Geodesy in the 21st century

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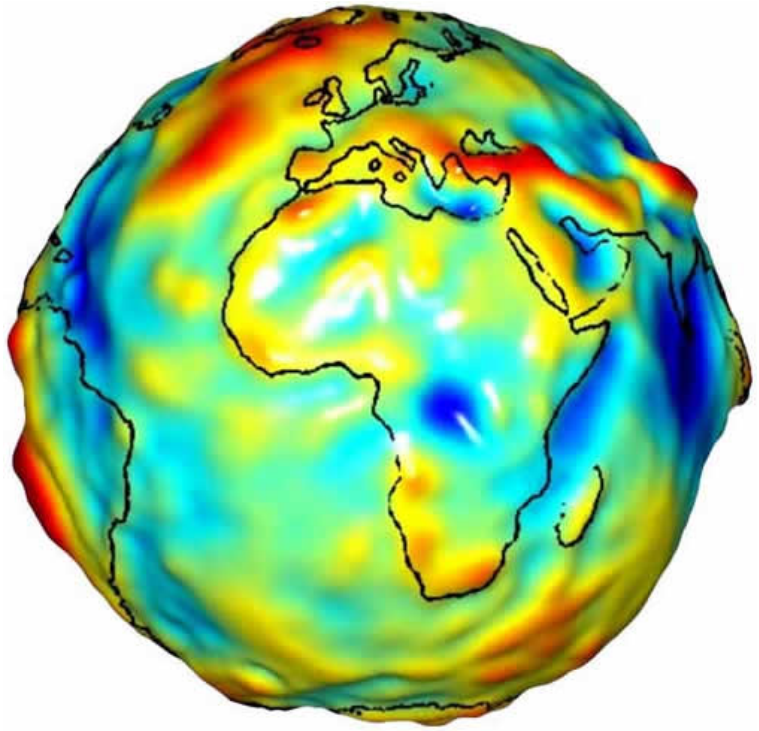
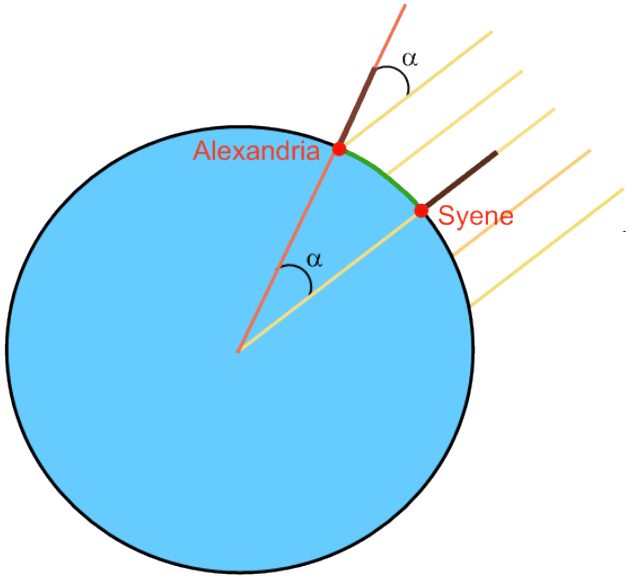
Geodesy

Geodesy is the science of accurately measuring the Earth's size, shape, orientation, gravitational field and the variations of these quantities with time.

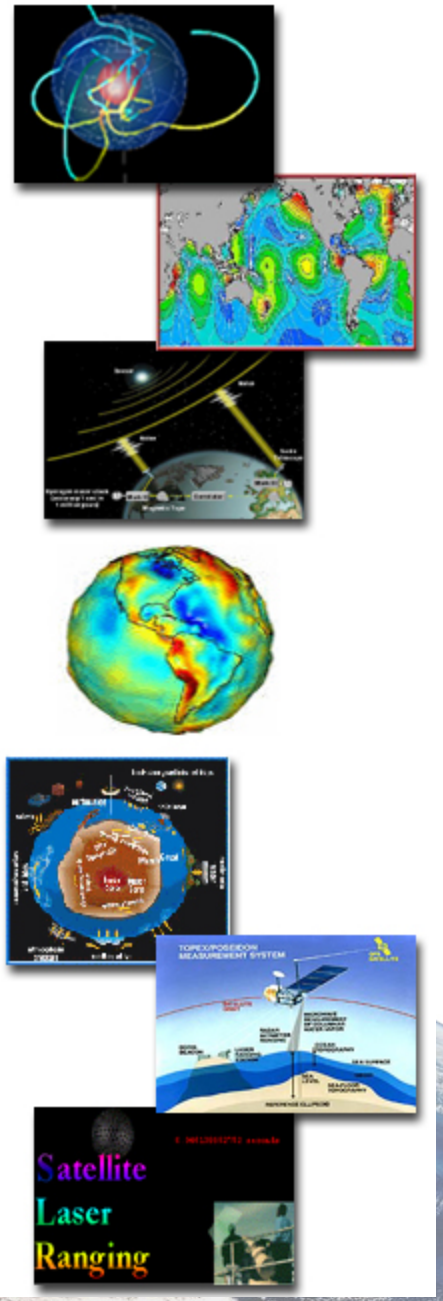


Historical perspective

Geodesy is one of the most ancient Earth Science disciplines with roots in the Greek era (600-100 BC).

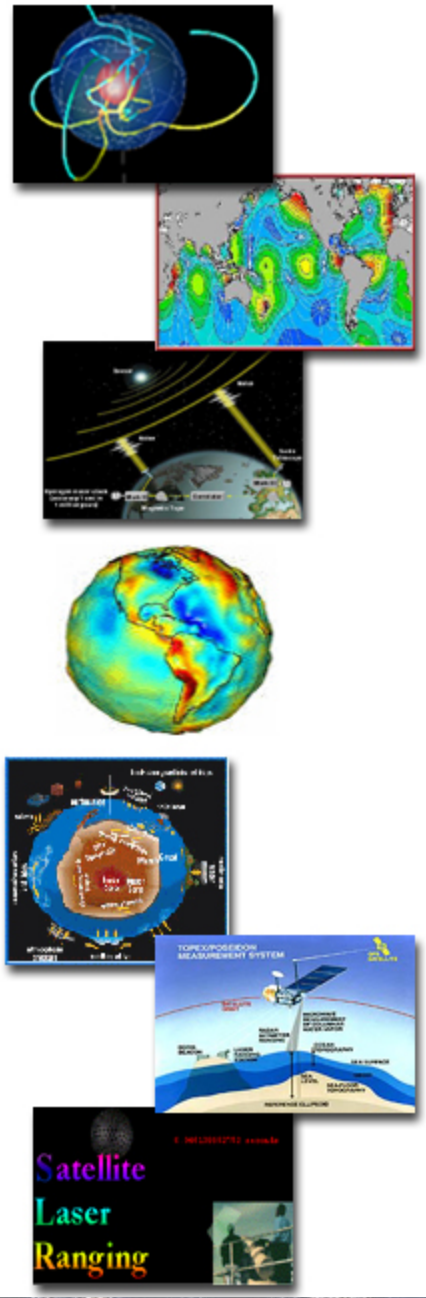


Eratosthenes (276 BC - 194 BC) measured the shade angle between Alexandria and Syene (Egypt) and distance.
He calculated the Earth's circumference as 252,000 strades (roughly 46,000 km, only 15% higher than the current estimate).



Space Geodesy

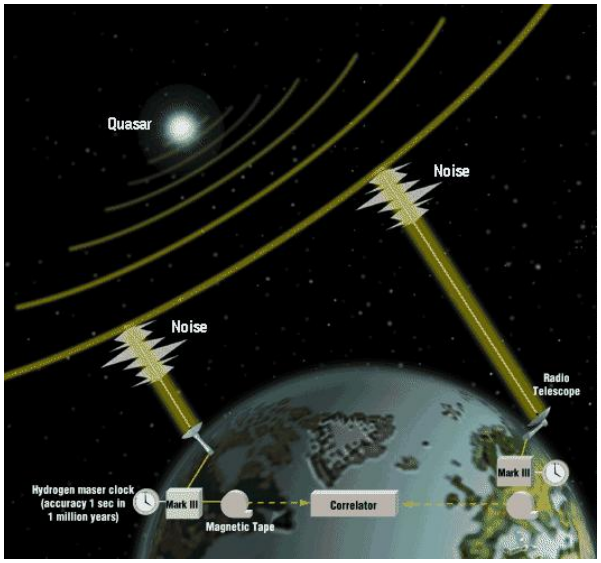
- Space or satellite geodesy completely revolutionized the field of geodesy in both accuracy and availability of measurements.
- This era began in the 1970's with the utilization of exciting radio-telescope technologies (Very Long Baseline Interferometry –VLBI).
- Initial accuracies – 5-10 cm.
- Current accuracies – sub-cm.



