Evaluation of the simulated spatio-temporal variability of the anthropogenic heat flux in the agglomeration of Toulouse, France

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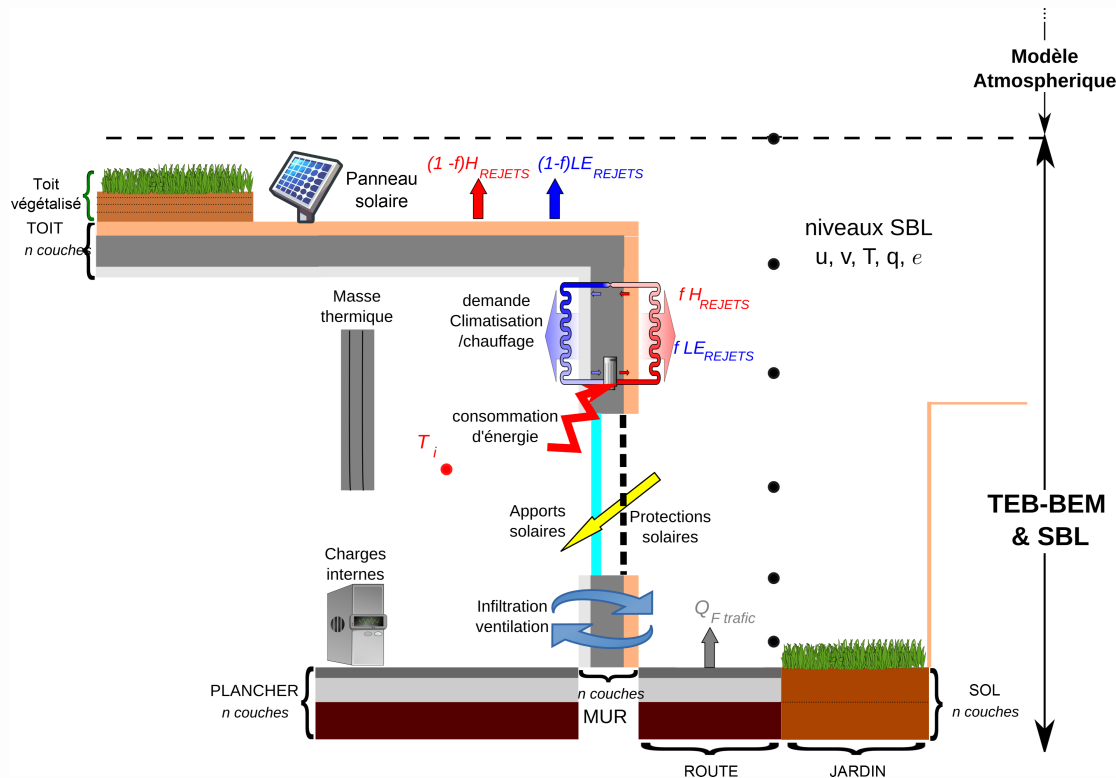
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Urban Canopy Parametrisation TEB (Masson, 2000)

- Surface energy balance in urban areas
- Coupled with Building Energy Model (BEM; Bueno et al., 2012)

