

# Norwegian Mapping Authority Analysis Center Biennial Report 2015–2016

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**Abstract** In 2015 Norwegian Mapping Authority (NMA) decided to discontinue the development of GEOSAT. Instead the development of a new software called Where started. Where will continue with some of the ideas from GEOSAT, but with a more modern software architecture and technology platform. The VLBI version of Where was almost complete by the end of 2016. NMA participated in VASCC2015 using GEOSAT and intends to participate with Where in the next phase of the campaign.

## 1 General Information

NMA has been an Associate Analysis Center within the IVS since 2010. The Analysis Center is operated by the Geodetic Institute at NMA with main offices in Hønefoss, Norway. NMA is a governmental agency and the IVS activities at NMA are completely funded by the Norwegian government.

NMA was using the analysis software GEOSAT. GEOSAT was originally developed by Per Helge Andersen (retired) at the Norwegian Defense Research Establishment (NDRE). The GEOSAT source code was finally abandoned in favor of creating a new software package with an improved architecture and using a more modern technology platform. The new software is called Where.

The new software should be able to process observations from VLBI, GNSS, SLR, and DORIS

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Norwegian Mapping Authority (NMA)

NMA Analysis Center

IVS 2015+2016 Biennial Report

and will become an important tool at NMA for improving the global geodetic reference frame. Where is implemented in Python and utilizes several well-known packages such as `numpy`, `scipy`, and `matplotlib`. In addition, more specialized packages such as `astropy`<sup>1</sup> and `jplephem`<sup>2</sup> are also used. Where is a command line tool, but the the results can be inspected using the graphical tool called There that is being developed alongside Where.

## 2 Staff

The Geodetic Institute at NMA has approximately 50 employees. Some of the responsibilities include maintaining the national reference frame, geoid, and height system. The Geodetic Institute also provides a network-RTK positioning service and operates the VLBI station at Ny-Ålesund. The Where project team consists of six members. These members are briefly described in Table 1.

## 3 Activities during the Past Year

In 2015, NMA decided to participate in the VLBI Analysis Software Comparison Campaign (VASCC2015) organized by Ph.D student Grzegorz Kłopotek at Chalmers University of Technology, Sweden. The goal of the campaign was to compare computed theoretical delays from different analysis

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<sup>1</sup> <http://www.astropy.org>

<sup>2</sup> <https://pypi.python.org/pypi/jplephem>

**Table 1** Where project team members.

Name	Background	Tasks
Laila Løvhøiden	Oil industry and co-chairing the UN-GGIM working group	Project manager
Michael Dähn	Dipl.-Ing. in geodesy from the Dresden University of Technology	GNSS implementation
Ingrid Fausk	Ph.D. in mathematics from the University of Oslo	SLR implementation
Geir Arne Hjelle	Ph.D. in mathematics from the Norwegian University of Science and Technology	Software architecture and assisting with all the techniques
Ann-Silje Kirkvik	M.Sc. in computer science from the Norwegian University of Science and Technology	VLBI implementation
Eirik Mysen	Ph.D. in astrophysics from the University of Oslo	Estimation techniques

software packages. NMA provided solutions using the GEOSAT software.

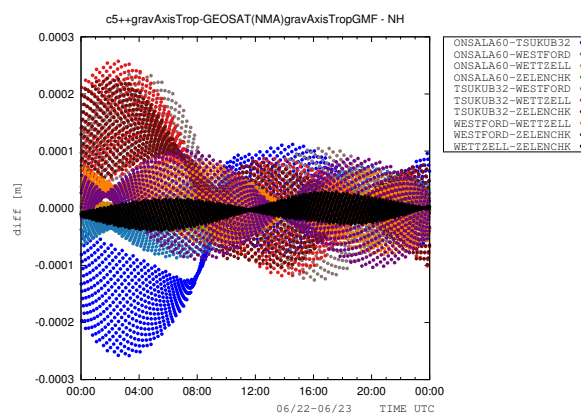
This work was very time consuming but turned out to be an extremely valuable experience. The need to modernize the software became exceedingly clear as GEOSAT was disassembled to be able to provide solutions for VASCC2015. GEOSAT provided consistent results compared with other software packages for geometrical, gravitational, and tropospheric delay and delay due to axis offset and thermal deformation. Figure 1 shows that the difference between c5++ and GEOSAT is less than 1 mm for all observations of that session. As mentioned in [2], the discrepancies between the software packages increased as high frequency EOP variations were included. The site displacement models still need to be compared.

