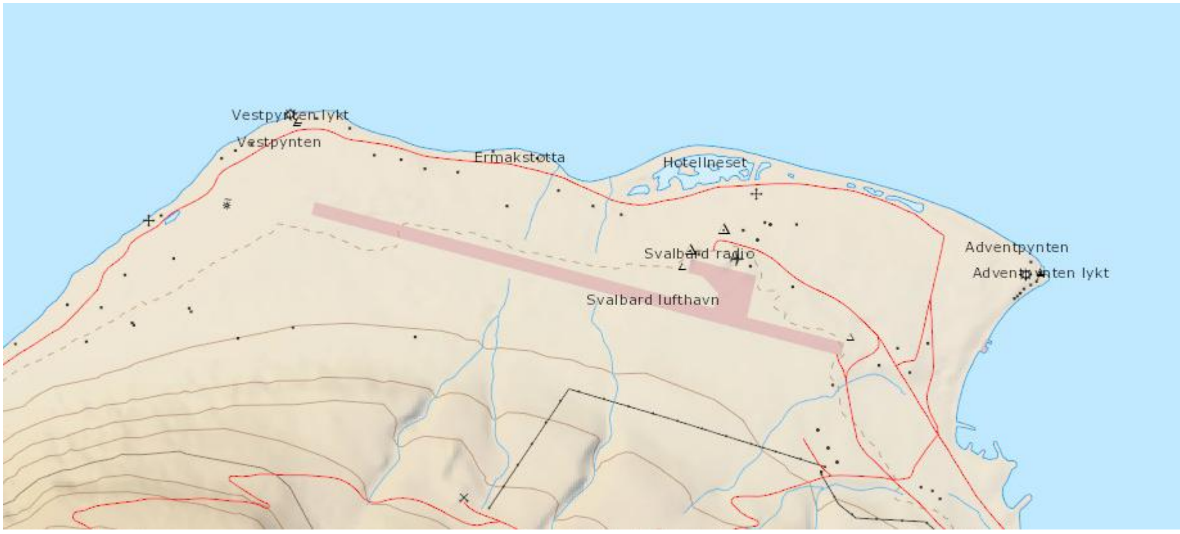
AT329 – UNIS February 2013

GNSS measurements at Vestpynten



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Contents

Introduction

This report is a result of fieldwork performed as a part of the course *Cold Regions Field Investigations* at UNIS, spring 2013. The goal of the fieldwork was to map the edge of the shoreline at Vestpynten, west of Longyearbyen. By mapping this shoreline several years in a row, one will be able to see how the erosion affects the shoreline. Also, one will be able to see the magnitude of this erosion and take action to prevent this erosion to reach the road and the airport.

1. GNSS field measurements

All field measurements rely on signals from enough satellites. In theory, one needs four satellites to get a correct position. Data from the four satellites solve the equation system with 4 unknowns; x, y, z and time. In reality one needs more than four, so that the additional satellites can correct the position you get from the first four. The more satellites you've got, the more correct your positioning will be. The RTK measurements of high quality receivers communicates with both the GPS, GLONASS and the Galileo system, making sure the required number of satellites always are available.

Our fieldwork was performed using real time kinematics (RTK). This is a method that highly improves the accuracy of the measurements compared to handheld consumer GNSS-systems available at the local hardware store. There are two important factors that distinguish RTK from handheld GNSS-systems: Phase measurements and real-time corrections from a reference base station. RTK measures the phase of the signal wave instead of the information content of the code sent from the satellite. Used correctly, this method can provide measurements with high accuracy. The relative accuracy of the measurements can sometimes reach millimeter-level, although the absolute accuracy will depend on the accuracy of the base station. This is very high compared to consumer GNSS-systems which offers an accuracy of maximum one meter.

Problems with RTK-measurements are connected to the phase-receiver. The receiver measures the signal of the carrier wave sent from the satellite. It can easily find the correct position within one wave length but it is difficult to accurately calculate the number of wavelengths between the satellite and the receiver. The position within each wavelength and the total number of wavelengths is used to calculate the travel time of the signal from the satellite to the receiver, which gives the distance between the two. The consequence of missing a given number of wavelengths is a drop of accuracy of about 20 centimeters (the wavelength of the signal), or a higher multiple of 20 centimeters. This makes a big difference when the accuracy we try to achieve is down to millimeters. High precision instruments are able to find the correct wave, and therefore have very high accuracy.

