

Improving the consistency of aerodynamic models and thermospheric density and wind data (PP)

Visser, Tim; March, Gunther

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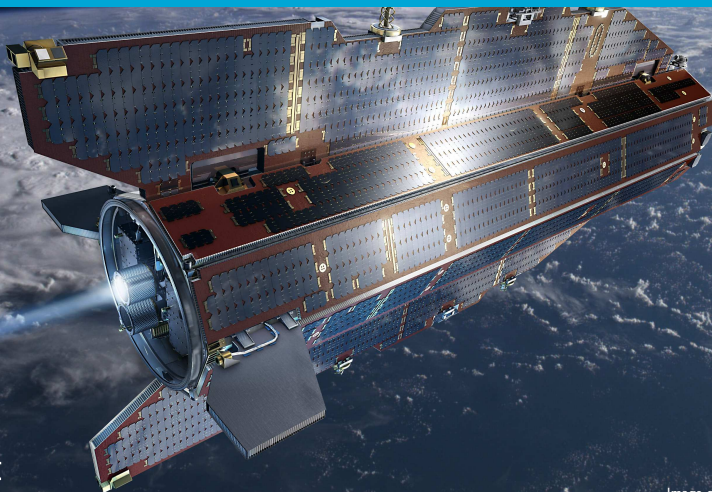
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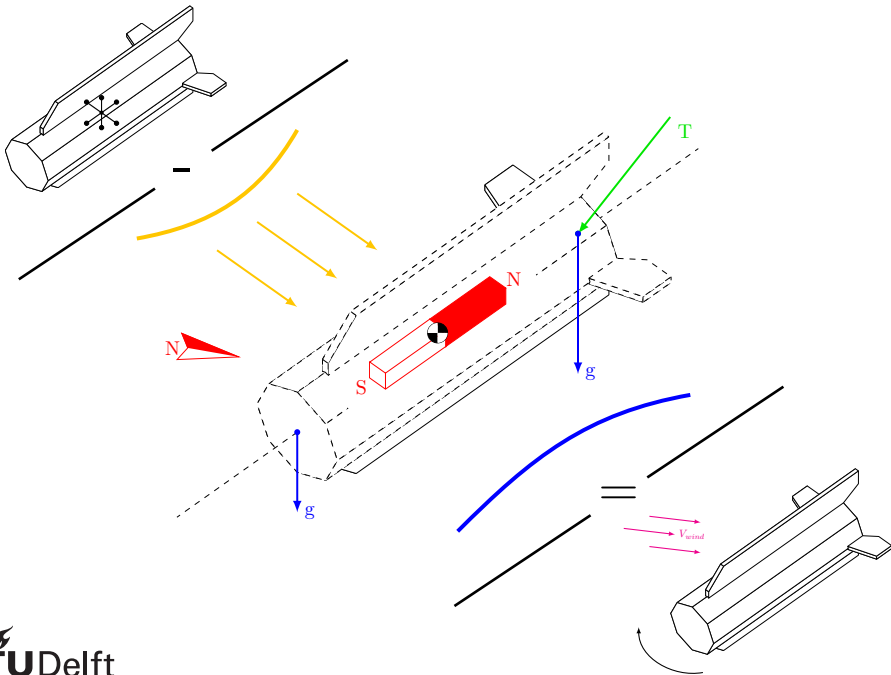
Thermospheric wind measurements from GOCE angular accelerations

T. Visser; Delft University of Technology

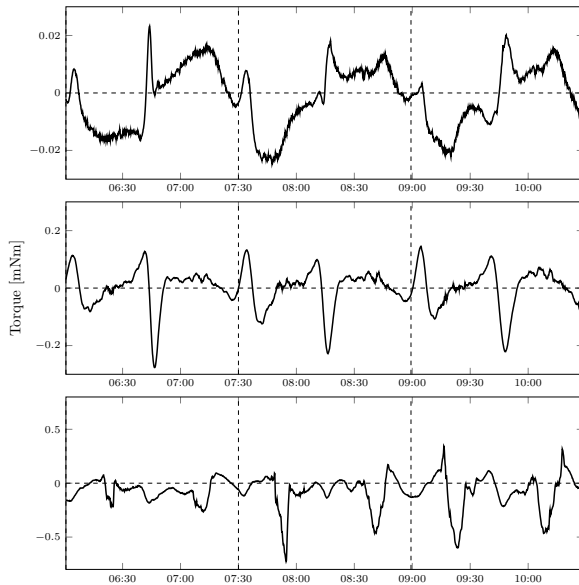
SPP1788 DynamicEarth Winter School, Kühlungsborn, Germany

