

# Is heat stress really a human health problem in hot countries? Heat acclimatization and vulnerabilities of people living in the Sahel. The case of Senegal



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## OBJECTIVES

This study addressed three issues:

- Are Sahelian populations less vulnerable to extreme heat?
- Does the effect of extreme heat on health vary with intensity and duration of exposure?
- Are the impacts of global warming and extreme events (HW) expressed differently in tropical areas?

## ABSTRACT

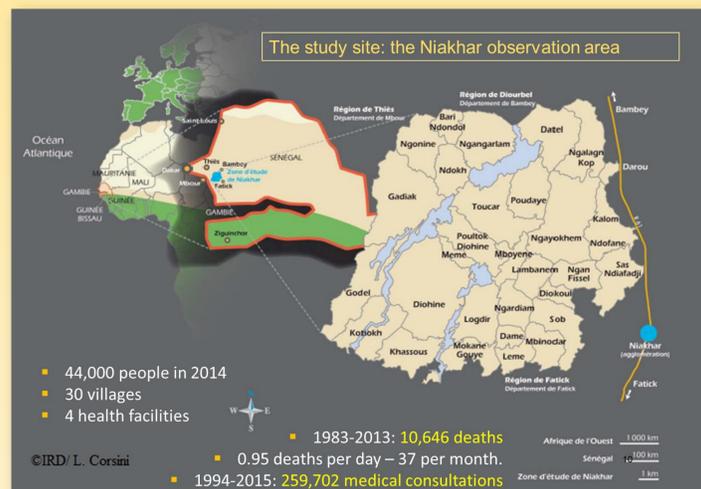
This study analysed the heat-related impact on mortality and morbidity for a rural population in Senegal. To evaluate the effect of the duration of heat exposure, we measured heat by the average apparent temperature (with effect of humidity) in a period preceding the event (medical visit, death) ranging from one, five, and ten to thirty days. We investigated the temperature-mortality or -morbidity relationship by vulnerable groups (children and elderly people) and by temperature type (daily minimum, maximum and average). Finally, we used three types of models: GLM, GAM and ARIMAX.

We found that, between 1984 and 2014, high heat resulted in an excess of mortality and medical diagnosed morbidity, especially among children and elderly people.

- Under-fives health is affected by high heat at a lower temperature threshold and after a shorter exposure than for the elderly.
- The health of the elderly (aged 55 and over) is mostly impaired by extreme heat and are therefore more vulnerable to heat waves. Extreme heat impacts the mortality risk of elderly people immediately (the same day) and after a long exposure. Finally, people over 55 are much more sensitive to humid heat than dry heat.

High heat affects bodies weakened by diseases, particularly cardiorespiratory diseases, and modifies the ecology of infectious diseases.

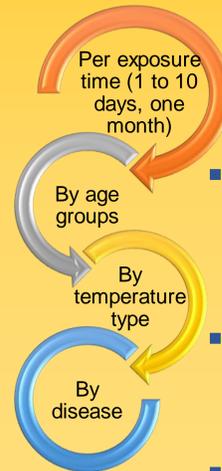
- The risk of visiting a health facility for cardiovascular problems increases with extreme heat and duration of exposure to this extreme heat.
- Medical visits at a health facility for malaria is all the more frequent than the number of very hot nights preceding the visit is high.



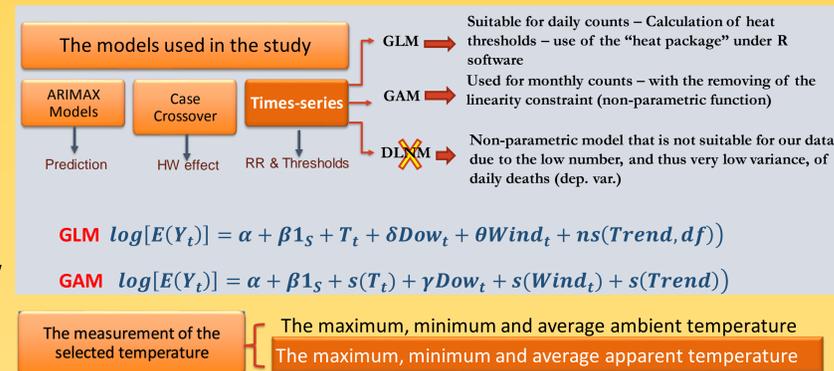
## MATERIAL AND METHODS

Data used are of three types:

- The GSOD or Global Surface Summary of the Day data provided by the US National Oceanic and Atmospheric Administration (NOAA) – Kaolack **weather dataset** (1984 – 2014)
- Mortality data** from the Health and Demographic Surveillance System in Niakhar (1984-2014)
- Morbidity data** from medical consultations in four health facilities in the Niakhar area (1994 – 2015)



- The implementation of standard analysis models faced incomplete statistical series based on a small number of observations (i.e. deaths on a daily count).
- The methodological challenge of the project was **to detect and model a weak signal**: very low variance and low signal-to-noise ratio.
- This constraint does not concern morbidity data.



