

# SHORT-TERM VARIATIONS OBSERVED AT EPN STATIONS

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# MOTIVATION

- For long-term behaviour of GPS permanent stations are characteristic following phenomena: linear trend due to plate motion, seasonal periodic variations of observed coordinates and sudden changes – jumps in the series.
- The aim of this paper is to investigate if in the coordinate time series besides the phenomena mentioned also other significant variations could be observed.
- The presented analysis concerns GPS stations analyzed at LAC Slovak University of Technology, Bratislava

# Sub-network analyzed at LAC SUT

- First weekly solution included into EPN combination: week 1182
- Analysed network in September 2002: 25 stations distributed over the whole European continent, status in June 2006: 37 active stations



# Data used in the presented analysis

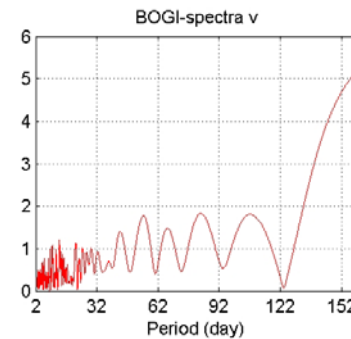
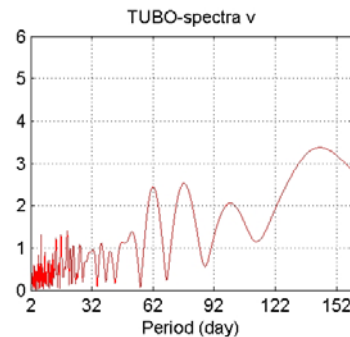
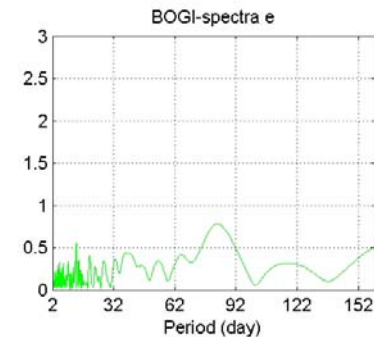
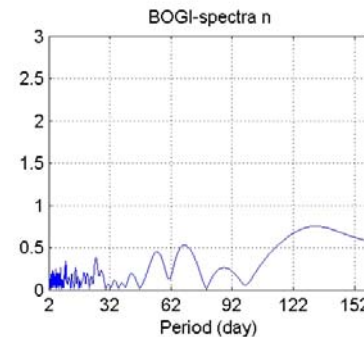
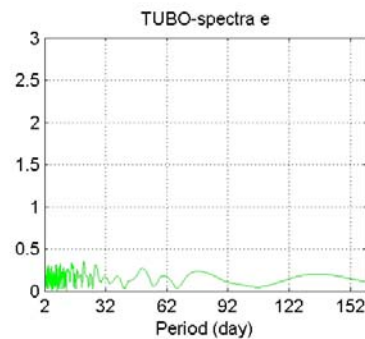
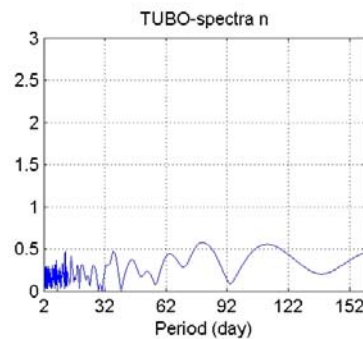
- **Network solutions obtained in the process of routine EPN analysis. Coordinate time series are computed for 24-hours intervals according to LAC EPN rules. These data will be used for investigation of phenomena with periods from two days up to semi-annual terms.**
- **Network solution with subdaily (4-hours) resolution. Data will be used for diurnal and semi-diurnal phenomena.**
- **Analysed data are from 30 stations and they cover time span 2004 - 2005**

# Time series for analysis of short-term coordinate variations

- Time series adjustment: Firstly, the „reference series“ is composed from detrended series of set of stable and reliable stations. Then all the station series are reduced for the reference series. The residual series represent the relative variations of site coordinates.
- The „reference series“ is based on 20 – 24 stations.
- The approach mentioned is applied separately as for daily so for 4-hour series
- Two types of time series analysis are performed:
- - Spectral analysis of individual station series ( $n$ ,  $e$ , and  $up$  components)
- - Least squares estimates of amplitudes and phases of harmonics with known frequencies.

# Spectral analysis of two-year interval of daily coordinates - range of periods 2-150 days

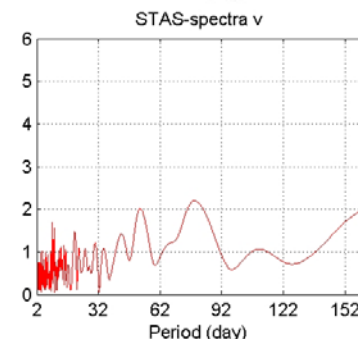
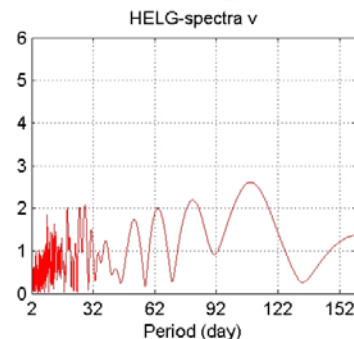
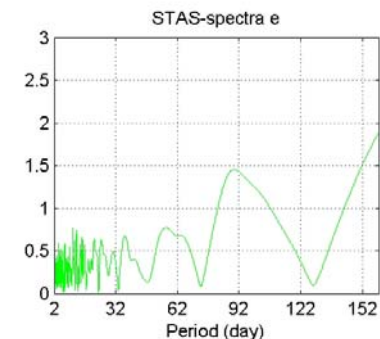
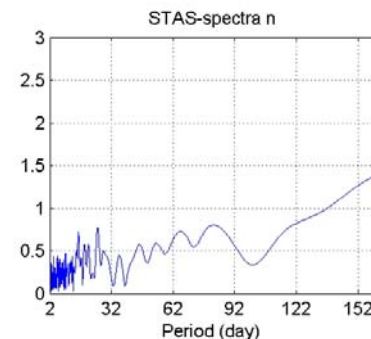
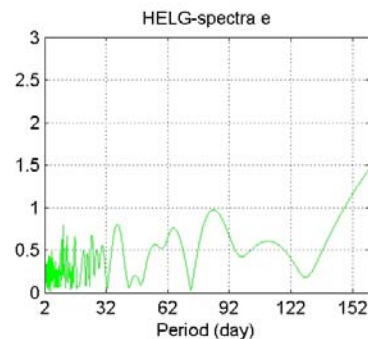
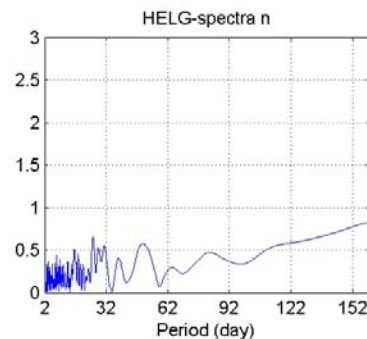
- **Example 1 - stations TUBO and BOGI (“central stations”): Horizontal variations with amplitudes under 1 mm, vertical up to 3 mm. No common significant periods for all 3 coordinate constituents.**





