Gravity Field Missions: status & studies for future missions

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A joint GGOS/IGCP565 – IAG – GEO Workshop
Towards a Roadmap for Future Satellite Gravity Missions
September 30 – October 2, Graz University of Technology, Austria

Delft Institute of of Earth Observation and Space Systems
Astrodynamics and Satellite Systems

Delft University of Technology

Outline

- Current missions:
  - Achievements
  - Limitations
  - Prospects
- Future missions:
  - Requirements
  - Technology
  - Mission design
  - Ongoing activities

Central theme:

Why do we need (a) new gravity mission(s)?

Why higher priority than other proposed Earth observation missions?

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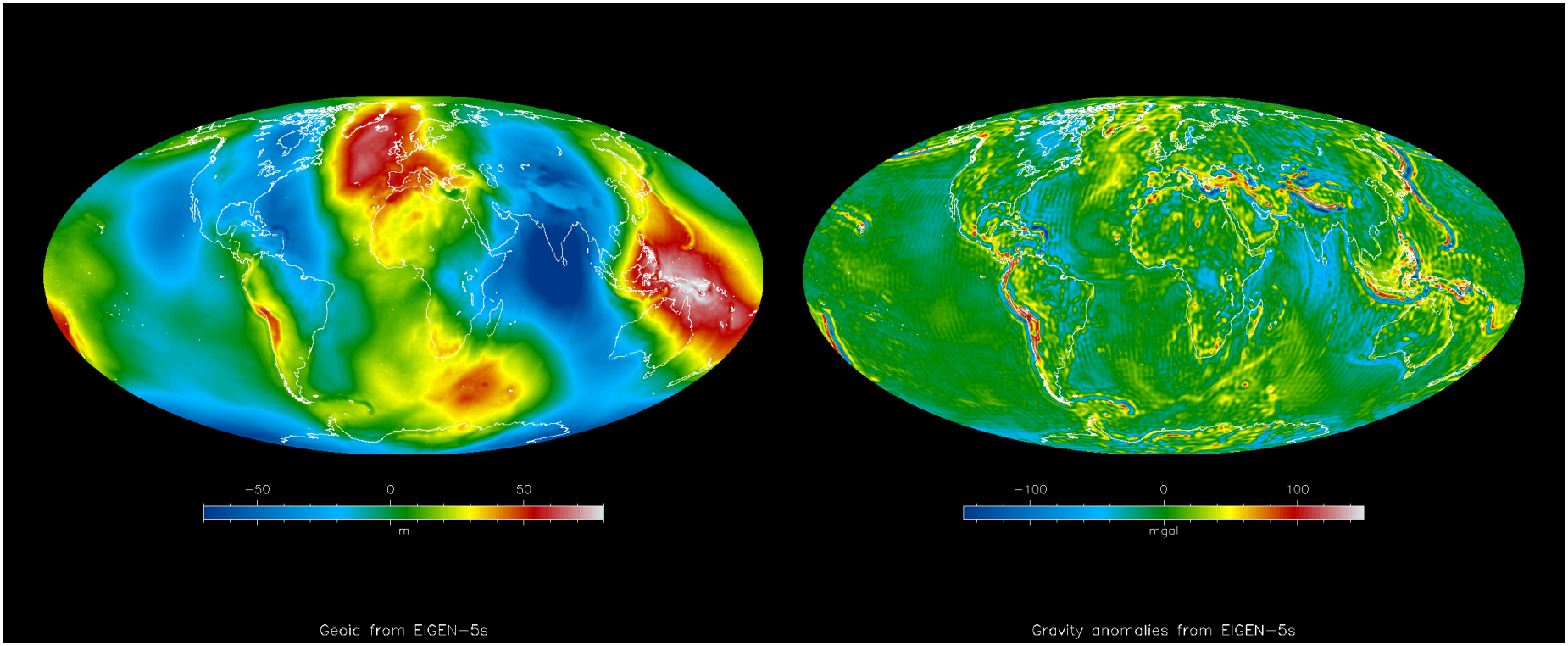
Achievements – static gravity

EIGEN-5S: coefficients from website GFZ, Potsdam



After GOCE: spatial resolution better than 100 km.

