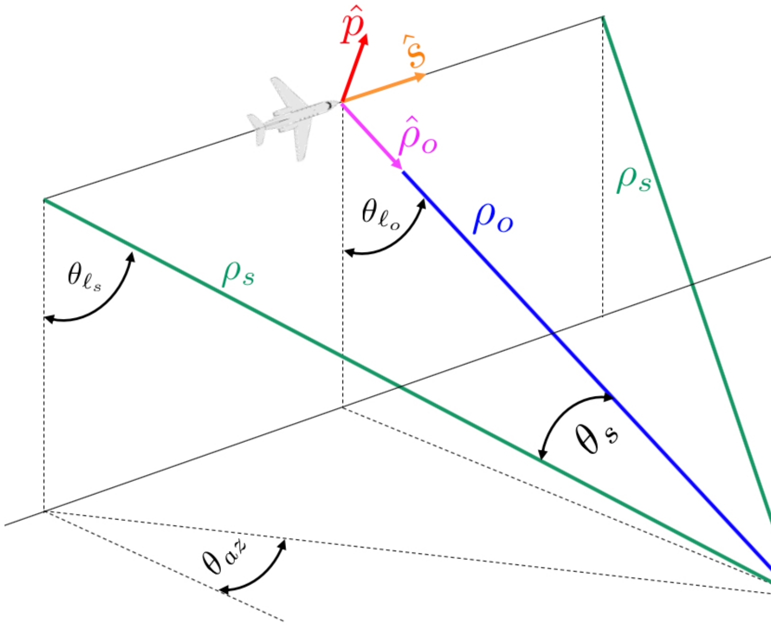
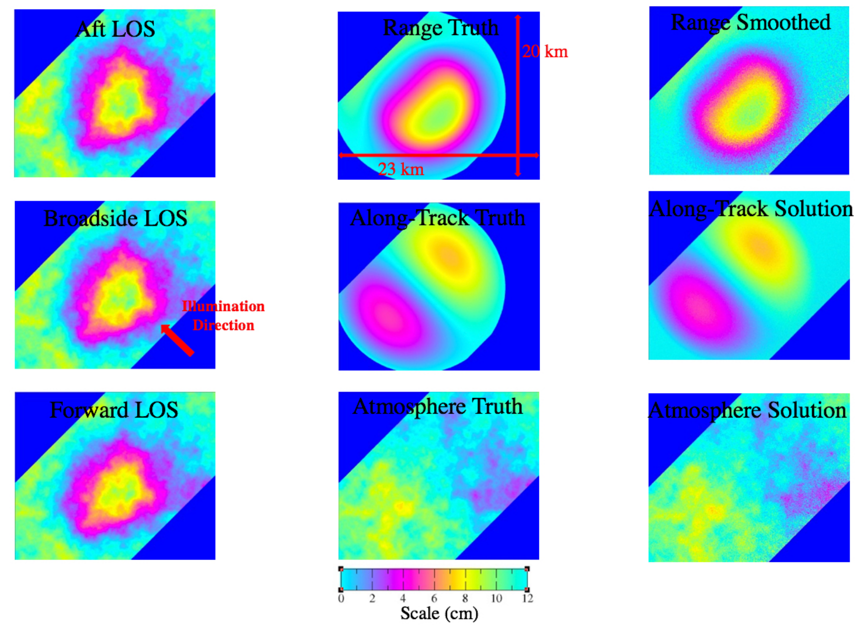




Virtual Research Presentation Conference

Validation of a Multi-Squint Vector Deformation Measurement Concept

Principal Investigator: Scott Hensley (334)
Co-Is: Brian Hawkins (334), Thierry Michel (334), Ron Muellerschoen (334), Curtis Chen (334) and Eric Fielding (329)
Program: Topic

