Benefits of explicit urban parameterization in regional climate modeling to study climate and city interactions

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Modeling of urban climate
Different approaches

For most of meteo/climate models:

- Cities do not exist and urban processes are not modeled (= vegetation)
- Cities are described as rock covers with high roughness and treated by SVAT models
  - Imperviousness
  - Surface heating capacities at daytime
  - Roughness effect on airflow

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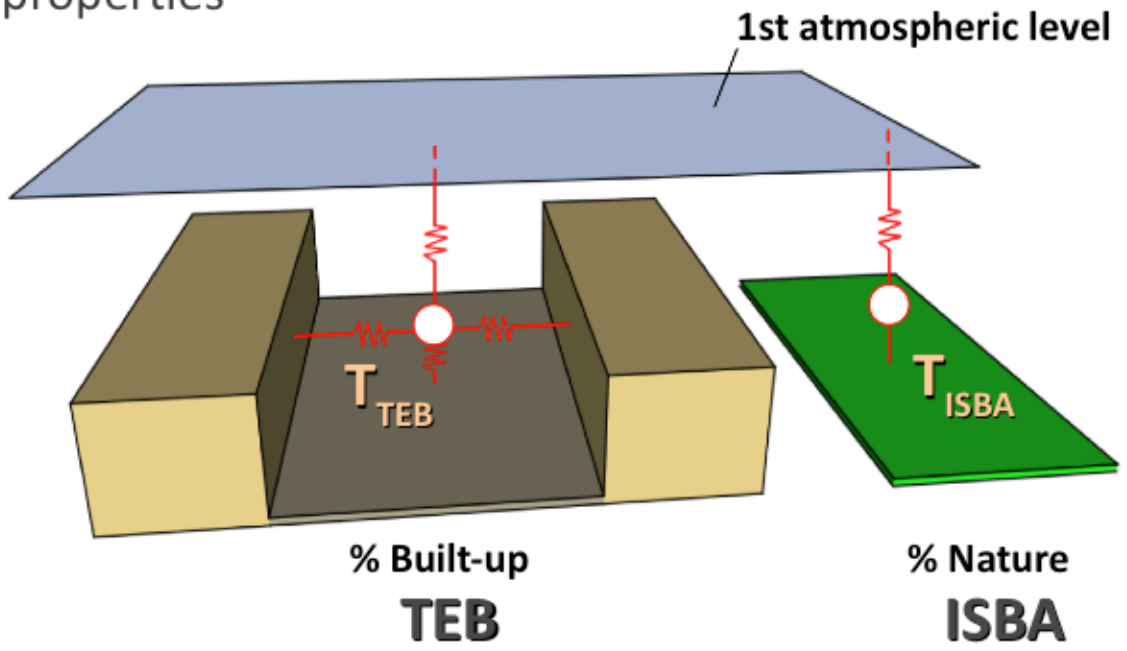
But not account for radiative effects related to 3D urban geometry

- **2000s : new generation of urban canopy models**

Modeling of urban climate
Town Energy Balance (TEB) model (Masson 2000)

- Concept of mean urban canyon (Oke 1982)
  - Urban elements: roof, road, walls
  - Mean morphological characteristics
  - Mean radiative and thermal properties

Source : Toulouse centre-ville, Google Earth

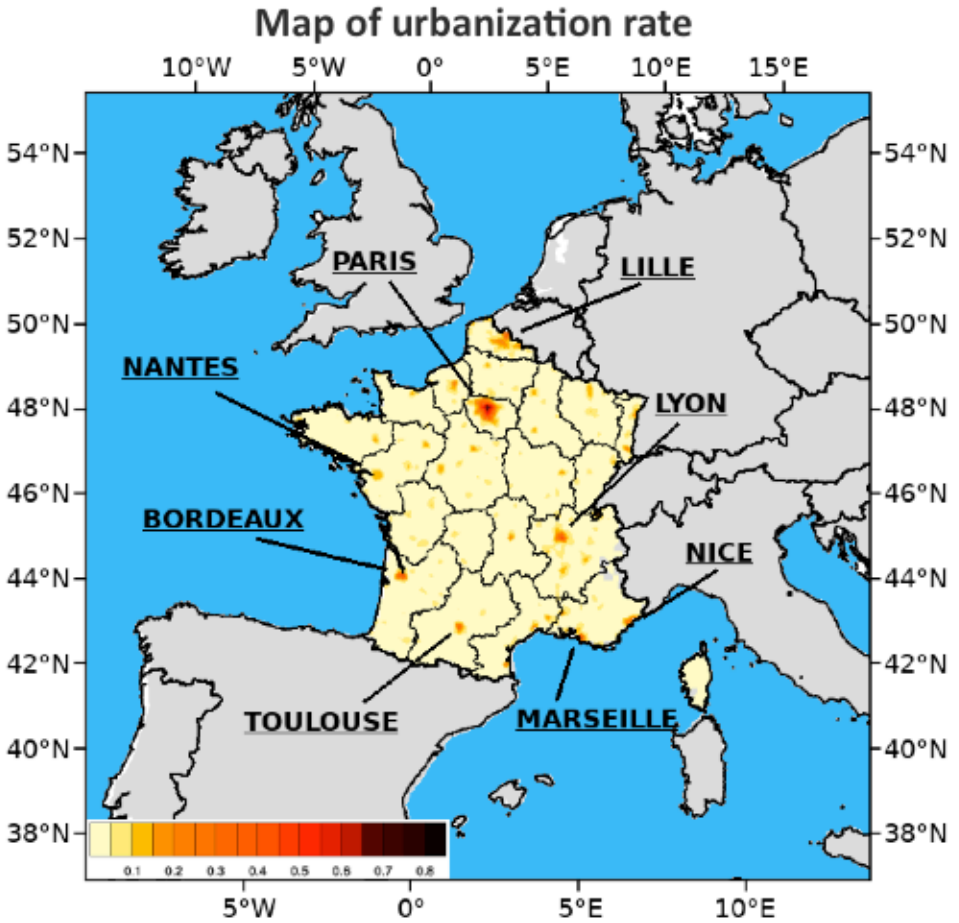


- Physical processes including :
  - Radiative and energetic exchanges
  - Water and snow
  - T,HU,U inside canyon

