Synspective

High-Frequency, High-Resolution Ground Displacement Measurement using the StriX Constellation

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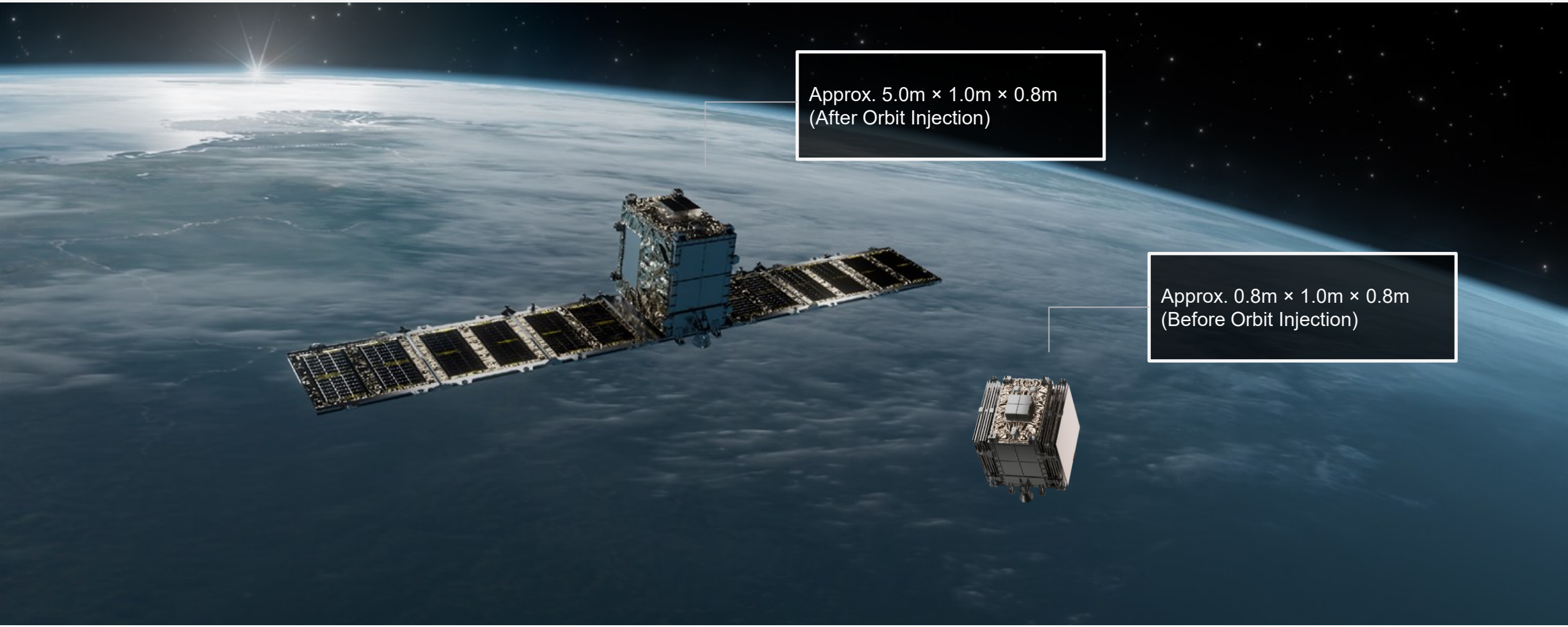
Fringe 2026 @ Jagiellonian University, Kraków, Poland

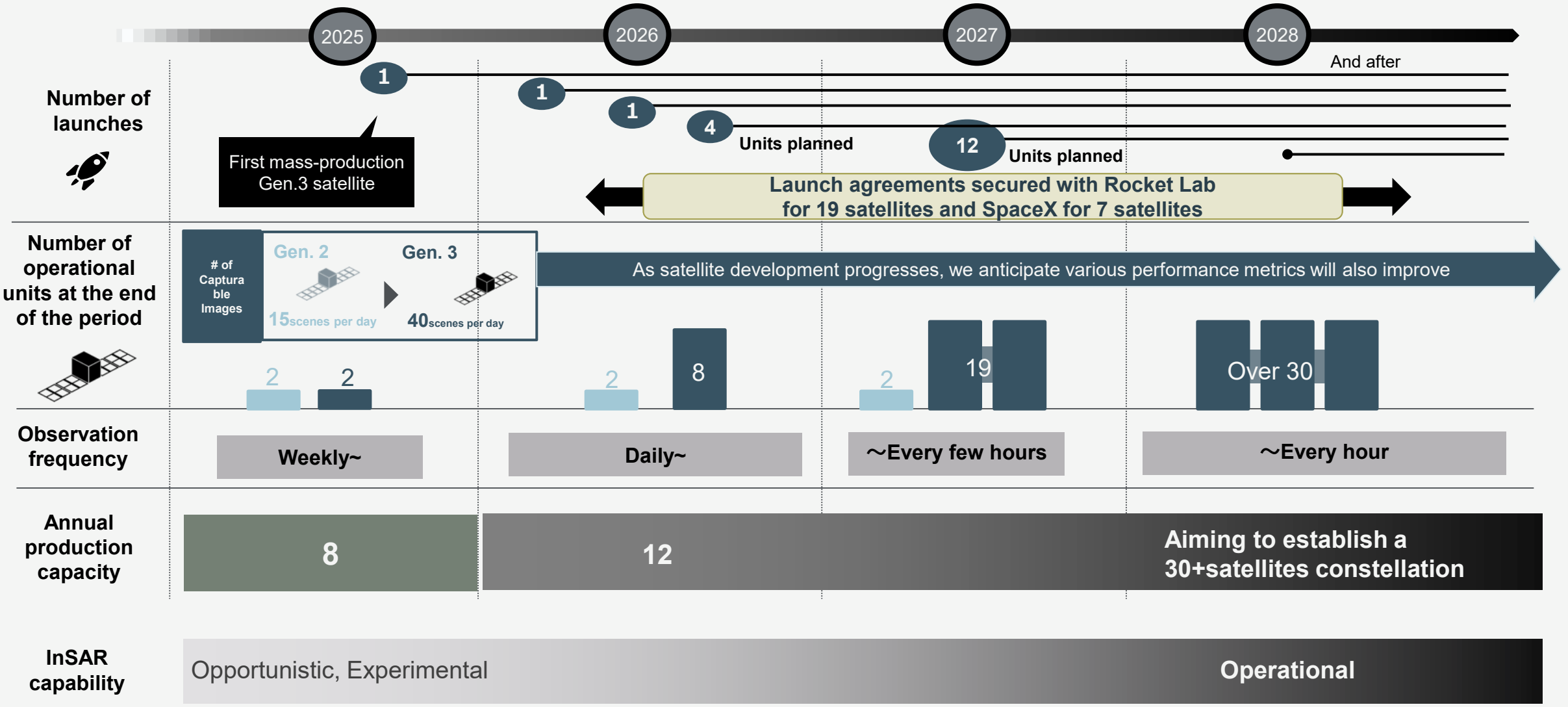
17 June 2026

StriX Constellation

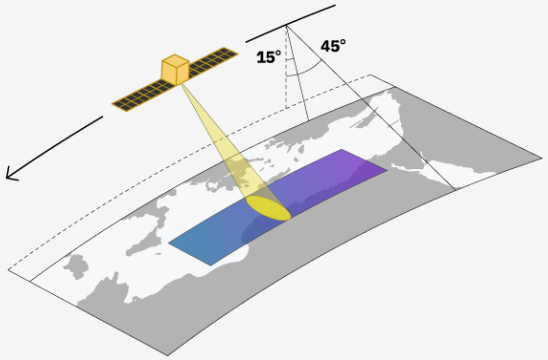
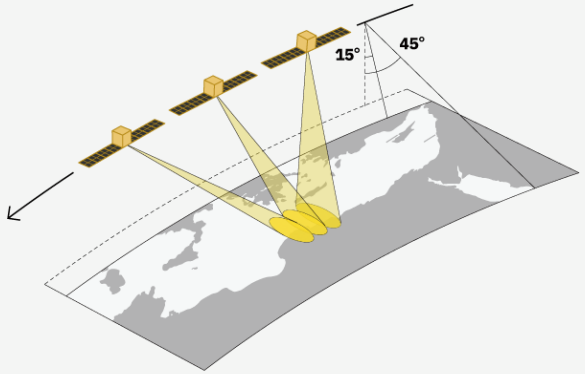
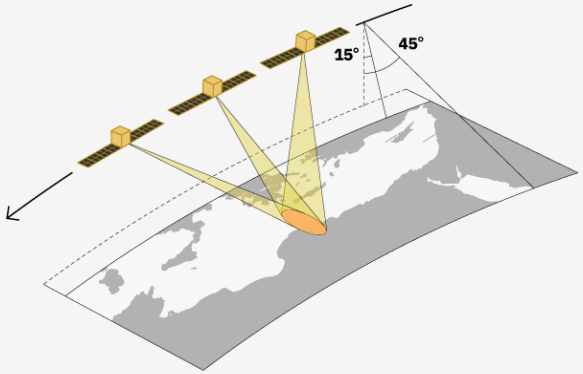
Synspective's X-band Small SAR Satellite "StriX"



