The Cryosphere Discuss., 8, C1941–C1946, 2014
www.the-cryosphere-discuss.net/8/C1941/2014/


The Cryosphere Discussions
Open Access



# *Interactive comment on* "Seasonal changes in surface albedo of Himalayan glaciers from MODIS data and links with the annual mass balance" *by* F. Brun et al.

**T. Painter (Referee)**

thomas.painter@jpl.nasa.gov

Received and published: 4 October 2014

This paper presents remote sensing retrievals coupled with in situ measurements and modeling for Himalayan glaciers toward accessing a remotely sensed proxy for glacier mass balance. The motivation for such an effort is strong given that we have very scarce quantitative knowledge of glacier mass balance and the controls on glacier mass balance in the Himalaya.

For the most part, the paper is well written and well reasoned. In general, caveats are provided in appropriate places with regards to in situ and remotely sensed observations. The goals are stated clearly in the introduction and followed well.



Full Screen / Esc
Printer-friendly Version
Interactive Discussion
Discussion Paper

However, there some confusing points that are rather critical that should be addressed before publication and one in particular related to the selection of pixels on Mera Glacier for calculating the “mean albedo of the glacier”.

I wish that there was a button between Minor Revisions and Major Revisions – in general I think the paper contributes well and is generally sound, but the issues discussed below I think need to be addressed and I would like to iterate on making sure they are clarified.

Introduction and 3.3 Glacier Masks The paper speaks frequently to the importance of the average albedo of a whole glacier surface. “The ELA, and thus the annual minimum albedo averaged on the whole glacier (AMAAG), is strongly correlated with the annual glacier mass balance . . ..”

In Figure 2, it is indicated that reasonably nearly all of the glacier is sampled for the AMAAG for the Chhota Shigri Glacier. However, in Figure 3 for Mera Glacier, a minority of the glacier is sampled. This is problematic for two main reasons – (1) it is inconsistent with the defined parameter AMAAG and (2) the selected pixels do not span the known ELA for all years. (1) is obvious in that only pixels that reach up to $\sim$5550 m elevation are sampled whereas the glacier runs up to 6420 m – this breaks the defined metric. It is of course impossible with the coarse pixels of MODIS to sample the whole glacier, but in this case, an enormous percent of the whole glacier is lost from the analysis. In the case of ELA (2), a paper in this journal last year shows that the ELA for Mera Glacier ranges from 5340 m (2010-2011) to > 6000 m. By the background presented in the present paper, it is indicated that the ELA is $\sim$5550m. So, this indicates that you are only sampling the ablation zone.

By contrast, there are 89 pixels used for Chhota Shigri Glacier, that appear to cover the whole glacier, consistent with the definition of the AMAAG.

I understand the issues related to cloud cover that are expressed in 3.3 Glacier Masks. However, the statement about monsoonal snow cover and trimming out those pixels seems to exclude the reality of that being a period of accumulation and its impact on albedo – which are in fact influential. In the end, the analysis appears to be inconsistent between Chhota Shigri and Mera glaciers – one is AMAAG and the other is "average albedo for a proper subset of the glacier that is mostly lower than the known ELA range".

While I am not enthused with the idea of suggesting a complete reanalysis with more pixels, it does seem that consistency with the AMAAG definition would be appropriate and would also lend confidence in the broader application of the AMAAG to other glaciers of the Himalaya. Please speak to this in reply so that we might understand how the inconsistency is OK.

3.1 Field data The paper indicates that at Mera Peak, the inferred clear sky, broadband atmospheric transmissivity is 0.99. This is excessive given scale height of about 8.5 km and your measurements are at 5.4 km. Most likely there is a strong contribution of irradiance from snow-covered terrain scattered radiation and/or a tilted up-looking pyranometer. This is not crucial to the outcome of this paper – it is simply the metric used to select when albedos are reasonable to use. However, it is erroneous and should be at least commented on and the reasonable plane parallel value given for Mera elevation and atmosphere.

With the SBDART model, I arrived at an atmospheric transmissivity of 0.89 in the liberal case defined below: âĂć wavelength range: 0.28 to 2.8 micrometers âĂć sub-Arctic winter atmos: column water vapor 0.418 g/cm2 âĂć substrate albedo: 0.85 âĂć solar zenith angle: 5 deg (summer solstice) âĂć elevation: 6 km

Even when I open it up to the elevation of the summit of Everest, I get just shy of 0.91. Of course SBDART is not perfect, but I doubt that it has that magnitude an error given .

