The Global Geodetic Observing System:
Space Geodesy Networks for the Future

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ABSTRACT

Ground-based networks of co-located space geodetic techniques (VLBI, SLR, GNSS, and DORIS) are the basis for the development and maintenance of the International Terrestrial Reference Frame (ITRF), which is our metric of reference for measurements of global change. The Global Geodetic Observing System (GGOS) of the International Association of Geodesy (IAG) has established a task to develop a strategy to design, integrate and maintain the fundamental geodetic network and supporting infrastructure in a sustainable way to satisfy the long-term requirements for the reference frame. The GGOS goal is an origin definition at 1 mm or better and a temporal stability on the order of 0.1 mm/y, with similar numbers for the scale and orientation components. These goals are based on scientific requirements to address sea level rise with confidence, but other applications are not far behind. Recent studies including one by the US National Research Council has strongly stated the need and the urgency for the fundamental space geodesy network. Simulations are underway to examining accuracies for origin, scale and orientation of the resulting ITRF based on various network designs and system performance to determine the optimal global network to achieve this goal. To date these simulations indicate that 24 – 32 co-located stations are adequate to define the reference frame and a more dense GNSS and DORIS network will be required to distribute the reference frame to users anywhere on Earth. Stations in the new global network will require geologically stable sites with good weather, established infrastructure, and local support and personnel. GGOS will seek groups that are interested in participation. GGOS intends to issues a Call for Participation of groups that would like to contribute in the network implementation and operation. Some examples of integrated stations currently in operation or under development will be presented. We will examine necessary conditions and challenges in designing a co-location station.

1 Introduction

Ground-based networks of co-located space geodetic techniques (VLBI, SLR, GNSS, and DORIS) are the basis for the development and maintenance of the International Terrestrial Reference Frame (ITRF), which is our metric of reference for measurements of global change. These networks provide measurements of static and time-varying components of the Earth's gravity field; precision orbit determination, calibration, and validation for active satellites systems for altimetry; and time transfer and determination of fundamental constants. Data from these networks provide Earth Orientation Parameters, time history of ground station positions and baseline length, strain models, mean sea level and ocean surface topography, marine tide models, atmospheric and ionospheric parameters.

2 GGOS and the Geodetic Reference Frame

The Global Geodetic Observing System (GGOS) of the International Association of Geodesy (IAG) has established a task to develop a strategy to design, integrate and maintain the fundamental geodetic network and supporting infrastructure in a sustainable way to satisfy the long-term requirements for the reference frame. The GGOS goal is an origin definition at 1 mm or better and a temporal stability on the order of 0.1 mm/y, with similar numbers for the scale and orientation components. These goals are based on scientific requirements to address sea level rise with confidence, but other applications are not far behind. Recent studies including one by the U.S. National Research Council (see Figure 1) have strongly stated the need and the urgency for the fundamental space geodesy network. The needs are articulated in more detail on *The Global Geodetic Observing System: Meeting the requirements of a global society on a changing planet in 2020 (Plag, H-P and Pearlman, M.R., 2009).* These levels of accuracy and precision are about a factor of 15 - 20 better than the current reference frame models and represent significant challenge in both measurement and modeling techniques.

