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Outstanding Student Poster & PICO Contest

EGU General Assembly 2022

Sensor and performance modeling of an optical accelerometer for future gravity field missions

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G4.1 Modern Concepts for Gravimetric Earth Observation, 26 May 2022

Sharing is encouraged

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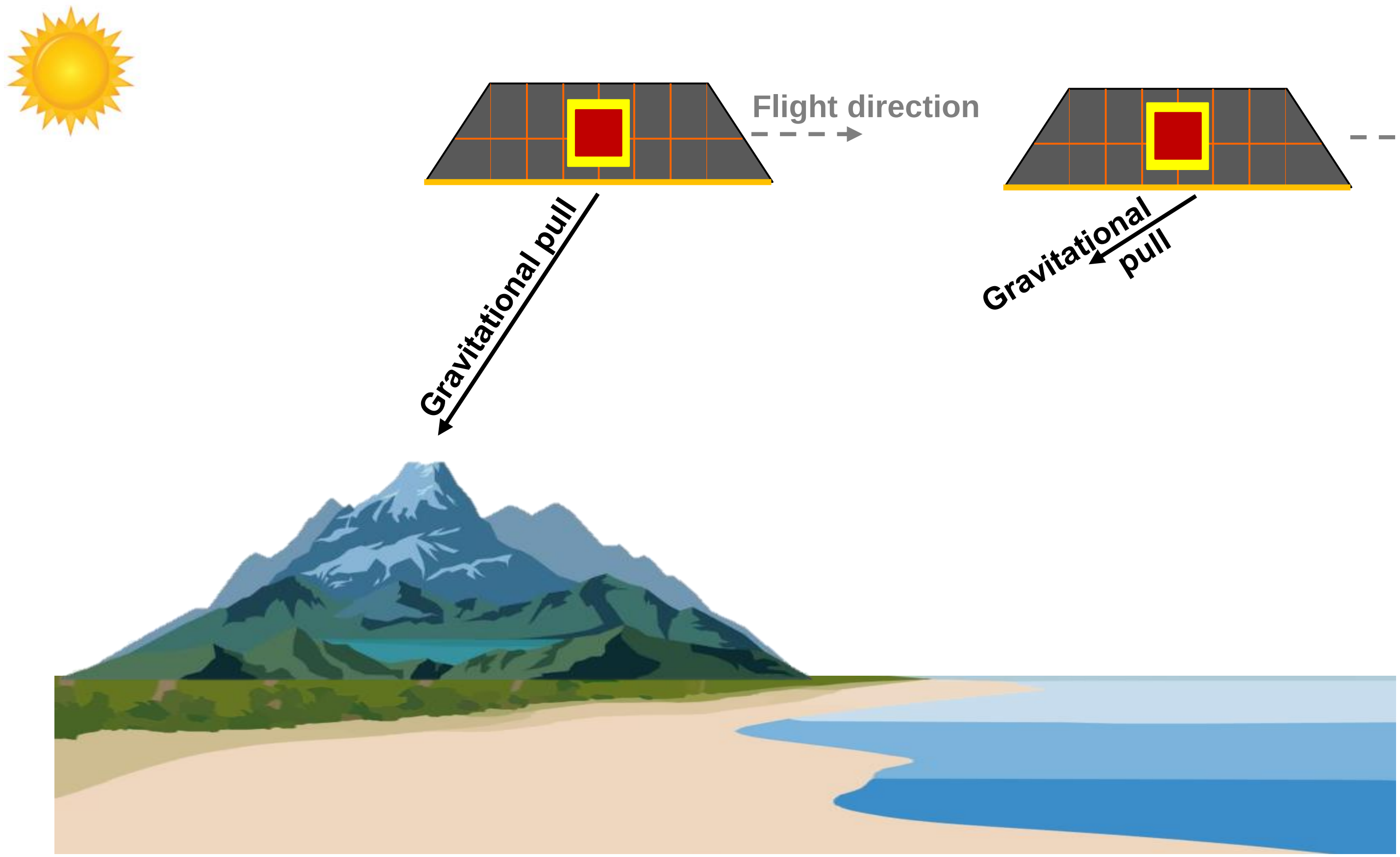
GRACE(-FO) measurement principle

