Review Response A - Snow Water Equivalent Retrieval Over Idaho, Part B: Using L-band UAVSAR Repeat-Pass Interferometry

October 2023

We wish to thank Dr. Andrea Manconi for her time and consideration of our study. We generally agree with her comments and provide specific replies to her comments (italicized).

(1) The authors state several times that they "utilized wrapped images when complete spatial or temporal coverage was necessary". However, this requires a clarification, especially to readers not aware of (or not used to) the differences between wrapped and unwrapped phase in radar interferometry. I suggest providing specific details what does it mean exactly and how you combined the results of wrapped phase and unwrapped phase

We agree that the difference between wrapped and unwrapped phase is an important and often challenging concept for readers to understand. We endeavor to provide a clear description of the wrapped vs unwrapped phase in lines 44-49. On re-reviewing that section I think that adding additional citations from (1) and (2) to provide readers in need of additional information on phase unwrapping will be helpful.

(2) The section 3.2. is unclear. I think I get the sense of what you mean when you need for a reference phase, but the process of how you get is not straightforward (at least not in your explanation) . I suggest to write down the formulas and also add a figure showing how the reference phase looks like.

We propose adding an equation that shows how mean phase of each scene is set using:

$$\phi_{scene}(t) = \frac{\triangle d_{insitu}(t) \times \lambda}{(4\pi)} \times \frac{1}{\cos\alpha - \sqrt{\epsilon_s(\rho_s) - sin^2\alpha}} \quad (1)$$

with $\triangle d$ representing the average change in snow depth across the in situ stations and ϵ calculated from the average density across the in situ stations.

(a) Spatial limitation: it is true that if the InSAR retrieved deformation field is smooth and continuous, implying also appropriate spatial sampling (pixel resolution), the wrapping limit is at 2pi. However, some discontinuities in the InSAR results might occur, i.e., the phase unwrapping (which is a gradient based approach, and needs thus continuity) would fail in providing accurate results. I don't have experience with L-Band interferograms related to snow height change, thus it is difficult for me to understand if the continuity condition is respected, especially in locations with high topographic relief. Including one or more interferograms (wrapped) either in the main text or in the supplementary would help in better understanding.

We agree that including a supplementary section showing figures with 3x3 subplots for unwrapped phase, 3x4 wrapped phase, and 3x4 for coherence so that readers could visualize the wrapped, unwrapped, and coherence images would be helpful.

*(b) Temporal limitation. The theoretical limit of phase aliasing between 2 acquisitions is = lambda/(4*dt). With lambda L-Band ca 24 cm this means that in case of changes larger than 1.5 cm/day on the same pixel, we would reach the ambiguity limit. If the spatial unwrapping works well (see point before) then it should be not a problem. However, what happens in the cases when the phase unwrapping does not work and you use the wrapped phase values?*

First, since we are setting the reference phase it is about relative changes

so if there is a large snowfall event with less than 24 cm of difference in snow fall across the scene then phase wrapping shouldn't be an issue and we should be able to use wrapped phase. We believe in areas where we have greater than 24 centimeters of change that using the wrapped phase would be a mistake and would lead to fairly obvious 24 cm errors in regions with wrapped phase and would then need to be unwrapped using a different method (SNAPHU) or other interpolation or corrections might be necessary. We think to better clarify both the spatial and temporal limitations of this phase unwrapping processes an additional paragraph should be added to section 7.3 (Limitations) to address the need to use the unwrapped phase for large temporal baselines with over 24 cm of variation in snow depth across a scene.

(4) related to the previous point, I find figure 7 of difficult reading. I know that it is convenient to put on a single graph several variables, but i think that for a better understanding you can put several graphs for different densities (using upper and lower boundaries) and/or different incidence angles. As mentioned in point (3a and 3b) spatial and temporal resolution play also an important role in the definition of the phase aliasing.

I can add a second 2 axis row of plots showing additional slices through the cube to showcase two sets of densities (a lower @ 200 and an upper @ 400) along with two incidence angles (30, 60) to improve the visualization on this plot.

(5) Missing units on the Figure 9 (y-axis)

Thank you for catching this. We will add the appropriate units to Figure 9's y-axis.

1 References

References

[1] Rosen, P. A. *et al.* Synthetic aperture radar interferometry. *Proceedings of the IEEE* **88**, 333–382 (2000).

[2] Goldstein, R. M., Zebker, H. A. & Werner, C. L. Satellite radar interferometry: Two-dimensional phase unwrapping. *Radio Science* **23**, 713–720 (1988).