Satellite Manufacturing and Launch Plan



Observation Modes

Observation Modes	Stripmap	Sliding Spotlight	Staring Spotlight
			
Nominal swath width	20 km	10 km	10 km
Nominal azimuth length	50 – 70 km (max 350 km)	10 km	3 km
Ground range resolution*	3.6 m	0.9 / 0.46 m	0.9 / **0.46 m**
Azimuth resolution	2.6 m	0.9 / 0.5 m	0.5 / **0.25 m**

* at 30° offnadir angle

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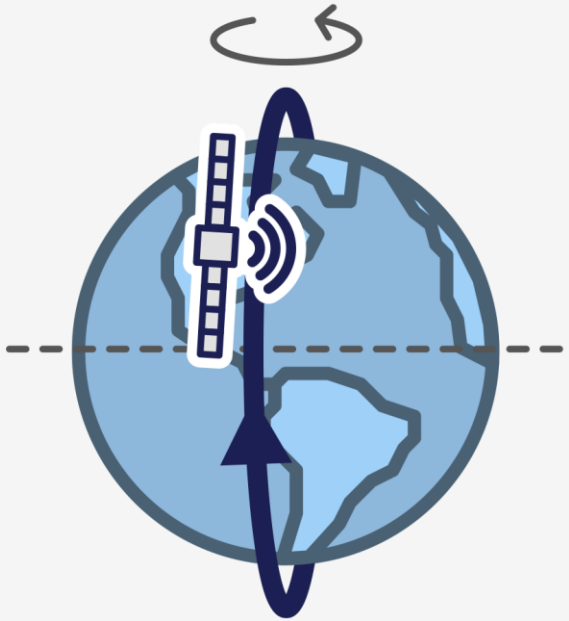
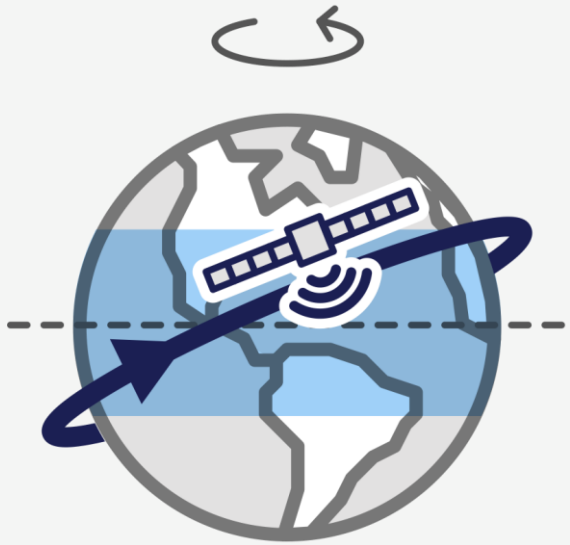
SSO (Sun-Synchronous Orbit)



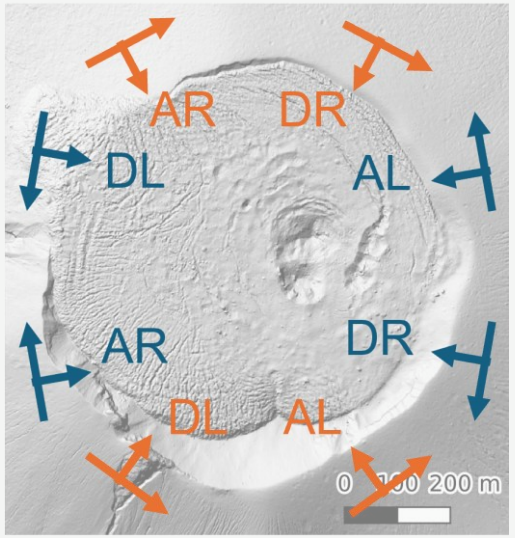
- Global coverage
- 1 day repeat orbit
- StriX-α, β, 1, 2, 3

MIO (Mid-Inclination Orbit)



- Frequent revisit in mid-latitude
- North-south sensitivity
- StriX-4, 5, 6

Observation geometry



Blue: SSO
Orange: MIO
A: Ascending
D: Descending
R: Right
L: Left

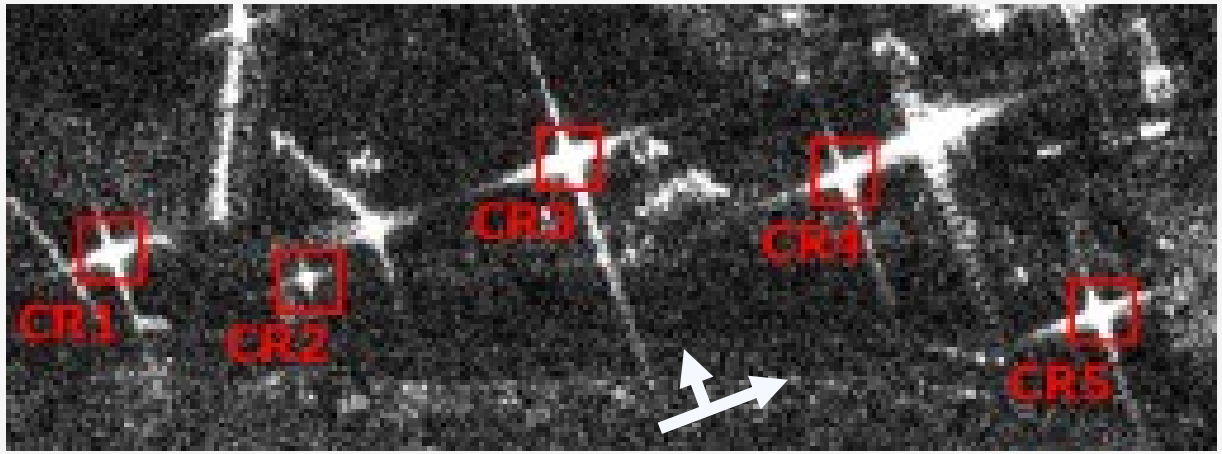
CR-Based Validation of mm-Level InSAR Accuracy (1-Day Repeat-Pass)

Acknowledgments:
This validation utilized deliverables from the FY2025 Demonstration Project Led by the Cabinet Office to Expand the Use of Small SAR Satellite Constellations. The installation and measurement of the CRs were carried out in cooperation with Pacific Consultants Co., Ltd.

CR and StriX Observations

75 cm per side

- CR3 and CR4 manually moved up/down by 1–2 mm several times
- Ground truth obtained by leveling



Satellite	StriX-4 (MIO)
Direction	Ascending, Left
Mode	Staring Spotlight 4 (0.46x0.25 m)
Period	13–23 December 2025 (n=11)
Interval	23 h 34 min
Bperp range	1200 m (Bcrit 31500 m)

