Processing and features of Ku-band SAR data over Trail Valley Creek from 2018-19 field season

Environment and Climate Change Canada / Environnement et Changement climatique Canada

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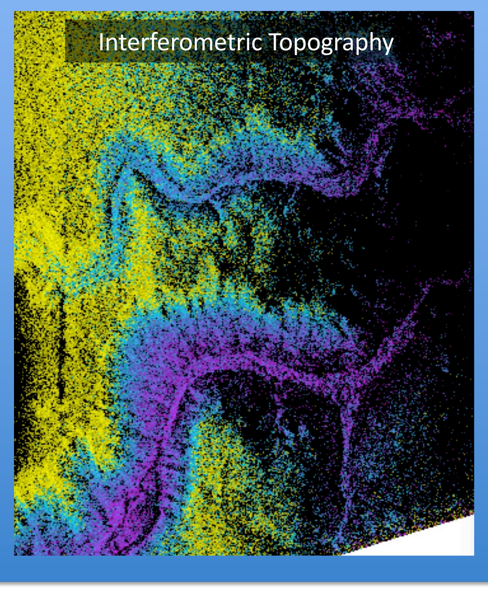
Introduction

In 2018, the University of Massachusetts, and Environment and Climate Change Canada partnered to develop and deploy a Ku-band SAR for the 2018-2019 winter season at Trail Valley Creek (TVC). The intent was to make repeated airborne measurements during the intensive operational periods of November, January and March, to use airborne SAR measurements in conjunction with ground validation and satellite measurements for creating a spatial map of snow characteristics over the region.

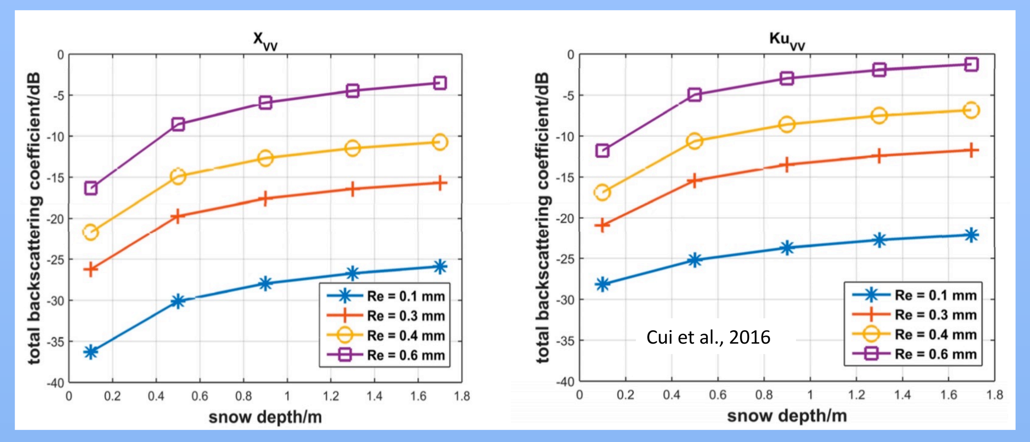
Prior to this effort, the UMass Ku-band system had been only locally deployed and had not be flown on an aircraft. The ECCC TVC experiment, supported by the Canadian Space Agency and seed funding from NASA's Terrestrial Hydrology program, the Ku-band system was adapted to a Cessna 208 (Caravan) platform and integrated with aircraft power and a GPS/INU system supplied by UMass.



Applications

The primary driver for the current effort is part of the proposed Dual-Frequency Ku-band Terrestrial Snow Mass Mission being explored by ECCC, CSA, the University of Massachusetts and Wilfred-Laurier University.

