Diurnal and semi-diurnal site coordinates variations resulting from processing with BV42 and BV50

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Motivation

- At the EPN LAC of the Slovak University Technology in parallel with the routine 24-hour solutions the coordinate estimates from shorter intervals are performed. The aim of these activities is to study the effects with diurnal and shorter periods.
- The experience with analysis of coordinate solutions from 3- or 4-hour intervals led to detection of variations with amplitudes up to ~3 mm and periods close to 1.0 and 0.5 days
- The observed effects were associated with station specific behavior, multipath, other periodic influences, and tidal ocean loading mismodeling
- Main experiences were achieved with the Bernese GPS software version 4.0 and 4.2 from series up to 2006.8. In this presentation we will summarize main outputs from analysis till the week 1400 and present the experience obtained from the analyses after 2006.8 with BV50

Content

- The processing strategy and applied time series analysis methods
- Analysis of series with subdaily resolution from two separate intervals 2004.0 – 2006.8 (BV42) and 2007.7 – 2008.7 (BV50)
- Results obtained from period 2004.0 – 2006.8 and their interpretation
- Results from the period 2007.7 – 2008.7 and the problems encountered

Analyzed sites – LAC SUT subnetwork

- Status in October 2008: 44 sites spread out over the whole continent
- The continual observation series from 2004.0 to 2008.7 are available at ~ 30 sites
- Till 2006.8 the BV42 and ITRF2000 used, after 2006.8 the BV50, new moldels and ITRF2005

Main features of the GPS data analysis with sub-daily resolution

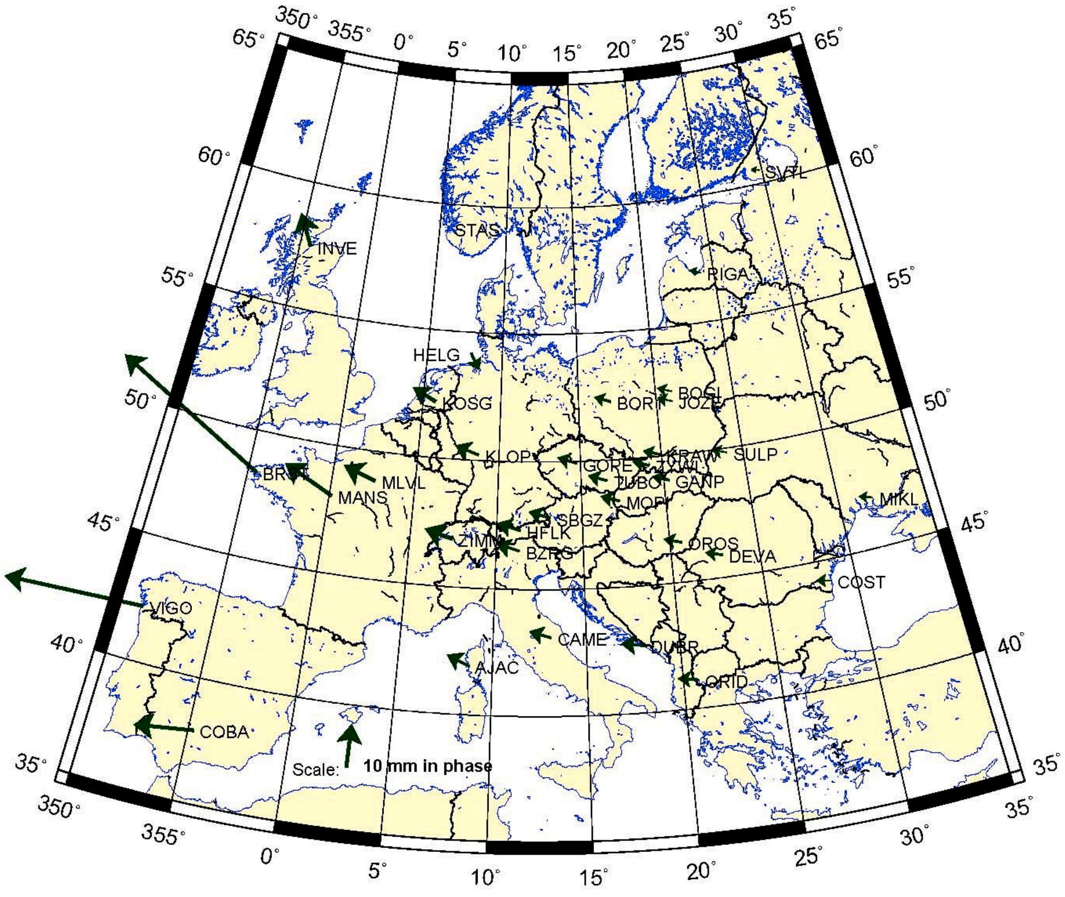
- Site coordinates are estimated from separate 4-hour intervals (6 coordinates per day) after completing the daily and weekly solution for EPN
- Ambiguities and hourly ZTD are taken from the daily solutions (one batch in 0-24 h)
- Generating of station coordinate time series with subdiurnal resolution: Firstly, the reference series based on set of ~20 stable stations is evaluated. Next, the residual variations of individual stations are obtained by reduction of the reference series.
- The series reflect the station variations relative to the 'mean' of the network.
- Two step analysis of time series:
  - Least squares spectral analysis of n-s, e-w and up components
  - Least square estimates of amplitudes of terms with main diurnal and semi-diurnal frequencies.

Solid earth tides and ocean loading modeling

- Solid earth tides are modeled consistently with IERS Conventions, 2003. The “step 1” and “step 2” corrections are implemented.
- For the site displacements due to ocean loading are recently available about 15 various ocean tidal models. These models account for 11 tidal terms – semidiurnal M2, S2, N2, K2, diurnal K1, O1, P1, Q1 fortnightly Mf, monthly Mm and semiannual Ssa.
- The largest amplitude differences among the models are up to 5 mm, generally being at the one millimeter level.
- We used for testing four recently applied tidal loading models, namely GOT00.2, FES2004, CSR4.0 and TPXO.7.1. For the EPN processing was used GOT00.2 till week 1400 and FES2004 after week 1400.

