Observed atmospheric and surface variability on heterogeneous terrain at the hectometre scale

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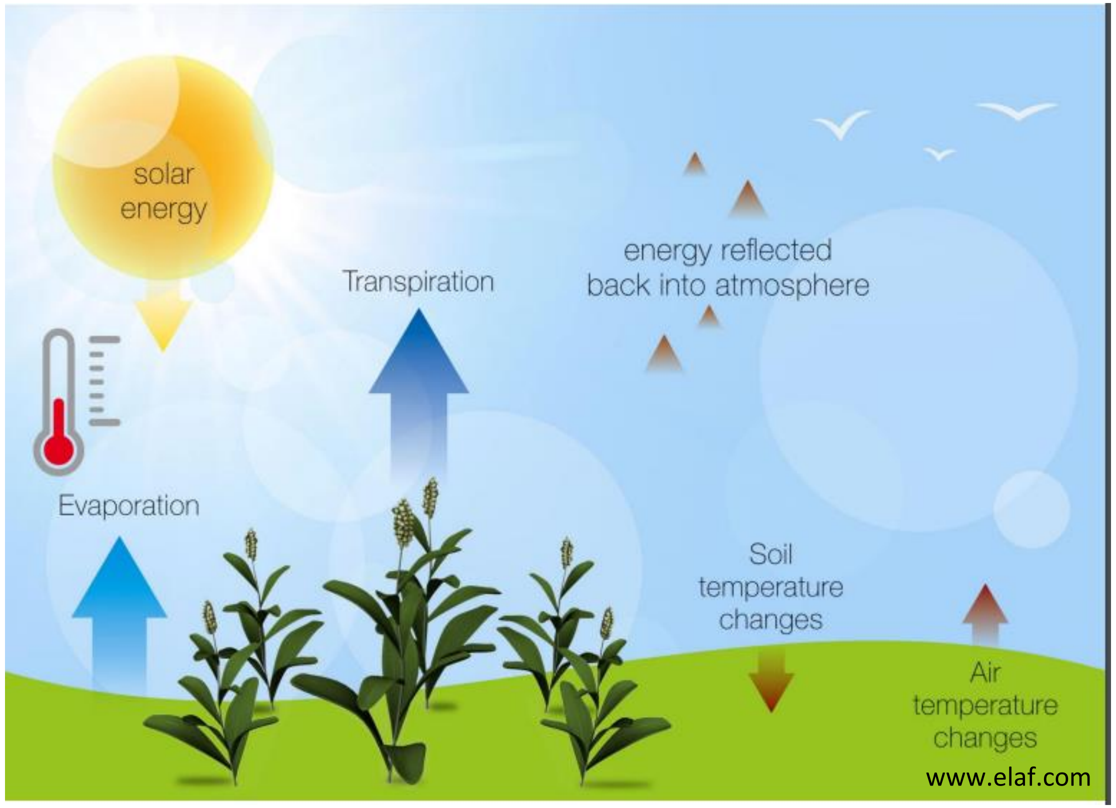
Outline:

- Motivation: is heterogeneity performing significant transport in the ABL?
- Hectometer scale variability as seen by a network of stations
- Conclusions

Surface energy budget imbalance: role of heterogeneity

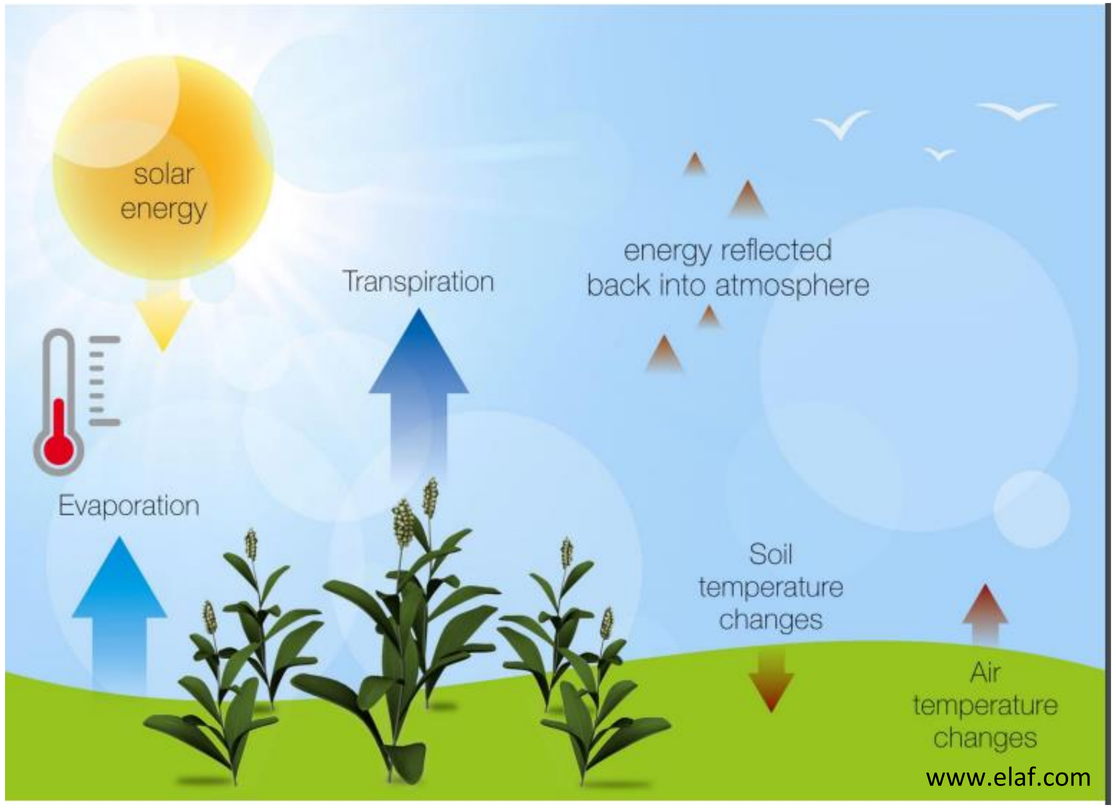
- Energy Exchanges
- Matter Exchanges
- Moment Exchanges



$$R_n + LE + H + G = 0$$

Surface energy budget imbalance: role of heterogeneity

- Energy Exchanges
- Matter Exchanges
- Moment Exchanges



Experimentally...

$$R_n + LE + H + G =$$

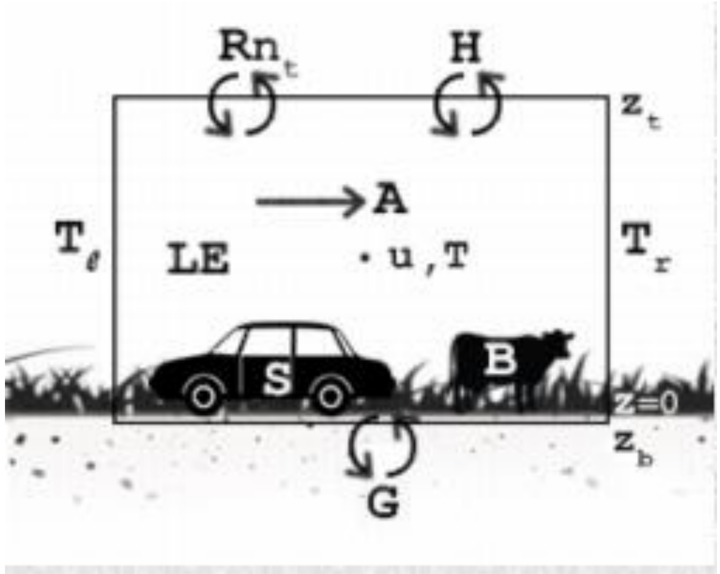
$$R_n + LE + H + G = \text{Imb}$$

Complete Surface Energy Budget Equation:

$$\frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} = -\frac{1}{\rho C_p}\frac{\partial Rn}{\partial z} - \frac{\partial \overline{w'T'}}{\partial z} - \frac{\partial G^*}{\partial z} + S^* + B^* + LE^* + Ot^*$$

$$TT + A = -\mathbf{Rn} - \mathbf{H} - \mathbf{G} + S + B - \mathbf{LE} + Ot$$

$$\mathrm{Rn} + \mathrm{H} + \mathrm{LE} + \mathrm{G} = -TT - A + S + B + Ot = Imb$$



The lack of imbalance is, most of the time, energy missing:

$$\boldsymbol{R_n \gg H + LE + G}$$

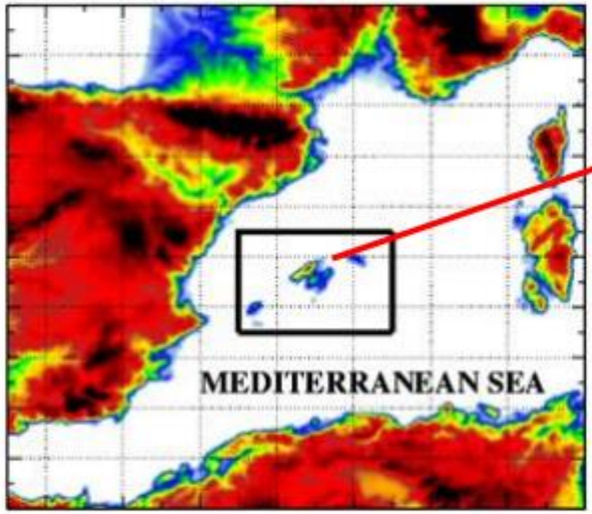
Suspected reasons:

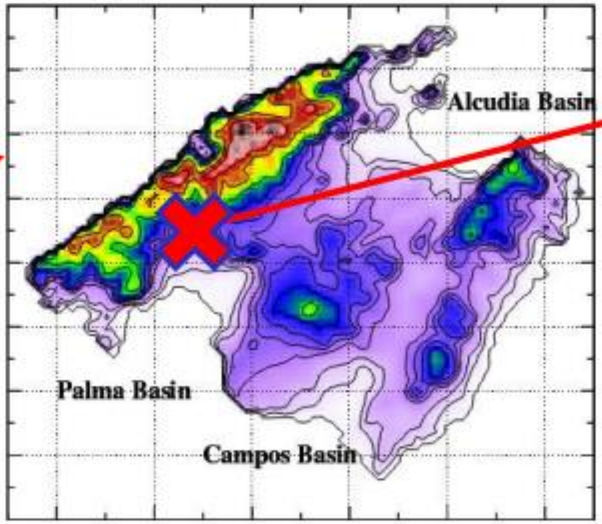
- Missing processes (A, S, B, ...)
- Underestimated processes (H, LE, G...)
- Instrumental problems
- Conceptual design of the experiment (each sensor sampling a different volume)

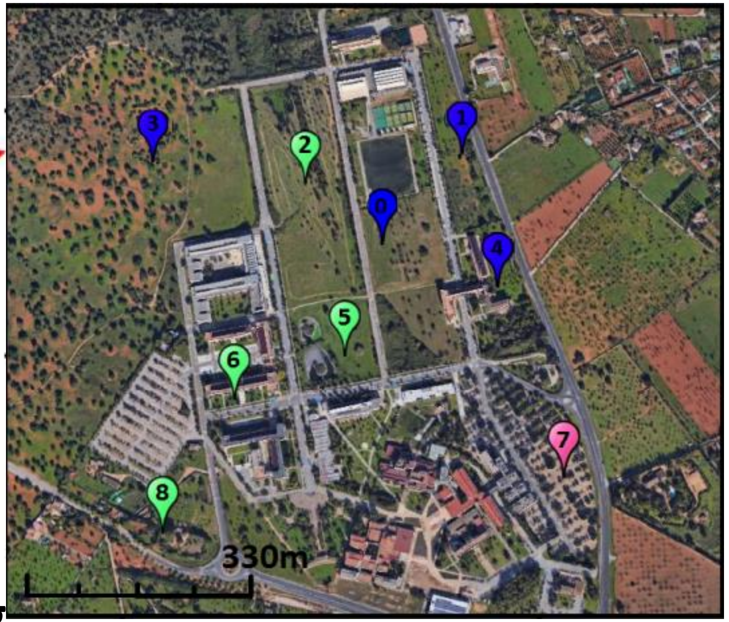
Evaluation of the surface energy budget equation with experimental data and the ECMWF model in the Ebro Valley, Cuxart, Conangla and Jiménez (2015)

Is heterogeneity performing significant transport in the ABL?