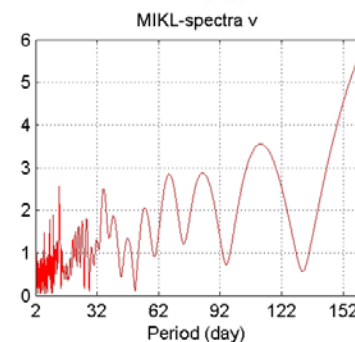
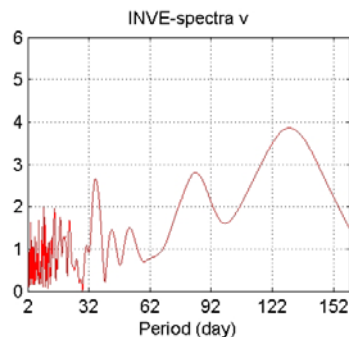
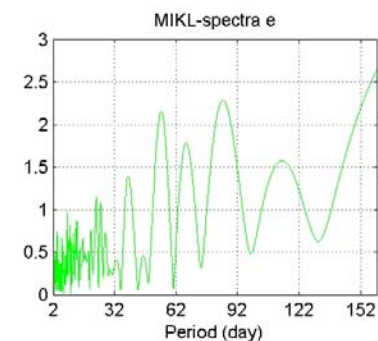
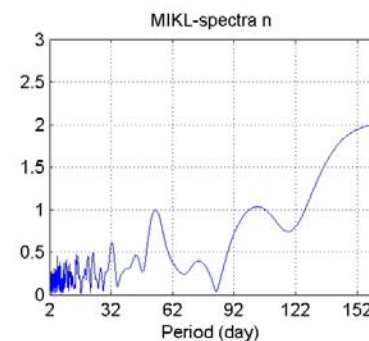
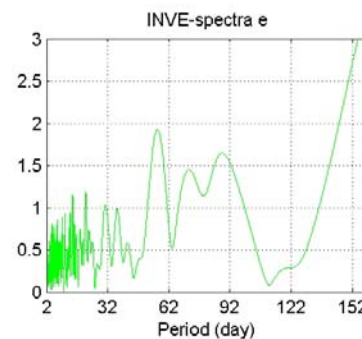
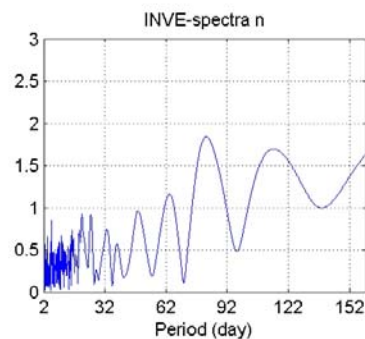
# Spectral analysis of two-year interval of daily coordinate - range of periods 2-150 days

- **Example 2 - stations HELG and STAS (“remote stations”): Horizontal variations with amplitudes under 1.5 mm, vertical up to 3 mm. No common significant periods for all 3 coordinate constituents**



# Spectral analysis of two-year interval of daily coordinate - range of periods 2-150 days

- **Example 3 – untypical stations: INVE and MIKL (“remote stations”):**  
Horizontal variations with amplitudes up to 2 mm, vertical up to 4 mm.  
No common significant periods for all 3 coordinate constituents





## Conclusions related to coordinate variations in range of periods 2 - 150 days

- Variability of majority of stations in the range of periods 2-150 days is less than 1.5 mm in horizontal coordinates and 3 mm in height. No common significant periods for all coordinate constituents were found
- There are few stations (INVE, BRST, MIKL, ORID, MIKL, SVTL) with slightly larger variability up to 2 mm in horizontal coordinates and 4 mm in height. However also for these stations no common significant periods for all coordinate constituents were found.
- There is weak correlation of amplitudes of variations and distance of station from centre of network observed.
- Conclusion: the analyzed stations do not demonstrate any significant variations with common periods, their spectra are rather individual.

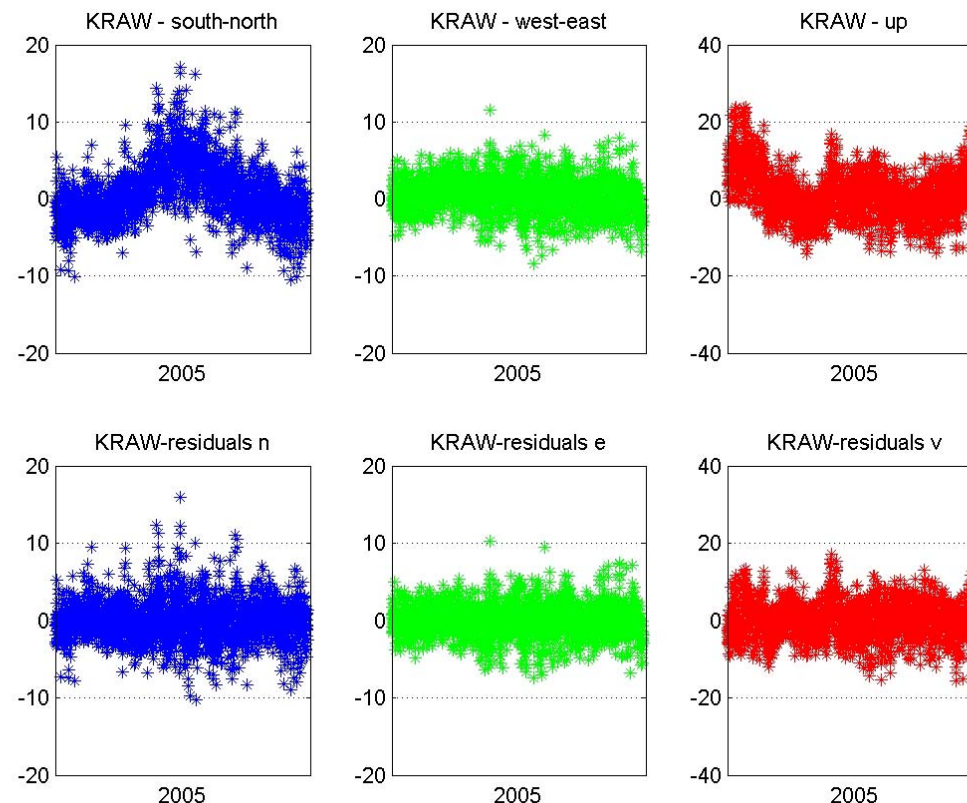


# Network solution with 4-hour resolution performed at LAC SUT

- Network processing in 4-hour separate intervals - “sub-daily” resolution: only coordinates are estimated, ambiguities and troposphere zenith delays are taken from 24-hour solutions.
- Main goals: monitoring of coordinate variations in diurnal and sub-diurnal bands (periods 0.33 – 2 days), possibility to detect tidal phenomena mismodelling in station positions, extraction of information which is absorbed in coordinate evaluation from 24-hour sessions.

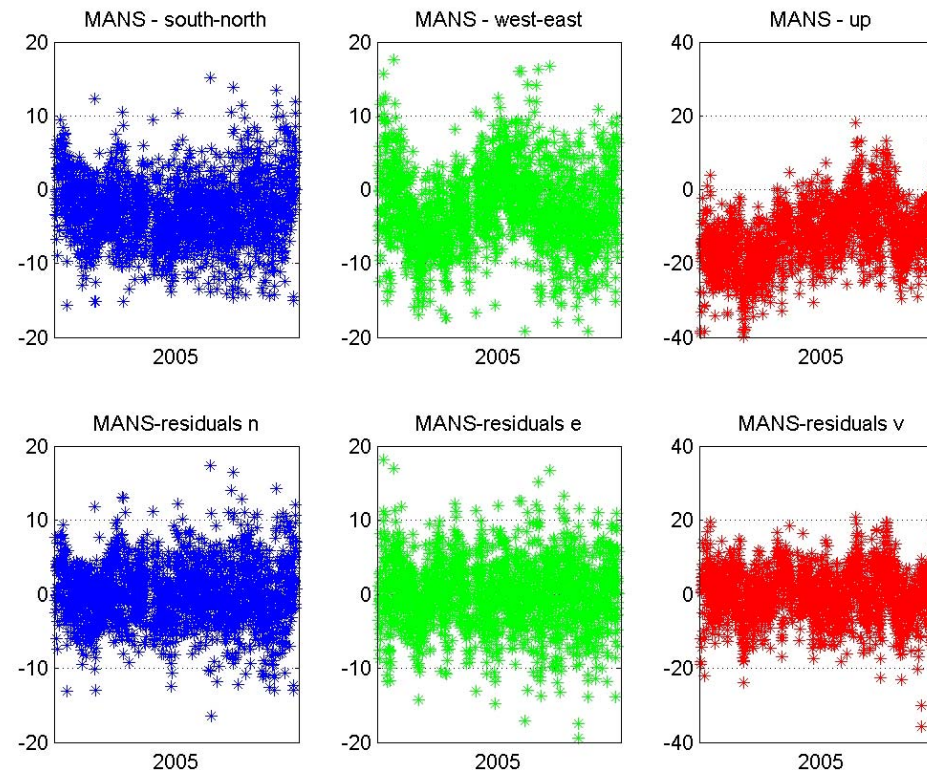
# Example of one-year time series (2005) used for evaluation of diurnal and sub-diurnal variations

