Dear Reviewer #1:

Thank you for reviewing our manuscript. I appreciate your time and critiques.

Your comments are in blue, our responses are in black, and text to be included in our revision is in red.

This article has an attractive title which unfortunately does not reflect its content. The authors present a comparison of the results obtained by backward reconstruction of the SWE from three different remote sensing products. The rationale for this study is actually more specifically given at the end of the introduction and is "considerable advances have been made in SWE reconstruction techniques as well as snow cover and albedo mapping, hence the justification for revisiting the effects of spatial and temporal resolution". But the advances in question are not specified. And the question of the albedo is not really studied in the rest of the paper.

Thank you for pointing this out. Our intention was to show that the advances in snow cover & albedo mapping as well as snow water equivalent reconstruction have been well-published, with many of the publications by the authors of this manuscript. We've inserted references into the quoted sentence.

Since those studies, considerable advances have been made in SWE reconstruction techniques (Bair et al., 2016; Rittger et al., 2016) as well as snow cover (Stillinger et al., 2023) and albedo mapping (Bair et al., 2019), hence the justification for revisiting the effects of spatial and temporal resolution.

Significant work has been done to perform these simulations, but the analysis of the results remains superficial and does not explore the mechanisms that explain the effects of the resolution on the modeling of snow cover.

We agree that the mechanisms explaining the effects of resolution are not fully explored. More on this below.

However, the conclusion that seems to emerge is that the resolution has no impact on the estimate of the resource, which is counterintuitive when compared to studies that immediately come to mind because I contributed to them (Baba et al. 2020, Bouamri et al. 2021) or earlier by Schlögl et al. (2016).

The characterization "that resolution has no impact on the estimate of the resource" is not accurate. The findings are that the basin-wide error, measured by bias, decreases with increasing resolution, while the per-pixel accuracy, measured by MAE, increases.

Likewise, previous studies show mixed results when increasing spatial resolution of the snow models. These studies are detailed in the literature review in the Introduction. We've added a reference to Schlögl et al. (2016) in the chronological literature review.

Contrary to Cline et al. (1998), Schlögl et al. (2016) report that SWE increases with DEM resolution in two alpine basins.

Baba et al. (2019) was also recommended by the Associate Editor, so we've included that as well.

Similarly, Baba et al. (2019) used an energy balance model with a DEM at 8-1000 m and report good agreement with fine resolution snow cover maps up to 250 m, but a loss in agreement at coarser resolution, likely due to excessive smoothing of topographic effects.

Bouamri et al. (2021) is also now in the Introduction.

Bouamri et al. (2021) examined differences between snowmelt models with and without solar radiation represented. Although the models with solar radiation better simulated the snowcover used for validation, aggregating the simulated snow cover from 100 to 500 m suppressed those improvements.

The fact that the source products also have different revisit times (and different processing algorithms) complicates the analysis of the effect of spatial resolution.

This is a good point. However, temporal vs spatial resolution is a fundamental tradeoff in remote sensing. As we point out in the Introduction, there is no single sensor that offers high spatial and temporal resolution. Further, Stillinger et al. (2023) show minor differences in snow mapping performance between the SCAG and SPIReS.

In fact, the discussion concerns the artefacts linked to the delimitation of the watershed, which does not seem to me to be a central issue.

We disagree. Comparing the same area across datasets is essential in spatial scale studies. We note that delineation artifacts were also reported by Cline et al. (1998) who normalized by the high resolution basin area, which was smaller than coarser spatial resolution model runs. However in the study, the opposite occurs, the basin decreases in size with resolution, illustrating differences in basin outlines and aggregation techniques. Starting with the third sentence of Section 3, we explain in detail how we arrived at the conclusion that these artifacts cannot be eliminated.

I think it is necessary to help the reader to interpret the results, perhaps through an analysis of the energy balance or semi-variograms of topographic variables.

