Impacts of the 2010 Chile Earthquake on Earth rotation

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Introduction

- On February 27, 2010, an magnitude 8.8 Earthquake occurred in Chile close to the city of Concepción
- The Earthquake caused significant displacements in a large region
- Such a strong Earthquake may have noticeable effect on the rotation of the Earth

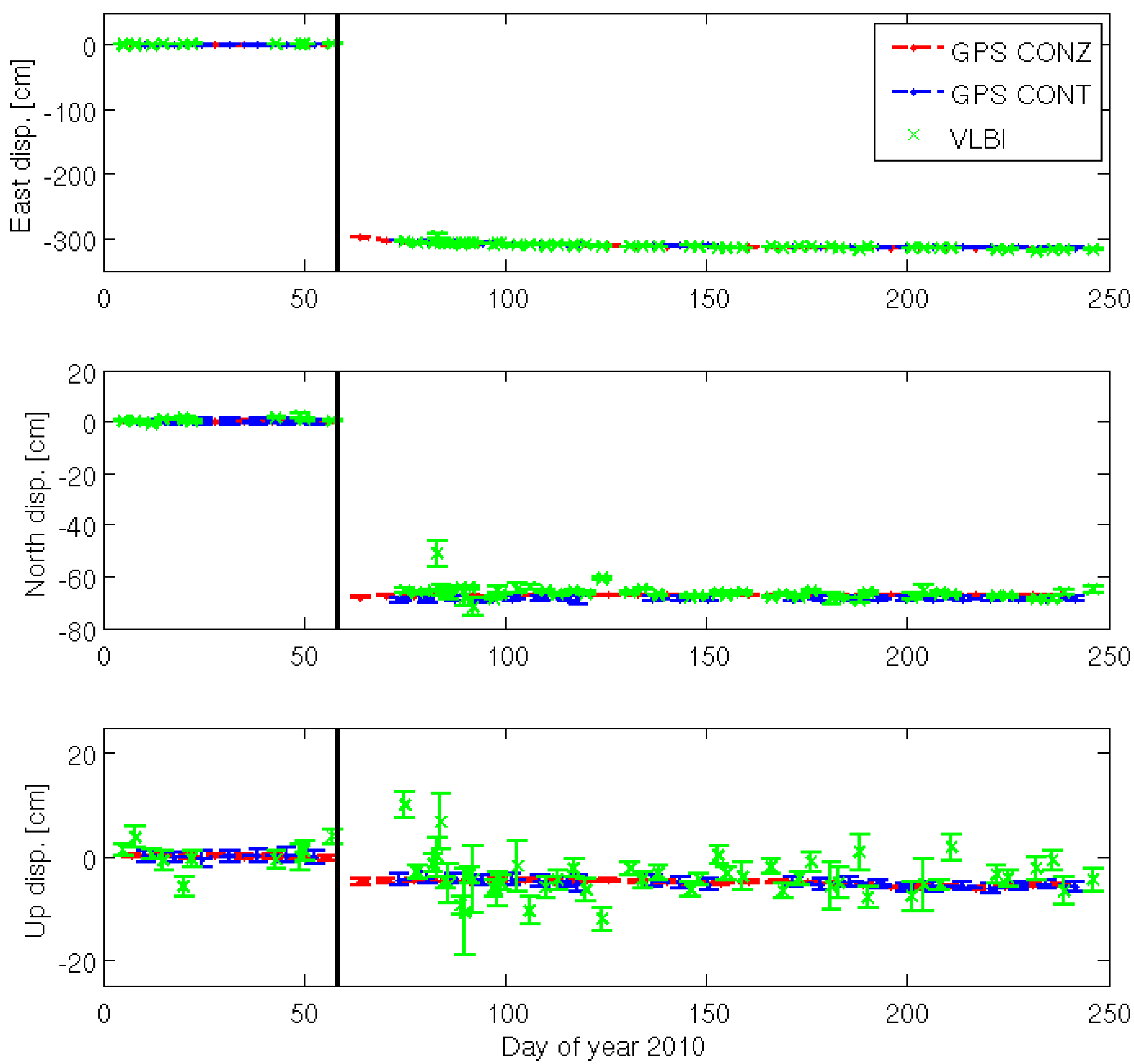
The TIGO station

- Fundamental station located in Concepción
- Several instruments: VLBI, GNSS, SLR, gravimeter, seismometer, meteorological sensors, etc.

