SIRGAS: reference frame for the GNSS applications in Latin America

Laura Sánchez
SIRGAS Vice-president

Claudio Brunini
SIRGAS President

Presented by **Ruth Neilan**

Third Meeting of the
International Committee on Global Navigation Satellite Systems (ICG)

December 8 – 12, 2008
Pasadena, California, USA

Sistema de Referencia Geocéntrico para Las Américas

(Geocentric Reference System for the Americas)

Objectives

1. Definition, realization, and maintenance of a geocentric reference system:

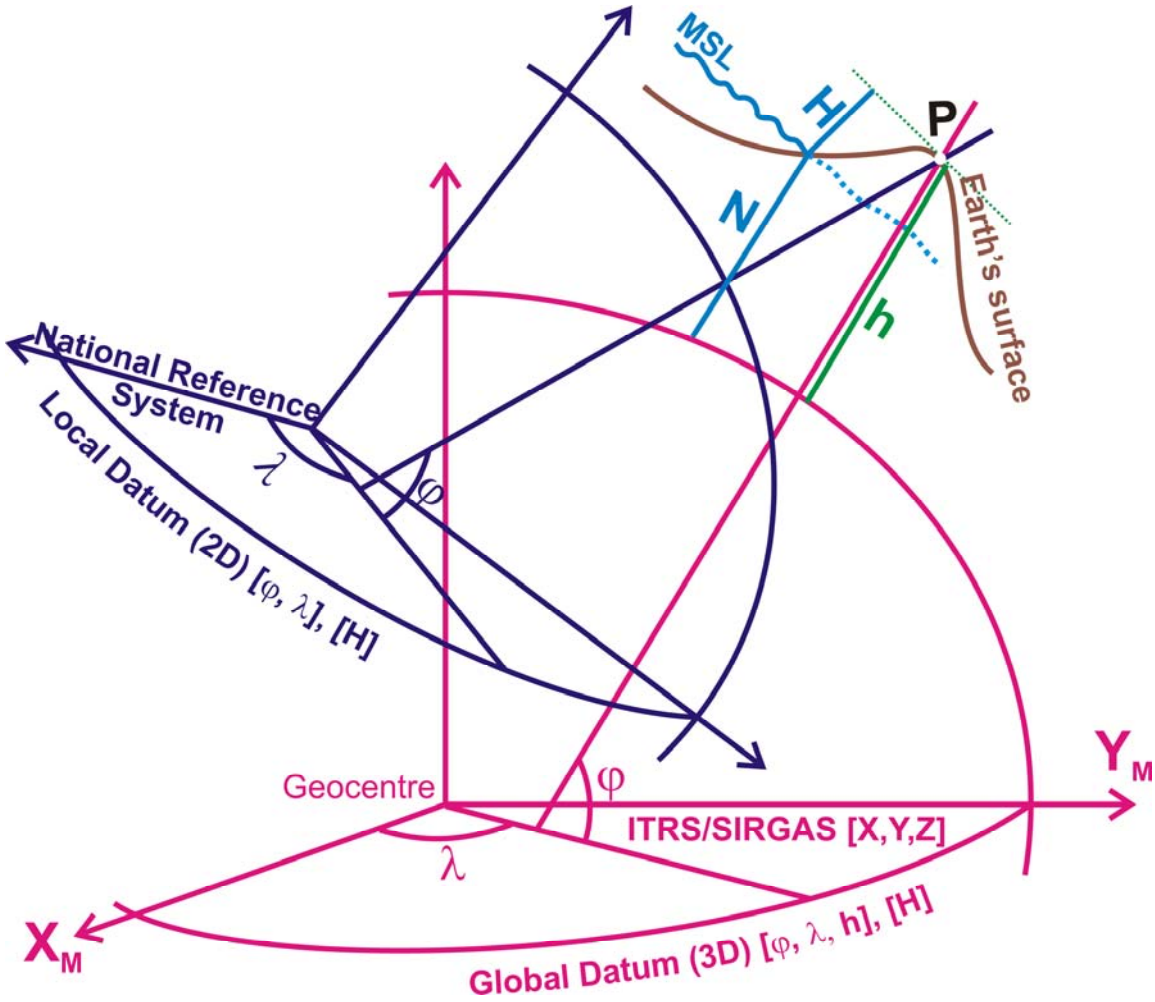
   $[X, Y, Z], [V_X, V_Y, V_Z]$

2. Densification (adoption and use) of the continental reference frame in the Latin American and Caribbean Countries:

