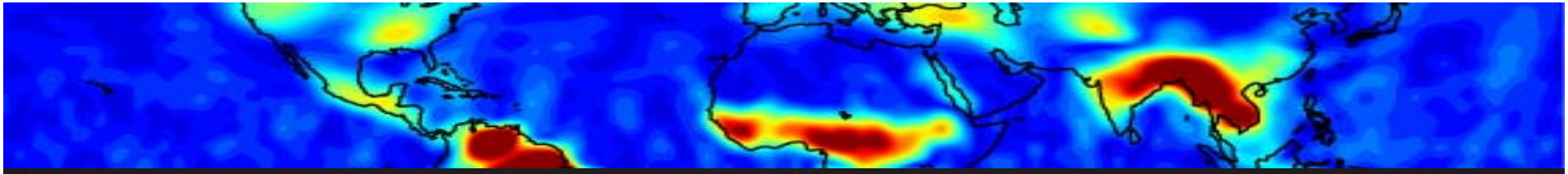
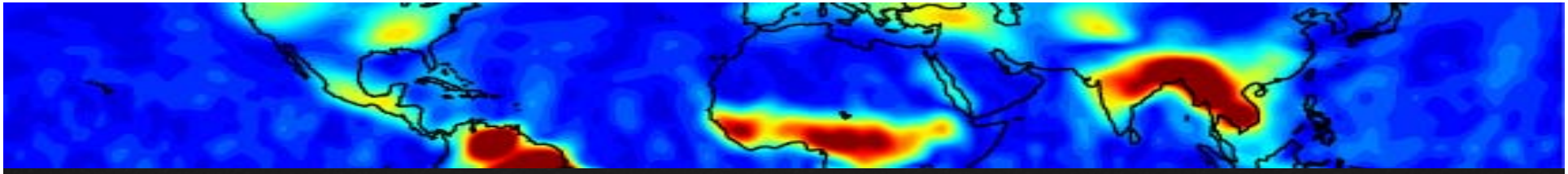


Precise Geodetic Infrastructure

National Requirements for a Shared Resource

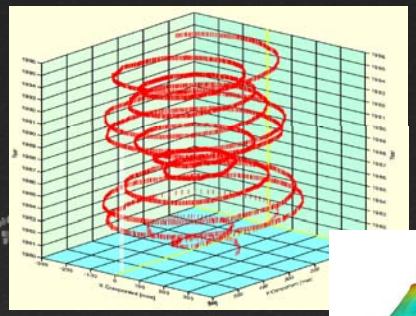
Jean-Bernard Minster

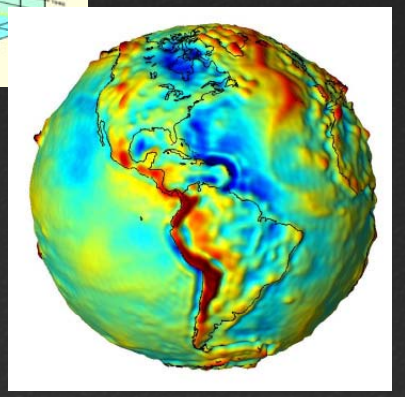
December 2, 2010 Briefing
SDR



GEODESY

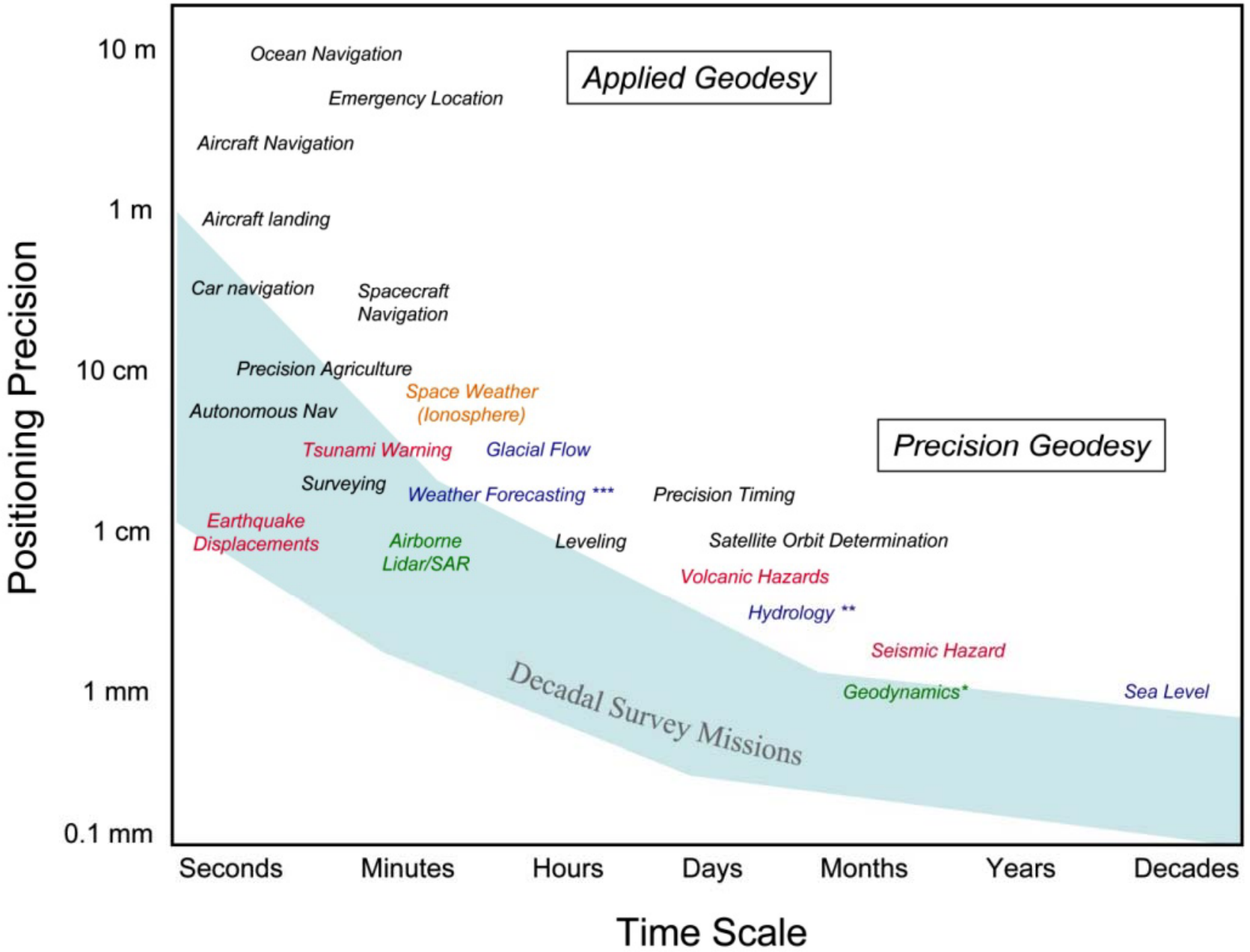
The science of accurately measuring and understanding three fundamental properties of Earth:

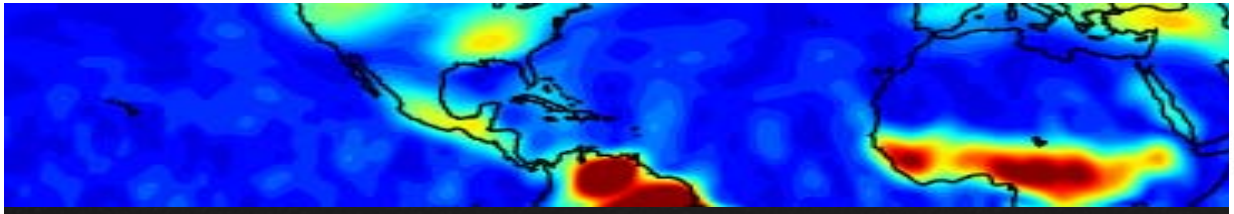




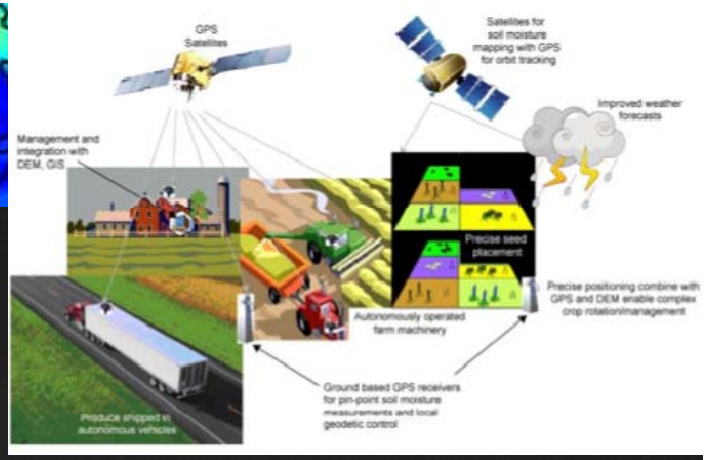
- its geometric shape,
- its orientation in space,
- its gravity field,

… and the changes of these properties with time.


Positioning Precision
10 m
1 m
10 cm
1 cm
1 mm
0.1 mm
Ocean Navigation
Emergency Location
Aircraft Navigation
Aircraft landing
Car navigation
Spacecraft Navigation
Precision Agriculture
Space Weather (Ionosphere)
Autonomous Nav
Tsunami Warning
Glacial Flow
Surveying
Weather Forecasting ***
Precision Timing
Earthquake Displacements
Airborne Lidar/SAR
Leveling
Satellite Orbit Determination
Volcanic Hazards
Hydrology **
Seismic Hazard
Geodynamics*
Sea Level
Applied Geodesy
Precision Geodesy
Decadal Survey Missions
Seconds
Minutes
Hours
Days
Months
Years
Decades
Time Scale

