The Global Geodetic Observing System (GGOS) of the International Association of Geodesy, IAG

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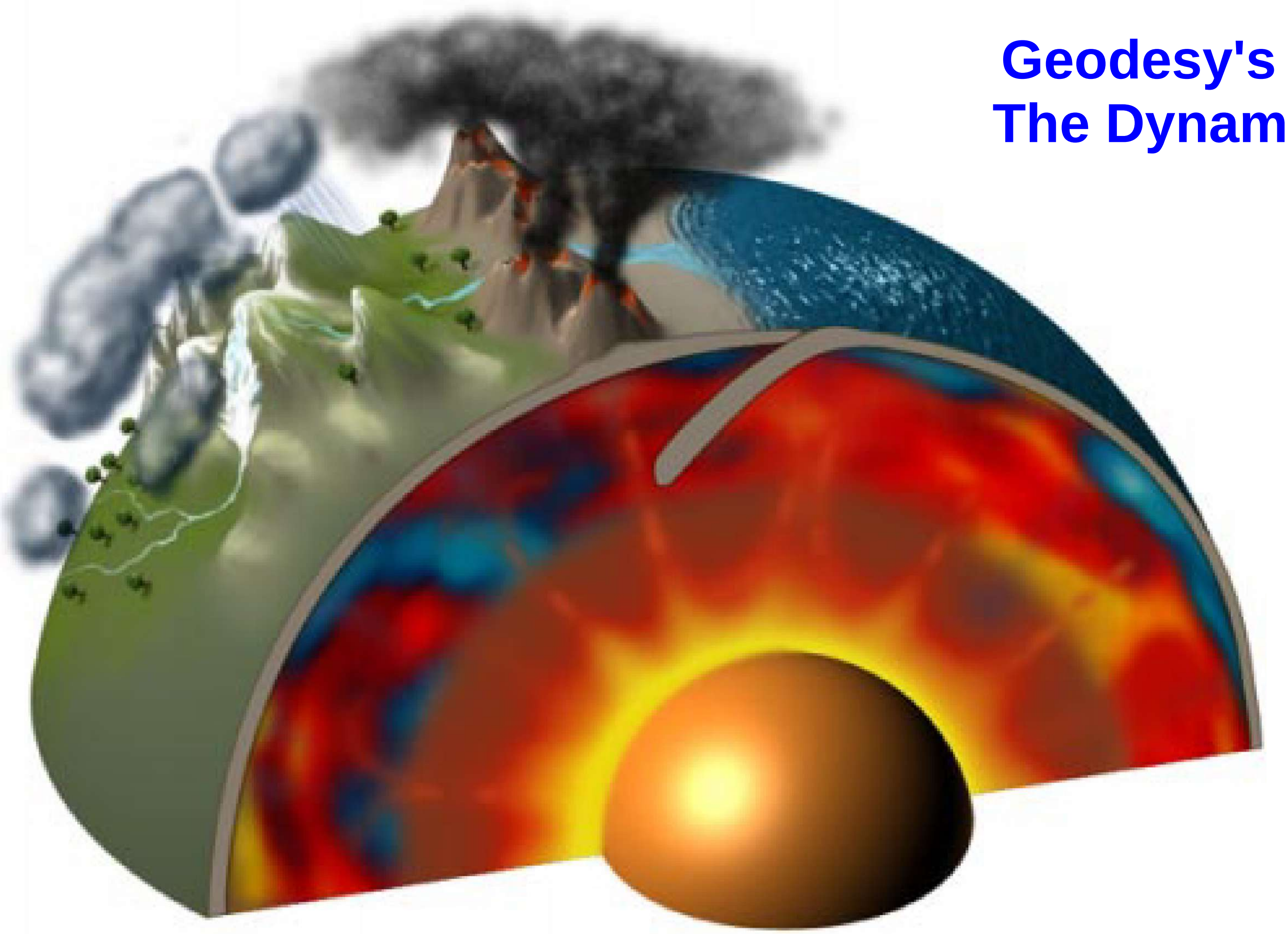
Overview

- Geodesy's contribution: The three pillars of geodesy
- Global Geodetic Observing System (GGOS)
- GGOS: The Scientific Vision
- The Science Basis for GGOS: An Earth System Dynamics Theme
- GGOS: The Implementation
- GGOS and IGOS-P Themes

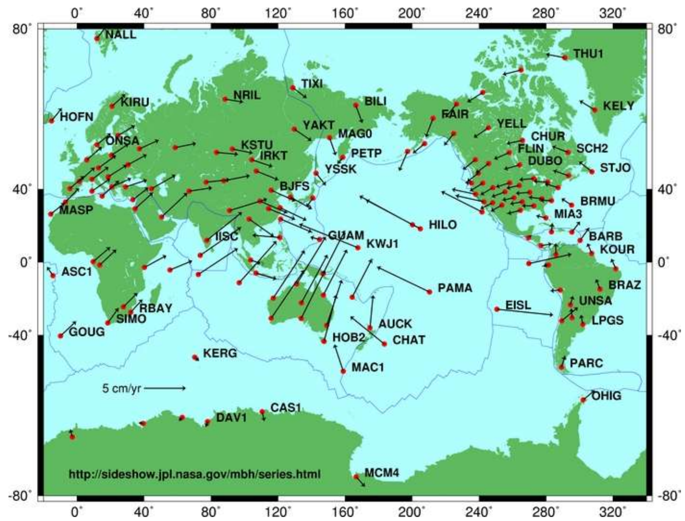
Geodesy's Contribution: The Three Pillars of Geodesy



Geodesy's Object: The Dynamic Earth

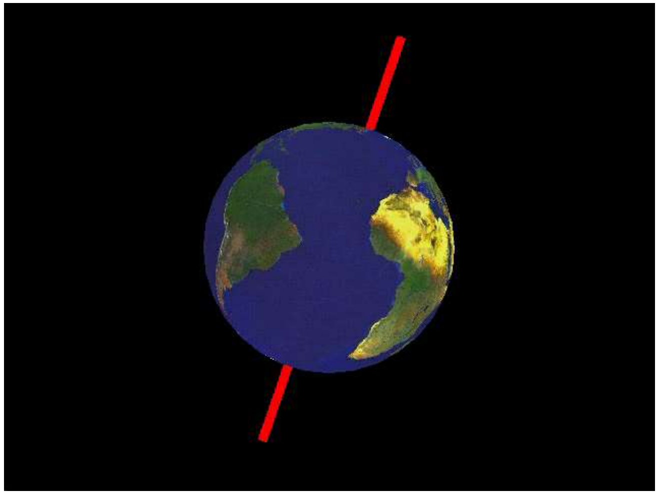
NASA Solid Earth Science Working Group report

