Precise Localization and Measurement of Slow Slip Events in Central Cascadia with InSAR – Seed Grant Update for CRESCENT

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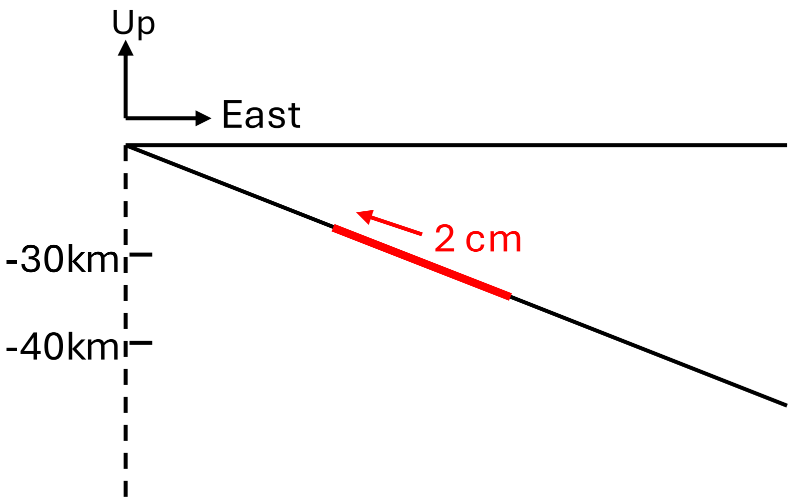
April 21, 2026

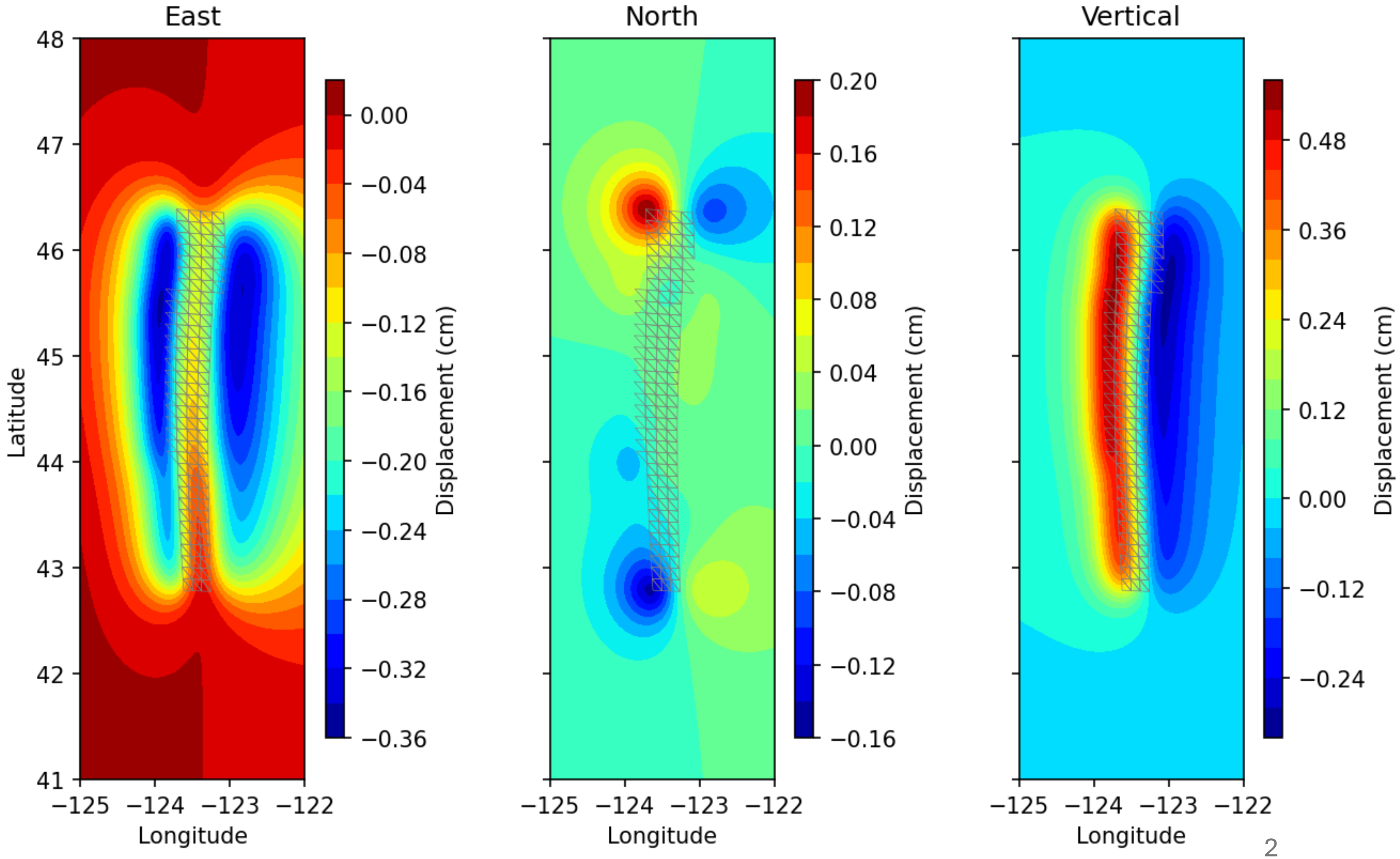
The Question for this study:

Where do slow slip happen at depth?

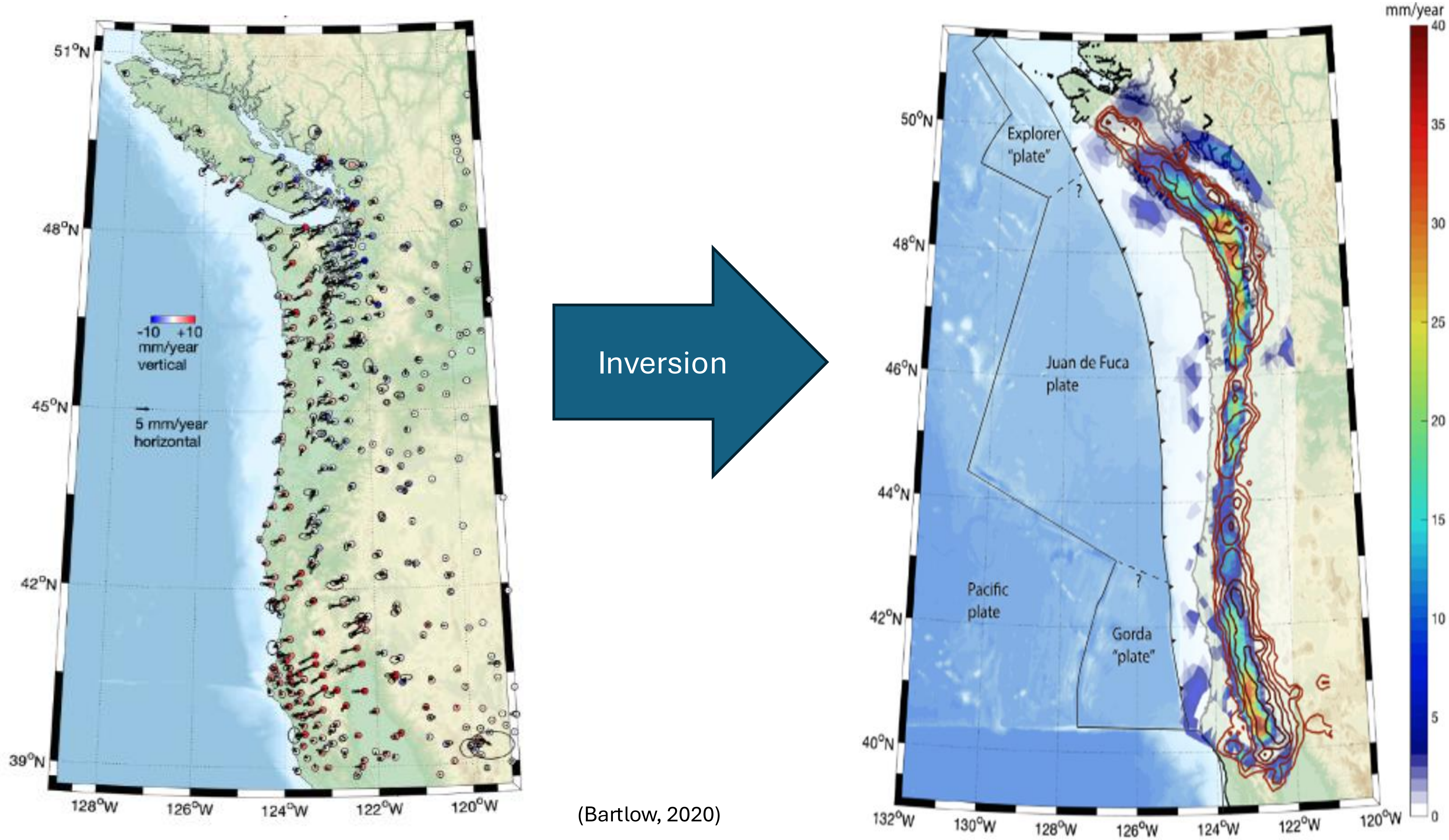
Slow slip generates measurable deformation on the Earth's surface

