Development and calibration of impact-based forecasting system for heat waves in South Korea integrated with Limited-area ENsemble prediction System (LENS)

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Introduction

- In 2018, was the most severe heat wave in Korea (heat stroke: 4458 patients, 48 deaths, Heat Wave Magnitude Index (HWMId) (Russo et al., 2015) = 55.6) (Figure 1)!
- The frequency of severe heat wave events notably increased in last decade (Figure 1).
- This results in increasing demand for more precise and more reliable early warning systems!
- Main goal: "develop and calibrate a heat wave impact-based warning system, which will consider other important factors than air temperature and likelihood of events."

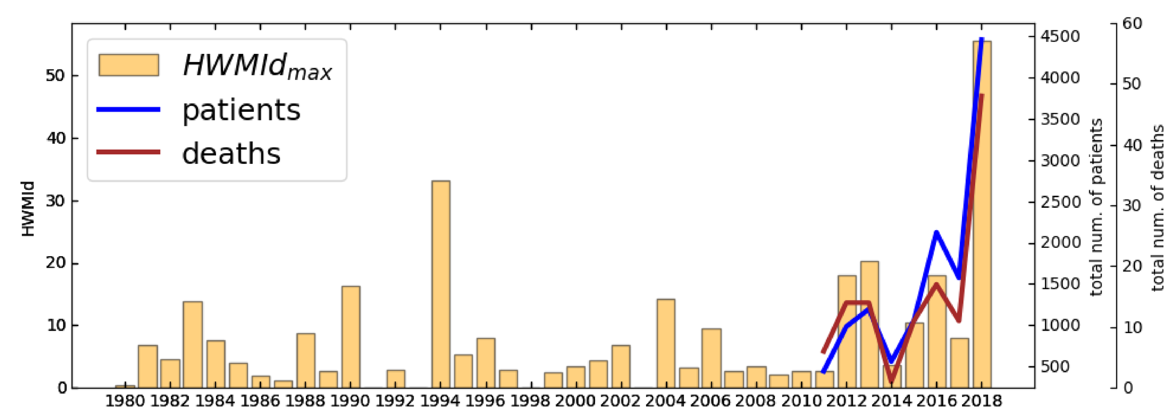


Figure 1: HWMId and heat related mortality and morbidity

Ensemble Prediction System

- We use data from Limited-area ENsemble prediction System (LENS) to construct probabilistic forecasts of thermal inidices.

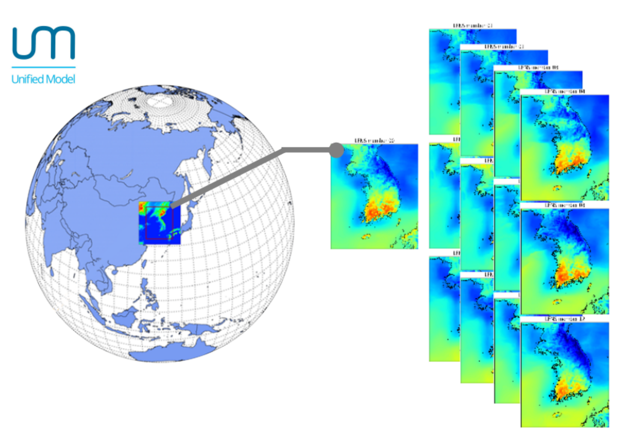


Figure 2: LENS specification: The LENS is based on Unified Model (Met Office) which produces 13 ensemble members downscales and forced by global EPS. The grid consists of 460 x 482 x 70 grid points with horizontal spatial resolution 3km x 3km. The LENS provides 72 hours forecast twice a day

- Predicted thermal indices derived from LENS hourly data:
- – daily maximum Air Temperature (T_{max})
- – daily maximum Perceived Temperature (PT_{max}) (Staiger et al., 2012)

$$PMV = \alpha\{M - W - (h'.(t_{sk} - et*) + E_{comf} + E_{diff}) + (C_{res} + E_{res})\} \quad (1)$$

- – where PMV is predicted mean vote, the M stands for metabolic rate, W is mechanical work expended from M, h' is the latent heat transfer coefficient, t_{sk} is mean skin temperature, $et*$ is effective temperature, E_{comf} is sweat under comfort condition, E_{diff} is diffusion of water from skin, C_{res} and E_{res} are sensible and latent heat, respectively.
- – For heat load the PT is estimated as $PT = 16.826 + 6.183PMV$.
- – The PMV was parametrized according Klima-Michel model and then computed using meteorological data form LENS.

