In-Situ Data Meets InSAR: Validating the NISAR Level-3 Permafrost Requirement

Contributors:

Franz J Meyer[1)], S. Zwieback[1)], A. Johnson[1)], G. Iwanaha[1)], J. Chen[1)], P. Rosen[2)], B. Chapman[2)]

[1)]Geophysical Institute, Alaska Satellite Facility, University of Alaska Fairbanks, Fairbanks

[2)]Jet Propulsion Laboratory, Pasadena, CA

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NISAR Implemented & led by

Jet Propulsion Laboratory
California Institute of Technology

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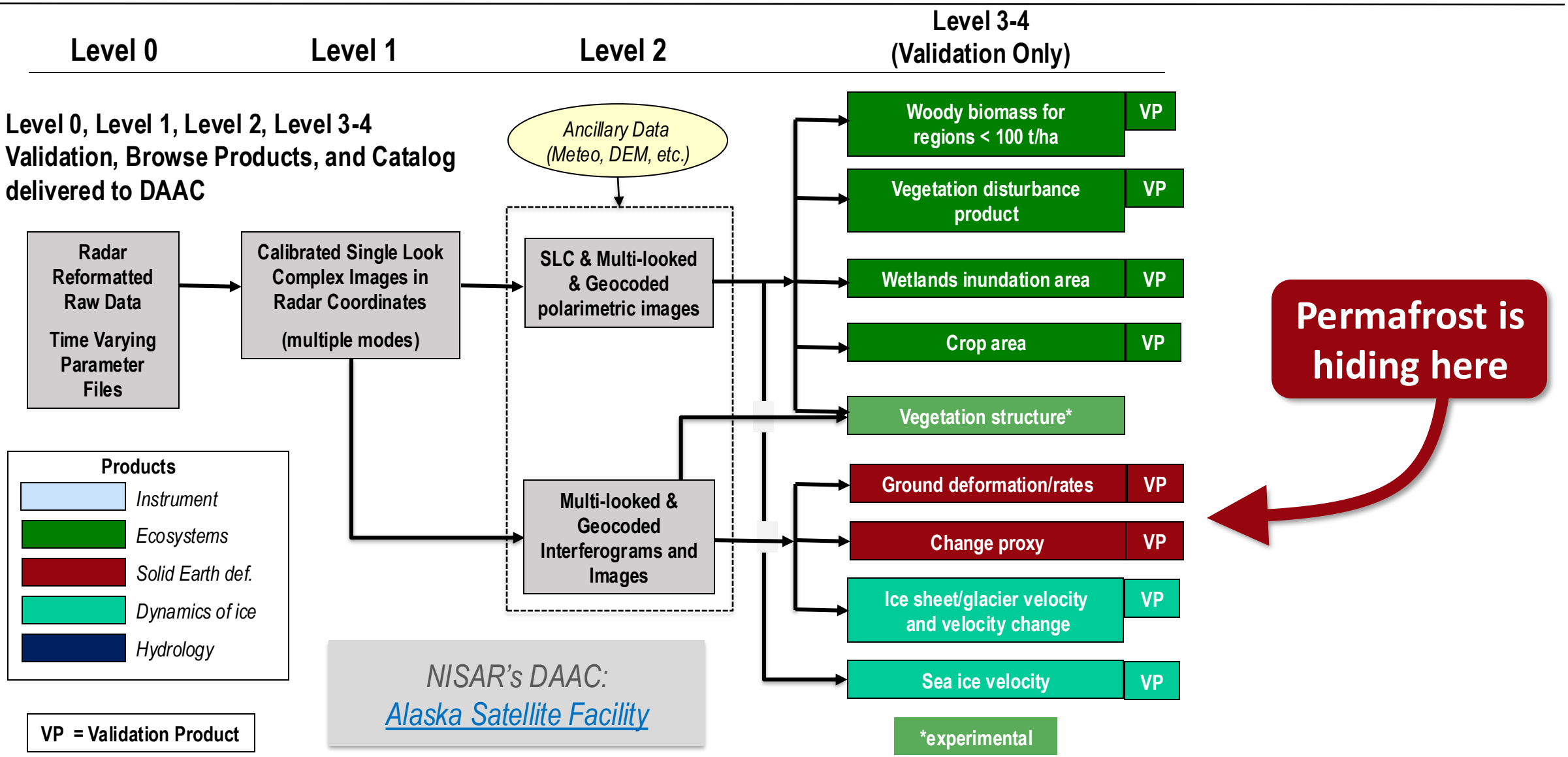
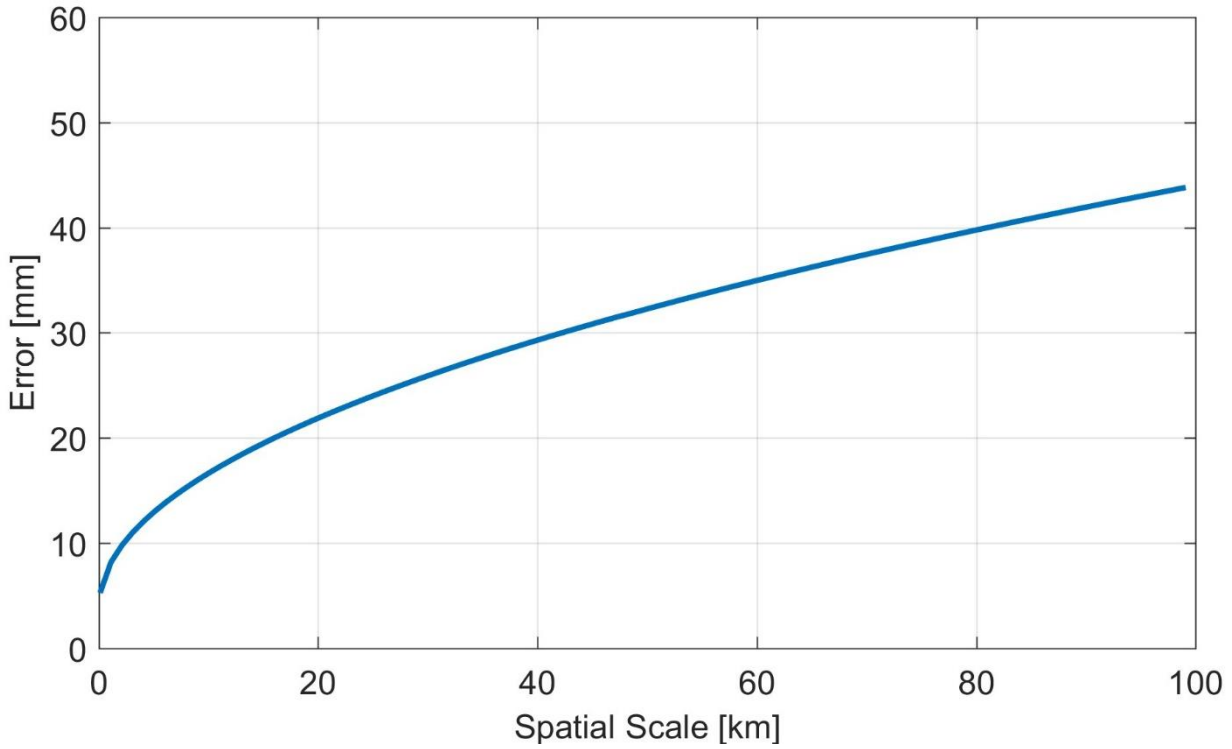
NISAR Science Data Analysis and Archive Approach



