Ground Survey and Local Ties at the Geodetic Observatory Wettzell

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ABSTRACT

The geodetic space techniques VLBI, SLR and GNSS are realized at the Geodetic Observatory Wettzell since several decades. The space observations are accompanied by an extensive local survey at more or less regular intervals. Beside local tie vectors, which are required for the combination of the different space geodetic techniques, the local survey provides evidence of the long term stability of the geodetic reference points defining the ITRF. The analysis of the different survey campaigns covering a time span of 24 years and the big number of geodetic markers allow a reliable identification of instable pillars and ground markers, while the reference points of the space geodetic techniques are considered as stable.

In addition this paper presents different techniques of determining the invariant reference points of the VLBI and SLR telescopes, which are usually not directly accessible.

1 Relevance of ground survey

Each measurement is affected by errors, either statistic or systematic. In the case of the geodetic space techniques these errors enter into global solutions degrading products like the international terrestrial reference frame (ITRF) or Earth orientation parameters (EOP). Measuring errors may arise from:

- local displacements of the antenna reference point
- unsufficient knowledge or variations of the phase center with respect to the reference point
- delays in cables and electronic components
- multipath effects

While statistic errors are reduced with the number of observations, the systematic errors can be identified only by comparison between different techniques. In order to compare station coordinates resulting from different measuring systems, the exact knowledge of the tie vectors connecting the reference points is essential. This is realized by a local network of geodetic markers, pillars or ground marks, using classical survey instruments like theodolites, tachymeter, or levels.

The second purpose of the local network, usually covering less than a few hundred meters, is the proof of the local stability of the reference points of the space technique systems, and the identification of unstable monuments.

A regional network usually spanning several or a few tens of kilometers could be established in order to demonstrate the stability of the surrounding area and to show whether the station is representative for the entire region. Such a network is mostly realised by GNSS stations.

2 The local network in Wettzell

2.1 Network description

The local network at the Geodetic Observatory Wettzell recently consists of 25 survey pillars and 22 ground marks, tying together a number of 12 space technique reference points (3 VLBI, 2 SLR and 7 GNSS monuments) (fig. 1). The network is measured in regular intervals, usually each 2-3 years, and the coordinates are determined in a free least square adjustment. Between 1985 (7 pillars, 8 ground marks) and 2009 (16 pillars, 20 ground marks) 11 measuring campaigns were performed. This allows the creation of time series showing the long term behaviour of the geodetic markers and the reference points.

