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Groundwater-soil moisture-climate interactions: compared impacts in three Earth system models

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Groundwater (GW) constitutes by far the largest volume of liquid freshwater on Earth. The most active part is soil moisture (SM), recognized as a key variable of land/atmosphere interactions, especially in so-called transition zones, where/when SM varies between wet and dry values. But GW can also be stored in deeper reservoirs than soils, in particular unconfined aquifer systems, in which the saturated part is called the water table (WT). The latter is characterized by slow and mostly horizontal water flows towards the river network, with well-known buffering effects on streamflow variability. Where/when the WT is shallow enough, it can also sustain SM by means of capillary rise, thus increase evapotranspiration (ET), with potential impact on the climate system (including temperatures and precipitation). The large residence time of GW may also increase the Earth system's memory, with consequences on the persistence of extreme events, hydro-climatic predictability, and anthropogenic climate change, particularly the magnitude of regional warming.

Here, our main goal is to explore the impacts of GW on historical and future climate, by comparing integrations from three different climate models (CESM, CNRM-CM, IPSL-CM). Their land surface component explicitly describe the spatio-temporal dynamics of GW with GW-SM interactions, but these processes are based on different physical assumptions representative of the state of the art (e.g. scale of GW flow, active depth, input parameters). For each climate model, two transient land-atmosphere simulations are performed, one with GW and the other one without GW, by deactivating the related processes. Each transient simulation is made of the concatenation of (i) one AMIP simulation, with historical sea forcing over 1979-2014, (ii) one "FutureAMIP" simulation from 2015 to 2100, corresponding to the SSP5-8.5 radiative forcing, with sea forcing deduced from a corresponding fully coupled CNRM-CM simulation (from ScenarioMIP).

Within this framework, we want to assess the sensitivity of the simulated climate to GW in a systematic way, by trying to identify robust features among the three models. Our main objectives are twofold: (1) Compare GW and NO-GW AMIP simulations to observations to assess if accounting for GW improves some simulated land or climate parameters; (2) Compare FutureAMIP to AMIP simulations to assess if GW is able to alter the manifestations of climate change. For instance, can we get weaker regional warming in areas with significant GW-SM interactions?