



Thermosphere Observations from Low-Earth Orbiting Satellites (TOLEOS)

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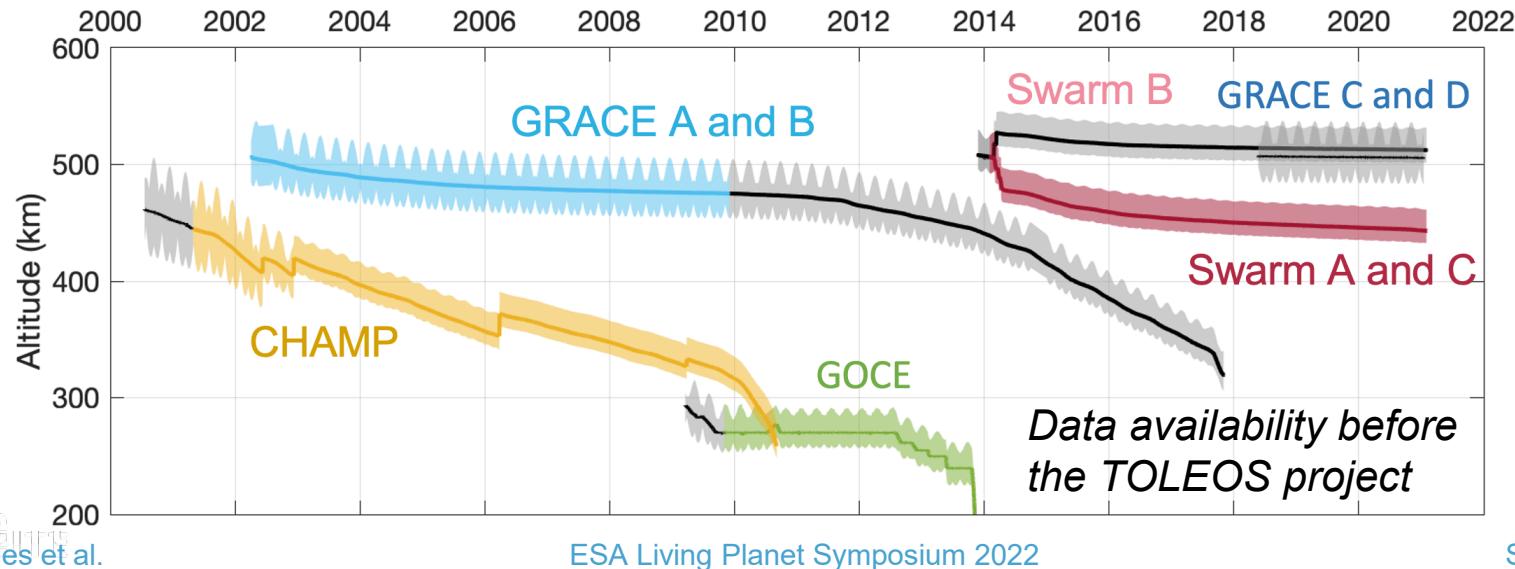
ESA Living Planet Symposium 2022

