DOCTORAL SCHOOL IN ENVIRONMENTAL ENGINEERING - XIX cycle

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Snow cover modelling at a local and distributed scale over complex terrain

Abstract of the doctoral thesis

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Snowmelt controlled Alpine basins require accurate modelling of snow cover evolution. So far many models, referred to as temperature index models, calculate snowmelt assuming it proportional to difference between air temperature and freezing temperature (when the difference is positive), but the determination of the coefficient is problematic for its strong variability in time and in space. As the availability of meteorological data is increasing, the use of physically based distributed models is becoming more and more interesting.

This work focuses on the GEOtop model, which is a full hydrologic distributed model, applied here to snow and ice covered basins. In this model the energy budget equation is solved for soil, snow and ice, taking into account the dependence of radiation on topography through slope, aspect, shadowing, and the sky view angle. The sensible and latent heat fluxes are calculated applying Monin-Obukhov similarity theory and using at least hourly meteorological data (air temperature, relative humidity and wind velocity).

A local applications of the model on two seasonally snow covered basins (Rio Valbiolo Catchment, Trentino, Italy – Niwot Ridge, Colorado, USA) was made to check the capability of the model to adequately reproduce the snow cover evolution in time in one point, with satisfying results. The role played by the different components of the energy balance is also analysed.

Although the energy balance is mainly controlled by radiation, GEOtop tends to delay snowmelt because of the underestimation the sensible heat flux, when the latter is directed towards the snow cover. This is probably due to the errors related to the approximations at the basis of Monin Obukhov similarity theory.

Actually, as it is reported in literature, when atmospheric stability conditions occur, the above mentioned theory tends to suppress turbulence more than it happens in reality, as other turbulence generating processes are not taken into account. It is also shown how the basic assumptions of temperature index models are not supported by the results of GEOtop model, as snowmelt is found to occur also below freezing temperature, being dominated by the radiation patterns.

A comparison of the modelled snow covered extension area for Brenta Basin (Trentino, Italy) with remotely sensed data (MODIS) is also drawn. Several maps were compared, and the snow patterns in GEOtop output maps are found to be in a good agreement with the patterns in MODIS maps. This

demonstrates that the model describes the main processes controlling the snow cover evolution in time and in space quite good, although meteorological data were measured only in few points inside and close to the basin.

The model is also applied to two glaciers, one in the alpine region (Adamello glacier, Trentino, Italy) and the other in the tropical region (Zongo glacier, Bolivia), with good results, although the value of the precipitation is only roughly estimated at the highest elevations. As in the glacier a particular microclimate develops, it is not correct to directly use measurements performed far outside the glacier. However, another parameterization of the turbulent fluxes taking into account the glacier microclimate is employed.

Although the model needs further developments and a more accurate distribution in space of the meteorological data, the results are satisfying. It was also possible to find information about the role played by the different components of the energy budget in snow and ice covered terrain during the accumulation and the melting seasons. However, more experimental data are needed to find a confirmation.