Assessment of GPS-based accelerometry performance with adaptive filter settings

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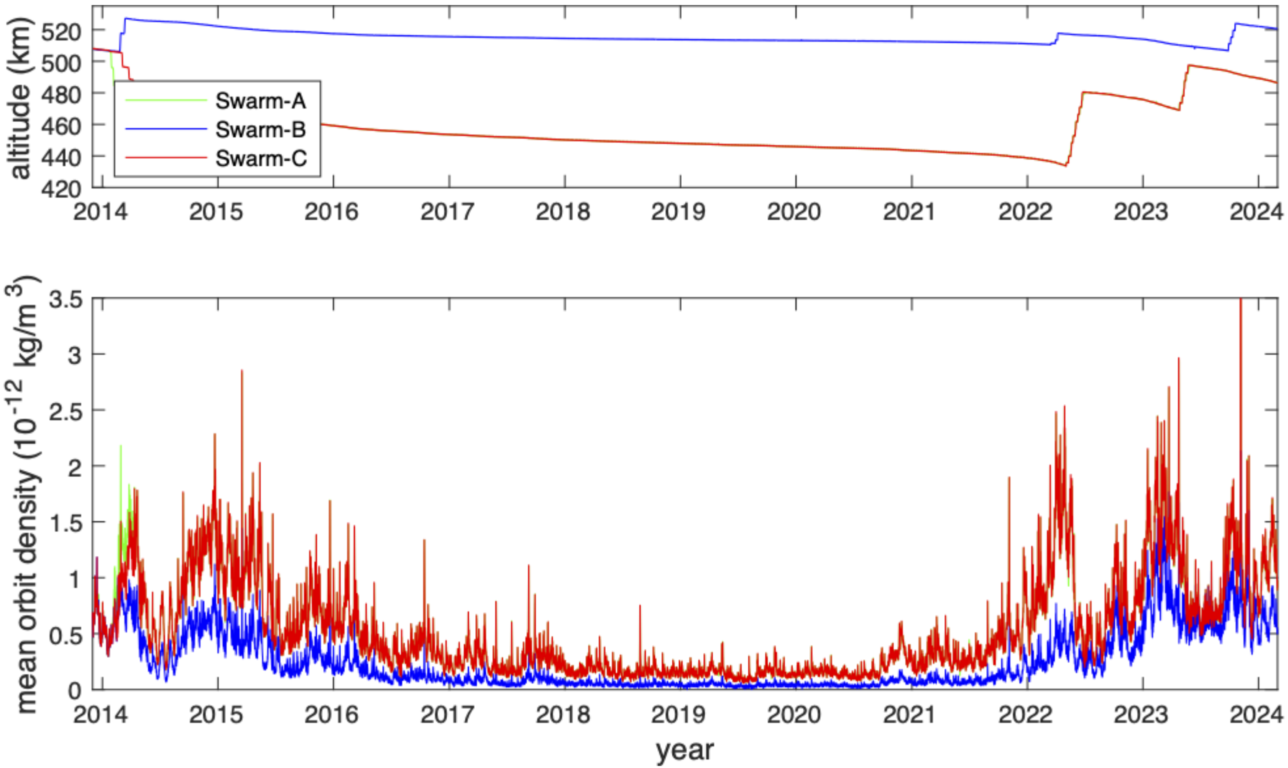
Swarm GPS-derived densities

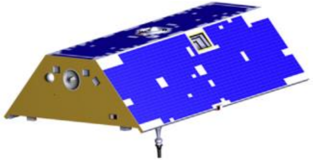


Density signal varies over the mission with clear impact of solar cycle and altitude.
GPS-based accelerometry settings are fixed and optimized for early mission.

GPS-accelerometry performance assessment using GRACE data

- The GRACE satellites deliver high-accuracy accelerometer data → allows accurate comparison with GPS-derived results
- The GRACE satellites have experienced a large range of density signals from 10^{-13} kg/m^3 to 10^{-11} kg/m^3 → allows tuning of filter settings for various conditions

