MODERN GROUND NETWORKS FOR SPACE GEODESY APPLICATIONS

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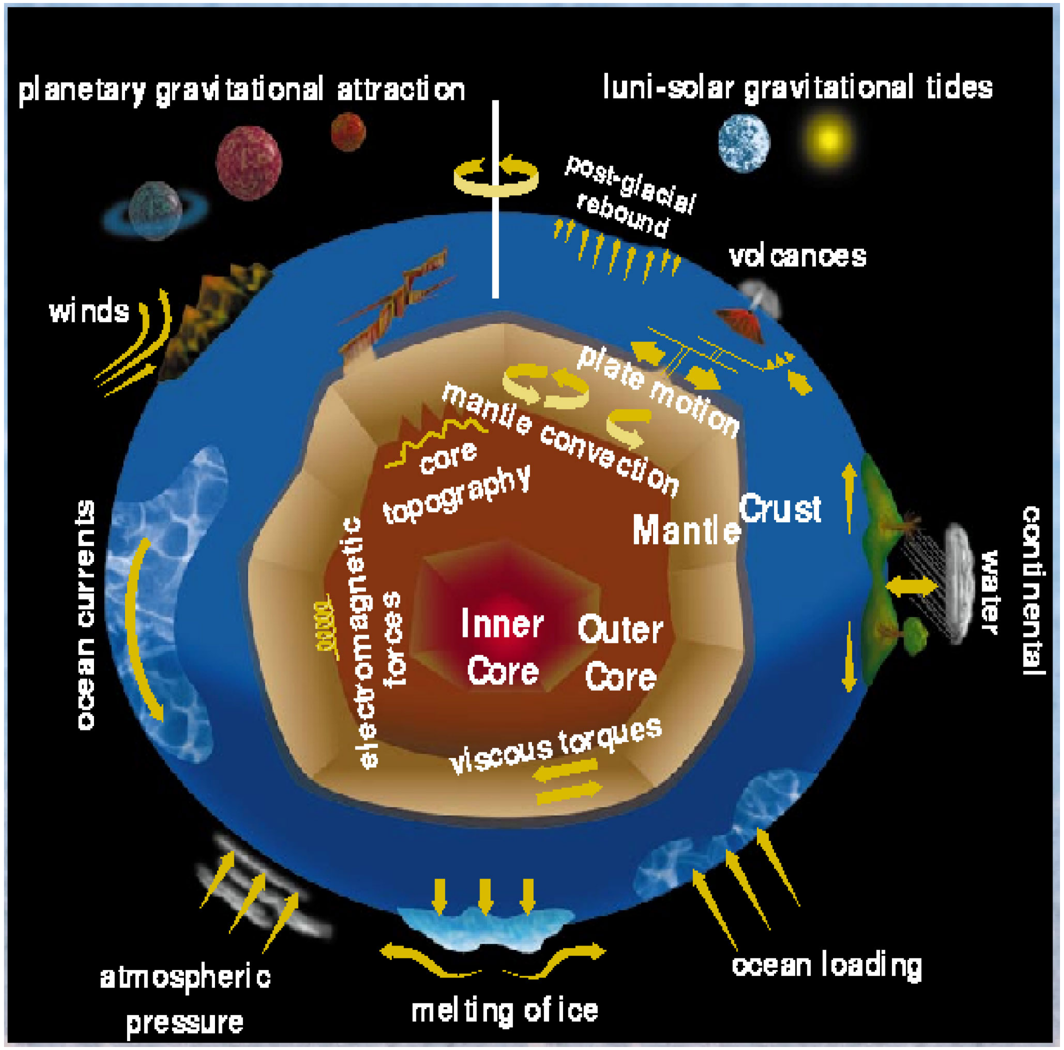
Content

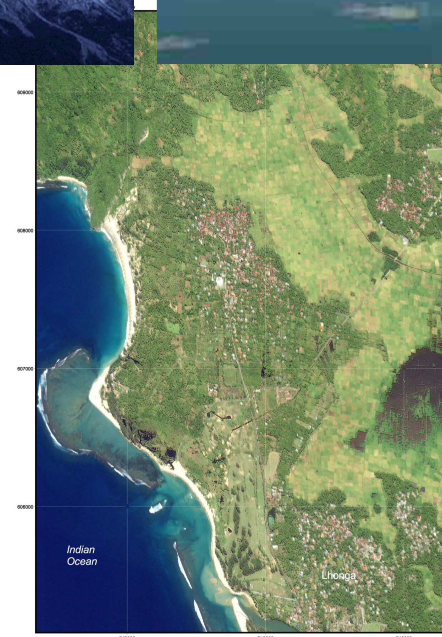
- Space Geodesy Techniques
- Science and Applications
- International Terrestrial Reference Frame
- Network/Station Requirements
- Organizations

Some people think the Earth looks like this:

But really – it looks like this:



Motivation: Monitoring the Earth System



Pillar 1: Geometry and Deformation of the Earth

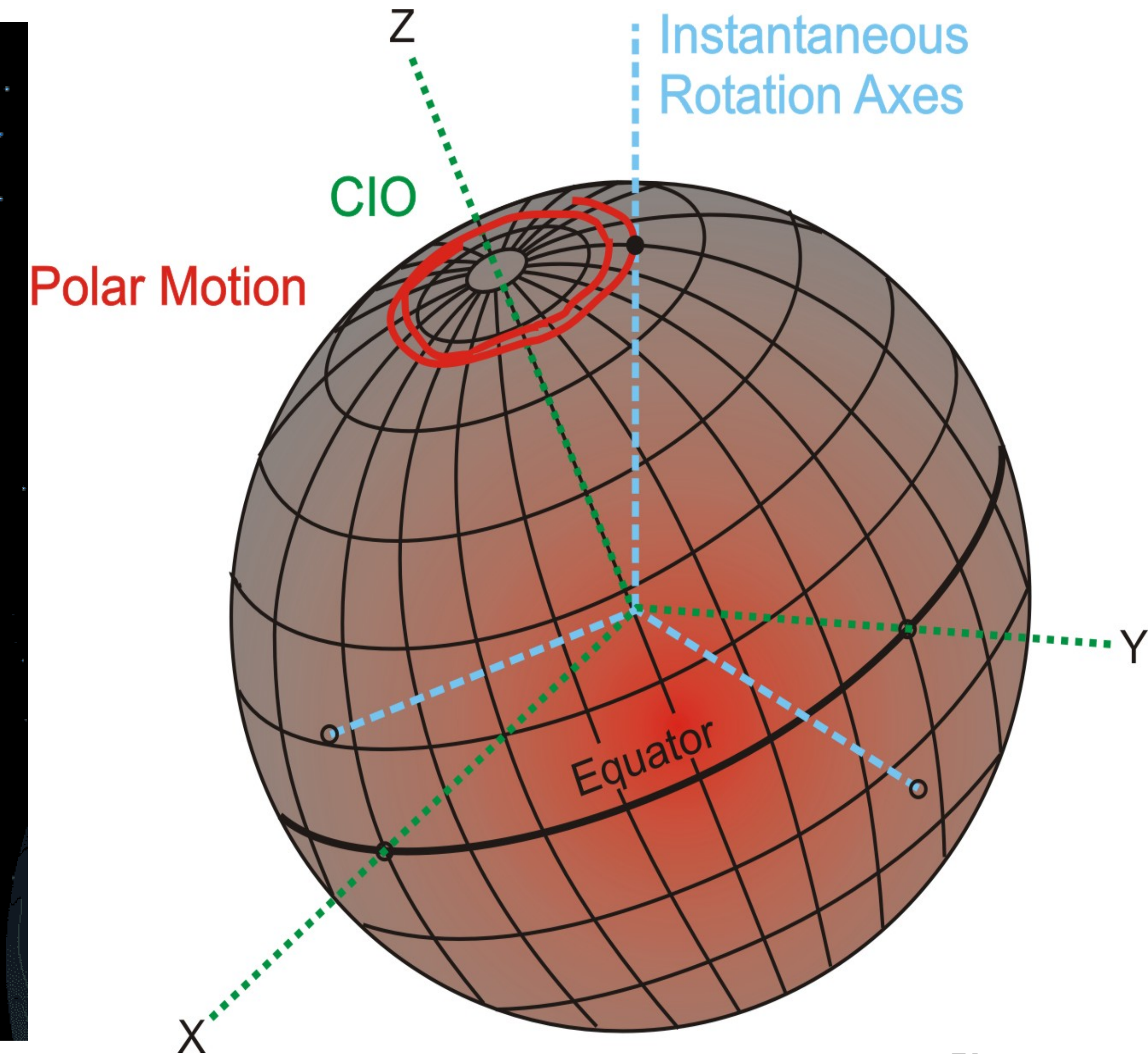
- Problem and fascination of measuring the Earth:

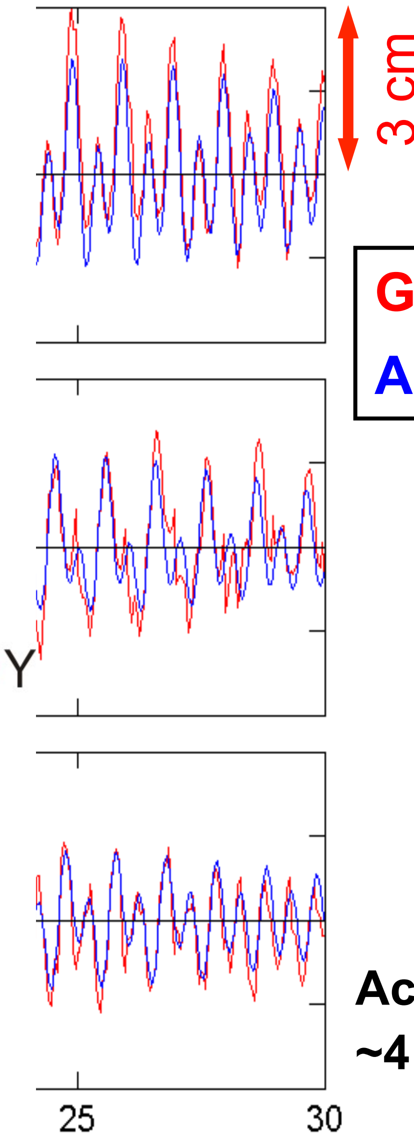
Everything is moving !

- 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**

Pillar 2: Earth Rotation (Sub-Daily Variations)

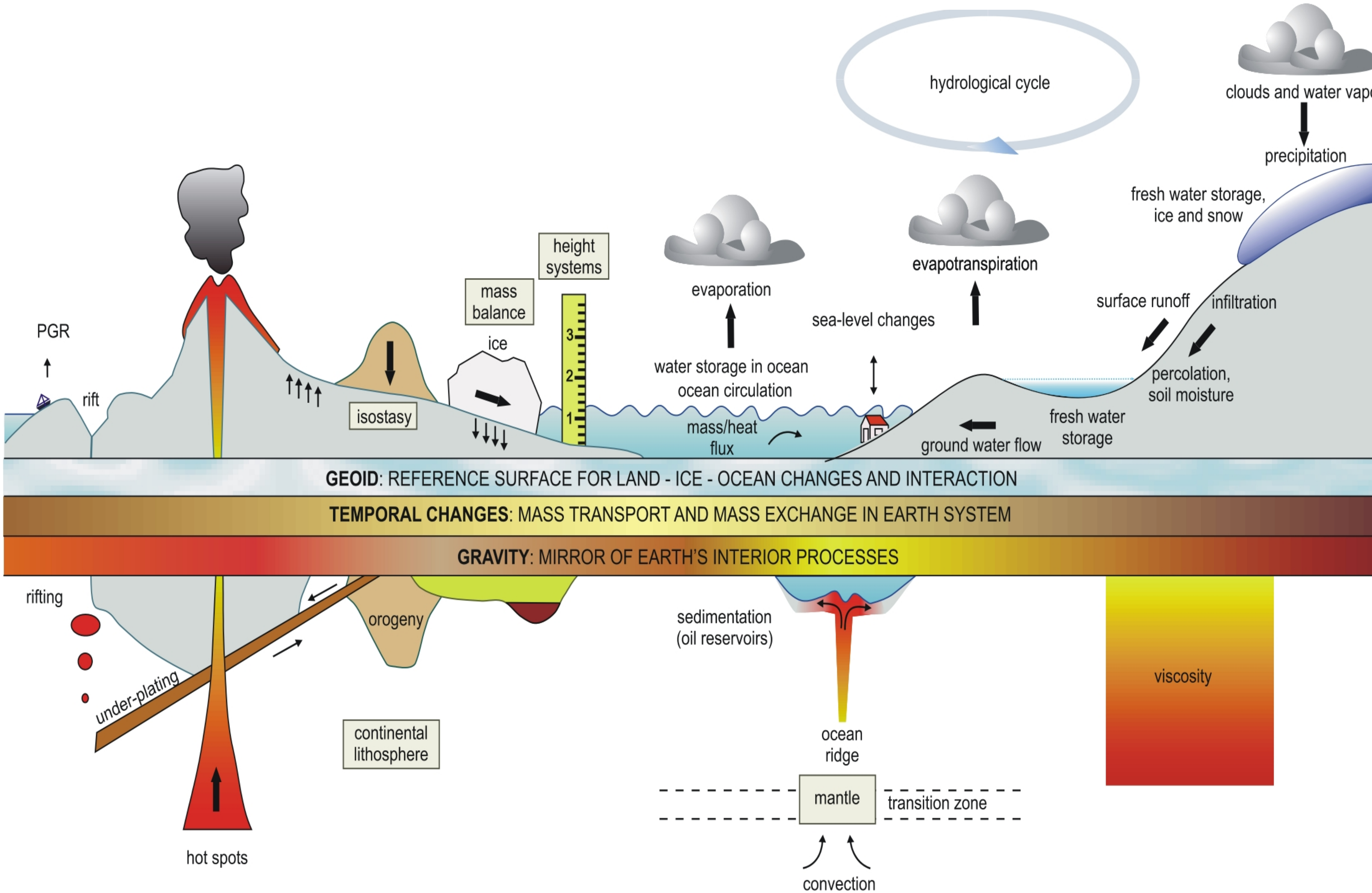




GPS (1h)
Altimetry

Accuracy:
~4 mm

Pillar 3: Gravity Field, Mass Transport



Ilk et al. (2005) Mass Transport and Mass Distribution in the Earth System, 2nd Edition, SPP1257 DFG

Space Geodetic Ground-Based Instruments

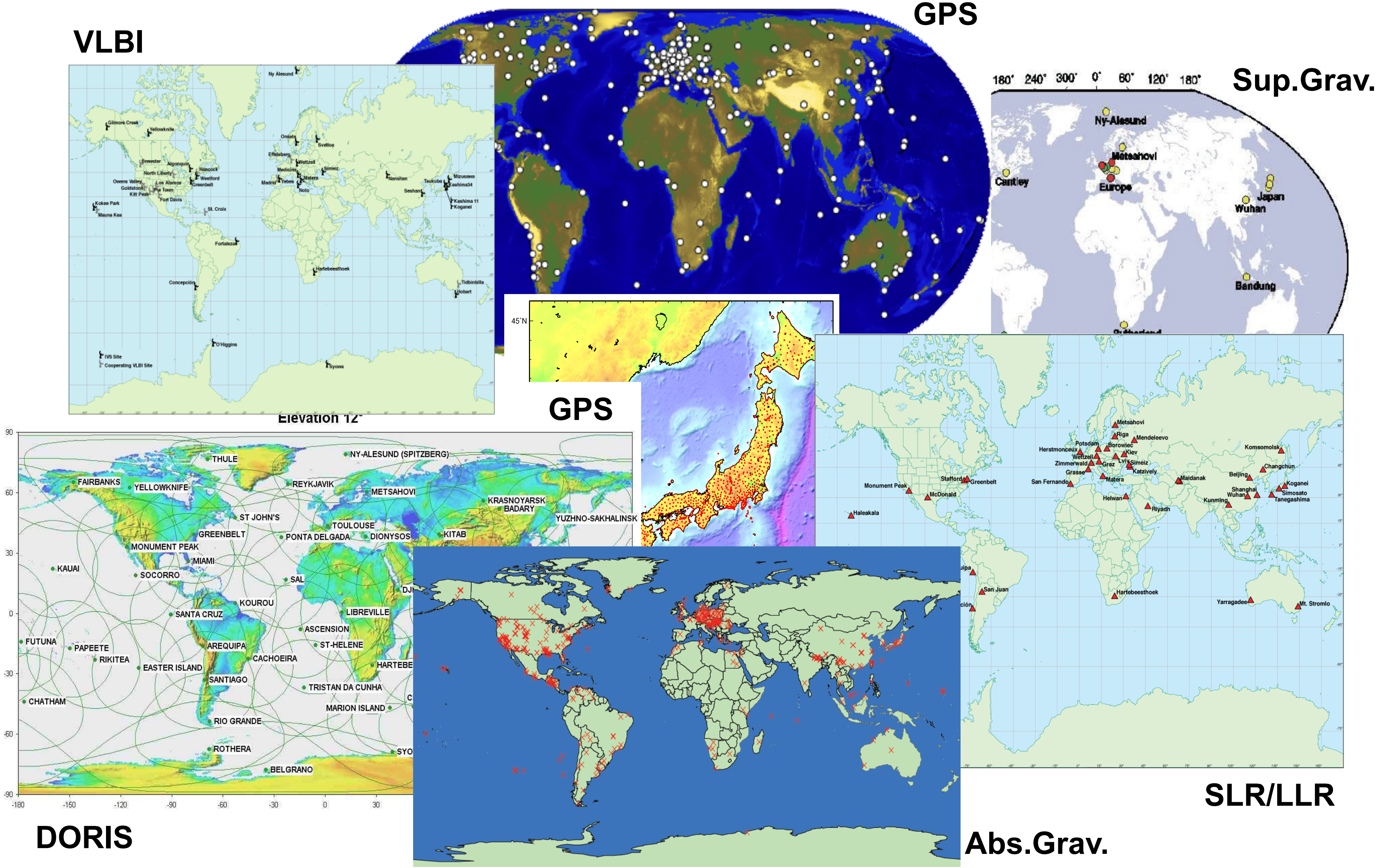
SLR/LLR

VLBI

GNSS

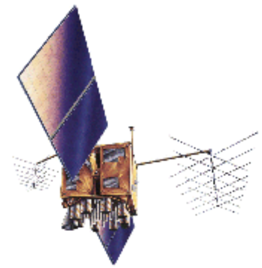
DORIS

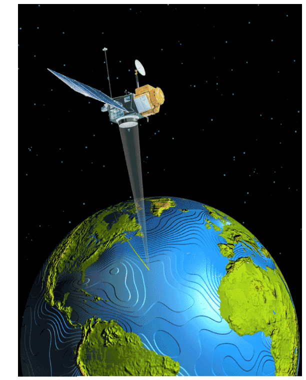
GGOS: the Ground-Based Component

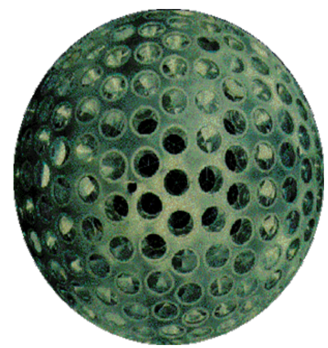


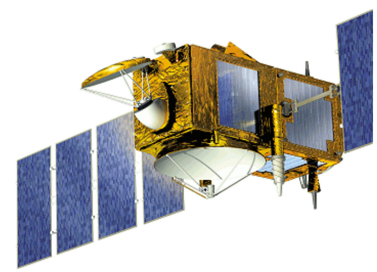
Space Components

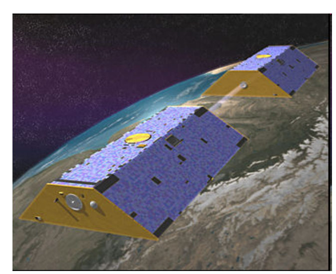
- **Quasars (VLBI)**
  - **Positions and velocity**
  - **EOP**
  - **Reference Frame**
- **Navigation Satellites**
  - **Position and velocity**
  - **Reference Frame (GNSS)**
  - **Space weather (occultation)**
- **Geodynamics Satellites**
  - **Positions and velocity**
  - **Reference Frame (Lageos)**
  - **Gravity Field (Starlette, Stella)**
- **Remote Sensing LEO Satellites**
  - **Altimetry (Jason, Envisat)**
  - **Gravity Field (Champ, Grace)**
  - **SAR, InSAR (TerraSAR-X, TanDEM-X)**

