



KINEMATIC DEFORMATION MODELING

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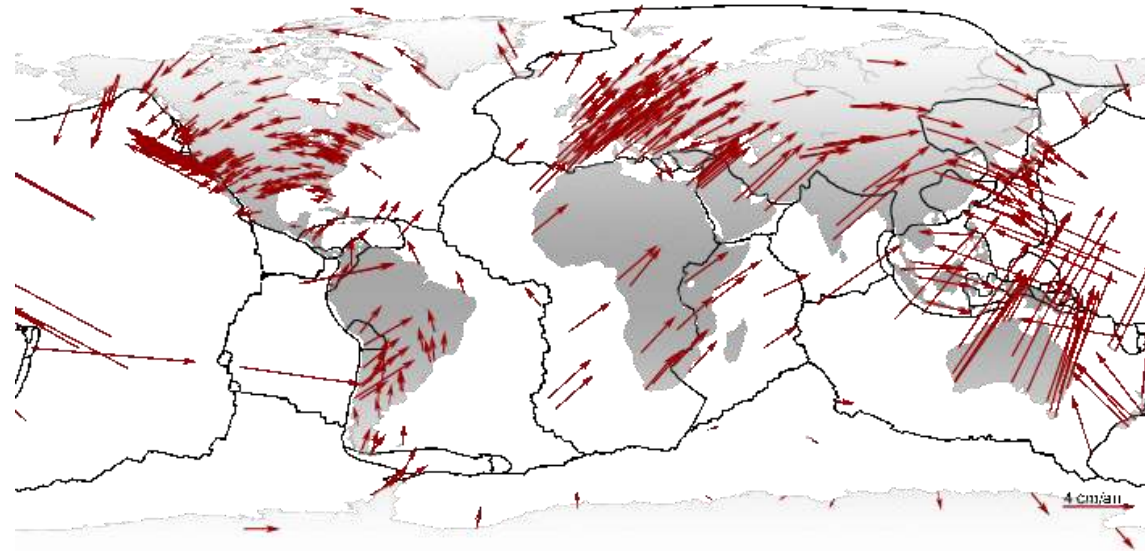
FIG/IGM-Chile Technical Seminar

Reference Frames in Practice



INTRODUCTION (1)

- GNSS allows us to obtain coordinates with a millimeter-level precision.
- These coordinates are expressed in a highly stable Reference Frame.
- The global frame is sensible to velocities, interactions between tectonic plates and other geodynamic effects => these effects should be taken into account.



http://gns.be/systems_tutorial.php

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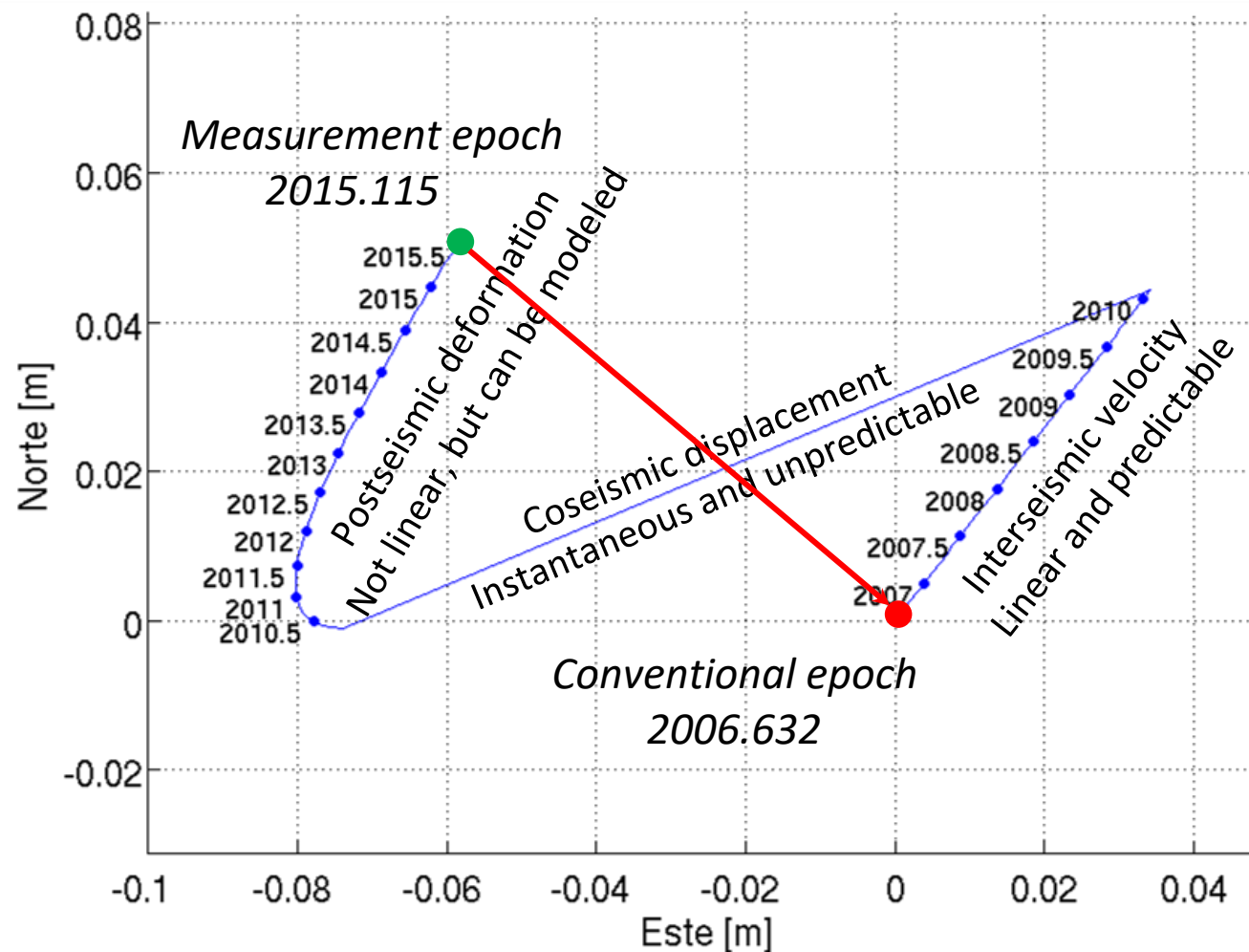
INTRODUCTION (2)

- POSGAR07 is the official reference frame of Argentina, which is based on ITRF2005 (conventional epoch 2006.632).
- Realized and maintained using RAMSAC.



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HOW DOES THIS AFFECT SURVEYORS? (1)