Modeled ocean tide loading displacements – FES2004

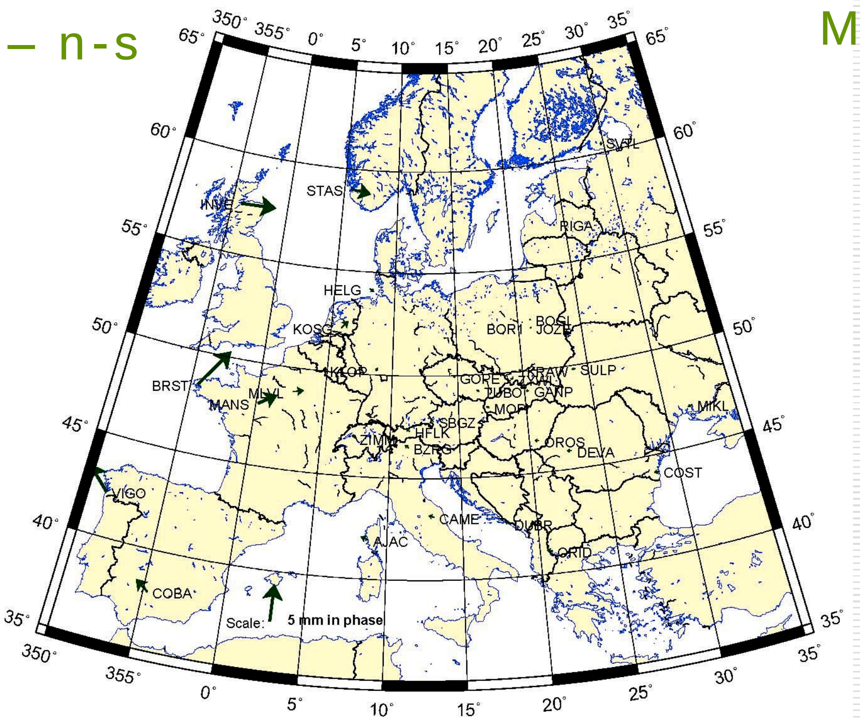
- M2 – the semidiurnal wave with 0. 5175 day periodicity
- M2 up component – the ocean loading effect with the largest amplitude
- The amplitude is from 3 mm in inland to 40 mm in the regions close to Atlantic
- Visualization: the in phase variations are represented in n-s direction, the out of phase constituent is in e-w direction



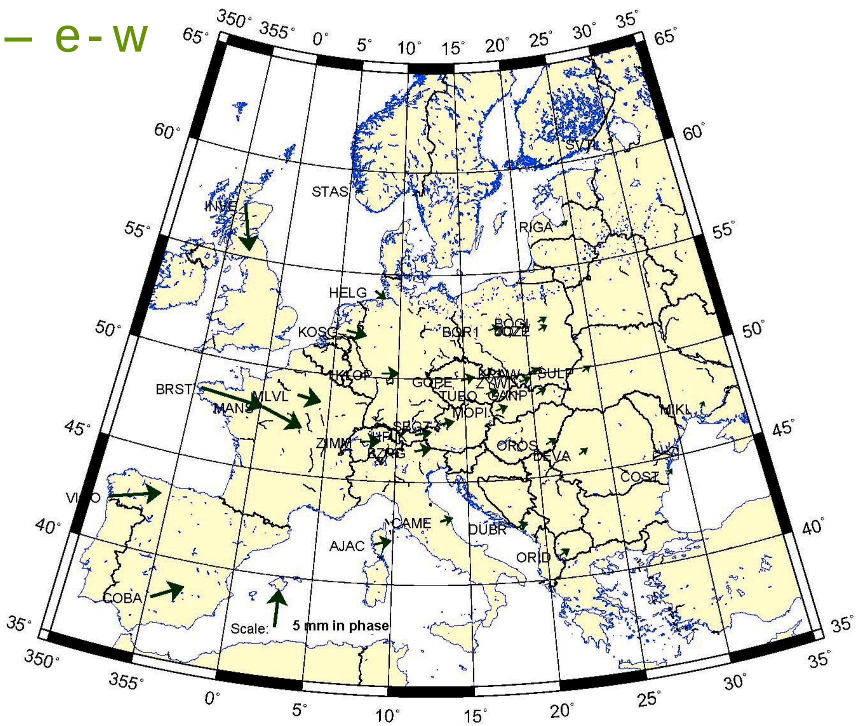
Modeled ocean tide loading displacements – FES2004

- M2 variations in n-s and e-w components
- The predicted amplitudes in the sites analyzed are from zero to 8 mm