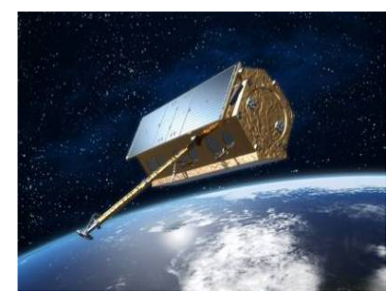






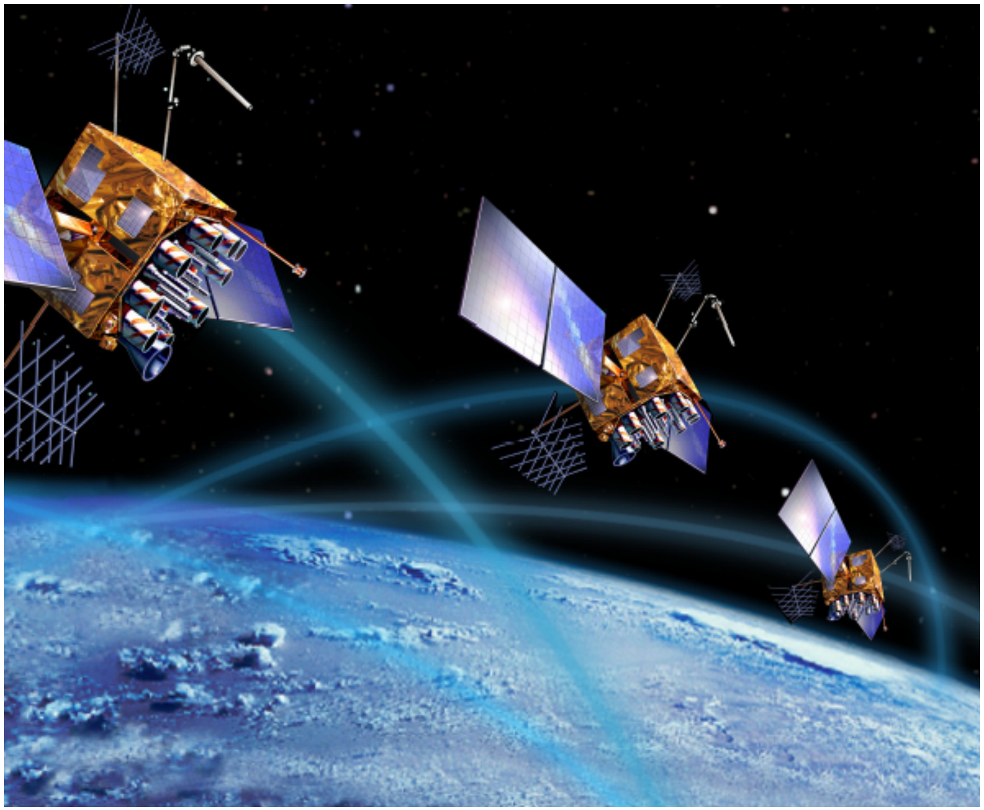






Global Positioning System

(Really GNSS: includes Galileo, Glonass, and COMPASS)

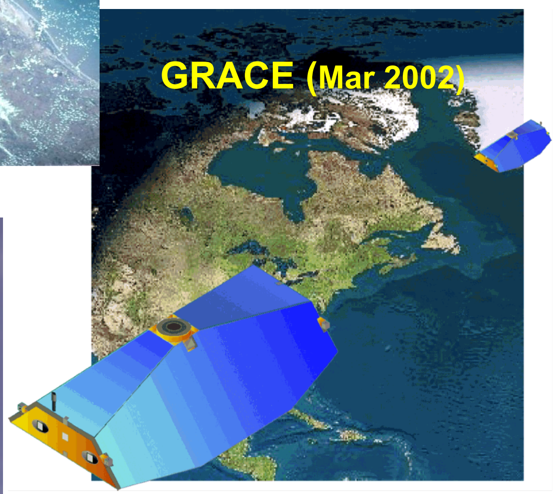


- The modern navigation tool
- The satellites broadcast and the ground stations receive to determine position and time ***anywhere*** on Earth
- Real-time position monitoring
- Receiver equipped satellites receive for precision orbit determination

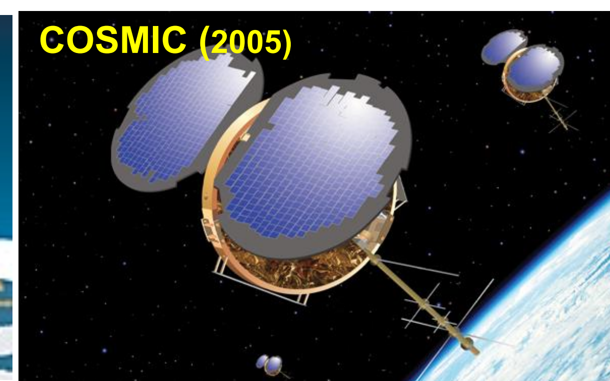
- Navigation, Surveying, Geodesy
- Understanding complex dynamic processes of the Earth
- Atmospheric and Space weather

Community is organized under the International Global Navigation Satellite Service (IGS)

GPS Precise Navigation - Low Earth Orbiters

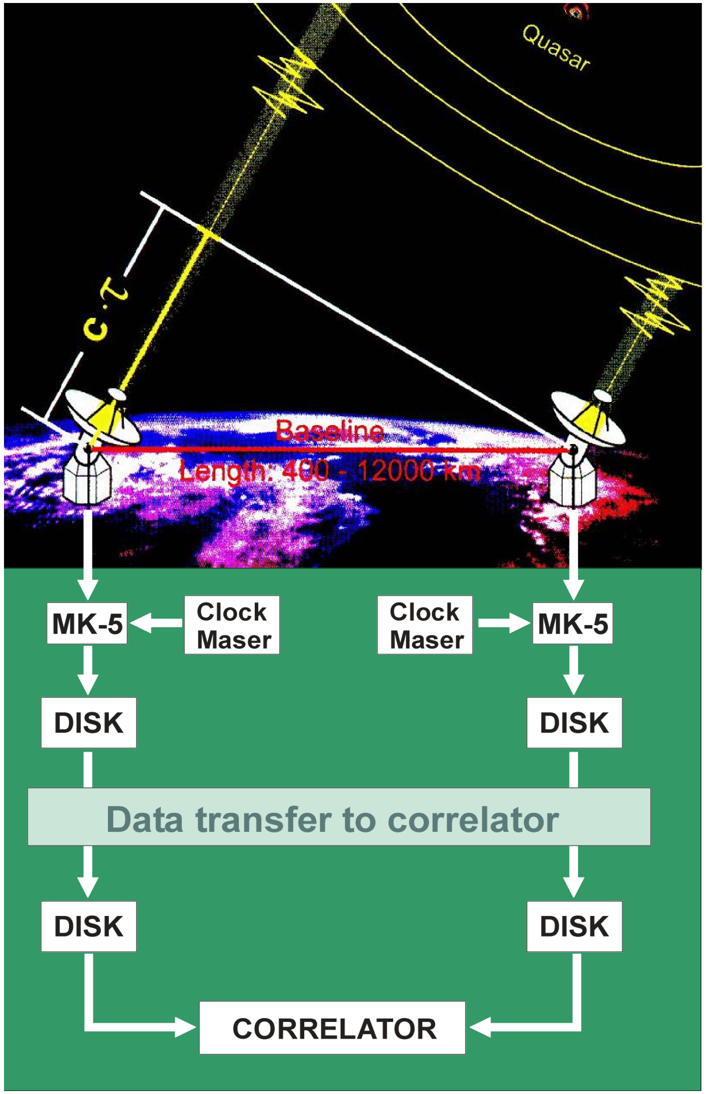


- *GPS Flight Receiver on board each*
- *LEO Missions Objectives/ Science Goals include:*
  - *Atmospheric remote sensing*
  - *Gravity, Magnetics*
  - *Ionospheric remote sensing*
  - *Ice and oceans*



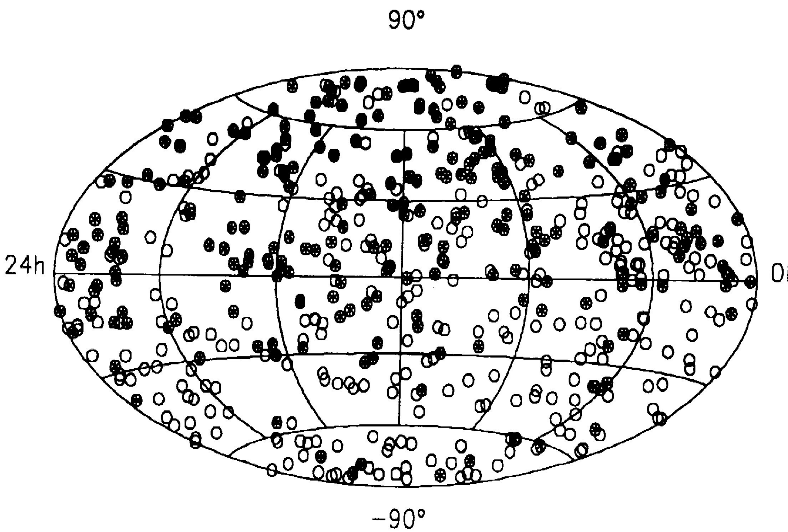
VLBI Observing System

- Radio signals from quasars or radio galaxies
  - 8 channels X-Band
  - 6 channels S-Band
  - Data stream 512 Mbit/s
  - Time & Frequency
    - (DF/F ~ 10^{-14})
  - Data recording
    - Harddisk (MK-5)
    - e-transfer
- Correlation
  - σ_t ~ 10 to 30 ps



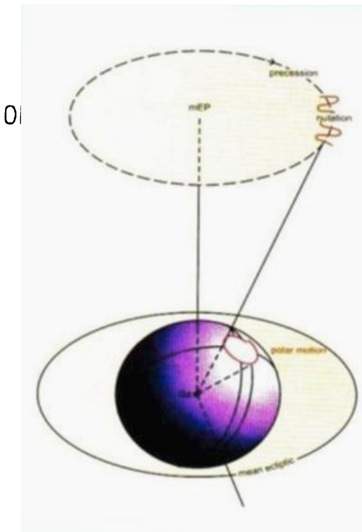
Community is organized under the International VLBI Service (IVS)

Role of VLBI



EOP: Earth Orientation Parameters

- Precession/Nutation
- Polar motion
- UT1 - UTC

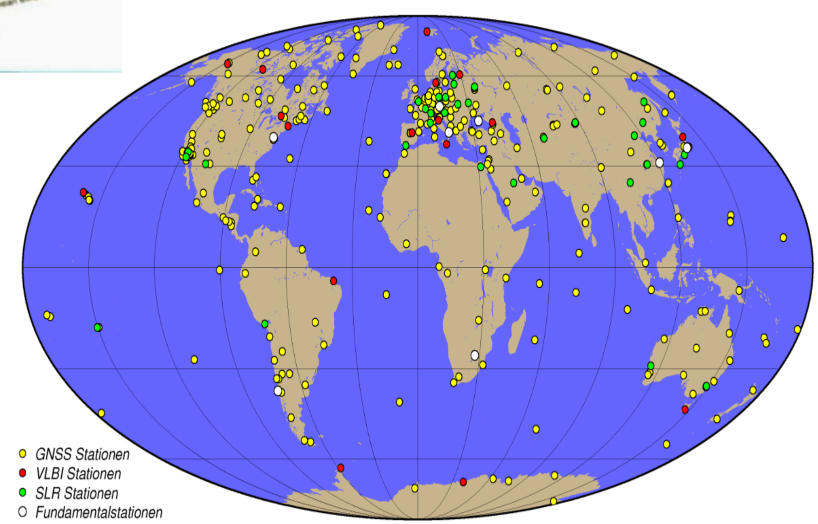


ICRF: International Celestial Reference Frame

- Quasar positions

ITRF: International Terrestrial Reference Frame

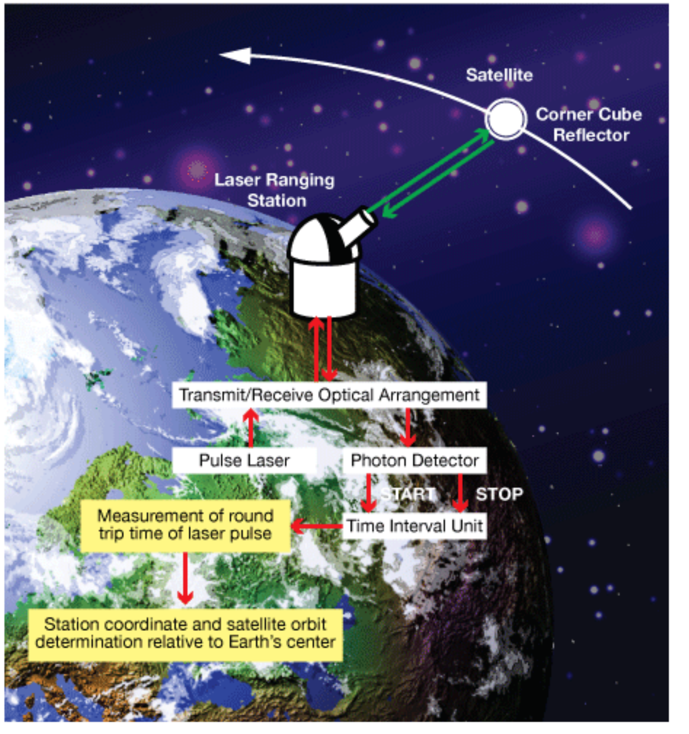
- Positions
- Velocities
- Time series
- EOP and Scale



Satellite Laser Ranging Technique

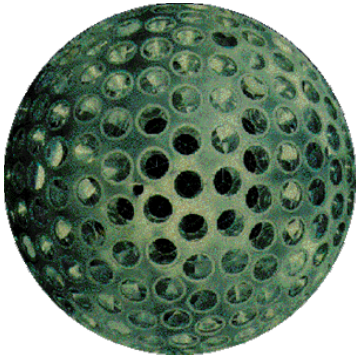
Precise range measurement between an SLR ground station and a retroreflector-equipped satellite using ultrashort laser pulses corrected for refraction, satellite center of mass, and the internal delay of the ranging machine.

