Analysis of high-resolution GOCE atmospheric densities

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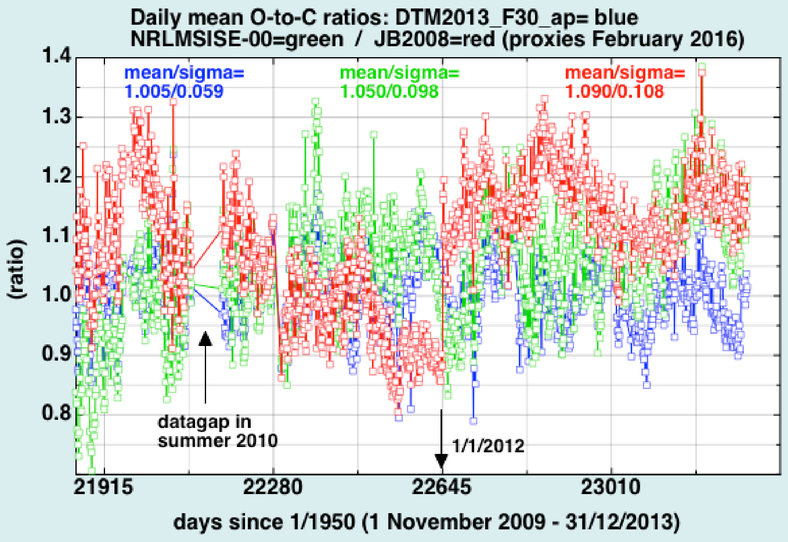
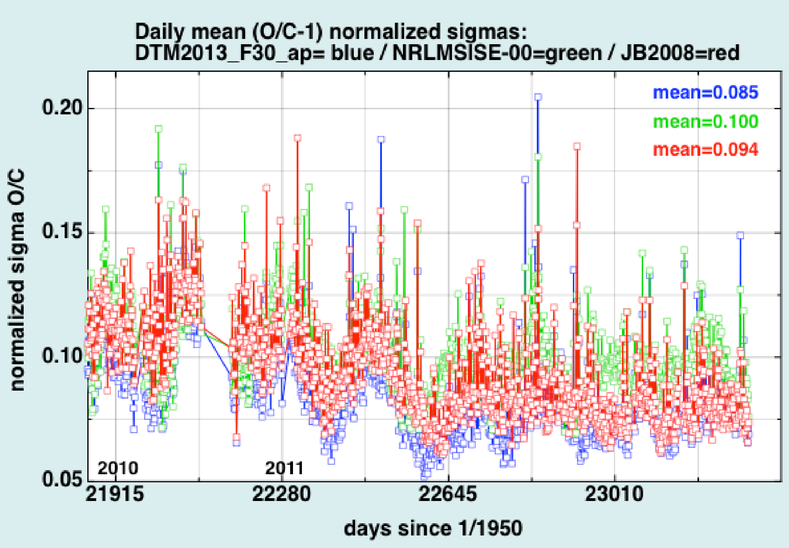
'PREGO': ESA CONTRACT 4000115173/15/F/MOS





Model performance at low altitude: GOCE

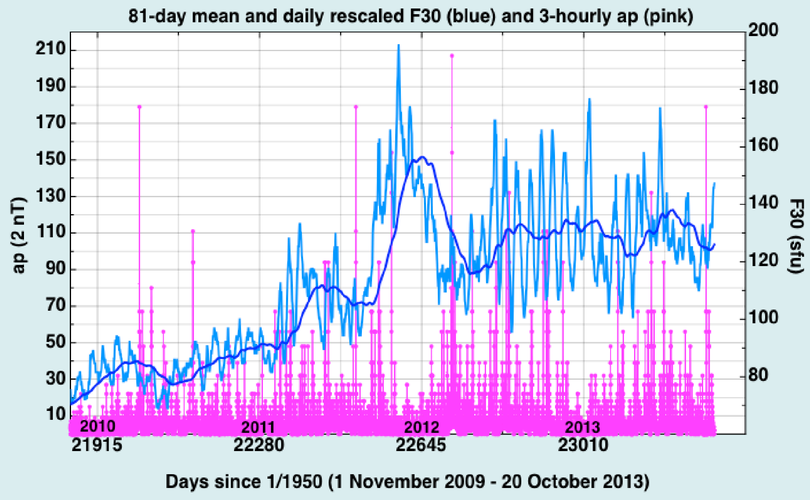
The official ESA GOCE densities for the entire Science Mission (1 November 2009 – 20 October 2013) have been compared with the three CIRA models NRLMSISE-00 , JB2008 and DTM2013. The densities have been scaled to the US Air Force HASDM model. The DTM2013 model has assimilated GOCE densities to May 2012, which explains its good performance. The model evaluation uses the following metric:

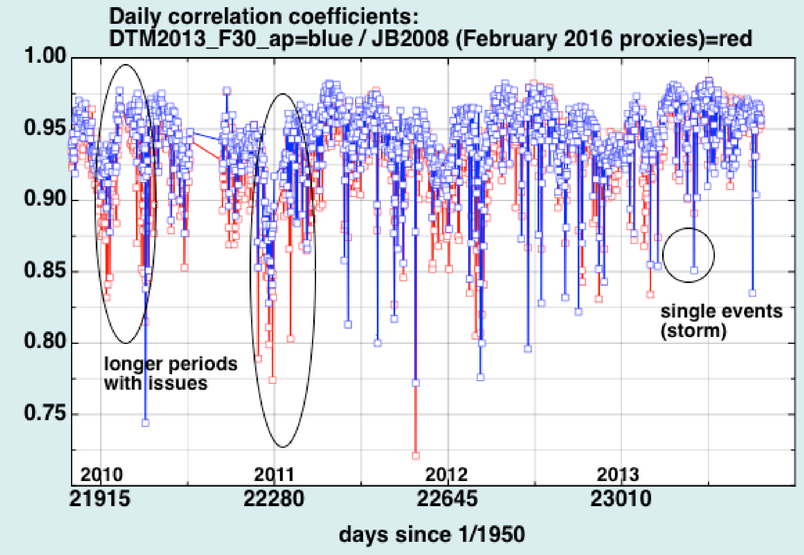
O/C = observation / model = bias
σ / RMS(O/C – 1) = relative precision
corrrelation coefficient

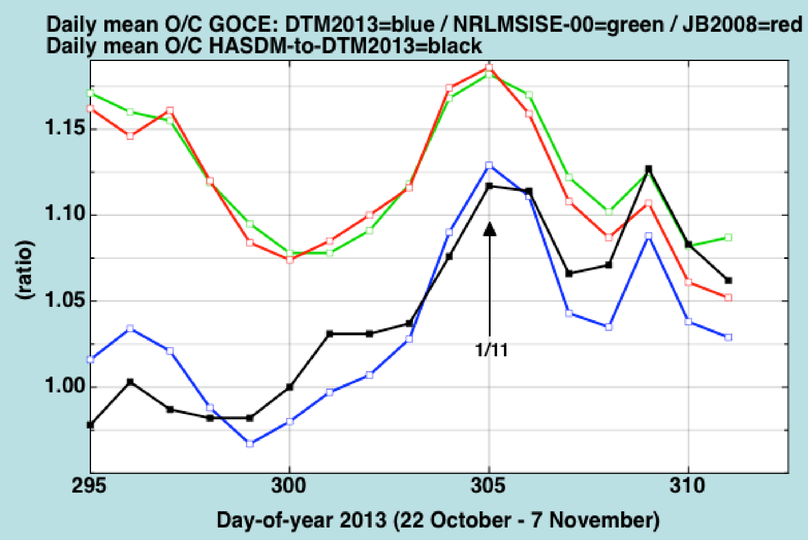
The evaluation was done in intervals ranging from years, (relevant to mission design, lifetime estimations) to months (orbit maintenance), to days (re-entry prediction) in order to quantify the model errors as a function of time scale. The results of comparison with the densities in the re-entry phase (22 October – 11 November 2013) can then be compared to the robust statistical results obtained on a representative 4 year sample.

The daily mean O/C is displayed on the left (top). DTM2013 reproduces the GOCE densities unbiased over the entire 4 year period, whereas NRLMSISE-00 is drifting up and various errors (drift, jump, annual) affect JB2008 (with February 2016 proxies). The σ (bottom left) decreases as solar activity picks (top right) up after the very low values in 2009 to well below 10% for DTM2013 and JB2008.