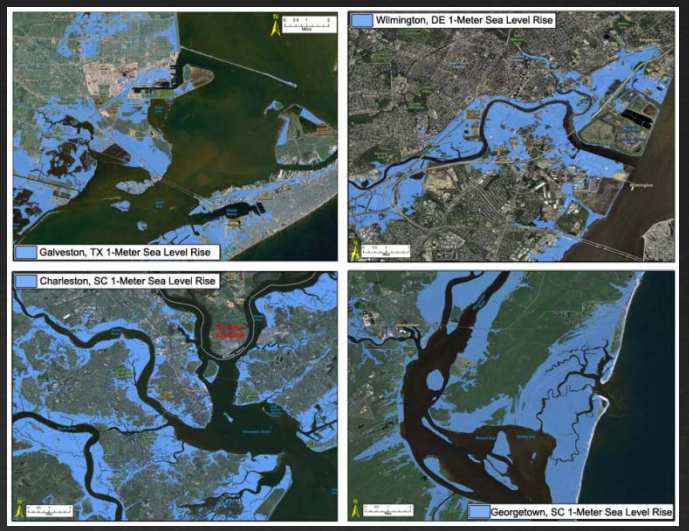


Geodesy for the benefit of society

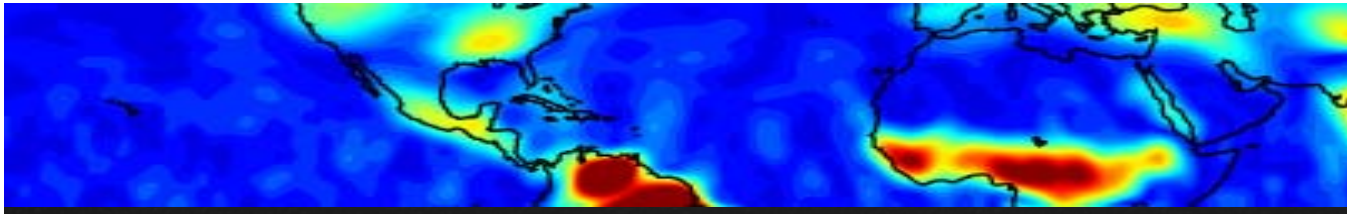


Military, research, civil, and commercial areas, e.g.:

- Real time positioning
- Autonomous navigation (roads, sea, air)
- Precision agriculture
- Surveying, floodplain mapping
- Forest mapping, biomass estimation
- Natural hazards monitoring and early warning
- Sea level change



… TIME IS OF THE ESSENCE!



Earth Science Requirements

Solid Earth Dynamics
- Geodynamics, PGR, EOP

Natural Hazards
- Volcano, Earthquake,Landslide, Flood, Tsunami

Ocean and Cryosphere Dynamics
- Sea Level Rise

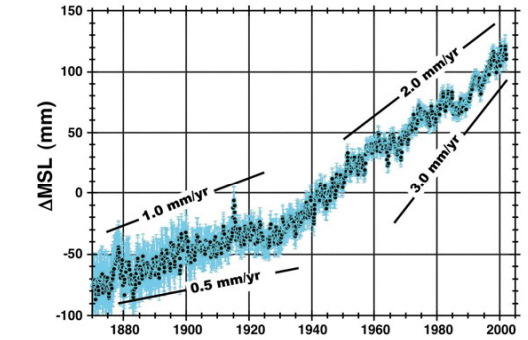
Hydrologic Cycle and Water Resources
- Storage, Subsidence, River and Lake Levels

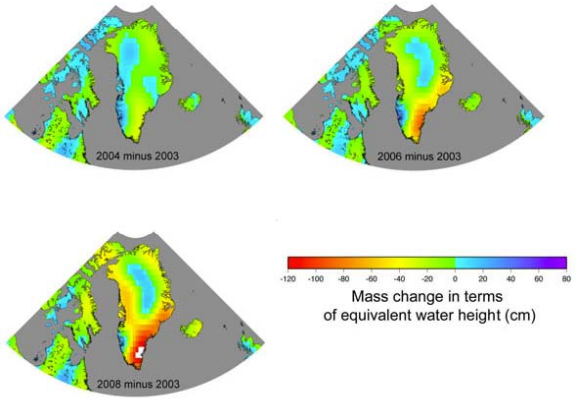
Weather .
- Ground- and Based, Space Weather

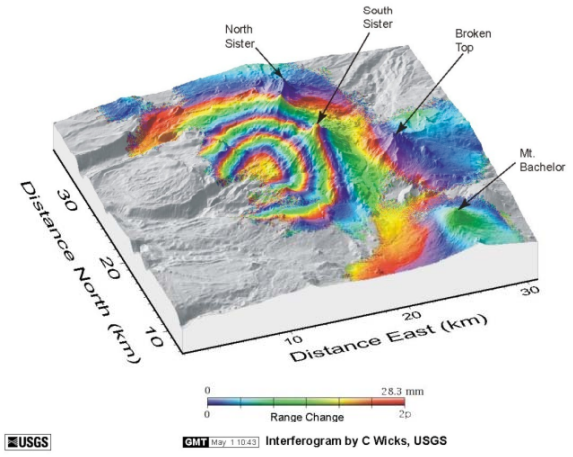
Precision Spacecraft Navigation
- Precision Orbit Determination, Interplanetary Navigation

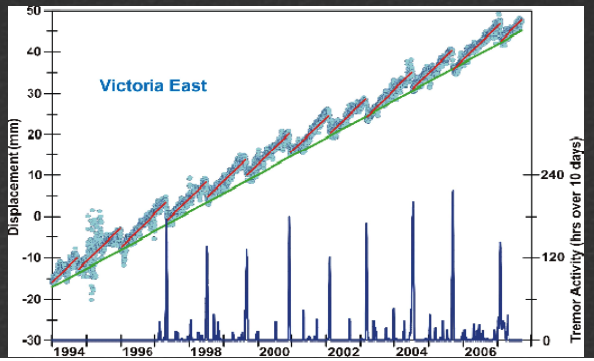
Timing and Time Transfer .