Geodesy's Contribution: The Three Pillars of Geodesy

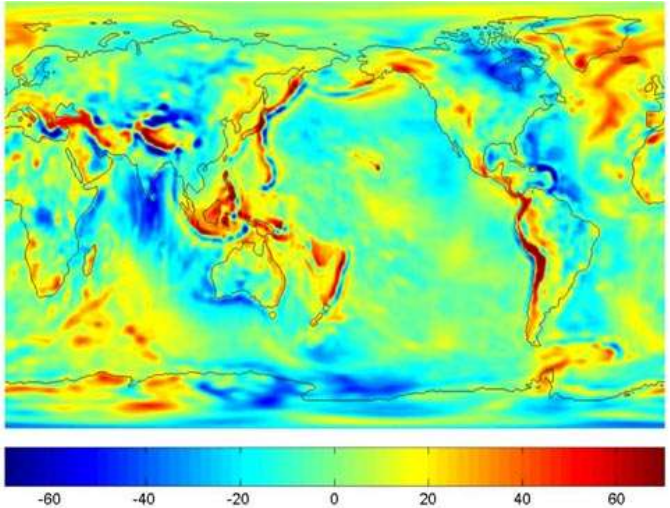


Shape & Deformation

Earth Rotation



Gravity & Geoid



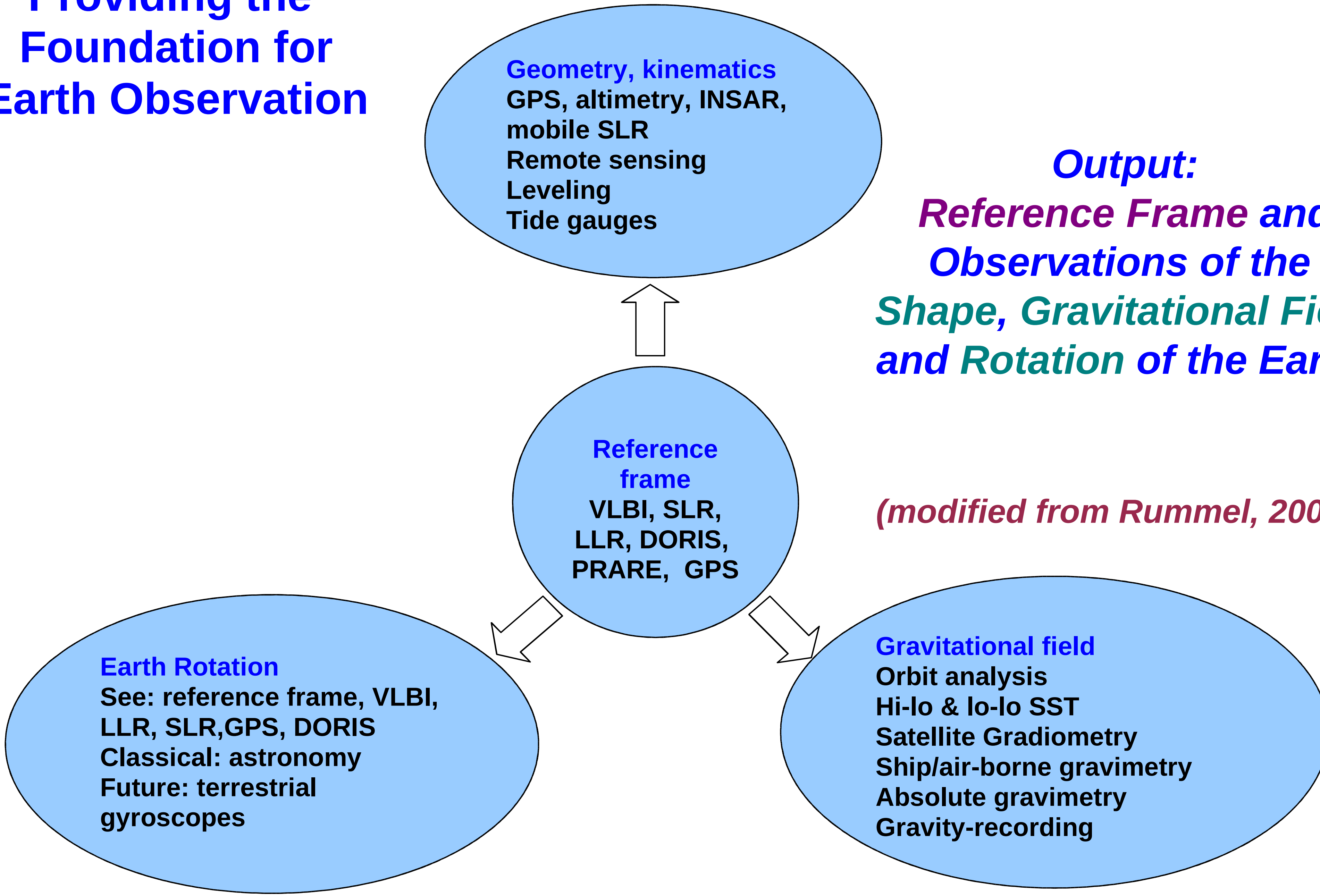
Geodesy's Contribution: The Three Pillars of Geodesy

The fundamental geodetic quantities

- Changes in the shape of the Earth (geometry):
  - displacements
  - kinematics
  - strain
- Changes in the gravity field of the Earth:
  - local gravity
  - geoid
  - gravity field
- Changes in the Earth rotation:
  - polar motion
  - length of day

The Global Geodetic Observing System (GGOS)