The correlation is shown for JB2008 and DTM2013 in the figure on the right (bottom). It is 0.94 on average, slightly lower for NRLMSISE-00, and the spikes down to 0.75 or less are during geomagnetic enhanced or storm times.

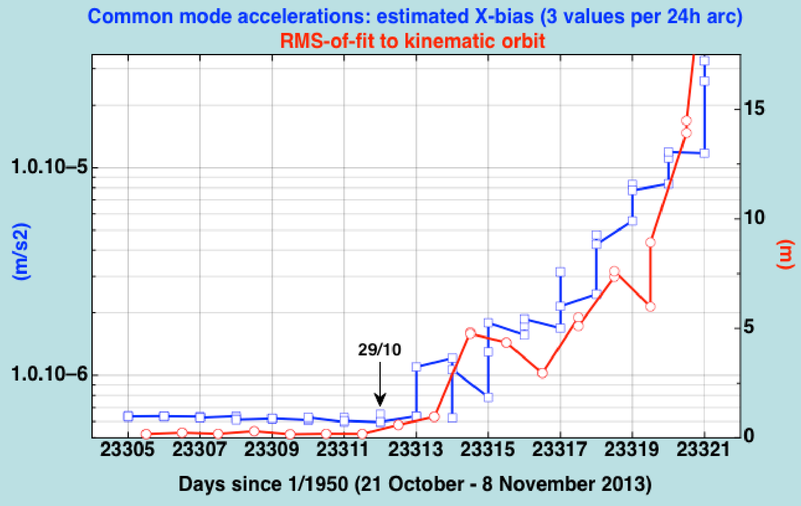






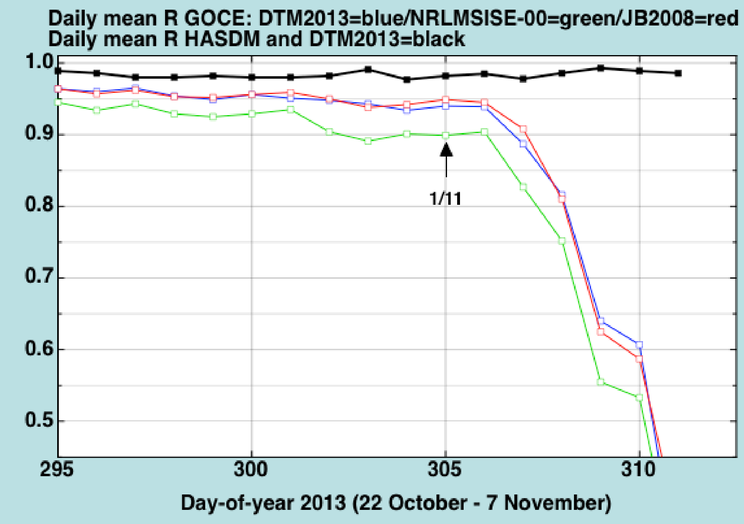
Re-entry period orbit and density computation

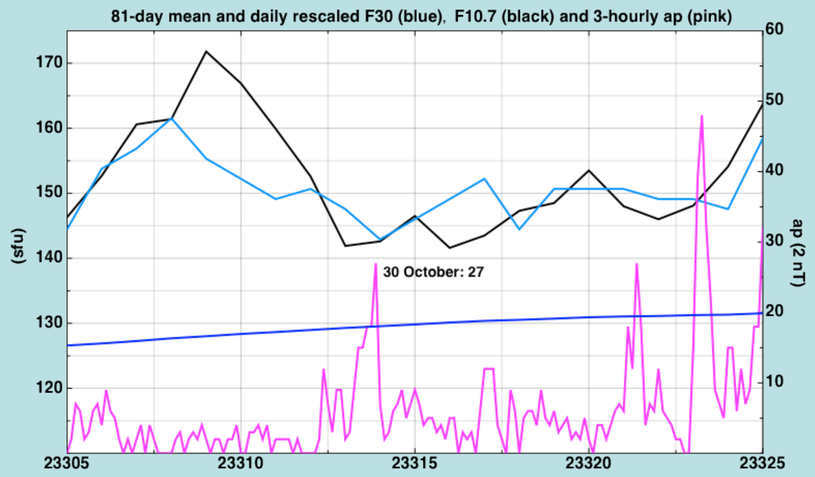
The densities for the re-entry period were computed with the GINS software and a simple 6-panel macromodel, which was the configuration also used in the validation procedure of the official ESA GOCE densities. The precise kinematic orbit positions were used as observations. For each 24-hr arc, the state vector at epoch and accelerometer bias parameters for the X and Y axes (along and cross track) were estimated.
The RMS of fit and the estimated X biases are shown to the right. For October, the RMS is at the 20 cm level and the bias is quite stable; then the bias and RMS start increasing rapidly and this is due to accelerometer errors (saturation). The problems actually started at the end of 30 October, as is demonstrated in the box on the bottom right.