Decadal Missions









Focus on: Natural Hazards

- Natural hazards (earthquakes, volcanoes, landslides, tsunamis, weather, and others) are:
  - Often **rapid events**
  - **Difficult to predict**
- To be able to bring science to bear on these problems, we must therefore have the **systems and capabilities in place** before the events
- Geodesy provides:
  - Information on the long- and short-term likelihood of natural hazards
  - Rapid early warning and response information
  - Significant enhancement to existing non-geodetic systems
  - Support for the operations of non-geodetic systems

Current and Future Socio-Economic Benefits of Geodesy

…have not been systematically assessed, but consider the following:

- Recent developments in positioning technologies could drive revenues from mobile location-based services to more than **$12.7 billion** by 2014[1]
- The benefit of GRAV-D to society has been estimated at **$4.8 billion** over 15 years[2]
- The National Spatial Reference System (NSRS) has been estimated to provide benefits equivalent to **$2.4 billion** annually[2]
- Successfully monitoring and forecasting Mount Pinatubo's cataclysmic eruption in 1991 prevented property losses of more than **$250 million**[3]
- An earthquake early warning system would have given San Franciscans a 20 sec warning of the 1989 Loma Prieta ("World Series") earthquake, with an estimated **drop of 13% in the fatality rate**[4]

- Many spheres of our society (e.g., civil aviation, mapping and surveying, military) now utilize products of the geodetic infrastructure
- Hundreds of large and small scientific projects (including satellite-based studies) whose economic benefits are dispersed throughout the nation depend on geodetic infrastructure

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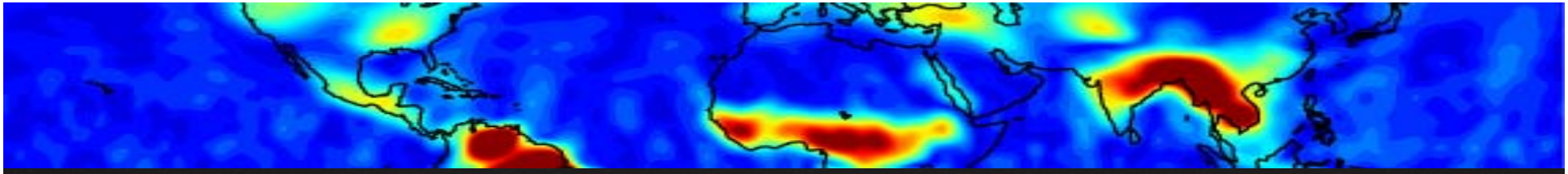
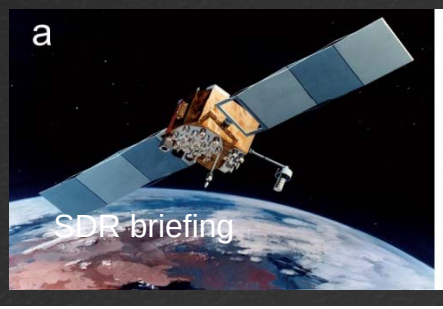
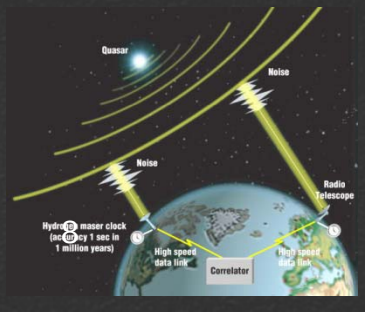
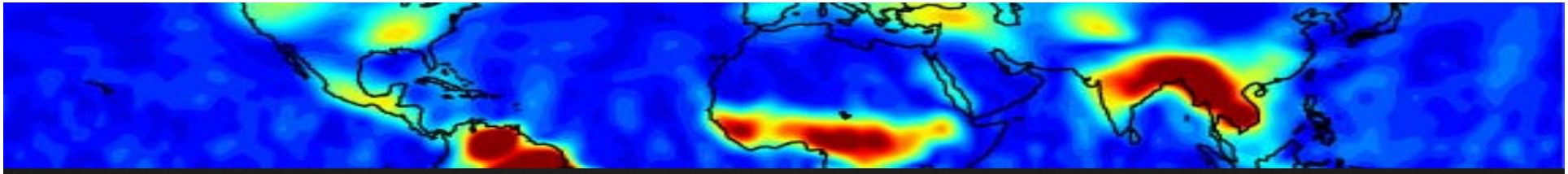


Geodetic Systems

- Very Long Baseline Interferometry (VLBI)
- GNSS/GPS
- Satellite and Lunar Laser Ranging (SLR and LLR)
- Doppler Orbit Determination and Radiopositioning Integrated by Satellite (DORIS)
- Ground and airborne gravity
- Tide gauges

