Comparison of Vienna Mapping Function (VMF1) and Global mapping Function (GMF) for NKG GNSS AC

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For the NKG GNSS AC, which is based on distributed processing, a common processing strategy is needed. One of the parameters to investigate is the choice of mapping function for the tropospheric modelling. The newest and most advanced models in the Bernese GNSS Software are the Global Mapping Function (GMF) and the Vienna Mapping Function (VMF1). This document presents the results of a comparison between estimated coordinates using the two mapping functions on one year of data from northern Europe calculated with the Bernese GNSS Software version 5.2.

NKG GNSS AC

The project "NKG GNSS analysis centre" started in the spring 2012 with the aim to provide a common and combined GNSS solution for the Nordic and Baltic countries. First a pre-study phase, including testing of processing strategies, was carried out and then processing routines, network design, solution archive e.t.c. were developed in the definition phase. The operational phase, producing daily and weekly coordinates solutions based on final IGS/CODE-products, started up in the summer 2014. This study of the troposphere mapping functions is a part of the pre-study phase.

Mapping functions

Troposphere mapping functions are used in the analyses of GNSS and VLBI to map zenith hydrostatic and wet delays to any elevation angle and vice versa.

Vienna Mapping Function (VMF/VMF1) and Global Mapping Function (GMF) as well as Niell Mapping Function (NMF) use continued fraction form according to the formula below. E is the elevation and a, b and c are coefficients dependent on at least latitude and day of year.

$$m_n(E) = \left(1+\frac{a}{1+\frac{b}{1+c}}\right) \Bigg/ \left(\sin E+\frac{a}{\sin E+\frac{b}{\sin E+c}}\right)$$

In case of VMF/VMF1 the b- and c-coefficients are based on empirical equations and the a-coefficient originates from numerical weather models for the actual time of observations.

GMF is using the same b-and c-coefficients as VMF1. The a-coefficients of GMF are obtained from an expansion of VMF1-parameters on a global grid of monthly mean from September 1999 to August 2002.

Questions

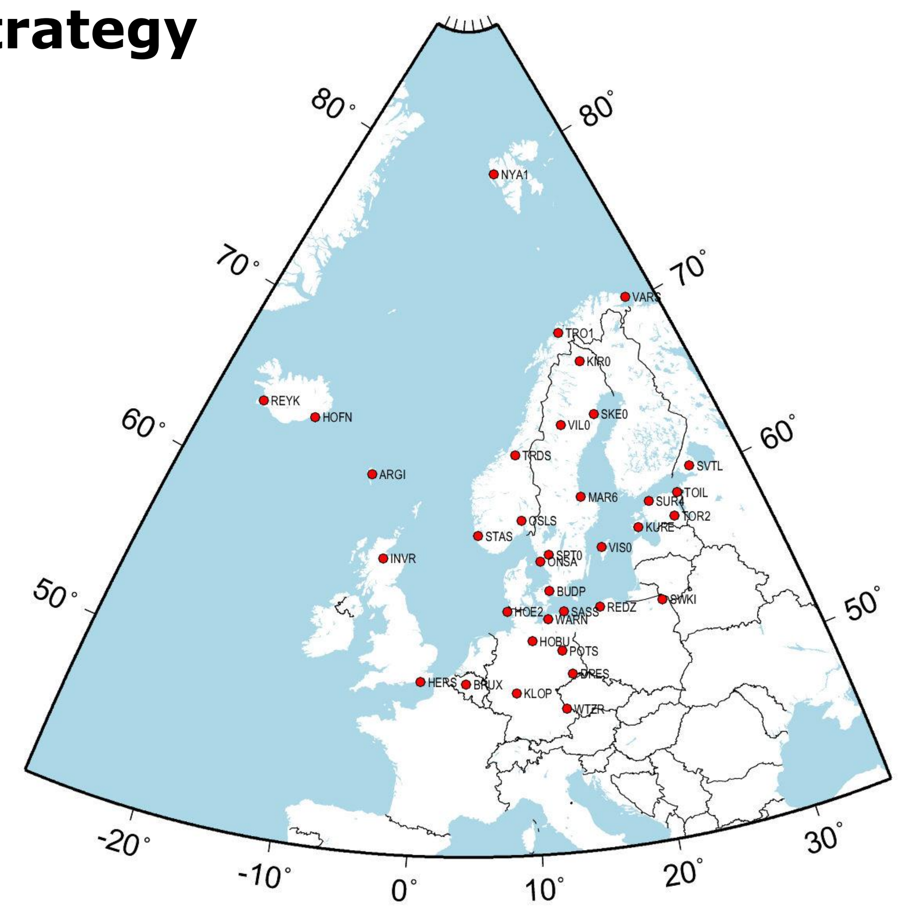
- Is VMF1 better than GMF?
- How large differences are there in general between coordinates estimated with VMF1 and GMF, respectively?
- Is there a systematic difference between GMF and VMF1 in estimated coordinates?

