Practical Consequences of Having a "Moving" Geodetic Network with Fixed Coordinates

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Introduction

Some months ago I started on a job where the objective was to find out how we shall monitor the movement of our country?

Following main questions were raised:

How many stations are necessary to give us velocities of our country in 3 dimensions with sufficient accuracy?

How often is it necessary to observe? Do we need permanent geodetic stations or is it sufficient with campaign based observations at regular intervals or my be the best solution is a combination?

During this work another question occurred.

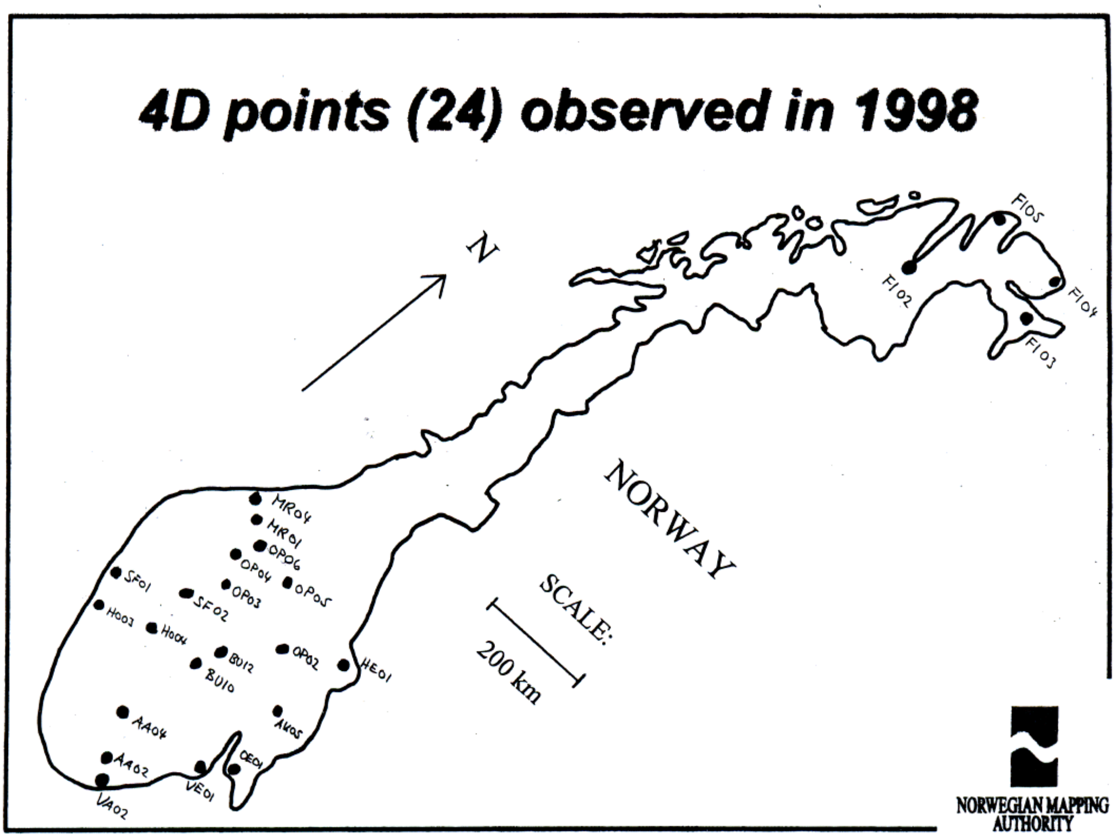
Is it possible to have a "moving" geodetic network with fixed coordinates?

This article describes an analysis of the movement which has taken place from 1989 to 1998. Further on I do an exercise of thinking about what impact has this movement on different "observation techniques".

Data acquisition

The data for the study were campaign based reobservation of 24 point in our basic geodetic network ("stamnettet") which were observed for the first time in 1994.

The reobservation was done in 1998. We called the points 4D points just to emphasize the time dimension in addition to geometric space dimension x,y,z. See figure below.



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The observations were done with Ashtech Z-Surveyor receivers (dual frequency) with chokering antennas. Observation time were 3 days of 24 hours. 12 of the points were observed in June 1998 and 12 points were observed in October 1998.

Data analysis

The 1998 data were analysed with the GIPSIY software (developed by JPL). The method was so called " Single point positioning". Face and code (dual frequency) data from only one station is used. In addition we need precise orbits, precise clock corrections and earth rotation parameters.

Comparison ITRF97 epoch August 1998 coordinates with EUREF89 coordinates.

When I compared these current epoch coordinates expressed in the reference frame ITRF97 with EUREF89 coordinates, I saw significant differences. That is of course what to be expected for many of you.

What I am bringing you into now is probably not very high scientific stuff. Something what I am writing may not be strictly correct or may be I am not telling you the whole truth because I do not know it yet.

But my intention, seen more from a surveyors viewpoint, is to take you into some exercise in regarding reference frames, crustal movement and different "observation techniques". The way of thinking is correct even if not the details my be strictly correct. And I hope it is as valuable for some of you as it was for me when I started this work.

I very soon realised that vertical movement (caused by post glacial rebound) gave me more trouble than the horizontal so I concentrated on the horizontal coordinates north and east.(topocentric system). I compared coordinates for 24 points expressed in reference frame ITRF97 at epoch August 1998 with coordinates for the same points expressed in EUREF89.(9.6 year difference). See table of differences in coordinates below.

