Global Geodetic Observing System (GGOS) and Core Sites

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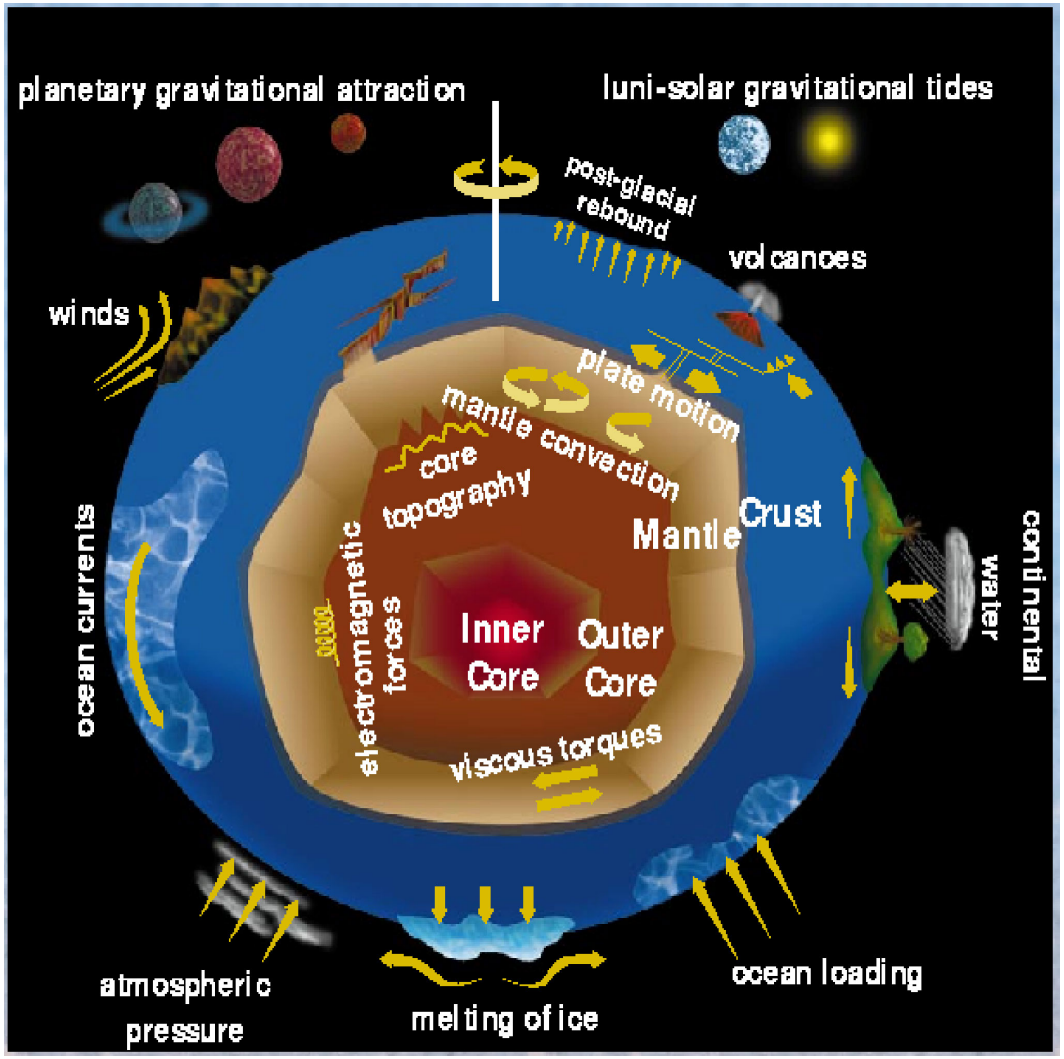
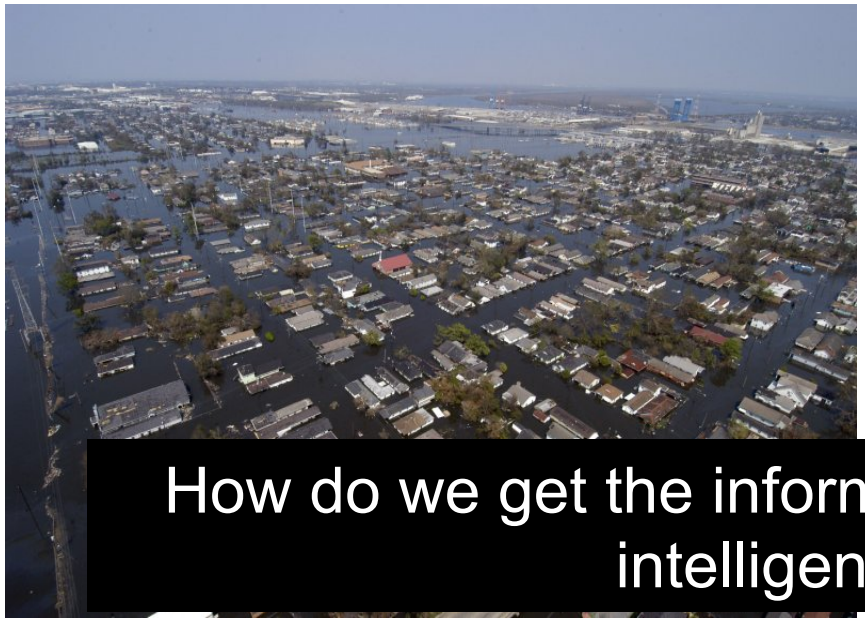
Some people think the Earth looks like this:

But really – it looks like this:



Motivation: Monitoring the Earth System



How do we get the information that we need to make intelligent decisions?