   $[\varphi, \lambda]_{Local} \rightarrow [X, Y, Z]_{SIRGAS}$

3. Definition and realization of a unified vertical reference system, supporting physical and geometrical heights:

   $h = H + N; (V_h, V_H, V_N)$

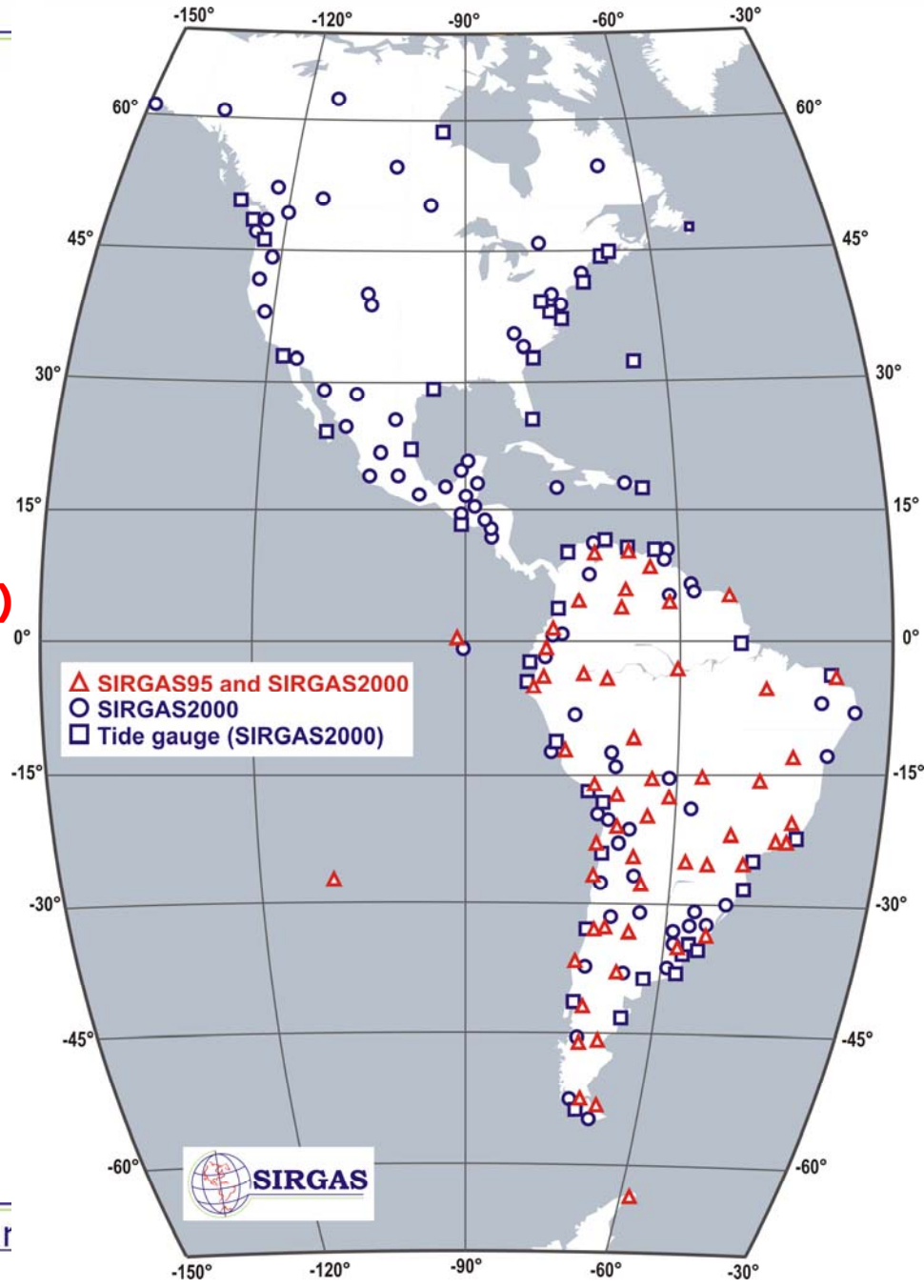


SIRGAS Realization

SIRGAS is a regional densification (**continental network**) of the global **ITRF** (International Terrestrial Reference Frame):

- by means of GPS campaigns:
  - **1) SIRGAS95 (ITRF94, 1995.4)** (58 stations over South America)
  - **2) SIRGAS2000 (ITRF2000, 2000.4)** (184 stations over North, Central, and South America)
- by means of continuously operating stations:
  - **3) SIRGAS-CON**