Space geodetic technologies

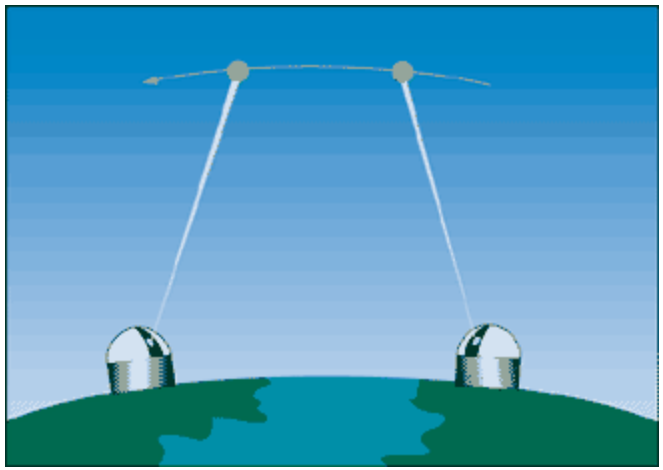
- Positioning techniques
- Global Navigation Satellite Systems (GNSS)
- Altimetry
- Interferometric Synthetic Aperture Radar (InSAR)
- Gravity missions

Positioning techniques



- **Very Long Baseline Interferometry (VLBI)**

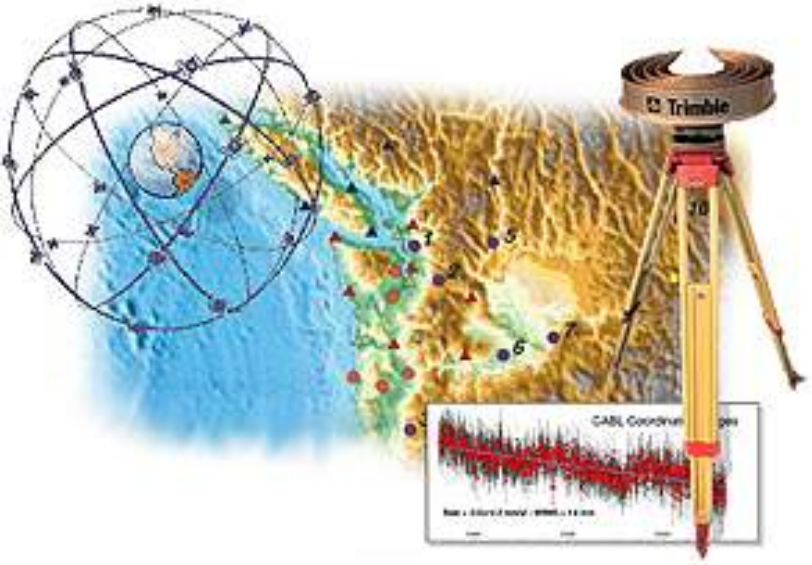
- **Satellite Laser Ranging**



- **Lunar Laser Ranging**
- **Doppler Orbit determination and Radiopositioning Integrated on Satellite (DORIS)**

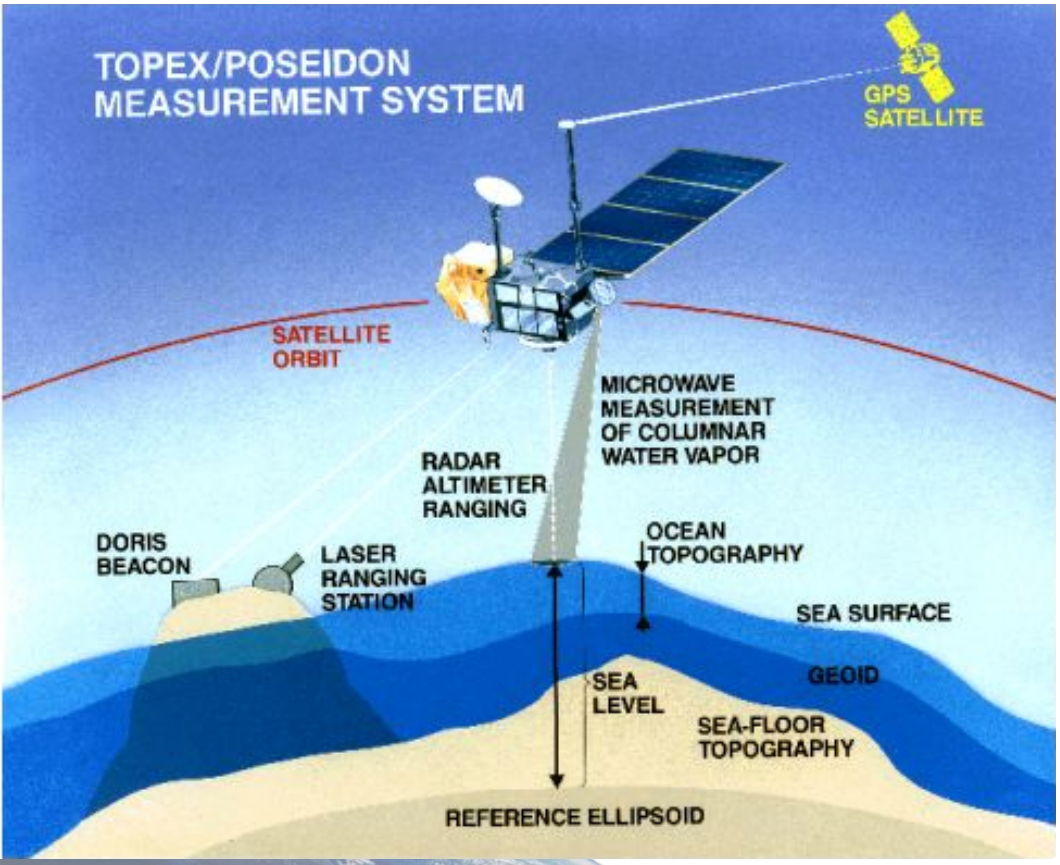
Global Navigation Satellite Systems (GNSS)

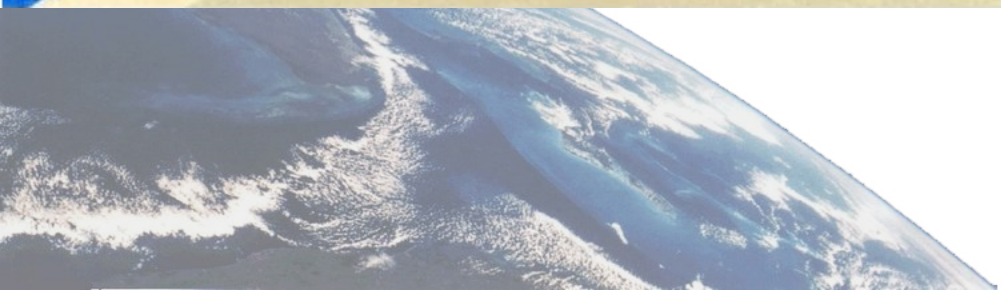
- **Global Positioning System (GPS)**



- GLObal NAvigatsionnaya Sputnikovaya Sistema (**GLONASS**)
- **Galileo** (European, 1st launched 2005)
- **Beidou-1** (China, test launch 2000)
- **IRNSS** (India, in planning)

Altimetry (Radar or Laser)



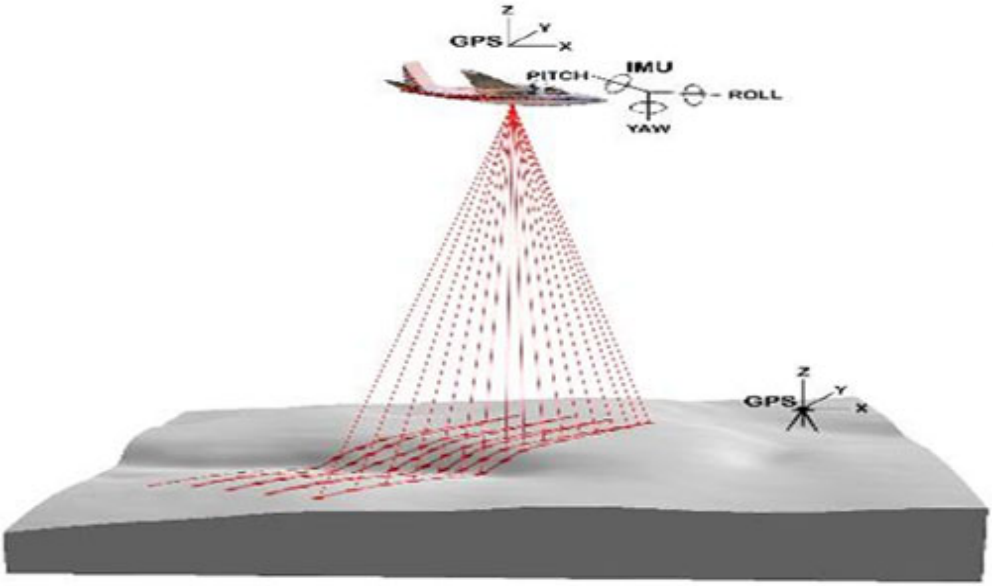


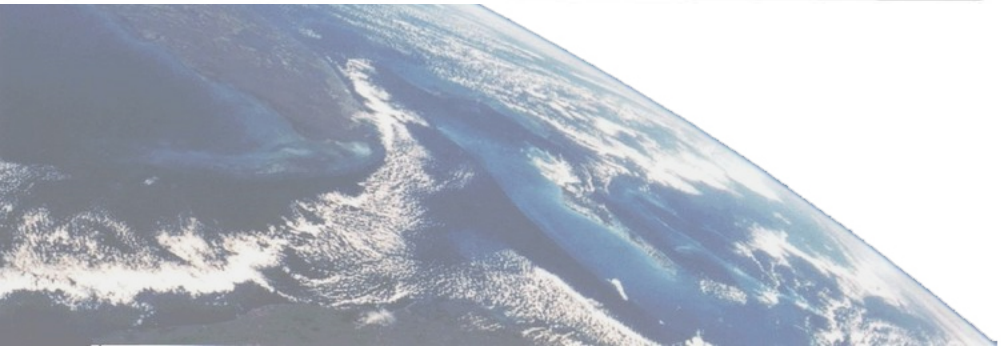
- SeaSAT
- GeoSAT
- TOPEX/Posiedon
- Jason-1
- ERS-2
- ENVISAT
- ICESAT
- CryoSAT

