Development of the GRACE Science Data System

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GRACE science data processing, archiving and distribution is performed in a shared Science Data System (SDS) between the Jet Propulsion Laboratory (JPL), the University of Texas Center for Space Research (UTCSR), and the GeoForschungsZentrum Potsdam (GFZ). The co-operative approach includes the development of the SDS, sharing of processing tasks, harmonization of product archives and validation and comparison of products.

The GRACE Science Data System Development Plan (JPL 327 710) describes the definition of the different GRACE processing and archiving facilities, the products and the overall data flow, the responsibilities within the project and the necessary documentation. In order to compare GRACE Level-2 gravity field products CSR and GFZ shall use common processing standards (reference systems, initial models, constants as described in IERS2000). Regular meetings and reviews with the US SDS partners guarantee the progress and success of the joint development. To calibrate and validate the monthly and mean GRACE gravity fields a US and European Science Working Team has been established. For the coordination of the national partners within the »GEOTECHNOLOGIEN Program« (Geodetic Institute University Stuttgart, Institute for Theoretical Geodesy

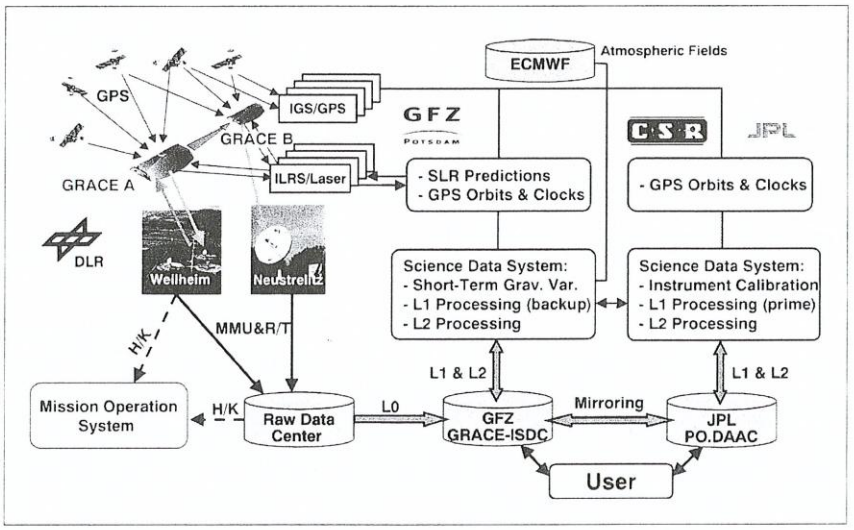

Figure 1: International team work in GRACE ground segment operations.

Bonn, Institute for Astronomical and Physical Geodesy University Munich), telecons and status meetings have been organized.

Figure 1 shows the overall data flow and responsibilities within the GRACE SDS. The onboard stored science instrument and housekeeping data of the GRACE twin satellites are regularly (several times a day) downloaded to DLR's (Deutsches Zentrum für Luft- und Raumfahrt) receiving stations in Weilheim and Neustrelitz. In the Raw Data Center (RDC) in Neustrelitz these telemetry data are decommutated and provided to the SDS in an rolling archive. GFZ and JPL acquire these Level-0 data and store them in a long-term archive at GFZ's Information System and Data Center (ISDC) respectively JPL's Physical Oceanography Distributed Active Archive Center (PO.DAAC).

JPL has developed the Level-0 to Level-1 processing software. In a first level of processing (Level-1A) the raw binary data are converted to engineering units and all sensor calibration factors are applied. In a next step the data are correctly time-tagged and the data sample rate is reduced to a higher rate. As a result calibrated Level-1B accelerometer, star camera and K-band ranging data are available with 0.2 Hz, GPS code and phase data with 0.1 Hz sampling rate. This primary GRACE instrument data are accomplished by different products describing the onboard time scale (satellite clock relative to GPS time), thruster firing events, satellite mass changes and housekeeping data such as magnetorquer currents or tank pressure values and temperatures.

