Kinematics of the SIRGAS Reference Frame

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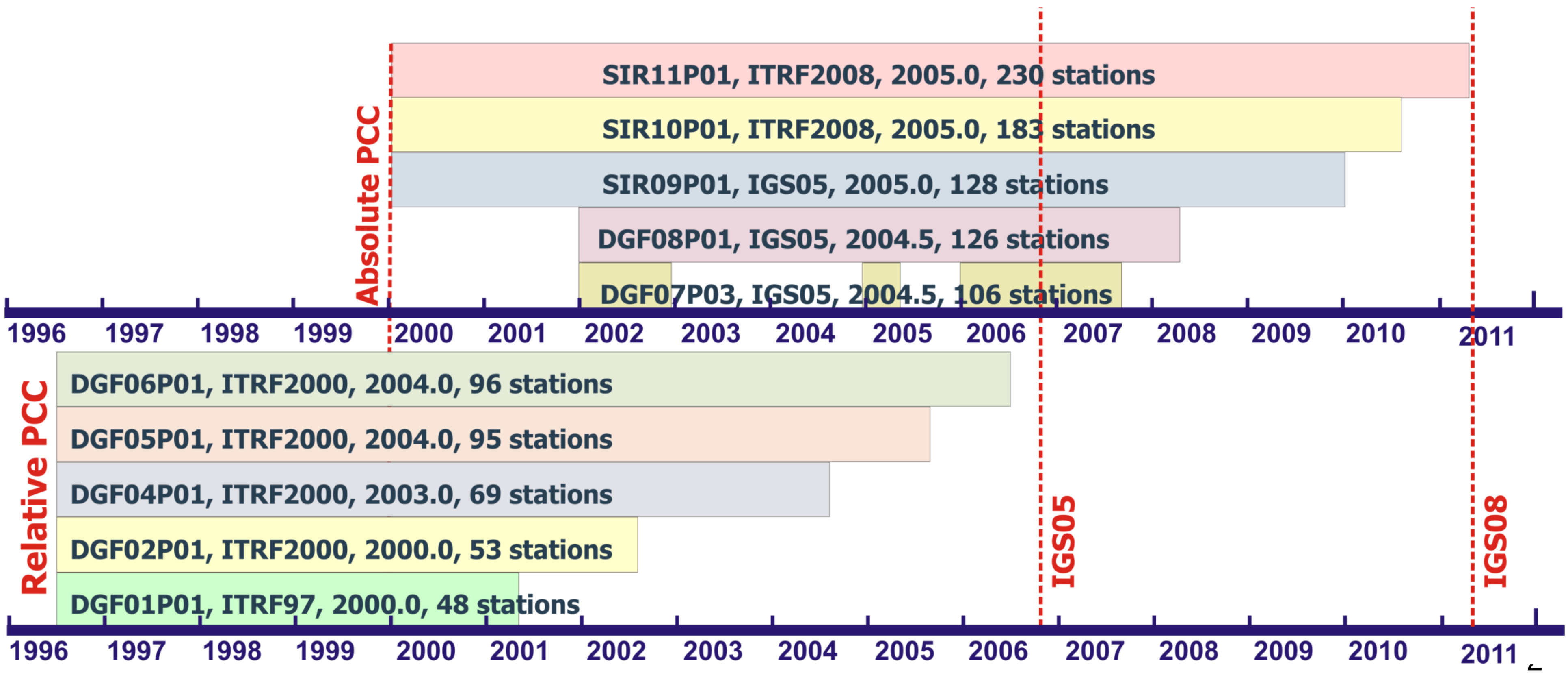
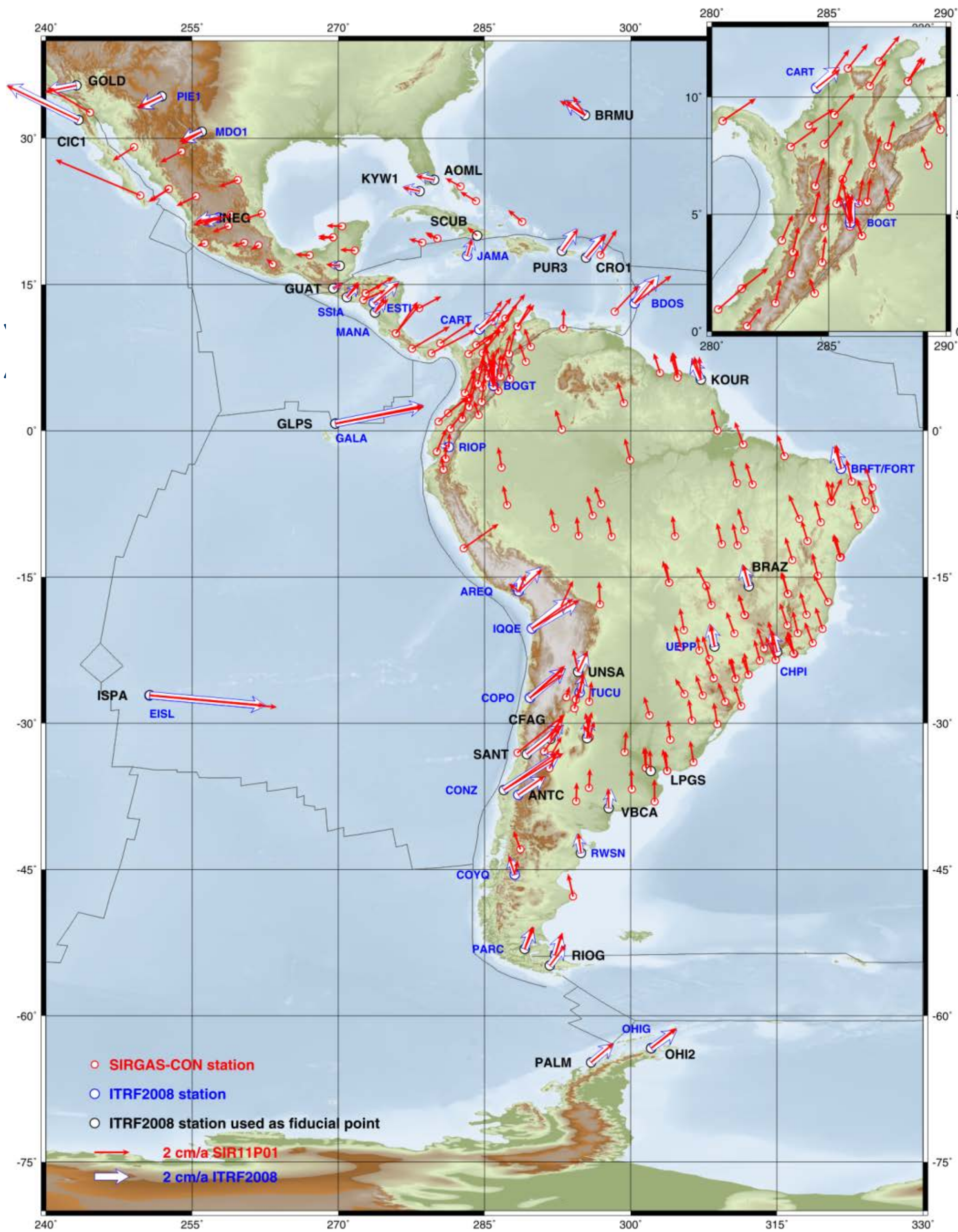
SIRGAS multi-year solutions