VLBI and GNSS at the TIGO station

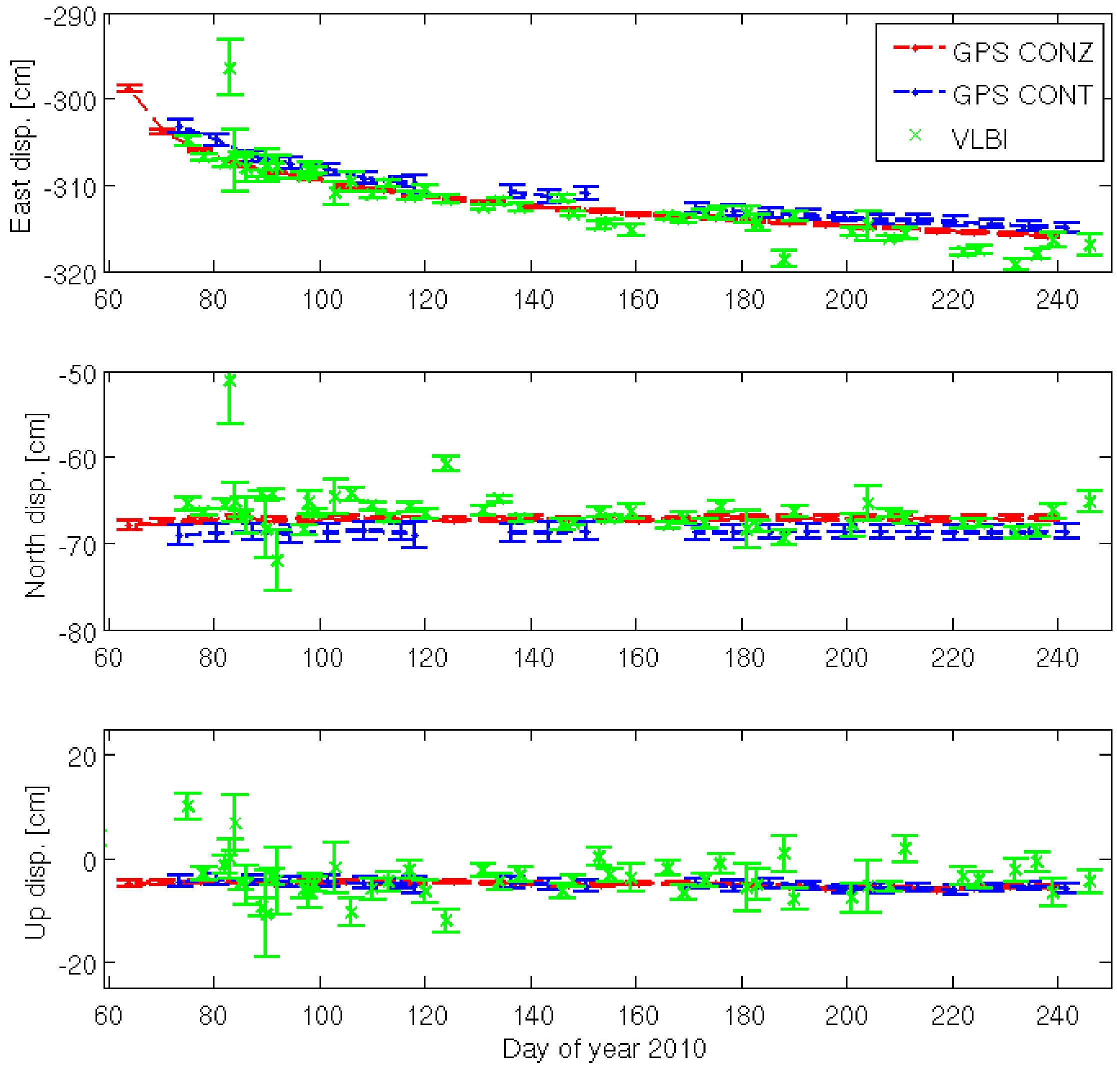
- Both the VLBI antenna (TIGO) and the two GNSS stations (CONZ and CONT) survived the Earthquake (although with some damages)
- Data from these instrument can be used to estimate the displacements caused by the Earthquake

