Estimation of the contribution of clouds in temperature variability at SIRTA

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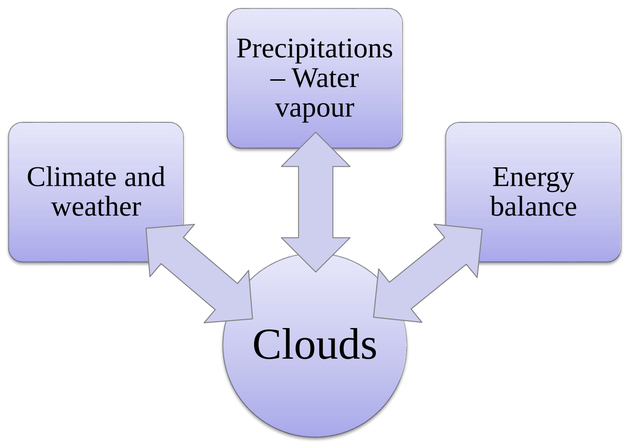
0. Motivations

Clouds are one of the main modulators of the climate system, via the atmospheric water cycle

- Climate very sensitive to small clouds changes
- They represent the largest contribution to the energy emitted to space
- They can either heat or cool the Earth (depending on their optical, microphysical and macrophysical properties and their altitude)
- Clouds are the main source of uncertainty for climate change predictions



Objective

- **Quantify the contribution of clouds to local temperature variability, according to different conditions**

Data

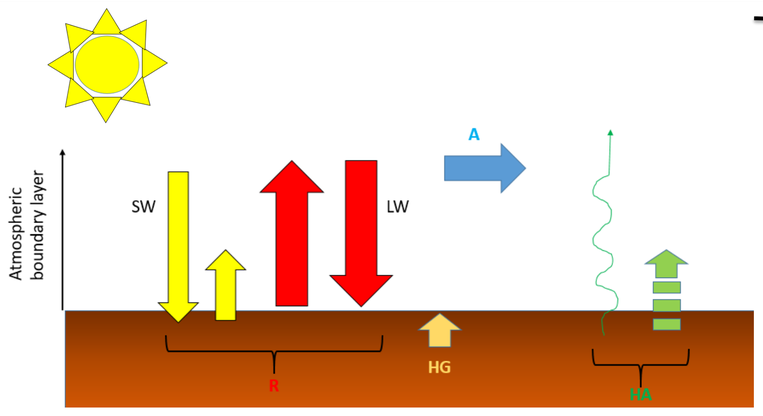
SIRTA – ReOBS: Hourly homogeneous multi-variables data in a single NCDF file.

For our study, all the necessary variables are <u>available</u> from January 2009 to February 2014

1. Our model

Temperature variability at 2m: $\frac{\partial T_{2m}}{\partial t} = R + HG + HA + A$

R = Radiative forcing = $R_{clear-sky} + R_{cloud}$
HG = Ground heat exhange
HA = Atmospheric heat exhange
A = Advection



Each of these terms can be estimated using the hourly observations available in SIRTA-ReOBS

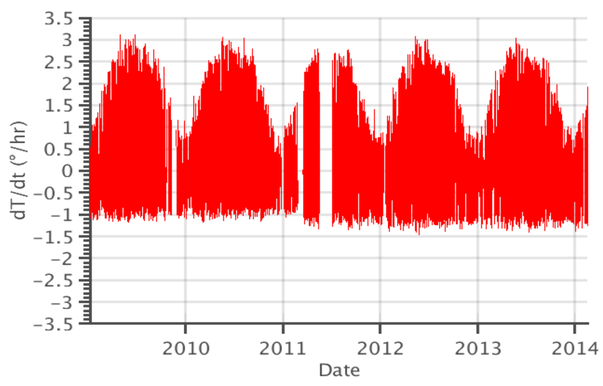
Our model will lead us to know:

- Which of these terms predomine, especially according to the seasons
- The value of R_{cloud} and the conditions under which it plays a leading role compared to other terms.
- Cloud characterization in cases when R_{cloud} becomes predominant