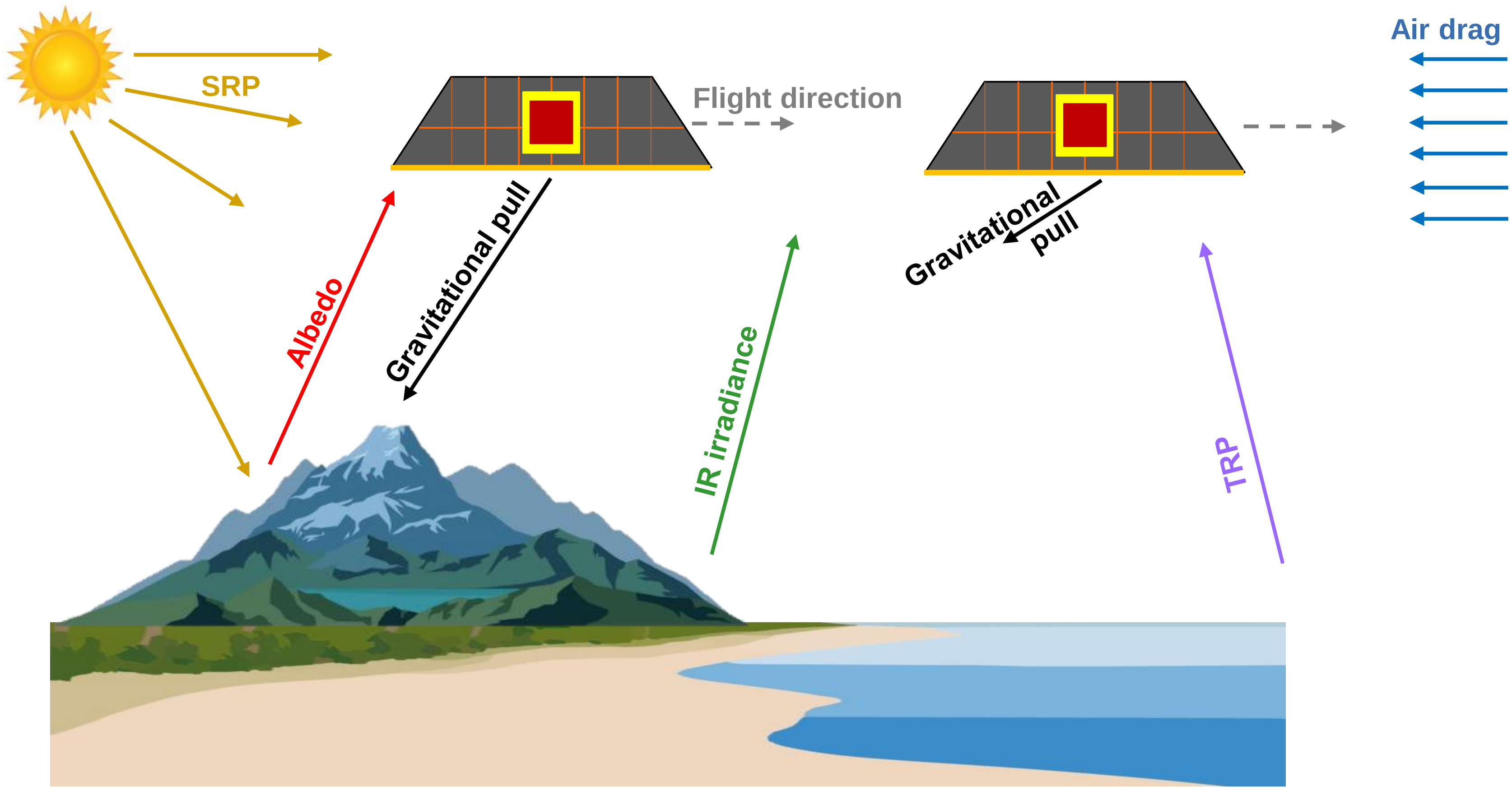
- In order to derive ***gravitational*** attraction of the Earth mases, the effect of ***non-gravitational*** forces have to be subtracted from measurements.



Measurement principle of GRACE(-FO) missions

GRACE(-FO) measurement principle

- In order to derive ***gravitational*** attraction of the Earth mases, the effect of ***non-gravitational*** forces have to be subtracted from measurements.
- Impact of ***non-gravitational*** accelerations on the inter-satellite distance removed using measurements from the accelerometers



Measurement principle of GRACE(-FO) missions

Limitations of electrostatic accelerometers

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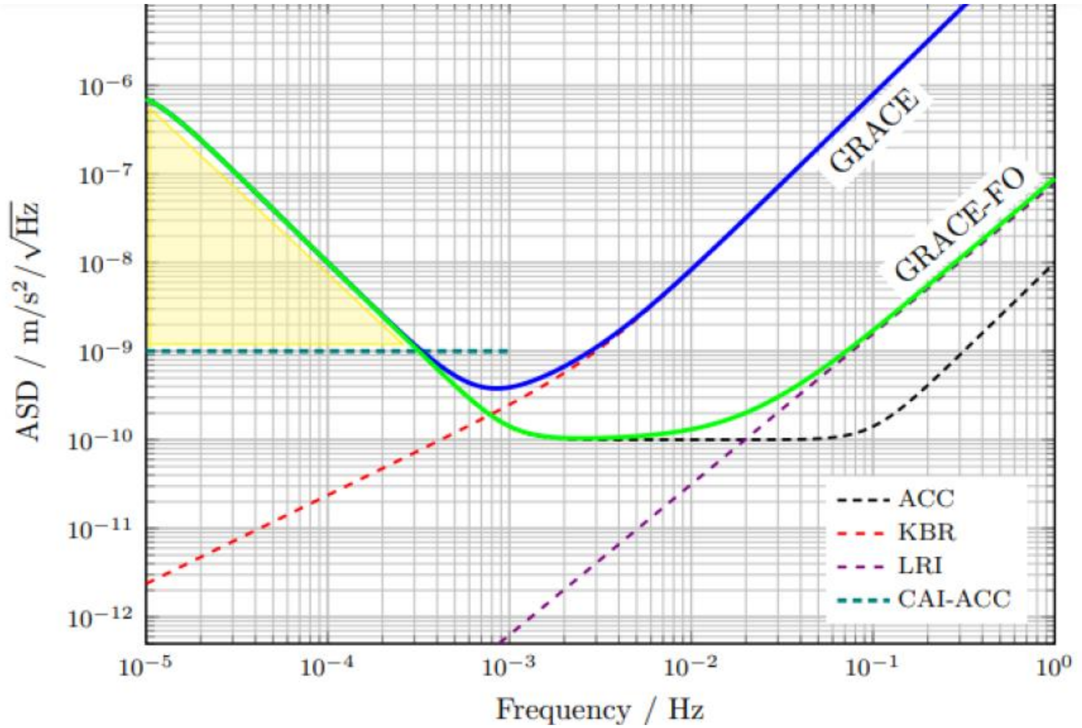
- Electrostatic accelerometers (EA) have poor resolution in low frequencies, due to:
  - Parasitic accelerations on the TM (e.g. stiffness of gold wire, Lorentz force etc.) [Frommknecht et al. 2003]
  - Temporal aliasing (under sampling of high frequency mass variations in Earth system) [Alvarez et al. 2022]



