Abstracts Solid Earth

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1. **CHAMP: Mission Status & Development**

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10 years ago the CHAMP mission concept was presented for the first time to the German Space Agency DARA and almost exactly 4 years passed since CHAMP was launched from the Plesetsk cosmodrome into its low, near polar orbit. Since this time the operation of the spacecraft, handled by DLR's Space Operation Center in Oberpfaffenhofen, is running smoothly and effectively and the CHAMP multifunctional and complementary instrumentation, controlled and managed by GFZ's CHAMP team, is in continuous operation since the end of the commissioning phase in May 2001.

The excellent performance of the CHAMP subsystems, of the onboard science instruments and of the CHAMP science data system has resulted up to now in the generation of about 120 different gravity, magnetic field and atmosphere sounding product types. More than 300 non-GFZ user groups access presently pre-processed CHAMP data via the ISDC and CHAMP mission data and data products have greatly influenced the application of new geopotential recovery procedures and the development of improved retrieval techniques for atmospheric quantities.

What has not yet been achieved with CHAMP is the planned reflection experiment with the nadir-looking GPS antenna, requiring S/W additions to the onboard software. But, after coherent reflections at grazing incidence were found in about 25 % of the CHAMP data received by the occultation antenna, the GPS bipath interferometry technique is being proposed to be applied with CHAMP for a longer ocean reflection experiment.

After two orbit manoeuvres carried out in 2002 it is very likely that the nominal 5 years duration of the CHAMP lifetime will be extended by another 3 years. This long mission duration will allow many important investigations related to long term changes, varying sensitivity. at lower altitudes and changing environmental conditions. The expected long mission duration will hopefully also allow to link CHAMP mission products to follow-on-mission results.

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2. **Status and Early Results from the GRACE Mission**

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The objective of Gravity Recovery and Climate Experiment (GRACE) is to map the global gravity field with unprecedented accuracy over a spectral range from 500 km to 40,000 km and with a temporal sampling of approximately 30 days. The measurement precision supports gravity field solutions whose accuracy is between 10 and 1000 times better than our current knowledge. Accurate measurements, with this spatial and temporal resolution, will allow studies of the gravitational signals associated with the seasonal mass exchange between the Earths solid, ocean and atmospheric system components. The two Grace satellites, which were launched on March 17, 2002, are completing their second year of operation. The initial

data has provided a significant improvement in the mean field and, during the first twenty four months of the mission, the results have demonstrated the ability to discriminate the time varying gravity signal associated with the seasonal redistribution of the mass in the earth's dynamic system. This presentation will describe the Mission Status and the characteristics of the recent solutions.

3. **ESA's First Earth Explorer Mission GOCE**

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In autumn 2006 the GOCE (Gravity field and steady state Ocean Circulation Explorer) mission will be launched. It will be the first core mission of ESA's newly defined "Living Planet Programme". Its objective is the determination of a global model with maximum spatial resolution of the quasi-stationary gravity anomaly field and geoid. This makes the mission complementary to GRACE, which is designed so as to determine temporal variations of the Earth's gravity field with highest precision at long to medium wavelengths. The gravity and geoid models derived from GOCE will be used in solid Earth geophysics, oceanography, geodesy and sea level research.

GOCE will be the first satellite to carry a gravity gradiometer and it will be for the first time that such a sensor combination with gradiometer, GPS receiver and active angular and linear control systems will be flown in space. Consequently, a new data processing scheme has to be developed adopted to this approach. It is the purpose of the GOCE-GRAND project to develop and test, in a co-operation of several institutes, a full processing chain for this new space-borne gravity sensor system. It consists of a comprehensive sensor analysis, global and regional gravity field determination based on satellite-to-satellite tracking and gradiometry, combination with GRACE data and model validation. The GOCE-GRAND project provides now the basis for the members to participate under ESA contract in the official high-level processing facility (HPF).

4.

Swarm

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SWARM is the fifth Earth Explorer mission. The objective of the SWARM mission is to provide the best ever survey of the geomagnetic field and its temporal evolution, in order to gain new insights into the Earth system by improving our understanding of the Earth's interior and climate. The mission is scheduled for launch in 2009. After release from a single launcher, a side-by-side flying lower pair of satellites at an initial altitude of 450 km and a single higher satellite at 530 km will form the SWARM constellation. High-precision and high-resolution measurements of the strength, direction and variation of the magnetic field, complemented by precise navigation, accelerometer and electric field measurements, will provide the necessary observations that are required to separate and model various sources of the geomagnetic field. This results in a unique "view" inside the Earth from space to study the composition and processes in the interior. It also allows analysing the Sun's influence within the Earth system. In addition practical applications in many different areas, such as space weather, radiation hazards, navigation and resource exploration, benefit from the SWARM concept.

5.

A New Isostatic Model of the Lithosphere of Antarctica Based on CHAMP/GRACE Gravity Data

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We use the new high-resolution global gravity field model EIGEN-CG01C generated from CHAMP/GRACE satellite missions and surface gravity data, to determine type and amount of isostatic compensation of the main structures of Antarctica and to reveal some principal characteristics of the lithosphere. The new gravity model offers a substantially better resolution and homogeneity, especially in the polar areas, compared to previous models. The difference to the pre-CHAMP/GRACE model (EGM96) in these areas reaches ±60 mGal. New high-resolution data on the ice thickness and basement topography are also available from the BEDMAP Consortium. These data provide a possibility to re-evaluate our knowledge about isostatic compensation of the main lithosphere structures in Antarctica.

It is found that upper crustal load and the ice shield load are compensated in essentially different ways. No deflections from classical local isostasy are found for the crustal load (bed topography/bathymetry variations and offshore sediments). The Antarctic ice-shield is not compensated in classical way. The value of effective elastic plate thickness, which characterizes regional compensation, is found to be around 50 km. This value characterizes both elastic and viscous reactions of the lithosphere and upper mantle to the external load. A new Moho map, which incorporates the different types of the crustal and ice load compensation, is constructed. The residual gravity field, which is not explained by the combined isostatic model, is inverted in terms of crustal densities and Moho variations. The obtained density and structural model of the lithosphere contains many new details, which will serve as a basis for further tectonic analysis awaiting future detailed seismic studies.

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6. **Dynamic Circum-Antarctic Ocean and the Search for a Crustal Rebound Signal in Satellite Gravity Change Data**

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During the next few years two space missions, one a NASA-DRL and the other a NASA-CNES collaboration, respectively, will take data to detect global gravity change (GRACE) and to map dynamic ocean topography (JASON). These experiments will simultaneously determine changes in surface mass and sea surface height. The data retrieved from these missions contribute to determining the sources of geodetic signature over the high latitude ice-covered, and/or ice-free, continental land masses. During the past 14 years a wealth of new data has become available from which the mass balance of the principal ice drainage basins of Antarctica can be quantified. A measurable bedrock vertical response to the post-facto determined ongoing ice mass change in Antarctica is likely to be as large as 2-8 mm/yr - with associated geoid changes ~ -2 mm/yr, even without consideration of deep mantle creep processes. One source of space and bedrock measurement noise is a poorly modelled non-tidal atmospheric and ocean loading. Here we quantify the multi-decadal and sub-decadal signals that are ocean mass change driven, as predicted by the JPL/ECCO ocean model. The secular geoid rebound trends are generally substantially larger ($|dN/dt| \sim 0.5$ mm/yr vs. $|dN/dt| < 0.05$ mm/yr) than the ECCO predicted signals. Evaluated at the IGS station positions in coastal east Antarctica, VESL and SYOG, secular geoid changes due do ocean loading are predicted to be about $dN/dt \sim -0.02 \pm 0.007$ mm/yr. More worrisome, however, are sub-decadal signals, and we discuss the problems that could be encountered with interpreting time series, of three years, or less, in duration.

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7. **GRACE-Based Arctic Ocean Geoids for Oceanographic and Sea Ice Investigations**

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A highly accurate geoid is required for the polar oceans to properly estimate the dynamic ocean heights as well as the 'freeboard' heights of sea ice. Thus we are working to develop suitable high-accuracy, high-resolution gravimetric geoids of the Arctic Ocean based on GRACE. We have completed a "hybrid" geoid by combining longer wavelength (full $\lambda >$ 750 km) gravity information from GRACE with shorter-wavelength, detailed gravity from the international (IAG) Arctic Gravity Project (ArcGP). For GRACE gravity we have used the GGM01S (UTCSR) and the JPL mean fields constructed from 111 and 191 days of GRACE data, respectively. This hybrid geoid has been compared with altimetric mean sea surfaces from ERS-1, ERS-2 and ICESat and evidence of dynamic topography (amplitudes on order of decimeters) can be seen. RMS difference between the hybrid geoid and an ERS altimetric mean sea surface is as low as 18 cm (all wavelengths) in an area encompassing about one third of the Arctic Ocean. Most of this rms difference is due to dynamic ocean topography. Similar magnitude differences are found using ICESat in place of ERS data. Elsewhere over the Arctic Ocean, such differences are considerably larger (order 60 to 80 cm in places). Errors in the hybrid geoid will be discussed. Long-wavelength errors in the hybrid geoid attributable to GRACE are less than 1 cm. The hybrid geoid and successor geoids will enable satellite altimeters to monitor and comprehensively map thickness plus mass flux of Arctic sea ice. Moreover, these geoids will allow the application of satellite altimetry from ERS, ICESat, ENVISAT and CryoSat to mapping of the Arctic Ocean circulation and surface geostrophic currents. Also, they will serve as a reference against which absolute measurements of time-varying oceanographic features, such as dynamic topography and sea ice cover, can be repeatedly calculated via comparison with altimetry.

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8. Regional-Residual Gravity Field Separation using GRACE and CHAMP Geopotential Models

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The separation of regional and residual gravity fields in geophysics generally involves filtering, polynomial fitting or computation of isostatic anomalies. However, these methods are susceptible to the ambiguities associated with selection of filter cut-off parameters, order of polynomial and isostatic assumptions. One possible way to overcome these ambiguities is to use Global Geopotential Models (GGMs) to define the long-wavelength regional gravity field. GGMs provide the advantage that a regional field can be computed based on real data.
As an example of the application of GGMs to regional-residual separation, we consider the highest parts of the central Andes where Bouguer anomalies (up to -450 mGal) are dominated by the thick crustal root (up to 80 km) compensating for the high topography (~4500 m).
After removing a regional field defined by various degree summations of CHAMP or GRACE GGMs (converted to Bouguer anomalies using a global terrain model), north-south-trending negative residual anomalies correlate with regions of high topography. These negative anomalies indicate the presence of low density melts and fluids within the crust that are also evident as low velocity zones in seismic tomography models.

