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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 Modeling 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.

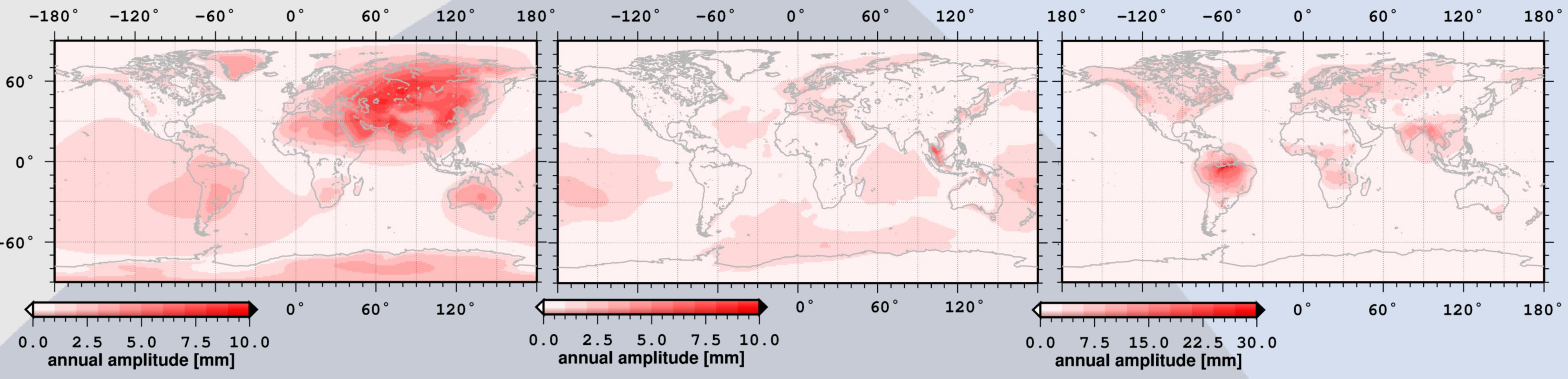

Fig. 1 *Annual amplitude of the surface deformation due to atmosphere (left), ocean (middle), and continental hydrology (right)*

GNSS Processing

GPS observations from 156 stations were processed for the time period GPS week 1460.2 (January 1, 2008) to GPS week 1982.0 (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.

observations	GNSS zero-difference phase observations
satellite orbits	24h arcs, ECOM-2 and 3 pulses at noon
satellite clocks	solved for at each epoch
coordinates	estimated w.r.t. ITRF2014
troposphere	zenith delays for 1 h intervals, 2 gradients for 24 h intervals
receiver clocks	solved for at each epoch
phase ambiguities	fixed

