Sistemas de Referência Geocêntrico no mundo

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International Association of Geodesy
Commission 1 “Reference Frames“

Reference Systems and Reference Frames

Definition:

Reference **systems** are needed to determine parameters (e.g., coordinates) from geodetic observations. They are **defined** by constants, models, etc., which serve as necessary constraints for the parameter estimation (e.g., speed of light, three-dimensional geocentric system, …).

Realization:

Reference **frames** realize (materialize) a reference system by a set of physical quantities with numerical values (e.g., a set of monuments at the Earth’s surface with given coordinates).

Classical and Modern Reference Systems

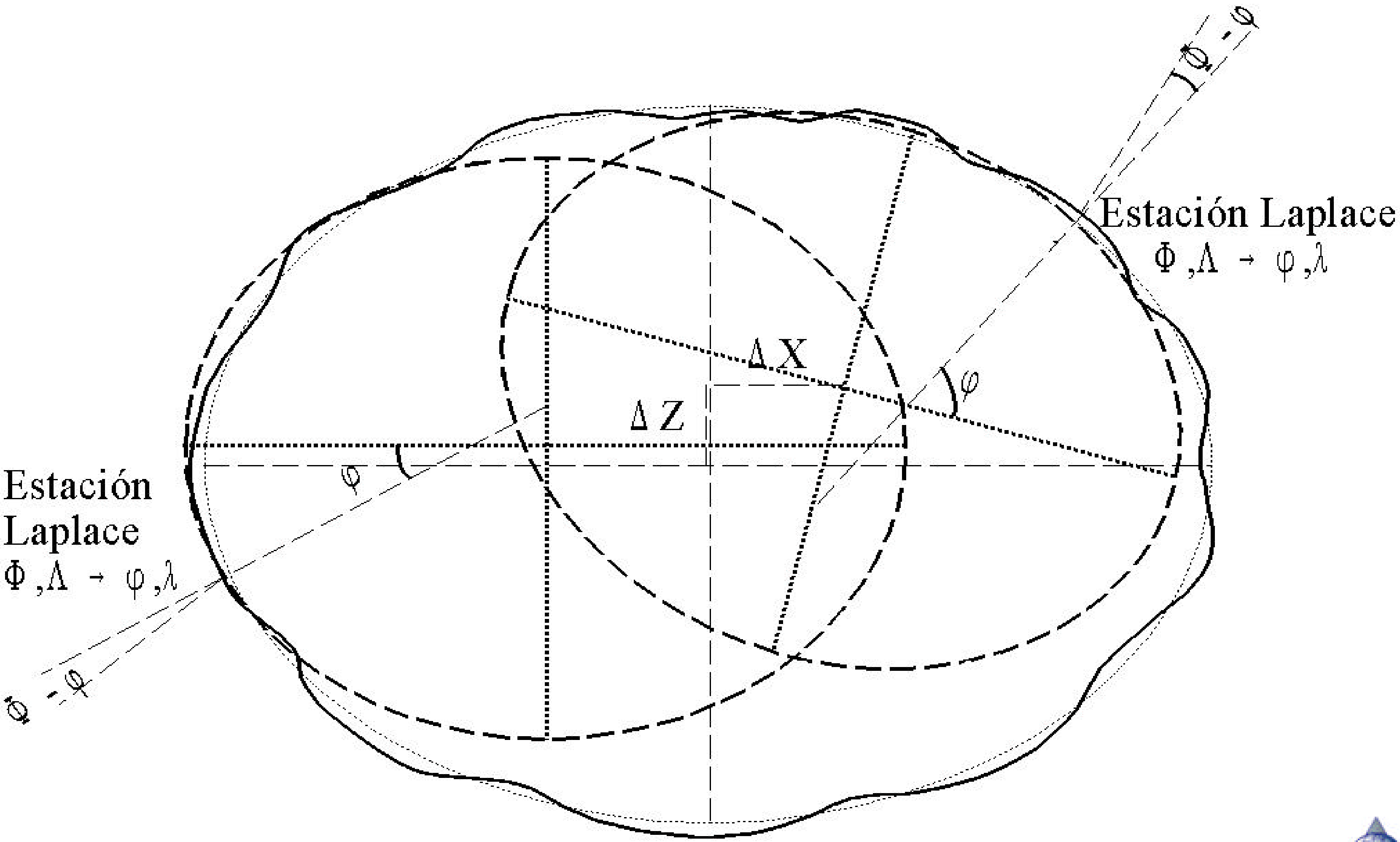
Classical reference systems connect **classical** observations (terrestrial directions, angles, distances, …) with **classical** parameters (e.g., regional coordinates).

They are in general locally defined in its position (given coordinates of a fundamental station) and spatial orientation (azimuth and deflections of the vertical), e.g., SAD $\Rightarrow$ Chua.

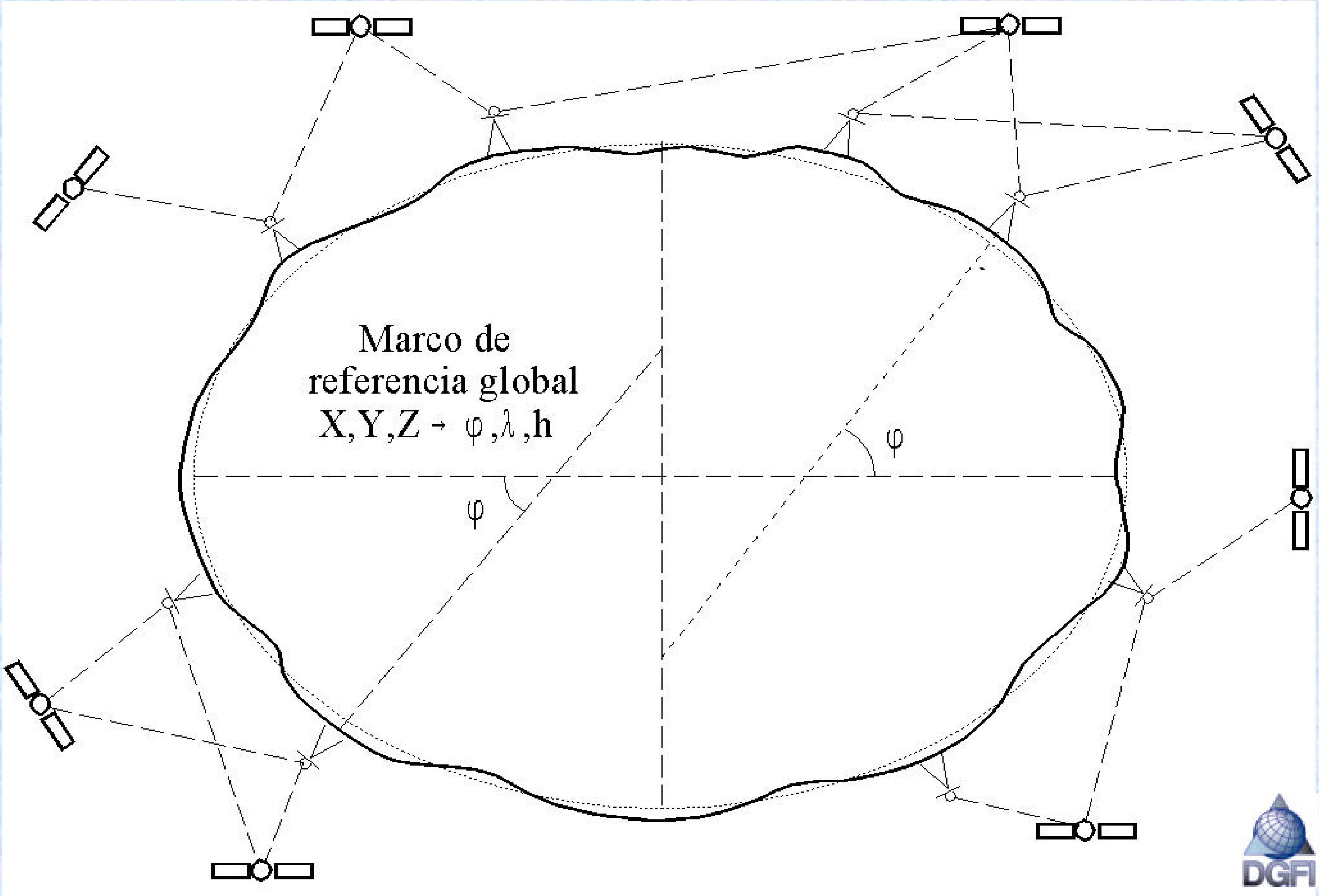
Modern reference systems connect **modern** observations (space techniques, e.g., GPS) with **modern** parameters (three-dimensional geocentric coordinates).

They are defined geocentrically because the satellites' orbits refer to the geocenter due to Kepler's law.