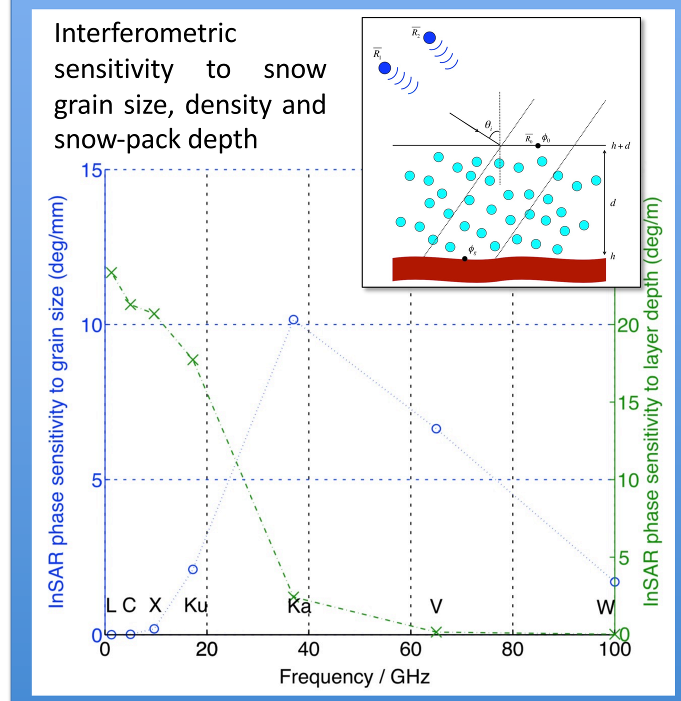
The mission concept relies primarily on the backscatter sensitivity to snow grain size and snow depth. By making measurements at two, closely-spaced frequencies (e.g. X- and Ku-band), it will be possible to estimate these snow-pack properties (Cui et al., 2016)

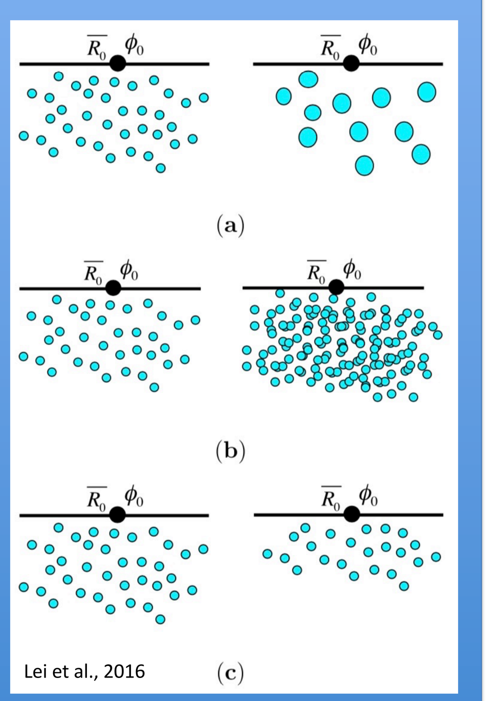


Similar studies (Lei et al., 2016) have shown that in addition to the radar cross-section signature, that interferometric SAR can also be used for exploring characteristics of the snow pack.

Coherent dense-media modeling of the snow pack in terms of grain size, grain density and snow depth (parts a, b and c of the lower right figure below) shows that the X-, Ku- and Ka-band InSAR signature of correlation magnitude and phase can be used to estimate these properties of the snow pack.

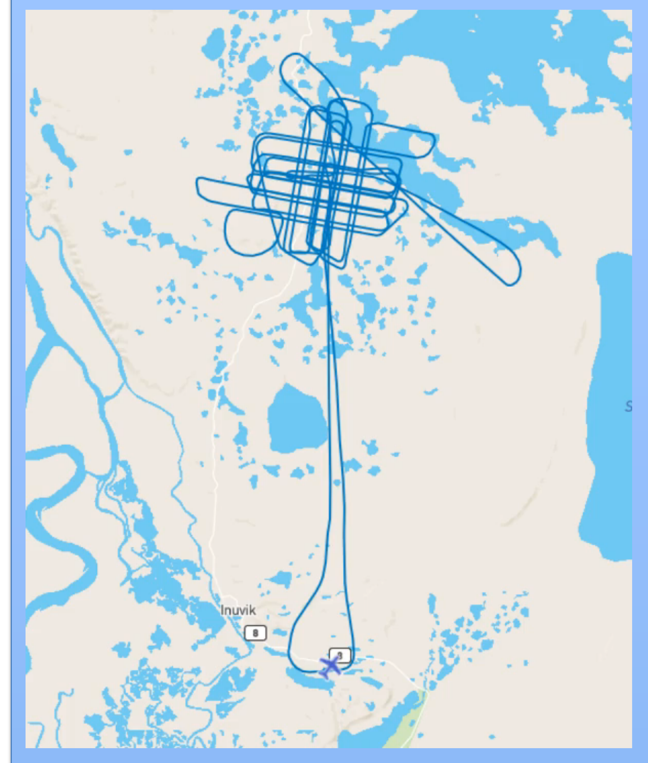
Interferometric sensitivity to snow grain size, density and snow-pack depth