Regional Climate Model simulations
Configuration

ALADIN-Climate regional climate simulations over France for past period

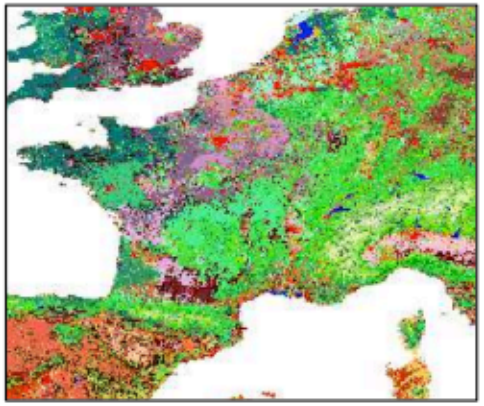
- Version: limited-area model ALADIN-Climate V6
- Spatial domain: Metropolitan France
- Horizontal resolution of 12 km
- Vertical grid: 92 levels
- Simulation period: 1980-2009
- Lateral boundary conditions: ERAinterim reanalyses (80 km resol)



Regional Climate Model simulations

Configuration

1-km ECOCLIMAP v2



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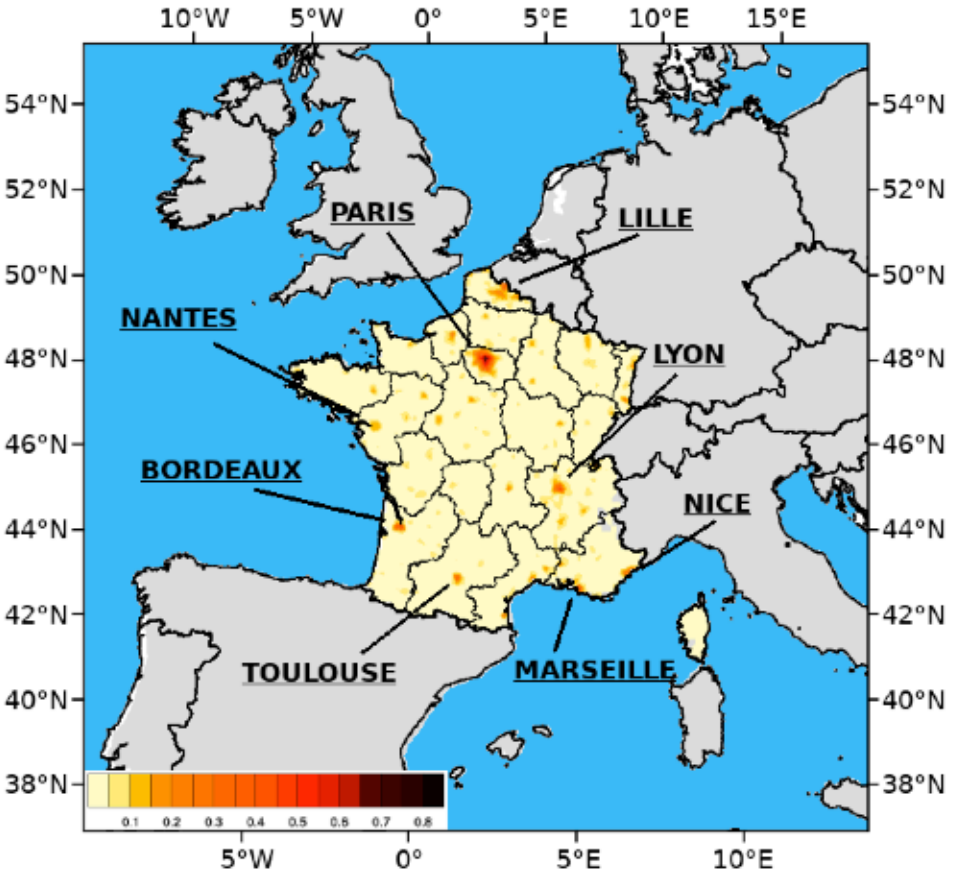
SURFEX land surface modeling system

- ISBA for natural soils and vegetation
- TEB for urban areas
- Land surface covers and properties defined with ECOCLIMAP v2 database
  - 3 % of France is « urban »

Map of urbanization rate



Sensitivity experiments

Sensitivity analysis on representation of urban areas and urban processes

- Exp **CITY** Urban areas explicitely modeled by **activating TEB in SURFEX**
- Exp **ROCK** Urban areas modeled as **rock covers with high roughness**
- Exp **VEG** Urban areas replaced by **local vegetation** and modeled with ISBA

1) **Evaluation of default configuration** (**ROCK**)
by comparison with SAFRAN analyses (8-km resolution over France)

	Seasonal biases (mod - obs)			
	DJF	**MAM**	**JJA**	**SON**
Daily precip rate (mm day-1)	+0,23	+0,40	-0,41	-0,07
Incoming solar rad (W m-2)	+12,7	+34,0	**+40,7**	+23,1
Tmin (°C)	-1,12	-1,13	+0,09	-0,21
Tmax (°C)	+0,64	+0,42	**+2,79**	+1,31