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9. Main and Crustal field models from CHAMP magnetic field measurements

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The accurate total field and vector measurements of the CHAMP satellite mission provide unprecedented opportunities for unraveling the temporal and spatial variations of the geomagnetic field. Here, we report on the latest improvements in our main and crustal field models. The Potsdam Magnetic Model of the Earth (POMME) was updated with a parametrization of the time varying magnetospheric field using the new Est and Ist indices (http://www.ngdc.noaa.gov/seg/geomag/est_ist.shtml), which separate the Dst index into external and internal induced contributions. We also report on advances in the treatment of

attitude bias and discuss the reliability and resolution of the estimated secular variation and acceleration. Our latest crustal field model MF3 is corrected for ocean tidal signals and polar electrojet fields. It extends to spherical harmonic degree 90 and provides a stable representation of the crustal field down to about 50 km above the Earth's surface.

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10. **Interpretation of CHAMP magnetic anomaly maps using a global GIS crustal model with induced and remanent magnetization**

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Studies of global crustal magnetic anomaly maps have shown that both induced and remanent magnetisation contributes to the anomaly over a region. While anomalies over the continents are generally well explained by induced magnetisation, ocean anomalies can only be understood if remanent magnetisation is taken into account. New global crustal field models produced from CHAMP magnetic measurements now allow for modelling these anomalies quantitatively. For this, we have developed a GIS based forward modelling technique to integrate information of the various geological provinces of continents and oceans, the seismic crustal structure, and standard susceptibility values of the rock types and compute a global Vertically Integrated Susceptibility (VIS) model. Based on paleo position, susceptibility and saturation magnetisation of the rock types and the thickness of oceanic crustal layers, a Vertically Integrated Magnetisation (VIM) model is compiled for the oceans. Using this VIS and VIM models, a vertical field anomaly map is predicted at a satellite altitude of 400 km for spherical harmonic degrees 16-80 and compared with corresponding CHAMP observed magnetic anomaly map. Following the discrepancies between the observed and the predicted anomalies, we demonstrate that the boundaries of the largely buried Precambrian provinces overlain by younger sediments can be traced effectively. Similar modelling of CHAMP satellite magnetic anomalies can constrain the subsurface structure hidden by Phanerozoic cover in many parts of the world. The anomalies observed over the Cretaceous Quite Zones (KQZ) in the oceanic region are also reproduced well in the predicted anomaly map, emphasising the importance of remanent magnetisation in the modelling of the oceanic crust. Using our existing GIS method, the new higher resolution field models prepared at lower satellite altitude can provide us an opportunity to model even the small-scale anomalies and to better understand the structure and composition of the lower crust.

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11. **Towards an Imminent Geomagnetic Field Polarity Change?**

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Some speculations in the recent past about an occurring geomagnetic field reversal were already formulated, but only recently this has emerged as a really constructive hypothesis to be better investigated. Based on the Shannon Theory, an Information Content analysis of global models of the geomagnetic field and geodynamo simulations provide results that within 1000-1500 years the geomagnetic field will likely change its polarity. In this work we present some considerations that support this possibility together with their geophysical

implications.

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12. Local time effects in CHAMP estimates of electromagnetic induction transfer functions

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CHAMP satellite high precision magnetic field measurements may offer new insight on the electrical conductivity of Earth's mantle. Electromagnetic induction transfer functions were estimated from three years of CHAMP scalar magnetometer data using robust processing and wavelet techniques. The responses show a clear variation with local time. A simple extension to the standard external source model of a symmetric magnetospheric ring current is proposed to account for asymmetries in the sources: addition of a temporally coherent quadrupole source term to the usual axial dipole explains the observations. Efforts to develop a more complete source model for satellite induction studies using CHAMP vector data and geomagnetic observatories will be discussed.

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13. On a possible approach for improving the accuracy of the general relativistic Lense-Thirring tests in the Earth gravitational field

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In this paper we propose a method for determining corrections Delta J_l to some selected even zonal harmonic coefficients J_l of the multipolar expansion of the Earth gravitational potential in a way which would cancel out any influence of a priori assumed values of some general relativistic effects on the so recovered values of J_l. Here we focus our attention on the first three even zonal harmonics which are the most powerful in biasing the recovery of the secular general relativistic Lense-Thirring effect. The adopted observables are three different linear combinations of the orbital residuals of the nodes Omega of the laser-ranged geodetic LAGEOS, LAGEOS II and Ajisai satellites and of the perigee omega of LAGEOS II. They allow to measure Delta J_2, Delta J_4 and Delta J_6 simultaneously and independently of each other and of the gravitomagnetic force itself. They can be determined by fitting with linear trends the time series of the residuals' combinations, calculating their slopes and dividing them by certain quantities X. It turns out that, by using the very preliminary GRACE-only GGM01S solution as reference gravity model, the obtainable accuracies for J_4 and J_6 might be better than those from the present-day Earth gravity models EGM96, EIGEN2 and GGM01S. It should be not so for J_2 due to a large number of uncancelled perturbations which would affect the combination proposed for determining it. Moreover, since the so obtainable values for the first three even zonal harmonics are, by construction, free from the so called Lense-Thirring `imprint' as well, they could be safely used in order to assess reliably the total error budgets in the measurement of the Lense-Thirring effect by means of the well known already proposed linear combinations of orbital

residuals of LAGEOS and LAGEOS II. It turns out that the systematic error due to even zonal harmonics of geopotential, calculated in a conservative way, is of the order of a few percent for the combinations which combine together the perigee of LAGEOS II and/or the nodes of the LAGEOS satellites. When the forthcoming, more robust and reliable solutions for the Earth gravity field from CHAMP and, especially, GRACE missions will be available, such estimates should further improve.

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14. Can we monitor tectonic processes using time varying gravity satellite data?

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State of problem. 1. We studied possible gravity field variations associated with elastic stress accumulation in locked areas of subduction zones and stress release by earthquakes. 2. We use fault-plane solutions for the Alaska-1964, Chile-1960 and Hokkaido-2003 earthquakes, and GPS-based strain accumulation data in locked areas of the Alaska subduction zone. 3. We developed and applied a statistical signal-recognition technique to identify signals caused by displacements of unknown magnitude on fault planes of given position and dimension. 4. We assumed different levels of data accuracy, ranging from the first GRACE model GGM-01S to two orders of magnitude better, corresponding to the target accuracy for GRACE and GOCE data.
Results. Using our approach we showed that accuracy level of the first GRACE model GGM-01S permits: (1) to recognize gravity field variations similar to those caused by Alaska-1964 earthquake; (2) to distinguish between different fault-plane models of the Chile-1960 earthquake with a probability approaching to 70%. Accuracy level of one order of magnitude better makes the signal recognition probability in both cases close to 99%. Our approach also allows recognition of time varying gravity signal associated with locked areas of the Alaska subduction zone using five years of GRACE data.

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15. Study of Slow Deformation Detection Using GRACE

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Tectonically driven spatio-temporal signals exhibit "slow" deformation and result from complex geophysical processes. These processes include convergent plate boundaries, earthquake deformation cycle, mantle convection, intra-plate deformations and Glacial Isostatic Adjustment (GIA). These "slow deformation" signals have spatial scales longer

than hundreds of km to continental and planetary scales, and temporal scales of a year to decades, and millennia. As an example, the measurement or accounting for GIA is critical for measuring Antarctic Ice Sheet mass balance. GRACE with its prelaunch speculated precision would be able to detect the largest earthquakes, e.g., the 1960 Chilean earthquake, and there has been simulation studies indicating that the GIA signals would be detectable. This paper will discuss simulation results in potential detection of these "slow" deformations such as GIA and the first use of released GRACE data products for this study.

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16. **Low Degree Gravitational Changes from GRACE, Earth Rotation, and Geophysical Models**

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We estimate low degree gravitational variations C21, S21, and C20 using accurately measured Earth rotational data and advanced geophysical models, including the NCEP reanalysis climate model, the ECCO data-assimilating ocean general circulation model, and a land data assimilation recently developed at NCEP Climate Prediction Center. These independent estimates are compared with preliminary monthly solutions from the Gravity Recovery And Climate Experiment (GRACE) mission. The Earth rotation-derived degree 2 gravitational changes agree very well with geophysical model predictions, in particular in the two non-zonal terms (i.e., C21 & S21). The GRACE observations show reasonably good agreement with Earth rotation and model-based estimates, especially in S21 and C20. We will characterize the comparison and analyze uncertainties of these estimations.

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17. **Comparison of Annual Gravity Field Variations from SLR/DORIS and GRACE**

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Comparison of Satellite Laser Ranging and DORIS derived gravity fields with the GRACE long-wavelength gravity amplitude and phase show promising agreement. Recent SLR-derived long wavelength gravity time series analysis has focused to a large extent on the effects of the recent large changes in the Earth's zonals, particularly J_2, and the potential causes, or the long-term secular rates. However, it is also possible to estimate the shorter wavelength coefficients, including non-zonals, over monthly time scales, and to connect these with known geophysical signals. Consequently, the SLR time series of *Cox and Chao* [2002] has been reprocessed to improve the time variable gravity field recovery, with the intent of recovering complete fields through maximum spherical harmonic degree 4. Initial comparisons of the average annual signals with the GRACE monthly fields shows a promising agreement over the continents, although there are differences over the ocean regions resulting from different processing strategies. Work is presently in progress to process the SLR and GRACE data using a common set of background models within GEODYN to allow a more complete assessment.

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18. **Surface Mass Variations from GRACE and GPS –Validation and Combination**

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We study seasonal gravity and load-induced deformation due to surface mass variations. A new and improved method is used to invert monthly global GPS data and TOPEX/POSEIDON-assimilated relative ocean bottom pressure model for spherical harmonic surface mass variations. The concurrent time series will be compared with GRACE coefficients to calibrate the time-variable gravity results. We also seek combined solutions of surface mass harmonics using GPS and GRACE data. The two independent data sets are highly complementary to each other. Combining them can achieve a more complete picture of the surface mass variations by including robust degree-1 surface mass estimates, which reflect the longest-wavelength hemispherical mass exchange, but are not included in the gravity solution. Joint solutions can also improve long wavelength estimates and serve to cross-validate the two techniques from their overlapping strengths.