Classical Reference Systems



Modern Reference Systems



Necessity of Consistent Reference Systems

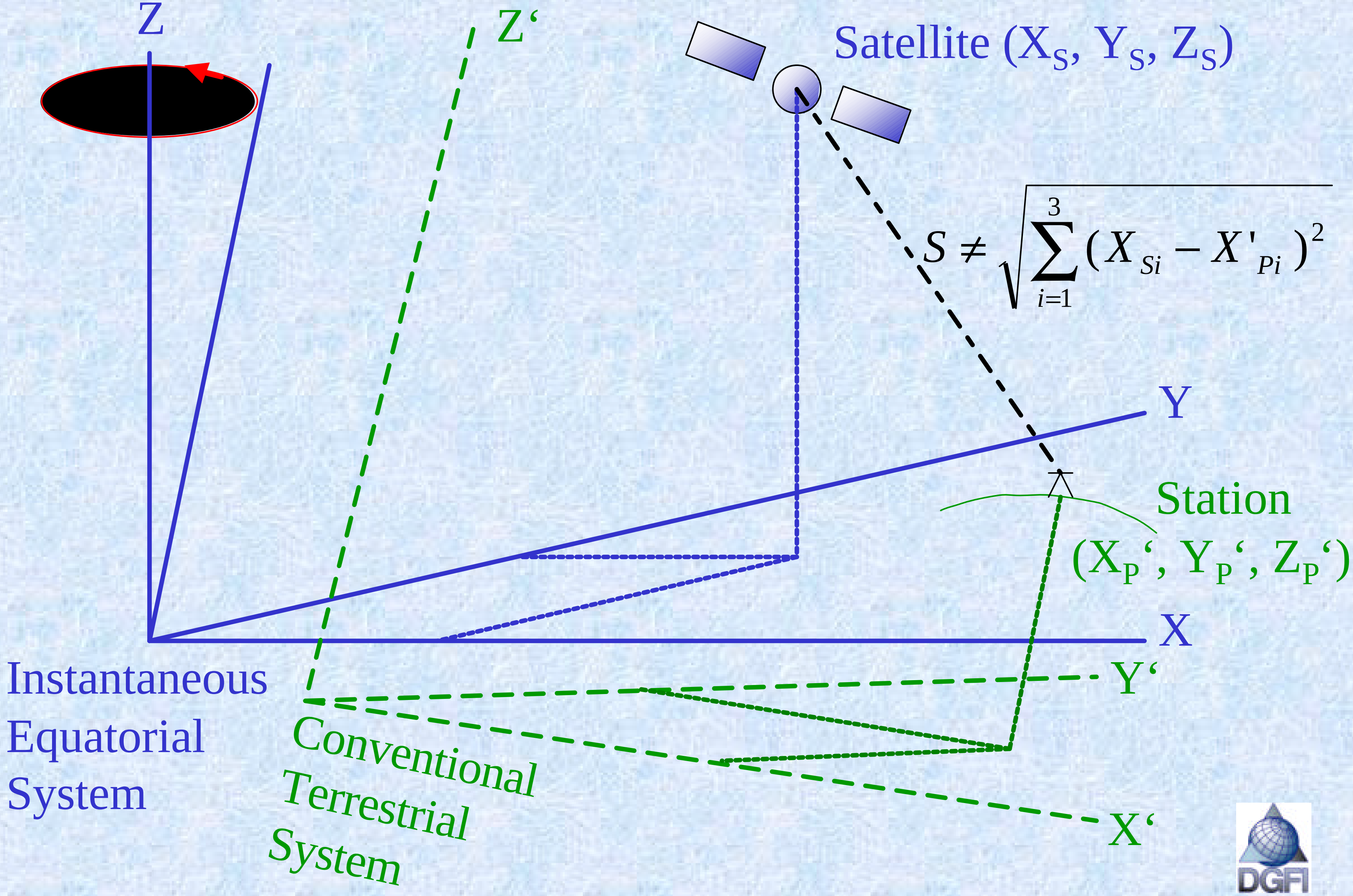
- Coordinates of the observation stations and targets (satellites) must always refer to the same reference system!
- According to Kepler‘s law, satellite orbits refer to the Earth‘s center of mass (geocenter).
- Satellite ephemeris are in general given in the geocentric International Terrestrial Reference Frame (ITRF).
  (WGS84 has adopted the ITRF2000 since January 2002)

⇒ Terrestrial coordinates have also to be given in the ITRF !

- The America‘s Reference System (SIRGAS) is a densification of the ITRF and therefore completely consistent.

⇒ Using GPS in South America one has to use the SIRGAS (ITRF) terrestrial coordinates! (no option, but a must!)

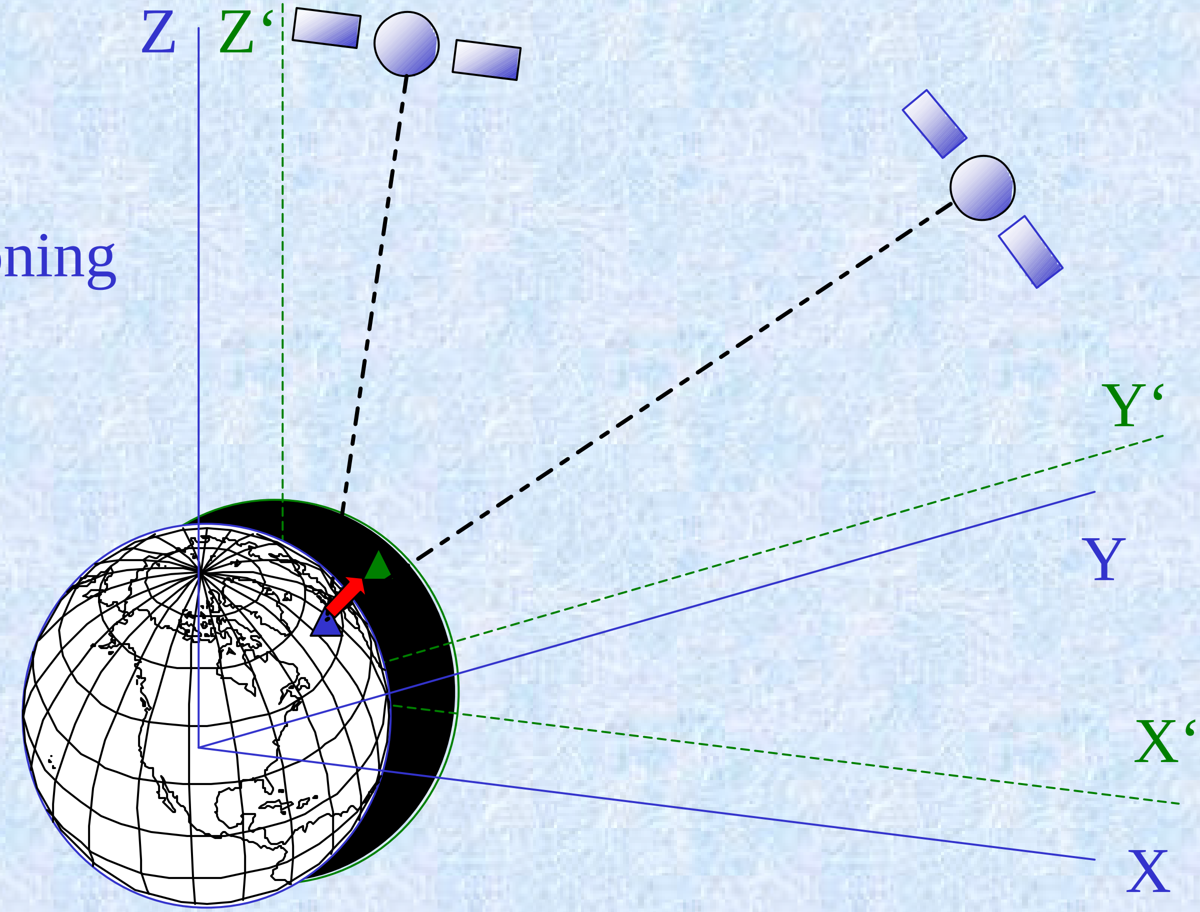
Necessity of Consistent Reference Systems



DGFI

Effect of Non-Consistent Reference Systems

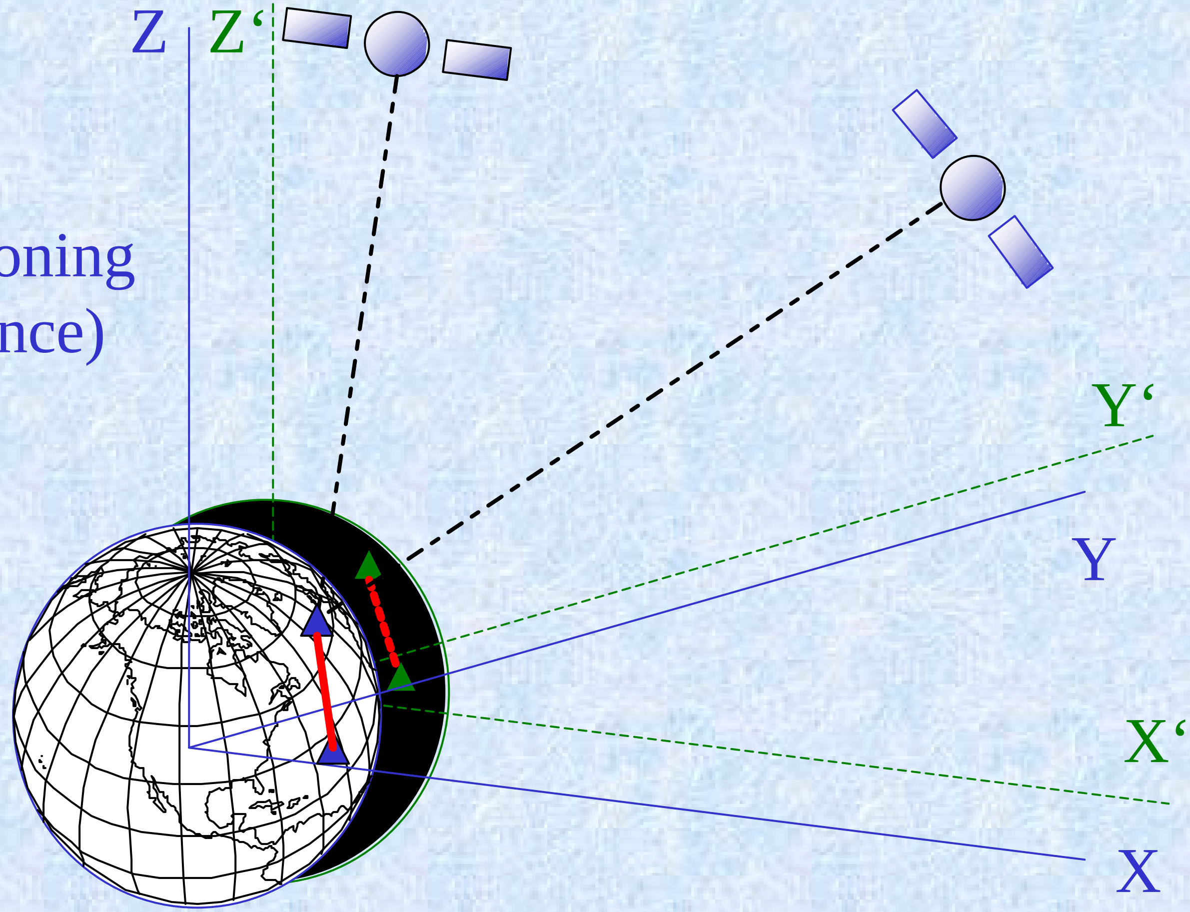
- Precise Positioning (single point)