29 January 2018



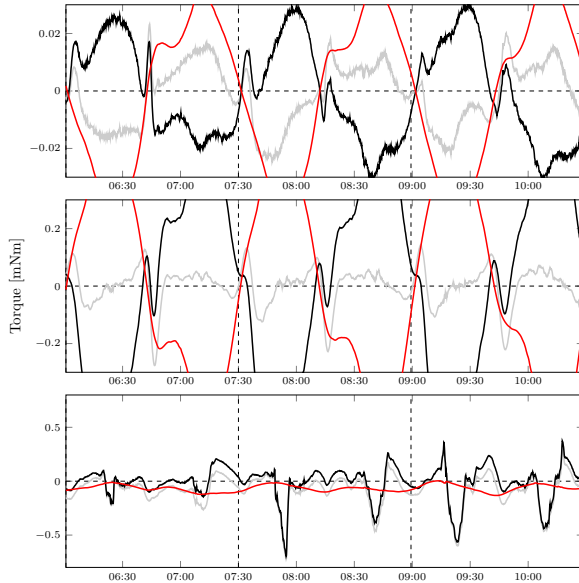


Measured torque



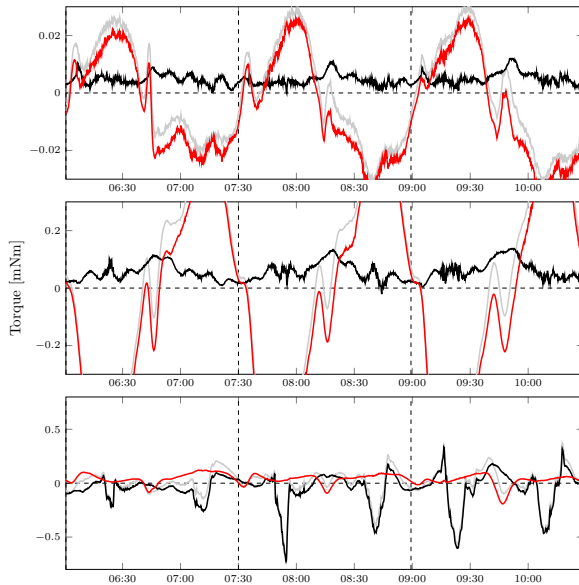
Measured torque

- Magnetic



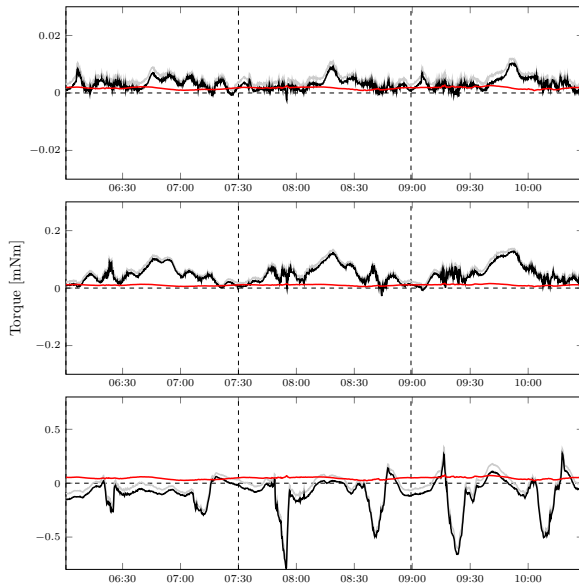
Measured torque

- Magnetic
- Control



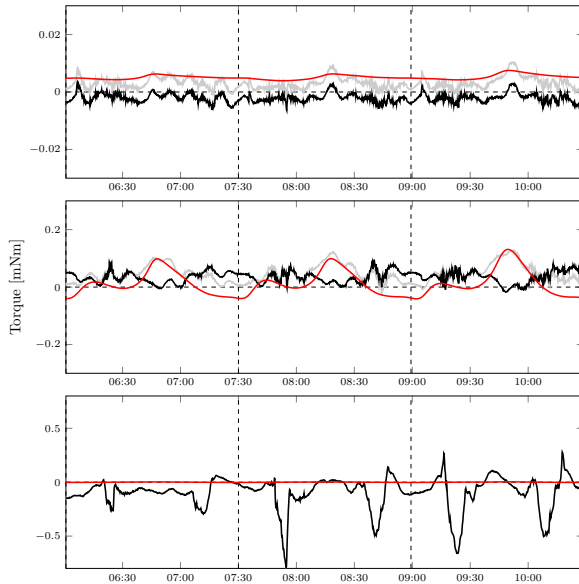
Measured torque

- Magnetic
- Control
- Thruster



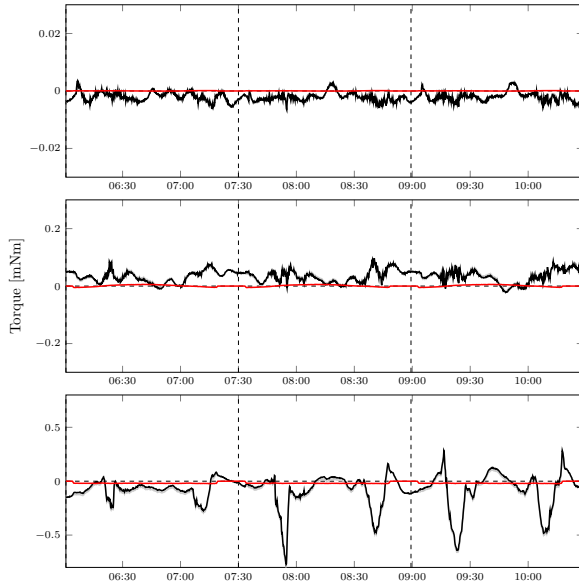
Measured torque

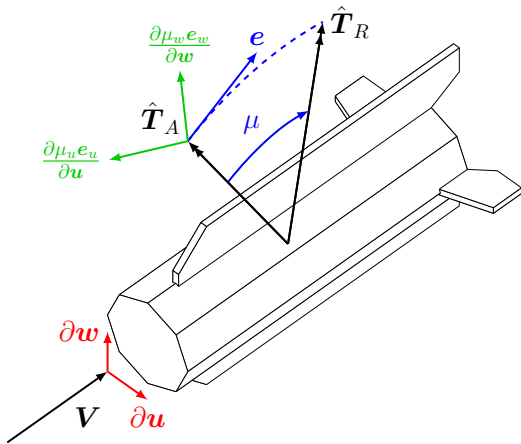
- Magnetic
- Control
- Thruster
- Gravity



Measured torque

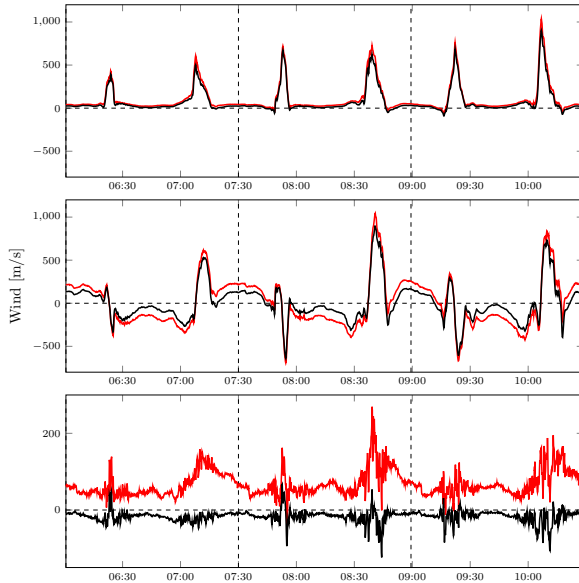
- Magnetic
- Control
- Thruster
- Gravity
- Solar radiation





Wind (North-East-Down)

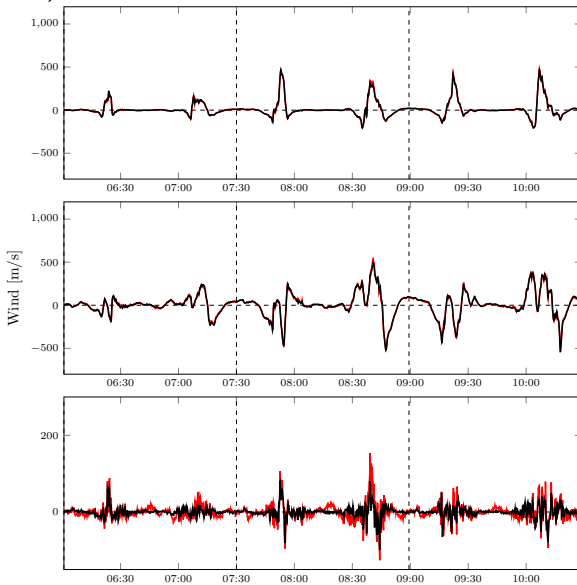
- From forces
- From torques



Wind (North-East-Down)

- From forces
- From torques

Filtered ($f \geq 3f_{orbit}$)





Improving the consistency of aerodynamic models and thermospheric density and wind data

Geometry and aerodynamic model improvement for thermospheric densities

Günther March
Ph.D. Candidate at TU Delft
g.march@tudelft.nl

Current panel models

Swarm Astrium Macro Model

| | | | | | | | |
|-------|---|---|---|---------|----------|-----|---------|
| PANEL | 0 | 1 | 1 | 1000101 | 0.0 | 0.0 | 1.0 |
| PANEL | 0 | 1 | 2 | 1000101 | 1.540 | | |
| PANEL | 0 | 1 | 3 | 1000101 | 0.03 | 0.0 | 0.01 |
| PANEL | 0 | 1 | 4 | 1000101 | 0.79 | 0.0 | 0.31 |
| PANEL | 0 | 1 | 5 | 1000101 | 0.68 | | |
| PANEL | 0 | 2 | 1 | 1000101 | -0.19766 | 0.0 | 0.98027 |
| PANEL | 0 | 2 | 2 | 1000101 | 1.400 | | |
| PANEL | 0 | 2 | 3 | 1000101 | 0.06 | 0.0 | 0.02 |
| PANEL | 0 | 2 | 4 | 1000101 | 0.17 | 0.0 | 0.20 |
| PANEL | 0 | 2 | 5 | 1000101 | 0.78 | | |

... for a total of (only) 15 panels

Current panel models

Swarm Astrium Macro Model

| | | | | | | | |
|-------|---|---|---|---------|----------|-----|---------|
| PANEL | 0 | 1 | 1 | 1000101 | 0.0 | 0.0 | 1.0 |
| PANEL | 0 | 1 | 2 | 1000101 | 1.540 | | |
| PANEL | 0 | 1 | 3 | 1000101 | 0.03 | 0.0 | 0.01 |
| PANEL | 0 | 1 | 4 | 1000101 | 0.79 | 0.0 | 0.31 |
| PANEL | 0 | 1 | 5 | 1000101 | 0.68 | | |
| PANEL | 0 | 2 | 1 | 1000101 | -0.19766 | 0.0 | 0.98027 |
| PANEL | 0 | 2 | 2 | 1000101 | 1.400 | | |
| PANEL | 0 | 2 | 3 | 1000101 | 0.06 | 0.0 | 0.02 |
| PANEL | 0 | 2 | 4 | 1000101 | 0.17 | 0.0 | 0.20 |
| PANEL | 0 | 2 | 5 | 1000101 | 0.78 | | |

