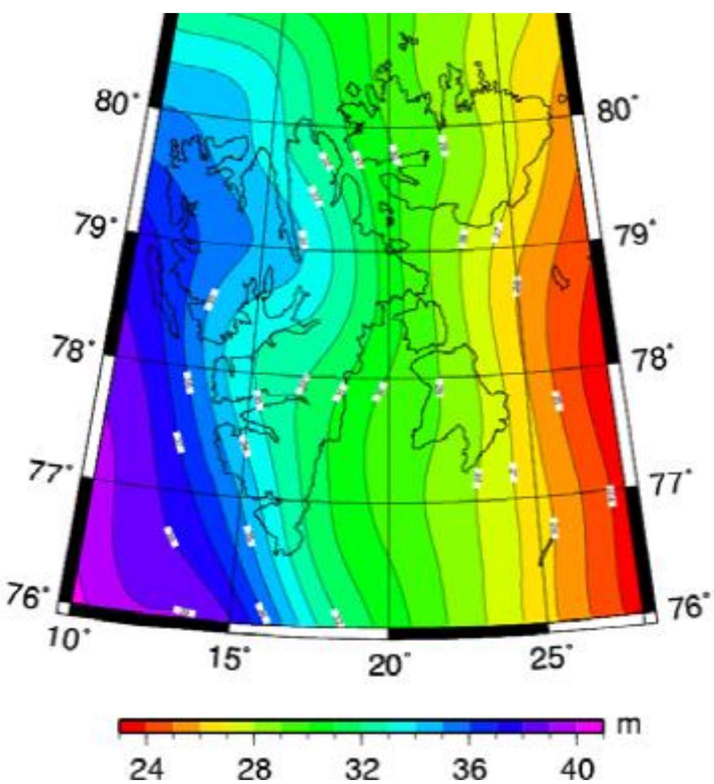
University Centre in Svalbard

AT-329 Cold Region Field Investigations
Spring 2011

DGPS measurements of drilling positions in Adventdalen

February 2011



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This paper discusses the measurement, processing steps and the problems involved to DGPS measurements nearby the weather station in Adventdalen

Abstract

"Traditional geotechnical investigations in remote areas in Arctic regions often require large resources and are therefore costly. Geophysical investigations are supplements to traditional investigations and the methods make it possible to obtain data as to stratigraphy and permafrost ground features with relatively light equipment."[1]

The following report provides a short overview to the background of Differential GPS measurements in cold regions by focusing on field work measurements realized during the course AT-329 in spring 2011.

The survey has been taken in Adventdalen near Longyearbyen to fix precise locations of a set of bore holes used for ground investigations.

Furthermore the report includes a discussion raw data post-processing and in particular mapping of coordinates between different reference systems.

The following report provides a short overview to the background of DGPS measurements in cold regions by focusing on field work measurements realized during the course AT-329 in spring 2011.

[1] AT-329 course description http://www.unis.no/10_STUDIES/1020_Courses/Arctic_Technology/at_329.htm

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Background Information

DGPS Principle

While GPS measurements with hand held receivers only achieve accuracy levels in the range of several meters, Differential GPS (DGPS) measurements reach a centimeter level of accuracy. This is done by measuring relative to a known reference spot. As the field site position and the reference point are close to each other we assume that the deviation from the real position to the measured position is nearly the same for both measured points. As we know the exact position of our reference point, we are able to calculate the position of the requested point in relation to this point. Thereby we filter out the faults due to ionospheric or tropospheric disturbance as well as satellite clock bias and orbit uncertainties.This principle is shown in Figure 1.

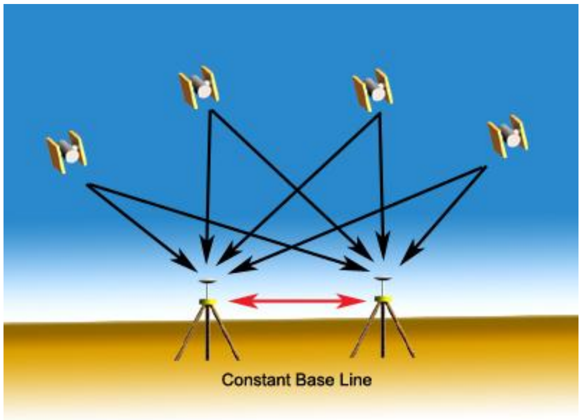


Figure 1 DGPS principle

In our case we took these reference GPS measurements at a point close to Sysselmannen (NP 124) over the whole period of the field site measurements.

