Progress report

Project Number: **637010**

Project Acronym: **EGSIEM**

Project title:

European Gravity Service for Improved Emergency management

Deliverable 1.2

Interim Progress Report

Period covered by the report: **1.1.2016 – 31.12.2016**

Progress report

1. Explanation of the work carried out by the beneficiaries and Overview of the progress

In the second year of EGSIEM continued progress has been made towards the project objectives (see section 1.1), and as one can see from section 1.2 work has continued on all Work Packages (WPs). Indeed, the consortium has been able to begin several tasks ahead of the initial schedule as specified in the Description of Action (DoA). For ease of reference the status of each task (started/completed etc) is specified for each WP in Section 1.2 below, where we also give a summary of the work undertaken which includes a short technical description of the work undertaken per task.

1.1 Objectives

The European Gravity Service for Improved Emergency Management (EGSIEM) project can be summarised into three key objectives:

- **Deliver the best gravity products for applications in Earth and environmental science research:**
  The unification of the knowledge of the entire European GRACE community will pave the way for a long awaited standardisation of gravity-derived products. Combining the results obtained from different Analysis Centers (ACs) of the EGSIEM consortium, each of which will perform independent analysis methods but will employ consistent processing standards, will significantly increase the quality, robustness and reliability of these data.
  The project started with the definition of common processing standards for all ACs. The discussions triggered by this task are still ongoing and proved to be very fruitful and resulted in a number of very significant improvements of the individual contributions (WP2). A first combination of monthly gravity fields was performed at the solution level (WP4). A clear reduction of noise with respect to the individual AC solutions was observed. Consortium partners and associated members evaluated the improvements to be at the impressive level of 10 to 50%.

- **Reduce the latency and increase the temporal resolution of the gravity and therefore mass redistribution products:**
  An increased temporal resolution from one month to one day and the provision of gravity field information within five days (essentially near real-time) will translate into tremendous added value for warning and forecasting the onset of natural hazards.
  First gravity field products with daily resolution were produced and provided for comparison with river discharge data. The correlation of the derived water heights with observed river discharge for the 2007 flood of the rivers Ganges and Brahmaputra, e.g., is at the level of 86%, clearly showing the potential of the gravity field products for monitoring large flood events at high temporal resolution.

- **Develop gravity-based indicators for extreme hydrological events and demonstrate their value for flood and drought forecasting and monitoring services:**

  Adequate data products and indicators will be provided to support operational satellite-based flood information services. The applicability and added value of these indicators will be exploited within the framework of the DLR's (Deutsches Zentrum für Luft- und Raumfahrt) Center for Satellite Based Crisis Information and international initiatives such as the Copernicus Emergency Management Service and the International Charter "Space and Major Disasters".

The work plan of the EGSIEM project is structured into seven distinct work packages (WP). To achieve the high-level objectives of the project, the objectives per WP are given below:

The following objectives are all listed within **WP1: Management**.

- Productive collaboration and integration of all partners
- Dealing with overall administrative and financial issues
- Meeting EC requirements
- Scientific coordination
- Risk management
- Reporting

These objectives are ongoing throughout the life of the project, so far all of the above objectives have been met and there is no divergence from the feedback given in the first periodic report.

The following objectives are all listed within **WP2: Gravity field analysis:**

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

  Completed, please see Deliverable 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. Currently, series of monthly gravity field solutions are being processed for two years 2006-2007 at the different ACs and were made available for combination (Task 2.3) at M18. During the course of the project we will endevour to provide longer time series.

- 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:

  The task concerning this objective (T2.4) has been completed and the GFZ E2E-simulator has been updated.

The following objectives are all listed within **WP3: Integration of complementary data (UL)**.

- Pre-processing of all necessary supplementary data which are needed for the gravity field analysis in WP2 and the combination with the gravity data and hydrological models in WP4-6:

  This objective is proceeding according to schedule, a series of regional ice models has been collected, which will contribute to a global GIA model (Task 3.8, end M36). Representative historical flood information during the years 2006-2007 was compiled in the first year, see First Periodic Report.

- Loading estimates derived from GNSS station time series are used for validation of the combined global, the near real- time and the regional gravity field solutions:

  This objective was completed in the first year.

- Lake and river levels from the Hydroweb project are used together with hydrological models in WP6 as well as Glacial Isostatic Adjustment (GIA) models for separating the hydrological trend.

  Altimetry-based water levels have been prepared and are provided by Hydroweb (Task 3.7, see first Periodic Report). Three suitable test basin have been identified and satellite derived flood information was compiled (Task 3.9). A global GIA model is currently being assembled (Task 3.8, ends M36).

The following objectives are all listed within **WP4: Scientific Service (UBERN)**.

- Combination of the global monthly gravity models from the individual ACs:

  This objective has now been fully designed and is currently undergoing operational testing, see Tasks 4.1 (completed M18 via D4.1) & 4.2.

- Provision of user-friendly Level-3 products

  Much work has been undertaken on the EGSIEM Plotter to provide L3 products in as accessible and innovative way as possible (see Task 7.2 below), following feedback received during the Mid-Term review the consortium is currently investigating the best way of ensuring the data is provided under the framework of the Data Management Plan.

- Validation of the individual and the combined gravity field solutions:

  The combined solutions were evaluated in terms of ice mass change in Antarctica, water mass variation during a major flood of Ganges river in India/Bangladesh and by comparison to a model of post glacial uplift in Fennoscandia (Task 4.3). Evaluation confirmed a clear reduction of noise in the part of the spectrum (up to spherical harmonic degree 60 and order 29) most relevant for the aforementioned applications.

The following objectives are all listed within **WP5: NRT and regional Service**.

- Provision of NRT mass redistribution products for all areas of interest:

Deliverable 5.1 set out a framework document which provided the preliminary design of the Near-Real Time (NRT) and Regional Service of EGSIEM. The NRT mass redistribution time series was completed at M18 (Service Readiness).

• Provision of regional gravity field solutions with increased spatial resolution:

The current methods to derive regional mass transport solutions are currently being improved (Task 5.4) and a reprocessing of these alternative models has been started for the complete mission period for dedicated areas of interest.The regional gravity solutions were refined and completed by M18 (Milestone: Service Readiness).

The following objectives are all listed within **WP6: Hydrological service**.

• Validation of new gravity products for historical flood events:

EGSIEM gravity products (daily regional product and combined monthly product) were analyzed for selected historical flood events in several central European and South-East Asian (Ganges-Brahmaputra, Mekong) river basins by comparing river discharge data and output from the WaterGAP Global Hydrological Model (WGHM) and the European Flood Alert System (EFAS). Results are still very encouraging, especially in the Ganges-Brahmaputra Delta (see Task 6.1).

• Provision of gravity-based indicators for forecasting of hydrological extreme events with lead times of several months up to near real time:

The European Flood Awareness System (EFAS) and the European Drought Observatory (EDO), both operated by the Joint Research Center (JRC) of the European Commission, are identified as potential users of the gravity-based indices. A user requirement, which followed from initial discussions, is that the gravity-based indices express a measure of relative total water storage (fraction of maximum total water storage).

• Improved mechanisms for automatic satellite-based flood services:

During M12 a meeting took place with the German Federal Office of Civil Protection and Disaster Assistance (BBK), which is the German authorized user for the Copernicus EMS (Emergency Management Service) as well as for the International Charter "Space and Major Disasters". During this meeting requirements for improvements of the rapid mapping workflow have been discussed based on recent very large floods such as the Elbe floods in 2013. Generally, the requirements for satellite rapid mapping products focus on timely and high frequency flood monitoring from the onset of a flood event with a special focus on mapping the flood extent at peak level until water levels have receded to near normal stages. For such cases a proactive satellite tasking based on external information such as gravity-based indicators is desirable and to be evaluated in EGSIEM (Task 6.2).

The final objective listed belongs to WP7: Dissemination and exploitation.

• Dissemination, exploitation and communication of and about the objectives and results of EGSIEM:

In addition to the regular news, blogs and features updated via the website and social media we have completed a further three newsletters. The newsletters and broschure are distributed at international conferences and by the EGSIEM website. The GRACE plotter is operational and is being regularly updated. Task 7.3 our first public education event (D7.3, teasure lecture in the frame of "Physik am Freitag" took place at the university of Bern, March 11, 2016.

1.2 Explanation of the work undertaken per WP

<u>WP1 – Management (UBERN) M01-M36</u>

Task 1.1 Legal and Financial Management (M01-M36)

<u>Status:</u>

Ongoing, so far all Tasks completed in line with the Description of Action.

<u>Summary:</u>

As set-out in the Consortium Agreement (CA – see first periodic report for a description) payments have been made at the very beginning of the project - 70% of the Pre-Financing payment received from the EU in line with the Grant Agreement. Following input received from all beneficiaries, and the acceptance of the first Periodic Report the remainder of the Pre-Financing (30%) was sent to all beneficiaries (apart from the coordinator, UBERN receives funding towards EGSIEM from the Swiss government). The below graphic of expected payments is shown at each project meeting to illustrate the expected cashflow:

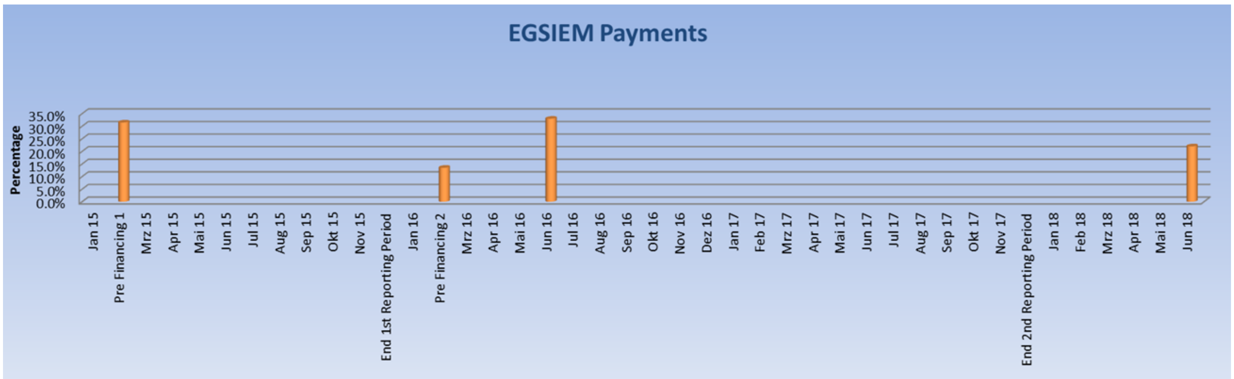

Figure 1: Illustration of expected beneficiary payments (assuming acceptance of reports and adherence to Consortium and Grant Agreements).

Thus far and in line with the DoA, EGSIEM meetings consisting of representatives from each beneficiary have taken place every six months, as follows:

- M01: Bern, Kick Off Meeting
- M06: Bern, Project Meeting
- M13: Luxembourg, General Assembly
- M18: Potsdam, Project Meeting

The next meeting will take place in Bern on the 18. - 19. January and will be attended by all beneficiaries, members of the Advisory board, Associate members, our Project Officer and Expert External Reviewer. Given the open nature of EGSIEM there will also be other guests interested in the project present.