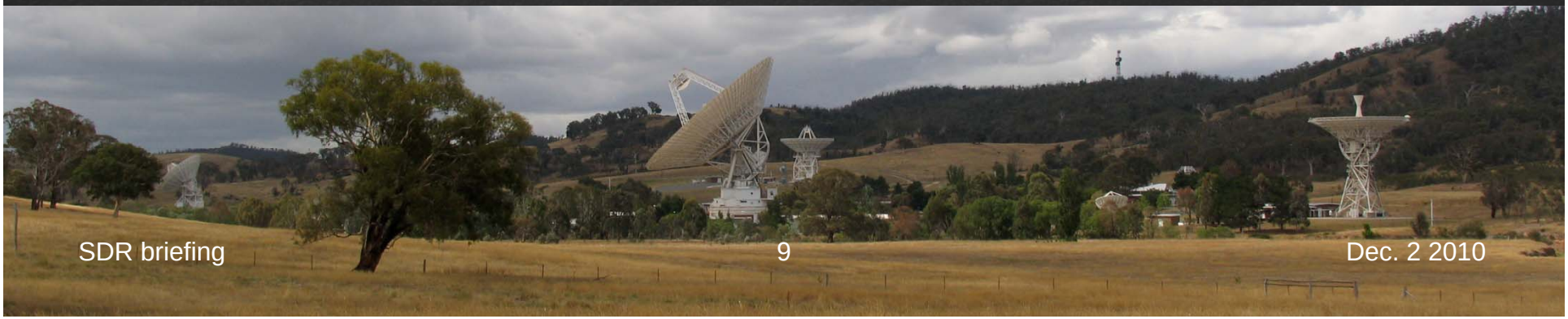


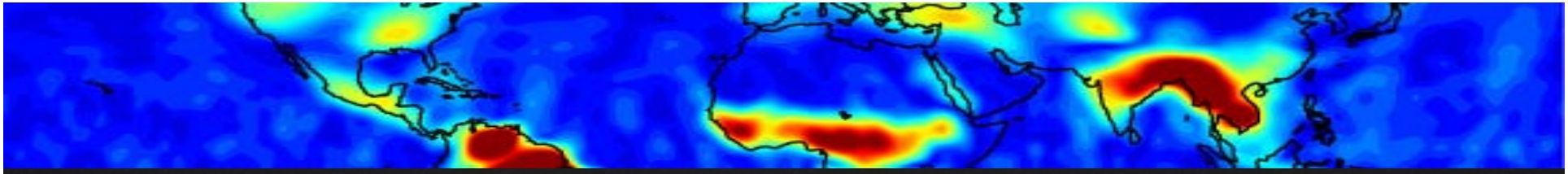




Geodetic Infrastructure

- Ground-based networks (local to global, temporary to permanent)
- Earth observation satellites (precise positioning, altimetry, gravity)
- Data collection, dissemination and stewardship facilities
- National and international services





Precision geodesy since Sputnik

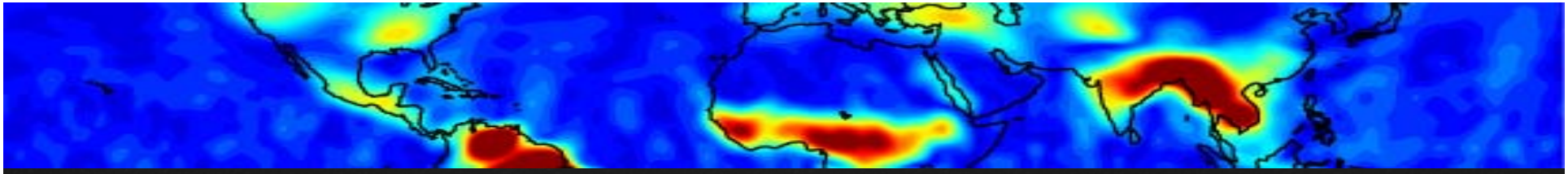
… advanced by about one order of magnitude each decade

… does not show any sign of slowing down!

… is now truly global

… pushed the envelope in spatial and temporal resolution

… is more and more driven by real time applications



So…what's the problem?

- Critical infrastructure in "danger of collapse"
  - Some critical networks are sparse and ill-balanced
  - Some sites rely on decades-old equipment
  - Cross-system connections are still not resolved satisfactorily
- Aging, small workforce: where are the new geodesists coming from?
- Nobody has overall long-term responsibility

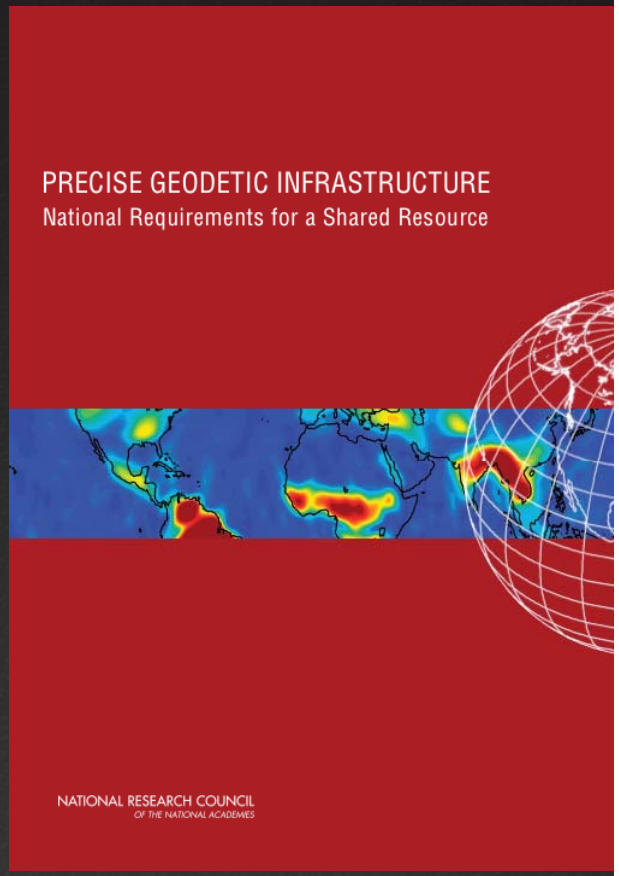
These combined factors pose a risk of a sudden, drastic loss of geodetic observing capability

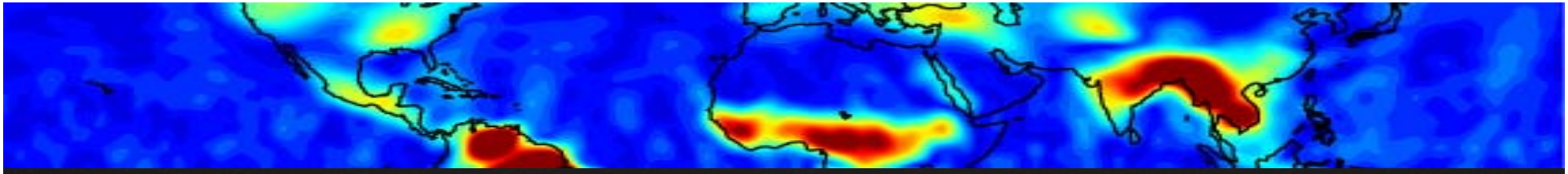
- How does the US support GEO/GEOSS in the long term?