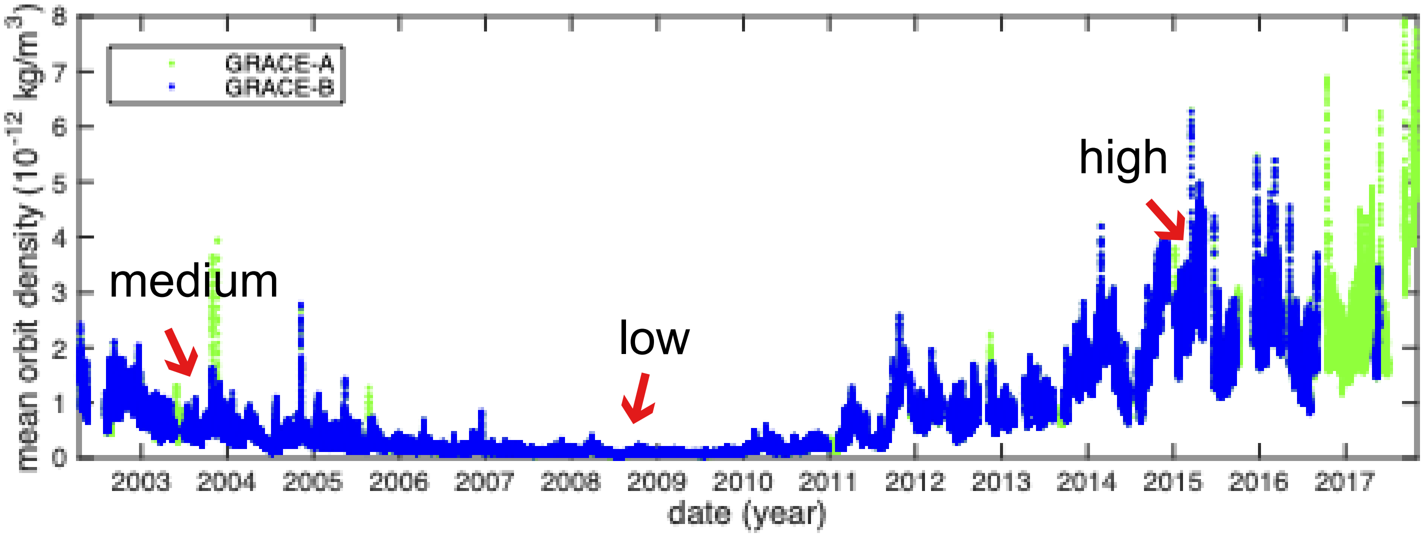
Swarm



Grace

Test periods

case	satellite	period	mean density
low	Grace-B	November 2008	1.01 10^{-13} kg/m^3
medium	Grace-B	November 2003	7.77 10^{-13} kg/m^3
high	Grace-B	April 2015	21.79 10^{-13} kg/m^3



Selection taking into account: temperature control / data gaps / maneuvers

Implementation GRACE GPS-based accelerometry chain

Implementation based on Swarm L2 GPS-based accelerometry chain

- Extended Kalman filter approach with DLR GHOST s/w using 26hr arcs
- Undifferenced ionosphere-free GPS observations
- Final CODE ephemeris and 5s clock product
- Attitude information from star tracker data
- GRACE PCV map provided by Astronomical Institute of University of Bern
- Estimation of float carrier phase ambiguities
- State-of-the-art gravitational modelling
- SRP, Earth albedo and infrared modeling based on 8-plate macro model with surface properties for absorbed, diffusely or specular reflected radiation
- Instantaneous reemission thermal modeling for non-solar panel surfaces
- Smooth empirical accelerations recover the aerodynamic signal

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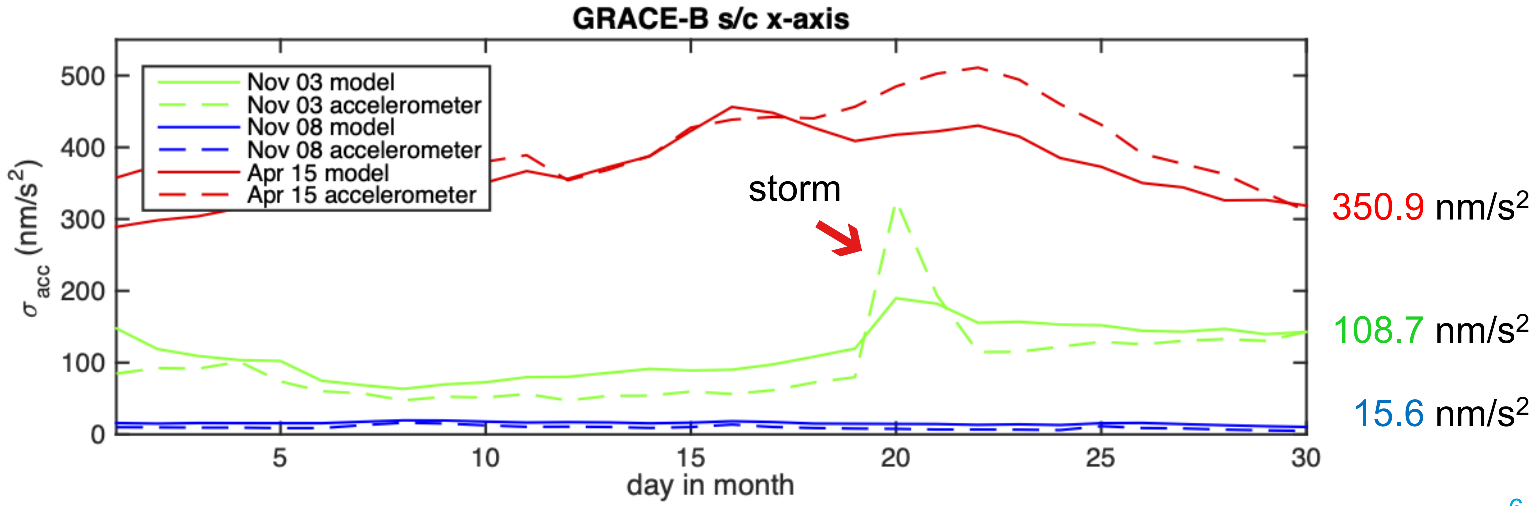
Tuning of emprical accelerations → adaptive σ_P