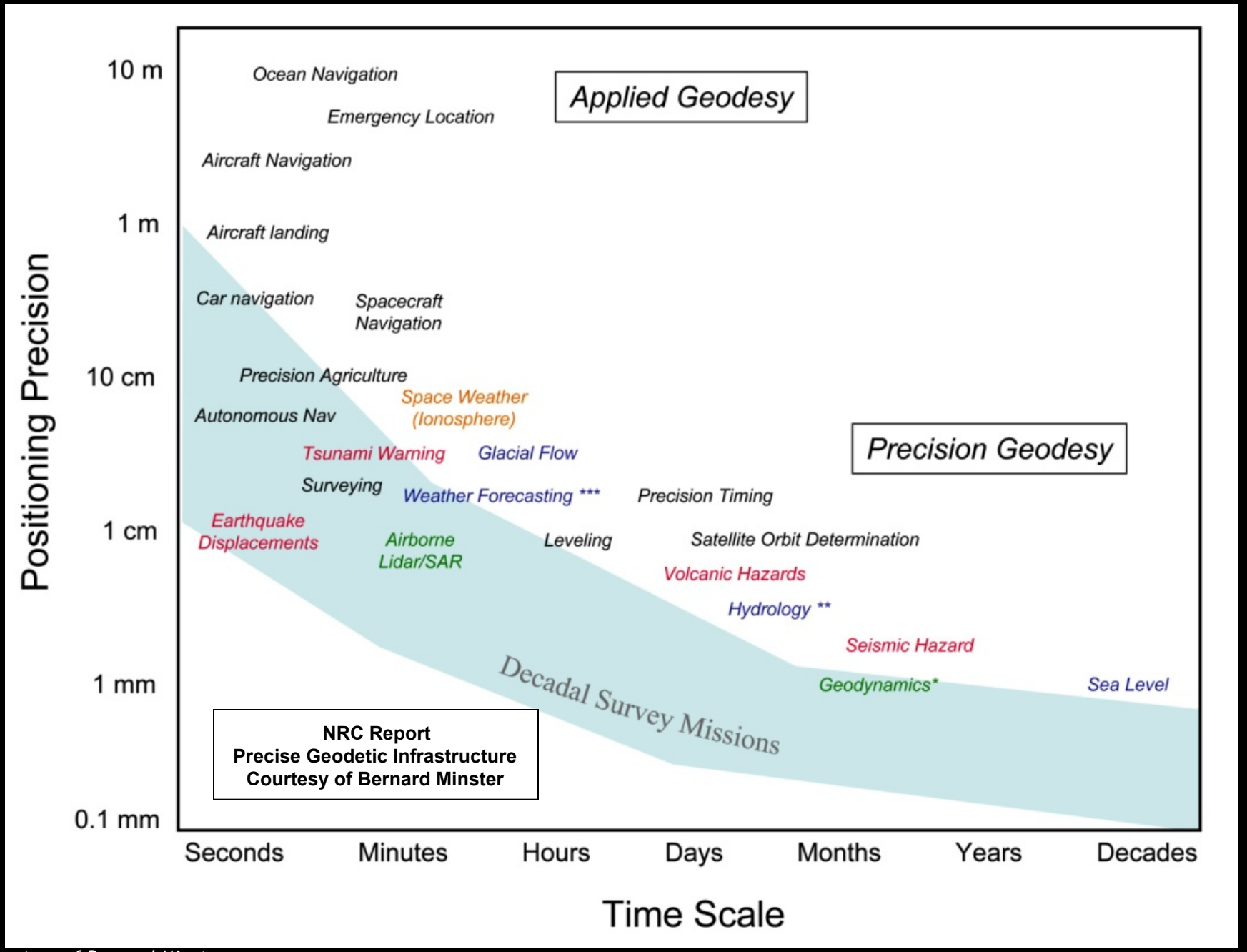
Geometry and Deformation of the Earth

- Problem and fascination of measuring the Earth:

Everything is moving !

- Monitoring today mainly by GPS permanent networks

- Examples:
  - Plate motions
  - Solid Earth tides (caused by Sun and Moon)
  - Loading phenomena (ice, ocean, atmosph.)
  - Earthquakes …
- **Continuous monitoring is absolutely crucial**

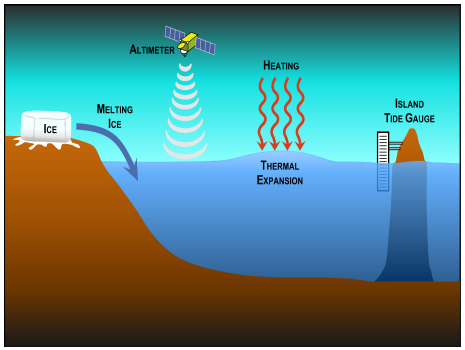


Courtesy of Bernard Minster
http://dels.nas.edu/Report/Precise-Geodetic-Infrastructure-National-Requirements/12954

What is the International Terrestrial Reference Frame (ITRF)?

- Provides the stable coordinate system that allows us to measure change (link measurements) over space, time and evolving technologies.
- An accurate, stable set of station positions and velocities.
- Foundation for virtually all space-based and ground-based metric observations of the Earth.
- Established and maintained by the global space geodetic networks.
- Network measurements must be precise, continuous, robust, reliable, and geographically distributed (worldwide).
- Network measurements interconnected by co-location of different observing techniques

The Geodetic Reference Frame
(International Terrestrial Reference Frame)



Requirement (Source GGOS 2020):

<1 mm reference frame accuracy

< 0.1 mm/yr stability

–Measurement of sea level is the primary driver

–Improvement over current ITRF performance by a factor of 10-20.

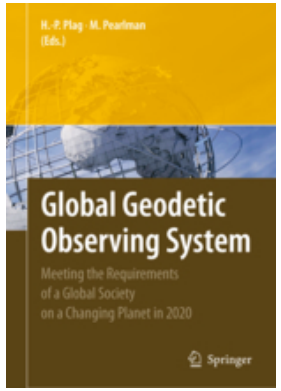
Means of providing the reference frame:

- **Global Network of co-located VLBI/SLR/GNSS/DORIS CORE SITES define the reference frame**
- **Dense network of GNSS stations to distribute the reference frame globally to the users**

Users anywhere on the Earth can position their measurements in the reference frame

This work is being done by the GGOS Bureau for Networks and Communication with the assistance of the the GGOS InterAgency Committtee (GIAC)

Global Geodetic Observing System (GGOS)



Official Component (Observing System) of the International Association of Geodesy (IAG) with the objective of:

Ensuring the availability of geodetic science, infrastructure, and products to support global change research in Earth sciences to:

- *extend our knowledge and understanding of system processes;*
- *monitor ongoing changes;*
- *increase our capability to predict the future behaviour; and*
- *improve the accessibility of geodetic observations and products for a wide range of users;*
- ***Improve and maintain the International Terrestrial Reference Frame (ITRF)***

Role

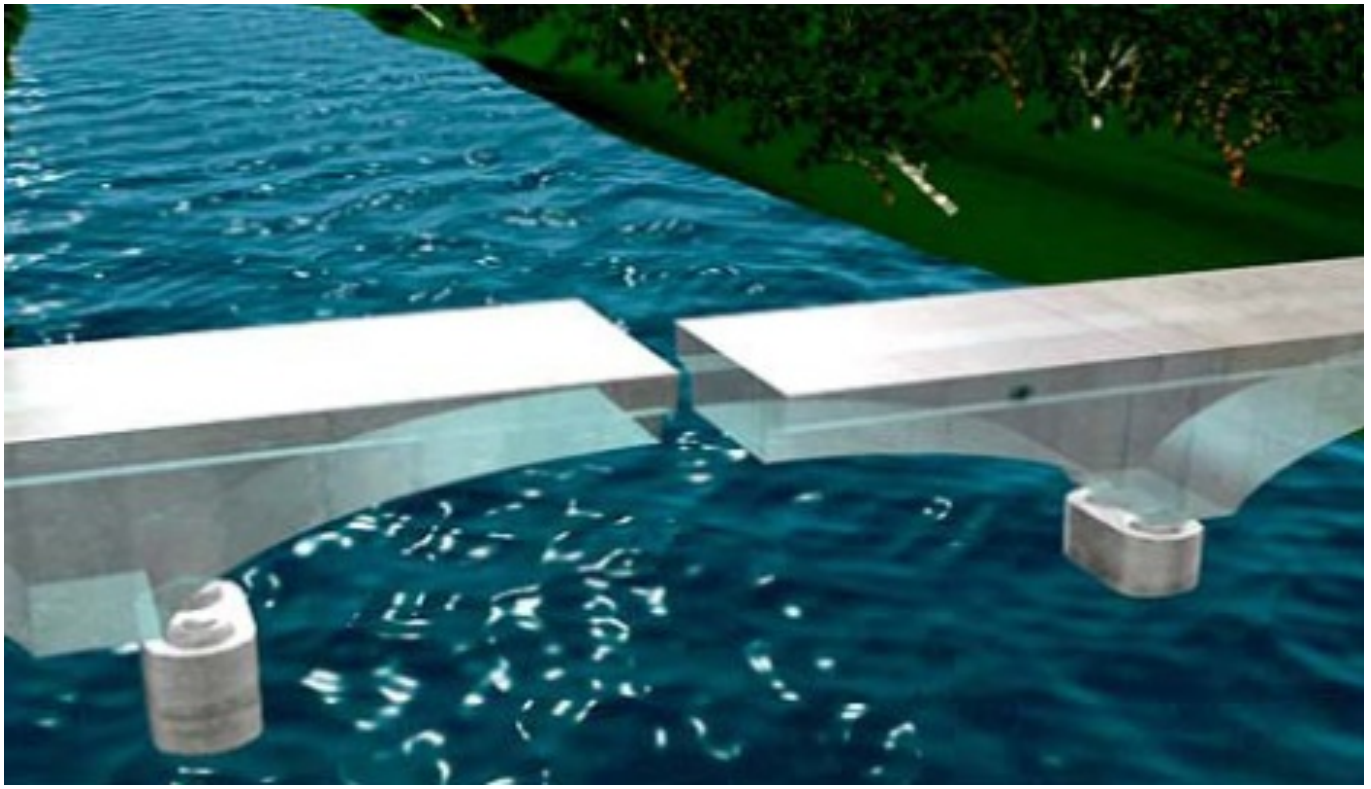
- **Facilitate networking** among the IAG Services and Commissions and other stakeholders in the Earth science and Earth Observation communities,
- **Provide scientific advice and coordination** that will enable the IAG Services to develop products with higher accuracy and consistency meeting the requirements of global change research.

