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COLD MAGICS – Continuous Local Deformation Monitoring of an Arctic Geodetic Fundamental Station

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Abstract

We describe the experience gained in a project to continuously monitor the local tie at the Geodetic Observatory Ny-Ålesund. A PC-controlled robotic total station was used to monitor survey prisms that were attached to survey pillars of the local network and the monuments used for geodetic VLBI and GNSS measurements. The monitoring lasted for seven days and had a temporal resolution of six minutes. The raw angle and distance measurements show clear sinusoidal signatures with a daily period, most strongly for a four-day period with 24 hours of sunshine. The derived topocentric coordinates of the survey prisms attached to the GNSS monument and the VLBI radio telescope act as approximation for the local tie. We detect clear signatures at the mm-level. With the current approach we cannot distinguish between real motion of the prisms and potential thermal influences on the instrument used for the observations. However, the project shows that continuous local tie monitoring is feasible today and in the future can and should be used for all geodetic co-location stations.

1. Introduction

The Global Geodetic Observing System (GGOS) [1] aims at a combination and integration of observations and results of various geodetic techniques. An important ingredient for the GGOS are geodetic co-location stations, often called Geodetic Fundamental Stations, that host equipment for several geodetic techniques. The local geodetic relations between the techniques' reference points, usually called "local ties", have to be known accurately in the spatial and temporal domain. The goal is up-to-date local ties with sub-mm accuracy and full variance-covariance information.

Usually local tie surveys are performed every couple of years only. This is mainly due to the fact that a local tie survey is a difficult and time consuming engineering task (e.g., [2], [3]). Often these surveys are a combination of direction and distance measurements with tachymeters, and height differences from spirit levelling. Some deficiencies of this approach are:

Inconsistency: Different survey campaigns and survey teams do not agree on the results. Did something really change or is it an effect of method, operator or instrumentation?

Insufficiency: The temporal sampling is too low. So, if something really changed, when exactly did it change? And what about possible periodic changes?

Interpretation: Depending on the size of the local network, the local systems are not necessarily truly cartesian systems that can be transformed easily to a global cartesian system.

One possible answer to the above listed deficiencies is the idea of continuous cartesian connections (CCC) [4], i.e., continuous local tie monitoring that is operated in an automatic mode and uses angular and distance measurements independently of the geoid's curvature. We tested this idea in the summer of 2009 at the Geodedic Observatory Ny-Ålesund on Svalbard.

2. The Geodetic Observatory Ny-Ålesund

The Geodetic Observatory Ny-Ålesund is a very important co-location station due to its northern location at 79° N. The station hosts a radio telescope for geodetic VLBI, several monuments for GNSS observations, and a superconducting gravimeter, and there is also a tide gauge and a DORIS station within 2 km distance.

Figure 1 shows an aerial photo of the station. The VLBI telescope and GNSS monuments and some of the survey pillars of the local survey network are depicted.

Figure 1. Aerial picture of the Geodetic Observatory Ny-Ålesund on Svalbard. The VLBI telescope and GNSS monuments and some of the survey pillars of the local survey network are depicted.

3. Method

We used a PC-controlled robotic total station (Leica TM30) (Fig. 2a) to measure distances and angles to 14 retro-reflecting prisms (Leica GPR112). Six prisms were attached to the survey pillars P91, P92, P94, P95, P96, and P97 (e.g., Fig. 2b). Another six prisms were attached with strong magnets to the structure of the radio telescope. Prisms T1-T5 were mounted directly on the non-moving telescope tower (Fig. 2c), while prism T6 was mounted on a moving part of the telescope. One prism was attached to the GNSS monument NYAL (Fig. 2d) which is a 5 m high steel truss mast on a concrete block foundation. Another prism was mounted close to the tide gauge in the harbor.

The total station was placed on survey pillar P93 (Fig. 2a) that had the best visibility to a large number of other survey pillars, the radio telescope, and the GNSS monument. The total station

