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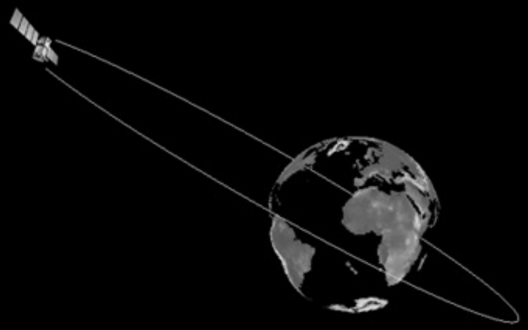

Precise orbit determination and accelerometer data modelling of the GRACE Follow-On mission

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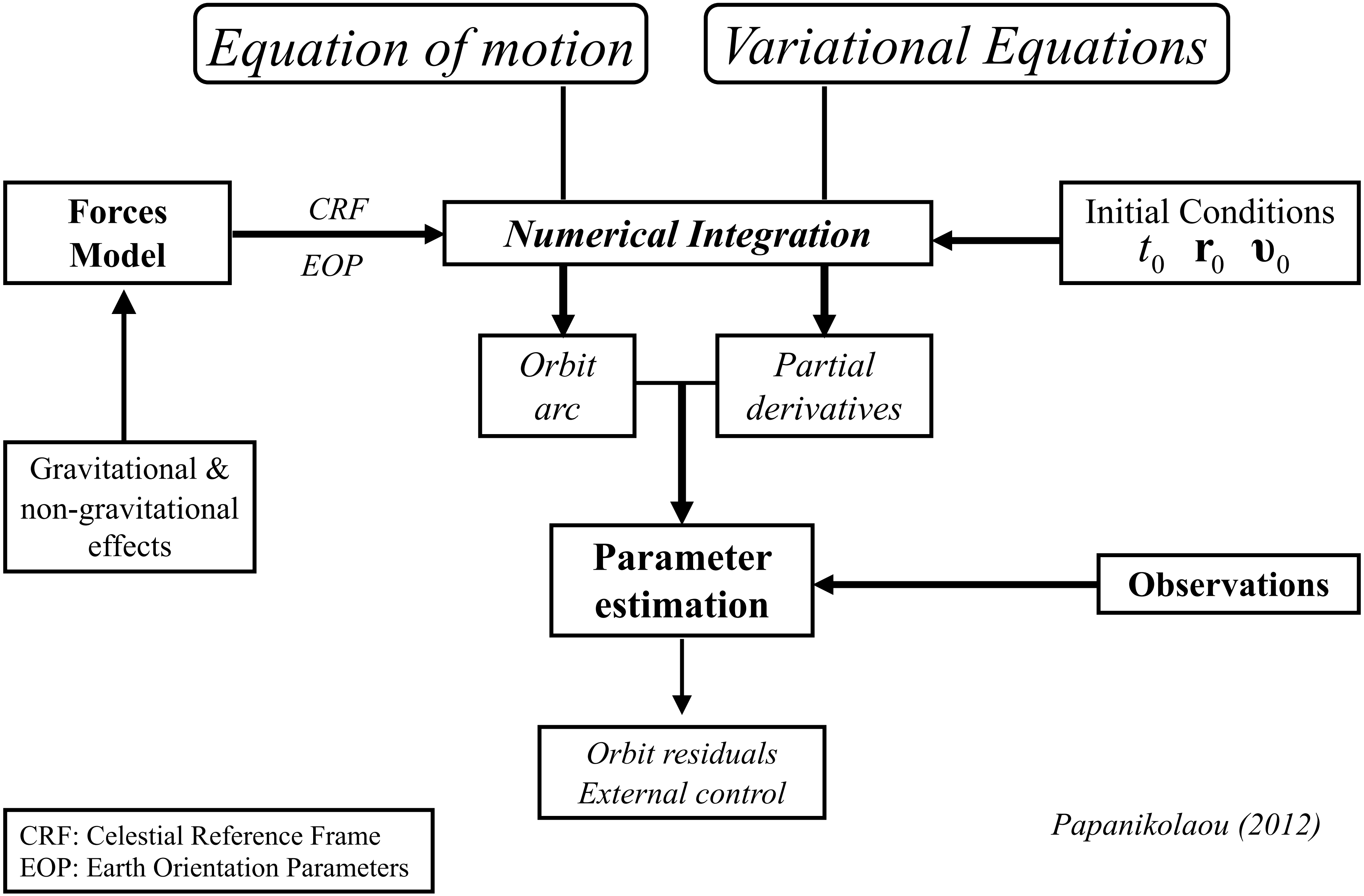
Outline