Predicted surface deformation due to 2 cm uniform updip slip between 30km to 40 km depth





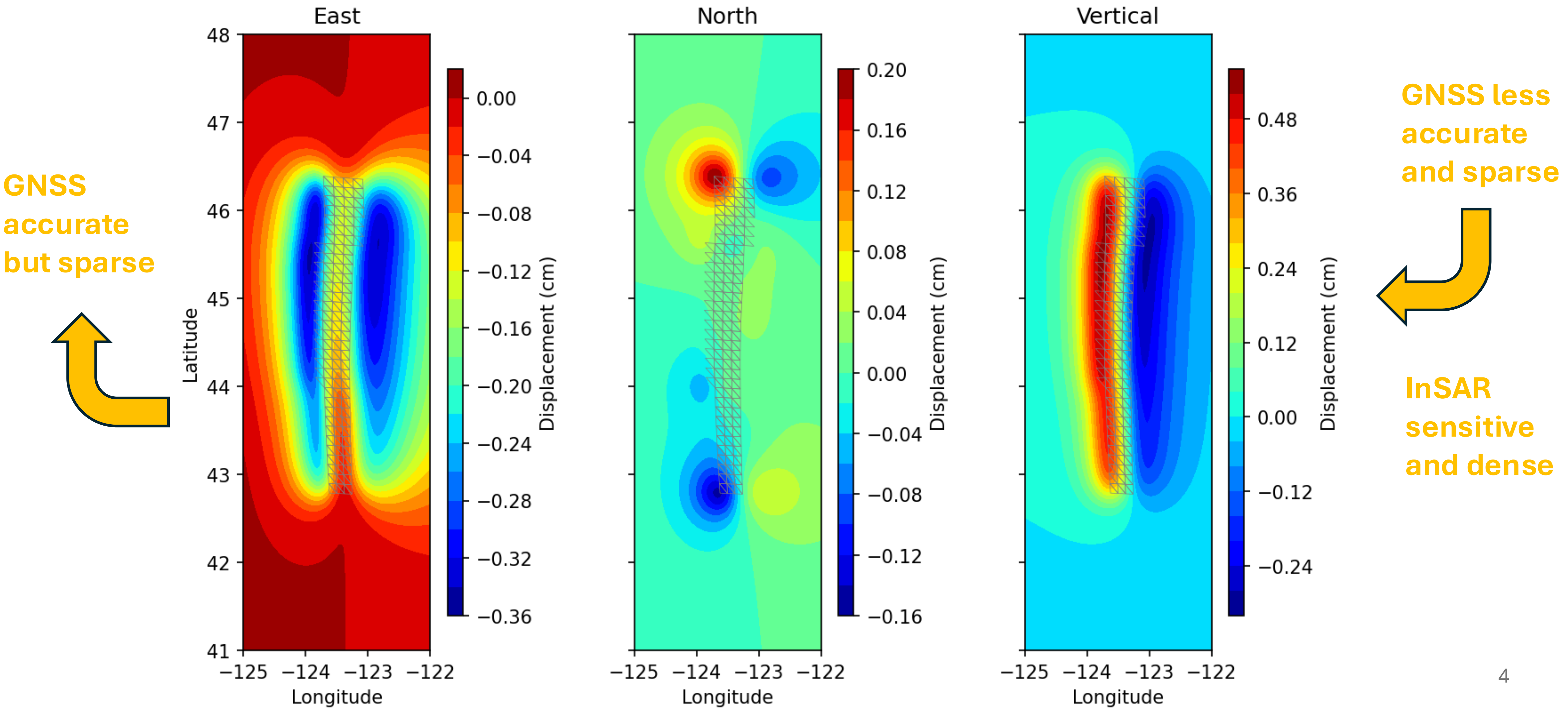
Cascadia SSEs from GNSS



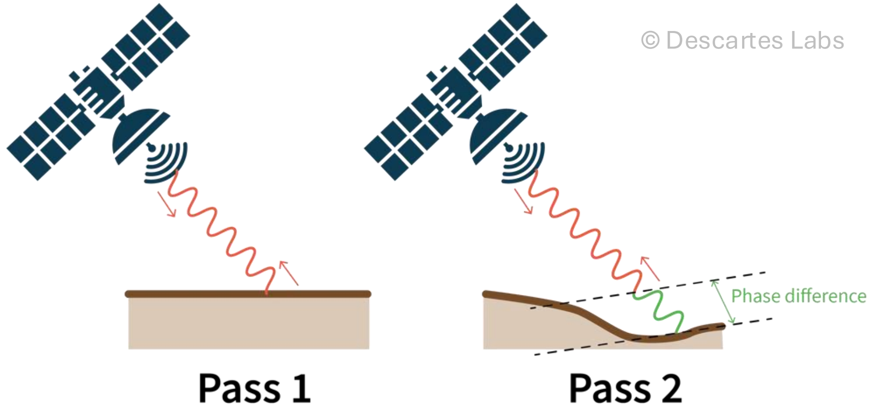
(Bartlow, 2020)

InSAR as a Complement to GNSS for Slow Slip Inversion

Predicted surface deformation due to 2 cm uniform updip slip between 30km to 40 km depth



