Temporal Variations of EPN Coordinate Time Series from Sub-Daily DGPS Analysis

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Abstract

A GPS network of 36 sites consisting of sites of the German Reference Network (GREF) together with selected IGS and EUREF sites has been processed to establish homogeneous coordinate time series. In a first step the years 2001 and 2002 have been computed, in the meantime the time span 2000.0 – 2003.99 is at our disposal. Ocean loading signatures are observed with a significant signal-to-noise ratio at each site while not correcting for ocean loading. Using the GOT00.2 corrections a complete cancelling of the listed tides has been reached. Amplitudes and phases of annual period in the vertical component at different stations enables a grouping of sites into Mediterranean and East European clusters. This conclusion is confirmed by an annual period also in the horizontal displacements. The sites show different polarization and their phase differences suggest, together with the vertical displacements, a loading process with annual period.

Introduction

Besides many projects dealing with coordinate time series derived from GPS observations, e.g. in the EUREF community [Kenyeres et al. 2002], coordinate time series stemming from sub-daily processing were analyzed for this work. Details about the network consisting of 36 GNSS sites in Europe and the processing scheme are given in [Schwahn, Söhne 2003]. Bernese software version 4.2 was used to process the data in a four hours observation window with a two hours shift. IGS final orbits and EOPs were used. No ocean loading was applied in a first run. Within the final adjustment one site was constrained with ± 0.1 mm to ITRF2000 coordinates and velocities, but changes in fixing can easily be obtained using the Bernese program ADDNEQ [Hugentobler et al. 2001]. In this paper WTZR is used as the constrained station. Time spans of two years (2001.0 – 2002.99) or four years (2000.0 – 2003.99) form the basis of the analyses.

Fig. 1: GPS sites (IGS, EUREF, GREF) used for the processing

Ocean Loading displacements

Figures 2a, 2b and 3 show the semi-diurnal spectra for some sites of the processed network. Since in the first trial no ocean loading corrections were applied during the GPS analysis the ocean loading signatures preserve in the resulting coordinate time series. It can be seen that, due to the low noise level, the M2 signal (12.42 h) can be detected in almost every of the coordinate time series (figure 2a and upper part of figure 3).

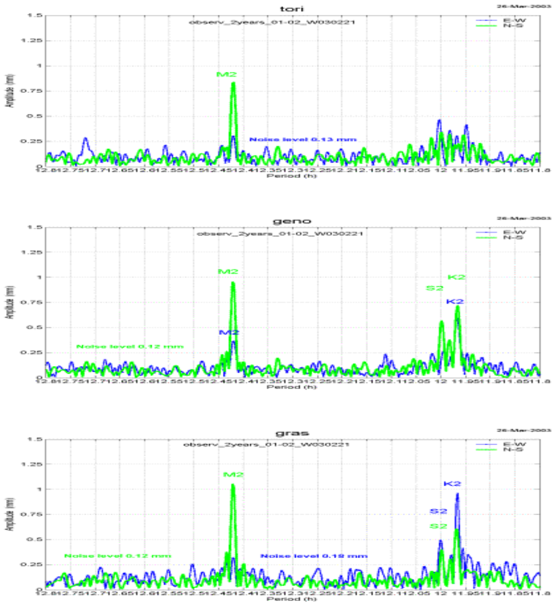


Fig. 2a: Spectra of the residuals in the semi-diurnal range for horizontal displacements for the sites at the Gulf of Genova w.r.t. WTZR (green north-south, blue east-west component) without ocean load correction; time span two years (2001.00–2002.99)