Empirical accelerations that absorb the aerodynamic signal are defined by a steady-state variance σ_a, process noise σ_P and correlation time τ.

In radial and cross-track direction small aerodynamic signal → σ_P = 5 nm/s^2.
In along-track direction large variation in aerodynamic signal → adaptive σ_P.
Adaptive σ_P is based on variance of NRLMSISE-00 model accelerations.



Quality measures

Comparison GPS-derived aerodynamic accelerations with accelerometer data

- Remove RP signal from accelerometer data using the same panel model
- Rotate GPS-derived accelerations from orbit to satellite body frame

Quality measures

- RMS differences (accelerometer – GPS)
- Relative recovery error (RMS_{diffs}/RMS_{acc})
- Correlation
- PSD

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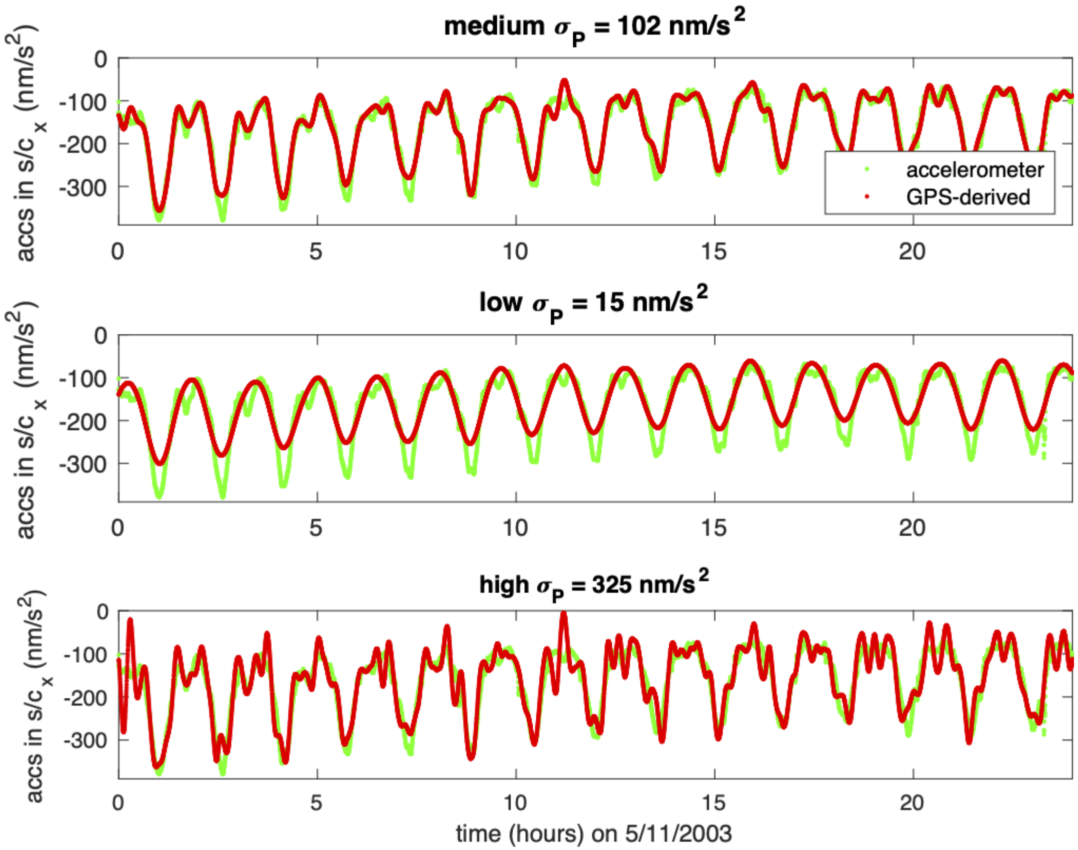
Impact of different process noise settings