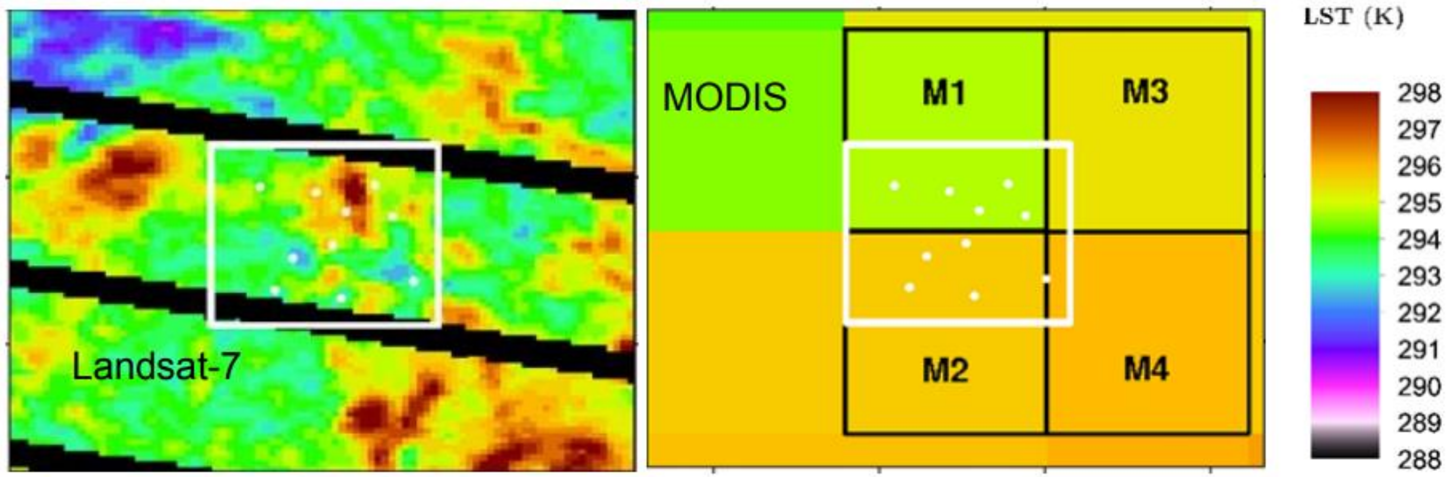
1) Heterogeneous Area: Campus of the University of the Balearic Islands





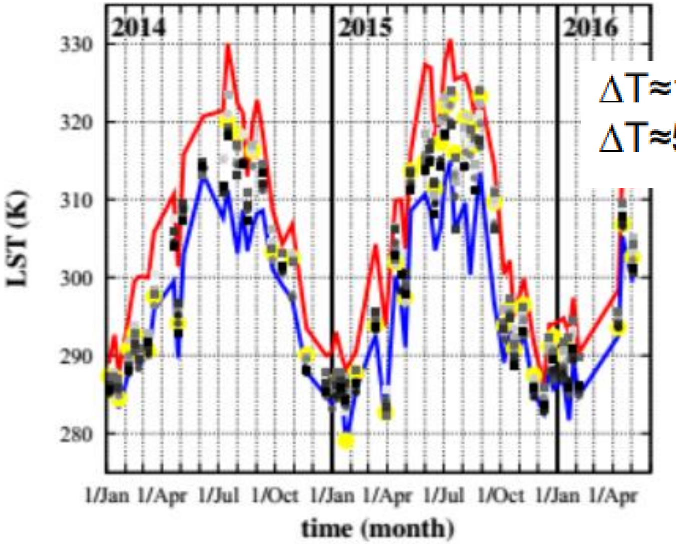


2) Previous study from satellite: Simó et al. 2016, Remote Sensing



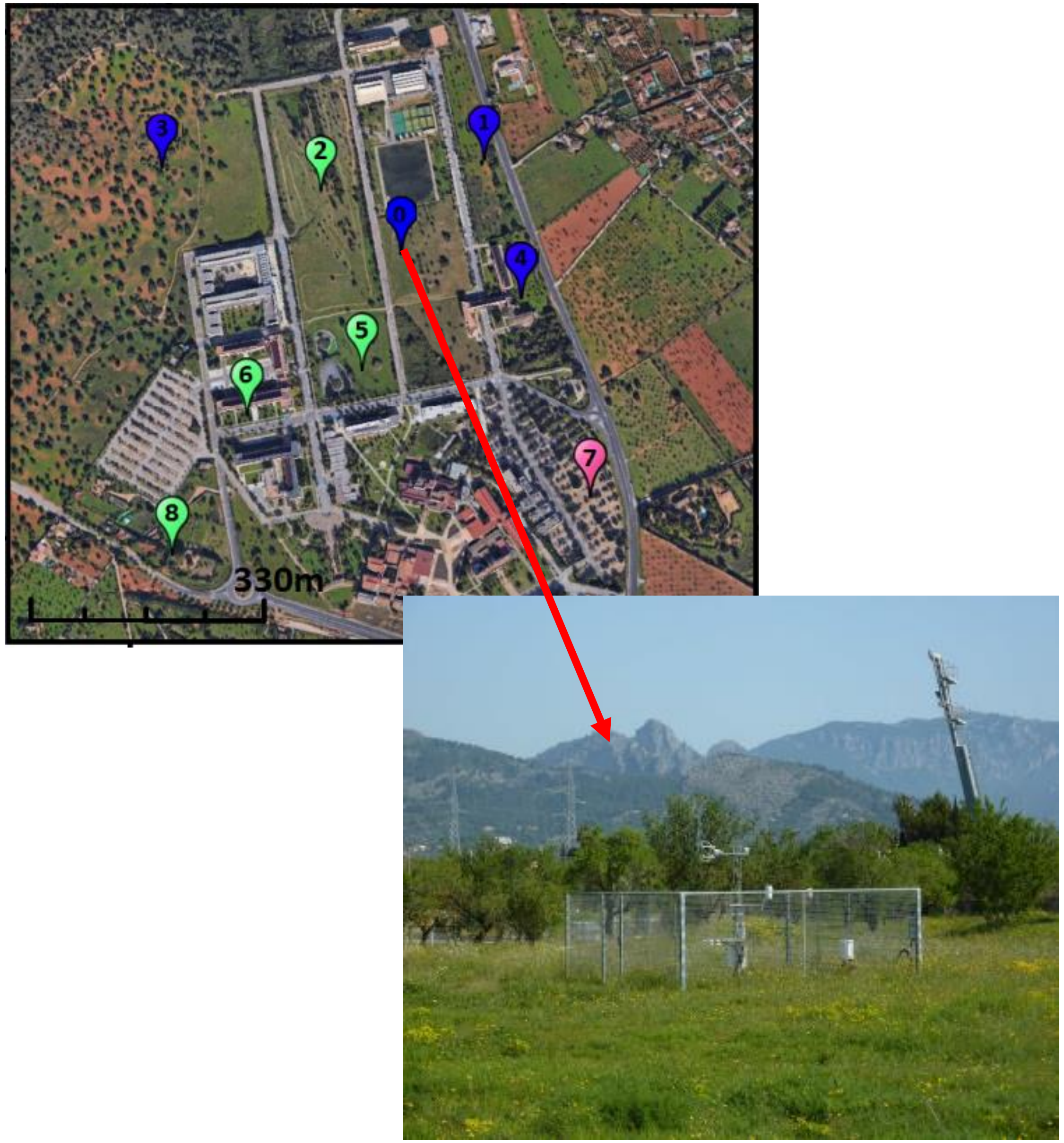
ΔT (full image) > 15K
ΔT (UIB pixel) > 12K

ΔT (full image) > 1.4K
ΔT (UIB pixel) > 1.2K



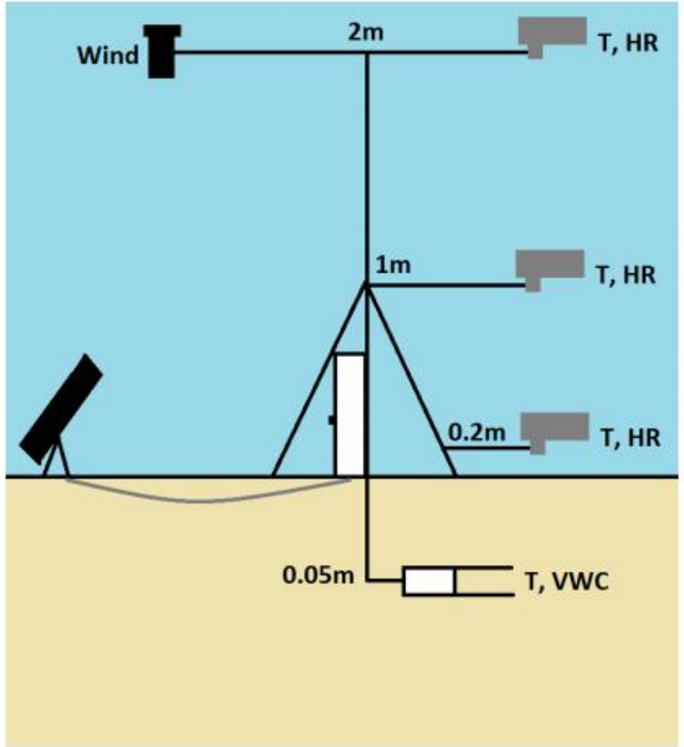
$\Delta T \approx$15-20K in summer
$\Delta T \approx$5K-10K cold seasons

