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SARlab

Linear Infrastructure and Permafrost Monitoring with Airborne SAR and Optical System – Theme 2

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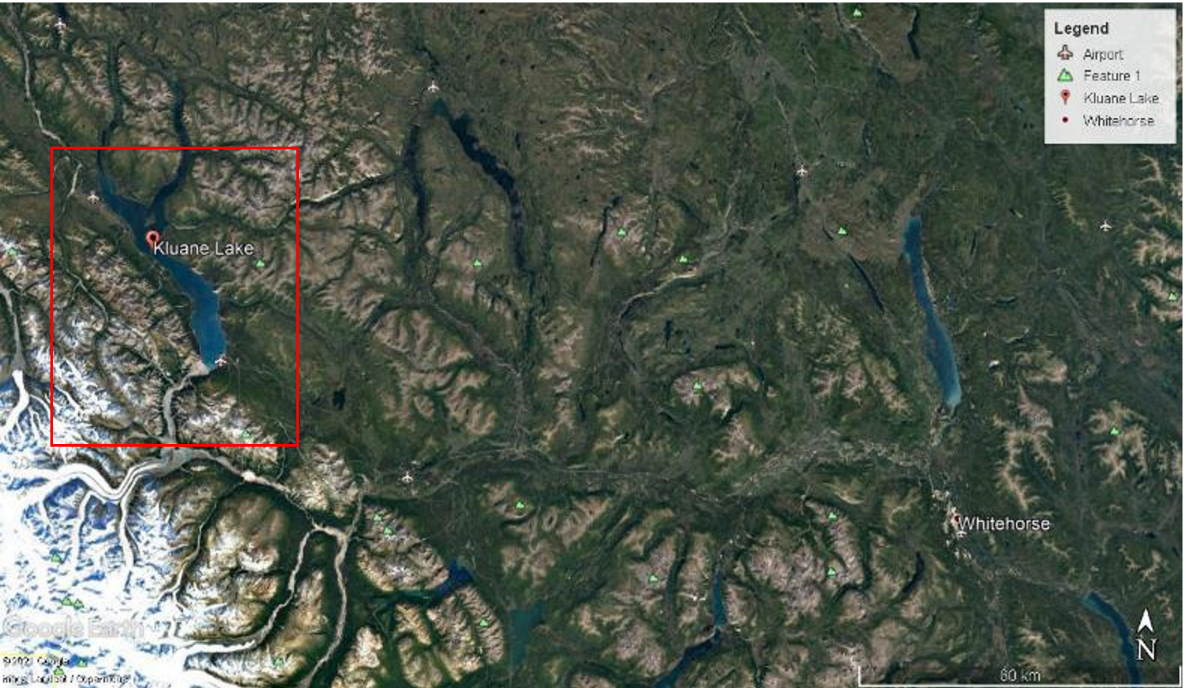
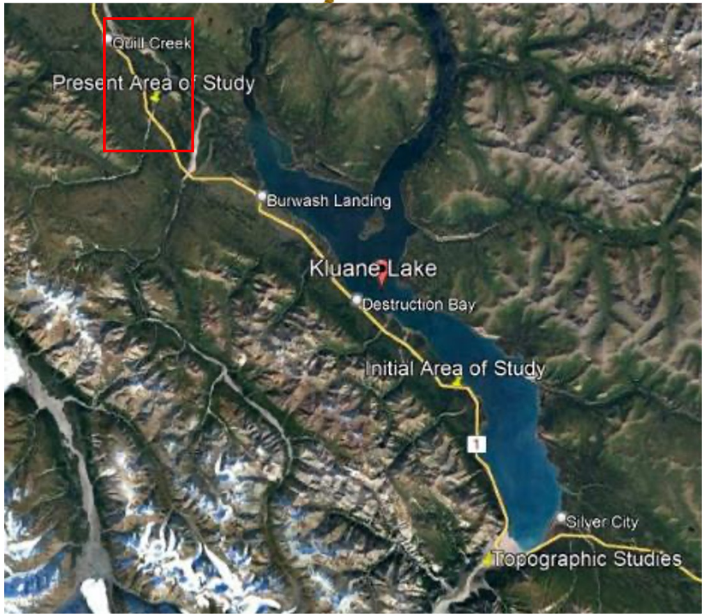
Area of Interest (AOI)

