*Text and example from WMO Guidelines on Multi-hazard Impact-Based Forecasts and Warning Services (https://library.wmo.int/pmb_ged/wmo_1150_en.pdf)

1.3 Guidance scope and focus

The scope and focus of this Guidance is to document and share good practices with WMO *Members*.

The objectives are:

- To show good practices from selected Demonstration Cities
- To articulate their common attributes
- To make recommendations on integrated urban services for WMO *Member* countries and city authorities
- Bridging gaps and strategies to support integrated urban services.

Box 4. Guidance target audience

WMO *Members* who wish to implement integrated urban services most applicable ("fit-for-purpose") for their cities.

City Authorities who wish to implement urban services for their cities.

Other Sectors who may wish to regulate, set standards, set policy for their cities.

As this is a cross-cutting initiative, mandates and responsibilities may extend beyond services provided by WMO *Members* and be relevant to other concerned agencies at different levels of government, universities, agencies, and in the private sector.

The provision of traditional urban services (e.g. transportation, planning, and zoning) fall under the mandate of the city governments.

It should be noted that the scope of the Integrated Urban Services follows the Role and Operations of Members and that the private sector and others may also provide services for businesses. Hence, agreements and collaboration are two critical aspects of the Integrated Urban Services concept and for its implementation.

Box 5. Benefits of IUS - useful, usable, used

- Resiliency through Multi-Hazard Early Warning Systems
- Sustainability through urban long-term planning
- Capability and capacity through cross-cutting services
- Efficiency through infrastructure cross-cutting services
- Consistency (hence, effective and efficient) through integration
- Effective service through Partnerships / Risk Communication

Box 6. Climate – Weather

"Climate is what you expect and weather is what you get"

Climate information services prepare users for the range of weather they will actually experience.

Traditionally, climate services involve the analysis of long-term high-quality data, including weather data, from national and international databases on temperature, rainfall, wind, soil moisture and ocean conditions, as well as maps, risk and vulnerability analyses and assessments. Increasingly, long-term projections and scenarios, are based not only on climate models but also high-resolution weather models for urban scales.

Depending on the user's needs, these data and information products may be combined with non-meteorological data, such as agricultural production, health trends, population distributions in high-risk areas, road and infrastructure maps for the delivery of goods, and other socioeconomic variables.

1.4 Guidance development process

To capture the cross-cutting aspects of urban services and of governance and mandates, contributions were solicited from a variety of experts and representatives through a broad consultation process. Experts were identified by all the WMO Commissions, WMO Secretariat urban focal points, external urban experts were engaged and surveys of WMO *Members* conducted. The Global Atmosphere Watch (GAW) Urban Meteorology (GURME) Science Advisory Group was appointed to lead the preparation of Volume II with contributions from the Commission of Hydrology and Climate Services. These Experts were appointed to an Urban Expert Task Team (UET) from which a writing team was formed and consisted of WMO *Members*, academics, urban councils, WMO Secretariat, scientific organizations and other UN agencies (World Health Organization). Contributors are listed in the Annex A3.1.

Information on Integrated Urban Services were provided by four complementary tools and are described in Table 1.1. The tools are described in Annex 2.

Table 1.1. Tools used to gather information

Tool	*Issued by*	*Target Respondent*	*Comment*	*Number of Responses*
Reflections Survey (RS)	GURME Science Advisory Group	Urban Experts	In Volume I, **urban project leaders, experts and researchers** in government and in academia were asked to share their experiences in an open- ended survey about **specific cities**. Respondents were given limited time and asked for their immediate reactions to the survey. The intent was to gather information quickly from urban experts. The opinions may not formally represent that of WMO *Members*.	21
Urban Focal Point Survey (UFPS)	GURME SAG	Members Urban Focal Points	In Volume I, a subset of the Reflections Survey was sent directly to the **Urban Focal Points of WMO *Members*** for their immediate reactions about **specific cities**. The intent was to gather information quickly and the opinions may not formally represent that of WMO *Members*.	11
Members Survey (MS)	WMO Secretary-General	WMO *Members*	As part of Volumes II and III, a **formal** WMO survey was sent to **WMO *Members***. Unlike the previous two surveys, the survey was designed for categorical responses, their urban services and **not specific to a particular city**. Chapter 2 provides an analysis of this survey to provide context of the Demonstration Cities. This survey will also be analysed in Volume III in the context of providing **Guidance** for Integrated Operational Service Delivery Platforms.	87
Demonstration City Summaries (DCS)			**UET members** were asked to work with respondents of the Reflections and the UFPS to produce a **structured summary of IUS for specific Demonstration Cities**. This forms the core material for Volume II. See Chapter 3 and Annex for more details.	27

Box 7. Climate mitigation by cities

Rationale: Cities are a critical part of the endeavour to limit global greenhouse gas emissions to achieve goals set out in the Paris Agreement. Urban areas currently account for 53% to 87% of global fossil fuel CO_2 emissions and their importance is expected to further increase with accelerating urbanization (IEA 2008; IPCC, 2013). Many City Authorities have responded to this challenge and, to date, 9378 cities have registered their climate actions on the Global Climate Action platform NAZCA of UN Climate Change[a]. Furthermore, over 4000 studies related to urban climate mitigation projects have been published (Lamb et al., 2019). The Demonstration Cities included in this Guidance (Annex 3) have planned over 500 mitigation activities to decrease their net emissions in the and over 100 adaptation actions[b]. City stakeholders are in need of science-based information for their decision-making and besides the different existing inventory approaches and datasets (e.g. Nangini et al., 2019), atmospheric observations can play an important role.

WMO activities to support urban mitigation activities through IG³IS: The Integrated Global Greenhouse Gas Information System (IG³IS) of WMO has been established to promote the use of atmospheric observations in combination with modelling tools and socioeconomic data to help provide relevant information to stakeholders to cost-efficiently and rapidly implement mitigation actions, as well as to track their success (WMO-IG³IS, 2018). Local City Authorities often cannot rely on their own resources to establish complex atmospheric monitoring and modelling activities, but many of the skills required to fill these gaps usually reside in national institutions, especially National Hydrometeorological Services. Therefore, one of the key goals of WMO-IG³IS is bringing the stakeholder community and their challenges together with, academics, government researchers and solution providers. WMO-IG³IS has started to establish good practices for urban GHG modelling and monitoring as well as endorsed multiple urban GHG projects that will demonstrate the usefulness of this integrated approach for fact-based decision-making and progress tracking related to GHG mitigation activities.

Implications for IUS

IUS Guidance does not only help to disseminate the WMO-IG³IS good practices for climate (mitigation) related services, but also ensures that WMO activities at urban scale will be consistent and services can be delivered efficiently. Many NMHSs can play a key role in assuring science-based information is provided to local authorities by defining performance standards, e.g. for atmospheric data to be used when creating these new urban climate services that are often delivered by a diverse set of actors, including the private sector. Urban scale studies focussing on mitigation tracking, for example, the WMO-IG³IS demonstration projects, also leverage existing infrastructure (for example, weather data as input in Chemical Transport Models). Future improvement of weather forecast models e.g. when used in addressing urban weather or air quality issues can also immediately feed into improved forecasting or analysis of urban GHGs when the services are integrated. Furthermore, integrating different urban services can highlight the additional benefits of many mitigation measures, i.e. often improved air quality, which has better health outcomes associated with it. Many of the cities (Annex 3) did not yet include their climate mitigation activities explicitly, but this Guidance should be seen as a step towards an inclusion of the medium to long-term climate mitigation challenges in the current framework centered around short-term hazards.

[a] http://climateaction.unfccc.int/
[b] Carbon Disclosure Project, http://www.cdp.net/

1.5 Guidance structure

A total of 7 Chapters are included. Chapter 2 provides an analysis of the *Members* survey, Chapter 3 provides an overview of the Demonstration City Summaries, Chapter 4 provides an overview of the analysis procedure which describes a theoretical framework to assess the attributes of Demonstration City IUS. Chapter 5 provides the results of the analysis. Synergies and recommendations are provided in Chapter 6 and, gaps, research priorities, the way forward is discussed in Chapter 7.

Two Executive Summaries are provided: (i) WMO *Members* and (ii) City Authorities in recognition that the language of the two groups can be quite different.

CHAPTER 2. OVERVIEW AND ANALYSIS OF THE MEMBERS SURVEY

2.1 Introduction

A survey asking about urban Weather, Climatological, Hydrological, and Air Quality services was sent to the Permanent Representatives of all WMO Member States (192) in 2018. Its purpose was to establish a baseline of WMO *Member* urban services for use in evaluating their development in future surveys. As such, the results represent a preliminary assessment of the current status of these services and the impediments to enhancing these. Here, the survey is used to set the context for subsequent chapters, which explore the types of services available for Demonstration Cities. The information in the survey is also used in Volume III, which provides Guidance for Integrated Urban Service Delivery Platforms.

Eighty-Seven *Members* completed the questionnaire. Most of those who responded were in NMHSs and the responses reflect their perspective. The survey measured the level of service provision in each area, the extent to which users and providers collaborate and the status of urban services currently provided. In addition to contact information, there were forty-nine questions focussing on six areas (number of questions in parentheses):

a) The main hazards in the urban areas (1)
b) Current activities in the area of urban services (16)
c) Other urban services in your country (2)
d) User connections and partnerships (13)
e) Capacity development and training (11)
f) International collaboration (6)

As an overview of the Member responses, each was categorized by region and income level using the World Bank scheme (Table 2.1). Of the 87 responses, about a third are from the European and Central Asian region. While the largest number (33 or 38%) of the respondents are from high-income countries, lower- and upper-middle income countries were well represented, and nine respondents are from low-income countries located mostly in sub-Saharan Africa. These data may be of some relevance in interpreting and making use of the Demonstration City information presented in the following chapters.

Table 2.1. Respondents by region and World Bank income level (% in grey). As an example, for Sub-Saharan Africa, the total number of responses were 17 out of which 47% were from low-income member countries, 41% from lower middle income and the remaining 12% from upper middle-income member countries.

Region	*Low income*	*Lower middle income*	*Upper middle income*	*High income*	*Total*
Sub-Saharan Africa	47	41	12	0	17
Latin America & Caribbean	0	13	63	25	16
Europe & Central Asia	0	10	21	69	29
South Asia	25	75	0	0	4
East Asia & Pacific	0	42	25	42	12
North America	0	0	0	100	2
Middle East & North Africa	0	17	50	33	6
Total	9	21	24	33	87

2.2 Geophysical characteristics and hazards of urban areas

Members were asked to place their urban areas in a geographical (coastal, inland, mountainous, desert and river/delta) and climatological (polar, mid-latitude and tropical) contexts. In addition, each Member was asked to identify the main urban hazards of relevance that they face. Table 2.2 shows a cross-tabulation of these geographical and hazard dimensions.

The most common urban topographic settings were inland, coastal, mountain, riverine/delta in that order, and a few in polar latitudes (2) or in desert environment (17). There are six main urban hazards identified (marked in bold in columns 2 and 3 of Table 2.2): heavy rainfall, flooding (both pluvial and fluvial), wind storms, heatwaves, air pollution and thunderstorms.

There are some links between the types of hazard and geographic parameters:

- Heavy rainfall, flooding, thunderstorms and air pollution are common hazards across all responses.
- Heat and cold waves, windstorms and snow/ice are more commonly identified as mid-latitude urban hazards, while tropical storms are emphasised as urban hazards in tropical urban areas.

Table 2.2. Geophysical and climatological characteristics and hazards of urban areas mentioned in questionnaire responses. Values are numbers of responses for a particular hazard (listed in the first column), except column 3 which gives the responses as a percentage out of a total of 87. Bold numbers in the second (Total) and third (Percent) columns indicate the most commonly identified hazards. Columns in grey shading provide the number of responses according to the 'geographical' context of the urban areas and the last three columns show the number of responses according to the 'climatological' context of the urban areas. The last row marked Total corresponds to the total number of responses that reported on urban areas according to the specific geographical and climatological categorizations indicated in the title row of the table. As an example, 98% of the responses were for urban areas that suffered heavy rainfall; 66 respondents reported on urban areas that were classified as 'inland' and 31 responses were for urban areas that could be classified as tropical.

	Total	*Percent*	*Coastal*	*Inland*	*Mountain*	*Desert*	*Riverine*	*Polar*	*Tropical*	*Mid-latitudes*
Heavy rainfall	**85**	**98**	65	66	49	17	41	2	31	32
Flooding	**75**	**86**	60	58	44	13	38	2	29	26
Water scarcity	41	47	30	31	28	11	21	0	18	17
Fog	46	53	30	37	28	14	23	1	16	22
Tropical storms	29	33	27	23	19	7	17	0	21	9
Coastal inundation	38	44	38	31	25	9	23	2	17	15
Windstorms	**60**	**69**	43	47	37	16	30	0	19	29
Heatwaves	**57**	**66**	39	46	32	14	31	1	17	32
Cold waves	38	44	23	32	24	11	23	1	12	24
Snow	33	38	22	26	20	7	20	2	6	23
Ice	23	26	15	17	13	3	15	1	4	16
Sandstorms	22	25	16	19	16	15	13	0	8	10
Air pollution	**54**	**62**	38	40	30	12	28	2	21	25
Thunderstorms	**70**	**80**	54	54	41	15	35	1	28	30
Volcanic ash	11	13	11	8	9	2	5	0	8	3
Other	23	26	21	18	16	6	15	0	15	7
Total	**87**	**100**	**66**	**66**	**49**	**17**	**42**	**2**	**31**	**34**

2.3 Services and level of development

Most *Members* indicated that their urban meteorological services were fully operational (79%); however, 8% are still at the research/planning stage (Table 2.3). Fewer respondents described their climatological services as fully operational. Hydrological and air quality (AQ) services are more diverse, with the latter the least developed. Fewer *Members* have fully operational climatological (55%), hydrological (47%) and air quality (36%) services; in the case of AQ, 32% indicated that such services are just at the planning stage. When the fully operational services are cross-tabulated with the common hazards identified, some of the gaps between the operational status are clear. For example, *Members* that are concerned with Tropical Storms have the fewest fully operational systems in all categories. By comparison, the meteorological support for heavy rainfall, flooding and thunderstorms is present in services but hydrological support is relatively weak.

Table 2.3. Services and level of development

	Weather	*Percent*	*Climatological*	*Percent*	*Hydrological*	*Percent*	*Air quality*	*Percent*
Fully Operational	69	79	48	55	41	47	31	36
Part/Moving to Operations	13	15	29	33	30	35	21	24
Research/Planning	7	8	10	12	13	15	28	32
By Hazard								
Heavy rainfall	67	77	48	55	40	46	31	36
Flooding	58	67	42	48	36	41	26	30
Tropical storms	25	29	20	23	17	20	8	9
Coastal inundation	30	34	22	25	19	22	13	15
Windstorms	49	56	33	38	28	32	23	26
Heatwaves	45	52	30	34	27	31	24	28
Air pollution	44	51	30	34	27	31	22	25
Thunderstorm	57	66	40	46	34	39	25	29

2.4 Service provision

Nearly all Member responses indicated that services are provided to official bodies and the public (Table 2.4). Additional targeted customers focused on water management, energy supply and transportation, that is, closely linked to many of the hazards identified. Less than half of the respondents indicate that they have an integrated platform to provide these services.

Table 2.4. Number of responses indicating the provision of member services to different recipients. For example, 75% of respondents indicated that they provide services to the transportation sector.

Recipients	*N*	*%*
General services to the public	84	96
Services to the Authorities (city, state, national)	85	97
Other customers		
Water management	72	83
Energy supply	65	75
Transportation	65	75
Health sector	55	63
Infrastructure design	54	62
Tourism sector	52	60
Road traffic	52	60
Special events	51	59
City planning	51	59
Food safety	42	48
Industry	40	46
Other	17	20
Respondents with systems that include Integrated Services	39	45

2.5 The use of impact-based forecasting for urban areas

Less than half of the *Members* (45%) provide impact-based forecasts for urban areas (Table 2.5). Those that currently do not provide such services, nearly 83% are planning for such services. The majority do use alert systems to communicate hazards/impacts and rely mostly on conventional media (TV, radio, web and e-mail). An analysis of the medium and the type of hazard did not reveal any differences in approach.

Table 2.5. Use of impact-based forecasting for urban areas by respondents. The last two columns show the number (N) and percentage of respondents who provide impact-based forecasts for urban areas.

Forecasting and alerts	*N*	*%*
Does your Service use impact-based forecasting for urban areas?	39	45
If 'no', do you plan for such services?	40	83
Weather alerts and warnings	85	98
Flood/drought alerts	73	84
Medium of communication		
Newspapers	60	69
TV	76	87
Radio	75	86
Telephone (including SMS alerts)	62	71
Web portal	74	85
E-mail	70	80
Digital display	29	33
Social media	58	67
Other	33	38

2.6 Service

The Member responses indicated that local government, disaster and water management areas were most prominent in development of urban products and services, while the energy, transport and health sectors were less involved, and the general public had little involvement. When hazard type is cross-tabulated against service user (Table 2.6), some relationships become clear. For example, tropical storm hazard is not linked to one sector only. By comparison, local government, disaster and water management are associated with developing services for heavy rainfall and flooding. The transport sector is linked to developing services with regard to air quality and excess water.

Table 2.6. Involvement of users of impact-based forecasting for urban areas in the development of urban services

	Local government	*Disaster management*	*Water management sector*	*Energy sector*	*Industry sector*	*Transportation sector*	*Road traffic sector*	*Food safety sector*	*Health sector*	*Tourism sector*	*General public*
Number of respondents	51	52	47	37	15	40	26	21	35	15	19
Percent	58	59	53	42	17	46	30	24	40	17	22
Hazard (percent)											
Heavy rainfall	52	52	46	38	14	40	26	22	36	16	20
Flooding	44	45	43	35	13	36	22	21	35	14	20
Tropical storms	19	18	20	14	5	12	8	7	14	10	8
Coastal inundation	22	25	24	17	6	18	10	9	19	9	8
Wind storms	34	35	31	27	11	28	20	18	23	11	13
Heatwaves	33	35	29	27	13	27	19	16	25	10	13
Air pollution	35	35	33	28	11	28	21	17	24	11	17
Thunderstorms	41	42	36	31	13	33	21	18	29	14	17

2.7 Partnerships and capacity-building

A number of questions asked about partnerships and the range and frequency of interactions (Table 2.7). About half of the respondents have formed partnerships to create and provide urban services. Social scientists have not generally been part of the process of developing these. Most *Members* have regular meetings with partners (72%); about half have conducted training workshops and a third have attended WMO training. The majority of respondents (72%) are interested in helping other *Members* develop urban services through twinning and 83% would like to avail of these services.

Table 2.7. Partnerships and capacity-building

Partnerships & Training	Yes	%
Has your Service formed partnerships in the provision of urban services?	50	57
Do you carry out regular surveys, such as for further development or for obtaining information on the benefits of your services, with your partners or relevant national/regional/local authorities?	50	57
Have you established regular meetings with your partners or relevant national/regional/local authorities?	63	72
Does your service work with economists on urban services?	8	9
Does your service work with social scientists/authorities on urban services?	25	28
Does your service measure the economic and/or social benefits of urban services?	15	17
Does an authority have responsibility for measuring the economic and/or social benefits of urban services?	14	16
Has your Service or another national/municipal authority organized capacity development activities, including training, on urban services that your staff has attended?	43	49
Have your staff attended any WMO organized capacity development activities, including training, related to developing urban products and services and associated infrastructures?	31	35
How does your service develop capacity and guide stakeholders, authorities and users in the interpretation and use of urban products and services?		
Do you organize training for them?	43	49
Do you have regular meetings with them?	49	56
Do you provide them with written Guides or Operative Procedures?	37	42
Does your Service conduct periodic exercises to ensure proficiency?	48	55
Is your Service collaborating with international partners on urban activities?	33	37
Would your Service be interested in providing twinning to a country/city in need of developing urban services?	63	72
Would your Service be interested in developing your urban services by twinning with a country/city already having expertise in urban services?	73	83

2.8 Conclusion

The survey of Weather, Climatological, Hydrological, and Air Quality services was completed by 87 WMO *Members*. While this is a sizable proportion of the population of 192 *Members*, it may not be representative of service provision for a couple of reasons. First, most respondents were drawn from NMHSs who may have incomplete knowledge of the range of urban services available in a Member state. Second, the completed survey responses may over-represent those *Members* with an interest in providing urban services. Nevertheless, these data provide a first-look at the provision of urban services by WMO *Members* and a baseline overview of the urban services provided and the nature of integration across services and with users.

- The common urban hazards are: heavy rainfall, flooding, wind storms, tropical storms, heatwaves, thunderstorms and air pollution.
- The meteorological operations are well developed, while the hydrological and air quality operations are significantly less well developed. Improving the operational status of hydrological and air quality services to match meteorology is needed to meet the common hazards identified.

- Many WMO *Members* have already developed relationships with users that are used to create and provide services and have communication systems that connect hazard impact to users. These established practices can be used to identify and engage with urban users and their distinct needs.
- About half of the WMO *Members* have created some type of urban services (including training), and of those that have not, the majority plan to do so. A large proportion of respondents indicate that they wish to learn from other WMO *Members* on how to develop these services.

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CHAPTER 3. IUS DEMONSTRATION CITY SUMMARIES

3.1 Introduction

In this section, selected Demonstration Cities with existing integrated urban services in weather, environment (water and air quality) and climate are reviewed for common or core elements (Table 3.1). Recognizing that there is great variation in this concept and to better articulate the core elements of both (i) the IUS concept, and (ii) the Guidance, WMO invited city specific experts, urban focal points and *Members* for advice and guidance on their IUS. The goal is to document and share good practices from these Demonstration Cities that will allow other cities to improve their resilience and sustainability of urban areas to the great variety of hazards/disasters and to help with long-term urban planning. Figure 3.1 shows the spatial distribution of the Demonstration Cities. Response summaries from each Demonstration City are presented in Annex 3.

Table 3.1. List of Demonstration Cities.
See Annex 3 for response summaries from these city representatives

City	*Country*	*Climate Zone*
Antwerp	Belgium	Temperate
Auckland	New Zealand	Subtropics (Marine)
Beijing	China	Temperate
Casablanca	Morocco	Subtropics (dry summer)
Dallas Forth Worth Metroplex	United States	Subtropics
Frankfurt am Main	Germany	Temperate
Hamburg	Germany	Temperate
Helsinki	Finland	Temperate
Hong Kong	China	Subtropics
Johannesburg	South Africa	Subtropics
London	United Kingdom	Temperate
Mexico City	Mexico	Tropics
Moscow	Russia	Temperate
New Delhi	India	Subtropics
New York City	United States	Temperate
Rotterdam	Netherlands	Temperate
Saint Petersburg	Russia	Temperate
Santiago	Chile	Subtropics Semi-arid
Seattle	United States	Temperate
Seoul Metropolitan Area	Korea	Temperate
Shanghai	China	Subtropics
Singapore	Singapore	Tropics
Stockholm	Sweden	Temperate
Stuttgart	Germany	Temperate
Toronto	Canada	Temperate
Toulouse and Paris	France	Temperate
Wellington	New Zealand	Temperate (Marine)

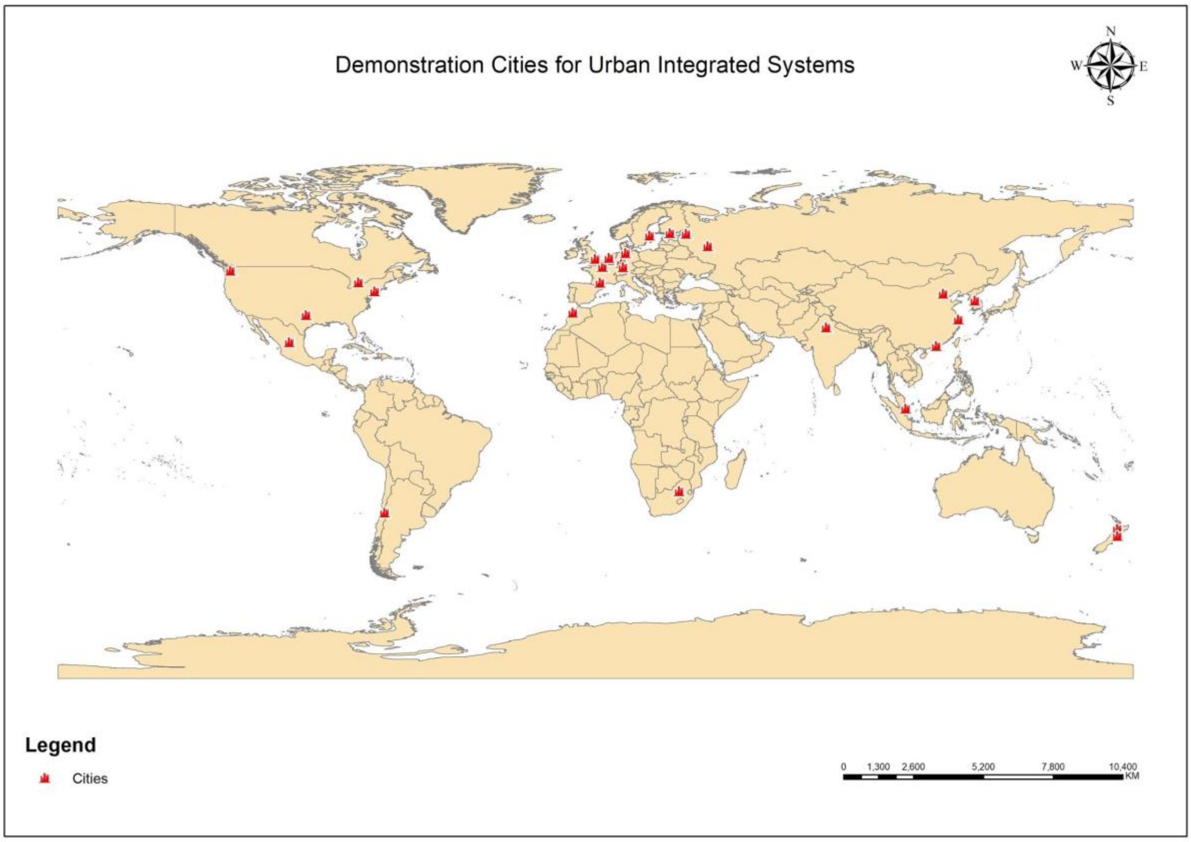


Figure 3.1. Location of the Demonstration Cities

Source: *Chandana Mitra*

3.2 Demonstration City Summary (DCS) Template - Overview

A common template was provided to gather information for each of the Demonstration Cities. The information gathered was organized into three major categories corresponding to general information, IUS needs and Service integration:

Section A: General information

- Socioeconomic condition (city size, isolated or agglomeration, economic condition (e.g. contribution to GDP), level of infrastructure (e.g. transport and communication, environmental management, monitoring and response mechanisms).
- Climate zone, weather classification and geographical position (inland, coastal, mountains, desert, and so forth).
- Governance structure (decision-making) – legal framework, autonomous or metropolitan/regional, responsibility pathway for addressing urban hazards, policymaking powers (local, regional, national).

Section B. Needs for the integrated services

- Most common hazards in the city and associated environmental risks (e.g. hydrological, elevated air pollution episodes, vulnerability to other regional hazards).

- Description of existing integrated urban services for meeting hazard challenges, or hazard-specific services, capability of monitoring, predicting and forecasting hazards.
- Providers of the urban services (dedicated *Members*, academia, consultancies and advisors and so forth).
- Users of the integrated urban services (government, environmental agencies, economic sectors, public, and so forth) – local, regional, national.
- Requirements for the services: short-term (DRR) or long-term/strategic (urban and national planning), scientific and technical expertise, capabilities (for example, observational, computing, training.

Section C: Services integration

- Short term: multi-hazard early warning and forecasting systems.
- Long term: urban planning for sustainable development, climate change mitigation and adaptation.
- Components integrated (and how):
    - at the level of observational infrastructure
    - at the level of modelling tools
    - at the level of the services/information delivery, communication.

3.3 Comparison of the Demonstration City Summaries (DCS) with the Members Survey (MS)

As some of the information gathered in the Demonstration City Summaries (DCS) and the Members Survey (MS) (Chapter 2) are similar, the overall results can be compared. However, one should be mindful of their differences. The DCS data are (i) city specific (rather than an expression of national urban needs), (ii) is selective in its coverage and (iii) contains much greater detail on existing IUS. In the following, results are presented as percentages based on the MS (N=87 members) and the DCS (N=27 cities, Table 3.1).

In the MS, of the fifteen hazards, heavy rainfall was the most frequently reported (98% of the responses). "Other" non-specific hazards were reported by 26% of the *Members*. The variety of hazards addressed by the DCS are broader in scope with 20 hazards explicitly identified (Figure 3.2). However, in terms of frequency of hazard mentions, there are differences between the MS and DCS data; for example, heavy rainfall is reported as a hazard by 98% in the MS but by just 67% in the DCS. This gap may represent a lower concern by the Demonstration Cities (DC) as it may already be routinely considered and so no longer a priority or the individual DC may have different foci. However, some cities see the critical advantage of additional in situ measurements (e.g. from their own rain radar data - see Dallas-Fort Worth or Hamburg in Annex 3). The DCS data indicates that a higher priority is placed on providing information on the impact of heavy rainfall, namely flash floods or riverine flooding, rather than the meteorological event itself. Flooding is identified most frequently as a hazard in the DCS data (78%). Both the DCS and MS data identify air pollution as a high priority hazard (63%) and generally agree on the importance of heatwaves and cold waves (63% and 48%, respectively). Demonstration Cities have a larger need for climate change information (26%) than probably assumed by *Members* which is portrayed in the "Other" services category at 26%.

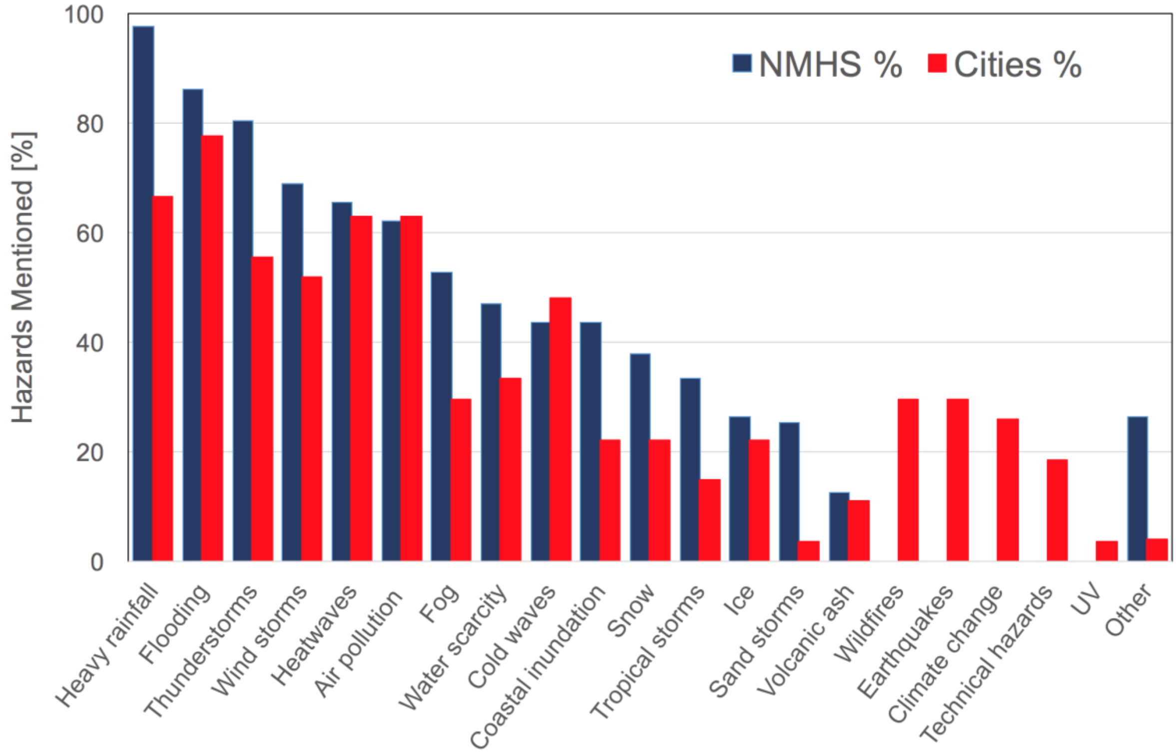


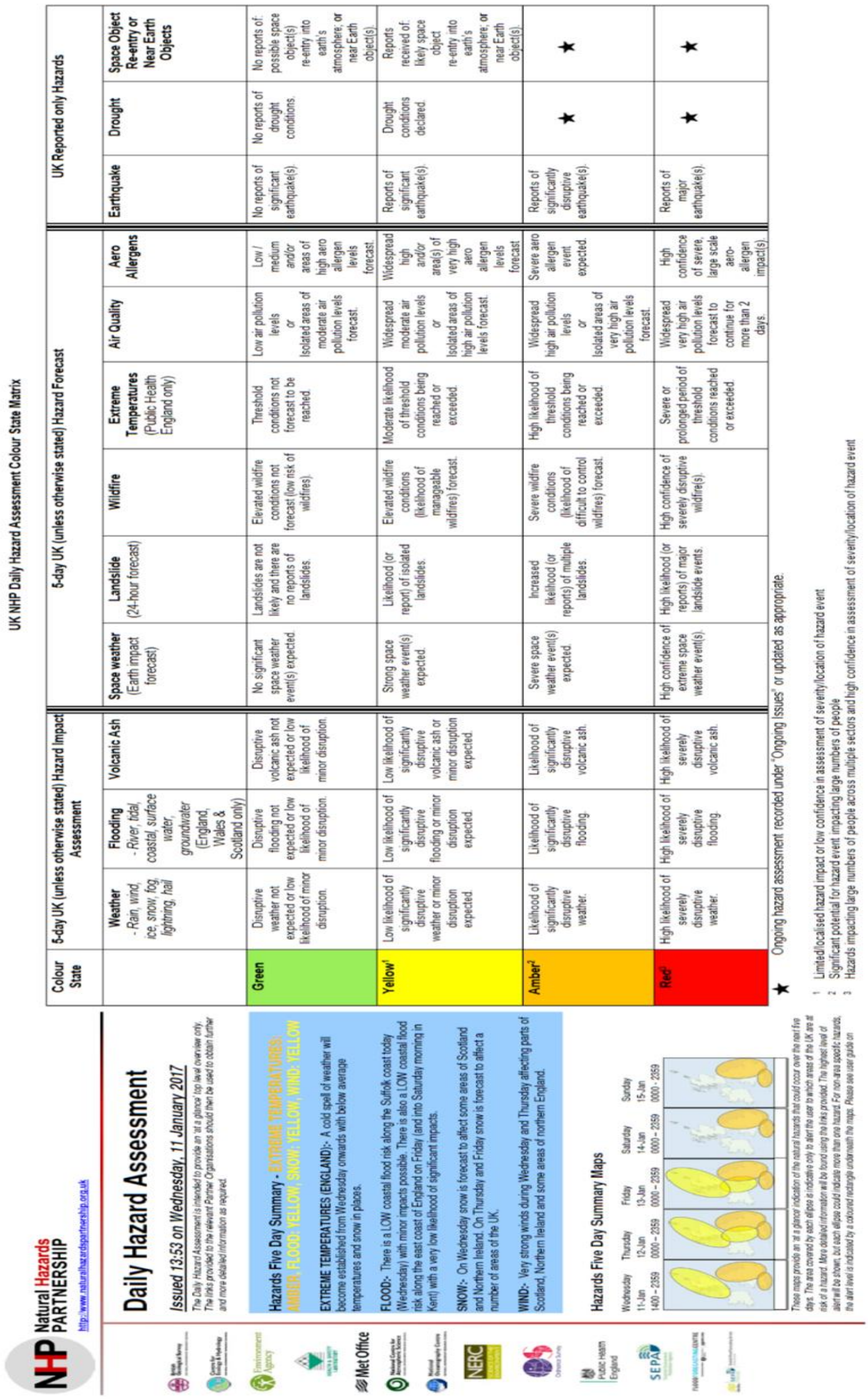
Figure 3.2. Frequency of specific hazards mentioned by Members in the Survey (blue, Chapter 2, sample size of 87) and by Demonstration Cities in the Summary (red, Chapter 3, sample size of 27).

Source: Heinke Schluenzen

Many of the DCS indicate the need to address hazards that lie outside the IUS concept adopted here. For instance, 30% of respondents require information on earthquakes. Additional collaboration and partnerships are needed to deliver such services (Figure 3.3).

The DCS also indicates a wider range of IUS hazards that are of concern. For example, 30% of the DC mention wildfires, which also affects visibility and air quality and so endanger both property and human health. Addressing this issue requires meteorological (wind and precipitation) and hydrological (ground conditions, water availability for firefighting) information to develop action plans. Furthermore, collaboration with Climate Services will assist in developing fire prevention plans for various climate change scenarios or projections.

However, the DCS express a greater need for climate change information (26%) although this was not a listed hazard in the MS. None of the MS respondents referred to climate change in the "Other" category. Mexico City indicates "vector-borne diseases, social and spatial inequality and high vulnerability related to climate change", Rotterdam, Stockholm and Hamburg mention "sea level rise" and Auckland mentions "coastal erosion". These, and others, are likely to change in the future and have big impacts on cities as climate changes (Box 8).



UK NHP Daily Hazard Assessment Colour State Matrix

Colour State	5-day UK (unless otherwise stated) Hazard Impact Assessment			5-day UK (unless otherwise stated) Hazard Forecast						UK Reported only Hazards		
	Weather - Rain, wind, ice, snow, fog, lightning, hail	Flooding - River, tidal, coastal, surface water, groundwater (England, Wales & Scotland only)	Volcanic Ash	Space weather (Earth impact forecast)	Landslide (24-hour forecast)	Wildfire	Extreme Temperatures (Public Health England only)	Air Quality	Aero Allergens	Earthquake	Drought	Space Object Re-entry or Near Earth Objects
Green	Disruptive weather not expected or low likelihood of minor disruption.	Disruptive flooding not expected or low likelihood of minor disruption.	Disruptive volcanic ash not expected or low likelihood of minor disruption.	No significant space weather event(s) expected.	Landslides are not likely and there are no reports of landslides.	Elevated wildfire conditions not forecast (low risk of wildfires).	Threshold conditions not forecast to be reached.	Low air pollution levels or isolated areas of moderate air pollution levels forecast.	Low / medium and/or areas of high aero allergen levels forecast.	No reports of significant earthquake(s).	No reports of drought conditions.	No reports of: possible space object(s) re-entry into earth's atmosphere; or near Earth object(s).
Yellow[1]	Low likelihood of significantly disruptive weather or minor disruption expected.	Low likelihood of significantly disruptive flooding or minor disruption expected.	Low likelihood of significantly disruptive volcanic ash or minor disruption expected.	Strong space weather event(s) expected.	Likelihood (or report) of isolated landslides.	Elevated wildfire conditions (likelihood of manageable wildfires) forecast.	Moderate likelihood of threshold conditions being reached or exceeded.	Widespread moderate air pollution levels or isolated areas of high air pollution levels forecast.	Widespread high and/or area(s) of very high aero allergen levels forecast.	Reports of significant earthquake(s).	Drought conditions declared.	Reports received of: likely space object re-entry into earth's atmosphere; or near Earth object(s).
Amber[2]	Likelihood of significantly disruptive weather.	Likelihood of significantly disruptive flooding.	Likelihood of significantly disruptive volcanic ash.	Severe space weather event(s) expected.	Increased likelihood (or reports) of multiple landslides.	Severe wildfire conditions (likelihood of difficult to control wildfires) forecast.	High likelihood of threshold conditions being reached or exceeded.	Widespread high air pollution levels or isolated areas of very high air pollution levels forecast.	Severe aero allergen event expected.	Reports of significantly disruptive earthquake(s).	★	★
Red[3]	High likelihood of severely disruptive weather.	High likelihood of severely disruptive flooding.	High likelihood of severely disruptive volcanic ash.	High confidence of extreme space weather event(s).	High likelihood (or reports) of major landslide events.	High confidence of severely disruptive wildfire(s).	Severe or prolonged period of threshold conditions reached or exceeded.	Widespread very high air pollution levels forecast to continue for more than 2 days.	High confidence of severe, large scale aero-allergen impact(s).	Reports of major earthquake(s).	★	★

★ Ongoing hazard assessment recorded under "Ongoing Issues" or updated as appropriate.

1 Limited/localised hazard impact or low confidence in assessment of severity/location of hazard event
2 Significant potential for hazard event impacting large numbers of people
3 Hazards impacting large numbers of people across multiple sectors and high confidence in assessment of severity/location of hazard event

Figure 3.3. An example of an Integrated Hazard Assessment issued at the national level for the United Kingdom
(http://www.naturalhazardspartnership.org.uk/products/hazard-matrix/).

Source: Natural Hazards Partnership, UK

Box 8. Heritage cities

Climate change is already having a considerable impact on some of the world's most spectacular built and natural heritage sites. The effects of climate change include sea level rise and flooding, increased temperature, desertification and coastal erosion, etc. In China, the Peking Man World Heritage Site at Zhoukoudian in Beijing was damaged by floods caused by the heaviest rainfall in six decades. The ancient city of Fenghuang in Hunan province was surrounded by rushing water for twelve hours in 2012 (Yung and Chan, 2015). Natural ecosystems, like the unique Great Barrier Reef (Australia) or the Wadden Sea (Netherlands, Denmark and Germany) are threatened by increasing water temperatures and sea level rise. Thus, immediate actions to protect the outstanding universal values, integrity and authenticity of the World Heritage sites from the adverse impacts of climate change are urgently needed. Pollution and acid precipitation can destroy cultural sites such as the Acropolis in Athens, or the Sphinxes in Egypt.

The World Heritage Committee convened a working group of experts, in collaboration with the World Heritage Convention's Advisory Bodies, interested States Parties and the petitioners to prepare a report on Predicting and Managing the Effects of Climate Change on World Heritage in 2007 and Case Studies on Climate Change and World Heritage, and a Policy Document on the Impacts of Climate Change on World Heritage Properties in 2008. The World Heritage Convention has gradually evolved into a tool of expertise to monitor the progress of climate change and to suggest pertinent practical measures to safeguard heritage sites (UNESCO, 2007).

WMO can convene members with skills and capabilities related to meteorology and heritage conservation to build a closer collaboration with the World Heritage Committee, experts from different disciplines and sectors to identify heritage sites which are prone to hazards in cities worldwide. IUS can employ advanced technology to provide micro-climate data and modeling of the heritage sites for more effective monitoring. Multi-disciplinary analyses can formulate effective protection, mitigation and adaption measures of the heritage sites from climate change hazards.

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CHAPTER 4. OVERVIEW OF INTEGRATED URBAN SERVICES

4.1 Introduction

While urban services can cover a wide range of areas, here the focus on Weather (W), Climate (C), Water (H) and Air Quality (AQ) services and consider integration across two or more of these to constitute an IUS. Of course, the IUS must also include communications with urban sectors (such as energy management and planning) for which these services are developed. The Demonstration City Summary (DCS) data provides a body of IUS examples that operate for different hazards, situated in a variety of institutional, political and legal contexts; and have varying levels of complexity. Here a set of IUS classification frameworks are presented that describe the interactions needed to develop an IUS from the outset. These frameworks allow the classification the attributes of IUS for Demonstration Cities that other cities can use as exemplars.

4.2 IUS classification frameworks

Qualitative analyse are intended to provide information on IUS (see Box 9 for terminology), specifically:

- Data exchanged between services (cross-service integration)
- Level of engagement with urban sectors (cross-sector integration)

4.2.1 Cross-service integration

An IUS is predicated on the exchange of appropriate data between each of the four services under consideration here. Table 4.1 shows examples of these exchanges. Note the information in the cells is not meant to be exhaustive but shows necessary and beneficial data flows between services. Practically, data gathering and hosting may be accomplished within one or more organizations, requiring institutional barriers to data transfer to be overcome. For example, often meteorological and air quality data are gathered by different organizations within the same jurisdiction of an IUS. Similarly, some services may gather the same variable for different purposes; thus, meteorological and hydrological services may both have raingauge networks that operate independently.

4.2.2 Cross-sector integration

Table 4.2 presents examples of potential IUS for various user types. One of the important measures of integration is the level of engagement by sectors in the use and co-design of IUS, including investments in personnel and infrastructure to support the IUS. The table outlines the types of information that might be needed to support short- to long-term issues, which entail cross-sector integration.

For large cities, data gathering and dissemination are often components of networks in which knowledge and information is shared. Network creation and sharing of data are very important part of building an IUS. Many applications may not be covered in the examples, such as small-scale wind studies for building construction; these are often performed by private companies.

Box 9: Partners and integration

In this Guidance, we define two types of partners in the design and delivery of an IUS:

Service partners are the providers of the IUS (defined here as weather, climate, hydrological and air quality services). Integration of these partners is referred as cross-service and is underpinned by the exchange, combining and merging (coupling) of scientific knowledge and information. In expanded definitions of IUS other service providers with a focus on, for example bio-diversity, environmental law, could be incorporated.