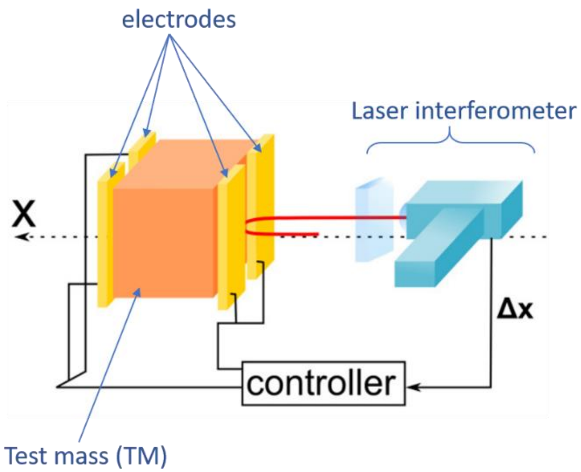
ASD of EA accelerometers for GRACE family missions

- **KBR** – K-band range ACC (microwave)
- **LRI** – Laser-range interferometer ACC
- **CAI** – Cold atomic ACC

Image source: Müller J, et al. [2021]

Improvements from optical accelerometers

- Electrostatic accelerometers sensing test mass (TM) motion by capacitive sensing.
  - Under the impact of the non-gravitational forces the TM moves
  - Capacitance varies linearly with the amplitude of the TM motion.
- Optical accelerometers sensing TM position by use of laser interferometry



Optical accelerometer configuration

Image source: modified from Douch K, et al. [2017]

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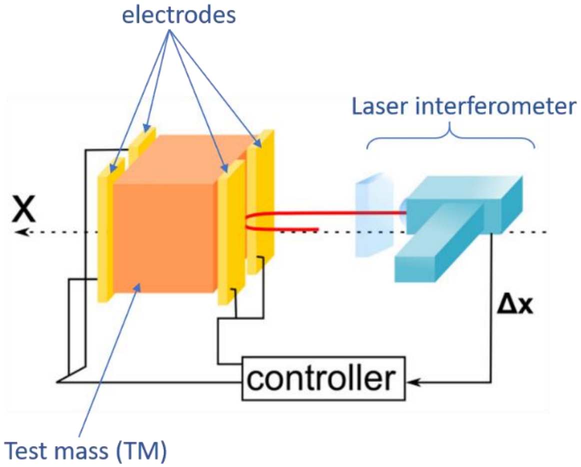

Optical accelerometer configuration

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- Optical ACC = Electrostatic control of TM + Optical readout of TM position

GRACE(-FO) LISA Pathfinder

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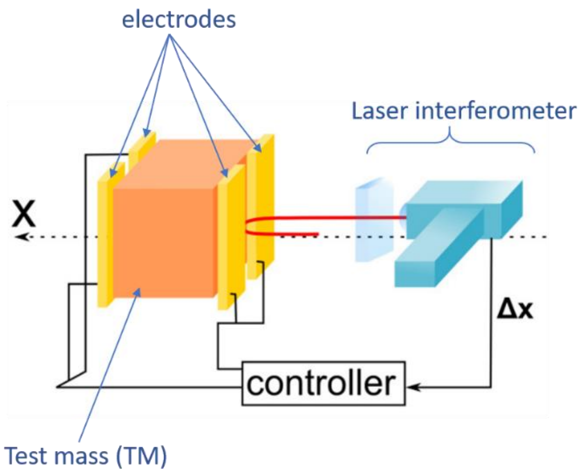

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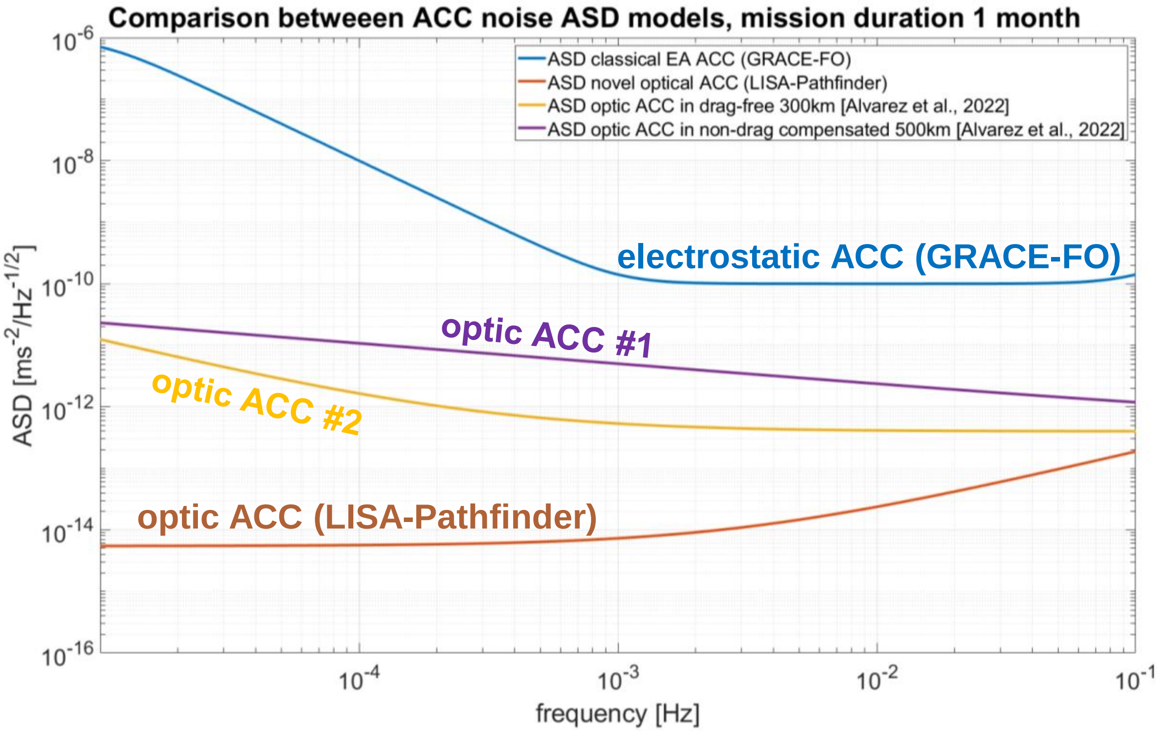

