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Uncovering Recent Tectonic Activity in Western Svalbard: A Reassessment of Fault Movements and Deformation Patterns

Laishram Sunil Singh[1], Arun Kumar[2]

[1]Department of Geology, Waikhom Mani Girls` College, Thoubal, Okram, Manipur, India
Email: *linus2k[at]gmail.com*

[2]Department of Earth Sciences, Manipur University, Imphal Canchipur, Manipur, India

Abstract: ***The western Svalbard fold - and - thrust belt has a complex tectonic history, that culminated with the opening of the North Atlantic Ocean. The last recognised important tectonic event in this area is dated from the late Tertiary, when sediments of the Ny Ålesund tertiary basin have been overthrusted by older, carboniferous rocks. From this late Tertiary event onwards, the area of Ny Ålesund (western Svalbard) is supposed to have mainly been affected by post - glacial rebound processes. By contrast, there is to date little or no information available for recent tectonic deformations. This has led previous workers to neglect or ignore a possible role of recent active tectonics in western Svalbard. However, in more recent times, high heat flow anomalies and a sparse seismic activity have been recorded offshore western Svalbard, suggesting that this province and its adjacent onshore continuation could still be tectonically active domains. The Ny Ålesund is located in the Brøgger peninsula, which is affected by several faults and deformation zones of uncertain age that, in places, control the landscape. Thus it represents a unique opportunity to attempt testing a possible activity for these structures, some of which are exposed in a spectacular section just below the antenna. The resultant vector is vector is 14.84 mm/yr with a azimuth 27.670 N with a vertical displacement of 7.62 mm/yr, which is not due to the isostatic rebound. It includes the local deformation. The preliminary results of our investigation appear broadly consistent with the hypothesis of active, or at least very recent tectonic activity in western Svalbard. If confirmed by further work, this finding may yield relevant constraints to an enhanced understanding of the recent tectonic evolution of the arctic region.***

Keywords: GPS, Crustal deformation, Ny Ålesund, isostatic rebound

1. Introduction

In order to carry out the crustal deformation studies of Artic Region an extensive geodetic network comprising of 3 stations (Figure1 and Table 1) has been established. The first GPS campaign measurements were first initiated during August 2009 with the establishment of 3 sites, in Ny - Alesund, Western tip of Ny - Alesund and Eastern tip of Ny - Alesund of Artic. These GPS campaign stations are equipped with Leica GX1200 GPS receivers with choke ring and Zephyr geodetic antennae. All the sites were been selected in the open area on the ground. The distance between two GPS point is about 30 km.