- **Station KRAW: upper graphs – original reduced series, bottom graphs – station trend and seasonal variations are removed (input for spectral analysis)**



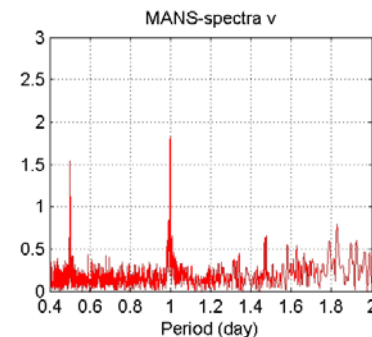
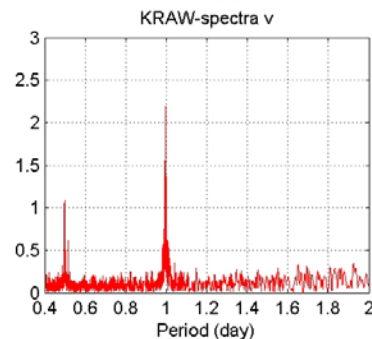
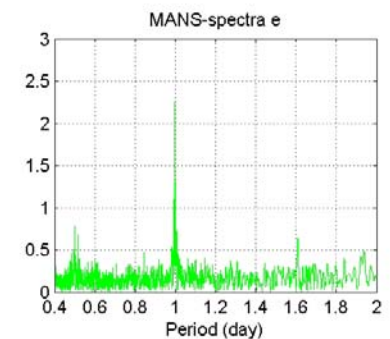
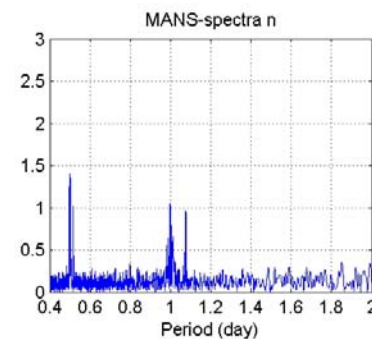
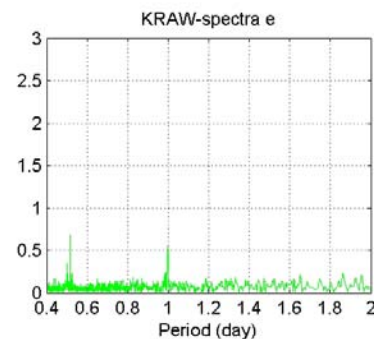
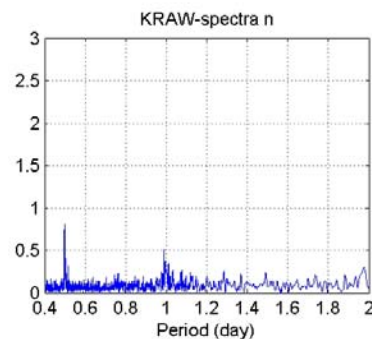
# Example of one-year time series (2005) used for evaluation of diurnal and sub-diurnal variations

- **Station MANS: upper graphs – original reduced series, bottom graphs – station trend and seasonal variations are removed (input for spectral analysis)**



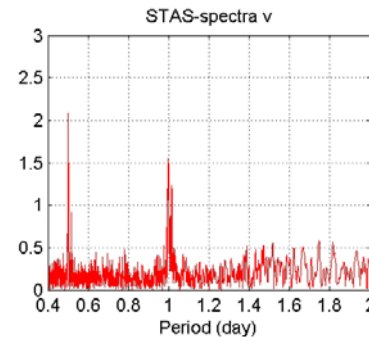
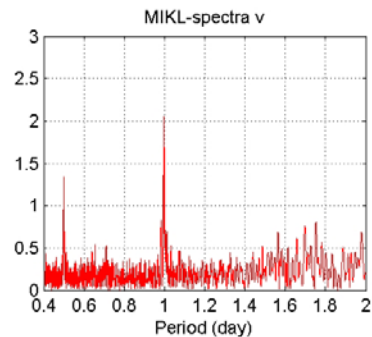
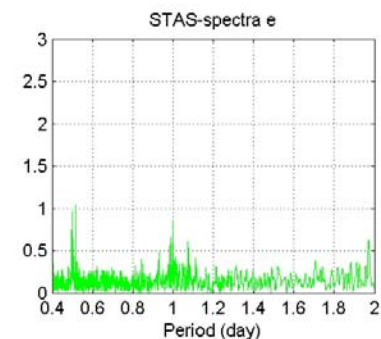
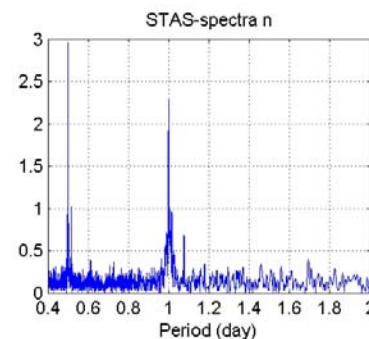
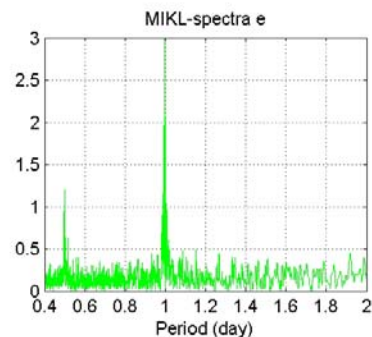
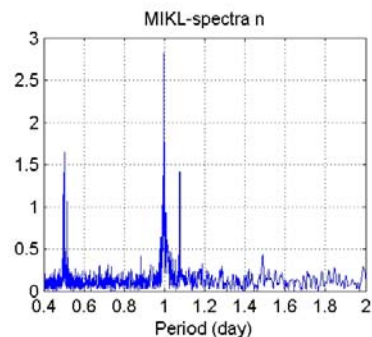
# Examples of LS spectral analysis

- Stations KRAW and MANS – observed are variations in horizontal coordinates and height in semi-diurnal and diurnal bands.
- Amplitudes are up to 2.5 mm for horizontal and for vertical constituents



# Examples of LS spectral analysis

- Stations MIKL and STAS – observed are variations in horizontal coordinates and height in semi-diurnal and diurnal bands.
- Amplitudes are up to 3 mm for horizontal and 2 mm for vertical constituents



