Meso-Nh surface scheme optimized for polar conditions: first validation tests for astronomical applications

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Description of ISBA model

- The goal of the study is to improve the surface temperature, in order to have better surface turbulent fluxes and so expect a better C_N^2
- ISBA : **I**nteraction **S**oil **B**iosphere **A**tmosphere, belongs to the soil vegetation atmosphere transfer model familly
- a Force-Restore method is used to describe as simply as possible the energy and water exchanges between the continuum soil-vegetation-snow and the atmosphere above
- A simple set of equations for surface and deep temperatures and soil water contents as well as a reservoir for the rain intercepted by plant leaves and finally snow water equivalent, density and albedo

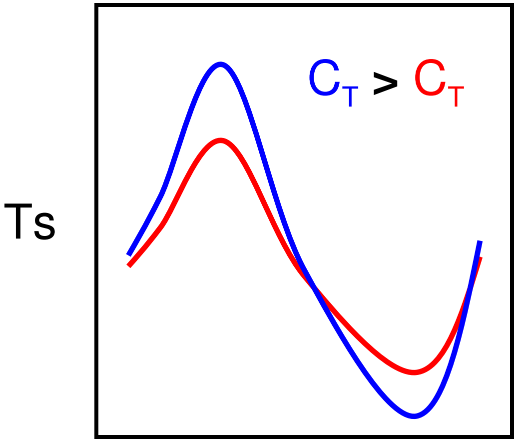
Equation system for temperature (1)

- Surface temperature Ts

$$\frac{\partial T_s}{\partial t} = C_T(G) - \frac{2\pi}{\tau}(T_s - T_2)$$

$$G = F_{net} - (F_{sensible} + F_{latent})$$

$$F_{net} = F_{net}(\alpha, \epsilon, Ts, radiation)$$

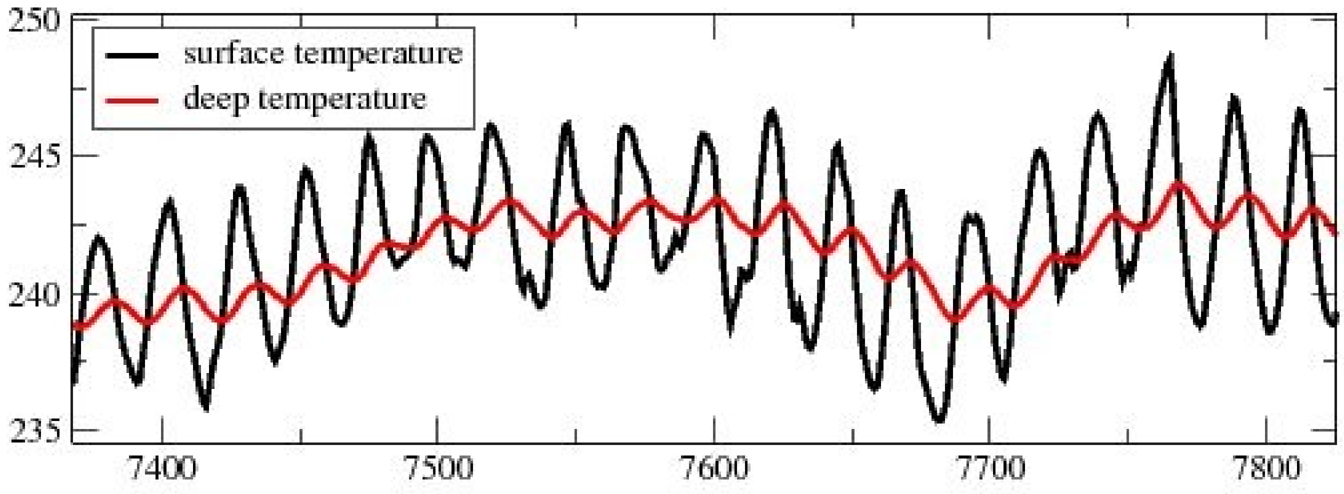


- C_T: thermal coefficient
- $F_{sensible}$ and F_{latent} are parameterized in the model
- *radiation* terms are computed by the atmospheric model

Equation system for temperature (2)

