

Phenomenological Comparison of NISAR and Sentinel-1 L-band and C-band InSAR Time Series

Howard Zebker and Paul Rosen

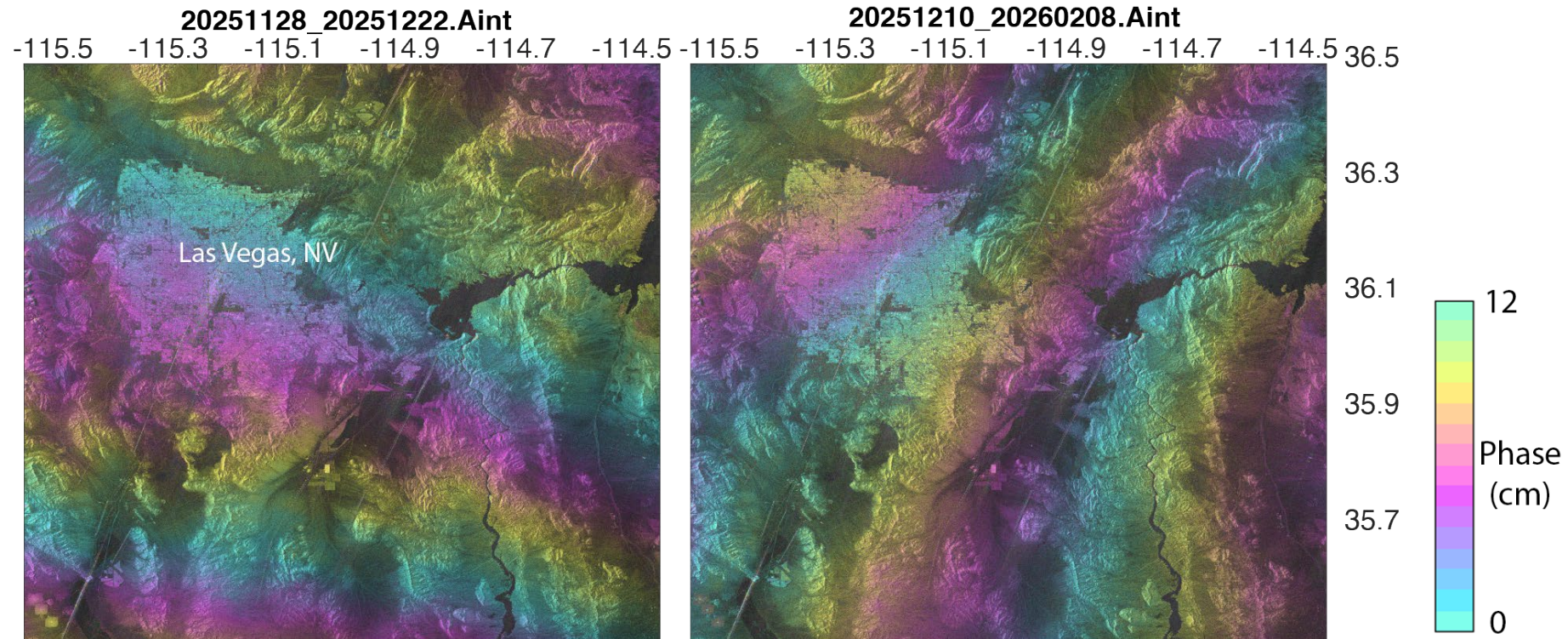
Stanford University, Stanford, CA, USA
Caltech Jet Propulsion Laboratory, Pasadena, CA, USA

Differences between Sentinel-1 and NISAR

- Wavelength – the primary difference
 - Sentinel-1: C-band, 5.66 cm
 - NISAR: L-band, 24 cm
- Resolution
 - Sentinel-1: For InSAR, roughly 5 m x 15 m on ground
 - NISAR: Several, but 5m x 5m for data shown here
- Wavelength dominates comparisons
 - NISAR fringes 4x wider
 - NISAR has a ~16 times higher level of ionospheric contamination
 - Scattering from the surface/subsurface will be quite different
- Our intention here is not that one is better than the other, just different

