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Impacts of urban spatial structure on air quality

an integrated modeling approach

Arthur Elessa, Julie Prud'homme, Isabelle Coll,

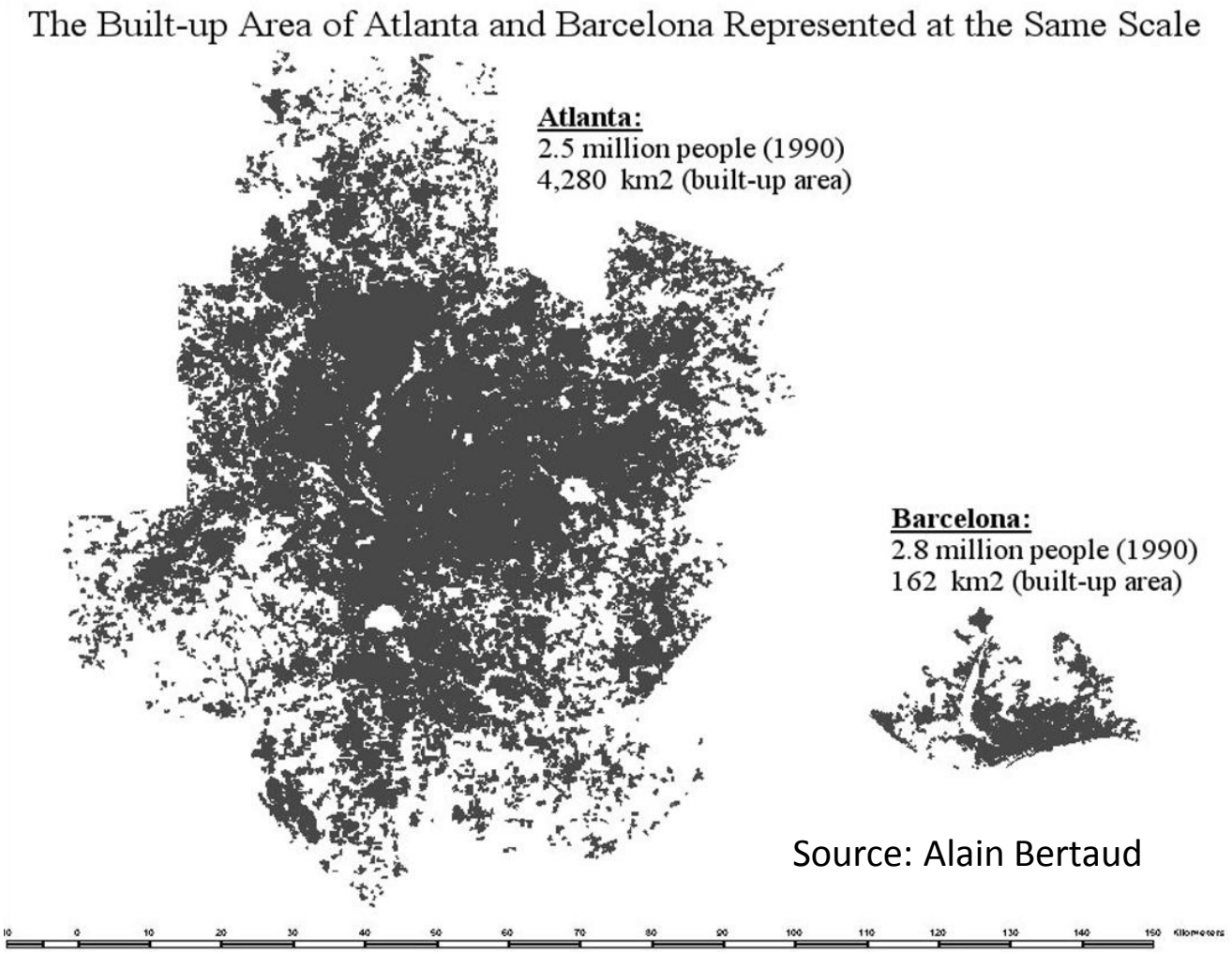
Vincent Viguié, Nicolas Coulombel

Work in progress !

C.I.R.E.D.
Jardin Tropical
45 bis avenue de la Belle Gabrielle
94736 Nogent-sur-Marne cedex - France

29/07/2015

Urban forms matter for greenhouse gas emissions…



Lower emissions in Barcelona because of:

1 - Shorter travel distance;

2 – Easier use of public transport:

Barcelona has 99 km of metro line.

To provide the same accessibility to metro in Atlanta, 3400 km would be necessary.