Further improvement needed? Continuity required? How about every now and then a snapshot? Synergy: altimetry, terrestrial/airborne gravimetry?

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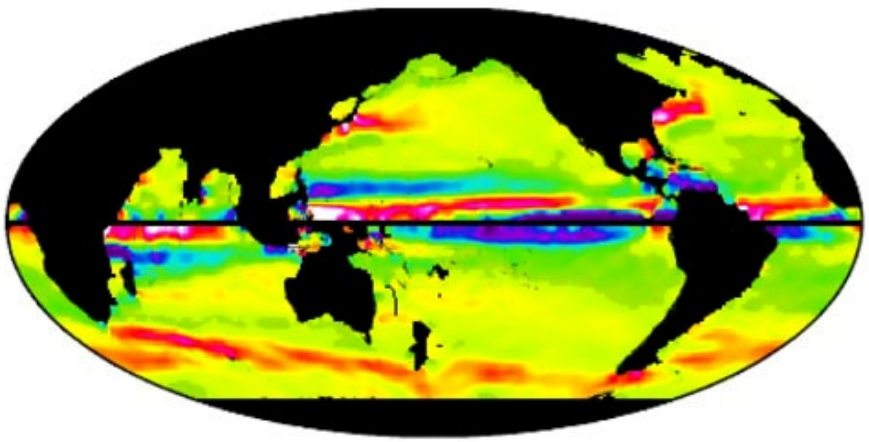
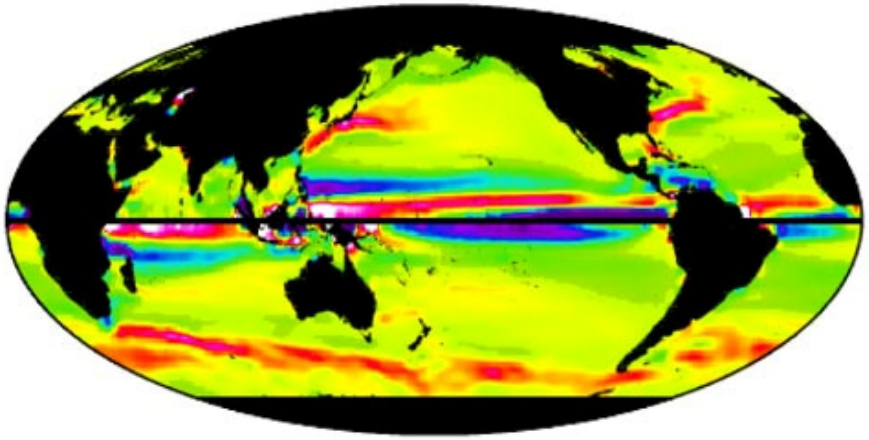
Achievements – ocean currents

*pictures from website CSR, Texas



Surface currents from World Ocean Atlas Data



Altimetry + GRACE geoid*

New gravity missions: added value? Synergy, e.g. global networks of buoys? Altimetry + SMOS?

Impact of enhanced spatial resolution (< 100 km)?