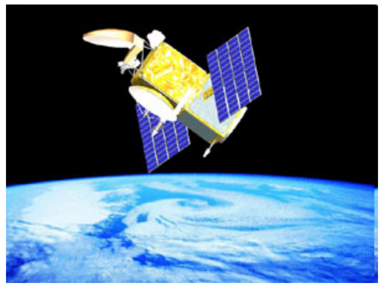
- Simple range measurement
- Space segment is passive
- Simple refraction model
- Night / Day Operation
- Near real-time global data availability
- Satellite altitudes from 400 km to synchronous satellites, and the Moon
- Centimeter satellite Orbit Accuracy
- Able to see small changes by looking at long time series

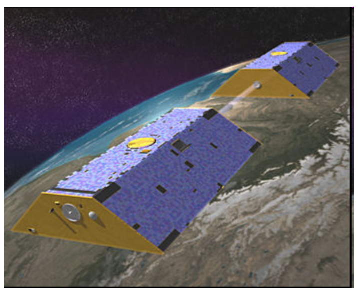


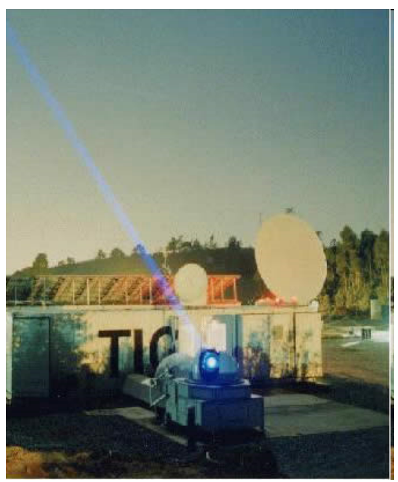
- Unambiguous centimeter accuracy orbits
- Long-term stable time series

Role of Satellite Laser Ranging







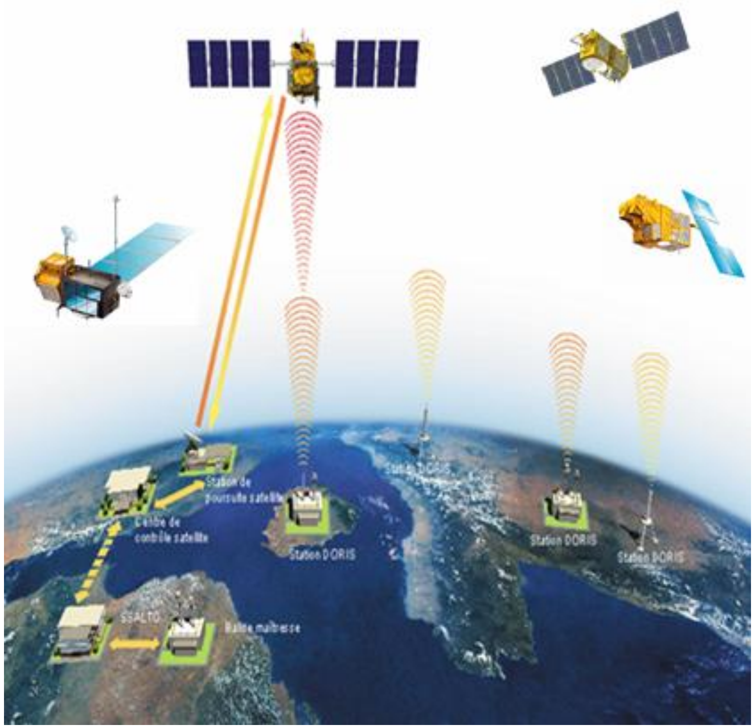


SLR/LLR products support:

- Terrestrial reference frame (Center of mass and scale)
- Position and velocity
- Static and time-varying gravity field
- Earth orientation and rotation (polar motion, length of day)
- Orbits, calibration, and validation of altimetry missions (oceans, ice)
- Total Earth mass distribution
- Space science (tether dynamics, etc.)
- Relativity measurements and lunar science

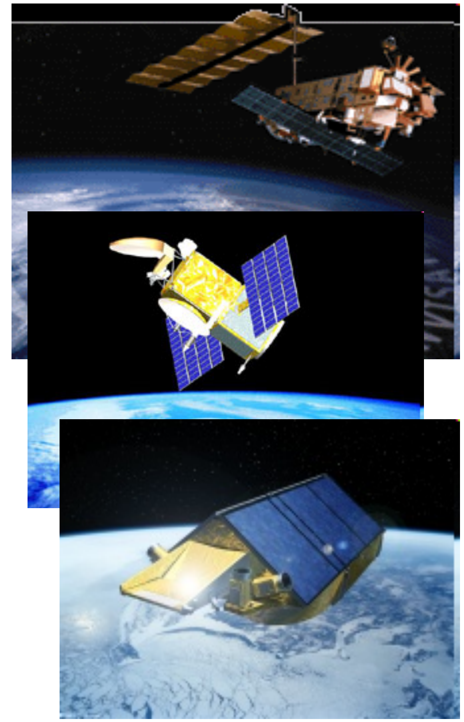
Doppler & Radiopositioning Integrated by Satellite (DORIS).

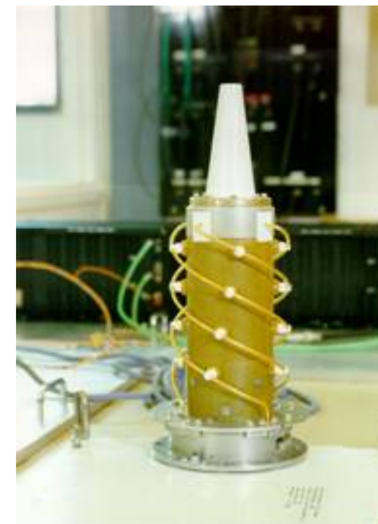
- Dual-Frequency Doppler Beacons (2.036 Ghz & 401.25 Mhz), Distributed at Ground Stations Around the World.
- Signals received and recorded on DORIS equipped satellites
- Developed by the CNES (Centre National d'Etudes Spatiales) & IGN (Institut Géographique National).
- The network was developed to support Precision Orbit Determination (POD) for LEO satellites, such as the SPOT Remote Sensing Satellites & Altimeter Satellites such as TOPEX/Poseidon.
- V.The oldest sites in the network occupied since the late 1980's (DORIS data are routinely available since 1992, or the launch of TOPEX/ Poseidon).



Role of DORIS

- Precise Orbit Determination for Earth Sensing Missions
- Station Position and Velocity
- Polar Motion
- ITRF
- Comprehensive Global Coverage
- Gravity field, geoid
- On board real time orbit determination for payload products location or platform navigation

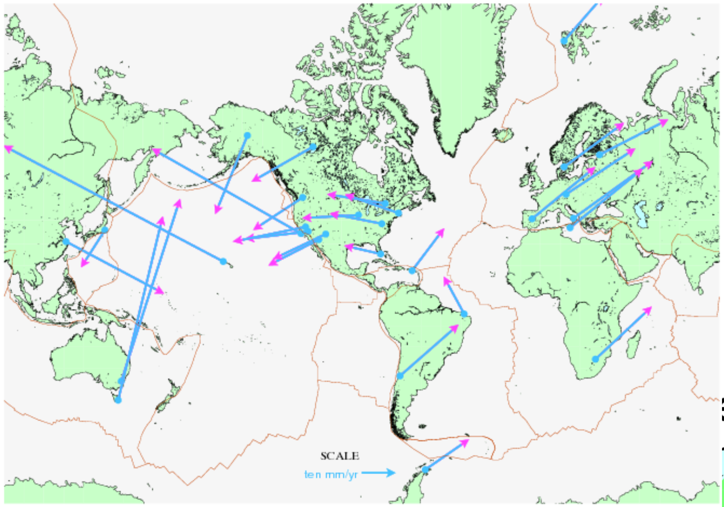




Earth Science Products

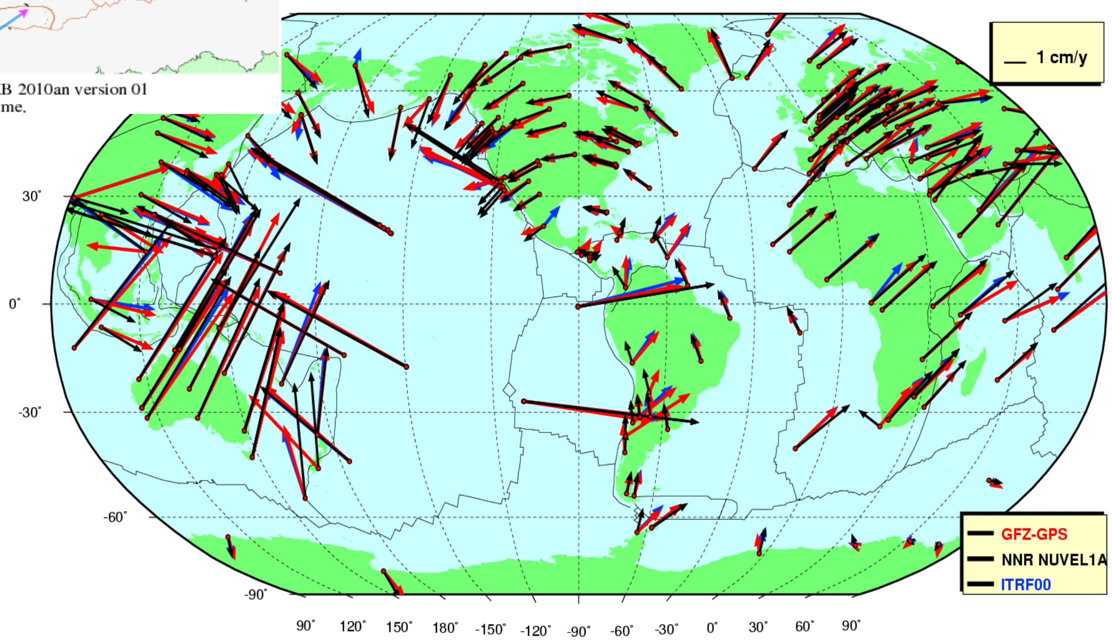
Global Plate Motion

Selected VLBI Velocities



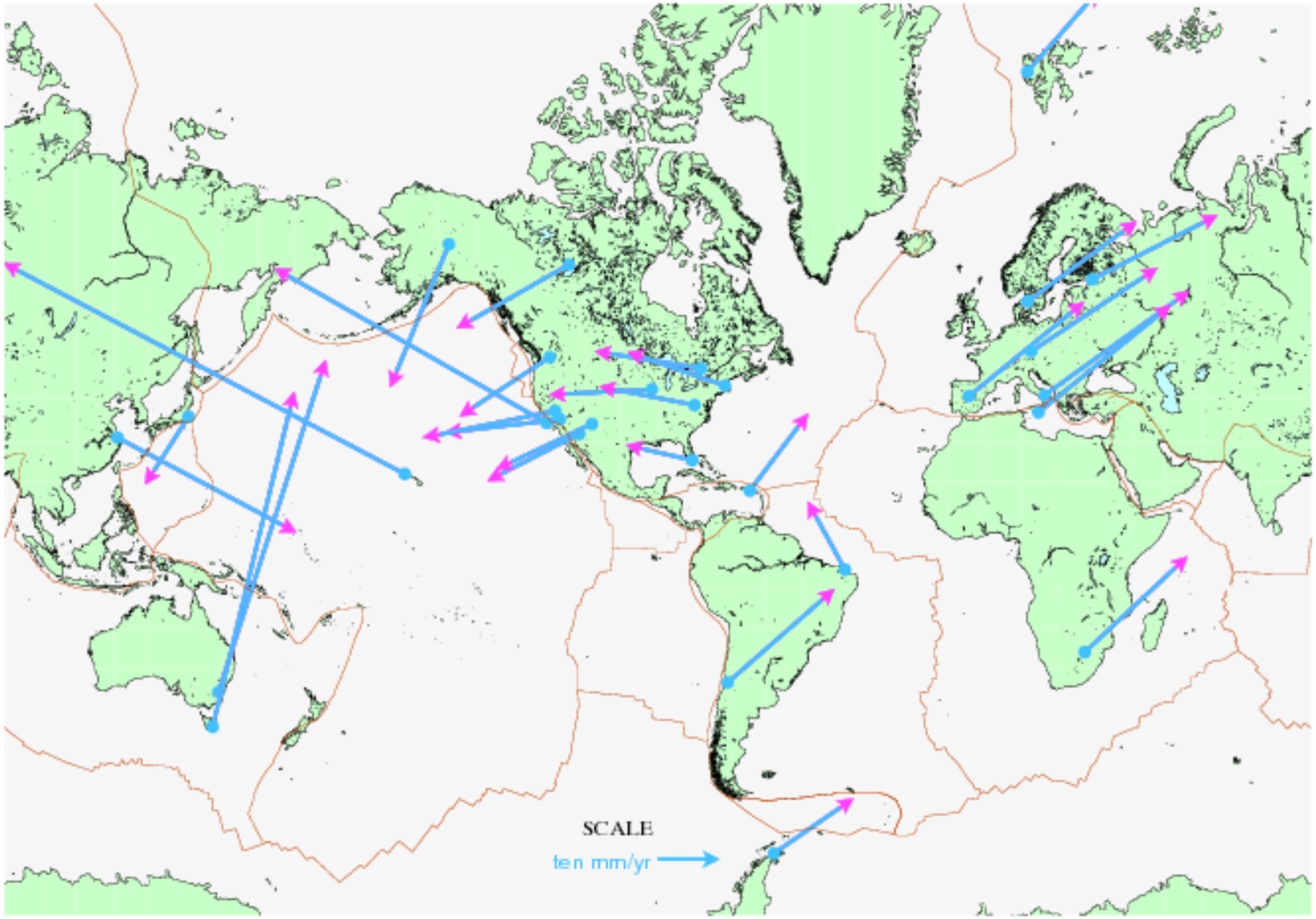
Goddard Space Flight Center VLBI solution KB 2010an version 01
NUVEL1A-NNR reference frame.

e velocities from 12 years of GPS data



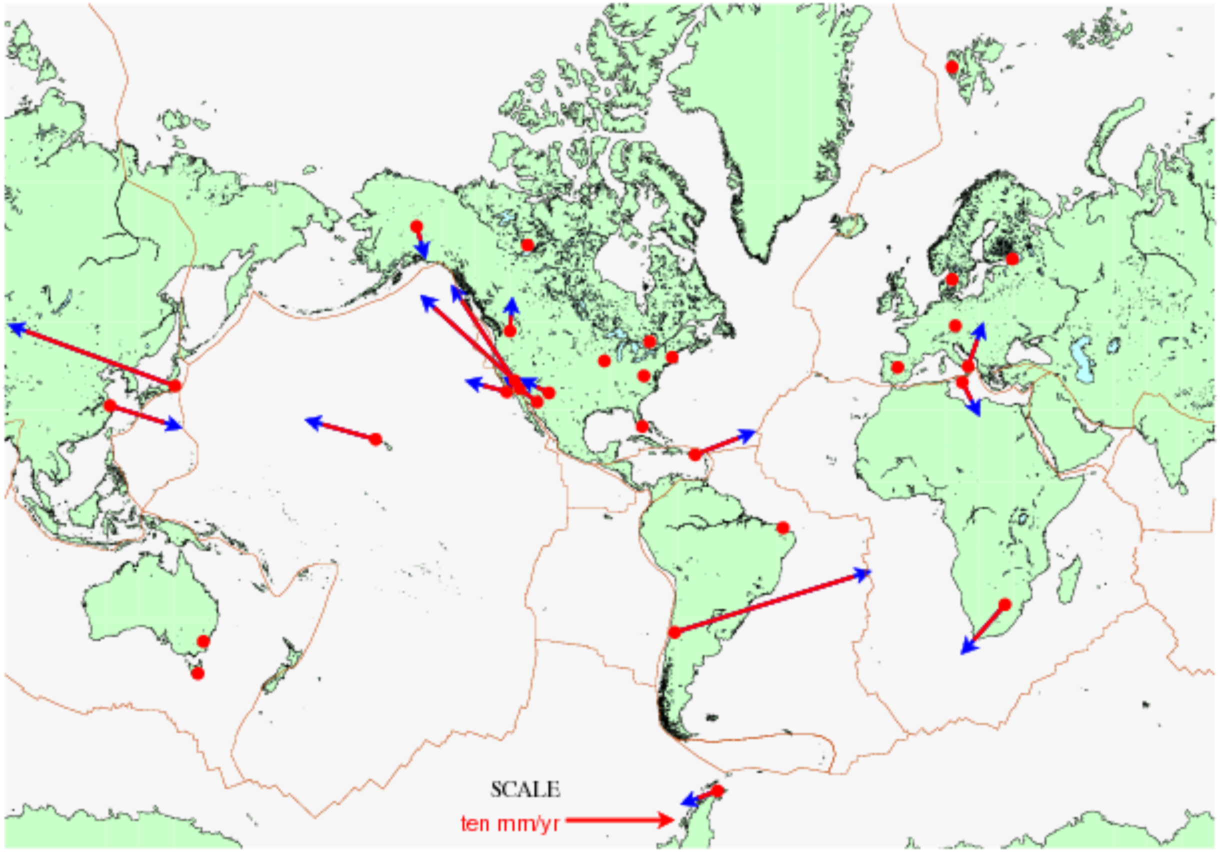
GPS data from 1993.0 to 2005.1

Selected VLBI Velocities



Goddard Space Flight Center VLBI solution KB 2010an version 01
NUVEL1A-NNR reference frame.

Differences between VLBI Velocities and Plate Model

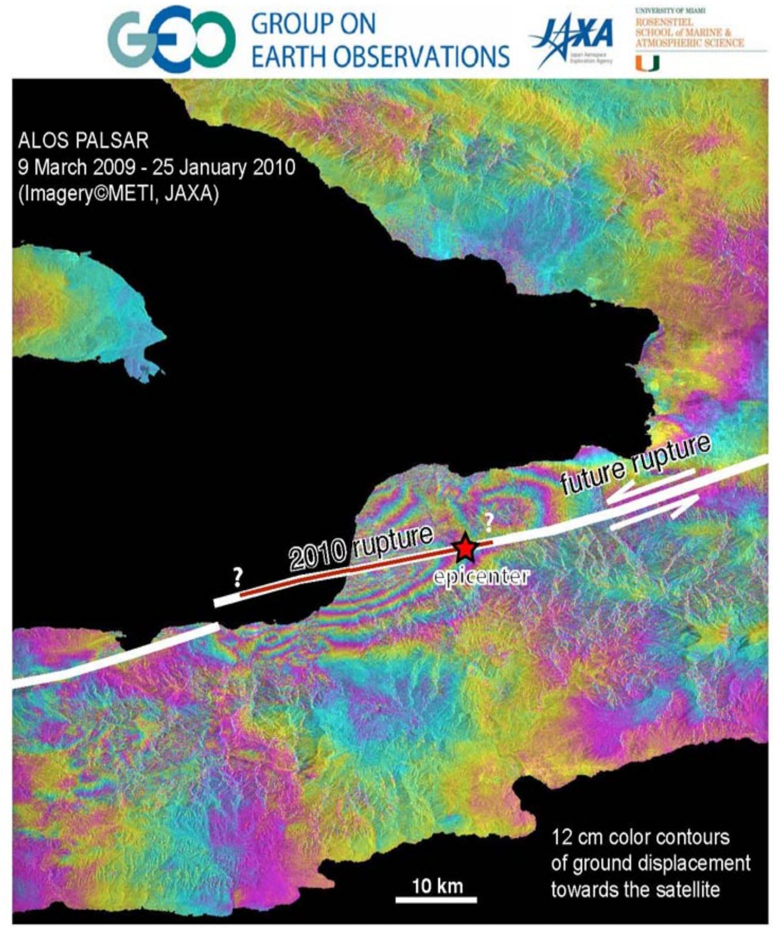


Goddard Space Flight Center VLBI solution KB 2010an version 01
Velocity residuals < 2 mm/yr are not displayed. NUVEL1A-NNR reference frame.

Geodesy and Natural Hazards

- Measure the deformation of the ground for a number of applications
- Provides unique information on the deformation due to natural hazards (volcanoes, landslides, earthquakes, etc.)