The challenge of the ionosphere

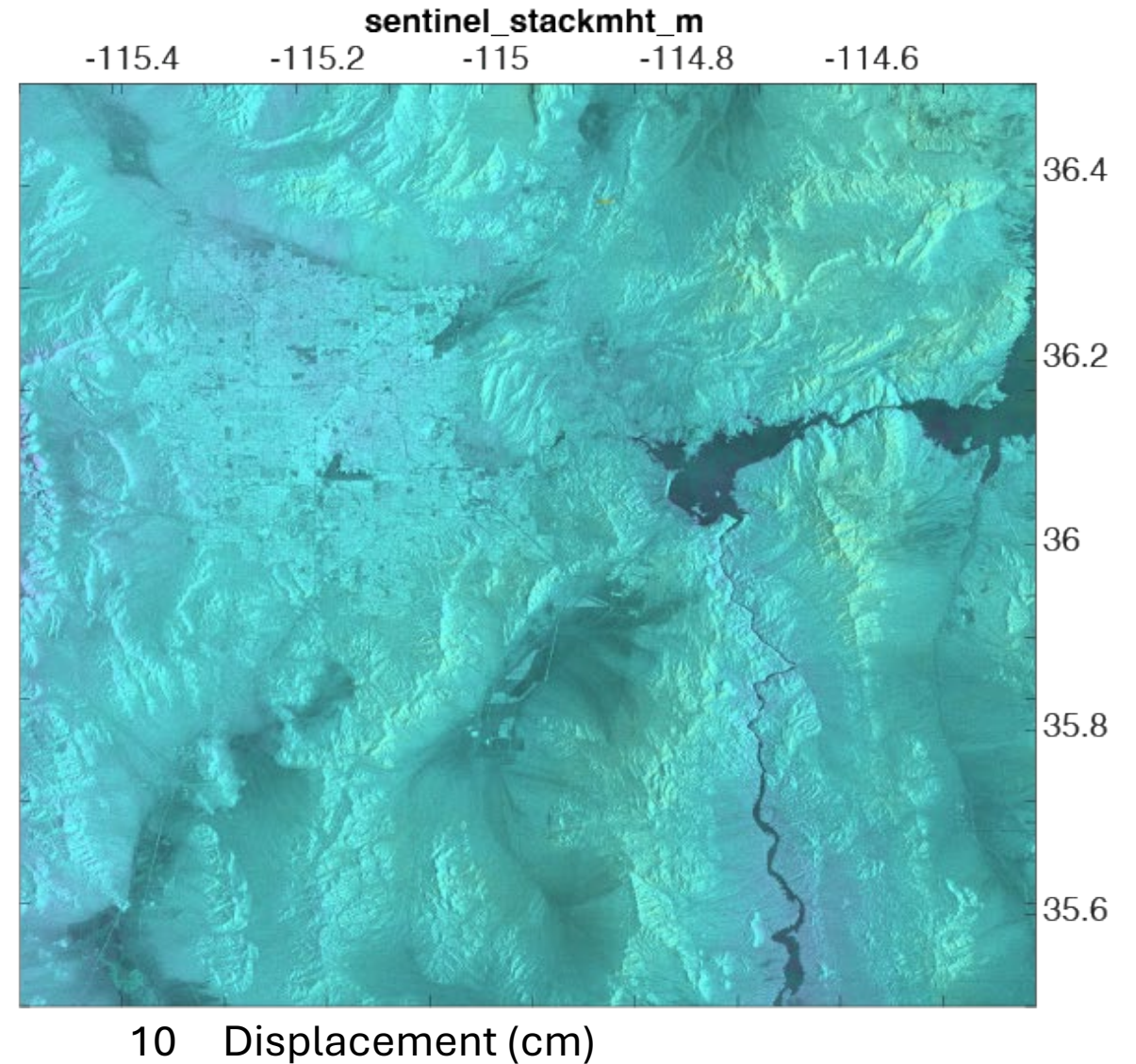
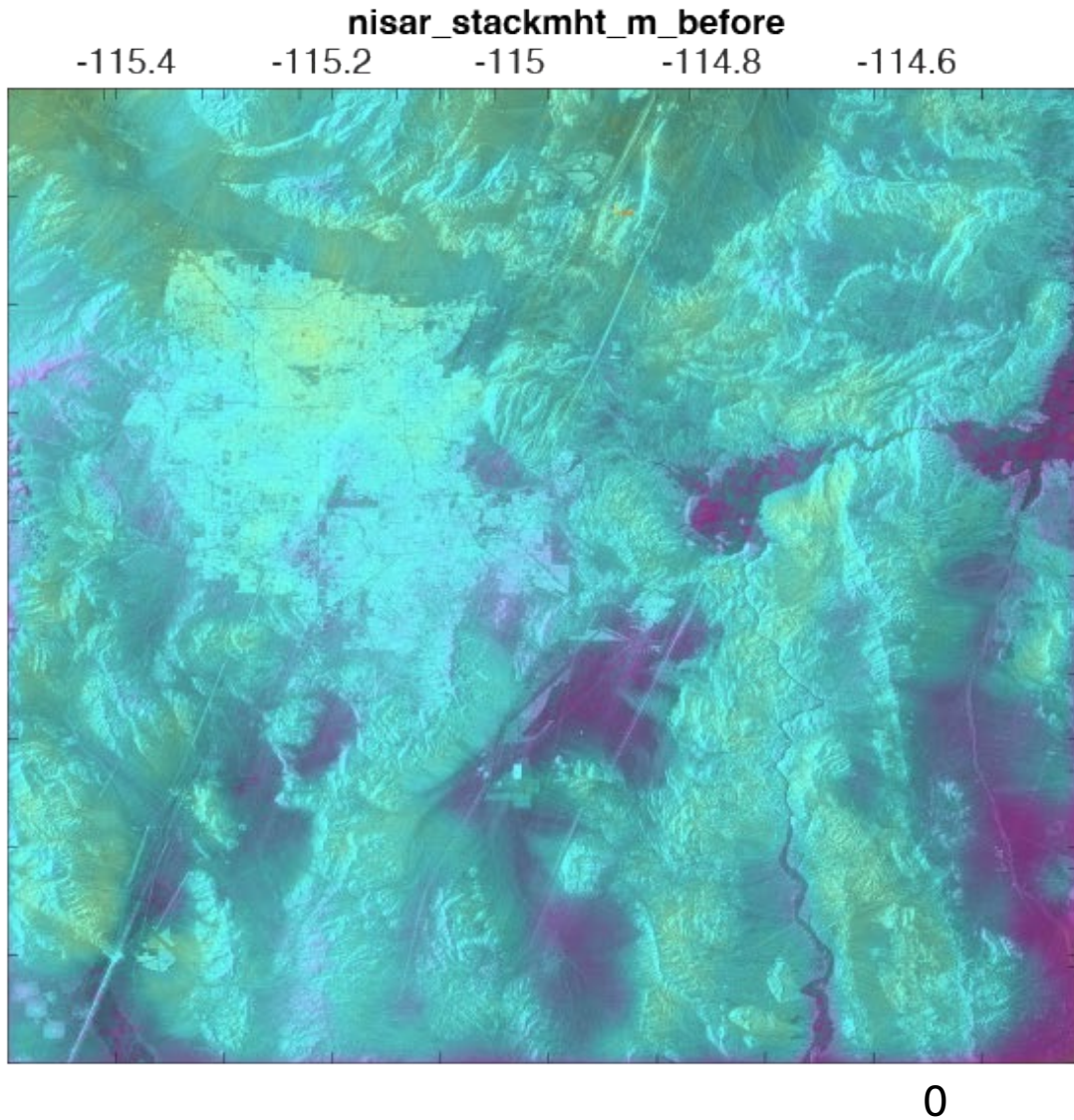
- Typical scenes from NISAR show from nearly zero to 100 cm ionospheric artifacts in raw interferograms
- These have to be corrected for usable data – now in Stanford time series processor



Example 1: Region near Las Vegas, Nevada, USA with little underlying deformation

Las Vegas, Nevada, USA 

Comparison with Sentinel-1



Why apparent difference?