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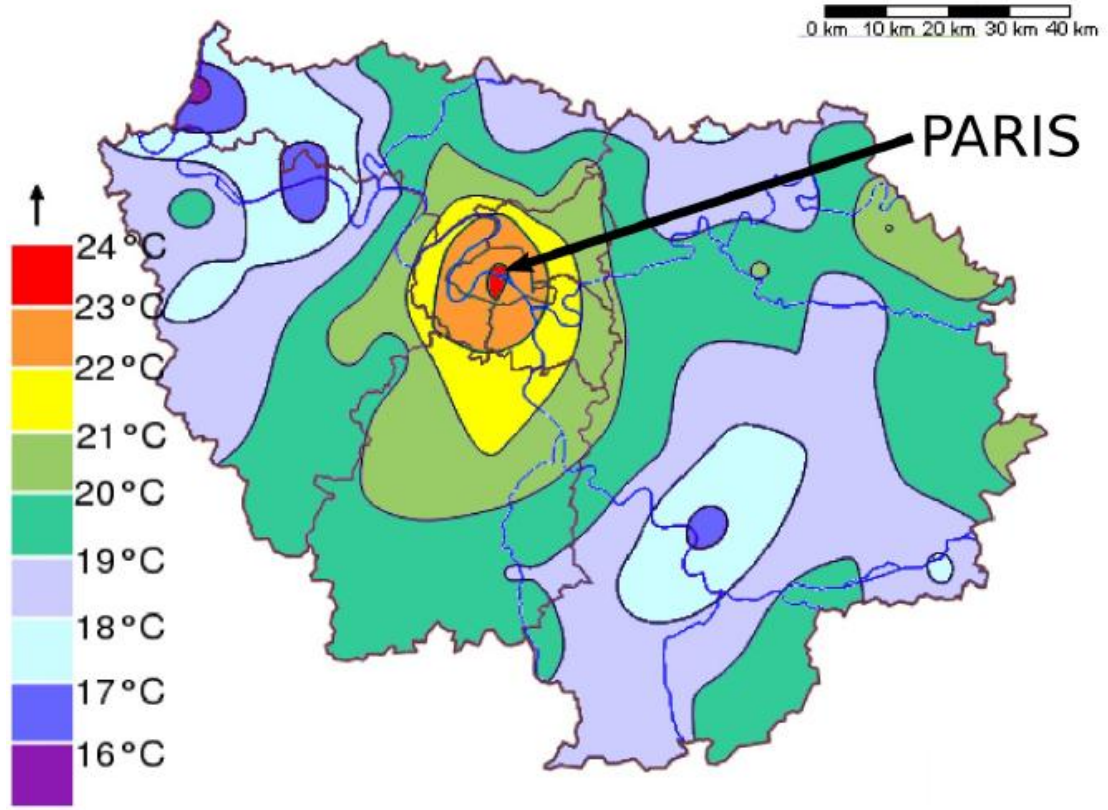
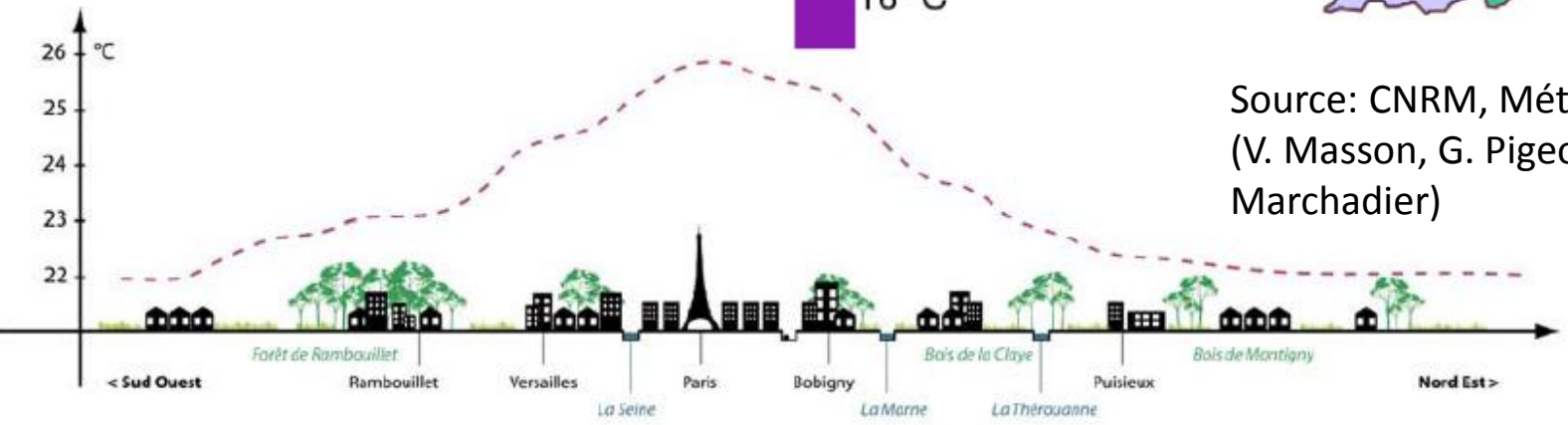
Urban forms matter for climate-change vulnerability…

Urban Heat Island effect

Temperatures are higher in cities than in rural areas, especially at night.

Example of the 2003 heat wave.