M2 – n-s



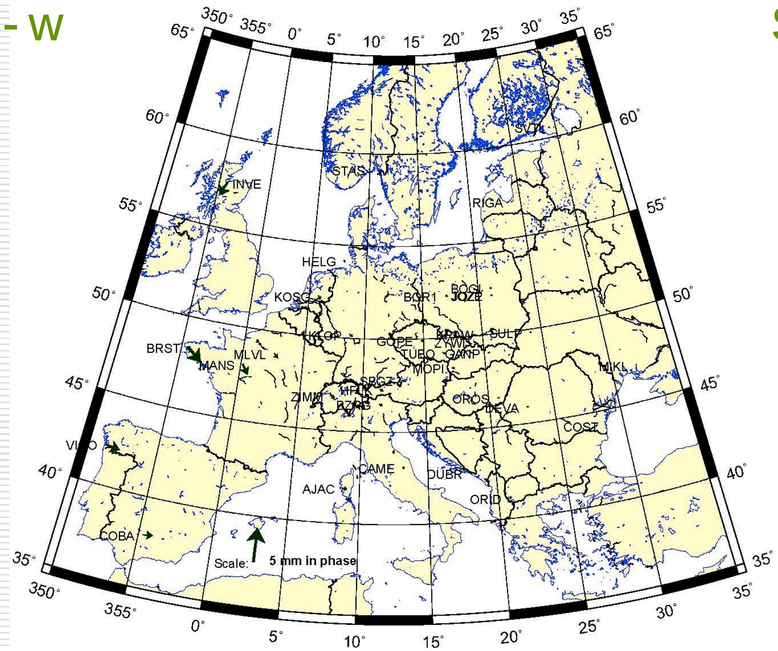
M2 – e-w



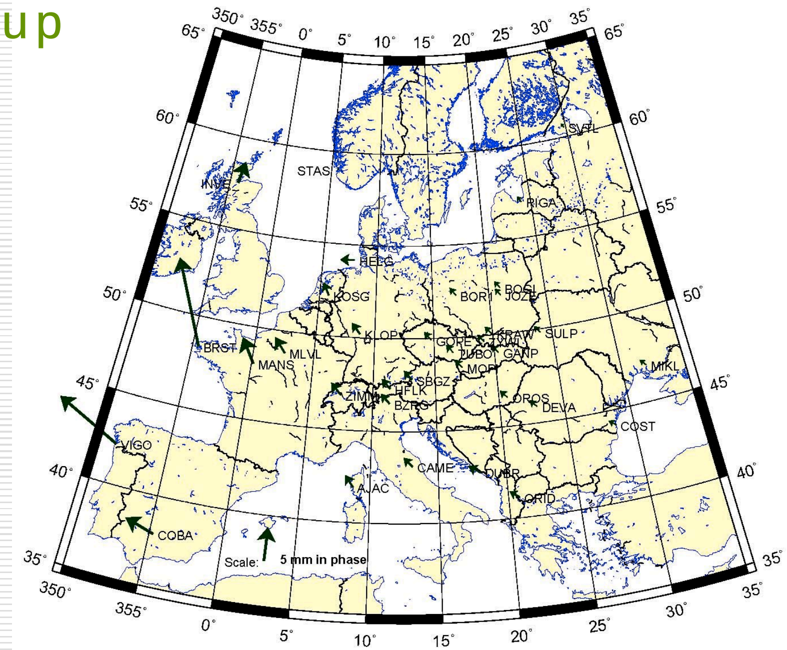
Modeled ocean tide loading displacements – FES2004

- S2 tide (period 0.5000 day) – e-w component (max. amplitude 2 mm) and up component (max. amplitude 13 mm)

S2 – e-w

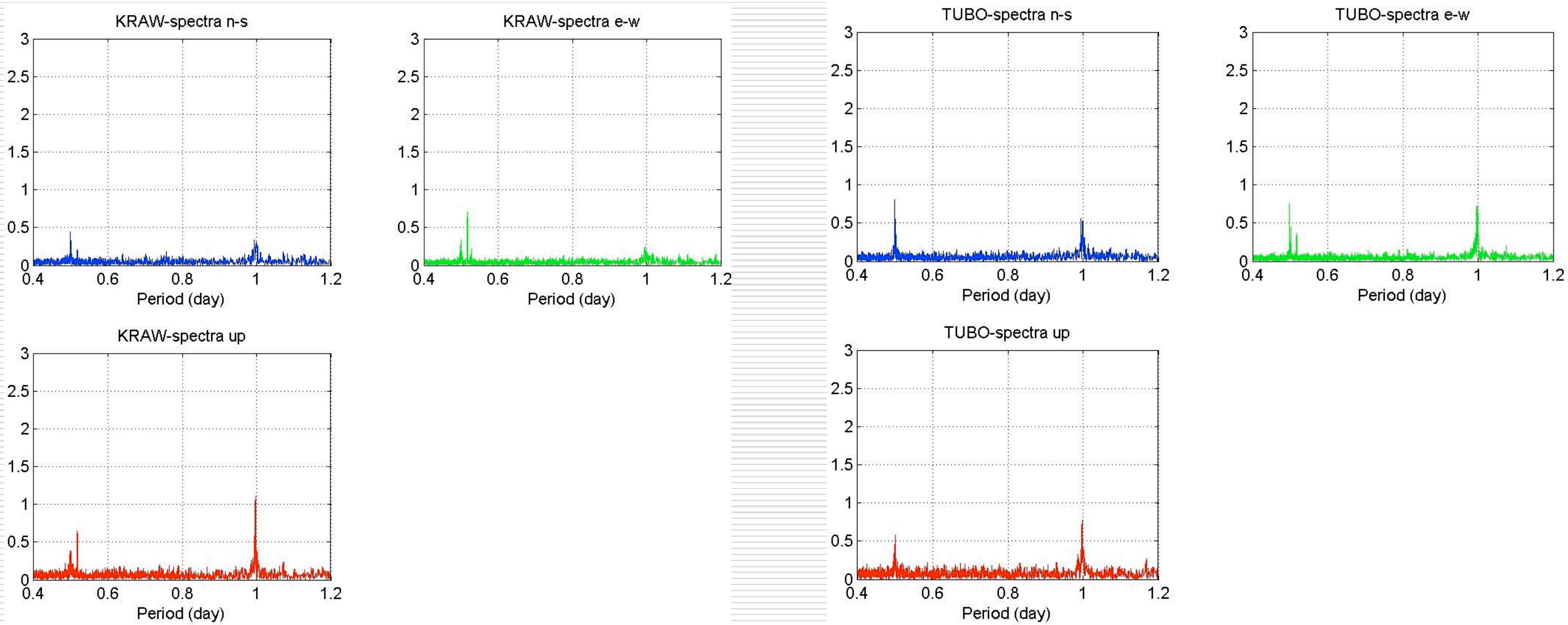


S2 – up



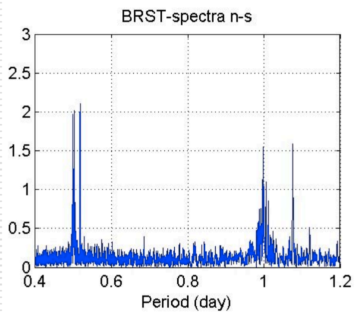
Examples of spectral analysis of n-e, e-w and up coordinates time series (based on observations from interval 2004.0 – 2006.8, reduced for GOT00.2) – inland stations

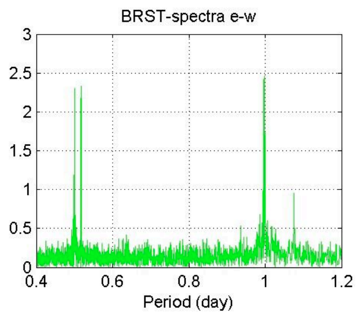
- The spectral peaks are concentrated around 0.5 and 1.0 periods. Amplitudes are up to 1 mm.
- Dominating are peaks with tidal periods S1, K1, S2, M2 and K2

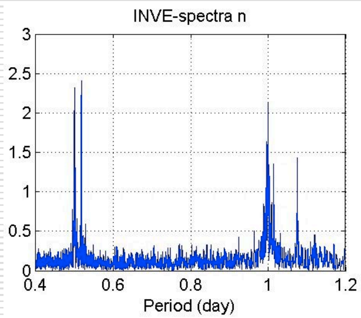


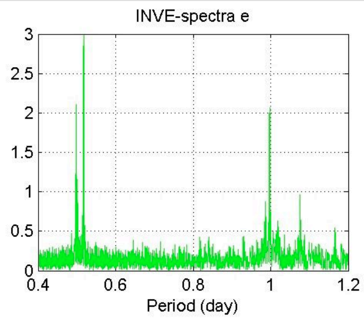
Examples of spectral analysis of n-e, e-w and up coordinates time series (based on observations from interval 2004.0 – 2006.8, reduced for GOT00.2) – stations close to coast