- DGFI as the IGS RNAAC SIR, yearly computes a cumulative solution containing all available weekly solutions delivered by the SIRGAS analysis centres to estimate the kinematics of the network and to provide station positions and velocities.
- These cumulative solutions include those models, standards, and strategies widely applied at the time in which they were computed and cover different time spans depending on the availability of the 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

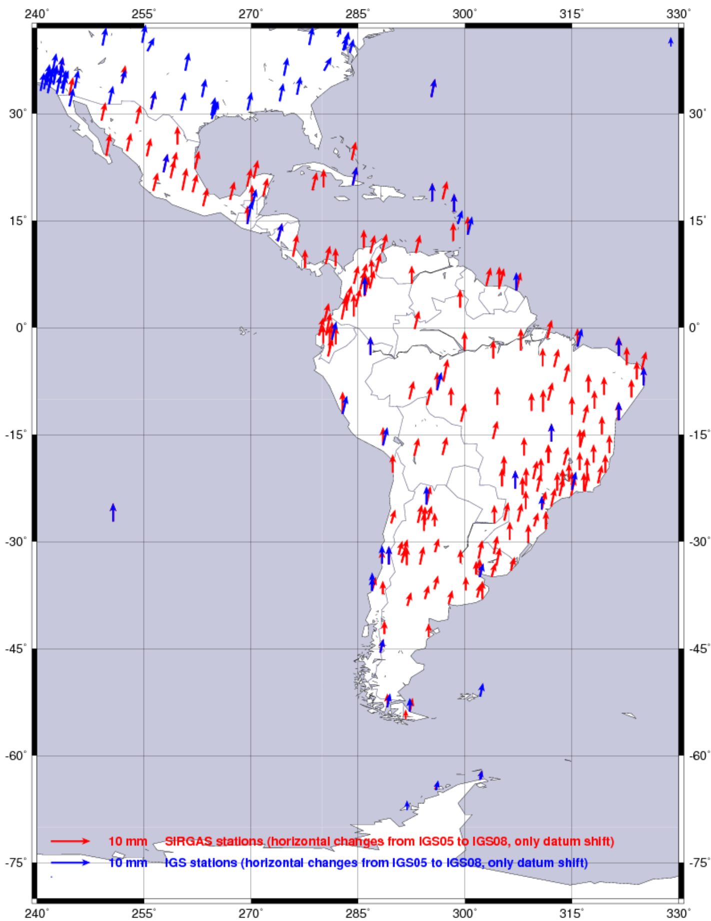


Introduction of the ITRF2008 as reference frame for the GNSS orbit computation

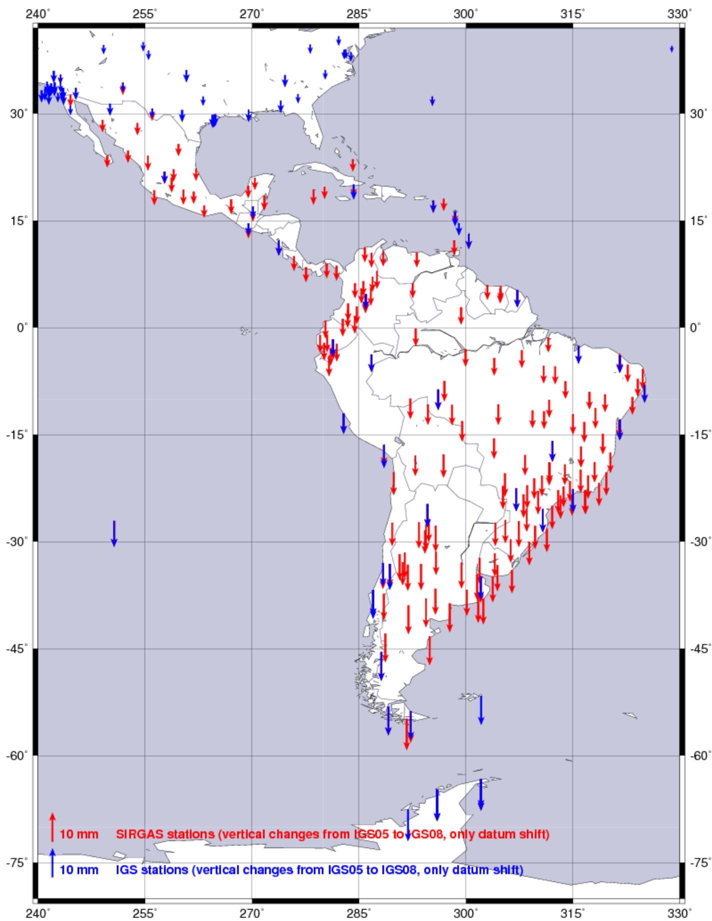
According to the [IGSMAIL-6354], the switch to the ITRF2008 has two main consequences on the station positions:

- Systematic effects due to the ITRF2005 and ITRF2008 datum changes;
- Station-dependent effects due to antenna calibration updates.

