The Need for Space Geodesy Networks

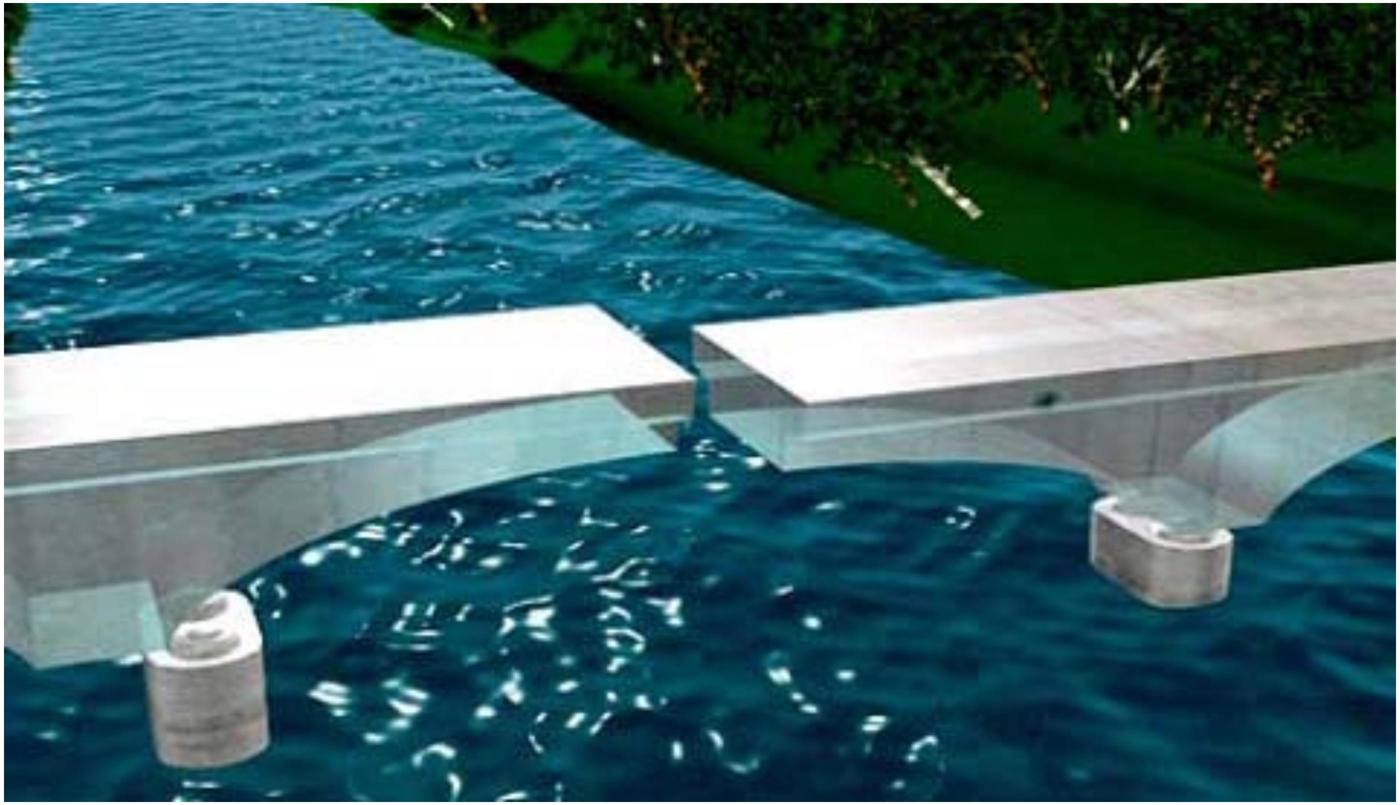
Michael Pearlman

<<Date>>

The need for monitoring Earth systems with Space Geodesy Networks

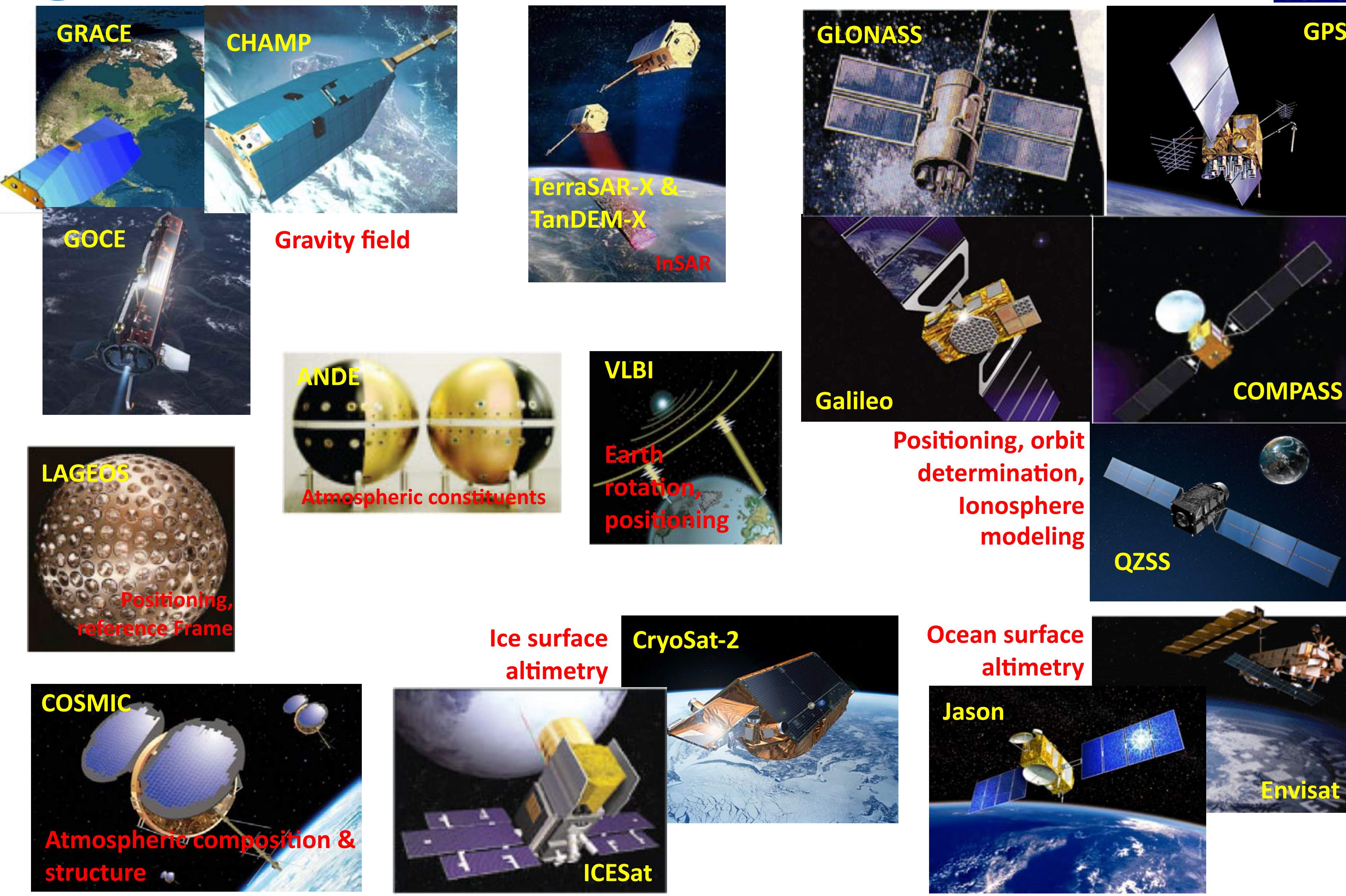
- Earth processes can have a devastating impact on our society and our economies (earthquakes, rising sea level, floods, drought, storms, tsunamis, etc.)
- Monitoring the Earth Systems will help us understand the environmental processes:
  - Land, oceans, land hydrology, atmosphere, etc.
- Major societal decisions will require many years to implement:
  - Building dikes, moving population, building codes, agricultural strategies, etc.
- Understanding environmental processes will help us make intelligent decisions early enough to have a timely impact
- Space geodesy networks are fundamental to the system to monitor and understand Earth processes for both ground space measurements
- Space Geodesy networks allow us to integrate national reference systems

When National Reference Frames are not integrated!