2. Estimation of each term

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

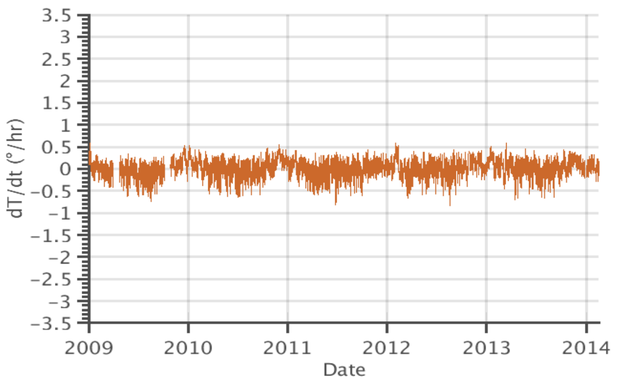
- α : shape parameter characterizing the form of the temperature profile
- MLH: Mixed layer height (ReObs)
- ΔF_{NET}: LW and SW Radiative fluxes (ReObs)



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

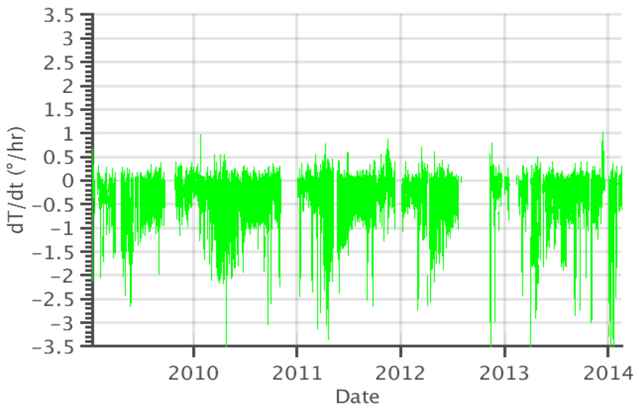
T_s : Temperature below the ground at -20cm (ReObs)

- T_{2m} : Temperature at 2m (ReObs)
- τ_s : relaxation timescale for ground exchanges
  -> Sensivity test: $\tau_s = 20\ hr$



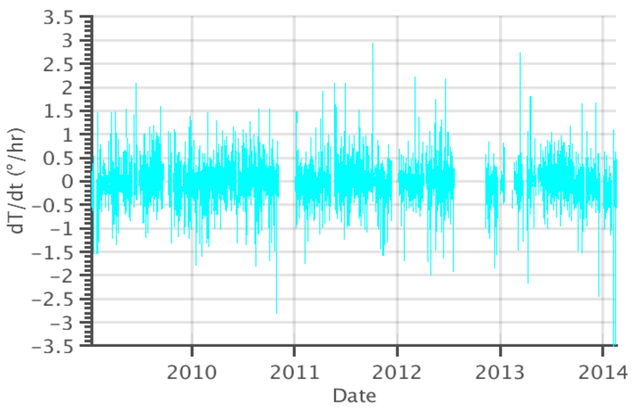
$$HA = \frac{T_{MLH} - T_{2m}}{\tau_a}$$

- T_{MLH} : Temperature at the mixed layer height (ReObs+ERA5)
- τ_s : relaxation timescale for atmospheric exchanges. Estimate a LUT from latent and sensible heat fluxes values



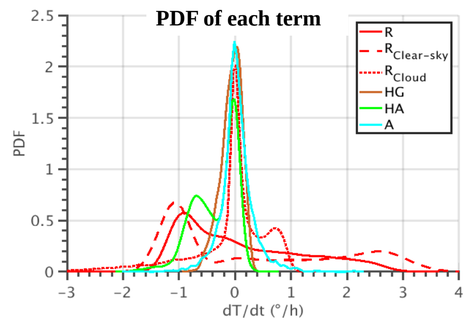
$$A = \left(u \frac{\partial T_{MLH}}{\partial x} + v \frac{\partial T_{MLH}}{\partial y} \right)$$

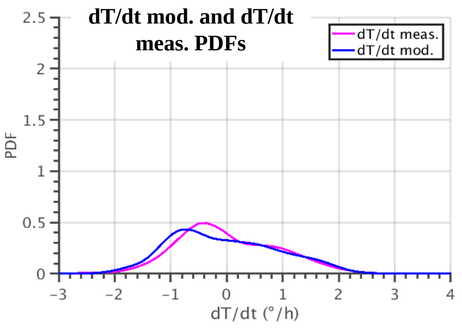
- u, v: Horizontal wind speed in x and y axes, respectively (ReObs + ERA5)

