Kinematics of the SIRGAS Reference Frame

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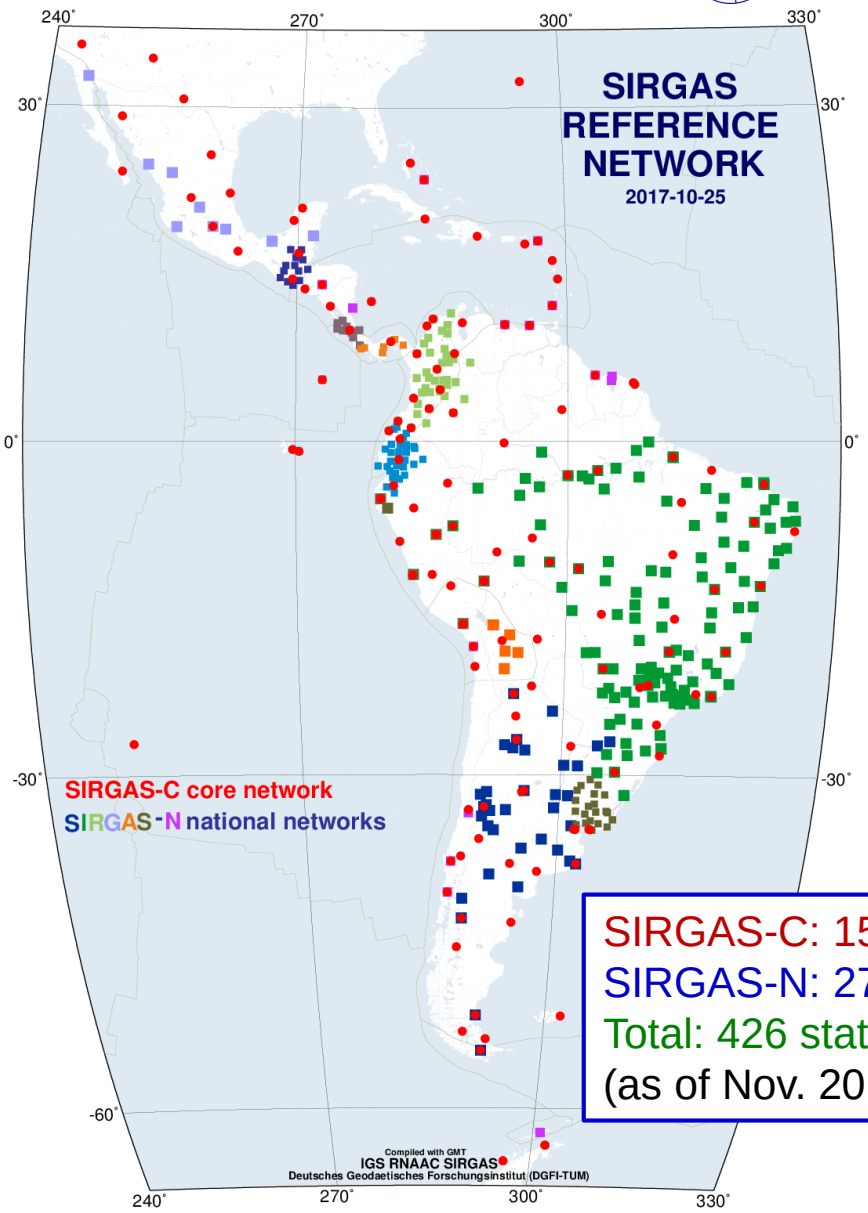
SIRGAS Reference Frame

The SIRGAS Reference Frame comprises

- a continental reference network (SIRGAS-C) as the primary densification of the ITRF in the region; and
- national densifications (SIRGAS-N) of the continental reference frame.

It guarantees

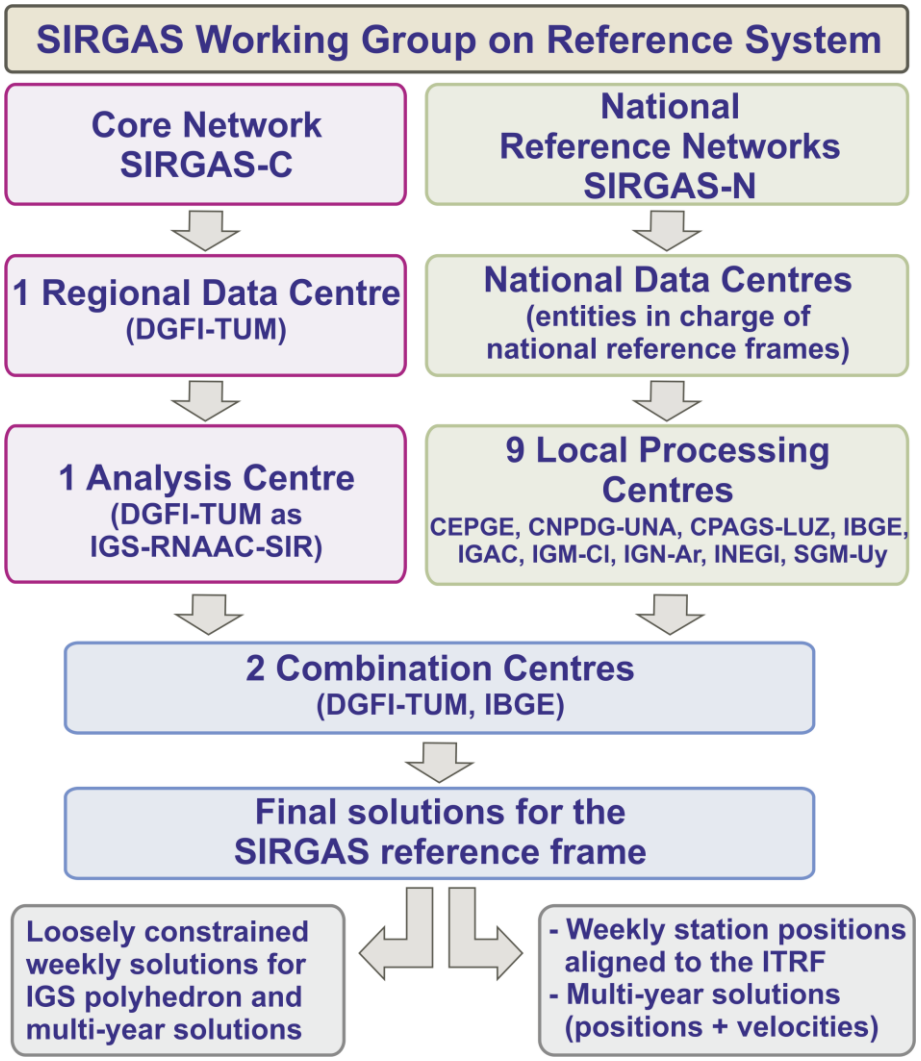
- accessibility to the global reference system at regional, national, and local levels and
- full consistency with the reference system of the GNSS satellite orbits.



SIRGAS-C: 150 stations
SIRGAS-N: 276 stations
Total: 426 stations
(as of Nov. 2017)

SIRGAS analysis centres

- Ten processing centres:
  IGM-Chile, CEPGE-Ecuador, IGN-Argentina, IBGE-Brazil, IGAC-Colombia, INEGI-Mexico, CPAGS-LUZ-Venezuela, CNPDG-UNA-Costa Rica, SGM-Uruguay, DGFI-TUM-Germany
- Two combination centres:
  IBGE-Brazil, DGFI-TUM-Germany.
- Each SIRGAS station is computed by three processing centres;
- Software:
  - Argentina and Mexico
    → GAMIT/GlobK 10.5
  - Brazil, Chile, Colombia, Costa Rica, Ecuador, Germany, Uruguay, Venezuela
    → Bernese GNSS Software 5.2



SIRGAS coordinates

1) Instantaneous weekly positions aligned to the ITRF
   - especially useful when strong earthquakes cause co-seismic jumps or strong relaxation motions at the SIRGAS reference stations making the previous coordinates useless.

2) Multiyear (cumulative) solutions providing station constant velocities and positions referring to a certain epoch
   - main purpose to monitor deformations of the reference frame.

Remarks:

1) The use of multiyear solutions in practice is restricted due to
   - the frequent occurrence of earthquakes, mainly in the western margin of Latin America
   - the omission of seasonal station motions; they are specially large in the Amazonas region.

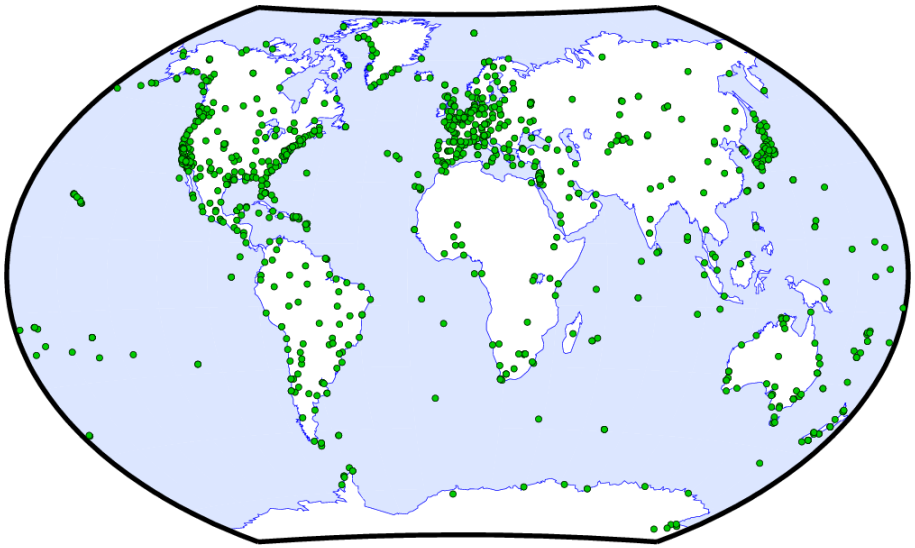
2) Therefore, it is recommended the use of the weekly station positions in precise positioning applications.

