CHAMP, GRACE, GOCE and Swarm thermosphere density data with improved aerodynamic and geometry modelling

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Introduction
Since 2000, accelerometers on board of the CHAMP, GRACE, GOCE and Swarm satellites have provided high-resolution thermosphere density data, improving knowledge on atmospheric dynamics and coupling processes in the thermosphere-ionosphere layer.

Most of the research has focused on relative changes in density. Scale differences between datasets and models have been largely neglected or removed using ad hoc scale factors. The origin of these variations arises from errors in the aerodynamic modelling, specifically in the modelling of the satellite outer surface geometry and of the gas-surface interactions. Therefore, in order to further improve density datasets and models that rely on these datasets, and in order to make them align with each other in terms of the absolute scale of the density, it is first required to enhance the geometry modelling. Once accurate geometric models of the satellites are available, it will be possible to enhance the characterization of the gas-surface interactions and the satellite aerodynamic modelling.

Methodology
Through detailed high fidelity 3-D CAD models and Direct Simulation Monte Carlo (DSMC) computations, flow shadowing and complex concave geometries can be investigated. This was not possible with previous panels method, especially because of the low fidelity geometries and the inability to model shadowing effects. The panel method consists of the application of Sentman’s equations to a simplified geometry model. A number of flat panels describe the entire structure of the satellite. Normal vectors and areas of each panel give the fundamental information needed to retrieve aerodynamic coefficients. This geometry and aerodynamic modelling turned out to have a large influence on derived densities, particularly for satellites with complex elongated shapes and protruding instruments and booms.

The geometry and aerodynamic modelling have been enhanced with the DSMC approach and the accelerometer data have been reprocessed leading to higher fidelity density estimates. In particular, the Stochastic Molecular Rarefied-gas Time-accurate Analyzer (SPARTA) simulator from SANTIA Laboratories has been used for the aerodynamic modelling. The collisions between atmospheric particles and satellite outer surfaces are simulated within a fixed domain. Pressures and shear stresses associated to each surface element are computed and processed to retrieve force coefficients.

Geometry Modelling
In order to improve previous panel geometries for CHAMP/GRACE, GOCE and Swarm, new geometries have been designed with CATIA V5 R21. These geometries have been the inputs for SPARTA DSMC simulations. Several attitude configurations have been simulated in order to describe all the possible flight configurations during mission lifetime.

Results and Future Work
A general improvement can be found comparing the mean ratio (µ*) between Panels and SPARTA models with the atmospheric models. New densities turned out to be higher, reaching a mean +11% for CHAMP, +5% for GRACE, +9% for GOCE and +32% for Swarm.

In the next months, further research is aimed at estimating Gas-Surface-Interactions (GSI) parameters and their influences on the thermospheric density datasets.

References