An Assessment of Radome Effects on Height Estimates in the EUREF Network

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Abstract

The antennas of GPS reference stations are often covered by radar domes to prevent damaging, wear and soiling. This holds also for a number of EUREF permanent stations. Unfortunately, these antenna covers affect the position estimates, in particular the vertical component. As long as the antenna setup configuration is not changed no discontinuity in the time series will occur, but the estimates will not refer to the physical antenna reference point.

At a number of EUREF sites a radome has been mounted or dismounted during the operational phase presumably leading to discontinuities in the time series of height estimates. In order to quantitatively assess the effects, we have performed dedicated processing of data series centered at the radome change epoch. The analysis is based on the assumption that neither the station height nor the environmental effects will change during the relatively short periods of less than four weeks. The height errors caused by radomes may reach several centimetres, they depend not only on the radome type but also on the elevation angle cutoff. The precision of the estimated effects is better than one millimeter.

1. Introduction

The repeatabilities of daily position estimates achieved with the Global Positioning System (GPS) are presently in the order of a few millimeters for the horizontal components and better than one centimeter for the ellipsoidal heights. However, an important concern is to distinguish between repeatability or precision on the one hand and accuracy on the other hand. As regards GPS, in particular the determination of the vertical position component may be affected by various error sources among them the tropospheric refraction modeling. A review of the capability of GPS for determining heights has recently been compiled by ROTHACHER (2002). There are also a number of antenna and site specific errors a discussion of which can be found in (JOHANSSON 1998). Investigations by ELÓSEGUI et al. (1995) and JALDEHAG et al. (1996a) show that individual elevation dependent phase errors due to multipath or signal scattering may occur even for identical antenna types. An analysis of data from the Swedish permanent GPS network indicated that also snow accumulation on the antenna may cause errors in the height estimates of some centimeters (JALDEHAG et al. 1996b).

An additional error source leading to elevation dependent phase errors and thus to height errors are radomes (radar domes) mounted in particular on permanent antennas to prevent damaging, wear and soiling. Extensive tests on very short baselines operating the antennas alternately with and without radome were performed by BRAUN et al. (1997). The conclusion of these tests was that the magnitude of the error depends on the type of the antenna and of the radome, the applied elevation angle cutoff and the thickness of the cover. When estimating also troposphere parameters, height errors of up to four centimeters occurred. Similar experiments were performed at the space geodetic observatory Wettzell (Germany). Complementing these local measurements with observations from several European permanent stations enabled to establish dedicated regional network scenarios. The results confirm that antenna radomes cause only some millimeters errors in local networks, but up to several centimeters height errors as soon as local troposphere modeling is to be performed in regional networks (KANIUTH and STUBER 1999, 2002).

In general, height estimates of GPS antennas equipped with a radome will not refer to the physical antenna reference point. Fortunately, the resulting error will cancel in all applications as long as the antenna configuration is not changed. However, any change such as mounting or dismounting a radome is likely leading to a discontinuity in the series of height estimates. Thus, a careful monitoring of such discontinuities is required to preserve the function as a reference station. In the course of the EUREF permanent network operation several radome setups and dismountings occurred. Therefore, this analysis tries to quantitatively assess the resulting height effects for a number of these sites.

2. Analysed Radome Configurations

It is obvious that such scenarios as established in our previous analyses (KANIUTH and STUBER 1999, 2002) were not feasible in case of the operational EUREF network. Therefore, we reviewed all EUREF site logs for identifying those sites where antenna radome changes occurred in the past. Among these are several sites where the mounting or dismounting of the radome, in a few cases accompanied by an antenna change, caused only very short tracking interruptions, thus still providing a continuous time series of daily data files. From these sites we selected those where the observations are readily available, but considering also the completeness of the data and the types of antennas and radomes involved.

