



Earth System Dynamics

***Toward A Theme Proposal initiated by the
Global Geodetic Observing System (GGOS)
of the
International Association of Geodesy (IAG)***

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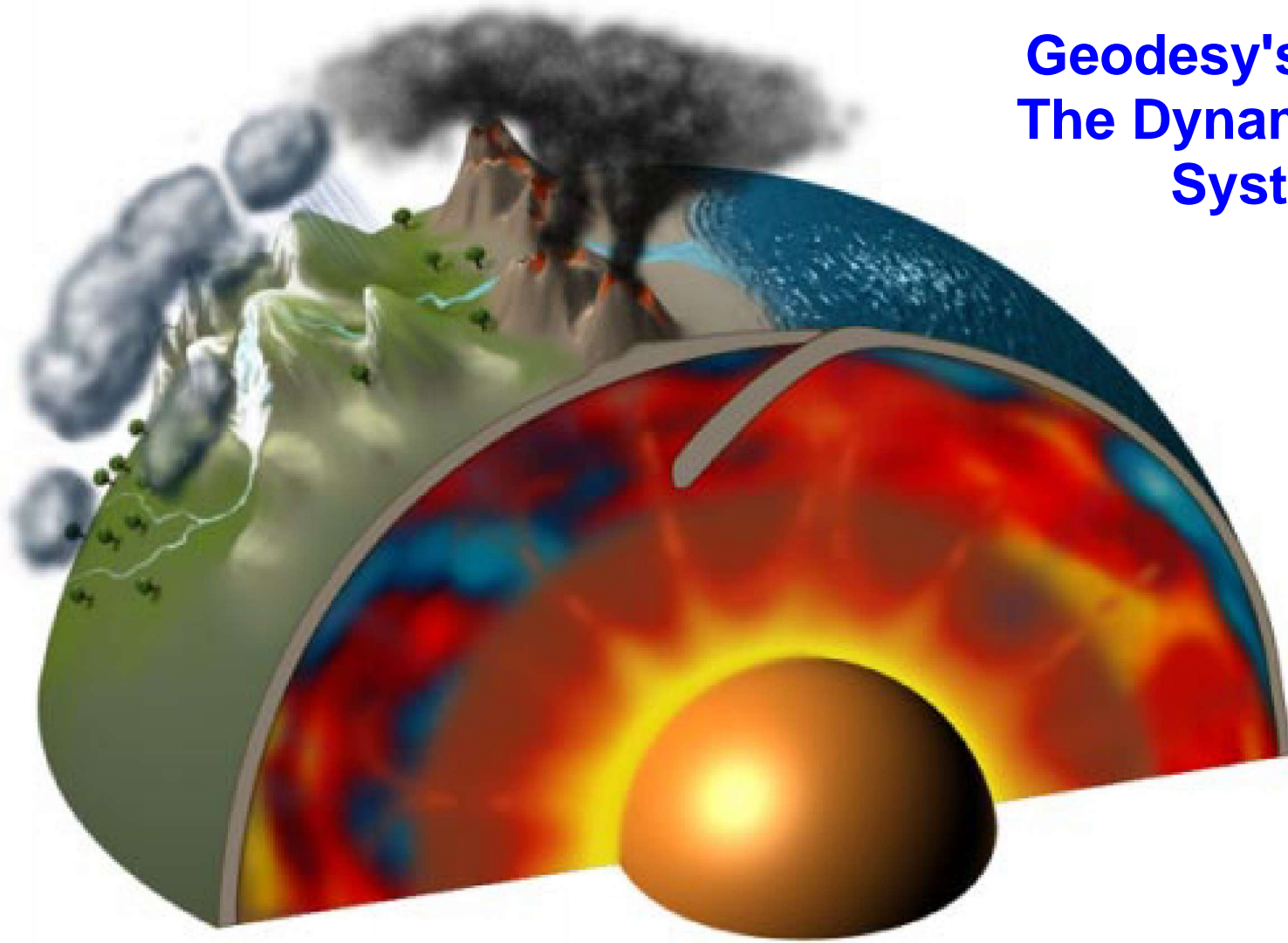
- **Geodesy's Contribution to Earth System Monitoring**
- **The Global Geodetic Observing System**
- **Interaction with IGOS-P Themes**
- **The Earth System Dynamics Theme: Main Idea and Status**

History

- Initial Idea presented to IGOS-P in 2004: Dynamic Earth Theme
- Main Concern: Overlap with existing themes
- Action Plan:
 - (1) GGOS membership in IGOS-P
 - (2) Dialog with existing themes to identify GGOS contributions
 - (3) Develop proposal for new theme (Earth System Dynamics)
- Up to now main focus on (1) and (2)