The NISAR Level-3 Permafrost Displacement Requirement

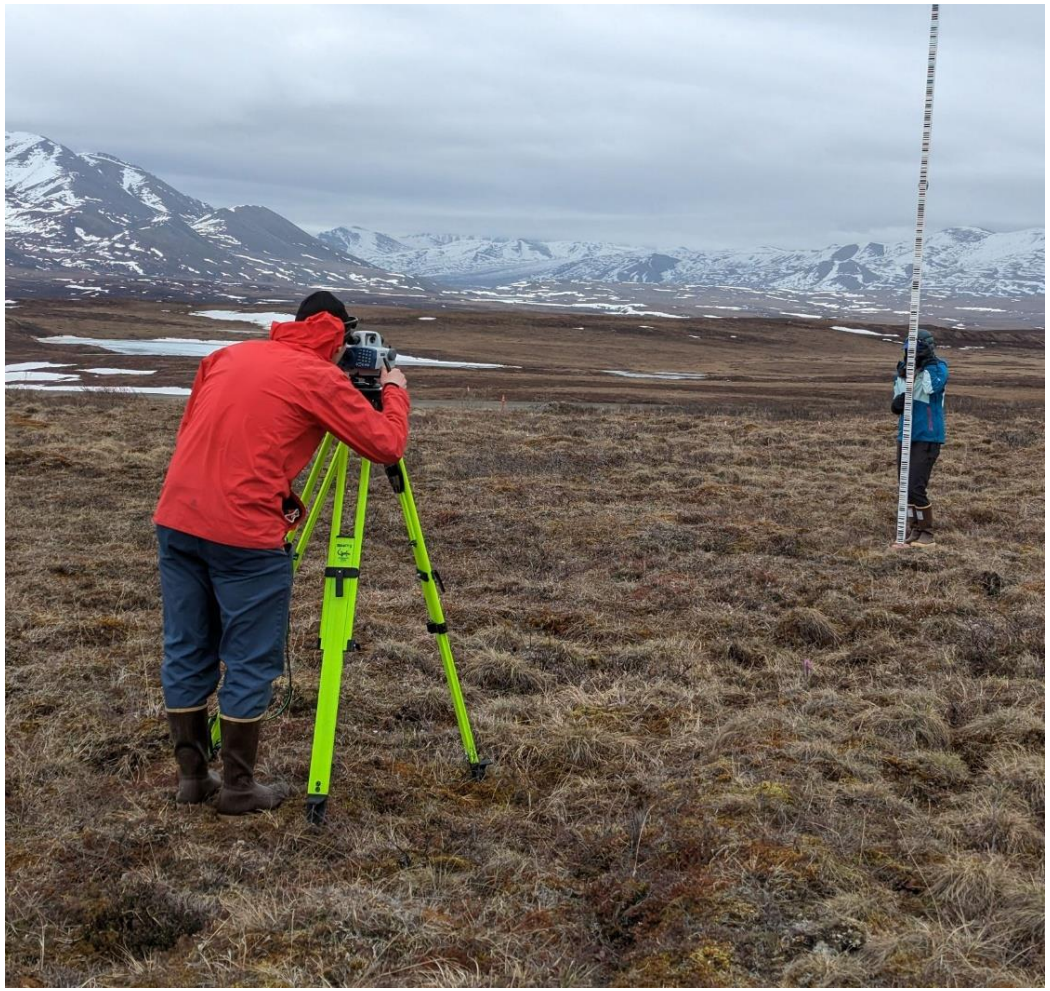
- **Phrasing of NISAR Permafrost Requirement**
  - *"The NISAR project shall measure surface deformation in permafrost-affected areas semi-monthly at **100-m resolution** during **snow free months** with accuracy of 4*(1+L^1/2) mm or better, over length scales 0.1 km < L < 50 km, **over 80% of selected regions** (see map to be provided by Science Team), and **over any 90-day interval.**"*

