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# Status and new perspectives of the SIRGAS Reference Frame


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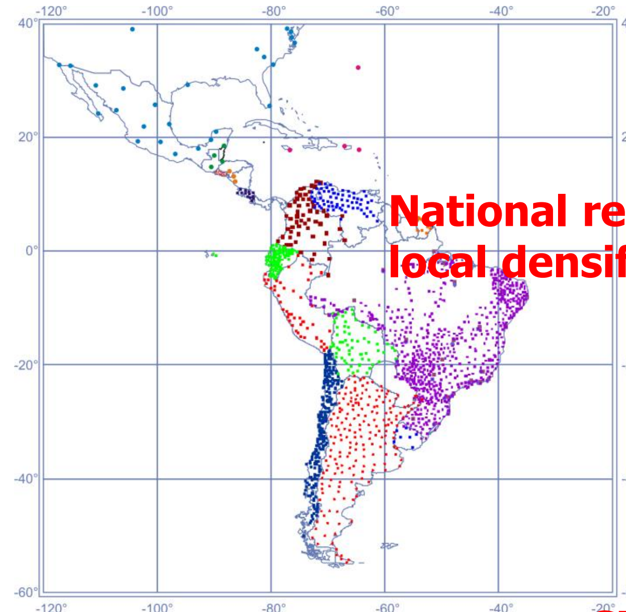
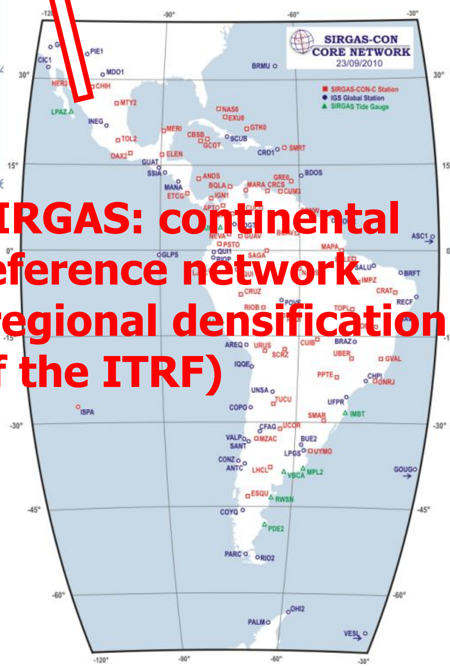
# SIRGAS realization

The realization of SIRGAS is a densification of the ITRF

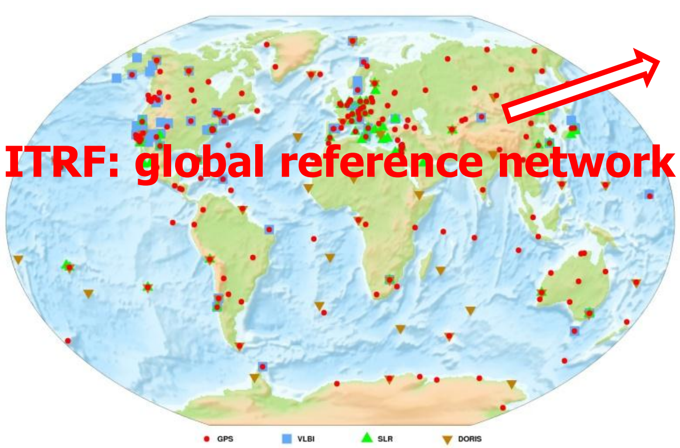
- to guarantee consistency between terrestrial reference stations and GNSS satellite orbits (provided by the IGS);
- to make the global reference frame available at national and local levels.