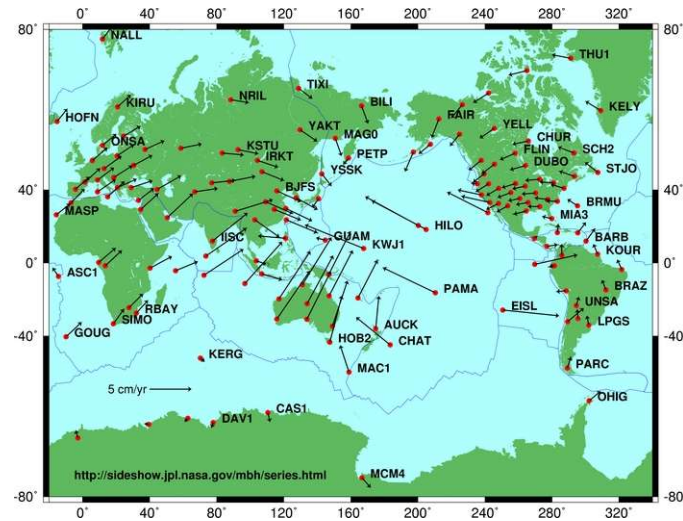
Geodesy's Contribution to Earth System Monitoring

**Geodesy's Object:
The Dynamic Earth
System**



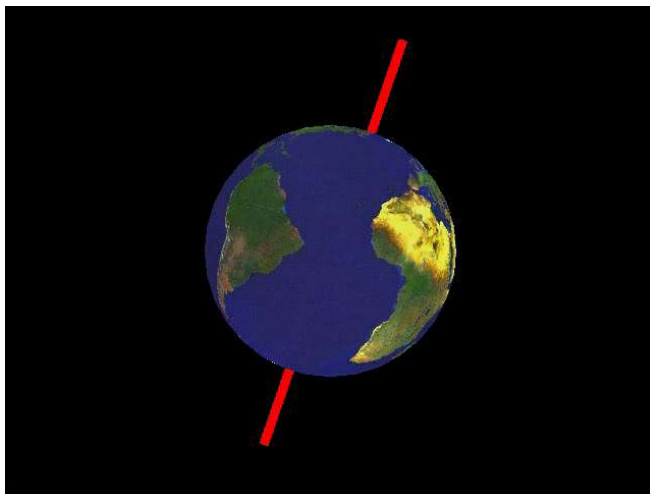
NASA Solid Earth Science Working Group
report

