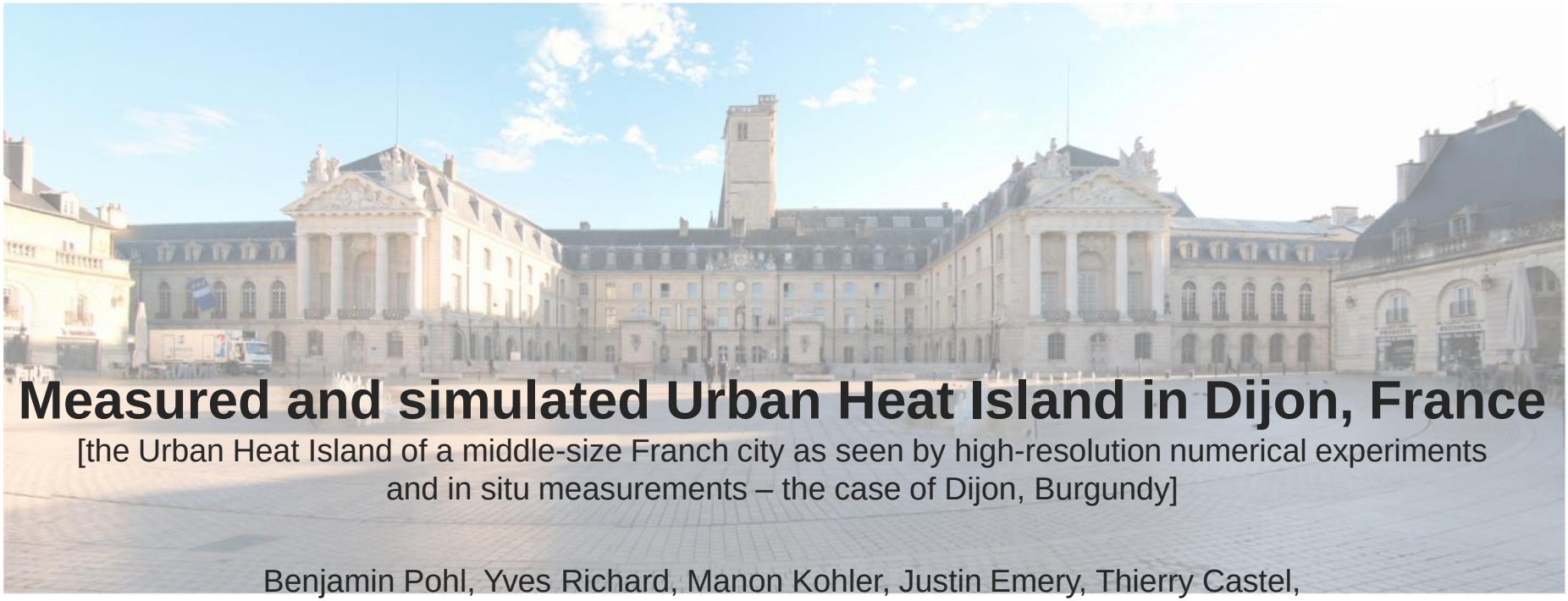

Measured and simulated Urban Heat Island in Dijon, France

[the Urban Heat Island of a middle-size Franch city as seen by high-resolution numerical experiments and in situ measurements – the case of Dijon, Burgundy]

Benjamin Pohl, Yves Richard, Manon Kohler, Justin Emery, Thierry Castel,
Benjamin De Lapparent, Denis Thévenin, Thomas Thévenin, Julien Pergaud

[benjamin.pohl@u-bourgogne.fr]

The UHI of Dijon

Little known about UHIs in middle-size cities in northeastern France

- marked interest of city services to prevent heat stress effects

- marked interest of our team to regionalize climate at fine scales (150m resol.)

Two complementary approaches

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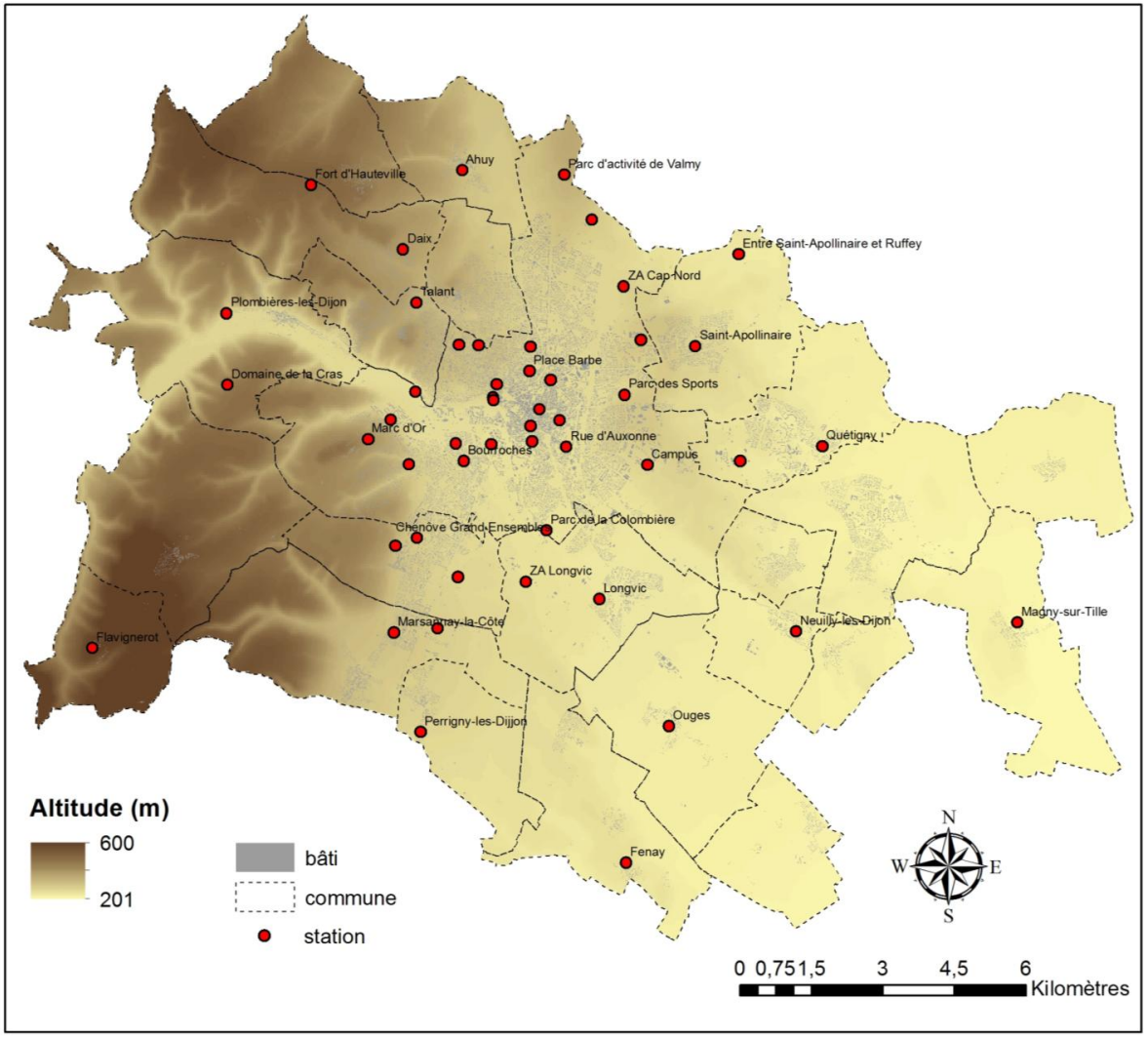

Two complementary approaches

- in situ measurements

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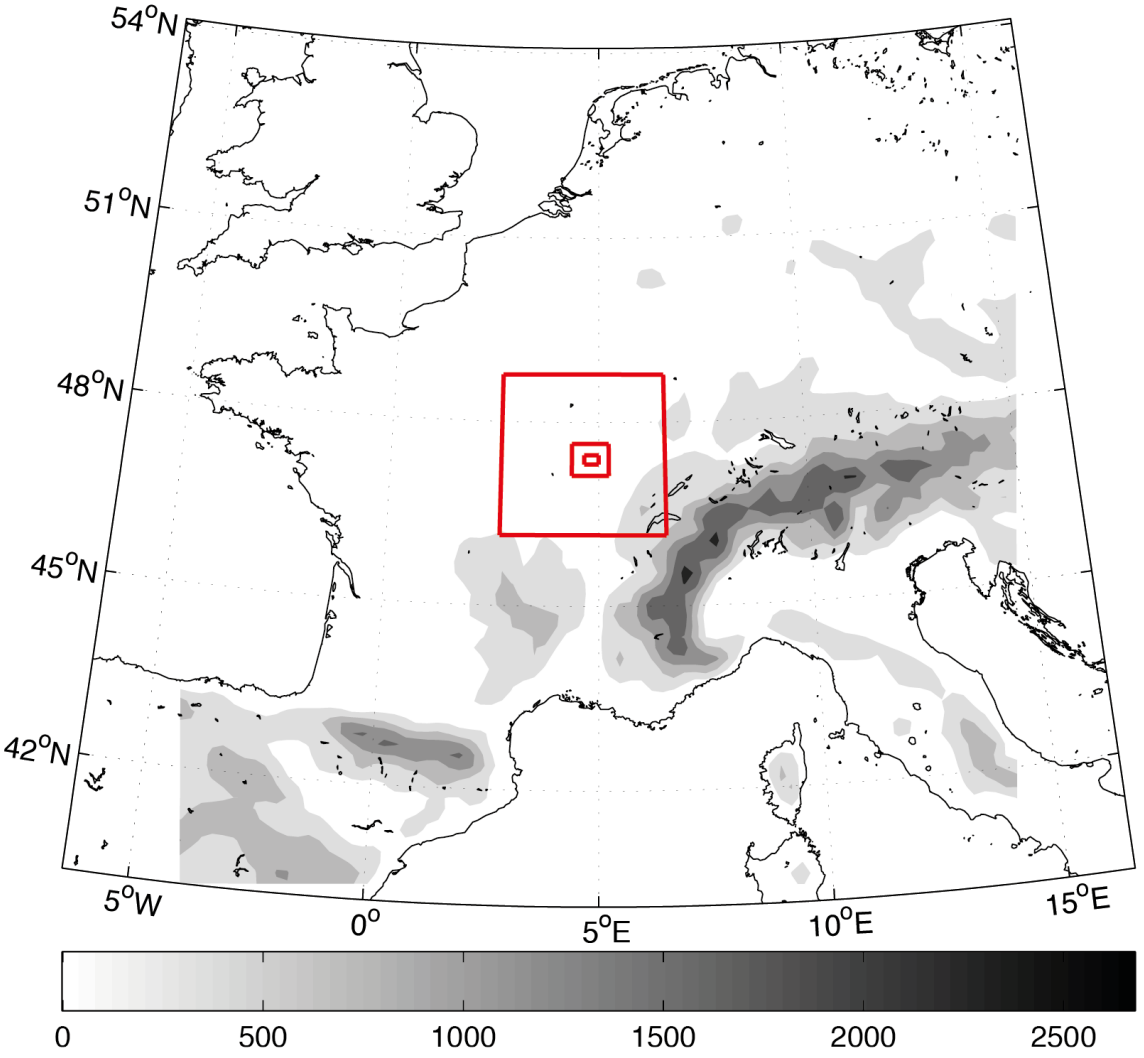
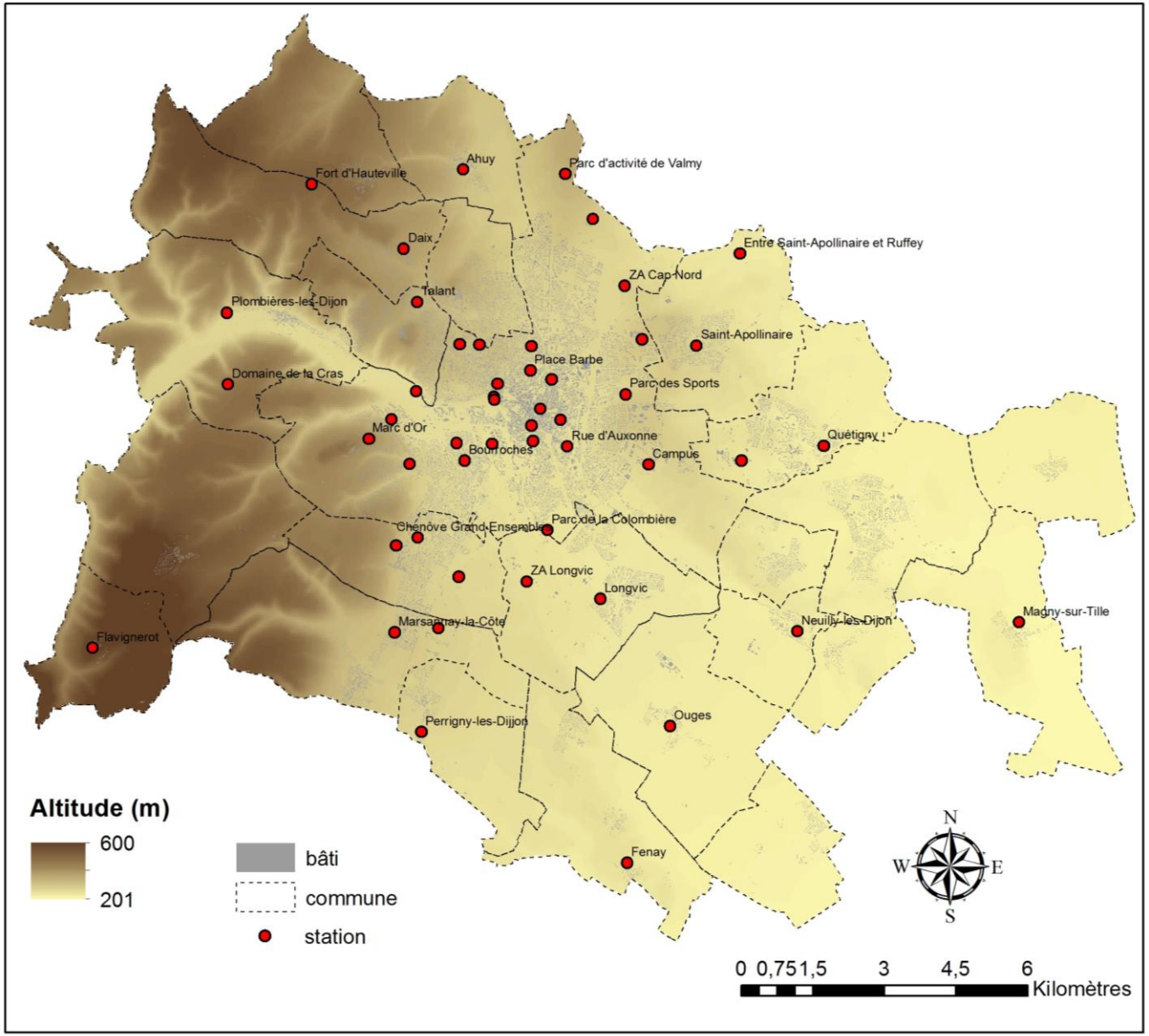


Two complementary approaches

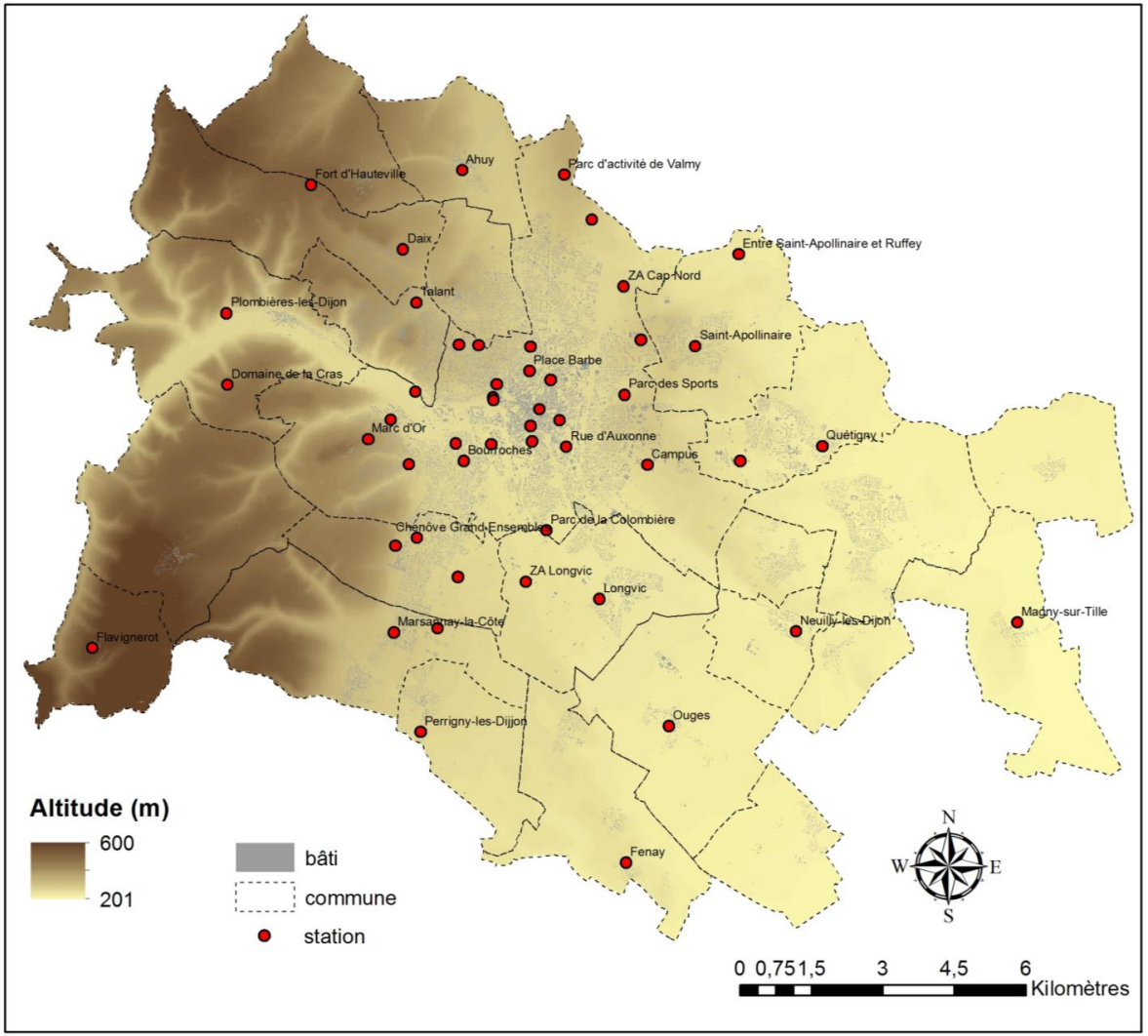
- in situ measurements
- numerical simulations