- While physically a cryosphere requirement, grouped along-side solid earth requirements due to similarity of validation approaches



Permafrost Validation Approach

- **Two approaches** to compare InSAR and field observations to validate the NISAR permafrost requirement (requirement #671).
  - **Approach #1 – Direct validation against field data**: Comparing surface displacement measurements from NISAR to field observations at four permafrost field sites
  - **Approach #2 – Noise assessment in non-deforming areas**: Structure function analyzing of NISAR InSAR data over non-deforming areas



Permafrost Validation Approach #1

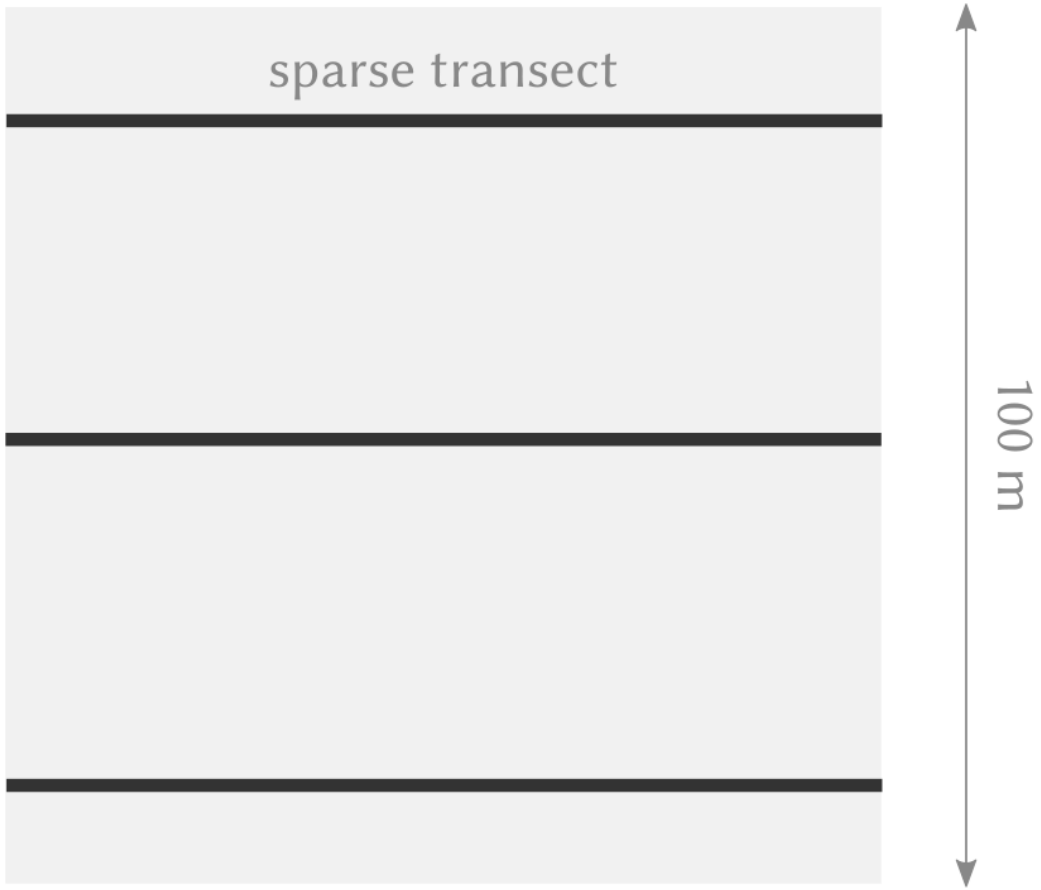
Four Field Validation Sites

all in tundra, continuous permafrost; variable ground ice and Quaternary history

Graduate student Rowan Biessel measuring thaw depth at Happy Valley note tussocks (clumpy sedges) and <0.3 m tall shrubs

Permafrost Validation Approach #1

Validation Approach



- **Three transects to capture ground displacement variability within 100 m by 100 m plot**
- 153 total points – 51 for each transect
- Dense sampling to capture high variability of surface displacements on length scales smaller than NISAR product resolution.
- Order-of-magnitude calculation → standard error of field sample average: 0.8 to 2.4 mm → more accurate than requirement (4.0 mm)