Processing a sufficient number of days immediately before and after the radome change should then allow to precisely

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determine the effect on the height estimates. The analysed constellations as well as the processed data periods are listed in table 1. The antenna and radome naming is according to the International GPS Service (IGS) conventions. The sites involved are Bolzano/Italy (BZRG), Euskirchen/ Germany (EUSK), Pecny/Czech Republic (GOPE), Hohenbünstorf/Germany (HOBU), Karlsruhe/Germany (KARL), Kloppenheim / Germany (KLOP), Lamkowko / Poland (LAMA), Onsala/Sweden (ONSA) and Tromsø/Norway (TRO1).

3. Processing Strategy

We used the Bernese software version 4.2 (BEUTLER et al. 2000) for the data analysis. As the Bernese processes double differences we had to include at least one further station for each of the sites and periods listed in table 1. We selected for each constellation two or three surrounding EUREF stations. The selection criteria for these reference stations were the distances between the sites, the type of the antenna in operation and the performance in terms of data completeness. A further requirement was that these fiducials themselves were not subject to any modifications during the analysed periods.

For each configuration common adjustments of all days of data and including both radome constellations were performed. The reference frame was realized by tightly constraining the fiducial stations to their epoch positions in the International Terrestrial Reference Frame 2000 (ITRF 2000). Consequently, all estimated heights are closely related to ITRF 2000, and the resulting differences due to radome changes are independent of the reference frame realization.

Table 1: Analysed antenna radome configurations, station ID and processed periods in days of year

Station	Period	Involved Radome(s)	Antenna Radome Configuration Change				
BZRG	2000, 324–344	LEIC/LEIS	LEIAT 503	LEIC	→	LEIAT504	LEIS
EUSK	2001, 117–141	DOME	TRM22020.00 + GP	DOME	→	TRM29659.00	
GOPE	2000, 196–216	SNOW	ASH701073	SNOW	→	TRM14532.00	
	2000, 268–288	SNOW	TRM14532.00		→	ASH701946.22	SNOW
HOBU	2000, 095–125	SNOW	TRM23903.00		→	TRM29659.00	SNOW
KARL	2001, 117–141	DOME	TRM22020.00 + GP	DOME	→	TRM29659.00	
KLOP	2001, 117–141	DOME	TRM22020.00 + GP	DOME	→	TRM29659.00	
LAMA	2000, 266–294	SNOW	AOAD / M_T		→	ASH700936F_C	SNOW
ONSA	1999, 022–043	DUTD/OSOD	AOAD / M_B	DUTD	→	AOAD / M_B	OSOD
TRO1	1998, 343–005	SNOW	AOAD / M_T		→	ASH701073_1	SNOW

The main settings for and characteristics of all performed adjustments can be summarised as follows:

- Modeling of the antenna phase center variations according to the IGS recommendations;
- No elevation dependent weighting applied to fully exploit the low elevation observations;
- Tropospheric delay prediction using the SAASTAMOINEN (1973) zenith delay model and the NIELL (1996) mapping function, residual delays estimated for each two hours interval.
- No troposphere gradients estimated because of the relatively small network extensions;
- Adjustment elevation angle cutoff varied from 10° to 20° in steps of 1°.

4. Results

The solution strategy outlined in the previous chapter yields height estimates for the investigated antenna in both constellations with and without radome in the same reference frame. Thus, any significant differences between the resulting heights as well as variations in the elevation angle cutoff dependence can be assigned to the radomes, provided the following assumptions hold for the processed time periods:

- There occur no changes in the antenna environment affecting the height estimates, such as multipath;
- The relative vertical movements between the fiducials and the radome station can be neglected;
- The radome site is not exposed to any local effects causing real vertical displacements.

In the sequel we present the obtained results for most of the analysed sites. The figures 1 and 2 display the height estimates for BZRG and ONSA. Both stations have in common that one radome type has been replaced by another. At BZRG the apparent height variation due to the replacement of the conical LEIC by the spherical LEIS radome is 10 mm from an adjustment with a 10° cutoff angle setting. This offset increases by more than 3 mm per degree cutoff angle rise, mainly due to a strong dependence of the LEIC results on the elevation angle. However, at BZRG also the choke ring antenna has been changed from LEIAT503 to LEIAT 504. The replacement of the DUTD by the OSOD radome at ONSA yields about 14 mm offset between the height estimates, and both configurations show almost no elevation cutoff angle dependence. It should be noted, that we have no information on whether or not the radomes at

ONSA were covered by snow during the analysed period.

