C35E-0919 : Avalanches in L-band InSAR imagery during the 2020-21 SnowEx Mission

Hans-Peter Marshall[1*], Zach Keskinen[1], Jeff Johnson[1], Scott Havens[2], Jack Tarricone[3], Eli Deeb[4], Jewell Lund[5], 6, Rick Forster[6]
1 *Cryosphere Geophysics And Remote Sensing (CryoGARS) lab and Department of Geosciences, Boise State University*
2 *Snowbound Solutions LLC*
3 *Department of Geography, University of Nevada Reno* **4** *U.S. Army Cold Regions Research and Engineering Laboratory*
5 *Cooperative Institute for Research in the Atmosphere, Colorado State University*
6 *Department of Geography, University of Utah*
* *email: hpmarshall@boisestate.edu, earth.boisestate.edu/cryogars*

Abstract

We investigate the impact of avalanches on L-band InSAR and the potential for detecting avalanches. In January 2024, NISAR will launch, providing global L-band InSAR data at 12 day intervals. We compare the impact of avalanches on the L-band InSAR signal for both 7-day and 14-day intervals, using airborne L-band InSAR imagery from UAVSAR, collected as part of the SnowEx 2020-21 time series campaign. To study temporal baselines shorter than one week, a car-based L-band InSAR was used. Future work will incorporate arrays of infrasound sensors to compare InSAR signatures to avalanche detections from the infrasound arrays. In the future, InSAR and infrasound could be combined to provide additional information about avalanche release for avalanche forecasters.

Figure 1: NISAR launches January 2024, providing 10-50m resolution InSAR globally every 12 days.

Figure 2: To test the capability of NISAR for measuring snow on the ground, the 2020-21 NASA SnowEx time series was performed with UAVSAR, an airborne L-band InSAR.

Introduction

- Dry snow is not expected to cause significant volume scattering at L-band frequencies (λ =24cm)
- If coherence is maintained, $\Delta\phi = f(H_s, SWE)$ (*Guneriussen et al.*, 2001; *Deeb et al.*, 2011; *Marshall et al.*, 2021)
- In ideal situations avalanches can cause measurable changes in phase (Fig. 3)

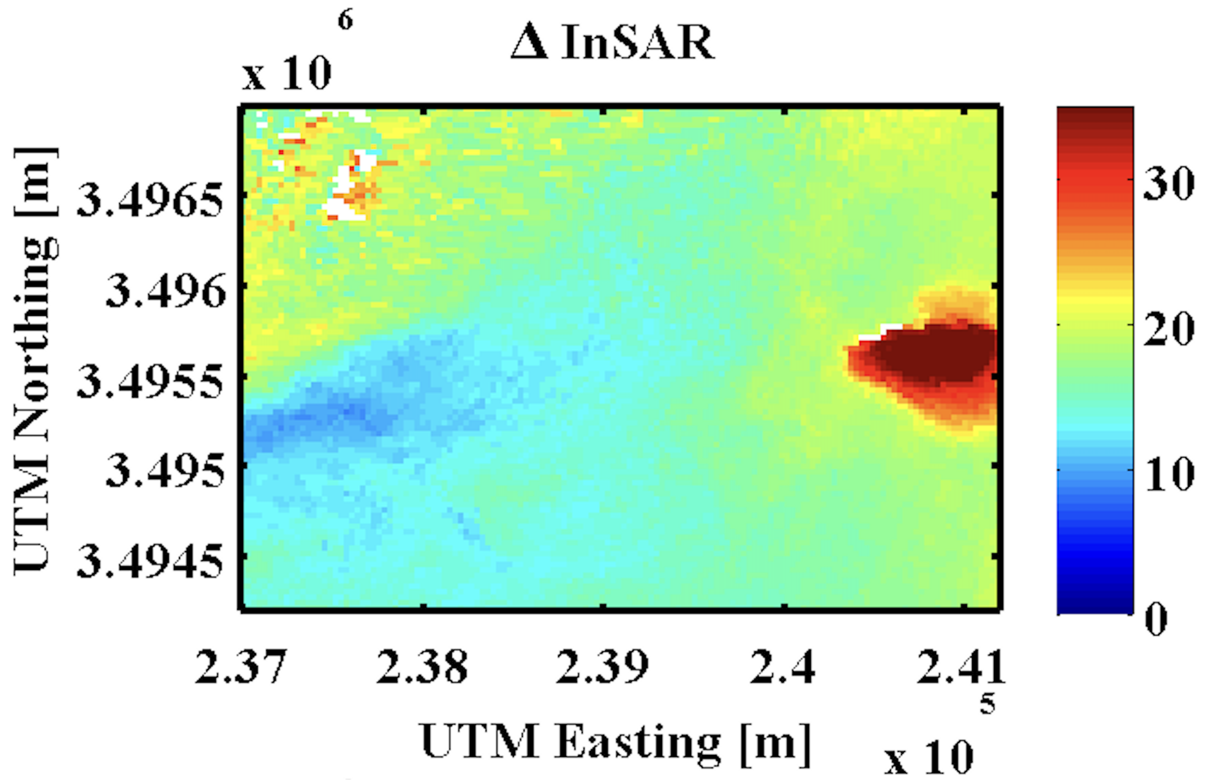

Figure 3: Example of a likely avalanche in satellite L-band InSAR data (PALSAR), over High Mountain Asia. Color shows phase change bracketing a storm, in steep mountain area with slope towards the east.

