Referee #2 Response Letter – Manuscript tc-2022-89

We thank Dr. Bertoldi for their constructive and helpful feedback on our manuscript. Please see our responses and proposed alterations **in bold.**

Introduction. Please define in a more precise way the paper's aims and formulate clear research questions.

To define our project's aim and research questions more precisely the Introduction has been modified starting on Line 78:

"We examine how the relation between SAR minima and snowmelt (Marin et al., 2020) is impacted by polarization, land cover, aspect, and hillslope in the Lajoie Basin. We further assess how estimates of snowmelt onset and duration can be verified with continuous records of SWE."

Section 4.2 snow disappearance times. Since Landsat has a low overpass time and images are often cloud covered, please better quantify the errors and uncertainties in days for the snow disappearance time.

Thank you for suggesting this. Reviewer One was also concerned about error propagation in snow disappearance estimates. Please see the last response in our reply to Reviewer One for further clarification:

Snowmelt durations are impacted by both errors in SAR onset estimates and optical snow disappearance estimates. Between study years SAR acquisitions are available every five to twelve days, averaging 6 days in each year. Optical observations are more variable between study years, and are summarized in Table 1.

Table 1. Revisit intervals for optical imagery from Sentinel 2 and Landsat 8 for the Lajoie Basin.

Year	Minimum Revisit Interval	Maximum Revisit Interval	Average Revisit Interval
2018	1 day	17 days	4 days
2019	1 day	15 days	4 days
2020	1 day	18 days	3 days
2021	1 day	8 days	3 days

We calculated errors in snowmelt durations (σ_D) using Equation 2.

$$\boldsymbol{\sigma_D = \sqrt{\sigma_{ONS}^2 + \sigma_{END}^2}} \qquad \text{Eq. 2}$$

where error in the onset (σ_{ONS}) is six days, and error in snow disappearance (σ_{END}) is the average revisit interval from the annual Landsat 8 and Sentinel 2 image collections. Rounding to the nearest day, this yields an average error in the duration estimates of ±7 days for all study years.

Ideally, a revisit time for SAR observations of three days would reduce this error to ±4 days. Daily SAR observations could reduce error in durations to ± 3 days; however, for reduced error, or operational applications, high-resolution optical imagery is needed at more frequent revisit intervals.

Table 3 (now Table 4 due to revisions) has been updated to include the revisit frequency of optical observations. Line 401 has been amended, and the following passage has been added.

"Inaccuracies in snowmelt durations are attributed to errors in SAR onset estimates and optical snow disappearance estimates. Between study years SAR acquisitions are available every five to twelve days, averaging six days in each year. Optical observations are variable between study years (Table 4); however, average revisit intervals are consistent at four days in 2018 and 2019 and three days in 2020 and 2021. We calculated errors in snowmelt durations (σ_D) using Equation 1.

$$\boldsymbol{\sigma_D} = \sqrt{\boldsymbol{\sigma_{ONS}}^2 + \boldsymbol{\sigma_{END}}^2} \qquad \text{Eq. 1}$$

where error in the onset (σ_{ONS}) and disappearance dates (σ_{END}) are taken as the average revisit interval for each data type and study year. Rounding to the nearest day, this yields an average error in the duration estimates of ±7 days for all study years. Ideally, a revisit time for SAR observations of three days would reduce this error to ±4 days. Daily SAR observations could reduce error in durations to ± 3 days; however, for reduced error, or operational applications, high-resolution optical imagery is needed at more frequent revisit intervals."

Section 5.2 Sensitivity - L233 - "the least accurate approximation in 2019" - please quantify in numbers, variance ...

SAR time series estimates are now quantified using the difference in days between SAR melt onset estimates and telemetry records. Section 5.2 has been modified, starting on Line 233:

"At Downton Lake Upper, SAR time series minima occurred within 0-10 days of SWE melt onset estimates for both polarizations (Figure 3). Comparing across four melt seasons at Downton Lake Upper, the maximum difference (+4 days) between onset estimates from VV polarized time series and telemetry records was produced in 2019. The minimum difference was produced in 2018 when there was no difference between telemetry records of melt onset and SAR estimates of melt onset. The maximum difference (-10 days) between estimates from VH polarized time series and telemetry records was produced in 2020 at Downtown Lake Upper. The minimum difference was produced in 2018, when, similarly to VV time series, there was no difference between telemetry records of melt onset and SAR estimates of melt onset. At Green Mountain, SAR minima occurred within 1-13 days of SWE melt onset estimates (Figure 4). Between study years, the maximum difference (+11 days) between onset estimates from VV polarized timeseries and telemetry records was produced in 2019. The minimum difference was produced in 2019 (-1 day). The maximum difference (-13 days) between onset estimates from VH polarized time series and telemetry records was produced in 2020 at Green Mountain. The minimum difference was produced in 2021, when there was no difference between telemetry records of melt onset and SAR estimates of melt onset."

L255 - besides slope, does the accuracy of results change also with the aspect?