Permafrost Validation Approach #1

Field Observations

Differential GNSS

Leveling

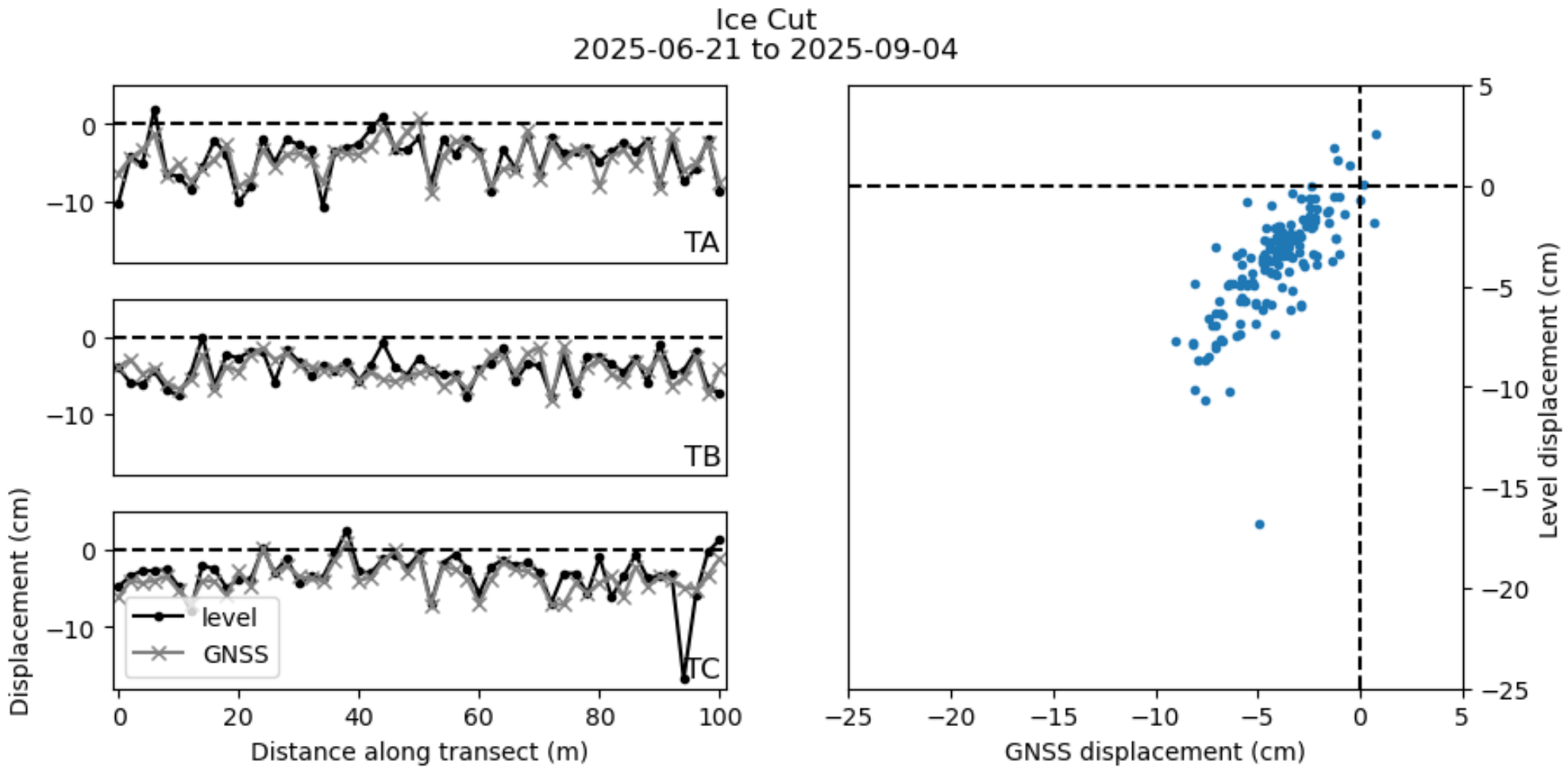
- Repeated Surface Elevation Observations in late spring and late summer
  - RTK GNSS with base station at nearby benchmark
  - Optical Leveling with survey equipment
- Thaw depth in late summer

High variability of individual measurements, mitigated by quantity of observations

All field data and ancillary data are accessible through NISAR validation data base