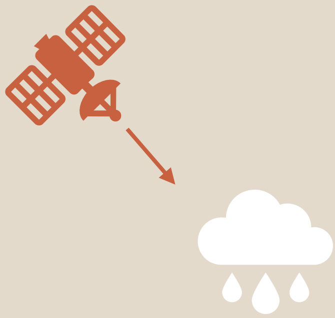
InSAR measures high-resolution deformation, but noise limits accuracy



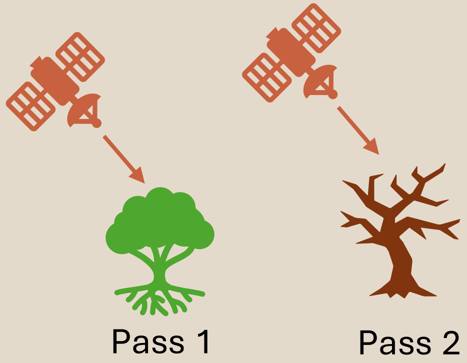
For two images acquired at times i and j,

$$\text{Phase Change } (\Delta\phi_{ij}) = \underbrace{\text{d}}_{\text{displacement}} + \underbrace{\epsilon_{\text{atmospheric}} + \epsilon_{\text{decorrelation}} + \epsilon_{\text{other}}}_{\text{Noise}}$$