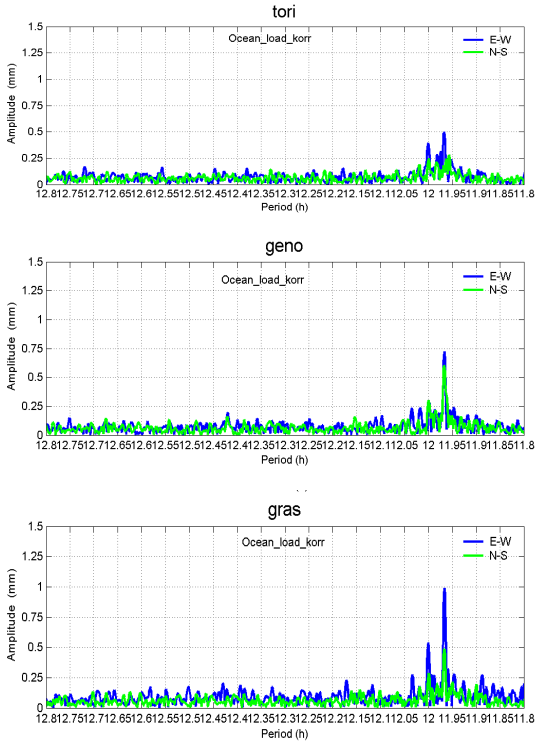


Fig. 2b: Spectra of the residuals in the semi-diurnal range for horizontal displacements for the sites at the Gulf of Genova

w.r.t. WTZR (green north-south, blue east-west component) with ocean load correction using the GOT00.2 model parameters; time span four years (2000.00–2003.99)

In a second run the ocean loading corrections were applied in Bernese software using the coefficients of ocean tide model GOT00.2 from website http://www.oso.chalmers.se/~loading by M.S. Bos and H.-G. Scherneck. The removal of the ocean load influences (see figures 2b and 3 (bottom)) is perfect for the waves M2 and S2 even for the sites nearby the Mediterranean sea, e.g. GENO. This marine area is not included in FES94.1 and its successor GOT00.2 (see http://www.oso.chalmers.se/~loading/emptyseas.gif).

The large amplitude for the K2 region (11.96 h) is probably due to the repetition of the satellite geometry and the station dependent conditions – compare the coherent M2 amplitude for TORI, GENO, GRAS (figure 2) versus the different ones in the K2 region. The longer time span used for figures 2b and 3 (bottom) yields to a considerably lower noise level.

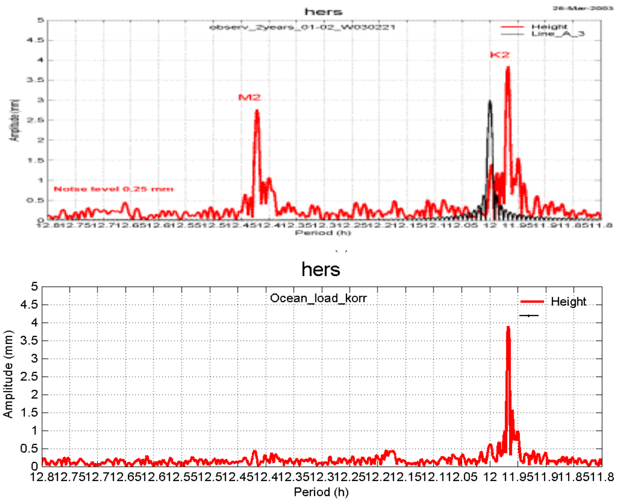


Fig. 3: Spectra of the residuals in the semi-diurnal range for vertical displacements (in red) w.r.t. WTZR for site HERS at the English Channel, in the upper part without, in the lower part with ocean load correction. The black curve is the benchmark spectrum for a line with A = 3 mm for the time span of two years.

Note for figure 3 the same conclusion concerning the station condition for K2 (in both figures the same amplitude!), but for ocean loading here additionally the N2 wave (12.658 h) has been removed significantly.

A detailed discussion about the ocean loading signatures in the height component is given in [Schwahn, Söhne 2003].