Realizations of SIRGAS by means of campaigns



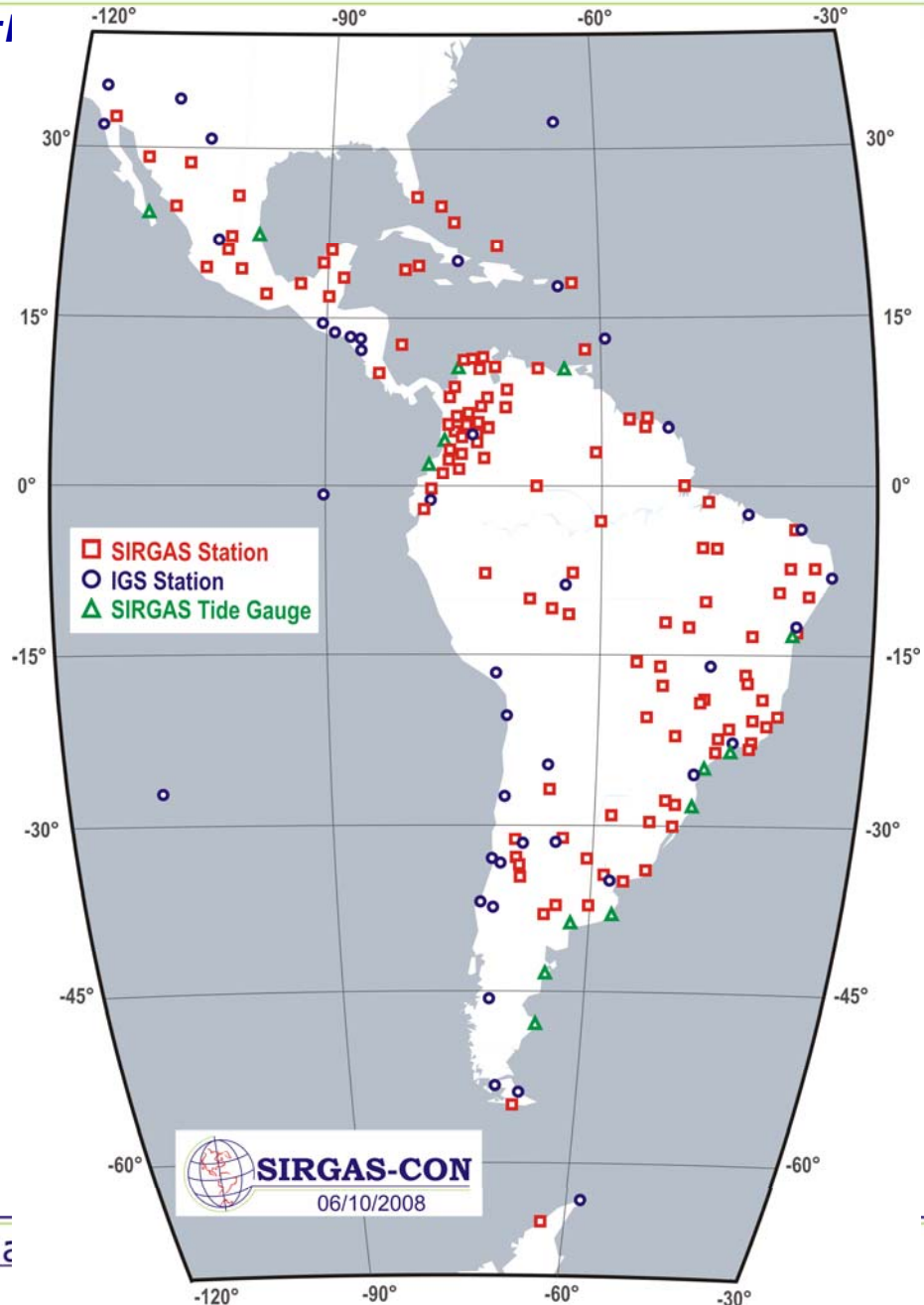
SIRGAS-CON

(SIRGAS Continuously Operating Networ

Realization of SIRGAS by means of continuously operating GNSS stations

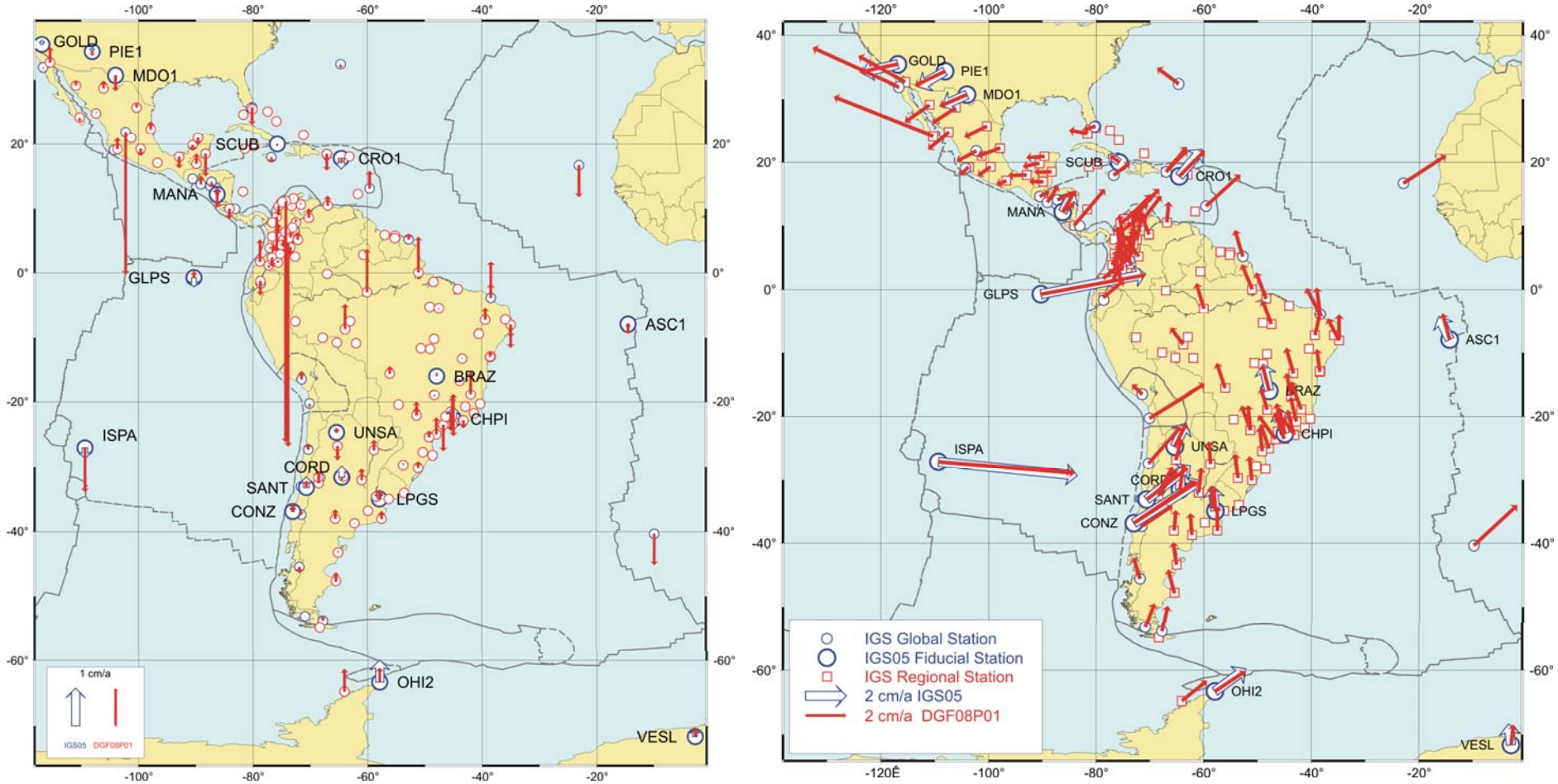
Number of continuously operating GNSS stations over 15 years of SIRGAS

Year	IGS Stations	Regional Stations	Sum
1993	5	0	5
1994	7	0	7
1995	10	0	10
1996	15	0	15
1997	15	6	21
1998	19	10	29
1999	24	14	38
2000	32	16	48
2001	35	17	52
2002	41	18	59
2003	47	19	66
2004	47	28	75
2005	48	55	103
2006	48	72	120
2007	48	128	176
present	**53**	**139**	**192**



SIRGAS-CON: Multi-year solution DGF08P01-SIR

ITRF2005 (IGS05), 2004.4. Precision: ± 2,2 mm (hor), ± 4,5 mm (up); ± 1 … 2 mm/a (vel).

