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Influence of the soil drainage boundary condition on land surface fluxes in a general circulation model

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The land surface model ORCHIDEE allows modeling the soil moisture in the unsaturated zone. It solves the Fokker-Planck equation over a 2-m soil depth, with an 11-layer discretization, using a free drainage bottom boundary condition, and the model of Mualem-Van Genuchten to determine unsaturated values of water conductivity and diffusivity (De Rosnay et al, 2000, GRL, 27: 3329-3332). This model provides land surface fluxes to the atmospheric general circulation LMDz.

The goal of this work is to assess the performances of the coupled model LMDz/ORCHIDEE, by comparison with data from the instrumented site SIRTA (located in Palaiseau, near Paris, France) which include near-surface meteorology, turbulent and radiative fluxes, surface temperature and soil moisture at five depths over the top 50 cms. To enhance comparability between simulated and observed data, we used a zoomed configuration centered on the SIRTA site, where the horizontal resolution drops to 100x100 km^2. To better describe the synoptic meteorology, we also used LMDz in a nudged mode, the large-scale circulation being adjusted toward ERA40 analyses outside the zoomed area, whereas the inside region can evolve freely (Coindreau et al, 2007, Mon. Wea. Rev.,135,1474-1489).

The first results, over 2000-2009, confirm the usefulness of nudging. The above configuration allows to simulate, radiative fluxes, air temperatures and humidity, and even precipitation rates, that are consistent with observations throughout the 10-year period. ORCHIDEE, however, fails to correctly reproduce the soil moisture records, with near-saturated values almost reaching the surface in winter, and soil moisture that remains high in summer. These observations are indicative of a shallow water table, in agreement with available geological studies revealing a shallow layer of impermeable clay.

The presence of a water table near the surface influences the bottom water fluxes, which cannot be as high as in free drainage conditions. Therefore, we introduced a drainage factor F in ORCHIDEE to adjust this boundary condition: F ranges between 1 (for free drainage) and 0 (for an impermeable bottom). To implement this factor, we had to change the vertical discretization of the soil column. The original version of ORCHIDEE, which focused on surface processes, used 11 soil layers, the thickness of which geometrically increased with depth from 1 mm to 1 m. For reasons of numerical stability, we refined the discretization of the bottom part of the soil columns, what lead to define 32 layers within the 2-m soil column.

Preliminary results show that ORCHIDEE much better reproduces the soil-atmosphere continuum at the SIRTA site using F values close to 0. We obtain a wetter soil, which is better able to meet the evaporation demand from the atmosphere, what reduces the overestimation of surface temperature and sensible heat flux that appeared in the initial simulation with F=1. We will eventually extend this analysis at the global scale, by testing the sensitivity to the drainage factor F in the coupled model LMDz/ORCHIDEE without any zoom nor nudging.