Seeing the unseen – Improved InSAR surface displacement monitoring with MDA CHORUS™

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SECTION 1

InSAR Monitoring

- Interferometric SAR (InSAR)
- MDA SAR Satellites
- MDA 3D InSAR Monitoring

Mississippi River east of New Orleans (XF0W2)

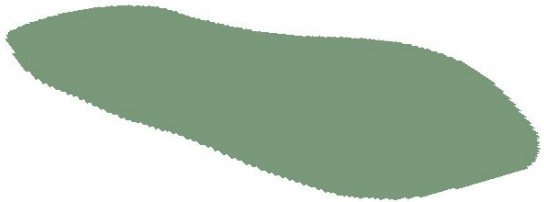
Interferometric SAR (InSAR)

- **Interferometric Synthetic Aperture Radar (InSAR)** is a SAR based technique used to measure deformation of the Earth's surface

- What InSAR can do:
  - Can be performed entirely remotely, no need to send workers to the field
  - Provide measurements over a very large spatial extent
  - Can be used for surveillance (detect deformation without a priori information)
  - Spatial resolution: 3m or greater
  - Highly sensitive to deformation: mm to cm accuracy
  - Line-of-sight (LOS) measurement can be projected to vertical (1D), east-west (2D) and north-south (3D) components depending on satellites available

- InSAR-based monitoring techniques:
  - Differential InSAR (DInSAR)
  - Coherent target monitoring (CTM)
  - Corner reflector (CR) monitoring

<InSAR Derived Vertical Deformation>



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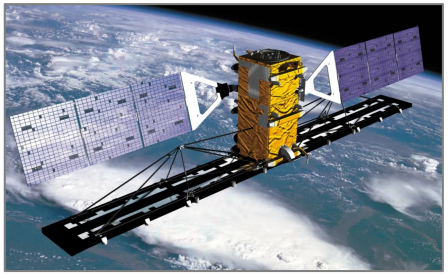
MDA SAR Satellites

Feature	RADARSAT-2	CHORUS-C/X
Operator	MDA	MDA/ICEYE (Collaborative)
Launch Year	2007 (Operational)	Scheduled Q4 2026
SAR band	C-band	C-band (primary) + X-band (trailing)
Orbit	Sun-Synchronous (polar)	Mid-inclined
Best Resolution	3m	3m
Max Swath Width	500 km (ScanSAR)	700 km (ScanSAR/Wide)
Polarization	HH, VV, HV, VH (Quad-pol)	HH, VV, HV, VH + Compact Polarimetry
Revisit	24-day	9.85-day
Look direction	Right/Left	Right/Left



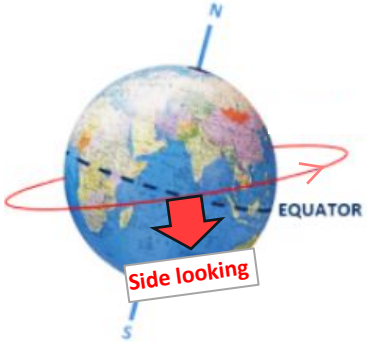
<RADARSAT-2>

<CHORUS-C/X>

MDA 3D InSAR Monitoring

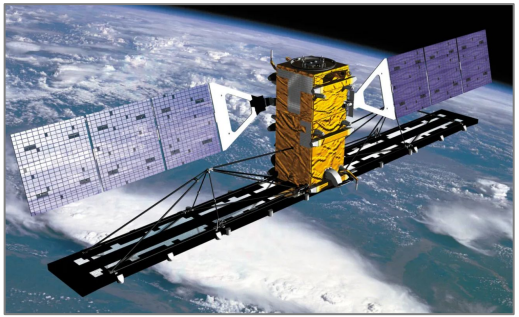
CHORUS-C/X

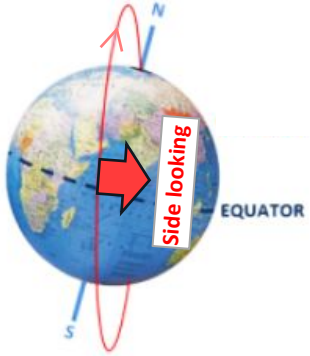
- CHORUS provides diverse viewing geometries allowing **3D InSAR**
- Mid-inclination orbit can provide north-south deformation using at least 3 SAR image stacks
- Deformation monitoring is available on 9.85-day basis for each stack