- Deep temperature T2

$$\frac{\partial T_2}{\partial t} = \frac{1}{\tau}(T_s - T_2)$$



Expression of fluxes in the model

- Turbulent fluxes:
  - $F_{sensible}$ and F_{latent} are parameterized according to Louis (1979) formulation and are used as boundary conditions in the atmospheric turbulent scheme
  - Fluxes are represented as the product of the vertical gradient of the state variable (temperature or humidity) times an aerodynamical resistance
  - Aerodynamical resistance is a function of air wind speed and drag coefficient that accounts for air stability and surface friction (roughness length)

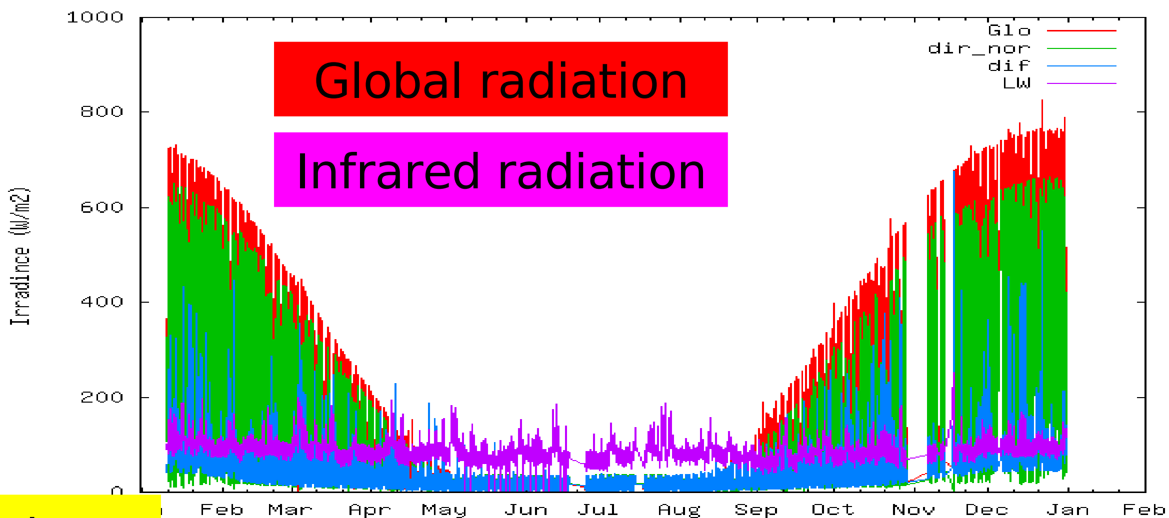
- Net flux:
  - Downwards and upwards short and long-wave radiation budget
  - Downwards radiation component are provided by the atmospheric model
  - Upwards radiation component depend on surface parameters like albedo, emissivity and surface temperature

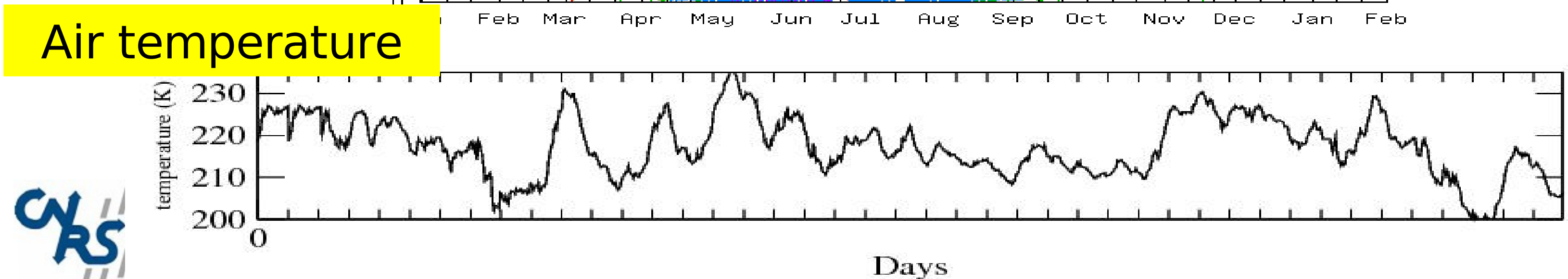
Adaptation of surface characteristics to polar conditions

