THE OHIO STATE UNIVERSITY

COSEISMIC DEFORMATION MODELS IN LOW-DENSITY GNSS NETWORKS

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Presentation Outline

Introduction

Methodology

Results: Maule earthquake

Results: Illapel earthquake

Conclusions

Introduction

- **Trajectory prediction modeling** is necessary to obtain the time evolution of arbitrary points located between continuous GNSS stations (CGNSS) in a geodetic Reference Frame (RF).

- If the RF includes areas that experience **coseismic deformation**, the **Trajectory Prediction Model (TPM)** needs to incorporate an estimate of the static deformation field generated by seismic activity.

- When the **observing GNSS network is sparse**, the coseismic effect **cannot be interpolated** due to the **roughness** of the deformation field

Methodology

- We use a geophysical model in a **hybrid (dynamic-kinematic) mode**: we use **elastic deformation** of a spherical earth to constrain the overall coseismic displacement field **without imposing the usual geodynamic constraints** on a fault slip distribution.

$$AX = L$$

A: Design matrix or Impulse response matrix (Static1D - Pollitz, 1996)
X: Slip distribution on the fault plane
L: Vector of observations

$$X = \left(A^T P A\right)^{-1} A^T P L$$

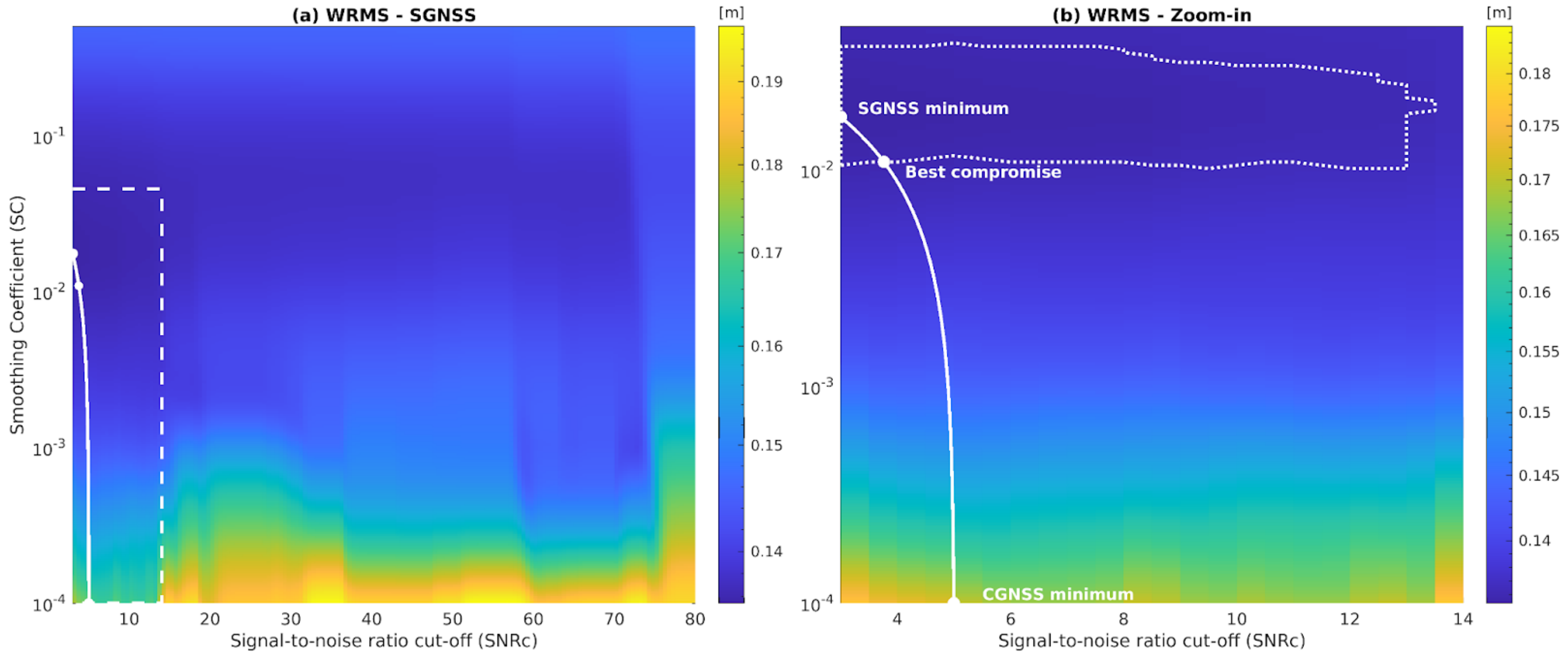
$$X = \left(N + SC \cdot N_c\right)^{-1} c$$

