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A parameter optimization tool for evaluating the physical consistency of the plot-scale water budget of the integrated eco-hydrological model GEOtop in complex terrain

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In mountain regions, the plot- and catchment-scale water and energy budgets are controlled by a complex interplay of different abiotic (i.e. topography, geology, climate) and biotic (i.e. vegetation, land management) controlling factors.

When integrated, physically-based eco-hydrological models are used in mountain areas, there are a large number of parameters, topographic and boundary conditions that need to be chosen. However, data on soil and land-cover properties are relatively scarce and do not reflect the strong variability at the local scale. For this reason, tools for uncertainty quantification and optimal parameters identification are essential not only to improve model performances, but also to identify most relevant parameters to be measured in the field and to evaluate the impact of different assumptions for topographic and boundary conditions (surface, lateral and subsurface water and energy fluxes), which are usually unknown.

In this contribution, we present the results of a sensitivity analysis exercise for a set of 20 experimental stations located in the Italian Alps, representative of different conditions in terms of topography (elevation, slope, aspect), land use (pastures, meadows, and apple orchards), soil type and groundwater influence. Besides micrometeorological parameters, each station provides soil water content at different depths, and in three stations (one for each land cover) eddy covariance fluxes.

The aims of this work are: (I) To present an approach for improving calibration of plot-scale soil moisture and evapotranspiration (ET). (II) To identify the most sensitive parameters and relevant factors controlling temporal and spatial differences among sites. (III) Identify possible model structural deficiencies or uncertainties in boundary conditions.

Simulations have been performed with the GEOtop 2.0 model, which is a physically-based, fully distributed integrated eco-hydrological model that has been specifically designed for mountain regions, since it considers the effect of topography on radiation and water fluxes and integrates a snow module. A new automatic sensitivity and optimization tool based on the Particle Swarm Optimization theory has been developed, available as R package on https://github.com/EURAC-Ecohydro/geotopOptim2.

The model, once calibrated for soil and vegetation parameters, predicts the plot-scale temporal SMC dynamics of SMC and ET with a RMSE of about 0.05 m3/m3 and 40 W/m2, respectively. However, the model tends to underestimate ET during summer months over apple orchards.

Results show how most sensitive parameters are both soil and canopy structural properties. However, ranking is affected by the choice of the target function and local topographic conditions. In particular, local slope/aspect influences results in stations located over hillslopes, but with marked seasonal differences. Results for locations in the valley floor are strongly controlled by the choice of the bottom water flux boundary condition. The poorer model performances in simulating ET over apple orchards could be explained by a model structural deficiency in representing the stomatal control on vapor pressure deficit for this particular type of vegetation.

The results of this sensitivity could be extended to other physically distributed models, and also provide valuable insights for optimizing new experimental designs.