



## Review of "Shift in seasonal snowpack melt-out date due to light absorbing particles at a high-altitude site in Central Himalaya"

Edward Bair (Referee)

---

Referee comment on "Shift in seasonal snowpack melt-out date due to light-absorbing particles at a high-altitude site in Central Himalaya" by Johan Ström et al., Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2021-158-RC2>, 2021

---

In "Shift in seasonal snowpack melt-out date due to light absorbing particles at a high-altitude site in Central Himalaya", empirical relationships are developed to estimate the impact of light absorbing particles (LAPs) on snowmelt over two seasons at a high-altitude glacierized site in the Central Himalaya.

The motivation for the study is convincing as this part of the world suffers from heavily polluted snow and this pollution affects the melt timing and hence downstream water supply. Likewise, the role of snow albedo on global climate and the hydrological cycle is mentioned.

After carefully reviewing this study, I find overwhelming flaws with the methodology that make the results and conclusions unconvincing. At best, the methods used are outdated and inaccurate. At worst, they are unreliable and not supported by previous research.

Simple statistical relationships, sometimes univariate, are employed that do not account for the relevant processes. For example, the air temperature is used as a key predictive measure for both snow albedo and snow melt even though snowmelt in most midlatitude mountains is driven by net radiation (Marks and Dozier 1992) and albedo is related to a number of snow microstructural parameters that do not depend on air temperature (Flanner and Zender 2006).

The methods for modeling snow albedo and degradation from LAP are also lacking. Snow albedo is difficult to measure and subject to a number of pitfalls that are not addressed. For example, any timeseries of snow albedo will show a decreasing albedo throughout the melt season due to a solar zenith effect alone, as albedo decreases with decreasing solar zenith angle due to the forward-scattering nature of snow. However, illumination conditions are not part of the employed relationship between snow albedo and specific surface area in Equation 2. No adjustment is made for the snow surface topography, which is unlikely to be flat and level at this site. Measured snow albedos above 0.90 and below 0.40 show experimental error and are physically impossible.

The assumption of a constant concentration of LAP ( $100 \text{ ng g}^{-1}$ ) on the snow surface is a poor choice. As stated by the authors, LAPs build on the snow surface and are present in

higher quantities during melt when the surface is not being refreshed with new snow. Likewise, the assumption that half of the light absorption comes from dust during is also flawed. Svensson et al. (2021) refer to this exposed layer as the "enriched LAP layer" and report much higher LAP concentrations, with mineral dust having up to 80% of the fraction of light absorption. Since this layer is exposed during spring and summer when insolation is highest, it will have a greater effect on snow melt than other layers.

For ablation estimates, decreasing snow depth is assumed to be ablation while settlement of the snowpack due to normal densification is ignored. These decreases in depth are used to erroneously estimate snow melt.

Last, the data availability section is not compliant with ACP policy.

Because of the shortcomings in the methods employed, I do not find the results convincing, e.g. that the melt out date at this site was decreased by 13 days due to the presence of LAP. The flaws in methodology are extensive enough that I recommend rejection, as I do not believe they can be overcome with revisions. I am sorry that I cannot be more encouraging and suggest the authors employ updated and more sophisticated modeling approaches that account for temporal variability in LAP concentration on the snow surface while addressing all of the pitfalls with in situ measurements of snow albedo.

NB 5/18/21

Works cited

Flanner, M.G., & Zender, C.S. (2006). Linking snowpack microphysics and albedo evolution. *Journal of Geophysical Research*, 111, D12208

Marks, D., & Dozier, J. (1992). Climate and energy exchange at the snow surface in the alpine region of the Sierra Nevada, 2, Snow cover energy balance. *Water Resources Research*, 28, 3043-3054

Svensson, J., Ström, J., Honkanen, H., Asmi, E., Dkhar, N.B., Tayal, S., Sharma, V.P., Hooda, R., Leppäranta, M., Jacobi, H.W., Lihavainen, H., & Hyvärinen, A. (2021). Deposition of light-absorbing particles in glacier snow of the Sunderdhunga Valley, the southern forefront of the central Himalayas. *Atmos. Chem. Phys.*, 21, 2931-2943

Please also note the supplement to this comment:

<https://acp.copernicus.org/preprints/acp-2021-158/acp-2021-158-RC2-supplement.pdf>