

# Spatial variability, horizontal anisotropy and diurnal evolution of measured infra- red fluxes in a city neighborhood of Toulouse

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# Outline

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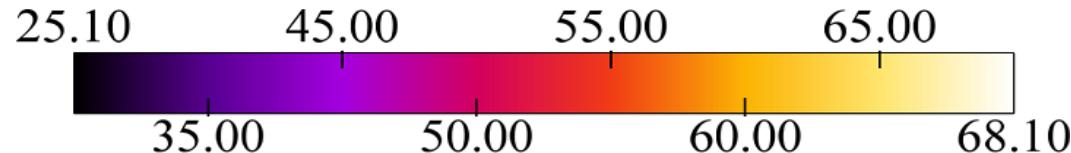
- **Context / Motivation**
- **Experimental methodology**
  - ANR project EUREQUA
  - Methodology
  - Data processing
- **Results for spatial inhomogeneity (and its evolution)**
- **Results for anistropy (and its time evolution)**
- **Conclusions / futur work**

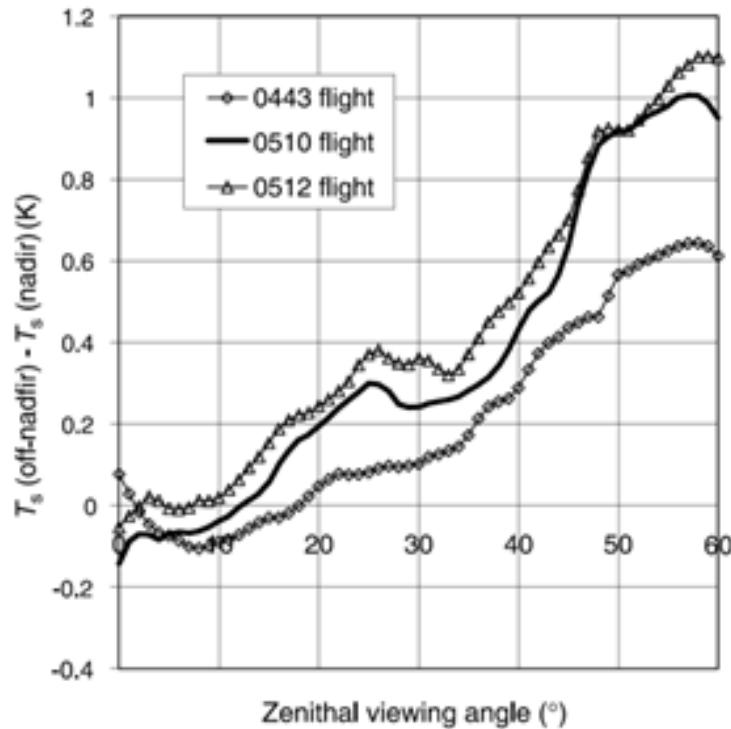
# Context / Motivation

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

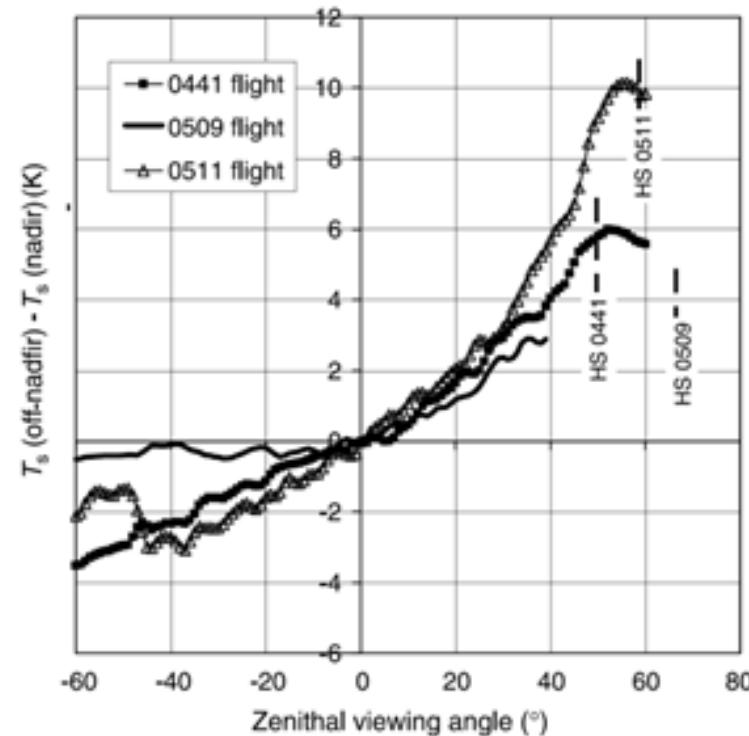


Measured  $T_{br}$  ( $^{\circ}\text{C}$ )





