The impact of atmospheric and hydrological surface loading corrections on GNSS orbits

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Overview

Time-dependent mass variations of near-surface geophysical fluids in atmosphere, oceans and the continental hydrosphere lead to significant and systematic load-induced deformations of the Earth's crust and variations of Earth's gravity field. Based on a reprocessed GNSS station network it is possible to assess the impact of time-dependent mass variations on the Earth's surface geometry and on GNSS satellite orbits. In general, the impact on GNSS orbits is small whereas a significant effect on coordinates can be observed.

GFZ surface loading products

The atmospheric and hydrospheric surface loading deformation products provided by ESMGFZ (Earth System Modelling Group of GFZ) contain vertical and horizontal crust deformations imposed by surface loading of geophysical fluids with a resolution of 0.5° and a temporal sampling of down to 3 hours (Dill and Dobslaw, 2013). Regular updates are available each day at 10 UTC including predictions for the following six days. Models provided in the CM-frame were applied in this study.

GPS observations from 156 stations were processed for the time period GPS week 1460.2 (January 1, 2008) to GPS week 1820.0 (December 31, 2017). The GNSS network processing scheme is summarized in Tab. 1. Initial orbits and clocks were taken from a GFZ internal reprocessing effort. Antenna changes and strong earthquakes were considered for discontinuity detection.

Impact on station coordinates

In order to assess the impact of non-tidal loading models on GNSS satellite orbits, solutions with and without applied models were compared against each other. In general, only small differences are visible between the two orbit solutions. The daily 3D-RMS of the orbit comparison is at the level of few mm as shown in Fig. 4. However, estimated translations show clearly periodical behavior (Fig. 5, red) which agrees in phase with translations estimated between the models provided in the CM and in the CF-frame. Fig. 6 shows for several spacecraft the differences in the semi-major axis between solutions with and without models. Satellites with similar differences were grouped according to estimated correlations which show a geographical pattern (Fig. 7).

Impact on GNSS satellite orbits

Fig. 6 Semi-major axis: difference between orbits with and without applied models; satellites with similar differences are grouped, as listed on the right side; each group except the first is shifted by 2 mm

Summary and Conclusions

Time-dependent mass variations of near-surface geophysical fluids in atmosphere, oceans and the continental hydrosphere lead to small but systematic variations in GNSS satellite orbits. Translations in z-direction reach 3 mm with a clear annual period.


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