SNOW COVER MONITORING BY SATELLITES AND REAL TIME RUNOFF FORECASTS

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Abstract

By satellite monitoring of the seasonal snow cover it is possible to evaluate the snow accumulation in mountainous areas. The changing areal extent of snow cover is an important input variable for snowmelt runoff models. Direct measurements of snow reserves are hampered by the difficult access and avalanche hazards in the remote parts of a mountain basin. Therefore remote sensing is being increasingly applied to help to solve these problems. As an example, the paper presents snowmelt runoff simulations for two hydroelectric stations.

Keywords: snow mapping, snow accumulation, runoff forecast, satellites

As an example, Fig. 1 shows the basin of the upper Rhine in the Swiss Alps (Rhein-Felsberg 3650 km², 560-3614 m a.s.l.). The snow cover is shown as it has been evaluated from Landsat-MSS data (Baumgartner, 1987). The areal extent of the snow coverage in different elevation zones can be evaluated for different regions-of-interest or subbasins. If consecutive snow cover maps resulting from different satellite overflights are available, depletion curves can be derived as shown in Fig. 2. In the figure the depletion curves of two smaller subbasins Sedrun (108 km², 1840-3210 m a.s.l.) and Tavanasa (215 km², 1277-3210 m a.s.l.) are given for comparison concerning the runoff season 1985. The two hydroelectric stations are located within the subbasin ilanz (Fig. 1).

As mentioned, remote sensing capabilities enable us to map the snow cover. Advanced digital image processing techniques are used and with the aid of a digital terrain model (DTM) the snow cover analyses are computed in different elevation zones. By that means the snow cover depletion curves can be plotted from a sequence of such recordings.

1. Monitoring of seasonal snow cover by satellites

Earth observation satellites allow to monitor the seasonal changes of the snow coverage in alpine regions. The seasonal accumulation of snow and the gradual decrease of the snow covered area during the snow melt season is a typical feature. Methods are being developed to quantify this process by periodical snow cover mapping.

2. Evaluation of the areal water equivalent of snow

The depletion curves reflect the seasonal decrease of the snow cover as it is influenced by temperature and precipi-

Fig. 1 Basin of the upper Rhine in Switzerland (Felsberg) with the snow cover evaluated from the Landsat overflight on 18-MAY-1982. Partial test areas are labeled I = ilanz and T = Tiefencastel.
Fig. 2 Depletion curves of elevation zones (B, C, D, and E) of the sub-basins a) Sedrun and b) Tavanasa for the snowmelt season 1985.

- **B** 1100-1600 m a.s.l.
- **C** 1600-2100 m a.s.l.
- **D** 2100-2600 m a.s.l.
- **E** 2600-3614 m a.s.l.

In order to get the initial accumulation of snow "modified depletion curves" can be derived as explained by Hall and Martinez (1985). These curves relate the areal snow coverage to the cumulative snowmelt depths. In Fig. 3 the modified depletion curves of the subbasins Sedrun and Tavanasa are shown.

In contrast to a conventional depletion curve of the snow coverage, the modified curve relates the snow coverage with the cumulative snowmelt depth (instead of time). A modified depletion curve thus indicates the initial water volume stored in the snow cover. It is the area between the curve and the x, y-axes. During the snowmelt season, it is also possible to read off the water volume which has flown off and the water volume which is still stored in the snow cover.

This evaluation is applied to the catchment areas of Sedrun and Tavanasa in Fig. 3. The volume available for Sedrun serves for peak electricity production from a reservoir while Tavanasa is a run-of-river power plant.

Both informations have been required by an electrical company and found important for an improved production of electricity.

3. Modelling of the snowmelt runoff for hydropower and flood control

The seasonal snow cover is a dominant runoff factor in mountain basins. Recently, the attention has been focused on snowmelt runoff models by a project of the World Meteorological Organization (WMO, 1986). Of the models tested, the SRM model (Martinec et al., 1983) exploits the increasing availability of snow cover mapping from satellites. Besides the air temperature and precipitation, the snow covered area from conventional depletion curves (Fig. 2) is the essential input variable used.

The deterministic snowmelt runoff model (SRM) is designed to simulate or to forecast the daily discharge in mountain basins, resulting mainly from snowmelt but also from precipitation.

Based on the above mentioned satellite snow cover mappings, the daily flows from April to September 1985 have been computed for the previously mentioned hydroelectric stations Sedrun and Tavanasa. As shown in Fig. 4, the daily runoff values have been simulated for both stations. The model accuracy is characterized by the coefficient of determination

Fig. 3 Modified depletion curves of the snow coverage in the sub-basins Sedrun and Tavanasa for the runoff season 1985 for comparison in the different elevation zones (C, D, E as in Fig. 2).
Fig. 4  
a) Computed and measured discharge from the catchment area of the hydroelectric station Sedrun.

Fig. 4  
b) Computed and measured discharge from the catchment area of the hydroelectric station Tavanasa.
of opportunities to obtain views of a given area. Exactly this property in addition with any further active sensor in orbit prepares the way for an operational procedure for snowmelt runoff forecast.

5. Conclusions
Remote sensing Landsat-MSS data enabled us to map snow coverages even in rather small catchment areas (as requested by a hydroelectric company) in order to serve the requirements of snowmelt runoff modelling.

The paper deals only with Landsat-MSS data, but with the advanced capabilities of the SPOT sensor system and any further earth observation satellite a sufficient frequency of overflights seems to be guaranteed.

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Bibliography