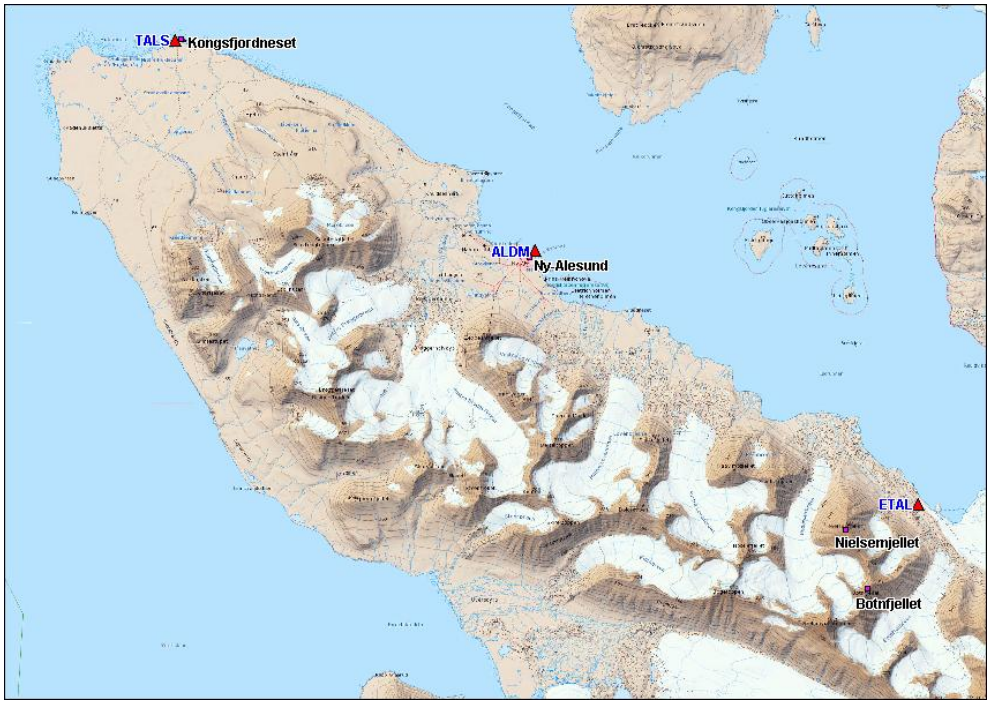

Figure 1: Location map of GPS Campaign site at Arctic Region

Geology & Tectonics

Ny- Alesund is located in NW Spitsbergen of Svalbard archipelago in the Arctic Ocean. It provides varied geo - logical structures and geo - historical development since the palaeo - Proterozoic time and is well known for having rocks of all the geological ages with multi orogenic development and prominent tectonic events [10, 11].

The last recognised important tectonic event in this area is dated from the late Tertiary, [12], when sediments of the Ny Ålesund tertiary basin have been overthrusted by older, carboniferous rocks. From this late Tertiary event onwards, the area of Ny Ålesund (western Svalbard) is supposed to have mainly been affected by post - glacial rebound processes.

Plag H. B. [13] of Norwegian Mapping Authority suggested that Western part of Svalbard, despite its nearness to the Mid - Atlantic ridge, is on the stable part of the European Plate. Tomasai and Rioja [14] further sup - ported the idea evident by small base line changes be - tween Ny - Alesund and Wettzell. However, in more re - cent times, high heat flow anomalies and a sparse seismic activity have been recorded from offshore western Sval - bard [15], suggesting that this province and its adjacent onshore continuation could still be tectonically active domains. Bockmann [16] reported indicate neo - tectonic movements and a possible small scale tectonic movement from the results of GPS campaign data in the region.

This region is usually considered to be stable from the plate tectonics standpoint. But if this is true for continental Scandinavia the situation of Svalbard is quite different. The western Svalbard fold - and - thrust belt has a complex tectonic history linked to the opening of the Northern Atlantic Ocean. This area is located close to the Horn - sund Fault Zone, one of the major active fault zones dur - ing the separation of the NE Greenland and Svalbard - Barents shelves. The last recognised important tectonic event in this area is dated from the Tertiary [12], when the Ny Ålesund Tertiary basin has been overthrusted by carboniferous rocks. But western Sval - bard is located only 150 km far from the Knipovich Ridge, which is considered an active segment of the Mid - Atlantic Ridge system. High heat flow anomalies and considerable seismic activity have been re - corded from offshore western Svalbard [15] showing that the area is tectonically active and in the Kings Bay area, minor seismicity may indicate some neo - tectonic activity. In this paper we introduce the GPS campaign network at Ny Ålesund, the GPS processing and present the results.

2. Network and GPS measurements

In order to carry out the crustal deformation studies of Artic Region an extensive geodetic network comprising of three stations (Figure1 and Table 1) has been established. The first GPS campaign measurements were first initiated during August 2009 with the establishment of three sites, in Ny - Alesund (ALDM), Western tip of Ny - Alesund (ETAL) and Eastern tip of Ny - Alesund (TALS) of Artic. These GPS campaign stations are equipped with Leica GX1200 GPS receivers with choke ring and Zephyr geodetic antennae. All the sites were been selected in the open area on the ground. The distance between two GPS point is about 30 km.

Table 1: GPS Campaign stations (WGS84: Geodetic - unprojected).

S. no	Name	Identifier	Latitude	Longitude	Height (m)
1	Ny Alesund	ALDM	78°55′38.11″	11°56′14.14″	33.46
2	Western tip of Ny Alesund	ETAL	78°52′17.66″	12°25′48.48″	65.98
3	Eastern tip of Ny Alesund	TALS	78°58′23.49″	11°28′28.38″	42.42

Figure 2: GPS Campaign site at Ny Alesund (ALDM)

Figure 3: GPS Campaign site at Western tip of Ny Alesund (ETAL)

Figure 4: GPS Campaign site at Eastern tip of Ny Alesund (TALS)

Methodology and data processing

The GPS data obtained from the permanent site has been converted into RINEX observation files and quality check has been performed using TEQC (Translation, Editing and Quality Checking Software). The quality check plots of all the GPS data were carefully examined and the data with high cycle clips were carefully examined and the data with high cycle clips multipath and <12 h observation were removed from the analysis.