The points are grouped geographically. The two letters indicates different counties. The points starting with letters FI indicates Finnmark county in the northern Norway. The others are in southern Norway. You can see a slight difference in the values given for these two groups. Later I will show that this is due to a small rotation around the vertical axis.

It was at that point I raised the question: Is it possible to use a geodetic network with fixed coordinates when the coordinates are really changing? I realized very soon that the answer could be both yes and no.

Table: Differences ITRF97aug1998 and EUREF89 in meters

Point id:	North direction	East direction:
FI02	0.209	0.086
FI03	0.205	0.092
FI04	0.218	0.083
FI05	0.202	0.086
MR01	0.193	0.105
MR04	0.181	0.105
OP02	0.193	0.114
OP03	0.195	0.114
OP04	0.195	0.106
OP05	0.195	0.110
OP06	0.195	0.115
SF01	0.183	0.117
SF02	0.192	0.115
HO03	0.189	0.113
HO04	0.190	0.113
BU10	0.196	0.113
BU12	0.187	0.128
HE01	0.195	0.114
AK05	0.196	0.116
AA02	0.183	0.124
AA04	0.185	0.121
OE01	0.192	0.121
VE01	0.193	0.114
VA02	0.181	0.128

Interpretation of the results

Why do we have these mentioned differences?

It is two reasons:

1. Changes in reference frames from 1989 to 1998.
2. Crustal movement from 1989 to 1998.

From a two dimensional transformation (Helmert transformation) between the given epochs we get the following results:

Shift in north:	0.193 m
Shift in east:	0.108 m
Rotation around the vertical axis:	0.005 sec
Scale:	0.036 ppb
Mean deviation on residuals in north:	3.9 mm (max 7 mm)
Mean deviation on residuals in east:	3.3 mm (max 12 mm)

What does this tell us?

First that the residuals after the transformation are very small and we can hardly expect better results from our basic geodetic network.

Second the change in coordinates fits very well to the results of a two dimensional transformation.

That could mean that Norway is moving like a rigid (stiff) plate if we regard horizontal coordinates. This is of course not new results, but rather a confirmation of what the scientific community knows.

Correction for "known Reference frame change" and computing of average velocity for Norway.

We know that an original shift exists between ITRF93 and EUREF89(ETRS89). The shift is -0.035 m in north direction and 0.048 m in east direction. (I have not found out yet what had happened from ITRF93 to ITRF97).

If we add the original shift to the average shift from the transformation we can compute the average velocity for Norway in the period 1989 to 1998.6.

Velocity in north: (193 - 35)mm/9.6 year = 16.5 mm/year

Velocity in east: (108 + 28)mm/9.6 year = 14.2 mm/year

IERS velocity values for Tromsø are: north 14.9 mm/year and east 12.8 mm/year, so it fits considerably well.

Interpretation of the transformation results

The shifts in north and east are values that are directly influencing the coordinates.

The scale of 0.036 ppb results in a 0.06 mm change on a straight line of 1700 km. This is the distance from Lindesnes (most southern in Norway) to North Cape (most northern in Norway).

The rotation of 0.005 sec means 41 mm (lateral deviation) acting on a straight line of 1700 km from Lindesnes to North Cape.

Observation techniques

We can choose to divide the observation techniques in three classes.

1. Angle and distance measurements
2. Relative GPS measurements
3. Absolute GPS measurements

By "angle and distance measurements" I mean classical measurements by theodolite and distance measuring equipment or a total station.

By "relative GPS measurements" I mean GPS measurements with two receivers. One receiver is located in a points with known coordinates and the other in a point with unknown coordinates. A vector between the known and the unknown point is computed. The reference frame is realized directly by using the actual coordinates for the reference frame in the known point.

By "absolute GPS measurements" I mean the use of only one receiver in a point with unknown coordinates. Additional information about orbits, clocks and earth rotation is necessary to compute the coordinates. This information is of course based on observations in points on the earth. It is in our case based on the IGS stations. Current epoch realization of the reference frame is based on IGS coordinates and an associated velocity field.

Shift and rotation has obviously no influence on angle and distance measurements because the plate is regarded as rigid for the whole country. Shift is no problem for relative GPS as long as the coordinates act as reasonable start values for the iteration in vector processing. They can actually be several meters out.

But the rotation will influence on the vector components.

For absolute GPS there is immediately a problem with both shift and rotation. In this case we need to know the velocity field with sufficient accuracy or some other kind of transformation.

Let us do an experiment concerning the rate of rotation. To compute that we have to distinguish between changes in reference frame and crustal movement. Between EUREF89 and ITRF93 there is no rotation in reference frame. I don't know if there is any rotation between ITRF93 and ITRF97, but I suppose there is no change on the accuracy level we are considering.

The rotation on 9.6 years is 0.005 sec. The rotation rate will then be 0.0005 sec/year. The effect of 0.0005 sec/year rotation around the vertical axis is shown in the table below:

Vector length:	Lateral deviation/year	Number of years until lateral deviation reach 1mm
10 km	0.024 mm/year	42 years
100 km	0.24 mm/year	4 years
1000 km	2.4 mm/year	0.5 year

Conclusions

Finally let me draw some conclusions for the future. There will be a need for better accuracy also for so called "practical purposes" in the future. Absolute point positioning with satellites will probably be the main observation method in the future. The consequences are that it will be more and more important to know the "movement" with high enough accuracy.