The difference between absolute code values and the relative phase values are large in satellite navigation. The absolute code values are sent from the satellite to the code receiver. It takes some time for this signal to travel to the receiver, and this time causes a delay between the local signal and the transmitted signal. This delay is calculated by matching these two signals. The problem is that the cycles of the code are so wide that even if you match the signals, there will still be some difference between the signals. This difference makes a very small signal time error, but as the wave is traveling at the speed of light the error in displacement can be several meters or more.

2. Reference base station

Local base:

Setting up a local base station is relatively straight forward. There are two options for obtaining coordinates of the base station. Either you know the coordinates from before (coordinates for public base points can be obtained from the mapping authorities) or you must perform a survey to measure the coordinates. If there are no base points within short distance the base point must be measured using the "classical static survey" method. Data is then collected over a time period of 20-120 minutes and averaged to obtain high quality coordinates for the base point. If you have other base points within 10 km you can calculate baselines from the existing base points to your desired local base point. A "short time static survey" is sufficient. Data is then collected over a time period of 2-10 minutes, the data is averaged and the result is high quality coordinates for the base point (given that the already existing base points have good quality coordinates).

Commercial base points:

Some commercial companies offer a network of base points in a range of countries. In Norway several networks are available, such as C-pos, Leica SmartNet and Blinken NTRIP. Leica SmartNet covers almost 100% of southern Norway and offers an accuracy of about 2 cm in ground plane and 4 cm in height. One of the advantages of the commercial networks is the ease of use offered. It eliminates the need of setting up a local base station. The rover antenna used for the measurements connects to the commercial network directly by GPRS. Also, the quality loss that occurs when the distance between rover and base station is large is almost neglected. All though you may find yourself miles from the nearest base station of the commercial network the network will automatically set up a virtual base station by cross-referencing the nearest base stations and thus minimizing the distance to the rover. The result is high quality measurements also in remote areas far from the nearest base station.

For our field measurements at Vestpynten no commercial base points supporting RTK were available. A local base station was set up using baselines from known base points in the area. The local base station was given the name P2013A. The baselines and the coordinates for the local base station were measured and calculated by the teacher and we were given the data for further processing.

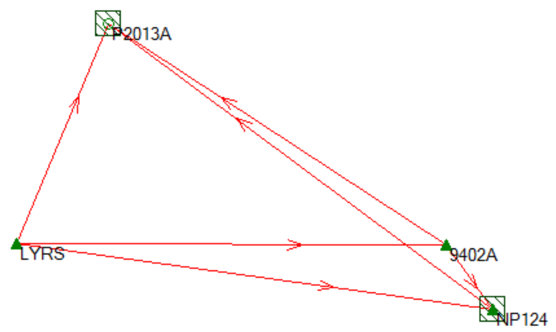

Figure 1: Known base points, baselines and the local base station P2013A

3. Control of baselines

The quality of the given baselines is highly important for the accuracy of the results of this report. This is due to the fact that they are used to calculate the coordinates for our base point P2013A, which directly affects the quality of the final points measured. To uncover errors in the baselines we have calculated the changes in the coordinates from one point to another. By summing these changes between all points and back to the starting point we should have a closed triangle, i.e. a sum of zero in the coordinate changes ΔX, ΔY, ΔZ and ΔHgt. However, there will be a small deviation from zero as perfect measurements are not possible to obtain by using GNSS. As long as this deviation is not too large the quality of the baselines is sufficient.

Table 1: Control of baselines

	9402 - P2013A	P2013A - NP124	NP124 - 9402	SUM
ΔX	-1346,935	1894,120	-547,183	0,002
ΔY	-4198,661	4880,021	-681,358	0,002
ΔZ	509,377	-624,316	114,940	0,001
ΔHgt	5,126	27,323	-32,447	0,002

As shown in Table 1 the summed deviations of the closed triangle consisting of the base points are limited to a few millimeters. This shows that the quality of the measured baselines is very good and we have established a good local connection between the base points. There may yet be a common error in the measurements giving poor results for absolute coordinates of P2013A if the quality of the given coordinates for the base points 9402 and NP124 are poorly established originally.

4. Control of base point P2013A

Calculating the new ellipsoidal height of P2013A:

By using the baselines from the different base points NP124, 9402 and LYRS to our base point P2013A we can calculate coordinates and ellipsoidal height of P2013A. The calculations are shown in Table 2 below. The final coordinates are obtained by averaging the coordinates from Table 2, the result is shown in Table 3. The largest difference in the coordinates from Table 3 gives us a measure of the accuracy of the averaged coordinates, as shown in Table 4. The result is an accuracy of about 2-3 cm for the northern and eastern coordinates and 1.3 cm for the ellipsoidal height. The accuracy of the ellipsoidal height is unusually good and the fact it is more accurate than the coordinates is troubling. However, it is important to keep in mind that the calculated accuracy will uncover irregularities between the given base lines only. A common error in the measurements will not be uncovered by this method of estimating the accuracy.

