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Foot-Print of the Space-Geodetic Observatory, Ny-Ålesund, Svalbard

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Abstract

The Space-Geodetic Observatory at Ny-Ålesund, Svalbard, which is operated by the Norwegian Mapping Authority, has developed over recent years into a fundamental geodetic station. At such fundamental sites, detailed knowledge of the stability of the station, both locally and with respect to the region, is essential for geodetic and geophysical applications of the observations. The extensive foot-print study for the observatory includes repeated GPS campaigns on a 50 km by 30 km control network and repeated classical surveys of the inner control network extending 400 m by 40 m. The results from the GPS campagins indicate neo-tectonic movements in the vicinity of the observatory.

1. Introduction

The geodetic observatory in Ny-Ålesund is a fundamental geodetic station located at 78.9°N and 11.9°E on the southern coast of the Kings Bay (Fig. 1). The geodetic infrastructure includes a 20-m VLBI-antenna, several GPS and GPS/GLONASS receivers, a tide gauge, a superconducting gravimeter and a co-located DORIS station (see e.g. [4] and [5] for a detailed description of the station).

The space-geodetic techniques provide point measurements with the baseline of the monument having typically a dimension of a few metres. In order to be able to interprete the observations in terms of geophysical signals, the actual foot-print size of the measured point needs to be known. The foot-print is determined by the stability of the monument with respect to the surrounding ground but also by how representative the location is with respect to the surrounding area and even region. This again is a consequence of the geophysical processes relevant at a given location.

The Western Svalbard fold-and-thrust belt has a complex tectonic history linked to the opening of the Northern Atlantic Ocean. The last recognised important tectonic event in this area is dated from the Tertiary [1] when the Ny-Ålesund tertiary basin was overthrust by carboniferous rocks. Today, Western Svalbard is located only 150 km away from the Knipovich Ridge, which is an active segment of the Mid-Atlantic Ridge system. High heat flow anomalies and considerable seismic activity have been recorded offshore western Svalbard [3]. In the Kings Bay area, minor seismicity may indicate some neotectonic activity. Some faults are relatively close to the observatory. This setting warrants a careful study of the actual foot-print size for the fundamental station in Ny-Ålesund.

Local monument stability has been studied in detail based on classical measurements on a local inner control network (see e.g. [2], [6]). For studies of the larger foot-print of the obervatory, campaign type GPS measurements are applied.

2. The GPS Control Network and Observations

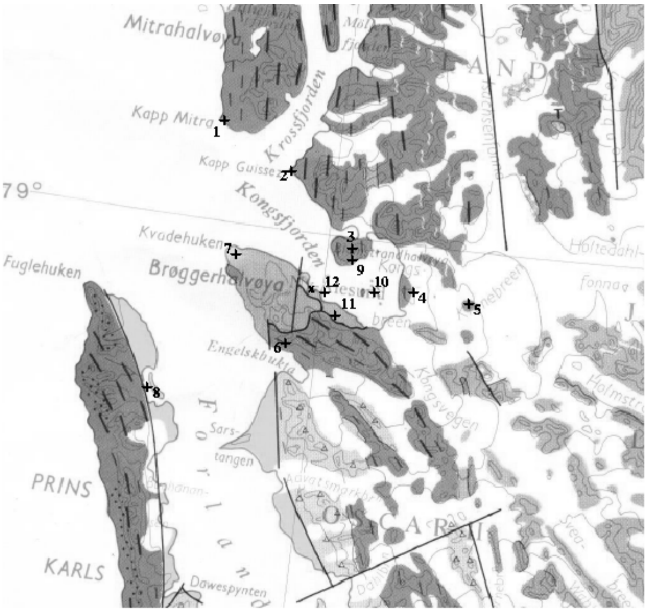

Figure 1. Location of the GPS control network
The numbers 1-8 denote the GPS markers established in 1998; those with number 9-11 were established in 1995, while number 12 is close to the tide gauge and was established in 2000. Colours denoted different geological units, with dark grey: Proterozoic; light grey: tertiary, intermediate grey (on Brøggerhalvøya): cretatious-permian. Note the fault and the small tertiary unit close to the geodetic observatory. From [5].