... for a total of (only) 15 panels

Current panel models

Swarm Astrium Macro Model

Normal vector components

| | | | | | | | |
|-------|---|---|---|---------|----------|-----|---------|
| PANEL | 0 | 1 | 1 | 1000101 | 0.0 | 0.0 | 1.0 |
| PANEL | 0 | 1 | 2 | 1000101 | 1.540 | | |
| PANEL | 0 | 1 | 3 | 1000101 | 0.03 | 0.0 | 0.01 |
| PANEL | 0 | 1 | 4 | 1000101 | 0.79 | 0.0 | 0.31 |
| PANEL | 0 | 1 | 5 | 1000101 | 0.68 | | |
| PANEL | 0 | 2 | 1 | 1000101 | -0.19766 | 0.0 | 0.98027 |
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| PANEL | 0 | 2 | 3 | 1000101 | 0.06 | 0.0 | 0.02 |
| PANEL | 0 | 2 | 4 | 1000101 | 0.17 | 0.0 | 0.20 |
| PANEL | 0 | 2 | 5 | 1000101 | 0.78 | | |

... for a total of (only) 15 panels

Current panel models

Swarm Astrium Macro Model

| | | | | | <u>Normal vector components</u> | | | |
|-------|---|---|---|---------|---------------------------------|-------|-----|---------|
| PANEL | 0 | 1 | 1 | 1000101 | <u>Area</u> | 0.0 | 0.0 | 1.0 |
| PANEL | 0 | 1 | 2 | 1000101 | | 1.540 | | |
| PANEL | 0 | 1 | 3 | 1000101 | | 0.03 | 0.0 | 0.01 |
| PANEL | 0 | 1 | 4 | 1000101 | | 0.79 | 0.0 | 0.31 |
| PANEL | 0 | 1 | 5 | 1000101 | | 0.68 | | |
| PANEL | 0 | 2 | 1 | 1000101 | -0.19766 | | 0.0 | 0.98027 |
| PANEL | 0 | 2 | 2 | 1000101 | 1.400 | | | |
| PANEL | 0 | 2 | 3 | 1000101 | 0.06 | | 0.0 | 0.02 |
| PANEL | 0 | 2 | 4 | 1000101 | 0.17 | | 0.0 | 0.20 |
| PANEL | 0 | 2 | 5 | 1000101 | 0.78 | | | |

... for a total of (only) 15 panels

Current panel models

Swarm Astrium Macro Model

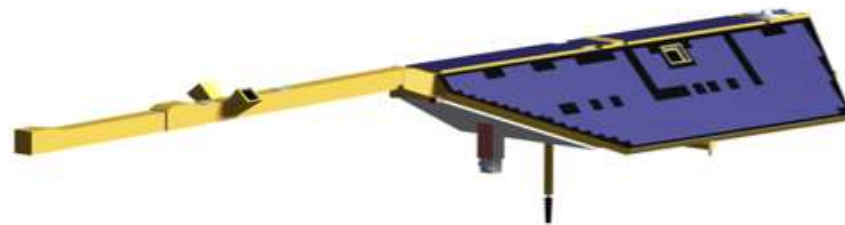
| | | | | | <u>Normal vector components</u> | | | |
|-------|---|---|---|---------|---------------------------------|-------|-----|---------|
| PANEL | 0 | 1 | 1 | 1000101 | <u>Area</u> | 0.0 | 0.0 | 1.0 |
| PANEL | 0 | 1 | 2 | 1000101 | | 1.540 | | |
| PANEL | 0 | 1 | 3 | 1000101 | | 0.03 | 0.0 | 0.01 |
| PANEL | 0 | 1 | 4 | 1000101 | | 0.79 | 0.0 | 0.31 |
| PANEL | 0 | 1 | 5 | 1000101 | | 0.68 | | |
| PANEL | 0 | 2 | 1 | 1000101 | -0.19766 | | 0.0 | 0.98027 |
| PANEL | 0 | 2 | 2 | 1000101 | 1.400 | | | |
| PANEL | 0 | 2 | 3 | 1000101 | 0.06 | | 0.0 | 0.02 |
| PANEL | 0 | 2 | 4 | 1000101 | 0.17 | | 0.0 | 0.20 |
| PANEL | 0 | 2 | 5 | 1000101 | 0.78 | | | |