3) The current objective of the multiyear solutions is to infer the present-day surface kinematics in the SIRGAS region.

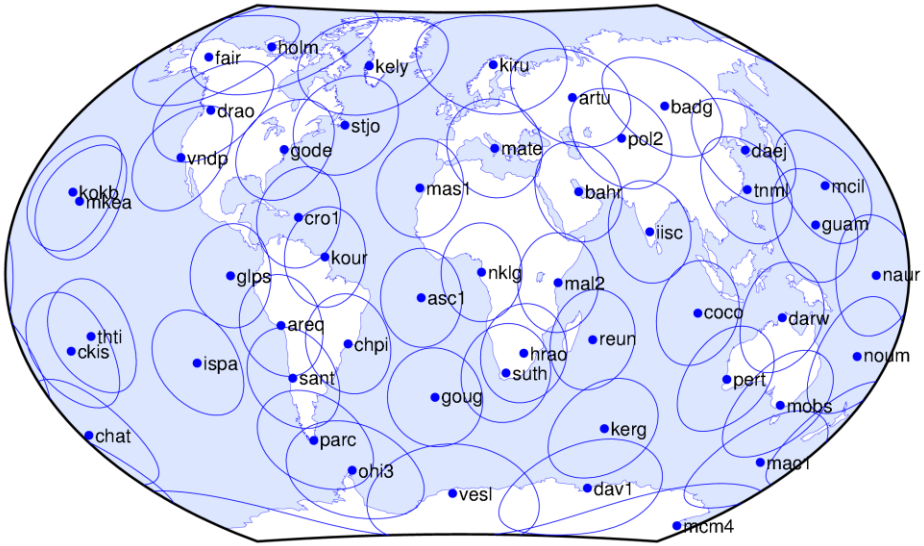
The ITRF2014 and SIRGAS

1) In the SIRGAS processing, the GNSS satellite orbits and clocks are introduced as known parameters. Consequently, the station coordinates refer to the same reference system/frame as the GNSS orbits.

2) As all GNSS stations included in the ITRF solutions do not present the same quality, the International GNSS Service (IGS) selects a set of globally distributed, stable ITRF GNSS sites to be used as the reference frame for the computation of the IGS final products (i.e. satellite orbits, satellite clock, Earth orientation parameters, corrections to the antenna phase centre variations (PCV)). This station selection is called IGS reference frame.



IGS/GNSS stations in ITRF2014



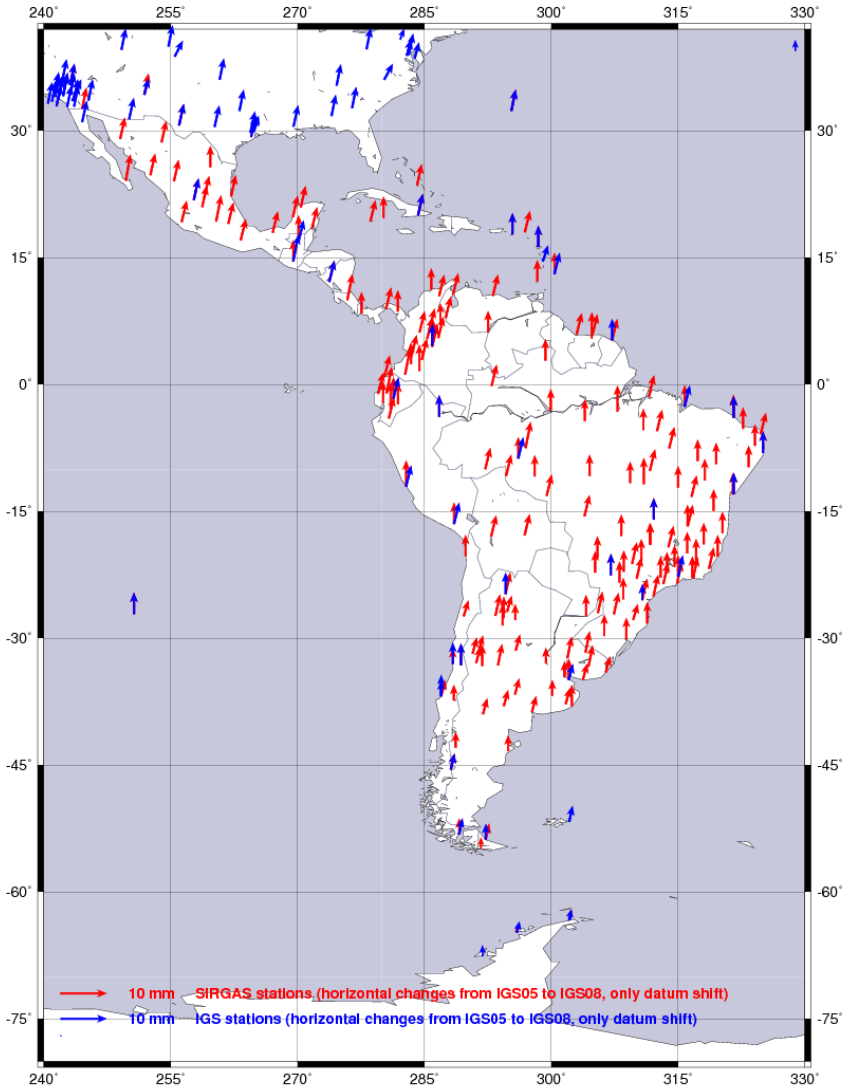
IGS14 reference (core) network

The ITRF2014 and SIRGAS

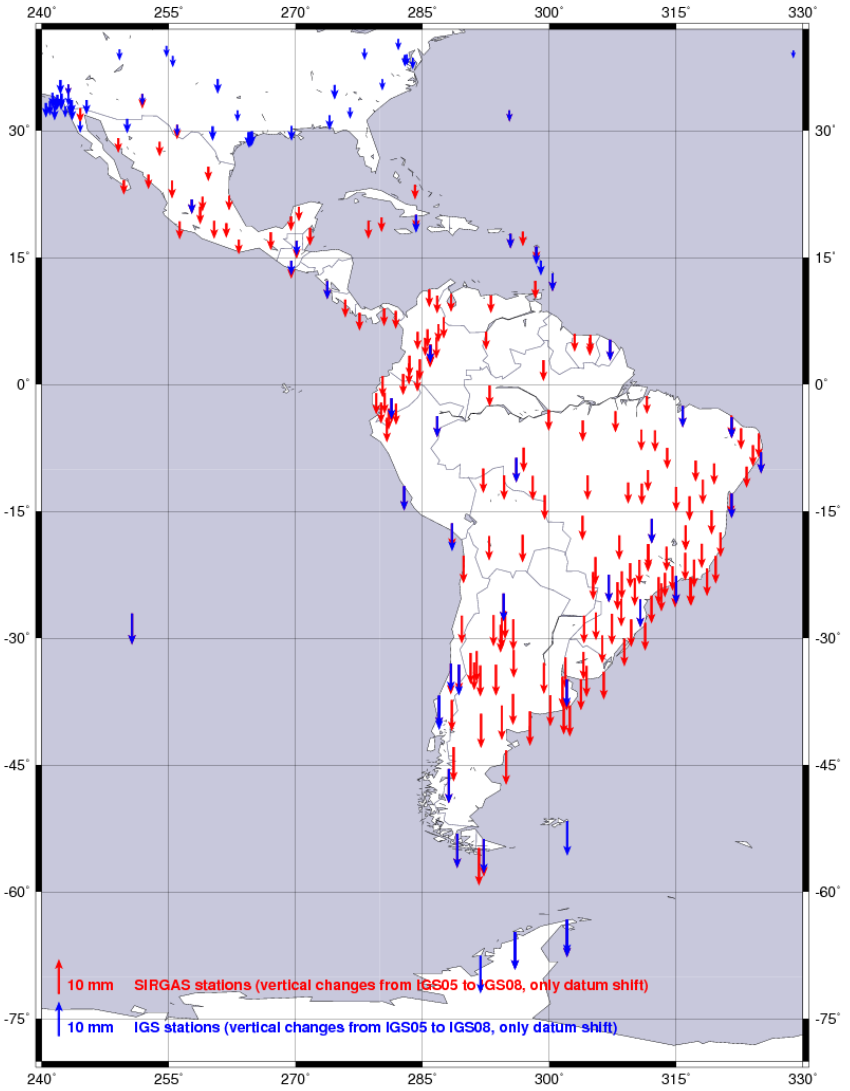
1) The publication of a new ITRF is quickly followed by the release of an updated IGS reference frame:
   - it includes station positions and velocities referring to the new ITRF and
   - new corrections for the antenna PCVs consistent with the new ITRF.
2) In this way, the SIRGAS weekly solutions refer, for instance:
   - To the IGS05 (ITRF2005) from November 4, 2006 to April 16, 2011
   - To the IGS08/IGb08 (ITRF2008) from April 17, 2011 to January 28, 2017
   - To the IGS14 (ITRF2014) since January 29, 2017.
3) It is expected that the IGS reference frames are completely equivalent to the corresponding ITRF in orientation, translation and scale. In this way, the IGS final products can be considered to be nominally in the current ITRF.
4) However, the introduction of a new reference frame causes artificial changes (discontinuities) in the station positions.