The processing of the GPS data from station are routinely performed at Department of earth Sciences Manipur University. For obtaining the yearly solution, the data for the complete year is processed together, to yield the station co - ordinates and baselines with data collected simultaneously with surrounding IGS (International GPS Service) in ITRF (International Terrestrial Reference Frame) 2008 reference frame.

3. Results and Discussion

A combined solution using the observations in 2009, 2010, 2011, 2012 and 2013 is performed. The repeatability and velocity plots obtained in the daily solutions for the GPS campaign sites are shown in fig.5 and Fig.6. respectively.

The resultant vector of TALS is more than ALDM and ETAL. The maximum and minimum root mean square (RMS) errors are 0.003 m and 0.001 m respectively. The small values of RMS indicate the results obtained are precise and reliable.

Table 2: Estimated velocity

Station Code	East (mm. yr $^{-1}$)	North (mm. yr $^{-1}$)	Up (mm. yr $^{-1}$)	Resultant Horizontal Vector (mm. yr $^{-1}$)	Azimuth
ALDM	6.89 ± 2.0	13.14 ± 1.0	11.10 ±3.0	14.84	N 27.67º
ETAL	9.06 ± 1.0	11.82 ± 2.0	7.62 ±3.0	14.89	N 37.47º
TALS	9.75 ± 1.0	14.69 ± 1.0	8.84 ±3.0	17.63	N 33.57º

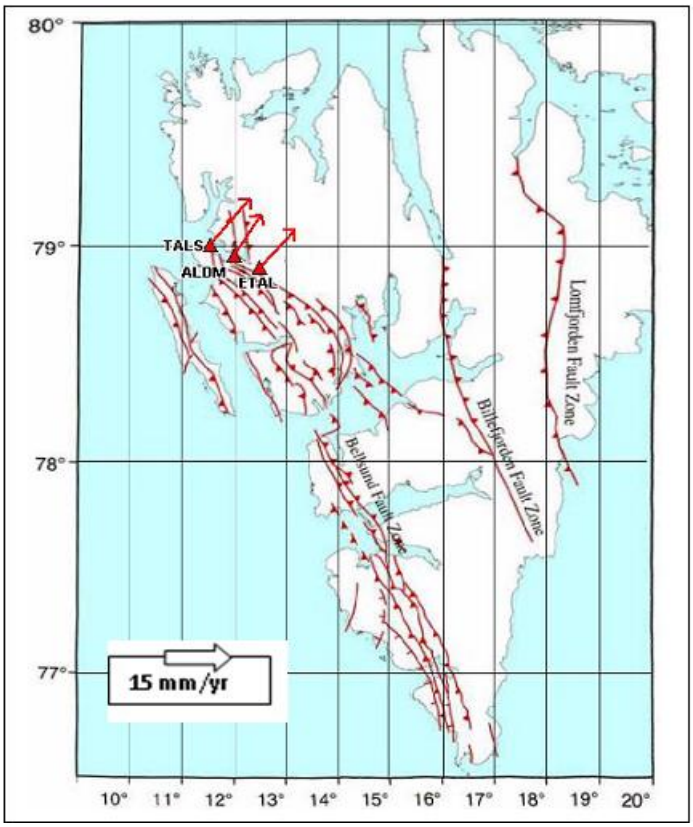

Figure 5: Estimated velocity plot along with the major tectonic features in and around Ny Ålesund area