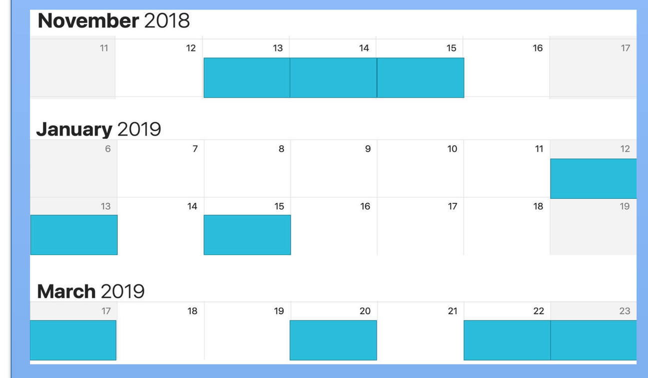




- Cui, Yurong, Chuan Xiong, Juha Lemmetyinen, Jiancheng Shi, Lingmei Jiang, Bin Peng, Huixuan Li, Tianjie Zhao, Dabin Ji, and Tongxi Hu. "Estimating Snow Water Equivalent with backscattering at X and Ku band based on absorption loss." Remote Sensing 8, no. 6 (2016): 505.
- Lei, Yang, Paul Siqueira, and Robert Treuhaft. "A dense medium electromagnetic scattering model for the InSAR correlation of snow." Radio Science 51, no. 5 (2016): 461-480