Optical properties

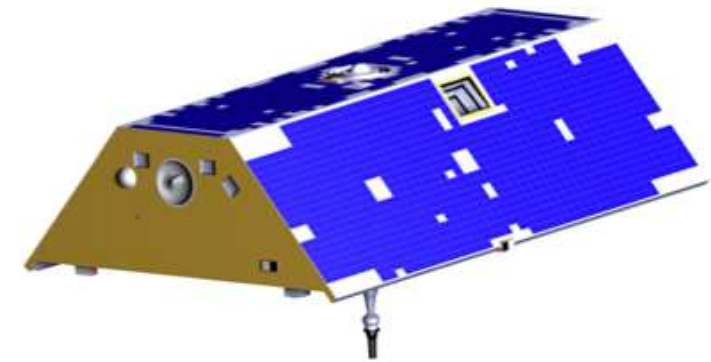
Optical properties

... for a total of (only) 15 panels

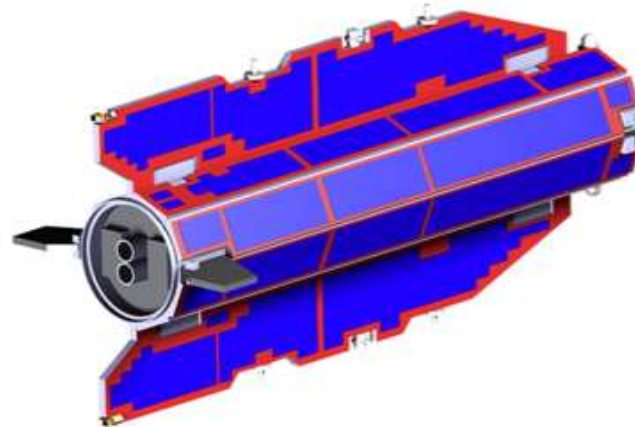
Improved geometry & aerodynamic model



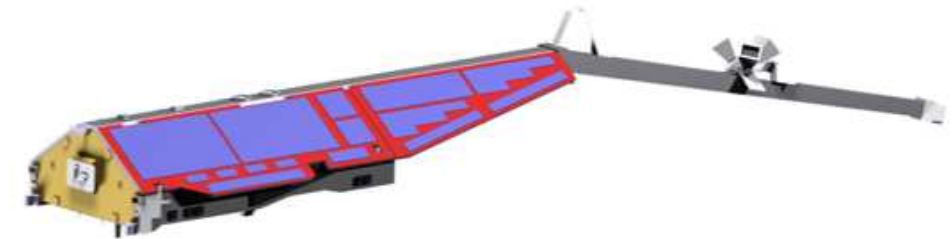
CHAMP



GRACE



GOCE



Swarm

Computational method for Rarefied flows

SPARTA DSMC Simulator

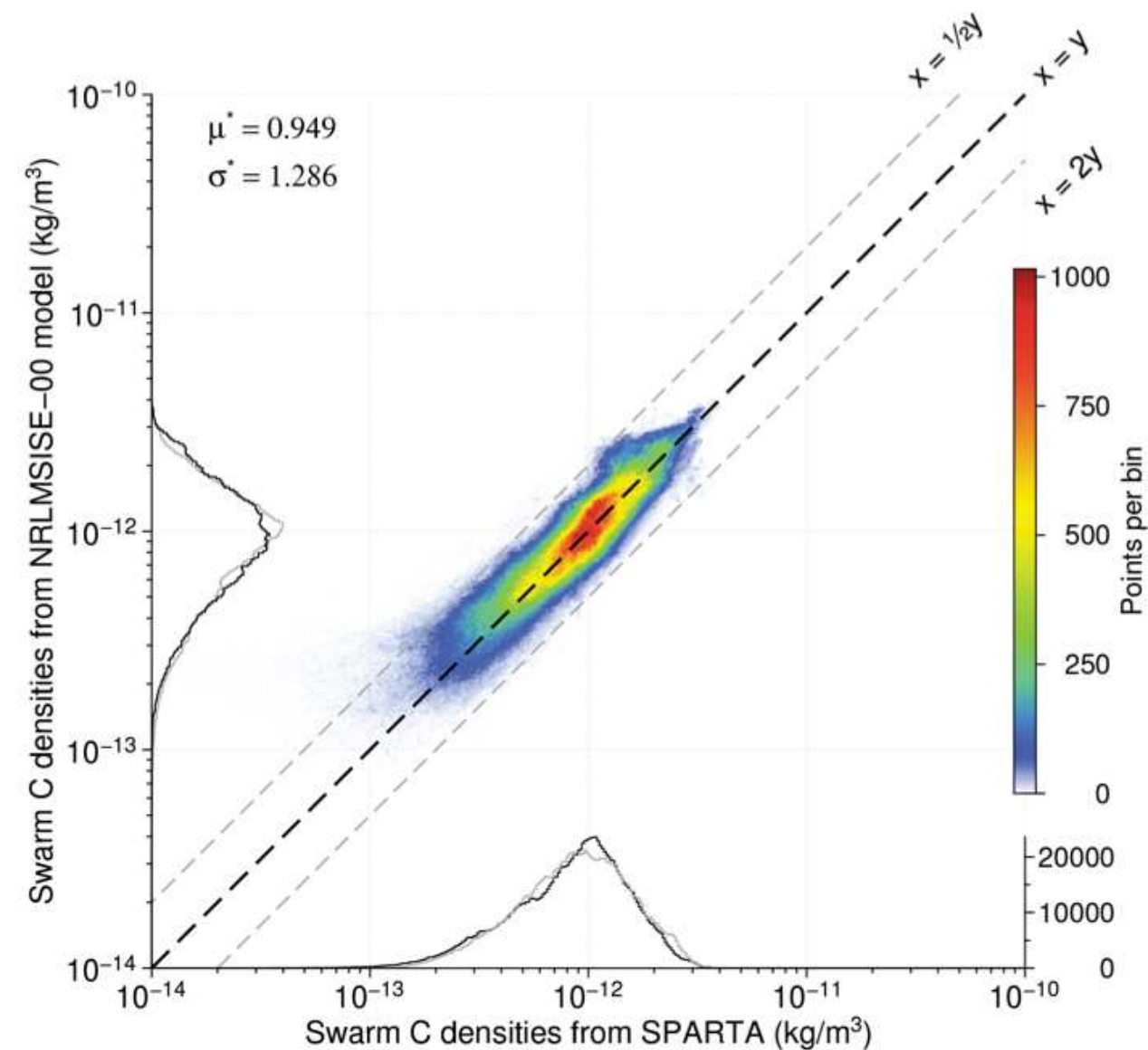
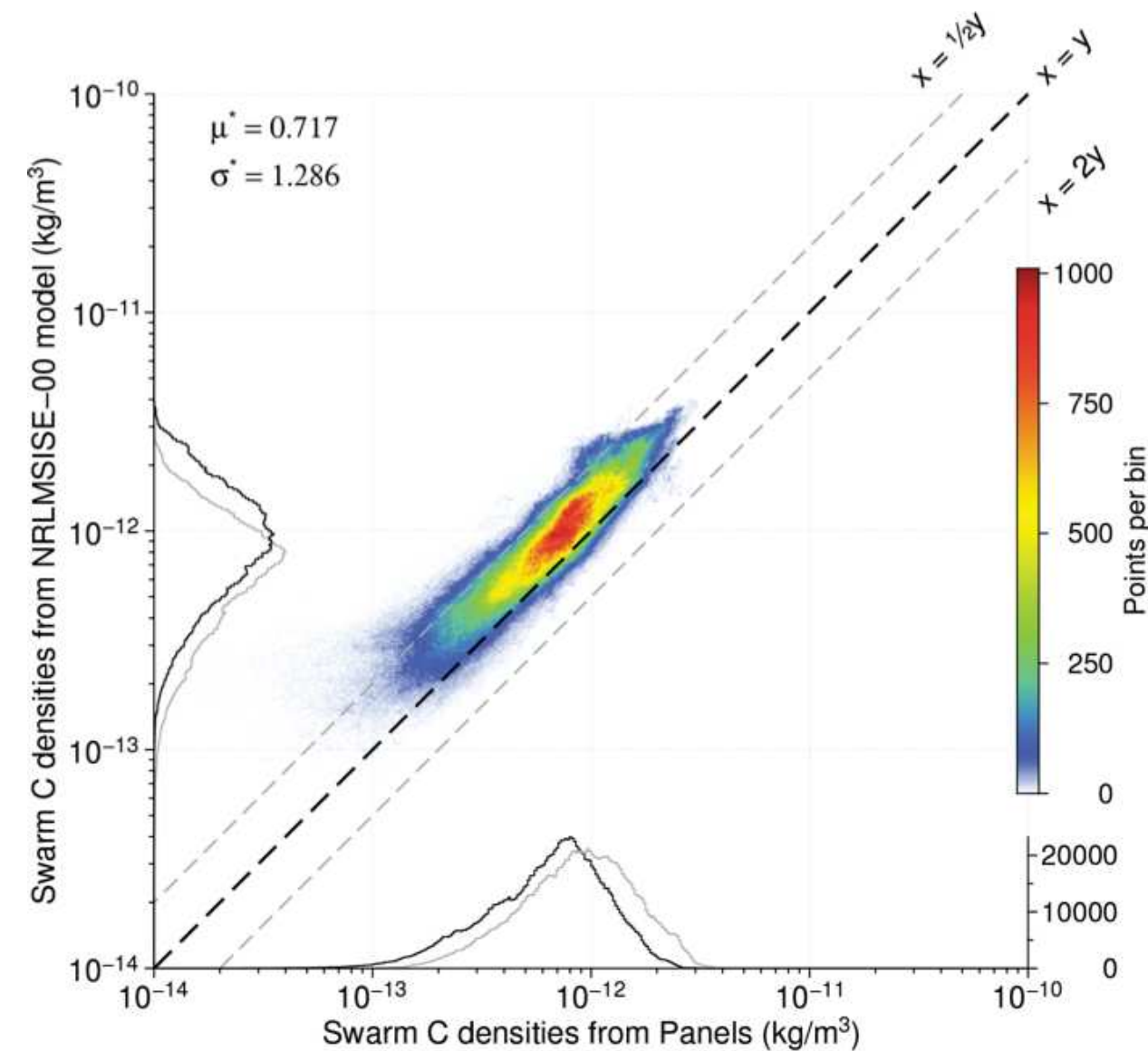
Stochastic **P**Arallel **R**arefied-gas **T**ime-accurate **A**nalyzer