The difference in reference systems (deviation from geocenter) enters completely into the coordinates (SAD [Chua]: ~ 70 m)

Effect of Non-Consistent Reference Systems

2. Relative Positioning
   (double difference)

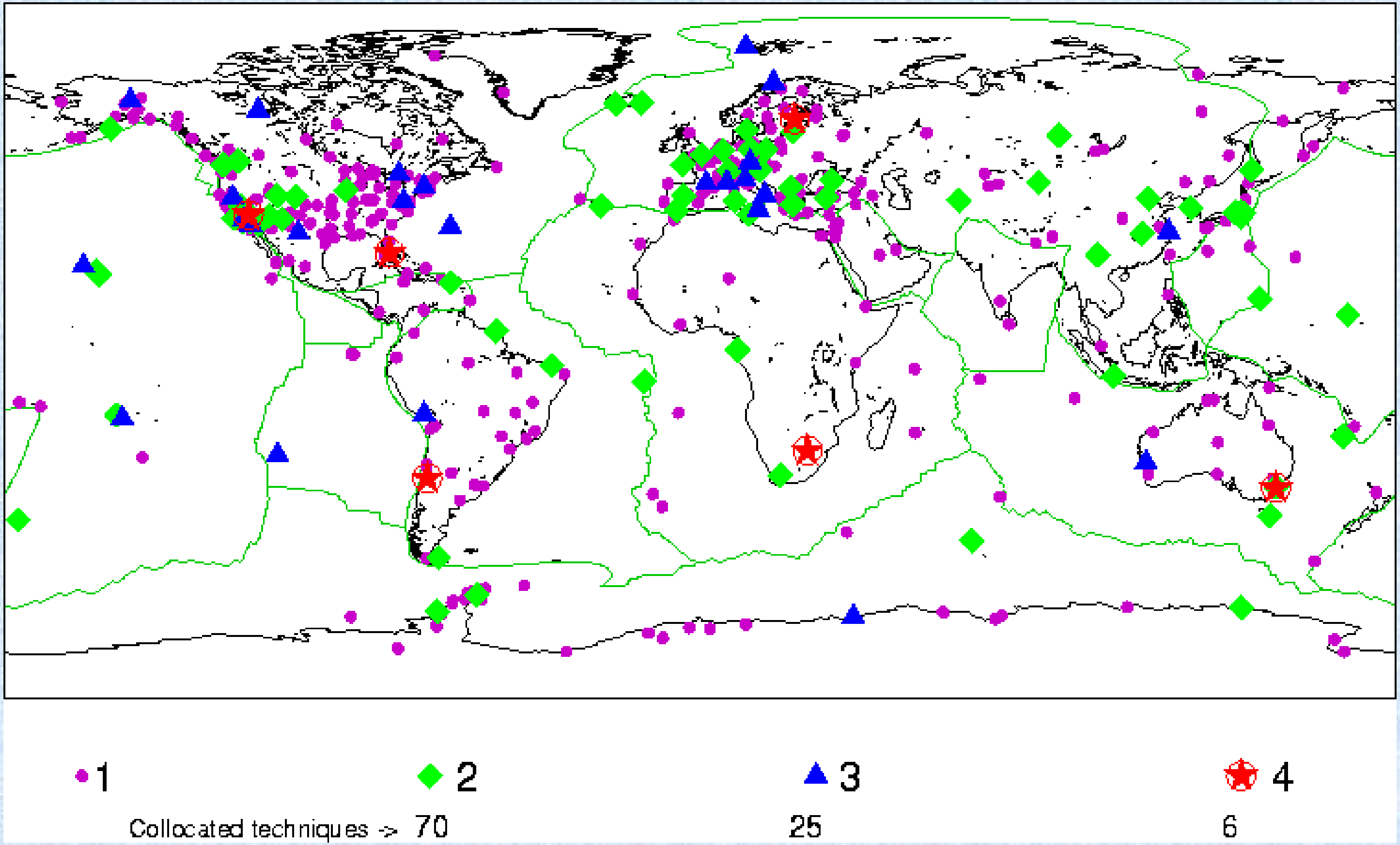


A scaling factor of ~ 2 ... 3 · 10^{-7} / meter enters into the baseline length (SAD [Chua]: ~ 2 · 10^{-5} , i.e., ~ 2 cm / km)

Realization of the International (Geocentric) Terrestrial Reference System (ITRS)

- The ITRS is realized by the International Earth Rotation and Reference Systems Service (IERS), a service of the International Association of Geodesy (IAG), the International Astronomical Union (IAU) and the Federation of Astronomical and Geophysical Services (FAGS).
- The realization is done frequently (every year to three years) by a combination of all the observations of geodetic space techniques: Very Long (Astronomic) Baseline Interferometry (VLBI), Global Positioning System (GPS), Satellite Laser Ranging (SLR), Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS).
- The latest realization is the International Reference Frame 2000 (ITRF2000) including 477 sites.

International Terrestrial Reference Frame 2000



Altogether 477 sites

Importance of the ITRF

The ITRF is today routinely used for all major practical and scientific applications:

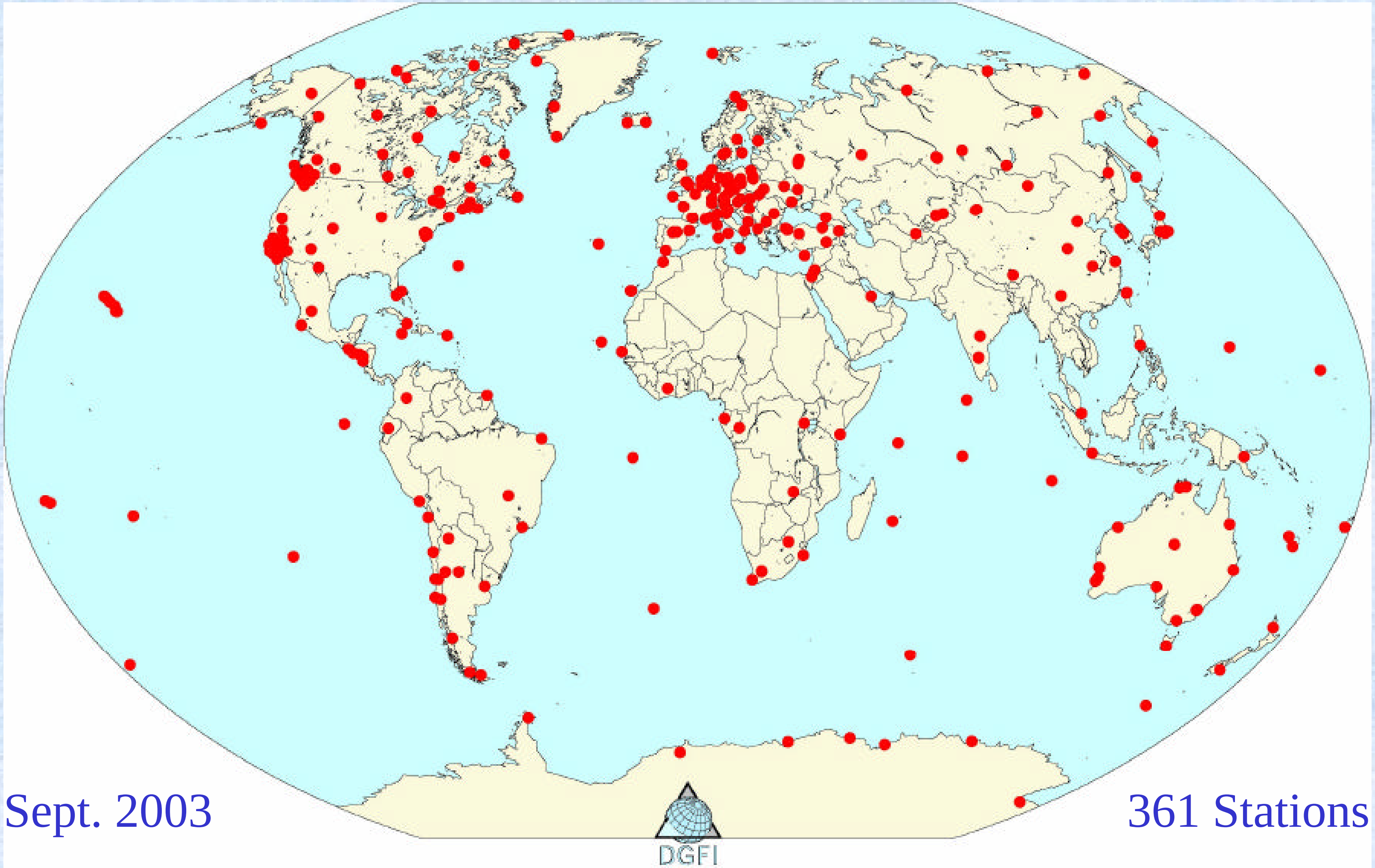
• Orbit computations, e.g., of GPS satellites (precise orbits by the International GPS Service, IGS, broadcast by NIMA: WGS84 adopted ITRF2000 since GPS Week 1150 (Jan. 2002).