Source: CNRM, Météo-France
(V. Masson, G. Pigeon, A. Lemonsu, C. Marchadier)

Cities and climate change

- **Urban forms matter for greenhouse gas emissions**
  - Transport, housing, …
- **Urban forms matter for climate-change vulnerability**
  - Urban heat island
  - Urbanization in flooding prone areas…
- **Urban forms matter for many other policy objectives, e.g., related to social and spatial inequalities, competitiveness...**
- **Urban forms cannot change rapidly, so we already need to take into account current and future constraints**
  - Unprecedented need to anticipate future constraints and objectives and to act with no delay

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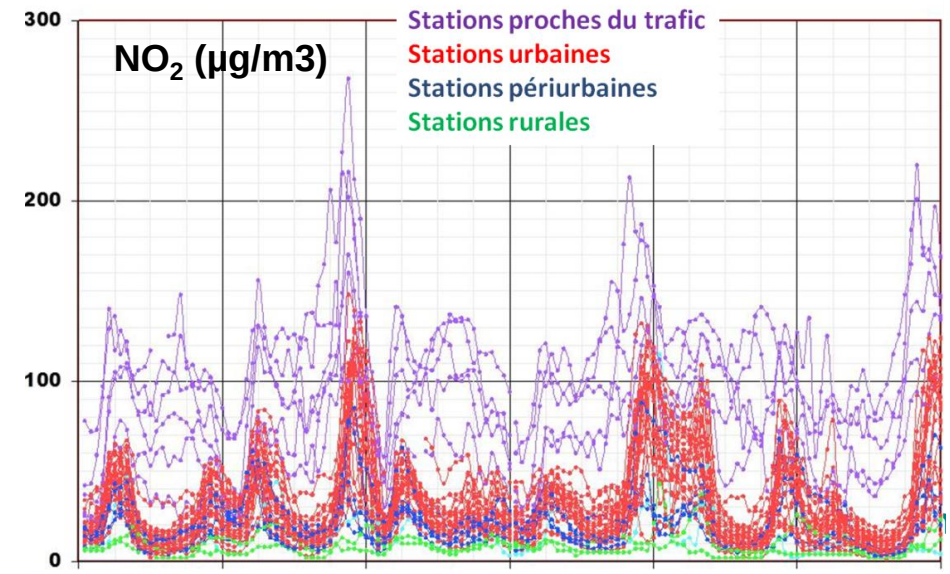
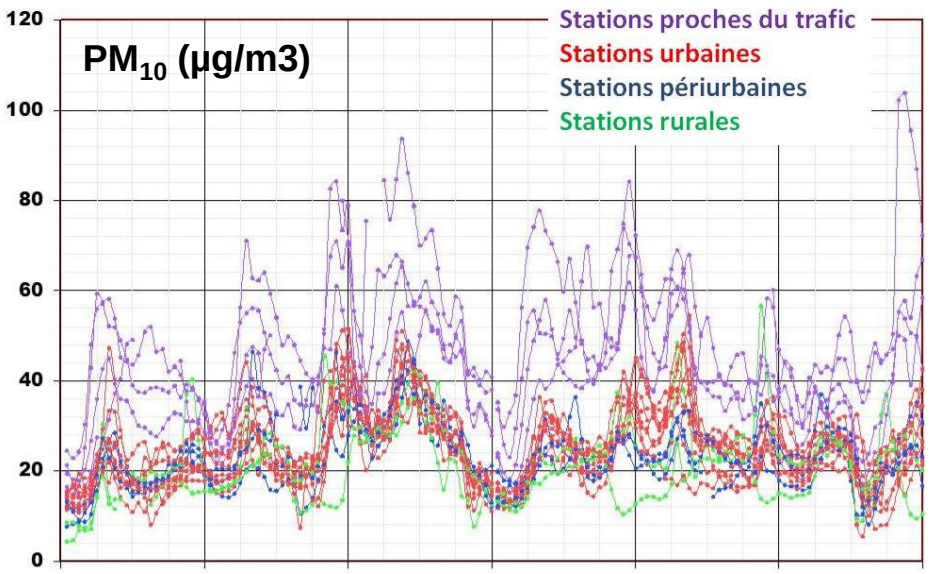
State of urban air quality in France / Europe

- **A European issue**
  - Air pollution levels remain a concern in many parts of Europe
  - Transportation is a major contributor to NOx (55%) and fine PM (30 %) emissions. It also generates very close proximity to emissions.

Evolution of hourly concentrations at all stations of the AIRPARIF air quality network for a week of summer 2007

Source: I. Coll





State of urban air quality in France / Europe

- **A European issue**
  - Air pollution levels remain a concern in many parts of Europe
  - Transportation is a major contributor to NOx (55%) and fine PM (30 %) emissions. It also generates very close proximity to emissions.

