National Aeronautics and Space Administration

FY23 Topic Areas Research and Technology Development (TRTD)

Snow Water Equivalent Retrieval Over Idaho Using Sentinel-1 Repeat-Pass Interferometry

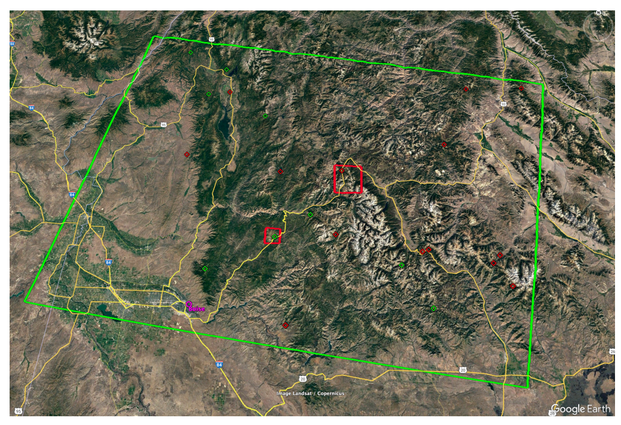
Principal Investigator: Shadi Oveisgharan (334)**; Co-Investigators:** Robert Zinke (334), Emre Havazli (334), Zachary Hoppinen (Boise State University)

Strategic Focus Area: Water and carbon cycles

Objectives: The objective of this work was to show for the first time the quantitative evidence to justify using repeat-pass interferometry as a viable new method for SWE retrieval. W were the first to propose evaluating the performance of InSAR SWE retrieval using a time series of "spaceborne" Seninel-1. We will recommend the optimum revisit time for SWE retrieval using differential interferometry for future NASA Snow mission.

Background: 2017 Decadal Survey calls for Snow Water Equivalent (SWE) measurement using active sensor (radar) as part of the DS Earth Explorer mission category. Different methods are used for SWE retrieval:
1) Multi-frequency passive (low resolution), 2) Lidar (does not work in cloud, limited foot print), 3) SoOp (extremely limited coverage, but penetration through vegetation), 4) Multi-freq (X- and Ku-) radar backscattered power (a priori information is needed, saturates at deep snow), 5) **Zero baseline repeat-pass interferometry** (loss of temporal coherence):

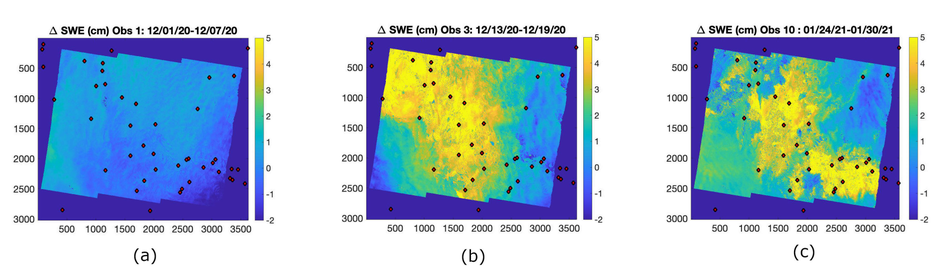
$$\Delta\phi = -2\kappa_0(\cos\theta - \sqrt{\epsilon - \sin^2\theta})\Delta d$$



Approach and Results:

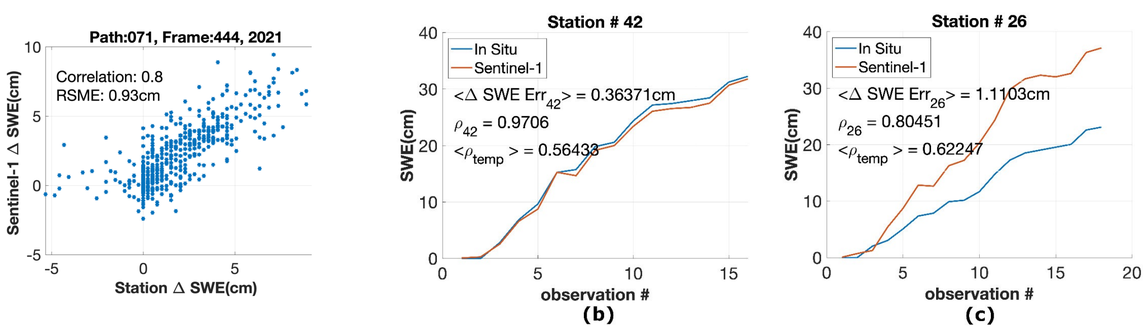
Using 6 days Revisit Sentinel-1 for DSWE Estimation