Test setup and analysis strategy

The network used for the benchmark test of NKG AC, i.e. 35 EPN-stations in northern Europe, were chosen for the test.

We analysed data from a full year and the period 2012 doy 154 – 2013 doy 153 was arbitrary chosen.

The analysis was made both on the **full year** but also on just the **summer months,** June-August 2012, to avoid periods with possible snow on antennas and radomes.



The data was processed with Bernese version 5.2 using the standard processing setup RNX2SNX, which is based on double difference processing. GMF was used as tropospheric mapping function for the float solution and the ambiguity resolution. Two final solutions were produced, one using GMF and one using VMF1. The elevation cut-off in the final solutions was set to 3°.

The daily coordinate repeatability was analysed as a measure of the quality of the estimated coordinates. The ITRF-coordinates were first transformed to UTM zone 33 to get the repeatability in north, east and up (height). As the ITRF-coordinates have a time dependent trend, this was extracted by linear regression before computing RMS-values of the residuals.

The daily differences for each station were also analysed to see if we could see any systematics between the two mapping functions and also to see how large the differences could be on a single day. The daily differences were calculated as residuals in a 4-parameter Helmert transformation, solving for translations and a scale factor. Daily maximum and minimum values were analysed as well as station-wise time series of the differences.

Coordinate repeatability

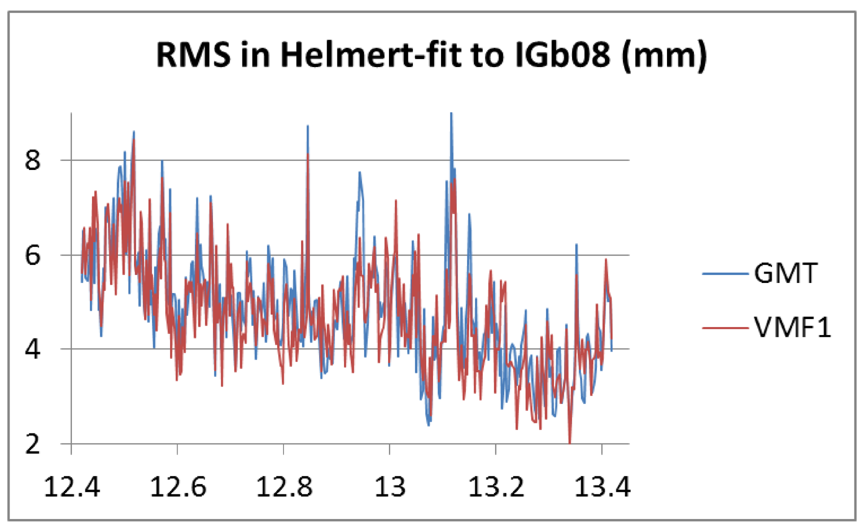
The daily RMS after extraction of a linear trend are on a general level c. 1-2 mm per horizontal component and 3-5 mm in height. The RMS are for most stations lower for VMF1 than GMF, on average 8-10% lower (GMF has 10-13% higher RMS than VMF1).

Full year			
RMS VMF/GMF			
Stn	N	E	U
ARGI	-3%	5%	-26%
BRUX	-2%	-5%	-11%
BUDP	-11%	-1%	-20%
DRES	12%	-2%	5%
HERS	6%	-2%	9%
HOBU	-4%	2%	-3%
HOE2	-16%	3%	-7%
HOFN	-1%	-2%	-4%
INVR	-11%	14%	-23%
KIR0	1%	0%	6%
KLOP	5%	-4%	0%
KURE	1%	0%	-20%
MAR6	2%	4%	-1%
NYA1	3%	-3%	-3%
ONSA	16%	1%	-3%
OSLS	2%	1%	0%
POTS	0%	0%	-10%
REDZ	0%	1%	-18%
REYK	-10%	13%	-4%
SASS	13%	-1%	-14%
SKE0	-3%	2%	4%
SPT0	9%	-3%	-1%
STAS	9%	10%	-10%
SUR4	-6%	-5%	-19%
SVTL	1%	-2%	1%
SWKI	2%	-2%	-15%
TOIL	-8%	-2%	-16%
TOR2	-2%	6%	-9%
TRDS	-10%	1%	-2%
TRO1	-6%	-5%	-23%
Average	**0%**	**1%**	**-8%**
Stdv	8%	5%	10%
Stdv_avera	1%	1%	2%
Sigma_leve	0.2	0.9	4.4