- **Always a key political issue in the agenda**
  - Epidemiological research confirms the significant long-term impact on human health
  - Increasing expectations of urban populations confronted with environmental and public health issues
  - … but
  - Uncertainties about the evolution of pollutant background concentrations
  - Incomplete implementation of existing air quality policies
  - Such trends remain incompatible with sustainable development

Research question

- **What are the impacts of the form of urban growth on air quality ?**
  - Go beyond the only consideration of emission control
  - Identify urban growth scenarios leading to low pollution levels

- **A confrontation of several mechanisms**
  1. In a compact urban form, pollutant emissions can be **lower** than in a sprawled city *(higher public transport/non-motorized travel modal share)*
  2. In a compact urban form, pollutant emissions can be **higher** than in a sprawled city *(increased congestion)*
  3. In a compact urban form, everybody leaves closer to emission sources…

Project goals

- **Several works have investigated into this issue**
  - E.g. Borrego et al. 2006, De Ridder et al. 2008, Martins 2012, Schindler et Caruso 2014…
  - The result of the confrontation of the 2 mechanisms depends on the **type of pollutant**, and on the **city**
  - Also depends on the type of vehicles → technological change can have an important impact

- **Many questions still need to be addressed**
  - What result for the case of Paris?
  - To what extent can mitigation policies (e.g. vehicle efficiency increases, electric vehicles…) influence this issue?
  - To what extent can adaptation policies (e.g. city greening) influence this issue?
  - Are there thresholds? Non-linear relationships ?
  - Is there an optimal density/urban form when considering both C02 emissions and air pollution?
  - Is the link between urban shape and air quality significant enough to play a role in the public debate?
  - …

Proposed approach

- **Integrated city modelling**

- **Build an integrated modeling chain from existing proven models**
  - Based on existing expertise rather than reinventing state-of-the-art models
  - Designed to provide new type of analyses, through thematic transversality

- **Challenges:**
  - Heterogeneity of philosophies
  - Heterogeneity of refinment degrees for a given parameter / urban component
  - Uncertainty cascade

Better model the interactions urban activities - Environment

Plysical parameters, choice of urbanization , transport ...

Environmental policies (urban forms , economics, energy)

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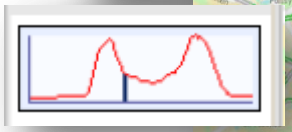
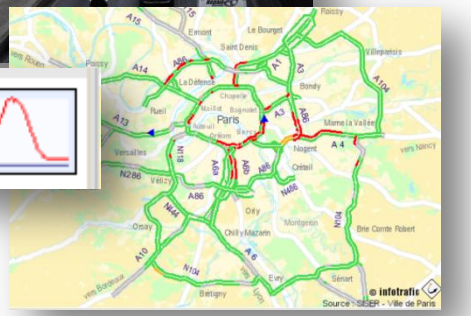
MODUS / GREEN models

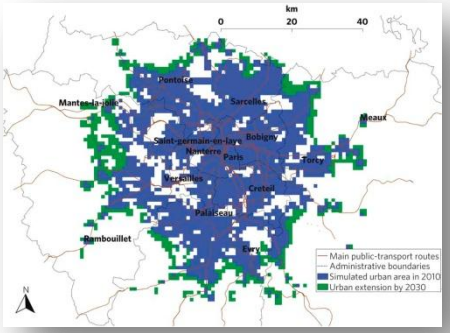
Model for modal allocation and traffic simulation
Construction of traffic flows
Calculating associated emissions





Emissions linked with road traffic

NEDUM 2D : Socio-economic model / interaction transport–landuse
Rearrangement of urban space
Transport costs
Rent cost



City structure & urban fabric

Urban consequences of policy choices
→ Location of new employment centers and residential areas
→ New landuse

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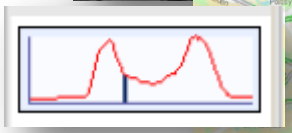

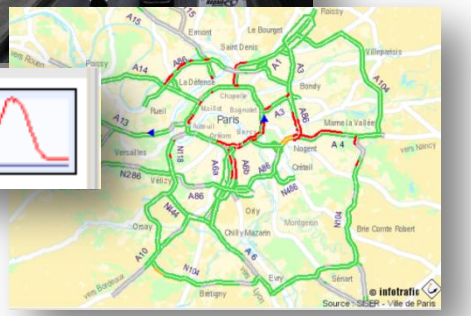

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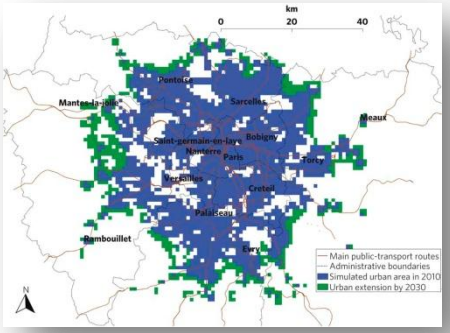
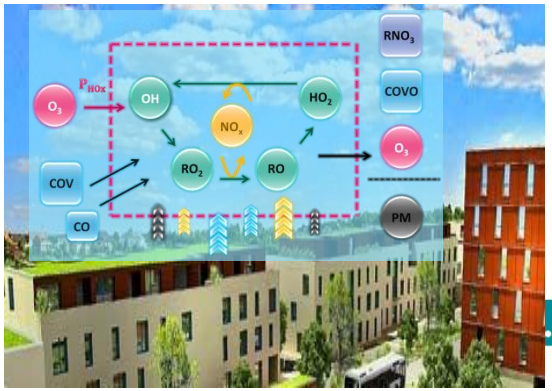
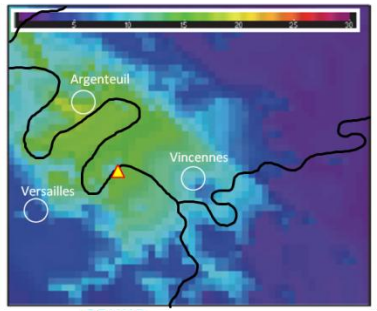