The UHI of Dijon | Measurements



The UHI of Dijon | Measurements

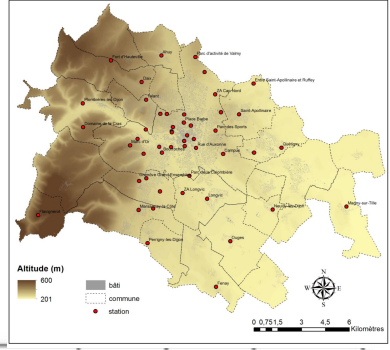
Since June 2014, 51 sensors measuring T and Q at 3m every 20’



The UHI of Dijon | Measurements

Since June 2014, 51 sensors measuring T and Q at 3m every 20'

- documents the **urban climate zones** defined by Oke (2006)
- open sites preferred to measure **climate background conditions**
- on public lampposts using specific (home-made !) fixations



Urban Climate Zone, UCZ[1]	Image	Rough-ness class[2]	Aspect ratio[3]	% Built (imperm-eable)[4]
1. Intensely developed [illegible] with detached close-set high-rise buildings with cladding, e.g. downtown [illegible]		8	> 2	> 90
2. Intensely developed high density urban with 2 – 5 storey, attached or very close-set buildings often of brick or stone, e.g. old city core		7	1.0 – 2.5	> 85
3. Highly developed, medium density urban with row or detached but close-set houses, stores & apartments e.g. urban housing		7	0.5 – 1.5	70 - 85
4. Highly developed, low or medium density urban with large low buildings & paved parking, e.g. shopping mall, warehouses		5	0.05 – 0.2	70 - 95
5. Medium development, low density suburban with 1 or 2 storey houses, e.g. suburban housing		6	0.2 – 0.6, up to >1 with trees	35 - 65
6. Mixed use with large buildings in open landscape, e.g. institutions such as hospital, university, airport		5	0.1 – 0.5, depends on trees	< 40
7. Semi-rural development, scattered houses in natural or agricultural area, e.g. farms, estates		4	> 0.05, depends on trees	< 10

Key to image symbols: buildings; vegetation; impervious ground; pervious ground

The UHI of Dijon | Measurements

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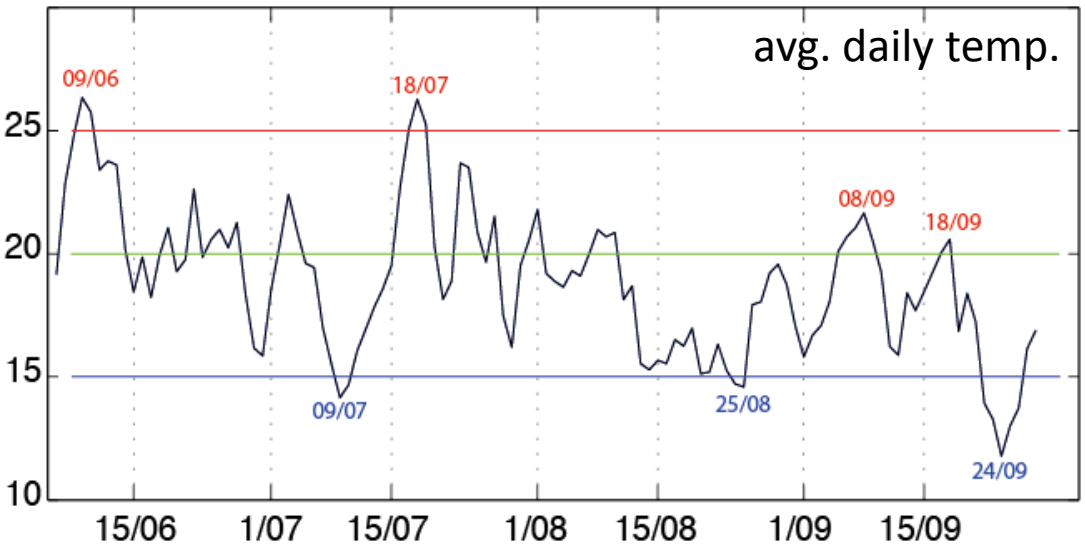

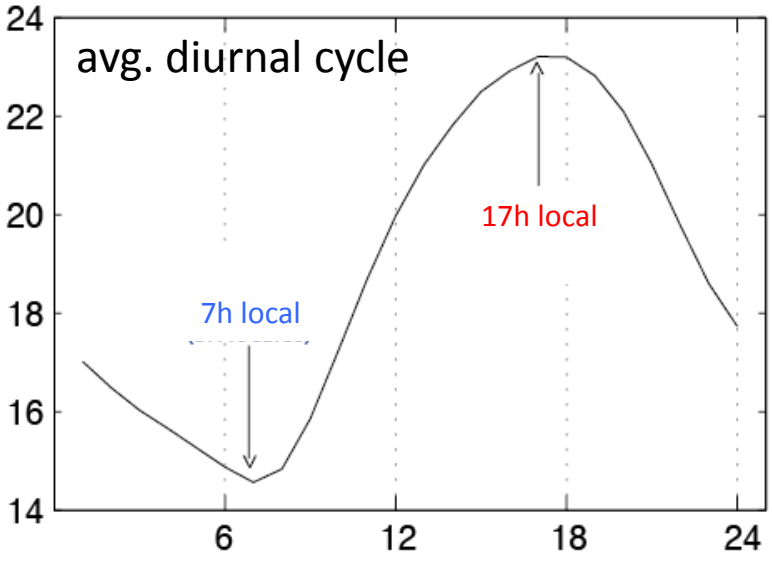

The UHI of Dijon | Measurements

in French we say "été pourri"
(lousy summer) ☹

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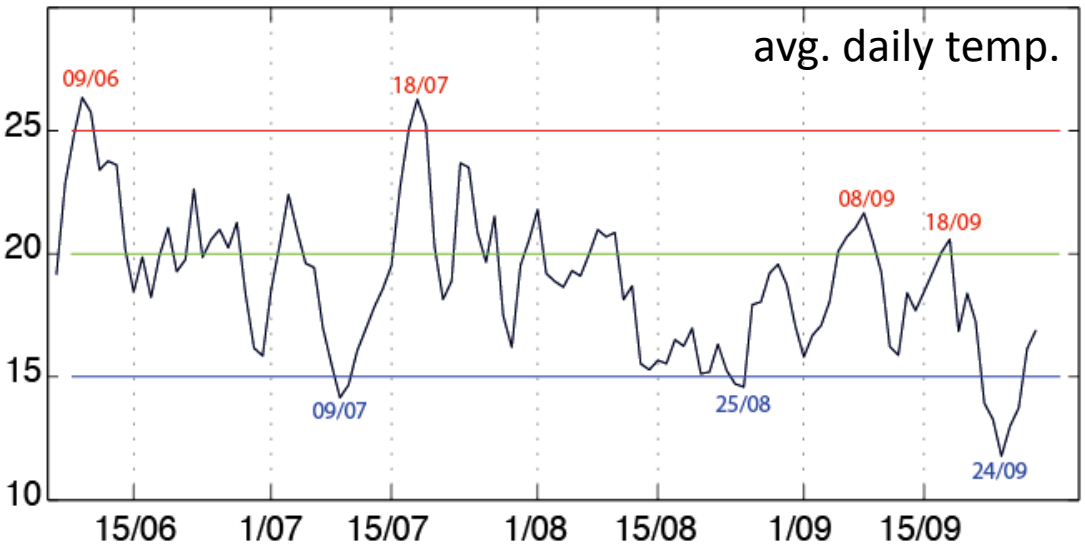
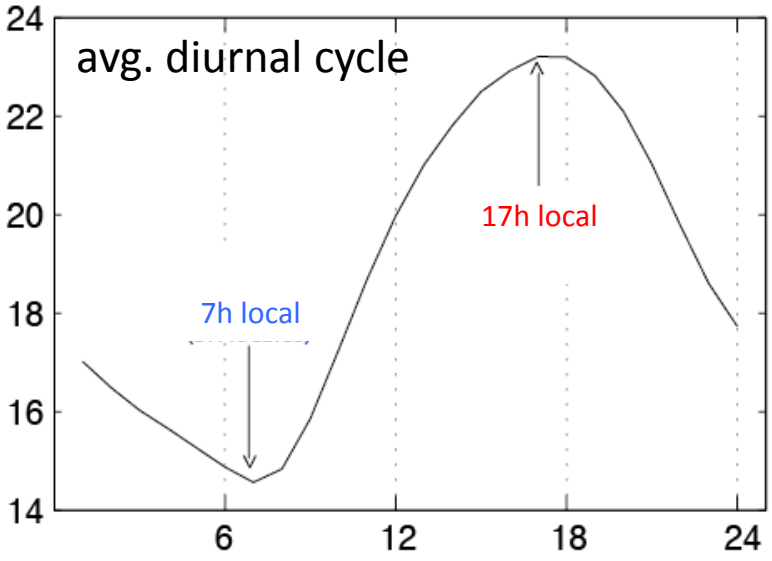




The UHI of Dijon | Measurements

Seasonal Mean Temperature
(JJAS 2014)

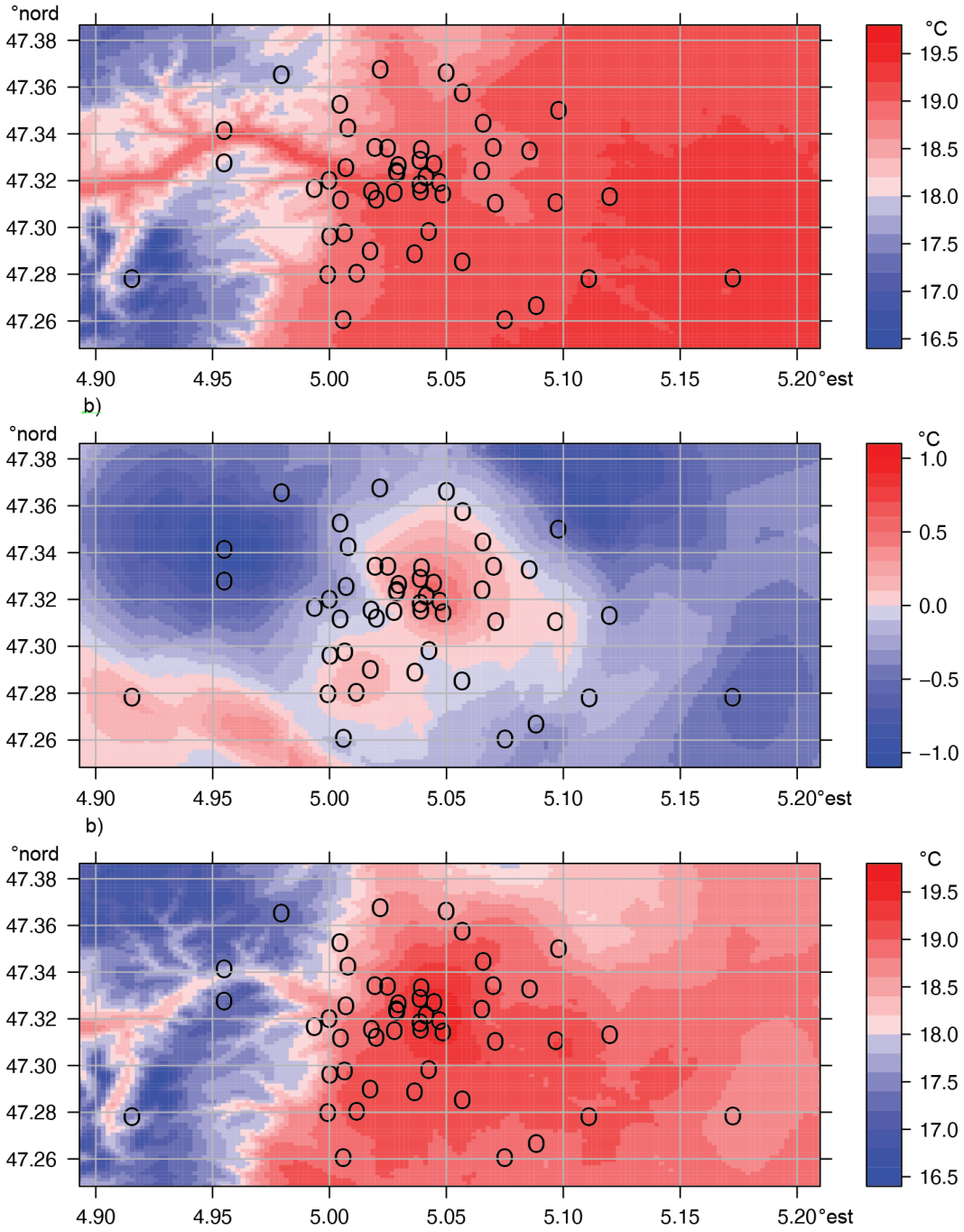
- Multiple linear regression based on DEM (alt/lat/lon) : alt. gradients dominant

- Kriging of residuals : no alt. effects, only land-use (UHI : +1°C on average)

  Dipole in the UHI: water and vegetation
  (a river runs through it…)

- RK : sum of both effects, seasonal mean temp.

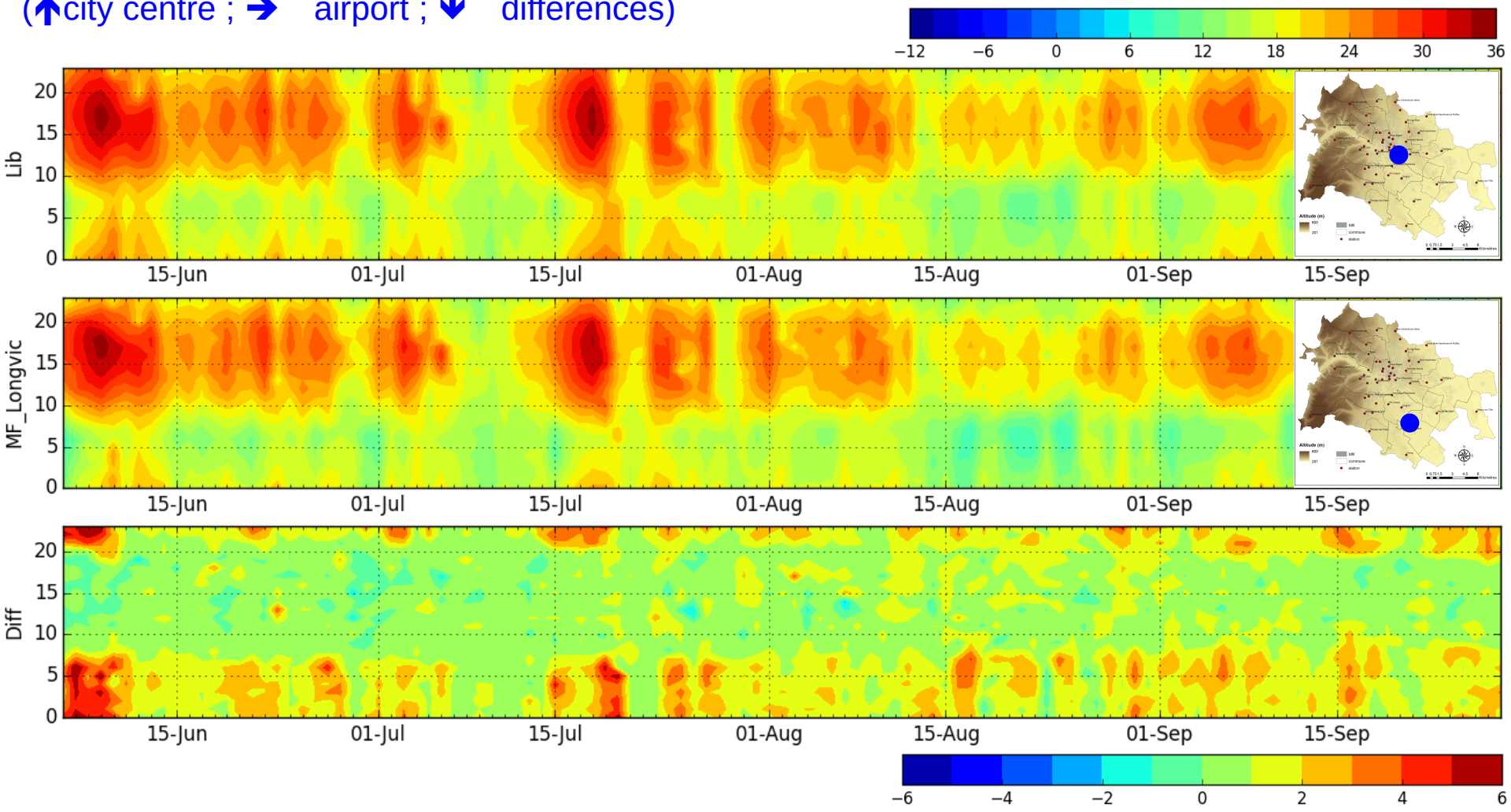
UHI = intermittent phenomenon



The UHI of Dijon | Measurements

Hour – Day graph (JJAS 2014)

(↑city centre ; ➔ airport ; 🡻 differences)