In order to study the stability of the Kings Bay area, a GPS control network was established in 1998 extending in east-west and north-south directions approximately 50 km by 30 km (see Fig. 1 and [5]). The points were selected in order to cover most of the different geological units in the surrounding of the observatory. Other criteria were the GPS horizon and the presence of bedrock. At high latitudes, GPS satellites are always seen at low elevations while satellites are also seen over the pole. A unperturbed horizon in all directions is an asset. Due to the steep topography and the effect of permafrost on rocks, both criteria are difficult to meet. Accessability of the points also had to be taken into account. However, most of the outer points are only accessible by helicopter, depending on weather conditions.

At points outside the inner control network with its elaborated pillars (see [6]), the GPS markers are brass screw bolts drilled and cemented into solid rock. Elevation of the top of the bolt above ground is of the order of 5 cm.

In Fig. 2, the surroundings of selected points are illustrated. The points at Kap Mitra (1 on Fig. 1, upper right in Fig. 2) and Kapp Guissez (2) on the northern coast of Kings Bay are located on bedrock exposed due to extreme high waves keeping the bedrock free from debris. For both sites, the horizon is almost unperturbed with some mountains towards north with maximum elevation angles of 5-6°. Engelsbukta (6, upper right on Fig. 2) is located on the lower part of the southern side of a mountain, with no view to satellites in the north. Bedrock is very scarce in that area and therefore the trade-off between site stability and horizon was decide in favour

Figure 2. Selected points of the Control network.

Upper left: Kap Mitra, view towards south-east; upper right: Engelsbukta, view to north-west; middle: Kvadehuken, view to south-west; lower: Knocktjørna, view to south. All photos by Plag, 1998.

of the former. Other areas where stable bedrock is scarcely found are Sarsfjellet (4) at the inner end of Kings Bay and the vicinity of the observatory itself. The marker in the outcroop within Kronebreen (5) has been abondoned since even with a helicopter accessibility is too difficult due to weather conditions. The points accross Kings Bay from Ny-Ålesund (3 and 9) are placed in bedrock but their northern horizon is obscured by mountains with elevation angles of more than 10°. Kvadehuken (7, lower left on Fig. 2) and Knockttjørna (8, lower right on Fig. 2) are in flat areas covered by broken-up permafrost material. At Kvadehuken, the marker is placed in an outcrop of bedrock of more than 20 m extension, while at Knockttjørna it is not clear whether the marker is in an outcroop or a larger block.

GPS campaigns were carried out in September 1998 (1 campaign), August 1999 (2 consecutive campaigns), and 2000 (3 consecutive campaigns). In 1998, seven points established in 1998 were measured. In both, 1999 and 2000, all points suitable for GPS measurements were occupied in two consecutive campaigns (see [5] for more details). A new campaign is planned for 2002.

In each campaign, the points were occupied for at least 4 complete days and in most cases for five full days. Care was taken to occupy, wherever possible, a given point each year with the same receiver and antenna pair. All campaigns were carried out by the same observer (LB).

Table 1. Movements for the markers in the control network.
Site velocities:

No.	ID	East	North	Height
		mm/yr	mm/yr	mm/yr
6	ENGL	9.6 +/- 1.0	14.5 +/- 0.8	4.9 +/- 1.5
2	KAPG	10.9 +/- 0.5	15.0 +/- 0.6	2.8 +/- 0.9
1	KAPM	9.4 +/- 0.5	14.9 +/- 0.6	3.6 +/- 1.2
8	KNOC	11.0 +/- 0.6	12.6 +/- 0.6	2.8 +/- 1.0
7	KVAD	10.0 +/- 0.6	14.2 +/- 0.6	-2.5 +/- 1.3
4	SARS	11.2 +/- 0.7	13.4 +/- 0.6	6.6 +/- 1.5
12	NYAL	12.4 +/- 0.5	15.1 +/- 0.5	-2.0 +/- 1.5
	NUVEL	12.95	13.60	
	NYAL	10.8 +/- 0.1	15.2 +/- 0.1	4.0 +/- 0.3
	NYA1	9.2 +/- 0.1	14.7 +/- 0.1	3.5 +/- 0.3