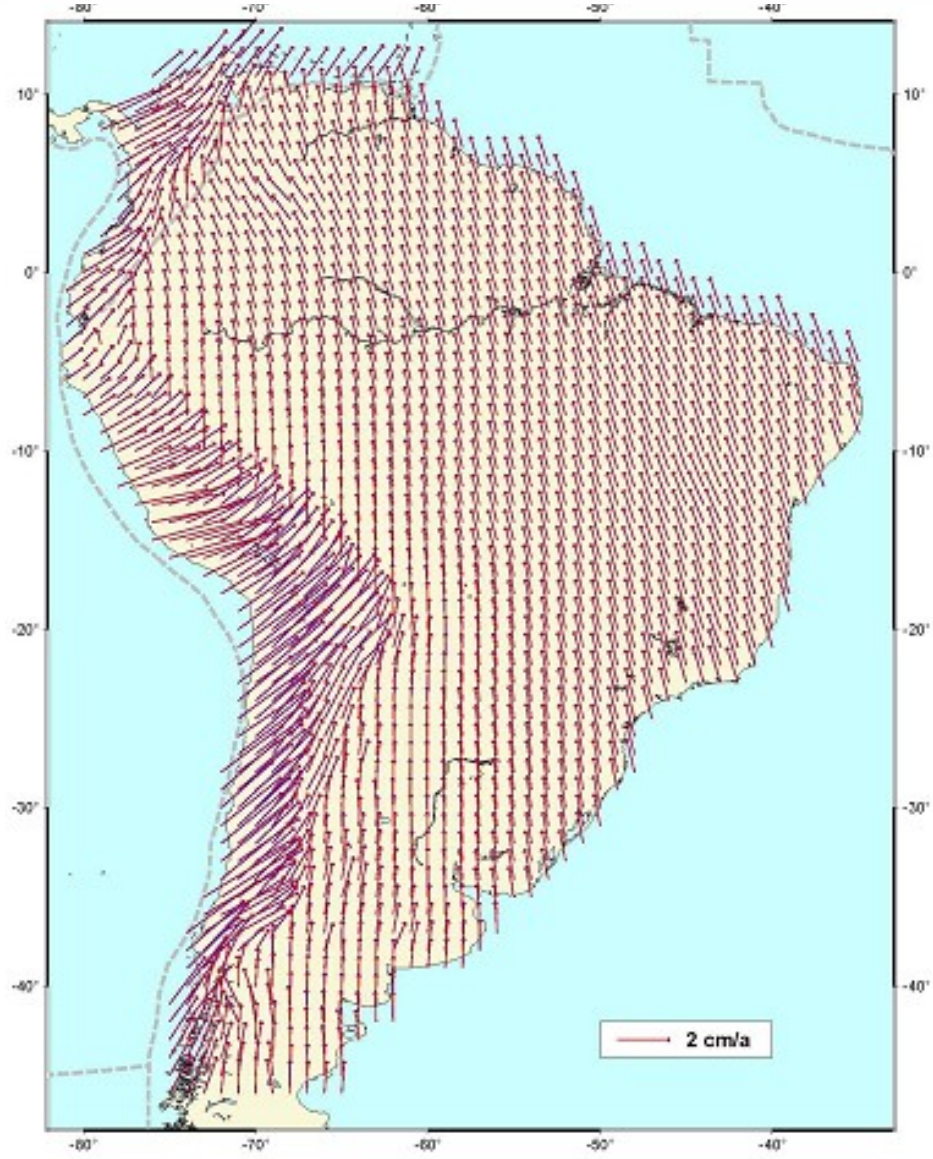


These velocities are applied to **translate station coordinates** from the observation epoch to the reference epoch of the different realizations (e.g. 1995.4, 2000.4, …)

Velocity Model for SIRGAS

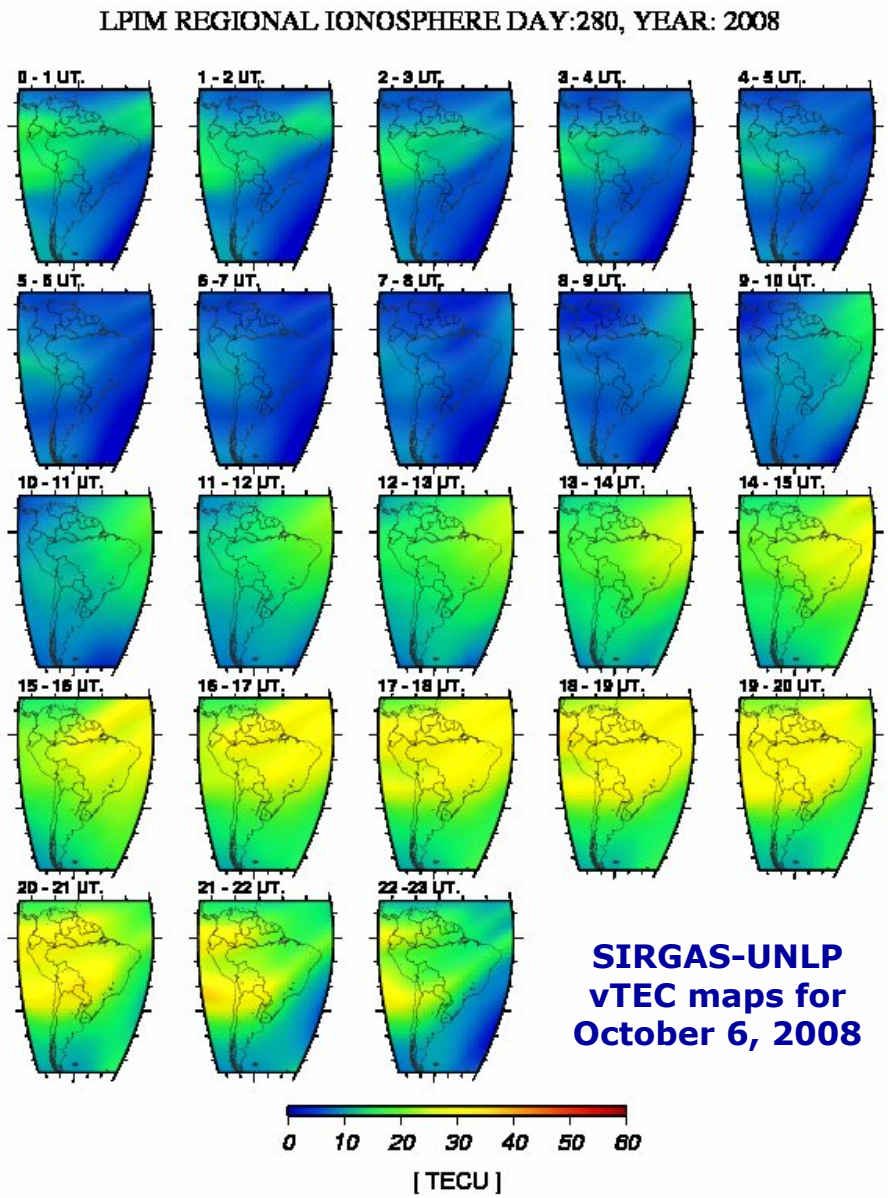
(Drewes and Heidbach 2005)

- Applied to **translate station coordinates** between reference and observation epochs for those stations not included in the multi-year solutions;
- Released in November 2003 (available at **www.sirgas.org**);
- Input data:
  - ✓ Velocities derived from SIRGAS95 and SIRGAS2000
  - ✓ SIRGAS-CON velocities
  - ✓ Velocities from geodynamic projects in South America (CAP, CASA, SAGA, SNAPP)
- The continuous velocity field is expressed in the **global** frame;
- Efforts are currently done to improve the velocity model, next version in 2008.