Annual component in vertical displacements

Figure 4 shows the residuals of the vertical component of the coordinate time series after removal of the mean and the linear trend for two sites: GRAS, located in the Mediterranean area and ZWEN, located in the continental area. The residuals were fitted by a function with annual term, with and without an additional semi-annual term. It can be seen that for GRAS the maximum is in the winter time and that there is a visible semi-annual component. On the other hand for ZWEN the maximum is in summer time with no significant semi-annual component.

These results are summarized for a number of sites in figure 5. The sites in the eastern part of Europe show more or less the same behaviour. The maximum values are during the summer. Some of the sites also show a small semi-annual constituent. The Mediterranean sites all have their maximum during the winter but the absolute values are much smaller. The semi-annual part is visible but very small.

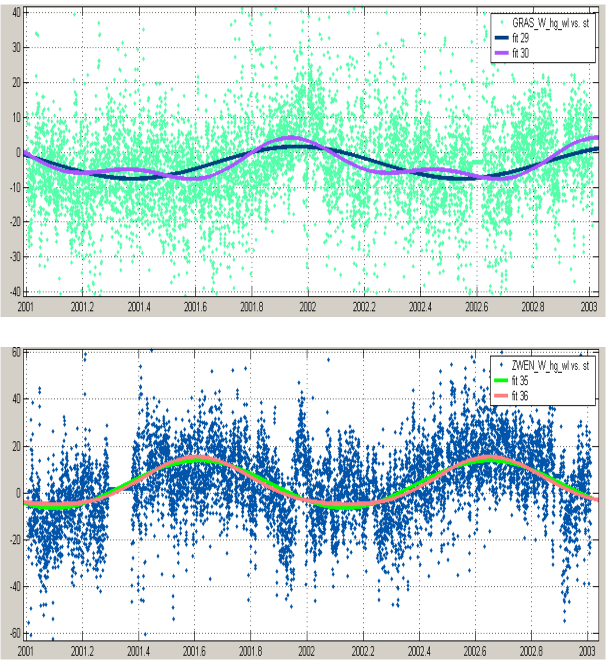


Fig. 4: Estimation of annual and semi-annual constituents in the up-component (in mm) for GRAS (top) and ZWEN (below) basing on two-hourly "readings". Mean and linear trend are eliminated. Note not only the different amplitude, but also the phase shift of approximately a half year.