P 1

Excess LOD compared with CMB fluid velocity inferred from satellite-supported global magnetic field data

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Global magnetic field data in the form of Gauss coefficients are generated for different degrees from terrestrial and satellite data with a procedure described in (Wardinski and Holme 2003, Proc. First Champ Science Meeting). With these data, the calculation of the CMB fluid flow in tangential geostrophic approximation can proceeed in different ways: (1) neglecting any mantle conductivity (harmonic downward continuation) or (2) accounting for a mantle conductivity model by a rigorous inversion process (non-harmonic downward continuation).
Time variations in the toroidal core flow calculated in this way can be balanced with the axial angular momentum of the core under special assumptions. We compare the excess of LOD from observations for 1980 until 2000 with the different predictions for this quantity derived from the CMB fields dependent on the degree of input data (n=5, n=10, n=15) and the used downward continuation methods.

P 2

On possibility a new jerk in 2002 year obtained from the CHAMP mission data

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Satellite magnetic surveys allow obtaining SH models of the field up to n=m=10 for each one day interval. Main goal of the presented work was to investigate series of daily SH coefficients on time interval of a few years longings. Such work was fulfilled on the time interval from May 2001 till March 2004. To make SH models comparable, they were obtained using X, Y, Z components along whole orbits, is spite of observation coordinates and geomagnetic activity. Two usual phenomena were discovered. First one disclosed an existence of quasiperiodic variations with characteristic time about a few months. The second

one was discovered being a jerk like changes of time series of some coefficient. Both phenomena have a rather big magnitudes comparing with the solar influenced noise level. Jerk-like event was going on the meddle 2002. dg_1^0 were 14.26 nT/yr before and 9.58 after the moment.

P 3

Near-surface magnetic anomaly predictions using CHAMP magnetometer data over Antarctica

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Significant improvement in predicting near-surface magnetic anomalies can be mapped at 400 km altitude using the high accuracy and numerous observations from CHAMP. Long-wavelength crustal magnetic anomalies are strongly masked by the core field and secular variations resulting in wavelength coupling in a spherical harmonics representation. Therefore it is difficult to isolate in these satellite measurements. However, in order to help separate regional lithospheric from core field components, the correlations between CHAMP magnetic anomalies and the pseudo magnetic effects inferred from gravity-derived crustal thickness variations can be utilized. In addition, we can use spectral correlation theory to filter the static lithospheric field components from the dynamic external field effects. Employing these procedures, we processed the CHAMP magnetic observations for an improved magnetic anomaly map of the Antarctic crust. In relation to the much higher altitude Ørsted and noisier Magsat observations, CHAMP magnetic anomalies reveal new details on the effects of intra-crustal magnetic features and crustal thickness variations of the Antarctic. Moreover, CHAMP data can be used to predict magnetic anomalies at near-surface altitudes where surface data have not been obtained. Our analysis suggests that considerable new insights on the magnetic properties of the lithosphere may be revealed by a further order-of-magnitude improvement in the accuracy of magnetic data at even lower orbital altitudes.

P 4

Correlation of gravity and magnetic features from CHAMP and GRACE data in the spherical harmonic degree 16 to 90 range

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We have analyzed gravity (EIGEN-GRACE01S) and CHAMP magnetic (MF3) anomaly models in the spherical harmonic degree range 16 to 90 using spherical harmonic and equivalent source methods and examined the respective fields, Poisson's relationship between the fields and the bulk susceptibility and density contrasts. The direct relationship

between the gravity and magnetic signals in this wavelength band is significantly poorer than at the level of individual geologic sources commonly observed in near-surface short-wavelength anomalies. This is mainly due to coalescence of signals from multiple unrelated geologic sources at high altitudes (e.g., 400 km) and failure of key assumptions of Poisson's relationship (namely, identical source configuration, uniform physical properties, and, when the remanence is present, the knowledge of the remanent magnetization direction. Despite this general assessment, the correlation between the fields is excellent when the geologic sources are large. The correlations and interpretations over oceanic plateaus (e.g., over Iceland, Bahamas, South Sandwich, Queen Maud Rise, Agulhas Plateau, Broken Ridge, etc.), ancient cratonic provinces (Midproterozoic age provinces in North America, Paleozoic central European foldbelts and the neighbouring Precambrian Russian Platform), and subduction zones (magnetic signatures primarily resulting from the upper plate island arc materials and gravity signature from subducting lithospheric slabs) give us important clues regarding their geologic and geophysical nature and suggest that more detail and careful examination of gravity and magnetic fields will likely improve our perspective of regional-scale geology of the Earth's lithosphere.

P 5 What Can Rotational Measurements Teach Us About Earthquake Rupture Histories?

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The general motion of a deformable body is uniquely specified by 3 components of displacement (those measured by classical seismometers), 6 components of strain, and 3 components of rotation.

While it is standard to observe translational motions, and quite usual to measure strain, rotations had little attention, partly because rotational effects generated by earthquakes were thought to be small (e.g., Bouchon and Aki, 1982), and partly because no instruments existed which directly measured absolute rotations.

Recently, there has been a revival of interest for rotations due to a growing body of observational evidence that, at least in some cases, rotational motions are indeed strong (Takeo and Ito, 1997, Takeo, 1998), while, at the same time, very precise instruments are becoming available.

Here, we numerically study the effects of various kinematic scenarios on rotations.

In some cases, the effects on rotations appear much more marked than those on translations, i.e., rupture histories with very similar translational seismograms show more pronounced differences in the collocated rotational motions.

We anticipate that taking into account rotational measurements will help constraining inversions of kinematic rupture histories.

P 6 A reanalysis and reinterpretation of tide-gauge, GPS, gravimetric and geomorphologic evidence of glacial-isostatic adjustment in the Churchill region, Canada

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GFZ Potsdam

We review the history of analyses of the tide-gauge record for Churchill, Manitoba, and present a new analysis of the record using a longer time series than that available to Tushingham (1992). The sensitivity of the mean rate of relative sea-level change obtained to the averaging procedure employed is demonstrated by calculating rates for sliding observation intervals of variable widths. Following this, the 'best' mean rate of relative sea-level change is compared with estimates of the mean rate of land uplift and the mean rate of gravity change based on GPS and absolute gravimetry data. As an additional type of observation, the postglacial relative sea-level change inferred from paleo-shoreline evidence in the Churchill region is also considered. Assuming that the governing process is glacial-isostatic adjustment, a joint inversion of the four types of data return upper- and lower-mantle viscosities of about 3 x 10**20 Pa s and greater than 5 x 10**21 Pa s, respectively.

P 7

Geoid, its temporal variation and dynamic topography as constraints in global geodynamics

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Density distributions derived from highly resolved seismic tomography and viscosity models of Earth's mantle are investigated in analytical flow models in order to fit the models' synthetic observables to the GRACE satellite-mission's gravity and geoid measurements while attempting to reproduce estimates of dynamic topography as an additional constraint. Advection of a given density distribution yields temporal variations of observed quantities.
We investigate whether identifiers of such mantledynamic processes may be discerned from other signals contained in GRACE-data, which may then permit predictions for regional mantledynamic contributions and render variations of the harmonic coefficients with time, thus possibly providing corrective fields to apply to measurements of temporal geoid variations. We found that, depending on the assumptions of the geodynamical modeling, the estimated spectral energy of temporal geoid changes due to mantle flow may reach the anticipated limits of accuracy. Isolating geodynamical effects from the much larger contributions due to the movement of water masses, however, may not be feasible.

P 8

CHAMP Geopotential data over selected tectonic regions

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For the first time, a single spacecraft (CHAMP) is simultaneously measuring both gravity and magnetic data from low-Earth orbit. From the previous magnetometer only missions we had to interpret crustal anomalies using only magnetization but now we are able to add density from these gravity field data for a more rigorous interpretation. Previous studies of

the large magnetic anomalies over the Kursk (Russia), Bangui (Central African Republic), Pannonian Basin (Hungary), South-Central Finland and Kiruna (Sweden) have been reexamined to include the gravity anomaly fields recorded by CHAMP. In addition we can test the validity of conducting a joint interpretation with Poisson's method. However, we find that there are different methods used to produce these gravity anomaly maps and that they provide a varying level of detail. The spherical harmonic analysis and energy integral methods can yield fields with dissimilar resolution. We examine these CHAMP anomaly results from two different gravity field analysis methods and evaluate them with reference to the geologic/tectonic and magnetic data.

P 9 **Benefits from the New GRACE+CHAMP Gravity Field Measurements for Studies in Atmosphere and Fundamental Physics**

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Earth's explorer missions as CHAMP and GRACE are going to dramatically improve the knowledge of the Earth's gravity field. The deep knowledge of the gravity field with unprecedented precision is making feasible new experiments and investigations in the field of geophysics and fundamental physics.

The present work plans to demonstrate that such improvements, together with the huge number of LEO satellites, will make possible model refinements of subtle physical effects acting on the orbital motion of Earth satellites like the smooth modulation of the solar radiation pressure through the Earth atmosphere (penumbra) and general relativistic effects. The refinement of the gravity field and a better assessment of penumbra effect on the orbits could concur to determine global changes of some atmospheric key parameters like the refractivity profiles and extinction. On the other hand it could make the existing constellation of Earth satellites suitable for measuring Lense-Thirring gravitomagnetic field.

P 10 **Satellite gravity drilling the Earth**

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Analysis of satellite-measured gravity and topography can provide crust-to-core mass variation models for new insight on the geologic evolution of the Earth. The internal structure of the Earth is mostly constrained by seismic observations and geochemical considerations. We suggest that these constraints may be augmented by gravity drilling that interprets satellite altitude free-air gravity observations for boundary undulations of the internal density layers related to mass flow. The approach involves separating the free-air anomalies into terrain-correlated and –decorrelated components based on the correlation spectrum between the anomalies and the gravity effects of the terrain. The terrain-decorrelated gravity anomalies are largely devoid of the long wavelength interfering effects of the terrain gravity and thus provide enhanced constraints for modeling mass variations of the mantle and core. For the Earth, subcrustal interpretations of the terrain-decorrelated anomalies are constrained by radially stratified densities inferred from seismic observations. These anomalies, with frequencies that clearly decrease as the density contrasts deepen, facilitate mapping mass flow patterns related to the thermodynamic state and evolution of the Earth's interior.