- Surface type: permanent snow
  - Roughness length: 10^{-3} m
  - Albedo: 0.84
  - Emissivity: 0.98
  - Elevation: 3233 m
- Treated as a snow layer:
  - No liquid water
  - Only presence of snow
- Thermal inertia:
  - Adapted to account for domeC conditions
    - Snow density=$350 Kg/m^3$
    - $C_T=9.47x10^{-6}\ m^2KJ^{-1}$

Observed data at DomeC

- Input data:
  - A full year (2005) of observed data at DomeC
    - Temperatures at –30cm, -15cm and –5cm in snow and radiation terms provided by S. Argentini
    - wind speed and direction at 3 meters, temperature at 1.2 meters and surface pressure from AWS provided by A. Pellegrini team (Osservatorio Meteo-Climatologico at Dome C)





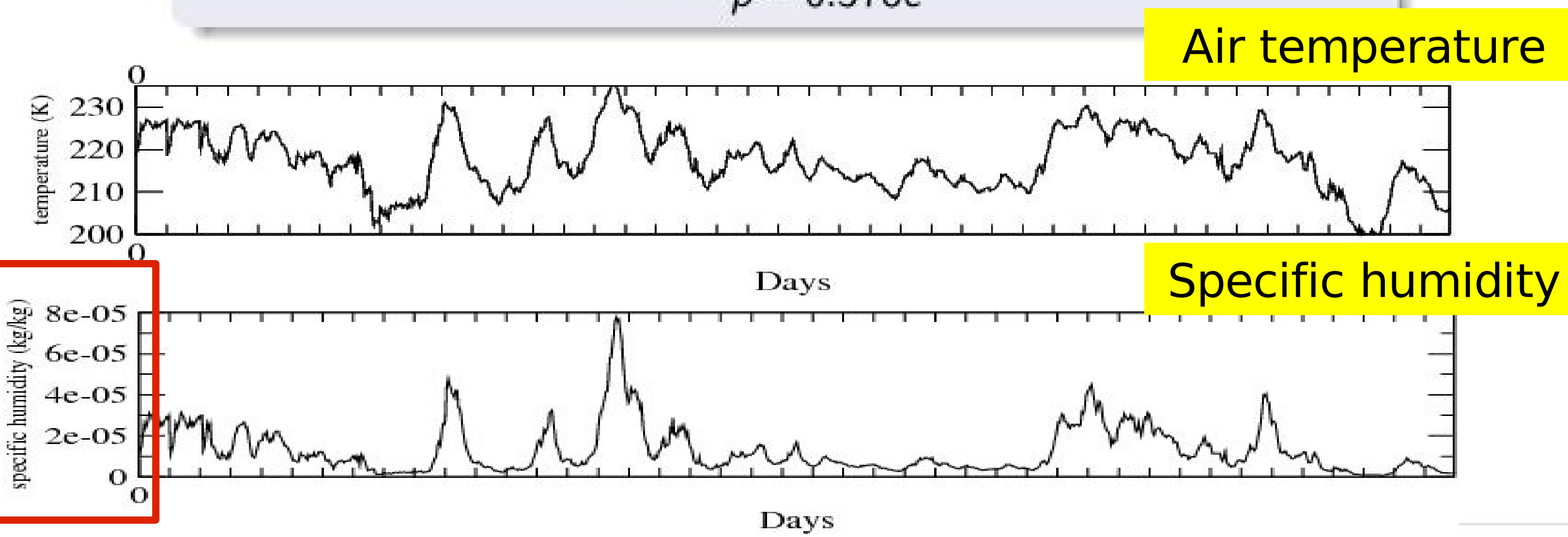
Computation of specific humidity q

- Specific humidity is computed from ice saturation vapour pressure (Goff & Gratch, 1961) assuming a relative humidity (RHU) of 50%