<Mid-inclination orbit>

RADARSAT-2





<Polar orbit>

- RADARSAT-2 is highly sensitive to east-west deformation and vertical motion allowing **2D InSAR**
- 2D InSAR requires at least 2 SAR image stacks
- Deformation monitoring is available on 24-day basis for each stack

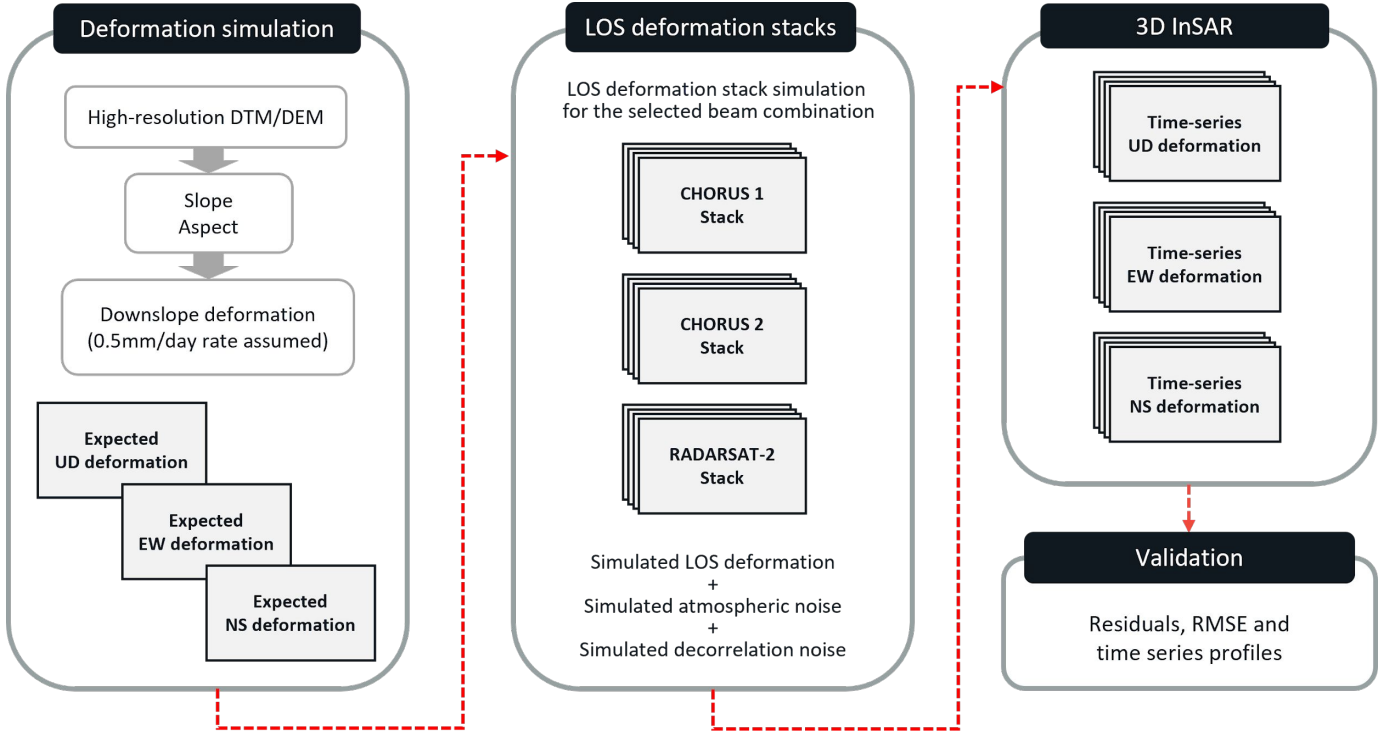
Overview

- InSAR time series monitoring is critical to ensuring safety and stability of infrastructure such as tailings dams
- Most SAR satellites operate in near-polar orbits and side-looking, providing almost no sensitivity to displacement in north-south plane
- MDA CHORUS™ with its mid-inclination orbit offers viewing geometry providing improved sensitivity to displacement in north-south plane
- MDA's 3D InSAR combines different imaging geometries from RADARSAT-2 and CHORUS for the best recovery of 3-dimensiontal components of surface displacement
- MDA's 3D InSAR algorithm also has a capability to effectively reduce impact of noise in data
- For this study, we present:
  - Simulated InSAR-derived LOS surface displacement over tailings dam structure
  - Selection of optimal and suboptimal SAR beam combinations for 3D InSAR test scenarios by MDA's data optimization