Horizontal



Vertical



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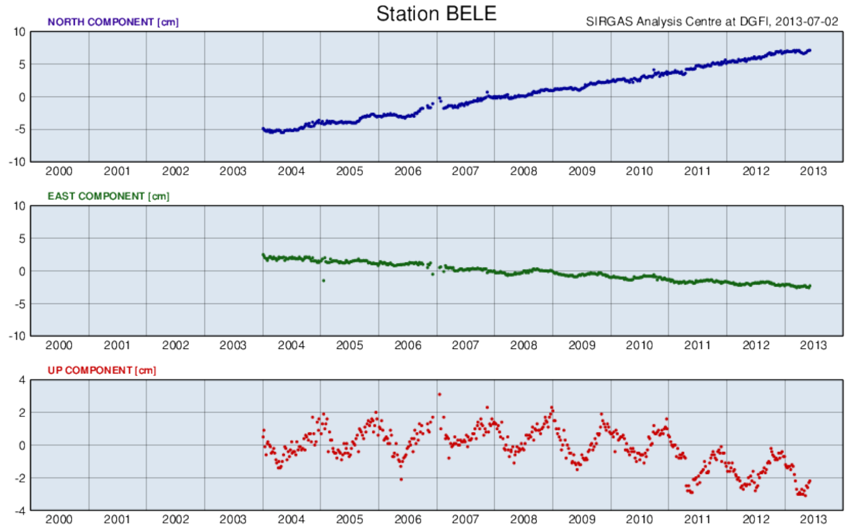
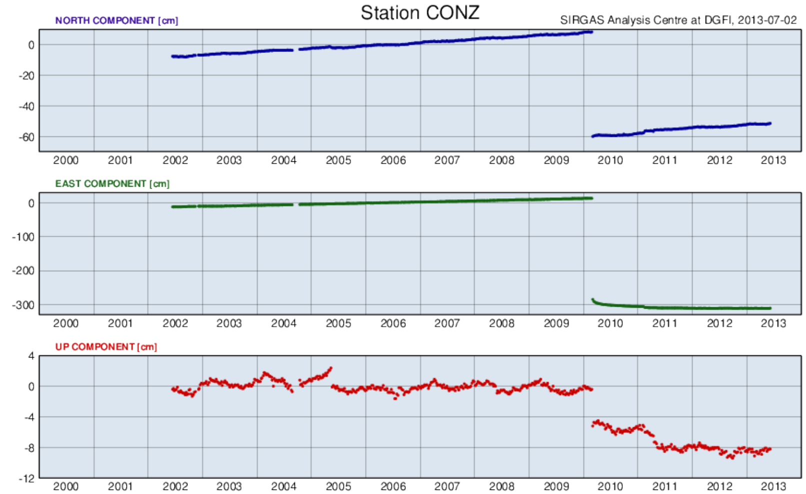
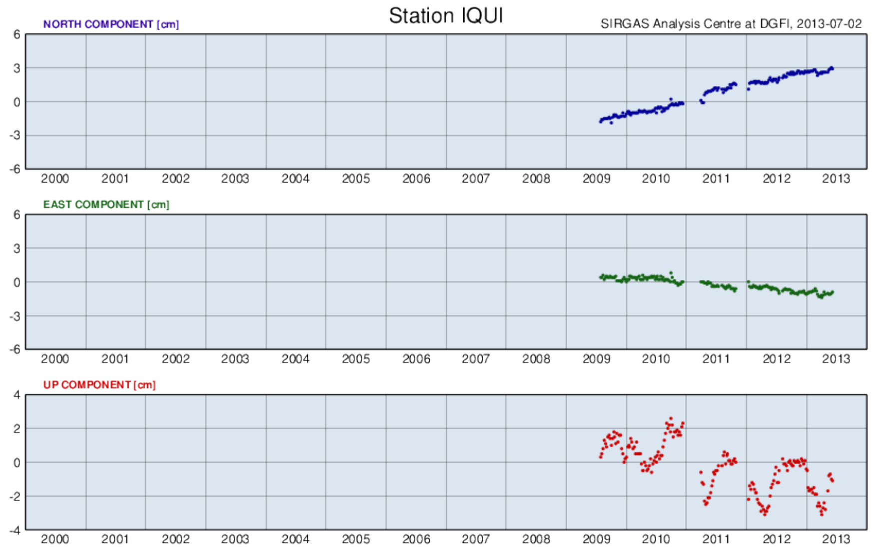
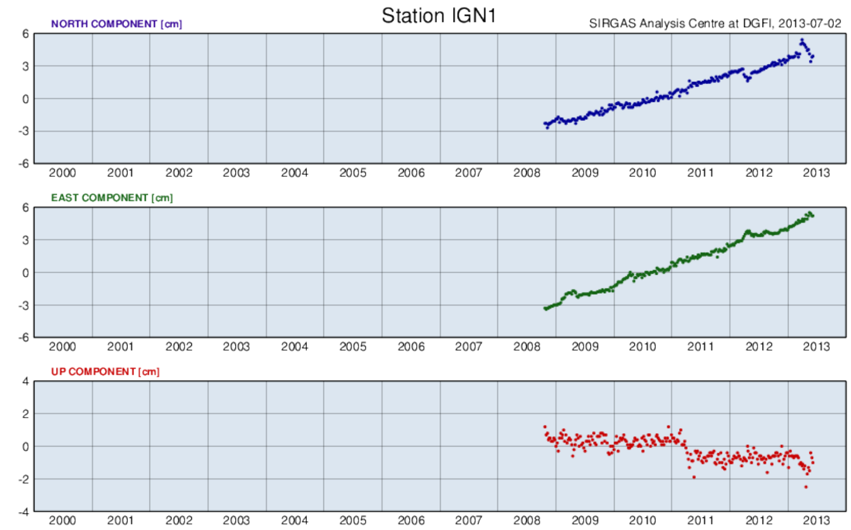
Introduction of the ITRF2008 as reference frame for the GNSS orbit computation