Permafrost Validation Approach #1

Field Observations – Example deformation one site



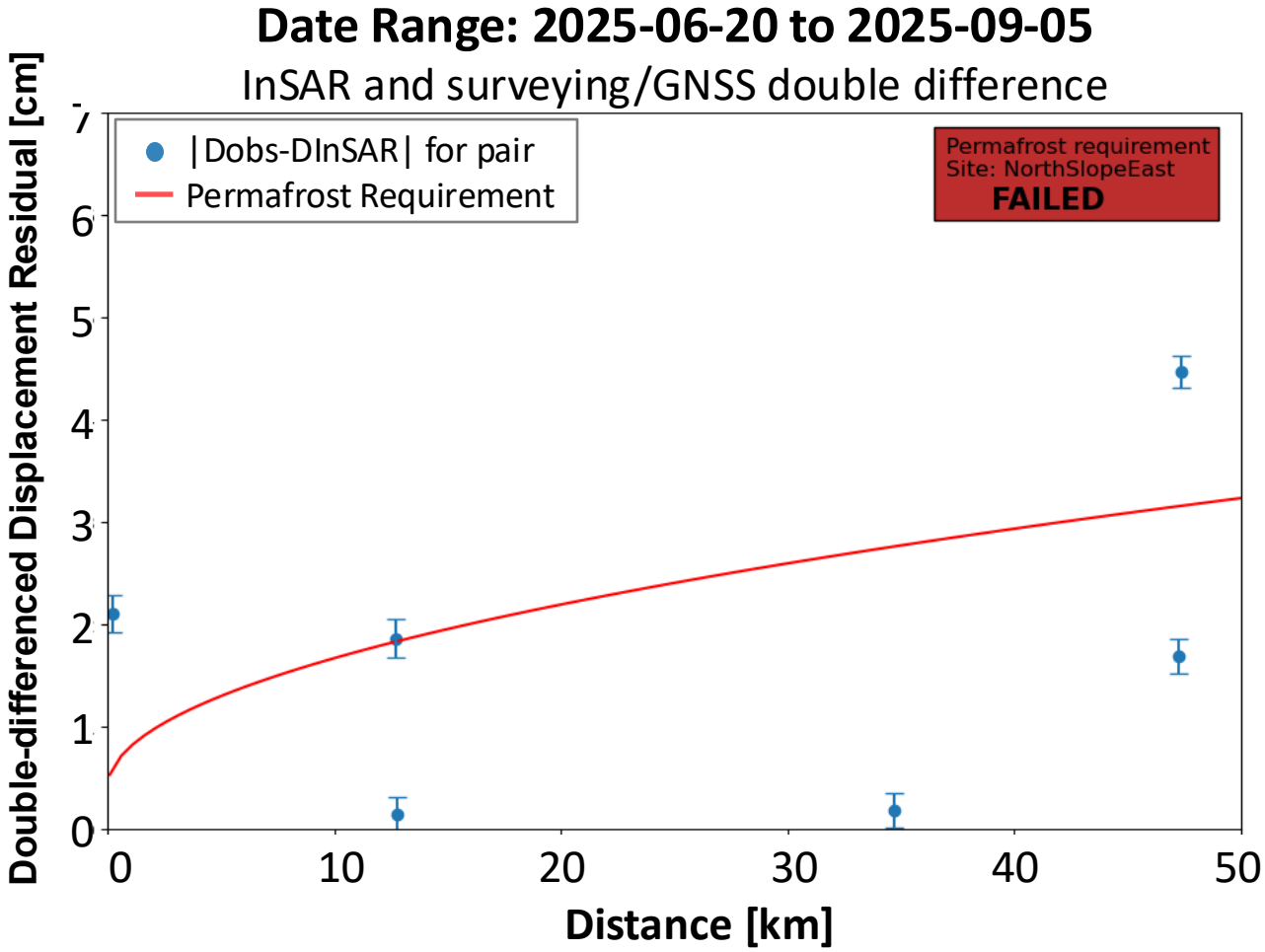
Overall displacement across site: −4.0 ± 0.1 cm

Preliminary Results

Approach #1

- Partial field data acquisitions began in 2022, full field data acquisition began in 2025 (using all 4 subsites).
- Measured field site deformation varies from 1 cm to 10 cm, by site and year
- Sentinel-1 analogue to demonstrate implementation. Corrections for troposphere, solid Earth tides, ionosphere, etc., not applied

Awaiting summer NISAR observations for permafrost deformation validation



Sentinel-1 analogue North Slope Alaska validation, 2025

2026 Field Observations Ongoing Right Now

2026 Early Summer Fieldwork

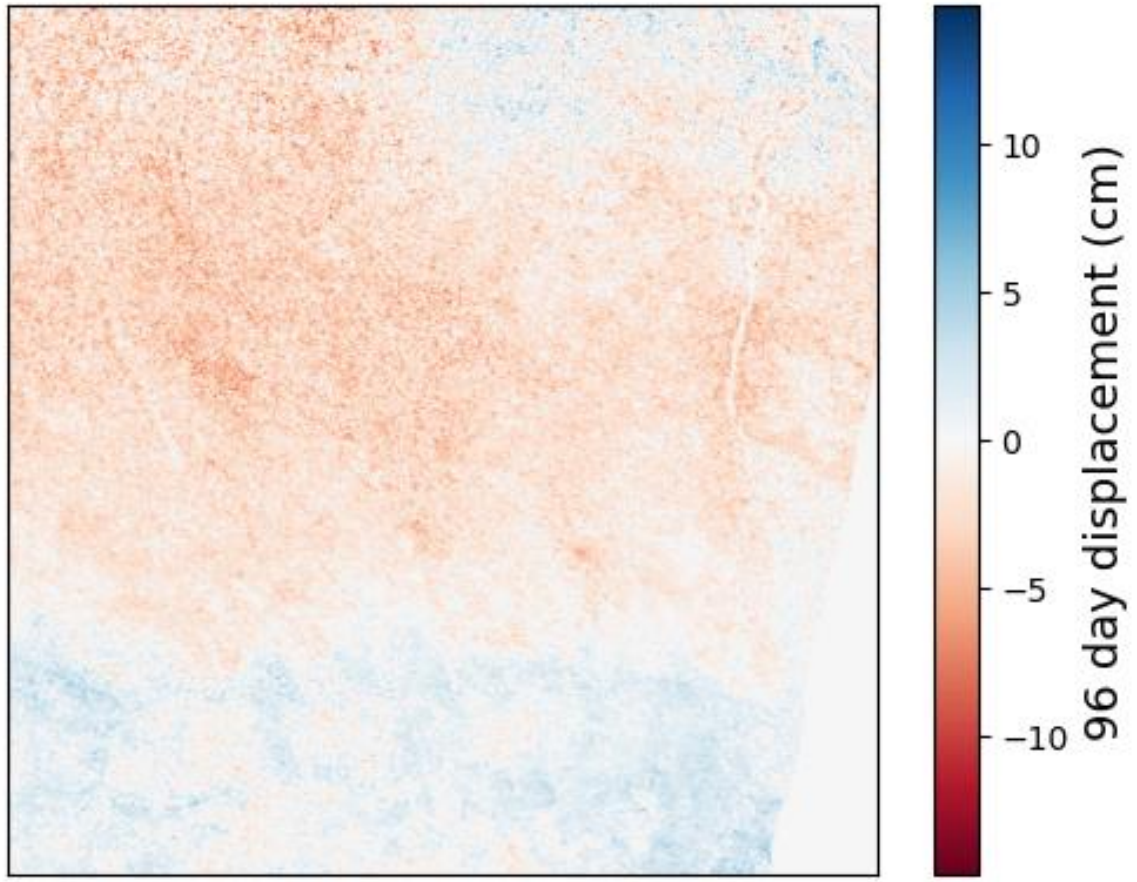
- Exceptionally thick snowpack paired with late melt
- Field team stayed out several extra days due to these delays
- Succeeded in surveying all sites despite changing weather conditions