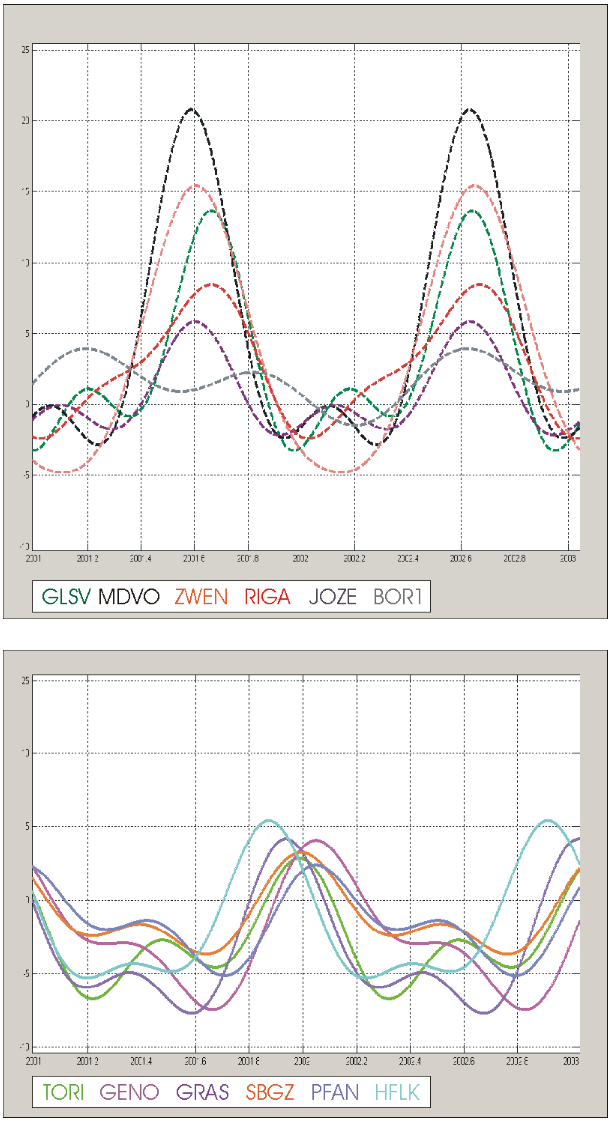


Fig. 5: Annual and semi-annual waves in the up-component (in mm) compiled for continental (top) and Mediterranean sites (below) for the years 2001 and 2002.

Annual component in horizontal displacements

A reliable vertical displacement should produce reliable horizontal strain in dependence of the distribution of the vertical movement. Concerning the annual periodicity it means that we must observe an annual term also in horizontal components and, in dependence of the location of the maximum vertical movement, different phases.

In figures 6, 7 and 8, basing on the 2-hourly “readings”, WTZR constrained, the weekly mean values without the linear trend (without “velocities”) are plotted for the horizontal EW- and NS- components in their temporal (vertical scale) resolution.

Figure 6 represents the variations for EUSK (a) and KARL (b), seen from (15, -15, i.e. from SE) at different heights above the EW-NS-plane. The perspective from “above” enables an insight (later on a numerical estimation) in the preferred direction (“polarization”) of the wave. We can observe a polarization in 30° NE / 210° SW in KARL, whereas EUSK has a circular pattern. This wave is an annual one which can be seen by moving the view point to a “slant” position: the maximum in the NE-direction in both time series is reached approximately at .25 each year, i.e. March/April. A synchronous behaviour can be stated.

The relations for three Mediterranean sites GENO, TORI and VENE are plotted in figure 7, additionally with a polar diagram (below). Here the different polarization for GENO and TORI at the one hand (weak in 60° NE / 240 SW) and for VENE on the other (strong elliptical in -35° SE / 125° NW) can be seen very clearly. The larger variations due to the elliptical polarization at VENE are visible in the picture on the central part of figure 7 in the “slant” (15,15)-perspective – this is from NE. Here for VENE (diamonds) the amplitudes to the right in 2001 and 2003 and left hand side in 2000.5 and 2003.5 exceed those for the other stations GENO and TORI (compare also with the picture from “above”). The phase relation in all the three stations is the same, because the temporal variation in NE–SW–direction is synchronous – look the „slant” perspective for (15,-15) (top). Even the comparison with sites EUSK and KARL yields the same temporal behaviour! These sites are situated in Western and SW Europe. If loading is acting in central continental areas, as the vertical displacements in figure 4 suggest, then a jump of 180° should be observable for sites at the opposite “border” of the loading area. This assumption can be confirmed, see figure 8. Here the variations in the horizontal components are plotted for RIGA at the northern Baltic Sea and GLSV nearby Kiev in the Ukraine. From the polar plot (below) and the “above” viewpoint picture (middle) a characteristic polarization can be derived: 45° (SW–NE) for RIGA and 0° (E-W) for GLSV. The temporal conformity can be seen in the 2nd picture. The optimal viewpoint for the estimation of the amplitudes at GLSV is a southern one. This amplitude yields 4-5 mm. Looking for the phases, the picture on the top of figure 8 represents the same temporal variations for both the stations, but, with respect to the sites KARL, EUSK, GENO, TORI, VENE (see figures 6a, 6b and 7) an opposite sign. Compare, for instance, at 2001.25: RIGA shows a diminished latitude, all the sites in Western Europe an increasing latitude. This hints to a contraction of the surface in the region between these two clusters of sites. The opposite behaviour, for instance at 2002.8 an increase in latitude in RIGA and GLSV and a decrease for the others, means a blowing up of central regions. E.g. a vertical increase as in figure 4 has been demonstrated for this time interval. Keep in mind that the displacements, vertical as well horizontal, are relative to WTZR.