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19. **CHAMP gravity field processing applying the Energy Integral Approach**

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The presentation will focus on the recovery of a full set of gravity field parameters (spherical harmonic coefficients) applying the Energy Integral approach on kinematic orbits derived from CHAMP satellite-to-satellite tracking in the high-low mode (SST-hl). The goal is the derivation of the gravitational potential (using only satellite data), represented by a spherical harmonic series expansion up to a maximum degree which is limited by the orbit characteristics of CHAMP. In contrast to the standard method for the exploitation of the orbit information, i.e. the integration of the orbit perturbations and variational equations, the energy integral approach uses a strictly linear observation model and gravity functionals are processed. The result (CHAMP-only gravity field) is compared with satellite-only gravity field models (EIGEN-3, TUM-2S) and with GPS-levelling data. The experiences made with CHAMP SST-hl data including data preprocessing and the estimation of the harmonic coefficients for the model of the Earth's gravity field, will finally be introduced in the analyses of GOCE SST-hl data (ESA mission; launch 2006).

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20. **Gravity Field modelling from CHAMP kinematic orbits using the energy balance approach**

Wermuth M., Földváry L., Svehla D., Gerlach Ch., Gruber T., Frommknecht B., Peters T., Rothacher M., Rothacher M., Rummel R., Steigenberger P.

A gravity field model has been computed based solely on CHAMP GPS orbit tracking and accelerometry, without any prior gravity information entering the computation. The basic characteristics of our approach are (1) the use of purely kinematic orbits, (2) a translation of velocities to gravity potential employing the principle of energy conservation and (3) correction for non-gravitational forces either derived from measured accelerations or from models.
The method of gravity field recovery using energy considerations has recently been tested successfully by various groups, and it has been shown, that it is possible to derive a solution independent of any prior knowledge only from purely kinematic CHAMP orbit. In this case the satellite velocities have to be determined from the kinematic positions separately. Now the two recent years of CHAMP data have been used to derive the gravity field model TUM-2S. The quality of the field has been tested by comparing the model to other state-of-the-art models as well as to terrestrial data. In order to improve the solution, the role of the accelerometer is investigated, and the correlations between different epochs are taken into consideration.

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21. **DEOS_CHAMP-01C_70: a new model of the Earth's gravity field derived from the CHAMP satellite data by means of the acceleration approach**

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A new model of the Earth's gravity field has been derived from a 1-year set of CHAMP data. The 3-point differentiation scheme has been applied to the kinematic orbit of the satellite in order to produce a set of accelerations (averaged within a sampling interval). The data have been carefully screened out and converted into a set of spherical harmonic coefficients up to degree and order 70. An accurate data weighting scheme has been applied, which takes into account both time-dependent accuracy of satellite positions and propagation of noise from positions into accelerations. The rms geoid height difference between the model obtained - DEOS_CHAMP-01C_70 - and the EIGEN-GRACE01S model (truncated at degree 70) is only 14 cm. Such an accuracy is comparable with or better than that of other CHAMP-derived models.

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22. **The GRACE baseline error model revisited**

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The GRACE baseline error model for gravity field coefficients has been derived before launch based on a priori performance estimates for the K-band ranging and the accelerometers and on a simplified linear error propagation model for low-low satellite-to-satellite tracking. It showed that GRACE is able to resolve the quasi-stationary gravity field up to a spherical harmonic degree of about 150 and to detect time variable gravity signals caused by mass variations in continental hydrology, oceans, ice and atmosphere.
Now that GRACE is flying for 2 years, actual sensor performance estimates are available. We repeat the error propagation which has been done to obtain the baseline error model, now using the actual performance values. The results are discussed with respect to data processing, sensor performance and geophysical signal components. This analysis could help to identify limiting factors in the processing chain and could give hints for further improvements.

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23. **Assessment of low degree harmonics in GRACE monthly solutions**

J. Ries & CSR Level-2 Team

Center for Space Research. University of Texas

This paper presents an assessment of the quality of the low degree harmonics in the RL01 GRACE monthly solutions from UTCSR. The degree 2 harmonics are compared with results from SLR tracking of other geodetic satellites, derived using comparable background models. The evolution of the quality of low degree harmonics over time is presented. The sensitivity of degree 2 harmonics to change in processing methodology is presented. Using these results, recommendations are made on including or excluding degree 2 harmonics when comparing with external geophysical models. Finally, the impact of the GRACE data processing methodology on the role of degree-1 harmonics in model inter-comparisons is briefly presented.

24. **A High Resolution Global Gravity Field Model Combining CHAMP and GRACE Satellite Mission and Surface Gravity Data**

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The striking improvements in long- to medium-wavelengths gravity field recovery achieved with GPS-CHAMP and GPS-GRACE high-low and GRACE KBR low-low satellite-to-satellite tracking gave rise to combine the satellite data with surface data from altimetry over the oceans and gravimetry over the continents to generate a new high resolution global gravity field model: EIGEN-CG01C. The model is complete to degree/order 360 in terms of spherical harmonics and resolves wavelengths of 100 km in the geoid and gravity anomaly fields. A special band-limited combination method has been applied in order to preserve the high accuracy from the satellite data in the lower frequency band of the geopotential and to form a smooth transition to the high-frequency information coming from the surface data. Compared to pre-CHAMP/GRACE global high-resolution gravity field models, the accuracy could be improved by one order of magnitude to 5 cm and 0.5 mgal in terms of geoid heights and gravity anomalies, respectively, at a spatial resolution of 400 km wavelength. The overall accuracy of the full model is estimated to be 25cm and 5 mgal, respectively, a gain by a factor of 2 compared to previous high-resolution combined models. The new model is best suited as a background model for regional geoid modelling (remove-restore-technique) and for geodynamic interpretation over a wide range of scales.

25. **Validation of static GRACE models by airborne gravimetry and GPS-levelling**

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A number of airborne gravity surveys and well-controlled terrestrial gravimetric data are used in an attempt to validate available static GRACE fields on different spatial averaging scales. The data sets analyzed include recent airborne surveys in the Arctic, North Atlantic and Nordic regions, as well as some low-latitude regions. Airborne gravity data are well-suited for this purpose due to the random sampling of the areas (no aliasing from topography) and a homogenous error distribution, with the best airborne gravity typically at 1-2 mgal accuracy. In addition geoid data from GPS-levelling (on land) and altimetry-dynamic topography (at sea) for selected Nordic-Greenland areas are compared to the different available fields. In spite of the large terrestrial data sets used, comparisons among different spherical harmonic models are rather similar for the longer wavelengths, whereas mixed satellite-surface models obviously perform better at the shorter wavelengths.

26. **GPS-Leveling and CHAMP & GRACE Geoid Models**

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GPS and leveling observations supplemented by gravity observations along leveling lines give the most direct measurements of the geoid heights at benchmarks with the precision of a few centimeters. They provide the most reliable external 'truth' to validate a gravimetric geoid model. The CHAMP and GRACE satellite missions are dedicated to map the long- and intermediate-wavelength geoid components at the centimeter accuracy. Properly combining new satellite models with terrestrial gravity data allows us to best determine the gravimetric geoid heights that are comparable with the GPS-leveling geoid heights at benchmarks. The differences between them are sensitive indicators to improvement from both the satellite models and the terrestrial data.
Our focuses for this presentation are the validation and calibration of the latest CHAMP and GRACE gravity models against the GPS-leveling data over Canada. First of all, we briefly described the method for the determination of geoid combining the satellite and terrestrial data. Second, the validation results are shown for EIGEN-3p, GGM01S, and the two latest GFZ and JPL GRACE static models along with two monthly GRACE models. Third, an attempt is made to calibrate the four static models by the Almost Unbiased Estimation (AUE) method for variance components. Finally, the unique role and limitation of the GPS-leveling data are discussed with regard to validation and calibration of satellite gravity models.

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27. **On the validation of CHAMP- and GRACE-type EGMs and the construction of a combined model**

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A number of new satellite-only EGMs become progressively available based on the CHAMP and GRACE satellite mission data. These models utilize the data collected by the aforementioned gravity-field dedicated satellite missions and promise higher (compared to older EGMs) accuracy in the determination of the low and medium harmonics of the Earth's gravity field. In the present study, the latest EGMs generated from CHAMP and GRACE data have been collected aiming at an initial validation w.r.t. their accuracy and performance when used for regular gravity field related work. Therefore, a spectral analysis of the new models has been carried out, employing their degree and error-degree variances. In this way, their performance against each other and with respect to EGM96 was assessed and the parts of the gravity field spectrum that each one describes more accurately have been identified. The results of this analysis led to the development of a combined geopotential model, complete to degree and order 360, whose coefficients were those of CHAMP until degree 5, GRACE until degree 116, and EGM96 for the rest of the spectrum. Finally, a validation of all models (the combined included) has been performed w.r.t. (a) GPS/Leveling data in dry-land areas, (b) TOPEX/Poseidon SSHs over sea and (c) marine and land gravity anomalies. From

the results obtained it was concluded that the combined EGM developed provides more accurate results (compared to EGM96), in terms of the differences with the validation datasets, at the about 1-2 cm and 1-2 mGal level (1σ). Furthermore, the absolute geoid accuracy that the combined EGM offers is 12.9 cm (1σ) for n=120, 25 cm for n=200 and 33 cm for n=360, compared to 29 cm, 36 cm and 42 cm for EGM96, respectively.

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28. **Verification of GRACE Gravity Solutions**

Dah-Ning Yuan, Da Kuang, and Michael Watkins

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GRACE Gravity solutions from Level-2 centers are derived from using a variety of background models (such as ocean tides, short term mass variations in atmosphere), parameterizations, data processing techniques, and solution strategies. Through the gravity solution verification process, the improvement in the solutions can be determined, and the accuracy of the solutions can be calibrated.
This presentation will emphasize on the comparisons of the mean and monthly GRACE gravity solutions from CSR, GFZ, and JPL. Gravity solutions derived from using different background ocean tide models in the orbit determination process will be investigated, and some ocean tide modeling options will be addressed. The modeling error of the ocean tides is still one of the contributors in the month-to-month variations of the gravity solutions. Comparisons of different gravity solution strategies are also included.