<http://sparta.sandia.gov>

Statistical comparison

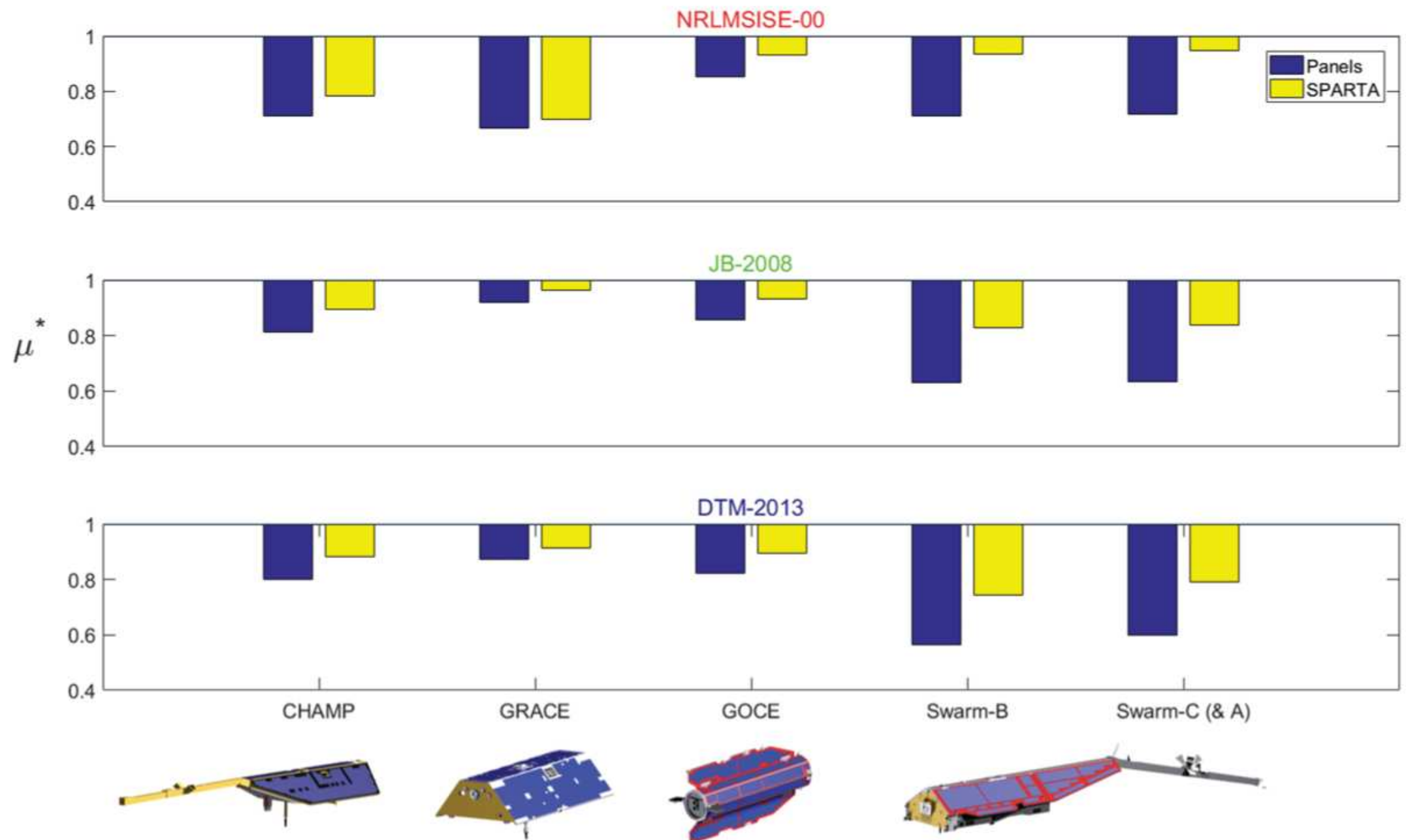
Swarm C density data for the period 19/07/2014 - 30/09/2016
with equivalent **NRLMSISE-00** model output.

Panels method densities (left) are compared with SPARTA results (right).



Consistency with other satellites

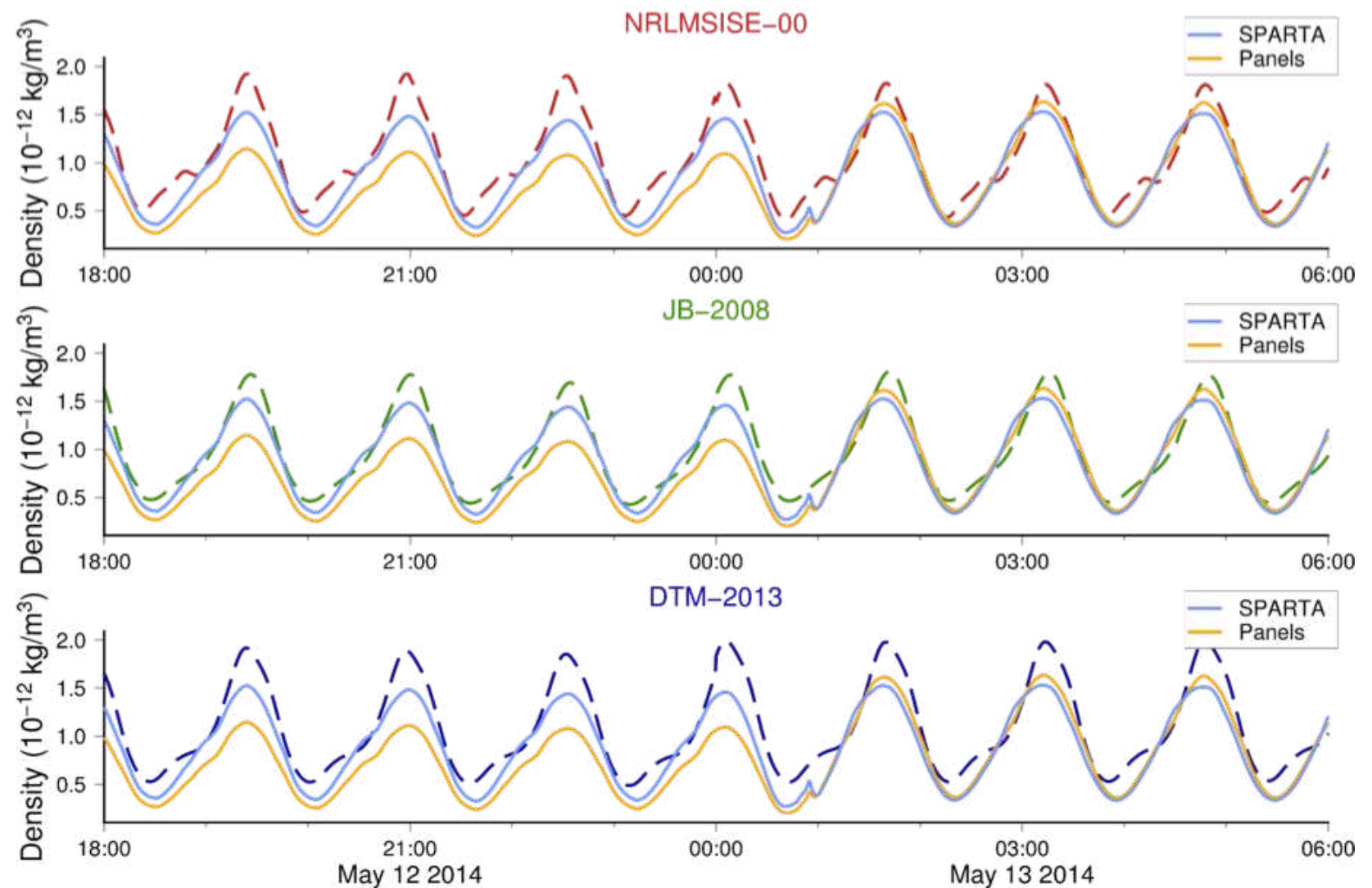
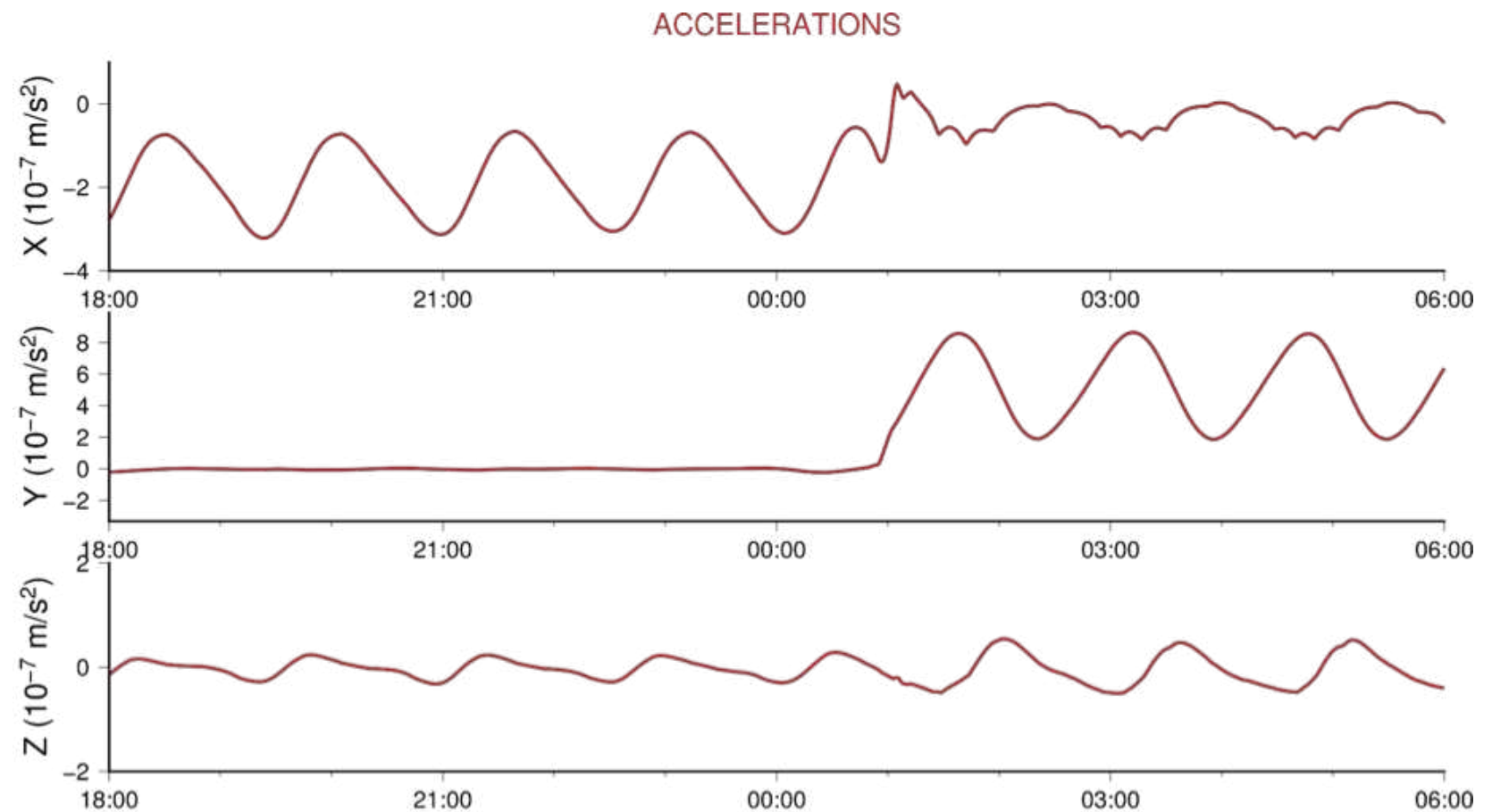
New densities turned out to be higher reaching a mean **+11%** for CHAMP, **+5%** for GRACE, **+9%** for GOCE and **+32%** for Swarm.



