

Heat exposure and socio-economic vulnerability as synergistic factors in heat-wave-related mortality

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Objective

Ecological analysis of the spatial heterogeneity of the August 2003 heat-wave-related mortality in France.

- Use a deprivation index (socio-economic disparities)
- Build a Heat exposure index (HEAT)
- HEAT variations with deprivation (exposure differentials)
- Interactions between HEAT and deprivation (vulnerability to exposure differentials)

Socioeconomic and exposure differentials relative to rural/urban gradient:

⇒ Specific analysis in each Urban Unit Categories (Rural, Quasi-rural, Quasi-Urban, Urban, Paris-and-suburbs)

Mortality

INSERM-CépiDc

Age: 55 years or more

Location: Canton of residence

Population

INSEE - Demography Department

Socio-economic data

Deprivation index (FDep99):

Principal Component Analysis of: Income, %Blue collar workers, %Unemployed, %High-school graduates

=> First component

Meteorological data

Daily minimum (Tn) and maximum (Tx) temperatures

Mean daily ozone concentration (O₃)

("MOCAGE" Météo France chemistry-transport model)

10-km step grid (4145 points)

Methods – Heat Exposure Index

Building the index of the spatial heterogeneity of heat exposure

Poisson model of the Heat-Wave Mortality Ratio (O/E):

$$\text{Log}[E(O_i)] = \text{Log}(E_i) + \alpha + \sum_k \beta_k \cdot \text{MI}_{k,i}$$

- Where:
- O_i : Observed number of deaths (from August 3rd to 15th, 2003)
 - E_i : Expected number of deaths (mean of July-August, 2000-2002)
 - MI : meteorological indicator
 - "i" : canton

Heat exposure index (HEAT) expressed in the mortality ratio unit:

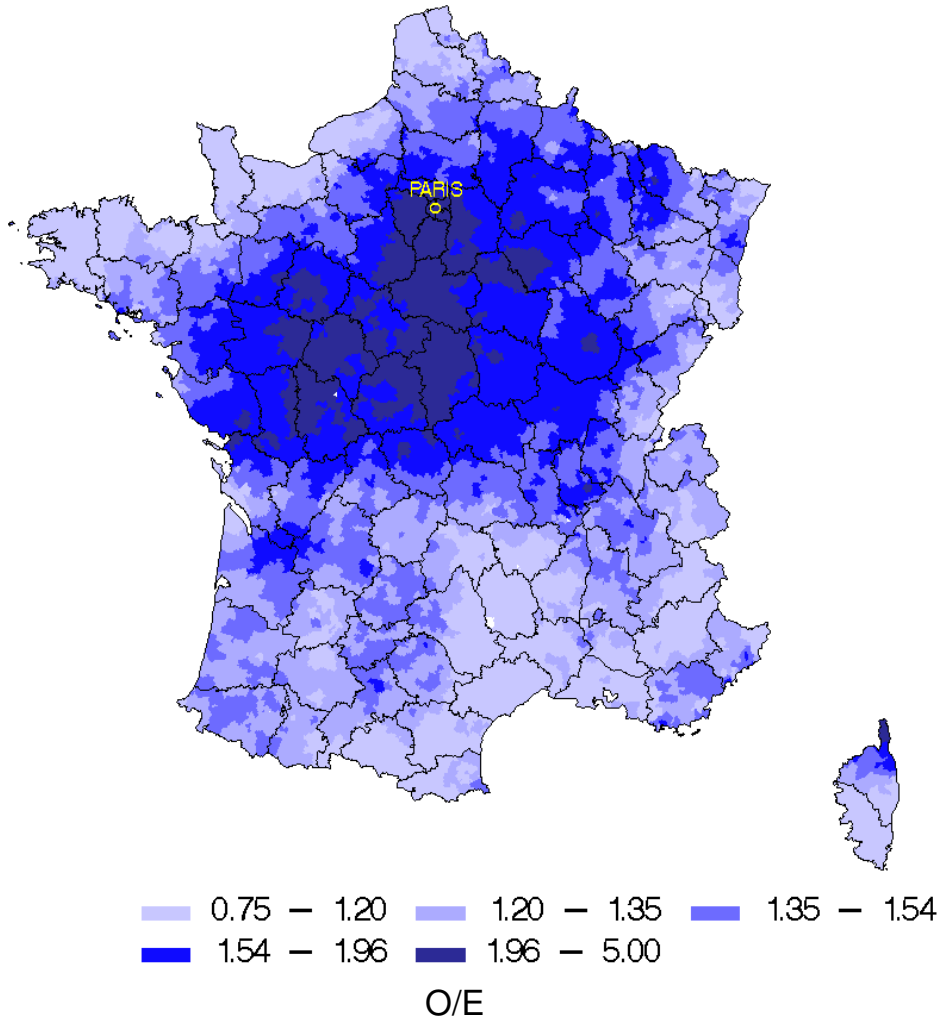
$$\text{HEAT}_i = \exp\left(\hat{\alpha} + \sum_{k \in S} \hat{\beta}_k \cdot \text{MI}_{k,i}\right)$$