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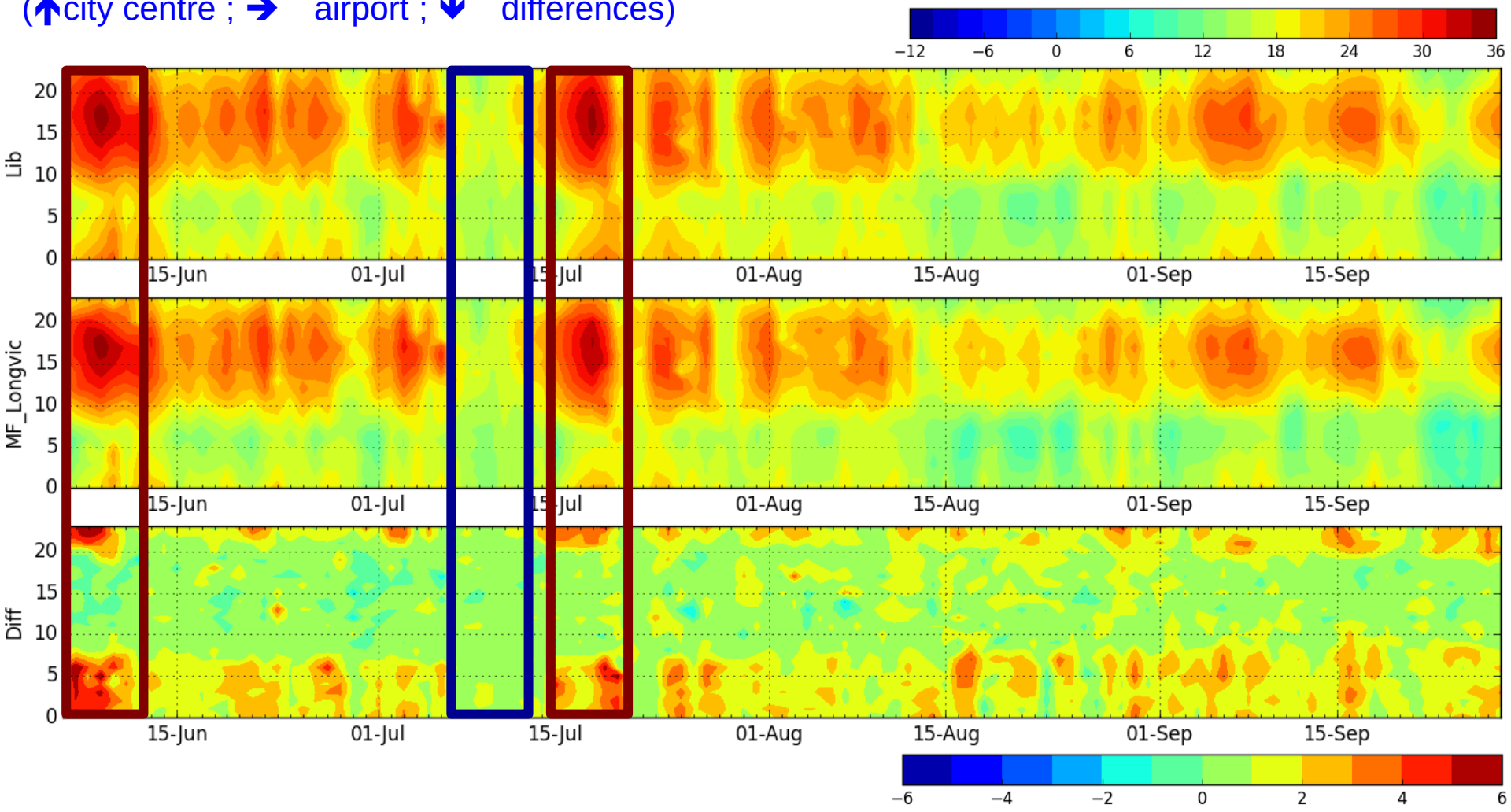

UHI = intermittent phenomenon ➔ **need an objective way to separate the days with and without UHI**

EOF analysis of hourly variables taken at the Météo-France synoptic station (Dijon-Longvic) :

Precipitations – Surface Pressure – Duration of Insolation – Surface Solar Radiation – wind@10m

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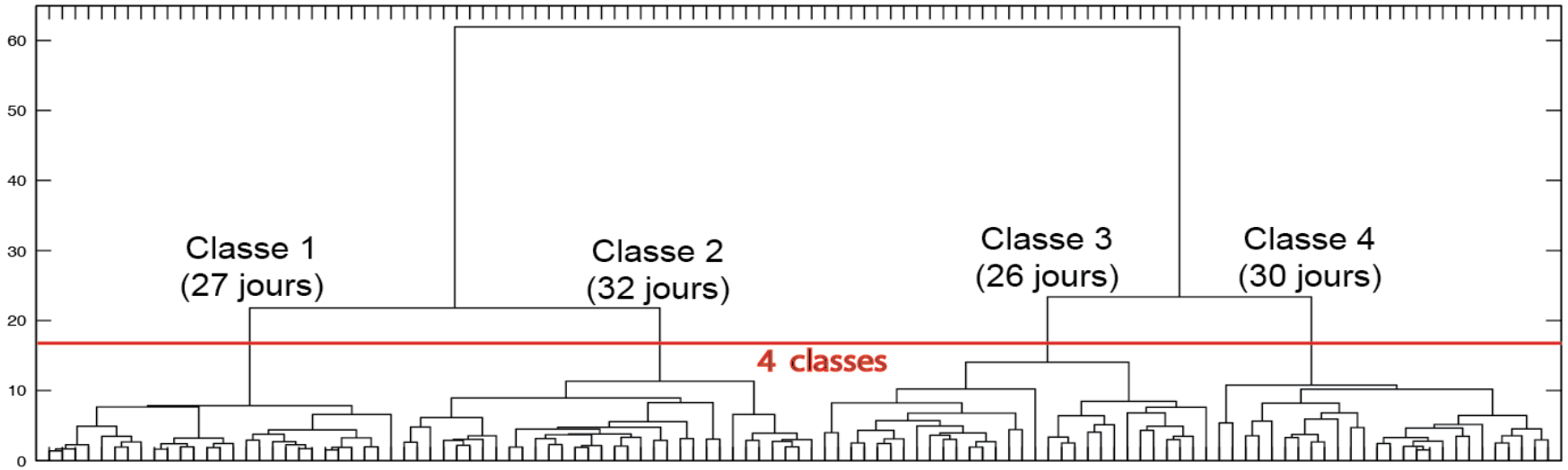
Hierarchical classification of diurnal cycles (1st eigenvector)



The UHI of Dijon | Measurements

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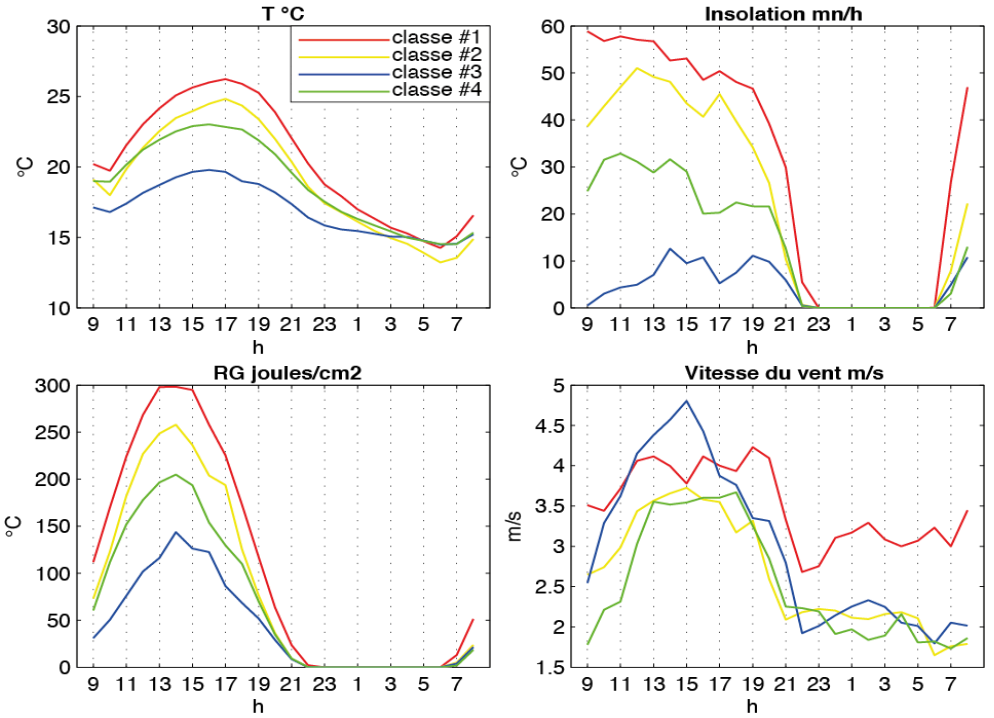
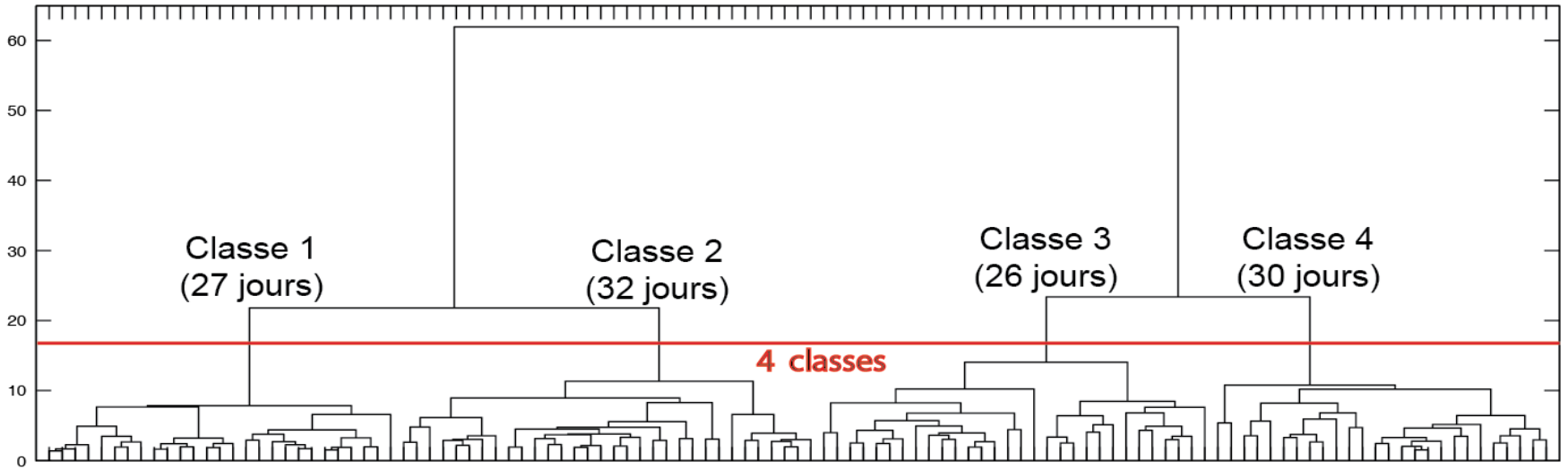
Hierarchical classification of diurnal cycles (1st eigenvector)

4 Classes discriminating radiation and insolation (and also temperature)

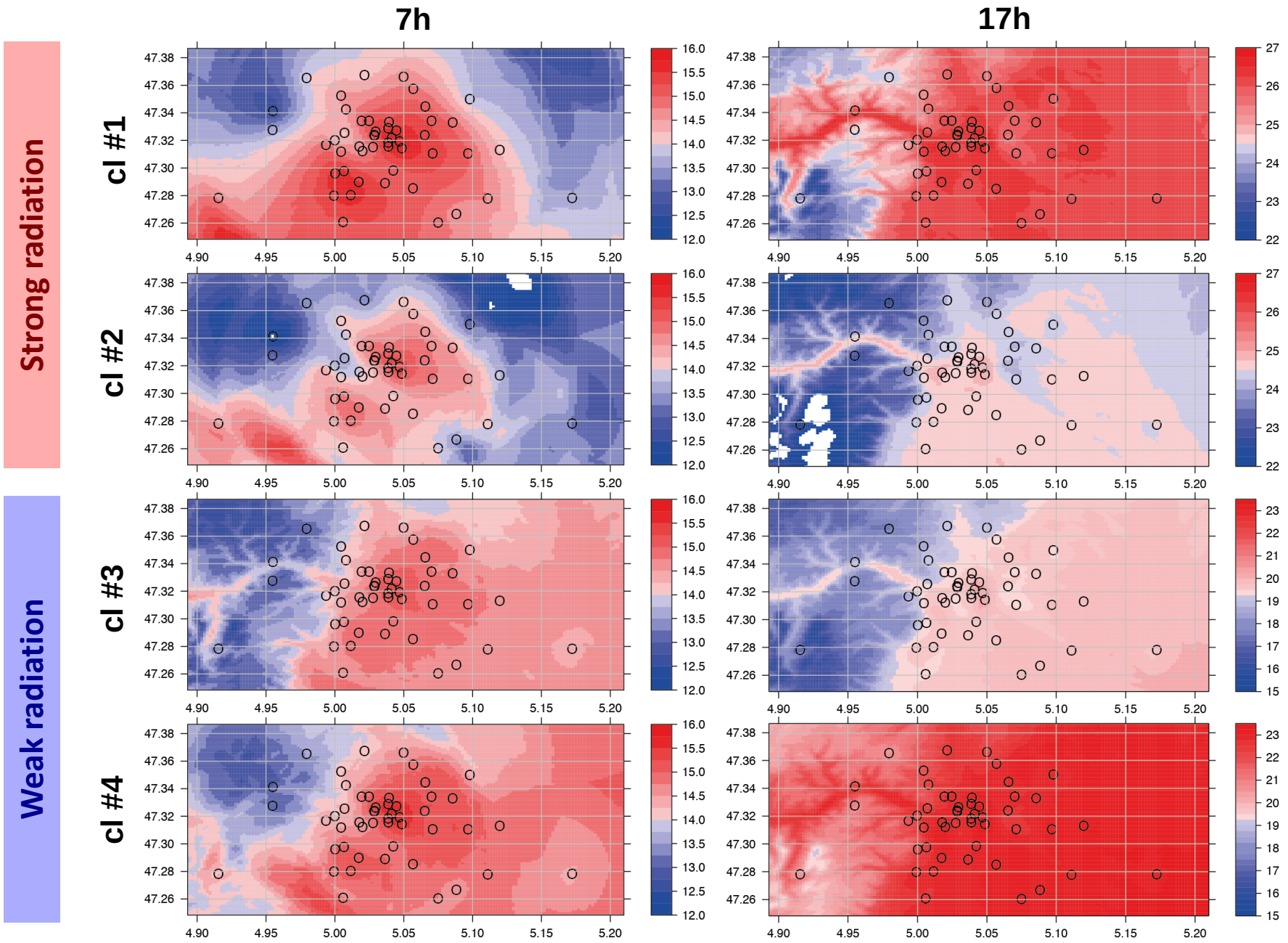
Precipitations – Surface Pressure – Duration of Insolation – Surface Solar Radiation – wind@10m