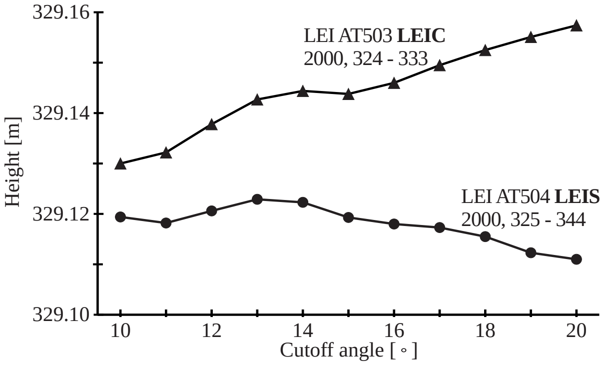

Fig. 1: Height estimates of BZRG for the LEIAT503 LEIC and LEIAT504 LEIS antenna/radome configurations in dependence on the elevation angle cutoff

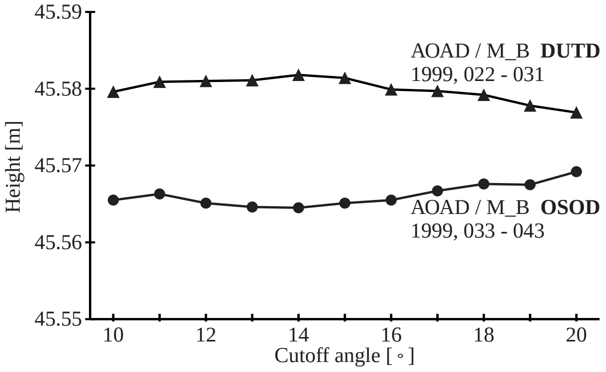

Fig.2: Height estimates of ONSA for the AOAD/M_B DUTD and AOAD/M_B OSOD antenna/radome configurations in dependence on the elevation angle cutoff

Due to the correlations between zenith troposphere and station height parameters, large variations of height estimates as a consequence of changing the elevation angle cutoff might be absorbed by the estimated tropospheric zenith delays. In order to verify to which extent this holds, we display in figures 3 and 4 the total zenith delays resulting for BZRG during each ten days of processing. The time resolution of these estimates is two hours. The figures show the results from adjustments with elevation angle cutoff settings of 10° and 20° respectively for both the LEIAT503 LEIC (figure 3) and the LEIAT504 LEIS (figure 4) antenna-radome configurations.

As the Bernese software processes double differences and as the distances between the fiducial sites and BZRG are only a few hundred kilometers, the estimated zenith delays cannot be considered absolute values. Therefore, it is not worthwhile at all to analyse the time series. However, it makes sense to look at systematic differences between the 10° and 20° solutions. In case of the LEIC radome attached to the LEIAT503 antenna there appears a highly significant bias of 14.7 ± 1.5 mm between both series. On the other hand, the offset for the LEIS radome on the LEIAT504 antenna is only 2.6 ± 0.6 mm. These numbers clearly indicate that the large height estimate variations associated with the LEIC radome in dependence on the cutoff angle are indeed reflected in the tropospheric zenith delays.