Methodology

- **System Development**

1. **Bias correction**

- – The LENS underestimates both daily T_{max} and daily PT_{max}. We removed the systematic error using decaying averaging technique:

$$d_{t+1} = (1-w)d_t + w(F-O)_t \quad (2)$$

$$F_{t+1} = f_{t+1} - d_{t+1} \quad (3)$$

- – In order to apply the bias correction on whole domain, the d_{t+1} was interpolated using Inverse Distance Weighting (IDW).

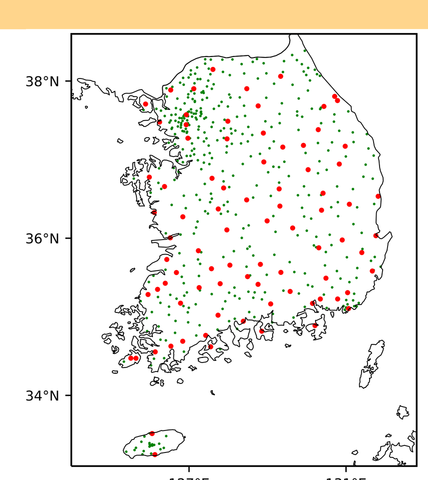


Figure 3: Location of stations used for bias correction. The green marks are the AWS and red marks the ASOS observation points.

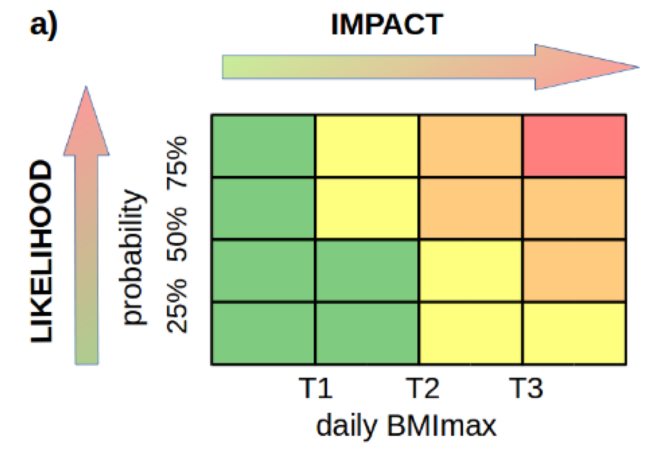
Methodology

2. **Constructing probabilistic forecast for threshold $T1, T2, T3$ from corrected ensemble forecast**

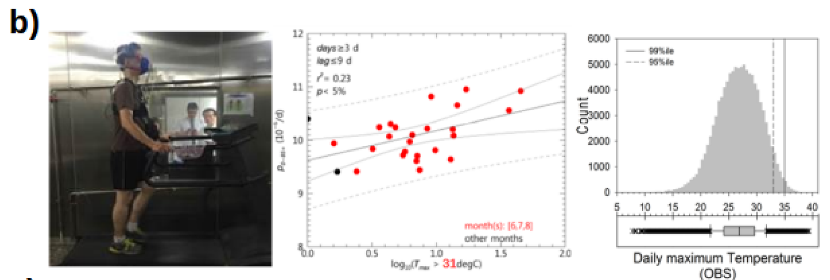
- – We used the probability density functions of normal distribution.

3. **Application and configuration of risk matrix for warning decision**

a)



b)



c)

Thermal index	T1	T2	T3
T_{max}	31.0	33.0	35
PT_{max} (spat. mean)	39.2	43.0	46.5

Figure 4: a) risk matrix b) threshold decision by physiological exams, risk assessment, climatological studies c) decision about $T1, T2, T3$ thresholds

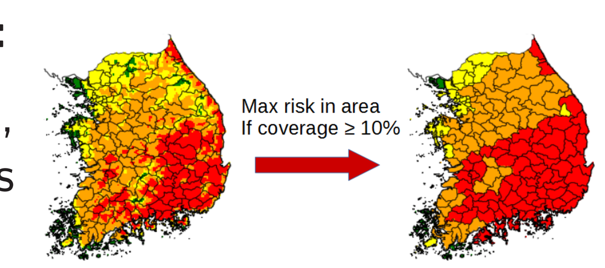
4. **Conversion of grid-point alerts to areal alerts for 165 regions**

