No. 4
January
2016

Newsletter

EGSIEM

European Gravity Service for Improved Emergency Management

Inside this issue:

EGSIEM SCIENTIFIC SERVICES III

The general concept of EGSIEM is based on using satellite data from Gravity, Altimetry, GNSS, SLR and Copernicus missions to create three scientific services, all tailored to the needs of governments, scientists, decision makers, stakeholders and engineers. These services are:

- **scientific combination service**
- **near real-time/regional service**
- **hydrological/early warning service**

Today we introduce the third scientific service - the hydrological/early warning service. The scientific combination service and the near real-time/regional service have been already featured in EGSIEM Newsletter no. 2 and 3 (download the newsletters here).

HYDROLOGICAL/EARLY WARNING SERVICE

The hydrological service

The objective of the hydrological service is to provide **gravity-based indicators of extreme hydrological events**, based on data from both the scientific combination and the near-real time regional services of EGSIEM. The concept of the hydrological service follows a strategy along the line of *(1)* evaluating the new GRACE data products, *(2)* understanding past extreme events and the value of gravity data for these events, and *(3)* preparing for the forecasting and rapid mapping of future events.

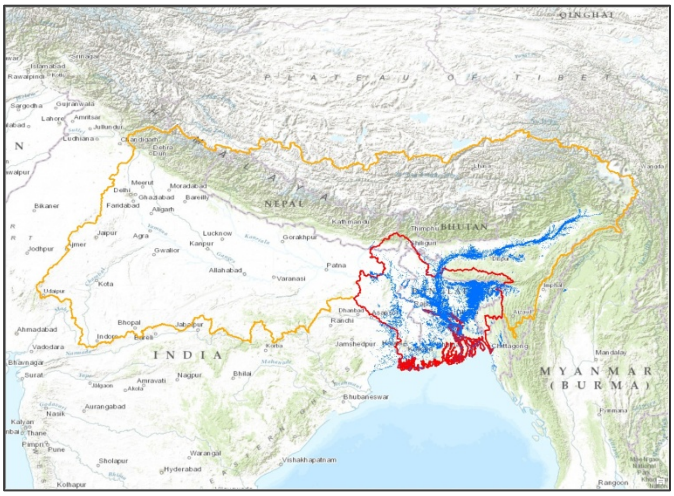
Contrary to other Earth Observation data, **gravity variations represent total water storage variations** (i.e., variations of all surface and subsurface water storage compartments) and thus provide unique information on the wetness state of a river basin. Looking at the water storage anomalies that emerge from the GRACE time series, the hydrological service aims at developing indicators of the actual flood generation potential of a river basin, or of its susceptibility to a drought. We expect this to deliver additional information on extremes as compared to, e.g., near-surface soil moisture products or precipitation-based indices, at least for particular event types and regions. In this way, **the hydrological service aims at contributing to existing flood and drought monitoring and alerting services**. In particular, this applies to present and planned components of the Copernicus Emergency Management Service, such as the European Flood Awareness System (EFAS), the Global Flood Awareness System (GloFAS), or the European Drought Observatory (EDO).

In its first stage, the hydrological service evaluates new EGSIEM GRACE products for hydrological extreme events by comparison to water storage data of hydrological models and of complementary observation-based data sets such as medium- to high-resolution optical/radar remote sensing data, and ground-based measurements, such as river discharge.

HYDROLOGICAL/EARLY WARNING SERVICE (cont.)

Flood volume estimation

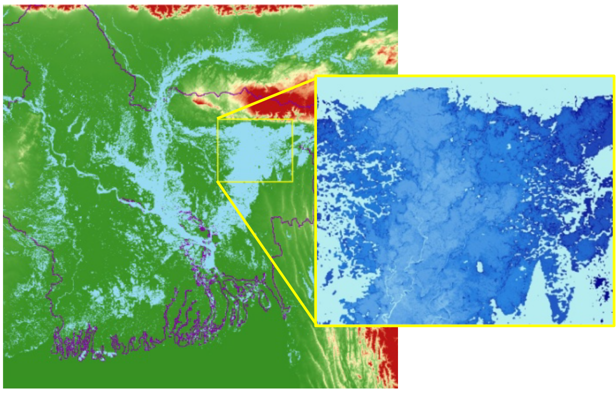
In order to compare gravity measurements from space with flood information derived from earth observation satellites, 3-D flood volumes need to be calculated instead of 2-D flood masks. **Flood volume** (i.e. the redistribution of water mass) **is a parameter against which daily GRACE solutions can be compared and validated in the case of very large flood events.** A new method for the estimation of flood volumes based on a 2-D flood mask derived from medium resolution SAR data in combination with a digital elevation model has been developed at DLR. 2-D flood masks are generated from SAR data via a semi-automatic classification approach (Martinis et al. 2009). The flood volume estimation builds upon previous research concerning the mapping of inundation depths from high resolution SAR data for the purpose of flood damage estimation. For EGSIEM a number of test sites (i.e. very large basins prone to extensive flooding) have been identified with respect to the availability of Earth observation (EO) data as well as hydrological models set up for certain flood events. An example is shown for a very large flood from August 2007 in the Ganges/Brahmaputra delta.