Ionosphere Analysis based on SIRGAS-CON

- Since July 2005, the **SIRGAS Analysis Centre for the Ionosphere** (Universidad Nacional de La Plata, Argentina), computes hourly maps of vertical total electron content (vTEC) in 1°x 1° grids over South America.
- These maps are applied for:
  1. validation of the International Reference Ionosphere (IRI);
  2. improvement of positioning with single-frequency GPS receivers;
  3. feasibility of computing ionospheric corrections for a satellite based augmentation system (SBAS) for the region (supported by the International Civil Aviation Organization - ICAO).
- SIRGAS-UNLP vTEC maps in numerical and graphical formats as well as in daily movies are available at **www.sirgas.org**.



SIRGAS-UNLP vTEC maps for October 6, 2008

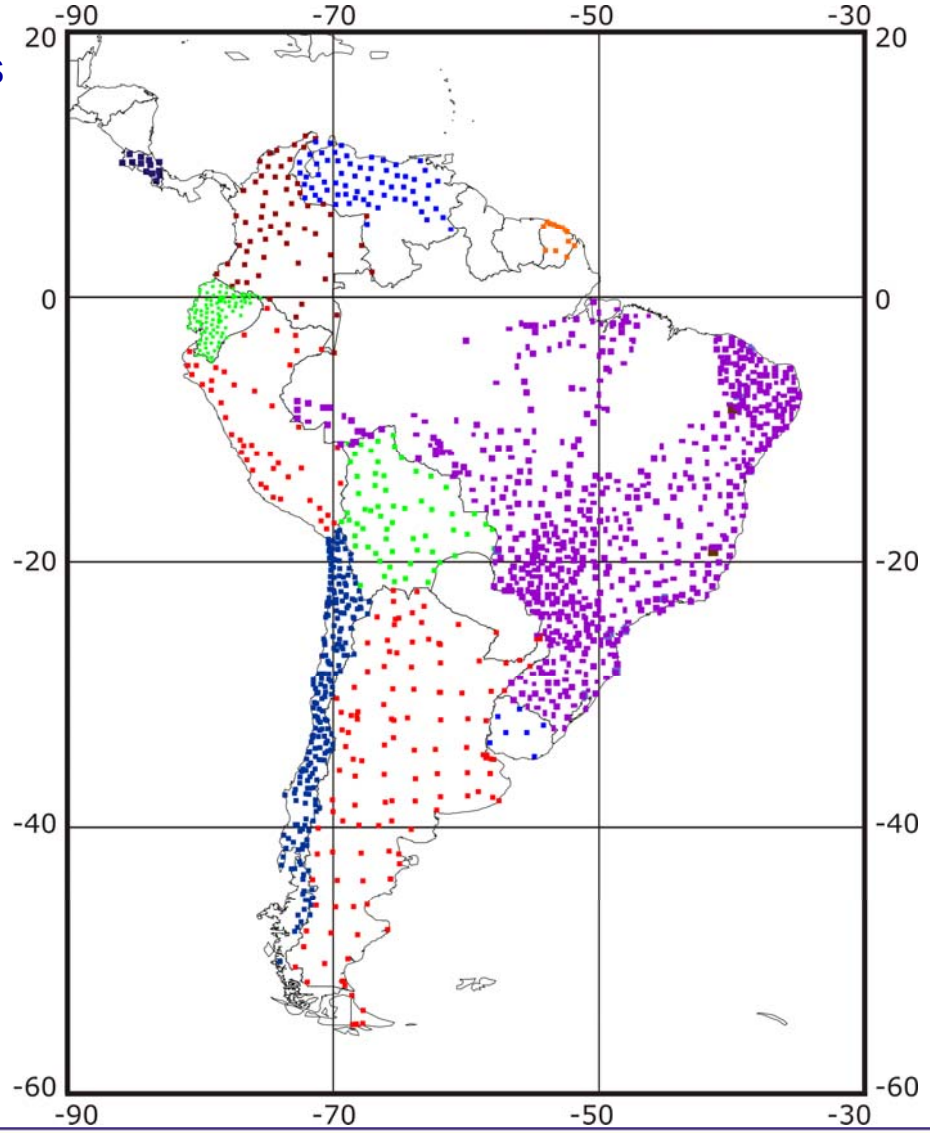
National densifications of SIRGAS

The national reference frames are **local densifications** of the continental network (national networks by means of campaigns and continuously operating stations, COS).