Geodesy's Contribution to Earth System Monitoring

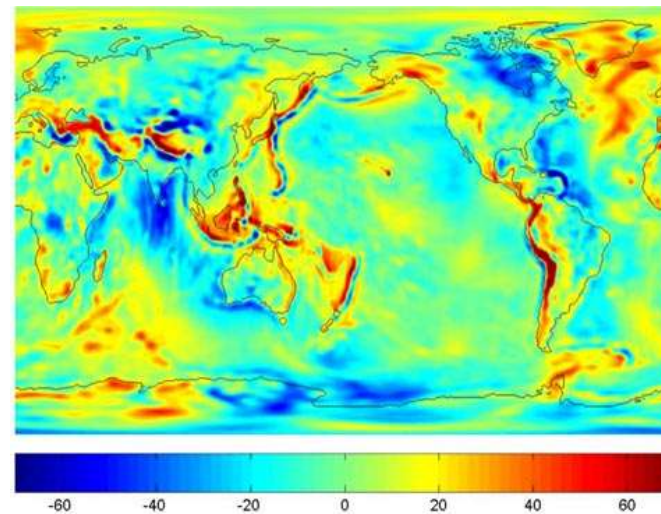


Shape & Deformation

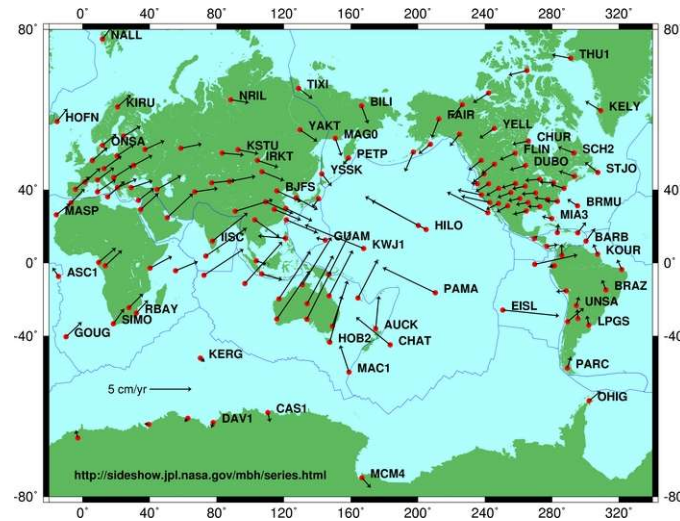
Earth Rotation



Gravity & Geoid



Geodesy's Contribution to Earth System Monitoring

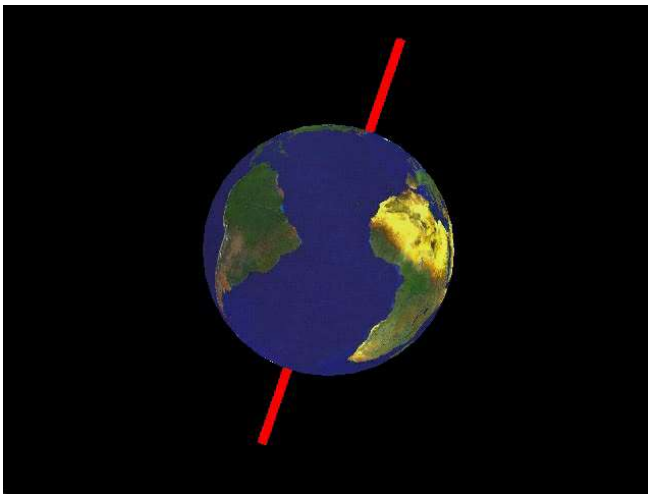


The three pillars
of geodesy:

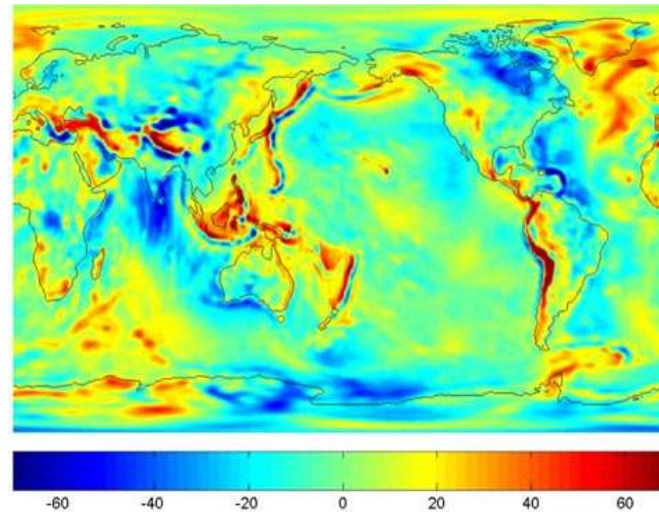
- geometry
- gravity
- rotation

Shape & Deformation

Earth Rotation

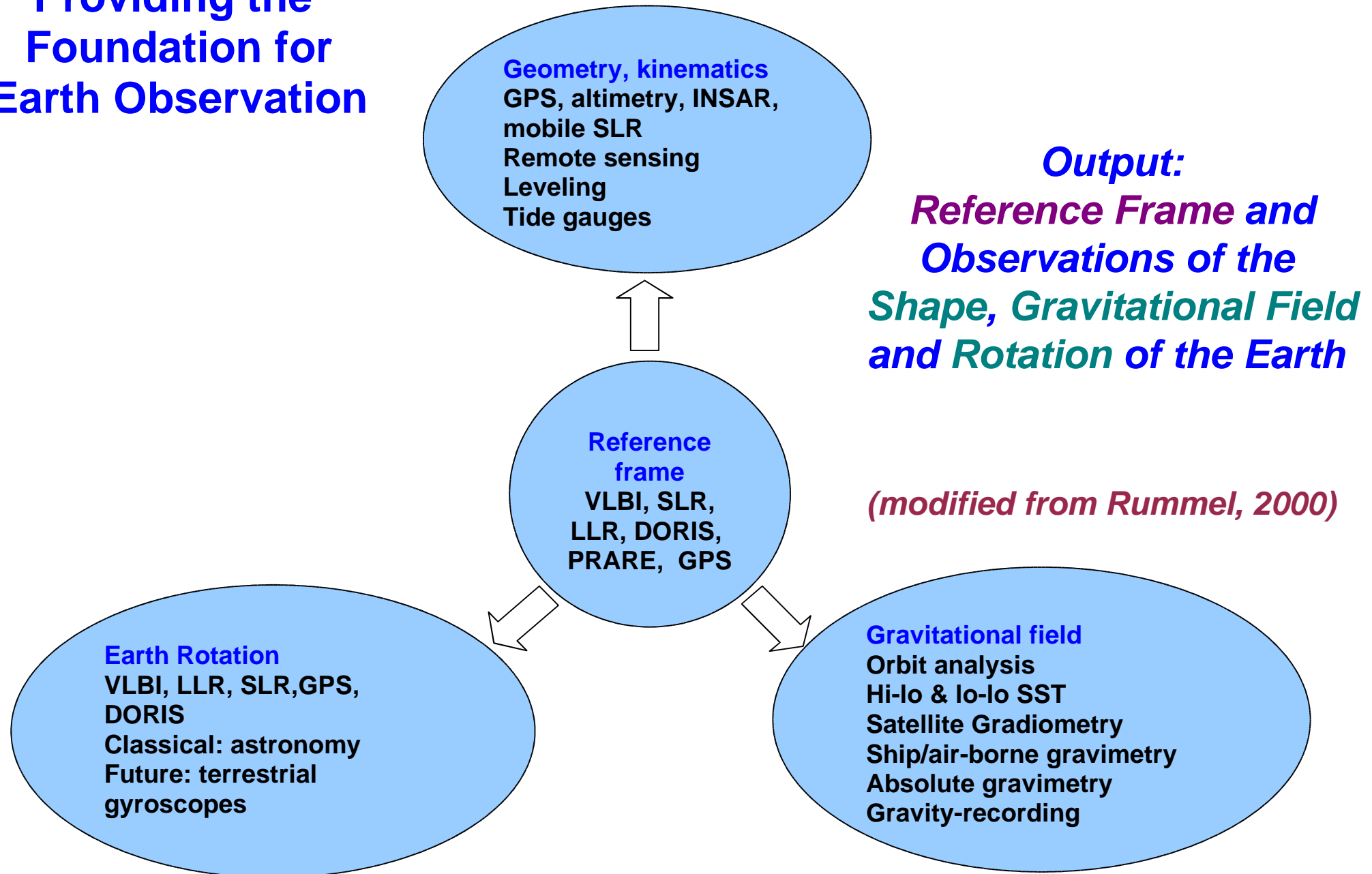


Gravity & Geoid