Providing the Foundation for Earth Observation

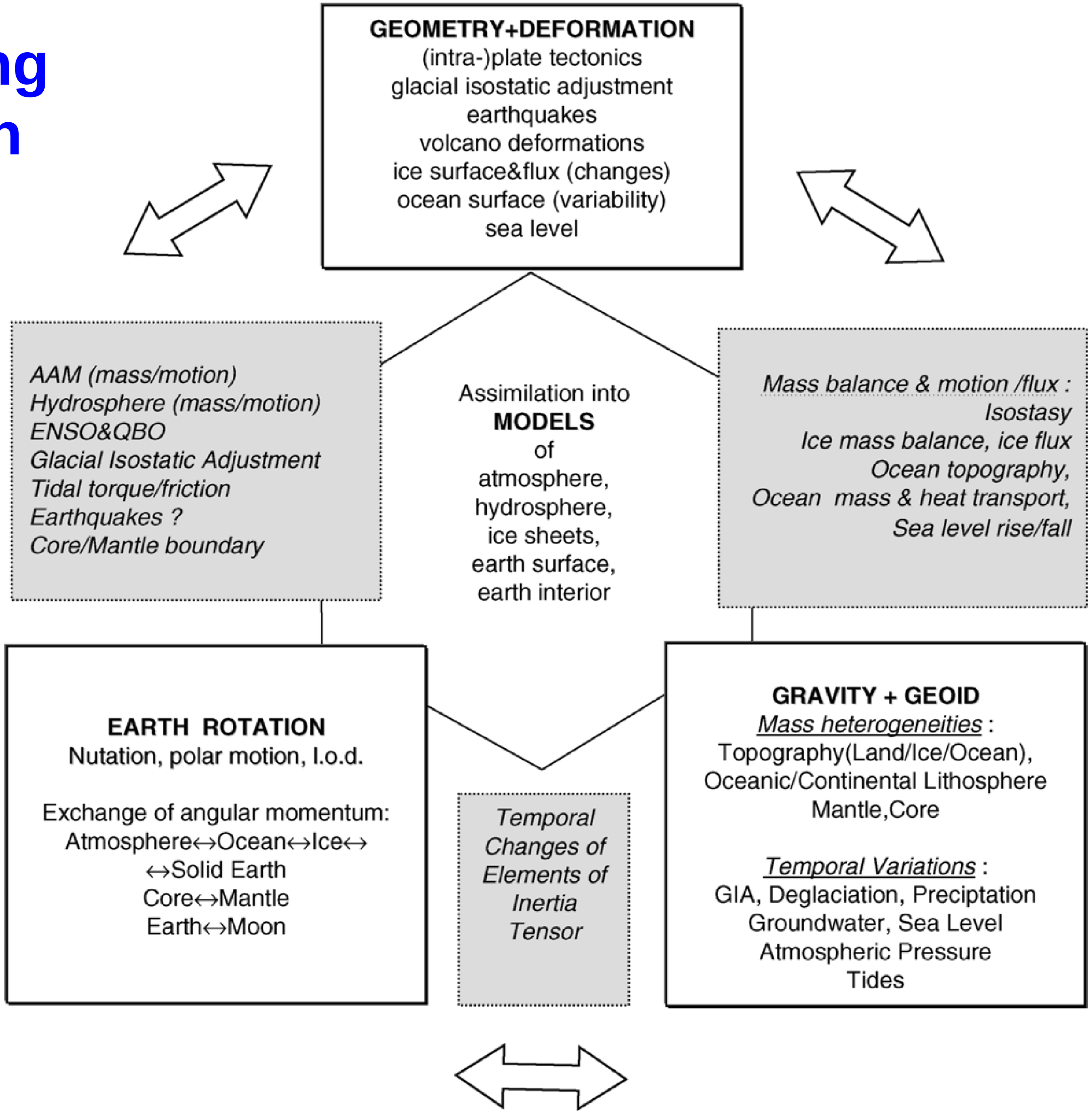


Output:
Reference Frame and Observations of the Shape, Gravitational Field and Rotation of the Earth

(modified from Rummel, 2000)

The Global Geodetic Observing System (GGOS)

Observing the Earth System



Rummel *et al.* (2005)

GGOS: The Scientific Vision

- Unify observations
  - Integration of networks and reference frames
- Unify models
  - Same model used to predict all geodetic observations
- Unify observations with models
  - Assimilate geodetic observations into models
- Earth system dynamics
  - Surface change (natural hazards)
    - Shape and deformation
  - Mass transport and exchange (climate change)
    - Gravity, geoid, and shape
  - Angular momentum exchange
    - Earth rotation

GGOS: The Scientific Vision

Unify observations:

- Eliminates inconsistencies
  - Between observations taken by different techniques
    - VLBI, SLR, GPS, DORIS
  - Between EOPs and reference frames
    - IERS Combination Pilot Project
    - Gravity
  - Between measurements taken in different reference frames
    - Example: satellite altimetric measurements of sea surface height and tide gauges
- Strengthens solution
  - Better global distribution of stations
    - VLBI + SLR + GPS + DORIS
  - More measurements
- Requires common standards

GGOS: The Scientific Vision

Unify models:

- Changes in observed shape, rotation, and gravity
  - Often have a common cause
    - Examples: atmosphere, oceans, hydrology, earthquakes, postglacial rebound
  - But are often modeled separately
    - Example: angular momemtum for rotation, linear momentum for displacements

Unify models and observations:

- Develop common models
  - From common shape, rotation, and gravity observations
    - Surface change
    - Mass transport and exchange
    - Angular momentum exchange

GGOS: The Scientific Vision

Earth System Dynamics:

The Dynamics of the Earth system are strongly linked to mass transports in the Earth system:

- mass transport in the atmosphere
- mass transport in the water cycle
- mass transport in the solid Earth

All these processes affect to certain levels:

- geometry of the Earth
- gravity field
- Earth rotation

All these processes interact on global and regional scales

Geodetic methods are inherently strong on regional to global scale

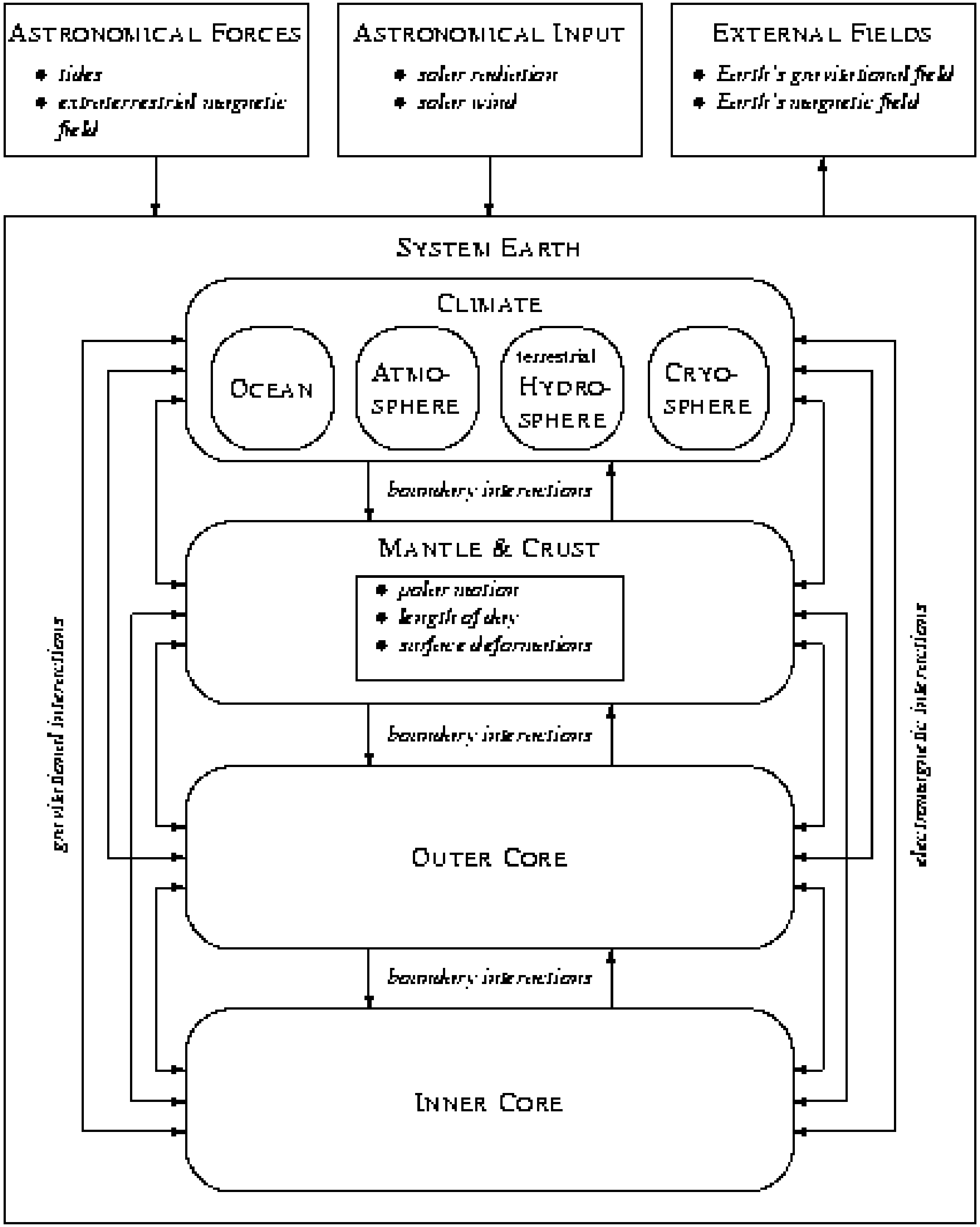
GGOS: The Scientific Vision

Earth System Dynamics:

- Understanding the dynamic processes
  - circulation and rotation
  - mass transport, gravity field, and surface kinematics
  - goal: development of predictive capabilities

- *Earth System Dynamics theme*
  - Geodetic quantities are relevant for several themes and benefit areas
  - Dynamic processes are a cross-cuting issue
  - Design the geodetic and geophysical observing system with focus on dynamic processes

The Science Basis for GGOS: An Earth System Dynamics Theme



In order to provide the appropriate metrological basis for Earth observation, geodesy needs to account for interaction between the subsystem.

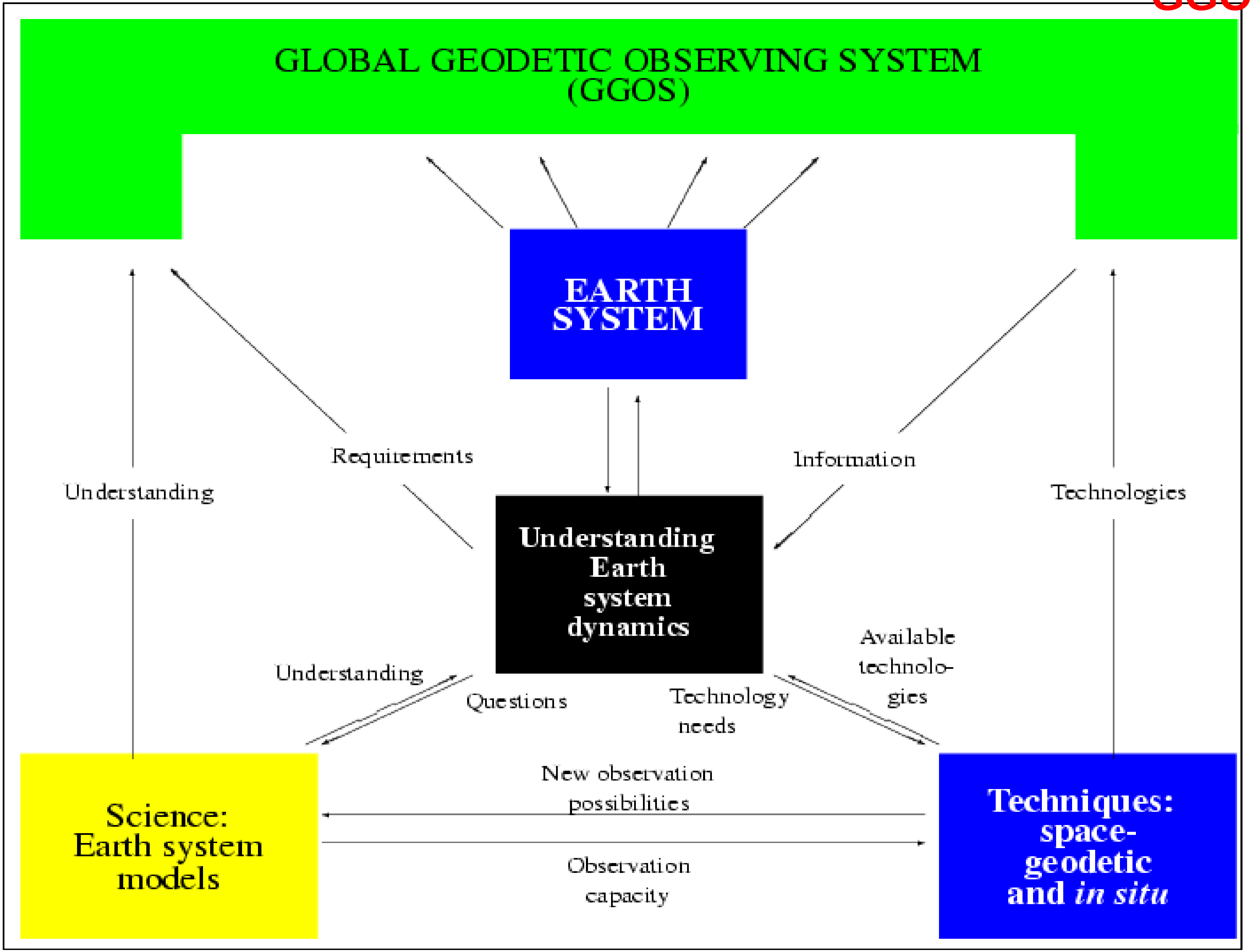
This requires an Earth system approach to modeling.

Earth system models are tools for
- understanding the processes
- assessment of impacts.