Model comparisons in the re-entry period

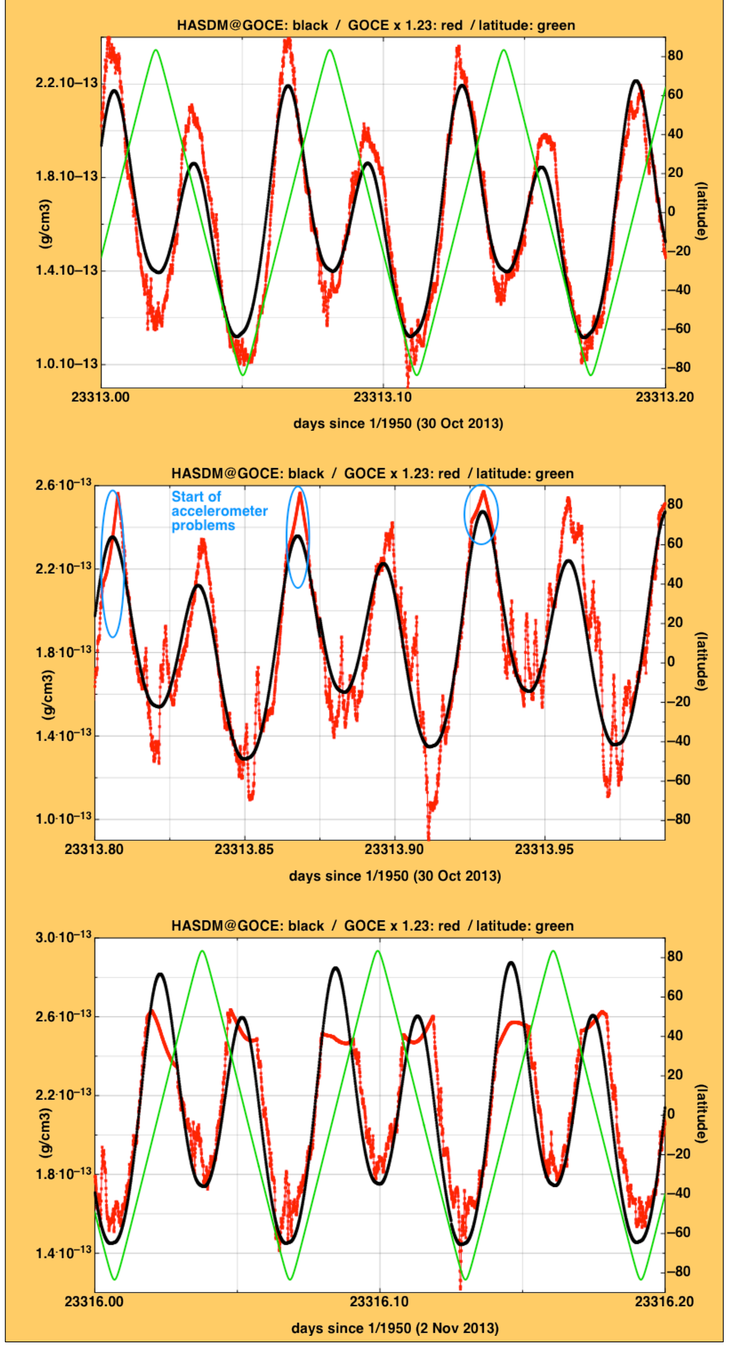
The GOCE densities were compared to the HASDM and CIRA models. The O/C ratios (top) and the correlations (bottom left) are shown, as well as the solar and geomagnetic activity (bottom right). Results should not be interpreted starting November due to the accelerometer saturation (it has not been edited out yet), which leads to the rapidly decreasing correlation. Results are in general agreement with model performance over the entire Science Mission.

