From Eötvös to mGal

Study Team 2 - Workpackage 5

The Polar Gap Problem

Space-wise approaches to gravity field determination in Polar areas.

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Summary

The polar gap problem arises due to the orbit inclination of GOCE. However, GOCE-only solutions may be valuable. Such solutions may be determined in an optimal manner using Least Squares Collocation (LSC) and the Slepian approach.

LSC is a general procedure, which permit the direct use of ground data (both inside the gaps and outside). In the general integration approach, data has to be predicted covering the gaps and converted to the same data type as otherwise used for the integration. This prediction may be made using regional LSC solutions.

The inclusion of e.g. gravity anomaly data from inside the gaps will have no important consequence for the sparseness of the matrices used in the conjugent gradient method with sparse preconditioners. This is because these preconditioners have been generated from a general kernel with compact support.

Finally an overview is given of current and planned gravity surveys in the polar areas.

5.1 Introduction.

The orbit inclination of GOCE leaves the polar areas north of 82 degrees and south of -82 degrees - the polar gaps - without data. These gaps may be filled in two ways

- with data from other satellite missions with a higher inclination
- with ground gravity data

We will in the following concentrate on how ground data can be utilized in the space-wise approach.

The new satellite missions, GOCE, GRACE and CHAMP have spurred an interest in having the polar gaps filled with data. We will give a (unfortunately incomplete) overview of the available data and of the at this time planned activities.

5.2 GOCE-only solutions.

It may be of interest to have solutions (spherical harmonic coefficients, ground geoid height and gravity values) based on only data from GOCE. Such solutions will be internally consistent. When including other data types, we may not know whether these are contaminated with systematic errors - or whether GOCE data contains such errors. A comparison of independent solutions will be important for the mission calibration and verification.

Both of the two space-wise methods, LSC and integration, may be used to obtain GOCE-only solutions. For LSC the solution is obtained by only using GOCE data. Data inside the gaps are not needed in order to obtain a solution, but using such data will obviously improve the solution.

For the integration method, the Slepian approach (Albertella et al., 1999, Albertella and Sneeuw, 1999) only used the data outside the gaps, and gives an improved solution compared to using the "global" harmonic function approach.

5.3 Combining GOCE data with gravity data in the gaps.

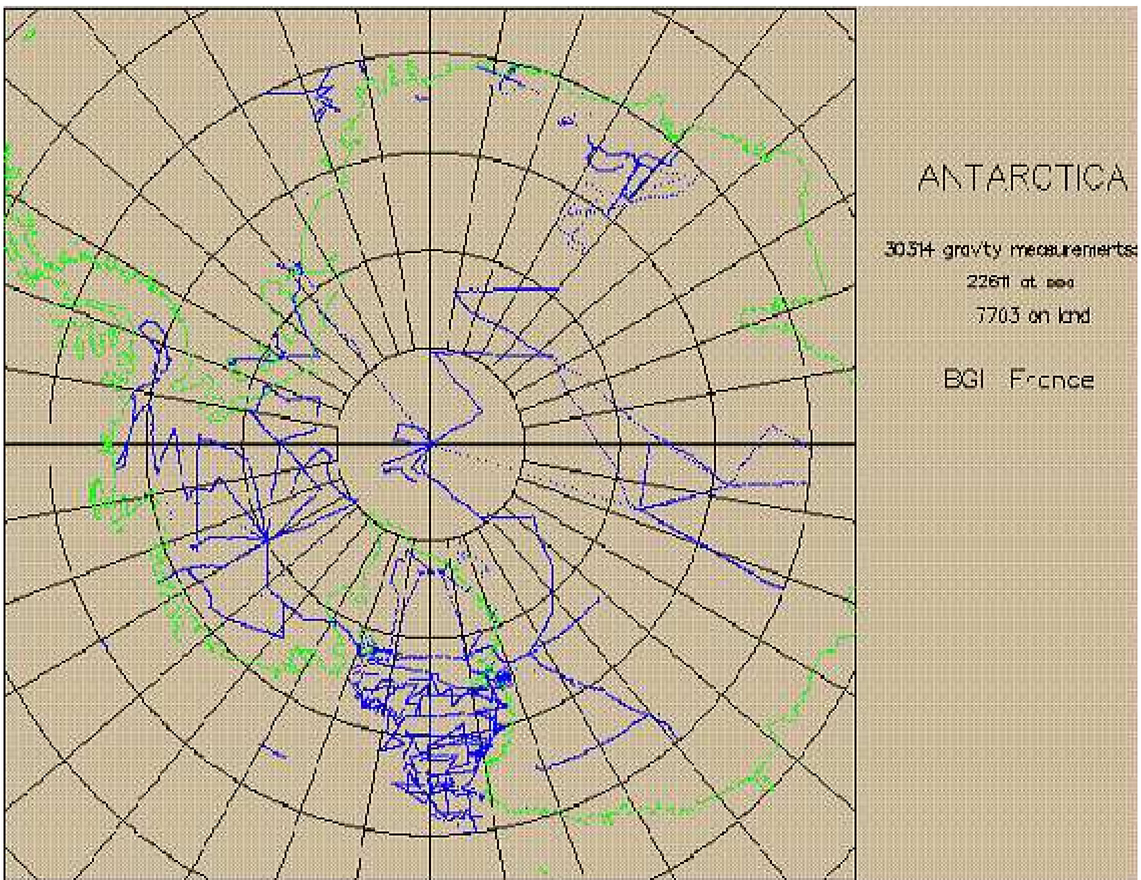
The integration approach is based on the use of only one datatype, with all data located on the same sphere. Let us suppose the sphere is having a radius equal to the mean radius of GOCE for the whole lifetime of GOCE. The data will be either gravity disturbances, T_z, or anomalous vertical gravity gradients, T_{zz}. Such quantities will be normal mean area values over blocks typically of size 0.3 degree * 0.3 degree, corresponding to a 4 second sampling of the GOCE data.

