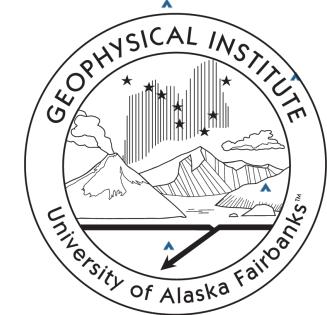


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Data-Driven Prediction & Removal of Systematic InSAR Closure Phases

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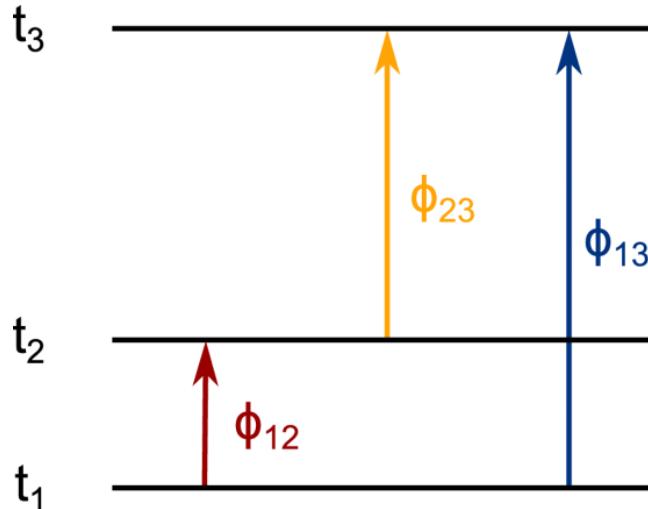
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What are Closure Phases?

Phase Closure is a quantification of the inconsistencies between interferometric phases.

$$\Delta\phi_{ij} + \Delta\phi_{jk} - \Delta\phi_{ik} = \Xi_{ijk}$$



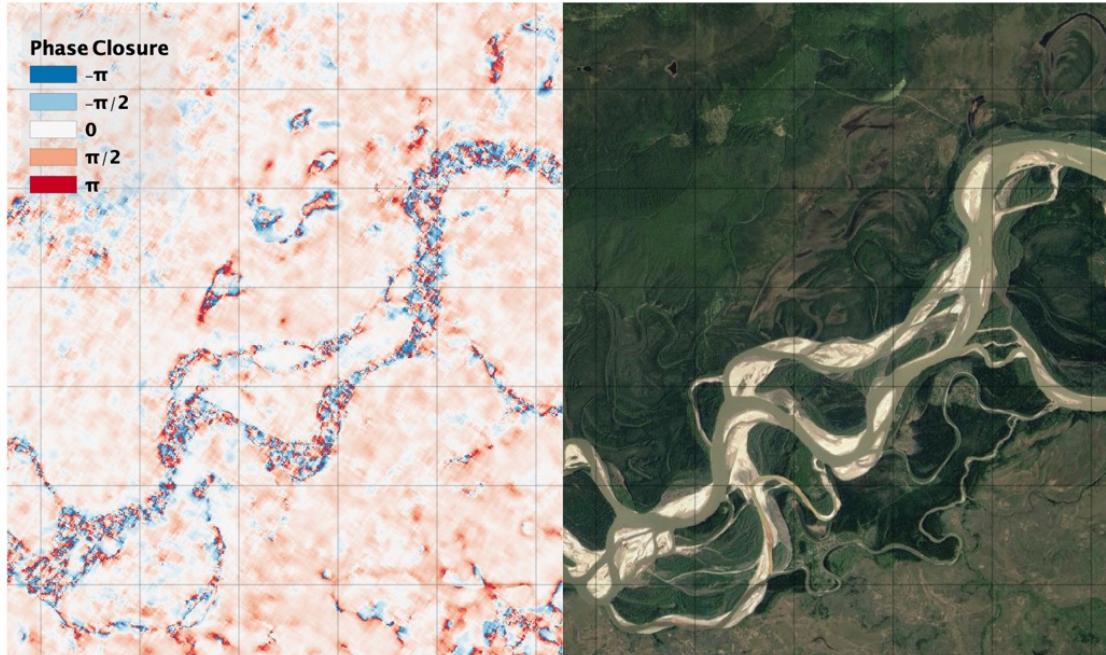
Timeseries estimation assumptions:

$$E[\Xi_{ijk}] = 0$$

Deviations exist due to random realizations of the phases due to decorrelation.
Such inconsistencies are related to observed coherences.

A Problem: Systematic Closure Phases

... deviate from the assumptions of timeseries estimators: $E[\Sigma_{ijk}] \neq 0$

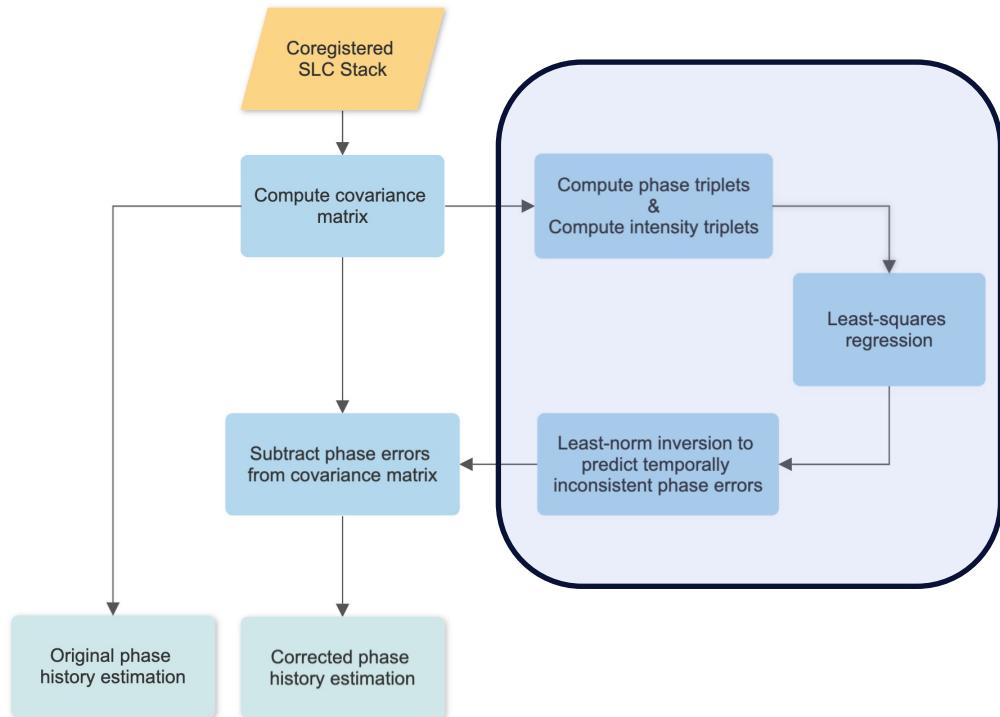


Goals & Methodology

- ✓ Separate systematic and stochastic closure phases
- ✓ Invert independently to assess impact on deformation estimates
- ✓ Demystify the origins of closure phases

Two Study Areas (Sentinel-1):

- Las Vegas, High Coherence
- Alaskan North Slope, Low Coherence



Intensity Triplets

- ✓ Dielectric changes will likely have a joint influence on the intensity.
- ✓ Intensities are derived from the covariance matrix: $\sigma = 10 \log_{10} \text{diag}(\mathbf{C})$

Mirroring the Mathematical Properties of the Closure Phase:

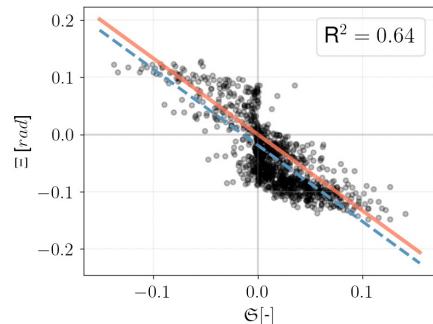
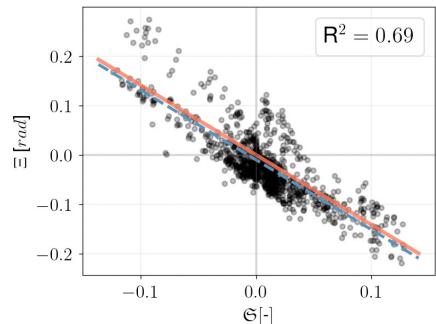
- Antisymmetric (permuting time indices reverses sign of triplet, odd)
- Temporally Inconsistent (nonzero)
- Equivalent linear mapping (same basis)

$$s(\sigma_i, \sigma_j) = \frac{1}{1 + e^{(\sigma_j - \sigma_i)}} - \frac{1}{2}$$

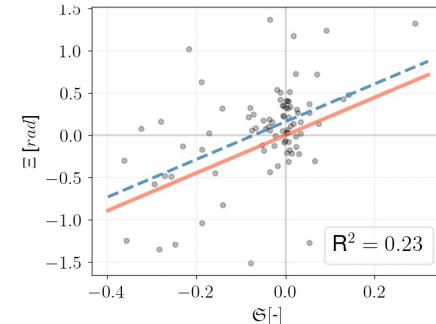
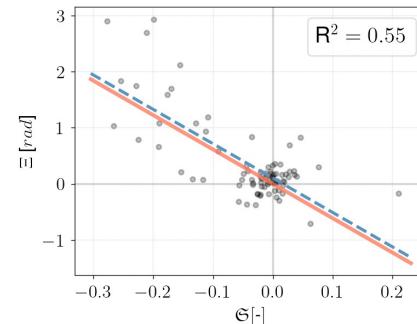
$$\mathfrak{s}(\sigma_i, \sigma_j, \sigma_k) = s(\sigma_i, \sigma_j) + s(\sigma_j, \sigma_k) - s(\sigma_i, \sigma_k)$$

Correlation & Prediction

Las Vegas, NV



North Slope, AK



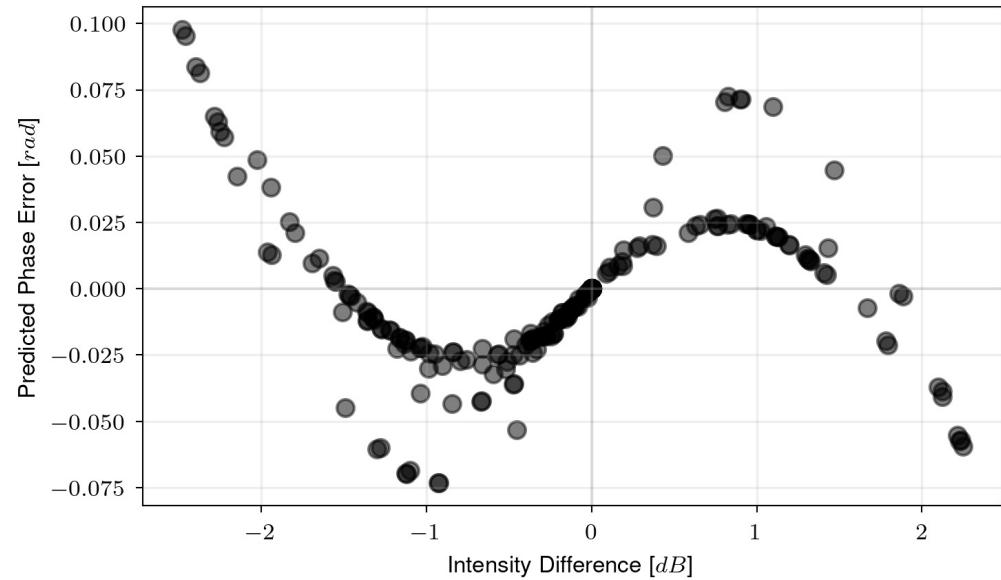
- ✓ Project closure phases onto line of best-fit that crosses the origin
 - ✓ Room for improvement: At what time scales is this relationship consistent? Logistic instead of linear fit
- ✓ An intercept term breaks internal consistency – evidence for additional systematic phase closures that are not captured by the intensity triplet
 - Mean residual closure phase

