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GRAVSOFT updates for SGG applications.

by

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Abstract: The GRAVSOFT package of FORTRAN 77 programs was originally developed mainly for gravity field modelling using data at the earths surface. The upgraded package includes programs for the generation of observation points along a (simple) satellite orbit and adding of random noise and biases to data. Existing programs implementing least-squares collocation (GEOCOL) and the Fourier method (GEOFOUR) has been upgraded to handle satellite gravity gradiometer (SGG) data. GEOCOL now handles data in a satellite reference frame, on the condition that the 'horizontal plane' of the instrument frame is close to the plane orthogonal to the normal to the reference ellipsoid.

With these upgrades may the package be used for rather general simulation studies of the recovery of gravity field information from SGG data or actual recovery from airborne gravity gradiometer data.

1. Introduction.

The GRAVSOFT package includes FORTRAN 77 programs for gravity field modelling and simulation and for the handling of gravity field data (selection, mean value formation, gridding). It was developed orginally at the Geodetic Institute of Denmark, which since 1989 form a part of Kort og Matrikelstyrelsen (KMS, National Survey and Cadastre - Denmark). Due to change of staff and further developments (such as these described in the following) the package is now managed jointly by KMS and the Geophysical Institute, University of Copenhagen.

The package was originally developed with ground applications in mind, such as precise regional geoid computations, and it has also been used for this purpose in Greece, Italy, UK and the Nordic Countries. It includes special programs to handle satellite altimeter data.

The methods implemented in the package are rather general, and it was decided to upgrade the package to be used with satellite gravity gradiometer (SGG) data as a part of the ESA CIGAR study. Some preparations had already been made in order to carry out simulation experiments for Dornier GmbH which were carrying out SGG studies for ESA (Tscherning, 1988, 1989).

2. The GRAVSOFT package.

The GRAVSOFT package consist of a number of FORTRAN 77 programs which uses nearly no machine dependent features. If they do, comments in the programs will indicate which changes to make. For the GEOCOL program updates, changes and known errors are summarized in a special document (Tscherning, 1989a). The original GEOCOL version was published in Tscherning (1974). Besides the programs, test data and related output is distributed.

The package consist of the following modules for which details about their use in connection with SGG data are found in the appendix to Arabelos and Tscherning (1989):

(a) GEOCOL - program for gravity field modelling and simulation using least squares collocation.

(b) COVFIT - program to generate tables of covariance functions of gravity field dependent quantities and for the determination of constants used when modeling analytically the empirical covariance function. (See Tscherning (1976, 1983), Knudsen (1987), Krarup and Tscherning (1984)).

(c) EMPCOV - program for the computation of empirical auto and cross-covariance functions. Here pairs of SGG data may be used, if the data are azimuth dependent.

(d) ALTCOR - program for the adjustment of satellite altimeter data (not updated in this study).

(e) TC - program for computation of terrain effects (see Forsberg (1984, 1987)).

(f) TCGRID - program for pre-processing terrain grid data.

(g) SELECT - program for selecting data from a larger data set, e.g. data closest to a set of grid points.

(h) FC - program for post-processing of grid data.

(i) TCFOUR - program to compute terrain effects by FFT.

(j) GEOFOUR - program for gravity field modelling by FFT.

(k) COVFFT - program for analyzing power spectra, covariance functions by FFT.

(l) GEOIP - program for interpolation of scattered data from grid data.

(m) GEOGRID - pogram to grid scattered data using local collocation or distance weighted interpolation.

Naturally, not all the programs had to be upgraded in order to be used with SGG data, but several had to be changed substantially. However, a few new programs were written:

(n) ORBIT - program for generation of observation points on a satellite orbit moving in a gravity field with only C(0) and C(2) included.

(o) ADDBIAS - program to add random bias to observations on the same satellite track.

In the following sections the various new implementations and updates will be described.

3. Module to produce data points on a simulated orbit.

From TU Delft we have received basic modules to compute the state vector components of a satellite, given its orbital elements and using a gravity field with C(2,0) included. The vector components are calculated for given intervals of time and time length.

It has been ugraded, so that only points in a geographical area are considered, and calculated in an Earth-fixed frame. The position part of the state vector is given as latitude, longitude and height above the GRS80 reference ellipsoid.

The azimuth and dip angles will be given in a coordinate system with 1. axis East, 2. axis North and 3. axis up, in the direction of the radius vector.