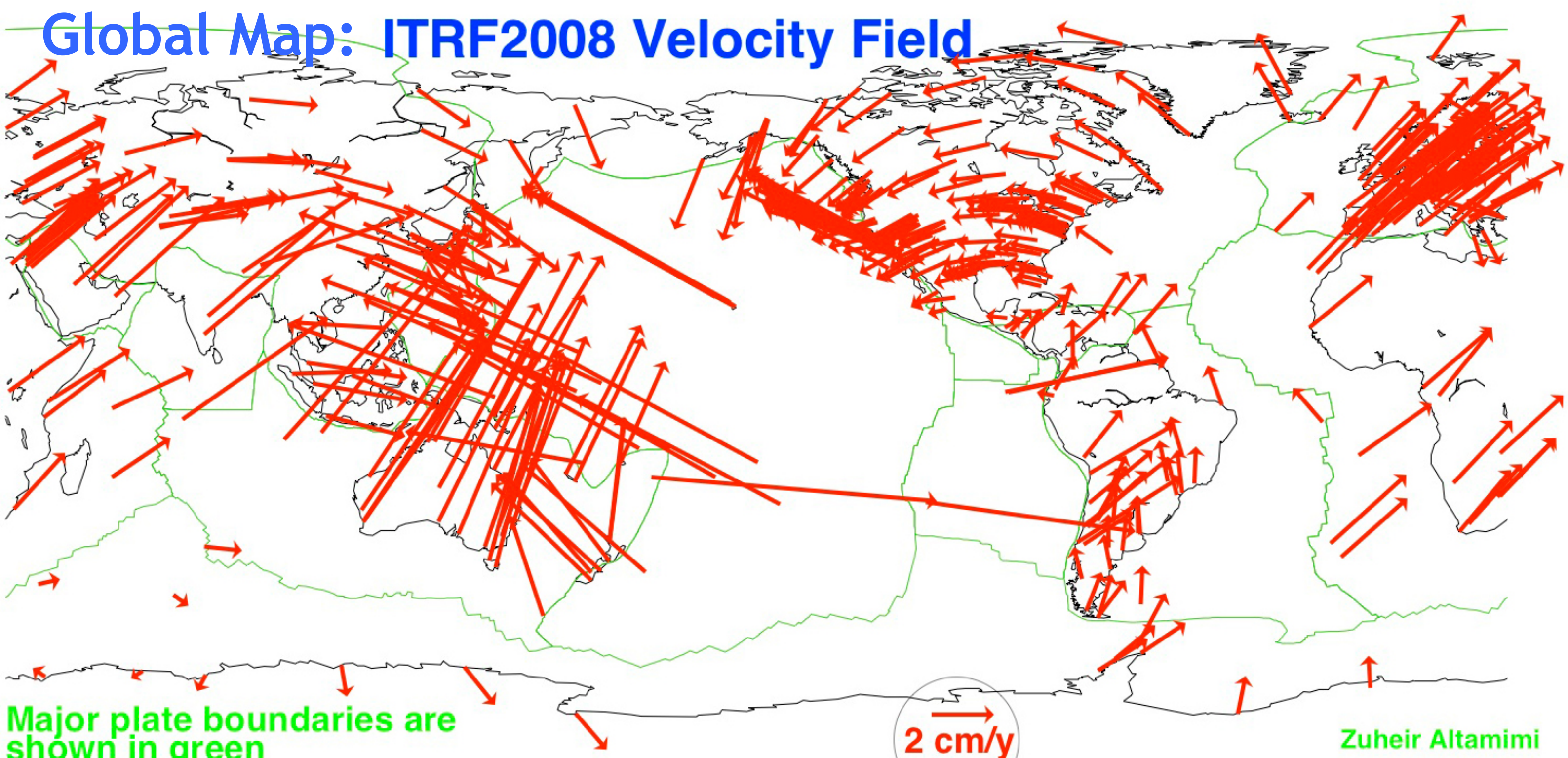


Design error at bridge construction in Laufenburg (2003): During the construction of the bridge across the Rhine river in Laufenburg, a control showed that a height difference of 54 centimeters exists between the bridge built from the Swiss side and the roadway of the German side. Reason of the error 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.

The Role of Space Components

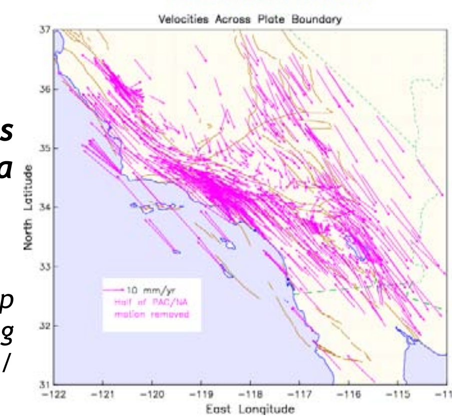


Space Geodesy Networks measure ground motions to map strain build up



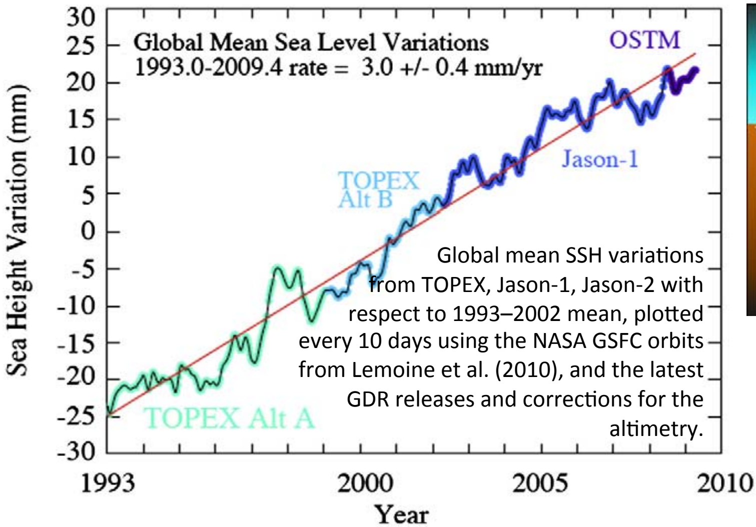
Zuheir Altamimi

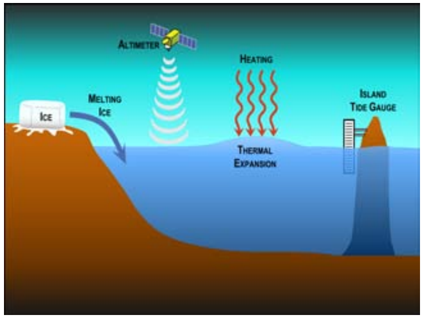
Regional strain measurements in Southern California