Map of the Ganges/Brahmaputra basin (yellow) and delta (red) superimposed with a flood mask derived from MODIS data (250 m resolution) from 20 Aug 2007 (blue)

A **flood mask derived from optical MODIS data** was used for the Ganges/Brahmaputra test case. Via the combination and intersection of the satellite derived 2-D flood mask with a global digital elevation model (GDEM) the absolute height of the water surface shall be determined. However, because of coarse spatial resolution of both datasets (MODIS: 250 m, SRTM-DEM: 90 m, combined resolution: 100 m) and inconsistencies between the two datasets, an accurate determination of the vertical water profile is hampered, though it is needed to derive flood volume. Hence, several assumptions have to be made and procedures have to be applied in order to assess the actual water level of each pixel of the flood mask from which the flood depth is then derived by subtracting the surface elevation of the DEM from the derived water surface.

A **raster approach** is proposed in which the flood mask is divided into several raster cells. It is assumed that each raster cell has a plain water surface without a direct slope in flow direction. This means that each raster cell has a fixed water level. In this way outliers out of the continuous water surface are eliminated. For each cell the flood volume is then derived as the sum of the water depth of all flood pixels per raster cell. Further tests have to be completed in order to identify the optimal raster size for the flood volume estimation based on the spatial resolution of the flood mask, flood shape and topography of the basin. Furthermore, an accuracy assessment shall be performed and results shall be compared and validated by means of other data sources, such as altimetry data and water gauge data.

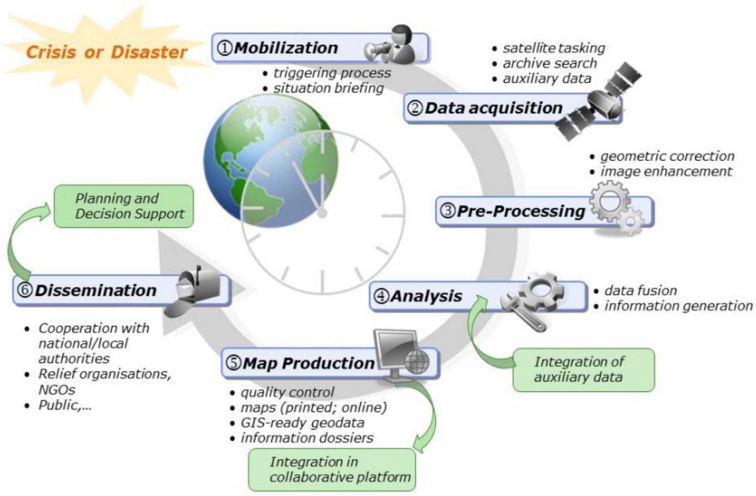


Left image shows a digital elevation map of the Ganges/Brahmaputra delta (purple border) superimposed with a flood mask from optical MODIS data (light blue); for the yellow box the inundation depth was derived for each flood pixel (dark blue = shallow water vs. light blue = deep water)

