Minutes, session 3, Geoid Determination from the Joint NKG Working Group meeting in Hønefoss, Norway, October 8-10, 2001.

The Geoid Determination session was opened by Dag Solheim. As for the WG meetings in Vilnius and Tallinn colleagues from the Baltic countries were invited in addition to one from Poland.

One way of computing the geoid is by solving Stokes integral, and this is the way the Nordic geoid is being computed today. To do this you need gravity data from in principal the whole earth. This is however not feasible at the moment so what is used is a combination of geopotential models and local gravity data for a limited geographical region. This limited region should be larger than the the core or main area of interest due to edge effects and possible lack of data from the area outside this region. Erroneous assumptions about the gravity field in the neighboring areas may propagate into errors of the geoid in the core area. The best way to avoid such errors is to have access to high quality gravity data by cooperating with the local geodetic and geological agencies. A cooperation between the Nordic and especially the Baltic but also other neighboring countries are therefore of utmost importance for the successful computation of a joint high precision geoid. I do also think that most, if not all of the WG members, do agree that this cooperation is quite natural both from a geographical and a political point of view.

Due to the limited time available, national reports on gravity and geoid activity were limited to only reporting on major developments since the WG meeting in Tallinn. Instead the focus for the session was on gravity and geoid at the NKG level, NKG gravity data base, NKG geoid solutions, theoretical work inside NKG with computational examples, adjustment to GPS/levelling (what most users want) and the release plan for the next NKG geoid.

The computation of high precision geoids has been the primary goal for the NKG WG on Geoid Determination. The first such model was computed by C.C. Tscherning and R. Forsberg in 1986. The computations were done by using the collocation technique and dividing the Nordic area into smaller blocks that were later glued together to form the first NKG geoid. The computations were done for 3 by 6 degree geographical cells of which the central 2 by 4 degree area was used. In 1988 the first Nordic FFT geoid was computed. This was so successful that FFT has been chosen for all the following NKG geoids. The next official NKG geoid was the NKG89 model computed by Rene Forsberg at KMS. This model was computed in the UTM zone 33. Later theoretical improvements like the 1D FFT and multiband FFT made this superfluous, and the last NKG model, the NKG96, was again computed in geographical coordinates. The NKG96 solution is in fact several separate solutions. There is one for Iceland, one for Svalbard, one for Greenland and one for the Baltic countries, Denmark, Finland, Sweden and Norway.

After this introduction Solheim continued with a short report about the NKG gravity data base. Much of this material was already known to the WG so only the major new gravity sources were mentioned. The joint Baltic and Nordic airborne gravity project in the Baltic Sea was especially mentioned likewise the similar campaigns in the Arctic, Greenland and Svalbard. The NKG gravity data base includes data from all the Nordic and Baltic countries and surrounding areas like Russia (to Ural) and Eastern Canada. There is however a gap in our coverage for the land areas in Great Britain and Ireland. The WG is so far awaiting the computation of the Irish and English geoid before approaching the proper authorities. The computation of the English/Irish geoid will be done by KMS at the beginning of next year (2002).

Rene Forsberg presented the NKG96 geoid. Describing the method being used, FFT and the remove restore technique where long wavelength features of the gravity field and the geoid is determined by a global geopotential model, in this case the EGM96. Short wavelength features are calculated by using digital terrain or elevation models. The remaining intermediate part of the geoid signal is computed by solving Stokes integral with Fast Fourier techniques. The DEM's used in the NKG96 solution was a 100m x 100m for Norway and a 500m x 500m for Sweden. The terrain correction computations for Sweden was done by KMS while the computations for Finland and Norway were done by the national agencies. Rene also reported on new NKG geoid solutions. The area of interest has increased, attempts with using modified kernels have been tried but so far there has not been any significant improvements compared to the NKG96 model. This seemingly lack of advance may however be the result of insufficient GPS/levelling data. The old Torge profile from 1987 and also the Swet profile from 1992 may not be adequate for such comparisons.

Forsberg also had a short presentation of the Arctic Gravity Project, AGP, see http://164.214.2.59/GandG/agp/ for further details. The goal of this project is to compile gravity data from all the Arctic Countries and release this as a grid to the scientific community in analogy to other similar Arctic projects like the Arctic Bathymetric Project, The AGP is planned to be finished in spring 2002. With the finalization of the AGP it might be time for us to start thinking about the Antarctic instead.