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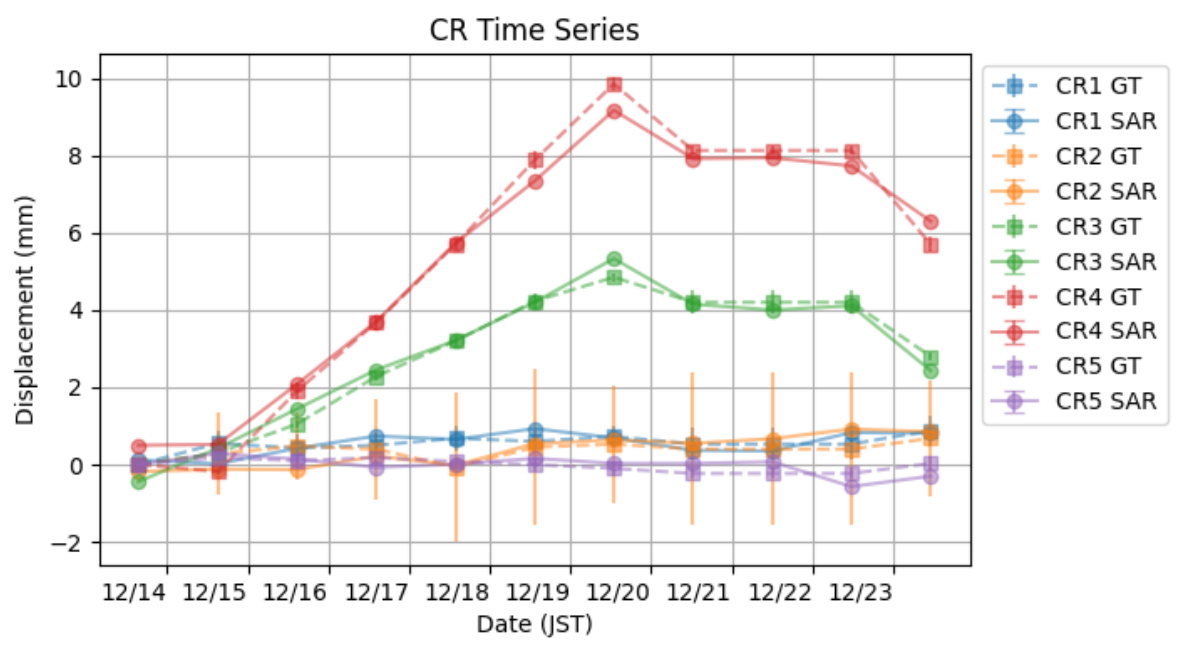
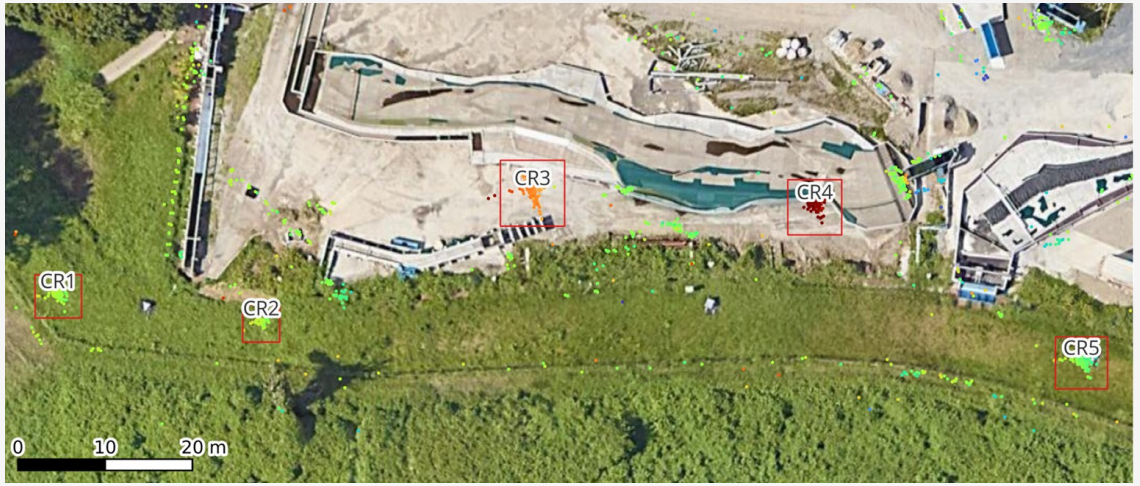
Displacement time series matched the ground truth (leveling) with **σ < 0.5 mm**



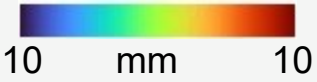
STD of SAR – GT (mm)

CR1	CR2	CR3	CR4	CR5
0.24	0.30	0.27	0.44	0.21



Google Earth, Image © 2026 Airbus

* SAR LOS displacement projected onto vertical



High-Resolution Pixel Offset Time-Series Analysis

InSAR vs Pixel Offset

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Feature	InSAR	Pixel Offset (e.g., ALOS-2/4 3 m resolution)	Pixel Offset (StriX <0.5 m resolution)
Measurement	Phase difference	Amplitude cross-correlation	Amplitude cross-correlation
Direction	1D (Line-of-Sight, Range)	2D (Range & Azimuth)	2D (Range & Azimuth)
Accuracy	High (mm - cm)	Low (10 - 30 cm)*	**High (1 - 5 cm)***
Resolution	High (10 m or finer)	Low (~100 m)	**High (10 m or finer)**
Large Displacement Sensitivity	Poor (decorrelation & unwrapping)	Excellent	Excellent
Baseline Requirement	Strict	Less strict	Less strict
Target Use Case	Subsidence, static structures	Glaciers, large earthquakes	Large-displacement structures

*Proportional to SLC resolution (typically 1/10 to 1/30 of SLC resolution)

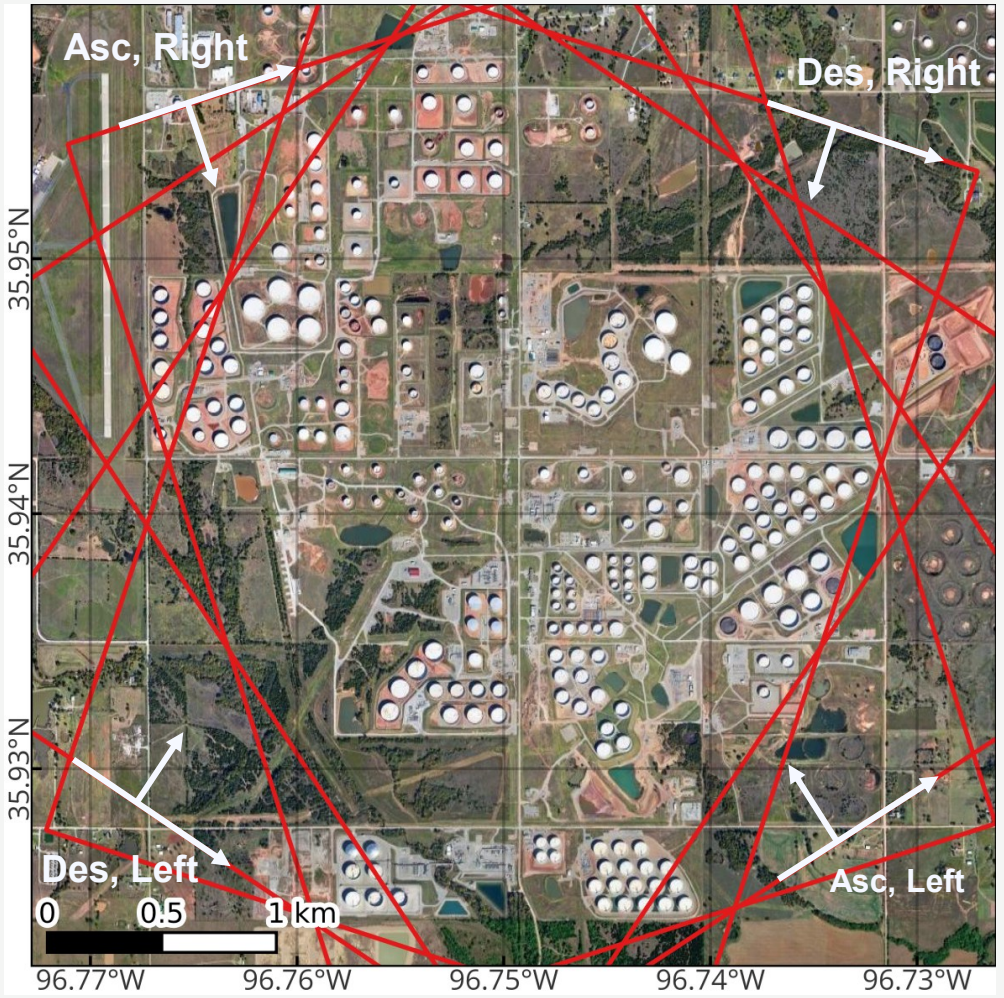
Case Study in Cushing, Oklahoma, US

Satellite	StriX-4 (MIO)
Directions	4 (Asc/Des, Right/Left)
Observation Period	Nov 30, 2025 - Jan 13, 2026 (17-40 images in each direction)
Revisit time	23 hr 33 min (<1 day)
Observation mode	Staring Spotlight 4 (ST4) (600 MHz, ~0.37x0.25 m @offn = 42°)
Bperp range	~45km (Bcrit ~45km)
Coregistration	To Jan 1, 2026 data (single prime)
Network for Time Series Analysis	3 consecutive pairs

https://www.worldrecordacademy.org/2023/10/worlds-biggest-tank-farm-world-record-in-cushing-oklahoma-423520

Number of tanks: ~400
Tank diameter: 30-80 m
Height: 10-20 m

"Pipeline Crossroads of the World“
Central hub within the United States and worldwide oil industry



