Validation of GOCE and GOCE/GRACE Data Products, Prelaunch Support and Science Studies

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ABSTRACT

During the current Decade of the Geopotential and for the first time ever, dedicated satellite gravity mapping missions, GFZ s CHAMP (launched July 2000) [Reigber et al., 1996], NASA/GFZ s GRACE (November 2001 launch) [Tapley et al., 1996], and ESA s GOCE (June 2005 launch) missions [Rummel et al., 1999], will be simultaneously operating and providing spaceborne measurements to improve the global gravity field with an anticipated geoid accuracy of 20 cm rms and spatial scale of 350 km or longer from GRACE and CHAMP, and an accuracy of 1 cm rms with a scale of 160 km or longer from GOCE. In particular, GOCE represents the primary data source to provide unprecedented accuracy in long-to-medium wavelengths of a global geoptential model. This paper describes the proposal of one U.S. component to support ESA s GOCE mission by (1) conducting prelaunch studies of instrument calibration and validation, assisting the European GOCE Gravity Consortium (EGG-C) in establishing model standards, including time-variable gravity model standards in anticipation of combined analysis of CHAMP, GRACE and GOCE data, and in refining definitions of Level 3 science data products, (2) conducting calibration and validation of GOCE measurement and data products over Dronning Maud Land, E. Antarctica, Syowa station, Antarctica, and over the U.S. continent, and (3) conducting postlaunch science investigations including high-resolution regional gravity field densification using gravity mission measurements and in situ gravity data (i.e., GPS/INS on airborne platforms, e.g., NIMA s Arctic gravity and other new data sets), potential use of spherical wavelet representation for model densification, ice sheet mass balance and oceanic mass variations for global sea level studies using combined GRACE and GOCE gravity mission data. The investigations will hope to be a collaborative effort with the international list of colleagues listed above.

PRELAUNCH SUPPORT STUDIES

The proposed prelaunch support of European GOCE Gravity Consortium (EGG-C) includes the establishment of model standards in support of GOCE data reduction and potential refinement for the generation of GOCE Level 3 science data products. In particular, we will support EGG-C in the identification and assessment of consistent (with GRACE) force models and the associated standards and constants for dynamic tide models, dynamic perturbation models on the spacecraft due to atmosphere, ocean and possibly hydrological processes. Refined definition of high level (Level 3) science data products from GOCE will be one of the major focuses of the study.

Prelaunch preparation of GOCE gravity field data product calibration and validation will be conducted using Antarctica and continental U.S. gravity data and other data (e.g., NIMA s Arctic gravity data). In particular, we will coordinate with colleagues from TU Dresden, NIPR, NAO, Kyoto University, NIMA, NGS, and possibly other collaborators to prepare for fieldwork and data sets for GOCE measurement and science data product calibration and validations.

We also propose to participate in the validation and accuracy assessment of prelaunch GOCE gravity field models, models to be developed by a number of agencies, e.g., GFZ/GRGS, University of Texas, NASA/GSFC, and others, using independent data sets similar to an effort undertaken to evaluate the EGM96 model [Lemoine et al., 1996; Sideris, 1997] and the current models such as PGM2000A [Pavlis et al., 2000], TEG-4 [Tapley et al., 2000], and GRIM4-C1 [Gruber et al., 2000]. There is a need for developing methodologies and independent data sets (e.g., airborne data, improved orthometric heights, data from absolute and superconducting gravimeters and others) for the evaluation of GOCE prelaunch gravity field models and also GRACE/CHAMP/GOCE gravity field models.

In the context of development of regional and high-resolution (10-30 km or longer wavelength) gravity field models using GOCE and other data sets (e.g., airborne vector gravimetry [Jekeli and Kwon, 1999; Kwon and Jekeli, 2001]), we propose to study methodology for the efficient combination of heterogeneous data sets. Another study is evolving around theoretical and numerical studies of representing the geopotential using a combination of spherical harmonics and spherical wavelets, possibly a biharmonic based wavelet function [Shum et al., 2000, Tseng, 2001, Shum and Schaffrin, 2001].