~50 km



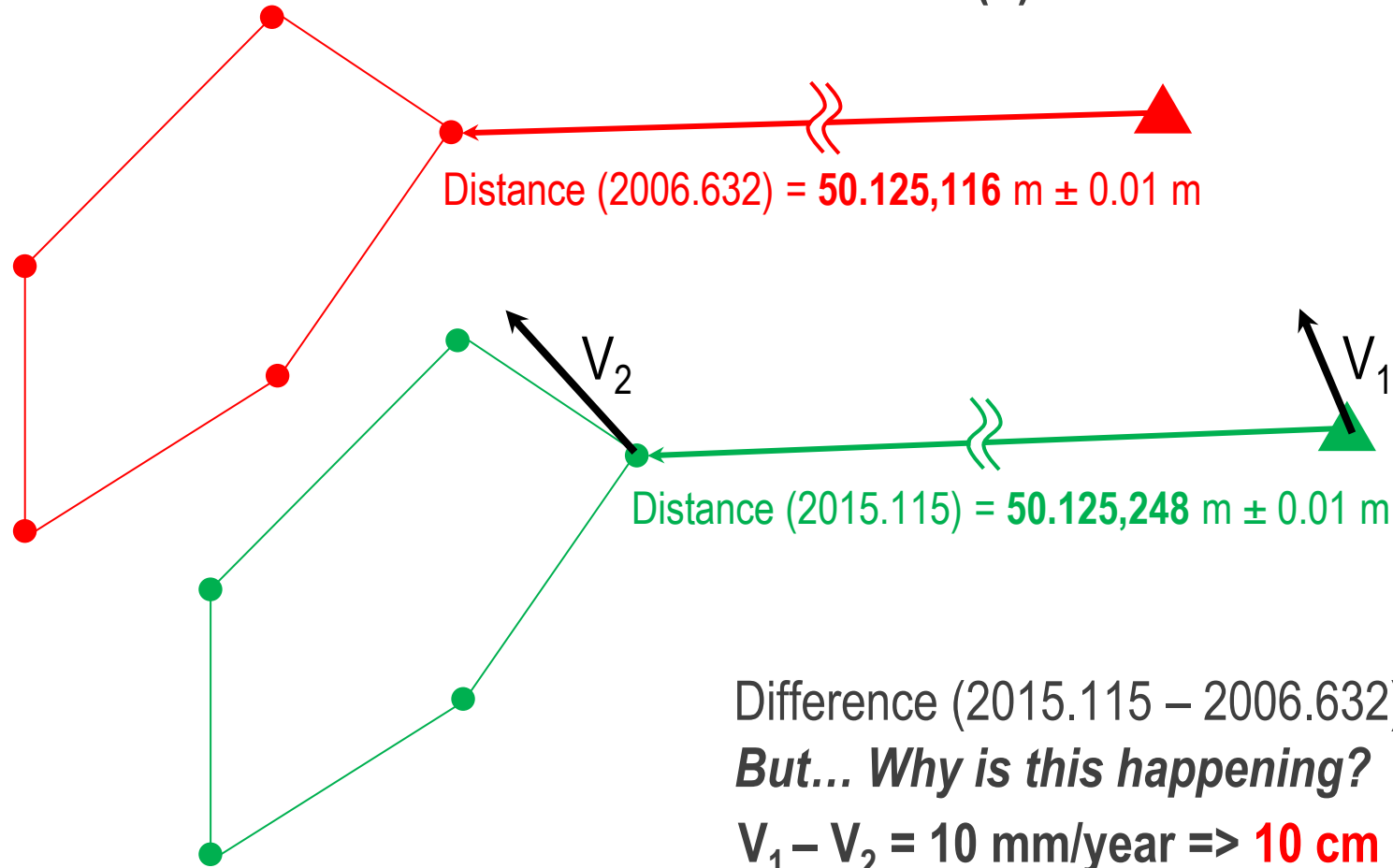
Continuous
GNSS
station

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HOW DOES THIS AFFECT SURVEYORS? (2)

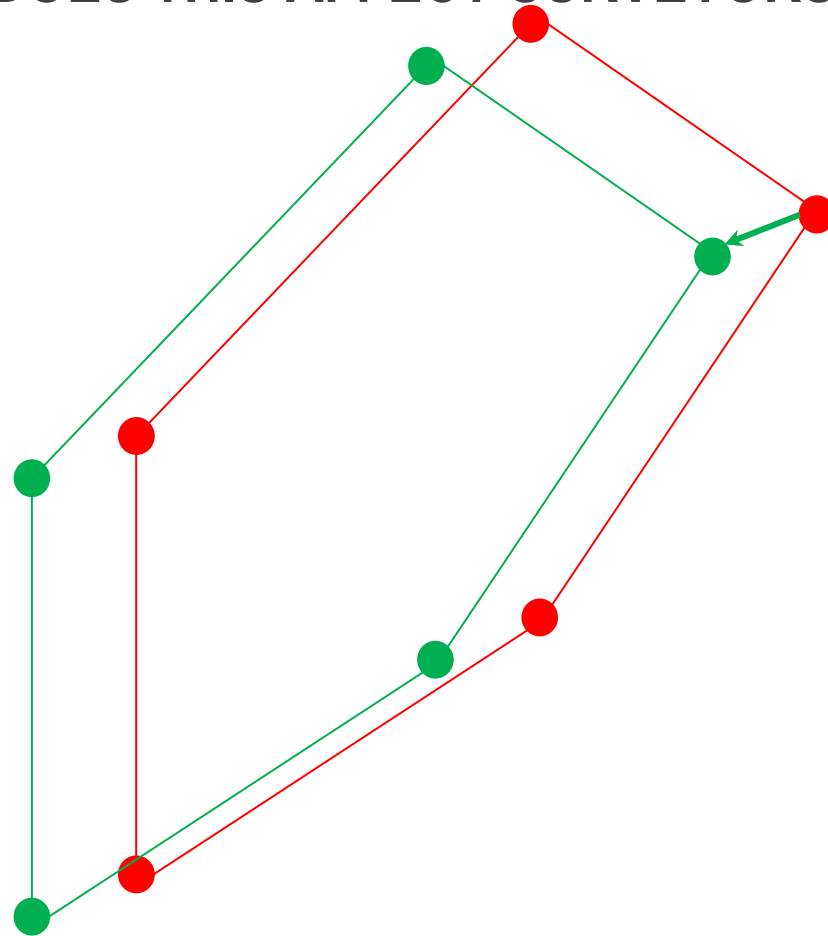


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HOW DOES THIS AFFECT SURVEYORS? (3)



0.132 m

This effect is *predictable*.
Therefore, it is possible to
reduce the difference by
utilizing a model.

We need to find V_1 and V_2 !

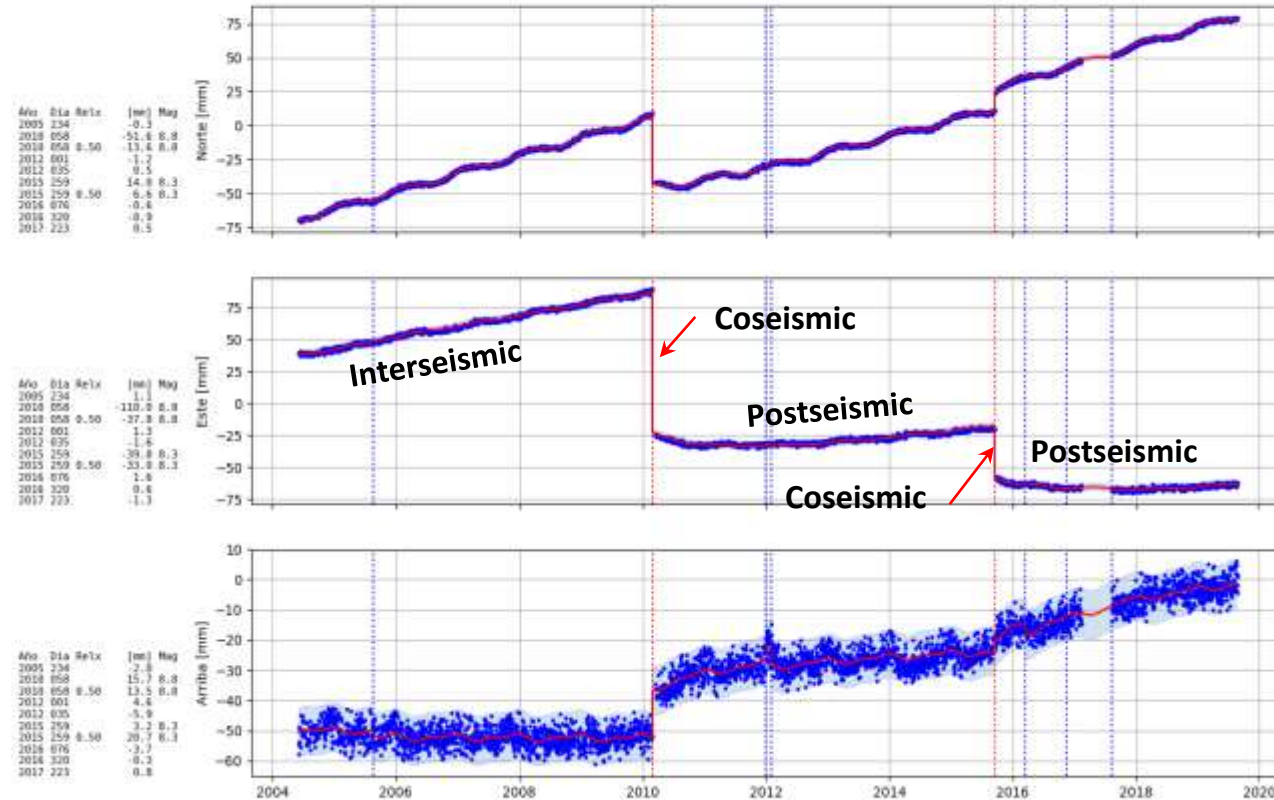
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V₁: CONTINUOUS GNSS STATIONS

Estación ras.azac (GARIT 97.07%) lat: -32.89515 lon: -68.87557
 Posición de ref. (2004.422) X: 1932282.677 Y: -5001226.529 Z: -3444667.857 [m]
 Velocidad N: 13.21 E: 8.41 U: -8.88 [mm/yr]
 Amp. Periódica (1.0 yr, 0.5 yr) N: 12.3 0.21 E: 10.7 0.11 U: 10.8 0.51 [mm]
 NEU wrms [mm]: 0.81 1.12 3.20



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EXTENDED TRAJECTORY MODEL (ETM)

- Methodology to model all components observed in time series.
- **ADVANTAGES:**
 - 1) Produces trajectory models that predict station position for longer periods of time.
 - 2) Shares the constant velocity model base.
- **DISADVANTAGE:** Some of the modeled components are not orthogonal, so there might be leakage from one component into another.