From IGS05 to IGS08/IGb08

Horizontal

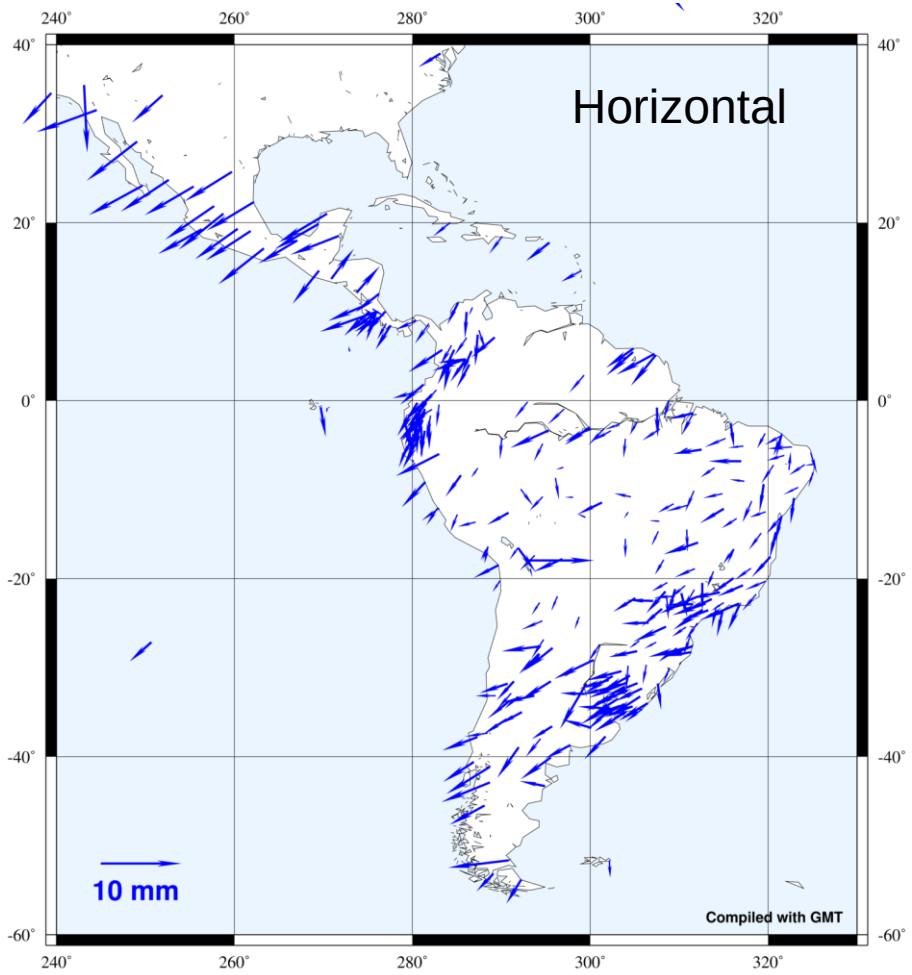


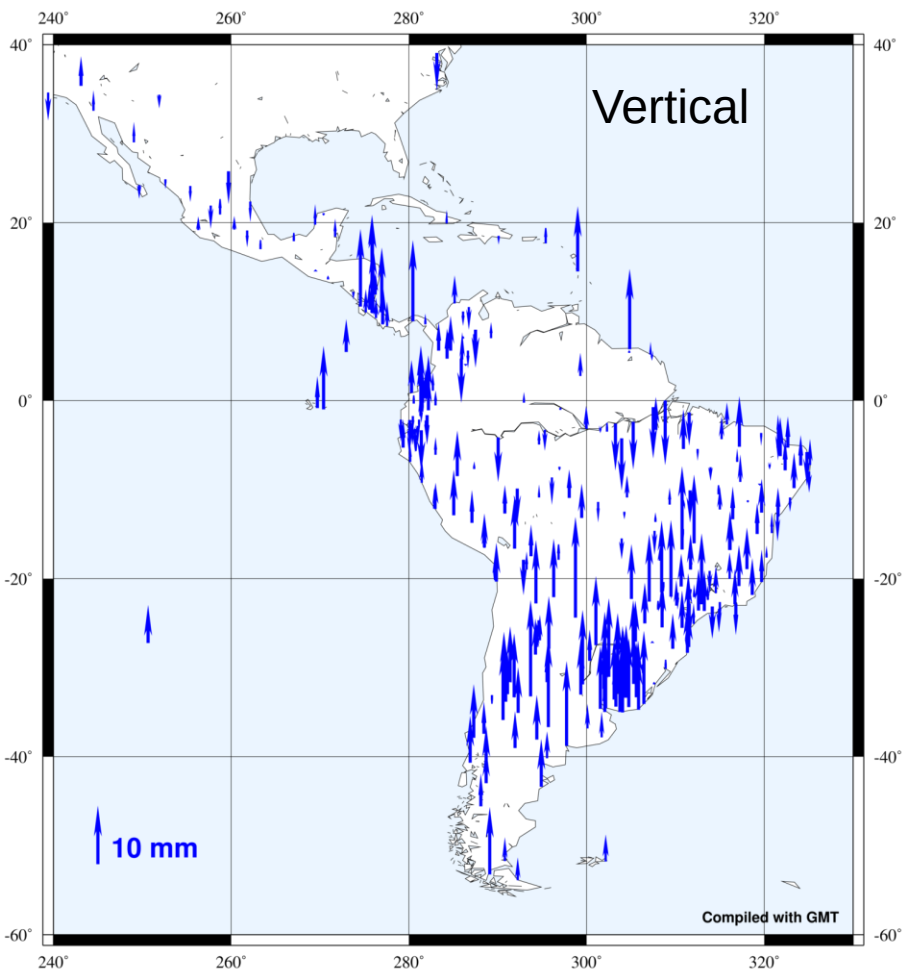
Vertical



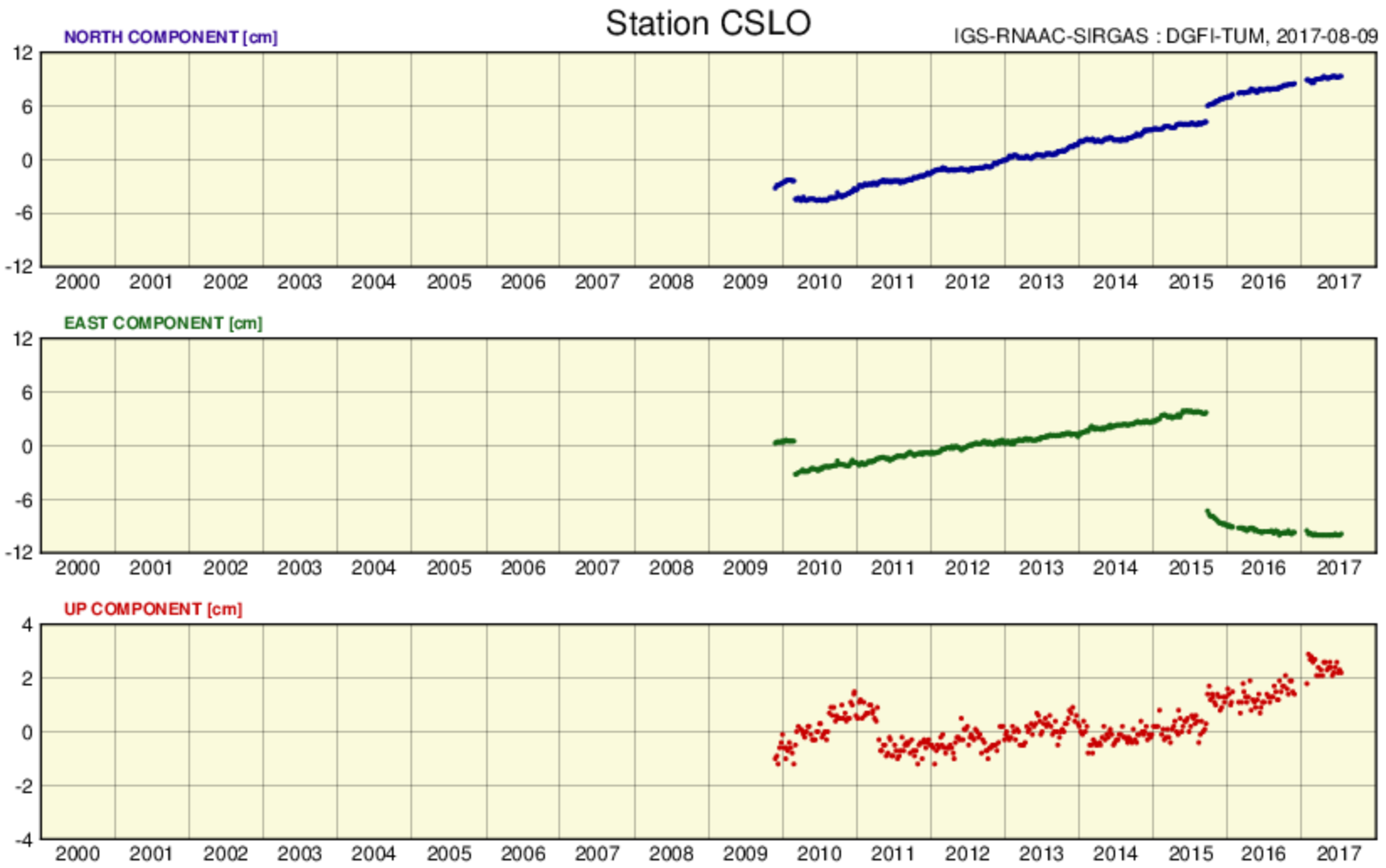
From IGS08/IGb08 to IGS14

1) Simultaneous processing of four weeks (January 2017) using IGb08-based and IGS14-based products.
2) Differences: N = -8.4 mm ... +5.4 mm; E = -8.5 mm ... +11.3 mm, h = -13.5 ... 18.8 mm.

