Recent activities of the IGS Regional Network Associate Analysis Centre for SIRGAS - IGS RNAAC SIRGAS

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Symposium SIRGAS 2016
Quito, Ecuador, November 16 - 18, 2016

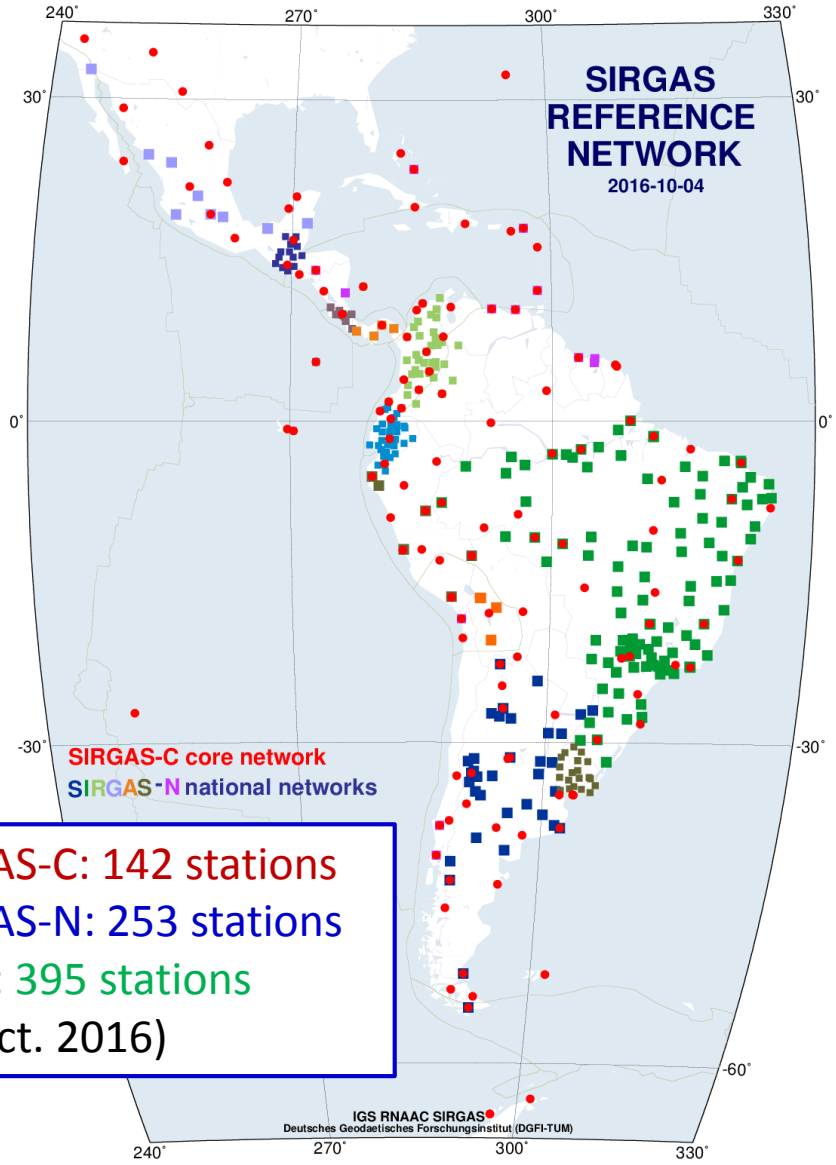
The SIRGAS Reference Frame

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

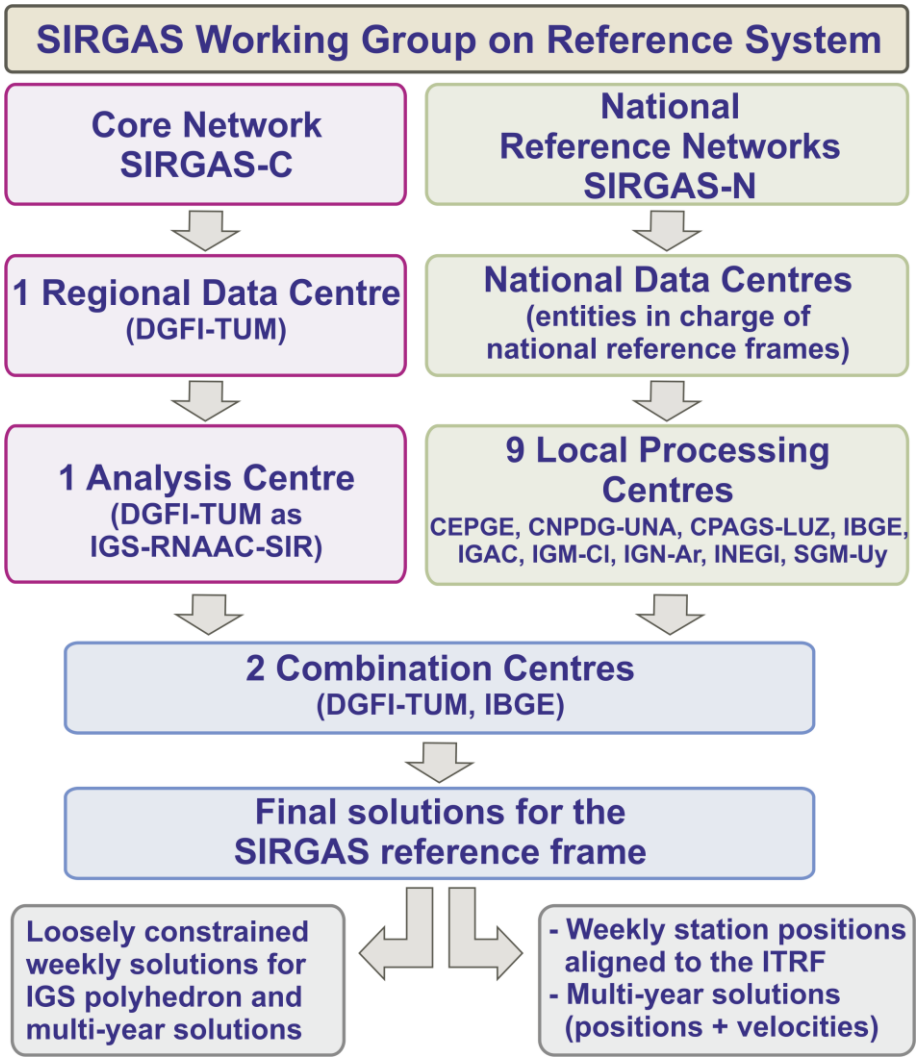
- accessibility to the global reference system at regional, national, and local levels and
- full consistency with the reference system of the GNSS satellite orbits.