GGOS Bureau for Networks and Communications

- Provide oversight, coordination, and guidance for the development, implementation and operation of the Network of Core (co-location) Sites.
- Develop a strategy to design, integrate and maintain the geodetic core network of co-located instruments and supporting infrastructure in a sustainable way to satisfy the long term (10 - 20 years) requirements identified by the GGOS Science Council.

Accepted as a Sub-Task under the Group on Earth Observations (GEO)

When National Reference Frames are not integrated!

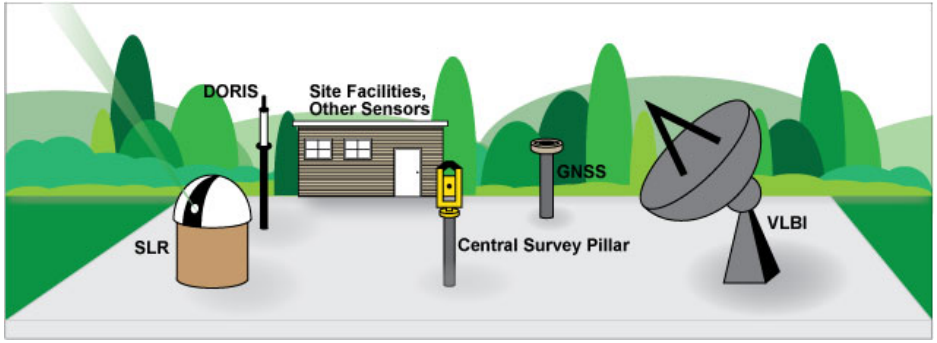


Design error at bridge construction in Laufenburg (2003): During the construction of the bridge across the Rhine river in Laufenburg, a control showed that a height difference of 54 centimeters exists between the bridge built from the Swiss side and the roadway of the German side. Reason of the error is the fact that the horizons of the German and Swiss side are based on different reference frames. Germany refers to the sea level of the North Sea, Switzerland to the Mediterranean.

Courtesy of Hermann Drewes/DGFI

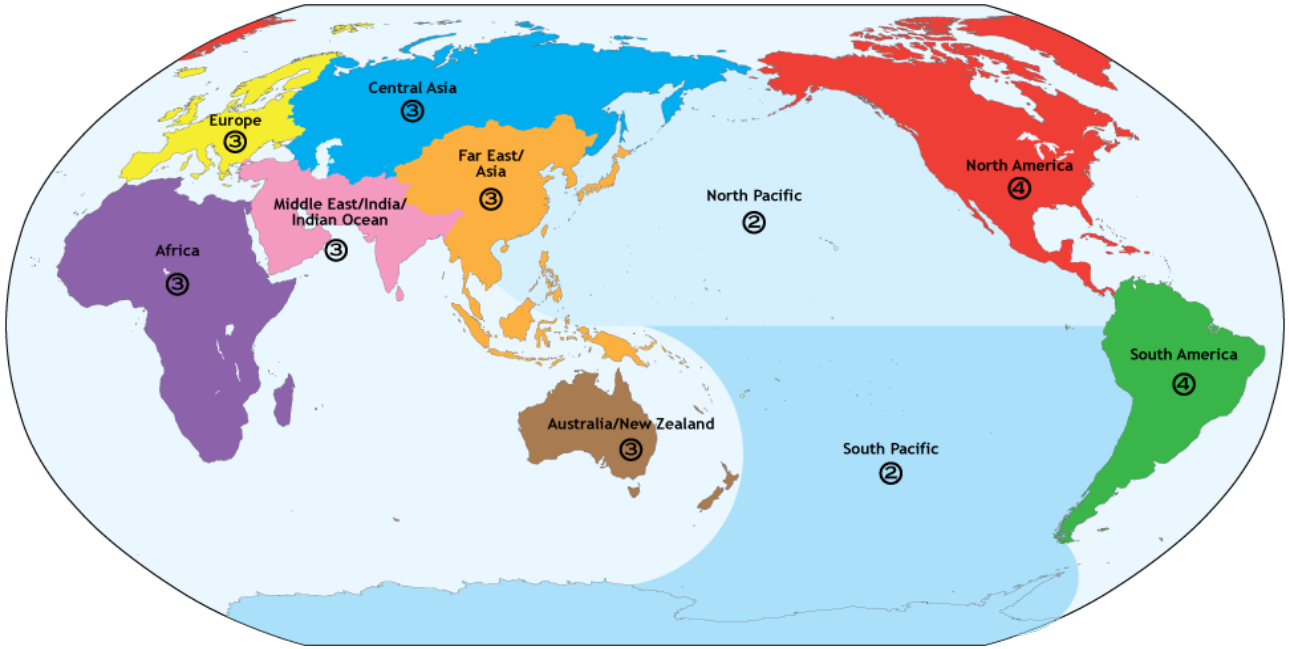
What is a Core Site?
(Terrestrial Reference Frame)

- A ground site with co-located SLR, VLBI, GNSS and DORIS (where available) so that their measurements can be related to sub-mm accuracy
- Why do we need multiple techniques?
  - Measurement requirements are very stringent
  - Each technique makes its measurements in a different way and therefore each measures something a little different:
    - Terrestrial (satellite) verses celestial (quasar) reference
    - Range verses range difference measurements
    - Broadcast up verses broadcast down
    - Radio verses optical
    - Active verses passive
    - Geographic coverage
  - Each technique has different strengths and weaknesses
  - The combination allows us to take advantage of the strengths and mitigate the weaknesses



Simulation Studies to Scope the Network of Core Sites (Fundamental Stations)

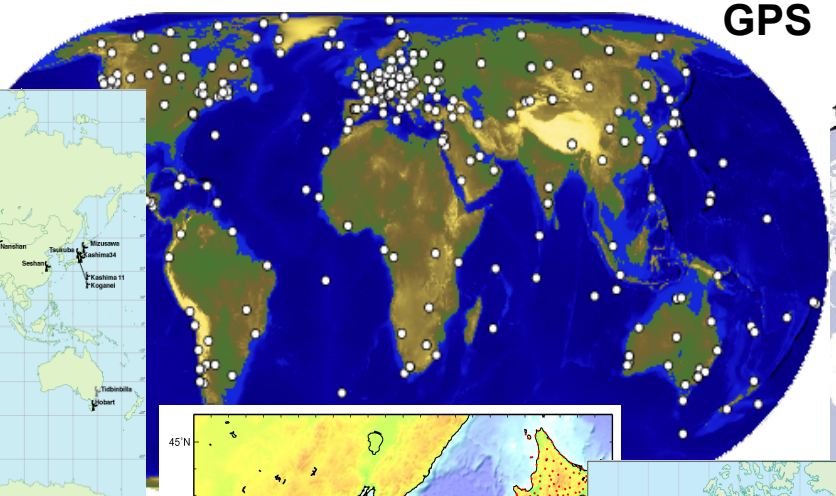
(Erricos Pavlis)

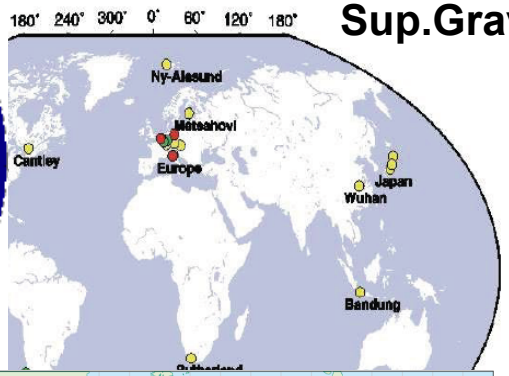


30 Core Sites required to satisfy reference frame requirements

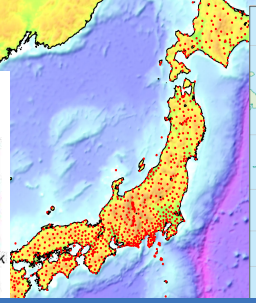
- Globally well distributed;
- Proper conditions;
- Modern technology;
- Operate routinely;
- Day/Night SLR tracking on GNSS complexes to calibrate the GNSS orbits;