The SCEC Crustal Motion Map
Z.-K. Shen, D. C. Agnew, R. W. King
http://epicenter.usc.edu/cmm3/

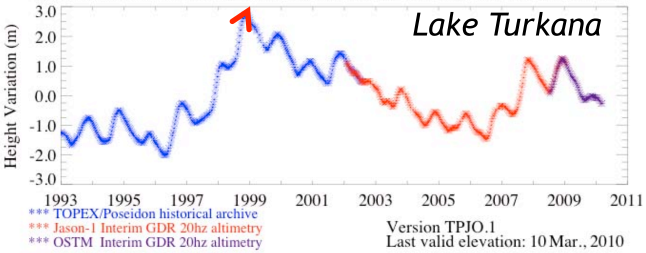
Satellite Altimetry

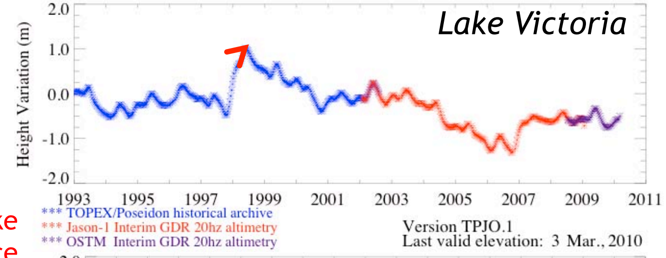




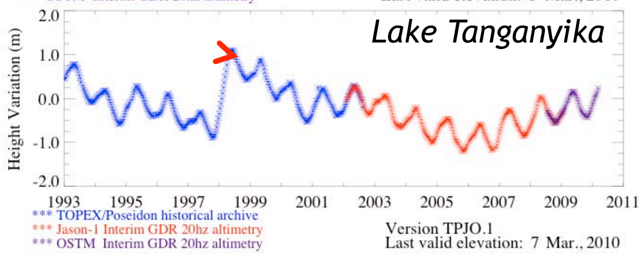
Satellite Altimetry measures Sea Surface rise due to melting of ice and increase in ocean temperature

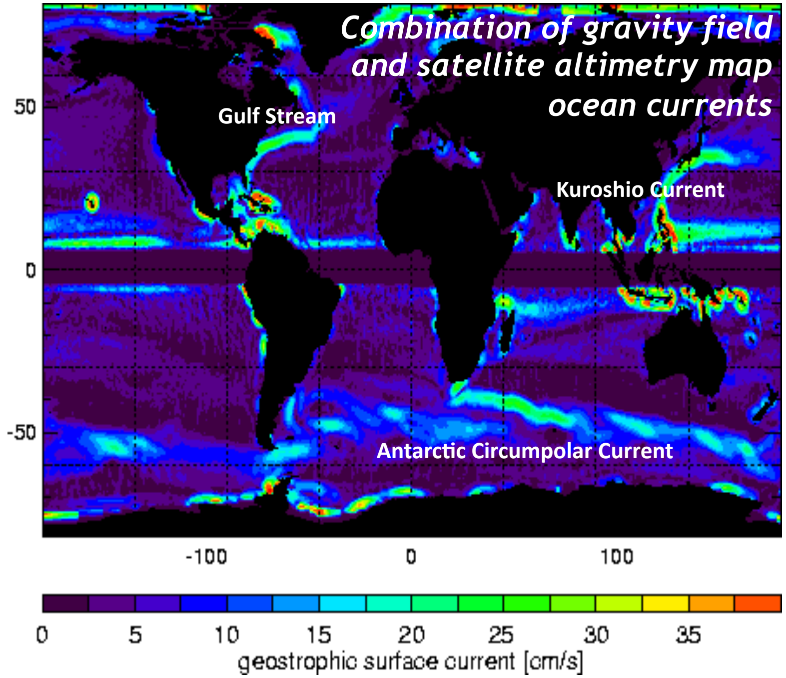
Satellite altimetry measures changes in height of lakes and rivers