S: Meteorological indicators from three subsets:

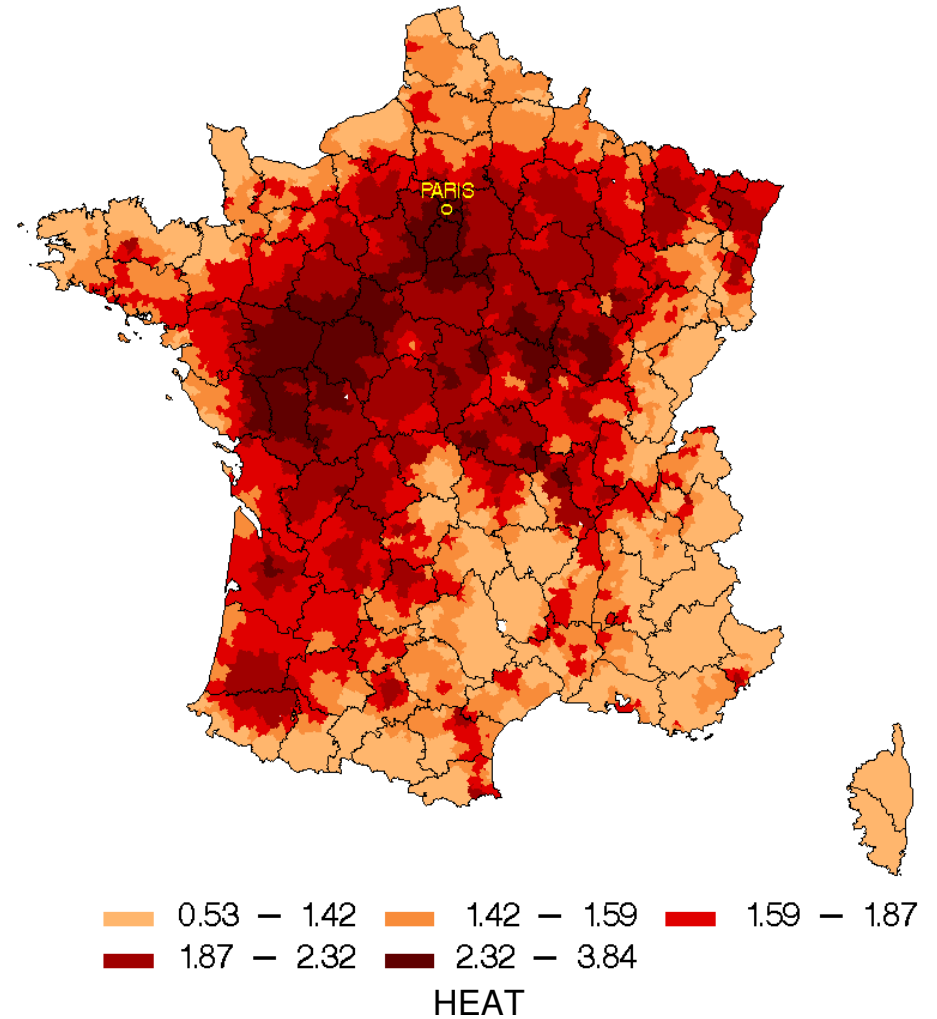
- **Basical** (Fouillet et al., 2006): Tx, Tn, Cumulative Tx, Moving average T, Interactions
- **Relative**: $\text{Tx} - \text{Tx}_{\text{ref}}$, $\text{Tn} - \text{Tn}_{\text{ref}}$, where T_{ref} = mean of July-August, 2000-2002
- **Ozone**: O_3 , Interactions

Results – France – August 3rd to 15th, 2003

Smoothed Heat-Wave Mortality ratio (BYM model)