Thank you for this suggestion. An energy balance analysis is problematic, as there is no validation source. We know qualitatively that variables like direct solar radiation should resemble the topography, but without a reliable spatially-distributed validation source, one cannot say whether, for example, the basin-wide mean direct solar radiation is more accurate for the fine or coarse spatial resolution product.

A variogram analysis provides an estimate of the scale break, thus as in Baba et al. (2019), we've added a semi-variogram analysis. Similarly, we find that the slope of the variogram flattens around 500 m, suggesting that the slope angle variation is not sufficiently captured by MODIS in the Tuolumne River Basin above Hetch Hetchy.

Another explanation for the poorer MAE performance from SPIReS-MODIS is that some spatial variation in topography is lost with the coarser resolution. To test this hypothesis, a semi-variogram of the terrain slope is examined, as in Baba et al. (2019). The semi-variogram shows a flattening around 500 m, indicating that variation in topography, which can manifest in topographically driven variables such as direct solar illumination, is poorly captured at MODIS and coarser spatial scales. This semi-variogram analysis confirms the above hypothesis.

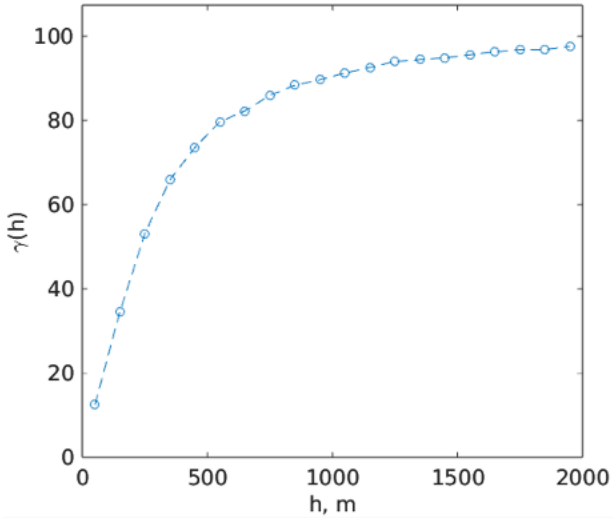

Figure 1:
Semi-variance of terrain slope of the Tuolumne River Basin above Hetch Hetchy. The slope of the semivariance (not the terrain slope itself) shows a flattening around 500 m, or about the MODIS pixel size.

Another thing puzzled me when reading the manuscript. The authors introduce a method for reconstructing the SWE before the accumulation peak which is a rescaling of the GLDAS SWE. This SWE is therefore produced from different forcings, which further complicates the interpretation of the results.

We agree this is confusing. A major limitation of SWE reconstruction is that it provides no information prior to peak SWE and further, without ancillary data such as snow pillow measurements (Rittger et al., 2016), the peak date is unknown. Scaling the GLDAS SWE prior to the peak is a method to overcome this limitation. As Figure 7 shows, 7/8 ASO flights over the Tuolumne occurred at or post peak SWE, thus the rescaling method, which we admit has not been validated during the accumulation season, has little impact on the results of this study. In any case, the same reconstruction methodology was applied to each of the three snow cover forcings, so any limitations or advantages related to modeling dates prior to peak SWE are consistent across the study.

Equation (1) is incomprehensible to me*.

Agree, thank you for highlighting this mistake. Equation 1 has been changed to

Pixels with the same snow cover duration are identified as

$$\mathrm{SWE}^{*}{}_{GLDAS} = \left(\mathrm{SWE}_{GLDAS,\Delta t_1} > 0, \mathrm{fsca}_{\Delta t_1} > 0\right) \,\&\, \left(\mathrm{SWE}_{GLDAS,\Delta t_2} = 0, \mathrm{fsca}_{\Delta t_2} = 0\right) \quad (1)$$

where the asterisk denotes the selected pixels and fsca is from the fine-scaled product e.g., Section 2.1 - 2.2. The Δt_1 and Δt_2 indicate different time periods.