Night flights

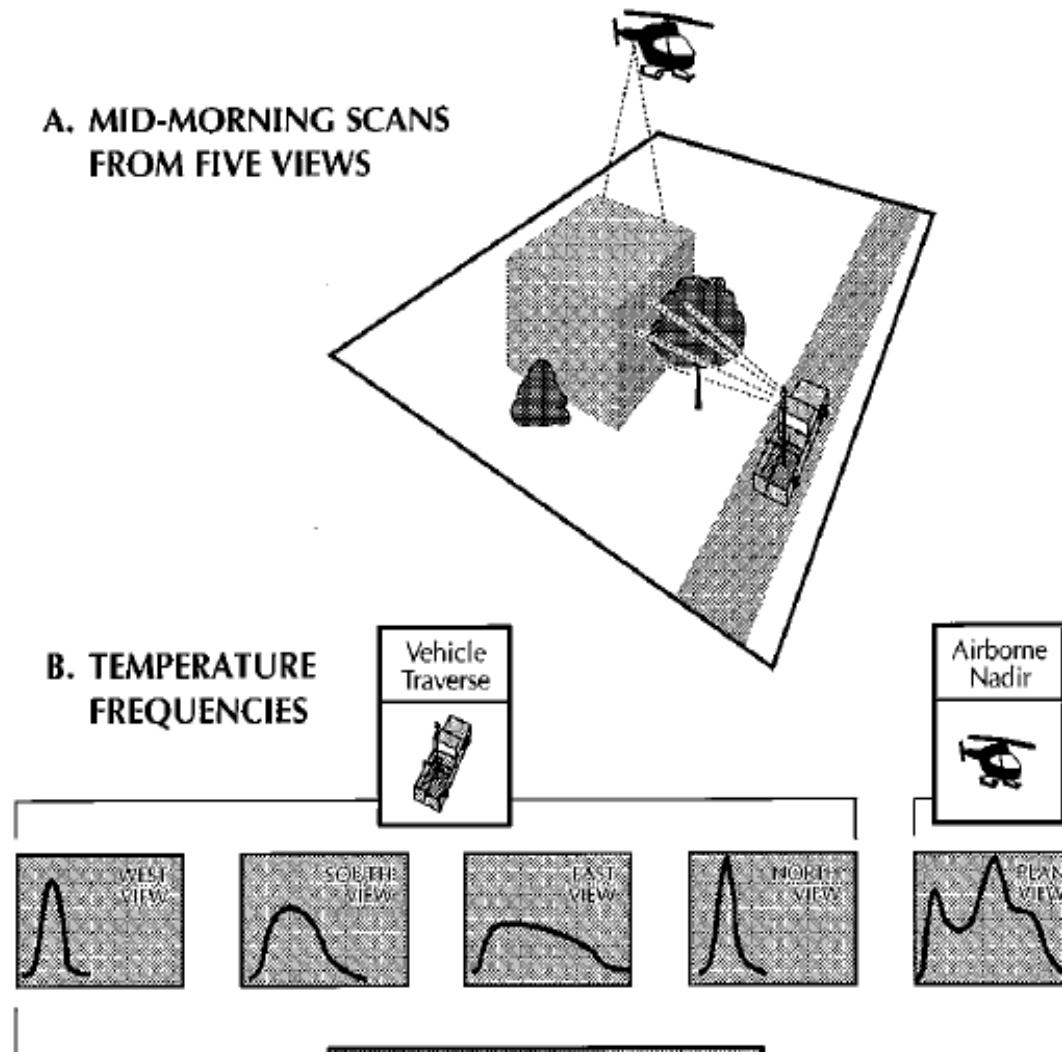


Day flights

?  
90

## « Complete » urban temperature

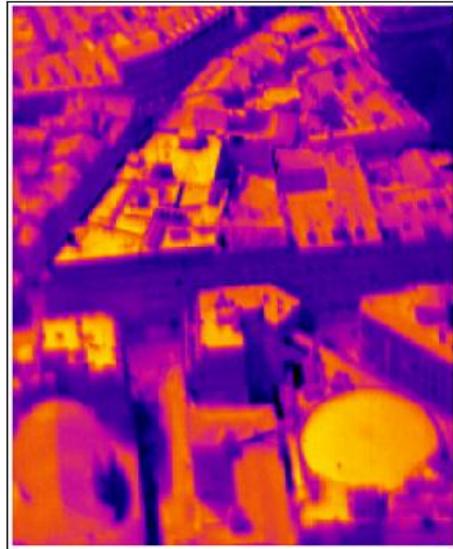
Voogt & Oke 1997



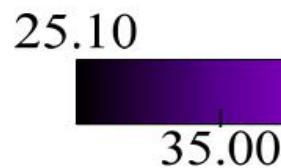
# Validation of building resolving micrometeorological models (A-CFD) with CAPITOUL dataset (Qu, 2012)

- Simulation of July 15<sup>th</sup> 2004

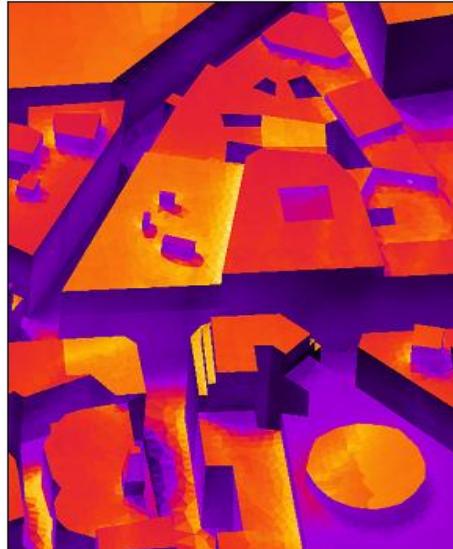
a) TIR aircraft camera



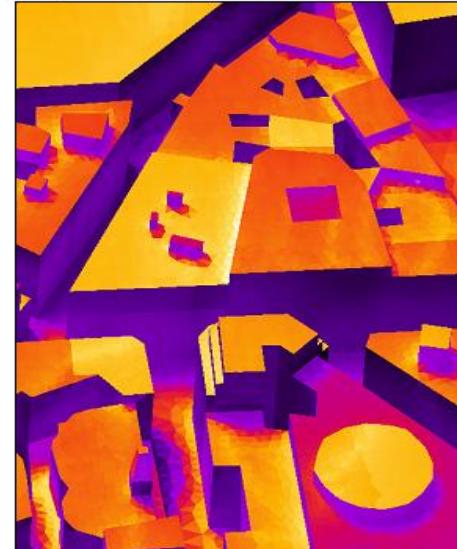
Measured  $T_{br}$  ( $^{\circ}\text{C}$ )



b) Simulation *Code\_Saturne* ([www.code-saturne.org](http://www.code-saturne.org))



Simulated  $T_{br}$  ( $^{\circ}\text{C}$ )

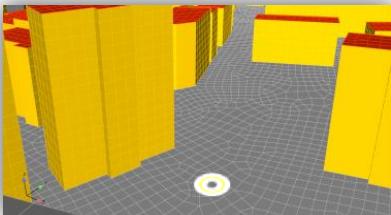


Simulated  $T_{sfc}$  ( $^{\circ}\text{C}$ )

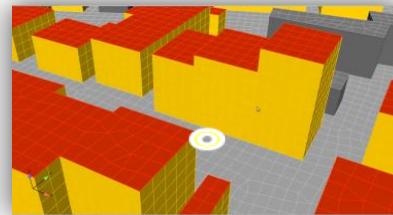
« virtual  
aircraft  
pictures »

**Model stop points  
for comparison with  
camera data**

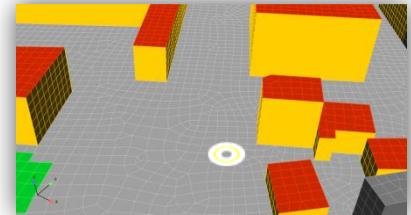
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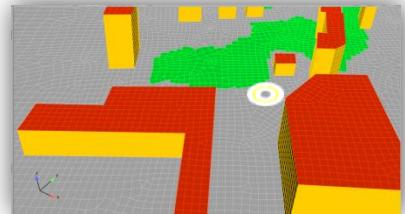
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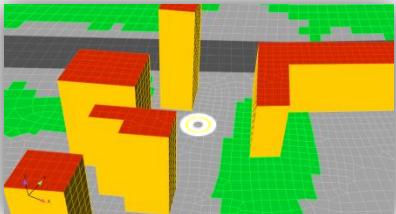
C3