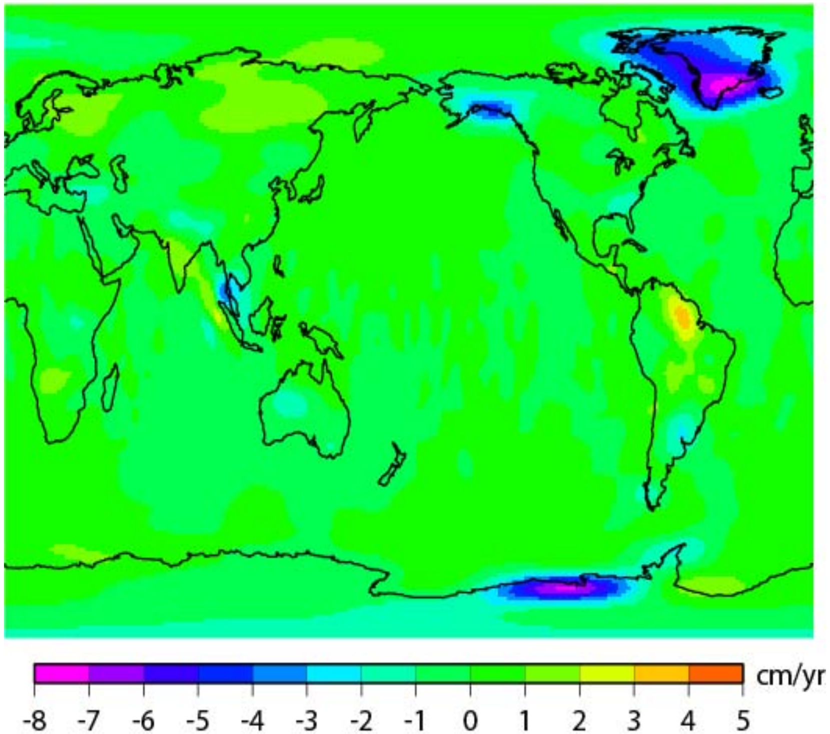


Decrease in lake water levels since 1997/98 El Nino



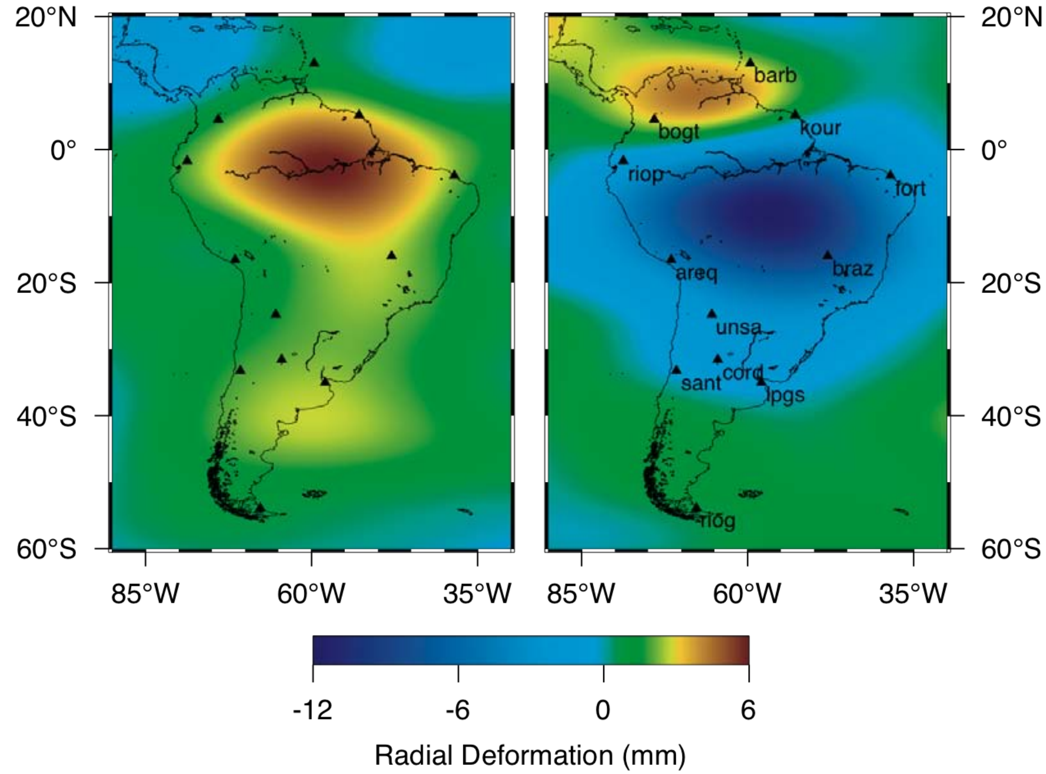


GRACE measures change in gravitational load



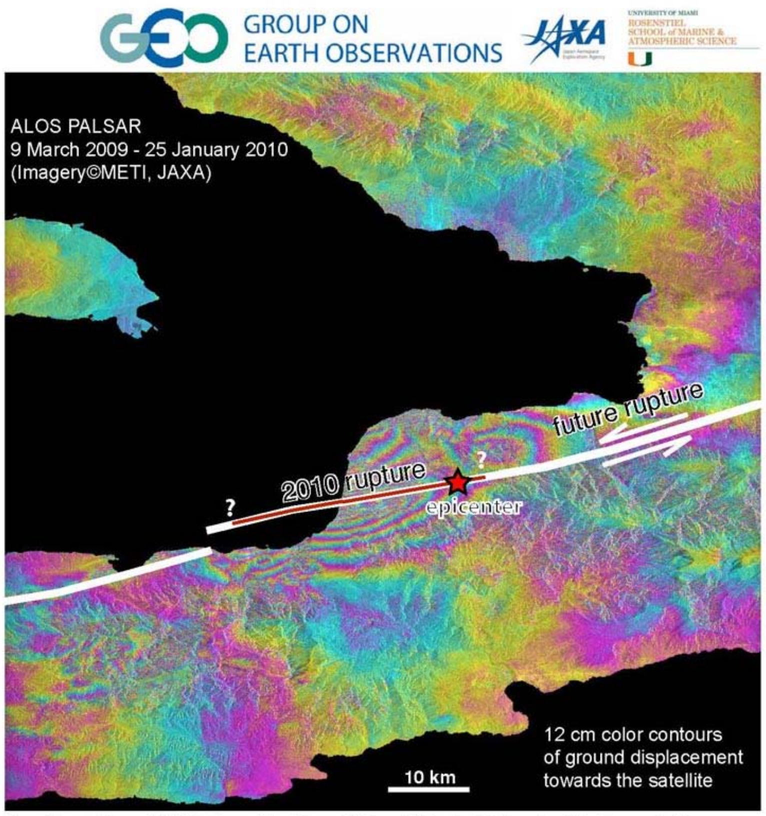
Gravity field mission measures patterns of ice loss, mass distribution due to earthquakes and hydrological signals (2002-2009).

Gravity field mission measures annual hydrological cycle in South America as periodic change in gravitational load, deforming the Earth when water is added or subtracted and the surface is pressed or released.



InSAR measurements to understand Natural Hazard Processes

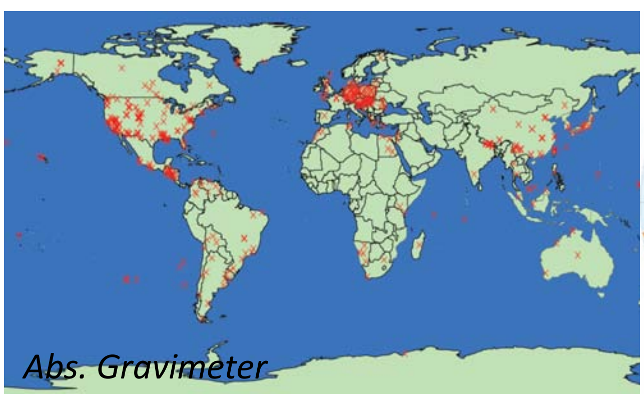
- InSAR measures ground displacement and deformation before and after Earthquakes, volcano eruptions, landslides, etc. to help us understand these mechanisms to help predict future risk.