5. **Optimization of decaying averaging weighting factor w**

- – by minimizing of $RMSE$ of ensemble mean, CRPS and correlation

4. **Final Verification of developed system:**

- – Reliability diagrams of probilistic forecasts, Spearman's correlation between risk levels and morbidity



Results: Bias-correction

- Optimization of deacying averaging factor w

w	0.10	0.11	0.12	0.13	0.14	0.15	0.16	raw
RMSE	1.516	**1.514**	**1.514**	**1.514**	1.515	1.516	1.518	2.621
R	**0.894**	**0.894**	**0.894**	**0.894**	**0.894**	**0.894**	**0.894**	0.887
CRPS	0.905	**0.903**	**0.903**	**0.903**	**0.903**	0.904	0.904	1.864

Table 1: Comparison of daily T_{max} forecast skills using different decay factor. The most optimal results are indicated by bold text and final decision by green color.

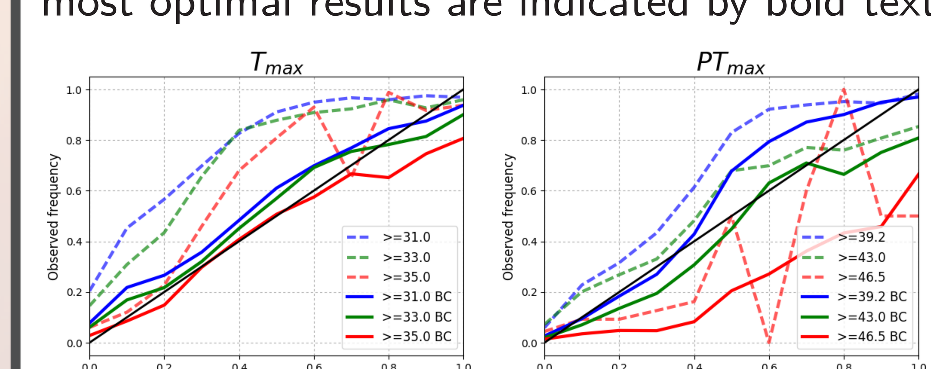


Figure 5: Reliability diagrams of probabilistic forecasts of daily T_{max} (left) and PT_{max} (right) threshold exceedence for raw (dash line) and bias-corrected (solid line) ensemble forecast

- Probabilistic forecast of T_{max} are more reliable than PT_{max}.

Results: Impact-based forecasts

- The developed system generates risk maps twice a day for 3 days ahead.
- The issued risk alerts in summer 2018 were compared with number of heat-related patients at emergency departments.

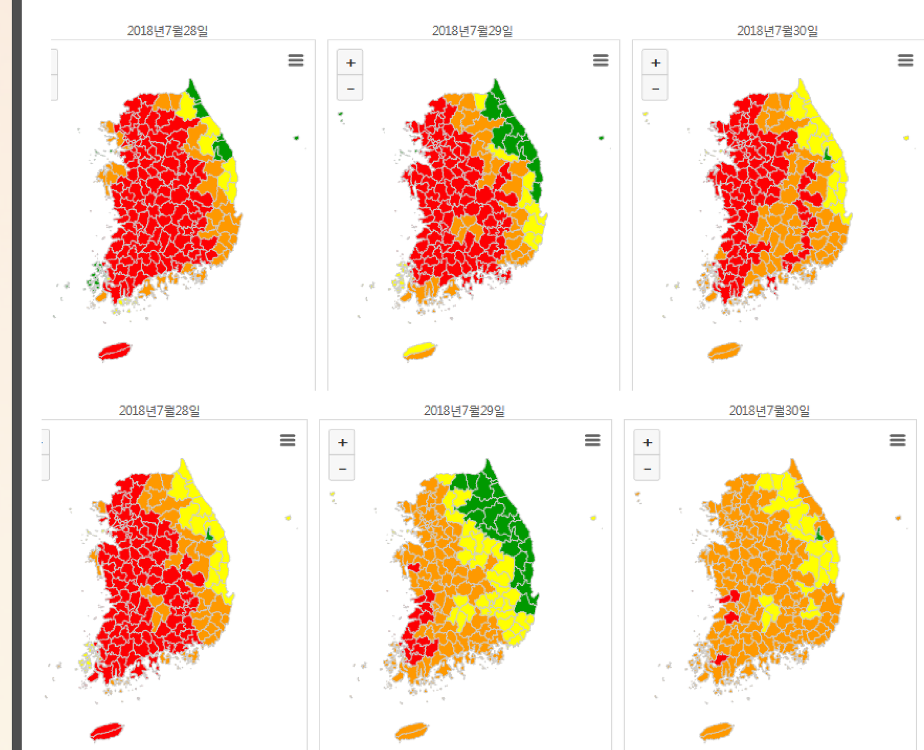


Figure 6: Examples of 3 day impact-based forecast issued at 2018.07.28 00:00 based on T_{max} (up) and PT_{max} (down)