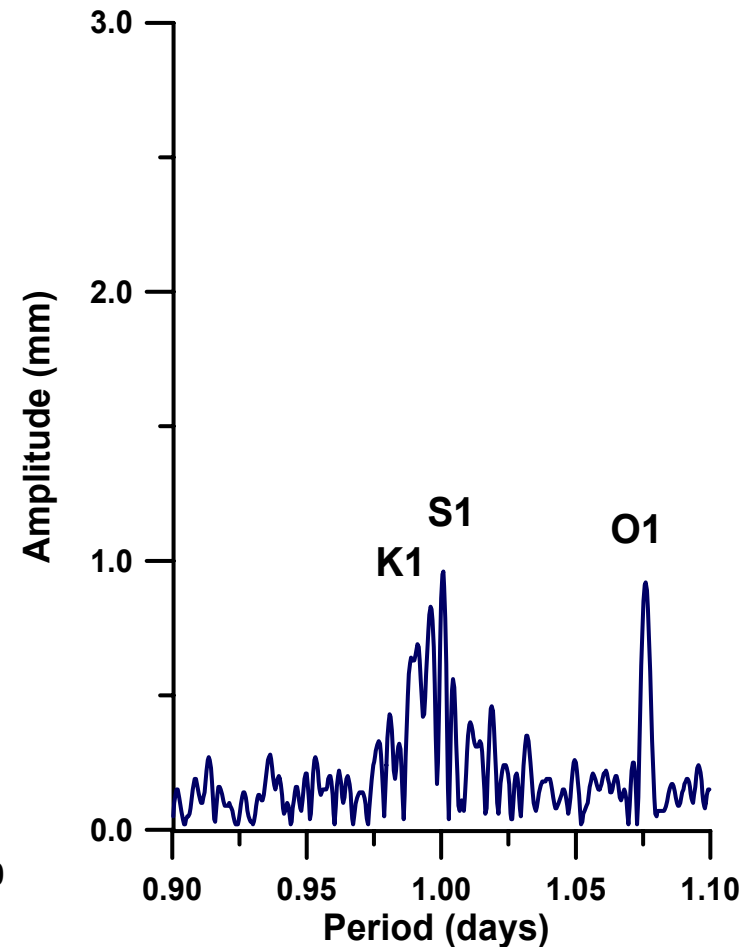
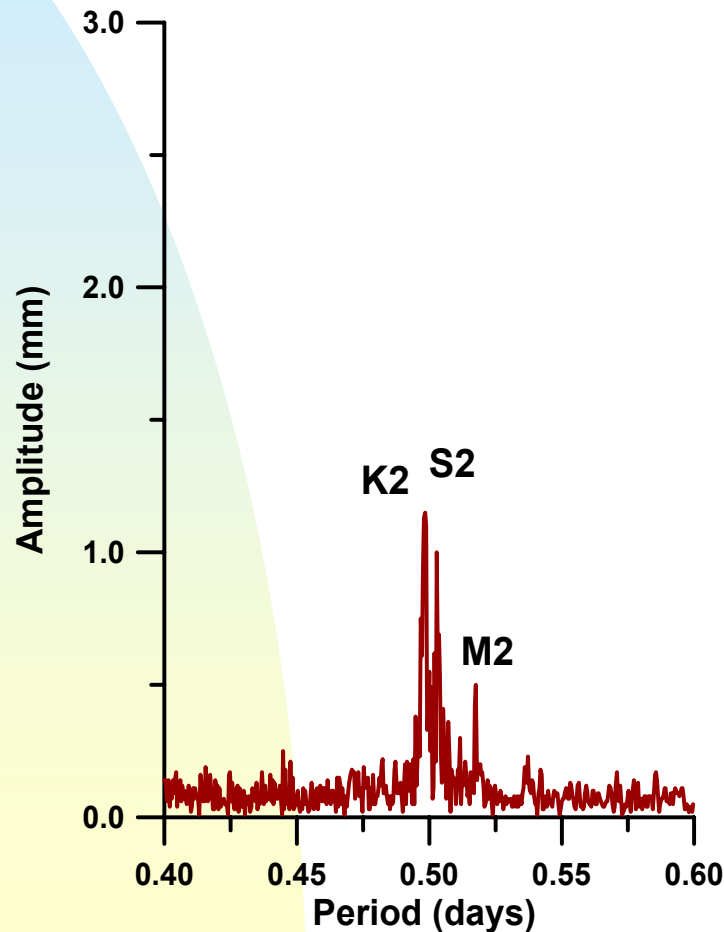


## Some remarks to spectral analysis results for periods 0.33 – 2.0 days

- For all the stations are detected in their spectra variations with diurnal and semidiurnal periods. Their amplitudes for individual stations are different, generally from 0.5 to 3 mm.
- No other significant amplitudes with periods common to more stations besides the diurnal and semidiurnal bands are pronounced.
- Note: the „tidal bug“ in BV42 affecting the height component was not removed. Because of referencing only the relative effect is expected to be observed.

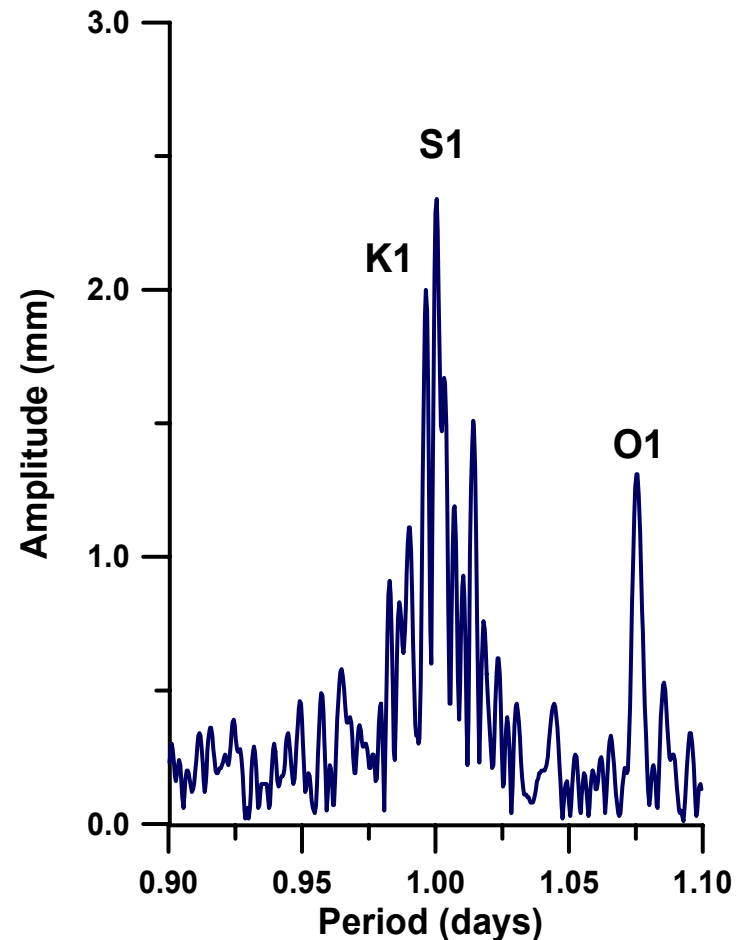
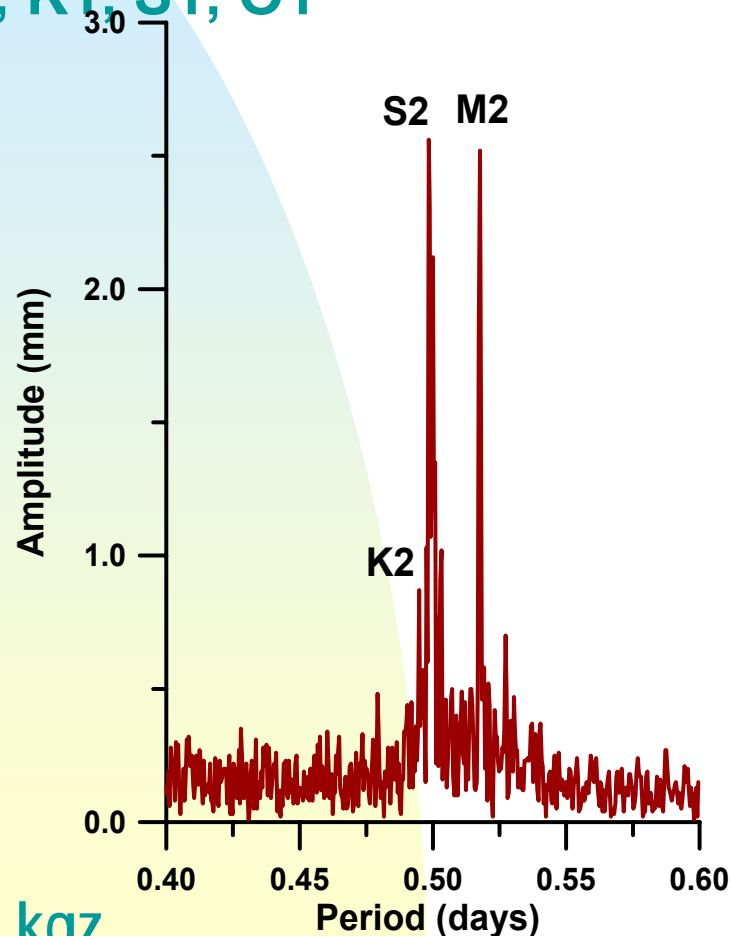
# Example of detailed spectra in semi-diurnal and diurnal band