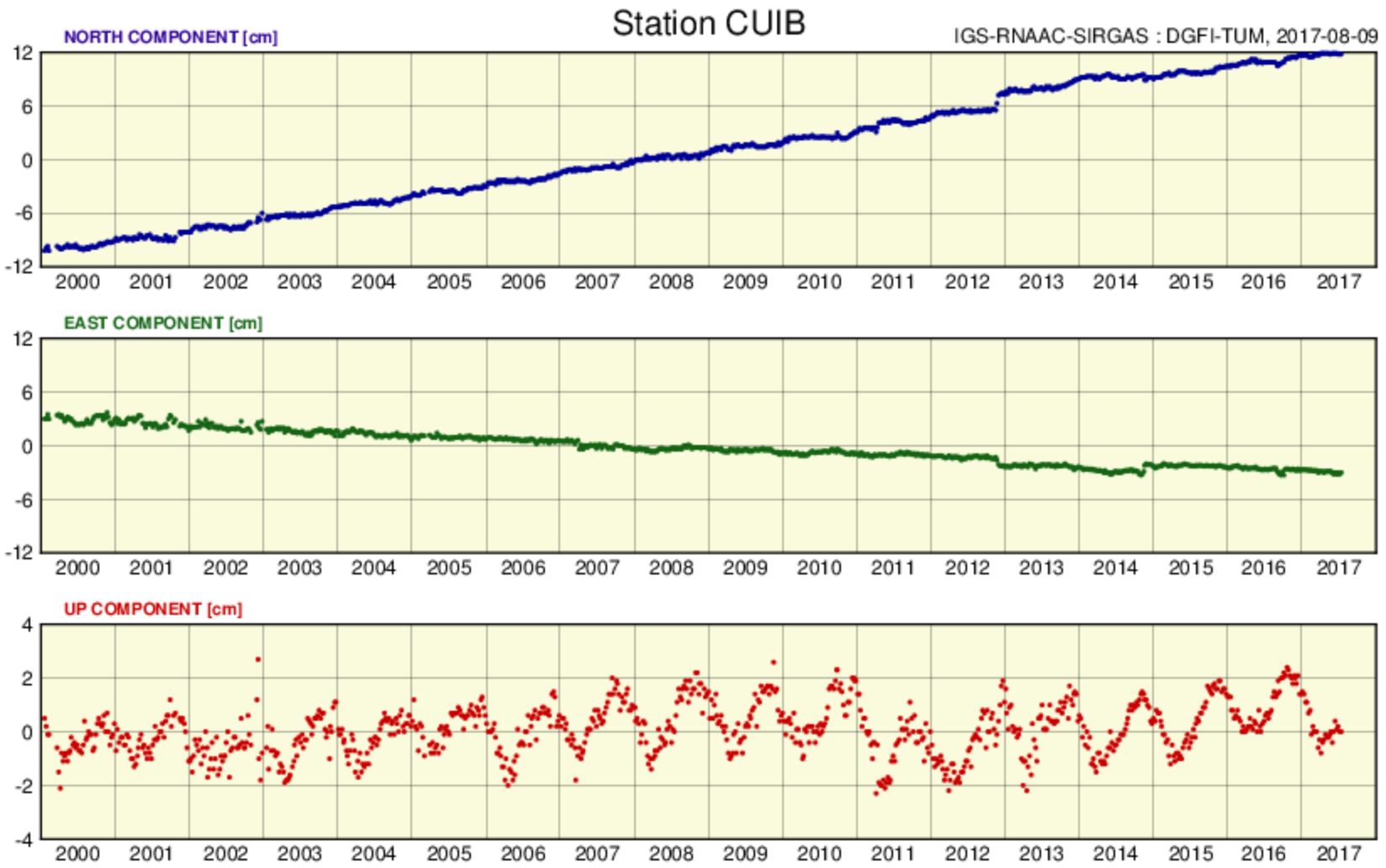




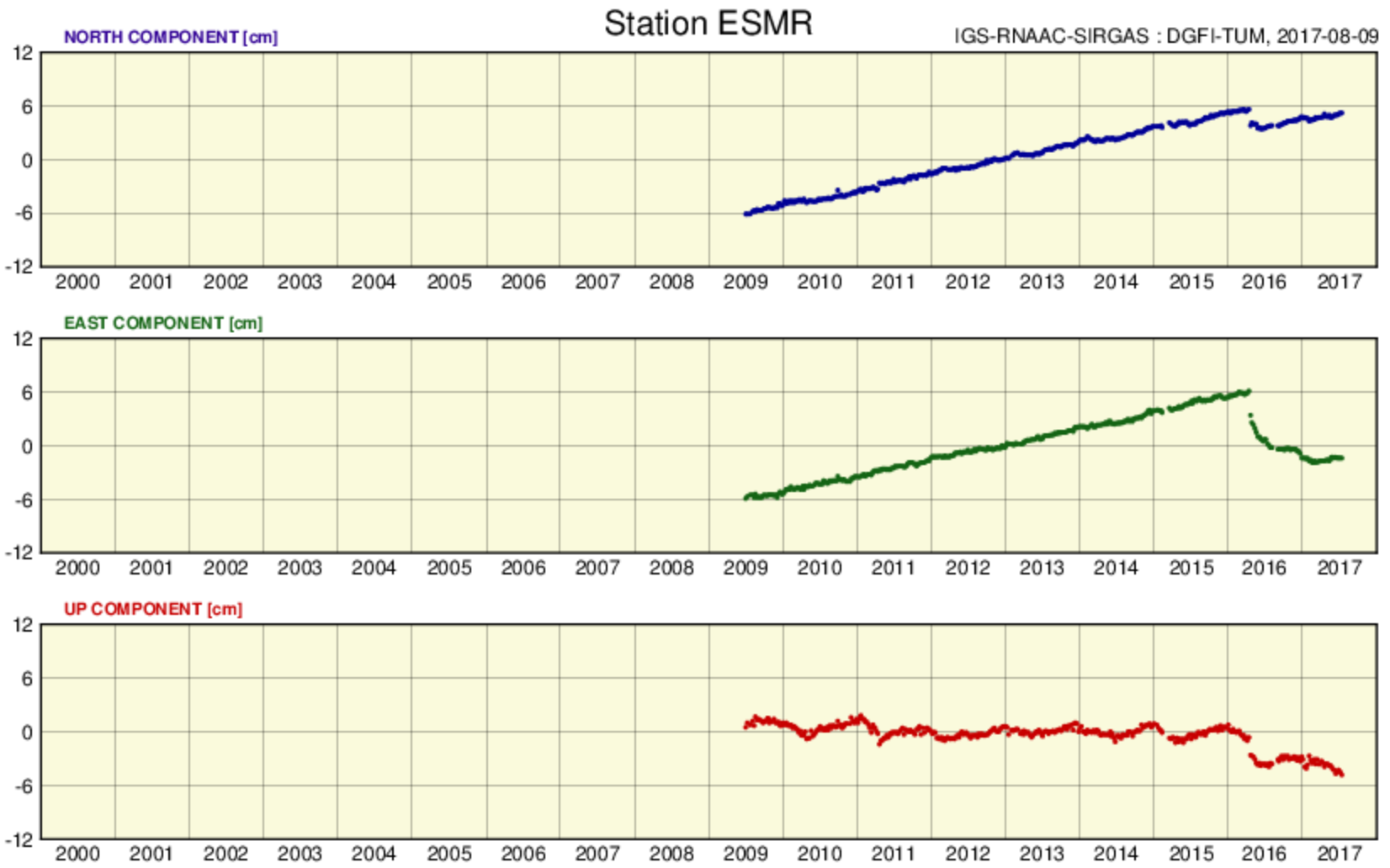
Time series discontinuities



Time series discontinuities



Time series discontinuities



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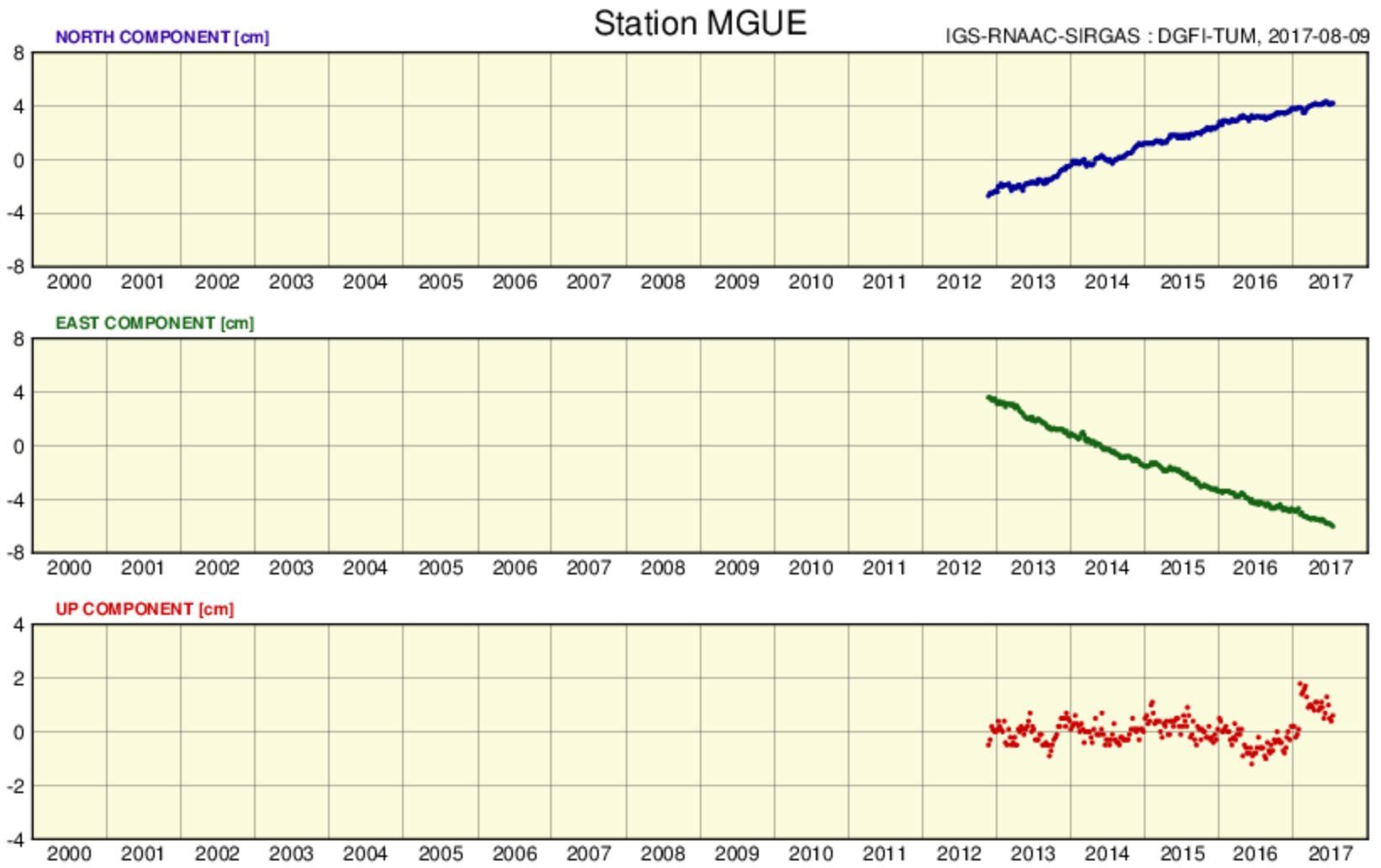
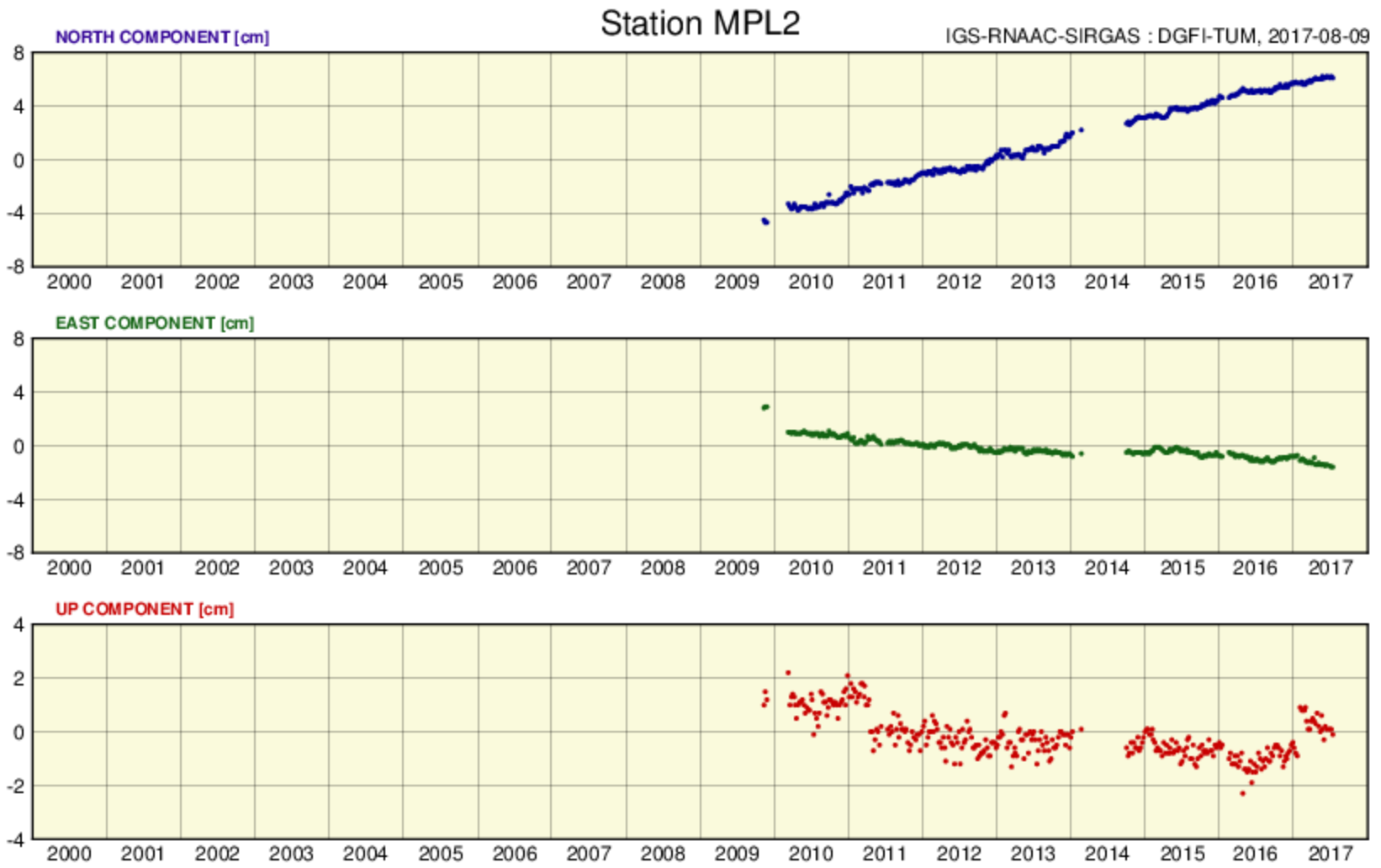


Time series discontinuities



Input data and reference coordinates

1) To avoid the artificial discontinuities caused by introducing the ITRF2014/IGS14, the present SIRGAS multiyear solution considers only free weekly Normal Equations (NEQ) referring to the IGS08/IGb08; i.e., from 2011-04-17 to 2017-01-28

2) The IGb08 frame solution covers from 1994-01-02 to 2012-08-21;
   the ITRF2014 from 1994-01-02 to 2014-12-27.

3) To minimize inconsistencies caused by possible changes in the reference station positions and velocities after December 2014, the fiducial coordinates for the present multiyear solution are taken from the cumulative solution published by the IGS for the GPS week 1956 (IGS17P27), which goes up to 2017-07-08.

4) IGS17P27 is aligned to the IGS14 reference frame and is consistent with the new igs14.atx PCV model. As the SIRGAS NEQs refer to the IGS08/IGb08 frame, they have to be aligned to the IGS14 before computing the final multiyear solution.

5) This is achieved by applying the station-specific estimates published by the IGS for the IGS stations and by inferring the correction to the regional SIRGAS stations according to the latitude-dependent PCV models also recommended by the IGS:

$$dX = a + c1*\cos(\varphi) + s1*\sin(\varphi) + c2*\cos(2\varphi) + s2*\sin(2\varphi) + c4*\cos(4\varphi) + s4*\sin(4\varphi)$$

From IGS08/IGb08 to IGS14

Latitude-dependent PCV models (ftp://igs-rf.ign.fr/pub/IGS14/lat_models.txt)