3) Mount a network of Poles (meteorological stations) within the Campus



Source: D. Martínez-Villagrasa

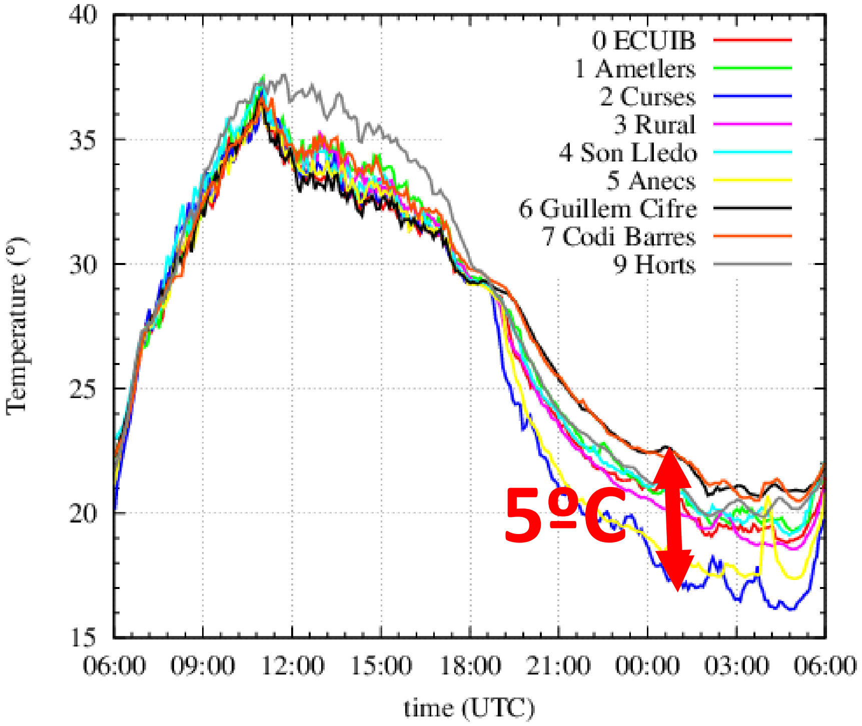
Design and photo of the Poles



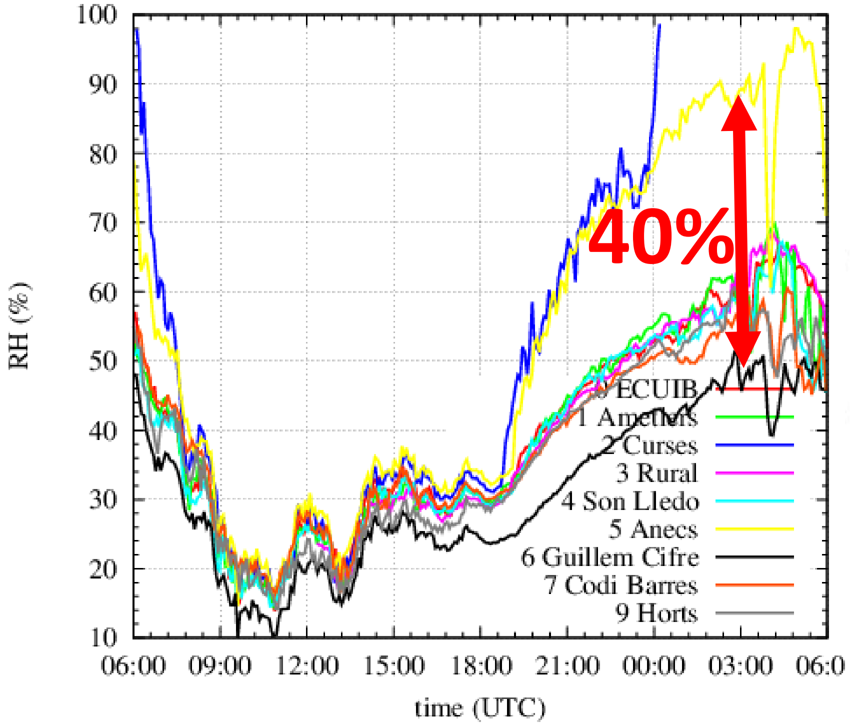
Permanent Research Station in the Campus (since 2015)

For one day: IOP5 (21/07/2016)

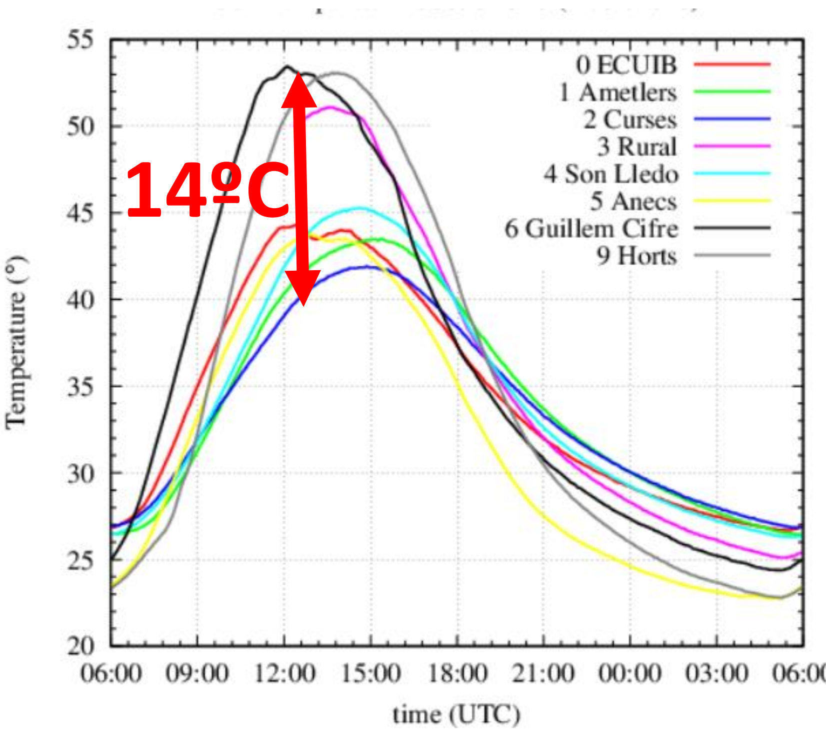
Air Temperature



Relative Humidity



Soil Temperature



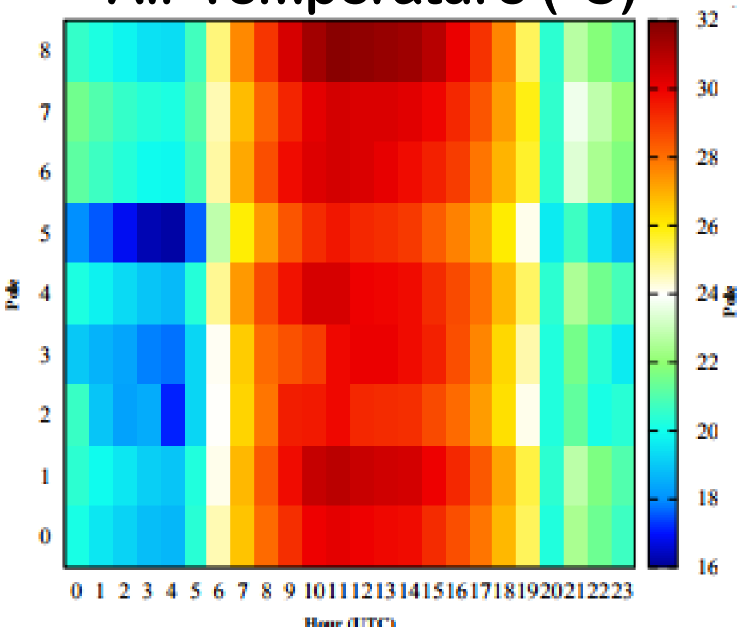
>> differences of Tair at night

>> differences of RH at night

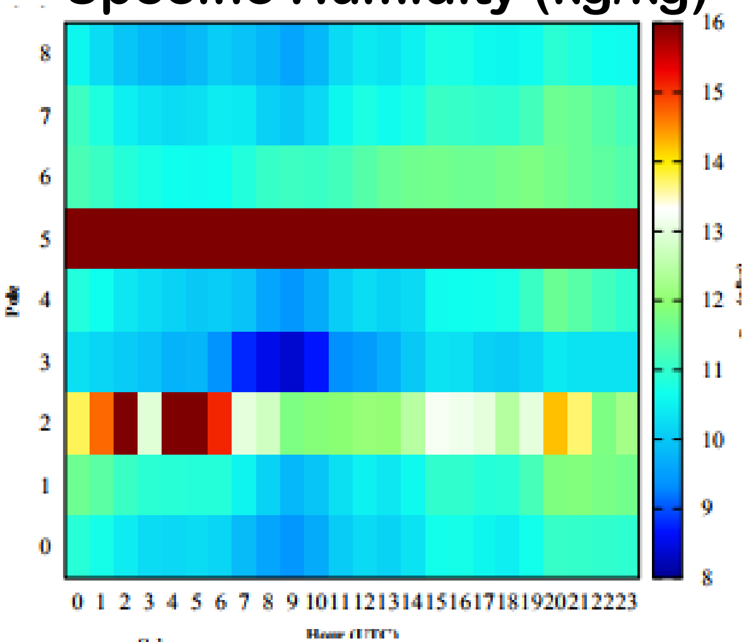
>> differences of Tsoil at day

Horizontal Variability (30/06/2016-26/07/2016):

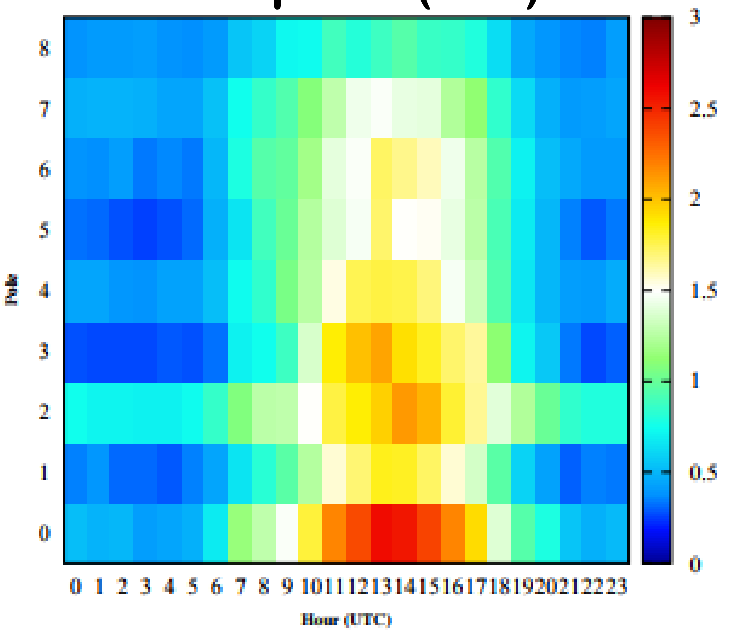
Air Temperature (°C)



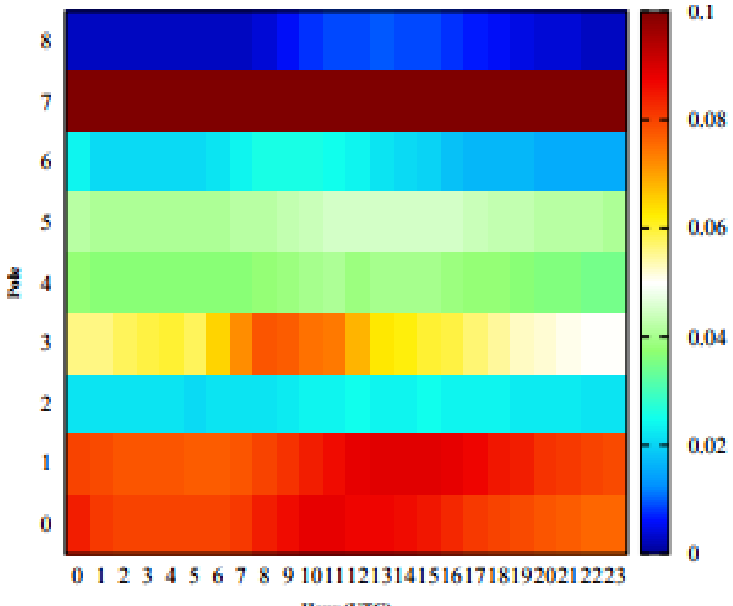
Specific Humidity (kg/kg)



