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

- (a) CGNSS stations horizontal residuals
- (b) CGNSS stations vertical residuals
- (c) North
- (d) East
- (e) Up

![Graphs showing residuals and distribution of CGNSS measurements in different directions.](image-url)
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

(a) InSAR LOS displacements

(b) Residuals
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 Trajectory 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.
THANK YOU!

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