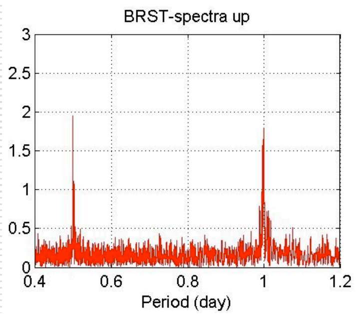
- Dominating terms are M2, S1, K1, O1, S2 and K2
- Their amplitudes vary from 1 to 3 mm. Amplitudes of the horizontal components are relatively larger than amplitudes for the up components

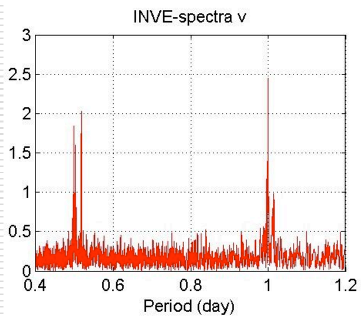








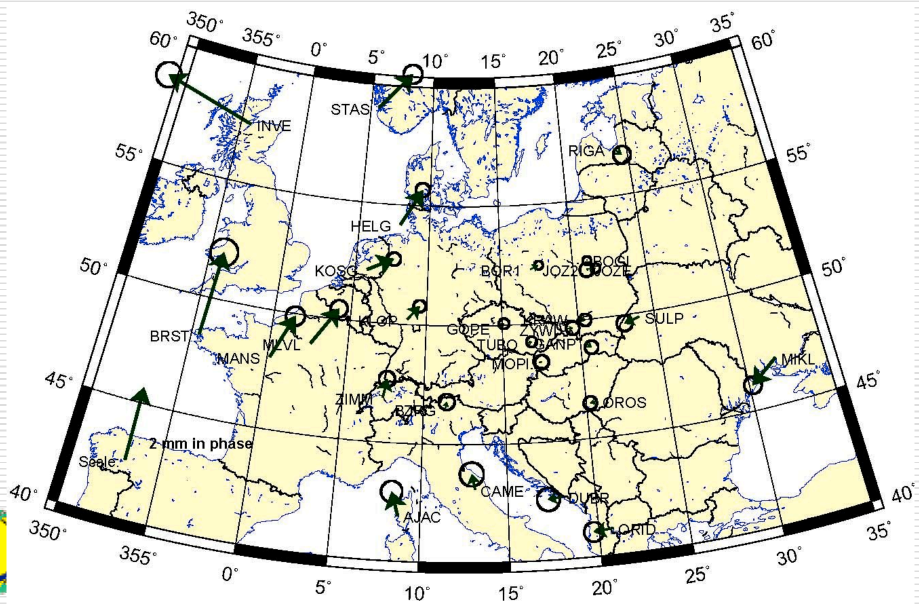




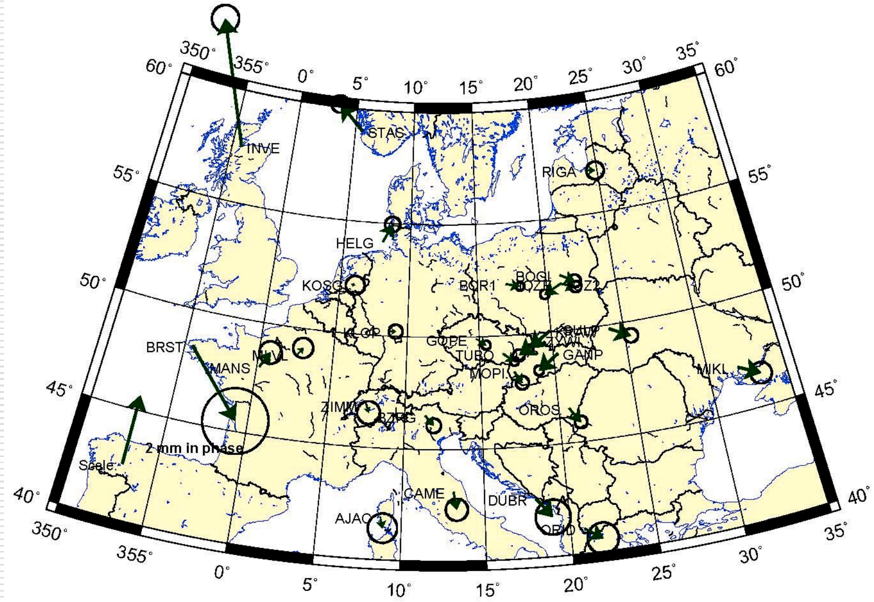
Regional distribution of observed residual horizontal variations with M2 period (reference GOT00.2 ocean loading model)

- Vectors represent the observed deficiencies in tidal modeling with the 95% error ellipses. These variations can be considered as the discrepancies with applied ocean loading model.
- In general, the largest amplitudes are for sites close to coast