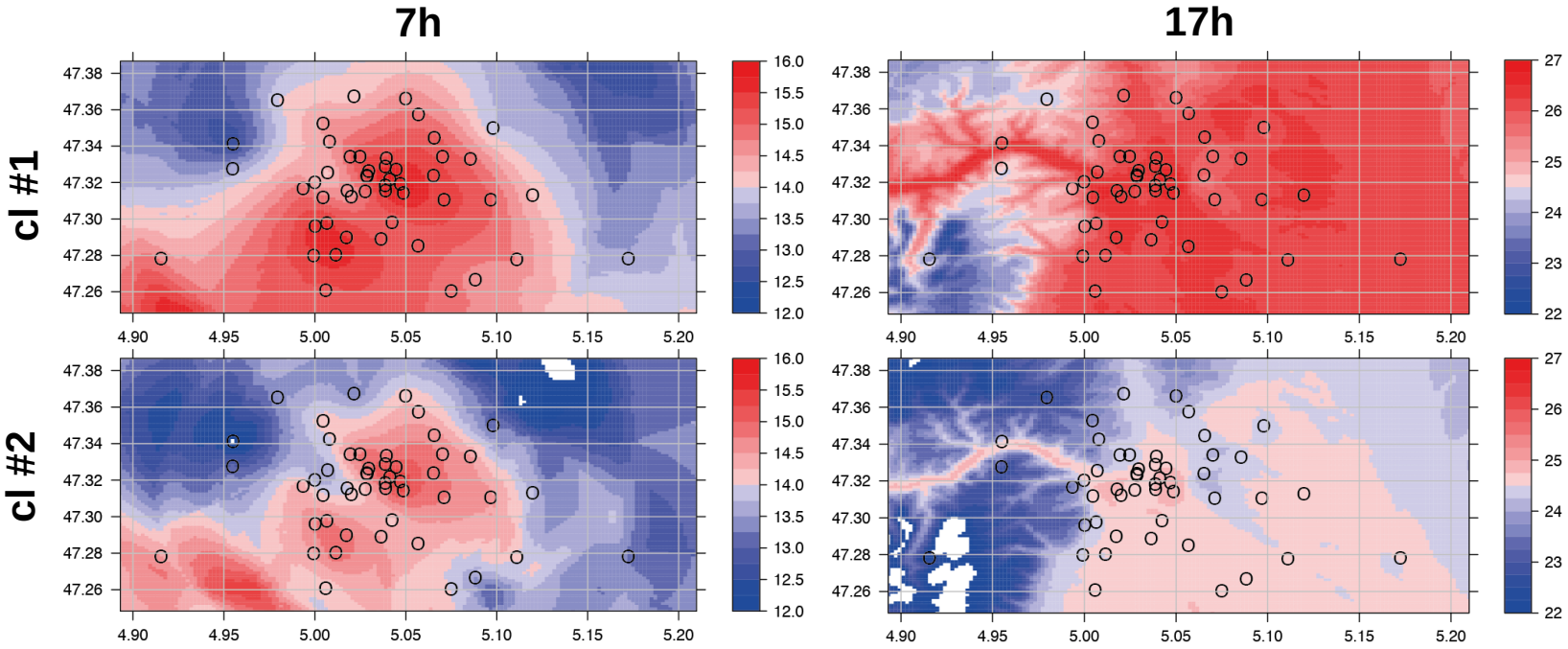


The UHI of Dijon | Measurements

4 classes : temperature at 7h and 17h local time



Strong radiation

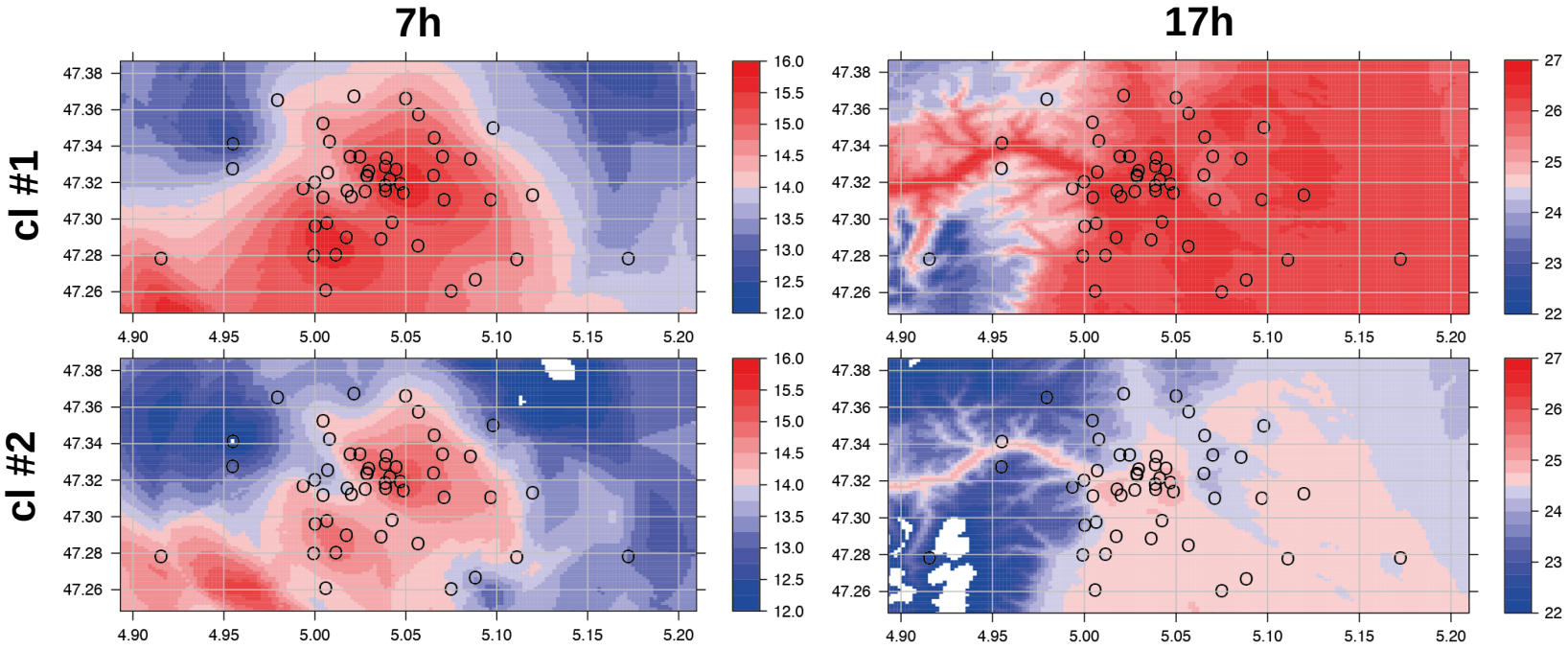


Class #1 (very strong radiation) :

- « warm » background conditions (no UHI effect)
- UHI : reaches +4°C on the morning *on avg.* (weaker on the evening)
- 2014 : class roughly 25% of the summer period (probably larger in july 2015)
- ΔT max ~ 5–6°C

Oke (1973) : $\Delta T_{max} = 1.93 \log_{10}(P) - 4.76$
for P = 250 000, $\Delta T_{max} = 5.69$°C.

Strong radiation



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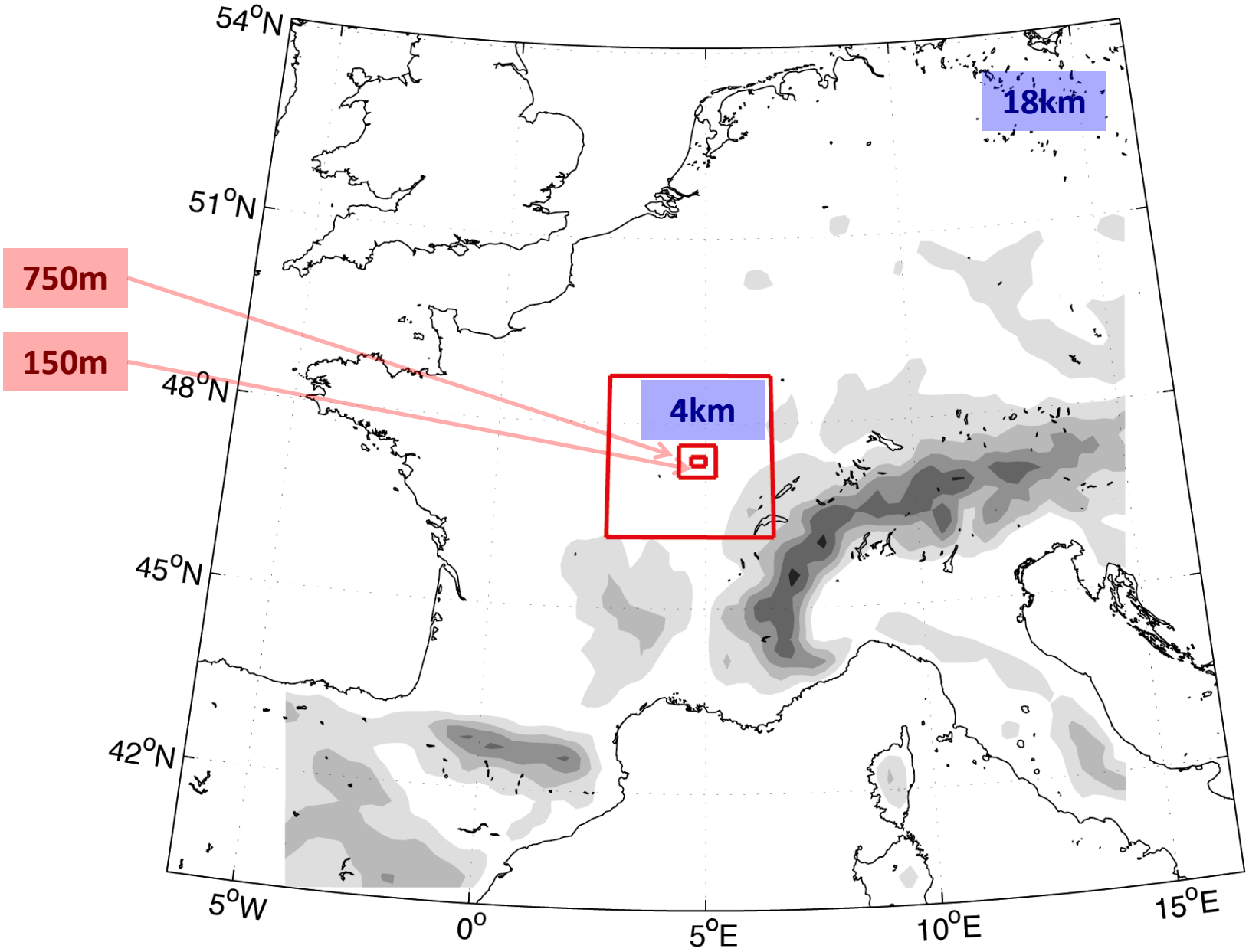
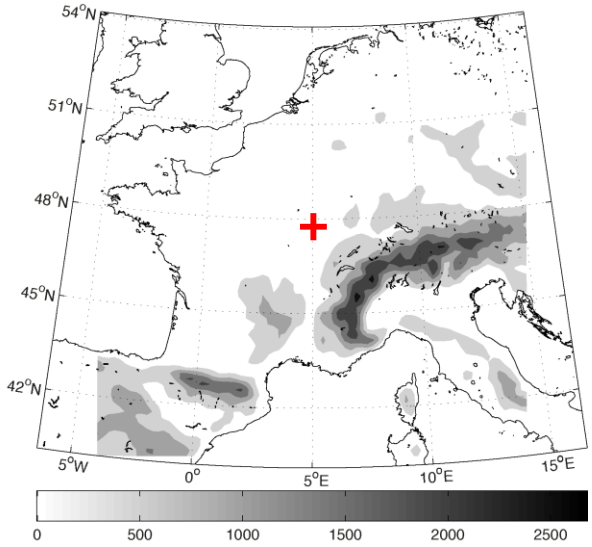
in 2015 the sensors are still running


54°N
51°N
48°N
45°N
42°N
5°W
0°
5°E
10°E
15°E
18km
4km
750m
150m

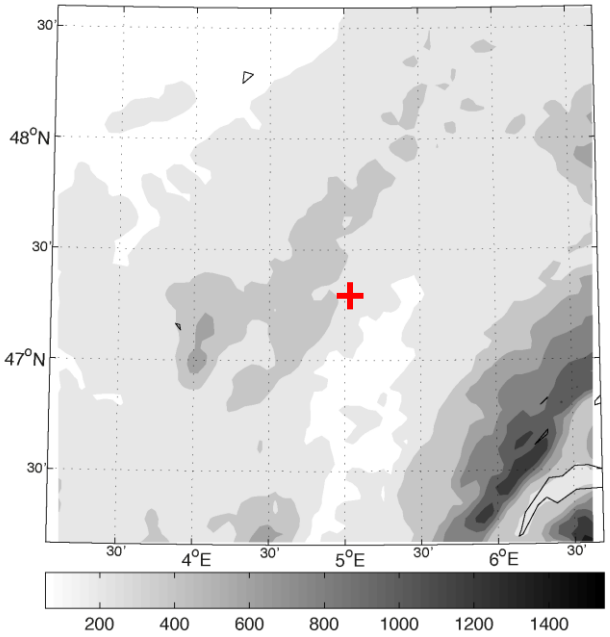
The UHI of Dijon | Simulations

High-resolution WRF simulations (WRF v3.6.1 + BEP-BEM)

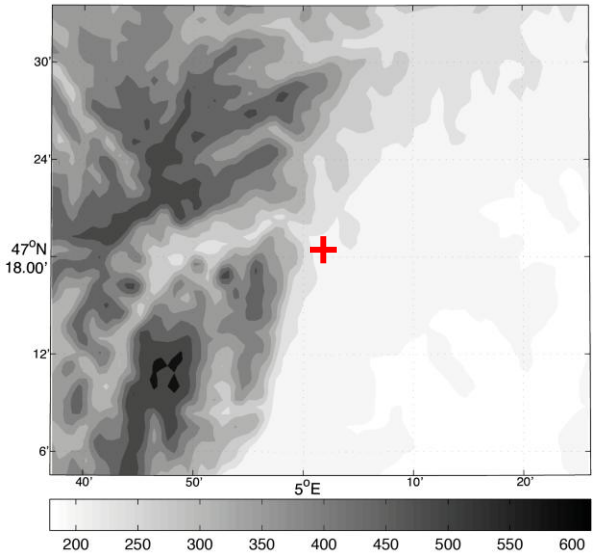


domain #1
Δx = 18750m
σ = 57 niv.
80 x 80 grid pts
364 800 voxels

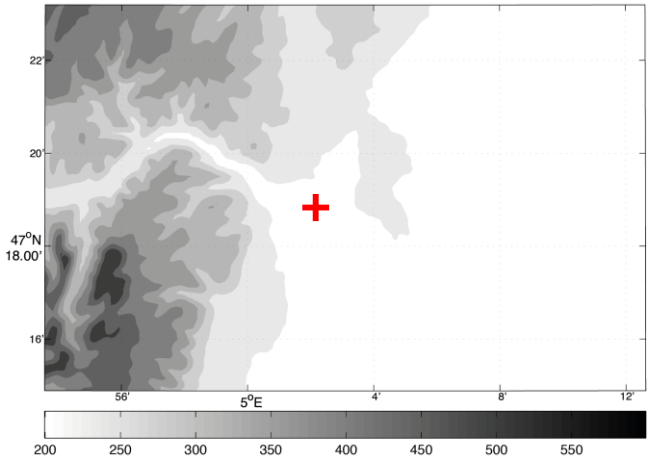
Nudged towards ERA-Interim



domain #2
Δx = 3750m
σ = 57 niv.
71 x 71 grid pts
287 337 voxels



domain #3
Δx = 750m
σ = 57 niv.
81 x 71 grid pts
327 807 voxels



domain #4
Δx = 150m
σ = 57 niv.
156 x 101 grid pts
898 092 voxels

Using urban canopy model BEP

∑ : 1 878 036 voxels

The UHI of Dijon | Simulations

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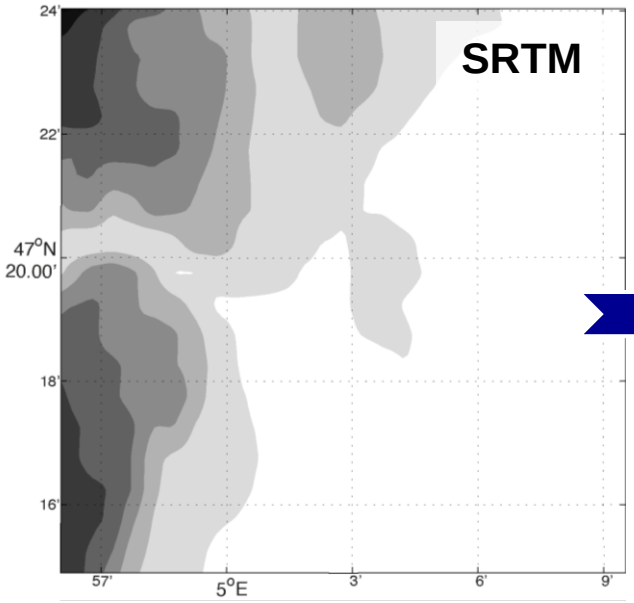
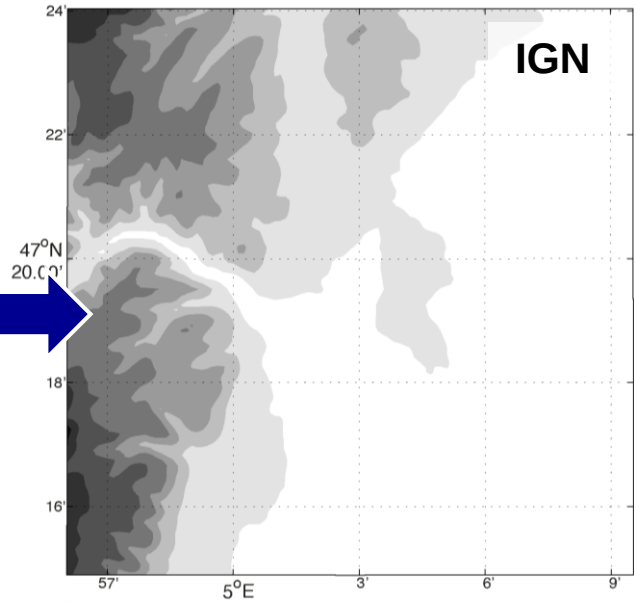
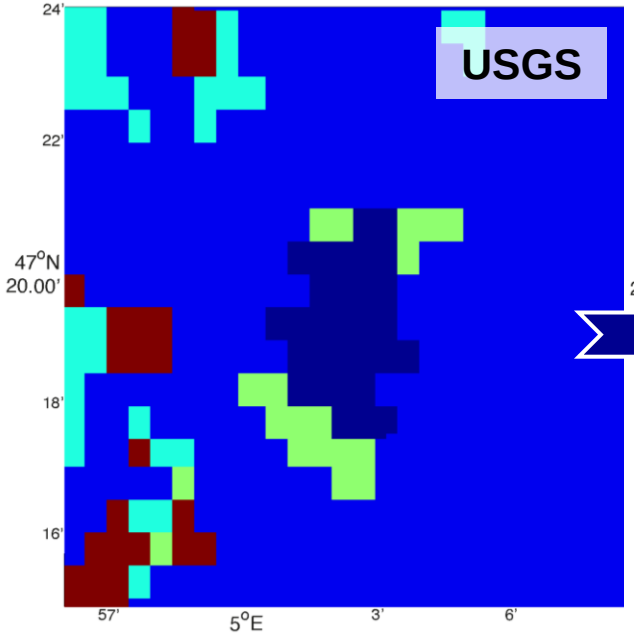
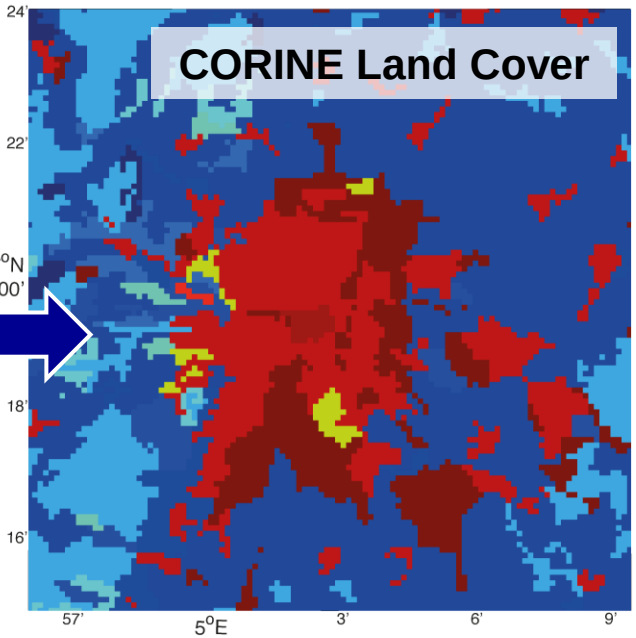
Huge work on boundary conditions

