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Modeling co- and post-seismic deformations in reference frame determination

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Abstract

Current realizations of reference systems, such as the ITRF2008 frame, are based on a piecewise linear model for the time evolution of station coordinates

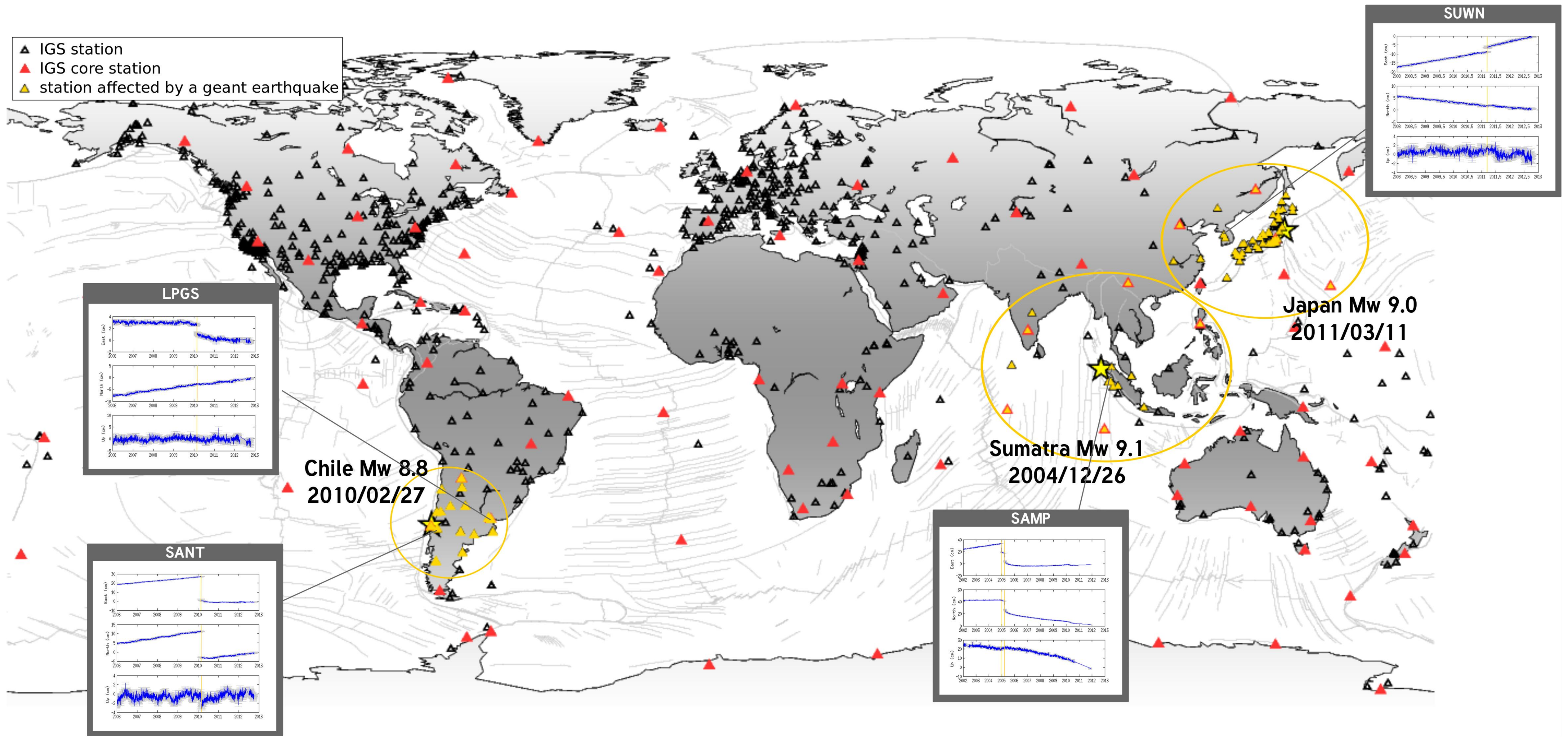
Continuous improvements in the precision of geodetic techniques impose to realize more accurate and stable reference frames

Is the reference frame model today the most adapted?