**National reference networks: local densifications of SIRGAS**




**SIRGAS: continental reference network (regional densification of the ITRF)**




**ITRF: global reference network**

# SIRGAS Reference Frame

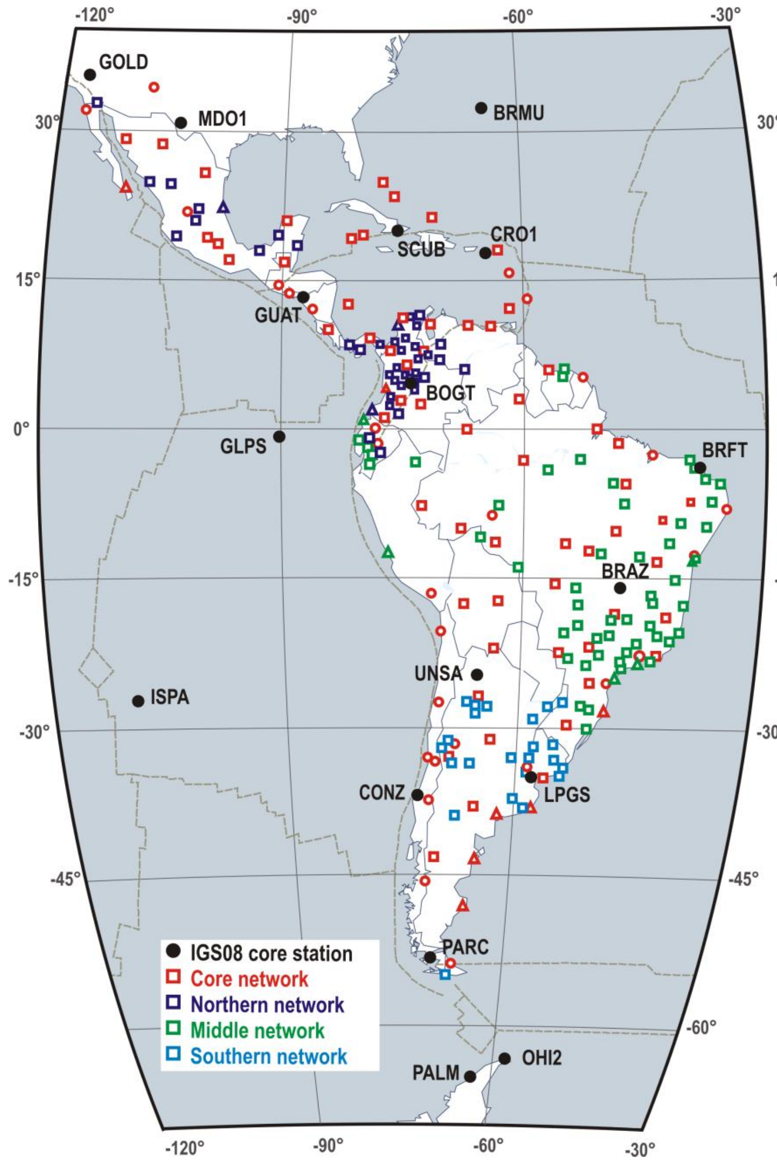
- 242 stations, 48 of them are IGS (i.e. ITRF) sites;
- Distribution of the stations in hierarchic networks (one core network and many densification sub-networks);
- 9 processing centres;
- 2 combination centres;
- each station processed by 3 analysis centres.

Alignment to the global reference frame in two ways:

1. Multi-year solutions wrt ITRF station positions and velocities:

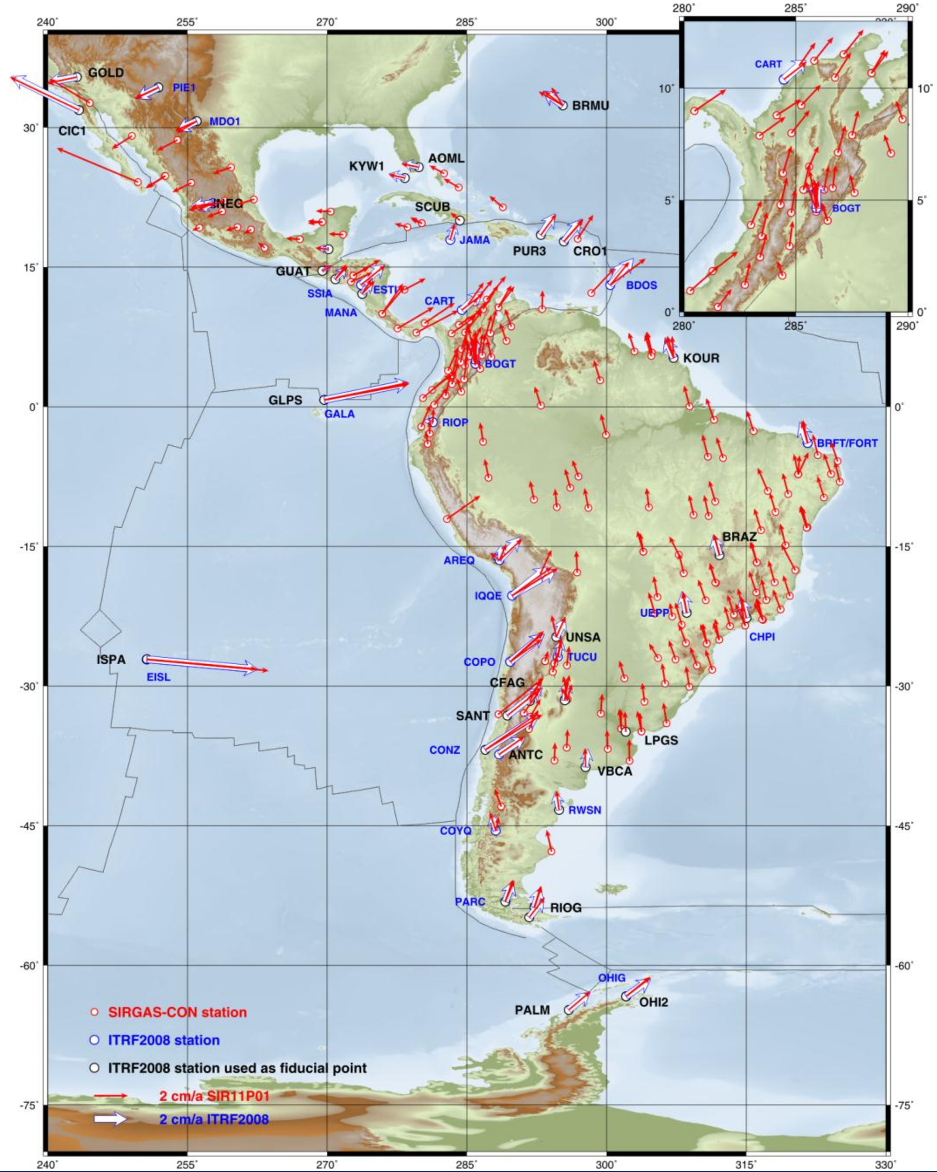
$$X(t_o) = X(t_i) - Vx(t_i - t_0)$$

2. Weekly station positions wrt IGS weekly solutions.



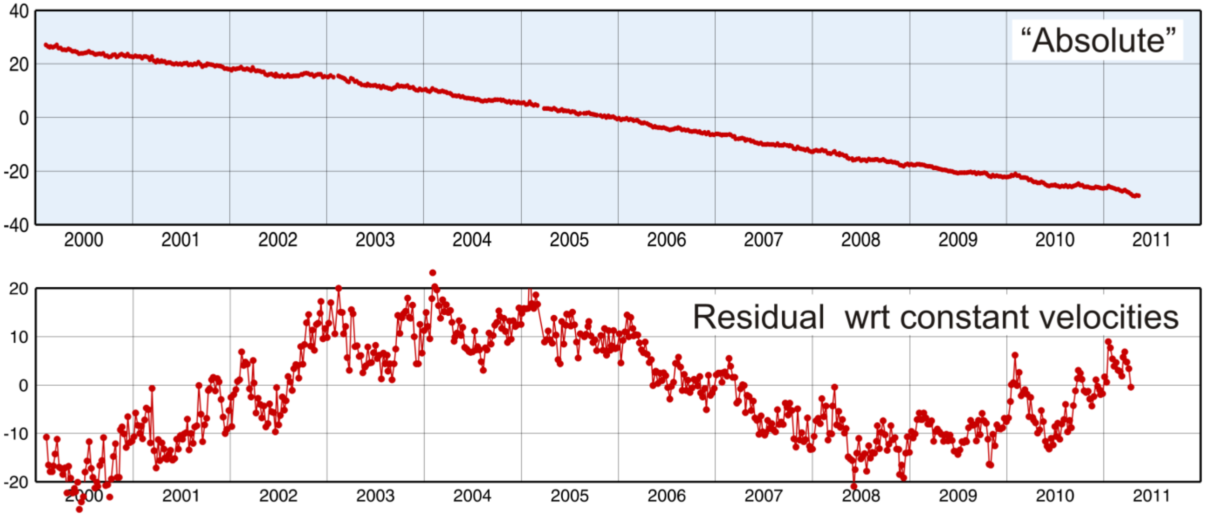
# Latest multi-year solution: SIR11P01

- Absolute corrections for PCV
- Satellite orbits and EOPs wrt IGS05
- Minimum constrained solution (NNR+NNT conditions wrt ITRF)
- Time period:
  02-01-2000 – 16-04-2011;
- Stations:
  229 (296 occupations);
- Reference frame:
  ITF2008, epoch 2005.0;
- Precision of positions at reference epoch:
  ± 0,5 mm (hor), ± 0,9 mm (up);
- Precision of velocities:
  ± 0,4 mm/a

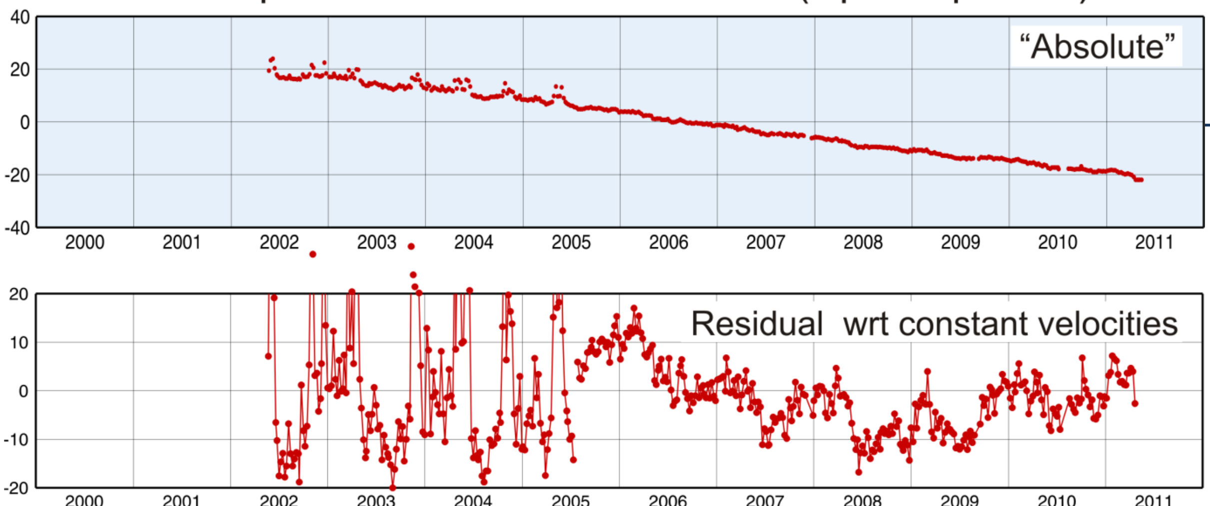


# Problem 1: Constant velocities are highly dependent on the considered time period

Station position time series of BOGA (Up component)