2026 Field Observations Ongoing Right Now

Permafrost Validation Approach #2

Structure Function Analysis

- **Noise evaluation in non-deformation areas**
- **Workflow:**
  - Perform time series analysis to calculate InSAR displacements over 90 day period
  - Extract pixels over stable ground
  - Calculate structure functions
  - Compare to scale dependent requirement
- **Site**: Alaskan North Slope
- For now, working with Sentinel-1 results as analogue, until full-summer season NISAR data are available



2025 North Slope summer displacement from Sentinel-1, with no corrections applied

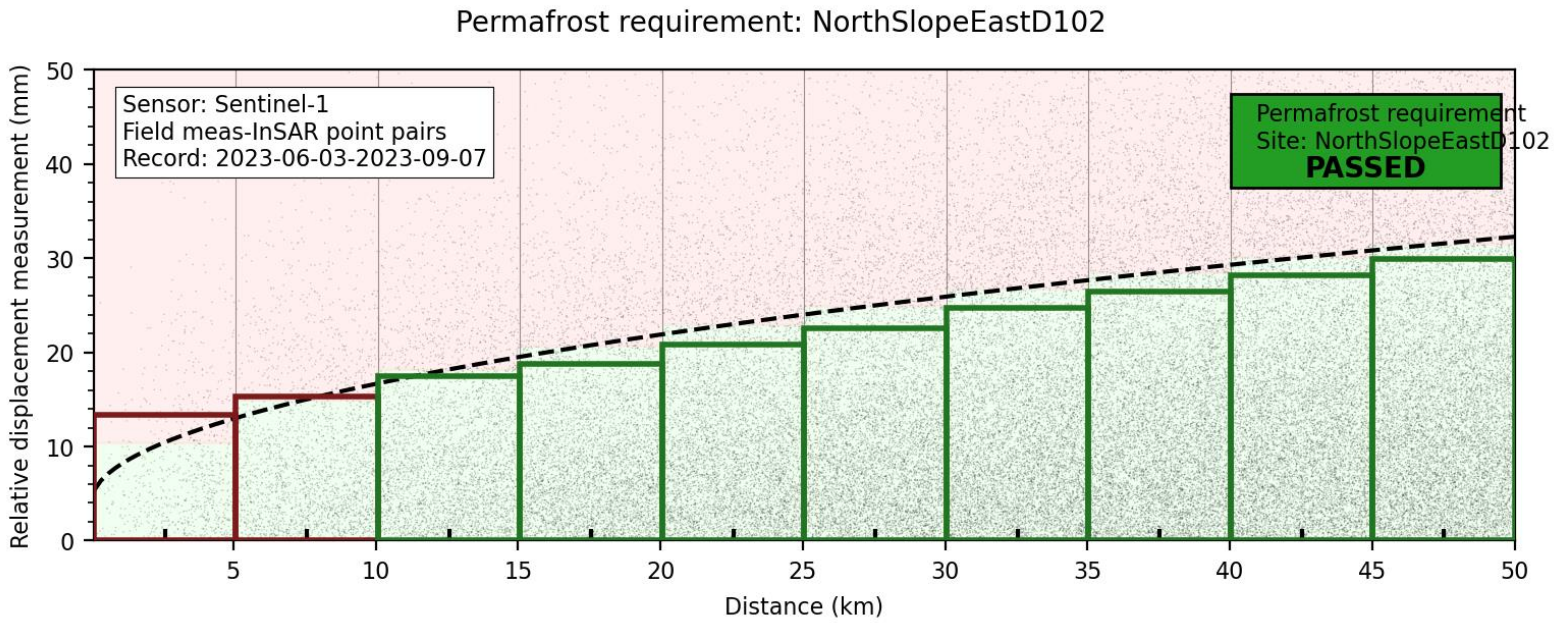
Permafrost Validation Approach #2

Preliminary Results

- Approach is applied to Alaska North Slope region, and is shown to provide acceptable results in Sentinel-1 analogue data