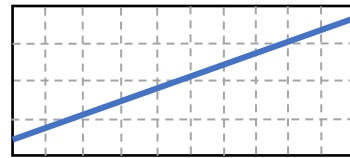
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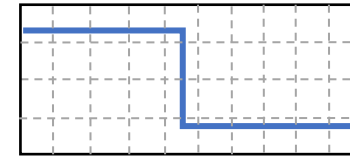
COMPONENTS MODELED WITH THE ETM

$$\sum_{i=1}^{n_p+1} \mathbf{p}_i (t - t_R)^{i-1}$$



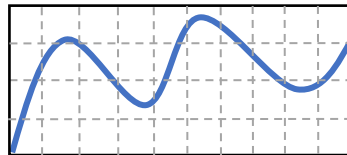
Linear: plate tectonics

$$\sum_{j=1}^{n_j} \mathbf{b}_j H(t - t_j)$$



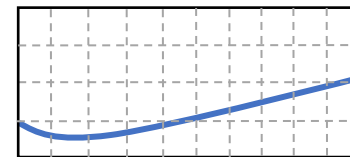
Jumps: earthquakes, equipment replacement

$$\sum_{k=1}^{n_F} [\mathbf{s}_k \sin(\omega_k t) + \mathbf{c}_k \cos(\omega_k t)]$$



Periodic: annual, semi-annual

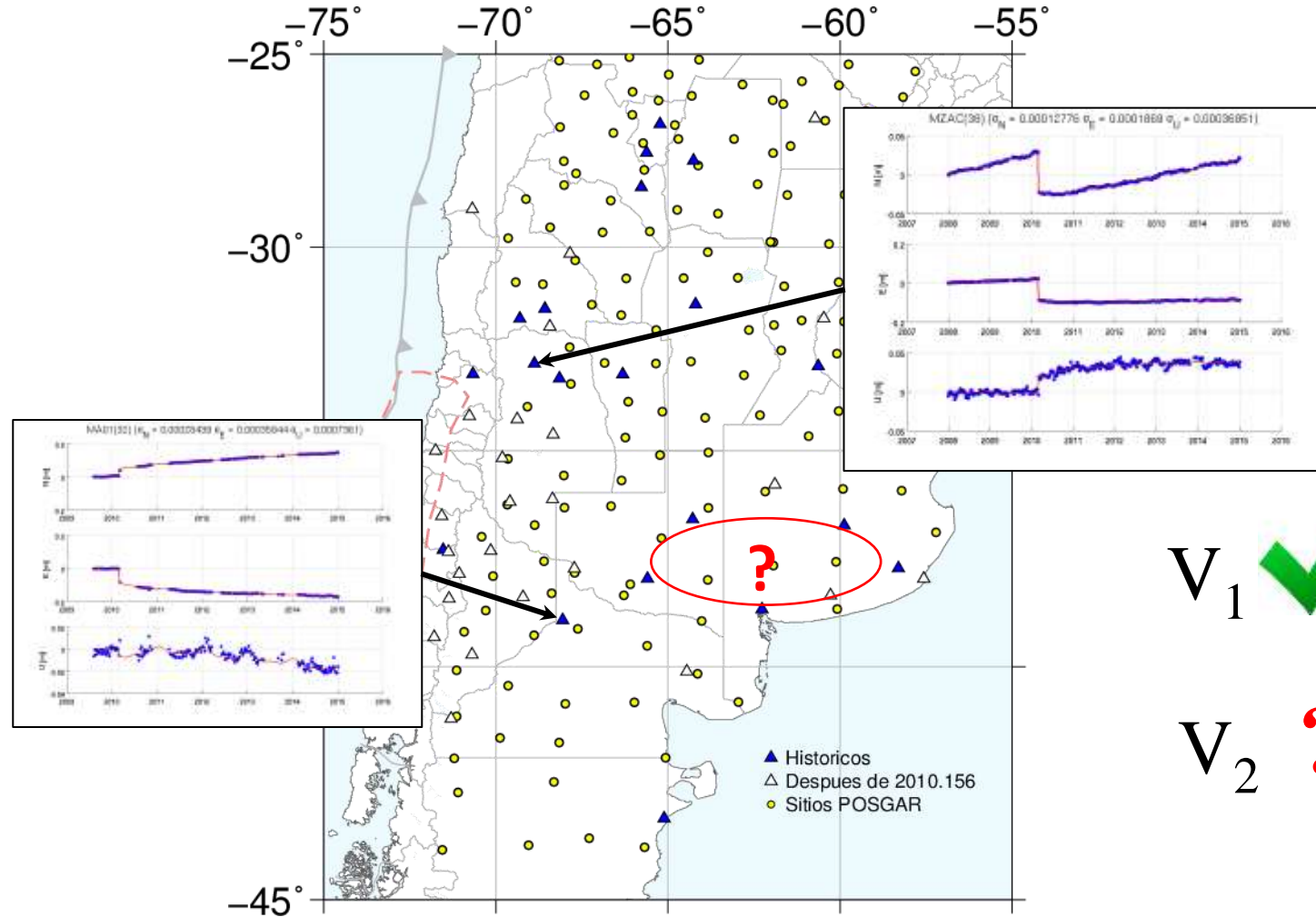
$$\sum_{i=1}^{n_T} \mathbf{a}_i \log[1 + (t - t_{EQ})/T_i]$$



Logarithms: viscoelastic relaxation

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V₁ ✓

V₂ ?



Instead of finding V_2 , could we use a **HELMERT TRANSFORMATION** to transform from the measurement epoch to the conventional epoch?

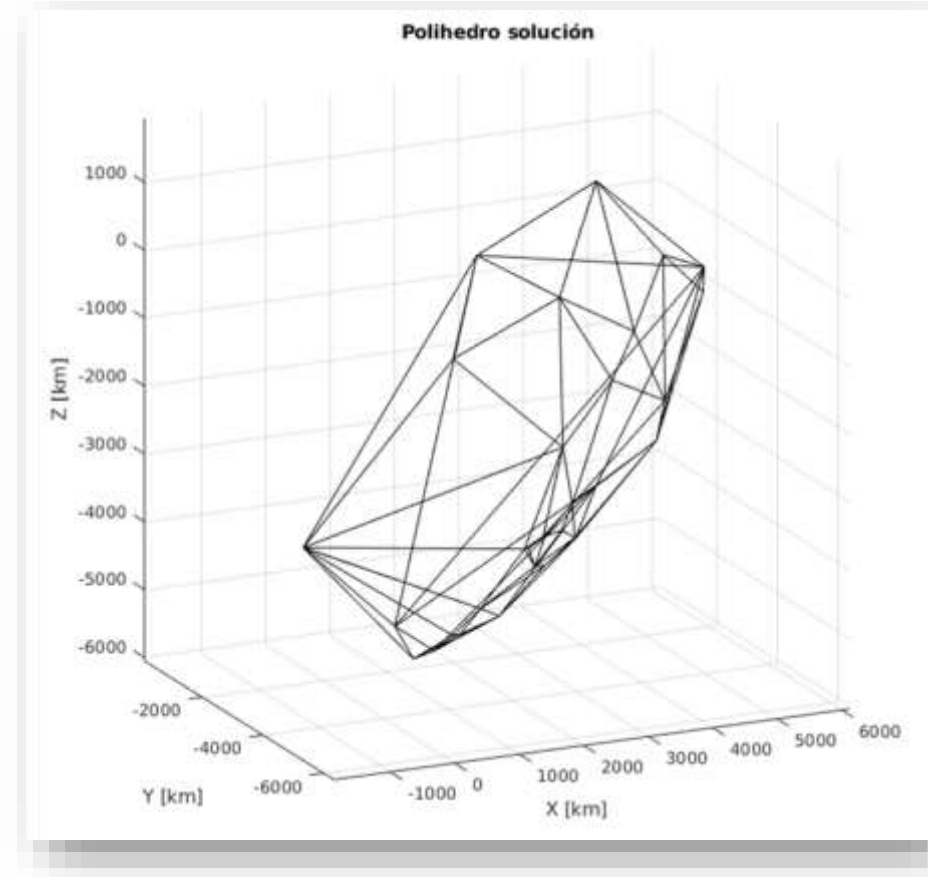
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INNER GEOMETRY

- Geometric figure (in this case it is tridimensional) with arbitrary position and orientation.
- The information is in the ΔX , ΔY , ΔZ between the vertices.
- It could have an arbitrary scale => $\alpha(\Delta X, \Delta Y, \Delta Z)$