Station position time series of BOGT (Up component)




Estimates for vertical velocity of BOGA:

Feb 2000 to Jun 2004
-0,0419 ± 0,0001 m/y

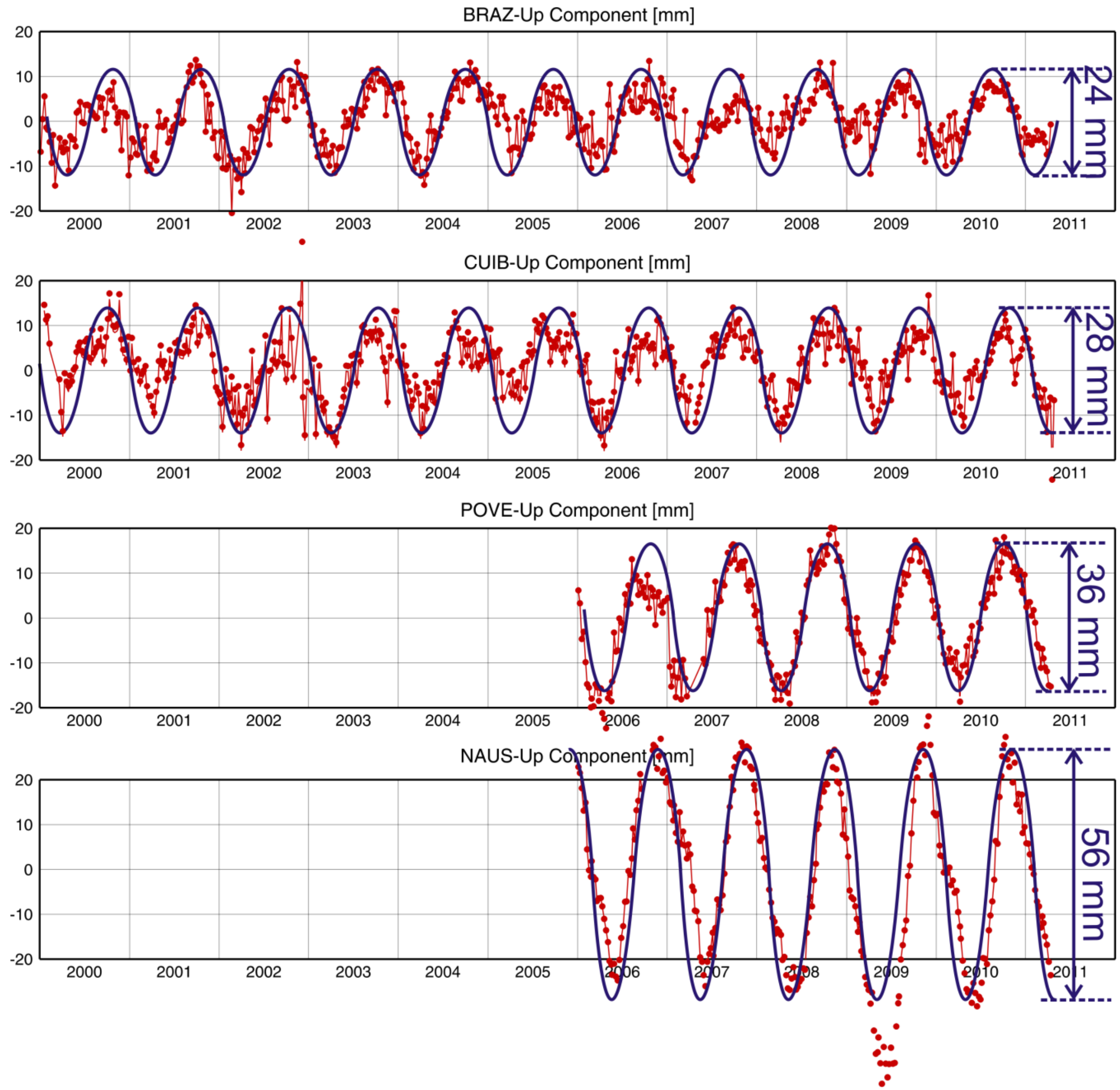
Jun 2004 to Dec 2008
-0,0612 ± 0,0002 m/y

Feb 2000 to Apr 2011
-0,0503 ± 0,0001 m/y

→ **Requirement 1: Longer time series to increase the reliability of position variation estimates.**