3. GPS Analysis and Results

Analyses were carried out with GIPSY, using a free network analysis (FNW) as well as a precise point positioning (PPP, see [7]). JPL precise satellite orbits and clocks and EOPs were used. Cut-off elevation angle for both solutions was set to 7°. For transformation to ITRF97, JPL's global transformation parameters were used. In the analysis, no ambiguity resolution was made. For identical data sets, no significant difference were found between the FNW and PPP solutions. The PPP has the advantage that the reference frame is realised by the satellite orbits, only, and therefore is independent of the actual sites measured. Thus, data gaps do not affect the reference frame. Moreover, for PPP consequtive campaigns on disjoint sets are in the same reference frame.

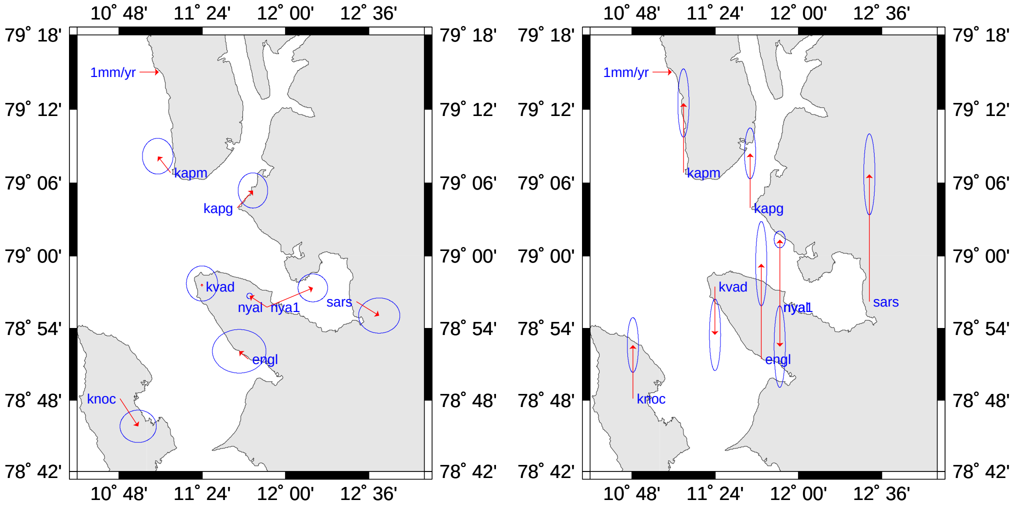

Figure 3. GPS determined motion of the control network.
Left: horizontal movement relative to ITRF97 velocity for Ny-Ålesund; right: vertical movement.

In order to account for long-period variations in the GPS time series, the day to day movements for the permanent station NYA1 are subtracted from the individual day to day results for the campaign stations. This reduces common variations at all stations due to orbit errors and unmodelled atmospheric and loading effects.

The resulting linear velocities are given in Table 1. For the horizontal components, all points show the same north-east movement with respect to ITRF. However, differences are of the order 2 mm/yr, and there is a systematic difference to the NUVEL-1A-NNR predictions. In order to elaborate the geographical pattern of the differences, the ITRF97 velocity for Ny-Ålesund has been substracted (Fig. 3). The resulting spatial pattern appears to be somewhat correlated with the fault structure. NYA1 shows a large difference to NYAL, and instability of the NYA1 is suspected.

Vertically, all points show uplift except for KVAD and NYAL (Table 1). NYAL and NYA1 show the same long-term trend (lower lines in Table 1), and the negative trend for NYAL in the campaign may be due to gaps in NYAL during one campaign. For KVAD, no data problems can explain the negative trend, and a tectonic origin cannot be excluded (Fig. 3).

4. Conclusions

The secular horizontal velocities determined from three repeated GPS campaigns indicate a possible small scale tectonic movement. More GPS campaigns in conjunction with classical surveys are needed to exactly determine the foot-print of the observatory with respect to horizontal and vertical movements

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