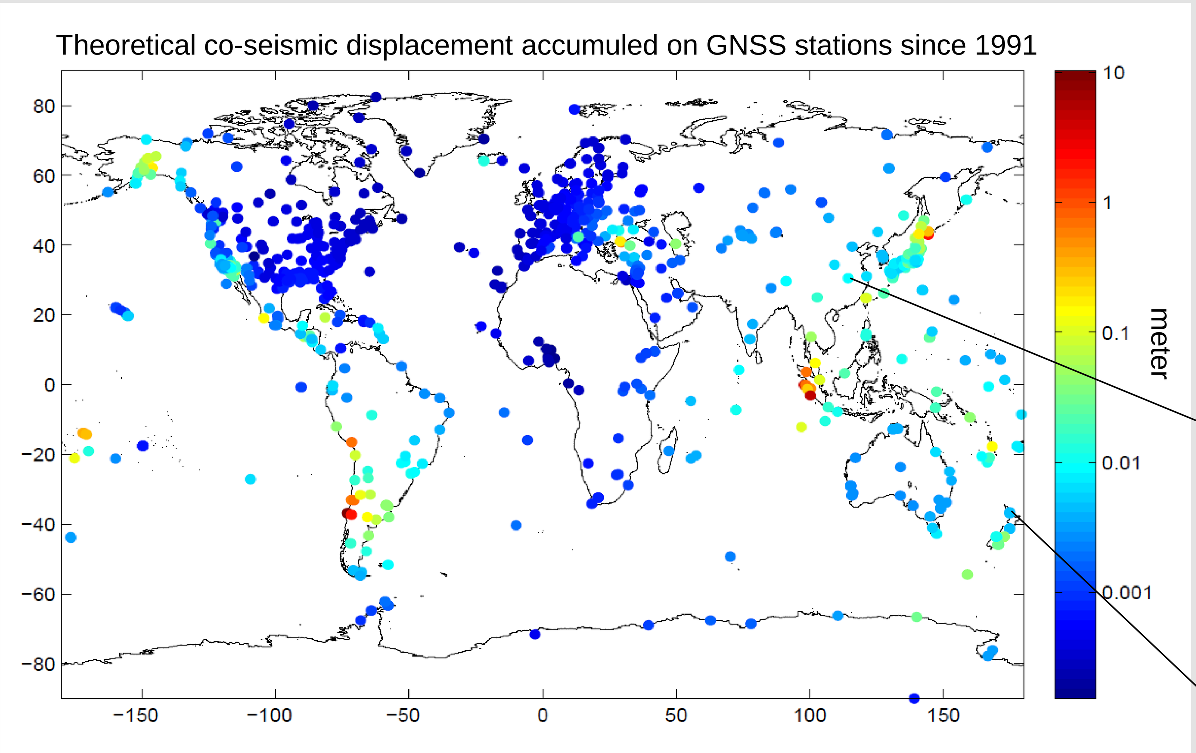
A major source of non-linear motion comes from co- and post-seismic deformations. We investigate here seismic induced non-linear motion using geophysical and post-analysis.

1. **Co-seismic deformation:** **from an empirical to a self-acting geophysical search of discontinuities in station position time series.**

2. **Post-seismic deformation:** **from a linear piecewise to a parametric representation of station coordinates.**



1. Co-seismic deformations



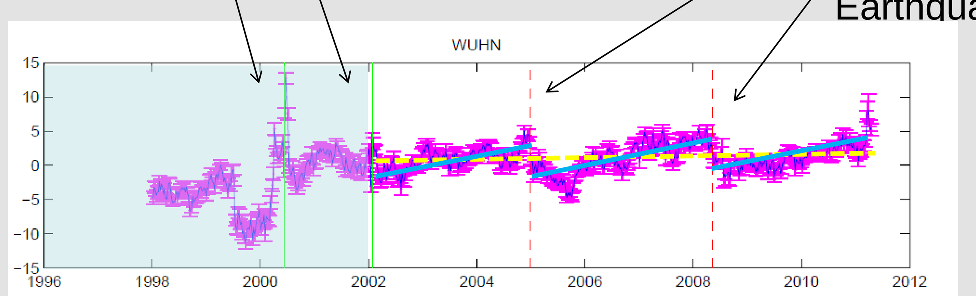
We develop a model that calculates surface co-seismic deformations. The model uses a global database of seismic information and has been applied over a global network of GNSS stations (see figure).