Observed displacement of TIGO

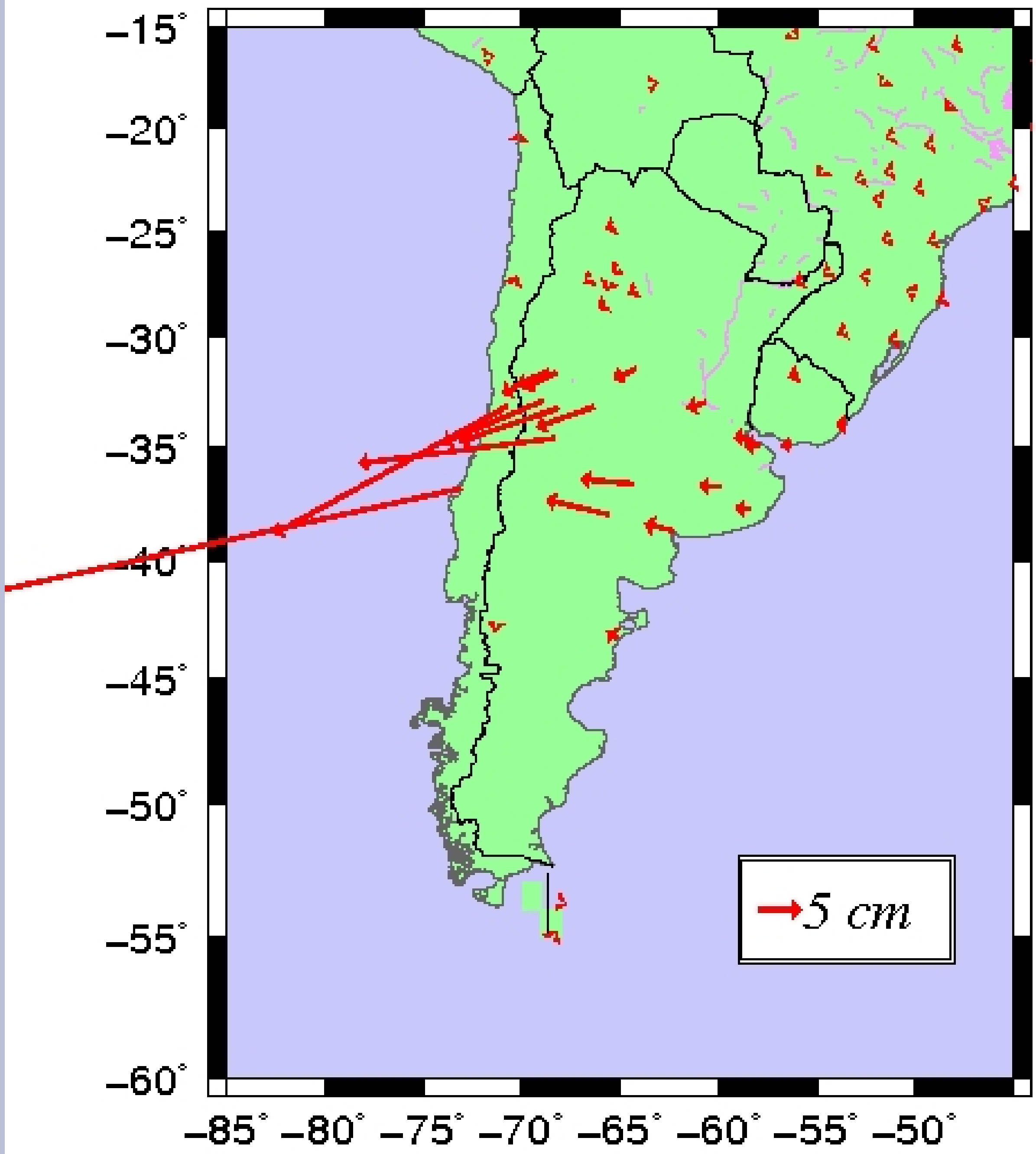


- Observed displacements of the VLBI and GPS stations in Concepción
- VLBI: results from 24 hour sessions
- GPS: IGS weekly solution
- Both techniques show a movement of over 3 m to the west and 60 cm to the south.

Post-seismic displacements



- After the Earthquake, Concepción has continued moving towards the west (so far about 10 cm)
- This motion goes along with hundreds of aftershocks and will continue for about a year



Observed displacements of GNSS stations in South America

The data are from the SIRGAS network, http://www.sirgas.org

Effects on Earth rotation (I)

- Earthquakes cause mass displacements in the Earth's crust. Thus the inertia tensor of the Earth will change, affecting the Earth rotation
- A very large Earthquake is required to have an effect that can be measured
- There have been no observations detecting a change in Earth rotation due to an Earthquake
- Was the 2010 Chile Earthquake strong enough to cause a detectable change in the rotation of the Earth?

Effects on Earth rotation (II)

- Modelling the change in the inertia tensor as a step function, the change in polar motion (Δp) and LOD (ΔLOD) can be described by:

$$\Delta p = \frac{1.61\,\Delta I}{C-A}\left[\frac{\sigma_{ch}}{\Omega} + \left(\frac{\sigma_{ch}}{\Omega}+1\right)\left(e^{i\sigma_{ch}(t-t_0)}-1\right)\right]$$

$$\Delta LOD = \frac{LOD_0}{C_m}\Delta I_{zz}$$