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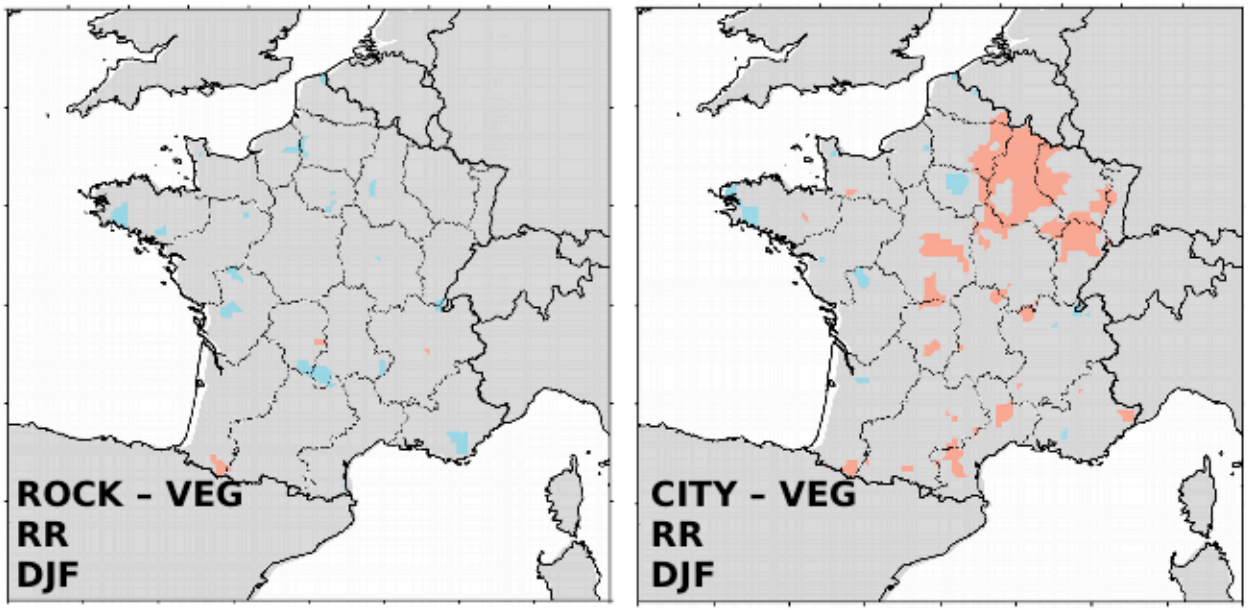
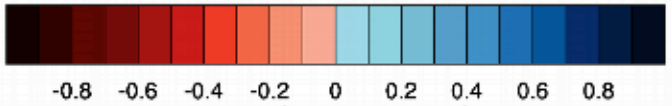
2) **Comparison of sensitivity experiments**
   for daily precipitation and near-surface temperatures
   - **ROCK vs VEG** >> What urban effects with simple approach ?
   - **CITY vs VEG** >> What benefit of sophisticated parameterization ?

Sensitivity experiment results

Daily precipitation rates





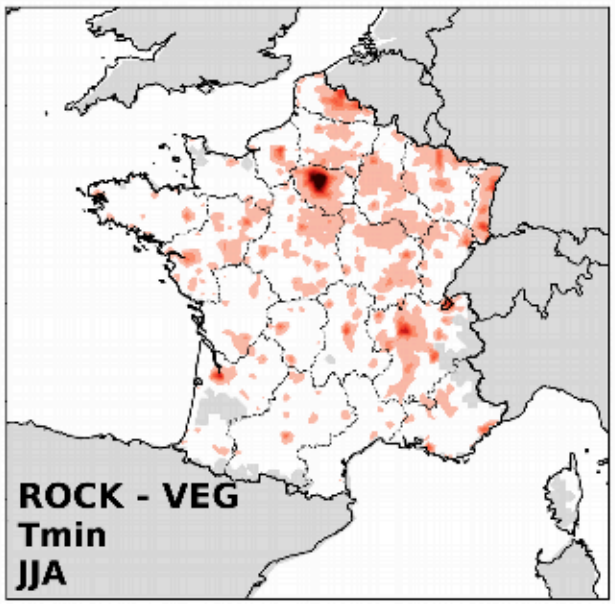
ΔRR (mm day-1)

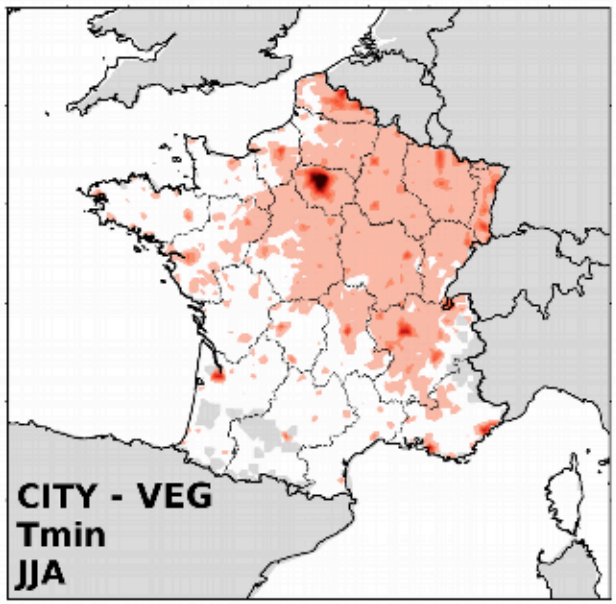
grey = non-significant difference

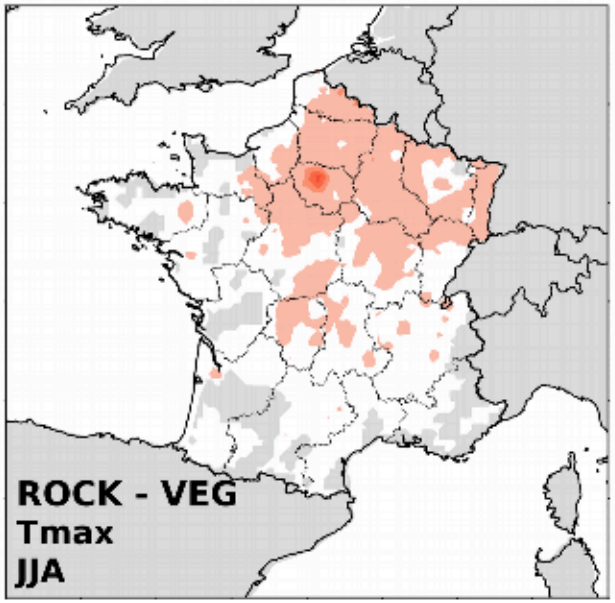
- **No significant impact on precipitation rates**