CALIBRATION AND VALIDATION

In collaboration with Reinhard Dietrich, Technische Universitaet Dresden, Germany; and Tadahiro Sato, National Astronomical Observatory, Japan, Yochi Fukuda. Kyoto University, Japan, and Kazuo Shibuya, National Institute of Polar Research, Japan, there is a proposal to set up multi-sensor calibration, validation and monitoring sites in Antarctica [Shum, 2000b]. Fig. 1 shows the Schirmacher Oasis, Dronning Maud Land in E. Antarctica proposed for IceSat and GRACE calibrations [Dietrich et al., 1998a, Dietrich and Shum, 1999]. Fig. 2 shows the Soyowa Station, Antarctica [Shibuya et al., 1999] region.

The Dronning Maud Land site (Fig. 1) has a blue-ice region which is well-surveyed by airborne gravity for detailed geoid and ice thickness measurements [Korth et al., 1997], by GPS surveys as part of the SCAR campaign [Dietrich et al., 1998a] and GPS traverses and fixed stations on bedrocks for ice surface velocity, tides, ice sounding lines [Dietrich et al., 1998b], by airborne Radar Echo-sounding Survey (RES) for ice thickness, bedrock topography, and DEM [Damm et al., 1997], and by extensive InSAR studies for ice velocity and grounding line [Dietrich et al., 1998b]. This site is currently conducting CHAMP GPS reflection experiment [R. Dietrich, personal communication, 2000]. This site has also been proposed for IceSat/GLAS laser altimeter calibration and monitoring [Dietrich and Shum, 1999], for GRACE calibration and validation [Shum et al., 1999, Shum, 2000b], and for ESA s Cryosat radar altimeter calibration [Shum, 2000a].

The Soyowa station, Antarctica region is also proposed to be one of the GOCE calibration and validation sites [Shibuya et al., 1999]. Fig. 2 shows the gravity anomaly survey conducted by Fukuda et al. [1990] and the region is part of the SCAR campaign network and is equipped with a superconducting gravimeter as part of the Japanese-Australian-Antarctica SG network. This site has been proposed for GRACE calibration and validation by NAO, NPIR and Univ. of Kyoto. Other instrumentations such as absolute gravimeter, GPS, bottom gauges will be deployed as part of the field work for the multi-sensor calibration site.

The other proposed region for calibration/validation of GOCE is the continental U.S. NIMA s proprietary gravity data sets [Kenyon and Pavlis, 1997] and other data sets such as the Arctic gravity; and NGS s Geoid 99 model [Smith and Roman, 1999] and its update, will be used to validate GOCE measurements and data products.

The anticipated mean gravity accuracy over the 250 by 550 km^2 Dronning Maud Land region, continental US, and the Soyowa station is <2 μGal or ~1 cm in accumulative geoid undulation. The temporal gravity field signal potentially observable from the Dronning Maud region and Soyowa station is estimated to be ~1 μGal/month or 5 mm/month of geoid change accuracy.

