

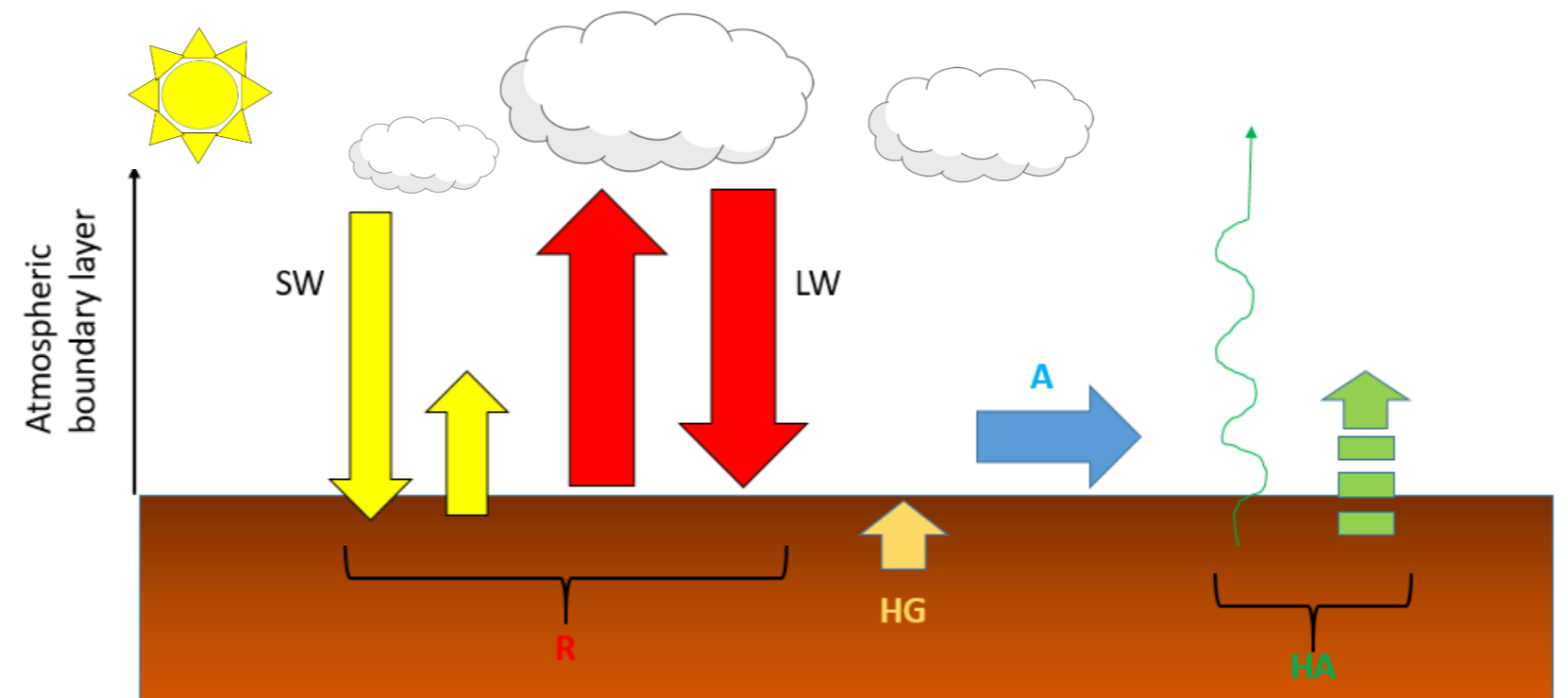
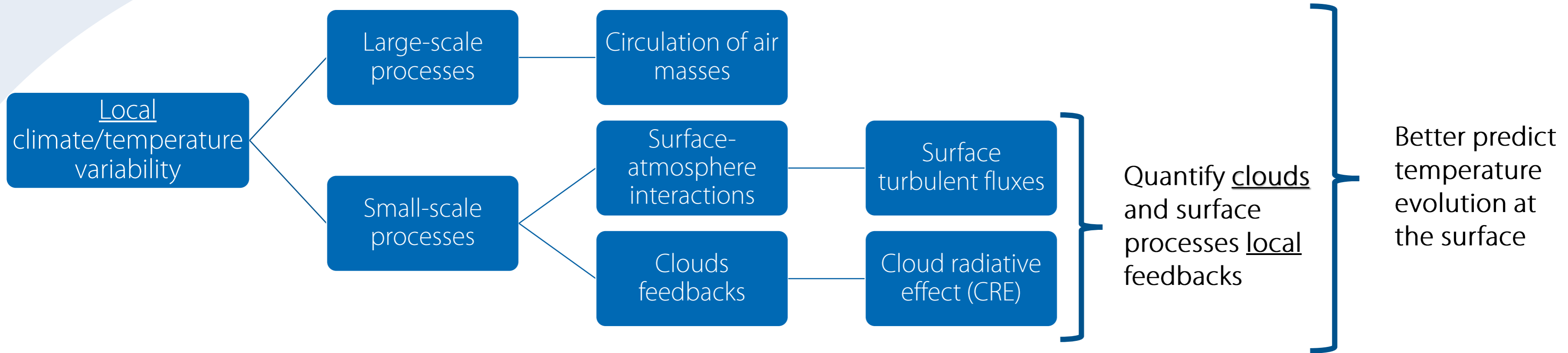
# Contribution of clouds radiative forcing to the local surface temperature variability

OSCAR ROJAS, MARJOLAINE CHIRIACO, SOPHIE BASTIN, JUSTINE RINGARD

LATMOS/IPSL, UVSQ Université Paris-Saclay, Sorbonne Université, CNRS, 11 bd d'Alembert,  
Guyancourt, France

Online presentation EGU2020, 01.04.2020 – 30.05.2020<sup>1</sup>

# Motivation



# Data

## ReOBS Re-quality control

Re-expertise



Re-formatting

Re-calibration

Re-averaging

## SIRTA-ReOBS:

Hourly long-term multi-variables dataset– NETCDF File:

<https://doi.org/10.5194/essd-10-919-2018>

- Temperature
- Wind speed
- Pressure
- Heat fluxes
- Radiosoundings
- Radiation
- ...

