Spatial heterogeneity of the 1rst wave of COVID-19 in France: a nationwide geo-epidemiological study

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https://www.thelancet.com/journals/lanpub/article/PIIS2468-2667(21)00006-2/fulltext

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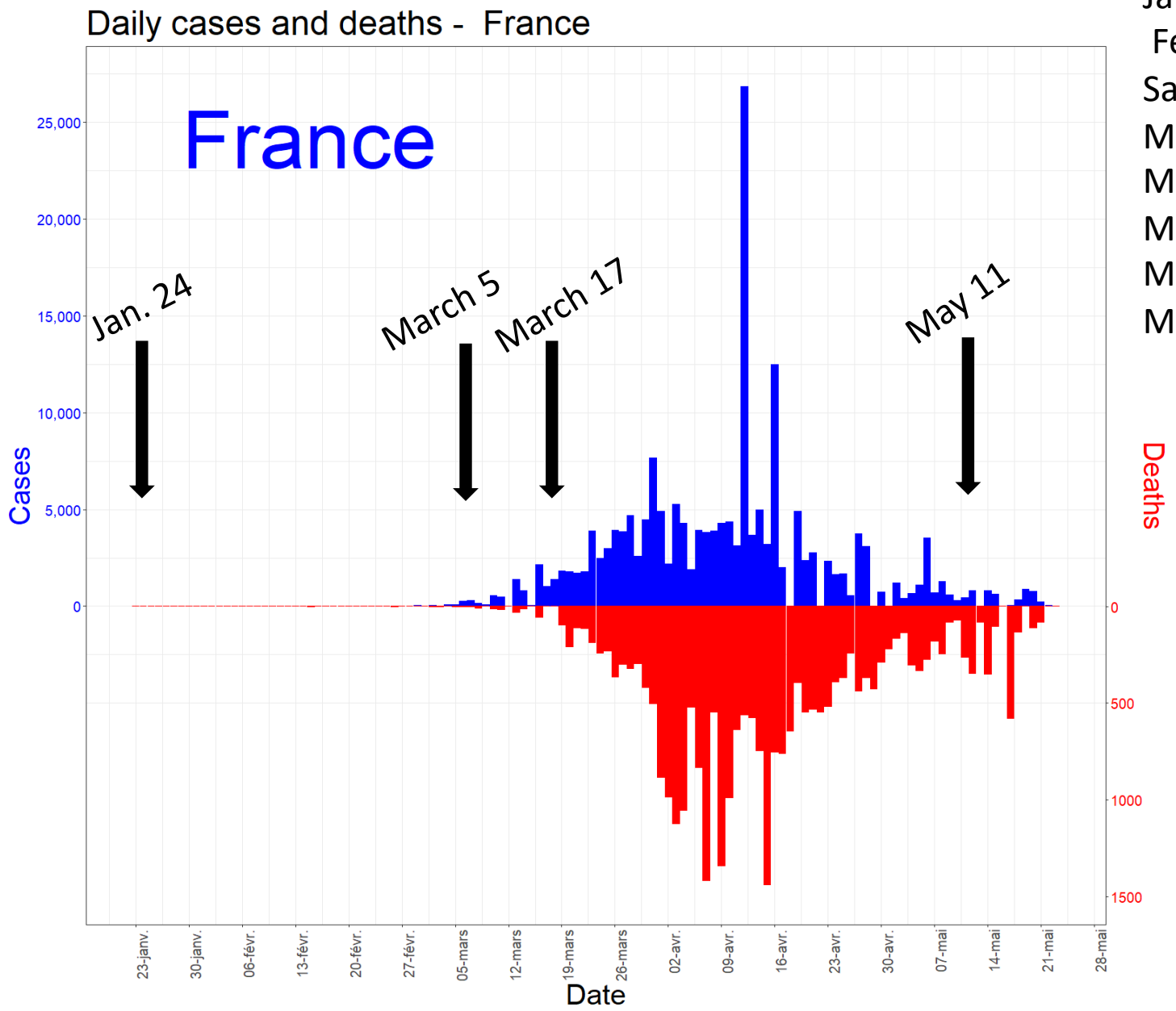
http://sesstim.univ-amu.fr/

