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Modelling carbon and water fluxes in mountain ecosystems

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The current tendency in the development of land surface models (LSMs) is towards ever-increasing complexity – with attendant loss of transparency, and even degradation of performance, in comparison to simpler, empirical models. Complex models also suffer from a multiplicity of parameters, allowing many combinations of values to yield apparently acceptable results and thus implying the risk of obtaining “right answers for wrong reasons”. We propose a different approach. Huge amounts of data from remote sensing and in-situ measurements, worldwide, with increasing temporal and spatial resolution, are becoming available – and offer the possibility of using observations far more systematically in the process of model formulation and development.
Mountain ecosystems, with their complex environmental gradients, shallow soils, defined drainage paths and practically impervious bedrock provide an opportunity to test new modelling approaches in a context that has received relatively little attention in a global context. We have achieved the high spatial resolution needed, without inflation of computational demand, by adopting analytical rather than numerical solutions for many processes. Starting from the SPLASH model, which uses analytical integrals to estimate accumulated energy fluxes through the day, we included slope corrections to the energy balance calculations, and an empirical partitioning of precipitation into snow and rain. We tested several existing runoff generation models, trying to relate model parameters mathematically to soil physical variables, without success. We therefore considered several physically based infiltration models that could be driven using freely available online datasets. We settled on the Green-Ampt model as the most robust and effective. We merged classic TOPMODEL concepts with Darcy’s theory and equilibrium water table concepts, exploiting the slope hydrology conceptualization (shallow soils and impervious bedrock), to build a subsurface runoff equation including the effects of temperature and pressure on hydraulic conductivity. The resulting model is undergoing a series of tests using independent soil moisture, runoff and latent heat flux measurements (from eddy covariance towers located on elevated plateaux). Simulations of snow water equivalent showed good agreement with SNOTEL data. Soil water contents were underestimated in snowy conditions, but otherwise show acceptable agreement. Simulated runoff dynamics matches observations at many sites although runoff is sometimes overestimated. Best data-model agreement was found for evapotranspiration, opening the way for a closer coupling of hydrological and primary production models.