Update on thermospheric density products from satellite observations

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Update on thermospheric density products from satellite observations

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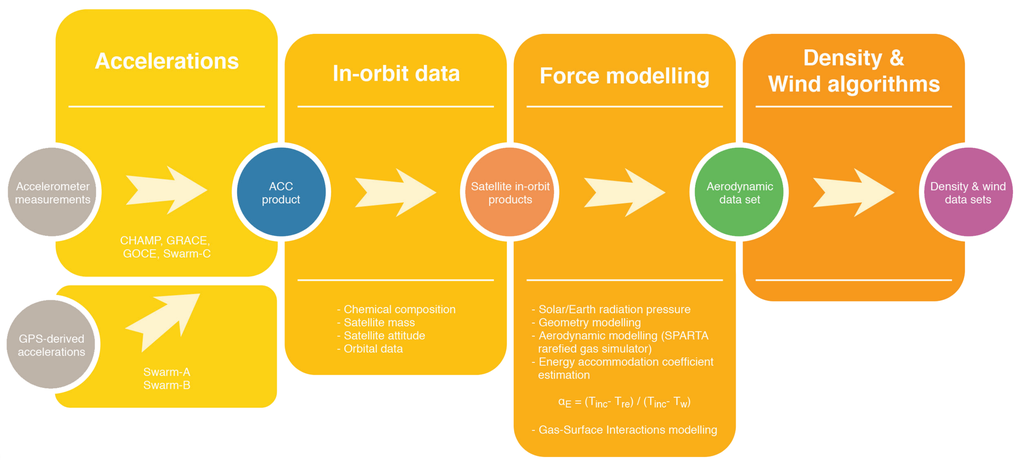
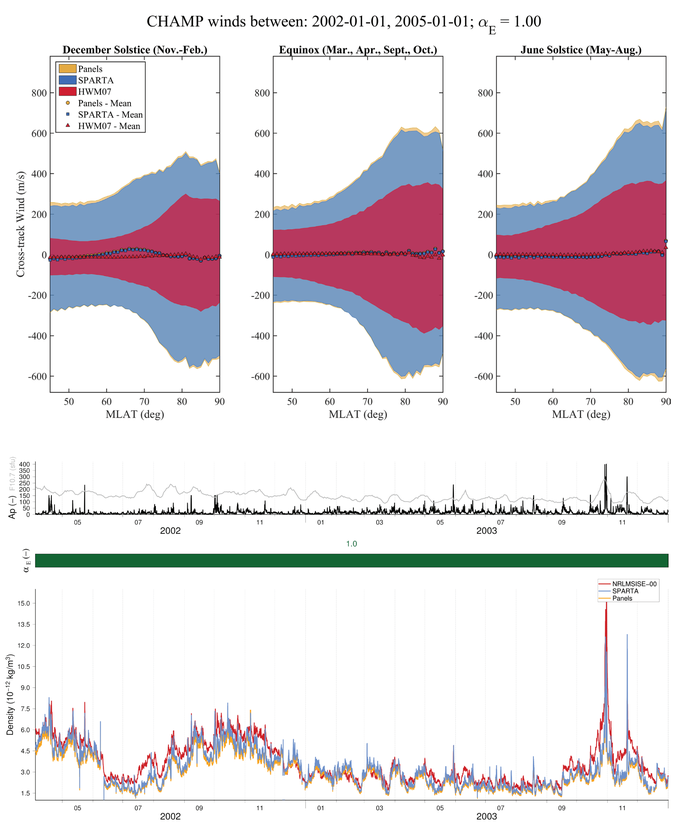
How do we process thermosphere data products?