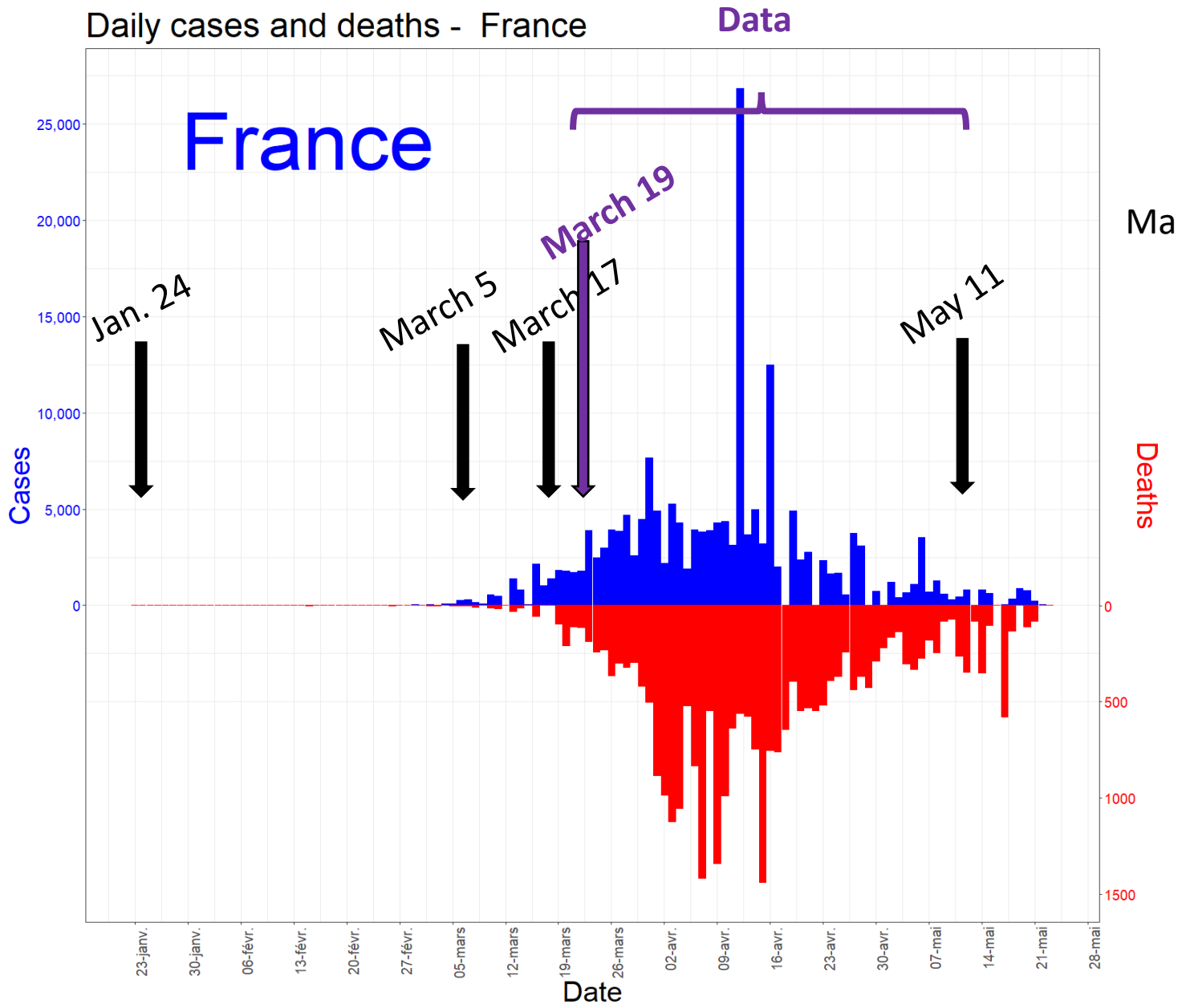
First wave in France



Jan 24 : 1rst 3 cases (Bordeaux, Paris)
Feb : 4 clusters (Haut-Rhin, Oise, Haute-Savoie, Morbihan)
March 5 : Mitigation measures
March 15 : Municipal elections
March 17 : Lockdown
March 31 : peak 7578 new confirmed cases
May 11 : Lockdown end

January to May :
272 cases /100 000 inhab.
(182 036 cases)
42 deaths /100 000 inhab.
(28 218 deaths)

First wave in France



March 19 : Hospital Information System

Aim

1/ Assessing spatial heterogeneity of 3 outcomes

- Incidence rate (cumulative number of **in-hospital** COVID-19 cases / 100 000 inhab.
- Mortality rate (cumulative number of **in-hospital** COVID-19 deaths / 100 000 inhab.
- Case Fatality Rate (cumulative number of **in-hospital** deaths / **in-hospital** cases)

2/ Assessing factors associated with the 3 outcomes

Method (1/3)

1/ Assessing spatial heterogeneity of 3 outcomes

- Maps & Moran I (global indicator of spatial clustering / Queen contiguity matrix)

Tiefelsdorf M. The saddlepoint approximation of Moran's I's and local Moran's Ii's reference distributions and their numerical evaluation. Geogr Anal 2002; 34: 187–206.

2/ Assessing factors associated with the 3 outcomes

- Lockdown / local epidemic onset = *March 17 – 1^{rst} death date*
- Age and sex
- Baseline population health and heath-care services
- Economic indicators
- Urbanisation
- Climate

Method (2/3)

Dimension reduction (*=> colinearity & curse of dimentionality*)

=> Principal Component Analysis + Hierarchical Ascendant Classification

Lê S, Josse J, Husson F. FactoMineR: an R package for multivariate analysis. J Stat Softw 2008; 25: 1–18.

Regressive approach : Generalized Additive Model (S. Wood)

- Negative – Binomial distribution (*=> overdispersion*)
- Log(Population) as offset (*=> standardized ratio*)
- Spline function (*=> non-linear relationships*)
- Gaussian process smoother (*=> spatial autocorrelation*)

covariance function : power-exponential model $\exp(-\left|\frac{d}{r}\right|^{k})$

François Bachoc. Parametric estimation of covariance function in Gaussian-process based Kriging models. Application to uncertainty quantification for computer experiments. Statistics [math.ST]. Université Paris-Diderot - Paris VII, 2013. English. tel-00881002

Wood S. Generalized additive models: an introduction with R. 2006.

