

INTRODUCTION

We aim to exploit synergy in SAR and Optical data for direct / indirect change detection in permafrost areas. High precision photogrammetric DEMs from airborne optical surveys can be used for direct change analyses. These DEMs also serve as a reference surface for Airborne SAR and interferometric SAR (InSAR) 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. Moreover, spaceborne SAR based timeseries analysis can augment the airborne results at a higher temporal but lower spatial resolution.

EXPERIMENTAL SETUP

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

METHODOLOGY

- Bi-Annual airborne SAR and Optical Data collection over the AOI
- Time series analysis of Fodar (Photogrammetric) driven DEMs
- Interferometric SAR (InSAR) timeseries analysis (Airborne/Spaceborne)
- Motion Compensation from photogrammetric block adjustment parameters for enhanced outputs

OBJECTIVES

- Linear Infrastructure and Permafrost Monitoring
- Direct and Indirect change analysis
- Enhanced SAR Motion Compensation
- Improved SAR/InSAR Accuracy
- SAR/Optical Fusion
- Land Cover / Land Use Segmentation
- Enhanced Change Maps

CHALLENGES

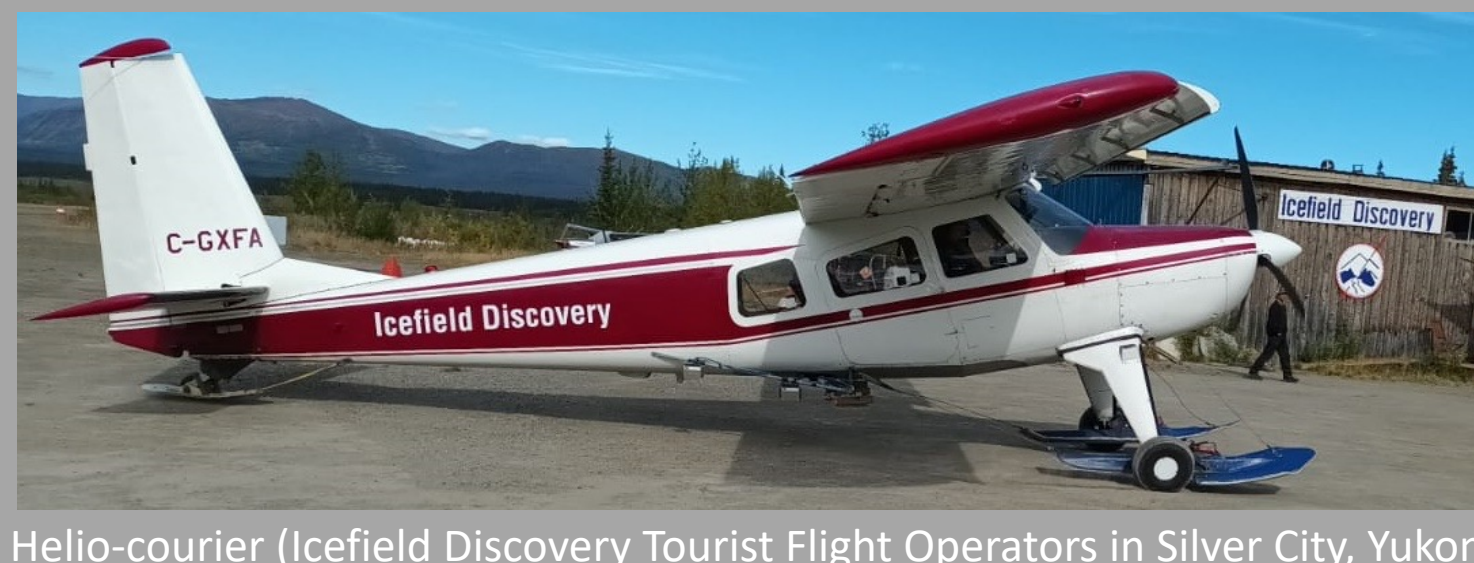
- Fodar DEMs repeatability issues
- Software Bugs led to data acquisition at different heights
- Interferometry not possible in-between various campaigns
- Ground Station not available in Aug 2020
- Differential GPS processing not possible PPP not as precise
- Covid related field work restrictions
- Aircraft engine malfunctioning
- Future campaigns might be affected