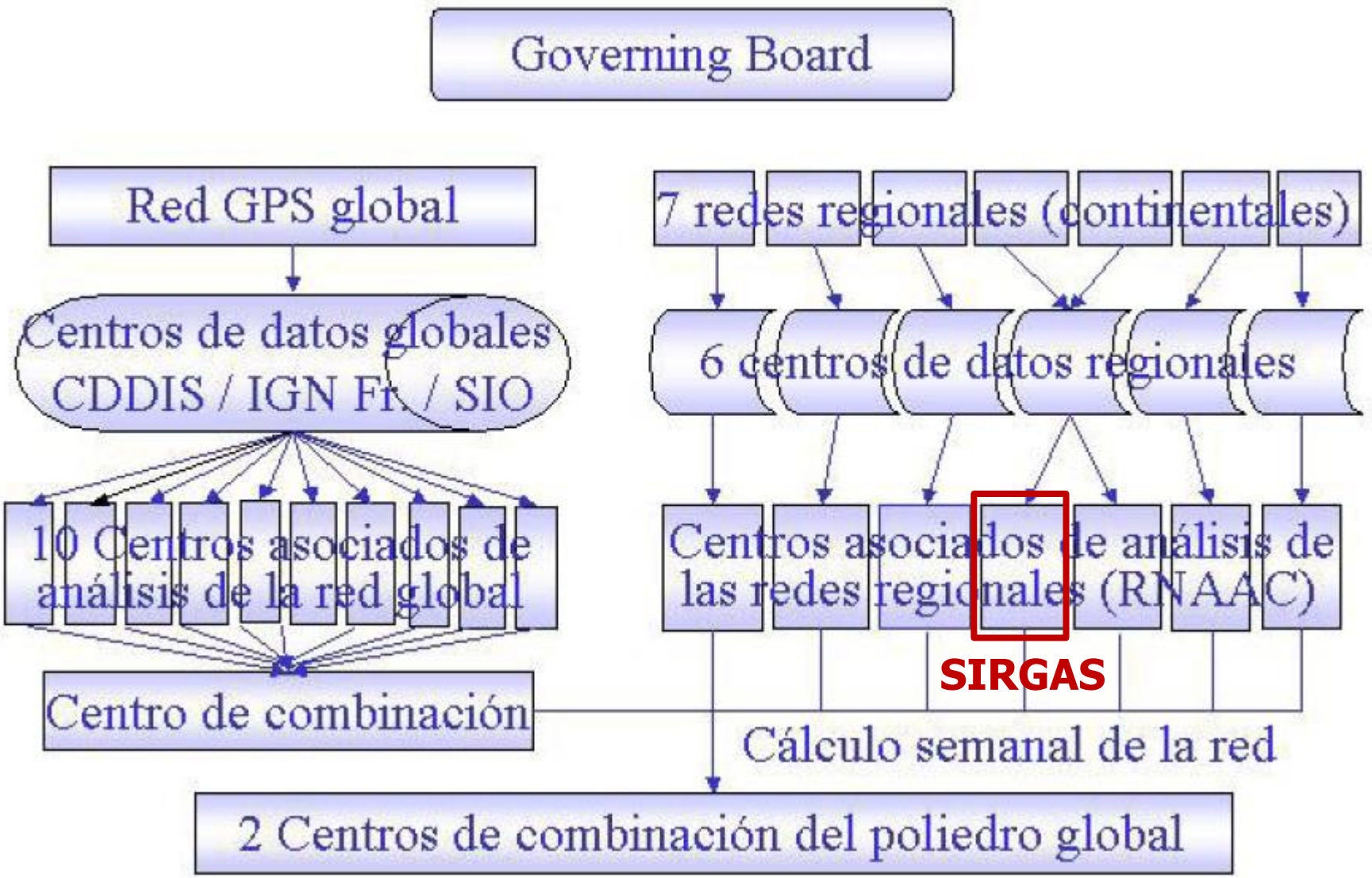
SIRGAS-C: 142 stations
SIRGAS-N: 253 stations
Total: 395 stations
(as Oct. 2016)

The SIRGAS Reference Frame

- 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



IGS RNAAC SIRGAS



IGS RNAAC SIRGAS

In operation since June 1996 under the responsibility of the Deutsches Geodätisches Forschungsinstitut, Technische Universität München (DGFI-TUM), Germany.

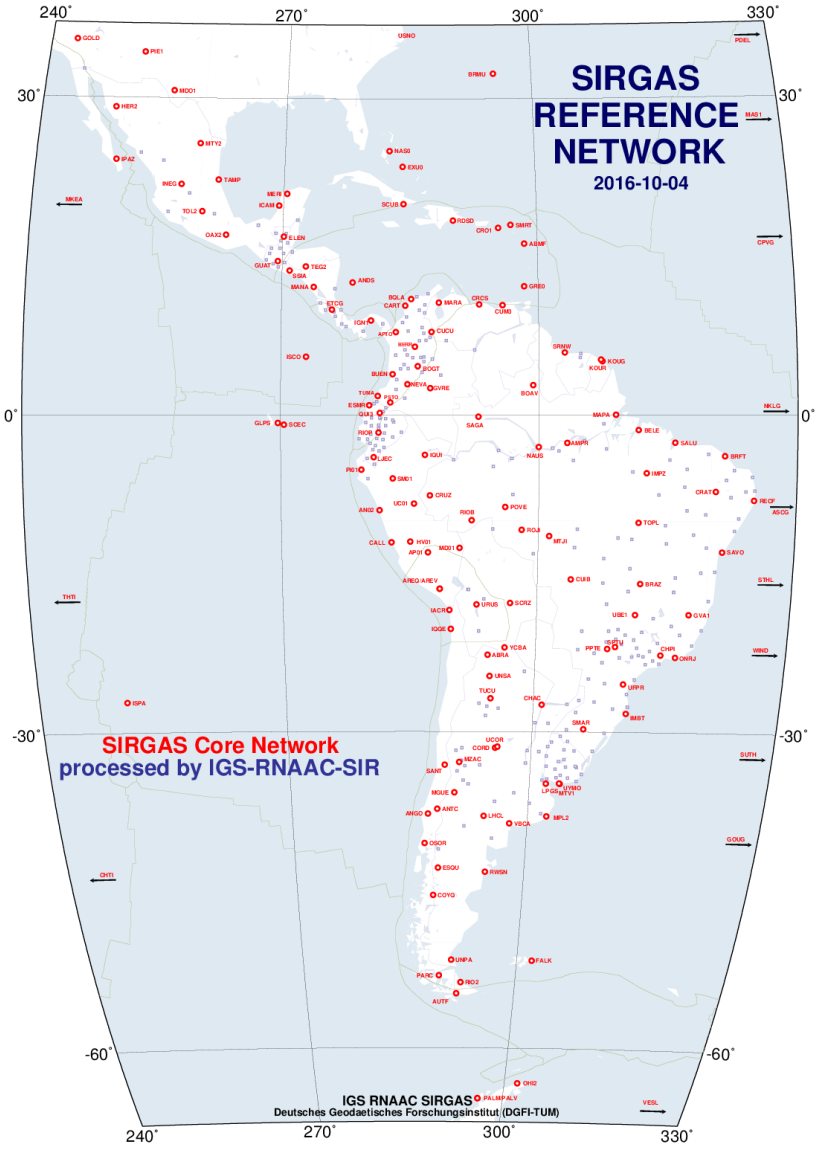
Objectives/responsibilities:

- Until August 2008, to process the entire SIRGAS reference network. At present:
- To process the SIRGAS-C core network.
- To combine the core network with the national reference networks.
- To ensure that the SIRGAS processing strategy meets the IERS standards and IGS guidelines.
- To develop strategies that guarantee the reliability of the reference frame over time, this includes:
  - estimation of the reference frame kinematics;
  - evaluation of the seismic impacts on the reference frame;
  - modelling crustal deformation in the SIRGAS region.
- To deliver the SIRGAS results to the IGS (International GNSS Service) and to the SIRGAS users via www.sirgas.org and ftp.sirgas.org.