Method (3/3)

Validation

- Classification approach

  ⇒ Data simulation

  ⇒ Centroid method for covariate space size reduction

  Gaudart et al. https://www.biorxiv.org/content/10.1101/420943v1

- Sensitivity analysis by substitution *(=> ecological bias*)

  ⇒ Emergency allergies

  ⇒ In-hospital allergies among patients at emergency departments

  ⇒ In-hospital allergies among emergency allergies

Results (1/5)

100 988 H-cases (ICU 16 597)
H-incidences :
19.4 to 489.5 cases / 100 000 inhab.

Moran I = 0.68 (p<0.0001)

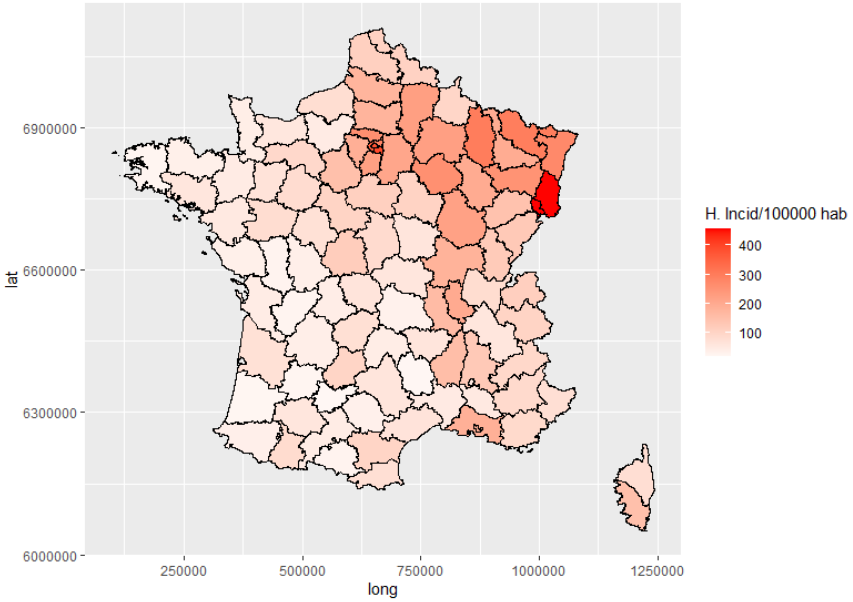
17 062 H-deaths
H-mortality :
1 to 119,2 deaths / 100 000 inhab.

Moran I = 0.68 (p<0.0001)

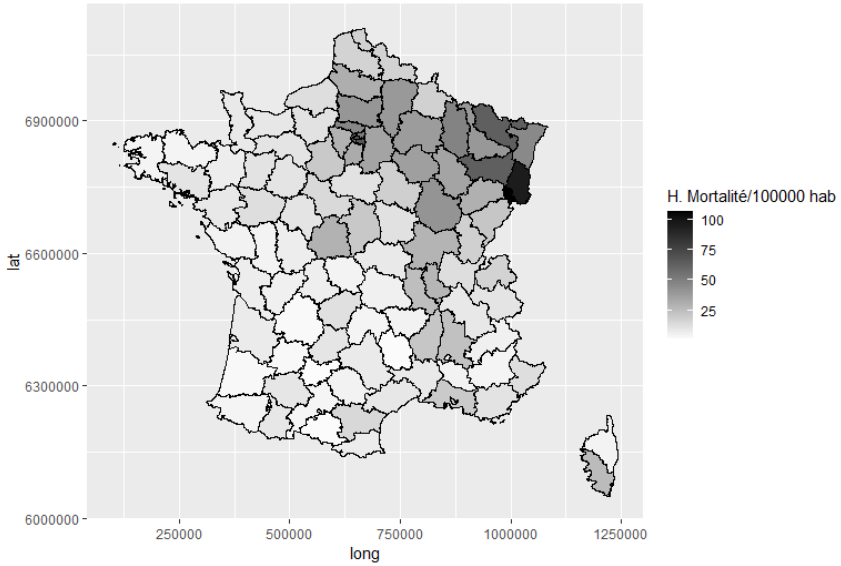
H-CFR :
4.8 to 26.2 % H-cases

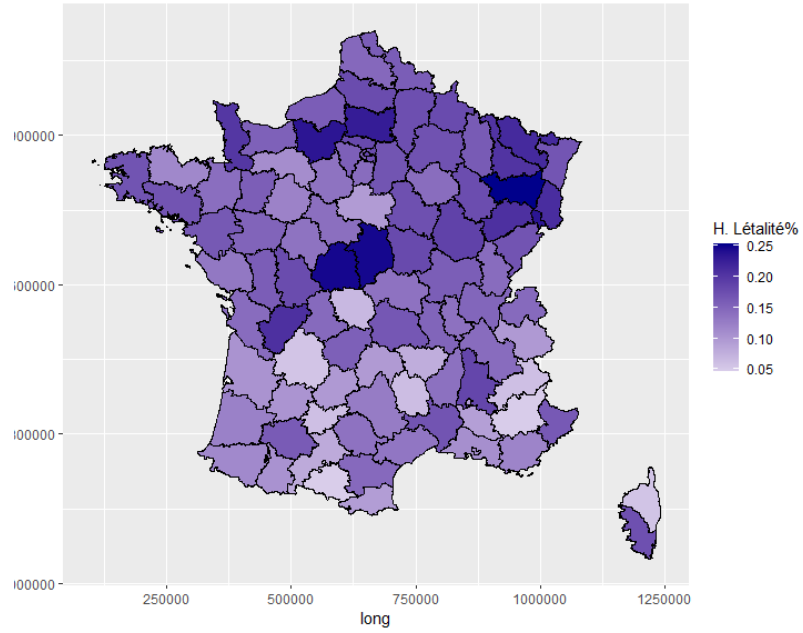
Moran I = 0.32 (p<0.0001)