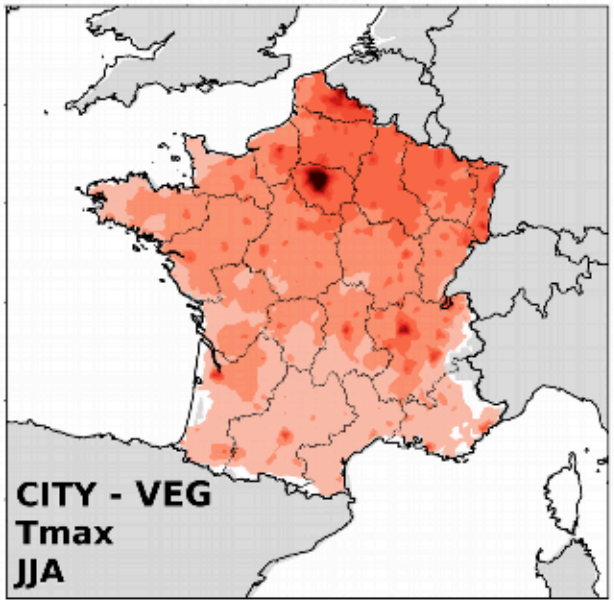
Sensitivity experiment results

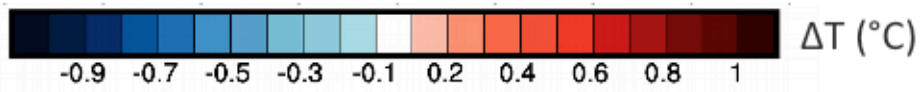
Near-surface temperatures











- **No significant impact on precipitation rates**
- **Significant impact on Tmin and Tmax** for all seasons
  - Maximum warming effect over urban areas
  - Regional impact of cities on temperature
  - Impact more pronounced for CITY than ROCK

Example for Paris

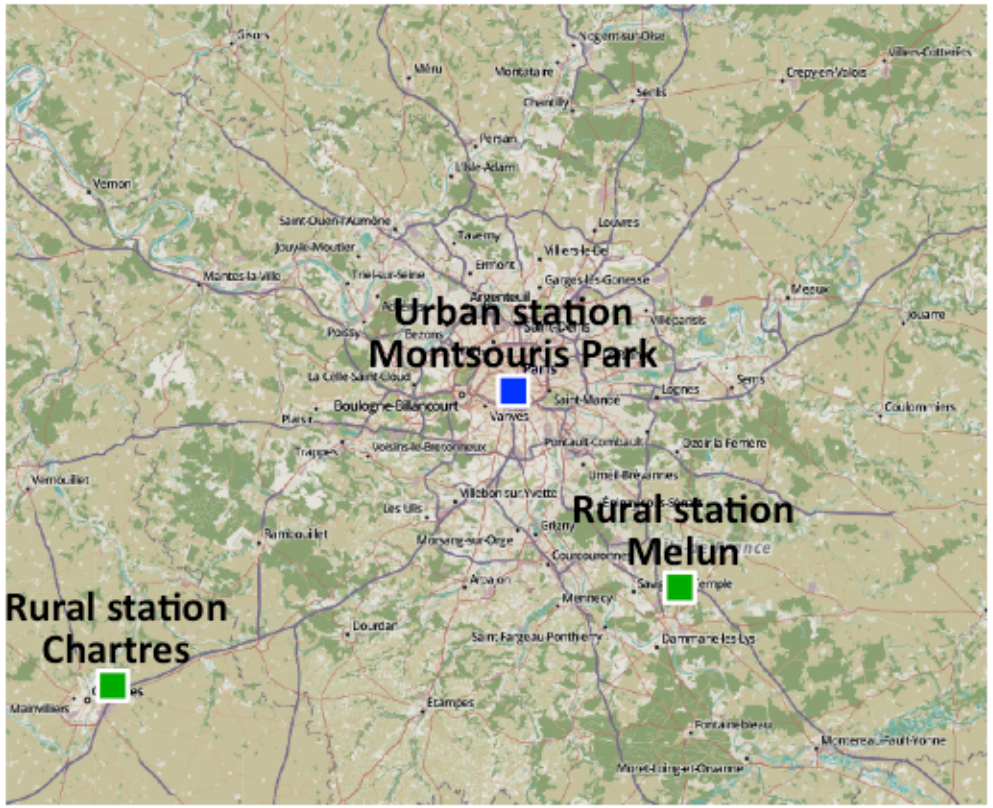
	JJA		DJF	
	Tmin	**Tmax**	**Tmin**	**Tmax**
CITY-VEG	**+1,5**	+0,7	**+1,3**	+0,7
ROCK-VEG	**+1,3**	+1,1	**+0,4**	-0,3