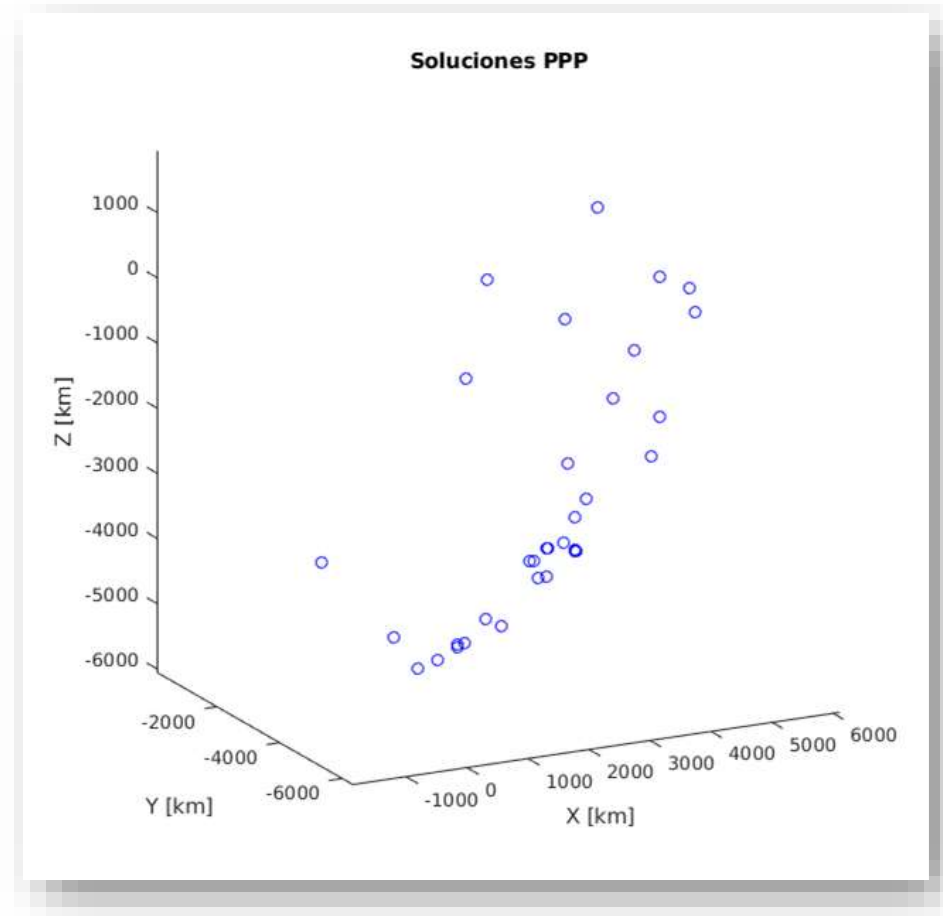
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OUTER GEOMETRY

- The X, Y, and Z coordinates of the vertices of the polyhedron, which are given in a specific reference frame.



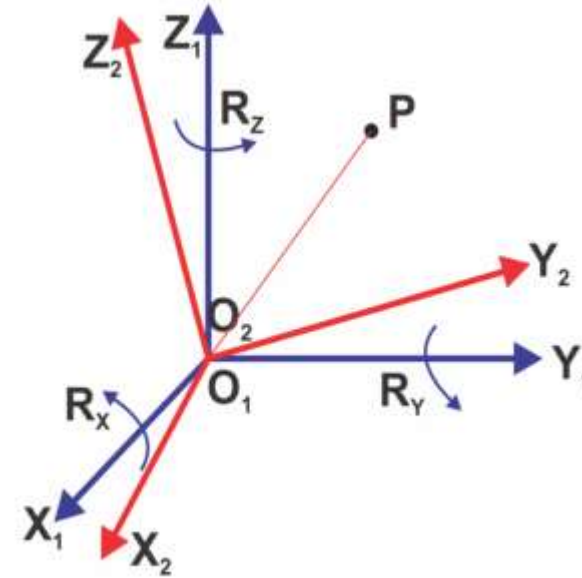
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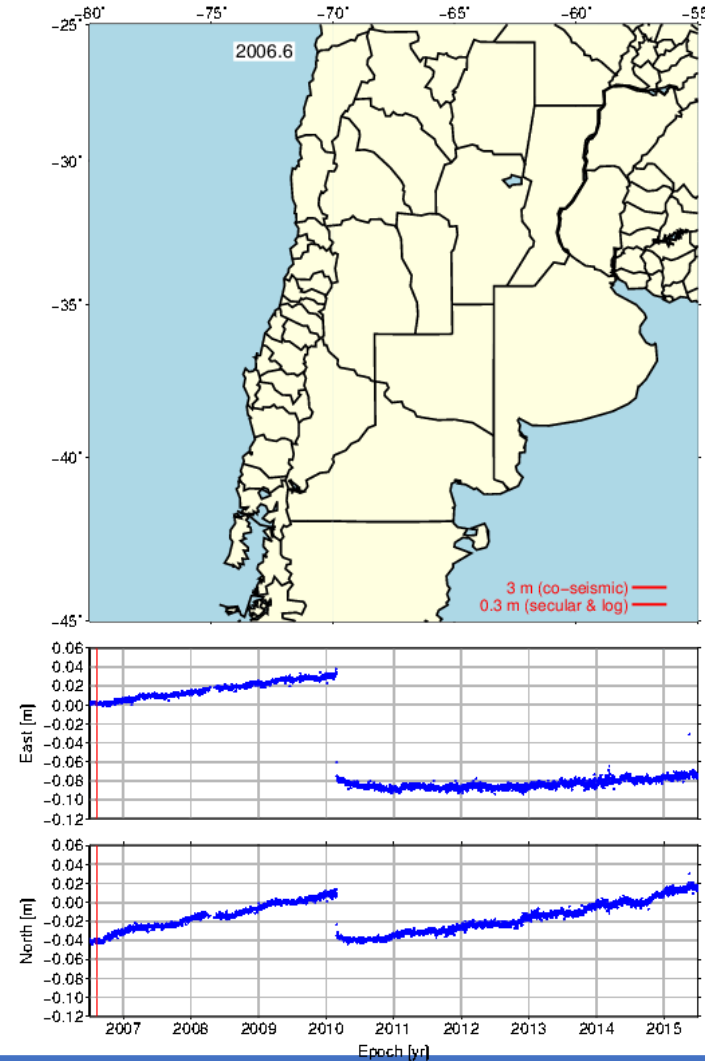
HELMERT TRANSFORMATION

- Transformation of 7 parameters (or 6, if we do not consider the scale factor):
- Translation from the origin (TX, TY, TZ)
- Rotations around axes (RX, RY, RZ)
- Scale factor (1+ μ)



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The **HELMERT TRANSFORMATION** is a rigid-body transformation. Therefore, it is not possible to apply it if there was **INNER DEFORMATION**.

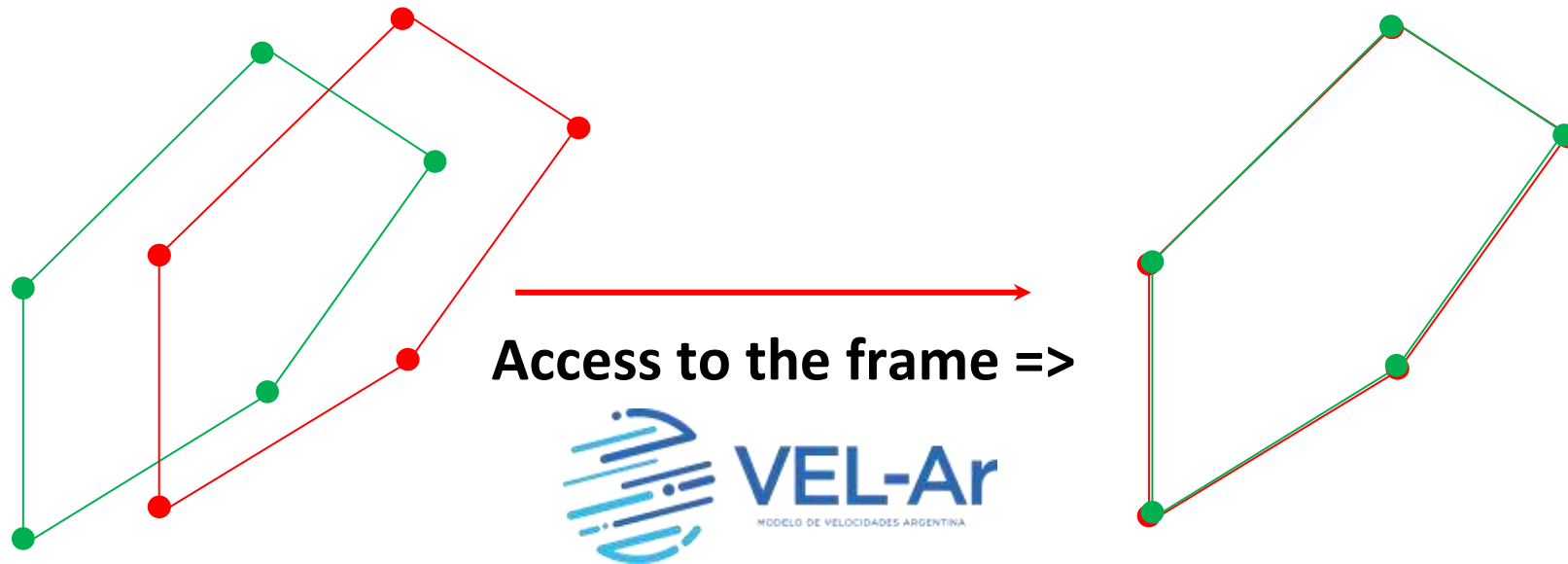
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SOLUTION TO THE PROBLEM

- A **Trajectory Prediction Model**, continuous in space and time, that allows us to predict the behavior of passive benchmarks.
- This model ensures the access to a geodetic reference frame after big earthquakes utilizing postseismic coordinates.