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GRACE(-FO) LISA Pathfinder

GFR solutions comparison (single sat. pair)

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- Monthly gravity field recovery (GFR) solutions comparison from GRACE-FO and NGGM concepts
  - EIGEN-6c4 reference gravity model, without AOD

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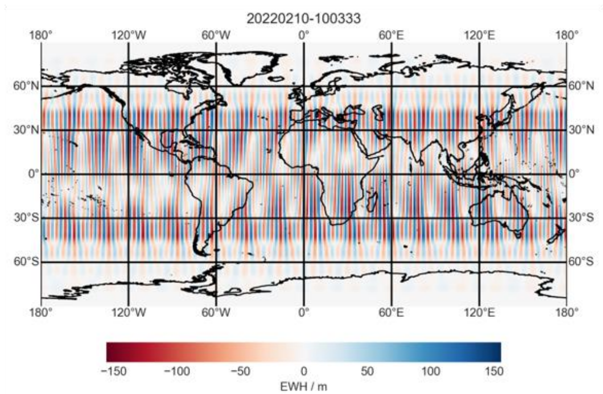
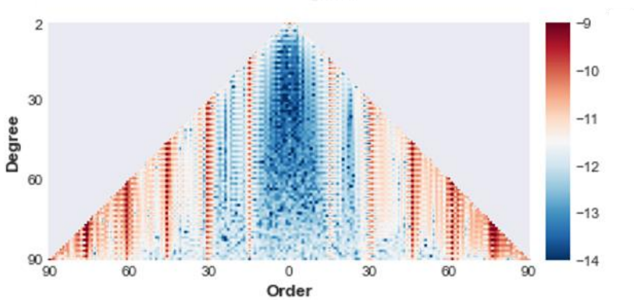
GRACE-FO

- Intra-satellite: classical electrostatic ACC
- Inter-satellite: KBR
- Dual satellite config., alt.: 450 km





EWH amplitude: **±150** m

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NGGM # 1

- Intra-satellite: novel optical ACC
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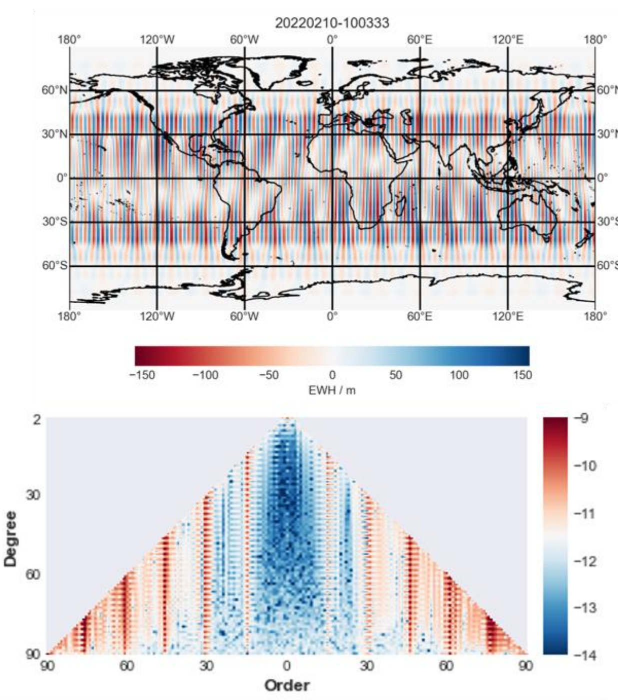

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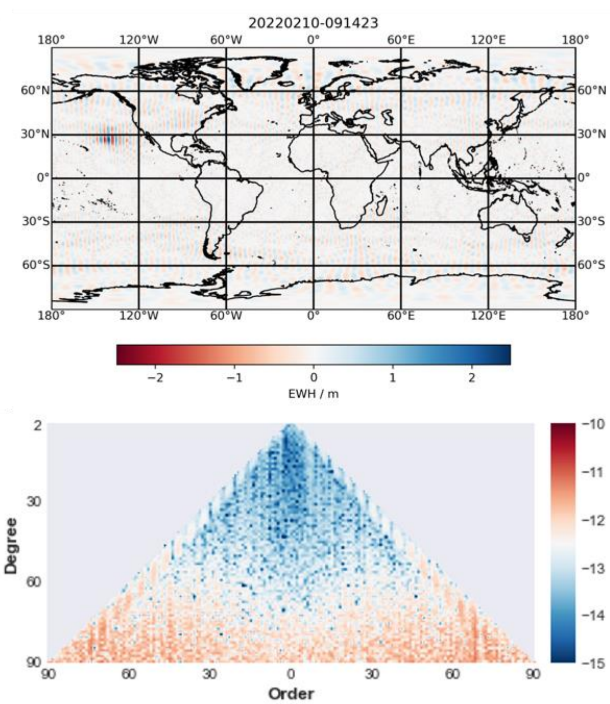