- Station Sulp – north-south component
- Dominant are variations with tidal frequencies : K2, S2, M2, K1, S1, O1



# Example of detailed spectra in semi-diurnal and diurnal band

- Station INVE – north-south component
- Dominant are the variations with tidal frequencies : K2, S2, M2, K1, S1, O1

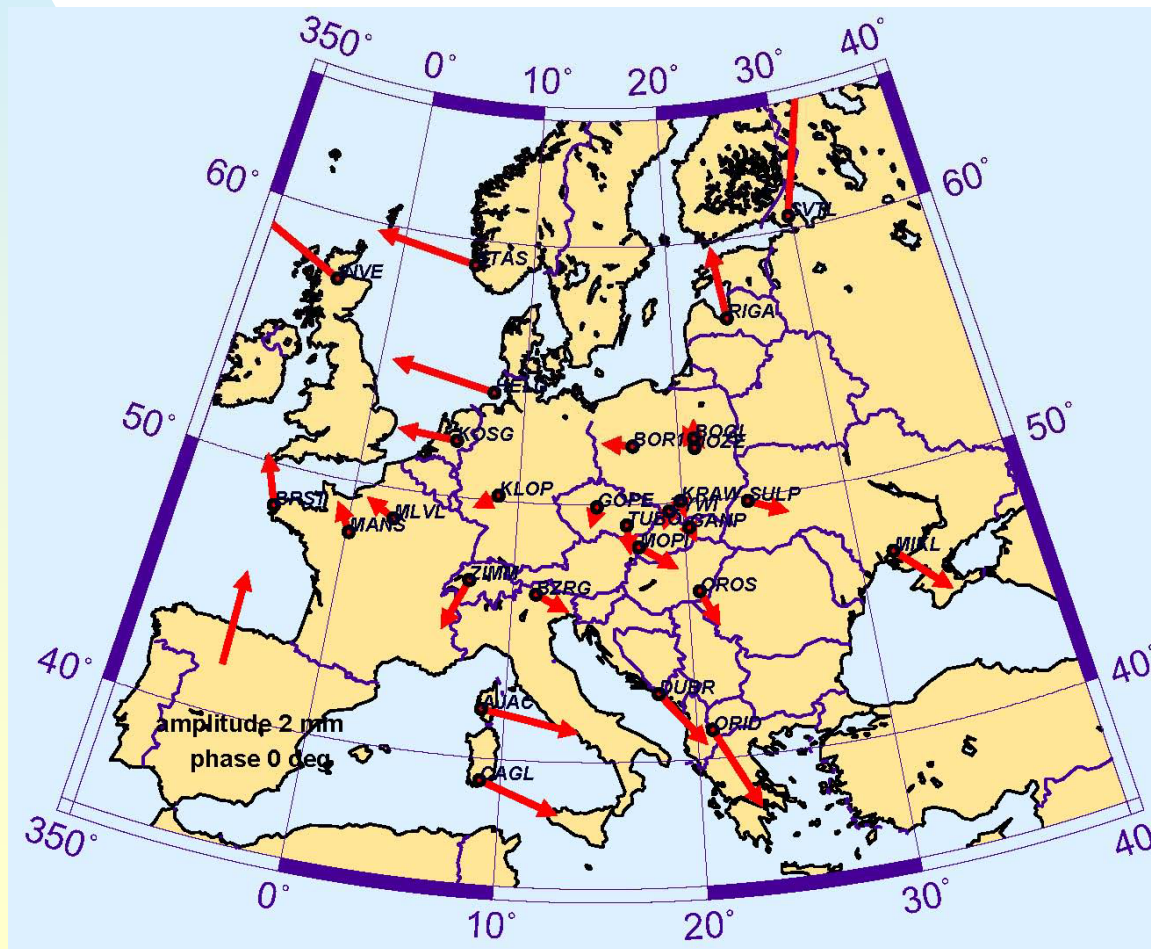


## Dominant terms in semi-diurnal and diurnal band

- Majority of the detected terms can be associated with 6 tidal frequencies: semidiurnal K2, S2 and M2 and diurnal K1, S1 and O1.
- K1 and K2 have relatively small tidal effect, their periods are corresponding to GPS satellite orbiting
- S1 and S2 are exactly with 1.0 and 0.5 day periods and can be associated with number of station effects (ZTD, atmosphere loading, thermic, etc.)
- M2 and partly also O1 have large amplitudes of solid earth and oceanic tidal effects. Their presence in GPS series can be associated with ocean loading effect mismodelling.