Google Earth, Image © 2026 Airbus

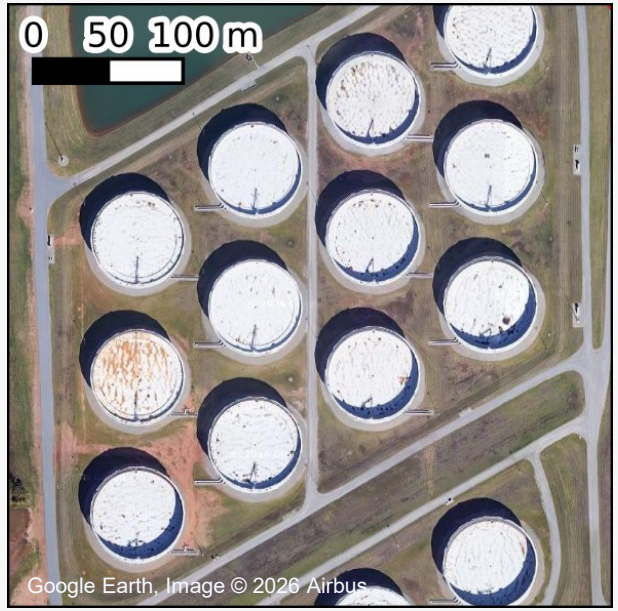
Pixel Offset Result Example

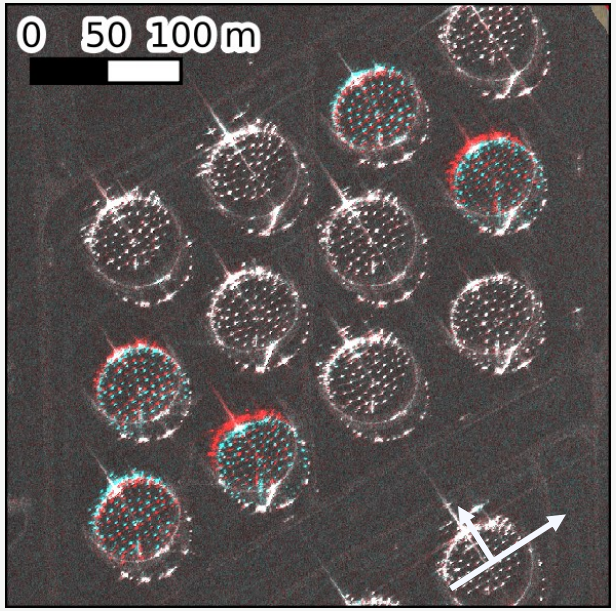
Synspective

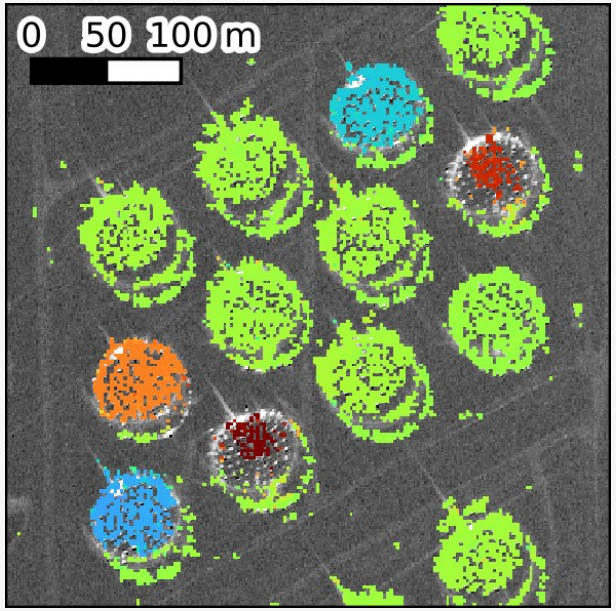
Amplitude Change Detection (ACD)

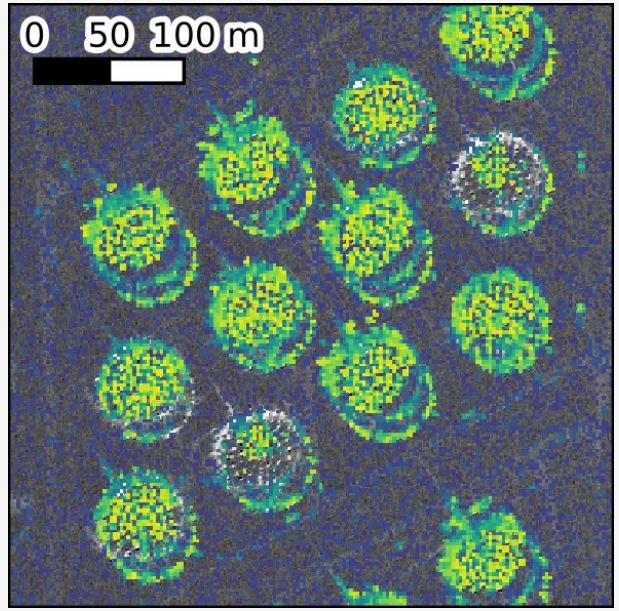
Range Offset (RgO)

Correlation Coefficient (CC)

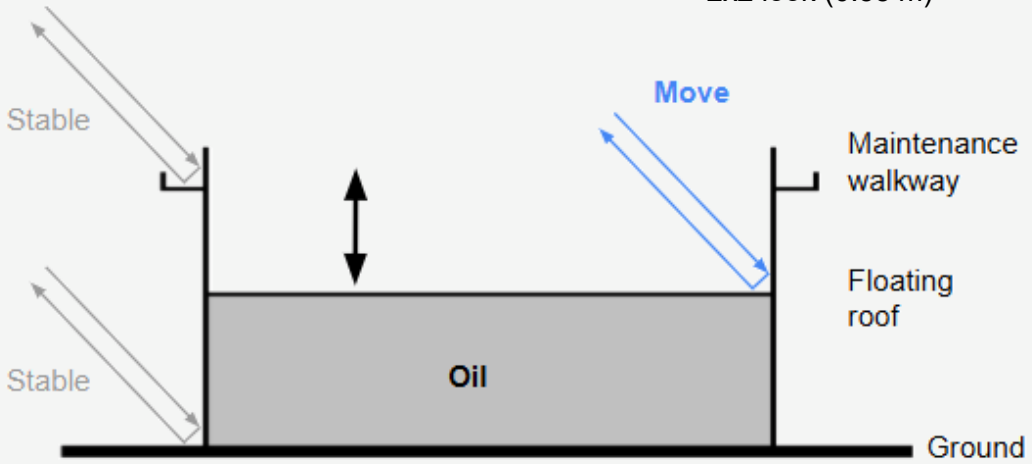








2x2 look (0.55 m)



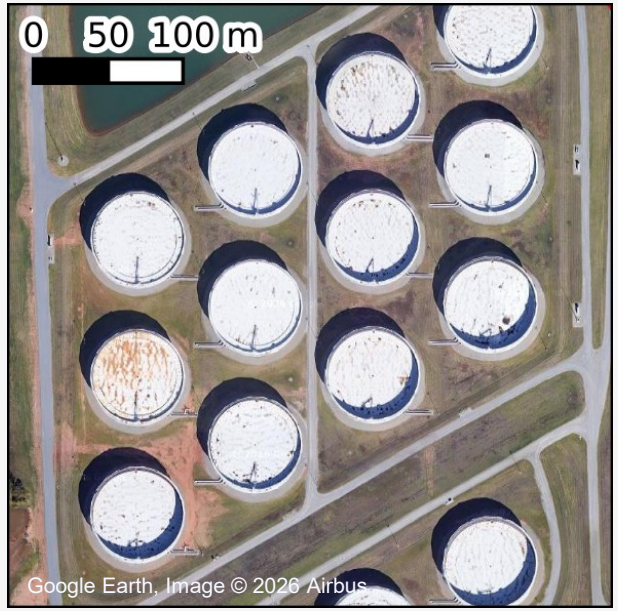
8x8 look (2.2 m grid)
Window size 16x16 (4.4 m grid)
Masked with CC>0.4

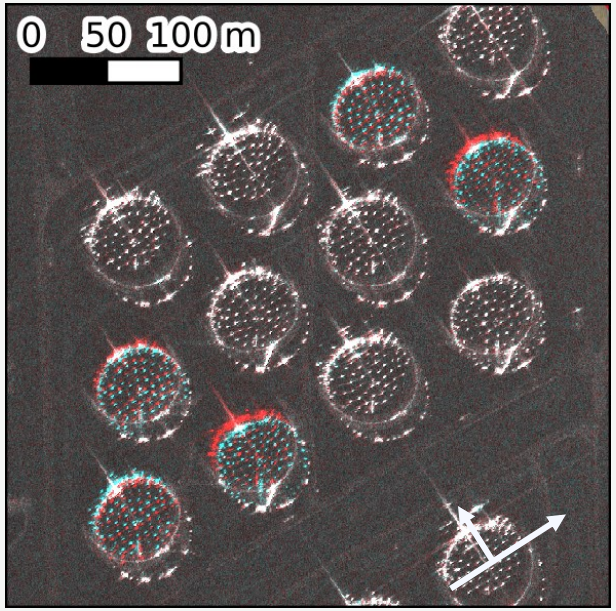
- 20260101-20260102
- Ascending Left
- Incidence angle 46.2°