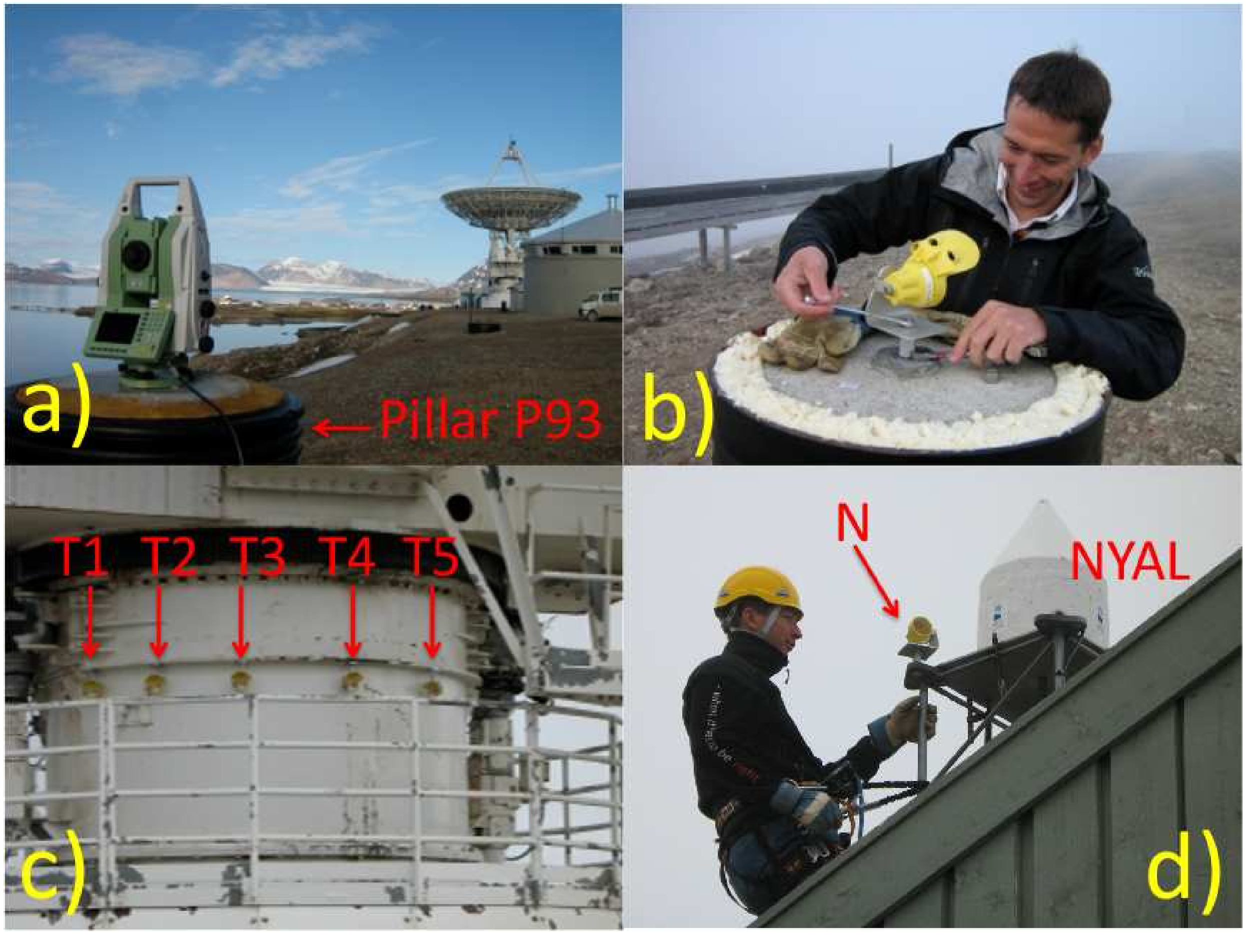

Figure 2. The measurement setup: (a) The total station on pillar P93; (b) One of the retro-reflecting prisms mounted on one of the survey pillars; (c) Five prisms mounted with strong magnets on the tower of the radio telescope; (d) The prism mounted on the GNSS monument NYAL.

was controlled and operated using software (Leica GeoMos). A temperature and air pressure sensor was connected to the data acquisition system in order to correct the distance measurements for refractive index variations.

4. Results

The total station performed measurements in two faces (angles and distances) and automatic target recognition (ATR) to all 14 prisms with a repetition cycle every 6 minutes. The instrument specifications with the used prisms are 0.30 mgon and 1 mm + 1 ppm for angular and distance measurements, respectively. In parallel, meteorological data were recorded at the total station every 1 minute. In this operation mode measurements were performed continuously for 7 days.

The measurements are shown in Fig. 3. Mean values of each time series are subtracted, and the series are offset with respect to each other to improve the readability of the plots. A common