*Chiriaco et al. 2018*

❖ All the necessary variables requested by the current study are available for the period going from January 2009 to February 2014 in an hourly scale

## SIRTA

Observatory located in a semi-urban area 20-km South-West of Paris



# General approach

Creation of a model of temperature variability at 2m at SIRTA

$$\frac{\partial T_{2m}}{\partial t} = R + HG + HA + Adv$$

R = Radiation =  $R_{clear-sky}$  +  $R_{cloud}$

HG = Ground heat exchange

HA = Atmospheric heat exchange

Adv = Advection

Main terms acting on the surface



Estimated from observations dataset

## Study steps:

1. Creation of a model of temperature variability
2. Statistical evaluation of the model
3. Which term is predominant, particularly in relation to the seasons
4. The value of  $R_{cloud}$  and the conditions under which it predominates over the other terms
5. Cloud contribution and characterization

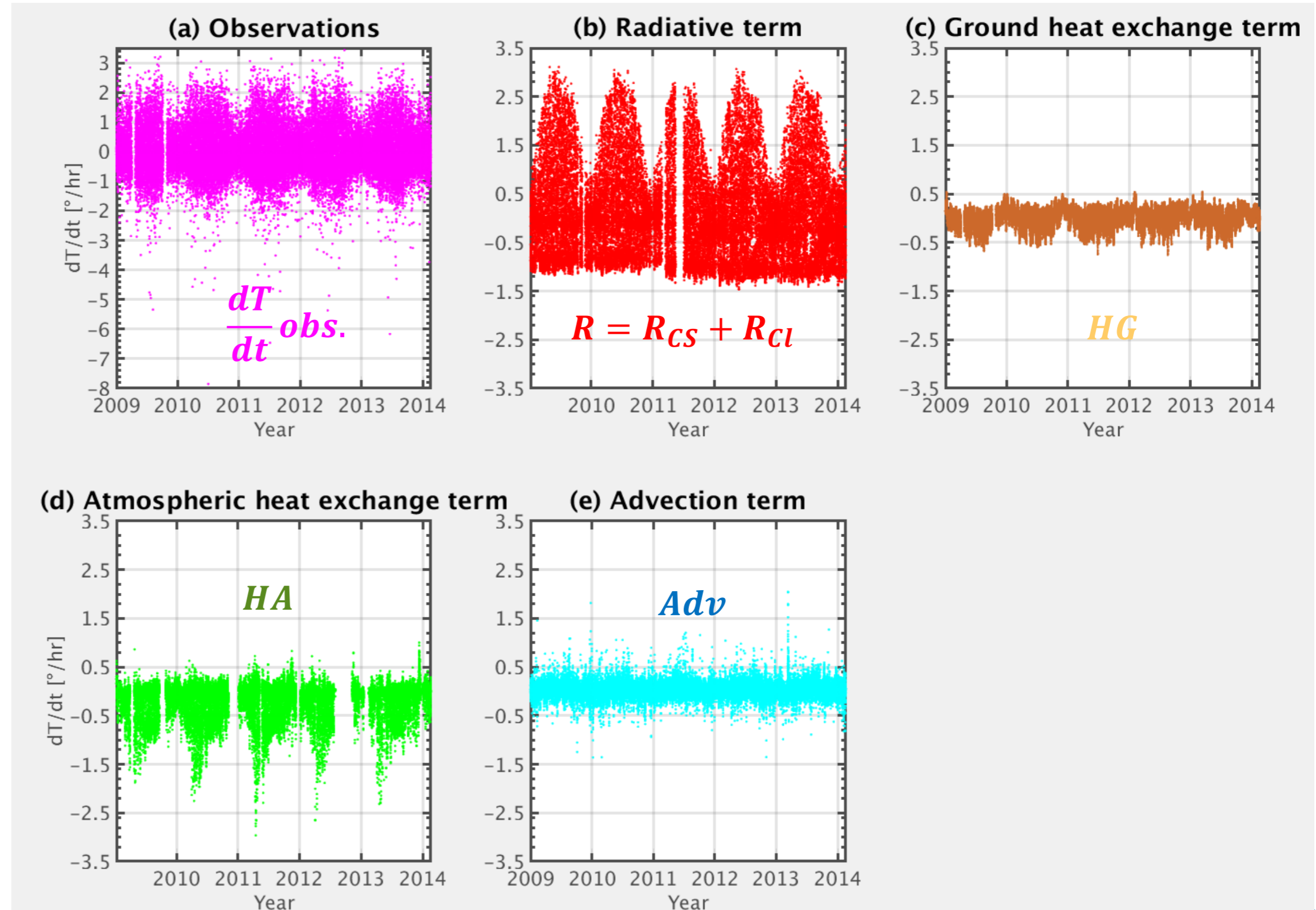


# Term estimation

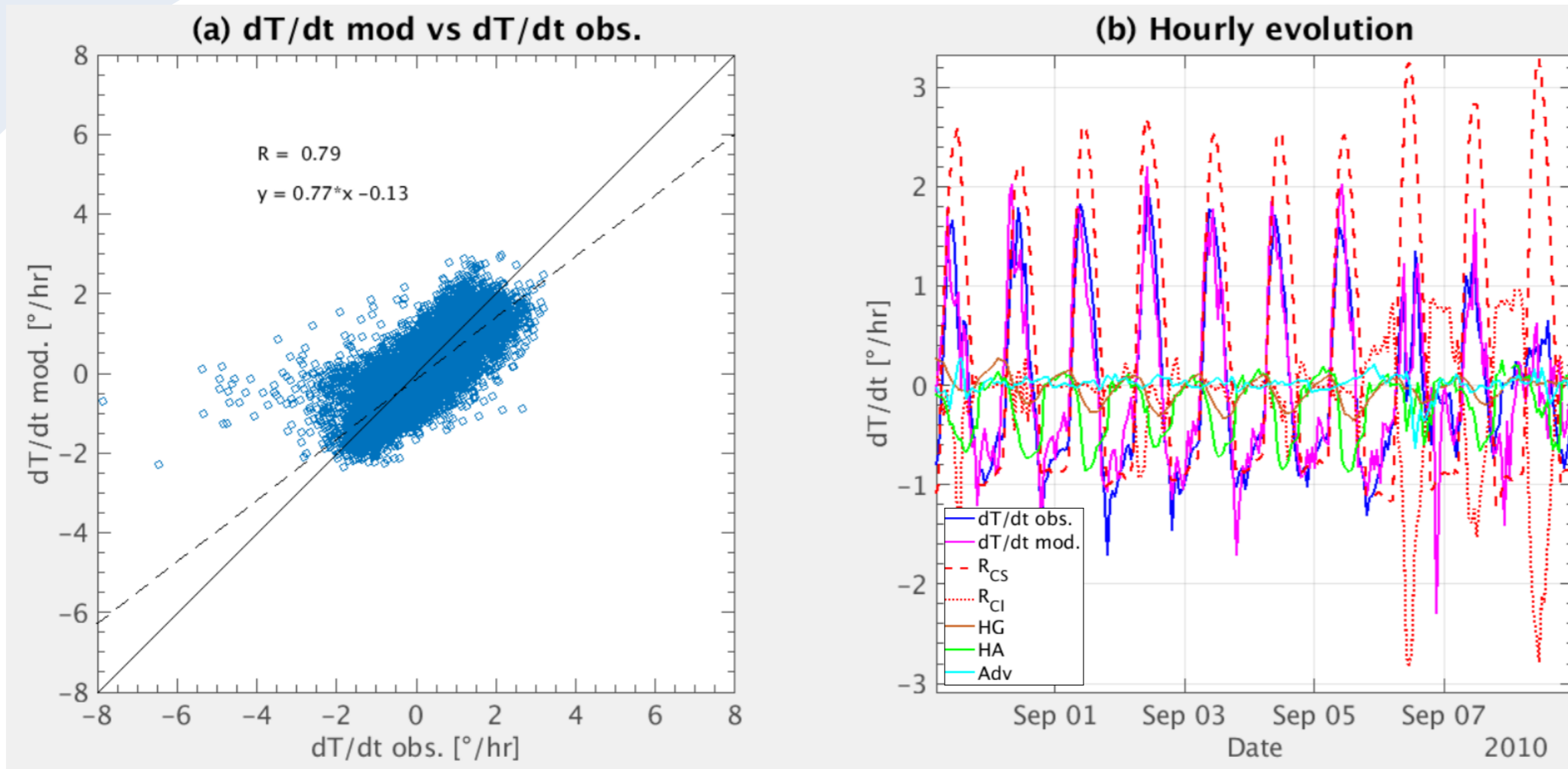
$$\underbrace{\frac{\partial T_{2m}}{\partial t}}_{\frac{dT}{dt} \text{ obs.}} = \underbrace{R_{cs} + R_{cl} + HG + HA + Adv}_{\frac{dT}{dt} \text{ mod.}}$$

Both  $\frac{dT}{dt} \text{ obs.}$  and  $\frac{dT}{dt} \text{ mod.}$  are estimated from SIRTA-ReOBS dataset

+ some assumptions on atmosphere stability, ground behavior, etc



# Statistical evaluation of the model



Statistics by season:

Season	Corr. Coeff.	Bias (°C/hr)	Standard deviation (°C/hr)
Summer	0,82	-0,20	0,55
Fall	0,79	-0,23	0,46
Winter	0,67	-0,31	0,43
Spring	0,80	-0,25	0,53

✓ Good coefficient correlation for all seasons ( $\sim 0,80$  on average) except for winter

✓ Good coefficient correlation between the model and the observations ( $R = 0,79$ ) (a)

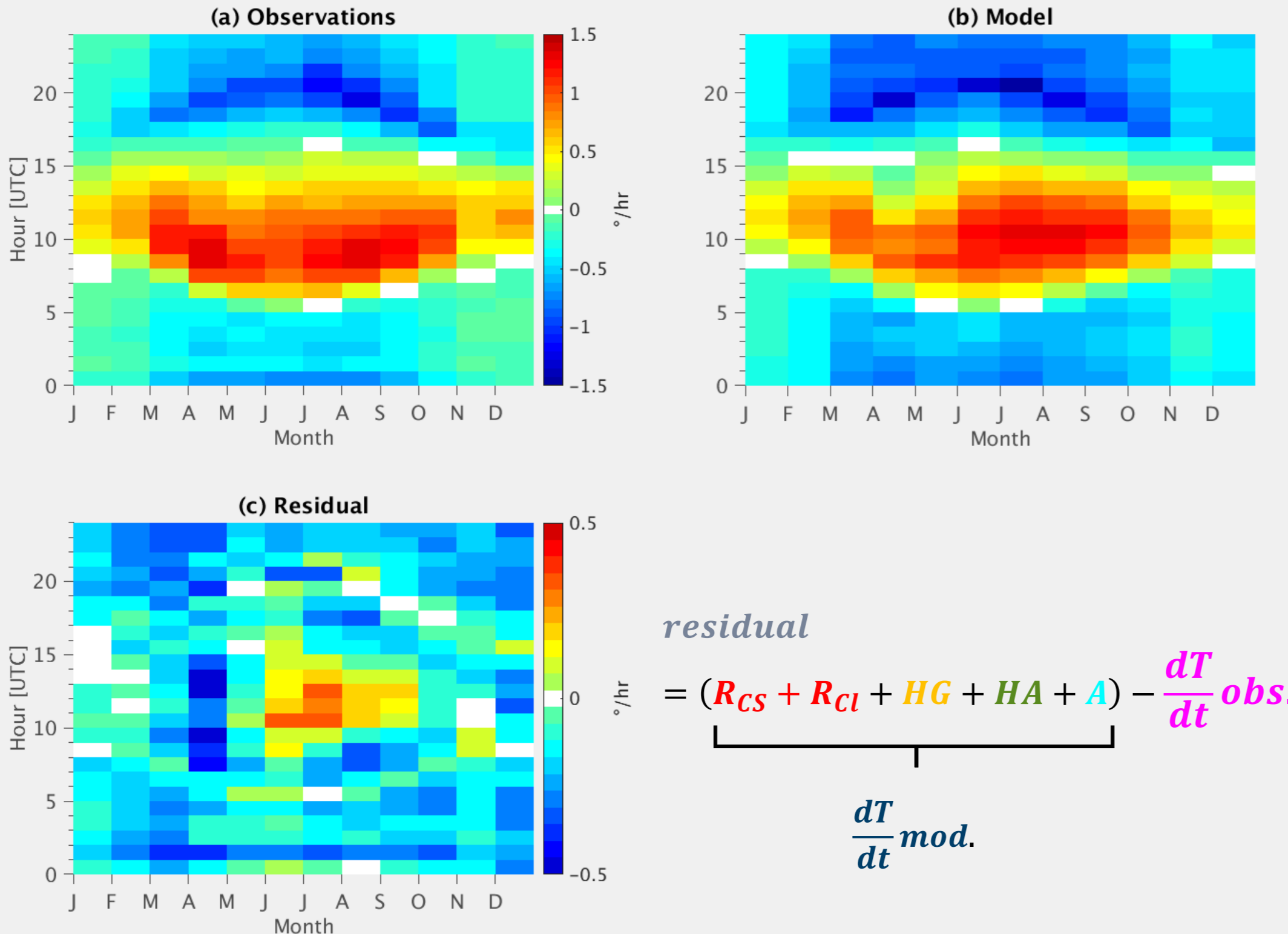
✓ The model follows quite well the observations (b)