Building energy demand
- prognostic variable of BEM
- depends on use and behaviour
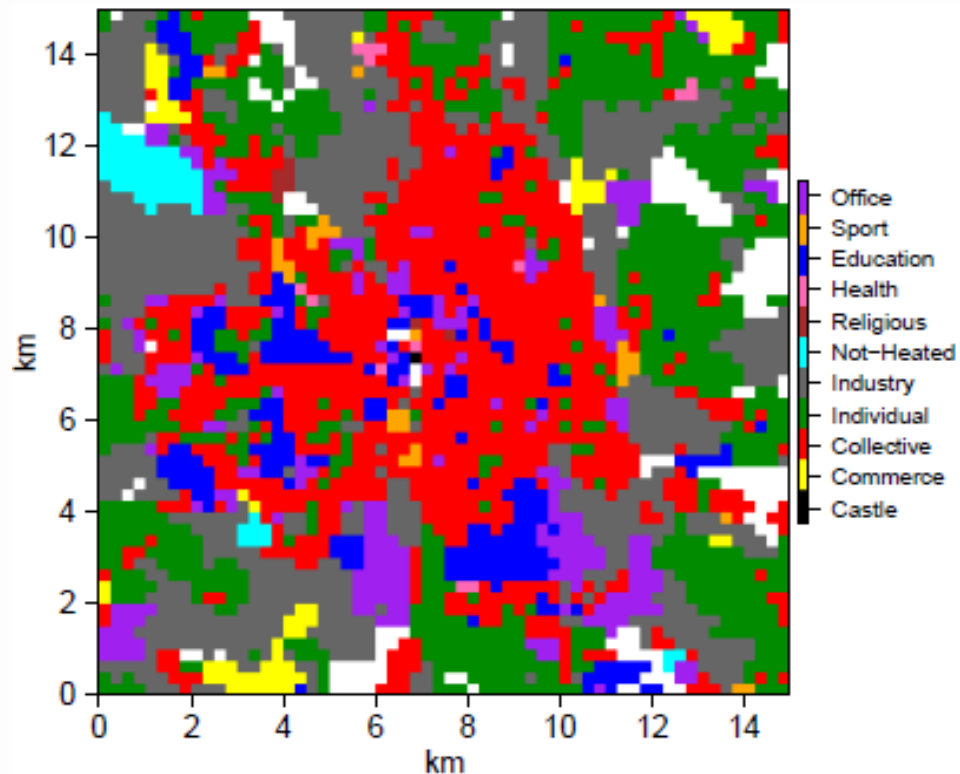- is it well simulated?

Outline

- **Variety of building use and human behaviour in France**

- **Parametrisation of use and behaviour in TEB**

- **Evaluation for the CAPITOUL campaign**
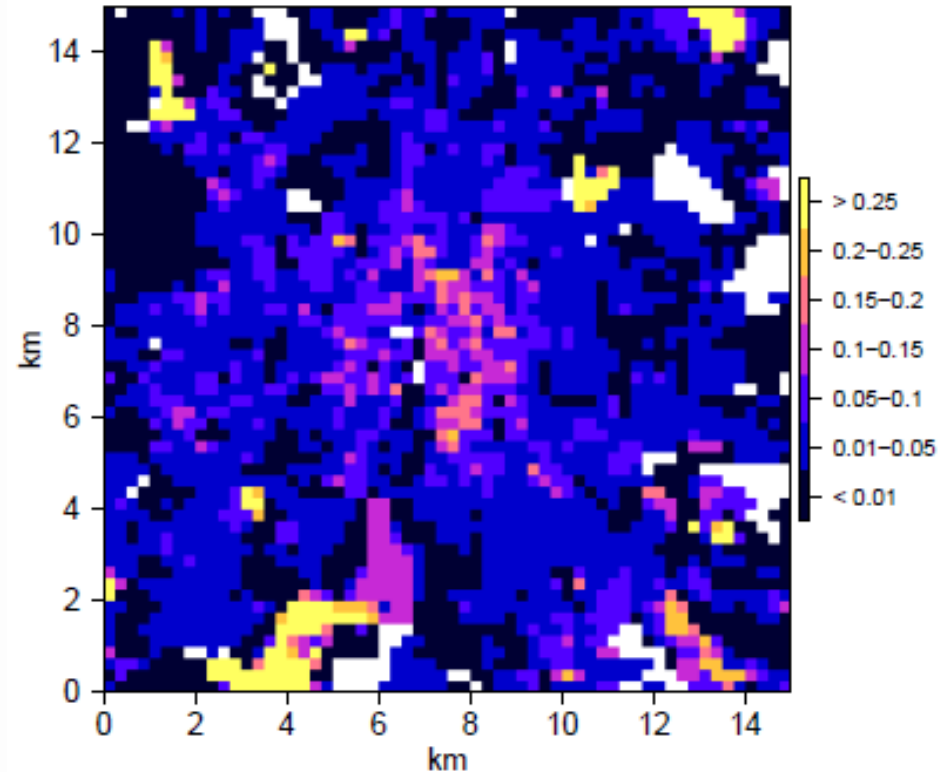
- **Conclusions and outlook**

Variety of building use in France

- **French administrative datasets**
  - Digital basic map BD TOPO (IGN)
  - Population density (INSEE)

Dominant use, Toulouse

Legend:
- Office
- Sport
- Education
- Health
- Religious
- Not−Heated
- Industry
- Individual
- Collective
- Commerce
- Castle