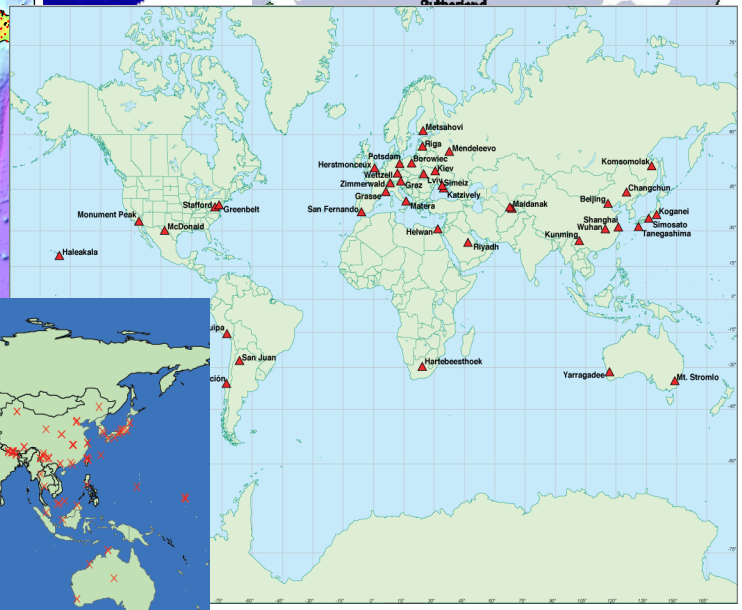
GGOS: the Ground-Based Component



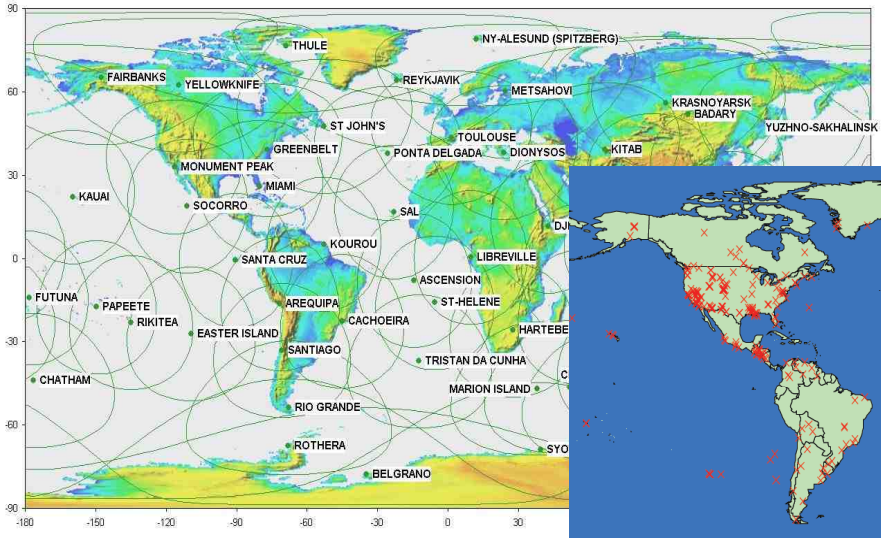


GPS

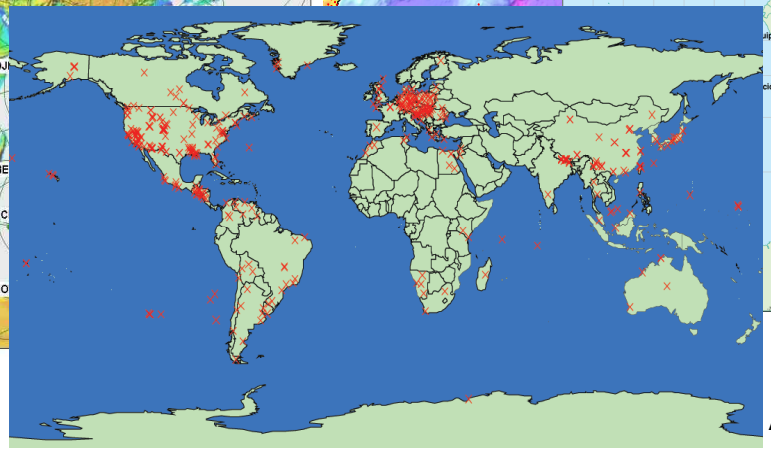




SLR/LLR



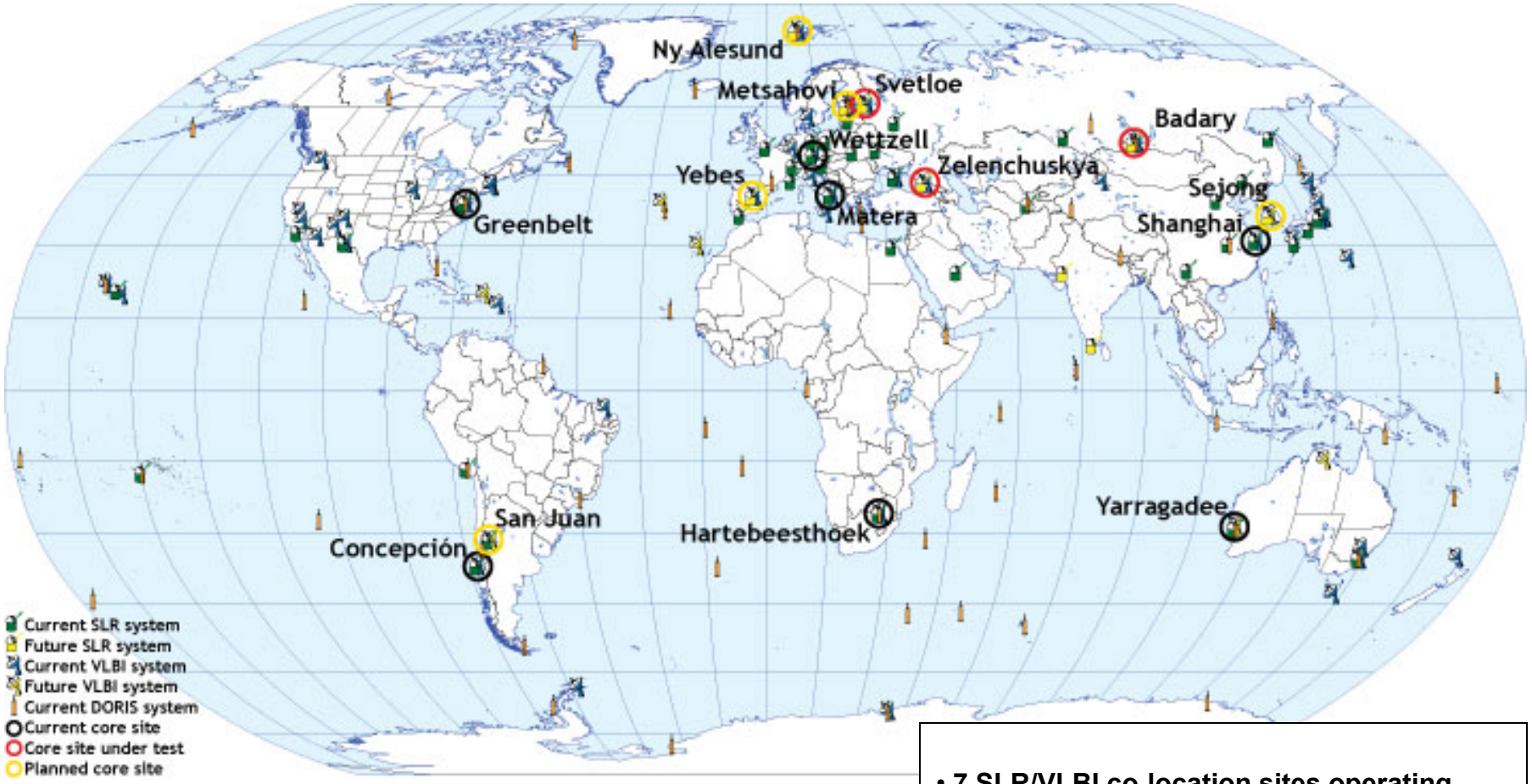
DORIS



Abs.Grav.