The final conclusion of the article "increased spatial and temporal resolution (...) are the future of Earth observations." could have been written before carrying out this study and concerns many other fields of application than snow. However, it does not seem to me that the results and the very design of the study support this conclusion.

Changed to the text below. Also made a similar change to the end of the Abstract.

In summary, conclusions are: 1) Spectrally unmixed snow cover and snow albedo from MODIS continues to provide accurate forcings for snow models and 2) increased spatial and temporal resolution through sensor design, fusion techniques, and satellite constellations are the future of Earth observations, but existing moderate resolution sensors still offer value.

In terms of presentation, the authors introduce additional analyzes in the results section which have not been presented in the method section as recommended for scientific articles.

Without an example, it's difficult to address this point. Perhaps the Reviewer is referring to the snow pillow data in Figure 7? Note the section is titled "Results and discussion." Presenting ancillary data, such as snow pillow data, or additional analysis is common in discussion sections. For example, in Baba et al. (2019), the semivariogram analysis is presented without any previous mention in the methods section for how the analysis was conducted.

In the end, all this leads me to think that this manuscript was prepared a little too quickly, which is regrettable given the work and calculation behind the production of these datasets. I'm sorry to give such a negative review, maybe another reviewer will disagree with me.

* The ⋀ operator is an "n-ary logical and" so the result should not be a SWE value but a boolean (vector) variable. Besides I don't understand if the pixels are selected by considering the time series of SWE and fsca (the time index does not appear).

See the revised Equation above

NB) I was unable to get the data from the ftp server indicated at the end of the manuscript. The connection is possible but not the download (I tried from two different networks)

Thank you for testing. The FTP server was having issues that have been fixed.

L66: found

Present tense (find) is used correctly here as it is used widely in scientific writing when describing results. "Winstral et al...find..." NOT "Winstral et al...found."

L89: the bowtie effect of MODIS acquisitions was known before this reference

Added Wolfe et al. (1998)

The baseline case uses MODIS at 463 m daily resolution, although the effective pixel size can be up to 5× as large for off nadir acquisitions (Wolfe et al., 1998; Dozier et al., 2008)

L98: parenthesis

Fixed

L98: any reason why HLS v2 was not available? What is the difference with v1 and would it change the results?

Yes, as explained on that line the data are incomplete in the NASA Earthdata Search archive for HLS v 2.0

L105: any clue why the revisit is not 2-3 days?

2-3 days is an unrealistic specification globally. The User's Guide confirms that the theoretical mean revisit of 3.8 days is close to what we found, 3.5 days.

L114: why eliminate certain images after visual inspection? this seems incompatible with a global application ("global snow").

As stated, the issue is that many of the scenes were 100% cloud covered or missing most of the watershed. This imaging pruning could be automated.

L124: This should be explained ("a second cloud filtering step using Superpixels and Gabor filtering was used")

Reference added

Because the initial filtering did not remove all clouds, a second cloud filtering step with Superpixels and Gabor filtering was used (Stillinger, 2019)

L131: "SPIReS, SCAG, and all other accessible snow mapping algorithms" I have checked this article and this assertion is incorrect.

changed to

For more details and a recent comparison between SPIReS, SCAG, and other snow mapping algorithms see Stillinger et al. (2022)

L173: why not use all ASO acquisitions? There are many more on this basin since 2017.

We were limited by the SCAG-fusion output, which did not extend past 2020.

L184: can you specify or indicate the tool? "using a mean-preserving technique with a weighted resampling covering the image". Imagine that a reader would like to use the same approach (I would).

Added a citation.

The ASO images were resampled from a cell size of 50 m to 2000 m (4× the MODIS resolution) and 120 m (4× the Landsat resolution), using a mean-preserving technique with a weighted resampling covering the image (mapresize, MathWorks, 2022).