Sectoral partners include the IUS providers, various urban customers (such as economists, sociologists, regulators and policymakers) and City Authorities. Integration of these partners is termed cross-sector; the level of integration is dependent on the degree of shared investment in the design and management of the IUS to facilitate information and data flow on more than one urban hazard.

Co-production describes higher levels of partnership.

The highest level of Integrated Urban Services occurs where it is the outcome of both cross-service and cross-sector integration.

Table 4.1. Service Integration: examples of data flow between urban services that would be needed to produce an IUS

Integration between services based on the flow of data from one service to one other. In each row, the data generated by each type of service that is of value to the other service (column) is shown; the diagonal columns are empty as the data generated is of obvious value to the service that generated it.

Services	*Weather*	*Hydrology*	*Climate*	*Air Quality*
Weather		Precipitation, tides, weather forecasting	Long term datasets (e.g. temperature, humidity, precipitation, cloudiness, brightness, visibility, wind, short-wave radiation, atmospheric pressure)	Drives day-to-day variability in air pollutant transport and concentration
Hydrology	Evaluation data, initial data for improving forecasting, moisture content, land type and use, ground water levels; surface temperatures of water bodies		Short-term data adding to long-term trends on water resources, soil moisture, precipitation, snow melt, ground water, river flows, droughts, flooding, run off, river levels, sea level	Land use, irrigation, fertilizers, ammonia emissions
Climate	Radiation, changes to weather patterns e.g. precipitation, wind, surface radiation, droughts, cold spells, heatwaves; UHI, changes in urban design; changes in vegetation cover	Climate driven long-term changes in sea level, land use, river flows, precipitation, ground water levels, water quality and availability, flooding frequency, urban planning / design		Changes in meteorological parameters (e.g. wind, mixing height, radiation); future air quality (e.g. PM, NOx, O_3), changes in air pollution emissions (e.g. biogenic emissions, pollen), pollen season; land use patterns, changes in frequency of high air pollution events, need for management and adaptability; new composition relations
Air Quality	Visibility, local radiation balance, cloud seeding, synoptic circulation regimes multi-hazards (e.g. air pollution episode and hot and cold spells)	Deposition of air pollutants on marine and other water bodies; deposition to soils (soil and groundwater pollution)	SLCP effect on radiation balance and climate; surface nitrification to assess ecosystem effects; determination of urban green (pollutant resistant)	

Table 4.2. Sectoral Users of an IUS. Potential users (customers) categorized into sectors, and the types of information that need contributions from different service types.

IUS	*Health*	*Disaster management*	*Water management*	*Energy management*	*Industry*	*Transport management*
Partners	Municipal urban planning					
	Health services / hospitals	Municipal services including civil defense	Civil bodies, water supply / management, industry	Energy production and infrastructure bodies	Industries	Roads / rail / airport / harbour authorities and corresponding users (e.g. airlines) and industries
Information	Health-specific information to responsible bodies. General information for public (diverse channels)	Rapid and timely warning systems to enable appropriate responses by official and public (TV and social media)	Information relevant to short, medium- and long-term excess / deficient water / snow resources, drink water amount and quality; data to establish risk statistics and standards	Information relevant to short, medium- and long-term decisions affecting energy demand, supply (black out) and production.	Directed information to relevant authorities that might include reports and detailed analyses; tailored IUS for relevant industries	Directed information to relevant authorities that might include reports and detailed analyses
Weather	Temperature, heat stress, wind and storm advice, UV radiation	Timely information that allows for rapid decision-making on meteorological hazards such as wind-storms	Precipitation distribution from short-term events to multi-year series for supporting decision-making	Energy demand (heat / cold wave) events, energy production (solar / wind) and distribution (infrastructure maintenance)	Design codes for building infrastructure storm tide events.	Disruptive weather including snow, ice, fog, high wind, etc. events,
Hydrology	Water quality, disease transmission	Rainfall, flooding, surface run off, drainage	Water resources for settlements, winter snow packs	Water resources for hydro-electric systems. Disruptive events such as flooding	Design codes for drainage infrastructure	Disruptive hydrological events.

Climate	Changes in urban climate, heat stress, drought and cold days, heatwaves, changes in diseases, changes in seasonality, deterioration in water and air quality, security, water availability, pollen season	Long-term changes to extreme weather and hydrological events, including heatwaves and intense precipitation events	Long-term systemic changes of climate, sea-level, ground water level	Heating and cooling degree days. Supporting information on renewable energy and limiting urban fossil fuel consumption	Codes for building infrastructure and settlements that may include urban design and planning	Long-term changes to infrastructure to regulate GHG emissions through technology, design and behaviour
Air Quality	Population exposure to air pollutants, increased mortality, adverse health outcomes	High pollution episodes that are linked to emissions within the city and transport from events outside the city such as forest fires	Atmospheric deposition into water bodies, acid precipitation	Emission controls on pollution sources through regulations, fuel management and measurement	Emission controls and source attribution	Emission change ("go green") and control

4.3 Assessing levels of integration

The sophistication of an IUS is assessed by the degree of cross-service and cross-sectoral integration. This assessment is applied to the Demonstration City Summary information to classify each according to the maturity of an IUS.

Cross-service integration is evaluated based on the information flow among the four Services (Table 4.1). As an example, hydrological services depend on inputs of weather data, primarily precipitation measurements and perhaps predictions. A high level of integration would be indicated if there is a partnership between the weather and hydrology agencies where the weather agency provides a tailored, dedicated fast transfer of the data to the hydrology service. Absence of integration is indicated if the hydrology service must obtain data from elsewhere or on its own. The diagonal elements in Table 4.1 represent the level of integration of each service itself. A city with multiple water courses, each in the responsibility of a separate hydrological service agency, would be poorly integrated in comparison with a city in which a single agency provides a single and consistent service.

In assessing Demonstration City IUSs along this axis, two questions are posed (Table 4.3):

a) What is the nature of a service (diagonal shaded cells)?
b) How is a service combined with another service (off-diagonal cells)?

Cross-sector integration is evaluated based on the urban impacts that an IUS is designed to address (e.g. health, disaster management, water management, energy, other industry and transport, Table 4.2). As an example, transport is impacted by weather (e.g. wind, road conditions such as ice and visibility), hydrology (e.g. sea conditions for shipping) and air quality (e.g. emissions regulations for vehicle engine regulations). Higher levels of integration are demonstrated by partnerships with representatives of relevant Sectors; such as an IUS providing information on exceedance thresholds, where significant impacts may be expected, that are defined by the international, national or municipal agencies responsible for AQ policy, standards and their regulation. A low level of integration is where for example AQ agencies use only the online generic public weather forecasts. The highest level of integration is where the Services work with Sectors to co-produce and co-maintain an IUS.

In assessing Demonstration City IUSs along this axis, three questions are posed (Table 4.4):

a) Which partners should be involved? What partners are willing to be involved?
b) Is the needed partner willing to provide the information? How can the IUS specific information be properly used and combined? What legal aspects are to be considered? Can a co-production be achieved and a win-win situation be created?
c) Type and form of weather, hydrological, climate and air quality (W/H/C/AQ) information needed by the health services?

A fully integrated IUS is demonstrated where the Services collaborate (through knowledge sharing based on information flows) and these are linked formally to urban-user needs through a process of co-design.

Table 4.3. Questions to assess the level of cross-service integration between and within services based on data flow from one service to another and the internal collaboration (diagonal shaded cells, Table 4.1) within a service (services do not have to be provided by only one institution).

Services	*Weather (W)*	*Hydrology (H)*	*Climate (C)*	*Air Quality (AQ)*
Weather	What is the nature of the W service – how integrated?	How does the H service obtain weather data – how closely coupled?	How does the C service obtain W data – how closely coupled?	How does the AQ service obtain W data – how closely coupled?
Hydrology	How does the W service obtain H data – how closely coupled?	What is the nature of the hydrology service (coastal/ fluvial/ pluvial flood & drought) – how integrated?	How does the C service obtain H data – how closely coupled?	Does the AQ service obtain H data – how closely coupled?
Climate	Does the W service obtain C data – how closely coupled?	Does the H service obtain climate data – how closely coupled?	What is the nature of the C service – how integrated (covers weather, hydrology & AQ)?	Does the AQ service obtain C data – how closely coupled?
Air Quality	Does the W service obtain AQ data – how closely coupled?	Does the H service obtain AQ data – how closely coupled?	Does the C service obtain AQ data – how closely coupled?	What is the nature of the AQ service – how integrated?

Table 4.4. Questions to assess impact of IUS services in various sectors

	Health	*Disaster management*	*Water management*	*Energy*	*Industry*	*Transport*
Partners	Which partners have to be involved? What partners are willing to be involved?					
Information	Is the needed partner willing to provide the information? How can the IUS specific information be properly be used and combined? What legal aspects are to be considered? Can a co-production be achieved and a win-win situation be created?					
W/H/C/AQ Service(s)	What type and form of W/H/C/AQ information is needed by the health services?	What type and form of W/H/C/AQ information is needed by the emergency - disaster management services?	What type and form of W/H/C/AQ information is needed by the water supply and drainage sector?	What type and form of W/H/C/AQ information is needed by the energy sector?	What type and form of W/H/C/AQ information is needed by industry?	What type and form of W/H/C/AQ information is needed by transport services?

4.4 Evaluating IUS in Demonstration Cities

In the following, the principles discussed above to map Demonstration Cities in terms of levels of integration are applied. Information provided in the Summaries (Annex 3) are used in this qualitative analysis. Keep in mind that the Summary template used to gather information was limited in scope and so this exercise should be seen as indicative of the range and complexity of the IUS already in place. It will also become clear that there are a variety of approaches to provide the same IUS. For example, note that some of the Demonstration Cities are part of a national system of service provision where IUS must be designed to suit city needs while other are 'city-states' where the distinction between general and urban services is moot.

The IUS in the Demonstration City Summaries are at different stages of maturity completeness with differing requirements. At each stage in the IUS development, challenges, issues, and new solutions, arise. Therefore, when designing or planning a new IUS, look both at services already completed and in development. This should be useful in the early stages of IUS planning.

4.4.1 Cross-service analysis

The IUS itself should provide a service that brings more value than just the juxtaposition of data from several sources, by a greater level of integration or combination of Services. For example, using a website where both meteorological and AQ data is available for use fulfills the lowest level of integration, but co-analysis of the meteorological and AQ data would provide added value (consistency, accuracy, efficiency) such as improved indicators and forecasts and is a higher level.

To integrate Services, useful data must exist and be available, at least between the partners involved in the construction of the IUS. For example, providing rainfall data from the Weather Service may allow the Hydrological Service to improve and produce precise flooding information. Thus, to provide the service, free and open data exchange, within and between WMO Members and Service provider partners is strongly recommended.

Ultimately, the IUS has to be delivered in a useful form otherwise it will not be used. This can happen in several ways, depending on the requirements of the end user and of the IUS itself. For example, it could be delivered to public or emergency services (through alerts and warnings via internet, TV and smartphones), newspapers, city documents (as urban planning legal documents), or even to ftp-sites for use by other institutions, and so forth. These will be highly tailored products and considered the highest level of integration.

The overall picture of cross-service integration extracted from the Summaries (Figure 4.1) shows that the links between Weather service and other services is by far the strongest, followed by Climate. Considering Service pairs, Weather/Hydrology are strongly integrated while Weather/Climate and Weather/Air Quality only slightly less. Hydrology/Air Quality integration is understandably weak. Climate/Hydrology is strong and Climate/Air Quality is less so. Air Quality services have the weakest overall integration (except to Weather) and was most likely to be part of a research project.

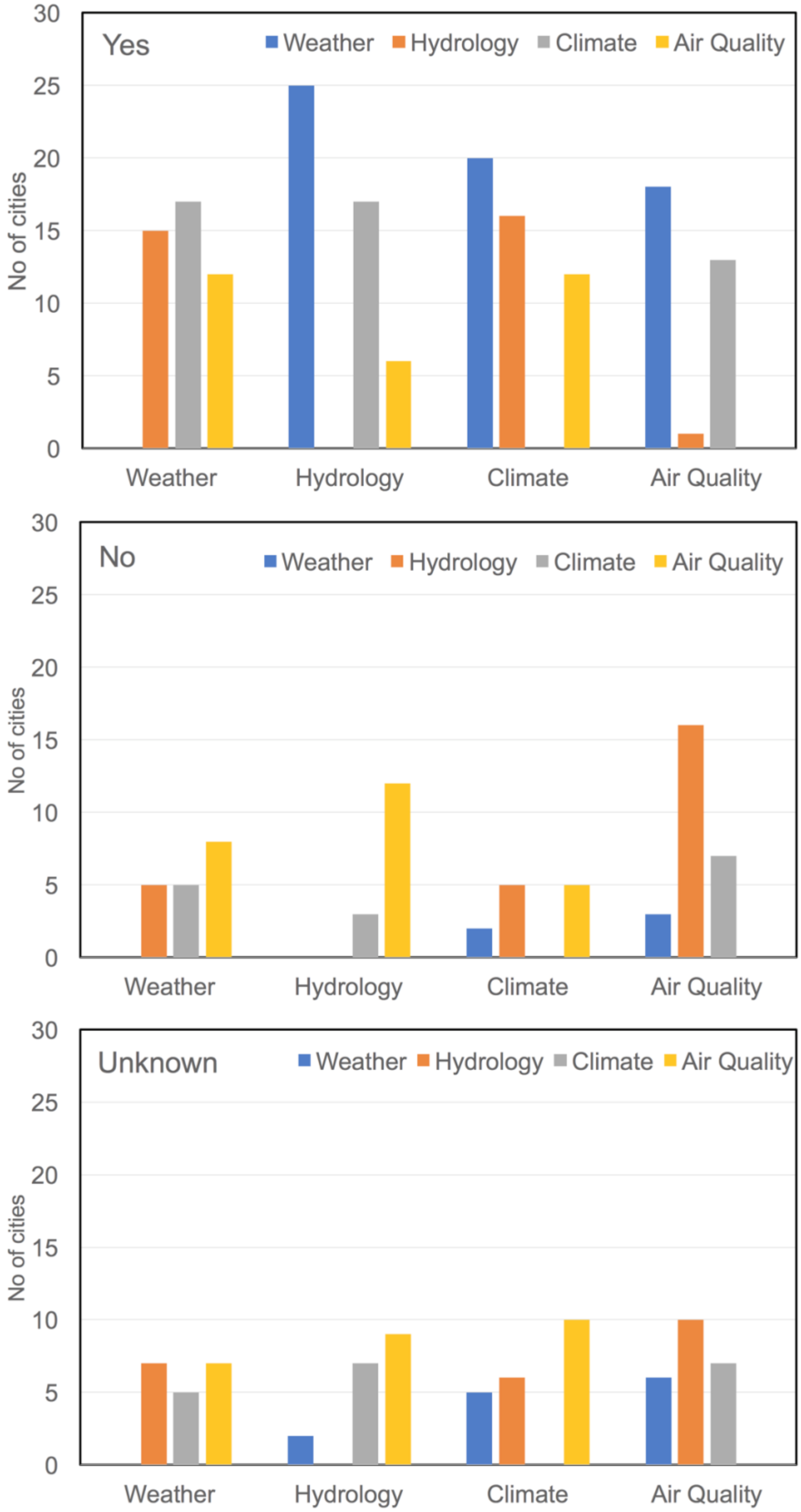

Figure 4.1. Number of Demonstration Cities with interaction between providing (labelled 'Yes', top), or not providing that service (labelled 'No, middle) or where provision of the service is unclear (labelled 'Unknown', bottom).
Total number of Demonstration Cities is 27.

Source: Heinke Schluenzen

4.4.2 Cross-sector analysis

The lowest level of integration occurs where the Services design and implement an IUS with no significant engagement with urban sectors or the city authorities. This is typically the case of services provided by WMO Members at the national level, where forecasts and warnings/alerts are provided for institutions and the public without regard to location. The Member may, for example, provide some general guidance for city inhabitants in case of extreme events (e.g. to avoid vehicle travel because of risks of tree falls, icy roads or river flooding) and may even have completed some minimal cross-sectoral engagement such as to identify needs. However, City authorities have had no substantial engagement with the design and evaluation of the IUS.

Higher level integration that produces specific, city-tailored IUS need the City Authorities (or acting agencies), to be involved in the creation and implementation process, through financial or in-kind (expertise, time and/or provision of fine scale urban data) investments. This requires also a specific investment from the WMO Member. This co-production will tailor Service provision to the specific needs of individual cities. For example, for urban planning and climate plans, City Authorities may simply use observed data from the nearest synoptic weather station (often the airport) to specify building codes. This would be a base level IUS. However, a more complex IUS, co-designed and co-constructed with City Authorities (e.g. contributing monitoring stations) might include fine scale urban and intra-urban meteorological data to include local urban climate. A temperature monitoring network within the city may provide information on the spatial nature of the urban heat island.

A higher level of partnership would involve IUS providers, City Authorities, researchers (e.g. social scientists) who would define improved ways to identify and transfer or translate the urban climate information, such as urban climate maps, for application to urban planning. Other high cross-sector partnerships include: (i) involving health expertise in specifying observation requirements and defining thresholds for hazardous AQ or temperature alerts (heat and cold), (ii) involving AQ expertise as well as legal, technical and socioeconomic expertise to alter the urban structure, land use, traffic and zoning by-laws. In terms of emissions, air pollutants and the urban structure have a complex relationship. Improving fine scale knowledge of emissions, air pollutants and particle concentration information in cities may lead to better predictions and therefore more effective health warnings.

The overall picture of cross-sector integration extracted from the Summaries (Figure 4.2) shows that the Weather Service is involved in the greatest number of IUS in the Demonstration Cities and was highest for Air Quality. Disaster Management (and reduction) is a sector needing all services. Weather for Health, Water Management and Transport, Hydrology for Water Management, and Air Quality for Health are noted in the Demonstration Cities. Energy applications are least developed; Energy, Industry and Transport are less common than Health, Disaster Reduction and Water Management. The lowest frequency Service / Sector pair was Air Quality for Water Management.

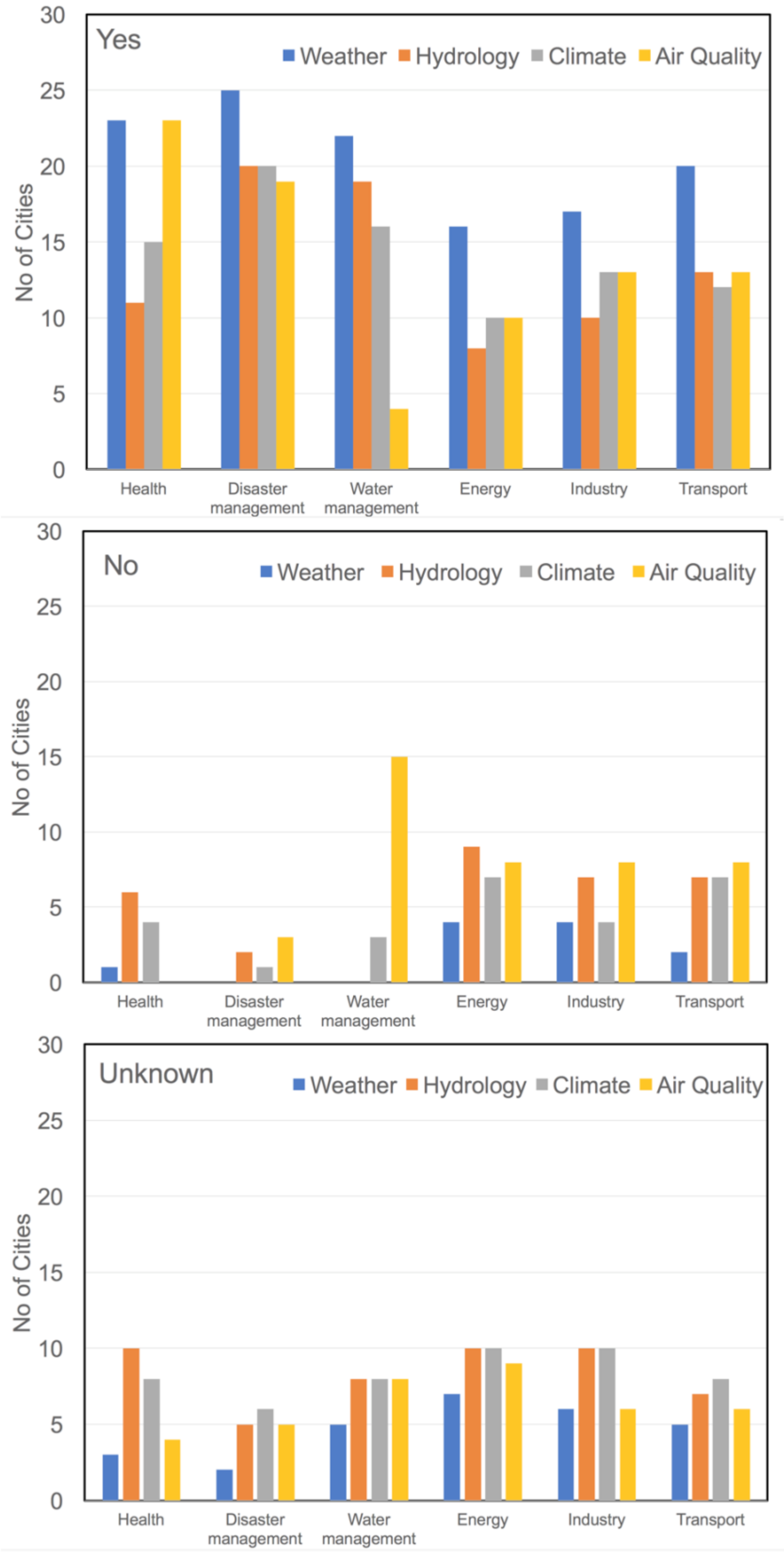

Figure 4.2. Sectors that used weather, hydrology, climate or air quality services based on the Demonstration City Summaries. 'Yes' indicates that it was clearly stated in the Summaries that the sectors used the services, 'No' that they did not and 'Unknown' indicates where it was not clear. Number of Demonstration Cities is 27.

Source: Heinke Schluenzen

4.5 Overview of the IUS in Demonstration Cities

The Urban Expert Team (UET) used the principles and analysis discussed above to place IUS examples for the Demonstration Cities within a schematic that consists of four quadrants (Figure 4.3). The vertical axis represents the degree of cross-service integration and the horizontal axis the degree of cross-sectoral integration. The symbols represent three types of IUS that deal with daily operations (e.g. weather forecasts), emergencies (short term, hazard events) and planning (long term, climate events) issues. A City that has several IUS can appear on this diagram in several places.

Moving from left to right is a measure of the level of integration between Service providers and urban partners (cross-sectors). On the left, services are provided but there is no substantive engagement with the urban partners and City Authorities in particular. On the right, the IUS is a product of ongoing collaboration with City Authorities and is likely to engage socioeconomic scientists, regulatory agencies and policymakers.

Moving from top to bottom indicates the level of integration among the four Services. At the top the IUS provides limited information (often just data) that has been generated by linking two or more Services. Toward the bottom, enhanced collaboration among the Services supported by data sharing supports the development of highly tailored products at urban scales using numerical and/or statistical models. Not all services need to be integrated in a particular city, it will depend on the requirements for the IUS; as examples, Mexico City and Stuttgart were judged to have a high level of cross-service integration.

The top left quadrant represents IUS that have limited cross-sectoral and cross-service integration; these IUS provide information that links few services, has undergone limited processing to support city-specific needs (Figure 4.4). The top right quadrant is distinguished by the level of integration with urban partners to meet their needs; this includes engagement to develop the IUS itself and link the information provided with decision-making. The lower left quadrant represents the development of sophisticated systems that joins the knowledge and products of individual services to create enhanced products such as climate projections and (multi)hazard forecasts for individual cities. The lower right quadrant represents the highest level of integration along both axes that is, sophisticated products developed in collaboration with urban partners.

It should be noted that as an IUS matures over time, a IUS will shift to the right and toward the bottom within this schematic. Naturally, the IUS will depend on the capacity, capability, maturity and resources of both WMO Members, City Authorities and other urban sectors. For the former, current WMO *Members* services may be sufficient to cover the initial needs of the city. In the latter case, the City Authorities and others will have contributed resources that may impact the design, construction, production and implementation of IUS.

The location on this diagram represents a judgement of the UET based on the evidence in the Summary data (Annex 3); Chapter 5 extracts aspects of these data to provide examples.

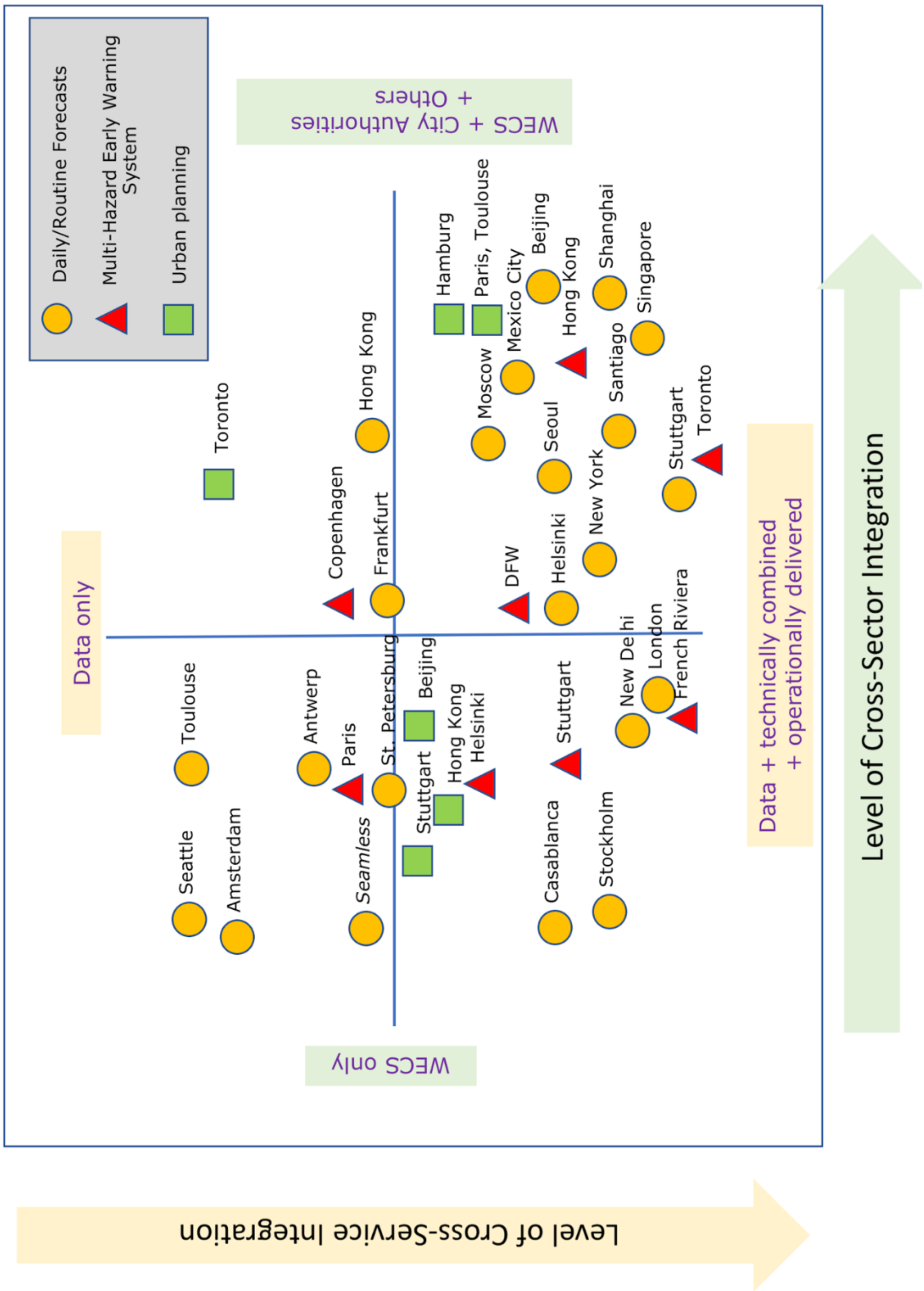

Figure 4.3. Demonstration Cities assessed by the UET, based on data provided in the Demonstration City Summaries. Data are plotted of the degree of multi-service integration with degree of multi-sector integration. Symbols represent the general application of IUS; a Demonstration City may be plotted more than once to represent the different status of a specific IUS component. WECS refers to weather, environment and climate services. Figure 4.4 provides interpretation of the cross-service and cross-sectoral integration and Table 4.5 provides a legend.

Source: Valery Masson

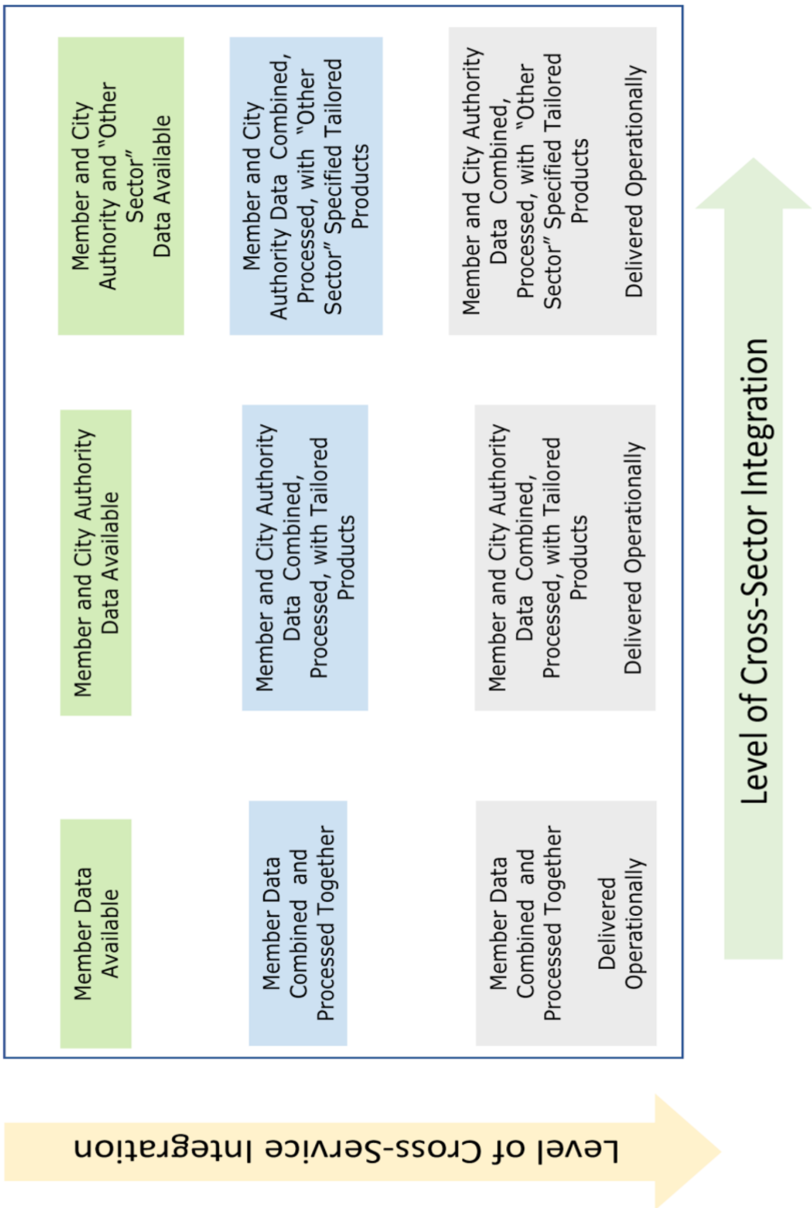

Figure 4.4. Explanation for the degree of cross-service with degree of cross-sector IUS classification

Source: Paul Joe

Table 4.5. Cross-service, cross-sector integration level legend

● Amsterdam	AQ data on website
● Antwerp	Flood control plan
● Beijing	Many sectors, Weather, Climate, Hydrology and AQ services with users
■ Beijing	Urban ventilation corridor and urban climate map for urban planning
● Casablanca	Weather forecast and climatological information for urban planning
▲ Copenhagen	Climate and extreme weather
▲ Dallas-FW	Severe storms hazard; Uses data generated by NWS, city agencies and third-level for severe storm hazard.
● Frankfurt	Weather services. Across all services
▲ French Riviera	Flood emergency local forecasts and assistance to emergency services
■ Hamburg	Multisectoral and multidisciplinary climate adaptation and mitigation strategy including adopted urban planning.
● Helsinki	Weather and Air Quality forecasts and warnings
▲ Helsinki	Forecast of dispersion (for security issues)
▲ Hong-Kong	Typhoon and storm surges for Emergencies
■ Hong-Kong	Typhoon and storm surges for daily operations
● Hong-Kong	Long term urban planning
● London	Thames barrier flood service
● Mexico City	Multi-hazard management in command center, comprehensive air quality and climate action plans, personal health index.
● Moscow	Comprehensive UIS for weather, AQ and hydrology feeding Moscow government, urban monitoring network and urban modelling in development.
● New Delhi	Air Quality warning to city management and traffic control
● New York	Integration in city office to make climate change projections
▲ Paris	Road watering for cooling in case of heatwave
● St-Petersburg	Operational IUS; ongoing development related to fresh water availability and urban planning.
● Santiago	Comprehensive air quality management and climate action plans, including daily forecasts of meteorology and air quality; Green tax on new cars, power plants and industries.
● Seattle	Diffusion of meteorological and air quality data on website
● Seamless	NMHSs seamless tools developments would typically be there
● Seoul	Integration of observations, model and user-specific services
● Stockholm	Copernicus project C3S UrbanSis on AQ, Weather and Climate
● Stuttgart	Heat Warning System. DWD forecast is used and modified with web-based and e-mail messaging.
● Shanghai	Weather link to AQ and AQ link to health
● Singapore	The 4 services produced with City Authorities with ongoing development.
● Toulouse	Dense open-data urban meteorological stations network
▲ Stuttgart	Heat warning system
■ Stuttgart	Urban development outline plan
■ Paris, Toulouse	Multidisciplinary evaluation of adaptation strategies and planning
▲ Toronto	AQ, weather, health forecasting for emergency services and PanAm organizers
■ Toronto	GHG, AQ modelling and monitoring with information for local stakeholders

CHAPTER 5. DEMONSTRATION CITY EXAMPLES

5.1 Introduction

In this chapter, the Demonstration City Summaries (Table 3.1), provided in Annex 3, are reviewed for good practices against the framework detailed in Chapter 4.

Volume I of the Guidance on Integrated Urban Hydrometeorological, Climate and Environmental Services[1] was dedicated to the concept and methodology. Chapter 6 lists seven recommendations. The current report illustrates these recommendations using examples from the Demonstration Cities.

5.2 Don’t wait for disaster

> Integrated Urban Services are assisting decision-makers and end users; it is important not to wait for a disaster to act. There are examples of well-functioning Integrated Urban Services that can be used as a template for development.

5.2.1 Pollution forecast and emission restrictions

In Santiago, the providers of urban services are mainly government services (ministries). The Ministry of the Environment together with the Chilean Meteorological Service are responsible for providing daily forecasts of meteorology and air quality. Air quality forecasting tools are included in the decision-making process and are required for predicting pollution episodes to reduce exposure to harmful levels of pollutants. A system forecasting $PM_{2.5}$ three days in advance has been implemented and has enabled the local government to make contingency-based emission restrictions. As a consequence, there were 36 pre-emergency and emergencies for $PM_{2.5}$ in 2013 but only 2 in 2017 (Annex 3). Forecasts and meteorological bulletins are published daily by the Chilean Meteorological Service through the website and television (news) and social media (e.g. Facebook, Twitter and Instagram).

5.2.2 Integrated severe weather, air quality and health warning system

Toronto hosted a high-profile sporting event, the Pan and Parapan Games in 2015. Many events occur simultaneously, at many venues, and with large crowds who may be exposed to heavy precipitation/flooding, lightning, strong winds including tornadoes, hail, heat stress and poor air quality. Toronto is situated near a lake and the lake breeze can have a significant impact on thunderstorm initiation, heat stress and air quality. Previous experience (Olympics, papal visit, music festivals) with events with large crowds established the requirement for high spatial and temporal precision and accuracy, multi-hazard nowcasts including public warnings for severe weather, air quality and heat stress (health) warnings at specific venues. An urban network of black globe thermometers (used to calculate heat stress) were deployed. The venue specific warnings, in addition to the normal public warnings (targeted for much bigger area), were disseminated to event organizers, emergency planners, police (multiple levels), civil and health authorities. Specialized briefings, tailored products and protected websites

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[1] https://www.wmo.int/pages/prog/arep/gaw/documents/UrbanIntegratedServicesPart1aConceptandMethodologyEC-70.pdf

were created. Specific training was developed and dedicated forecasters provided interpretations as required.

5.2.3 *Integrated city service for disaster prevention*

In New York City (NYC), government, stakeholders and end users plan together to prepare for disasters. The NYC city planners are responsible for the regulations, laws, plans and policies and the NYC emergency management look after mitigation and preparedness strategies for hazards and disasters. Different providers such as Volunteers of America, Center for Urban Community Services, Samaritan Village, Project Renewal and others work together at the time of crisis[2]. Academic institutions such as State University of New York and Columbia University, work together to mitigate climate change risks and hazards. Different programmes and initiatives such as Notify New York City, New York City Severe Weather, Know Your Zone and Partners in Preparedness have developed adaptation analyses and regulations. For example, Community Risk and Resiliency Act are in place to understand and provide service at times of hazards[3]. NYC has a presence on many social media channels. It facilitates real-time, two-way communication between City Authorities and the public.

5.2.4 *Integrated service for public health, water, energy with infrastructure design for disaster risk reduction*

In Hong Kong, the Hong Kong Observatory (HKO, the meteorological authority in Hong Kong) has successfully cultivated close partnerships with various stakeholders to enhance its weather and climate services over the years. In alignment with the priority areas of the Global Framework for Climate Services (GFCS) of WMO (WMO, 2018) the Big Data concept was used in recent years (Shun and Chan, 2017), in particular in areas related to disaster risk reduction, energy, water, and health.

HKO has been studying, in collaboration with other government departments, tertiary institutions, and social enterprises, the impact of weather on public health in Hong Kong. Some examples include:

- With Chinese University Hong Kong (CUHK) collaborated to develop the Hong Kong Heat Index (HKHI) for use in hot and humid sub-tropical climate in Hong Kong (Lee et al., 2016) and to study the health impacts of extreme hot weather events to the city (Wang et al., 2018; Lau and Ren, 2018).
- Collaboration with microbiologists of the CUHK to study the seasonal variations of influenza in Hong Kong (Chan et al., 2009).
- Working closely with the Senior Citizen Home Safety Association to study how weather and climate impact the health of senior citizens (Mok and Leung, 2009; Wong et al., 2015) and to enhance care services for the elderly in Hong Kong through the utilization of weather and climate information (HKO, 2018; Lee and Leung, 2016).

To support water resource management, HKO has been providing monthly forecasts of yield in Hong Kong reservoirs to the Water Supplies Department since 2010. Verifications showed that the yield forecast is generally better than climatology, demonstrating the benefits of climate prediction for managing water resources (Lam and Lee, 2012).

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[2] https://www1.nyc.gov/site/dhs/shelter/providers/providers.page
[3] https://www1.nyc.gov/site/em/index.page; https://www.dec.ny.gov/energy/100236.html

After Severe Acute Respiratory Syndrome happened in 2003, a series of application-based urban climate related governmental consultancy projects were launched, design measures formulated and implemented into local planning and development (Figure 5.1) (Ng, 2009; Ren et al., 2011). HKO has been providing technical support and weather records in these consultancy projects. Knowledge of the impact of high density urban morphology on local climatic condition and design related outcomes from Hong Kong have been adopted by other application-based projects in mainland China and overseas (Ren et al., 2018).

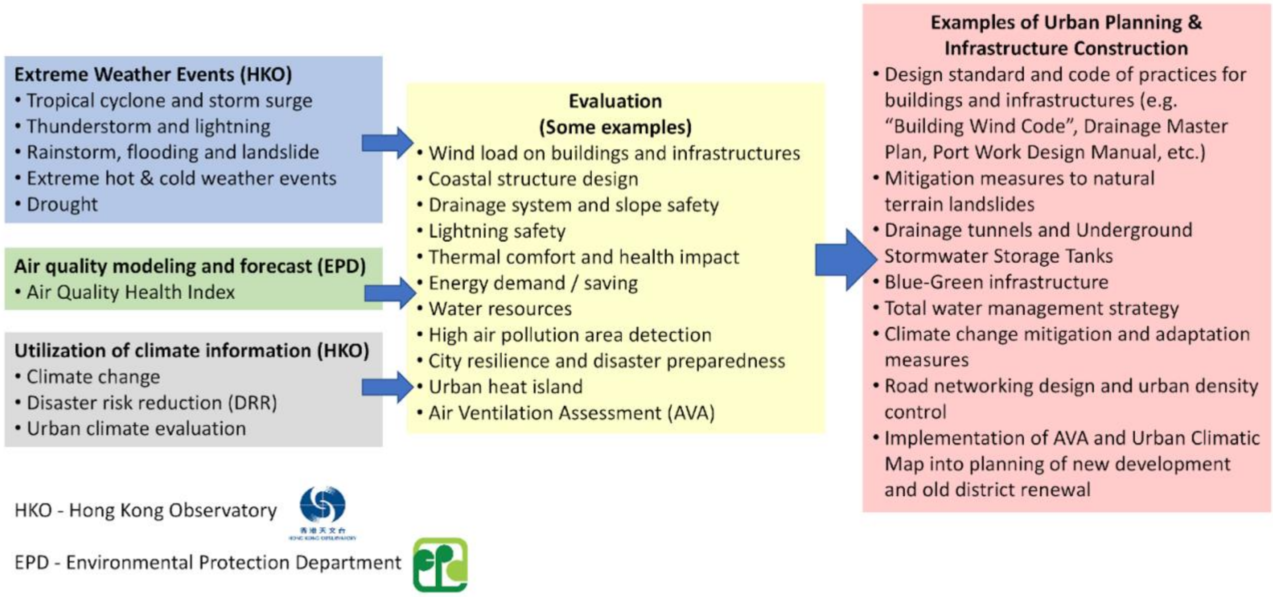

Figure 5.1. Examples of the integrated weather, climate and environmental services in urban planning and infrastructure in Hong Kong

Source: T.C. Lee, HKO

With a view to promoting energy efficiency and conservation, HKO and Power Hong Kong Limited have collaborated to provide a 9-day Energy Forecast from the HKO 9-day weather forecast. The energy forecast allows property managers to plan energy saving measures to reduce electricity consumption and peak loading under hot weather situations with significant results (Cheung et al., 2016).

Over the years, HKO has worked closely with different engineering departments and professional bodies to establish, and regularly review, the engineering design standards and codes of practices appropriate to local conditions for protecting the city and public safety against various weather hazards and natural disasters. Some examples include the Code of Practice on Wind Effects; estimation of extreme rainfall return periods and probable maximum precipitation; and anticipated highest sea level is incorporated in the Port Works Design Manual.

5.2.5 Leadership by WMO Members

Encourage Members to lead and contribute in partnership to the promotion, development and coordination of Integrated Urban Services, including knowledge transfer.

WMO *Members* have the capability and experience to conceive and implement IUS.

Since 2007, Shanghai Meteorological Service (SMS) has successfully conducted four WMO programmes including Shanghai Multi-Hazard Early Warning System (MHEWS), Shanghai GURME, and Shanghai Typhoon Land Falling Forecast Demonstration Project under the support of China Meteorological Administration. The research projects effectively promoted the development of modern meteorological practice and played an important role in crises and risk management. In August 2013, WMO convened the MHEWS and Megacity Implementation Plan Expert Meetings in Shanghai.

Through introducing advanced technology and weather / climate disaster management theory, Shanghai Integrated Urban Weather and Climate Service Demonstration Project (IUWCS) aims to develop seamless multi-time-scale weather forecast capability. With the use of numerical models, the project will develop an impact-based forecasting and warning system, improve urban climate services, interact with users of information services and help the city to manage risks caused by climate change. The project is an extension of Shanghai MHEWS as well as a demonstration of how GFCS can be applied to urban areas. At the research frontier of disaster prediction and reduction, IUWCS represents the international community’s joint efforts to adapt to climate change.

Box 10. Beat the heat!! - Ahmedabad India – UNESCO Heritage City

Since 2011, Ahmedabad, a city in western India with over a 7 million population, along with national and international organizations developed an efficient and effective Heat Action Plan (HAP)[a]. The three key strategies were: 1) to build public awareness and community outreach on the risks of heatwaves and practices to prevent heat related diseases; 2) initiate an early warning system to alert residents; 3) training of medical professionals to recognize and respond to heat related diseases.

Figure 5.2. (left) Heat Action Plan (Indian Institute of Public Health). (right) Local resident reads advertisement in Gujarati with tips on how to stay cool during extreme heat events.