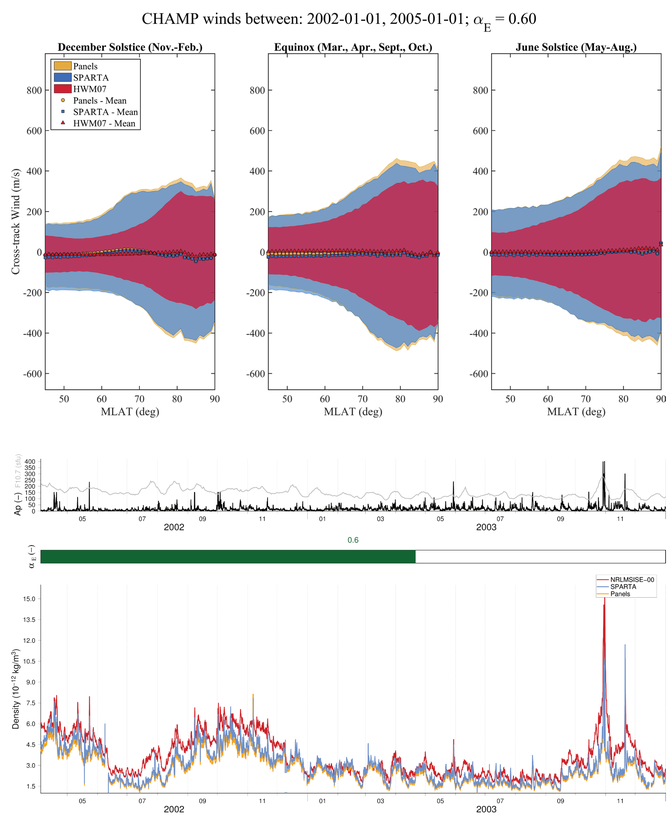
Accelerometers and GPS reveivers on satellites provide information about aerodynamic accelerations, which are controlled by density and wind in the upper atmosphere. With the help of High-Fidelity satellite geometries and rarefied gas simulatons, we can retrieve this information from the satellite data. These data are further processed using satellite position and attitude to provide information on the local atmosphere. So far, data sets are available for the CHAMP, GRACE, GOCE and Swarm satellites. In order to enhance products fidelity, it is important to estimate the gas-surface interactions (GSI) parameters. One of these crucial parameters is the energy accommodation coefficient (α_E), which provides a tangibile value for the exchanged energy in the collisions between atmospheric particles and satellite surfaces. This study shows the influence of the energy accommodation coefficient on thermospheric products. The selection of accurate GSI parameters will provide improved thermospheric data and satellite drag estimations.



Density and wind data sets

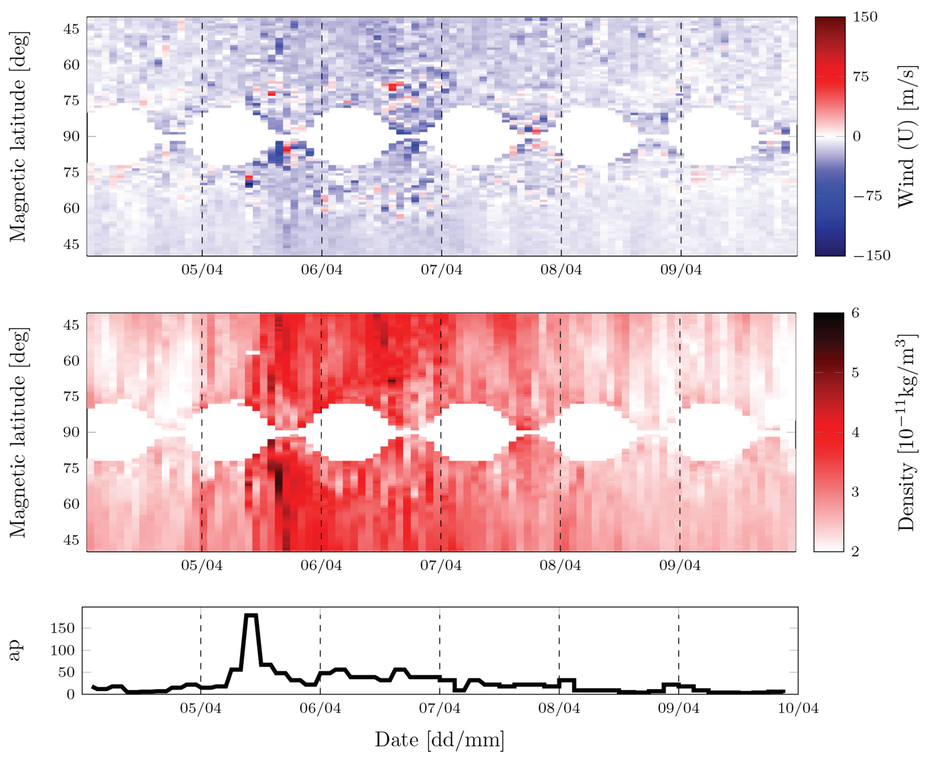
The use of accelerometers allows for high resolution observations of the thermosphere. The following plots show the newly derived winds and densities (SPARTA) for CHAMP. Comparisons with the previous generation data (Panels), and HWM-07 (for winds) and NRLMSISE-00 (for densities) models are represented in the diagrams. For the cross-track wind, data are available for three periods. Two energy accommodation coefficients (1.00, 0.60) are available in the figures. The neutral density is directly connected with the geomagnetic activity. Varying the value of accommodation coefficient a different behaviour with respect to models is obtained. The density data turn out to agree less well with the NRLMSISE-00 model for low values of accommodation coefficients, whereas the opposite behaviour is achieved for winds and HWM-07.