4.1.1 Comparison with field measurements This section is puzzling in light of Figure 5. The paper states that RMSE for MODImLab and MOD10 for albedo were 0.067 and 0.071, respectively. Looking at the data in Figure 5, unless there is an enormous



TCD
8, C1941–C1946, 2014

number of data points atop one another very near the 1:1 line, it appears impossible for the RMSEs to be as low as stated. Can you please clarify this as it seems unlikely – but without the data, we cannot say for sure.

Likewise, the average albedo errors are reported as 0.03 and 0.18. Given the large overestimates at lower AWS albedos and large underestimates at higher AWS albedos, these numbers are not that informative. Instead, please report the mean absolute errors.

In Figure 5, why, if the MODImLab acquisitions are a subset of the MOD10A1, are there not AWS albedos below 0.6 in the MOD10A1 comparison? Perhaps I did not understand the separation of MODImLab and MOD10A1 acquisitions.

4.2 Multi-annual trend of albedo signal: In Figure 7, the albedos for the highest pixel are plotted. Albedos in excess of 0.9 appear and likewise, albedos lower than 0.2 appear. These are not physically realistic in the former case and less likely in the latter case (lower) given that these are the highest pixels respectively (although with the domain on Mera being in the ablation zone, it is possible to be that low). I wonder if the data show this because you include MODIS albedos for acquisitions when the sensor zenith angles are large. This forces erroneous irradiance calculations in the MODIS processing and also the pixels are severely mixed. Please analyze the sensitivity to sensor zenith angle, a product that is available. Note the discussion in Dozier et al (2008) regarding sensor zenith angle and the impact on ground instantaneous field of view.

Please indicate the significance of the linear trends presented (+0.0013 and -0.0025 yr-1, respectively). Provide 95% confidence intervals.

4.3 Seasonal variations of albedo You linearly interpolated between the dates w information. Not much of a way to get around it without fabricating data of course, but please speak to why and how this is likely erroneous, and give a feeling for how much impact there is (e.g. albedo may be elevated but irradiances are lower). Also, please



TCD
8, C1941–C1946, 2014

indicate from the in situ measurements what the cloud cover probabilities are for diurnal and then seasonal and how the diurnal probabilities relative to the instantaneous MODIS acquisitions are influencing your results.

Figure 1 What is the source of the map of glacierized areas? RGI? MODICE? Please include in caption.

Figure 2 Several pixels in the 5 October 2004 albedo retrieval are between 0.95 and 1.0 – this is physically unrealistic. Please determine the source of error and correct.

Figure 4 Again, there appears to be a problem with the atmospheric transmissivity calculation – in particular it appears that the measured irradiances are too high.

Figure 5 Again, please look at these scatterplots in light of the reported RMSE of 0.06 and 0.07 – looks to be markedly erroneous but perhaps there are a lot of points on top of each other near the 1:1 line.

Figure 7 I was surprised to see so many more acquisitions for Mera than for Chhota Shigri given the statements about cloud climatology for Mera and why you selected a smaller area for the average albedo for Mera. It also seems inconsistent with the temporal densities expressed in Figure 8.

Figure 9 Please plot confidence intervals around the Chhota Shigri and Mera fits and give the uncertainty in the slope. Speak to the fact that there can be large variation in the minimum mean albedo during ablation season when annual mass balance is near 0 to slightly positive. Please note in the caption the differences in the y-axes between Chhota Shigri and Mera.

Figure 10 It is surprising that there is such a small uncertainty in 2003 and 2004 at Mera given the paucity of observations and the large uncertainties in the regression for Mera shown in Figure 9.

References: Dozier, J., T. H. Painter, K. Rittger, and J. Frew (2008), Time-space continuity of daily maps of fractional snow cover and albedo from MODIS, Advances in



TCD
8, C1941–C1946, 2014

Water Resources„ doi: 10.1016/j.advwatres.2008.08.011.

Tom Painter Jet Propulsion Laboratory California Institute of Technology

---

Interactive comment on The Cryosphere Discuss., 8, 3437, 2014.