# Problem 2: omission of seasonal position variations

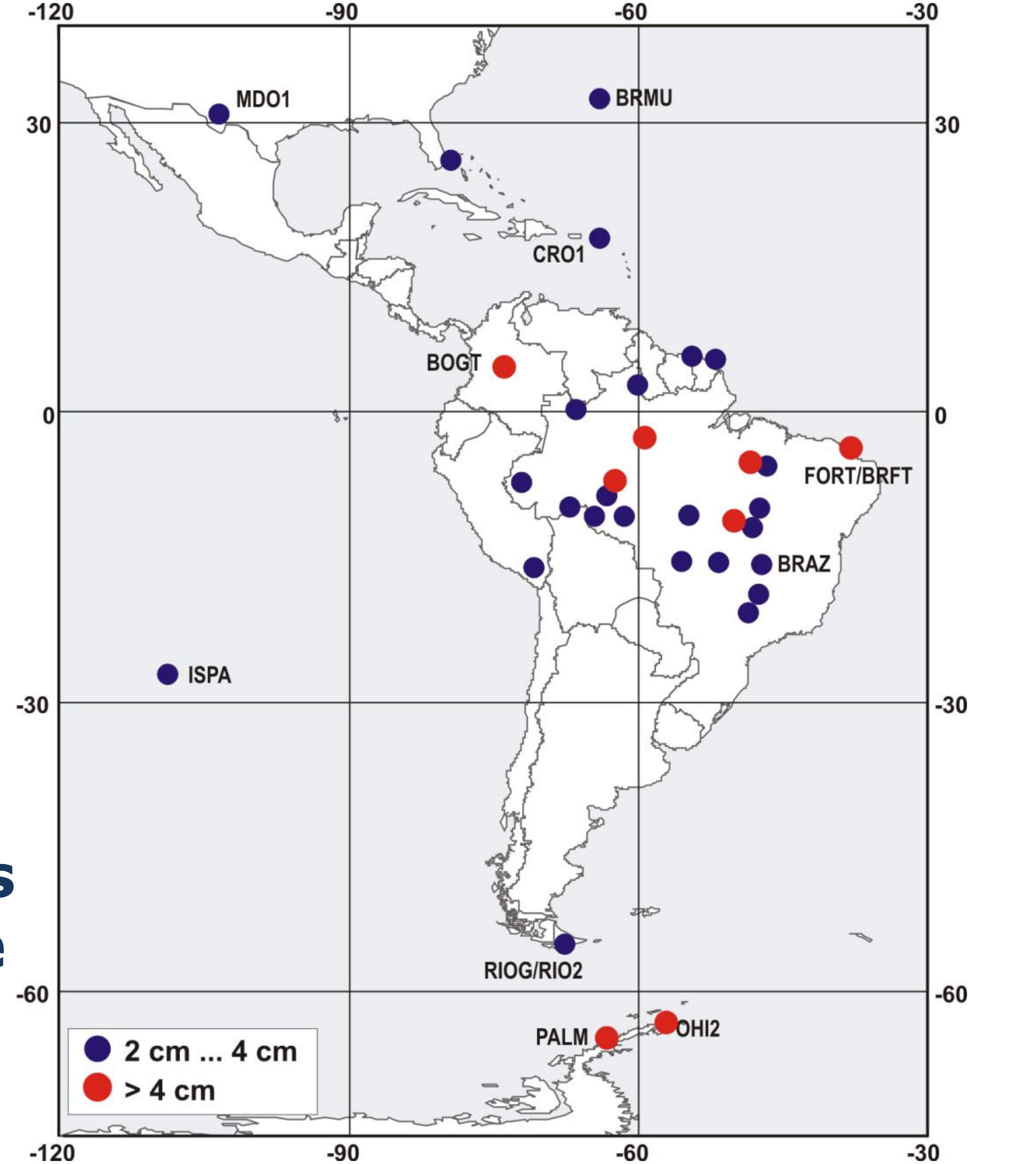
Most of the SIRGAS-CON stations present significant seasonal position variations (mainly in the Up component). These variations are ignored when constant velocities (linear position changes) are computed.



# Amplitude (cm) of seasonal variations in the height component of the SIRGAS-CON stations

SIRGAS stations with seasonal movements with amplitude larger than 2 cm

→ **<u>Requirement 2</u>: analysis and modelling of seasonal station positions variations within the reference frame computation.**