In addition to those Associate Members listed in the DoA, and the first periodic report a number of other institutions have or are in the process of signing Service Level Agreements with the project

(German Federal Agency of Cartography and Geodesy (signed August 2016), TU Delft and IWF, University of Wroclaw), more information on this can be found below in Section 2.

Task 1.2 Scientific coordination (M01-M36)

Status:

Ongoing

Summary:

There have been no changes in the methods of coordinating EGSIEM, the project leader is still supported by an Executive board which communicates regularly. Since the first periodic report was submitted (M14) there have been few Deliverables submitted but this follows the program as set out in the DoA.

Work package 2: Gravity field analysis (TUG) M01-M18

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. As mentioned in the first periodic report and in accordance with the DoA, significant effort has been devoted to harmonizing and improving the gravity field analysis at the different EGSIEM Analysis Centers (ACs).

Task 2.1 Processing Standards and Models (M01-M02)

Status:

Complete, please see the description in the first periodic report.

Task 2.2 Improved Processing Tools (M01-M10)

Status:

Complete, please see the description in the first periodic report, or Deliverable 2.2.

Task 2.3 Data Analysis (M11-M18)

Status:

Complete, reporting period 1 tasks complete.

Summary:

Four of the five Analysis Centers (ACs) provided two years (2006 and 2007) of monthly normal equations (NEQs) in accordance with the EGSIEM standards in SINEX format. The contribution of UL was delayed due to outages in personal at UL (first Matthias Weigelt left UL, then his replacement, Zhao Li was on maternity leave) but the first UL monthly solutions have just became available in

December 2016. 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). GFZ has reprocessed two years (2006 and 2007) of monthly GRACE gravity field solutions. As a baseline for the reprocessed solutions, the operational GFZ RL05a solutions relative to which the following modifications have been applied:

- The GPS constellation (orbits and clocks of the GPS satellites) including Earth Orientation Parameters (EOPs) provided by AIUB within EGSIEM has been used instead of the GPS constellation routinely processed at GFZ (with EOPs provided by the IERS)
- The mean pole convention as described in the IERS2010 conventions has been applied
- For the time-variable background gravity field model, a monthly mean of the time-variable part of the EIGEN-6C model has been used instead of evaluating the EIGEN-6C model daily
- The FES2014 model up to degree and order 100x100 has been used as ocean tide background model instead of EOT11a up to 80x80
- The relative weighting between GPS and K-Band measurements has been modified such that GPS is slightly down-weighted (i.e. the a priori sigma of the GPS phase measurements has been increased from 0.7 to 1 cm)
- The parameterization of the accelerometer (ACC) measurements has been modified as follows: the step size of the ACC biases has been increased from 1 hour to 3 hours, and 3-hourly ACC scale factors are estimated instead of fixing the scale factors to the value of 1

Compared to the official GFZ RL05a solutions, significant improvements in terms of noise reduction have been achieved.

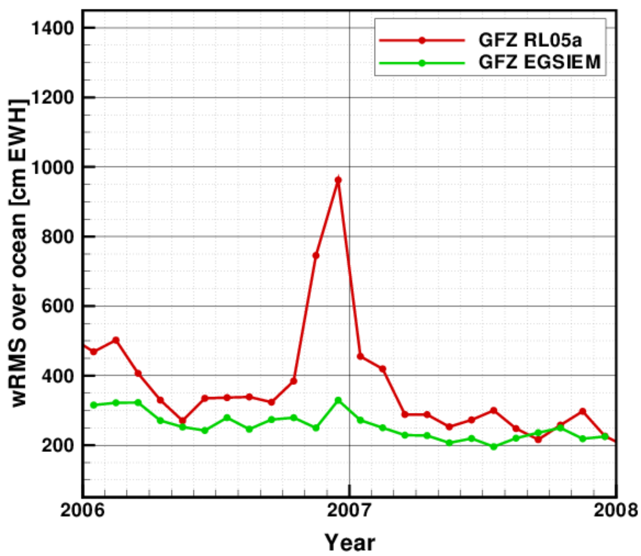

Figure 2: Weighted root mean square over ocean areas of unfiltered GFZ GRACE solutions for the official RL05a time series (red) and the time series generated for EGSIEM (green). Bias, annual and trend signal is removed from all solutions.

During 2016, UL focused on the implementation of the rigorous acceleration approach (Acc. Rig.). The contribution of UL was delayed but fortunately, the complete code for the Acc. Rig. have been finished in early November, and it is now undergoing testing. The process includes two steps: Firstly, it follows the celestial mechanics approach (CMA, Beutler et al., 2010a, 2010b) to obtain a priori orbits for GRACE A and B using both kinematic positions and K-band range rates. Secondly, it uses the previously obtained orbit as input for final orbit and gravity field determination. The full expression of the mathematical model for Acc. Rig. is:

$$\ddot{\rho} - \ddot{\rho}^0 = (\nabla V_B - \nabla V_A) \cdot \boldsymbol{e}_{AB} - \left(\nabla V_B^0 - \nabla V_A^0\right) \cdot \boldsymbol{e}_{AB}^0 + \frac{1}{\rho}\left(\dot{\boldsymbol{X}}_{AB} \cdot \dot{\boldsymbol{X}}_{AB} - \dot{\rho}^2\right) - \frac{1}{\rho^0}\left(\dot{\boldsymbol{X}}_{AB}^0 \cdot \dot{\boldsymbol{X}}_{AB}^0 - \left(\dot{\rho}^0\right)^2\right)$$

The following Figure gives the degree RMS of the monthly solutions for January 2006 (test month) with respect to EGM2008 provided by different processing centers. Up until now, the Acc. Rig. is simply another implementation of the variational equations. However, a gravity solution using CMA can also be obtained (blue curve, ULUX_CMA for comparison). It can be observed that ULUX's Acc. Rig. (red curve, ULUX_CMA) produces GRACE gravity solutions at the same level of precision as the other approaches. In addition, the test results are even better than some solutions from other institutions, particularly for degree 15 to 75. Compared with AIUB's CMA solution, ULUX_CMA appears to be worse as we did not down weight the GPS component during orbit determination. Furthermore, the a priori orbit obtained is similarly not as good as that from AIUB. Work has been undertaken that will, by the end of 2016, parameters and background models to improve the approach. In this way, the full Acc. Rig. solutions will be provided by the end of June 2017.

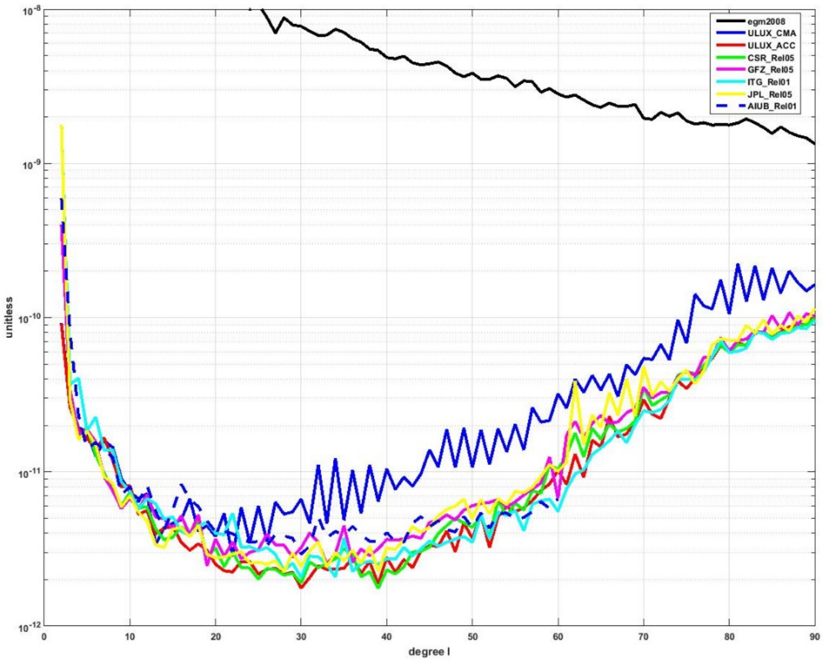

Figure 3: Degree RMS of the monthly solutions for January 2006 w.r.t EGM2008 provided by different processing centers.

Task 2.4 Instrumental Behaviour and End-to-End simulator (M06-M18)

Status:

Complete, reporting period 1 tasks complete

Summary:

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). The consortium continued the full-scale simulations based on nearly identical processing standards and models as used within EGSIEM WP2. In addition, GFZ analyzed the improvements which can be achieved with lower observation noise such as for the low-low 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.

Work package 3: Integration of complementary data (UL) M01-M36

WP3 prepares all auxiliary data and products needed for the GRACE data processing in WP2, the validation of the derived gravity field products from WP2, and for the validation of flood and drought indices derived in WP6. In accordance with the DoA, significant effort has been devoted to improving the reference frame products which are underlying the GRACE data processing in WP2. The importance of WP3 is also reflected by the fact that it is closely related to Milestone 2.

Task 3.1 Reference Frame Reprocessing (M03-M10)

Status:

Complete, please see the description given in the first periodic report.

Task 3.2 SLR normal equations (M07-M09)

Status:

Complete, please see the description given in the first periodic report.

Task 3.3 NRT reference frame reprocessing (M03-M06)

Status:

Complete, please see the description given in the first periodic report.

Task 3.4 Operational NRT reference frame reprocessing (M28-M33)

Status:

In line with the project timetable, this task has not yet been undertaken.

Task 3.5 Validation of GRACE gravity products with GNSS site displacements (M19-M36)

Status:

Ongoing, began earlier than anticipated and is advanced with regards to the DoA

Summary:

To date, UL has finished evaluating the combined monthly GRACE gravity products (test version) provided by UBERN last December. The entire validation procedure starts with processing the GNSS and GRACE products, respectively. In addition to the JPL and SOPAC GNSS products that we used in 2015, we also include the latest ITRF2014 residuals from IGN (Rebischung et al., 2016) into the validation procedure. These residuals are free of outliers and offsets, detrened and considered as the best GNSS time series to date. 394 common stations are selected from the three products. Daily vertical time series are accordingly averaged into monthly solutions to be compared with GRACE. In addition to the combined gravity field solutions, additional gravity solutions from six different institutions (JPL RL05.1, CSR RL05, GFZ RL05a, ITSG2016, AIUB RL02, GRGS RL03v1) are included in the procedure as well. A standard GRACE data processing chain is applied which includes replacing C20 from SLR (Cheng et al., 2011), adding back degree-1 coefficients from Swenson et al. (2008), filtering with a Gaussian filter of 500 km radius and adding back AOD1B atmospheric and oceanic dealiasing products. GRGS RL03v1 data has already been stabilized during their data processing and we only need to restore the dealiasing products. Subsequently, vertical displacements at these common stations are derived using gravity fields and are compared with GNSS-observed counterparts.