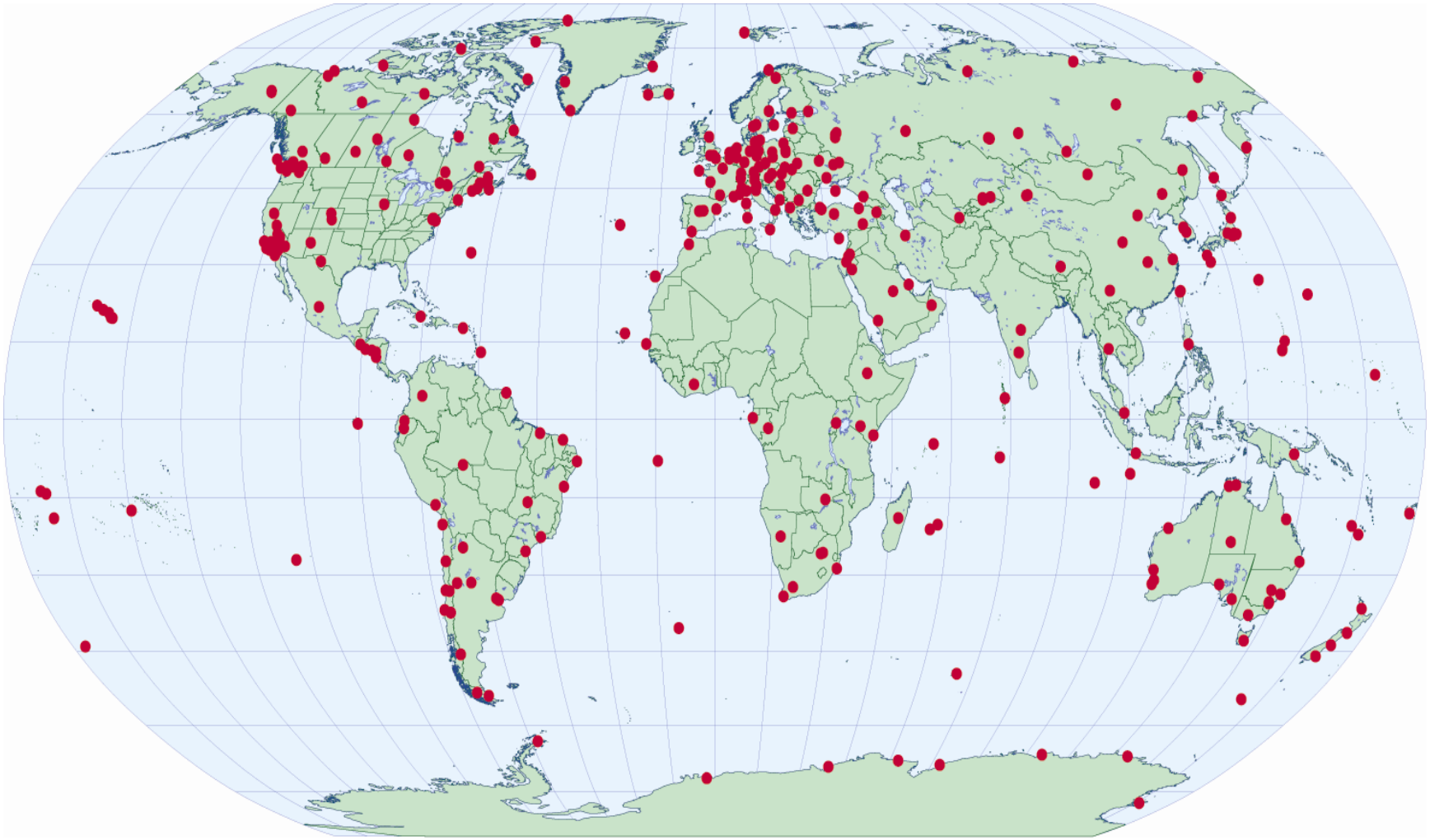
SLR+VLBI Networks

(with SLR/VLBI Co-locations noted)



- **7 SLR/VLBI co-location sites operating**
- **All co-locations sites have GNSS**
- **3 more sites in process**
- **Several more sites in planning**

GNSS (IGS) Network



Example Core Site

NASA Goddard Space Flight Center, Greenbelt MD, USA

- Goddard Geophysical and Astronomical Observatory (GGAO) has four techniques on site
  - Legacy SLR, VLBI, GPS, DORIS
  - NGSLR semi - “operational”
  - VLBI2010 systems in testing
- GGAO will be the location for the prototype next generation multi-technique station

Concepcion, Chile

New Co-located Sites in Russia

Badary

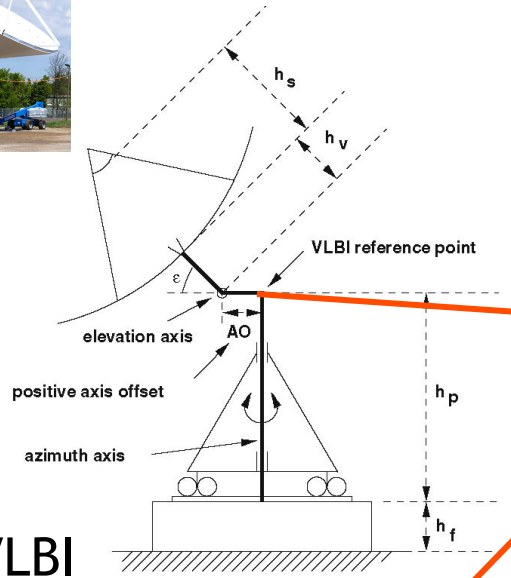
Zelenchukskaya

Techniques are all Making Progress

- Satellite Laser Ranging
  - Many systems working in the 0.1 – 2 Khz regime;
  - Single photon detection;
  - Increased data yield and daylight ranging on the GNSS satellites;
  - Several new systems in Russia;
  - Progress on the GPS-3 arrays;
- VLBI
  - Prototype VLBI 2010 in testing at GSFC and Wettzell;
  - New Systems Systems
    - Tasmania, Katherine, Yarragadee Stations;
    - Wettzell twin telescopes;
- GNSS
  - Multiple constellations
  - Additional frequencies
  - New ground stations
- DORIS
  - Nearly complete network already
  - Additional satellites
  - New beacons

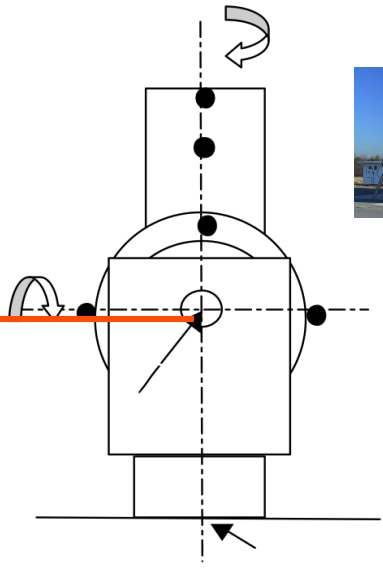
Fundamental Station Ground Co-location

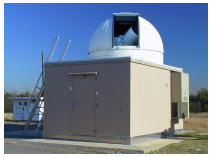
and the essential role of the intersystem vector



