Site surveys at the fundamental geodetic station in Ny-Ålesund, Svalbard

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Abstract

The Space-Geodetic Observatory at Ny-Ålesund, Svalbard, was officially opened in 1995 and is operated by the Norwegian Mapping Authority. Over recent years it has developed 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 outer control network and repeated also for most of the inner control network extending 400 m by 40 m. Gravity measurements have been carried out for these nets. In addision are also classical surveys carried out for the inner network. 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. Planning and construction work was carried out in the period 1992–1994. Test observations began in October 1994, and it was oficially opened in 1995. The observatory is situated 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 colocated 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 know. The foot-print is determined by the stability of the monument with respect to the surrounding ground but also by the representativity of the location 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 has been overthrust

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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 International activity at the Geodetic Observatory

In table 1 the international activity for the recent years is listed. In addition was the inner network surveyed by clasical triangulation and trilateration in 1993 and 1995.

Persons involved	Country	Title
1998		
Susanna Zerbini	Italy	Establish local GPS network
Antonio Rius	Spain	GPS Tomography
Bernd Richter	Germany	Absolute gravity measurements
Lars Bockmann	Norway	GPS campaign
1999		
John Ponsonby	U.K.	Atomic clock and frequency
Paolo Tomasi	Italy	Geodetic link
Detlef Wolf	Germany	Changes in the ice-caps
Alexander Braun	Germany	Calibration of ERS
Trevor Baker	U.K.	Ocean tide models
Lars Bockmann	Norway	GPS campaign
2000		
Paolo Tomasi	Italy	Reference point for VLBI
Antonius Rius	Spain	Tropospheric water vapour
Axel Nothnagel	Germany	Conventional survey tie
Rüdiger Haas	Sweden	GPS-VLBI tie
Jacques Hinderer	France	Absolute gravity measurements
Lars Bockmann	Norway	GPS campaign
Leif Grimstveit	Norway	Classical survey
2001		
Joana Diaz Pont	Spain	Climate research and public
Hans-Joachim Kuempel	Germany	Stability controls GPS and VLBI
Bernd Richter	Germany	Absolute gravity measurements
2002		
Hans-Joachim Kuempel	Germany	Stability controls GPS and VLBI
Martin Lidberg	Sweden	Stability of tide gauge
Alan Dodson	U.K.	Ionospheric Scintillation on GPS
Olivier Francis	Luxembourg	Absolute gravity measurments
Lars Bockmann	Norway	GPS campaign
Bjørn G. Harsson	Norway	Relative gravity measurments

Table 1: Activity in Large Scale Facility.

3 The GPS control network and observations

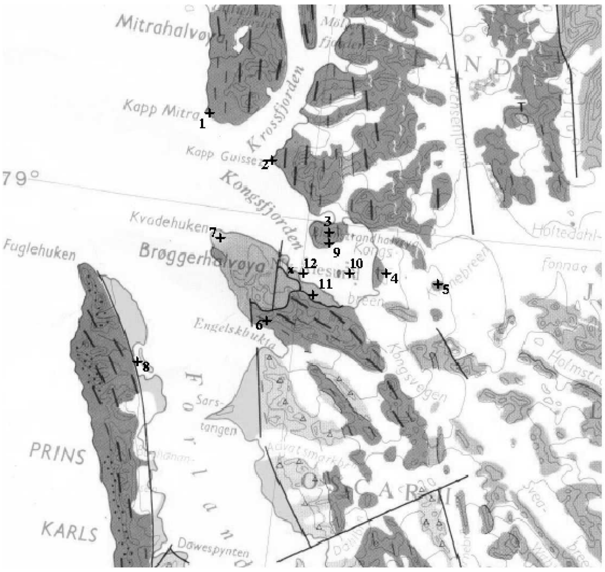


Figure 1: Location of the GPS control network. The numbers 1–8 denote the GPS markers established in 1998; those with number 9–11 were established in 1995, while number 12 is close to the tide gauge and was established in 2000. Colours denoted different geological units, with dark grey: Proterozoic; 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 boat or 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.

