Hydrol. Earth Syst. Sci. Discuss., 11, C6229–C6234, 2015
www.hydrol-earth-syst-sci-discuss.net/11/C6229/2015/

Hydrology and Earth System Sciences
Discussions

Interactive comment on "A snow cover climatology for the Pyrenees from MODIS snow products" *by* S. Gascoin et al.

S. Gascoin et al.

simon.gascoin@cesbio.cnes.fr

Received and published: 30 January 2015

Response to J. Parajka

First, we would like to thank Juraj Parajka for his careful evaluation of our work and his valuable comments. We will strive to improve the manuscript according to his suggestions. We have written a point-by-point response below.

General comments

The study evaluates the accuracy of daily MODIS snow cover products and estimates mean monthly snow cover duration in Pyrenees region. The MODIS snow cover maps are compared with in situ snow depth measurements at 19 stations and Landsat snow

images in the period 2002-2010. The results show good snow cover mapping accuracy of MODIS and indicate snow cover duration anomalies which are likely responsible for decreasing hydropower production. Overall, the study is interesting and within the scope of HESS. The novel scientific contribution is, however, not clearly presented. What is the main research question here? There are many studies evaluating accuracy of MODIS snow products (as already indicated in the manuscript),but it is not clear what is going to be novel here, how this study contributes to some new scientific knowledge and/or improved understanding of spatial and temporal snow cover variability. Although authors indicate the importance of the role of topography, land cover and climate on snow cover variability (i.e. p. 12536, l.24-25), the results do not show a clear message to this question. In order to more clearly demonstrate the scientific contribution, more in depth analyses are needed in the results section as well as a comprehensive discussion section need to be added to the manuscript (i.e. in a separate section). This will allow to compare the results with other studies and more clearly demonstrate the added value of the findings. The climate setting in the Pyrenees is likely quite different as compared e.g. to the Alps, so this aspect could be highlighted more as well.

We also agree to incorporate more analyses on the spatio-temporal dynamics of the snow cover based on this new snow cover climatology, e.g. we can show an interesting figure on the snow cover duration variability as a function of the slope's aspect that could complement the Fig. 9 (snow cover duration per elevation band). It shows that the snow last longer on north-facing and east-facing slopes. This is consistent with the expected effect of the solar radiation on the snowpack energy balance. North-facing slopes receive less solar energy. West and east facing slopes are exposed to the same insolation but west-facing slopes receive solar radiation in the afternoon at the hottest time of day, which explains why the snow melts faster than on the east-facing slopes. If we further normalize the SCD with respect to the mean monthly SCD (not shown), we see more clearly that the difference between east and west facing slopes increases along the snow season (from November to June). This is again consistent with the previous comment. These results will be included in a new "Discussion" section.

We understand that our paper is a bit atypical because we deal with several aspects related to the MODIS snow products (comparison with station data, comparison with Landsat data, gapfilling, spatio-temporal analysis), which are typically treated separately and more thoroughly. However, few papers actually make use of the snow products to actually draw a conclusion in direct relation with the water resources economy (in our case hydropower). We believe that this approach is also interesting to illustrate the potential of MODIS data to better inform decision-making in snow-dominated watersheds. With this respect, we think that there is also a bit of "novelty" here. Note that this intention to make the link with actual water management issues also motivated our effort to characterize the snow detection threshold. "Can you tell me what is the minimum amount of snow when MODIS detects snow?" is a question that arose from a discussion with a water management engineer. It was impossible to answer him in the case of the Pyrenees based on the scientific literature only because this snow detection threshold is an empirical parameter, which will depend on the mountain range. We will rework the introduction to better emphasize this aspect.

I would suggest to compare not only the overall mapping accuracy, but also seasonal differences, potential spatial and temporal variability in the detection threshold, as well as seasonal variability in the cloud coverage. The comprehensive Landsat dataset can be potentially also used to evaluate the factors controling MODIS sub-grid snow cover variability.

The temporal variability in the MODIS accuracy was already addressed in the case of the Landsat comparison (in Fig. 6 the colors indicate the month of the year), and there was no evidence of seasonal differences. However this was not done in the case of the comparison with in situ data. As suggested, we can include a discussion on the seasonal difference in the detection threshold i.e. by testing the results obtained for the accumulation season vs. melt season. We will provide the thresholds but we will not include a new figure to limit the number of figures as recommended. We can also give the mean monthly cloud coverage. This information will beef up the discussion

on practical issues related to the application of MODIS products under real time conditions. Regarding the accuracy of the MODIS subpixel detection (snow cover fraction, SCF), we think that it is out of the scope of our paper. It is true that full resolution Landsat images could be used to validate the SCF and not only the binary product (SCA), but for this study we have chosen to focus on the SCA because, in our view, this product is sufficient to characterize the snow cover at the scale of the Pyrenees. In addition, a new analysis of SCF would raise some specific methodological issues. In the Pyrenees, where the forest cover is important, as stated by Rayleigh et al. (2014) errors in the MODIS subpixel snow coverage cannot really be assessed with Landsat images, because the Landsat sensor line of sight is obstructed by forest canopy (see also Kane et al., 2008). In addition, another kind of gap-filling algorithm must be implemented to interpolate the SCF. That is why we would like to keep the focus on the SCA in a revised version of the manuscript.