25 May 2022, Bonn, Germany

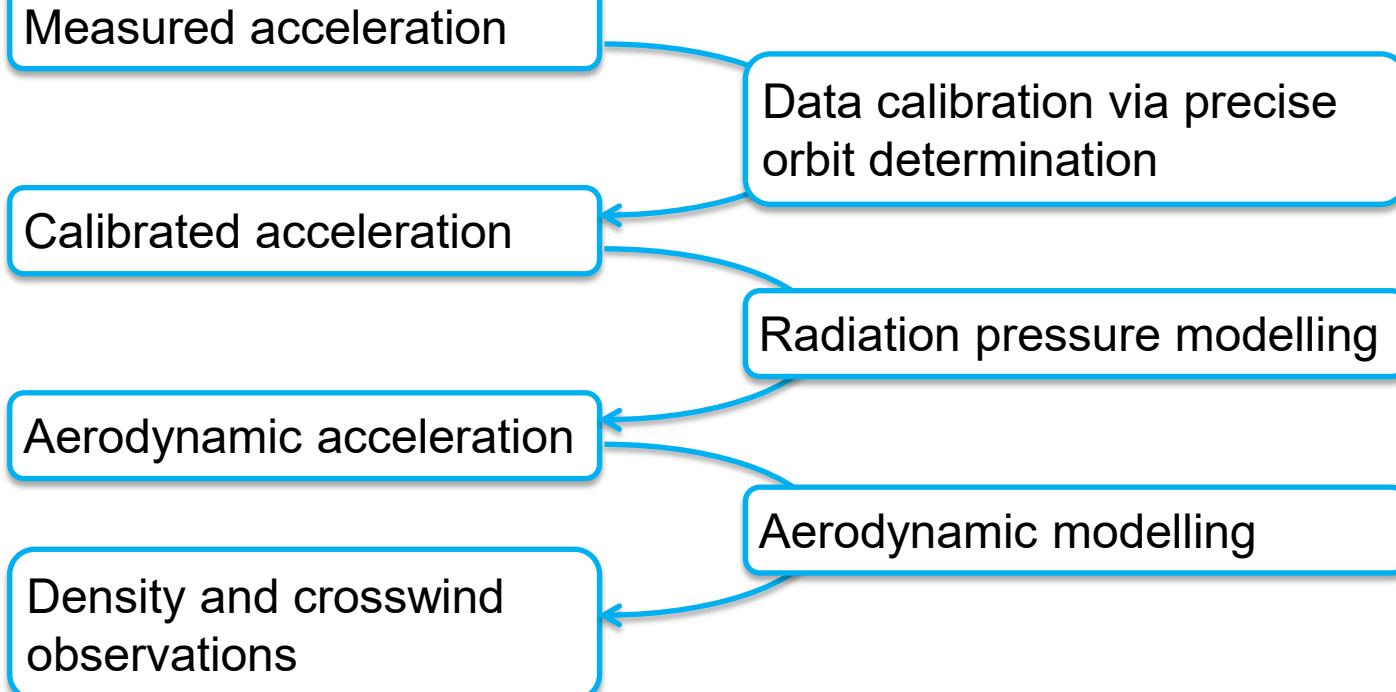


Introduction to project

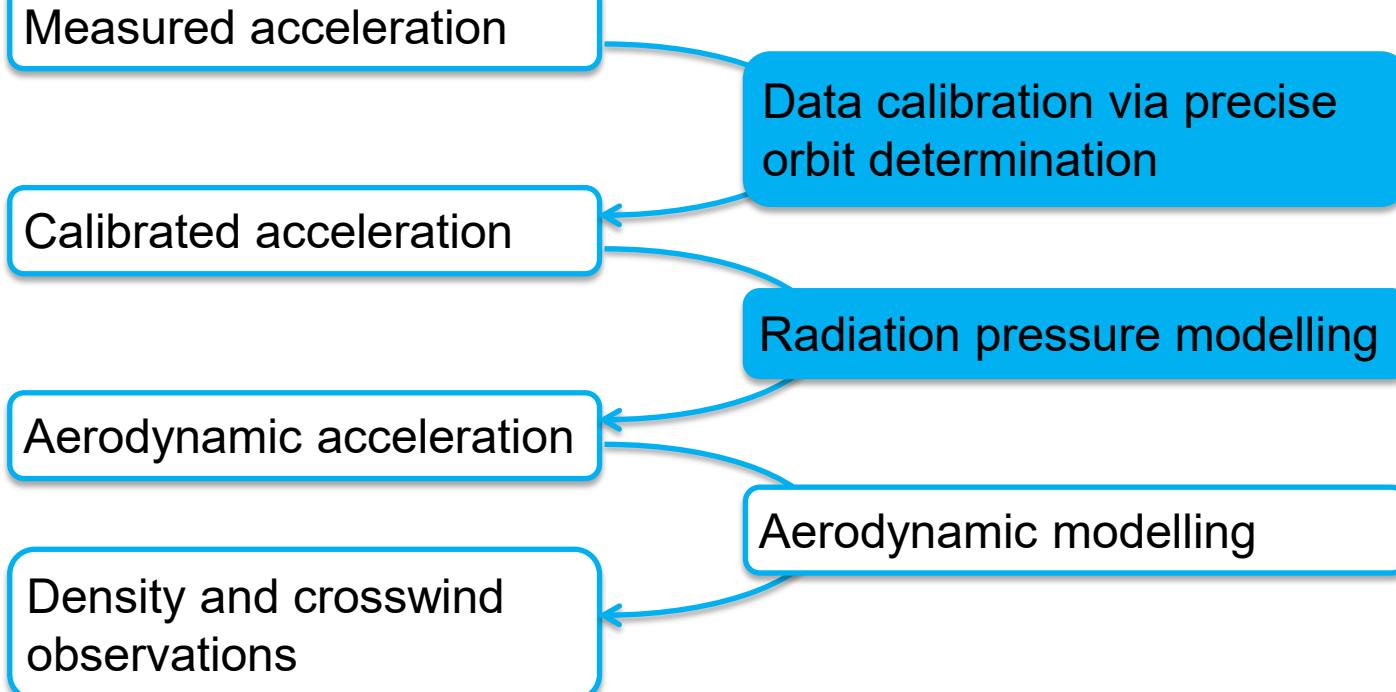
- Objective to produce thermosphere density and crosswind observations from GRACE A – D and CHAMP data (complements existing GOCE and Swarm data sets)
- Project funded by the Swarm Data, Innovation, and Science Cluster (



Density from acceleration



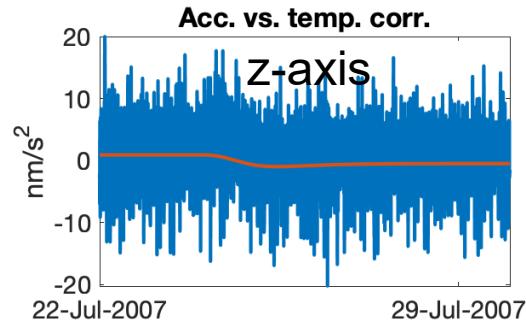
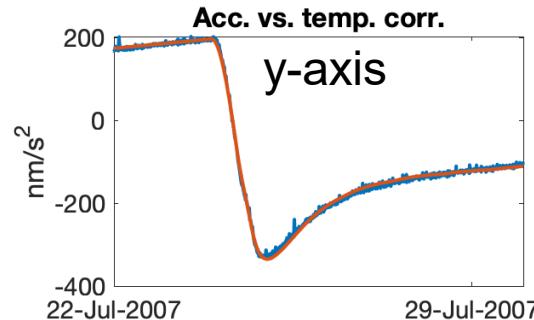
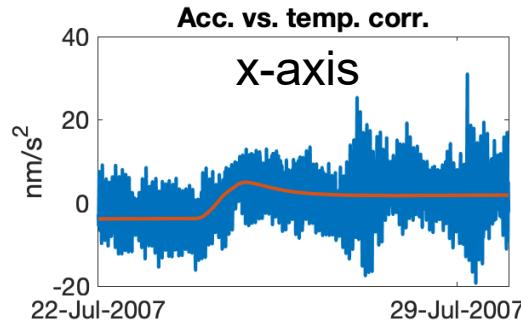
Density from acceleration