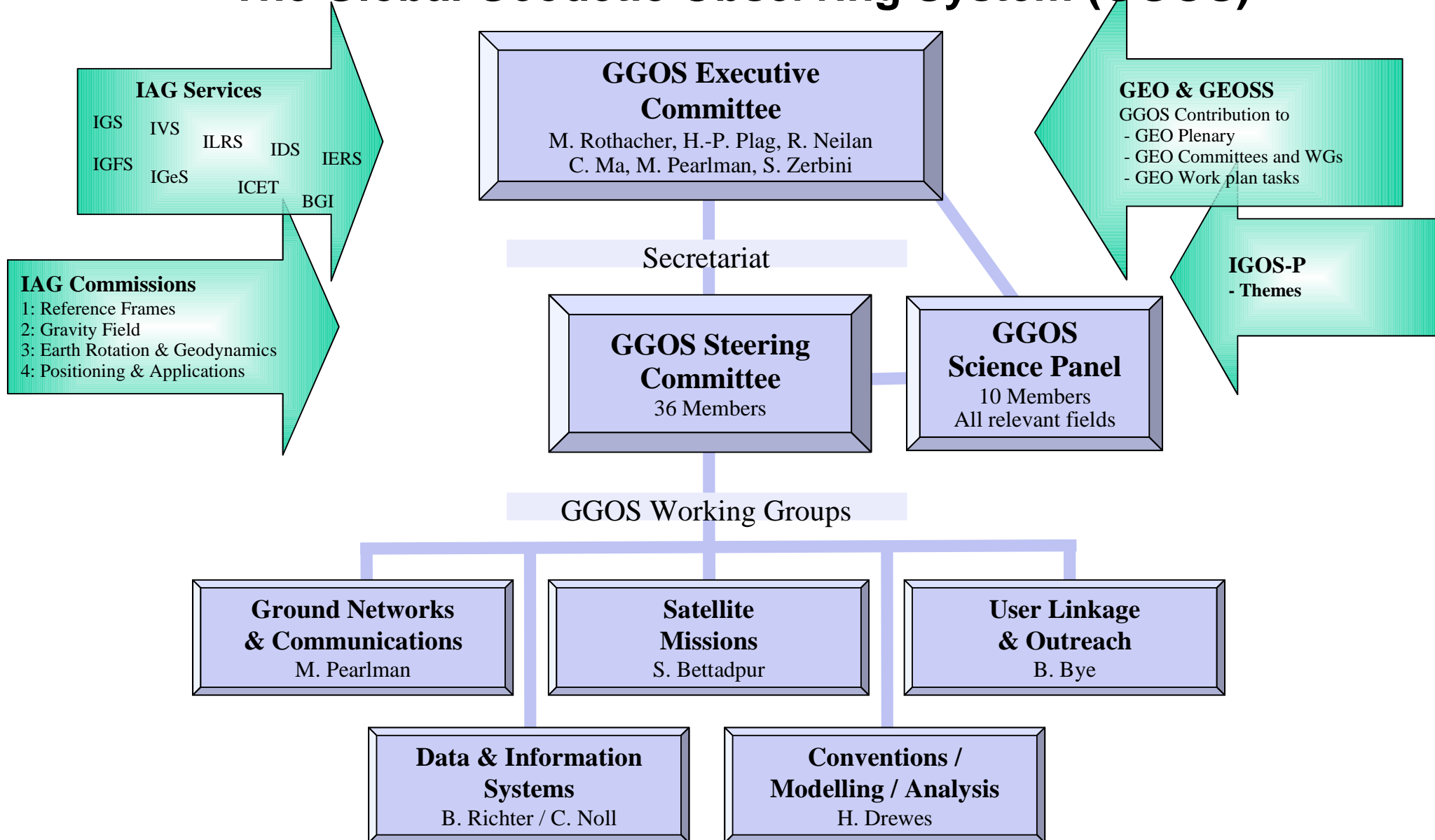


The Global Geodetic Observing System (GGOS)

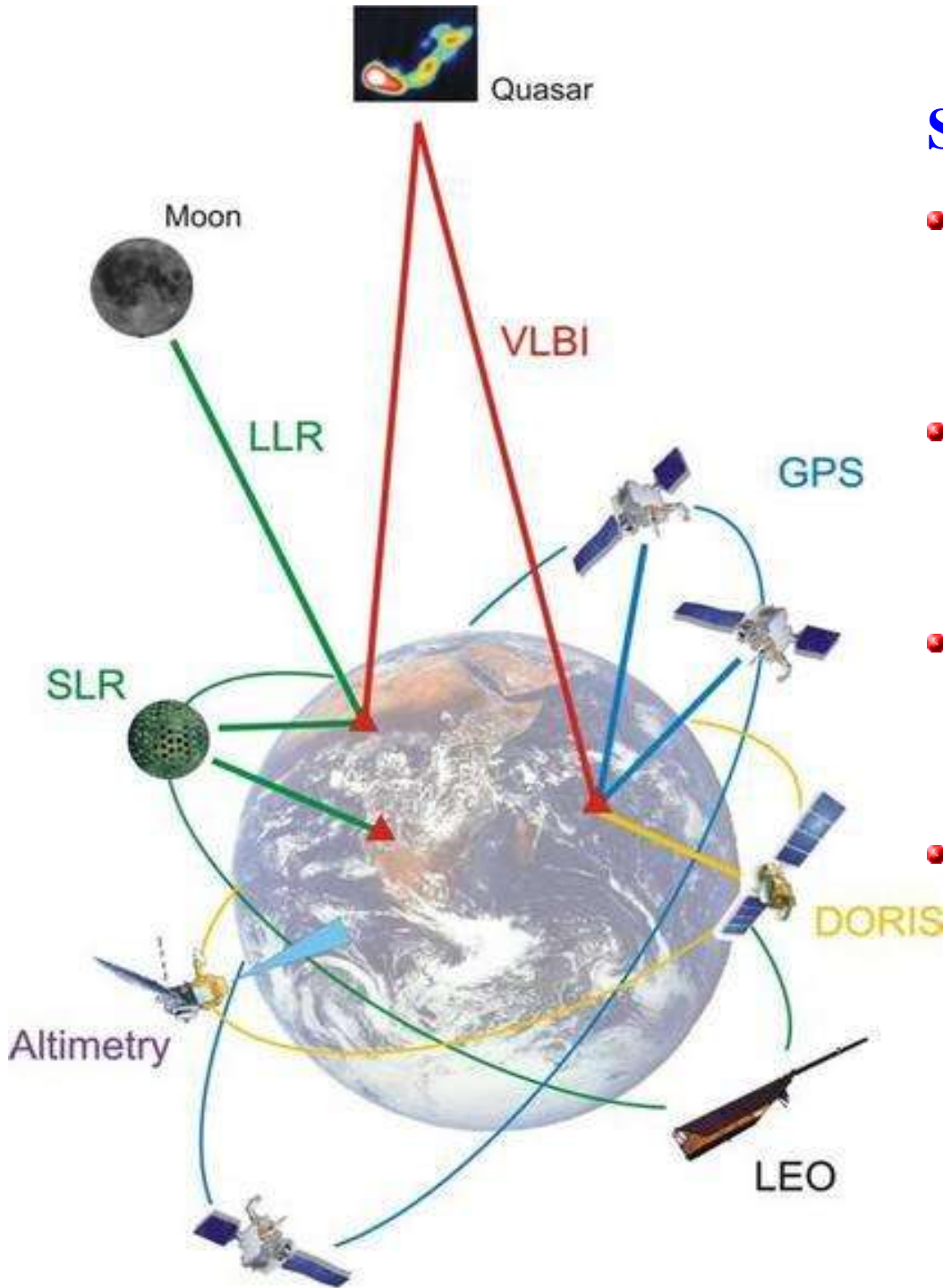
**Providing the
Foundation for
Earth Observation**