Atmospheric Noise



Decorrelation Noise

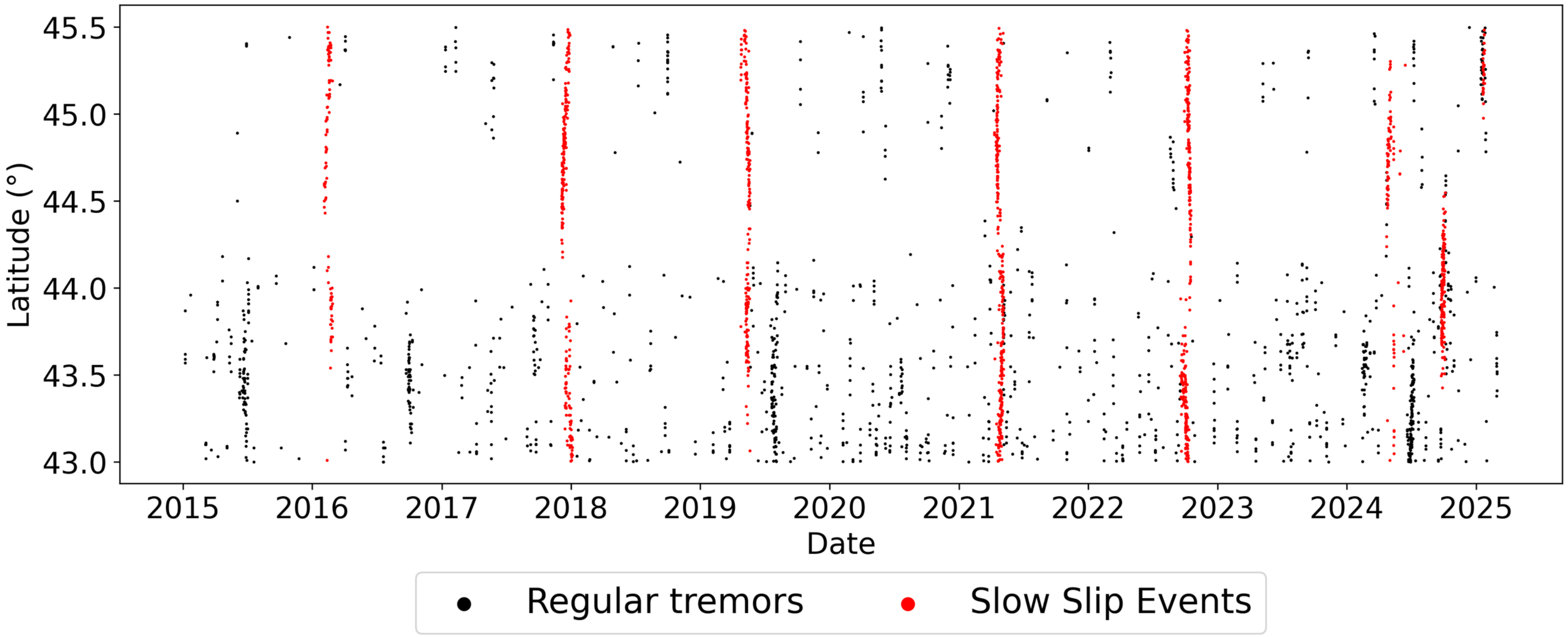


Other Noises

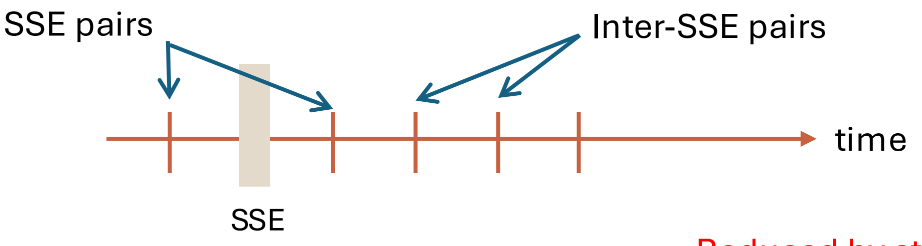
- Phase Unwrapping Errors
- Thermal Noise
- Topographic Noise

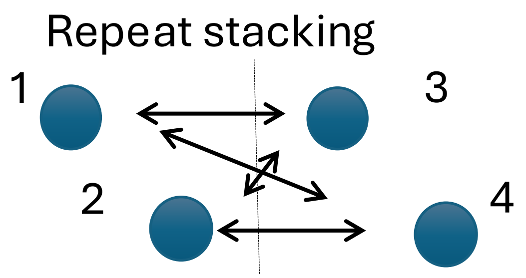
A large but noisy InSAR dataset spanning 6 SSEs

During this time, there are 640 SAR acquisitions (Sentinel-1) at an average interval of 6 to 12 days, which correspond to more than 200k interferograms!



Repeat-Stacking Interferograms to improve SNR





Reduced by stacking

Easily estimated or negligible for modern SAR sensors

For SSE pairs, $\Delta\phi_{SSE} = d_{SSE} + vT_{ij} + \epsilon_{\text{atmospheric}} + \epsilon_{\text{decorrelation}} + \epsilon_{\text{other}}$

Averaging, $\frac{\sum \Delta\phi_{SSE}}{N_{SSE}} = d_{SSE} + v\frac{\sum T_{ij_{SSE}}}{N_{SSE}}$ .... [1]

For Inter-SSE pairs, $\Delta\phi_{Inter-SSE} = vT_{ij} + \epsilon_{\text{atmospheric}} + \epsilon_{\text{decorrelation}} + \epsilon_{\text{other}}$