Base Station : Silver City Airstrip Near Kluane Lake, Yukon
Area of Interest : Alaska Highway near northern part of the Lake





Silver City Air Strip

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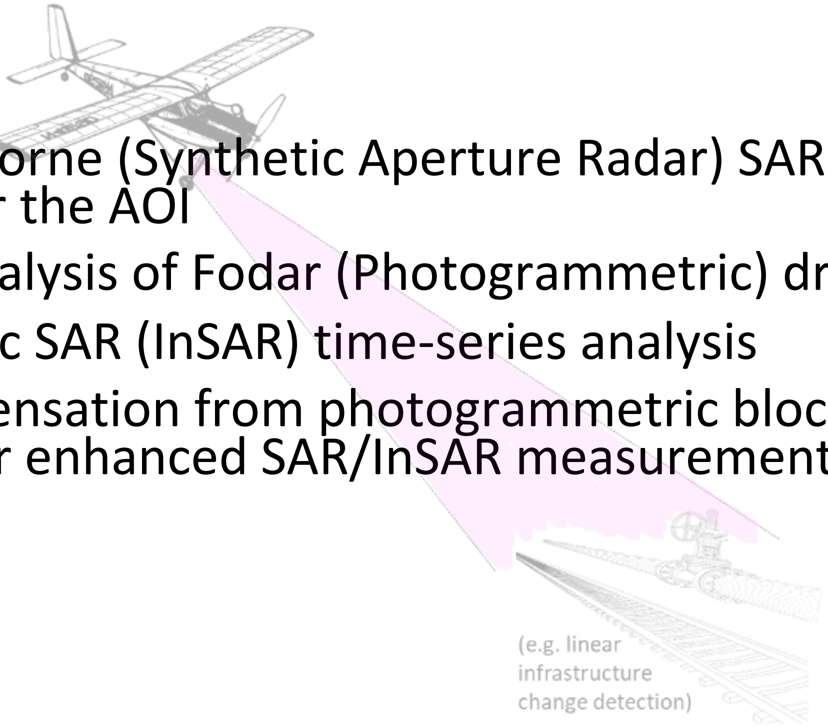
Methodology



- Bi-Annual Airborne (Synthetic Aperture Radar) SAR and Optical Data collection over the AOI
- Time series analysis of Fodar (Photogrammetric) driven DEMS
- Interferometric SAR (InSAR) time-series analysis
- Motion Compensation from photogrammetric block adjustment parameters for enhanced SAR/InSAR measurements

Research Objective

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

System Specifications and Configuration

- Fodar (Optical System)
  - **System Components**
    - DSLR Camera (Nikon-D850)
    - Intervalometer
      - Synchronizes the Camera Flash events with the IMU data
    - Inertial Measurement Unit (IMU)
    - Agisoft Metashape® Professional Edition
      - Processing the photogrammetric data
  - **System Configuration**
    - Oblique Looking vs Nadir Looking (Conventional)
      - Co-incident Optical and SAR footprint
      - More sensor fusion potential