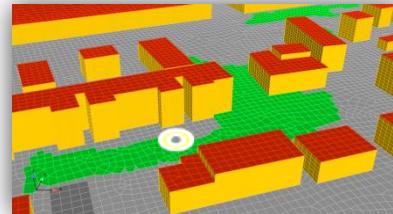
C4



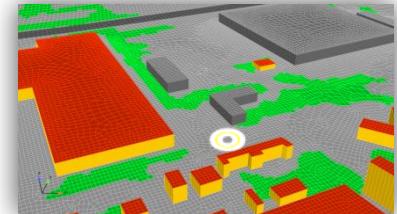
C5



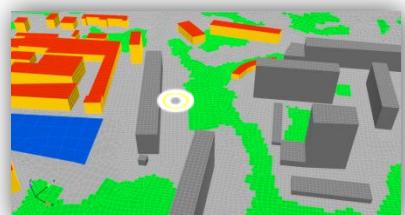
C6



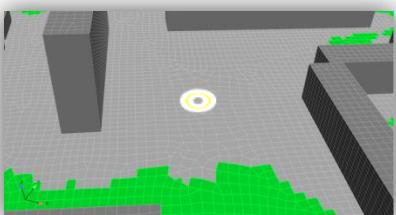
C7



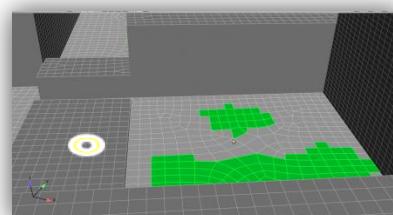
C8



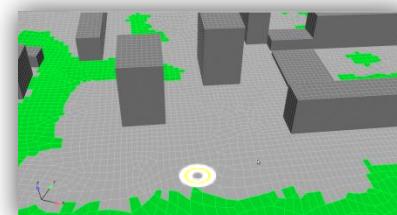
C9



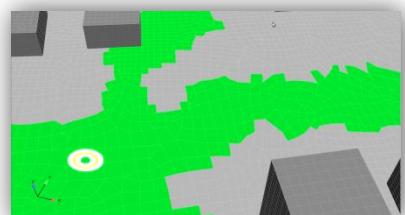
C10



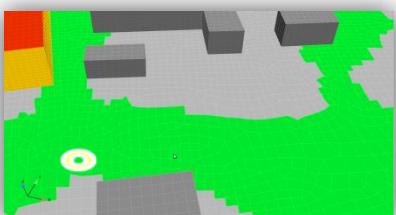
C11



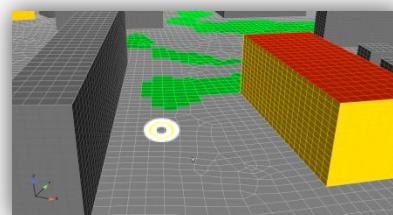
C12



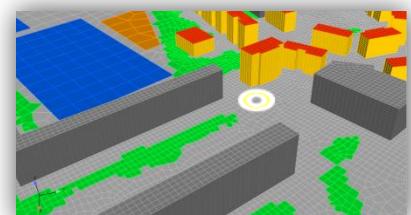
C13



C14

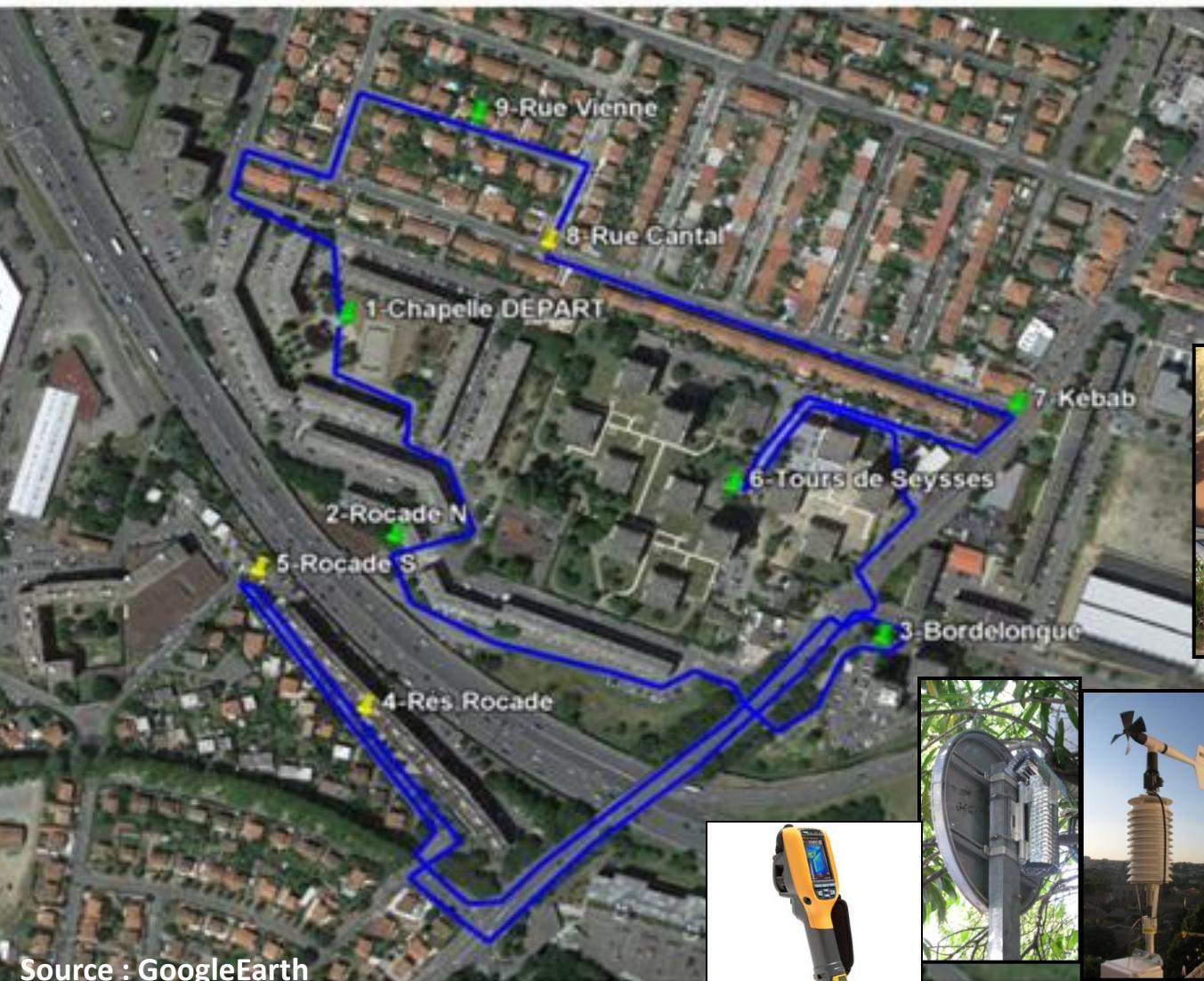


C15



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)



# Infrared camera



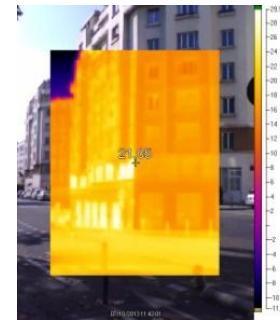
File « xxx.is2 »  
(Fluke format )