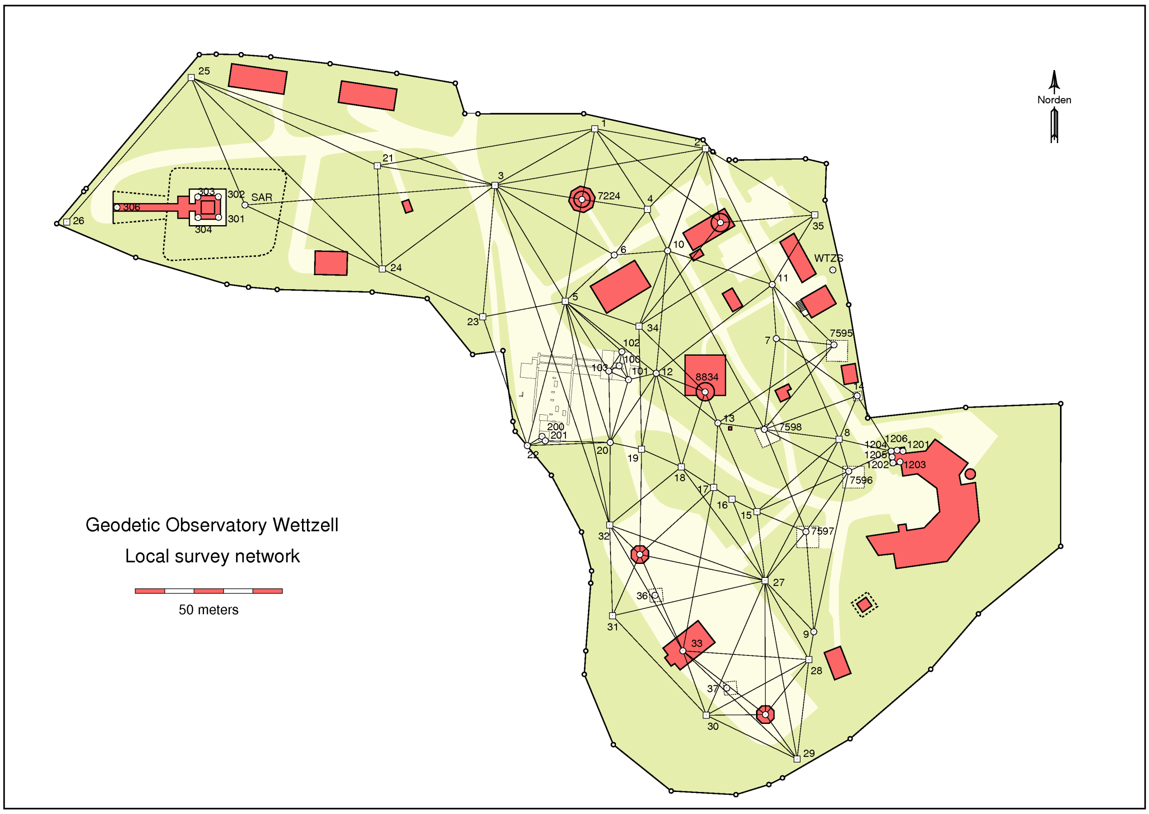

Figure 1: Local survey network at the Geodetic Observatory Wettzell.

2.2 Height variations

The height uncertainties (1 sigma) of the adjusted solutions are less than 0.1 mm in most cases. They may reach up to 0.5 mm for the reference points of the radio telescope (RTW) and the laser ranging telescope (WLRS) due to the difficulty in the point determination. This high precision allows the identification of very tiny displacements of individual markers. As an example the pillars 1-5 being distributed around the radio telescope show height variations of less than 0.5 mm over 13 years with the exception of the year 2004, when a subsidence of up to 1 mm is detectable at each pillar (fig. 2 left). This is obviously a consequence of the very dry summers in 2003 and 2004, having lead to a shrinking of the soil. One ground mark (11) being located directly beside an access road shows a continuous subsidence of 2.4 mm over 16 years, pointing to a soil compaction by traffic. Sudden changes in height are related to close construction work in most cases, e.g. 1.4 mm at ground mark 10 between 2004 and 2006.

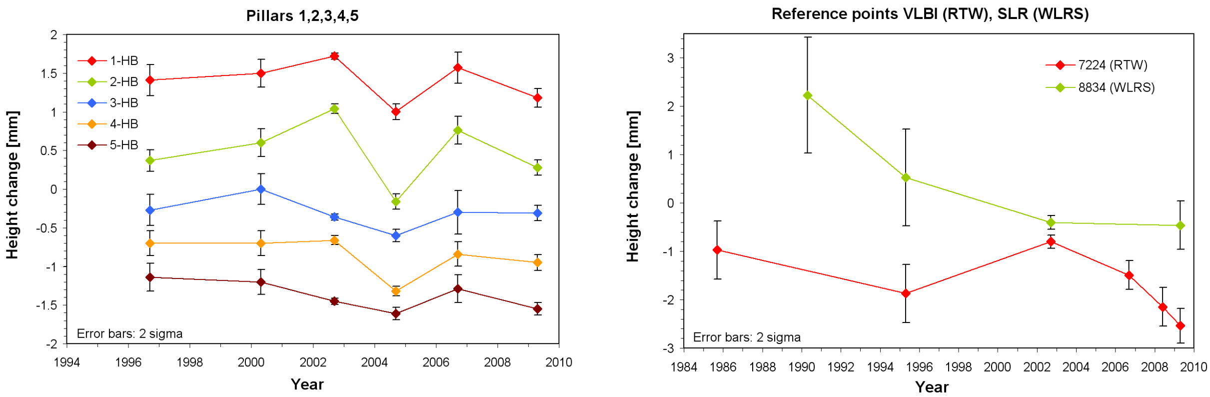

Figure 2: Height variations of survey pillars (left) and reference points of the VLBI and SLR system (right).