$$dX = a + c1*\cos(\varphi) + s1*\sin(\varphi) + c2*\cos(2\varphi) + s2*\sin(2\varphi) + c4*\cos(4\varphi) + s4*\sin(4\varphi)$$

# Antenna type		axis	a	c1	s1	c2	s2	c4	s4	WRMS
AERAT2775_43	SPKE	East	-4.48	0.00	0.00	0.19	1.60	-0.17	-1.49	0.39
AERAT2775_43	SPKE	North	2.93	0.00	0.00	0.07	-0.55	-0.04	1.00	0.19
AERAT2775_43	SPKE	Up	-1.24	0.00	0.00	-2.44	-0.01	-1.43	-0.15	0.60
AOAD/M_T	DUTD	East	5.47	-7.01	-0.92	2.80	0.31	0.00	0.00	0.53
AOAD/M_T	DUTD	North	2.50	0.00	0.00	0.30	0.15	-0.07	-0.49	0.31
AOAD/M_T	DUTD	Up	-51.34	98.85	-0.76	-35.11	1.30	0.00	0.00	2.30
AOAD/M_T	NONE	East	0.31	0.00	0.00	-0.01	-0.18	-0.01	0.16	0.05
AOAD/M_T	NONE	North	-0.48	0.00	0.00	0.01	-0.07	-0.03	0.14	0.02
AOAD/M_T	NONE	Up	0.54	-0.71	-0.09	0.00	0.00	-0.27	0.01	0.06
AOAD/M_TA_NGS	NONE	East	0.31	0.00	0.00	-0.01	-0.18	-0.01	0.16	0.05
AOAD/M_TA_NGS	NONE	North	-0.48	0.00	0.00	0.01	-0.07	-0.03	0.14	0.02
AOAD/M_TA_NGS	NONE	Up	0.54	-0.71	-0.09	0.00	0.00	-0.27	0.01	0.06
ASH700936A_M	NONE	East	1.48	0.00	0.00	0.07	0.45	-0.11	-0.49	0.13
ASH700936A_M	NONE	North	1.20	0.34	-0.10	0.00	0.00	-0.04	0.07	0.10
ASH700936A_M	NONE	Up	5.56	0.00	0.00	-0.10	0.09	-1.21	0.25	0.37
ASH700936C_M	SNOW	East	-0.46	0.00	0.00	0.01	0.11	0.03	-0.11	0.05
ASH700936C_M	SNOW	North	0.08	0.00	0.00	0.02	-0.03	0.01	0.05	0.02
ASH700936C_M	SNOW	Up	-1.51	5.30	-0.14	-2.02	0.23	0.00	0.00	0.14
ASH700936D_M	SCIS	East	2.07	-0.30	-0.27	0.00	0.00	0.00	0.00	0.19
ASH700936D_M	SCIS	North	1.93	0.00	0.00	-0.15	0.09	0.04	-0.27	0.12
ASH700936D_M	SCIS	Up	31.59	-40.09	-1.48	15.31	1.03	0.00	0.00	0.65

This alignment is a transitory measure to align the new SIRGAS multiyear solution to the IGS14. The only possibility to ensure a reliable consistency is an entire reprocessing of the historical SIRGAS GNSS observations using the new antenna calibrations and satellite ephemeris referring to the latest ITRF/IGS reference frame release.