Attitude manoeuvre Comparison

(90° Yaw man.)
13/05/2014

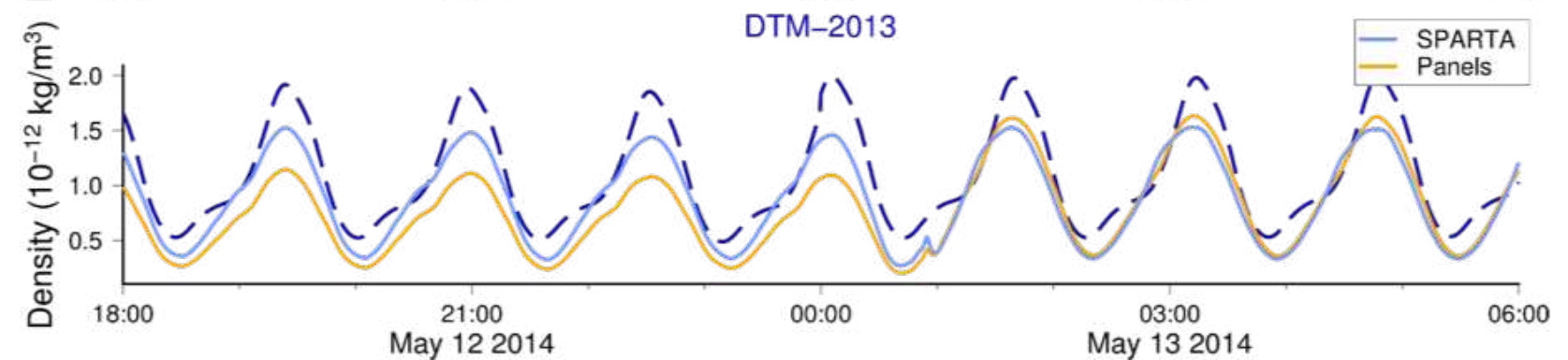
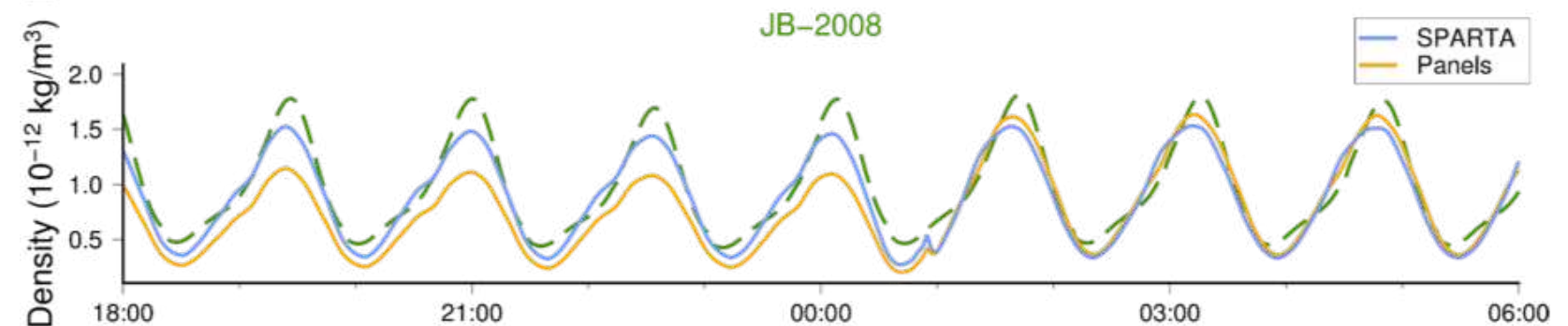
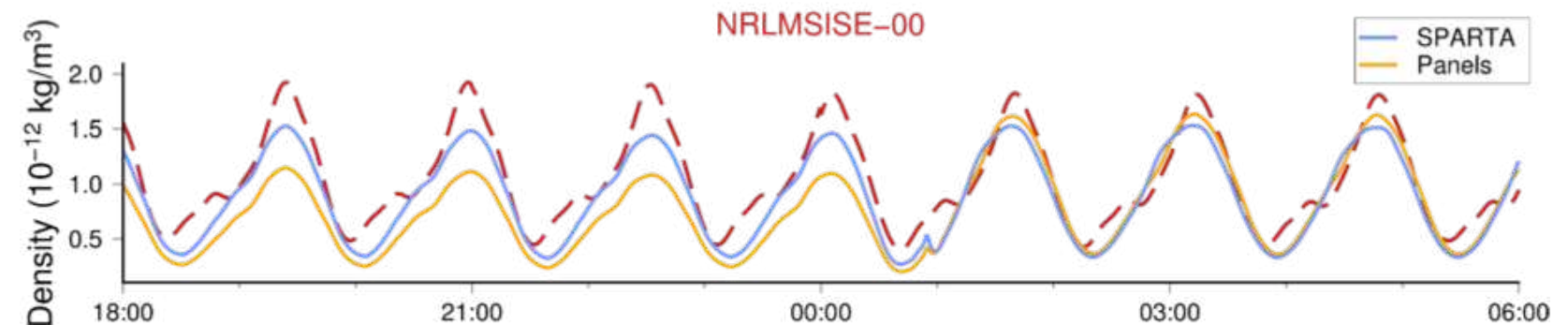
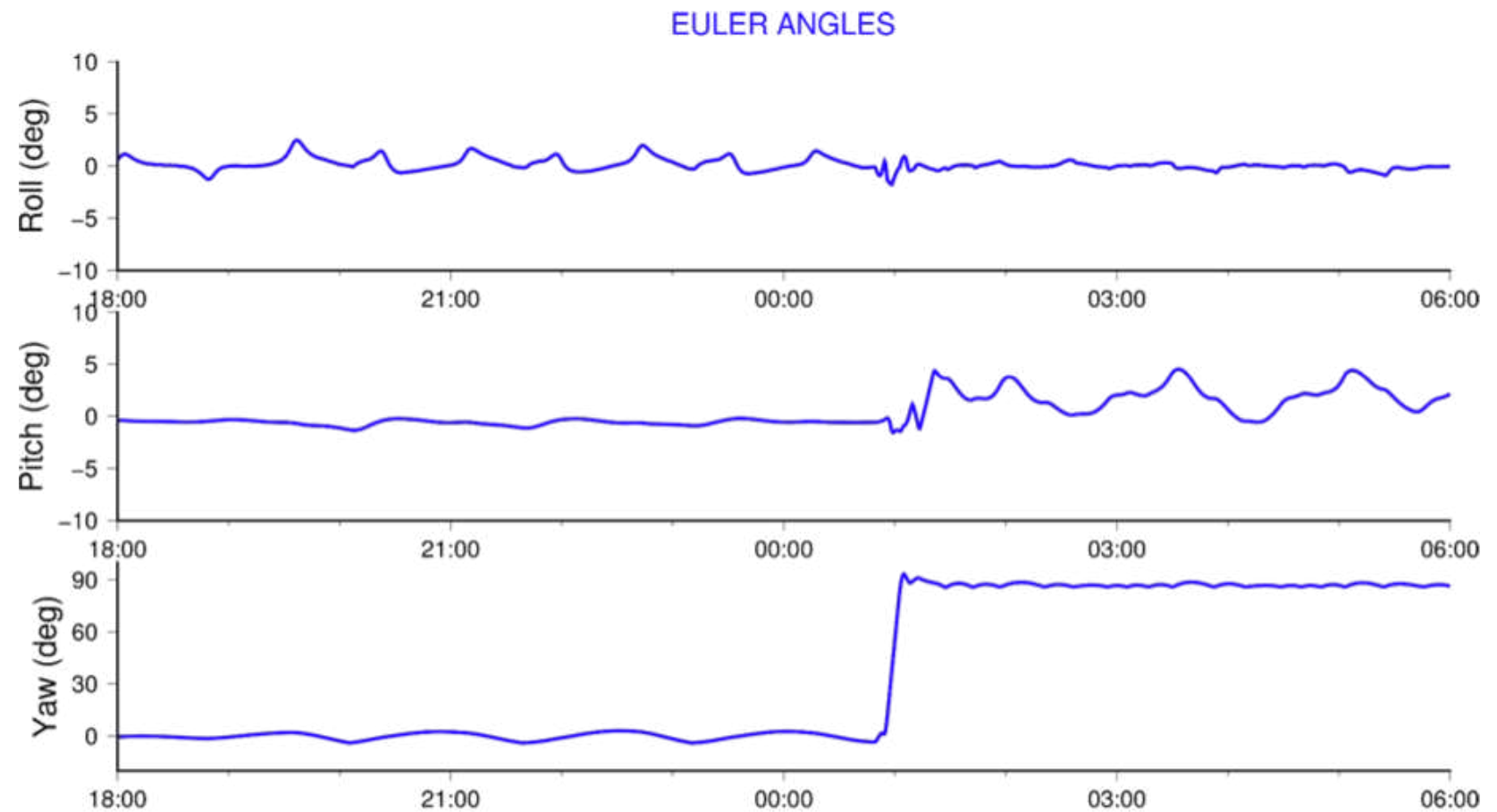
X-Y-Z Accelerations
&
Density comparison with 3
atmospheric models



