Activities of the GGOS Working Group on Ground Networks and Communication

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The mission and the organization of the Global Geodetic Observing System (GGOS) were presented previously in this session by Markus Rothacher.

The Working Group

The Charter of the GGOS Working Group on Ground Networks and Communications is to work toward the implementation of properly designed and structured ground-based geodetic networks to materialize the reference systems to support sub-mm global change measurements over space, time and evolving technologies. The Working Group is to work with the IAG measurement services (the IGS, ILRS, IVS, IDS and IGFS) to develop a strategy for building, integrating, and maintaining the fundamental network of instruments and supporting infrastructure in a sustainable way to satisfy the long-term (10-20 year) requirements identified by the GGOS Science Council.

The Working Group is working toward the implementation of properly designed and structured ground-based geodetic networks that would encompass all of the user requirements, but focus on the reference system as a common thread to support sub-mm global change measurements over space, time and evolving technologies.

In forming the Working Group we have tried to include people from many of the involved disciplines (See table 1).

Table 1. Working Group Members

IGS	Angelyn Moore, Norman Beck
ILRS	Mike Pearlman, Werner Gurtner
IVS	Chopo Ma, Zinovy Malkin
IDS	Pascal Willis
IGFS	Rene Forsberg, Steve Kenyon
ITRF and Local Survey	Zuheir Altamimi, Jinling Li, Gary Johnston
IERS Technique Combination Research Centers	Marcus Rothacher
IAS (future International Altimetry Service)	Wolfgang Bosch
Data Centers	Carey Noll
Data Analysis	Erricos Pavlis, Frank Lemoine, Frank Webb, John Ries, Dirk Behrend

The Working Group Activities

The early steps in the process are:

- Take stock of what presently exists in terms of stations, products, surveys data etc:
- Determine the user requirements;
- Define critical contributions each technique contributes to the TRF, POD, EOP;
- Consider first the TRF since its accuracy influences all other GGOS products;
- Characterize the improvements anticipated over the next 10 years for each technique;
- Using simulation techniques, quantify the improvement in the TRF as stations are added and station capabilities (co-location, data quantity and quality) are improved; and
- Scope the network that would satisfy the user requirements.

In the development of a plan for full network integration we will need to consider the full range of applications including the geometric and gravimetric reference frames, EOP, POD, geophysics, oceanography, local deformation monitoring, and other geodetic and gravimetric applications required for the long-term observation of global change. The network must include a sub-network of fundamental stations with colocated techniques and an adequate system of ground survey control. In addition to colocated instruments on the ground, colocated techniques on the satellites is essential to resolve differences in technique contributions to the reference frame. Provision must be made to match data and product communication with requirements. In some cases data latency must be very short, approaching real time.

Taking Stock

A data table space geodesy ground stations is now available at

http://indigo.nasa.gov/sgp_locations_full_db_country.html

The Table includes all ILRS/SLR, IVS/VLBI, and IDS/DORIS colocations along with instrument types, site codes, DOMES numbers, period of operation, whether or not it is included in the ITRF and the status of site tie information.

Service and data product information is available for the IGS, ILRS, IVS, IDS, and IERS at:

http://indigo.nasa.gov/indigo_serva.html

These tables include organization, links to mailing lists, data centers and storage locations, formats, analysis center information, and product structure and availability.

Efforts are currently underway to add gravity and tide gauge site information and data products to these tables.