Methodology

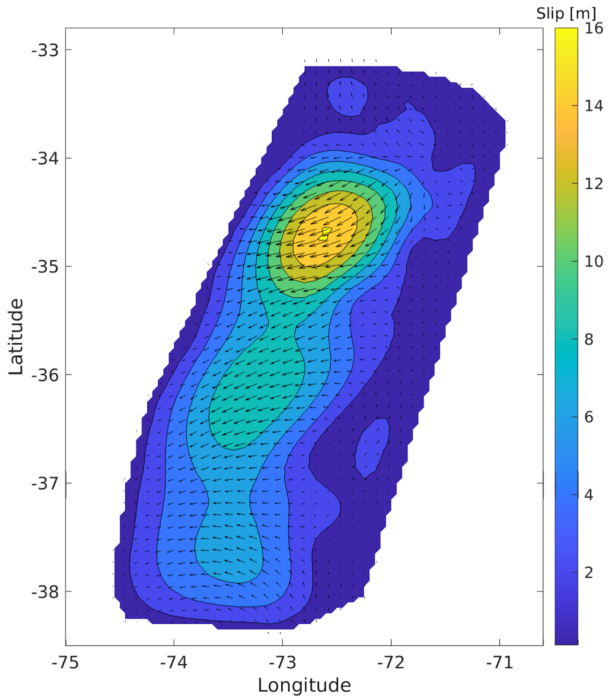
- **Overparameterized fault:** to image the fault slip with **more resolution.**
- **Why?:** reduce the surface deformation misfit using regularization techniques that **avoid displacement artifacts** due to data overfitting
- **Problem:** more **parameters** than **observations**
- **SOLUTION: We add the Laplacian operator and the Smoothing Coefficient to control it**

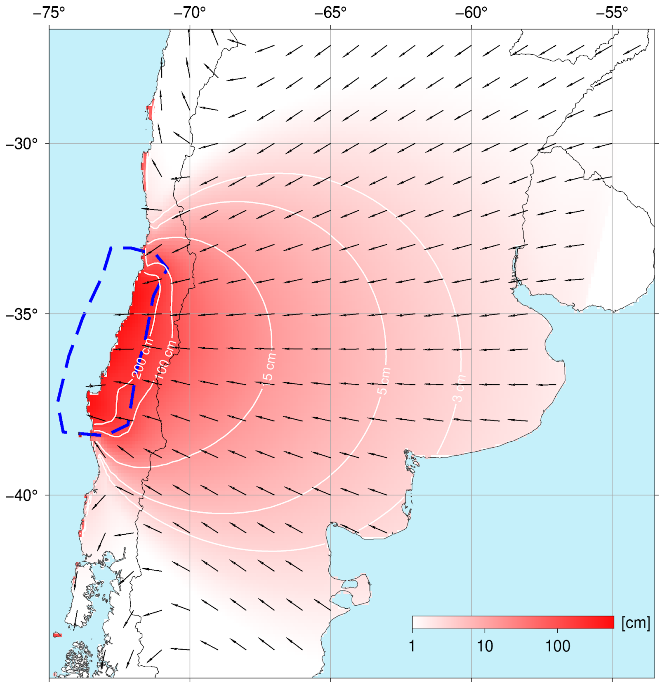
- **Weights:** applied to make the far- and near-field data have **equal weights.**
- **Why?:** Gómez et al. (2017) showed that the far-field data can greatly **help constrain the slip** on the fault.
- **Problem:** far-field data, which tends to be **noisier**, can introduce artifacts in the inverse fault slip distribution.
- **SOLUTION: We add a Signal-to-noise ratio cut-off (SNRc)**

