

# NMA Analysis Center 2013 Annual Report

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**Abstract** During the last few years, the Norwegian Mapping Authority (NMA) has had a close cooperation with the Norwegian Defence Research Establishment (FFI) in the analysis of space geodetic data using the GEOSAT software. NMA has taken over the full responsibility for the GEOSAT software. NMA has been an Associate Analysis Center of IVS since 28 October 2010. NMA's contributions to the IVS as an Analysis Center focuses primarily on routine production of session-by-session unconstrained and consistent normal equations by GEOSAT as input to the IVS combined solution. Several test solutions were uploaded to an IVS Combination Center during 2013. After the last improvements, the VLBI results produced with GEOSAT are in good agreement with results from the other VLBI Analysis Centers.

## 1 General Information

A number of co-located geodetic stations with more than one observation technique were established. In principle, all instruments at a given co-located station move with the same velocity, and it should be possible to determine one set of coordinates and velocities for each co-located site. In addition, a constant eccentricity vector from the reference point of the co-located station to each of the individual phase centers of the co-located antennas is estimated using constraints in accordance with a priori information given by the ground

surveys. One set of Earth orientation parameters (EOP) can be estimated from all involved data types, while, for instance, geocenter coordinates only can be estimated from satellite techniques and source positions only can be estimated from VLBI. Combining the individual techniques at the observation level gives the possibility of taking the benefit of the strengths of the individual techniques and suppressing their weaknesses. As one example, the present dominating error source of VLBI is the water content of the atmosphere, which must be estimated. The introduction of GPS data with a common VLBI and GPS parameterization of the zenith wet delay and atmospheric gradients will strengthen the solution for the atmospheric parameters. The inclusion of SLR data, which is nearly independent of water vapor, gives new information which will help in the de-correlation of atmospheric and other solve-for parameters and will lead to more accurate parameter estimates.

These, and many more advantages with the combination of independent and complementary space geodetic data at the observation level, are fully provided by the GEOSAT software developed by FFI [1, 2]. GEOSAT is also useful for single technique analysis. The VLBI module of GEOSAT is now further developed by the NMA [4]. The goals are both to act as an IVS Analysis Center delivering session-by-session unconstrained and consistent normal equations to the IVS Combination Centers and to provide quality control for the different modules used in GEOSAT.

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## 2 Activities during the Past Year

During 2013, the NMA continued the work of making the VLBI module of the GEOSAT software compatible with other VLBI analysis software delivering results to IVS. In addition, there is a lot of activity going on at NMA to further develop the multi-technique software GEOSAT (see the FFI TDC 2011 annual report). The VLBI module has been upgraded to be compliant with IERS Conventions 2010 [3], and some errors have been eliminated — for instance errors in the SINEX files due to misinterpretation of the format specification. NMA submitted several smaller solutions to an IVS Combination Center, and adjustments were made in GEOSAT based on the feedback from the IVS Combination Center. Finally, all R1 and R4 sessions from 2006 were submitted to the IVS Combination Center, and the solutions were found to be comparable to that of the other Analysis Centers (S. Bachmann, private communication). With this stabilized version of the software, 11 years (2003-2013) of R1 and R4 sessions were processed and are awaiting evaluation.

## 3 Future Plans

As soon as the 11-year test is compared with the individual solutions from the other ACs and the combined solutions from IVS and the outcome of the comparisons are found to be satisfactory, NMA will implement the GEOSAT VLBI processing in an automated processing chain. We will integrate the VLBI processing into the NMA control center which already monitors several geodetic applications. The NMA control center is always manned during working hours.

In addition, a lot of effort is being put into passing on the knowledge of Per Helge Andersen to the team that will maintain GEOSAT in the future. This work will continue in 2014 and has a very high priority. The new GEOSAT team will consist of five to seven members, where a few members are only partially involved.

NMA will start to deliver unconstrained normal equations in the SINEX format to the IVS Combination Center on a routine basis. As soon as this work is satisfactory, NMA will apply for the status of a full IVS Analysis Center.

Unlike most of the other VLBI analysis software GEOSAT is based on a UD Kalman filter. This al-

lows changing the stochastic behavior of the system. NMA will test different stochastic parameters especially for the troposphere. Station and epoch dependent stochastic parameters based on input from numerical weather models and IGS tropospheric products will be tested and evaluated. Tests of different models are also planned — for instance, a comparison of results using VMF1 and 3D ray tracing.

To produce VLBI solutions for IVS is the first part of a larger strategic plan from NMA. The next step is to include other geometric geodetic techniques (GNSS, SLR, and DORIS) in a common solution where the different techniques are combined at the observation level. The long-term goal of this large effort is to also include data from the gravity satellites GRACE and GOCE and from altimeter satellites.

## 4 Staff

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