Biases in the estimated ZTD related to elevation cutoff angle

Military University of Technology

How to find the optimal minimum elevation angle for climate studies, when its affect differently the ZTDs at different stations ?

This work was supported by statutory founds at the Institute of Geodesy, Faculty of Civil Engineering and Geodesy, Military University of Technology (No. PBS/23-933/2016)

Andrzej Araszkiewicz
Zofia Bałdysz
Grzegorz Nykiel

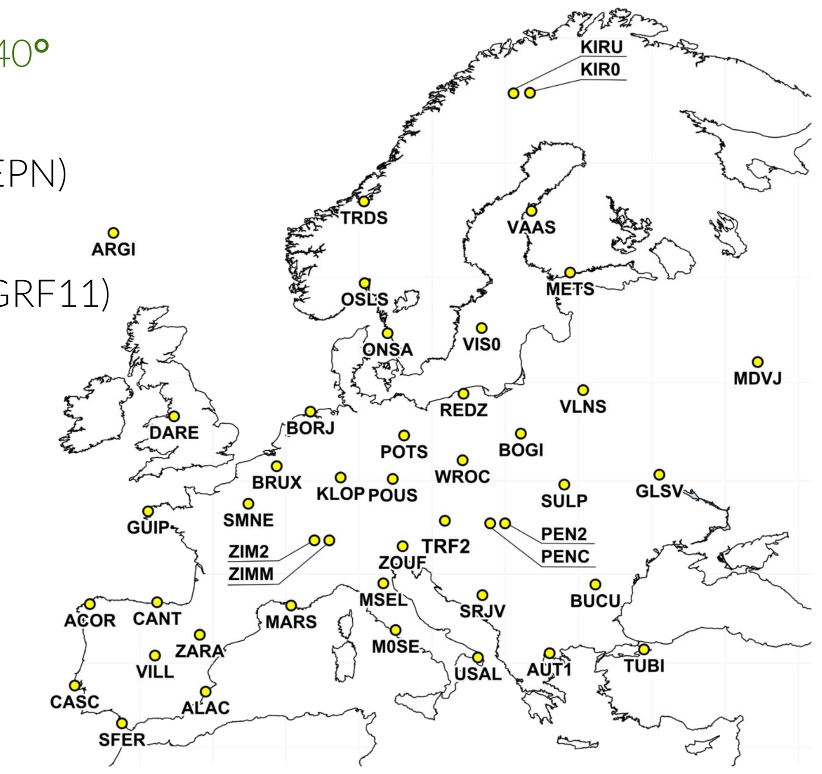
Introduction

For the GPS observations it is well known that observations at a very low elevation angle are more erroneous due to the signal propagation effects (e.g. atmospheric delay, multipath or antenna phase centre variations) than rest of them. From the other hand Davis (1986) showed that higher cutoff elevation angle results in greater uncertainty in estimated height and higher correlation between estimated height and zenith tropospheric delay (ZTD). Consequently, for many years scientists were focused on reducing modelling errors at low elevation angles to break this correlation and decrease the uncertainty of the estimated parameters. Progress in this filed led to the situation that nowadays rather low elevation masks are used in the routine processing. However, Elgered et al. (2012) showed that for climate studies GPS observations cutted above 25° give us better compatibility with the radiosonde data.

Method

To better understand how exactly the adopted cutoff angle affects the estimated tropospheric delay, we compared ZTD annual time series (for the year 2015) estimated for 45 EPN stations with using different cutoff elevation angle: from 0 to 40°, every 5°. Except this, all the rest parameters of GPS data processing remained unchanged and were identical to our contribution to EPN repro2. ZTD time series obtained from solution with adopted minimum elevation mask (0°) was taken as reference. Next, the remaining eight ZTD data sets were compared to it.

Software:	GAMIT 10.50
Period:	01.01.2015 - 31.12.2015 (1 year)
Observations:	GPS, 30 sec.
Elevation mask:	0°, 5°, 10°, 15°, 20°, 25°, 30°, 35°, 40°
Orbits:	CODE
Antennas:	type mean (igs08_1880.atx) + ind. (EPN)
Troposphere:	VMF1, ZTD(1h) + grad (24h)
Ionosphere:	„iono-free" + HOI (CODE VTEC + IGRF11)
EOP:	IERS2010
Tides:	IERS2010
Loadings:	ocean (FES2004), atmosphere (NCEP + ECMWF)
Reference frame:	IGb08



Results

No doubt various minimum elevation angle affect the estimated ZTDs as well as their formal error. In general, the higher minimum elevation angle the higher formal error. However, formal error is not the best factor of reliability of the estimated ZTD. In general, it grows together with the decreasing number of observations and it can be helpful to evaluate the quality of estimated ZTD in the same solution (no to compare them).

