CLIMATE CHANGE, AIR POLLUTION, AND PERINATAL HEALTH: THE COMBINED EFFECTS OF TEMPERATURE AND AIR POLLUTION IN SENSITIVE POPULATIONS

PhD Research Proposal

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2018-10-24

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IAB EPIGENETICS CHRONIC DISEASES CANCER

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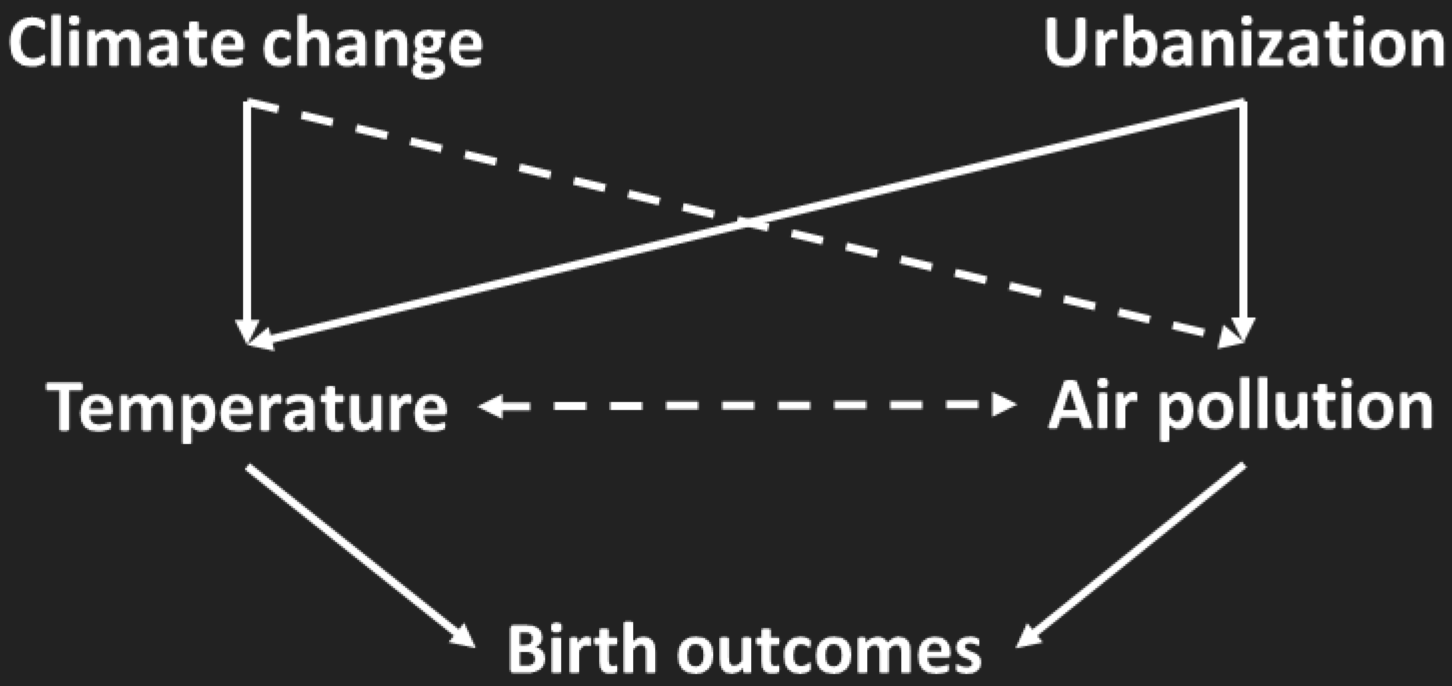
OUTLINE

1. Context
    1. Overview
    2. Adverse birth outcomes
    3. Ambient temperature & particulate matter
2. Proposed research
    1. Objectives
    2. Exposure models
    3. Birth outcomes study

CONTEXT

OVERVIEW



Climate change
Urbanization
Temperature
Air pollution
Birth outcomes

ADVERSE BIRTH OUTCOMES

Preterm birth (<37 weeks gestation)

- Leading cause of child mortality (Liu et al., 2016)
- 11% of all births and increasing (Harrison and Goldenberg, 2016)
- Sequalae in childhood and adulthood (e.g. asthma, cerebral palsy, behavioural problems) (McCormick et al., 2011)