AREA OF INTEREST

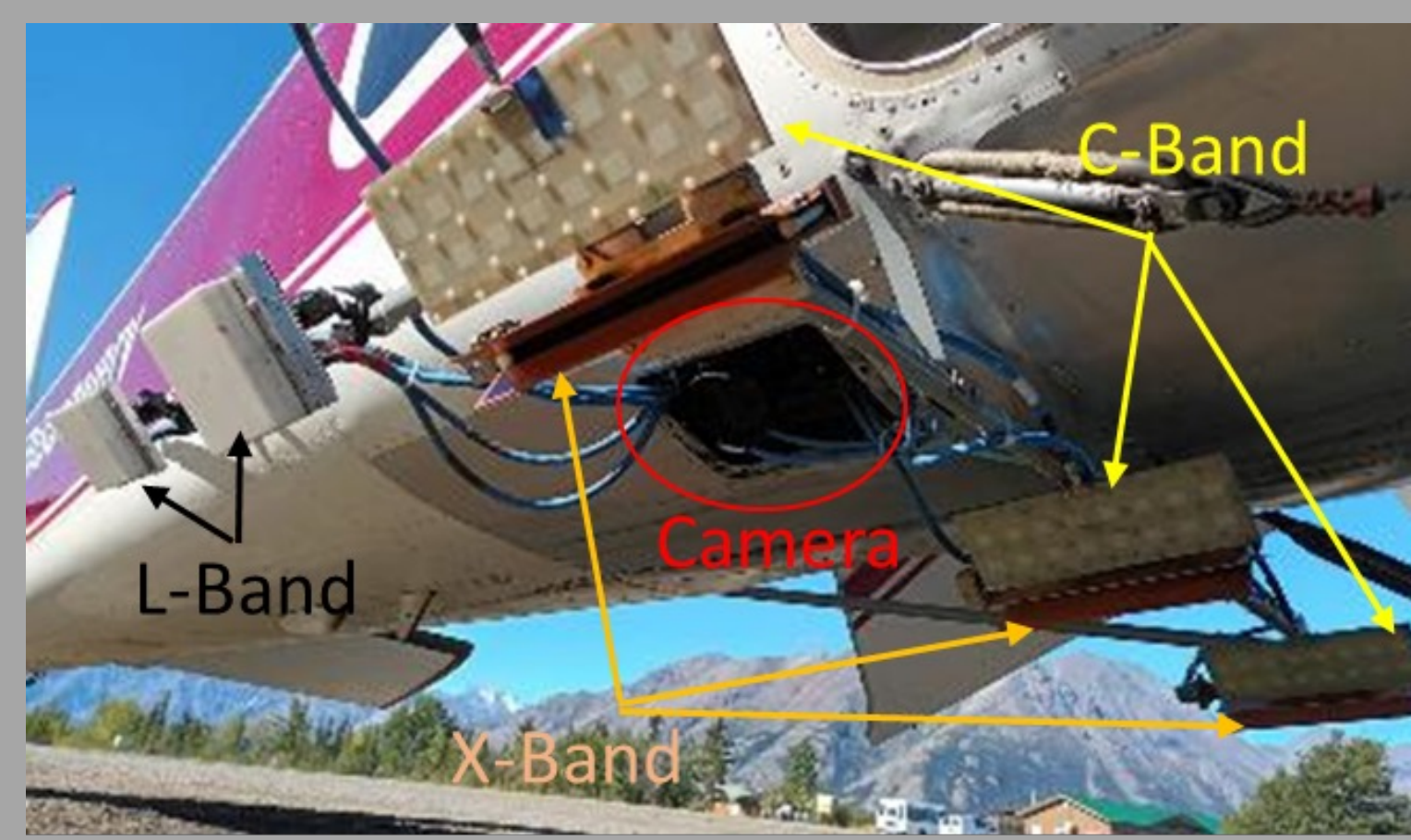
Alaska Canada Highway, near Kluane Lake, Silver City, Yukon