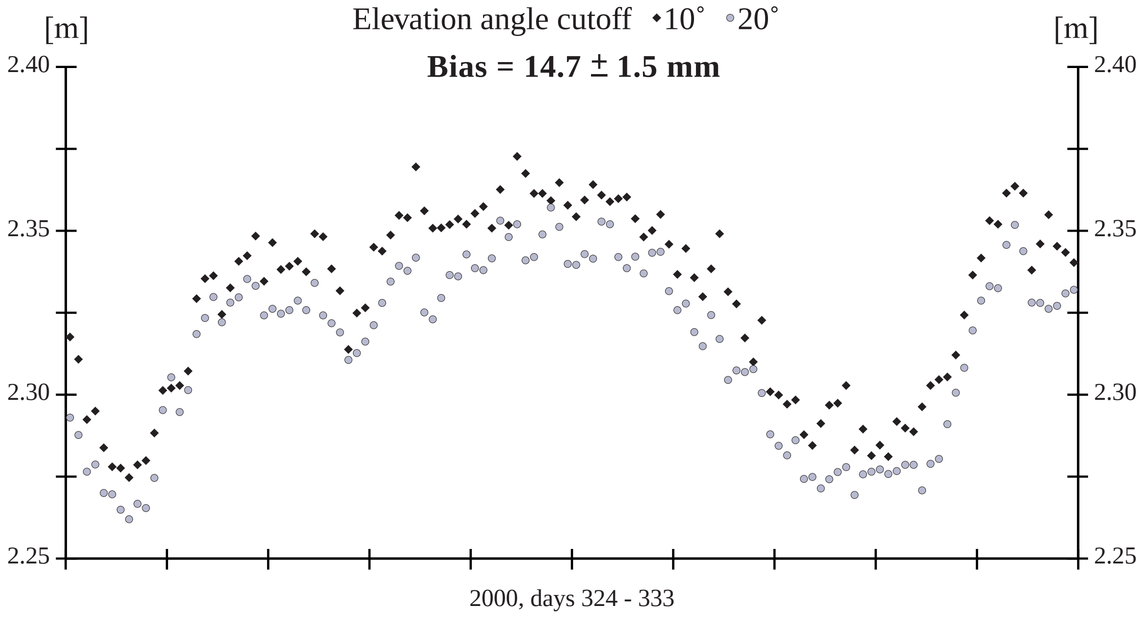

Fig. 3: Total tropospheric zenith delay estimates at BZRG LEIAT 503 LEIC for 10° and 20° elevation angle cutoff adjustments

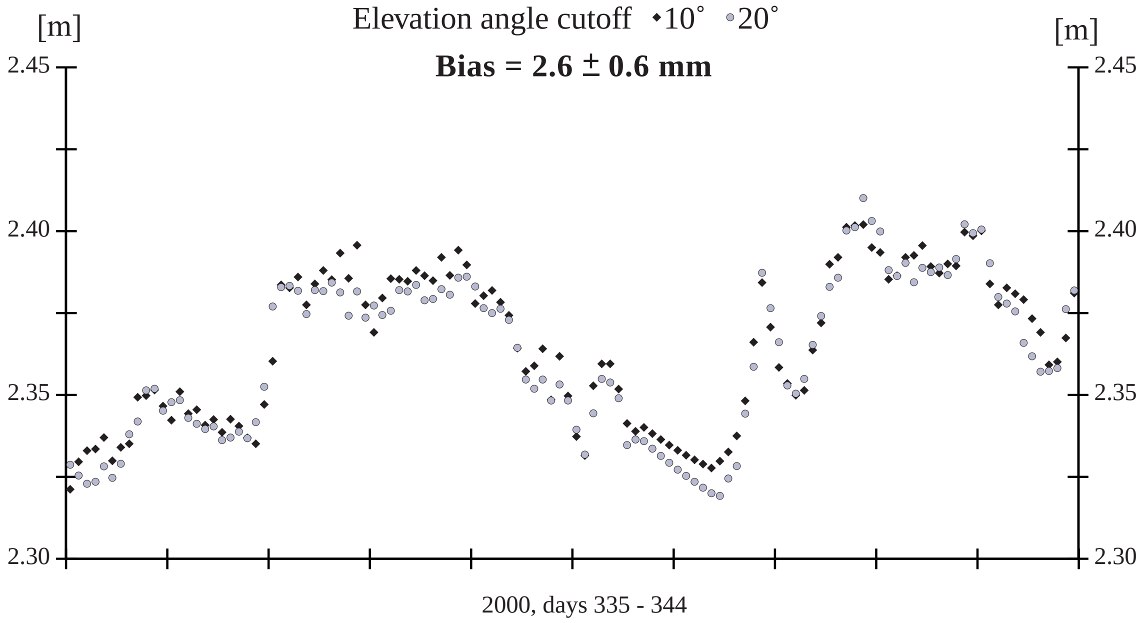

Fig. 4: Total tropospheric zenith delay estimates at BZRG LEIAT 504 LEIS for 10° and 20° elevation angle cutoff adjustments