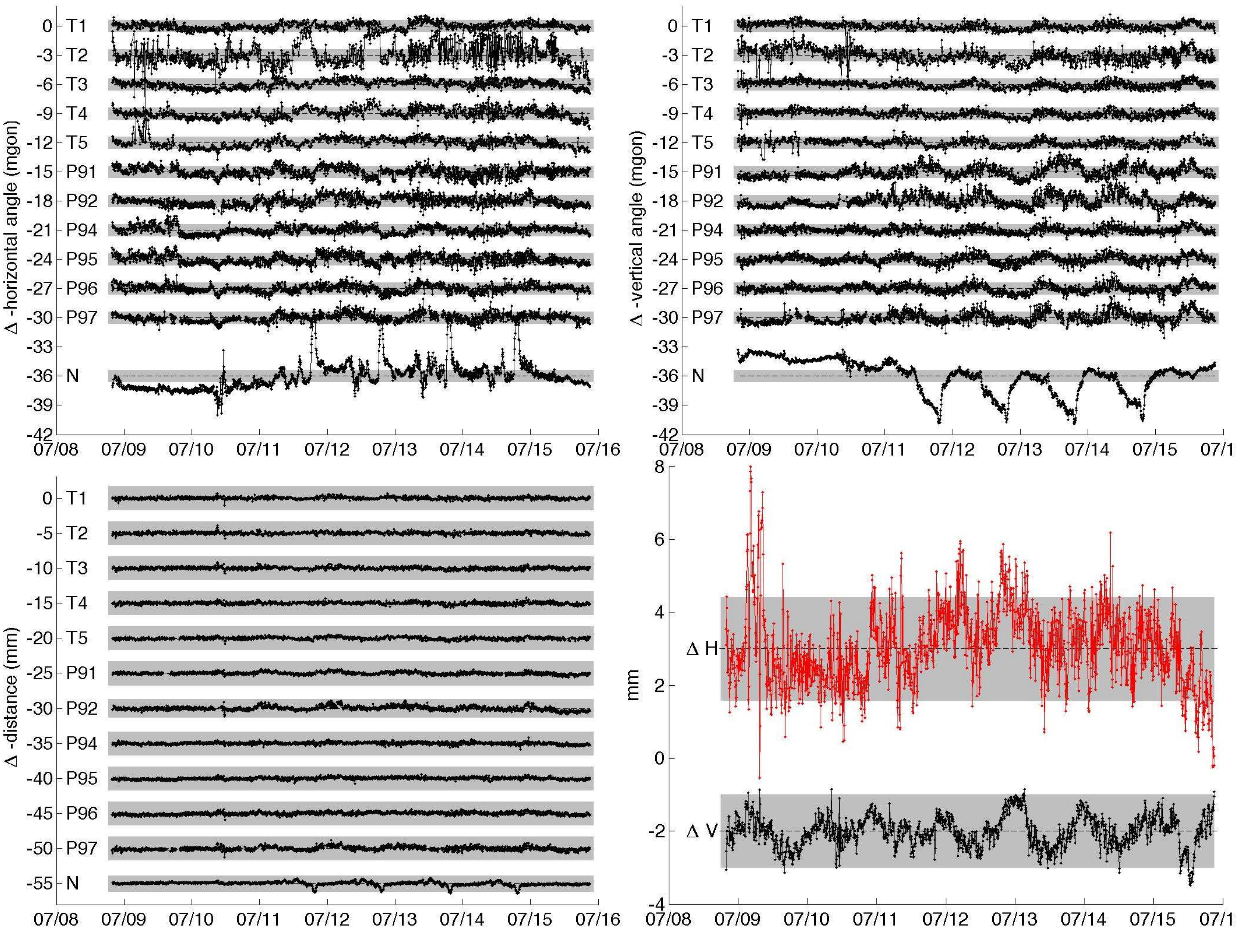

Figure 3. Measurements of horizontal angles (upper left), vertical angles (upper right), and distances (lower left). Mean values of each time series are subtracted and offsets introduced to improve readability. The gray background gives the 2-sigma uncertainties according to the instrument specifications. The horizontal and vertical distance between the prism N at the GNSS monument NYAL and the fitted center of the tower of the radio telescope are shown in the lower right picture. Mean values are subtracted and the gray background gives the expected uncertainties (1-sigma).

horizontal angle drift, possibly related to an unfortunate but necessary use of shims when fastening the total station's tribrach, has been removed.

The grey background of each time series shows the expected 2-sigma uncertainty according to the instrument specifications. It becomes clear that in particular several of the angle measurements show sinusoidal signatures that are larger than the expected 2-sigma uncertainties based on the instrument specifications. The prism N that was attached to the GNSS monument NYAL shows very large variations of horizontal and vertical angles.

The measurements show in general diurnal signatures for many prisms, most clearly during July 11-15. During these four days we experienced 100 hours of consecutive sunshine, confirmed by solar radiation observations with a strong sinusoidal signature of a 24-hour period [5].

In the next step we used the angle and distance measurements for every epoch to determine coordinates in a local system by polar point determination. Then we fitted circles to the horizontal positions of prisms T1-T5 for every epoch and calculated the mean vertical position. These coordinates can to some extent be regarded as representing the center of the tower of the radio telescope. Thus, the geometric relation between the center of the radio telescope tower and the prism at the GNSS monument are regarded as an approximation for the local tie between the IVS and IGS monuments. Variations of this geometric relation are shown in the lower right graph in Fig. 3. Daily signatures are visible in the coordinate differences, both for the horizontal (upper series) and vertical components (lower series). The uncertainty band is dominated by the distance measurements.

5. Conclusions and Outlook

We monitored the local network at Ny-Ålesund continuously for 7 days using an automated observation strategy.

The diurnal signatures seen in our raw measurements are often larger than the expected measurement uncertainties. In particular the angular measurements have signatures that are larger than 2-sigma. Measurements to the prism (N) attached on the GNSS monument NYAL (5 m steel truss mast) show the strongest signatures.

Topocentric coordinates for the observed prism were determined every epoch by simple polar point determination. We identify diurnal signatures at the mm-level in the coordinate differences between the VLBI telescope and the GNSS monument. At this point we cannot distinguish if this apparent coordinate variation is real local deformation due to thermal effects or due to thermal influences on the instrument used for the observations, since we lack redundant observations. However, the concept of continuous monitoring of local ties appears to work fine. Future continuous monitoring projects should thus use several total stations for redundancy purposes and include a dense network of meteorological sensors.

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