• Navigation: Flight navigation of airplanes is done in ITRF, airport coordinates are given in ITRF. Car navigation is done in ITRF. The same is under work for ships and harbours.

• International Services IGS (GPS), ILRS (Satellite Laser), IVS (VLBI), IDS (DORIS) use ITRF coordinates.

• National GPS reference frames in ITRF replace the classical triangulation networks.

IGS Global Network (continuous observations)



Sept. 2003

361 Stations

The Use of ITRF in Regional Networks

- The ITRF covers about 65 countries, i.e., not all countries of the world are covered.
- The IGS installed a GPS densification network in the ITRF as a global polyhedron in order to provide a better access to the ITRF. This network is routinely (weekly) processed by Regional Network Associate Analysis Centers (RNAAC). The actual coordinates are available in the IGS data bases.

  - Australia (AUSLIG) including Antarctica

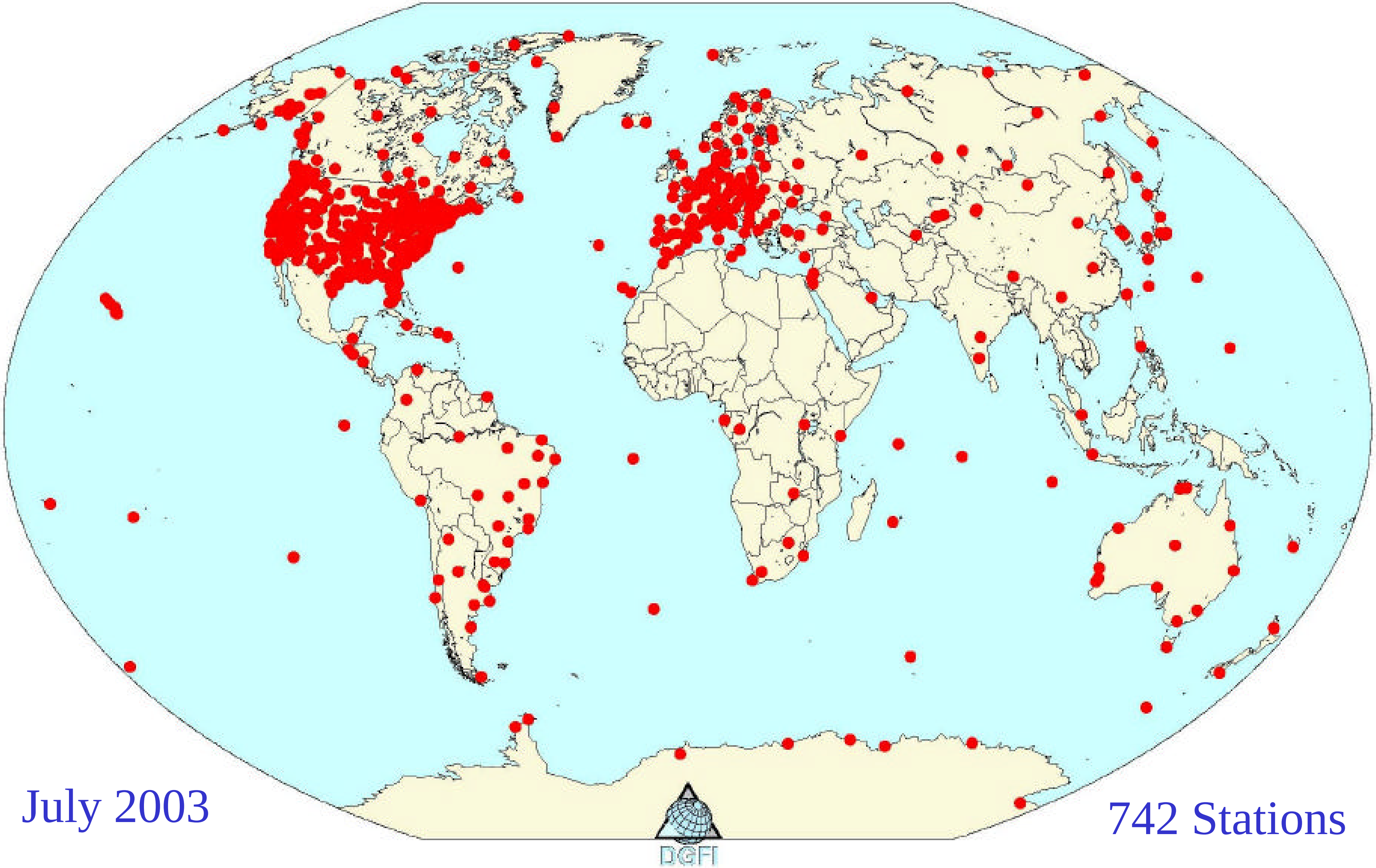
  - Europe (EUREF) with some stations in Africa and Asia

  - Japan (GSI)

  - North America (PGC, Canada)

  - South America (SIRGAS)

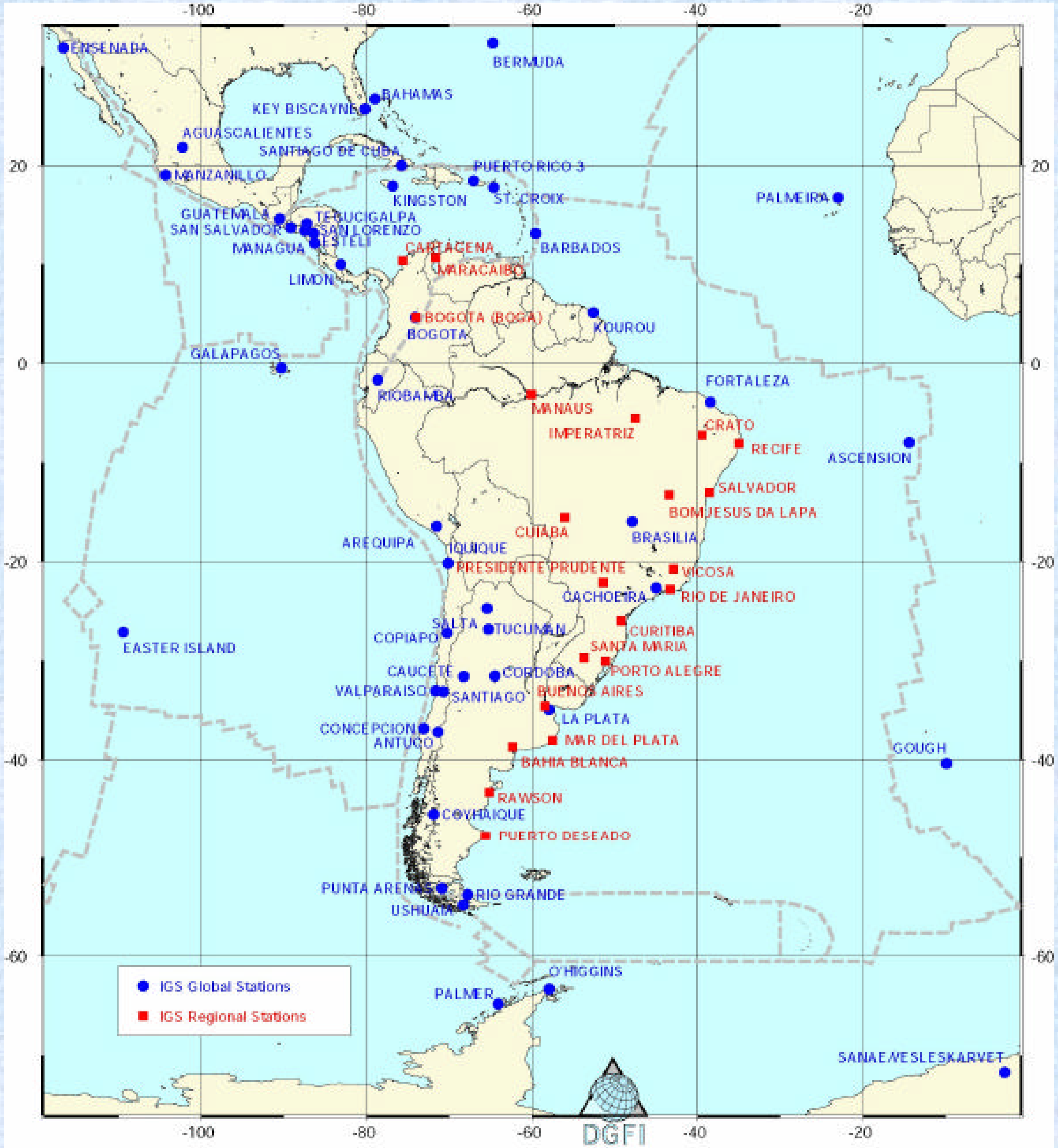
IGS Global Polyhedron



July 2003

742 Stations

IGS Regional Network for South America (SIRGAS)