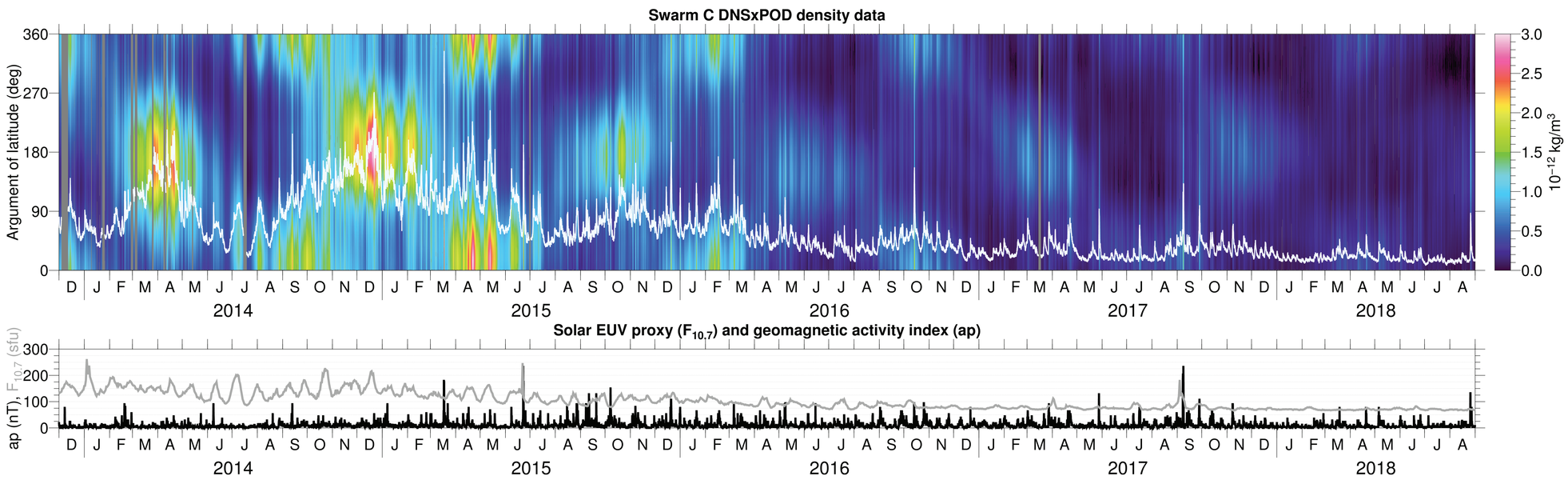
GOCE

The highly accurate data sets offer the opportunity to investigate special geomagnetic activities. The following plots show the vertical wind (only available for GOCE) and neutral density in the thermosphere during the April 2010 geomagnetic storm. Especially at the onset of the storm, on 5 April, a clear peak can be observed in the vertical wind. The neutral density responds directly to this vertical wind peak, as high density air is transported from below to the satellite's location.



Swarm

Accelerometers onboard of the Swarm satellites provided data with many anomalies. The development and production of GPS-derived accelerations has been necessary for density processing. Swarm GPS measurements have been converted to accelerations using a precise orbit determination approach. A Kalman filter approach was used to compute acceleration data, which are available as the L2 ACCxPOD product. In a second step, GPS-accelerations are converted into thermosphere neutral density data (L2 DNSxPOD products) using the high-fidelity geometry information. The following figures provide an overview of the processed data for Swarm-C. Density increments due to solar and geomagnetic activity can be detected, as well as local time, seasonal and latitude effects.