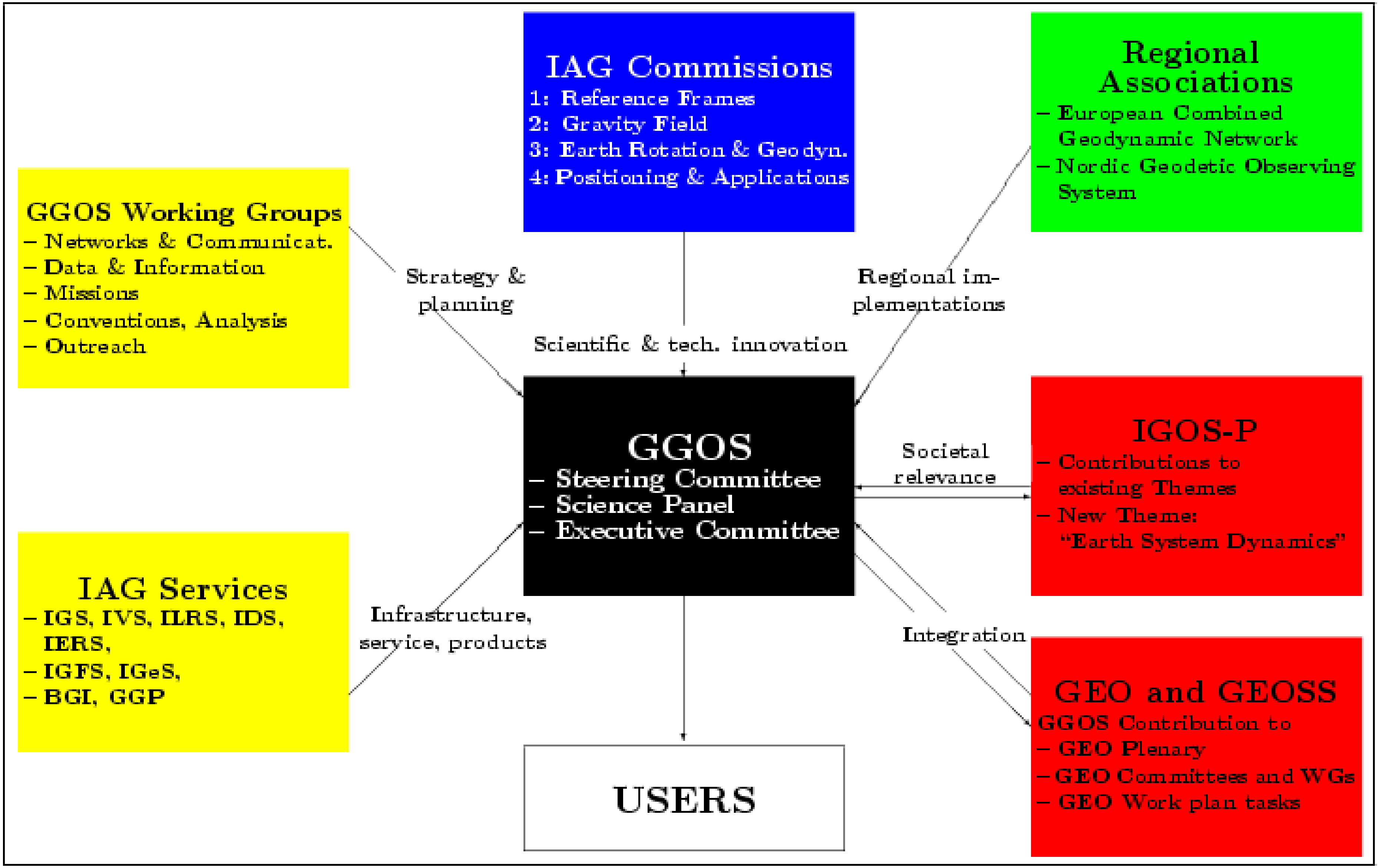
The Earth System Dynamics Theme responds to societal problems of
- climate
- geohazards
- water cycle
- ocean
- coastal zone
- sustainable development

The Science Basis for GGOS: An Earth System Dynamics Theme

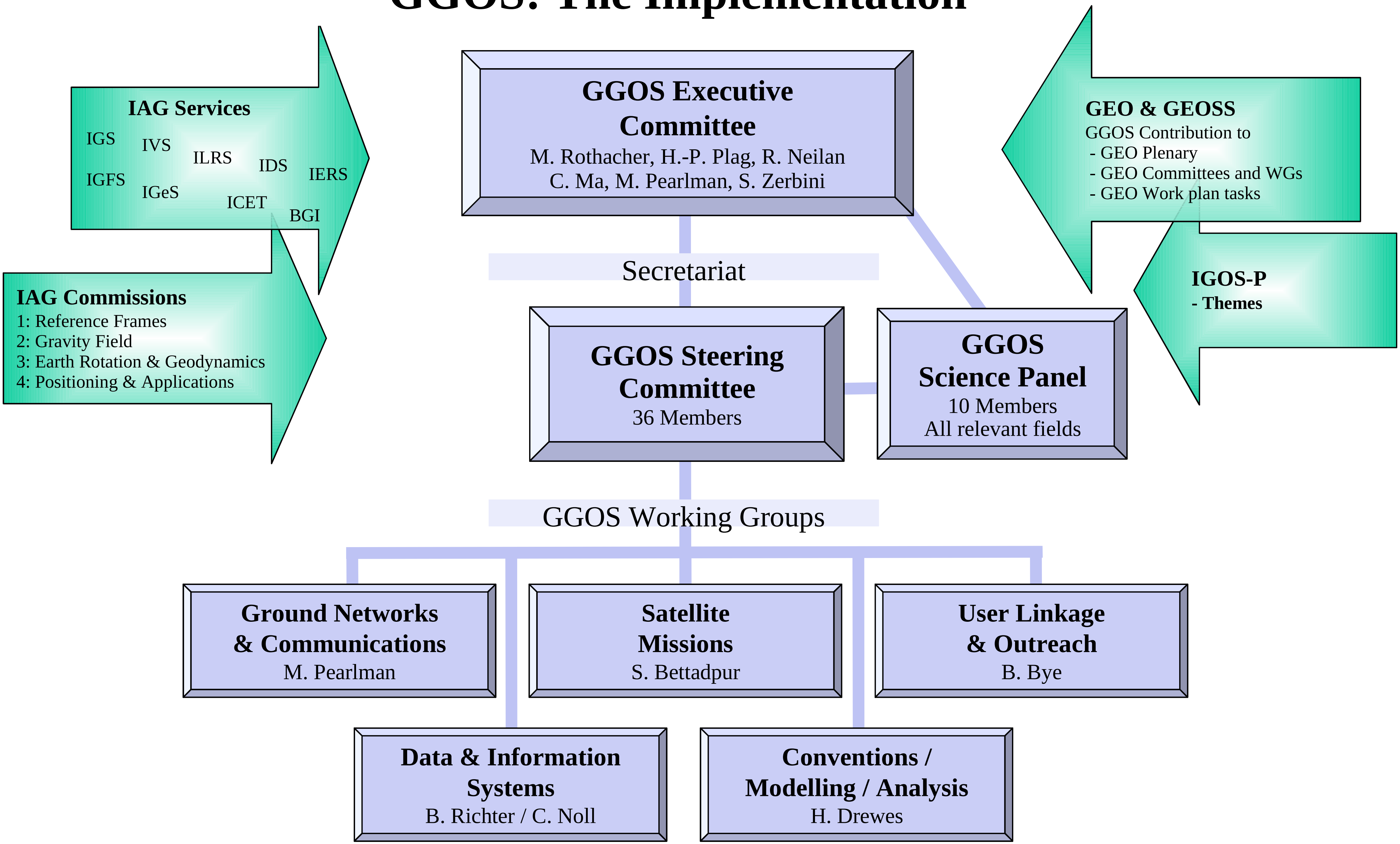
GGOS



GGOS: The Implementation



GGOS: The Implementation



GGOS and IGOS-P Themes

The Geohazards Theme: Plate tectonics, pre-, co- and post-seismic strain, processes associated with volcanos, early warning for tsunamies, subsidence, precarious rocks, landslides, and local and regional predictions of sea level rise are examples of topics that link this theme to geodetic observations.