- At right is an InSAR map of the ground displacement from the January 2010 M7 Haiti earthquake
- Each band of color contours is 12 cm of, so the total displacement was ~1 m over a large area



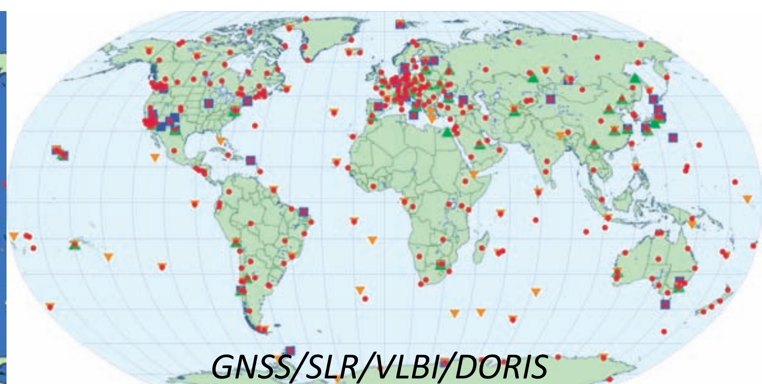
Sang-Hoon Hong, Falk Amelung, Tim Dixon, Shimon Wdowinski, Guoqing Lin, Fernando Greene
Rosenstiel School of Marine & Atmospheric Science, University of Miami

Ground-based Space Geodesy Networks are essential to monitoring and understanding Earth processes

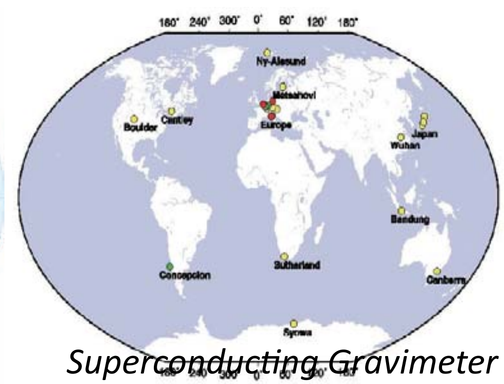
- Ground-based space geodesy networks provide the International Terrestrial Reference Frame that allows us to <u>measure change (link measurements) over space, time and evolving technologies</u>
- An accurate, global set of stable station positions and velocities.
- Foundation for virtually all space-based 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 the different observing techniques