Equipment

Figure 2 Leica GPS 1200 receiver

Our tools for taking the DGPS data out in the field are two Leica GPS system 1200 receivers (Figure 2). One receiver was set up at the base station at Sysselmannen (NP124), while another receiver was used to take the actual points in the field. We observed quite a good satellite contact receiving signals from nine up to twelve distinct satellites.

Still we did not get any valid signals from the Russian GLONASS system satellites. The reason for that is unknown.

Data Collection Methods and Terms

Total logging time is the duration at which measurements are taken at every point. A larger time window improves the accuracy of the taken GPS coordinates. In our case we supposed a 10-12 min logging time as sufficient.

Logging time interval describes the time interval between capturing a signal sample as long as the equipment is logging. A shorter interval results in higher data consistency and possibly higher data quality. We set the interval to 2 seconds which leads us to about 330 measurements at every point (at 11min sampling time).

Antenna height is the height of the GPS receiver relative to the actual measuring point. The GPS receiver is mounted on a pole which in our case has been 207cm long. Overall there might be some inaccuracy limiting the sampling quality as the underground wasn't well defined. Snow and ice cover of the surface may lead to divergences in the measured heights depending on the force where the pole has been pressed on in the snow interface.
As we in our case we are only interested in the position of the drilling holes, height is not important for this matter.

Cut-off angle describes the minimum angle for satellite signals we still take into account for our measurements. Signals from satellites which have a position to low above the horizon may be inaccurate due to high ionospheric and tropospheric noises or multipath errors from mountains or buildings. Typical cut-off angels are between 10° and 15° (Figure 3 using 15°), in our case we have set the cut-off angel at 10°.

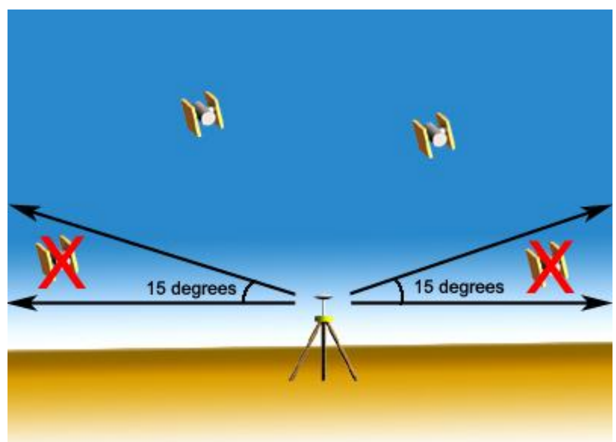


Figure 3 Cut-Off Angle

Kinematic surveys are used for measuring point locations where an accuracy of several cm is sufficient. Also kinematic surveys require a setup with two units including the stationary base unit and one (or more)mobile rover units. Kinematic surveys rely on continuous tracking to resolve the integer ambiguity. While the rover receiver/antenna may be moving during the surveys, continuous lock on the satellite signals must be maintained. Since the data processing software is able to both resolve the ambiguity and track the antenna motion, fixed-integer solutions are obtained nearly instantaneously.

Code, Float and Phase (Fix) solutions describe different levels of accuracy obtained for GPS observations. Code solutions have the least precision when the receiving unit is not able to determine a float or phase solution. This typically happens when survey time window is too short in relation to the distance between (stationary) base unit and the (moving) mobile rovers.

Accuracy for code solutions can reach a sub-meter range. Float solutions have a higher accuracy in signal data and may reach precision in centimeter ranges, but still are not as accurate as phase (or fix) solutions. Phase solutions require sufficient observation time which is dependent on distance to base unit, but signal quality is also depending on the number of satellites to be received as well as ionospheric influences such as noise. Fix solutions will reach accuracy in low or even sub-centimeter range.

Survey Setup and Description

The DGPS survey has been take at a field site in Adventdalenand is used as basis for this report. The raw data collected in during the survey is been processed using the Leica Geo Office computer program. Coordinates have been transformed from WGS84 datum to EUREF89 datum and UTM-projection using 3rd party mapping application.
To transform the heights of the four drilling holes above the geoid to the ellipsoidal heights, reference data from the two control points (NP124, NP136) and a detail point (bore hole BH82) close to Longyearbyen are used.
By using the new (EUREF89) coordinate system and the data of the two control points NP124 and NP136, coordinates of the four points in the EUREF89 datum are also transformed to the ED50 datum using a conformal Helmert transformation.

