A comparison of scale factors for the thermospheric density from satellite laser ranging and accelerometer measurements

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Introduction and Motivation

- The knowledge of the thermospheric density is of crucial importance not only for precise orbit determination (POD) of low Earth orbiting (LEO) satellites at altitudes below 1,000 km, but also for re-entry predictions and satellite maneuvers, as well as for geo-scientific applications such as remote sensing, and satellite gravimetry.
- Several empirical thermospheric models, such as NRLMSISE-00 or JB 2008, provide the thermospheric density among other parameters.
- Since these models are based on different input data sets, they can give quite different results, especially for strong space weather events.
- Since LEOs are sensitive to atmospheric drag, appropriate on-board instrumentation (accelerometers, trackers, reflectors, etc.) can be used to derive density information.
- As satellites above 550 km are usually not equipped with accelerometers, the question arises if SLR measurements to LEO satellites provide a suitable complement to accelerometer measurements to obtain thermospheric density information?

Procedure

- We distinguish between:
  - 1st Approach utilizes the POD of LEO satellites to estimate scale factors of the thermospheric density from SLR tracking measurements.
  - 2nd Approach consists in the calculation of scale factors of the thermospheric density from the evaluation of the aerodynamic acceleration using satellite accelerometer (ACC) measurements.

Thermospheric density and selected satellite missions

- In the equation of motion of a LEO satellite the aerodynamic acceleration is defined as
  $$\alpha_{aero} = -\frac{1}{2} \frac{\rho_{aero}}{m_{sat}} \frac{v_{sat}}{r_{sat}} \frac{r_{sat}}{m_{sat}}$$

Procedure (cont.)

- The 1st approach is typically applied to spherical LEO satellites
- In this case, the drag acceleration is given by:
  $$\alpha_{aero} = -\frac{1}{2} \frac{\rho_{aero}}{m_{sat}} \frac{v_{sat}}{r_{sat}} \frac{r_{sat}}{m_{sat}}$$

Results

- Figure 3 shows the estimated scale factors after smoothing with a 10-day moving average filter to remove noise.
- It can be seen that the estimated scale factor time series from SLR and ACC data agree very well.
- This indicates to what extent the NRLMSISE-00 model density values differ from the measured thermospheric densities derived from SLR and ACC measurements.
- To relate the filtered scale factor time series to the solar activity, the top panel in Fig. 3 depicts the time series of the 10-day averaged F10.7 Index.

Conclusions

- For the first time, we have compared scale factors of the thermospheric density derived from SLR and ACC measurements.
- Correlations of 0.7 to 0.8 are obtained between the estimated scale factors from SLR and ACC measurements depending on the height.
- The mean values of the estimated scale factors of the thermospheric density provided by the NRLMSISE-00 model for various solar altitudes as obtained from our analysis of SLR measurements to 4 satellites at mean altitudes of 681 to 957 km and from GRACE and CHAMP ACC measurements are 0.89 to 1.01 at LSA and 1.10 to 1.20 at HSA.
- SLR measurements to LEO satellites are a very well suited complement to ACC measurements to obtain information on the thermospheric density.

Publications (selected)