Data

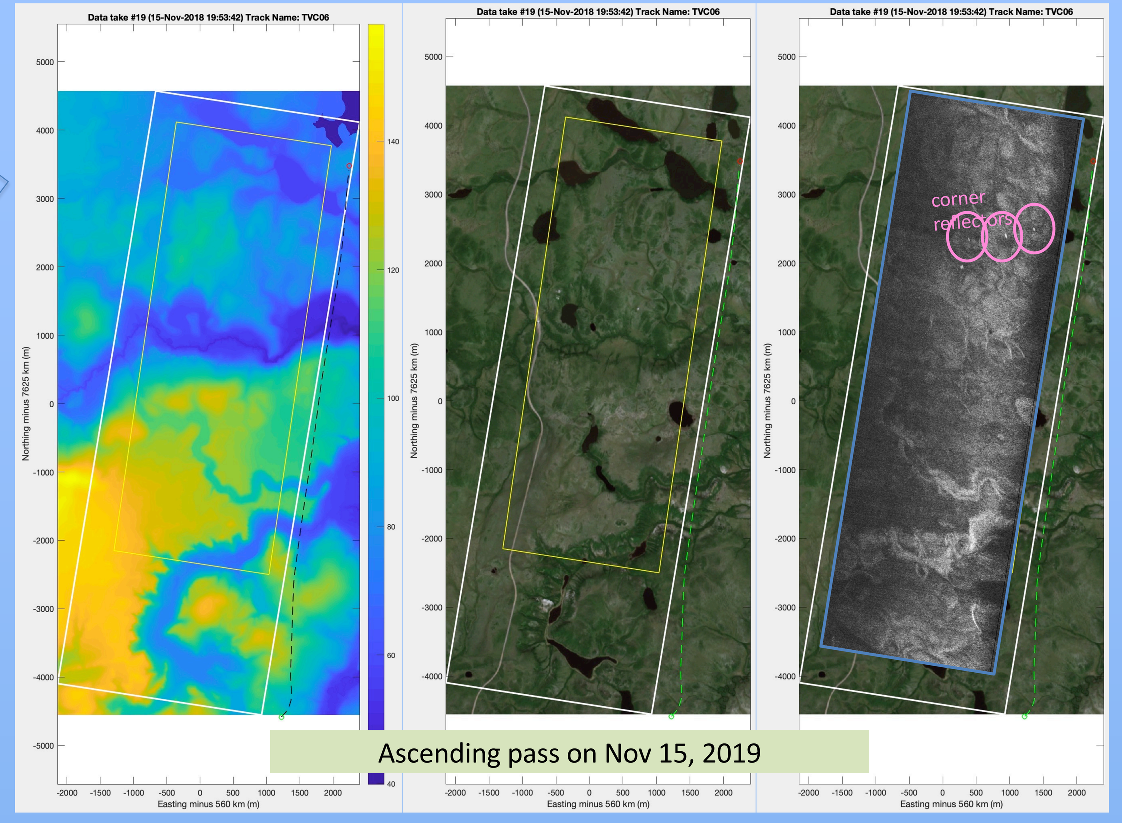




Data were collected over three intensive observation periods in the Trail Valley Creek region, near Inuvik in NWT, Canada. A dense grid if overflights assured that sufficient collections were made over the site.

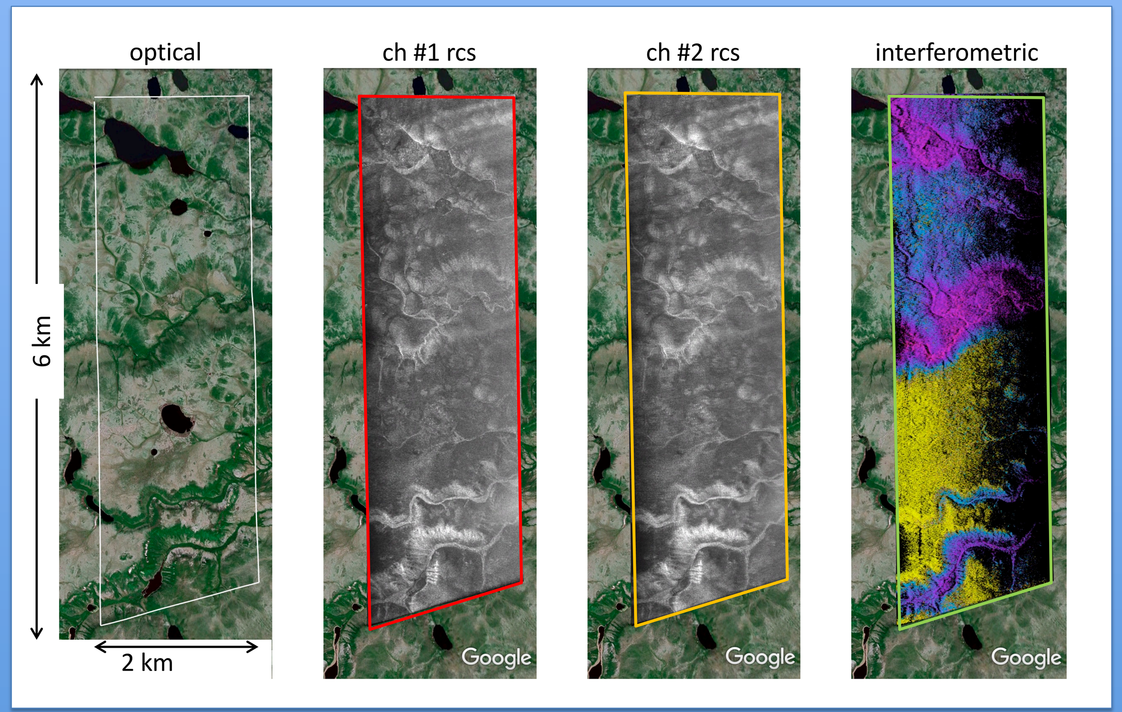
Putting the data into a geographic context

The path of the Cessna 208 platform is overlain onto the DEM and optical imagery to understand the landcover and to begin the focused SAR processing