M2 – n-s



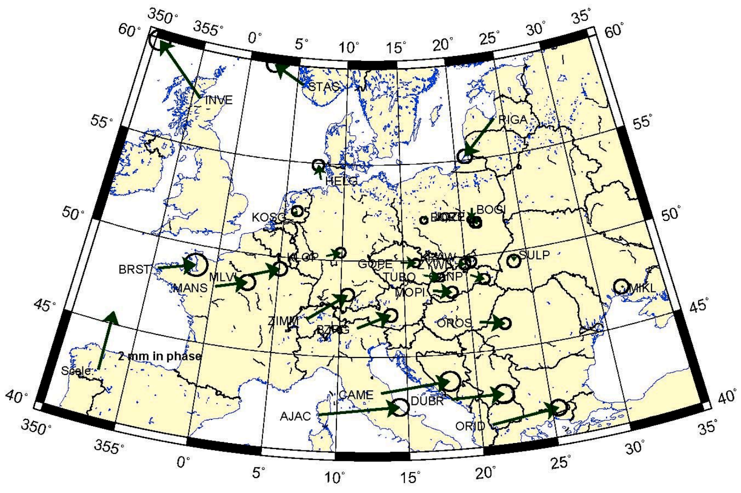
M2 – e-w



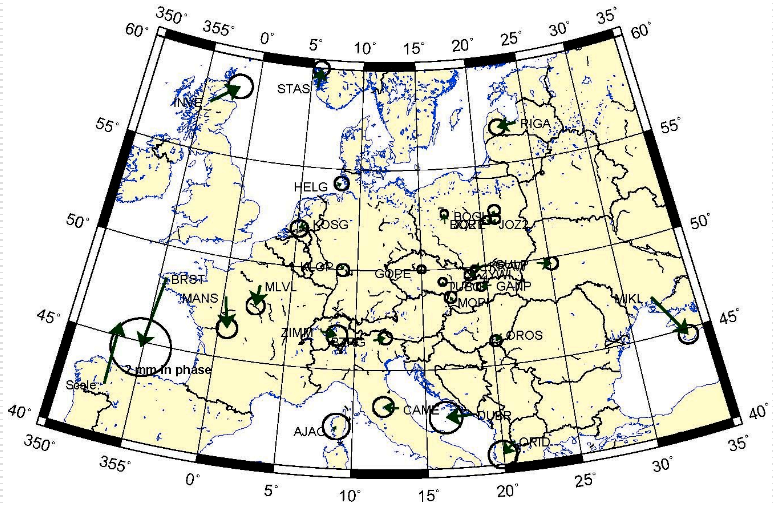
Regional distribution of observed residual horizontal variations with S2 period (reference GOT00.2 ocean loading model)

- Vectors represent the observed variations with period of S2 (exactly 0.500 day) with the 95% error ellipses. These variations with ~ 2 mm amplitude have regional pattern and cannot be be considered as the discrepancies with applied ocean loading model.

S2 – n-s



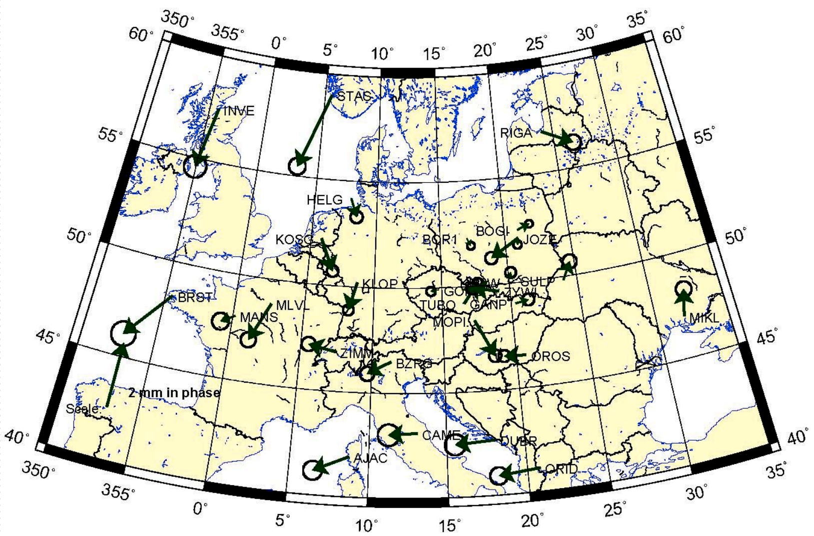
S2 – e-w



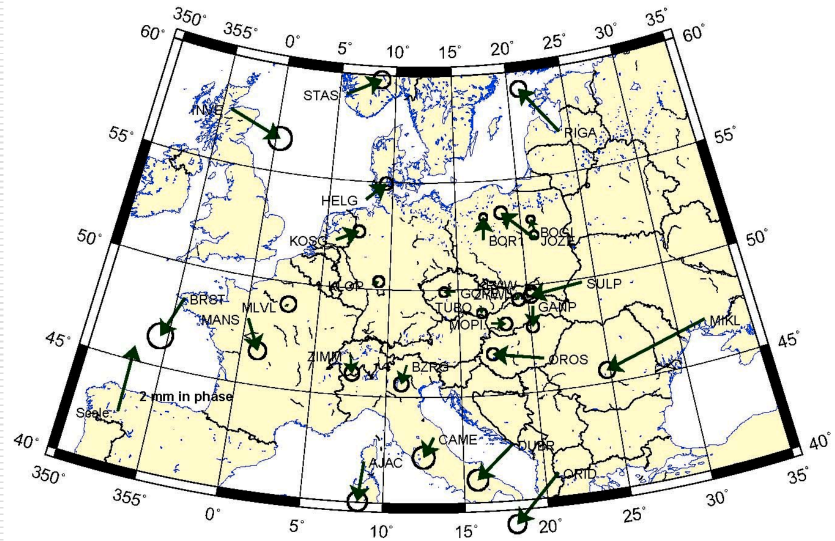
Regional distribution of observed residual n-s variations with K2 and K1 periods (reference GOT00.2 ocean loading model)

- The K2 (0.4986 day) and K1 (0.9973 day) variations are associated with GPS satellites orbiting and repeating of satellite constellation as well as with multipath effects.
- The K2 and K1 residual variations are very probably not the consequence of ocean loading mismodeling.