- Dynamic Orbit Determination application to GRACE-FO
- GRACE-FO acceleromer calibration modelling
- Empirical parameter estimation (acclerations, 1-CPR)
- LRI intersatellite ranging data analysis



Papanikolaou (2012)

GRACE-FO orbital dynamics and Accelerometer calibration modelling	
Orbit arc length	Daily orbit arcs
Earth Orientation	IERS Conventions 2010 (Petit and Luzum 2010) and updates
EOP	IERS 08 C04; IAU2006/200A
Numerical Integrator	Gauss-Jackson 12th order; RKN7(6)-8 start integrator (Papanikolaou and Tsoulis 2016)
Integration step	10 sec
Pseudo-Observations	Kinematic Orbit XYZ (Suesser-Rechberger et al. 2020)
Gravity Model (d/o)	GOCO06s (Kvas et al. 2019)
Planetary/Lunar Ephemeris	DE423 (Folkner et al. 2009)
Solid Earth Tides	IERS Conventions 2010 (Petit and Luzum 2010)
Ocean Tides	FES2014b model (Lyard et al. 2021)
Pole Tide	Solid Earth Pole Tide and Ocean Pole Tide (IERS Conventions 2010)
Atmosphere and Ocean De-Aliasing effects	AOD1b RL06 data processing (Dobslaw et al. 2017)
Relativistic effects	IERS Conventions 2010 (Petit and Luzum 2010)
Accelerometers	ACC1B data (McCullough et al. 2019) + estimated parameters: Full Scale matrix (9 parameters), Bias (XYZ), (optional: Bias drift 1st and 2nd order)
Empirical Forces of periodic terms	One-Cycle per revolution (1-CPR) accelerations
Empirical accelerations (bias)	Piecewise Accelerations per 1 revolution with interval 15 min in orbital frame (RTN) or spacecraft frame (SRF)
Intersatellite range-rate data	Laser Ranging Interferometry LRI1B (as observations and external validation tool) K-Band Ranging KBR1B (as external accuracy assessment)
External Orbit Comparison	GNV1B orbit data (Wen et al. 2019)

GRACE-FO accelerometer calibration modelling

- **Calibration modelling**: Bias, Full Scale matrix (9 parameters), Bias Drift (1^{st} and 2^{nd} derivatives) as optional estimation (replaced via estimation of empirical parameters)

- **Empirical accelerations**: Piecewise-Constant accelerations per 1rev/1h, time interval 15 to 30 min

- **Periodic accelerations**: 1 cycle per revolution (sin and cos terms)

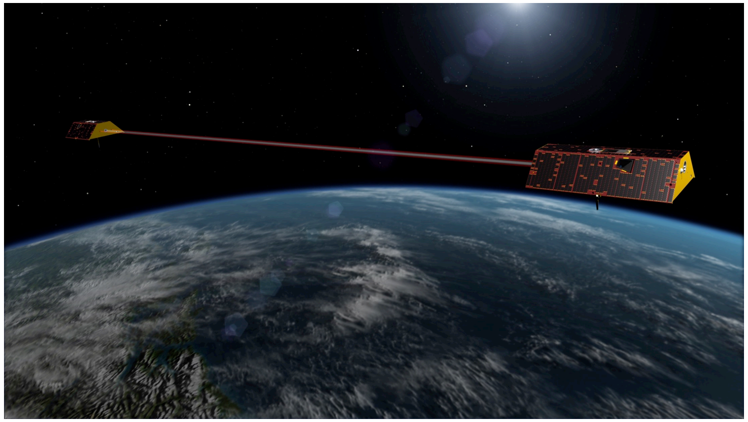
- **Reference Frame**: Orbital frame (RTN or TN) or Spacecraft frame (SRF)

$$\mathbf{f}_{\mathbf{non-grav}} = \mathbf{f}_{\mathbf{acc}} + \mathbf{a}_{\mathbf{bias}} + \mathbf{a}_{\mathbf{CPR}}$$

$$\mathbf{f}_{\mathbf{acc}} = \mathbf{b} + \mathrm{R} * \mathrm{ACC}_{1\mathrm{B}} + \left(\dot{\mathrm{b}}\mathrm{t} + \ddot{\mathrm{b}}\mathrm{t}^2\right)$$