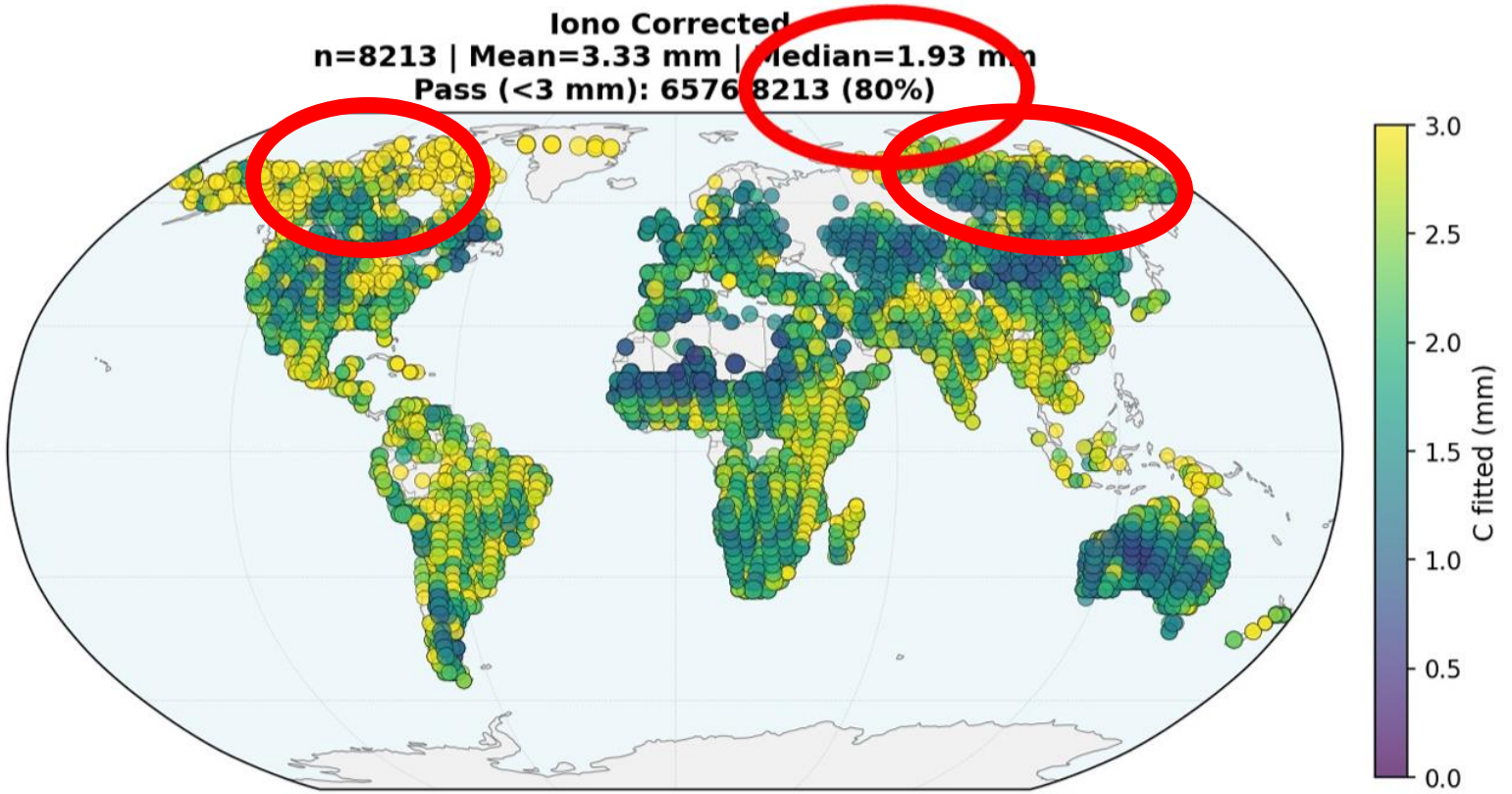
- With first NISAR GUNW data available, we have started the analysis NISAR

Example result (96 day cumulative displacement):



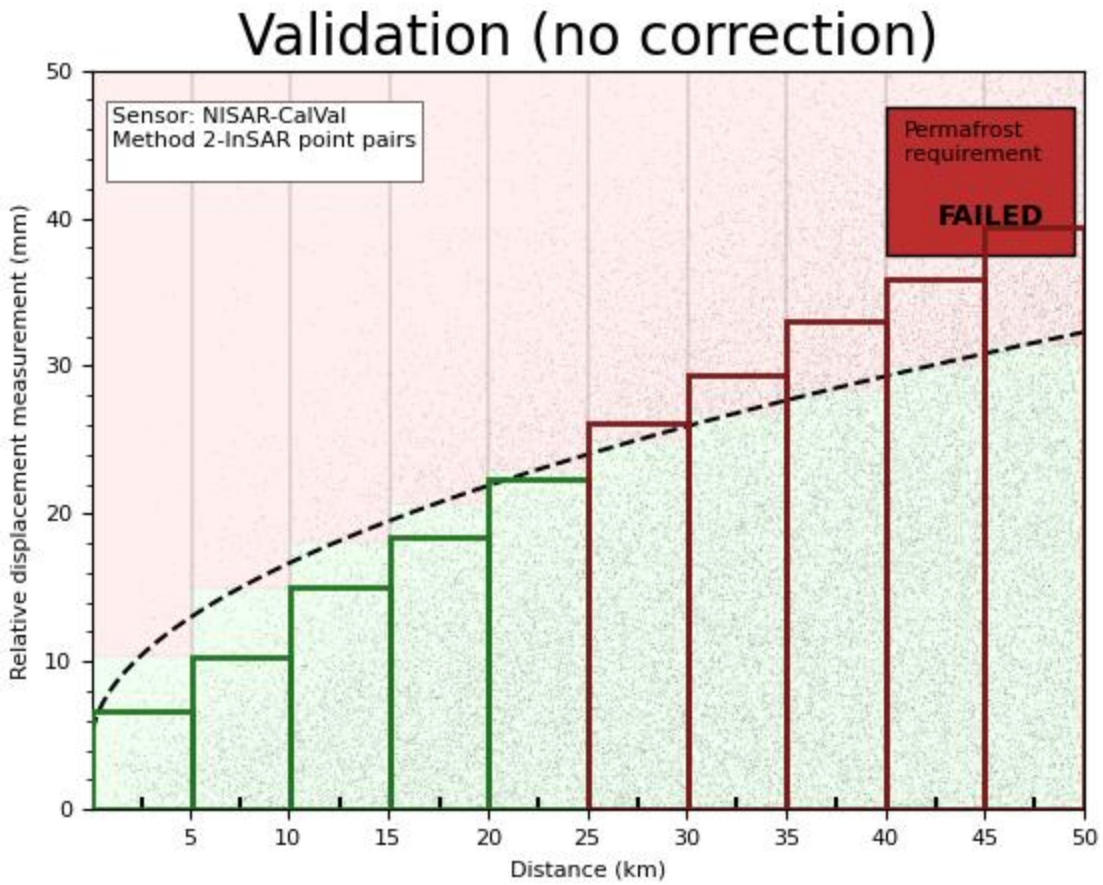
Structure Function Analysis of NISAR InSAR Observations