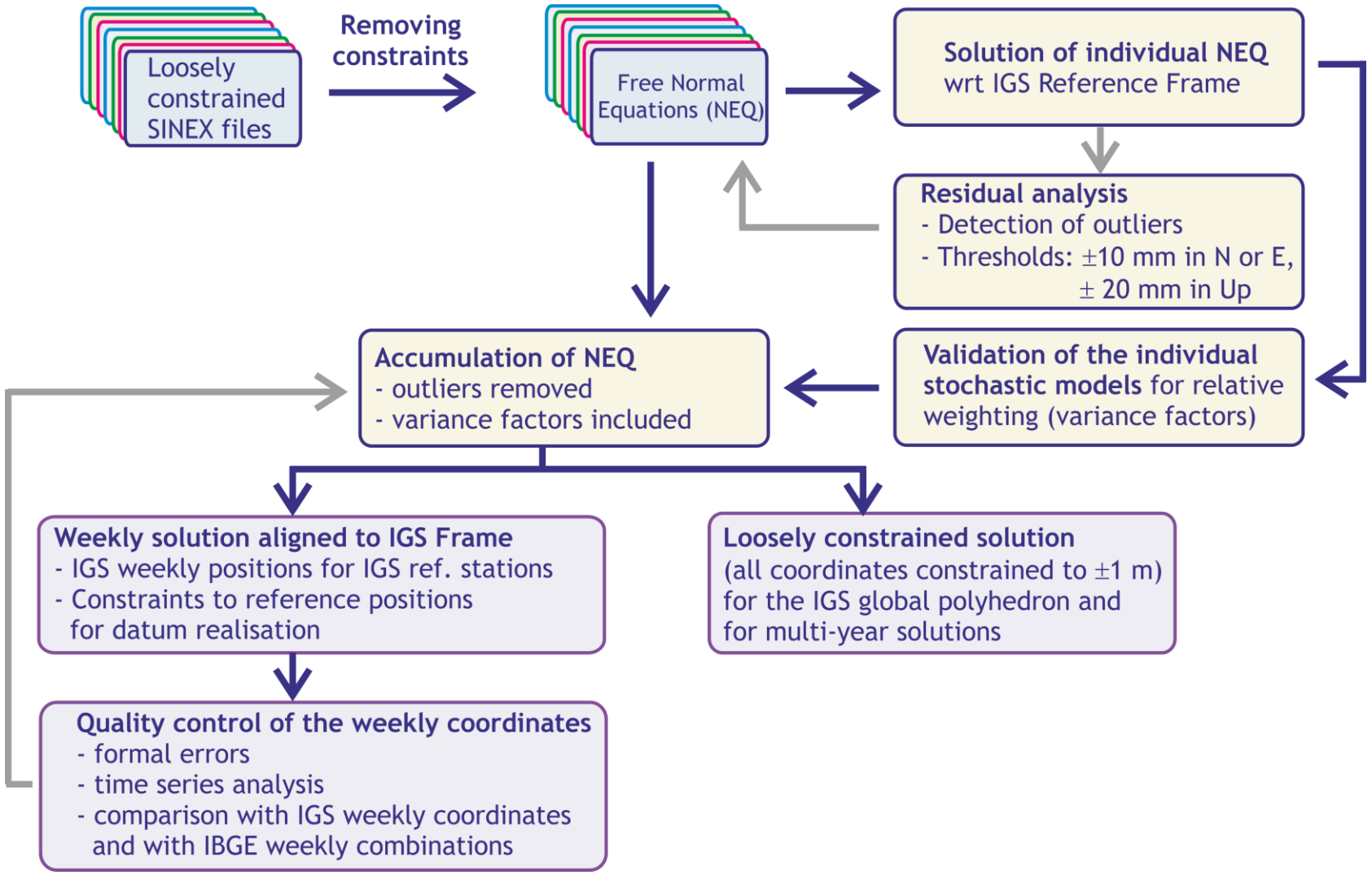
Processing of the SIRGAS-C core network

- Loosely constrained weekly solutions DGF*wwww*7.SNX.
- 142 stations.
- From 14 to 20 inactive stations for the period 01-09-2015 to 10-10-2016.
- Routinely processing of GPS and GLONASS observations according to the SIRGAS guidelines (IGS, IERS).
- Mean precision of the loosely constrained weekly solutions for the period 01-09-2015 to 10-10-2016 :

  N = 1.4 mm, E = 2.2 mm, Up = 4.6 mm
- Weekly solutions delivered to be combined with the SIRGAS-N networks.



Combination of the solutions delivered by the SIRGAS Processing Centres



Quality control of the individual solutions

Criteria:

- Standard deviation of station positions after solving the individual solutions with respect to the IGS reference frame (formal errors of the individual solutions).
- Weekly repeatability of station coordinates for each Processing Centre (individual precision of the weekly coordinate solutions).
- Comparison with the IGS weekly coordinates for common stations (reliability of the individual solutions).

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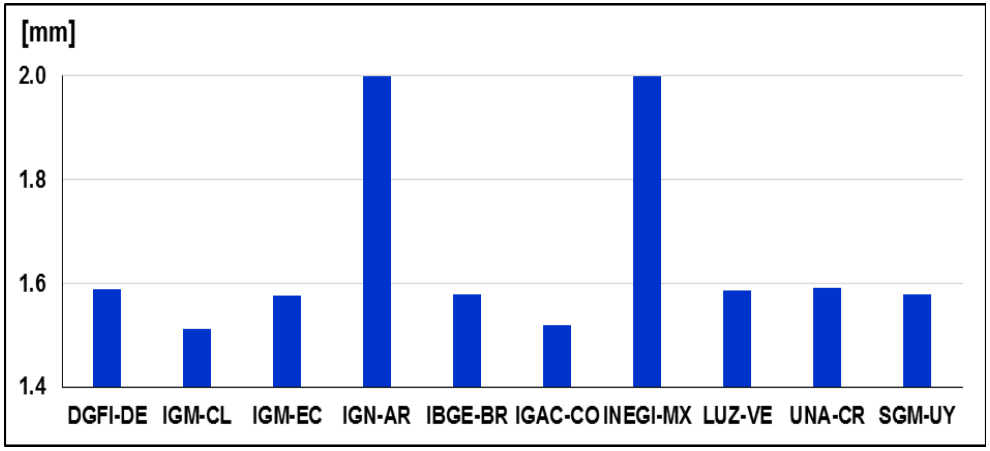
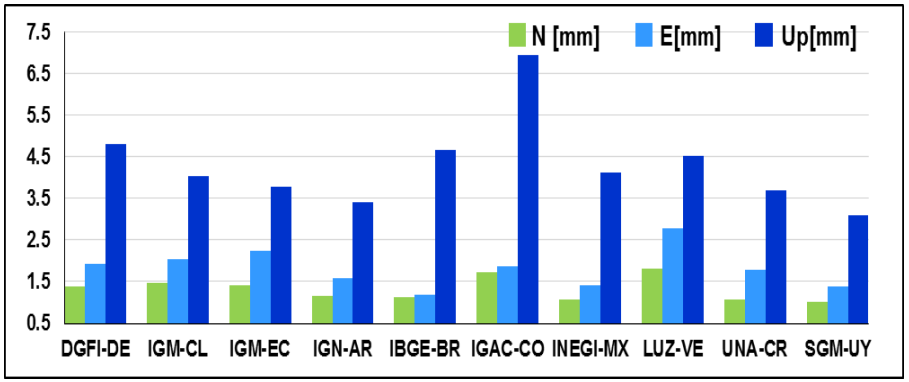
Formal errors of the individual solutions:



1) Individual standard deviations agree quite well:
   - ± 1.51 mm (IGM-CL, IGAC-CO)
   - ± 1.58 mm (DGFI-DE, IGM-EC, IBGE-BR, LUZ-VE, UNA-CR, SGM-UY)
   - ± 2.0 mm (IGN-AR, INEGI-MX)
2) Variance factors:
   - Bernese solutions: 1.0
   - GAMIT solutions: 0.8

Quality control of the individual solutions
(mean values between 01-09-2015 and 10-10-2016, 58 weeks)

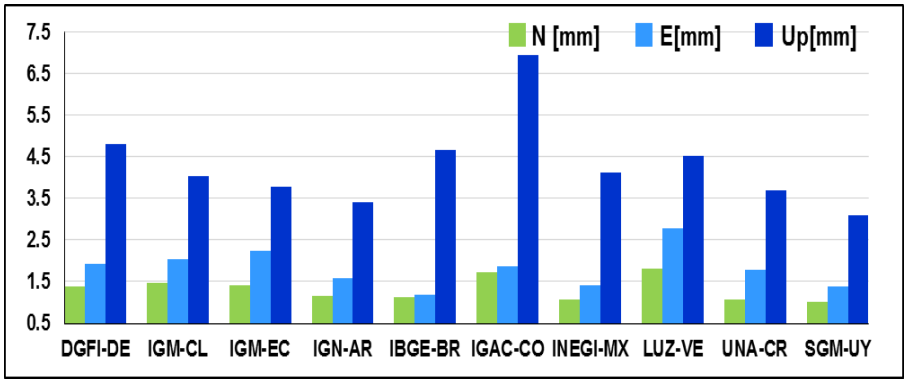
Consistency of the weekly coordinate in the individual solutions



1) Stations affected by earthquakes removed.
2) Internal consistency of the individual solutions:
   - horizontal: ±1.8 mm
   - Vertical: ±3.5 mm
3) Large values in the IGAC solutions unclear.