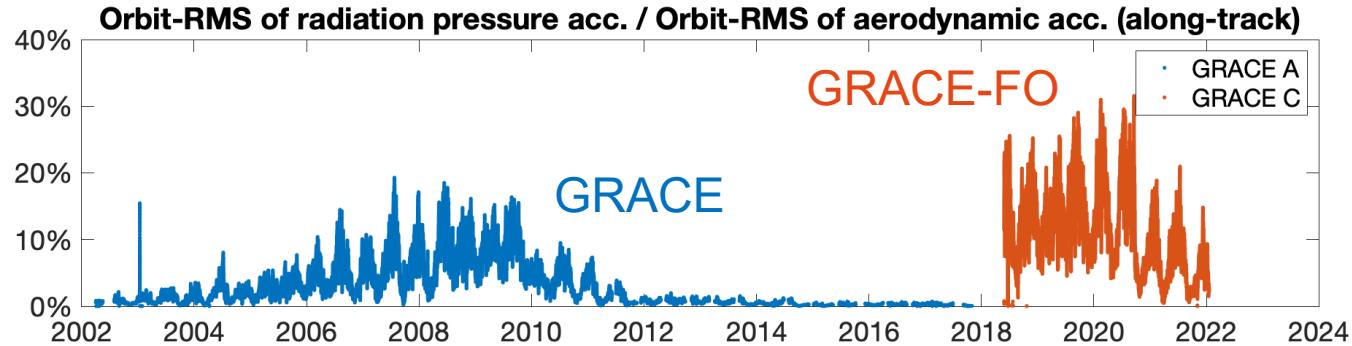
Accelerometer data calibration

Accelerometer data calibrated via precise orbit determination

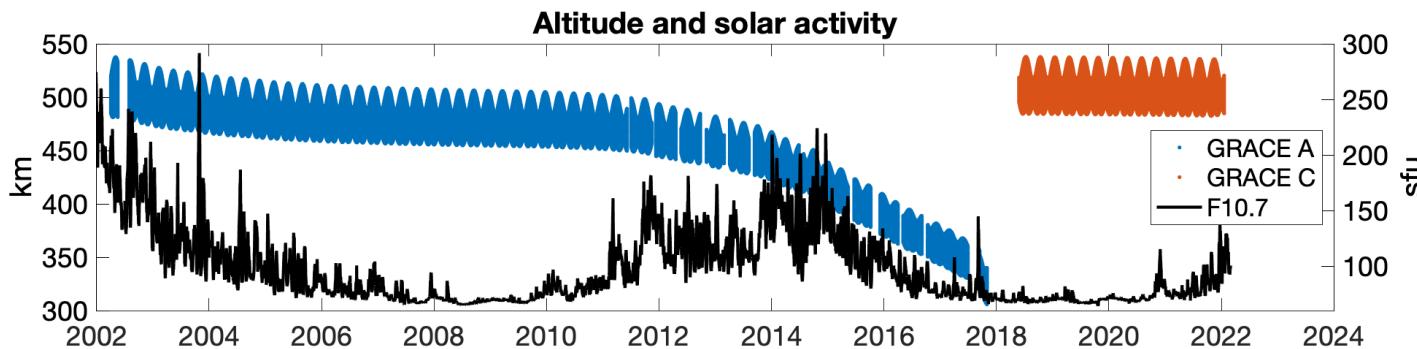
- Consistently re-calibrated all GRACE and GRACE-FO accelerometer data (CHAMP pending)
- Developed model for thermally induced bias variations for GRACE