$$\Xi_{\text{systematic}} = \mathfrak{S}(\sigma_i, \sigma_j, \sigma_k)m$$

Inversion & Correction

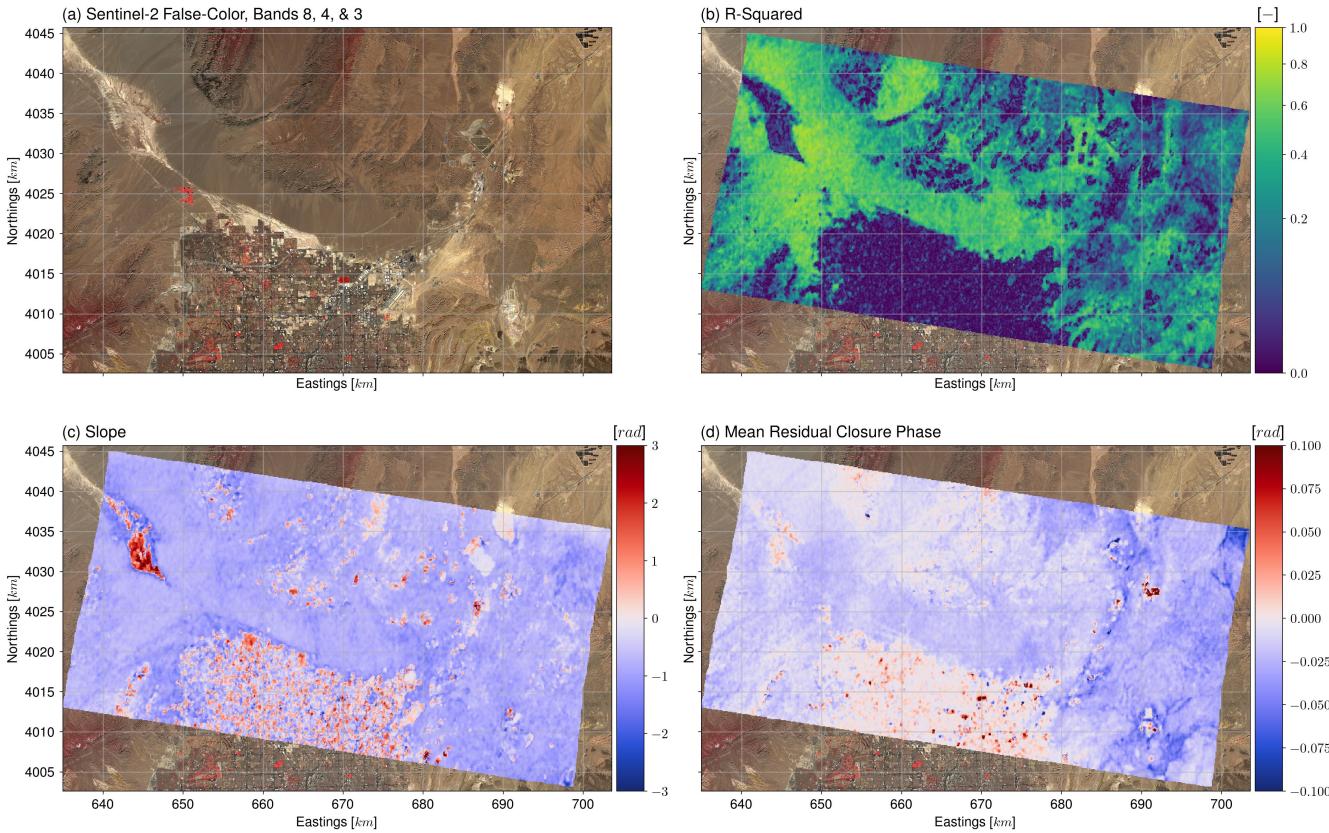
$$\phi_{syst} = mA^\dagger \mathfrak{S}$$