- ΔI: change in inertia tensor, C and A: principal moments of inertia, σ_{ch}: Chandler wobble frequency, Ω: Earth's rotation frequency, t_0: time of Earthquake, LOD_0: nominal LOD
- The main effects are a change in the Length of Day and in the amplitude of the Chandler Wobble, and a shift of the figure axis of the Earth (i.e. a shift in the polar motion excitation functions). The direct effect on polar motion will be small (about 0.23% of the change in the polar motion excitation functions)

Effects on Earth rotation (III)

- The effect of an Earthquake on Earth rotation can be calculated e.g. using the model by *Dahlen (1971, 1973)*

$$\Delta I_{zz} = M_0 \sum_{i=1}^{3} \Gamma_i(h)\, j_i(\theta, \phi, \alpha, \delta, \lambda)$$

- (expressions for ΔI_{xz} and ΔI_{xz} are similar)
- Requires knowledge of the location (latitude θ, longitude φ), geometry (described by the strike angle α, dip angle δ, and slip angle λ), and moment magnitude of the Earthquake M_0
- Assumptions: spherical symmetric Earth, Earthquake displacement can be described by a step function

Effects on Earth rotation (IV)

- Using the *Dahlen (1971,1973)* model and the parameters from a moment tensor solution for the Chile Earthquake, the effect on the Length of Day (LOD) and polar motion excitation (χ) can be calculated:

	ΔLOD [μs]	$\Delta\chi_x$ [mas]	$\Delta\chi_y$ [mas]	X-pole[1] [μas]	Y-pole[1] [μas]
Global CMT	0.3	-0.1	2.5	-0.2	-5.8
USGS	0.5	-0.4	2.8	-0.9	-6.4

