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The kinematics of Ny-Ålesund from space geodetic data

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ABSTRACT

We have compared coordinate time series from several space geodetic observing techniques to derive the kinematical motions of Ny-Ålesund, Svalbard. Velocity estimates from VLBI, GPS, and DORIS scatter more than the expected error estimates from each technique, and also between individual GPS solutions with different software and analysis strategies. A statistical combination yields average topocentric velocity components of 14.3 ± 0.2 mm/year (north), 9.8 ± 0.7 mm/year (east), and 8.2 ± 0.9 mm/year (vertical) for 1993–2007. The horizontal velocity is in agreement with a combined prediction of NUVEL-NNR-1A and the effects of post-glacial rebound and present day ice melt of nearby glaciers. The observed uplift is twice that predicted by the two latter processes. The non-linear time series of both VLBI and GPS data suggest that the uplift rate increases from 7.0 mm/year before 2003 to 10.8 mm/year after 2003. We conclude that this has a geophysical origin since no monument motions have been detected. A recent sea level decrease (1993–2007) of 4.7 ± 0.9 mm/year supports an absolute sea level increase of 3.2 mm/year as determined elsewhere by satellite altimetry.

1. Introduction

The Geodetic Observatory in Ny-Ålesund, Svalbard is located at 78.9° N and 11.9° E, on the south coast of Kings Bay (Fig. 1). The instrumentation includes a 20 m radio telescope dedicated to geodetic Very Long Baseline Interferometry (VLBI), several Global Positioning System (GPS) receivers, an automatic tide gauge, and a gravimetric laboratory, which houses a superconducting gravimeter and an absolute gravity point. A Doppler Orbitography and Radiopositioning Integrated by Satellites (DORIS) station operated by French Polar Institute - Paul Emile Victor (IPEV) and installed and maintained by Institut Geographique National (IGN) (Fagard, 2006), is also located in Ny-Ålesund. Observational data are submitted to the International VLBI Service (IVS) (Schlüter and Behrend, 2007), the International GNSS Service (IGS) (Dow et al., 2005), the International DORIS Service (IDS) (Tavernier et al., 2006) and Permanent Service for Mean Sea Level (Woodworth and Player, 2003).

The VLBI and GPS antennas are closely collocated. The DORIS ground tracking station is about 2 km from the other space techniques. The three consecutive DORIS antennas are located within 1 m, see full details in the DORIS station log file at http://ids.cls.fr/html/doris/stations/station.php3. The DORIS antenna needs to be sufficiently far away from the VLBI antenna, as its transmits at 2 GHz and 400 MHz. The 2 GHz frequency may interfere with the signal received from the quasar and recorded by the VLBI antenna.

The local ties between the geometric techniques are listed in Table 1. The local ties between NYA1 and the DORIS beacon agree at the 2 mm level with the local ties given in Steinforth et al. (2003). The local ties between NYA1 and VLBI agree with the mean of the 2000 and 2002 survey (see Steinforth et al., 2003). Relative to NYA1 the absolute gravity point is located 3 m east and the superconducting gravimeter 6 m east. The tide gauge is 1.5 km east of NYA1.

Ny-Ålesund contributes to determination of earth orientation parameters and to the realizations of international reference systems by International Earth Rotation and Reference Systems Service (IERS). The station is an important part of Global Geodetic Observing System (GGOS) (see Rummel et al., 2005, for a complete description of the scientific goals). Its high latitude provides a unique location for detection of global change effects.

The geodetic observing systems in Ny-Ålesund have been introduced and developed over a time span of two decades, often resulting from ad hoc processes in several institutions. Between 1976 and 1994 both terrestrial and space geodetic instruments were acquired and put into long term operation (see Fig. 2). The

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Table 1
Local ties Ny-Ålesund.

	ΔX (m)	ΔY (m)	ΔZ (m)
NYA1 - NYALES20 [a]	28.7970 ± 0.0020	102.1670 ± 0.0020	−6.4640 ± 0.0020
NYA1 - SPIA [a]	360.0158 ± 0.0020	1530.8425 ± 0.0020	−163.1802 ± 0.0022
NYA1 - SPIB [a]	360.0615 ± 0.0011	1530.8522 ± 0.0011	−162.9417 ± 0.0013
NYA1 - SPJB [a]	360.6707 ± 0.0012	1531.0386 ± 0.0012	−163.0782 ± 0.0013
NYA1 - NYAL [b]	−3.3186 ± 0.0002	−5.5789 ± 0.0002	−4.9743 ± 0.0004
NYA1 - NYA2	−54.3584 ± 0.0004	−157.7181 ± 0.0004	13.7831 ± 0.0010
NYA1 - SPKT	69.1208 ± 0.0003	258.3720 ± 0.0003	−33.6454 ± 0.0009

[a] Local ties used in ITRF2005 (from Altamimi et al., 2007).
[b] Note that the marker for NYA1 is the antenna reference point, while NYAL is referred to a brass marker on the foundation of the 5 m steel tower. This explains the 4.9 m difference in the Z component.

inclusion of VLBI led the Norwegian Mapping Authority (NMA) to establish Ny-Ålesund Geodetic Observatory in 1994 with permanent presence of technical staff for operation and maintenance. This represented a major strategic decision founded on national and international scientific goals. We briefly summarize the history of each observing technique as it was introduced in Ny-Ålesund.

A tide gauge was mounted by the Norwegian Polar Institute in 1976. It was operated (with some breaks) till 1992 when the Hydrographic Office of NMA installed an automatic tide gauge system at the new pier in Ny-Ålesund. These instruments have produced a time series of 3 decades.