Quality control of the individual solutions
(mean values between 01-09-2015 and 10-10-2016, 58 weeks)

Consistency of the weekly coordinate in the individual solutions



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2) Internal consistency of the individual solutions:
   - horizontal: ±1.8 mm
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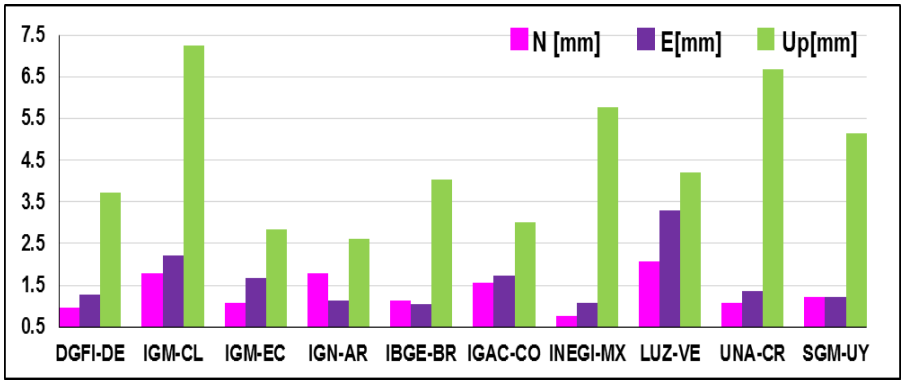
Reliability of the individual solutions (comparison with IGS)



1) Reliability (external accuracy) of the individual solutions:
   - horizontal: ±1.3 mm
   - vertical: ±4 mm
2) Large up values in INEGI-MX, LUZ-VE, UNA-CR solutions caused by Mexican stations processed by IGS with wrong antenna model.
3) Large values in LUZ-VE solutions caused by inactive IGS stations in the Caribbean.
4) Large residuals in IGM-CL solutions caused by a lack of IGS reference stations in the southern part of the SIRGAS region.

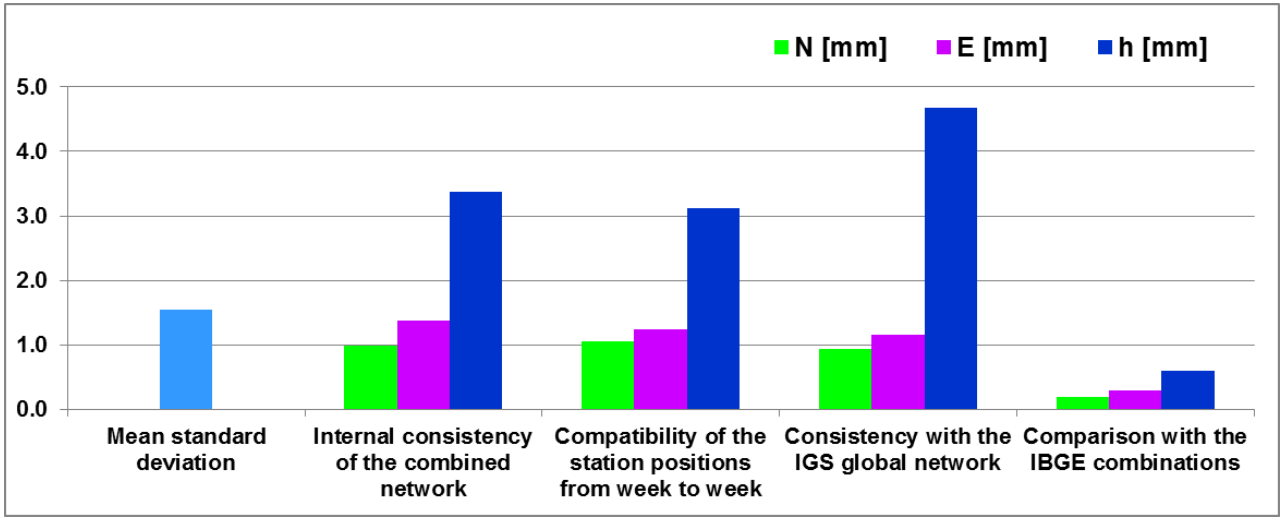
Quality control of the SIRGAS weekly coordinates

Criteria:

- Mean standard deviation for station positions after aligning the network to the IGS reference frame (formal error of the final combination).
- Residual analysis after combining the individual solutions (internal consistency of the combined network).
- Time series analysis for station coordinates (compatibility of the combined solutions from week to week).
- Comparison with the weekly IGS coordinates (consistency with the IGS global network).
- Comparison with the IBGE weekly combination (redundancy to ensure the quality of the SIRGAS weekly station positions).

Quality control of the SIRGAS weekly coordinates

(mean values between 01-09-2015 and 10-10-2016, 58 weeks)



1) Agreement between standard deviations (of individual solutions and combination) indicates that the quality of the individual solutions is maintained and their combination does not deform or damage the internal precision of the entire SIRGAS reference network.
2) Precision (internal consistency) of the weekly combinations is about ±1.0 mm in the horizontal component and ±3.0 mm in the vertical one.
3) Reliability of the final coordinates (external accuracy) is about ±1.0 mm in the horizontal position and ±4.7 mm in the height (similar to the individual solutions).

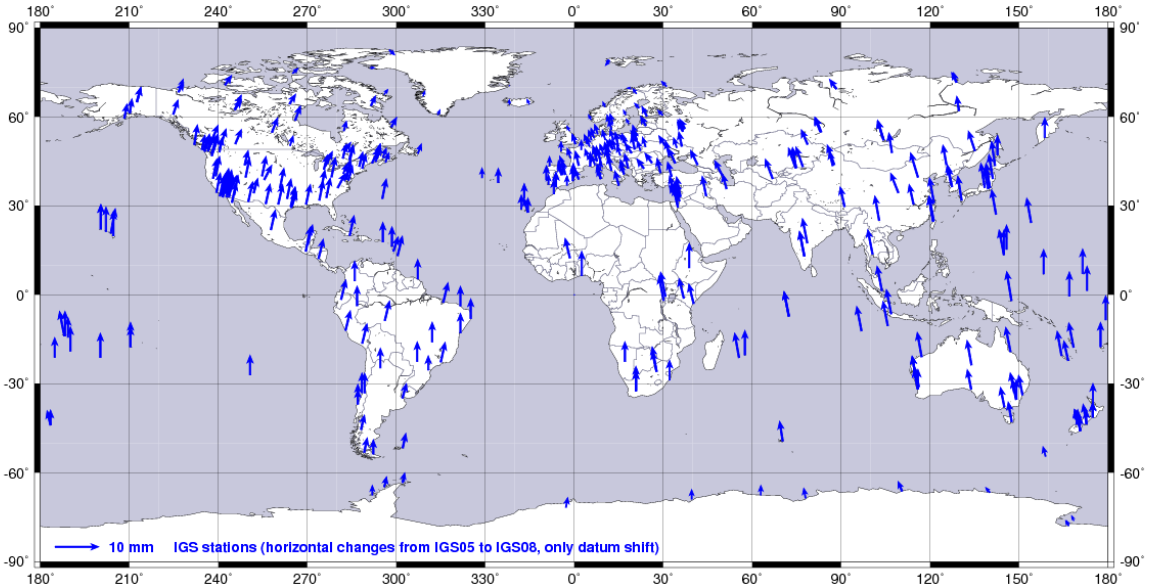
The ITRF and the IGS reference frames

1) The GNSS stations included in the ITRF solutions do not present a homogenous performance and precision.
2) The IGS periodically selects a set of globally distributed, stable GPS sites to be used as the reference frame for the computation of the IGS final products (i.e. satellite orbits, satellite clock estimations, Earth orientation parameters, etc.).
3) The main selection criteria are the station performance, track record, monumentation, co-location with other geodetic space techniques, and geographical distribution.
4) These so-called IGS reference stations are in principle minimally constrained to the current ITRF and their coordinate sets are internally more consistent than the original ITRF coordinates.
5) It is expected that the network (frame) composed by the IGS reference stations is completely equivalent to the ITRF in orientation, translation and scale. In this way, the IGS final products can be considered to be nominally in the current ITRF.