RMS	18.0 nm/s^2
rel error	10.1 %
correl.	0.973

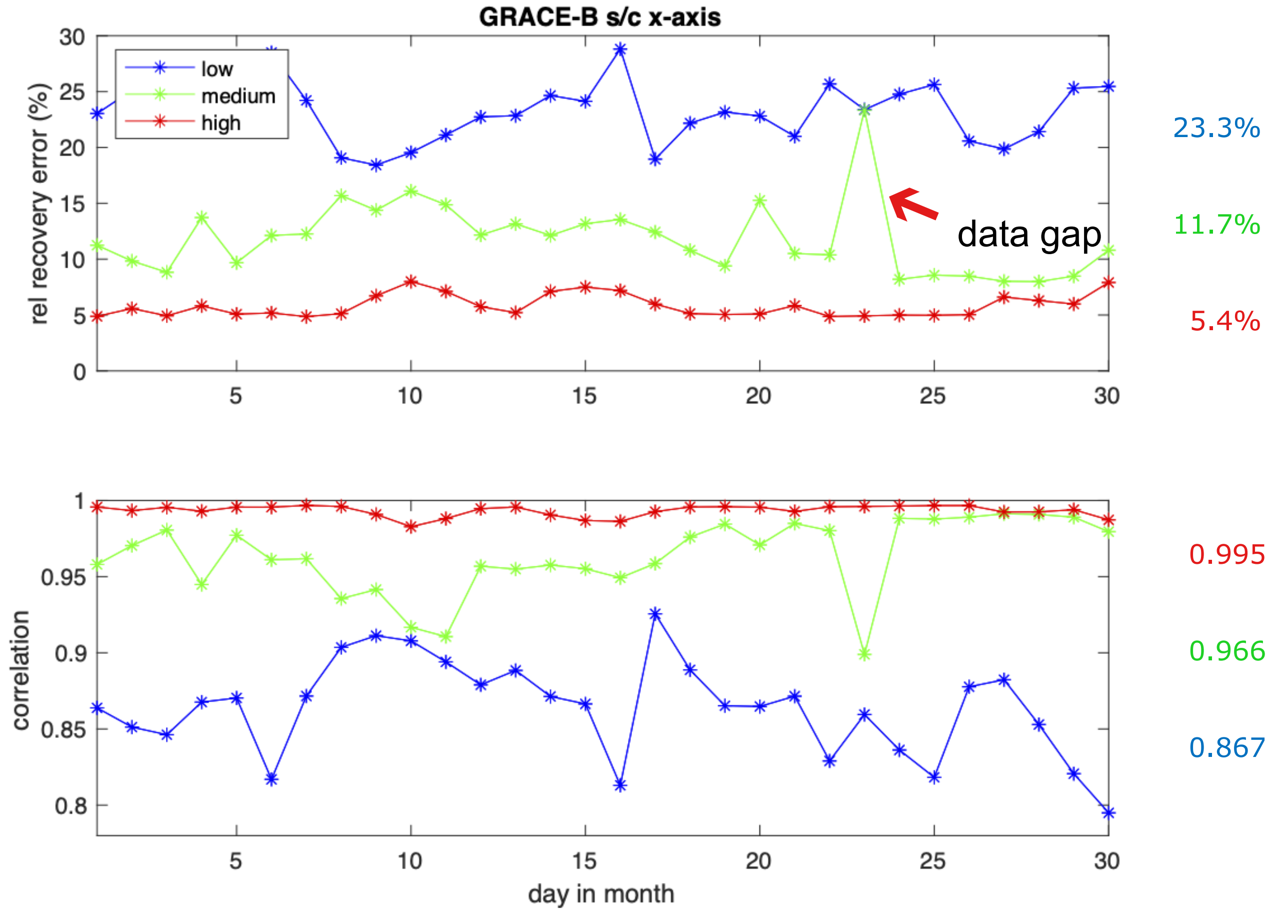
RMS	30.3 nm/s^2
rel error	16.9 %
correl.	0.931

