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Process-based modeling of vegetation dynamics, snow, evapotranspiration and soil moisture patterns in an alpine catchment

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Mountain regions are particularly sensitive to climate change and at the same time they represent a key water resource not only locally but as well for lowland areas. Because of the complexity of mountain landscapes and the high climatic variability at a local scale, detailed quantification of key water budget components as snow cover, soil moisture and groundwater recharge is required. Therefore, there is a strong need to improve the capability of hydrological models to identify patterns in complex terrain (i.e. when variability of spatial characteristics counts), and to quantify changes of the water cycle components explicitly, considering interactions and feedbacks with climate and vegetation. Process-based hydrological models represent promising tools for addressing those needs. However, even if their inherent complexity sometimes limits their applicability for operational purpose, they offer great potential in terms of tools to test hypotheses, which can be verified in the field.

GEOtop is a hydrological model that calculates the energy and mass exchanges between soil, vegetation, and atmosphere, accounting for land cover, water redistribution, snow processes, glacier mass budget and the effects of complex terrain and thus is one of the few models that was built with this complexity in mind. Recently, it has also been coupled with a dynamic vegetation model in order to simulate alpine grassland ecosystems.

In this contribution, we want to present an application of the GEOtop model in simulating above ground biomass (B_{ag}) production, evapotranspiration (ET), soil moisture (SM) and snow water equivalent (SWE) patterns for a catchment of about 100 km^2, located in the Venosta/Vinschgau valley in the European Alps. Despite the Alps are one of the "water towers of Europe", water scarcity issues can affect the region where the model is applied, and an intensive hydrological and ecological monitoring activity with ground observations and remote-sensing products has been established in the last five years.

Simulations results showed that, along south-facing slopes, ET and B_{ag} did not decrease with elevation, as it happens along north facing slopes, but showed a maximum at an intermediate elevation around ca. 1500 m a.s.l., because of the contrasting trends of a shorter vegetation season at higher elevations and water stress at lower elevations. Therefore, results suggest that in this region south-facing pastures and woodlands below the elevation band of 1000 – 1500 m a.s.l. are the locations exposed to more frequent water stress conditions. Future climate change will likely worsen drought frequency.

This contribution highlights that the collected data set permits a multi-scale and multi-process evaluation of the model. Plot scale observations of evapotranspiration, soil moisture and snow cover, combined with remote sensing observations of snow and soil moisture help to discriminate between uncertainties in input data (i.e. snow/rainfall partitioning) and model parameterization. Moreover, we want to show with practical examples how, when dealing with coupled process-based eco-hydrological models is essential considering the physical consistency between different processes as modeled in GEOtop. For example, accounting the role of subsurface water lateral distribution on surface soil moisture; considering both water and energy budget constrains; introducing the control of snow cover on vegetation phenology. This introduces additional constraints in model parameterization that allow a better understanding of some processes dynamics, and can lead to a more coherent and accurate estimation of the catchment hydrological behavior than the one, which is possible with simpler models.