Abs. Gravimeter

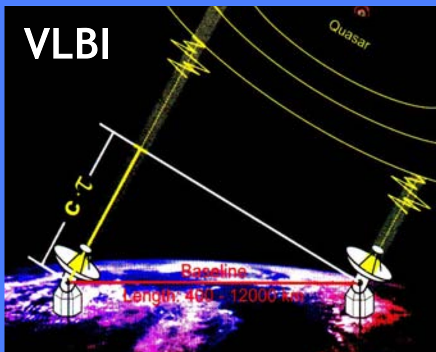


GNSS/SLR/VLBI/DORIS

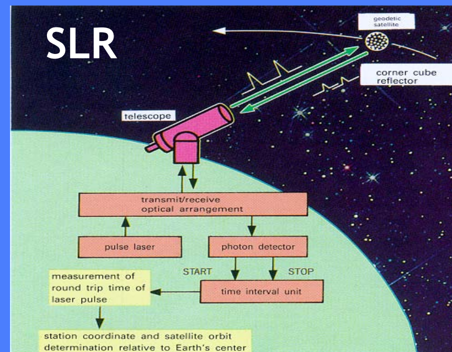


Superconducting Gravimeter

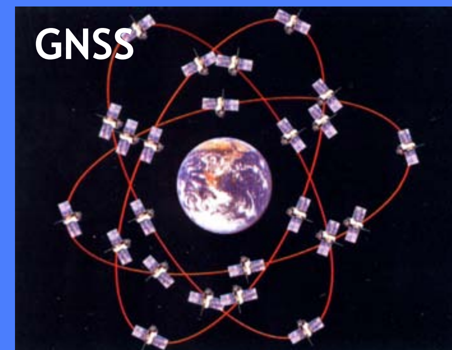
The combination of Space Geodesy Techniques provides the consistency and accuracy necessary for the the quality of the Terrestrial Reference Frame



Very Long Baseline Interferometry

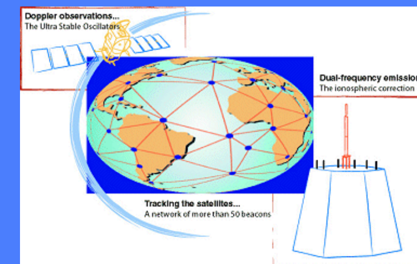


Satellite Laser Ranging



Global Navigation Satellite System

DORIS



Doppler Orbitography and Radio Positioning Integrated by Satellite

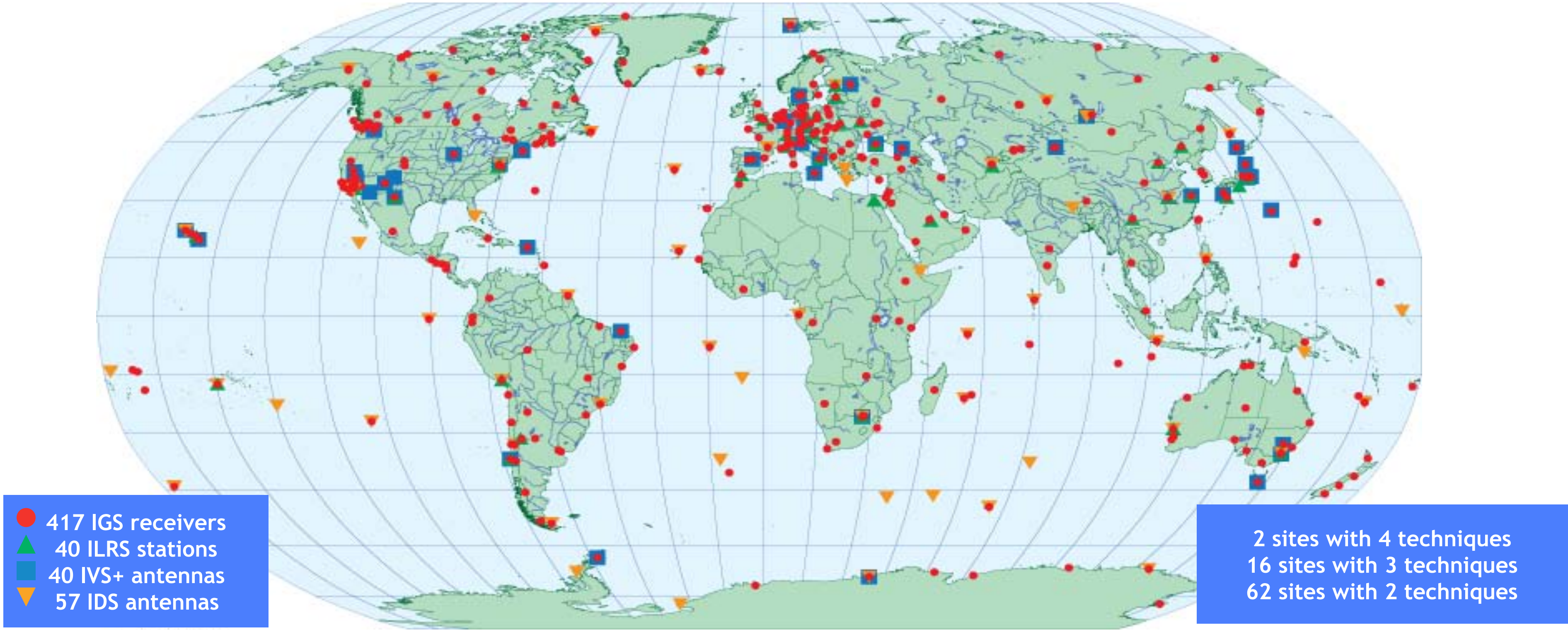
- Space geodetic systems provide the measurements that are needed to define and maintain the International Terrestrial Reference Frame (ITRF)
- Each of the space geodetic techniques has special properties that bring unique strengths to the reference frame;
  - Radio verses optical
  - Active verses passive
  - Terrestrial (satellite) verses celestial (quasar) reference
  - Broadcast up verses broadcast down
  - Range verses range difference measurements
  - Geographic coverage