Country	SIRGAS/ITRF Densification	No. Stations Pillars/COS
Argentina	SIRGAS95, 1995.4	139 / 22
Bolivia	SIRGAS95, 1995.4	125 / 8
Brazil	SIRGAS2000, 2000.4	1903 / 56
Chile	SIRGAS2000, 2002.0	269 / 13
Colombia	SIRGAS95, 1995.4	70 / 35
Costa Rica	ITRF2000, 2005.8	34 / 1
Ecuador	SIRGAS95, 1995.4	135 / 4
F. Guiana	ITRF93, 1995.0	7 / 1
Mexico	ITRF92, 1988.0	0 / 17
Panama	ITRF2000, 2000.0	20 / 3
Peru	SIRGAS95, 1995.4	47 / 1
Uruguay	SIRGAS95, 1995.4	17 / 3
Venezuela	SIRGAS95, 1995.4	156 / 4

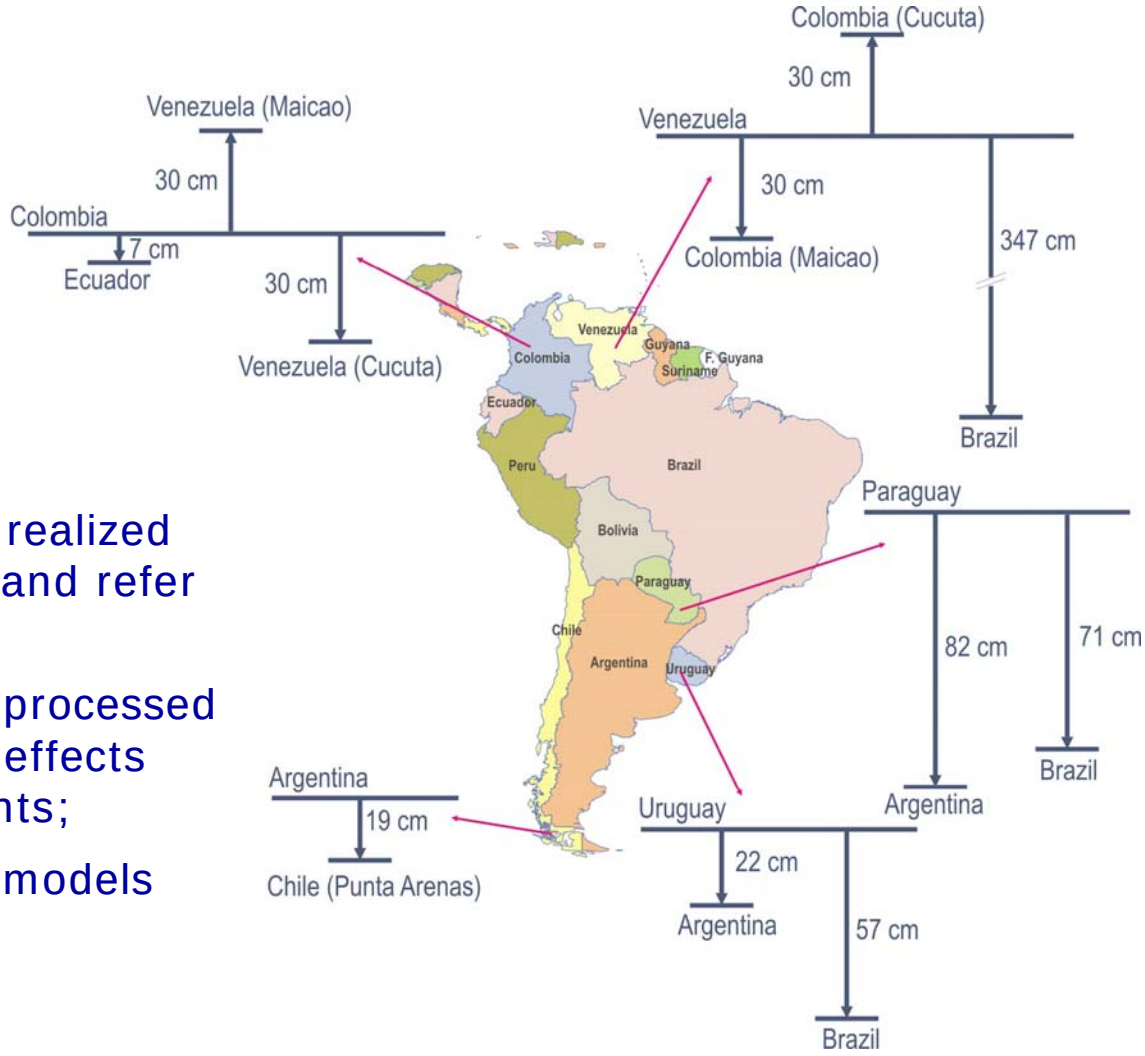
SIRGAS is the official national reference system in **13 of 18** member countries.