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

~6000 IR pictures  
+ visible



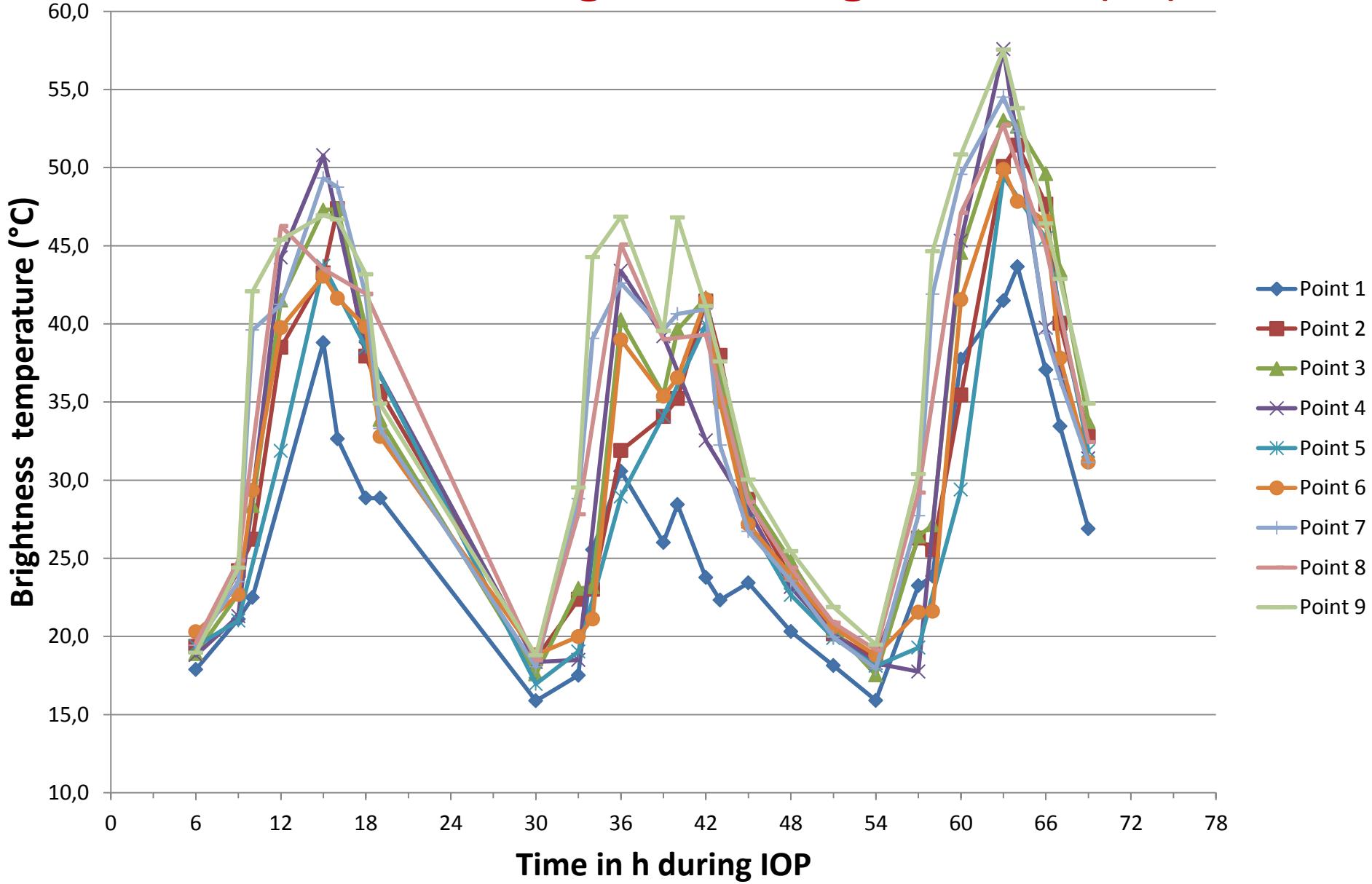
Visible image



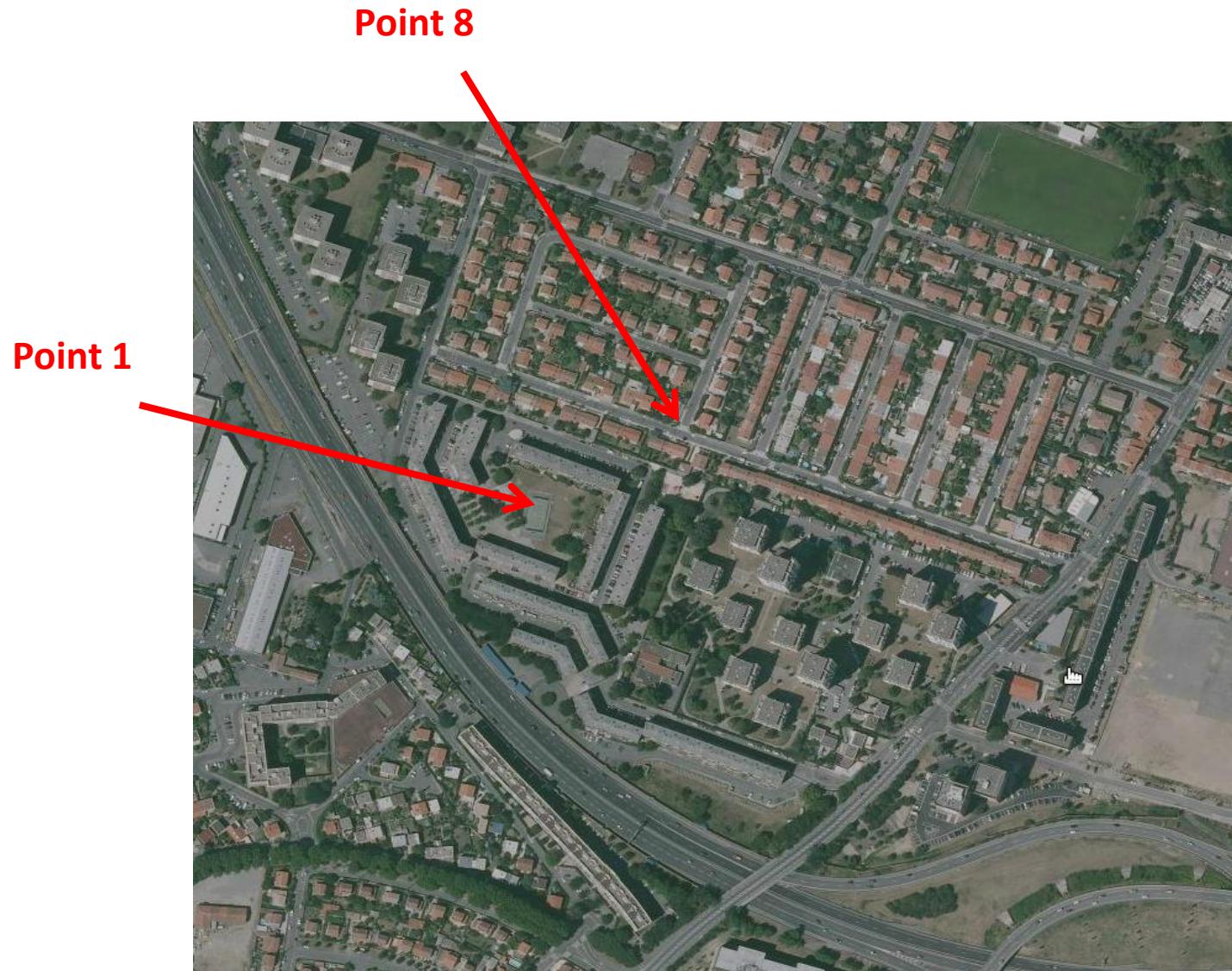
+ IR image

Toutes les températures dans °C.											
Z:\0\100FLUKE\IR003434.IS2											
1	~11,13	2	~11,17	3	~11,23	4	~11,23	5	~11,33	6	~11,17
2	~11,08	3	~11,03	4	~11,23	5	~11,42	6	~11,23	7	~11,08
3	~10,58	4	~11,03	5	~10,88	6	~11,03	7	~10,48	8	~11,13
4	~10,94	5	~10,73	6	~10,83	7	~10,64	8	~10,53	9	~10,83
5	~10,39	6	~10,34	7	~10,53	8	~10,64	9	~10,44	10	~10,73
6	~10,34	7	~10,44	8	~10,48	9	~10,64	10	~10,05	11	~10,69
7	~10,44	8	~10,14	9	~10,48	10	~10,05	11	~10,05	12	~10,73
8	~9,84	9	~10,05	10	~9,99	11	~9,85	12	~10,05	13	~10,00
9	~9,84	10	~9,89	11	~9,80	12	~9,75	13	~9,98	14	~9,95
10	~9,41	11	~9,61	12	~9,52	13	~9,75	14	~9,66	15	~9,56
11	~9,36	12	~9,41	13	~9,47	14	~9,61	15	~9,61	16	~9,56
12	~9,31	13	~9,36	14	~9,56	15	~9,27	16	~9,36	17	~9,03
13	~9,08	14	~9,27	15	~9,08	16	~9,03	17	~9,41	18	~9,03
14	~9,17	15	~8,83	16	~8,98	17	~8,83	18	~8,69	19	~8,78
15	~8,69	16	~8,83	17	~8,59	18	~8,73	19	~8,55	20	~8,78
16	~8,41	17	~8,25	18	~8,41	19	~8,45	20	~8,64	21	~8,50
17	~8,11	18	~8,17	19	~8,56	20	~8,48	21	~8,16	22	~8,16
18	~7,83	19	~7,97	20	~7,87	21	~7,96	22	~7,96	23	~7,98
19	~7,92	20	~7,73	21	~7,97	22	~7,64	23	~8,02	24	~7,92
20	~7,88	21	~7,73	22	~7,69	23	~7,59	24	~7,69	25	~7,69
21	~7,27	22	~7,59	23	~7,55	24	~7,50	25	~7,41	26	~7,41
22	~7,36	23	~7,13	24	~7,03	25	~7,13	26	~7,31	27	~7,41
23	~6,78	24	~7,03	25	~7,03	26	~7,36	27	~7,41	28	~7,17
24	~6,50	25	~6,69	26	~6,69	27	~6,78	28	~6,94	29	~7,17
25	~6,14	26	~6,50	27	~6,64	28	~6,73	29	~6,94	30	~7,13
26	~5,81	27	~6,14	28	~6,14	29	~6,59	30	~6,33	31	~6,55
27	~5,48	28	~5,95	29	~6,14	30	~6,86	31	~6,38	32	~6,38
28	~5,44	29	~5,72	30	~5,81	31	~6,00	32	~6,09	33	~6,09
29		30		31		32		33		34	
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95		96		97		98		99		100	
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137		138		139		140		141		142	
138		139		140		141		142		143	
139		140		141		142		143		144	
140		141		142		143		144		145	
141		142		143		144		145		146	
142		143		144		145		146		147	
143		144		145							

