Linear Infrastructure & Permafrost Monitoring with Airborne SAR & Photogrammetry Data

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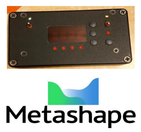
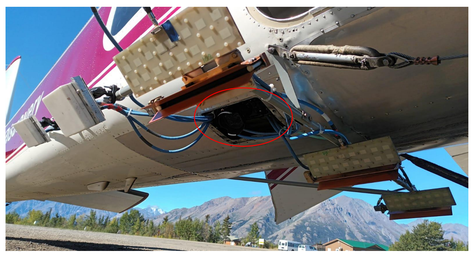
INTRODUCTION

We are exploring full spectrum of single platform based airborne SAR and Optical data fusion scenarios for direct / indirect change detection in permafrost regions. We are producing high precision photogrammetric DEMs, to map direct change in the region of interest over a certain period. These DEMs also serve as a reference surface for interferometric and tomographic SAR applications. Photogrammetric block adjustment parameters can fine-adjust the flight trajectory for enhanced motion compensation for repeat pass Interferometric SAR, thus producing high precision interferometric change detection maps for the area.

EXPERIMENTAL SETUP

- Tri Band (L, X & C) SAR Sensor.
- Fodar (Photogrammetry system)
  - Nikon D850 and Intervalometer





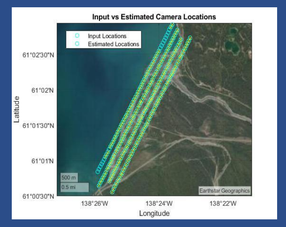
OBJECTIVES

- Linear Infrastructure and Permafrost Monitoring
  - Direct and Indirect change analysis
- Enhanced SAR Motion Compensation
  - Improved SAR/InSAR product accuracy
- SAR/Optical Fusion
  - Land Cover / Land Use Segmentation
  - Change Detection for focused land types, etc

Area of Interest

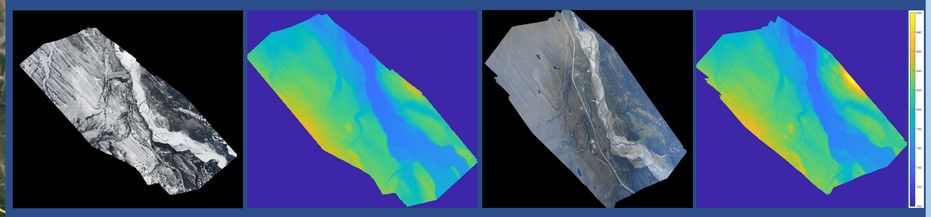
Alaska Canada Highway,
near Kluane Lake, Silver City, Yukon

Fodar/SAR Acquisition Profile



Orthomosaic

Silver City Airstrip DEM



April, 2022 Orthomosaic & DEM

August 2022 Orthomosaic & DEM

Fodar Processing Chain

Step 1: Camera Acquisitions (Nikon D850)

Step 2: Camera Flash Event Recording with GPS stamp (Intervalometer)

Step 3: GPS/IMU/ Intervalometer processing (Inertial Explorer®)

Step 4: Image association with camera positions (Python)

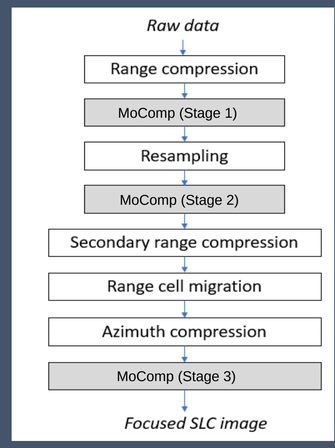
Step 5: Photogrammetric Processing (SfM) (Agisoft Metashape®)

Step 6: Exporting DEM and Camera position Etimations

Outputs

- High Resolution DEMs – ~10x10 cm^2
  - Time series analysis – Direct Change
  - DEMs as reference surface for SAR/InSAR
- Motion compensation estimates for orbit refinement of Airborne SAR / InSAR (Block adjustment parameters)
  - Refined Interferometric measurements
  - Precise change detection – InSAR stack analysis

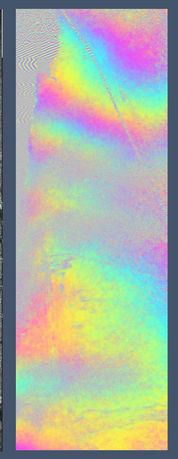
SAR Processing Chain



Optical Image

SAR Image

Interferrogram



Conclusion / Future Goals

- Motion Estimates from Photogrammetric block adjustment has improvement potential – yet to be tested
- Direct Change resulting from fodar DEM timeseries analysis can be a strong tool at submeter scale – under investigation
- Incorporation of Fodar DEMs into SAR/InSAR chain
- Data augmentation with spaceborne datasets