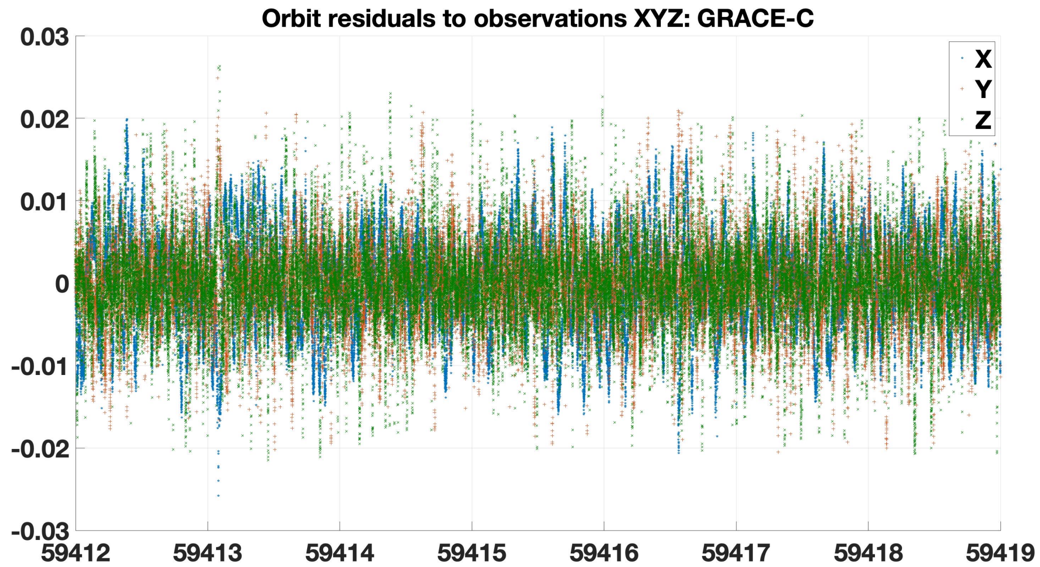
$$\mathbf{a}_{\mathbf{bias}}(t) = \sum_i \delta(\mathrm{t} - \mathrm{t_i}) \cdot \mathbf{a}_{\mathbf{t_i}}$$ at predefined epochs $t_i^0 < t_i \leq t_i^0 + \Delta t$

$$\mathrm{a}_{\mathrm{CPR}}^{\mathrm{e}} = \mathrm{C_e}\cos(\mathrm{u}) + \mathrm{S_e}\sin(\mathrm{u})$$

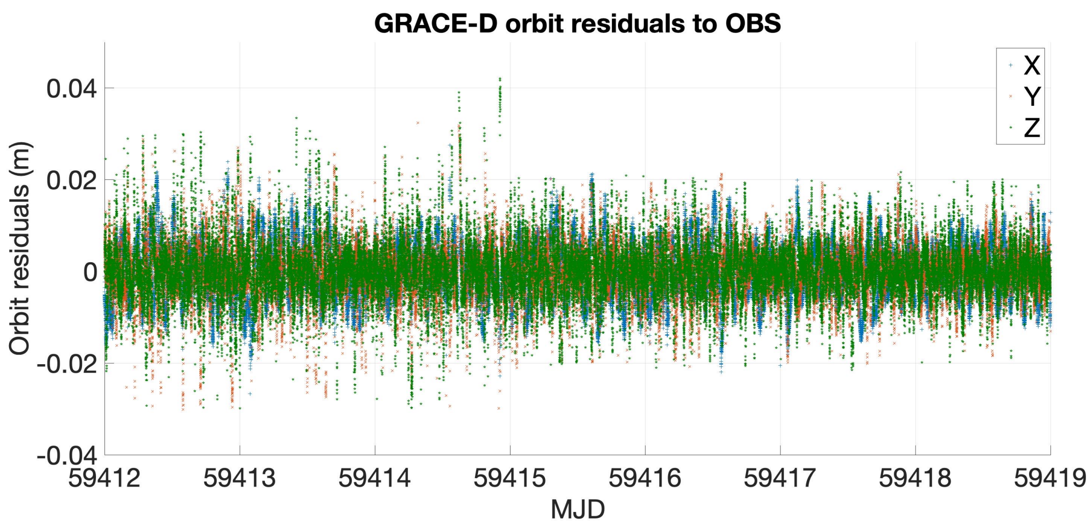


GRACE Follow-on mission (Credit: NASA)