Densifications of SIRGAS by means of campaigns



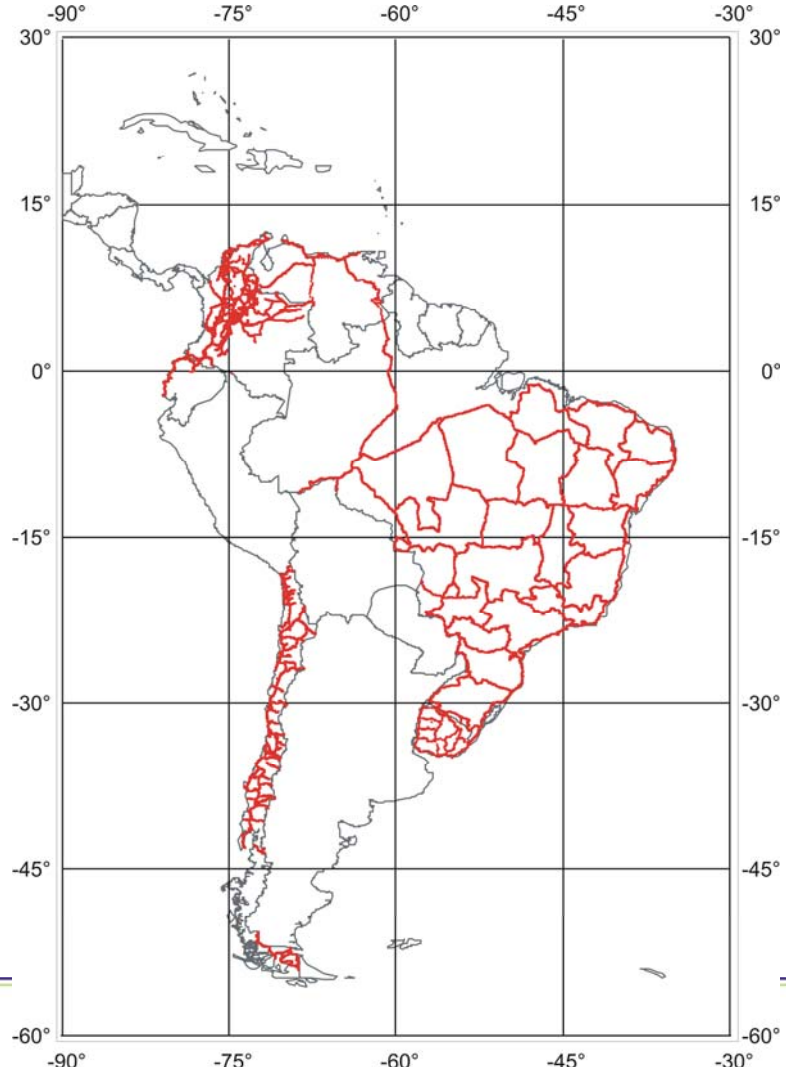
Height systems in Latin America

- Existing height systems in Latin America are not consistent, neither with each other nor with the GNSS-derived heights (in combination with geoid models), i.e. **h ≠ H + N**;
- Reference levels (H = 0) are realized by different mean sea levels and refer to different epochs;
- Vertical networks have been processed omitting Earth's gravity field effects and vertical crustal movements;
- High resolution (quasi)geoid models are not accurate enough.



Vertical Reference System for SIRGAS

- It shall support $h = H^N + \zeta \ (\approx H + N)$ in a global frame with high accuracy ($> 10^{-9}$)
- It comprises: a geometrical component **[h(t), dh/dt]** and a physical component **[H^N(t), dH^N/dt, ζ(t), $d\zeta/dt$]**;
- Geometrical component **is achieved** by adopting and applying SIRGAS as reference frame.
- Physical component requires (**on-going activities**):
  1. To refer all national vertical networks to one and the same equipotential surface (**continental adjustment** of first order levelling lines in terms of geopotential numbers);
  2. To reduce all physical heights to a unified reference epoch (**vertical movements** of mean sea level, of reference tide gauges, of levelled points);
  3. Determination of a **unified quasigeoid** model for the SIRGAS region.



Closing remarks

- The 7th United Nations Regional Cartographic Conference for the Americas (New York, January 2001) recommended the adoption of SIRGAS as official reference frame in all countries of the Americas.
- In the 15 years of SIRGAS, the geo-data community and non-specialist users gradually understand the necessity and convenience to take SIRGAS as reference frame for their activities. Today SIRGAS is the basis for e.g. digital cartography, geo information systems, spatial data infrastructures, navigation, augmentation systems, geophysical exploration, engineering projects, etc.
- SIRGAS is also the platform for a wide range of scientific applications such as the monitoring of cortical deformations, vertical movements, sea level variations, atmospheric studies, etc.
- Besides providing a geodetic reference frame for Latin America and the Caribbean, SIRGAS has been a crucial tool for capacity building in these regions. Thanks to the knowledge transfer and training, today many Latin American scientists are responsible and evolved in scientific projects and analysis centres, which performance is at the same quality level of those from “developed” countries.
- In a global frame, SIRGAS represents one of the most successfully initiatives in international (voluntary) cooperation.