Smoothing coefficient and Signal to Noise Ratio cut-off grid search - MAULE

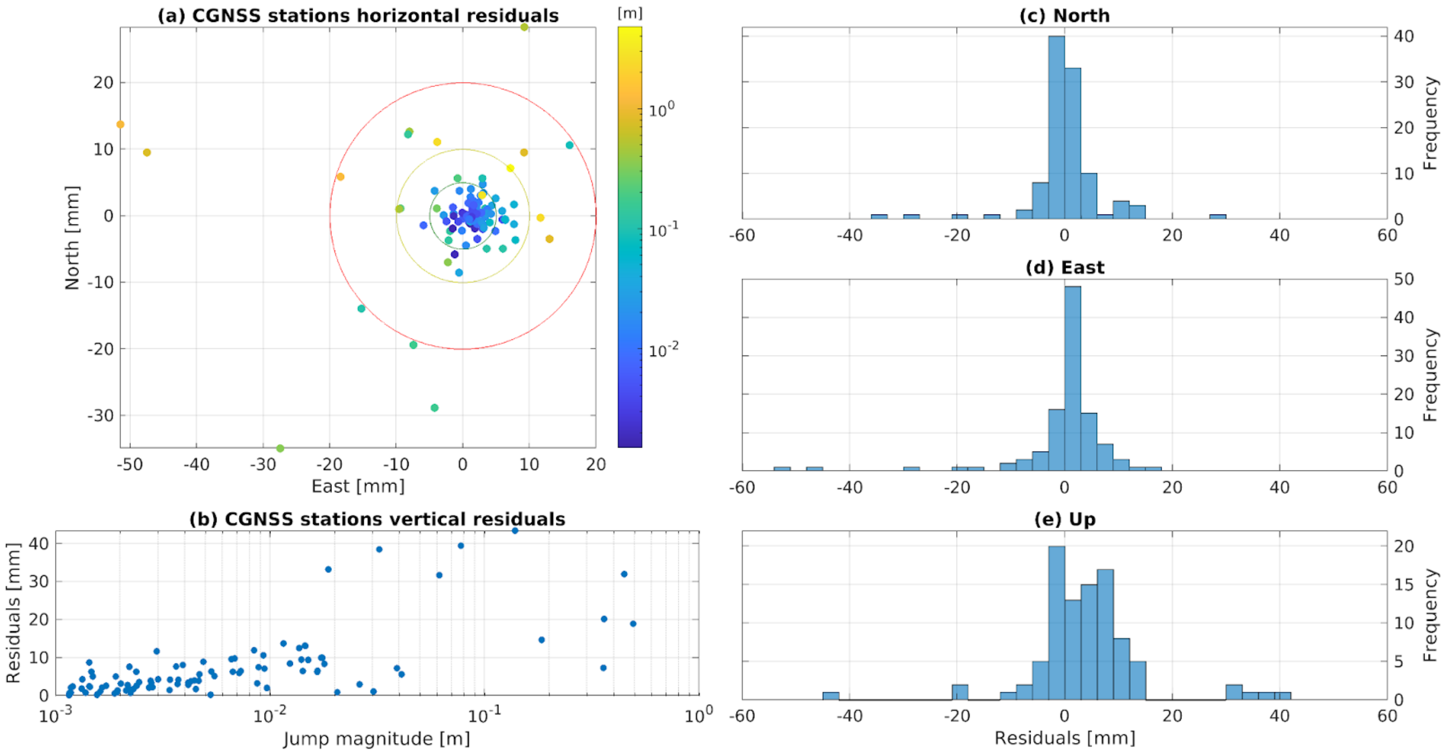


Slip distribution and coseismic deformation grid - MAULE