In the gaps such values may be predicted from ground data using the upward continuity capability of LSC with harmonic kernels (GEOCOL) or FFT based upward continuation from gridded ground data (GEOFOUR), see Tscherning et al. (1992, 1994). Both ground and airborne gravity anomalies as well as the GOCE data close to the cap boundary should be used.

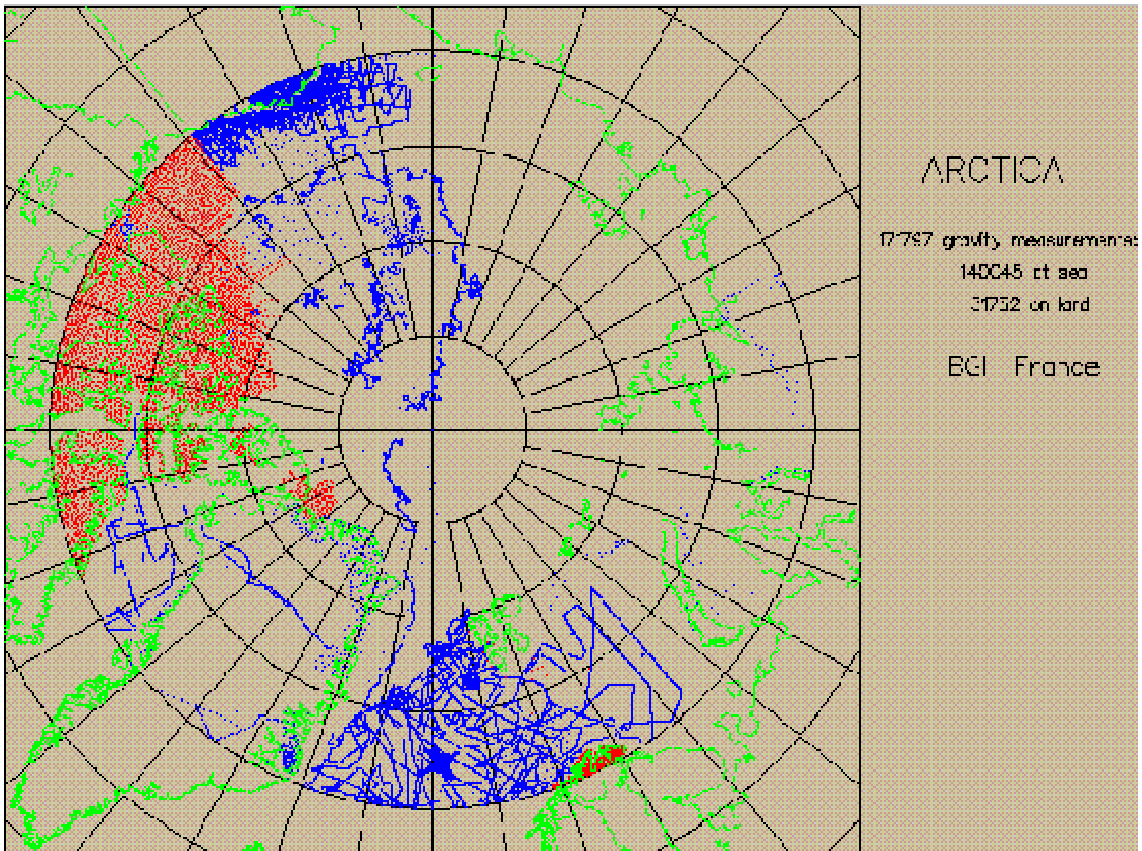
Using LSC, data in the gaps may readily be combined due to general purpose character of the method. One could here worry about the structure of the sparseness of the banded matrix arising when using sparse preconditioners. However these preconditioners have been developed from general sparse kernels (Moreaux et al. 1999, Moreaux, 1999). Only if the correlation is larger for the ground data than the GOCE data will the bandwidth be larger, probably a factor 2 in the worst case.