Requirement for the International Terrestrial Reference Frame

- Most stringent requirement comes from sea level studies:
  - "accuracy of 1 mm, and stability at 0.1 mm/yr"
  - This is a factor 10-20 beyond current capability
- Accessibility: 24 hours/day; worldwide
- Space Segment: LAGEOS, GNSS, DORIS Satellites
- Ground Segment: Global distributed network of "modern", co-located SLR, VLBI, GNSS, DORIS stations
- Co-locate with and support other measurement techniques including gravity, tide gauges, etc.
- Simulation studies to date show a need for:
  - ~30 globally distributed, well positioned, co-location stations will be required to define and maintain the reference frame;
  - ~16 of these co-location stations must track GNSS satellites with SLR to calibrate the GNSS orbits which are used to distribute the reference frame.




Current Space Geodesy Networks



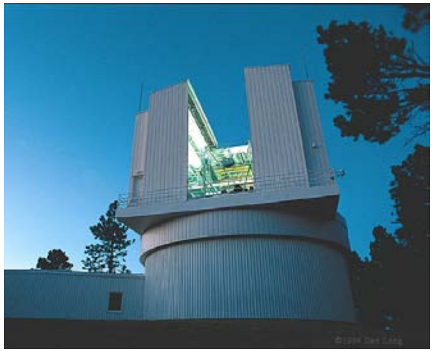
Deficiencies in current space geodesy network:

- Insufficient co-locations
- Although all of the Services have gaps in geographic coverage, the geographic gaps in SLR and VLBI are of particular concern.
- All of the networks are an anachronistic mix of legacy systems (in some cases decades old) and modern systems.
- Performance differences between stations and system deterioration over time have seriously compromised overall network performance.

Reference accuracy and stability will require 30 globally distributed, multi-technique co-location ground stations

- Considerations for site co-locations:
  - Geographic locations (globally distributed network)
  - General and local geology (geologically stable)
  - Clear Weather (for SLR)
  - Quiet Radio Frequency Interference conditions
  - Local topography and land constraints
  - Wide-Band Communications for near real-time data transfer and instrument control and monitoring
  - Accessibility and shipping constraints
  - Available local infrastructure (power, roads, etc.)
  - Technical and personnel support, etc
  - Site security

- Conceptual 30 station Network
  - North America - 3 stations
  - South America - 3 stations
  - Europe - 3 stations
  - Africa - 3 stations
  - Central Asia - 3 stations
  - India/Indian Ocean regions - 3 stations
  - Far East/Asia - 3 stations
  - Australia/New Zealand - 3 stations
  - North Pacific - 3 stations
  - South Pacific - 3 stations



Space Geodesy Stations in South America

- Stations in South America are not well distributed
- Some of the current stations in South America have inadequate meteorological and geological conditions severely limiting data quality and quantity

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

Arequipa

Fortaleza

Concepcion

San Juan

NASA Space Geodesy Project

- Provide NASA's contribution to a worldwide network of modern space geodesy fundamental stations;
- Phase 1 Proposal developed for a 2–year activity:
  - 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 (VLBI 2010) instruments;
  - Co-locate these instrument 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;
- Follow-on phase for deployment for up to 10 stations;
- Separate Proposal for building of first retroreflector array for future GPS satellites