The ESA/ESOC Analysis Center: Progress, Improvements and Enhancements in the GNSS data processing

T.A. Springer, F. Dilssner, J. Feltens, C. Flohrer, F. Pereira, I. Romero,
W. Enderle, R. Zandbergen
Navigation Support Office (HSO-GN), European Space Operations Centre (ESA/ESOC),
Robert-Bosch-Str. 5, D-64293, Darmstadt, Germany

Abstract

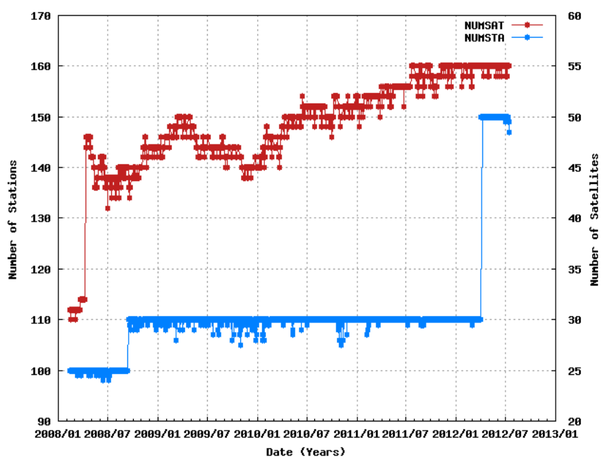
ESA/ESOC continues to be an active IGS Analysis Center. This poster presents the recent improvements in our processing software NAPEOS, the increased quality and consistency of the ESA/ESOC products, and the plans for future improvements.

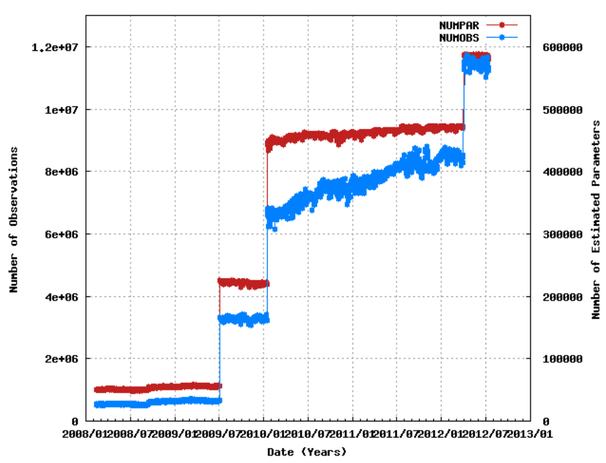
Continuous Improvements

As analysis center ESA/ESOC is permanently working on improving the quality of its solutions. Since switching to the NAPEOS software in January 2008 a very significant number of improvements was made to the software and the ESA IGS analysis strategy that have made the ESA products to be among the most complete and the best IGS products.

The figure below on the left shows the number of stations and satellites used in the ESA Final IGS analysis. The jump in the number of used satellites, early in 2008, marks the time where the official ESA IGS final products became true GNSS products, i.e., GPS + GLONASS orbits and clocks. The number of stations used in our final processing was changed twice. Once from 100 to 110 in 2008, and recently in 2012 we further increased to 150 stations. These enhancements were made possible thanks to memory and speed improvements of the NAPEOS software.

The figure below on the right shows the number of observations and parameters that participate in our parameter estimation when generating the ESA final products for the IGS. The two jumps in 2009 mark the times where we firstly switched from 300 seconds (5min) sampled data (clocks) to 60 seconds and secondly to 30 seconds. The jump in 2012 corresponds to the increase in the number of stations.

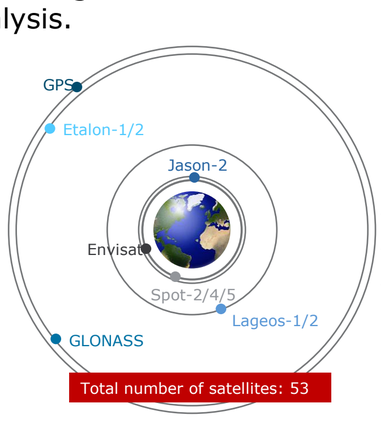


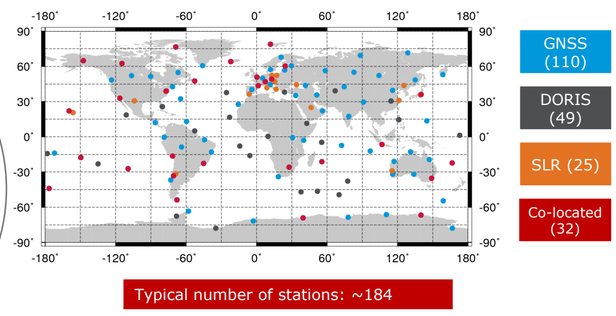


Combination On the Observation Level (COOL)

