National Aeronautics and Space Administration

FY24 Topic Areas Research and Technology Development (TRTD)

# Snow Water Equivalent Retrieval Using Sentinel-1 and UAVSAR Repeat-Pass Interferometry

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**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. We 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):

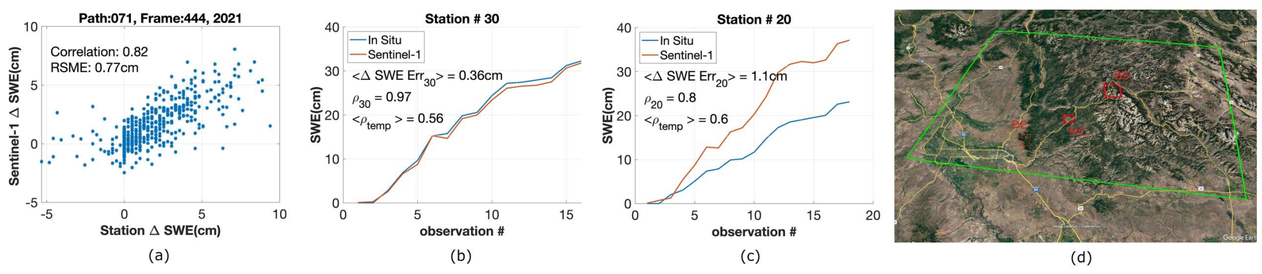
$$\Delta\phi = -2\kappa_0(\cos\theta - \sqrt{\epsilon - \sin^2\theta})\Delta d$$

## Approach and Results:

### *Using 6 days Revisit Sentinel-1 for ΔSWE Estimation*

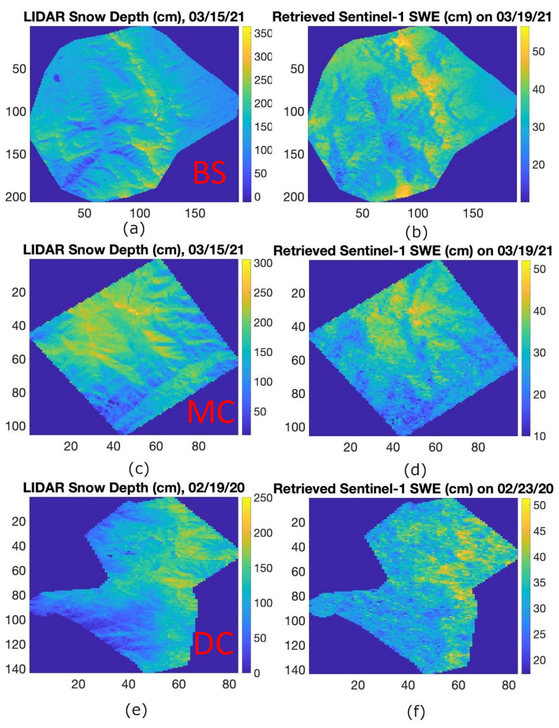
- 6-day repeat Sentinel-1 time series data is used between 12/1/20 to 3/30/21 over Idaho
  - Tropospheric noise from the unwrapped phase is removed by using the Miami InSAR Time-series software in Python (MintPy)
  - The unwrapped phase is converted to ΔSWE
  - The average of two in situ stations is used as the reference point

### *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 $SWE(t_k) = \Sigma \Delta SWE(t_i)$ $(t_i < t_k)$
- 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**.

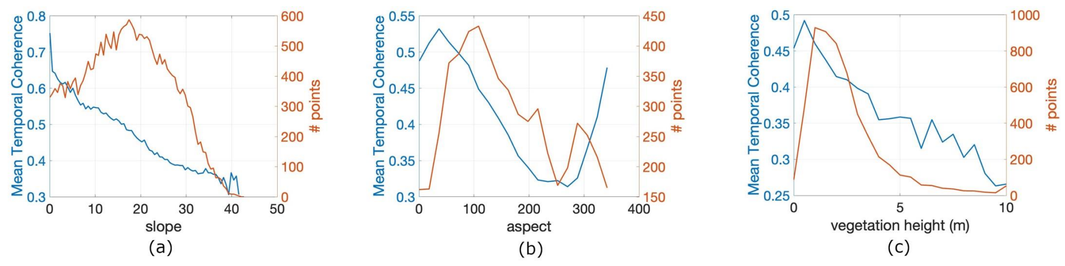
### *Comparing Retrieved Sentinel-1 and In Situ total SWE*




| Site | LDIAR Date | Correlation |
|---|---|---|
| BS | 2/19/20 | 0.51 |
| BS | 3/15/21 | 0.47 |
| MC | 2/19/20 | 0.66 |
| MC | 3/15/21 | 0.59 |
| DC | 2/19/20 | 0.56 |

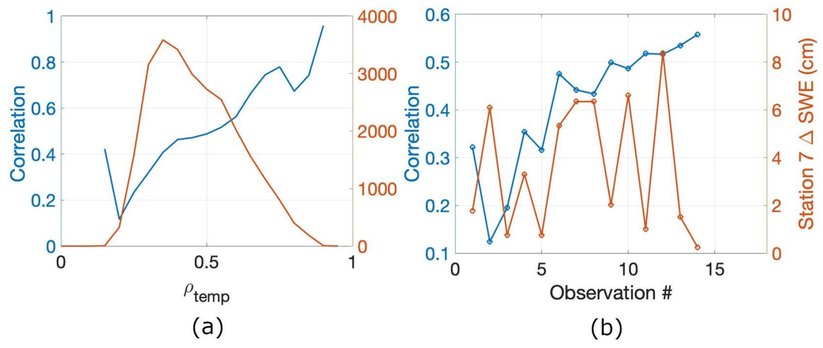
- There is very good resemblance and correlation (between 0.47 to 0.66) between LIDAR snow depth and Sentinel SWE. **The highlight of this study.**

### *Different Parameters Effect on Temporal Coherence*




- Temporal coherence decreases with the increase of slope and vegetation height as expected.
- Temporal coherence is minimum around 270 aspect angles, facing west. These regions face the sun in the afternoon and snow melting occurs accordingly

### *Temporal Coherence Effect on SWE Retrieval Performance*




- The correlation between retrieved SWE and LIDAR snow depth increases with higher temporal coherence. Therefore, temporal coherence has a huge impact

## 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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## Publications:

[A] Shadi Oveisgharan, Robert Zinke, Zachary Hoppinen, Hans Peter Marshall, "Snow water equivalent retrieval over Idaho – Part 1: Using Sentinel-1 repeat-pass interferometry," submitted to The Cryosphere, Feb. 2024

[B] Shadi Oveisgharan, Emre Havazli, Robert Zinke, Zachary Hoppinen, "Evaluating the Performance of SWE Retrieval Using Sentinel-1 Interferometric Data and QSI LIDAR data," Presented to IGARSS 2024, Athen, Greece.

[C] Shadi Oveisgharan, Emre Havazli, Robert Zinke, Zachary Hoppinen, "Evaluating the Performance of SWE Retrieval Using Sentinel-1 Interferometric Data and QSI LIDAR data over Idaho and California," in preparation to submit to The Cryosphere

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