Examples illustrating the effect of the Trimble radome DOME on the height estimates are given in figures 5, 6 and 7. All three stations EUSK, KARL and KLOP were equipped with the TRM22020.00 + GP antennas with radome which have then been replaced by TRM29659.00 choke ring antennas without radome. The height offsets between the two configurations from 10° cutoff angle adjustments are 27, 26 and 11 mm respectively with standard deviations of less than one mm. All three figures demonstrate in accordance with each other the large elevation angle dependence of the TRM 22020.00 + GP DOME configuration amounting to 2.5 mm height variation per degree cutoff angle change. This effect might not be exclusively caused by the DOME, the additional ground plane attached for fixing the radome might also contribute by creating multipath effects. The examples demonstrate agreement to a great extent but suggest also some superpositions by local effects.

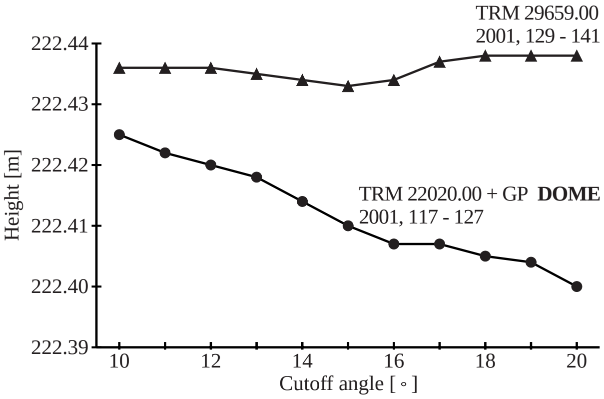

Fig. 7: Height estimates of KLOP for the TRM 29659.00 NONE and TRM22020.00 + GP DOME antenna/radome configurations in dependence on the elevation angle cutoff

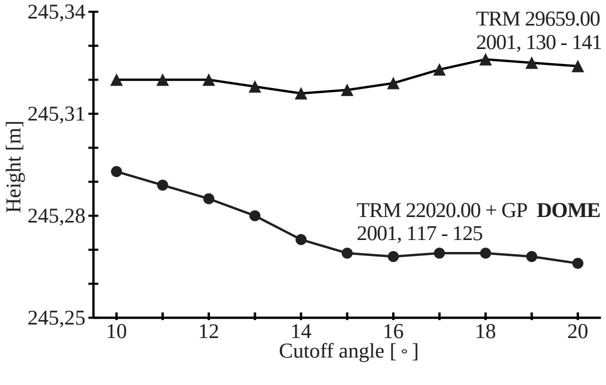

Fig. 5: Height estimates of EUSK for the TRM 29659.00 NONE and TRM22020.00 + GP DOME antenna/radome configurations in dependence on the elevation angle cutoff

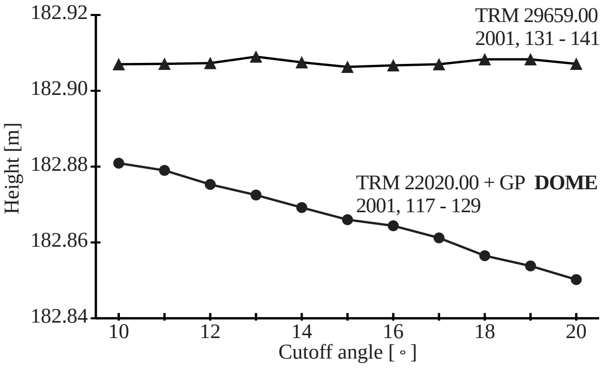

Fig. 6: Height estimates of KARL for the TRM 29659.00 NONE and TRM22020.00 + GP DOME antenna/radome configurations in dependence on the elevation angle cutoff

The figures 8 and 9 show two examples demonstrating the impact of the conical Ashtech radome SNOW, namely at the stations GOPE and LAMA.