The Global Geodetic Observing System (GGOS)



The Global Geodetic Observing System (GGOS)



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
 - Mass transport and exchange
 - Angular momentum exchange

The Global Geodetic Observing System (GGOS)

- The **accuracy level** targeted by GGOS for the three fundamental geodetic quantities (and their mutual consistency level) is **10^{-9} or better**.
- At this level of accuracy, a big variety of mechanical **interactions between the different Earth system components** are relevant and need to be treated consistently.
- In this respect, **modern geodesy requires a system approach to the dynamics of the Earth** and **involves expertise from all Earth sciences** in the analysis and interpretation of the geodetic observations.

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 movements of water through 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

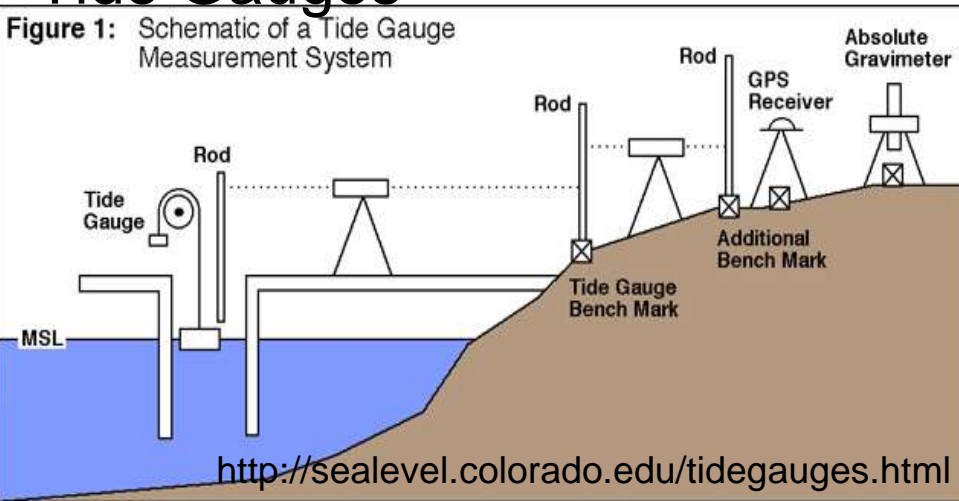
Relevant for:

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

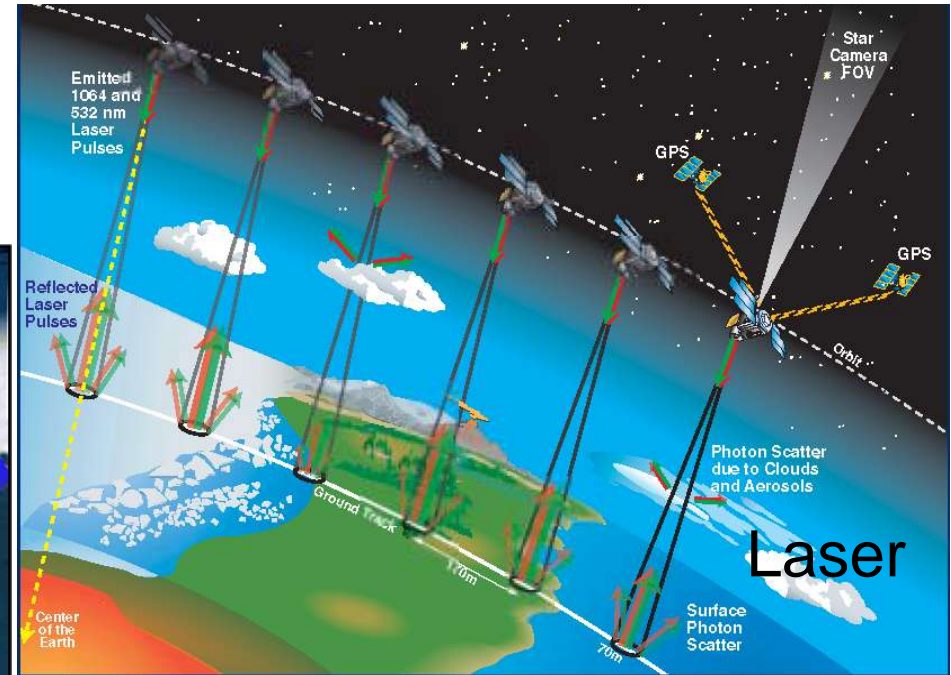
GGOS and IGOS-P Themes

Tide Gauges

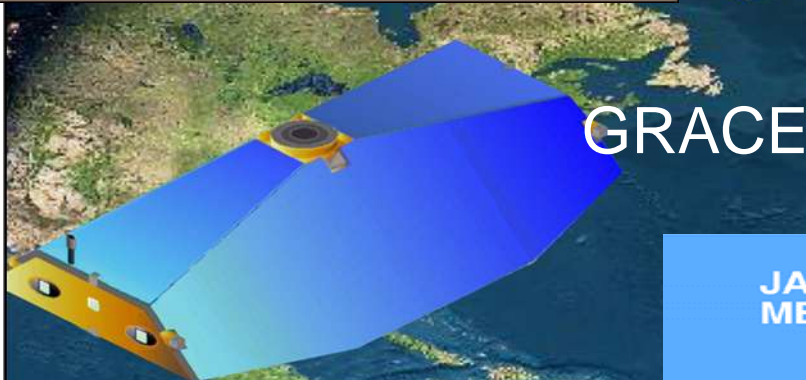
Figure 1: Schematic of a Tide Gauge Measurement System



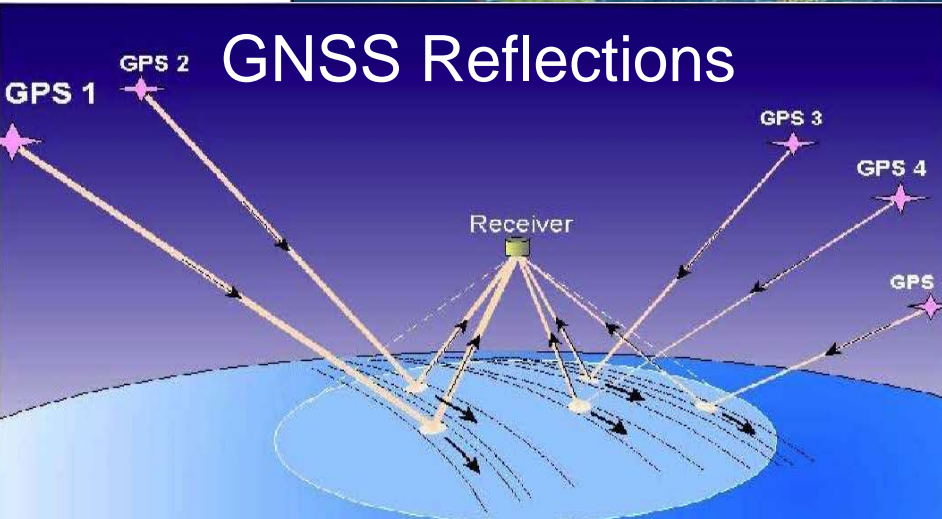
<http://sealevel.colorado.edu/tidegauges.html>