What we need to do!

The United States, to maintain leadership in industry and science, and as a matter of national security, should invest in maintaining and improving the geodetic infrastructure, through:

- **upgrades in network design and construction**
- **modernization of current observing systems**
- **deployment of improved multi-technique observing capabilities, and**
- **funding opportunities for research, analysis, and education in global geodesy.**



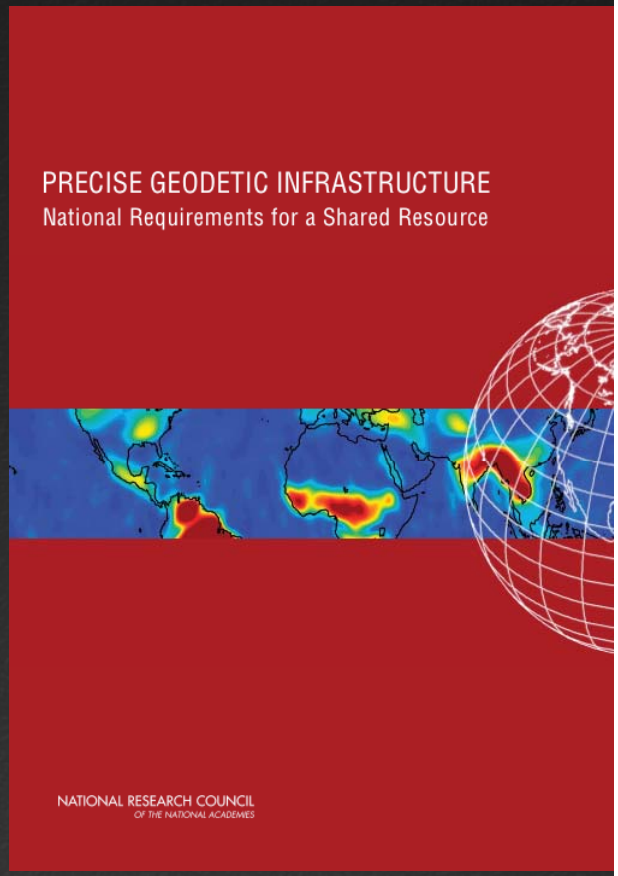


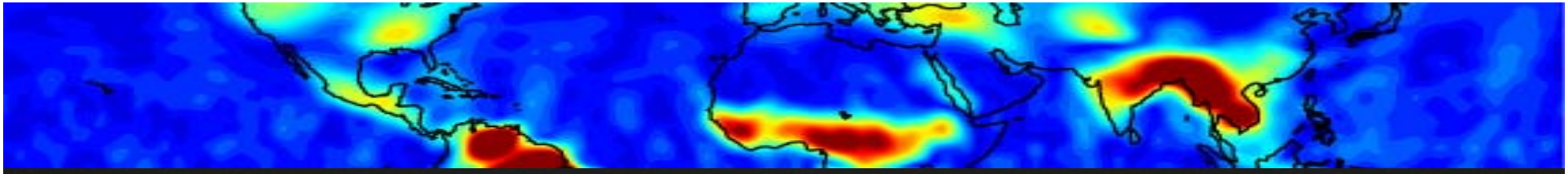
Specifically, in the near-term..

- **The United States should construct and deploy the next generation of automated high-repetition rate SLR tracking systems at the four current U.S. tracking sites in Hawaii, California, Texas, and Maryland.**

- **It also should install the next-generation VLBI systems at the four U.S. VLBI sites in Maryland, Alaska, Hawaii, and Texas.**

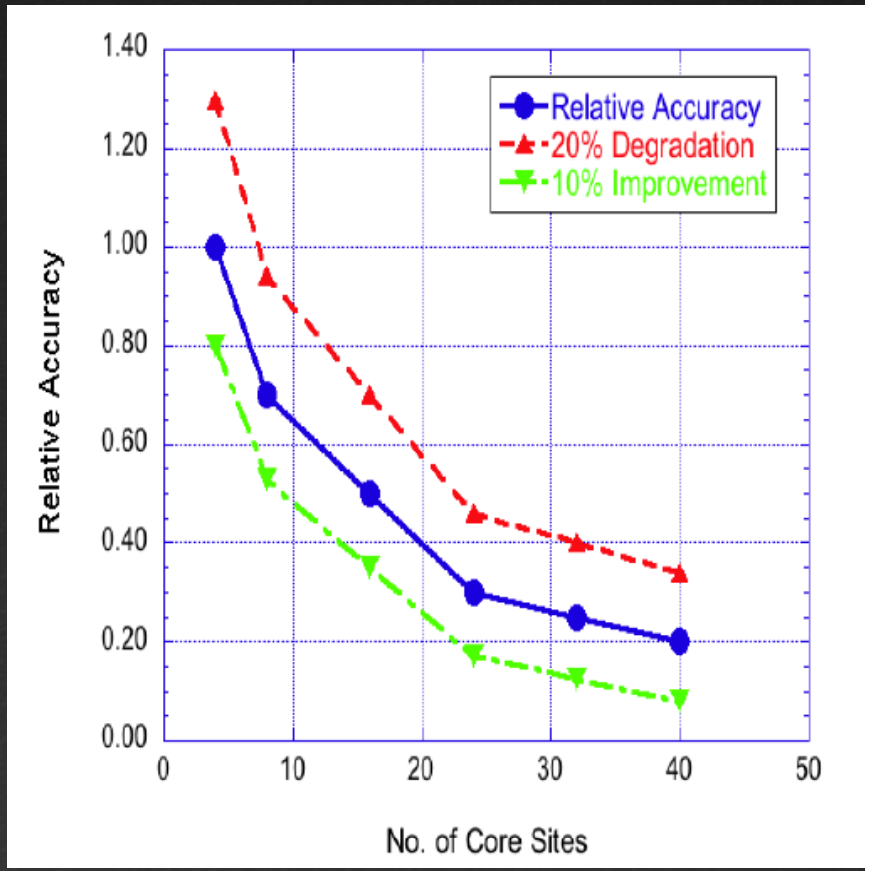
Maintaining the long history of data provided by these sites is essential for reference frame stability as we transition between ever-evolving geodetic techniques.