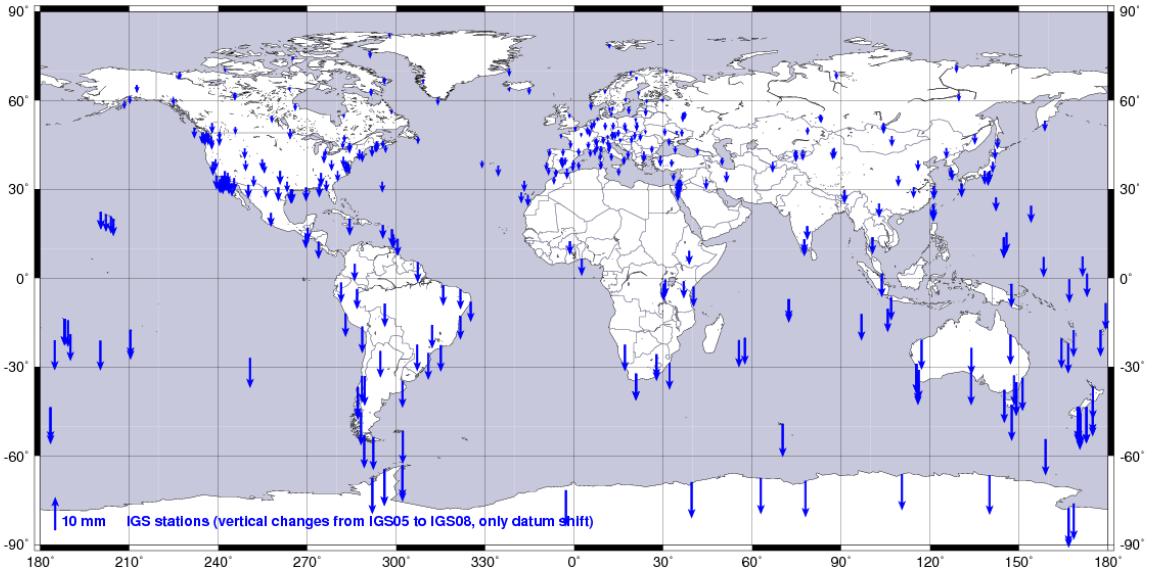
The ITRF and the IGS reference frames

Period of utilization	ITRF	IGS reference frame	Main characteristics
1994-01-02 to 1994-12-31	ITRF92		
1995-01-01 to 1996-01-29	ITRF93		
1996-01-30 to 1998-02-28	ITRF94		
1998-03-01 to 1999-07-31	ITRF96		
1999-08-01 to 2000-06-10	ITRF97		
2000-06-11 to 2001-12-01	ITRF97	IGS97	51 reference stations, IGS cumulative solution for week 1046 minimally constrained to the ITRF97 values.
2001-12-02 to 2004-01-03	ITRF2000	IGS00	54 reference stations, IGS cumulative solution for week 1131 minimally constrained to the ITRF2000 values.
2004-01-04 to 2006-11-04	ITRF2000	IGb00	106 reference stations, IGS cumulative solution for week 1232 minimally constrained to the ITRF2000 values.
2006-11-05 to 2011-04-16	ITRF2005	IGS05	132 reference stations, parallel processing using absolute and relative phase centre corrections for 34 weeks.
2011-04-17 to 2012-10-06	ITRF2008	IGS08	232 stations, 91 of them are core stations. Differences between IGS08 and ITRF2008 coordinates are station-specific and they reflect antenna calibration updates.
2012-10-07 …	ITRF2008	IGb08	50 IGS08 stations are lost (earthquakes, removed, etc.). 36 additional ITRF2008 stations are included to the IGS frame.