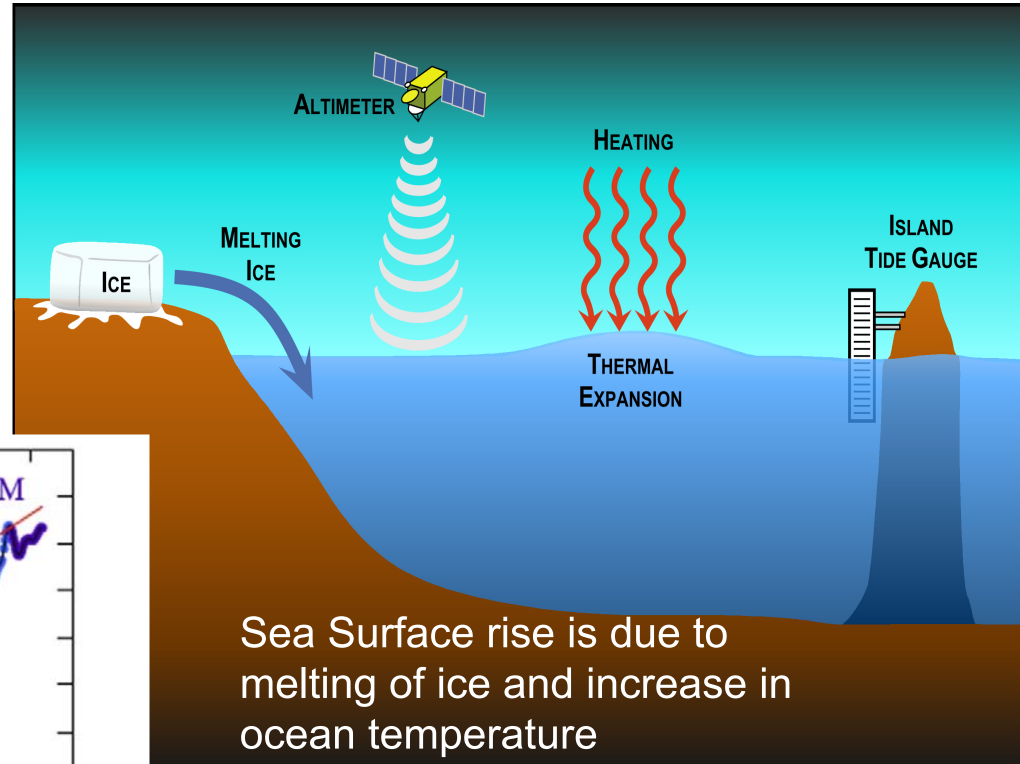
- At right is an InSAR map of the ground displacement from the January 2010 M7 Haiti earthquake
- Each band of color contours is 12 cm of, so the total displacement was ~1 m over a large area
- Measurements help us predict areas of future risk

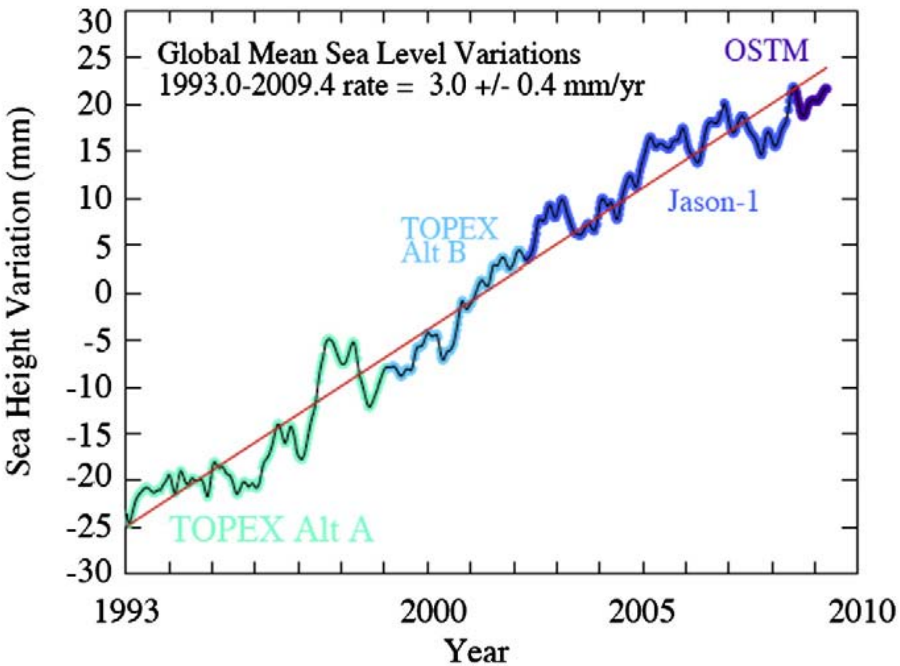


Sang-Hoon Hong, Falk Amelung, Tim Dixon, Shimon Wdowinski, Guoqing Lin, Fernando Greene
Rosenstiel School of Marine & Atmospheric Science, University of Miami

Measure Sea Surface Height with Altimetry

Global mean SSH variations from TOPEX, Jason-1, Jason-2 with respect to 1993–2002 mean, plotted every 10 days using the NASA GSFC orbits from Lemoine et al. (2010), and the latest GDR releases and corrections for the altimetry.

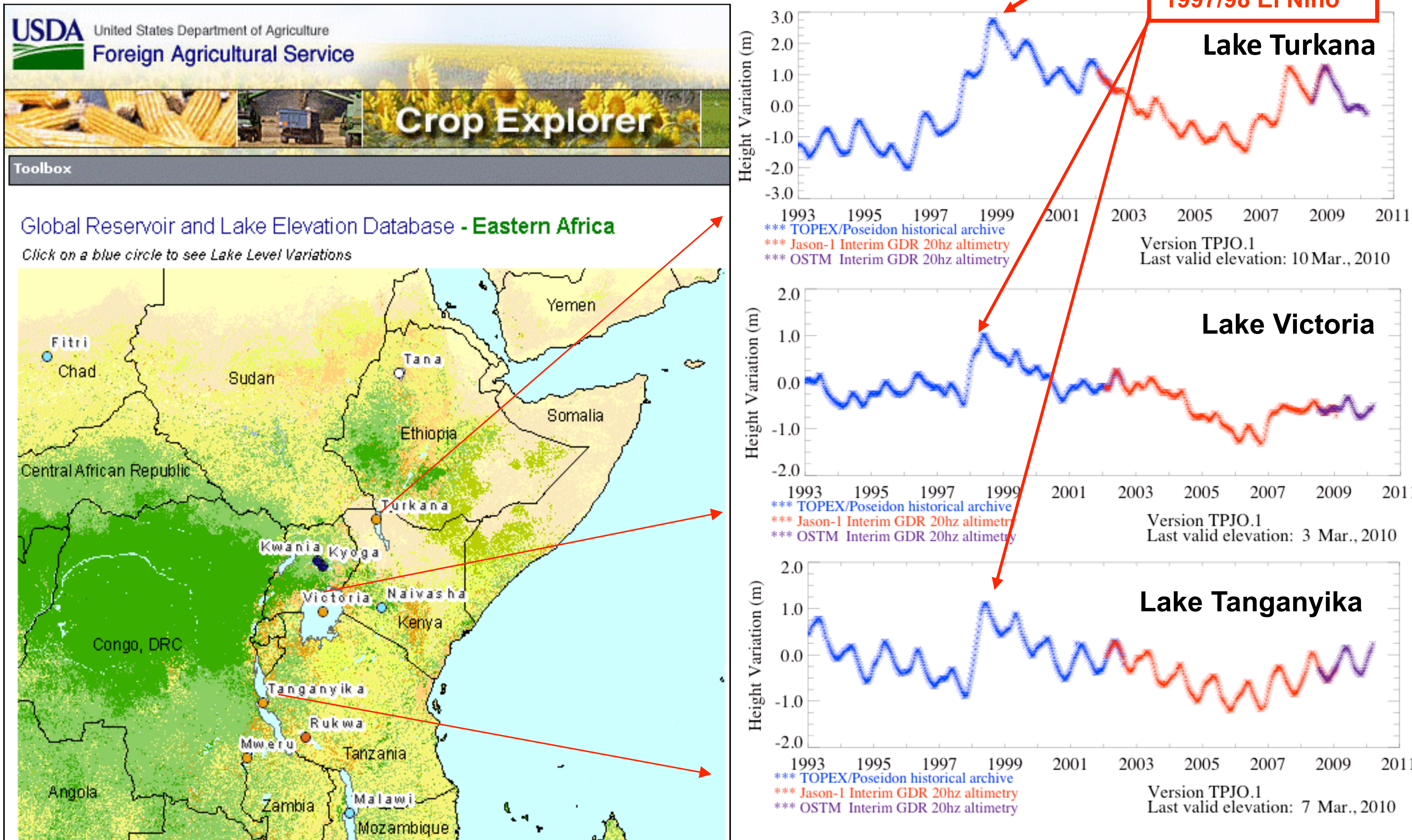




Source: Lemoine, F.G., et al. Towards development of a consistent orbit series for TOPEX, Jason-1, and Jason-2. J. Adv. Space Res. (2010), doi:10.1016/j.asr.2010.05.007

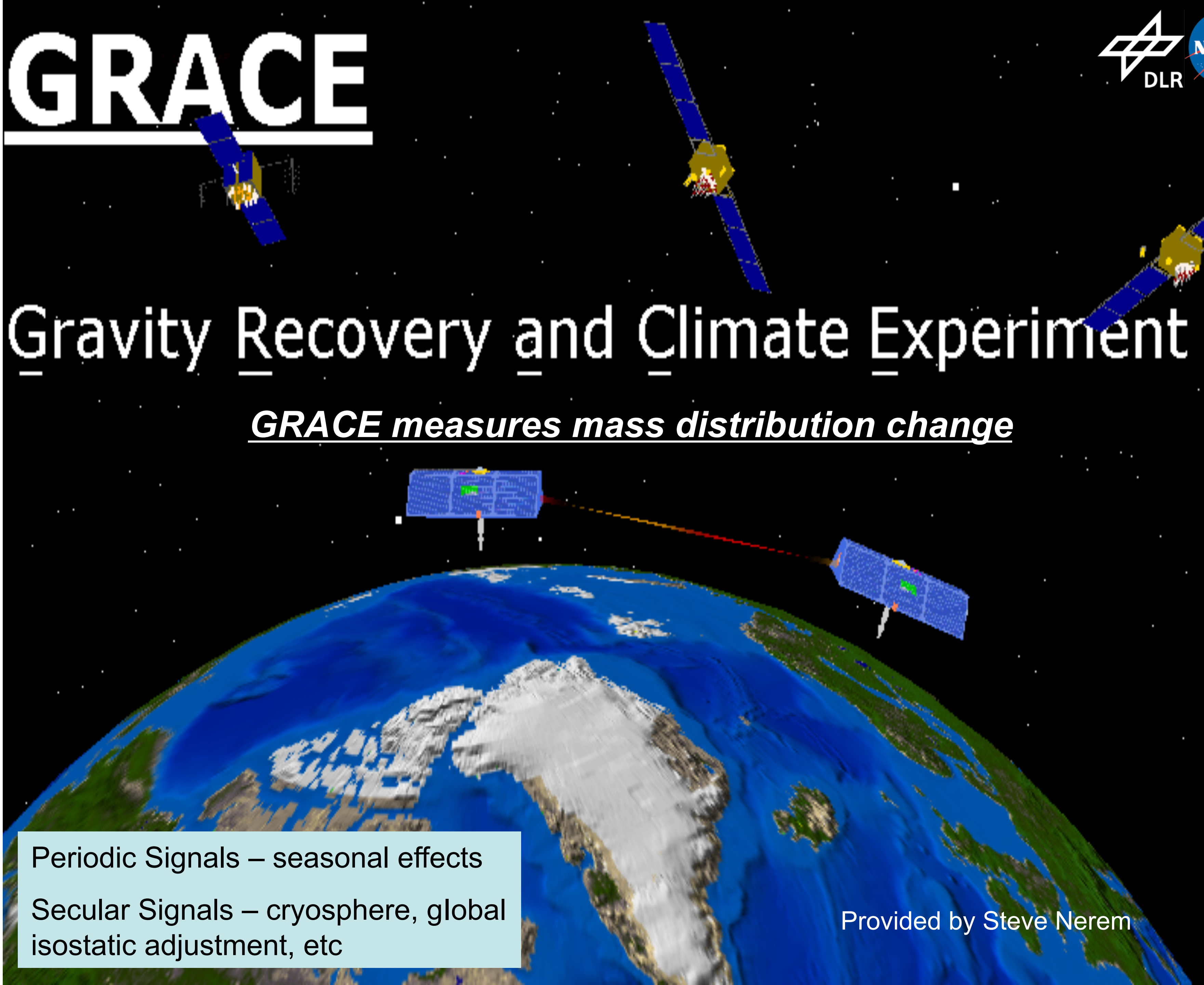
Near Real Time Lake Level Monitoring

Decrease in lake water levels since 1997/98 El Nino



Reprocessed altimeter data better enables the monitoring of lake levels for the Foreign Agriculture Service under the U.S. Department of Agriculture for crop predictions and irrigation management.

Provided by Steve Klosko



GRACE measures mass distribution change

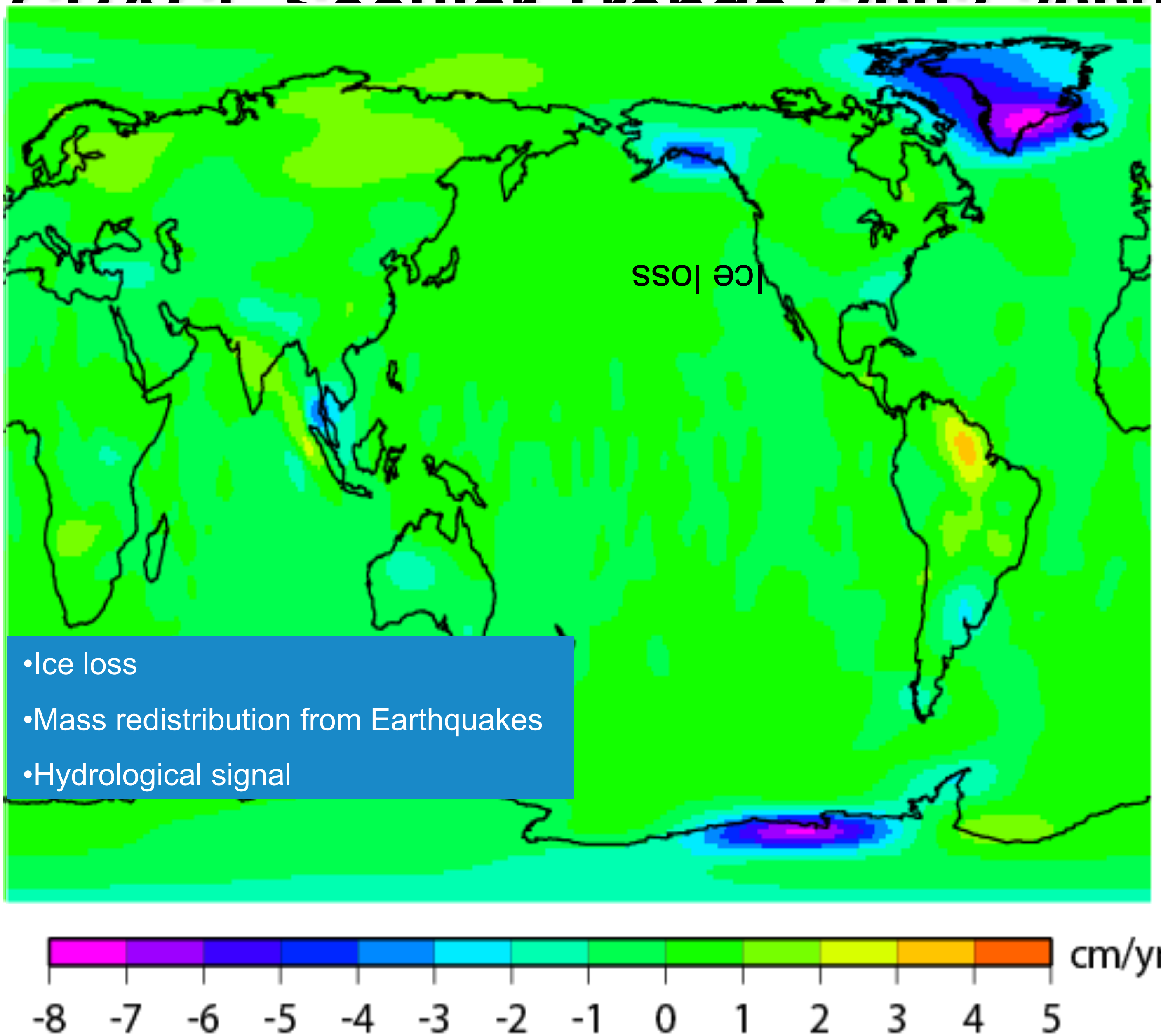
Periodic Signals – seasonal effects

Secular Signals – cryosphere, global isostatic adjustment, etc

Provided by Steve Nerem

GRACE Secular Trends (2003-2009)

PGR model removed

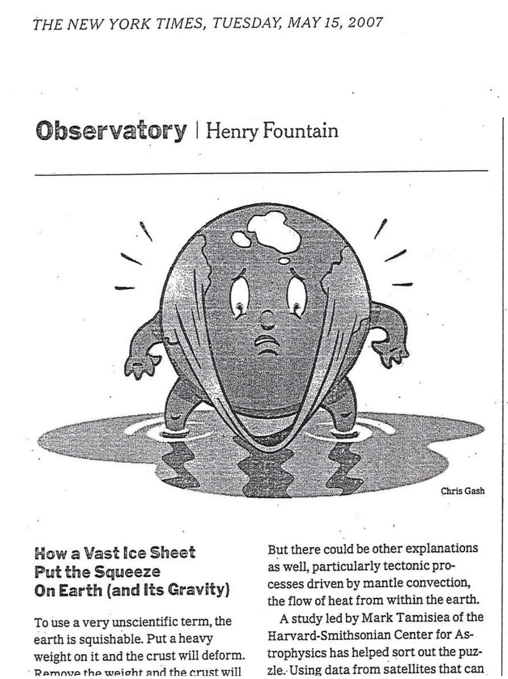


- Ice loss
- Mass redistribution from Earthquakes
- Hydrological signal

[Wahr, 2009]

The Impact of Ancient Ice Sheets

GRACE measures mass redistribution from post glacial uplift



THE NEW YORK TIMES, TUESDAY, MAY 15, 2007

Observatory | Henry Fountain

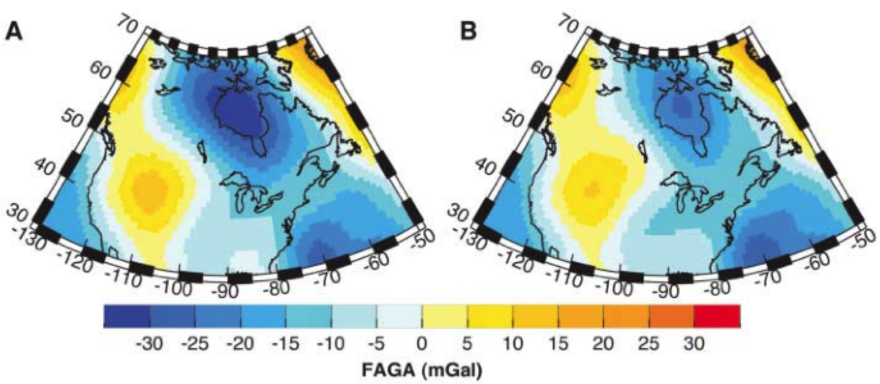
Chris Gash

How a Vast Ice Sheet Put the Squeeze On Earth (and Its Gravity)

To use a very unscientific term, the earth is squishable. Put a heavy weight on it and the crust will deform. Remove the weight and the crust will

But there could be other explanations as well, particularly tectonic processes driven by mantle convection, the flow of heat from within the earth.