✓ Variability of T mainly driven by R radiation on this time scale (b)

✓ Marked strong diurnal cycle for  $R_{CS}$ , and a weak one for HA (b)



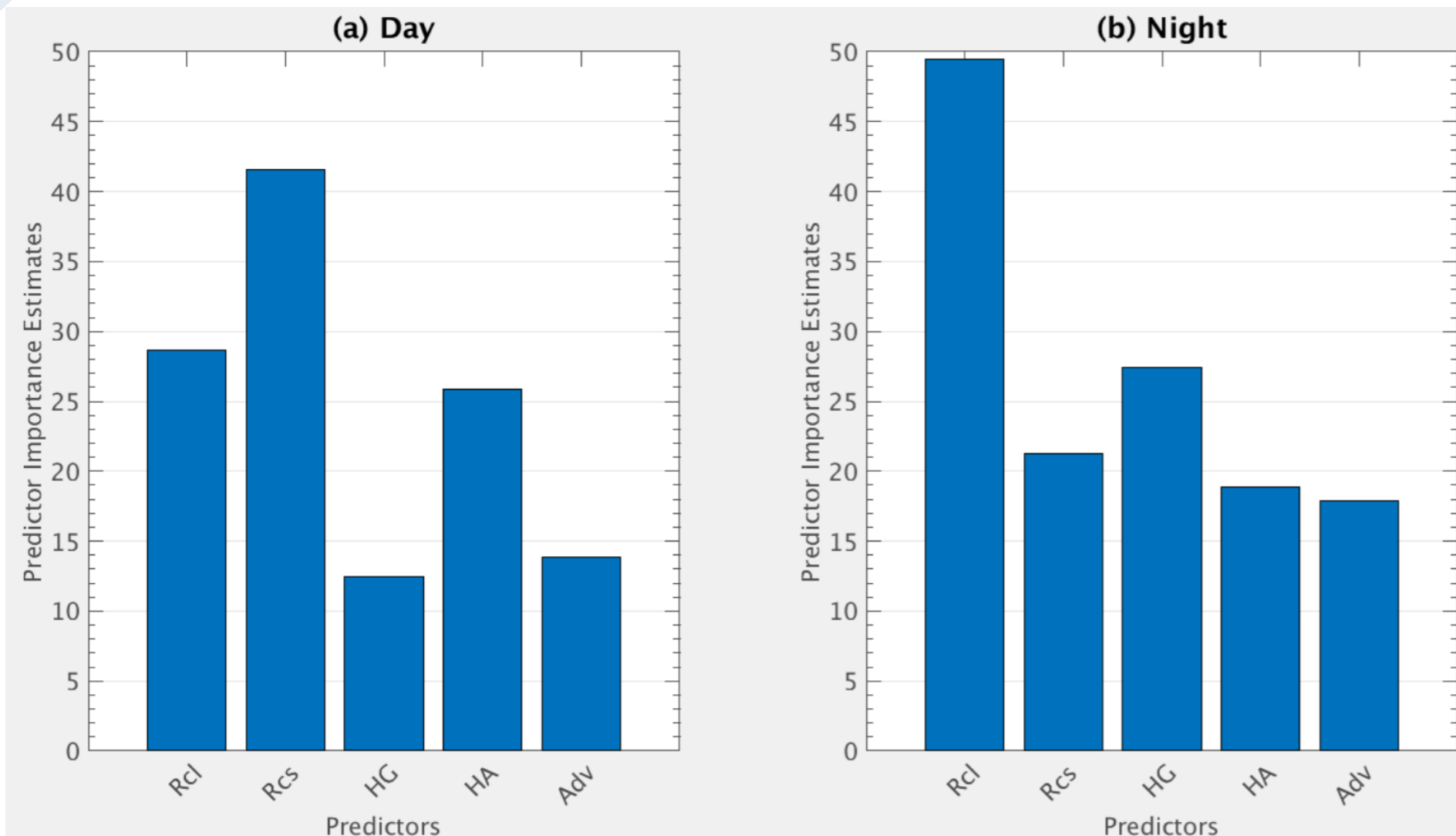
# Monthly-hourly cycle



- Weak mean residual values, with a max absolute mean value around 0,45 °/hr
- The largest underestimation (overestimation) is found in april (july) during daytime



# Results: 1) Relative weight of each term on temperature variability



Day:

✓  $R_{CS}$  contributes the most, followed by  $R_{Cl}$  and  $HA$

Night:

✓  $R_{Cl}$  dominates temperature change

✓  $HG$  contributes by warming the surface

Bootstrapped-aggregated decision trees

Main advantage: Reduce of overfitting

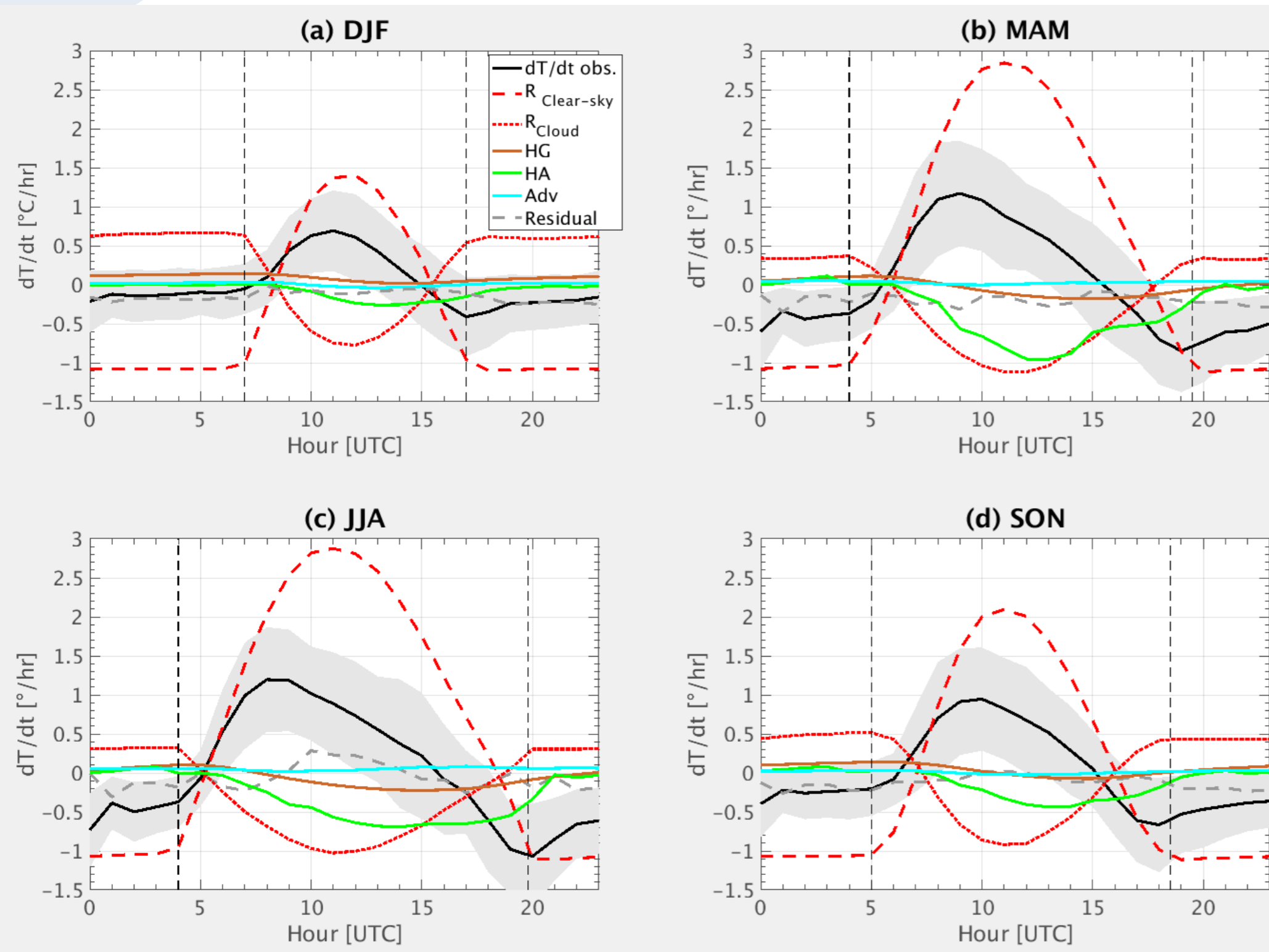
Objective: Show the importance\* of each term on  $\frac{dT}{dt} mod.$

\* For further information on how this value is calculated, please refer to: <https://www.analyticsvidhya.com/blog/2016/04/tree-based-algorithms-complete-tutorial-scratch-in-python/>





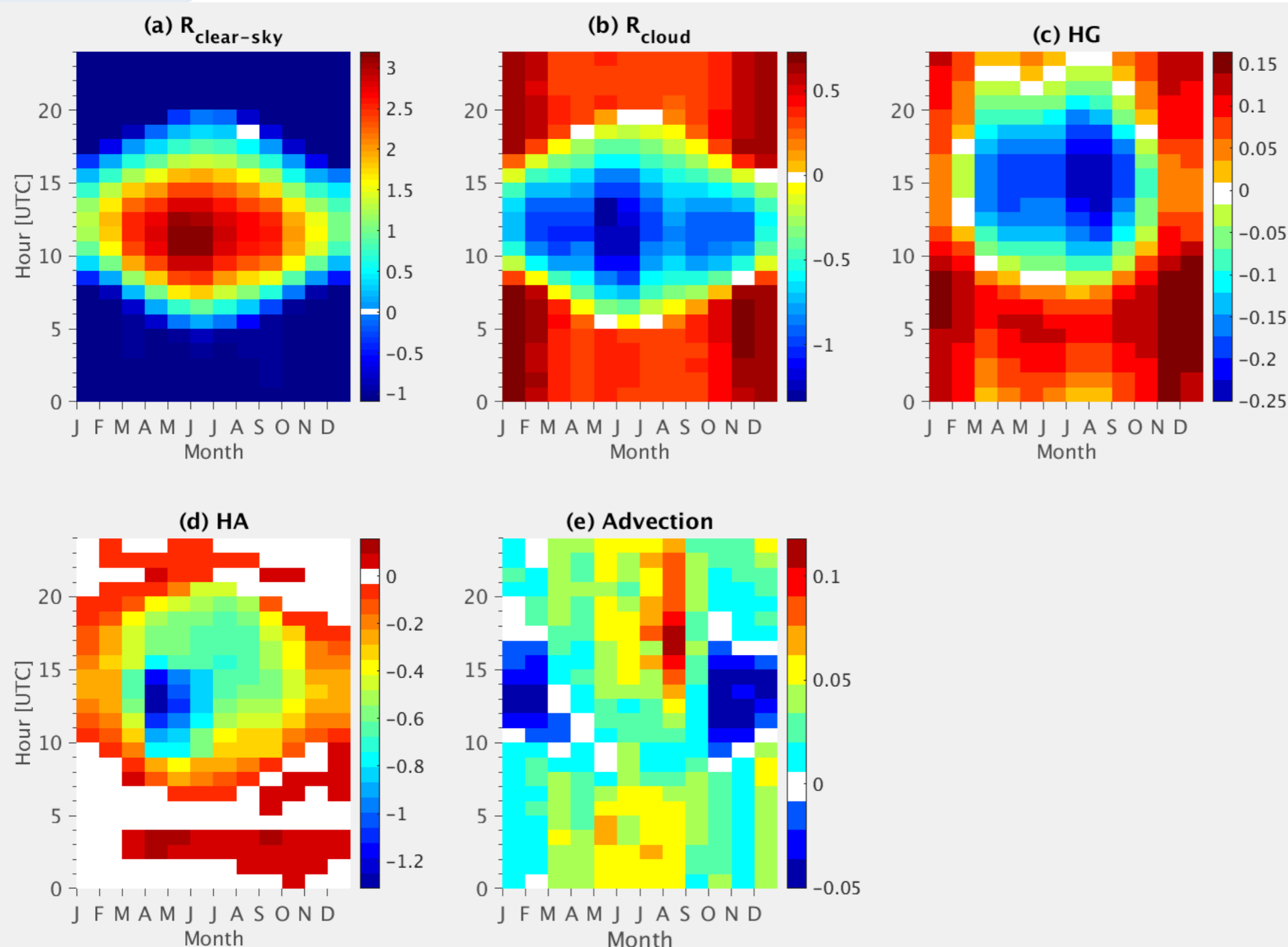
# Results: 2) Diurnal cycle of each term