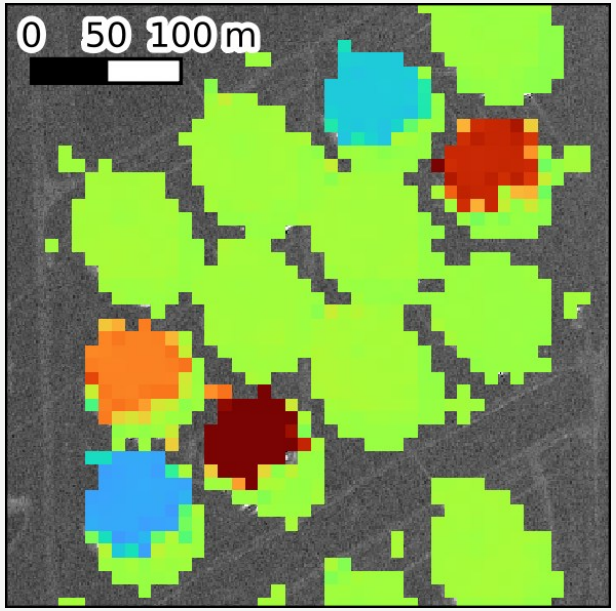
Pixel Offset Result Example

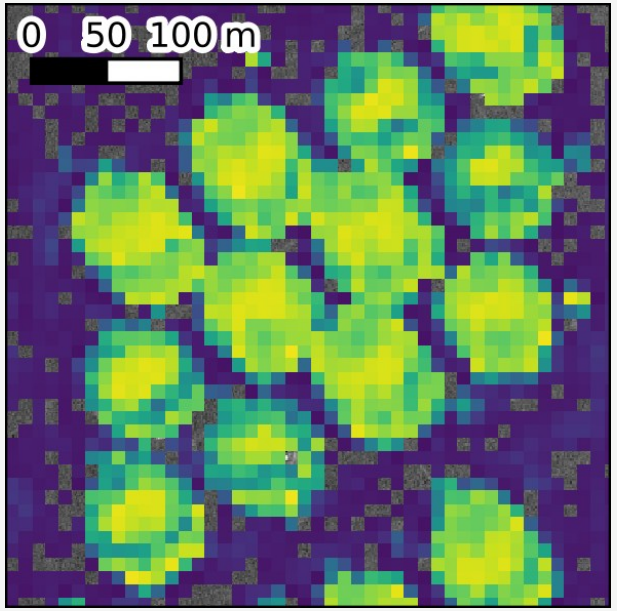
Synspective

Amplitude Change Detection (ACD) | Range Offset (RgO) | Correlation Coefficient (CC)





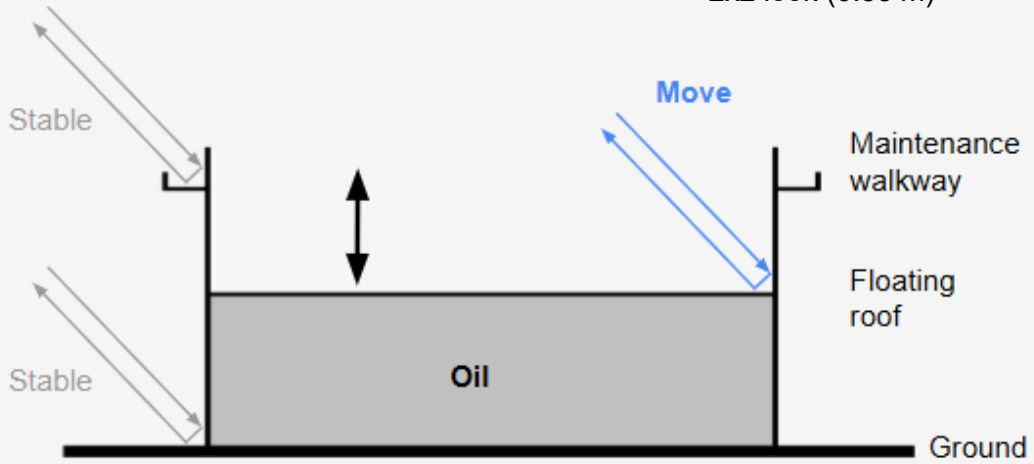




2x2 look (0.55 m)

-3 m 3

0 1



32x32 look (8.8 m grid)
Window size 64x64 (17.6 m grid)
Masked with CC>0.2

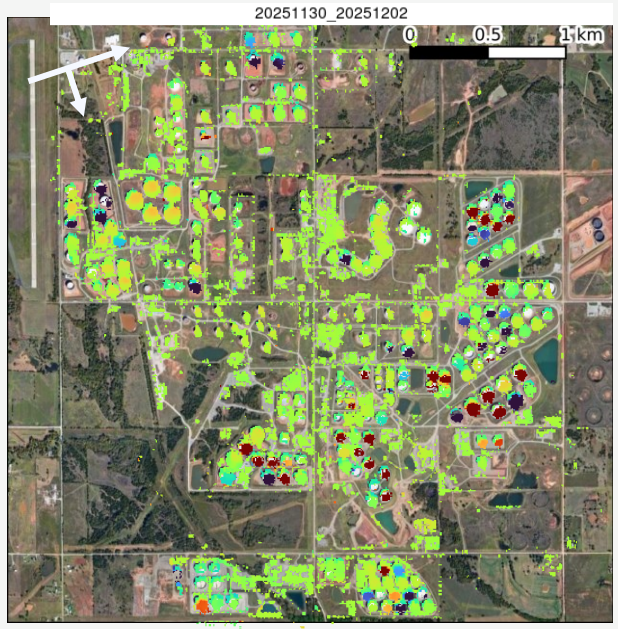
- 20260101-20260102
- Ascending Left
- Incidence angle 46.2°