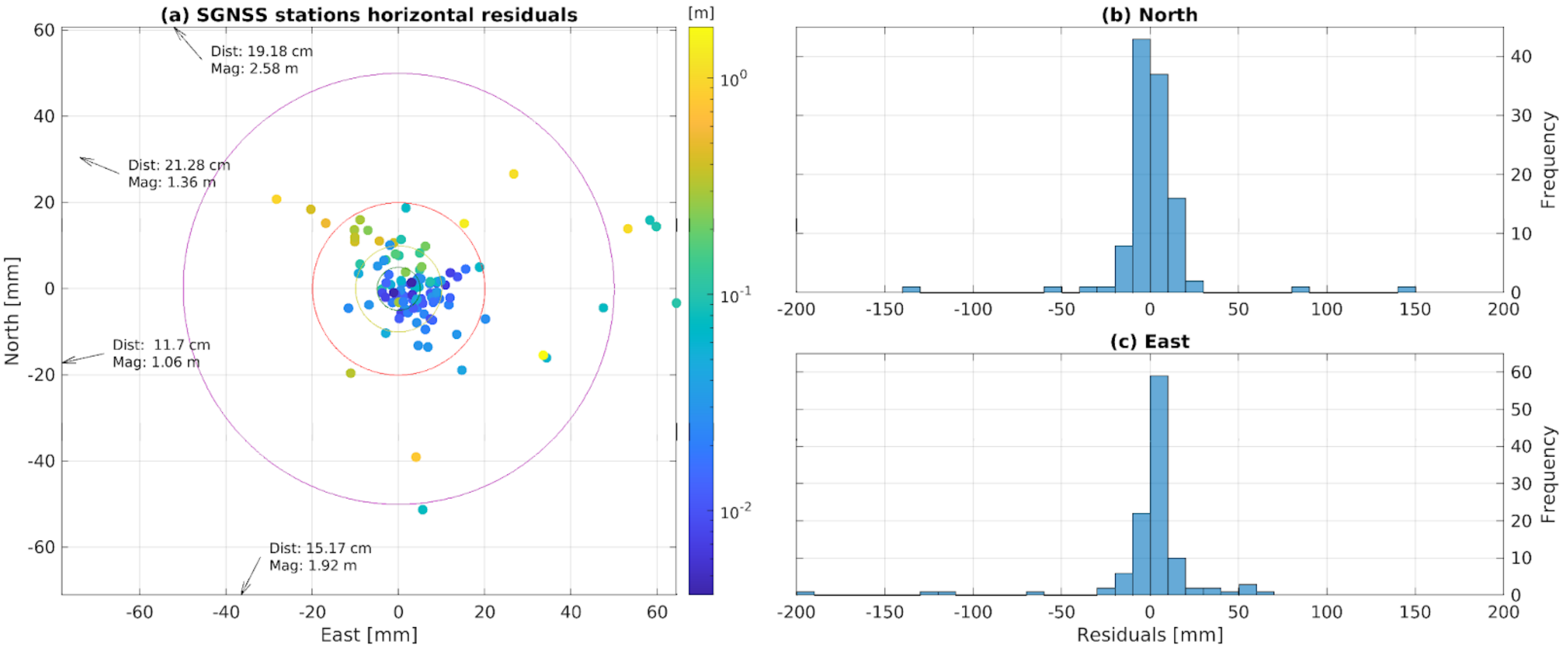




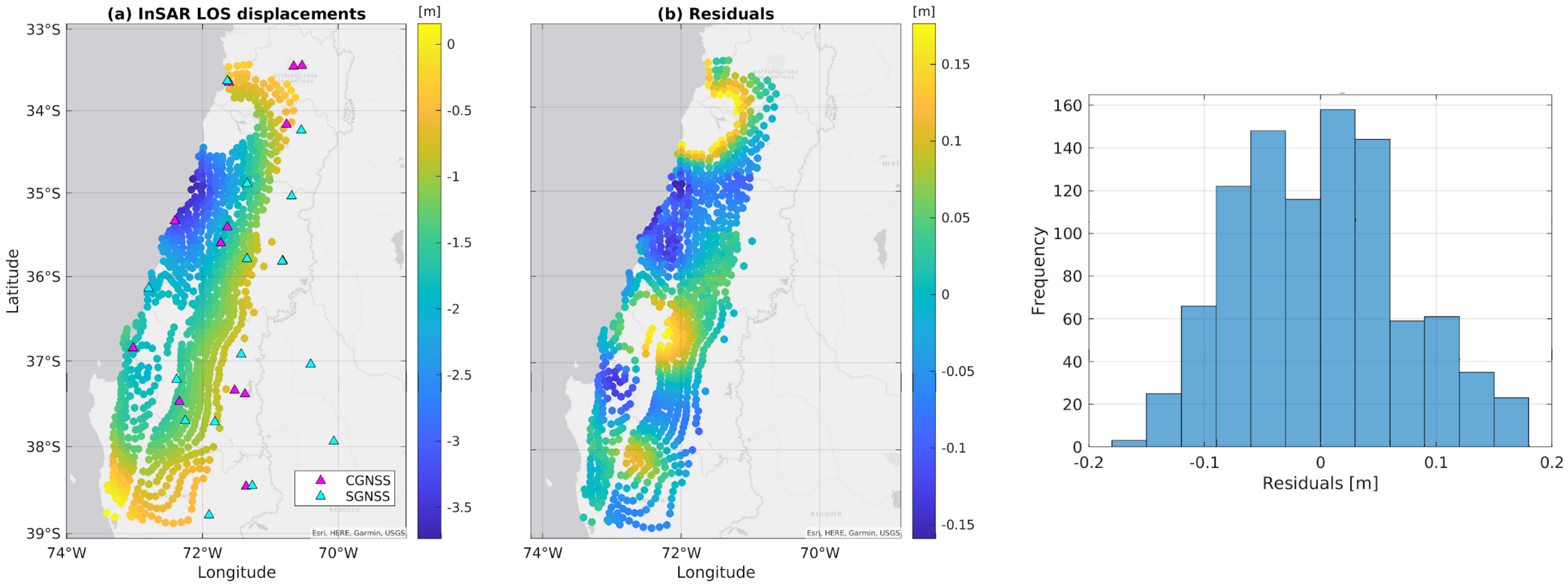
Prediction capacity of the model (CGNSS) - MAULE