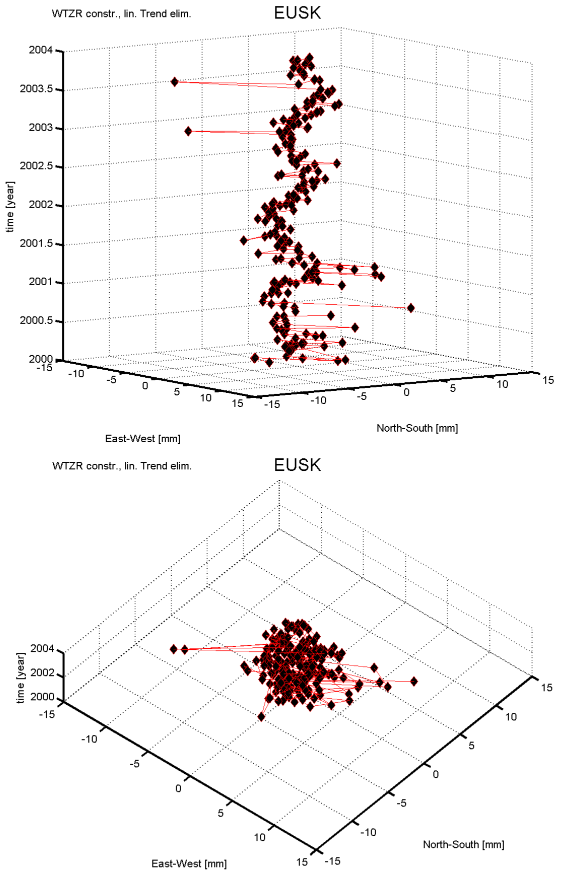


Fig. 6a: Distribution of horizontal positions for site EUSK seen from south-east viewpoint: from “above”(below) and a slant view

