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Operational Snow Cover Mapping and Analysis in the Canton of Valais Based on MODIS Data

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In alpine catchments, snowmelt is a factor that can significantly accentuate flow rates during flood periods. Indeed, during a heat wave and heavy rain periods, water accumulated as snow is released and contributes directly to the increase of river flow rates. Therefore, the monitoring of snow cover over a study basin is essential to understand and prevent potential risk situations.

The methods presented in this paper are based on data from the Moderate Resolution Imaging Spectroradiometer (MODIS) carried by the Aqua and Terra satellites, from the Earth Observing System (EOS) program of the NASA. The data is automatically acquired and processed on a daily basis over a 5520 km² area representing the Upper Rhone River basin, mainly located in the Canton of Valais (Switzerland). The processing chain is operational and produces daily snow maps and related statistics. The results are available to hydro-meteorological experts and are used for decision support.

One of the main limitations of MODIS technology is the presence of clouds in the data, which cover on average 56% of the images in the Rhône basin. Indeed, MODIS detects wavelengths ranging between 0.4 and 14 µm, which cannot penetrate clouds. In order to enable a complete statistical analysis of the data, a methodology has been set up to reduce cloud obscuration in MODIS data. First, the data collected from the Aqua and Terra satellites, which pass daily at an interval of 3 hours, is combined to reduce the total number of clouded pixels by around 10%. Then, the remaining cloud areas are filled in using a time interpolation-based method (López-Burgos et al., 2013). If a pixel is obscured by clouds, the most recent value from up to 7 previous days is used instead. The remaining obscured surface is thus reduced by a further 93%. On average, the final cloud obscuration rate thus obtained is less than 1%.

After cloud obscuration processing, a daily map of snow cover and relevant statistics are calculated for the whole Rhône basin and for twenty two hydrological sub-basins. For each daily map of snow cover, statistics of replaced clouds based on previous days are presented as a pie chart (Figure 1). Statistics on snow cover are generated for both daily and monthly time steps. The snow cover is then calculated and compared to the quantiles calculated over the available 12 past years data (figure 2).

A preliminary comparison of MODIS processed data and the snow cover data (interpolated from meteorological stations) from the Institute for Snow and Avalanche Research (SLF) has been realized for the periods of Dec. 2013 to May 2014. The MODIS data usually estimates sensibly less snow cover than SLF data. During winter and depending on the region, 0 to 5% less snow cover can be observed on average. During spring time, the variation can be greater, from 0 to 10% less than SLF. Further analysis is planned for future work.

The MODIS data processing could greatly enhance our knowledge about spatial snow cover distribution and its temporal evolution throughout the year. It offers a way to assess the inter-annual variability in space and time of snow covered areas that could be linked to climate change. It provides additional information that reduces the uncertainty on the hydrological state of the basin. In addition, the snow cover data is used to validate the snow cover simulated by the hydrological model of the MINERVE system (García Hernández et al., 2013), which generates real-time hydrological forecasts for the Upper Rhone River basin. MODIS data is also useful for water resources management within the project STRADA (CREALP, Projet INTERREG III_A – STRADA, 2013-2014).