- Sentinel-1 shows little deformation
- Hypothesis: Different observed “displacements” follow from penetration into surface
- Predicted by several theoretical developments for soil moisture:
 - e.g., Ansari (2021), De Zan (2014,2015), Zwieback (2017), Michaelides (2019), Wig (2024, 2025)

A simple model for penetration echoes

From Wig (2025)

Math

- Echo is sum of surface and subsurface reflections

$$s = s_s + s_d e^{-j\frac{4\pi}{\lambda}nd} = s_s + s_d e^{-jn_x} \text{ (simplified notation)}$$

- Then interferogram is

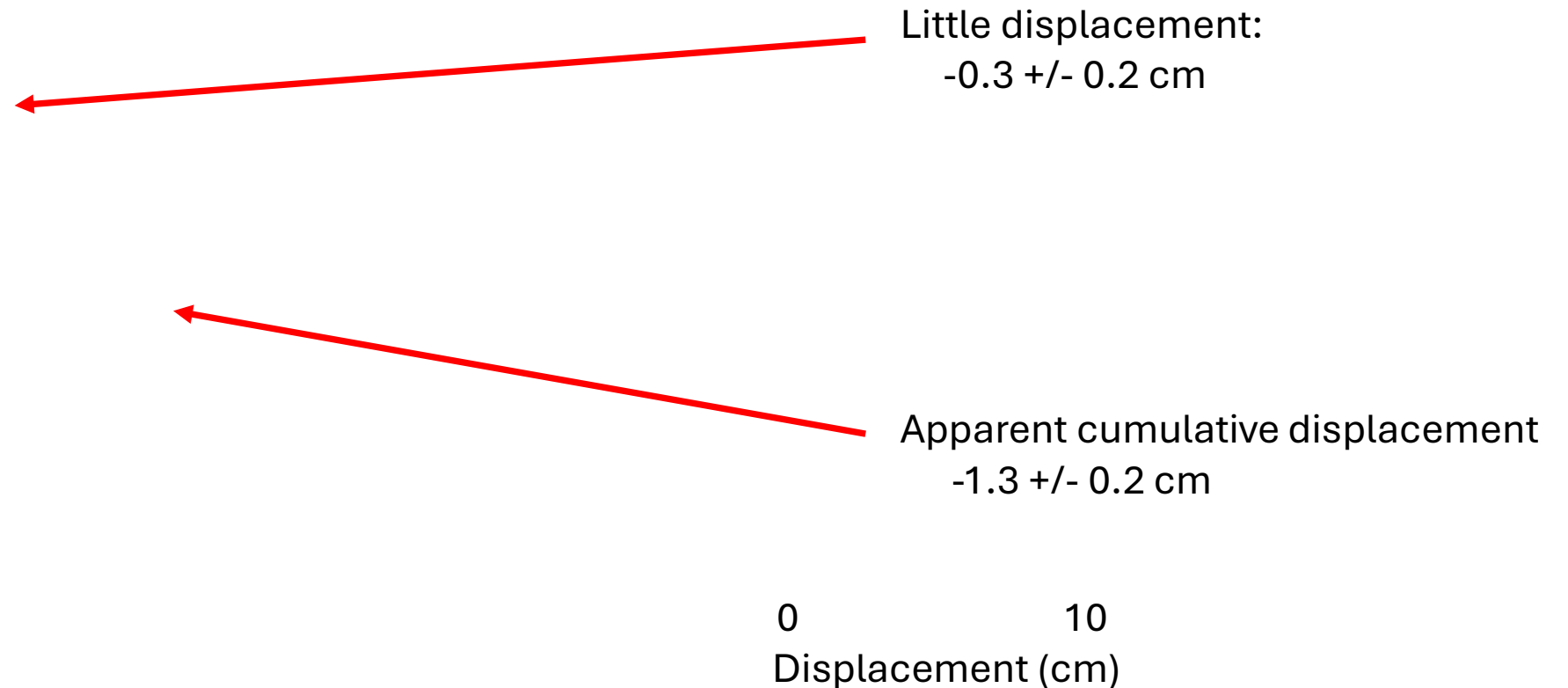
$$\begin{aligned} s_1 s_2^* &= (s_s + s_d e^{-jn_1 x}) (s_s^* + s_d^* e^{jn_2^* x}) \\ &= s_s s_s^* + s_s s_d^* e^{jn_2^* x} + s_d s_s^* e^{-jn_1 x} + s_d s_d^* e^{-jn_1 x + jn_2^* x} \end{aligned}$$

- After multilooking

$$\langle s_1 s_2^* \rangle = \sigma_s^0 + \sigma_d^0 e^{-jn_1 x + jn_2^* x}$$

- Thus interferogram phase increases with depth (x) and difference in index of refraction $n_1 - n_2$