EXPERIMENTAL SETUP

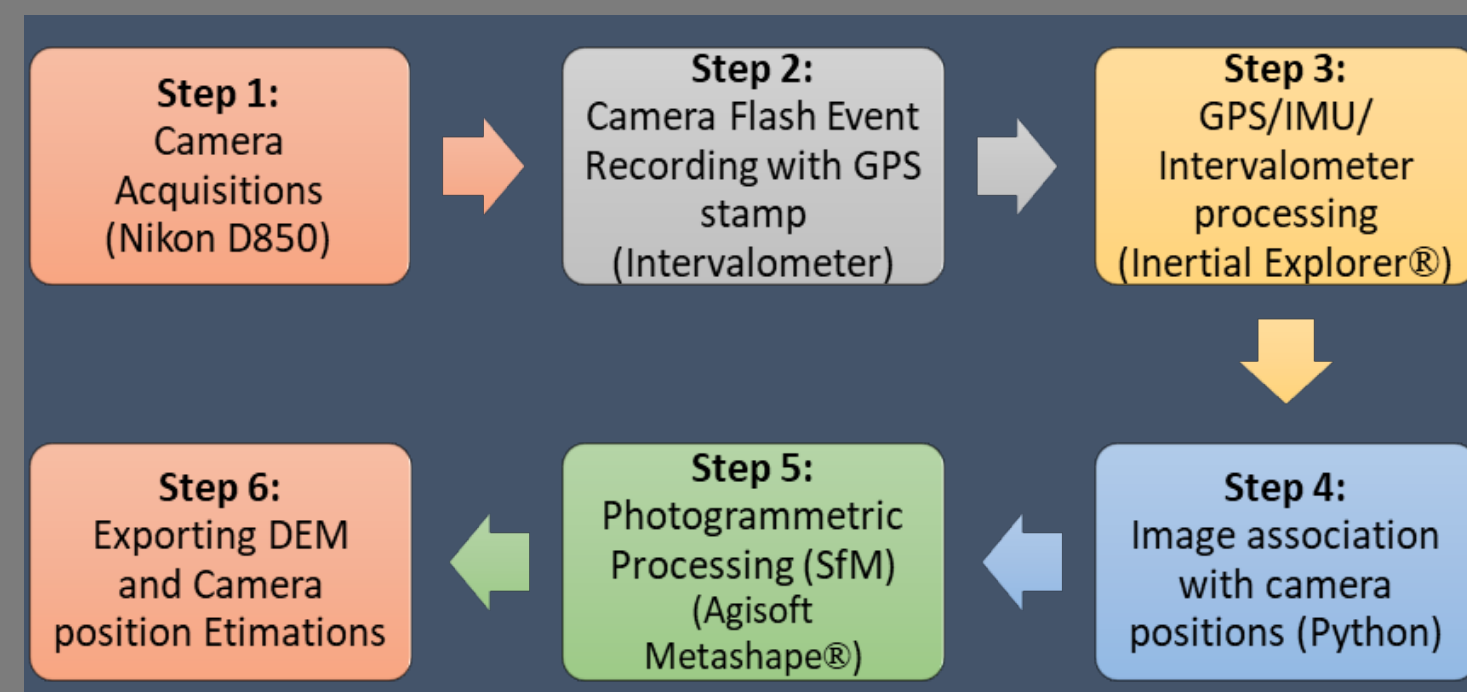


Hello-courier (Icefield Discovery Tourist Flight Operators in Silver City, Yukon)