EWH amplitude: ±**2** m

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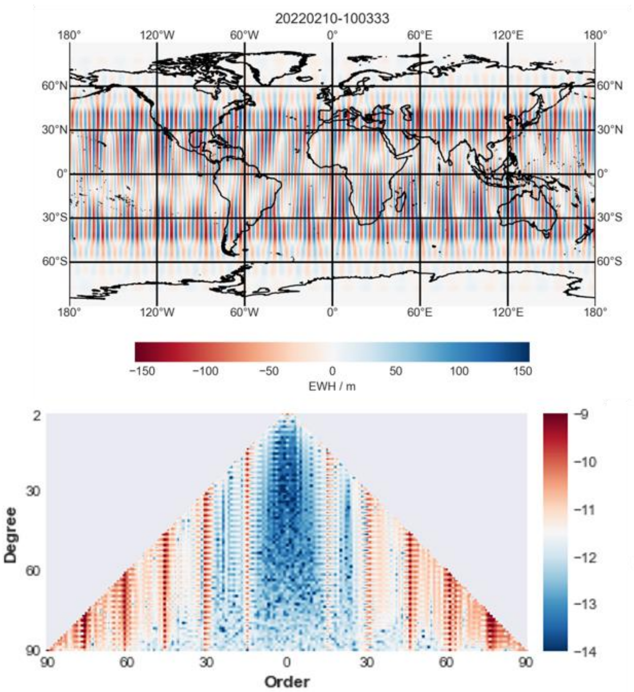
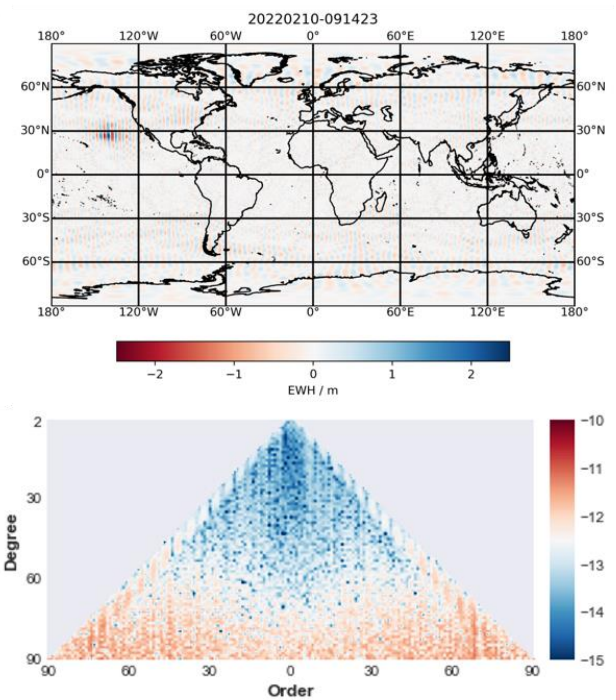
NGGM # 2
- Intra-satellite: novel optical ACC
- Inter-satellite: LRI
- Dual satellite config., alt.: 450 km



EWH amplitude: ±**150** m



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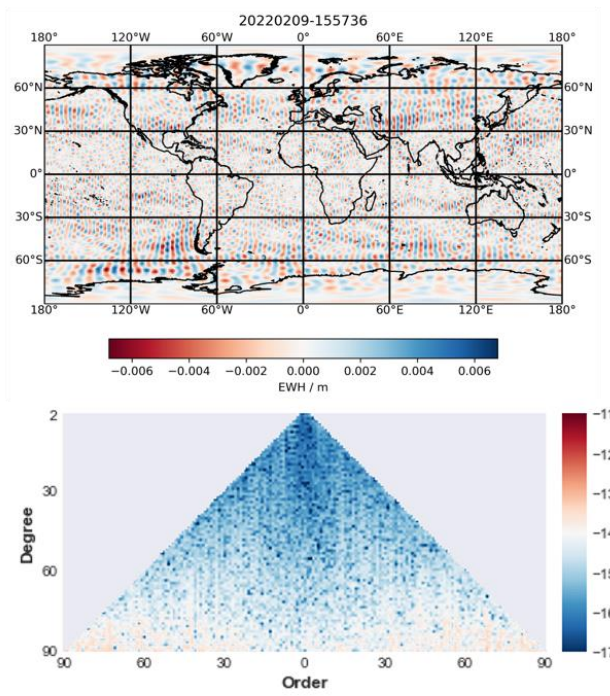

EWH amplitude: ±**0.006** m

GFR from Bender constellation

- Monthly gravity field solutions for the Bender (2 satellite pairs) configuration
    - Inter-satellite LRI
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    - EGM2008 reference gravity model, without AOD:

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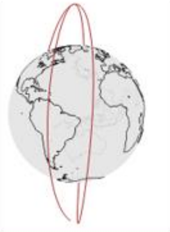

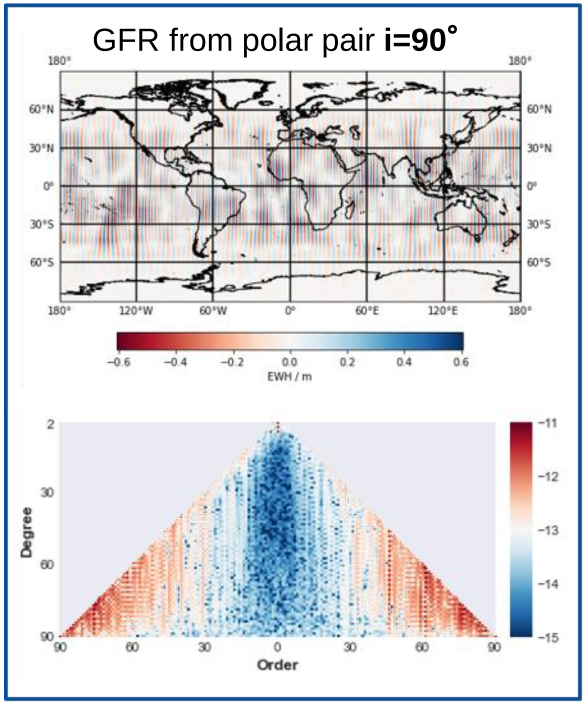

EWH amplitude: ±**0.6** m

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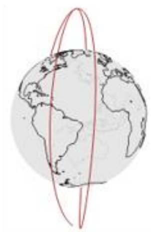