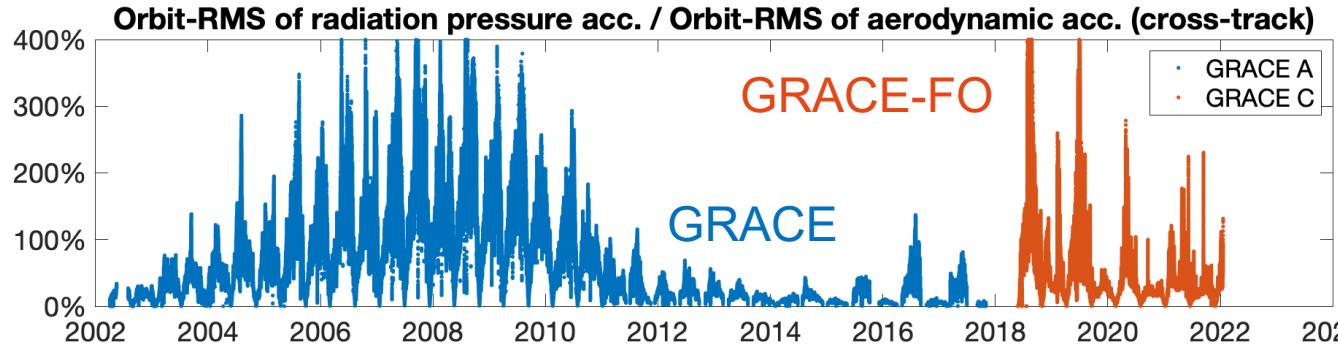
Radiation pressure modelling



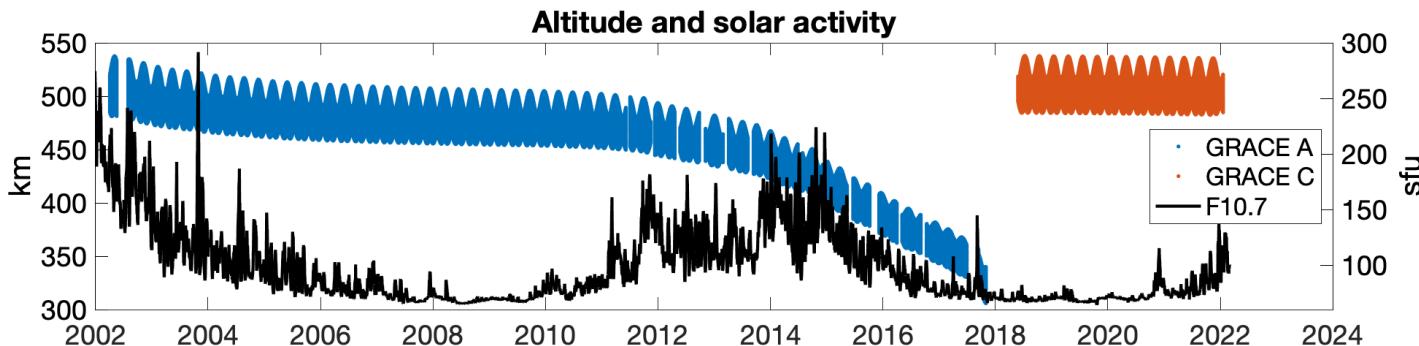
Relevant for density observations



Radiation pressure modelling



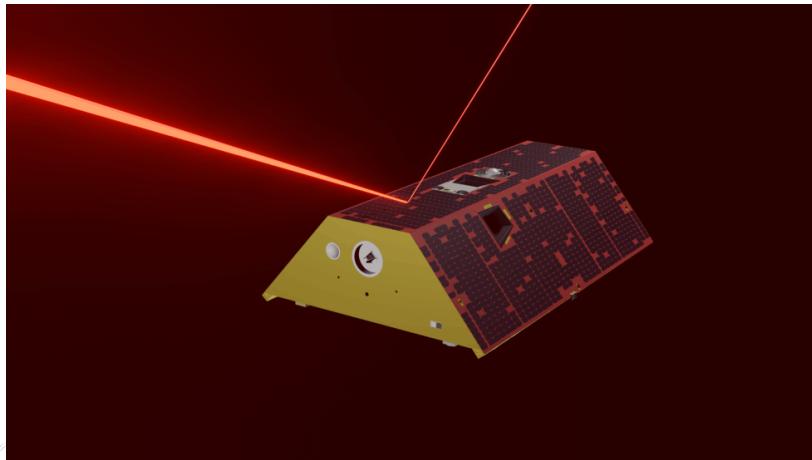
Highly relevant for crosswind observations



Radiation pressure modelling

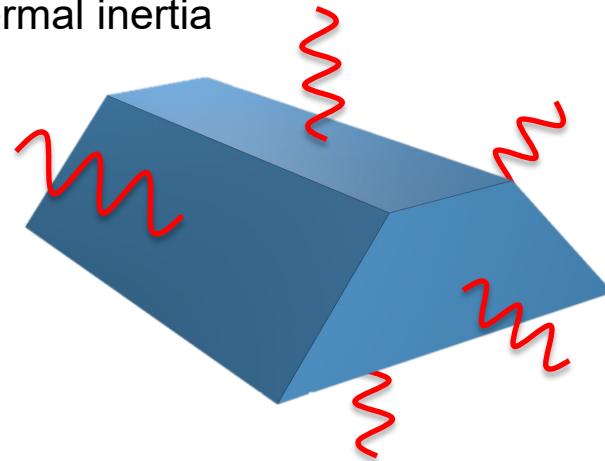
Ray tracing

- Detailed geometry
- Shadowing and multiple reflections



Thermal model

- Heat exchange between panels, body, space
- Thermal inertia



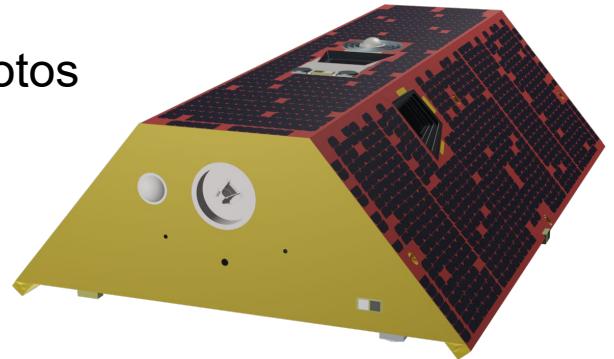
See poster by Hladczuk et al. presented on Thursday, 26 May: "Improved radiation pressure modelling for the Swarm satellites"

Detailed geometry models

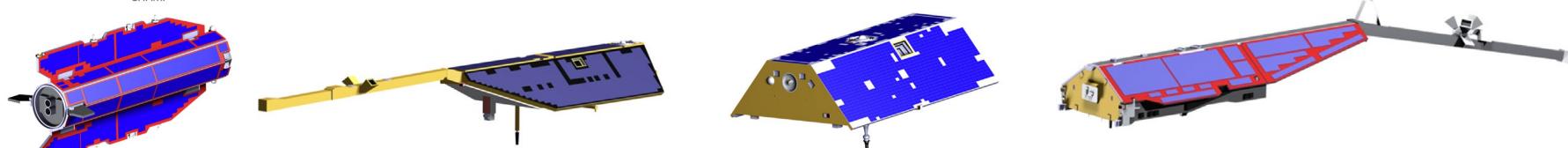


GRACE-FO model

- Derived detailed geometry from CAD model and photos
- Augmented surfaces with materials
- Basis for ray tracing and aerodynamic modelling