During our field survey the receiver was configured for kinematic survey mode. While static survey style has a typical accuracy in sub-cm precision, the kinematic style allows for an average accuracy of few centimeters andhas been considered sufficient for the measurements taken in our course. To deliver the high accuracy of static survey, data collection is typically run for multiple hours and up to several days. The way we collected data at the field site is also called stop-and-go survey or rapid static survey, and allows capturing of data rather quickly with just enough survey time to be able to resolve integer ambiguity. Recommended time window in this mode is 10min per point. The profile survey we did at the field is considered a true kinematic survey and allows to capturing of data in just a few seconds still with an accuracy of few centimeters.

Field Location

A stationary base unit has been setup as reference point at a well-known location close to the Sysselmannen office in Longyearbyen marked as NP124. The survey area is located in Adventdalen southeast to the reference point in distance of about 5100m.
The map in Figure 4 displays the position of the reference point and positions of investigated drilling holes in the survey area.

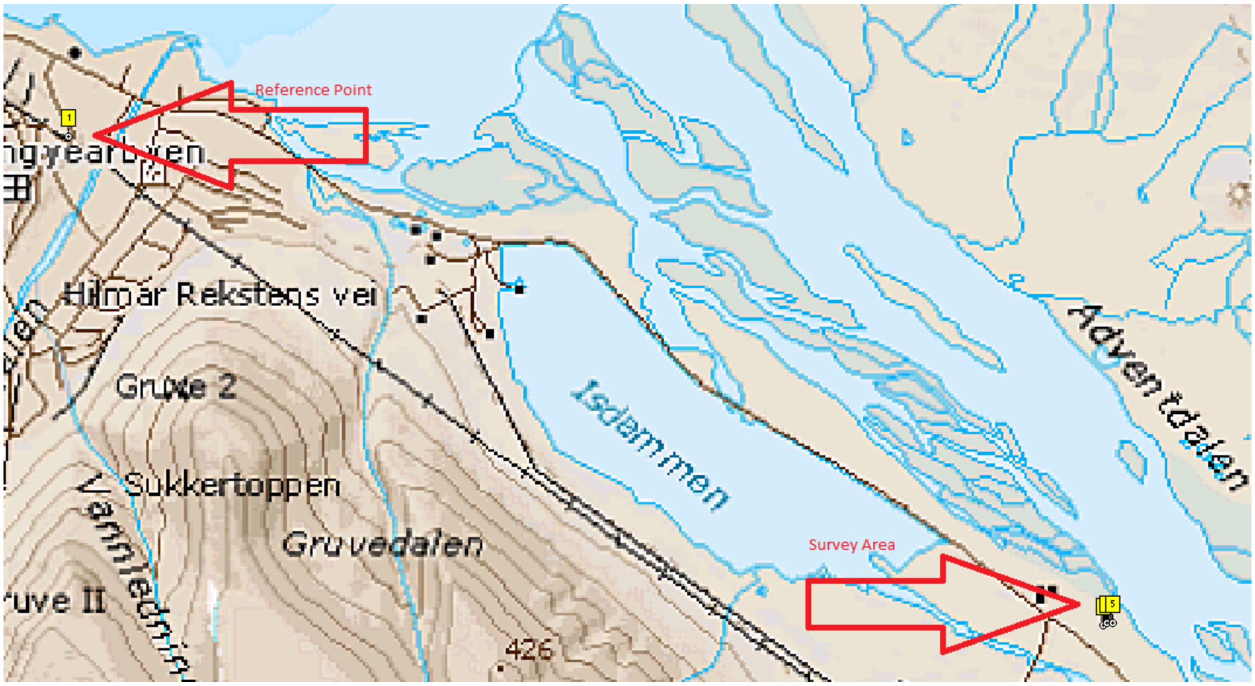


Figure 4 Location of reference point and field survey area

The Table 1 shows the known data for the reference base station and data captured from our mobile rover during the survey.