Specific comments

1) I would suggest to consider using consistent terminology with the other MODIS assessment papers. For example, the overall accuracy (index) instead of Kappa, MODIS over-, under- estimation errors. See e.g. a synthesis of MODIS studies in Parajka and Blöschl (2012).

We will modify the terminology accordingly throughout the manuscript

2) Landsat processing. It is not clear why and how are the maps resampled to 240m spatial resolution? Why not to look at MODIS subgrid variability?

The Landsat were resampled to 240 m because the multi-temporal cloud detection algorithm requires much computer time and also performs better at lower resolution. This tradeoff allowed us to process 160 Landsat dates, which is rarely done, and thus to increase the potential range of snow cover properties. As commented above, we agree that the full resolution Landsat images could potentially be used to validate the SCF product, which is provided in addition to the SCA in the daily MODIS products. In

our opinion, the SCA product is already very useful at the scale of the mountain range to determine the snow cover duration for a given pixel, as illustrated in the section devoted to the 2012 drought.

3) SD detection threshold: How it is estimated to 105mm, when the resolution of snow depth reading is 1 cm?

We thank you for this comment, because it was an unfortunate mistake. It should read 150 mm.

4) There are 13 Figures, however, text in the results section is rather short. Please consider to present more in depth analyses to balance the overall structure and story of the paper.

We agree to expand the discussion on the spatio-temporal dynamics of the snow cover as explained above, in line with the suggestions of Referee 2 (see the reply to his review).

5) Figures: When looking on Figures, it is difficult to see some clear story and take home message of the paper. Please consider to show the main results more clearly (e.g. instead of all stations, present in more detail some typical or interesting, those which will support the message of the paper).

We propose to merge the Figures 3 and 4 into one single Figure showing only "Orciceto" station SWE and SD time series.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 11, 12531, 2014.

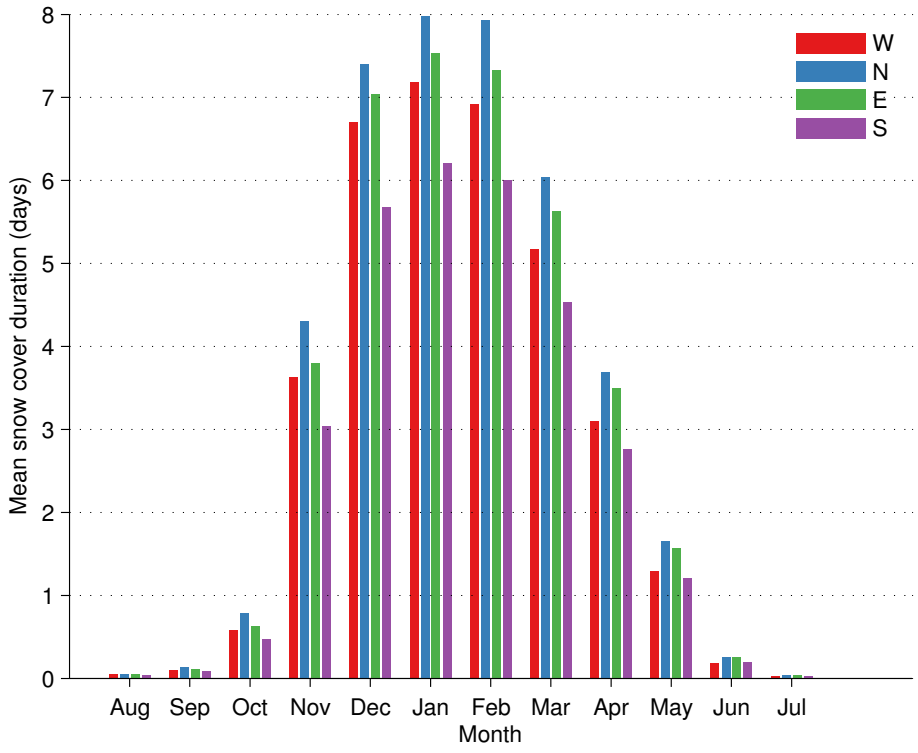

Fig. 1. Mean snow cover duration over 2000-2013 for different aspect classes