System arrangement on the aircraft

FODAR PROCESSING CHAIN



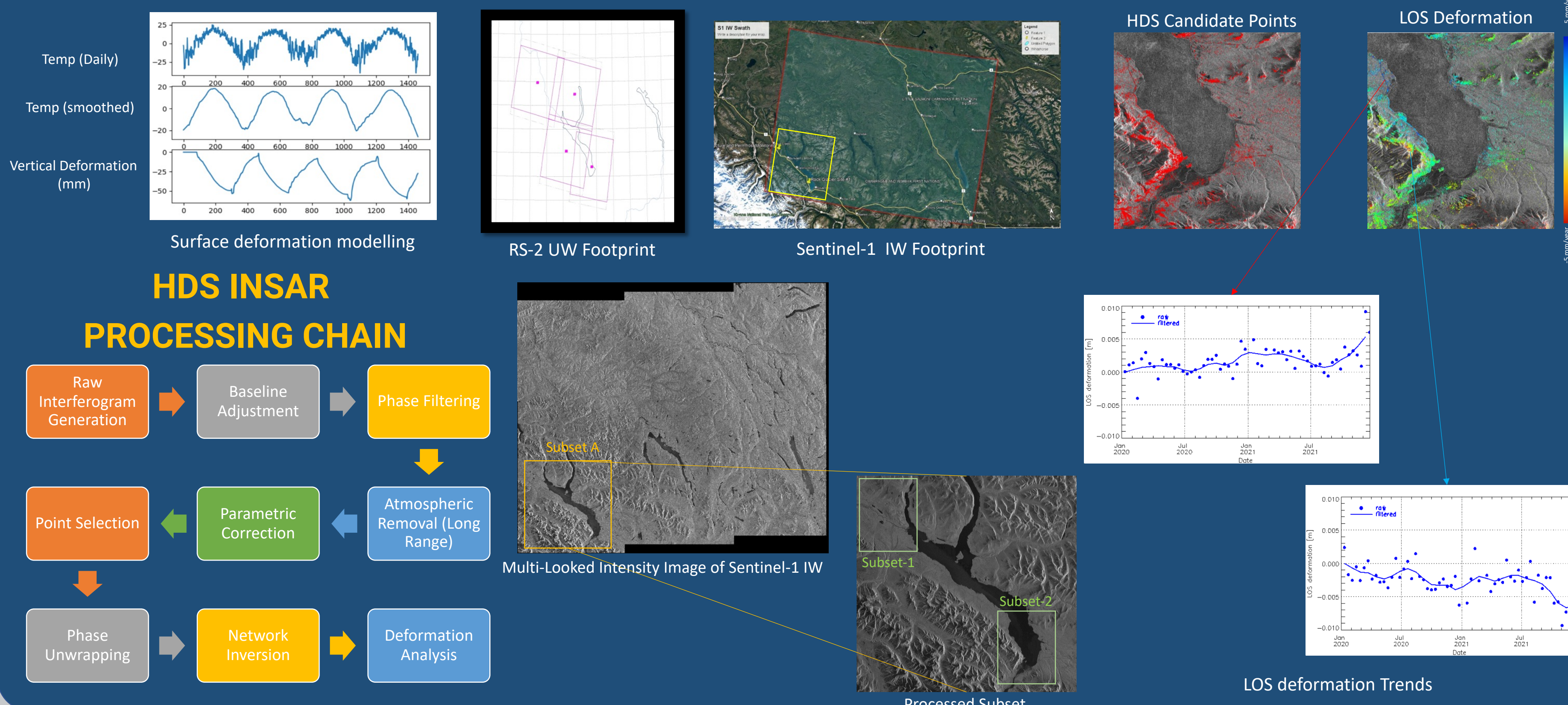
IMPROVEMENTS IN EXPERIMENTS

- Ground Control Points (GCP) & Local Differential GPS Station
 - Trimble R7
- Controlled Changes (mimicking Permafrost changes)
- Extending Profiles into the Borehole [BH07]
 - YukonU Permafrost and Geoscience Group
 - Borehole data for modelling effects of sub-surface properties