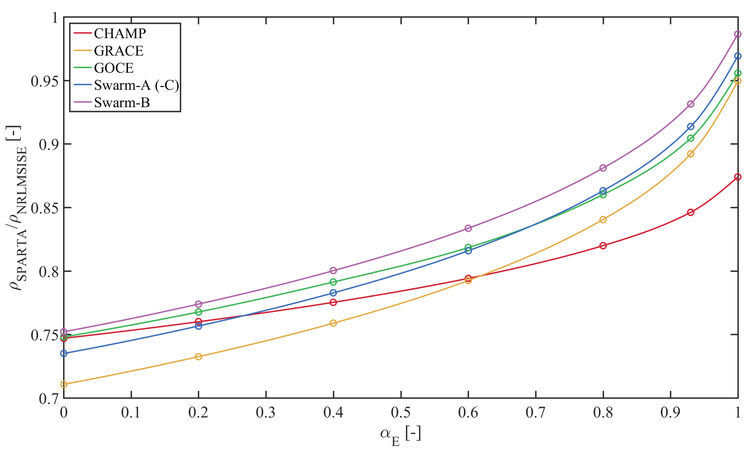


Gas-Surface Interactions

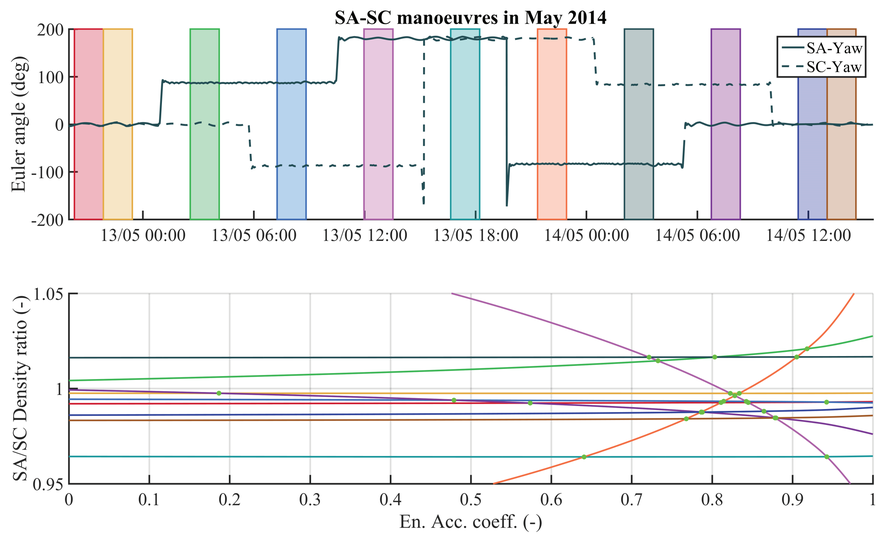
The accommodation coefficient turned out to have a different impact on density and wind if analyzed in comparison with semi-empirical models. Lower densities are reached for low accommodation coefficients. This results in a larger disagreement with atmospheric models like NRLMISISE-00. Whereas, the horizontal winds are in better agreement for lower accommodation coefficients.

In order to find a suitable value to process new products, two studies are currently under investigation. The first one is focused on long period density ratios with respect to NRLMSISE-00, the second investigates the density ratio between Swarm A and C within attitude manoeuvres. From preliminary results, lower values of Energy accommodation coefficients might be needed with respect to the currently adopted value of 0.93.

Future work is going to provide a better estimate of gas-surface interactions parameters, which will improve current thermospheric products and models.



Long periods include data within 2003-2004 for CHAMP & GRACE, 2010-2012 for GOCE and 7/2013-1/2015 for Swarm. Looking at the plot above, it is possible to find different intersections and a nearly constant density ratio bandwidth for α_E lower than 0.60. Values higher than 0.93 show a larger range in density ratios.



Swarm A & C manoeuvres between 13-15 May 2014 provide interesting results. Assuming a uniform accommodation coefficient, the intersections suggest optimal values for α_E below the currently used value of 0.93 converging to a value around 0.83.

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