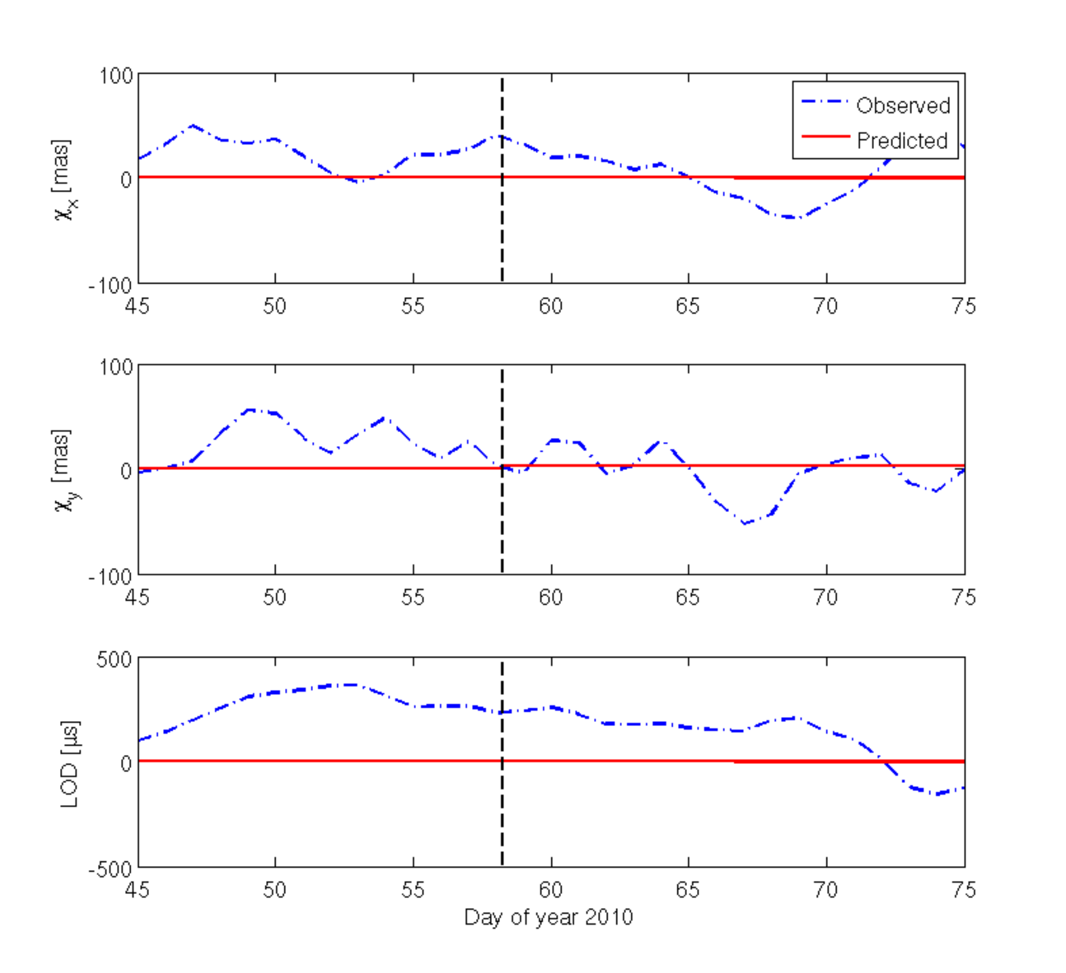
[1]: values are for the instantaneous change in the pole position

Global CMT: http://www.globalcmt.org/
USGS: http://earthquake.usgs.gov/

Can these changes be detected?