- Validation Method #2 can now be applied to NISAR data
- Strong ionosphere is present at high latitude causing phase errors beyond the requirements if uncorrected
- Operational ionospheric correcting using split-spectrum algorithm leads to substantial improvements of phase errors

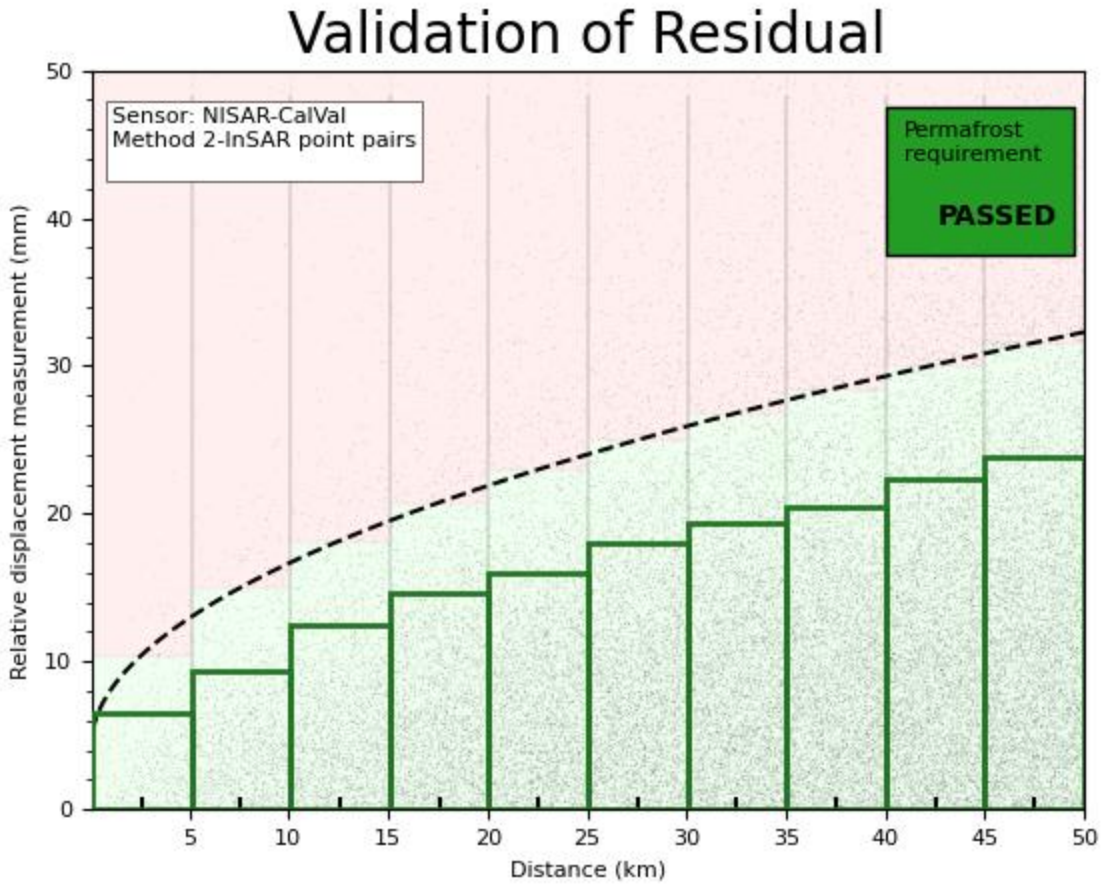


Courtesy: Matt Pritchard, Cornell

North Slope May 2026: Before vs After Ionosphere Correction



Within requirement: 75%



Within requirement: 90%

Summary

- **NISAR performs validation on all of its Level 3 science requirements**
- NISAR CalVal method for permafrost deformation is ready for NISAR data, but will require 90-day summer time series
- Field observation scheme can achieve measurements of surface deformation of 1 to 2 mm accuracy across NISAR product resolution
- **Field observations available to the community through the NISAR CalVal database**

Contact: fjmeyer@alaska.edu

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