(a) Kap Mitra, view towards south-east

(b) Engelsbukta, view to north-west

(c) Kvadehuken, view to south-west

(d) Knocktjørna, view to south

Figure 2: Selected points of the Control network.

In Fig. 2, the surroundings of selected points are illustrated. The points at Kap Mitra (site 1 in Fig. 1 and Fig. 2(a)) 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 (site 6 in Fig. 1 and Fig. 2(b)) 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 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 (site 7 in Fig. 1 and Fig. 2(c)) and Knockttjørna (site 8, and Fig. 2(d)) are in flat areas covered by brocken-up permafrost material. At Kvadehuken, the marker is placed in an outcroop 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 (one campaign), August 1999 (two consecutive campaigns), August 2000 (three consecutive campaigns) and August 2002 (two consecutive campaigns). All the seven points established in 1998 were also measured that year. In 1999, 2000 and all points suitable for GPS measurements were occupied in two consecutive campaigns (see [5] for more details). In 2002 each point was observed five complete days or more.

In each of the previous campaigns, 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 pair of receiver and antenna. All campaigns were carried out by the same observer (LB).

4 GPS analysis and results

Analyses were carried out with GIPSY, using a precise point positioning (PPP, see [7]). JPL precise satellite orbits, clocks and EOPs were used. Cut-off elevation angle for both solutions was set to 7°. For transformation to ITRF2000, JPL's global transformation parameters were used. In the analysis, no ambiguity resolution was made. 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 effect the reference frame. Moreover, for PPP consequtive campaigns on disjunct sets are in the same reference frame.

In order to account for long-period variations in the GPS time series, a weighted mean of the day to day movments for the permanent stations NYA1 and NYAL 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 2. 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 ITRF2000 velocity for Ny-Ålesund has been substracted (Fig. 5). The resulting spatial pattern ap-

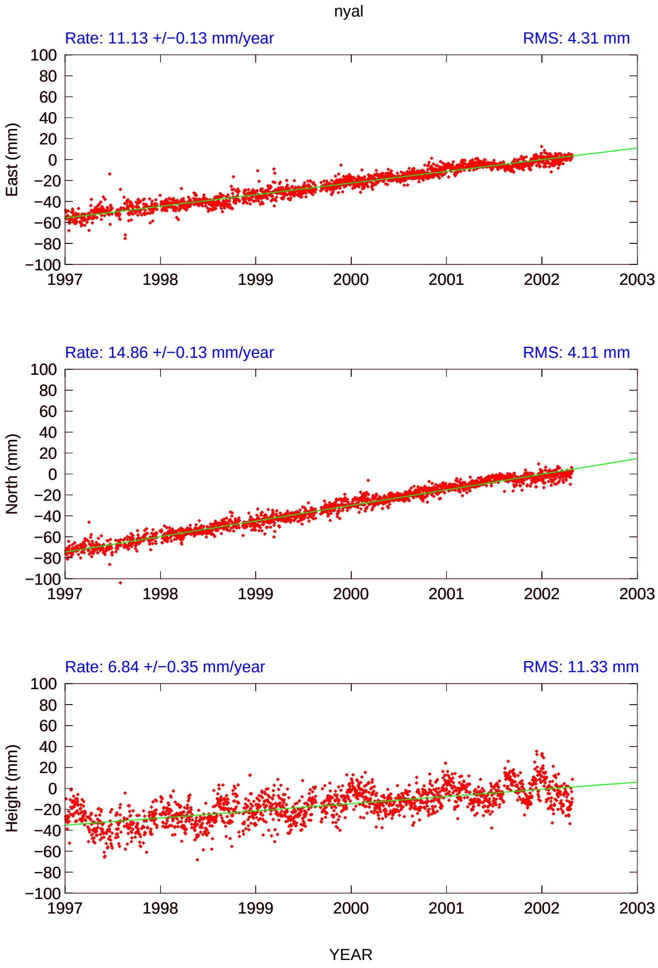


Figure 3: Timeseries NYAL.