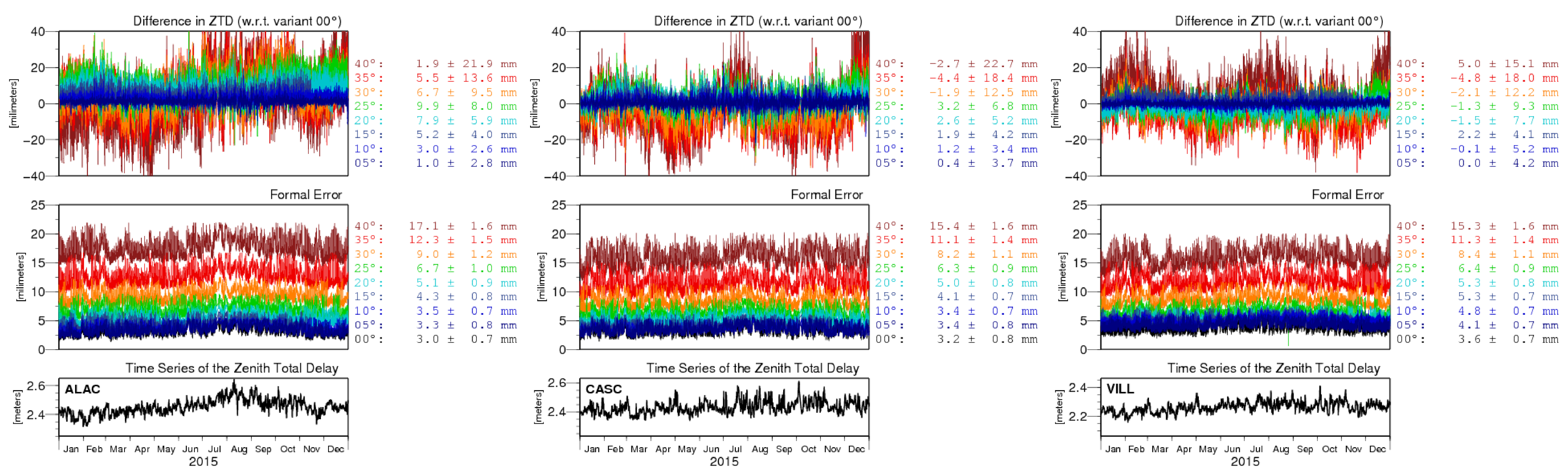


Fig. 1. Example results for three selected stations. Top box shows differences between estimated ZTD from each of eight solutions and estimated ZTD from solution „00°". Middle box shows cleaned formal error for each of nine solutions. Bottom box shows estimated ZTD from solution „00°". Each solution plotted with a different color. Numbers correspond to the mean values of the differences (or formal error) with the RMS of respectively parameter.

What is worth noting, changes between solutions in the estimated ZTD are high correlated (negative correlation) with the changes in the estimated height (**Fig. 2, Fig. 3**). It probably means that changes in the estimated height are somehow compensated by the ZTD estimates. It can be assumed that ZTD time series derived from solutions for which higher elevation mask was applied, are flawed by the higher uncertainty of the estimated height.