  - How CHORUS will improve measurement of 3D surface displacement component and reduce noise by MDA's 3D InSAR algorithm

Study Area

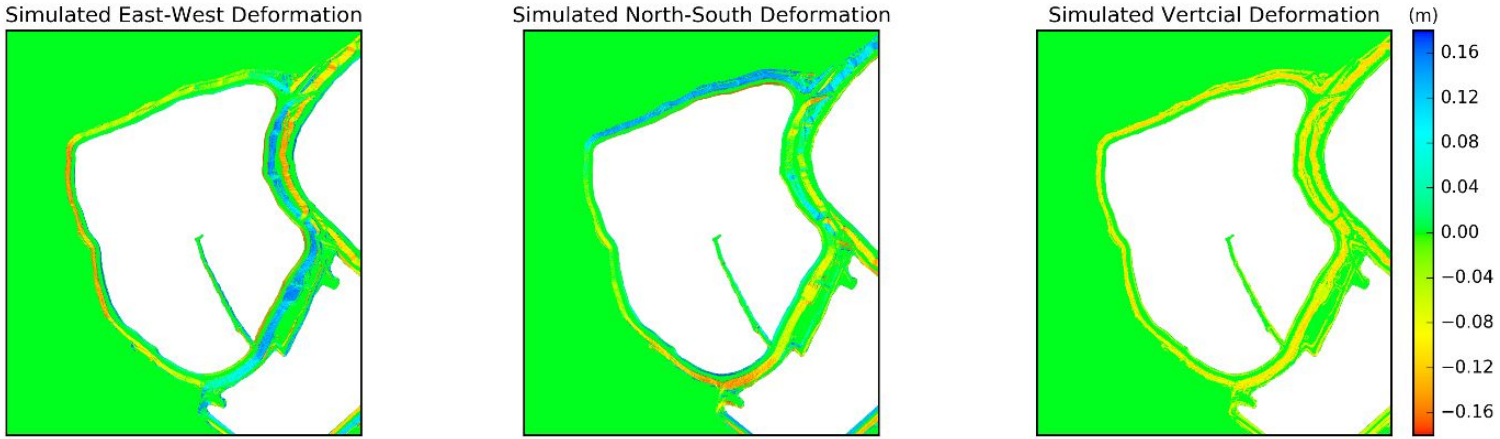
- The Lac des Iles (LDI) palladium mine located 90 km north of Thunder Bay, Ontario, Canada
- Study area contains the open pit, tailings management facilities (TMFs), reclaim water reservoir and other processing facilities
- We focus on TMF located southwest of the LDI mine
- Linear downslope deformation rate is assumed along its embankment for the deformation simulation

3D InSAR Workflow



3D Deformation Simulation

- Downslope surface displacement with an assumption of a 0.5 mm/day deformation rate for all slopes > 15°
- Deformation is assumed to occur along the embankment of the selected TMF
- Noise-free simulated 3D deformation components:



SAR beam combination

- MDA developed the data optimization algorithm to select the best beam combination for the selected AOI
- RADARSAT-2 and CHORUS SAR imaging geometries selected for two test scenarios:

Optimal beam combination

Scenario	Beam ID	SAR satellite	Orbit direction	Look direction	Incidence angle	Beam heading
Case 1	U17AR	RADARSAT-2	Ascending	Right	42.8°	350.6°
	ST3m20AL	CHORUS-C	Ascending	Left	57.4°	48.8°
	ST3m08DR	CHORUS-C	Descending	Right	40.8°	96.7°