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29. **Comparison of Superconducting Gravimeter and GRACE Satellite Derived Temporal Gravity Variations**

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The recovery of temporal Earth gravity field variations is one objective of the satellite gravity mission GRACE. The gravity resolution is in µgal range for a half wavelength spatial resolution of 2000km (l_{max} = 10) and the temporal resolution is 1 month.
Of fundamental interest is the combination of satellite-based and terrestrial time varying gravity measurements. On the Earth surface high-precision gravity measurements are carried out with Superconducting Gravimeters forming the SG network of the Global Geodynamic Project (GGP). These measurements have a gravity resolution in ngal range and a linear drift of some µgal per year.
GRACE derived temporal gravity variations are compared with ground measurements at selected SG stations. Therefore both data sets are reduced for the same known gravity effects (Earth and ocean tides, pole tide, atmosphere) by using the same models. The atmospheric pressure reduction of the SG data is carried out with a new 3D model. Because of GRACE's large spatial resolution all known local gravity effects are

removed from the SG measurements. The influence of local groundwater table variation on the SG data is shown. GRACE and SG gravity variations show a quite good agreement within their estimated error bars for most of the stations.
The remaining gravity variations of both data sets are mainly caused by hydrological effects. For comparison the loading Love numbers h' and k' are used to adapt satellite and ground gravity variation measurements. Additionally a comparison is performed with gravity variations derived from global hydrological models. The adjustment to the GRACE and SG data sets is shown.

P 11

A parallel iterative algorithm for large-scale problems of type potential field recovery from satellite data

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Against the background of present and forthcoming innovative geoscientific satellite missions numerical solution strategies for large linear and ill-posed systems of equations in terrestrial gravitational field recovery are of great interest. Due to the character of the harmonic potential analysis, namely to overcome the task of solving a highly overdetermined problem, least squares procedures have to be applied. To accomplish the arising challenge from the computational point of view an iterative algorithm based on bidiagonalization and QR decomposition is presented, referred to as LSQR method. The application of techniques such as regularization and preconditioning is investigated. We present the LSQR algorithm in an effective parallel programming approach applied on satellite data of type CHAMP, GRACE and GOCE. Implementation of the approach on a 16 processor Itanium2 shared memory platform provided by the High Performance Computing Centre Stuttgart allows for several case studies.

P 12

ITG-Champ02: An Improved Gravity Field Model from a Two-Year Observation Period

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Improved global gravity field models have been determined based on kinematical orbits covering an observation period of two years, provided by D. Svehla and M. Rothacher from the FESG München. The kinematical orbits are available as two sets of position vectors, the first one with a sampling rate of 10 seconds the second one with a sampling rate of 30 seconds. Various versions of the gravity field model have been derived depending on the regularization method applied and the observed ephemeris used. A first version was based on the potential coefficients of the gravity field model EGM96. A second model has been determined based on Kaula's rule of thumb and a third one has been derived without regularization at all. In the latter case no additional information has been used to derive the potential coefficients complete up to a degree 90. The physical model of the gravity field recovery technique is the same as those used for the derivation of the recently published model ITG-CHAMP01. The set of observation equations are formulated in space domain by dividing the total observation period in short pieces of arcs, not exceeding a time span of approximately 30 minutes. For every short arc a variance factor has been determined by an

iterative computation procedure. The gravity field models have been validated based on various criteria.

P 13

CHAMP Gravity Field Recovery

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Using dynamic method to recover gravity field is a basic and most efficient method. By using dynamic method, a gravity field of degree 40 and order 40 was recovered from CHAMP phase and persuade range data, the orbit determination strategy and the gravity recovery approach were presented and discussed in this paper. At last, the result was discussed and compared with other's results.

P 14

CHAMP normal equation analyses for assessing sensitivities and parameter correlations

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We present a work in progress on CHAMP's sensitivity to different gravity field components and on the question of an adequate parametrisation of recent satellite gravity solutions. For this aim we analyse CHAMP normal equation matrices using an eigenvalue decomposition.
In a first analysis we decompose a normal equation matrix that is already reduced to the gravity field parameters only. Doing so, we obtain a decomposition of the gravity field to components which can be determined with uncorrelated errors and which are ordered by their estimability. We find that the best estimable components show patterns related to resonance effects. They are followed, as expected, by components with more and more increasing dominant degrees. Near-sectorial Stokes coefficients are in general more sensitively detected than other coefficients of the same degree.
In a second analysis we study a normal equation still including non-gravitational correction parameters such as accelerometer biases and scaling factors. We analyse error correlations between gravity field patterns and the non-gravitational corrections and we assess the reliability of some of the corrections solved for. We conclude with a discussion on possible effects of the parametrization of non-gravitational corrections on the gravity field solution.

P 15

The Regional Refinement of Global Gravity Field Models Derived from Kinematical Orbits

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The determination of global gravity field models derived from satellite observations is an improperly posed problem which usually needs a proper regularization. In most cases a

Tichonov-type regularization is applied where the regularization factor has been derived by the L-curve procedure, by cross validation or by a recently proposed method of variance component estimation. In most cases, the establishment of the regularization matrix is based on Kaula's rule of thumb. In this way no bias coming from additional real data models will be introduced in the regularized model. The disadvantage of this sort of uniform global regularization is that the regularization factor is selected such that an overall filtering of the observations leads to a mean dampening of the global gravity field features. The consequence is an over-dampening of the rough gravity field features, while the smoother parts usually need a slightly stronger regularization. On the other hand, satellite-only solutions derived in case of densely covered orbits with observations, represent the rough gravity field structures quite well and, obviously, better than the Kaula-regularized solutions, while the smooth gravity field regions show oscillation effects in the satellite-only solutions which surmount those of the regularized models. It seems that only a regionally adapted regularization procedure can solve this problem properly. In the present investigation, this problem is discussed based on the determination of regional solutions in geographical regions of different gravity field structures from kinematical orbits of CHAMP. Various regularization scenarios are investigated and compared to unregularized regional gravity field solutions. The regional gravity field is modelled by spherical harmonics to cover the long wavelength features and a linear combination of spherical splines to model the detailed structures in the specific regions of interest.

P 16

Global and Regional Gravity Field Solutions from GRACE Observations

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A new approach is presented for processing GRACE SST range and range-rate data. The physical model of this gravity field recovery technique is based on Newton's equation of motion, formulated as a boundary value problem in the form of a Fredholm type integral equation. The set of observation equations is formulated in space domain by dividing the total observation period in short pieces of arcs. First results of this recovery technique are presented. The gravity field models are composed of a global spherical harmonics representation and additional regional refinements, represented by space localizing base functions.

P 17

Global gravity field modelling using GRACE observables

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This presentation summarizes methods and sample results of global gravity field modelling from GRACE data at the Stuttgart University. The so-called space gravity spectroscopy based on balancing relative inter-satellite acceleration with geopotential gradient differences is used for derivation of global geopotential models. They are represented by either a finite set of the Stokes coefficients or surface integral means of geopotential corresponding to geographical cells on the surface of a reference sphere. A newly developed numerical algorithm allows for estimation of approximately 20,000 unknowns with a full variance-

covariance matrix on an ordinary personal computer. This corresponds to degree/order 140 of the spherical harmonic expansion. The model is further completed for short-periodic effects (high-frequency temporal de-aliasing) such as solid Earth tides, ocean tides and atmospheric mass variations. Sensitivity of the model to observation noise (commission errors) as well as truncation of the spherical harmonic expansion (omission errors) is also discussed.

P 18

High-Resolution Regional Gravity Field Recovery from GRACE

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The primary GRACE Level 2 science data product includes monthly time series of spherical harmonic coefficients representing observed Earth gravity field signals. These are derived from traditional orbital perturbation analysis using high-low GPS tracking and low-low KBR measurements. Alternatively, disturbing potential and gravity disturbance differences at altitude can be computed on the basis of energy conservation and kinematic acceleration models using precise orbits and KBR measurements. These in situ data can be used to develop global and regional, high-resolution gravity models by fitting harmonic functions and downward continuation without numerical integration. In this presentation, we will show our progress on processing GRACE Level 1B data, distributed to GRACE science team, for precise determination of in situ disturbing potential and gravity differences. The current GRACE L1B orbits seem to meet the requirement of the absolute orbit accuracy, however, the quality of relative orbits derived from differencing both absolute orbits is below the requirement. We will present our approach and results to improve the inter-satellite orbits by incorporating KBR measurements. Finally, we will discuss the high-resolution, regional and static gravity fields focused on the Arctic and Antarctic areas and high-resolution, temporal gravity fields for hydrologic mass variation over the Amazon and Parana-Uruguay basins (South America).

P 19

Dealising for Fast Ocean Motions

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As part of the ground system processing for GRACE, signals with time scales shorter than the approximately 1 month combinations to estimate a gravity field are removed. Those require models for tides (ocean and solid), atmospheric and oceanic mass (see paper by Flechtner et al, this meeting). This work concentrates on the ocean model.
The model currently in use (PPHA v1.1) is a barotropic model (uniform density) forced by ECMWF operational wind and pressure. This model is shown to have significantly less energy (variance in bottom pressure) than various other comparable models (ECCO baroclinic with data assimilation, ECCO baroclinic without data assimilation, ECCO barotropic), as well as an older run of the POP model without data assimilation.
However, the fit of this model's ocean bottom pressure (OBP) to Topex/Poseidon sea surface height is comparable to those of the ECCO model, and the fit of this model's Earth rotation quantities to observed Earth rotation data (minus the atmospheric component) is better than that obtained with ECCO without data assimilation, although not as good as when ECCO

with data assimilation is used.
There is a strong need to perform an experiment in which the GRACE ground system estimates 1 or 2 monthly gravity solutions, and the ONLY difference is the ocean model, with a second, reasonable but maximally different model (for example, ECCO with data assimilation; or the barotropic model of Carrere & Lyard, and see which one actually reduces the KBR residuals more, and whether the difference in resulting gravity field models is significant or not.

P 20 **Unique approaches to analysis of time-variable gravity from GRACE**

F. G. Lemoine[1], S. B. Luthcke[1], D. D. Rowlands[1], C. M. Cox[1,2],
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We have developed an innovative analysis strategy for analysis of GRACE data. We have developed a capability to recover local/regional gravity changes using non-global functional representations (i.e. surface anomalies vs. global spherical harmonics) from the GRACE data. Our approach can take regularly or irregularly shaped regions, populate them with surface anomaly blocks of suitable area and solve for the resulting mass flux with respect to a mean field. The surface mass or gravity anomalies benefit from the application of spatial and temporal constraints to add stability to the solution. In this paper we discuss the analysis of four months of GRACE Level 1B data (accelerometry, intersatellite data, attitude information and precise orbits) from July to October 2003, recently released to the GRACE Science Team. We compare and contrast this local approach to gravity recovery, with the more conventional approach using global spherical harmonics. We review simulations of this technique which allow us to pinpoint optimum strategies for applications of this local gravity recovery approach.