Source: Photo credit: Nehmat Kaur

Heat predictions were made 5-7 days in advance and accordingly utilized the early warning system to alert the governmental agencies, the Met Centre, health officials and hospitals, emergency responders, local community groups, and media outlets of forecasted extreme temperatures. Besides these action items, several preventive measures are also implemented, which include public awareness, community outreach, training health officials and access to potable drinking water and cooling spaces during extreme heat days. The Plan mainly focuses on those individuals who are most at risk during heatwaves, including slum communities, outdoor workers, elderly and children. The preventive measures include few very simple but vital measures like learning about early signs of heat exhaustion, limiting heavy work during extreme heat, drinking water, staying out of the sun; wearing light clothing, checking on neighbors, and informing their fellow community members about how to keep cool and protect themselves from heat.

The Ahmedabad HAP is the first one in south Asia, showcasing a unique example of integrated urban systems approach. With the leadership of the National Disaster Management Authority and Indian Meteorological Department as well as partners such as NRDC and the Indian Institute of Public Health - Gandhinagar (IIPHG), the HAP has now been implemented in 11 Indian states and 30 Indian cities.

[a] https://www.nrdc.org/sites/default/files/ahmedabad-heat-action-plan-2018.pdf

5.3 Governance of IUS

Ensure that legal and institutional frameworks are in place in partnerships with cities that clearly define government agency mandates, interactions, roles and responsibilities to enable creation and maintenance of Integrated Urban Services.

5.3.1 State-wide regulations helping cities

The UK Civil Contingencies Act, 2004 (CCA) provides the governance framework for dealing with all types of threat to the public in the UK. It applies to all levels from UK to national to city to business to individual, providing a scalable model that could be copied elsewhere. It was enacted in the wake of perceived weaknesses in the emergency response to several major disasters around the year 2000, including floods, an animal disease epidemic and rioting. It defines an "emergency", as a human or natural threat that threatens serious damage to human welfare. It superseded the previous concept of civil defense against military threats that grew up following the Second World War.

It also broadened the scope of those involved beyond local government and the emergency services to include utilities and infrastructure authorities. It lays down requirements for risk assessment and for contingency plans, and defines who has responsibility and who has authority.

It mandates use of a Gold-Silver-Bronze command structure. Two types of emergency responder are defined in the CCA: Category 1, the core group of responders, consists of Local Authorities; police, fire, ambulance and coastguard services, health services, the Environment Agency, Scottish Environment Protection Agency and Natural Resources Wales. Category 2, consists largely of infrastructure operators: electricity, gas, water and telecommunications providers; railway, highways, airports and harbour companies; together with the Health & Safety executive and voluntary agencies. In an emergency, each responder has its own command structure but contributes to a multi-agency structure, hosted and chaired by the police. The gold commander provides remote strategic oversight. The Silver Commander manages its implementation, formulating actions that are implemented locally by the Bronze commander. The multi-agency silver command is typically located in a command vehicle at or near the scene.

Supporting legislation requires Category 1 responders to have regard to the Met Office's duty to warn the public, and provide information and advice, if an emergency is likely to occur or has taken place. This duty includes issuing warnings such as for severe weather and pollution episodes, together with tidal alerts.

5.3.2 Regulations at different levels – from state to local

In Mexico, Civil protection is supported by different levels of Mexican legislation, including:

(a) Constitution: article 123 covers security and health of workers in facilities.

(b) State Law: General Act for Civil Protection defines the general terms of each state law on civil protection and the regulation of each state on civil protection. Because Mexico City is also the capital of the nation, it can never become a state; however, Mexico City has the same level of autonomy comparable to that of a state. The following institutions are responsible for addressing urban hazards and the policymaking process:

1) National Water Commission: national plans and mandate for flood management.
2) National Meteorological Service: provides meteorological information at national and local levels; manages the climatological database.
3) National Centre for Disaster Prevention: in charge of risk management and disaster prevention in Mexico to reduce population exposure to meteorological, hydrological, geological and chemical hazards such as volcanic eruptions, flooding, tropical storms, earthquakes, and chemical releases, among others.
4) Secretariat of Environment of Mexico City: responsible for climate action plans and air quality management programmes, including air quality and meteorological forecast to alert the public about critical pollution levels and prevent exposure to harmful pollutants; announces contingency actions when measured pollutants levels are above critical threshold.
5) Megalopolis Environmental Commission: covers Mexico City and five surrounding states (Puebla, Tlaxcala, Morelos, Hidalgo and Mexico) in central Mexico. The commission plans and execute policies, handles air quality monitoring, emissions standards and smog-check issues in this region.

(c) The urban services for Mexico City are provided by the city government through the different agencies that report to the Mayor and to the public. The Center for Command, Control, Computation, Communications and Citizen Contact (C5) integrates the urban services to provide rapid response against emergencies in the city; agencies send information to C5 which reports directly to the Mayor.

5.3.3 Regulations for a city in a state

"Shanghai Implementation Regulation of the Meteorological Law of the People's Republic of China" was issued by Shanghai People's Congress on 1 October 2006. "Measures for the Defense of Meteorological Disasters" in Shanghai issued by Shanghai Municipal Government on 1st March 2017. These clarified the mandate of Shanghai Meteorological Service (SMS) in Disaster Risk Reduction (DRR) and weather/climate/environment service. Weather departments are required to provide services through multi-agency cooperation, and to receive support and feedback from different sectors, e.g. water, traffic and transportation, environment, emergency response and so forth.

Stuttgart introduced the "Feinstaubalarm" (PM_{10} alarm system) in 2016. This alarm system informs citizens during periods with poor air pollution dispersion conditions (October to April each year) that high PM_{10} concentrations are expected and the alert triggers actions for citizens, e.g. voluntarily switching to alternative transportation or prohibit use of woodstoves during the high PM_{10} alert period. A law was introduced managing the non-essential use of "comfort fireplaces" or woodstoves. The law was introduced by the city government in agreement with national and European law but is specific to Stuttgart. The PM_{10} alarm is disseminated via E-mail, websites, twitter, Facebook, radio stations, newspapers and several display panels in the city.

5.3.4 Regulations for a city state

The Meteorological Service Singapore (MSS) is a division of the National Environment Agency (NEA), which is a statutory board under the Ministry of the Environment and Water Resources (MEWR). The MEWR also oversees the Public Utilities Board (the national water agency) and the Singapore Food Agency (SFA). Synergistic issues of climate/weather, water, air quality and food security come under the remit of a single ministry (MEWR), enabling a holistic approach to policymaking.

The National Environment Agency Act, empowers the NEA, through MSS, to provide meteorological services for users, including government agencies, aviation and shipping communities and the public; maintain reliable climatological records of Singapore; and furnish advice on meteorological matters.

As a low-lying island state that is vulnerable to the impacts of climate change, the Government of Singapore is actively dealing with the challenges of climate change. To reduce carbon emissions, a carbon tax was introduced in 2019, which targets large industrial facilities. Under the Carbon Pricing Act, taxable facilities have to engage a third part verifier to verify their annual emissions report.

Cross-sectoral coordination necessary for the delivery of integrated urban services is enabled through a "Whole-of-Government" (WOG) approach adopted by Singapore government agencies. This approach allows the establishment of institutional frameworks to better manage and coordinate cross-cutting issues such as transboundary haze and climate change. For example, an Inter-Ministerial Committee on Climate Change was set up to enhance WOG coordination on climate change policies, such as long-term adaptation planning in areas such as coastal protection, water resources, public health, biodiversity and network infrastructure.

5.4 Involve multiple stakeholders

Engage with relevant stakeholders (academia, agencies, non-government organizations, the public, other Members, city government, private sector, businesses) from the beginning including raising awareness and getting feedback.

5.4.1 From city level to national actions

The benefit of IUS for cities has been shown in many cases. After initial research projects, French cities Paris and Toulouse decided to continue the co-development of operational IUS. Toulouse decided to install an observation network for urban climate. Paris city council commissioned a first research study in 2008 on adaptation strategies for heatwaves (present and future). Numerical modelling explored the influence of building color, vegetation and road watering in inner Paris and gathered evidence of the impact, efficiency and optimization of road watering during heatwaves and found potential impacts of more than 1°C on the thermal comfort index.

A national programme was initiated to understand the limitations and to determine which cities would benefit from IUS. A collaboration between the *Members*, the French federation of urban planning agencies (with 51 agencies) and social scientists was formed. A survey found the urban planning agencies do not have: 1) access to the same data, 2) the same expertise in climate and local meteorology, and 3) the same political environment. Another general conclusion of City Authorities was that it is not sufficient to have evidence from elsewhere, but there is a need to replicate the experience and develop experimental evidence in one's own locale. Experiences in other cities has helped to reach the first stage in the planning, development and use of an IUS.

A good way to initiate this use and coproduction of IUS with cities was common sources of information such as urban data (from the national mapping service) and meteorological data (which has the advantage of crossing administrative boundaries). During the project MApUCE, urban parameters were computed for 50 French agglomerations and are distributed freely as open-data. This access to new data, designed for urban climate studies, favours the coproduction of an IUS locally. Higher resolution data can be used, as local Authorities recognize the need.

Actions with French national stakeholders and institutions that support the needs of local ones has bolstered the diffusion of IUSs needs to city and agglomeration scale.

5.5 How research helps

Further research, including multidisciplinary cross-cutting studies, is needed to develop Integrated Urban Services capabilities.

5.5.1 National programmes

Because cities are a complex system, interdisciplinarity is essential to progress an IUS. Several research projects in Paris and other French cities had the objective of improving IUS capabilities for urban planning and adaptation of cities to climate change. These projects needed the collaboration of scientists from various disciplines: meteorologists, hydrologists, architecture, geography, sociology, economics, acoustics and environmental law. In addition, the participation of urban planning agencies and city administration is a key to success. Engaging such interdisciplinary researchers takes years, because of the different languages and expertise, but is extremely rich and allows the integration of several interconnected pieces of the urban system. This poses an important implication for *Members*, as urban characteristics such as city growth, human behaviour and architecture, are pertinent to developing urban modelling tools to evaluate the interactions between the urban heat island and the heat/air quality and waste heat release. It is also pertinent to study the interactions between climate change and city growth on population exposure depending on different density and urban vegetation strategies.

In some fields, the modelling tools are an efficient way to explore different concepts. Field studies help to explore and build a common interdisciplinary culture (e.g. micro-climate, acoustic, social perception) around a common urban area. Such interdisciplinary research sometimes leads to pure disciplinary advances, necessary to unlock questions asked by other disciplines. For example, to improve the transfer tools to urban planners, the development of local weather types (based on local weather near the city, e.g. from an observation stations) led to new Climate and Weather knowledge.

These research findings are now applied in operational IUS. Construction requirements of the Olympic Villages for Paris 2024, for example, were specified using (i) local weather characteristics, (ii) present and future climate conditions, (iii) classical climate zones, (iv) small-scale patterns of the city and (iv) classifying its Urban Heat Index. Interdisciplinary research, while long and demanding to put in place, is not only necessary for urban climate services studies, but also very rich and scientifically profitable, from the point of view of encouraging cross fertilization of different disciplines.

5.5.2 City programme for urban services

In Beijing, the Study of Urban-Impacts on Rainfall and Fog/Haze Project was launched in 2014 to investigate urban, terrain, convection, and aerosol interactions to improve weather and air quality forecast accuracy. Comprehensive multi-scale observations and modeling enable an international team of scientists to study, to understand and to better predict urban effects on heavy summertime convective precipitation as well as wintertime fine-particle pollutant episodes in the Greater Beijing Metro Area. The Rapid-refresh Multi-scale Analysis and Prediction System was developed including five off-line, one-way nested components: Nowcasting Model, Short Term Model, Urban Model, Integration Model, and Chemistry Model. The system operationally runs in the Institute of Urban Meteorology starting with global forecasts and terminating with weather and air quality forecasts for use by health, energy, hydrologic, climate change, air quality, planning, and emergency response managers.

5.5.3 City state research programme

In Hong Kong, HKO and the CUHK collaborated to develop the Hong Kong Heat Index (HKHI) for use in hot and humid sub-tropical climate in Hong Kong (Lee et al., 2016) and to study the health impacts of extreme hot weather events to the city (Wang et al., 2018; Lau and Ren, 2018). In-house heat stress monitoring systems automatically measure the dry bulb, natural wet bulb, and globe temperatures required to compute HKHI.

5.6 Open access data policy

Encourage Members to facilitate wider accessibility of data via influencing ownership issues and technical support.

5.6.1 City wide measurements

As part of an urban planning collaboration, the city of Toulouse (France) decided to build a monitoring network for urban climate. This could be expanded to air quality measurements in the near future. This meteorological network is composed of 60 semi-professional stations, and is included in the smart city policy of the city (Figure 5.3). The objective of this network is to better observe the environmental conditions of the area and to allow the production of IUS. It may facilitate display of fine scale urban weather forecasts, building heating systems pilots or design and so forth. Critically, these will soon be open access data, in order to promote the production of such IUS.

This shows the interest of the freely and open access data, both from cities and *Members* which could be extended to private companies (e.g. the NETATMO[4] personal stations network). All *Members* and actors are encouraged to make their data available freely for IUS production.

[4] https://www.netatmo.com/en-ca

Figure 5.3. Urban monitoring using compact stations in Toulouse. Note that the full three-dimensions of the atmosphere may need to be monitored, not just enhancements within the urban canopy layer as shown here.

Source: Valery Masson

5.6.3 City wide data

Dallas Fort-Worth provides open access data and information at the local government level as well as data from National Oceanic and Atmospheric Administration, National Weather Service, United States Geologic Survey and the Environmental Protection Agency. Several platforms which integrate and share data, inform end users of the benefit from the integrated systems. One such platform is the North Central Texas Council of Governments (NCTCOG), a voluntary association of, by and for local governments, established to assist in regional planning. Another is the Texas Commission on Environmental Quality (TCEQ), the environmental agency for the state of Texas. TCEQ manages a network of air monitoring sites across the Metroplex in accordance to national Environmental Protection Agency (EPA) regulations. The status of regional air quality is compiled annually in the North Central Texas Council of Government's Air Quality Handbook. These are easily available to all agencies and end users and support is provided to analyse and interpret. NCTCOG has organized the Urban Area Security Initiative.

This provides financial assistance to address the unique planning, equipment, training, and exercise needs of high-threat, high-density urban areas, and to assist them in building an enhanced and sustainable capacity to prevent, respond to, and recover from threats or acts of terrorism.

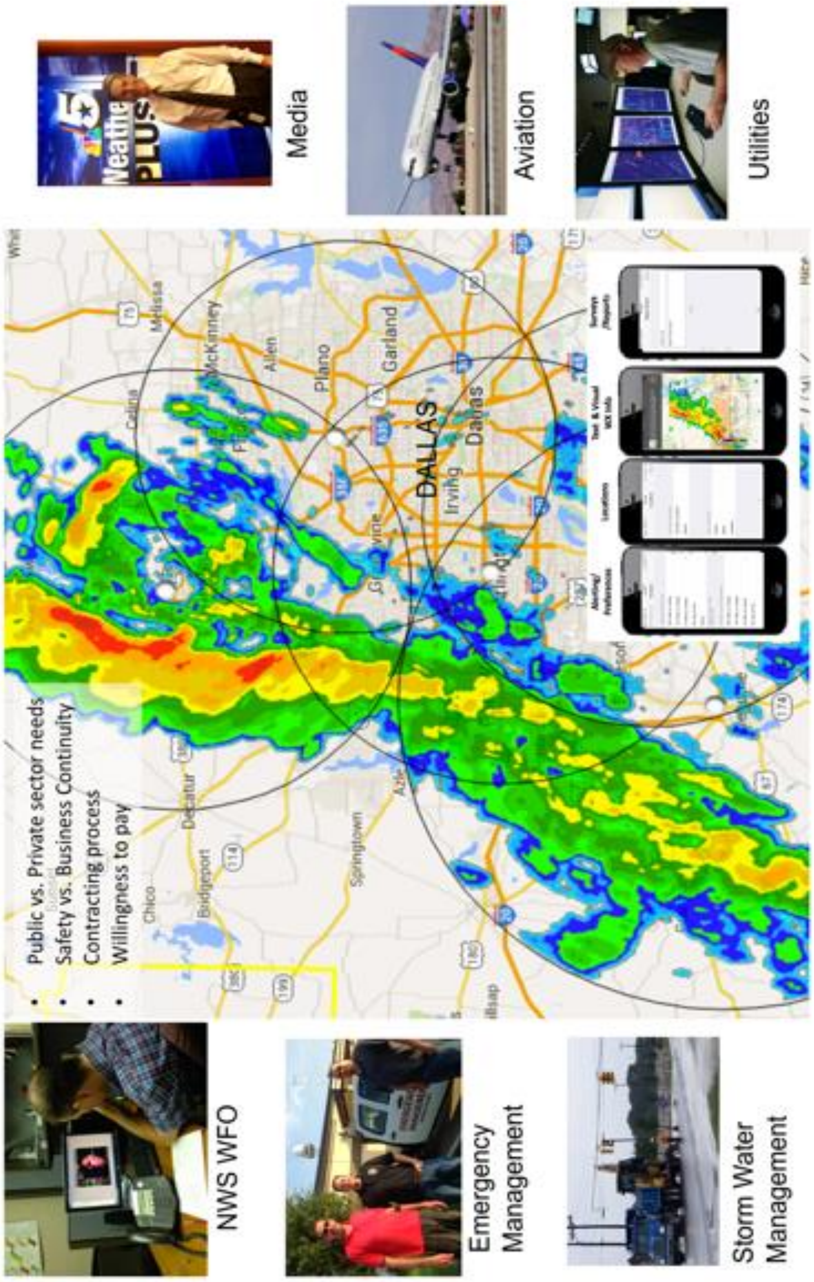

Figure 5.4. Urban Radar Network (Dallas-Fort Worth) provides high resolution, accurate low-level winds and heavy rain information for a variety of users. Information is communicated to and from users via mobile technology.

Source: Brenda Phillips

5.6.4 Open access data policy

The city of Hamburg introduced an open access data policy that covers measurements (e.g. for air quality indicators or warnings), all consultancy reports on assessments of environment, air quality or planning approaches or climate. This allows for a larger involvement of the citizens as well as ensures knowledge exchange between administration and researchers. Knowledge exchange was supported by the round table "Klima Campus Hamburg" where researchers and administrators regularly sit together and discuss latest research results, emerging regulatory problems, future research approaches and possible solutions.

5.7 Showcase IUS

Encourage Members to showcase and demonstrate their Integrated Urban Services projects for the benefit of all Members and other interested agencies.

5.7.1 Showcase from early times to now

Stuttgart (600,000 population in Stuttgart and 2.6 million in the region) has a very long history of concern for urban climate and air quality[5] because of its specific geographic setting in a river valley between vineyards and thick woodland. The city spreads over several hills (549 m) and valleys with steep slopes surrounding the city center (207 m) on three sides. This impacts surface radiation, air temperature, wind and air pollutant concentrations. Low air exchange and frequent inversions hinder dispersion of pollutants. In 1689, with 13,000 inhabitants, the upper council of the time feared that new buildings could hinder the transport of fresh air to the city making it unhealthy. Consequently, a number of first measures have been suggested. To this day, Stuttgart takes measures to improve air quality and urban climate. Responsibility for each measure and the legal basis are openly communicated on a web page[6]. All measurements are also available. Many cities worldwide have been inspired by the Stuttgart example and introduced IUS especially for planning implementation.

5.7.2 Showcase by publication

The Integrated Urban Services project for Toronto has been showcased through articles published in the WMO Bulletin[7] and the Bulletin of the American Meteorological Society (BAMS)[8] and an Environment and Climate Change Canada report (Federal Government publication). These publications are not only highly read by the meteorological community but also more broadly. In particular, lessons learned through retrospective examination of the project are most valuable to progress the development of IUS. Together, these provide evidence that the Toronto project was communicated to both a broad and relevant audience. Appearance in the published literature provides a legacy of information that can be accessed by anyone; BAMS (after a short embargo) and the WMO Bulletin are freely available online, the Government report is available via the web and is catalogued with an ISBN number. The scope of the available material provides an example of good practice. In particular, the Government report, "The Toronto 2015 Pan and Parapan American Games Experience: an Environment and Climate Change Canada Perspective"[9], provides substantial details on the outcomes and lessons learned from the IUSs. It has been written to provide a synthesis and guidance for the improvement of meteorological services in Canada. The report provides details on the initiation, planning, execution and outcomes of the IUSs and thus can serve as a template for other cities who may embark on similar projects.

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[5] https://www.stadtklima-stuttgart.de/index.php?luft_rueckblick_1698
[6] https://www.stadtklima-stuttgart.de/index.php?luft_luftreinhaltung_massnahmentabelle
[7] Environment and Climate Change Canada, 2016*a*: Toronto 2015*a* – Pan and Parapan American Games, An Environment and Climate Change Canada Perspective, WMO Bulletin No 65(1), 42-47. https://public.wmo.int/en/resources/bulletin/toronto-2015-–-pan-and-parapan-american-games-environment-and-climate-change
[8] https://journals.ametsoc.org/doi/full/10.1175/BAMS-D-16-0162.1
[9] http://donnees.ec.gc.ca/data/weather/predict/TO2015_Pan_and_Parapan_American_Games_Experience/TO2015_Pan_and_Parapan_American_Games_Experience.pdf

CHAPTER 6. SUMMARY AND RECOMMENDATIONS

6.1 Summary

Chapter 2 presented the results of a survey of Integrated Urban Services sent to Permanent Representatives of all 192 WMO Member States. The questions focused on 6 areas: 1) main hazards in the urban area, 2) current activities in the area of urban services, 3) other urban services in the country, 4) user connections and partnerships, 5) capacity development and training, and 6) international collaboration.

A total of 87 responses (45%) were received. The respondent countries span a range of geographical and income categories but may not constitute a fully representative sample, with a possible bias towards *Members* with an existing interest in urban services.

The responses indicate approximately half of the WMO *Members* have some type of urban services, and in countries where these services are lacking, most *Members* are planning to initiate such services. Meteorological services are the most developed whereas improvements are required to hydrological and air quality services to help meet the main identified hazards (heavy rainfall, flooding, windstorms, tropical storms, heatwaves, thunderstorms and air pollution). Most WMO *Members* provide services to a range of users (water management, energy supply and transportation sectors dominate) and have communication systems that connect hazard impact to users. These form a template for further identifying and engaging urban users in defining additional needs. A key service need is disaster management. Finally, a clear demand is expressed from WMO *Members* to learn from others on how to better develop their urban services.

Chapter 3 provides background on the Demonstration City Summaries. These are Demonstration Cities with existing integrated urban services in meteorology, hydrology, climate and air quality for which city-specific experts were asked to write short (~2 page) reports. The reports describe the experience of their city in terms of the need for integrated urban services and urban service integration. These reports (Annex 3) provide guidance on urban services and their delivery from a range of cities.

Chapter 4 presents the methodology for a qualitative analysis of the Demonstration Cities (Table 3.1, Annex 3). This provides a theoretical framework to determine the integration level between services based on the flow of data from one service to another, the range of applications of IUS, and the degree of city involvement and interdisciplinarity. A matrix of services was constructed to visualize the integration between services and a second matrix of services provided to applications was also tabulated. To assess the degree of city involvement and interdisciplinarity, integrated urban services provided by the Demonstration Cities were assessed on the degree of complexity of the partnerships, and the degree of completeness of the IUS.

Chapter 5 undertakes the analysis. Weather services are most strongly integrated into the other services, followed by climate and then hydrology. Air quality had the weakest overall integration and was more likely to be integrated instead as a research project. The matrix of services to applications showed that weather services were well integrated into most applications, with the other services somewhat less so, but not substantially different from each other. Of the applications, the Demonstration Cities were most likely for Disaster Management and Health. Energy was the application that was the least developed. Flooding, heavy rainfall, air pollution and heatwaves were the most named hazards by Demonstration Cities.

Differences with the hazards, identified by WMO *Members*, may partly explain the presence or absence of IUS for particular hazards in a given city. Wildfires and climate changes are examples where integration of urban services to tackle a hazard outside the normal IUS domain can be helpful in developing plans for more resilient cities. The extension to other domains is common, paving the way for new services to be developed. The analysis of the degree of complexity of the partnerships and degree of completeness, showed a wide spread on the complexity of partnership axes and two main groupings on the degree of completeness axis. One group represents a service production stage wherein value is added to basic available data to provide the urban service. The other represents more mature IUS that operationally deliver urban services to users. Among the Demonstration Cities, Paris, Hong Kong, Shanghai and Singapore illustrated the greatest combined integration and degree of completeness because they incorporate an additional service beyond that provided just to City Authorities.

Finally, in Chapter 5, the seven Recommendations from Volume 1 are illustrated using examples from the Demonstration Cities. These provide "good practices" and example starting points, analogs or templates for other cities seeking to build or extend integrated urban services.

6.2 Recommendations from Volume I and the responses based on the Demonstration Cities

The Recommendations from Volume I also serve as the basis for section 6.3 (below) to provide an overview of how the Demonstration Cities are achieving the goals of providing Integrated Urban Services.

Volume I, R1: Assist decision-makers and end users in developing Integrated Urban Service capabilities. It is important not to wait for a disaster to act. There are examples of well-functioning Integrated Urban Services that can be used as templates for development and implementation in specific situations.

In this Guidance report the motivations for developing IUS are diverse; including as a result of a beneficial research exercise and a need created by a large-scale event planning (for example, Olympics). However, evidence suggests that once initiated, the value of urban services is clear and that other services and partnerships develop as a consequence. Broadening the scope of partners for cities with existing IUS is a pathway for improving integration of urban services.

Volume I, R2: Contribute to the development of coordination and promotion of Integrated Urban Services, including knowledge transfer.

Several cities (e.g. Hong Kong, Mexico City and Stuttgart) have developed techniques for integrating *Members* services with urban users to create city-specific tools (forecasts, projections and communication systems) to support emergency management and disaster response and short and long-term planning decisions. These Demonstration Cities have hosted workshops and published materials to demonstrate their IUS.

Volume I, R3: Ensure that legal and institutional frameworks are in place in the partnerships with cities. These should clearly define Member mandates, roles and responsibilities to enable, create and maintain Integrated Urban Services.

It is clear from the Demonstration City responses that providing IUS is a complex political and administrative process that requires collaboration across institutions and administrative boundaries. There is no simple solution to overcoming these difficulties as the obstacles to creating IUS vary. Nevertheless, the Demonstration Cities capture a range of legal and political frameworks that provides a basis for developing IUS in specific urban political systems.

Volume I, R4: Engage with relevant stakeholders, (for example, agencies, universities, the public, other *Members*, city governments and the private sector) right from the beginning, including in raising awareness and obtaining feedback.

It is clear from surveys that *Members* already engage with a variety of stakeholders across a range of services and sectors. Many indicate that their services (including communication) are tailored for user needs. The Demonstration Cities show that it is possible to extend the range of stakeholders to include even more users. Developing services is beneficial to meet urban needs that may affect many users simultaneously in space and time and require co-ordination between urban needs providers (e.g. emergency response, health care providers, traffic and energy systems to respond to disruptive storm events).

Volume I, R5: Conduct further research, including multidisciplinary cross-cutting studies, to develop Integrated Urban Services capabilities.

Many of the Demonstration Cities have IUS that are still in the research phase or have just moved into the operational category. While many of these services are focused on common hazards (e.g. flooding, heat stress, air quality), there are other needs to support short- and long-term hydrometeorological urban needs, such as climate change mitigation adaption policies. More work is needed to develop such services, which entails greater engagement with non-government organizations and social scientists.

Volume I, R6: Facilitate wider accessibility of data by influencing ownership issues and providing technical support.

The transfer of data within and among *Members* and urban service users is critical to developing IUS. Many of the Demonstration Cities rely on high-quality information provided by WMO *Members* to make decisions and support policy; in some cases, the city draws upon the data from many different sources and attempts to integrate these at an urban scale. City agencies often have access to data that can support *Members* operations; this may include information on land use and land cover that can be used to assess GHG emissions and hydrological risk, for example.

Volume I, R7: Showcase demonstration projects to promote and advance development and implementation of Integrated Urban Services.

The Demonstration Cities show evidence of showcasing and demonstrating IUS through a variety of publication forums, from journal articles to government reports. The *Members* survey indicates that 50% currently have some form of urban services but of those that do not 80% are planning to develop such services. Moreover, the majority of respondents indicated a desire to learn from other cities about how to develop and operate an IUS.

6.3 Recommendations arising from Demonstration City analysis

The assessment of the Demonstration Cities experience through the information sources described in this document give rise to some additional recommendations. These complement the recommendations from Volume I which are still key.

1) Initiate discussion with urban users (such as city officials, urban planners, traffic storm and water engineers) to understand their needs. Complete a gap analysis to examine how existing services can be modified and/or addressed to meet the new needs identified. Identify what data the city has (e.g. land use, land cover) that can be usefully employed to improve *Members* operational services and communicate warnings and information effectively.
2) Integrated Urban Services can be initiated through a single service when co-produced by a city for a particular hazard – i.e. starting simple makes sense! The experience of the Demonstration Cities shows this is most likely to occur in the weather service sector (Figure 5.3 and 5.4) but cities are encouraged to begin with the hazard of greatest importance. The experience of developing IUS in a particular sector provides an important template for the further expansion of IUS to other services and with greater integration.
3) Integrate the provision of services at a technical level through the sharing of data at appropriate time and space scales. Ideally, this information flow should be integrated directly into the provision of that service, where required. This integration is an important step but has a particular relevance for the provision of urban services because of the concentration of people and infrastructure and the added impact of the urban effect on weather, climate, hydrology and air quality.
4) In many cases, data exist to support urban services. The key to creating additional value is to provide technical integration in the form of observational analyses, dedicated geographic information system layers, or modelling. This provides additional value relative to the separate use of such data.
5) Implementations of IUS in support of a specific event can provide an efficient means of developing IUS capabilities for a Member and for identifying the partners. The experience gained can then be used to develop a longer-term plan for the IUS.
6) For cities with experience in IUS, the goal is to improve the integration of IUS through the incorporation of a greater range of partners with experience in substantially different areas. These partners assist with providing a completely different type of service that provides an important feedback to the *Members* that results in changes to one or more of IUS services provided and improving scales (time and space) of delivery.
7) WMO *Members* should support the showcase and demonstration of IUS through a number of targeted ways such as joint workshops, publications and dissemination of IUS activities. Workshops might most usefully target *Members*/cities at the initiation level (little current IUS) or separately, support interactions amongst *Members*/cities with current IUS to help them expand their capabilities.

6.4 Targeted guidance and recommendation for stakeholders

6.4.1 WMO Members recommendations

1) *Members* must improve data sharing pathways amongst services and also externally. This technical improvement will facilitate the ability to provide IUS in partnership with cities because of the concentration of people and infrastructure that are exposed to hazards.
2) *Members* need to develop partnerships with specific urban users.
3) Establish a two-way information transfer between *Members* and the users. This will support users with relevant information and allow *Members* to improve their services.
4) Be prepared to support development of urban scale observation networks in support of particular hazards or initiatives to ensure compatibility with existing services.
5) Meet with urban "customers regularly to assess success of IUS and its costs, impacts and benefits.
6) Look for "initiation opportunities" such as major events, that may provide a source of additional support needed to begin IUS or to expand and/or further develop an existing IUS.
7) Support knowledge exchange between *Members* and cities by partnering to help initiate IUS in more cities.
8) Develop a list of urban experts that can be drawn upon by *Members* and/or Demonstration Cities to provide guidance and expertise.
9) Support knowledge transfer to city/*Members* partners via training workshops to help advance IUS in cities ready to initiate IUS or seeking to expand their capabilities in IUS.

6.4.2 City Authority recommendations

1) Look for Demonstration City analogs. This guidance document provides a range of examples of how Demonstration Cities have achieved recommendations from Volume I. These can be used to identify cities with needs, hazards, governance structures, and Member services that are similar in nature and which can be used as a template for IUS development.
2) Engage further with your *Members* on the provisions for IUS – identify a point of contact and determine existing data sources exist on which a IUS can be built.
3) Start simple and then build.
4) Have a specific target for improved urban service within a sector.
5) Be prepared to invest (time/human resources, funds). Money may be needed for infrastructure; time is needed to understand the current availability of resources, and to identify partners.
6) Engage with researchers (for example, academic community) from the outset to evaluate and help develop the IUS. The Demonstration City Summaries provide ideas of project-based work that may be relevant for your community.

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CHAPTER 7. BRIDGING GAPS AND STRATEGIES

7.1 Gaps

In this section, the "value chain for provision of weather-related warning" concept[10] is used to categorize the gaps in understanding (Figure 7.1). The starting point is the decision that needs to be made and then progress through the different levels of information that contribute towards enabling the decision to be the right one. Not all levels will be needed for all decisions.

7.1.1 Decision-making

The value of an urban service for weather-related hazards and climate change risks lies in the decisions that could be made differently if a service could possibly have been provided.
Some cities identified a problem, often from a failure in a disaster. Solution of the problem may require one or more decisions to be made in a specific city environment. Consistency of decision-making is important, whether in the context of long-term planning or of rapid response to a disaster. Integrated services can significantly contribute to achieving consistency and leading to more efficient, sustainable and resilient cities.

Further work is required in the following areas:

1) Classify the weather-related decisions that city managers and residents would like to be able to make, in response to weather- and climate-related hazards, and the information needed to make them, including minimum required levels of precision, accuracy and reliability. Such decisions might relate to land-use planning, drainage and energy provision, stockpiling of equipment, rostering of staff, evacuation, search and rescue amongst others.
2) Understand how urban dynamics (such as population and traffic density, road, buildings (for example, commercial and residential), land and resource use and policies) influence weather/climate/water/environmental conditions which can amplify the state of these to become hazardous to society and human well-being, for example, air quality, water quality and quantity, ecosystem, urban heat island effect, disease transmission.
3) Identify a subset of these requirements that could be met, in principle, bearing in mind uncertainty associated with rapid and random variability in the surface and near surface environment.
4) Set limits to the lead-time for which such information could be provided and the growth of that uncertainty with lead-time due to non-linear interactions.
5) Partition the decisions that city managers would like to be able to make into those for which information could be provided (in principle) and those that it will not be possible to meet.
6) Establish conditions where integration of services will bring particular benefit by minimising the risk from multiple hazards to the urban area and under which relevant information can be provided and exchanged, such as organizational governance, infrastructure, observation accuracy, model configuration and resolution.

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[10] https://www.wmo.int/pages/prog/arep/wwrp/new/documents/J_Lazo_presentations_27April2016.pdf

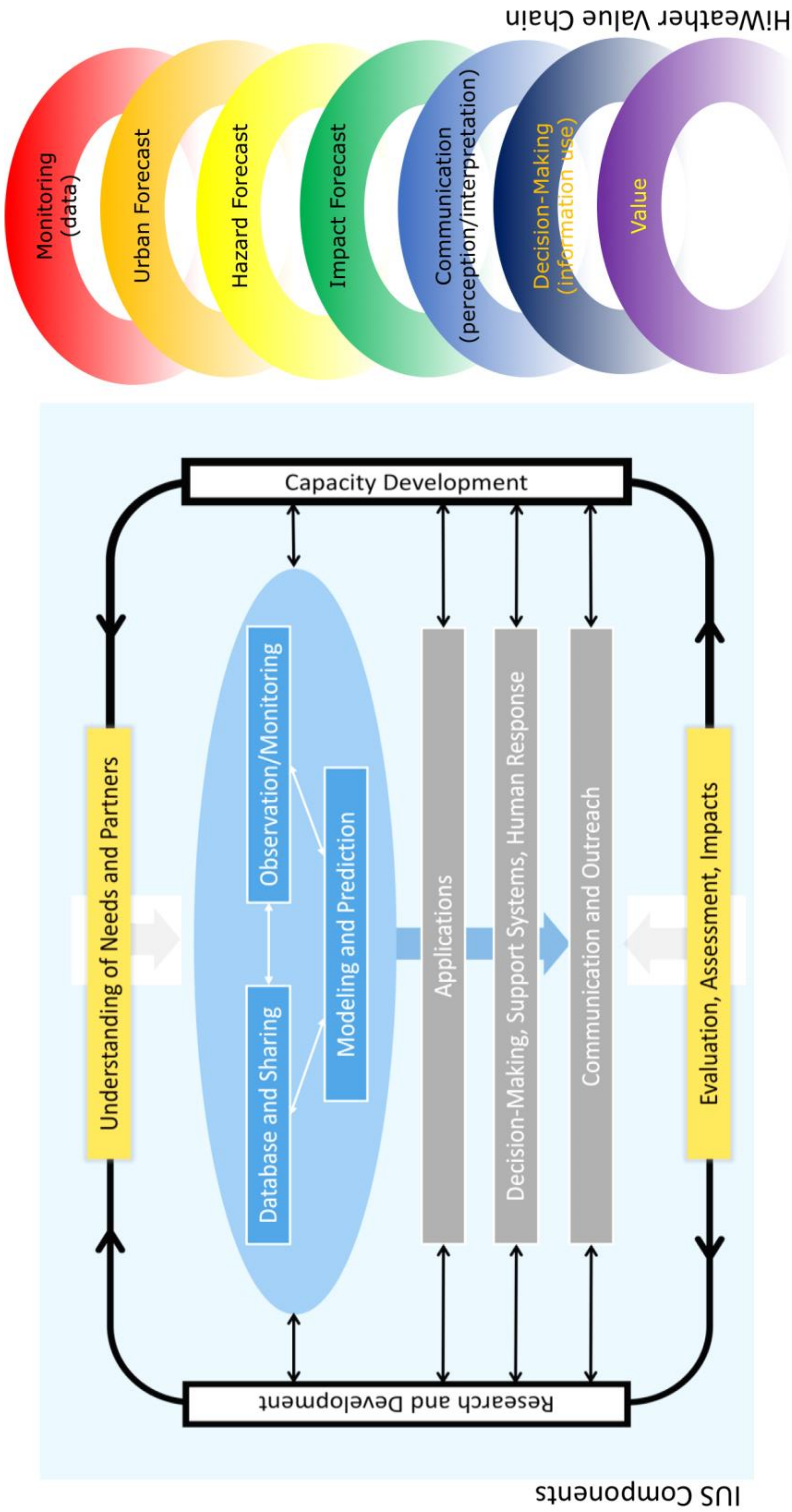

Figure 7.1. (left) IUS Components (Volume I) and (right) the HiWeather Value Chain representing information flow from decisions that need to be made and tracing backwards through the different levels of contributing information and forward to assess the value of the decision made.

Source: adapted by WMO

7) Understand and communicate the range and critical limit values of hazard-related variables and indices based on an integrated framework operating for urban services with respect to human health and environmental protection.
8) Establish the reusability of information prepared to support real-time risk-reduction decisions for use in long-term planning within an integrated framework for urban services set in the national context.
9) Develop Integrated Decision Support Systems to efficiently present to technical experts and the public, relevant, often uncertain and conflicting information, to support warning decision-making at appropriate timescales. These systems should take into consideration the timing of impacts (now, imminent, decades), governance, societal impacts, consequences and action statements. Understanding the impact of an event on human response and behaviour is part of the decision-making process.

7.1.2 Communication of information to decision-makers (including members of the public)

For a useful decision to be made, the decision-maker needs to receive and understand the required information at the required time and location. This is particularly important when multiple services are operating within an integrated framework to ensure the efficient use of information that may reflect different hazards and urban and national departments.

Examples in this guidance document fall largely into two types: communication of information to experts, in which care is taken to design a system by which the specific needs of the recipient are met; and "open" communication, in which website design or other media determines how well communication will occur. Consistent communication of information in an integrated system helps to facilitate effective access and use by decision-makers.

Further work is required in the following areas:

1) Identify the portfolio of communication channels needed to reach the whole population at risk, given the characteristics of the nature of hazard or hazards, multiagency response, the population affected, including gender, language and cultural diversity and those with special needs.
2) Identify the most effective means of preparing people to take protective action in the case of single or multiple hazards, including through education (school and adult), awareness raising events, exercises and pre-warnings. Bearing in mind research suggesting that the reason people do not respond is that they did not know what to do; identify means to help people identify responses depending on the nature of the hazard and emergency and be prepared to take them. For those unable to respond themselves, identify procedures to ensure they receive help.
3) Standards for the use of language and graphics to represent information, including the need to use appropriate idioms which may span a combination of different hazard disciplines when communicating in multiple languages, reflecting the importance of context, and appropriate use of symbols as an alternative or reinforcement to words.
4) Practices that build and destroy trust and belief of the information received, including identification of its source, sharing of information on skill and track record, compatibility with prior knowledge (including indigenous knowledge, community memory, religious belief, age).

5) Language that communicates a useful perception of risk, incorporating both the likelihood of the event and the severity of the likely impact, to both expert users and to the general public, in both emergency response and future planning situations (Figure 7.2).
6) Good practices in working with decision-makers to design integrated systems that promote effective use of information provided, for example, enabling merging of environmental data with the decision-maker’s system status data, and/or drilling down into detail to clarify specific detail.
7) Design standards for open delivery platforms using an array of appropriate communication techniques that facilitate wide receipt and comprehension of information within an integrated framework.

7.1.3 Production of information on the expected socioeconomic impact related to the hazard

Increasing evidence is accumulating about the benefits to decision-making of providing integrated information on the geophysical, chemical, biochemical and socioeconomic impact of hazards on all timescales. However, a common issue amongst examples in the Guidance is the challenge of obtaining data to support the provision of such impact information especially in the case of multi-hazard situations, either because the data are not gathered, or because they are difficult to access, or because they are confidential (e.g. health data or proprietary business data). Further work is required in the following areas:

1) Cost-effective methods of observing weather and climate-change related impacts or of extracting such impact information from related data.
2) Standards for exposure and vulnerability data used in impact assessment.
3) Scope and standard of impact assessment required to inform disaster response and planning, including air quality, health, energy and water.
4) Methods for assessing multiple, cascading, compound and indirect impacts.
5) Methods for dealing with weather- and climate-related impacts resulting indirectly from geological, technical or security hazards.
6) Methods for dealing with slowly responding impacts, particularly in health, including vector-borne diseases related to climate change.

7.1.4 Production of information on the weather-related hazard

The heart of the hazard information production process is observation of the current state of the environment and projection forward using dynamical and/or statistical models. Short-term information is conditioned on the currently observed state, using initial value approaches, including nowcasting, numerical weather prediction and machine learning. Long-term climate-change information is conditioned on specification of the changing boundary conditions of factors such as atmospheric composition and land use, using analysis of past observations and future climate modelling. In both cases, dealing with the relevant environmental processes requires appropriate levels of coupling of models to represent the different environmental domains (such as a city within national and regional domains). In both cases, statistical post-processing may be required to represent the statistical distribution of unresolved variability. Examples in the Guidance emphasise benefits of integrating and linking models, particularly weather/hydrology and weather/air quality, and also of using modelling for short-term application to feed into long-term applications. Further work is required in the following areas:

1) Define the observation requirements for the urban predictions needed to support the desired services under single and multi-hazard situations. These will include observations of and within the urban fabric (i.e. with the urban canopy layer) that most directly connect to the relevant impacts, observations around and above the urban canopy that will drive the prediction models (i.e. roughness sub-layer, constant flux layer and through the boundary layer), observations that can be used to evaluate and tune the models, and observations that enable processes to be described and understood.
2) Define and establish an infrastructure to support integrated observational and prediction information that will arise from coupled response systems such as weather/hydrology and weather/air quality, with links to health and socioeconomic impacts. Such an infrastructure should take account of different users, knowledge base and technical requirements.
3) Define the characteristics of the urban environment, and their spatial and temporal resolutions, that need to be known to achieve required levels of precision and skill in the predicted hazards. These include building structure (e.g. height, density and materials), surface (e.g. materials, drainage and vegetation) and anthropogenic effects (e.g. heat, pollutant emissions and concentrations). Some change slowly in time, while others change quickly. The latter changes need to be specified in predictions and projections. Metadata need to be updated at appropriate time intervals.
4) Distinguish the variables and their spatial and temporal scales that need to be predicted/projected dynamically from those that can be adequately inferred or downscaled. Identify appropriate strategies for incorporating the latter in datasets.
5) Solve the problem of initialising dynamical atmospheric models consistently at weather system scale, at convection scale and potentially at boundary-layer eddy scale and of specifying initial and process perturbations that enable ensemble prediction of the distribution of uncertainty.
6) Develop appropriate coupling strategies for different space and timescales that represent the significant sensitivities and that enable consistent prediction of hazards in separate and integrated environmental domains, while minimising the complexity of the technical solution.
7) Develop methods for incorporating a wider range of processes associated with important single and multi-hazards into weather and climate change modelling frameworks, including air and water quality, ecosystem responses, disease occurrence, sediment transport, wildfires, duststorms, appropriately for short- and/or long-term applications.