5.4 Data in the polar gaps.

Earlier gravity data has been collected on the ground using traditional gravimetry. These data are available through the Bureau Gravimetric Internationale, Toulouse, see Fig. 1 and 2. There is one problem connected with the land data from Antarctica, namely the errors in the associated altitude. Heights must be determined using levelling, which is a very tedious procedure. In polar areas it is often substituted by barometric levelling, which may have errors larger than 2 m, if not done very carefully.



Figur 1. BGI Data holdings on Antarctica as of January 2000.



Figur 2. BGI Data holdings in the Arctic as of january 2000.

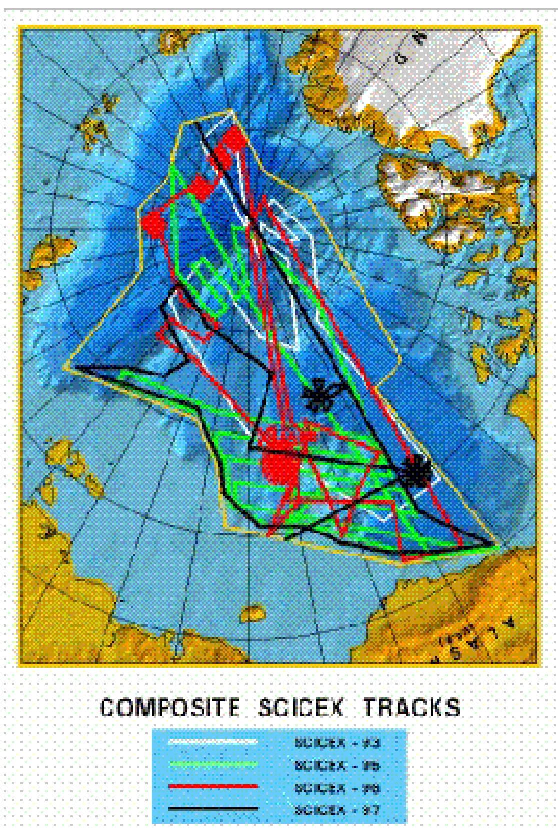


Fig. 3. Submarine gravity tracks.

Today GPS is used to calculate the ellipsoidal height so the height problem is solved. Furthermore airborne gravity techniques have been developed, and are the only reasonable method to use on land areas.

In the Arctic ocean submarines collect gravity data, see Fig. 3.

The international scientific community is aware of the importance of collecting gravity data for the gravity satellite missions. The International Association of Geodesy (IAG) did at its General Assembly in Birmingham, July 1999 adopt the following resolution:

Resolution 5
The International Association of Geodesy

recognizing
1.the need for terrestrial and airborne gravity measurements due to the lack of gravity coverage over the polar caps by the planned satellite missions, and
2.the need for improved geoid models in the polar regions,
recommends
a concerted international effort to compile existing available gravity data and to encourage new gravity surveys in the polar regions.

Besides passing the resolution, the association established a project (formally a working group under the IAG Gravity and Geoid Commission), the Arctic Gravity Project. The home-page of the project is

http://164.214.2.59/GandG/apg/index.htm

where information about the project can be found. In the project the aim is to be able to produce a free-air gravity map of the Arctic at the end of 2000. It is planned to release a final grid product with 5' spacing in 2001.

On Antarctica, the Scientific Committee for Antarctic Research (SCAR) has a geodesy and geographic information working group (SCAR-GGI), which also deals with the collection of gravity data, see

http://www.scar-ggi.org.au/geodesy/physgeod/index.html

A gravity reference network has been established and several groups are working here to collect airborne gravity data. The aim is to produce a much needed geoid map of Antarctica, see e.g. Capra and Gandolfi (1999).

The Alfred Wegener Institute for Polar and Marine Research (AWI), Bremerhafen, has in January 2000 completed its third airborne gravity survey. AWI aims at mapping the off-shore area in the Eastern Weddell Sea. The British Antarctic Survey files regularly over the Antarctic Continent. The US also collects airborne data (U.Meyer, GFZ Potsdam, personal information, January 2000). However, the Antarctic is very large and not easy to access. But a stronger effort is needed here.

5.5. Conclusion.

Methods exist for a GOCE-only solution, which does not include data from the polar gaps. But obviously the inclusion of gravity data will improve the estimates of the spherical harmonic coefficients, for which the quality depends on the availability of global data. Software enabling the use of such data in combination with GOCE data are available.

However a large international projects are aiming at providing new gravity data. The Arctic will be covered at the end of 2000 with a 5' grid. The Antarctic is a very difficult area due to its size and inaccessibility.

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