VLBI

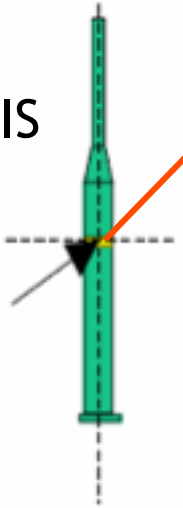
Co-Location System



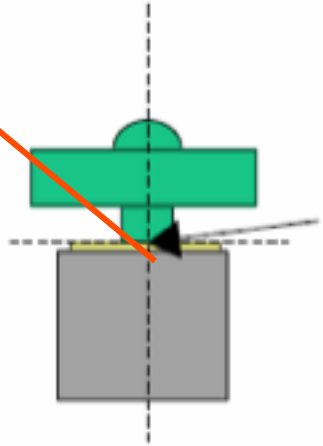


SLR

DORIS



- GNSS and DORIS reference points
  - Extrapolate to measurement phase center
- VLBI and SLR reference points
  - Extrapolate to measurement phase center
  - RP through indirect approach
  - Targets mounted on system structure
  - Rotational sequence about axes of space geodetic instrument
  - Model to determine axes location



GPS

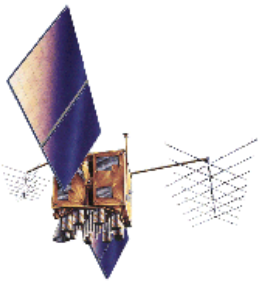
Co-location in Space
(Complimentary to Ground Survey)

Compass

GNSS/SLR

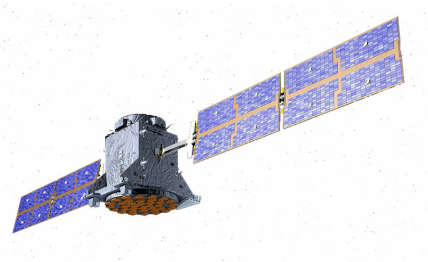
GLONASS

GNSS/SLR



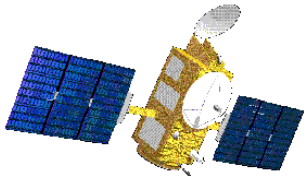
GPS

GNSS/SLR



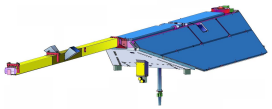
GIOVE/Galileo

GNSS/SLR



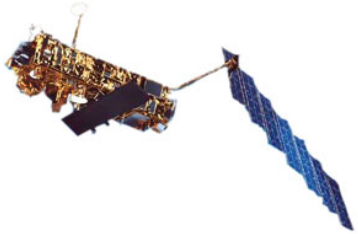
Jason

DORIS/GNSS/SLR



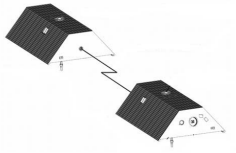
CHAMP

GNSS/SLR



Envisat

DORIS/SLR



GRACE

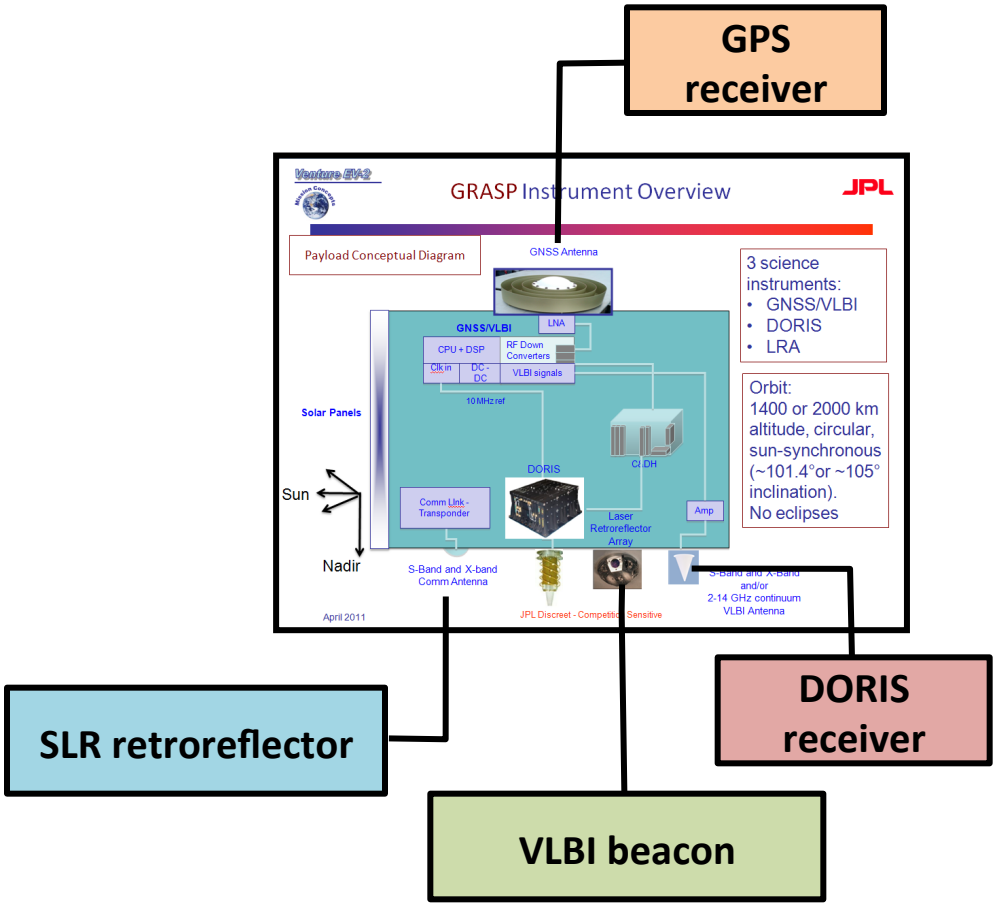
GNSS/SLR

PROBLEM: Limited technique combinations and inadequate spacecraft calibrations

GRASP

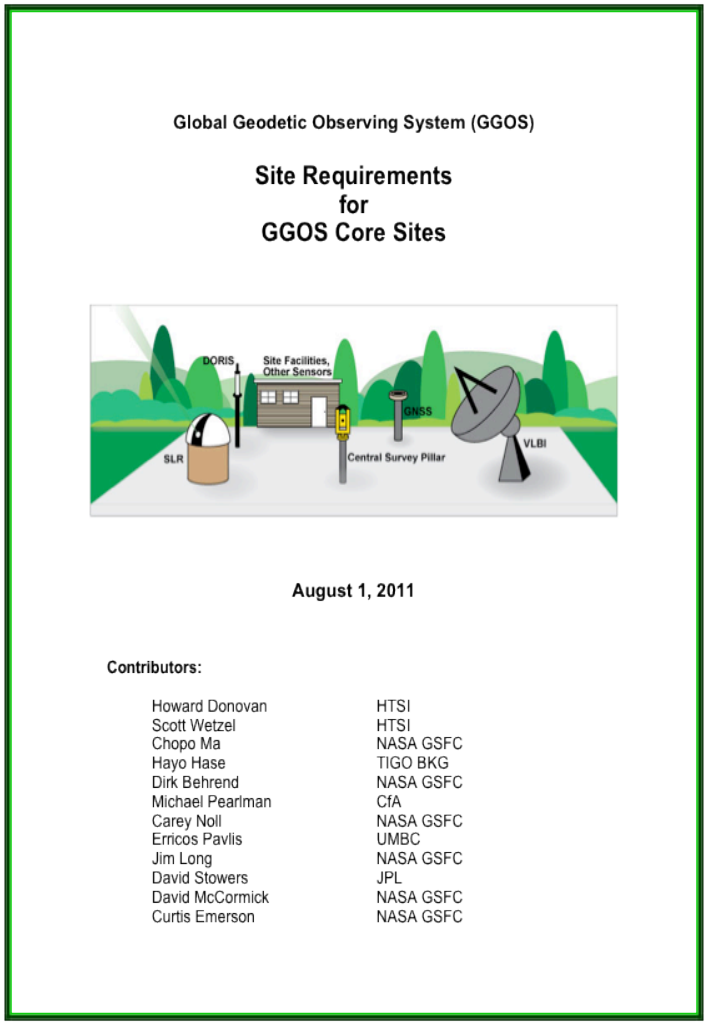
Geodetic Reference Antenna in Space

- Co-location of geodetic techniques contributing to the TRF.
- Determine TRF with 1 mm accuracy and 0.1 mm/yr stability.
- Orbit:
  H = 1400 – 2000 km
  polar, sun-synchronous.