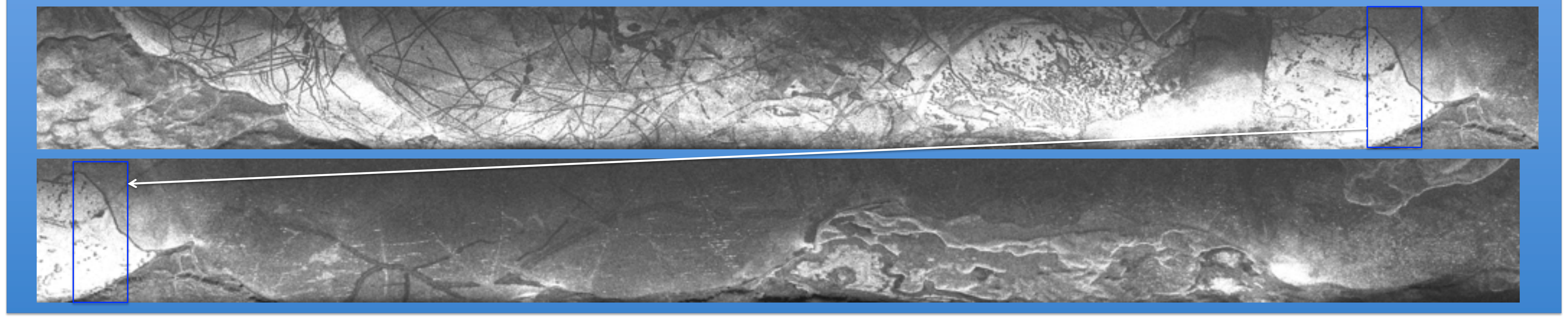


Unfocused SAR images are made for all data takes to get an idea of basic performance and signal to noise characteristics. Focusing of the SAR to its highest resolution requires incorporating motion data, a DEM, and a time-domain processor to take into account all effects in the observing process. Below, Ku-band data are shown in ground-projected radar coordinates, also known as stripmap data)

Since last year at this time, we have made significant progress in the processing of SAR data, and are now able to systematically generate two channels of radar cross section (one for each antenna of the interferometric pair), and a SAR ointerferogram (far right) that shows the interferometric correlation magnitude and the interferometric phase (propostional to the topography; see the panel at far right).



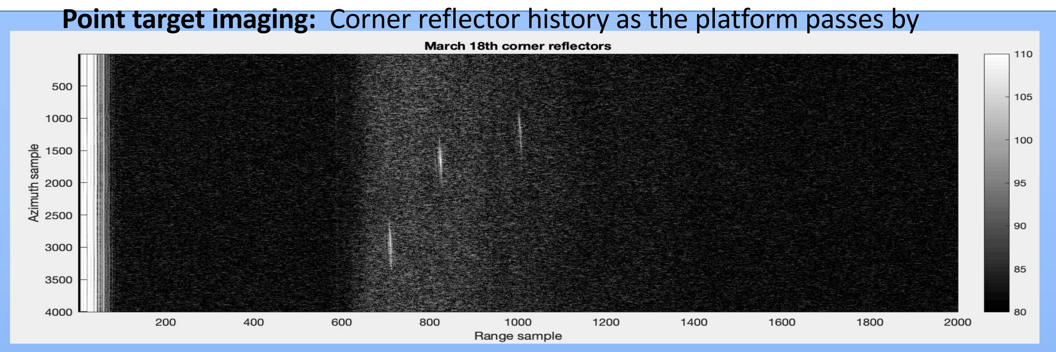
Another example of the long data takes is shown over the lake region to the northeast of TVC (see optical image above).



Focusing of SAR data

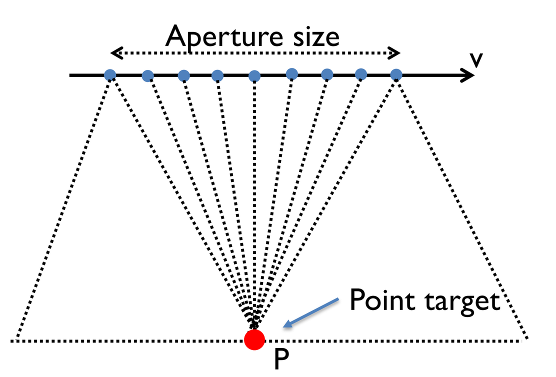
The focusing of the radar data into SAR imagery takes place by accounting for the changing distance and Doppler history of the radar as it passes by targets in the systems field of view. This requires precise knowledge of the aircraft position, attitude and antenna pointing. For this purpose, point targets such as deployed corner reflectors are use for adjusting and monitoring the success of this focusing.

