The Cryosphere Discuss., 8, C1974–C1979, 2014
www.the-cryosphere-discuss.net/8/C1974/2014/

The Cryosphere
Discussions
Open Access

Interactive comment on "Elevation dependency of mountain snow depth" *by* T. Grünewald et al.

T. Grünewald et al.

gruenewald@slf.ch

Received and published: 7 October 2014

We want to thank the anonymous reviewer for his/her constructive comments. We are confident that his/her input helps to considerably improve the manuscript. We are providing our answers to the important comments - for clarity we always repeat the comment first (marked with R). The answers are marked with A

R: The introduction suggests orographic precipitation processes may account for the ob- served dependences between elevation and seasonal snow depth. However, the au- thors do not discuss this in light of their observations or reconcile their comparisons of precipitation, a flux (L/t), with cumulative seasonal snow depth, a single component of SWE. I agree the comparison is a valid proxy, as suggested in the introduction, but this needs to be developed further, along with addressing orographic response, in the discussion. While the role of local gravity and wind driven snow redistribution is a plausible expla- nation for decreasing snow depths at higher elevations there may be other reasons rooted in atmospheric physics that should be considered see (Roe and Baker 2005). The exhaustion of precipitable water in ascending air masses and the reduced lift from leveling or descending terrain may reflect upon these results as well.

A: We fully agree and will include some discussion on atmospheric processes that might affect orographic effects of precipitation and how it might be reflected in our data sets. In fact, we think of the current study as one puzzle piece in distinguishing processes that lead to observed snow distribution and exhaustion of water in the atmosphere is something we consider to be relevant (as discussed in our recent publication Mott et al. (2014)) but since the data used in this study does not allow to specifically assess this process, we need to formulate it as an hypothesis.

R: Please provide an overview of the processing of photogrammetry and ALS and how differences in their uncertainties may affect your analysis.

A: We are going to provide more information on the processing (see reply to J. Parajka). The uncertainties of ADP and ALS (airplane) can be considered to be similar, both methods are known to be less reliable in very steep (>50°) terrain. However, such areas are very small in our data sets and – for ADP – many of them have been masked out and set to Nodata. The uncertainties of the ALS data obtained from Helicopter (WAN, LAG; ARO) with a sensor that was tilted perpendicular to the surface are much smaller. The gradients calculated from these data sets did not show significant qualitative differences to those obtained from the other data sets (ADP, ALS – plane). We can therefore assume that also the latter data sets are plausible for our interpretations. These uncertainties are already discussed in section 6 of the paper.

R: How might “rocky areas” with high surface roughness impact the DEM creation and the bare earth minus snow surface calculation?

A: It is correct that extreme surface roughness at the very small scale (below the footprint/ spatial resolution of the raw data), for example small boulders or debris, induces some uncertainty, especially for the summer DSMs. The size of the footprint of the laser and the aggregation to DEMs of 1m cell size smoothes some of rough bare earth surfaces and induces some random uncertainty to the DEM which is then transformed to the snow depth map on the small scale. However, as we aggregate to larger areas the impact on the mean snow amounts should be rather small and can be neglected for the purpose of this study.

R: While intuitive the definition and classification method for “level of rocks” is not sufficiently outlined for a reader to recreate the results.

A: The basis of the detection of this level is the rock signature as indicated in the topographic maps (1:25000 or 1:50000) in combination with high resolution hillshaed-images of the respective areas. As mentioned in the text, this method is a currently fully-subjective, visually-based approach. We would like to keep it in the analysis as it provides useful qualitative information and can serve as a starting point for comparison and further analysis as more datasets become available in future. In some cases a clear elevation level of rocks cannot be obtained (e.g. rocks in different elevation zones, only a section of a elevation zone might have rocks...), especially if the area of interest is large (e.g. sub-catchment) We try to clarify the definition in the text.

R: Please report the point return density for the ALS data sets?

A: The mean point density of the raw data is about 1m for HEF and NUR and about 5m for LAG, WAN and ARO. This information has been added.