Commercial fraction, Toulouse

Legend:
- > 0.25
- 0.2−0.25
- 0.15−0.2
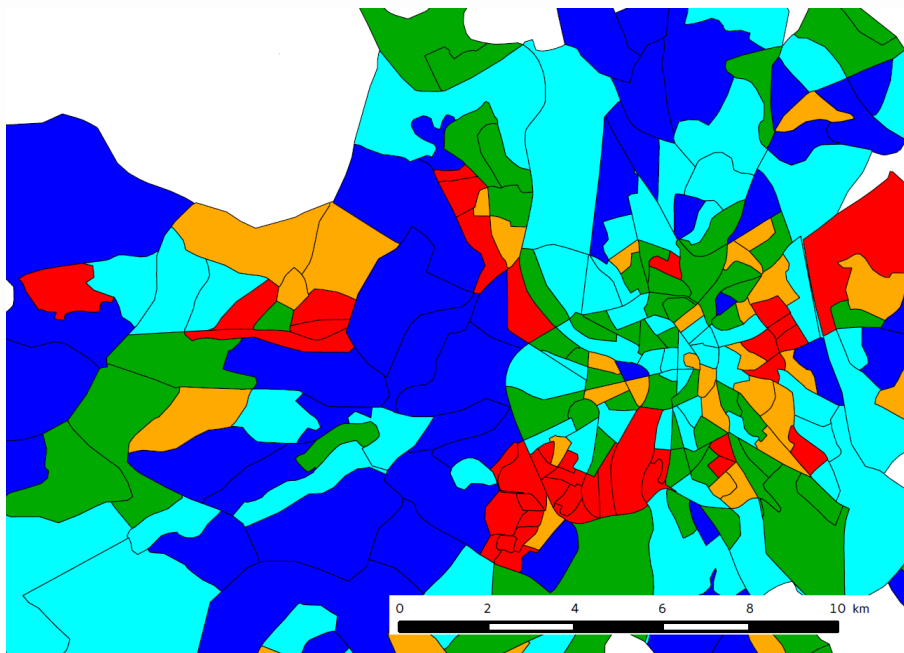- 0.1−0.15
- 0.05−0.1
- 0.01−0.05
- < 0.01

# Variety of energy-related human behaviour

- **Methodology**
  - Basic data: surveys on behaviours, census of French population
  - Statistical model links surveys and census data

- **Results: behavioural indicators**
  - Regulation Tendency → f (type and combustible of heating system, age)
  - Equipment-Intensity-of-Use → f (#people, floor area, age)

Percentage of households with high Regulation Tendency for Toulouse

🟥	0% - 20%
🟧	20% - 40%
🟩	40% - 60%
🟦	60% - 80%
🟦	80% - 100%

Parametrisation of use and behaviour in TEB
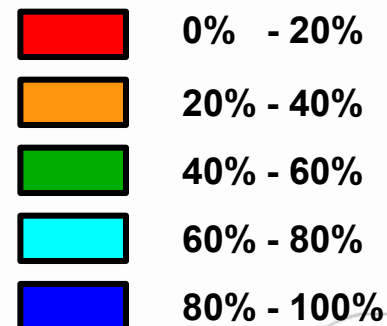
- **Methodology**
  - Multiple calls of BEM for different uses and behaviours
  - Aggregation of fluxes towards building envelope and street canyon
  - Avoids multiple calls of TEB

- **Assumption: differences in use and behaviour have a higher influence on the indoor than the outdoor thermal conditions**