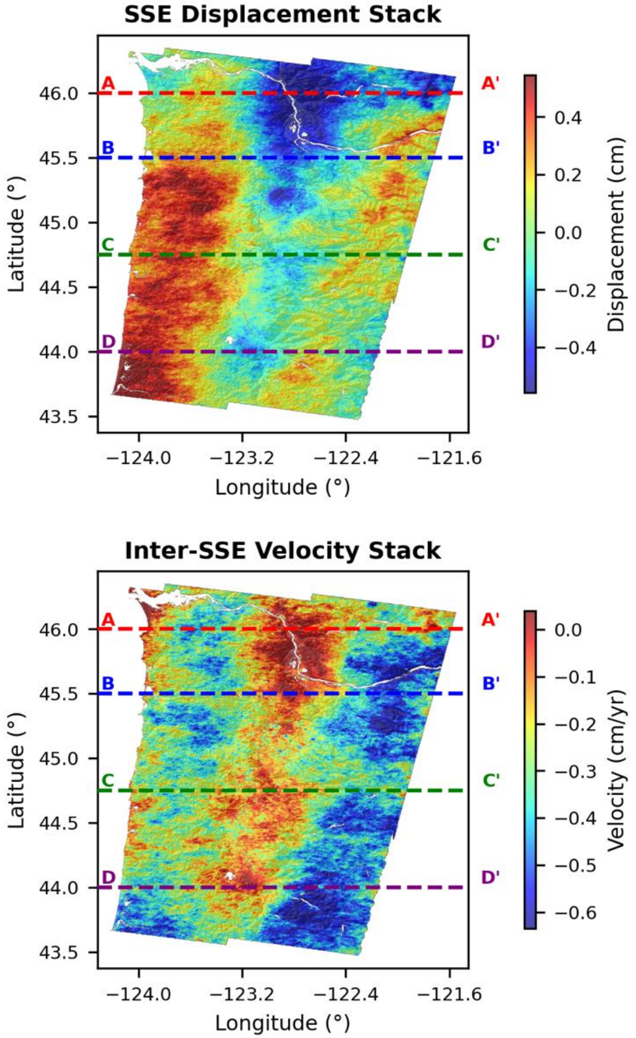
Temporally averaging, $\frac{\sum \Delta\phi_{Inter-SSE}}{\sum T_{ij_{Inter-SSE}}} = v$ .... [2]