Table 2: Calculation of coordinates for P2013A using baselines

				From point to P2013A			*Coordinates for P2013A*		
	UTM, N	UTM, E	H_{ell}	ΔN	ΔE	ΔH_{ell}	UTM, N	UTM, E	H_{ell}
9402	8683919,365	513764,316	34,073	2440,447	-3705,504	5,1256	8686359,812	510058,812	39,1986
NP124	8683206,137	514280,549	66,535	3153,671	-4221,758	-27,3231	8686359,808	510058,791	39,2119
LYRS	8683937,586	509048,138	495,682	2422,198	1010,666	-456,4823	8686359,784	510058,804	39,1997

Table 3: Calculated coordinates for P2013A from baselines

Coordinates for P2013A		
UTM, N	UTM, E	H_{ell}
8686359,801	510058,802	39,203

Table 4: Accuracy of calculated coordinates for P2013A

Accuracy for P2013A [m]		
ΔN	ΔE	ΔH_{ell}
0,028	0,021	0,013

From the results obtained above the new ellipsoidal height of P2013A is set to 39.203 m.

5. Setup in the field

Receiver at the base station:

While performing the measurements of our desired points the rover was continuously given corrections from the local base station. The GNSS-receiver at the base point was set up using the previously calculated coordinates of P2013A. The receiver calculated the deviations between the position measured by signals from satellites and the known coordinates of the base point. These deviations were sent to the rover via GSM as real-time corrections of the measurements performed. In order to achieve high quality base station measurements the receiver at the base station was set up using both GPS and GLONASS satellite data. The cut-off angle was set to 10 degrees to avoid disturbances from signals travelling through large distances in the atmosphere. Logging time interval was set to 2 seconds.

Rover:

The measuring method GNSS Standard was chosen. Raw data logging was set to static (2 seconds). The rover was told to collect data from both GPS and GLONASS satellites to ensure a good connection and high accuracy results.

Table 5: Settings for both rover and base station

Coordinate system:	*Euref89 UTM33Utv*
Geoid model:	*N/A*
Code list:	*GisLine GPS*

As shown in Table 5 both receivers were set up using Euref89 UTM33Utv. This enables us to present the data in a coordinate format that is used by the authorities at Svalbard and makes it easy to plot the data in an appropriate mapping program or a printed map. No geoid model is available for Svalbard, the geoid height is therefore calculated using known heights of base points in the nearby area.

6. Calculation of geoid heights and final coordinates

To find the height of the geoid in P2013A we had to use the coordinates for NP124, 9402 and S082. From this coordinates we could make a plane, and then extrapolate this plane to the coordinates of P2013A and achieve the geoid height in this point.

Table 6: Known coordinates and geoid heights

	UTM N	UTM E	H geo	H ell	N
NP124	8683206,137	514280,549	34,9	66,535	-31,635
9402	8683919,635	513764,316	2,53	34,073	-31,543
S082	8686066,308	511260,593	17,601	49,374	-31,773
P2013A	8686359,81	510058,802	Ukjent	39,203	Ukjent

This was done by finding the projection of the plane onto a straight line northwards from P2013A, and then finding the slope of this projection. We did this by finding the northern gradient when moving eastward. Then we extrapolated the line from NP124/9402A through S082 to a line straight north from P2013A. This calculation can be seen in Table 7. Combining this with the slope of the lines through S082 we found two points with different height straight north from P2013A, as seen in Table 8. This line was then followed to our base point, P2013A, finding the difference between the ellipsoidal height and the height of the geoid in P2013A. As seen in Table 9 this height was found to be -32.263 meters. Then we had a straight line, and could easily find the geoid height in P2013A.

Mark: All the calculations are performed using 39.206 as the height of the geoid in P2013A.