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New processing standards and conventions outlined by the IERS
(International Earth Rotation and Terrestrial Reference Systems)

- Detailed description of standards and conventions for GNSS processing: http://acc.igs.org/reprocess2.html
- Most of them are related to the orbit determination and directly integrated into SIRGAS by using the final orbits of the International GNSS Service (IGS)
- The main issues for SIRGAS here are:
  - the use of the ITRF2008 in previous solutions to guarantee the time series consistency;
  - the application of the new model/mapping function for modelling the troposphere effects.
- Previous model (combination of Niell and Saastamoinen):

$$\delta\rho_{trp}(z) = m_{t,d}(z)\delta^{0}_{trp,d} + m_{t,w}(z)\delta^{0}_{trp,w}$$

$$m_t(z) = \frac{1}{\cos z}$$

$$\delta\rho_{trp}(z) = \frac{2277\,x\,10^{-6}}{\cos z}\left(P + \left\{\frac{1255}{T} + 0{,}05\right\}\cdot e - 1{,}16\tan^2 z\right)$$

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New processing standards and conventions outlined by the IERS
(International Earth Rotation and Terrestrial Reference Systems)

- New model: **Vienna Mapping Function**:

$$\delta\rho_{trp}(z) = m_{t,d}(z)\delta^{0}_{trp,d} + m_{t,w}(z)\delta^{0}_{trp,w}$$

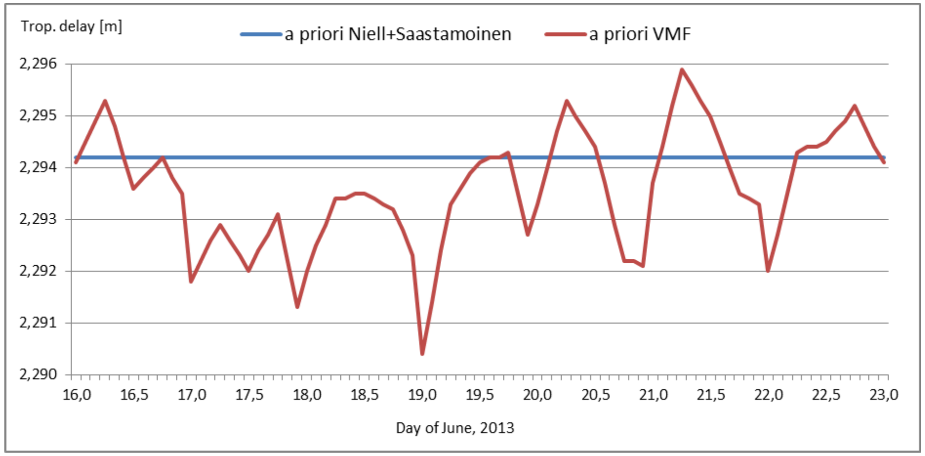
$$m_t(e) = \frac{1 + \dfrac{a}{1 + \dfrac{b}{1+c}}}{\sin e + \dfrac{a}{\sin e + \dfrac{b}{\sin c + c}}} \qquad z = 90° - e$$

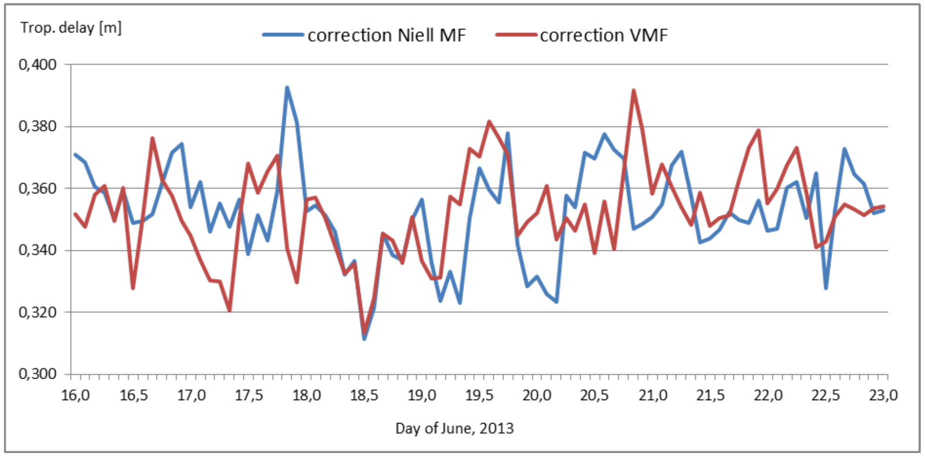
- The coefficients a, b, c are computed from climate numerical models provided by the ECMWF (European Centre for Medium-Range Weather Forecasts).
- The corresponding values are presented in grids of 2,5°x2,5° for each six hours.
- Mean global corrections over a longer time period (40 years) and at a 15°x15° grid are known as **Global Mapping Function**.