Urban heat island modeling
Evaluation for Paris area

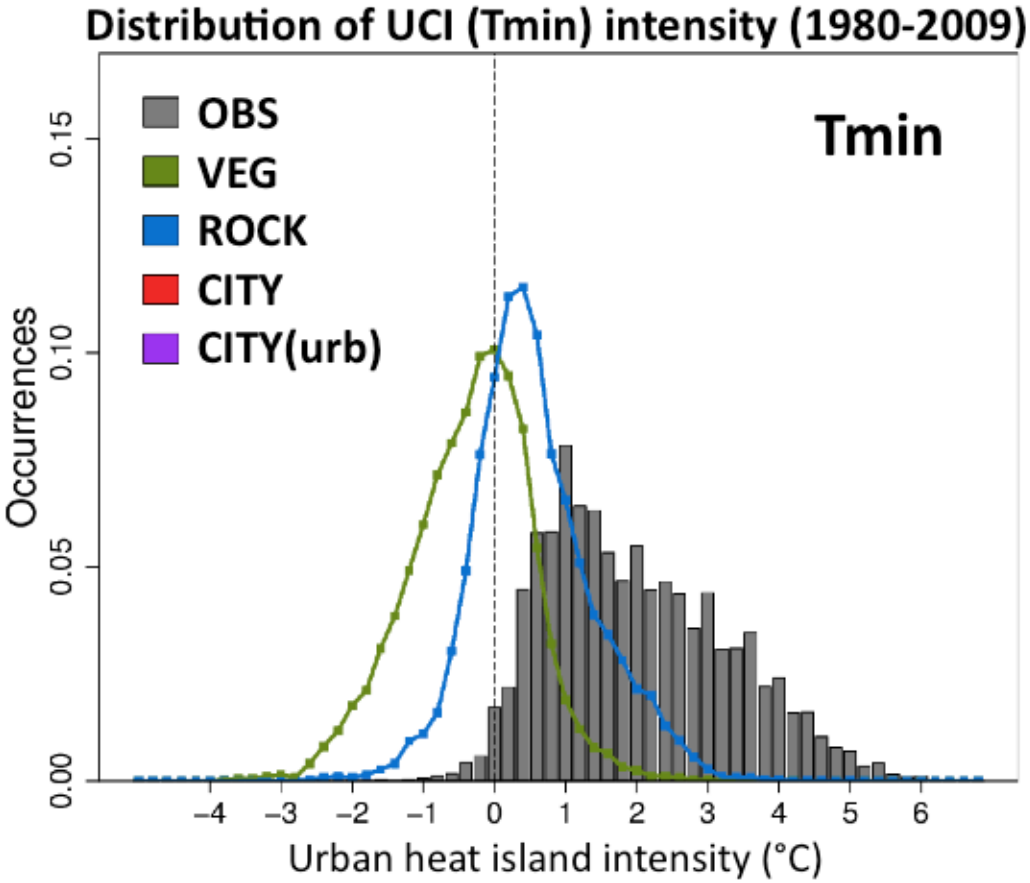
Evaluation of urban heat island modeling by comparison with long-term observation time series in Paris region

ICU = Turb - Trur$_{avg}$

ICU (°C)	OBS	VEG	ROCK
Avg	+2.1	-0.2	+0.7
Q99	+5.3	+1.8	+2.9



Source : https://www.geoportail.gouv.fr/carte



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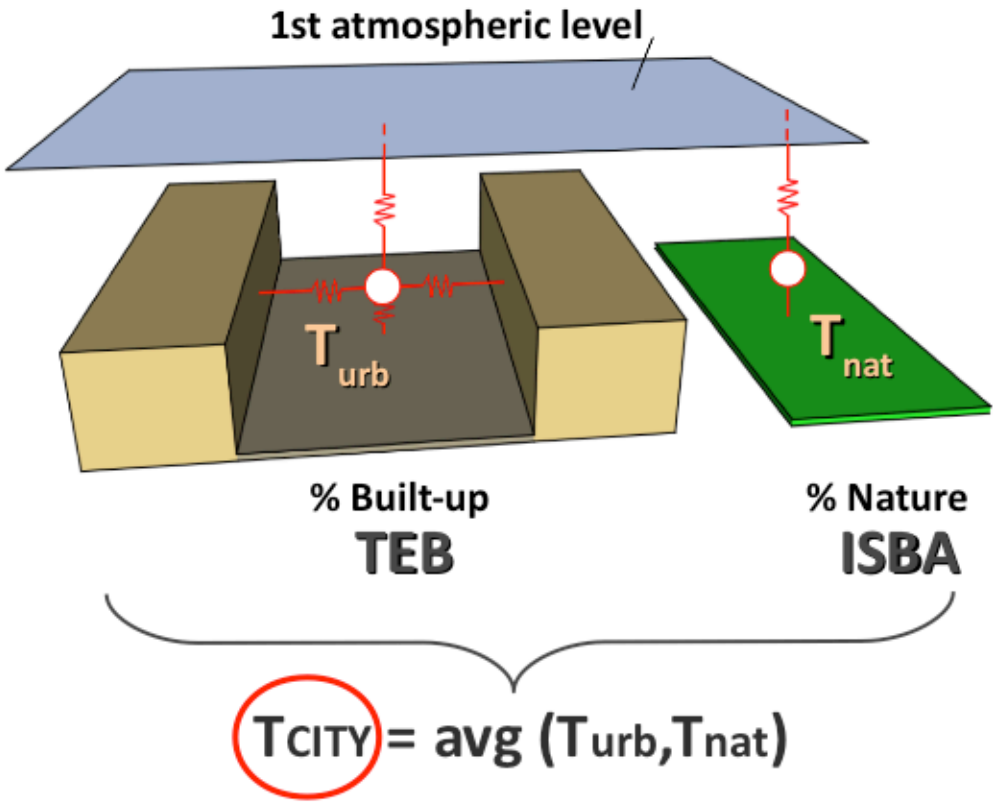