And in the long-term…

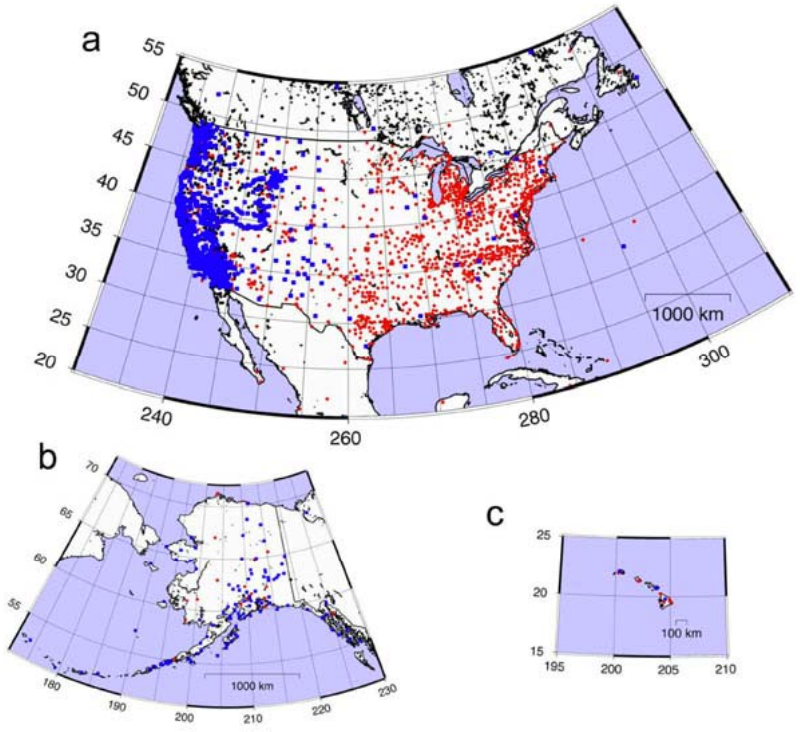
The United States should deploy additional stations to complement and increase the density of the international geodetic network, in a cooperative effort with its international partners, with a goal of reaching a global geodetic network of at least 24 fundamental stations.

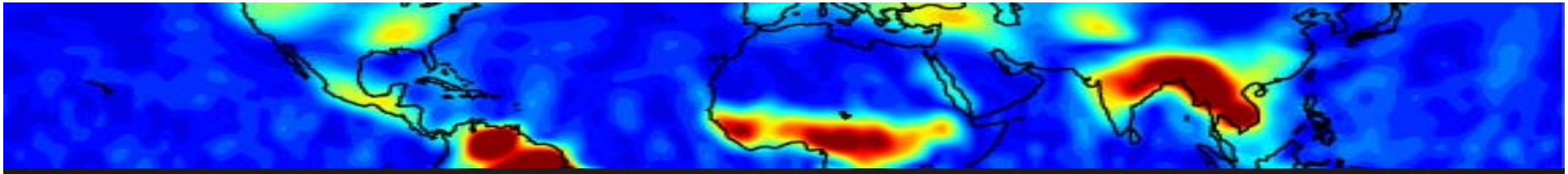


Meanwhile …

The United States should establish and maintain a high-precision GNSS/GPS national network constructed to scientific specifications, capable of streaming high-rate data in real-time.

All GNSS/GPS data from this network should be available in real-time without restrictions (and at no cost or a cost not exceeding the marginal cost of distribution), as well as in archived data files.





Global responsibility, national interest…

The United States should continue to participate in, and support the activities of, the international geodetic services (IGS, ILRS, IVS, IDS, IGFS and IERS) by providing long-term support for the operation of geodetic stations around the world and by supporting the participation of U.S. investigators in the activities of these services.