L185: the geolocation accuracy of S2 is about 1 pixel of 10m, not 1-2 pixels of 30m. See the data quality reports by ESA. Note that recent GRI reprocessing should result to subpixel accuracy (<10m). Also, Storey et al. (2016) report that Landsat OLI has a geolocation accuracy of 18 meters (CE90), not 1-2 pixels of 30m.

Storey et al. (2016) write "...however, the Landsat-8 framework, based upon the Global Land Survey images, contains residual geolocation errors leading to an expected sensor-to-sensor misregistration of 38 m (2σ)." To our knowledge, this sensor-to-sensor error has yet to be fixed, as acknowledged in Claverie et al. (2018), the article describing the HLS dataset.

Thus, it is not unreasonable to assume a geolocational uncertainty of 1-2 pixels when comparing products from the two sensors.

Changed to

The upscaled cell sizes account for geolocational and sensor-to-sensor uncertainty of 1-2 pixels for MODIS and Landsat/Sentinel-2 (Tan et al., 2006; Storey et al., 2016).

L204: I may have missed somethin but why not make this comparison for other products? as it stands, this part on the albedo does not add much to the study.

The comparison has already been done for the SCAG product, as stated in the next two sentences. "These improvements in remotely sensed snow albedo over previous assessments, showing RMSE values of 4.6 to 4.8% with 0.7-1.3% bias for MODIS (Bair et al., 2019; Bair et al., 2021)." The HLS product albedo has yet to be evaluated for snow albedo accuracy. It's likely that the errors are similar, given similar surface reflectance errors to MODIS.

The point is that the snow albedo errors are comparable to the surface reflectance errors and are quite low, thus they are not a major source of uncertainty.

L271: shown

Fixed

L305: S2C should replace S2A hence it will not improve revisit time (except for a short period). https://labo.obs-mip.fr/multitemp/some-news-from-esa-regarding-the-coming-sentinels-1-and-2/

Changed to

Future satellite missions that leverage existing and planned constellations such as Landsat Next will improve revisit times, as gaps between observations are still an issue for the HLS data.

References

Baba, M. W., Gascoin, S., Kinnard, C., Marchane, A., and Hanich, L.: Effect of Digital Elevation Model Resolution on the Simulation of the Snow Cover Evolution in the High Atlas, Water Resources Research, 55, 5360–5378, https://doi.org/10.1029/2018WR023789, 2019.

Bouamri, H., Kinnard, C., Boudhar, A., Gascoin, S., Hanich, L., and Chehbouni, A.: MODIS does not capture the spatiotemporal heterogeneity of snow cover induced by solar radiation, Front. Earth Sci., 9, https://doi.org/10.3389/feart.2021.640250, 2021.

Schlögl, S., Marty, C., Bavay, M., and Lehning, M.: Sensitivity of Alpine3D modeled snow cover to modifications in DEM resolution, station coverage and meteorological input quantities, Environmental Modelling & Software, 83, 387–396, https://doi.org/10.1016/j.envsoft.2016.02.017, 2016.

References

Baba, M. W., Gascoin, S., Kinnard, C., Marchane, A., and Hanich, L.: Effect of digital elevation model resolution on the simulation of the snow cover evolution in the High Atlas, Water Resources Research, 55, 5360-5378, 10.1029/2018WR023789, 2019.

Bair, E. H., Rittger, K., Davis, R. E., Painter, T. H., and Dozier, J.: Validating reconstruction of snow water equivalent in California's Sierra Nevada using measurements from the NASA Airborne Snow Observatory, Water Resources Research, 52, 8437-8460, 10.1002/2016WR018704, 2016.

Bair, E. H., Rittger, K., Skiles, S. M., and Dozier, J.: An examination of snow albedo estimates from MODIS and their impact on snow water equivalent reconstruction, Water Resources Research, 55, 7826-7842, 10.1029/2019wr024810, 2019.

Bair, E. H., Stillinger, T., and Dozier, J.: Snow Property Inversion from Remote Sensing (SPIReS): A generalized multispectral unmixing approach with examples from MODIS

and Landsat 8 OLI, IEEE Transactions on Geoscience and Remote Sensing, 59, 10.1109/TGRS.2020.3040328, 2021.