Table 7: Plane projected onto a line northwards from P2013A

	dN	dE	N/E	N	dN for P2013A
NP124 - S082	2860,171	-3019,956			
			-0,947090289	1138,204585	844,7025852
9402A - S082	2146,673	-2503,723			
			-0,857392371	1030,406435	736,9044353
S082 - P2013A	293,502	-1201,791			

Table 8: Geoid heights of points projected on a line northwards from P2013A

	Lengths	dH	dh/dL	Lenghts	H extrapolated	H
NP-S	4159,412506	-0,14	-3,31778E-05	1655,237531	-0,054917078	-31,82791708
9402-S	3298,004522	-0,23	-6,97391E-05	1583,047387	-0,110400364	-31,88340036

Table 9: Line trough projected points to P2013A, finding the geoid height

Line:	dH	L	H Extrapolated	N P2013A
P2013A	0,055483286	107,7981499	0,434765117	-32,26268219

When we had the difference between ellipsoidal height and the height of the geoid we could find the height above mean sea level (AMSL) for our base point and sampling points. This was done easily by correcting from the ellipsoidal height. The AMSL height for our base point was found to be 6.940 meters. The other results are presented in Table 10 below.

Table 10: Final coordinates

Point	North	East	AMSL [m]
P2013A	8686359,81	510058,802	6,9403
F001	8686425,891	509843,416	4,8103
F002	8686427,019	509836,333	5,0233
F003	8686429,356	509826,152	4,8493
F004	8686430,007	509820,2	4,9963
F005	8686432,249	509812,155	4,8423
F006	8686436,519	509799,386	4,5193
F007	8686438,579	509792,986	4,3893
F008	8686440,437	509787,71	4,3383

To visualize this results we have made an overview in the figures below. Figure 2: Plot of measured heightsFigure 2 shows the height of the coordinates, while Figure 3 shows the eastern and northern coordinates for our measurements. The base point, P2013A, is marked with a red dot, the rest of the sampling points are shown as blue dots.

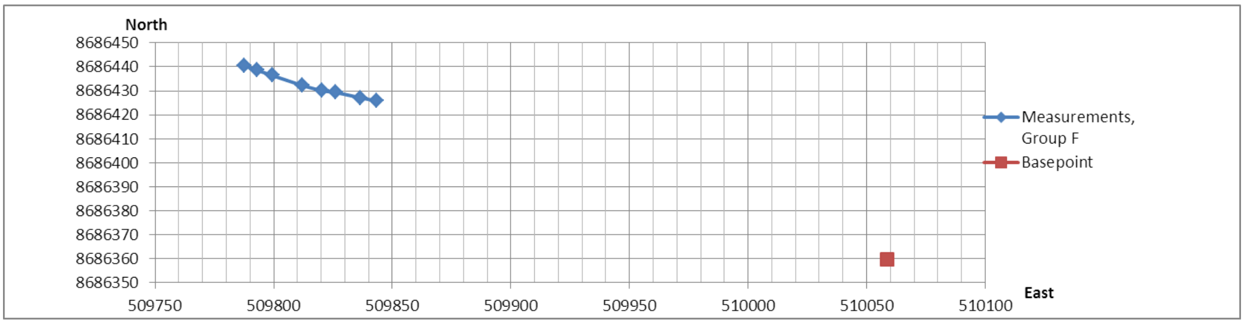

Figure 2: Plot of measured heights

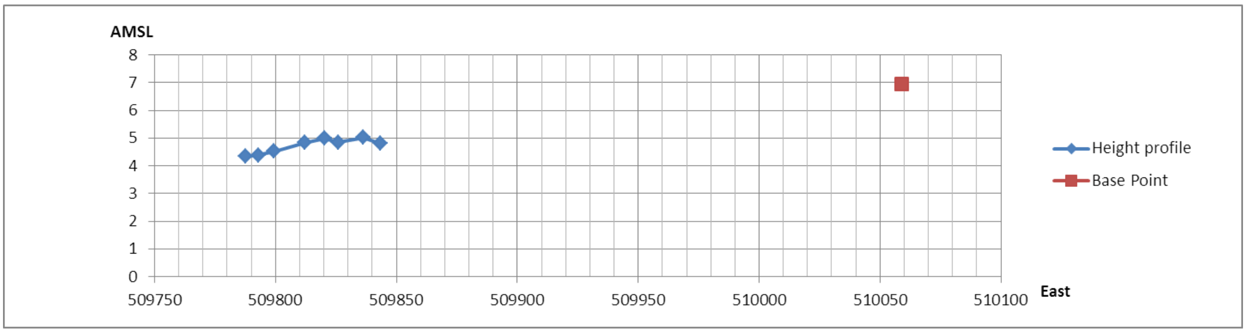

Figure 3: Plot of measured coordinates

7. References

All background information was obtained from GNSS lecture notes available for the AT329 course.