City structure & urban fabric

Chimere

CHIMERE model : air quality / concentration fields





Urban consequences of policy choices
→ Location of new employment centers and residential areas
→ New landuse

CHIMERE TOOL : Chemistry Transport Model

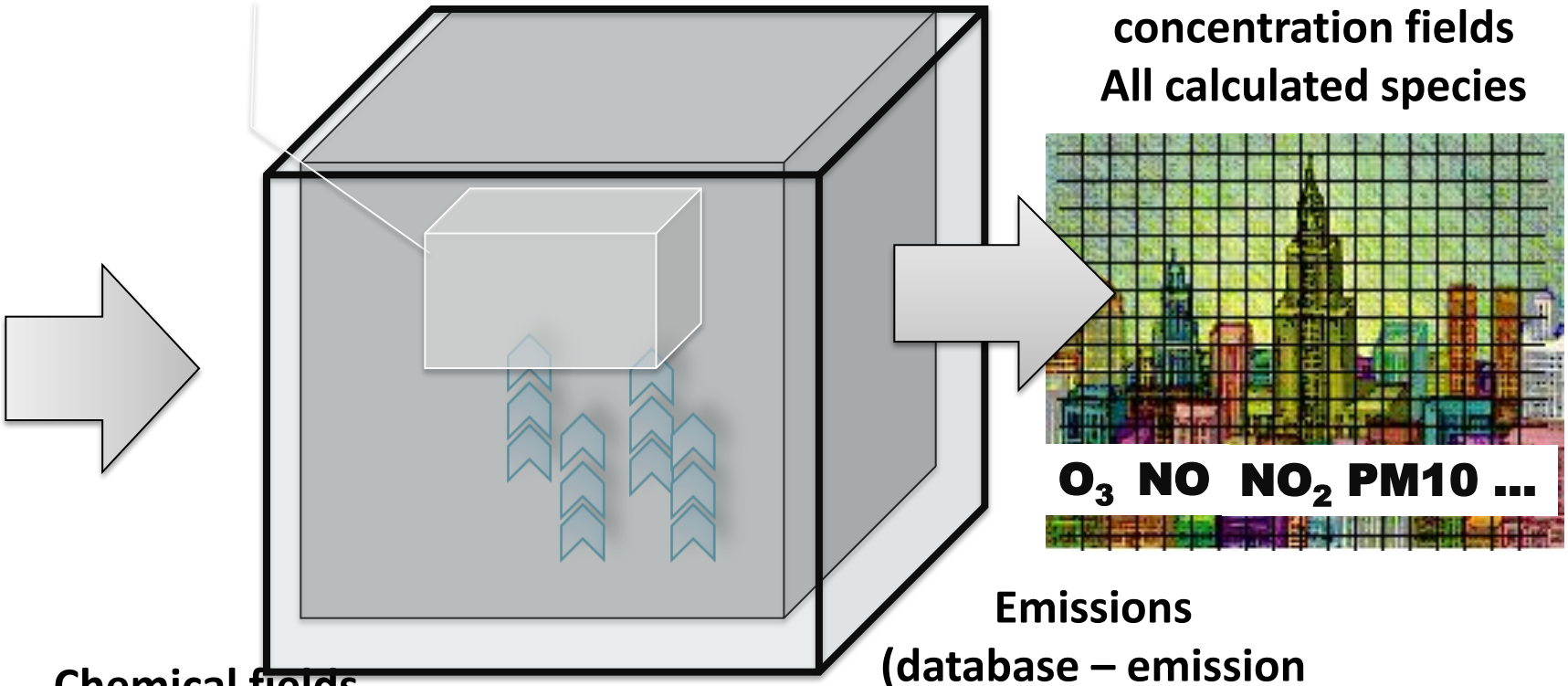
Internal modules for calculation

Chemical scheme /
Thermodynamics
Transport scheme
Solver

Chimere

Meteorological Parameters (model)

Gridded concentration fields
All calculated species



Chemical fields
(large scale models)

Emissions
(database – emission models)

First results (work in progress)

- **We compare 2 scenarios**
  - Paris today (**reference** case)
  - **Compact scenario**: Paris, as if strong land-use policies had been implemented since 1960 to promote a compact city development