- 6-day repeat Sentinel-1 time series data is used between 12/1/20 to 3/30/21 over Idaho
  - Tropospheric noise from the unwrapped phase is removed by using the Miami InSAR Time-series software in Python (MintPy)
  - The unwrapped phase is converted to ΔSWE
  - The average of all in situ stations is used as the reference point
- The retrieved ΔSWE matches qualitatively with the average of in-situ ΔSWE
  - The left top is close to zero
  - The two right top ones show snowstorm
- The correlation drops when there is snowstorm (the two right bottom ones)



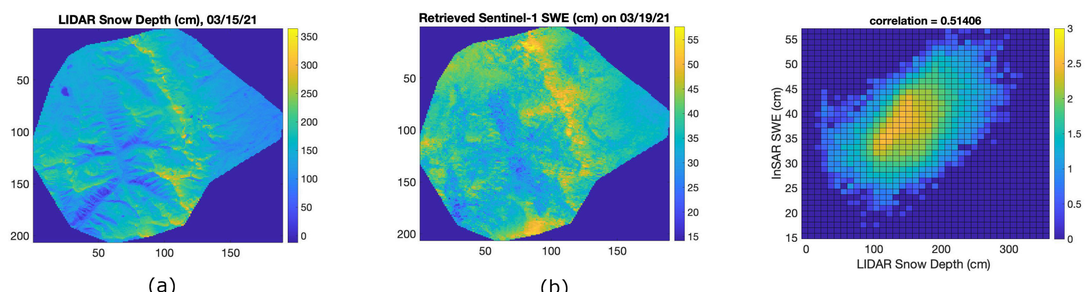
<ΔSWE$_{in\ situ}$> = 0.01cm **<ΔSWE$_{in\ situ}$> = 2.72cm** **<ΔSWE$_{in\ situ}$> = 4.33cm**

Comparing Retrieved Sentinel-1 and In Situ DSWE



- There is **0.82 correlation** between Sentinel-1 and In Situ ΔSWE. The RMSE error is 0.76cm. **The highlight of this study**.
- We use ΔSWE for the time series to come up with SWE(t_k) = Σ ΔSWE(t_i) ($t_i < t_k$)
- In almost all the stations there is **very good correlation** between in situ and Sentinel-1 SWE
- For some stations (**16 out of 31 stations**), the total SWE error is less than **2 cm**. **The highlight of this study**.

Comparing Retrieved Sentinel-1 and In Situ total SWE



- There is very good resemblance and correlation between LIDAR snow depth and Sentinel SWE. **The highlight of this study.**

Significance/Benefits to JPL and NASA:

- The successful SWE retrieval results shown in this study would become the basis for a new and more accurate SWE retrieval approach for the snow community. It will help in generating **SWE product using NISAR** data with **a reliable estimate of the uncertainty**.
- In the next 10 years, we have the opportunity to launch an InSAR mission for SWE retrieval with sufficiently frequent revisits by **adding of a small-sat** to the future **SDC/NISAR/ROSE-L** missions.

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Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

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Publications:

[A] Shadi Oveisgharan, Robert Zinke, Zachary Hoppinen, Hans Peter Marshall, "Snow Water Equivalent Retrieval Over Idaho, Part A: Using Sentinel-1 Repeat-Pass Interferometry," submitted to The Cryosphere, (July 2023)
[B] Shadi Oveisgharan, Robert Zinke, Zachary Hoppinen, Hans Peter Marshall, "ESTIMATING SNOW WATER EQUIVALENT USING SENTINEL-1 REPEAT-PASS INTERFEROMETRY," Presented to IGARSS 2023, Pasadena, CA, 2023.

PI/Task Mgr. Contact Information:

Email: Shadi.Oveisgharan@jpl.nasa.gov
Phone: 650-353-1661