# Time evolution of ground brightness T (°C)



## Time evolution of local anisotropy : two locations selected



## Visible images



**W**



**N**



**E**



**Point 1**

**S**



## Visible images



**W**



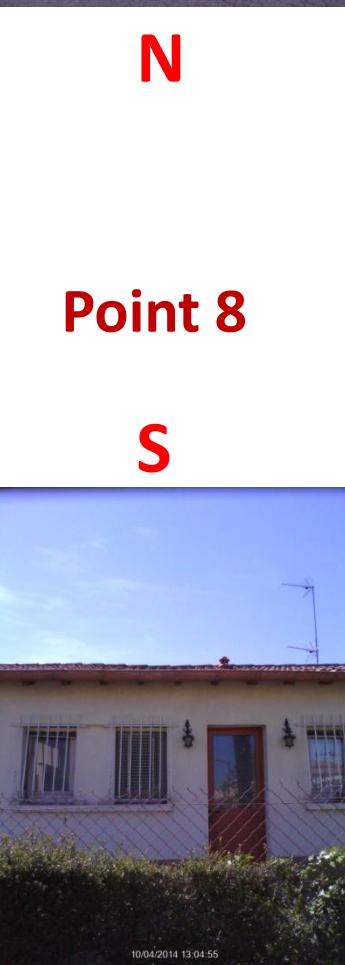
10/03/2013 13:05:04



**N**

**Point 8**

**S**



10/04/2014 13:04:55

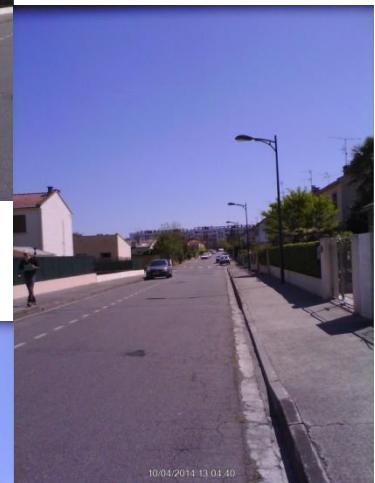