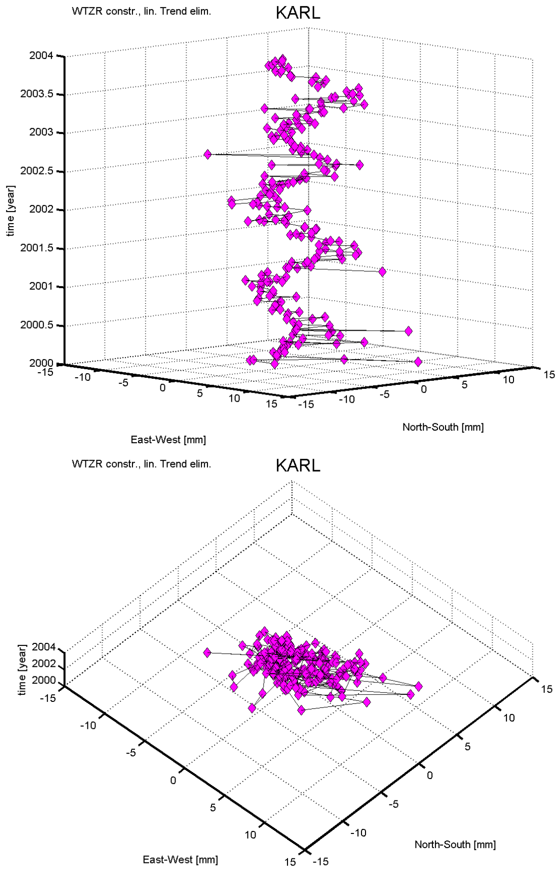
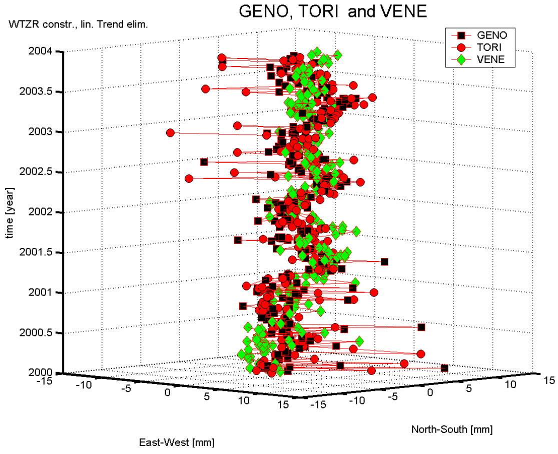
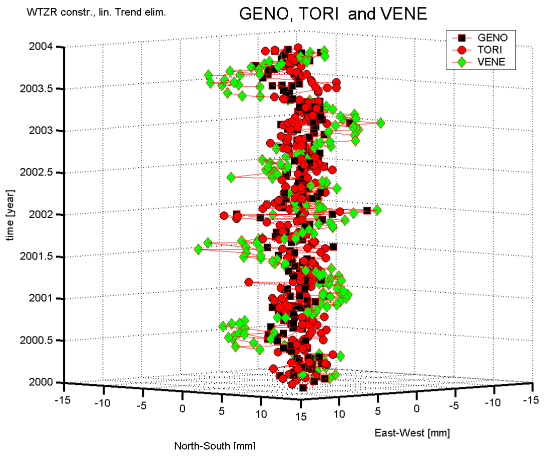
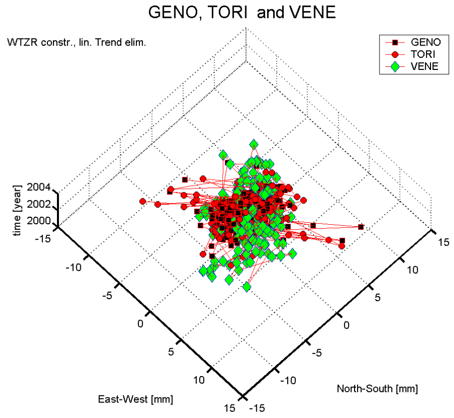


Fig. 6b: Distribution of horizontal positions for site KARL seen from south-east viewpoint: from “above”(below) and a slant view