Lidar

(Light Detection and Ranging)

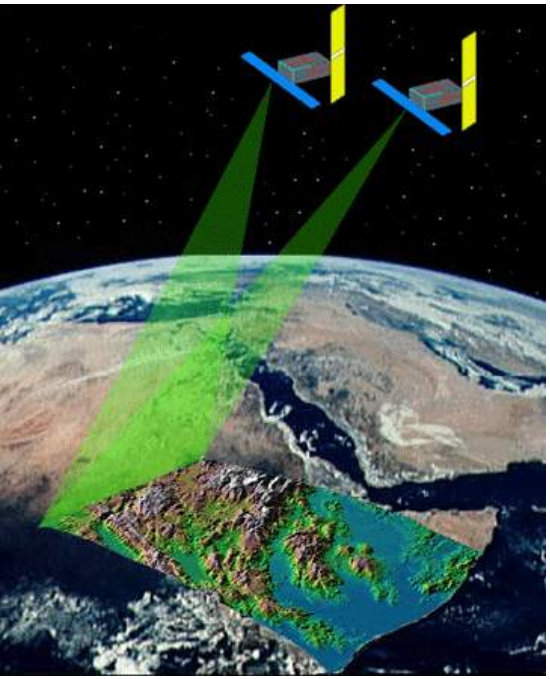
Airborne Lidar





Terrestrial Laser Scanner

Interferometric Synthetic Aperture Radar (InSAR)

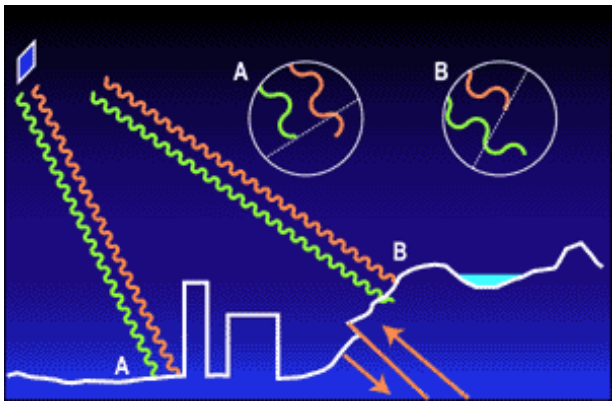


Data acquisition

- Repeat path (satellites)
- Simultaneous by two antennas (space shuttle)

- **SeaSAT**
- **ERS-1/2**
- **JERS-1**
- **RADARSAT-1**
- **Space Shuttle**
- **ENVISAT**
- **ALOS**
- **RADARSAT-2**
- **TerraSAR-X**
- **COSMO-SkyMed**

Calculating phase changes

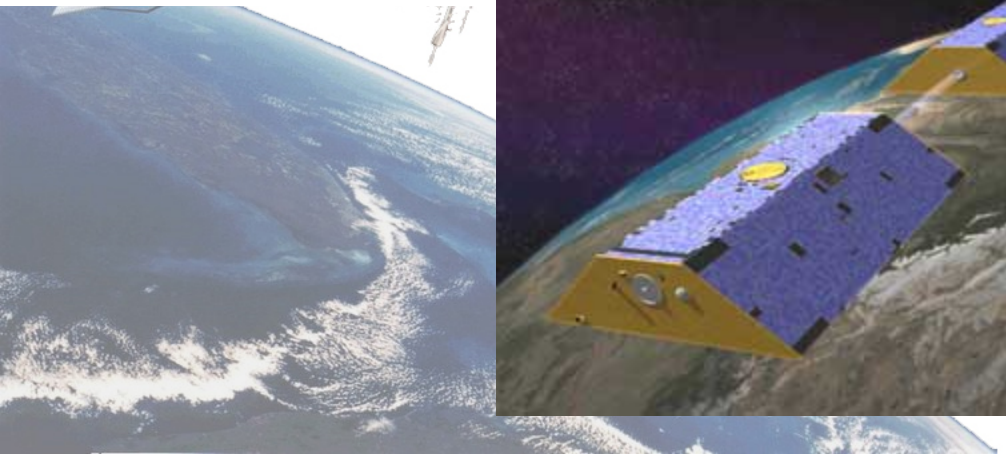


Gravity missions

Measurements of small changes in the Earth's gravitational field

- **LAGEOS-1/2**
- **Ajisai**
- **CHAMP**
- **GRACE**
- **GOCE**

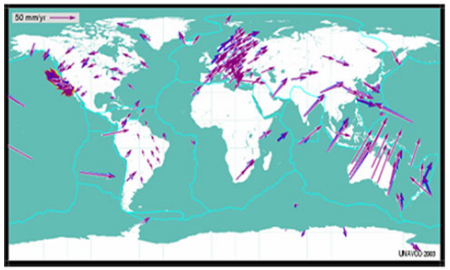
LAGEOS-1



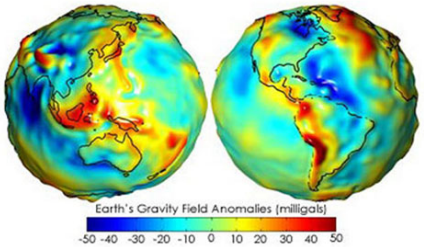
GRACE

Applications

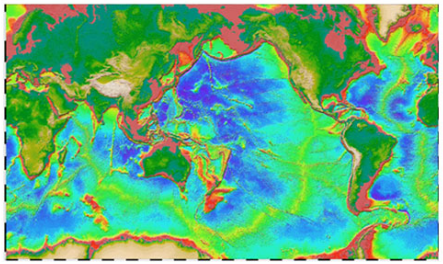
(a) Tectonic plate motion (SE)



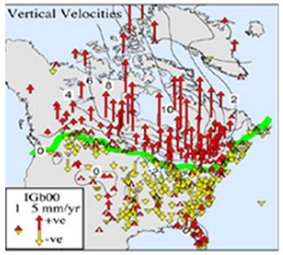
(b) Geoid determination (SE)



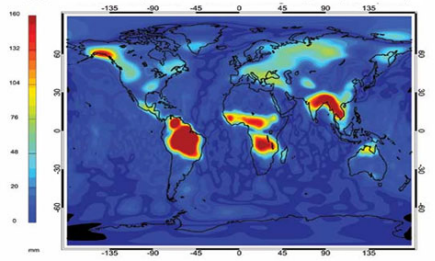
(c) Bathymetry (Ocean)



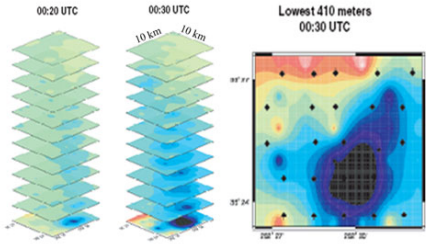
(d) Glacial Isostatic Adjustment (SE)



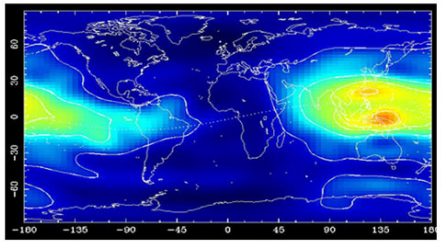
(e) Global/regional water budget (Hydro)



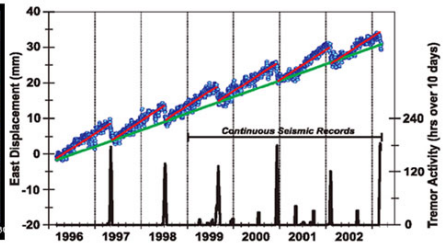
(f) Precipitable water (Atmosphere)



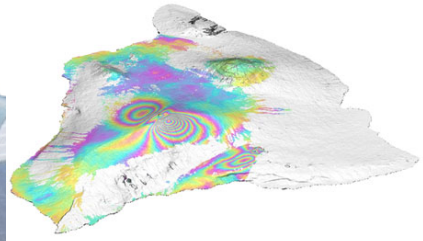
(g) Total Electron Content (Ionosphere)