K2 – n-s

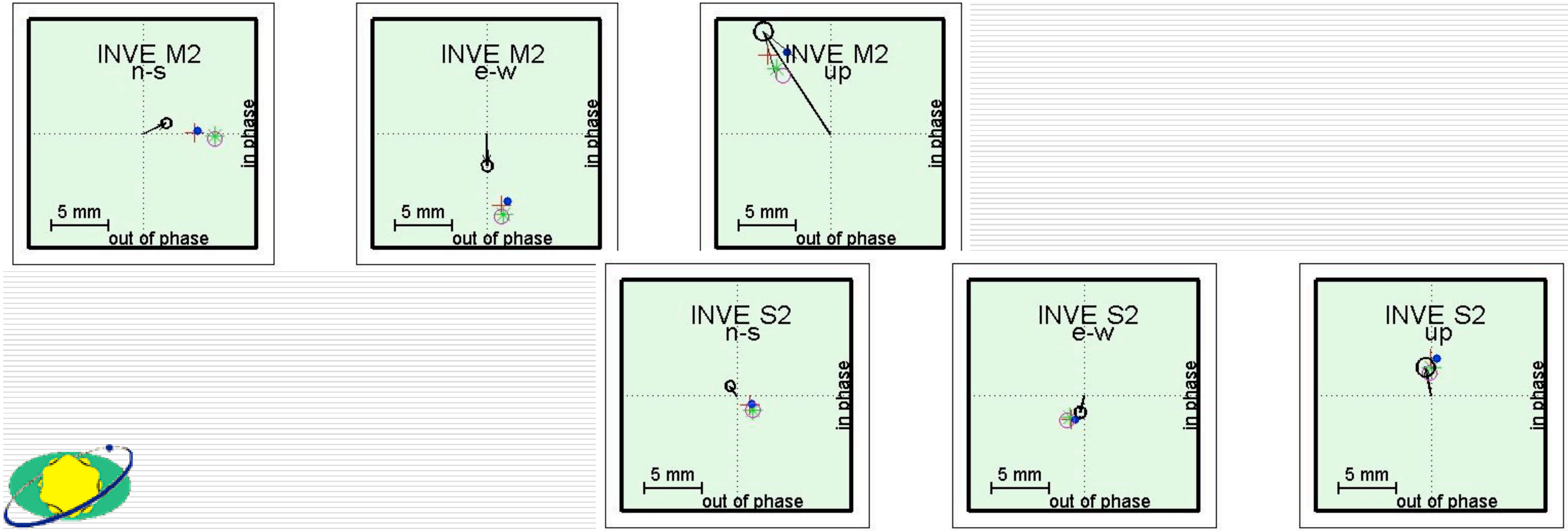


K1 – n-s



Phasor diagrams of observed and modeled ocean tidal loading displacements. Example: station INVE, M2 and S2 tidal waves

- The tidal models: + FES2004, . GOT00.2, o CSR4.0 and * TPXO.7.1
- Arrows with 95% confidence ellipse – the GPS estimates
- Inconsistencies among observations and models in range 2-3 mm are detected for INVE M2 (all constituents) and S2 (n-s)

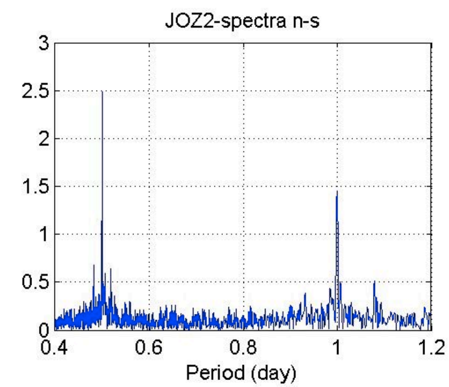


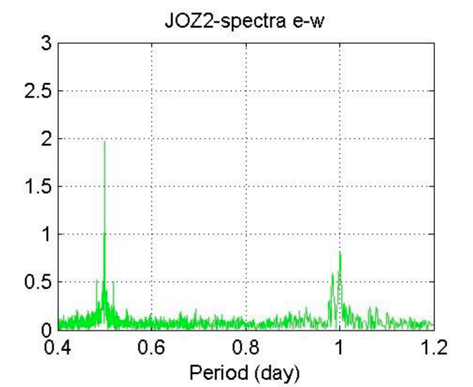
Summary and interpretation of results obtained from the period 2004.0 – 2006.8

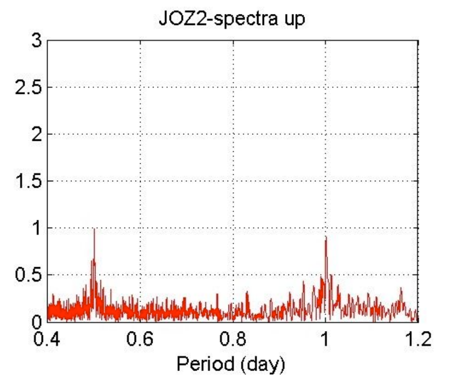
- All the observed periodical variations can be associated with tidal periods - semidiurnal M2, S2, and K2 and diurnal O1, S1 and K1.
- Their amplitudes are in range from 0.5 to 3 mm, dominating are M2 variations, mainly for coastal stations.
- The possible reasons for the observed variations are the ocean tides, effects associated with GPS orbiting and troposphere/ionosphere effects.
- Similar conclusions about deficiencies of modeling of ocean loading effects were reported on basis of VLBI analysis and GPS analysis in several studies by various authors.

Examples of spectral analysis of n-e, e-w and up coordinates time series (based on observations from interval 2006.8 – 2008.3, reduced for FES2004) – inland stations

- In the spectra are dominating S1 and S2 variations. The other tidal terms – M2, O1, K2 and K1 are much weaker or even not clearly distinguishable.
- The amplitudes of S2 n-s component exceed 3 mm also for some inland stations.
- The amplitudes of the up component are significantly smaller.

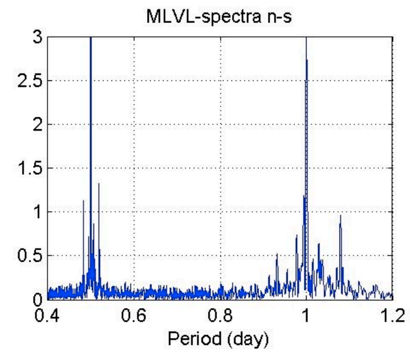


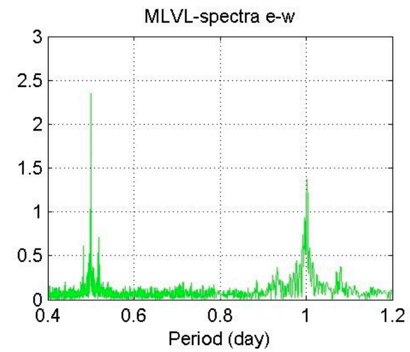


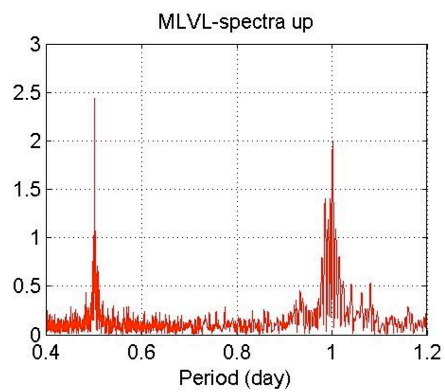


Examples of spectral analysis of n-e, e-w and up coordinates time series (based on observations from interval 2006.8 – 2008.3, reduced for FES2004) - stations close to coast

- In the spectra the S1 and S2 are dominating. The other tidal terms – are much weaker or not clearly distinguishable
- The amplitudes of S2 are over 6 mm for some stations on the border of the network
- There are visible also other peaks which are not associated with tidal frequencies, namely 0.482, 0.519, 0.930, 1.079 day periods.







Comparison of spectra before and after 2006.8 in semidiurnal band – station INVE, n-s component

- In the spectra after week 1400 the S2 peak is dominating, also K2 is visible, but no M2 signal.
- The amplitudes of S2 are large up to 10 mm and are above 3 mm also for inland stations
- In the majority of stations two non-tidal freguencies 0.482 and 0.519 are visible (sidelobes of S2?)