→ Accelerations are too smooth

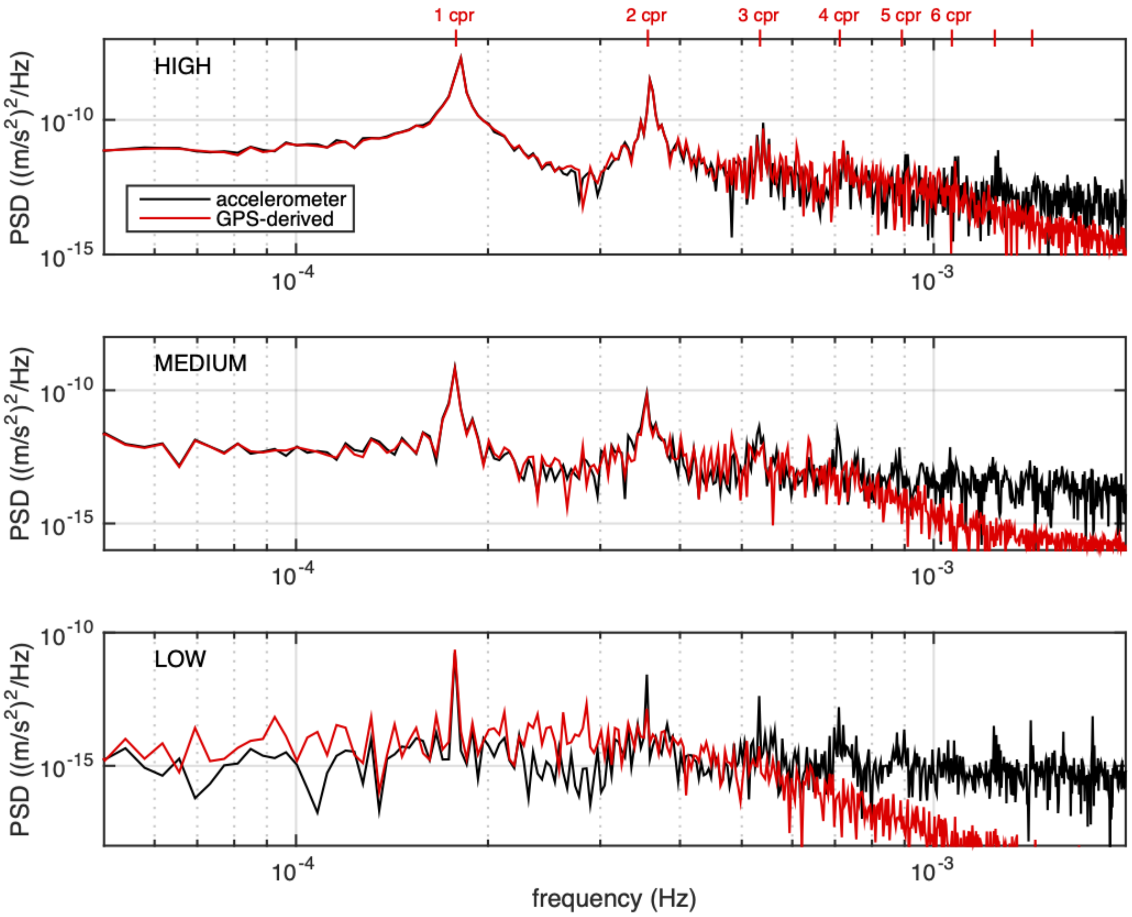
RMS	32.7 nm/s^2
rel error	18.3 %
correl.	0.908