Summer			
RMS VMF/GMF			
Stn	N	E	U
ARGI	-4%	3%	-19%
BRUX	-16%	-8%	-8%
BUDP	-1%	-1%	-28%
DRES	21%	0%	0%
HERS	-6%	2%	5%
HOBU	-8%	0%	-4%
HOE2	-10%	4%	-24%
HOFN	2%	11%	1%
INVR	-6%	4%	-24%
KIR0	-2%	-3%	-3%
KLOP	5%	-2%	-1%
KURE	3%	3%	-23%
MAR6	2%	4%	-2%
NYA1	3%	-1%	-11%
ONSA	8%	1%	-16%
OSLS	-4%	2%	2%
POTS	1%	0%	-9%
REDZ	-1%	4%	-23%
REYK	-5%	6%	6%
SASS	9%	0%	-9%
SKE0	-3%	-1%	4%
SPT0	1%	-1%	-3%
STAS	0%	5%	-13%
SUR4	2%	-3%	-27%
SVTL	-3%	-1%	-1%
SWKI	2%	-2%	-21%
TOIL	1%	-5%	-20%
TOR2	4%	10%	-24%
TRDS	-7%	1%	-3%
TRO1	1%	-6%	-9%
Average	**0%**	**1%**	**-10%**
Stdv	7%	4%	11%
Stdv_avera	1%	1%	2%
Sigma_leve	0.3	1.1	5.2

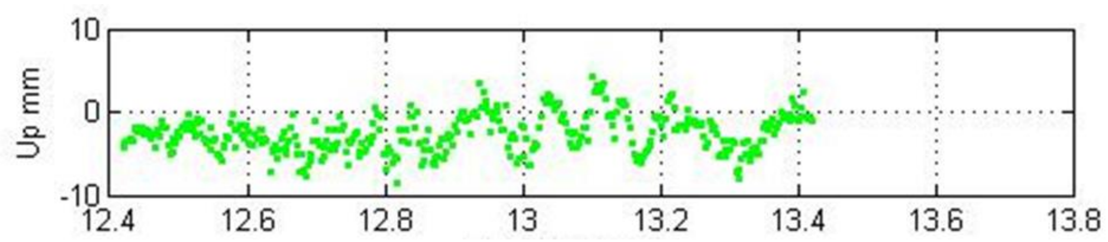
Helmert-fit to IGb08

The daily Helmert-fits (solving three translations) to the official IGb08-coordinates show slightly smaller values for VMF1 than GMF – the mean of the RMS for VMF1 is 4.7 mm compared to 4.9 mm for GMF.



Coordinate differences

The daily differences between the solutions with GMF and VMF1 after a 4-parameter Helmert transformation are up to 14 mm in height and 2 mm in the horizontal components during the full year. The maximal differences for a single day are on average c. 0.5 mm in the horizontal components and 6 mm in height for the same period. The values are quite similar for the summer period.



Time series of height differences between VMF1 and GMF for HOBU, which has the largest systematic difference.

Conclusions

- A small improvement of the repeatability of the height component is noted for VMF1 compared to GMF, in average c. 0.4 mm in the RMS, corresponding to 8-10% lower values for VMF1 than for GMF. This is valid both for the full year and for the summer period.
- The coordinate differences on a single day could be up to 14 mm in height and on average up to 6 mm. This is too much to neglect when combining solutions from different sub-networks, which means that it is important that we use the same mapping function for all national analysis centres contributing to NKG AC.
- For one third to half of the stations (depending on selected time period) there were systematic differences in estimated heights between VMF1 and GMF significant on 2 sigma level. The largest difference was 3.6 mm, but there were just two stations with a significant systematic difference larger than 2 mm.

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