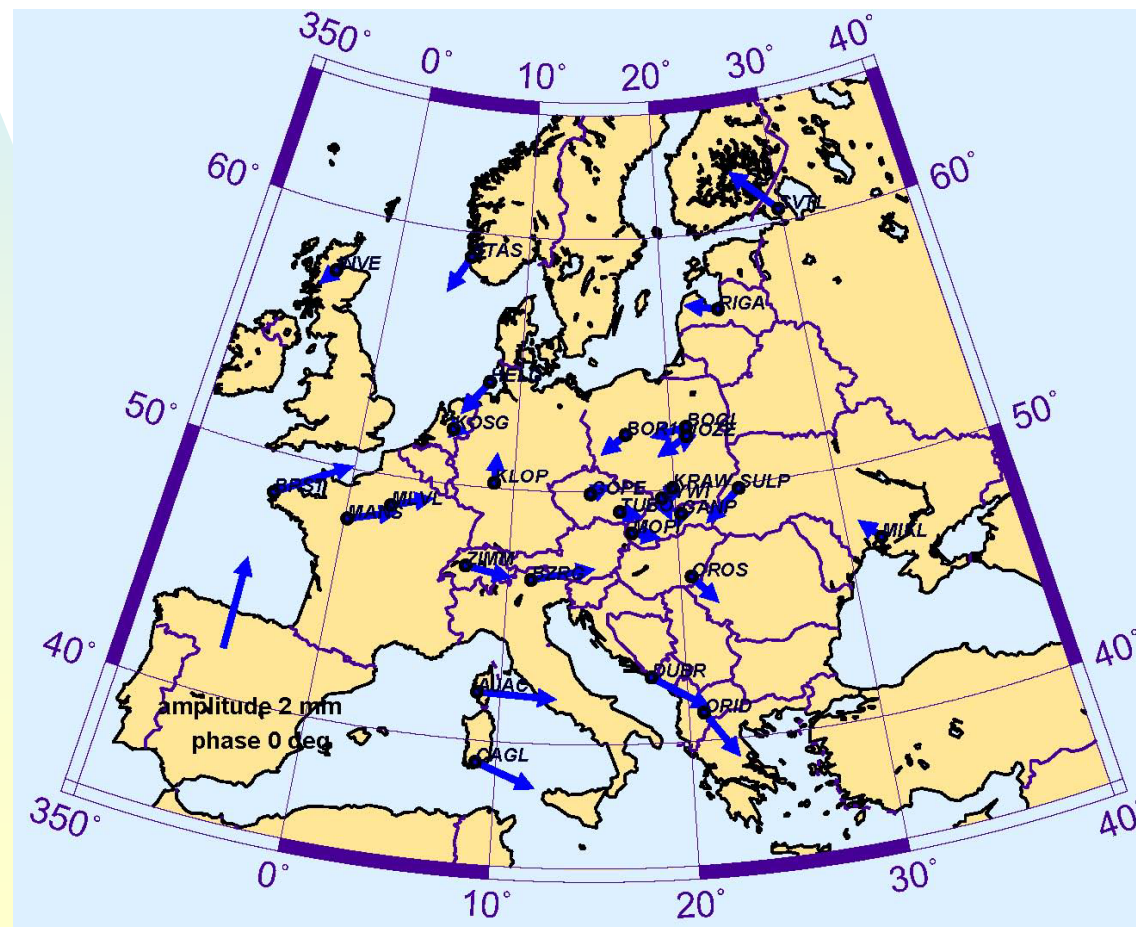
# Amplitudes and phases of north-south variation with S1 frequency (period = 1.000 day)

- Length of the arrows corresponds to observed amplitude, its direction to phase. Up direction means „in phase“ effect.
- Regional variability in amplitude (0-2 mm) and phase



# Amplitudes and phases of east-west variation with S1 frequency (period = 1.000 day)

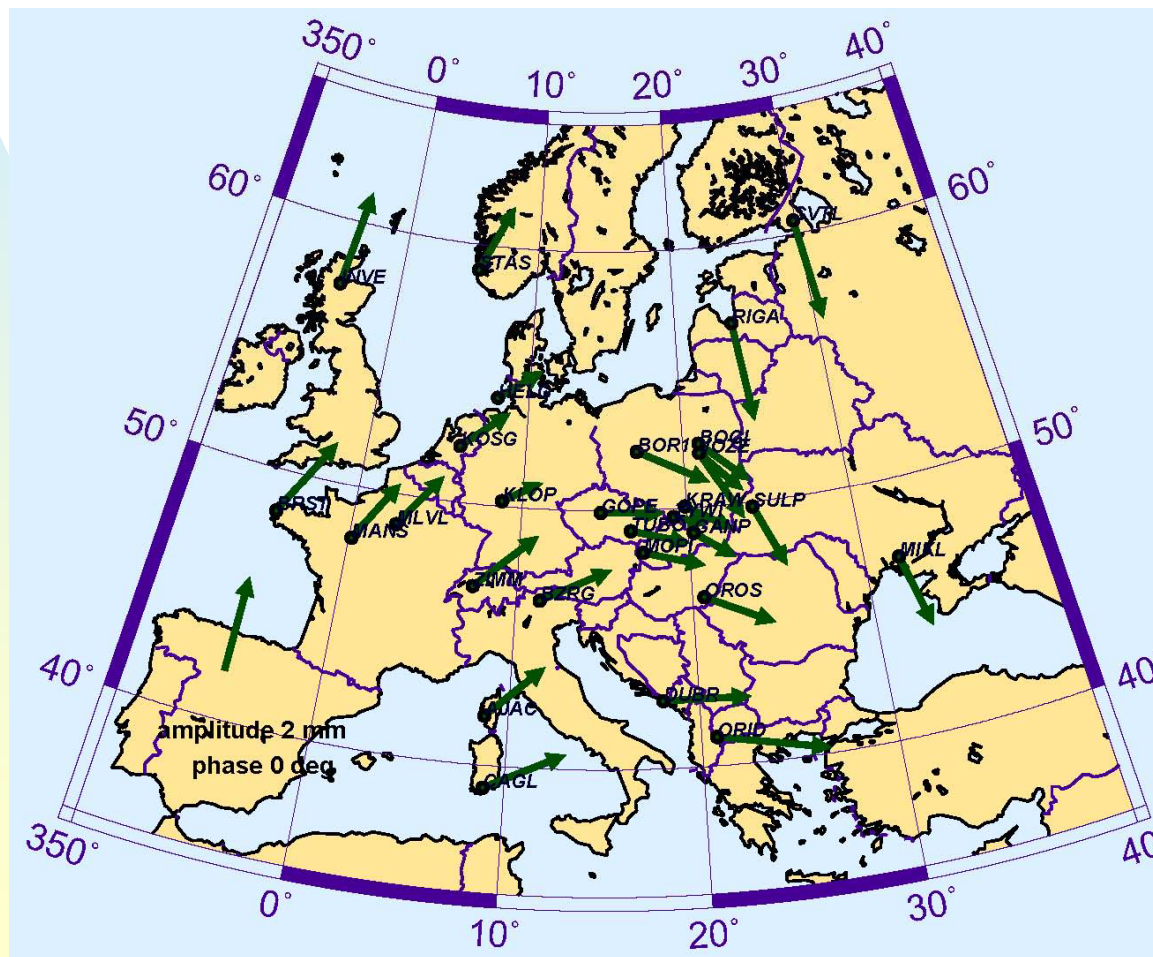
- Length of the arrows corresponds to observed amplitude, its direction to phase. Up direction means „in phase“ effect.
- Regional variability in amplitude (0-1.5 mm) and phase





# Amplitudes and phases of up-component variation with S1 frequency (period = 1.000 day)

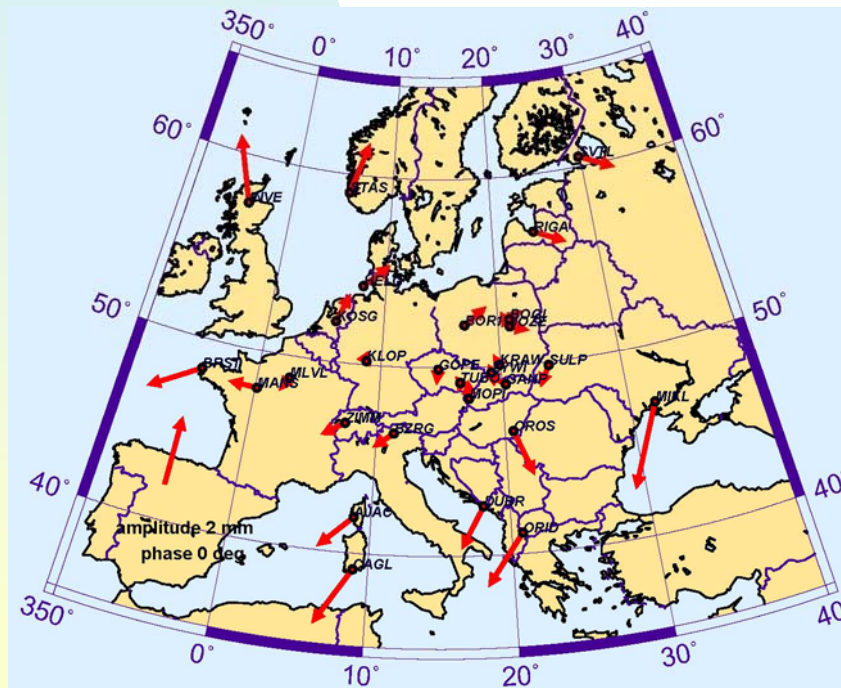
- This variation can be influenced by the „tidal bug“ in BV42
- Regionally stable amplitude, variation of phase