10/04/2014 13:03:34

**E**

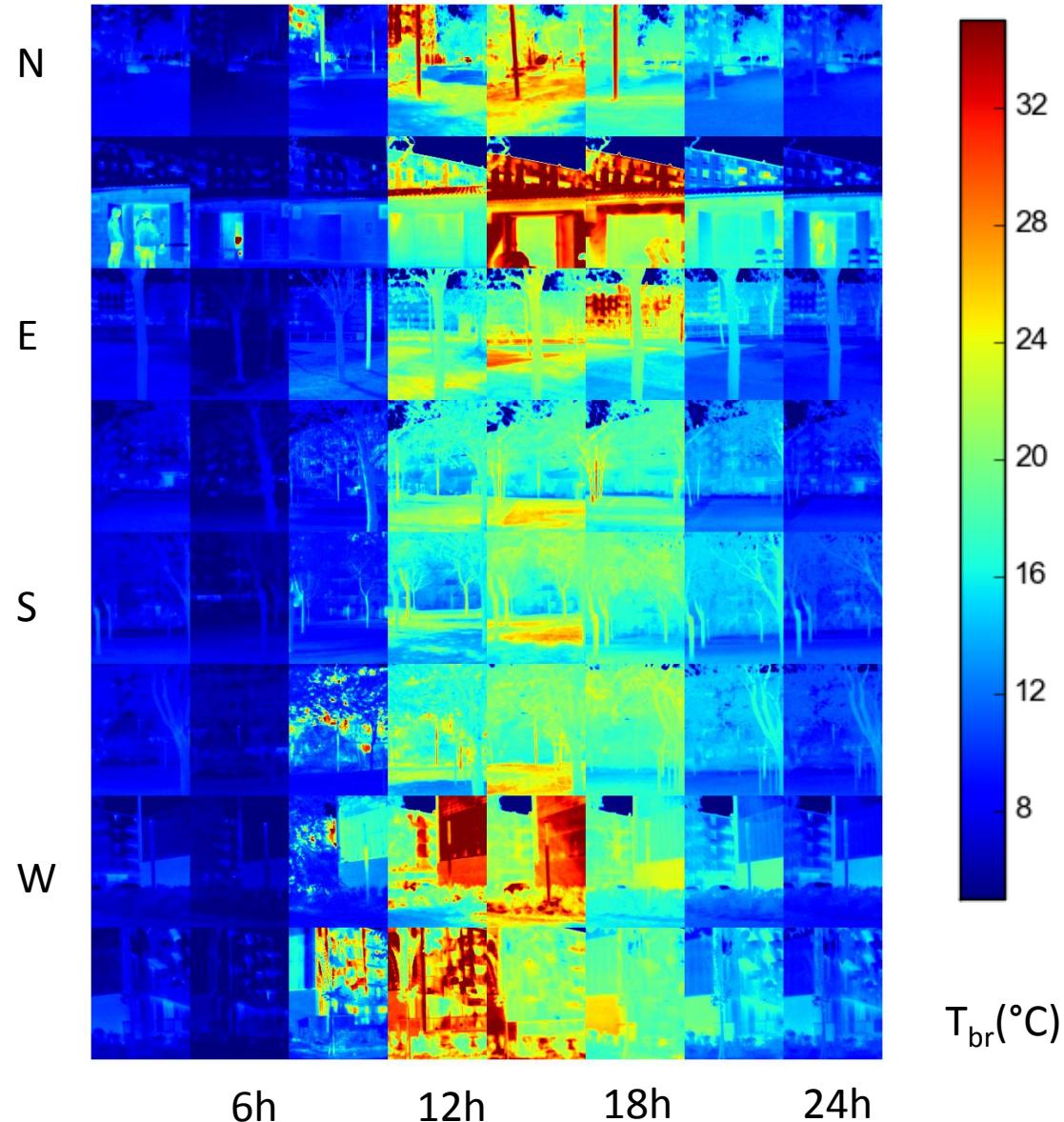


10/04/2014 13:04:47

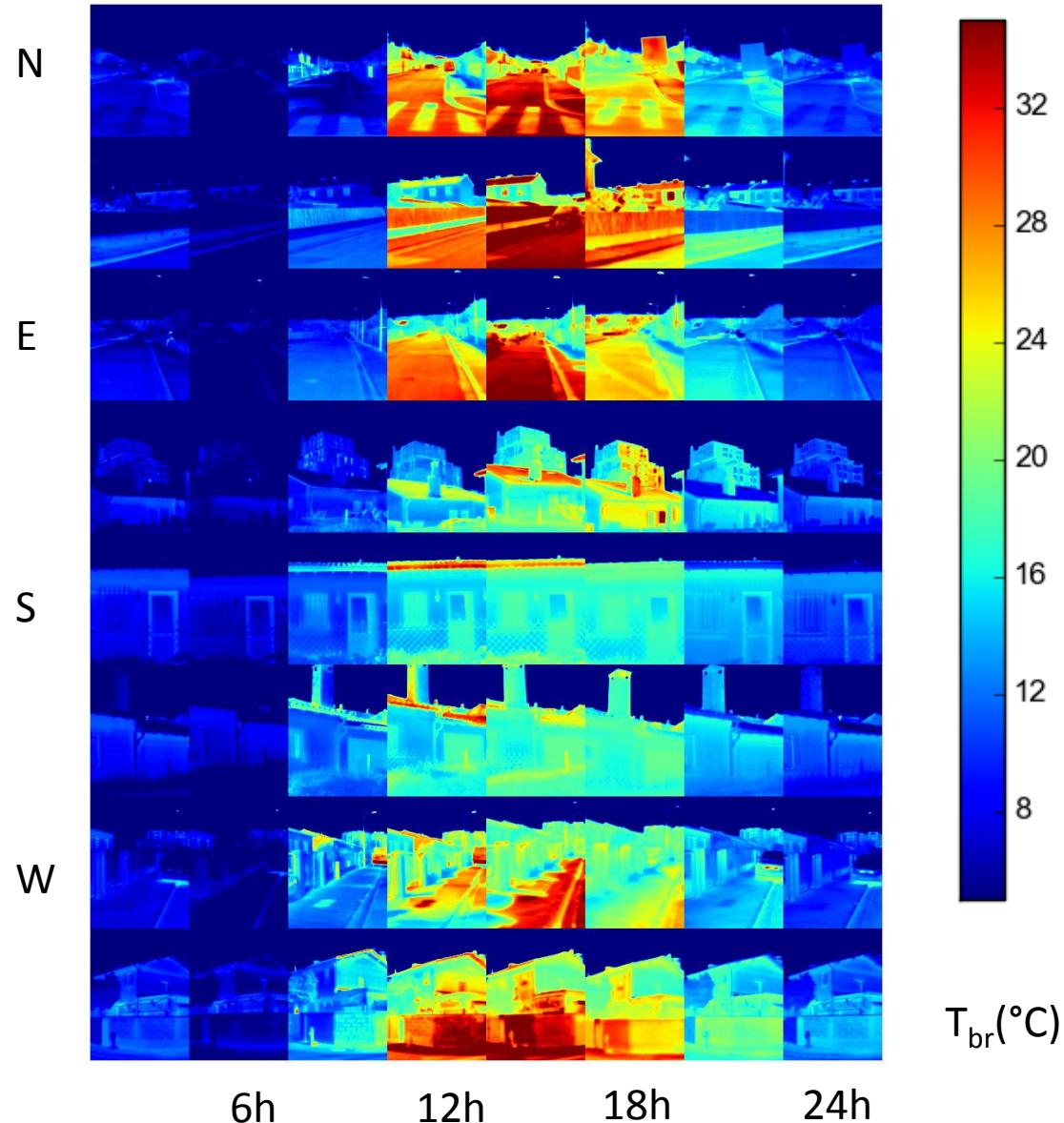


10/04/2014 13:04:40

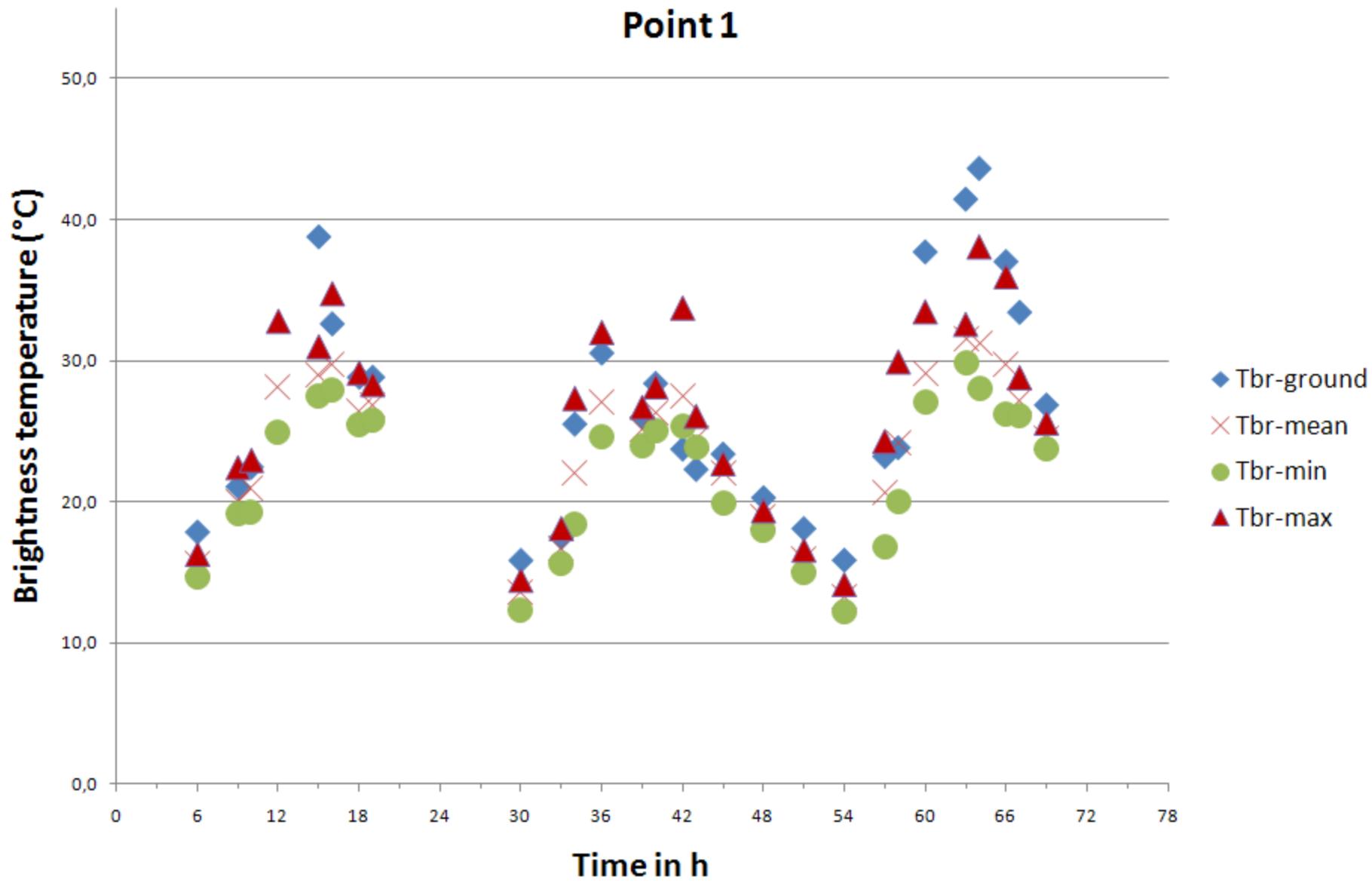
# Point 1

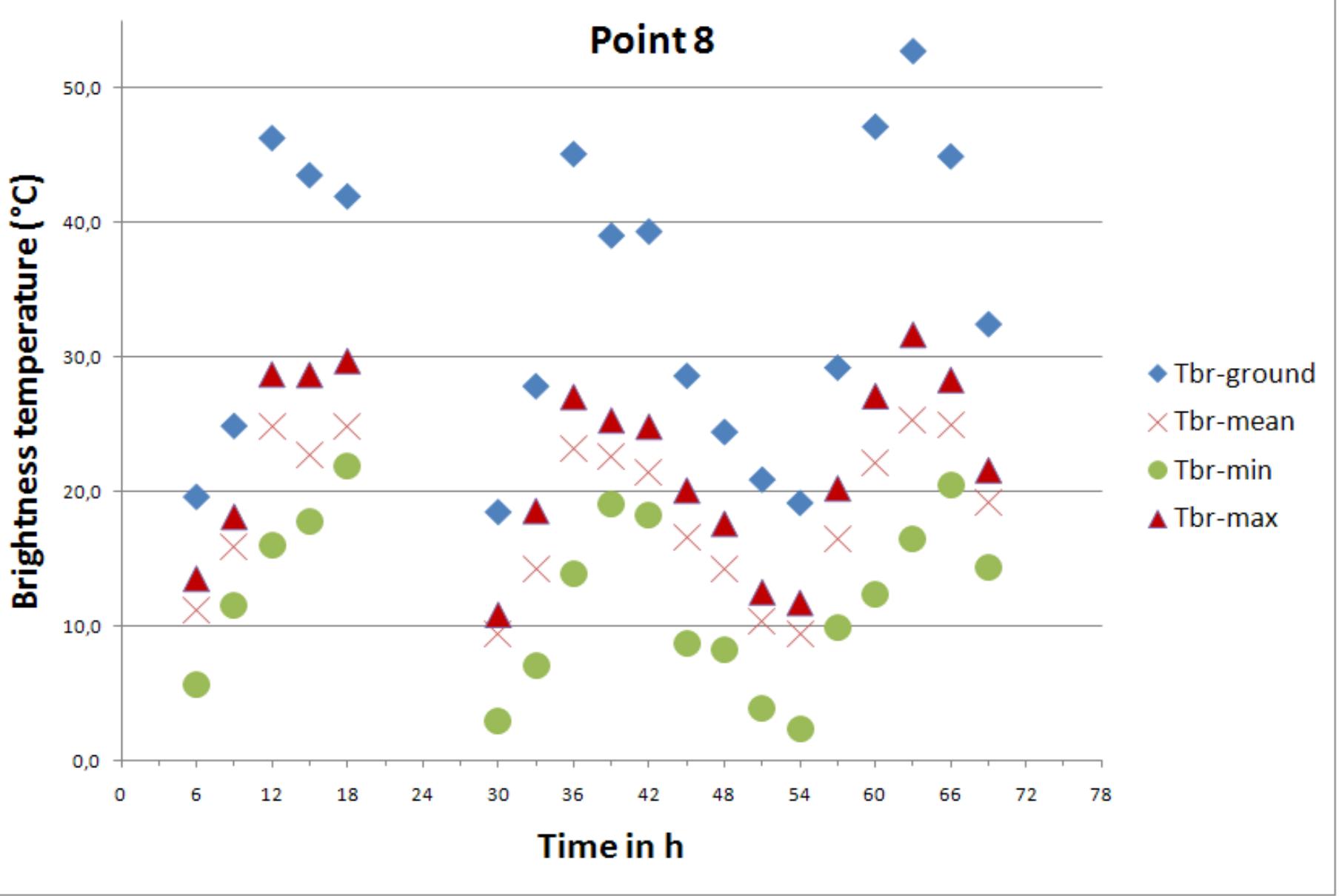


## Point 8



# Point 1





# Conclusions and further work

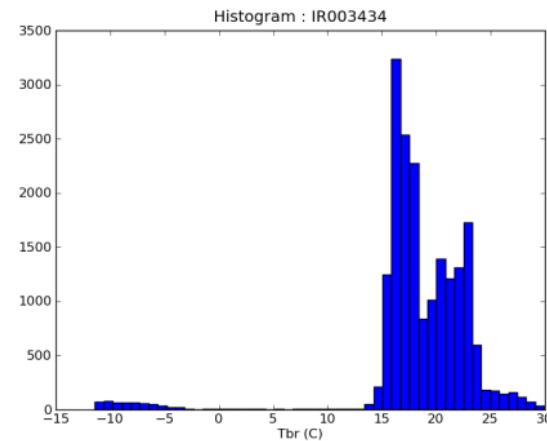
- very extensive database of more than 6000 IR images (Toulouse, 12000 total) (and simultaneous visible images)
- spatial variations within the neighborhood :
  - small in late night
  - much more pronounced during the day, depending on location
  - important effect of vegetation clearly visible.
- anisotropy 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