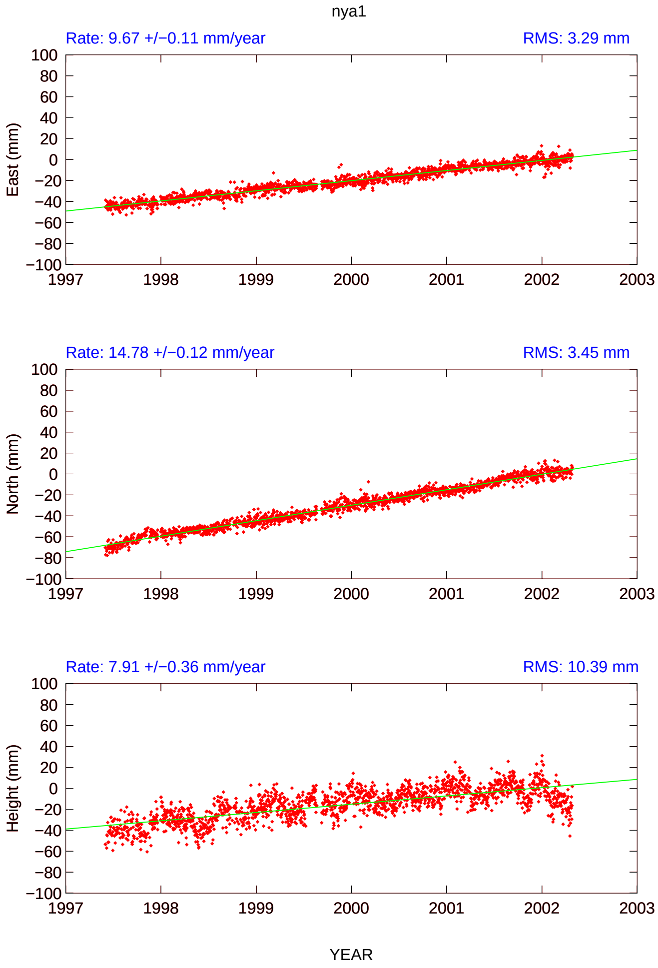


Figure 4: Timeseries NYA1.

pears 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 (Table 2). NYAL and NYA1 show the same long-term trend (lower lines in Table 2). Fig. 5).

5 Conclusions

The secular horizontal velocities determined from three repeated GPS campagins indicates 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.

References

[1] Blythe and Kleinspehn. Tectonically versus climatically driven Cenozoic exhumation of the Eurasian plate margin, Svalbard: Fission track analyses. *Tectonics*, 17:4 621–4 639, 1998.

[2] L. Grimstveit and S. Rekkedal. Geodetic control of permanent sites in Tromsø and Ny-Ålesund. In H.-P. Plag, editor, *Book of Extended Abstracts for the Ninth General Assembly of the Working group of European Geoscientists for the Establishment of Networks for Earth-science Research. Second Edition*, pages 25–28. Norwegian Mapping Authority, 1998.

[3] S. Høgden. *Seismotectonics and crustal structure of the Svalbard Region.* PhD thesis, Department of Ge-

Site velocities (1998-1999-2000-2002):

St.No.	**ST.ID**	**North**	**East**	**Height**
		mm/yr	mm/yr	mm/yr
3	BRAT	15.6 ± 0.4	9.9 ± 0.3	5.0 ± 0.8
6	ENGL	13.5 ± 0.3	9.8 ± 0.6	7.5 ± 1.3
2	KAPG	15.3 ± 0.4	9.8 ± 0.4	4.6 ± 0.8
1	KAPM	15.2 ± 0.3	9.9 ± 0.3	4.9 ± 1.0
8	KNOC	14.6 ± 0.4	9.8 ± 0.3	6.9 ± 0.9
7	KVAD	13.8 ± 0.2	9.4 ± 0.3	5.7 ± 0.7
4	SARS	14.8 ± 0.4	10.9 ± 0.4	9.6 ± 1.4
11	GRAV	13.7 ± 0.8	12.1 ± 0.6	0.3 ± 1.7
12	KAIA	12.5 ± 0.4	10.9 ± 0.6	8.0 ± 1.9
9	LOND	13.6 ± 0.5	10.7 ± 0.4	6.9 ± 0.9
10	OBSE	14.1 ± 0.6	10.2 ± 0.4	6.0 ± 1.0
	NUVEL	13.60	12.95	13.60
	NYAL	14.9 ± 0.1	11.1 ± 0.1	6.8 ± 0.3
	NYA1	14.8 ± 0.1	9.7 ± 0.1	7.9 ± 0.3

Table 2: Movements for the markers in the control network.