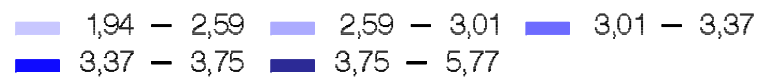
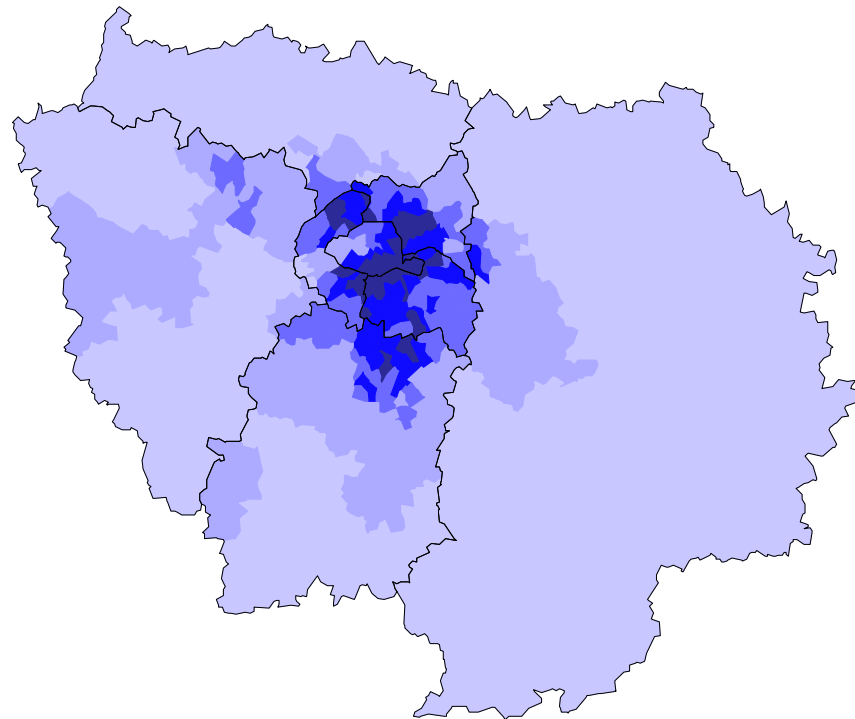


Heat Exposure Index (HEAT)



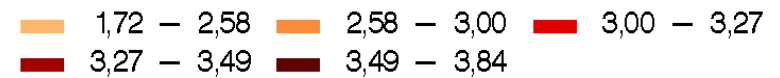
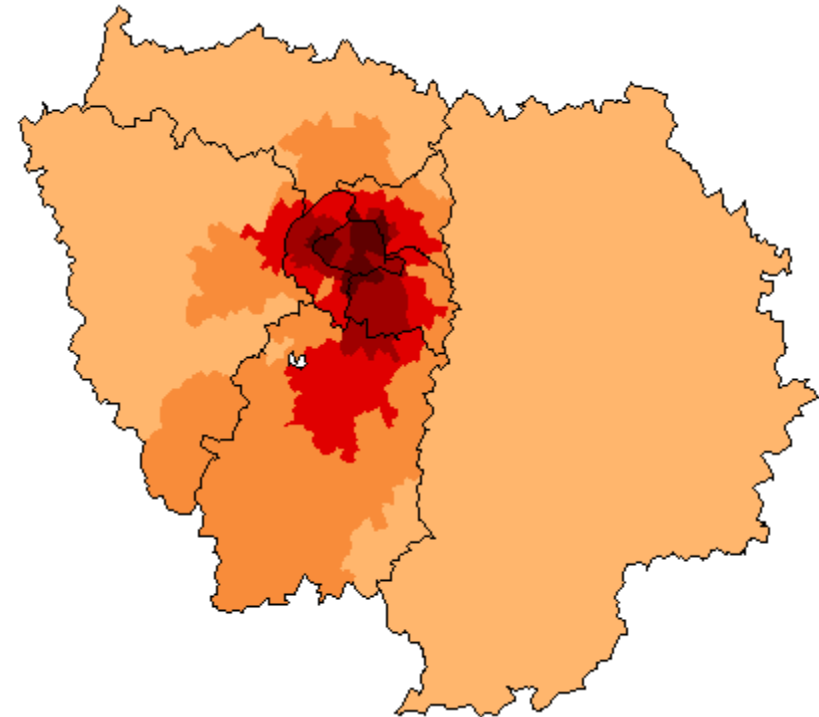
Results – Paris region – August 3rd to 15th, 2003

Smoothed Heat-Wave Mortality ratio (BYM model)



O/E

Heat Exposure Index (HEI)