Toutes les températures dans °C.												
Z:\D\100FLUKE\IR003434.IS2	1	2	3	4	5	6	7	8	9	10	11	12
1	-11,13	-11,12	-11,23	-11,23	-11,33	-11,17	-11,17	-11,08	-11,08	-10,98	-11,17	-
2	-11,08	-11,03	-11,23	-11,42	-11,23	-11,08	-11,13	-11,13	-11,23	-10,78	-10,98	-
3	-10,58	-11,03	-10,88	-11,03	-10,48	-11,03	-11,03	-10,73	-10,83	-10,53	-	-
4	-10,94	-10,73	-10,83	-10,64	-10,53	-10,69	-10,69	-10,63	-10,69	-10,69	-10,73	-
5	-10,39	-10,34	-10,53	-10,64	-10,44	-10,48	-10,73	-10,69	-10,53	-10,23	-	-
6	-10,44	-10,14	-10,48	-10,05	-10,05	-10,14	-10,00	-10,44	-10,00	-10,14	-	-
7	-9,84	-10,05	-10,09	-9,95	-9,80	-9,95	-9,95	-10,00	-9,61	-10,09	-9	-
8	-9,84	-9,84	-9,80	-9,80	-10,05	-9,75	-9,84	-9,75	-9,84	-9,75	-9,70	-9
9	-9,49	-9,61	-9,52	-9,61	-9,69	-9,61	-9,61	-9,61	-9,61	-9,49	-9,49	-9
10	-9,36	-9,31	-9,47	-9,61	-9,67	-9,61	-9,31	-9,31	-9,47	-9,13	-9	-
11	-9,31	-9,36	-9,56	-9,27	-9,36	-9,41	-9,03	-9,27	-9,31	-9,08	-9	-
12	-9,08	-9,27	-9,08	-9,08	-9,03	-8,88	-9,13	-9,31	-9,08	-8,88	-8	-
13	-9,17	-8,93	-8,98	-8,84	-8,84	-8,85	-8,85	-8,85	-8,85	-8,85	-8,88	-8
14	-8,69	-8,88	-8,59	-8,73	-8,59	-8,59	-8,59	-8,59	-8,59	-8,55	-8,58	-8
15	-8,41	-8,25	-8,41	-8,45	-8,64	-8,59	-8,50	-8,59	-8,31	-8,20	-8	-
16	-8,11	-8,31	-8,45	-8,36	-8,45	-8,45	-8,16	-8,36	-8,31	-8,06	-8	-
17	-7,83	-7,97	-7,97	-8,16	-8,11	-8,36	-7,88	-8,02	-7,97	-7,97	-7	-
18	-7,88	-7,73	-7,73	-7,64	-7,62	-7,62	-7,58	-7,83	-7	-	-	-
19	-7,88	-7,73	-7,69	-7,59	-7,69	-7,69	-7,69	-7,69	-7,69	-7,50	-7	-
20	-7,36	-7,59	-7,55	-7,50	-7,41	-7,31	-7,41	-7,17	-7,41	-7,13	-7	-
21	-7,27	-7,59	-7,03	-7,13	-7,36	-7,36	-7,17	-6,98	-7,27	-7,13	-7	-
22	-6,94	-6,93	-6,94	-6,94	-6,94	-6,94	-6,94	-6,94	-6,94	-6,94	-6	-
23	-6,50	-6,50	-6,69	-6,78	-6,73	-6,64	-6,45	-6,94	-6,73	-6,83	-6	-
24	-6,14	-6,50	-6,64	-6,69	-6,64	-6,55	-6,64	-6,33	-6,55	-6,38	-6	-
25	-5,81	-6,38	-6,14	-6,14	-6,50	-6,38	-6,09	-6,14	-6,28	-6,09	-6	-
26	-5,48	-5,95	-6,14	-6,14	-5,86	-6,19	-6,09	-5,91	-6,05	-5,95	-6	-
27	-5,44	-5,72	-5,81	-6,00	-5,63	-5,77	-5,77	-5,80	-5,48	-6,00	-5	-



Base de données (format .xls) contenant les statistiques et les repères spatiaux temporels (entrées manuelles)

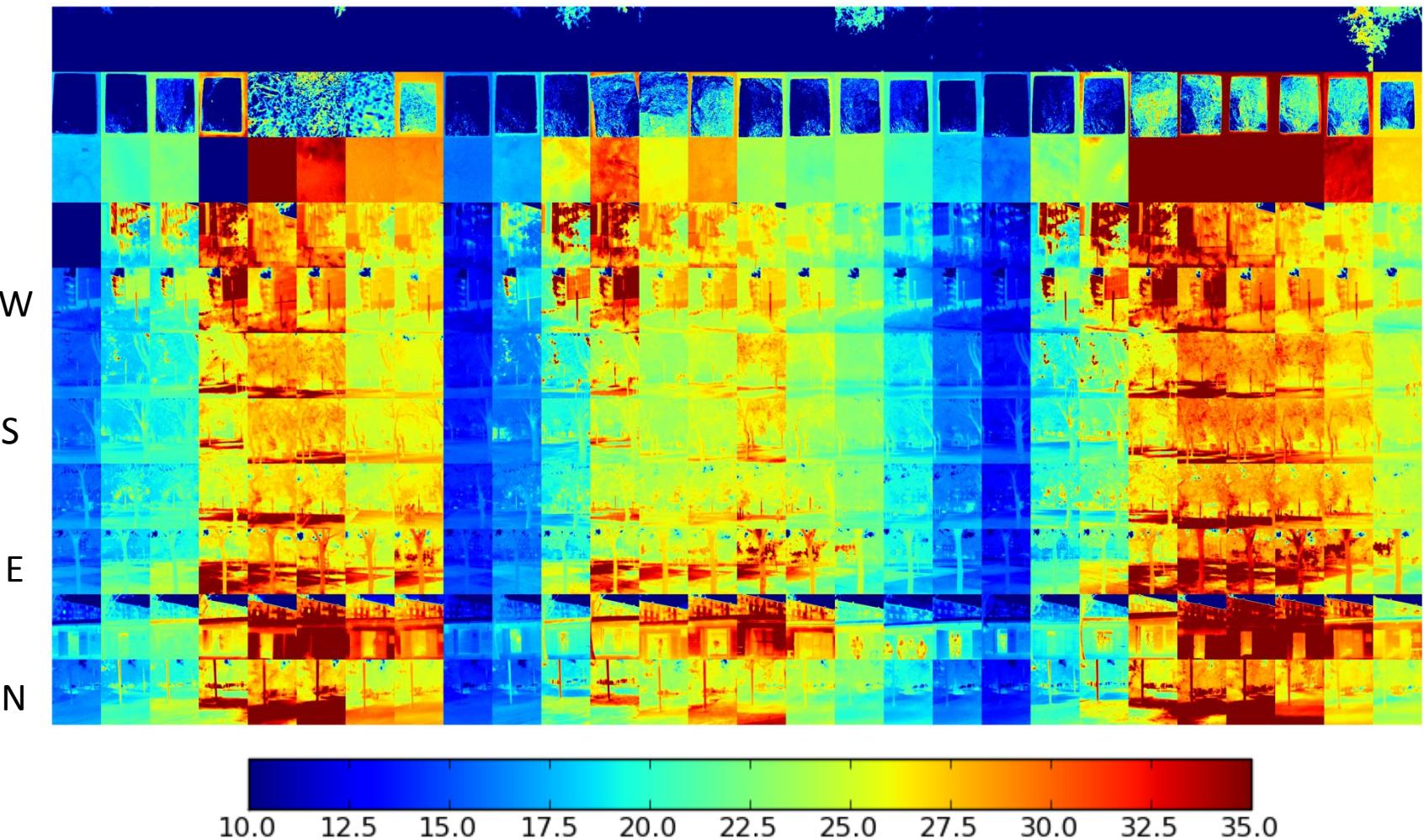
Filename	Day	Hour	Location	Direction	Choice	Tspot	Tmin	Tmax	Tmean	Tstd	Tp05	Tp10	Tp25	Tp50	Tp75	Tp90	Tp95
IR003539	7	18	3	-1	1	20,83	20,36	22,06	21,09	0,31	20,66	20,72	20,83	21,02	21,34	21,56	21,63
IR003540	7	18	3	-2	1	16,77	4,95	22,78	18,93	2,26	14,97	15,69	17,02	20,55	20,77	20,88	20,98
IR003541	7	18	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

# array of IR images, scaled and assembled

Time



Ex : Toulouse POI 3 /Point 1



# array of IR images, scaled and assembled

Time



Ex : Toulouse POI 3 /Point 2

W  
S  
E  
N

