Answer to Anonymous Referee #2

Inter-annual variations of snow days over Switzerland from 2000-2010 derived from MODIS satellite data

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General comment to Anonymous Referees

We are grateful to both of the reviewers who have taken the time to read and assess our manuscript. The constructive suggestions will certainly improve the manuscript.

Answer to Anonymous Referee #2

1. Comment. Gap-filling approach was first used in the Hall et al. 2010 (cited already in the paper). Not sure how different they are? Need some clarifications. also I see some confusions about forward and backward. Please make clear, using the previous days, it calls backward; using the later days, it calls forward. I also wondering why you do not use the closest days (when it is cloud free)? After the filling, I believe your so-called daily product (not daily any more) is cloud free, right?

   Our main goal is to derive the total number of days with snow on an annual basis. The method by Hall et al. (2010) was developed for the purpose of data assimilation systems (Hall et al., 2010). Both techniques have a similar approach concerning the gap-filling; taking into account the temporal evolution of the cloud cover. The cloud-gap-filled MODIS daily snow cover product by Hall et al. includes valuable ancillary information such as the age of the observation (so called cloud-persistence count CPC) per grid cell. In our approach we fill the cloud-covered gaps including the latest cloud-free information of a specific grid-cell independent of the length of the time period. This method is applied in two "directions": 1) forward gap-filling by filling the gaps with the same value

provided from the latest cloud-free image cell and 2) backward by starting e.g. filling the cloud-cover grid cell (e.g. 30 September 2004) with the cloud-free information from the cloud-free day "before" (e.g. 1 October 2004). Figure 4 b) and c) in the manuscript highlights both approaches. The latest cloud free information is included (either snow fraction or snow free) and the daily product is "cloud-free". For the final annual product, we calculate the mean of the total number of snow days from the forward and backward gap-filling procedure. Due to the backward gap-filling, our approach is not suitable for near-realtime applications. The manuscript will be modified to clarify our methodology.

2. Comment. Almost all studies used the MOD10A1 or 10A2 products for such studies, since they have better resolution (500m), while the paper uses the 10C1 which has around 5km pixel size. Based on our studies, 500 m is already kind of coarse for such type of studies (validation and producing SCD maps), why the paper uses the 10C1? Need some rational and explanations, in particular, for alpine snow pack, the snow cover variation is large.

We agree that the MOD10A1 is the most frequently used MODIS snow cover product based on the initial MODIS snow cover product (MODIS Terra Snow Cover 5-Min L2 Swath 500 m; MOD10_L2).

Prior to the study presented here, we analysed and evaluated the impact of different spatial resolutions on the number of cloudy pixels, for the period from 1 - 31 January 2009. Based on the MOD10_L2 we generated daily snow cover products at 0.05, 0.03 and 0.01 degree grid resolution. The figure below shows the variability of the snow cover fraction (%) for (a) the operational MOD10C1 product, (b) the MOD10_L2 0.01 degree, (c) the MOD10_L2 0.03 degree and (d) the MOD10_L2 0.05 degree, for one specific inneralpine station (Meiringen). Grey bars indicate cloudy pixels, blue bars the snow cover fraction and small green bars visualize snow free ground. This pilot-study underlines the tendency that with a higher spatial resolution the number of cloudy pixels and therefore the number of gaps increases. A comprehensive sensitivity analysis will further investigate this hypothesis. Due to this tendency we focused on the operational MOD10C1 product to calculate the annual number of snow days although a higher spatial resolution would allow for a more precise pixel vs. point observation. However, the sub-pixel problem remains, which has been addressed

in the discussion chapter of the manuscript. A subsequent study at the variability of snow days on a higher spatial resolution will be based on aggregated MOD10_L2 data.