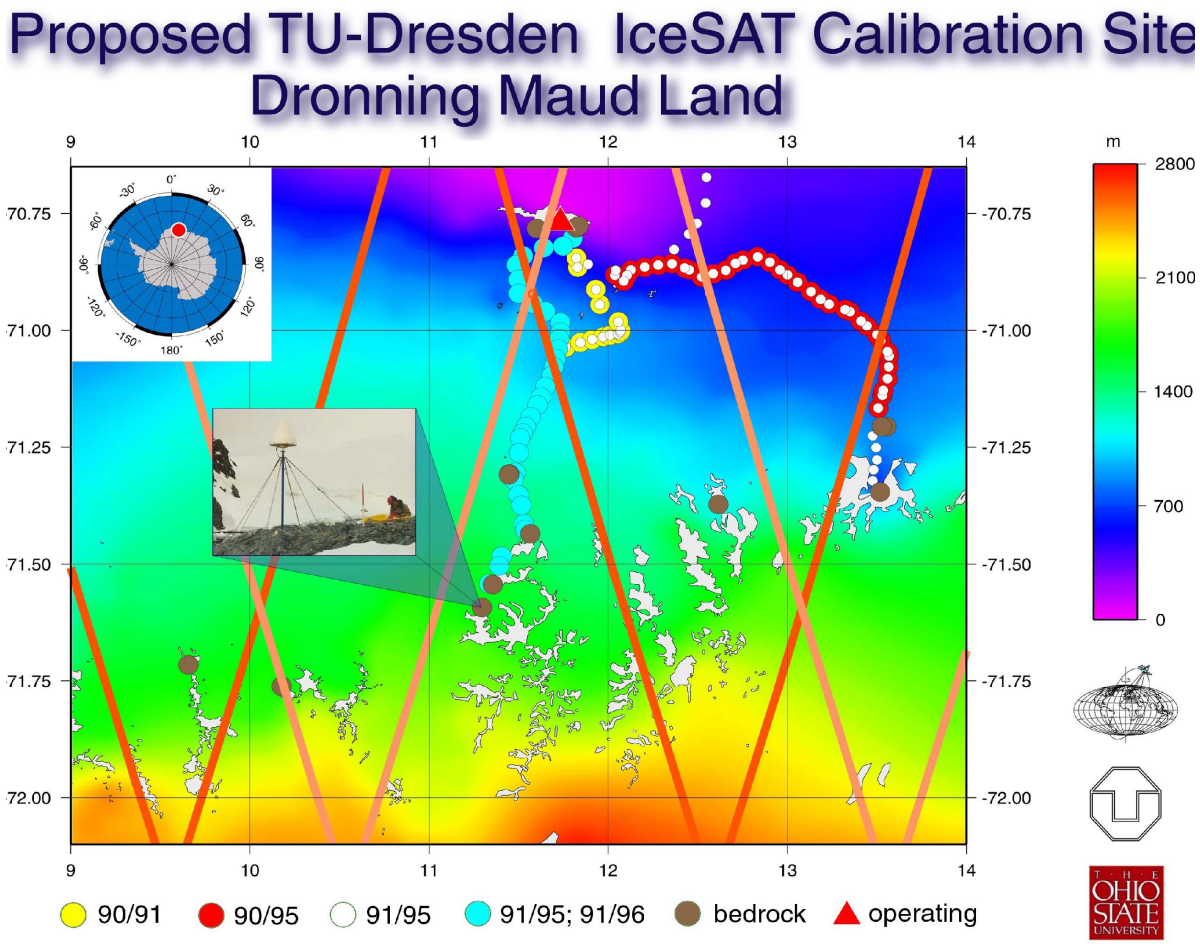

Fig. 1. Proposed GOCE instrument and data product calibration, validation and monitoring site: Schirmacher Oasis, Dronning Maud Land, E. Antarctica site [Dietrich and Shum, 1999]. The site has a blue-ice region with 250x550 km^2 and has been well surveyed with gravity, GPS, radar, and has been proposed also for IceSat, GRACE and Cryosat data product and instrument calibration and validations.

POSTLAUNCH SCIENCE INVESTIGATIONS

We propose the combination of GOCE data with GRACE and CHAMP data for the development of high-resolution mean regional gravity field models obtained by adding terrestrial and airborne gravity data, and for studies of ice sheet mass balance and oceanic variations, for the characterization of causes of global sea level change. Mass-conserved ocean model runs [Wenzel et al., 2000] will be used for prediction and quantification of observations (GRACE, GOCE, altimeters). The addition of GOCE data will significantly enhance the accuracy for temporal gravity field extractions from GRACE, by allowing the mean or static gravity field to be more accurately determined. GRACE in turn will help in the modeling of dynamic tides as well as provide critical data coverage in the polar gap. Theoretical studies of alternative geopotential representations using a combination of spherical harmonics and spherical wavelet based functions such as biharmonic are being conducted [Tseng, 2001, Shum et al., 2000, Shum and Schaffrin, 2001]. Radar altimeter and other data will be used to help quantify the contribution of mass changes in the ocean with the corresponding mass balance budgets using GRACE/GOCE data. We also propose to conduct independent evaluations of GOCE and GOCE/GRACE mean and temporal gravity field models.