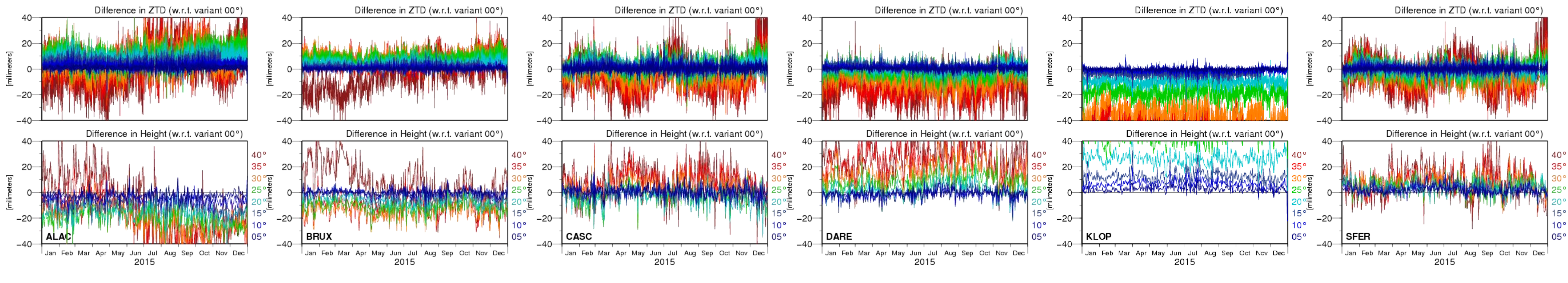


Fig. 2. Comparison of the differences in ZTD and Height estimates. High negative correlation is clearly visible (e.g. Pearson's linear correlation coefficient for variant 30° for station CASC is **-0.54**). Note that ZTD and vertical component were estimated in the same processing stage.

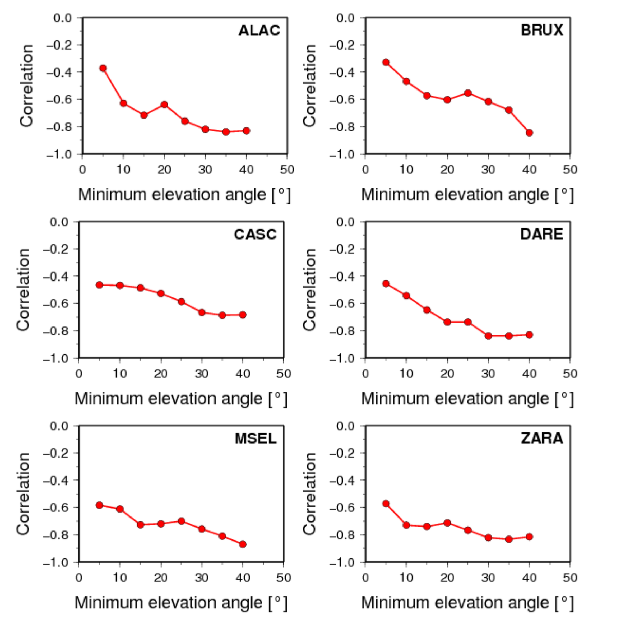


Fig. 3. Pearson's linear correlation coefficient between estimated differences in ZTD and Height for analysed variants.

Changes in ZTD, resulted from increasing the cutoff angle, are different for individual stations (**Fig. 2**). In some cases, it cause large and systematic differences (e.g. KLOP), other the seasonal (semiannual ?) oscillations (e.g. CASC, SFER) or even linear trends (e.g. BRUX). Almost no correlation between obtained biases and location of the stations shows that they are not latitude-dependent effects. At least it is not the key factor. The reason must lie elsewhere and it is more locally.

Three cases of close stations (KIR0/KIRU, POT2/POTS, ZIM2/ZIMM – **Fig.4**) show that beside **site-dependent biases** (related to the weather condition or direct impact of observation geometry, that in general are identical at the same site), there appear also **station-dependent biases** (related to the specific signal propagation at each stations).

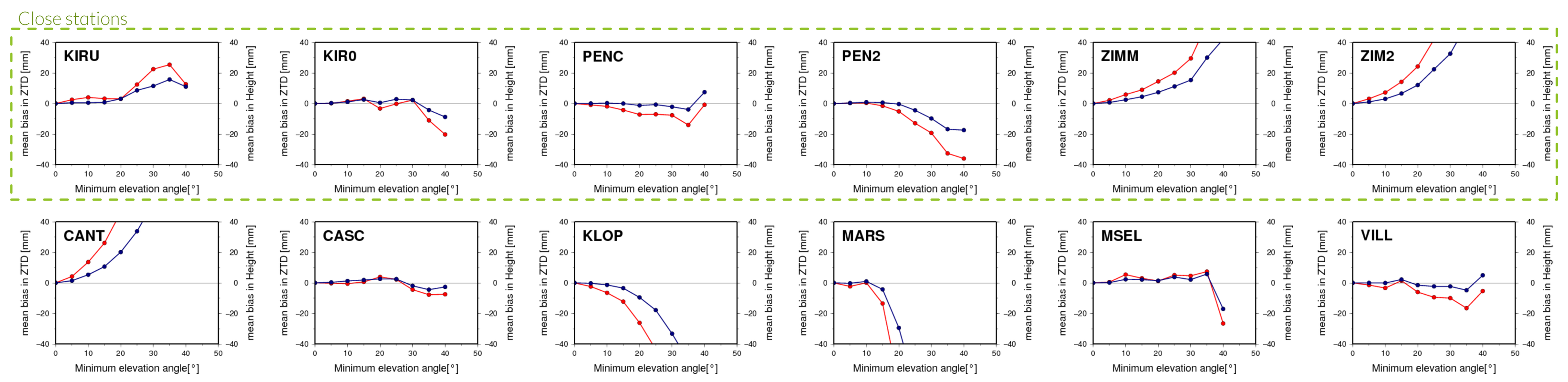


Fig. 4. Mean biases in ZTD (navyblue) and height (red) as a function of applied minimum elevation angle.