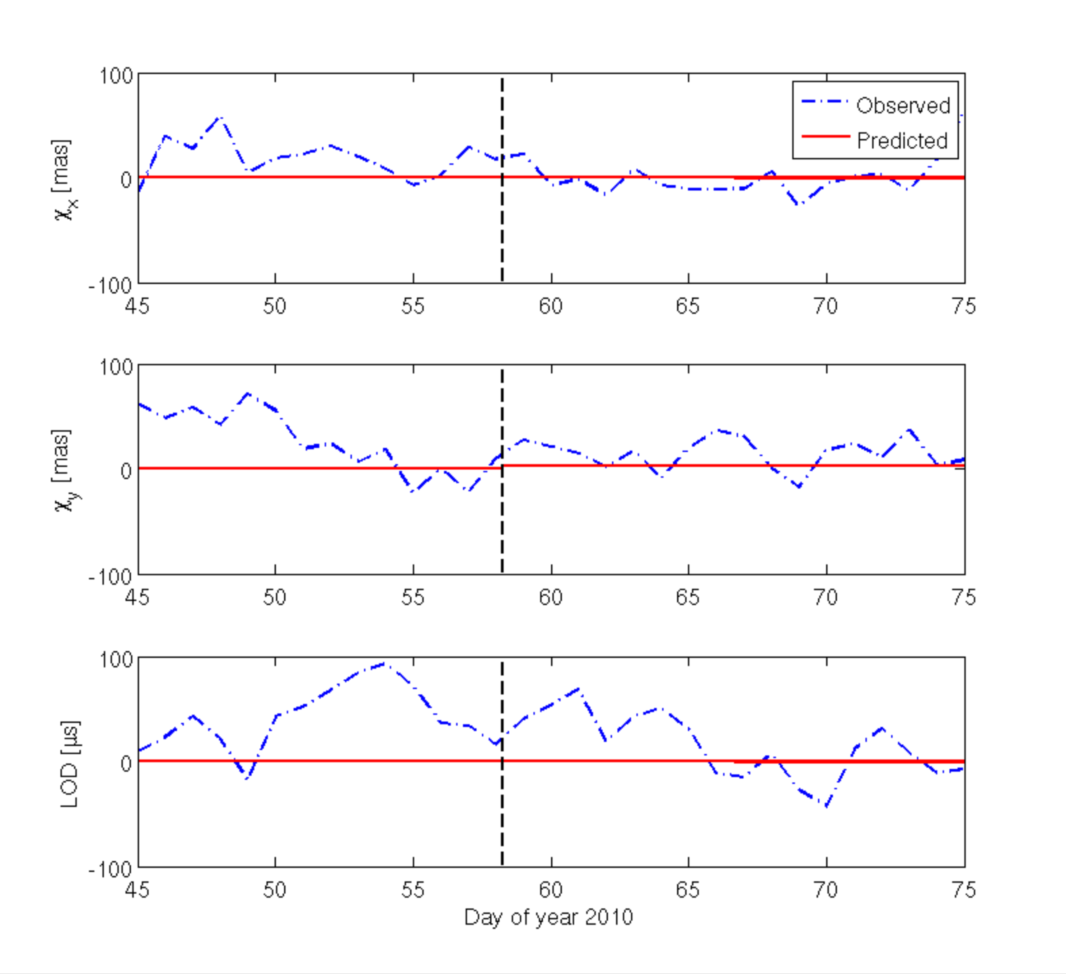
- **Problems:**
  - Predicted changes are smaller or similar to the current measurement accuracies (5-10 µs for LOD, 50-100 µs for polar motion, 5-10 mas for polar motion excitations)
  - Processes in e.g. the atmosphere and the oceans cause variations in the Earth rotation parameters which are much larger than the predicted changes due to the Earthquake. Can we predict these variations with high enough accuracy?

Observed Earth rotation variations (I)



- Polar motion excitation and LOD around the time of the Earthquake (calculated from IERS 05 C04)
- Predicted variations due to Earthquake plotted as comparison (difficult to see due to the scale)

Observed Earth rotation variations (II)



- After removing excitations from atmosphere, oceans and hydrology from the observed time series (obtained from: *Dobslaw et al, JGR, 2010* *ftp.gfz-potsdam.de/home/ig/ops*)
- Still unexplained variations more than a magnitude larger than the predicted effect of the Earthquake

Conclusions

- The 2010 Chile Earthquake displaced the city of Concepción by more than 3 m in the WSW direction. Significant displacements were also observed in many other locations in South America
- The Earthquake has affected Earth rotation. However, the effect is too small to be observed

Thank you for your attention