The Ocean Theme: Ocean circulation, sea level rise, postglacial rebound, dynamic sea surface topography, are linked to the three geodetic quantities, both for the monitoring and studies of the ocean's variability as well as model validation.

Water Cycle Theme: The geodetic observations provide a unique tool to monitor the global to local scale movememts of water throught the Earth system and the theme is strongly linked to geodesy.

The Coast Observation Theme: Sea level and ocean circulation are relevant parameters influencing the dynamic processes in the coastal zone and linking the theme to geodesy.

The Cryosphere Theme: Ice mass balance, glacially induced deformations, and induced sea level variations all are important parameters, that are directly observed by the geodetic observation techniques.

The Land Theme: Changes in the elevation are directly observed by geodetic techniques.

GGOS and IGOS-P Themes

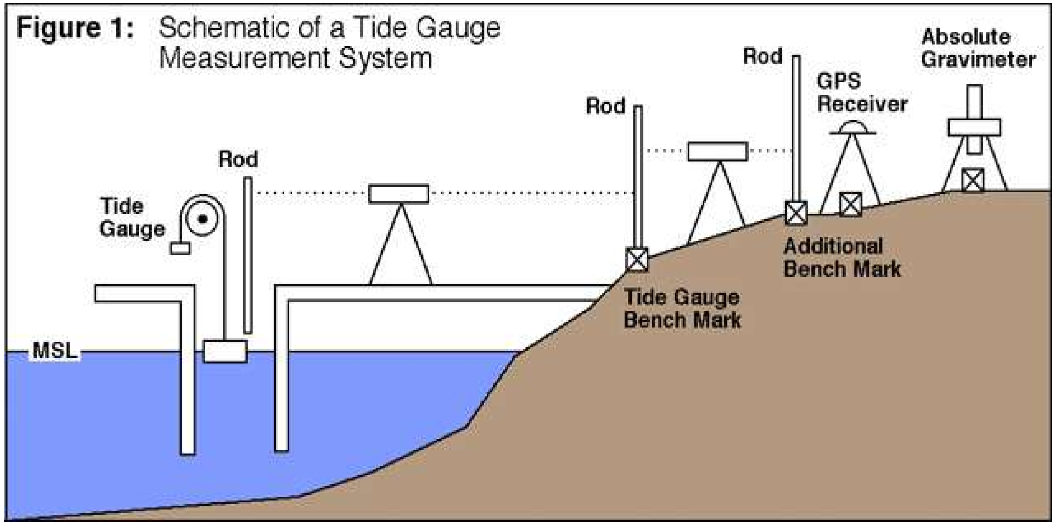
Example: Sea Level and Ice Sheets Trends

Relevant for:

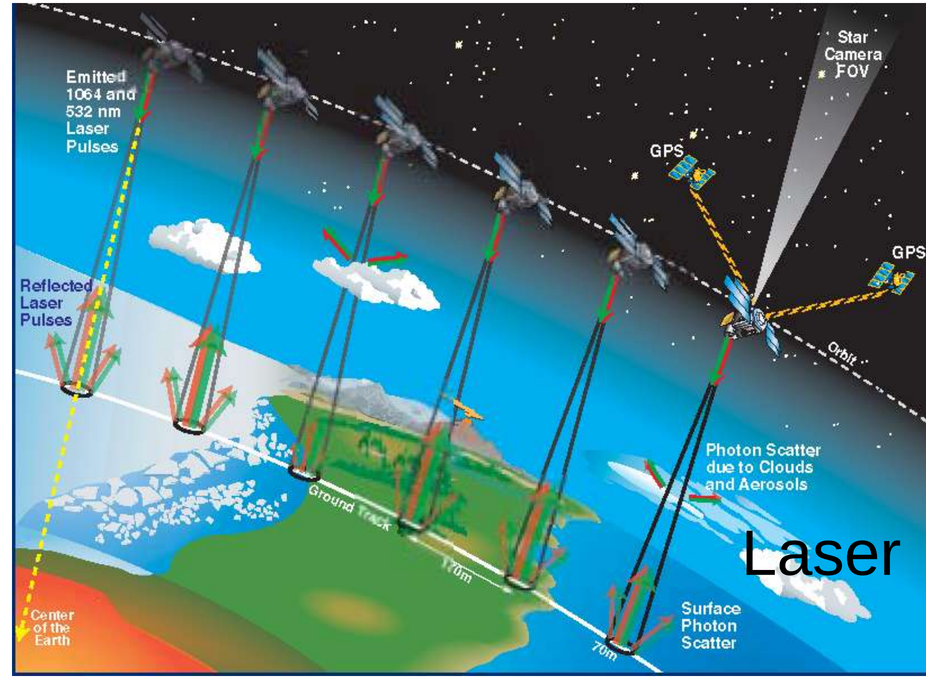
- Ocean Theme,
- Coast Observation Theme,
- Water Cycle Theme,
- Cryosphere Theme