Paris : 397.6 cases / 100 000 inhab
B-d-R : 200.5 cases / 100 000



Paris : 74.9 cases / 100 000 inhab
B-d-R : 23.0 cases / 100 000 inhab

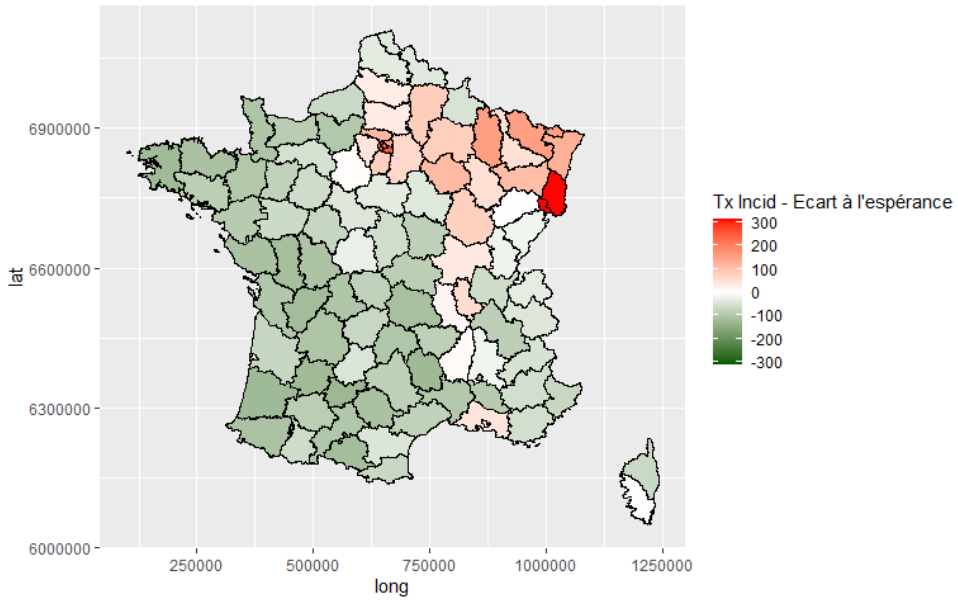




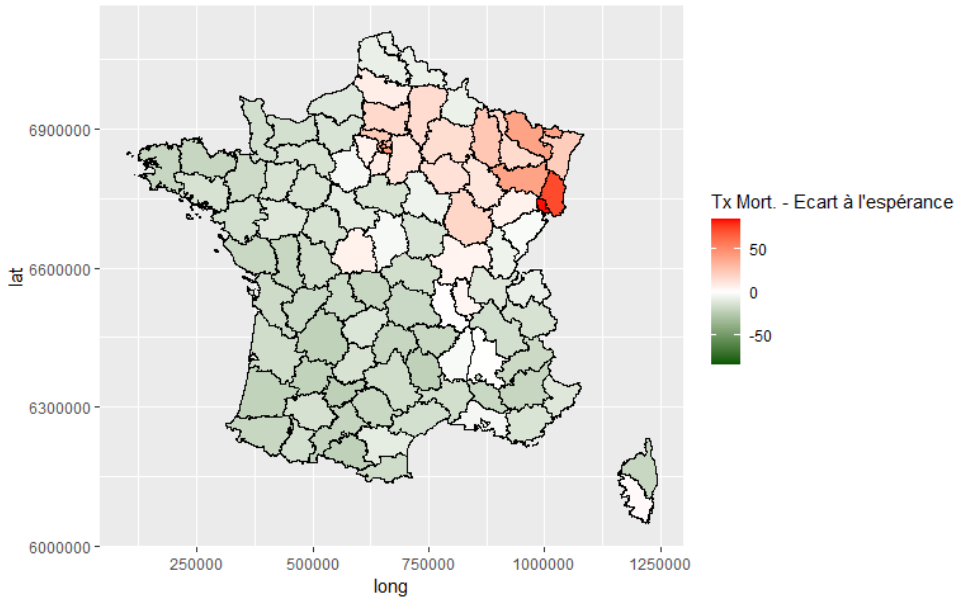
Results (2/5)