As can be expected the vertical displacements of the big telescopes are somewhat bigger. The WLRS monument subsided by 2.5 mm during the first 10 years and is stable since then (fig. 2 right). The RTW shows vertical variations of less than 1 mm up to the year 2002. Then it starts to subside by 1.5-2 mm until 2009. This points to a beginning abrasion of the elevation bearing, which had to be changed in 2010 due to destruction.

One survey in January 2009 has been rejected due to extreme deviations of up to 20 mm for some ground marks. Vertical expansion by frozen water is obviously a severe problem for some kind of markers.

2.3 Horizontal displacements

The 1 sigma uncertainties for the horizontal position is mostly below 0.2 mm. Poorly constrained points at the network rim reach up to 0.6 mm. Most of the pillars and ground marks show an irregular variation in position of 1-3 mm over 2 decades (fig. 3 top). One pillar (4) moved by 18 mm over 24 years and is clearly identified as unstable. Another pillar (2) being close to the entrance gate shows a sudden displacement of 3 mm, which can be clearly related to construction work.

The horizontal displacements of space technique reference points are similar small. After a horizontal motion of 2 mm between 1985 and 1995, the RTW remained stable within 1 mm since then (fig. 3 bottom). The displacement of the WLRS reference point is less than 1 mm since 1995. The position of the GNSS points at the roof of the GNSS tower varied by up to 1.5 mm.

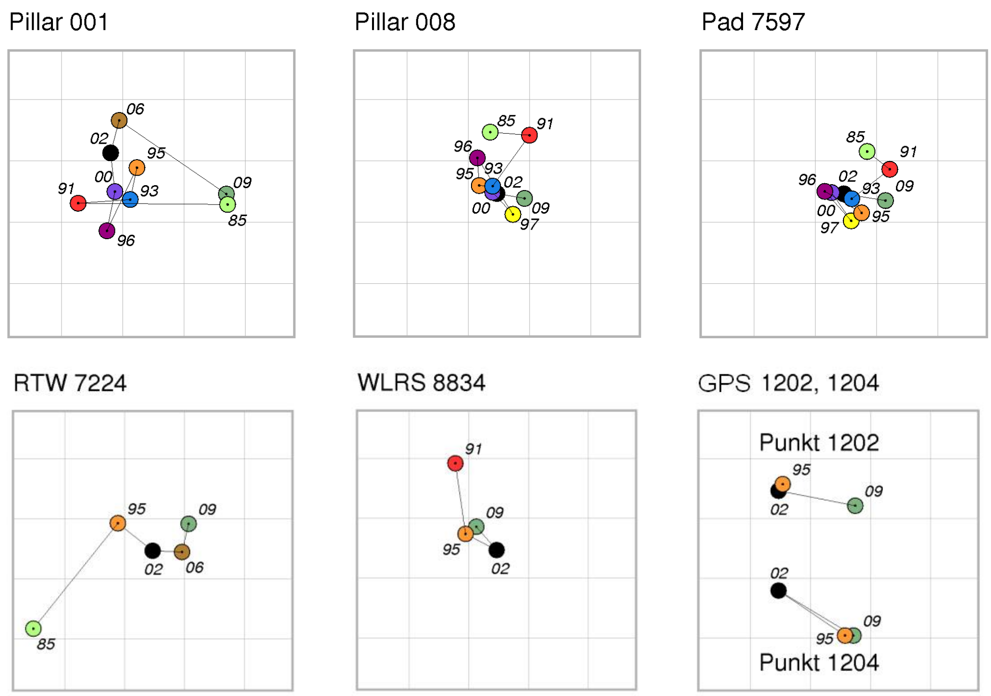

Figure 3: Horizontal motion of selected survey marks (top) and reference points (bottom). Line spacing is 1 mm, years are indicated by numbers.