Modified kernels, for the solution of Stokes integral, have become quite a hot topic in geoid computation lately and Ove Omang has been studying this as part of his Ph. D thesis. The next NKG geoid will probably use some kind of kernel modification. Ove gave us a short introduction to this and the work that he has done. The effects of using modified kernels are quite significant and this requires further investigation.

The Swedish Royal Institute of Technology in Stockholm, KTH, have substantial experience on this and on the theory of geoid determination in general. Jonas Ågren presented the work being done at KTH, and his intention of actively taking part in the NKG geoid computations. The WG appreciates this very much and hopes that sufficient funds will be made available for his participation.

As has already been mentioned international cooperation and exchange of data is of vital importance for geoid computations. For the Nordic geoid we need data from countries like Poland, and Jan Krynski presented the geoid and gravity work being done in Poland.

For practical purposes what most users want is a "geoid" which in combination with GPS will give them a height in the local vertical datum. The first presentation about this subject was by Dag Solheim who presented the work being done in Norway. Norway has selected to use an iterative or stepwise procedure allowing local adjustments to be done as more GPS/levelling data is being collected leaving the geoid outside this local region unchanged. Harli Jürgenson from Estonia talked about similar work being done there.

Discussions:

The first item on the discussion list was to agree upon a final deadline for supplying (gravity) data for the next NKG geoid, and February 1, 2002 was adopted by the WG.

One of the main reasons for the delay of the new NKG geoid has been the request by Sweden to wait so that they could fill in some of the gaps in their gravity coverage. Andreas Engfeldt presented the status of this work and estimated that it would be finished by the end of October 2001.

Thanks to the new satellites that have been or will be launched, physical geodesy can look forward to some very interesting years. These missions will lead to significantly improved geopotential models and geoids. The WG will investigate the suitability and advantages of using these models as soon as they are released. For the next NKG geoid there may be available new models based upon data from the German satellite CHAMP which already have been launched. Next year (2002) GRACE will be launched and in a few years time we will have the ESA satellite GOCE. Preparation for and use of data from these satellites not only for land areas, but especially for marine areas will be one of the major goals for the WG.

The NKG 2002 geoid will be computed by Rene Forsberg at KMS. The computations are planned to take place in February 2002 with active contribution from Jonas Ågren and Dag Solheim, and the new model should be ready by the beginning of March 2002.

There was some discussion about what the WG should deliver. A clean non adjusted geoid, an adjusted geoid or both. The WG does not intend to do a detailed adjustment. This is left to the national agencies, but the WG is thinking about a long wavelength adjustment to a very limited number of carefully selected GPS/levelling points within the Nordic and Baltic countries.

The "market" for geoid solutions is divided into land and marine areas. So far most of the work has been concentrated on land areas and the combination with GPS. We must however not forget about the marine areas, and in Norway the offshore industry has already approached Kartverket and expressed their interest for a high precision marine geoid. The optimal use of satellite altimetry do also require such a geoid model. Future NKG geoid models should take this into account, and this is one of the reasons why we are planning on not having several geographically separate NKG 2002 models but one model covering all of the Nordic area. This area encompasses Iceland, Greenland, Svalbard, all the Nordic and Baltic countries and not to forget all the intervening marine areas. Whether this actually is feasible will be determined in February next year. Geoid computations of large areas, like Australia, has lead to unforeseen problems like apparent tilt in the model, so there may be some challenges we have to face and solve before achieving our goal.

At the meeting in Tallinn, 2002, there was some discussion about the validity of the methods and formulas being used. No further conclusions were made at this meeting. No one disagrees on the fact that the formulas and the approximations are too inaccurate for a 1 cm geoid, but the remove restore technique may come to our rescue. Because when using the remove restore technique the formulas and approximations in question are used on the reduced gravity anomalies whose contribution to the geoid signal is much smaller than the total geoid N but nevertheless very important. Let us for simplicity say that the error is of the order of the flattening of the earth times the signal. Then it is obvious that the formulas do not give us a 1 cm geoid, but when we are looking at the contribution from the reduced gravity anomalies this signal is much smaller and the corresponding error in the computed geoid will also be smaller, but what remains to be determined is how big this error will be. This is one of the challenges that the WG would like to focus on in the future.

Dag Solheim