Rapid Mapping Concept

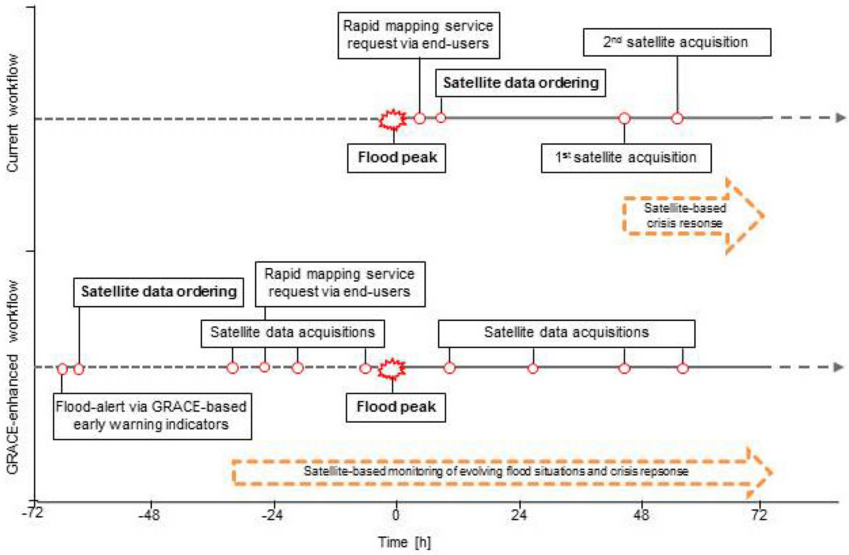
The rapid mapping concept of the operational DLR/ZKI rapid mapping service has been developed and refined over the years based on experiences made in rapid mapping activities for national, European, as well as international users in the domain of disaster relief and civil protection.

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. 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 is the case at the International Charter or the European Copernicus Emergency Management Service.



Rapid Mapping Workflow; showing the 6 main processing steps of a rapid mapping activation with 'Data acquisition' being the most time critical process

HYDROLOGICAL/EARLY WARNING SERVICE (cont.)



Improved satellite tasking by using GRACE measurements as flood early warning indicators

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 requests are received relatively late and satellite tasking cannot be put into effect until the flood event peak has already passed the area the user was interested in. For such cases **a proactive satellite tasking based on external information such as gravity based indicators 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.

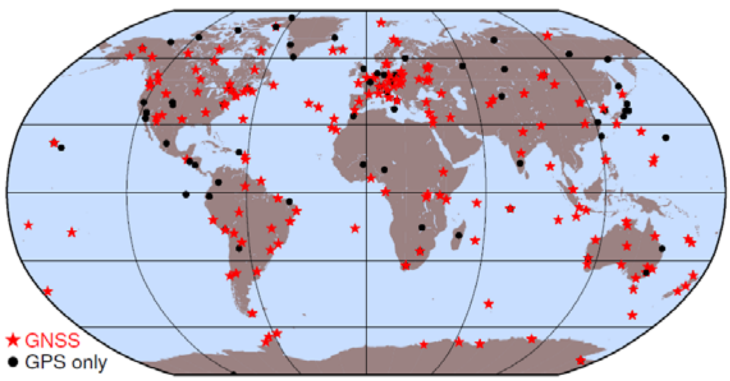
References

Martinis, S.; Twele, A.; Voigt, S. (2009) Towards operational near real-time flood detection using a split-based automatic thresholding procedure on high resolution TerraSAR-X data. *Nat. Hazards. Earth Syst. Sci.*, *9*, 303-314.

REFERENCE FRAME PRODUCTS

The reference frame products are a prerequisite for the computation of precise GRACE satellite orbits in the frame of gravity field determination. They provide the link between the geometrical (station coordinates) and physical (gravity field) description of the Earth. To get a consistent series of GNSS satellite clock corrections, GNSS orbits, Earth rotation parameters (ERPs), and station coordinates, University of Bern (UBERN) has homogeneously processed more than 250 globally distributed tracking stations of the International GNSS Service (IGS) for the interval between 2000 to the end of 2014.

Last, but not least, first GRACE orbit determination, using the newest GNSS orbit and clock products, is underway at UBERN. Initial results are showing slightly better performance compared to the results obtained using operational products at UBERN. In particular this is valid for the completeness of the new products. These results will be published at the upcoming EGU Meeting in Vienna in April 2016.



Geographical distribution of the IGS station network used in the current reprocessing activities (as of 2014).

EGSIEM @ EGU 2016

At the EGU General Assembly in Vienna in April this year, you have a great opportunity to learn more about our research progress and to personally meet the members of the EGSIEM consortium. The following contributions will be presented in Section G - Geodesy.

- **Maier et al.:** SLR in the framework of the EGSIEM project
- **Meyer et al.:** Combination of GRACE monthly gravity models on normal equation level
- **Jean et al.:** Simulation study on combination of GRACE monthly gravity field solutions
- **Li et al.:** Validation of the EGSIEM combined monthly GRACE gravity fields
- **Gruber et al.:** GFZ NRT approach and validation
- **Gouweleeuw et al.:** Evaluation of GRACE daily gravity solutions for the Ganges-Brahmaputra Delta flooding in 2007
- **Poropat et al.:** Validation of GRACE daily/monthly products with in-situ and model Ocean Bottom Pressure data
- **Klinger et al.:** Towards a new ITSG-Grace release: improvements within the processing chain
- **Kvas et al.:** TUG results of the NRT daily solutions
- **Mayer-Gürr et al.:** European Gravity Service for Improved Emergency Management - Status and project highlights
- **Horwath et al.:** Evaluation of recent GRACE monthly solution series with an ice sheet perspective

EGSIEM CONSORTIUM INTRODUCES ITSELF

Interview questions:

1 - What interests you about Geodesy?