More details on the model:

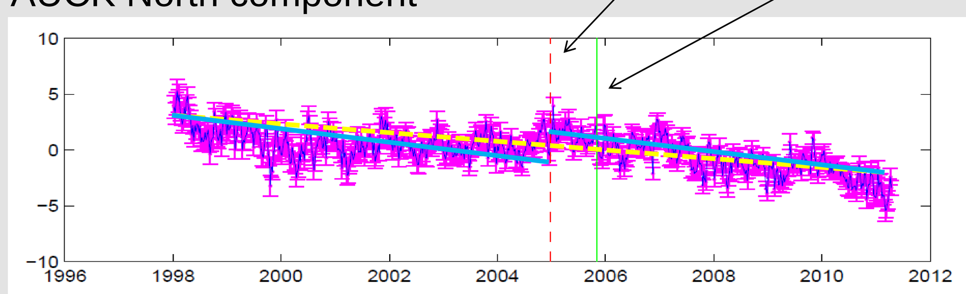
- USGS NEIC moment tensor catalogue:
  40,000 earthquakes with Mw > 5 from 1977 to 2010
- Earthquake source parameter scaling:
  Tests of statistical models (e.g. Wells & Coppersmith, 1994)
- Co-seismic displacement modeling using Okada approach (Okada, 1984).

Search of seismic discontinuities in time series: discontinuities in GNSS time series due to giant Earthquakes are usually detected visually. Based on our geophysical modeling, we develop a method to detect the impact of unexpected co-seismic deformations in GNSS time series. For example:

Case of giant earthquakes in the far-field



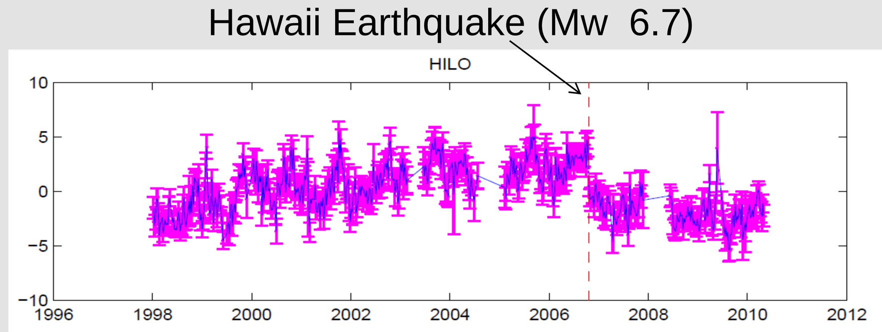
Station velocity change: + 1.4 mm/yr WUHN East component