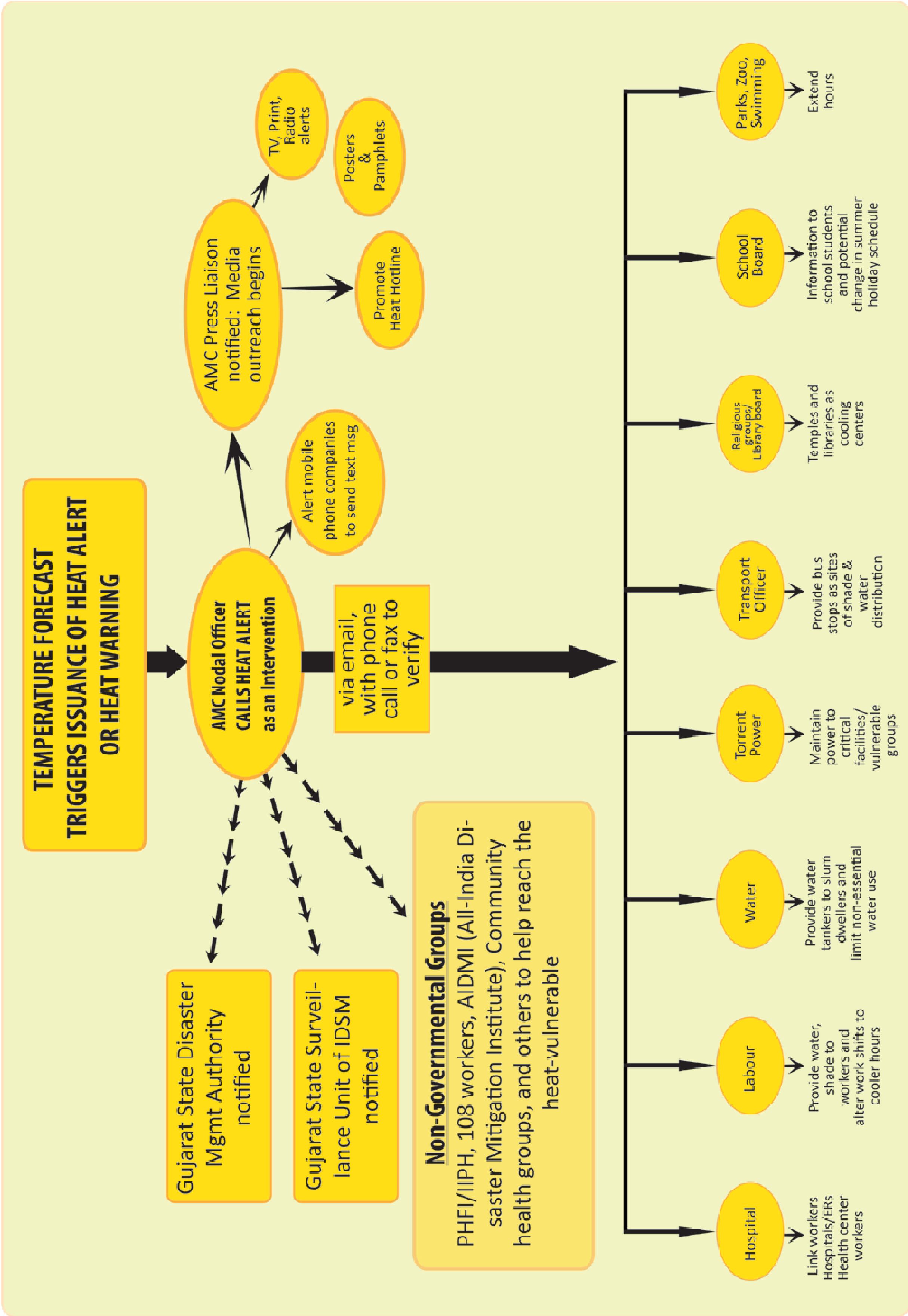

Figure 7.2. Communication Plan when the Ahmedabad Municipal Corporation Nodal Officer activates a Heat Alert

Source: Indian government

7.1.5 Optimizing and evaluating the production and delivery chain

The value in the urban service lies in the benefits of the decisions that are taken at the end of the chain. Investment should be informed by the relative costs and benefits of improving each component of the chain as well as the benefits of integrating the components along the chain. It is currently difficult to carry out that analysis due to lack of information about how each component contributes to the overall value and to lack of understanding of how to attribute value to the contributors. Typical weather service verification can quantify the accuracy or skill of weather forecasts. Surveys and reviews provide snapshots of end value, typically of a whole service. Examples in this guidance document provide such measures of the end benefit of specific interventions. This needs to be done in a routine and consistent way if end-to-end optimisation is to become possible particularly where integration is shown to be beneficial. Further work is required in the following areas:

Setting standards for routine evaluation of urban services, including data collection, analysis and distribution, decision-specific and user-oriented process evaluation, and impact evaluation of socioeconomic benefits and costs of the integrated system.

1) Methods for modelling the value chain to enable routine assessment of the contributions of different components and their integration where appropriate.
2) Intercomparison of end-to-end evaluation using different production chains to enable analysis of the sensitivity of the end value to production differences.

7.2 Way forward

Arising from the gaps identified above, the following key areas appear for promoting collaborative work, integration and partnership development and dialog with actors managing urban services.

1) Promoting the capturing and sharing of observations of environmental and human impact and response information of all kinds, including from unconventional data sources. To facilitate sharing of (potentially) low quality data, standards for sharing of metadata will be important. Much work is being done, especially in academia, but it needs to be better shared through tailored pilot projects that also examine the benefits of integration, dedicated workshops, conferences and publications.
2) Progressing research on the need for better modelling capabilities for urban areas, encompassing the scales needed, the degree of detail in the representation of the urban fabric, and the degree of coupling required between different environmental domains. Intercomparison experiments and forecast testbeds could provide powerful opportunities for taking such work forward. This could be undertaken in the context of an opportunistic event, such as the forthcoming Paris Olympic Games and explore where integration will prove to be beneficial to addressing urban hazards.
3) There are currently a few international projects that are attempting to bring together toolboxes of impact-prediction models especially in an integrated framework. This activity needs to be reinforced, extended to a wider range of countries and applications, and focused on an identified set of requirements for urban hazard and risk awareness services.
4) Behavioural psychology and other similar disciplines have the skills and methods to define good practice in communication of information from different disciplines.

Working in the application of the expertise in communication of weather and climate information needs to be enhanced, and coordinated. Promotion of a community of practice in this area is a high priority. A methodology for comparing different approaches in real life could be tested alongside a forecast experiment such as that suggested above for the Paris Olympics.

5) Successful modelling and analysis of the value on the individual components and the integrated chain for urban services could yield substantial gains in effectiveness and efficiency. An attempt to achieve this would be worth taking forward.

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GLOSSARY

Integration is a generic term that can mean several things from: organizational integration, single access point for services or data, merging monitoring networks, coupled modelling, creating products from distinct systems or providing expertise at the service level. High-resolution local area meteorological modeling is one foundational element for sub-urban scale services (e.g. city block scale) but large-scale phenomena (e.g. typhoons or synoptic storms) also affect cities.

Urban services, in the traditional sense, and in the context of city management (by mayors and other city agencies), refers to transportation, housing, water management, waste management, snow clearance, and so forth.

In this report, **Integrated Urban Services (IUS)** refers to the provision of weather, climate, hydrology and air quality services including infrastructure (data, observations, predictions, and tailored products) that may be used to support traditional (and new) urban services. These services may be provided directly through Member operations or indirectly through stakeholders or partners in public and private agencies. **Integrated Urban Services** includes weather forecasts, thunderstorms, typhoons, coastal inundation, flooding, air quality, health-related stress warnings as well as climate services for building codes, zoning, planning and design.

Integrated Urban Services are inherently high resolution (compared to a region) and are provided at roughly the spatial scale of the urban footprint and smaller. However, they are highly dependent on the application, requirements, and local and regional factors. The urban domain is defined by local governments and may include nearby cities, the areas and roads in-between cities, rural watersheds and locations of industries, in order to capture their impacts. Urban planners may include surrounding areas as planning in major metropolitan areas will affect housing, transportation and recreation in those areas.

At the most basic level, provision of **integrated services** means that the end user receives an appropriate product that takes into consideration two or more of meteorology, climate, hydrology and air quality. These services have generally been delivered individually through different programmes or agencies. Some, if not all, of the critical urban applications are inherently integrated due to co-dependencies. For effective services and efficient delivery, the core issues to resolve are mandate and collaboration.

Service partners are the providers of the IUS (defined here as weather, climate, hydrological and air quality services). Integration of these partners is referred as **cross-service integration** and is underpinned by the exchange, combining and merging (coupling) of scientific knowledge and information. In expanded definitions of IUS other service providers with a focus on bio-diversity, environmental law, and the like could be incorporated.

Sectoral partners include the IUS providers, various urban customers (e.g. economists, sociologists, regulators and policymakers) and City Authorities. Integration of these partners is termed **cross-sector integration**; the level of integration is dependent on the degree of shared investment in the design and management of the IUS. Co-production describes higher levels of partnership.

SURVEYS

A2.1 Members Survey

(issued in October 2018, used for Volume II and III)

Contact information

Q1. Please choose your Country or Territory

Q2. Contact information (Mandatory - Free-text up to 256 characters for each textbox): Name of service; Name of person; Position/Title; Address; E-mail.

Q3. Additional Contact Information

Information on main hazards in the urban areas

Q4. What are the main hazards the urban areas face in your country (please tick as many boxes as required)? If needed, use the "Other" box for free text to specify the hazards in more detail, such as the type of flooding: Heavy rainfall; Flooding; Water scarcity; Fog; Tropical storms; Coastal inundation; Windstorms; Heatwaves; Cold waves; Snow; Air pollution (including smoke and haze); Thunderstorms.

Information on your activities in urban services

Q5a. Is your Service providing, or planning to provide, any urban services in the areas listed below in b?

Q6b. In which area (meteorological, climatological, hydrological, air quality) and at which stage of development (planning stage … fully operational) are the services? Please tick as many boxes as apply as you may have services at different stages of development.

- Meteorological (including severe weather) Fully operational
- Climatological (including seasonal forecasts) Fully operational
- Hydrological (including water resources management support and flooding)
- Fully operational
- Air quality or other related parameters (such as UV Index) Fully operational

Q7c. In your country, what are the main geophysical characteristics of the urban areas for which you provide, or plan to provide, urban services? (please tick as many boxes as required): Coastal; Inland; Mountainous; Riverine or delta; Polar; Mid-latitudes; Tropical.

Q8d. In which cities and urbanized areas are you providing, or planning to provide, your services? (Free-text)

Q9e. Do these services include: General services to the public? yes/no

Q10f. Do these services include: Services to the authorities? yes/no

Q11g. Do these services include: Targeted services to specific customers (please tick as many boxes as required): City planning; Infrastructure design; Energy supply; Water management; Industry; Transportation; Road traffic; Health sector; Tourism sector; Special events.

Q12a. Does your system include an integrated platform for these services? Yes/no

Q13b. If your answer to the preceding question was "YES", what components does your platform include? (Free text)

Q14c. If your answer to the preceding question was "No", is there any integration in the system of your Service between any of the different components for giving urban services? (Free-text)

Information on your activities in urban services

Q15a. Does your Service use impact based forecasting for urban areas? Yes/no

Q16b. If your answer to the preceding question was "No", do you have plans to use impact based forecasting for urban areas? Yes/no

Q17a. Weather Alerts and Warnings? Yes/no

Q18b. Flood/Drought Alerts? Yes/no

Q19 By which methods does your Service disseminate and communicate your urban products and services? Telephone (including SMS alerts); Web portal; E-mail; Digital display; Social media.

Q20 Please write below any possible comments on this section D (Free-text).

Information on other urban services in your country

Q21a. Do you know of any institutes other than yours that provide urban services? Yes/no

Q22b. If your answer to the preceding question was "YES", please provide information on those institutes below, for example the name of the institute, their area of work, and/or products and services provided (Free text).

User connections and partnerships

Q23a. Are any groups of service users involved in (developing) your urban products and services? Yes/no

Q24b. If your answer to the preceding question was "YES", who? (please tick as many boxes as required): Local government and/or authorities; Water management sector; Road traffic sector

Q25a. Has your Service formed partnerships in the provision of urban services? Yes/no

Q26b. If Yes, with whom? (Free-text up to 500 characters).

Q27c. Do you carry out regular surveys, such as for further development or for obtaining information on the benefits of your services, with your partners or relevant national/regional/local authorities? Yes/no

Q28d. Have you established regular meetings with your partners or relevant national/regional/local authorities? Yes/no

Q29e. What kind of arrangements and/or agreements (such as for example Memorandum of Understanding) have you established with them? (Free-text up to 500 characters).

Q30a. Does your service work with economists on urban services? Yes/no

Q31b. Does your service work with social scientists/authorities on urban services? Yes/no

Q32a. Does your service measure the economic and/or social benefits of urban services? Yes/no

Q33b. Does an authority have responsibility for measuring the economic and/or social benefits of urban services? Yes/no/don't know

Q34c. If your answer to the preceding question was "YES", which authority? (Free-text).

Q35 Please write below any possible comments on this section (Free text).

Capacity development and training

Q36a. Has your Service or another national/municipal authority organized capacity development activities, including training, on urban services that your staff has attended? Yes/no

Q37b. If your answer to the preceding question was "YES", please fill in below: regularly, irregularly.

Q38c. Which subjects (Free-text)

Q39a. Have your staff attended any WMO organized capacity development activities, including training, related to developing urban products and services and associated infrastructures? Yes/no

Q40b. If your answer to the preceding question was "YES", please provide below more information, such as examples (Free-text).

Q41 How does your service develop capacity and guide stakeholders, authorities and users in the interpretation and use of urban products and services? a. Do you organize training for them? Yes/no

Q42b. Do you have regular meetings with them? Yes/no

Q43c. Do you provide them with written Guides or Operative Procedures? Yes/no

Q44d. Other (Free-text)

Q45 Does your Service conduct periodic exercises to ensure proficiency? These can be joint activities or exercises between a number of agencies and/or individuals to try out and practice activities and processes which might be taken up in the event of an hazardous occurrence. Yes/no

Q46 Please write below any possible comments on this section.

International collaboration

Q47a. Is your Service collaborating with international partners on urban activities? Yes/no

Q48b. If so, please mention the most relevant (Free-text)

Q49a. Would your Service be interested in providing twinning to a country/city in need of developing urban services? Yes/no

Q50b. Would your Service be interested in developing your urban services by twinning with a country/city already having expertise in urban services? Yes/no

Q51 Please write below any possible comments on section H. (Free-text)

Q52 Please provide below any possible suggestions regarding the provision and the development of functional urban services. (Free-text)

A2.2 Reflections Survey

(issued December 2017, for Volume I)

A2.2.1 Introduction

A survey was created to solicit information on the current status of integrated urban services to inform and shape the Guidance. The survey is attached below and was designed to be open ended.

As the schedule to prepare the Guidance was very short, a two-week response deadline was set.

The responders were explicitly asked to provide their immediate thoughts and impressions and not necessarily be comprehensive in order to facilitate a quick but broad response.

Twenty-six specific Demonstration Cities were identified by experts and the response rate was over 80% (21 responses). The surveys were sent to urban experts that included academics, city managers, researchers and not necessarily National Meteorological and Hydrometeorological Services (see Annex B).

A2.2.2 Terminology

The terminology has been altered from the time of the survey. The term Integrated Urban Hydrometeorological, Climate and Environmental Services (Integrated Urban Services or IUS for short) is the current terminology instead of Integrated Urban Weather, Environment and Climate Services.

A2.2.3 The Survey Template

Specific Background of Integrated Urban Services:

Two Key Concepts

Integrated Services – The services that are being considered are related to weather, water, air quality and climate. The over-arching premise is that their integration is "the way to go". The crux of the Guidance is to articulate the objectives (what, what services), articulate the benefits (why), articulate how and to whom.

Urban - Are there specific urban services? Who are the clients? What are their requirements? How does urban services impact operations – different than global/regional, what are the characteristics of urban observation systems, their spatial/timescale of reporting, spatial scale of services and how are urban services delivered?

Notes:

- We are interested in your specific experience with your city.
- Feel free to adapt the questions and to add extra slides.
- Feel free to expand the scope. We may not have captured all your objectives and diverse issues.
- The idea is to quickly capture your reflections. We can follow up with additional questions later.

- Please provide your inputs by 8 December 2017
- Reference two links:
  - Baklanov A., C.S.B. Grimmond, D. Carlson, D. Terblanche, X. Tang, V. Bouchet, B. Lee, G. Langendijk, R.K. Kolli, A. Hovsepyan From Urban Meteorology, Climate and Environment Research to Integrated City Services Urban Climate 10.1016/j.uclim.2017.05.004
  - Grimmond S., Tang XU, A. Baklanov,2014: Towards Integrated Urban Weather, Environment and Climate Services. WMO Bulletin, 63, 1, 10-14

2. Objectives/Context of your City's Integrated Urban Services

- What are your city's objectives/goal?
- Did it include all the services: weather, water, air quality and climate? Did it include others? Sandstorm, Wildfires?
- What were the spatial and temporal scales of the urban services?
- How did your iServices project originate? (World event like Olympics, Expo or other)
- This may be found in your overview documents or project web site. It is fine to refer to that material.
- Are there references that you can provide?

3. Urban Services

- What are the "urban" services provided?
- How are these services integrated?
- How and who are they delivered? (We are interested in the "Last Mile", delivery to the end user)
- Are there references that you can provide?

4. Urban Techniques

- What did you have to do to provide "urban" services?
- Observations (mesonet, update in temporal sampling, spatial distribution, new technologies, data sharing, define standards).
- Modelling (high resolution (how high), data assimilation, meteorological and air quality parameterizations, hydrological model).
- If high resolution modelling was implemented, did the numerical weather or environment prediction systems have a specific urban component? Yes/no
- Implementation (part of national, regional or local infrastructure), service changes (urban central office, distributed sectorial offices)
- Communications (direct, generic, push, pull)?
- We appreciate that this can be detailed but short bullets are sufficient.
- How was the urban environment characterized in the model?
- Were unconventional observations used (e.g. crowdsource)
- Are there references that you can provide?

5. Integration Techniques

- Where was "integration done" – at the technical level or at the services level? Please describe.
- Are there references that you can provide?

6. Institutional Integration

- Which agencies/institutions did you work with to deliver the Integrated Services?
- To whom did you deliver the services – directly (specific agency/institution) or indirectly (via public message or other)? Did you work with them to design the service/product/message (tailored to their thresholds or requirements)?
- Are there references that you can provide?

7. Key Performance Indicators Evaluation/Impacts/Societal Benefits

- How is success defined? Is there a key success indicator for your specific city?
- Are there references that you can provide?

8. Best Practices

- What was done right?
- What was the role of research?
- How did the technology process from research to operations happen?
- Are there references that you can provide?

9. Challenges/Lessons Learned

- What would you do differently? Where should more thought be given? What was more difficult than originally thought?
- What issues need science, technology, research, social science, public health development? What would you give more effort to?
- How has science (includes social and political) contributed to Integrated Urban Services?
- Are there references that you can provide?

10. Technology Transfer

- GURME has a focus to promote and exploit scientific advances that are cross-cutting and require an integrative approach. See GURME website.
- How did science (e.g. air pollution, climate change, disaster risk reduction) drive, impact policy, create an enabling environment or create requirements (e.g. climate change) for an Integrated Urban Services programme.
- How did operational requirements/expectations drive the science agenda?
- Are there references that you can provide?

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A2.2.4 The Respondents

The following is a list of the cities that responded to the Reflections Survey (A2.2). Note that in most cases, the contacts solicited the inputs from many others.

City	*Country*	*Contributor and Affiliation*
Amsterdam	Netherlands	Gert- Jan Steeneveld, Wageningen University
Beijing	China	Shiguang Miao, Institute of Urban Meteorology,
Copenhagen	Denmark	Jens H Christensen and Eigil Kass, Danish Meteorological Institute
Dallas-Fort Worth	USA	Brenda Phillips, U. of Massachusetts
Helsinki	Finland	Dr Ari Karppinen, Finnish Meteorological Institute Prof. Ttuukka Petaja, U. of Helsinki Leena Järvi, U. of Helsinki
Hong Kong	China	Chao Ren, The University of Hong Kong, Tsz-Cheung Lee, Hong Kong Observatory Kenneth Kai Ming Leung, Environmental Protection Department
Jakarta	Indonesia	Dr A. [Sena] Sopaheluwakan
Johannesburg	South Africa	Kobus Pienaar, North-West University
London	United Kingdom	Damian Wilson, MetOffice
Mexico City	Mexico	Luisa Tan Molina, Molina Center for Energy and the Environment (lead) Tanya Müller, Former Secretary of the Environment Mexico City (contributor)
Moscow	Russia	Evgenia Semutnikova, Elena Tarasova, Roshydromet
Paris	France	Valèry Masson, Météo-France
Santiago	Chile	Pablo Hernandez, Ministerio del Medio Ambiente Pablo Saide, U. of California Los Angeles
Sao Paolo	Brazil	Lais Fajersztajn, U. of São Paolo Mariana Matera Veras, U. of São Paolo
Seattle	USA	John Labadie, Consultant
Seoul	South Korea	Jae-Cheol Nam; Korea Meteorological Administration
Shanghai	China	Jianguo TAN, Shanghai Meteorological Bureau
Singapore	Rep of Singapore	RAIZAN Rahmat, YAP Chui Wah; Meteorological Service Singapore
St Petersburg	Russia	Elena Akentyeva, Main Geophysical Observatory
Stockholm	Sweden	Lars Gidhagen and Jorge H. Amorim, Swedish Meteorological and Hydrological Institute
Stuttgart	Germany	Jasmin Hoefgaertner, Rayk Rinke, Ranier Kapp Office for Environmental Protection Municipality of Stuttgart
Toronto	Canada	Sylvie Leroyer, Environment and Climate Change Canada

A2.3 Urban Focal Point Survey

(Issued January 2018, for Volume I)

A2.3.1 Introduction

In collaboration with Public Weather Services, a survey was sent to selected National Meteorological and Hydrological Services regarding the urban services or their plans for the provision of urban services. It was an open-ended survey. The survey is attached below. Due to the short schedule, a two-week response was requested. Seventeen surveys were received.

A2.3.2 The Survey Template

1. *Integrated Urban Services*

- What system(s) are you currently using to forecast weather and/or environmental conditions (hydrology, flooding, air quality, heat) for urban centers? What are you using in the Climate and urban planning context?

- What is/are the spatial resolution of the system(s)? Is it sufficient for your particular context?

- Is your organization developing an integrated forecasting system at the urban scale for operational use?

  - What level of integration does your system includes between the following: weather, water, air quality and climate? Did it include others? Sandstorm, Wildfires, Volcanic Ash, pollen…?
  - How did your system originate? (World event like Olympics, Expo, other)
  - How far are you planning to expand the services? How are the user needs evaluated and included in the development?
  - How is this work coordinated/collaborated with city governments/administrations and other stakeholders/end users?

- If not, what are the main reasons? (cost of development, cost of computing, mandate, lack of demonstration of capacity, responsibility of other agency, training, guidance, …)

- What should the IUS Guidance document address in priority to support your organization?

2. Notes:

   1. We are interested in your organization specific experience.
   2. Feel free to adapt the questions and to add extra slides.
   3. Feel free to expand the scope.
   4. The intent is to quickly capture some initial.
   5. Please provide your inputs by 4 December 2017
   6. Reference: Grimmond S., Tang Xu, A. Baklanov, 2014: Towards Integrated Urban Weather, Environment and Climate Services. *WMO Bulletin*, 63, 1, 10-14.

A2.3.3 Respondents

The following responses were received.

NMHS	Name
Argentina	Celeste Saulo
Canada	Veronique Bouchet
Congo	Jean Louis Ebengo B. Mpotokole
Denmark	Knud-Jacob Simonsen
France	Cyrille Honore
Germany	Karolin Eichler
Italy	Col. Paolo Capizzi
Japan	Kenji Oshio
Kenya	Ayub Shaka
Malaysia	Zaidi B. Zainal Abidin
Maroc	Said El Khatri
Mexico	Ricardo Prieto González
Netherlands	Hans Roozekrans
New Zealand	Chris Noble
Nigeria	Mosunmola Idumu
Russian Federation	Marina Makarova
Sweden	Karro Ilmar
U.S.A.	Elliott Jacks

DEMONSTRATION CITY SUMMARIES

A3.1 Contributors

City	*Contributors*
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Auckland	David Johnston, Peter Kreft, Chris Noble
Beijing	Shiguang Miao
Casablanca	Rachid Sebarri
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Delhi (India)	Gufran Beig
Frankfurt am Main	Petra Fuchs
French cities (Paris, Toulouse)	Valery Masson
Hamburg	Heinke Schluenzen, Bert Jan Davidse
Helsinki	Ari Karppinen
Hong Kong, China	Chao Ren, Tsz-Cheung Lee
Johannesburg	Ezekiel Sebago
London (England)	Brian Golding
Mexico City (Ciudad de México)	Luisa Molina, Tanya Mueller
Moscow	Dmitri Kiktev
New York City	Chandana Mitra
Rotterdam	Marie-Claire tenVeldhuis
Saint Petersburg	Elena Akentyeva
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Singapore	Matthias Roth, Chui Wah Yap
Shanghai	Jianguo Tan
Stockholm	Jorge Amorim, Christer Johansson, Magnus Sannebro
Stuttgart	Rayk Rinke
Toronto	Felix Vogel, Sylvie Leroyer
Wellington	David Johnston, Peter Kreft, Chris Noble

A3.2 Caveats

The Demonstration City Surveys are provided as they were written, respecting the contributions of the authors. Only formatting of section headers was done.

A3.3 ANTWERP

Prepared by Patrick Willems

Section A: General information

The city of Antwerp is the second largest city in Belgium after Brussels. It lies in the Dutch (Flemish) speaking part of Belgium. It is the capital of the province of Antwerp and has a total population of more than half a million people. With 60% of all European consumers located within a 500 km radius, the port of Antwerp plays a significant part in Belgium's economy serving as Europe's second biggest port, handling 214 million tonnes of freight in 2016. As Belgium's most important logistical centre, Antwerp generated a total GDP of USD67 billion in 2016, accounting for 14% of the country's total GDP.

The climate is sub-oceanic, humid and rainy, influenced by the Atlantic Ocean: winters are cold but not freezing, while summers are quite cool. The average temperature is 3.5 °C in January, and 18.5 °C in July. Precipitation is relatively abundant, about 850 mm per year, but above all it is common and distributed throughout the year. The rainiest seasons are summer and autumn; the least rainy season is spring. Rainfall often occurs in the form of short showers or drizzle.

The city of Antwerp is situated on the Scheldt River, about 88 km from the North Sea. The Scheldt, together with the Meuse and the Rhine, forms the biggest estuary in western Europe. The city is located at a vulnerable spot along the Scheldt: where the river downstream from Antwerp has the shape of a funnel, it narrows up significantly near the city. Although the Scheldt represents a large potential threat, Antwerp has not been flooded by it recently. The city is, however, regularly (almost on an annual basis) affected by pluvial floods and less frequency by floods along rivers that cross the city and that are downstream connected to the Scheldt.

Four governance levels have an influence on the policymaking: the Federal government of Belgium, the regional government of Flanders, the city council of Antwerp, that plays an important role in the management of the different types of hazards and that is strongly supported by the city administrations, and the councils of the nine city districts. In terms of risk governance, there are three sub-arrangements, which each focus on a specific part of the policy domain. A first is the urban spatial and water management arrangement, which includes pre-dominantly spatial planners at municipal and regional level. The flood defence arrangement consists of water managers at several governmental levels, which are in charge of the maintenance of a specific river. The central cornerstone of this sub-arrangement is the Sigma Plan, which provides protection measures against flooding along the Scheldt river. The flood preparation arrangement is formed by emergency planners of the city and the federal level. It aims to reduce the damage caused by flooding through the development of actions plans.

Section B. Needs for the integrated services

The main hazards in the city are River Scheldt flooding (tidal influence), Pluvial flooding, Droughts, Heat stress and Air pollution.

Studies have been conducted to assess the hazards and risks related to river Scheldt flooding (by Flanders' Ministry of Public Works; risk maps are available; revised Sigma Plan is being implemented), heat stress (by research institute VITO for the City Authorities), river and pluvial flooding (by KU Leuven university for the City Authorities and i.c.w. the sewer system managing company Water-link for the pluvial flooding).

The Sigma Plan, revised in 2005, involves many flood control areas installed along the Scheldt and more upstream rivers, combined with nature management, and increasing dike crest levels and walls along the urban areas. The goal of that plan is to protect cities within the Scheldt basin against a river flood with a return period of 4000 years.

Also for the flood management along the other rivers, a move has been made from an exclusive focus on flood defence to a discourse on 'making space for water'. This discourse shift was triggered by the floods of 1998 and by new regulation of the Flemish government, in particular by the instrument of the so-called "water test" (no new building permits in high flood risk areas and mitigation measures such as water storage and infiltration to be taken on public and private domains when new building projects involve additional pavement, loss of water storage or new rain water drainage network).

A real-time flood forecasting system has been developed (at Flanders Hydraulics for the Scheldt and at Flemish Environment Agency for the other rivers).

To study air pollution, recently a crowdsource based measurement campaign has been held. This has drawn strong public attention. The city has taken measures by installing a low emission zone in the city centre. This means that old cars with high concentrations of fine dust emissions can no longer enter the city centre.

Section C: Services integration

Drought related risks are currently being studied by the City Authorities. To cope with the pluvial and drought related risks, a water plan is being developed, looking at the interactions between the sewer and river systems and spatial planning (considering blue-green solutions). Strong attention goes to green roofs and there are also pilot projects on green walls in specific streets (living labs), collective rainwater reservoirs, rainwater treatment, and so forth. The EU-H2020 project BRIGAID even tested in Antwerp a so-called "smart greenroof", at which the water storage is controlled in real time based on weather forecasts.

A raingauge network is being installed and river and groundwater levels are being measured but at a limited number of locations. There are plans to install X-band radars to measure the rainfall over the city with high resolution and to set up a pluvial flood forecasting system. There is a need for more coordination of the different flood risk management strategies. Today, all strategies are present but they work rather independently from one another, which in some cases leads to ineffectiveness and inefficiency. Coordinating flood risk governance in Antwerp is complicated since it involves a large number of actors. In recent years, however, steps have been taken to reduce the fragmentation level and to strengthen informal coordination networks. The City's planned development of a climate adaptation strategy might lead to a further intensification of the coordination between the different actors involved.

A3.4 AUCKLAND

Prepared by David Johnston/Peter Kreft

Section A: General information

Socioeconomic

Auckland, in the North Island of New Zealand, is by far the largest urban area of the country. The city is expected to continue growing faster rate than the rest of the country. The core of Auckland City is the Auckland central business district, a major financial and commercial centre, surrounded by many suburbs. The city is the major financial centre of New Zealand.

Population and area

The Auckland urban area is comprised of one city with a population of over 1.7 million people (one-third of New Zealand's population) and an area of 1,102.9 km^2.

Geography and climate

Auckland City lies between the Hauraki Gulf of the Pacific Ocean to the east, the low Hunua Ranges to the south-east, the Manukau Harbour to the south-west, and the Waitakere Ranges and smaller ranges to the west and north-west. The populated areas are a combination of gently rolling hills and flat land, generally a few tens of metres (or less) above sea level. The Auckland Volcanic Field is an area of about 360 km^2 centred on Auckland city; within this field are over 50 separate volcanoes. Many of the volcanoes have been quarried or become public parks. Auckland's existing volcanoes are unlikely to become active again, but the Auckland Volcanic Field itself is young and still active. Auckland has a subtropical oceanic climate, with warm humid summers and mild damp winters.

Governance

The Auckland Council is the local government council for the region. The governing body consists of a mayor and 20 councillors, elected from 13 wards. Besides providing many of the services required by its community, Auckland Council provides environmental and emergency management, flood protection and land management, provision of regional parks, public transport planning and funding, and metropolitan water supply.

Section B: Needs for the integrated services

Hazards[11]

- Tsunami
- Earthquake
- Coastal erosion
- Wildfire
- Volcanic eruption
- Storms (both subtropical and local)
- Landslips
- Flash flooding
- Storm surge
- Air and swimming water quality.

[11] https://www.aucklandcouncil.govt.nz/building-and-consents/Pages/natural-hazards.aspx

Providers

- Seismological information is provided by the Institute for Geological and Nuclear Sciences (GNS Science), a government science department.
- Tsunami Watches and Warnings are provided by New Zealand's Ministry of Civil Defence & Emergency Management (MCDEM), with support from GNS.
- Fire information is provided by Fire and Emergency New Zealand (FENZ), with support from the National Institute for Water and Atmospheric Research (NIWA), a government science department.
- Weather observing and forecasting is conducted by the Meteorological Service of New Zealand Limited (MetService), New Zealand's National Meteorological Service. MetService provides Outlooks, Watches and Warnings of both broad-scale and local-scale (convective) severe weather.
- Flood warnings and forecasts of air and swimming water quality are provided by Auckland Council (that is, local government), with support from MetService.

Users

General public, government departments, local government (including disaster management, water supply and stormwater management), energy providers, national and local roading authorities, port authority and shipping companies, airport authority and airlines, industry, media.

Requirements

- Forecasting of rainfall-induced landslips and their consequences (e.g. road closures, evacuations).
- Longer lead times on forecasts of urban flooding during periods of convective rainfall
- Longer lead times and greater accuracy of forecasts of flow in river and stream catchments, and urban waterways, of all sizes.
- Inclusion of likely impacts in forecasts and warnings of geophysical hazards.
- Forecasts of coastal inundation (storm surge and tsunami) of greater specificity and longer lead time.
- Forecasts of wind storms and their impacts (e.g. power outages) of greater specificity and longer lead time.

Section C: Services integration

Responsibility for the provision of information about natural hazards and their impacts is widely distributed. While there is good collaboration among the providers of hazard information, there is no "single source of truth" on either hazards or their impacts. Further, it is common for managers of weather-related risks to use weather information from multiple sources in their decision-making.

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A3.5 BEIJING

Prepared by Shiguang Miao

Section A: General information

Socioeconomic

- Total area of about 16,411 km2
- Urban area of about 1,401 km²
- About 21.7 million people (2017)
- 16 municipal districts
- Core city of Jing-Jin-Ji city agglomeration
- GDP of about 2.8 Trillion RMB
- Modern and highly urbanized metropolitan
- Superb infrastructure (e.g. advanced land and air transport and communication systems, reliable water and power supplies, etc.)

Climate zone

- Northern temperate semi-humid continental climate with summer and winter monsoons
- Inland city with mountainous topography

Governance structure

- Beijing is a municipality directly under the central government of China

Section B. Needs for the integrated services

Most common hazards

- Heavy rain, thunderstorms, heatwaves, cold surges, fog, air pollution, water scarcity, landslide

Description of existing integrated urban services

- Meteorological service
- Climate service
- Environmental meteorological service (Haze)
- Air quality service

Providers of the urban services

- Beijing Meteorological Service (BMS) – weather and climate monitoring/forecast/warning
- Beijing Municipal Ecological Environment Bureau (BMEEB) – air quality monitoring/forecast and water quality monitoring

Users of the integrated urban services

- Government departments
- General public
- Transportation sectors (land and air)
- Energy sector
- Water management
- Industry sector
- Health sector
- Tourism sector

- Insurance sector
- Disaster risk management

Requirements for the services

Short term (DRR)

- In situ weather observations (rainfall, temperatures, relative humidity, pressure, wind speed/direction, visibility, solar radiation, evaporation, etc.)
- Regular upper-air soundings and the high-resolution remote sensing images including radars, satellite, and lightning location, etc.
- Wide range of weather forecasts covering multi-timescales.
- Warnings and advisories for various weather hazards (e.g. thunderstorm, heavy rain, landslide, flooding, cold and very hot weather, etc.)
- Tailor-made meteorological services for energy departments as well as other weather-sensitive users.
- Air pollution monitoring and forecast.

Long term (urban planning)

- Climatological monitoring and information
- Seasonal predictions
- Climate data and expert advices for different sectors (e.g. infrastructure and building designs, urban planning, air ventilation assessment, public health, water resource management, public utilities (energy), research communities, etc.)

Section C: Services integration

Short term*:* multi-hazard early warning and forecasting systems

Long term*:* urban planning for sustainable development, climate change mitigation and adaptation

Components integrated (and how)

Short term:

1) At the level of observational infrastructure

Weather

- In total over 400 automatic weather stations (AWS) providing a wide range of meteorological measurements (e.g. rainfall, temperatures, relative humidity, pressure, winds, visibility, solar radiation, and evaporation, etc.)
- 1 S-band and 6 X-band weather radars, 7 wind profilers, 7 microwave radiometers, 7 cloud radars, 10 ceilometers, satellite reception systems and a lightning location network
- One regular upper-air soundings station, twice per day at 0000 and 1200 UTC

Air and water quality

- BMEEB

2) At the level of modelling tools

Weather

- State-of-the-art numerical weather prediction (NWP) products from major global models (e.g. ECMWF, NCEP, JMA, etc.)
- Rapid-refresh Multi-scale Analysis and Prediction System (RMAPS) includes five off-line, one-way nested components, each with its own horizontal grid spacing (Δx). The system starts with ECMWF Global forecasts (at 3 h intervals) and terminates with hourly weather and air quality forecasts. Relationships between these internal operational components are described below:

  - Nowcasting (NOW) Model (Δx of 5 and 2.5 km): uses input from the Variational Doppler Radar Analysis System (VDRAS) for 6 h real time forecasts, with ingested data from seven S-band weather radar and all AWS sites.
  - Short Term (ST) Model (Δx = 9 and 3 km): uses WRF Data Assimilation (WRFDA), and either the WRF Noah (for rural grid points) or SLUCM (for urban grid points) land-surface modules for operational 72 h forecasts, for which regional and local data are assimilated.
  - Urban Model (Δx =1 km): for urban weather forecasts with the multi-level BEP + Building Energy Model (BEM) urban PBL modules for 24 h real time (but not yet operational) forecasts and research studies, where BEM, BEP, and their urban LU/LC input data are used and where its AWS data are assimilated.
  - Integration (IN) Model: combines observations into the NOW, ST, and Urban model forecasts for objective 12 h forecasts, where its input (QPE) are radar data and are calibrated by AWS raingauge observations.
  - CHEM Model (Δx = 9 km and 3 km): for 96 h chemical forecasts from the WRF-Chem model.

3) At the level of the services/information delivery, communication

Weather

- By integrating comprehensive weather observations and numerical weather prediction products, BMS provides a wide range of forecasts covering multi-timescales (e.g. nowcasting, 3-day forecast, 10-day forecast) and different spatial resolutions in Beijing, including territory wide, district, and specific sites.
- Warnings and special advisors are issued whenever Beijing is threatened by severe weather conditions such as rainstorms, thunderstorms, very hot or cold weather.
- Various weather information, forecast and warnings of BMS are timely disseminated to the general public, government departments and other specialized users through different channels, including media (TV, radio and newspaper), webpages, mobile platforms and social media.
- Online information service and location specific weather services are available from BMS's website and Tianqitong app for urban dwellers to access various first-hand weather information anywhere and anytime.
- BMS launched its Micro-blog page and WeChat platform to enhance communication with the public through social media in July 2013.
- Pre-flood season seminars, training courses, briefings and visits are conducted for relevant government departments and weather sensitive stakeholders to promote their awareness of, and community preparedness for natural disasters.

Air and water quality

- BMEEB

Long term

1) At the level of observational infrastructure

- Continuous observations of essential surface meteorological observations for over 100 years at 54511 meteorological station (such as temperatures, rainfall, pressure and relative humidity).
- Regular upper air soundings at 54511 since 1950s.
- High temporal and spatial resolution meteorological observations from AWS networks since 2000s.

2) At the level of modelling tools

- BMS adopts an ensemble approach to formulate its seasonal forecast for Beijing, taking into consideration available products from major climate prediction centres and the Regional Climate Model (RCM) operated in CMA.

3) At the level of the services/information delivery, communication

- The meteorological observations collected in Beijing are compiled and published regularly for monitoring the monthly, seasonal, and annual climate status in Beijing. Long term variations of various meteorological elements and indices, such as temperature, rainfall, and extreme weather events, are also conducted to assess the climate change in Beijing due to global warming and local urbanizations
- Seasonal forecasts of average temperature and total rainfall and annual outlook of rainfall in broad terms are prepared.
- Establish close partnerships with various stakeholders in the city to enhance its weather and climate services. For examples:

    - Providing monthly forecast of yield collected in Beijing reservoirs to support water resource management.
    - Joining hands with energy sector to enhance energy consumption forecast to reduce the electricity consumption and peak loading under hot weather situation;
    - Providing meteorological service and expert advice for Urban Planning Department and other professional bodies to establish guidelines to assess and regulate the impact of potential city, community and building developments on urban climate and atmospheric environment.
    - Working closely with different engineering departments and professional bodies to establish and regular review the engineering design standards and codes of practices appropriate to local conditions for protecting the city and public safety against various weather hazards and natural disasters.

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A3.6 CASABLANCA

Prepared by Rachid Sebbari

Section A: General information

Socioeconomic

Total area of about 1117 km2; population of about 4.27 million (2014 census). Casablanca is a coastal city located in the north-western Morocco and bordered by the Atlantic Ocean to the north and northwest. The Grand Casablanca, which includes Casablanca and Mohammedia cities, is the economic heart of the Moroccan economy. It generates 19% of national GDP, owns 40% of industrial establishments, attracts 48% of investments and has 30% of the banking network. Please refer to the following URL for economic conditions and more: https://www.hcp.ma/reg-casablanca/. Modern and highly urbanized metropolitan. Superb infrastructure (e.g. advanced land, sea and air transport and communication systems, reliable water and power supplies, etc.).

Geographical

Casablanca is a coastal city and has a Mediterranean climate influenced by the Ocean (Köppen climate classification Csa). Because of its proximity to the Atlantic Ocean, climate of the region of Casablanca-Settat undergoes the maritime influence and is of oceanic type. It is mild, moderate and rainy in winter and humid and temperate in summer. Casablanca is located in the Chawiya Plain with the Bouskoura forest as the only natural attraction in the city and the closest permanent river is Oum-Rabia, 70 km to the south-east.

Governance

The Wilaya of Grand-Casablanca consisted of two prefectures and two provinces. It is a part of the Administrative Region called Casablanca-Settat. Please refer to the link below for more details: http://casablanca.ma/

Section B. Needs for the integrated services

Hazards

Heavy rain, thunderstorms, flooding, extreme winds, heatwaves, cold surges, water scarcity, fog, air pollution.

Users

General public, Government departments, Energy sector, Water management, Industry sector (building), Transportation sectors (land, sea and air), Health sector, Tourism sector, Insurance sector, Disaster risk management

Providers

National Meteorological Service – weather and climate monitoring/forecast/warning; air quality monitoring/forecast[12]. Basin Management Agency of Bouregreg and Chaouia[13].

[12] http://www.marocmeteo.ma/
[13] http://www.abhbc.com/index.php

Requirements

Short term (DRR)

- In situ weather observations (rainfall, temperatures, relative humidity, pressure, wind, solar radiation, evaporation, etc.) and air pollution measurements (Ozone, Nitrogen dioxide, particulate matter, Sulphur dioxide, Carbon monoxide, etc.)
- Regular upper-air soundings and the high-resolution remote sensing images including radars, satellite, and lightning location, etc.
- High resolution weather forecasts for different timescales.
- Marine forecasts for short term.
- Air pollution monitoring and high-resolution forecast.
- Warnings and advisories for various weather hazards.
- Tailor-made meteorological services for aviation (Mohamed V airport) and marine communities as well as other weather-sensitive users such as Water and Power Authority (Lydec).

Long term (urban planning)

- Climatological information and Climate data and expert advices (e.g. such as Normals, Intensity-frequency-duration of extreme rainfall events, etc.) for different sectors (e.g. infrastructure and building designs, urban planning, public health, water resource management, public utilities (energy), research communities, etc.)
- Climate projections of temperature, rainfall, mean sea level based on IPCC climate model data.

Section C: Services integration

Components integrated (and how):

1) At the level of observational infrastructure

Weather

- Over the administrative region where Casablanca is located, there are 6 manned stations (4 located in Grand-Casablanca) and 12 automatic weather stations (4 located in Grand-Casablanca) providing a wide range of meteorological measurements (e.g. rainfall, temperatures, relative humidity, pressure, winds, visibility, solar radiation, etc.)
- 1 Doppler weather radar, satellite reception systems receiving data from different meteorological satellites and a lightning location network.
- Daily upper-air measurement using radiosonde.
- Two radars of high frequency for the measurement of ocean wave height, length and period and also surface ocean current.

Air quality

- 13 air quality monitoring stations of EPD for regularly monitoring O3, NOx, SO2, CO, PM10, Methane, COV.
- 1 air quality mobile station.

Climate

- Continuous observations of essential surface meteorological observations since 1911 for the main Casablanca station (such as temperatures, rainfall, pressure etc.).