A study led by Mark Tamisiea of the Harvard-Smithsonian Center for Astrophysics has helped sort out the puzzle. Using data from satellites that can

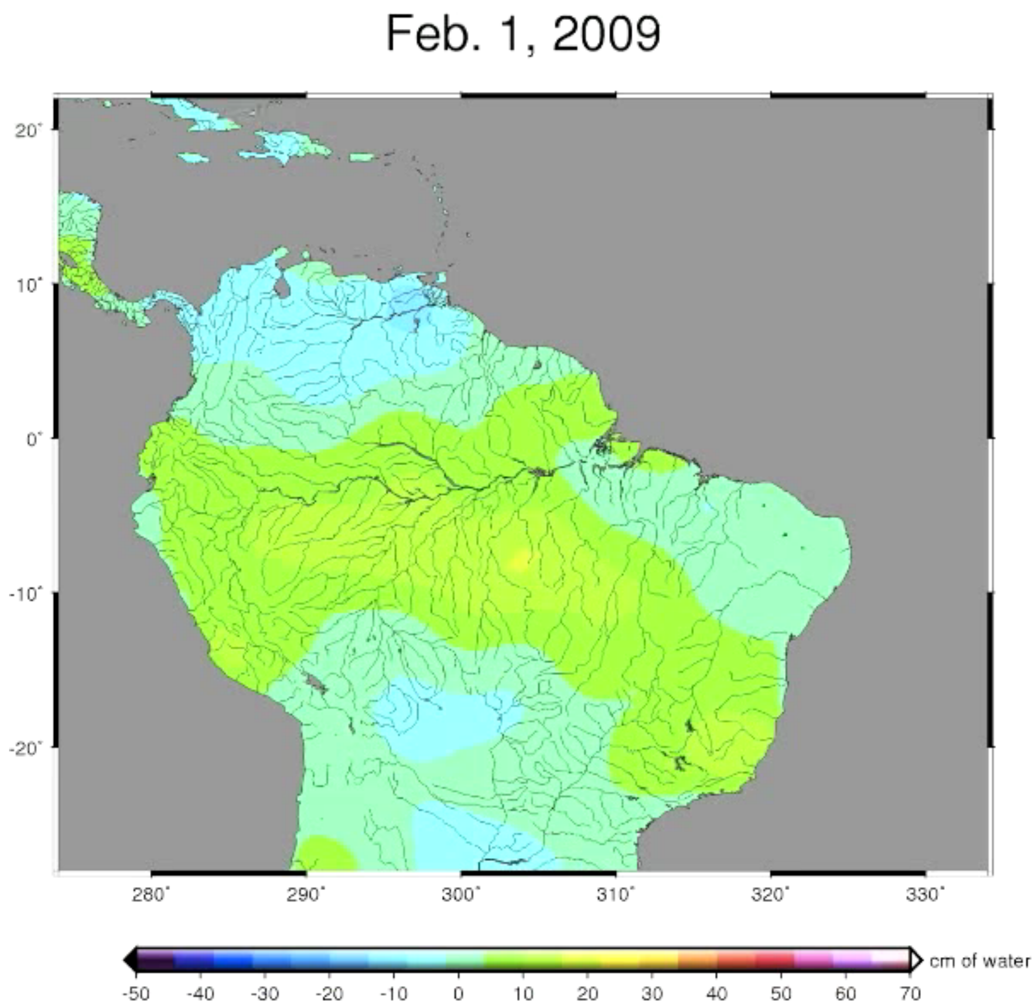


- The thick (~3 km) ice sheets that began melting ~20,000 years ago have left the Earth deformed

- Is this the cause of the "low" in the free air gravity anomaly (FAGA) of northern Canada? (left, A, as measured by GRACE)
- The best predictions of the viscoelastic deformation using GRACE rates (left, B) only explain about 50% of the signal
- The conclusion of *Tamisea et al.* [2007] is that the remaining 50% is caused by convection in the Earth's mantle

Provided by Jim Davis

GRACE Measures Continental Hydrology
(June 2009 Amazon Flood)



GRACE CSR preliminary near-real time solution (Dec 8, 2008–June 25, 2009): 15-day solutions with 1-day steps. Latency: 7 days after data acquisition and with newest data lagging ~1 day in real time

Decorrelation, filtering (200x300 km), & land signal leakage correction [Duan et al., 2009; Guo et al., 2010]

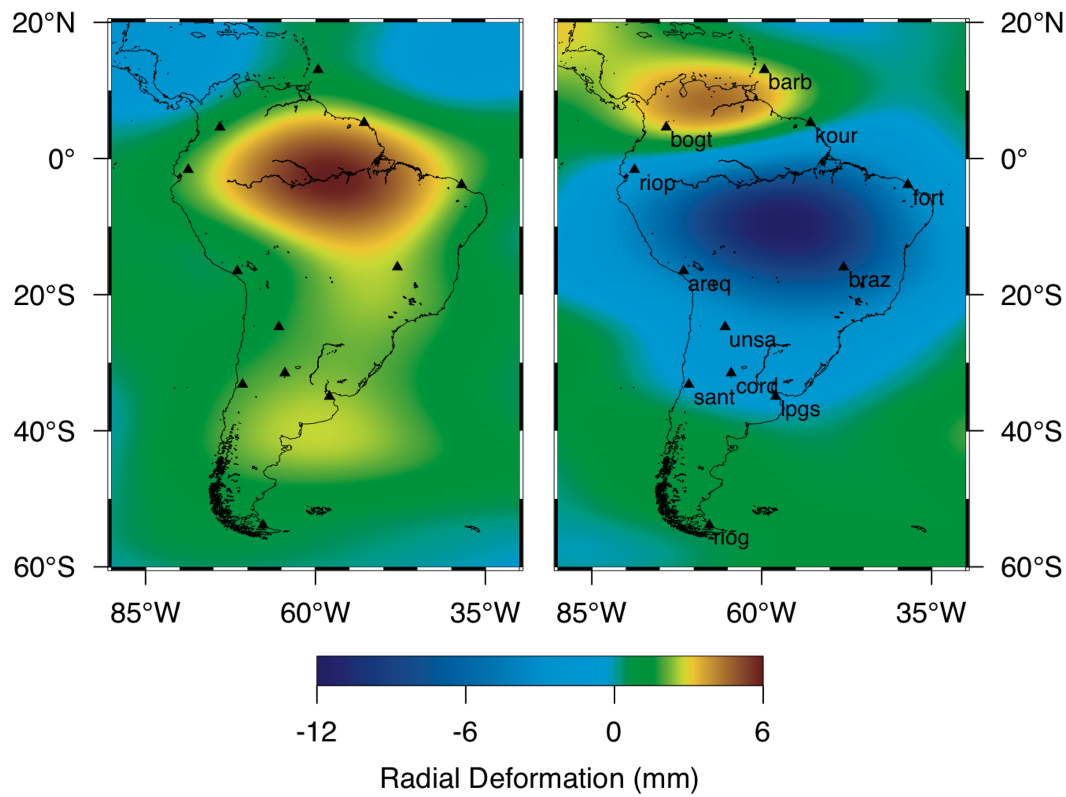
Provided by C.K. Shum

THE OHIO STATE UNIVERSITY

Deformational Impact of the Hydrological Cycle

- Annual hydrological cycle will act as a periodic change in gravitational load, deforming the Earth
- The GRACE mission measures the presence of water on the surface
- At the right is a map of the annual amplitude of surface deformation in South America estimated from GRACE data [*Davis et al.*, 2004]
- Also shown in map: some continuous GPS sites

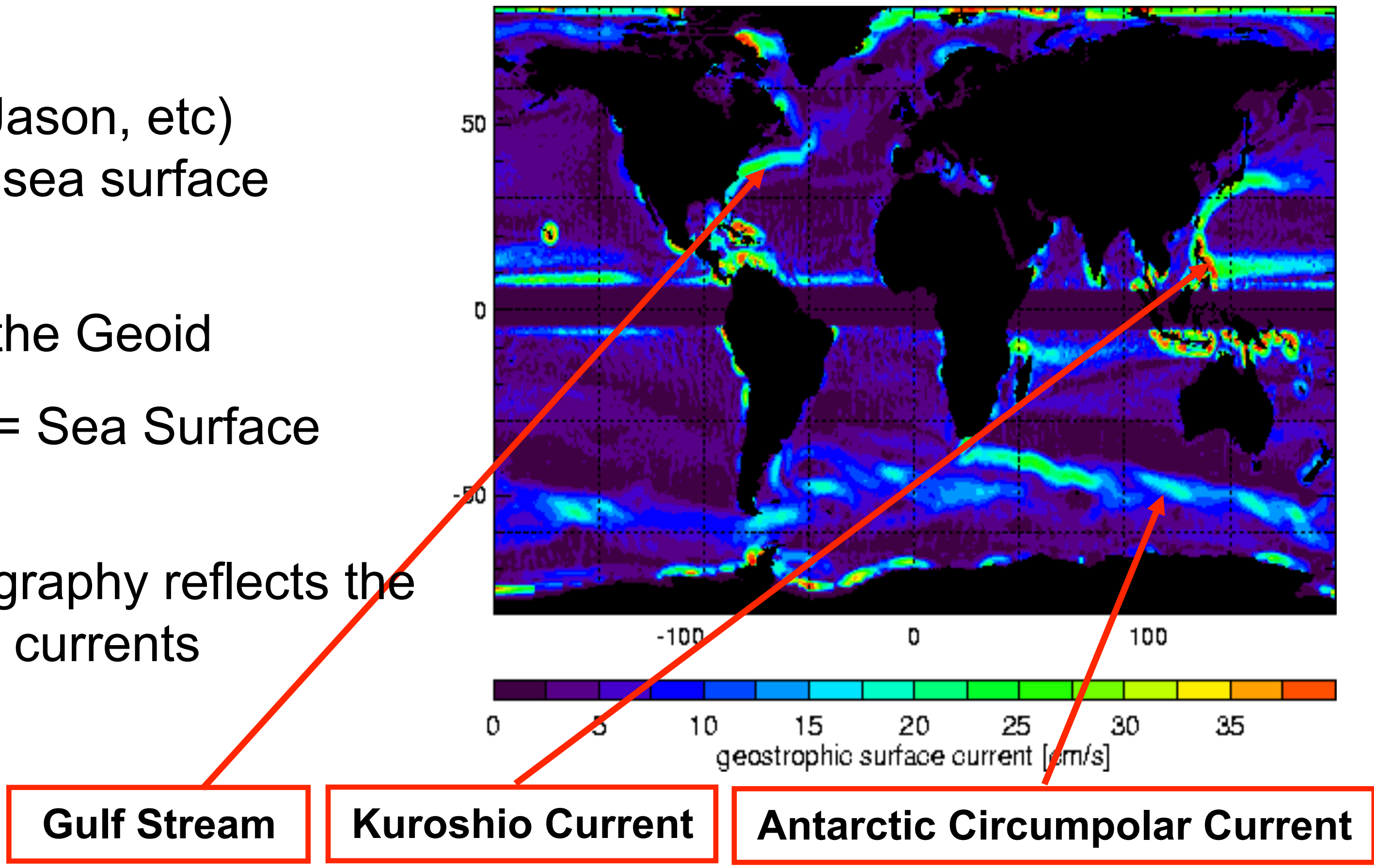
- As water is added or subtracted, the surface is pressed or released



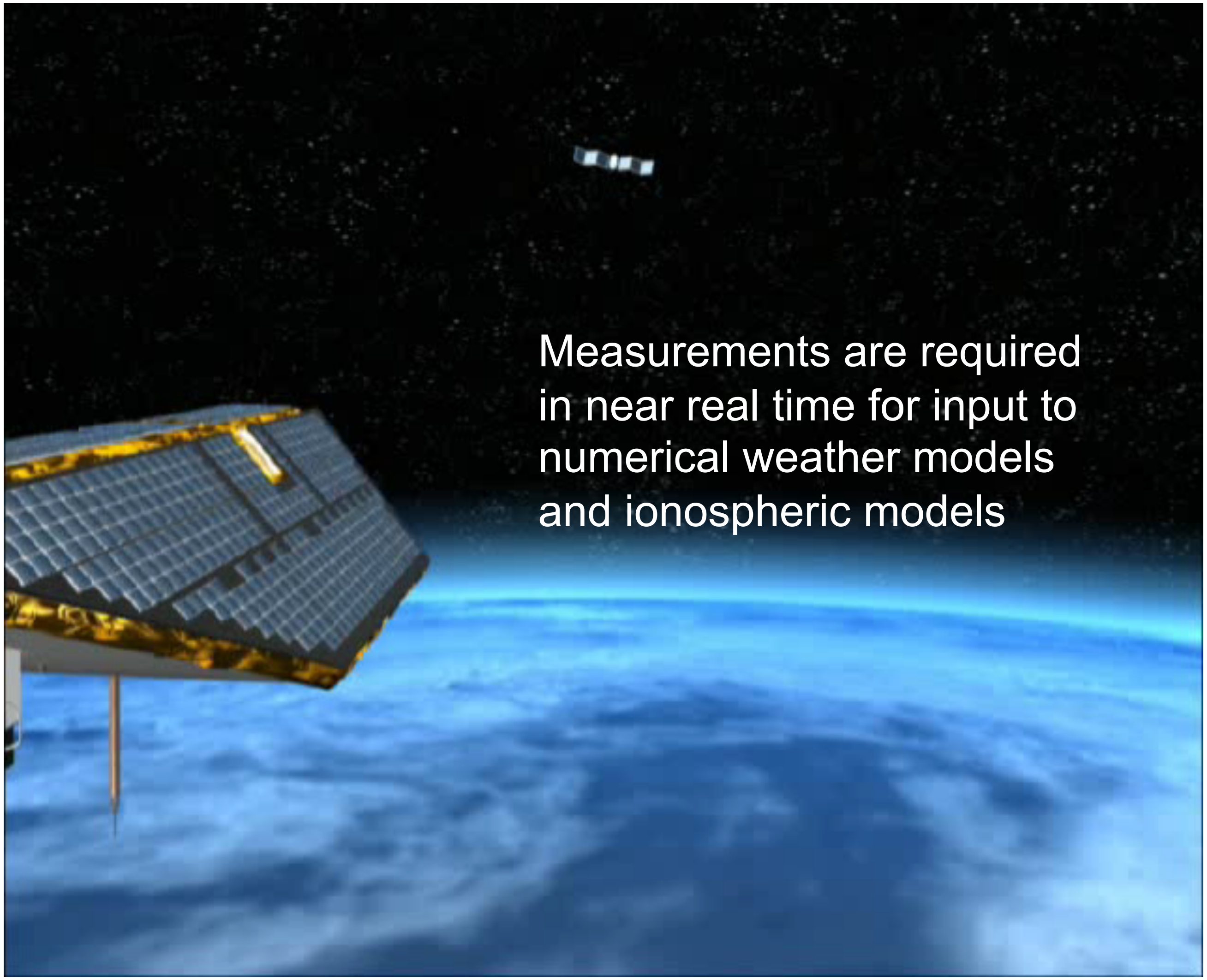
Provided by Jim Davis

Ocean Currents from GRACE and Altimetry

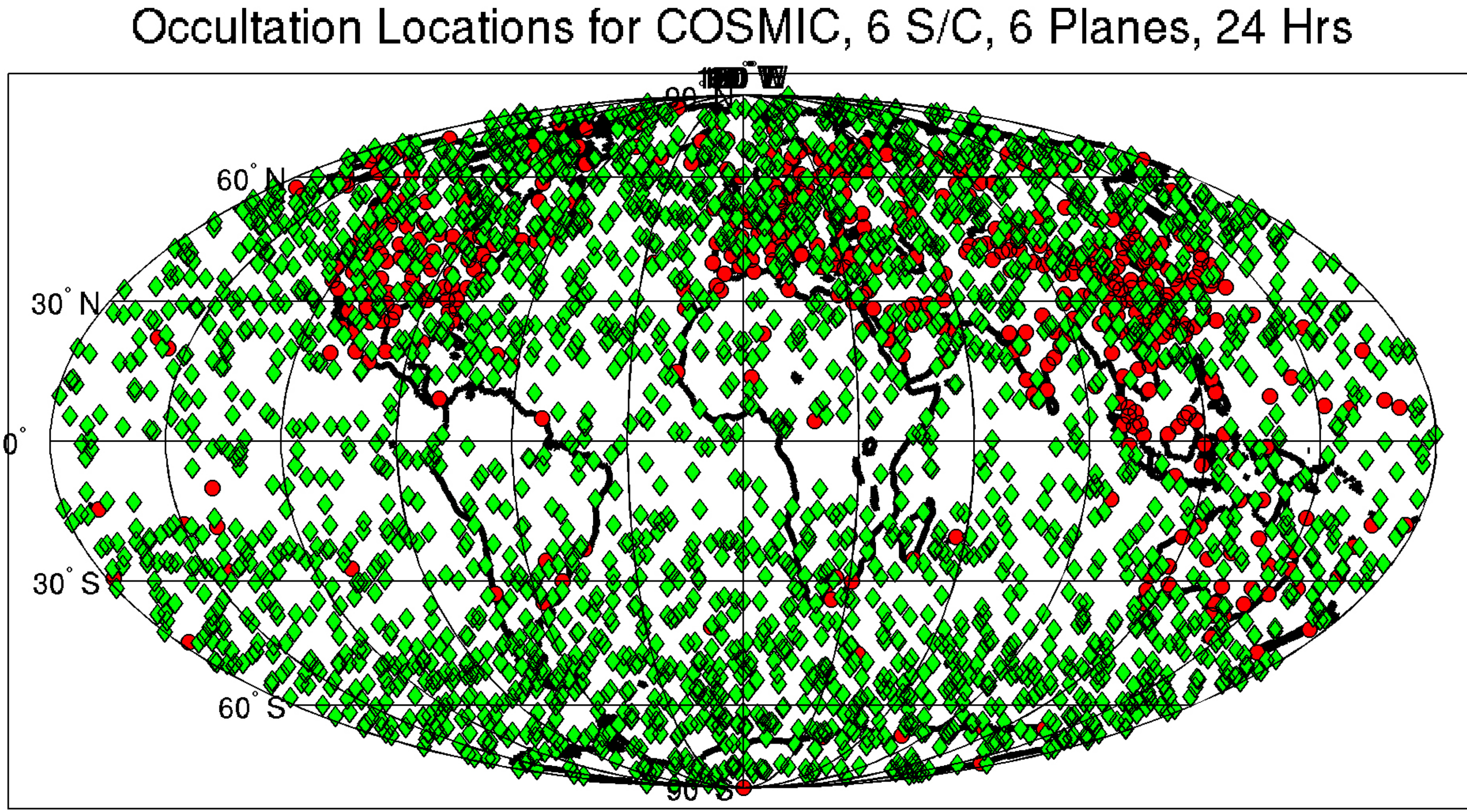
- Altimetry (Topex, Jason, etc) provides the mean sea surface topography
- GRACE provides the Geoid
- Altimetry – Geoid = Sea Surface Topography
- Sea Surface Topography reflects the global mean ocean currents