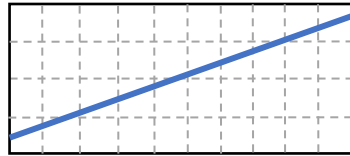
FIG/IGM-Chile Technical Seminar

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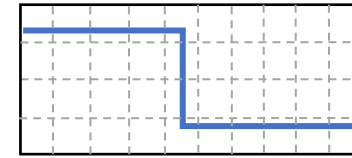
COMPONENTS MODELED WITH THE ETM

$$\sum_{i=1}^{n_p+1} \mathbf{p}_i (t - t_R)^{i-1}$$



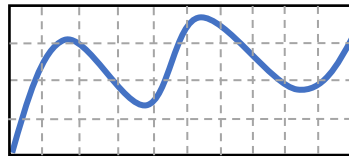
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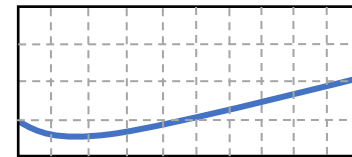
Jumps: earthquakes, equipment replacement

$$\sum_{k=1}^{n_F} [\mathbf{s}_k \sin(\omega_k t) + \mathbf{c}_k \cos(\omega_k t)]$$



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$$\sum_{i=1}^{n_T} \mathbf{a}_i \log[1 + (t - t_{EQ})/T_i]$$



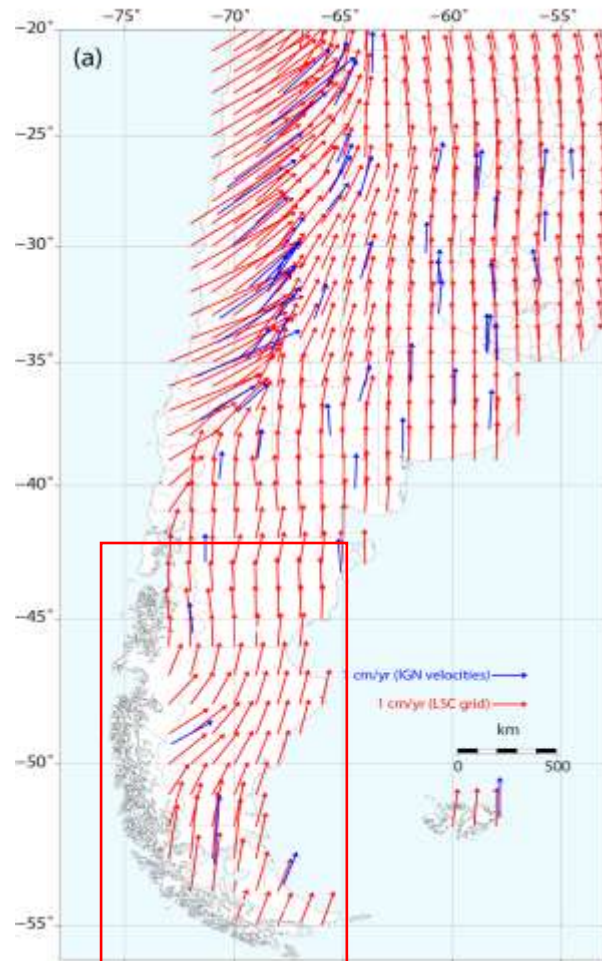
Logarithms: viscoelastic relaxation

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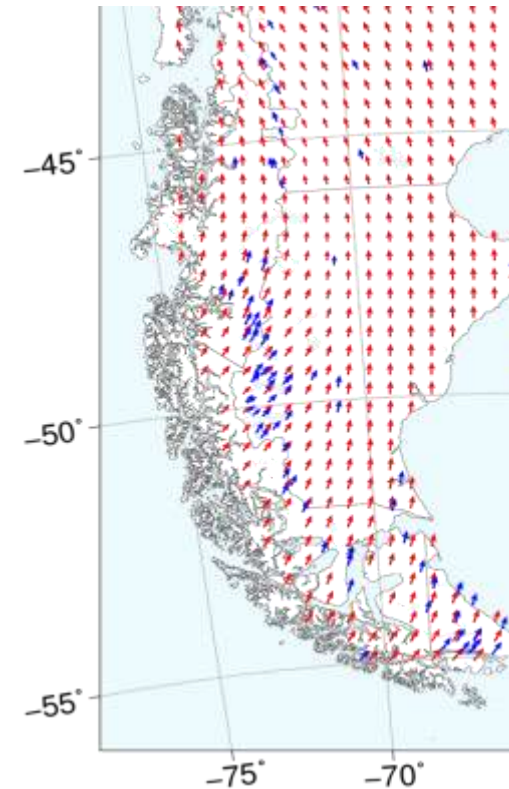
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INTERSEISMIC COMPONENT



2015
Version



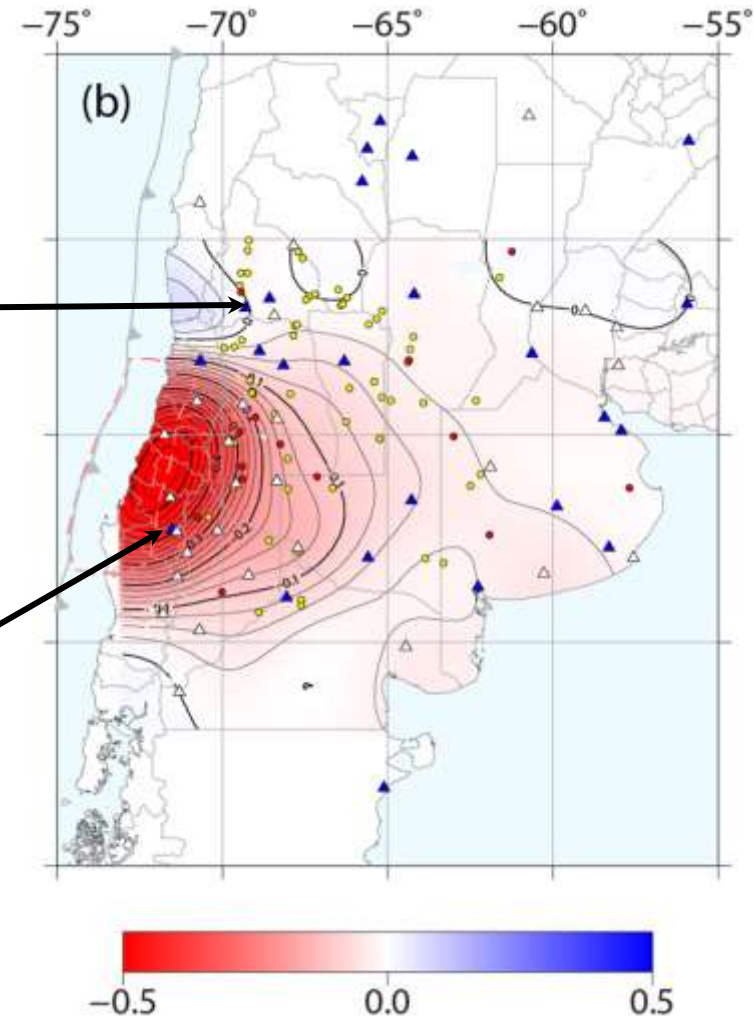
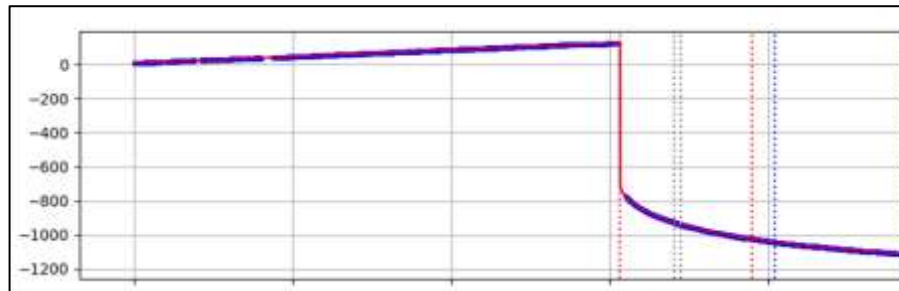
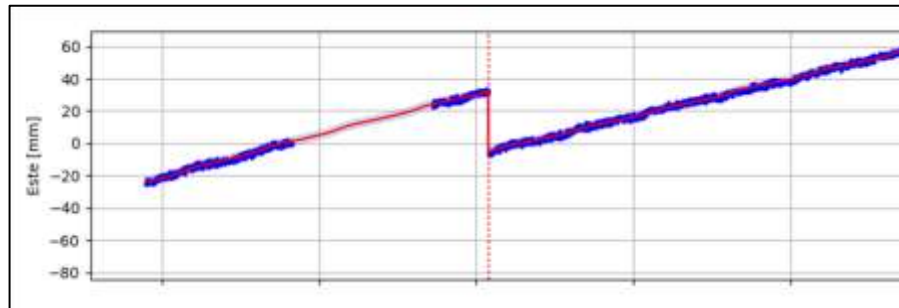
2020 Version
+ Campaign data
+ Grid density