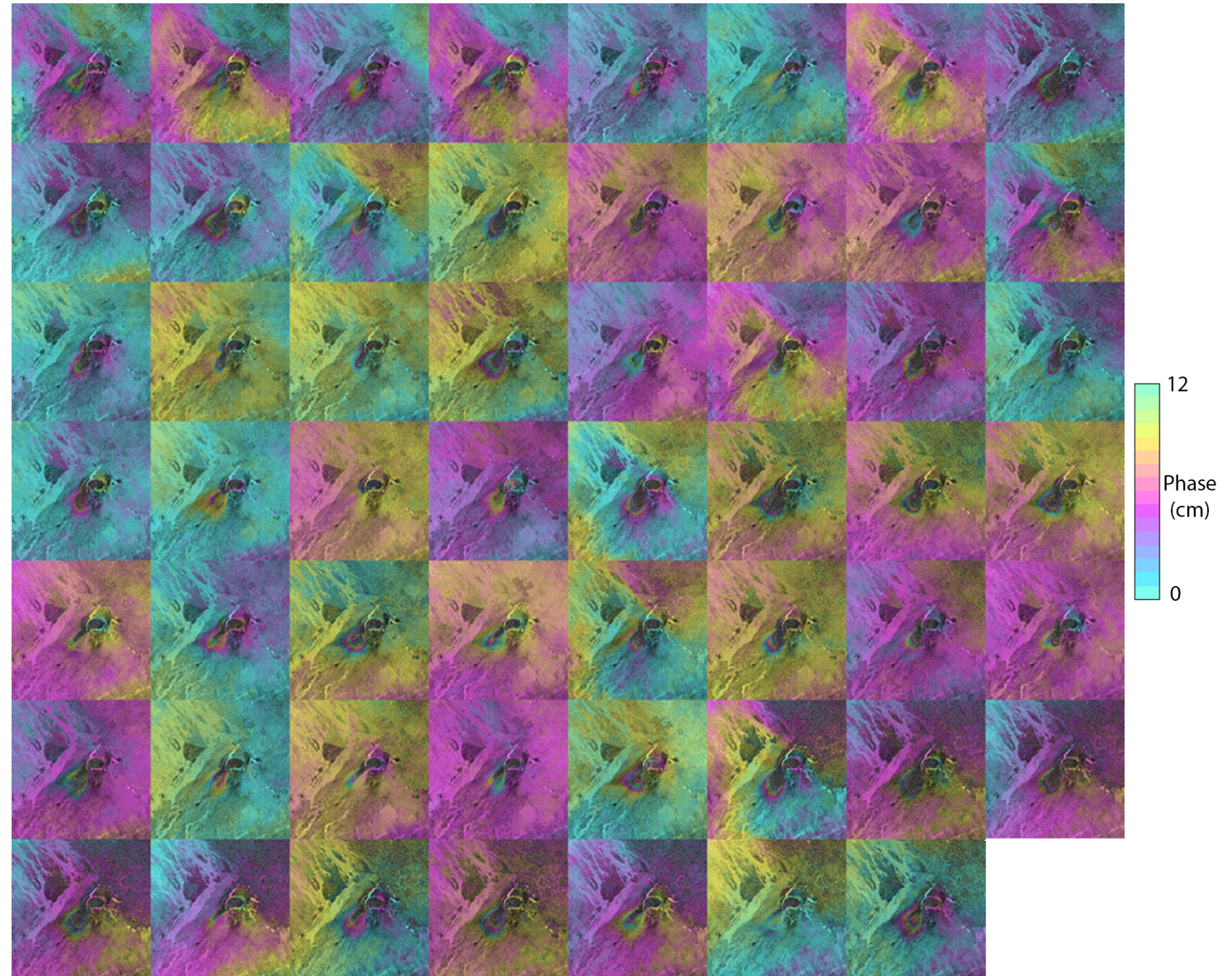
Las Vegas region: GPS sites and NISAR statistics



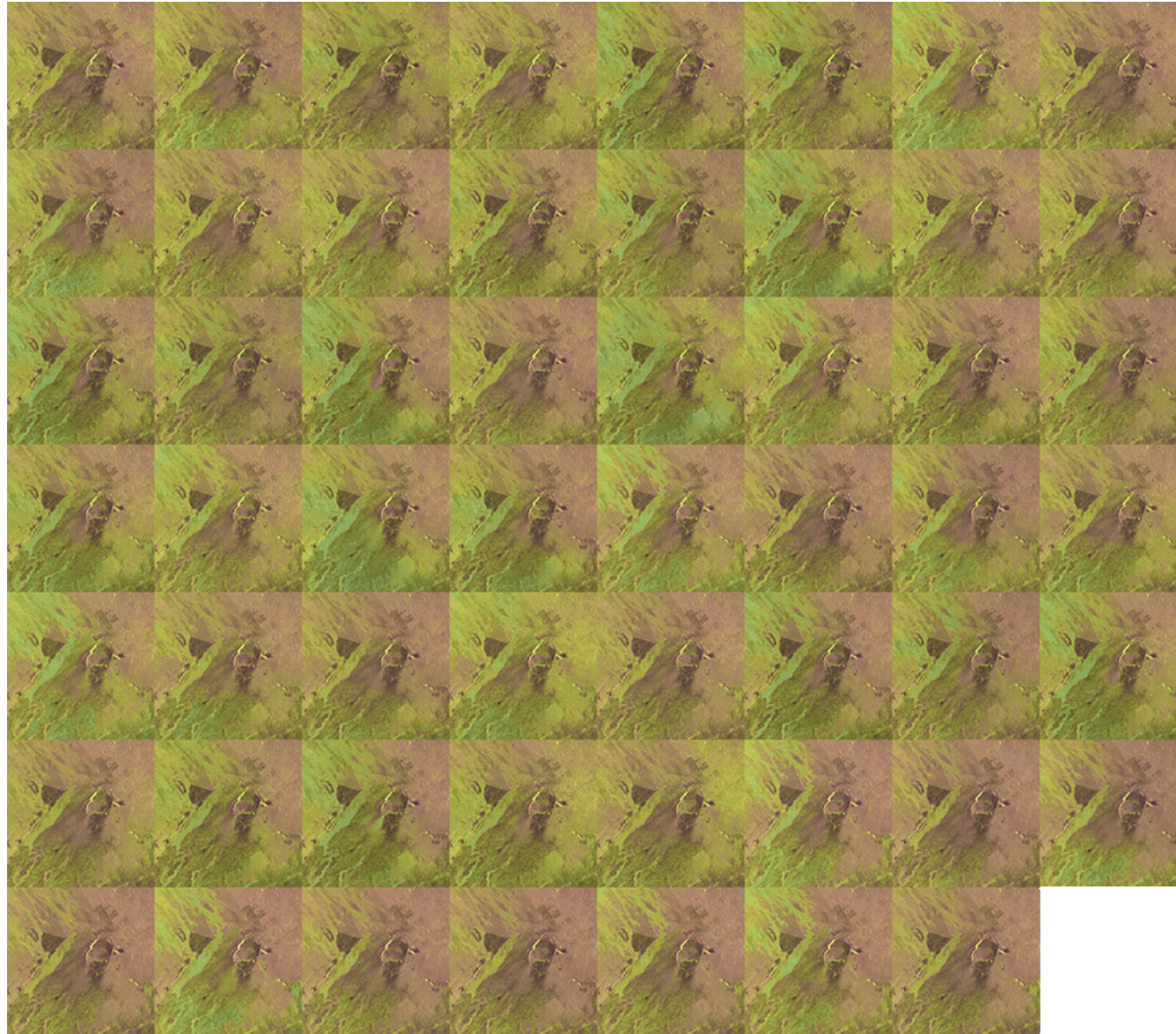
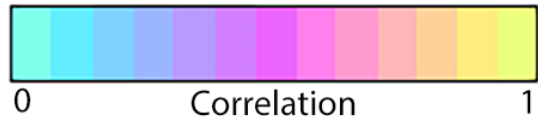
Example 2: Deformation near Kilauea, Hawaii