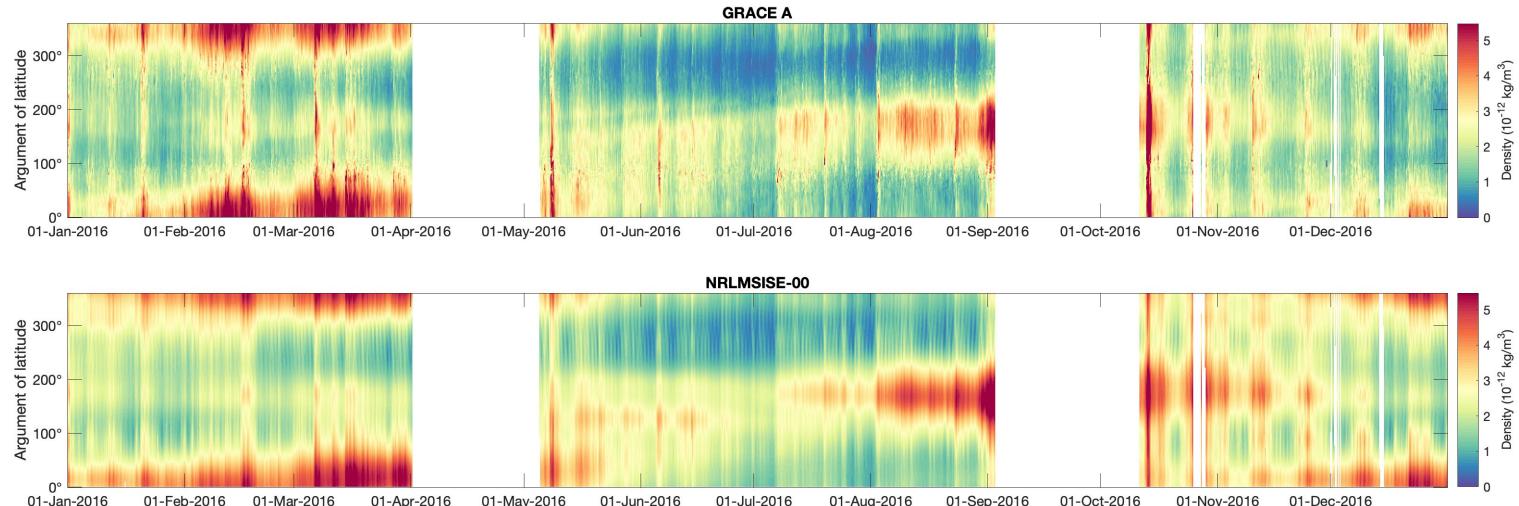
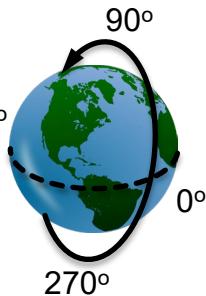
Complements existing models for GOCE, CHAMP, GRACE, and Swarm



Density results

GRACE A density observations in 2016 (typical result)

Argument of latitude



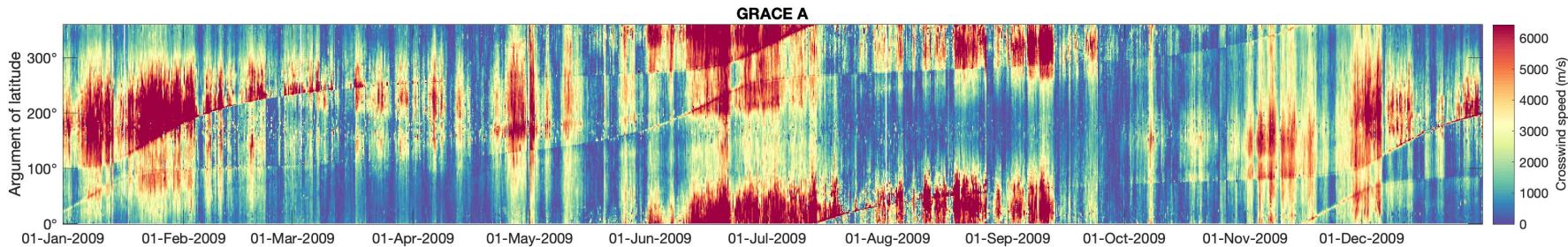
For validation, see poster by Kodikara et al. presented today:

Crosswind results

GRACE A crosswind observations in 2009

- Altitude 470 km
- Deep solar minimum

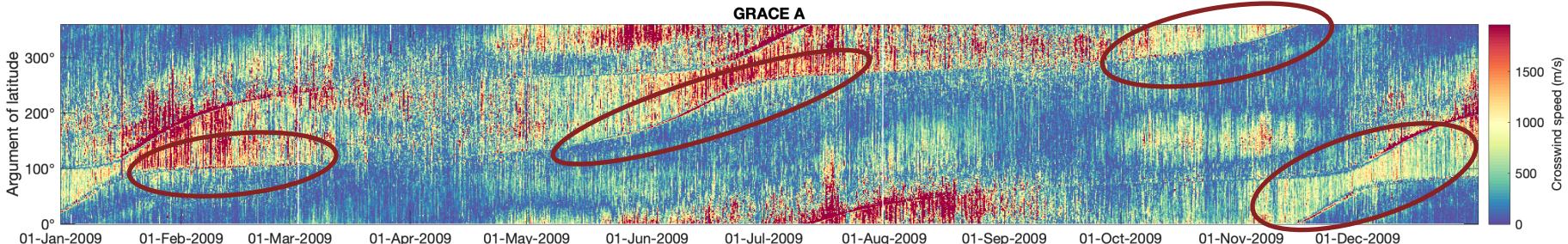
→ Expect to see mostly noise in crosswind observations



Fine-tuning (part 1)

Calibration of cross-track acceleration data via POD is known to be difficult
Transfer good calibration of along-track to cross-track acceleration data