GRACE-FO orbit residuals: Weekly analysis

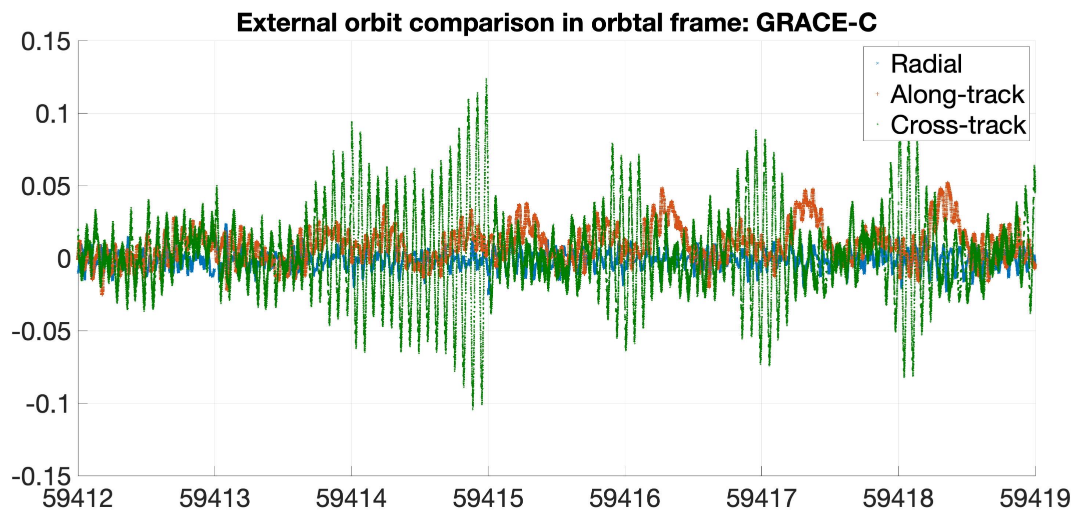


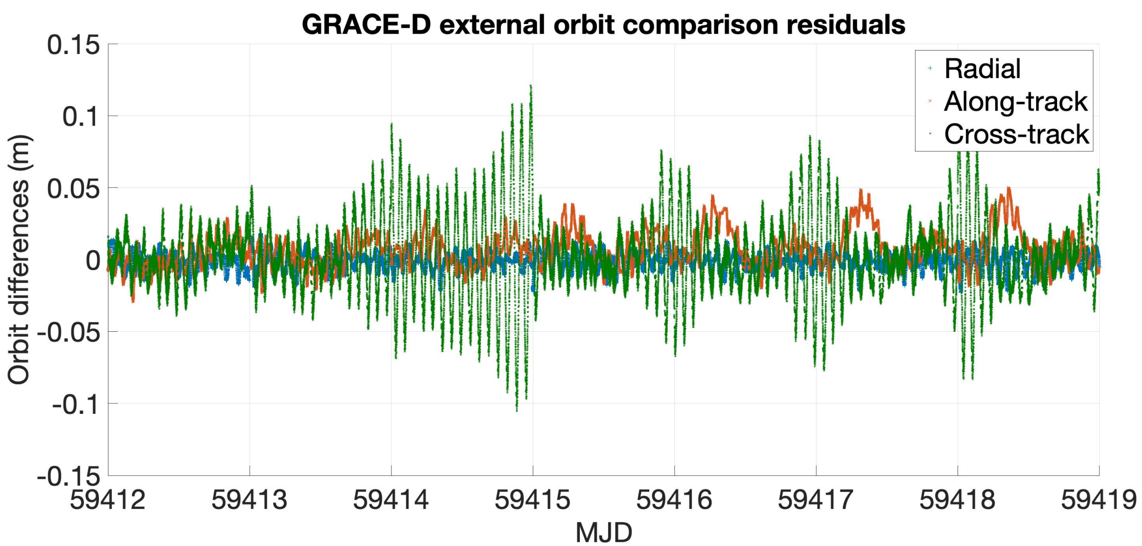
RMS: 8.8 mm



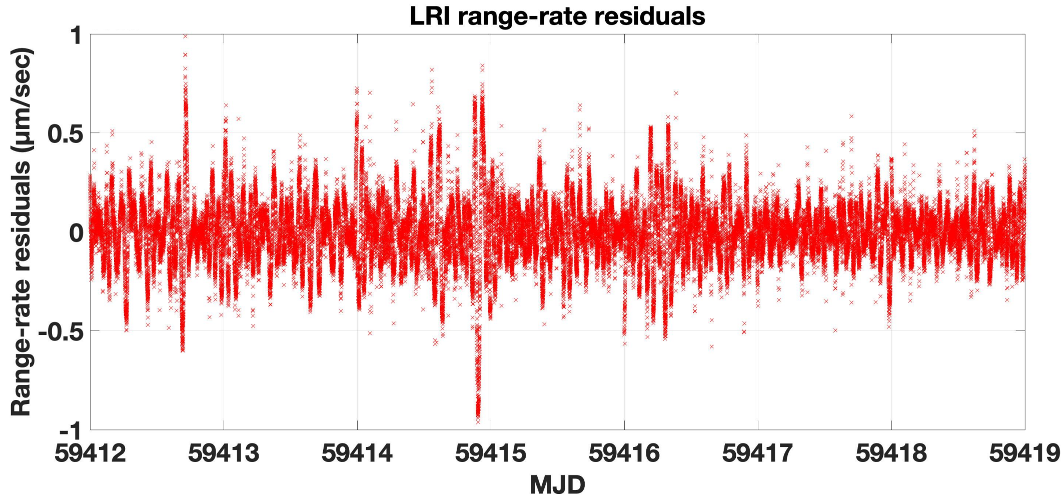
RMS: 9.7 mm

GRACE-FO external orbit comparison

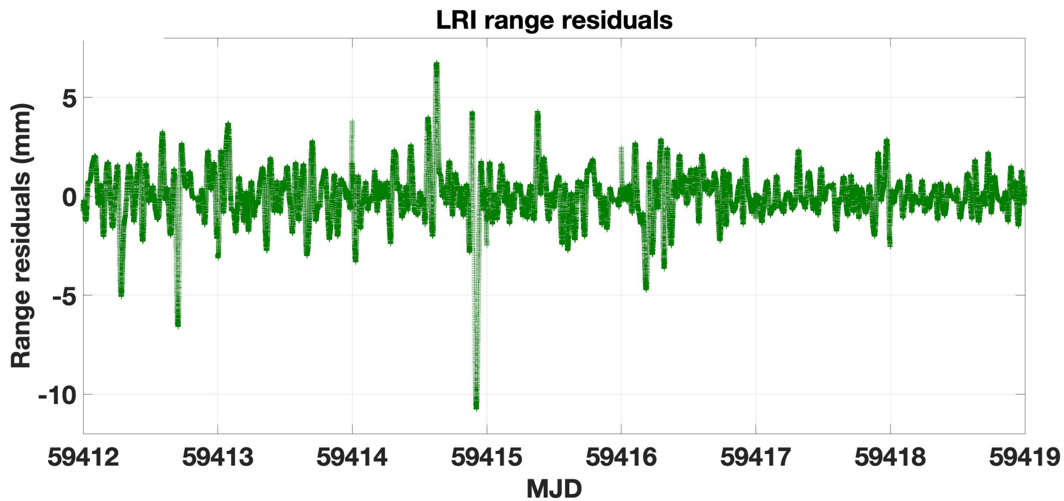




GRACE-FO LRI range & range-rate data



RMS: 1.5 µm/sec



RMS: 1.3 mm

GEORB

GEORB (GEodetic ORBit analysis)

- Precise Orbit Determination of LEOs
- Data analysis of satellite gravity missions (GRACE-FO, GRACE, GOCE)
- Orbit Design of future satellite missions
- References: Papanikolaou (2022; 2012), Papanikolaou and Tsoulis (2018)
- Release as open source (https://github.com/Thomas-Loudis/georb)

Summary and Future steps

- GRACE-FO orbit determination (few mm to cm)
- Acclerometer calibration modelling (calibration parameters and empirical bias accelerations per revolution)
- LRI range-rate residuals at few μm/sec
- LRI range-rate to be applied as observations (preliminary results show improvement)
- LRI range-rate as constraints of the accelerometer calibration parameters over the along-track (and normal track) direction

Thank you for your attention