Tab. 1*: Processing summary; the GFZ software package EPOS.P8 was used*

Impact on station coordinates

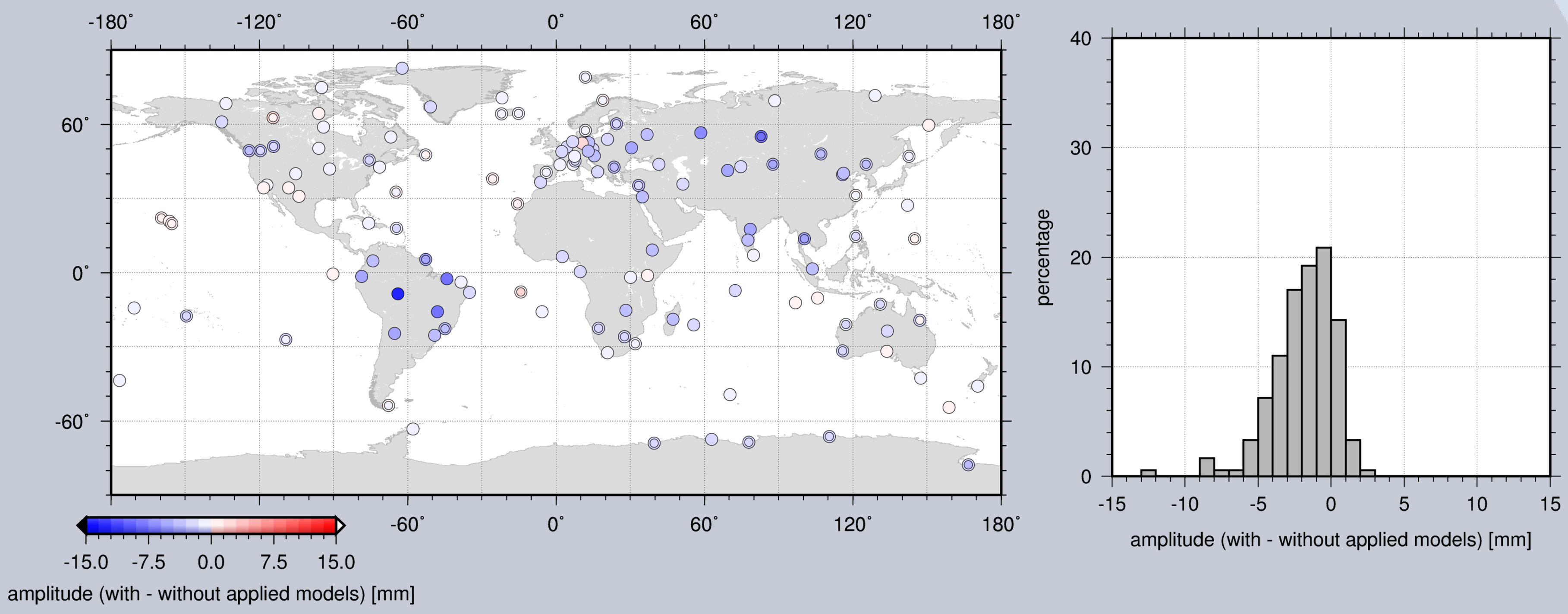

Fig. 2 *Differences in annual amplitude (time series shorter than 900 days were skipped)*

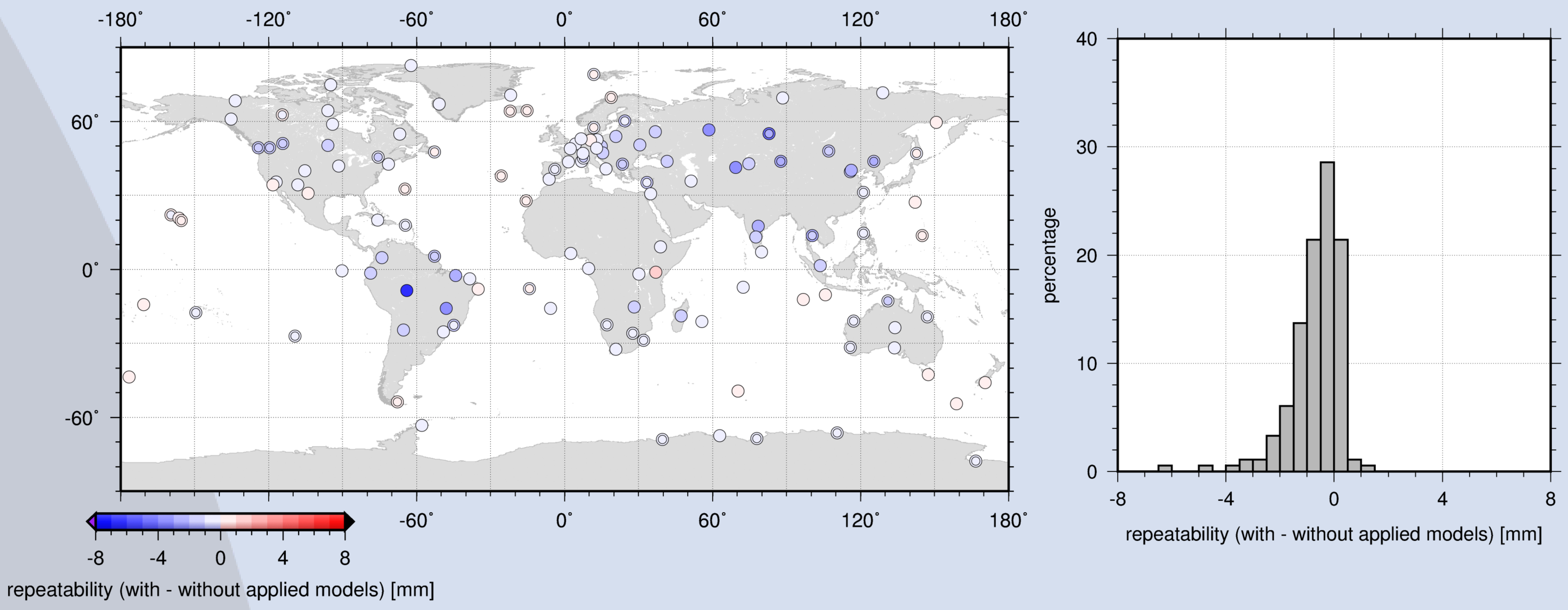

Fig. 3 *Differences in station coordinate repeatability (based on linear velocity model)*

Impact on GNSS satellite orbits

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).