2) At the level of modelling tools

Weather

- State-of-the-art numerical weather prediction (NWP) products from ALADIN/Al Bachir Model with 7.5 km resolution (forecasts up to 72H) and AROME Model with 2.5 km resolution (forecasts up to 48H), ECMWF (forecasts up to 15 days) and Météo-France (forecasts up to 96H) major global models.
- A fog nowcasting system is operated for Mohamed V (GMMN) international airport. It makes use of the single column detailed physics COBEL-ISBA model and conventional and mast measurements.
- WAVEWATCH3 marine model with 0.25° resolution is used to produce wave height, length and period forecasts up to 72H and also wind speed and direction forecast.
- ALJAZR model for tidal predictions.
- Forecasting accidental marine pollution drift is performed by MOTHY model with forecasts up to 72H.

Air quality

- Regional air quality model named "Casablanca-Air" and since 2014 is providing 48 hours forecasts of air quality on daily basis for major atmospheric pollutant (including NO_2, SO_2, O_3 and PM10) with a resolution of 200 metres. The system used is ADMS-Urban (Atmospheric Dispersion Modelling System).
- The MOCAGE (MOdèle de Chimie Atmosphérique à Grande Echelle) runs daily for one day and produces NO_2, SO_2, O_3, PM10, PM2.5 and CO forecasts. Its simulations are carried out on two nested domains: the globe at 1° of horizontal resolution and Morocco at 0.2°.
- DMN uses also air quality products of the Copernicus Atmosphere Monitoring Service (CAMS) to follow air quality (NO_2, SO_2, O_3, PM10, PM2.5 and CO).
- AERMOD model is used at DMN since 2012 for research purposes related to pollutants transport and dispersion modelling with the main objective of forecasting continuous or accidental dispersion of emitted pollutants.

Climate

- DMN uses ALADIN Climat model to produce high resolution and dynamical downscaling of climate projections up to 2100.
- Climate projections of temperature, wet-bulb temperature, rainfall, mean sea level, extreme events return period are computed based on IPCC climate model data using appropriate downscaling methods; dynamical or statistical.

3) At the level of the services/information delivery

Weather

- By integrating comprehensive weather observations and numerical weather prediction products, DMN provides a wide range of forecasts covering different timescales (up to 15-days forecasts) and different spatial resolutions in Morocco, including territory wide, district or regional level, and specific sites.
- Three hourly (up to 72H) and hourly (up to 48H) meteographs for rainfall, temperature, humidity, wind speed and direction are provided for Casablanca.
- Warnings and special advisors are issued whenever Casablanca is threatened by severe weather conditions particularly thunderstorms, rainfall exceeding specified threshold, hot or cold spells, abrupt changes in temperature, heavy swell, strong wind, extreme tidal.

- Various weather information, forecast and warnings from DMN are timely disseminated to the general public, government departments and other specialized users through different channels, including media (TV, radio and newspaper) and webpages.
- Regular visits are conducted for relevant government departments and weather sensitive stakeholders to promote their awareness of, and community preparedness for, natural disasters.
- DMN provides weather information for Mohamed V International Airport in support of international aviation navigation.
- DMN provides marine meteorological information and forecasts to serve international shipping on Atlantic coastal waters.

Air quality

- Air Quality information including the Air Quality Index are released to the public via a website and through regular weekly and monthly bulletins. http://www.marocmeteo.ma/aircasa/public/

Climate

- The meteorological observations collected by DMN are compiled and published internally for monitoring the monthly, seasonal, and annual climate status in Morocco and at the administrative regional level.
- Studies of long term variations of various meteorological elements and indices, such as temperature, rainfall, sea level, and extreme weather events, are also conducted to assess the climate change in Casablanca due to global warming and local urbanizations and shared with many institutions.
- Climate data and products of Casablanca are accessible by contacting the DMN with the possibility of access through the Extranet of DMN by signing a memorandum of agreement.
- Seasonal forecasts of average temperature and total rainfall are prepared and made available online for users' reference and also published through the North Africa Regional Climate Centre.
- DMN established close partnerships with various stakeholders in the city to enhance its weather and climate services for the priority areas of WMO GFCS on energy, water, health, and disaster risk reduction.

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A3.7 DALLAS-FORT WORTH METROPLEX

Prepared by Chananda Mitra

Section A: General information

Population and area

Dallas-Fort Worth-Arlington, Texas Metropolitan Statistical Area is known as Dallas-Fort Worth Metroplex or simply DFW.

- DFW population in 2017 was about 7.4 million encompassing 12,800 square miles
- DFW is made up of 13 counties. The City of Dallas is the most populous city with 1.34 million inhabitants, followed by Fort Worth with 874,168.
- Real GDP was over $511 billion in 2016 making DFW the 11th largest economy in the world.

Infrastructure

- DFW International Airport is the largest airport in Texas and one of the busiest airports in the USA.
- This region has thousands of lane-miles of freeways and interstates.
- The Dallas Area Rapid Transit (DART), Trinity Metro and Denton County Transportation Authority offer extensive public transportation options expanding across the Metroplex.

Climate zone and geographical position

- The DFW region is situated about 250 miles north of the Gulf of Mexico, at an elevation of between 500-800 feet.
- According to the National Weather Service, the region's climate is humid subtropical with hot summers. It is also continental, which is characterized by a wide annual temperature range (average 37°F in January to 98°F in August). Precipitation varies considerably, which ranges from less than 20 to more than 50 inches[14].

Governance structure (decision-making)

Legal Framework: Although DFW is considered as single Metroplex, its governance is separate as evidenced by separate authority for each city in the area. Each city (Dallas, Fort Wort, Arlington, etc.) has separate same type governance. Council-City Manager system prevails where city council appoints a manger to monitor and coordinate all activities. The council also appoints city secretary, city attorney, city auditor, municipal court judges and citizens who serve on city boards and commissions.

Responsible Institutions for addressing urban hazards, policymaking powers:

Federal Emergency Management Agency (FEMA): The mission of FEMA is to reduce the loss of life and property and protect institutions from all hazards by leading and supporting the nation in a comprehensive, risk-based emergency management programme of mitigation, preparedness, response, and recovery. Texas is part of FEMA region VI.

[14] https://www.weather.gov/fwd/dnarrative

Floodplain Management: Floodplain management for the DFW region is overseen at a local, regional, and state level. Each city has its own Stormwater Management department within its own local government. On a regional level, the Trinity River Authority promotes conservation, reclamation, protection and development of the natural resources of the river basin for the benefit of the public. Multiple water districts support clean water and flood protection measures such as the Tarrant Regional Water District and the North Texas Municipal Water District. The National Oceanic and Atmospheric Agency's West Gulf River Forecast Center monitors river levels and produces river forecasts and products.

National Weather Service (NWS): The NWS provides weather, water, and climate data, forecasts and warnings for the protection of life and property and enhancement of the national economy. The Fort Worth/Dallas Weather Forecast Office (FWD WFO) provides regional forecast and weather warning products to the general public and regional partners such as emergency managers, media, energy and transportation officials, airports, hospitals, schools and universities. NWS disseminates weather warning products via the Emergency Alert System, Wireless Emergency Alerts, NOAA Weather Radio, Integrated Public Alert and Warning System. FWD WFO incorporates data from various meteorological networks such as agricultural stations, US Geological Services rain and flood gauges, military, airports, universities, and multiple radar networks including (NEXRAD, Terminal Doppler Weather Radar (TDWR) and the Center for Collaborative Adaptive Sensing of the Atmosphere (CASA).

North Central Texas Council of Governments: This is a voluntary association of, by and for local governments, established to assist in regional planning. Programmes include transportation planning, environment and development, aging and disability resources, emergency preparedness, demographic research, regional training, criminal justice, and police resources.

Texas Commission on Environmental Quality: This is the environmental agency for the state of Texas. It manages a network of air monitoring sites across the Metroplex in accordance to national Environmental Protection Agency (EPA) regulations. The status of regional air quality is compiled annually by the North Central Texas Council of Government's Air Quality Handbook. Individual cities making up the DFW Metroplex are responsible for monitoring air quality for their respective jurisdiction. For example, the City of Dallas Air Pollution Control Programme provides data to TCEQ, and monitors for the presence of criteria pollutants, including ozone, identified by the EPA as detrimental to public health.

United States Geological Service (USGS): serves the Nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect quality of life.

Section B. Needs for the integrated services

Most common technical hazards

- Transportation accidents
- Utility (water or energy interruption)
- Fuel pipeline accidents
- Terrorism
- Dam and levee failure
- Biological

Most common natural hazards

- Flooding (riverine and flash flood)
- Severe Thunderstorms (high winds, hail, lightning)
- Tornadoes: DFW is the largest metropolitan area in "Tornado Alley" (a zone that stretches from northern Texas through Oklahoma and into Nebraska where the strongest tornadoes occur most frequent). Rapid movement of air is enhanced due to flat terrains, while high humidity of the Gulf Stream further induces instability in the atmosphere. Tornado hazards need significant consideration for this region due to the evidence of devastating impacts from previous tornado occurrences.
- Winter storms (snowstorms, blizzards, cold waves, and ice storms)
- Drought
- Extreme heat and associated health impacts
- Wildfire
- Seismic: Due to the position in relatively stable geologic platform with no active fault systems, DFW experiences only minor seismic activity due to oil and gas extraction and injection activities. However, the Meers Fault System of Southwestern Oklahoma and the Reelfoot Rift Region of Southern Missouri pose some risk in terms of high magnitude seismic events. (FEMA 1997 Multi-Hazard Identification and Risk Assessment. Seismic Hazards, Chapter 16).
- Expansive soils hazards pose a risk in Blackland Prairie areas (Dallas, Ellis, Collin, Kaufman, Rockwall counties etc.)[15]

Providers of the urban services

- Individual city governments are mainly responsible bodies for providing urban services
- Government agencies such as NOAA, USGS, EPA, etc. Government organizations provide important services in terms of land use/ cover change information, weather/climate data etc.

Users of integrated urban services

- Government agencies (environment, energy, water management, transportation, health, tourism, disaster risk management)
- Industries (energy, health, airports, insurance sector)
- General public
- Media

Requirements for the services

- Requirements for *short term* DRR (Disaster Risk Reduction) are rainfall, temperature, precipitation, humidity, wind speed, solar radiation, evaporation rate, remote sensing images such as Landsat, SPOT, MODIS, QuickBird, wide range of weather forecasting, warnings for weather hazards, air quality etc.
- For long term urban planning we need climatological data and seasonal predictions. Climatologic data for urban design, building design initiatives, public utilities, water resources management, etc.

[15] https://www.nrc.gov/docs/ML0929/ML092990302.pdf
http://www.dallascounty.org/Assets/uploads/docs/hsem/2015_12_01_Dallas_County_HazMAP_APA_Copy.pdf

Section C: Services integration

National Weather Service (of NOAA) provides a huge range of weather/climate related data such as temperature, precipitation, snowfall, wind data, sky cover data, relative humidity, sunrise/sunset etc. FEMA (maintained by U.S. Department of Homeland Security) is behind the "National Response Framework (NRF)." NRF provides guidelines for all response partners to deliver a unified national response to disasters and other emergencies. Local agencies (of U.S. Emergency Management System, comprised with local, state, federal E.M. agencies) and Non-Governmental Organizations (such as the Red Cross) work at weather warning stage like increasing awareness, providing presentations, etc.[16]

Urban Area Security Initiative (UASI) provides financial assistance to address the unique planning, equipment, training, and exercise needs of high-threat, high-density urban areas, and to assist them in building and enhanced and sustainable capacity to prevent, respond to, and recover from threats or acts of terrorism. This initiative is organized in DFW through the North Central Texas Council of Governments (NCTCOG).

Observational infrastructure

- NEXRAD S-Band radar (NWS)
- TDWR C-Band Radar (Federal Aviation Administration)
- CASA X-Band Radar (Collaborative Adaptive Sensing of the Atmosphere (CASA) Dallas-Fort Worth Urban Testbed)
- ASOS/AWOS surface data (NWS National Mesonet Program distributed via NOAA Meteorological Assimilation Data Ingest System (MADIS)
- SODAR wind profilers (WeatherFlow)
- Surface-based radiometers (Radiometrics)
- Aircraft data (MDCRS and TAMDAR)
- High-frequency pressure and GPS-Met data (CASA installed weather stations)
- Citizen and private weather service surface observations (CWOP and Earth Networks)
- Commercial systems (GST MoPED and Understory)
- Stream gage networks (USGS)
- Raingauge networks (Local municipalities, CoCoRaHS)
- The NCTCOG has worked to create a regional flood warning software tool called OneRain, Inc. with the goal to enable communities to see storms as they track across the region and the impacts they are having in neighboring communities, allowing for better preparedness and collaboration.

Services/information delivery and communication

- NWS disseminates official weather warning products via the Emergency Alert System, Wireless Emergency Alerts, NOAA Weather Radio, Integrated Public Alert and Warning System. Alerts and warnings are disseminated by the media, emergency management and public officials via social media (Facebook, Twitter) as well as emergency notification systems and traditional methods such as TV, radio and newspapers. These have been effective mediums for disseminating information at pre, during and post hazards/disaster stages for making the public aware about possible impacts.

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[16] https://www.wmo.int/pages/prog/drr/projects/Thematic/MHEWS/GoodPractices/USA/UnitedStates.pdf

A3.8 DELHI (INDIA)

Prepared by Gufran Beig[17]

Section A: General information

Population and area

Delhi National Capital Territory (NCT): 20M inhabitants occupying 1484 km^2 area. The NCT comprises of nine districts, 27 tehsils, 59 census towns, 300 villages, and three statutory towns, the Municipal Corporation of Delhi– 1,397.3 km^2, the New Delhi Municipal Council– 42.7 km^2 and the Delhi Cantonment Board– 43 km^2.

Infrastructure

Delhi City Atmospheric Monitoring System has a wide geographic coverage and good data collection capacity. It has monitoring of weather parameters, climate parameters, hydrology and air quality parameters. The emission inventory of Delhi and surrounding fringe areas was first developed in 2010 by SAFAR (System of Air Quality and Weather Forecasting and Research). Emission Inventory has recently been upgraded for 2018. Emission inventory is available for 8 parameters- NOx, CO, $PM_{2.5}$, PM_{10}, SO_2, BC, OC and HCs. Transport infrastructure includes public transportation infrastructure (urban buses, Metro train service), motorized transport (bike sharing programme). The city has good communication infrastructure.

Climate zone and geographical position

Delhi is located at 23.38 degree north and 77.13 degree east in the Northern part of India and bounded by Haryana State on the Northwest and South, Rajasthan state on the Southwest and Uttar Pradesh state on the east. The metropolis city is demarcated into three parts, with the Gangetic plains forming the major part, the Yamuna flood plain and the Delhi ridge. Delhi lies in the landlocked Northern Plains of the Indian Subcontinent. Its climate is greatly influenced by its proximity to the Himalayas and the Thar Desert, causing it to experience both weather extremes. Delhi has 5 distinct seasons, viz. Summer, Rainy, Autumn, Winter and Spring. But there are three major seasons - Monsoon (Rainy): July, August, September; Hot, Pleasant during rains; v High to very high humidity; Heavy precipitation. Summer starts in early April and peaks in May, with average temperatures near 32 °C although occasional heatwaves can result in highs close to 45 °C (114 °F). Winter starts in late November or early December and peaks in January, with average temperatures around 12–13 °C (54–55 °F). Although winters are generally mild, Delhi's proximity to the Himalayas results in cold waves leading to lower apparent temperature due to wind chill. Delhi is notorious for its heavy fogs during the winter season. In December, reduced visibility leads to disruption of road, air and rail traffic.

Governance structure

As a first-level administrative division, the National Capital Territory of Delhi has its own Legislative Assembly, Lieutenant Governor, council of ministers and Chief Minister. Members of the legislative assembly are directly elected from territorial constituencies in the NCT. The Municipal corporation handles civic administration for the city as part of the Panchayati Raj Act. The Government of India and the Government of National Capital Territory of Delhi jointly administer New Delhi, where both bodies are located.

[17] https://safar.tropmet.res.in/

Responsible Institutions for addressing urban hazards, policymaking powers
India Meteorology Department (IMD) is a national weather services agency and plans and mandate meteorological information at national and local levels; manages the climatological database. It shares information in newsletters or special advisories through news bulletins, phone or internet to specific users, common public and Govt. ministries.

National
Disaster Management Authority of India (NDMA) is in charge of risk management and disaster prevention to reduce population exposure to meteorological, hydrological, geological and chemical hazards such as volcanic eruptions, flooding, tropical storms, earthquakes, and chemical releases, among others. Central Pollution Control Board (CPCB) and Ministry of Environment and Forest and Climate Change (MOEFCC) handles air quality monitoring, emissions standards to deal with air pollution and climate change aspects and implement the control measures. Delhi state Environmental Secretariat manages Delhi's environment. SAFAR (System of Air Quality and Weather Forecasting and Research is India's first metro air quality forecasting system and also a pilot project of GURME, WMO is implemented and operationalized by Indian Institute of Tropical Meteorology, Pune under the Indian Ministry of Earth Sciences. The SAFAR is responsible for Air Quality Monitoring, forecasting and issues air quality and meteorological forecast to alert the public about critical pollution levels in terms of Air Quality Index (AQI) and prevent exposure to harmful pollutants[18] using giant LED display boards, IVRS services, MobileApp (SAFAR-Air).

SAFAR –Products

1) Air quality: Color-coded Index based Current & 3-days forecast with health advisories.
2) Harmful Radiation: Severity of UV radiation (UVI) with associated skin advisories.
3) Weather: Current & 3 days advance forecast, sea, tide and severe weather.
4) Extreme Events: Alert for extreme pollution and weather events.
5) Emission Scenario: Accounting location-wise sources of air pollution.

Section B. Needs for the integrated services

Most common hazards in the city and associated with environmental risks. Delhi is highly affected by extreme pollution events caused due to cold winter in a land lock city Delhi, stubble burning in the neighbouring states, long-range transport from Indo-Gangetic Plane region and duststorm in summer from Gulf region and neighbouring province Rajasthan Desert.

Extreme weather events leading to floods and landslides. Health impacts caused by heatwaves and dehydration, handles/ air quality monitoring, emissions standards, handles air quality monitoring, emissions standards earthquake, social and spatial inequality & high vulnerability to climate change, vector-borne diseases related to climate change and other pollution.

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[18] https://safar.tropmet.res.in/

Existing integrated urban services for meeting hazard challenges

Ministry of Earth Sciences, Govt of India operationalized the first Air Quality Forecasting Services SAFAR for Indian Megacities, indigenously designed and developed by Indian Institute of Tropical Meteorology, Pune. SAFAR is a seamless early warning system enriching local people with 3 days advance information on air quality, related health advisory, weather, harmful radiations, extreme event and environmental awareness to deal with their adverse impacts and hence protect citizens by early preparedness and interventions.

The MOEF&CC has formed a monitoring committee to formulate short and long-term measures to solve air pollution of Delhi NCR. The GRAP, Graded Response Action Plan is one such plans to combat air pollution of Delhi NCR. GRAP laid down a stratified action which is required when the concentration of pollution reaches a certain level. This is the first ever plan of its kind that designates short, medium and long-term measures for all key sources of pollution and will help the Delhi NCR region to make a sustained improvement in air quality.

The job of ensuring implementation of the action plan will be EPCA's, which will delegate the responsibility to the concerned departments. The government has also established the Earth Quack Seismology Services, Agrometeorological advisories for farmers by IMD. Risk alerts system by NDMA, etc.

Requirements for the services

Short term

Environmental monitoring and forecast: provide timely information to different sectors of Delhi population about weather, water, air quality, climate, wildfires, volcanic hazards. Improve the performance of air quality forecasting systems SAFAR using updated IITM emission inventories, satellite data assimilation, dust module and updated environmental data. A new initiative on the line with SAHAS (SAFAR-Air Health Alert System) envisages an action based management system where advance Air Quality information, precautions, advisory in terms of ALERTS go hand in hand with ACTION on the ground with people's participation to protect Human health. SAHAS also engineers awareness drive by educating Public, Medicos and Executives to pave the path to develop mitigation strategies. The programme will benefit policymakers for sustainable action plan, researchers and educationist, and general public by creating awareness and early preparedness from air pollution and weather extremes. It is also leading to better understanding of linkages among emissions, weather, pollution and climate.

Long term

Invest in infrastructure and personnel for the monitoring network due to changes in the sources of emissions and pollutants and the expansion of urban areas to the periphery and many other metropolitan cities. Enhance measurement of vertical profiles of meteorological parameters using balloon, aircraft and satellite monitoring. In-depth analysis of the increase in atmospheric temperature on the air quality in the NCT and the impact of meteorology on air pollution. Reinforce epidemiological surveillance and implement an integrated regional land use-transportation-air quality management system involving close cooperation of the relevant authorities (environment, transportation, urban development, and public works) with public participation. Expand model coverage and air quality forecasting to include the megalopolis region. Expand and strengthen capacity-building for technicians and scientists.

Section C: Services integration

Short term

There is an urgent need to integrate weather services of IMD, air quality forecasting services of SAFAR, Climate services of MoEFCC and IITM, Seismic and Tsunami warning system services of INCOIS of MoES, air quality monitoring and expansion of services of CPCB and Delhi government.

Long term

Delhi City need to be under Smart City Mission launched by the Central Government. This must integrate following 5 pillars: i) Foster regional coordination; ii) Promote water resilience as new paradigm to manage water in the Mexico Basin; iii) Plan for urban and regional resilience; iv) Improve mobility through an integrated safe and sustainable system; and v) Develop innovation and adaptive capacity.

Indian government has started a nation-wide programme namely, NCAP (National Clean Air Programme) with a specific target to reduce pollution levels by at least 30% in a limited time frame. Government has taken actions to mitigate emissions of greenhouse gases and short-lived climate pollutants by integrating air quality and climate action plans in the design of environmental policy to realize potential synergistic benefits, such as emission control standards for vehicles, energy efficiency programmes for public and private buildings, improve collection and disposal of solid waste with more efficient solutions including potentially using landfill gas recovery to supply clean energy.

1) Observational infrastructure

- Extensive and robust air quality monitoring (data with high time and coverage resolution)
- Updated emissions inventory (criteria and toxics pollutants, GHGs)
- Health standards and air quality risk index
- Vehicular Inspection and maintenance programme
- Industry regulation and surveillance
- Open data with high access and transparency and integrated app.

2) Modelling tools

Research has play an important role in designing, implementing and improving many of the urban services; Delhi City has a long history of collaboration with research institutions, both national and international. Recent field measurement campaigns under the Indo-UK (MoES-NERC) programme "Air Pollution in Indian Mega city (APHH) have provided comprehensive data sets for updating and improving tour understanding on air quality of Delhi, the chemistry, dispersion and transport processes of the pollutants emitted to the Delhi NCR atmosphere and their regional transport, transformation and impacts. The information is being used for modelling studies. Air quality modelling and forecasting services are the result of collaborations with national and international research institutions. Forecasting of air quality conditions on short timescales in SAFAR, support the city government with information to take effective actions through mitigation to exposure to high concentrations of pollutants and lay the groundwork for developing policies to reduce emissions for air quality improvement and other co-benefits (e.g. climate, food security, etc.)

3) Services/information delivery, communication

SAFAR has taken a lead in developing various communication strategies to disseminate information to the public, including real-time report of ambient air quality data and forecasting, which are available to the public via website and mobile application (SAFAR-Air), and are used by the news media in weather forecast to alert the public of high pollution episodes and severe weather events. This need to be expanded under NCAP national wide and in other hazard related programmes in climate services.

A3.9 FRANKFURT AM MAIN

Prepared by Petra Fuchs

Section A: General information

Socioeconomic condition

- City size: appr. 750 000 inhabitants, fifths largest city of Germany
- Area: 248 m^2
- Forms a conurbation with the neighbouring city of Offenbach am Main, and its urban area has a population of 2.3 million and is the centre of the larger Rhine-Main Metropolitan Region, which has a population of 5.5 million
- contribution to GDP: According to a ranking list (2001) produced by the University of Liverpool, Frankfurt is the richest city in Europe by GDP per capital
- High level of infrastructure (e.g. airport, public transport)
- Environmental management established (organized by environmental agency), monitoring of air quality, consideration of urban climate conditions in the planning process.

Geographic conditions

- Frankfurt is located in the mid latitudes at the river Main and has a temperate-oceanic climate (Köppen) with an average annual temperature of 10.6 °C , with monthly mean temperatures ranging from 1.6 °C in January to 20.0 °C in July, annual precipitation: 629 mm (169 rainy days), 1662 sunshine hours (35% possible sunshine).

Governance structure

- Federalism in Germany is made of the states of Germany and the federal government. The central government, the states, and the German municipalities have different tasks and partially competing regions of responsibilities ruled by a complex system of checks and balances. Frankfurt is a municipality with autonomy in decision-making, which is also applicable for responsibility pathway for addressing urban hazard.

Section B. Needs for the integrated services

Most common hazards in the city and associated environmental risks

- Heatwaves
- Air quality
- Extreme events (e.g. heavy rainfall, storm)
- Flooding

Description of existing integrated urban services

- Observation and monitoring of weather and climate conditions
- Weather forecasts
- Weather warning system (downscaled to urban districts)
- Heat health warning system
- Pollen forecast
- Urban climate models and online information systems for assessing the impact of climate change
- Continuous monitoring of urban climate and air quality.

Providers of the urban services

- Members (DWD)
- City of Frankfurt
- Federal state Hesse

Users of the integrated urban services

- Municipalities
- Environmental agency
- Disaster control
- Infrastructure sector
- Energy sector
- Health service
- General public
- Planning offices
- Media

Requirements for the services

- Precise forecasts and warning systems in high temporal and spatial resolution (high hardware requirements) especially for temperature, wind, precipitation, thunderstorm, air quality
- Forecasts from nowcasting to long term
- Monthly, seasonal and decadal climate prediction
- Development of applications based on climate projection
- Data provision in common formats
- Integration of socioeconomic information
- Development of common terminology for better understanding.

Section C: Services integration

At the level of observational infrastructure

- Observation network in WMO standard, data provided with high quality
- Operation of a ground based network of weather radar systems
- Implementation of network of urban climate stations
- Mobile measurements
- Use of remote sensing data
- Monitoring of radio activity

At the level of modelling tools

- Development and operation of complex NWP models for global and regional weather prediction, as well as special applications like sea state and the environmental tasks (e.g. dispersion of radioactive particles, volcanic ash and mineral dust)
- Nowcasting applications based on spatially and temporally high resolved observations with rapid update cycle
- automatic warning guidance on nowcast and very short-term scale
- Development of urban climate models
- Downscaling of regional climate models to urban scale
- Information tools for climate adaptation.

At the level of the services/information delivery, communication

- Downscaling of complex scientific information to easily understandable information
- Integration of weather and climate information.

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A3.10 FRENCH CITIES (PARIS, TOULOUSE)

Prepared by Valery Masson

Section A: General information

Socioeconomic condition

- High socioeconomic level. Cities can be ancient, with historical city center several centuries old, and difficulties to modify these for understandable cultural and architectural reasons. Cities growth is limited compared to other parts of the world.

Climate zone

- Temperate oceanic climate. Inland, coastal and mountain cities.

Governance structure

- Decision-making is mostly done, for big agglomerations, at agglomeration level (municipalities grouped together). Paris is a specific case, with some higher-level coordination (regional, Paris itself is both a city and an administrative department) that is added (not replacing municipalities).

Section B. Needs for the integrated services

Main hazards in the city and urban area

Given the variability in geography and climate in France, cities focus on several and different hazards on adaptation strategies in urban planning. In general, coastal cities are more concerned by sea level rise and, especially around the Mediterranean Sea, on flash flood events, that are recurrent in Autumn. Inland cities however, are more focused on heatwaves and river flooding. For these cities, the expected climate change especially points to the risk of future increases in the frequency and intensity of heatwaves. This is why, even if this is not the only hazard, adaptation to heatwaves and mitigation of Urban Heat Islands has become a priority for many French cities, such as Paris, Lyon, Toulouse, Lille, and Rennes, even though these cities are under contrasting summer climates (much warmer in Toulouse than Rennes or Lille).

Description of existing integrated urban services

- See below

Providers of the urban services

- Providers of the presented UCS on adaptation of cities to climate change are mostly academia. Members provides information on meteorological hazards, emergencies and climate change. Consultancies certainly also provide some dedicated UCS, but often more on CO2 and Greenhouse Gas emissions reductions or local adaptation strategies in local building operations.

Users of the integrated urban services

- Mostly, all, depending on the UCS. For adaptation strategies to climate change UCS, local and regional collectivities, and national environmental agencies (for diffusion to other collectivities).

Requirements for the services

- Always need of a dedicated people (internally or externally) that is motivated and knows of the climatic issues and understand the need for the UCS. This greatly helps diffusion and appropriation.

Section C: Services integration

Short term: multi-hazard early warning and forecasting systems

- Emergencies (heatwave, heavy rain, thunderstorms, flooding) are fully operational from systems that cover the whole territory, not only the cities. Some dedicated behavior indications to follow in case of emergency are provided. There is institutional contact and organization with all emergency and security institutes for the operations.
- Urban meteorological services are mostly in the commercial domain. Therefore, cities do indicate by public procurement what they want. Cities may want something more or less elaborated, for: security, transportation systems, public works, water resources, energy, etc. Some cities have their own observation systems, and share it with their meteorological operator. In some cases, this is done by the meteorological operator (definition, installation, maintenance).
- Other IUS were developed in collaboration between the local authorities, Météo-France and the Predict Services company, to provide for some urban areas on the French Mediterranean Coast impact-based forecast and hydrometeorological monitoring. This IUS aims to help to manage the crisis and activate appropriate response plans. Diagnostics of vulnerability of the city is done beforehand, and a safety plan is co-constructed. There are local meteorological forecasters giving tailored information to the city administrations during heavy rain and flooding crises, and that helps the mayor to take good decision in relation with the communal safety plan.

Long term

- Proposition and evaluation of adaptation strategies to climate change demand a quantification of the combined UHI and heatwave impacts, in terms of exposure of people, sanitary issues, and the development of interdisciplinary urban climate services (UCS).
- Because questions of mitigation of and adaptation to climate change are driven by very long-term horizons, a common tool to address these is numerical modelling. However, a city is a very complex system, with its, own evolution, influencing strongly the local meteorology (e.g. a growing city is likely to lead to a larger UHI). Studying future urban climate require UCS to consider the interactions between city and climate changes, including city evolution models (that include socioeconomics and architectural aspects) and state-of-the-art urbanized atmospheric models.
- Using modelling approaches, UCS should be delivered on the urban agglomerations at the city-scale (both processes and impacts cover the entire agglomeration), with a spatially fine-scale (typically 200m). This allows assessment at the neighborhood scale, which is considered by French urban planners as the pertinent scale for the study of energy transition policies concerning urban planning related to buildings energy consumption.

Components integrated (and how)

1) At the level of observational infrastructure:

- A crucial point for city administrations is to anchor the state-of-the-art knowledge, coming from researchers or experiences in other cities, into their own city. This is preliminary to concrete action and realization of an adaptation strategy.
- Experimental studies are then considered necessary for cities to reach this objective. Two examples are used to illustrate this need. In Toulouse, the city administration decided to build a city-owned real-time urban network of meteorological stations (60, semi-professional), with the aim of finely mapping the urban heat island and other meteorological parameters within the agglomeration. In order to reach a spatial resolution fine enough for communities, meteorological information needs to be combined with urban features. Further urban climate services issued from these data will be built. While most urban meteorological networks are deployed and owned by research centers, this was the initiative of the municipality. The municipality will gather the data to allow for future conception and production of UCS, internally or externally. One such UCS, that is relevant for long-term planning, is the diagnosis of the current state of the city, in term of urban climate.
- The city of Paris launched an experimental study focused on the estimation of the impact of the watering of sidewalks and roads during summer days. This experiment was performed after previous numerical studies evaluating adaptation scenarios on Paris (based on white roof and street watering), in order to gain both experimental evidence and a first assessment of feasibility. A meteorological station was installed on a sidewalk, and several heat flux measurements were performed within the sidewalk and the road. Watering time intervals by water trucks were optimized, and daytime cooling of 0.8°C on air temperature, and 1.5°C on UTCI comfort index were observed. Such experimental implementation also eases the knowledge exchange with the stakeholders.

2) At the level of modelling tools

- One example UCS covered the evaluation of the meteorological impacts of an urban renewal operation (Marseille, at 100 m resolution), including the impact of a park and use of sea-cooled air conditioning system. Quantification of impacts on city and population (UHI, comfort, energy consumption, water needs) and effects of adaptation strategies on these, were performed over Paris and Toulouse. The wide range of impacts but also the large scope of the adaptation scenarios (limited only by the imagination of people) require the use of, and sometimes the development of, many specific parameterizations within the numerical modeling system.
- Many scenarios are based on the application urban vegetation in various configurations (e.g. ground vegetation, street trees, vegetated walls and green roofs). Impacts on hydrology are now included in the model and will allow study of the combined UHI-hydrology impacts on Paris and its suburbs. The model developments also permitted testing of implementing alternative urban energy systems such as solar panels. Air conditioning can increase night-time temperatures in more densely built parts of Paris by more than 1°C, so a Building Energy Module is also a desirable component of the modelling system to evaluate anthropogenic heat fluxes to the atmosphere. Energetic human behavior has been including in TEB thanks to a collaboration with sociologists. The modeling system then permits testing the impacts of not only changes to the character of the urban structure (insulation), but also eventually, societal change, such as aging of the population, who may demand greater use of building cooling during

summertime. This emphasizes the interdisciplinary interactions that are needed to study the urban system and build UCS.

3) At the level of the services/information delivery, communication

- In order to be pertinent, such UCS need to be co-constructed between several actors, including city administrations. Such UCS co-construction can typically emerge from research projects, as national level (e.g. MApUCE project[19]) or European level[20]. This has been initiated by direct collaboration with urban planning agencies in research projects with local communities (through meetings, co-funded PhD thesis), and by the inclusion of sociologists and researchers in urban law in the research projects, in order to facilitate knowledge transfer and the proposition of modification of the legal documents to better consider energy and micro-climatic issues in the making of the city.
- In the collaboration between several actors, especially institutional and academic ones, one field where co-construction is particularly important is during scenario development. During the conception of UCS, urban scenarios are built at both the services and technical levels: they are built in a cooperative way with the stakeholders, and then translated into input variables for the models. This allows definition of practical tools for UCS, but also to exchange knowledge between sectors and between planners and academics.

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[19] https://www.umr-cnrm.fr/ville.climat/spip.php?rubrique120

[20] URCLIM project, http://www.urclim.eu/

A3.11 HAMBURG

Prepared by Heinke Schluenzen
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Section A: General information

Socioeconomic and governance

- Hamburg is the second largest city in Germany, and growing with currently 1,83 Mio. inhabitants (compared to 1,793 Mio. in 1970). The city Hamburg is part of a bigger metropolitan area of which it builds the centre (total population 5,36 Mio.). Hamburg covers an area of 755 km² with 8% water surface and 25 % being agriculturally used and 7% forest areas[21]. The Free and Hanseatic City of Hamburg is both a municipality and a city-state within the Federal Republic of Germany.
- The city has been growing in its economic performance (GDP from 15,984 Mio. Euros, 1970, to 117.572 Mio. Euros, 2017)[22]. The economy is made up of one third by trade, transport, tourism, information and communication (31,9%) and another third by finance, housing, company services (32,1%), the rest consists of public services and education (17,9%), production (14,8%), construction industry (2,4 %), agriculture and forestry (0,1%)[23]. The harbour is a major economic driver. Hamburg over proportionally contributes to the national gross domestic product (3,6% in year 2017 with 2,2% of Germany's population). Hamburg has the highest GDP per person and income per person compared to the other federated states of Germany.

Geographic setting

- Hamburg is located in the north-west of Germany (53°33'N, 10°0'E). The city has an outside territory, the island Neuwerk and its surroundings, which are part of the transboundary World Heritage site Wadden Sea, the largest uninterrupted system of intertidal sand and mudflats worldwide (since 2010). In addition, the Speicherstadt and Kontorhausviertel, with traditional buildings close to the water, are UNESCO world heritage and to be protected cultural sites.
- Hamburg's area is characterized by a relatively flat topography, with the highest elevations of 116 m above sea level located in the south-west of the city and lowest site 0.8 m below sea level close to the river Elbe. The tidal river Elbe is running through the city, constituting a close link to the North Sea (distance 100 km) and thus of major importance for the harbour of the city. The regular high tide is about 2,1 m above average water level. About once a year storm tides of more than 5 m occur, but extreme tides have occurred as well (1962, 5.7 m above sea level; 1973, 5.33 m above sea level; 1976, 6.45 m above sea level; 1990 and 1994, 6.02 above sea level; 1995, 6.02 above sea level; 1999, 5.95 m above sea level; 2007 and 2013, 6.09 m above sea level). Therefore, around 100 km dykes alongside the Elbe and several backwaters protect the citizens. The UNESCO world heritage site Speicherstadt is located outside of the regular flood protection and thus depends on individual flood protection measures on the buildings itself.

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[21] Statistisches Bundesamt, Wiesbaden 2016: Land- und Forstwirtschaft, Fischerei - Bodenfläche nach Art der tatsächlichen Nutzung.
[22] https://de.statista.com/statistik/daten/studie/5014/umfrage/entwicklung-des-bruttoinlandsprodukts-von-hamburg-seit-1970/
[23] Data: Shares of the sectors of total gross value creation in the city of Hamburg in 2017.
Source: https://www.hamburg.de/contentblob/1005676/9c5c492e6dde8c4bd758cb0ccecc0c92/data/statistisches-jahrbuch-hamburg.pdf, S. 197.

- Hamburg's overall climate is mild with a maritime influence. The average annual air temperature is 9,4 °C (period 1981-2010) with an increase of about 1,4°C from 1881 to 2013[24]. There are in the 1981-2010 climate average 16,4 (4,5) days per year with maximum temperatures below 0°C (above 30°C) and 70 (0,8) days per year with minimum temperatures below 0°C (above 20°C)[24]. Precipitation is around 790 mm per year with an increase of average values, consisting of a tendency for larger increases in winter and smaller ones in summer. Heavy precipitation events become more frequent[27]and snow amounts decrease. Wind speed average is 4 m/s; 10% of the days have average wind speeds of 7 m/s and more[25.]
- The city's geographical location, the topographical characteristics and its maritime climate have a positive impact on urban climate and avoid building of an in the average very intense urban heat island and reduce air quality problems. Nonetheless, urban heat values are in the climate and summer average 3°C (1,5°C) in the summer (winter) months, based on differences in minimum temperatures[27]. Due to ships and their emissions, the airport in the city, industrial production, commuting movements of around 350.000 people (coming from outside of city borders), emissions and pollutant concentrations are still high in some places within the city and close to the harbour.

Section B: Needs for integrated services

Main hazards

- Climate change induced sea level rise, river level rise, storm tides, heatwaves, cold waves, heavy rain events, draughts, groundwater level increase, longer pollen season, air pollution, noise pollution.
- With its close distance to the sea, Hamburg is especially vulnerable to climate change. Sea level rise and more frequently occurring storm tides are hazards for about 109.000 households (around 250.000 people). A higher variability of growing conditions and a longer vegetation period with expected draughts in summer create the urgency to ensure water provision for agriculture and urban green. Additionally, heavy rainfalls occur more frequently and higher the risks of inland flooding.
- The city of Hamburg faces the challenge to prepare well regarding increasing climate change effects for the safety of its people and simultaneously meet the needs of its growing population and businesses economically which are met with enormous building activities. In part, these needs seem to be opposed, for example increasing rainwater infiltration in soil is inhibited by further sealing of ground/soil and therefore raises the risk of inland floods. In spite of the air quality enhancement through the marine air, Hamburg is highly exposed to emissions of ships, the airport, industrial production, trade and commuting traffic. In summer, heatwaves are a threat to the health of its population.
- Hamburg suffers regularly from inland floods after heavy rainfalls, causing negative impacts on transport infrastructure, the ecology of water bodies and economic impacts due to flooded stores and cellars.

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[24] Meinke I., D. Rechid, B. Tinz, M. Maneke, C. Lefebvre, E. Isokeit, 2018: Klima der Region – Zustand, bisherige Entwicklung und mögliche Änderungen bis 2100. Aus Hamburger Klimabericht – Wissen über Klima, Klimawandel und Auswirkungen in Hamburg und Norddeutschland. (H. von Storch I. Meinke M. Claußen, eds) Springer, https://www.springer.com/de/book/9783662553787

[25] Schlünzen K.H., P. Hoffmann, G. Rosenhagen & W. Riecke, 2010:: Long-term changes and regional differences in temperature and precipitation in the metropolitan area of Hamburg. *International Journal of Climatology*, 30:1121-1136, DOI 10.1002/joc.1968.

Actions taken

Flood warning system

- Storm tides of up to 4,5 m above sea level (NHN) are announced by the federal office of maritime traffic and hydrography (Bundesamt für Seeschifffahrt und Hydrographie, BSH), higher storm tides are announced and updated by the Hamburg Service for Storm Tide Warning (Sturmflutwarndienst WADI) of the Hamburg Port Authority (HPA) every half an hour. The Hafenstab (HASTA) as part of the Katastrophenschutz (disaster warning service; under the HPA) takes measures to protect the population, infrastructure etc. Reacting to water levels published by the Central Disaster Response Unit (Zentraler Katastrophendienststab, ZKD) police, fire service, and aid organizations are activated to take the required measures of protection. Information about an upcoming storm tide is spread (depending on height of water level rising) by gun salutes six hours before a flood (+3,5 m NHN); sound vans in city districts (+4,5 m NHN); radio and television warnings (+5 m NHN); sirens (+7,3 m NHN). In any case, information about upcoming storm tides can be obtained by calling the services (numbers are found online and in information brochures) or checking water levels online[26]. HPA offers a free service for warnings via sms or e-mail for self-registered persons (Flutwarn Hafen).
- General information on storm tides threatening Hamburg, recommended individual behaviour practices and help services can be found in brochures, online, or be acquired by telephone calls. The flood warning system is crucial for the implementation of the individual flood protection measures on the buildings of the Speicherstadt. These measures are only installed in case of a real flood risk.
- Katwarn is a German-wide online warning system through which public authorities, police, fire service etc. inform the public via smartphone-app or e-mail/sms about various bigger hazards like fires, windstorms, diffusing toxic substances and others. It includes storm tides for Hamburg. Warnwetter is a weather information and warning system by the German Meteorological Service (DWD) for informing disaster control (Katastrophenschutz) and the broader public about natural hazards and dangerous weather conditions. The Smartphone-App “NINA” combines these two services and offers action recommendations for precaution additionally to the warnings.
- In cases of extreme heat the city’s agency for health and consumer protection informs, based on information provided by the DWD, the management of nursing homes in order to take precautionary actions for safeguarding the residents.

Air quality measuring net (Luftmeßnetz)

- Several monitoring stations record the air quality within Hamburg at urban hotspots, the urban background and in the more rural parts. The values of five air pollutants (nitrogen dioxide, sulphur dioxide, ozone, carbon monoxide and fine dust) are measured and published every hour, graded singularly and combined as one general indicator (air quality index). This way potential health risks for the population are tracked and the public informed. The air quality plan (dated July 2017) defines measures to meet the EU-standard of air quality (esp. for nitrogen dioxide) as soon as possible. Measures include: Extension of bike routes and public transport (underground and suburban railway), new climate-neutral busses, new charging stations for electro-mobility, restriction of Diesel-cars for certain streets, cooperation with car producers for more electro-cars at existing car sharing offers; shore power and liquefied natural gas to reduce the nitrogen oxide emitted by harbours.

[26] Water levels: https://www2.bsh.de/aktdat/wvd/lf/StPauli_lf.htm

Climate plan Hamburg

- In its climate plan, Hamburg has set out climate mitigation and adaptation strategies for various sectors. In order to decelerate global warming, and consequently contributing to the protection of UNESCO values like, ecologically, the Wadden Sea, and culturally, the buildings of Hamburg's Speicherstadt and Kontorhausviertel, Hamburg has set various measures to reduce carbon emissions. Over-all long-term goals are a carbon reduction of 50 percent until 2030, and of 80 percent until 2050 compared to 1990. More short term, CO2-emissions shall be reduced by 2 mio.to until 2020 compared to 2012.
- Mitigation measures are amongst others: Fostering low-emission mobility (expansion of extended bike routes, creation of public charging stations for electric cars, partnerships with firms to inform and promote conversion to electro mobility). The repurchase of the district heat and gas network enables the municipality to influence the energy supply of Hamburg towards renewability, as part of the nationwide Energy Transition. The public administration aims to be CO2-neutral in their agencies in 2030 through higher energy savings, efficiency and conversion to renewable energy sources (CO2 compensation of flights of business trips, the prioritization of transport by train for business trips (run by renewable energy), conversion of the car fleets of public agencies to electric cars).
- Adaptation is part of the climate plan with an emphasis on new rainwater and flood management approaches. The RISA-process, contained in the climate plan, aims for a new sustainable rainwater management system, aiming at retaining rainwater on properties instead of instantly draining it through the sewage system. Thus, the rainwater can naturally seep into the soil, providing a close to natural system and supporting evapotranspiration. RISA is established by a broad cooperation network of water related agents in Hamburg. In this context, a green roof strategy has been implemented, to support rainwater retention on rooftops and reducing the amount of 100 % sealed surfaces.