Satellite Altimetry <http://icesat.gsfc.nasa.gov>

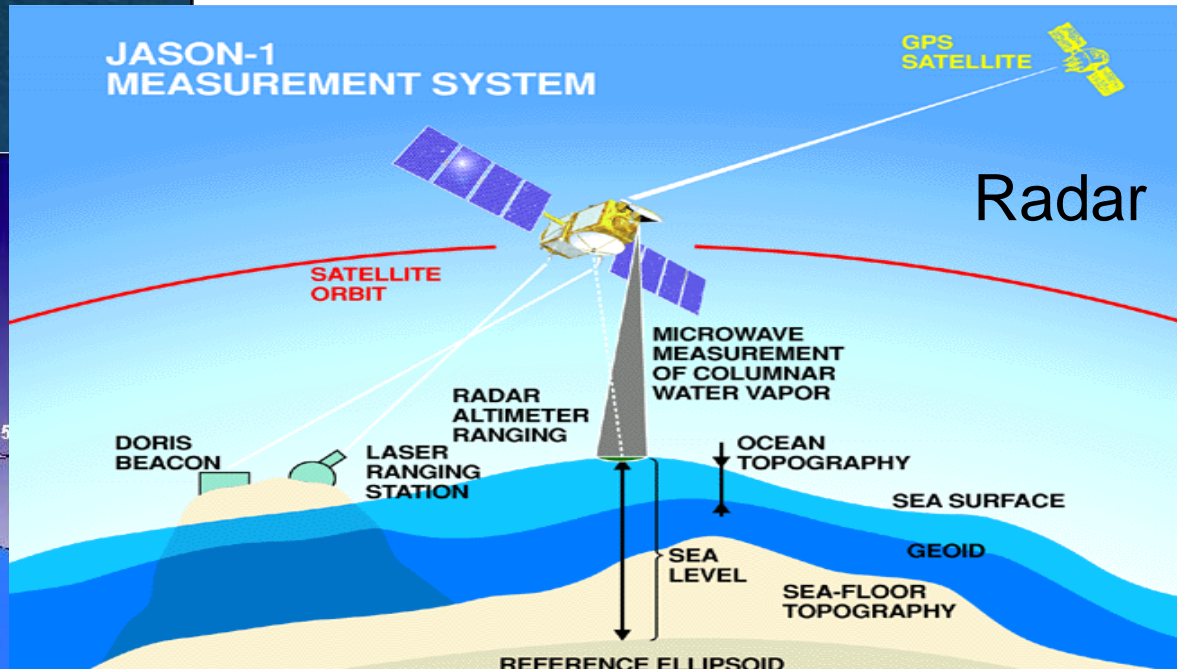


GRACE



GNSS Reflections

Zufada & Zavorotny (2004)



Courtesy NASA/JPL-Caltech

Radar

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

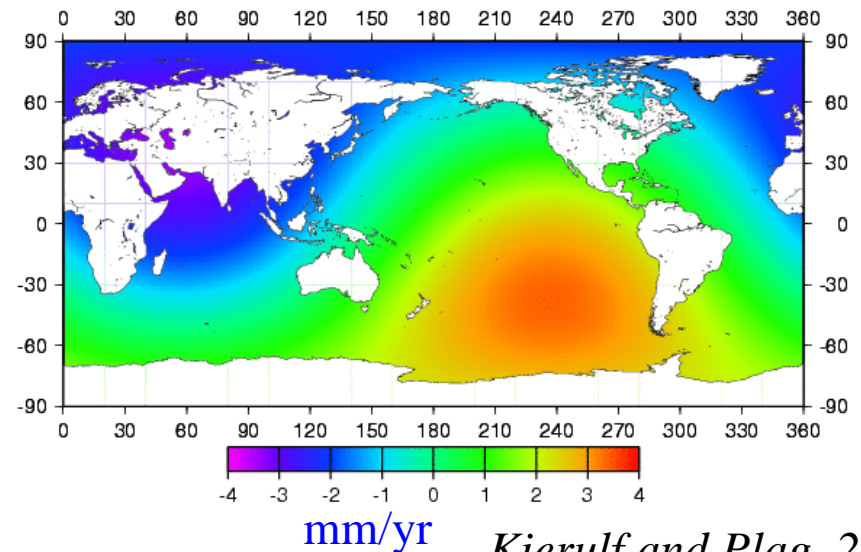
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Uncertainties in relation between reference frame origin and Center of Mass of Earth System (CM):

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

Earth System Dynamics Theme

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

- the atmosphere
- the water cycle
- the solid Earth

All these processes affect to certain levels:

- geometry of the Earth
- gravity field of the Earth
- Earth rotation

All these processes interact on global and regional scales.

Geodetic methods are inherently strong on regional to global scale.

Earth System Dynamics Theme

Geodetic quantities are relevant for several themes and benefit areas

Dynamic processes are a cross-cutting issue:

- climate
- geohazards
- water cycle
- ocean
- coastal zone
- sustainable development

Goals:

Design of the geodetic and geophysical observing system with focus on dynamic processes

Development of predictive capabilities

Conclusions

- GGOS needs an Earth System Dynamics theme (or a similar approach)
- Earth system dynamics are a cross-cutting issue for several themes
- A Earth system dynamics theme will link existing themes

Expected Progress

- GGOS has started the process of writing the theme proposal
- GGOS has started to write a science document:
 - Tentative title “The Global Geodetic Observing System: Meeting the requirements of a growing society on a changing planet in 2020”
 - Support available for the writing from NASA and other GGOS Contributors
 - Time schedule:
 - First complete draft by October 2006
 - Hearing phase October to December 2006