Assigned Presentation # RPC-066

Jet Propulsion Laboratory
California Institute of Technology

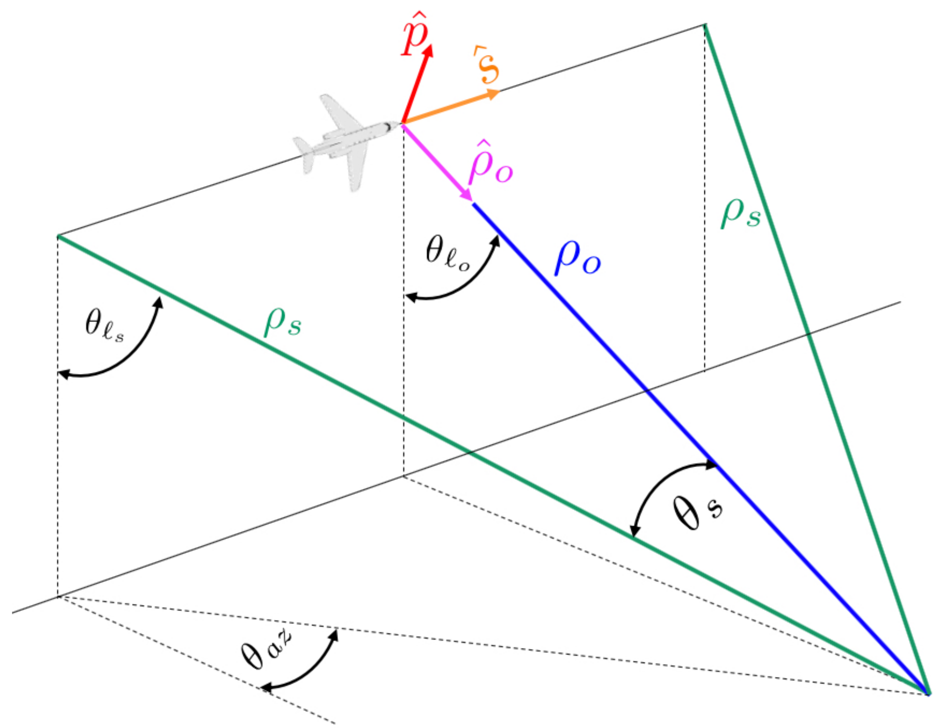
Tutorial Introduction

Abstract

Line-of-sight surface deformation measurements made from interferometric phase measurements are the most sensitive way to measure surface deformation. To obtain full vector deformation measurements, multiple measurements from different line-of-sights are combined to give the deformation vector in the desired reference frame. Any measurement concept that reduces the number of observations or mitigates the impact of atmospheric water variation between observations, a dominant noise source in repeat pass radar interferometry, is highly desired.

UAVSAR, an L-band electronically scanned SAR flown on a NASA GIII aircraft has the capability of acquiring images from 3 aspect angles simultaneously by scanning the beam in azimuth forward, aft and broadside. Using repeat pass multi-squint observations two components of the motion, along-track and line-of-sight along the broadside direction, as well as the atmospheric noise level can be obtained.

We examine the sensitivity of this technique and perform a proof on concept demonstration with UAVSAR multi-squint data collected at the Slumgullion landslide of Colorado.



Problem Description

a) Presently to obtain vector surface deformation measurements, highly desired for understanding and modeling the underlying geophysical processes, requires at least the number observations from aspects and the number of vector components to be determined. This has several disadvantages.

   a) For spaceborne observations the time interval to acquire the needed observations aspects may allow the scene to decorrelate in time or for there be surface deformation between the different aspect observations.

   b) For airborne data there is cost for additional flight hours to acquire all the desired observations.

   c) Water vapor changes between observations is a dominant error source for repeat pass observation and normally requires multiple observations to reduce this noise source. Techniques that can reduce the noise level with fewer observation are highly desired.

b) Relevance to NASA and JPL

   a) For the UAVSAR program this would allow reduced flight hours (hence reduced cost) to obtain vector deformation measurements.

   b) The 2018 Earth Science Decadal Survey report prioritized a designated mission for surface deformation and change with primary science of Earth surface dynamics from earthquakes and landslides to ice sheets and permafrost as one of five designated observables to be implemented following the current generation of missions under development. Multi-squint acquisitions are one of the top mission contenders for providing these measurements for the next generation of satellites beyond NISAR.

Methodology

a) In this research, we exploited the innovative multi-squint capability of the UAVSAR L-band SAR system to measure vector components of surface deformation in the presence of atmospheric noise. Additionally, we use simulated data to quantify the sensitivity to of the technique to wind speed and direction as well the power spectral density profile of the atmospheric water vapor.

b) We developed an analytic expression for the the multi-squint solution as well is its covariance. This showed a sensitivity of the range and atmosphere components to the squint angle that required a better estimation of the residual baseline.

c) We acquired UAVSAR data at Rosamond Lake Bed and the Slumgullion Landslide in Colorado to test the multi-squint technique.

d) The major innovations developed during this research are:

    a) Characterization of wind and the spectral shape of the tropospheric water vapor to the multi-squint solutions.

    b) Developed a new multi-squint residual baseline estimation algorithm.

    c) Demonstrated the multi-squint technique with UAVSAR data.

Results

a) The main results of our research are:

   a) A new analytic formulation of the multi-squint solution showing that the range and atmosphere components of the solution vary a the inverse of the sine of the squint angle squared whereas the along-track component varies only as the inverse of the sine of the squint angle. This dependence means the there is more sensitivity to error sources in these components compared to the along-track direction.

   b) We characterized the sensitivity of the solutions to the ”frozen-slab” approximation to the atmosphere to wind speed an direction and to the shape of Kolmogorov spectrum of the atmospheric water vapor. We showed as the wind speed becomes larger than 3-5 m/s the error dramatically increases.

   c) We showed that the range and atmosphere components are extremely sensitive to residual baseline estimation and developed a new multi-squint residual baseline estimation procedure to mitigate this sensitivity.

   d) Demonstrated the capability to extract the along-track component of the deformation from multi-squint data acquired at the Slumgullion landslide of Colorado.