Deviation to the mean

H-Incidence



H-Mortality



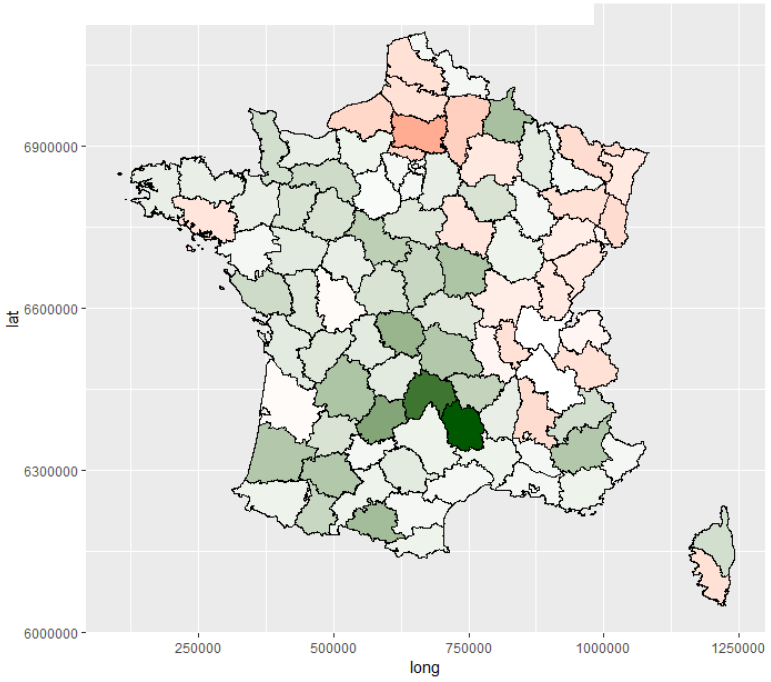
Results (3/5)

Lag between 1rst death and lockdown

H-incid. **1.02 (1.01-1.04)**

H-mort. **1,04 (1,02-1,06)**

H-CFR **1,01 (1,005-1,02)**

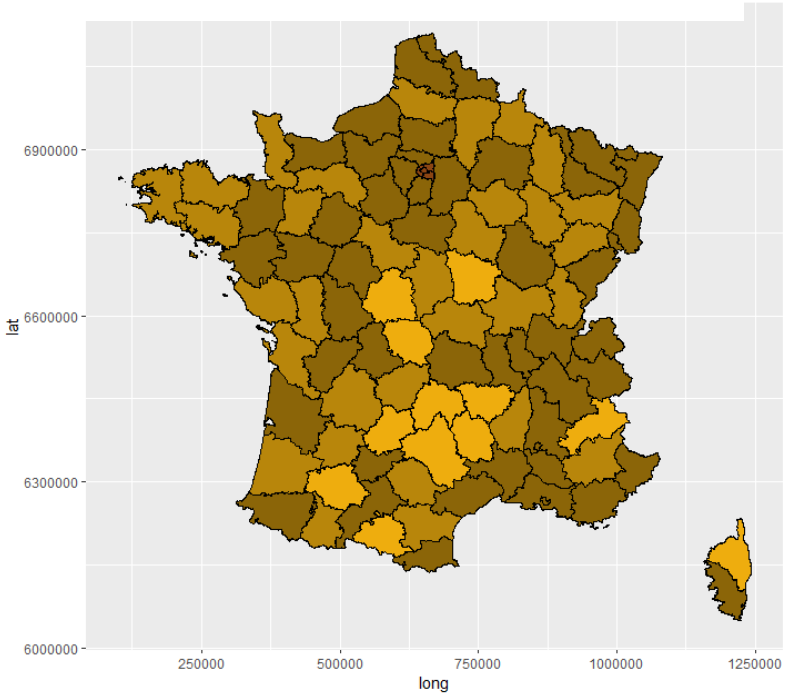


Urbanisation

H-incid. 0.94 (0.47-1.88)

H-mort. XX

H-CFR XX

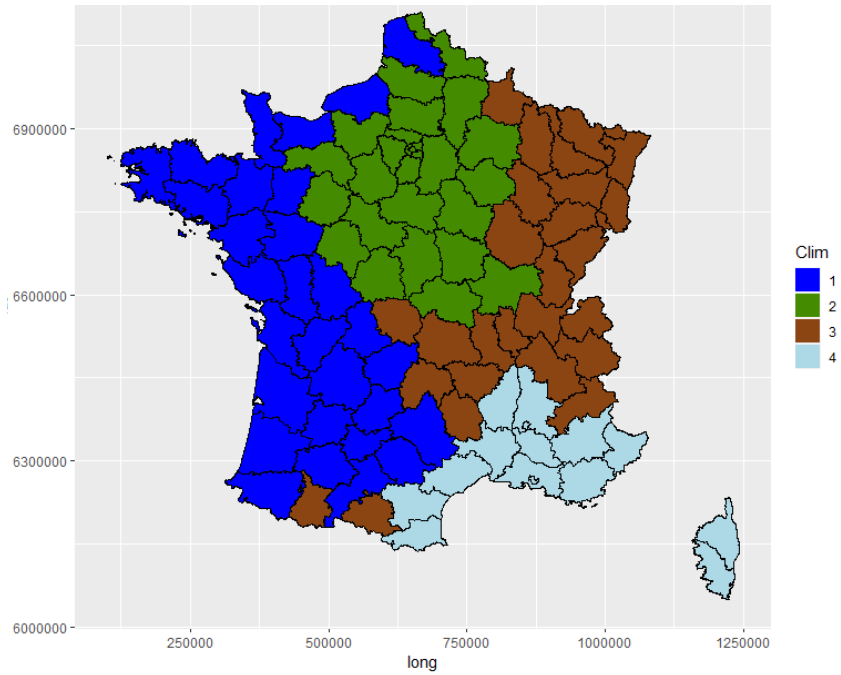


Climate

H-incid. 0.81 (0.57-1.17)