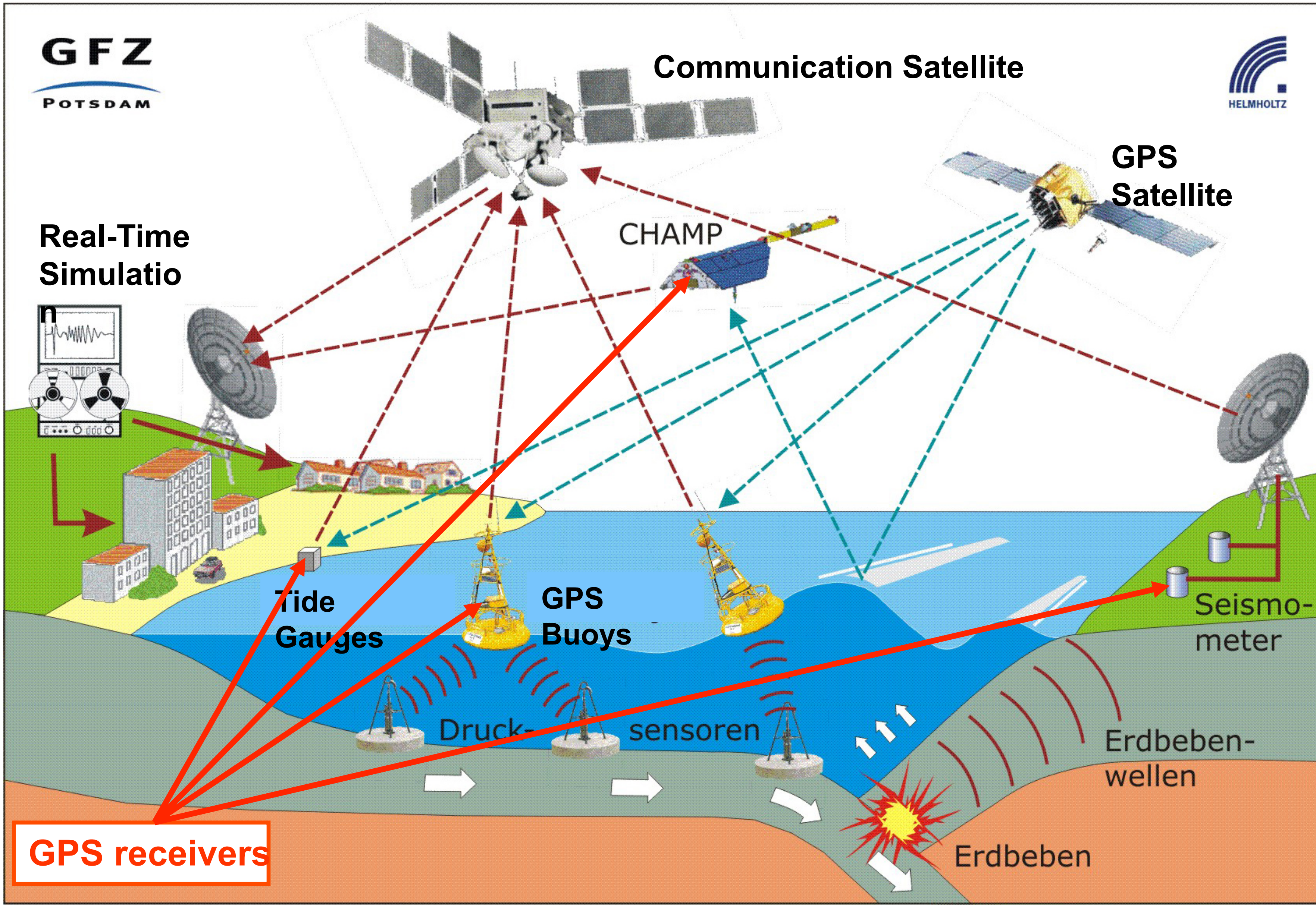
Occultation measurements between GPS and LEO satellites provide height profiles of water vapor, pressure, and temperature and ionospheric profiles

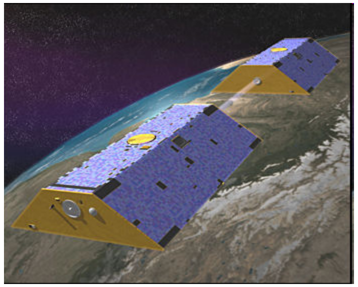


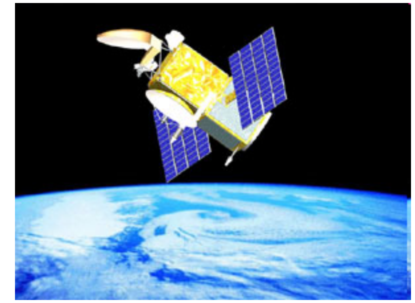
COSMIC: 2500 Occultations per Day



Example: GPS and a Tsunami Early Warning System

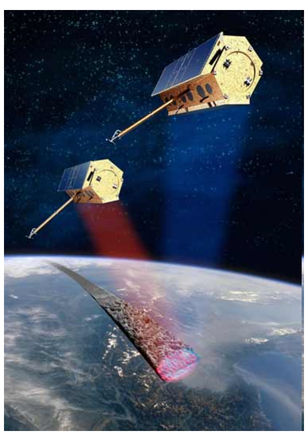


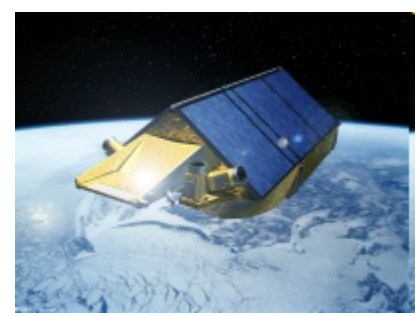




Common Thread:

- Reference Frame
- Precision Orbit Determination

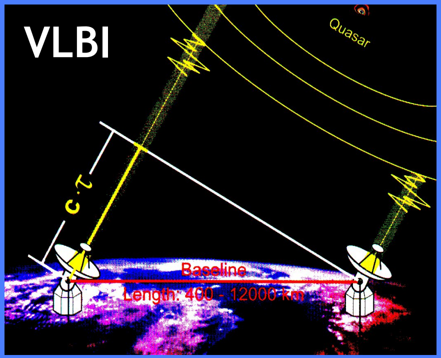




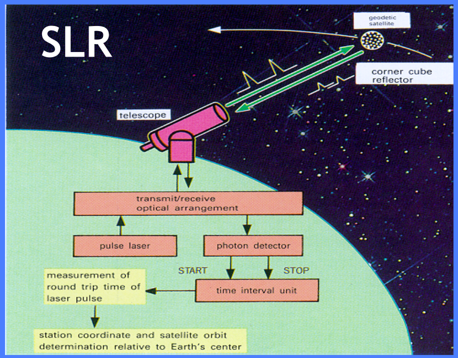
International Terrestrial Reference Frame (ITRF)

- 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 the different observing techniques

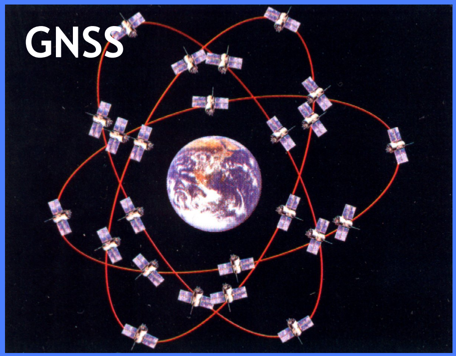
Space Geodetic Techniques



Very Long Baseline Interferometry

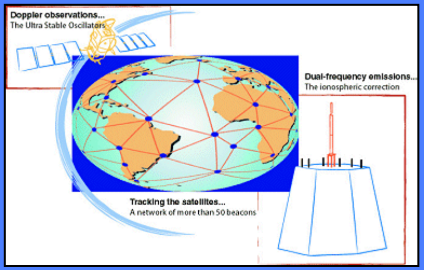


Satellite Laser Ranging



Global Navigation Satellite System

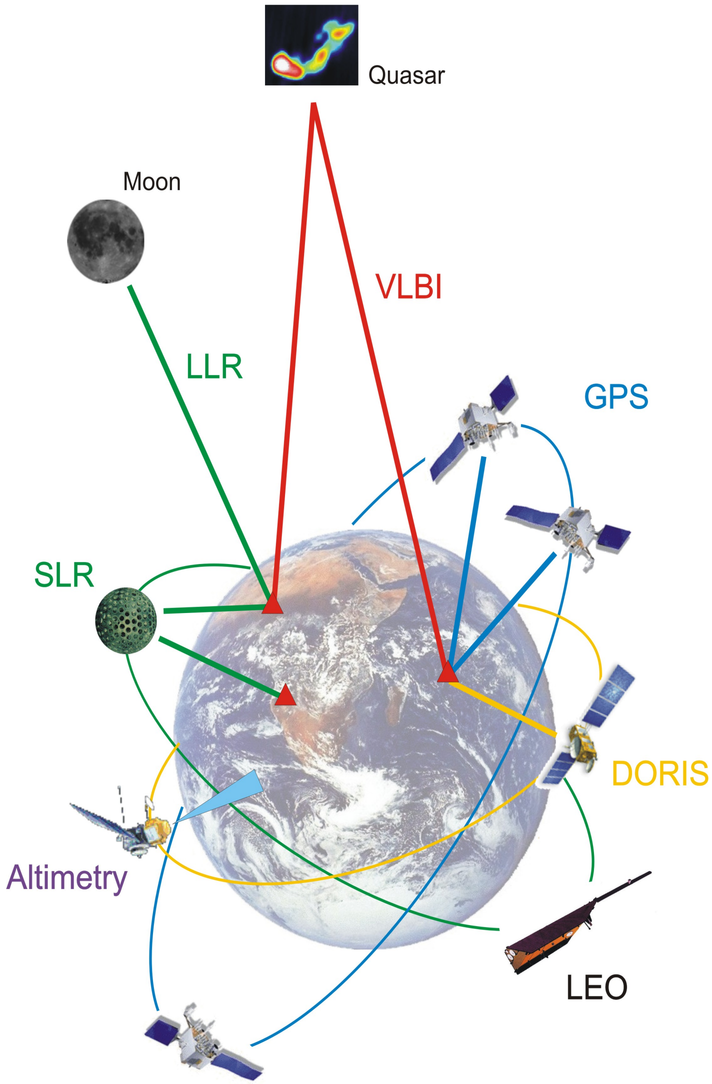
DORIS



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

Combination / Integration



- Ensure the **consistency** and can improve the **accuracy** of the resulting geodetic products
- **Complementary use** of the individual techniques to strengthen the solutions
- Benefits from observing instruments **co-located at the same site/satellite**
- Distinguish **genuine geodetic/geo-physical signals** from **technique-specific systematic biases**
- Crucial to **separate different components and processes** in the Earth System (e.g. mass transport)

International Terrestrial Reference Frame

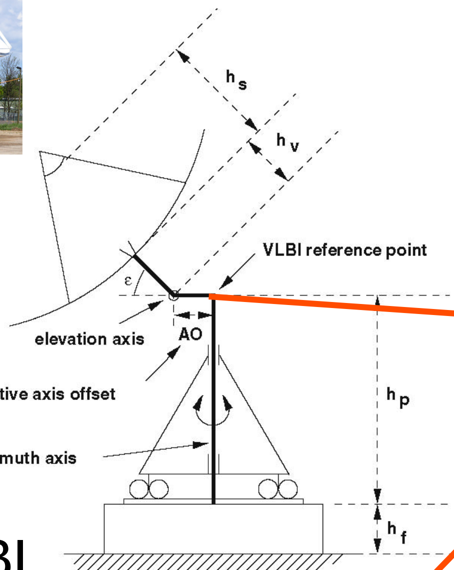
- VLBI provides EOP
- SLR provides Earth Center of Mass
- VLBI and SLR together provide Scale
- GNSS and DORIS strengthen the RF and provide global coverage and distribution

Global Geodetic Observing System Reference Frame Requirement

- 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 indicate:
  - ~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.

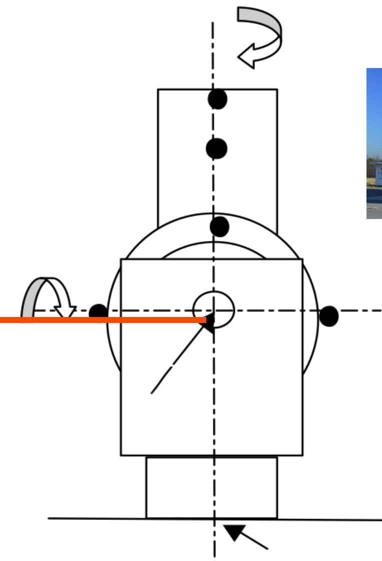
Fundamental Station Ground Co-location

and the essential role of the intersystem vector



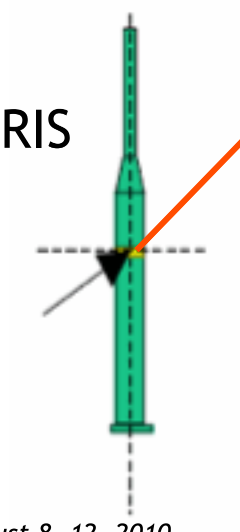
VLBI

Co-Location System



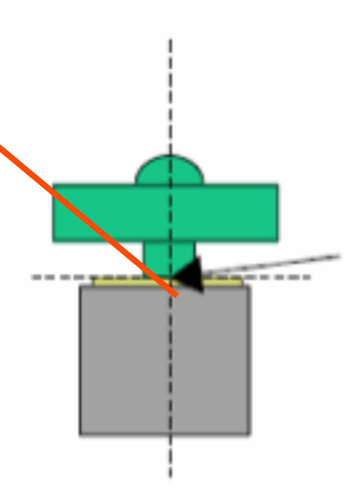
SLR

DORIS

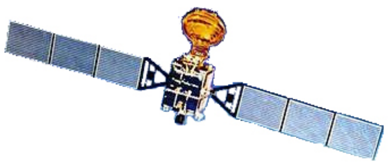


- GNSS and DORIS reference points
  - Extrapolate to measurement phase center
- VLBI and SLR reference points
  - Extrapolate to measurement phase center
  - RP through indirect approach
  - Targets mounted on system structure
  - Rotational sequence about axes of space geodetic instrument
  - Model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