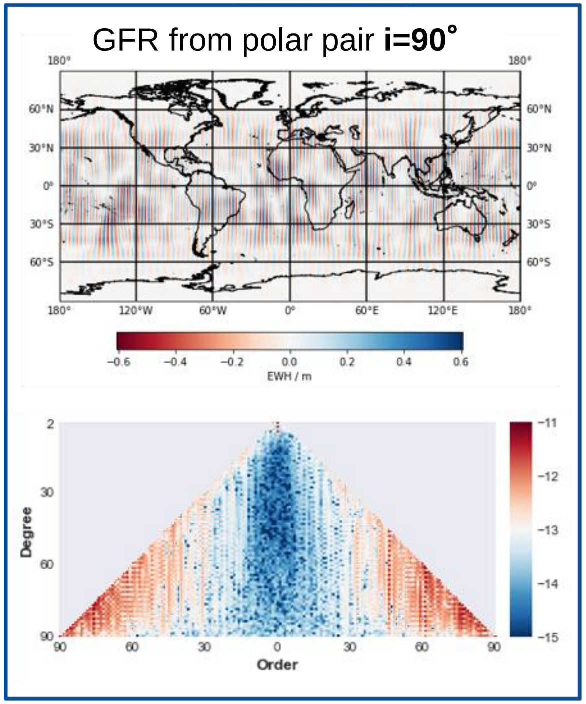

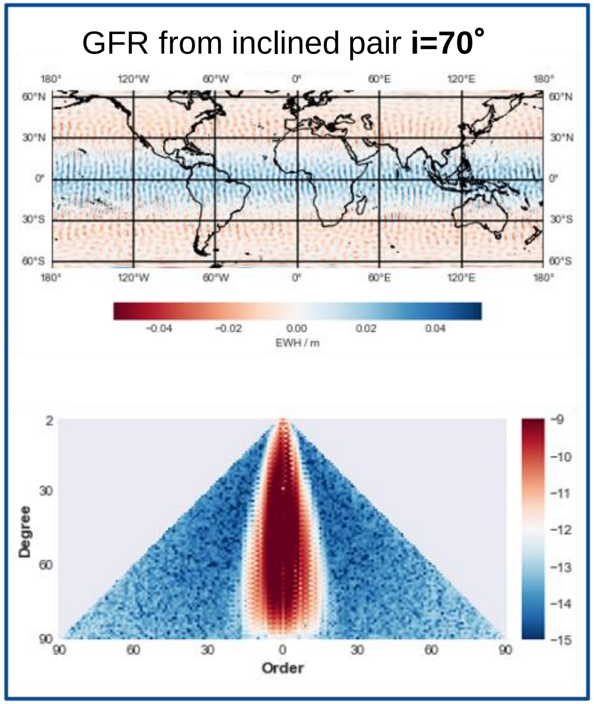

EWH amplitude: ±**0.6** m

EWH amplitude: ±**0.04** m

GFR from Bender constellation

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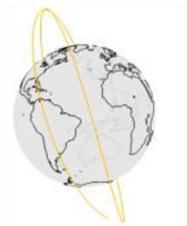
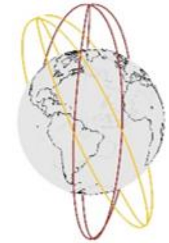
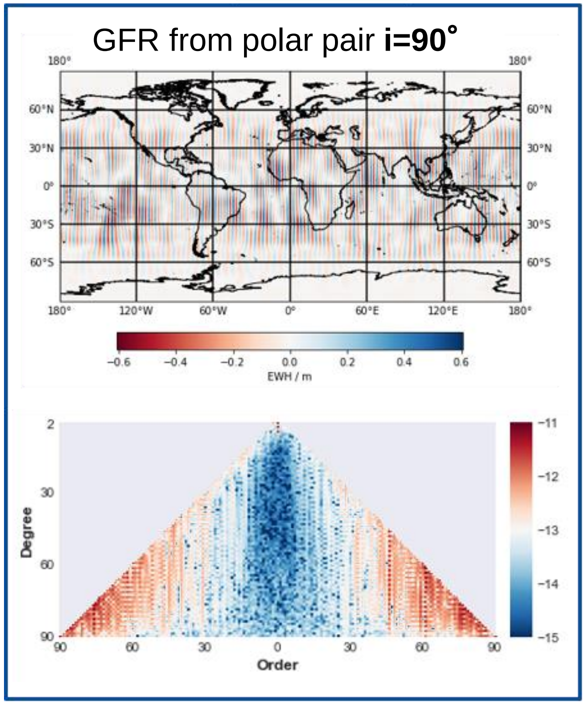
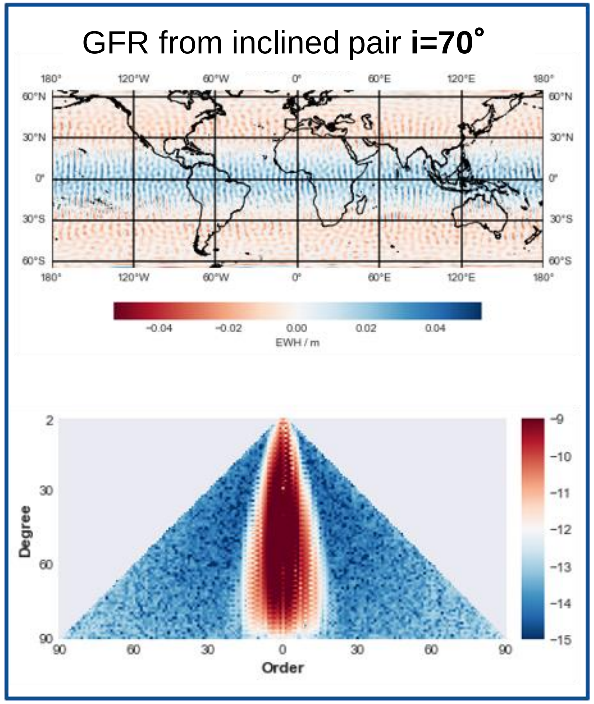
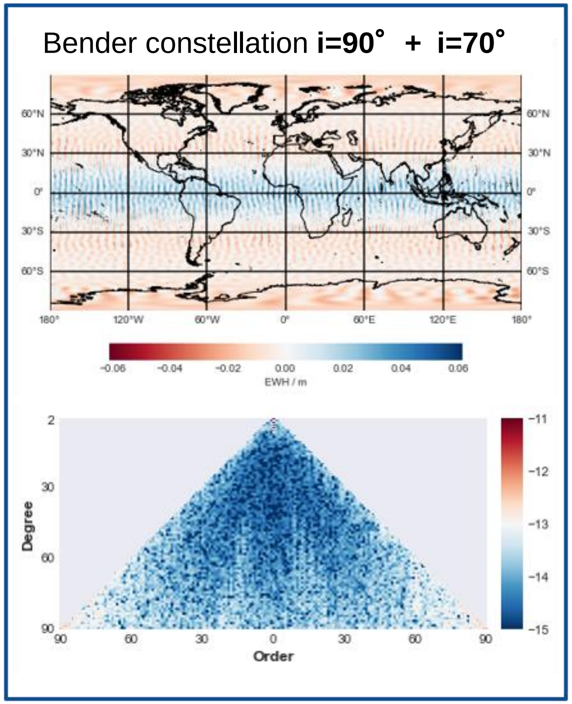