Prediction capacity of the model (SGNSS) - MAULE



Prediction capacity of the model (InSAR) - MAULE



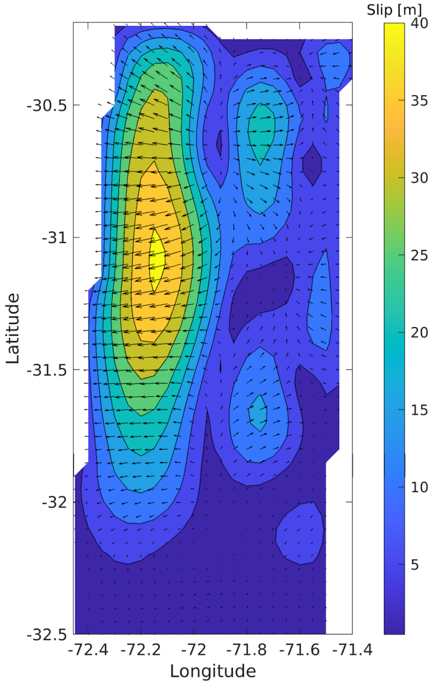
Prediction capacity of the model (statistics) - MAULE

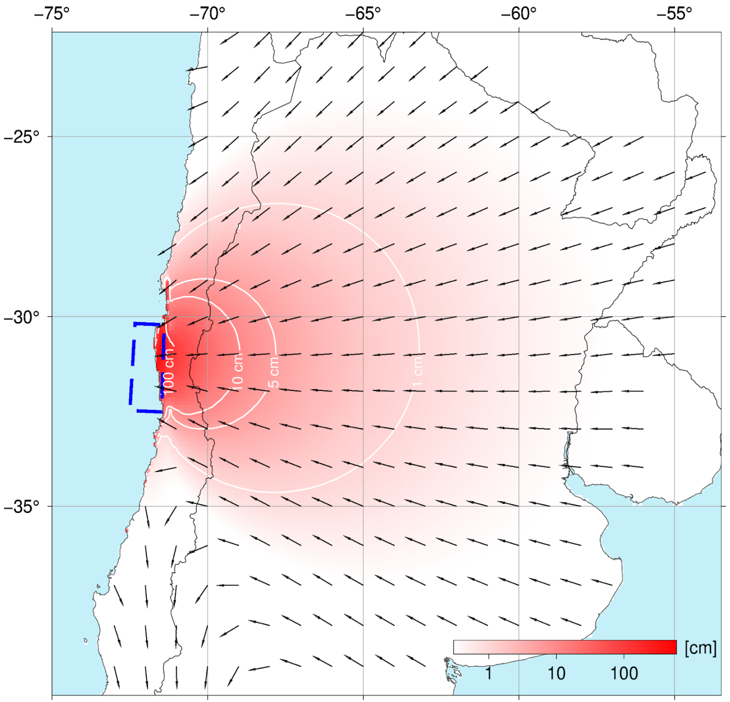
- **CGNSS** stations: error **< 2 cm for 93%** of the stations. Root mean square (rms) misfit of **~1 cm** (95% confidence interval).