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POSTSEISMIC COMPONENT

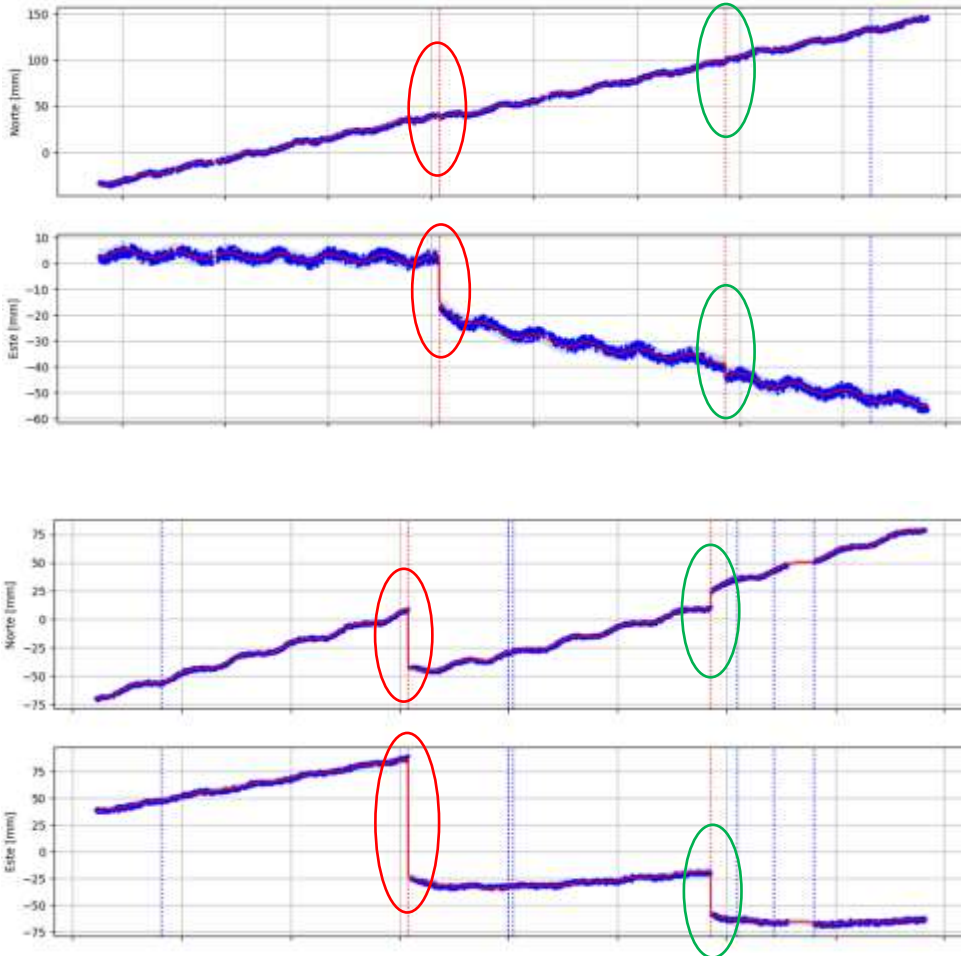


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COSEISMIC COMPONENT



VEL-Ar 2015 Version: Maule (2010)

VEL-Ar 2020 Version: Illapel (2015)

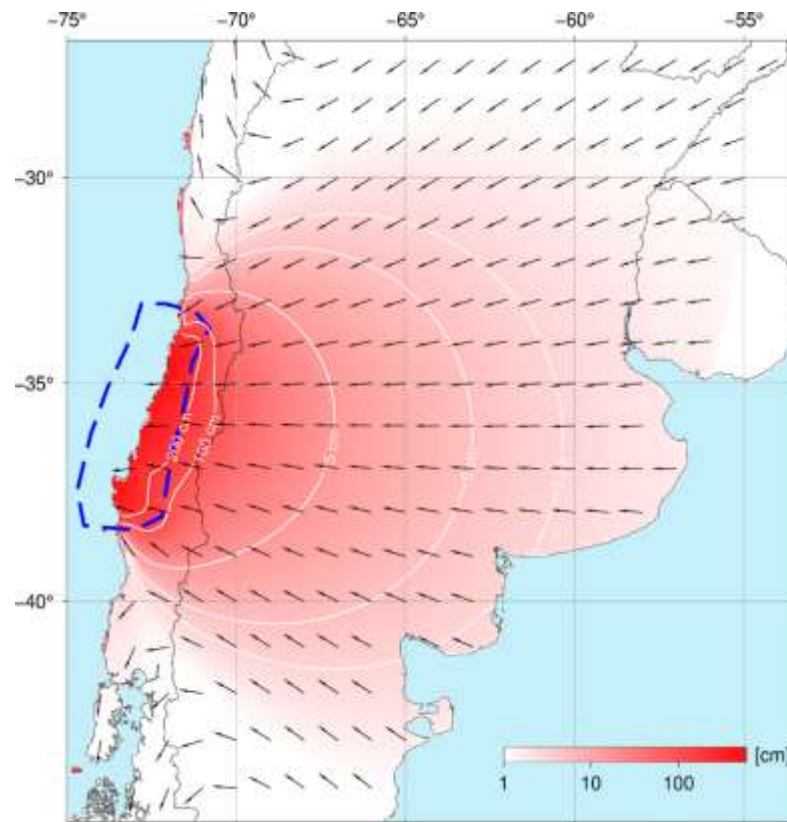
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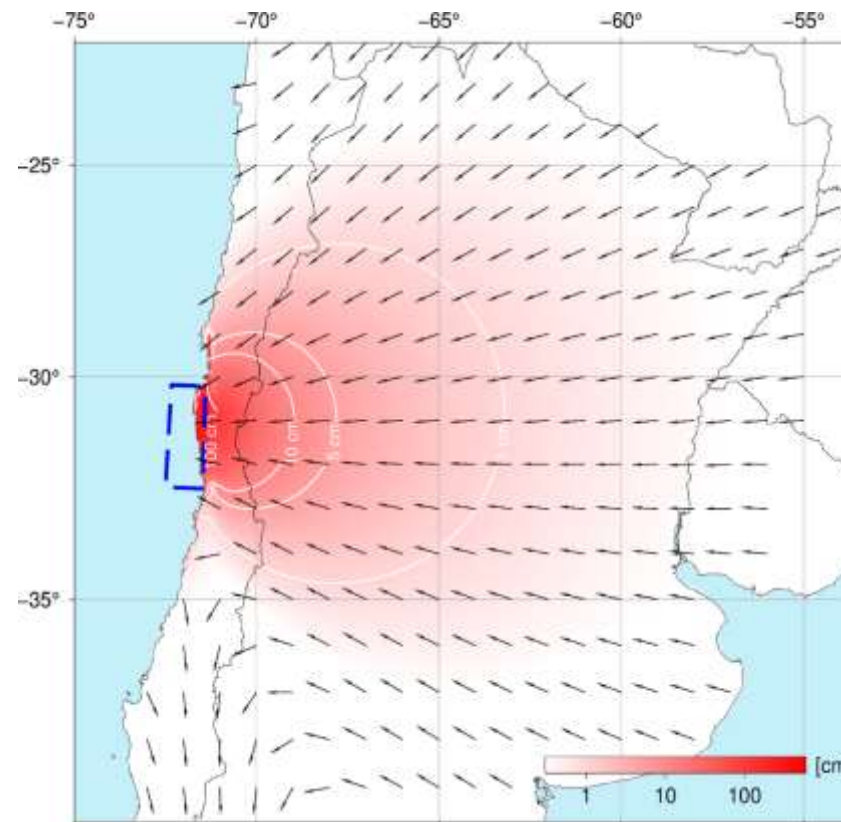