SIRGAS multiyear solution SIR17P01

Input data:

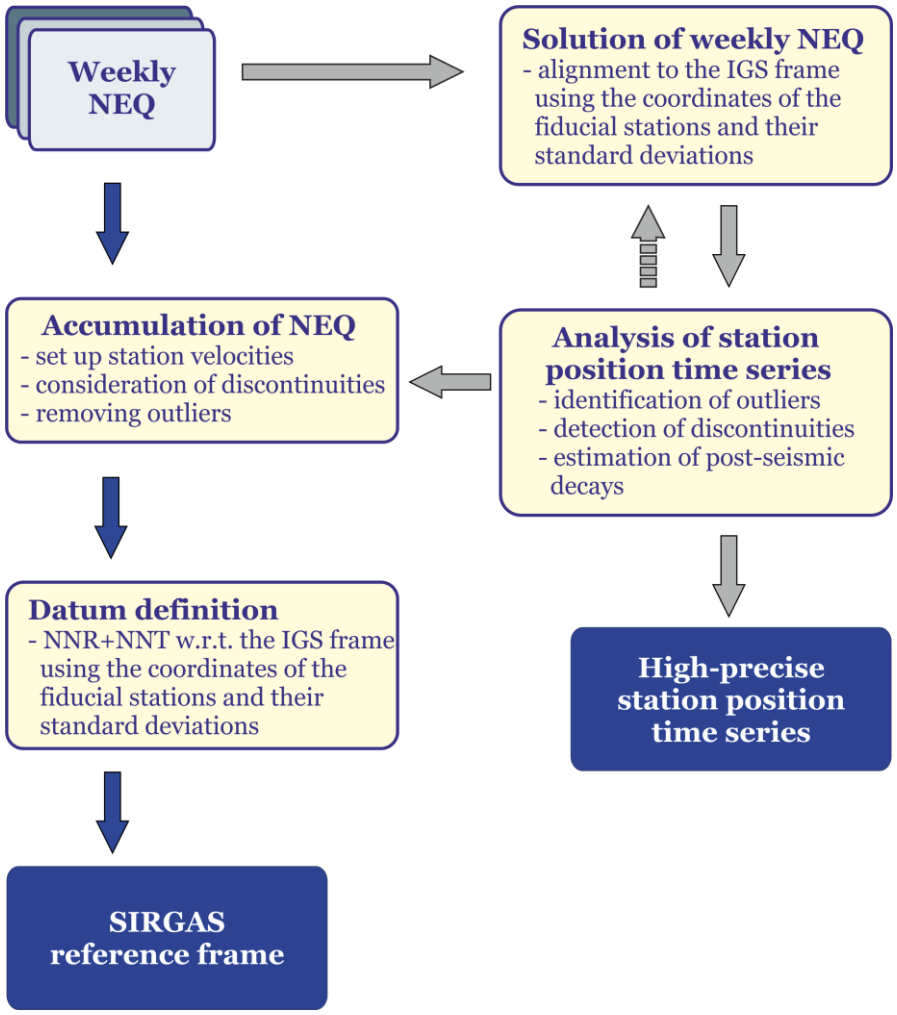
– weekly free NEQs aligned to the IGS14 from 2011-04-17 to 2017-01-28

Geodetic datum definition

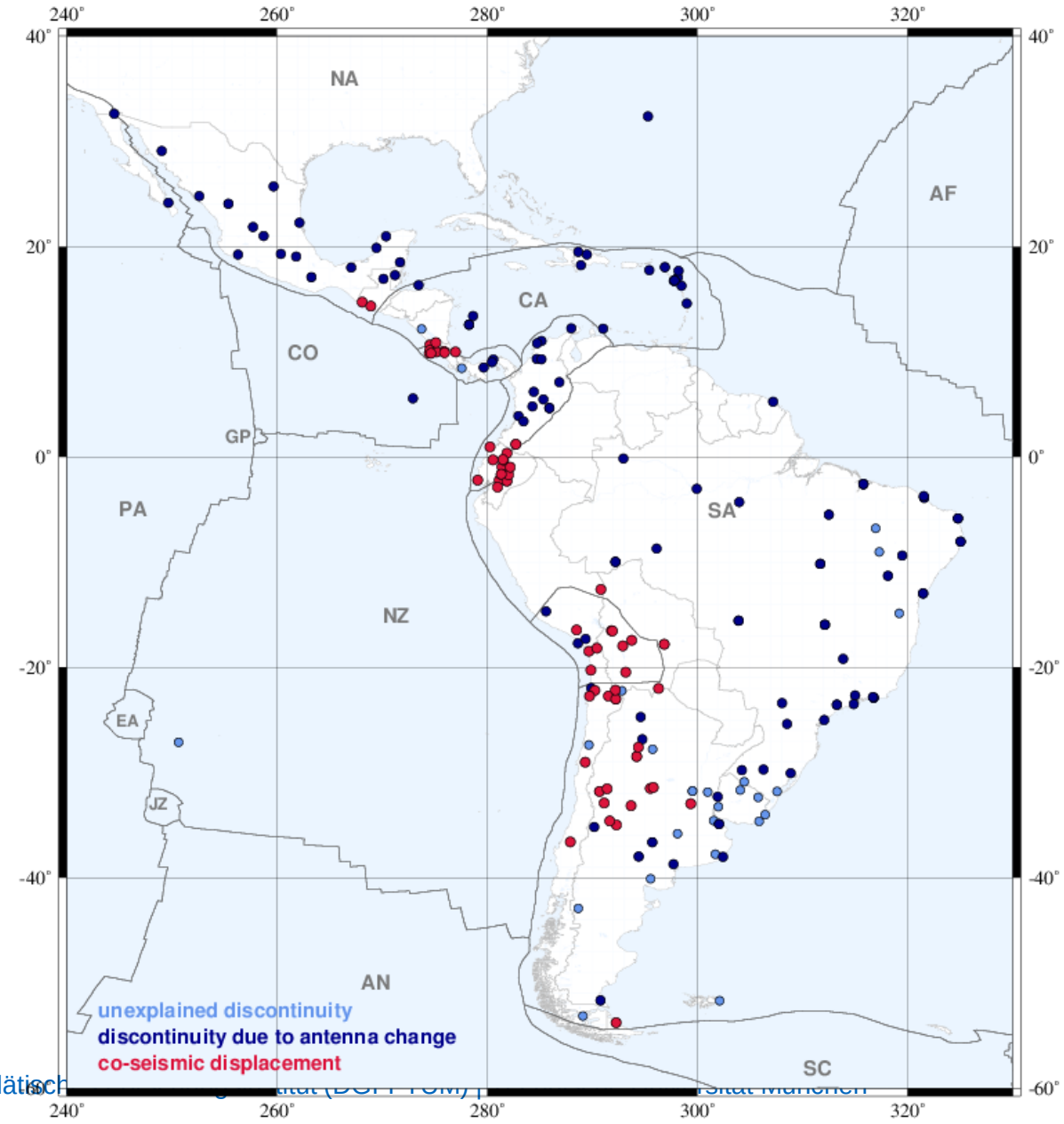
– no-net-rotation (NNR) and no-net-translation (NNT) conditions
– with respect to the IGS17P27 coordinates (positions + velocities) of a set of reliable fiducial stations

Fiducial stations

– well distribution along the area covered by the SIRGAS network
– low number of equipment changes without co-seismic jumps
– a nearly complete coverage of the time-series from April 2011 to January 2017.