Parametrisation of use and behaviour in TEB
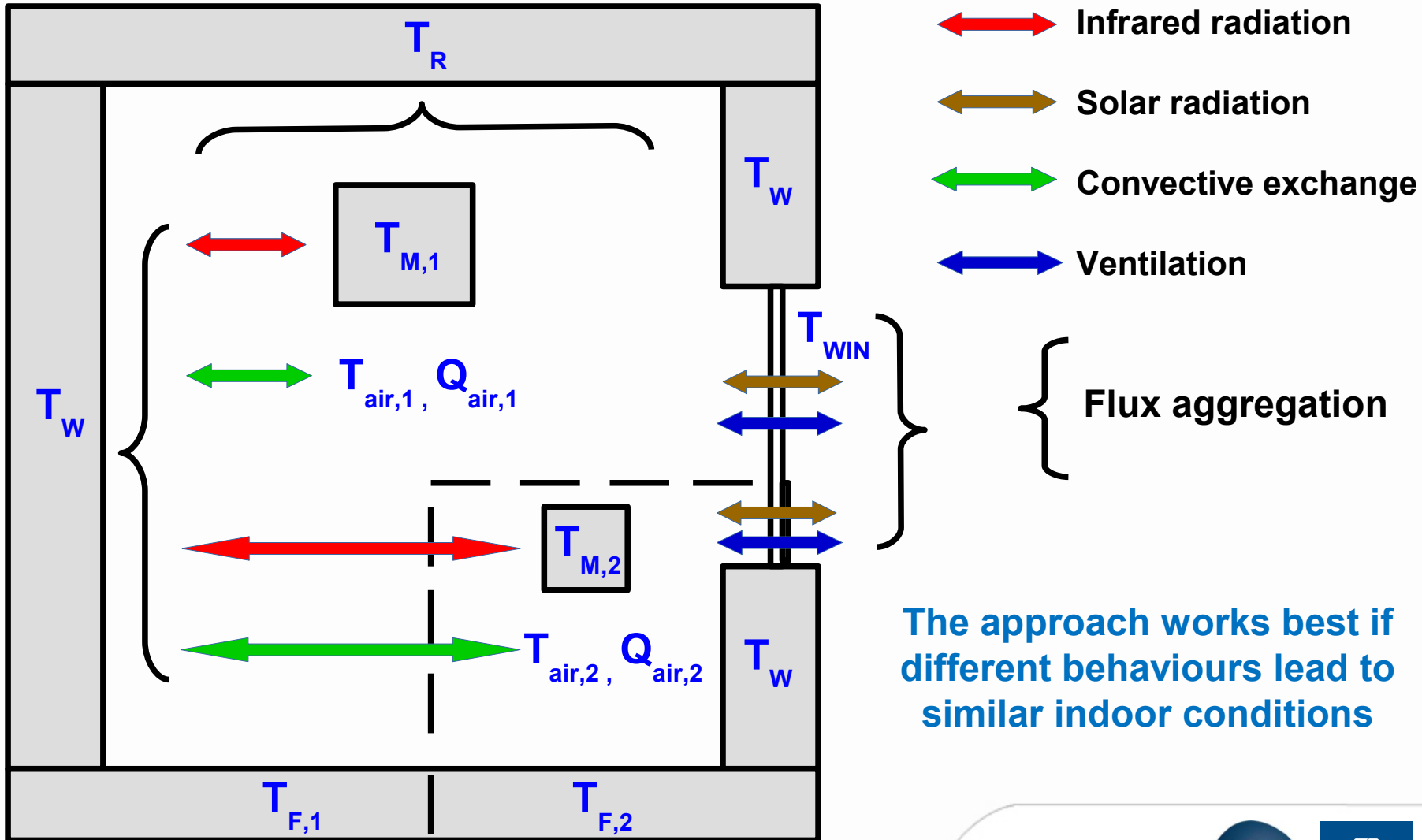
Initialisation of behaviour-related parameters in TEB for simulations in France

- **6 types of use/behaviour per building**
  - Non-heated, office, commercial, 3 design temperatures for heating
  - Design temperatures for heating based on Regulation Tendency
  - Internal heat release based on Equipment-Intensity-of-Use

- **Meteorology-dependency of behaviours**
  - Smooth formula for ventilation $\rightarrow f(T_{int}, T_{ext})$
  - Smooth formula for shading $\rightarrow f(R_{sol})$

Evaluation for the CAPITOUL campaign

- **Does TEB capture the spatio-temporal variability of building energy consumption?**