Pixel Offset Time-Series Results

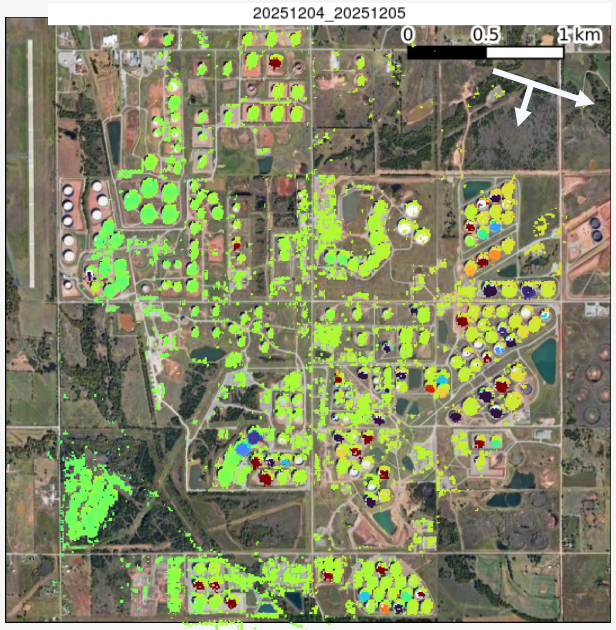
Synspective

1-day interval range offsets

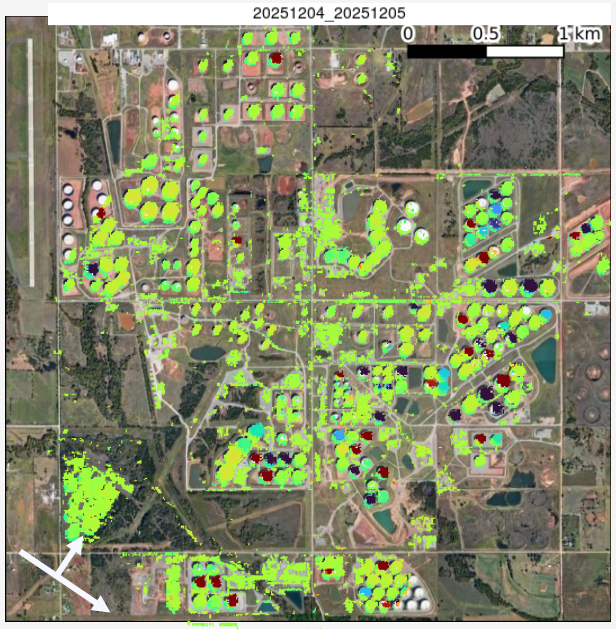
Ascending Right



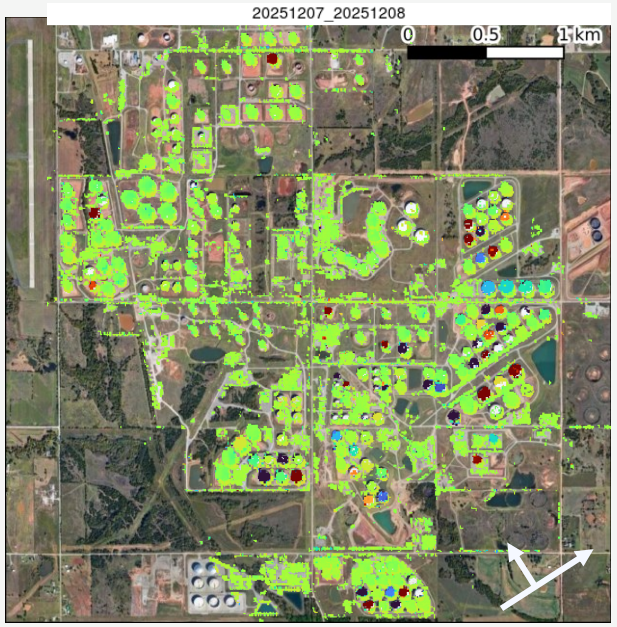
Descending Right



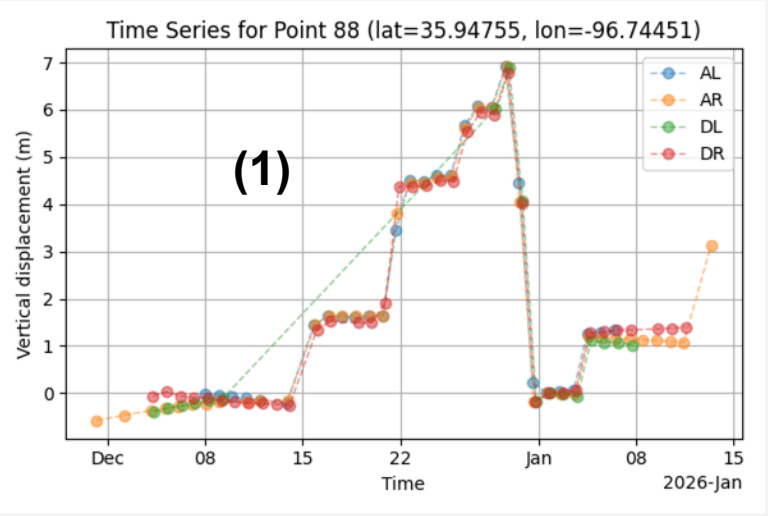
Descending Left

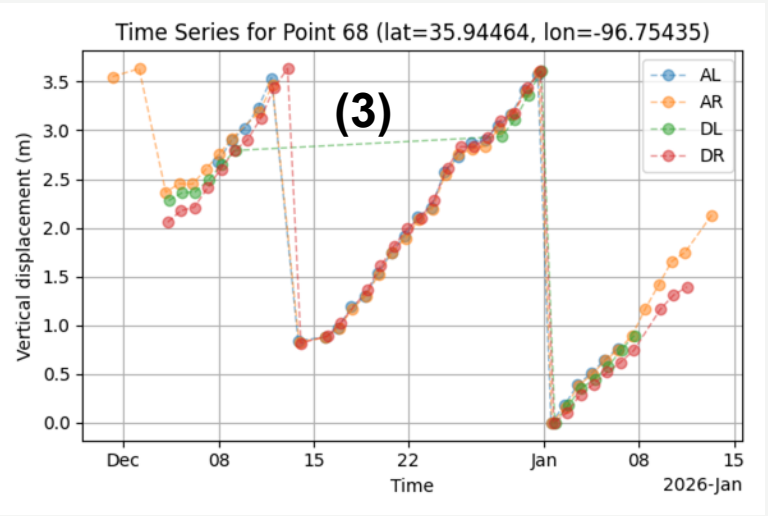


Ascending Left

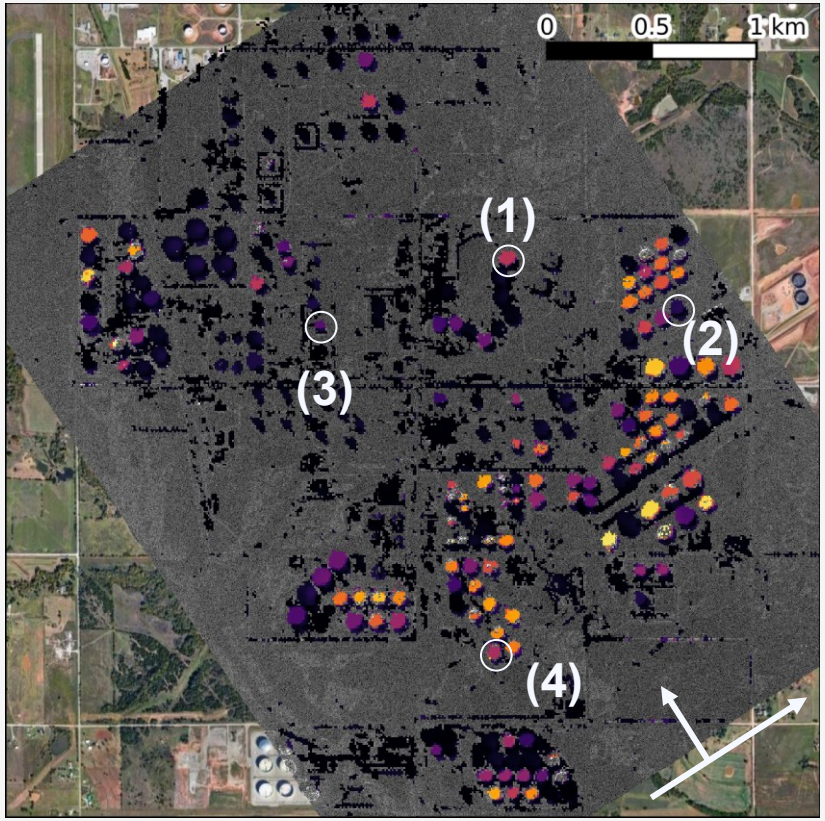


Pixel Offset Time-Series Results

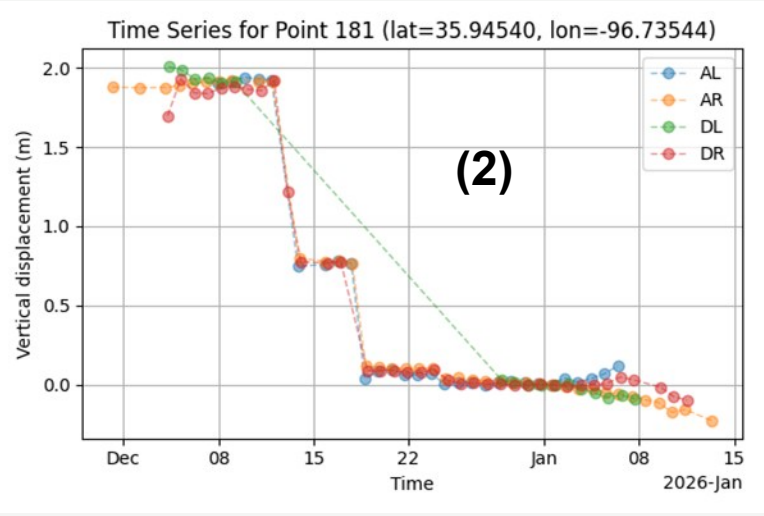


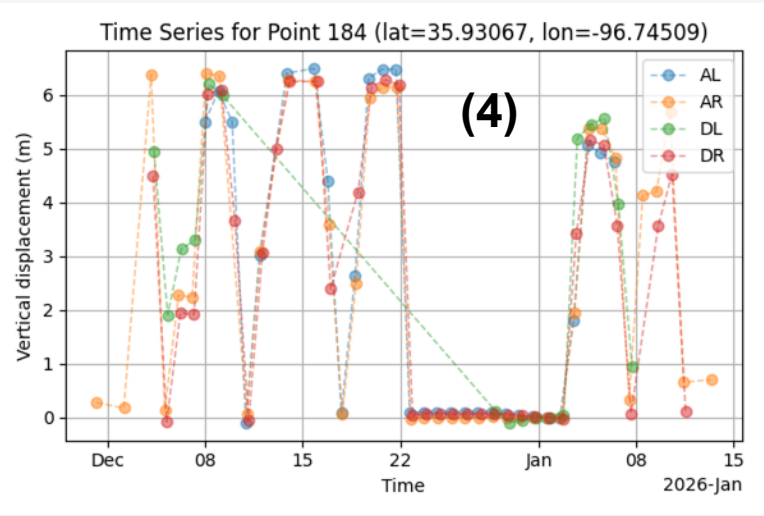


Max Range Offset In AL



Range offsets from each direction were converted to vertical by *1/cosθ





Uncertainty Estimation

Synspective

Theoretical uncertainty of pixel offset:

$$\sigma = \sqrt{\frac{3}{10L}} \frac{\sqrt{2+5\gamma^2-7\gamma^4}}{\pi\gamma^2} p_{\mathrm{spa}}$$

(De Zan, 2014)
L: Number of independent samples
γ: **Correlation Coefficient**
p_{spa}: Pixel spacing of SLC

