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Role of the Soil Thermal Inertia in the short term variability of the surface temperature and consequences for the soil-moisture temperature feedback

Frederique Cheruy, Jean-Louis Dufresne, Sonia Ait Mesbah, Jean-Yves Grandpeix, and Fuxing Wang
LMD/IPSL. UPMC, Paris France (cheruy@lmd.jussieu.fr)

A simple model based on the surface energy budget at equilibrium is developed to compute the sensitivity of the climatological mean daily temperature and diurnal amplitude to the soil thermal inertia. It gives a conceptual framework to quantity the role of the atmospheric and land surface processes in the surface temperature variability and relies on the diurnal amplitude of the net surface radiation, the sensitivity of the turbulent fluxes to the surface temperature and the thermal inertia. The performances of the model are first evaluated with 3D numerical simulations performed with the atmospheric (LMDZ) and land surface (ORCHIDEE) modules of the Institut Pierre Simon Laplace (IPSL) climate model. A nudging approach is adopted, it prevents from using time-consuming long-term simulations required to account for the natural variability of the climate and allow to draw conclusion based on short-term (several years) simulations.

In the moist regions the diurnal amplitude and the mean surface temperature are controlled by the latent heat flux. In the dry areas, the relevant role of the stability of the boundary layer and of the soil thermal inertia is demonstrated. In these regions, the sensitivity of the surface temperature to the thermal inertia is high, due to the high contribution of the thermal flux to the energy budget. At high latitudes, when the sensitivity of turbulent fluxes is dominated by the day-time sensitivity of the sensible heat flux to the surface temperature and when this later is comparable to the thermal inertia term of the sensitivity equation, the surface temperature is also partially controlled by the thermal inertia which can rely on the snow properties;

In the regions where the latent heat flux exhibits a high day-to-day variability, such as transition regions, the thermal inertia has also significant impact on the surface temperature variability . In these not too wet (energy limited) and not too dry (moisture-limited) soil moisture (SM) “hot spots”, it is generally admitted that the variability of the surface temperature is explained by the soil moisture trough its control on the evaporation. This work suggests that the impact of the soil moisture on the temperature through its impact on the thermal inertia can be as important as its direct impact on the evaporation. Contrarily to the evaporation related soil-moisture temperature negative feedback, the thermal inertia soil-moisture related feedback newly identified by this work is a positive feedback which limits the cooling when the soil moisture increases.

These results suggest that uncertainties in the representation of the soil and snow thermal properties can be responsible of significant biases in numerical simulations and emphasize the need to carefully document and evaluate these quantities in the Land Surface Modules implemented in the climate models.