GGOS and IGOS-P Themes

Tide Gauges



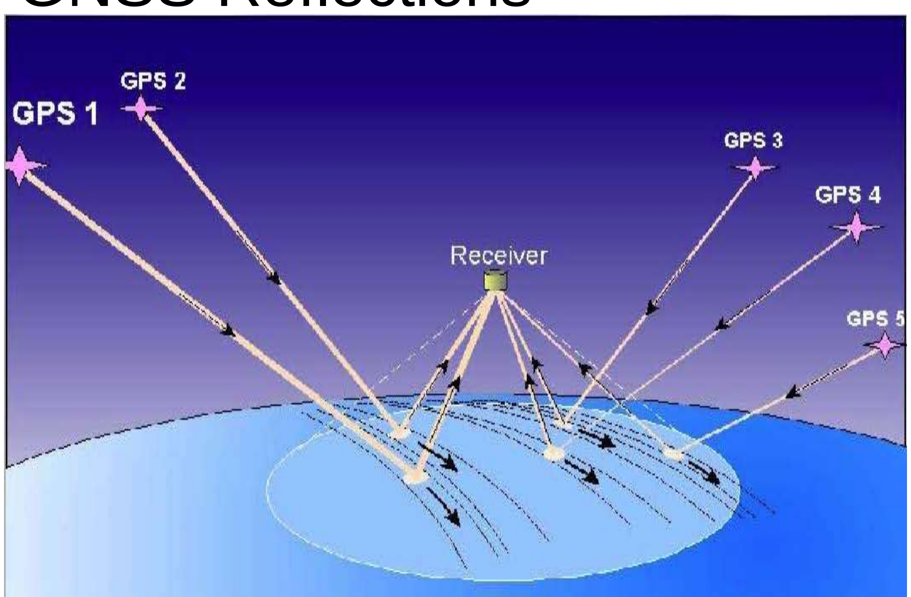
http://sealevel.colorado.edu/tidegauges.html

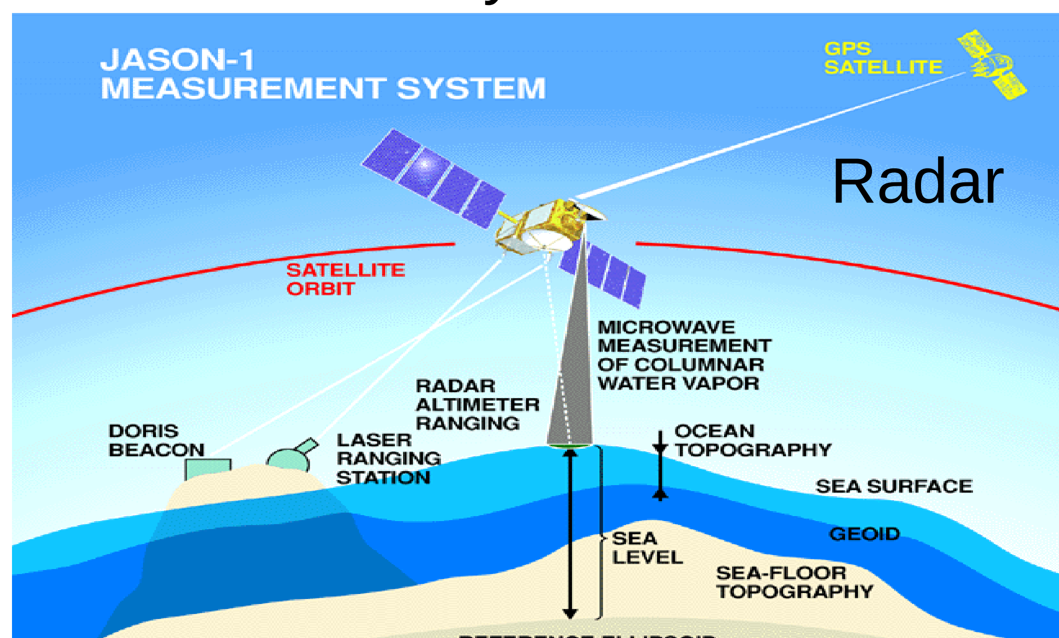


http://icesat.gsfc.nasa.gov

Satellite Altimetry

GNSS Reflections





Zufada & Zavorotny (2004)

GGOS and IGOS-P Themes

GGOS Contribution:

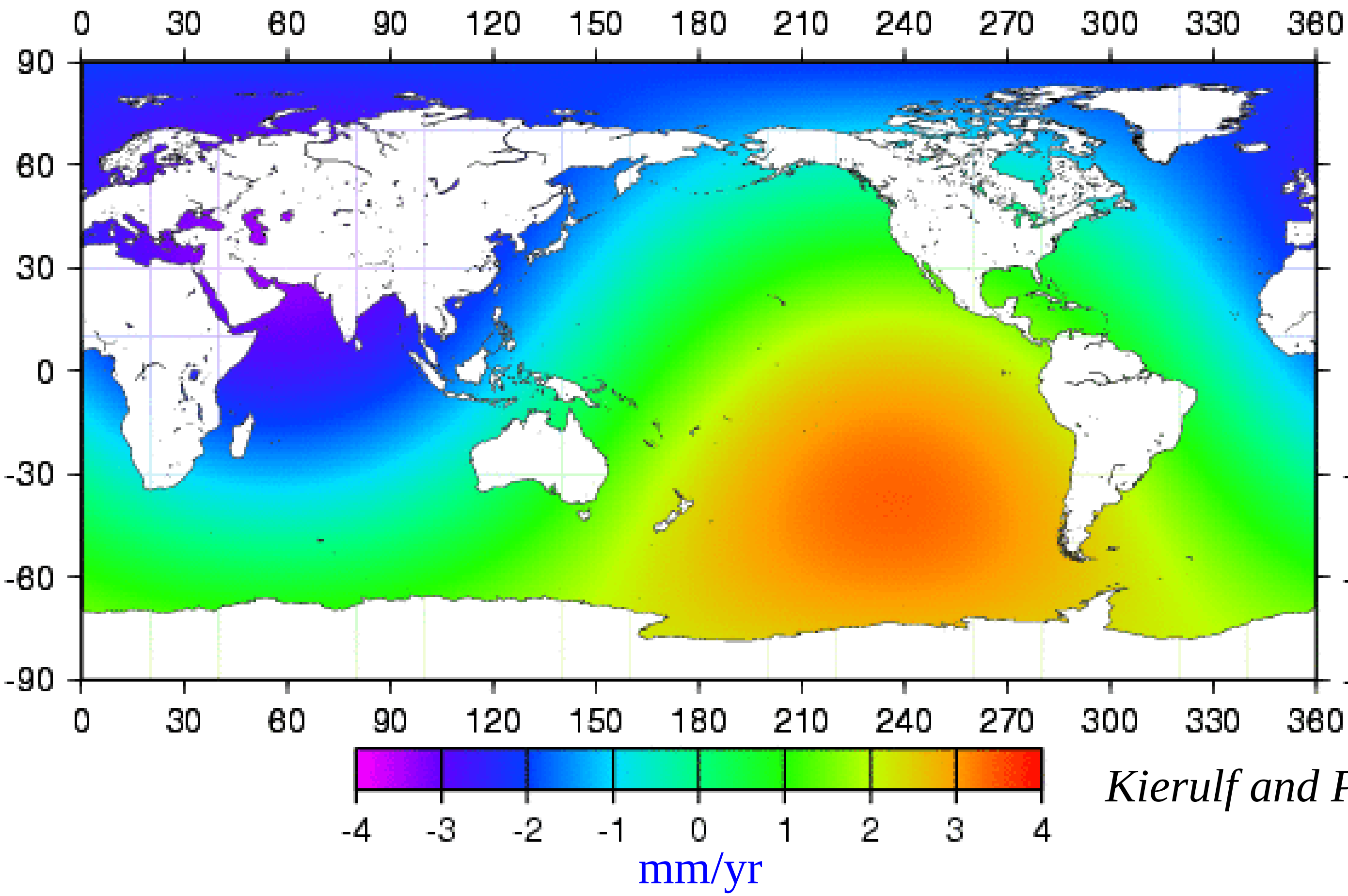
- Terrestrial and celestial reference frames
- Precise positioning
  - Monuments on ground
    - Tide gauges
  - Satellites in space
    - Radar and laser altimeters
- Gravity measurements
  - Time variable
    - Ocean-bottom pressure
  - Static
    - Mean ocean circulation
- GNSS reflections