A DORIS instrument (SPIA) was installed in 1987 on the roof-top platform of the Norwegian Polar Institute in Ny-Ålesund. It operated till 1999, when it was replaced by another unit (SPIB). A third (SPJB), now in operation, was installed in the same location in 2003. These instruments have produced a time series of 2 decades.

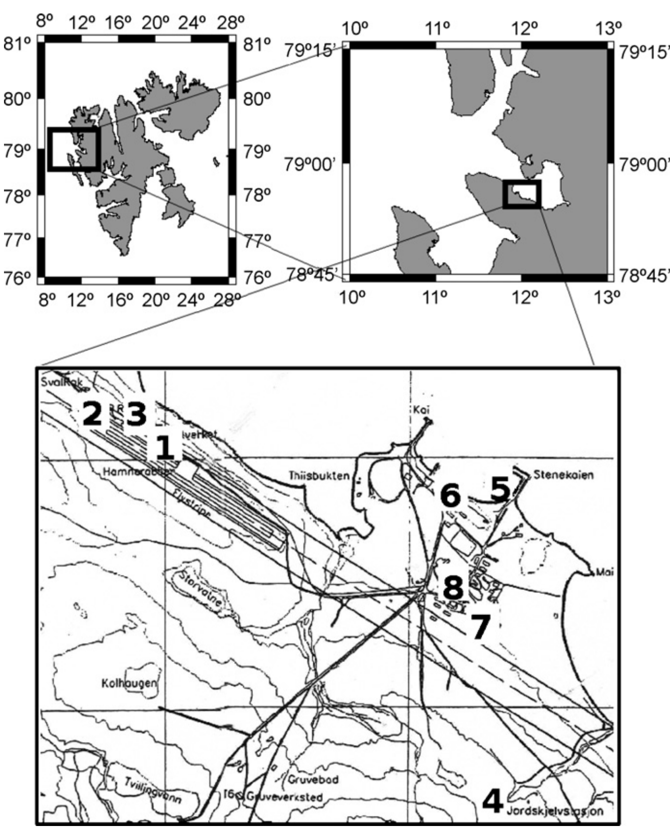

Fig. 1. Location of geodetic instruments in Ny-Ålesund. (1) VLBI antenna; (2) GPS receiver (NYA2); (3) GPS receivers NYAL and NYA1 as well as superconducting gravimeter and absolute gravity point; (4) Relative Lacoste–Romberg Earth tide gravimeter, also seismic observatory; (5) tide gauge; (6) tide gauge bench mark; (7) DORIS ground tracking station; (8) water vapour radio meter and balloon sounding.

A GPS system was installed by the Geodetic Institute of NMA in 1991 for participation in the GIG91 observing campaign organized by IERS. It became a permanent contributor to the global IGS network in 1992 with station name NYAL (NYAL is sometimes referred to as NALL, i.e. http://sideshow.jpl.nasa.gov/mbh/series.html and Sato et al., 2006b). A second GPS system, NYA1, was mounted nearby and has contributed to IGS since 1997. Other systems have been added later on separate monuments to serve a variety of purposes.

A VLBI facility was established by the Geodetic Institute of NMA in 1992–1994 in collaboration with National Aeronautics & Space Administration (NASA). Observations began on 26 October 1994.

A gravimetric laboratory was built by the Geodetic Institute of NMA. Absolute gravimetry has been made at this location since 1998 (Sato et al., 2006b). Since 1999 it houses a superconducting gravimeter owned by the National Astronomical Observatory of Japan (Sato et al., 2006a). It contributes data to the Global Geodynamics Project (see Crossley et al., 1999). See also Plag et al. (2000) for more details about the station.

Earlier studies have revealed inconsistent results between different observing techniques and different analysis strategies in Ny-Ålesund. For instance, in the ITRF2005 catalogue (Altamimi et al., 2007; http://itrf.ensg.ign.fr/ITRF_solutions/2005/ITRF2005_files.php) the vertical velocities are significantly discrepant. The VLBI up-component is 7.6 mm/year. The uplift of NYAL changes in 2003 from 9.1 mm/year to 14.4 mm/year. NYA1 changes in 2003 from 7.6 mm/year to 14.4 mm/year. DORIS vertical velocities range from 8.7 mm/year to 0.6 mm/year. Monument instability is indicated as a possible explanation, but is not qualified. A complete list of velocities from ITRF97, ITRF2000 and ITRF2005 are included in Table 2. Sato et al. (2006b) also note systematic differences between absolute gravity, VLBI, and GPS. They argue that a possible scale problem in the GPS system may explain the differences between GPS and VLBI.

In this paper we critically review the current coordinate data sets of each observing technique and the results derived from them. Particular efforts have been devoted to the identification of deviat-

Table 2
ITRF velocities for Ny-Ålesund.

	North (mm/year)	East (mm/year)	Up (mm/year)
ITRF2005			
NYAL(−2003)	15.4 ± 0.1	10.1 ± 0.1	9.1 ± 0.4
NYA1(−2003)	14.3 ± 0.1	9.8 ± 0.1	7.6 ± 0.1
NYAL(2003−)	14.3 ± 0.1	10.3 ± 0.1	14.4 ± 0.5
NYA1(2003−)	14.3 ± 0.1	10.3 ± 0.1	14.4 ± 0.5
NYALES20	14.2 ± 0.1	9.9 ± 0.1	7.6 ± 0.1
SPIA/SPIB (−2002)	14.8 ± 0.3	9.5 ± 0.3	8.7 ± 0.3
SPIB/SPJB (2002−)	9.9 ± 1.0	7.5 ± 0.9	0.6 ± 1.0
ITRF2000			
	14.0 ± 0.1	10.4 ± 0.1	6.4 ± 0.6
ITRF97			
	14.1 ± 0.3	10.0 ± 0.3	5.0 ± 0.9