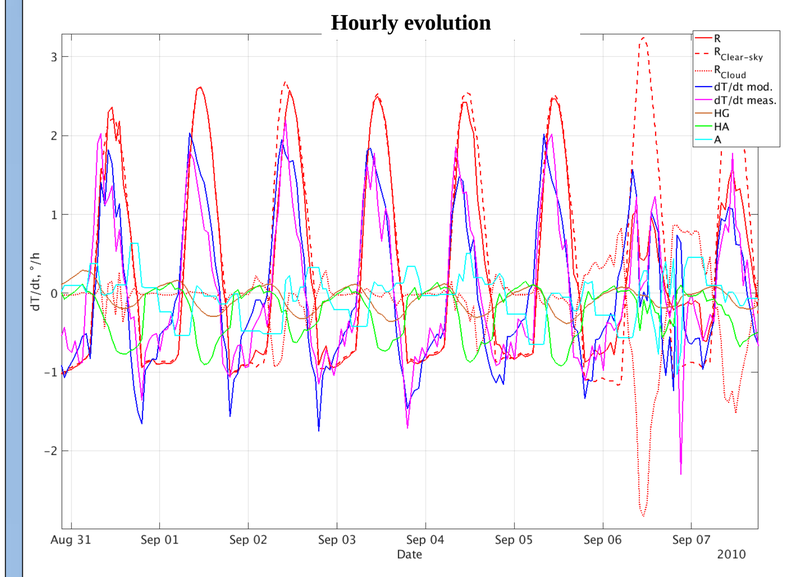


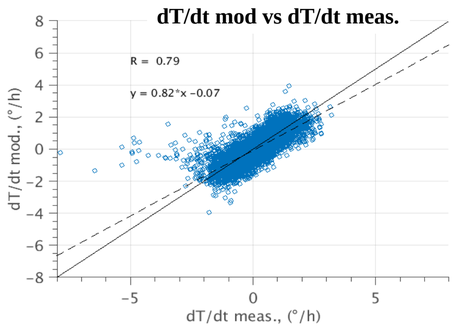
3. Evaluation of the method

$$\underbrace{\frac{\partial T_{2m}}{\partial t}}_{\frac{dT}{dt} meas.} = \underbrace{R_{clear-sky} + R_{cloud} + HG + HA + A}_{\frac{dT}{dt} mod.}$$









$\frac{dT}{dt}$ meas. vs $\frac{dT}{dt}$ mod. Statistics by season

Season	Corr. Coeff.	Bias	Standard deviation (° C/hr)
Summer	0,79	-0,18	0,61
Fall	0,75	-0,22	0,52
Winter	0,62	-0,28	0,51
Spring	0,76	-0,24	0,58

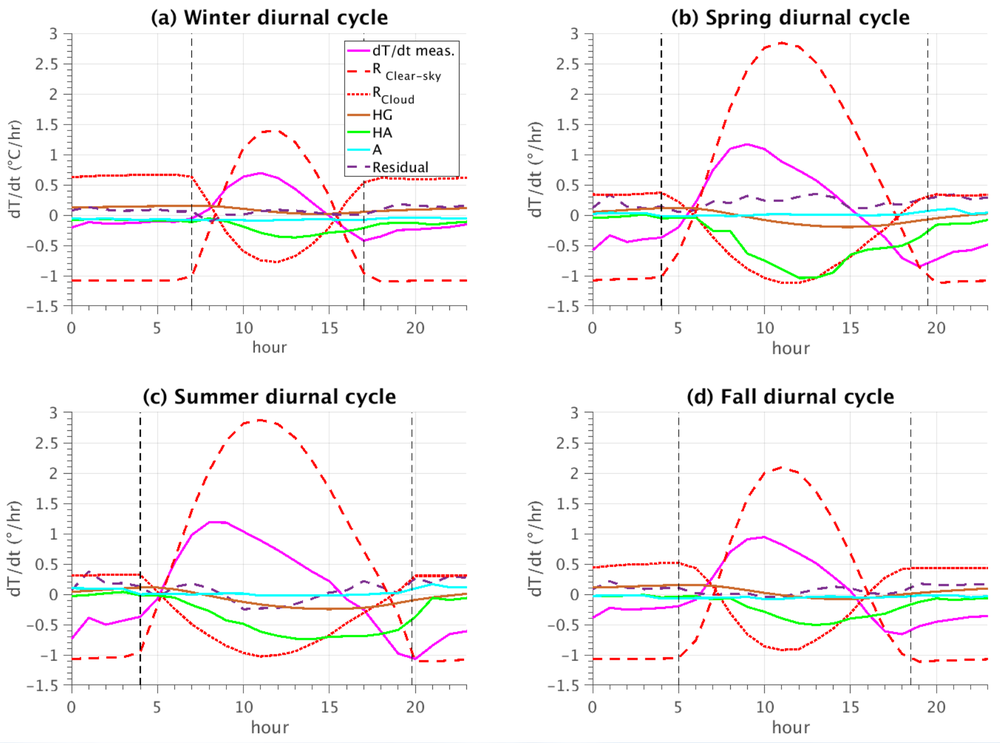
$\frac{dT}{dt}$ meas. vs $\frac{dT}{dt}$ mod. Analysis