- topography
- land-use
- urban morphology









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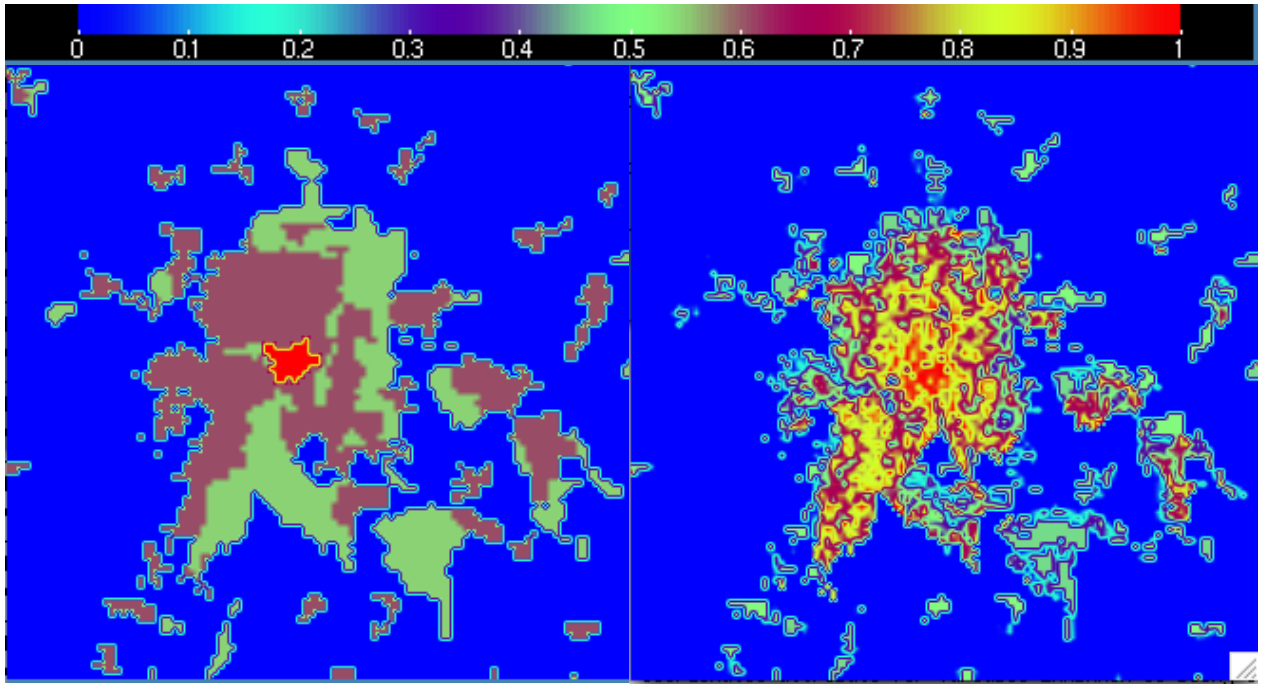

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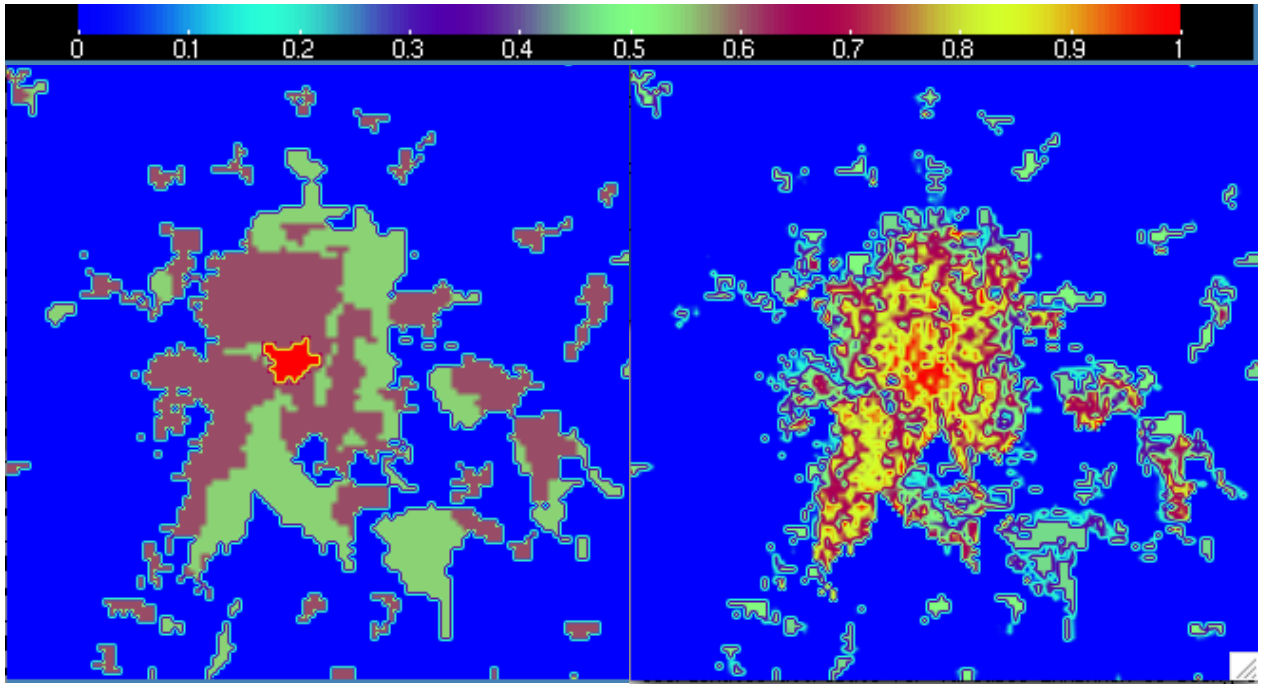
82.476 buildings (11km^2)
3.224 green areas
19.123 streets/roads (15km^2)
2 billions elementary cells

Σ 40 Gb data processed



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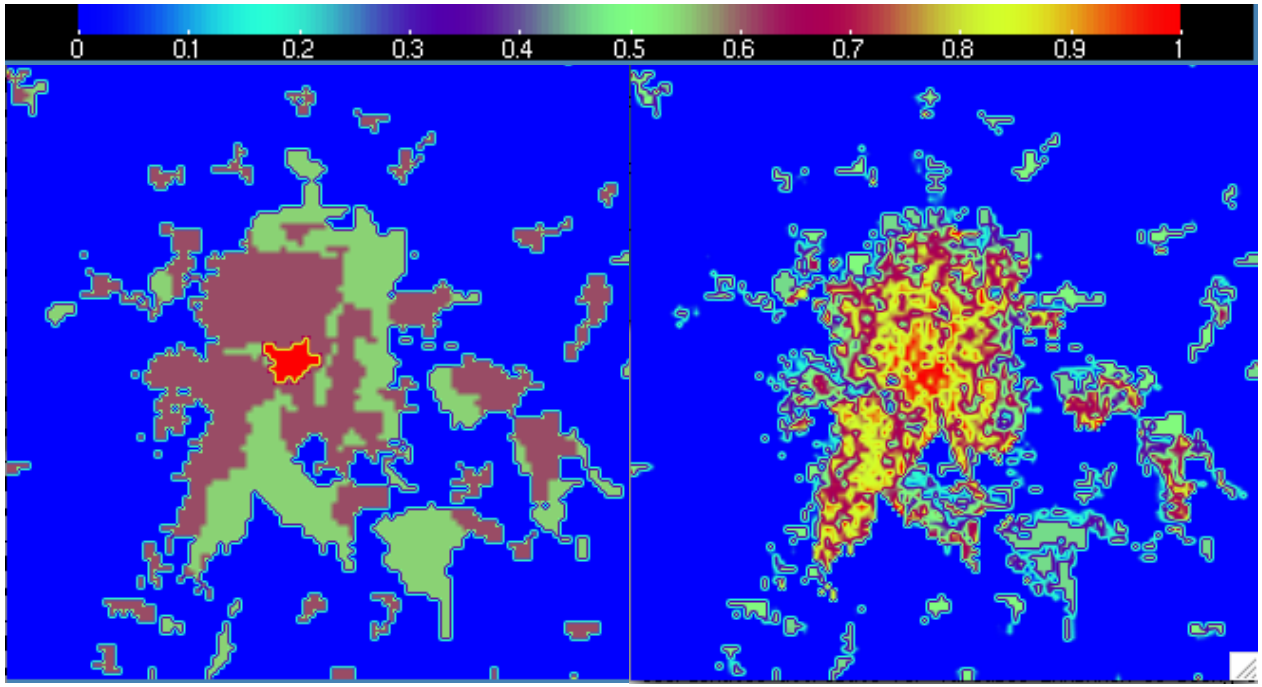

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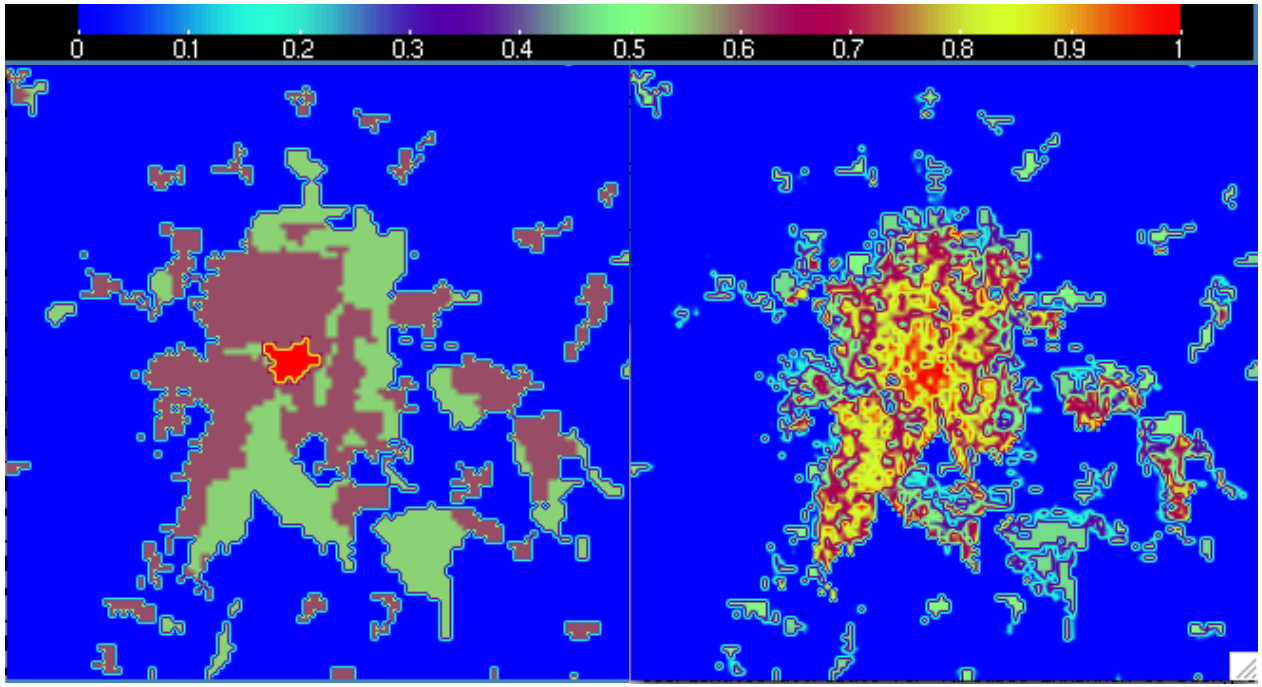

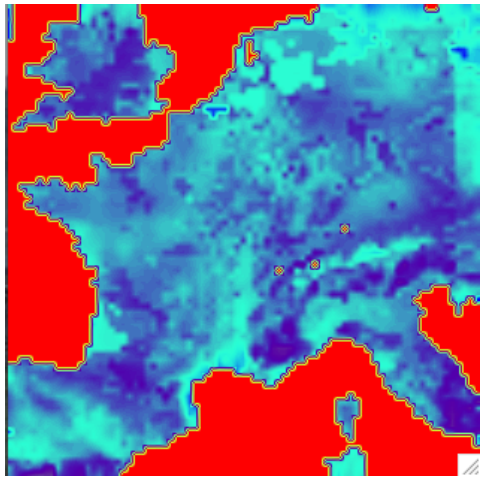

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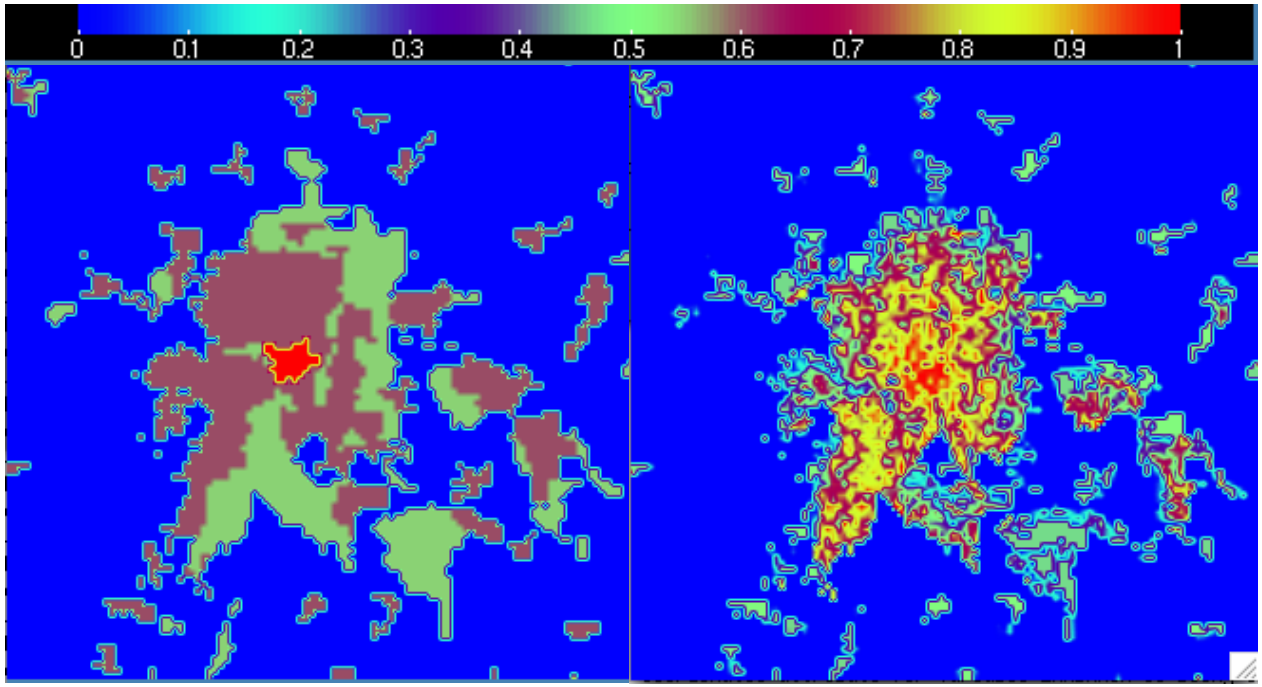

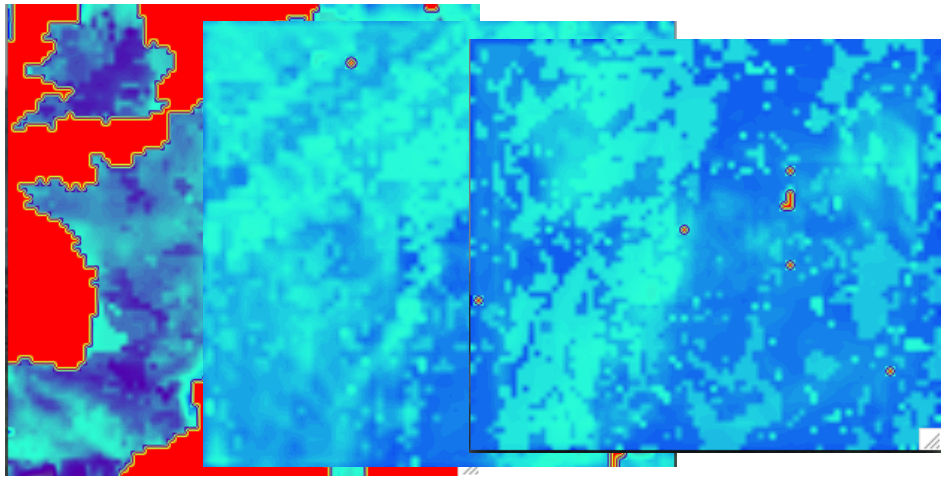

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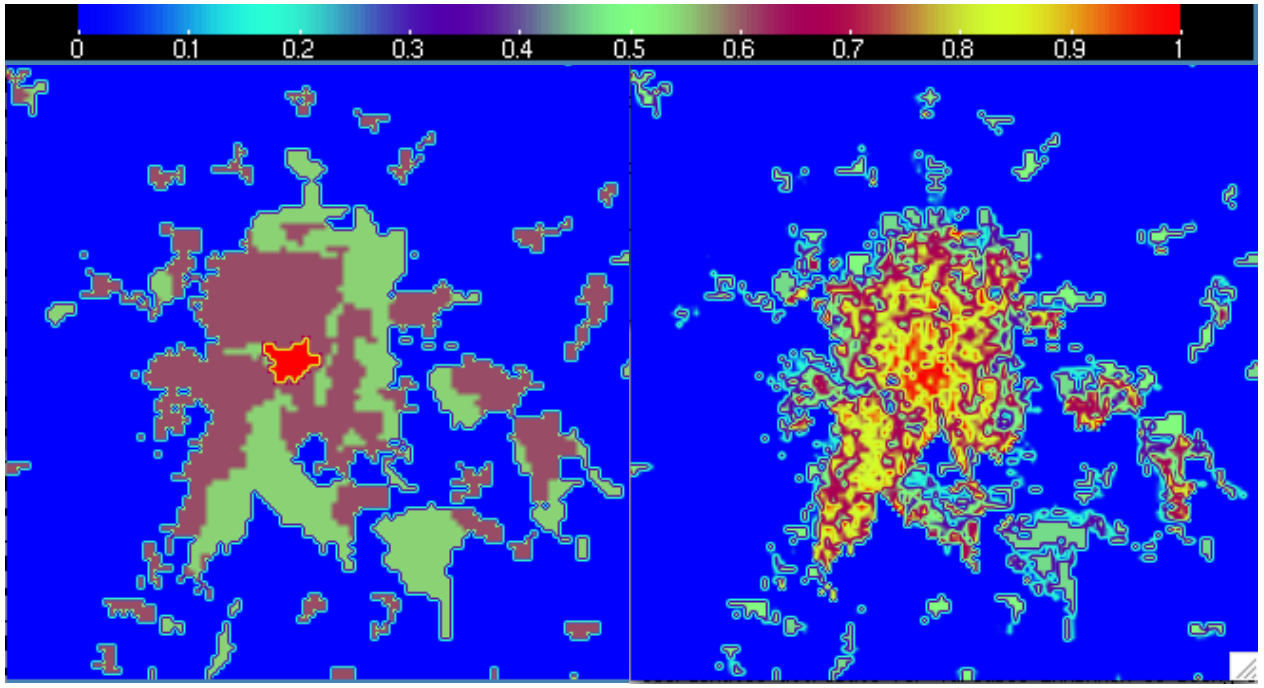

