1st ESA ADVANCED TRAINING COURSE ON REMOTE SENSING OF THE CRYOSPHERE

INSTRUCTIONS FOR THE:

GRACE MASS BALANCE PRACTICAL

CONTACT POINTS

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1 Objectives

The general purpose of this practical is to utilise GRACE monthly gravity field solutions for the inference of mass change time series for the Antarctic Ice Sheet (AIS) and selected drainage basins and aggregations. These time series are compared with alternative GRACE-derived products as well as data sets based on independent observations and geophysical modelling. Finally, the mass change time series are used to derive estimates for the mass balances of the respective region.

The drainage basins to be considered during the practical are shown in Figure 1, and are based on the basin definitions of Zwally et al. (2012). In addition, basin aggregation for the Antarctic Peninsula (basin 29: 24, 27, 28), East Antarctica (basin 30: 2-17), West Antarctica (basin 31: 1, 18-23) and the entire AIS (basin 32) can be studied. For the sake of clarity your investigations should first be focussed on the entire AIS (basin 32) as well as on basin 6 (part of Dronning Maud Land) and basin 24 (Bellingshausen Sea Sector), where additional data sets, to be used for intercomparison exercises, are available.

The practical is divided into four parts:

1. **Modelled global mass change signals in space domain and spherical harmonic domain**

   In this part, the characteristics of mass changes in different sub-systems of the Earth are explored by means of modelled mass changes. For this purpose the difference between two monthly solutions of ESA's Earth System Model (ESM) (Dobslaw et al., 2015) are used. The conversion between the space domain and the spherical harmonic domain is demonstrated. Moreover, the principal concept of filtering, using a simple isotropic Gaussian filter, is demonstrated.

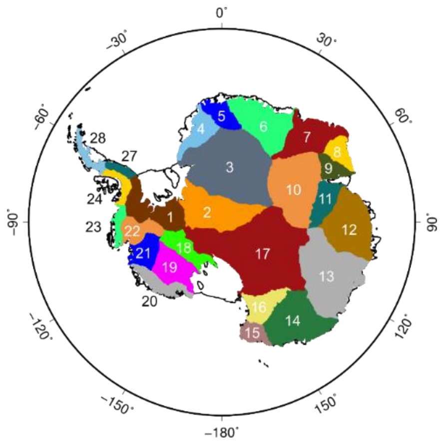

Figure 1: Drainage basin of the AIS.

2. **GRACE-observed global mass change signals in space domain and spherical harmonic domain**

   The differences between two monthly solutions of the GRACE release ITSG-Grace2016 (Klinger et al, 2016) are used to perform investigations similar to those of part 1. By exploring the differences between the modelled and the GRACE-observed mass changes, signals and errors of the GRACE monthly solutions can be studied.

3. **Regionally integrated mass change time series from GRACE monthly solutions**

   The regional integration approach, in combination with a Gaussian filter, is implemented in the spherical harmonic domain to derive mass change time series from GRACE monthly solutions on basin scale. The inferred time series are corrected for solid Earth mass changes due to glacial isostatic adjustment (GIA) using a set of GIA models. By using Gaussian filters with different filter radii, the effect of filtering on the mass change estimates is studied. Finally, mass balance estimates and the corresponding contributions to changes in global mean sea level are derived.

4. **Intercomparison with alternative GRACE results and independent data**

   In this part, the inferred mass change time series and the mass balance estimates are compared with the Gravimetric Mass Balance (GMB) products derived within the ESA Climate Change Initiative (CCI) project on the Antarctic Ice Sheet (AIS_cci). Differences between both data sets are used to conclude on limitations of the method applied in the practical. Possible modifications to overcome these limitations are demonstrated. In addition, the AIS_cci GMB products are compared to time series of changes in the mean surface elevation of basins 6 and 24. This data set is also provided by the AIS_cci project. Finally, the AIS_cci GMB products are compared to modelled cumulative surface mass balance anomalies. This intercomparisons allows to conclude on the different signal components reflected by both data sets.

2 Data sets

All data sets and tools required to complete the practical are provided and are located in the `data` and `tools` directories. Whenever a data set needs to be obtained in the course of the practical, this is explicitly stated. The following data sets are used during the practical:

1. Monthly mass changes modelled by the ESA Earth System model (Dobslaw et al., 2015). Additional information on the model and the model itself is available from: http://www.gfz-potsdam.de/en/esmdata/esa-esm.
2. GRACE monthly solutions of release ITSG-Grace2016 (Klinger et al., 2016). The solutions are freely available from: https://www.tugraz.at/institute/ifg/downloads/gravity-field-models/itsg-grace2016/.

3. Spherical harmonic coefficients of degree one need to be added to the GRACE monthly solutions. Coefficients derived by the method of Swenson et al. (2008) can be obtained from: ftp://podaac.jpl.nasa.gov/allData/tellus/L2/degree_1/.
4. The spherical harmonic coefficient of degree 2 and order 0 has to be replaced, e.g. by an estimated derived from satellite laser ranging (SLR) observations (Cheng et al., 2013). This data set is available from: ftp://podaac.jpl.nasa.gov/allData/grace/docs/.
5. Three different glacial isostatic adjustment models are provided (in the spherical harmonic domain). Namely: IJ05_R2 (Ivins et al., 2013), W12a (Whitehouse et al., 2012) and ICE-6G (Peltier et al., 2015).
6. Elastic Load Love Numbers (LLN), describing the Earth's elastic response on a surface loads (Farrell, 1972) are required to perform the conversion between Stokes coefficients and coefficients of the equivalent water height (EWH).
7. The provided basins outlines, basin areas and region functions (given in the spherical harmonic domain) are based on the definitions of Zwally et al. (2012), which are available from: http://icesat4.gsfc.nasa.gov/cryo_data/ant_grn_drainage_systems.php.
8. The GMB basin products and the GMB basin mass balance estimates generated by TU Dresden within the AIS_cci project need to be **downloaded** by each participant. After registration the products can be downloaded from https://data1.geo.tu-dresden.de/ais_gmb/. Both unpacked files need to be stored in the `data` directory.
9. The Surface Elevation Change (SEC) products generated by the Centre of Polar Observation and Modelling (CPOM) within the AIS_cci project need to be **downloaded** by each participant. After registration the data sets are available from http://www.cpom.ucl.ac.uk/csopr/icesheets/. The unzipped files have to be stored in the `data` directory.
10. Cumulative surface mass balance (SMB) anomalies were derived from modelled fluctuations in SMB according to the regional atmospheric climate model RACMO (version RACMO2.3/ANT27) (van Wessem et al., 2014). The model is available on request.

3 Course of the practical

Nearly all steps of the practical are already included in the central Matlab script `grace_mb_practical.m`. It is your task to go through the script and run it step by step. Comments, describing the purpose of the individual step, are added throughout the script. It is explicitly stated whenever input from your side is needed. Missing code to be added is denoted with '**..**'.

You will find 20 questions/tasks within the script, which need to be answered. Whenever results are generated within the script you should output and carefully study them. Ask yourself what causes visible phenomena or the differences revealed by an intercomparison.

At the end of the script you have the opportunity to save all your results in a *.mat file (binary) and to save all the figure generated so far.

The central directory of the practical contains the following files and subdirectories:

`grace_mb_practical.m`	- the central Matlab script
`data`	- directory holding all the input data
`tools`	- directory holding all required Matlab tools
`figures`	- directory for storing the generated figures

4 References

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