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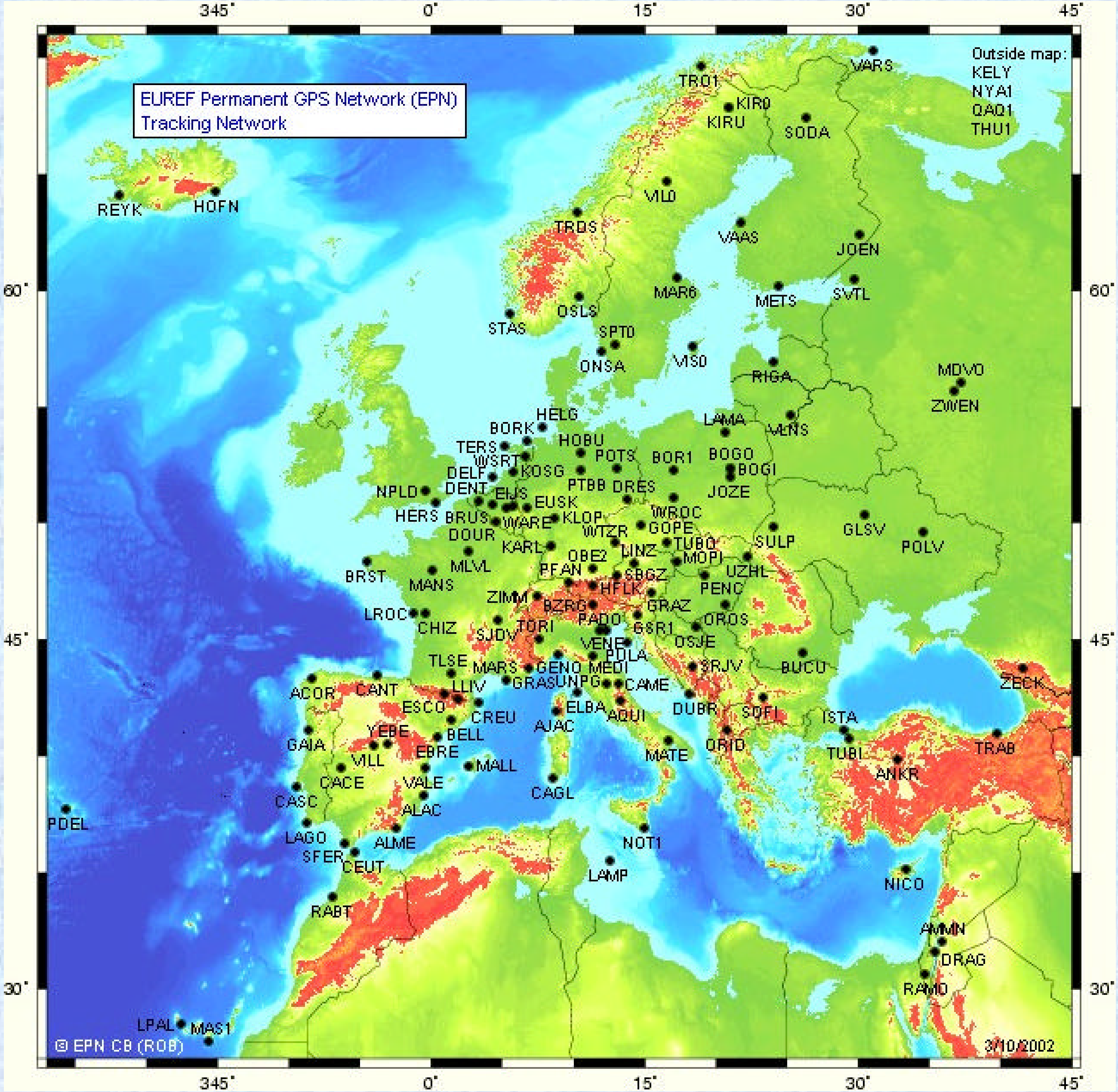
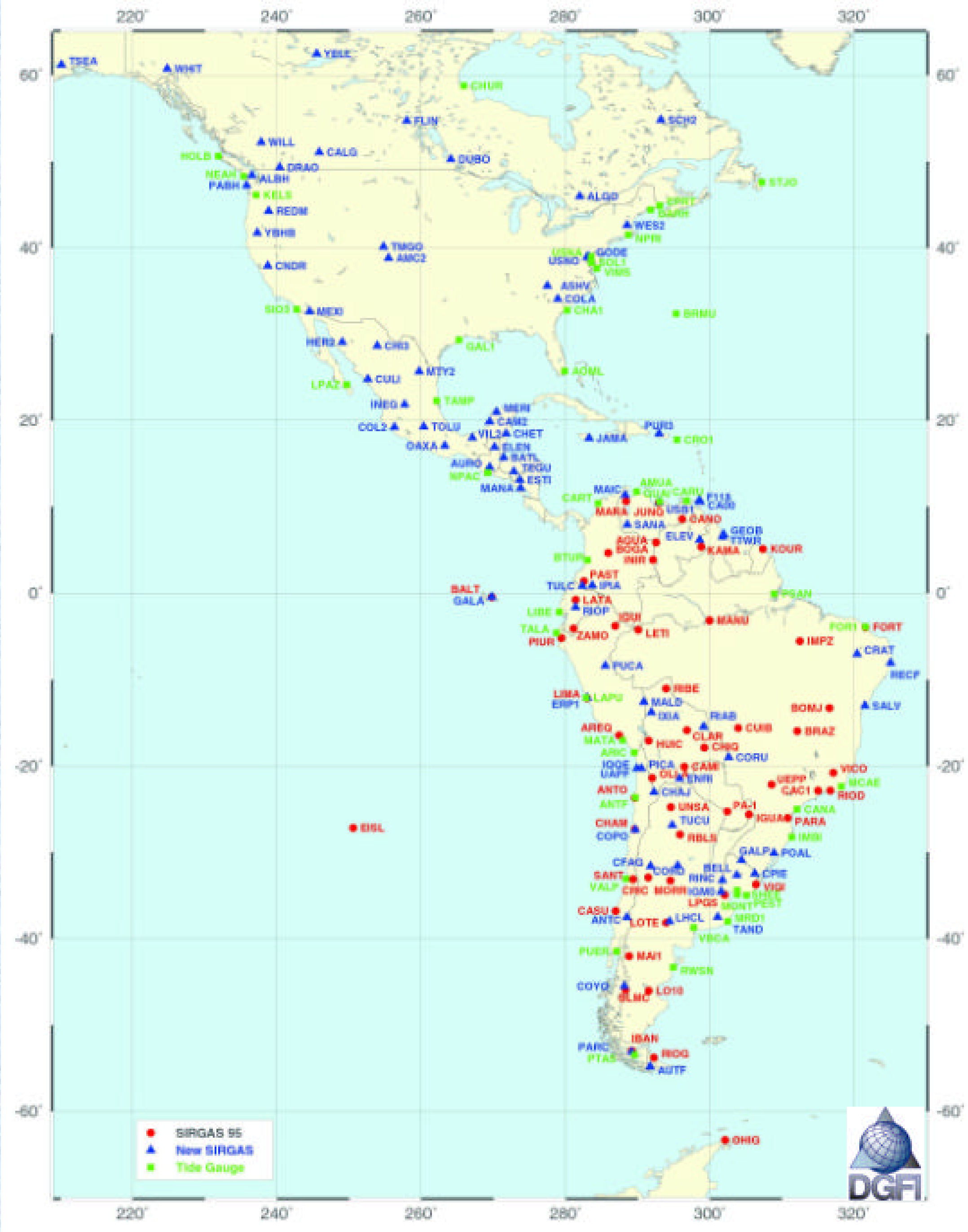


IGS Regional Network for the European Reference Frame (EUREF)