The Requirements

Although input on the GGOS requirements will eventually come from the GGOS Science Panel after it is fully established, we have solicited comments from some members of the community so that we can begin to scope the network requirements. Some of the comments were:

- Measure Earth CoM variability to 0.1 mm with monthly resolution and resolve seasonal (annual and semi-annual) signals to 0.05 mm in amplitude and 5 degrees in phase;

- Measure the scale of the TRF with a long-term accuracy of 0.01 ppb/yr;

- Maintain a global vertical datum (Core Observatories' heights) with an accuracy of 0.1 mm/yr (excluding seasonal signals);

- Measure UT1- UTC at 2-3 microsecond every day and nutation at 25-50 microarcseconds each day, (VS WG2 report);

- Measure Earth Orientation parameters with an accuracy of 0.050 mas (polar motion) and 0.025 mts (LOD) for daily averages);

- Measure long-wavelength gravity changes (zonal terms to degree 10 and tesserals/sectorials to degree 4, 6) with weekly resolution and an accuracy better than 10% of the signal;

- Improve by an order of magnitude the ties between the Solar System Barycentric frame with the TRF, using SLR tracking of planetary probes and interplanetary missions with multiple tracking systems (RF Doppler, VLBI, etc.), to improve the TRF and Conventional Inertial Reference Frame ties.

These are not necessarily self consistent, but it gives a very clear view that requirements are in the 0.1 mm range and will be very challenging.

The Vision of the Measurements Techniques

At the Working Group splinter meeting at EGU 2006 in Vienna the Measurement Services gave reports on their current status and their vision of where they could be in the next 10 – 20 years if resources were available.

Material on the plan for the GNSS technique and the IGS was provided by Angie Moore and Frank Webb. It is assumed that the IGS network (see Figure 1) will be at least as robust is it now, with some filling in where there are presently gaps. The second civilian signal (L2C) on GPS will be fully operational by 2013; the Block IIF/L5 satellites with the 3rd civil signal will be launched starting in 2007, with full operational control in 2014. Launch of the GPS Block III satellites are scheduled to begin in 2013. There are currently 13 operational GLONASS satellites with plans to return to the full 24 satellite array by 2011. The recent M satellites have a second civilian signal (L2); the K satellites with a third civilian signal will be launched 2008. The first of the Galileo test satellites was launched in December; the second is scheduled for launch in November. The plan includes four operational satellites by 2008 and a full operational complex of 30 satellites by 2010. Many more low orbiting satellites tracked with GPS are anticipated. Over time all of the ground stations need to be updated to accommodate the added satellites and frequencies. The GLONASS and Galileo satellites and perhaps the GPS III satellites will have retroreflectors for verification of performance and improved dynamic modeling.

Werner Gurtner and I compiled the vision for SLR and the ILRS. The SLR network (see Figure 2) has been enhanced in the Southern Hemisphere over the past decade, but closures and cutbacks have had a detrimental effect on the network distribution, and significant holes still exist.

Fortunately the stations in Maui and Arequipa are being reopened. It is anticipated that the ILRS ground stations systems will fall into a bi-modal distribution with a small globally distributed network of stations with extended range capability for the higher satellites (Lageos altitudes and beyond), and a larger, more comprehensive, globally distributed network that will ranges routinely to Lageos altitudes and to lower satellites. Ground systems will likely work at kilohertz ranging frequencies, with faster satellites acquisition and pass interleaving, higher resolution event-timers with picosecond timing, and real-time communication for immediate data flow. Two-wavelength operation should be available from a few sites to support development of better atmospheric refraction delay recovery models. Systems will have much more autonomous operations, making eye safe power levels very desirable. Improvements in the satellite segment will improve with new array designs using hollow cubes and perhaps the Luneberg reflector. Transponders for lunar and planetary ranging are being planned.

Chopo Ma provided information on the status and the improvements anticipated by the IVS. The VLBI network is also much denser in the Northern Hemisphere (see Figure 3). As with SLR, different stations have different capabilities and levels of participation. Although not an official part of the IVS network, the VLA stations in North America contribute to many measurement programs. A large constraint on VLBI programs currently is the limitation on the throughput of the correlators.

The IVS plan for upgrading and enhancing capability is detailed in the document VLBI 2010 report. Mounts should be faster slewing, more robust, and more stable; antennas will be more efficient. Cryogenic feeds and receivers will be very wide bandwidth and much better calibrated. Backends will be all digital, wide bandwidth, and programmable. Recording will be at higher bandwidth and frequency standards will be more stable. The correlators will have higher throughput, being able to process more stations and higher data rates. Operations with e-VLBI will provide real-time data submission.