H-mort.XX

H-CFRXX



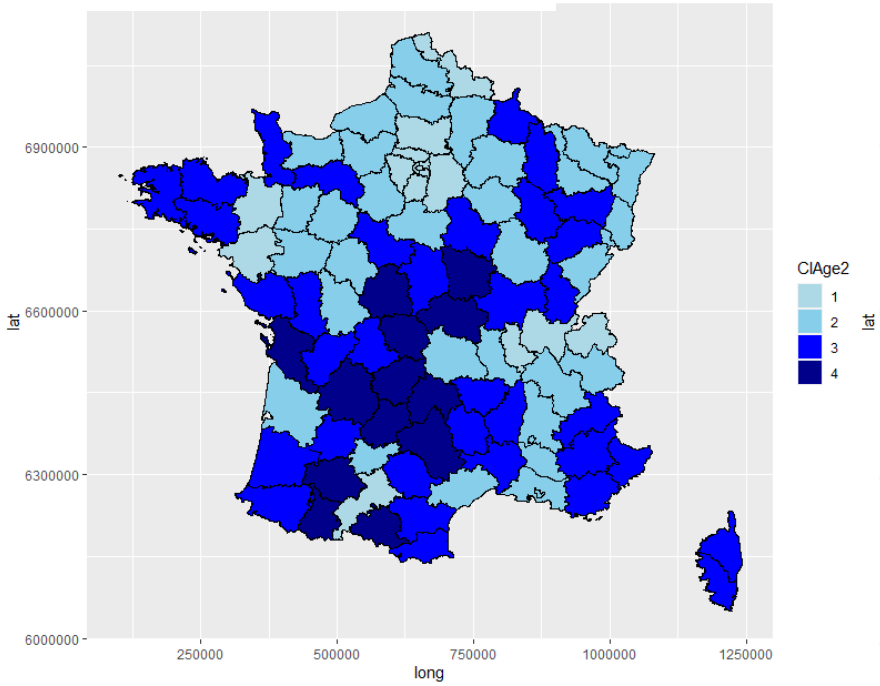
Results (4/5)

Population age structure

H-incid. 0.92 (0.51-1.66)

H-mort. **2,17 (1,20-3,90)**

H-CFR **1,43 (1,08-1,88)**

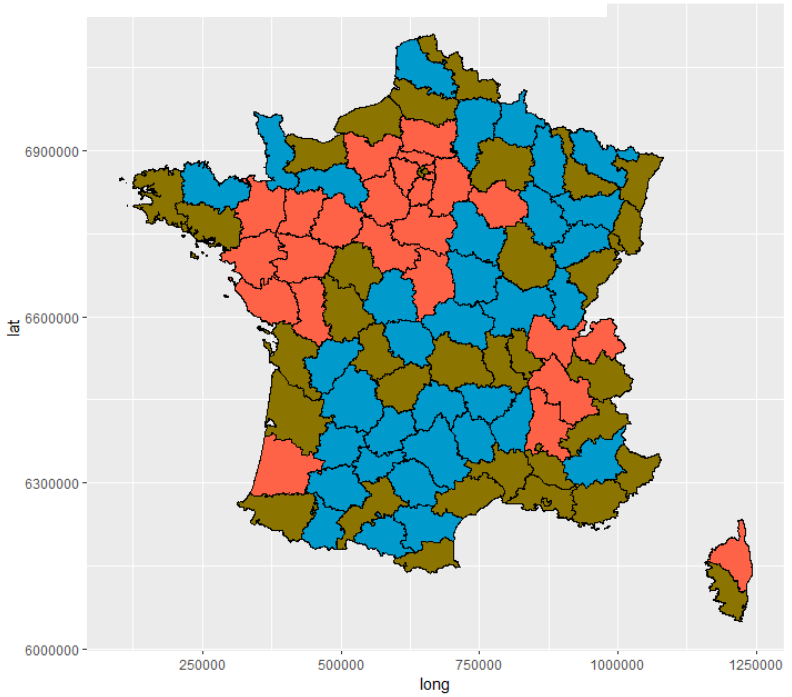


Baseline population health and health-care services

H-incid. 0.96 (0.71-1.31)

H-mort. 0,87 (0,61-1,23)

H-CFR 0,83 (0,69-0,99)

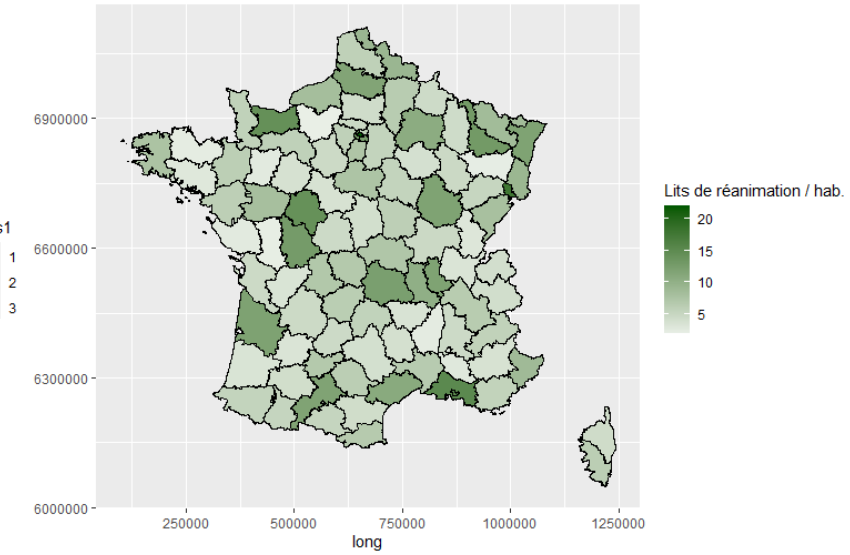


ICU beds in 2018

H-incid. XX

H-mort. 1,00 (0,99 -1,003)