- Kilauea region nearly continuously active since 1980's
- Much deformation ranges from Kilauea caldera east through rift zone
- Some activity late 2025-early 2024
- These slides span Nov 27 – Feb 19 (descending passes)
- And Nov 20 – Mar 8 (ascending passes)

Hawaii Kilauea – Initial interferograms, ascending

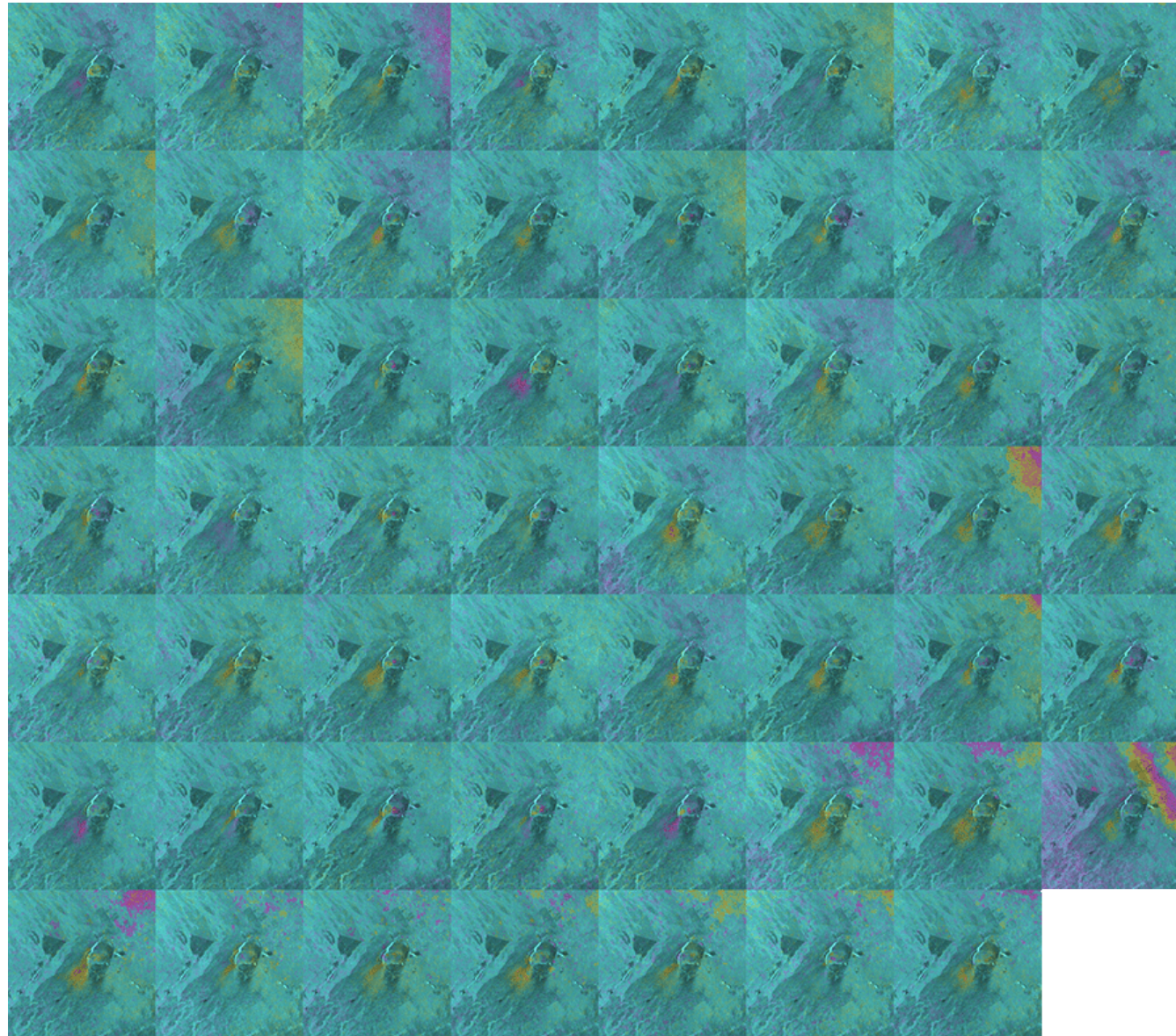


Hawaii Kilauea – Correlation



Hawaii Kilauea – Inferred displacement

0 30
Displacement
(cm)