- **What are the benefits of more detailed representation of use and behaviours?**
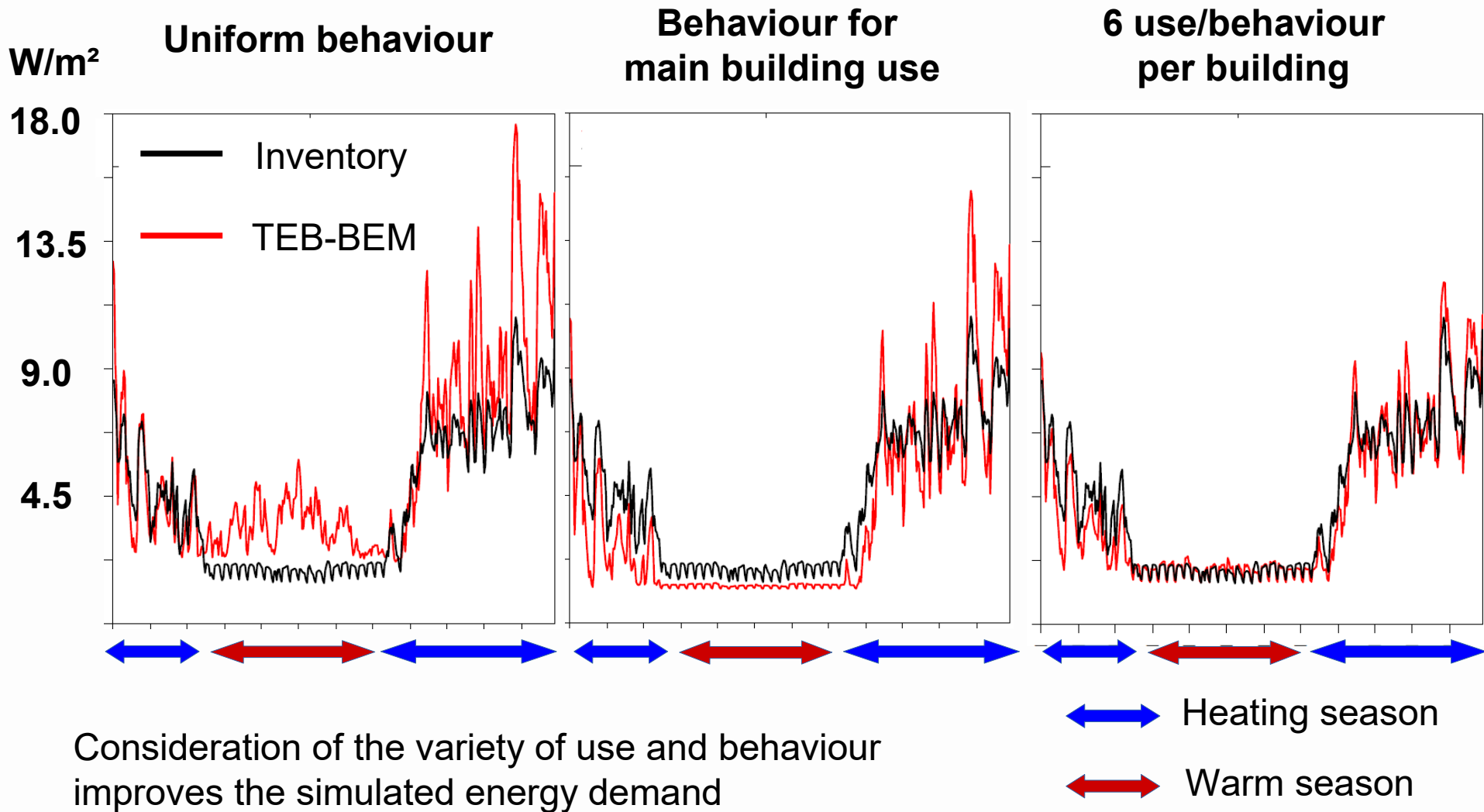
Setup of TEB simulation