H-CFR 1,00 (0,99-1,002)



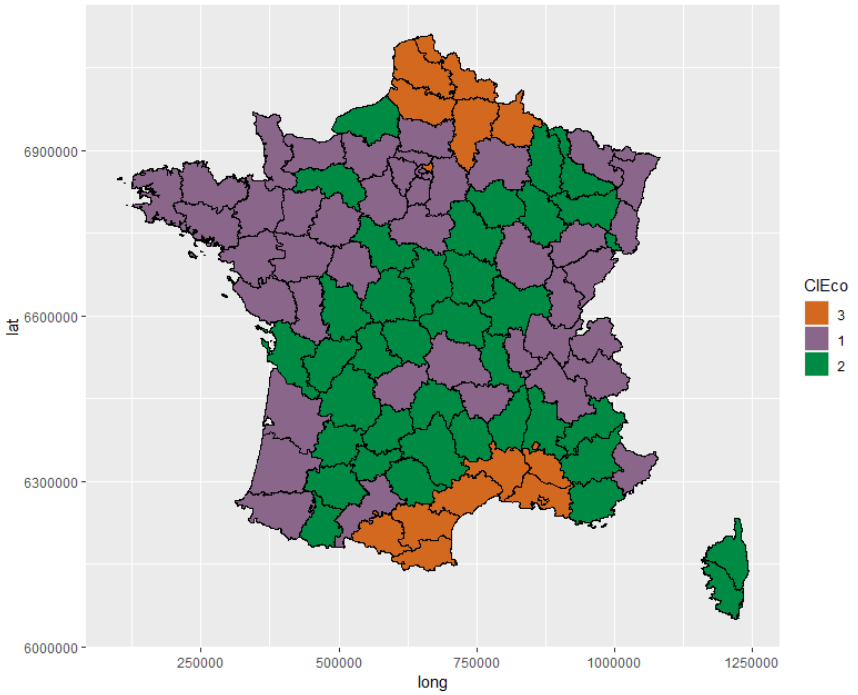
Results (5/5)

Economic indicators

H-incid. 0.97 (0.68-1.38)*

H-mort. XX

H-CFR XX

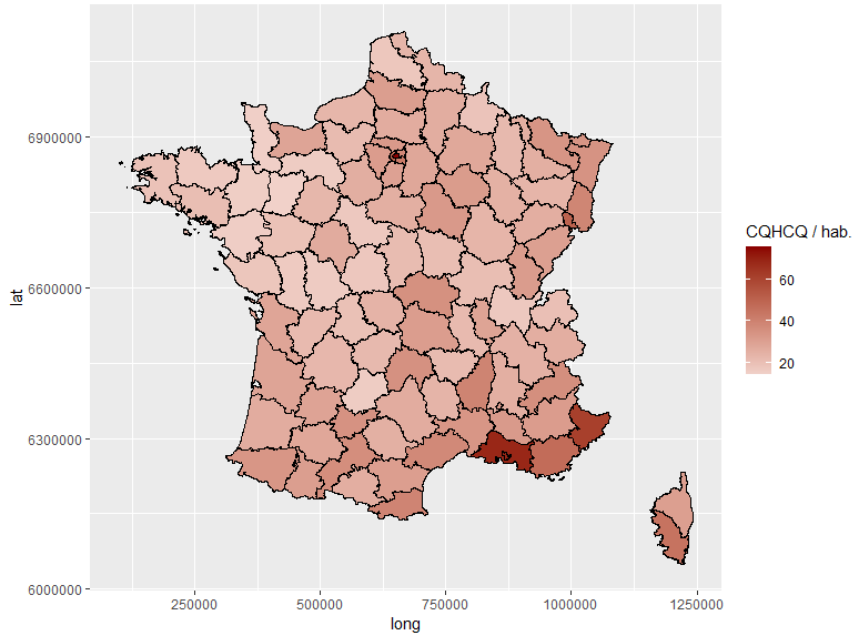


CQ-HCQ dispensations

H-incid. 1.00 (0.99-1.001)

H-mort. 1.00 (0.99-1.001)

H-CFR 1.00 (0.99-1.001)



Discussion (1/3)

- Clear spatial heterogeneity of in-hospital COVID-19 incidence and mortality

  ⇒ Spread of the epidemic before the lockdown

- Population age structure associated to in-hospital deaths
- Climate and Economic indicators not associated