P 21 **Validation of Marine Gravity Data Using GRACE Gravity Field Models**

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In spite of dedicated gravity field missions, the very high frequency information of the gravity field will be further based on surface gravity data. With a grid resolution of 2'Â´2' the most recent data sets of marine gravity anomalies provide a much higher resolution than any satellite based gravity field model. The recovery of marine gravity anomalies from satellite altimetry, however, is susceptible to systematic and long wavelength errors. GRACE-only gravity fields allow for the first time to study medium and long wavelength errors of the marine gravity data. It is investigated if such errors can be localized and quantified. Both, altimetric gravity data and the GRACE-only gravity field are rigorously smoothed to obtain comparable wavelengths. Even a smoothing of the GRACE-only gravity fields is required as long as these fields exhibit a certain 'trackiness'. Preliminary results indicate significant errors in the Antarctic circumpolar current.

P 22 **Observing Fennoscandian Geoid Change for GRACE Validation**

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Tide gauge records, multi-epoch precise levelling, and time series of GPS data have revealed both vertical and horizontal movements of the Fennoscandian crust due to glacial isostatic adjustment. The oval-shaped uplift area has a linear extension of 1750 km along the major axis (oriented approximately northeast) and 1000 km along the minor axis. Maximum uplift (1 cm/yr) is observed in the northern part of the Bothnian Bay.
Existing time series of relative and absolute gravity for a few sites and GIA model calculations indicate an annual gravity change of -2 µgal and a geoid rate of 0.6 mm/year in the central uplift area. Gravimetric detection of this phenomenon is within reach of FG-5 absolute gravimeters, but may require a time series of 5 years or more. Similarly the geoid rate may be determined by the gravimetric satellite mission GRACE. Terrestrial observations may thus be used for validation purposes.
Initiated by *Institut für Erdmessung,* a multi-national cooperation has been set up for frequent collection of absolute gravity data in a dense Fennoscandian network. Three recently acquired FG-5 absolute gravimeters will visit 30 sites annually in Denmark, Finland, Norway, and Sweden, some by several instruments for comparison purposes. The first observing run was carried out in 2003, which also included the participation of BKG, Germany. The campaign has been continued in spring and summer 2004. The national mapping agencies in all four countries have made observing sites available to the project, and even prepared new sites. This poster describes the present status of the project.

P 23 Gravitational Field Recovery from GRACE Data of Type High-Low and Low-Low SST

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An approach to recover spherical harmonic coefficients of the terrestrial gravitational field from the GRACE observation scenario is presented and evaluated on various noise-free as well as noisy synthetic datasets. High-Low SST observations are handled on the level of satellite accelerations derived from kinematic positions by means of Gregory-Newton interpolation and numerical differentiation. Low-Low SST observations enter the harmonic estimation procedure on the level of range-accelerations. Results achieved based on the analysis of a low-low SST scenario only and results comprising both observation types are discussed. In the latter case of a joint inversion of both types of data the possibility of introducing relative weights for different observations is investigated. A parallel implementation of the algorithm on a shared-memory high performance computing platform (NEC TX-7) allows for case studies up to degree and order 120-160. Furthermore two methods, namely a brute-force approach vs. an iterative LSQR approach for solving the normal system of equations are compared. Aspects such as Preconditioning and Regularization are addressed.

P 24 **Development of an Interferometric Laser Ranging System for a Follow-On Gravity Mission to GRACE**

R. S. Nerem, P. Bender, B. Loomis, University of Colorado
M. M. Watkins, W. Folkner, Jet Propulsion Laboratory
M. Stephens, T. Delker, J. Leitch, and R. Pierce, Ball Aerospace Corp.

The Gravity Recovery and Climate Experiment (GRACE) has ushered in a new era for satellite measurements of the Earth system. GRACE provides monthly estimates of the time-varying gravity field, which are largely due to the redistribution of water mass in the Earth system, with a spatial resolution of ~500 km and an accuracy of 1 cm equivalent water. This is accomplished via a suite of instruments including a microwave ranging system, precision accelerometers for measuring non-gravitational forces, and a GPS navigation system. These measurements are providing a new observing tool for hydrologists, oceanographers, glaciologists, and many other disciplines. These tremendous advances made by GRACE have led to an interest in launching a follow-on mission with even better performance. The spatial resolution can be improved by improving the ranging performance, implementing a drag-free control system, and flying at a lower altitude. This presentation will focus on improving the ranging performance by developing an interferometric laser ranging system that we expect to perform near the 1 nm/sec level or better over 5 second intervals, which when coupled with other mission improvements, would improve the spatial resolution to ~100 km for 1 cm water equivalent accuracy. We will present our design for the laser ranging system. We plan to build an engineering model of the instrument and demonstrate its accuracy in the laboratory over the next few years. The laser system will range directly to the proof masses of the drag-free system, eliminating many of the difficulties associated with post-processing the accelerometer data on GRACE. We will also present the results of an error analysis for the ranging system, how these errors are expected to propagate into the gravity field estimates, and discuss the potential science benefits.

S 1 **CHAMP kinematic orbit processing for use in gravity field determination**

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CHAMP orbit data has become available from dynamic, reduced dynamic and kinematic (purely geometric) approaches. All of them have been used in gravity field determination. However, the kinematic orbits enjoy higher acceptance since they do not employ any a-priori gravity field model. Unfortunately, kinematic orbits suffer from higher noise levels and outliers. Hence, improving kinematic orbits will directly influence the quality of the gravity field model. In this paper, a pre-processing strategy for kinematic orbit data will be presented. Based on a a-priori gravity model and accelerometer data, outliers are detected and excluded from further processing.

S 2 **CHAMP and GRACE in Tandem: POD with GPS and K-band Measurements**

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The BlackJack GPS receiver on-board the CHAMP satellite allowed for the first time to compute highly accurate LEO kinematic orbits and the development of new methods for gravity field determination based on kinematic POD. Several groups estimated Earth gravity field coefficients and studied their temporal variations using these CHAMP kinematic positions and making use of the energy balance approach or boundary value method rather than classical numerical integration. The validation of gravity field models computed in such a way showed that CHAMP kinematic positions contain high-resolution gravity information and that the accuracy of the derived gravity models is comparable to that of official GRACE models.

Here we present POD for CHAMP and GRACE for a period of two years and four months, respectively. The main focus will be on the double-difference GRACE baseline in space and the study of zero- and double-difference, kinematic and reduced-dynamic POD approaches for the GRACE formation flying. We compare ambiguity resolution methods like Melbourne-Wübbena wide-laning with narrow-lane bootstrapping and the quasi-ionosphere-free (QIF) approach for the GRACE baseline and demonstrate that 95%-100% of the ambiguities of can be resolved. The ambiguity-free and ambiguity-fixed results for kinematic and reduced-dynamic POD are compared with the K-band measurements (KBR) . The best POD approaches show an agreement on the level of 3 mm with KBR, which is an improvement of a factor of about 7 compared to the zero-difference and ambiguity-free cases. Finally, a combination of the ambiguity-resolved GPS phase measurements with the KBR phase measurements is performed and the role of a constellation of LEO satellites, forming a LEO network in space, is studied from the point of view of future gravity missions.

S 3 Champ's Triple Passage through 31st-order Orbit Resonance

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To increase its lifetime, the Champ satellite orbit was raised twice, in June and December 2002, and so passed through 31:2 resonance three times in the last two years. This gave an unprecedented opportunity for determining the values of certain *lumped* geopotential harmonic coefficients of 31st and, for the first time, 62nd order, via the recently revived technique that capitalizes on the resonant variation of appropriate orbital elements, the inclination in particular.

Preliminary values for four pairs of such coefficients were published earlier, based on the daily 'TLEs' (Two-Line Elements) of rapid availability but limited accuracy. With a longer span of TLEs now available, as well much more accurate 'POMEs' (Precise Orbit Mean Elements, obtained from State Vectors supplied at 30-sec intervals), more accurate analysis has become possible, leading to better results.

As previously, the new values have been compared with those derivable from various global gravity models. It is concluded, in particular, that the '1st overtone values' (associated with 62:4 resonance) are likely to be more accurate than any equivalent values from the global models.

S 4 **Improvements of the quality of altimetry satellite orbits using new CHAMP-GRACE geopotential models**

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Studies of sea level changes based on satellite altimetry observations need precise orbits of altimetry satellites computed in a well defined reference frame. Progress reached in the recent time in the creation of geopotential, ocean tide and some other models has allowed us to derive more precise satellite orbits. The paper shows improvements in the quality of orbits of altimetry satellites ERS-1, ERS-2 and TOPEX/Poseidon obtained using the recently developed CHAMP-GRACE geopotential models in comparison with old ones. Use of new CHAMP-GRACE geopotential models has also allowed us to improve a reference frame, in particular, for the DORIS subsystem. The quality of the improved orbits is illustrated using the results of single crossover analysis.

S 5 **Scale difference between GRACE orbits computed at GFZ and those of JPL**

S. Zhu, C. Shi, H. Neumayer, F-H. Massmann, F. Flechtner,
R. Schmidt, U. Meyer, Ch. Reigber

GeoForschungsZentrum Potsdam

The GRACE orbits computed at GFZ for gravity solutions are compared with the GNV1B-GRACE orbits (GPS NaVigation level 1B orbits) provided by JPL. One sees clearly a scale difference at about 0.8ppb for both GRACE A and GRACE B.
One of the possible reasons is that different GPS orbits are used by the two institutions.
In the GPS orbit computation different GPS sender phase center values (at z-direction) are used for BLOCK IIR satellites. They cause scale differences in the station coordinates as well as a scale difference of the LEO orbits (which can be seen as moving stations).
Orbit scale systematic errors will affect the GM solution (if taken as unknown), and a few other low-degree gravity coefficients.

S 6 **A new CHAMP gravity field model based on the GIS acceleration approach and two years of kinematic CHAMP data**

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Recent results of the project “Harmonic analysis of the Earth´s gravitational field from semi-continuous ephemeris of the low-earth-orbiting GPS-tracked satellite CHAMP” (BMBF grant No. 03F0333C) are presented in terms of a new CHAMP gravity field model based on two years of kinematic CHAMP data. Accelerations are deduced from the kinematic orbit positions by means of Gregory-Newton interpolation and numerical differentiation. These accelerations are related to the spherical harmonic coefficients of the gravitational field model based on Newton´s Law of Motion. In terms of preprocessing the kinematic orbits,

which were recently provided by TU Munich (Svehla, Rothacher), wavelet-filtering methods have been tested, in order to smooth certain outliers out without disturbing the rest of the signal. By application of regularization techniques solutions up to degree and order 90 are discussed. Comparisons to other CHAMP- or GRACE-based models will be presented.