Term low birth weight (<2500 g)

- Increased morbidity and mortality in childhood and adulthood (Barker, 2004; Belbasis et al., 2016)

AMBIENT TEMPERATURE (T_A)

- Heat, cold, or variable T_a can increase risk (Zhang et al., 2017)
- Response may depend on local population & climate
- Hard to synthesize findings

	Preterm birth	**Birth weight**	**Term low birth weight**
Exposure	Cold (<10th %ile)	IQR Ta increase	Heat (>95th %ile)
Window	Weeks 1–7	Last 30 days	Trimester 3
Statistic	Relative risk	Decrease	Odds ratio
Effect	1.09 [1.04–1.15]	16.6 g [5.9–27.4]	1.31 [1.15–1.49]
Study	(Ha, D. Liu, et al., 2017)	(Kloog et al., 2015)	(Ha, Y. Zhu, et al., 2017)

PARTICULATE MATTER (PM)

$PM_{10} \uparrow 10\ \mu g/m^3$ entire pregnancy

	Preterm birth	Birth weight	Term low birth weight
Statistic	Pooled odds ratio	Pooled decrease	
Effect	0.97 [0.86–1.08]	10.3 g [7.1–13.6]	Too few studies
Study	(Lamichhane et al., 2015)	(Lamichhane et al., 2015)	

$PM_{2.5} \uparrow 10\ \mu g/m^3$ entire pregnancy

	Preterm birth	Birth weight	Term low birth weight
Statistic	Pooled odds ratio	Pooled decrease	Pooled odds ratio
Effect	1.13 [1.03–1.24]	15.9 g [5.0–26.8]	1.09 [1.03–1.15]
Study	(Sun et al., 2015)	(Sun et al., 2016)	(Sun et al., 2016)

PROPOSED RESEARCH

OBJECTIVES

1. Model daily min, mean, and max T_a in France 2000–2016
   - 1 km estimates entire area
   - 200 m estimates for urban areas
2. Model daily PM_{10} and $PM_{2.5}$ in France
   - 1 km estimates entire area
   - 200 m estimates for urban areas
3. Study associations between T_a, PM, and birth outcomes
   - Windows of susceptibility
   - Acclimatization to T_a
   - Interactions between T_a and PM