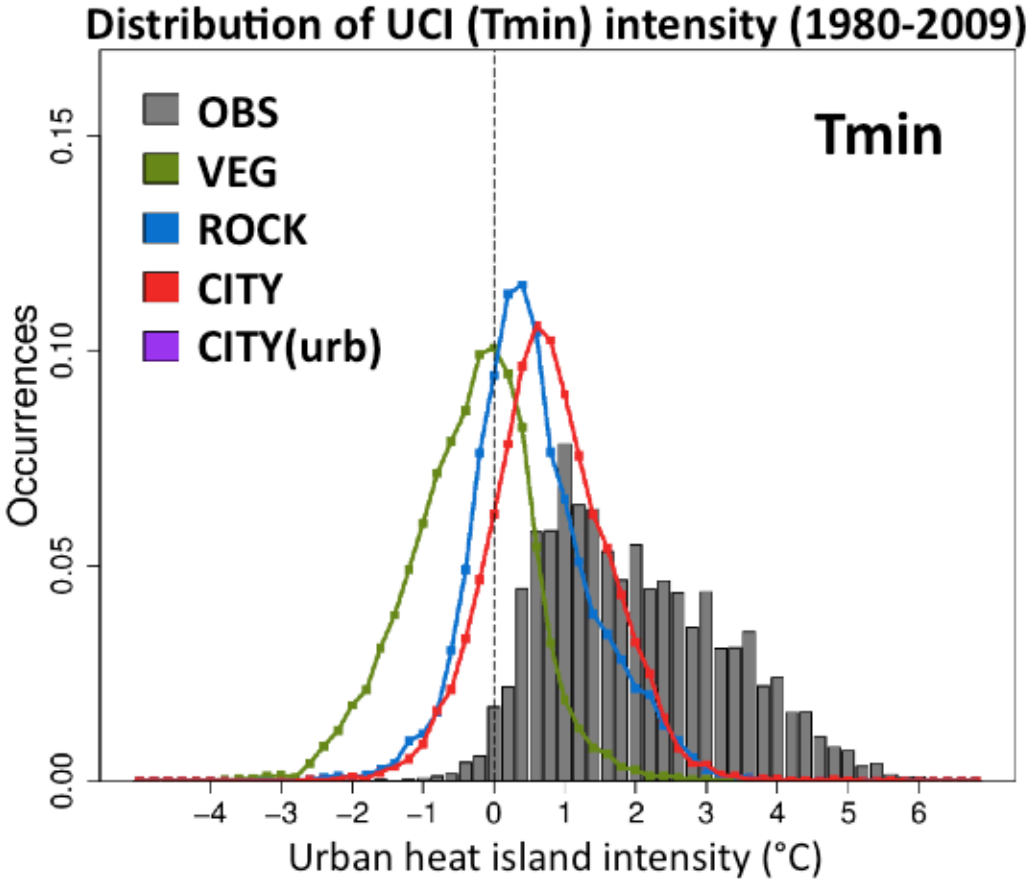

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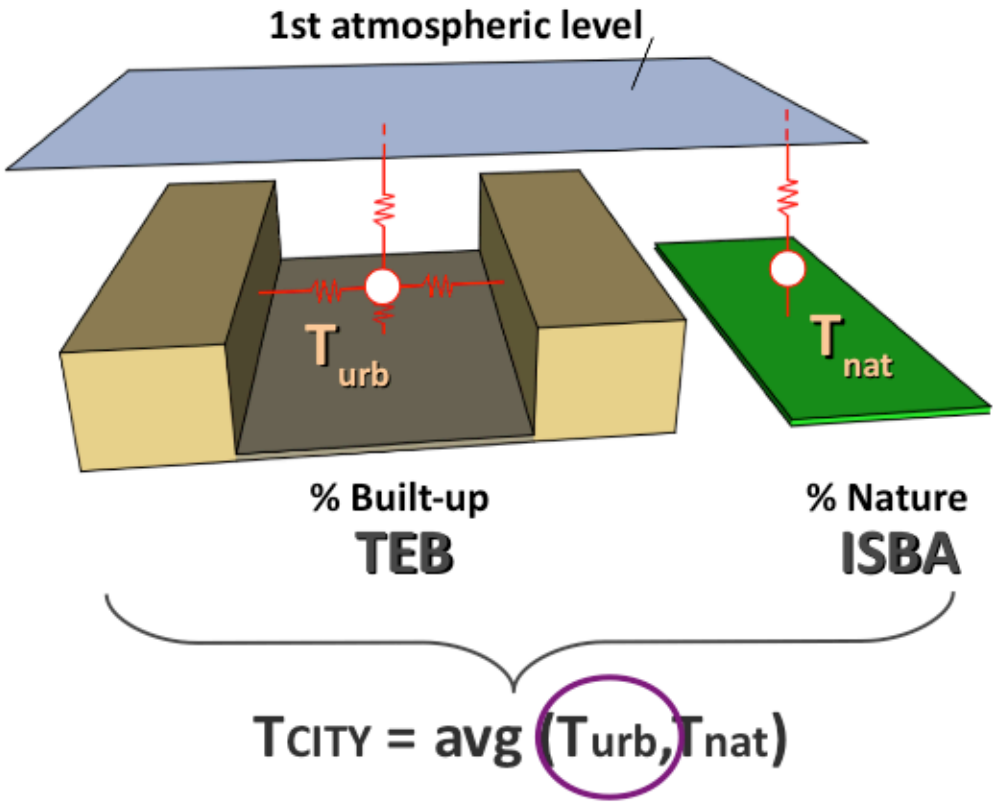

