REPRODUCTION OF SPATIAL PATTERNS OF SNOW MELT WITH THE HYDROLOGIC DISTRIBUTED MODEL GEOtop

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Summary

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The model

GEOtop (Endrizzi et al., 2004; Rigon et al., 2005) is a key distributed hydrological model. It can be regarded as both a rainfall-runoff model simulating the hydrological cycle in a continuous mode and an attempt to incorporate an adequate treatment of hydrological variability at small scales into Land Surface Models (LSM).

Like a rainfall-runoff model it calculates the discharge at the outlet of the watershed and estimates the surface and subsurface water fluxes, the water content in the saturated and the unsaturated portions of the soil layer.

Like an LSM it estimates the local values and the spatial distribution of numerous hydro-meteorological variables, such as snow cover, soil moisture, surface temperature, radiative fluxes, turbulent Heat fluxes and heat fluxes in the soil, taking into account the topography effects (slope and aspect), the solar radiation dependence on the weather conditions, and the soil and snow physics.

The snow accumulation and melting module (Zanetti et al., 2004) in GEOtop is an adaptation of the EBB model (Tarboton and Liu, 1995). The snow cover is characterized by 3 state variables: SWE (snow water equivalent), U (internal energy, which defines both the energy content and the liquid fraction of the snow) and t (age of snow, used for albedo calculation).

The state variables are solved at each time step solving numerically the energy balance equations.

Surface energy balance and heat fluxes

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\begin{align*}
R_{n} & \text{ net radiation} \\
H & \text{ sensible heat flux} \\
Q_{a} & \text{ latent heat flux} \\
Q_{1} & \text{ latent heat flux from the snow surface} \\
Q_{2} & \text{ sensible heat flux} \\
Q_{3} & \text{ solar radiation absorbed by snow} \\
\end{align*}
\]

The Moderate Resolution Imaging Spectroradiometer (MODIS) is a 36-channel sensor measuring the spectral range from visible to thermal-infrared. It was launched as part of the payload of the Terra (1999) and Aqua (2002) satellites. Among other products, daily and 8-day composite snow-related maps are produced at 500 m and 1000 m resolution. The maps created over land include daily snow extent and 8-day maximum snow extent. For the latter multiple sets of observations for a cell are examined. If snow cover is found for at least one day, the cell is indicated as snow. Other values are taken as cloud, ocean, water-filled lakes (day and night). If no snow is found in the cell, the most frequent value of the last 20 days is assumed. Due to the 8-day composing technique the impact of clouds is minimized (Rigon et al., 2003).

In this study we used the MODIS 8-day composite maximum snow extent data at level 1H. The data were processed in GRASS GIS (Neteler, 2005).

Conclusions

The GEOtop maps show a good agreement with the MODIS maps in autumn and in spring, during the melting time (although there are some errors in the remotely sensed data), while the snow spatial patterns are mainly dominated by elevation (maps 1, 3, 7, 8, 9, 10).

Differential melting in north facing and south facing slopes (maps 5, 6, 7) is predicted.

The GEOtop overestimates the snow limit elevation in late autumn (maps 2, 6), probably because of the incorrect assumption of the lapse rate.

GEOtop underestimates the snow melting in winter (maps 3, 4), as it understimates the surface temperature in winter for clear sky days, probably because of an incorrect parameterization of the upward heat fluxes under strong stability conditions in a non-homogeneous topography.

MODIS maps are affected by some errors, the some snow cover spots at low elevations (maps 1, 9, 10) and snow free areas in north facing vegetated or steep slopes at high elevations during winter.

References