Development of Where started in the second half of 2015. The experience from VASCC2015 was very helpful when implementing the VLBI model in Where, but no source code from GEOSAT has been used in Where. Where uses external libraries and functions such as SOFA<sup>3</sup> and the IERS Conventions 2010 software<sup>4</sup>. When the VLBI model was implemented in Where, the dataset from VASCC2015 was used to compare the theoretical delays with delays from GEOSAT. The results are shown in Figure 2, and they indicate that Where can calculate theoretical delays at the same level as the software packages that participated in VASCC2015. As with GEOSAT, the site displacement models and EOP variations still need more extensive testing.

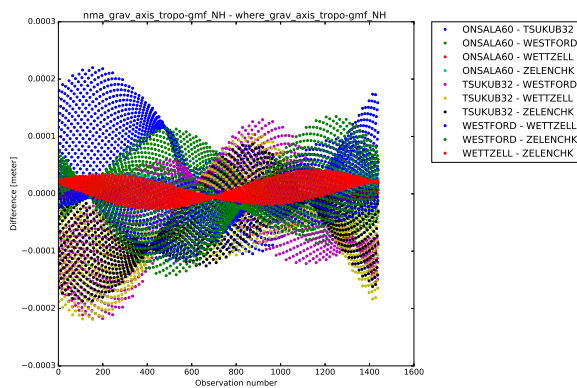
<sup>3</sup> [http://www.iausofa.org/2015\\_0209\\_F/sofa/sofa\\_pn.pdf](http://www.iausofa.org/2015_0209_F/sofa/sofa_pn.pdf)

<sup>4</sup> <http://maia.usno.navy.mil/conv2010/software.html>

The Where project team visited Onsala Space Observatory in June 2016, where the group photo in Figure 3 was taken. The goal of this meeting was to share experiences and explore future possibilities for collaborations. The space geodesy field is very small in Norway, and being able to cooperate with similar groups in neighboring countries would be very beneficial. The meeting went well, and a new meeting is planned for February 2017 in Norway. This meeting also will include Toshimichi Otsubo, who is on a sabbatical at Onsala Space Observatory, which will provide an excellent opportunity to learn about the SLR implementation in c5++.



**Fig. 1** Comparison of theoretical delays between c5++ and GEOSAT for the session 15JUN22CC.NH. This includes geometrical, gravitational, and tropospheric delay and delay due to axis offset. High frequency EOP variations and station displacement models are not included. Figure provided by Grzegorz Kłopotek.



**Fig. 2** Comparison of theoretical delays between GEOSAT and Where for the session 15JUN22CC.NH. This includes geometrical, gravitational, and tropospheric delay and delay due to axis offset. High frequency EOP variations and station displacement models are not included.

## 4 Current Status

The VLBI implementation in Where is almost ready for a beta release. The software can read NGS files and applies a VLBI model consistent with conventions ([5], [4]). Parameters are estimated using a Kalman filter (and smoother) where the nuisance parameters clocks and troposphere are modeled as continuous piecewise linear parameters. Using the results from [3], it is possible to create unconstrained normal equations in SINEX format based on the Kalman filter solution. This requires that all target parameters be estimated as a constant for the whole session.

The GNSS implementation is currently limited to GPS and the implementation of a Precise Point Positioning solution in Where, which is still under development. Development of the SLR implementation was halted due to maternity leave, but basic orbit determination was implemented. Development is expected to resume in the second half of 2017. Implementation of DORIS is completely on hold until the necessary resources become available.

## 5 Future Plans

The immediate main goal is to get a working version for VLBI analysis. The next step is to implement support for the new observation format vgosDb [1]. It has also been announced that the VLBI Analysis Software Comparison Campaign will continue in 2017, and NMA intends to participate using Where.

## References

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**Fig. 3** Visit at Onsala Space Observatory in June 2016. Back row from the left: Grzegorz Klopotek, Thomas Hobiger. Front row from the left: Joakim Strandberg, Niko Kareinen, Eirik Mysen, Geir Arne Hjelle, Laila Løvhøiden, Ingrid Fausk, Ann-Silje Kirkvik. Photo: Michael Dähn.