GGOS and IGOS-P Themes

Uncertainties in relation between reference frame origin and Center of Mass of Earth System (CM):

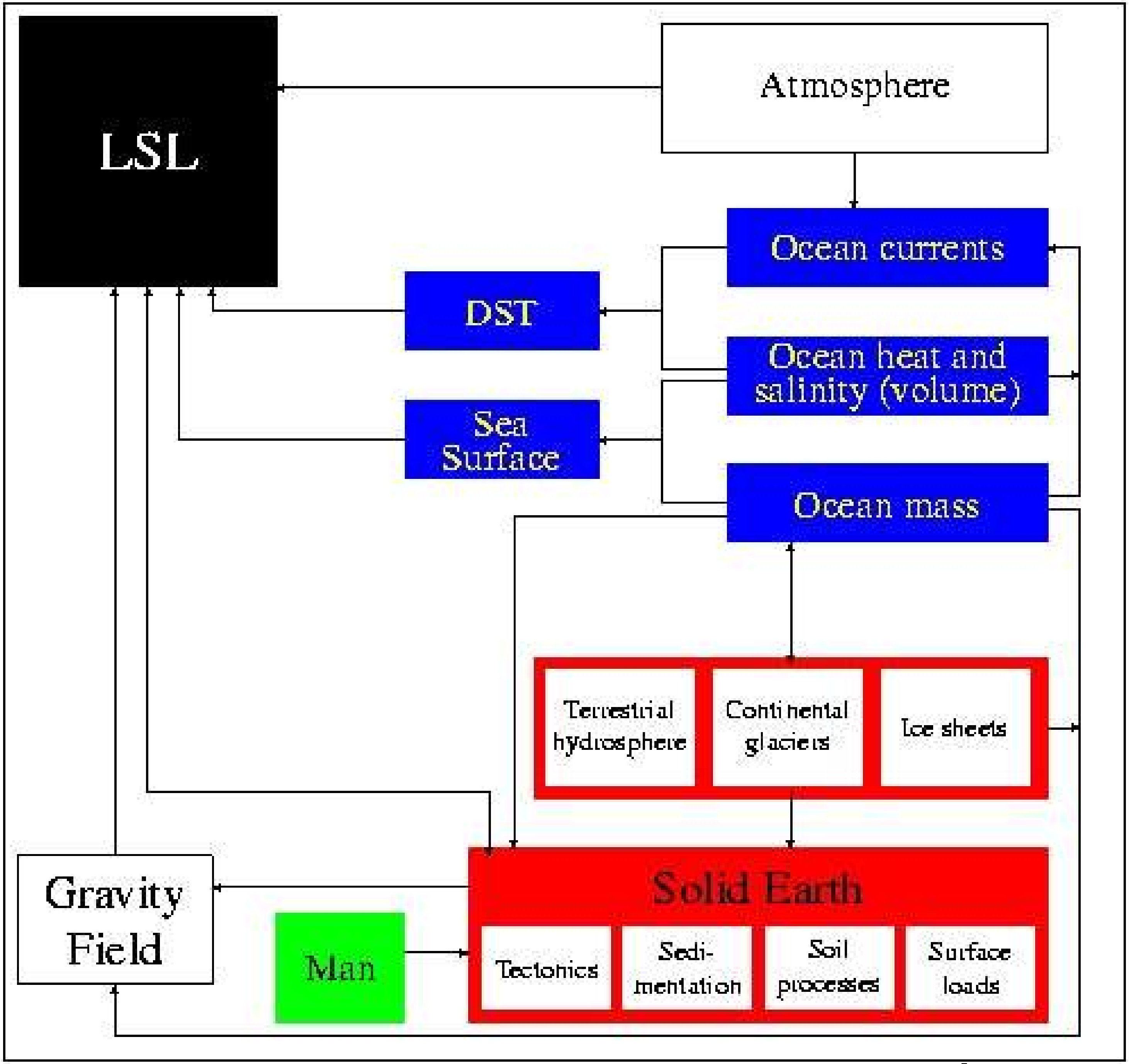
Uncertainty of 2 mm/yr affects:

- global sea level by 0.4 mm/yr
- ice sheet trends by 1.5 mm/yr
- local sea level by 2 mm/yr



Kierulf and Plag, 2005

GGOS and IGOS-P Themes



Plag, 2006

Local Sea Level (LSL)

Link between LSL and global sea level complex (Water cycle and Ocean themes).

LSL depends on local, regional and global processes (Coastal Theme).

Satellite altimetry measures sea surface height, not LSL: geodesy provides the link.

GGOS and IGOS-P Themes

Water Cycle and Geodesy

- Gravity field variability measurements
- Degree-1 mass transport
- EOP as a constraint
- Ice sheets
- Sea Level & Circulation
- Radio Occultations
- Surface loading (geometry)

GGOS and IGOS-P Themes

Water Cycle and Geodesy

- Areas:
  - Ground Water Storage Changes
  - Climate/Weather Models
  - Snow-melt & run-off forecasts
- Current deficiencies are:
  - Latency (GGOS can solve this)
  - Data Gaps (GGOS can solve this)
  - Resolution (GGOS cannot solve this alone)

GGOS and IGOS-P Themes

Geodesy contribution to IGWCO Theme:

- Long-term changes in ground-water storage change
  - Even if geodetic spatial scales are too large, there is no other unified, practical & global measurement set available within hydrology
- Weather model boundary conditions
  - Large-scale P-E estimates
- Snow Cover Changes
- These contributions are of twofold importance:
  - Monitoring of the “state” of water cycle
  - Assimilating into models for calibration of models

Conclusions

- Geodetic techniques are indispensable for Earth observation systems
- GGOS coordinates global networks for monitoring displacements, gravity variations and Earth's rotation variations
- GGOS provides the backbone for Earth observations: ITRF
- GGOS provides observations related to the dynamics of the Earth
- Users are (still) not fully aware of the potential of geodetic observations