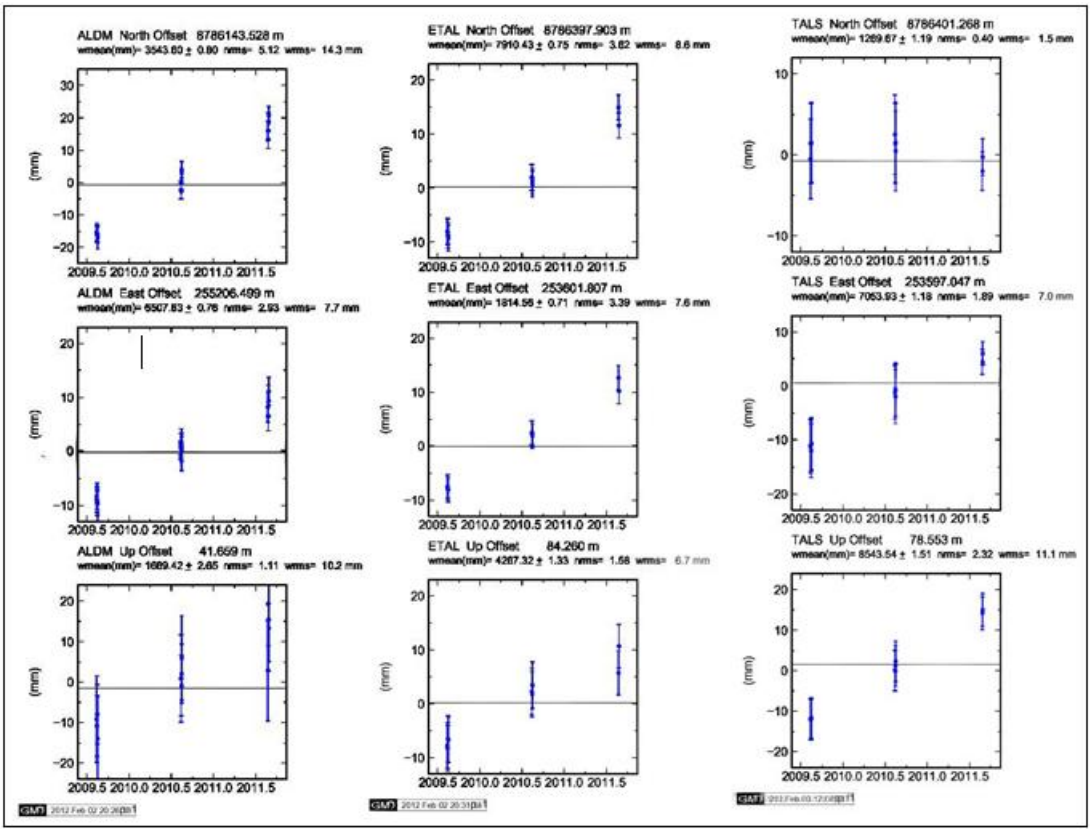

Figure 6: Time series plot of the campaign sites

It is readily seen that the RMS statistic is very well behaved and that there is no tension as each day of observation is added to the next. In particular there is no tension for the campaign data between the 2009, 2010, 2011, 2012 and 2013. This means that the detected movement at stations, ALDM, TALS and ETAL was well determined. There are local deformations along existing faults, which seems to be active.

We also compared our results with secular displacement and gravity rates observed in the Swalbard region where the Predicted Present Day Ice Melting rate of 2.04 mm. yr−1 for

the nominal melting rate of −47 cm. yr−1 gives a uplift rate of 5.1 mm. yr−1 that is consistent with the observed rate of 5.2± 0.6 mm. yr−1

4. Conclusion

It can be concluded from the above discussion that there are local deformations along existing faults, which seems to be active. The resultant vector of Ny - Ålesund (ALDM) is 14.84 mm. yr - 1 with an azimuth 27.67oN with a vertical displacement of 7.62± 3.0 mm. yr - 1, which is not due to only the isostatic rebound. The resultant vector is 14.84 mm. yr - 1 with an azimuth 27.670oN, a vertical displacement of 7.62±3.0 mm. yr - 1, which seems to be a higher estimate for isostatic rebound only at Arctic region.

The previous geodetic observations from Ny Ålesund and Greenland suggest the 5.6 mm yr - 1, in which the viscosity and gravity rates are considered in the isostatic rebound process. There is another effect of the ongoing geological processes (erosion, raised shore lines) which are due to the ice melting phenomenon at Ny Ålesun.

Our results are within the estimated rates of vertical displacement 12.5 to 6 mm. yr−1 from west to east. (Salvigsen et al.1991). Both poles have ice sheets, which exert more stress in the isostatic rebound.

We need to continue more observations of GPS campaigns to rectify the errors for precise results. Since, Svalbard archipelago consists of number of islands, a carefully designed follow - up micro - earthquake activity in the Svalbard region is necessary to correlate the deformation rates with tectonic and glacial quakes in order to derive the best estimates for isostatic rebound, which is due to the snow melting vis - a - vis climate change

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