Monitoring

- In the context of the climate plan, a monitoring system is being developed, to monitor the effects of climate change and the implementation of adaptation measures. Climate change IMPACT indicators have been developed for five fields (continuously extended) to track climate change and its according impacts within the city. Furthermore, response indicators are being developed to monitor the climate change adaptation measures within the city. Current IMPACT indicators are related to inland flood prevention, coastal flood prevention, urban and landscape planning, agriculture and health. Special attention is given to the potential spreading of the tiger mosquito (Aedes albopictus). The institute for hygiene and environment in Hamburg conducts monitoring investigations for the discovery of tiger mosquitos since 2009 (until now, none were found).

Existing cooperation

- Northern German Climate Monitor (Norddeutscher Klimamonitor): collects and presents information of climate and climate changes in the different regions of northern Germany. It is an information product for the public by a cooperation of the Norddeutsches Klimabüro of Helmholtz-Zentrum Geesthacht (HZG) and Regional Climate Bureau Hamburg of the German Meteorological Service (DWD). The Klima Campus Hamburg is a round table of Hamburg based national and local authorities and several research institutions including Hamburgs universities and focuses in climate related topics. To give a few examples, the Climate Service Center Germany GERICS, the DWD, the federal hydrological service BSH as well as the Center of Earth System Sciences and Sustainability of Universität Hamburg sit at the round table jointly with representatives from different agencies (e.g. Hamburgs agency for Environment and Energy). Several services have been and are coproduced by administration and research institutions.

Providers of urban services

- Municipality (office for environmental protection), technical authorities (German meteorological service DWD, federal hydrological service BSH, environmental agencies).

Users of urban services

- General public, municipality, technical authorities, ministries (of the federal state and nation), health sectors, companies, industry and transportation sectors, press agencies.

Requirements

Observation data (for warning systems, and model validation)

1) Meteorological measurements, including high-resolution precipitation measurements (provided by DWD and Universität Hamburg)
2) Water levels in Hamburg rivers, specifically the tidal river Elbe
3) Air pollutant concentrations
4) Climate indicators
5) Weather and water level forecast.

Section C. Services integration

Short and long term

- In several fields (see above) short term and long term integrated services or strategies exist. The aim is to enhance the combination of the above-mentioned services to increase the effectiveness of measures. Flood warning systems and traffic monitoring could for instance be combined to optimize traffic flow during flood events with according closures of important streets. Furthermore, a combination of weather services and rainwater retention systems can increase the capacity to deal with heavy rainfall. If heavy rainfall is likely, retention systems can be emptied just before the event, without decreasing the availability of water in case of droughts and heatwaves. The data of the Climate Monitor and the monitoring of the climate change effects can be used to optimise urban planning regarding climate change adaptation. Furthermore, a digitalised register of the entire urban rain water system within the city is currently under construction, this system will improve the capability to deal with heavy rainfall in the early stages of urban planning. In addition, research in the Universität Hamburg cluster of excellence CLICCS (Climate, Climatic Change, and Society) will address the needed complexities of urban planning/management systems to assess water induced stresses. There also ground water levels will be considered.

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A3.12 HELSINKI

Prepared by Ari Karppinen

Section A: General information

Socioeconomic

Helsinki is the capital city and most populous municipality of Finland. Located on the shore of the Gulf of Finland, it is the seat of the region of Uusimaa in southern Finland, and has a population of 648,650. The city's urban area has a population of 1,268,296 making it by far the most populous urban area in Finland as well as the country's most important center for politics, education, finance, culture, and research. Helsinki is located 80 kilometres (50 mi) north of Tallinn, Estonia, 400 km (250 mi) east of Stockholm, Sweden, and 390 km (240 mi) west of Saint Petersburg, Russia. It has close historical ties with these three cities.

Together with the cities of Espoo, Vantaa, and Kauniainen, and surrounding commuter towns, Helsinki forms the Greater Helsinki metropolitan area, which has a population of nearly 1.5 million. Often considered to be Finland's only metropolis, it is the world's northernmost metro area with over one million people as well as the northernmost capital of an EU member state. After Stockholm and Oslo, Helsinki is the third largest city in the Nordic countries. The city is served by the international Helsinki Airport, located in the neighboring city of Vantaa, with frequent service to many destinations in Europe and Asia.

Geographical

Called the "Daughter of the Baltic", Helsinki is on the tip of a peninsula and on 315 islands. The inner city is located on a southern peninsula, Helsinginniemi (”Helsinki’s peninsula”), which is rarely referred to by its actual name, Vironniemi(”Estonia’s peninsula”). Population density in certain parts of Helsinki's inner city area is comparatively higher, reaching 16,494 inhabitants per square kilometre (42,720/sq mi) in the district of Kallio, but as a whole Helsinki's population density of 3,050 per square kilometre (7,900/sq mi) ranks the city as rather sparsely populated in comparison to other European capital cities. Outside of the inner city, much of Helsinki consists of postwar suburbs separated by patches of forest. A narrow, 10 kilometres (6.2 mi) long Helsinki Central Park, stretching from the inner city to Helsinki's northern border, is an important recreational area for residents. The Helsinki urban area is an officially recognized urban area in Finland, defined by its population density. The area stretches throughout 11 municipalities, and is the largest such area in Finland, with a land area of 66,931 square kilometres (25,842 sq mi) and approximately 1,2 million inhabitants.

Governance

As is the case with all Finnish municipalities, Helsinki's city council is the main decision-making organ in local politics, dealing with issues such as urban planning, schools, health care, and public transport. The council is chosen in the nationally-held municipal elections, which are held every four years.

Section B. Needs for the integrated services

Hazards

The most common disasters and hazards in the city are flooding, extreme winter conditions, traffic and slipping injuries, strong wind and thunderstorm impacts and fires.

Existing
Preparedness for such risks is part of advance operational and resource planning. This is aimed at securing the provision of services and limiting the damage caused by the situation. The goal is to secure the organization's operational capability in all conditions[27].

Users
The users of these services vary from General public, Government departments, Energy sector, Water management, Industry sector (building), Transportation sectors (land, sea and air), Health sector, Tourism sector, Insurance sector, Disaster risk management, etc.

Providers
Finnish Meteorological Institution is the responsible organization for providing the cities all the relevant information related to climate, weather and air quality related risk and hazards.
The municipal central administration defines the general guidelines for preparedness and continuity management in the municipality, issues joint guidelines for planning to be applied by each sector in their own plans, and maintains overall preparedness in the municipality. The City of Helsinki has prepared operational models for various disruptions, such as those caused by extreme weather and other unexpected circumstances. The City maintains a tight network of cooperation with Government authorities in safety and security matters. Continuity management and other planning that reinforce preparedness are the responsibility of the Helsinki Mayor, and the routine management of the operations is carried out by the City Executive Office.

Housing companies, enterprises and institutions are required by the Rescue Act to be prepared for emergencies and draw up an emergency plan for a building or other site to secure the safety of people. The emergency plan should specify potential emergencies, provide instructions on how to prevent them and name the persons in charge. It should also specify the actions to be taken in emergencies. The Finnish Government has defined (Government Bill on Rescue) the sites that need an emergency plan. These sites include workplaces that accommodate more than 50 people at a time and residential buildings with more than three dwellings. The owner or manager of a property is responsible for producing a preparedness plan for the property. The Rescue Department provides information on how to produce a preparedness plan.

Section C: Services integration

Short term
Multi-hazard early warning and forecasting systems are all operated/integrates by FMI – and the final products and services are tailored to meet exactly the user/city needs.

Long term
Urban planning for sustainable development, climate change mitigation and adaptation
Both FMI, Universities, some other institutes and cities themselves have their own activities related to long-term planning- but already now, especially FMI has a very close cooperation with the Helsinki area in assessing the climate and air quality related risk.

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[27] https://www.hel.fi/static/kanslia/Julkaisut/2018/hybridiraportti_eng_020818_netti.pdf

Components integrated (and how)

For operative weather measurements, fully integrated (FMI responsibly).

For operative air quality, partially integrated: Helsinki Metropolitan Area Council carries the main responsibility for this, and operates the official monitoring network (~10 stations); the responsibility of supporting measurements built during several research project (~40 stations), is divided between several operators (Companies, University, FMI. HSY); but the results are already integrated through FMI-EnFUser model.

All existing operative modelling tools (weather, AQ) are integrated/developed/provided by FMI, while information delivery and communication is a shared responsibility of several operators the cities, Helsinki Area Metropolitan council, FMI and University provide all some services of their own. Still the official responsibility of communication is quite clearly defined: FMI is the responsible organization for weather related communications/info in the area while HSY is the responsible organization for AQ related info/communication.

A3.13 HONG KONG, CHINA

Prepared by Chao Ren/TC Lee

Section A: General information

Socioeconomic

Total area of about 1106 km2 and about 7.4 million people (2017). Hong Kong is a coastal city situated at the southeastern coast of China and over the eastern part of the Pearl River Delta (PRD). HK is a modern and highly urbanized metropolitan with superb infrastructure (e.g. advanced land, sea and air transport and communication systems, reliable water and power supplies, etc.)[28]

Geographical

Sub-tropical climate with tropical and mid-latitude weather systems together with summer and winter monsoons. Coastal city with mountainous topography. Steep slopes over 20 percent of the total land area, most of the urban activities are concentrated on built-up areas which take up about 24 percent of land.

Governance

Hong Kong is an autonomous Special Administrative Region of the People's Republic of China, except in defence and foreign affairs[29].

Section B. Needs for the integrated services

Hazards

Heavy rain, Thunderstorms, Tropical Cyclones, Coastal inundation/Flooding, Landslides Heatwaves, Cold surges, Water scarcity, Fog, Air pollution.

Users

General public, Government departments, Energy sector, Water management, Industry sector (building), Transportation sectors (land, sea and air), Health sector, Tourism sector, Insurance sector Disaster risk management, Mass Media.

Providers

1. Hong Kong Observatory (HKO) –meteorological authority in Hong Kong, China; weather and climate monitoring, weather forecasting and warnings of severe weather.
2. Environmental Protection Department (EPD) – air quality monitoring/forecast/advisories
3. Civil Engineering and Development Department (CEDD) – raingauge network, landslip risk, coastal and port engineering.
4. Drainage Services Department (DSD) - raingauge network, stormwater drainage services and flood prevention.
5. Other government departments / bureaus on urban planning, emergency rescue and disaster risk reduction (e.g. Security Bureau, Fire Services Department, Planning Department, etc.)

[28] https://www.yearbook.gov.hk/2017/en/pdf/E03.pdf.
[29] https://www.gov.hk/en/about/govdirectory/govstructure.htm

Requirements

Short term (DRR)

1) In situ weather observations (rainfall, temperatures, relative humidity, pressure, wind speed/direction, tidal information, visibility, solar radiation, evaporation, etc.)
2) Regular upper-air soundings and the high-resolution remote sensing images including radars, satellite, and lightning location, etc.
3) A wide range of weather forecasts covering multi-timescales
4) Timely and effective warnings and advisories for various weather hazards (e.g. tropical cyclone, thunderstorm, heavy rain, landslide, flooding, cold and very hot weather, etc.)
5) Tailor-made meteorological services for aviation and marine communities as well as other weather-sensitive users
6) Air pollution monitoring and forecast

Long term (urban planning)

1) Climatological monitoring and information services as well as seasonal predictions for different sectors (e.g. infrastructure and building designs, urban planning, air ventilation assessment, public health, water resource management, public utilities (energy), research communities, etc.)
2) Climate projections of various elements in Hong Kong based on IPCC climate model data.
3) Research development and public education.

Section C: Services integration

Components integrated (and how)

1) At the level of observational infrastructure

Weather

1) Over 200 automatic weather stations (HKO, CEDD, DSD) providing a wide range of meteorological measurements (e.g. rainfall, temperatures, relative humidity, pressure, winds, tidal information, visibility, solar radiation, and evaporation, etc.)
2) Regular upper air soundings and a full range of remote sensing observations (including Doppler weather radars, wind profilers, microwave radiometers, Doppler LIDARS, SODARs, satellite reception systems, and a lightning location network)
3) Automatic tide gauge network for tidal predictions, real-time monitoring of storm surges and tsunamis
4) Developed in-house a set of heat stress monitoring system which automatically measures the dry bulb, natural wet bulb, and globe temperatures in Hong Kong for computing the Hong Kong Heat Index which caters for the climate and environment of Hong Kong
5) Community Weather Information Network (Co-WIN) http://cowin.cse.cuhk.edu.hk/
6) Air quality: 16 air quality monitoring stations of EPD for regularly monitoring O_3, NO_2, SO_2, CO, PM_{10} and $PM_{2.5}$

Climate

1) Continuous observations of essential surface meteorological observations for over 130 years at HKO headquarters
2) Regular upper air soundings at HKO’s King's Park Meteorological Station since 1950s

3) Tide gauges for monitoring water levels since 1950s
4) Automatic weather station networks since mid-1980s
5) Raster based Urban Climatic Map data for urban planning and air ventilation assessment.

2) At the level of modelling tools

Weather

1) State-of-the-art numerical weather prediction (NWP) products from major global models (e.g. ECMWF, NCEP, JMA, etc.)
2) HKO's Aviation Model which is a WRF-based system providing hourly-updated, detailed short-term meteorological forecasts for the PRD region down to the urban scale
3) In-house developed rainstorm nowcasting system called SWIRLS (Short-range Warnings of Intense Rainstorm of Localized Systems) to support rainstorm related high-impact weather services for public and special users.
4) Air quality: Regional air quality model "Pollutants in the Atmosphere and their Transport over Hong Kong (PATH)" and air quality forecasting system based on WRF model and the Community Multiscale Air Quality (CMAQ) model. The operation of WRF is supported by the NWP results provided by HKO.

Climate

1) HKO adopts an ensemble approach to formulate its seasonal forecast for Hong Kong, taking into consideration available products from major climate prediction centres and the Global-Regional Climate Model (G-RCM) operated in house.
2) Climate projections of various elements (e.g. temperature, wet-bulb temperature, rainfall, mean sea level) in Hong Kong are computed based on IPCC climate model data.

3) At the level of the services/information delivery

Weather

1) HKO provides a wide range of forecasts covering multi-timescales (e.g. nowcasting, 9-day forecasts, etc.) and different spatial resolutions in Hong Kong, including location-specific weather forecast for the next 9 days through the Automatic Regional Weather Forecast (ARWF) service and "Extended Outlook" featuring probabilistic forecast of maximum and minimum temperatures up to 14 days ahead and the tropical cyclone track probability forecast up to the following 9 days.
2) Warnings and special advisors are issued for various weather-related hazards such as tropical cyclones, rainstorms, thunderstorms, very hot or cold weather.
3) Various weather information, forecast and warnings of HKO are timely disseminated to the general public, government departments and other specialized users through different channels, including media (TV, radio and newspaper), Dial-a-Weather service, webpages, mobile platforms, social media and tailor-made information dissemination systems.
4) Online information service and location specific weather services (e.g. ARWF and nowcast products for rainfall and lightning) are available from HKO's "MyObservatory" mobile app and website for urban dwellers to access various first-hand weather information anywhere and anytime.
5) HKO launched its Facebook page and Instagram platform to enhance communication with the public through social media in March 2018. Facebook posts on weather

information and various weather phenomena were released regularly to enhance public understanding of the weather.
6) Pre-wet season seminars, training courses, briefings and visits are conducted for relevant government departments and weather sensitive stakeholders to promote their awareness of, and community preparedness for, natural disasters.
7) HKO's Airport Meteorological Office, via web-based Aviation Meteorological Information Dissemination System (AMIDS), provides weather information for Hong Kong International Airport and the Hong Kong Flight Information Region (HKFIR) in support of international aviation navigation.
8) HKO provides marine meteorological information and forecasts to serve international shipping on the high seas, fishing in coastal waters and local water transport and recreation offshore.

Air quality

1) Air Quality information and the Air Quality Health Index (AQHI) are released to the public via various channels, including website, mobile app, computer desktop alert wizard and telephone hotline.
2) PATH provides 3-day air quality forecasts for internal reference and to support the AQHI forecast for next 24 hours.

Climate

1) The meteorological observations in Hong Kong are published regularly by HKO for monitoring the monthly, seasonal, and annual climate status in Hong Kong. Analysis of long term variations of various meteorological elements and indices are also conducted to assess the climate change in Hong Kong due to global warming and local urbanization.
2) HKO has set up the Climatological Information Services and Climate Change webpages to provide one-stop-shop online access to climate data/statistics of Hong Kong, the latest global and local climate change status, climate projections and educational resources on climate subjects.
3) Seasonal forecasts of average temperature and total rainfall and annual outlook of tropical cyclone activity and rainfall in broad terms are prepared and made available online for users' reference.
4) HKO has established close partnerships with various stakeholders in the city to enhance its weather and climate services by embracing the spirit of the Big Data concept, especially for urban-focused services concerning the priority areas of WMO Global Framework for Climate Services on energy, water, health, and disaster risk reduction.

   For example:

   - Working closely with different engineering departments and professional bodies to establish and regularly review the engineering design standards and codes of practices for protecting the city and public safety against various weather hazards and natural disasters.
   - Collaborating with other government departments, tertiary institutions, and social enterprises to study the impact of weather on public health.
   - providing meteorological data and expert advice for Planning Department and its consultants as well as other professional bodies to establish guidelines to assess the impact of urban developments on air ventilation and micro-climate;
   - Joining hands with energy sector to enhance energy saving and resilience of energy infrastructure.

- Providing monthly reservoir yield forecast to support water resource management.
- Coordinating Research Forums to interact with experts and researchers to apply research results for the benefits of the society.
- Collaborating with government departments and stakeholders to promote public awareness on climate change issues.

A3.14 JOHANNESBURG

Prepared by Ezekiel Sebago

Section A: General information

Socioeconomic

The City of Johannesburg (CoJ) is located in the Gauteng province in the north-eastern part of the Republic of South Africa, at 26.2041 deg S, 28.0473 deg E. It is the largest city in South Africa covering an area of 1645 square kilometers and the most populous with 8% of the national population (close to 5 million). The city's population has been growing over the last decade as it continues to attract people from other parts of the country and internationally, who are looking for better economic opportunities and quality of life. CoJ has some world class infrastructure in the fields of telecommunications, transportation, water, power, and with globally competitive health care and educational facilities. However, the city also has great contrasts – home to both wealthy and poor, residents and refugees, global corporations and emerging enterprises.

The main economic sectors found in the city are finance and business services, retail and wholesale trade, community and social services and the manufacturing sector. It contributes 40% to the provincial economy and almost 16% to the national economy.

Climate

Johannesburg is located on the high-veld plateau region of South Africa with an average elevation of around 1500m above mean sea level. The climate of Johannesburg is classified as sub-tropical, with mild and mostly sunny winters (cold nights with occasional frost), and warm summers but with thunderstorms at times mostly in the afternoon and evening. Most of the rainfall is concentrated in the summer months.

Governance

The City of Johannesburg is made up of a legislative arm (the council); an executive arm (consisting of the executive mayor and the mayoral committee); and an administrative arm. The council focuses on legislative, oversight and participatory roles, delegating its executive function to the executive mayor and the mayoral committee. The council's principal role is as lawmaker, with the other key role to debate and discuss issues affecting the city. The city is sub-divided into 11 districts.

Section B. Needs for the integrated services

Most common hazards in the city are due to severe thunderstorms which are prevalent in the spring and summer seasons. Occasional heavy downpours from these storms often result in flash-floods which result in most of the damage that occurs in CoJ, especially in informal settlements. Loss of life due to drownings have also been experienced. Road flooding has also resulted in many traffic accidents. Another common hazard from storms is hail (large in size or abundance of small, on occasions) which causes damage to housing and vehicles. Strong winds can also cause damage which could lead to disruption in the service delivery, especially power. Duststorms do occur and result in poor visibility, but are rare. Although heatwaves could occur during the summer, CoJ's elevation ensures that they are as common as surrounding areas with lower elevation.

Description of existing integrated urban services for meeting hazard challenges, or hazard-specific services, capability of monitoring, predicting and forecasting hazards….

The South African Weather Service (SAWS) has several automatic weather stations within the precincts of CoJ, the city administration has also installed automatic rainfall stations in identified areas. In addition, CoJ lies within a good coverage area for the S-Band weather radar situated in the neighboring City of Tshwane. The METEOSAT Second Generation (MSG) satellite is in usage. For air quality, CoJ owns several monitoring stations across the city.

Providers of the urban services

SAWS is responsible of all weather-related hazards, including flash-flooding. This is currently done on a thresh-hold basis, but a switch to impact-based is expected soon. There are plans to issue air quality forecasts in the future.

Users of the integrated urban services

The main users are the Disaster Management structures, from National, provincial and city. Other users are emergency responders, government departments, media and non-governmental relief organizations.

Requirements for the services

SAWS is busy procuring a forecaster workstation which will allow for efficient visualization of all meteorological parameters (observations and models).

Section C: Services integration

Short term: multi-hazard early warning and forecasting systems

An impact-based severe weather warning system to be implemented. This will be used in conjunction with existing systems like the flash flood guidance system.

Long term

1) At the level of modelling tools

SAWS plans to run the local version of the Unified Model at a sub-km resolution. There are also plans to implement data assimilation from AWS, ARS and radar.

2) At the level of the services/information delivery, communication

Air quality forecasts to be issued. Dynamic vulnerability data to be made available on a GIS platform to ensure improved impact-based weather warnings.

A3.15 LONDON (ENGLAND)

Prepared by Brian Golding

Section A: General information

Socioeconomic

The Greater London administrative area is a cosmopolitan urban area of 9M people covering an area of 1600sq km. Its GDP of $0.75bn is almost 30% of the English GDP. The London economic area extends beyond this to much of south-east England in an extended agglomeration covering about 15,000 sq km with a total population of 18M people. This area abuts the economic areas of other major cities which, together, take in almost 50% of the area of England and over 80% of its population of 53M. London is well provided with infrastructure: power (integrated electricity and gas supply grids cover England), transport (served by 5 international airports, high speed rail links to all parts of England, high speed highways to all parts of England, port with connections to other UK ports, European and global ports), communications (wired grid covers England), water (supplied by reservoirs round the periphery of London) and drainage. Much of the infrastructure in central London is of 19th century construction.

Geographical

England is set in the middle latitudes, with a maritime climate on the eastern edge of the Atlantic Ocean. London is influenced by proximity of the Eurasian land mass to its East, but that influence is ameliorated by the North Sea. London is on the Estuary of a major river with numerous small tributaries, many of them confined in channels or pipes within the urban fabric. It is open to fluvial and coastal hazards. The terrain is rather flat, mostly flood plain, surrounded by gentle hills. The latter are largely of chalk and contain the main aquifer water sources.

Governance

The UK is a sovereign kingdom of four nations: England, Scotland, Wales and Northern Ireland. The UK government has authority for defence and foreign affairs. For internal affairs, the nations have varying levels of independent authority, with Scotland having most. There is no separate English national authority. Within England, the primary sub-division is into Counties/Unitary Authorities/Metropolitan Boroughs, of which London is a special case of the last. Within London are lower tier authorities: boroughs and parishes. Emergency management is the responsibility of the top tier of local authority. However, operational arrangements (police, fire & rescue, ambulance) do not always align with this administrative structure.

The Met Office is a UK government institution under the Department of Business, Energy and Industrial Strategy and funded by customer government departments and private industry. The primary weather forecasting and warning capability is funded through the Public Weather Service, in which a variety of government customers are represented through the Public Weather Service Commissioning Group. Flood warnings (fluvial, coastal and surface water) for England are the responsibility of the Environment Agency which is an institute of and funded by the Department of Environment, Food and Rural Affairs (DEFRA). The Met Office and Environment Agency work closely together, especially through the joint Flood Forecasting Centre, based in the Met Office. Air quality and pollution forecasts and warnings are provided by the Met Office on behalf of DEFRA. Weather-related health forecasts are provided by the Met Office on behalf of Public Health England.

The civil contingencies act (2005) defines the responsibilities of emergency responders, including the emergency services and infrastructure operators. These include identifying weather-related risks and drawing up response plans. All responders are required to take note of weather warnings, which they receive through a dedicated web portal, Hazard Manager. Their use of the forecast and warning information is supported by Met Office Civil Contingency Advisors. The response to a disaster is layered at gold (strategic), silver (tactical), and bronze (operational) levels, involving all affected actors, but with the police providing the lead at each level.

Prior to 1987, severe weather warnings in the UK were focused on 18 urban areas. Since 1987, that concept has been dropped in favour of a national service that covers all populated areas. The affected area is indicated graphically on maps, with affected administrative areas listed in the text. The presence of an urban area influences the issue of a warning, since the warnings are impact-based and impacts tend to be larger in highly populated areas.

Section B. Needs for the integrated services

Hazards

Wind Storm, Flood (fluvial, surface & coastal), Fog, Snow/Ice, Thunderstorm, Cold, Heat, UV, Air pollution.

Existing

- National (UK) service by Met Office (separate urban services merged following 1987 storm disaster review) for storm, heavy precipitation, snow/ice/fog, separate customer-defined for heat, cold, AQ, pollen, UV, space weather.
- London-specific Air pollution warning service delivered through the Mayor’s office (other cities also have local air pollution services).
- Birmingham (and possibly other cities) have integrated travel information services, including weather-related hazard information
- National Flood warning service (England), with warnings for specific river reaches and coast sectors.

Providers

NMS, Environment Agency, Private Sector (consultants, media, insurance). Government departments, Infrastructure authorities and Businesses are responsible for obtaining their information to enable risk to be managed. Information may be obtained from free sources or paid-for services. In the latter case, the source may be the Met Office or a private provider. There are some large providers (e.g. Meteogroup), but many smaller, niche, providers.

Users

General public; Central Government departments; Local government; Energy; Water management; Transportation sectors (land, sea and air); Health; Insurance; Telecommunications; Military; Business; Education.

Requirements for the services

Short term (DRR)

- Observations of weather hazards: precipitation maps from radar, in situ observations of extreme wind, temperature, snow, ice, fog, lightning.
- Forecasts of weather hazards: precipitation, wind, temperature, snow, ice, fog, lightning.
- National Severe Weather Warning Service warnings of weather hazards classified by likelihood and impact: covers wind, rain, snow, ice, fog, thunderstorm.

- Flood guidance (joint with Environment Agency) warnings of flooding from coastal, fluvial, surface water and ground water sources by area classified by likelihood and impact.
- Bespoke forecasts/warnings for vulnerable sectors such as marine, aviation, rail, road, crane operators
- Air quality forecast
- UV forecast
- Heatwave and Cold Wave health guidance
- Pollen forecast.

Long term
The primary input to long term planning is the UK Climate Projections, which are updated every 10 years, and contain the spatial distribution of trends and probability distributions of key variables, both over the UK for internal planning, and more widely for strategic and business analysis.

Section C: Services integration

Short-term plans - Components integrated (and how)

1) Observational

Met obs integrated; AQ separate; road met separate; hydrology separate.

- The Met Office observing network provides WMO standard meteorological observations at approximately 50km spacing over lowland England. These observations represent the environment within which urban development modifies the surface weather characteristics.
- The Met Office and Environment Agency jointly operate a network of C-band dual-polarisation, Doppler radars that cover lowland England within a range of approximately 100km. Precipitation is also monitored with raingauges: of which a subset are available in real time, but the bulk are daily gauges read manually.
- Upper air conditions are predominantly inferred from assimilation of satellite data into models. However, substantial and increasing use is made of automatic aircraft observations. Monitoring of volcanic ash is carried out with a network of lidars and sun photometers.
- River flow and/or level and coastal tide levels are monitored by the Environment Agency. Data from these networks feed into the joint Met Office/Environment Agency Flood Forecast Centre.
- The Met Office manages a network of pollen gauges which feed information into the Met Office pollen warning system.
- There are several networks of air quality monitors in England, mostly operated by private companies for specific City Authorities. The Environment Agency operate a baseline network of about 130 air composition measuring stations, of which 16 are within Greater London. These stations monitor a selection from PM_{10}, $PM_{2.5}$, NOx, SOx, O_3 and feed routine data into the Met Office for use in the national Air Quality forecasting system.
- Road weather is monitored using roadside observations operated by private companies, which are fed into prediction systems, some privately operated and some Met Office operated.
- Several industries make observations to inform their own operations. These include power transmission, rail transport, wind and solar power generation, nuclear power

plants, chemical plants, agriculture. Many of these stations are reported through on-line hubs, including Weather Underground and Weather-on-the-Web (WoW). The latter is operated by the Met Office and the observations are used in the forecasting process.

2) Modelling

Met & AQ & hydrology & surge integrated; river catchment hydrology separate

- The Met Office operates a unified weather prediction model (UM) for forecasting from minutes ahead at km-scale resolution up to long term climate change at 100s of km resolution. Km-scale forecasts for the UK are updated hourly using the latest observations.
- The UM has the capability for interactive coupling with ocean, land hydrology, ice and atmospheric chemistry models as required. Currently such coupling is used for seasonal and climate prediction but not for short range NWP, except for the AQUM regional coupled chemistry configuration used for UK air quality forecasting. Fluvial and Coastal flood prediction and pollution transport use stand-alone models driven by meteorological input from the UM. The STEPS nowcasting system is used to adjust NWP output to match observations at the start of the forecast.

3) Services/information delivery, communication

- Warnings of the main weather hazards are communicated through a single standard warning system: the National Severe Weather Warning Service, which provides seamless warnings using a colour-coded probability/impact matrix up to the limit of hazard predictability – typically 5 days for windstorms and major fluvial floods, but much less for flash floods, snowstorms and fog. A web portal is used to communicate this information, together with supporting material, to emergency responders.
- A broader range of hazards, including space weather and geological hazards, are summarized in the Daily Hazard Assessment, prepared by the Met Office for government on behalf of all of the government natural hazard institutes.
- The joint Met Office/Environment Agency Flood Forecasting Centre produces a daily Flood Guidance Statement, using the same probability/impact matrix as the NSWWS, for all forms of flooding up to 5 days ahead.
- The hydrologically-related government institutes collaborate to produce a monthly hydrological summary and outlook providing the status of water resources and likelihood of floods and/or drought over the following season.
- The Met Office provides a monthly seasonal outlook to government from the available seasonal forecasting systems.
- The main service supporting government, utilities and commerce at climate timescales is the UK Climate Projections, updated every 10 years and produced by the Met Office, based on its own and CMIP climate runs, and drawing in partner information on hydrology, oceanography etc.

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A3.16 MEXICO CITY (Ciudad de México[30])

Prepared by Luisa Tan Molina

Section A: General information

Socioeconomic

Mexico City Metropolitan Area (MCMA): 21.4 M inhabitants occupying 7585 km^2, consists of:

- Mexico City: 8.8 M inhabitants in an area of 1485 km^2
- 59 municipalities of the State of Mexico: 12.5 M inhabitants in an area of 6000 km^2
- 1 municipality of the State of Hidalgo, 130,000 inhabitants in an area of 100 km^2

Mexico City Atmospheric Monitoring System has a wide geographic coverage and good data collection capacity; the emission inventory is very well developed and is now compliant with the BASIC+ certification issued by C40; the inventory is updated every two years and includes criteria and toxic pollutants, black carbon and greenhouse gases. Transport sector includes comprehensive public transportation infrastructure (urban buses, Bus Rapid Transit (Metrobus), subway (Metro), light rail) and non-motorized transport (bike sharing programme). The city has maintained an extensive communication infrastructure.

Geographical

The MCMA lies in an elevated basin at an altitude of 2240 m above mean sea level and is surrounded on three sides by mountains and volcanoes, with an opening to the Mexican Plateau to the north and a mountain gap to the southeast. Subtropical highland climate: a cool dry season from November to February is followed by a warm dry season until May and a rainy season from June to October.

Governance structure

Civil protection is supported by different levels of Mexican legislation: (a) Constitution: article 123 covers security and health of worker in facilities, (b) State Law: General Act for Civil Protection defines the general terms of each state law on civil protection and the regulation of each state on civil protection. Because Mexico City is also the capital of the nation, it can never become a state; however, Mexico City has the same level of autonomy comparable to that of a state.

There are a number of institutions responsible for addressing urban hazards and have policymaking powers:

- **National Water Commission (CONAGUA):** national plans and mandate for flood management
- **National Meteorological Service (SMN):** provides meteorological information at national and local levels; manages the climatological database. SMN shares information in newsletters or special advisories through fax, modem, phone or internet to specific users such as Interior Ministry, National Defense, Navy, Environmental Secretary, oil companies, electricity companies, Tourism Secretary, state governments, mass media, airports, hospitals, insurers, general public and the National Service of Civil Protection. SMN has begun collecting information from meteorological networks from other

[30] https://www.cdmx.gob.mx/

institutions, such as electricity companies, agricultural stations, the navy, and universities.

- **National Centre for Disaster Prevention (CENAPRED):** in charge of risk management and disaster prevention in Mexico to reduce population exposure to meteorological, hydrological, geological and chemical hazards such as volcanic eruptions, flooding, tropical storms, earthquakes, and chemical releases, among others.
- **Secretariat of Environment (SEDEMA):** manages Mexico City's Air Quality Monitoring System (SIMAT); issues air quality and meteorological forecast to alert the public about critical pollution levels and prevent exposure to harmful pollutants; announces contingency actions when measured pollutants levels are above critical threshold. URL: https://www.sedema.cdmx.gob.mx/
- **Megalopolis Environmental Commission (CAMe):** covers Mexico City and five surrounding states (Puebla, Tlaxcala, Morelos, Hidalgo and Mexico) in central Mexico. The commission plans and execute policies, handles air quality monitoring, emissions standards and smog-check issues in this region.

Section B. Needs for the integrated services

Hazards

- High pollution events due to high pressure systems and thermal inversion
- Extreme hydrometeorological events leading to floods and landslides
- Health impacts caused by heatwaves and dehydration
- Earthquake
- Volcanic eruptions
- Wildfires
- Social and spatial inequality & high vulnerability to climate change
- Vector-borne diseases related to climate change

Existing

The government has established the Center for Command, Control, Computation, Communications and Citizen Contact (C5) to monitor multi-hazard and respond within five minutes of an incident:

- Environmental Contingency Programme (air pollution)
- Air quality forecast system
- Hydrometeorological alert system
- Seismic system
- Volcanic alert
- Hydrometeorological Bulletin
- Risk Atlas
- Contingency task force for water scarcity

Providers

The urban services are provided by the city government through the different agencies that report to the Mayor and to the public.

- Center for Command, Control, Computation, Communications and Citizen Contact (C5) integrates most of the urban services to provide rapid response against emergencies in the city; agencies send information to C5 which reports directly to the Mayor.

- Secretariat of Environment is responsible for climate action plans and air quality management programmes. The General Director of air quality management is responsible for ambient air quality monitoring and forecasting, updating emissions inventory.

Users
Government agencies responsible for the environment, energy, water management, transportation, health, tourism, disaster risk management, National Service of Civil Protection; Industries, hospitals, airports, insurance sector General public and; Mass media.

Requirements

Short term
- Environmental monitoring and forecast: provide timely information to different sectors of Mexico City population about weather, water, air quality, climate, wildfires, volcanic hazards.
- Improve the performance of air quality forecasting systems using emission inventories and updated environmental data.

Long term
- Invest in infrastructure and personnel for the monitoring network due to changes in the sources of emissions and pollutants and the expansion of urban areas to the periphery.
- Enhance measurement of vertical profiles of meteorological parameters.
- In-depth analysis of the increase in atmospheric temperature on the air quality in the MCMA and the impact of meteorology on air pollution.
- Improve data collection in the health system in Mexico, including better temporal and spatial resolution, diagnostics and historical exposure data, reinforce epidemiological surveillance.
- Develop and implement an integrated regional land use-transportation-air quality management system involving close cooperation of the relevant authorities (environment, transportation, urban development, and public works) with public participation.
- Expand model coverage and air quality forecasting to include the megalopolis region.
- Expand and strengthen capacity-building for technicians and scientists.

Section C: Services integration

Short term
Mexico City government has established the Center for Command, Control, Computation, Communications and Citizen Contact (C5) to monitor multi-hazard with rapid respond.

Long term
Mexico City government launched the Resilience Strategy on 2016 to build resilience in specific areas at the community level and includes the following 5 pillars: i) Foster regional coordination; ii) Promote water resilience as new paradigm to manage water in the Mexico Basin; iii) Plan for urban and regional resilience; iv) Improve mobility through an integrated safe and sustainable system; v) Develop innovation and adaptive capacity.

Mexico City government has taken actions to mitigate emissions of greenhouse gases and short-lived climate pollutants by integrating air quality and climate action plans in the design of environmental policy to realize potential synergistic benefits, such as emission control standards for vehicles, energy efficiency programmes for public and private buildings, improve collection and disposal of solid waste with more efficient solutions including potentially using landfill gas recovery to supply clean energy.

1) *observational*

- Extensive and robust air quality monitoring (data with high time and coverage resolution)
- Updated emissions inventory (criteria and toxics pollutants, GHGs)
- Health standards and air quality risk index
- Vehicular Inspection and maintenance programme
- Industry regulation and surveillance
- Open data with high access and transparency and integrated app.

2) *modelling*

- Research has play an important role in designing, implementing and improving many of the urban services; Mexico City has a long history of collaboration with research institutions, both national and international.
- Recent field measurement campaigns have provided comprehensive datasets for updating and improving the emissions inventory, the chemistry, dispersion and transport processes of the pollutants emitted to the MCMA atmosphere and their regional transport, transformation and impacts. The information is being used for modelling studies.
- Air quality modeling and forecasting services are the result of collaborations with national and international research institutions.
- Forecasting of air quality conditions on short timescales, support the city government with information to take effective actions through mitigation to exposure to high concentrations of pollutants and lay the groundwork for developing policies to reduce emissions for air quality improvement and other co-benefits (e.g. climate, food security, etc.)

3) *services/information delivery, communication*

- Mexico City government has deployed various communication strategies to disseminate information to the public, including real-time report of ambient air quality data and forecasting, which are available to the public via website and mobile application, and are used by the news media in weather forecast to alert the public of high pollution episodes and severe weather events, as well as provide hydrometeorological notices and risks atlas.

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A3.17 MOSCOW

Prepared by Dmitri Kiktev

Section A: General information

Socioeconomic

Moscow is a major political, economic, cultural, and scientific center of Russia with a population of more than 12.5 million people. Moscow has one of the biggest municipal economies in Europe. It accounts for more than one-fifth of Russia's gross domestic product (GDP). The city is a busy transport node. Moscow is served by four international airports and nine railway terminals.

Geographical

Moscow is the northernmost and coldest megacity on the planet. The city is situated in a plane area on the banks of the Moskva River and stretches for 40 km from west to east, and for 52 km from north to south. By its territorial expansion southwest in July, 2012, the area of the capital more than doubled, going from 1,091 to 2,511 square kilometers.

The region’s climate is humid continental. High weather variability and variety of natural hazards are typical for the area of the Moscow city.

Governance

The Mayor of Moscow is the leading official in the executive, leading the Government of Moscow, which is the highest organ of executive power. All local city laws must be approved by the Moscow City Council (Duma). The Government of Moscow is the highest executive body of state authority of Moscow.

Moscow Department for Environmental Management and Protection is an executive authority and has the rights of special empowered authority for environment protection, atmosphere air protection, fauna and its habitat protection, biological diversity saving, state ecological expertise.

Responsibility pathway for addressing urban hazards: the Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet) is responsible for general purpose weather forecasts and warnings; a special municipal meteorological office is responsible for specialized urban meteorological forecasts and services.

Section B. Needs for the integrated services

Hazards

The list of most common hazards in the city includes windstorms, heavy precipitation, icing, visibility reductions (fog, blizzards), thunderstorms, air pollution, forest fires, pollen.

Existing services

A Unified System of Environmental Monitoring was developed and implemented for Moscow megapolis basing on automated monitoring methods for priority indicators of the state of natural environment and meteorological characteristics. The system is a high-tech integration platform exploiting modern geoinformation technologies for large data sets of meteorological parameters, concentrations of air pollutants, industrial emissions, residents' complaints etc. A special city-wide information resource, Unified City Database for Environmental Monitoring is developed for the City Authorities and decision-makers. An information-analytical center was established for 24/7 operational monitoring of the environmental situation in Moscow megapolis, timely detection of environmental issues, warnings and organization of rapid response to environmental incidents.

Providers

Services are provided by the respective federal and municipal entities (Federal State Budgetary Institution (FSBI) "Hydrometcenter of Russia" and Central Regional Administration of Roshydromet, Autonomous Non-Profit Organization "Hydrometeorological Bureau of Moscow and the Moscow Region" (along with Roshydromet Moscow is served by its own municipal meteorological office), State Environmental Budgetary Institution (SEPI) «Mosecomonitoring» under umbrella of the Department of Environmental Management and Protection of the city of Moscow.

Users

General public, local government, disaster risk management, transportation sectors (land and air), energy sector, housing and communal services, health sector, tourism sector, insurance sector, etc.

Requirements for the services

- Ensuring the hydrometeorological and ecological security of the city population and economy.
- Improvement of reliability, diversity and outreach of environmental information services.
- Optimization of city services maintenance and development of the smart city infrastructure.
- Timely assessment and prediction of the flooded areas taking into account the dynamics of hydrometeorological processes.
- Realization and development of monitoring of atmospheric air condition, water objects, hydrometeorological characteristics in the city of Moscow, assessment of the state and dynamics of natural environments, determination of the main sources of pollution.
- Operational forecasting of atmospheric air pollution, taking into account forecasts of the meteorological situation with differentiation across the city.
- Development of technologies for assessing the effectiveness of urban activities for reducing air and water pollution, taking into account weather and climate factors.

Short term (DRR)

- Dense in situ weather observations and air pollution measurements.
- High-resolution remote sensing (radars, satellite, profilers, lightning detectors, etc.)
- High resolution weather forecasts with differentiation across the city.
- Air pollution monitoring and high-resolution forecasting with differentiation across the city.
- Tracing of the main sources of the environmental pollution.
- Warnings and advisories for various weather hazards with differentiation across the city
- Tailored meteorological services for various weather-sensitive users (for transportation, energy sector etc.).

Long term (urban planning)

- Stage-by-stage development of seamless environmental forecasting system and its integration into the city decision-making support systems.

Section C: Services integration

Components integrated

1) At the level of observational infrastructure

According to the approved city Roadmap for development of weather monitoring, forecasting and warning services for the Moscow city, a network of gradient meteorological observations (automatic meteorological stations at 3 levels w.r.t. to the ground at 120 towers of mobile communication) and 42 surface automatic meteorological stations is to be established in Moscow region in the nearest 3 years. It should be integrated with observational in situ and remote sensing network of Roshydromet, Universities and private providers.

2) At the level of modelling tools

In the nearest 2-3 years a limited area numerical weather prediction system COSMO/ICON with a sub-kilometer grid spacing and assimilation of high-resolution network observations is to be operational for the Moscow region for the purposes of deterministic weather forecasting. Limited area ensemble prediction system is to be developed for probabilistic forecasting of natural hazards in the Moscow megapolis. Chemical transport model COSMO/ICON-ART and CHIMERE systems are to be used for the air quality forecasting.

Further development of forecasting tools for forecast ranges from nowcasting to climate projections.

3) At the level of services/information delivery, communication

Development of interfaces and information gateway between the Moscow city bodies, Roshydromet, Universities and private information providers, development of “tailored” applications for various categories of users, promotion of Common Alerting Protocol (CAP).

A3.18 NEW YORK CITY

Prepared by Chananda Mitra/Dev Niyogi

Section A: General information

New York City (NYC) is often considered emblematic of a complex, heterogeneous, and vibrant urban locale. NYC is on the northeastern coast of the United States, along the Hudson River. The city covers an area of 303 square km and is home to 8.6 million people (Census 2017). It is one of the most urbanized cities in the face of the earth and has highly modernized infrastructure (e.g. transportation, communication, reliable water and power supplies). The metro region has a broader population of over 20 million and houses around 1 million buildings[31].

Geographically, New York city has 5 boroughs, 59 community districts and number of neighborhoods[32]. Each borough has extensive stretches of shoreline, and all except the Bronx are islands unto themselves (Manhattan and Staten Island) or part of one (Brooklyn and Queens are part of Long Island). The water bodies border and contain are as diverse as the urban landscape: canals, creeks, ponds, inlets, straits, rivers, estuaries, bays, a sound, and an ocean. It is classified to have warm humid subtropical climate.

Politically, the City government, which is led by a Mayor and a Council of 51 members, employs more than 300,000 civil servants – including public safety, sanitation, transportation, professionals, artists- enabling safety, well-being, vibrancy, and opportunities in the City. The city governance is done through elected Mayor, borough Presidents, City Council Members, Public Advocates, and Comptroller[33].