Displacement vs. GPS – Ascending pass

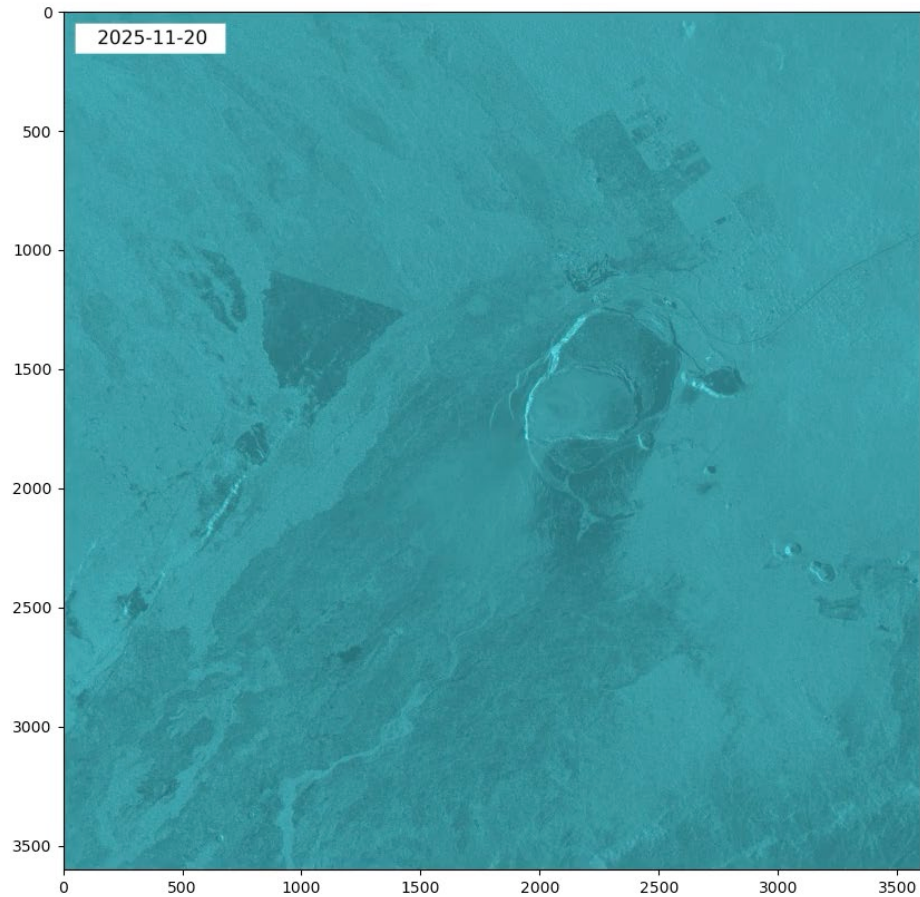
Displacement vs. GPS – Descending pass

GPS comparison – RMS difference (m)

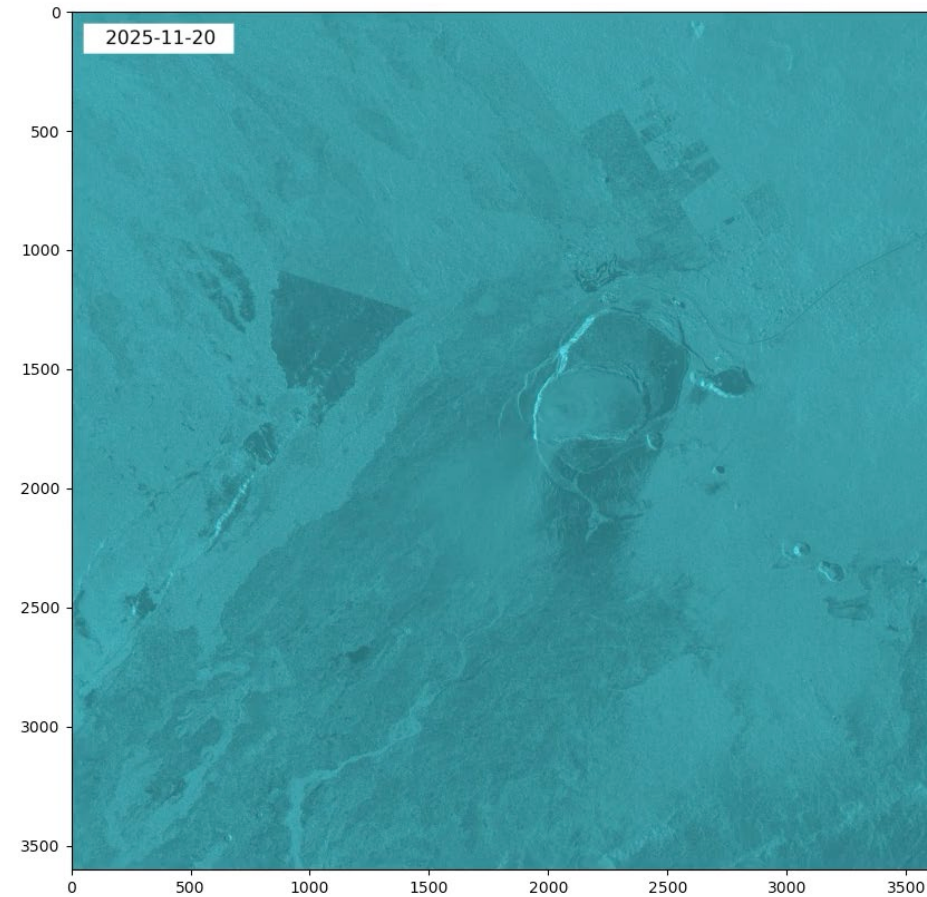
Site name	Ascending rms (m)	Descending rms (m)
AHUP	0.007	0.022
BYRL	0.014	0.025
CNPK	0.019	0.024
CRIM	0.009	0.031
DVLT	0.007	0.025
GOPM	0.009	0.019
KOSM	0.013	0.026
MALU	0.007	0.029
MANE	0.007	0.027
MLPR	0.008	0.012
OUTL	0.007	0.032
PUHR	0.007	0.023
TDES	0.014	0.012
UWEV	0.008	0.024