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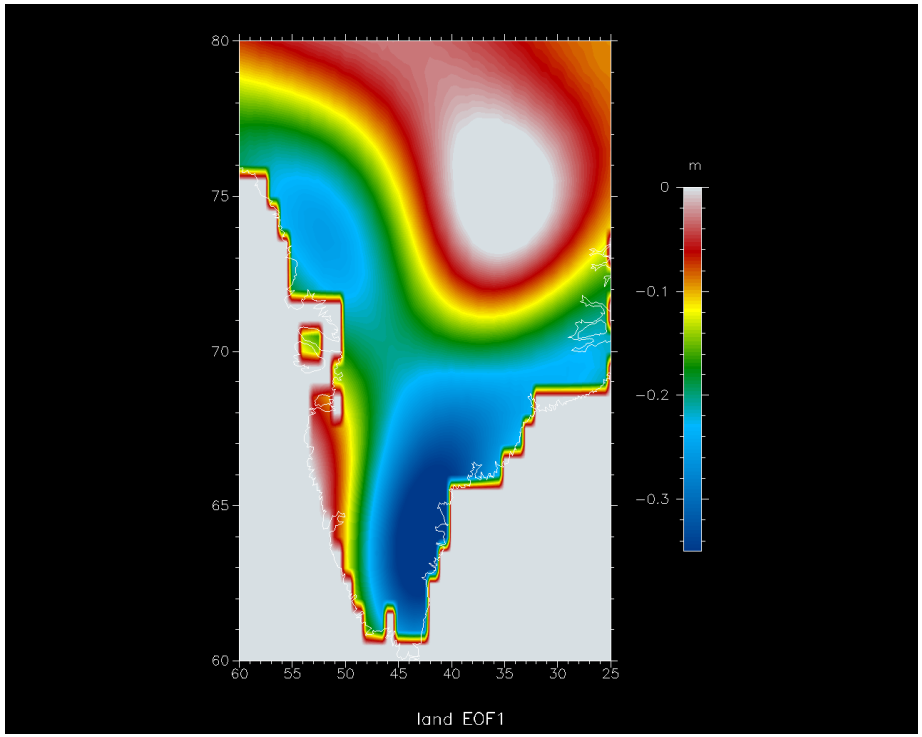
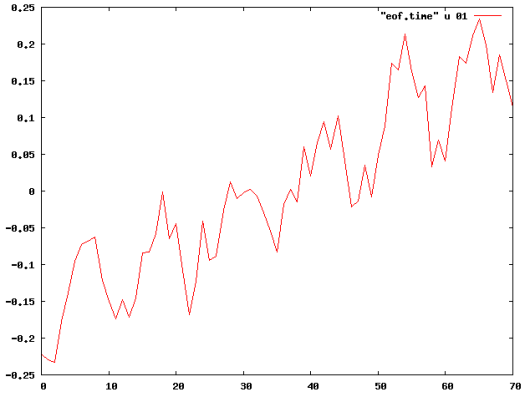
Achievements – Greenland (GRACE)





Mass loss ≈140 Gt/yr
(Jan 03 – Dec 08)

First EOF EQWH
(CSR RL04, SH 50, SM 1 DEG)

In-situ, SAR, altimetry, etc.? Gravity missions for calibration of models? Do we need continuous observation by gravity missions or every now and then a snapshot?