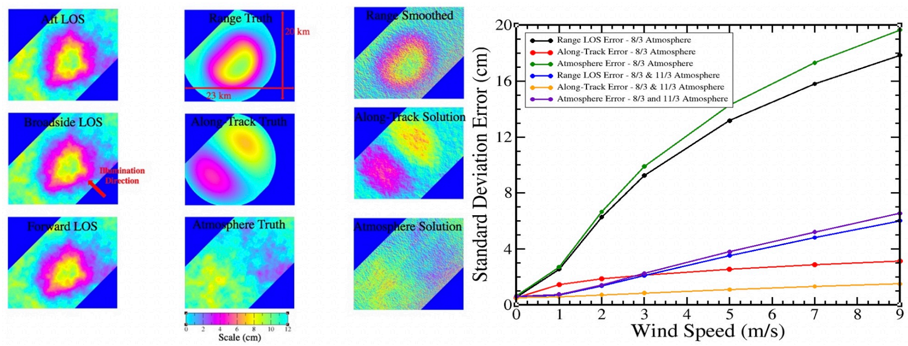
b) Significance

   a) The technique could greatly reduce the number of observations either for airborne or spaceborne data to acquire vector deformation measurements and reduce atmospheric noise.

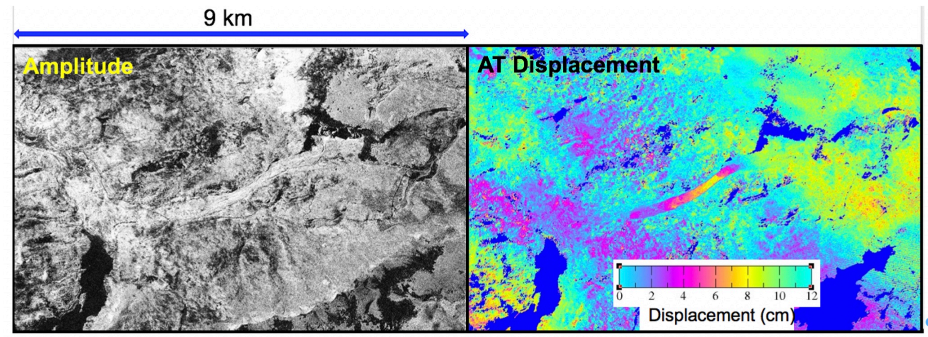
c) Next Step

   a) We still have some residual error that is affecting the range and atmosphere components of the retrieval that don’t show up in our simulations. We were unable to pin down the source suing point target simulated data. We need to finish analyzing this data.

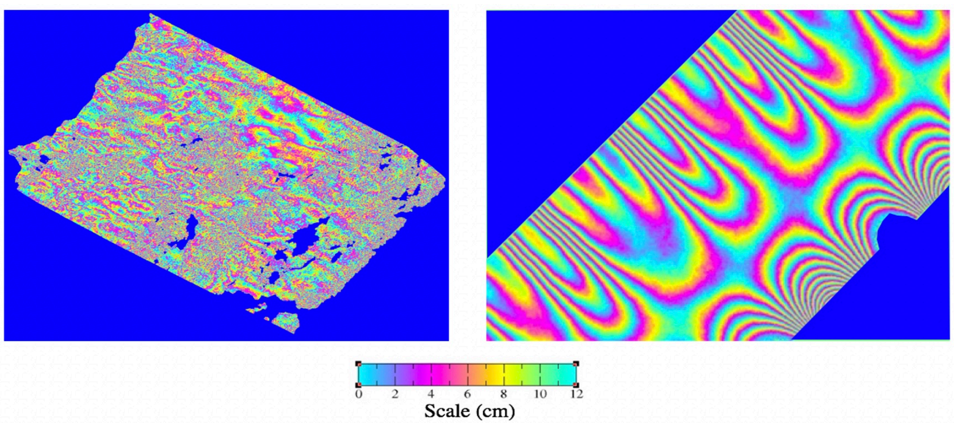
Representative Results



Wind Speed Characterization



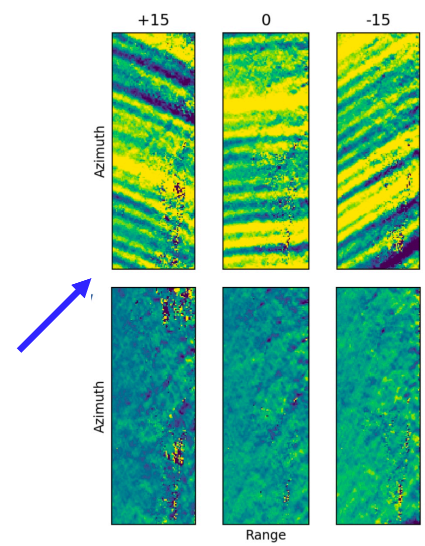
Slumgullion Demonstration



Residual Baseline Errors and Estimation

Multi-squint data processed to common radar coordinate grid.

Azimuth co-registration offsets before/after residual motion estimation (±15 cm color scale).



Publications and References

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[4] Monahan, A.H., Y. He, N. McFarlane, and A. Dai, 2011: *The Probability Distribution of Land Surface Wind Speeds,* J. Climate, 24, 3892–3909.

[5] Brian Hawkins, Thierry Michel, and Scott Hensley, *Residual Motion Estimation for Multi-Squint Airborne SAR*, Proceeding of IGARSS 2020, Virtual Conference, Sept. 2020.