4. Computations of terrain effects.

Changes to TC has been identified, so that the second order derivatives of the terrain potential may be given in an orbit related frame. At present the derivatives are computed in a spherical reference frame and the 3*3 matrix must be rotated to the orbit frame using the azimuth, roll and dip angles.

5. Upgrades of GEOCOL.

5.1 Expansion of possibilities for handeling more observations simultaneously.

Expansions made so that 3000 observations with 2000 base points may be handled simultaneously.

Normal equation blocking factor increased to 19600 (from 4800). This resulted in a factor 4 in increase of the speed of solving the normal equations.

5.2 Acceptance of observations given in an orbit related frame.

Input specifications changed for second order derivatives if identified by ordinary kind-codes + 40. Logical variable LSATF will be set true, and stored for each dataset in the dimensioned variable LSAT.

An observation record must have the following format, which permit to identify if the observations are on separate tracks and their time difference, as used for satellite altimetry:

<unique identifier> <position> <observation(s)> 1. record.
<azimuth> <dip> <roll> angles in decimal degrees, 2. record.
<unique identifier>::= observation time in seconds since launch or revolution number * 10000 + sequence number.
<position>::= <latitude, longitude (angular units), height (m or km)>,
<observations>::= <up to 6 real numbers in E.U.> .

For each observation file, the geodetic reference system, the angular units, and the sequence and type of the observations must be known. As kind-codes for the observations we will use (for a coordinate system with x orthogonal to the flight direction, y in the flight direction and z "up") Vzz : 55, Vzx,Vxz : 60, Vyz,Vzy : 61, Vxy,Vyz: 63, Vyy : 62, Vxx : 64 and Vxx-Vyy : 65.

5.3 Computation of reference values in an orbit oriented reference frame.

GPOTDR and RGRAV changed to produce the 3 * 3 matrix B of 2-order derviatives in a right handed frame. GEOCOL changed, with the call of a new subroutine ATBA which will rotate the matrix of second order derivatives (B) according to the rotation matrix A.

5.4 Calculation of covariances in an orbit related frame.

We will suppose that this only requires a rotation in the plane orthogonal to the radius vector, and may be done in spherical approximation. This then only requires that the azimuth is saved, and transferred to the subroutine PRED.

The 2*2 matrix of covariances computed by COVC may then be rotated, and a subroutine SATROT has been written to execute this. This works for the pairs Tzx,Tzy and 2*Txy,(Txx-Tyy), but need to be implemented for Txx and Tyy separatly.

5.5 Calculation of biases and time dependent tilts.

The determination of biases is a general feature of GEOCOL, and the determination of time dependent parameters has now been implemented. This has required substantial changes in the main program of GEOCOL and in the subroutines APARM, CXPARM and WRPAR.

5.6 Upgrade for faster computations of covariances.

For fixed heights, a fast computation of covariances has been done using spline interpolation of tabulated values. This makes the the computation of covariances 4 times faster.

6. Upgrades of SELECT.

6.1 Adding random noise to simulated observations.

The program SELECT has been modified, so that random noise with given standard deviation may be added to observations, or observation pairs.

7.Upgrades of GEOFOUR.

7.1 Modification of GEOFOUR for downward continuation of Tzz.

The program GEOFOUR has now been modified, so that gravity may be computed from gridded values of Tzz. As a new feature must the noise of Tzz and the gravity anomaly variance at the prediction altitude be input.

8. Biass addition.

A new special purpose program addbias has been written to add biases per satellite track with normal distributed random noise. Random tilts may easily be added, but it has not yet been implemented.

9. Conclusion.

The GRAVSOFT package has been upgraded so that it may handle SGG observations in an earth-oriented frame. For certain observations also an instrument or orbit related frame may be used. This requires that one pair of instrument axes span a plan which form a small angle with the tangential plane to the Earths ellipsoide. However, there are no theoretical restrictions in using an arbitrary frame, but this requires change of some very complex subroutines, some of which were written in the early 1970's.

The upgraded version has been tested extensively with simulated data as described in Arabelos and Tscherning (1989). Also the work described in Arabelos and Tscherning (1987) with torsion balance data shows the capability of GRAVSOFT.

The new GRAVSOFT-version enables a user to set up computer runs for the study of:
- how instrument biases may be solved for
- the change in the error of local gravity recovery due to change on sampling rate, instrument noise and regularization factor
- the contribution of surface data to local recovery
- the effect of changing the statistical parameters used to characterize the gravity field
- the effect of topography and/or its isostatic compensation.

We therefore now have a tool, which we with confidence may use in further simulated of SGG missions or hopefully once to handle real SGG data.

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