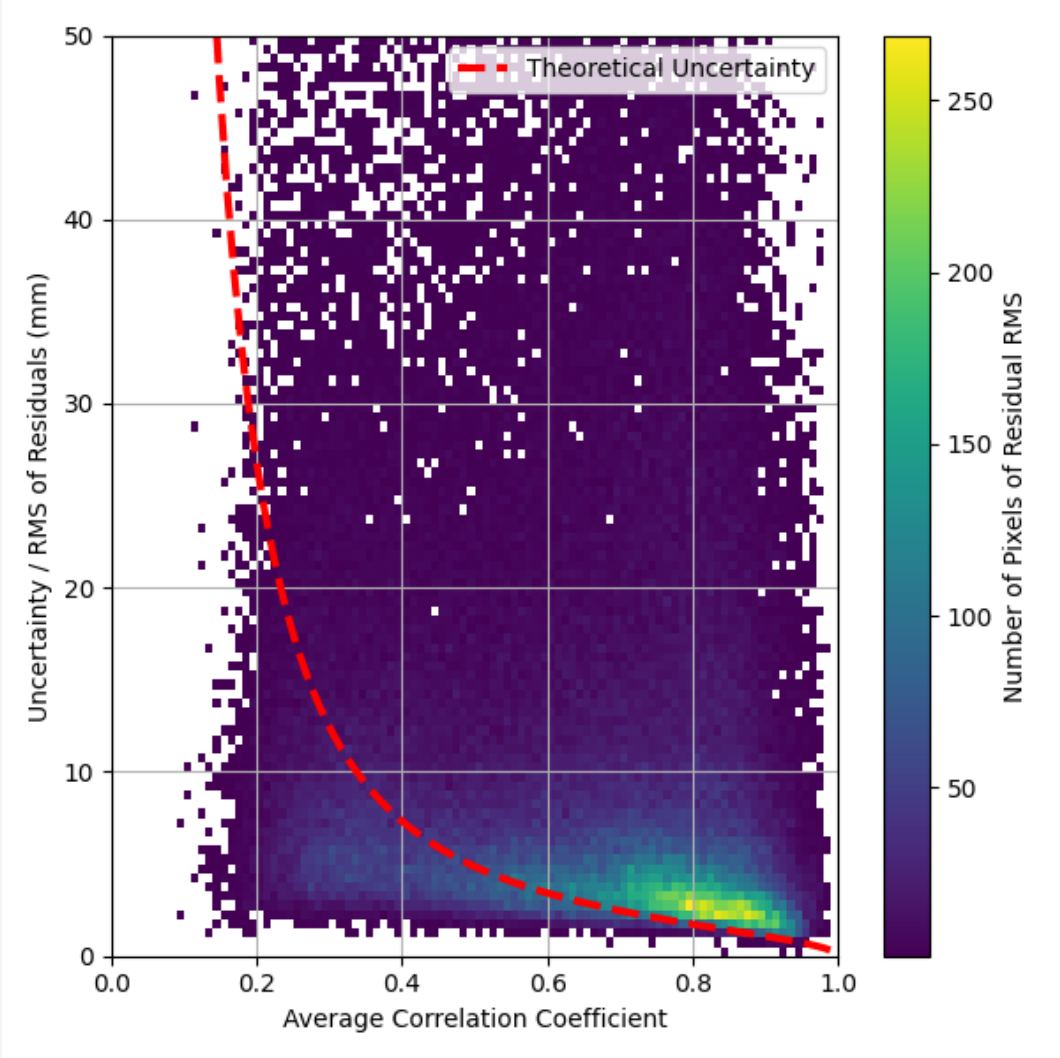
Residual RMS (empirical uncertainty):

RMS of residuals of each observation from the least-square solution in the time series inversion

Most oil tanks have

- **Correlation Coefficient > 0.7**
- **Residual RMS < 5 mm**
- **Consistent with theoretical uncertainty**

Note: This uncertainty reflects only random errors. Systematic errors (e.g., atmosphere, stereoscopic effect (∝Δh & Beprp)) are also included the displacement time series.

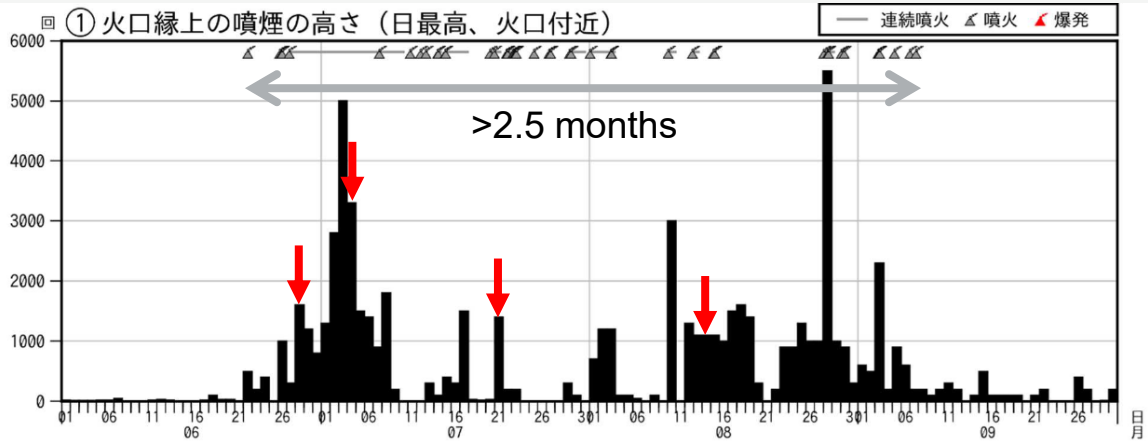


Volcanic Activity Monitoring

Mt. Shinmoedake Eruption in 2025

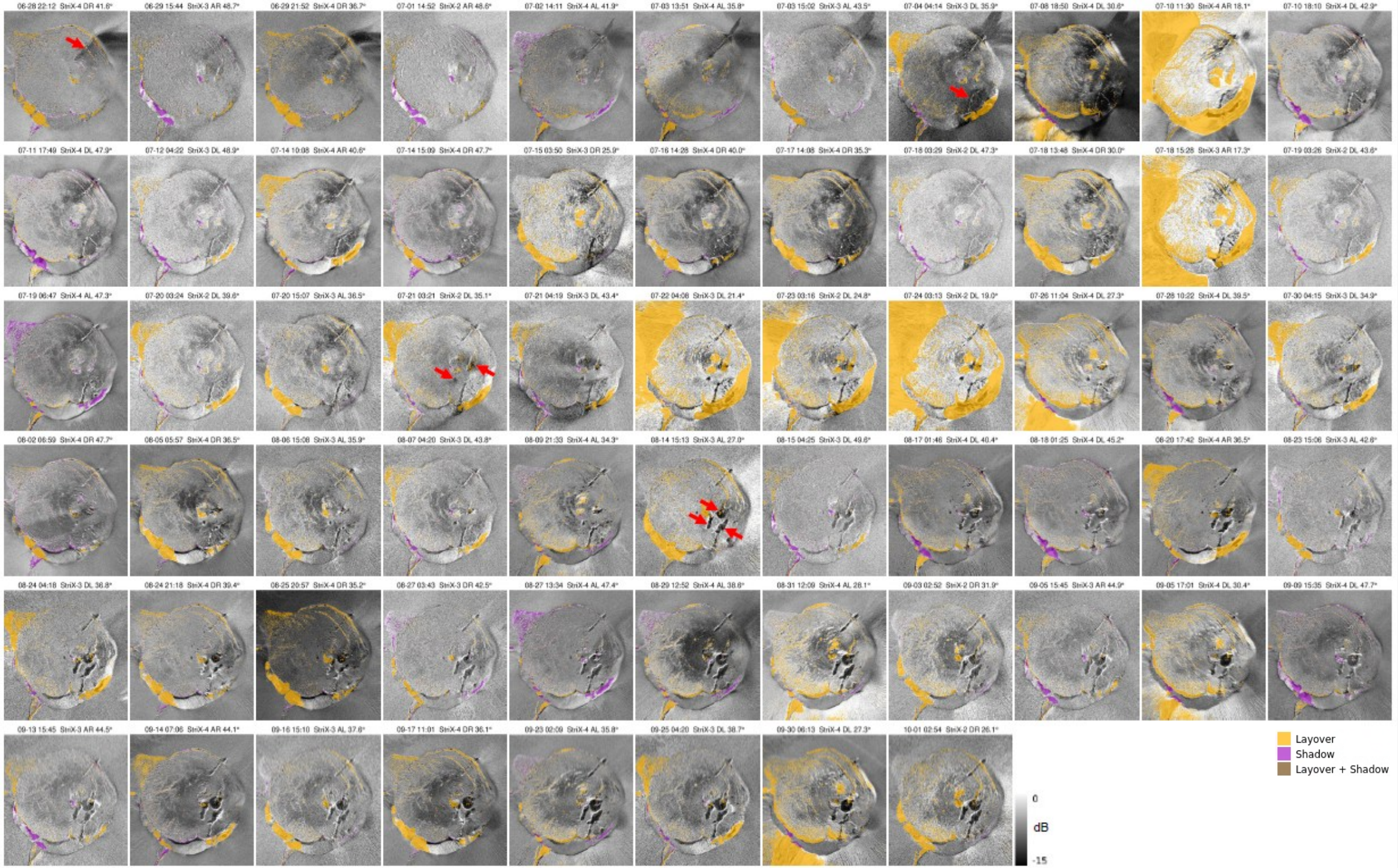
- First eruption in seven years occurred on 22 June 2025
- The initial eruption occurred on the northeastern side within the crater, and activity was also confirmed on the southeastern side from around 3 July
- The series of eruptions continued until September 8
- StriX's high-frequency (63 images over 96 days, average interval of ~1.5 days) and high-resolution (<1 m) observations clearly captured topographic changes around the crater

The maximum daily height of the plume above the crater rim (near the crater)