Point target imaging: Corner reflector history as the platform passes by

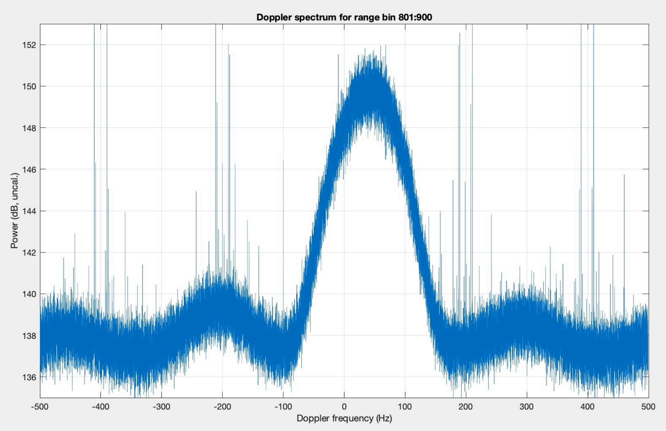


Plot of antenna position during SAR imaging

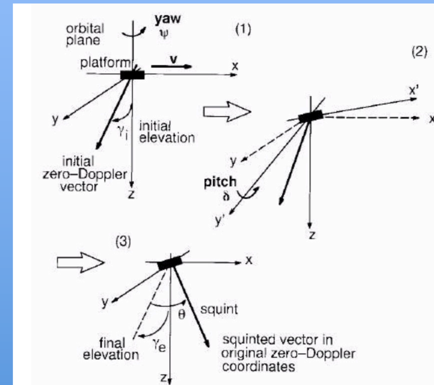
At each position, both magnitude and phase of echoes are recorded. Thus a 'synthetic' antenna array or 'aperture' is formed.



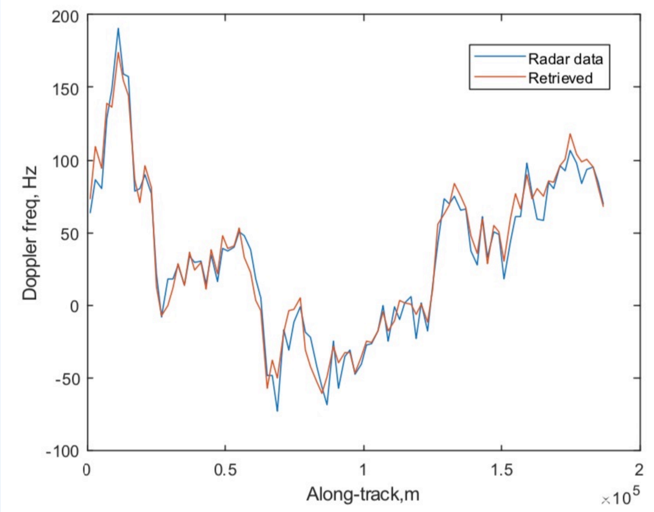
Synthesized aperture size resolution is:
$\lambda / (2\lambda/L*R) * R = L / 2$
L is the antenna length (1m)