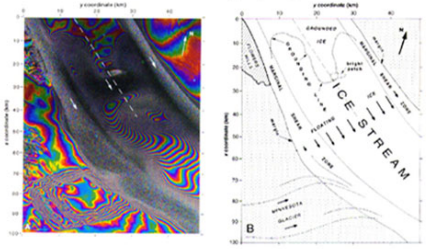
(h) Earthquake deformation cycle (SE)



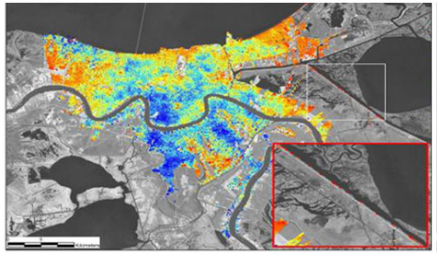
(i) Magmatic-induced deformation (SE)



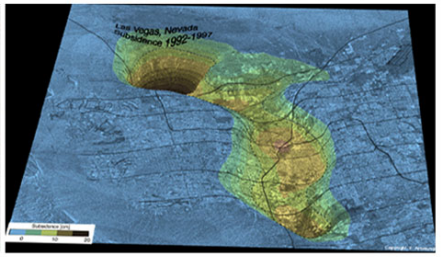
(j) Glaciar flow (Cryosphere)



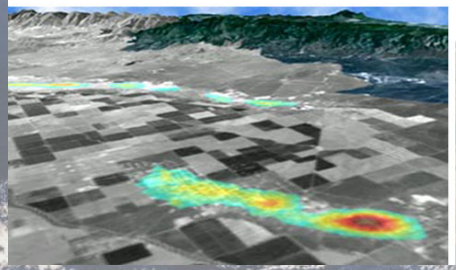
(k) Urban and infrastructure subsidence (GT)



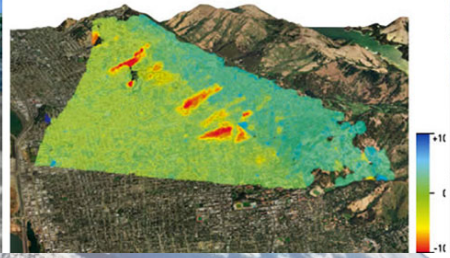
(l) Aquifer-system response (Hydro)



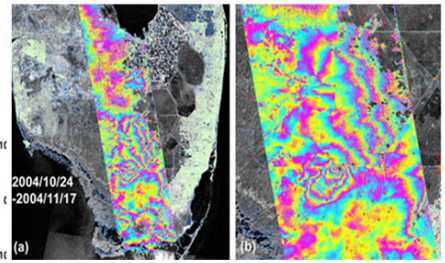
(m) Hydrocarbon production (GT)



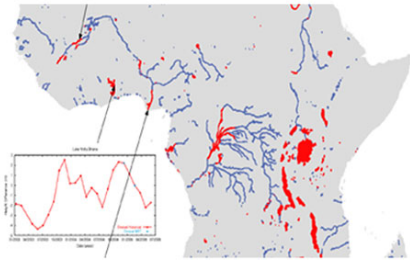
(n) Landslides (Geo-hazard)



(o) Wetland water level changes (Hydro)

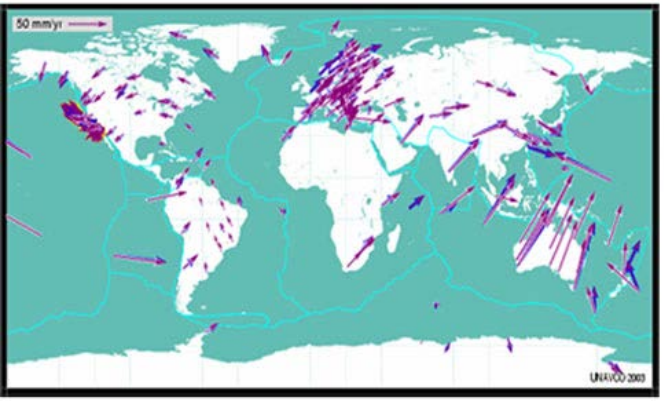


(p) River and lakes water level (Hydro)

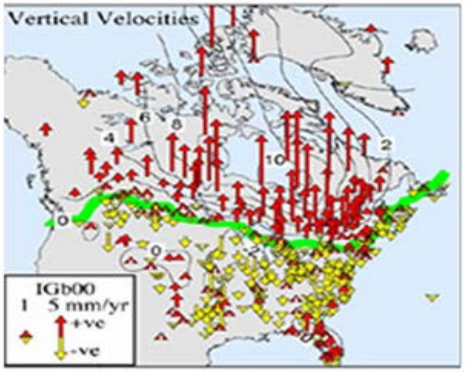


Solid Earth

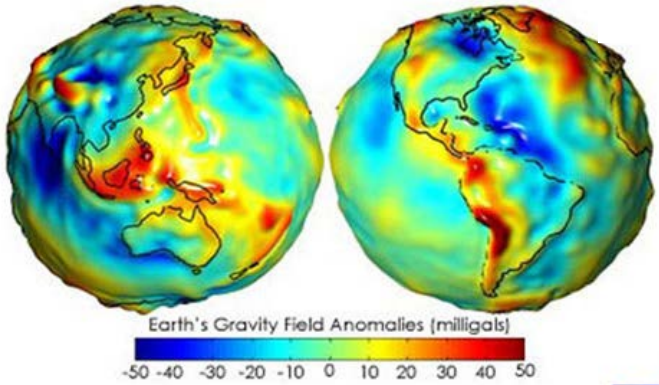
(a) Tectonic plate motion (SE)



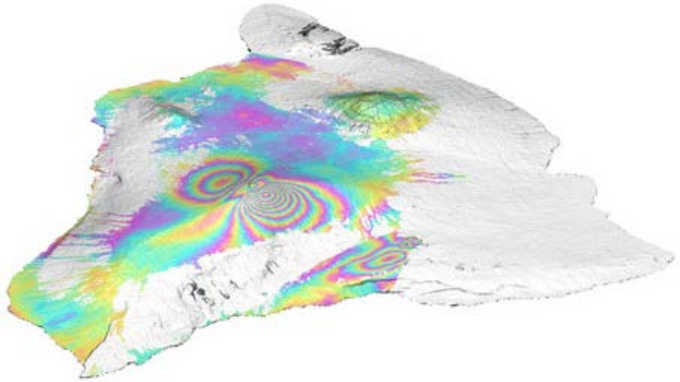
(d) Glacial Isostatic Adjustment (SE)



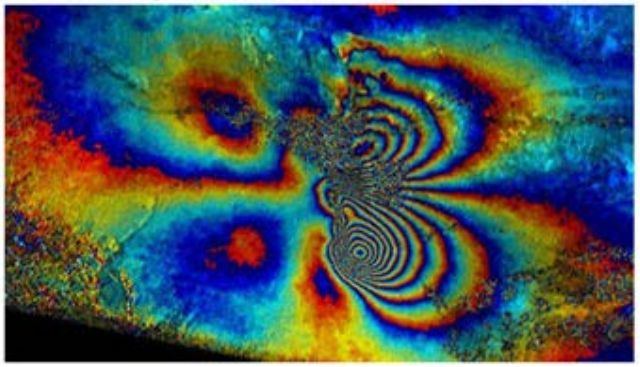
(b) Geoid determination (SE)



(i) Magmatic-induced deformation (SE)

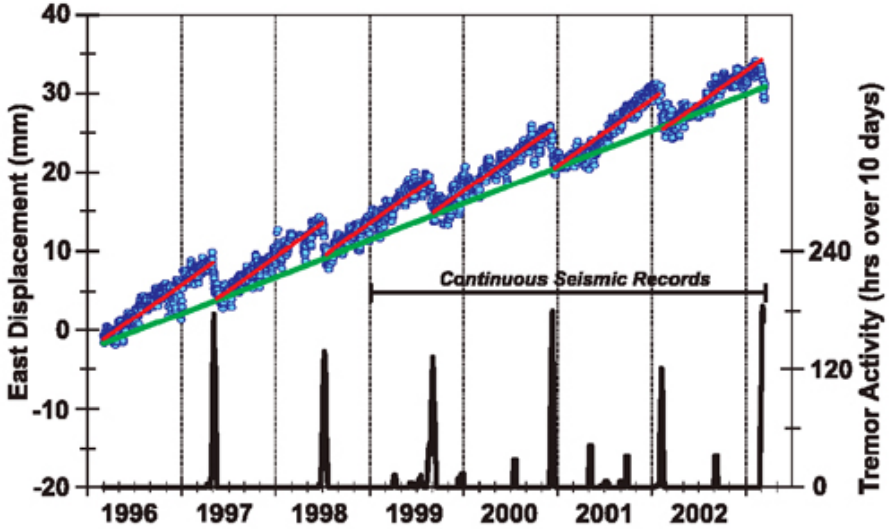


Earthquake-induced deformation (SE)