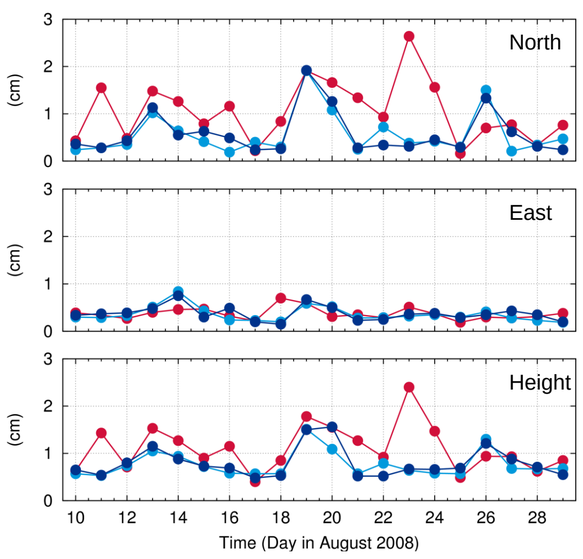
The NAPEOS multi-technique capabilities allow combining the observations from the different techniques (GNSS, DORIS, and SLR) on the observation level. One obvious major benefit is that it ensures that identical models are used for all techniques and thus all the data is processed homogeneously. A second major benefit is that the combination on the observation level offers the unique possibility to tie the techniques together not only through the terrestrial local site ties, at collocated sites, but also through their space ties, i.e., the physical distances of the instruments as mounted on the satellite spacecraft body. Here it is worthwhile to point out that these space ties are not used when generating the ITRF solutions!

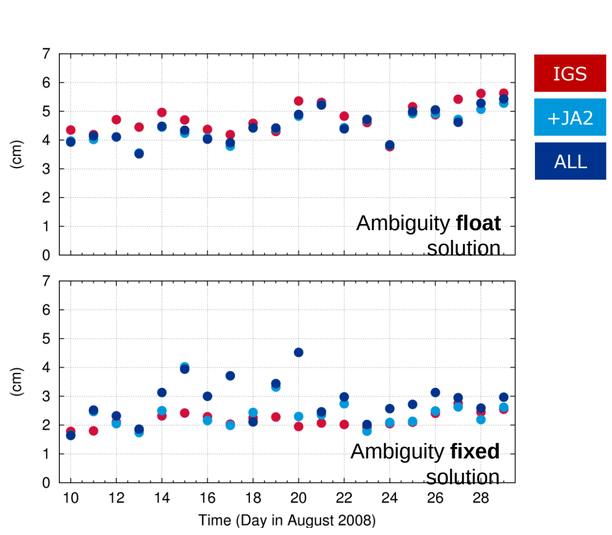
It should be mentioned that with these significant NAPEOS abilities we contribute to the efforts of the IERS working group for Combination on the Observation Level (abbreviated COL, but we prefer to abbreviate it as COOL). As initial test of our capabilities we have analyzed a three week data set covering the VLBI CONT'08 campaign. The two figures below show the satellites and station network used in this initial COOL analysis.





The two figures below show the effect of the inclusion of JASON-2 in our IGS analysis and, as a further step, the effect of a full COOL solution. The figures demonstrate that the multi-technique combination does improve the reference frame realization (left figure). It also improves the GNSS orbits of the float solution but surprisingly little, or even a negative, effect is seen in the ambiguity resolved solution (right).





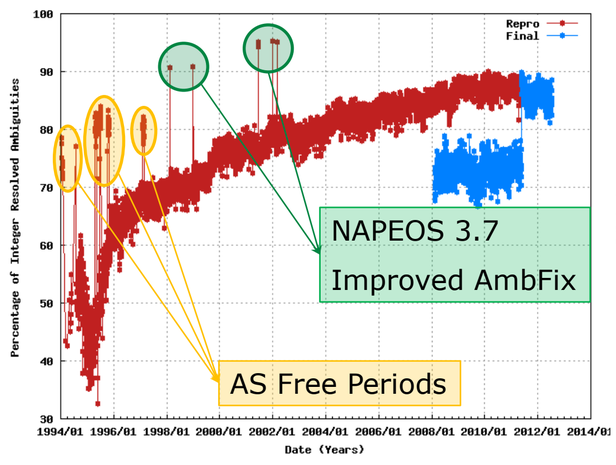
IGS Reprocessing (repro2)

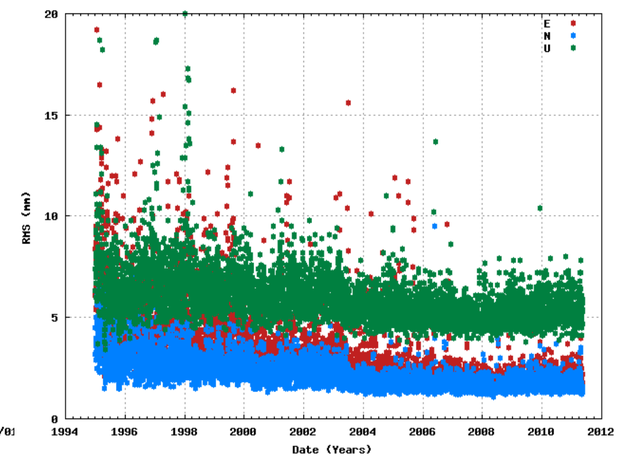
Soon after the IGS adopted the ITRF2008 reference frame we repeated our IGS reprocessing, using all data from 1994 to day 134 in 2011.