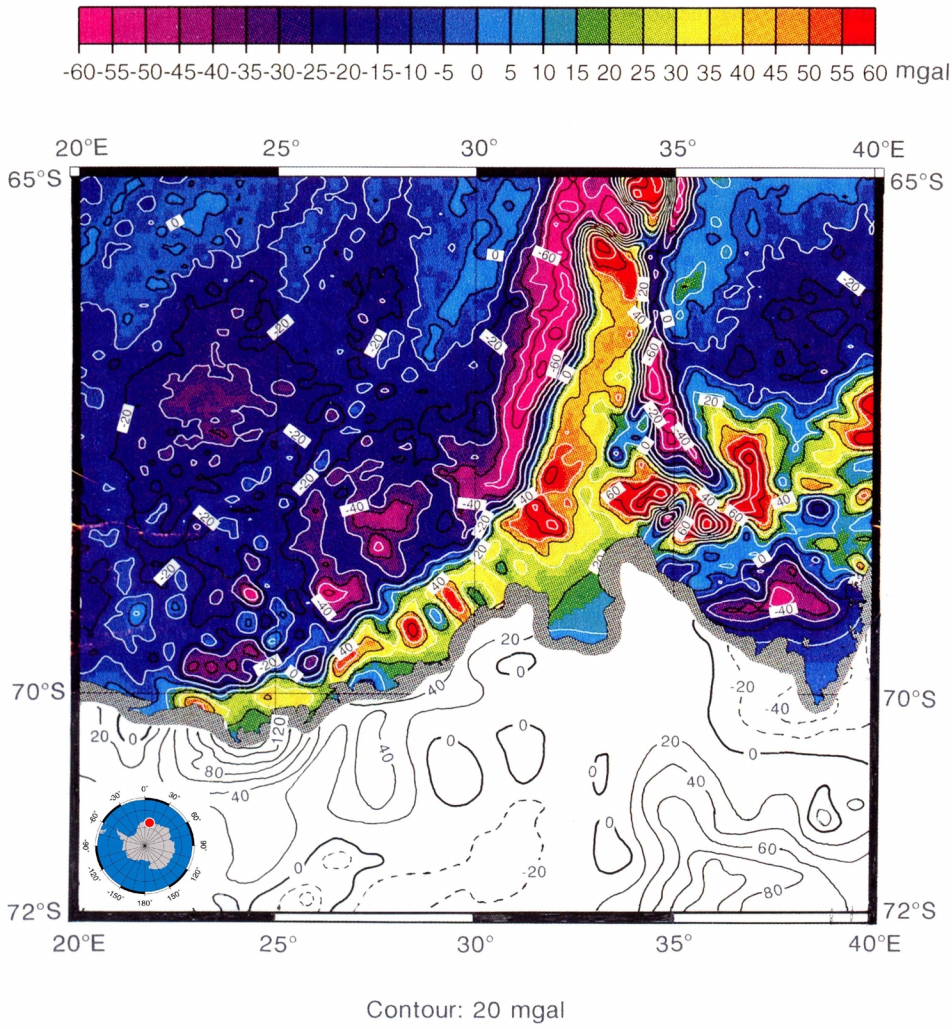

Fig. 2. Proposed GOCE calibration site in Syowa station (69.0^{0}S, 39.6^{0}E), Antarctica [Shibuya et al., 1999]. The proposed site will be proposed for GRACE data product calibration and validation and is equipped with absolute and superconducting gravimeters, tide gauges (ocean bottom gauges), GPS, barometers and other instrumentations [Shibuya et al., 1999, Fukuda et al., 1990].

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