Avalanche detection

- Accurate avalanche observations are required to investigate the potential for avalanche signals in InSAR imagery
- We leverage observations from avalanche forecasters, and arrays of infrasound sensors (*Havens et al.*, 2014; *Johnson et al.*, 2021)

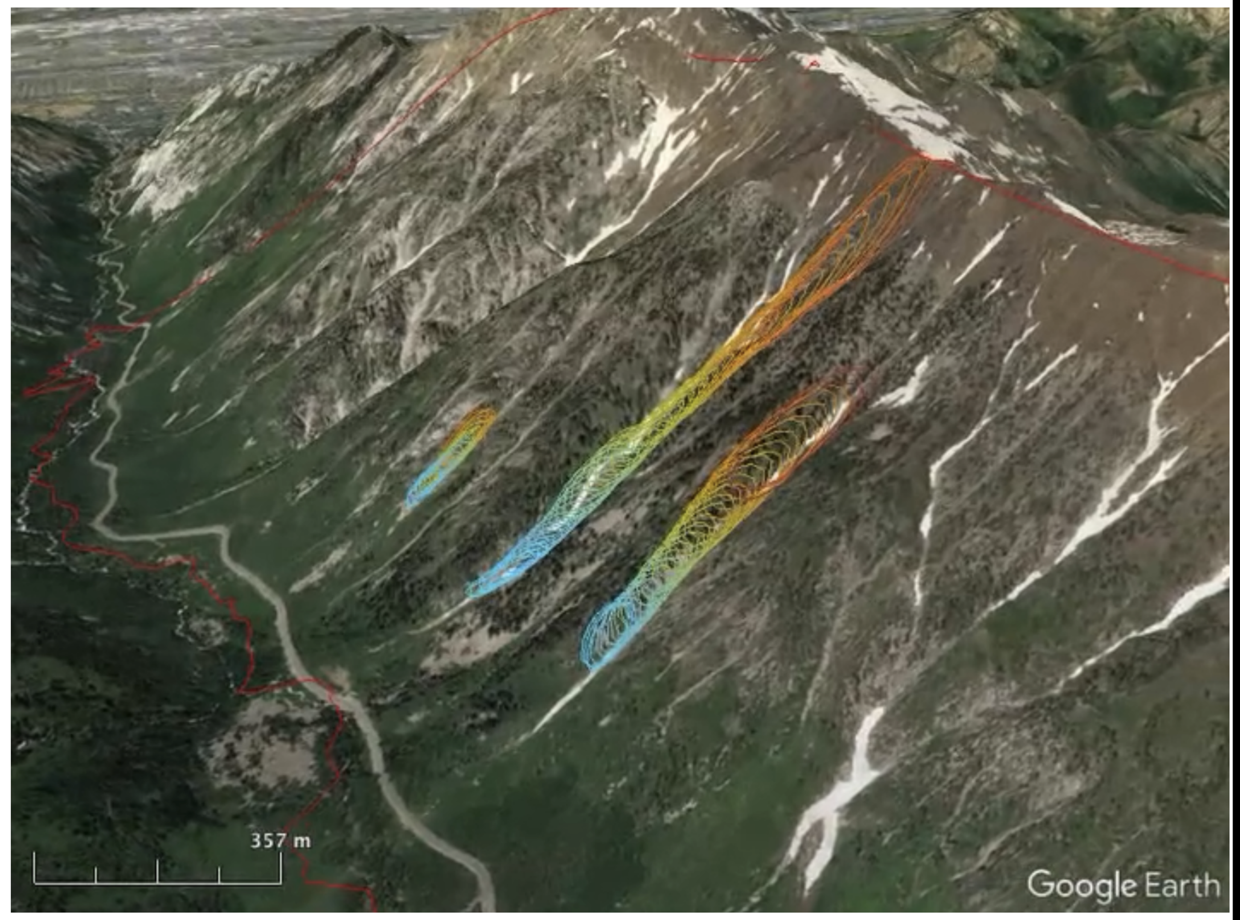

Figure 4: Avalanche detection, location, and tracking with multiple infrasound arrays. Colors indicate progression of time as the avalanche releases in the starting zone, and moves along the path (*Johnson et al.*, 2021)

Building from the ground up: CarSAR

- Mobile L-band InSAR allows control of temporal baseline, and enables short temporal baseline observations
- CarSAR deployed in Little Cottonwood Canyon during SnowEx 2021, coincident w/ UAVSAR overflights
- Changes in coherence correlated with locations where avalanche control was performed with small releases

Figure 5: Mobile L-band InSAR, built by GAMMA Remote Sensing, deployed on a car.