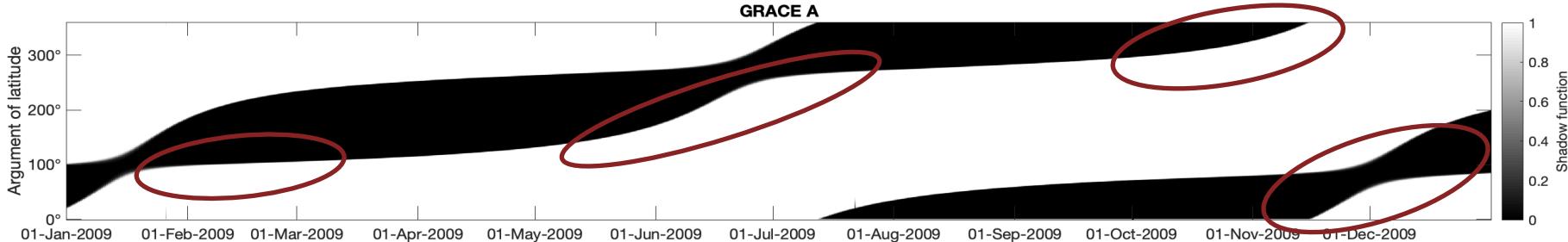
$$\mathbf{a}_{aero} = \frac{1}{2} \frac{A}{m} \rho v^2 \mathbf{C}_{aero} \quad \rightarrow \quad a_{aero,y} = \frac{c_{aero,y}}{c_{aero,x}} a_{aero,x}$$



Fine-tuning (part 1)

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$$\mathbf{a}_{aero} = \frac{1}{2} \frac{A}{m} \rho v^2 \mathbf{c}_{aero} \quad \rightarrow \quad a_{aero,y} = \frac{c_{aero,y}}{c_{aero,x}} a_{aero,x}$$



Fine-tuning (part 2)

Change optical surface properties → reflections more specular



Solar array (Si glass), visible light:

Diffuse:	0.30	→	0.05
Specular:	0.05	→	0.23
Absorption:	0.65	→	0.72

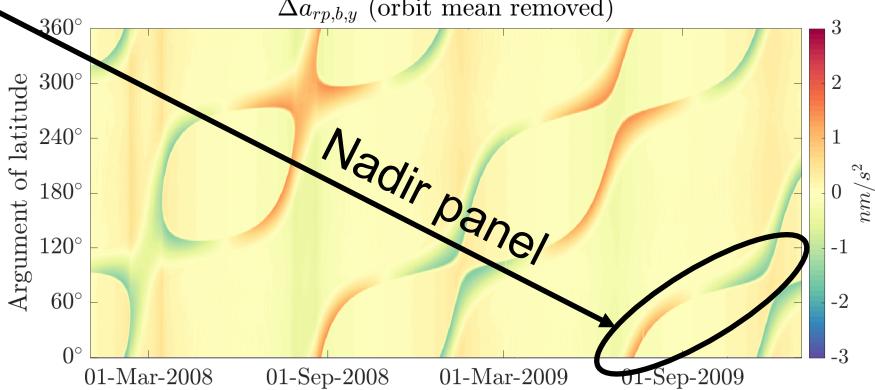
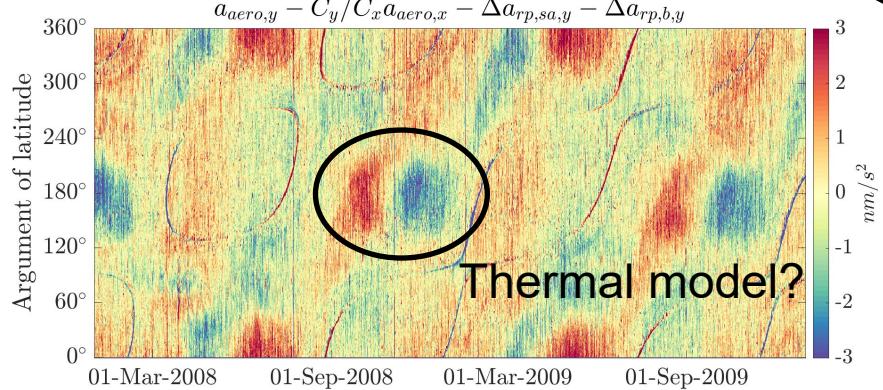
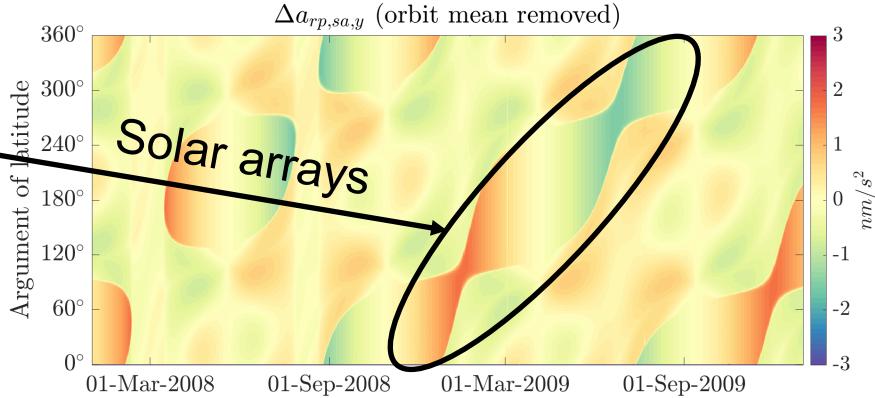
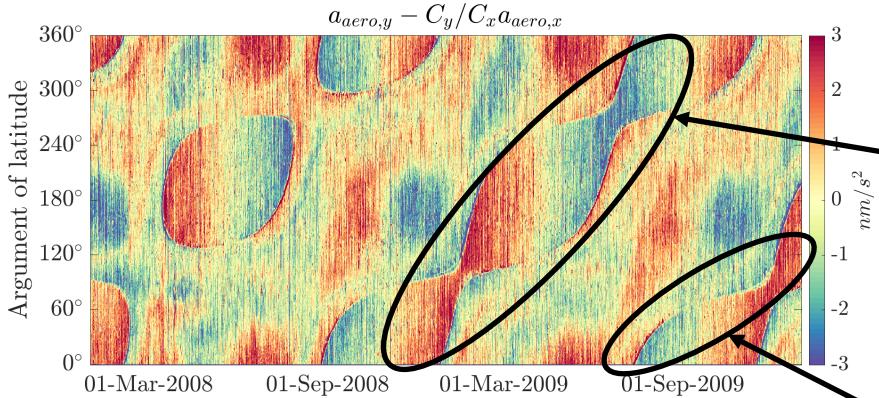