S 7

On different physical content of the geomagnetic field models for the Earth´s surface and for satellite altitudes

Wigor A. Webers
GeoForschungsZentrum Potsdam

The internal SHA magnetic field model is determined as a set of Gauss coefficients for a reference surface according to its functional system. The functional system depends on the parameters of the reference surface (sphere, ellipsoid etc.). Therefore, SHA field models referred to different concentric reference surfaces have different Gauss coefficients and consequently, magnetic field models referred to the Earth´surface in comparison to the satellite altitudes have different physical contents.
This is in agreement with the fundamental theorem for potential fields that there is only a unique relation between the field and its source if the field is available in all points of the three-dimensional space including all points of the source region.
Differences between independently and simultaneously determined field models referred to concentric reference surfaces can be evaluated approximately by mathematical upward and downward field continuations of high quality. These comparisons enable to separate internal and external magnetic field contributions being contained differently in the different data sets.
Analytical formulae and figures for CHAMP and Oersted are given for demonstration purposes.

S 8

Validation of Gravity Models from CHAMP/GRACE Gravity Missions Using the GPS/leveling Data from the US Continent

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The United States Height Modernization program requires the height at anywhere in the territory of the U.S. be determined with an accuracy of 2-cm (2s). The ellipsoidal height at almost any point on the earth¡¯s surface can be measured by using the Global Positioning System (GPS) within 2 cm accuracy, when it is nested with the NGS monitored hundred CORS stations. To convert these ellipsoidal heights into a vertical datum system, such the NAVD88, and retain the same accuracy, an accurate geoid is needed. The CHAMP/GRACE gravity missions have released two gravity models GRACE Gravity Model 01 (GGM01) and EIGEN-3p. Our goal is to validate and choose the better model for use in U.S. geoid computations.
NGS has maintained a GPS/leveling database that consists of more than 14,000 points with A, B and 1st order GPS on 1st, 2nd, and 3rd order leveling. By using the implied geoid heights from these GPS/leveling data, the gravity models GGM01 and EIGEN-3p (augmented by EGM96 up to degree and order 360) are compared in absolute and relative fashion. As a reference, the EGM96 that has been used as the reference field in the geoid computations, and it is also included in the comparisons.

S 9 **Analytical models of the Earth's gravity field for the European part of Russia and their comparison with CHAMP and GRACE models**

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We compiled low degree regional analytical models of the Earth's gravity field for the European part of Russia (EURUS) incorporating 48 GPS/levelling points at first order bench marks. These models were compared with satellite-only models from CHAMP and GRACE, but also with the EGM96 and the European geoid model EGG97. We present the numerical results for the region between 45 - 63 N, 28 - 49 E, where the quasigeoid varies between -9 m and +19 m. Although derived from a limited amount of terrestrial data the EURUS models show a good performance when compared to i) gravity anomalies and ii) geoid heights observed in the investigated area, but also when comparing them with synthesized values from the latest satellite-only models.
Therefore, regional EURUS models can be used for validation purposes, providing a long-wavelength and independent check on the ground of satellite-only derived models.

S 10 **What is the Problem with the Degree 2 Harmonics Quality of CHAMP/GRACE Solutions?**

Rolf König, Christoph Reigber, Sheng-Yuan Zhu

GeoForschungsZentrum Potsdam

The degree 2 harmonics of time variable gravity field model solutions from CHAMP/ GRACE data display considerable uncertainties. Reasons will be discussed and examples be given. Attempts to improve the situation by using different solution approaches and data combinations will be presented in the form of numerical examples.

S 11 **Satellite and airborne gravimetry: Possibilities in evaluation and combination**

Uwe Meyer

GeoForschungsZentrum Potsdam, Department 1: Geodesy and Remote Sensing, Section 1.3: Gravity Field and Earth Models

The unprecedented quality and coverage of satellite gravity missions such as CHAMP and GRACE lead to the question whether airborne gravimetry can be used to evaluate observations from space in the range of some 100 km wavelengths and how both datasets might be combined to generate a high resolution gravity field.
Airborne gravimetry is a well established reconnaissance and exploration technology by now. Using medium to long range aircraft, wavelengths up to 400 km and more are resolved. The lengths of the airborne profiling and the recent quality of the measurements allows an overlap with satellite measurements. The accuracies of both gravity observations in this range are comparable which enables a well controlled combination of both data sets but makes a direct evaluation of satellite data by airborne gravimetry difficult. Blurred signals ranging in the high end of the spectral range of satellite gravity can be significantly enhanced by combination with airborne gravity. Test areas to compare the regional resolution and quality

of airborne and satellite data are the Azores islands and the south Chilean trench system. Although problems arise in using airborne gravimetry for satellite data evaluation, aerogravity is one of the best tools available to check terrestrial data. Especially land-based data is measured point wise, resulting in high error variations and adoptions to local or regional gravity networks that introduce systematic offsets due to different datum systems. Airborne gravimetry has the advantage to overlap the spectral contents of both, terrestrial and satellite data. Therefore, it can not only be used to enhance the regional gravity field by additional information but helps to evaluate local to regional surface data as will be shown for southern Chile. Well controlled, systematic airborne gravity surveys will play a most important part in the improvement of combined satellite / surface gravity models.

S 12

First monthly gravity field determinations at CNES

S. Bruinsma, R. Biancale, S. Loyer*, J.-C. Marty, F. Perosanz,
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The first monthly gravity field determinations, using GRACE, CHAMP and LAGEOS data, are presented. The data processing model, which employs the ECMWF 3D atmosphere and the MOG2D (barotropic ocean model forced by atmosphere) models, is described. The orbit parameterizations and the resulting GPS and KBR post-fit statistics are also presented. Data from July and August 2003 were processed, and individual and combined satellite solutions were computed.
The contributions of CHAMP and/or LAGEOS in the combined solutions are evaluated. The effects on the GRACE solutions of solving for specific ocean tide parameters, accelerometer calibration parameters, constraining of the empirical (bias, drift and 1 cpr) KBR parameters etc., are evaluated. The quality of these first solutions is evaluated by computing error spectra and by comparing their geoid heights to those of other GRACE-only gravity fields and hydrological models.

S 13

GRACE Level-1 Processing Status and Product Improvement

Gerhard Kruizinga, Willy Bertiger, Larry Romans, Michael Watkins and Sien Wu

JPL Pasadena

For more than two years the GRACE spacecraft have produced nearly continuous telemetry data (Level-0) which are processed into reformatted and calibrated Level-1 data, which are then used as input for the gravity field determination process (Level-2)
The emphasis of this talk will be the Level-1 processing status. Furthermore, the experience of the last two years will be discussed and how it can be used in improving the Level-1 processing. In particular, improvements in accelerometer data and spacecraft attitude will be highlighted. Finally, possible new Level-1 products will be discussed.

S 14

Performance assessment of SuperSTAR accelerometers"

S. Bettadpur, R. Eanes, D. Hudson, Z. Kang, G. Kruizinga, P. Nagel

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Center for Space Research. University of Texas

This paper presents the status of the evaluation of the GRACE SuperSTAR accelerometers. A brief overview of the instrument operating principles and performance specifications is presented. The in-orbit performance and calibration parameters for the data are described. Additionally, the presence of certain "twang" artifacts in the data, and their impact on the accelerometer products are presented. The presentation closes with a discussion of the plans for re-calibration of the SuperSTAR for satellite environmental effects.

S 15 **Status and Prospect of the GRACE Atmosphere and Ocean De-aliasing Product**

Frank Flechtner

GeoForschungsZentrum Potsdam, Department 1: Geodesy and Remote Sensing

To reach the unprecedented GRACE gravity field accuracy all short-term mass variations have to be taken into account during monthly data processing. To correct for non-tidal atmospheric and oceanic mass variations a GRACE level-1B product (AOD1B) is routinely derived at GFZ Potsdam based on 6-hourly ECMWF atmospheric fields and a barotropic ocean model provided by JPL.

The presentation will focus on the status of the current AOD1B release 01 and will discuss some items which should be further investigated and decided before starting the processing of a possible next product release. Such open issues are the influence of the mean field period used to derive mass variations, the background ocean model or processing standards such as load love numbers.

S 16 **Integrated Sensor Analysis GRACE**

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The purpose of the integrated sensor analysis is to construct a simulator of the gravity measurement system of the GRACE mission. It is based on mathematical models of the individual sensors (accelerometers, K-Band Ranging, star sensors etc.) as well as of their interaction. The simulator in its final stage is also capable of processing real GRACE data for error identification and analysis purposes.

The following sensor systems are currently implemented in the GRACE System Simulator:

- Accelerometer measurement system (only linear accelerations)
- K-Band measurement system
- Star Camera measurement system

Additionally, the Attitude Control System including cold gas thrusters and magnetic torque rods is modelled.

In co-operation with the GeoForschungsZentrum Potsdam (GFZ), several tests on real data were conducted during the validation phase:

- Noise level assessment for the Star Camera measurement system
- Noise level assessment for the K-Band Measurement system
- Noise level assessment for the Accelerometer Measurement System
- Augmentation of Satellite Attitude through combination of star sensor and accelerometer measurements

S 17 **Preview of next generation improvements to GRACE gravity models**

Srinivas Bettadpur

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Fourteen monthly solutions, processed with the so-called Release 01 GRACE standards have been made available so far to the GRACE Science Team for evaluation. Creation and analysis of monthly fields in this data release has also pointed out the areas where the data processing and background modeling can be improved. This paper will summarize the candidate improvements being considered at UTCSR prior to the next product release. The focus will be on the discussion of size and spectra of background gravity model improvements - and the consequent impact on the GRACE Level-2 product quality.