Pascal Willis gave an update on the IDS and DORIS. As with the GNSS network, it is anticipated that the GNSS network (see Fig. 4) will be at least as robust is it now, with some new stations to fill gaps. Several new satellite launches are expected in the 2008-2009 timeframe, but the long-term DORIS constellation is difficult to predict. The added satellites will have new multi-channel receivers on-board to accommodate more data from more ground stations. It is expected that geodetic results will improve with better phase measurements and additional Analysis Centers.

Rene Forsberg, Steve Kenyon and Jacques Hinderer provided some information on the gravity networks. Jacques participated in the Vienna meeting. There are many different kinds of instruments, ground-based, airborne, and now space borne instruments (GRACE) that furnish information to support gravity modeling activities. The IGFS is now trying to bring better organization and semblance to the gravity community. Figure 5 show the current network of coordinated superconducting gravimeter observatories that have been active in measurement campaigns. For a small network, coverage is pretty good with the usual concentration in Europe and Japan. Figure 6 shows the coverage of the NGA absolute gravimeter network.

Philip Woodworth and Svetlana Jevrejeva from Proudman Oceanographic Laboratory supplied material on the tide gauge networks. The website maintained by Guy Woppelmann and Tilo Schoene at: http://www.sonel.org/stations/cgps/surv_update.html contains many tables and maps of tide gauge sites including those participating in Global Sea Level Observing System (GLOSS) GLOSS and Permanent Service for Mean Sea Level (PSMSL).

PSMSL collects monthly mean data from approximately 2000 globally distributed stations. The GLOSS Core Network includes about 300 stations that provide high frequency data. Approximately 200 stations support both networks. Of particular note is the map included here in Figure 7 showing the network of colocated GPS receivers and tide gauges. In many cases the separation of the GPS and tide gauge is only a meter or two; at others, however, the separation is measured in kilometers. For approximately 100 stations the separation distance is missing. According to the website, local leveling is not done routinely and in cases where the separations are large, it is likely neglected. In addition, where it is done, leveling errors over these larger distances can be significant and can corrupt the results unless the local region is very stable.

Guy Woppelmann, Tilo Schoene, and others are engaged in the Tide Gauge Benchmark Monitoring (TIGA) Pilot Project (see http://adsc.gfz-potsdam.de/tiga/index_TIGA.html), a pilot study of the IGS to establishing a service to analyze GPS data from stations at or near tide gauges on a continuous basis.

Approach to Scoping the Network

In the activity to scope the network, we have started with the reference frame and assumed that the GNSS and the DORIS Networks will be at least as robust as they are presently with some augmentation to fill in the network and with ground system upgrades to accommodate the new satellites capabilities. For SLR and VLBI, each has chosen a critical parameter or parameters in the reference frame formulation that will be used as a measure to scope the networks. For SLR and VLBI it is Earth center of mass and EOP parameters respectively. In addition, the networks must be sufficiently global to determine scale and to ensure that inter-network transformations are robust. At the moment, the Working Group is examining options for 1 mm and 0.1 mm/yr reference frame stabilities.

John Ries, Erricos Pavlis, and Frank Lemoine are working on the development of a mechanism for reliably evaluating the impact of changes in the SLR network. It must to be able to evaluate current level of TRF errors, optimize use of available or future SLR resources, and determine level of tracking needs to meet the science requirement. The mechanism must use the recovery of geocenter variability as a quick proxy for TRF origin improvement. They will generate a set of simulated SLR data incorporating their best estimate of the dynamical and observation modeling errors and then calibrate modeling errors to be consistent with observed performance with LAGEOS-1/2 (realistic spectrum of errors, include systematic biases as well as stochastic errors. They will insert a seasonal geocenter signal (3-6 mm in this case) and compare recovery to the actual performance from LAGEOS-1/2. They will then test selected SLR network scenarios, examining the realism of the SLR data distribution and acquisition patterns. The question is "How many SLR stations with the anticipated capability will it take to recover the geocenter".