- **SGNSS** stations: error **< 5 cm for 92%** of the stations. Root mean square (rms) misfit of **~3 cm** (95% confidence interval).

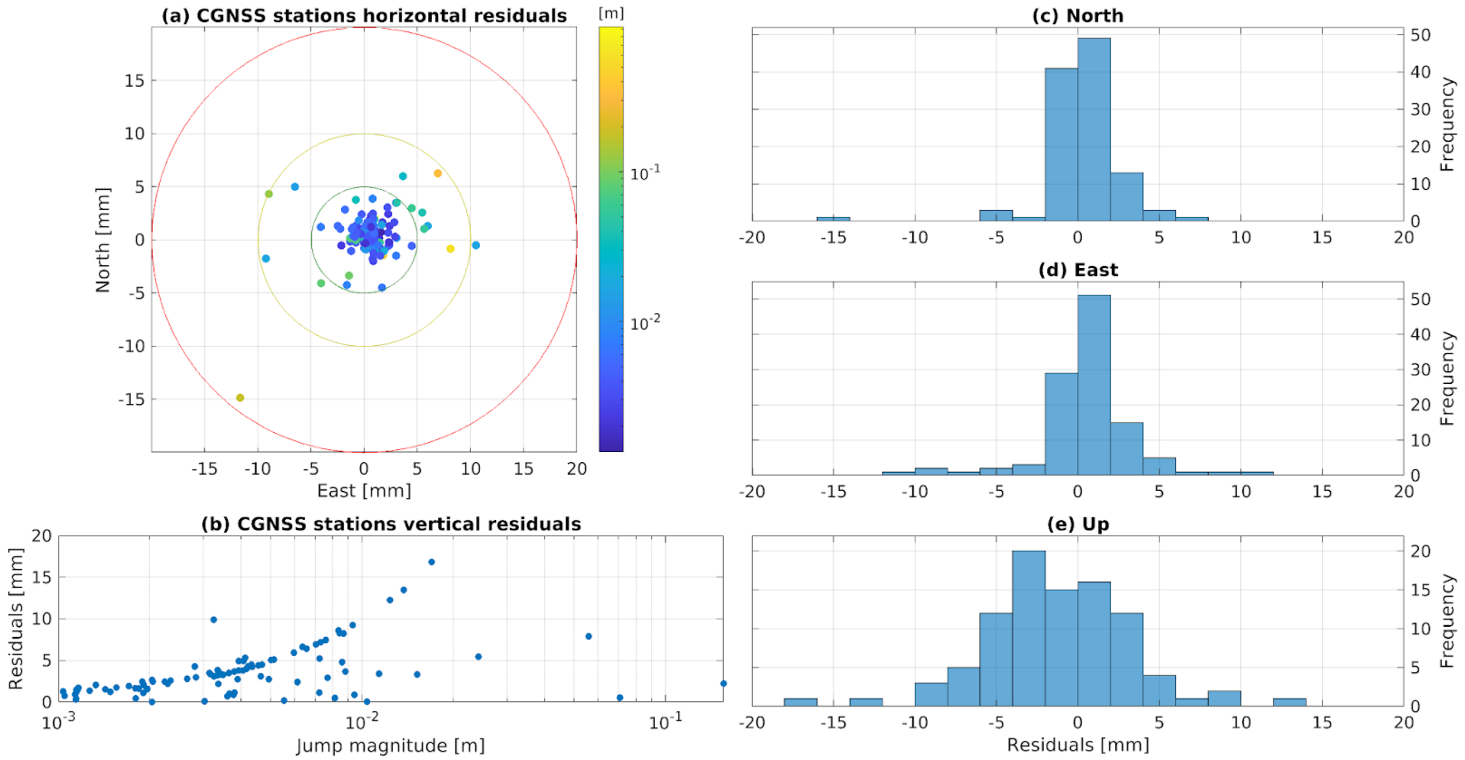
- **InSAR** residuals have a standard deviation of **~7 cm.**