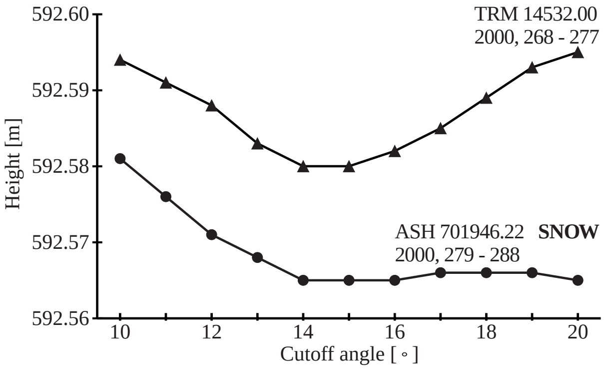

Fig. 8: Height estimates of GOPE for the TRM 14532.00 NONE and ASH 701946.22 SNOW antenna/radome configurations in dependence on the elevation angle cutoff

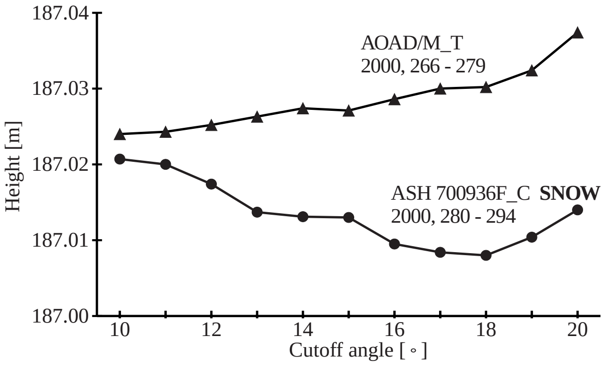

Fig. 9: Height estimates of LAMA for the AOAD/M_T NONE and ASH700936F_C SNOW antenna/radome configurations in dependence on the elevation angle cutoff

The results do not agree as nicely as in the case of the Trimble radome. This holds also for the two other sites not displayed here.

As regards GOPE, the reason may be a somehow worse tracking during both processed periods compared e.g. to the fiducial sites. In the case of LAMA the AOAD/M_T antenna without radome has been replaced by an ASH700936F_C SNOW because of its very poor performance leading to a high loss of observations. Anyhow, also the SNOW examples show the systematic effect that antennas with radome lead to lower height estimates than antennas without. The dependence on the elevation angle cutoff agrees in sign with the conical Trimble radome, but the rate is smaller with about 1.0 to 1.5 mm per degree cutoff angle variation.

5. Conclusions

The performed analyses aimed at quantitatively assessing the impact of antenna radomes on height estimates for a number of EUREF stations. The results can be summarised as follows:

- The analysis is based on the assumptions that during the processed periods of a few weeks each neither the station height itself nor the environmental effects change. The results are also not sensitive to the reference frame realisation. Therefore, the estimated height variations can be assigned to the antenna radomes.
- In general, radomes yield a lowering of the height estimates compared to antenna setups without radome. This holds for all analysed sites. The apparent height change between the two configurations depends mainly on the radome type but to a certain extent also on the local environment. In case of a 10° cutoff angle solution the biases range from some mm to almost three cm.
- Compared to setups without radome, at least conical antenna radomes tend to further affect the height estimates in dependence on the elevation angle cutoff. The rates differ, but extreme values of as much as three mm per degree cutoff angle variation occur.
- As regards the EUREF permanent network, analyses of time series of height estimates may primarily suffer from the different elevation angle cutoff settings applied in the past by the analysis centers. Moreover, comparisons with heights resulting from other techniques should consider that height estimates of GPS antennas covered by radomes do not refer to the physical antenna reference point.

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