Point	Latitude	Longitude	Ellipsoidal height, H_{ELL}
NP124	78° 13' 18.70038" N	15° 37' 36.18429" E	66.799
P1	78° 12' 06.71099" N	15° 49' 39.08617" E	37.159
P2	78° 12' 07.23916" N	15° 49' 41.08461" E	37.651
P3	78° 12' 07.45547" N	15° 49' 45.16361" E	37.703
P4	78° 12' 07.45693" N	15° 49' 45.16470" E	37.618

Table 1 Reference point and drilling holes datasampling

Processing

Every measured point is consisting of an average of around 330 single measurements. But these measurements can still be wrong in the range of several meters. By processing the data and combining it with the data of the reference point NP124 we reach the accuracy we are looking for. Dependent on the quality of the data we may reach a code, float or phase solution. We had some problems with our data probably because the reference point was too far away from our measurements (about 5km). We probably should have measured even longer than 11 minutes to reach a phase solution with an accuracy in the range of 0.5-1 centimeter for all four points. We only reached two float and two phase solutions.

Calculations

Datum shift to UTM (EUREF89)

Our GPS receivers took coordinates in the geodetically reference system WGS84. In many cases it is more practical to use Cartesian coordinates as UTM (Universal Transverse Mercator). UTM data requires a map system reference, in our case this is EUREF89, UTM, zone33. Without given references UTM data could not be used at all.

Further calculations have been done using Microsoft Excel, the result for our own point measurements are shown in table 3 below, while the profile measurements result in table 2.

Datum shift to ED50

It might be necessary to handle old positioning data from Svalbard. This data is often taken in another UTM datum called ED50. This datum is around 200m shifted to the North and 80m shifted to the East.

Norwegian Map Authorities (Statens Kartverk) released a software application which helps transforming coordinates for different reference systems, but this solution can only be used for coordinates on Norwegian mainland. For Svalbard however, different mathematical formulas have to be used. To map the collected coordinates from EUREF89 into ED50 compatible dates, the following formulas (Helmert transformation) have been used:

$$N_{ED50} = 278.1890 + 0.9999920655 * N_{EUREF89} -1.22007 * 10^{-5} * E_{EUREF89}$$

$$E_{ED50} = -36.0839 + 0.9999920655 * N_{EUREF89} + 1.33007 * 10^{-5} * E_{EUREF89}$$

We exemplary calculated the datum shift forthe profile data ofthe group 3 at Nykai and Bykai as we did not have an own profile. The results are shown in Table 2. The results of our own data are shown in Table 3 further down.

Point	N	E	EUREF89 N	EUREF89 E	ED50 N	ED50 E
100	78°13.3711’	15°36.5029’	8683772.544	513981.694	8683974.996	514057.032
101	78°13.3727’	15°36.5060’	8683777.525	513983.565	8683979.977	514058.903
102	78°13.3740’	15°36.5094’	8683780.857	513985.373	8683983.308	514060.711
103	78°13.3761’	15°36.5138’	8683787.467	513988.078	8683989.918	514063.416
104	78°13.3771’	15°36.5160’	8683790.525	513989.364	8683992.976	514064.702
105	78°13.3811’	15°36.5259’	8683802.826	513995.530	8684005.277	514070.868

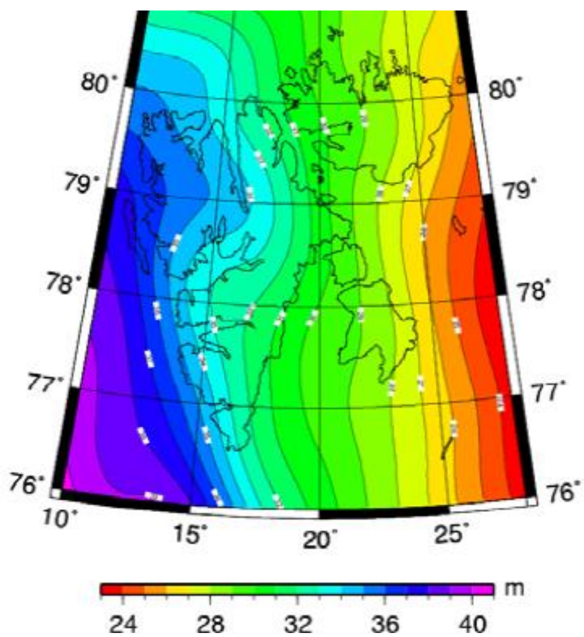
Table 2 Profile data sampling

Geoidal height

The geoidal height model is taking into account that the earth surface is not a perfekt ellipsoid. The variations to this ellipsoid are shown n principal in Figure 5. The model sets local mean sea level values at every point of the surface. With help of Figure 6we can observe that the geoididal height is between 26 and 38 meters above the ellipsiodal surface for the Svalbard area.