At UL we applied the WRMS reduction measure to evaluate the performance of each gravity field. A summary of the statistics is provided in Table 1. The results show that more than 80% of the stations have a positive WRMS reduction from all seven gravity solutions. In addition, around 20% mean WRMS reductions are obtained with the ITRF2014 residuals. Cross comparison of the EGSIEM combined solutions against other solutions demonstrates that its quality is equivalent to CSR RL05 and ITSG2016. Further, it is slightly better than the other gravity solutions. Another result to be gleaned from the table is the quality of the JPL and SOPAC GNSS time series. It seems that JPL performs better when compared with GRACE while SOPAC showed better statistics when compared with models (see the last report).

	JPL		SOPAC		ITRF2014	
	Mean [%]	Positive [%]	Mean [%]	Positive [%]	Mean [%]	Positive [%]
GFZ RL05a	14.97	88.32	13.18	81.98	20.49	87.06
CSR RL05	16.42	91.62	14.38	85.03	22.35	88.58
JPL RL05.1	15.64	89.85	13.12	83.50	20.64	88.83
AIUB RL02	15.65	89.85	13.33	82.74	20.60	87.31
GRGS RL03v1	14.15	85.79	12.73	80.96	19.93	84.77
ITSG2016	16.32	90.86	14.27	85.03	21.82	88.83
EGSIEM	16.64	92.13	14.07	84.77	22.14	88.32

Table 1: Mean and positive WRMS reductions between seven GRACE products and three GNSS solutions

In addition to the comparison between GNSS and GRACE, we have also implemented the comparison between seven GRACE gravity fields and four continental water loading models (see the first periodic report) at the displacement level. We again demonstrated that the combined EGSIEM solutions is at least equivalent to CSR RL05 and ITSG2016 and better than others. The methodology and early results of the validation work have been presented at EGU in April 2016 (Li et al., 2016) and at the first DAAD Thematic Network workshop in July 2016 (Chen et al., 2016).

Apart from this validation work, we have also started assessing the reference frame products produced by UBERN. An offset database has been obtained and it will be applied to the GNSS data processing in the near-real-time validation.

Task 3.6 Validation of GRACE products with Ocean Bottom Pressure (M25-M36)

Status:

Started early and at an advanced stage with regards to the DoA.

Summary:

To objectively assess the differences in results from different groups and to evaluate the impact of changes in the data processing in preparation of a new GRACE data release, a validation of the time variable GRACE gravity fields against independent observations is required. For such a validation we can use the data from a set of globally distributed ocean bottom pressure sensors because ocean bottom pressure is directly comparable to the variations of the gravity field over the oceans.

A set of in situ time series from about 100 globally distributed locations has been pre-processed to remove outliers, drifts, trends, jumps, and all tidal signals. The time series from re-deployments of sensors at the same station were stacked together and the temporal sampling is reduced to one hour. Finally, the time series are filtered in the time domain to allow us to focus on specific frequency bands in the validation of the GRACE solutions.

In order to prepare and test the validation procedure for EGSIEM products, planned for 2017, the procedure has been already applied to the official GRACE RL05 monthly solutions from CSR, GFZ and JPL ("GRACE SDS solutions"), as well as to two daily EGSIEM solutions (ITSG 2014 and the latest GFZ daily solution). All three considered GRACE monthly solutions display very similar results. While there is relatively good agreement with in situ data at higher latitudes, where GRACE data explained up to 60% of in situ measurements, the explained variances of all validated GRACE monthly solutions in tropics are mostly negative. Detailed results have been presented in a poster at the EGU General Assembly 2016.

The validation of the GRACE daily fields is performed for three different frequency bands: 1-3 days, 3-10 days, and 10-30 days. In all considered frequency bands we find that the ITSG daily solutions show relatively higher explained variances compared to GFZ daily, particularly in the Atlantic Ocean. All details of the validation are contained in a manuscript submitted to the Proceedings of the GGHS meeting for possible publication in the Springer IAG series entitled “Validation of time-variable gravity field products with globally distributed in situ ocean bottom pressure observations”.

Task 3.7 Preparation of Hydroweb Data (M07-M10)

Status:

Complete, please see the description given in the first periodic report.

Task 3.8 GIA for Hydrology (M11-M36)

Status:

This task was begun earlier than initially scheduled and is currently ongoing.

Summary:

Glacial Isostatic Adjustment (GIA) is the response of the Earth in terms of deformation as well as stress, rotation and geopotential changes due to changing ice-ocean load distributions on the Earth's surface. This process is well known in northern latitudes, e.g. in Fennoscandia, and generates a strong signal in many observations such as GRACE or GNSS, thus overlapping other signals of interest, e.g., from hydrology. Tilting due to the GIA strongly affects groundwater flow and lake surface control, therefore it will be modeled by applying the latest GIA models. The Associated Member Lantmäteriet (LM; the Swedish mapping, cadastral and land registration authority) in Sweden is currently developing a new series of GIA models which will be provided to the EGSIEM consortium for helping to separate the hydrological trend.

A GIA model generally consists of an ice history model that describes the load variation during (at least) the last glaciation and an earth structure. A physical description of the GIA process and the corresponding sea-level variation combines these two models and at the same time calculates (among other things) corresponding ocean load changes due to the glaciation (water is taken from the oceans to generate the ice sheets described in the ice history model). When it comes to the ice history model, LM follows a different approach compared to common GIA modelling. Instead of using a global model such as the commonly used ICE-6G_C (Peltier et al. 2015), LM combines regional ice history models to a global one. During the last two years, LM has collected a series of regional ice models, kindly provided by their developers, which can be combined to form a global ice model. The following models are available at LM:

- Greenland: HUY3 (Lecavalier et al. 2014), ANU-ICE (Lambeck et al. 2014)
- Fennoscandia, British Isles and Barents Sea: GLAC (Hughes et al. 2015, Nordman et al. 2015, Root et al. 2015), ANU-ICE (Lambeck et al. 2010)
- Iceland: ANU-ICE (Lambeck et al. 2014)
- North America: GLAC (Tarasov et al. 2012), NAIce (Gowan et al. 2016)
- Antarctica (including Antarctic Peninsula): W12 (Whitehouse et al. 2012), IJ05_R2 (Ivins et al. 2013), GLAC (Briggs et al. 2014), ANU-ICE (Lambeck et al. 2014)
- High Mountain Areas: ANU-ICE (Lambeck et al. 2014)
- Patagonia: ANU-ICE (Lambeck et al. 2014)

For most regions at least two models are available, which allows different combinations of these models. Major goal is to achieve a sea-level equivalent (the amount of corresponding ocean water included in the ice sheet volume) that comes closest to estimates of about 120 m at the last glacial maximum. This is a difficult task as it is known ("Missing Ice"-Problem) that combined regional models cannot match this value. Another difficulty in the development of the ice model is the different spatial and temporal resolution of the regional ice models.

The first model that was generated is based on the GLAC ice history for northern Europe, North America and Antarctica, HUY3 for Greenland and ANU-ICE for Patagonia, Iceland and High Mountain Areas. A snapshot of the ice thickness at 22000 a BP is shown in Fig. 1. The model consists of 53 time steps of ice thicknesses on a 0.5x0.5 degree grid.

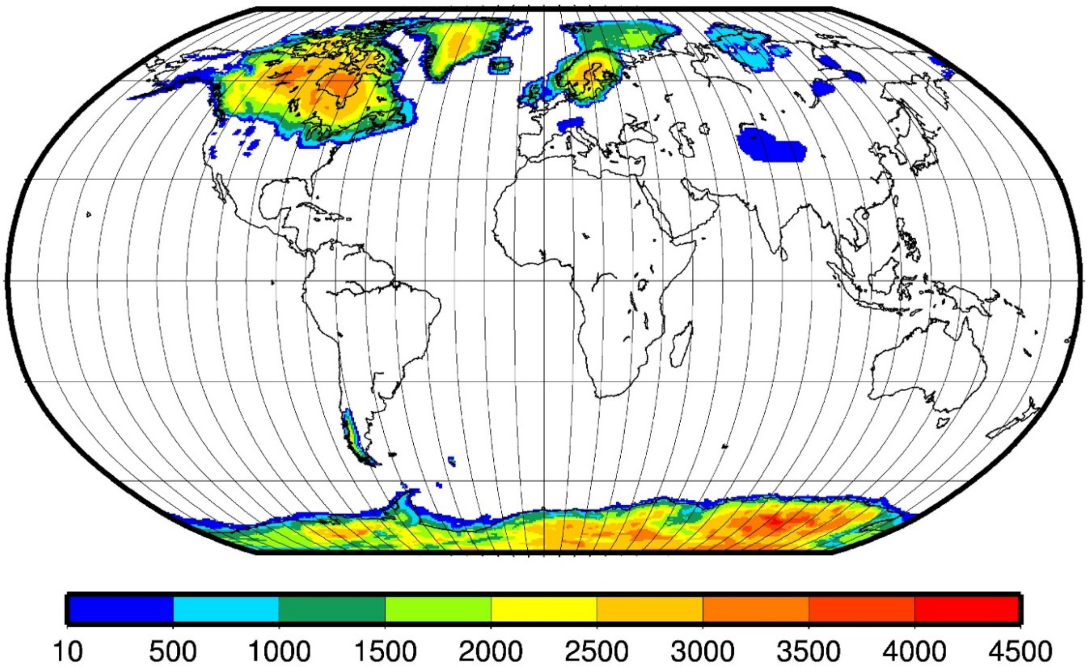

Figure 4: Ice thickness at 22000 a BP of the first ice model based on a combination of regional models.

Task 3.9 Compilation of representative historical flood situations (M01-M10)

Status:

Complete, please see the description given in the first periodic report.

Work package 4: Scientific Service (UBERN) M07-M33

WP4 is the core activity of the scientific combination service. Gravity field solutions of superior quality shall be generated by combining solutions established at the individual EGSIEM ACs. In accordance with the DoA, the design and concept were established by M18. Various combination strategies have been implemented and critically assessed as described in the first periodic report. A detailed summary is given below.

Task 4.1 Design and concept (M07-M18)

Status:

This task has now been completed

Summary

Test combinations of publicly available time-series of monthly gravity fields had been provided to all EGSIEM partners for validation in Nov. 2015 (M11). The validation results led to a specific investigation in a simulation study that was presented at EGU2016 (Jean et al. 2016). Finally, iteratively determined field-wise weights based on pairwise comparison of the individual gravity fields to their monthly mean using variance component estimation were chosen for operational combination on solution level.

In parallel the tools for combination on normal equation (NEQ) level were developed and applied to a set of monthly NEQs provided by GFZ, TUGRAZ and UBERN. In detail the following steps have to be performed on the NEQs:

- transformation from SINEX to Bernese format,
- transformation to common tide system (bias on C20),
- transformation to common Earth radius and GM (degree-specific rescaling of NEQs),
- parameter transformation to common a priori gravity model,
- weighting and combination of individual NEQs.