The SAR snowmelt signature, or the decrease of backscatter during ablation and subsequent increase after snowmelt has occurred, varies in amplitude between aspects (Figure 1). While the snowmelt signature is discernable in all aspects, it is the most pronounced on eastern and northern slopes when compared to southern and western. This phenomenon may relate to the distribution of slopes within the Lajoie. We observe the largest amplitude of the snowmelt signal in open, low slopes (Figure 4 in the manuscript). Low gradients (i.e., < 20°) are the most prevalent on North and East facing slopes in the Lajoie and may contribute to the larger amplitude observed in these aspects. Satellite look angle may also influence the strength of the SAR snowmelt signature between aspects. Overall, SAR onset estimates are more consistent by aspect when compared to slope (Figure 7 in the manuscript) and were of lesser focus in the analysis.

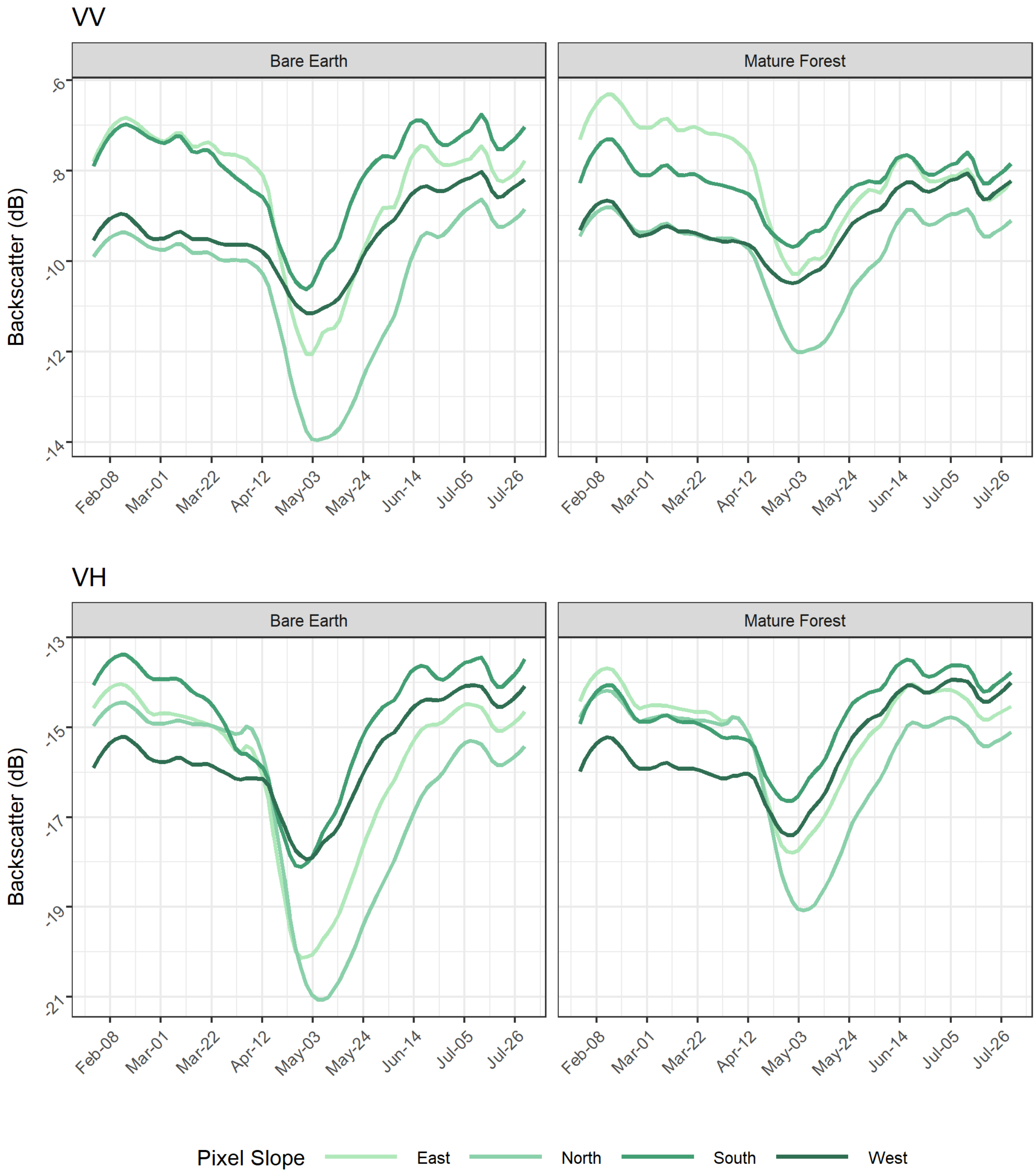

Figure 1. SAR backscatter time series in the Lajoie Basin from pixels located between 1600 and 1800 m from VV (top) and VH (bottom) polarized images. Observations under mature forest cover are displayed on the right, whereas observations in open areas are displayed on the left. Average backscatter for each cover type is shown by the shaded lines, with each line representing a different aspect. Observations are from 2021.

Paragraph at line 315 - Interesting! Maybe an additional Figure can support this!

A figure supporting this was formerly in the Supplement (Figure S9). It has been moved into the main manuscript for easier reference.

L324 - What do you mean by Data Fusion? Please explain better!

We use data fusion to describe the process of combining remotely sensed datasets to estimate snow disappearance and snowmelt duration. To improve clarity, the term data fusion has been replaced with “multi-source” or “optical-radar” throughout the manuscript.