Slip distribution and coseismic deformation slip - ILLAPEL

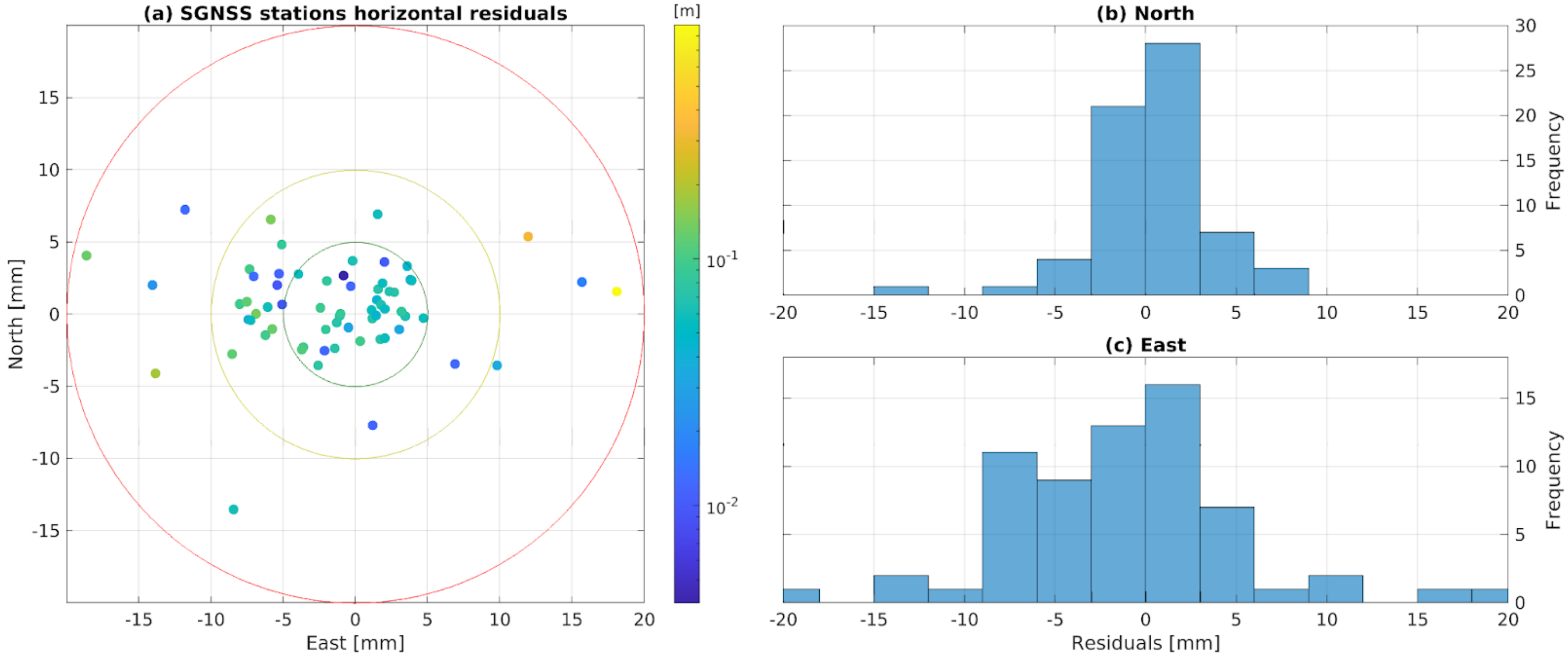




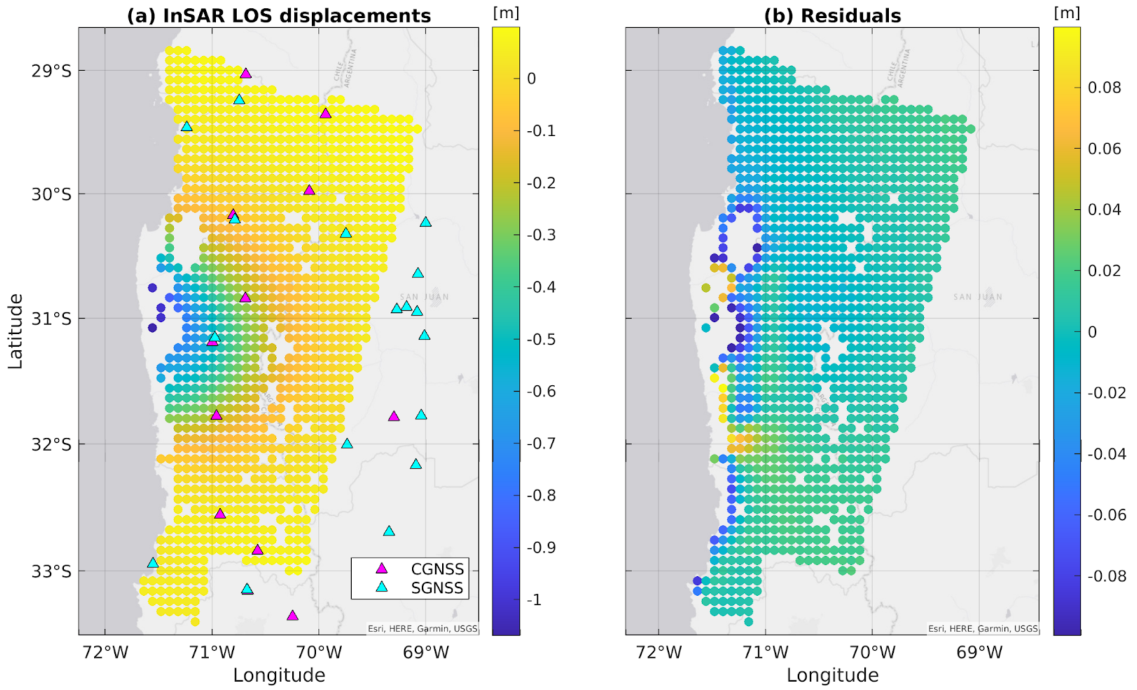
Prediction capacity of the model (CGNSS) - ILLAPEL

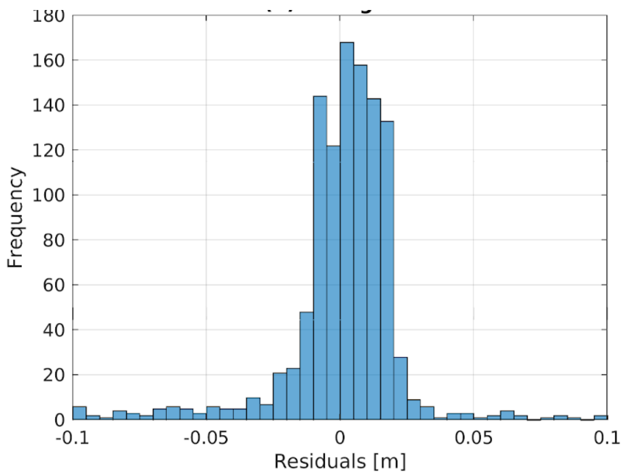


Prediction capacity of the model (SGNSS) - ILLAPEL



Prediction capacity of the model (InSAR) - ILLAPEL





Prediction capacity of the model (statistics) - Illapel

- **CGNSS** stations: error **< 1 cm for 98%** of the stations. Root mean square (rms) misfit of **~1 cm** (95% confidence interval).

- **SGNSS** stations: error **< 2 cm for 95%** of the stations. Root mean square (rms) misfit of **~2 cm** (95% confidence interval).

- **InSAR** residuals have a standard deviation of **~2 cm.**

Conclusions

- The hybrid approach of this work has shown that **centimeter-level coseismic displacement** residuals are possible even in the near-field of both the Maule and Illapel earthquakes.
- Without the usually imposed **geodynamic constraints**, the slip distribution on the faults of both modeled earthquakes have slip rakes and magnitudes that are not consistent with the tectonic settings.
- Some of the observed differences in fault slip can be attributed to **leakage of the postseismic signal into the coseismic estimate**, since we are using a **single logarithmic transient** to fit the GNSS trajectories.
- These coseismic models are introduced as part of **VEL-Ar**, the T**rajectory Prediction Model** of Argentina. VEL-Ar is used to access **POSGAR07**, the official Reference Frame of Argentina, and to reduce the coordinates obtained by **PPP-Ar** to its **conventional epoch**.

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THANK YOU!

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Gómez DD, Figueroa MA, Sobrero FS, Smalley R, Bevis MG, Caccamise DJ, Kendrick E. (under review) On the determination of coseismic deformation models to improve access to geodetic reference frame conventional epochs in low-density GNSS networks. J Geod.