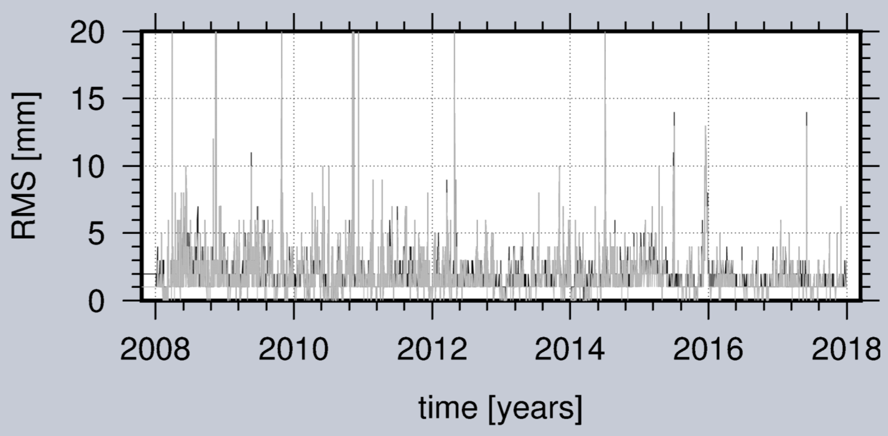

Fig. 4 *RMS of orbit comparison without (black) and with transformation (grey)*

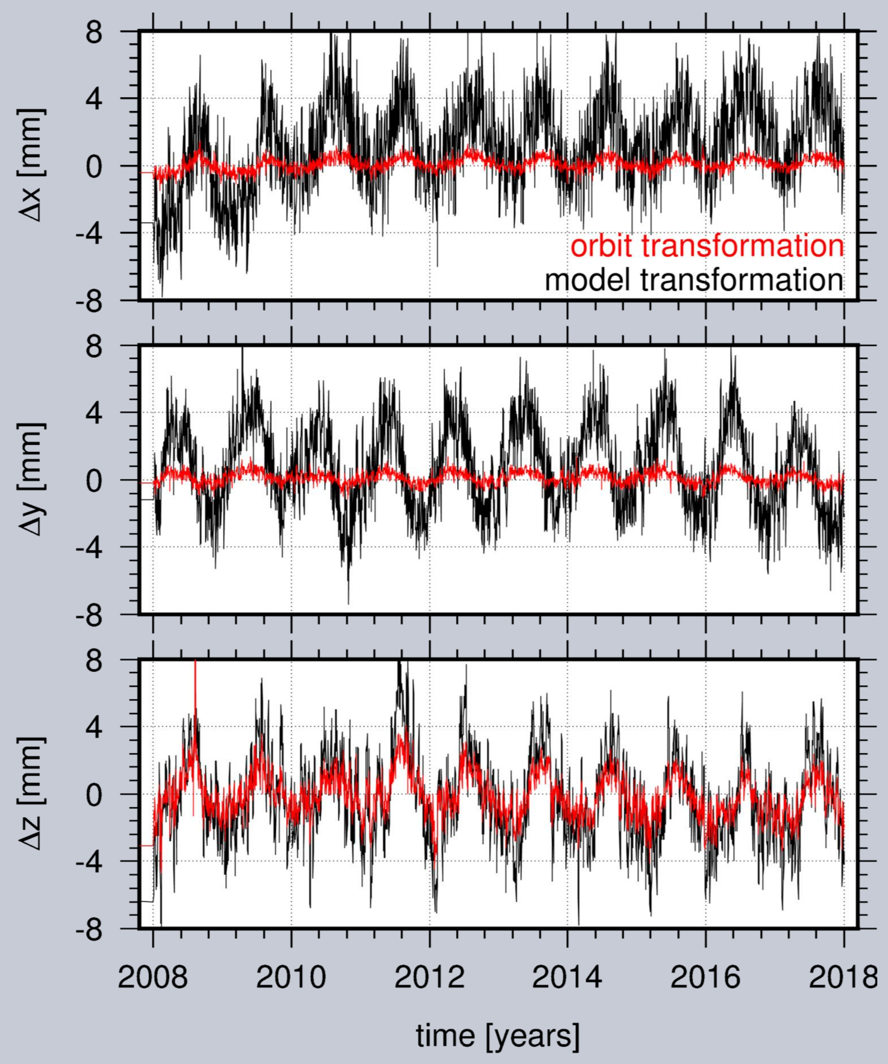

Fig. 5 *Translations between orbits with and without applied models (red) and translations computed between the deformations provided in CM and CF-frame (black)*

