EGSIEM

European Gravity Service for Improved Emergency Management

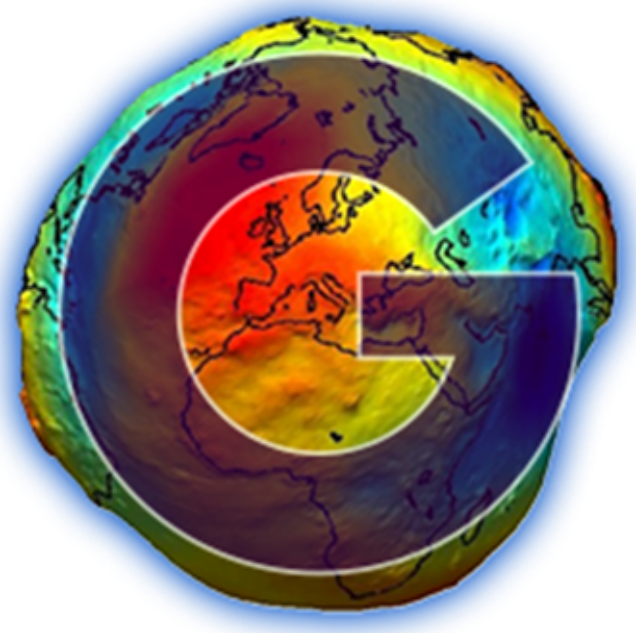
HORIZON 2020

EO-1-2014: New ideas for Earth-relevant space applications
Research and Innovation action

Action acronym:	**EGSIEM**
Action full title:	European Gravity Service for Improved Emergency Management
Grant agreement no:	637010

Deliverable 2.2
GRACE/GRACE-FO Product report

Date: 2016-06-30



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1.Change Record

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GRACE Product report	Torsten Mayer-Gürr, Andreas Kvas	2016-06-30	D2.2

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2.Terms

This document provides a description of all products generated in Work Package 2 (WP2) and presents an overview of what has been achieved.

3. Overview

Background

WP2 is closely related to the first objective of the EGSIEM project, namely to deliver the best gravity products for applications in Earth and environmental science research. In accordance with the Description of Action, significant effort has been devoted to harmonizing and improving the gravity field analysis at the different EGSIEM Analysis Centers (ACs). The importance of WP2 is reflected by the fact that it is closely related to Milestones 1 and 2. Both Milestones have been fulfilled and the WP2 tasks have been accomplished. A detailed summary is given below.

Objectives

The following objectives are all listed within WP2:

Gravity field analysis:

• Critical analysis of GRACE processing standards, background models, reference frames and algorithms:

The Processing Standards and Models technical note (Deliverable 2.1) was compiled. It serves as a record of the processing standards, models and parameters adopted for the generation of the GRACE level 2 products by EGSIEM (Task 2.1).

• Consistent orbit parameter estimation process and gravity model reprocessing for a time frame of two years by five gravity ACs:

The improvement and harmonization of the processing tools (Task 2.2) according to the standards document (D2.1) has successfully been closed. A series of monthly gravity field solutions have been processed for two years 2006-2007 at the different ACs. Some ACs have already processed longer time series which have been made publicly available.

• Establishment of a realistic GRACE-FO instrumental error behavior to be used in GFZ's E2E gravity data simulator to investigate the gain for hydrological applications which can be expected from GRACE-FO or Next Generation Gravity Missions using LRI observations (T2.4). The GFZ E2E-simulator has been updated.

4. Processing Standards and Models

The Deliverable 2.1 Processing Standards and Models was submitted to the Project Officer in March 2015. The technical note serves as a record of the processing standards, models and parameters adopted for the generation of the GRACE level 2 products by EGSIEM. Along with all other deliverables this is hosted on the internal section of the EGSIEM website. The document (it is expected) will serve as the basis for institutions outside of the EGSIEM consortium that expressed an interest in contributing to the combination service

5. Improved Processing Tools

All ACs have implemented the processing standards and refined their processing workflow. Four out of five ACs (UBERN, GFZ, TUG, CNES) achieved considerable improvements in terms of product precision and quality. UL faced additional problems with their approach but have subsequently identified the problem.

Most processing tool improvements are already contained in the first EGSIEM Periodic Report submitted in February 2016. The following is a summary of the improvements made by the individual ACs in the period of M13-M18, which are not covered in this report.

UBERN validated the data exchange interface, which also included tests of the file format definition (SINEX, see chapter 6.1).

GFZ performed an evaluation and validation of the new AOD1B RL06 pre-release on the basis of monthly GRACE solutions. Furthermore a new stochastic modelling approach is currently implemented.