- **Domain of investigation is Toulouse (southern France)**
- **March 2004 to March 2005**
- **Meteorological forcing by mast observation**
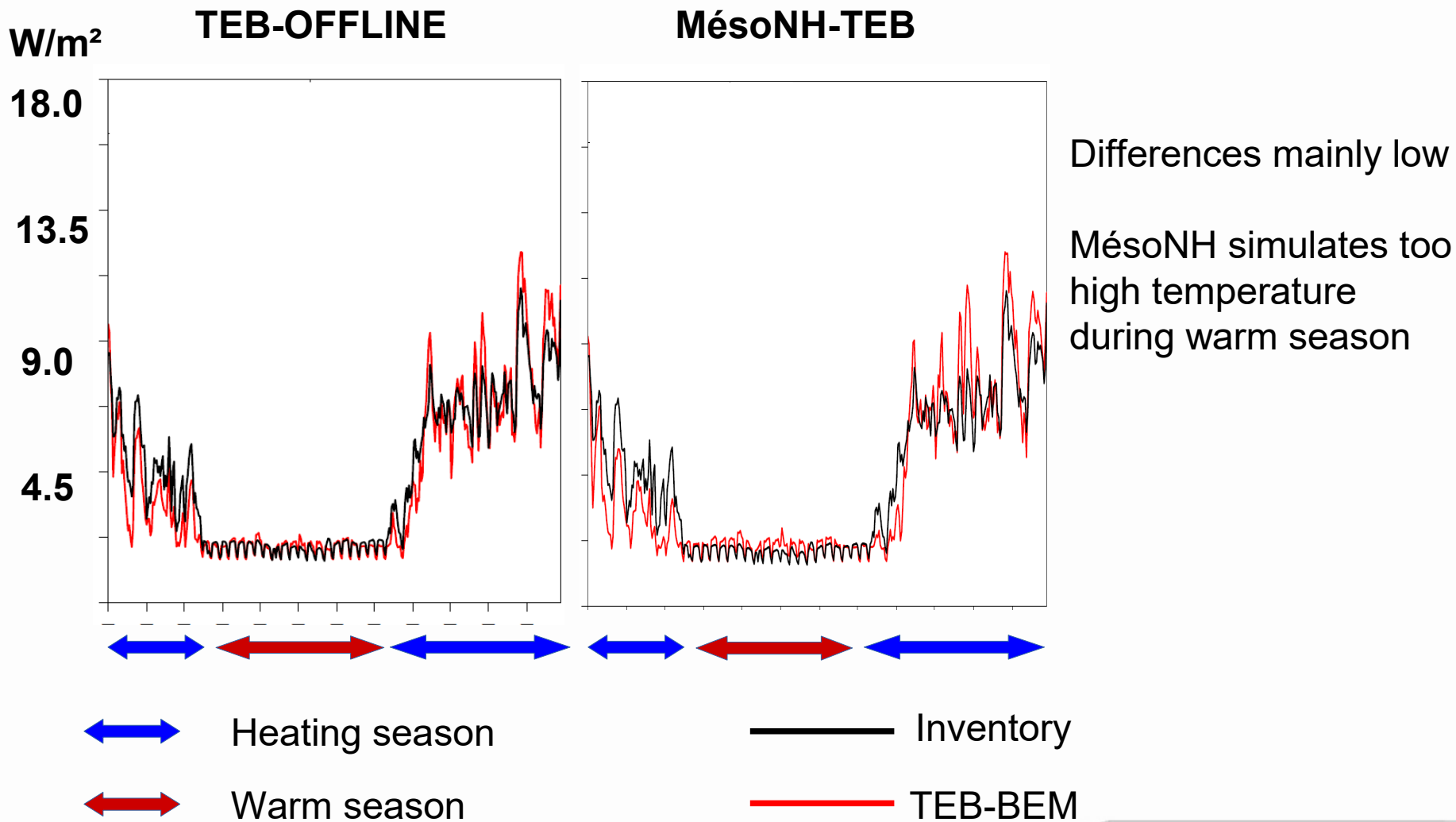- **Urban morphology and architecture based on MApUCE database**

Inventory of building energy consumption

- **Basic data (Pigeon et al., 2007)**
  - 10-minute values of electricity consumption
  - Daily values of gas consumption
  - Urban heating, fuel, and wood consumption estimated based on census

- **Spatial disaggregation (similar to Pigeon et al., 2007)**
  - Average consumption per heating system type
  - Floor area of residential and tertiary buildings

- **Uncertainty of inventory**
  - About 10% for the domain-averaged energy consumption
  - Spatial consumption can be highly uncertain at single grid points

Domain-averaged energy consumption
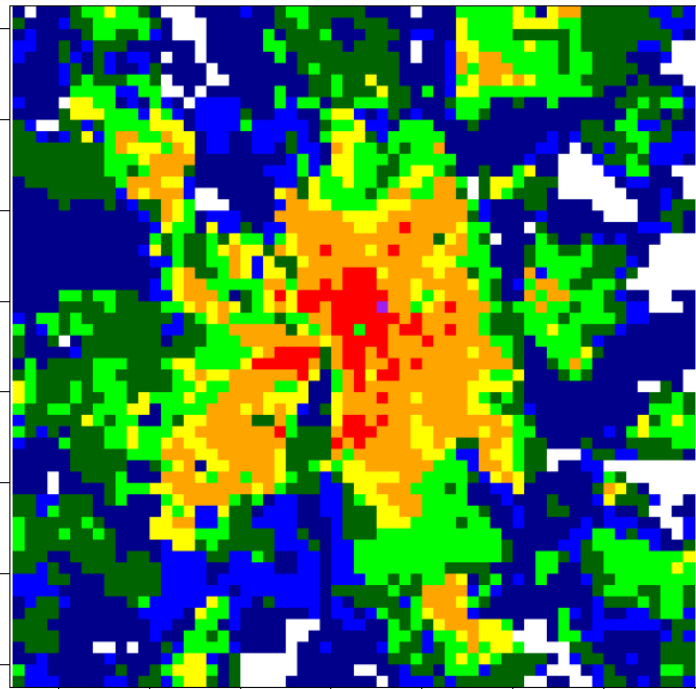# - Influence of behavioural model. complexity