→ Accelerations are too wobbly

Performance of low/medium/high signal cases



Performance of low/medium/high signal cases



~6-cpr

~3-cpr

~2-cpr

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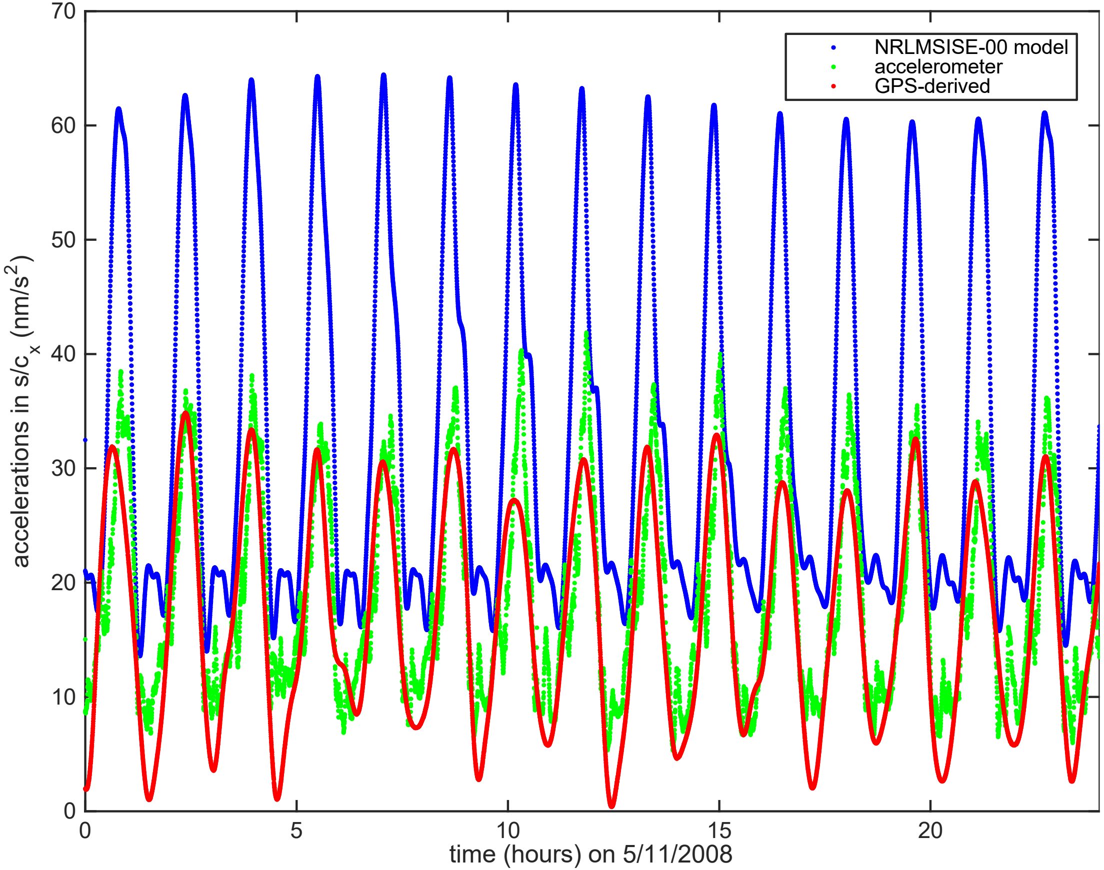
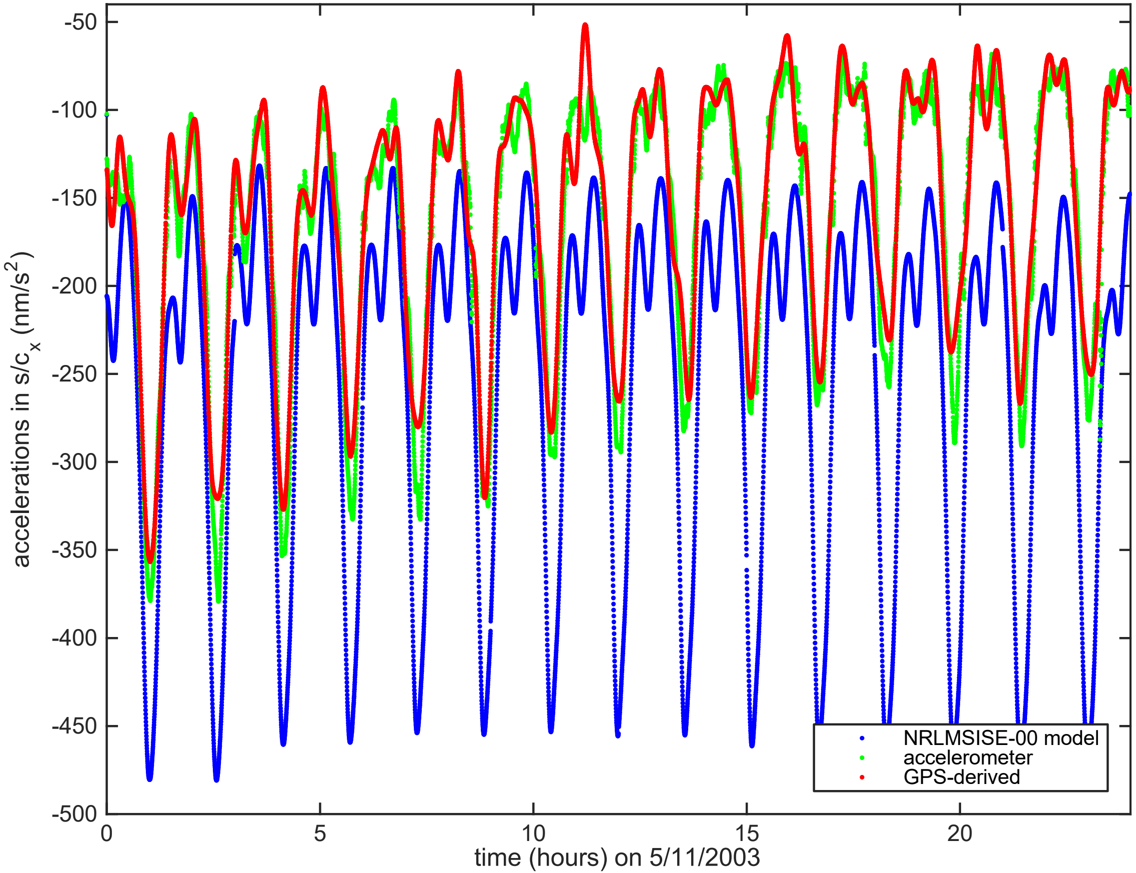
Low signal example day