For the combination and inversion of the combined NEQ system the standard tools of the Bernese Software are used. In addition, tools to perform a contribution analysis of the individual NEQs were developed. A first test combination was presented at EGU 2016 (Meyer et al. 2016a).

The relative weighting of the NEQs more challenging than expected. Standard procedures based on variance factors fail due to the inhomogeneous approaches for noise modeling applied by the different ACs. The proposed way out of this situation consists of two steps: Firstly, empirical weights are determined that lead to an approximately equal contribution of the individual NEQs to pairwise combinations. Secondy the weights based on the relative noise levels, as derived for the combination on solution level, are applied to the NEQs to account for their different signal to noise ratios.

The EGSIEM Level-3 products consist of geographic grids of equivalent water heights that are provided in ASCII format. They can be visualized on the EGSIEM plotter webpage (plot.egsiem.eu) and downloaded at the same site or from the ISDC 2.0 portal (http://icgem.gfz-potsdam.de/ICGEM/).

As outlined in the first periodic report and in D4.1 the final EGSIEM Level-3 products will rely on corrections and external data that are currently under development within the framework of the GRACE-FO project at GFZ. As long as no dedicated auxiliary products are available, preliminary Level-3 products are computed using publicly available data (see below).

T4.1 was closed in M18 (June 2016) with the provision of deliverable D4.1: Concept of Scientific Service.

Task 4.2 Operation (M19-M33)

Status:

This task is currently ongoing.

Summary

With the start of T4.2 in M19 (July 2016) four of the five ACs provided two years (2006 and 2007) of monthly NEQs and gravity field solutions specifically computed in WP2 in accordance with the EGSIEM standards. The contribution of UL was delayed due to outages in personal at UL (first Matthias Weigelt left UL, then his replacement, Zhao Li was on maternity leave) but the first UL monthly solutions have just became available in December 2016, and these will be incorporated in the combination, if they pass the quality checks.

The individual contributions were evaluated and combined on solution and NEQ-level at UBERN as outlined in D4.1. The combined gravity fields were presented at GSTM in Potsdam (Meyer et al. 2016c). Internal validation and comparison with the individual contributions indicate a gain in quality relative to the best individual contribution that is most pronounced in the combination on NEQ-level (Fig. 5). After externel validation (T4.3) the combined gravity fields will be distributed to the users via the EGSIEM plotter (foreseen for the end of January 2017).

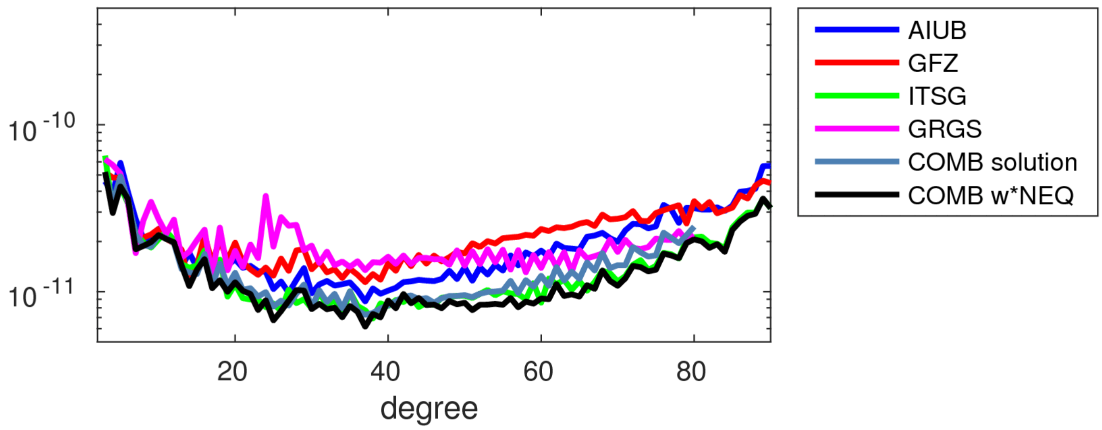

Figure 5: Degree amplitudes (orders 0..29) of anomalies with respect to a deterministic model of secular and saisonal temporal variations. The high degrees (beyond 40) represent the noise level of the individual contributions and the combined solutions. The lowest noise is achieved by the weighted combination on NEQ-level.

In consideration of the probable data gap between GRACE and GRACE-FO it was decided to extend the EGSIEM combination service to GPS-only gravity fields as may be derived from GRACE even after the expected switch off of the K-Band link and accelerometers, for example from the SWARM satellites. Test combinations of GRACE and SWARM GPS-NEQs computed at UBERN were presented at GGHS in Thessaloniki (Meyer et al. 2016b). A gain in quality was achieved by the combination, especially in low degree coefficients that are impaired in the individual GPS-only gravity field solutions by ionosphere induced errors (Fig. 4.2).

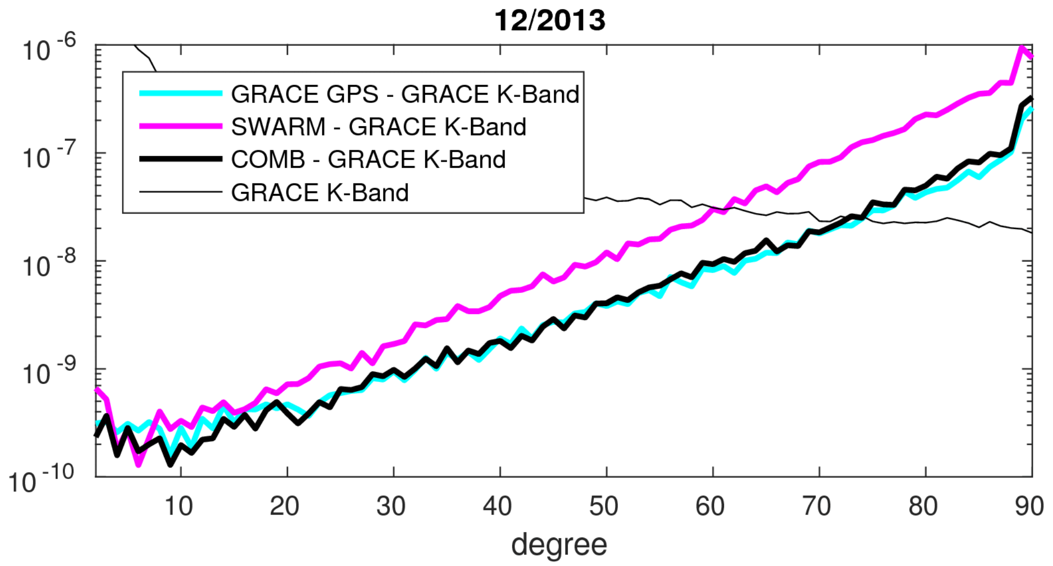

Figure 6: Difference degree amplitudes of individual and combined GRACE and SWARM GPS-only solutions with respect to GRACE K-Band solution.

Provision of user-friendly Level-3 products;

As described in the first periodic report, several "manipulations" to the Level-2 products (given in spherical harmonic coefficients (SHC)) have been developed for the development of user-friendly GRACE/GRACE-FO Level-3 products. These have been implemented and tested at GFZ and also at project partner TUG. This includes the addition of degree 1 coefficients which are not observed by GRACE/GRACE-FO, substitution of the degree 2 zonal SHC which is not sufficiently observed by GRACE/GRACE-FO and alternatively derived e.g. from satellite laser ranging, a posteriori correction of un-modeled signals such as glacial isostatic adjustment or de-correlation and smoothing of Level-2 products (for further details see the first periodic report). Level-3 products based on the approach followed by colleagues at TUG have been applied to EGSIEM individual and combined products to be used in various Earth science applications, e.g. monitoring of ice mass loss in Antarctica or Greenland.

In parallel, GFZ is further investigating alternative approaches of generating Level-3 products in the frame of preparation of the GFZ contributions to the GRACE-FO Science Data System. These new approaches will also be made available to the EGSIEM project in order to be applied to final Level-2 products end of 2017.

Validation of the individual and the combined gravity field solutions;

During quality control processes the individual gravity field contributions are evaluated in terms of signal and noise. The signal content is assessed by the amplitude of seasonal variations of equivalent water height within selected river basins, and by the mass trend in Greenland and at the west coast of Antarctica, where strong ice mass loss is observed. The noise content is assessed by anomalies, i.e., residuals of a deterministic model of secular and seasonal mass variations that are either defined in the spectral domain per spherical harmonic coefficient, or spatially on the cells of a global grid. In both domains ranges of coefficients or grid cells are defined that are governed by noise and therefore well suited for noise assessment. In the spatial domain these are the ocean areas, in the spectral domain we concentrate on the high degree but low order coefficients (the high degree and high order coefficients are commonly removed by filtering and therefore less meaningful for the assessment of the quality of the gravity field solutions). The same quality control is performed for the combined solutions that are compared in terms of signal and noise content to the individual contributions and to the official GRACE SDS gravity field series CSR-RL05, GFZ-RL05a and JPL-RL05.

Task 4.3 External validation (M19-M33)

Status:

This task is currently ongoing.

Summary

External validation using the GNSS loading follows the procedure developed in Task 3.5 (Validation of GRACE gravity products with GNSS site displacements). The validation of the first set of official EGSIEM combined solutions has just started, the results will be presented at the January EGSIEM progress meeting, preceding the distribution of the combined solutions via the EGSIEM plotter and ISDC 2.0 that is scheduled in January 2017 directly after the meeting. The GNSS products from Jet Propulsion Laboratory (JPL), SOPAC, the latest ITRF2014 residuals as well as the reference frame products provided by UBERN are used. Daily vertical component GNSS time series are averaged to monthly values. The gravity fields of the five ACs and their combinations are converted into displacements at the selected GNSS stations following the spherical harmonic approach. They are validated at the displacement level using the monthly means of the GNSS loading time series. Likewise, the correlation and WRMS reduction measures are used to evaluate the performances of each gravity field.

Work package 5: NRT and regional service (GFZ) M01-M36

Task 5.1 Requirements and concept (M01-M03)

Status:

Complete, please see the description given in the first periodic report.

Task 5.2 NRT Solutions: Processing (M04-M27)

Status:

Ongoing

Summary

NRT gravity field solutions have been improved by enhancements of the individual methodologies (radial basis functions, spherical harmonic solutions) and through feedback from dedicated evaluations against ground truth for the case of extreme events. The necessary adoptions for the real time processing chain, concerning access, availability and quality of NRT data and Earth Orientation Parameter predictions have been undertaken and tested.

Both NRT processing centers, TU Graz and GFZ, have established the full NRT data life-cycle from acquisition of the Level-1B quick-lock data as well as predicted Earth orientation parameters, GNSS orbit constellations and clocks from AIUB, WP3 in accordance with MS3 - Service Readiness. After the definition of the interface routines, the software framework allows for an automated processing of daily batches, with latencies that meet the initial requirement of maximum 5 days. This is due to a concentration of effort concerning software efficiency for the implemented algorithms, as well as the availability of required auxiliary data, which has been provided with shorter delays than initially expected.