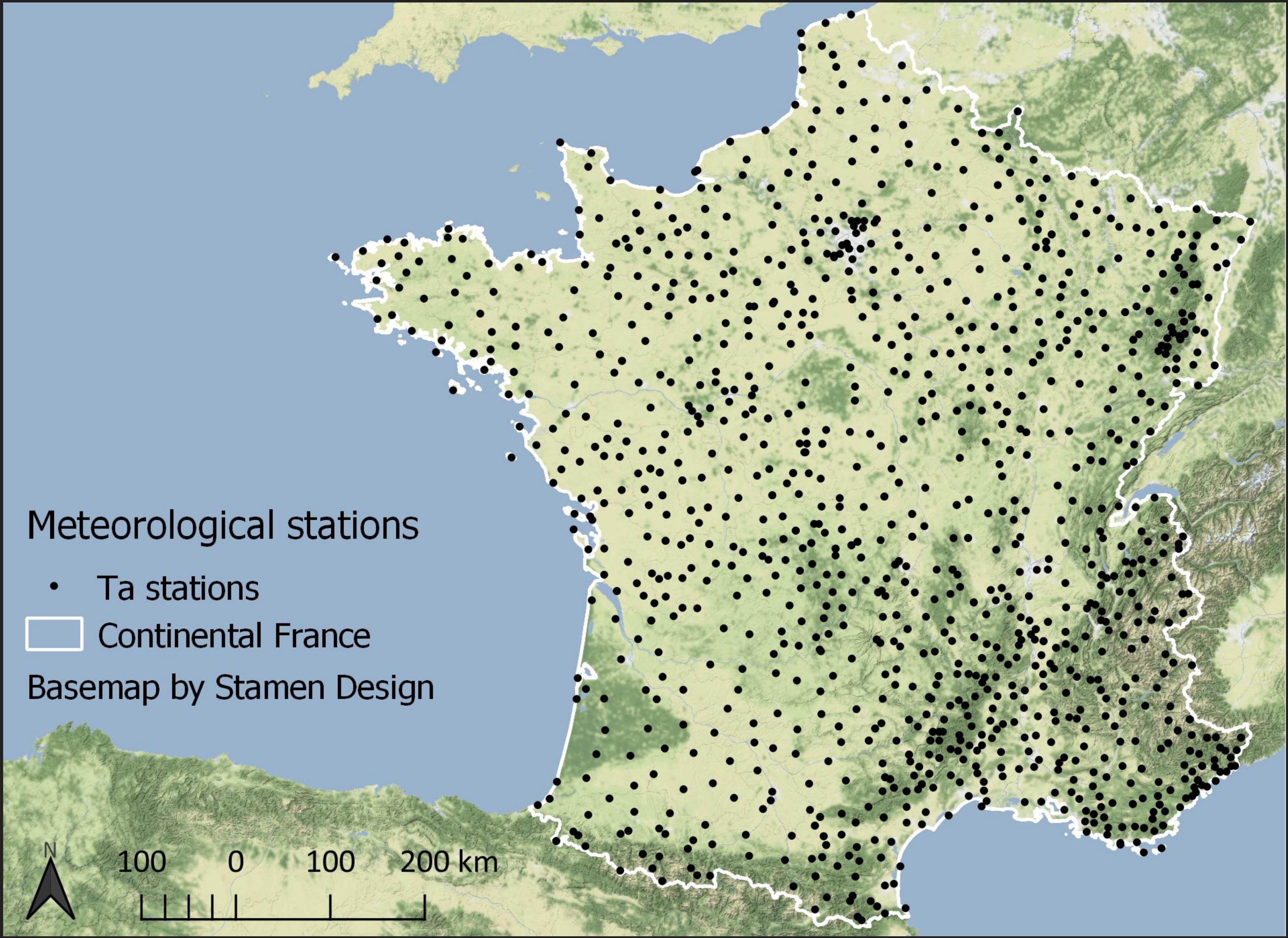
EXPOSURE MODELS

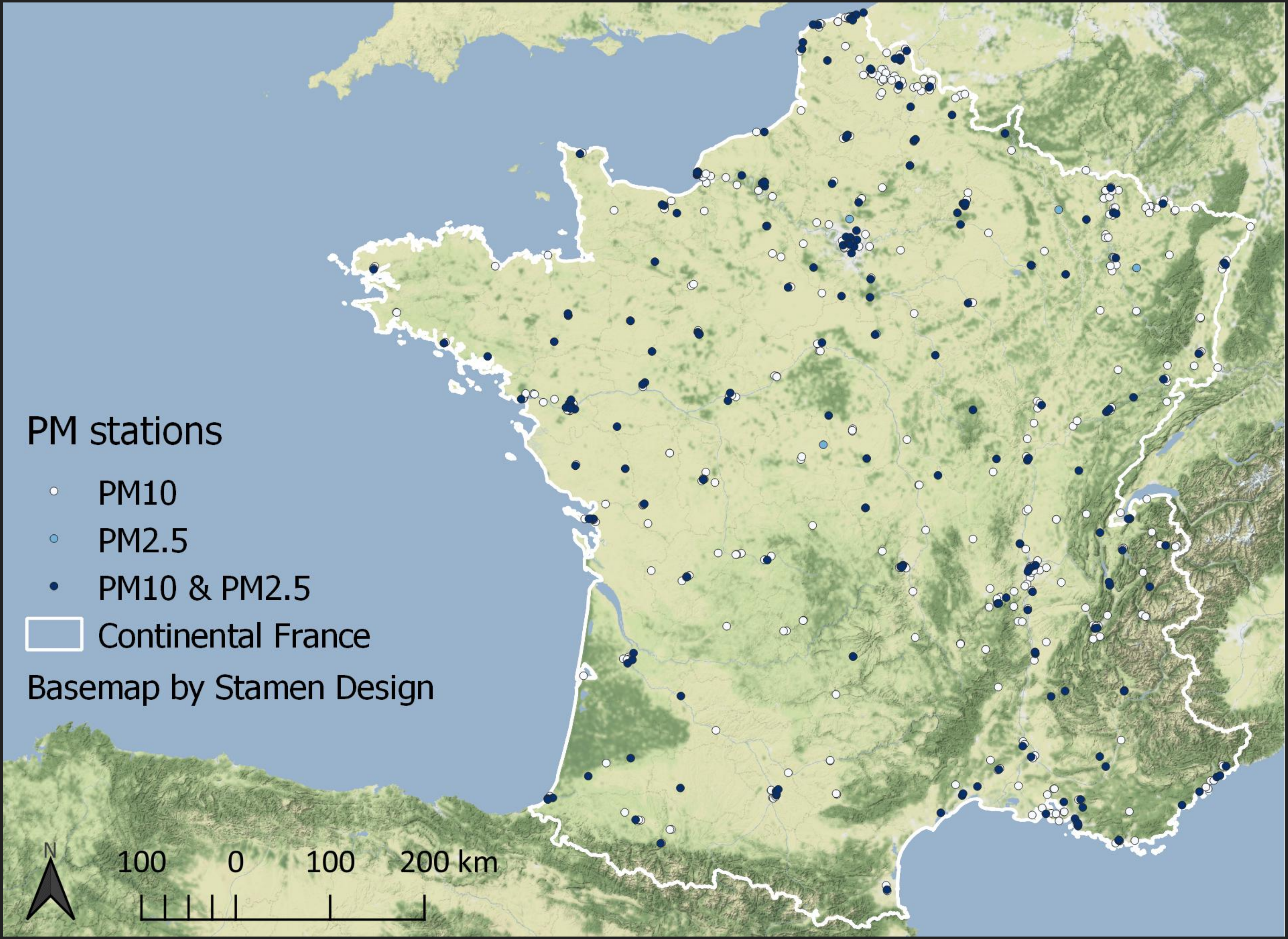
WHY MODEL T_A AND PM?