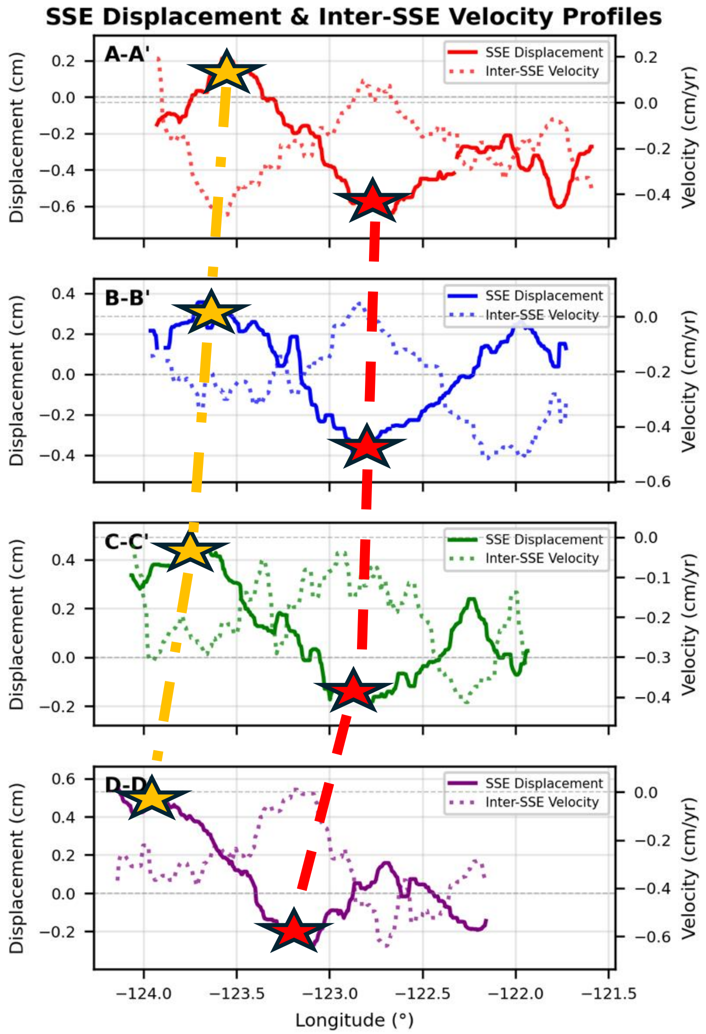
where,

$\boldsymbol{\Delta\phi}$	Phase difference in interferogram formed by *i* & *j and converted to distance*
$\boldsymbol{d_{SSE}}$	Displacement due to the SSE (SSE signal)
$\boldsymbol{v}$	Inter-SSE velocity (plate velocity)
$\boldsymbol{T_{ij}}$	Temporal baseline of interferogram formed by *i* & *j*
$\in$	Noises in the interferogram
$\boldsymbol{N_{SSE}}$	No. of SSE pairs

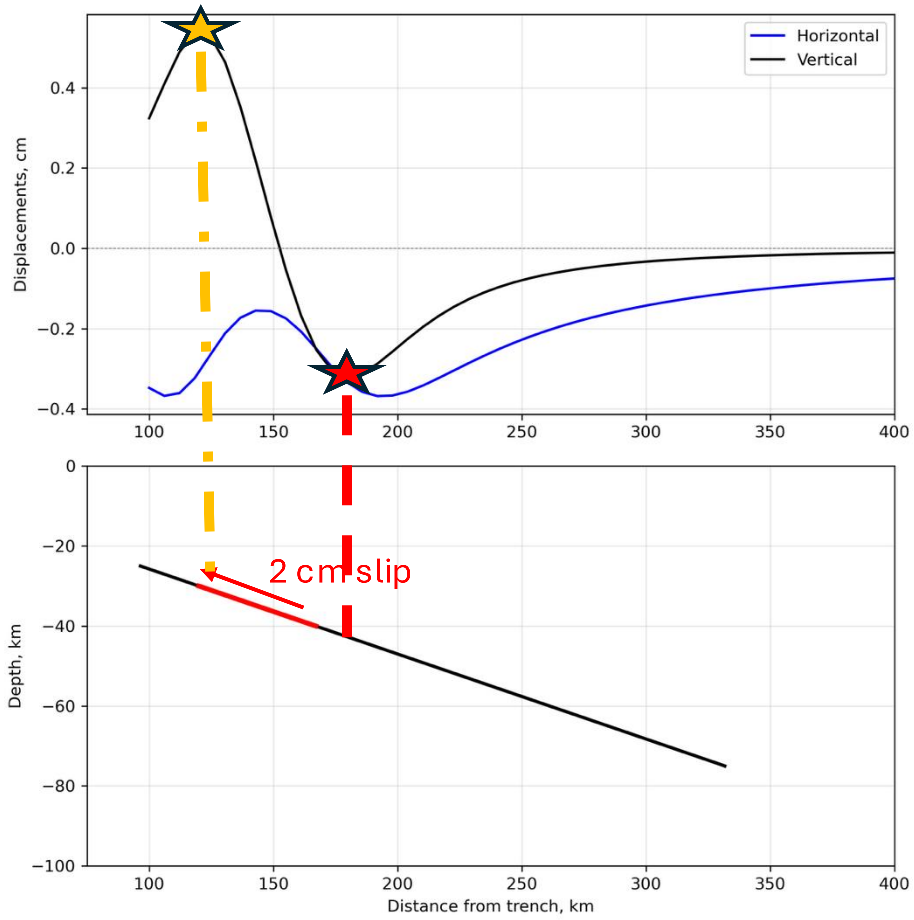
d_{SSE} can be calculated by substituting the value of v calculated from equation 2 into 1.