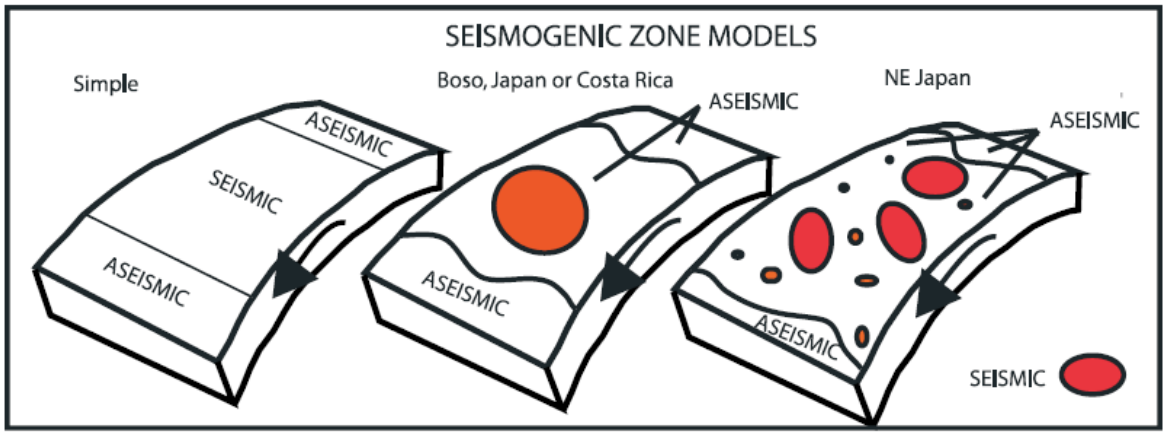


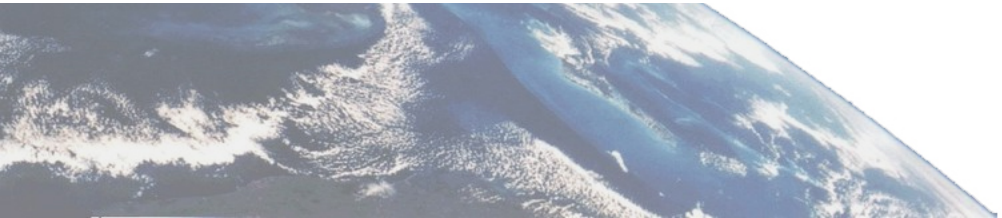
Slow slip events

Seismicity and hazard
at subduction zones



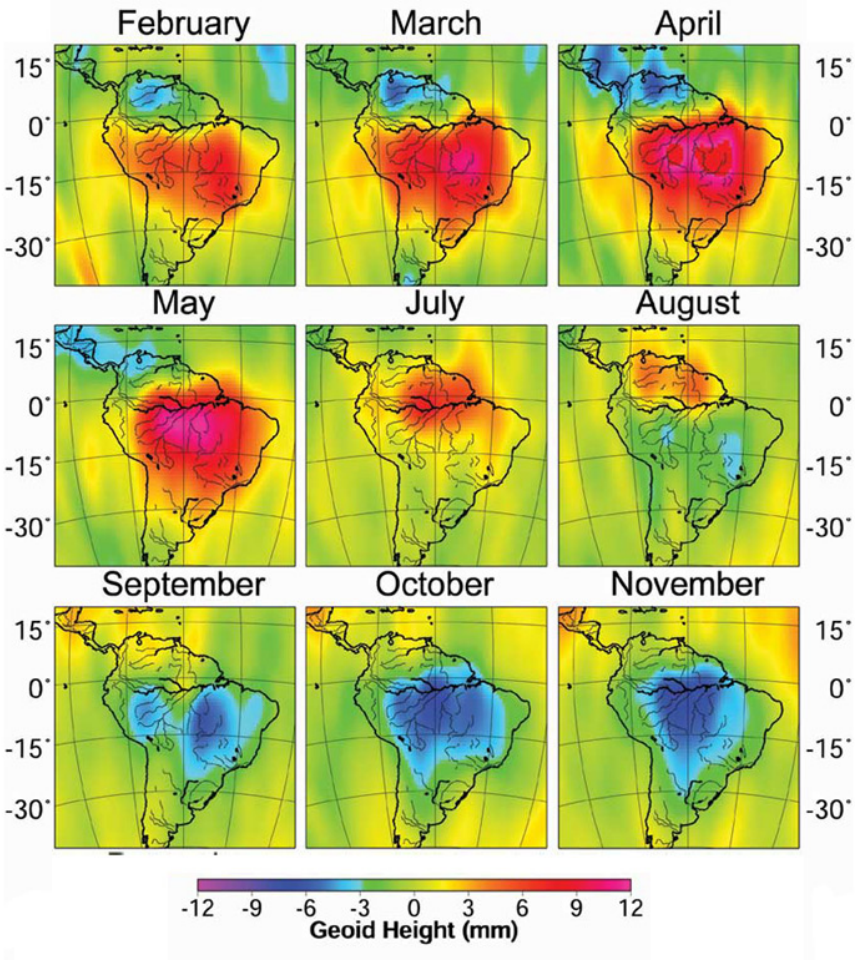
Slip and tremor activity observed for the Victoria area, from Rogers and Dragert, Science, 2003.

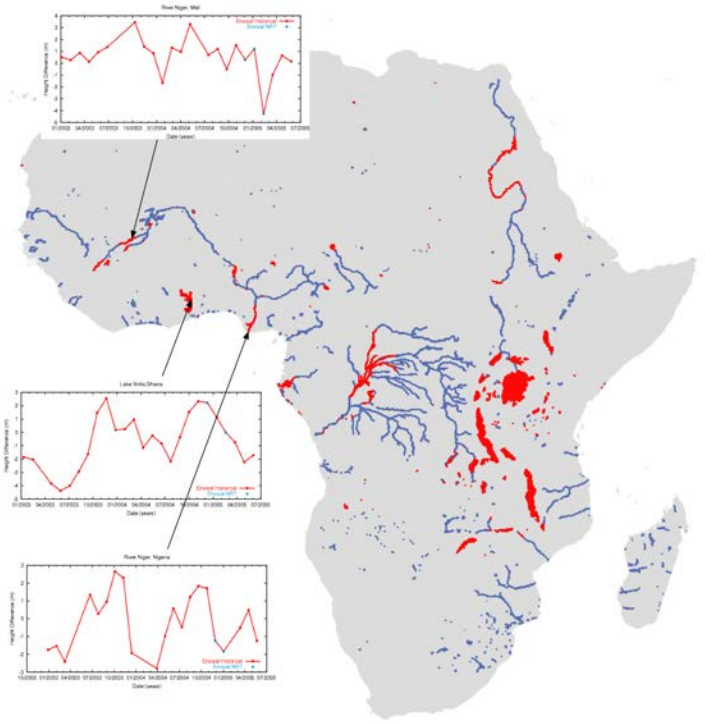




Global and continental-scale hydrology

GRACE: Short-term changes of the geoid reflect mainly water and ice mass redistribution

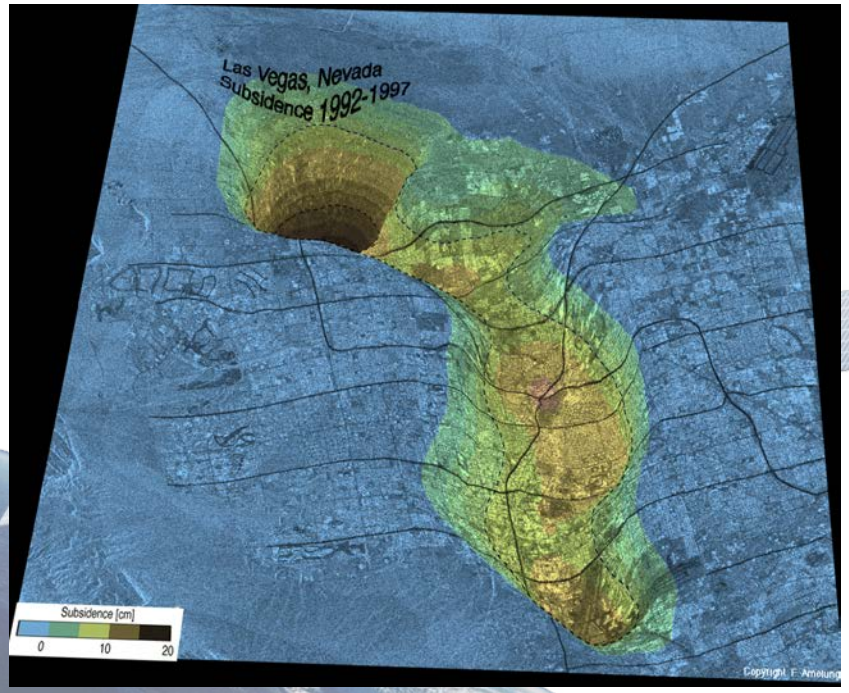




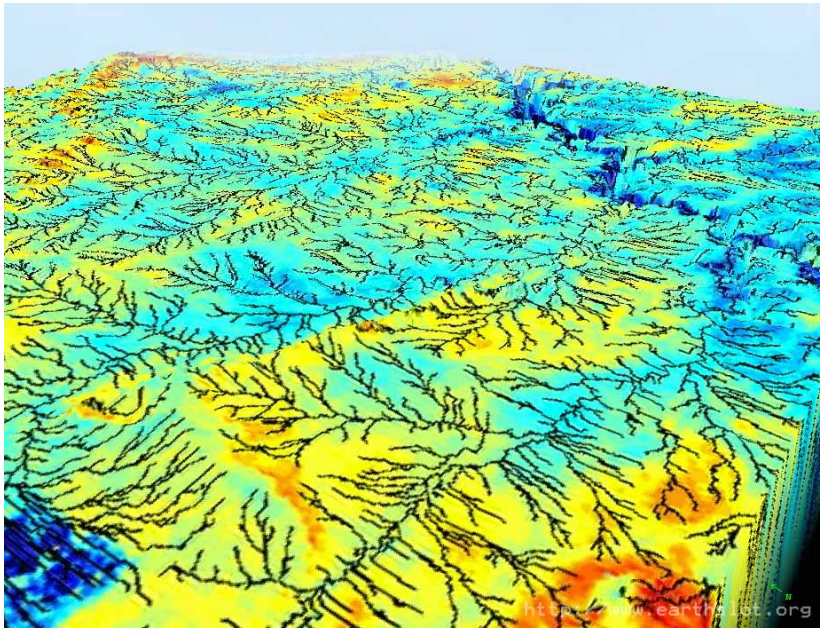
Altimetry: Remote monitoring of water resources