*No photo of GRACE nadir panel found on the web
If similar to GRACE-FO, then it is almost fully specular*

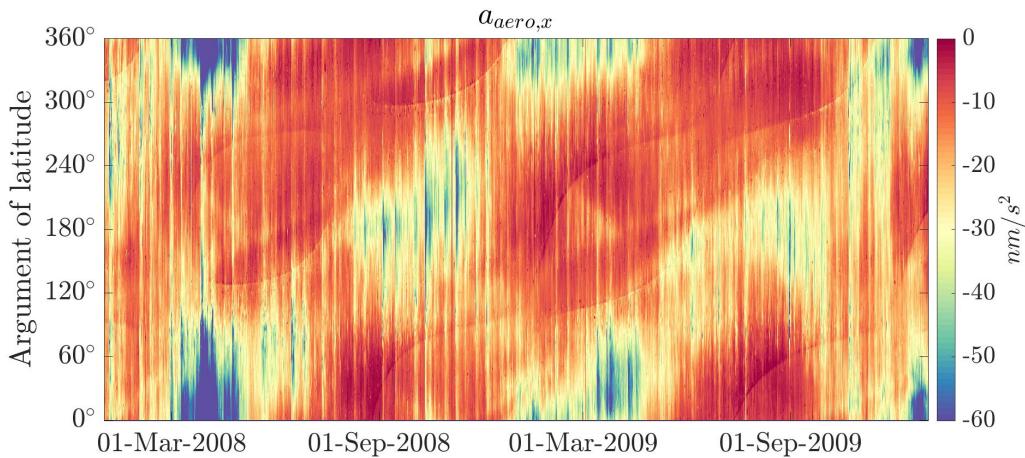
Nadir panel (Teflon):

Diffuse:	0.20	→	0.06
Specular:	0.68	→	0.82
Absorption:	0.12	→	0.12

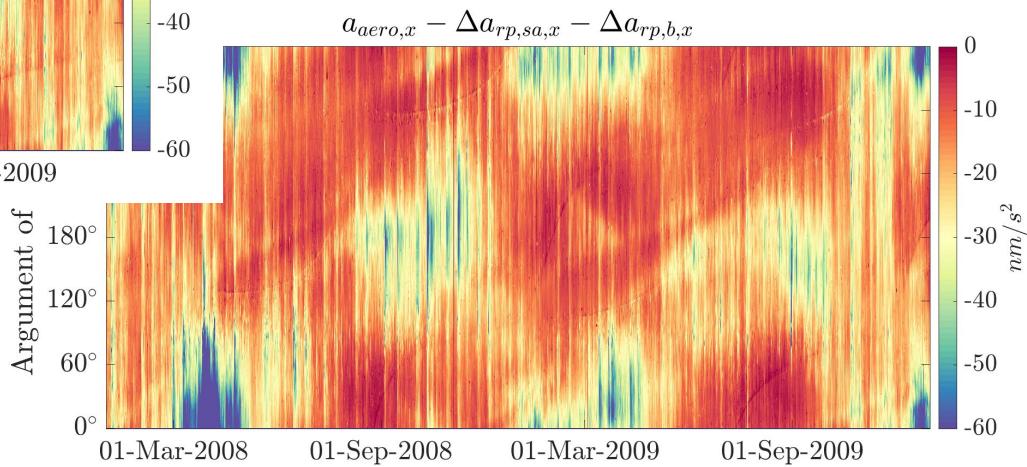
Fine-tuning (part 2)



Fine-tuning (part 3)



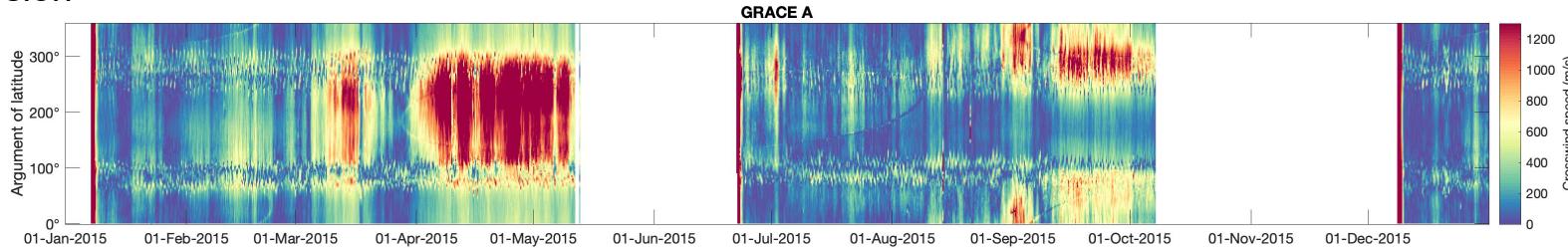
Along-track aerodynamic acceleration shows less pronounced artifacts at eclipse entries and exits, even though it was not used in the optimisation process



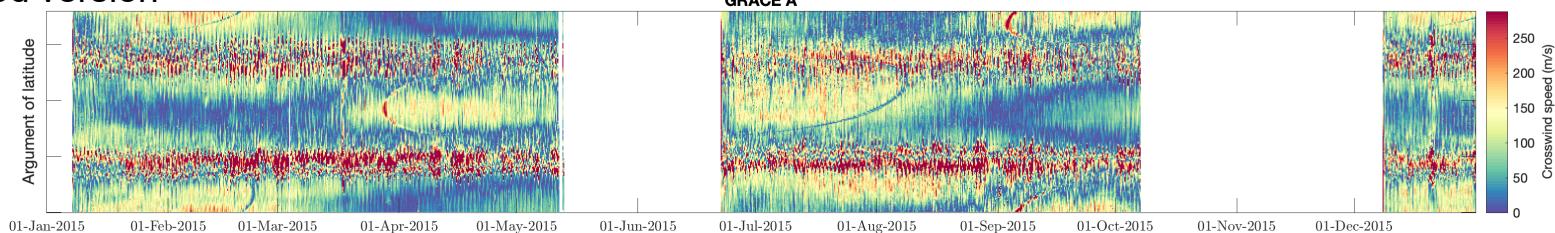
Crosswind results (updated)