New processing standards and conventions outlined by the IERS (International Earth Rotation and Terrestrial Reference Systems)

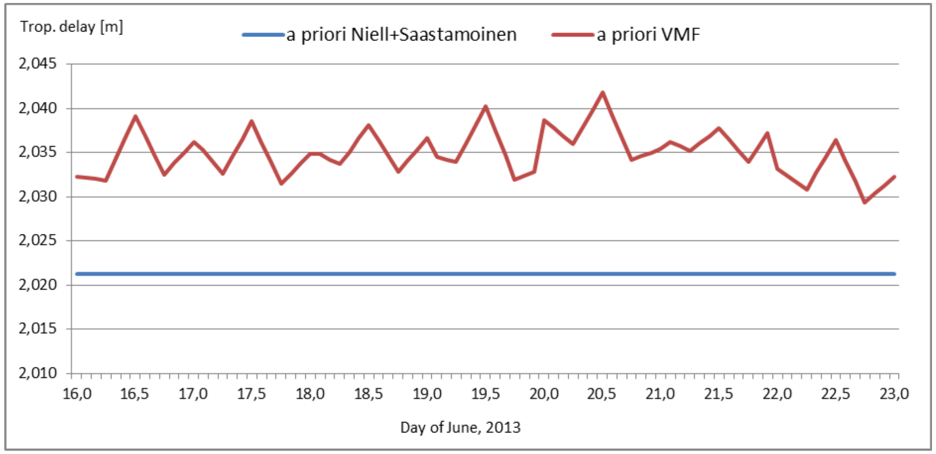
Comparison between previous and new model for the troposphere delay estimation

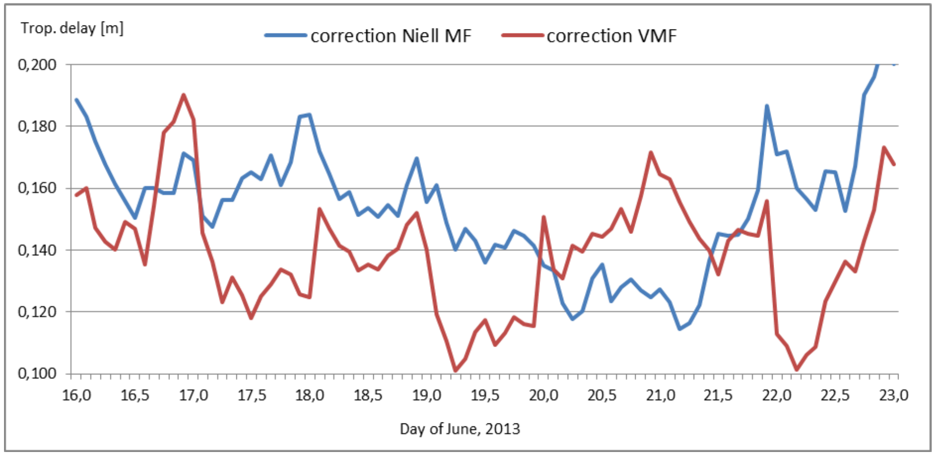
Station IGN1 (Panama City)





Station BRAZ (Brasilia)





Processing strategy for the computation of weekly normal equations

- Basic observable **ionosphere-free linear combination** (L3).
- Sampling rate **30 sec**; Elevation cut-off angle **3 deg**; Elevation-dependent weighting **cos(z)**2 .**
- Satellite orbits, satellite clock offsets, and Earth orientation parameters are fixed to the combined **IGS weekly solutions** (Dow et al. 2009).
- Satellite antenna to centre of mass offsets: **spacecraft-specific z-offsets** and **block-specific x- and y-offsets** from file igs08.atx (Schmid et al., 2007).
- Phase centre variations (PCV) **absolute model for receiver and satellite antennae**, file igs08.atx (Schmid et al., 2007).
- **Phase ambiguities for L1 and L2** are solved by applying the **quasi ionosphere free (QIF) strategy** of the Bernese GNSS Software V.5.2 (Dach et al. 2007).
- Troposphere modelling: the **a-priori zenith delay (dry part) is modelled using the Vienna Mapping Function** (Boehm et al., 2006) and **further atmospheric parameters (wet part) are estimated in a 2-hours interval within the network adjustment using also the Vienna Mapping Function** (Boehm et al., 2006). In addition, **horizontal gradient parameters** are estimated to model azimuthal asymmetries (model described in Chen and Herrring, 1997).

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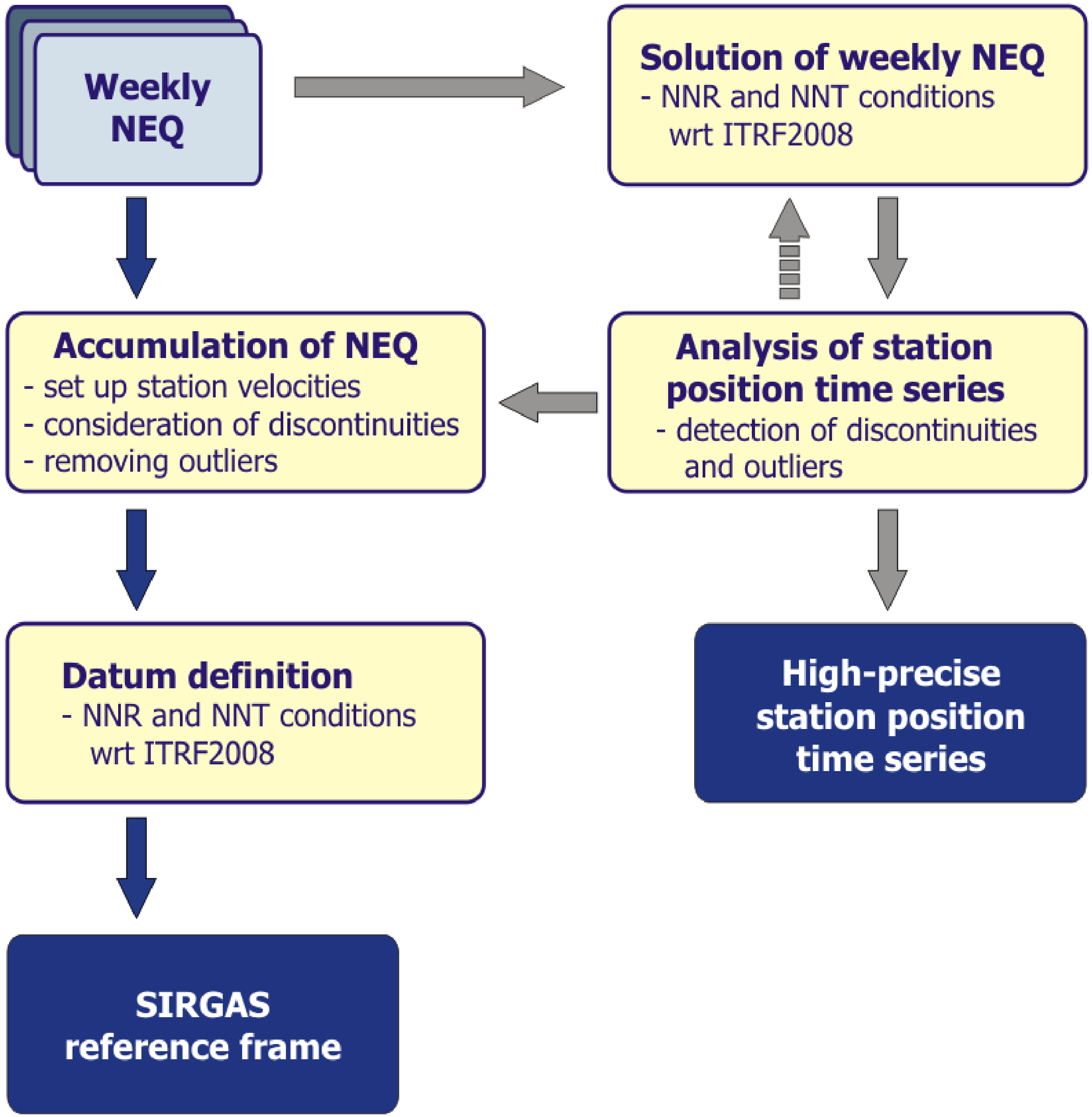
Processing strategy for the computation of weekly normal equations