From IGS05 to IGS08: changes in the global network



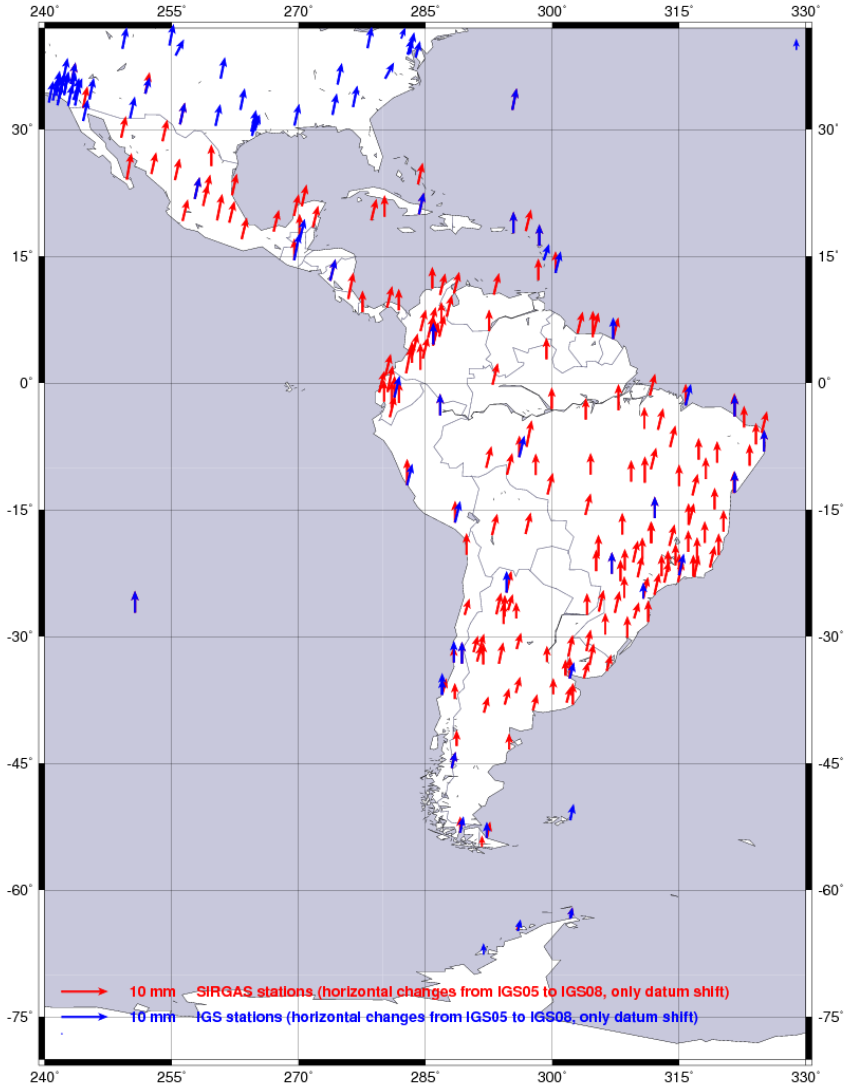
Horizontal



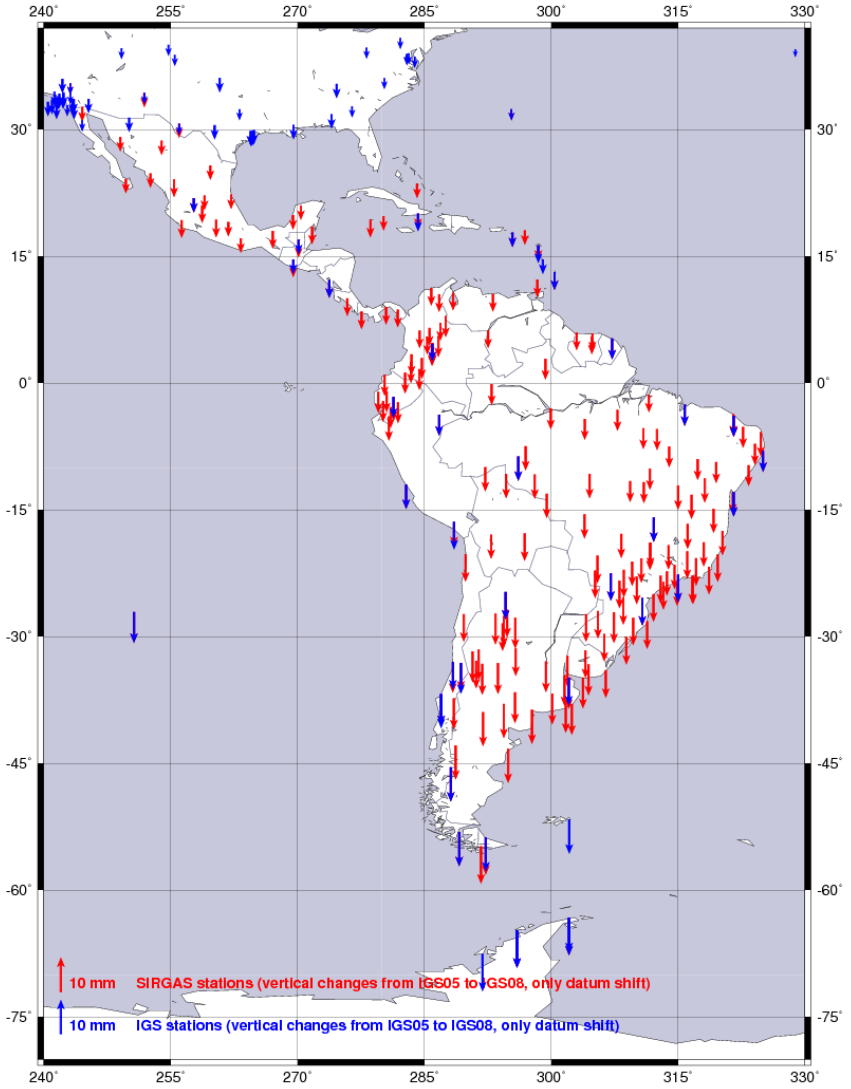
Vertical

From IGS05 to IGS08: changes in the SIRGAS network

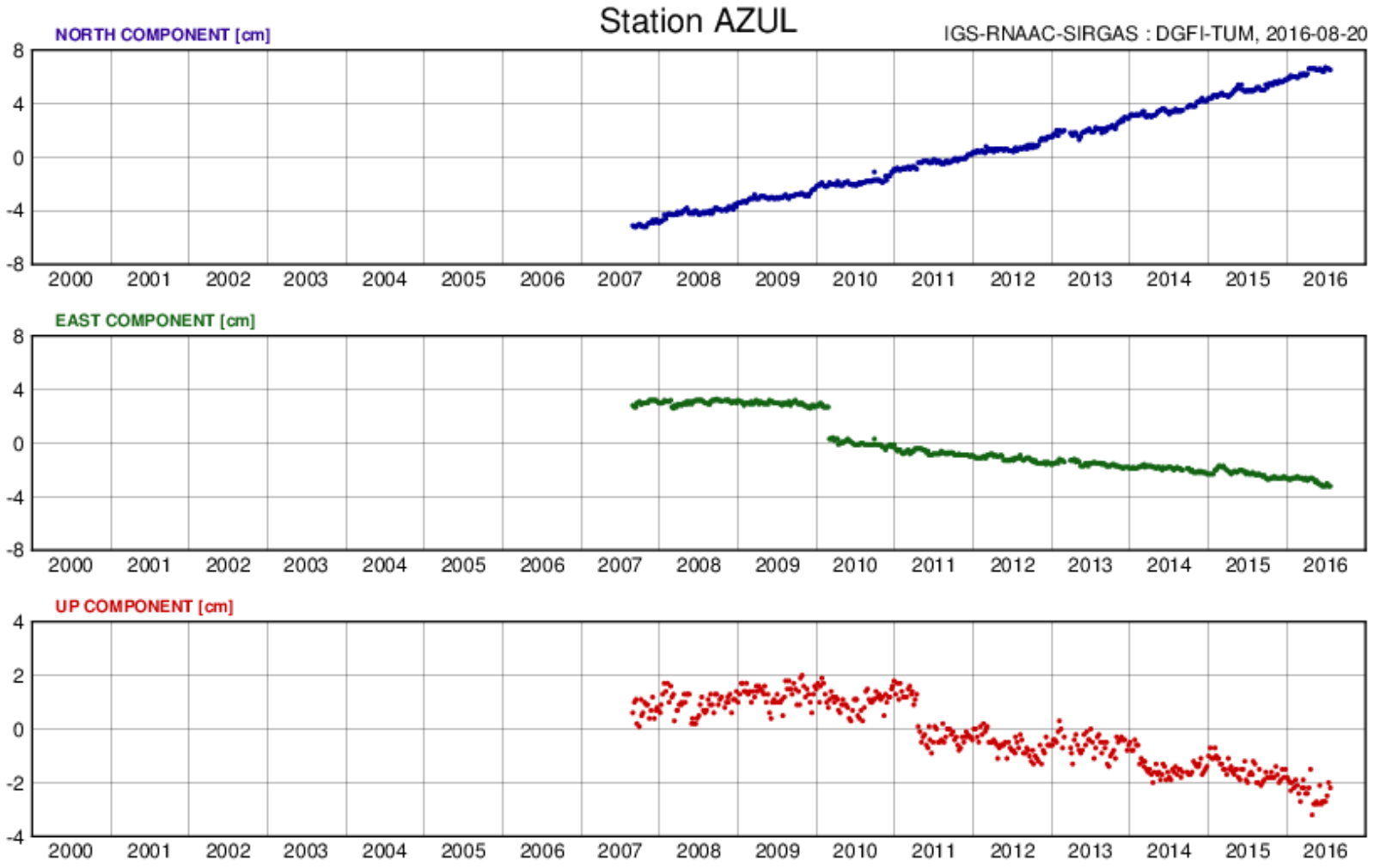
Horizontal



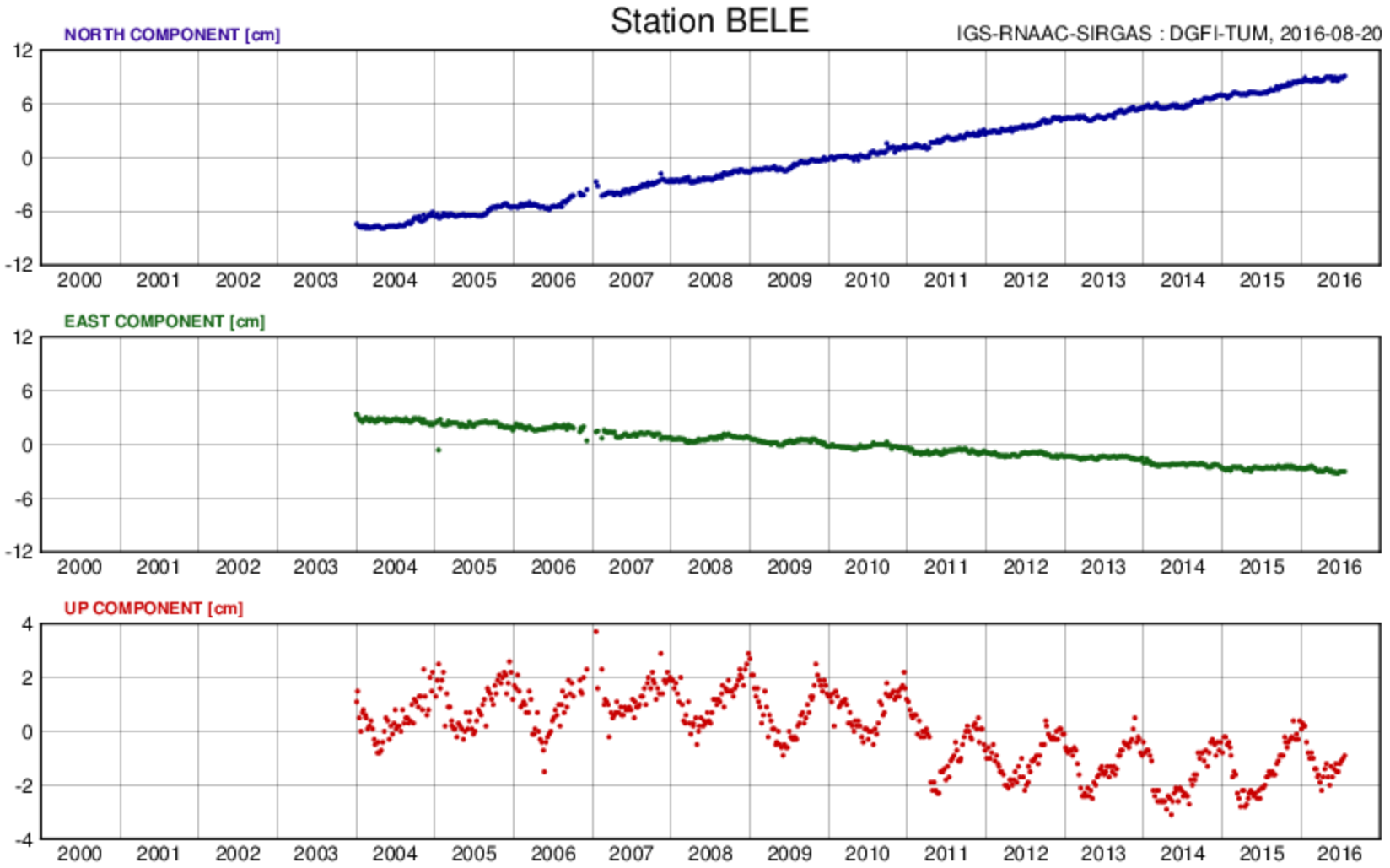
Vertical



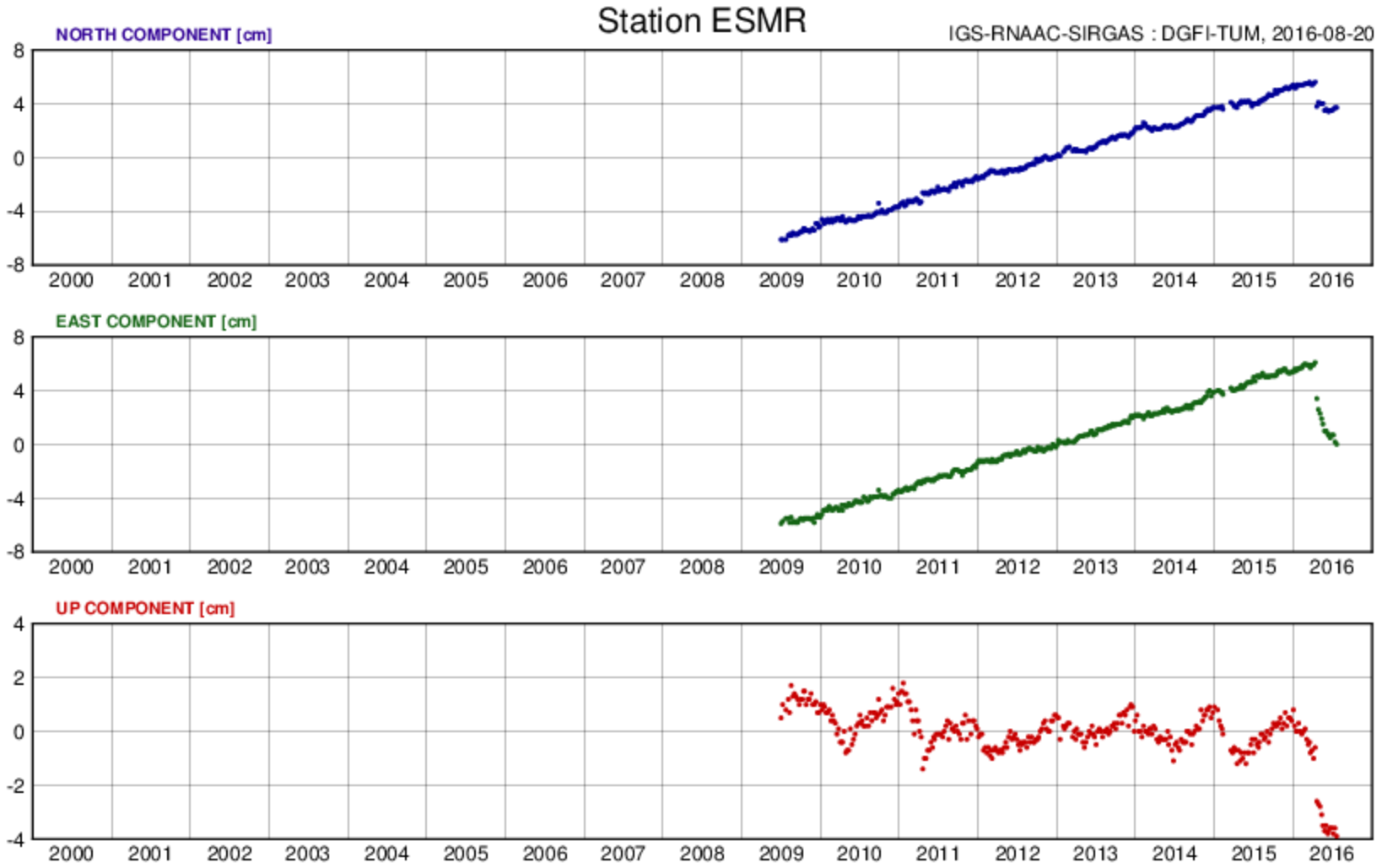
From IGS05 to IGS08: changes in the SIRGAS network



From IGS05 to IGS08: changes in the SIRGAS network