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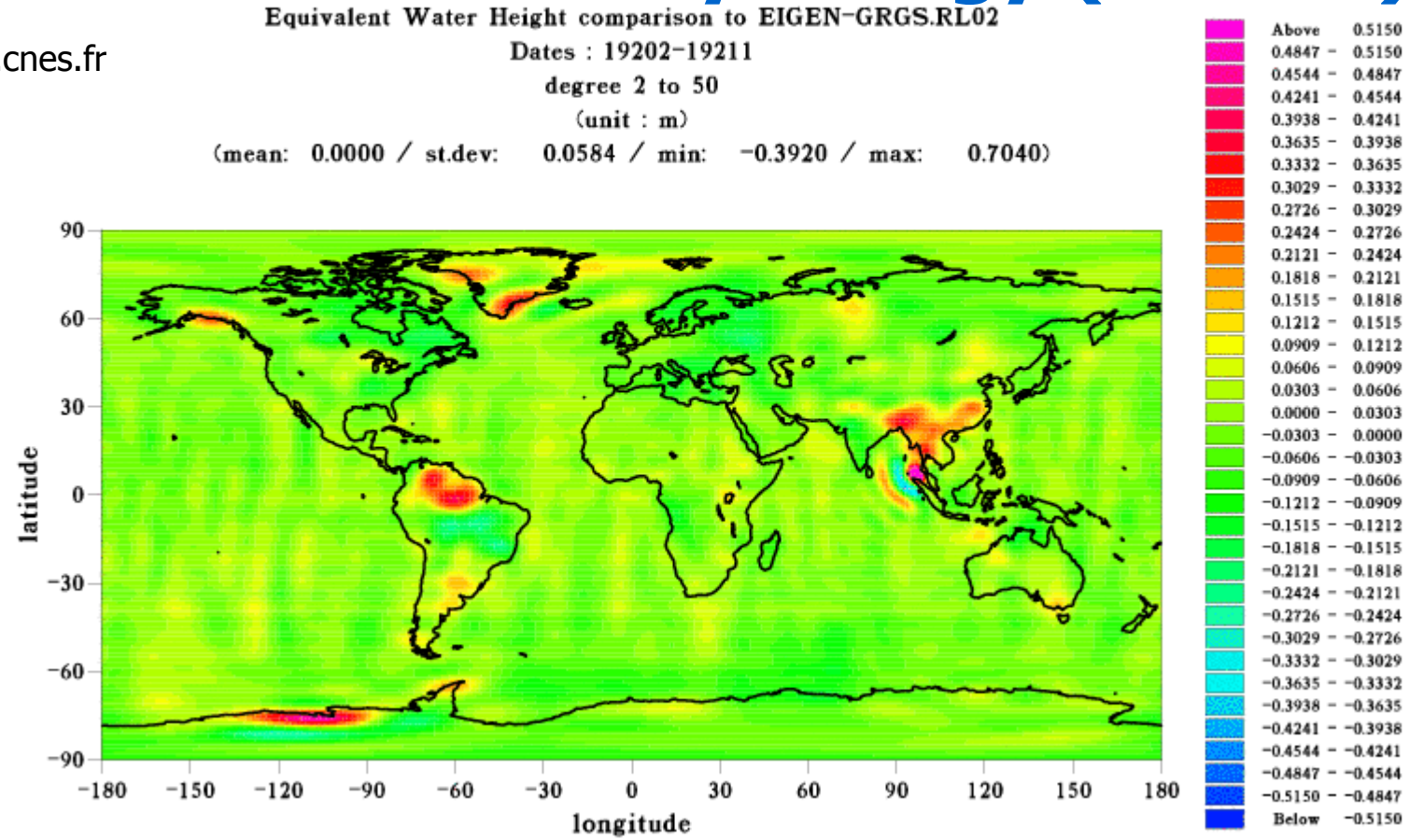
Achievements – Hydrology (GRACE)

Credit: bgi.cnes.fr



Calibration of models possible with GRACE? Focus on continuity or enhanced spatial resolution (10-50 km)?

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(Anticipated) achievements – Solid Earth

Since the gravity measurements taken by GOCE reflect density variations in the Earth's interior, the resulting data will lead to new insights into processes occurring in the lithosphere and upper mantle - down to a depth of about 200 km. This detailed mapping along with seismic data is expected to shed new light on the processes causing earthquakes and volcanic activity and potentially lead to an improvement in the prediction of such events.

GOCE will also further our knowledge of land uplift due to post-glacial rebound. This process describes how the Earth's crust is rising a few centimetres in Scandinavia and Canada as it has been relieved of the weight of thick ice sheets since the last Ice Age - when the heavy load caused the crust to depress. As a result, there is global redistribution of water in the oceans. Hence, a better understanding of these processes help in assessing the potential dangers of current sea-level change. *(ESA web pages)*

General: slow processes → focus on spatial resolution?