2.4 Transformation

In order to compare the locally measured coordinates with the solutions of the geodetic space techniques, they have to be transformed into the global geocentric system. For this purpose the data from two GPS campaigns performed in 2000 and 2003 were used. The 2000 campaign lasted 4 days and 4 points of the station network were occupied by GPS antennas. During the 2003 campaign 6 station network points were occupied measuring continuously over 9 days. Data from the 4 permanently runnings GNSS stations were also included in the analysis.

For the combination the GPS solutions were downweighted in such a way that they only provide the orientation of the network, while the scale is dominated by the high precision of the ground survey.

3 Determination of invariant points

The geodetic reference point at a moving telescope is defined as the intersection of the azimuth and the elevation axis, which is the invariant point (IVP). It is usually not directly accessible and has to be constructed through observations of markers being attached to the telescope at different telescope positions. There are 3 different ways to construct the IVP:

- determine azimuth and elevation axis independently, intersect both axes
- determine center of elevation arcs at different azimuths, construct center of azimuth circle
- 3D least square adjustment of sphere surface

Table 2 shows the results of 2 different IVP determinations. While the different adjustment techniques yield nearly the same results, the use of different instruments or the analysis of different campaigns yield differences of up to 0.5 mm or 1 mm, respectively.

Method	East	North	Up
	Tachymeter data:		
2D adjustment + height (NetzCG)	269.71713	187.69011	622.46484
3D adjust. (JAG3D)	269.71715	187.69011	622.46482
circle adjustment	269.71720	187.69008	622.46502
max. difference	**0.07 mm**	**0.03 mm**	**0.2 mm**
	Laser tracker data:		
3D adjust. (JAG3D)	269.71739	187.69056	622.46506
Difference to above	**0.24 mm**	**0.45 mm**	**0.24 mm**

Method	East	North	Up
	Campaign 09-23-2009:		
sphere adjustment (MatLab LSGE-bib)	316.92438	180.04237	616.51454
3D adjust. (PANDA)	316.92439	180.04240	616.51425
circle adjustment	316.92438	180.04250	616.51454
max. difference	**0.01 mm**	**0.13 mm**	**0.29 mm**
	Campaign 09-01-2009:		
3D adjust. (PANDA)	316.9253	180.0426	616.5134
Difference to above	**0.9 mm**	**0.1 mm**	**0.85 mm**

Table 2: Results from IVP determination of the Radio Telescope Wettzell (Lösler 2008, left) and the Satellite Observing System Wettzell (right) using different adjustment techniques, instruments, and measuring campaigns.

4 Conclusions

Repeated ground surveys at the Geodetic Observatory Wettzell show that the reference points of the space technique systems are stable with respect to the local network. The good repeatability, also when using different instruments, indicate small systematic errors. Stable markers show displacements not exceeding 2-3 mm in 24 years. A few unstable markers were clearly identified since the network is made up by a sufficient number of markers forming a stable geometry. Construction work is a major source of marker displacements.

The determination of invariant points yield the same results within ± 0.15 mm when using different adjustment techniques. Difference between tachymeter and laser tracker results do not exceed 0.5 mm. However, different survey campaigns yielded differences up to 1 mm, which is a consequence of different network geometry, environmental conditions, and deformations.

It is concluded that the accuracy of the local ties in Wettzell are in the order of 1-2 mm.

References

Lösler, M., 2008: Reference point determination with a new mathematical model at the 20 m VLBI radio telescope in Wettzell. J App Geod, 2, S. 233-238, doi: 10.1515/JAG.2008.026.

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