The figure below on the left shows the percentage of integer resolved ambiguities over the full timespan of the reprocessing (in red). It also includes (in blue) the results from the ESA routine processing. Three interesting aspects may be observed in this figure.

1. The percentage of resolved ambiguities increases gradually over the time.
2. AS-free data gives much better performance
3. NAPEOS version 3.7 has an improved Ambiguity Resolution method

The figure below on the right gives the RMS in East, North, and Up of a comparison of the daily coordinates estimates (compared to the "previous" day) over the full period of the reprocessing. The results demonstrate the excellent homogenous quality of the reprocessed solutions.





The products of our current "repro2" solution are available on request. However, we will repeat the reprocessing to be fully inline with the agreed models for the official IGS repro2 campaign. Last but not least we will make use of our latest software version, the soon to be released NAPEOS version 3.7. Besides the improved ambiguity resolution this version is also much faster (factor of 30% for IGS processing) and is capable of estimating ionosphere maps.

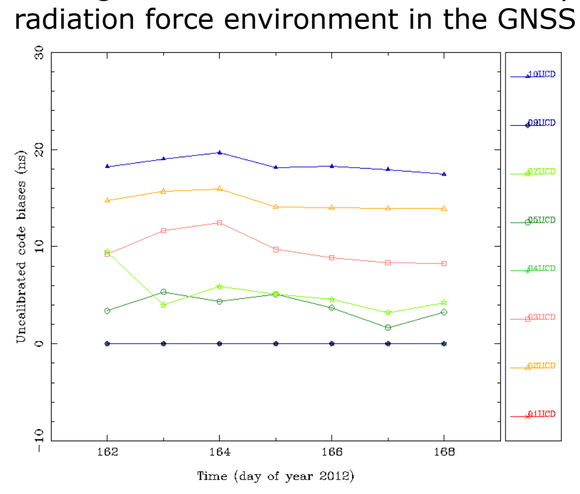
Miscellaneous (MGEX, Orbit Modelling)

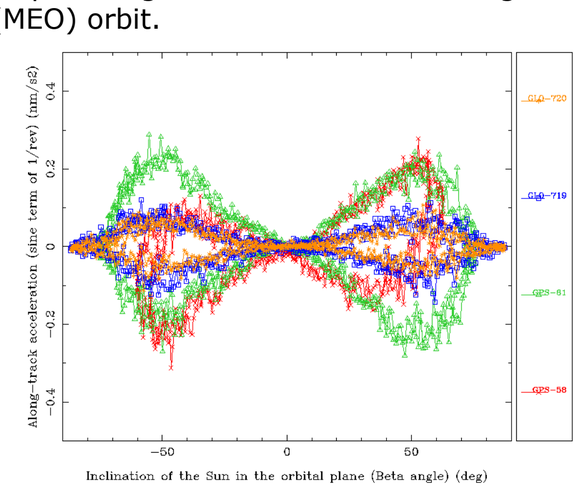
The figure below on the left shows the uncalibrated code delays (UCDs) for the station ABMF of the MGEX campaign. The code biases are given for all the GPS, GALILEO, and GLONASS signals as observed by this station.

- GPS L1, L2, and L5 (UCDs 01 (fixed to zero), 02, 03, in reddish colors)
- GALILEO E1, E5, and E7 (UCDs 04 (fixed to zero), 05, 07, in green colors)
- GLONASS L1 and L2 (UCDs 09 (fixed to zero), 10, in blue colors)

The figure nicely demonstrates the significant amount of biases a multi-GNSS solution will have to deal with. Our "raw" processing method gives us direct access to all these biases.

The figure below on the right shows the estimated sine term of the once per revolution along-track accelerations, as estimated in our routine analysis, for two GPS and two GLONASS satellites. Clearly there are some very significant signals present. Our ambition is, also in the scope of the orbit working group, to significantly enhance our understanding of the forces acting on the GNSS satellites. We are also looking at the ETALON satellites as they help us to get a better understanding of the radiation force environment in the GNSS (MEO) orbit.





Conclusions

Over the recent years major changes have taken place with respect to the IGS analysis at ESOC. These changes have made the ESA analysis center to be one of the best and one of the most complete within the IGS. At the same time we have also contributed significantly to different important aspects of the GNSS technique in general and the IGS in particular.

Over the recent years the Navigation Package for Earth Orbiting Satellites, NAPEOS, as developed and maintained at the European Space Operations Centre (ESOC) of the European Space Agency (ESA) has evolved to a great tool for satellite geodesy. NAPEOS is capable of processing data from all GNSS systems, all DORIS, and all SLR observations. And, NAPEOS is used for generating state of the art products for all three satellite geodesy techniques: IDS, IGS, and ILRS. At ESOC NAPEOS is routinely used for a large number of tasks. Most relevant is the fact that one and the same version of NAPEOS is used for generating the ESOC analysis center products for the IGS, ILRS, and IDS.