Suboptimal beam combination

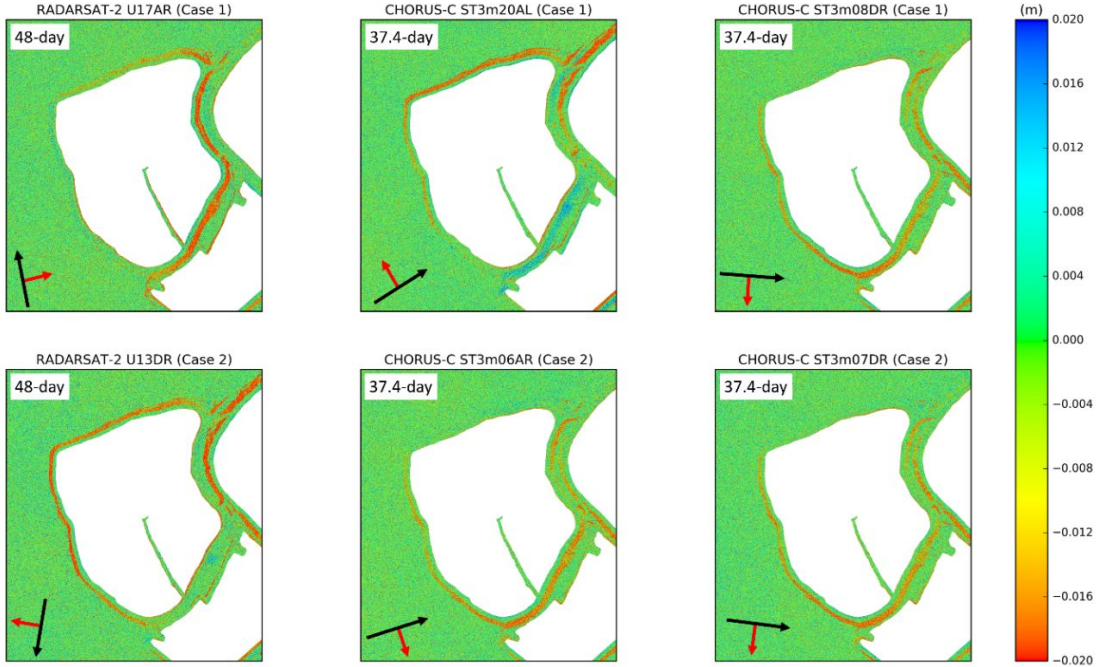
Scenario	Beam ID	SAR satellite	Orbit direction	Look direction	Incidence angle	Beam heading
Case 2	U13DR	RADARSAT-2	Descending	Right	40.0°	189.7°
	ST3m06AR	CHORUS-C	Ascending	Right	37.5°	79.5°
	ST3m07DR	CHORUS-C	Descending	Right	38.9°	96.7°

LOS Deformation Stack Simulation

- LOS stacks are simulated for up to 4th sequential pairs (i.e., 96-day for RADARSAT-2 and 37.4-day for CHORUS-C)
- Example of noise-added simulated LOS deformation for 2nd RADARSAT-2 and 4th CHORUS-C sequential pairs:

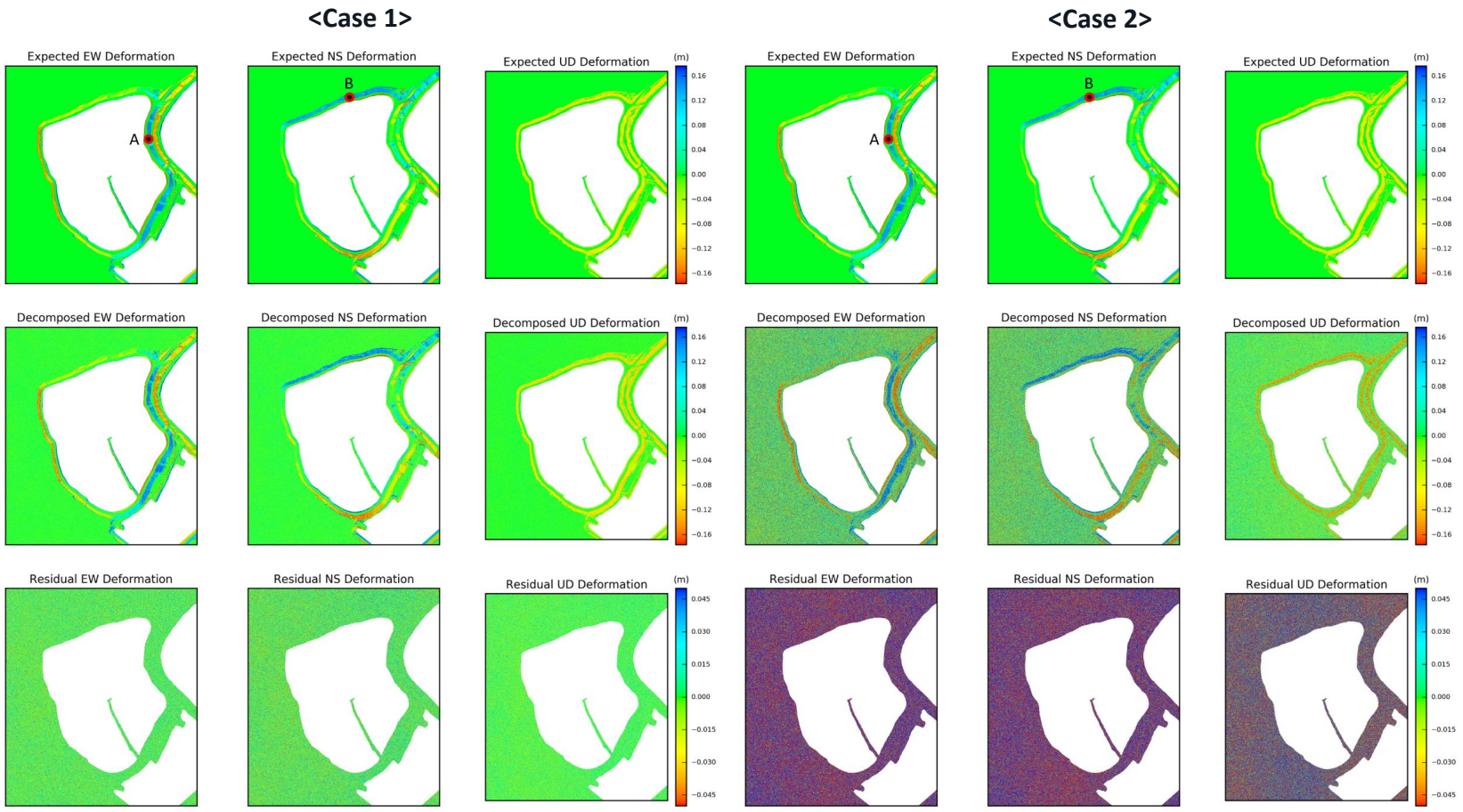
<Case 1>

<Case 2>

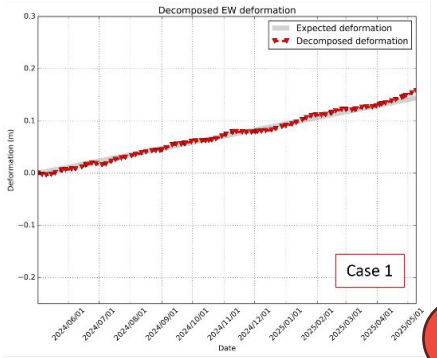


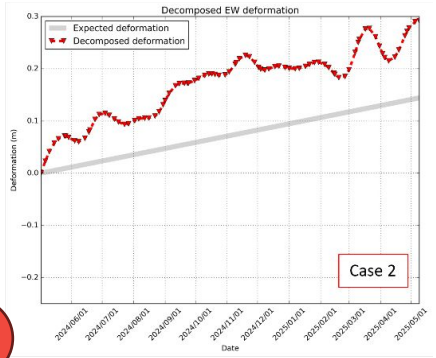
LOS measurement
=
ground deformation
+
decorrelation noise
+
atmospheric noise