Can decompose asc/desc to horizontal/vertical

Horizontal



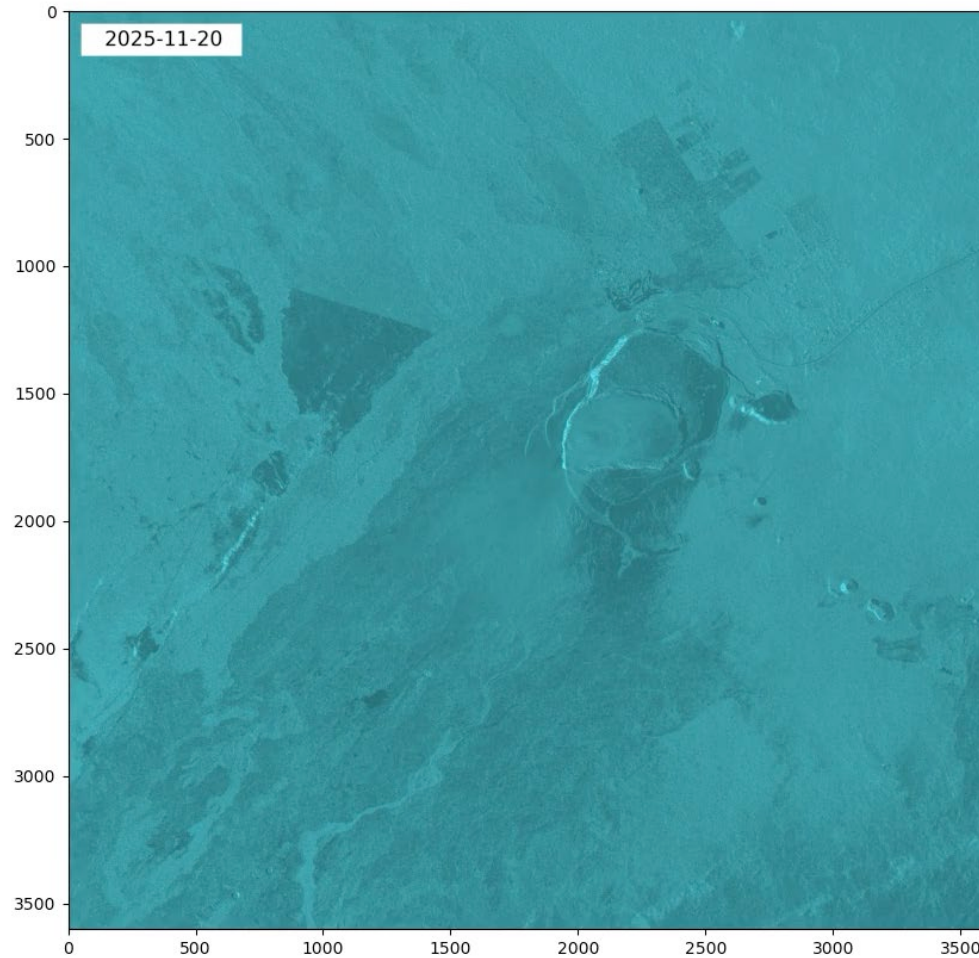
Vertical



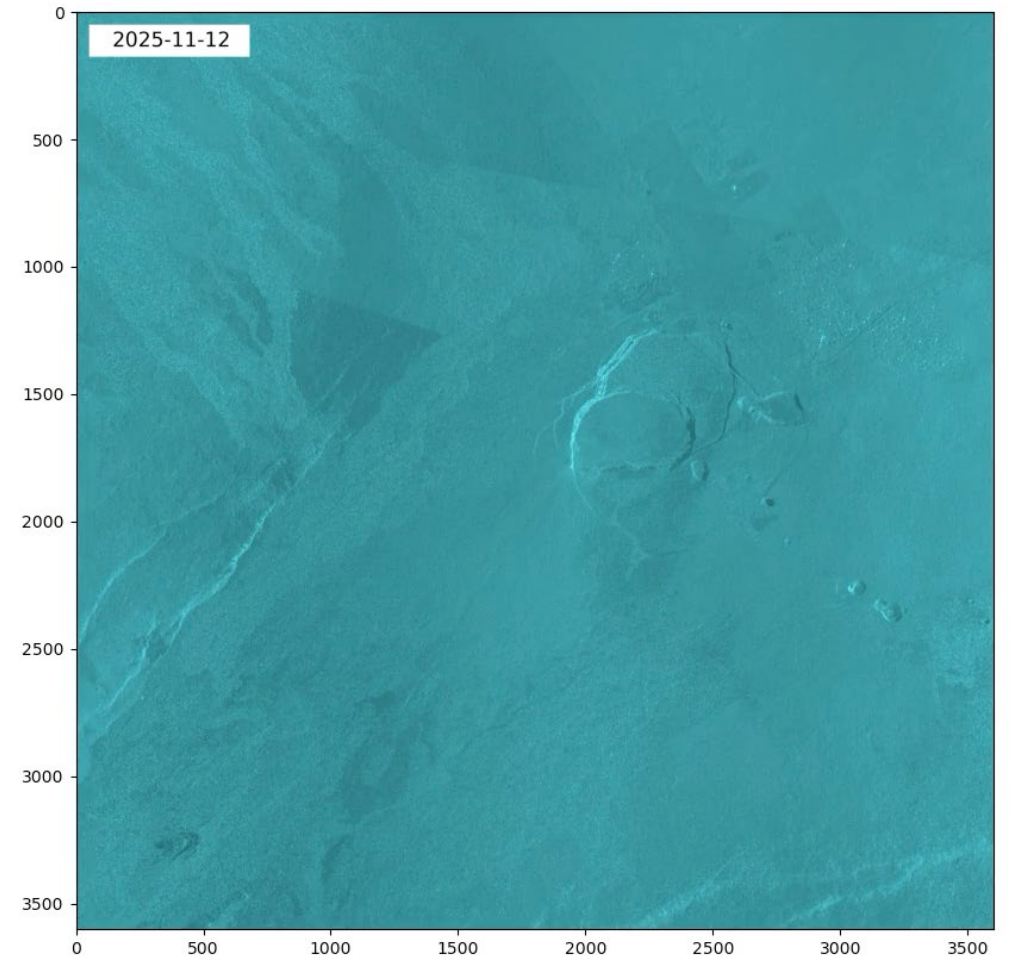
0 30
Displacement (cm)