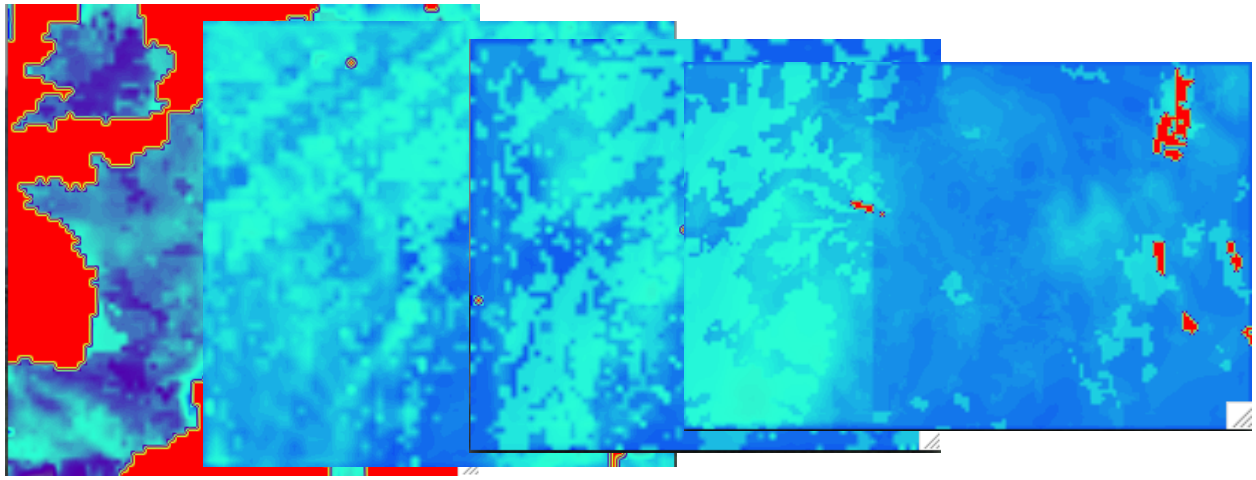

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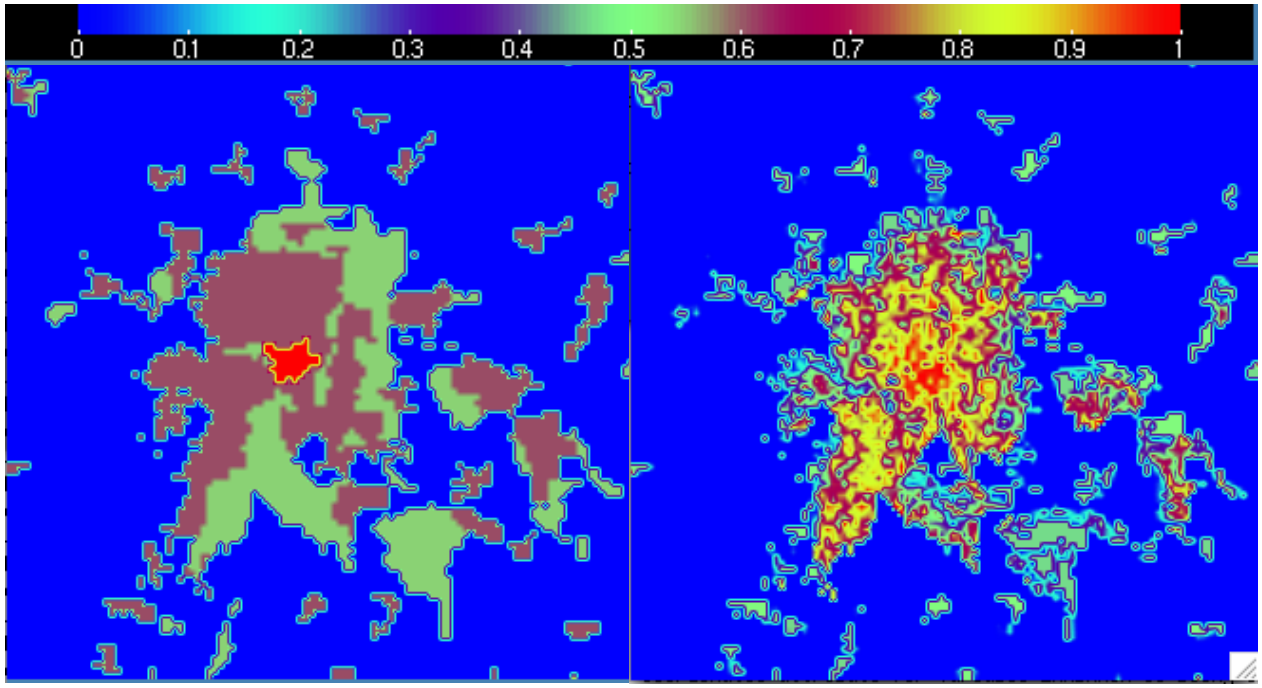

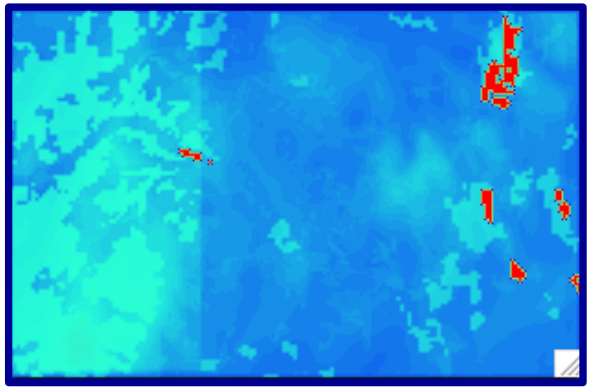

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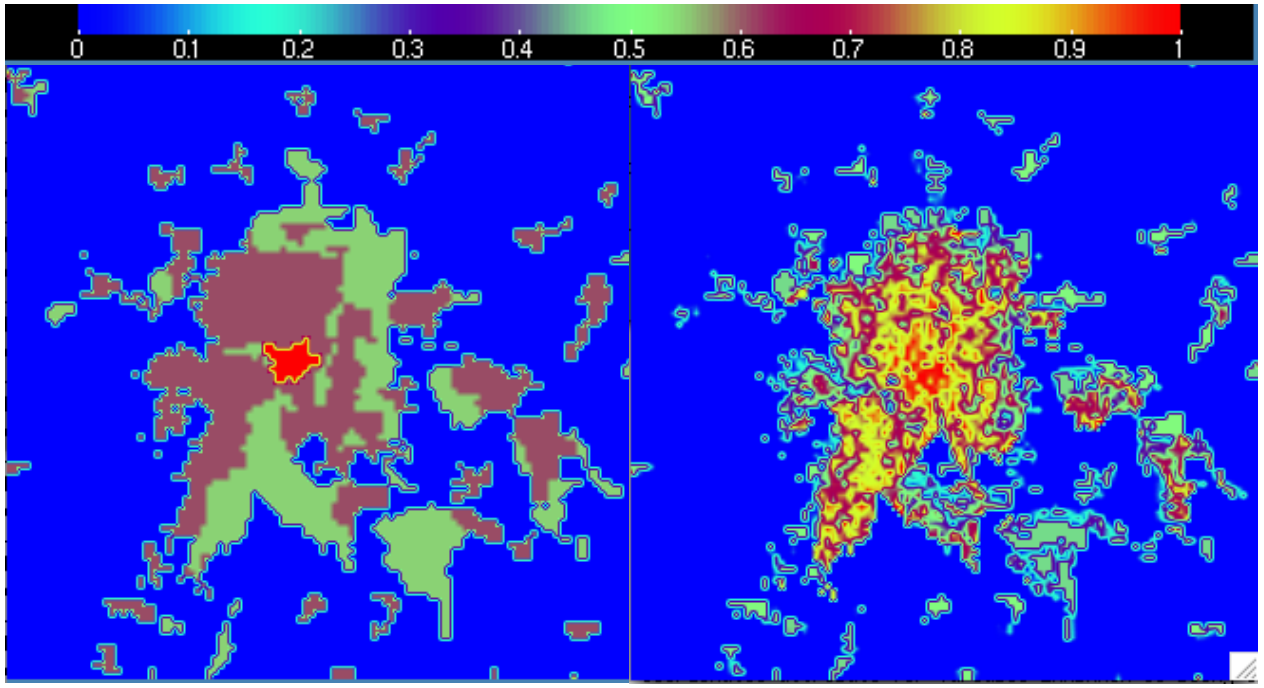
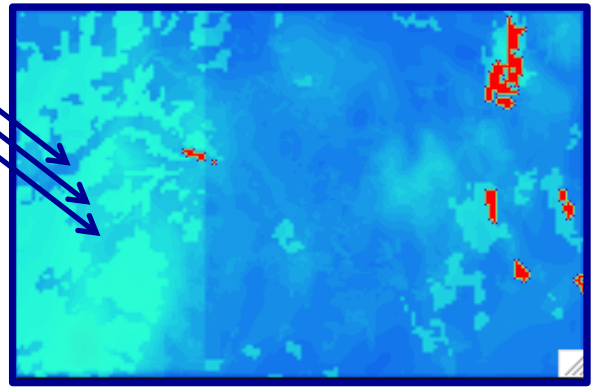


"land-use effect" ☺



The UHI of Dijon | Simulations

High-resolution WRF simulations (WRF v3.6.1 + BEP-BEM)

Huge work on boundary conditions

- topography
- land-use
- urban morphology

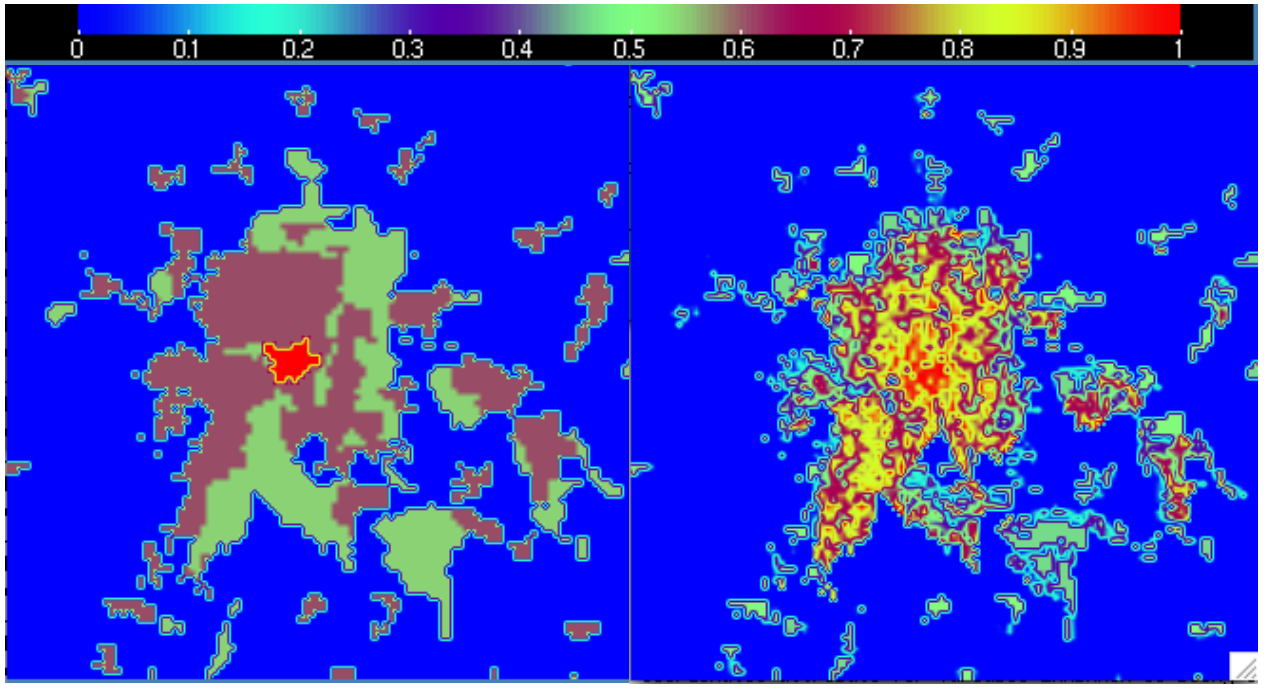
Improvement of BEP (land artificialisation quantified for each grid-point)

82.476 buildings (11km^2)
3.224 green areas
19.123 streets/roads (15km^2)
2 billions elementary cells

Σ 40 Gb data processed

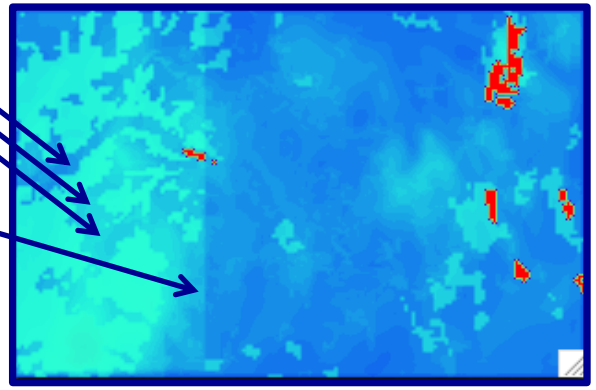
Using public / open-access databases to have a generic and reproducible methodology