- **Tidal corrections for solid Earth tide,** permanent tide and solid Earth pole tide as described in Petit and Luzum (2010). **Ocean tide loading** reduced with the FES2004 model (Letellier, 2004) and **atmospheric tide loading for S1 and S2** reduced with the model of Van Dam and Ray (2010).
- **Non-tidal loadings** as atmospheric pressure, ocean bottom pressure, or surface hydrology **are not reduced**.
- Daily free normal equations are computed by applying the double difference strategy (Bernese GNSS Software 5.2, Dach et al. 2007). The baselines are created taking into account the maximum number of common observations for the associated stations.
- **Daily free normal equations are combined for computing a loosely constrained weekly solution for station positions** (all station coordinates are loosely constrained to +/-1 m).
- Stations with **large residuals** in the weekly combination (**more than +/-20 mm in the N-E component, and more than +/-30 mm in the height component**) are reduced from the normal equations.

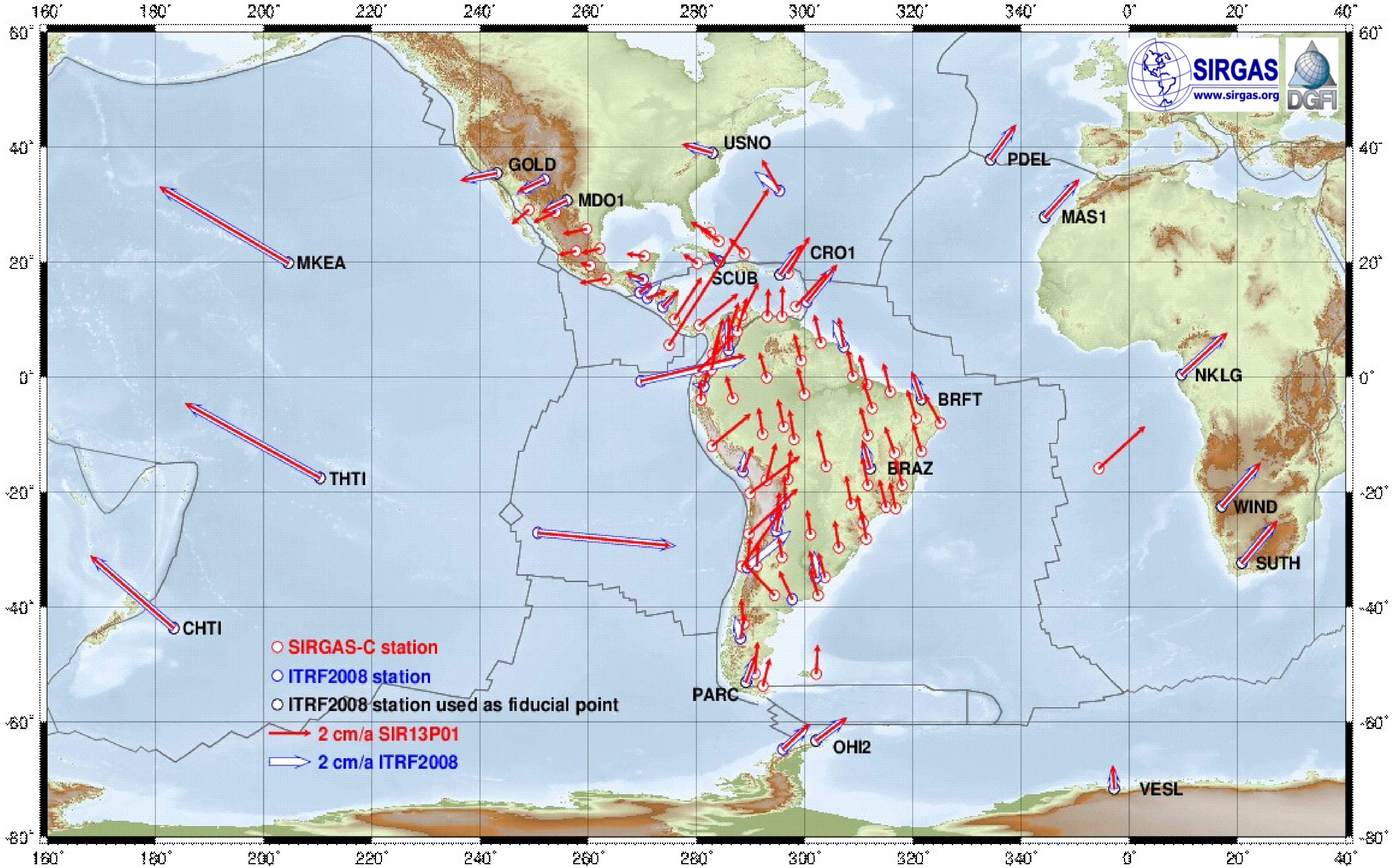
Processing strategy for the computation for the multi-year solutions