- ✓ Residual is generally weak
- ✓ Clouds are the main modulator of the variability of T at the SIRTA at this time scale (one hour).
- ✓ **HA** term becomes important in spring and summer in the late afternoon -> + of sensible and latent heat fluxes



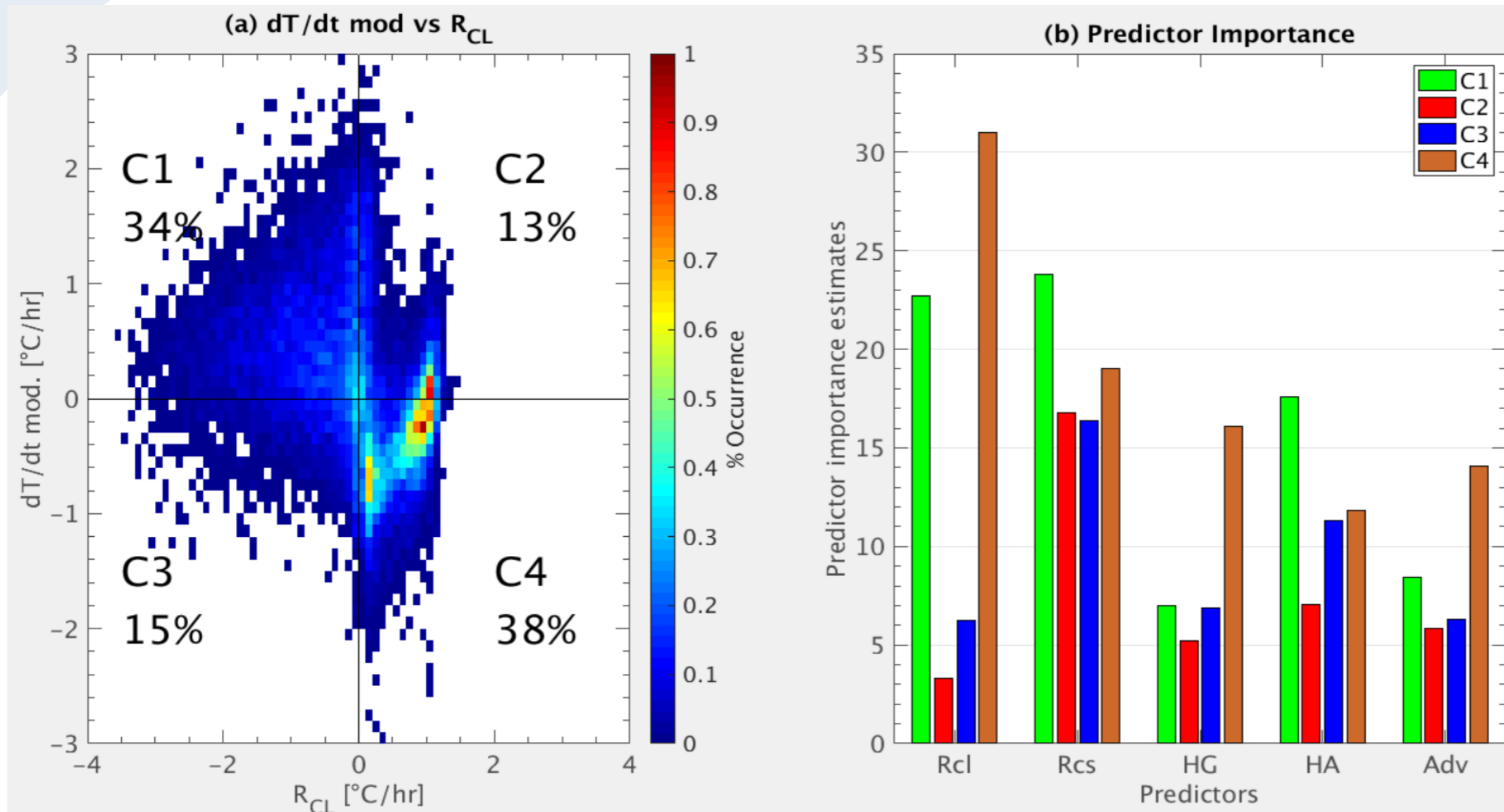
# Results: 3) Monthly-hourly cycle of each term



- All terms have a clearly marked monthly-hourly cycle
- Maximum positive (negative) contribution of  $R_{CS}$  ( $R_{cl}$ ) in June at 10h00 UTC
- Clouds cool the surface up to 1,4°C/hr (in average)
- HA term becomes important in Spring and its contribution during night is practically zero
- All terms except  $R_{CS}$  warm the surface during the night