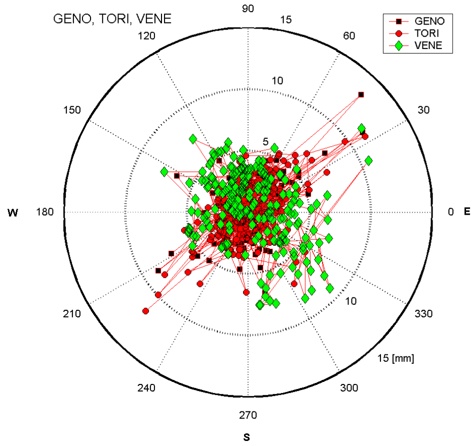
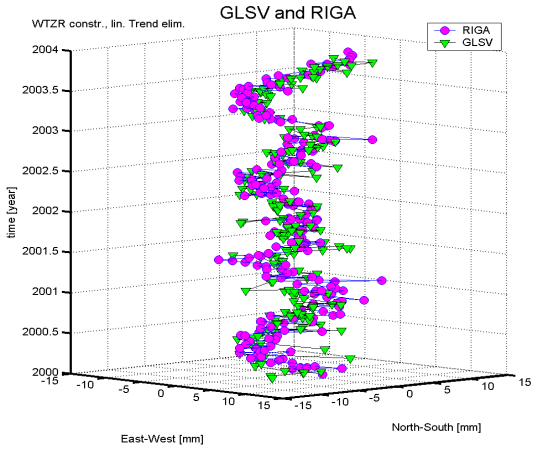
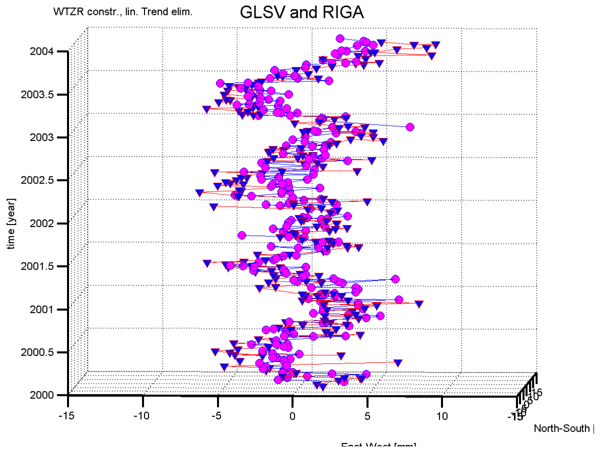
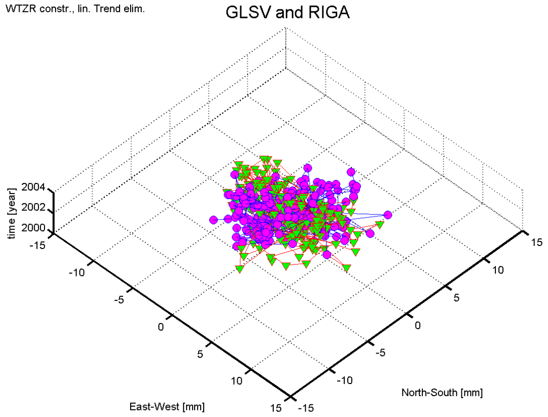


Fig. 7: Distribution of horizontal positions for sites GENO, TORI and VENE
Two upper plots show the 3D-distribution of the time-varying horizontal positions seen from south-east (up) and north-east (2nd) viewpoint. 3rd plot shows a 3D-slant view from south-east. 4th plot is a pure 2D polar diagram "condensing" the temporal perspective to underline a possible polarization, observable for VENE (diamonds)







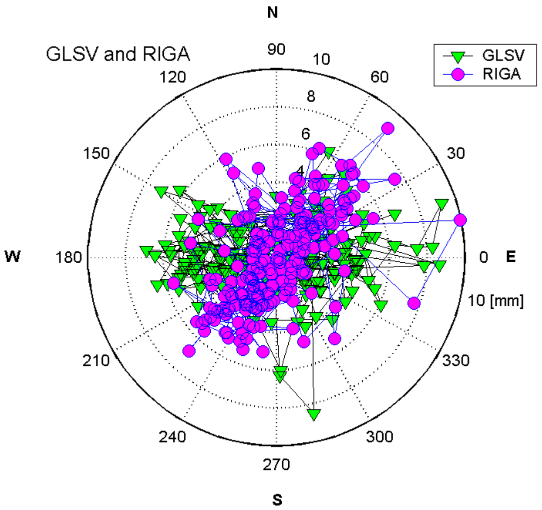


Fig. 8: Distribution of horizontal positions for sites GLSV and RIGA
Uppermost plot shows 3D-time-varying horizontal positions seen from south-east viewpoint comparable with those for the other sites. 2nd plot shows a slant view from south demonstrating the larger variations in E-W-direction for GLSV (triangles). The polar diagram (bottom) demonstrates the nearly linear polarization for GLSV in E-W-direction, for RIGA in NE-SW-direction.

Conclusions

The annual term is existing in all three components of site displacements besides the small amplitude (3 to 5 mm) in the horizontal component. A reasonable picture yields regarding the latitude and longitude variations as components of a station displacement vector. The spatial distribution of their amplitudes and phases suggests an upraising surface in Middle and Eastern Europe due to load deficit in summer time and a load surplus in winter time.

References

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