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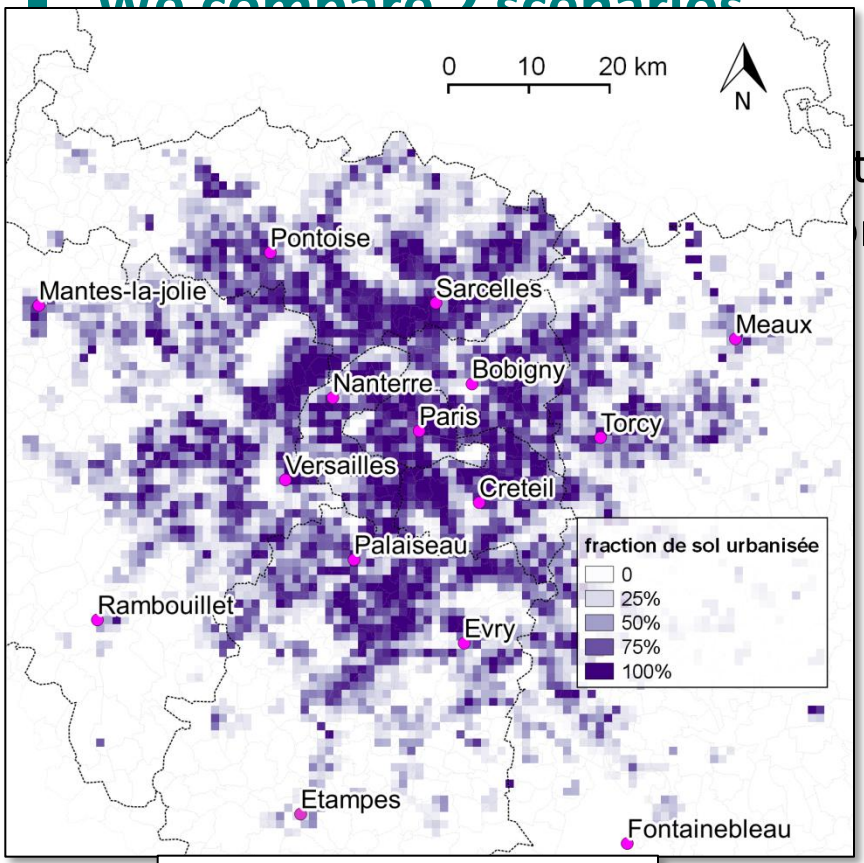
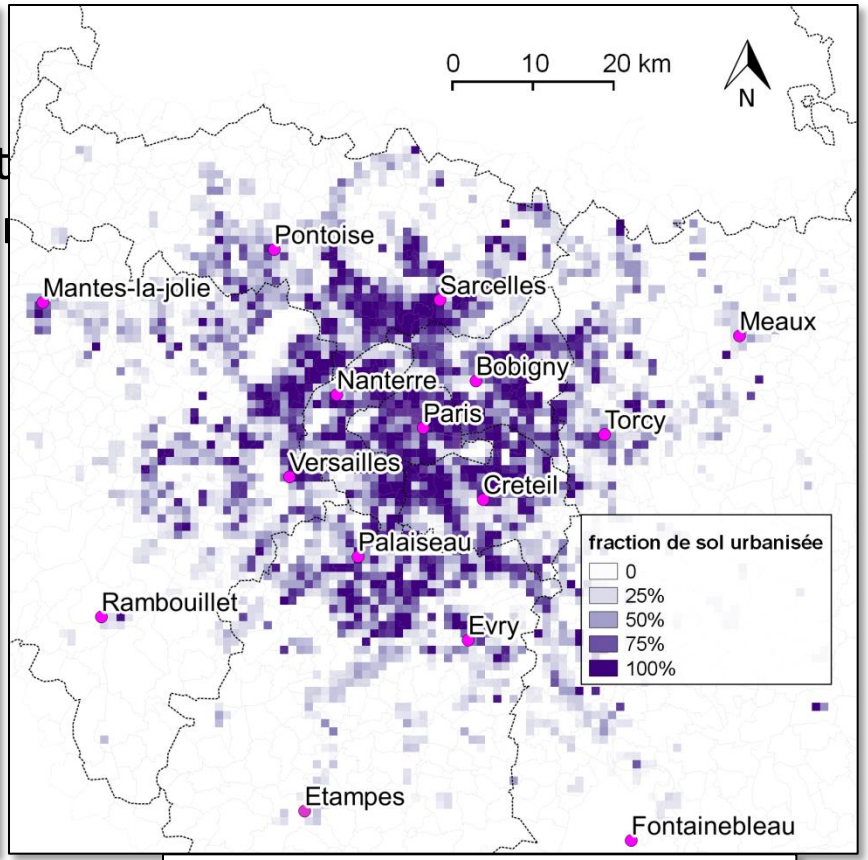
First results (work in progress)

- We compare 2 scenarios



2008 : REAL SITUATION



2008 : DENSIFYING ONLY
1960 EXISTING URBAN AREAS

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First results (work in progress)