COSEISMIC COMPONENT

Maule 2010



Illapel 2015

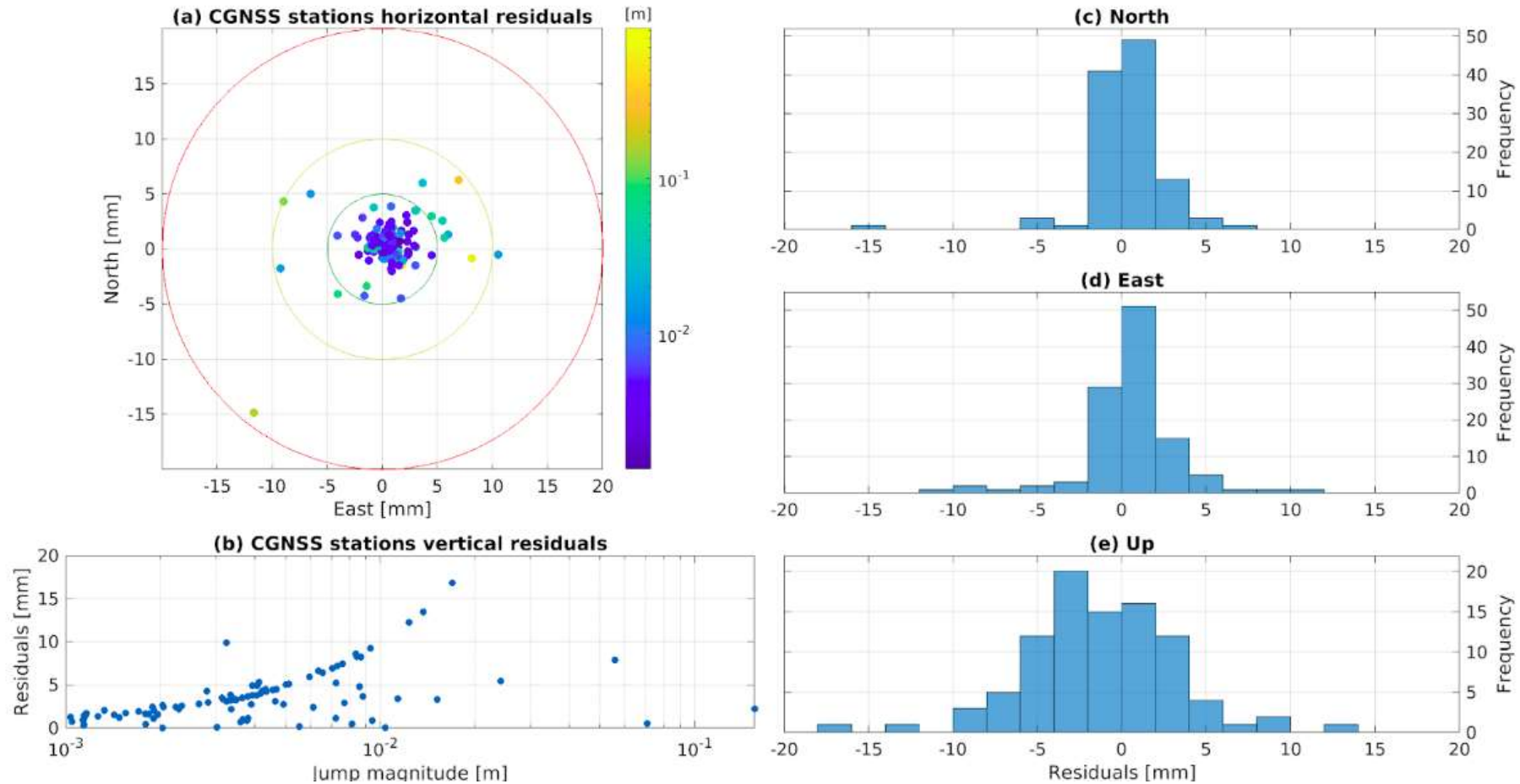


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PREDICTION CAPACITY OF THE I I ADEL MODEL (CGNSS)

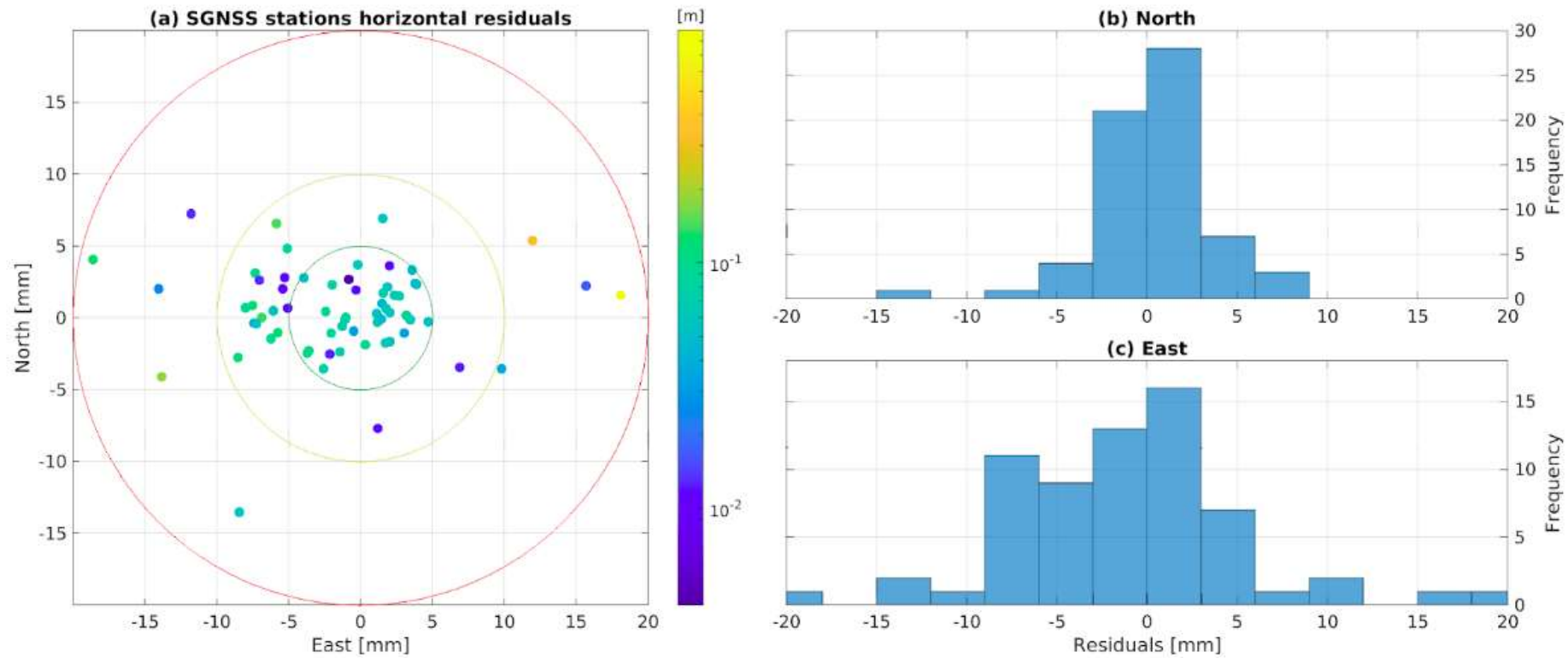


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PREDICTION CAPACITY OF THE ILLAPEL MODEL (SGNSS)

