The ESA/ESOC Analysis Center Progress and Improvements

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Abstract

ESA/ESOC is one of the most active Analysis Centers within the IGS and it is providing some of the best products available. This poster presents the quality and consistency of the ESA products over the last years. This poster highlights the changes, developments and improvements that were made in recent years.

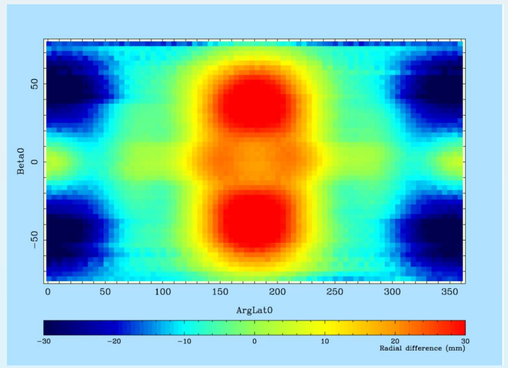
ESA/ESOC has contributed in the Second Data Reprocessing Campaign (repro2) for the IGS. Selected results of this reprocessing campaign are also be presented in this poster.

We have also included some selected results of the ESA/ESOC activities in the Multi-GNSS Experiment (MGEX).

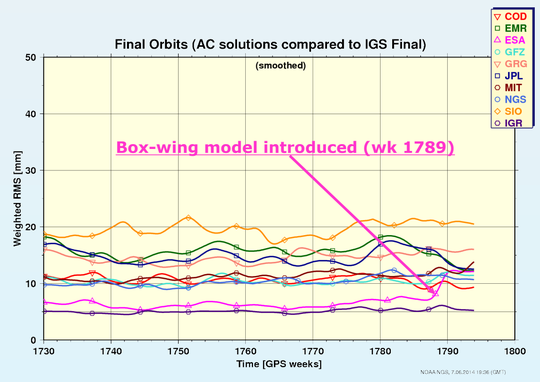
GNSS Box Wing Modelling

For the second reprocessing campaign we experimented with using a box-wing model to account for the solar radiation pressure acting on the GNSS satellites. Based on the very encouraging results we got, we activated the box-wing model for the reprocessing and consequently, early in 2014, also for our IGS routine products.

The box-wing model generally improves the quality of all our products by 10 to 20%. But the orbit differences are very significant (figure on the left) which do make our orbits look worse in the IGS combination (figure on the right)



Mean Radial Orbit Differences between IGS and ES2 (reprocessing) for 2013



IGS Final orbit comparison

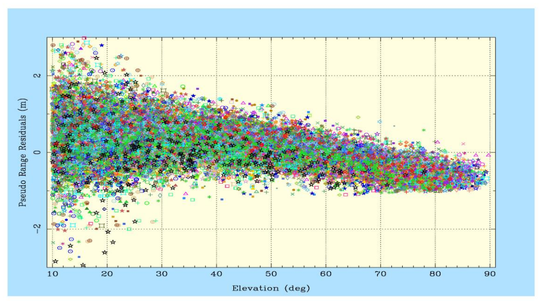
See our dedicated box-wing poster for much more details!

MGEX Activities

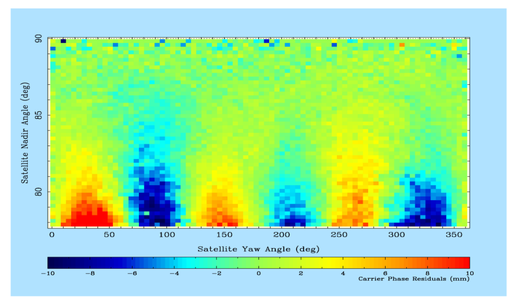
We periodically analyze the data from the IGS Multi-GNSS Experiment (MGEX). At the current stage we prefer the detailed analysis of the MGEX data over routine analysis. The main interesting features and challenges we have found so far are presented here in the three figures on the left.

In the scope of the MGEX we have furthermore derived a consistent set of BeiDou PCO/PCVs. See our dedicated poster in the Antenna session for more details.