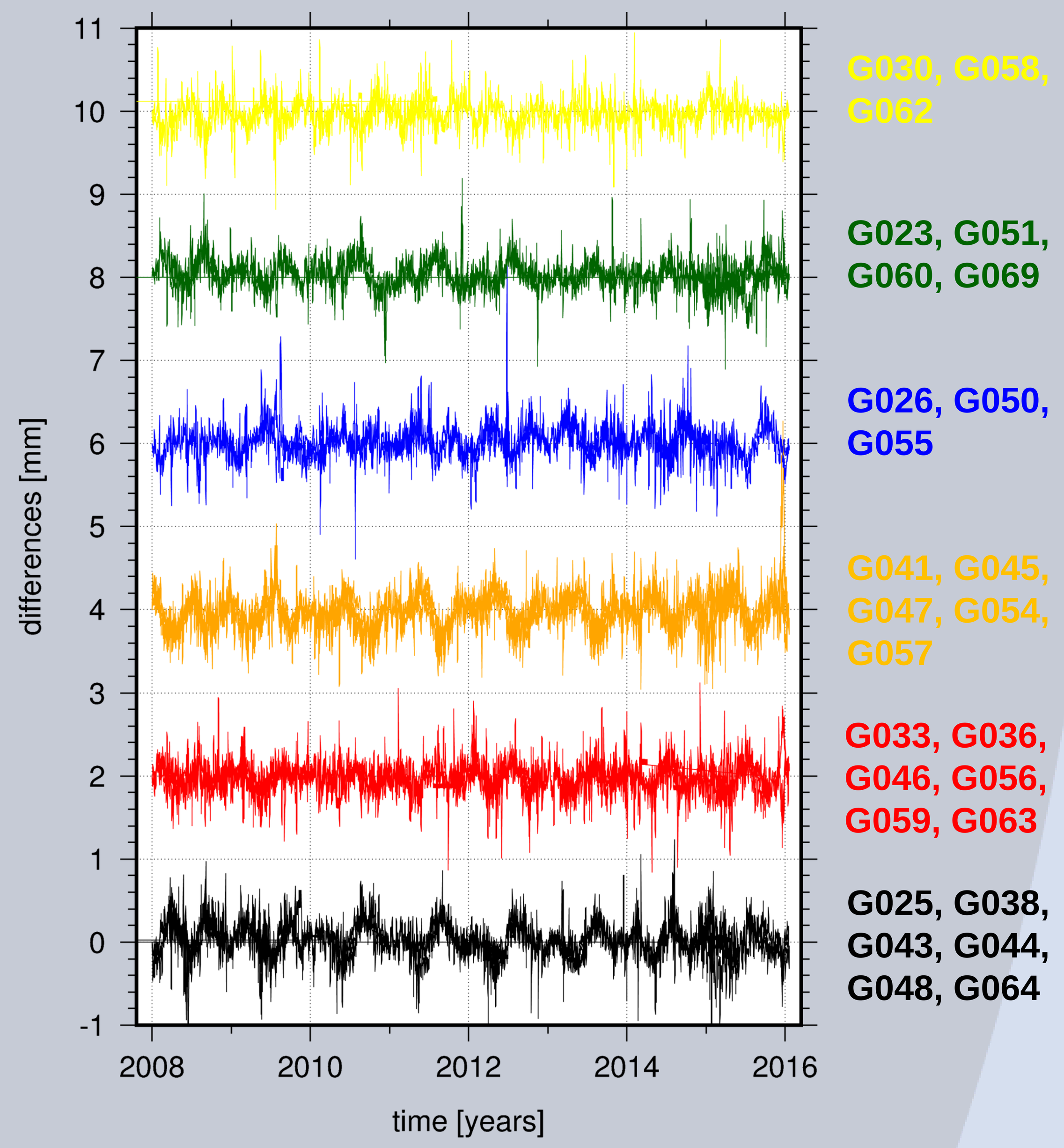

Fig. 6 *Semi-major axis: difference between orbits with and without applied models; satellites with similar differences are grouped, as listed on the right side; each group except the first is shifted by 2 mm*

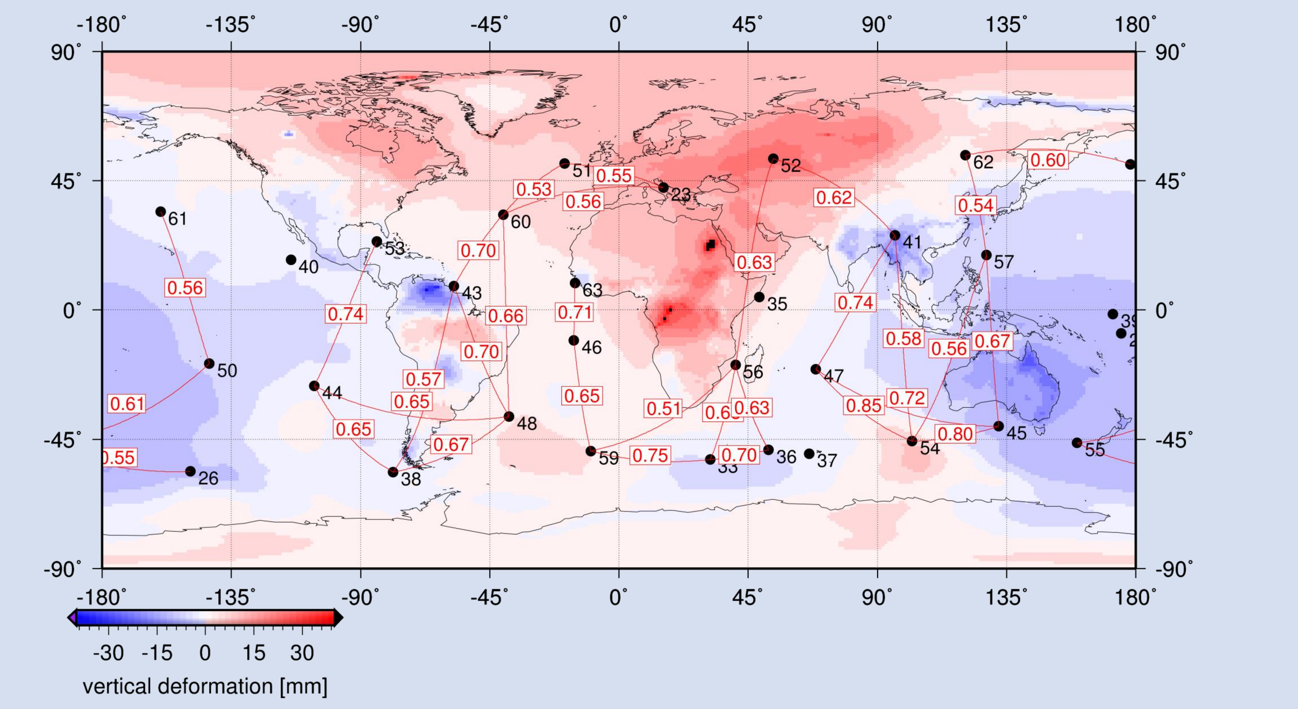

Fig. 7 *Correlation factors between the differences in semi-major axis (cf. Fig. 6) plotted with respect to satellite positions (correlations below 0.5 were skipped); satellite positions and vertical deformations as of August 5, 2012 (GPS week 1700.0)*

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.

Reference: Dill, R. and H. Dobslaw (2013), Numerical simulations of global-scale high-resolution hydrological crustal deformations, J. Geophys. Res. Solid earth 118, doi:10.1002/jgrb.50353.