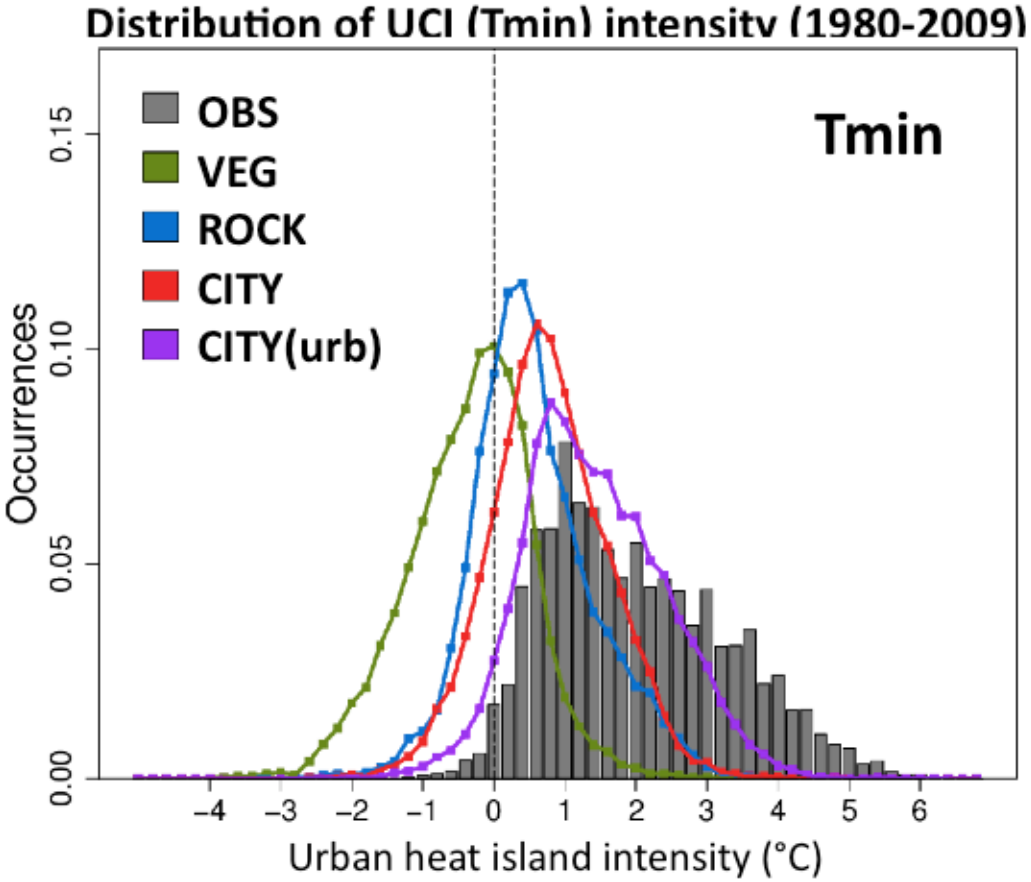

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Avg	**+0.5**	+0.3	+0.4	+1.1	+1.3
Q99	**+2.5**	+1.6	+2.1	+2.8	+3.6