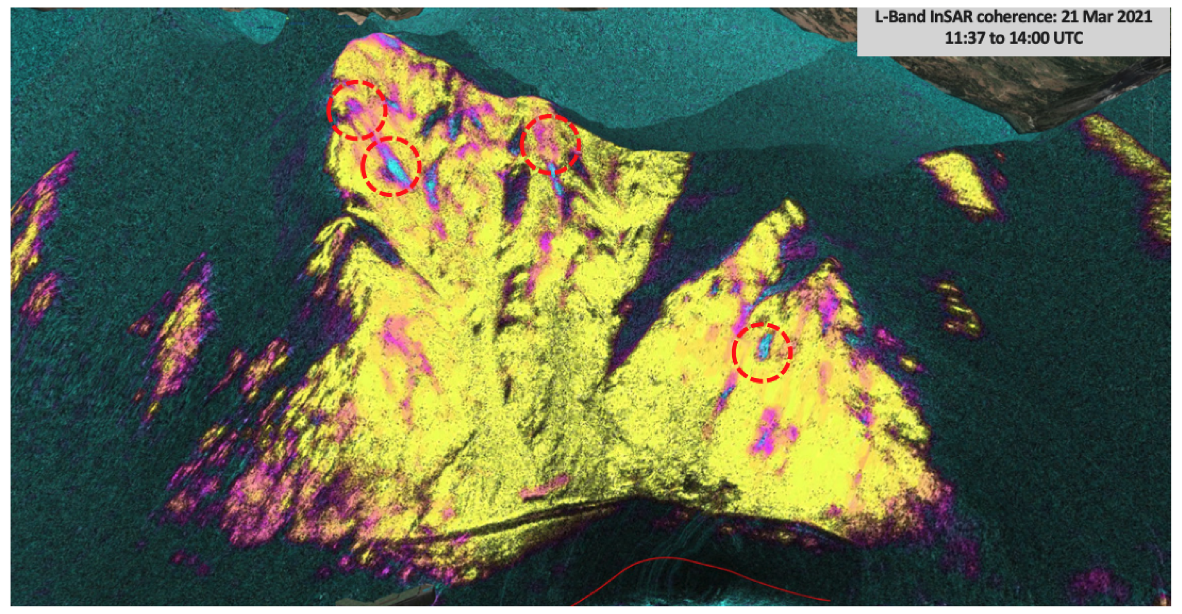

Figure 6: Changes in InSAR coherence indicate areas where avalanche control work was performed.

Airborne L-band InSAR during SnowEx

- Similar to recognition of handwritten numbers

Acknowledgments

This work was funded by the NASA Terrestrial Hydrology Program, grant #NNX17AL61G and U.S. Army CRREL, "Advancement of snow monitoring for water resources, vehicle mobility, and hazard mitigation: using optical, microwave, acoustic, and seismic techniques", # W913E520C0017, and by NASA Terrestrial Hydrology Program, "Spatiotemporal Patterns in Snow Remote Sensing", #NNX17AL61G. The authors thank the UDOT avalanche forecasters in Little Cottonwood Canyon.

References

Deeb, E. J., R. R. Forster, and D. L. Kane, Monitoring snowpack evolution using interferometric synthetic aperture radar on the North Slope of Alaska, USA, *INTERNATIONAL JOURNAL OF REMOTE SENSING*, 32(14), 3985–4003, 2011.

Guneriussen, T., K. Hogda, H. Johnsen, and I. Lauknes, InSAR for estimation of changes in snow water equivalent of dry snow, *IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING*, *39*(10), 2101–2108, 2001.

Havens, S., H. Marshall, J. B. Johnson, and B. Nicholson, Calculating the velocity of a fast-moving snow avalanche using an infrasound array, *Geophysical Research Letters*, *41*(17), 6191–6198, 2014.

Johnson, J., J. Anderson, H. Marshall, S. Havens, and L. Watson, Snow avalanche detection and source constraints made using multiple infrasound sensor arrays, *Journal of Geophysical Research-Earth Surface*, *126*(3), e2020JF005741, 2021.

Marshall, H., E. Deeb, R. Forster, C. Vuyovich, K. Elder, C. Hiemstra, and J. Lund, L-band InSAR depth retrieval during the NASA SnowEx 2020 Campaign: Grand Mesa, Colorado, *Proceedings of the International Geoscience and Remote Sensing Symposium (IGARSS)*, 2021.