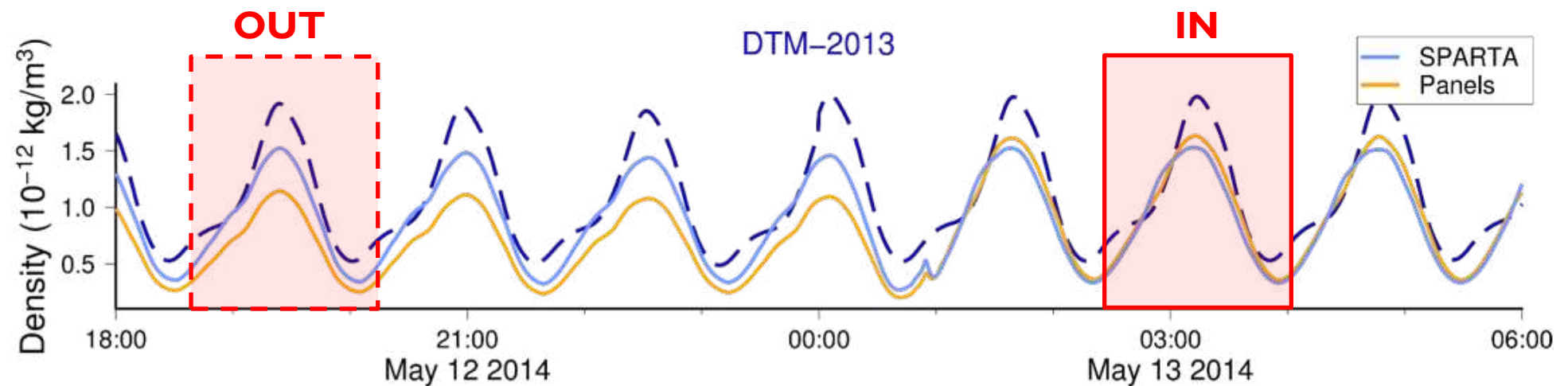
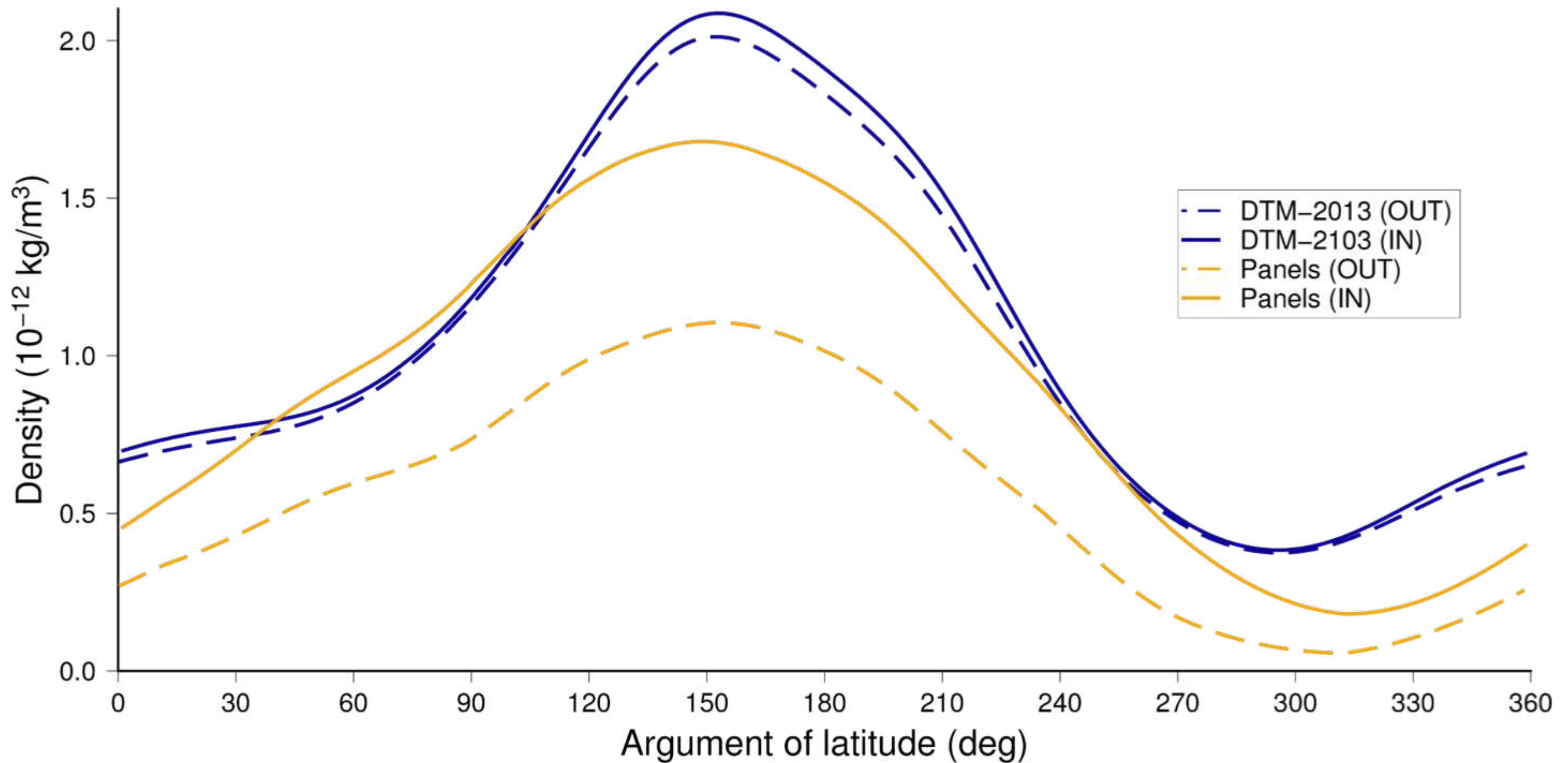
Attitude manoeuvre Comparison