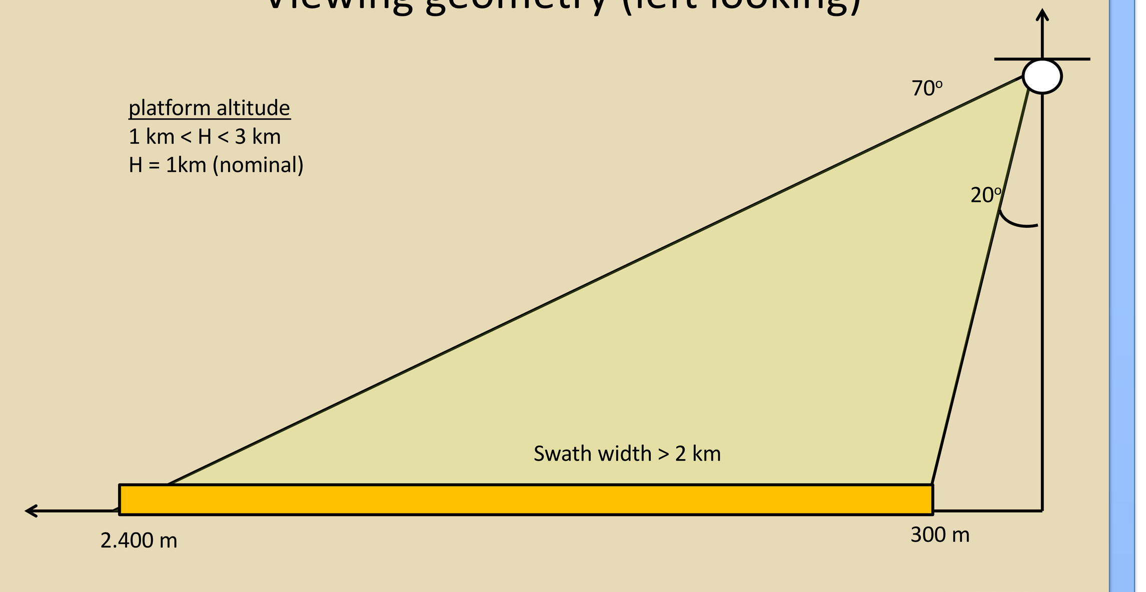
A plot of the Doppler shift indicates a forward squint (positive Doppler) for this particular data collection. Doppler spectra such as this are used for determining the precise attitude of the antennas with respect to the aircraft.

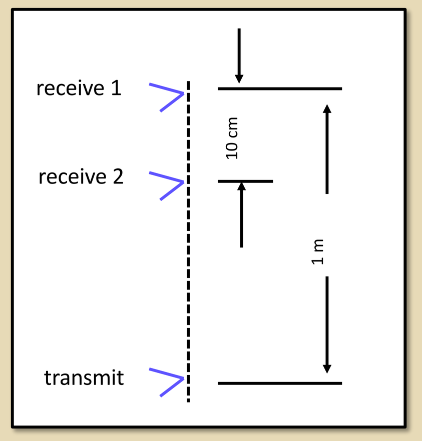


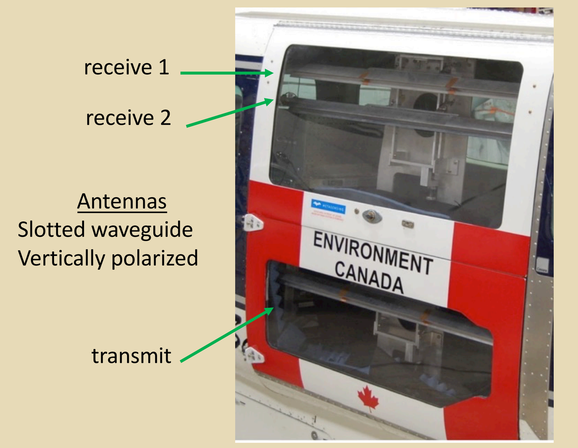
Platform attitude estimation. The Doppler history is used to refine estimates of the platform attitude, a necessary step in further processing)



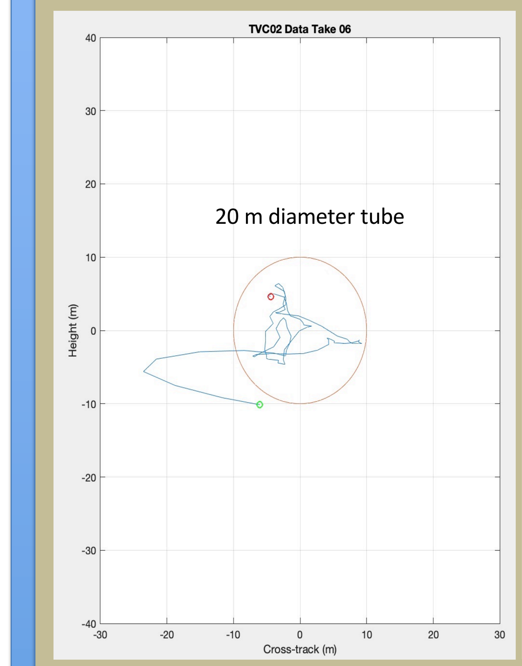
Viewing geometry (left looking)