Regional-scale hydrology

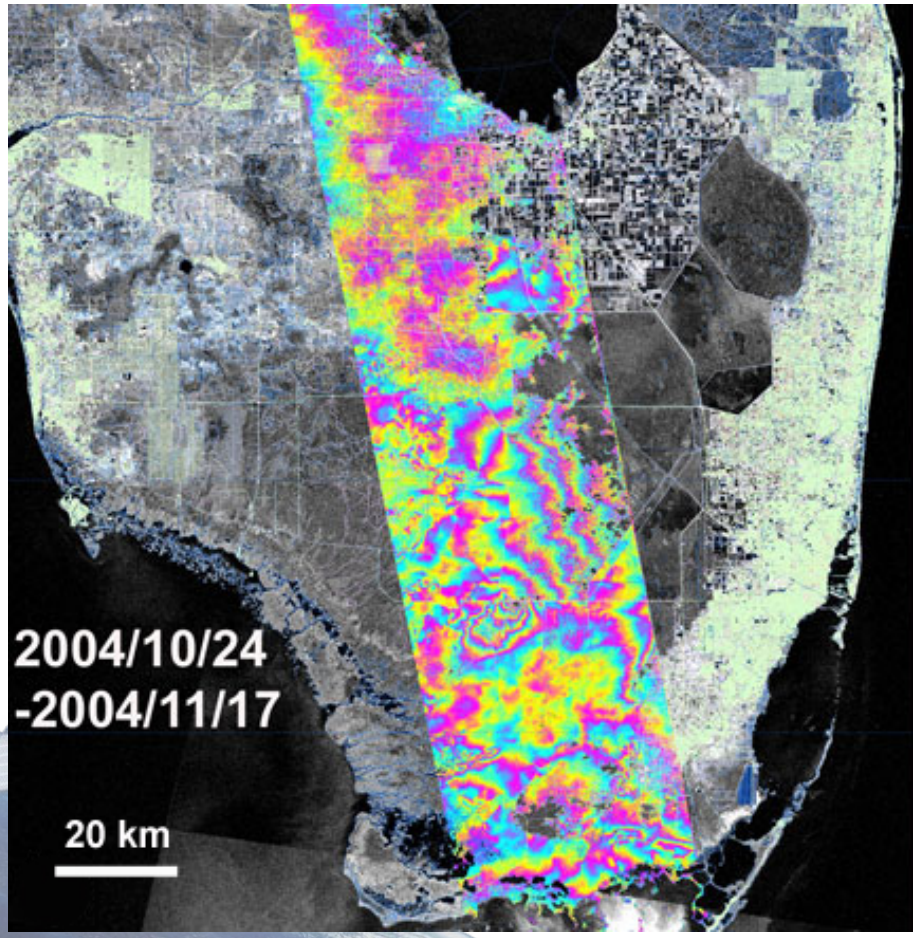
Aquifer system deformation (Las Vegas)



Soil moisture

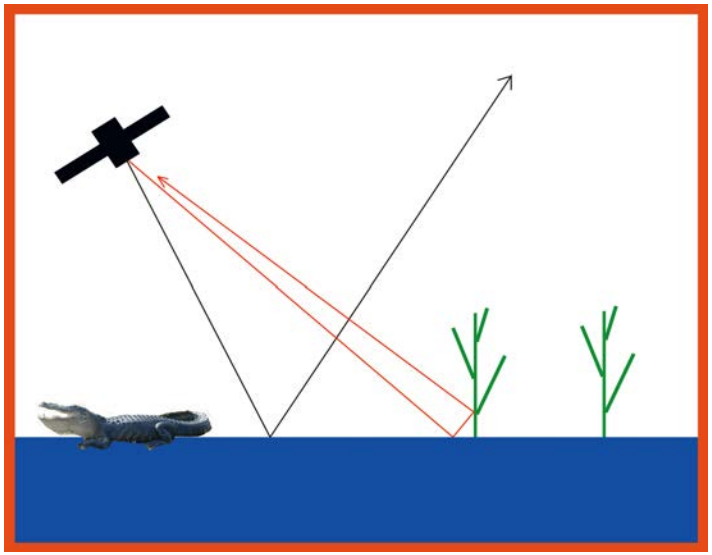


Wetland water level changes



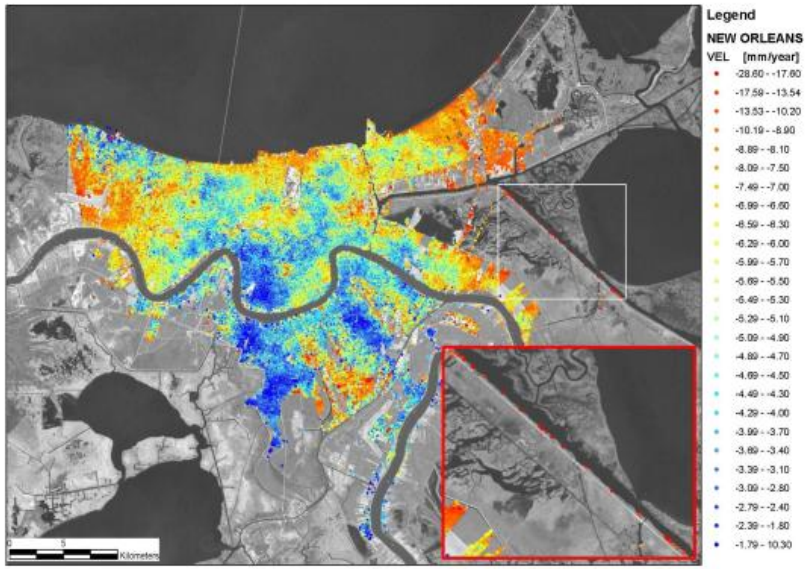
InSAR monitoring of water resources (Everglades, south Florida)