	GPS	model
RMS (nm/s²)	4.9	17.1
rel error (%)	24.2	84.2
correl.	0.870	0.867

Medium signal example day



	GPS	model
RMS (nm/s^2)	17.3	103.5
rel error (%)	9.7	57.8
correl.	0.977	0.923

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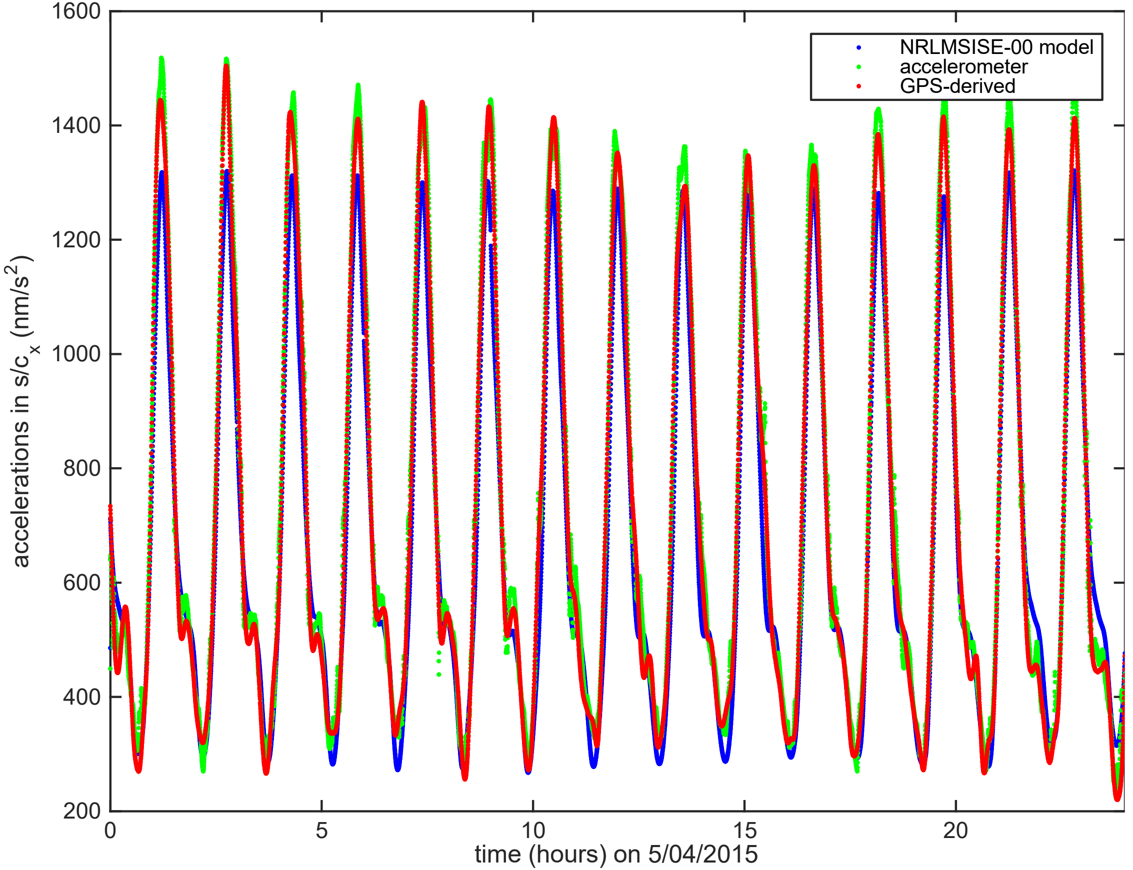
High signal example day



