Spatial variability, horizontal anisotropy and diurnal evolution of measured infrared fluxes in a city neighborhood of Toulouse

B. Carissimo, Y. Qu, R. Bresson, N. Daviau, N. Gaudio*, M. Milliez

* Meteo France

ICUC9 – Toulouse 20-24 /7/2015
Outline

• Context / Motivation
• Experimental methodology
  – ANR project EUREQUA
  – Methodology
  – Data processing
• Results for spatial inhomogeneity (and its evolution)
• Results for anistropy (and its time evolution)
• Conclusions / futur work
Context / Motivation

- CAPITOUL (Masson et al., 2008)
- Thermal infrared (TIR) airborne images 1412 UT during flight 432 (Henon, 2008; Lagouarde et al., 2010):

![Thermal image](image)

Measured $T_{br}$ (°C)

Legend:

- 25.10
- 45.00
- 55.00
- 65.00
- 68.10
Night flights  

Day flights
«Complete» urban temperature

Voogt & Oke 1997
Validation of building resolving micrometeorological models (A-CFD) with CAPITOUL dataset (Qu, 2012)

- Simulation of July 15th 2004

a) TIR aircraft camera

b) Simulation Code_Saturne (www.code-saturne.org)

Measured $T_{br}$ (°C)

Simulated $T_{br}$ (°C)

Simulated $T_{sfc}$ (°C)

25.10
45.00
55.00
65.00

35.00
50.00
60.00
68.10

« virtual aircraft pictures »
Model stop points for comparison with camera data

EUREQUA stop points (Marseille)
Toulouse 2014 field campaigns (3)
(also 1 in Paris and 1 in Marseille)

Fixed and mobile network:
- Meteo
- AQ
- Sound
+ traffic counts
+ questionnaires (10,16,19h)

Source: GoogleEarth
Infrared camera

File « xxx.is2 » (Fluke format)

9 stop points
8 horizontal dir. + 3 vert.
~Every 3h, 3 days (20)
January, April, June

~6000 IR pictures + visible

Visible image + IR image

IR data

→ Manual classification (time consuming team work!)
Toulouse POI 3 June 2014

Time evolution of ground brightness $T \, (^{\circ}C)$

![Graph showing time evolution of ground brightness](image_url)
Time evolution of local anisotropy: two locations selected
Visible images
Visible images
Point 1

\[ T_{br}(\degree C) \]

N
E
S
W

6h 12h 18h 24h
Point 8

\[
\begin{array}{cccc}
\text{N} & \text{E} & \text{S} & \text{W} \\
\text{T}_{br}(^\circ\text{C}) & \text{6h} & \text{12h} & \text{18h} & \text{24h}
\end{array}
\]
Conclusions and further work

• very extensive database of more than 6000 IR images (Toulouse, 12000 total) (and simultaneous visible images)
• spatial variations within the neighborhood:
  – small in late night
  – much more pronounced during the day, depending on location
  – important effect of vegetation clearly visible.
• anisotropy found is very pronounced, above 20°C in some area & also strongly dependant on location.
• finer analyses possible before using it for model comparison with 3D IR schemes capable of reproducing the radiation budget in complex urban geometries.
Filière de traitement (python):
- Relecture des fichiers .txt
- figures
- statistiques

| Filename | Day | Hour | Location | Direction | Choice | Tspot | Tmin | Tmax | Tmean | Tstd | Tp05 | Tp10 | Tp25 | Tp50 | Tp75 | Tp90 | Tp95 |
|----------|-----|------|----------|-----------|--------|-------|------|------|-------|------|------|------|------|------|------|------|------|------|
| IR003539 | 7   | 18   | 3        | -1        | 1      | 20.83 | 20.36| 22.06| 21.09 | 0.31 | 20.66| 20.72| 20.83| 21.02| 21.34| 21.56| 21.63|
| IR003540 | 7   | 18   | 3        | -2        | 1      | 16.77 | 4.95 | 22.78| 18.93 | 2.26 | 14.97| 15.69| 17.02| 20.55| 20.77| 20.88| 20.98|
| IR003541 | 7   | 18   | 3        | 0         | 1      | 18   | -1.33| 24.44| 18.08 | 1.86 | 16.56| 17.02| 17.55| 18.14| 19.16| 19.59| 19.73|
| IR003542 | 7   | 18   | 3        | 1         | 1      | 18.7 | -17.58| 20.91| 17.66 | 3.18 | 15.47| 17.22| 17.7 | 18.38| 18.59| 18.81| 18.97|
| IR003543 | 7   | 18   | 3        | 2         | 1      | 18.48| 16.8 | 21.2 | 18.97 | 0.47 | 18.19| 18.45| 18.7 | 19   | 19.27| 19.48| 19.67|
| IR003544 | 7   | 18   | 3        | 3         | 1      | 19.27| -12.33| 22.06| 18.00 | 2.55 | 15.34| 16.98| 17.81| 18.33| 19.08| 19.59| 19.89|
| IR003545 | 7   | 18   | 3        | 4         | 1      | 19.67| -0.45| 27.59| 17.78 | 3.04 | 11.72| 15.97| 17.92| 18.67| 19.11| 19.38| 19.52|
| IR003546 | 7   | 18   | 3        | 5         | 1      | 18.97| 3    | 26.83| 17.71 | 2.11 | 15.63| 16.98| 17.55| 18.08| 18.52| 19.08| 19.38|

Base de données (format .xls) contenant les statistiques et les repères spatiaux temporels (entrées manuelles)
array of IR images, scaled and assembled

Ex: Toulouse POI 3 / Point 1
array of IR images, scaled and assembled

Ex: Toulouse POI 3 /Point 2