National Densifications

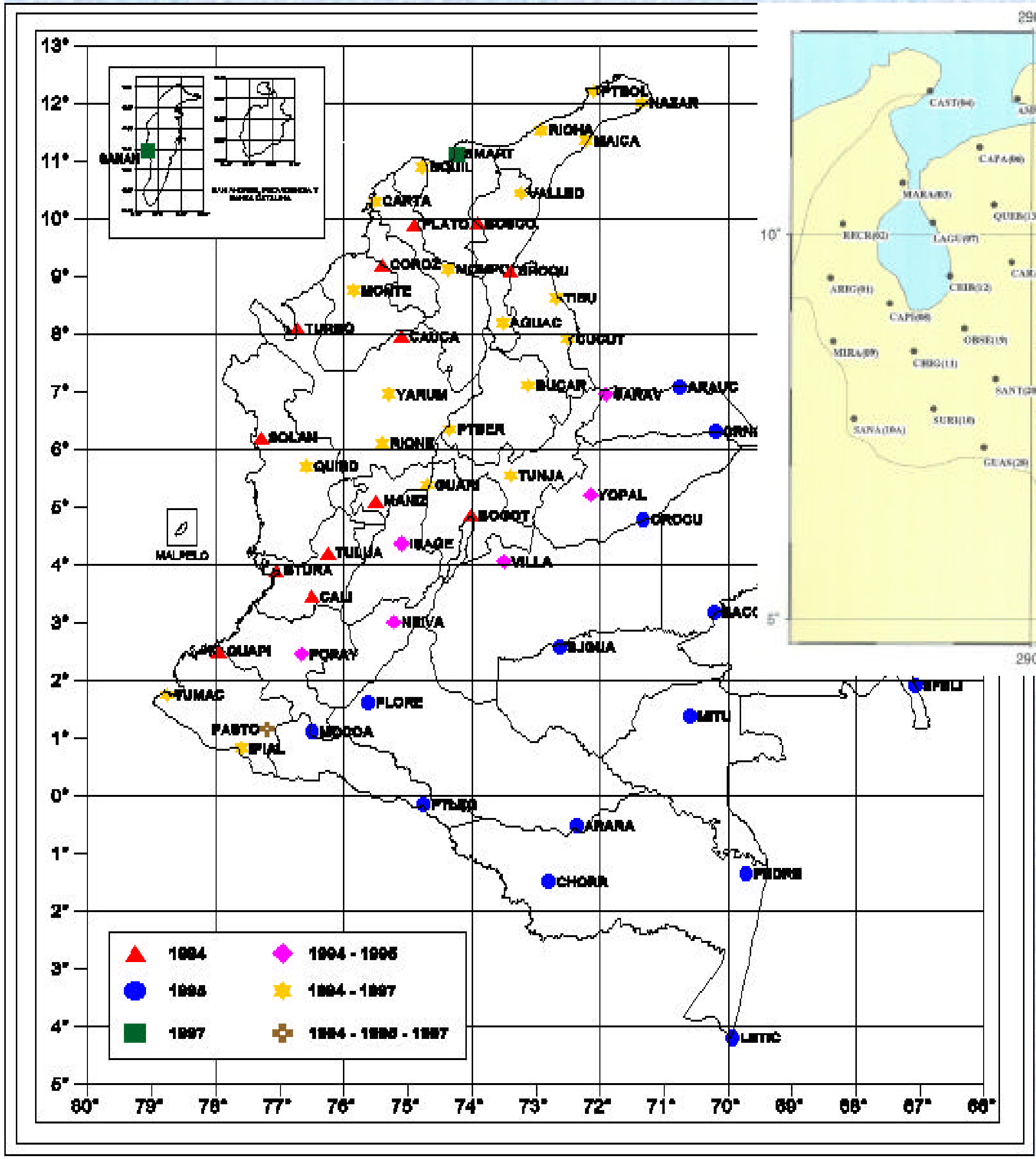
- Some continents / countries installed further densification networks to provide even better national access and to improve the accuracy of positioning.
- The national / continental networks may be observed by GPS campaigns, continuously observing stations (CORS) or active GPS stations transmitting the data by radio.
- The continental / national GPS networks guarantee the consistency with the satellites‘ reference system (ITRF) and replace the classical networks (triangulation).
- They are the proper basis for the use of any kind of GPS positioning in the countries.

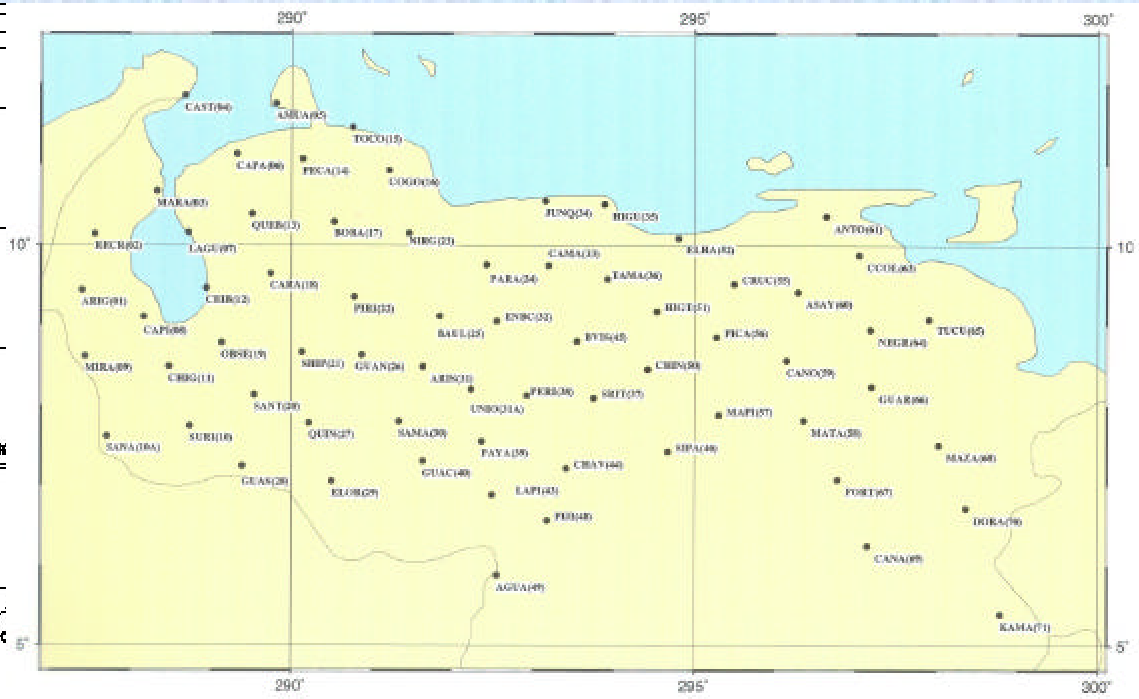


SIRGAS: Sistema de Referencia Geocéntrico para las Américas

(campaign type continental GPS densification network)