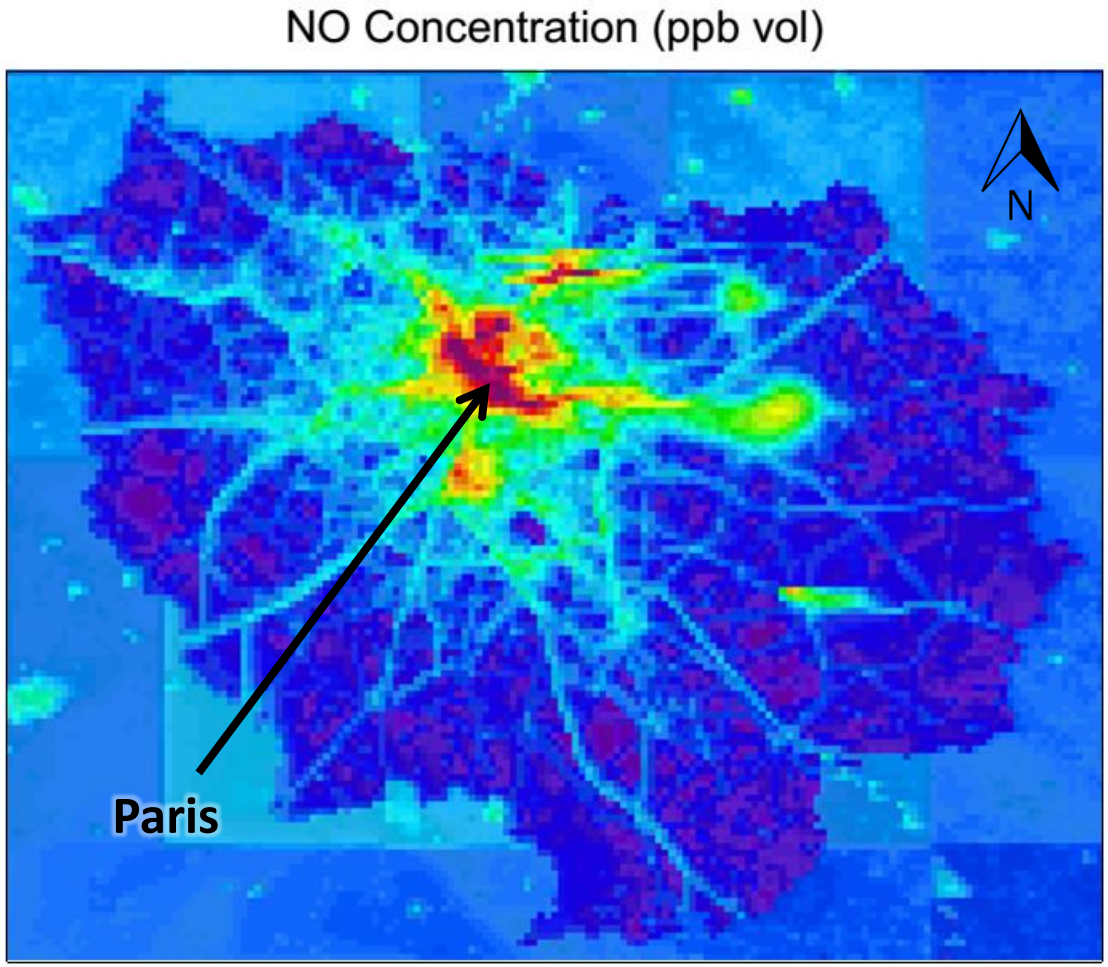
- **We compare 2 scenarios**
  - Paris today (**reference** case)
  - **Compact scenario**: Paris, as if strong land-use policies had been implemented since 1960 to promote a compact city development

- **Apart from transport related emissions, all emissions are the same**

- **Simulation for the weather of the first week of January 2009**
  - NB: we only simulate emissions due to commuting trips
  - We make here no difference between week days and weekend

First results (work in progress)