CNES revised their solution algorithm which significantly improved the performance of the gravity field solution in the polar regions. This also led to the release of a new monthly and 10-day GRACE gravity field time series (CNES RL03-v2).

TUG implemented a new parameterization of the accelerometer scale factors. This parameterization includes terms of the misalignment of the accelererometer reference frame versus the satellite reference frame as well as non-orthogonality of the accelerometer axis. A significant improvement of the estimated Earth's oblateness was observed as a result. All advances in the processing standards cumulated in a new gravity field release of TUG (ITSG-Grace2016). The improved methodology has also been presented at conferences (e.g. Klinger et al. 2016, Ellmer and Mayer-Gürr 2016) and was summarized in an article currently under review.

UL has improved the dynamic orbit integration procedure, however the inclusion of SST range rate data in the orbit adjustment still yields suboptimal results.

6.Data Analysis

All Analysis Centers (ACs) have re-processed at least two years of GRACE data for gravity field determination. TUG additionally released a new solution of the complete GRACE time span called ITSG-Grace2016. CNES/GRGS provided a new solution of monthly and 10-day solutions from August 2002 up to March 2015 (RL03v2). Kinematic GRACE positions based on improved reference frame products have already been computed. They were made available to the EGSIEM consortium via FTP (server hosted at UBERN).

6.1 Monthly GRACE normal equations in SINEX format

The individual GRACE monthly gravity field solutions generated by the different ACs should be distributed in the form of normal equations. It was decided to use the "Solution (Software/technique) INdependent EXchange Format" (SINEX). The SINEX format is defined and updated by the IERS.

```
%=SNX 2.02
+FILE/REFERENCE
+FILE/COMMENT
+SOLUTION/STATISTICS
+SOLUTION/NORMAL_EQUATION_VECTOR
+SOLUTION/NORMAL_EQUATION_MATRIX U
+SOLUTION/ESTIMATE
+SOLUTION/APRIORI
%ENDSNX
```

Figure 1: Normal equation exchange format definition.

Within this format it is possible to store the normal equation system for the monthly gravity field of the Earth in terms of spherical harmonics coefficient. As the format is very general and can be used for different data types a lot of optional data blocks can be included. For the exchange between the ACs the following data blocks have been defined as mandatory

- FILE/REFERENCE
- FILE/COMMENT
- SOLUTION/STATISTICS
- SOLUTION/NORMAL_EQUATION_VECTOR
- SOLUTION/NORMAL_EQUATION_MATRIX U
- SOLUTION/ESTIMATE
- SOLUTION/APRIORI

Some additional information is required for the correct interpretation of the data which are not defined within the standard SINEX format description document. Therefore it was decided to

include the additional information in the FILE/COMMENT block. The format of this block should be followed by the definition of the header in the ICGEM format and must include at least the following constants

- earth_gravity_constant
- radius
- max_degree
- tide_system

The system of normal equations are reduced by the applied models of each AC defined in the standards document. The solution of the normal equation system does not contain the apriori solution. The SOLUTION/APRIORI block contains the monthly mean of a subset of the mentioned models only. To follow the definition of the official GRACE solutions of the official ACs (GFZ, CSR, JPL) it was decided not to include the dealiasing products of ocean and atmosphere (AOD1B), all tidal effects, as the motion of the solid Earth and the ocean due to the change in the centrifugal force (pole tide and ocean pole tide).

7.GRACE/GRACE-FO E2E Simulator

The work undertaken below, including the most recent simulations will help to better define cost and science-effective future missions including GRACE-2 (a potential GRACE-FO successor).
The GFZ E2E-simulator has been successfully updated in order to assess the gain for hydrological applications which can be achieved with GRACE-FO and other Next Generation Gravity Missions (NGGM). To achieve the desired results the consortium performed full-scale simulations based on nearly identical processing standards and models as used within EGSIEM WP2 in order to investigate “What Can be Expected from the GRACE-FO Laser Ranging Interferometer for Earth Science Applications?” (Flechtner et al., 2015)
In addition to the work above, GFZ analyzed the improvements which can be achieved with lower observation noise such as for the lowlow satellite-to-satellite tracking or the accelerometer instruments or improved constellations such as two-pair Bender or one-pair Pendulum, in order to obtain realistic numbers for NGGMs.

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8.Glossary

CNES	Centre national d'études spatiales
GFZ	German GeoForschungsZentrum
GRACE	Gravity Recovery And Climate Experiment
GRGS	Groupe de Recherche de Géodésie Spatiale
IERS	International Earth rotation and Reference system Service
SINEX	Solution (Software/technique) INdependent EXchange Format
SST	Satellite-to-Satellite Tracking
TUG	Graz University of Technology
UBERN	University of Bern
UL	University of Luxembourg