$$\log_{10}(e_i) = a - b * T - c/T + d \log_{10}(T)$$

$$e = e_i \times RHU$$

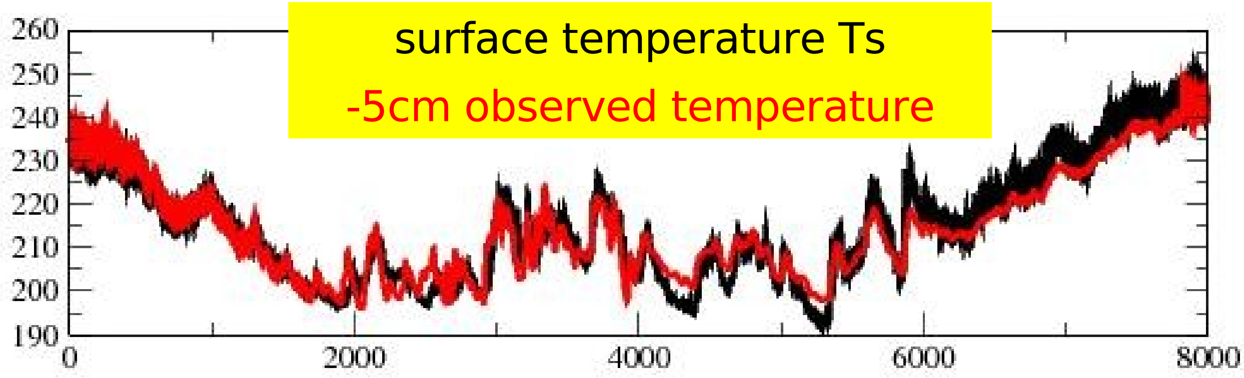
$$q = \frac{0.622e}{p - 0.378e}$$



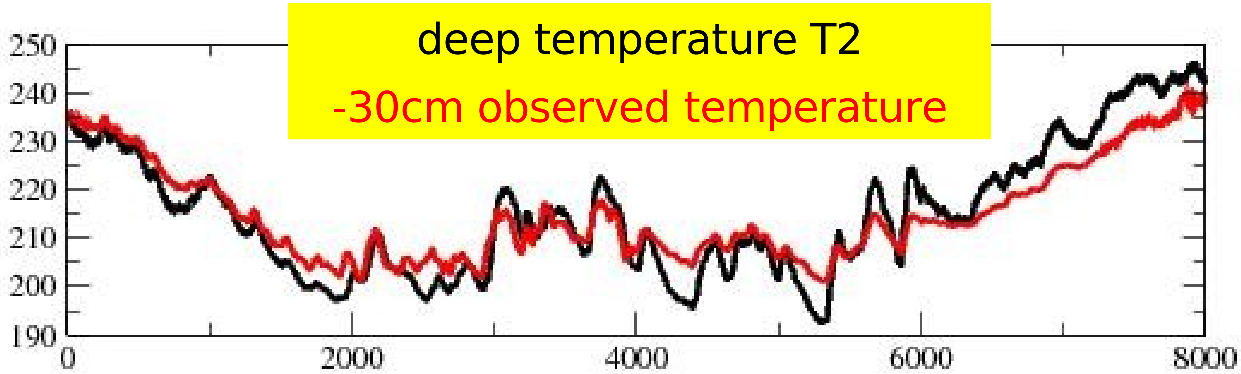
100 times smaller than at our latitudes

Reference simulation

- Off-line simulation:
  - Time series of meteorological variables are observed for year 2005
  - Computed surface temperature compared to temperature observed at –5cm in snow



  - Computed deep temperature compared to temperature observed at –30cm in snow



Surface scheme improvement for deep temperature equation

- New term in equation of T_2

$$\frac{\partial T_2}{\partial t} = \frac{1}{\tau}(T_s - T_2) + \frac{1}{\gamma\tau}(T_c - T_2)$$