GPS



Co-location in Space

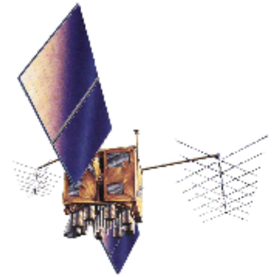


Compass

GNSS/SLR

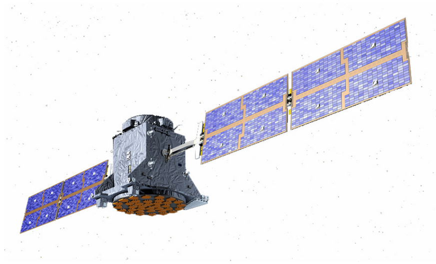
GLONASS

GNSS/SLR



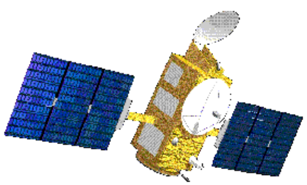
GPS

GNSS/SLR



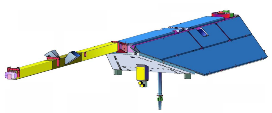
GIOVE/Galileo

GNSS/SLR



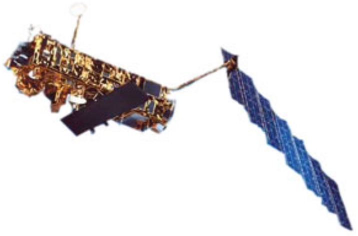
Jason

DORIS/GNSS/SLR



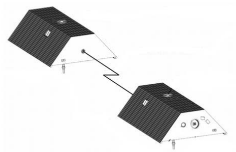
CHAMP

GNSS/SLR



Envisat

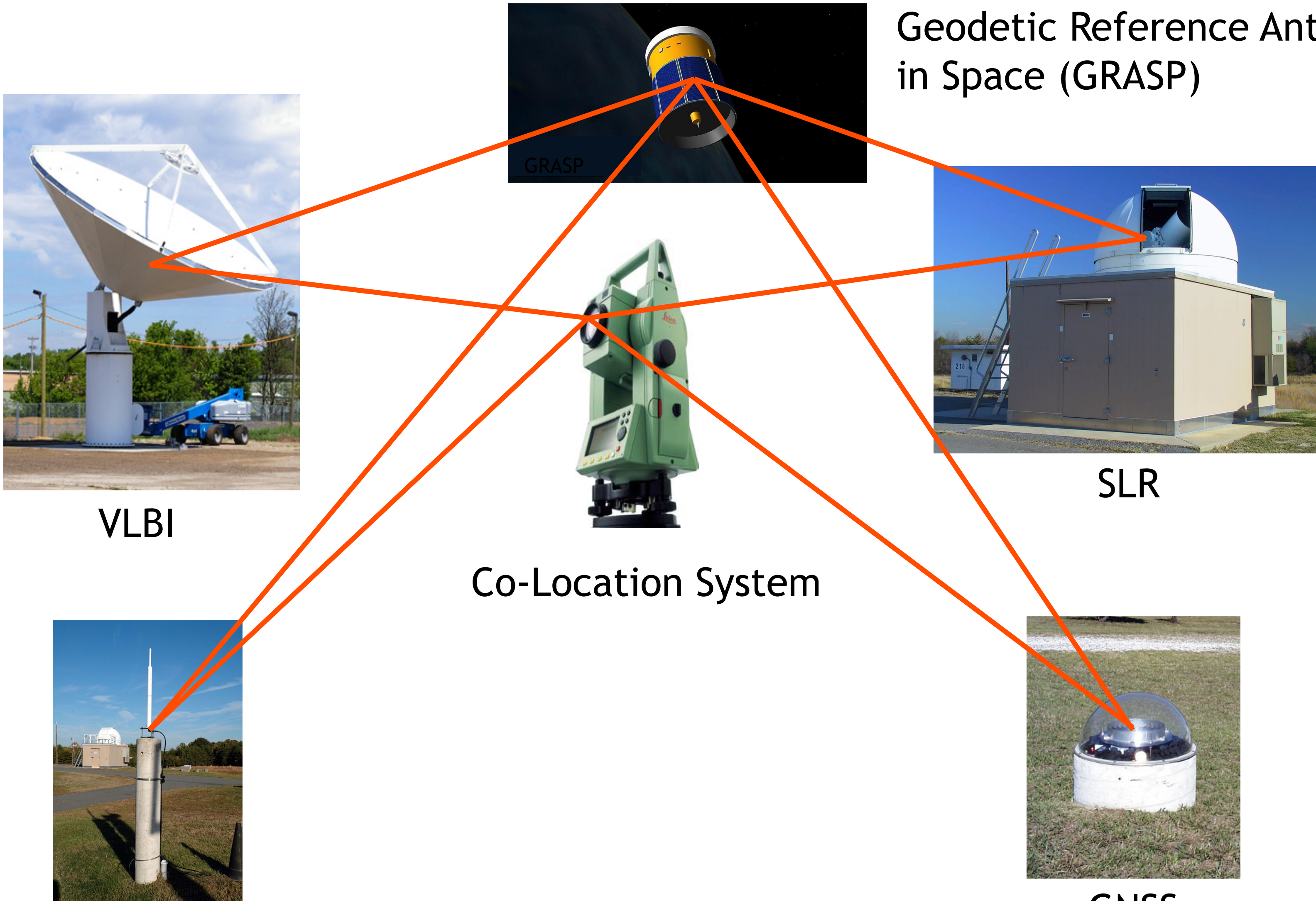
DORIS/SLR



GRACE

GNSS/SLR

Fundamental Station Space Co-location



Considerations for Site Locations

- Geographic locations (globally distributed network)
- General and local geology (geologically stable)
- Weather (SLR)
- 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)

- Preference to stations already established

Design Aspects of the VLBI2010 System

Progress Report of the IVS VLBI2010 Committee
June 2009

NASA/TM-2009-214180

NASA/TM-2009-214180

Design Aspects of the VLBI2010 System

Progress Report of the IVS VLBI2010 Committee

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National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

June 2009

IVS VLBI2010 Committee Site Recommendations

Station Recommendations

In order to establish a high quality VLBI2010 station, criteria are required for site selection, for local surveys, and for instrumentation (Malkin, 2008a). The VLBI committee recommendations for the site include:

The site should…

- **be geologically stable, i.e. located on firm, stable material, preferably basement outcrop, with small groundwater fluctuations to support a stable antenna foundation**
- have a robust tie to a well-designed regional footprint should be developed
- **be free of existing and forecastable obstructions above 5° for at least 95% of the horizon**
- **have minimal RFI from existing and forecastable local transmitters**
- be co-located with other space geodesy techniques (SLR, GNSS, DORIS, and gravimetry), preferably with long observational histories
- adhere to site criteria for other geodetic techniques that may be introduced in the future
- include space for a second VLBI2010 antenna if possible
- be near an existing or planned high-speed data link with a long-term goal of a data transmission rate of at least 4 Gbps
- be connected to regional/national geodetic networks
- be developed in coordination with IVS, IAG/GGOS, and IAU directing bodies
- be secure and have access to power, transportation, and personnel

IVS VLBI2010 Committee Site Recommendations
(continued)

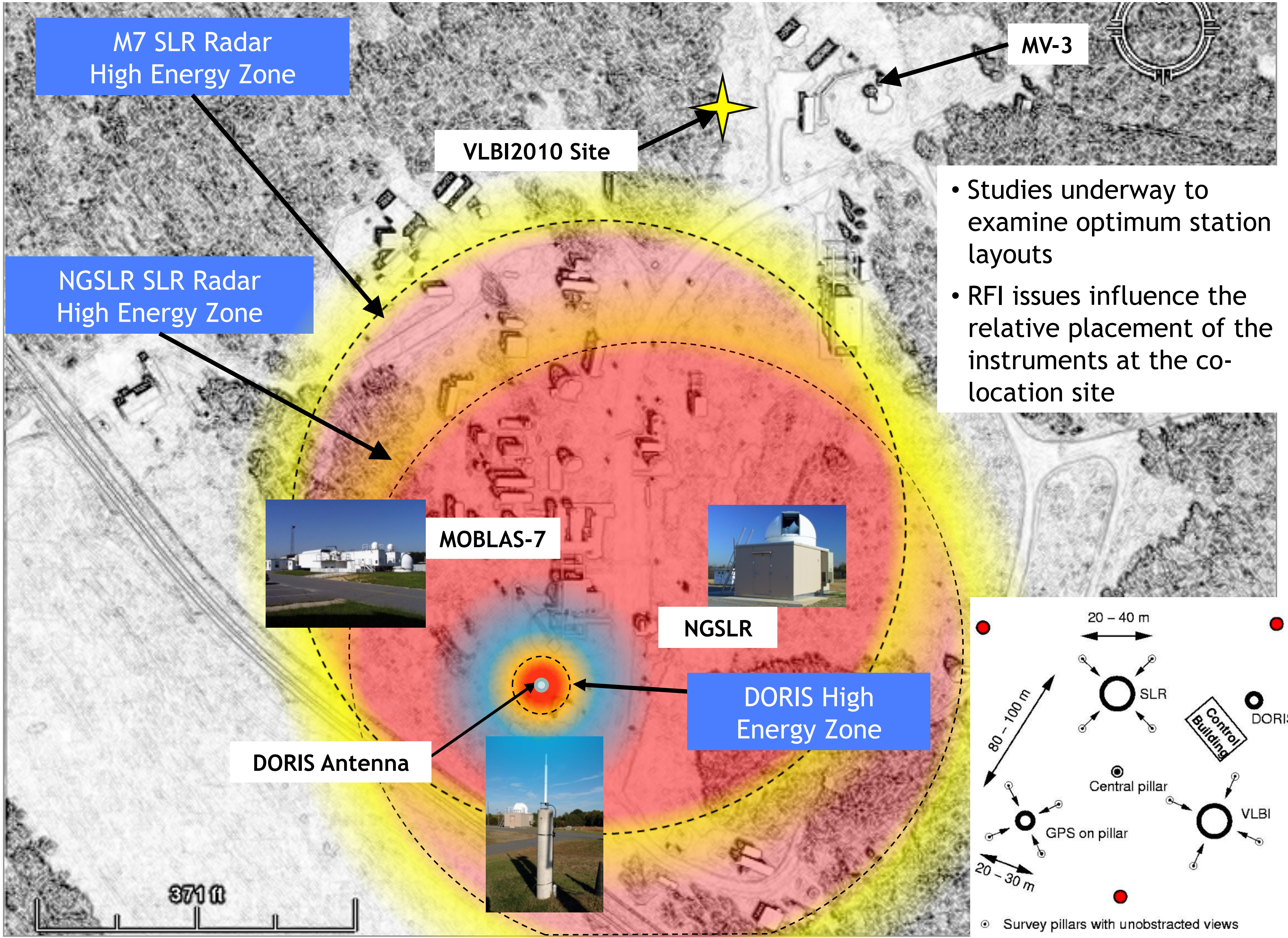
Local Geodetic Networks

The local network should consist of a station network and a regional footprint network. The accuracy of the surveys should be ***significantly better than 1 mm***, and all survey data should be rigorously reduced to provide 3D geocentric coordinate differences in the ITRF system.

The station network should…

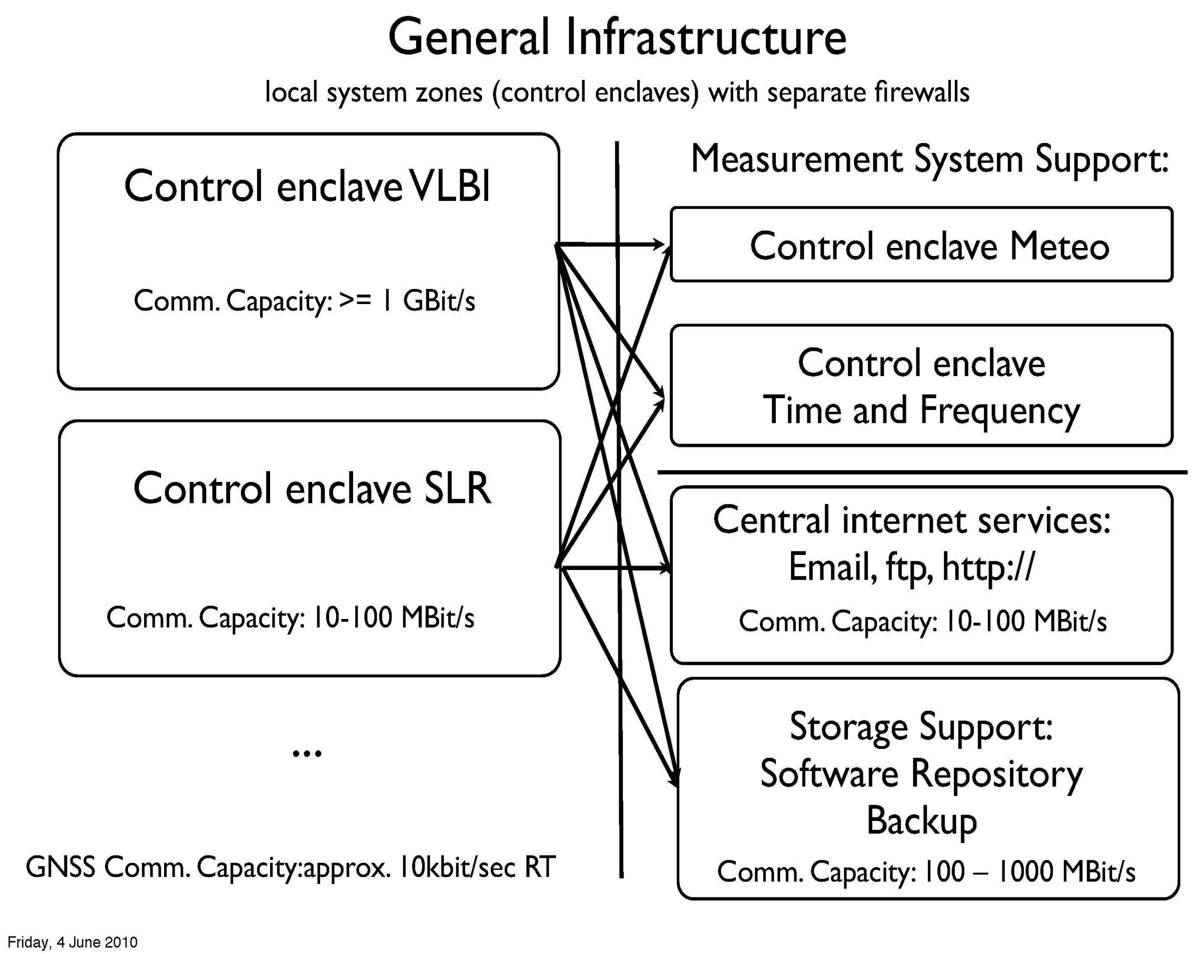
- be at least three ground monuments around each VLBI antenna at a distance of 30−60 m (up to 100 m for large antennas)
- provide visibility from ground monuments to the other space geodetic techniques
- have monuments that correspond to the local geological conditions and provide maximum stability over time
- be surveyed at least as often as once every 2.5 years with measurements of the temperature-adjusted VLBI antenna reference points and axis offsets as defined (Böhm et al., 2008, Heinkelmann et al., 2008)

Co-located Station Layout

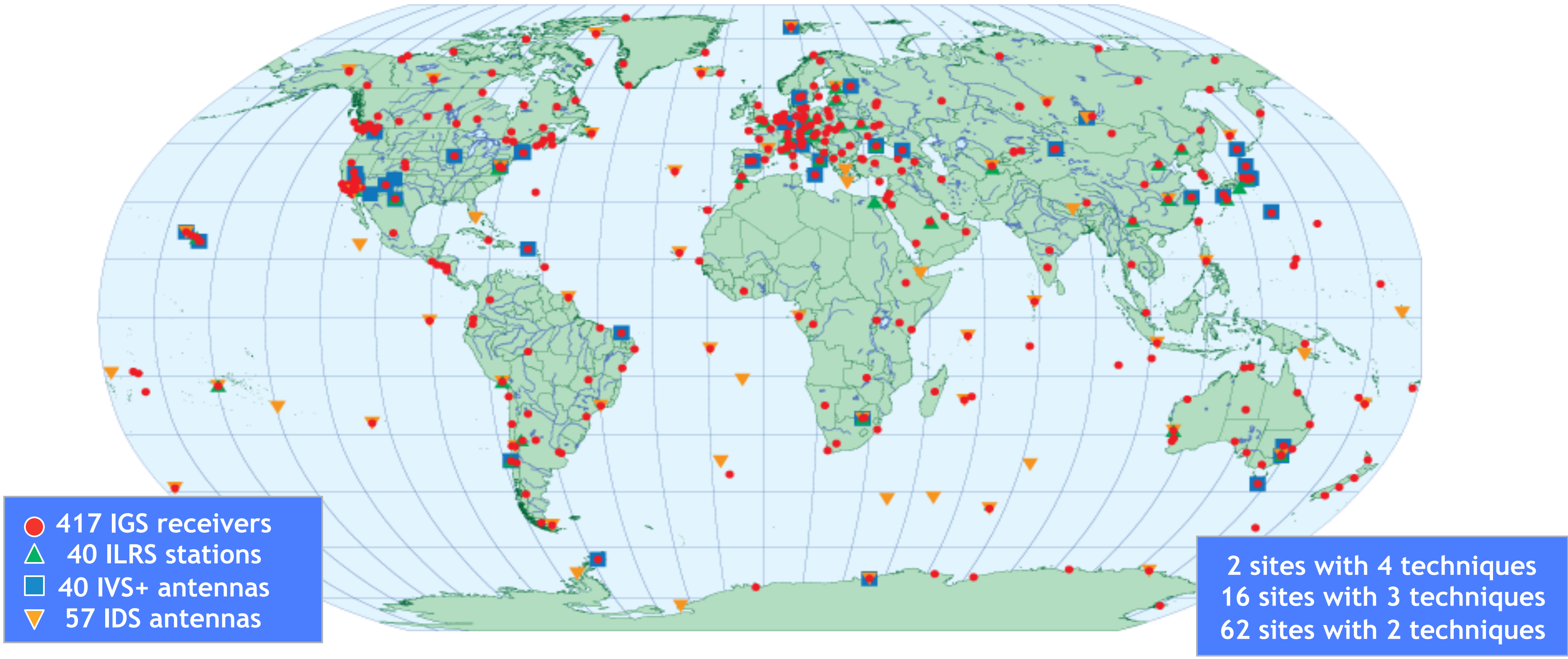


- Studies underway to examine optimum station layouts
- RFI issues influence the relative placement of the instruments at the co-location site

Space Geodesy Network Communications



Current Global Space Geodesy Network

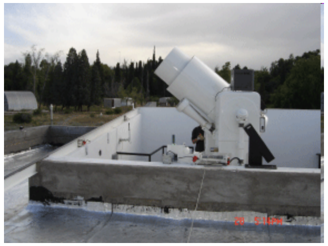


- Insufficient co-locations
- Although all of the Services have gaps in geographic coverage, the geographic gaps in SLR and VLBI are of particular concern.
- All of the networks are an anachronistic mix of legacy systems (in some cases decades old) and modern systems.
- Performance differences between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