# Problem 3a: deformation of the reference frame due to seismic events

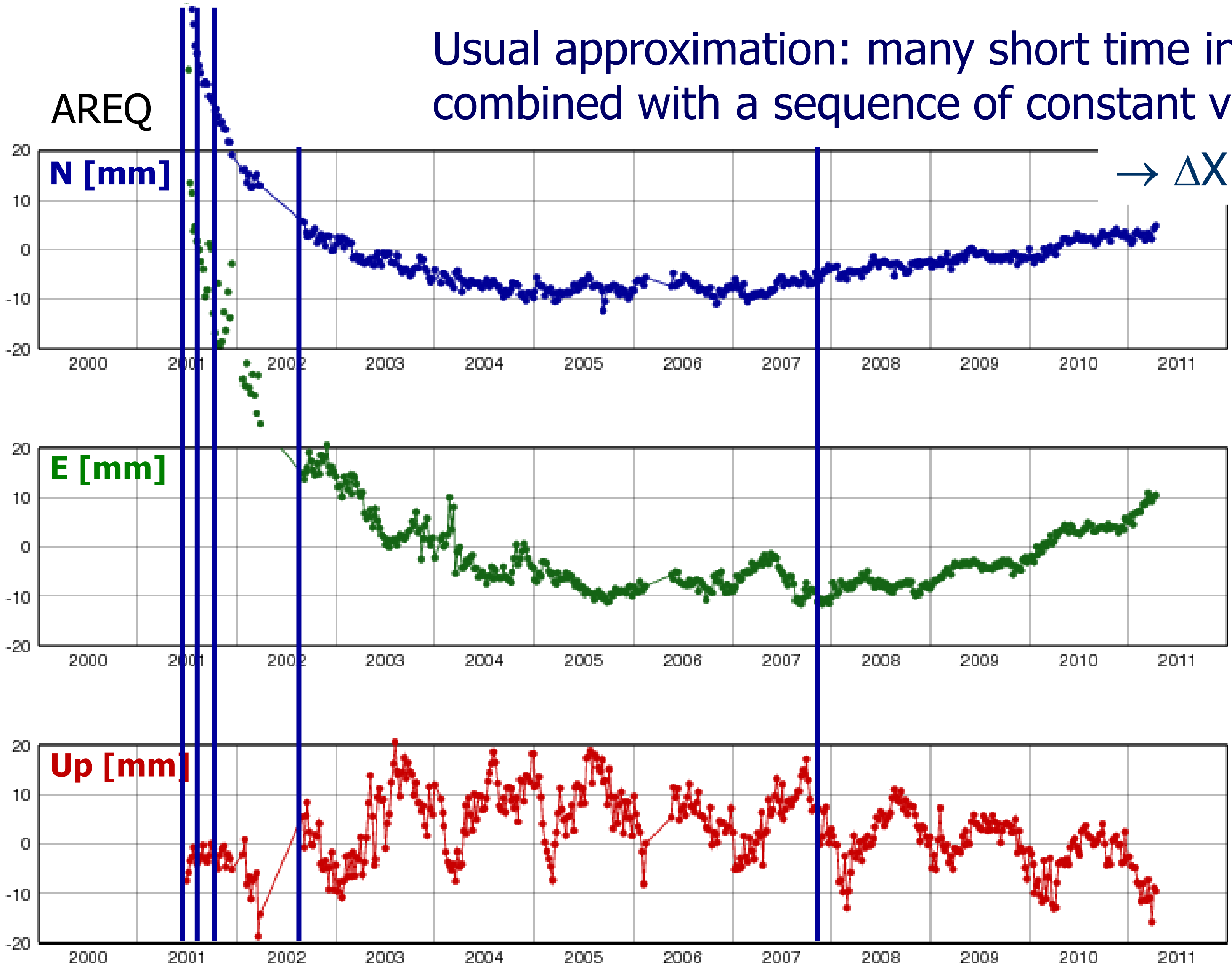
SIRGAS stations strongly affected by earthquakes since 2001

| Location | Date | Mw | Coordinate change | Affected stations |
|---|---|---|---|---|
| Concepción, Chile | 2011-02-12 | 6,1 | 2 cm | CONZ |
| Mexicali, Mexico | 2010-04-04 | 7,2 | 23 cm | MEXI |
| Chile | 2010-02-27 | 8,8 | 1 to 305 cm | 23 stations |
| Costa Rica | 2008-01-08 | 6,1 | 2 cm | ETCG |
| Martinique | 2007-11-29 | 7,4 | 1 cm | BDOS, GTK0 |
| Copiapo, Chile | 2006-04-30 | 5,3 | 2 cm | COPO |
| Tarapaca, Chile | 2005-06-13 | 7,9 | 6 cm | IQQE |
| Managua, Nicaragua | 2004-10-09 | 6,9 | 1 cm | MANA |
| Arequipa, Peru | 2001-06-23 | 8,4 | 52 cm | AREQ |
| El Salvador | 2001-02-13 | 7,8 | 4 cm | SSIA |