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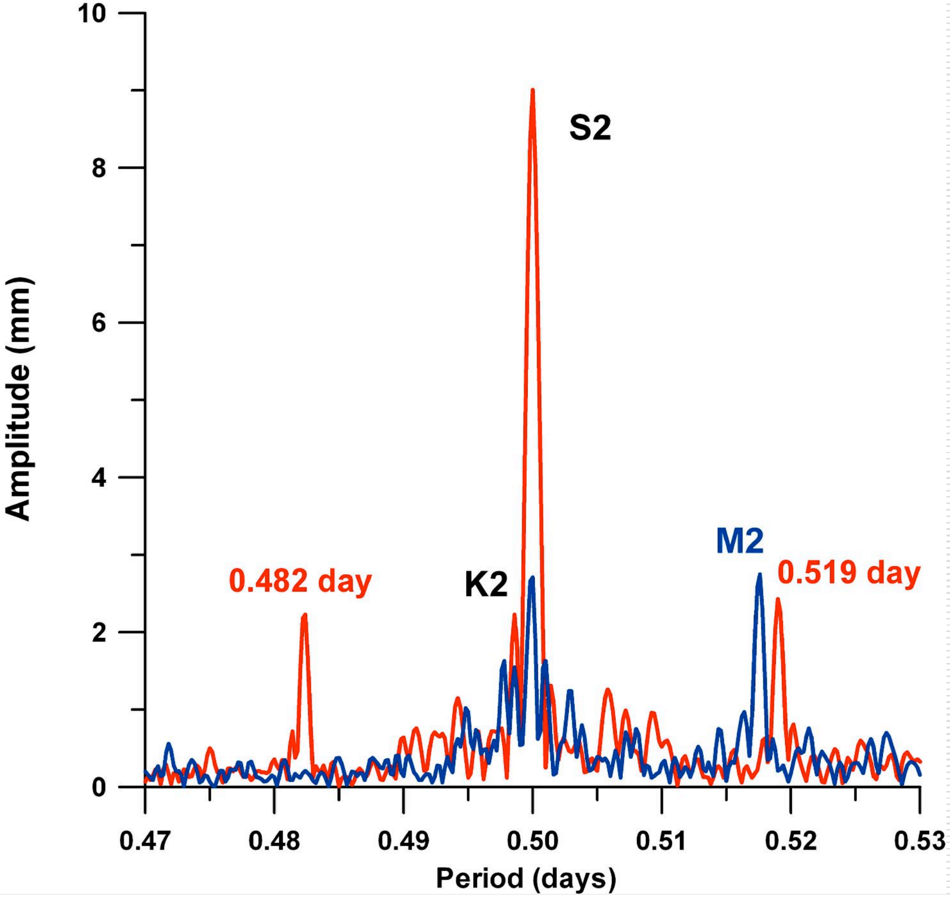
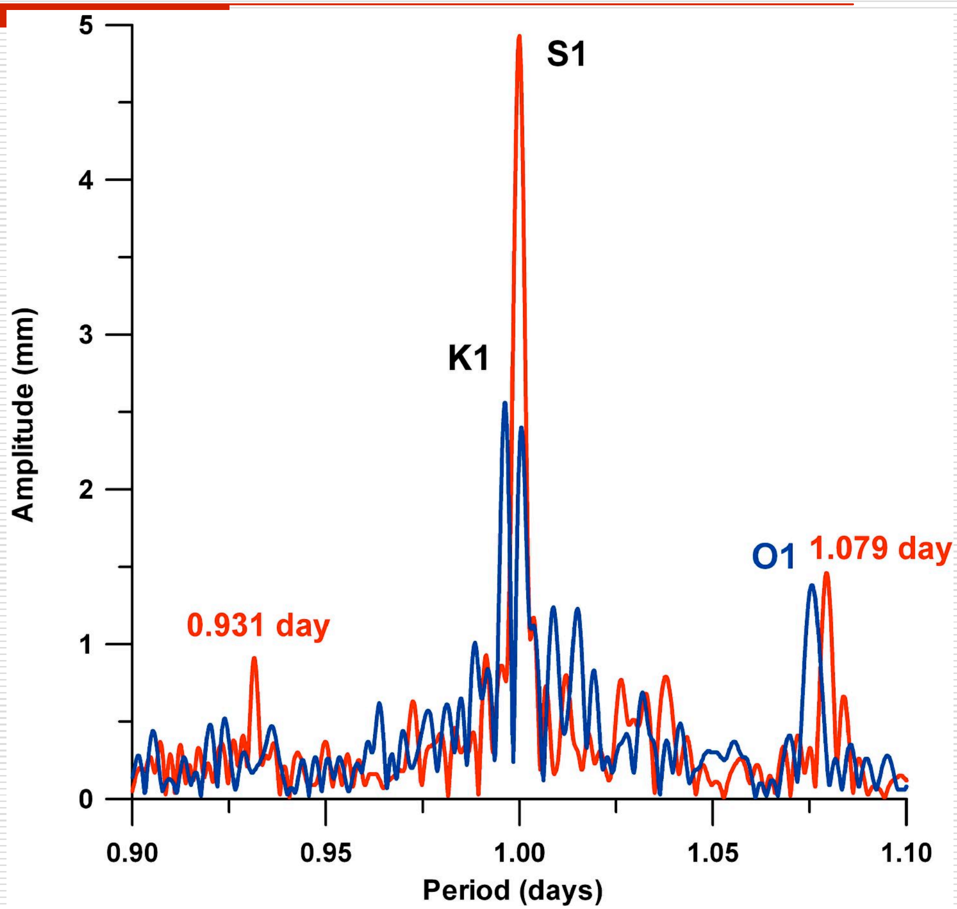


Comparison of spectra before and after 2006.8 in diurnal band – station INVE, n-s component

- In the spectra after week 1400 the S1 peak is dominating, also K1 is visible, but no O1 signal.
- The amplitudes of S1 are up to 5 mm and are above 2 mm also for inland stations.
- In spectra of majority of stations also two non-tidal periods 0.931 and 1.079 are dominating (sidelobes of S1?)