The height above sealevel corresponds to

H = E – G , where E is the ellipsoidal height and G is the local geoidal height.



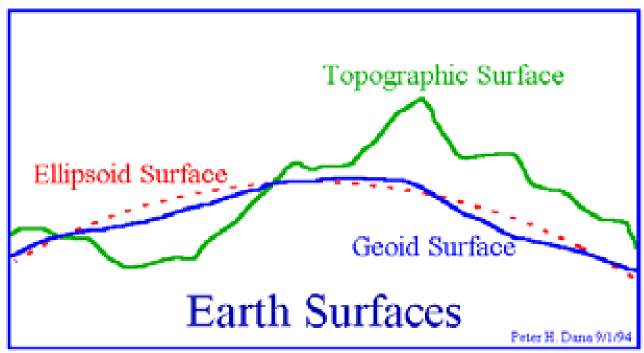


Figure 5 Geoidal Height model

Figure 6 Geoidal Height Reference Map

Furthermore there is a local model for calculating the geoidal height at any point in the Svalbard area in relation to a given point. We know that the geoidal height at Sysselmannen (NP124) is 31.729m. With

N = Dx + Ey + F , where

N = Geoidal height (HMSL) at the given point
D = $1.71540833 * 10^{-06}$
E = $9.62418251 * 10^{-07}$
F = 31.729 m
x = distance in x value to reference point
y = distance in y value to reference point

we get N for every point in our measurements and can also determine the actual heights above means se level. In our case we found N to be 31.737m for all four points we measured (Table 3). This is not surprising as the points are located very close to each other.

Point	*N* EUREF89-UTM-zone 33	*E* EUREF89-UTM-zone 33	*N* ED50-UTM-zone 33	*E* ED50-UTM-zone 33	Ellipsoidal height, H_{ELL}	Height above mean sea level, H_{MSL}	Geoidal height, *N*
NP124	8683206.071	514280.722	8683408.523	514356.050	66.799	35.070	31.729
NP136	8690118.116	513390.278	8690320.525	513465.705	67.608	35.868	31.740
BH82	8686066.304	511260.759	8686268.758	511336.112	49.374	17.643	31.731
P1	8681031.414	518887.690	8681234.393	518962.953	37.159	5.422	31.737
P2	8681047.965	518900.128	8681250.944	518975.391	37.651	5.914	31.737
P3	8681055.036	518925.892	8681258.015	519001.155	37.703	5.966	31.737
P4	8681055.082	518925.898	8681258.060	519001.161	37.618	5.881	31.737

Table 3 Datum system mapping for bore hole coordinates

In addition we exemplary calculated the geoidal heights for the profile data of the group 3 at Nykai and Bykai as we did not sampled own profile data.
For point 100 we get a value of 31.730m calculating the geoidal height from the reference point NP124. The other points and distances (Table 4) we have calculated from this point 100 as a reference. Again we get the same geoidal height value for all points (Table 5). This is expected since the points are so close located to each other as mentioned before.

Point	EUREF89 East	EUREF89 North	$X - X_{P100}$	$Y - Y_{P100}$	Distance to Point 100
100	513981.694	8683772.544	0.000	0.000	0.000
101	513983.565	8683777.525	4.981	4.981	7.044
102	513985.373	8683780.857	8.313	8.313	11.756
103	513988.078	8683787.467	14.923	6.610	16.321
104	513989.364	8683790.525	17.981	9.668	20.415
105	513995.530	8683802.826	30.282	12.301	32.685

Table 4 Datum system mapping for profile coordinates

Point	Geodial Height	Ellipsoidal Height	HMSL
100	31.730	34.581	2.851
101	31.730	34.548	2.818
102	31.730	33.141	1.411
103	31.730	33.330	1.600
104	31.730	32.834	1.104
105	31.730	32.586	0.856