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Prospects existing missions

- GRACE:
  - Extension to 2011 approved*
  - Predicted lifetime 2013* (11-yr lifetime!)
- GOCE:
  - Successful commissioning
  - First MOP started
- Generic:
  - Improved processing: possibilities?

*GSTM2008

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Prospects – improved processing

- Continuous updates of de-aliasing products: atmosphere, oceans, tides
- Possibilities for co-estimation and/or filtering of e.g. tides
- Observation pre-processing (calibration, satellite attitude reconstruction)
- Gravity field representation, e.g. local support functions such as mascons
- Longer time spans (>10 yr for GRACE?) → better possibilities for separating signals
- …??

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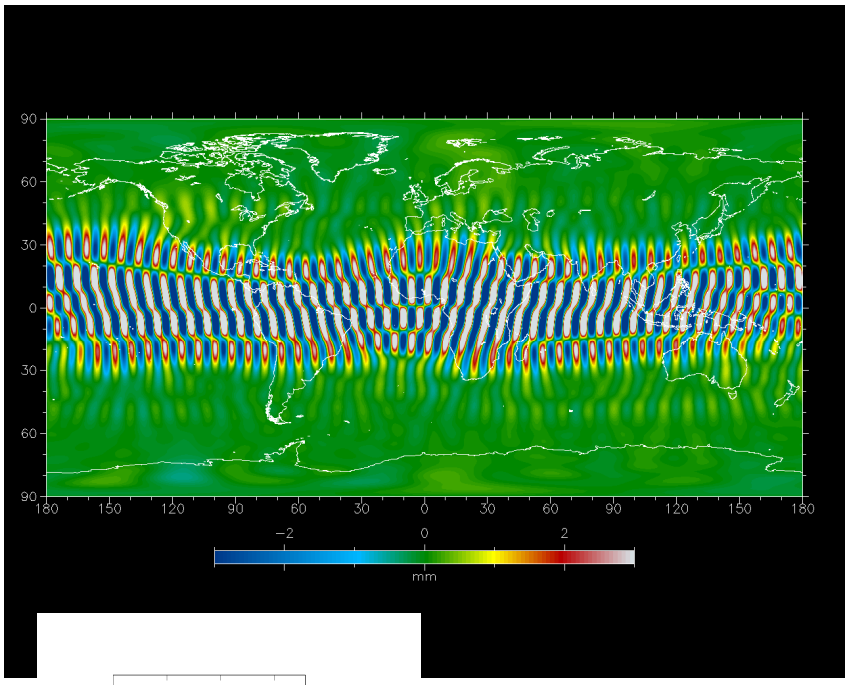
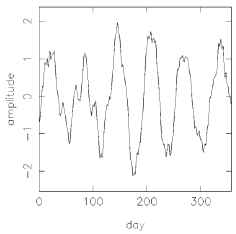
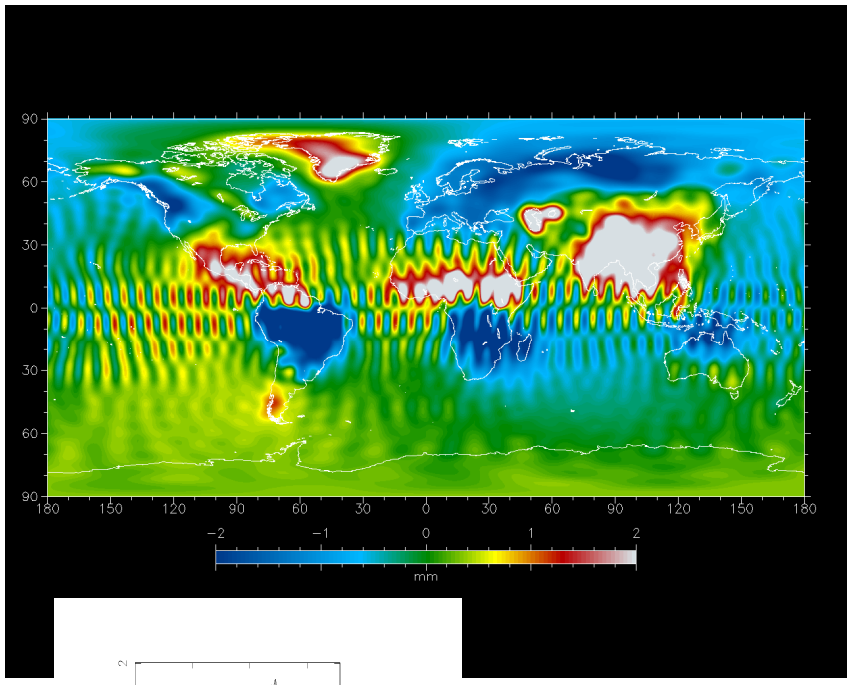
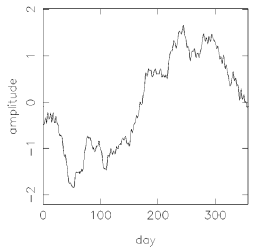
Filtering out of ocean tides: example from end-to-end simulation





