Assessing Liquid Water Content Development Within a Snowpack Compared to Sentinel-1 SAR-Derived Melt Onset Estimates

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Background and Motivation

- Since 1955, 90% of snow monitoring stations in the western U.S. show a decline in April 1 SWE, accounting for a total loss of 15-30% (Mote et al., 2018).
- Interferometric synthetic aperture radar (InSAR) has emerged as a promising method of SWE retrievals but is hindered by liquid water content (LWC) in the snowpack.
- Sentinel-1 synthetic aperture radar (SAR) has been utilized for snowmelt onset detection (Gagliano et al., 2023; Lund et al., 2022, 2023).

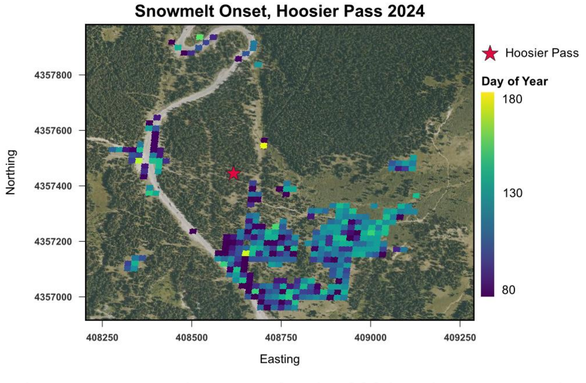
Methods

Field Methods

- We conducted biweekly snowpit surveys coincidental with Sentinel-1 SAR overpasses throughout the melt season at five sites adjacent to SNOTEL stations in Summit County, CO
- The snowpack was characterized by measuring snow density, temperature, permittivity, and manual wetness recorded at 10 cm intervals

Sentinel-1 SAR Methods

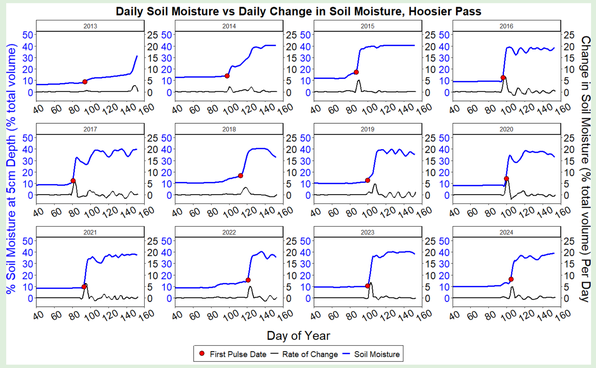
- Building upon methodology developed by Gagliano et al. (2023), we evaluated the spatiotemporal distribution of snowmelt onset for an 8-year period within a 1 km^2 area centered around each SNOTEL site
- We masked dense vegetation and pixels outside of a 100 m elevation range



Snowmelt onset composite raster for the 2024 melt season at the Hoosier Pass SNOTEL site after masking/thresholding. Pixel values correspond to estimated snowmelt onset day of year (DOY)

Preliminary Results

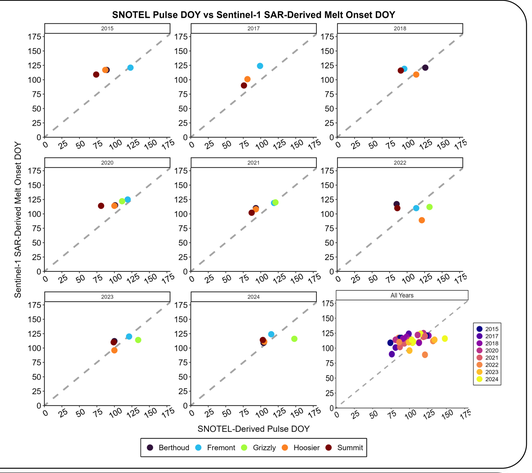
SNOTEL-Derived Estimates of Melt Output



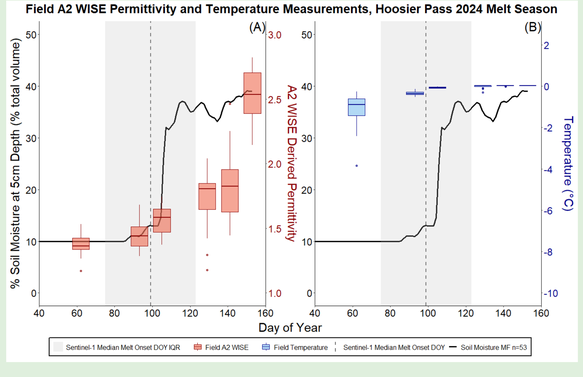
- SNOTEL measurements of soil moisture were utilized to identify the first instance of meltwater output from the snowpack
- The soil moisture rate of change (black) is used to identify the onset of meltwater output (red point)
- This rapid increase in soil moisture indicates meltwater output, which lags LWC development in the snowpack

Sentinel-1 SAR-Derived Estimates of Melt Onset

- The timing of the soil moisture pulses were compared to Sentinel-1 SAR backscatter minima-based estimates of melt onset
- Preliminary results from five sites over eight years found that on average Sentinel-1 dates preceded SNOTEL station-derived dates by ~8 days, with a median difference of 11 days
- Strong interannual and inter-site variability was observed between Sentinel-1 and SNOTEL estimates of melt onset, resulting in an R^2 value of 0.10.



Integration of Remote Sensing, SNOTEL, and Field Observations



- Snowpit measurements collected during the 2024 melt season document permittivity (related to density and LWC) and temperature increases.
- Permittivity increased from 1.41 to 2.02 from the pre to post soil moisture increase
- Snowpack temperatures were isothermal on our DOY ~105 survey.

Ongoing Work

- Continue development of a statistical relationship between SNOTEL-derived metrics to predict the soil moisture pulse for ~400 stations across the western U.S.
- Finalize workflow to automate the detection of soil moisture pulses
- Publish scripts and workflows to Github for open-source use
- Look for updates during the SnowEx Session (C024) at AGU 2024!

References

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Field work for this research was conducted on the traditional and ancestral homelands of the Arapaho, Cheyenne, and Ute Nations and peoples. We recognize the Indigenous peoples as original stewards of this land and all the relatives within it.