# Results: 4) Specific cloud contribution in cloudy cases



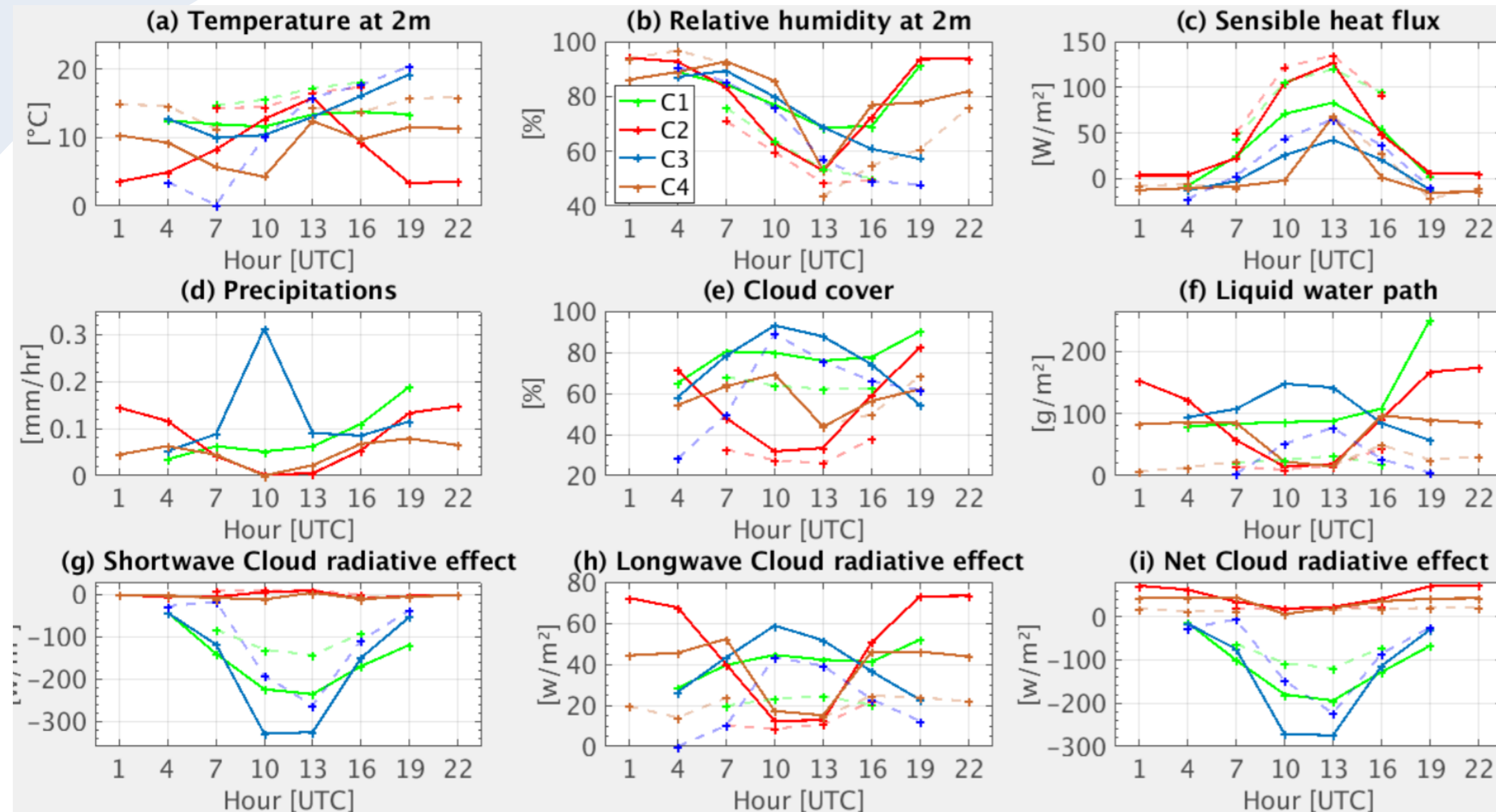
- Scatterplot of  $\frac{dT}{dt} mod.$  vs  $R_{cl}$  only for cloudy cases\* and creation of four study categories (a)
- Clouds can cool (warm) up to  $-3,8^{\circ}C/hr$  ( $1,8^{\circ}C/hr$ ) (a)
- The treebagger analysis exposes a continuous dominance from  $R$  term for all the categories (b)

\*Cloudy case:  $CRE_{SW/LW} \geq 5 W/m^2$



# Results: 5) Diurnal cycle

$R_{CL} < 0$ : C1 and C3 -> Only day cases found



- Slightly temperature and LWP change during the day for C1 (a) except in the late afternoons -> cloud cover (e) and precipitations (d) increase
- Important cloud cover (e) for C3 during daytime: precipitable clouds with a max value compared to the others categories (d) and an important LWP (f) and a strong negative SW and LWCRE (g,h)

$R_{CL} \geq 0$ : C2 and C4 -> Mostly night cases, few ones for the day

- Marked temperature diurnal cycle for C2 with the coolest temperatures for the night and the highest at 10h00 and 13h00 (a): very low cloud cover (e) and a strong sensible heat flux (c) at those hours
- Smallest temperatures values during the day for C4: very small CRE<sub>sw</sub> and CRE<sub>lw</sub> values

Solid lines represent all the data available from 2009 to 2014 for each category in cloudy cases, and the dashed ones are for the moments when Lidar measurements are available



# Summary

- Development of a model to estimate the different sources of temperature variability at SIRTA, based almost entirely on observations.
  - Estimates and adjustment of all components characterizing this local variability (SIRTA-ReObs + ERA5)
  - Good results for the hourly temperature variability: good correlation coefficient and a weak residual for all seasons
  - Overall, the model tends to underestimate the observations: probably because of the important lack on some variables
- For all seasons, clouds are the main modulator of temperature variability over the time scale considered, warming for both night and day, whereas they never cool during night
- Other terms act as modulators of  $R_{CS}$  but with a much lower contribution
- All terms remain necessary in order to obtain the best coefficient estimator between the directly measured observations and the method
- Temperature diurnal cycle less marked when cloud cover is important, corresponding to clouds with high amount of liquid water