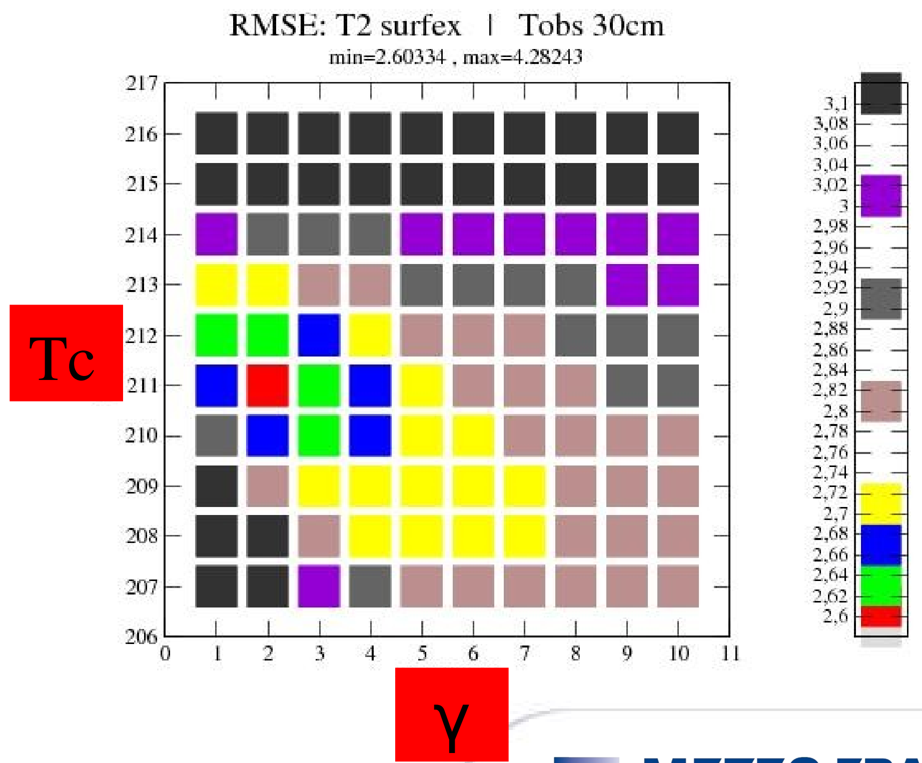
- Tc is a climatological temperature associated to a relaxation time γ:
  - The influence of Tc decreases with an increase of γ:
    - For example, if γ=1 then Tc is as important as Ts in the evolution of T_2
- Tc and γ are calibrated to have T_2 as close as possible to temperature observed at –30cm

Calibration of relevant parameters Tc and γ

- Princip:
  - Monthly minimisation of **rmse** of T_2-T_{30cm}
  - Tc varies from 207 and 216K
  - γ varies from 1 to 10

$$b = \frac{1}{n}\sum_{i=1}^{n}(S_i - O_i)$$

$$rmse = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(S_i - O_i)^2}$$



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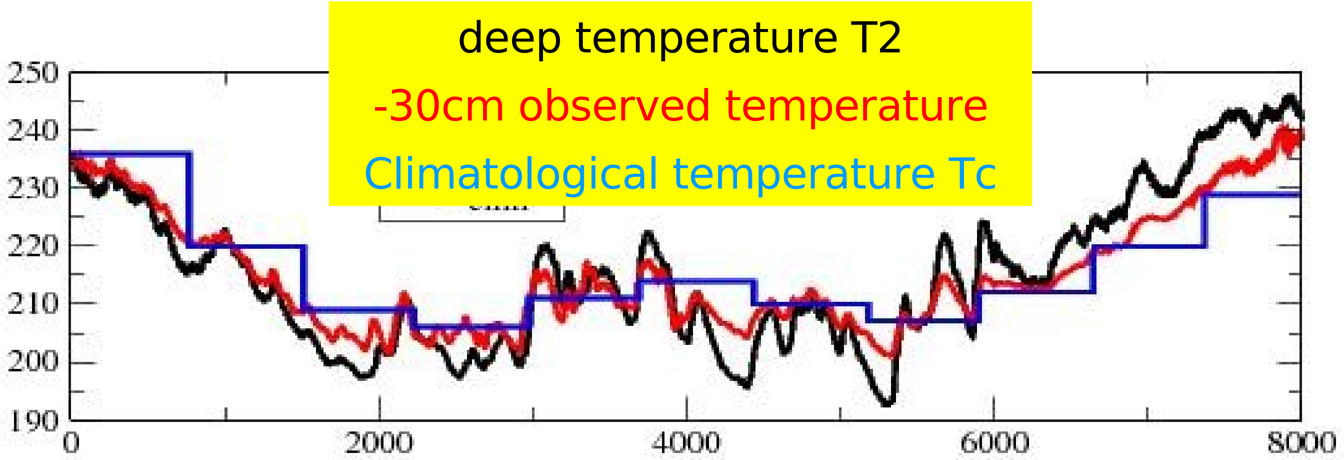
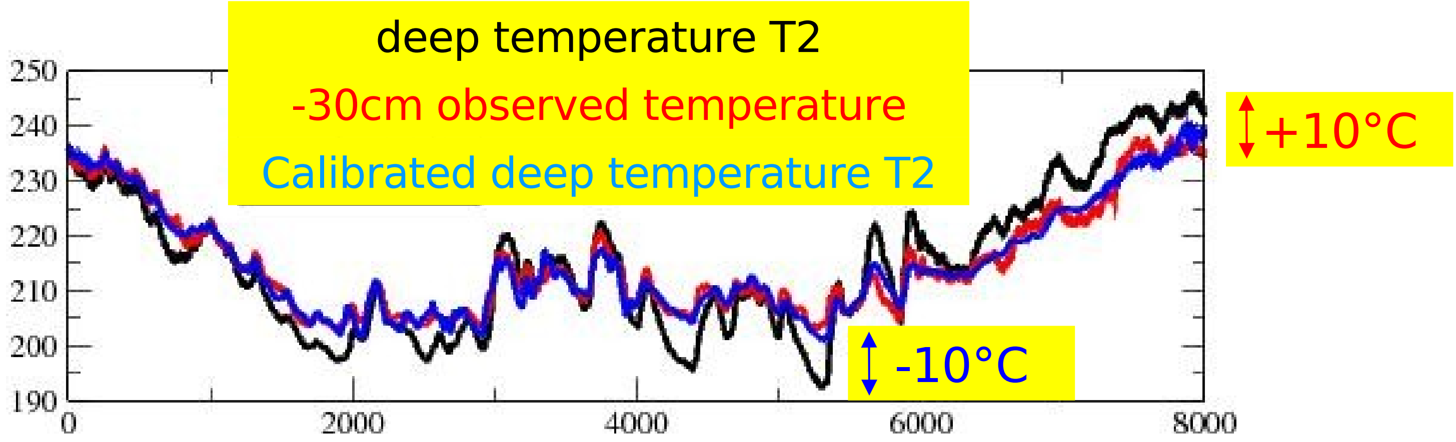
Calibration of relevant parameters Tc and γ