Section B. Needs for the integrated services

New York as a coastal city has hazards such as erosion, and coastal storms, thunderstorms, flooding, winter storms, droughts and technological/anthropogenic infrastructure failures (earthquakes, cyber threats).

The City through its Emergency Management has developed a hazard mitigation programme. Additionally, there is a concerted effort related to climate resiliency assessment and planning. A full hazard mitigation plan is available with detailed guidance related to different hazards to be tackled including ways of detection, early warning, actions during emergencies and post disaster phase[34].

The users of these services vary from the general public, government departments, energy sector, water management, industry sector, transportation sectors (land, sea and air), health sector, tourism, insurance sector, disaster risk management, etc. The NYC department of city planning looks after all the regulations, laws, plans and policies and NYC emergency management regulates the mitigation and preparedness strategies at times of hazards. Different providers including volunteer services and organizations work together at the time of crisis in the city of New York[35]. For more details refer: Academic institutions such as City College/City University of New York, Columbia University, New York University also work

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[31] https://datausa.io/profile/geo/new-york-northern-new-jersey-long-island-ny-nj-pa-metro-area/
[32] https://www1.nyc.gov/site/planning/data-maps/city-neighborhoods.page
[33] https://www1.nyc.gov/nyc-resources/about-the-city-of-new-york.page
[34] https://www1.nyc.gov/site/em/ready/hazard-mitigation.page
[35] https://www1.nyc.gov/site/dhs/shelter/providers/providers.page

together to mitigate the risks of climate change and hazards in the city. Different programmes and initiatives such as OneNYC plan, Notify NYC, NYC Severe Weather, Know Your Zone, Partners in Preparedness, etc. with adaptation analysis and act such as New York's ClimAID Analysis and Community Risk and Resiliency Act (CRRA) are in place to understand and provide service for hazard response and long-term climate resiliency[36].

Short term services[37] and long-term services include plans for different hazard mitigation, seasonal predictions, Climate data and expert advices for different sectors (e.g. infrastructure and building designs, urban planning, air ventilation assessment, public health, water resource management, public utilities (energy), research communities, etc.) and Climate projections of temperature, temperature, rainfall, mean sea level in New York based on IPCC climate model data, and the city's climate resiliency plan. NYC has its own mitigation plans where the planning effort was led by New York City Emergency Management and the Department of City Planning in close collaboration with the Mayor's Office of Recovery and Resiliency. What resulted was a comprehensive approach to risk reduction[38].

Section C: Services integration

To assess risk and identify appropriate management strategies, the planners pursued a rigorous process of analysis and research, drawing from the historical record, the latest scientific and technical information, various city plans and reports, and consultation with many parties. The Department of City Planning is responsible for the City's long-term planning, including land-use and environmental review; preparation of plans and policies; and providing technical assistance and information to government agencies, public officials, and community boards. The New York City Panel on Climate Change (NPCC), a body of leading climate and social scientists and risk management experts, was convened by the City in 2008 to produce climate projections for New York City and inform City government's decision-making and the public. They also work on the latest climate models, observations about climate trends, and new information about greenhouse gas emissions. The City uses its Zoning Resolution and Construction Codes to control the built environment and create a safer, healthier, more resilient city. Zoning is developed and written by the Department of City Planning and enforced by Department of Buildings. There are programmes such as Notify NYC alerts for emergency activity in all five boroughs, NYC Emergency Management's Advanced Warning System to alert individuals with special needs to hazardous weather, utility or transportation disruptions, public health emergencies, and incidents requiring evacuation, Wireless Emergency Alerts for governmental officials to send geographically targeted emergency alerts to enabled mobile devices on the AT&T, Sprint, T-Mobile, and Verizon wireless networks, Ready New York to encourage New Yorkers to prepare for a variety of emergencies. Also, New York City now has a presence on many social media channels. It facilitates real-time, two-way communication between the City and the public. These programmes and initiatives are part of short-term communication strategies which include these:

- Sending emergency alerts prior to severe winter weather events, taking care to target populations with special needs, ensuring that communication is multi-lingual, and reaching out to populations who are homeless.

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36 https://www1.nyc.gov/site/em/index.page, https://www.dec.ny.gov/energy/100236.html, https://onenyc.cityofnewyork.us/
37 https://www1.nyc.gov/site/em/ready/hazard-mitigation.page
38 https://www1.nyc.gov/site/orr/challenges/nyc-panel-on-climate-change.page

- Sending weather notifications to property owners, contractors, and developers, advising them of measures they can quickly take to prepare for a winter storm, such as clearing gutters and removing snow or ice from roofs.
- For major storms or prolonged periods of extreme cold, coordinating with multiple City agencies to communicate a consistent message about weather conditions and steps New Yorkers can take to prepare. Severe weather events may require mayoral press conferences.
- Communicating via as many media as possible: social media, press releases, notifications to elected officials, and alert systems. For social media platforms, providing real-time updates as conditions worsen or improve. Whereas long-term strategies aim for these objectives:
- Help the public learn how to prepare for severe winter weather events.
- Help homeowners learn how to maintain buildings to reduce heat loss, roof leaks, and roof collapses.
- Help households understand the potentially lethal dangers of carbon monoxide poisoning that can be caused by gas appliances in their homes.

A3.19 ROTTERDAM

Prepared by Marie-Claire ten Veldhuis

Section A: General information

Socioeconomic

Rotterdam is 325,8 km^2 and has a population of approximately 620.000 people, agglomeration. Part of Randstad positive contribution to GDP (15%). Rotterdam is a harbour city at the west coast of Europe, with one of the biggest harbours of the world.

It also has a very strong national connectivity especially Rotterdam – Amsterdam is a very good connection. This great connectivity is a result of the four big highways surrounding the city.

Rotterdam has a pro-active approach to climate-adaption, with a lot of innovative projects going on.

Climate

Rotterdam has a very moderate climate. Oceanic climate (very near to the North Sea, coastal) it also has a big river running through the middle of the city (The Maas). Urban heat islands are a serious issue because of the high urbanization rate.

Rotterdam has a very flat environment mostly below sea level (this is because the city is built on reclaimed land).

Governance

Rotterdam's decision-making structure:

The Municipal Executive Committee and the City Council jointly govern the city and make up the City Government. The City Council sets out general policy and passes bills. The Executive Committee is the executive body which submits bills, implements policy and does day-to-day decision-making. Long-term climate adaption plans will go through the City Council, but if there's an emergency hazard, the Executive Committee will make the decision.

Rotterdam belongs to the Kingdom of the Netherlands and at national level the Dutch government does the decision-making.

Section B. Needs for the integrated services

Most common hazards

Because of the large harbour in Rotterdam air pollution is a serious issue as a result of diesel powered ships passing through Rotterdam.

For Rotterdam, the most dangerous environmental risk is fluvial and coastal flooding because it lies below sea level. If we take sea level rise into account this is the biggest risk.

Pluvial flooding could also do a lot of damage to both cities, but it is highly unlikely to cause dangerous situations for the citizens. Nevertheless, urban pluvial flooding should be treated seriously. Over the years, the accumulation of relatively small local events has resulted in substantial aggregate damages (Ten Veldhuis, 2009).

Existing integrated urban services

Rotterdam relies on the hazard forecasting by the KNMI. Which is done with a lot of different tools like radar and satellite data. This is an organization funded by the Dutch government and is available for every city in the Netherlands

Providers of the urban services
KNMI, Aeolis (for precise, detailed and specific meteorological information), Consultancies, for example Royal HaskoningDHV (which provides advice at for instance flood risk management), Universities: UVA, TU Delft, Erasmus Rotterdam.

Users of the integrated urban services

- General public
- Government (local)
- The Port of Rotterdam
- Transportation sectors
- The general public transportation network (Train, tram, metro, bus)
- Airport of Rotterdam
- Insurance sector
- Disaster risk management

Requirements for the services

Short term (DDR)

- In situ weather observations (rainfall, temperature, humidity, air pressure, tidal information (Maas), etc.
- Air quality monitoring to measure pollution
- Warning systems in case of extreme weather events
- Special meteorological services for the port of Rotterdam

Long term (urban planning)

- Big database of all the collected weather data
- Climate data experts to advise the city council (with urban planning, infrastructure, air quality, water management)
- Accurate sea level data (for coastal flooding protection)
- Seasonal predictions (to warn the public in case of extreme drought or wet periods, and what they can do to anticipate in these scenarios)

Section C: Services integration

Short term: multi-hazard early warning and forecasting systems

Long term: urban planning for sustainable development, climate change mitigation and adaptation.

Components integrated (and how)

1) At the level of observational infrastructure

Short term (Weather/Air quality/Tidal measurements)

- In the Netherlands are 30 continuously monitored weather stations (They measure: Temperature, wind direction and strength, relative humidity, precipitation, solar radiation and air pressure)
- Seismologic monitoring
- Two identical 5.6 GHz Doppler weather radars (One in the Bilt and the other one in Den Helder)
- Tidal gauges of the Maas
- Air quality monitoring by the RIVM (Rijksinstituut voor Volksgezondheid en Milieu) and the Rijksuniversiteit Groningen. (Measuring fine dust PM2.5, PM10, NO2, NO, CO, CO2, O3, BC, SO2, H2S and Ultra Fine Particles UFP).

Long term (Climate prediction)

- KNMI DataCenter (KDC) has observations for over 300 years (temperatures, precipitation, etc.)
- In Europe, there is an observational institution European Climate Assessment & Dataset which receives data from 63 different countries in Europe and has more than 50000 different series of data. These series are in 12 different categories: Maximum Temperature (TX), Minimum temperature (TN), Mean temperature (TG), Sunshine (SS), Snow depth (SD), Precipitation amount (RR), Sea level pressure (PP), Humidity (HU), Wind gust (FX), Wind speed (FG), Wind direction (DD), Cloud cover (CC).
- The ECA&D also works together with the WMO for region VI (Europe and the Middle East).

2) At the level of modelling tools

Short term

ECMWF, Global model from the European Weather Centre in Reading (United Kingdom). Forecasts up to 14 days on a 9 by 9 km grid (around 600 squares in The Netherlands). HARMONIE Model for The Netherlands and a bit of the surroundings. Is used since 2012 for forecasts up to 2 days on a 2.5 by 2.5 km grid (around 10000 squares for The Netherlands CRIME, Cloud Representation, Improvement and Evaluation in the HARMONIE model.

Long term

The department Research and Development of Weather and Climate models investigates and develops research tools for weather and air quality prediction applications and climate models. RDWK participates in some international projects and is the Focal Point of the Netherlands to the IPCC.

RDWK consists of about 45 research professionals (including PhD and technical support staff). We have a strong international network, and most activities are executed in collaboration with partners in e.g. HIRLAM/Harmonie, EC-Earth, ECMWF and universities.

RDWK is structured in 3 clusters: Mesoscale modelling develops tools for regional numerical weather prediction (NWP) and climate analyses; Large scale modelling focuses on global climate and atmospheric chemistry; Postprocessing and Analysis develops statistical analyses, applications and climate services[39].

3) At the level of the services/information delivery, communication

Short term

Weather prediction is a very common thing which is provided to the public through a lot of different communication types such as television (more national approach), newspapers, radio, internet webpages and even social media platforms.

Weather alarms and warnings are special advice provided by the KNMI on a national scale, but they can be given for certain regions in The Netherlands. You can select your region by province. There can be alarms for different types of weather issues such as heavy rainfall, gusts of wind, snowy conditions and slipperiness, heatwaves, whirlwinds, fog (especially for traffic information), thunderstorms and extremely low temperatures[40].

For air quality, there is an internet website where all the data of The Netherlands is stored together for the different types of particle in the air. You can find actual data on the site http://www.luchtmeetnet.nl/

Long term

Almost all data from ECA&D is open access, and can be downloaded from their websites. There are organizations who use this data to do climate predictions, which are communication by the government through news stations to the public.

The KNMI website is a place where long term climate information is being provided to the public with a lot of 'simple' explanations so the common public can understand.

Instances such as WMO Global Framework for Climate Services on energy water, health and disaster risk reduction is more focused on the big data concept, so they try to get as much data as possible from all over the world to do climate predictions as precise as possible. WMO lets engineers and professionals from different departments work together to process this data.

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[39] https://www.knmi.nl/research/weather-climate-models
[40] https://www.knmi.nl/nederland-nu/weer/waarschuwingen/utrecht

A3.20 SAINT PETERSBURG

Prepared by Elena Akentyeva

Section A: General information

Socioeconomics

Saint Petersburg is the second-largest city in the Russian Federation after Moscow. It's situated in North-western Federal District of Russia, on the Neva River, at the head of the Gulf of Finland on the Baltic Sea.

As a federal subject Saint Petersburg contains, besides Saint Petersburg proper, a number of towns, 21 municipal settlements, as well as rural localities. The total territory of the federal subject comprises 1439 km². The area of Saint Petersburg city proper is 605.8 km². The federal subject's population is 5,281,579 or 3.6% of the total population of Russia (2017). Saint Petersburg is the important industrial, scientific and cultural centre of Russia. It takes the 2nd place on economy scales among all subjects of the Russian Federation, conceding only to Moscow and contributes 5,4% of Russian GDP (2016). Its specialization includes oil and gas trade, shipbuilding yards, aerospace industry, technology, including radio, electronics, software, and computers, machine building, heavy machinery and transport, mining, instrument manufacture, chemicals, pharmaceuticals, and medical equipment, publishing and printing, food and catering, wholesale and retail, textile and apparel industries, and many other businesses.

Climate

Saint Petersburg experiences a humid continental climate of the cool summer subtype (Köppen: Dfb), due to the distinct moderating influence of the Baltic Sea cyclones. Summers are typically cool, humid and quite short, while winters are long and cold but with frequent warm spells. The average winter minimum is about -9°C, and the record low temperature is -35.9°C recorded in 1883. Solid frozen ground is a normal part of winter there. The Neva River within the city limits usually freezes up in November-December (recent years in January), while break-up occurs in April. On average, there are 123 days with snow cover (stable from December to March), which reaches the average of 24 cm by February. The frost-free period in the city lasts on average for about 135 days. There is some temperature variation within the city limits, and the city itself experiences a climate slightly warmer than its suburbs. The highest temperatures of July and August, 37.1°C, were reached in 2010. Weather conditions are, however, quite variable all over the year. Average annual precipitation varies across the city, being about 600–750 mm per year on average and reaching maximum in late summer and in the north (daily maximum is 89 mm). Though this number is not high by itself, soil moisture is almost always excessive because of low evapotranspiration due to the cool climate. Relative humidity of air is also high (78% on average), and overcast is common throughout the year (165 days a year on average).

Governance

The political life of Saint Petersburg is regulated by the Charter of Saint Petersburg adopted by the city legislature in 1998. The superior executive body is the Saint Petersburg City Administration, led by the city governor. Saint Petersburg has a single-chamber legislature, the Saint Petersburg Legislative Assembly, which is the city's regional parliament. Committee on Natural Resource Management and Ecology is an executive authority that pursues a policy of environmental conservation, and coordinates activities of other executive branches of the Saint Petersburg government in this area[41].

Section B. Needs for the integrated services

Hazards

High wind and wind-driven floods, heavy rain, snowfall, hail, snowstorm, ice and snow loads, strong fog, severe cold, intense heat, and fire hazards. Hydrological risks are connected with surges, backwater from jams, ice dams, storms, and coast erosion. Ecological risks can be caused by elevated air pollution under conditions of atmospheric inversion, surface- and sea water contamination, soil and ground water pollution.

Existing

Main integrated urban services for meeting hazard challenges are the North-West Territorial Administration for Hydrometeorological and Environmental Monitoring and Hydrometeorological Centre of St. Petersburg. They are the branches of Federal Service for Hydrometeorology and Environmental Monitoring of Russia (Roshydromet)[42]. Meteorological observation network in the region of Saint Petersburg includes 3 basic meteorological stations, 7 automatic stations, 35 precipitation gauges, and 27 air monitoring stations. Hydrological observation network consists of 15 stations and 22 hydrologic sections on 15 water bodies.

Providers

Hydrometeorological service provides information on climate and hydrology, forward-looking information including forecasting hazards, and tailored hydrometeorological and environmental information for agriculture, energy, transport, building construction, housing and public utilities in Saint Petersburg. This service checks calibration of hydrometeorological instruments, and carries out licensing activities in the area of hydrometeorology and ecology. Private companies who have license agreement with Roshydromet can also provide hydrometeorological services. There are several research institutes of Roshydromet in Saint Petersburg that explore urban climate pattern, impact of changing climate conditions on economy sectors, human health and environment, create hydrological, weather- and climate models. They carry out scientific and technical expertise for all Russian territory. For example, Voeikov Main Geophysical Observatory (MGO) is the oldest institute of Roshydromet. Its areas of research cover structuring of observational network, air pollution analysis and modelling, climate services for economy and social sphere, analyses of past and current climate, creation and development of hydrodynamic atmospheric climate models of different classes, statistical interpretation of model calculations and the use of model estimates in applied research, including analysis of the impact of climate change on sectors such as the economy, transport, construction, energy, and social sphere, climate related risk assessment as well as elaboration of adaptation strategies taking into account economic appraisal[43].

Users

The Committee on Natural Resource Management and Ecology of Saint Petersburg, Emergencies Ministry (regional and national), regional water services companies, design and construction companies, energy providers, Leningrad nuclear power plant, traffic committee, Russian Railways, airport Pulkovo, river – and seaport.

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[41] https://www.gov.spb.ru/gov/otrasl/ecology/

[42] http://www.meteo.nw.ru/

[43] http://voeikovmgo.ru

Requirements

Since 2010, Roshydromet has organized the annual training on "Climate services for economic and social sectors in the context of climate variability and change" at the MGO. Participants of the training are exposed to the different types of tailored climate products, methods of calculation and data formats for the different user groups in the context of the current and future climate. Intended audience: climatologists and meteorologists from Russian Meteorological and Hydrological Services and other organizations that deal with the climate services for the various economic and social sectors. MGO gives similar training on methods of observation over meteorological indexes and air pollution. Training on hydrological observations and forecast is given by the State Hydrological institute[44]

Section C: Services integration

Short term

North-West Territorial Administration for Hydrometeorological and Environmental Monitoring and Hydrometeorological Centre of St. Petersburg realize multi-hazard early warning and real-time forecast of dangerous events for Saint Petersburg administration, Emergencies Ministry, mass media, and other interested organizations.

Long term

Committee on Natural Resource Management and Ecology, research institutes of Roshydromet, and Institute of urban development work out long-term urban planning.

In 2016-2017 Climate strategy of Saint Petersburg was created. It was based on urban area development plan, and results of regional climate modeling. The main goal of this strategy is the adaptation of urban infrastructure to current and future climate change as well as climate change mitigation. When developing Climate strategy, the results of international research projects were taken into account.

For example, the objective of the Russian-Finnish project RAINMAN was to develop feasible and innovative solutions to ensure good state of freshwater resources within changing climate and intensified land use and to integrate selected solutions into city development guidelines and plans. The members of this project were meteorological and hydrological services, regional water services companies, State Hydrological institute, MGO[45].

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[44] http://www.hydrology.ru/
[45] https://www.researchgate.net/project/RAINMAN-Integrated-Heavy-Rain-Risk-Management

A3.21 SANTIAGO

Prepared by Pablo Hernandez

Section A: General information

Socioeconomic
The city of Santiago (33,5ºS; 70,5ºW) is the capital of Chile. It has 5.2 million inhabitants and an area of 641 km^2. This city is located in Metropolitan region (the region has a total of 7.1 million inhabitant and 15403 km^2 of surface). It's modern and urbanized, and the 16,8% of the energy matrix is based on renewable energy. Chile is a country with the economy centralized in Santiago.

Geographical
Geographically Santiago is surrounded by the Cordillera de la Costa (west), Cordillera de Los Andres (east) and with mountain ranges, Angostura de Paine (south) and Cordón de Chacabuco (North). The geography discourages the ventilation of the basin, because the Cordillera de la Costa is opposed to the propagation generated by the sea.
Its climate is warm temperate with winter rains that reach 300 mm per year, with a prolonged dry season.

Governance
Chile has a presidential republic system[46].

Section B: Needs for the integrated services

Hazards: Droughts, earthquake, air pollution, wildfire, landslides and floods.

Providers
The providers of urban services are mainly public services (ministries). The Ministry of the Environment (MMA) together with the Chilean Meteorological Service (DMC) are in charge of providing daily forecasts of air quality and providing real-time information on the current state of the atmosphere (meteorology and air quality. This information must be always displayed (air quality[47], weather[48]). The Meteorological Service provides daily meteorological forecasts for 5 ~ 7 days, seasonal bulletins (3 months) and long-term annual information (climate change 2030 to 2060). In addition, it also provides emergency bulletins for volcanic ash, wildfires and floods. There is also the National Seismological Center (CSN) of the University of Chile and the National Emergency Office of the Ministry of the Interior (ONEMI), which is responsible for announcing alerts during an emergency.

Users
The general public, public sector (ministries, sub-departments), private sector (industries, companies).

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[46] http://www.ceacgr.cl/CEA/pdf/Organigrama-de-la-administracion-del-Estado.pdf
[47] https://sinca.mma.gob.cl/
[48] http://www.meteochile.gob.cl/PortalDMC-web/index.xhtml

Requirements

In terms of requirements, whether short or long term, everyone needs observed data. For meteorology, observed data is required to be used in modeling with data assimilation and input data from global models (such as GFS) is required to start the model. For air quality, it is the same but without data assimilation. Also, to carry out modeling and forecasting, it requires machines dedicated to High Performance Computing (HPC) and people who can manage them. These machines are found in universities and some public services.

Section C: Services integration

Observational infrastructure

In Santiago, there are 11 air quality monitoring stations that measures in real-time concentrations of CO, SO_2, NO, NO_2, NO_X, O_3, PM_{10} and $PM_{2.5}$ that also measure meteorological variables of relative humidity (%), ambient temperature, Wind direction and wind speed. These stations are provided by the Ministry of the Environment. In addition, the Chilean Meteorological Service has a network dedicated to measuring meteorological variables, such as: Temperature 2m, Temperature 10m, wind direction, wind speed, humidity, pressure at sea level and water fall.

Modelling tools

For meteorological and air quality forecasts, the model used is WRF-Chem (Weather Research and Forecasting with Chemistry), which is used in operational mode for forecasting particulate material (PM10 and PM2.5) with national coverage. Also, they use MOS statistical models (Model Output Statistics) and other models based on linear regressions. On average, the forecast horizon is 3 days. For weather forecasts, the WRF model is also used, as well as information extracted directly from global models (GFS). On average, the forecast shows for the next 5-7 days.

For climate, experimental data is used that allows modeling from periods of 2030 to 2060 with WRF for studies and research. Software such as CPT (Climate Predictability Tool) is also used to make seasonal forecasts.

Services/information delivery, communication:

Meteorology

Forecasts and meteorological bulletins are published daily by the Chilean Meteorological Service through the website and television (news). In addition, these products are announced through social networks (Facebook, twitter, Instagram, etc.).

Air quality

Air quality forecasts are published daily by the Ministry of the Environment through the website, E-mail, television (news). In addition, these products are announced through social networks (Facebook, twitter, Instagram, etc.).

Climate

The Chilean Meteorological Office publishes monthly and annual newsletters on the website. They also publish information for agricultural, aeronautical and maritime purposes.

A3.22 SEATTLE

Prepared by Chandana Mitra/John Lebadie

Section A: General information

Population and area

Seattle City: 730,400 inhabitants occupying 83 mi^2, consists of:

- 7 City/District Council
- PUMA (Public Use Microdata Area)[49]

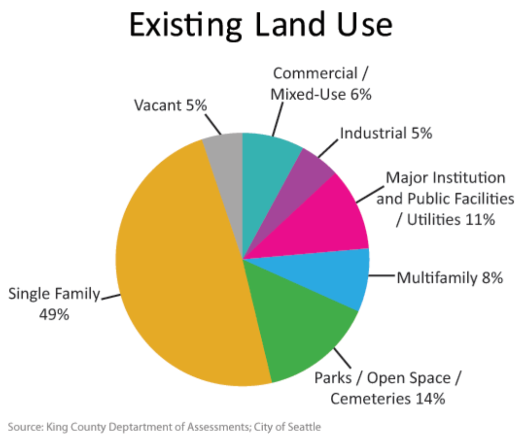
Infrastructure

The density of the city is 11.6/acre. 5003 acre parks and 8.9 acres open spaces per 1000 people. Percent of the population that lives with ¼ mile of a city-owned open space: 85%. Percent of the city in single-family zoning (excluding parks and rights-of-way): 54%. Net new housing units added since 2004: 29,330. Square feet of non-residential space built between 1995 and 2005: Over 25 million.

Nearly all of Seattle's population, 97.5%, lives within ¼ mile of a transit stop with some level of service. Ranks 7th of the 25 largest U.S. cities in transit service with a Transit Score of 59 (Walk Score).

Land use distribution

Seattle's land area remains mostly single-family in nature, but most residential development capacity, 93.5 percent, is in the multifamily zoning types with 73 percent in designated growth areas[50].



Residential construction permits: Seattle is experiencing high volumes of residential permits with historic highs of residential units in the permit pipeline for 2012[51].

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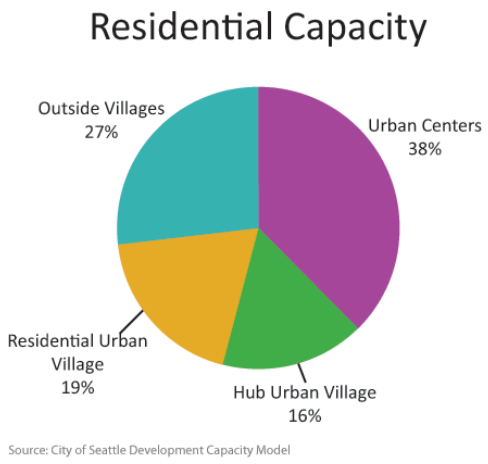
[49] http://www.seattle.gov/opcd/population-and-demographics/about-seattle - landuse
[50] http://www.seattle.gov/Images/Departments/OPCD/Demographics/AboutSeattle/Existing Land Use Full Size.png
[51] http://www.seattle.gov/Images/Departments/OPCD/Demographics/AboutSeattle/Unit Count Line Graph.png



Climate zone and geographical position

The Seattle has 29 NWS station (Seattle Tacoma Airport station lies in an altitude of 427 m above mean sea level)[52]. The Seattle municipal area is 91.5685 square miles. This includes 88.4997 square miles of land area and 3.0688 square miles of water area. This figure was compiled by the Seattle Engineering Department and is included in the department's official history, Public Works in Seattle. The area includes all water areas between the north and south City Limits from the Pierhead Line on Puget Sound to the Pierhead Line on Lake Washington. Annexed water areas outside these lines are not included.

Seattle is situated on a series of hills in a lowland area on Puget Sound's eastern shore between the Olympic Mountains to the west and the Cascade Mountains to the east. Westerly air currents from the ocean and the shielding effects of the Cascade range produce a mild and moderately moist climate, with warm winters and cool summers. Extremes in temperature are rare and of short duration, and the daily fluctuation is slight. While Seattle is known for its pronounced rainy season and frequent cloudy weather, the average annual rainfall is actually less than that of many other cities in the United States, including New York and Atlanta[53].

Seattle’s climate is temperate, with cool summers and mild winters. To the west, the Olympic Mountains provide protection from the heavy winter rains that frequently inundate the Pacific coast of Washington, while the tall Cascades to the east shield the city from mid-continental extremes of heat and cold. Average high temperatures in July seldom exceed the mid-70s F (about 24 °C), while average highs in January are in the upper 40s F (about 8 °C). The temperature drops below freezing for about 10 to 15 days annually. Owing to the confluence of humid continental and oceanic weather systems, the sky is often overcast. However, the city receives an average of only 37 inches (940 mm) of precipitation each year. The summer sky is usually at least partly clear, but overall there are fewer than 60 completely sunny days annually[54].

Average Temperatures: January, 40.8° F; August, 66.1° F; annual average, 52.4° F
Average Annual Precipitation: 36.6 inches.

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[52] https://www.wrh.noaa.gov/mesowest/mwmap.php?wfo=sew&map=sew&list=1&sort=name&limit=1
[53] http://www.city-data.com/us-cities/The-West/Seattle-Geography-and-Climate.html
[54] https://www.britannica.com/place/Seattle-Washington

Governance structure (decision-making)

Legal Framework: The mayor-council form is the oldest form of government found in Washington cities and was the only option available to most cities from statehood in 1889 until 1910 when the commission form was first introduced[55].

This form consists of an elected mayor (elected at-large) who serves as the city's chief administrative officer and a council (elected either at-large or from districts) which is responsible for formulating and adopting city policies. The mayor-council form is characterized by a separation of executive and legislative powers and a system of checks and balances patterned after traditional national and state governments. In all but the largest cities, elected city and town mayors and council members serve on a part-time basis leaving most of the day-to-day operations to various full and part-time administrative personnel[56].

Seattle is designated as a first-class Charter City under RCW 35.01.010, operating under a Mayor-Council form of government.

The Seattle City Charter embodies the fundamental principles of the City, defines the City's powers and duties, and guarantees certain rights to the people. The City Charter also sets forth the powers and duties of the City Council.

City Departments and Offices are established by the Seattle Municipal Code, Title 3 and the City Charter[57].

Responsible Institutions for addressing urban hazards, policymaking powers:

The Seattle Department of Finance and Administrative Services (FAS): FAS is responsible for Facilities and Emergency Response Programme (Fire Facilities and Emergency Response Levy), Facility Assessments and Pre-Disaster Mitigation Planning and Seismic Risk Assessment.

Office of Sustainability and Environment: The Office of Sustainability and Environment delivers cutting-edge policies and effective programmes to address Seattle's environmental challenges while creating vibrant communities and building shared prosperity. OSE collaborates with City departments, business partners, non-profit and community-based organizations, and learning institutions to develop and implement initiatives in the following areas: climate protection, buildings and energy, urban forestry, green stormwater infrastructure, and food policy. They have the authority to make Seattle Climate Action Plan and Citywide Climate Change Preparedness Strategy.

Public Health – Seattle & King County: Public Health – Seattle & King County provides public health services for the City, including services for children and youth, persons with chronic disease, and communicable diseases; immunization services; environmental health services; public health emergency preparedness; emergency medical services; violence and injury prevention services; a medical examiner; nutrition support services; and tobacco prevention programmes.

[55] https://www.seattle.gov/cityclerk/agendas-and-legislative-resources/seattles-form-of-government
[56] http://mrsc.org/getdoc/88bd80e7-61ce-49ba-a848-0b2c070c3ef9/Trends-in-Forms-of-Government-in-Washington-Cities.aspx
[57] https://www.seattle.gov/cityclerk/agendas-and-legislative-resources/seattles-form-of-government

Department of Planning and Development: The Department of Planning and Development provide rapid assessment of damaged buildings following earthquakes. The Department of Planning and Development manages the City's National Flood Insurance Program (NFIP). Conduct public outreach with the intent of providing expert advice for property owners to manage landslide-prone areas.

Seattle Fire Department: The Fire Marshal's Office (FMO) administers the SFD fire prevention programme to provide a reasonable level of life safety and property protection from the hazards of fires, explosions, and dangerous conditions, including releases of hazardous materials for Seattle's residents, workers, and visitors.

Office of Emergency Management: The Seattle Office of Emergency Management (OEM) is responsible for managing and coordinating the City's resources and responsibilities in dealing with all aspects of emergencies. Its basic mission is devoted to citywide disaster preparedness, response, recovery, and mitigation. It places a strong emphasis on individual and community preparedness and provides a key liaison function between the city and its state and federal emergency management counterparts.

Seattle City Light: The Dam Safety Programme of Seattle city light involves the coordination, monitoring, and oversight of activities for six major dams to reduce the risk and impacts from dam failure due to natural and man-made hazards.

Seattle Public Utilities: Seattle Public Utilities (SPU) is comprised of three major direct-service providing utilities: water, drainage and wastewater, and solid waste. The water utility provides more than 1.3 million customers in King County with a reliable water supply; the drainage and wastewater utility collects and disposes of sewage and storm water; and the solid waste utility collects and disposes of recycling, yard waste, and residential and commercial garbage. All three utilities strive to operate in a cost-effective, innovative, and environmentally responsible manner. SPU also houses the engineering services line of business, which serves both City departments and outside agencies, providing efficient, customer oriented engineering services that assist clients with replacing, improving, and expanding facilities with the least possible disruption to the community[58].

Section B. Needs for the integrated services

Hazards

Unlike other parts of the country, Seattle doesn't have any regular catastrophic events to deal with on a yearly basis. They don't have tornadoes. They don't have hurricanes. They get a lot of rain and can sometimes get high winds during storms, but these don't usually result in disaster-level damages (although, fallen trees are no joke if you live under any tall fir trees). But make no mistake—Seattle is not immune to major disasters. Quite the contrary, this region has the potential for major and massive natural disasters to strike, so major in fact that the entire region could even be destroyed if the worst-case scenario were to happen (think huge Cascadia Subduction Zone earthquake followed by an equally destructive 9.0 earthquake). From earthquakes to tsunamis, no matter how remote the chances are, it's best to understand what could happen and how to be prepared[59].

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[58] http://www.seattle.gov/Documents/Departments/Emergency/PlansOEM/HazardMitigation/Seattle 2015 - 2021 HMP Final.pdf
[59] https://www.tripsavvy.com/seattle-natural-disasters-2965046

A Washington State Department of Health study examined incidents occurring in 1992. According to the report there were 118 events in King County, about 10.2% involving transportation and 89.8% occurring at fixed facilities. Twenty-six incidents caused a total of 66 injuries, most commonly involving acids and volatile organic compounds. Additionally, 29 incidents resulted in the evacuation of nearly 1400 people. The report indicates that 44 incidents in King County occurred within one quarter mile of residential areas, indicating some risk to people not directly involved with the released chemicals.47 A recent Washington State Hazard Identification and Vulnerability Analysis cited an average of 960 emergency spills occurring annually in King County. Significant events in King County detailed by the study include: the release of 2500 gallons of fuel from Olympic Pipeline at their Renton pumping station, the release of hydrofluoric and nitric acids from Boeing's Auburn plant, numerous drug lab events, metal finishing company fires at Boeing and Universal Manufacturing, a spill at UPS in Redmond, numerous releases of ammonia from cold storage facilities and the release of a small amount of chorine from a public water company. Response teams have narrowly averted some potentially large releases[60].

Existing integrated urban services

The government has established the Center for Command, Control, Computation, Communications and Citizen Contact (C5) to monitor multi-hazard and respond within five minutes of an incident:

- Environmental Contingency Programme (air pollution)
- Air quality forecast system
- Hydrometeorological alert system
- Seismic system
- Volcanic alert
- Hydrometeorological Bulletin
- Risk Atlas
- Contingency task force for water scarcity

Providers of the urban services

It has been stated in the paragraph under "*Responsible Institutions for addressing urban hazards, policymaking powers*"[61].

Section C: Services integration

Short term: multi-hazard early warning and forecasting systems

Long term*:* urban planning for sustainable development, climate change mitigation and adaptation.

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[60] https://www.kingcounty.gov/safety/prepare/EmergencyManagementProfessionals/Plans/~/media/safety/prepare/documents/HIVA/Hazmat.ashx

[61] http://www.seattle.gov/Documents/Departments/Emergency/PlansOEM/HazardMitigation/Seattle 2015 - 2021 HMP Final.pdf

A3.23 SEOUL METROPOLITAN AREA

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Section A: General information

Socioeconomic

The Seoul Metropolitan Area (SMA) is located on central part of the Korean Peninsula. It was ranked to include the fifth largest built-up urban area by population in 2018 (Demographia, 2018). The SMA consists of three administrative provinces: Seoul Special City (Seoul City), Incheon Metropolitan City (Incheon City), and Gyeonggi Province. Seoul City, the capital city of South Korea, is surrounded by Gyeonggi Province (to the north, south, and east) and Incheon City (to the west). Incheon City is located between Seoul City and the Yellow Sea. The Gyeonggi Province surrounds Seoul City and Incheon City. The SMA covers an area of 11,799 km^2 and is home to 25.8 million people[62]. Seoul City has an area of 605 km^2 and the highest population density of 16,142 km^{-2}, while Gyeonggi Province has the highest population of 13.1 million people, but the largest area of 10,184 km^2, thus the lowest population density of 1,285 km^{-2}. The SMA's gross regional product was 698 billion USD, generating 49.5 % of the country's total GDP. The SMA has ranked as the fourth largest urban economy in the world.

Geographical

The SMA has very complex geography, topography, and land cover. The Gyeonggi Bay is in the Yellow Sea in the west of the SMA, and has a very irregular coastline. The western part of the SMA comprises relatively low-lying farmland or urban areas, while the eastern part contains high-altitude mountain ranges, some of which are higher than 1,000 m. Most mountains are covered with forest. The Han River flows from east to west, and divides the SMA and Seoul City. Seoul City is surrounded by several high mountains: Bukhan Mt. and Dobong Mt. in the northern part, Surak Mt. and Bulam Mt. in the north-eastern part, and Gwanak Mt. and Cheonggye Mt. in the southern part. There is a small mountain (Nam Mt.) in the center of Seoul City. The SMA's climate is classified as temperate with four distinct seasons: hot and humid summers due to the North Pacific high-pressure system, and cold and dry winters due to the Siberian high-pressure system (Jung et al., 2002).

Governance

Seoul City is comprised of 25 districts, Incheon City is comprised of 8 districts and 2 Guns, while Gyeonggi Province is comprised of 28 Cities and 2 Guns. Each City is led by a mayor, while Gyeonggi Province is led by a governor. Mayors and Governors as well as heads of district are elected by provincial election. KMA (Korea Meteorological Administration) and ME (Ministry of Environment) are responsible for meteorology and air quality related service, respectively. The Seoul Metropolitan Office of Meteorology (SMOM) and the Metropolitan Air Quality Management Office (MAMO), a subsidiary organization of KMA and ME, are responsible for the meteorology-related and air quality-related services in SMA, respectively. NIMS (National Institute of Meteorological Sciences) and NIER (National Institute of Environmental Research) are responsible for research-based or technical support for KMA and ME, respectively.

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[62] http://kosis.kr

Section B. Needs for the integrated services

Hazards

Recently, the SMA has experienced severe Asian dust/haze/smog events frequently in every winter and spring, blackouts of more than 1.6 million houses due to failure in electric power demand prediction after extremely hot weather in autumn, massive damage from shallow landslides due to heavy rainfall in 2011, several inundations by flash floods, traffic accidents as a result of road ice, and deaths due to annual heat/cold waves. Especially, visibility reduction and health effects by long-range-transported or domestic air pollutants became one of the nationwide concerns. To meet the needs to decrease PM concentration and to reduce damages by fine-dust, a special law on fighting find dust pollution has been established to be obligated to take emergency dust reduction measures under high $PM_{2.5}$ concentration in 2019.

Existing

There are many meteorological and air quality stations in the SMA: 7 ASOSs (Automatic Synoptic Observation System), 108 AWSs (Automatic Weather Station), 4 radars, 2 wind profilers, 2 microwave radiometers, and 2 rawinsonde stations operated by KMA; 201 air quality monitoring stations operated by ME and local administrations. The Weather Information Service Engine (WISE) project was launched in 2012 to deliver high-quality meteorological information customized for users' demands for the purpose of urban resilience and sustainability (Choi et al., 2013). Under the project, high-resolution urban observation system in the SMA (UMS-Seoul) has been installed in 2013-2017 (Park et al., 2017). It includes 14 surface energy balance systems, 7 surface-based remote sensing instruments (7 microwave radiometers, 6 wind lidars, 2 ceilometers, and 2 aerosol lidars), and applied meteorological observation instruments (6 road-weather, agro-meteorology). The user-specific weather information services such as flash flood, road weather, agro-meteorology, urban micro-climate, energy-use, released hazardous materials diffusion, and urban ecology were developed.

Users

The users for these services cover all kinds of sectors: governmental departments, transportation sectors, water management, energy sectors, health sectors, disaster risk management sectors, general public, etc. policymakers make their own guidance for each hazard and deliver it to the relevant general public.

Providers

Meteorological information is provided by KMA, while air-quality information is provided by ME and NIER (National Institute of Environmental Research). The WISE project had installed UMS-Seoul observation platform, and had developed user-specific services in the SMA. After the project was completed in 2017, the services were transferred to KMA and NIMS (National Institute of Meteorological Sciences) since 2018. UMS-Seoul, as an observation platform, was maintained by HUFS (Hankuk University of Foreign Studies) and KMI (Korean Meteorological Institute) in 2018, and was transferred to NIMS in 2019. As a result, observed data and services will be provided by NIMS and KMA in collaboration with HUFS since 2019.

Section C: Services integration

The SMA is to integrate not only observed meteorological (operated by KMA) & air quality (operated by ME) data, meteorological and applied model outputs, and user-specific services. These services will help to prevent possible damages from extreme disaster in advance, to give the best timely guidance to citizens during an unexpected disaster, and to optimize the efficiency of urban planning and reconstruction.

***Short term**:* The SMA is to:

- Integrate all kinds of observation data: UMS-Seoul (operated by NIMS), 108 AWSs and 7 ASOSs and other remote sensing instruments (operated by KMA), air quality (SO2, NOx, CO, O3, PM10, PM2.5) (operated by ME), road weather information (road surface temperature and status, water depth) (operated by NIMS).
- Construct real-time data acquisition, quality check, and display system in near future.
- Share the data with relevant users: NIER (ME) for the purpose of severe fine dust, The Seoul Institute (SI) and Seoul Institute of Technology (SIT) for the purpose of urban planning and thermal adaptation, SMOM for urban meteorology, researchers in universities and research institutes for urban resilience and sustainability.
- Transfer WISE-developed services (e.g. flash flood, road weather, urban climate, dispersion) to other SMART Cities (e.g. Busan (LCT) and Sejong).

Long term*:* The SMA is to:

- Improve the Seoul Urban Meteorological Model by applying the input variables (building height, plane area density, frontal area density, surface roughness length, zero-plane displacement length, albedo, thermal capacity and diffusivity, etc.), assimilating observed data, and improving the urban boundary-layer processes (e.g. urban canopy, boundary-layer turbulence, surface scheme, etc.).
- Develop the high-resolution and high-quality reanalysis data with the use of available observation data obtained from UMS-Seoul, KMA, and satellites.
- Improve the spatial and temporal resolution, accuracy and quality of services continuously.

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A3.24 SINGAPORE

Prepared by Matthias Roth/Chui Wah YAP

Section A: General information

Singapore is an island city state nestled in the centre of the Southeast Asia region. A large part of its 724 square kilometres of land area is densely built-up. The island is relatively flat, and much of the island lies 15m above sea level with about 30% less than 5m above sea level. The highest point is 163m above sea level.

Singapore is highly urbanized with a population of 5.6 million people (as at June 2018). The population is served by a highly modernized infrastructure that includes an inter-connected bus and rail network, world class air and maritime ports, extensive communication networks, reliable energy and water supply. According to Mercer's 19th annual Quality of Living survey in 2017, Singapore was ranked first for city infrastructure.

Climate of Singapore

Singapore has a tropical climate that is relatively uniform throughout the year with little variation in seasonal weather. The main features of Singapore's climate are uniform temperature, high humidity and abundant rainfall throughout the year due to maritime influence and the island's close proximity to the Equator. Daily variations in these elements are typically diurnal in nature, driven by solar heating.

Singapore experiences two main monsoon seasons each year – the Northeast Monsoon which typically lasts from December to March and the Southwest Monsoon from June to September. The Northeast Monsoon season is wetter and accounts for about half of the annual rainfall while the Southwest Monsoon season is relatively drier and accounts for about a third. The monsoon seasons are separated by inter-monsoonal periods (April to May and October to November), during which the winds are generally light and variable in direction, sea breeze induced thunderstorms are common.

Governance structure

The Government of Singapore is modelled after the Westminster system, with 3 separate branches: the Legislature, the Executive and the Judiciary. The Executive branch administers the law and comprises the Cabinet led by the Prime Minister, who is the Head of Government. The Meteorological Service Singapore (MSS) is a division of the National Environment Agency (NEA), which is a statutory board under the Ministry of the Environment and Water Resources (MEWR), along with the Public Utilities Board (PUB – the national water agency) and the Singapore Food Agency. MEWR's mission is to ensure a clean, sustainable environment, and supply of water and safe food for Singapore. Synergistic issues of climate/weather, water, air quality and food security come under the remit of a single ministry (MEWR), enabling a holistic approach to policy-making.

The National Environment Agency Act, empowers the NEA, through MSS, to provide meteorological services for users, including government agencies, aviation and shipping communities and the public; conduct meteorological observations and maintain reliable climatological records of Singapore; and furnish advice on meteorological matters.
As a low-lying island state that is vulnerable to the impacts of climate change, the Government of Singapore is actively dealing with the challenges of climate change. To reduce carbon emissions, one of the key measures introduced is a carbon tax, which targets large industrial facilities. The Government consulted businesses extensively before introducing the carbon tax.