HEAT

Results – Exposure differentials

Urban Unit Categories	Rural	Quasi-rural	Quasi-urban	Urban	Paris-and-suburbs
Population 55 yrs and +	3 963 675	1 761 097	3 489 292	4 478 146	2 169 228
FDep99 D5-D1 (100 for Paris)	40%	51%	48%	62%	100%
Average HEAT	1.68	1.63	1.63	1.69	3.12
Adjusted HEAT¹ [CI _{95%}]	1.00 [Ref.]	0.99 [0.97; 1.01]	1.00 [0.99; 1.02]	1.11 [1.09; 1.13]	1.32 [1.26; 1.38]
HEAT_{D5} / HEAT_{D1}¹ [CI _{95%}]	1.03 [1.00; 1.06]	0.99 [0.94; 1.04]	1.02 [0.99; 1.06]	0.91 [0.88; 0.94]	0.90 [0.86; 0.93]

¹: Calculated by analysis of variance of log HEAT adjusted for the 22 Regions

²: Calculated by multiplying the linear association between deprivation and log HEAT by the difference between the average deprivation in the first and fifth quintiles, adjusted for the 22 Regions

D5 : The most deprived quintile ; D1 : The less deprived quintile

Results – Vulnerability to exposure differentials

Variation in the age- and gender-standardized excess mortality rate between the first (D1) and the fifth (D5) quintile of deprivation = $(RmO_{D5} - RmE_{D5}) - (RmO_{D1} - RmE_{D1})$ (deaths / 100 000 / day)

Heat exposure index quintiles	Urban Unit Categories				
	Rural	Quasi-rural	Quasi-urban	Urban	Paris-and-suburbs
HEAT 1 st quintile	-0.1 [-2.3; 2.0]	2.3 [-1.1; 5.7]	2.5 [0.0; 5.1]	-0.4 [-2.3; 1.5]	1.7 [-5.9; 9.2]
HEAT 2 nd quintile	-1.1 [-3.3; 1.1]	0.2 [-3.3; 3.7]	1.8 [-0.4; 4.0]	2.0 [-1.4; 5.3]	-1.1 [-5.6; 3.4]
HEAT 3 rd quintile	0.3 [-2.2; 2.9]	-0.7 [-4.1; 2.8]	-0.2 [-2.6; 2.1]	-0.8 [-3.0; 1.3]	9.6 [4.2; 15.0]
HEAT 4 th quintile	-1.1 [-3.6; 1.4]	2.0 [-2.6; 6.6]	1.4 [-0.8; 3.7]	1.8 [-0.7; 4.4]	10.6 [6.6; 14.6]
HEAT 5 th quintile	0.1 [-2.3; 2.6]	-1.8 [-5.2; 1.6]	2.1 [-1.0; 5.2]	5.3 [1.2; 9.4]	10.3 [6.4; 14.2]

RmO: Observed mortality rate

RmE: Expected mortality rate

Discussion

Summary

- Higher heat exposure in urban areas (Urban Heat Island Effect)
- Higher heat exposure in less deprived cantons, in urban areas
- Higher vulnerability of the most deprived cantons in Paris-and-suburbs, where:
 - Exposure and excess mortality were the highest
 - Are living the less deprived populations in France, less vulnerable
 - Spatial heterogeneity of deprivation is the highest

However

A marked increase in mortality related to heat wave exposure for every urban unit categories and deprivation levels

No subpart of the population must be considered without risk

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Results – Vulnerability to exposure differentials

Urban Unit Categories	Rural	Quasi-rural	Quasi-urban	Urban	Paris-and-suburbs
FDep99 D5-D1 (100 for Paris)	40%	51%	48%	62%	100%
Ratio of the association HEAT – O/E¹ between D5 and D1 [95% CI]	1.01 [0.88; 1.16]	0.97 [0.81; 1.17]	1.18* [1.02; 1.36]	0.99 [0.86; 1.15]	1.16** [1.08; 1.24]

¹: Derived from a Poisson model of O/E with over-dispersion
D5 : The most deprived quintile ; D1 : The less deprived quintile

* : $p < 0,05$; ** : $p < 0,0001$

Discussion

- Similar results by taking into account the spatial autocorrelation (BYM model)
- Subjects localized by their residence: possible erroneous exposure estimation, specially in this vacation period

However: 96% of the deaths occurred in the Region of residence

- Significant Interaction in Paris-and-Suburbs maybe due to a greater homogeneity and comparability of social and meteorological situations

However: no such association in other urban centres with a population of 500,000 or more