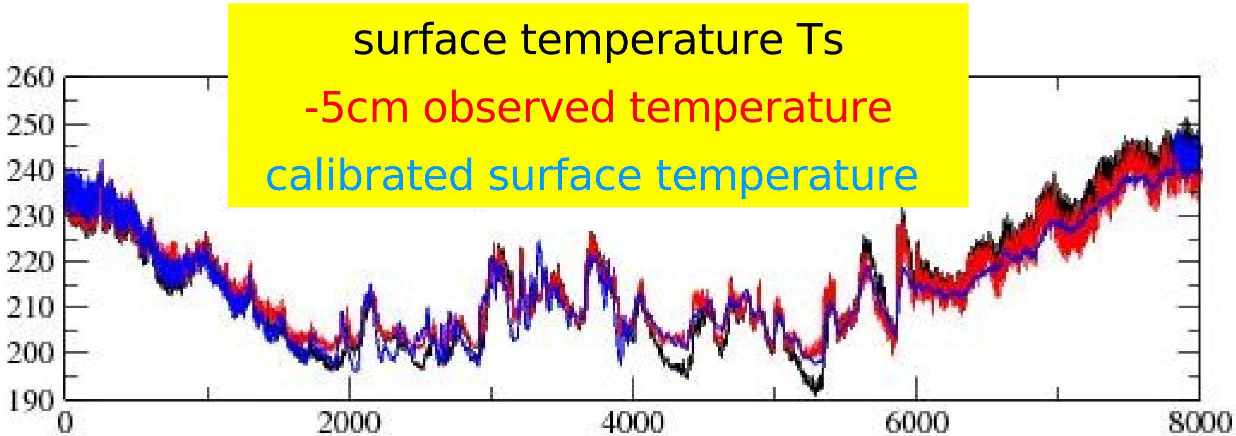
- Monthly minimisation for year 2005

month	J	F	M	A	M	J	J	A	S	O	N	D
Tc	236	236	220	209	206	211	214	210	207	212	220	209
γ	4	4	4	3	1	2	3	1	1	1	1	2