- Temporally **inconsistent** phase errors are non-linear with log-intensity difference
- Nullity of A includes temporally **consistent** error, still to be estimated



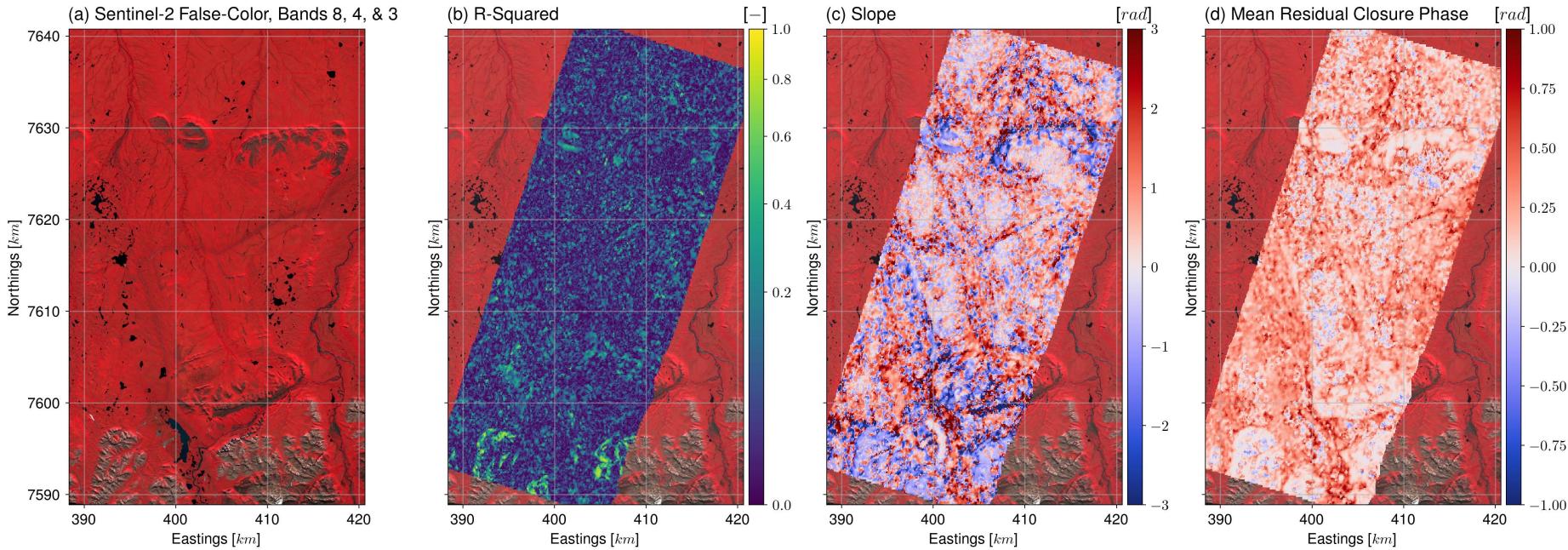
Results – Las Vegas

- Spatially agreeable parameter estimates
- Intercept term also seems to be significant



Results – North Slope

- Slope less consistent in sign – heterogenous soils
- Order of magnitude higher mean residual/intercept