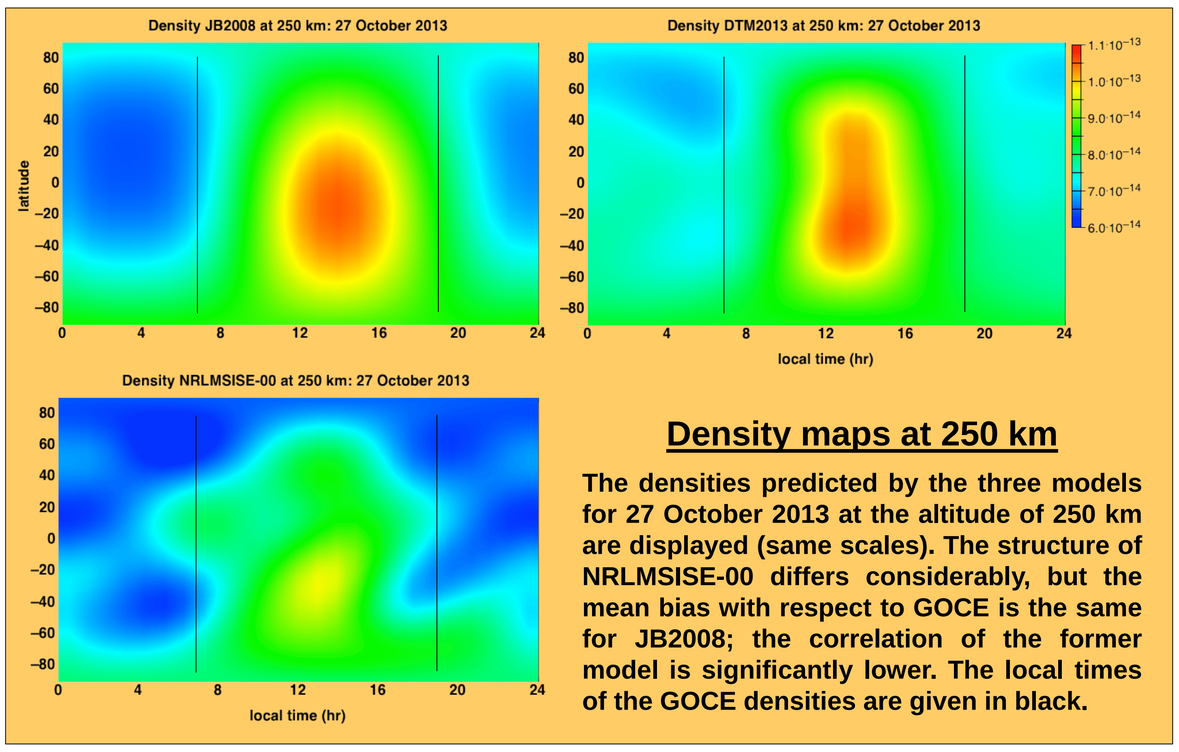




Accelerometer saturation

The GOCE and HASDM densities are shown below for 30 October, the day on which the problems started, and 2 November, when the saturation is clearly visible.





Density maps at 250 km

The densities predicted by the three models for 27 October 2013 at the altitude of 250 km are displayed (same scales). The structure of NRLMSISE-00 differs considerably, but the mean bias with respect to GOCE is the same for JB2008; the correlation of the former model is significantly lower. The local times of the GOCE densities are given in black.

Conclusions

- DTM2013 is unbiased, lowest RMS and standard deviation, highest correlation
- JB2008 is more or less biased, depending on the proxy file version (!)
- NRLMSISE-00 has small bias, except for first months of the mission (very low flux)
- Daily mean standard deviation (i.e. the precision of a *calibrated* model) at GOCE altitude varies from 12% for very low flux to 7-8% at medium flux levels

Re-entry phase:

- GOCE accelerometer-inferred densities, and the bias parameters, are affected by instrument errors from 31 October onward (saturation?)
- Remarkable agreement between GOCE densities and HASDM from 22-29 October
- DTM2013 is least biased from 22-30 October, NRLMSISE-00 and JB2008 about 15% *constant* bias