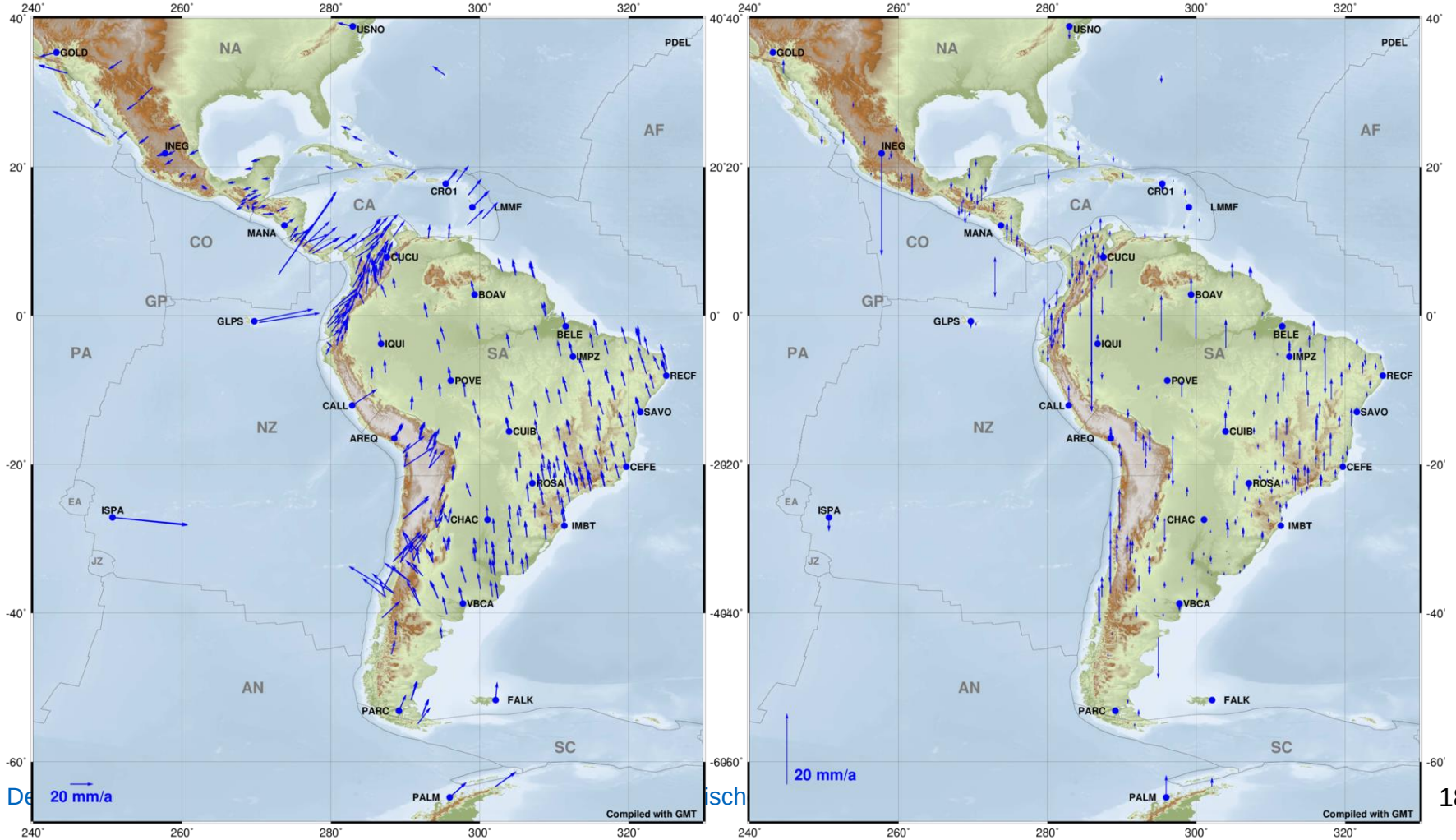


Time series discontinuities in SIR17P01



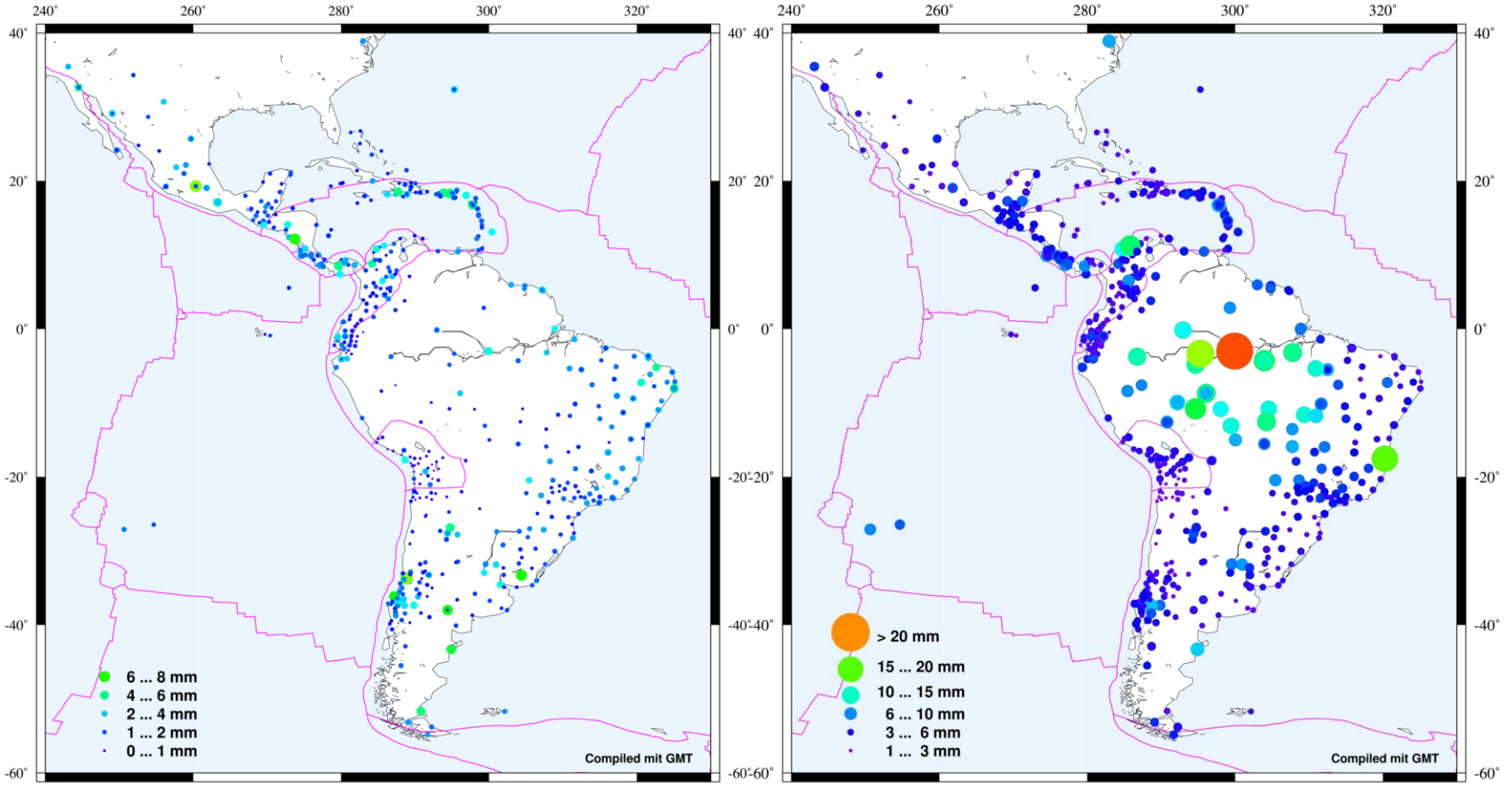
Multiyear solution SIR17P01

- 345 stations with 504 occupations.
- Coordinates refer to the IGS14, epoch 2015.0.
- Precision for the positions: ±1,2 mm (horizontal) and ±2,5 mm (vertical).
- Precision for the velocities: ±0,7 mm/a (horizontal) and ±1,1 mm/a (vertical).



Residual station position time series

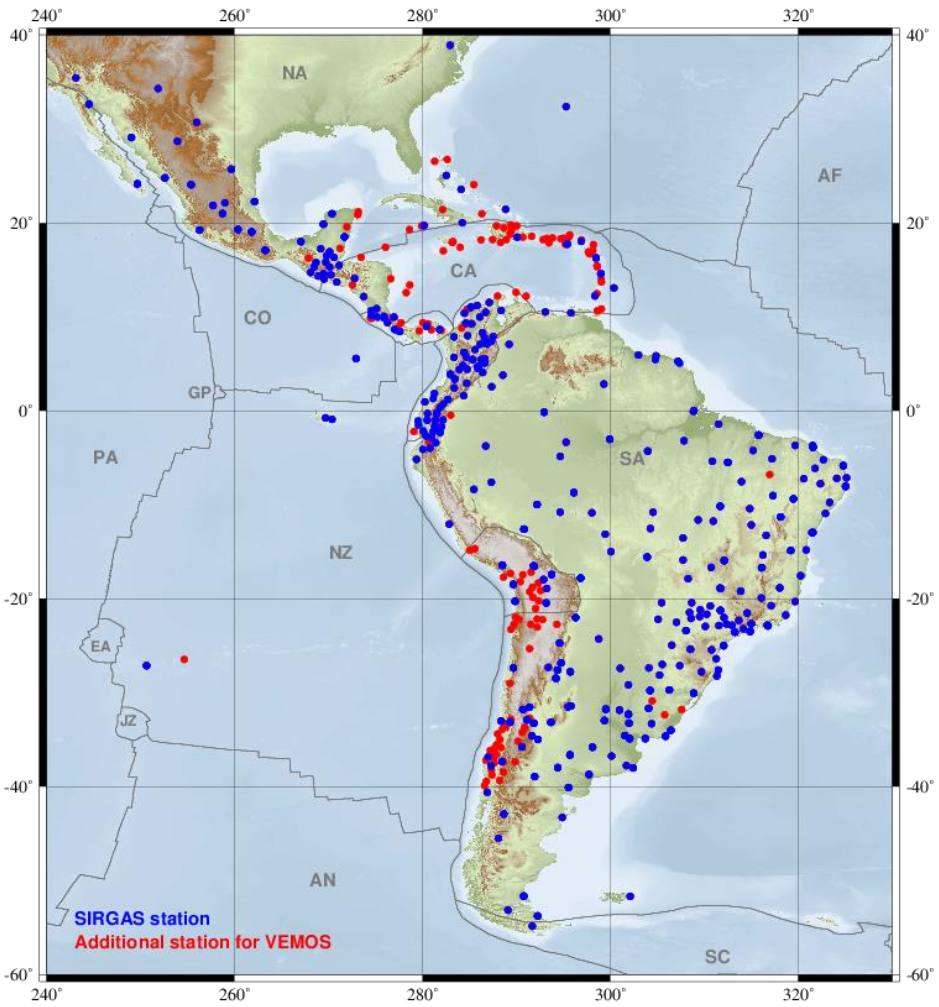
- Omission of seasonal motions.
- Mean RMS values of about ±2 mm in the horizontal and ±4.5 mm in the height.
- Some stations show larger values in the vertical component (in the order of ±10 to ±20 mm) mainly in the Amazonas region.
- The largest mean RMS occurs at the SIRGAS station located in Manaus, Brazil.