From IGS05 to IGS08: changes in the SIRGAS network

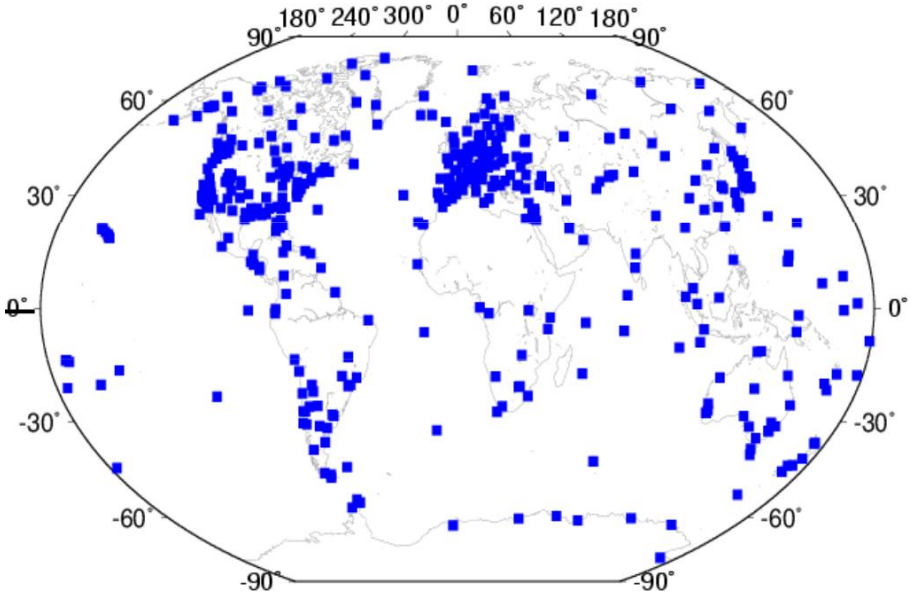


The ITRF2014 and SIRGAS

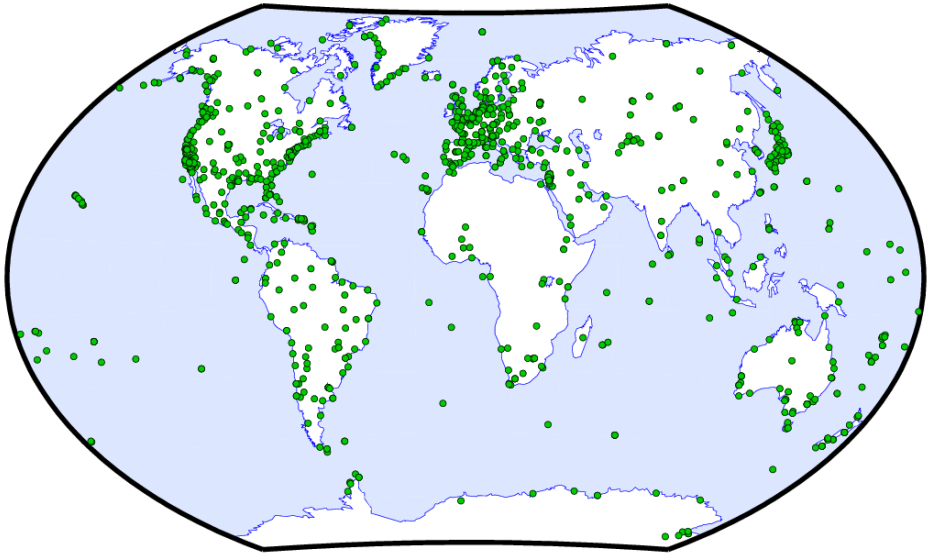
1) The new ITRF2014 was released in January 2016.
2) The IGS is adapting its processing strategies and reference network (IGS14) to adopt the ITRF2014 as reference frame for the generation of its products.
3) Once the IGS introduces the ITRF2014 as reference frame, SIRGAS has also to migrate to the ITRF.
4) It is expected, this happens in January 2017.