- Good correlation between our model and the observations for all seasons
- Similar PDFs for summer
- The termes **HG** and **A** have a weak influence in the temperature variability compared to the **R** and **HA** terms
- Temperature variability at SIRTA is mostly controlled by the radiation

4.1 Diurnal cycle

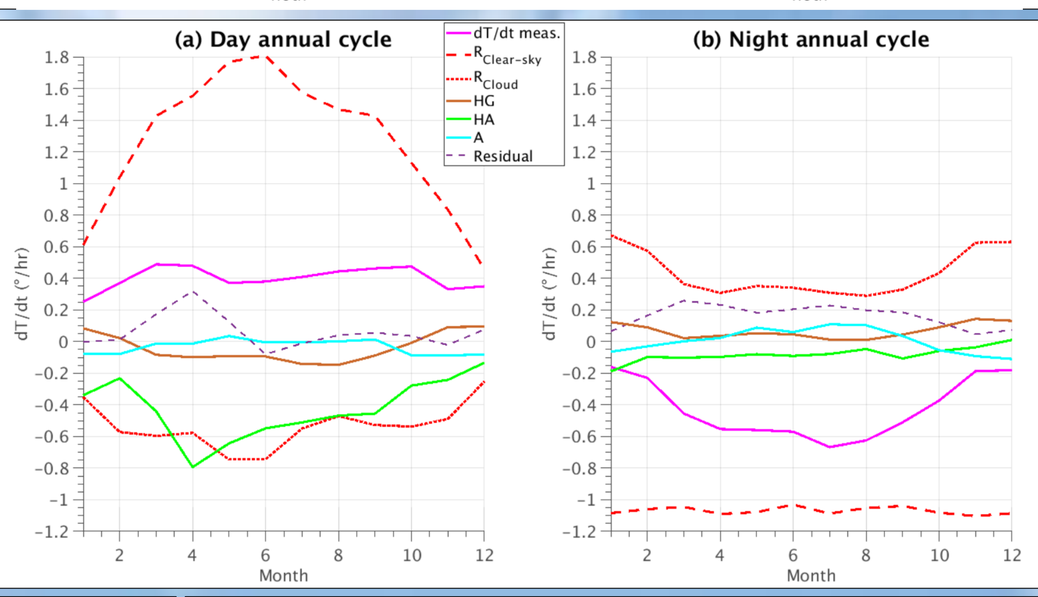
$$Residual = \frac{dT}{dt} meas. - \frac{dT}{dt} mod.$$

- Residual is weak for all four seasons and near zero for winter
- Clouds are the main modulator of the clear sky contribution in the temperature variability at SIRTA at 1-hour scale time
- The **HA** term becomes important and has more influence in the temperature variability in spring and summer -> Increase in turbulent latent and sensible heat fluxes
- In the late afternoon, HA dominates the temprature variability



4.2 Annual cycle

- There is not a remarkable annual cycle during the day for the observations
- At night, annual cycle is more distinguished -> More variability in summer due to an important cloud contribution
- Clouds are the dominant parameter to cool the surface during daytime and warm it at night.
- Less contribution of R_{cloud} (LW radiation) at night during summer -> less amount of clouds



5. Conclusions

- Development of a model to estimate the different sources of temperature variability, based almost exclusively on observations
- Radiative term dominates the temperature variability at SIRTA in all seasons at hourly scale
- Clouds drive this variability by heating at night and cooling during daytime.

References

- Bennartz, R. et al. (**2013**). July 2012 Greenland melt extent enhanced by low-level liquid clouds. Nature, vol. 496, pp. 83-86.
- Chiriaco, M. Dupont, J. C., Bastin, S., Badosa, J., Lopez, J., Heffelin, M., … & Guzman, R. (**2018**). ReOBS: a new approach to synthetyze long-terme multi-variable dataset and application to the SIRTA supersite. Earth System Science Data, 10(2), 919.