Sparse monitoring networks

→ Error in exposure estimate

→ May bias effect estimates towards null


Meteorological stations
Ta stations
Continental France
Basemap by Stamen Design
N
100 0 100 200 km


PM stations
PM10
PM2.5
PM10 & PM2.5
Continental France
Basemap by Stamen Design
N
100 0 100 200 km

MODELLING APPROACHES

Physical models

- Numerical weather prediction → complex
- Dispersion / chemical transport → complex

Statistical models

- Inverse distance weighting → poor performance
- Land use regression → low temporal variability
- *Hybrid models*

HYBRID STATISTICAL MODELS

1. Satellite data (& other spatial predictors)

- T_a ← land surface temperature (LST)
- PM ← aerosol optical depth (AOD)

MODIS (Terra + Aqua)

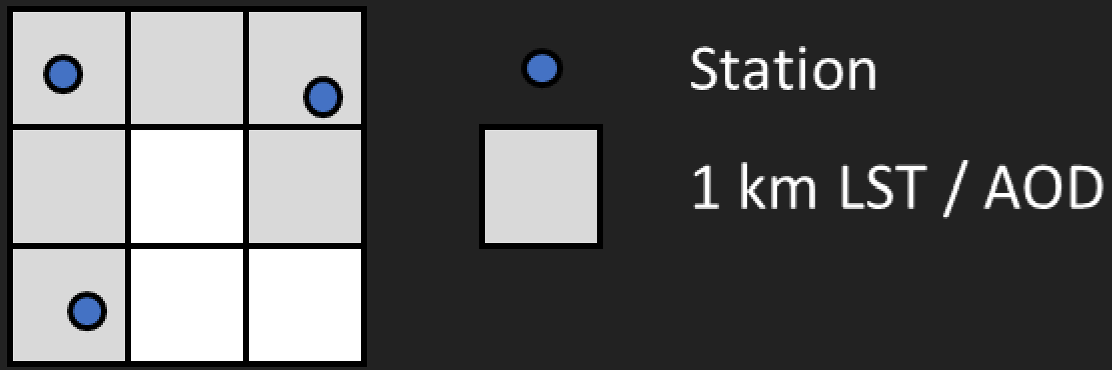
- 1 km spatial resolution
- LST 2x / day + 2x / night
- AOD 2x / day
- Free ready-to-use products (LST and AOD)