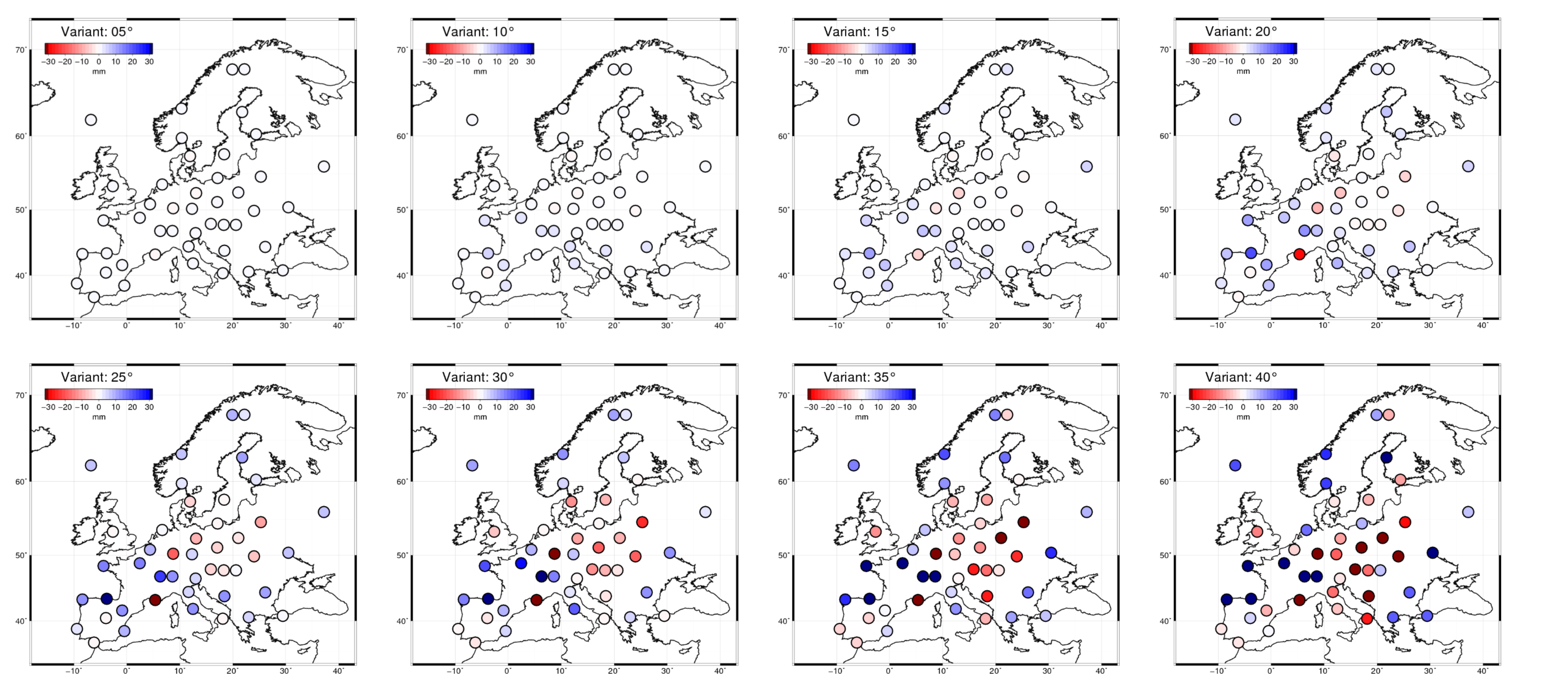


Fig. 5. Mean differences (biases) of the estimated ZTD between each of eight solutions and estimated ZTD from solution „00°". Brown and navyblue dots correspond to biases, that exceeded the range of used colorscale limits (-30 mm to 30 mm).