Uniform behaviour   **Behaviour for main building use**   **6 use/behaviour per building**

Consideration of the variety of use and behaviour improves the simulated energy demand

Domain-averaged energy consumption
- Influence of coupling

W/m²

TEB-OFFLINE   **MésoNH-TEB**

Differences mainly low

MésoNH simulates too
high temperature
during warm season

↔ Heating season   ▬▬ Inventory

↔ Warm season   ▬▬ TEB-BEM

Spatial distribution of building energy consumption averaged over the winter season

Simulation

Inventory

15 km

15 km

Legend:
- > 100 W/m²
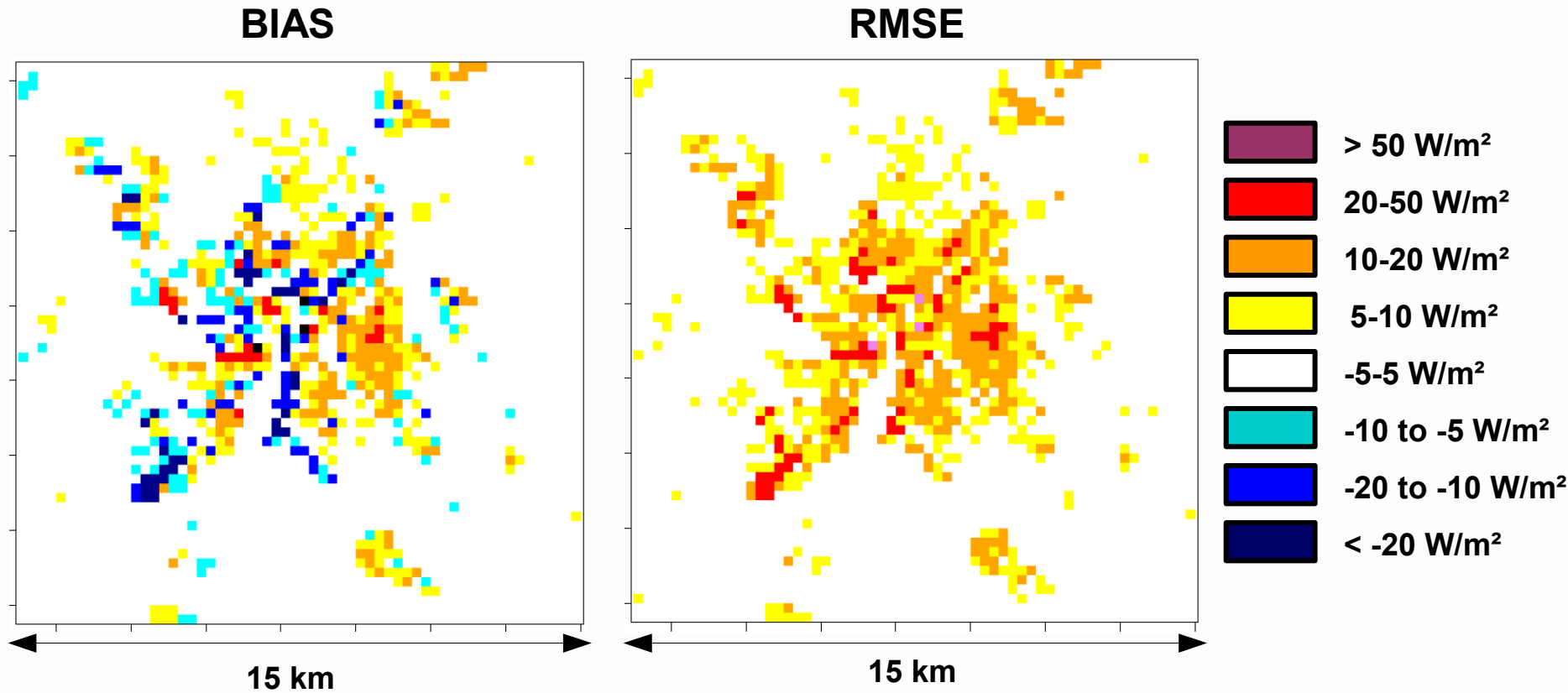- 50-100 W/m²
- 20-50 W/m²
- 10-20 W/m²
- 5-10 W/m²
- 2-5 W/m²
- 1-2 W/m²
- 0-1 W/m²
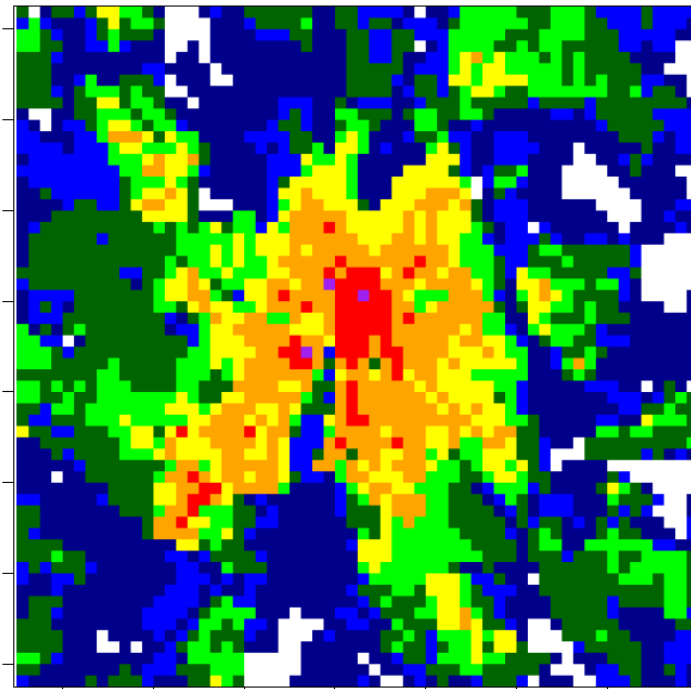
Spatial pattern represented well