Unfiltered





Filtered

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Existing missions: limitations

- GRACE:
  - Temporal resolution ≈ 10 days – 1 month
  - Spatial resolution ≈ 500 km (≈ 200 km for mission "static")
- GOCE (TBC):
  - 1.5-3(?) yr snapshot of static gravity field at spatial resolution of ≈ 100 km
  - Temporal gravity for short periods at enhanced spatial resolution (combination with GRACE)?
- Generic:
  - Inhomogeneous: confluence of tracks (better performance) at poles

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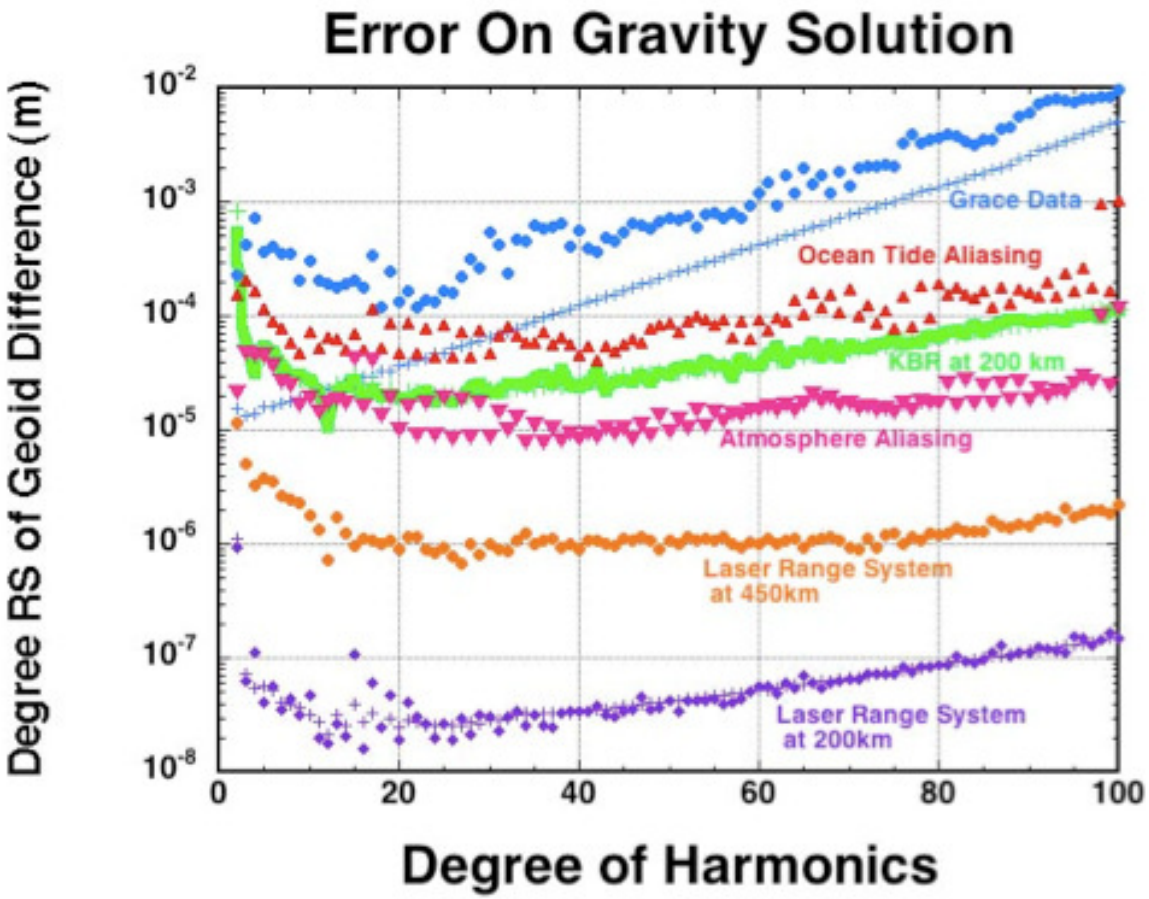