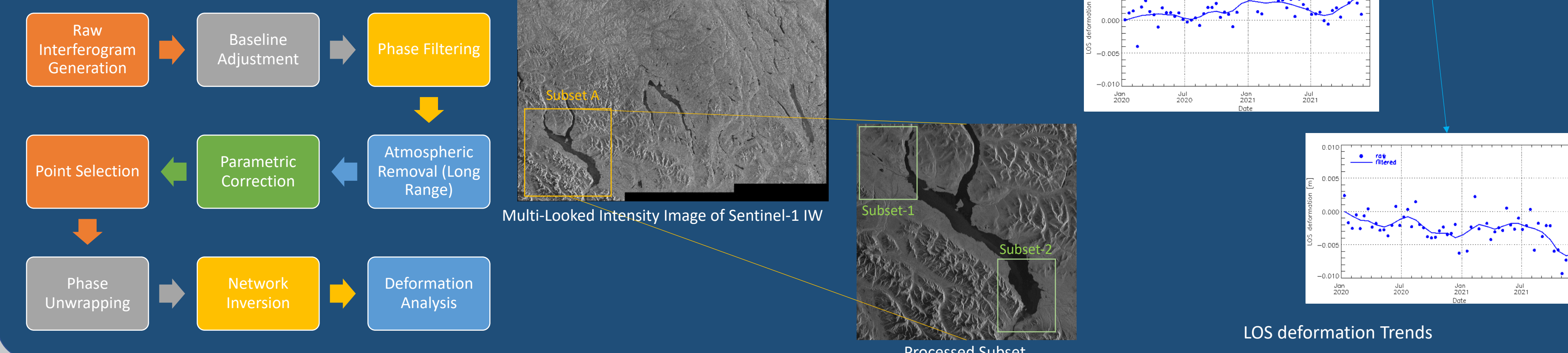


SPACEBORNE INSAR ANALYSIS

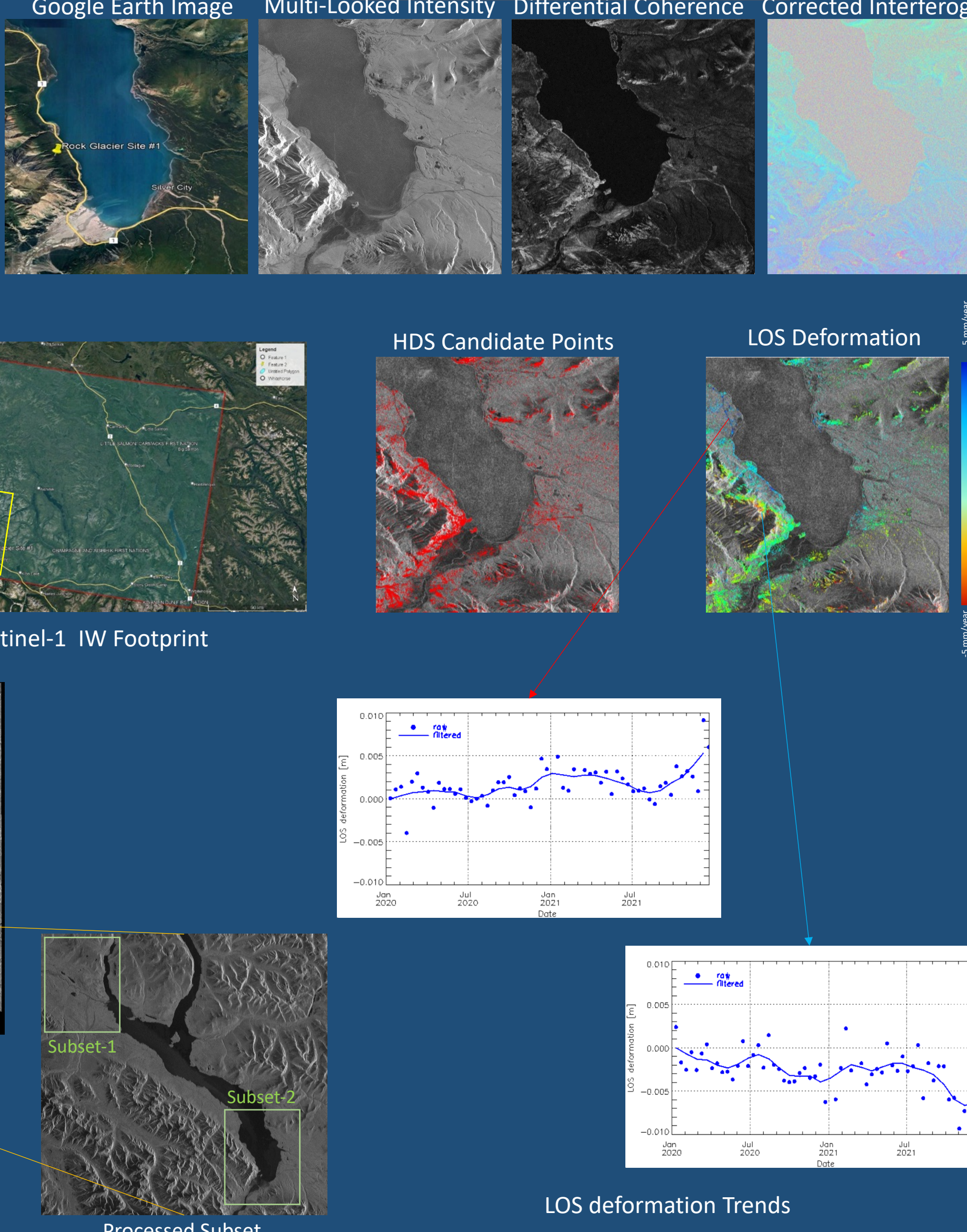
Spaceborne data to support and validate the airborne findings
 Radarsat-2 Ultra-Wide Mode Stack (13.5m x 7.7m) – July 2022 for 2 years
 Sentinel-1 IW Swath (~2.5 m x 13 m) – 2020 onwards – 2 years – 58 Images
 Homogeneous Distributed Scatterers Interferometry (HDS InSAR) processing and active Layer modelling with surface temperatures
 Time series analysis of LOS deformation