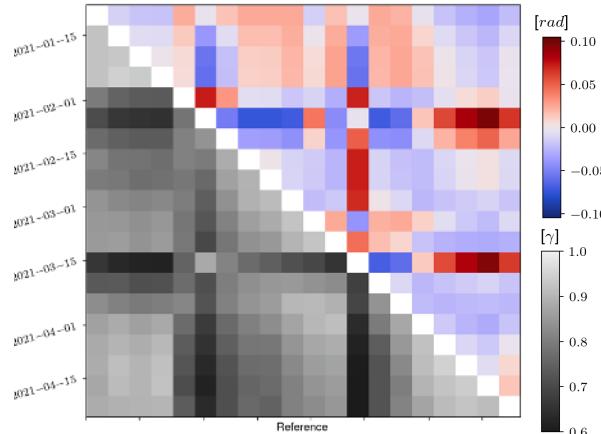


A Closer Look...

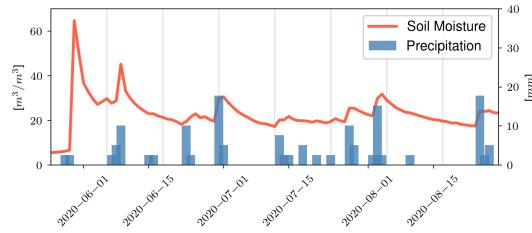
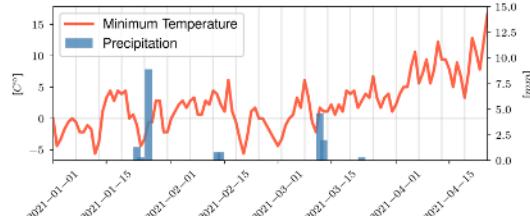
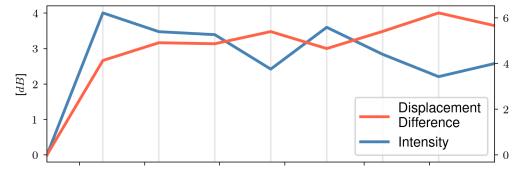
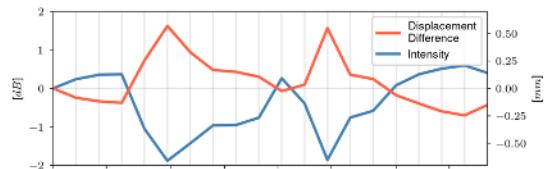
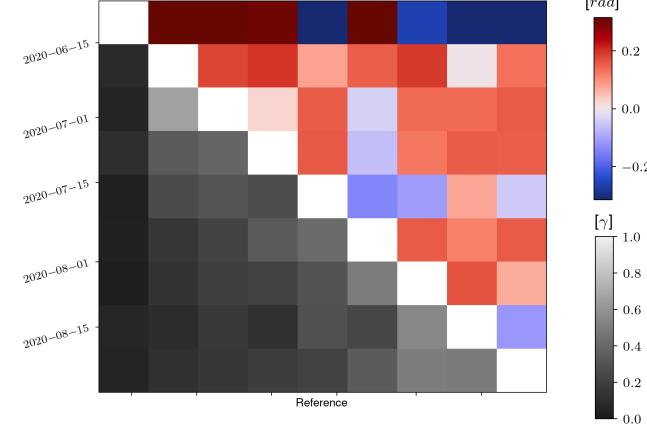
Impact on displacement can be related to:

- Snow
- Freeze-thaw
- Soil moisture

Las Vegas, NV



North Slope, AK



Key Takeaways

- An intensity metric can capture a great portion of the variability in the closure phases.
- Soil moisture may impact the phase history but so can other influences on the dielectric properties of the surface such as snowfall or thermal/phase state.
- However, these influences don't account for all of the systematic closure phase (intercept term ambiguity). How can we capture the variability of other potential mechanisms?

Questions?

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