Hydrology and Earth System Sciences Discussions

Interactive comment on "Validation of MODIS snow cover images over Austria" *by* J. Parajka and G. Blöschl

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1) General Evaluation

The manuscript addresses the scientific questions concerning an application of satellite images (only MODIS is used) to the field of water resources more specifically hydrological modeling which is within the scope of HESS. The paper attempts to fulfill three objectives in terms of snow recognition study namely:

- To analyze the temporal and spatial variability of one of the snow parameters (snow cover area only) using MODIS - To examine the accuracy of products against a large number of snow depth in-situ data at 754 climate stations - To identify the main sources of misclassification influencing the accuracy of the MODIS snow covered area product.

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As an overall evaluation, the presentation is well structured with fluent and precise language. The length of daily records covering the period from February 2000 to December 2005 over Austria is very good and provides the authors to draw more conclusive comments and discussions than in previous publications on similar subject.

The authors review a list of valuable works which were concentrated on the studies in North America (as mentioned by the authors) It could be worth to note that consistency of MODIS snow covered area products was also analyzed in "Using MODIS snow cover maps in modeling snowmelt runoff process in the eastern part of Turkey" (Tekeli et al., 2005) Remote Sensing of Environment, Vol 97, 216-230, where MODIS products were validated against mountainous regions of Turkey. There are common problems encountered with in both studies.

2) Technical Comments

The following technical issues should be addressed as individual questions to improve the final revised version of the manuscript:

The abstract may require more complete summary of error sources discussed in the text. The main misclassification source is attributed to time shift within the current form of the abstract.

The manuscript in present form presents the ideas of potential sources of misclassification but the tools are not given. Since no correction/updating of the existing developed algorithm is attempted to mask the cloud (with respect to cloud type) and land cover etc. but the references are properly credited for the previous works.

As it is mentioned in the measurements or other similar works done on the subject; the following elements are very sensitive on the algorithm for cloud masking and classification of images. Cloud type, patchiness and thickness of snow and land cover. As we all know that validation of optical satellite data of snow cover images requires clear sky days. The selection of single image products for the cases when high percentages

of clouds are observed (63 % in Austria) restricts to draw continuous snow depletion curve for each sub zone of catchments which is the critical input parameter for the model studies. So, more discussion is expected to be presented in the discussing paper to compare daily and MODIS 8-day products for hydrological applications. The use of satellite data in hydrologic modeling and data assimilation is very important as emphasized within the text, such a work should have been carried out as well. It would be good idea to mention about the timing of processing and the number of images to be selected for real time runoff forecasting.

Other methods of monitoring snow covered by satellites are expected to be discussed beside MODIS satellite products within the text. Due to high cloud cover percentage during the whole period, it could be recommended to use microwave satellite products other than optic satellite products.

The explanation "Snow depth observations at the climate stations were considered as ground truth for the pixel that was closest to each station" brings "how close or how representative" question. In these kind of studies it is recommended to take neighbouring cells into acoount to prevent misclassification due to downscaling. This may reduce misclassification errors to some extent due to patchy snow.

The MODIS maps from 16 pixel classes are generally reduced to four classes to be used in quantitative validation. It may be recommendable to further classify the land as frozen/none frozen and cloud type when they are masked.

Since the snow depth measurements were only available daily at 7 00 a.m but the satellite passages were in the early afternoon, the patchy and partly shallow snow covered pixels are affected during validation stage and the ablation period at lower altitudes where the melt rate may be 4-6 mm/day/oC. One day shift in the daily comparisons (Tekeli et al. 2005) may prevent misclassification due to inconsistency in time periods. One day shift comparison may also increase the validation accuracy during cloudy days.

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In the present study, pixels were regarded as snow covered when the measured snow depth at the climatic station exceeded or equaled 1 cm. This is the assumption of Maurer et al 2003 also. On the other hand, Simic et al 2004 have proposed the threshold value to be larger than 25.4 mm. This selection is highly depends on elevation, and topographic features (slope, aspect) and very critical at the snow cover edges. The edges of the snow covered areas and land surfaces may be mapped as cloud. This seems to be one of the problems causing misclassification in the current version of the algorithm.

As it is mentioned in the paper, the station locations with respects to land cover classes (Fig 2, right) were not fully representative. Hall et al (1998) addressed the same issue stating that correct classification series were defined as 99% for grid cell having vegetation $< 50\%$ and decreased with the increase of vegetation coverage. For the forest areas this reduction in accuracy is expected to be larger.

Evaluation of the station arrangement can also be checked showing the cumulative frequency diagram with respect to station elevations vs accumulated precipitation records. The comparison is needed with the basin hypsometric curve. As it is mentioned in the manuscript that 6% of Austria are not represented by any climate station (above the elevation of 2290 masl)

3) Format

The manuscript must include the flow diagram of the existing algorithm used in the study instead of verbal explanations.

Finally the referee would like to make some additional discussion with his team members as the joint authors in order to provide more discussion to the scientific community on the same issue when someone applies similar methodology to mountainous regions covered with abundant snow but with limited number of ground survey and automated stations using MODIS products.

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