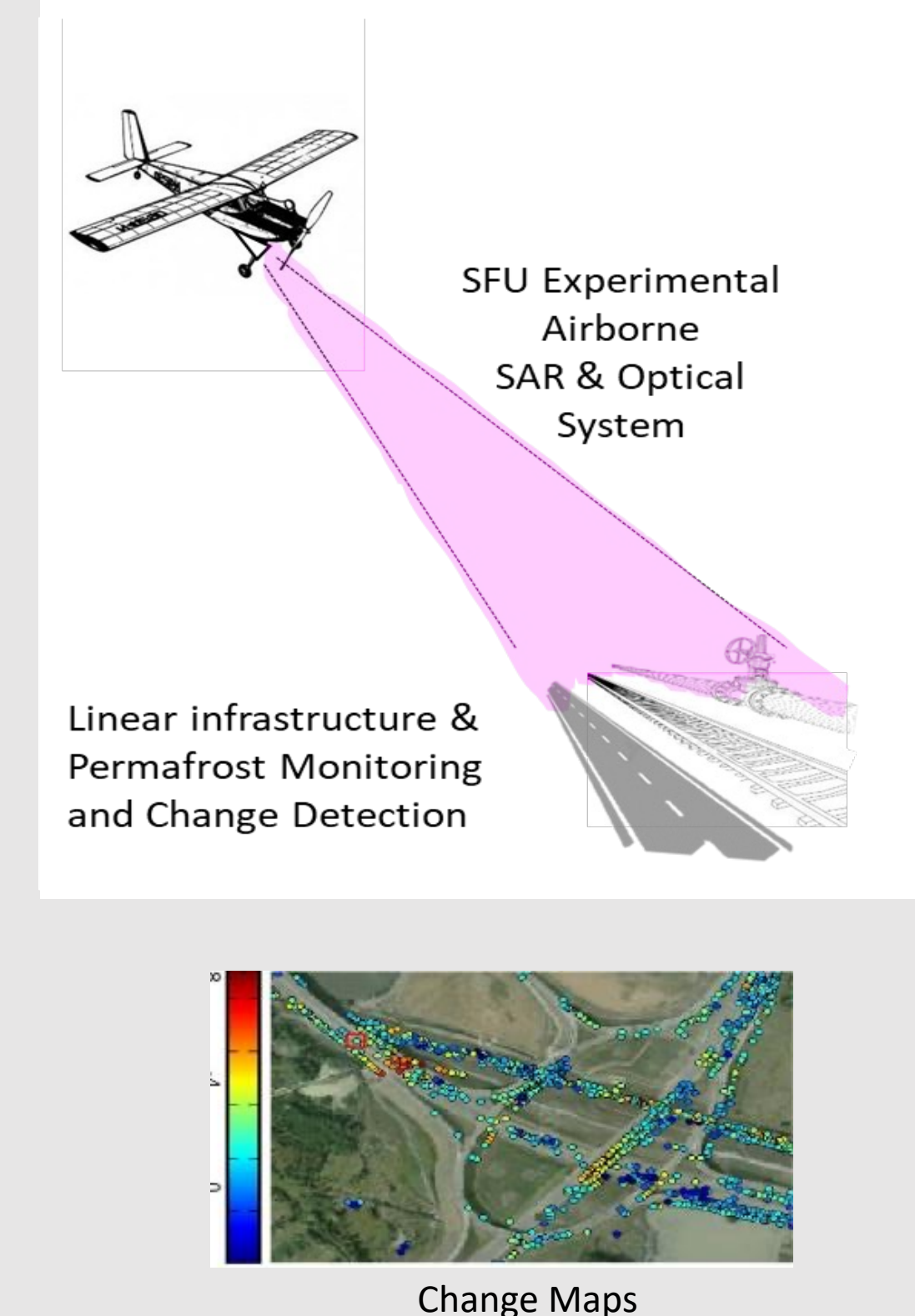
HDS INSAR PROCESSING CHAIN



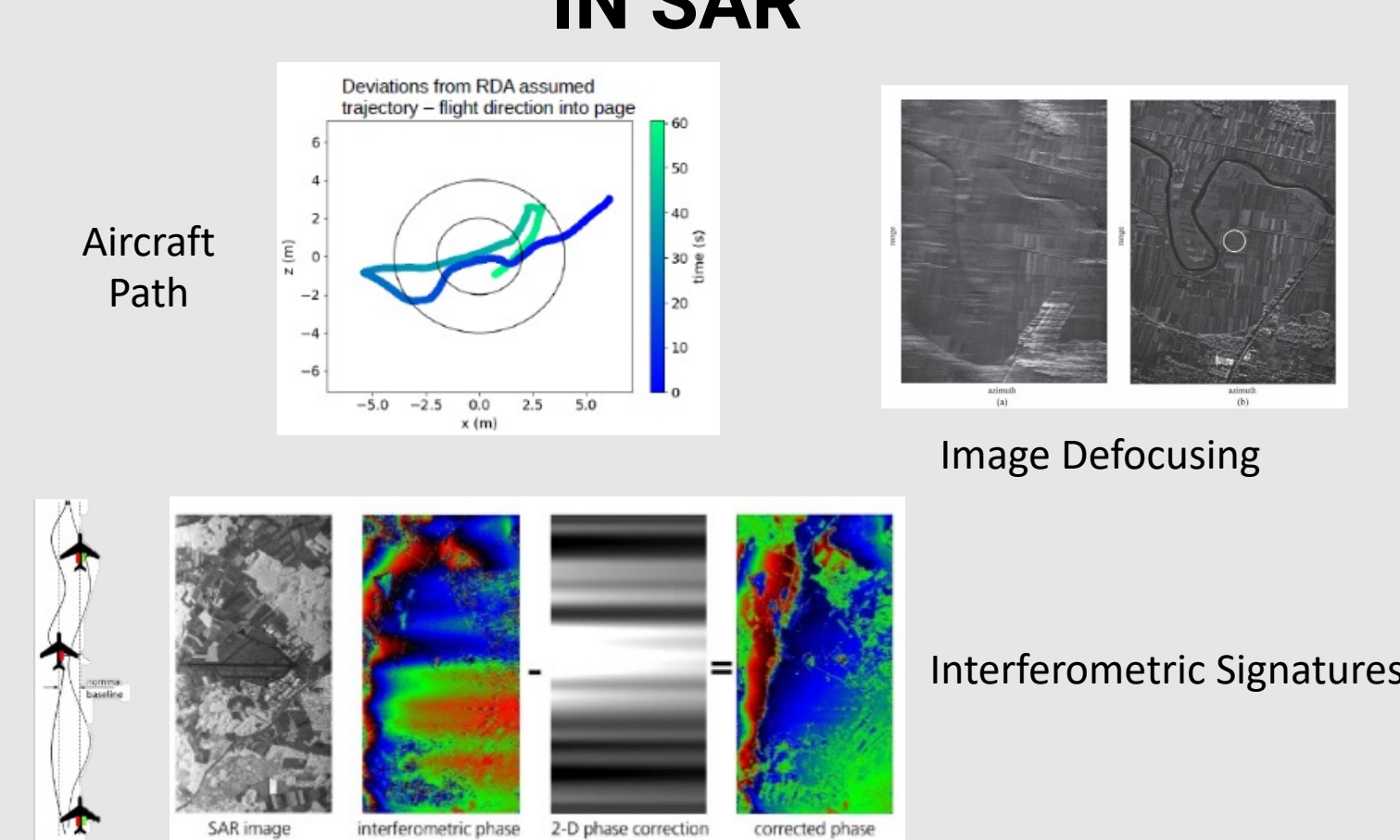
SUBSET-2 RESULTS



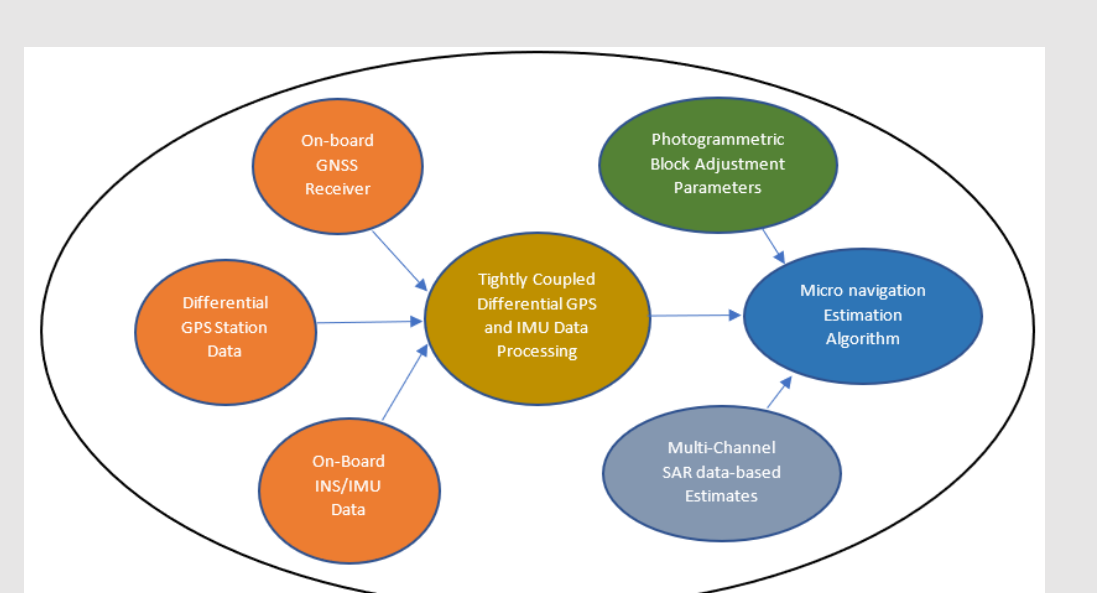
RESEARCH CONCEPT



IMPORTANCE OF MICRO-NAVIGATION IN SAR



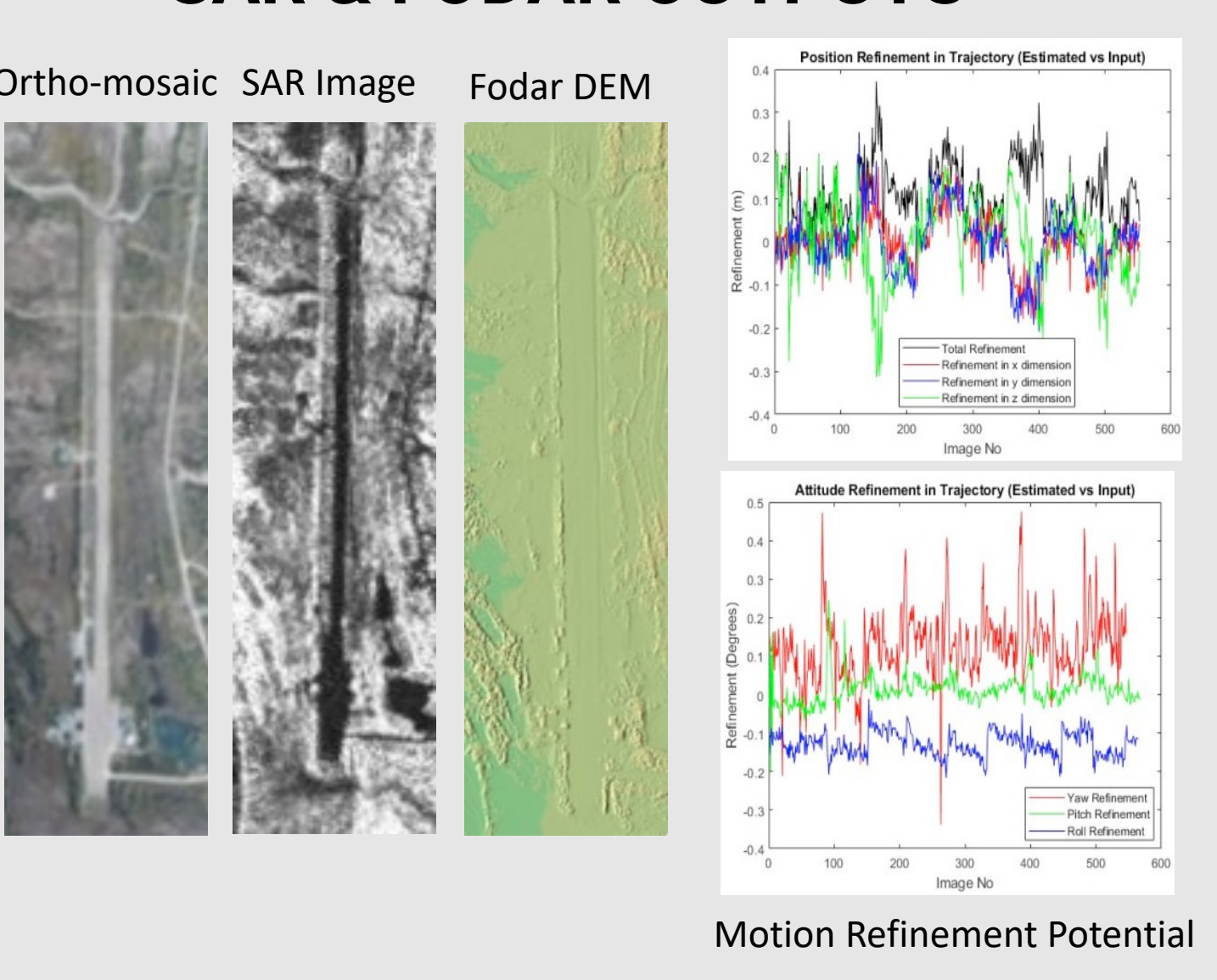
CONCEPT OF MICRONAVIGATION



SAR SYSTEM SPECIFICATIONS

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

SAR & FODAR OUTPUTS



FUTURE WORK

- Improving the Photogrammetric results further by analyzing timeseries data and incorporating borehole data in modelling the expected changes.
- Airborne repeat-pass InSAR implementation and testing to be done with TDBP based SAR processing
- Implementing motion refinements estimated by fodar system to gauge the improvements in the InSAR performance.
- Improving Spaceborne HDS InSAR analysis by incorporating non-moving reference areas and tackling snow penetration phase bias in winters.

SCHOLARLY CONTRIBUTIONS

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, B. Rabus, "Linear Infrastructure & Permafrost Monitoring with Airborne SAR and Photogrammetry Data" Poster Presentation at Yellowknife Geoscience Forum, 2022.
3. U. I. Ahmed, B. Rabus, "Advanced Interferometric High-Resolution SAR for Infrastructure Monitoring at Simon Fraser University Burnaby Campus and Surroundings" TerraSAR-X Science Meeting, DLR, 2023.

SUCCESSES

- Fodar DEMs repeatability issue resolved
- Time Domain Back Projection (TDBP) Algorithm for SAR focusing completed
- Radarsat-2 Ultra-Wide Stack of 1 year (13.5m x 7.7m) - archived
- Sentinel-1 Interferometric Wide (IW) based InSAR stack analysis chain completed
- 4 years worth of Summer Campaign data with 2 years worth of Winter Campaign data

ACKNOWLEDGMENTS

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