At GFZ, modifications concerning the external GNSS constellations and clocks are still ongoing. First results showed similar deviations from the reference solutions in the range of several centimetres in terms of equivalent water heights that can probably be further reduced in the upcoming 3 months. At TU Graz the NRT processing chain was refined based on the experience made with online processing of historical L1B data. This included the proper treatment of long data gaps in the instrument noise estimation, as well as tweaking the automated outlier detection in the L1B data. The NRT software was deployed on the planned production hardware in preparation for MS4.

All historical data have been processed in two updated versions for GFZ´s radial basis functions (v100 and v101), and the ITSG-Grace2016 time series has been updated to include all available final GRACE data. These updated time series shall serve as reference for the NRT processing chain for the overlapping time period. Furthermore, a gravity field time series spanning from 2016-02 to 2016-07 was computed at TU Graz using the implemented NRT processing chain. These historical NRT solutions have been used for comparisons with ITSG-Grace2016 on observational level as well as daily and monthly gravity field solutions were undertaken to ensure the robustness of the NRT product. These investigations showed that the impact of the NRT processing chain on the solutions, while noticeable, is small which means the NRT solutions will be on a comparable quality level to the standard L2 products. During this evaluation period, an offline feedback loop with ULux was established (Task 5.6).

The main efforts in the next months and the time after the progress meeting, Jan 2017, will be the preparation of the operational NRT service readiness (Milestone 4). This will primarily involve the definition and technical implementation of interfaces for a seamless data exchange between GFZ, TUG and DLR/ZKI.

Task 5.3 Operational NRT solutions: Processing (M28-M33)

Status:

In line with the project timetable, this task has not yet been undertaken.

Task 5.4 Regional solutions: Concept and Processing (M04-M27)

Status:

Ongoing

Summary:

For the processing of refined regional solutions in possibly high density grid points (1ºx1º) the global NRT solution will be subtracted from the data outside the areas of interest and a new solution will be computed inside the areas of interest. An independent software clone has already been created for this purpose at GFZ end of 2015 and was refined in 2016. The generation of required global NRT solutions has highest priority in order to be prepared for the milestone M4 (Operational Service Readiness). Refined densities will then be computed according to the availability of enhanced external data (covariance information) for specific basins. This will be done with project partners from WP6 till mid of 2017. From that point we are slightly behind schedule but the overall success of the project is not in danger.

Task 5.5 Generation of Area Mean Values (M19-M36)

Status:

Ongoing

Summary

Area Mean Values have been generated for a number of selected medium to large-scale river basins, which have experienced widespread flooding since the start of the GRACE mission and for which daily discharge observations are available, e.g. the Danube, Rhine, Elbe (Europe), Mississippi (North-America) and Mekong and Ganges-Brahmaputra (South-East Asia).

Task 5.6 Validation/Feedback (M19-M36)

Status:

Ongoing

Summary

Validation with hydrological data: Extensive validation has been carried out for the Ganges-Brahmaputra Delta, where daily gravity field products are highly correlated with river discharge data for flood events in 2004 and 2007 (see Task 6.1) (Gouweleeuw et al., 2016). Validation for the Danube (2006) and Mississippi (2011) basin also result in high correlations (Kvas et al., 2016; Jäggi et al., 2016). Further validation of global daily gridded data, presented as wetness indicator of gravity anomaly in dimensionless units of standard deviation, is currently ongoing by comparison to databases of hydrological extremes (Dartmouth Flood Observatory, EM-DAT, GloFAS). A validation test with altimetry satellite orbits has been carried out at GFZ (Gruber et al. 2016).

Validation with GNSS loading data: To ensure the quality of the near-real-time (NRT) GRACE solutions, validation using external measurements is essential. To this end, we have preliminarily validated the daily GRACE solutions provided by TUG (ITSG2016) and GFZ (V100) in T5.2 using the latest daily ITRF2014 residuals (Rebischung et al., 2016). The validation procedure here follows the similar data processing as described in Task 3.5, but with different treatments towards the daily GRACE data. Unlike the monthly GRACE solutions, the daily GRACE solutions require no filtering and no C20 term replacing. As for the reference frame issue, i.e. degree-one terms, we tentatively follow the methodology as proposed by Tesmer et al. (2011). Further tests regarding the use of interpolated degree-one terms are planned.

In addition to the daily GRACE solutions, we included the daily hydrological models, e.g. GLDAS and WGHM, into the validation procedure to serve as references. The early results shown in the Table below demonstrates the quality of the generated daily GRACE solutions. Obviously, ITSG2016 and GFZ V100 slightly outperforms the hydrological models. Additionally, the updated version of the GFZ daily solutions (GFZ V101) will be validated soon as well, which is expected to deliver better statistics.

	ITRF2014				
	Max [%]	Min [%]	Mean [%]	Median [%]	Positive [%]
GFZ V100	64.59	-10.99	7.11	5.29	80.31
ITSG2016	66.44	-12.28	7.59	5.84	86.55
GLDAS	34.74	-14.31	6.03	3.82	79.39
WGHM_STD	46.01	-22.61	6.87	4.61	79.22
WGHM_CRU	44.32	-10.83	7.03	4.58	84.22

Table 2: WRMS reductions of the comparison between the latest ITRF2014 residuals and the daily GRACE solutions, the daily hydrological models at selected 394 GNSS stations

To fulfill the milestone of the operational NRT validation (due to begin in M28), we have also started to automate the above-described procedure for a just-in-time validation service. Instead of the ITRF2014 residuals, the NRT reference frame data provided by UBERN in T3.4 will be used along with the clean and detrended JPL and SOPAC GNSS time series. The automatic data acquisition and processing chain is taking shape and further refinement is under development.

Work package 6: Hydrological Service (GFZ) M01-M36

Work Package 6 provides the above described gravity products with real world validation by comparison with historical flood events, and uses the same products to derive rapid forecasting of flood and drought monitoring by defining user requirements for hydrologists and using gravity-based water storage anomalies to measure catchment area wetness, thereby providing indicators for hydrological extremes. WP6 is also dedicated to developing a rapid-mapping service to assist emergency management teams in targeting high/medium resolution satellite services to the correct areas as quickly as possible.

Task 6.1 Evaluation of historical flood events (M07-M30)

Status:

Ongoing

Summary:

- Validation and evaluation of the daily, near-real time and regional gravity products on water storage anomalies for selected flood events by a combination of complementary observation data sets and hydrological/hydraulic modelling
- Understanding mechanisms of the formation and dynamics of extreme events
- Preparation of a flood data catalogue to summarize the suite of multi-method data sets for the selected events

Daily regional gravity products were analyzed for selected historical flood events in several central European (Danube, Rhine, Elbe) (Figure 9) and South-East Asian (Ganges-Brahmaputra, Mekong) river basins (Figure 7) by comparing them to river discharge data and output from the WaterGAP Global Hydrological Model (WGHM) and the European Flood Alert System (EFAS). The river discharge data for flood events in 2004 and 2007 are vey similar to the daily gravity field products in the Ganges-Brahmaputra Delta. As a result of these promising results the delta is an excellent area of focus for more detailed analysis and modelling. This will alow us to understand the mechanisms of the formation and the governing dynamics of extreme events in this region, as described in Gouweleeuw et al (2016). In addition, complementary hydrological data (groundwater level, surface water level, additional river discharge) have been collected from the Bangladesh Water Development Board (BWDB) for further analysis.

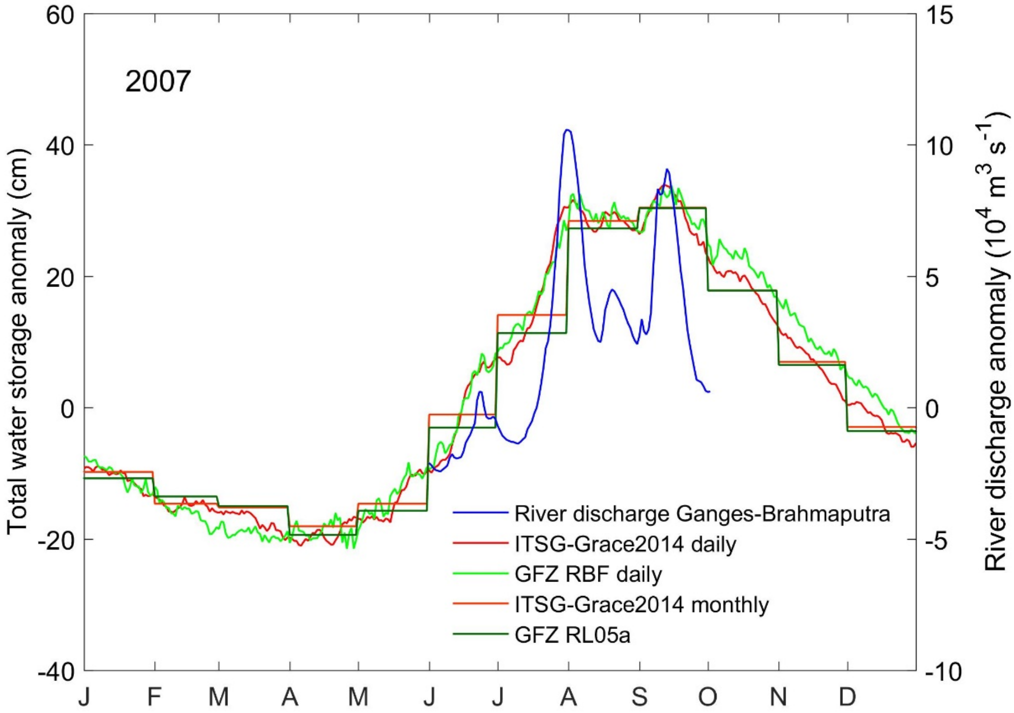

Figure 7: Daily and monthly area-average GRACE solutions together with river discharge anomalies for the Ganges-Brahmaputra Delta in 2007.