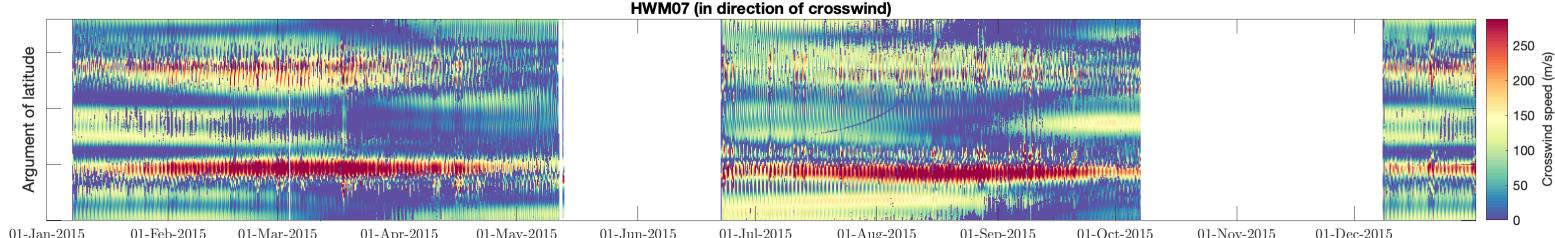
First version



Fine-tuned version

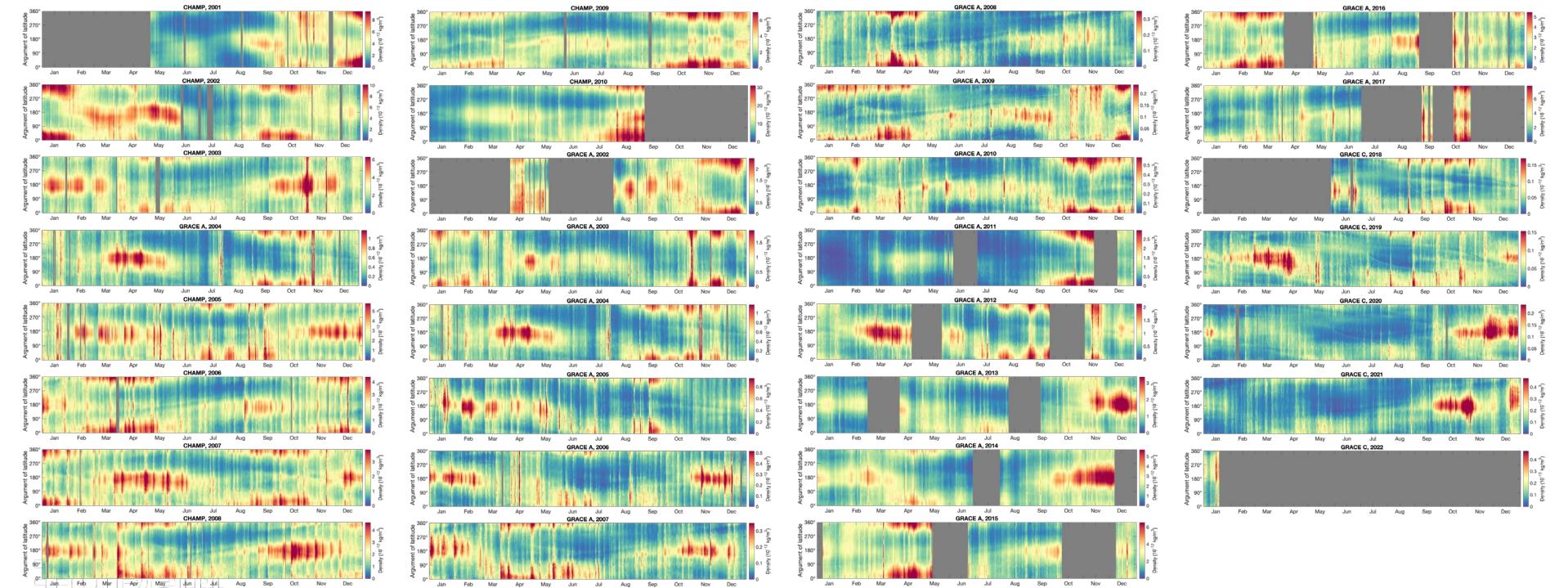


HWM07



Summary

31 years of consistently processed thermosphere observations from CHAMP, GRACE A, and GRACE C



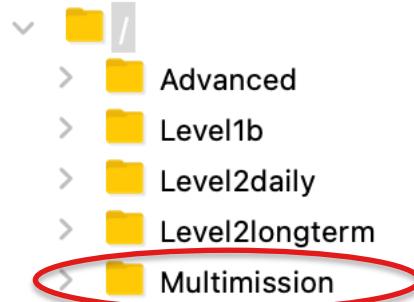
Summary

New observations and models → Will be published in summer

- Density and crosswind observations
- Geometry model for GRACE-FO
- Radiation pressure models
- Aerodynamic models

ESA's Swarm PDGS:

- <ftp://swarm-diss.eo.esa.int>
- <http://swarm-diss.eo.esa.int>



TU Delft's thermosphere observation data base (includes models):

- <ftp://thermosphere.tudelft.nl>