Nikon
D850

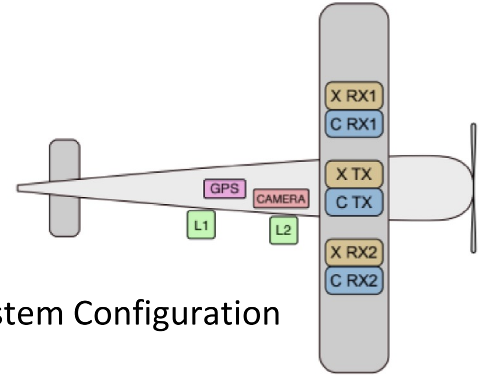
IMU

Intervalometer

Metashape

System Specifications and Configuration

- SAR System – SlimSAR (X & L Band) and MicroASAR (C Band)
  - C & X Band in Across Track Configuration
    - Snow Penetration and Topography Generation etc
  - L-Band Along Track Configuration
    - Radial Velocity and Motion Compensation etc
  - Repeat Pass for Deformation Monitoring



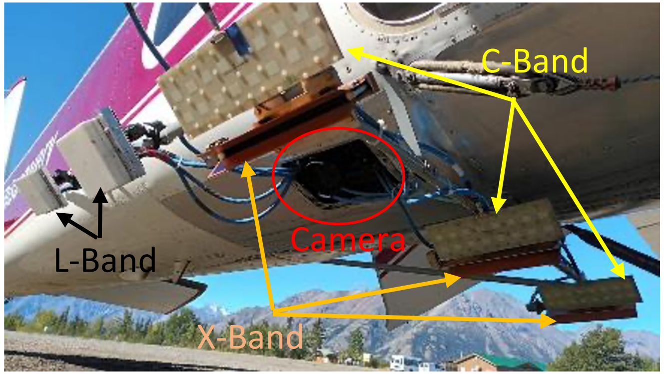
System Configuration

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

System Specifications

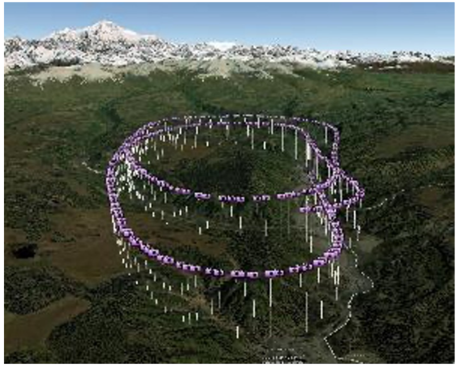
Experimental Setup

- Transport Canada Certified Mounts
- Helio-courier (propeller driven aircraft)
  - Operated IceField Discovery
    - Tourist flight operators



Fodar™

- Foto Detection and Ranging
- Photogrammetry Technique
  - Structure from Motion (SfM)
- Courtesy Fairbanks Fodar™ - Dr. Matt Nolan
- Different from conventional photogrammetry
  - COTS small format camera (DSLR) vs Sophisticated Photogrammetric Imagers
  - On-boards survey grade GPS/IMU vs Ground Control Points (GCPs) for georeferencing



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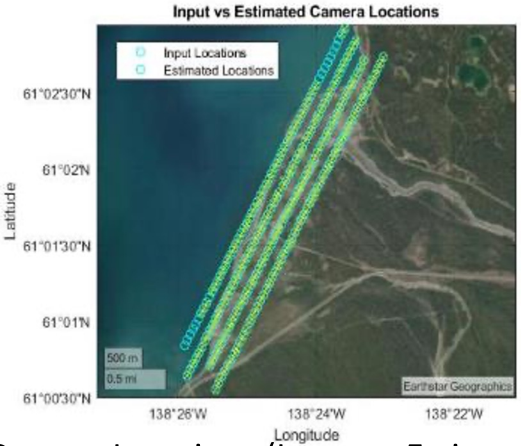
Fodar Outputs & Research Objectives

Outputs:

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

Fodar Benchmarking



Camera Locations (Input vs Estimated)