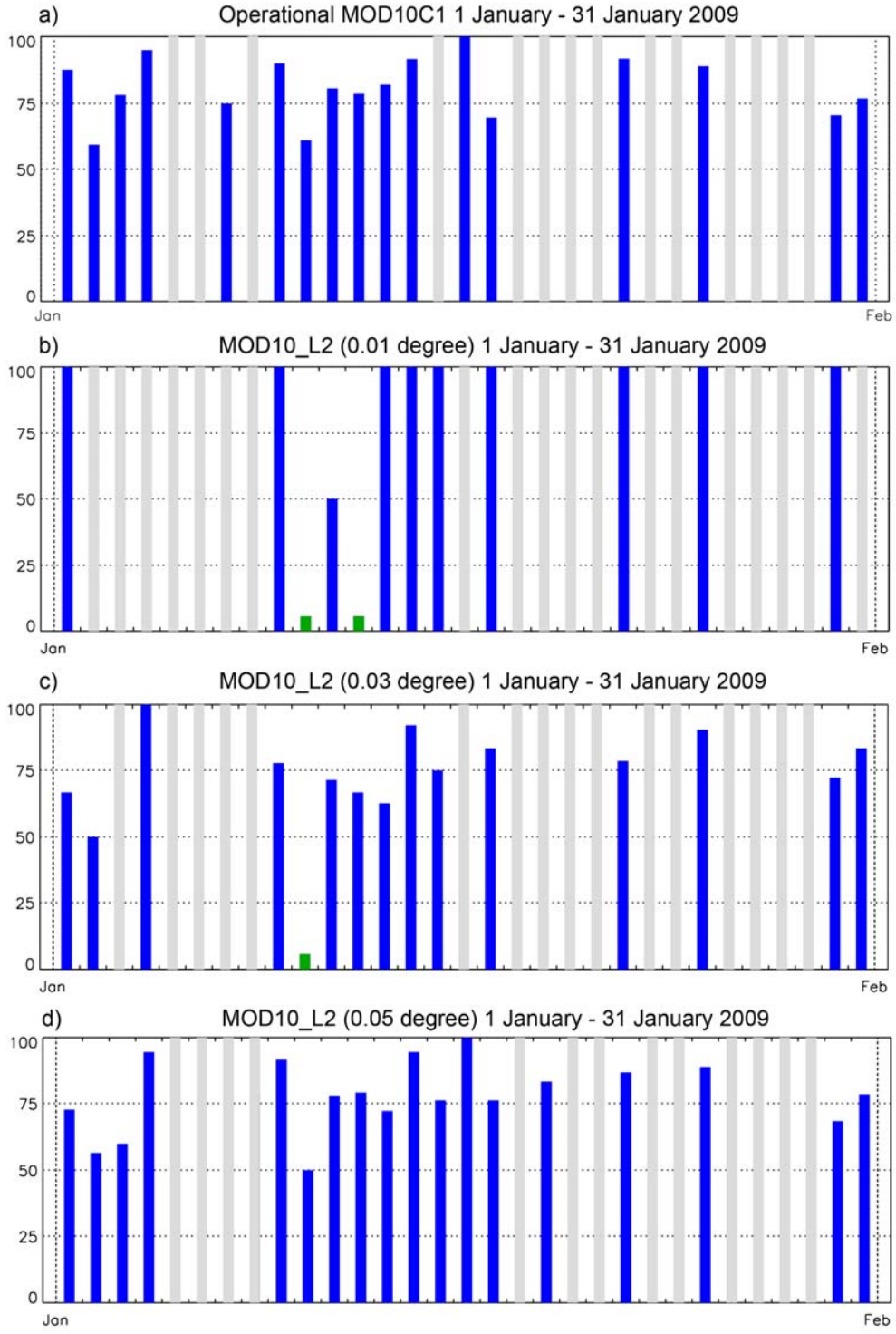

Figure 1: Variability of the snow cover fraction (%) for (a) the operational MOD10C1 product, (b) the MOD10_L2 0.01 degree, (c) the MOD10_L2 0.03 degree and (d) the MOD10_L2 0.05 degree for the station site Meiringen. Grey bars indicate cloudy pixels, blue bars the snow cover fraction and small green bars visualize snow free ground.

3. Comment 3. Since you treat the in situ SCD as ground truth, when you do a difference, you should use MODIS_SCD – In Situ_SCD, not the reverse. So I strongly recommend you to change all of them (tables and figures and text). So when you talk about MODIS overestimates, the difference is positive, not the negative, as you presented in the paper.

   This will be adjusted in the figures and tables as well as in text.

4. Comment 4. Suggest to read this paper below and make comparsion of their results with your results (for the validation of SCD maps), also it is strongly recommended to calculate the snow cover index as proposed in the paper below, so you can provide more information about the snow condition for each hydrological year.

   Wang, X. and H. Xie, 2009. New methods for studying the spatiotemporal variation of snow cover based on combination products of MOIDS Terra and Aqua. Journal of Hydrology, Vol 371:192-200. doi:10.1016/j.jhydrol.2009.03.028

   We agree that papers by Wang and Xie (2009) and Gao et al. (2011) provide interesting insight into the definition of new snow parameters describing the snow cover conditions such as the inter-seasonal or annual variation of the Snow Cover Duration (SCD). A reference to these papers will be included in the manuscript. It is absolutely worth to follow the approach of Wang and Xie (2009) and to adapt the Snow Cover Index (SCI) as well as the Snow Cover Onset (SCOD) and Melting Dates (SCMD) to our data set. However, we believe that the calculations of these parameters in detail, will be outside of the scope of our paper. With the calculation and inclusion of several new statistical indicators (see comments Referee #1), we think, our method and its performance compared to ground-based observations is discussed extensively. In a next step of snow duration analysis in the Swiss Alps, the various proposed indicators (SCD, SCI, SCOD and SCMD) will be calculated from 2000 to 2010 based on the MOD10C1 product or on newly aggregated MOD10_L2 data sets and compared with further in situ snow measurements.

5. Comment 5. I am kind of confusing of your validation of SCD compared with other papers that did validation of snow cover accuracy. You conclude your results are in agreement with other studies. Please clarify this. To me, there are very few papers

validate the SCD, besides the Wang and Xie, 2009 above, you might want to read this paper as well:

Gao, Y., H. Xie, and T. Yao, 2011. Developing snow cover parameters maps from MODIS, AMSR-E and blended snow products. Photogrammetric Engineering and Remote Sensing. Vol 77(4):351-361

It is correct, that the papers mentioned in our manuscript focus on accuracy assessments of snow cover mapping based on MODIS data and not on snow cover days explicitly. Due to the fact, that we use a re-classified MODIS product, we intended to discuss our results with other published results to point out certain tendencies in the performance (e.g. seasonal variations) without presenting any quantitative comparison. We will carefully go through the discussion and moderate any quantitative statements from the inter-comparison with other published results.