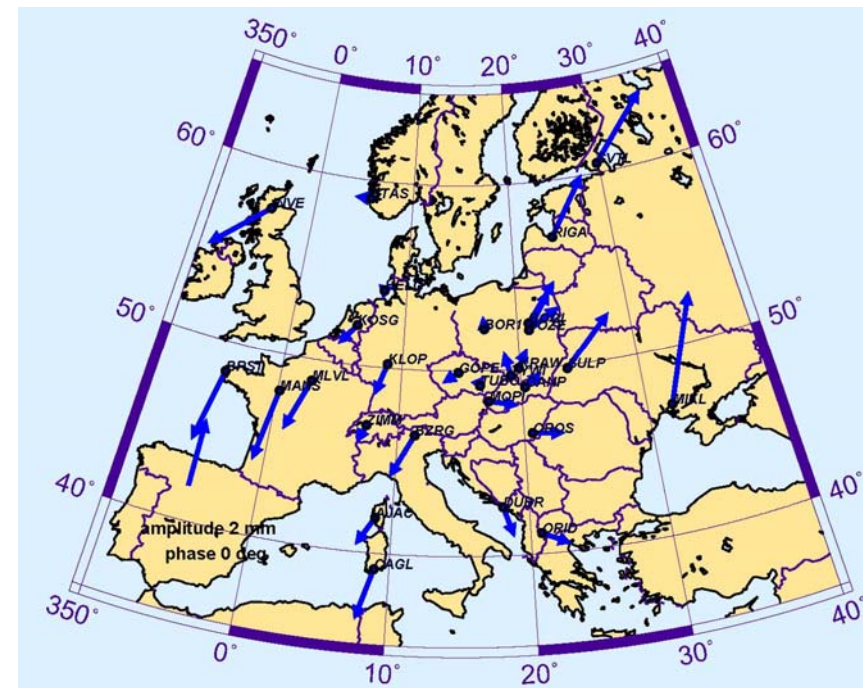
# Amplitudes and phases of horizontal variations with K1 frequency (period = 0.997 day: one sidereal day)

- Regional variability in amplitudes (0-3 mm) and phases („central symmetry)
- Related to GPS satellite orbiting, e.g. multipath

North-south



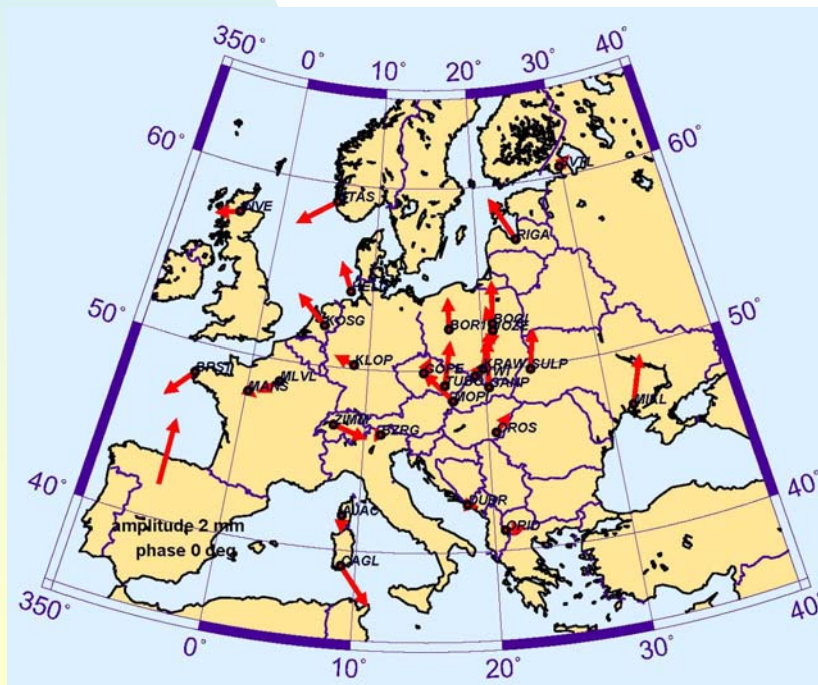
east-west



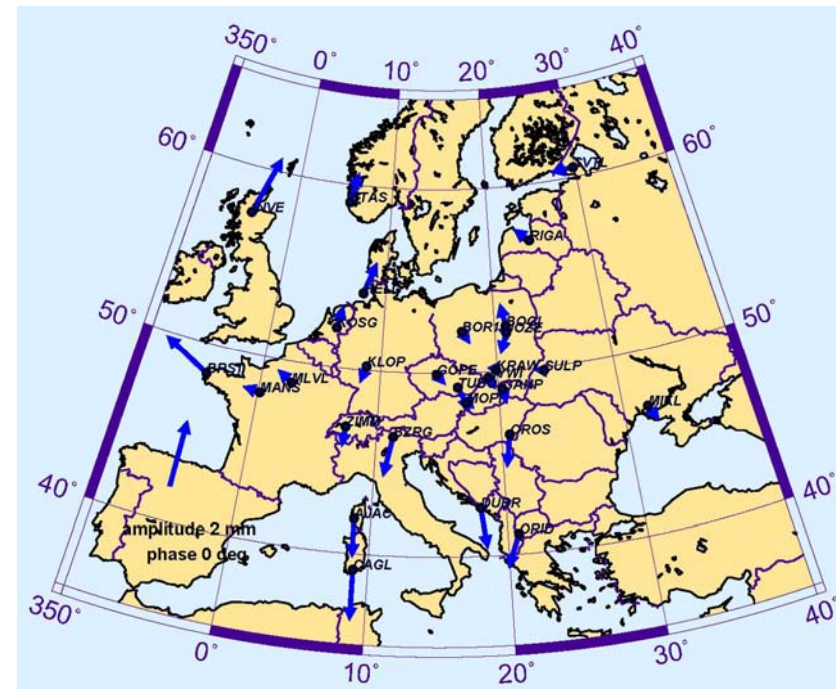
# Amplitudes and phases of horizontal variations with K2 frequency (period = 04986 day: period of GPS satellite orbiting)