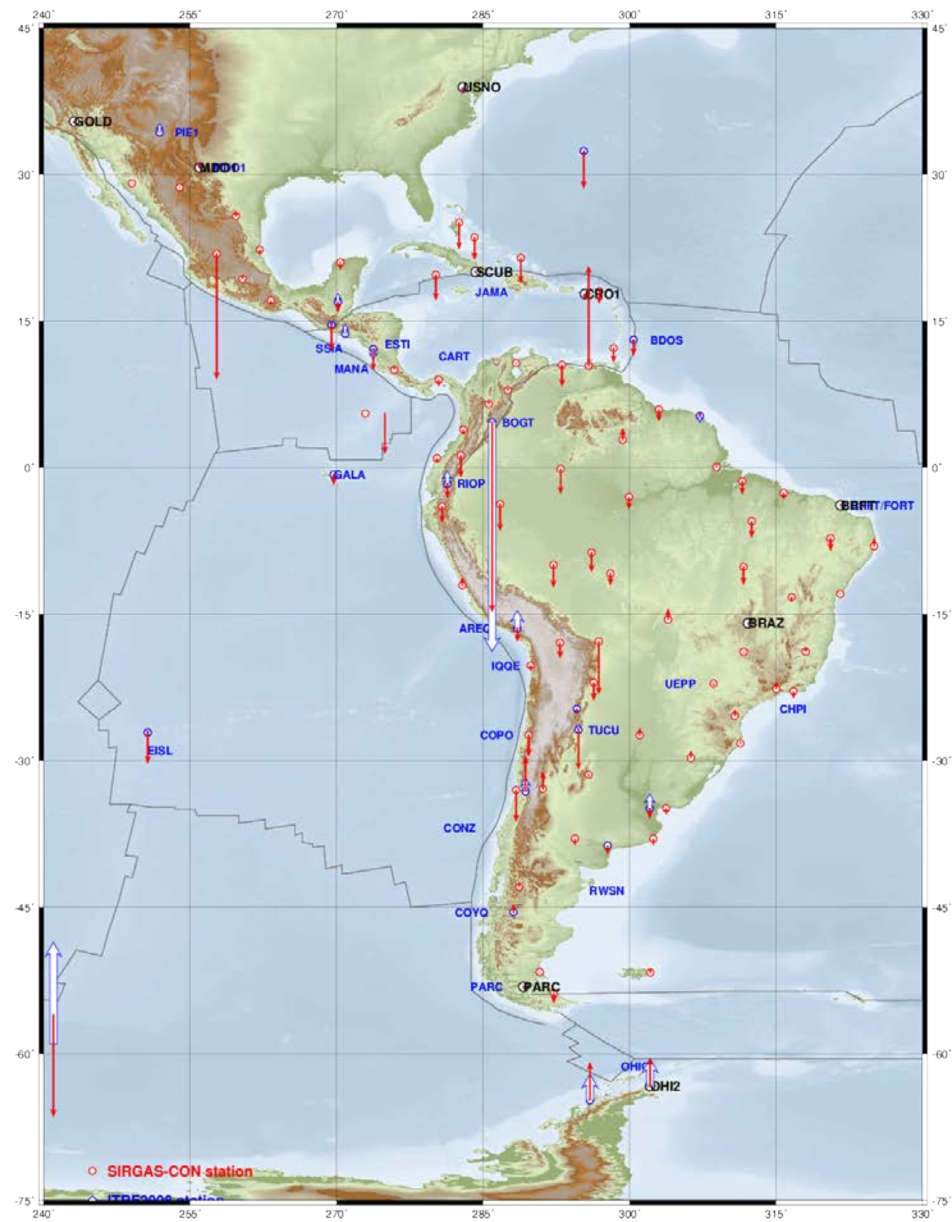
Multi-year solution: SIR13P01

- Recomputed weekly normal equations from April 10, 2010 to June 2013, each four weeks.
- For the weekly solutions before April 16, 2011, the GNSS orbits computed by CODE were applied. After that time, the final IGS orbits were included.
- Only SIRGAS-C core stations (108), because the other SIRGAS Processing Centres have not adopted the new standards yet;
- Stations with jumps caused by Earthquakes (Chile, Mexico) were excluded.
- ITRF2008, 2012.0
- Precision: Pos.: N/E = ±1,4 mm, h = ± 2,5 mm;
  Vel.: N/E = 0,8 mm/a; h = 1,2 mm/a.