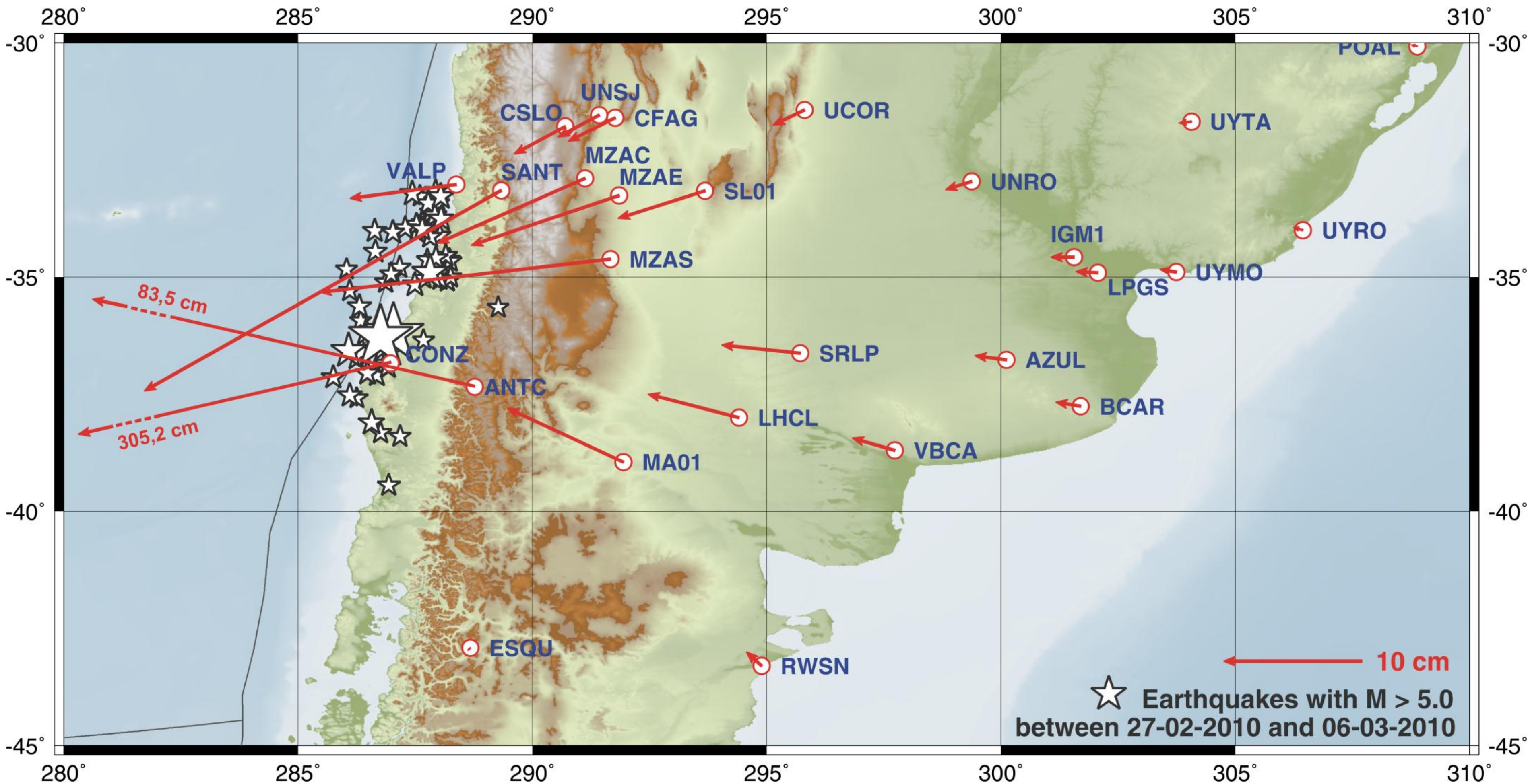
# Problem 3b: not only co-seismic jumps, but also changes in the “normal” movement

Usual approximation: many short time intervals $\Delta t_i$ combined with a sequence of constant velocities $V_i$