(90° Yaw man.)
13/05/2014

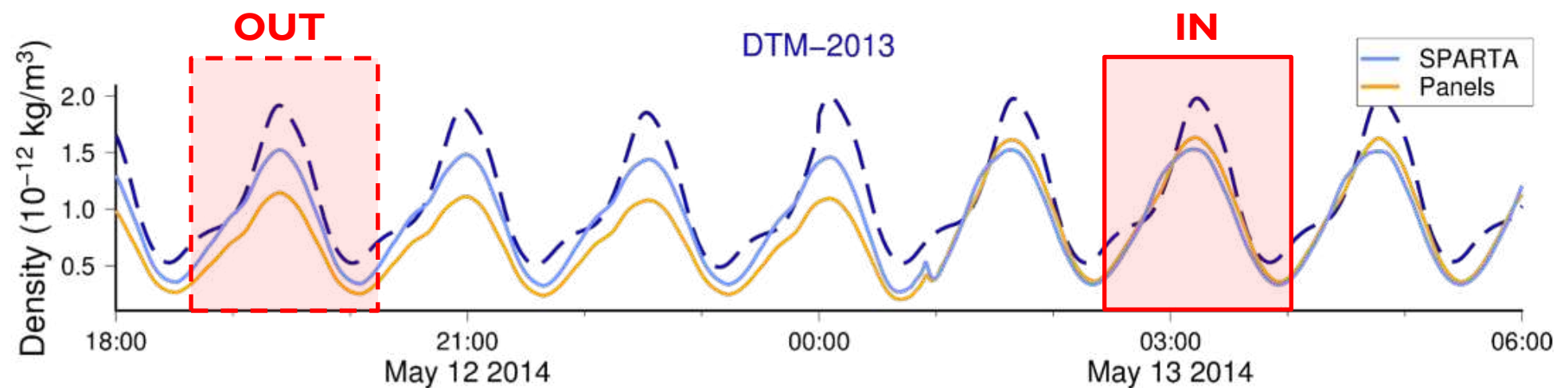
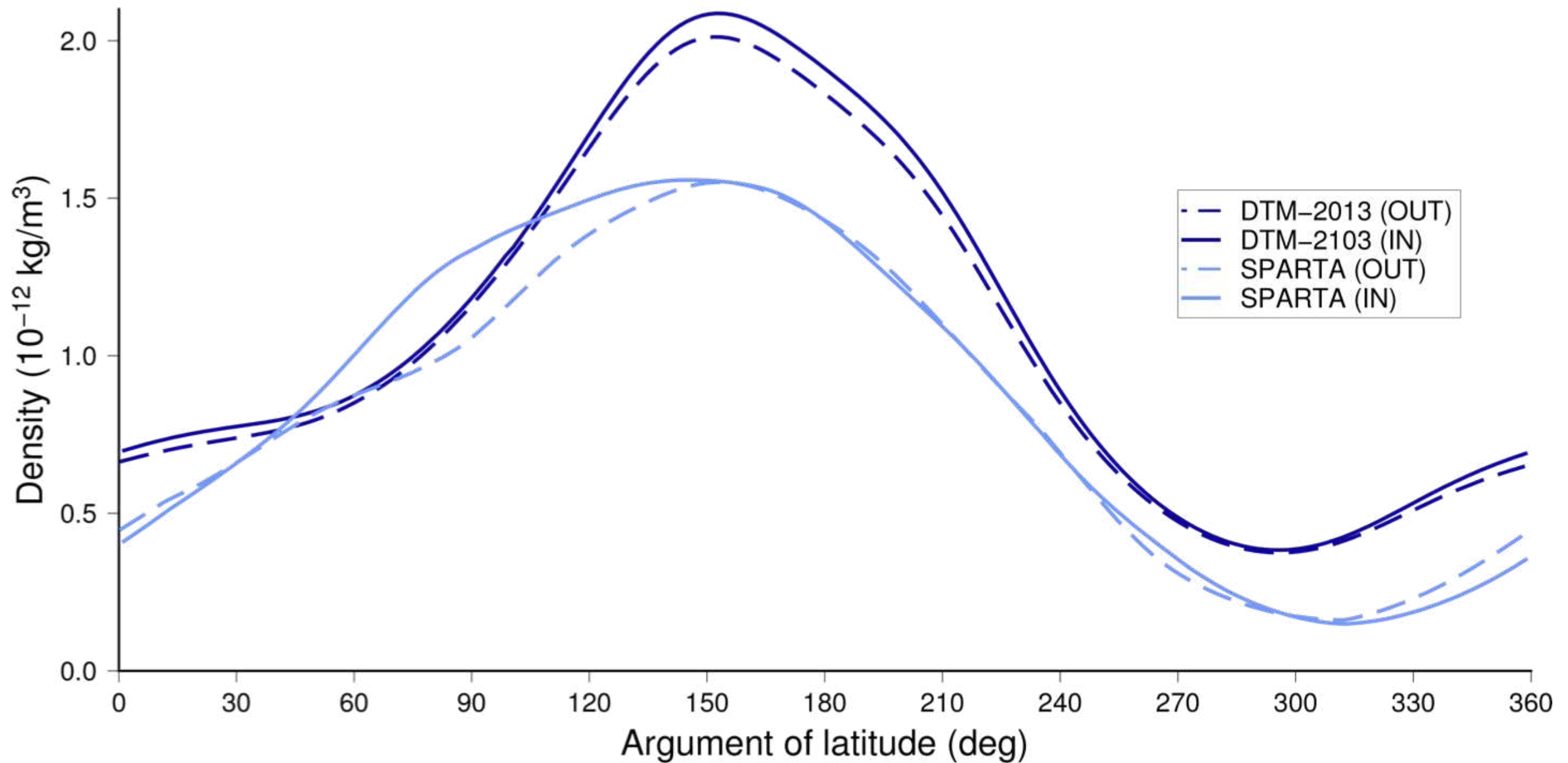
Euler Angles
&
Density comparison with 3
atmospheric models



Attitude manoeuvre comparison (90° Yaw)



Attitude manoeuvre comparison (90° Yaw)

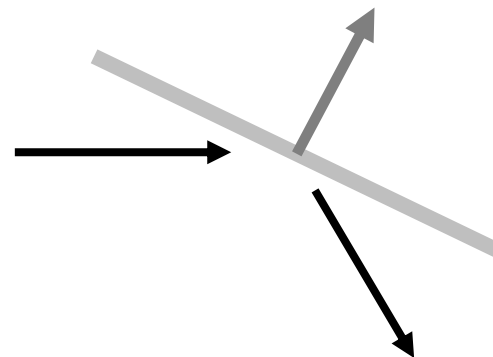


Summary & Outlook

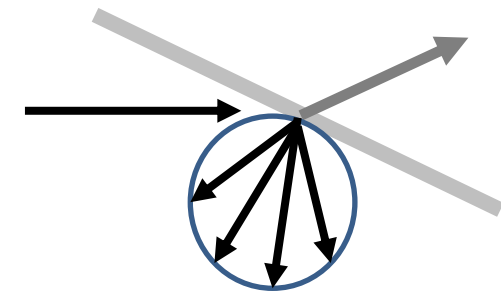
SPARTA data set is currently adopted for L2 DNS-POD product

Gas-Surface Interactions

Specular reflection



Diffuse reflection



Solar radiation pressure modelling