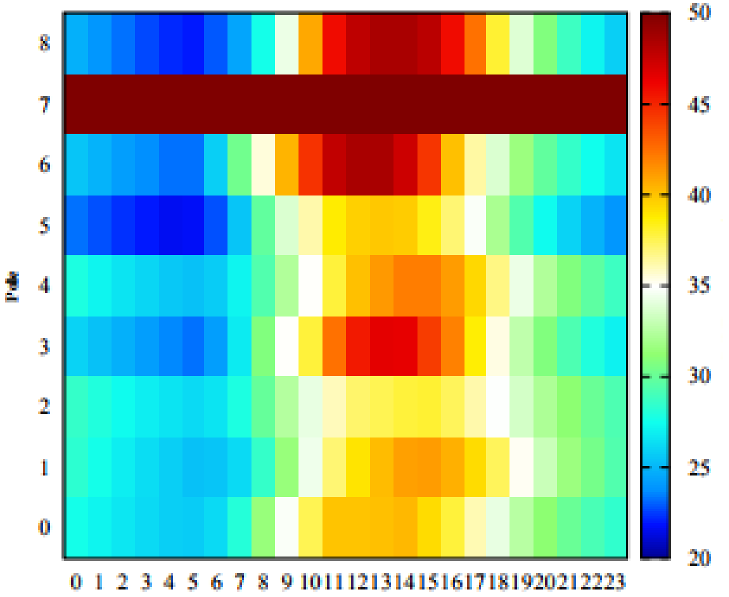
Wind Speed (m/s)

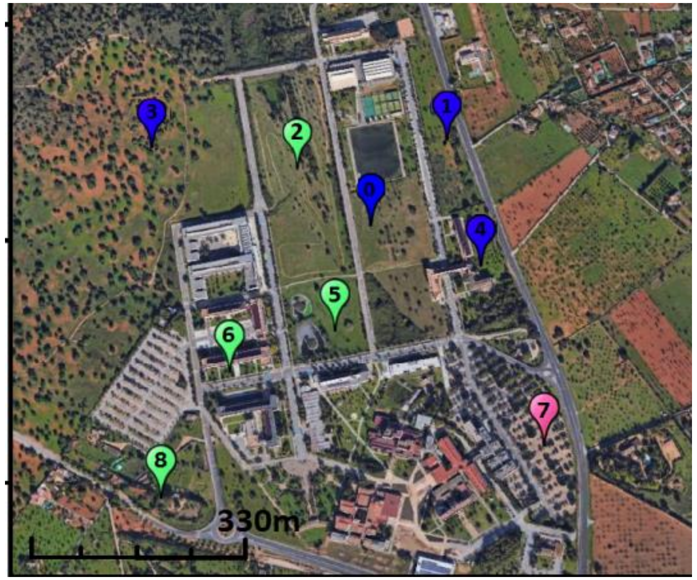


VWC (m^3/m^3)

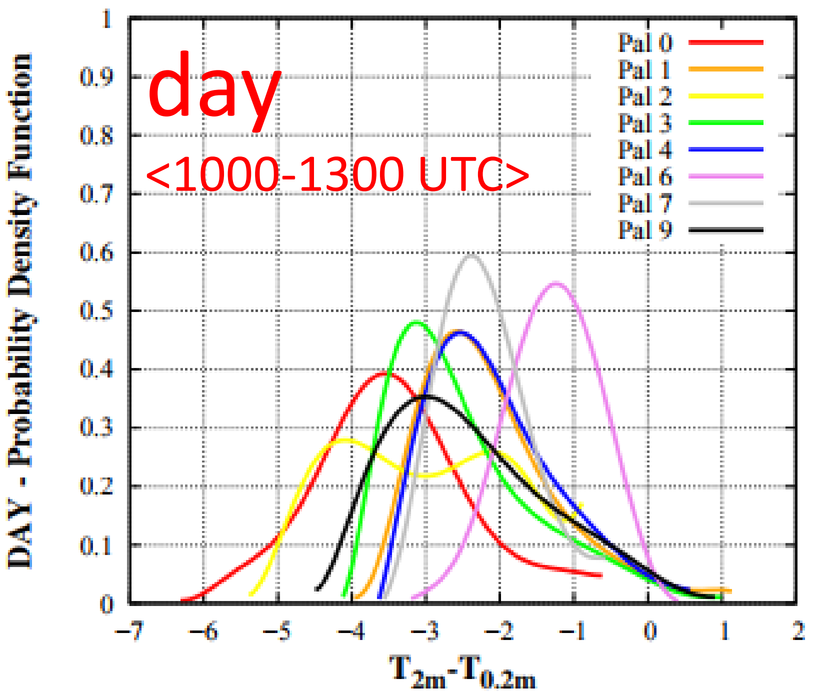


Soil Temperature (°C)



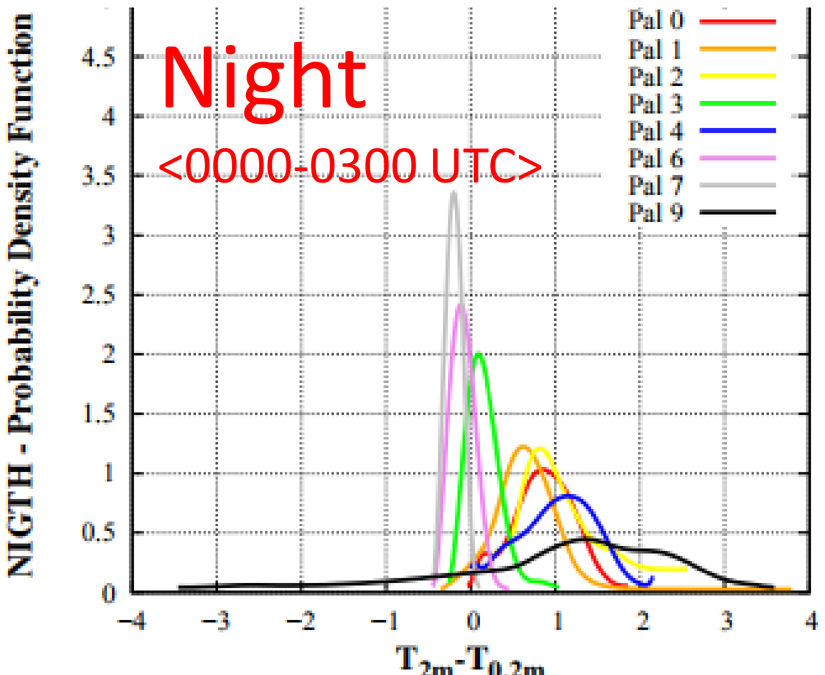


Vertical Variability (T2m - T20cm):



- maximum of the PDFs → negative values → unstable conditions
- width of the PDFs → similar → variability very close

Variability at day >> variability at night



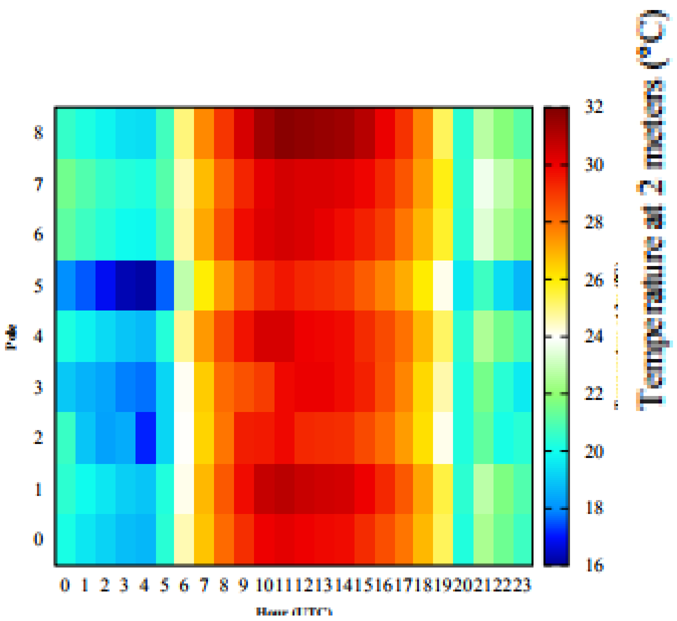
- maximum of the PDFs → positive values → vary from neutraly to very stable conditions
- width of the PDFs → different → large variability

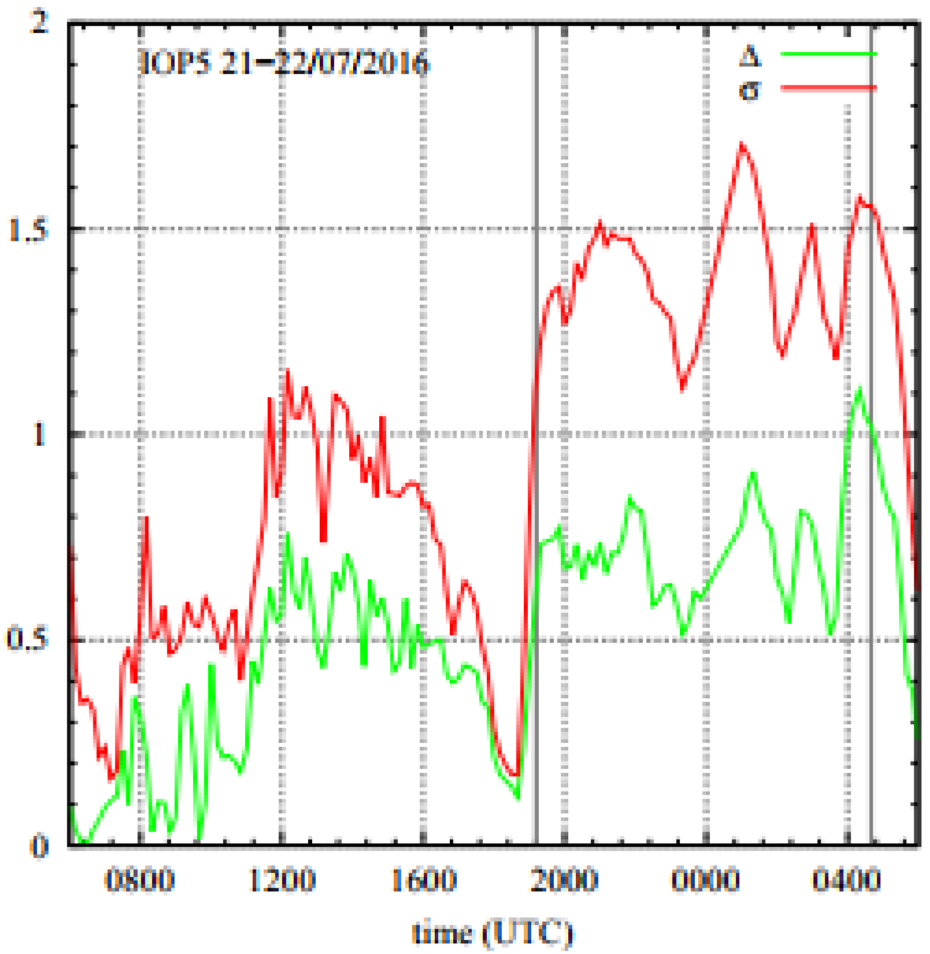
Can the standard deviation be approximated with the average of the differences between the measurement points?