On-going and planned activities

1) To prepare the introduction of the ITRF2014 (IGS14) as reference frame (as replacement of the IGb08):
   - To select additional IGS stations to be processed within SIRGAS (to increase the availability of fiducial stations)



IGS/GPS stations in ITRF2008



IGS/GNSS stations in ITRF2014

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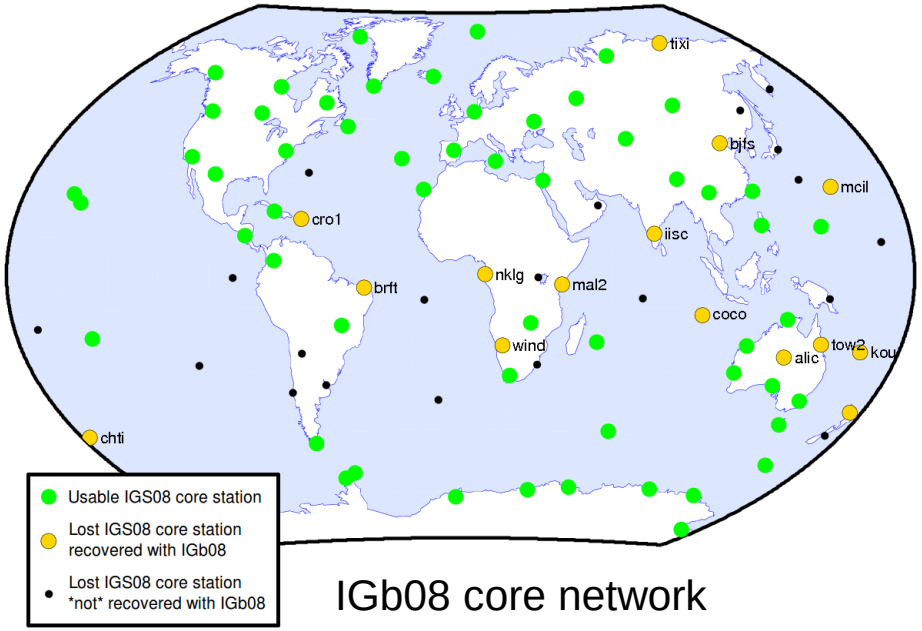
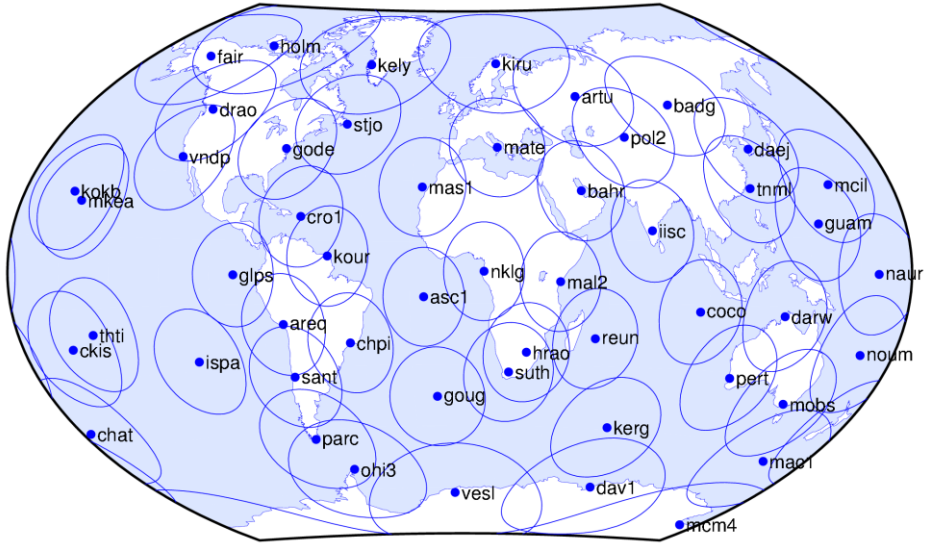


IGb08 core network



IGS14 core network

- IGS stations used at present as fiducial stations in SIRGAS (21 stations): BOGT, BRAZ, BRFT, CHTI, CRO1, GOLD, GUAT, MAS1, MDO1, MKEA, NKLG, OHI2, PALM, PARC, PDEL, SCUB, SUTH, THTI, USNO, VESL, WIND (in red IGb08 stations excluded from IGS14 core network, 13 stations)
- Stations within the SIRGAS reference frame newly declared as IGS core reference stations (4 stations): AREQ, CHPI, ISPA, KOUR

On-going and planned activities

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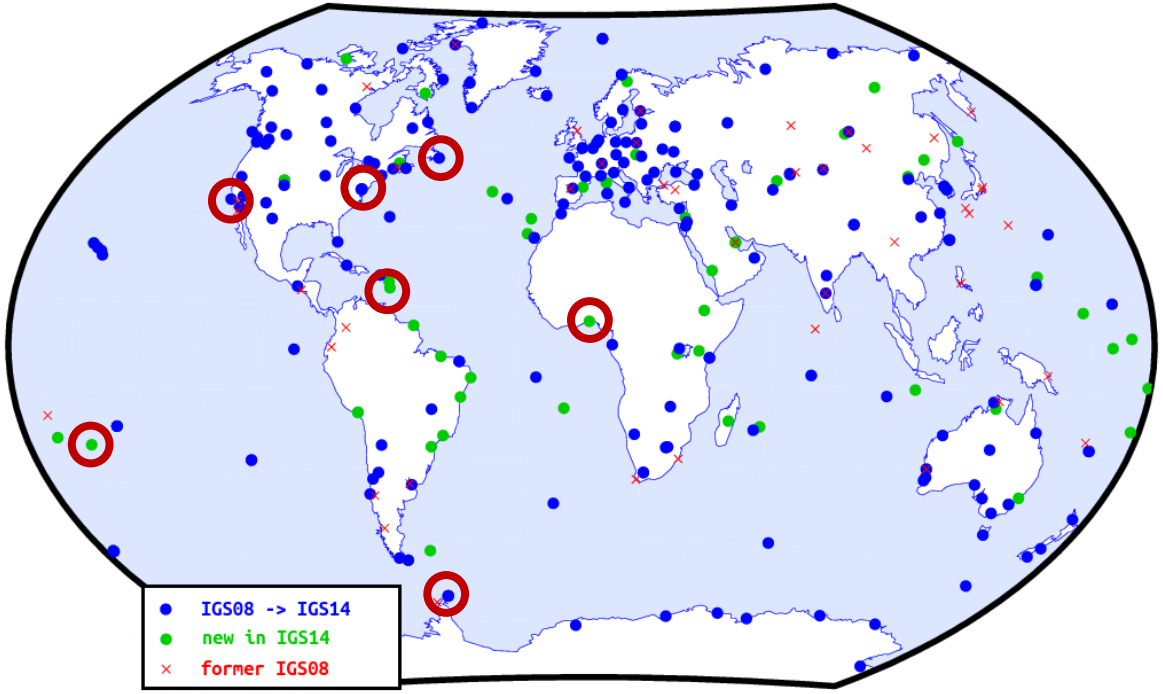
   - To select additional IGS stations to be processed within SIRGAS (to increase the availability of fiducial stations)

In agreement with the SIRGAS-WG1, following IGS stations are added to the SIRGAS network:

BJCO	CKIS
GODE	KOKB
LMMF	OHI3
STJO	VNDP



IGS14 core network

On-going and planned activities

1) To prepare the introduction of the ITRF2014 (IGS14) as reference frame (as replacement of the IGb08):
   - To select additional IGS stations to be processed within SIRGAS (to increase the availability of fiducial stations).
   - To evaluate the impact of the IGS14-based antenna phase centre offsets and variations on the ground stations' coordinates: They all exceed 1 mm in at least one component except for AOAD/M_T NONE, AOAD/M_TA_NGS NONE, TPSCR.G5 TPSH, TRM29659.00 NONE.

On-going and planned activities

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   - To evaluate the impact of the IGS14-based antenna phase centre offsets and variations on the ground stations' coordinates: They all exceed 1 mm in at least one component except for AOAD/M_T NONE, AOAD/M_TA_NGS NONE, TPSCR.G5 TPSH, TRM29659.00 NONE.
2) Parallel processing of weekly solutions for the SIRGAS-C core network referred to the IGb08 and to IGS14 to detect possible issues in the transition to the new reference frame.
3) To start reprocessing the SIRGAS reference network using the IGS14 as reference frame since 1997 until 2016. If IGS does not performed a new reprocessing of the global network, we will use IGb08-based products combined with the antenna model referred to IGS14. This is suitable as the transformation parameters between IGb08 and IGS14 are smaller than the accuracy of the IGS14 coordinates.

On-going and planned activities

5) Estimation of a new kinematic solution for the SIRGAS reference frame based on the reprocessed weekly solutions including:
   - Constant station velocities.
   - Approximation of post-seismic decays using logarithmical and exponential functions.
   - Estimation of annual and semi-annual signals (see Brunini et al. presentation).
6) Estimation of a new (updated) VEMOS model (see Drewes and Sánchez presentation).