Nadir vs Reference

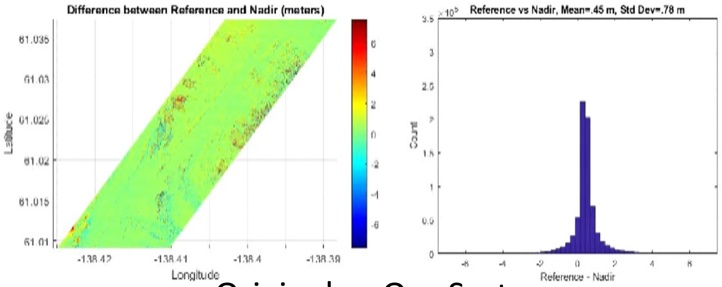
Mean 0.45 m Std Dev 0.78 m

Oblique Vs Nadir

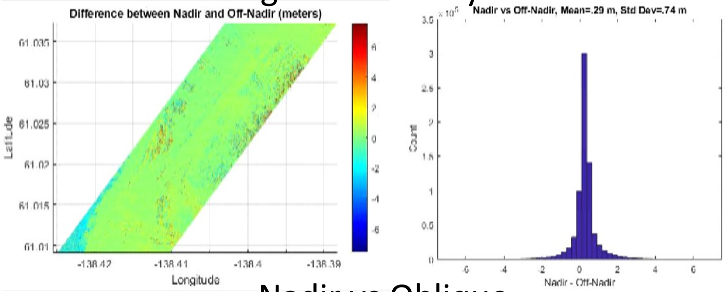
Mean 0.29 m Std Dev 0.74 m

Oblique vs WorldDEM™

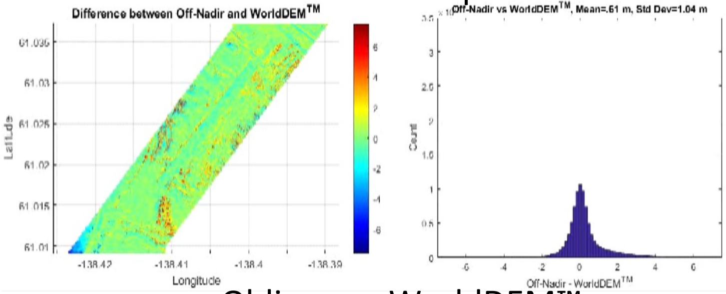
Mean 0.61 m Std Dev 1.04 m



Original vs Our System



Nadir vs Oblique



Oblique vs WorldDEM™

Ortho-mosaic

DEM

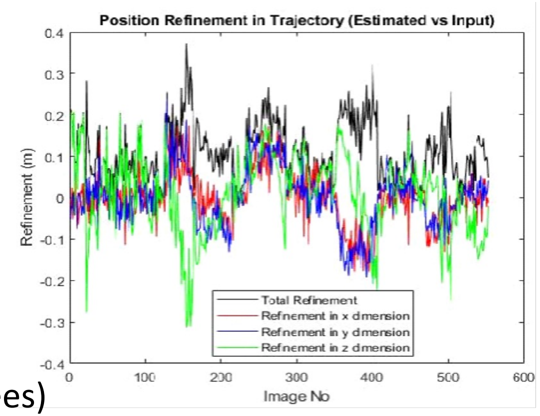
Motion Compensation Potential

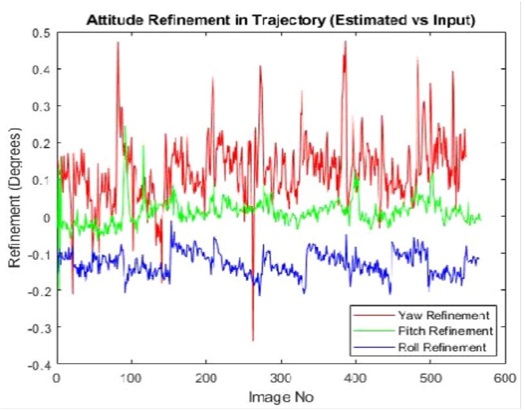
Mean Refinement (meters)

- Mean – 0.3 m
- Std Dev – 0.09 m

Attitude Refinement (degrees)