Region	T_{max}	PT_{max}
Seoul	0.817	0.791
Busan	0.777	0.818
Daegu	0.695	0.639
Daejon	0.492	0.439
Gwangju	0.800	0.692
Ulsan	0.777	0.747
Incheon	0.819	0.801

Table 2: Correlation between heat morbidity and risk levels

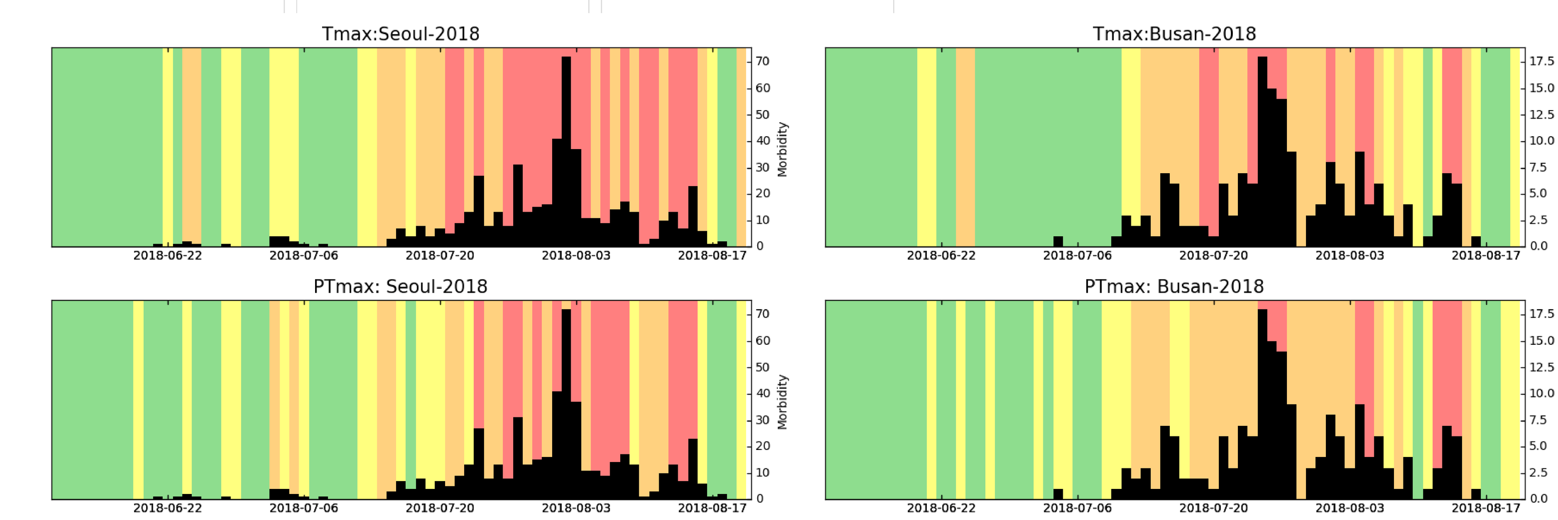


Figure 7: Time-series of heat morbidity (black) and issued risk alerts (color) in Seoul (left) and Busan (right) in 2018 based on $Tmax$ (up) and PT_{max} (down).

Conclusions

- Bias-correction by decaying averaging method improved reliability of both, probabilistic forecasts of daily T_{max} and PT_{max} .
- Issued alerts are well correlated with heat-storke morbidity. However, based on PT_{max} approach, the system tends to decrease alert levels.
- Potential improvement is in reconfiguration of risk matrix thresholds.

References

Russo, S., J. Sillmann, and E. M. Fischer 2015. Top ten european heatwaves since 1950 and their occurrence in the coming decades. *Environmental Research Letters*, 10(12):124003.

Staiger, H., G. Laschewski, and A. Grätz 2012. The perceived temperature–a versatile index for the assessment of the human thermal environment. part a: scientific basics. *International journal of biometeorology*, 56(1):165–176.

Acknowledgements

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