ICSU WORLD DATA SYSTEM

ICSU International Council for Science

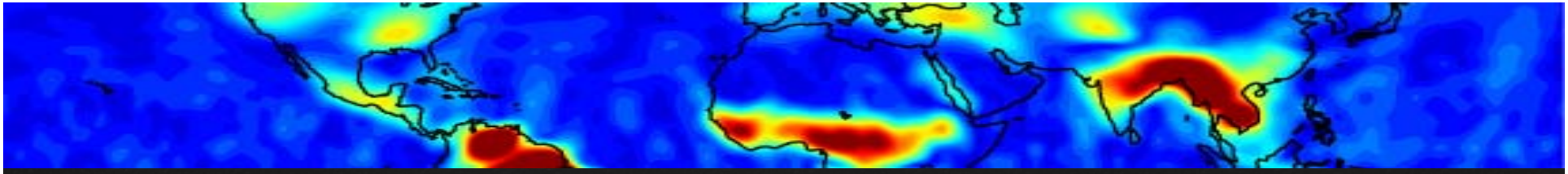
IAG GGOS

International Laser Ranging Service

IGS International GNSS Service
Formerly the International GPS Service

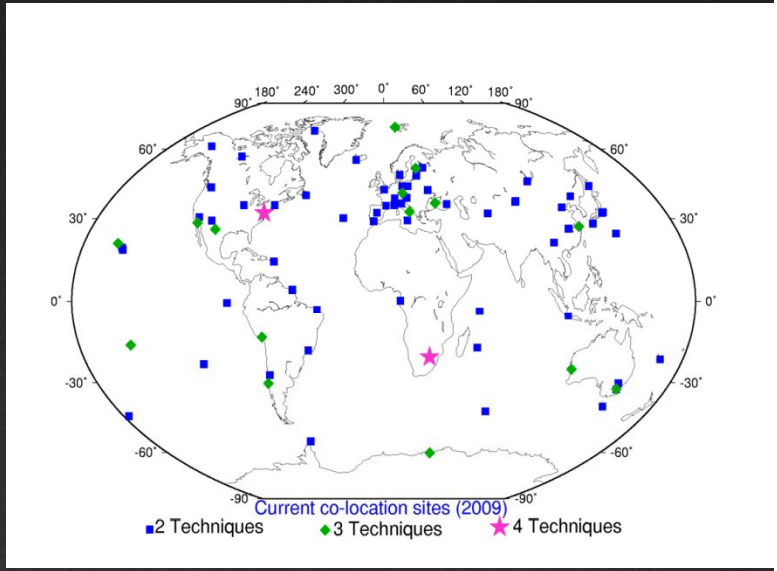
IDS INTERNATIONAL DORIS SERVICE

IERS International Earth Rotation and Reference Systems Service



A long-term global reference frame…

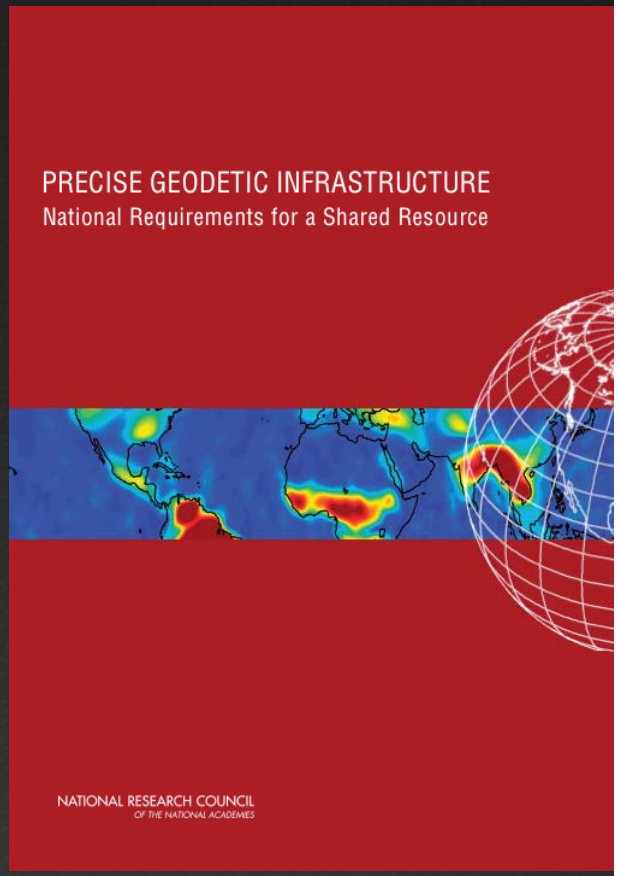
The U.S., through the relevant federal agencies, should make a long-term commitment to maintain the International Terrestrial Reference Frame (ITRF) to ensure its continuity and stability. This commitment would provide a foundation for Earth system science, studies of global change, and a variety of societal and commercial applications.

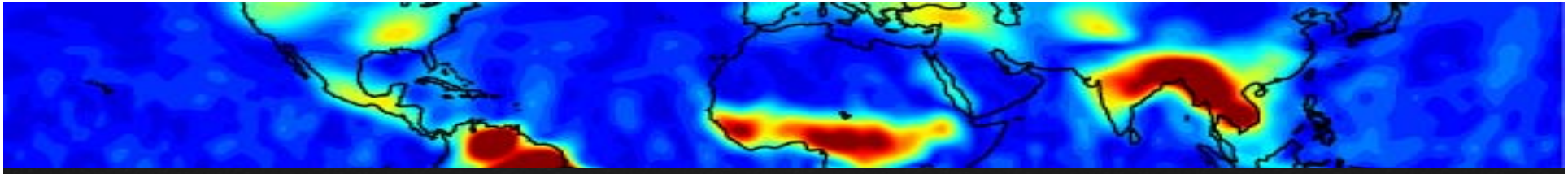


MORE TIES, please!

How do we make this work?

The United States should establish a federal geodetic service to coordinate and facilitate the modernization and long-term operation of the national and global precise geodetic infrastructure to ensure convenient, rapid, and reliable access to consistent and accurate geodetic data and products by government, academic, commercial, and public users.





… but we'll need trained people!

A quantitative assessment of the workforce required to support precise geodesy in the United States and the research and education programs in place at U.S. universities should be undertaken as part of a follow-up study focused on the long-term prospects of geodesy and its applications.