  ⇒ Few variations between departments

- ICU bed (2018) and Health-care services not associated to in-hospital deaths

  ⇒ Hospital re-organisation to absorb the shock

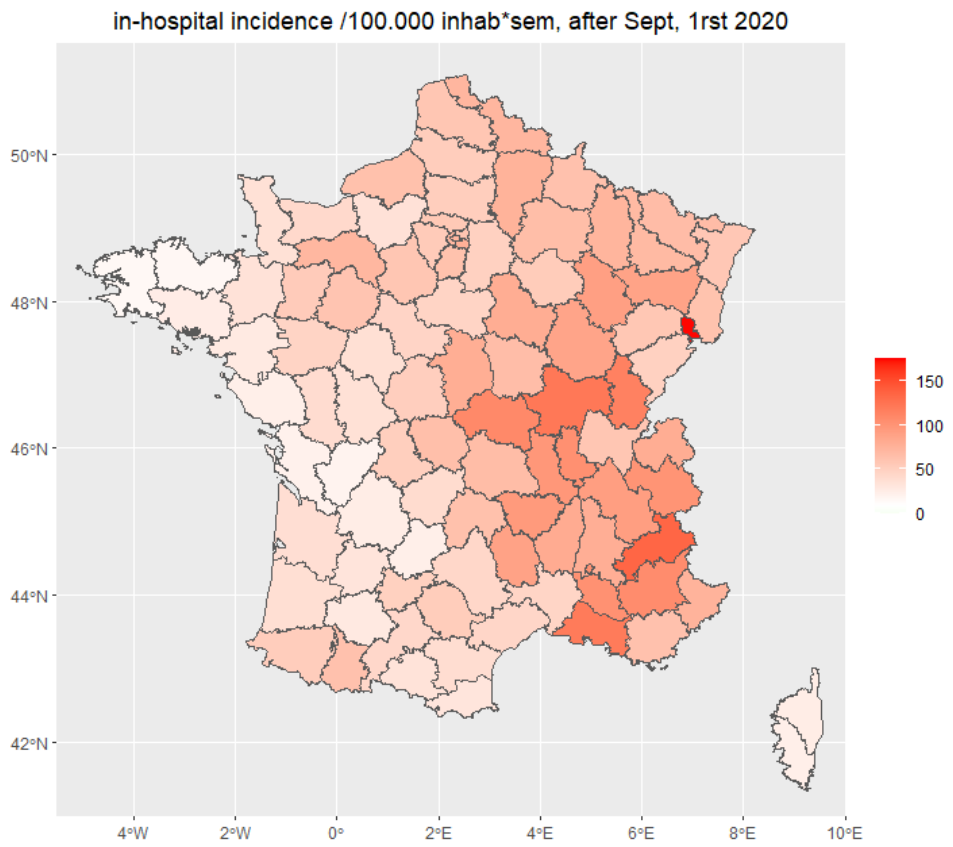
- Lockdown efficacy on H-incidence, mortality and CFR: the earlier the better

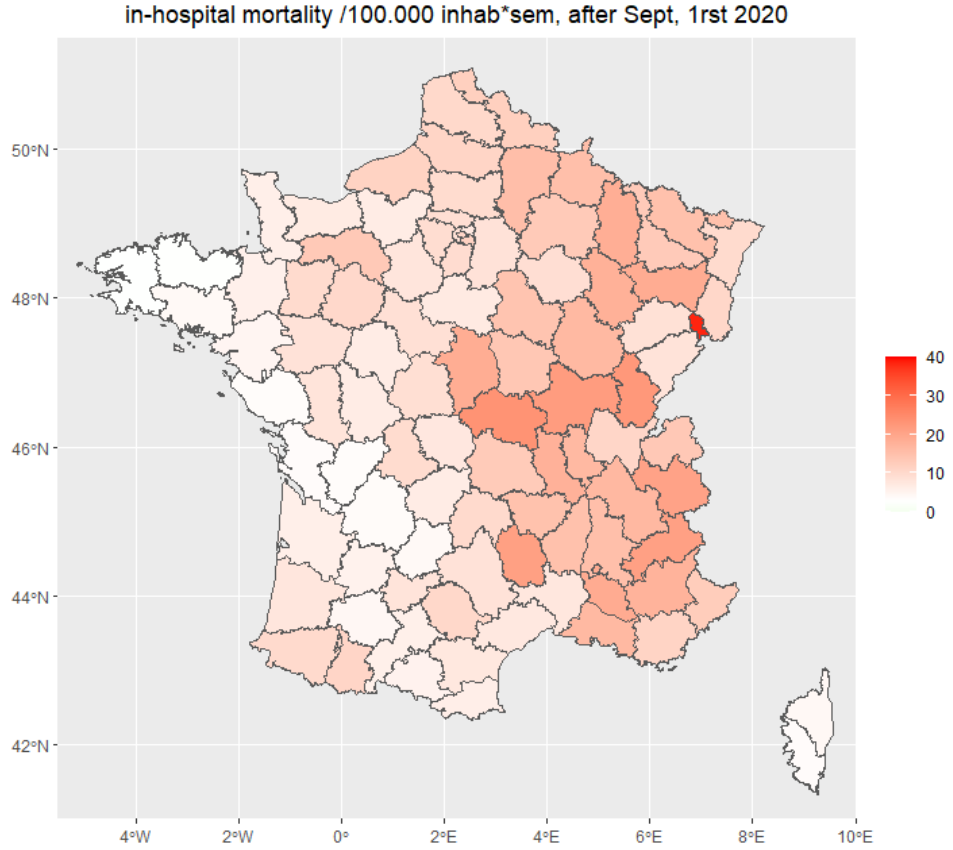
  ⇒ Event adjusted on population age structure, urbanisation, climate, health-care services, treatments

  ⇒ Weakness of the French preventive and public health organisation

Discussion (2/3)

Current Situation





Discussion (3/3)

Current Situation