- Regional variability in amplitudes (0-2 mm) and phases

North-south



east-west



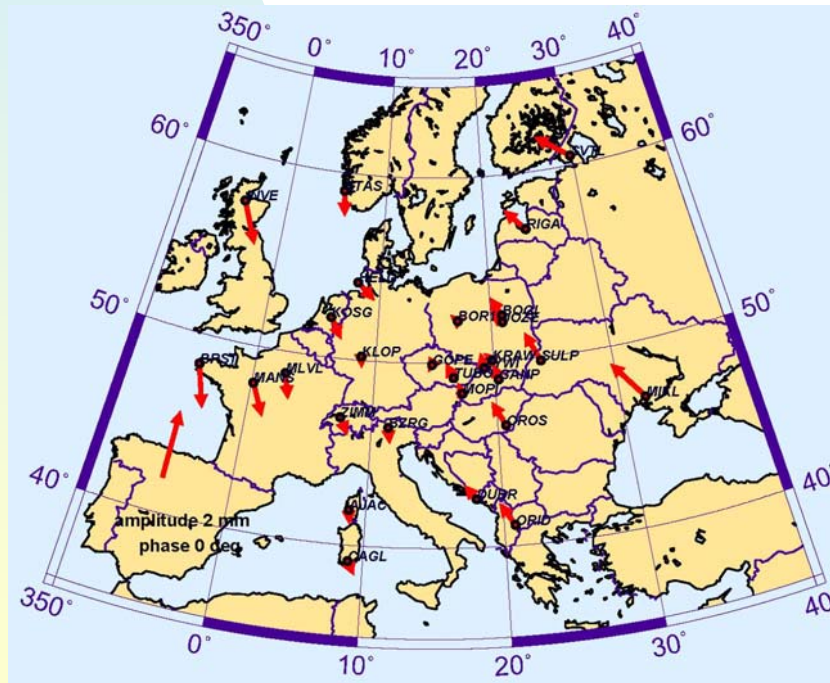
kgz



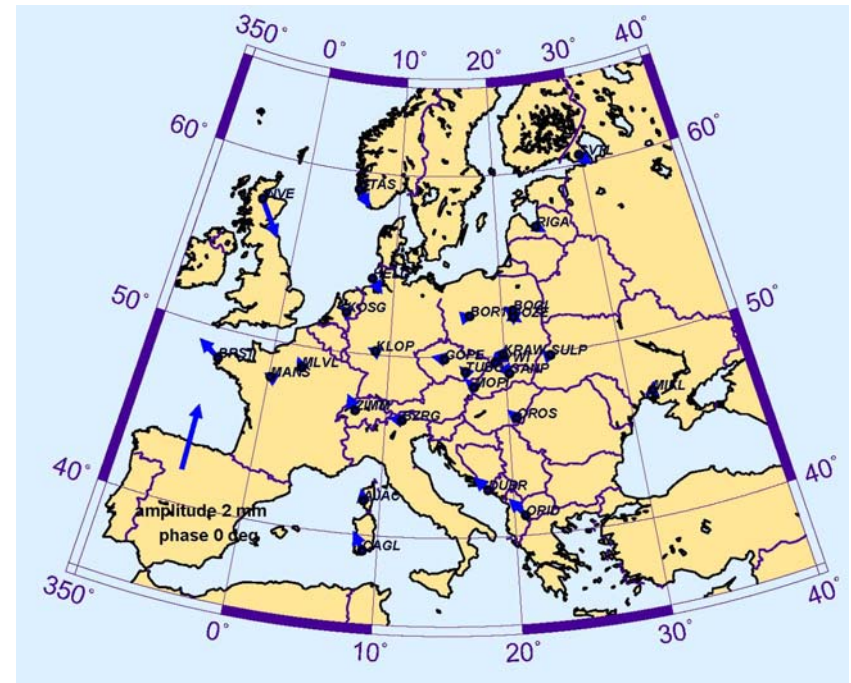
# Amplitudes and phases of horizontal variations with O1 frequency (period = 1.0758 day)

- Relatively small effect (less than 2 mm)
- Mostly affected are coastal stations

## North-south



## east-west

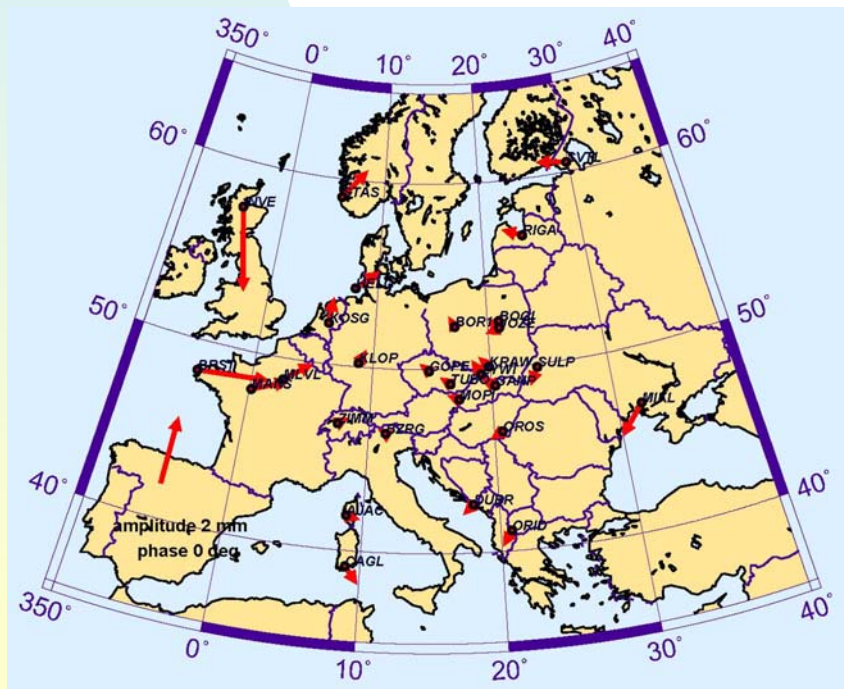


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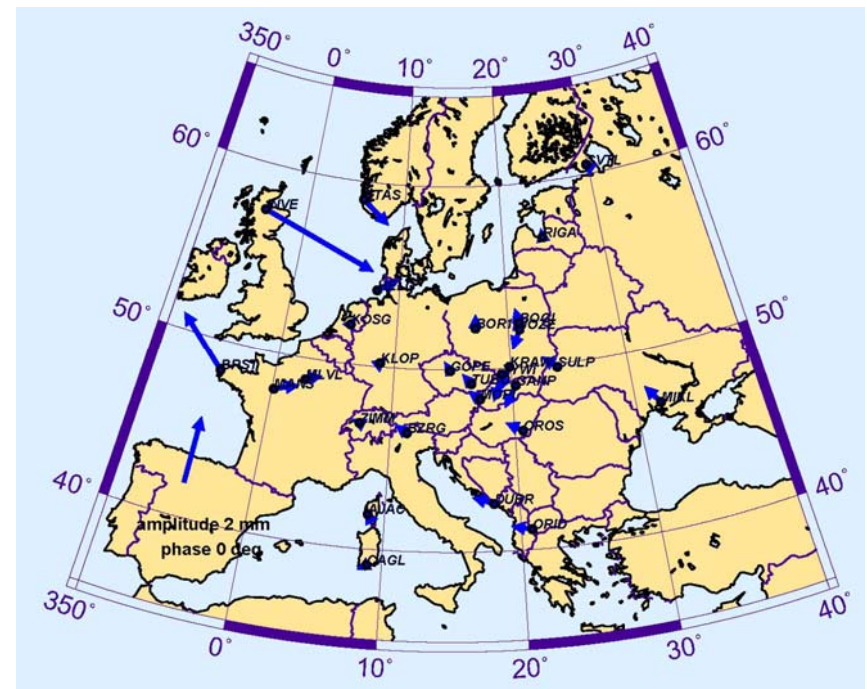
# Amplitudes and phases of horizontal variations with M2 frequency (period = 0.5176 day)

- Large effect (up to 4 mm), significant for some coastal stations (INVE, BRST)
- Observed variations have 50% amplitude of Scherneck ocean loading effect

North-south



east-west



kgz

# Conclusions related to diurnal and semi-diurnal variations

- The daily and subdaily variations with K1, K2, S1 and S2 frequencies are dominant (amplitudes 1-3 mm) for majority series both in horizontal coordinates and in height.
- The regional pattern of these variations, particularly the phase of detected variations point out that these variations are not characteristic for individual stations, but similar for close sites.
- The reliable explanation of these periodic effects in site coordinates is not given up to now, but very probably they do not reflect the real station position variation.
- The O1 and M2 variations indicate their correspondence with ocean loading displacement modelling.