For backup reasons and to extract Level-1A GPS navigation solutions in order calculate twice per day Satellite Laser Ranging (SLR) prediction elements the Level-1 software has also been installed at GFZ. For the precise calibration of the Level-1B instrument data JPL is

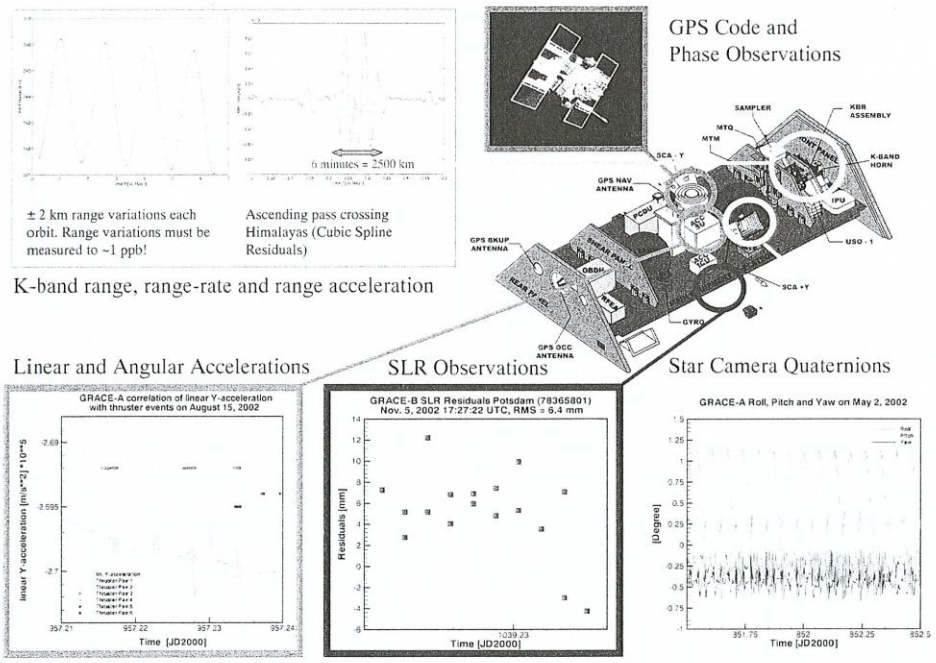

Figure 2: Primary GRACE Level-1B instrument products.

responsible for the analysis of regularly performed center of mass trim and accelerometer to star camera frame alignment maneuvers.

Additionally, based on 6-hourly atmospheric fields, which are regularly acquired from ECMWF (European Center for Medium Weather Forecast), and a barotropic ocean model (Pakanowski, Ponte, Hirose, Ali) which was provided by JPL, GFZ generates with a maximum of 3 days time delay a Level-1B product which is used in later Level-2 processing to de-alias the monthly gravity field solutions from atmospheric and oceanic short-term mass variations.

As for the Level-0 data all Level-1 products are archived in GFZ's GRACE ISDC and JPL's PO.DAAC. Both archives will be regularly harmonized on the basis of JPL product tables and Directory Interchange Format (DIF) meta data to guarantee common data contents. The data access rules will be defined by the GRACE PI and Co-PI. The GRACE ISDC has been developed on the basis of the successfully operated CHAMP ISDC. The products can be accessed by the GRACE users in a batch, direct and retrieval mode. It is planned to complement this data access procedures by a Graphical User Interface (GUI) in the very next future.

The Level-1 products and a set of ancillary data which are regularly generated by GFZ (GPS orbits and clocks) or acquired from international services like ILRS, IGS or IERS (GRACE SLR data, GPS ground station observations, Earth rotation parameters) are the basis for the Level-2 processing of monthly and mean gravity field solutions. Therefore a Level-1 preprocessing software has been developed, which reads the different GRACE instrument data, transforms the GRACE science reference frame to GFZ's EPOS software (Earth Parameter and Orbit System) internally used reference frame, applies all corrections to the K-band data and coarse bias parameters to the linear accelerometer observations, interpolates star camera and accelerometer data gaps and writes a chronologically binary output file. Additionally the inter-satellite K-band ranging observation was implemented in EPOS to generate the theoretical observations and to solve for empirical K-band parameters (bias, bias drift, periodic terms). Due to the huge number of GRACE observations and unknowns EPOS was optimized to generate gravity field partials and to manipulate and solve great normal equation systems in a timely sufficient manner. To process the extreme K-band data micrometer precision different modules of EPOS have to be investigated on numerical accuracy (e.g. numerical integration). Finally, for quality control of GRACE derived gravity fields different test procedures were developed such as comparisons with independently derived gravity fields (CHAMP, CSR GRACE gravity fields), global and regional gravity anomalies on different grids, altimetric and GPS leveling derived geoids or sea surface topography calculated from oceanographic models.