

# ***Interactive comment on “Using SAR satellite data time-series for regional glacier mapping” by Solveig H. Winsvold et al.***

## **Anonymous Referee #1**

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Review of “Using SAR satellite data time-series for regional glacier mapping” By S. Winsvold and others

## Summary

The authors present and analyze trends and statistics from Sentinel-1A and B and Radarsat-2 Synthetic Aperture Radar (SAR) backscatter data time-series over glaciers in arctic and sub-arctic Norway. The premise of the paper is that dense, high-resolution SAR satellite data time-series can lead to improved mapping of time-variable surface and subsurface glacier properties and features. The authors present results from five separate, but related analyses of SAR backscatter times-series that focus on variable patterns of backscatter change, including transient snow line mapping, glacier facies mapping, firn evolution, detection and extent mapping of winter rain-on-snow events,

and mapping glacier extent.

The paper acknowledges and utilizes the extensive background of research in using microwave remote sensing to map time-varying glacier properties, and extends this topic by utilizing higher-resolution SAR satellite data with faster revisit times. The authors illustrate an enriched characterization of glacier properties at the catchment scale resulting from the improved spatial and temporal resolution of SAR satellite data, and present an interesting comparison of SAR backscatter data time-series with modeled firn air and moisture levels, which is not entirely convincing without ground validation. Overall, the manuscript is well organized, but it requires some attention in specific areas to improve writing, phrasing, and organization in order to facilitate reader understanding and comprehension. I have some general comments, as well as a number of targeted comments and questions detailed below.

### General Comments

The authors make very good use of the data. Plots are informative with necessary explanatory support. In the absence of in situ snow/firn data, all possible influences on radar energy must be addressed or explained with reference to relevant previous studies; authors should augment interpretations accordingly.

### Targeted Comments

P1 L11: Suggest rephrasing "...used descriptive methods for outlining the possibilities..."

P1 L20: Eliminate "Finally"

P1 L23-25: This final statement of the abstract should be re-written to be more specific to this study. In its current form it can apply to nearly all glacier remote sensing studies. Also, "semi-automatically" is probably more appropriate at this stage.

P2 L27: Suggest adding the descriptive modifier "high-resolution" to "...dense SAR satellite image time-series..." as this reinforces the case that this is "new potential"

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P4 L4: Given the specific applications of the data from these sensors, it would be helpful to remind the reader of the wavelength.

P5 L23: Consider describing the process of “multi-looked” rather than using it as a verb in this sentence.

P6 L5: Change to “. . . outdated, coarser. . .).

P7 L20: Readers would likely benefit from a reminder that QuikSCAT is a Ku-band sensor.

P7 L24: Re-phrase the first sentence of this paragraph as the statement in its current form is untrue or partially correct.

P8 L3: This is an interesting result, which adds credence to the use of dense, high-resolution SAR satellite data for this type of analysis. Other sensors used for this purpose would not have provided this level of detail in the melt patterns that are controlled by terrain parameters. It would be worth highlighting this.

P8 L6-7: Sentence should be re-written for clarity. Also, consider depth of snow as this can scale inversely with backscatter. Do you see this influence here?

P8 L10-14: This section of text needs to be re-written to achieve clarity.

P8 L17: Were the SMB gradients not determined through in situ measurements?

P8 L20: Hyphenate “. . . optical-derived”

P8 L22-23: This sentence needs clarification as the current writing is ambiguous.

P8 L28: List should be written in a consistent manner according to “valuable for” in the leading sentence. Consider colon usage and proper listing format.

P8 L28: More appropriately written as “Refining spatial variations in the melt pattern of well-studied. . .”

P9 L2 : Should be “SAR backscatter imagery can be used to. . .”

P9 L2: Second use of SAR is redundant.