HYBRID STATISTICAL MODELS

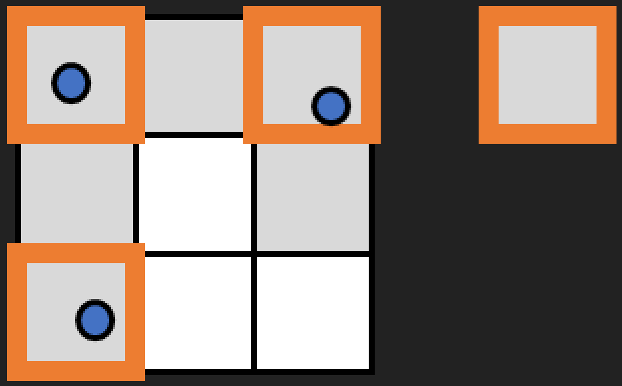
2. Statistical model

- Linear regression
- Geographically weighted regression
- Spatiotemporal regression-kriging
- *Linear mixed models* (Just et al., 2015; Kloog et al., 2014, 2017; Shtein et al., 2018)
- Random forest, gradient boosting, elastic net, etc.

LINEAR MIXED MODEL APPROACH



STAGE 1: CALIBRATION



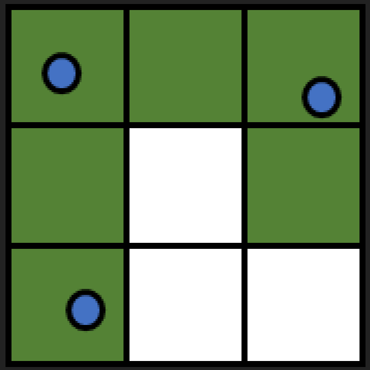
1 km calibration

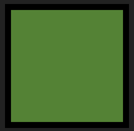
$$T_a = (\alpha + \mu_{jr}) + (\beta_1 + \nu_{jr}) \cdot LST + \beta_2 \cdot Emissivity + \beta_3 \cdot NDVI + \beta_4 \cdot Elevation + \beta_5 \cdot Population + \beta_6 \cdot LandCover + e$$