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(\hat{x} - x_i)^2}{n}}$$

$$\Delta = \frac{\sum(x_i - x_j)}{n}$$

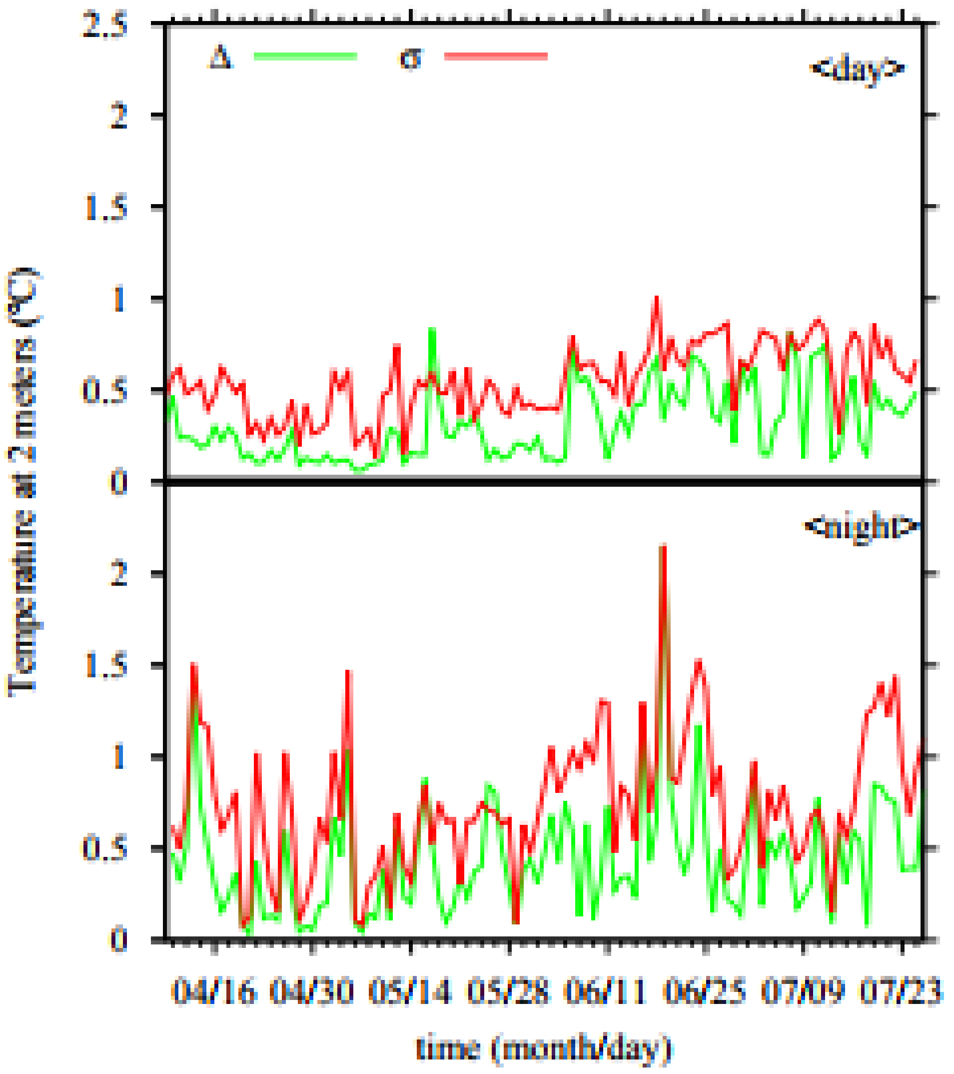
σ = Δ ??





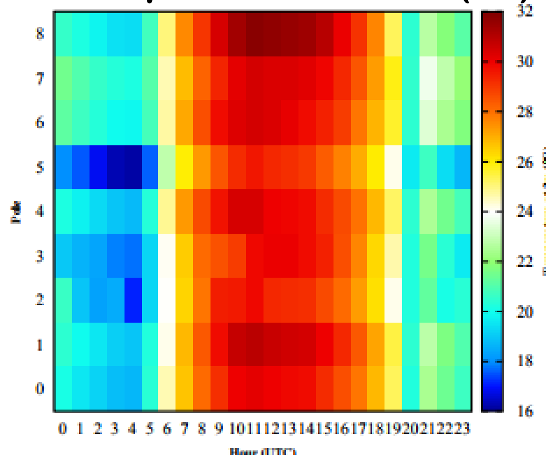
The qualitative evolution of the two quantities is almost identical, being larger at nighttime than at daytime.

Temperature at 2m (°C)

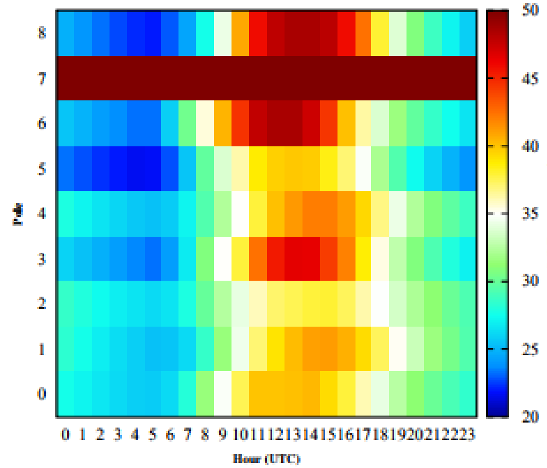


σ and Δ larger during nighttime

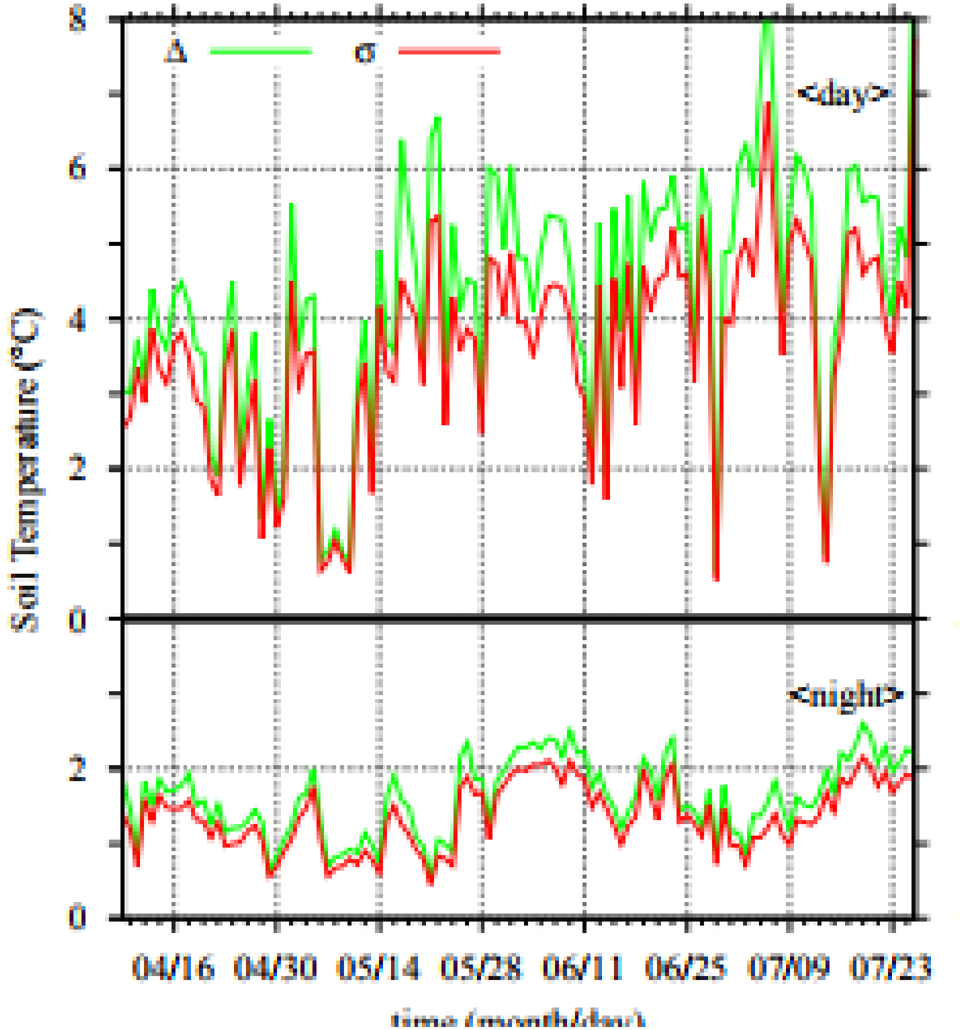
Temperature at 2m (°C)



Soil Temperature (°C)



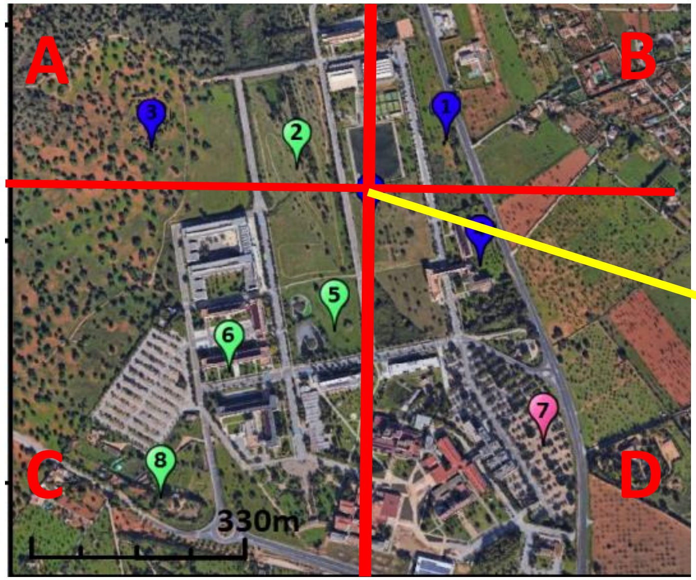
Soil Temperature (°C)