P9 L2: There is inconsistent use of SAR glacier zones and glacier facies throughout the paper. Define these and strive for consistency in usage as it will be difficult for the readers if this isn't addressed. It will be important to start with a clarification about what is being classified and what is interpreted from these classifications. For example, "SAR backscatter imagery can be used to identify distinct zones of consistent backscatter levels that correspond to glacier facies. . ." Is there ambiguity in the classifications? Do SAR glacier zones directly relate to glacier facies? If so, the two terms should be treated separately, if not, they should be referred to as glacier facies.

P9 L7-8: Consider re-phrasing to clarify. "Zones" don't correspond to previous literature, rather to previous interpretations found in the literature.

P9 L17: How do you know this?

P9 L8: Just a clarification: The dry-snow glacier facies is absent here and the interpretation of the SAR backscatter data are consistent with this repeated observation.

P9 L18-20: Should be re-written to make the message clearer. Also, be careful not to present conflicting information about the winter glacier-ice zone.

P9 L22 : Should be "... we found the following. . ."

P9 L 23: Delete "frozen."

P9 L 24: Why isn't superimposed ice part of the list in the previous sentence? How do you know it isn't a saturation facies within the firn zone?

P9 L 27: Why not keep the reader directed at Fig. 2 instead of Fig. 6a?

P9 L 28-29: This might be best explained/defined at the beginning of this section as mentioned above.

P9 L29: Perhaps this is a better lead sentence for this paragraph.

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P9 L33: Is this image combination available to add as a figure? If so, this would provide useful evidence for the chosen facies interpretation.

P10 L3-6: Consider re-phrasing this sentence. "...changing seasonally in response to changes..." Need to qualify or provide some scale for "local melt water streams" relevant to the frequency of the sensor used. Also consider the drying effect of melt water channeling and how that impacts the backscatter.

P10 L23: Updated from what to what?

P10 L25: Delete "elevation"

P10 L26-27: Please reword for clarification. Optimized – not "against." I'm assuming you mean "for"?

P10 L32: Please clarify "Several modeled outputs are directly or indirectly related to wetness." How does this relate to the previous sentence?

P11 L1: How is firn air content a direct measure of anything if it is a model simulation product?

P11 L3: delete "where"

P11 L6: This introductory sentence needs to be rewritten for clarity.

P11 L17-34: Good discussion. It would be worth including in the discussion, the size definition of a target that is considered transparent, compared to those considered good specular or diffuse reflectors at the c-band frequency.

P11 L21: Re-word: A perennial firn aquifer was found containing liquid water.

P11 L22: Clarification required. Is the firn aquifer depth 3.5-15 m, or is it located below the surface 3.5-15 m?

P12 L1: Backscatter values can't be absorbed, please reword/rephrase.

P12 L1-6: This contradicts the explanatory statements starting at P11 L28. How can

you be certain that SAR penetration depth is increasing? This needs to be reconciled, along with an explanation of possible contributing parallel processes occurring in an evolving snowpack exposed to a penetrating winter cold wave.

P12 L7-14: Suggest reorganization of this section to make it easier for the reader to follow. Also, include a transitional/introductory sentence to link the previous paragraph to this.

P12 L10: Modify. "... intensity can not 'be used to' identify..."

P12 L25: Change last word to 'surfaces'

P13 L23: Explain why an increase in pore space is occurred.

P13 L24: Delete 'with'

P13 L28: Case change 'p'

P13 L29: Rephrase sentence, change 'deeper snow depth'

P13 L29-32: This section needs a better explanation of the processes involved to support the conclusions. Why 'higher permittivity'? Could there be another explanation for a sharp increase in backscatter? Snow saturation and superimposed ice is common with these events – are these identifiable?

P15 L17: Rearrange wording – 'glaciers with high spatial resolution'

P15 L21: 'SAR-zones' should be 'glacier facies'

P15 L27-28: Rearrange/rephrase for reader clarity.

P17 L5: Rephrase

P29: Minor - Consider switching the color blocks for 'Cold season' and 'Warm season' to reflect customary warm and cool color designations.

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Interactive comment on The Cryosphere Discuss., <https://doi.org/10.5194/tc-2017-136>, 2017.