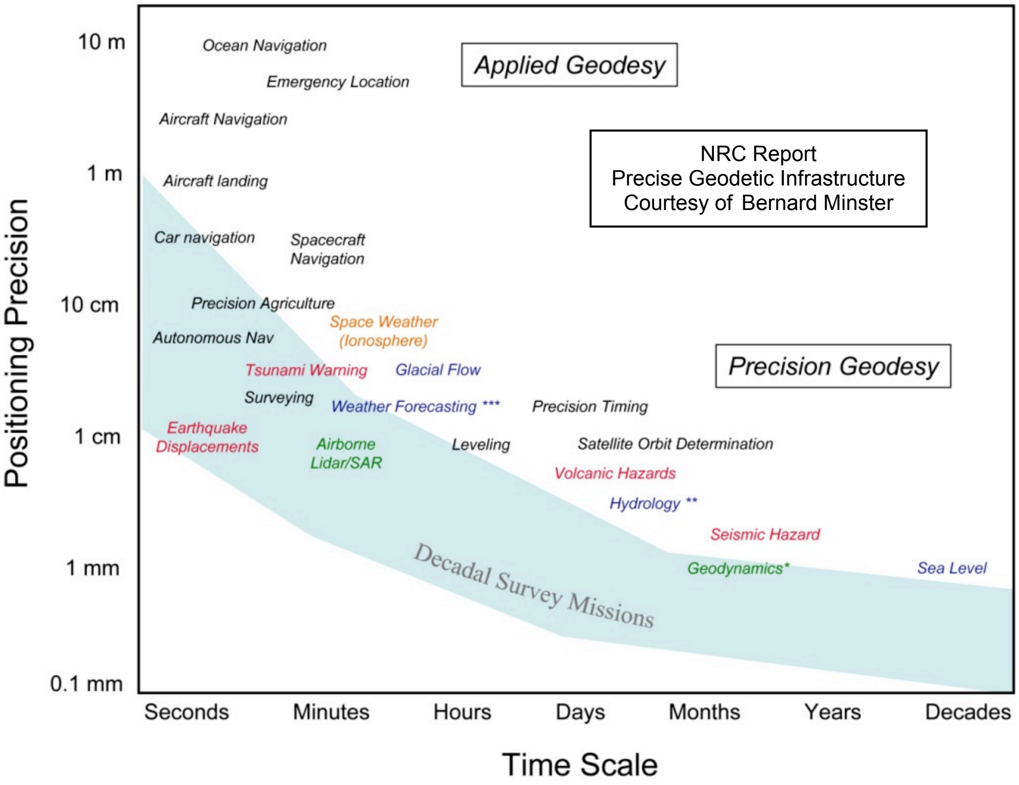

Figure 1. Positioning precision requirements

3 The Fundamental Station

The reference frame is defined through a global network of co-located VLBI, SLR, GNSS and DORIS Fundamental Stations and a more dense network of GNSS and DORIS ground stations will be required distribute the reference frame globally to the users so that geophysical measurements anywhere in the world can be positioned in the frame any time of day. The four techniques measure different quantities in different ways and each has a different set of systematic errors. Proper combination allows us to take advantage of the strengths and mitigate the weaknesses of each. The techniques are co-located so that the measurements among them can be related to sub-mm accuracy. These sites will also have ancillary measurement including absolute and cryogenic gravimeters, tide gauges, seismometers, etc, to connect other geophysical measurements to the reference frame (see Figure 2).

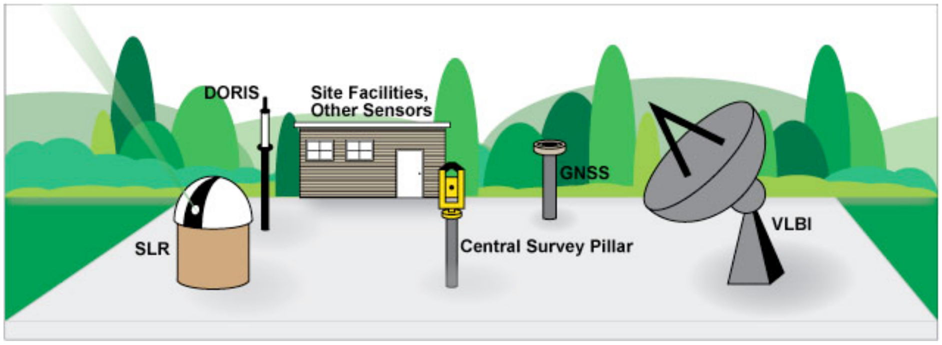

Figure 2. Schematic of a fundamental station

The first version of a Site Requirements for a GGOS Fundamental Station has been written, and is available at *http://cddis.gsfc.nasa.gov/docs/GGOSSiteRequirements_v1.pdf*. The document includes the justification for a Fundamental Site and desirable site conditions. It is recognized that not all sites will meet all conditions, so some trade-offs will be necessary.

4 Network Simulations

Simulations have been conducted by E. Pavlis to examine accuracies for origin, scale and orientation of the resulting ITRF based on various network designs and system performance to determine the optimal global network to achieve this goal. These simulations show that about 30 co-located stations, with modern technology, will be adequate to define the reference frame. Stations in the new global network will require geologically stable sites with good weather, established infrastructure, and local support and personnel.

Today nearly all SLR and VLBI stations have GNSS and some have DORIS. SLR and VLBI are the most costly systems at Fundamental Stations, so co-location of these techniques is the largest undertaking. There are presently eight stations with co-located SLR and VLBI and several more are in the process of being built or are planned, as shown in Figure 3. The co-location network is building, but there will still be significant shortfalls on numbers and geographic coverage.