Multi-year solution: SIR13P01



Multi-year solution: SIR13P01



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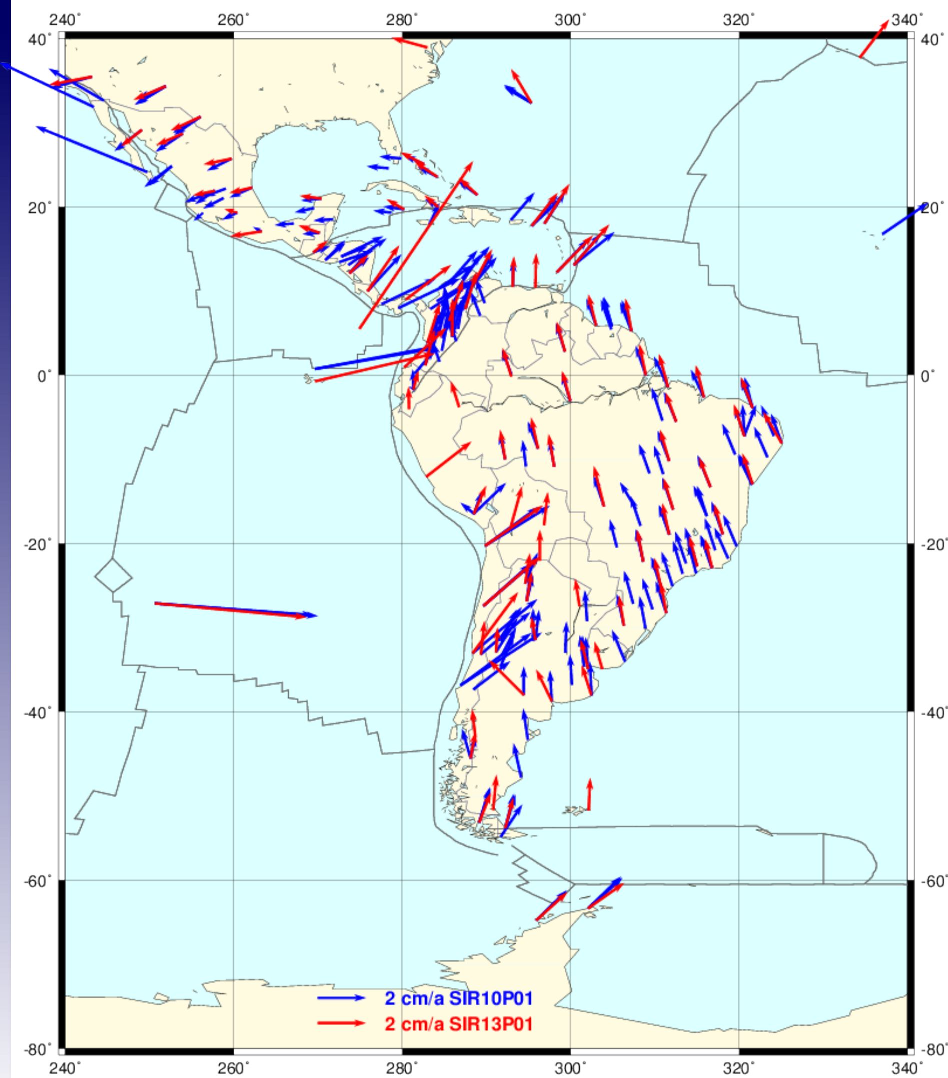
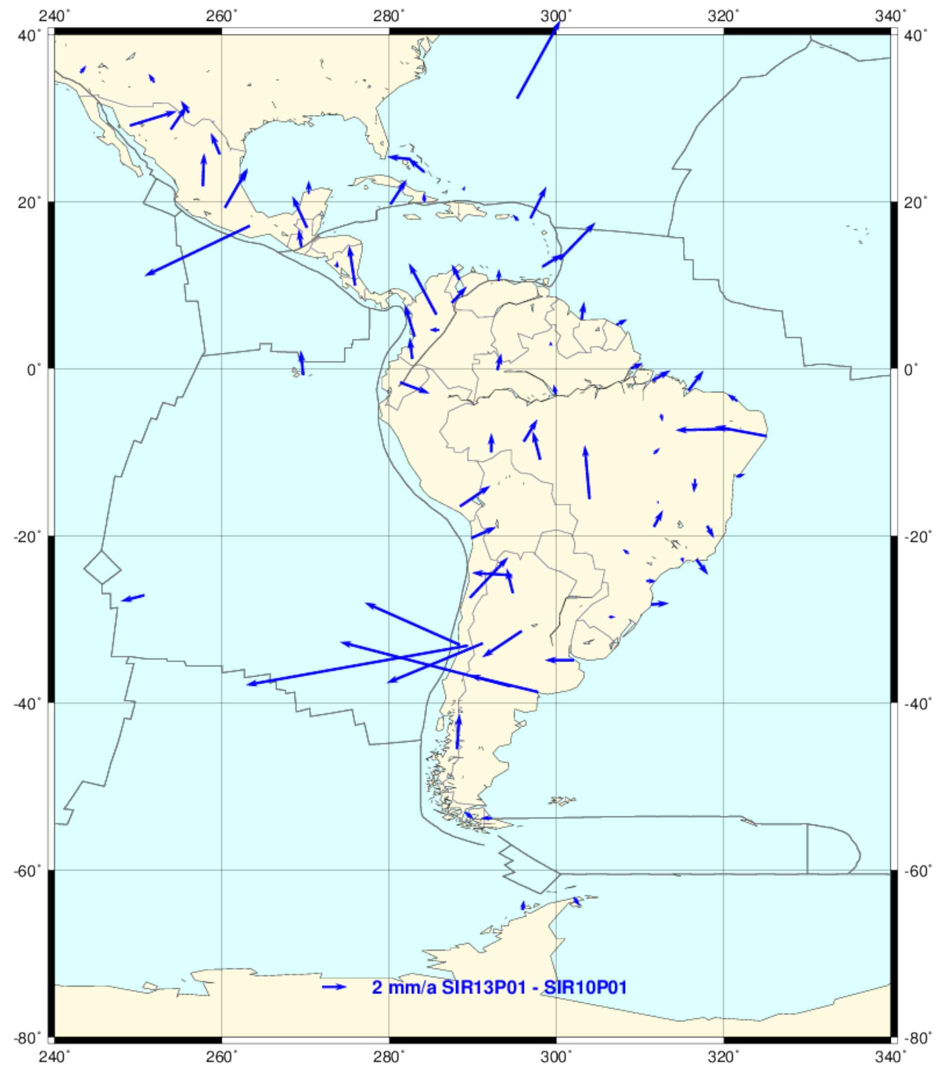
Comparison SIR10P01 (before the earthquake in El Maule) and SIR13P01 (after the earthquake in El Maule)





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Closing remarks

- The usage of GNSS products for the estimation, modelling and understanding of effects affecting the Earth System requires the application of the newest standards and models outlined by the IGS/IERS;
- The reliable computation of station position time series and kinematics of any reference network, not only for geodetic purposes but also for geodynamic projects or atmospheric studies, requires the re-processing of all weekly solutions referring to the new ITRF2008 and applying homogeneous standards and models.
- SIRGAS and its processing centres shall face this challenge as soon as possible, keeping in mind that in the future new re-processing will be required, when the methods are refined.

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