Compare to Sentinel-1

NISAR Ascending



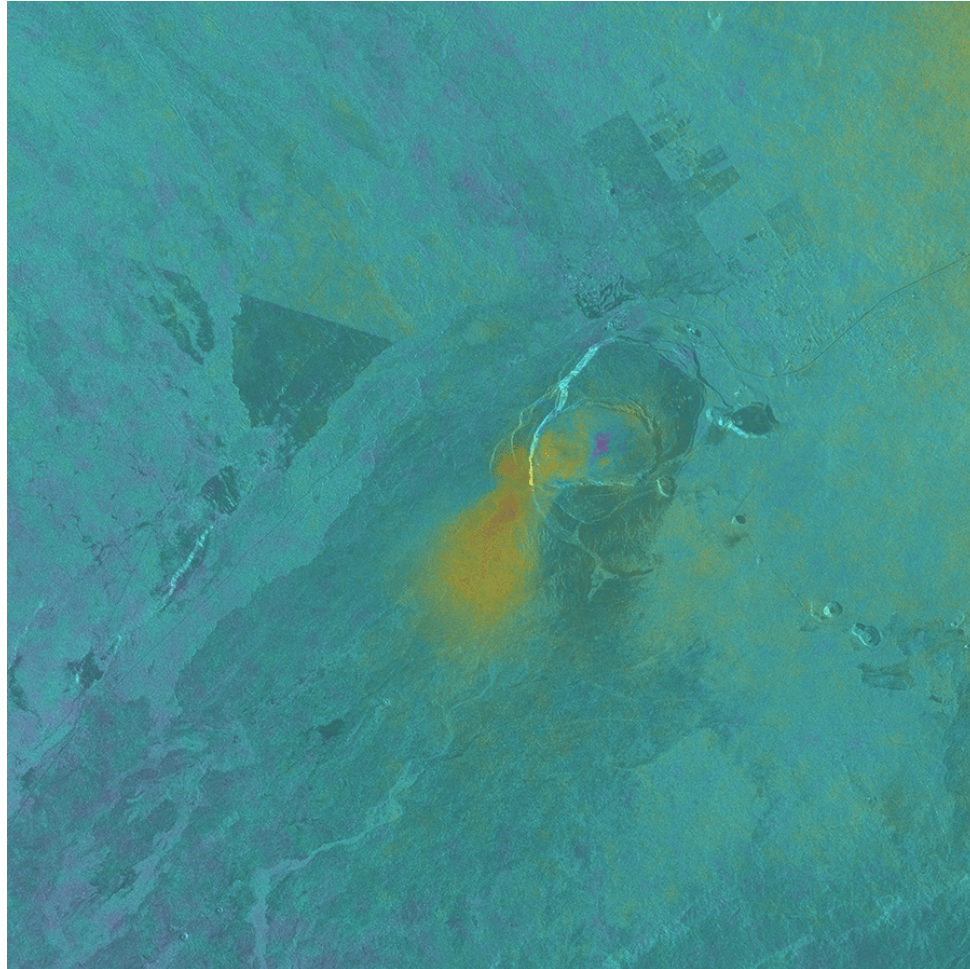
Sentinel-1 Descending



0 30
Displacement (cm)

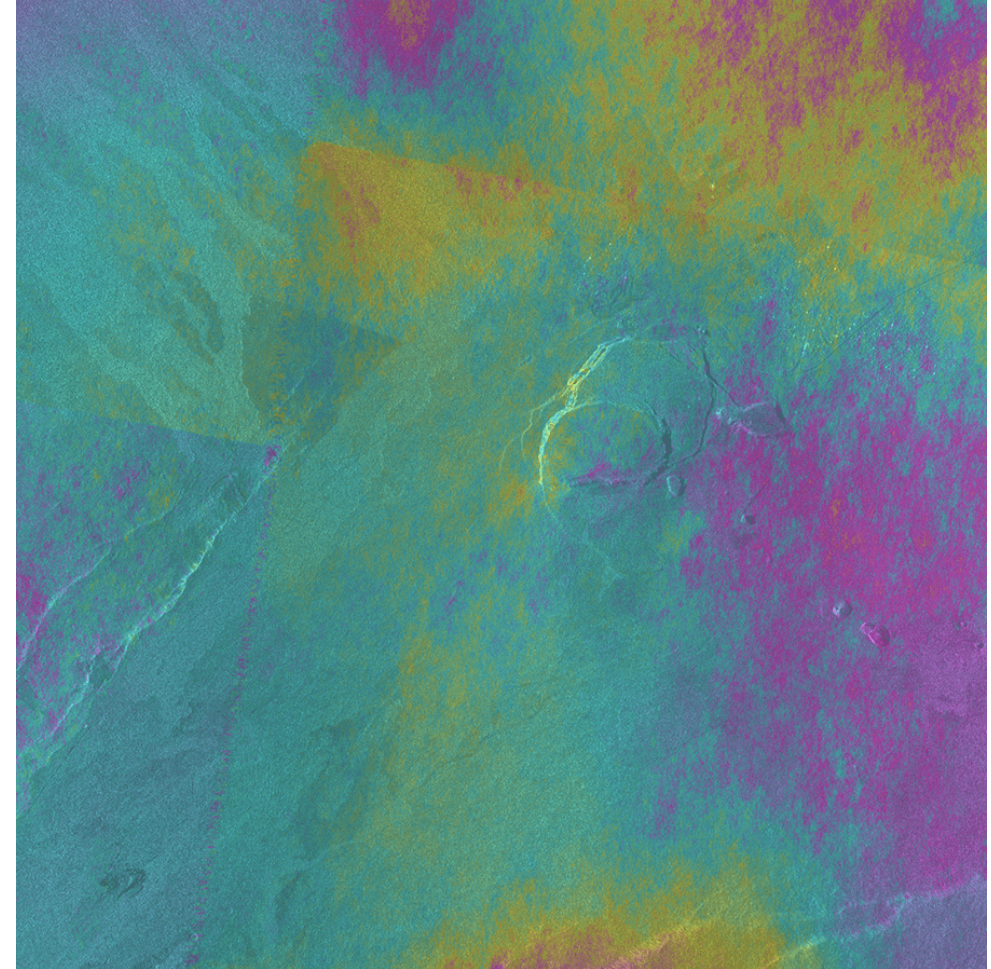
Cumulative deformation from both sensors

NISAR Ascending



NISAR – a best case

Sentinel-1 Descending



Sentinel-1: Little deformation, much decorrelation

0 30
Displacement (cm)

Lest you think all ionosphere artifacts are easily reduced

Interferograms

0 2π
(radians)

Region west of
Fairbanks, Alaska

64.75

Displacement

0 30
(cm)

63.75

-150

-148

Summary

- Wavelength difference is significant
- NISAR may be more sensitive to subsurface echos
- Sentinel-1 does not suffer from ionosphere artifacts, but many NISAR scenes do and are to date uncorrectable
- Correlation is higher in vegetated regions with NISAR, Sentinel-1 misses Kilauea deformation due to decorrelation in a non-vegetated area
- Not discussed here, but Sentinel-1 has a 12 year time series already
- Many opportunities from using both wavelengths to be explored