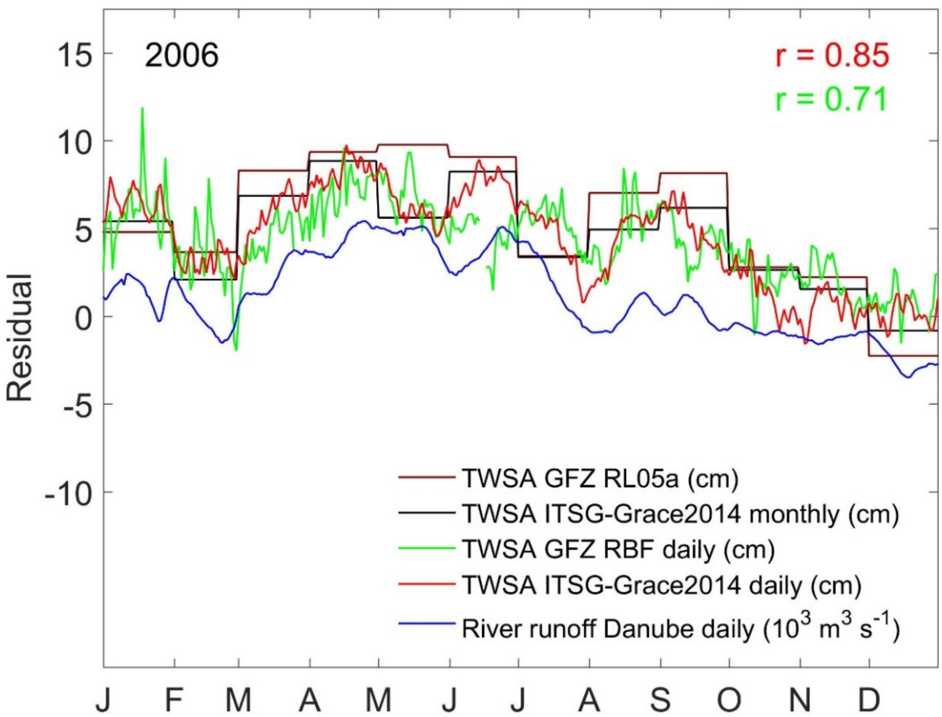

Figure 8: Daily and monthly area-average GRACE solutions together with river discharge anomalies for the Danube river basin in 2014. River runoff data is taken from Ceatal Izmail (Rumania) gauging station at the basin outlet.

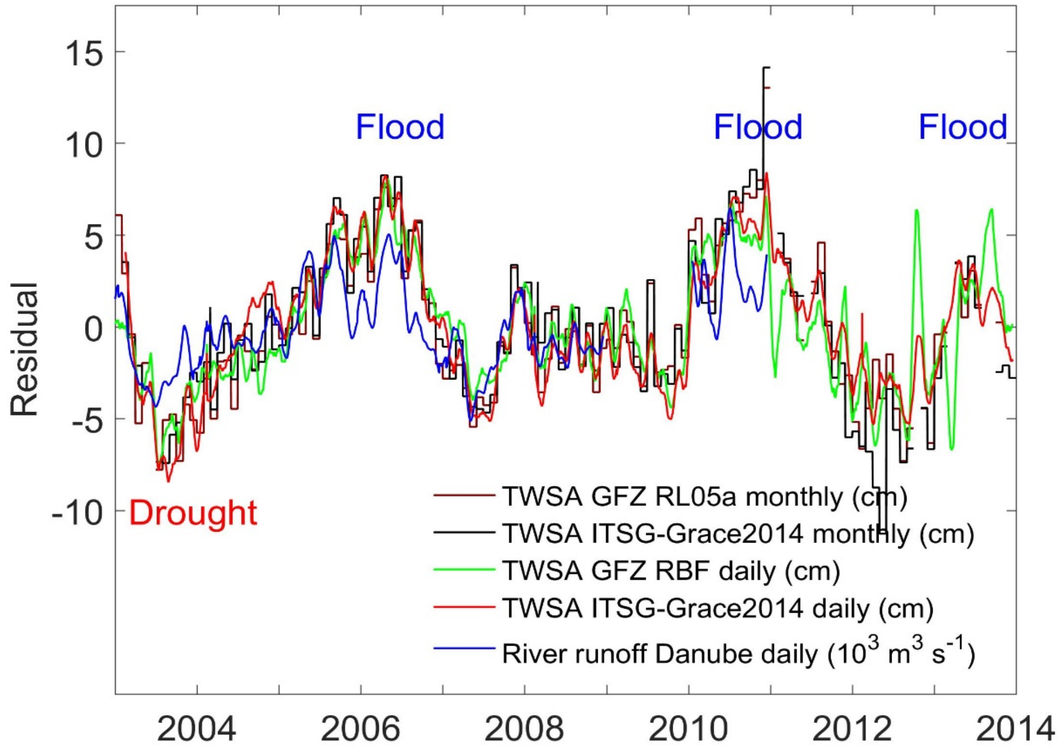

Figure 9: Total water storage anomalies (TWSA) in the Danube basin by monthly and daily GRACE data (seasonal cycle removed).

In order to compare gravity measurements from space with flood information derived from earth observation satellites, a workflow for flood volume calculation based on the combination of SAR scenes during a flood and a digital elevation model (DEM) has been developed for a test area in Bangladesh. First of all, the water mask of the flooded areas had to be extracted from ENVISAT ASAR and Sentinel-1 data. Afterwards, a DEM is clipped so only flooded pixels with height information remain. Over those pixels a fishnet grid is laid in order to compute a histogram for each grid cell. For each of those histograms a threshold is calculated to separate "real" flooded pixels and such with unrealistic height information. Afterwards, pixels which are defined as flooded are summed up in total to receive the volume of water stored during flooding. This workflow was already tested with ENVISAT ASAR data in combination with the SRTM DEM. Results have been produced for seven ENVISAT-ASAR scenes which cover the large flood event in Bangladesh during July-Octover 2007. However, the results also showed that identifying a suitable threshold for flooded pixels is not possible with a DEM having a limited accuracy in the vertical dimension. Hence, a data proposal for TanDEM-X DEM data has been submitted to test the approach with a higher accuracy DEM.

The GBD is also involved in an ongoing exchange project with the University of Bonn, Institut für Geodäsie und Geoinformation, started half-way the second project year, which addresses the assimilation of daily gravity data products into WHGM. Preparations to summarize the suite of multi-method data sets for this and other selected events in a flood data catalogue are ongoing.

Task 6.2 Development and evaluation of gravity-based indicators for flood forecasting and drought monitoring (M01-M36)

Status:

Ongoing

Summary:

- Definition of user requirements for flood and drought indicators in monitoring and forecasting systems
- Development of indicators as a measure of catchment wetness from gravity-based water storage anomalies
- Evaluation of indicators in their performance for forecasting hydrological extreme events by calibration and data assimilation schemes for hydrological models and by statistical forecasting approaches
- Contribution to early-warning services for hydrological extremes

An inventory of the literature (for flood, e.g. Reager and Famiglieti (2009); for drought, e.g. Thomas et al. (2014)), analysis results in Task 6.1 and continued discussion on user requirements with the Joint Research Center of the European Commission, which (co-)operates the European/Global Flood Awareness System (E/GloFAS) and the European Drought Observatory (EDO), has led to the development of a wetness indicator, presented as gravity anomaly in dimensionless units of standard deviation. Testing of the proposed global indicator against databases of hydrological extremes (Dartmouth Flood Observatory, EM-DAT, GloFAS) is currently ongoing. Additionally, the evaluation of indicators in their performance of monitoring hydrological extreme events through data assimilation into the WaterGAP Global Hydrological Model forms part of the exchange project with the University of Bonn, Institut für Geodäsie und Geoinformation (see Task 6.1). This will follow to some degree the approach in Houborg et al. (2014), who derived drought indicators for North America that were incorporated into the U.S. Drought Monitor based on extended large-scale hydrological model simulation into which GRACE water storage observations were assimilated.

Task 6.3 Rapid mapping concept (M07-M36)

Status:

No changes relative to last annual report as these activities are planned for M25-M36.

Summary:

The rapid mapping concept of the operational DLR/ZKI rapid mapping service has been developed and refined over the years based on experiences made in rapid mapping activities for national, European, as well as international users in the domain of disaster relief and civil protection. The operational rapid mapping concept shall be enhanced by the integration of an early warning component based on gravity based indicators for flood forecasting and drought monitoring which are outcomes of EGSIEM (task 6.2). Requirements expressed by the users of satellite rapid mapping products focus on timely and high frequency flood monitoring from the onset of a flood event with a special focus on mapping the flood extent at peak level until water levels have receded to near normal stages. For this task a number of SAR and optical satellites have to be tasked, as it is done within mechanisms such as the International Charter or the European Copernicus Emergency Management Service. Both mechanisms are activated upon user requests which mean that satellite tasking does not start before a user request has been received. In some cases, i.e. when a large flood evolves quickly or has not been considered as evolving into a major flood event, user request came in relatively late and satellite tasking could not be put into effect until flood peak had already passed the area the user was interested in. For such cases a proactive satellite tasking based on external information such as gravity based indicator would have been desirable. In order to enhance the rapid mapping service with such indicators operational workflows for improved on demand programming of high and medium resolution satellite data shall be developed and evaluated. This will be implemented during the last year of the project (M25-M36).

Work package 7: Dissemination and exploitation (UBERN) M01-M36

The last EGSIEM Work Package covers the communication and possible exploitation of the work being undertaken by the consortium. In contrast to the first periodic report (which only covered the first year) there are now some published papers, in addition to the regular project updates given by social media, Newsletter etc.

Task 7.1 Project information (M01-M36)

The project website is being continuously added to, this features regular updates and Blog entries on the main page (20 in 2016), in addition to hosting presentations & posters from events where EGSIEM has been discussed and of course serving as the host for our quarterly newsletter.

Overall the number of page hits seems to be relatively steady, there was a spike in mid-October which we would assume was linked to our campaign to advertise the EGSIEM Competition (see Task 7.3). As of January until mid-December 2016 the project website had received 10’867 page views, with the majority of visitors coming from Russia.

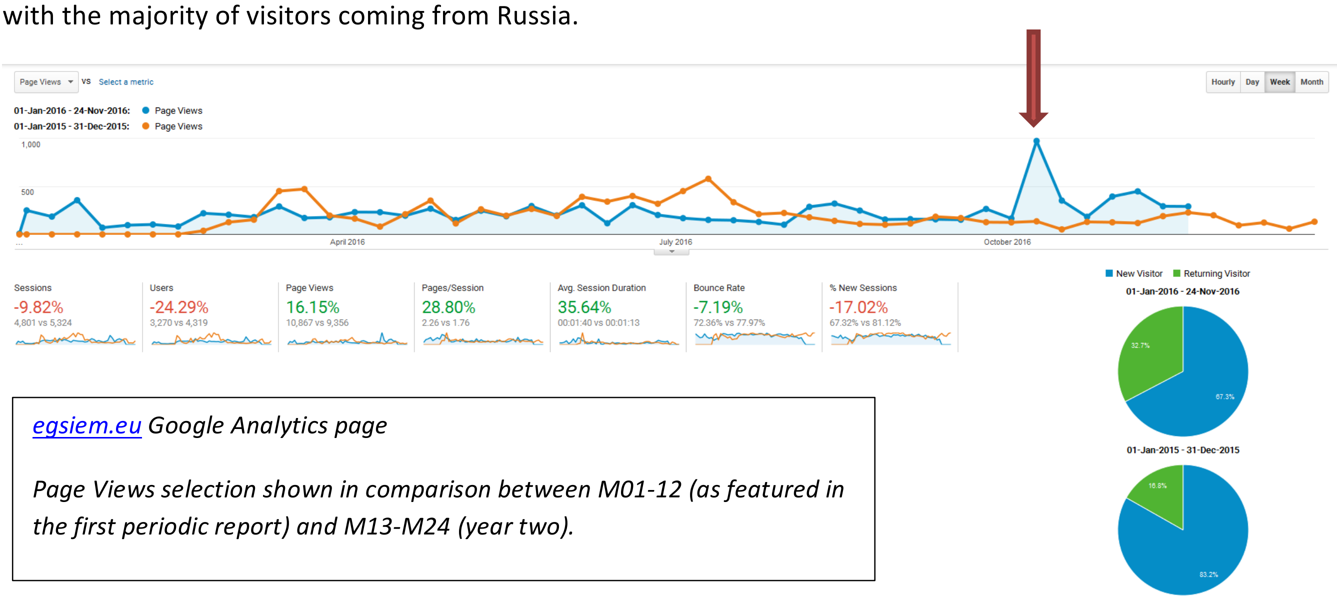

Figure 10: Comparison of webpage hits for egsiem.eu

Task 7.2 GRACE plotter (M01-M36)

Since the last periodic report new features have been added to the EGSIEM Plotter in 2016.