j = day

r = climatic region

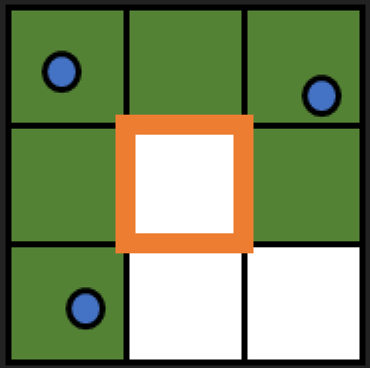
STAGE 2: PREDICTION

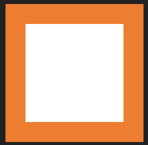




1 km predicted

STAGE 3: GAP FILLING



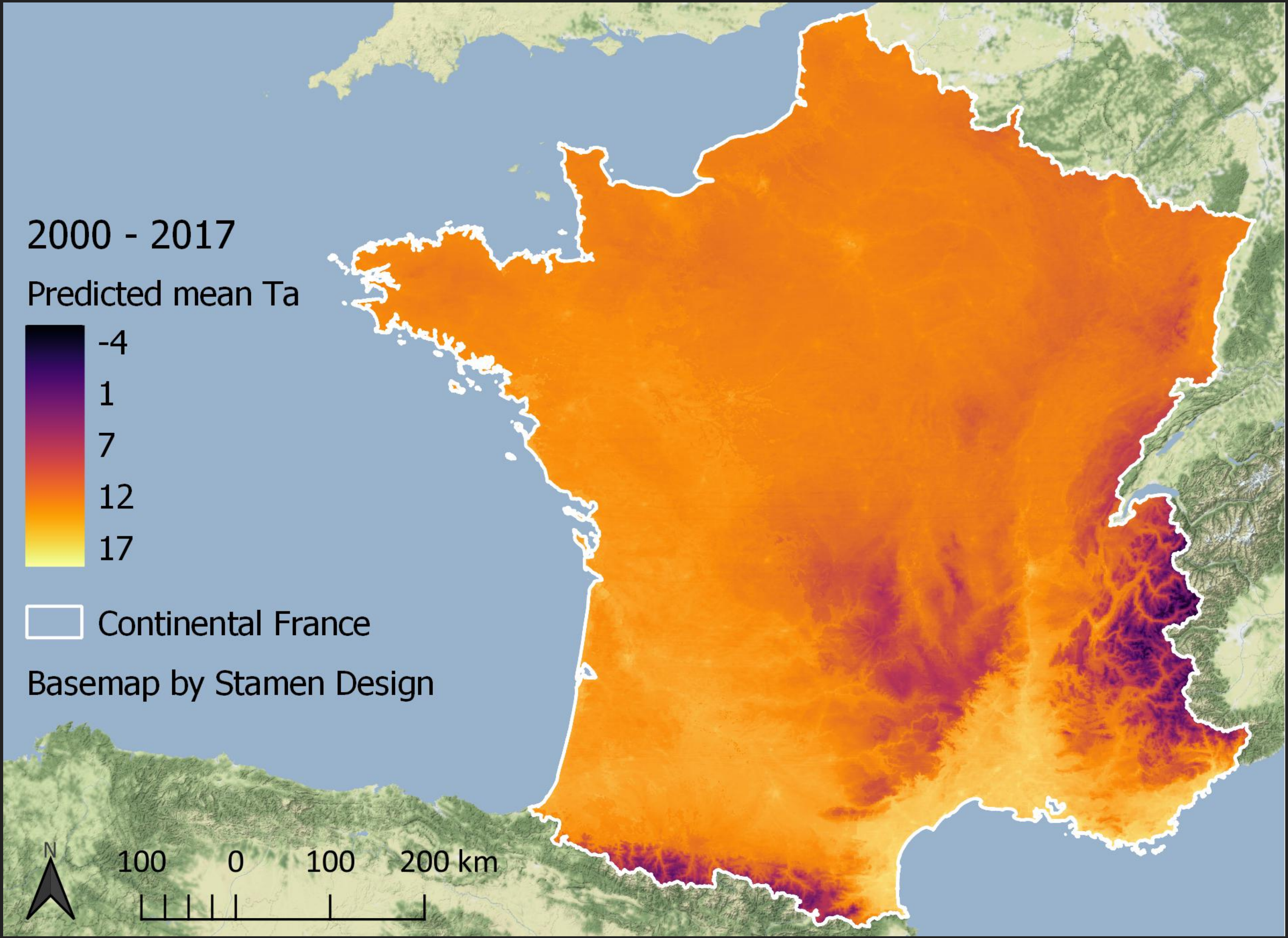


1 km gap-filling

$$T_{a\,predicted} = (\alpha + \mu_{ip}) + (\beta_1 + \nu_{ip}) \cdot T_{IDW} + e$$

i = grid cell

p = two-month period


2000 - 2017
Predicted mean Ta
-4
1
7
12
17
Continental France
Basemap by Stamen Design
N
100
0
100
200 km