2 - Describe your role in EGSIEM?

3 - What is the one aspect of EGSIEM you are most interested in?

Prof. Dr.-Ing. Torsten Mayer-Gürr

1 - Geodesy is an interesting field of research as it gives the possibility to investigate effects and signals on a broad range of scales. For example for the processing of GRACE satellite data we have to consider instrumental corrections in terms of a few micrometer and geophysical signals such as ocean tides with an extension of thousands of kilometers. Additionally, the processing of GRACE data is not possible without programming skills and knowledge about parallel processing on large computer clusters. The most important aspect is that our work helps other geoscientists to understand the dynamic system Earth. Conversely, it is impossible to compute a GRACE gravity field solutions without knowledge about tides in the ocean, elastic deformation of crust and mantle, atmospheric pressure variations, and so on. I like the interdisciplinary discussion with other scientists. All in all it is the broad spectrum of fields of sciences that makes geodesy so interesting.

2 - TUG provides daily GRACE solutions in near real time. Additionally TUG is one of the analysis centers and provides monthly GRACE solutions. We are working hard to improve our solutions by analyzing the behavior of each single instrument, modeling the observation noise and by trying to understand the geophysical processes that affect our solution strategy.

3 - To me, the most interesting aspect is the communication and the knowledge transfer between the different groups. Improving the gravity field solutions and finding possible error sources is like looking for a needle in a haystack. Without hints and tips from other processing groups this task is close to impossible. Additionally, I am very pleased to see the use of our results in hydrological applications such as flood predictions.

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Dipl.-Ing. Beate Klinger

1 - Geodesy and its applications help us to better understand the dynamic system Earth. The sensors onboard dedicated satellite missions, like GRACE, provide invaluable geodetic observations, which allow us to monitor the temporal variations within this complex system by means of monthly gravity field solutions. For me, the interdisciplinary aspect of geodesy is fascinating, as it integrates different scientific fields, like mathematics, engineering or geophysics.

2 - TU Graz is one of the analysis centers (AC) of EGSIEM providing monthly GRACE gravity solutions based on the short-arc approach. I am mainly involved in the preprocessing of the sensor data, which is in turn necessary as input for the monthly gravity field recovery. This includes improving and adapting current preprocessing methodologies. An improved understanding of possible error sources within the sensor data and their impact on the monthly gravity field solutions is not only essential for increasing the accuracy of current solutions but also for future follow-on gravity field missions.

3 - The realization of a monthly combined gravity field solution, which will exploit the advantages of the different processing strategies from the participating ACs. Additionally, the intercomparison of different approaches will stimulate further progress w.r.t the gravity field recovery. Therefore, I am expecting that the combined solution will provide a more robust and precise alternative to existing individual solutions and will be established as a standard product within the user community.

Dipl.-Ing. Andreas Kvas

1 - The Earth's time variable gravity field has accompanied me now for the better part of two years, starting with my Master's thesis and now through the EGSIEM project. GRACE has radically changed our view of the geophysical processes on our planet's surface and it is quite fascinating to look at the Earth through the "eyes" of the twin satellites. This holds especially true if you consider short term (read: daily) mass variations. The limited data coverage in this time span leads to special characteristics of the derived gravity solutions, which (although sometimes challenging) are a very interesting field of research.

2 - In EGSIEM, I am responsible for the computation of global, daily gravity field solutions from GRACE data for the upcoming near real-time (NRT) service operations which will be run at GFZ and TUG. This involves improving and adapting the current processing strategies we employ as well as implementing the software infrastructure to ensure a smooth service run.

3 - Working with the entire European GRACE community as well getting direct user feedback for our gravity products is a great experience. This combined knowledge will lead to a better understanding of the satellite data and consequently more robust and user friendly gravity field solutions. To me, the appealing challenge lies in translating these insights to near real-time and providing a unique gravity product for Earth monitoring applications.

MEET EGSIEM

EGSIEM General Assembly, Luxembourg,
January 18th-19th, 2016

European Geosciences Union, Vienna
April 17th-22nd, 2016

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