Double bounce effect

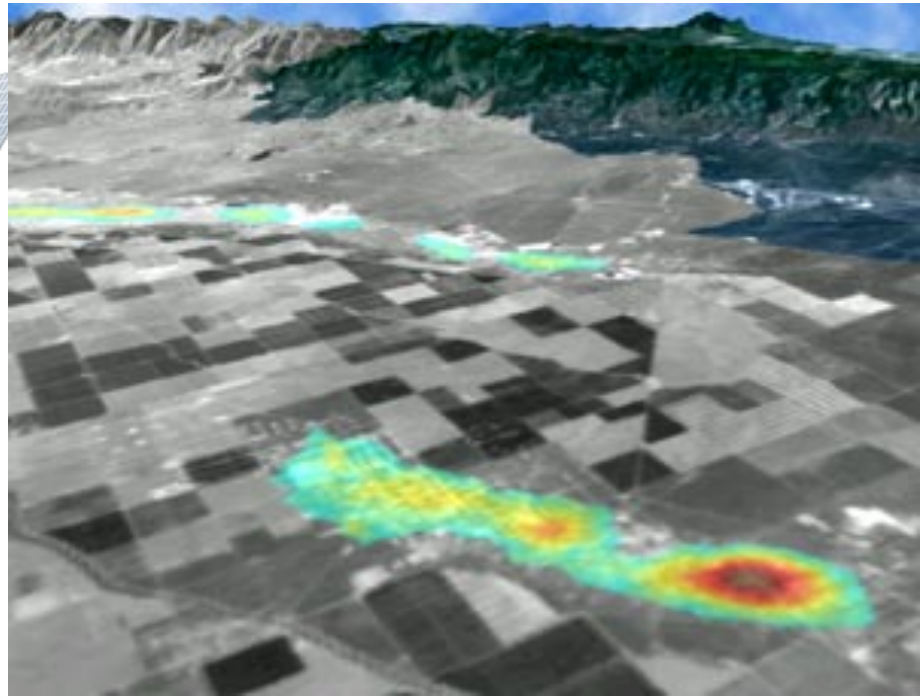


Geotechnical

New Orleans subsidence (2002-2004) prior to Hurricane Katrina

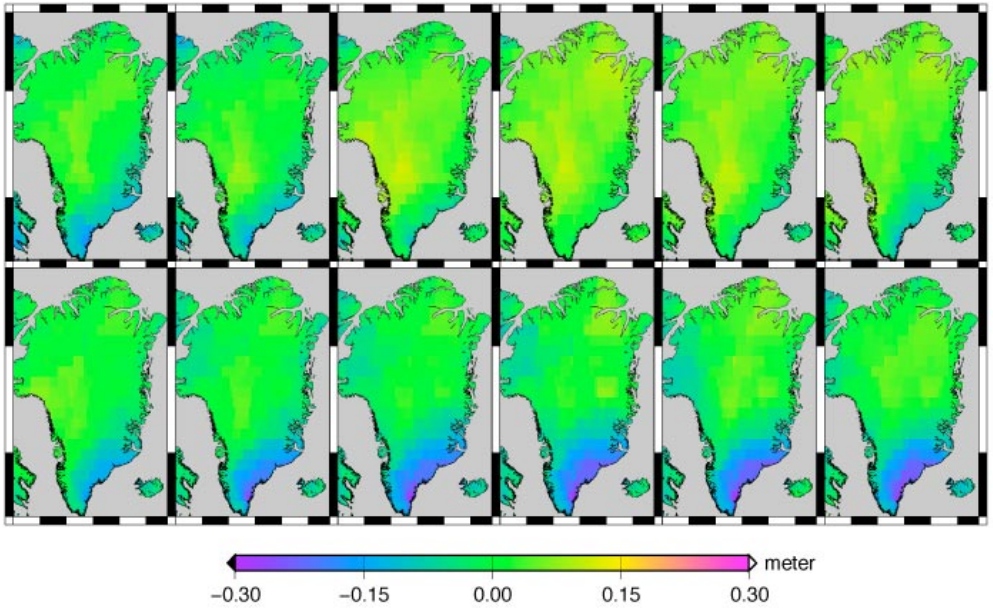


Surface subsidence due to oil extraction

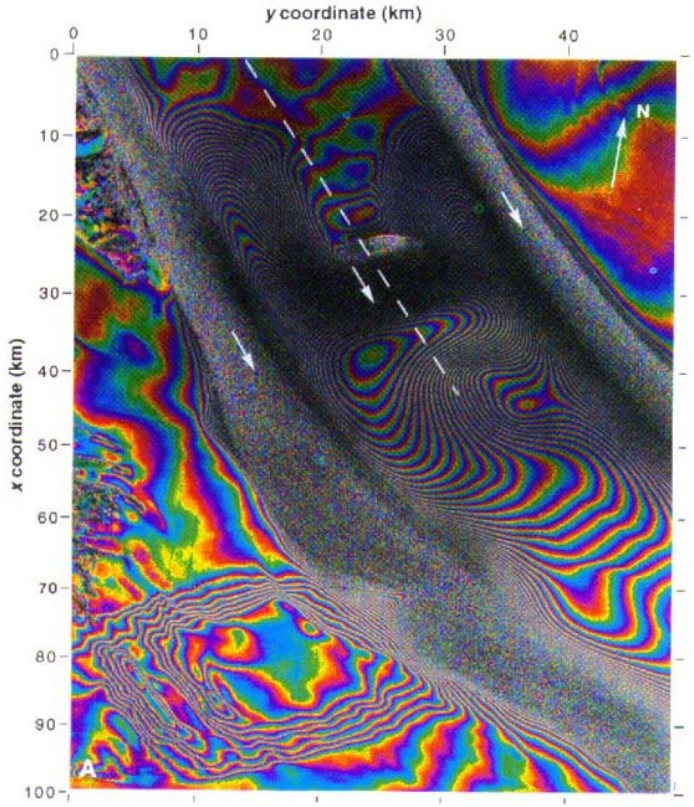


Cryosphere

GRACE: changes in the mass of Greenland's ice sheet coverage

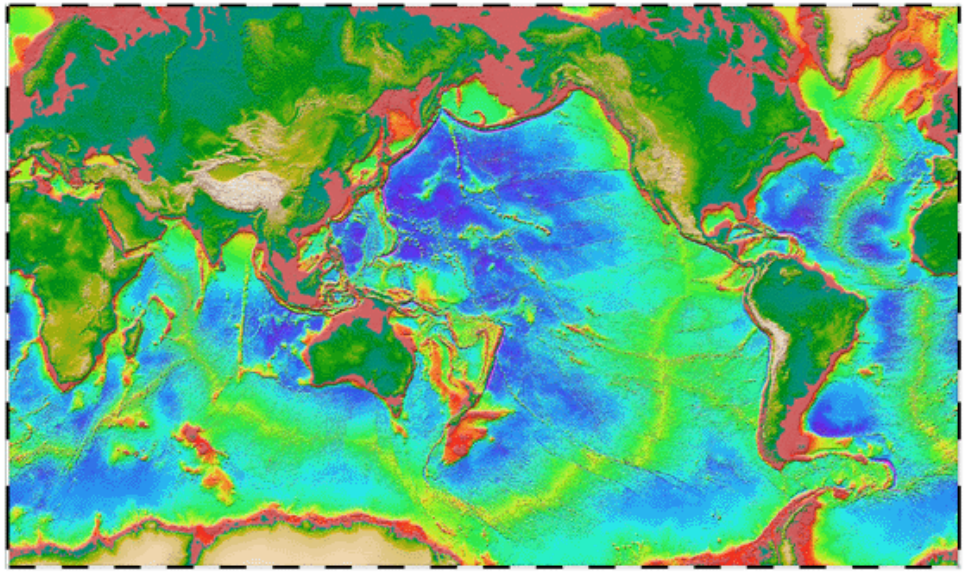


InSAR: Glacier flow

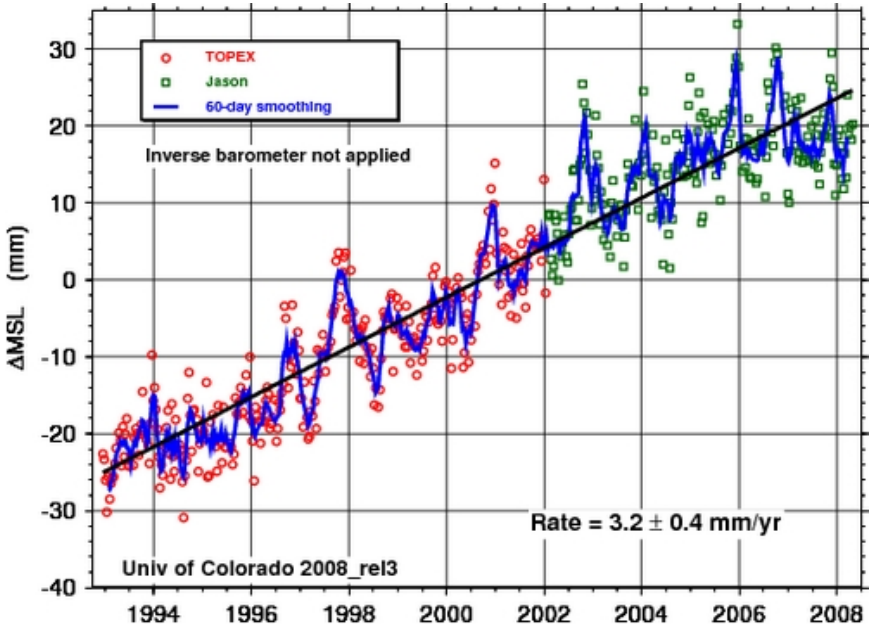


Oceanography

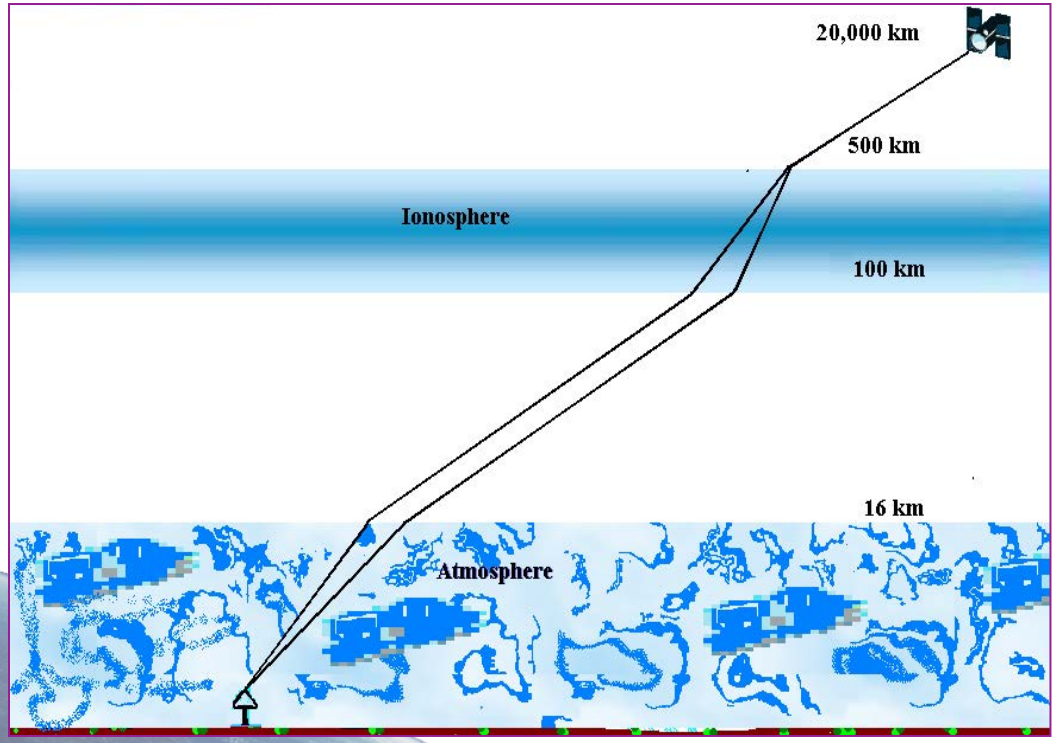
Seafloor determination using satellite **altimetry**