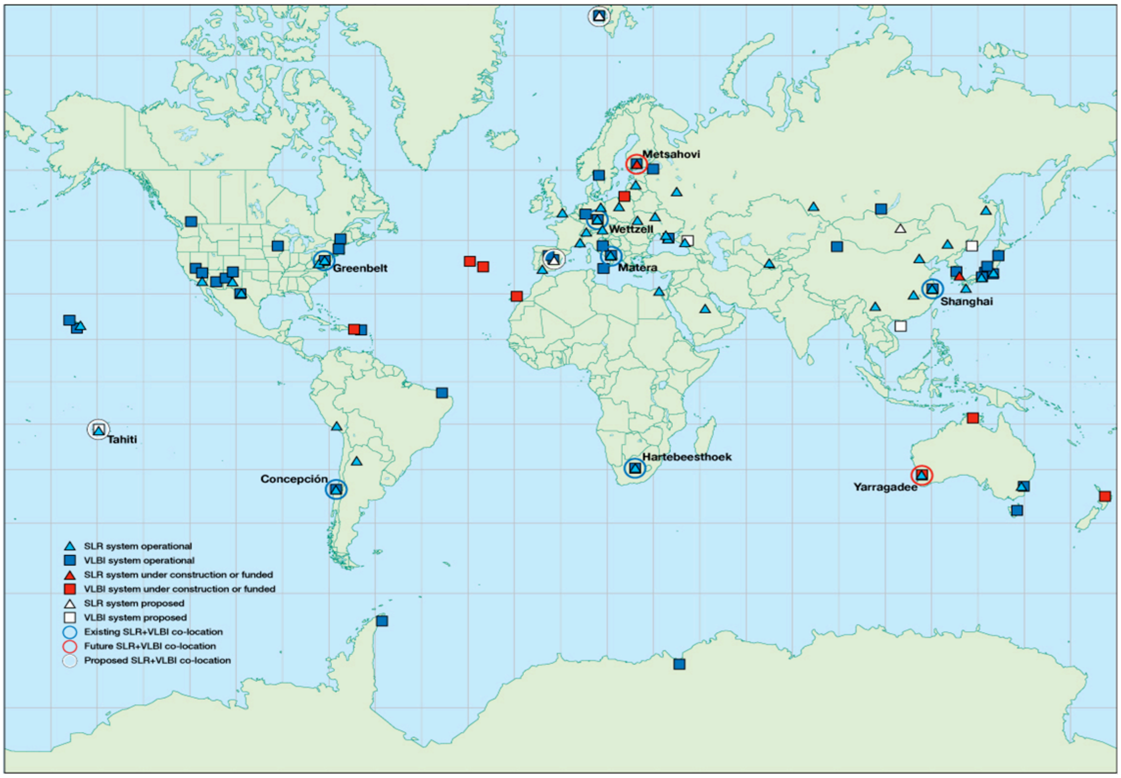

Figure 3. Map of SLR and VLBI stations with Co-Locations highlighted

An essential aspect to co-location are the intersystem vectors that must be determined to sub-mm accuracy in order to place the measurements from the separate systems in the same reference frame. Baselines between closely located, accessible geodetic markers can be measured to sub-mm accuracy with modern instruments, but the necessary extrapolation to system reference points (intersection of the axes, antenna phase centers, etc) which are not readily accessible is the real challenge. This requires fairly elaborate measurement and extrapolation procedures to estimate the reference points, which limits the overall accuracy and in many cases, is a limiting factor in the overall reference frame itself. Approaches continue to be refined and one recent proposed methodology is to use a multi-technique, well-calibrated satellite to determine the co-located intersystem vectors from space.

5 System Upgrades

All of the space geodetic techniques are in the process of upgrading their technologies. SLR has several systems working at higher repetition rates (100Hz – kHz), new fast detection, and automated control systems with the resulting increased data yield, data quality and daylight ranging. Considerable progress is being made on the placement of retroreflector arrays on GNSS satellites. The VLBI2010 prototype with its new front and back ends providing substantially increased observation and recording bandwidth is deployed at several stations, including the new stations at in Tasmania, Katherine, and Yarragadee.

GNSS performance is improving with additional frequencies and new constellations. The DORIS network is already nearly at its planned global distribution and will benefit from additional satellites schedule for launch and from new beacons now being deployed.

6 NASA’s Space Geodesy Project

As a part of the GGOS Network, NASA has undertaken a program to provide its contribution to a worldwide network of modern space geodesy fundamental stations. The first phase of a proposal has been funded for a 2-year activity to:

- Complete network simulations to scope the network and examine geographic, operational and technical tradeoffs based on LAGEOS and GNSS tracking with SLR;
- Complete the prototype SLR (NGSLR) and VLBI (VLBI2010) instruments;
- Co-locate these instruments with the newest generation GNSS and DORIS ground stations at GSFC;
- Implement a modern survey system to measure inter-technique vectors for co-location;
- Develop generalized station layout considering RFI and operations constraints;
- Undertake supporting data analysis;
- Begin site evaluation for network station deployment;
- Develop a full network implementation plan for a follow-on phase for deployment for up to 10 stations

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