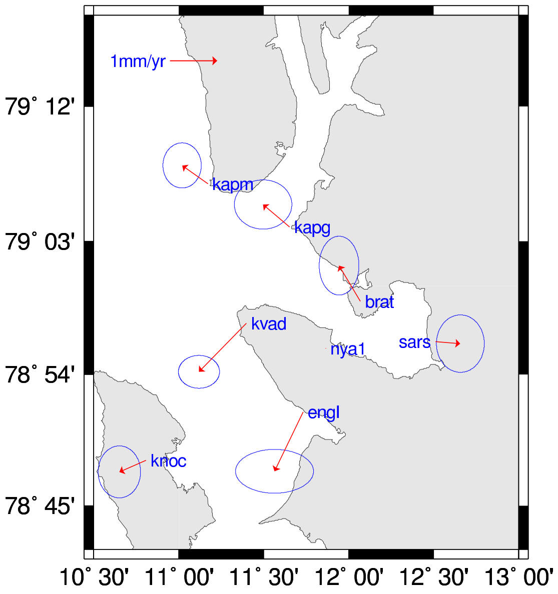
ology, University of Oslo, 1999.

[4] H.-P. Plag. Space-geodetic contributions to global-change research at Ny-Ålesund. In *Proceedings for the 27-th Int. Symp. on Remote Sensing of Environment: Information for Sustainability, June 8-12, 1998, Tromsø, Norway*, pages 227–231. Norwegian Space Centre, 1998.

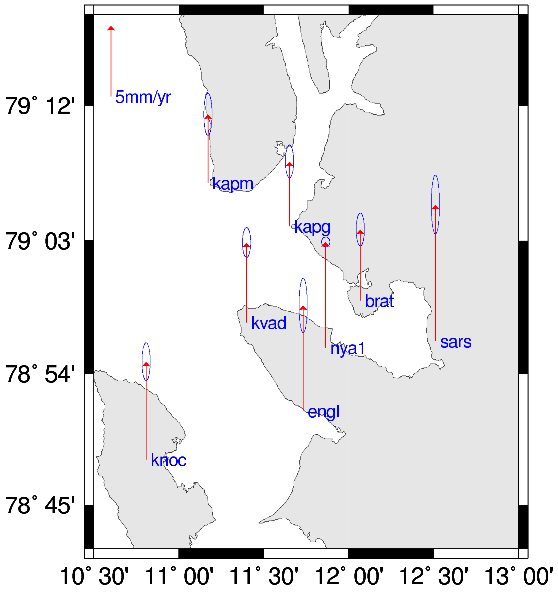
[5] H.-P. Plag, L. Bockmann, H. P. Kierulf, and O. Kristiansen. Foot-print study at the space-geodetic observatory, ny-ålesund, svalbard. In P. Tomasi, F. Mantovani, and M.-A. Perez-Torres, editors, *Proceedings of the 14th Working Meeting on European VLBI for Geodesy and Astrometry, Castel San Pietro Terme, Sept. 8 - Sept. 9, 2000*, pages 49–54. Consiglio Nazionale Delle Ricerche, Istituto di Radioastronomia, 2000.

[6] P. Tomasi, P. Sarti, and M. Rioja. The determination of the reference point of the VLBI antenna in Ny Ålesund. *Memoirs of National Institute of Polar Research, Japan*, 54, 2001. 319–330.

[7] J. F. Zumberge, M. B. Heflin, D. C. Jefferson, and M. M. Watkins. Precise point positioning for the efficient and robust analysis of GPS data from large networks. *J. Geophys. Res.*, 102:5005–50017, 1997.



(a) horizontal movement relative to ITRF2000 velocity for Ny-Ålesund



(b) vertical movement

Figure 5: GPS determined motion of the control network.