- Yaw – 0.13 deg
- Pitch – 0.05 deg
- Roll – -0.14 deg

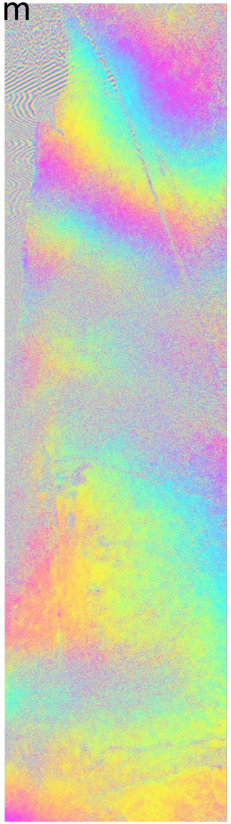




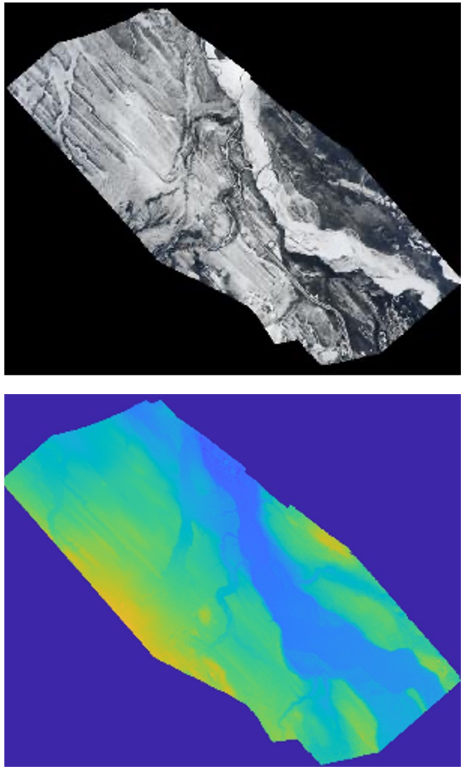
Ortho-mosaic

SLC

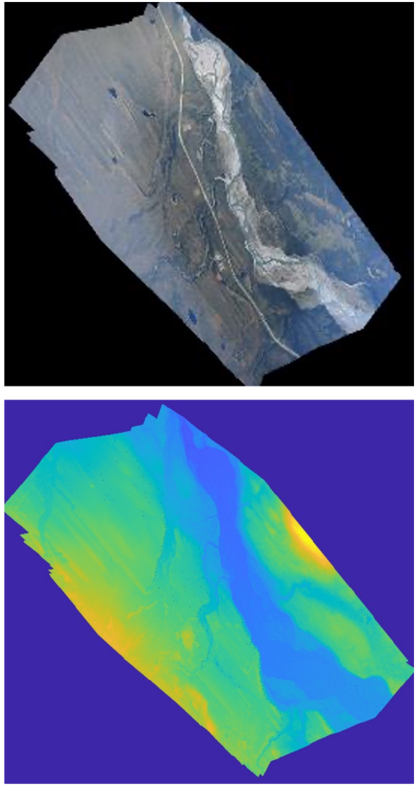
Interferrogram



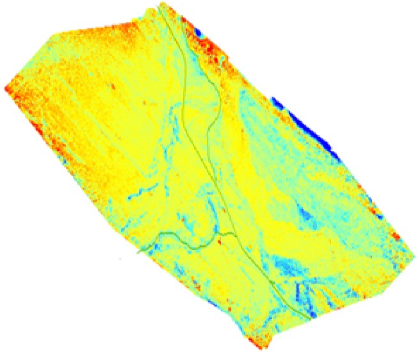
Fodar Analysis over Northern Site (Under Investigation)



April 2022 Orthomosaic & DEM



August 2022 Orthomosaic & DEM



Difference of the DEMs

Future Work

- Motion Estimates from Photogrammetric block adjustment has improvement potential – yet to be tested
- Direct Change resulting from fodar DEM time-series analysis can be a strong tool at submeter scale – under investigation