Dan MacMillan, Dirk Behrend, Leonid Petrov, Dave Rowlands, and Erricos Pavlis have been developing simulation and covariance analysis to analyze network performance for VLBI. This work includes generation of observing schedules for hypothetical networks and station configurations and the application of model noise to real and hypothetical observations. They plan to optimize in a geometrical sense the design of a new network of VLBI antennas, improving the geographical distribution and determining the required performance characteristics of new antennas and antenna upgrades to meet overall network goals. They will analyze simulated data to estimate Earth orientation parameters and station positions and perform Monte Carlo simulations by generating simulated observations and making repeated runs with different input simulated model errors. They will examine the precision of estimated parameters and compare them with formal parameter errors. The procedures to analyze VLBI data with GEODYN have been implemented. Simulation activity is now underway using both VLBI-SOLVE and GEODYN/SOLVE.

Summary

The IGS, IVS, ILRS, IDS, IERS are talking regularly to each other, meeting several times a year and participating in weekly telecons. Information on the networks and Service products are on line. Simulations are under underway with SLR and VLBI, trying to get the networks scoped by the end of the year. We are pressing hard for reports on surveys already performed. There is still a lot of work to do.

A preliminary discussion on these items is included in our Poster paper from the IAG Cairns meeting which is being published in the IAG Meeting 2006 Proceedings and is available at:

M. Pearlman, et al, “GGOS Working Group on Networks, Communication, and Infrastructure” (http://cddis.gsfc.nasa.gov/docs/GGOS_IAG_0508.pdf)

An expanded version of the paper is being prepared for Geomatica.

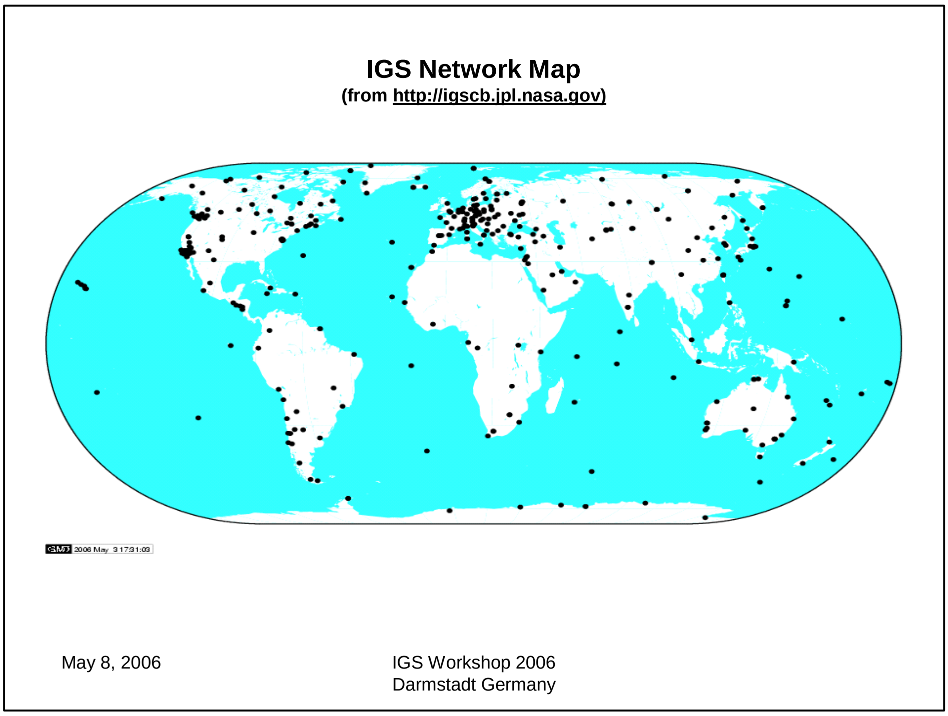

Figure 1. IGS Network (from http://igscb.jpl.nasa.gov)

