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Incorporation of water vapour flux in the JULES Land Surface Model: implications for key soil variables and land surface fluxes

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This study focuses on the mechanisms underlying water and heat transfer in upper soil layers, and their effects on soil physical prognostic variables and the individual components of the energy balance. The skill of the JULES (Joint UK Land Environment Simulator; Cox et al., 1999) land surface model (LSM) to simulate key soil variables, such as soil moisture content and soil temperature, and fluxes such as soil evaporation, is investigated. The Richards equation for soil water transfer, as used in most LSMs, was updated by incorporating isothermal and thermal water vapour transfer (see e.g., Milly, 1982). We also explored the impact of the model's vertical soil resolution on the simulation of within-soil physical processes and the partitioning between evapotranspiration, surface runoff and drainage. The model was tested for two sites: Anduo (Tibet) and Drayton St Leonard (Oxford), representative of a semi-arid and subhumid climate, respectively. Water vapour flux was found to contribute significantly to the water and heat transfer in the upper soil layers mainly due to thermal vapour diffusion, cooling mainly the near-surface, but also the deep soil layers. Inclusion of water vapour flux had an effect on the diurnal evolution of evaporation, soil moisture content and surface temperature.

Diurnal variability of soil water content and thermal vapour flux was more important for days representative of drier environmental conditions. Overall, the magnitude of the thermal vapour diffusion is similar for both sites with some variability as a result of the climate and soil properties. Generally, the multi-layer scheme configuration improved soil water dynamics in the upper layers, as well as heat transfer and coupling of these processes. Upper soil layers seemed to be more sensitive to the increment of the vertical soil resolution, and almost no differences were found from 60 cm soil depth and deeper. An increase of vertical soil resolution slightly improved soil moisture content predictions for both sites, although not the soil temperature predictions, apart from that in the deeper layers. The incorporation of new processes, such as water vapour flux among others, into LSMs, in combination with a finer vertical soil resolution, may improve the coupling between the upper soil layers and the atmosphere, which in turn could modify current and future climate predictions.

References:

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