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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Cloudiness and snow cover in Alpine areas from MODIS products" *by* P. Da Ronco and C. De Michele

P. Da Ronco and C. De Michele

pierfr7@msn.com

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We thank the Referee for precious comments. Basing on his suggestions, we are going to improve the quality of the manuscript.

Referee comment: **I agree with the referee #1, that the introduction does not provide a balanced context for the research objectives. Research questions and substantial novel contribution should be very clearly indicated.**
Author response: The state-of-art (previously in the methods section) will be added to the Introduction. Then, research questions and novel contribution will be emphasized. We will focus on aspects related to the combined use of different methods in

order to improve the performance of the procedure for our case study. One of novel contributions is related to the sequence order, that has been designed so that moving from step 1 to step 5, the temporal window of the data interested in the procedure is progressively increased, from one day to the entire year (seasonal filter).

Summarizing the procedure:

- Step 1 combines Aqua and Terra images of the same day;
- Step 2 is a conservative temporal filter (+2/-2 days: cloud pixels are reclassified only in cases when ground conditions can be supposed stationary since they were observed both before and after the assessment day [Gafurov and Bardóssy, 2009]);
- Step 3 uses the regional snow and land lines, extracting information from the same daily map. Step 3 follows step 2 because the latter provides a greater amount of cloudless areas on which we can estimate regional snow/land lines;
- Step 4 consists in a six day backward temporal filter. This ensures a temporal resolution higher than one week for each pixel of the output maps;
- Step 5 is a yearly seasonal macro-cycle, which determines the most likely condition for each pixel given for each day.

As the results indicate, the procedure improved cloud reduction and mapping accuracy when compared to a basic backward temporal filter, with respect to our case study. Temporal filters are widely used for cloud reduction. Thus, a series of steps able to improve the accuracy without any additional data required seemed a good target for our research.

Referee comment: **I would suggest to revise the structure as well, presenting methodology first in a separate section, then case study data description. Please consider to include the accuracy assessment (equations) into methodology**.
Author response: We are providing a new structure for the manuscript: 1) the state-of-art will be added to the Introduction and within the same section we will emphasize the novelty of the combined use. 2) Subsection 2.1 and 2.2 ("MODIS snow-covered area products" and "Data pre-processing") will be aggregated and shifted to a new Section "Methods", which will contain even the cloud removal procedure. The validation methodology will be added to this section as well. This adjustment will lead to a compact Section "Case study", where we will provide only the description of the basin. In the revised version of the manuscript, the "Cloud removal procedure" section will be organized as follows. We report firstly the steps of the procedure, secondly the motivation of the sequence order, and thirdly the detailed description of each step.

Referee comment: **In order to increase the contribution, I would suggest to more clearly demonstrate the efficiency of new steps in comparison with methods already published. This is essential for providing substantial new contribution. For example, showing the improvements of accounting different aspect classes in the snow line step or a typical 2-day filter with respect to step 2. The justification of the sequence of steps is not very clear.**
Author response: Additional analysis will be provided for step 3. We are going to demonstrate that the "signal" of aspect exists even at the regional scale, where other meteo or morphologic variables might rule snow distribution over altitudes. We will show the altitudes of the regional snow lines across the melting season, for days with less the 50% cloud cover in output maps by step 2 (before the application of step 3). North and south classes of aspect will be considered. If the south class presents a regional snow line systematically higher than that of north class, it means that exposure provides a perceptible difference even at the regional scale. Consequently,

the procedure may just take an advantage from our subdivision. The aspect matrix is directly derived from the DEM. Hence, our step 3 does not require additional data and there is no reason for not considering aspect classes once we demonstrate that this help in representing snow distribution over altitudes.
In the validation, the conservative temporal filter in step 2 will be compared against a typical 2-day filter as suggested. We expect less effectiveness (percentage of cloud pixels re-classified) but higher accuracy. Our step 2 was conceived with this aim.

Referee comment: **I agree that the validation methodology could be designed in more balanced and robust way.**
Author response: Both type of validation (ground-based and artificial clouds) have advantages and disadvantages, as we discussed in our reply to referee #1. Acquisition and validation of in-situ data for the Po basin are managed by different local administrations and has not been possible to obtain measurements for an adequate number of locations within the broad domain considered. However, it is clear the procedure could take advantage by the possible no-likelihood of artificially-masked maps to time series of clouds that can occur. For example, masking a clear-sky image which is included within several continuous days of clear weather, basically step 2 (which is also the most accurate) removes the clouds. In order to prevent this situation, our 25 testing days were chosen within time frames of cloudy days alternated with clear-sky days. This allows to involve all the steps of the procedure. Such results can be seen from Table 8 for two days. Tables such as Tab.7 and Tab.8, were produced for each validation day (25 days in total). These will be added as additional material in the revised version of the manuscript, in order to demonstrate that the validation strategy is more robust than it might seem.
Since Referees do not appear convinced by our validation, we plan two actions for the revised version of the manuscript. First, we will increase the number of days for validation. In this case, we will use clear-sky maps extracted from years that have not yet been considered for the validation (2003, 2007, 2008 and 2010). However,

artificial clouds will be introduced to several continuous days of clear weather for simulating atmospheric disturbances that interest several days covering large part of the domain. We will refer to this additional test by the name "artificial multi-temporal mask". Second, we will provide an additional table/plot, showing the contribution of each step for the whole sample of validation and the average contributions. This will help to emphasize that all the steps are tested, as well as they intervene in the application of the procedure to those 10 years of images (Fig. 6).

Bibliography:

Gafurov, Abror, and András Bardossy. "Cloud removal methodology from MODIS snow cover product." Hydrology & Earth System Sciences 13.7 (2009).

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