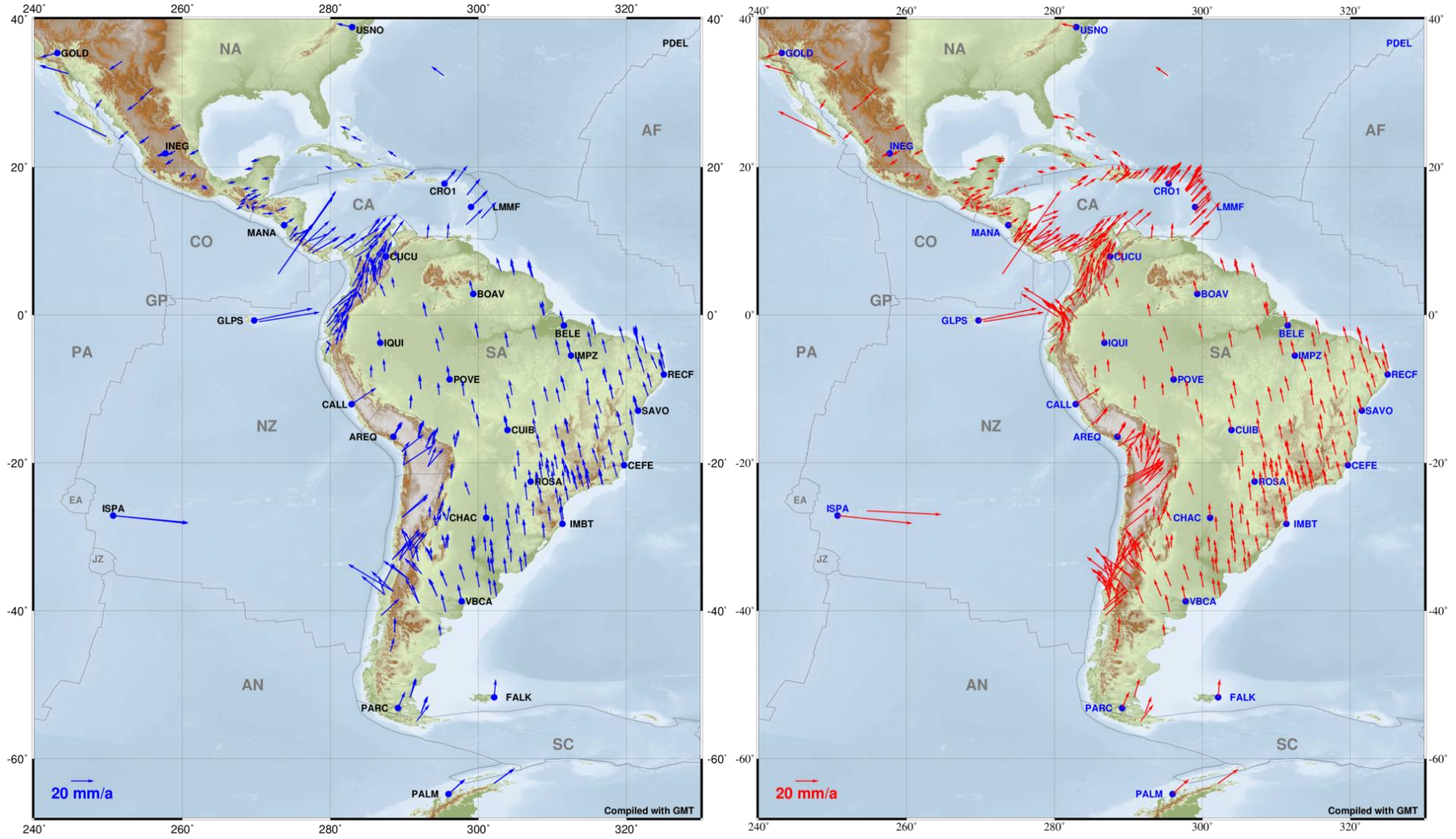
Additional stations

1) To improve the distribution of input stations for the computation of VEMOS, 150 additional stations provided by UNAVCO, NGS and other sources are included.
2) NEQs for those stations were computed by DGFI-TUM for the same time-span applying the SIRGAS strategy.
3) Two multiyear solutions were computed simultaneously:

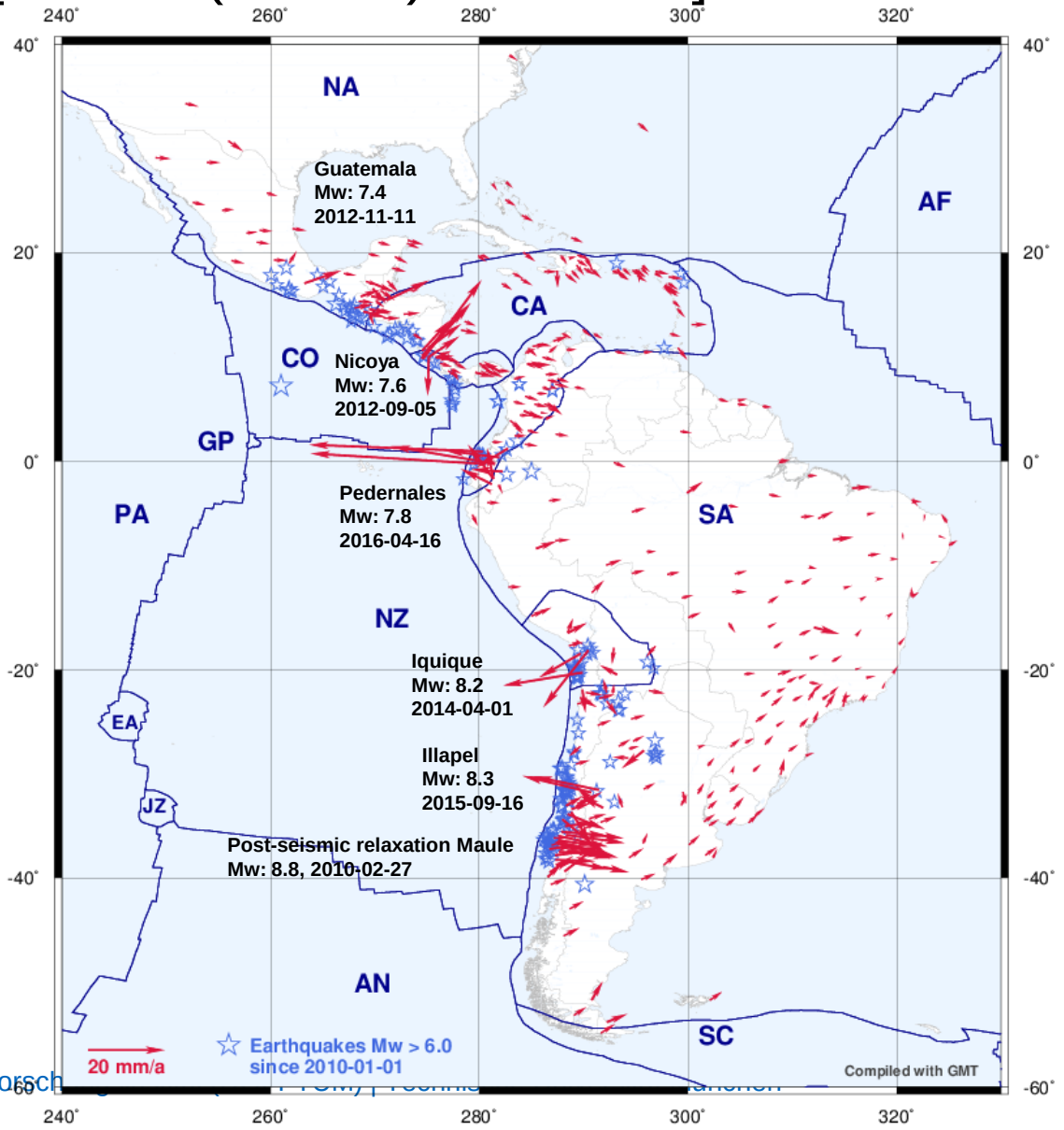
- SIR17P01:
  - only SIRGAS stations,
  - time series larger than two years,
  - several occupations at the stations
  - April 2011 to January 2017
- VMS17P01:
  - SIRGAS + UNAVCO + NGS + ... stations
  - time series larger than six months
  - only (the last) one occupation per station
  - January 2014 to January 2017



SIR17P01 and VMS17P01



VMS17P01 [2014.0 ... 2017.1] vs. VMS15P01 [2010.2 (2012.2) ... 2015.2]



Conclusions

- Changing the ITRF2008/IGS08(IGb08) by the ITRF2014/IGS14 introduces artificial discontinuities of several mm in the station position time series.
- Therefore, a new SIRGAS multiyear solution (SIR17P01) has been computed. It includes only weekly solutions referring to the IGS08/IGb08 and covers the time span from 2011-04-17 to 2017-01-28.
- SIR17P01 contains 345 stations with 504 occupations; it refers to the IGS14, epoch 2015.0 and its precision is about ±1,2 mm (horizontal) and ±2,5 mm (vertical) for the station positions and ±0,7 mm/a (horizontal) and ±1,1 mm/a (vertical) for the constant velocities.
- The main objective of this solution is the computation of an updated deformation model for Latin America (VEMOS). Therefore, 150 additional stations were processed and linear station motions from 2014-01-06 to 2017-01-28 were computed. This “extended” solution, called VMS17P01, is the input for VEMOS2017 (see Drewes and Sánchez presentation).
- To ensure consistency of SIRGAS as reference frame through time, it is necessary the entire reprocessing of the historical SIRGAS GNSS observations using the new antenna calibrations and satellite ephemeris referring to the latest ITRF/IGS reference frame release.
- Based on this reprocessing, the modelling of seasonal motions and seismic effects should be considered.