S 18 **ISDC for CHAMP and GRACE –**
Product Management and User Requirements in Operational Service

Bernd Ritschel, K. Behrends, S. Freiberg, R. Kopischke, H. Palm, A. Schmidt

GeoForschungsZentrum Potsdam

As the CHAMP Information System and Data Center (ISDC) has been developed for the management of the processed CHAMP satellite and GPS groundstation products, the advanced GRACE ISDC is responsible for the management of all GRACE satellite products. More than 400 national and international users and user groups share the CHAMP ISDC infrastructure in order to retrieve and request products by means of metadata from a stock of nearly 4 billion products round-the-clock. More than three years CHAMP ISDC operation present different experiences in the realization of the product management functions as well as in the fulfillment of the user requirements. The breakdown of these experiences are permanently used for further system and service improvements.

P 25 **The Synergy of CHAMP and GRACE Products**
with Traditional Satellite Tracking Data

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The gravitational fields derived from the new missions such as CHAMP and GRACE, are now reaching a mature level. At this point the combination with the traditional information from satellite tracking should be examined to understand where new information can come from in deriving high degree and resolution models for multiple uses. One of the many enhancements that this new development incorporates is the modeling of temporal variations for the long wavelength components of the field, in order to avoid aliasing of these signals and a consequent degradation in the quality of the new model. Currently, and until we accumulate several years of GRACE data, the best data source for determining these variations are satellite laser ranged geodetic targets (such as the LAGEOS, ETALON, AJISAI, STARLETTE, STELLA, etc.). While the data from these satellites provide the definition of the underlying TRF, the detailed components of the gravitational model are

primarily determined from the data of the dedicated missions (CHAMP, GRACE, and GOCE in the future). We will present preliminary results of a new analysis, taking advantage of the currently available models using NASA Goddard's GEODYN/SOLVE II software.

P 26

Combined Processing of GPS, SLR and DORIS Data from CHAMP, GRACE, JASON and Ground Stations

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Today Low Earth Orbit satellites (LEOs) play an important role for the Global Observing System. Primary they are used for gravity, altimetry, earth magnetic field and atmospheric studies. Most of the LEOs have multi-techniques on-board. They provide a kind of 'on-board location', which could be used to strengthen the Terrestrial Reference Frame (TRF).
In this presentation, we combined GRACE, CHAMP, JASON-1 with 40 GPS ground stations to solve the orbits of high (GPS) and low (LEOs) satellites, the position of the ground station etc. The data types included GPS, SLR and DORIS observations. The result shows that a significant improvement can be achieved in GPS single daily orbit quality compared to the case where no LEO data are used. And the LEO orbits also improved compare with two-step results. Another benefit of this combination is to determine the phase center correction of the LEO on-board GPS receiver, the one one-step method and combination solution give more stable results.

P 27

CHAMP and GRACE Accelerometers Evaluation

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This poster deals with the analysis of the STAR and Super-STAR accelerometer measurements from the CHAMP and GRACE satellites. The status of the STAR accelerometer based on the 3 years of level 2 data available is presented. Specific instrumental aspects like signal "jumps" and sensitivity to external events (instrumental reboots or satellite temperature variations...) are discussed. First results of the Super-STAR in orbit calibration based on one month of GRACE data processing are also presented. The signal power spectral density from the two mission instruments is compared.

P 28

Synthesis on the radial problem of the STAR accelerometer on CHAMP

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From the beginning of the CHAMP mission, the radial component of the STAR accelerometer, as well as the roll and pitch ones, have shown abnormal and erratic behaviours. Several clues led us to think at a disconnection of one of the X3 electrodes of the accelerometer. After having analysed different possibilities of failure, ONERA presented a

computational way, according to certain assumptions, to overcome the problem in order to deliver a plausible correction to the radial channel. This correction is delivered within the data file in ISDC STAR products.
On GRACE, both Super-STAR accelerometers work well. They give us an opportunity to evaluate the radial correction on CHAMP and even to test a new computational method to deduce the most realistic radial acceleration from the tangential one. In fact, due to the quite strong inclination of the front side of CHAMP, the lift/drag ratio can be applied to infer a quite realistic value of radial accelerations, taking into account some other modelling, particularly of the radiation forces.
We present a synthesis on this problem and its solutions which should conclude definitely on this topic.

P 29 **Relationship Between Earth Gravity Field and SST by Numerical Simulation**

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Satellite-to-Satellite Tracking (SST) can provide a new technique for the earth gravity field determination. For discovering the relationship between the earth gravity field and SST observation, the JGM-3 and EGM96 are adopted and some numerical simulations are put in practice. In this paper, the variations of SST observation including the line of sight distance, the line of sight velocity and the line of sight acceleration are compared with the different degree and order and the two earth gravity models – JGM-3 (8×8, 36×36, 50×50, 70×70), EGM96 (70×70, 100×100, 150×150, 180×180, 200×200, 250×250, 300×300, 360×360). With these simulation analyses, some directly results can be drawn:

1. In general, the higher degree and order earth gravity model can provide more excellent simulation results. For example, the difference between 200×200 and 180×180 is less than the difference between 70×70 and 100×100 of EGM96.
2. A phenomenon that is not normal happens at the more than 200×200 degree and order. For instance, the difference between 300×300 and 360×360 is greater than the difference between 200×200 and 360×360 of EGM96.
3. The results simulated by the two difference models, JGM-3 and EGM96, have obvious biases

Finally, some conclusions and suggestions are given.
Keywords: SST; GRACE; Earth Gravity Field; Numerical Simulation

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P 30 **Combined Determination of Orbit and Accelerometer Calibration Parameters from GPS SST Data and Accelerometer Data**

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Highest quality reduced-dynamic orbits (e.g., for CHAMP) based on GPS SST data may be obtained without any use of additional accelerometer data if the orbit is modeled by an adequate number of so-called pseudo-stochastic parameters (e.g., piecewise constant or piecewise linear accelerations) which compensate for deficiencies in the dynamic model. For

the CHAMP satellite such estimated accelerations show at least in certain directions a good agreement with the measured accelerations from the STAR accelerometer. Encouraged by such comparisons a combined processing procedure of GPS and accelerometer data can be considered. For this purpose simulated GPS SST and accelerometer data as well as real measurements (from CHAMP) shall be used in an attempt to establish a statistically correct combination of both measurement types where accelerometer data are treated as additional observations to the GPS SST observations. Results from such a procedure will be discussed and compared with those of other approaches (e.g., no use of accelerometer data, introduction of accelerometer data as additional acceleration).

P 31

Design and Implementation of an ISDC-Portal

Thomas Busch and Bernd Ritschel

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Webportals provide user surfaces independent from certain operating systems as well as the possibility of a "personal WUI" (Web user interface). The most important portal functions are personalisation, user administration, dynamic content and Webpublishing, integration of external and enterprise applications.
Concerning existing ISDC services such an portal can be considered an extension of that services and functionality. Now such a portal is to be implemented as an entry area for different ISDCs in the context of a diploma. Analyses of user requirements derived from surveys and user interviews build up the basis for the draft of such an portal. After that different frameworks will be evaluated and finally, using one of those frameworks, selected ISDC-applications will be integrated into the portal.

P 32

GRACE Data Processing and Distribution at JPL PO.DAAC

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The JPL Physical Oceanography Distributed Active Archiving Center (PO.DAAC) is supporting the GRACE mission as the component of the GRACE Science Data System that performs the Level 0 to Level 1B data processing. After retrieving the satellite telemetry from the Raw Data Center in Neustrelitz and processing it, PO.DAAC sends the resulting Level 1B data to both UTCSR and GFZ/ISD, where each produce gravity fields. These gravity fields, as well as lower level data, are then archived and distributed by JPL O.DAAC and the GFZ/ISDC.
The estimates of time variations in the gravity field obtained from GRACE, in conjunction with other satellite and in-situ data, and geophysical models, will provide improved measurements of deep ocean currents, ocean bottom pressure, sea level rise, sea ice mass variation and distribution, soil moisture, groundwater transport, and land density. PO.DAAC provides global oceanographic data from spaceborne instruments and produces higher-level data products. In addition to ocean surface topography, sea surface temperature, and ocean vector winds, other holdings include data on ocean wave height, ionospheric electron content, atmospheric moisture, land/sea ice, and heat flux, as well as in-situ data related to the main satellite holdings. Instruments that provide these data include the following: Topex/Poseidon and Jason altimeters and radiometers, SeaWinds on QuikSCAT and ADEOS-II scatterometers, NASA Scatterometer (NSCAT), NOAA Advanced Very High

Resolution Radiometer (AVHRR), Seasat scatterometer and altimeter, and the MODIS radiometer on the NASA Terra and Aqua satellites.

P 33 **Application of Persistent Identifiers to CHAMP- and GRACE-Products**

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The three main objectives to apply persistent identifiers to the products of the high precision measurements which permanently occur under these satellite missions are the following:

1. to enhance the accessibility of geoscientific data on the internet,
2. to make these data quotable as a basis for geoscientific publications,
3. to enhance the transparency of geoscientific research and its results.

Accessibility of data is inseparable from timeliness ensured by means of suitable interfaces.
Persistent identifiers enlarge the researcher's reputation in order to guarantee the quotability of primary scientific data, thereby a freshness is given to both, the market of scientific information and the role of the authors.
The technical requirements for such an application are already at hand.
To improve the dissemination processes concerning the results of geoscientific research it is inevitable to establish acceptance within the community of potential users.

P 34 **Science for Kids – Kids for Science**

Students of the Weinberg-Gymnasium Kleinmachnow, Bernd Ritschel

The necessity to encourage children and students to deal with modern science and technology as well as the general liability for scientists and engineers to invest in public outreach and education compose the ideas of a 2-years cooperation project „Science for Kids" between the Data Center of the GFZ Potsdam and a grade of school of the Weinberg-Gymnasium Kleinmachnow. The project objectives are both the transfer of scientific and technical knowledge by colleagues of the Data Center ISDC-Team and teacher of the high school to the students and the creation of „Science for Kid" Web pages by the project participants for children and students. The scientific frame of the project activities are the objectives and results of the satellite projects CHAMP and GRACE and the appropriate Information Systems and Data Center (ISDC) designed and operated by the ISDC Team.
B. Ritschel and ISDC-Team (K. Behrends, S. Freiberg, R. Kopischke, H. Palm, A. Schmidt)
Teacher and Students of the Weinberg-Gymnasium (Ch. Göpel, H. Helmer; M. Bahrke, A. Dobrzinski, M. Eckstein, M. Gereke, M. Hinsche, Ch. Kuhlmey, S. Lippoldt, H. Mauersberger, T. Neuenkirchen, D. Prätsch, Ch. Ritschel, S. Schrödter, F. Tomm, Ch. Wittke)