Results



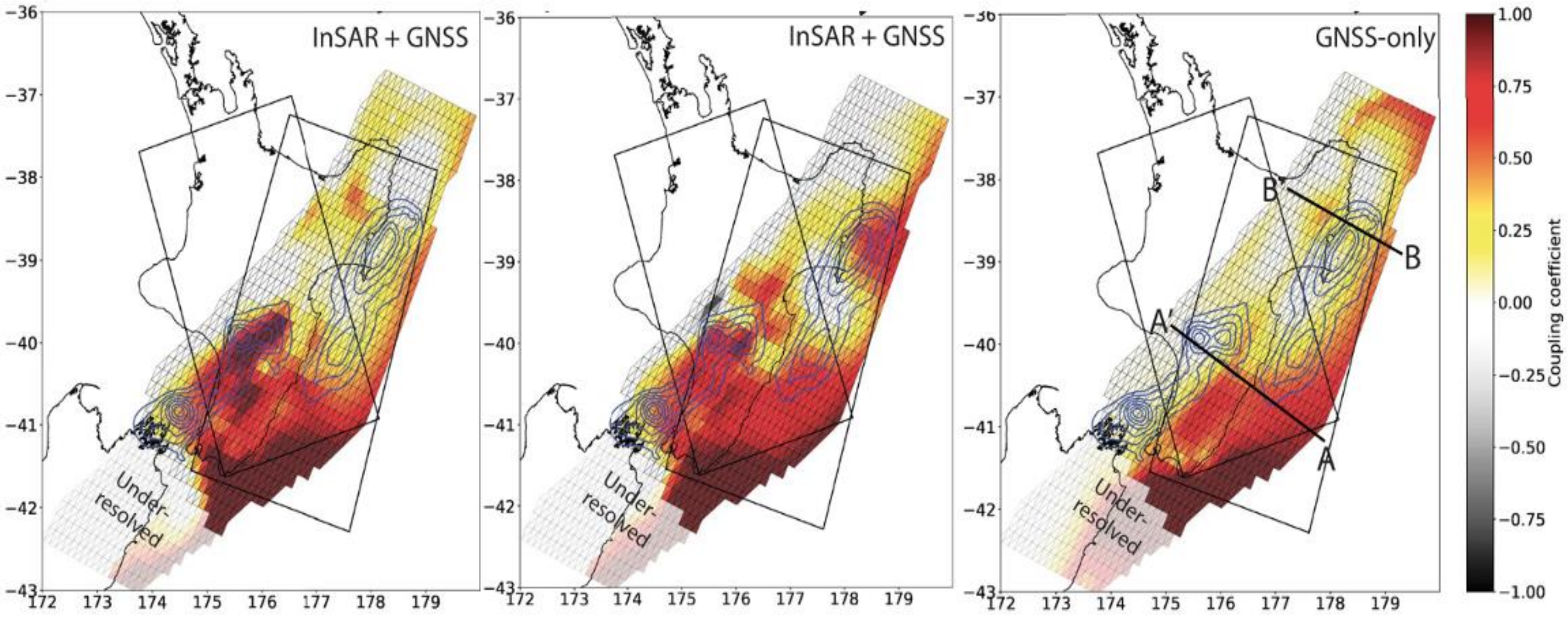


Forward Model

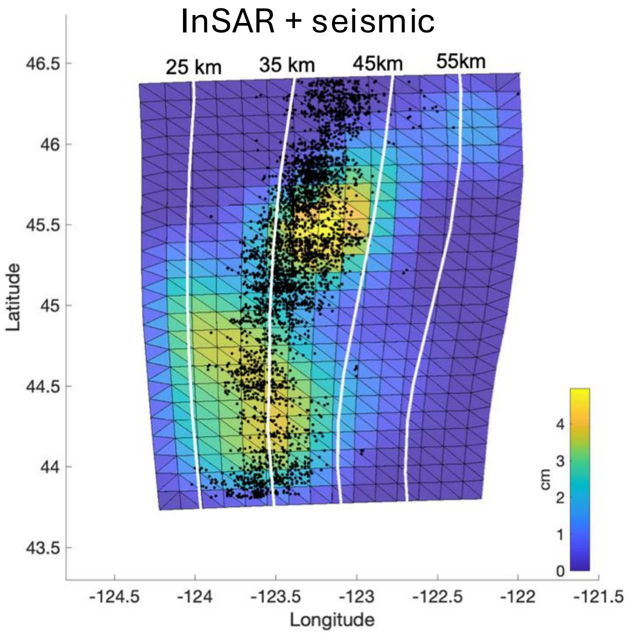


Take-aways

1. InSAR can add spatial detail and vertical sensitivity to slow slip observations in central Cascadia
2. This seed grant explores that potential and builds toward broader integration



(Maubant et. al., 2023)



Zheng, 2019

What's Next?

1. Produce validated InSAR-derived SSE and inter-SSE deformation datasets with uncertainty estimates
2. Joint analysis of InSAR+GNSS+SEISMIC datasets
3. Assess whether InSAR can resolve temporally varying slip