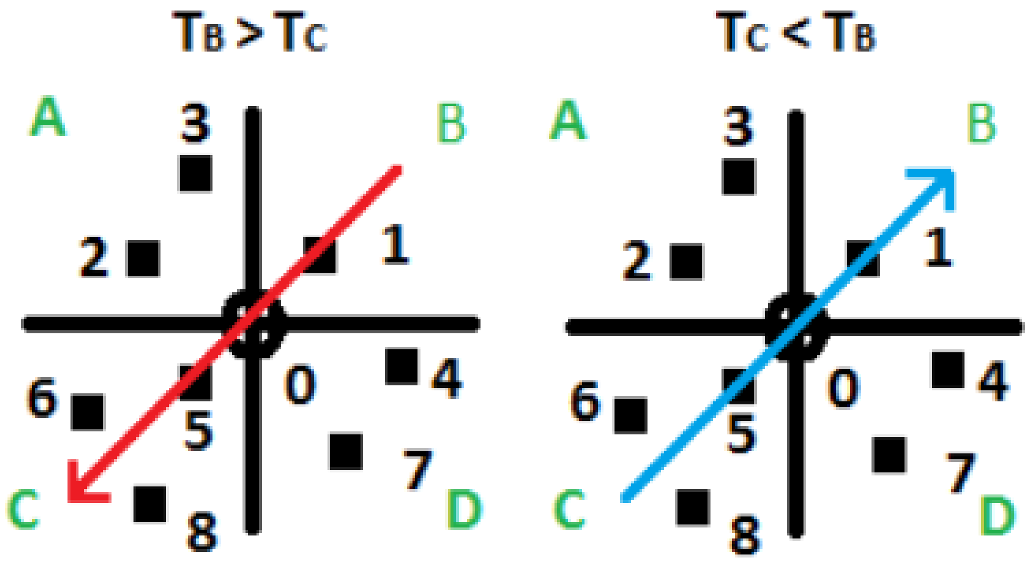
σ and Δ larger during day time

Calcultion of Advection (centred on Pole 0)

$$A = -v_0 \left[\frac{T_f - T_i}{\Delta x} \right]$$



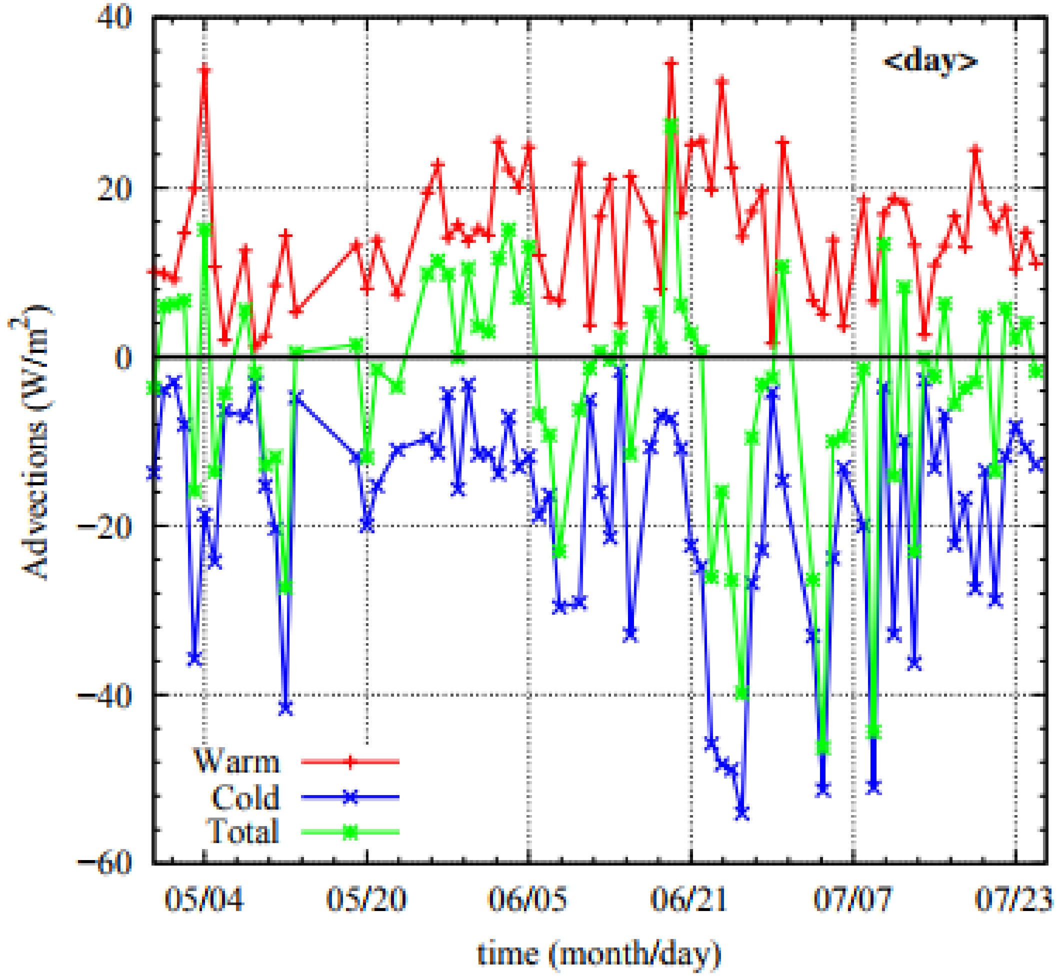
Source: D. Martínez-Villagrasa



$$R_n + LE + H + G = \text{Imb}$$

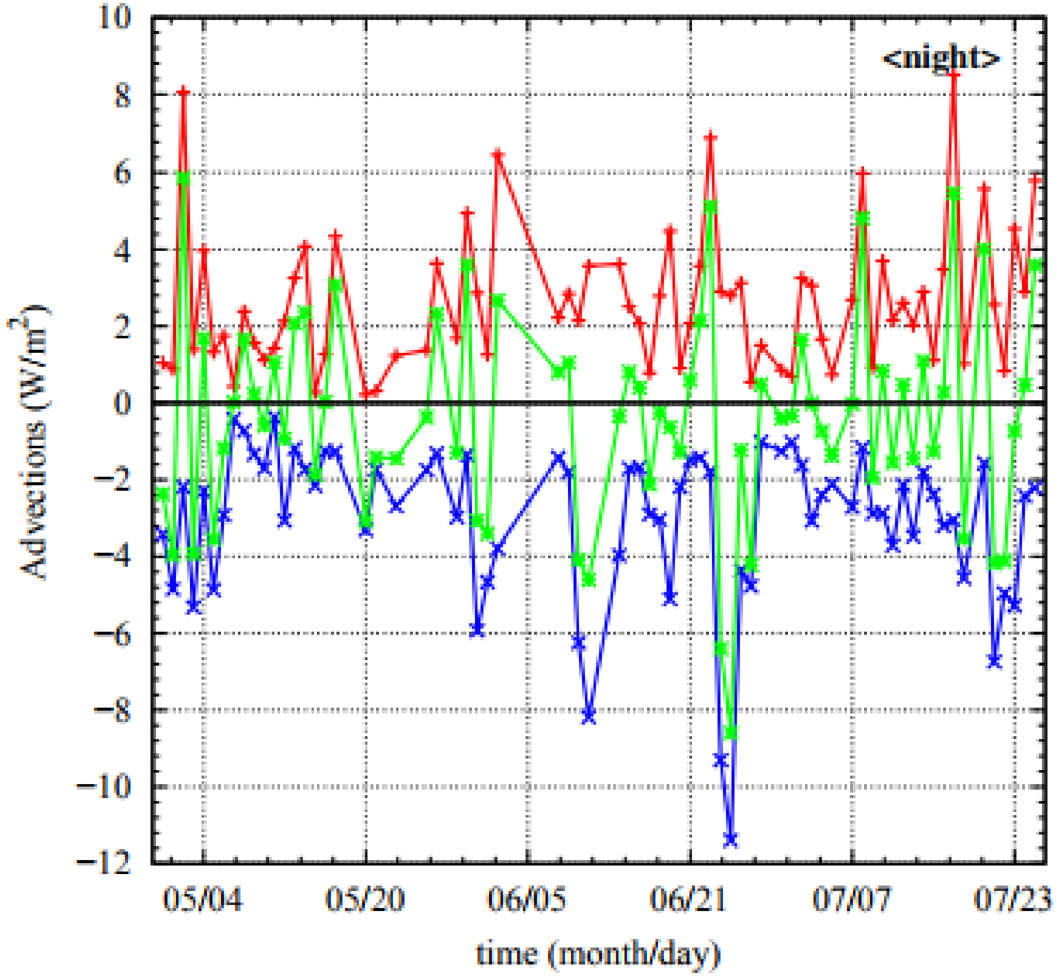
Time serie of advection in Pole 0:

<day>



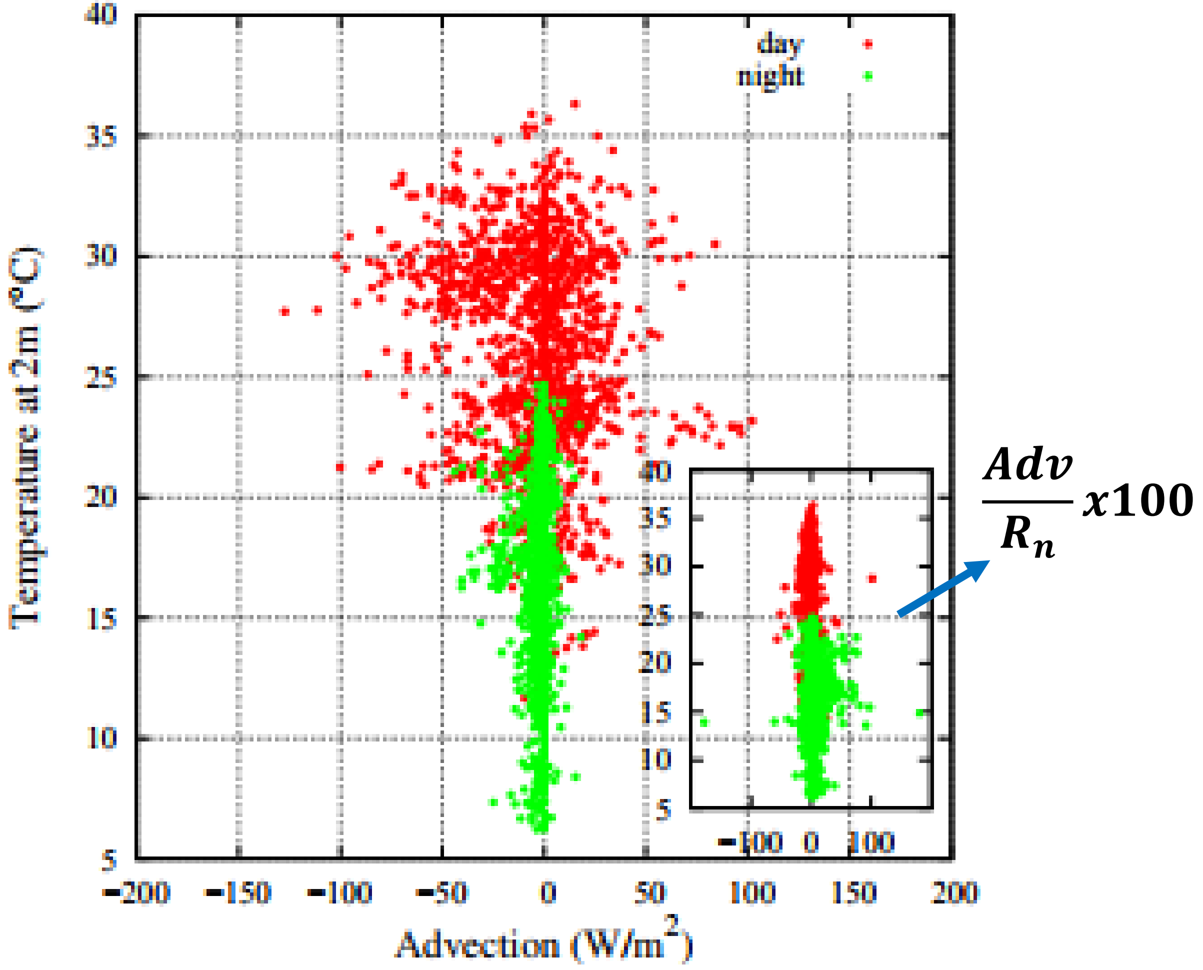
$$Adv_{day} \approx (-20, 20)\ W\ m^{-2}$$