GGOS Site Requirements Document

(http://cddis.gsfc.nasa.gov/docs/GGOS_SiteReqDoc.pdf)



Global Geodetic Observing System (GGOS)

Site Requirements
for
GGOS Core Sites

August 1, 2011

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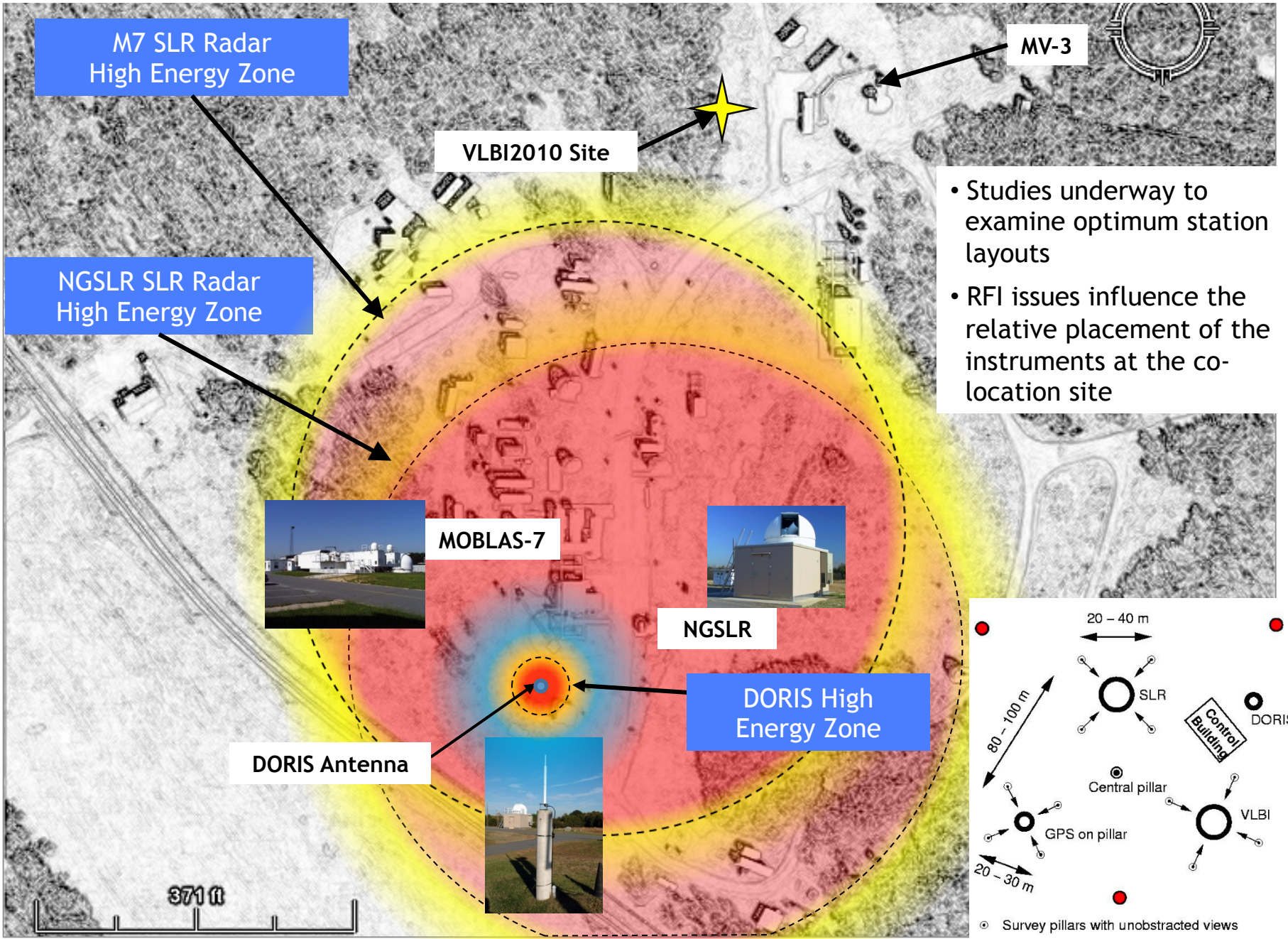
- Introduction and Justification
  - What is a Fundamental Station?
  - Why do we need the Reference Frame?
  - Why do we need a global network?
  - What is the current situation?
  - What do we need?
- Site Conditions
  - Global consideration for the location
  - Geology
  - Site area
  - Weather and sky conditions
  - Radio frequency and optical Interference
  - Horizon conditions
  - Air traffic and aircraft Protection
  - Communications
  - Land ownership
  - Local ground geodetic networks
  - Site Accessibility
  - Local infrastructure and accmmodations
  - Electric power
  - Site security and safety
  - Local commitment

Considerations for Site Locations

- **Geographic locations (globally distributed network)**
- **General and local geology (geologically stable)**
- **Weather (clear conditions for SLR)**
- **Clear Horizon**
- **RFI conditions**
- **Local topography and land constraints**
- **Communications**
- **Accessibility and shipping constraints**
- **Local infrastructure (power, roads, etc.)**
- **Technical and personnel support, etc**
- **Site security**
- **Political considerations (can do business in a practical manner)**

- **Operations:**
  - **Year round**
  - **Day and night**

Co-located Station Layout

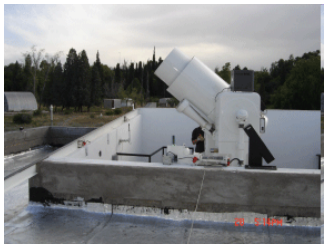


- Studies underway to examine optimum station layouts
- RFI issues influence the relative placement of the instruments at the co-location site

Space Geodesy Stations in South America

- 1 station with SLR/VLBI/GNSS
- 1 station with VLBI/GNSS
- 1 station with SLR/DORIS/GNSS
- 4 stations with DORIS/GNSS