Sea level change

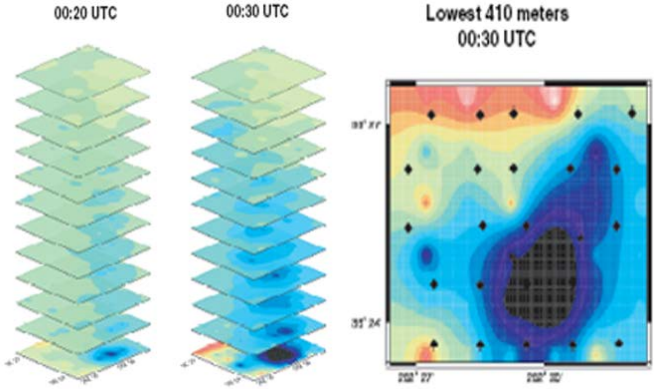


Measuring the Atmosphere and Ionosphere

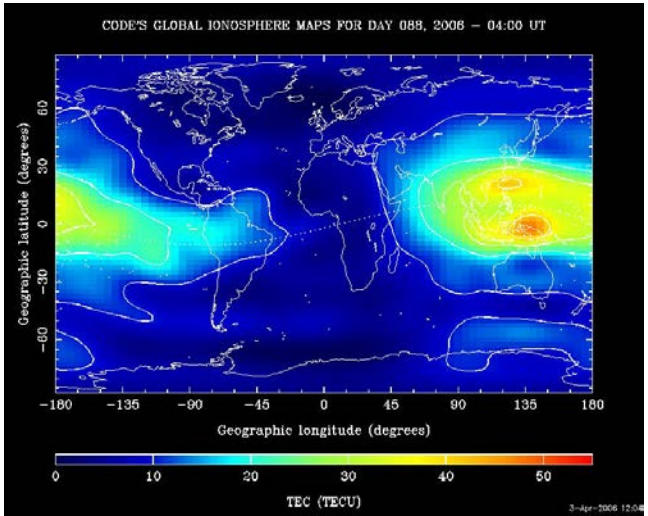


GPS measurements are sensitive to changes in the atmosphere and ionosphere.

Perceptible water

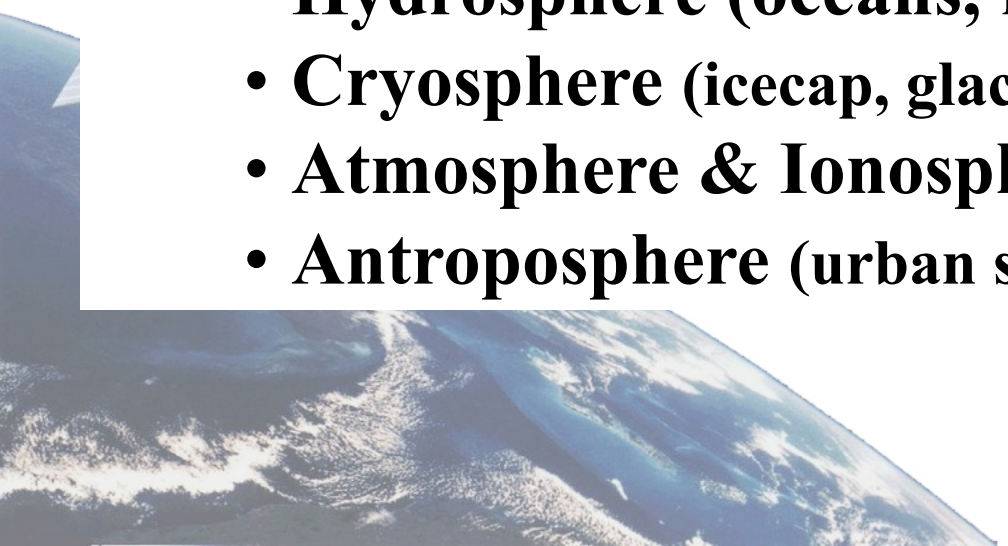


Total Electron Content



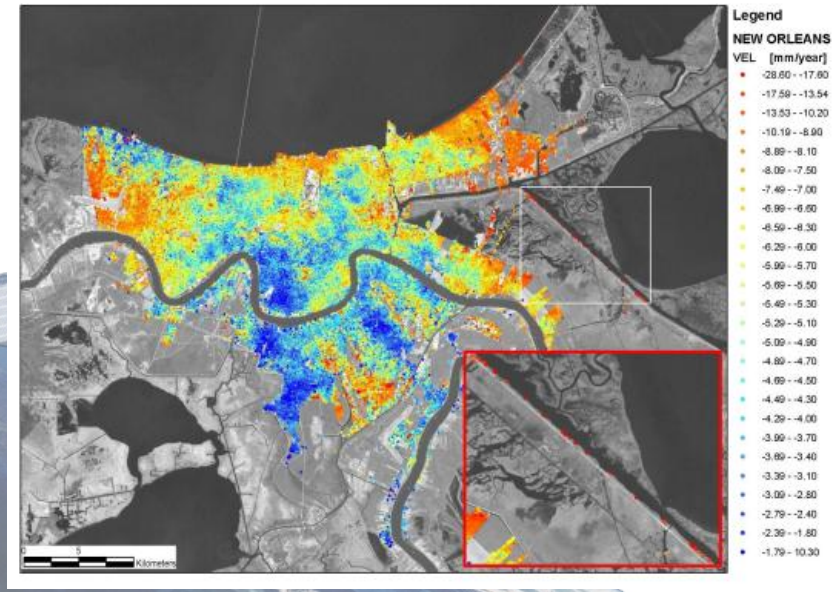
Summary

- **Space geodetic techniques can measure small changes of the Earth's solid and aquatic surfaces with cm- and sub-cm level accuracy**
- **The measurement can be applied to a variety of application, including**
  - **Lithosphere (earthquakes, volcanoes, subsidence)**
  - **Hydrosphere (oceans, rivers, lakes, wetlands)**
  - **Cryosphere (icecap, glaciers)**
  - **Atmosphere & Ionosphere (Perceptible water, TEC)**
  - **Antroposphere (urban subsidence, oil fields)**

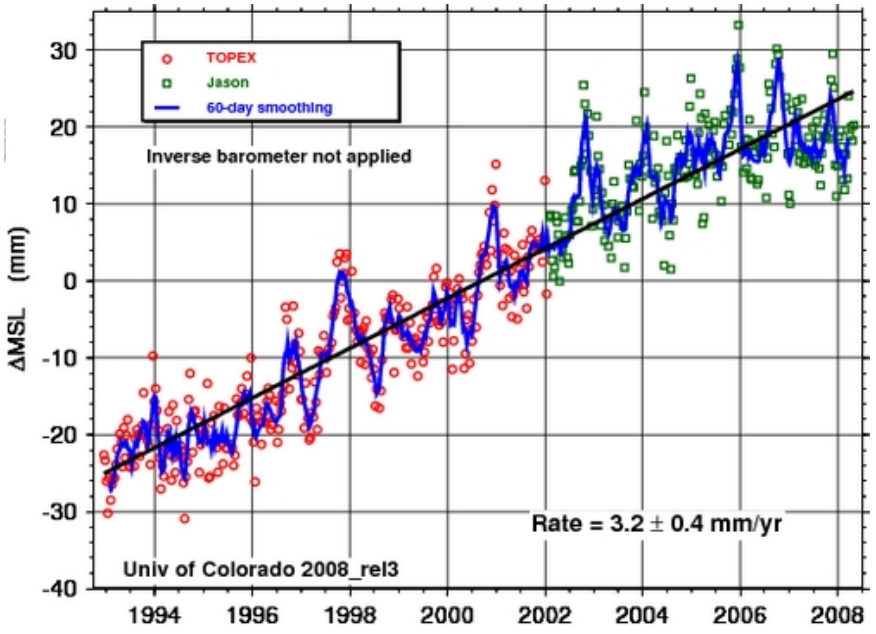


Geodesy in the 21st century

Space geodesy has application in areas of great societal impact such as climate change, water resources, and natural hazards and disasters.



New Orleans subsidence



Sea level change