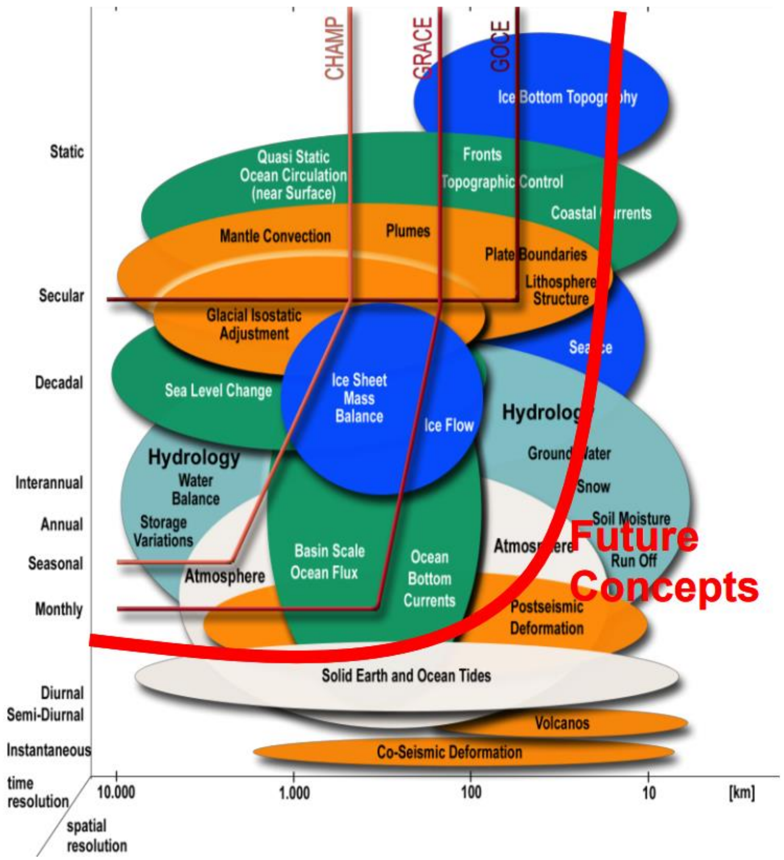
EWH amplitude: ±**0.6** m

EWH amplitude: ±**0.04** m

EWH amplitude: ±**0.06** m

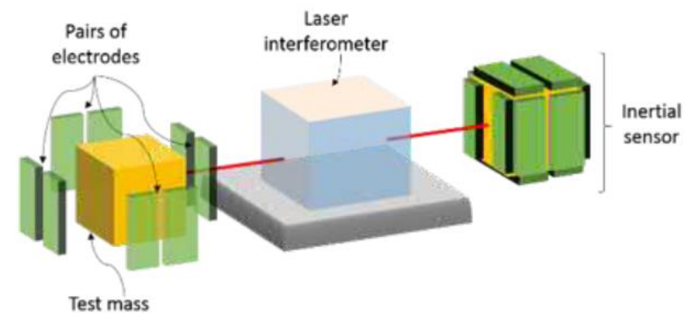
NGGM optical gradiometery

- Enhanced gradiometry (consisting of optical ACCs) would improve determination of the ***static*** gravity field and might even observe ***time-variable*** gravity changes



Spatial and temporal signatures of the gravity signal covered by CHAMP, GRACE and GOCE

Image source: Massotti L., et al. [2013]