An introductory tab now presents a Youtube video that demonstrates the functionalities of the tool and is hosted on the front page of the egsiem plotter (Figure 11).

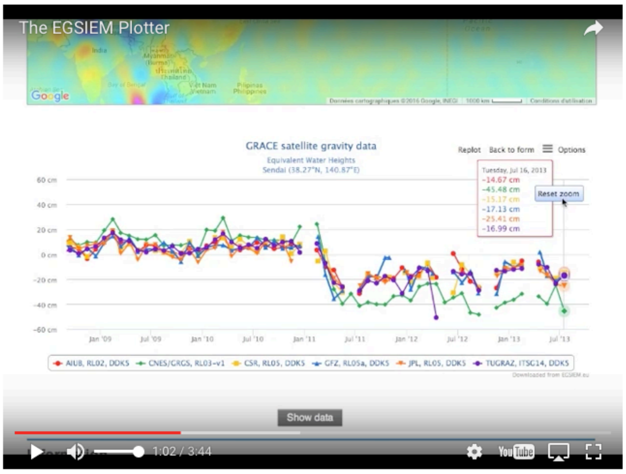

Figure 11: Explanatory YouTube video hosted on the EGSIEM Plotter

The time-series extraction page has been regularly updated with the most recent data, as well as new series. Code improvements have been performed, as well as maintenance and bug fixing. The data processing chain, from spherical harmonics to web database format, has been strongly improved and automated. A new « Images » tab has been created, in order to visualize every gravity solution from every center in terms of geoid heights and equivalent water heights, in rectangular maps, polar maps, spherical harmonics amplitude and spectrum by degree and order.

The design of the images has been revised in order to offer the most complete profile of each solution in the minimum amount of space.

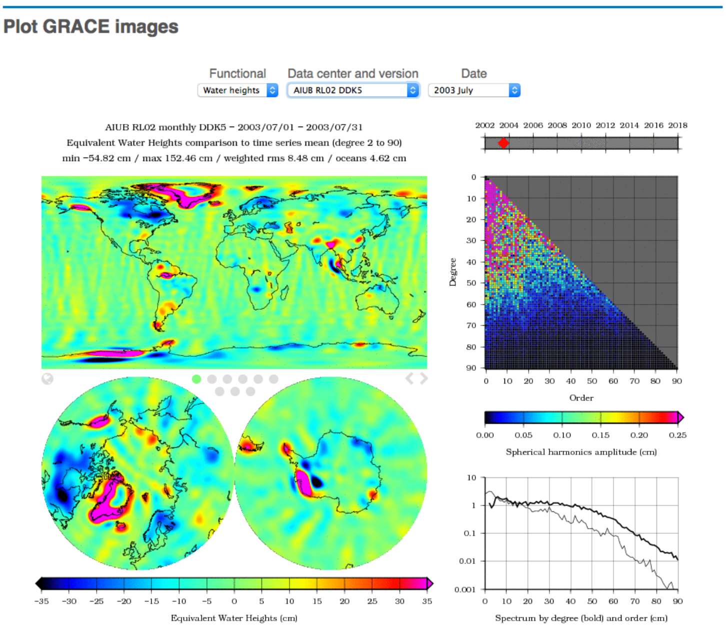

Figure 12: New EGSIEM Plotter 'Images' Visualisation tool

This allows useful and extensive comparison between solutions, shedding light instantly on some similarities and differences on visible (geographical maps) and invisible characteristics (spectrum) -

for example, the SVD inversion technique removes all stripes in CNES solution in September 2004. Site browsing is made easy by dropdown menus and by smart buttons, the latter providing a simple way to click back and forth in order to compare images and analyze details closely. A third tab has been created in order to plot simple time series of statistics : GRACE altitude, inter-satellite distance, number of revolutions per day, etc. The tool has the possibility to plot two series on the same graph for comparison purposes (black and red), with dual axis when units are different.

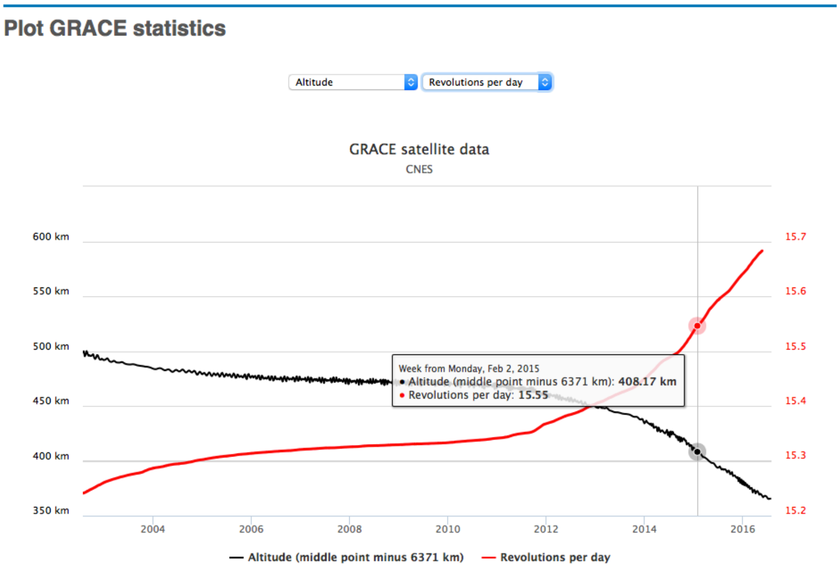

Figure 13: New EGSIEM Plotter 'Statistics' Visualisation tool

A standard format has been established for data (including title, units, origin, comment), so the tool is ready to host any future statistics series provided by any member of the consortium. This tool has an averaging feature that allows users to plot very long time-series on screen within a reasonable amount of time (one point per day over 12 years), and a zoom feature that reveals the details over a shorter period of time (non averaged data when zoomed in).

Both new tools (image and statistics) have been designed in a process of multiple trials and improvements, with the objective of maximizing utility and ease of use. The next step of the development, which commenced at the end of 2016, is to design a new page focused on the recent very specific results of the project, i.e. the combination of the normal equations of the different groups (L3 products). This functionality will include the on-demand construction of products, including or not: mean field, ocean tides, atmosphere, cryosphere, hydrology, etc. This implies a new design (which should still fit in a small space, and not become complicated) and new programmatic functions in the background (possibly interfacing with compiled languages).

Another interesting possibility in development is to study a method to save the online configuration designed by the user in the time-series extraction module and proved the option to share the results with a colleague by a simple email link. This would require further study and development, but could be theoretically possible, and would provide a very attractive feature for scientists.

Task 7.3 Competition (M01-M36)

In autumn 2016, EGSIEM launched "The EGSIEM Challenge", a Europe-wide student competition, which provided a unique opportunity for young scientists to explore the worlds of geodesy, hydrology, flood & drought monitoring and emergency management. The goal of the competition is to educate students in geodesy, hydrology and emergency services, with a focus on EGSIEM research topics; to increase students' awareness of the importance of Earth observation and the usage of data for the monitoring and forecasting of natural hazards; and to awake students' interest, and curiosity in this field. The groups targeted were university students, both undergraduates and graduates, residents of the European Economic Area (EEA).

The challenge was divided into two rounds, the first of which was opened on the 1st October 2016 (at the dedicated website www.challenge.egsiem.eu) and was divided into two parts: “registration” and the “challenge”. Registration involved the provision of limited personal details e.g. first name, last name, email address etc.) in order to check multiple registrations of a single participant, and to avoid internet security issues at the survey website. Every day, new registrations were downloaded and were checked manually. Any duplicate entries were checked via IP address, first name, last name, e-mail address, date of birth, PIW and etc. and an invitation was then sent to the email address provided by the participant within 24 hours of registration (see Fig 2).

Relatively easy 1st round questions were provided in the challenge to increase the students interest, curiosity and awareness of the fields. Initially it was planned that any student who could answer at least 15 (or more) questions would be considered for the 2nd round. Subsequently we decided to widen the pass rate to 12 questions so as to encourage a broad spectrum of applicants in the next round.

The following measures were undertaken to advertise the Challenge:

- Sending of personalized EGISEM advertisement e-mail to almost 300 professors and scientists at universities, organisations and research centers in the European Economic Area
- Providing EGSIEM student challenge advertisement poster to every EGSIEM beneficiaries in various physical and electronic formats
- An article was included in the EGSIEM Newsletter
- Utilized existing extended EGSIEM network (Associate Members, Advisory Board Members)
- Social Media (Twitter/Facebook/Project Website)
- In lectures by EGSIEM members

The twenty first round questions were presented in a manner that a participant would be able to skip a question and come back to that particular question according to his or her preference. The answer options to each question also appeared randomly in order to avoid the possibility of bias.

Each question was made available for 15 minutes in total (this was tracked via a Token), once a participant had opened a question, the time remaining to answer that question was shown. If a participant failed to answer a question within 15 minutes, that question was automatically disabled. If a participant delayed starting the challenge, after a considerable amount of time a reminder email with the same invitation link was sent.

A participating certificate and small souvenir were sent to each participant.

Those participants who progressed to the second round (37 in total from c. 100 entrants, see below) were then given another 20 questions designed to address a deeper understanding of the topics central to EGSIEM. These questions had to be answered in an essay-style, where the answers had to utilize such skills as, equation-solving, map-making and brain-storming etc. The questions were designed to become progressively harder as the participant progressed. Each participant was given 30 days to answer all of the questions (via email or post).

The first round was open until the middle of November and on the 15th November 2016, the 2nd round of the EGSIEM student challenge was declared open. The overall winners of the EGSIEM challenge will be announced on the 20th December 2016.

Important Events	**October**				**November**						**December**			
	1	**8**	**15**	**22**	**1**	**8**	**11**	**12**	**15**	**22**	**1**	**15**	**20**	**22**
EGSIEM challenge 1st round online														
Registration, Invitation, Challenge														
Deactivation of challenge 1st Round														
Announcement of 1st round Winner														
EGSIEM challenge 2nd round online														
Sending prizes														
Deadline of Challenge 2nd Round														
Announcement of Challenge Winners														

Table 3: GANTT Chart of the EGSIEM Challenge

In the course of the 45 day registration period a total of 102 individuals registered themselves for the EGSIEM challenge. The valid number of registered participants was 92 (10 incomplete or ineligible entrants). Young scholars and students from 15 countries and 51 institutes successfully registered themselves for the challenge. In total 63 registered participants participated in the 1st round of challenge. Among them, 37 participants answered the twenty questions correctly within the given timeframe.