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

Concepcion earthquake horizontal displacements

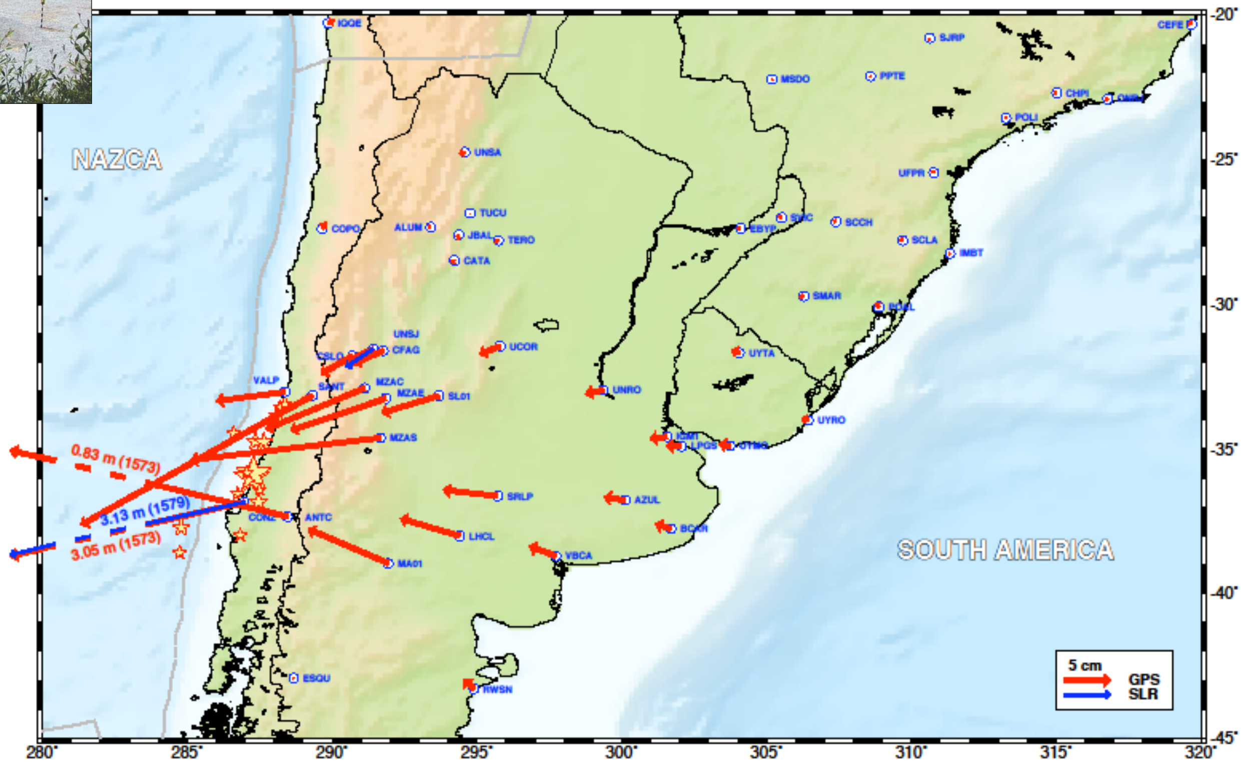
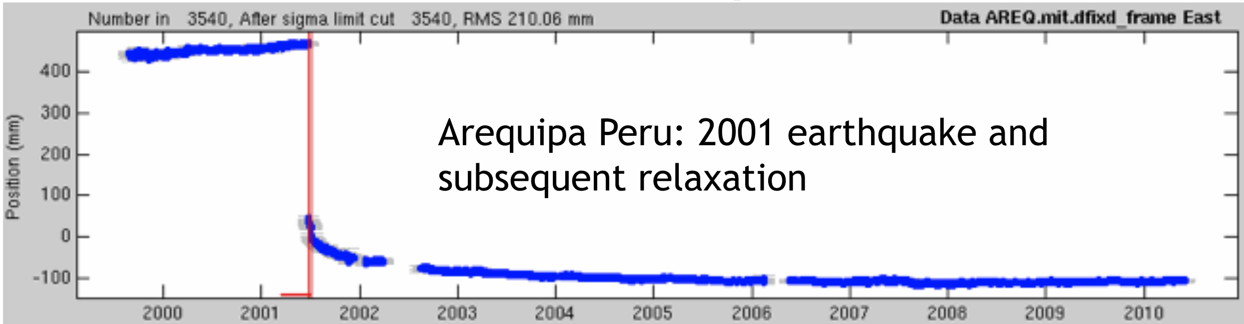


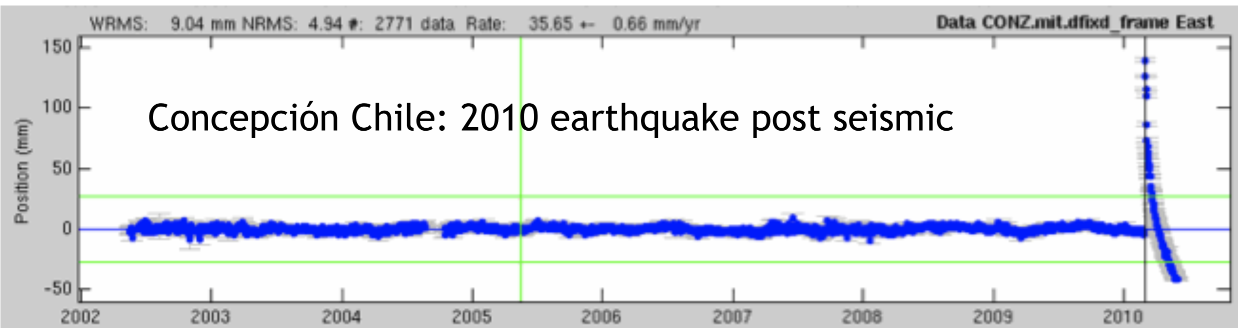
Figure courtesy of DGFI

Time History of Station Positions

Examples of Local Stability

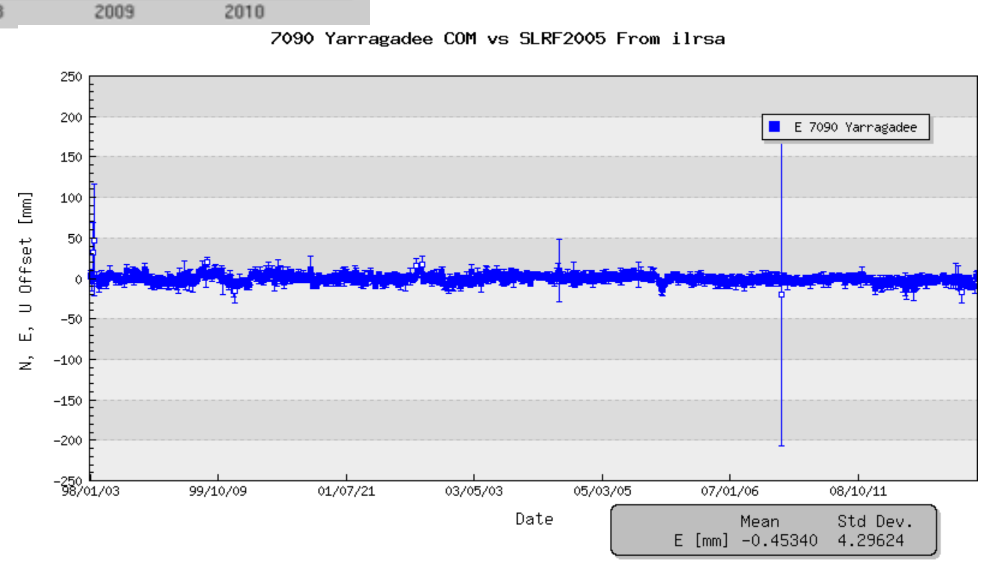


Arequipa Peru: 2001 earthquake and subsequent relaxation



Concepción Chile: 2010 earthquake post seismic

Arequipa and Concepción plots courtesy Tom Herring/MIT



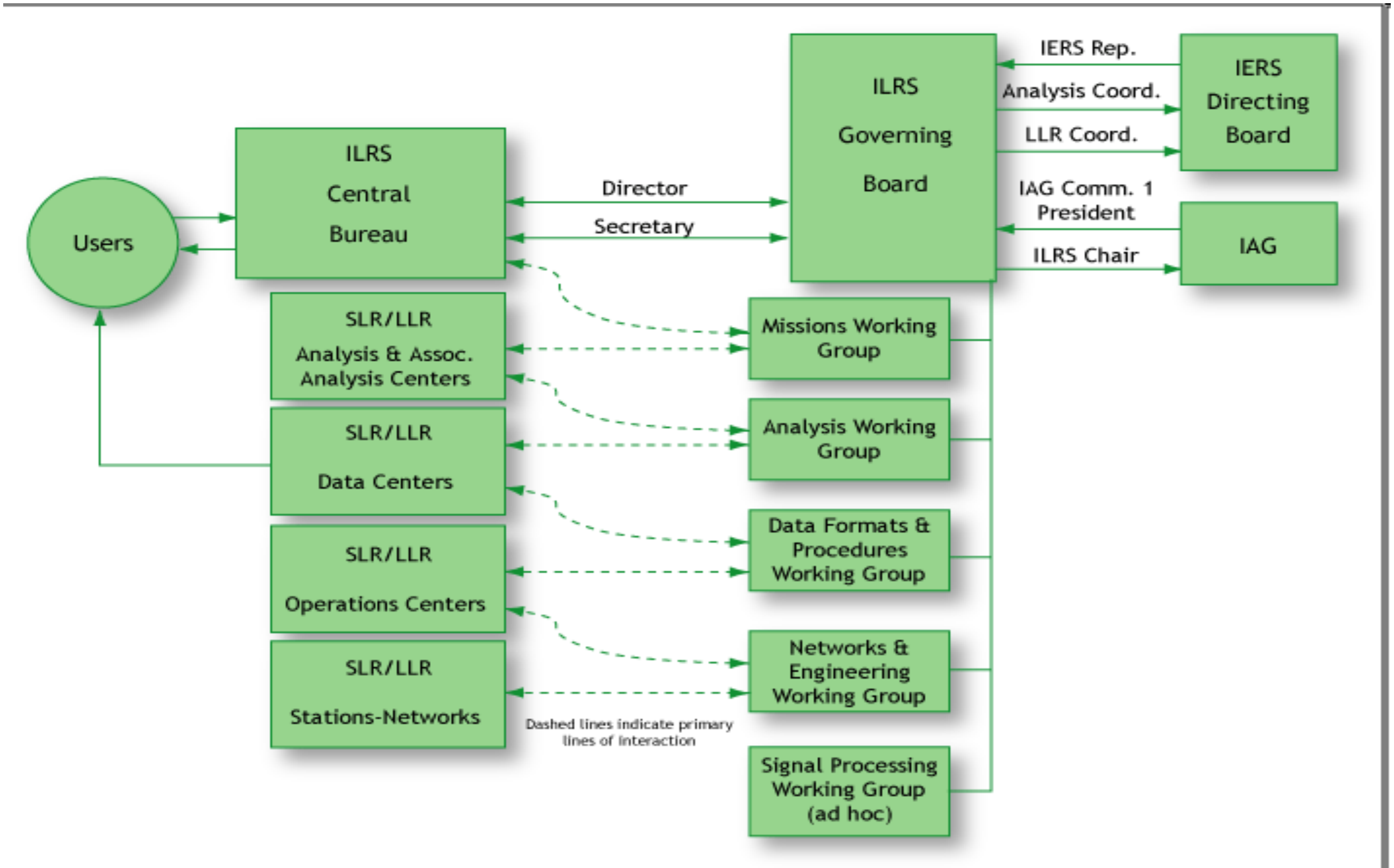
Yarragadee Australia: stable site

ORGANIZATIONS

IAG Services

- Services
  - International Global Navigation Satellite Service (IGS)
    - http://igscb.jpl.nasa.gov/
  - International VLBI Service (IVS)
    - http://ivscc.gsfc.nasa.gov/
  - International Laser Ranging Service (ILRS)
    - http://ilrs.gsfc.nasa.gov/
  - International DORIS Service (IDS)
    - http://ids-doris.org/
- Role
  - Organize activities, priorities, standards, data acquisition and flow, data products, encourage technology sharing, etc.

Example Organization
International Laser Ranging Service



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.*

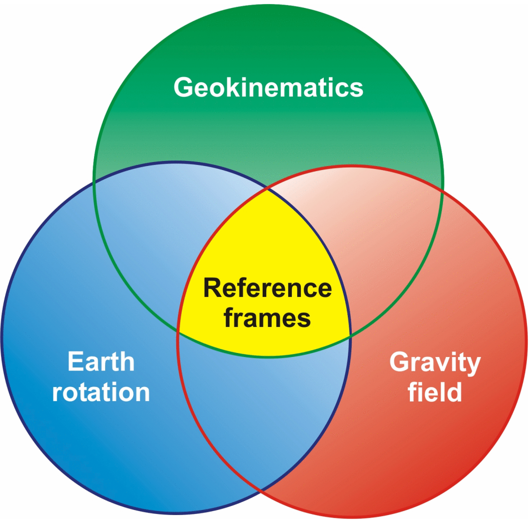
Role

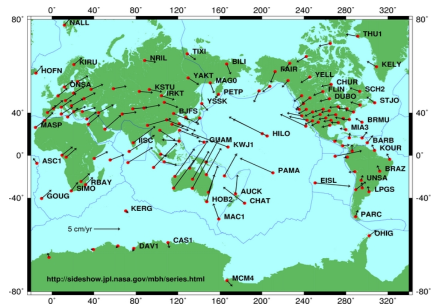
- **Facilitate networking** among the IAG Services and Commissions and other stakeholders in the Earth science and Earth Observation communities,
- **Provide scientific advice and coordination** that will enable the IAG Services to develop products with higher accuracy and consistency meeting the requirements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

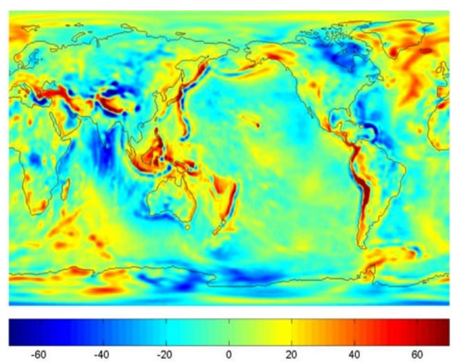
GGOS Bureau for Networks and Communications

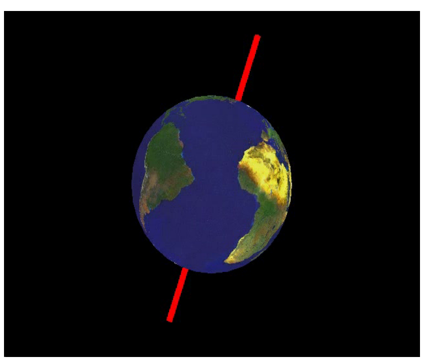
- Provides oversight, coordination, and guidance for the development, implementation and operation of the Network of Core (co-location) Sites.
- Develops a strategy to design, integrate and maintain the fundamental geodetic network of co-located instruments and supporting infrastructure in a sustainable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

Underlying Concepts and Main Issues









The 'three pillars of geodesy':

- Earth's Shape (Geokinematics)
- Earth's Gravity Field
- Earth Rotation

Output:

- Reference Frame
- Observations of the Shape, Gravitational Field and Rotation of the Earth

Challenges:

- Consistency of the three pillars
- Global change effects are small
- Reference frame available anywhere, any time

Solutions:

- Integration of Systems, Observations, Analysis, and Models

Catch the Earth!

GGOS is a program of the International Association of Geodesy (IAG):

- Ensures observations of the three fundamental geodetic observables and their variations: Earth's shape, gravity field and rotational motion
- Integrates different geodetic techniques, models, and approaches to ensure long-term, precise monitoring of observables in agreement with the Integrated Global Observing Strategy (IGOS)
- Is a recognized member of the Global Earth Observing System of Systems (GEOSS)
- Is a powerful tool consisting mainly of high quality services (e.g., IGS), standards and references, and of theoretical and observational innovations

NASA Space Geodesy Project (NSGP)

- 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

The Earth Sciences Decadal Survey (Space Studies Board, 2007) made the following strong statement:

"The geodetic infrastructure needed to enhance, or even to maintain the terrestrial reference frame is in danger of collapse ... Investing resources to assure the improvement and the continued operation of this geodetic infrastructure is a requirement of virtually all the missions for every Panel in this study ... "

- *NASA responded, leading the way to meet the GGOS requirements*
- *Major participation from international partners is essential*

Summary and Outlook

The **Global Geodetic Observing System (GGOS)** allow the monitoring of:

- **Deformation of the Earth** and **Earth rotation** with sub-mm accuracy
- **Global gravity field** and its time variations with unprecedented accuracy and resolution (satellite missions)
- **Water vapor** in the troposphere, tropospause height, **electron density in the ionosphere** (atmospheric processes relevant for global warming)
- Many types of **natural hazards and disasters** (early warning systems)

Combination/integration:

- all **observation techniques** (complementary, systematic biases)
- **comprehensive modeling** of the interactions in the Earth system

→ New insights into the geophysical processes

→ Realization of the **Global Geodetic Observing System**' (GGOS)

→ Basis for a **deeper understanding of the Earth System** and the

GGOS Approach

- Integrate different techniques, models, and approaches in order to achieve a better consistency, long-term stability and reliability, and the spatial and temporal resolution required for the understanding of geodetic, geodynamic and global change processes;

- View the Earth system as a whole by including the solid Earth as well as the fluid components and the interactions of these components;

- Improve the geodetic models at the level required by the observations;

- Ensure consistency among the separate measurement techniques;

- Ensure the consistency between the different geodetic standards used in the services and the geosciences community, in agreement with the international unions and programs;

- Reach an overall accuracy and consistency of GGOS products of the order of 10^{-9} or better;

High Level Tasks

- Identify a consistent set of geodetic products and establish the requirements concerning the products' accuracy, temporal and spatial resolution, latency, and consistency;
- Develop the strategy for GGOS appropriate to meet these requirements;
- Identify IAG service gaps and develop strategies to close them;
- Ensure the availability, consistency, reliability and accessibility of geodetic observations, products, and models.

Present Status and Activities

- GEO: Task AR-07-03: Global Geodetic Reference Frames

  (1) Understand the user requirements of the nine SBAs in terms of access to a global reference frame (accurate positions) AND geodetic observations;

  (2) Improve the framework conditions for the maintenance of the geodetic infrastructure, support for transition research to operational.

- The Global Geodetic Observing System: Meeting the Requirements of a Global Society on a Changing Planet in 2020 (GGOS 2020)
  - Strategy process of GGOS/IAG
  - Deliverable of Task AR-07-03
  - Basis for the future development and implementation of GGOS