$$\rightarrow \Delta X = \Sigma(V_i * \Delta t_i)$$



# Co-seismic displacements caused by the event of 2010-02-03



# Comparison of pre-seismic and post-seismic (constant) velocities (the first year after)

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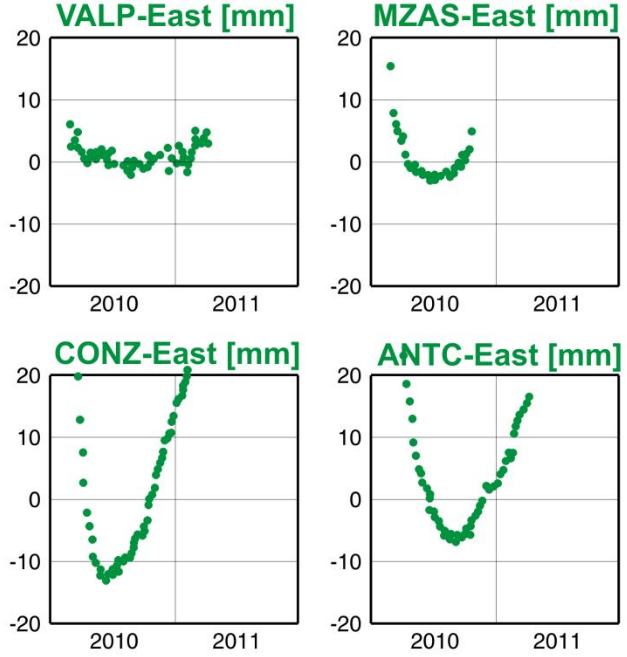
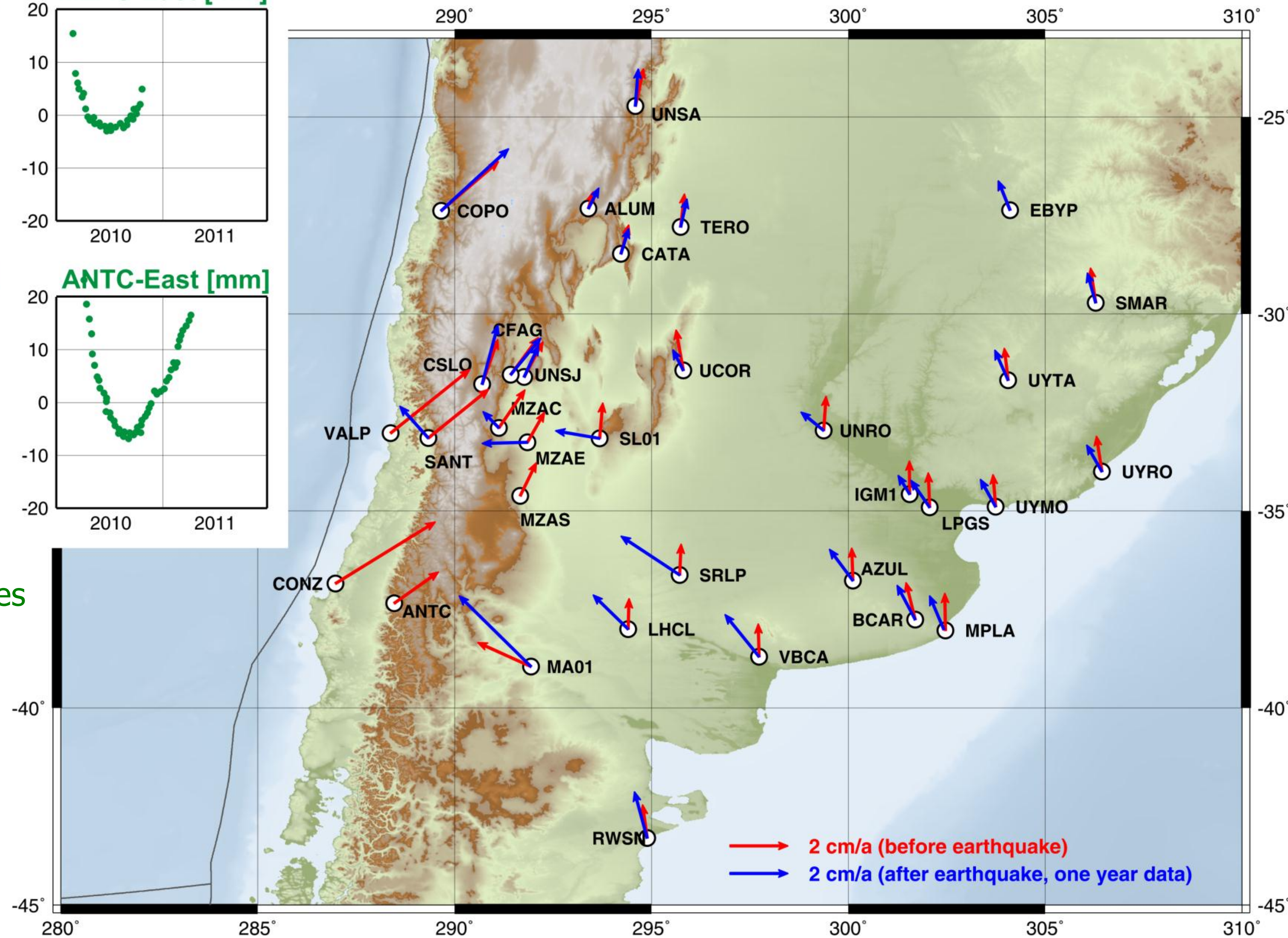



Residual time series wrt constant velocities (East component)



# Drawback of $\Delta X = \Sigma(V_i * \Delta t_i)$

1. The national reference frames contain a high percentage of non-continuously operating stations and the sequence of velocities after an earthquake cannot be reliably determined;
2. The SIRGAS Reference Frame is composed by almost 250 continuously operating stations; nevertheless, their geographical distribution does not provide the required density (coverage) to interpolate (model) the effects of the seismic events with high accuracy for other stations.

# Further shortcomings by the integration of SIRGAS into the ITRF

SIRGAS shall be a densification of the ITRF, but

1. in practice weekly solutions refer to the IGS Reference Frame (i.e. IGS05, IGS08);
2. discontinuities in the time series of IGS stations are different within the ITRF and the SIRGAS solutions;
3. seismic deformations in the SIRGAS region make the existing ITRF solutions unusable and ITRF updates (re-computations) take too long;
4. the change from IGS05 to IGS08 does not allow to compute new multi-year solutions without a reprocessing of the entire observations using the IGS08 (satellite orbits, EOPs, PCVs).

# Recommendations and coming activities

1. Improvement of the national reference frames by installing more continuously operating GNSS stations;
2. The transformation between the pre-seismic and the post-seismic frame realizations must be based on a deformation model derived from discrete (weekly) station positions. Usual network transformations (similarity or affine) cannot be applied;
3. The reference frame definition must include, together with the usual linear terms, seasonal variations to improve the modelling of the reference site motions and to make it more reliable;
4. In the mean time, SIRGAS weekly solutions are aligned to the IGS Reference Frame by constraints to the IGS weekly coordinates. In the same way, in precise positioning, users have to apply epoch (weekly or monthly) positions as reference coordinates instead of those derived from a reference epoch and (a sequence of) velocities.