Table 5 Geodial height calculation for profile sampling

Other Observations

While processing data we observed that we could not get phase solutions for all of the sampled data points. We assume that the average observation time of 11min per data point was not sufficient in relation to the distance to the reference point of more than 5km. Unfortunately there was no option available at the field side to draw this conclusion. If higher accuracy data is required based on phased solutions, a new survey needs to be setup including larger time windows for data sampling at each point.
Another noticeable observation is the varying quality of satellite data. While most of the received satellite signals reached a reasonable signal level, data from some satellites seem to have a low quality, which could be raised by background noise or other ionospheric signals (Figure 7). For data processing in LGO software, we therefore disabled data from these satellites which helped to improve quality of data during the processing steps.

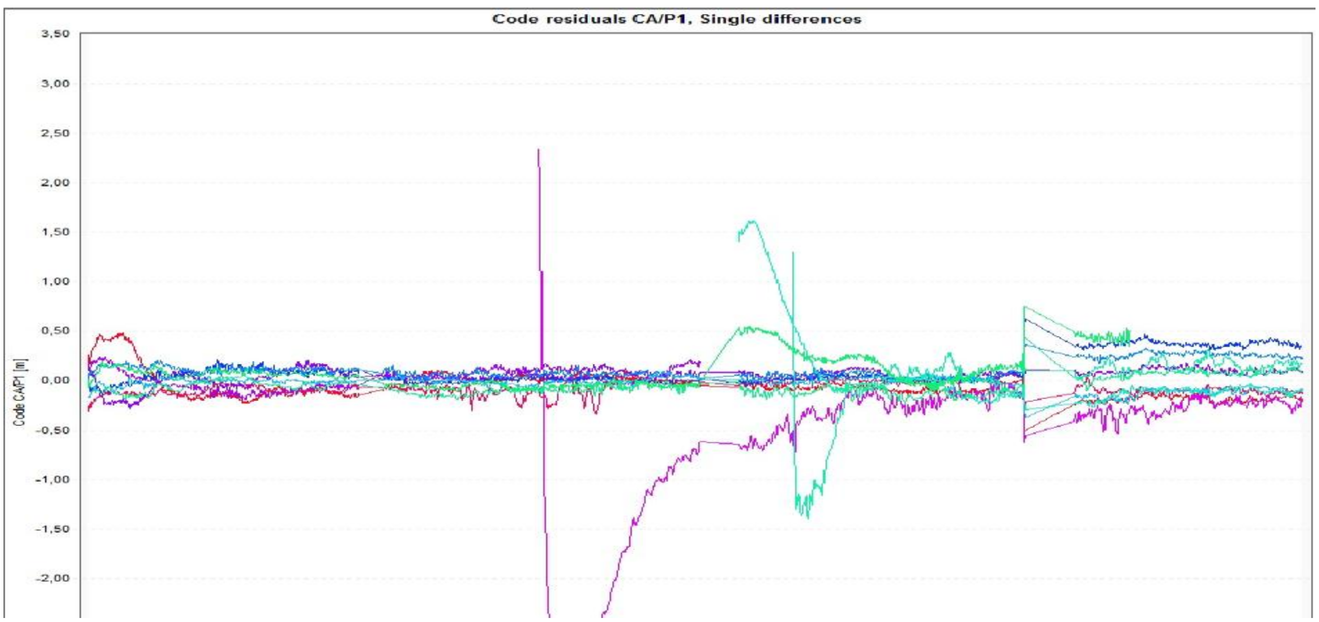


Figure 7 Satellite signal data quality

Conclusion

Differential GPS allows position fixing on earth surface with a high level of accuracy, compared to other methods and conventional GPS surveys. However as part of the exercise we learned that there are a number of conditions which can influence the accuracy of surveys, such as satellite based issues due to background noise or ionospheric influence on the signal data. Also the distance from base station is an important factor to be considered during survey setup, and in particular the sampling time window will have impact to the accuracy one can expect from DGPS measurements.

Another important part to keep in mind for position determination is the reference system to be used. There are different reference systems available and collected data could be transformed between the systems. However for each position data sampling it is important to know which reference system has been used as base.

As there is no geoidal height model for Svalbard available, heights had to be calculated based on the date for the reference point NP124 which may limit accuracy of the height coordinates. However for the drilling holes surveyed, height is not of that same importance as accurate position.