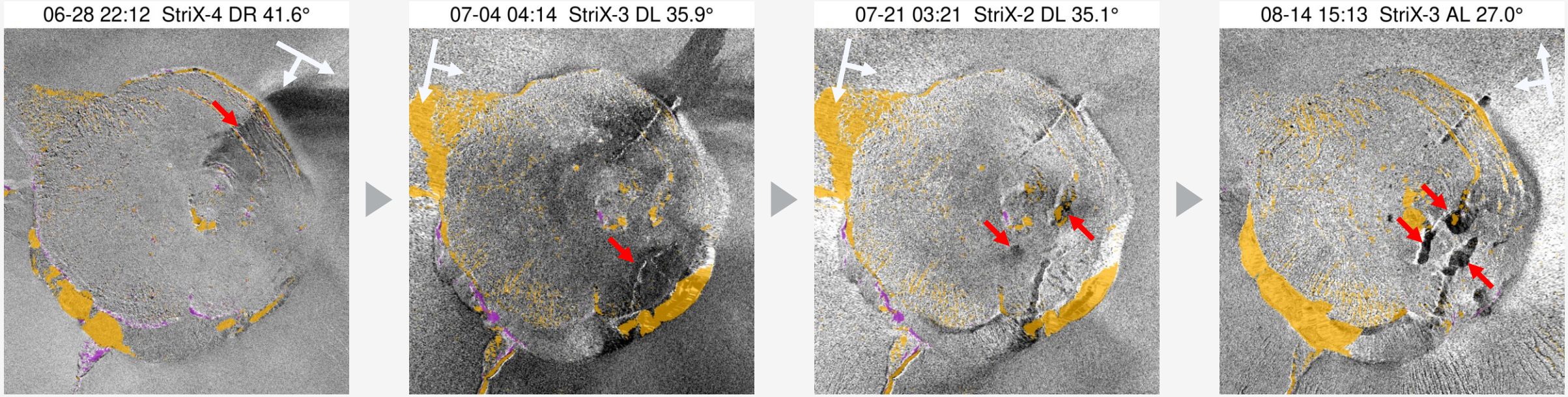


気象庁 火山活動解説資料（霧島山）年報（2025）
https://www.data.jma.go.jp/vois/data/report/monthly_v-act_doc/fukuoka/2025y/505_25y.pdf

On 3 July 2025 https://www.gsj.jp/hazards/volcano/kirishima/index.html


Layover
Shadow
Layover + Shadow
0
dB
-15

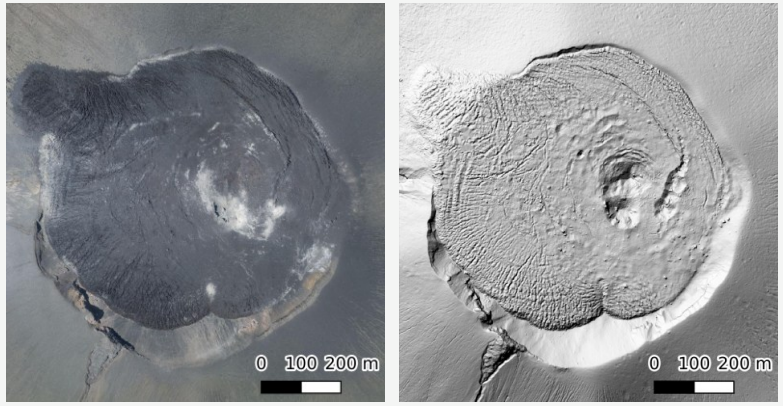
Intensity Time-Series (Radiometric Terrain Corrected γ_0)



Layover
Shadow
Layover + Shadow

Before Eruption

Optical (2023) 1mDEM (2018)



Optical: GSI Tiles, Latest Nationwide Photographs (Seamless) (https://cyberjapandata.gsi.go.jp/xyz/seamlessphoto/{z}/{x}/{y}.jpg)
1mDEM: Created by processing GSI Fundamental Geospatial Information (DEM) (https://service.gsi.go.jp/kiban/app/)

Height Change Measured by Post-Eruption Repeat-Pass InSAR (InSAR dDEM)

Synspective

(1) Select short dt and appropriate Bperp pair

SLC 20251227

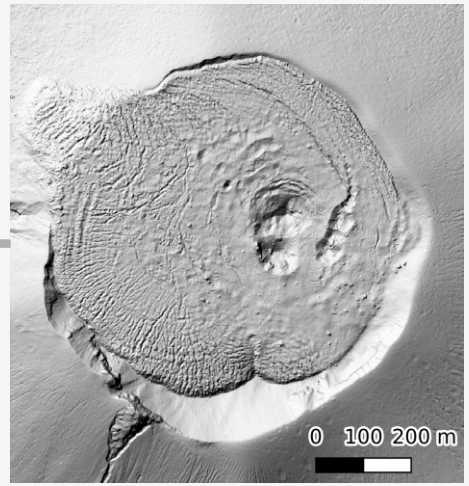
SLC 20251228

Bperp: 512 m
Height ambiguity: 14.4 m

$$\Delta\phi = \cancel{\phi_{atm}} + \cancel{\phi_{orb}} + \cancel{\phi_{disp}} + \phi_{topo} + \cancel{\phi_{noise}} + \cancel{2k\pi}$$

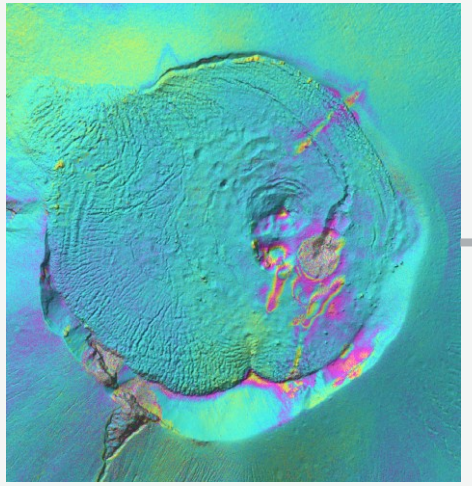
(2) (2) (1) (1)(3) (1)(3)

Reference DEM
(Before eruption)



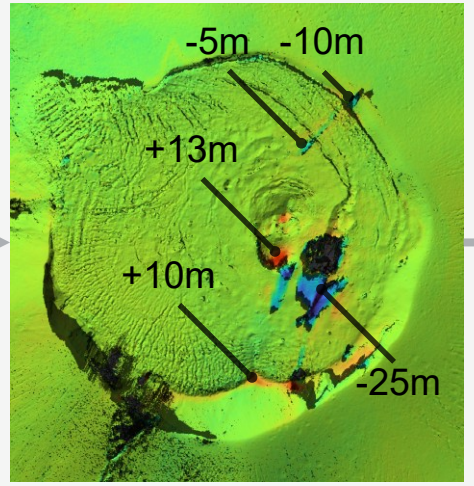
(2) Remove long-wavelength component
(3) Noise filter & unwrap

$\Delta\phi \approx \phi_{topo}$

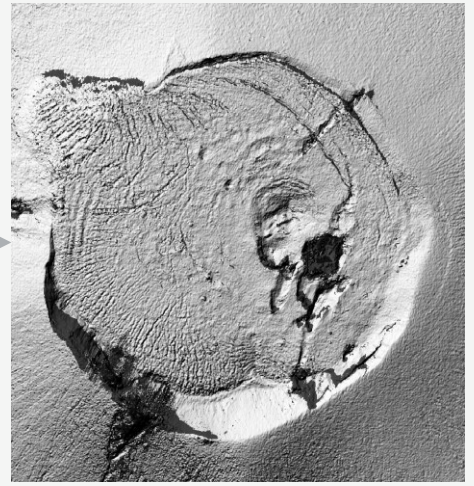


$$dh = \frac{\lambda r \sin\theta}{4\pi B_{\perp}} \phi_{topo}$$

Height change
(DEM error)



Refined DEM



The StriX constellation enables high-frequency, high-resolution ground displacement measurement

- **1-day repeat-pass InSAR (CR validation):** Daily InSAR with StriX achieved mm-level accuracy ($\sigma < 1$ mm vs. leveling) for artificial 1–2 mm CR displacements.
- **High-resolution Pixel Offset (Cushing oil tanks):** Sub-meter SLC enabled an offset grid finer than 10 m, yielding cm-level roof displacements consistent across 4 independent geometries.
- **Volcanic monitoring (Mt. Shinmoedake 2025):** 63 observations over 96 days (~1.5-day avg interval) at 0.25–1 m resolution captured crater changes; repeat-pass InSAR dDEM revealed >20 m topographic change with meter-order accuracy.
- **SSO + MIO synergy:** Combining orbits adds North–South sensitivity and provides various viewing geometries, enabling 3D displacement reconstruction and mitigation of layover/shadow in steep terrain.
- **Outlook:** The planned 30+ satellite constellation (from 2028) will deliver more frequent observation capability, opening operational daily-to-hourly monitoring.

Synspective