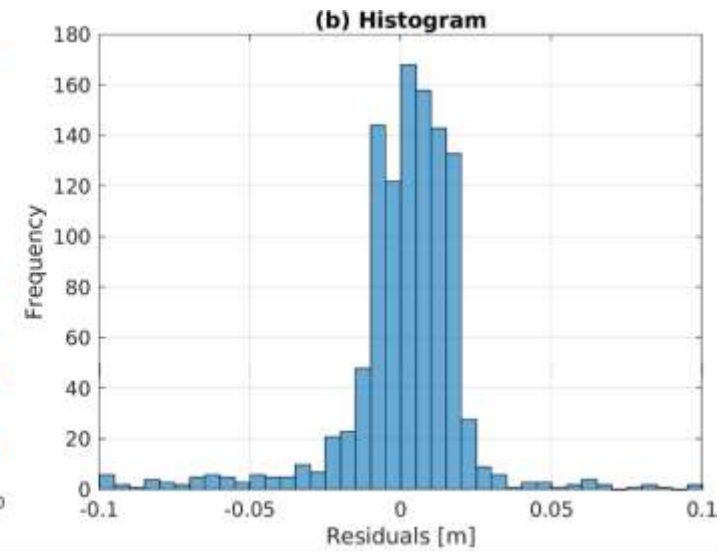
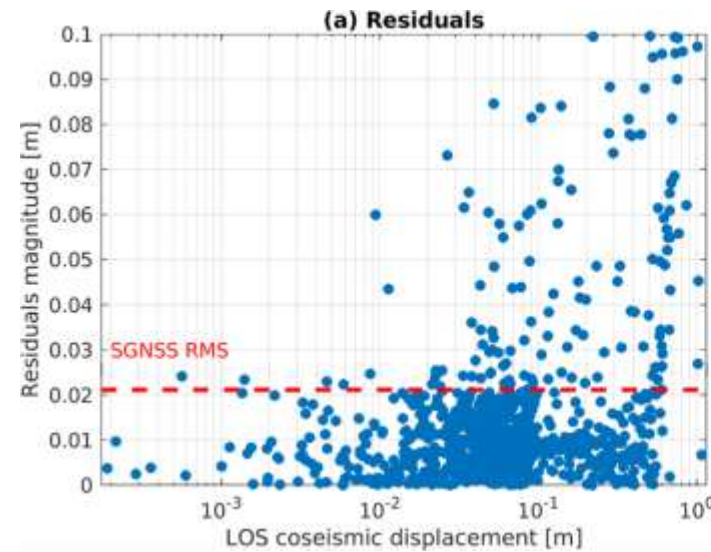
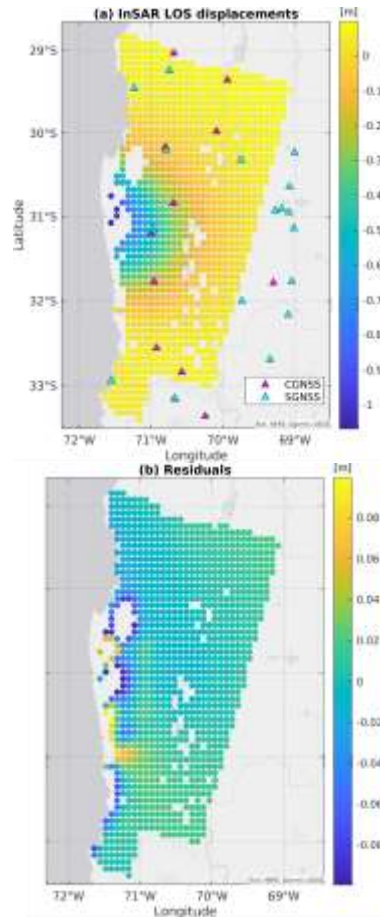


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PREDICTION CAPACITY OF THE ILLAPEL MODEL (InSAR)

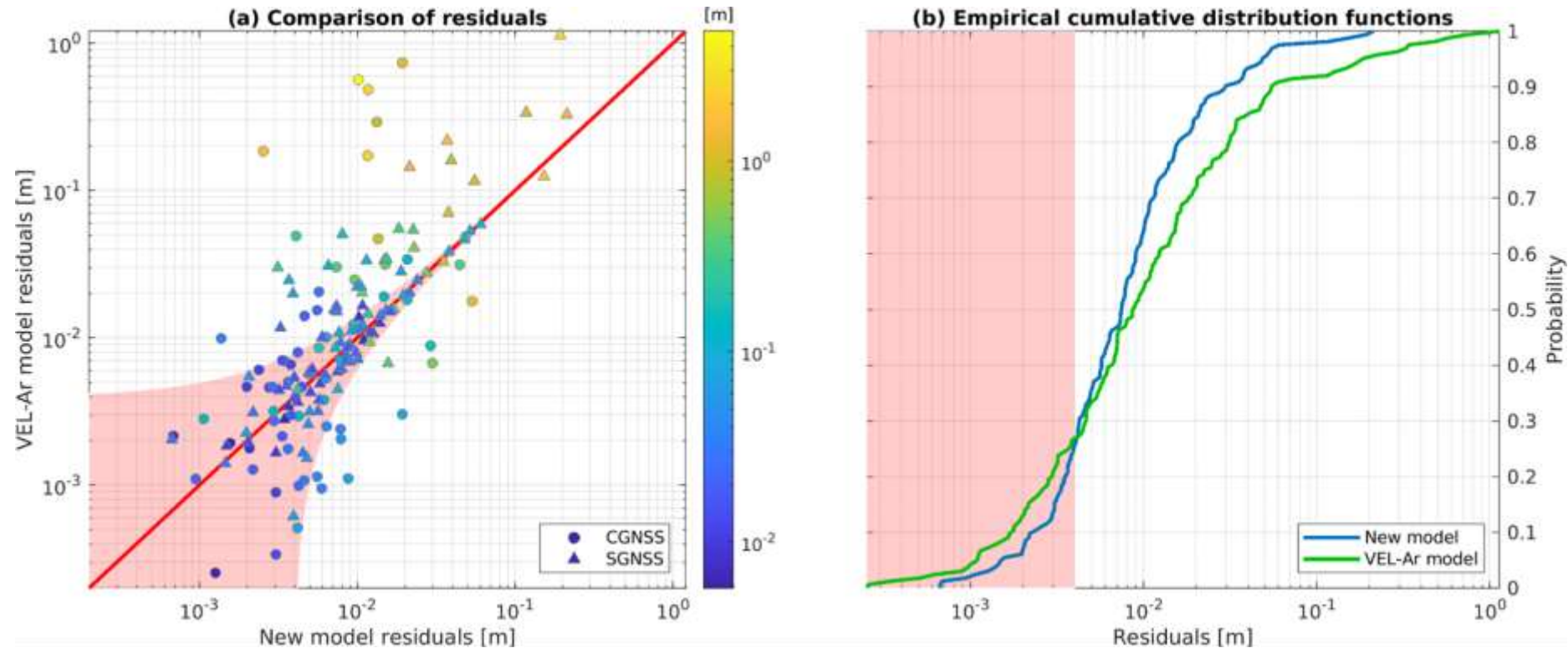


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COMPARISON OF NEW MAULE COSEISMIC MODEL VS. PREVIOUS VERSION IN VEL-Ar



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SERVICES BASED ON VEL-Ar

A screenshot of the PPP-Ar website. The page has a blue header with the IGN logo and navigation links. The main content area is titled 'INTRODUCCIÓN' and features the PPP-Ar logo and a description of the service. The left sidebar contains a menu with categories like 'INSTITUTO' and 'ACTIVIDADES'.

IGN Argentina Ministerio de Defensa

Nuestro Instituto | Nuestras Actividades | Nuestros Servicios

INSTITUTO

- Institucional
- Representaciones Internacionales
- Administración
- Marco Legal
- Transparencia

ACTIVIDADES

- Geodesia
 - Introducción
 - RAMSAC
 - RAMSAC-NTRIP
 - POSGAR 07
 - POSGAR 94
 - PPP-Ar**
 - Introducción
 - Acceso al servicio
 - Consultas frecuentes
 - Documentación técnica

INTRODUCCIÓN



PPP-Ar

SERVICIO DE POSICIONAMIENTO PUNTUAL-PRECISO DE LA REPÚBLICA ARGENTINA

PPP-Ar es un servicio en línea gratuito que le permite a los usuarios de la tecnología GNSS obtener coordenadas precisas vinculadas al marco de referencia geodésico POSGAR07, a partir del envío de datos en formato RINEX de receptores doble frecuencia que operan en modo estático.

El servicio PPP-Ar utiliza el programa CSRS-PPP desarrollado por la División de Geodesia del Instituto Canadiense de Recursos Naturales (NRCan) para obtener coordenadas referidas al marco de referencia geodésico de las órbitas de los satélites (actualmente IGB14) y en la época de medición. CSRS-PPP utiliza órbitas precisas de los satélites y correcciones a los relojes que genera IGS (Servicio Internacional GNSS), entre otros productos y modelos.

Luego, PPP-Ar introduce el modelo de trayectorias VEL-Ar para trasladar las coordenadas determinadas por el programa CSRS-PPP en la época de medición a la época convencional (2006.632) del marco de referencia oficial POSGAR07. Por último, se aplican parámetros de transformación para determinar las coordenadas oficiales POSGAR07 (época 2006.632).

Ante cualquier inquietud o consulta técnica envíe un correo electrónico a ppp@ign.gob.ar

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CONCLUSIONS

- Extended trajectory models ensure a more precise model of GNSS time series.
- It is possible to extend the use of ETMs to produce a Trajectory Prediction Model.
- VEL-Ar ensures the access to the official reference frame of Argentina utilizing postseismic coordinates with an error of < 3 cm ($\sim 91\%$).
- We presented the new version of VEL-Ar (2020), which incorporates the Illapel earthquake.

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THANK YOU!

Contact: figueroaberroca.1@osu.edu

VEL-Ar publications:

Gómez DD, Piñón DA, Smalley R, et al (2015) Reference frame access under the effects of great earthquakes: a least squares collocation approach for non-secular post-seismic evolution. *J Geod.* <https://doi.org/10.1007/s00190-015-0871-8>

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.*