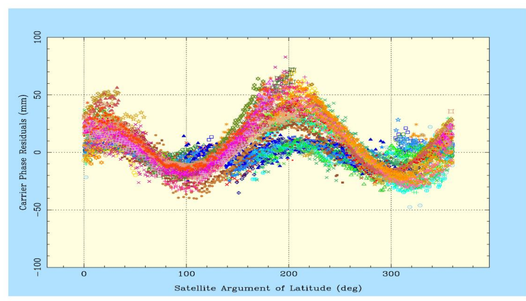
- Strong elevation dependent pattern in the BeiDou pseudo range residuals for the MEO satellites



- Strong azimuthal dependent pattern in the Galileo carrier phase residuals. Azimuthal ANTEX pattern needed.



- Severe inconsistency between the three GPS phase signals (L1, L2, and L5); a periodic effect of 50 mm visible.

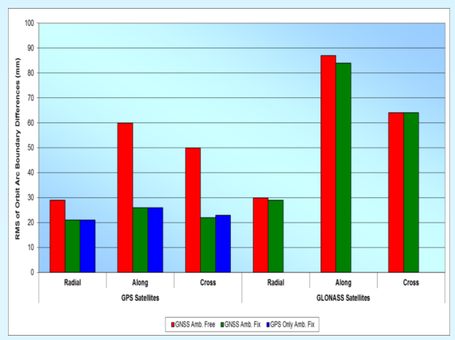


True GNSS Routine and Reprocessed Products

From January 2008 onward the ESA/ESOC final products have been true GNSS (GPS + GLONASS) products. Since February 2010 also the Rapid and Ultra-rapid products have become true GNSS products. The generation of Rapid and Ultra-rapid GNSS products has been driven by the fact that firstly the density and timeliness of the GNSS stations in the IGS tracking network has increased to a level that allows precise orbit determination of all GNSS satellites in near real time. Secondly, it was driven by significant customer interest. As a consequence we have now generated true GNSS products also in our reprocessing. Based on the availability of an adequate global GLONASS tracking network our reprocessed products are based on GPS and GLONASS starting from 2009.

The figure shows the effect of GPS ambiguity resolution and the inclusion of GLONASS on the orbits of the GPS- and GLONASS satellites. Note that only GPS ambiguities are integer resolved. The significant improvements thanks to integer ambiguity resolution on the GPS orbits is clearly visible. On the GLONASS orbits no effect is visible from the GPS ambiguity resolution.

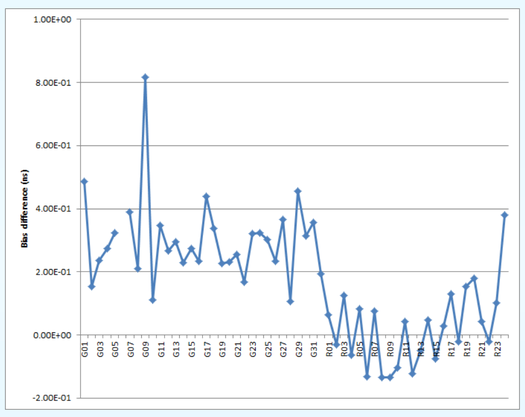
The figure further demonstrates that there is no negative effect on the GPS orbits due to the inclusion of the GLONASS satellites. The results presented here are based on the ESA/ESOC reprocessing effort (ES2 products).



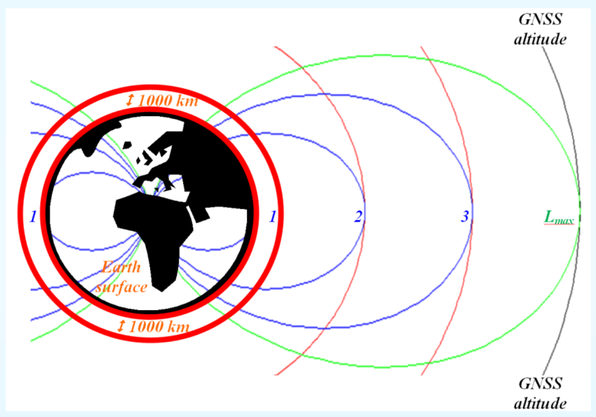
Ionosphere Modelling

Main Activities:

- Routine contributions to the IGS with Iono products: 2h IONEX files in final & rapid mode, 1h IONEX files in rapid mode, 1 and 2 days ahead predicted IONEX files.
- Coincidence analysis of CHAMP topside reconstructions with IMAGE RPI data as part of efforts to establish a new model for the plasmasphere, cooperation project with DLR Neustrelitz, Germany.
- Routine IONMON runs in 1h rapid mode at ESA's Space Situational Awareness (SSA) Space Weather Data Centre (SWE DC) at Redu, Belgium, since April 2012.
- Media calibration service (troposphere & ionosphere) for ESOC Flight Dynamics, currently under establishment.