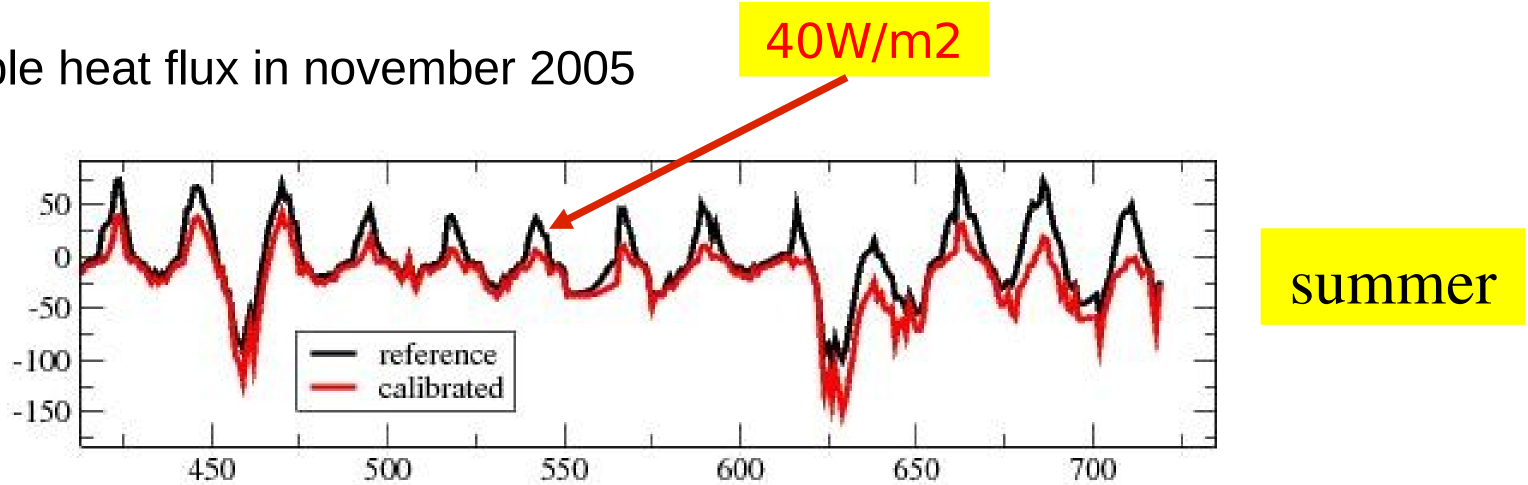
Impact of calibration on temperatures



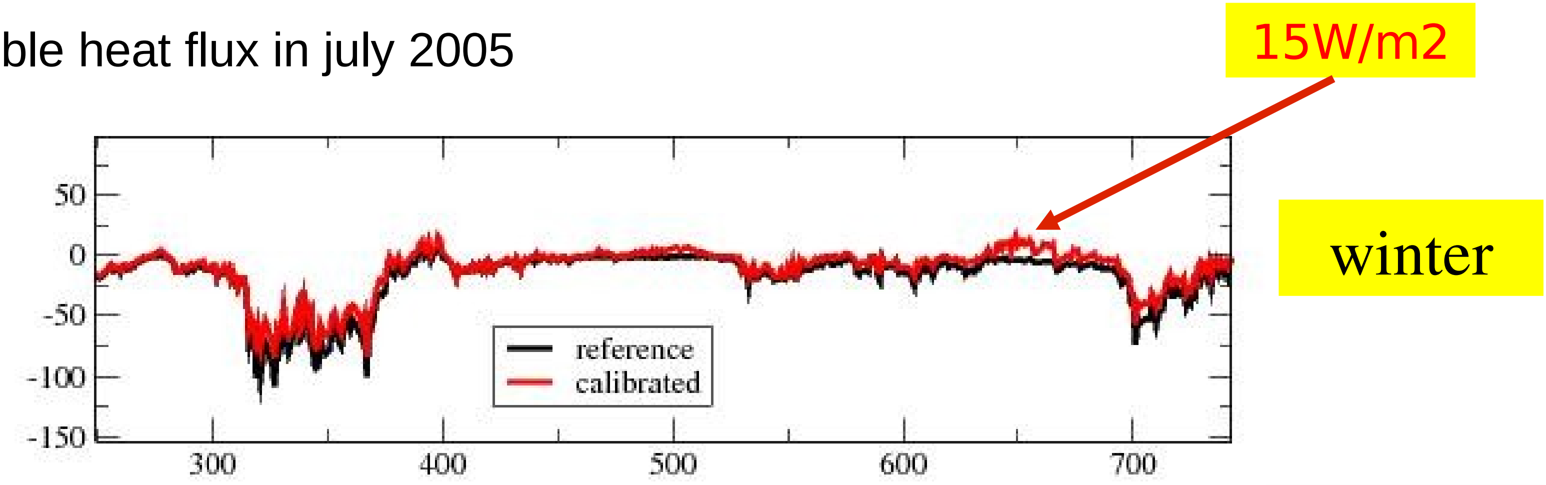


Impact of calibration on turbulent fluxes

- Sensible heat flux in november 2005



- Sensible heat flux in july 2005

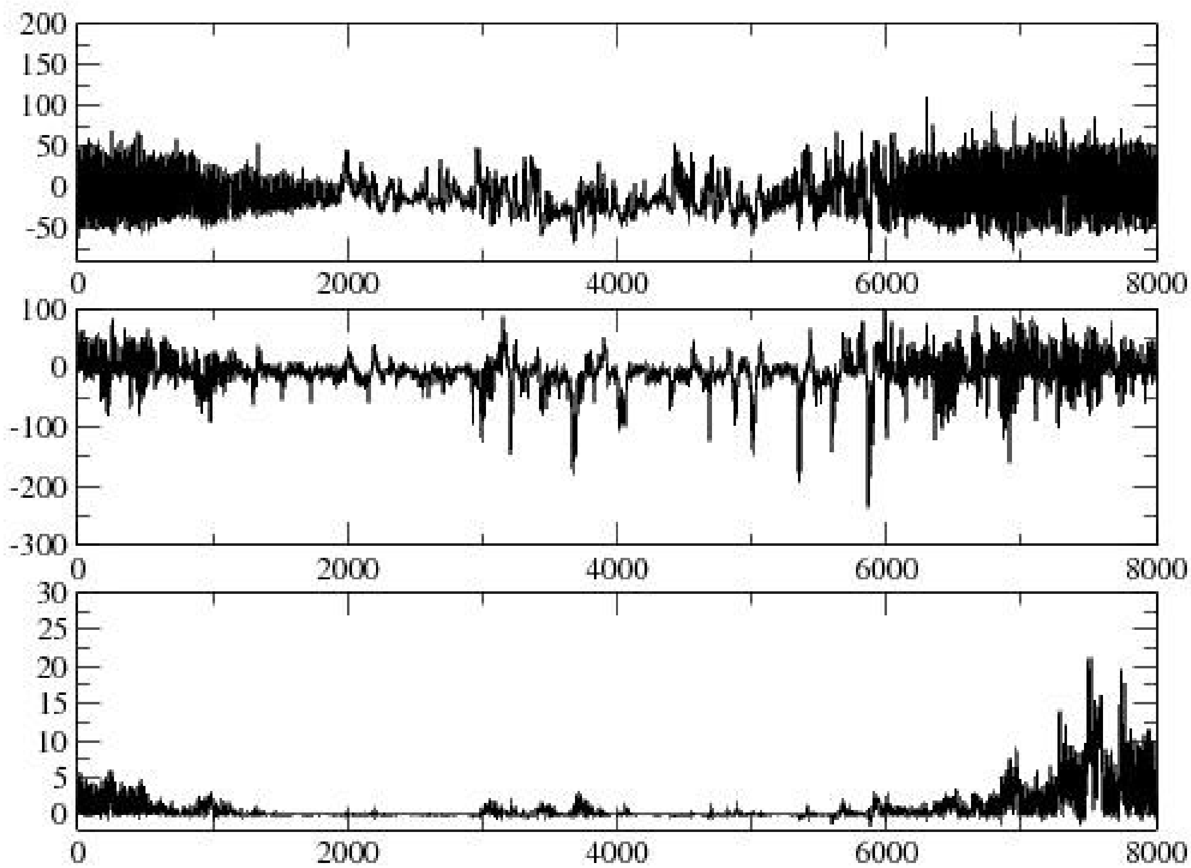


Budget of simulated fluxes

F_{net}

$F_{sensible}$

F_{latent}



$F_{latent} << F_{sensible}$

Conclusion and perspectives

- Very interesting dataset over DomeC:
  - From AWS (Pellegrini)
  - From in situ measurements at Concordia (Argentini)
- Use of the model in very extreme conditions
- Need of more observations especially for turbulent fluxes
  - Difficult to represent stable cases in models
- Need to know in more details the DomeC site characteristics to setup the model

Perspectives:

- Need to evaluate more carefully the impact of the calibrated system:
  - By realizing coupled simulation with mesoNH atmospheric model