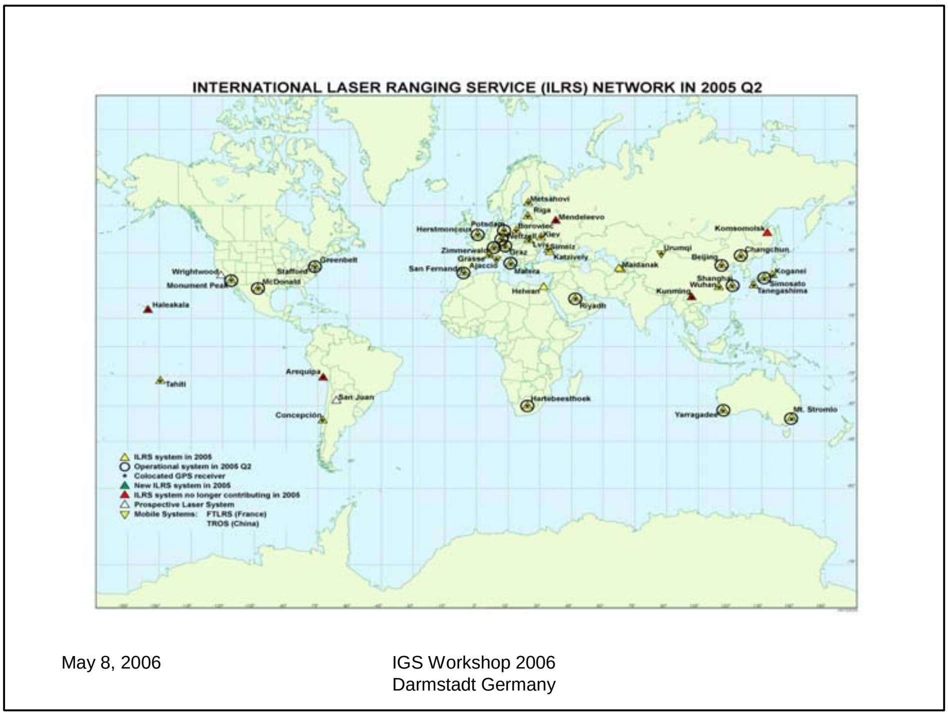

Figure 2. ILRS Network (http://ilrs.gsfc.nasa.gov)