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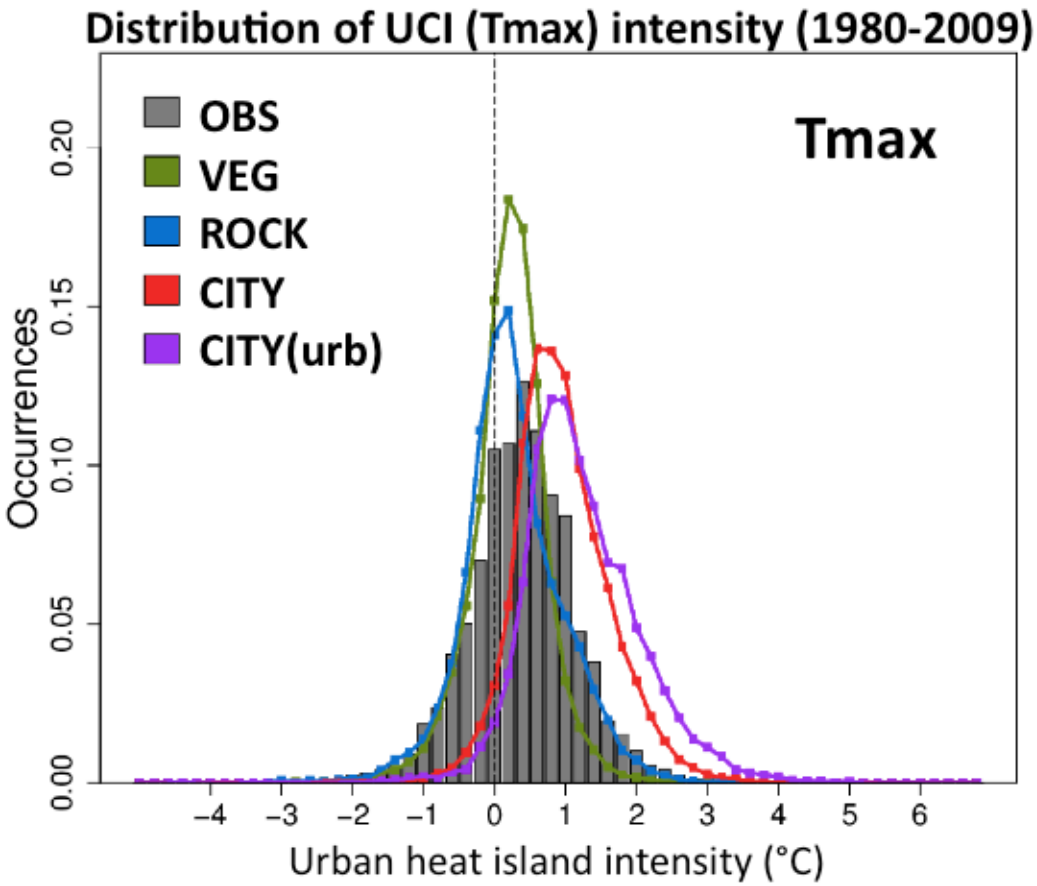
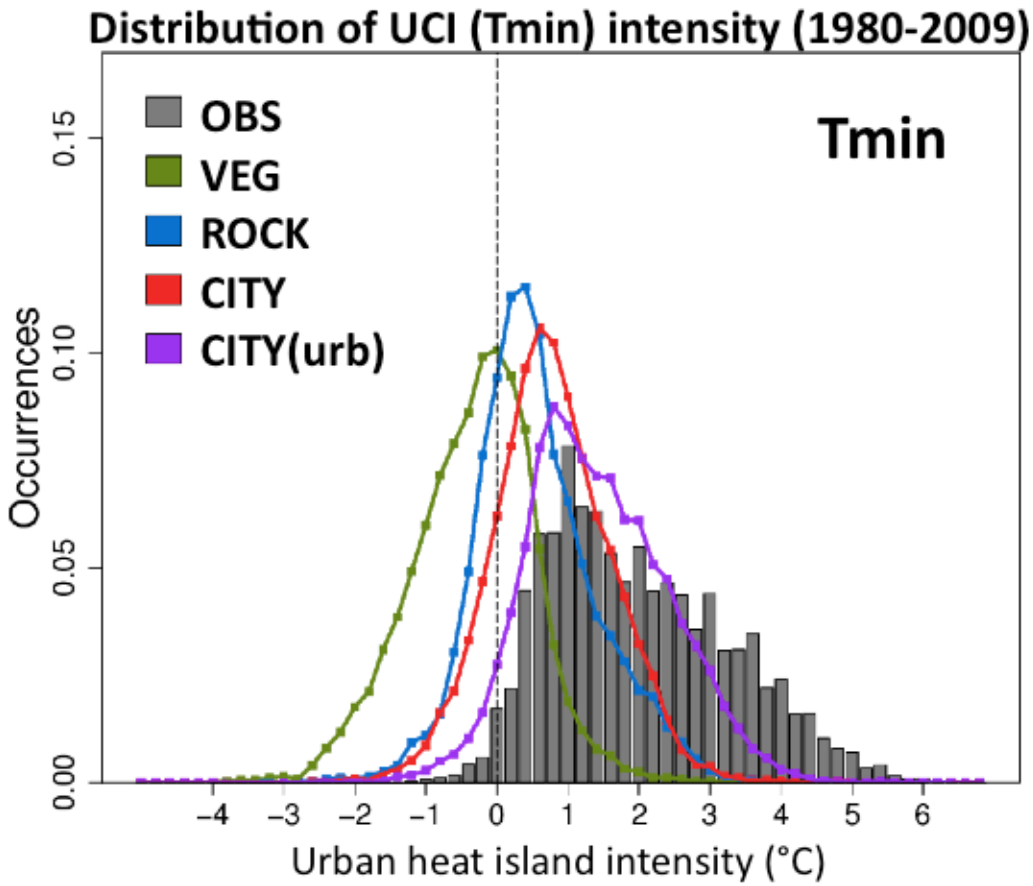
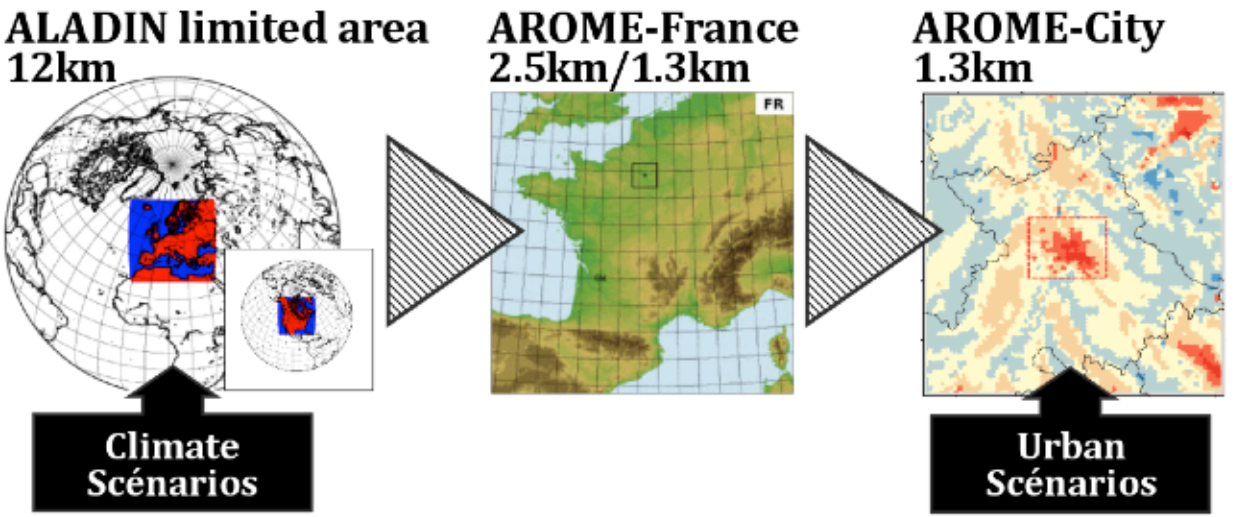




Conclusions

- Regional impact of cities on near-surface temperatures (even at 12-km spatial resol) with a maximum warming effect localized over cities
- Using the TEB model instead the simple slab approach:
  - More pronounced urban effects (intensity and spatial extension)
  - Better simulation of nocturnal urban heat island with TEB
    >> important for sanitary impacts on urban population
- Relevant to activate urban canopy model for RCM simulation
  - No additional computational cost
  - Impact studies



Thank you for your attention

Contact : aude.lemonsu@meteo.fr

M. Daniel, A. Lemonsu, M. Déqué, S. Somot, A. Alias, V. Masson, 2018: Benefits of explicit urban parameterization in regional climate modeling to study climate and city interactions, Climate Dynamics, in review