To investigate how the signal propagation is „mismodelled" we analysed the post-fit phase residuals (**Fig.6**). All effects related to the signal scattering, like antenna phase centre modelling, multipath effect or atmospheric delay should be reflected here. What is already shown by others (e.g. Elosequi et al., 1995) strong multipath can cause regular change in height (also in ZTD) when one increases the minimum elevation angle of observation. This kind of propagation effect is usually visible in post-fit residuals below 20° elevation angle and should be repetitive from day to day (e.g. KIRU, KLOP, MSEL, PENC, VILL). For selected stations, when mostly this phenomena is visible, the bias in height and ZTD for solution „10°" (MSEL, VILL – **Fig.4**) can be noticed clearly. However, the highest biases appeared together with the higher fluctuation of the post-fit residuals in the whole range (MARS – inappropriate antenna PCC ?) or in high elevation angle (CANT). As it was noticed also for few Nordic stations, higher biases (together with the higher post-fit residuals) appear also during winter (VAAS – **Fig.7**).

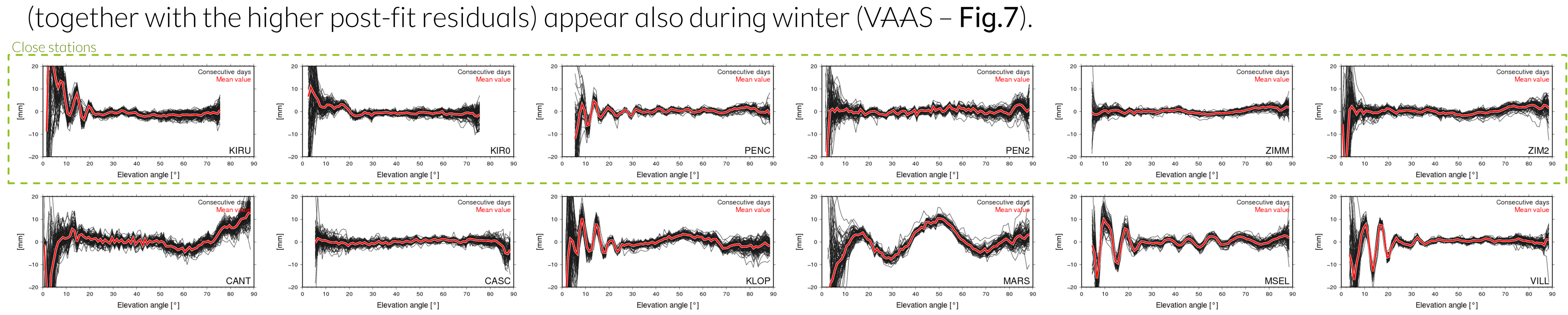


Fig. 6. Post-fit phase residuals versus elevation angle for 100 consecutive days (14.08.2015 – 31.12.2015).

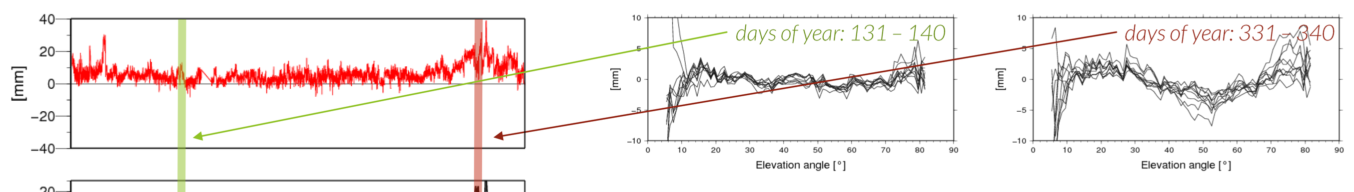


Fig. 7. Above: Post-fit phase residuals vs elevation angle for selected 10 consecutive days. On the left: Differences between ZTD from solutions „20°" and „0°" (red), height changes from sol. „0°"

Summary

Switching elevation mask from 0 to 40 degree caused changes in estimated value of ZTD. These changes were, however, various for various stations and there were no significant latitude dependency between them. For some of stations, applying higher cutoff angle elevation caused increasing of ZTD value and for the other ones it caused decreasing. Despite the character of these biases (positive or negative) they appeared together with the changes in estimated Height. Negative correlation proves that these biases are rather artificial effects related to increasing uncertainty of estimated Height than real improvements. Additionally, performed analysis of tween stations showed, that despite local weather conditions and related to them atmosphere modelling, also other factors have to had influence on character and size of estimated biases.

contact: andrzej.araszkiewicz@wat.edu.pl

EUREF Symposium 2016
May 25-57, 2016
San Sebastian, Spain