Challenges

- Software Bugs in the flight guidance led us to acquiring the data at wrong heights
  - Interferometry might not be possible between various 2020, 2021 & 2022 collects
- Ground Station not available in Aug 2020
  - Differential GPS processing not possible
  - PPP not super precise
- Covid related field work restrictions

Radar Specs (SlimSAR – X and L Band, microASAR – C Band)

Parameter	X-band	L-band	C-band
Waveform	Pulsed LFM	Pulsed LFM	LFM-CW
Frequency (GHz)	9.35 – 9.65	1.215 – 1.4	5.43
Max. Bandwidth (MHz)	245	185	160
Transmit Power (W)	25 (+ 50 w/ amplifier)	60	1.0
Antennas	1 Tx, 2 Rx	2 Rx/Tx	1 Tx, 2 Rx
Polarizations	VV	HH, HV, VH, VV	VV

Successes

- First Winter Campaign in April 2022
- Radarsat-2 Ultra-Wide Stack of 1 year (13.5mx7.7m)
- 3 years worth of Summer Campaign data
- Fodar DEM should still be usable

ACKNOWLEDGMENTS

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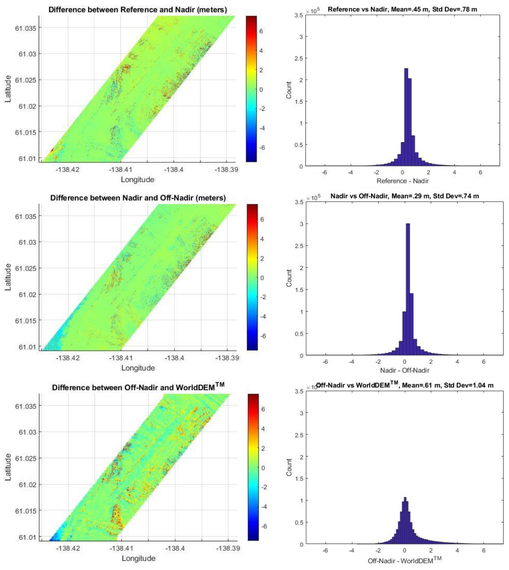
RESULTS - FODAR



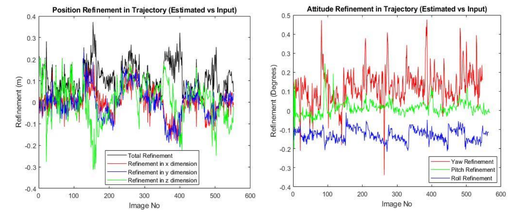
Nadir vs Reference
Mean 0.45 m Std Dev 0.78 m

Oblique Vs Nadir
Mean 0.29 m Std Dev 0.74 m

Oblique vs WorldDEM™
Mean 0.61 m Std Dev 1.04 m

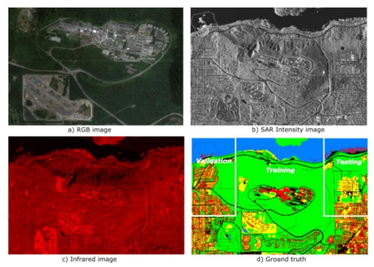
Mean Refinement (meters)
Mean – 0.3 m
Std Dev – 0.09 m

Attitude Refinement (degrees)
Yaw – 0.13 deg
Pitch – 0.05 deg
Roll – -0.14 deg



Control Point	fodar™ DEM	Nadir DEM	Off-Nadir DEM	Trimble R7 Measurement
1.	799.74 m	799.68 m	799.78 m	799.90 m
2.	799.32 m	799.45 m	799.25 m	799.00 m
3.	800.31 m	800.25 m	799.98 m	800.55 m

RESULTS – SAR/OPTICAL FUSION



Publications:

1. U. I. Ahmed, B. Rabus and M. Kubanski, "Off-Nadir Photogrammetry for Airborne SAR Motion Compensation: A First Step," *2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS*, 2021, pp. 8519-8522, doi: 10.1109/IGARSS47720.2021.9553861.
2. U. I. Ahmed, A. Velasco and B. Rabus, "Semantic Segmentation of Land Use / Land Cover (LU/LC) Types Using F-CNNS on Multi-Sensor (Radar-IR-Optical) Image Data," *2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS*, 2021, pp. 4700-4703, doi: 10.1109/IGARSS47720.2021.9554051.