Spatial distribution of building energy consumption averaged over the winter season

BIAS

RMSE

Legend:
- > 50 W/m²
- 20-50 W/m²
- 10-20 W/m²
- 5-10 W/m²
- -5-5 W/m²
- -10 to -5 W/m²
- -20 to -10 W/m²
- < -20 W/m²

15 km

15 km

BIAS mostly explainable by the building construction period

The simulated fluxes might be partly better than the inventory

Conclusions and outlook

- **TEB enhanced to represent the variety of use and behaviours**

- **Building energy demand for CAPITOUL captured well, but**
  - Good knowledge on urban morphology, architecture, behaviours
  - Variety of building use and human behaviours needs to be considered
  - Uncertainties on building refurbishment and heating system capacity

- **Outlook**
  - Simulation of urban climate and building energy consumption for a variety of French cities
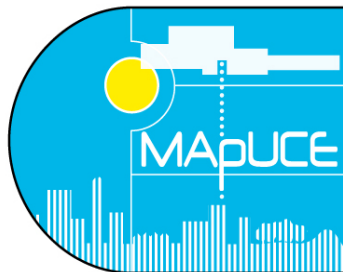
GAME
FNAU
IRSTV
LATTS
LIENSs
LIEU
LISST
LRA

References

- **Bueno, B., G. Pigeon, L.K. Norford, K. Zibouche and C. Marchadier, 2012:** Development and evaluation of a building energy model integrated in the TEB scheme. Geoscientific Model Development, 5, 433-448.

- **Masson, V., 2000**: A physically-based scheme for the urban energy budget in atmospheric models. Boundary-Layer Meteorology, 94, 357-397.

- **Masson, V., L. Gomes, G. Pigeon, C. Liousse, V. Pont, J.-P. Lagouarde, J. Voogt, J. Salmond, T.R. Oke, J. Hidalgo, D. Legain, O. Garrouste, C. Lac, O. Connan, X. Briottet, S. Lachérade and P. Tulet, 2008:** The Canopy and Aerosol Particles Interactions in TOulouse Urban Layer (CAPITOUL) experiment. Meteorology and Atmospheric Physics, 102, 135-157.

- **Pigeon, G., D. Legain, P. Durand and V. Masson, 2007**: Anthropogenic heat release in an old European agglomeration (Toulouse, France). International Journal of Climatology, 27 (14), 1969-1981.