- Stations crowded together
- Some of the stations have inadequate conditions



Concepción

The Right Station in the Wrong Place for ITRF

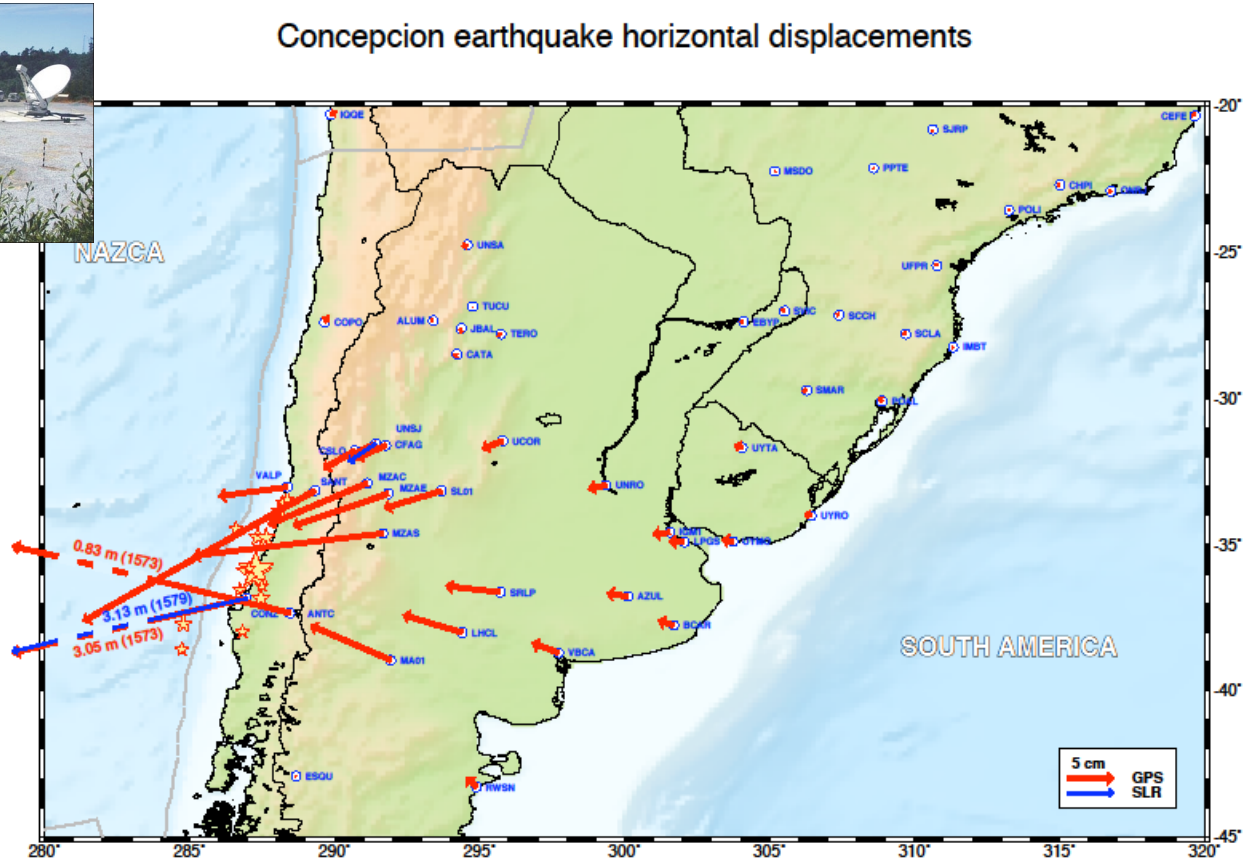
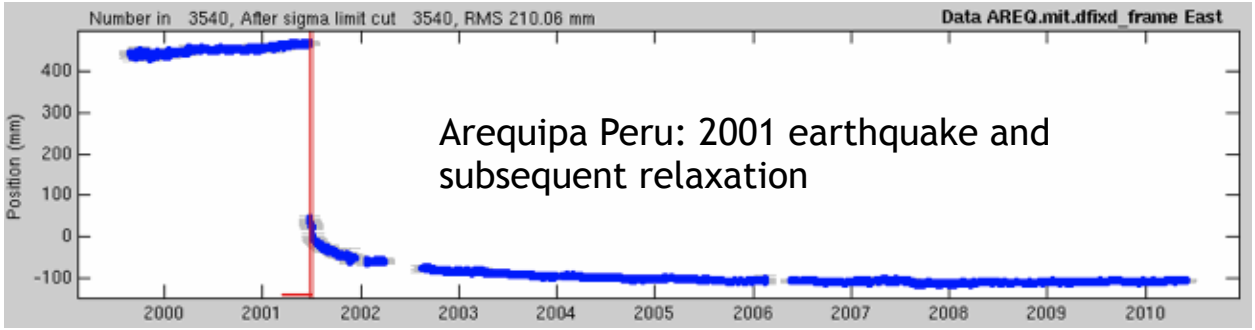


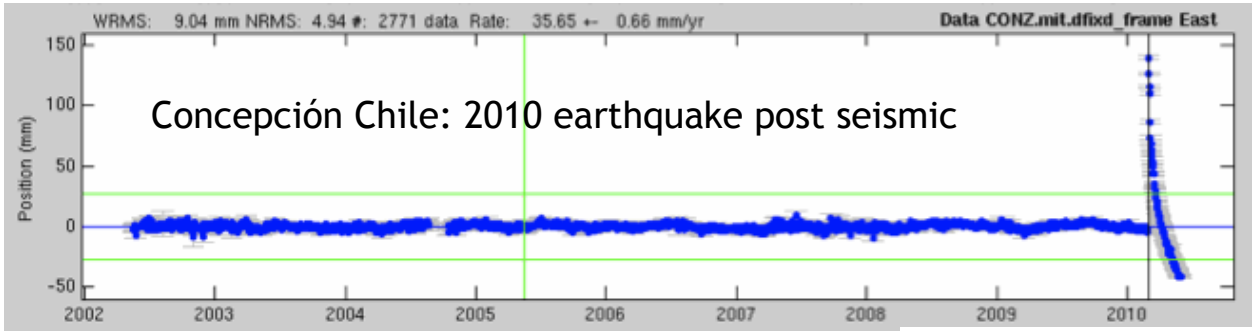
Figure courtesy of DGFI

Time History of Station Positions

Examples of Local Stability



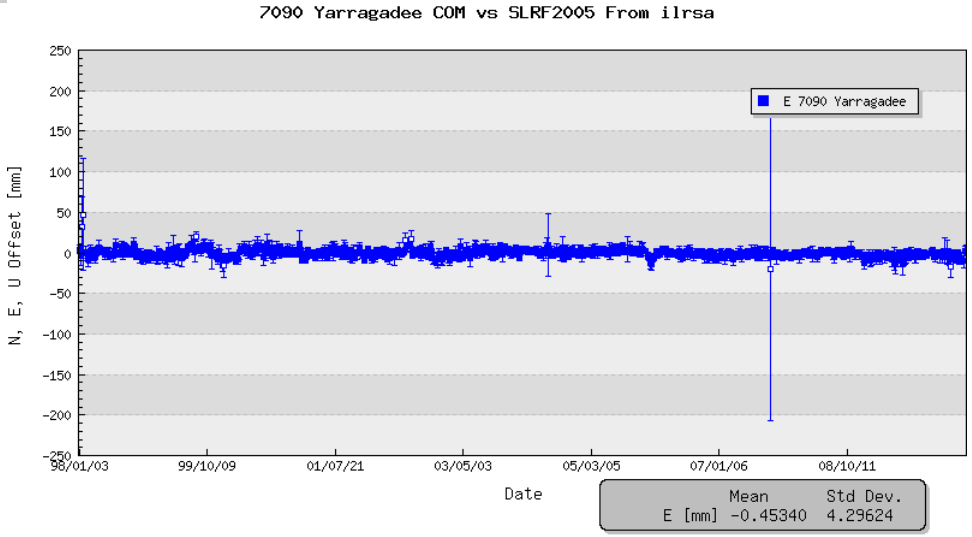
Arequipa Peru: 2001 earthquake and subsequent relaxation



Concepción Chile: 2010 earthquake post seismic

Arequipa and Concepción plots courtesy Tom Herring/MIT

Yarragadee Australia: stable site



GGOS Call for Participation;
The Global Geodetic Core Network:
Foundation for Monitoring the Earth System
(Issued 15 August 2011; due 15 November 2011)

We seek proposals from organizations that would participate in the development, implementation and maintenance of the GGOS Global Geodetic Core Network.

- **To implement and operate core space geodesy stations including:**
  - **existing stations that already have the four techniques implemented and plan for upgrade to the next generation systems;**
  - **existing stations that have one or more techniques operational, are planning for upgrade to the next generation systems and for the implementation of the remaining techniques;**
- **To support the network design and planning activity with analysis, simulations, site research (geology, weather, logistics, personnel, etc). To help design and develop the inter-technique vector systems and operational procedures.**
- **To provide applicable space geodetic instruments for implementation at a GGOS Global Geodetic Core Site in cooperation with a local organization.**
- **To implement and operate core stations offered by others;**
- **Call for Participation has been issued through the Services and the IAG.**
- **The Call is available on the NEWS page at: http://www.ggos.org/**

Conclusion

- ***The global network will require four core sites, well distributed in South America***

- ***Major participation from international partners is essential to meeting the reference frame requirements.***