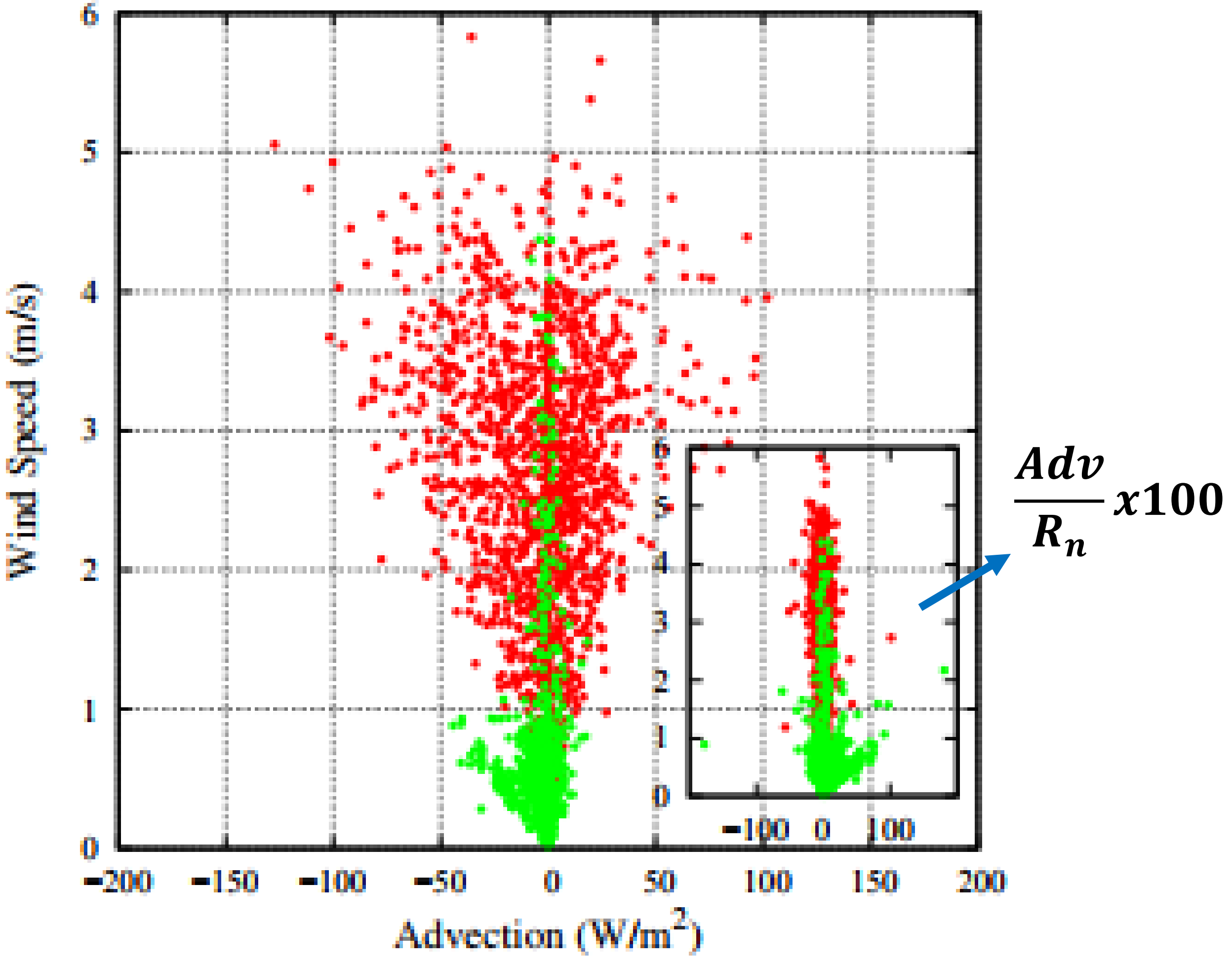
<night>



$$Adv_{night} \approx (-2, 2)\ W\ m^{-2}$$

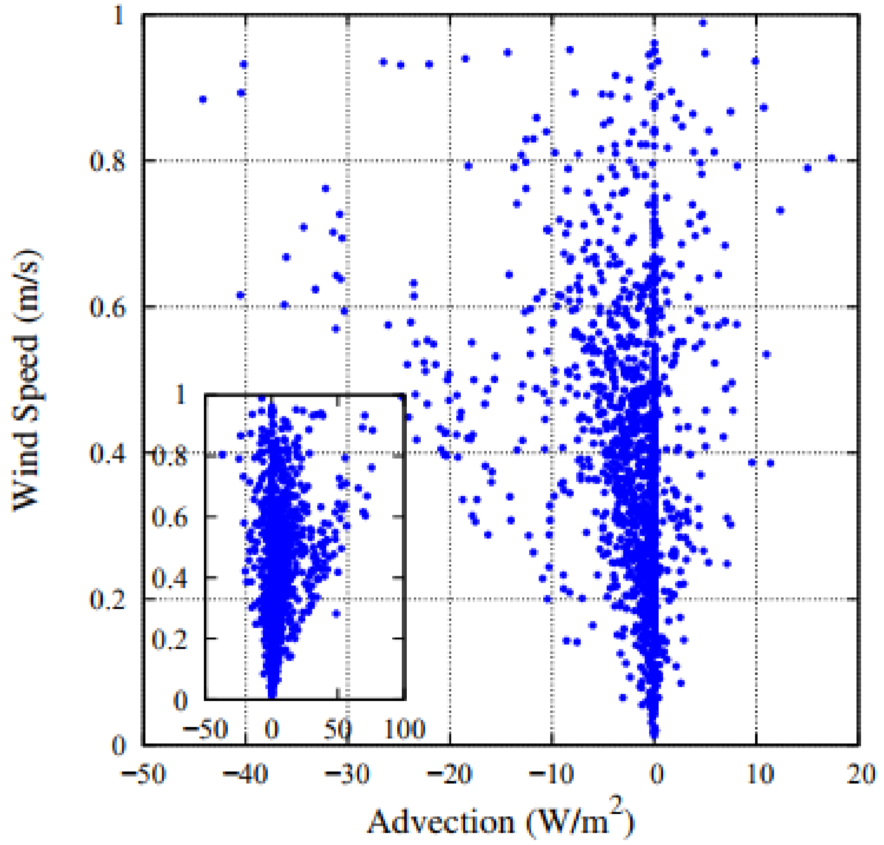
Advection depending on temperature and wind speed:

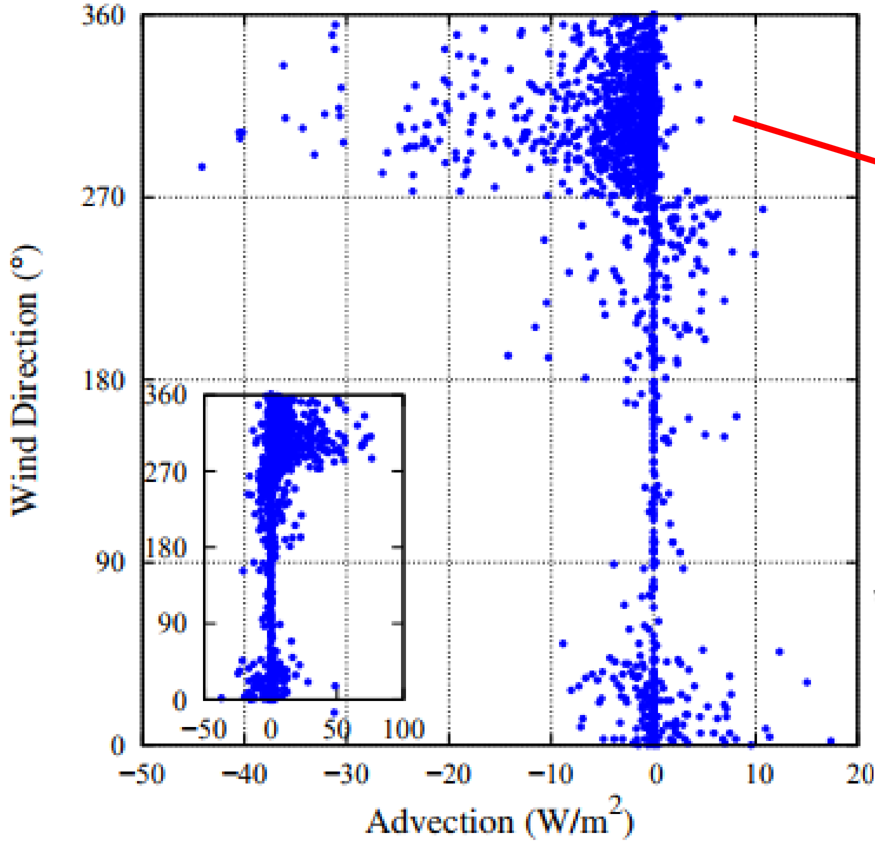




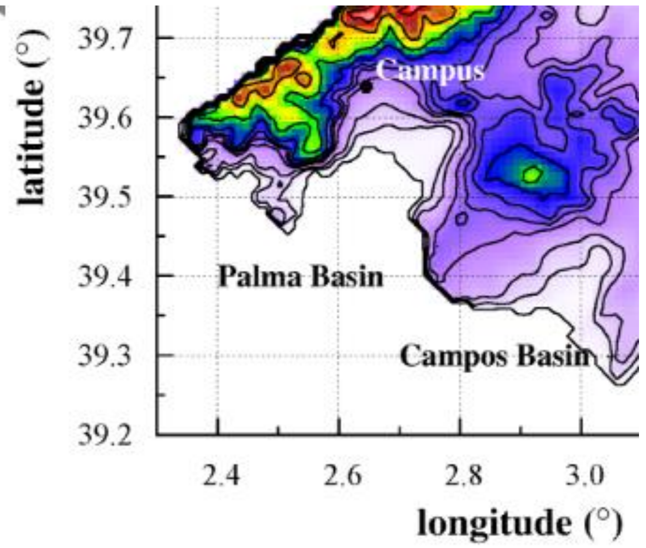
- In the daytime, the values of the advection grow with increasing air temperature and wind speed. The ratio with Rn remains almost constant, below 30%.
- During the nighttime, the values are smaller. The ratio with Rn is larger than in the daytime, especially for weak winds.