3D InSAR Results



3D Deformation Profile





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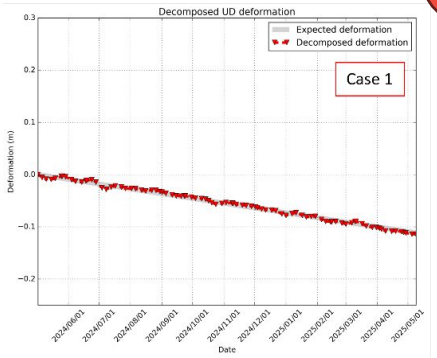
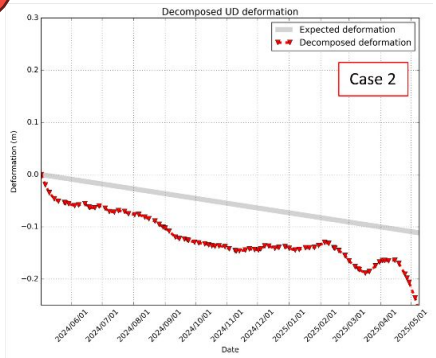
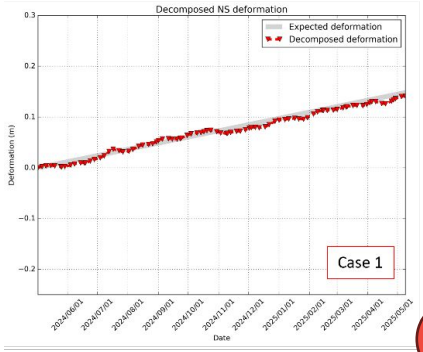
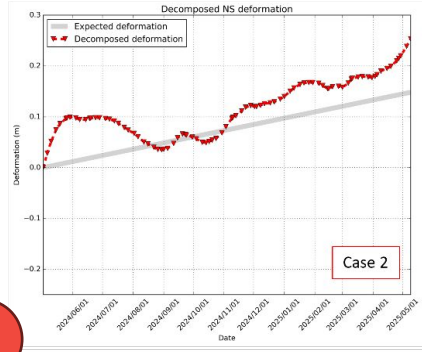




Case 1	UD RMSE	0.019 m
	EW RMSE	0.024 m
	NS RMSE	0.026 m





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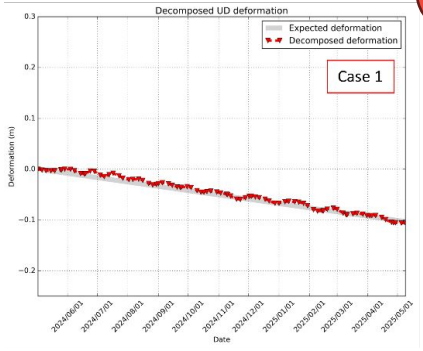

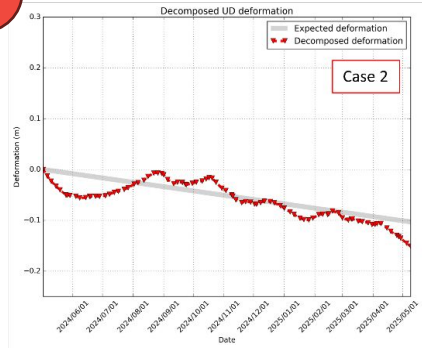

Case 2	UD RMSE	0.082 m
	EW RMSE	0.116 m
	NS RMSE	0.115 m

Summary

- Our study shows that CHORUS provides north-south component of deformation with its mid-inclination orbit
- Optimal beam combination can reconstruct reliable temporal measurement of 3D deformation
- 3D InSAR performance is strongly affected by the different viewing geometries of SAR satellites
- MDA’s data optimization can offer the best beam combination for the selected AOI
- MDA’s 3D InSAR algorithm can combine different beams and mitigate the noise to get the best 3D components of surface displacement

THANK YOU

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