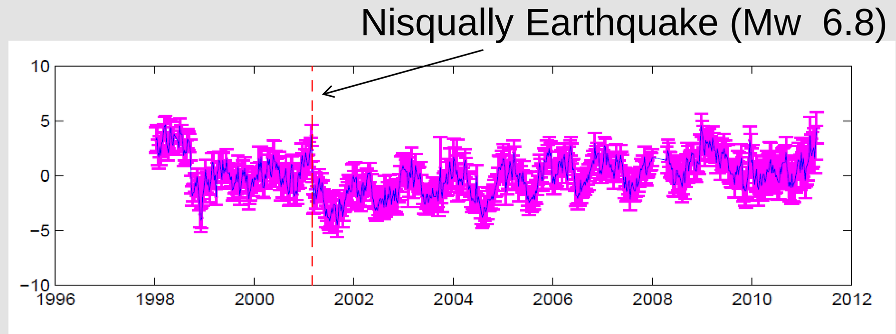
AUCK North component

Station velocity change: - 0.2 mm/yr

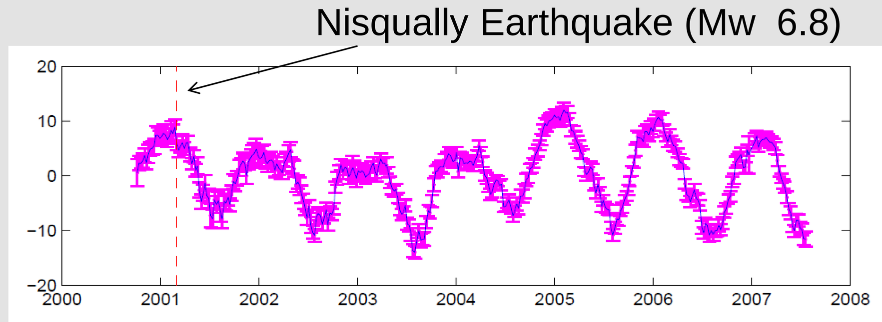
Case of smaller earthquakes in the near-field



HILO East component



SEAT North component



DWH1 North component

New discontinuity based on the co-seismic modeling

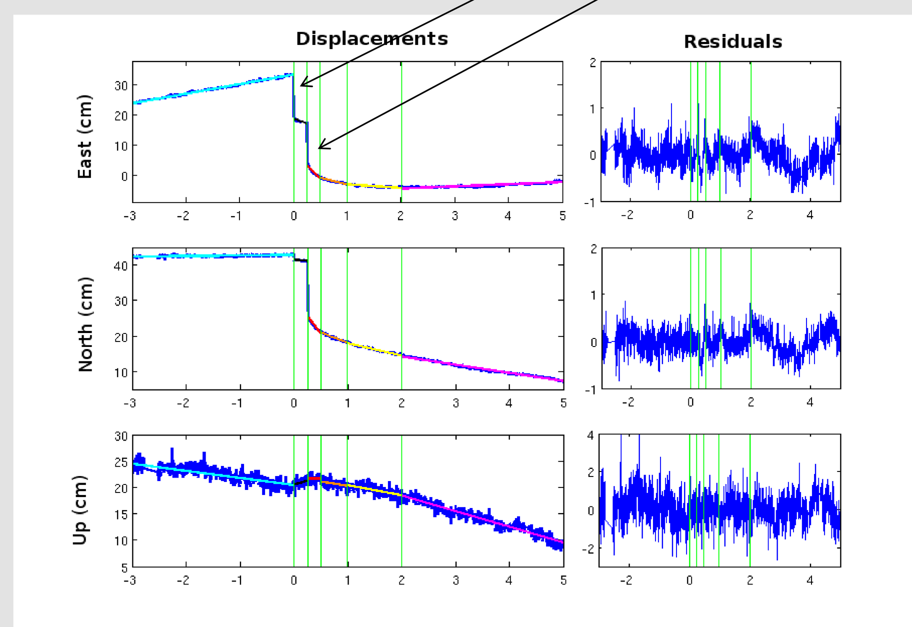
2. Post-seismic deformations

According to the IERS Conventions (2010), instantaneous coordinates can be obtained by adding corrections to the ITRF coordinates $\vec{X}_R(t)$:

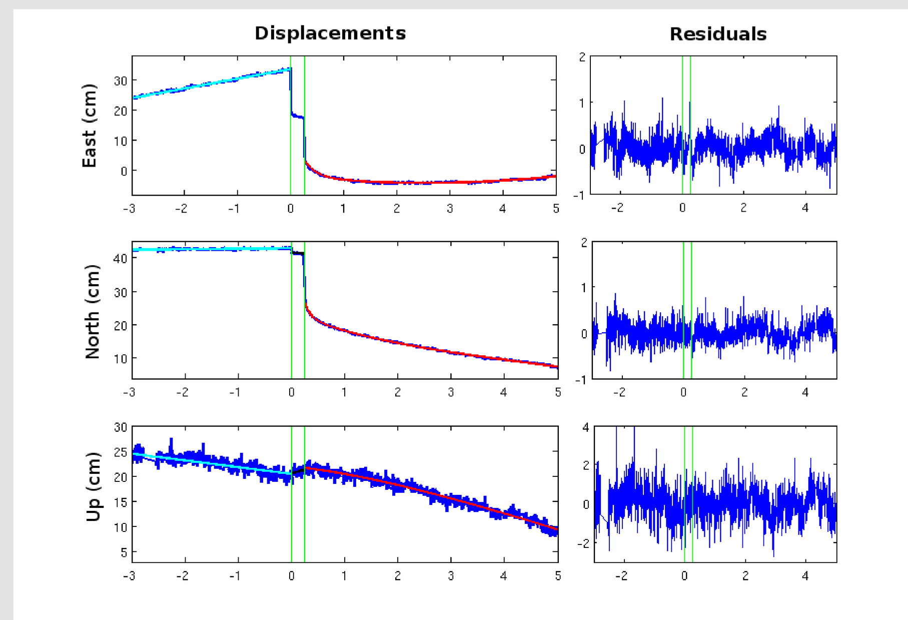
$$\vec{X}(t) = \vec{X}_R(t) + \sum_i \Delta\vec{X}_i(t).$$