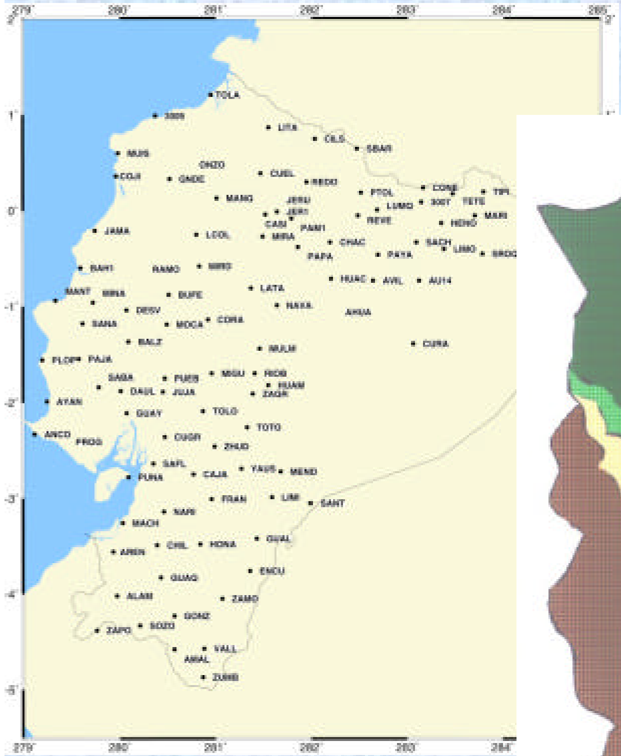
National Densification Networks

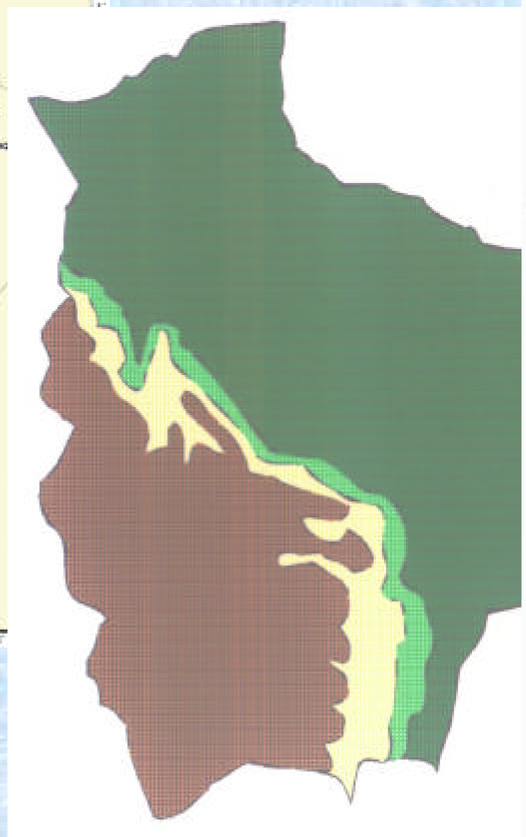




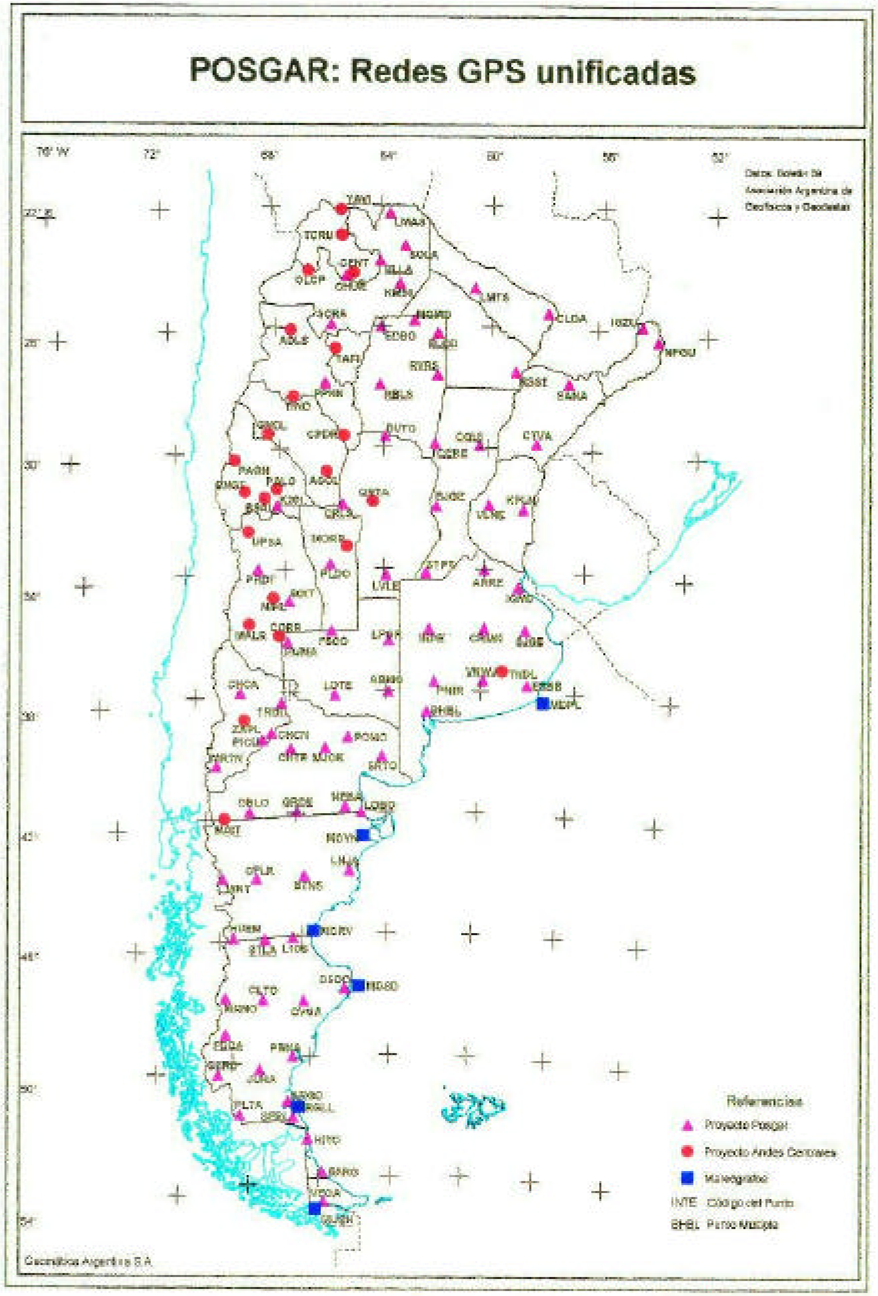
Colombia and Venezuela:
Campaign type networks, introduced by law as the national reference frames.

National Densification Networks





Ecuador, Bolivia, Peru:
Campaign type networks,
introduced as official reference



National Densification Networks

Uruguay and Argentina

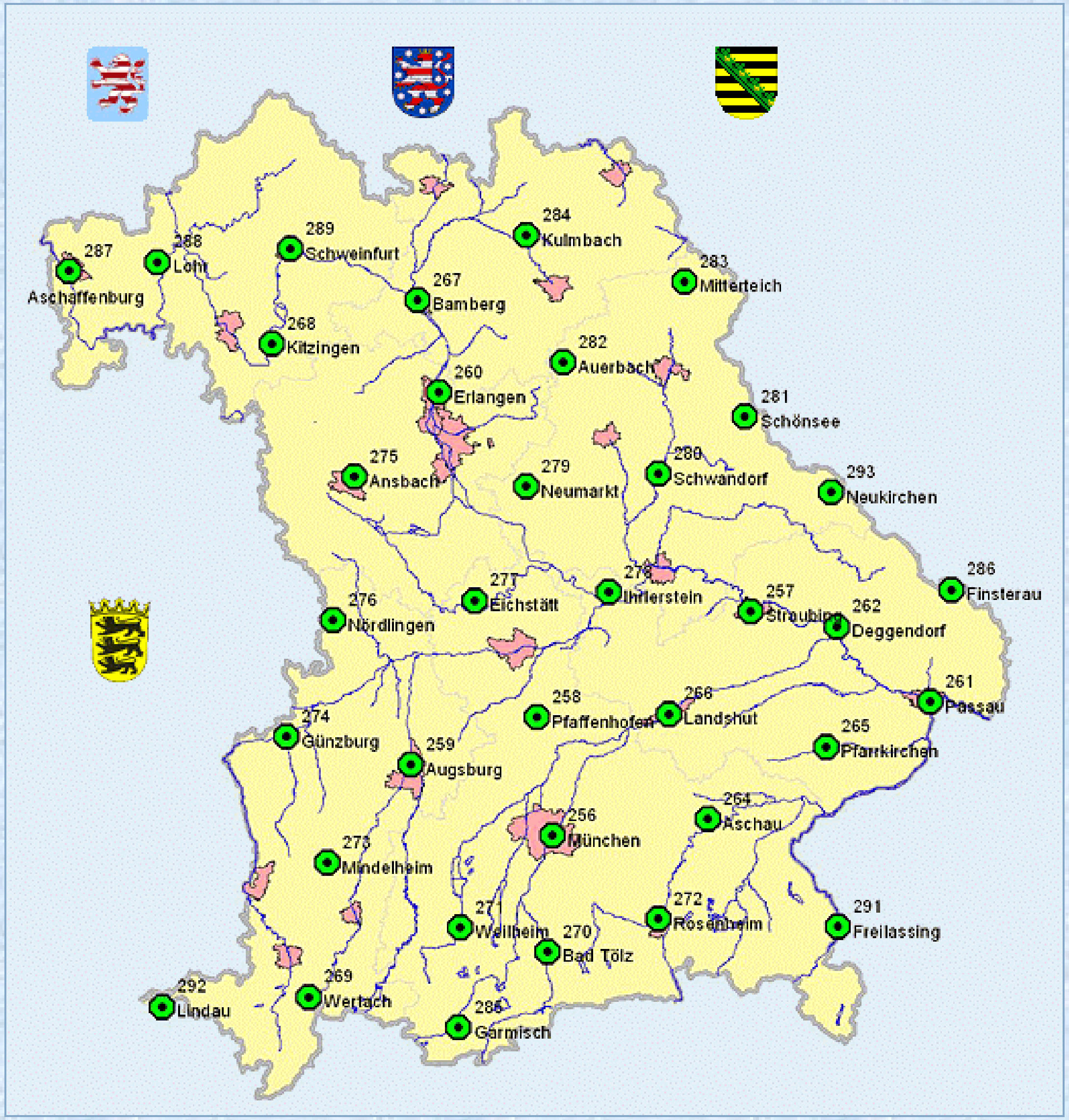
Campaign type networks, introduced by law as the national reference frames.

The Use of ITRF in the World

- **Europe:** Nearly all states are using ITRF based reference systems, except some states of the former Soviet Union and Yugoslavia.
- **North America:** ITRF is introduced in Canada and USA. The NAD83 is continued to be used in practice.
- **Australia:** ITRF is introduced and used in practice (about 20 permanent stations including about 5 in Antarctica).
- **Asia:** A few countries introduced the ITRF. Japan has got the most dense network (< 1000 permanent stations). China, Indonesia, Malaysia, ... are on the way.
- **Africa:** Very few GPS stations in Africa. An initiative AFREF is on the way, supported by IAG Commission 1.

Modern GPS Reference Networks

Modern GPS reference networks are installed by active GPS stations. Positions are continuously computed (in real time); corrections to the reference coordinates are transmitted to the users by radio.



Example:
Satellite Positioning System (SAPOS) of Germany, Bavarian part.

Active GPS Stations

Real time corrections are transmitted for two principal reasons:

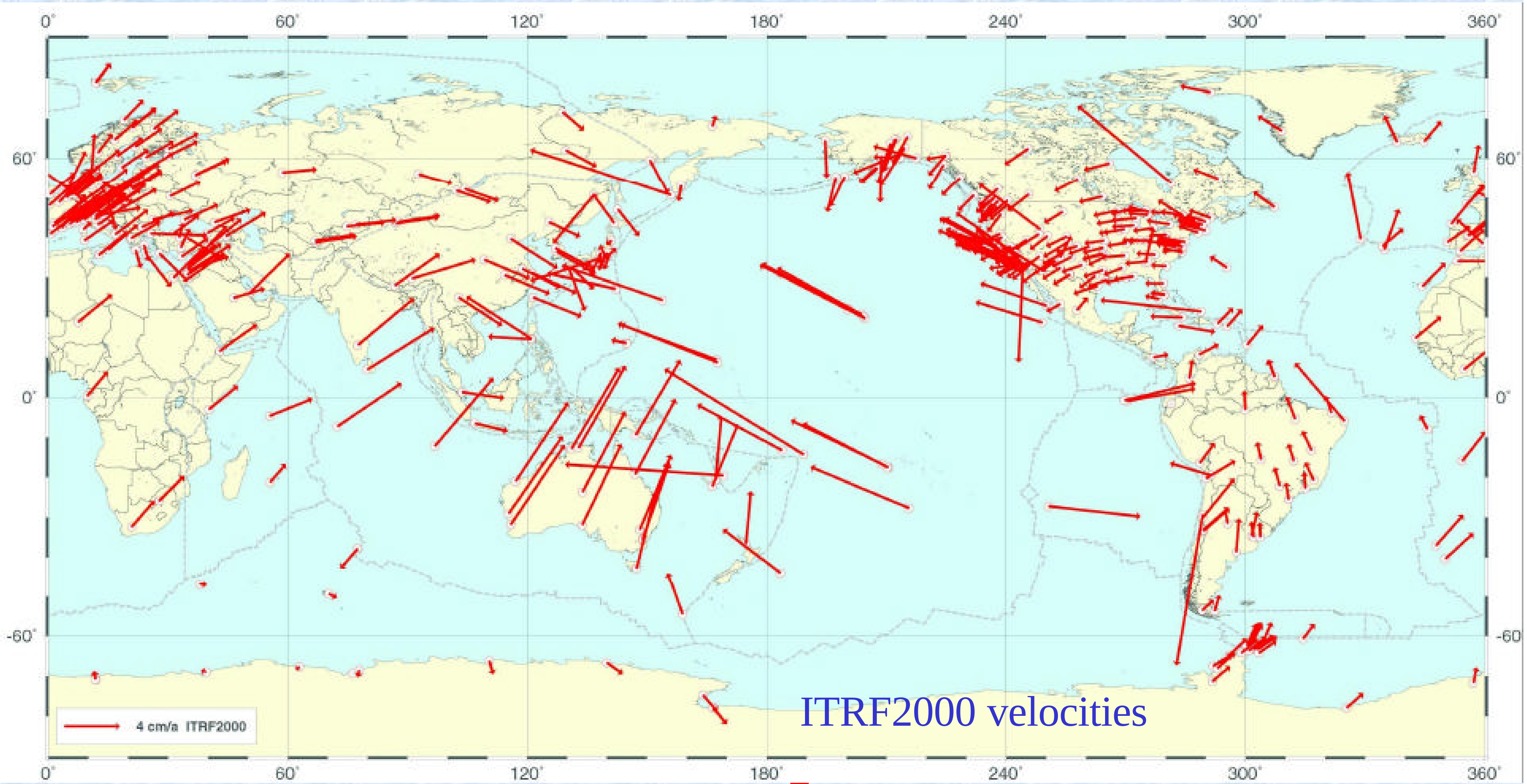
- Corrections because of signal disturbances (tropospheric refraction)
- Displacements of stations (e.g., tectonic deformation)

