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Effects of climate model resolution on land-atmosphere coupling in global simulations

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The land surface is recognized as a key driver of the climate. There are particular regions of the Earth with strong land-atmosphere coupling, where the land surface state represented by the soil moisture have a direct effect on the overlying atmosphere. On these hot-spots, soil moisture modulates land-atmosphere feedbacks through the exchanges of latent and sensible heat fluxes. It also interacts and modifies runoff, leading to potential changes in river flows. Through these processes, the state of the land-atmosphere coupling can modify the persistence and intensity of droughts or wet spells.

In this study, we seek to evaluate the effect of the increasing GCM resolution on the land-atmosphere coupling. To this end, we (a) quantify the land-atmosphere coupling for a set of HadGEM 3.1 simulations at different resolution, and (b) advance in the understanding of resolution effects on the interplay between soil moisture and surface fluxes. We use a set of global runs for the period 1950-2014 produced by CMIP6. The simulations are organized in two ensembles with different resolution (low and high). Each ensemble is composed by three members. The coupling is evaluated using the Terrestrial Coupling Index which highlights regions where soil moisture changes drive surface fluxes variability.

The results show hot-spots (high coupling) on regions with semi-arid climate, particularly those with hot semi-arid climate (eg. Sahel, India, south of Africa and north of Australia). On other areas, the coupling is weak because the soil is too dry and there is no evaporation or the soil is too wet and any increase of soil moisture does not produce significant changes in evapotranspiration. On other hand, when the resolution of the model is increased, the land-atmosphere coupling rise for all seasons. While the global average change is about +2% for high resolution, on some hot-spots and seasons the magnitude of the change is above 20%. It suggests that at high resolution the simulated soil moisture is more likely to vary between the wilting point and the field capacity. With this soil condition the soil is able to evaporate and the vegetation to transpirate leading to a more humid lower atmosphere that can produce more precipitation.

In future works the analysis will be extended to other CMIP6 models as part of the goals of the Process-based climate sIMulation: AdVances in high resolution modelling and European climate Risk Assessment (PRIMAVERA) Project.