Improving sensor/satellite systems vs. improving post-processing, de-aliasing models?

*GSTM2008

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Future missions - requirements

Why do we need follow-ons?:

- Enhanced temporal and spatial resolution: scientific and societal justification (political, agencies support) – trade-offs?
- Most prominent breakthroughs in hydrology, glaciology and oceanography: what's next?

User community:

- Geodesists need to stimulate user community (even) more
- Potential for extending the current user community
- How to make user community more (pro-)active?

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Future missions – technology (H/W)

- Low-low satellite-to-satellite tracking: laser (shorter baselines), microwave (longer baselines)
- Accelerometers
- Drag-free control
- Attitude control/observation/reconstruction (STR, …)
- GNSS (GPS, GLONASS, Galileo, …)

- Constellation (expensive)

- General question: is significantly improved spatial resolution uberhaupt possible with the above techniques or do we need more exotic technologies, e.g. atomic clocks?

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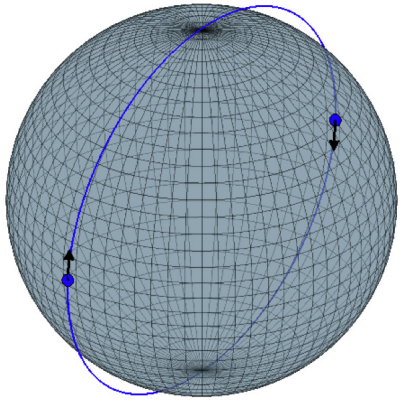
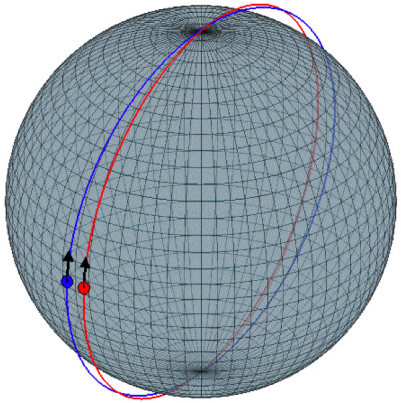
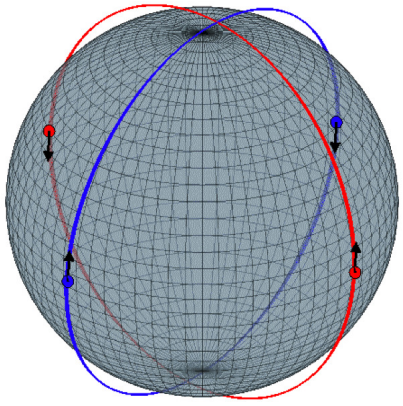
Mission concepts