R: Specific Comments: 3667; 26-, Please distinguish wind saltation and re-suspension from orographic effect.

A: This sentence refers to precipitation (snow fall) and not to snow transport on the ground. The redistribution of snow on the ground is discussed later in the text. We are suggesting wind erosion and transport (including both, saltation and suspension) as a potential process that reduced snow depth in these high elevations. We do not specifi-

TCD
8, C1974–C1979, 2014

cally distinguish between saltation and suspension in that context as these processes loose their characteristic distinction in very steep terrain.

R: 3668; I suspect sublimation would be more prevalent at high elevations where temper- atures are lower and turbulent flux is higher.

A: With sublimation, in that context, we refer to sublimation of snow on the ground and for this process the temperature signal is dominant. Therefore, higher sublimation rates are to be expected in lower (warmer) areas. For drifting snow, we agree that higher sublimation rates can be expected in higher elevations due to higher wind and dryer air. However, it has been shown that the mass loss of drifting snow sublimation is rather local and relatively small (e.g. Groot Zwaaftink et al. 2011).

R: 3669; 6, It's not clear why other studies have not been "systematic" but this one has. There are many earlier studies considering elevation and snow distribution over large areas, from climatic, seasonal and synoptic perspectives, as the authors have noted. The uniqueness of this study seems to be the fine-scale snowdepth measurements over large regional elevation gradients, which distinguishes it, and Grünewald and Lehning (2011), from the previously mentioned works. However, there are other ex- amples of this also (e g. Deems, Fasnacht, Elder, 2006; Trujillo, Ramirez, Elder, 2007; Kirchner et al., 2014).

A: With "systematic" we mean that it was the main purpose to analyse the elevation gradient of snow depth. It is correct that earlier studies identified the principal existence of elevation gradients but they did not (with the exception of Kirchner et al. 2014) provide an in depth analysis and discussion of this specific finding. We are going to reformulate this statement and include a detailed discussion on the finding of Kirchner et al 2014.

R: 3671 Please state if these data sets are published and or publically available if so include citation and electronic source

TCD
8, C1974–C1979, 2014

A: All data sets are published. References to the original works are provided in the manuscript. WAN and LAG are going to be open-source in the near future (in the meantime they can be requested from the authors), for DIS and STRE Yves Bühler can be contacted (buehler@slf.ch). The other data sets are not freely available and need to be requested with the data owners.

R: 3673;24 What is the classification method used? Please provide sufficient information or a citation that would allow a reader to recreate your results.

A: see answer above

R: 3678;20 figure does not match description, a and b seem to be mislabeled in caption

A: That's correct. The figure caption is wrong and will be changed.

R: 3681:23-25 I do not understand this sentence.

A: The sentence means that the cumulative snow amount of single snow falls (without redistribution of snow on the ground) is expected to show an elevation gradient. We will reformulate the sentence.

R: 3690 figure is unnecessary the specific viewing angles could be stated in the text.

A: We'll remove the figure.

R: 3691 Please provide a figure(s) that show the location of all the study sites, left should be replaced with "right" in caption

A: We are going to include a figure which shows the location of the study sites.

R: 3694 figure b is missing gridlines.

A: We will adjust that...

R: 3695 consider using different symbol and color schemes but the same elevation scale to aid the reader with interpretation of these figures.

TCD
8, C1974–C1979, 2014

A: Colours and symbols will be adjusted.

Literature: Groot Zwaaftink, C. D., H. Löwe, R. Mott, M. Bavay, and M. Lehning (2011), Drifting snow sublimation: A highresolution 3âĂŘD model with temperature and moisture feedbacks, J. Geophys. Res., 116, D16107, doi:10.1029/2011JD015754.

Mott, R., Scipion, D., Schneebeli, M., Dawes, N., Berne, A., and 955 Lehning, M.: Orographic effects on snow deposition patterns in mountainous terrain, Journal of Geophysical Research: Atmospheres, 119, 1419–1439, doi:10.1002/2013jd019880, 2014.

Interactive comment on The Cryosphere Discuss., 8, 3665, 2014.