still problems with soil maps…

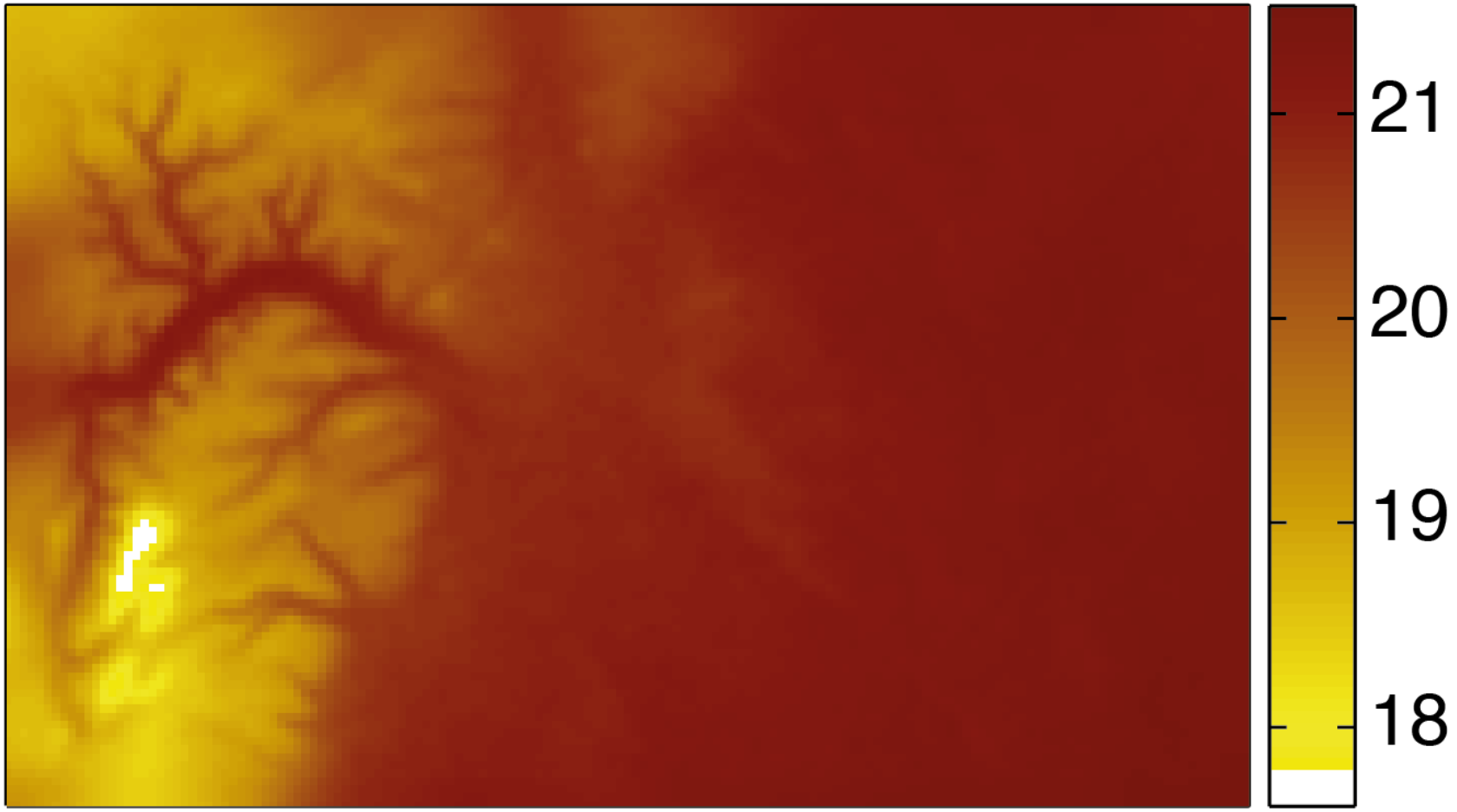


"land-use effect" ☺

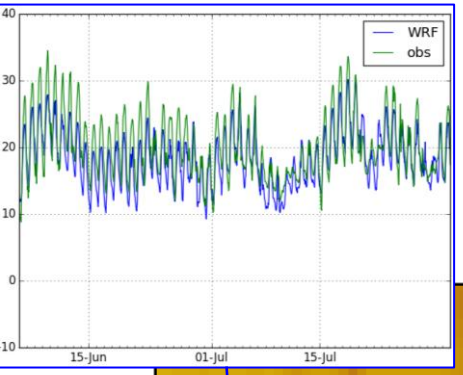
"soil map effect" ☹

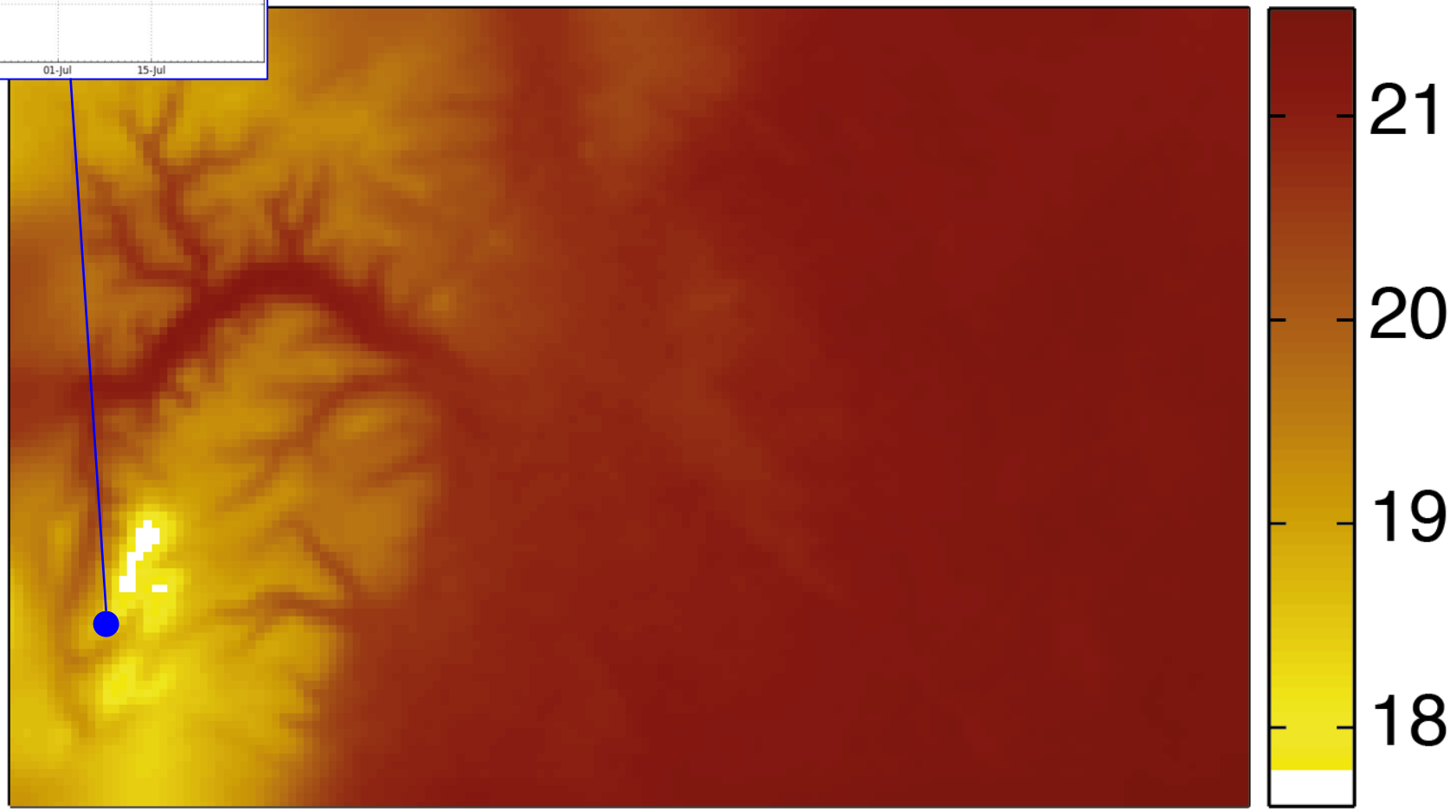


Simulated air temperature, 12h UTC, σ lev. 0.990, 15 June – 31 July 2014



The UHI of Dijon | Simulations





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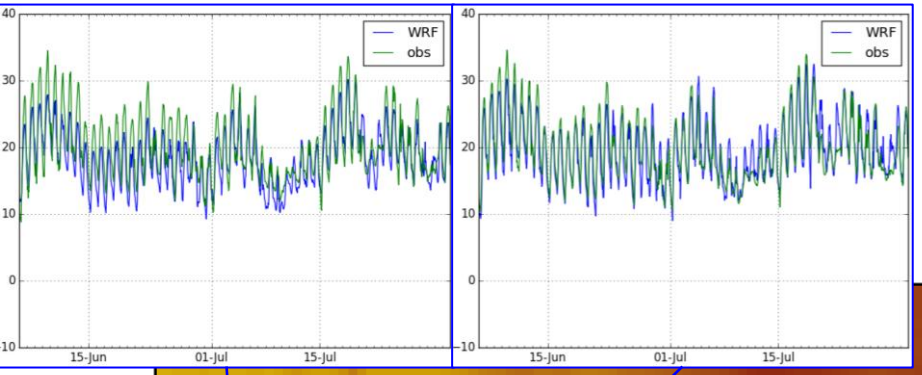

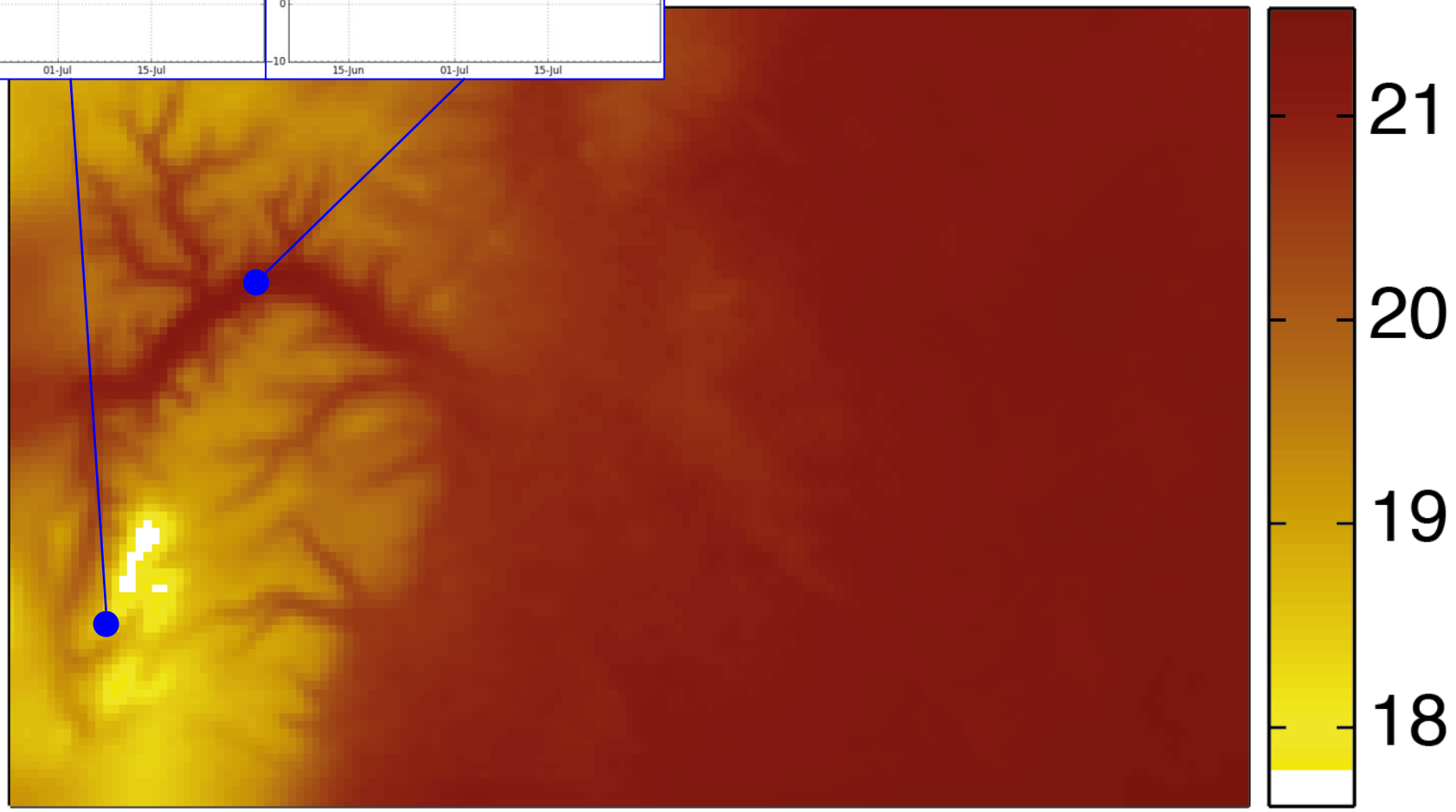

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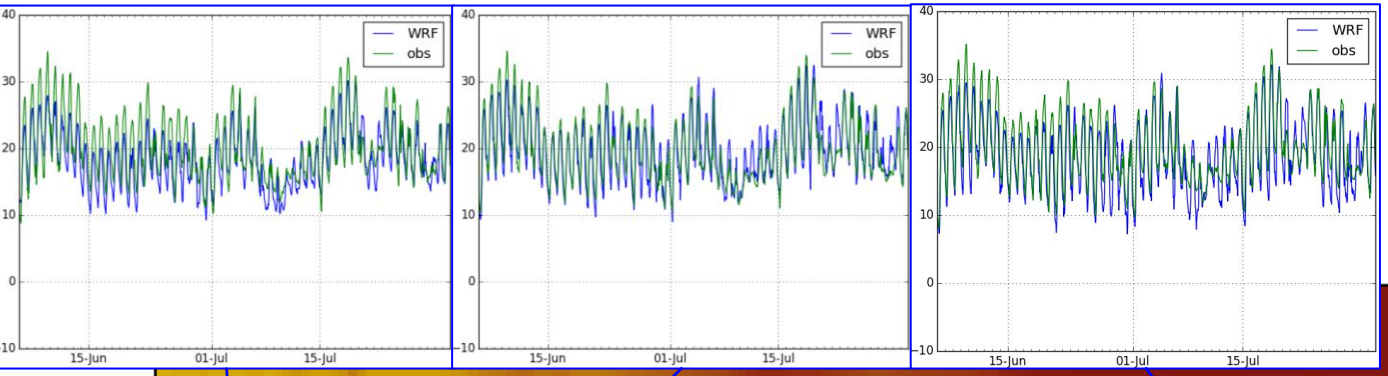

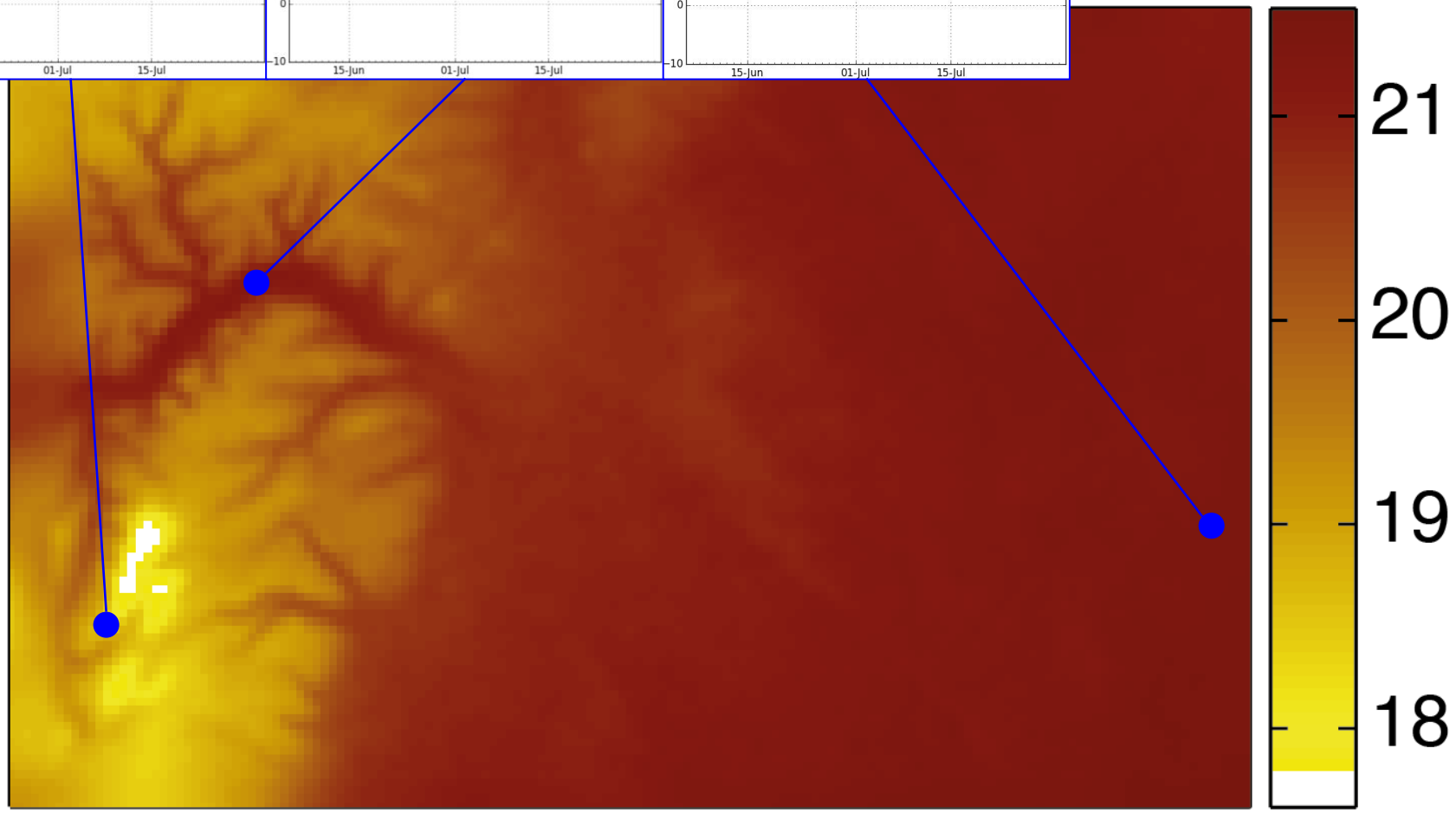

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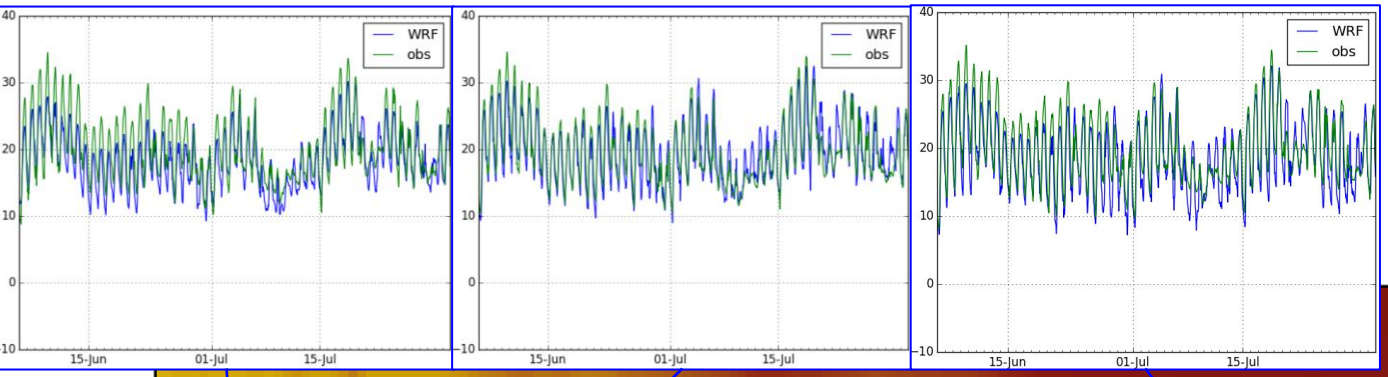