- **NO concentration in the *reference* scenario**



7 a.m. at the end of a week corresponding to the first week of January 2009

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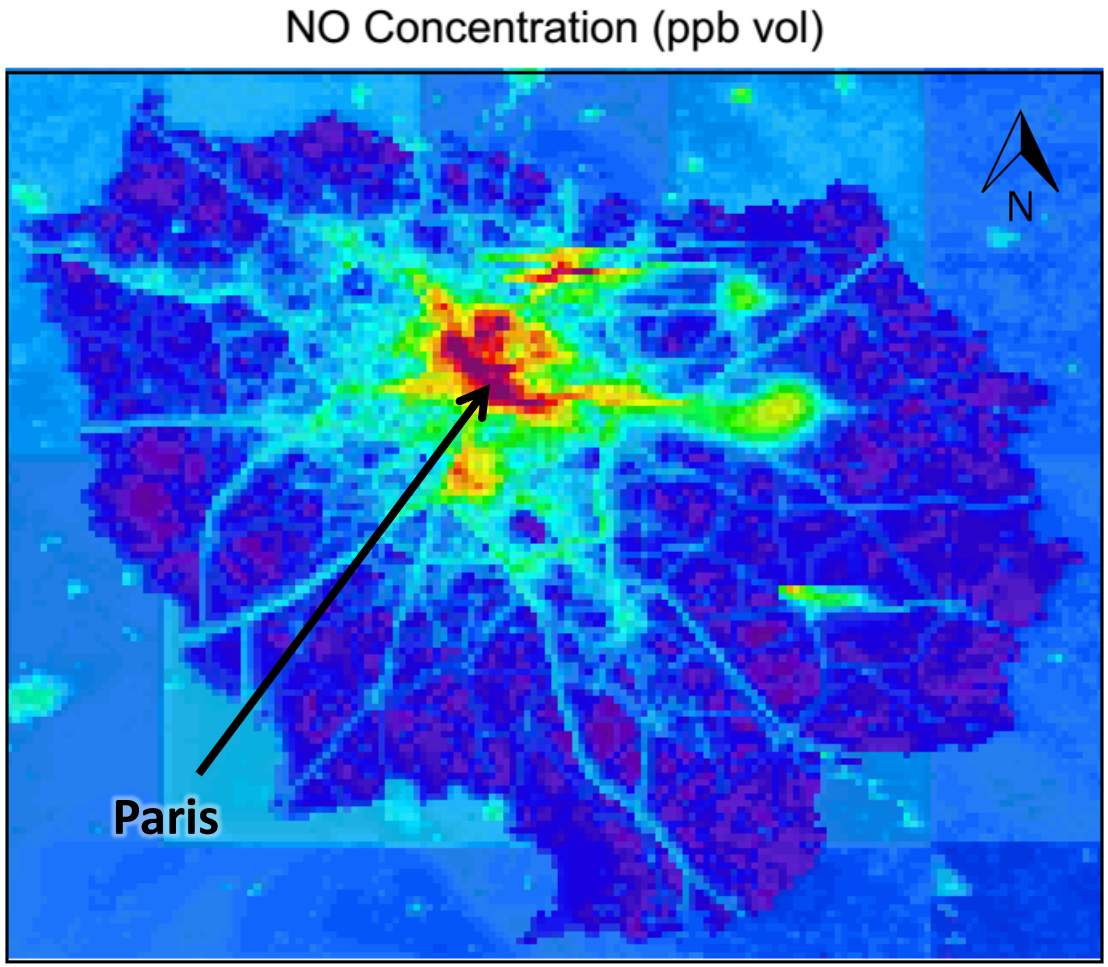
First results (work in progress)

- **NO concentration in the *compact* scenario**



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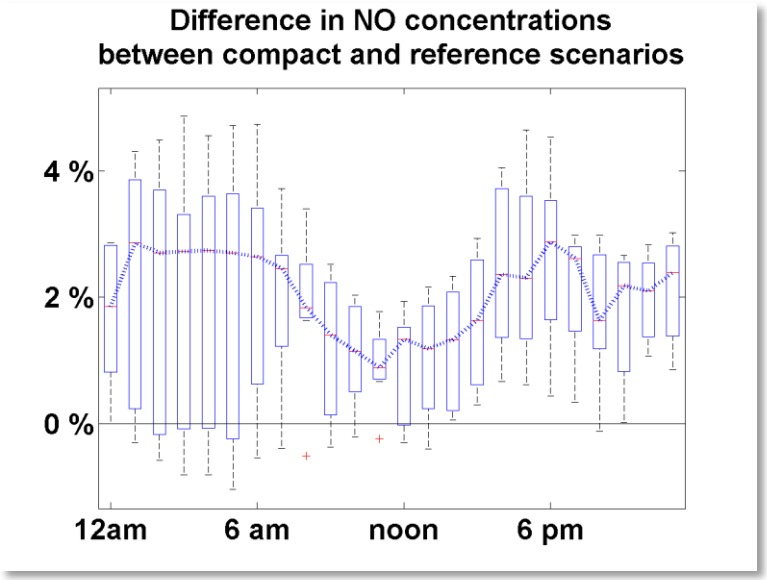

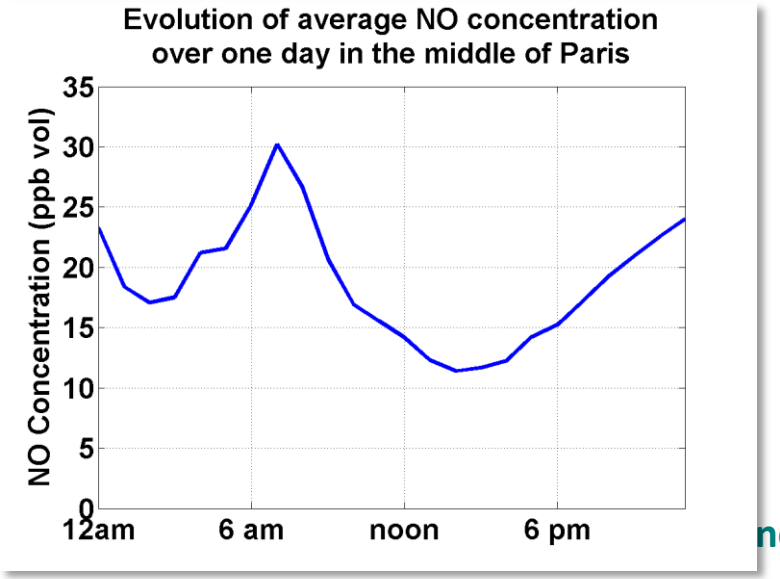

- In the middle of the city, NO concentration appears higher, in average, in the compact scenario
- But the difference is very small…
- *Work in progress ! (issue with congestion ?...)*

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