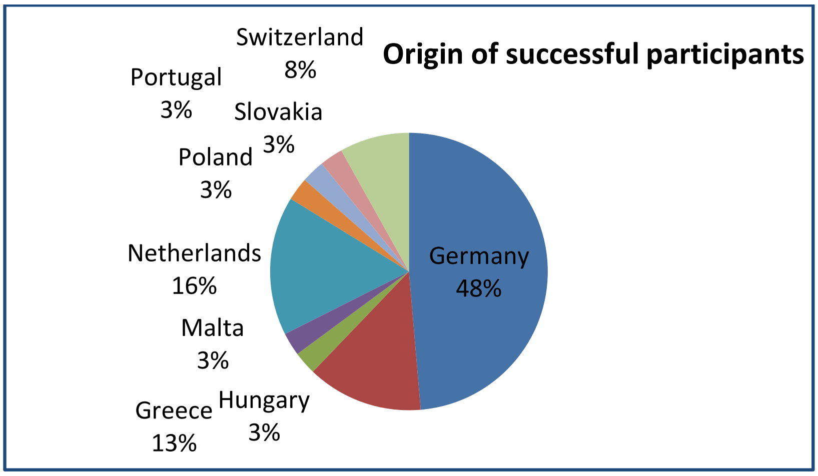

Figure 14: Origin of EGSIEM Challenge participants

Task 7.4 Public education (M01-M36)

During the second year of EGSIEM the following outreach activities have taken place:

- Physik am Freitag http://www.egsiem.eu/88-egisiem-physik-am-freitag (see also Deliverable 7.3)
- Geodätische Woche http://www.egsiem.eu/115-blog-entry-geoday2016-at-graz-university-of-technology
- EGSIEM in the News http://www.egsiem.eu/106-blog-entry-egsiem-in-the-news
- ESA Living Planet Symposium (LPS) http://www.egsiem.eu/101-blog-entry-egsiem-at-lps16
- EGSIEM was presented at various events and sessions at AGU 2016

Task 7.5 Dedicated sessions at conferences (M01-M36)

In 2016 EGSIEM related activities were featured at the GRACE Science Team Meeting held in Potsdam, Germany.

B.6 Applications

This session focuses on the applications of GRACE/GRACE-FO, together with other remote sensing, in-situ or numerical model data, to inform resource management, policy development, and decision-making at all time-scales. Some examples include EU's **EGSIEM** project, NASA's Applied Sciences Program, and other such efforts. Session Convener: Annette Eicker

Task 7.6 Summer school (M25-M36)

Given the necessary lead-time on this task, planning started very early, a broad range of hosting options was evaluated and requests to funders were made. The consortium are pleased to announce that the school will now take place in Potsdam in September 2017 following a generous influx of funfing from beneficiaries GFZ.

The consortium will now begin detailed planning and promotion of the summer/autumn school, however the list of speakers partaking in the school is relatively confirmed.

1.3 Impact

Product/measure	Status
• **Combined gravity products have an improved data quality and increased spatial resolution for regions of interest.**	Two years of combined products are being actually validated with external data and will be distributed to the users via the EGSIEM plotter in January 2017. Internal validation showed significant improvement of the combined gravity fields over the individual contributions.
• **The near real-time and daily products will, for the first time allow for monitoring applications that will enable new research.**	Daily products are available from two processing centers and correlations with hydrological extreme events have been identified.
• **EGSIEM also responds to the needs of the non-specialist user community by providing data in easy to interpret formats.**	User needs have been identified and two platforms (EGSIEM-plotter & ICGEM/ISDC) are under constant development and refinement.
• **The application potential of the project will be demonstrated by the production of hydrological drought and flood indices and their inclusion into early warning services.**	The quality of the daily products confirm the sensitivity of the satellite data to hydrological extreme events. The derivation of indices is an ongoing task and the inclusion into early warning systems is subsequently foreseen.
• **Products will be freely available and actively disseminated.**	Products are available via the EGSIEM plotter and will also be provided on the GFZ ICGEM and ISDC portals. The group regularly informs the community about the progress within the projects at conferences via the project newsletter and blog. Several measures to address the general

	public have been undertaken.
• **Countless applications will be possible with the products.**	For example we would highlight the SLA with TU Dresden supporting their ice mass balance and ice sheet investigations in the Antarctic. Further collaborations are expected as soon as more products become available (see below).

An integral part of the project will be to improve the early indication of hydrological extreme events such as floods and droughts in support of the International Charter "Space and Major Disasters" which aims at providing a unified system of space data acquisition and delivery to those affected by natural or man-made disasters. The disastrous floods in May 2014 which affected Serbia, Bosnia-Herzegovina, Austria, Hungary, Slovakia, Czech Republic, Poland, Romania, Croatia and Macedonia, resulted in a death of more than 60 people. One of the main reasons why these reported flood events developed has been that the ground was already saturated. Since one of the main objectives of the project is to identify these regions it is more relevant than ever. Beyond Europe we have identified and confirmed also the suitability of other areas of the world, i.e. the concept and products can be applied anywhere in the world due to the global nature of the satellite observations. We extended therefore the areas of interest also to the Ganges-Brahmaputra (see Task 6.1) in order to demonstrate the increasing value of the project and to engage other research groups in this area.

Global humanitarian and natural crises require swift and profound decision making. This includes acute events such as floods but also evolving scenarios frequently seen with droughts and in longer time-spans, climate change. Decisions therefore have to be reliable and sustainable which take into account as many factors as possible. It is therefore of utmost important to not only focus on temporary emergencies but also to collect and include information and observations of the developments in the Earth "system". Due to the achieved increase in the performance and precision of the products as well as the global coverage we expect that the project will also be able to provide important insights into climate sensitive areas. Allowing the scientific community to strive for a better understanding of natural cycles and the interplay of its compartments.

2. Update of the plan for exploitation and dissemination of results (if applicable)

In addition to those Service Level Agreements (SLAs) we have concluded in the first period the consortium has begun a campaign of liaising with institutes dealing with Satellite Laser Ranging (SLR). Representatives from the Bundesamt für Kartographie und Geodäsie (BKG) are due to attend the next General Assembly meeting in Bern (M25) and an SLA was concluded in August 2016. There is a further SLA in the pipeline between EGSIEM and the Institute of Geodesy and Geoinformatics, Wrocław University of Environmental and Life Sciences, Poland. This network of EGSEIM SLR associates will all contribute to a detailed comparison and combination campaign which is due to be led by DGFI-TU München. It is therefore hoped that the SLR biases will be further understood, this builds on the suggestions made by the external reviewer at the meeting held in Brussels in March (see section 4 below).

3. Update of the data management plan (if applicable)

At the time of application EGSIEM was originally not required to draw up a specific Data Management Plan (DMP), although the handling of data is mentioned in the DoA and there have been no changes to how the consortium envisages the release of such data. However, following feedback given during and after the mid-term review (see below) we have begun to complete an initial DMP with the assistance of the Digital Curation Centre's DMP Online Tool.

As of early December 2016, beneficiary G&C was completing the FAIR details in the online tool concerned with the Level 3 products which will be made available via the EGSIEM Plotter. Following the DoA, this is where the bulk of the data will be made available. Access to Level-2 data lies with existing providers (such as ICGEM) which falls outwith the EGSIEM project.

4. Follow-up of recommendations and comments from previous review(s) (if applicable)

The Work Package leaders attended a Mid Term Review Meeting on the 7th March in Brussels with representatives of the EU. Overall the feedback received was positive, however we did receive the following recommendations:

> ***Recommendations concerning the period under review:***
> *Important that the "combined" L2 product incorporates low-degree corrections from Satellite Laser ranging [SLR]. This will ease the use of the "combined" product for scientific users. This was confirmed at the review meeting. L3 products for general hydrology users will already provide this integration.*

We found this to be a very useful recommendation and the consortium has begun to seek SLR expertise from outwith the consortium via a series of Service Level Agreements with other European agencies. A campaign to compare and combine SLR biases has been initiated and will be led by colleagues from DGFI-TUM.

> *Try to get a combined GRACE product to cover as long period as possible, especially up to present (again, will enhance users interest in utilizing the product). This is maybe especially true for Cryosphere applications; hydrology needs and interest will probably be much more directed towards the NRT service (5 day latency).*

This is one of the additional aims of the project and is something that the consortium is very keen to act upon, however, the DoA promised two years worth of processed data and as such this is our first priority. If there is any spare capacity in the last year of the project we will pursue additional years

> *I suggest also to reference/link to TELLUS (the US GRACE outreach/data portal).*

As we already have links to the EGSIEM Plotter and the ICGEM website under our DATA heading, there now exists a link to the GRACE/TELLUS Data webpage in the same section.

> ***Recommendations concerning future work***
> *Future work plans presented sound and healthy. No need to change focus or scope. Make sure a good link is maintained across a large span of hydrology scientists and users.*
>
> ***[Option for projects taking part in the Open research data pilot Has the Data Management Plan (DMP) been appropriately executed? Give details if an update of the DMP is needed.***
>
> *Project so far not in the "Open research data pilot" (as I understand it). However as the project is apparently in line with the objectives of the EU pilot, it should take the necessary steps to join, by issuing a DMP and consulting the REA on possible other steps.*

This point is currently being addressed, see Section 3 (Update of the data management plan) above.

5. Deviations from Annex 1 (if applicable)

There are no further deviations from the Description of Action other than those set out in the first periodic report. There is, however, one small update:

- Dr. Matthias Weigelt left his position at the Université du Luxembourg (UL) in September 2015 (M09) – he remained closely associated with EGSIEM whilst being employed at the German Bundesamt für Kartographie und Geodäsie (BKG) and continued to act as the project disseminations manager. In October 2016 Dr. Weigelt joined the Leibniz Universität Hannover (LUH) who are one of the beneficiaries of EGSIEM.
  Dr. Weigelt continues to contribute to EGSIEM at no cost to the project.

5.1 Tasks

At this stage of the project most Tasks are proceeding broadly as planned, except for Task 5.4 Regional solutions: Concept and Processing (M04-M27) which (as mentioned above) has been temporarily delayed due to concentrating resources on the earlier Task 5.2 (upon which it depends), there should be no serious delay to the project because of this. Task 2.3 has also suffered from a small delay in year two of EGSIEM which is now being made good.

5.2 Use of resources

No significant divergence has occurred from the budget as set out in the application.

Because of the change in relationship between Switzerland and the EU, UBERN submits a separate expenditure report to their funder the Staatsekretariat für Bildung, Forschung und Innovation (SBFI).

5.2.1 Unforeseen subcontracting (if applicable)

This section has been left blank as no subcontracting has taken place.

5.2.2 Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

Not applicable.

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