GNSS DCBs: ESA vs. CODE biases



Ionosphere and the Earth magnetic field

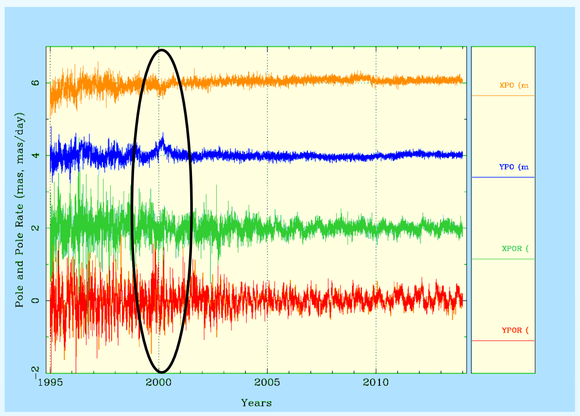
Recent Developments:

- The current 2D IONMON used for the IGS contribution was integrated into the multi-purpose software package NAPEOS. With the usage of NAPEOS, it has been possible to estimate the DCBs. Figure on the left, shows the comparison of these estimated biases with the equivalent from the CODE AC. It serves as good quality check of our current GNSS (GPS and GLONASS) process.
- 3D Modelling is being developed (will replace the current processing):
  - Algorithms for 3D background model.
  - Algorithms for assimilating TEC and Ne data from very different sources into the background model, few minutes update intervals should be possible.
  - Dedicated algorithms: special coordinate systems (see figure on the right), data assimilation schemes & related statistics, TEC integrators, exploitation of already existing IONMON algorithms, etc.
  - Documentation of algorithms in a new ESOC-internal technical note (currently still draft).
  - F90 coding of the new algorithms.
  - Currently preparations for testing the new software.

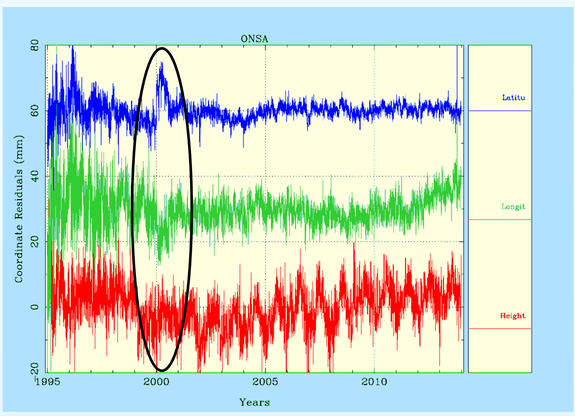
Reference Frame and Reprocessing

In 2013, after the switch to the submission of daily SINEX files, it became clear that our method of realising the reference frame for our IGS solution was suboptimal. Significant rotations were observable between the ESA and IGS solutions. We thus, finally, switched to using true minimal constraints in our routine processing together with the set of the defined IGS reference stations. Since then the reference frame realisation of the ESA routine products has become excellent.

However, for the reprocessing, the realisation of the reference frame does pose some challenges and we will need some software enhancements to be able to do a robust, accurate and fully automated reference frame realisation in our reprocessed solutions in the future. The figures below shows an example of the issue we need to resolve for our reprocessing. A clear anomaly can be seen in the beginning of the year 2000 affecting our X- and Y-pole and the North and East components of several stations (here only Onsala is shown). The reason for this is in the set of stations that were used and the coordinates available for the problematic period.



ESA repro2 time series of X- and Y-pole and X- and Y-pole rate compared to IERS Bulletin A



ESA repro2 time series of Onsala (ONSA) station position estimates

Conclusions

- The ESA/ESOC Analysis Center remains fully dedicated to the IGS
- Despite 20 years of service still significant progress can be made, see box-wing model
- The internal consistency of the IGS products is higher then their absolute accuracy
- The MGEX data is showing some very interesting issues and features
- GPS and GLONASS can be combined without any issues. Combined solutions are starting to outperform GPS-only solutions
- Significant activities are taking place at ESA/ESOC with respect to troposphere and ionosphere modeling
- The realization of a stable reference frame over decades poses a significant challenge as all meta data and geophysical discontinuities must be known and handled correctly

European Space Agency