Temporal resolution



Spatial resolution



Combined

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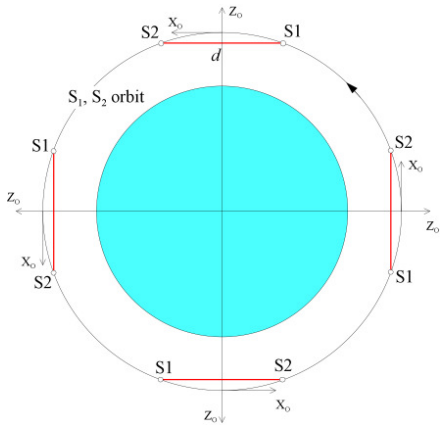
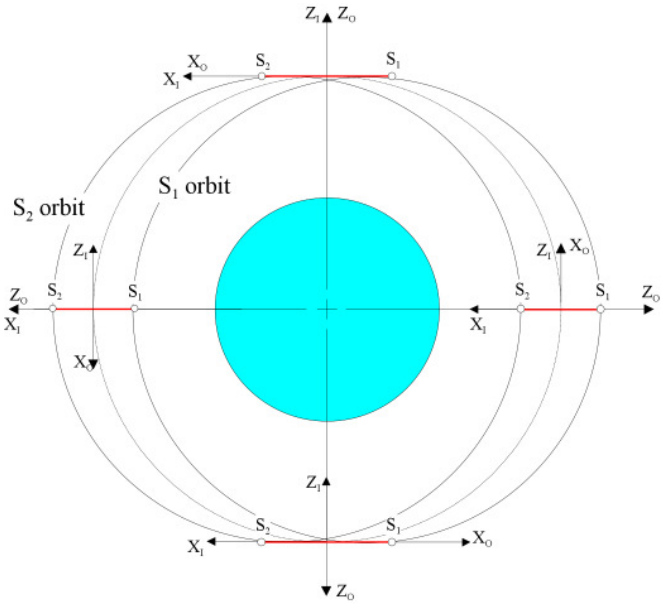
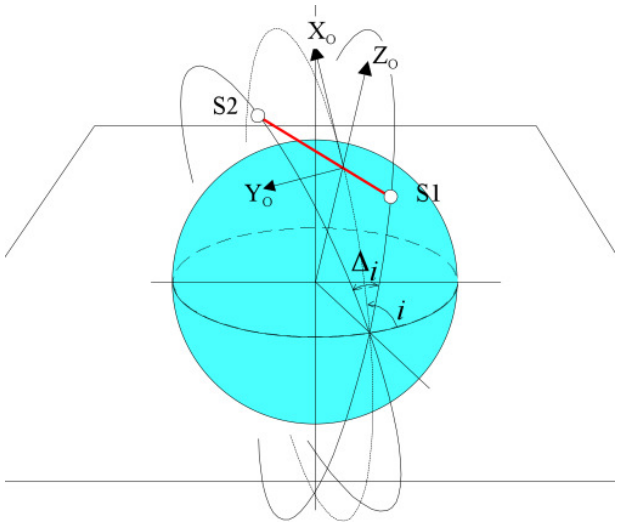
Mission concepts



Phase difference



Cartwheel



Pendulum

Future missions – ongoing activities

- GRACE Follow-on/II (NASA)
- NGGM (ESA)
- National initiatives (Germany, France, Japan, …)

Characteristics of these efforts:

- Combined expertise of industrial and scientific teams
- Focus on low-low SST by laser

General: many studies focus on mission design (also on improving gravity estimation methods). Stronger focus on applications required?

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Conclusions

- Fascinating, impressive results achieved with GRACE and anticipated for GOCE: do/will these results justify continuous/enhanced space-borne gravimetry?
- Technology vs. post-processing: biggest return on investment?
- Further stimulation, growth of user community?
- Many ongoing activities: how to converge, organize ourselves?

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