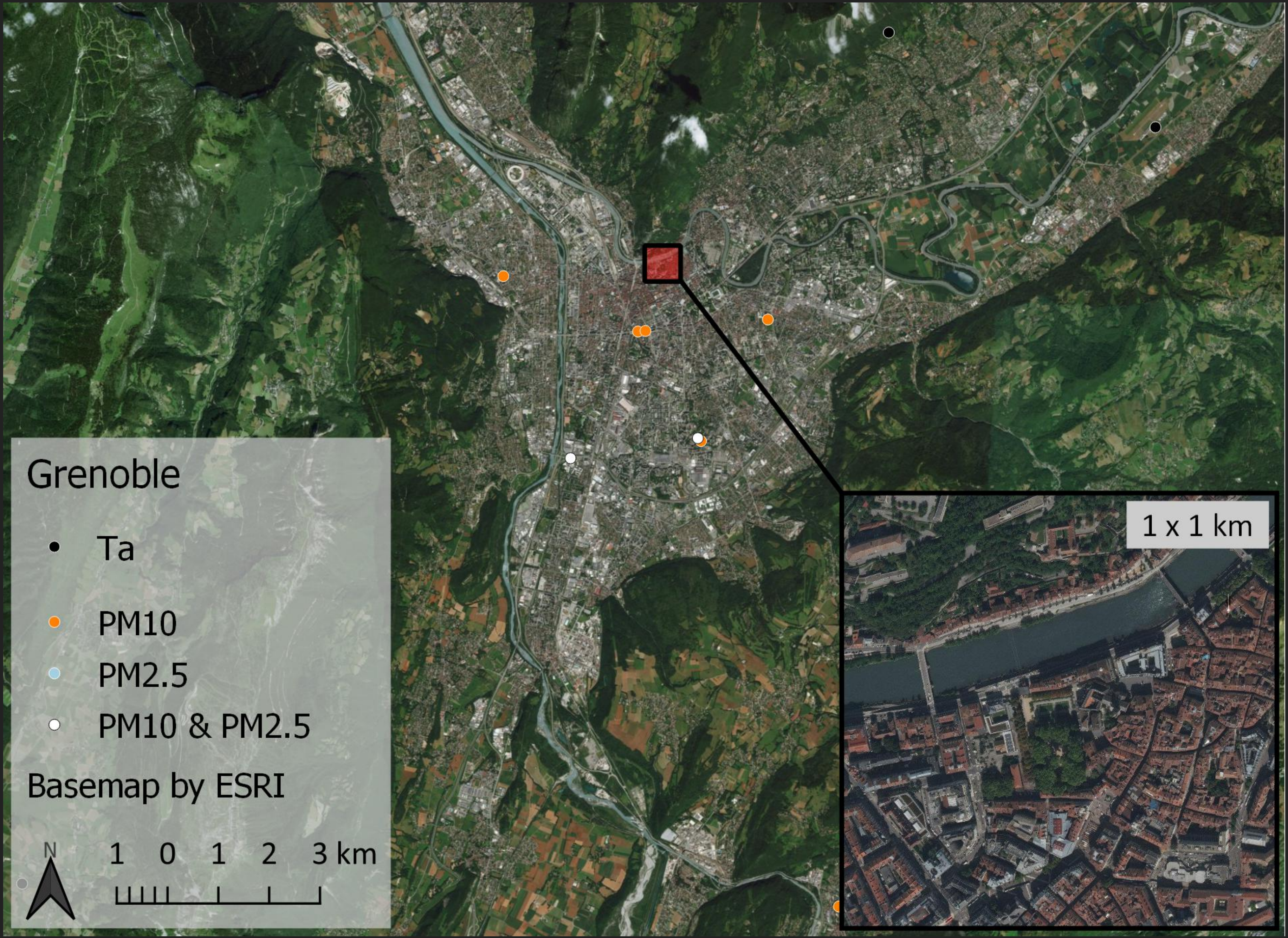
MODEL PERFORMANCE

Cross-validated 1 km predictions

2000–2016	R^2	RMSE	Spatial R^2	Temporal R^2	Spatial RMSE
T_a min	0.92	1.89	0.83	0.93	0.97
T_a mean	0.97	1.29	0.95	0.97	0.57
T_a max	0.95	1.81	0.89	0.96	0.99

Improvement over previous model (Kloog et al., 2017)

2000–2011	R^2	RMSE	Spatial R^2	Temporal R^2	Spatial RMSE
T_a mean	0.02	0.25	0.04	0.01	0.09


Grenoble
Ta
PM10
PM2.5
PM10 & PM2.5
Basemap by ESRI
N
1 0 1 2 3 km
1 x 1 km

URBAN 200 M PREDICTIONS

Landsat 5 / 7 / 8 (ETM+ / TIRS)

- 60 m / 120 m spatial resolution
- One overpass every 16 days (sometimes 8 days)
- No precalculated LST (at-satellite brightness temperature)

Building footprints + height

- Skyview factor

T_A MODEL STATUS

Complete

- T_a 1 km estimates

In progress

- T_a 200 m urban estimates
- T_a paper

PM MODEL STATUS

In progress

- PM data preparation

Forthcoming

- PM 1 km estimates
  - Estimate $PM_{2.5}$ at PM_{10}-only stations
  - Reduce MAIAC error using AERONET data (Just et al., 2018)
- PM 200 m urban estimates
- PM paper

BIRTH OUTCOMES STUDY

UNRESOLVED QUESTIONS

Windows of susceptibility

- Mixed results to date
- PM exposure tends to be correlated across trimesters

Acclimatization

- Suggested for mortality (Gasparrini et al., 2015; Lee et al., 2014)

Interactions between T_a and PM

- Synergy suggested for mortality (Kioumourtzoglou et al., 2016; Li et al., 2017)

STUDY DESIGN

- 5923 mother-child pairs from three prospective cohorts
- Birth weight, term low birth weight, preterm birth
- High, low, and variable T_a and PM
- Windows of susceptibility
  - Day, up to 7 days, week, 4 weeks, trimester, entire pregnancy
- Acclimatization
- Interactions
- Linear / logistic / Cox models
  - Distributed non-linear lags

THANK YOU!

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