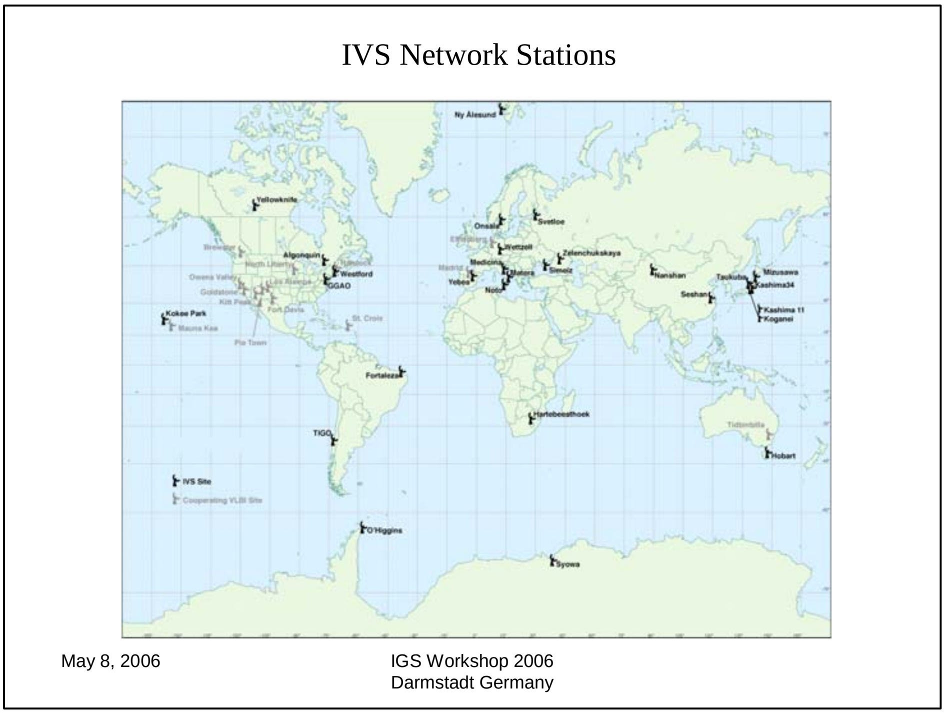

Figure 3. IVS Network (provided by Dirk Behrand/GSFC)

Figure 4. DORIS Network (http://ids.cls.fr/images/world_map_doris.jpg)

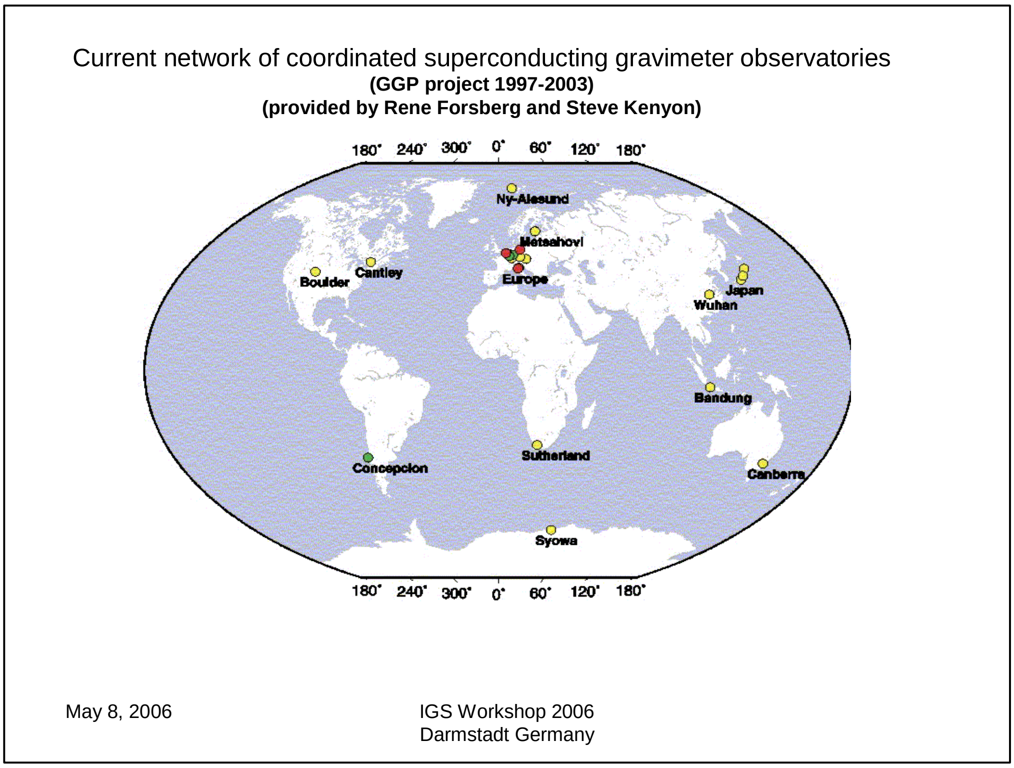

Figure 5. Current Network of Coordinated Superconducting Gravimeter Observatories (http://www.eas.slu.edu/GGP/ggpmaps.html)