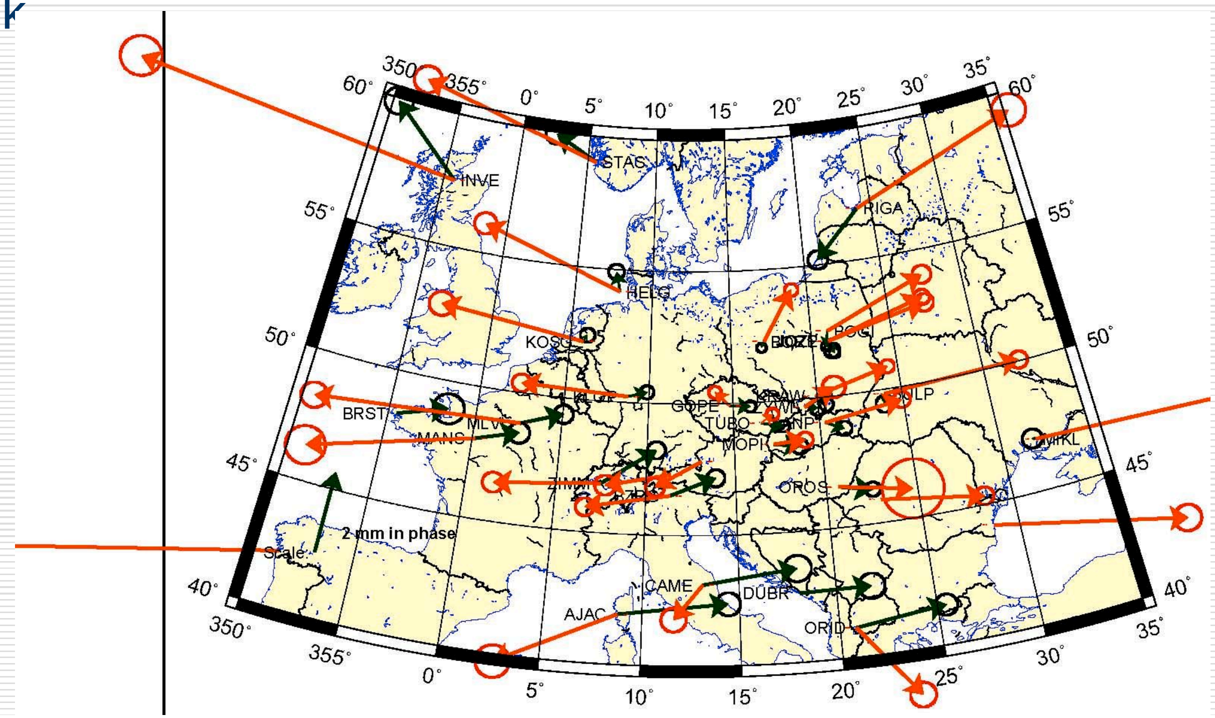


Regional distribution of observed residual horizontal n-s variations with S2 period

- The S2 (0.500 day) variations after 2006.8 have amplitudes more than 5 times larger than before 2006.8
- The amplitudes and phases have regional pattern with increase from the centre of network

BV42 before 2006.8

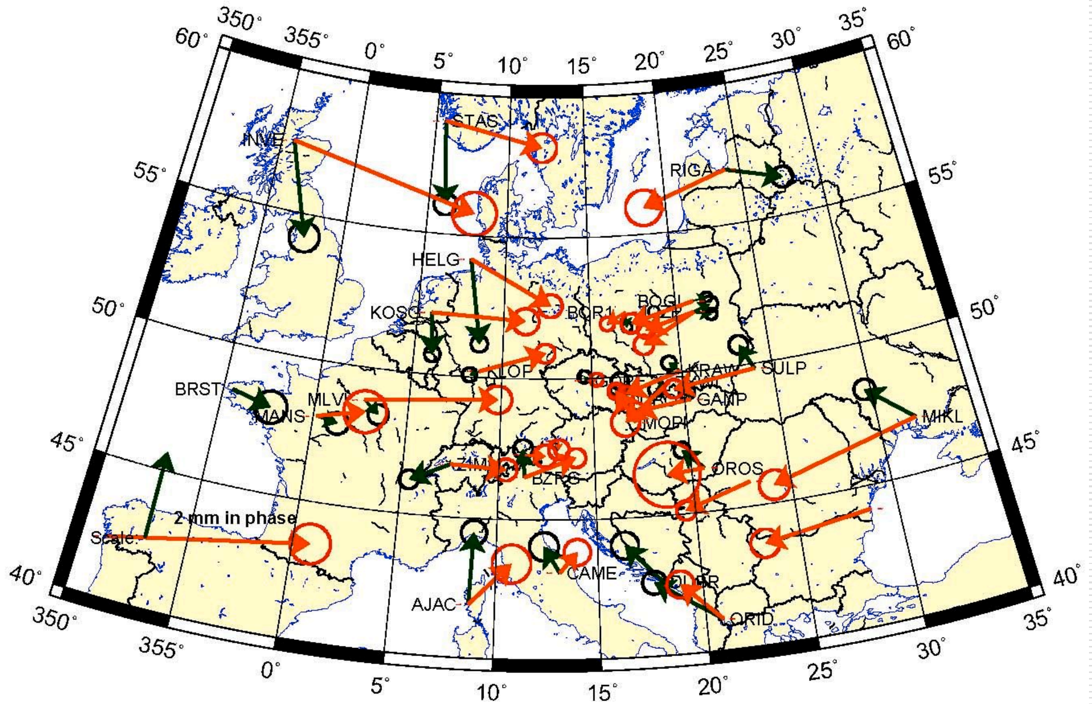
BV50 after 2006.8



Regional distribution of observed residual horizontal n-s variations with S1 period

- The S1 variations after 2006.8 have amplitudes larger than before 2006.8 but no more than twice
- The amplitude and phase have regional pattern with increase from the centre of network

BV42 before 2006.8
BV50 after 2006.8



Conclusions

- We encountered very strange unexpected results when analyzing the diurnal and semi-diurnal variation at EPN stations after the analysis changes in 2006.8.
- The main feature of observed variations after 2006.8 is the very strong S2 signal with amplitude about 6 mm in horizontal components for stations on the border of analyzed network. The regional pattern of phase and amplitude of S2 is clearly pronounced.
- The M2 and O1 signal have been strongly reduced in the coordinate time series after 2006.8, more than it can be expected from transition of GOT00.2 to FES2004.
- As the strategies for subdaily estimates and analysis before 2006.8 and after 2006.8 are similar, and the critical are 0.5 and 1.0 day periods, we assign the reasons to residual effects of troposphere handling (influence of troposphere gradients in the sub-daily series?). However also other reasons cannot be excluded. We are optimistic to solve this problem in near future.

Thanks for your attention!