It is anticipated that the corrections are identical in reference station and in rover station. Therefore, the distance must not be too large (< 30 ... 50 km).

For many applications real time positioning is not required. **Continuously observing** GPS reference stations, however, are favourable because they detect position changes of the reference stations (velocities) which have to be corrected.

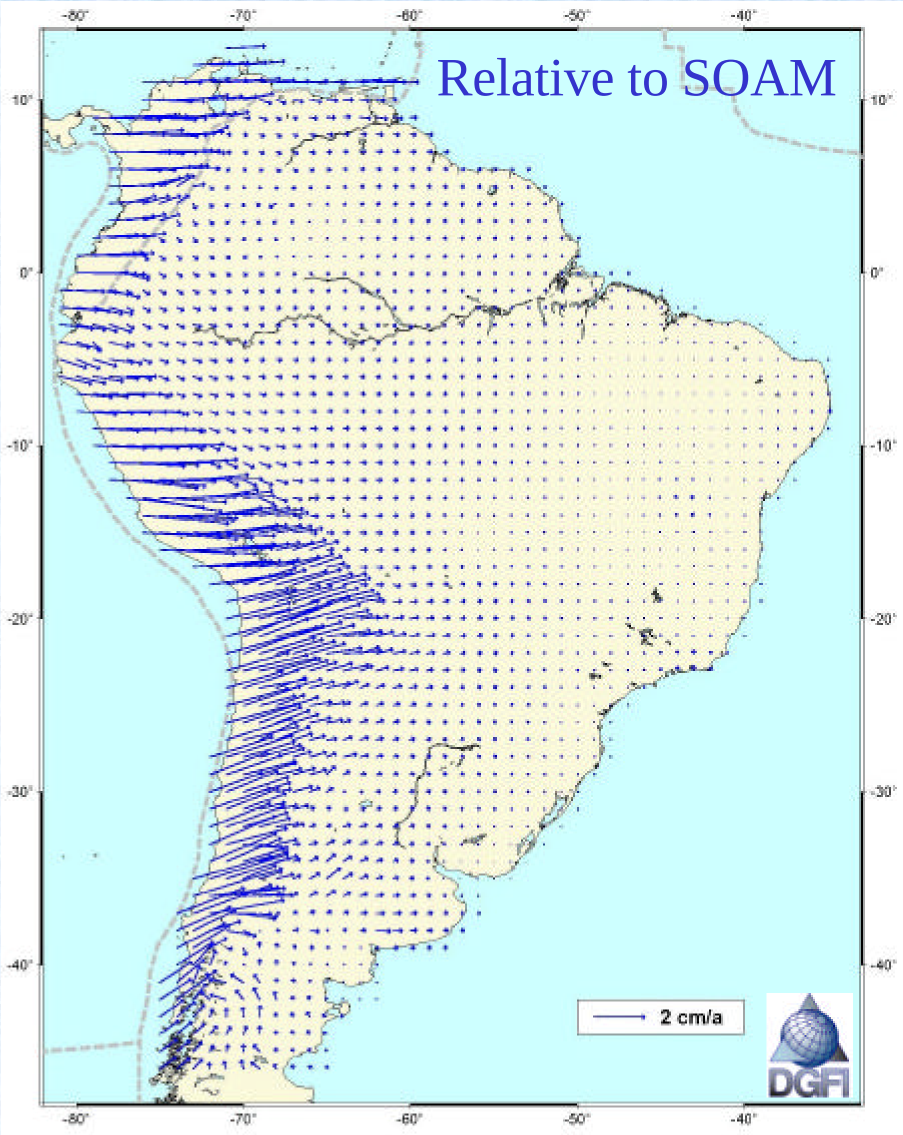
Geodetic Use of ITRF for Precise Positioning

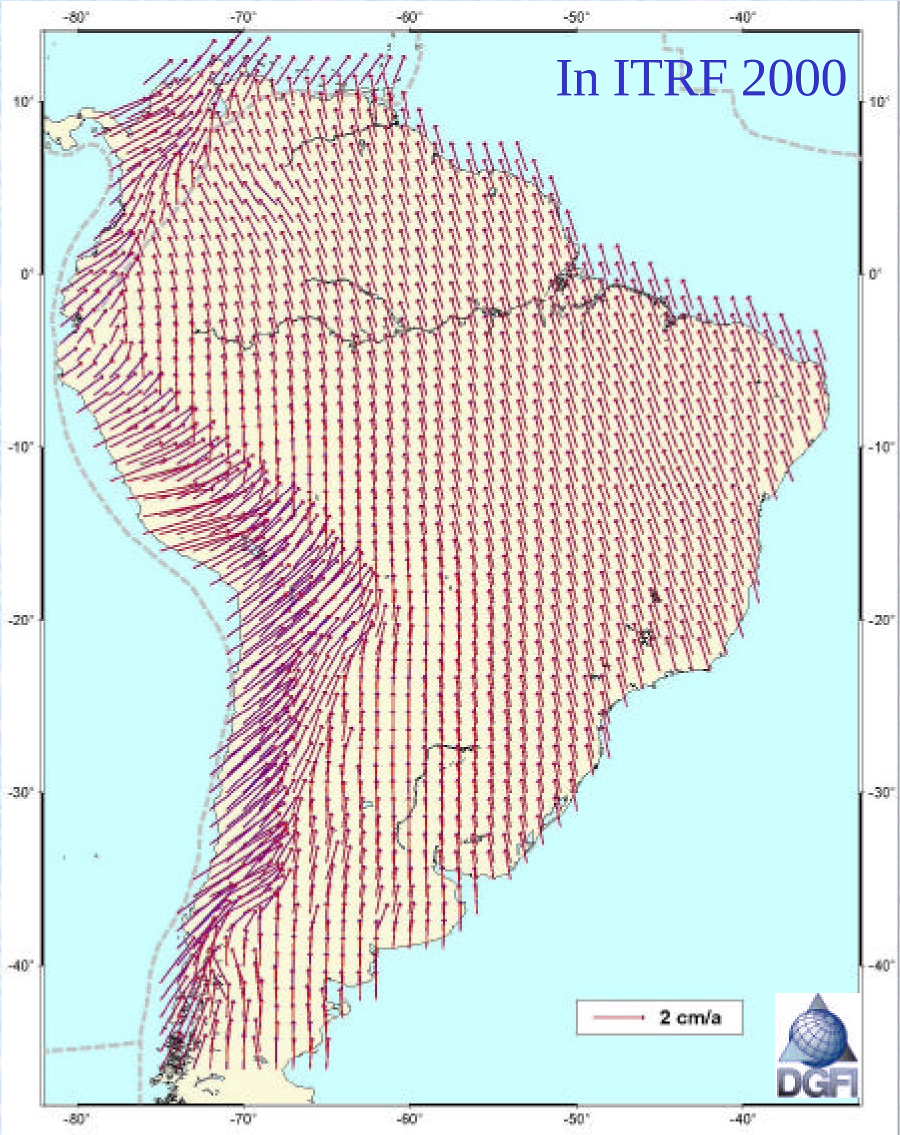
($< 10^{-7}$, i.e. < 1 cm / 100 km)



Problem: Velocities of new stations

Velocity Field of South America





Summary and Conclusion

- Using GPS positioning (differential methods) with SAD coordinates as a reference (fiducials) instead of SIRGAS (= ITRF) causes errors of $\sim 2 \cdot 10^{-5}$, i.e., 2 cm / km.

⇒ ITRF (SIRGAS) coordinates have to be uses in most geodetic applications (not an option but a must!).

- For precise positioning ($< 10^{-7}$, i.e. < 1 cm / 100 km) the station velocities of ITRF (SIRGAS) have to be applied.

⇒ This is the case for first order reference networks.

- Most of the South American countries introduced SIRGAS officially as their national reference system. For the unification of continental control networks (boundaries!) the remaining countries should join them.

Thank you!