# Appendix

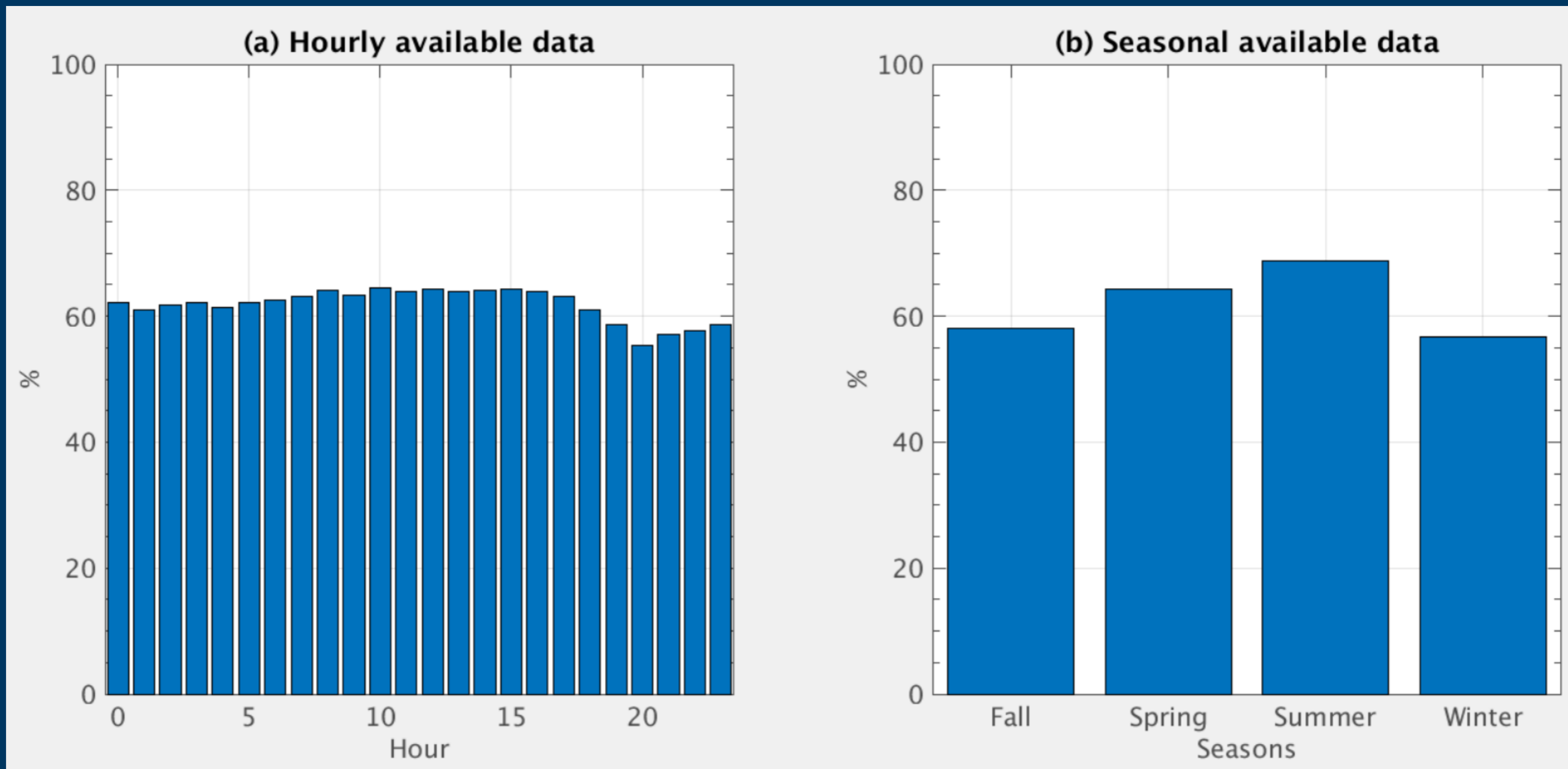


# Variables used as inputs for the model

Variable, unit	Notation	SIRTA-ReOBS Available Data from 2009 to 2014, in %
2 m air temperature, K	$T_{2m}$	97
Soil temperature below the ground, K	$T_s$	99
Temperature at the mixing layer height*, K	$T_H$	71
Surface downwelling LW radiation, $W/m^2$	$F_{LW}^{\downarrow}$	100
Surface downwelling SW radiation, $W/m^2$	$F_{SW}^{\downarrow}$	100
Surface upwelling LW radiation, $W/m^2$	$F_{LW}^{\uparrow}$	91
Surface upwelling SW radiation, $W/m^2$	$F_{SW}^{\uparrow}$	94
Surface downwelling LW radiation for clear sky, $W/m^2$	$F_{LW,CS}^{\downarrow}$	97
Surface downwelling SW radiation for clear sky, $W/m^2$	$F_{SW,CS}^{\downarrow}$	97
Surface upward sensible heat flux, $W/m^2$	$F_{sens}$	73
Surface upward latent heat flux, $W/m^2$	$F_{lat}$	5
Mixing layer depth, m	MLD	71



# Data availability





# Term estimation

## Radiative term

$$R = \frac{\alpha + 1}{c_p \rho MLH} \Delta F_{NET}$$

$$\Delta F_{NET} = SW \downarrow - SW \uparrow + LW \downarrow - LW \uparrow$$

$MLH$ : Mixed layer height

$c_p$ : Specific heat of air

$\rho$ : Air density

$\alpha$ : Shape parameter of vertical temperature profile

## Ground heat exchange term

$$HG = \frac{T_s - T_{2m}}{\tau_s}$$

$T_s$ : Soil temperature below the ground

$T_{2m}$ : 2m air temperature

$\tau_s$ : relaxation timescale

## Atmospheric heat exchange term

$$HA = \frac{T_{MLH} - T_{2m}}{\tau_a}$$

$T_{MLH}$ : Temperature at the mixed layer height

$\tau_a$ : relaxation timescale\*

$$\tau_a = - \frac{T_{MLH} - T_{2m}}{(F_{sens} + F_{latent})(\alpha + 1)} \rho C_p MLH$$

## Advection

$$Adv = u_{10m} \frac{\partial T_{2m}}{\partial x} + v_{10m} \frac{\partial T_{2m}}{\partial y}$$

$u, v$ : Horizontal wind speeds

\* See next slide



$\tau_a$ 

$$\bullet \frac{\partial T_{2m}}{\partial t} = \frac{\alpha+1}{c_p \rho H} \Delta F_{NET} + \frac{T_s - T_{2m}}{\tau_s} + \frac{T_{MLH} - T_{2m}}{\tau_a} - \left( u \frac{\partial T_{2m}}{\partial x} + v \frac{\partial T_{2m}}{\partial y} \right)$$

$$\frac{T_{MLH} - T_{2m}}{\tau_a} = - \frac{\alpha + 1}{c_p \rho MLH} (F_{sens} + F_{latent})$$

$$\tau_a = - \frac{T_{MLH} - T_{2m}}{(F_{sens} + F_{latent}) * (\alpha + 1)} * \rho C_p MLH$$



# Why a lookup table for $\tau_a$ ?

$$\tau_a = - \frac{T_{MLH} - T_{2m}}{(F_{sens} + F_{latent}) * (\alpha + 1)} * \rho C_p MLH$$

Common period very limited : Just a year and a few months of the measures available at the same time.