Under the Carbon Pricing Act which came into effect in Jan 2019, taxable facilities have to engage a third part verifier to verify their annual emissions report.

Cross-sectoral coordination necessary for the delivery of integrated urban services is enabled through a "Whole-of-Government" (WOG) approach adopted by Singapore government agencies. MSS works closely with PUB on water resource management and drainage issues, the Pollution Control Department of NEA on air quality issues, and a wide cross-section of government agencies on climate change issues. Beyond that, MSS serves as a multi-hazard early warning centre to provide alerts and advisories to national response agencies for emergency preparedness.

Institutional frameworks are in place to better manage and coordinate cross-cutting issues. For example, there is an Inter-Ministerial Committee on Climate Change (IMCCC) to enhance WOG coordination on climate change policies. A Climate Resilience Working Group under the IMCCC guides adaptation planning by government agencies overseeing coastal protection, water resources and drainage, biodiversity and greenery, public health and food security, network infrastructure, and building structures. There is also an Inter-Agency Haze Task Force comprising over 20 government agencies that manages transboundary haze pollution that occasionally affects Singapore during the traditional dry season. The Task Force, led by the NEA, coordinates the respective agencies' response plans for mitigating the effects of haze on public health and various sectors of the economy.

Section B. Needs for integrated services

Main hazards

The most common weather hazard in Singapore is extremes in rainfall. On one end, intense rain from short-lived thunderstorms or prolonged rain (from monsoon surges during the Northeast Monsoon season) often trigger flash floods. Thunderstorms and lightning are the most common severe weather phenomenon in Singapore, with an annual average of 168 thunderstorm days. On the other end, prolonged dry weather can pose a problem for water resource management. Other weather-related hazards include strong wind gusts (from localized thunderstorms and squall lines), and warm temperatures leading to heat stress. Occasionally, Singapore experiences windborne transboundary pollutants that can lead to deterioration of local air quality. A common air pollutant is transboundary smoke haze from land and vegetation fires in the surrounding region. Other potential pollutants include ash cloud from volcanic eruptions with potential to affect air quality and disrupt aviation operations in the region.

As a low-lying island city state, Singapore is susceptible to sea level rise due to climate change. Like other parts of the world, Singapore is expected to experience more frequent and intense weather events such as heavy rain, prolonged dry weather, and heat stress, due to the climate change.

Singapore may be affected by geohazards although such impacts are normally mild, for example, tremors due to strong earthquakes in the nearby region.

Existing services

- Operational weather services to support safe and efficient operations of government sector and business, and for the public to better prepare for impact of severe weather

  - Weather information: real-time information of rain locations, lightning, weather elements (rainfall, temperature, humidity, surface wind) from automated observation networks, and UV index.
  - Forecast: nowcast (2-hr), forecast (24-hr, 4-day), and fortnightly weather outlook.
  - Alerts and advisories: lightning risk, heavy rain, prolonged high temperatures, prolonged dry weather, strong winds (from squall lines), and monsoon surges.
- Multi-hazard watch and warning services to enable public agencies to better plan and respond to hazards for disaster risk reduction and better prepare the public.
  - Daily smoke haze advisory on outlook for haze situation and forecast air quality band.
  - Advisories on potential air contamination by volcanic ash or radiological fallout.
  - Multi-tier alert system for tsunami.
  - Reports and assessments of major earthquakes, volcanic eruptions, and tropical cyclones in the region.
- Climate services to support longer-term planning and building climate resilience.
  - Climate projections: climate scenarios for Singapore up to 2100 and assessment of climate change effects to guide national climate adaptation planning.
  - Sub-seasonal and seasonal predictions: forecast of climate variability and extreme weather conditions to support advance planning for climate-sensitive sectors including water resource, forestry and environment, agriculture and disaster management.
  - Climate statistics & climate studies: provide climate data and climate assessment and review for the media and public, research community and academia, government agencies and businesses such as insurance and construction industry.

Requirements

Short term:

- City-scale forecasts of air quality (24-hour Pollutant Standards Index).
- Early warnings with improved accuracy and longer lead times of weather hazards such as heavy rain and high temperatures.
- Improved advisories on risk of lightning for outdoor sporting and labour activities.
- Heat stress information.

Long term:

- Observation networks to study the urban environment such as the Urban Heat Island (UHI) effect.
- Multi-year predictions to support medium-term planning in water resource management and food security.
- Long term climate projections for Singapore, updated in alignment to the latest IPCC Assessment Report.

Section C: Services integration

Observations

- WEATHER: network of ~ 100 automatic weather stations, 5 manned weather synoptic stations, 1 upper air observatory, 1 wind profiler, satellite reception ground station, 2 Doppler weather radars, 2 LIDARs (upper winds and aerosol), network of lightning detection sensors, 5 Wet Bulb Globe Temperature (WBGT) stations, and 5 seismic monitoring stations comprising broadband sensors and accelerometers linking to a central processing system (operated by MSS).

- Air quality: 22 air quality monitoring stations measuring PM10, PM2.5, NO2, SO2, CO, O3 (operated by Pollution Control Department (PCD) of NEA).
- Water: 208 water level sensors for monitoring drainage system, 49 CCTVs (operated by PUB).

Modelling

- Numerical Weather Prediction (NWP): development of convective-scale NWP with data assimilation and using an ensemble approach.
- Nowcasting: various approaches combining the use of radar data and high-resolution NWP models are being tested.
- Atmospheric dispersion modelling: operational model to forecast the transport of smoke haze, volcanic ash and radioactive contaminants from radiological fallout.
- Air quality modelling: development of air quality prediction model with chemistry configuration.
- Urban modelling: study the Urban Heat Island effect and impact of urbanization on key climate processes over Singapore.
- Regional climate modelling: develop understanding of the changing climate in the region and generate long-term climate projections to support national resilience planning; high resolution climate model simulations with explicit convection are also conducted.

Integrated components

- Data from MSS' weather observing network and PUB's water level sensors are integrated to provide warnings of heavy rain and water levels exceeding certain thresholds (in various locations island-wide) to the public and business sector. The information enables users to prepare for any potential occurrence of flash floods.
- Singapore's air quality is occasionally affected by haze from land and vegetation fires in the nearby region or from local sources. Monitoring and assessment of the haze and air quality situation is carried out using data from the weather observing network and air quality monitoring stations. A daily forecast of the air quality (24-hr PSI) for the next 24 hours is done jointly by MSS and PCD/NEA for certain periods of the year.
- The Urban Heat Island (UHI) effect coupled with global warming is a concern as it affects the thermal comfort of the population. Plans to make the outdoor environment cooler are being undertaken, and one such initiative is the Cooling Singapore project (www.coolingsingapore.sg). MSS is contributing its weather data and modeling expertise to the project, together with other government agencies overseeing urban planning, building construction, transport and biodiversity.
- MSS is working with a panel of experts from the health and related sectors to develop a heat stress information service. The information is based on WBGT measurements.
- Dengue is endemic in the tropical and sub-tropical regions of the world, including Singapore. MSS' weather observation data and seasonal prediction feed into the dengue prediction model run by the Environmental Health Institute.
- Amongst various clean technologies, solar energy is the most promising renewable energy source for Singapore. The main challenges are Singapore's limited size, and intermittency of solar output which is dependent on weather conditions. MSS is contributing its data and expertise in a national solar forecasting programme which involves the participation of local research institutions.

- The Government of Singapore has put in place a comprehensive Climate Action Plan mapping out various long-term adaptation and mitigation measures. MSS is responsible for the generation of long-term climate projections to guide long-term adaptation planning by government agencies overseeing coastal protection, water resources and drainage, biodiversity, public health, food security and network infrastructure. This entails extensive engagement between MSS and the agencies to ensure their needs and requirements are appropriately factored in the climate modelling. Further engagement is carried out to interpret the results and explain the uncertainties of the projections to agencies, so that they are properly applied in adaptation planning.

Services/information delivery, communication

- Warnings of main weather hazards and geohazards are issued by a single authoritative source (MSS) to the public. Additional assessment and situation reports are communicated to the relevant government agencies to assist in their contingency planning and decision-making.
- Service delivery to the public via the internet, mobile applications and social media, print and broadcast media, location-specific alert services via SMS or push notification, and to response agencies via direct line to operations rooms.

Water management

- 7-day outlook, monthly weather assessment, 3-month seasonal outlook, rainfall trends for Singapore and its reservoirs and catchments are provided to Singapore's national water agency (PUB) for better planning and water resource management. Weather consultation services as well as advisories of heavy rainfall that could lead to flash floods are also provided.

Air quality

- During the haze season, MSS works closely with PCD/NEA to issue a daily Haze Situation Update. The advisory includes the forecast of air quality over Singapore and health advisory on whether to curtail outdoor activities. It is issued to the public, schools and government agencies. A dedicated haze website (www.haze.gov.sg) is set up as a one-stop site for all information relating to haze, such as the latest air quality, haze situation in the region, etc.

Weather extremes

- Special advisories issued for very warm weather (heatwave), cool weather, prolonged dry weather, prolonged heavy rain to keep the public updated on developing weather conditions and for better preparedness.

Fortnightly outlook

- A video presentation of the fortnightly outlook of the weather for Singapore is produced and updated twice a month online by MSS. MSS leverages on the video format to better engage the public and cater to a social-media generation.

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A3.25 SHANGHAI

Prepared by J. Tan

Section A: General Information

Socioeconomic
Shanghai is one of the most populated cities in China and had an area of 6340.5 km^2 and a population greater than 24 million in 2018(Shanghai Municipal Statistics Bureau,2018), with more than 2.6 million automobiles, more than 32,000 tall buildings (>30 m tall), and over 1,200 skyscrapers (>100 m tall) in 2012. (Tan et al., 2015). Current population density in the city center of Shanghai exceed 15 000 people km^{-2}. Also, Shanghai is the economic, financial, shipping and trade center of China, generating 3267.987 billion Yuan GDP ranked by the first city in China.

Geographical
Shanghai is a coastal city located at the middle of China's coastline and the mouth of Yangtze River and Hangzhou Bay, with water on two of its three sides. Shanghai is flat with mean elevation of 4m above sea.

Governance
Shanghai is a direct-controlled municipality which is administratively equivalence to a province, including 17 districts.

Section B: Needs for the integrated services

Hazards
Shanghai experiences a subtropical monsoon climate with four distinct seasons. Winters are generally cold and dry, with only 1 or 2 days of snowfall in average, while summer are hot and humid, with two to three typhoons annually. Most common hazards in Shanghai and associated environment risks are typhoons, severe rain, heatwaves, thunder and lightning, fog, storm surges, and air pollution episodes. With its rapid urbanization and population growth, Shanghai has become more vulnerable to disasters. Shanghai has vast infrastructures—for example, transport networks, transmission lines, drainage networks, and underground spaces (e.g. metro lines, parking garages). These are all vulnerable to weather and climate events and can benefit from integrate service. Since 2010 World Expo in Shanghai, a multi-hazard early warning system has been put in use, but integrated weather, climate and environmental service are also needed. Owing to magnification effect and domino effect in the city, sometimes non-severe weather may bring serious problems because an increasing number of activities are more sensitive to weather and climate.

Providers
Shanghai Meteorological Service play the role in disaster watches and warnings, and Shanghai Emergency Warning Center (EWC) was officially established in 2013, through which all kinds of emergency warnings in Shanghai could be issued.

Users
Integrated services were directed towards four major end users, such as city government and relevant agencies, community, industrial sector or private enterprise, and individual citizen. For example, flood control agencies need data on precipitation (rain, snow) distribution and runoff, as well as the water storage capability of urban pervious surfaces, drainage systems,

and water-logged ground. Power plants, grid operators, and local utilities need high-resolution air temperature for assessing energy demand and resulting loads on the electric grid. Wind and solar radiation are also needed for renewable energy assessments. Urban planners and design departments need information on the UHI, vegetation stress index, urban air quality, and wind. Public health agencies want to know pollutant emissions and concentration, solar radiation, wind, humidity, and air temperature are needed at appropriate scales for street level, air quality, pollen, and predictions of heat stress. Transport agencies need data on strong winds (especially channeling wind), precipitation and its forms (i.e. rain, freezing rain, sheet, or snow), surface state (dry, wet, ice covered), and high-resolution spatial forecasts (e.g. roadway scale) for metros, highways, and seaports. Urban emergency response agencies need timely and accurate information on extreme weather, such as detailed street-level flood information, and high spatial- and temporal-resolution wind, temperature, and moisture data in and above the urban canopy.

Section C: Services integration

A WMO Demonstration Project, Shanghai Integrated Urban Weather and Climate Service, is being carried by Shanghai Meteorological Service. Through introducing advanced technology and weather/climate disaster management theories, the project is aimed at developing seamless multi-time-scale weather forecast supported by numerical models, developing impact-based forecasting and warning system, improving urban climate services, interacting with users by information services and helping the city to manage risks caused by climate change.

Integrated observation: To understand the interactions between the urban surface and atmospheric processes, improve the performance of urban weather, air quality, and climate models; and provide key information for city end users, Shanghai's Integrated Urban Meteorological Observation Network (SUIMON), a network of observation networks, has been established from different systems and instrumentation deployment types (See Tan et al., 2015). The ultimate goal of SUIMON is to provide integrate measurements of all the processes that influence Shanghai's regional environment and the city itself, including both physical and chemical characteristics of the boundary layer and the free atmosphere, so linkages can be better understood.

Integrated forecast system: *A* seamless forecast system including nowcasting, short-term, mid-term, extended range and long-term forecast has been established to integrate of weather forecast and climate prediction, including high resolution regional NWP system up to 3 km horizontal resolution and High-resolution regional climate models and air quality models.

Integrated urban Service: Impact-based weather forecasting and risk warning system has been established to integrate the weather and risk management, including demand-oriented, user-interactive system of impact-based weather forecasting and risk warning system(urban flood, aviation, marine navigation, health, and transportation, etc.) based on high resolution numerical forecasting, a user-interactive urban climate service platform for improving the resilience of the city, and a public service quality management system, standardize the process of emergency warning for improving meteorological disaster prevention/reduction and public service.

A3.26 STOCKHOLM

Prepared by Jorge H. Amorim (SMHI), with contributions from Christer Johansson (Stockholm City) and Magnus Sannebro (Stockholm City)

Section A: General information

Socioeconomic

Stockholm is the financial center of Scandinavia with the largest gross regional product. With an official plan to build 140 000 new homes by 2030, it is also one of the five fastest growing metropolitan areas in Europe, with Stockholm Royal Seaport standing as one of the largest urban development areas in northern Europe. The proximity to expanding markets around the Baltic Sea makes Stockholm a very attractive city for investors. The Scandinavian countries, along with the Baltic Sea area, are increasingly viewed as one collective market by global companies. In 2013, Standard & Poor's Ratings Services affirmed its 'AAA' long-term and 'A-1+' short-term issuer credit ratings on the City of Stockholm.

Sweden's capital city Stockholm has an urban population of nearly 1 million inhabitants and 1.8 million inhabitants living within the Greater Stockholm. The city is growing fast and new housing is needed. The increasing share of the Swedish population living in dense urban environments will become more vulnerable to environmental and climate hazards, calling for innovative planning solutions for the city that converge housing and mobility needs with well-being and health. Intensive impervious sealing of surfaces and human densification are important drivers of the urban microclimate and how it will respond to climate change in the future.

Geographical

Stockholm has a maritime-influenced humid continental climate (Köppen Climate Classification Dfb), with warm summers and cold winters. Stockholm is located on Sweden's east coast, where the freshwater Lake Mälaren, Sweden's third largest lake, flows out into the Baltic Sea. The central parts of the city consist of fourteen islands that are continuous with the Stockholm archipelago.

Stockholm city is located at the border between the large lake Mälaren and the Baltic Sea, thus highly sensitive to future changes in river runoff as well as lake and sea levels. The underground subway, as well as the different existing and planned road traffic tunnels, are also highly vulnerable to extreme precipitation events. Another significant risk is failure in electricity supply, as well as IT- and tele communications. Expected climate change effects include higher rainfall intensities, with 25% rise in extreme rain events by the end of the century. Recent modelling results by SMHI suggest an even higher increase in rainfall intensity. As a result, the Stockholm area will experience a rise in both intense flash floods and "pluvial flooding" that may last for weeks or even months and cover large areas. This strains the sewer networks and built environment and poses a risk for the population.

Governance

Sweden has 290 municipalities of which Stockholm is the largest. The City Council is the supreme decision-making body of the City of Stockholm. The City provides Stockholm's inhabitants with a multitude of different municipal services. Most of the municipal activities in Stockholm are carried out in administrative or corporate form.
Stockholm has been working on climate change mitigation since the 1990s, and adaptation for at least a decade. The city is a real frontrunner, with well implemented climate action plans

and pioneering policies to ensure it meets its ambitious environmental targets. The carbon dioxide emissions have been cut by 25% per citizen since 1990. Stockholm was the first city to receive the award European Green Capital by the EU Commission in 2010.

The Environment and Health Administration of the city of Stockholm (EHA) has as key priority to ensure that Stockholm remains a sustainable city, while offering an attractive and inspiring living and working environment. The climate action group coordinates implementation and monitors the results of all climate actions undertaken in the city. Their long-term aim is to become completely fossil-fuel free by 2040.

The City of Stockholm´s work with Climate Adaptation is process-based, and focuses on producing strategies for different climate risks. The first strategy deals with cloudburst protection, and is expected to be adopted by the City Council during 2019. Development of a new strategy is suggested for heat stress and health impacts of extreme temperatures. The Climate Adaptation work is organized as a coordination group where several administrations are included under the direction of the City Executive.

The Swedish Meteorological and Hydrological Institute (SMHI) is an expert agency under the Ministry of the Environment and Energy. It offers high quality products and services to professional clients and carries out R&D in the fields of meteorology, climate, hydrology and oceanography with a strong international cooperation. SMHI is the National Focal Point for the IPCC and has coordinated the Copernicus C3S proof-of-concept project Urban SIS (2015-2017), which provides high resolution data on climate, hydrology and air quality over the Stockholm region for present and future time windows.

SMHI is currently engaged in several initiatives together with the City of Stockholm aimed at understanding and quantifying the impact of heatwave events in Stockholm. One can mention the HazardSupport project, funded by the Swedish Civil Contingencies Agency (MSB), the Horizon2020 project CLARITY, funded by the EC, and the recently started project GreenWave, funded by the Swedish Research Council for Sustainable Development (FORMAS).

Section B. Needs for the integrated services

Hazards
Cloudburst and flooding, air pollution, heatwave, snow and ice. In the long-term: sea-level rise.

Existing
SMHI provides daily forecasts at the national level and issues multi-hazard early warnings. Climate scenario data is also produced and delivered by SMHI. Monitoring and modelled data is available to the public through SMHI´s Open Data API[63].

As an example of an Integrated Urban Service, the Copernicus climate change services (C3S) project UrbanSIS delivered 1km resolution ECVs and impact indicators on climate, hydrology and air quality for 3 5-year time windows representing past, present and future climate conditions in Stockholm. This dataset is available for visualization and download[64]. New climate and urban planning scenarios for Stockholm are being simulated in the projects HazardSupport, CLARITY and GreenWave.

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63 https://opendata.smhi.se/
64 http://urbansis.climate.copernicus.eu/

Supervision of air quality in Stockholm and neighbouring cities is carried out by SLB analysts, a Department at the Environment and Health Administration of the city of Stockholm. This includes extensive regulatory monitoring of regulated air pollutants as well as some key unregulated pollutants (black carbon and nanoparticles), short term forecast reported on the web and to newspapers and radio and also long term prognoses of impacts of urban planning on air quality and health. SLB is the operator of the Eastern Sweden Air Quality Association with 60 member organizations including 50 other cities in Sweden.

Alarms of high air pollutant concentrations are reported to Naturvårdsverket (the Swedish Environmental Protection Agency), who informs the public. In the event of an accidental release of e.g. toxic chemicals it is firstly the fire brigade's responsibility.

The cloudburst model is the most strategic climate service tool that Stockholm holds at the moment. The results are available to both internal City of Stockholm users, as well as external users through the web data portal Stockholm Open Data[65]. However, the functionality is much higher for internal users, with the possibility to do overlay-analyses with thematic maps. Stockholm Vatten och Avfall (Stockholm Water Company) has also developed a web-based User Guide to the cloudburst model, aimed at developers and city planners within the City of Stockholm. This guide is only accessible to internal users, and is designed as a tool for cloudburst analyses of a specific area.

Stockholm Vatten och Avfall has developed a coupled flooding model for the river Bällstaån, in close cooperation with DHI. It is calibrated against actual rainfall and discharge data, and is used especially for urban development in the Bällstaån catchment.

General flood mapping is carried out by the Swedish Civil Contingencies Agency (MSB). Regarding heat-waves and heat stress, a map of mean radiant temperature over the city is also accessible from the same web portal as mentioned above.

Providers
SMHI, City of Stockholm, SLB Analys, Stockholm Vatten och Avfall, the Swedish Civil Contingencies Agency, the Swedish Environmental Protection Agency, universities and research institutes, consultancy companies.

Users
Swedish authorities, multiple organizations, municipalities, consultant companies, private companies from different sectors and general public.

Requirements for the services

Short term (DRR)

- In situ weather observations
- Atmospheric remote sensing
- Air quality monitoring and short-term forecast
- Warning systems in case of extreme weather events

[65] http://dataportalen.stockholm.se/dataportalen/

Long term/strategic (urban planning)

- Climatological analysis
- Seasonal predictions
- Climate projections

Section C: Services integration

Short term: multi-hazard early warning and forecasting systems

Long term: urban planning for sustainable development, climate change mitigation and adaptation.

Components integrated (and how)

1) at the level of observational infrastructure
2) at the level of modelling tools
3) at the level of the services/information delivery, communication

A3.27 STUTTGART

Prepared by Rayk.Rinke@stuttgart.de

Section A: General information

Socioeconomic

Stuttgart is the capital of the state of Baden-Wuerttemberg located in southwestern Germany. As the sixth-largest city in Germany, Stuttgart has a population of about 600.000 and is the centre of a densely populated area, the Greater Stuttgart Region, with a population of 2.6 million. Stuttgart covers an area of 207 km^2 thereof 49 percent are settlements. It is one of the greenest cities in Germany. Greenery in the form of vineyards, forests, parks, etc. is prevalent throughout the city. In Stuttgart 39 percent of the surface area has been listed as protected green belt land or nature conservation area. Despite this greenery populated, industrial and commercial areas are densely built-up. The population density is about 5410 person/km^2.

Geographical

Stuttgart's area is characterised by a complex topographic situation with local distinctions.

The city's geographical location and the topographical characteristics have a negative impact on urban climate and cause an intense urban heat island and air quality problems. The city is located in a river valley nested between vineyards and thick woodland. Stuttgart's center is situated close by, but not on the River Neckar. The city area is spread across a variety of hills and valleys. Steep hill slopes surround the city center on three sides. The elevation ranges from 207 m to 549 m asl. The complex terrain has a significant influence on all climatic elements like radiation, air temperature, wind and air pollutant concentrations, resulting in large climatic distinctions within the city area. Stuttgart's overall climate is mild with an average annual air temperature of about 10 °C in the Stuttgart basin (city center) and about 8 °C in the more elevated outskirts situated about 400 m asl. Besides the Upper Rhine Valley, Greater Stuttgart is one of the warmest regions in Germany. A major element of Stuttgart's climate is the light wind, which causes a lack of adequate air exchange. The whole Neckar Valley is known for low wind speeds and very frequent lulls. This is the result of small air pressure differences common to Southern Germany and Stuttgart's sheltered position between the Black Forest, the Swabian Alb, the Schurwald and the Swabian-Franconian Forest. The sheltered position between the surrounding mountain ranges leads to a frequent development of local wind systems, especially at the slopes and in the valleys. In addition, cold air is produced over large green areas in the surrounding and the city area especially at the higher altitudes during the night-time and it generates cold air streams. Even if these winds have no high wind speeds, they play a significant role in the ventilation and local fresh or cold air supply for some city districts.

Governance

A mayor, seven deputy majors (different areas of responsibilities, financial, urban planning and environment, social, law and order, culture, education, administration) and a Council of 60 members *lead by the city government*. The majors are elected every eight years (the deputy majors are elected by the Council); the citizen elects the members of the Council every 5 years.

Section B: Needs for the integrated services

Hazards
Global climate change, heatwaves, episodic raise in air pollution, heavy rain events, thunderstorms (hail), noise pollution, high traffic amount and many hours of traffic jam.

Existing
A dense network of monitoring stations (meteorology and air quality). These measurements are used for warning systems.

The municipality has established (in cooperation with the German weather service and ministries of the state Baden-Württemberg) warning systems for:

1. Heatwaves
2. High air pollutant concentrations

In addition:
The state of Baden-Württemberg and the German weather service have established warning systems for several natural hazards (floods, thunderstorms, storms)

Users
General public, municipality, technical authorities, ministries (of the federal state and nation), health sectors, companies, industry and transportation sectors, press agencies.

Providers
Municipality (office for environmental protection), technical authorities (German weather service, environmental agencies).

Requirements

Observation data (for warning systems, and model validation)
1. air pollutants - especially VOCs and more particle parameters (numbers, UFP, substances – black carbon).
2. vertical profiles (air temperature, humidity, aerosol) - for us very important data related to mixing layer height.
3. wind – flows in street canyons for a better understanding of heat and air pollutant transport and local wind systems (cold air streams).

Weather forecast
1. Forecast (urban scale) with consideration of the influence of cities on the atmospheric fields (triggering of rain events, urban heat island, air pollutants).
2. Emission data with high temporal and spatial resolution for air quality forecasts.
3. better "translation" between atmospheric scientists and urban planners, citizens, politicians, industry.
4. better understanding of the effective measures for improving the urban climate and air quality taking into account the special conditions in specific cities.

Section C: Services integration

The section urban climatology at the office of environmental protection is a part of the municipality of Stuttgart. Colleagues in this section are experts with a scientific background in the sectors meteorology, urban climate, global climate change, air quality control and noise reduction. One important part of the sections work is the transfer of solutions for urban atmospheric problems from science to urban planning, public and political boards. Also part of the sections work is the development and the integration of strategies and action plans to solve problems related to the different sectors.

Short term

Heat warning system Stuttgart:
Since 2005/2006 all federal state in Germany have implemented the heat health warning system of the German Meteorological Service (DWD).

On the local level Stuttgart has developed the HITWIS as the heat warning system including the parts of the urban climate, health care and social welfare. The HITWIS is in line with the official heat health warning system but with a strong focus on specific local needs. Within HITWIS it has been recommended to provide the public with an easily accessible mapping of drinking water dispensers and cooling zones in the city. The heat warning is disseminated via E-mail and the city website.

Feinstaubalarm:
In 2016 Stuttgart introduced the "Feinstaubalarm". This is an alert system to inform citizens from October to April during weather periods with worse dispersion conditions when the PM_{10} concentrations are expected to raise. With the Feinstaubalarm, the city and the state of Baden-Württemberg are appealing to all people in Stuttgart and commuters from the region to use their cars as little as possible in Stuttgart. The alarm will be triggered in the winter season between 15 October and 15 April when the German Meteorological Service (DWD) forecasts particular limitations in atmospheric airflow on at least two consecutive days or if current dust concentrations in the city exceed the European short-term limit value for PM_{10}. The criteria on which the proclamation of the alert are based on several meteorological forecasts like wind speed, rainfall and nightly ground inversion. Currently the switching on alternative mobility forms is voluntary but **s**ince woodstoves contributes also to a higher PM_{10}concentration, Stuttgart introduced a regulation that prohibits the use of woodstoves during the Feinstaubalarm period. With an improved local transport service and numerous benefits from the various mobility partners, switching to green means of transport during the Feinstaubalarm is both straightforward and appealing. With the Feinstaubalarm, everyone can check her or his environmental and mobility patterns. The alarm is disseminated via E-mail, websites, twitter, Facebook, radio stations, newspapers and several display panels in the city. The Feinstaubalarm is part of the clean air action plan in Stuttgart.

Long term

Local global climate protection programme (KLIKS):
Since 1995, the city of Stuttgart has a local global climate protection programme (KLIKS) that define measures for Stuttgart's contribution to protecting global climate. In 2007 a second version was worked out were additional measures are added based on ideas from politics and public. What is special with Stuttgart's Climate Protection Programme is that the traffic sector

and the traditional energy sector are treated equally. With KLIKS strategies to protect the environment in the form of two scenarios (the first scenario with optimum targets, the second as a realistic and practical scheme) including concrete and Stuttgart specific measures to reduce carbon dioxide emissions were developed. These measures were valued on account of the reduction potential, the technical, economic and legal feasibility as well as the profitability and planning interval for their application. On the basis of this programme, Stuttgart's administration section has established a binding action programme, which is not only thought to address to the administration section itself. It is rather addressed to all companies, drivers, homeowners and many others, who are invited to apply the depicted measures wherever they can.

Urban development outline plans:
Urban development outline plans (UDOPs) constitute a non-formalized level of spatial planning. The UDOPs proved to be a valuable and flexible tool to steer urban development within built up areas. It is an essential function of UDOPs in Stuttgart to define the municipality's development and planning goals for those parts of the city that show tendencies of urban change. In practice, the planning intentions for public spaces and streets can be described more precisely than those for private building sites. In Stuttgart UDOPs are used to set up the urban planning strategy for a sustainable future development and restructuring of single city districts weighting all aspects of urban living, economy and nature, environment and climate protection. UDOPs in Stuttgart contain several measures to improve the local climatic situation and to reduce the negative impacts of the urban heat island effect.

Clean air action plan:
Air pollutant measurements along highly polluted road sections in Stuttgart have revealed that the European limit values for the air pollutants particulate matter (PM_{10}) and nitrogen dioxide (NO_2), are exceeded. This is why a clean air action plan needed to be drawn up in Stuttgart. The measures defined therein foremost are to bring short-term improvement, but also measures which have a medium-term and long-term focus are be taken in order to control air pollution sustainable. The first clean air action plan was developed in 2005 (updates in 2010 and 2018). The clean air action plan contains over 40 measures for bettering air quality in the city area, including the improvement of the local public transport, the conversion of public vehicle fleets, infrastructural and road building measures, increased parking fees in the inner city as well as a ban on the combustion of solid fuels and garden waste.

Observational infrastructure:
In total 11 long-term measurement stations (6 meteorology, 5 meteorology and air quality) including also one radio sounding and more than 15 short-term hotspot measurement stations (air quality) provide a wide range of observation data. The municipality, the German weather service, the University Hohenheim or the environmental agency of the state Baden-Württemberg operates the stations.

Most of the observation data are published in the internet.

Modelling tools:
The micro-meteorological models ENVIMET, MISKAM and KLAM21 are used in Stuttgart to simulate the impact of urban structures on meteorological fields (temperature, wind, cold airflows, air pollutants, radiation flux densities, thermo-physiological assessment indices and heat). We use the simulation results to analyze the effectivity of urban planning strategies to improve local urban climate and air quality. The simulations are a basis for the development of clean air action plans and urban development outline plans.

PROKASonline:
PROKASonline is a simplified screening model for the simulation of air pollutants caused by traffic emissions along roads. In Stuttgart, the model is currently used for the online (operational) simulation of $PM_{10}$and NO_2 concentrations based on real traffic data (traffic amount and composition and traffic flow) in the inner-city area. It's planned to extend the model domain to the whole city area. The hourly updates simulation results are published in the Internet for public information[66].

PALM-4U:
PALM-4U (**Pa**rallelized **L**arge-Eddy Simulation **M**odel for Atmospheric and Oceanic Flows) is a new extensive non-hydrostatic urban-scale model. The model is currently in development within the [UC]^2 Urban Climate Under Change project founded by the BMBF. The city of Stuttgart is partner of the project. In future, we will use this new model for our work, to simulate the urban atmospheric conditions with more detail and a higher quality.

Services and information delivery

Climate Atlas Region of Stuttgart
Since planning-related statements refer to specific areas, the use of maps as an informational basis is recommended. Maps in this context are a very significant tool for the planner, and are a meaningful method of communicating information for politicians and the interested public. In the Climate Atlas produced by the Stuttgart Regional Federation for the territory of the federation and the bordering parts of the Middle Neckar Region the concerns of climate and air are incorporated into cartographic representations for land use planning.

The climate atlas consists of two parts. First the regional climatic situation and the role of urban climate and the atmosphere itself in municipal planning are described in words. Also the methods used for the creation of the maps are demonstrated. The second part of the climate atlas comprises cartographic representations in form of basic information-maps, result-maps and analysis-maps. The maps covering the Greater Stuttgart Region with about 3654 sqkm and containing to date spatial information of the urban climatic, bioclimatic and air pollutant concentrations in the Greater Stuttgart Region. The basic information-maps representing maps, which are relevant for quantifying and evaluating the urban climatic situation (e.g. altitude, land use, localization of measurement stations). In addition, cartographic representations of traffic noise are included in the basic information-map part.

In the result-map section of the climate atlas cartographic representations of surface temperatures, annual temperatures, areas for cold air production, amount of cold air production and cold airflows are included. In addition, the result-map part shows maps of wind speed and wind direction in respect to the local topographic situation. The spatial distribution of typical mean temperatures in special episodes, for example on hot days, summer days, days with frost, ice or closed snow cover are also presented in the result-maps. Beside the climatic-maps, also maps depicting the air pollution concentrations are include in the result-map part of the climate atlas.

The analysis-map part summarizes the most important climatic information of the result-maps and gives planning references. In addition, several contents of the result-maps are valuated and connected with each other for estimating to date and future bioclimatic exposure.

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[66] http://www.stadtklima-stuttgart.de/

Recreation areas and highly air-polluted areas with potential of human health risks are also included in the cartographic representation of the analysis-map part.

Information system: Urban Climate 21

The information system Urban Climate 21 provides multitude information to currently and future urban climate, bioclimatic exposure and air pollution in the Greater Region of Stuttgart for planning experts and interested public. The motivation for Urban Climate 21 is the planned redevelopment of a railway area (i.e. "STUTTGART 21") situated in the climatically sensitive city basin, which makes it necessary to provide relevant information on climate and air quality and to assimilate this information into the planning as early as possible. The used methods within the studies range from model calculations and simulations to experiments with a full-scale model in the wind tunnel and to measurements, drilling, mapping and nature observation in the plan area and its surroundings. The studies performed for the project and the analysis of already existing data provided a wealth of information, mainly in digital form. Besides climatic and environmental information. Altogether, the DVD-ROM "Urban climate21" contains 400 area and line datasets, more than 100 point datasets, 420 text files and 1000 photos and pictures. The DVDROM "Urban climate21" is a prominent source about the urban climate of Stuttgart.

Climate Booklet for Urban Development (available in German and English)

The Climate Booklet for Urban Development is a booklet created and updated by colleagues of our office that provides an insight in urban climatic processes. The booklet addresses urban planners and interested persons. Relevant physical and chemical processes are described as simple as possible to provide a basic understanding of the urban atmosphere and the interactions between urban structures (urban conditions) and the urban atmosphere. Urban planners in several German cities use the booklet. An online version is available[67].

Website www.stadtklima-stuttgart.de

The section urban climatology at the office of environmental protection has an own website[68], where information (publications, maps, about the work of the section and the urban climatic situation in Stuttgart are published. Also, basic information about urban climate, global climate change and the observation data from the measurement stations operated by the section are published at the website.

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67 https://www.staedtebauliche-klimafibel.de/
68 www.stadtklima-stuttgart.de

A3.28 TORONTO

Prepared by Felix Vogel/Sylvie Leroyer

Section A: General information

Socioeconomic

The Greater Toronto and Hamilton Area (GTHA) is the most populated place in Canada with circa 7 million inhabitants. The population density in the City of Toronto is over 4300 inhabitants per km2 and around 850 inhabitants per km2 in the GTHA (Statistics Canada 2019). It is an important region of economic activity generating about ¼ of Canada's GDP and also hosts the second largest financial centre in North America. The GTHA continues to experience both population increase and urban sprawl. For example, between 2011 and 2016 the population increased by nearly 6 % and 4.5 % for the metropolitan area and City of Toronto respectively.

Geographical

Geographically the GTHA is located in Southern Ontario and stretches along the Northwestern shore of Lake Ontario (43.7 N 79.4 W, Toronto Midtown). It falls within the lake Simcoe-Rideau ecoregion, which has a mostly mild and moist climate (Crins et al., 2009).

The terrain is generally flat and the air shed is strongly influenced by the lake effect caused by Lake Ontario and the slope between the lakeshore and the hinterland (Mohsin et al., 2010).

Governance

The GTHA consists of 30 municipalities with very limited cross boundary agencies. Besides the role of the individual cities and municipal regions to manage activities at local scale the City of Toronto established 'The Atmospheric Fund' (TAF) as an agency to finance initiatives to combat climate change and improve air quality for the entire GTHA. Furthermore, the provincial government of Ontario and the Federal government have legislative influence.

Section B: Needs for the integrated services

Hazards

The region is characterized by the regular occurrence of complex hydrometeorological conditions with high impact. These have led to recurrent infrastructure damage in the region due to isolated extreme rainfalls or strong winds and lightning, blizzard, problematic thermal stress conditions related to high levels of humidity in summer and cold weather in winter, occurrence of unhealthy air quality episodes, risks of high water levels along stream networks and coastal flooding in the springtime. An additional need for information beyond hazards relates to the plans of the City of Toronto and TAF to reduce greenhouse gas emissions levels by 80% emission in 2050 relative to 1990 levels.

Providers

The TO15 Environment Canada and Climate Change (ECCC) science project provided the opportunity to showcase the capacity of ECCC to implement advanced technical tools and to ensure to provide derived products to end users.

Users

Integrated services for this event were directed towards three major end users: the TO15 organization (regular briefings), the police, and public health organizations (partnership for the extended region surrounding Toronto). The ongoing continuous greenhouse gas monitoring is conducted to provide information to citizens and TAF.

Requirements

Communications between researchers and those involved in operations and services for the different sectors (weather, air quality, UV, nowcasting, emergency preparedness, marine, public health) and for different organizations (ECCC, Health Canada, public health regional and municipal organizations, some universities, and a network of provincial and municipal government partners). ECCC project objectives for the Games were: 1) to issue weather warnings 2) to forecast weather conditions (in particular at the sport venues sites), 3) to provide climatological information, 4) to support critical weather sensitive government services, and 5) to monitor atmospheric conditions (ECCC, 2016*b*). Underlying wider objectives were to provide legacy to the involved partners and the scientific community by developing: 1) monitoring strategies, 2) prediction models, 3) forecast methods, 4) data acquisition processes, and 5) distribution applications.

Section C: Services integration

Observational infrastructure

The observational network was designed to provide environmental conditions at the sport venues sites and to capture meteorological patterns specific to Toronto, such as lake-breeze front tracking (as they can lead to high-impact weather or modify local conditions rapidly, e.g. Mariani et al., 2018), heat stress conditions (monitored by globe temperature sensors, e.g. Herdt et al., 2018) or atmospheric pollution (e.g. using vehicle traverse sampling, Wren et al., 2018). It was composed of fixed networks for weather, lightning, air quality and UV monitoring, mobile measurements with equipped vehicles (Joe et al., 2018). 55 fixed weather stations were deployed at ground-level and rooftop locations using compact, inexpensive, and easily sited weather instrumentation together with high speed cell technology that increased bandwidth and memory capacity. Once installed, data from the mesonet network successfully reached users with 95% 'up time'. The new high-resolution data acquisition system (60 observations per minute) for the weather mesonet was supported by existing operational network protocols to facilitate the use post-Games. Since the TO15 project four continuous greenhouse gas monitoring stations have been integrated and multiple field campaigns to identify CH_4 emission hotspots were conducted.

Modelling tools

The meteorological and air quality forecasting is based on the Global Environmental Multiscale (GEM) Model (Girard et al., 2014) with several configurations used as per the product target and forced with available operational forecasts (the Canadian regional NWP system with 10 km grid spacing, Fillion et al., 2010). The surface-atmosphere interactions are modeled with a tiling approach with ISBA as the land surface scheme. For the TO15, high-resolution forecasts were provided with a pan-Canadian system with 2.5 km grid spacing and updated four times a day (system that became operational afterwards, Milbrandt et al., 2016). The urban-scale forecasting was achieved down to 250 m grid spacing (Leroyer et al., 2018) using in addition the single layer urban canopy scheme TEB (Masson 2000), soil moisture, and temperature daily analysis (Carrera et al., 2015) and lake surface temperature and ice conditions hourly forecasts (Durnford et al., 2018). Operational regional air quality forecasts are provided with the GEM-MACH system (Modelling Air quality and CHemistry) with 10 km grid spacing. In addition high-resolution air quality forecasts for a large region surrounding Toronto were provided down to 2.5 km grid spacing (Stroud et al., 2011). Since the TO15 experiment, this system has been extended to the two most important anthropogenic greenhouse gases. i.e. CO2 and CH4 and includes TEB as well.

Services/information delivery, communication

During Pan American and Parapan American Games: Service integration included on site briefings provided by meteorologist team to the clients, a weather portal for sharing observations, forecasts and alerts to sporting federations and TO15 organization, push-type communication with a mobile application for integrated health ("EC Alert me"), and pull-type communication such as the weather and public health decision web-portal based on the Web-Mapping Services (WMS).

Legacy: After the TO15 experiment the development of a demonstration for applications relevant to greenhouse gas emission studies in the GTHA was started. ECCC and the University of Toronto have successfully built a high-resolution (2.5 x 2.5 km2) sector-specific emission inventory 'SOCE' (Southern Ontario Carbon Emission) for CO2 based on air quality emission maps for the TO15 domain (Pugliese et al., 2018). Furthermore, this inventory was benchmarked against other existing emission estimates by investigating their ability to predict atmospheric concentrations compared to ECCC's continuous CO_2 observations.

A3.29 WELLINGTON

Prepared by David Johnston/Peter Kreft

Socioeconomic

Wellington is located at the south-western tip of the North Island of New Zealand and is the country's capital. The economy is primarily service-based, primarily around government, but also including finance and business services. It is the centre of New Zealand's film and special effects industries, and a hub for information technology and innovation.

Population and area

The Wellington urban area is comprised of four cities:

- Wellington City, on the peninsula between Cook Strait and Wellington Harbour; area 1,388 km^2, population 216,000
- Porirua City, on Porirua Harbour; area 182 km^2, population 57,000
- Lower Hutt City; area 377 km^2, population 106,000
- Upper Hutt City; area 540 km^2, population 44,000

Geography and climate

The cities of Wellington and Porirua are on hills surrounding natural harbours. The cities of Lower Hutt and Upper Hutt are largely on the floor of a large river valley and are also surrounded by hills. Because of the area's situation at the southwestern tip of the North Island and its proximity to Cook Strait (the narrow channel between New Zealand's North and South Islands), it is reasonably windy and has a moderate maritime climate. The area is also subject to earthquakes and has three major fault lines running through it.

Governance

Each of the four cities has its own governance organization, a Council, which is led by an elected Mayor and Councillors. Each Council is responsible for providing many of the services required by its community. The Greater Wellington Region, which includes the cities of Wellington, Porirua, Lower Hutt and Upper Hutt, provides environmental and emergency management, flood protection and land management, provision of regional parks, public transport planning and funding, and metropolitan water supply.

Section B: Needs for the integrated services

Hazards[69]

- Tsunami
- Earthquake
- Wildfire
- Wind storms
- Landslips
- River and flash floods.

Providers

- Seismological information is provided by the Institute for Geological and Nuclear Sciences (GNS Science), a government science department.
- Tsunami Watches and Warnings are provided by New Zealand's Ministry of Civil Defence & Emergency Management (MCDEM), with support from GNS.

[69] https://wellington.govt.nz/about-wellington/emergency-management/hazards

- Fire information is provided by Fire and Emergency New Zealand (FENZ), with support from the National Institute for Water and Atmospheric Research (NIWA), a government science department.
- Weather observing and forecasting is conducted by the Meteorological Service of New Zealand Limited (MetService), New Zealand's National Meteorological Service. MetService provides Outlooks, Watches and Warnings of both broad-scale and local-scale (convective) severe weather.
- Flood warnings are provided by Greater Wellington Regional Council (that is, local government), with support from MetService.

Users

General public, government departments, local government (including disaster management, water supply and stormwater management), energy providers, national and local roading authorities, port authority and shipping companies, airport authority and airlines, industry, media.

Requirements

- Forecasting of rainfall-induced landslips and their consequences (e.g. road closures, evacuations).
- Longer lead times on forecasts of urban flooding during periods of convective rainfall.
- Longer lead times and greater accuracy of forecasts of flow in river and stream catchments of all sizes.
- Inclusion of likely impacts in forecasts and warnings of geophysical hazards
- Forecasts of coastal inundation (storm surge and tsunami) of greater specificity and longer lead time.

Section C: Services integration

Responsibility for the provision of information about natural hazards and their impacts is widely distributed. While there is good collaboration among the providers of hazard information, there is no "single source of truth" on either hazards or their impacts. Further, it is common for managers of weather-related risks to use weather information from multiple sources in their decision-making.

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