Robert G. Steadman (1979, 1984):  
 $AT = -2,653 + 0,994 * T_a + 0,0153 * T_d^2$

## IMPORTANT RESULTS

Studies have shown that the temperature optimum corresponding to the minimum mortality rate (threshold) varies across different latitudes. We found that the apparent temperature threshold in rural Senegal is higher than in Europe ( $23^\circ C < T_x < 35^\circ C$  according to the European cities, Baccini et al., 2008), indicating that studied communities are sensitive to heat but at higher apparent temperatures.

Our results provide evidence of an effect of intensity and duration of exposure of heat on mortality and morbidity. Between 1984 and 2014:

- The mortality risk increased beyond the threshold occurring at  $37^\circ C$  maximum daily apparent temperature. Deaths increased by 1.3% per additional degree. During the dry and warm season, the threshold occurred at the daily optimal temperature of  $44^\circ C$  and the rate of increase in mortality is 1.08% per additional degree.
- Over a month, a 10% increase in the average apparent temperature causes a 9.3% increase in the number of deaths in the same month.
- The probability of visiting a health facility increased beyond the  $36^\circ C$  threshold and medical consultations increased by 7.4% per degree above  $36^\circ C$ .

After 2008, medical visits increased faster (12.4%) per added degree above  $37^\circ C$  than before 2008 (5.8%).

temperature type	Age groups	Entire Year (12 months)				
		GLM+NS (daily counting)			GAM (Monthly counting)	
		Thres. in °C	RR in %	DDL	Visual thres.	Shape
Maximum apparent temperature	Overall population	36,8	1,29	10	36,5	
	Children under the age of five	35,0	1,20	10	---	
	Adults (15-54 years)	---	---	---	39,0	
Average apparent temperature	Elderly persons (over 55 years)	44,0	11,67	10	40,0	
	Overall population	30,2	3,67	8	30,0	
	Children under the age of five	30,0	2,67	10	29,0	
Minimum apparent temperature	Adults (15-54 years)	---	---	---	34,0	
	Elderly persons (over 55 years)	30,6	1,42	10	32,0	
	Overall population	---	---	---	---	
Minimum apparent temperature	Children under the age of five	---	---	---	24,0	
	Adults (15-54 years)	---	---	---	---	
	Elderly persons (over 55 years)	20,8	1,13	8	---	

### Children

- Children are very sensitive to short exposure to high  $T^*$  max. They react very quickly to high heat, probably due to the increased risk of dehydration that may be associated with diarrhea. Beyond the  $35^\circ C$  threshold, the risk of death increases by 1.2% per additional  $^\circ C$ .
- Children are sensitive to long exposure to high night heat (beyond  $24^\circ C$ ). This result suggests a risk associated with the transmission of malaria. Anopheles breed quicker and are more aggressive as nighttime heat rises. In addition, the use of an impregnated mosquito net decreases with night heat.

### Elderly people

- Elderly people are the most vulnerable to high heat. The mortality risk increases by 12% per additional  $^\circ C$  above the threshold of  $44^\circ C$  of apparent  $T^*$  max.
- Elderly people are sensitive to a long exposure of a high  $T^*$  max. They are probably vulnerable to heat accumulation, which weakens the body (decompensation effect).
- Nights beyond  $21^\circ C$  increase the mortality risk by 1.13%, probably due to a lack of physiological recovery from sustained period of high nighttime heat.

## CONCLUSION

- This research shows that in a rural area in Senegal:
  - People, like everywhere else, can be affected by direct heat-related illnesses (heat strokes) and mostly through other various biological mechanisms.
  - Sustained periods of hot weather probably explain, as much as extreme events (HW), the excess mortality associated with high temperature.
  - The communities studied are affected by both extreme heat and its accumulation effect (long exposure producing decompensation among adults).
  - Very high heat (with or without humidity) affects bodies weakened by cardiovascular and respiratory diseases and modifies the ecology of infectious disease vectors.
  - Without a thermal improvement of the habitat conditions, heat related health impacts should be higher as global warming, urbanization and elderly people increase.

## ADDITIONAL INFORMATION

The risk of visiting a health facility for cardiovascular problems and malaria increases with extreme heat and duration of exposure to this extreme heat.

- Consultations for cardiovascular problems increase: i) by 3,7% per additional degree for each day above a  $42^\circ C$  threshold; ii) by 4,5% per additional degree for 5 continuous days above a  $41^\circ C$  average threshold; and iii) by 23% per additional degree for 10 continuous days above a  $42^\circ C$  average threshold.
- When temperature reaches a  $32^\circ C$  average for the five nights before the medical visit, the probability of visiting a health facility for malaria increases by 22% per additional degree above the  $32^\circ C$  threshold for 5-night period.
- Survival of under-fives is also threatened by long-term exposure to nighttime heat, above an average monthly threshold of  $24^\circ C$ .
- These findings suggest an increased risk of malaria transmission during very hot nights. Anopheles vectors breed faster and are more aggressive as nighttime heat rises. In addition, the use of the mosquito net decreases during extremely hot nights.

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