Bouamri, H., Kinnard, C., Boudhar, A., Gascoin, S., Hanich, L., and Chehbouni, A.: MODIS does not capture the spatial heterogeneity of snow cover induced by solar radiation, Frontiers in Earth Science, 9, 10.3389/feart.2021.640250, 2021.

Claverie, M., Ju, J., Masek, J. G., Dungan, J. L., Vermote, E. F., Roger, J. C., Skakun, S. V., and Justice, C.: The harmonized Landsat and Sentinel-2 surface reflectance data set, Remote Sens Environ, 219, 145-161, 10.1016/j.rse.2018.09.002, 2018.

Cline, D., Elder, K., and Bales, R.: Scale effects in a distributed snow water equivalence and snowmelt model for mountain basins, Hydrological Processes, 12, 1527-1536, 10.1002/(SICI)1099-1085(199808/09)12:10/11<1527::AID-HYP678>3.0.CO;2-E, 1998.

Dozier, J., Painter, T. H., Rittger, K., and Frew, J. E.: Time-space continuity of daily maps of fractional snow cover and albedo from MODIS, Advances in Water Resources, 31, 1515-1526, 10.1016/j.advwatres.2008.08.011, 2008.

MathWorks: MATLAB Mapping Toolbox 5.4: User's Guide, The MathWorks, Natick, MA, 814 pp., 2022.

Rittger, K., Bair, E. H., Kahl, A., and Dozier, J.: Spatial estimates of snow water equivalent from reconstruction, Advances in Water Resources, 94, 345-363, 10.1016/j.advwatres.2016.05.015, 2016.

Schlögl, S., Marty, C., Bavay, M., and Lehning, M.: Sensitivity of Alpine3D modeled snow cover to modifications in DEM resolution, station coverage and meteorological input quantities, Environmental Modelling & Software, 83, 387-396, 10.1016/j.envsoft.2016.02.017, 2016.

Stillinger, T., Rittger, K., Raleigh, M. S., Michell, A., Davis, R. E., and Bair, E. H.: Landsat, MODIS, and VIIRS snow cover mapping algorithm performance as validated by airborne lidar datasets, The Cryosphere Discuss., 2022, 1-37, 10.5194/tc-2022-159, 2022.

Stillinger, T., Rittger, K., Raleigh, M. S., Michell, A., Davis, R. E., and Bair, E. H.: Landsat, MODIS, and VIIRS snow cover mapping algorithm performance as validated by airborne lidar datasets, The Cryosphere, 17, 567-590, 10.5194/tc-17-567-2023, 2023.

Stillinger, T. C.: Observing Snow from Space: Snow/Cloud Discrimination and Opportunities in Water Supply Forecasting, University of California, Santa Barbara, United States -- California, 152 pp., 2019.

Storey, J., Roy, D. P., Masek, J., Gascon, F., Dwyer, J., and Choate, M.: A note on the temporary misregistration of Landsat-8 Operational Land Imager (OLI) and Sentinel-2 Multi

Spectral Instrument (MSI) imagery, Remote Sens Environ, 186, 121-122, 10.1016/j.rse.2016.08.025, 2016.

Tan, B., Woodcock, C. E., Hu, J., Zhang, P., Ozdogan, M., Huang, D., Yang, W., Knyazikhin, Y., and Myneni, R. B.: The impact of gridding artifacts on the local spatial properties of MODIS data: Implications for validation, compositing, and band-to-band registration across resolutions, Remote Sens Environ, 105, 98-114, 10.1016/j.rse.2006.06.008, 2006.

Wolfe, R. E., Roy, D. P., and Vermote, E.: MODIS land data storage, gridding, and compositing methodology: Level 2 grid, IEEE Transactions on Geoscience and Remote Sensing, 36, 1324-1338, 10.1109/36.701082, 1998.