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Violation of the flux-matching criteria in land-surface simulations by Noah-MP at different spatial resolutions over diverse regions

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Land-surface models use process representations to calculate terrestrial energy, water and biogeochemical fluxes. These process descriptions are usually derived from point measurements but are up-scaled to coarser resolutions in applications that range from about kilometers in catchment hydrology to hundreds of kilometers in global climate studies. Both, hydrologic and climate models are run nowadays at different spatial resolutions, using exactly the same land surface representations.

A fundamental criterion for the applicability of the same land surface model on different spatial scales is that the model calculates the same exchange fluxes at different spatial resolutions, i.e. the flux-matching criterion. Here, we evaluate fluxes simulated by the Noah-MP land surface model, which considers only a single soil and vegetation entity per model grid cell and neglects thus subgrid variability of soil parameters and land cover. A promising approach to derive scale-independent parameters is the Multiscale Parameter Regionalization (MPR) technique, which consists of two steps: first, it translates high-resolution data (such as 100 m soil maps) via transfer functions directly into effective model parameter fields, conserving the spatial information content. Second, it up-scales these high-resolution parameter fields to the model resolution by using appropriate upscaling operators. It has been shown in previous studies that MPR improves the scalability of hydrologic models substantially.

Here, we identify a set of regions within the contiguous United States with contrasting inter- and intra-regional variability of meteorology (NLDAS2 forcing), vegetation patterns (MODIS IGBP) and soil textures (STATSGO). The spatial variability of the agreement between fluxes of energy and water calculated at two spatial resolutions is correlated to the underlying spatial variability in the regions' vegetation and soil patterns. Changes in evapotranspiration are linked mainly to variability in vegetation while effects on runoff come mostly from variability in soil texture. Using the dominant soil type during upscaling of model parameters from a resolution of 0.125 to 0.5 degree introduces deviations of up to 17 and 85% in evapotranspiration and total runoff, respectively (quantified by normalized mean absolute errors). Applying MPR to the three most sensitive soil parameters of Noah-MP (i.e. porosity, saturated hydraulic conductivity, and Clapp-Hornberger's b parameter) reduces the flux mismatch considerably. MPR in Noah-MP provides improvements in the physical consistency of simulations on different spatial scales, which we expect to be achievable also in other land-surface schemes.