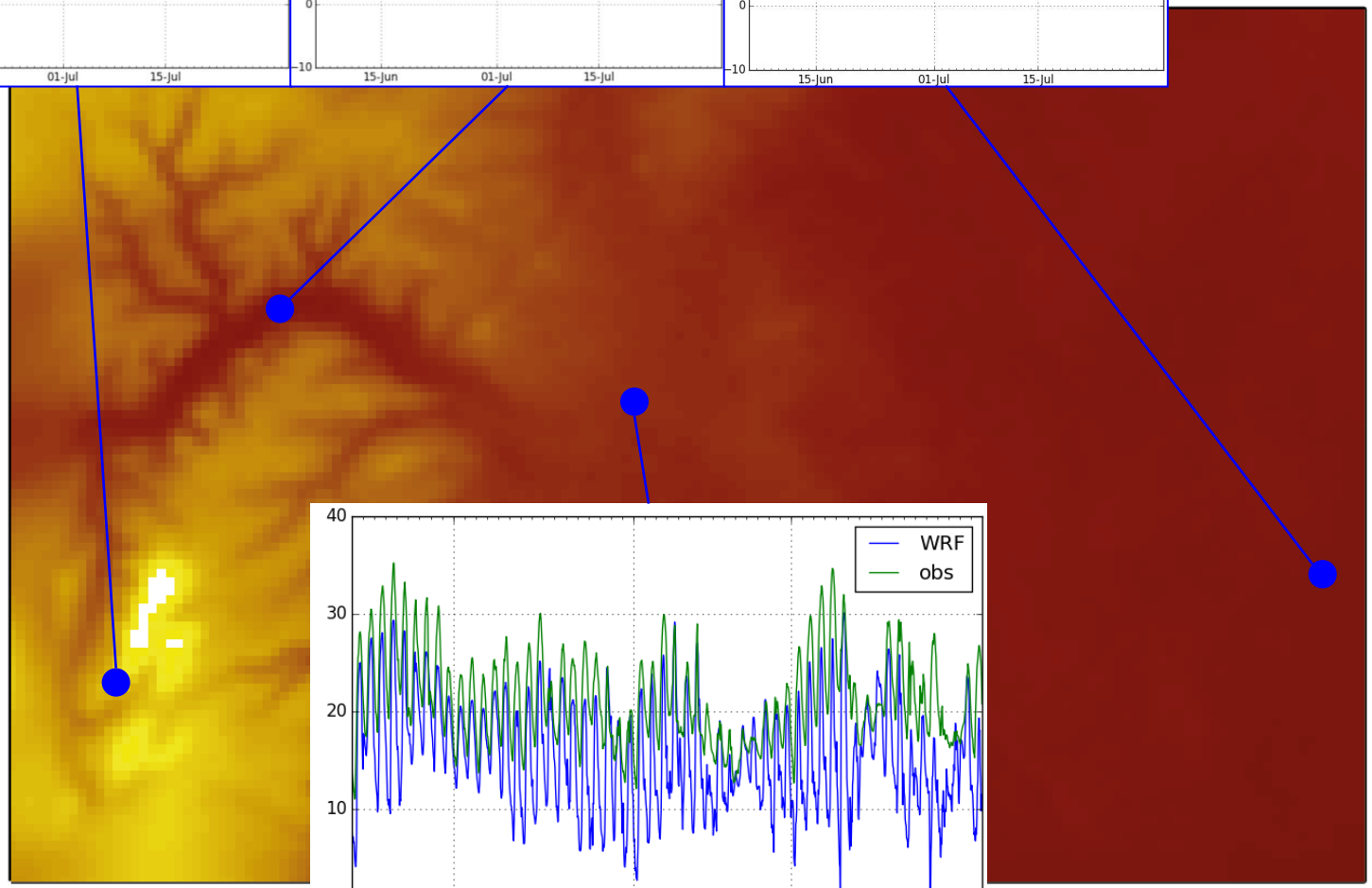

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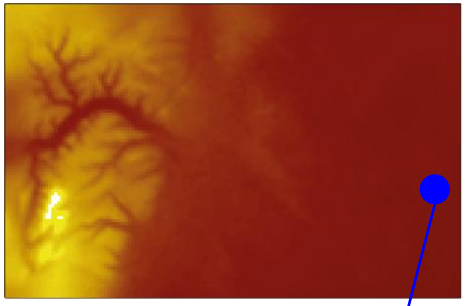

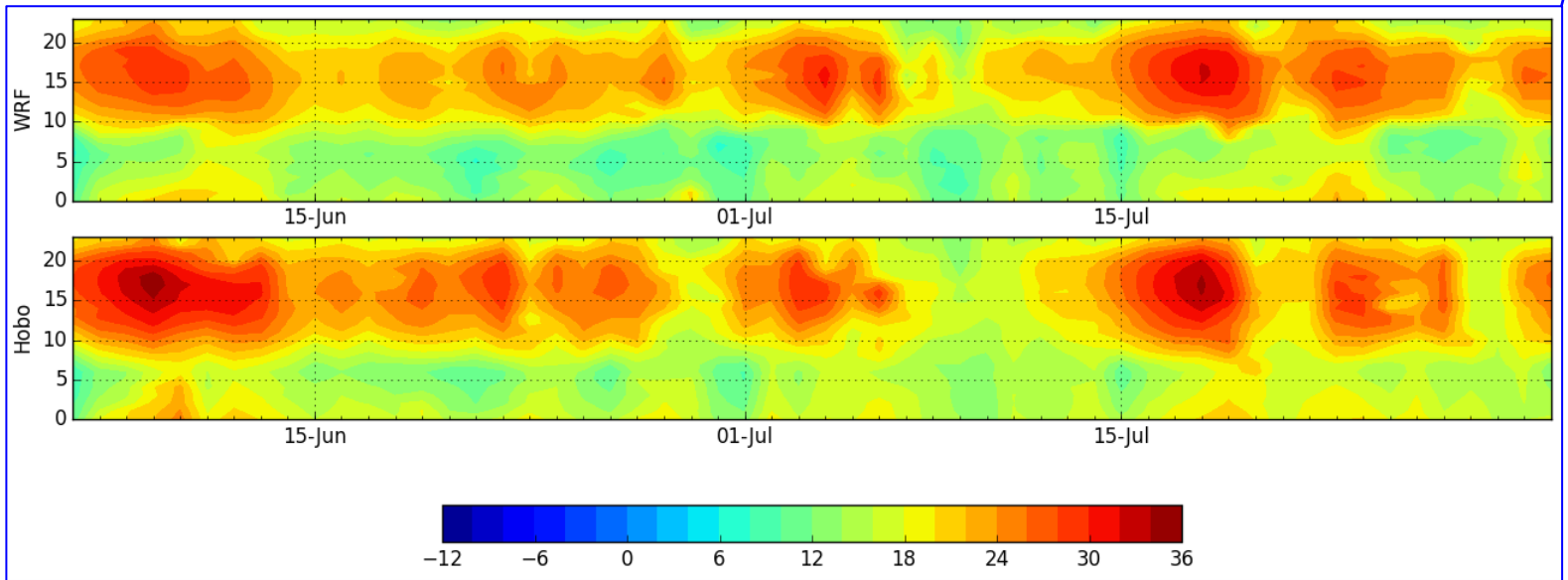

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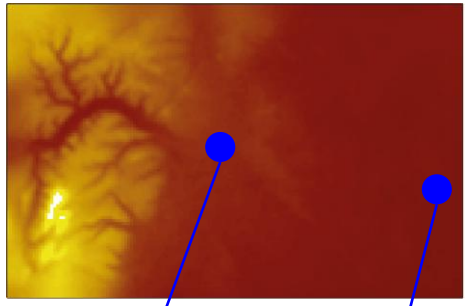
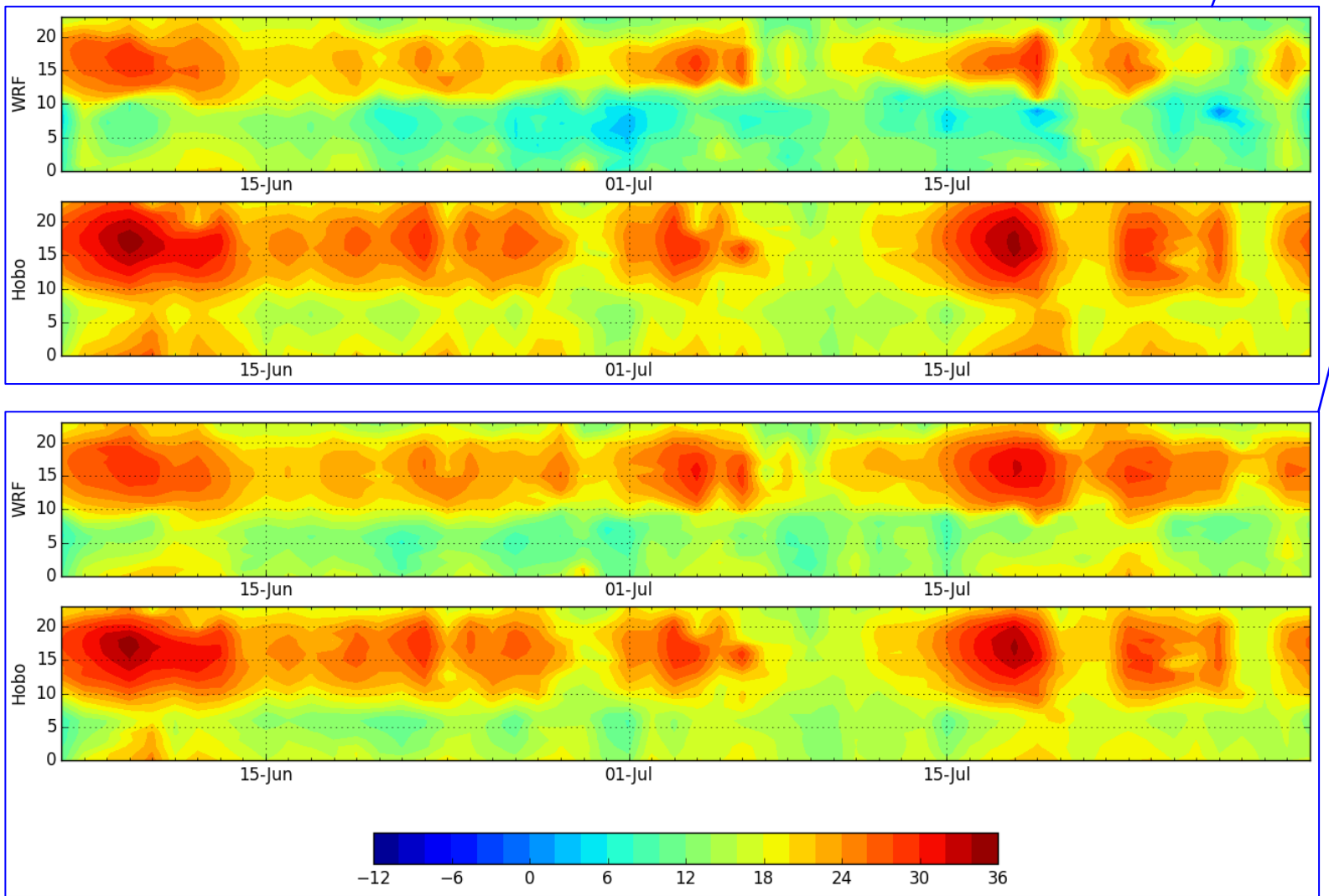
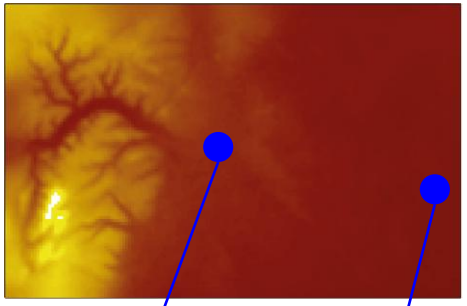
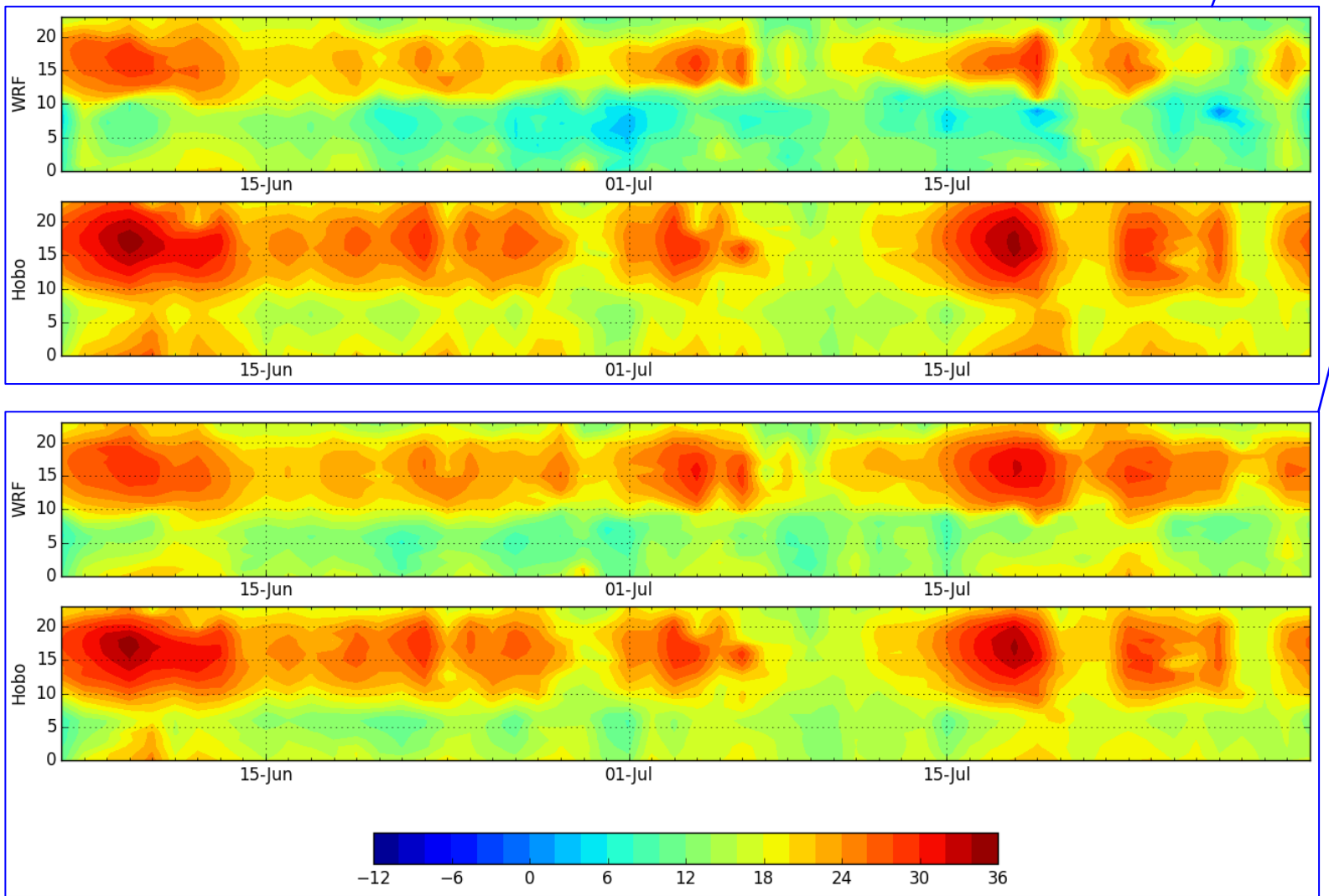




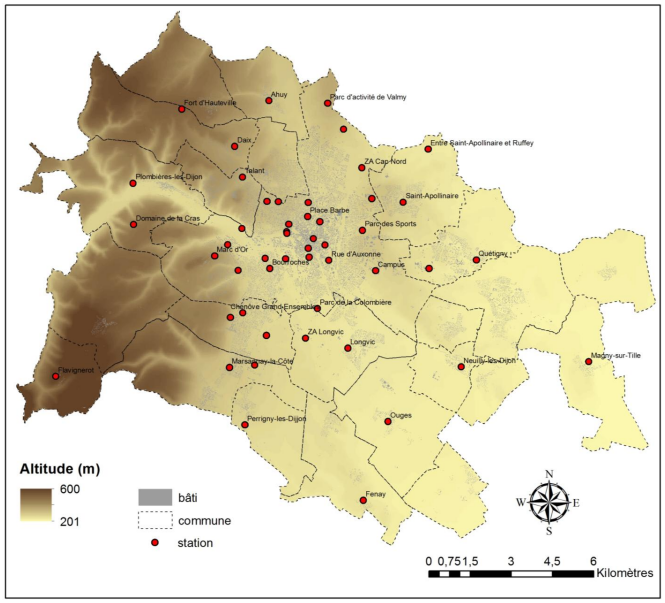
The UHI of Dijon | Simulations

for 2015, still some problems to fix… ☹





The UHI of Dijon | Conclusions



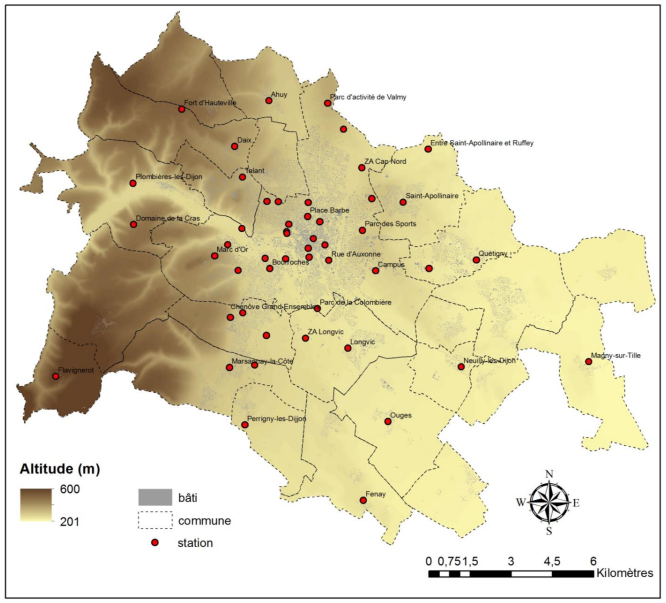
- **Summertime UHI = dipole** : role of vegetation and water (= latent heat fluxes)

- Analysis of **wintertime UHI**
- Analysis of the **summer 2015 UHI**
  ΔT max > 5–6°C or ΔT max already reached … ?

- In the future, link thermal environment to **urban ecology**

BIOGÉOSCIENCES

The UHI of Dijon | Conclusions



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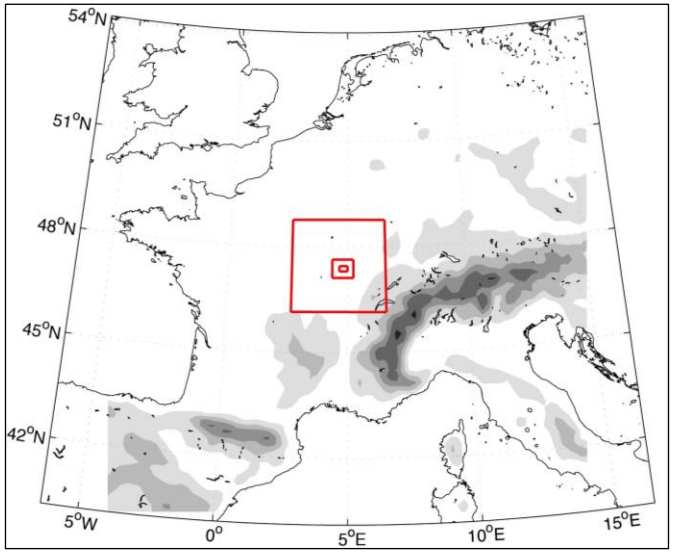

- Underestimation of **UHI amplitude**

INRA SCIENCE & IMPACT

- **High-res soil databases** needed
- BEP coupled with WRF through 1D turbulence schemes: not optimal for high-res. Towards **LES simulations**.

- in the future, use BEP-BEM for wintertime, and of course BEP for the 2015 summer period
- use a urban expansion model for sensitivity experiments (local UHI increase vs. climate change)

ThéMA UMR 6049

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