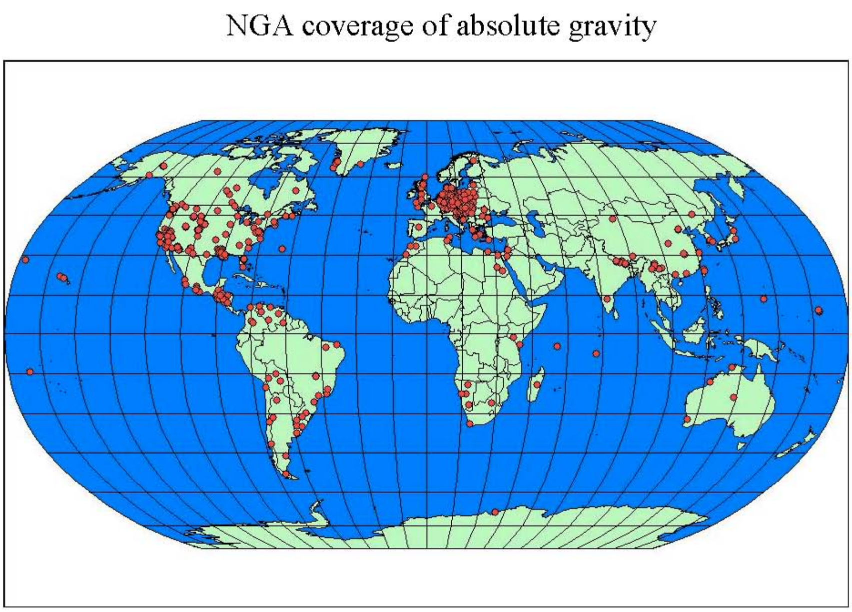

Figure 6. NGA coverage of absolute gravity site (provided by Steve Kenyon/NGA)

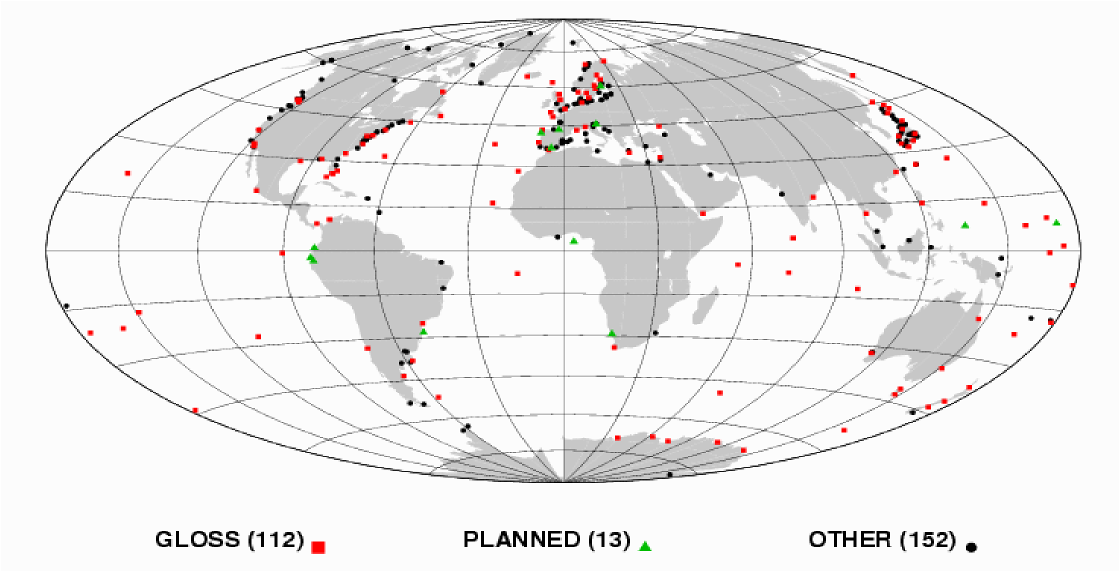

Figure 7. Colocated GPS and Tide Gauges
(from http://www.sonel.org/stations/cgps/surv_update.html)