Scheme of the optical, single-axis gradiometer

Optical Vs. Electrostatic gradiometer

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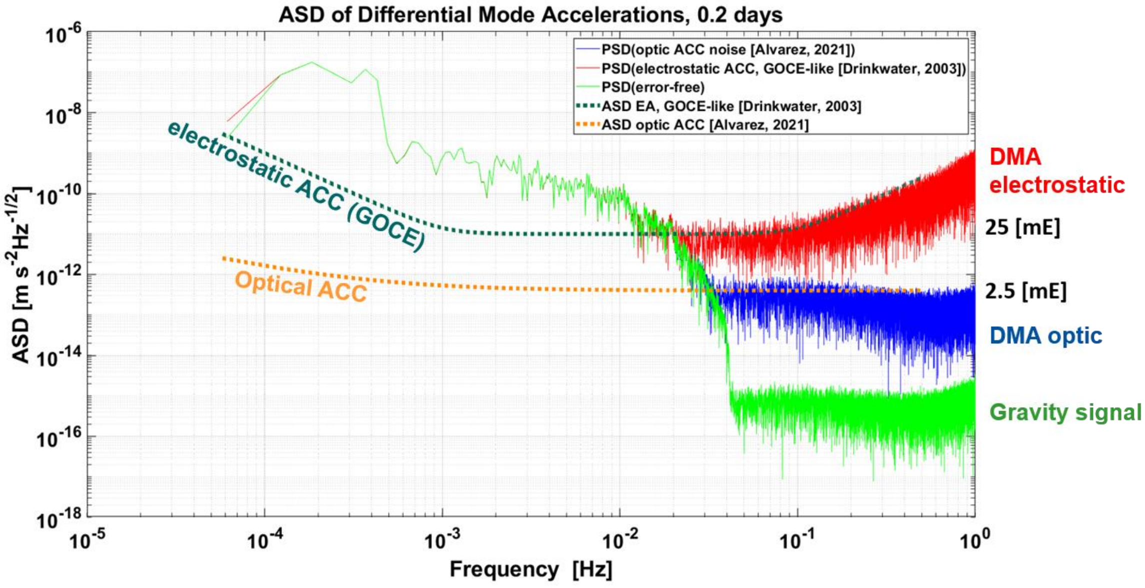
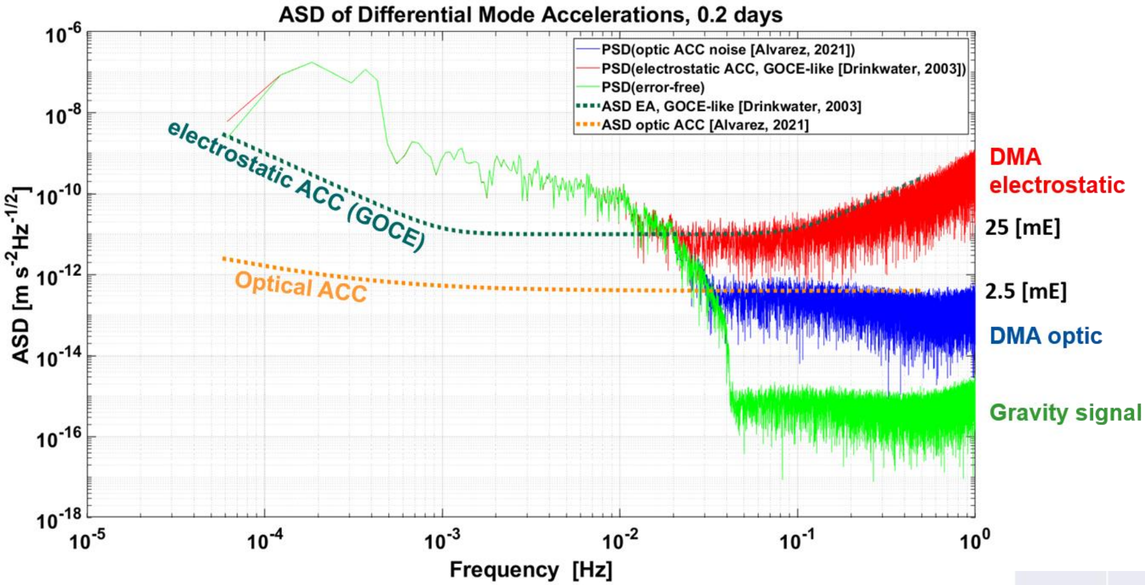


ASD of Differential Mode Accelerations (DMA) for electrostatic and optical ACCs

Optical Vs. Electrostatic gradiometer



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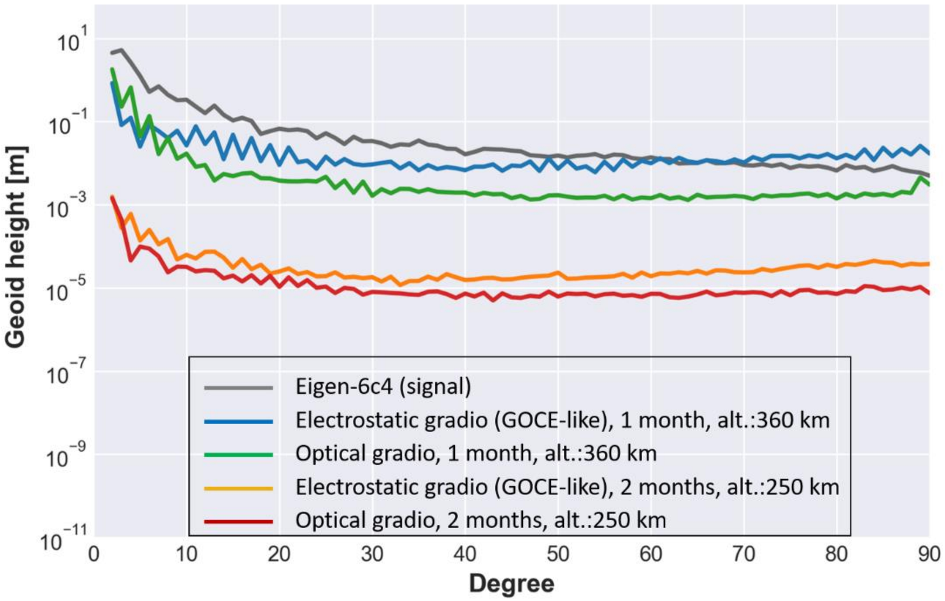

Degree medians of the Eigen-6C4 signal and of the errors of various simulations

(medians of the coefficients difference between recovered and reference gravity fields)

Conclusions & Acknowledgements

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- Novel optical gradiometers can improve not only spatial, but also temporal resolution in comparison to GOCE mission

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