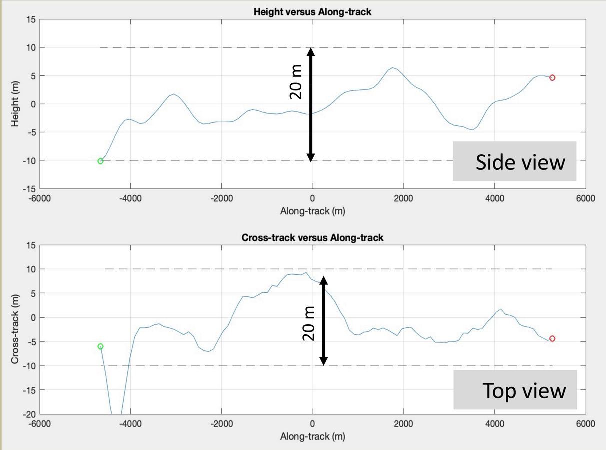


Motion measurement and control

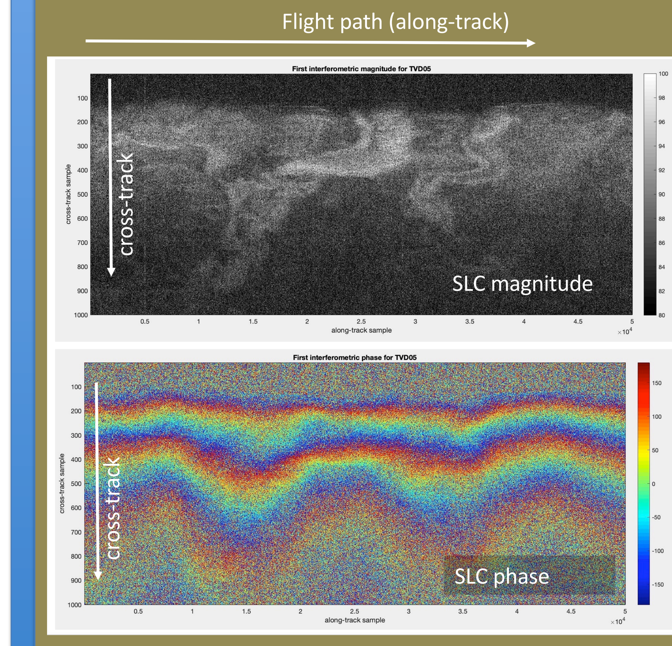


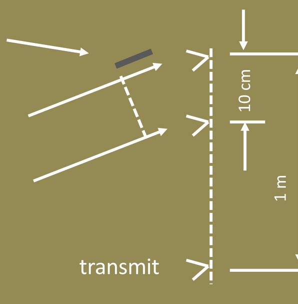
Aircraft motion is controlled by the pilot. Motion measurement is achieved through a Novatel SPAN GPS/IMU that measures platform position to better than 10mm position and 10 mdeg attitude.

A 20m diameter tube (dashed lines) is used to gauge flight control accuracy during a data take



Interferometric data





Differential path length, as a function of the look angle, leads to interferometric fringes in the cross-track direction.

Changing phase as a function of the flight path, can be converted into topography and estimates of the snow depth

Next Steps

Prior to the November flights over TVC, the system had flown only one time before, in the Muskoka region of Canada, in order to test basic capabilities.

Now that the science data are collected we are continuing to process data form the campaign. The next steps are to finish processing the data and make it available to users.

Those wishing to download data sets can visit the UMass website:

https://umass.box.com/v/UMass-TVC-data

This website will be updated as processing continues.
Inquiries about the data and instrument can be sent to: siqueira@umass.edu