Nights with wind speeds < 1m/s

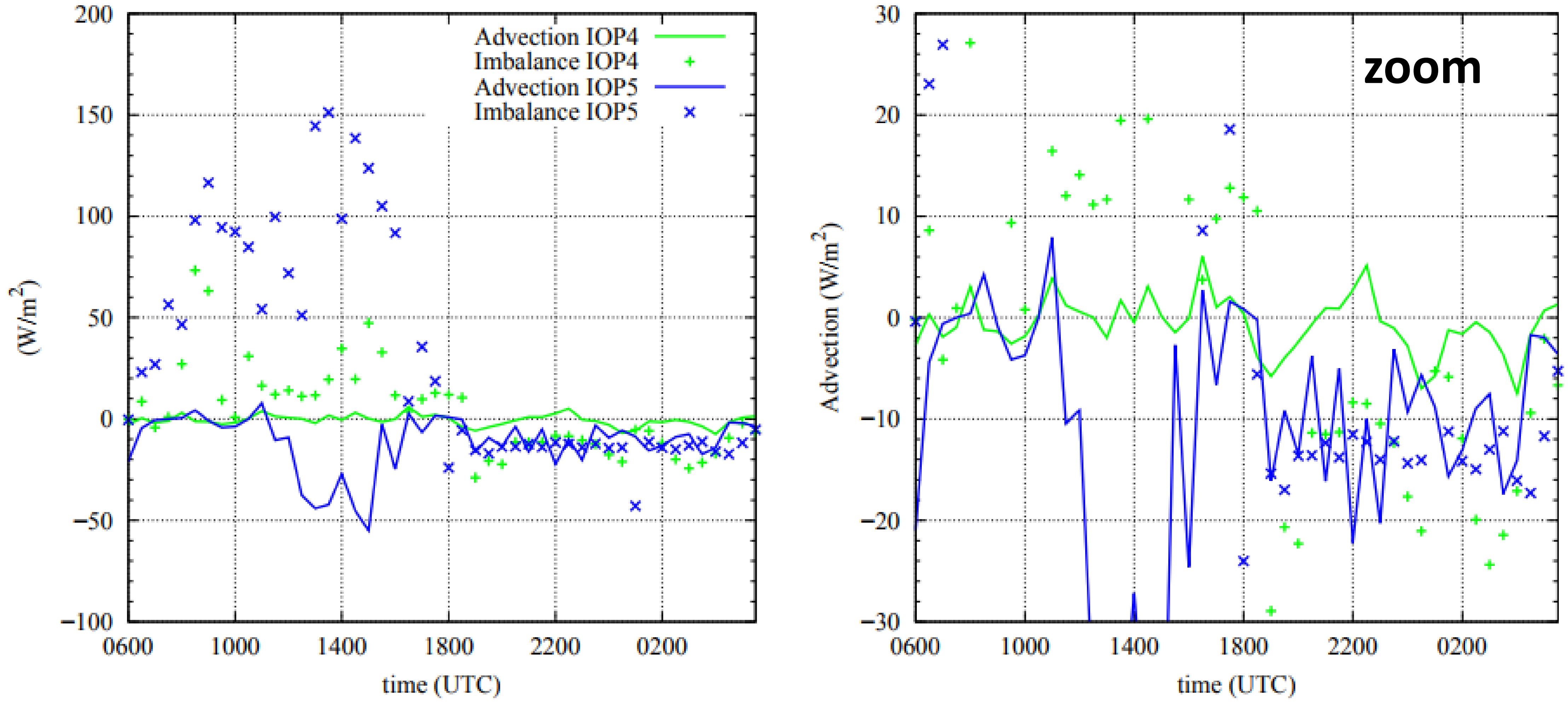




Nocturnal weak winds blow from the Northern sector



Advection vs Imbalance



Conclusions:

- The variability of the air and the soil temperature is due to the surface heterogeneities of the Campus.
- The type of soil cover (bare, vegetated or paved soil) influences this variability.
- The variability has a diurnal cycle.
- σ and Δ are good parameters to represent this variability and can be approximated.
- With these Poles it has been possible to estimate the advection, and during the day it helps us to explain part of the imbalance in the Surface Energy Balance Equation.

Acknowledgments:

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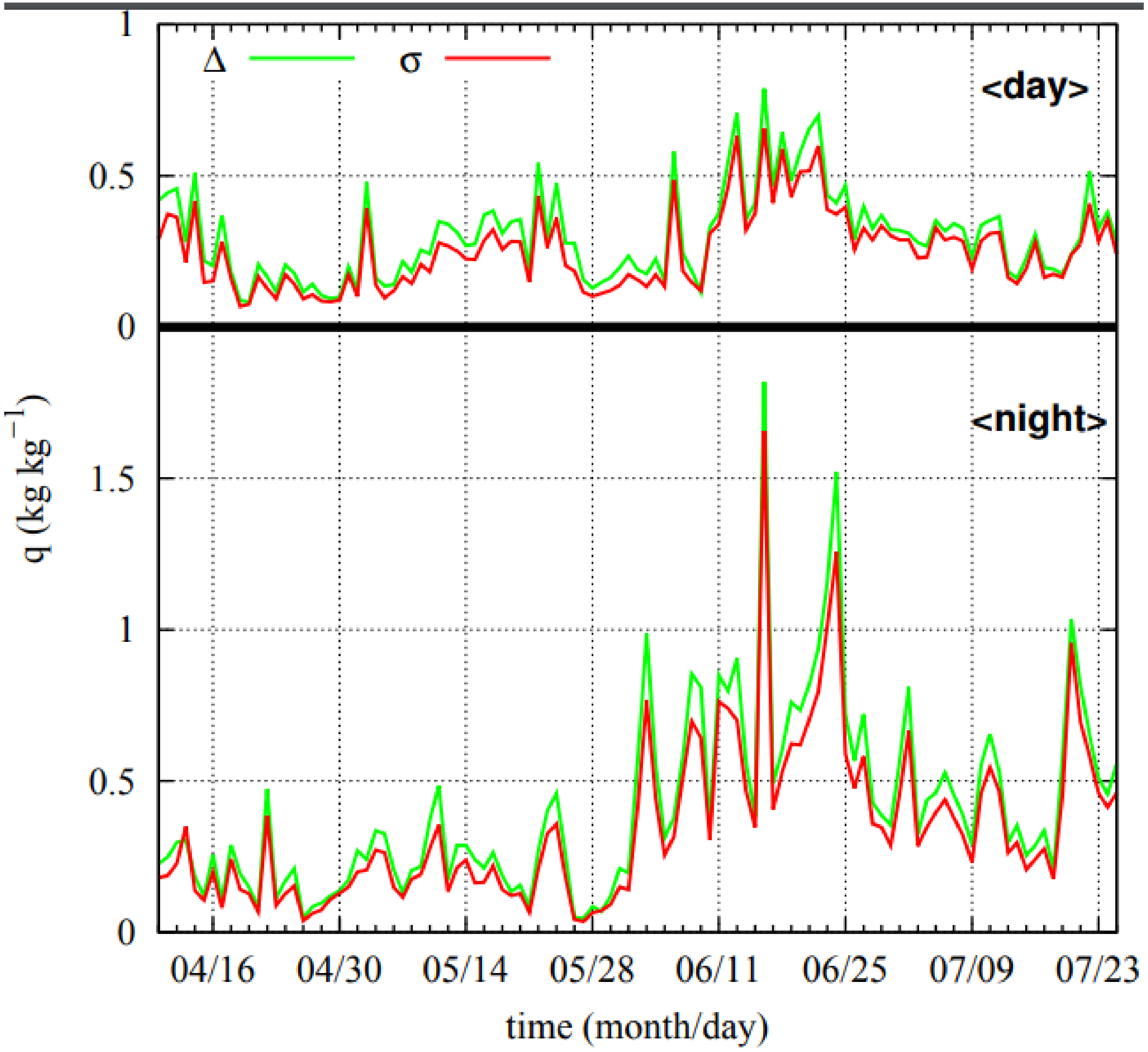
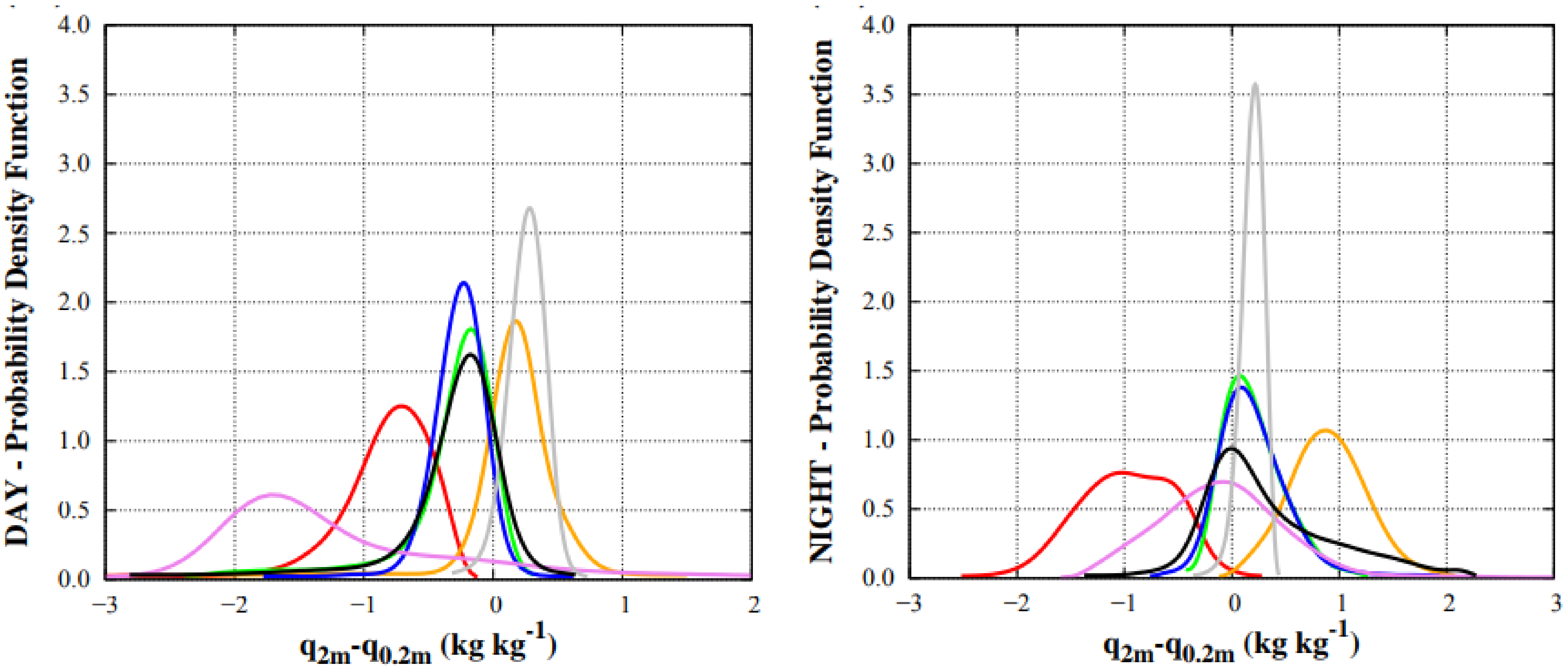


Δ
σ
<day>
<night>
1
0.5
0
1.5
1
0.5
0
q (kg kg^{-1})
04/16
04/30
05/14
05/28
06/11
06/25
07/09
07/23
time (month/day)


DAY - Probability Density Function
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−3
−2
−1
0
1
2
q_{2m}-$q_{0.2m}$ (kg kg^{-1})
NIGHT - Probability Density Function
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−3
−2
−1
0
1
2
3
q_{2m}-$q_{0.2m}$ (kg kg^{-1})