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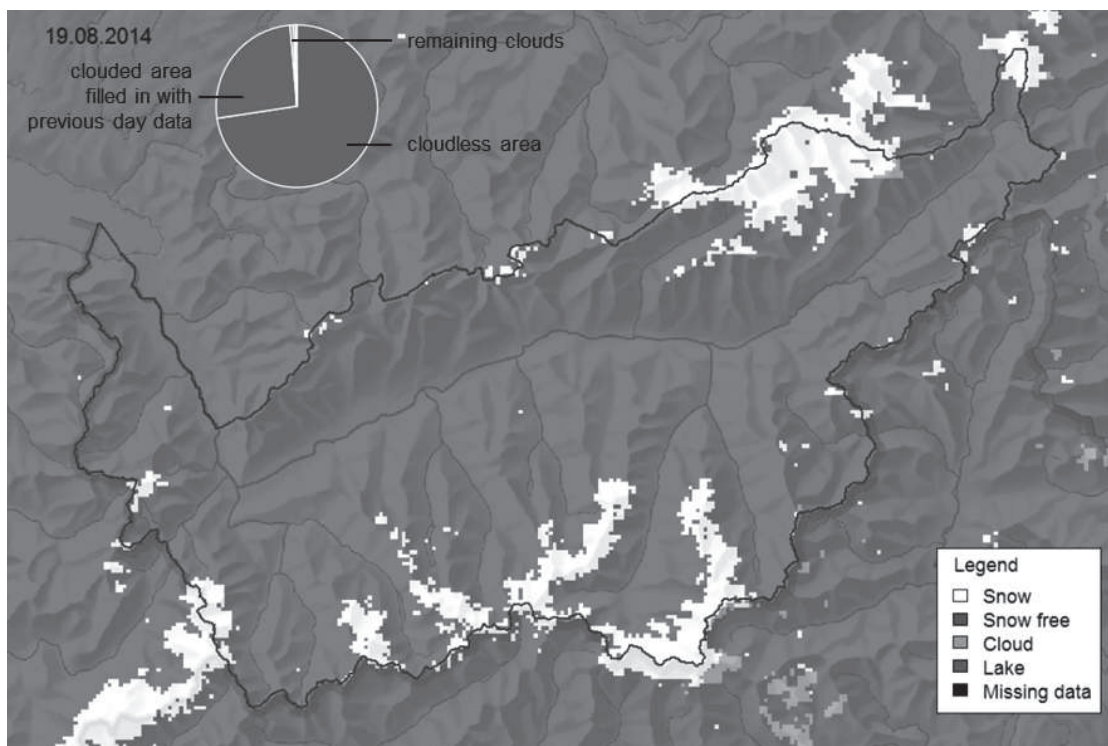


Figure 1. Valais snow cover and pie chart with cloud replacement information

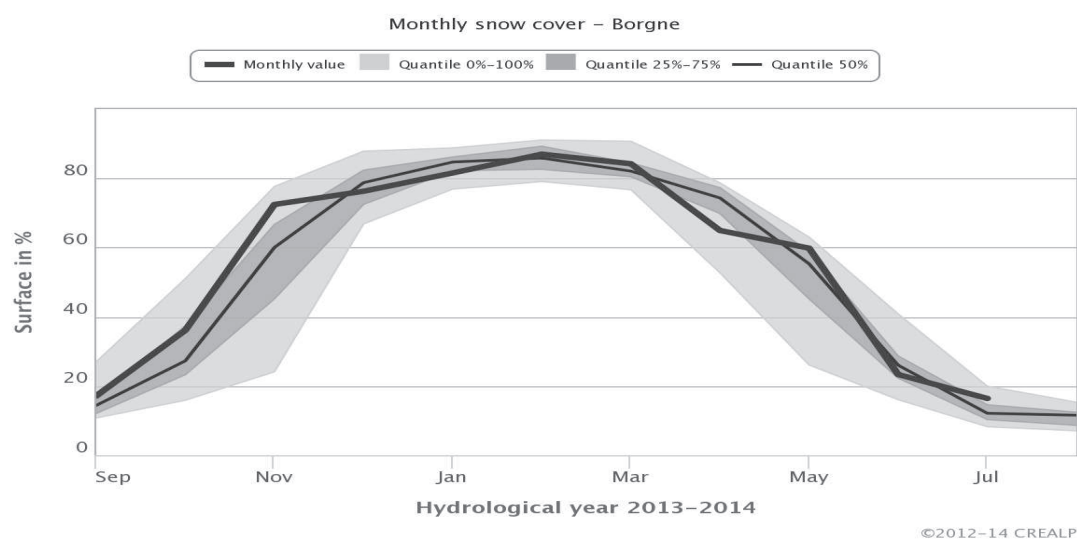


Figure 2. Monthly snow cover area for the Borgne basin in Valais.