Displacements related to earthquakes can be either applied as conventional corrections $\Delta\vec{X}_i(t)$ or included in ITRF coordinates. In this case, parametric models for post-seismic displacements should be used.

SAMP station example:

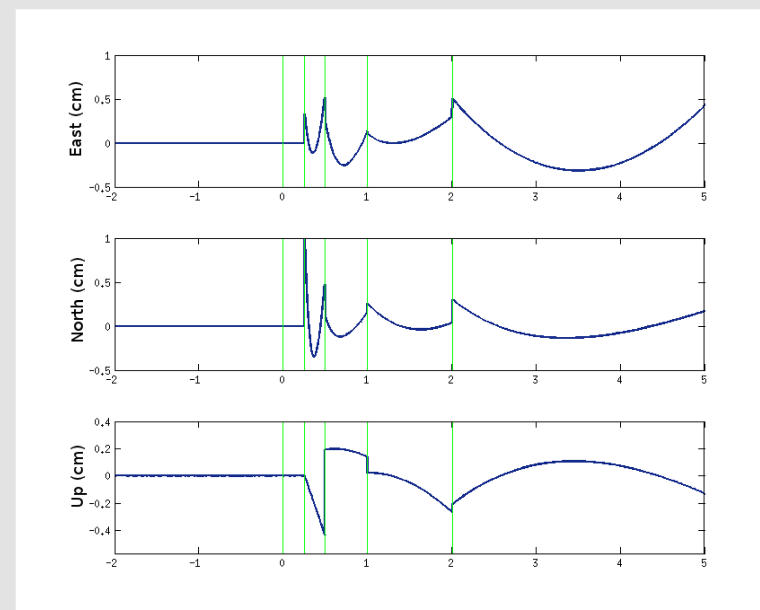


Piecewise linear modeling of the station coordinates and residuals with respect to observations



Parametric modeling of the station coordinates and residuals with respect to observations

Differences between the linear piecewise and the paramteric modeling approaches for SAMP station.



Differences between the classical and parametric approaches may reach 1 cm.

Aknowledgement: GPS position time series used in section 1 were computed from IGS combined SINEX files (Rebishchung et al., 2011). Residual position time series used in section 2 were downloaded from NASA/JPL web site (Heflin et al., 2012). we used a Okada code developed by F. Beauducel.

Heflin, M., A. Moore, S. Owen, Desai, S. D., W. Bertiger, J. Gross, B. Haines, N. Harvey, C. Selle, A. Sibthorpe & J. P. Weiss (2012). GPS position time series web site http://sideshow.jpl.nasa.gov/post/series.html

IERS Conventions (2010). Gérard Petit and Brian Luzum (eds.), (IERS Technical Note ; 36) Frankfurt am Main: Verlag des Bundesamts für Kartographie und Geodäsie, 2010. 179 pp., ISBN 3-89888-989-6

Okada Y. (1985). Surface deformation due to shear and tensile faults in a half-space, Bull. Seismol. Soc. Am., 75:4, 1135-1154.

Rebischung, P., B. Garayt, X. Collilieux & Z. Altamimi (2012). *IGS Reference Frame Working Group Coordinator Report 2011* , IGS Technical Reports 2011, Astronomical Institute of the University of Bern.

Wells, D. L., & K. J. Coppersmith (1994). New Empirical Relationships among Magnitude, Rupture Length, Rupture Width, Rupture Area, and Surface Displacement, Bull. Seis. Soc. Am., 84(4), 974-1002.