	GPS	model
RMS (nm/s^2)	41.4	96.8
rel error (%)	5.1	11.9
correl.	0.996	0.987

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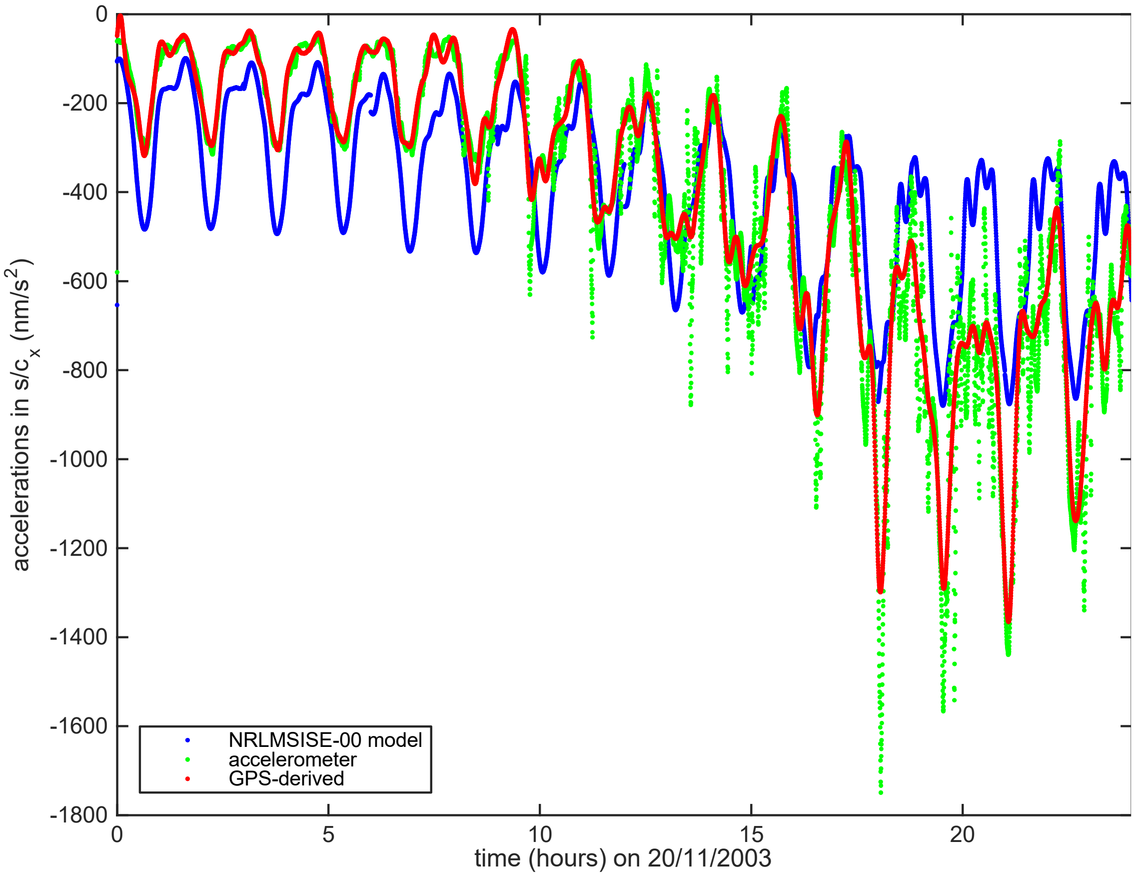
Geomagnetic storm example day



	GPS	model
RMS (nm/s^2)	81.1	203.5
rel error (%)	15.3	38.3
correl.	0.971	0.822

Conclusions and outlook

Conclusions

- Adaptive process noise improves the recovery of aerodynamic accelerations
- GPS-based accelerations show better agreement with accelerometer data than NRLMSISE-00 model accelerations
- Best performance with strong signal (0.995 correlation, 5.4% recovery error)
- Limited performance with low signal (0.867 correlation, 23.3% recovery error)

Outlook

- Apply adaptive process noise to Swarm GPS-based density retrieval
- Further improve SRP modelling (Poster 56 Natalia Hladczuk)
- Further improve GSI modelling (Poster 54 Sabin Anton)
- Add uncertainty information to our densities (Siemes et al., Uncertainty of thermosphere mass density observations derived from accelerometer and GNSS tracking data, ASR, 2023)
- Apply GPS-accelerometry to other missions: NanoMagSat, GDC…

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