G71A-0959 0830h POSTER

The IVS Observing Program

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Starting in 2002 the IVS (International VLBI Service for Geodesy and Astrometry) is coordinating a unified geodetic and astrometric observing program to provide data for EOP and for the terrestrial and celestial reference frames. Following from the recommendations of the IVS Working Group 2 for Product Specification and Observing Programs, the unified observing program augments the previously existing weekly 24-hr EOP measurements with a second weekly, rapid-turnaround series called R1. The R1 sessions are observed with a fourfold increase in data rate using Mark IV compared to the 1993-2001 NEOS sessions, which are now designated R4. Baseline repeatability tests indicate that the R1 measurements are better than the R4 measurements. However, the R1 EOP measurements do not show a comparable improvement.

The future enhancements of the IVS observing program described in the IVS WG2 report should permit detection of time variations in harmonic signals with relevance to studies of internal and external global geophysical fluids. Inclusion of other VLBI systems (e.g., the Japanese K4 and Canadian S2) with the standard Mark III/IV and introduction of new technologies such as the disk-based Mark V recorders (data rate increase up to a factor of 4 beyond the current R1 series) will increase the density of geodetic measurements and the reliability of the program.

G71A-0960 0830h POSTER

Secular Sea Level Change in the Russian Sector of the Arctic Ocean

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Sea level change in the Arctic Ocean is investigated based upon approximately 50 years of the monthly mean data from 57 tide gauges. Analyses of the raw data show that at the majority of stations the sea level rises at a rate of aproximately 1.4 mm/year. When the secular rates of change are corrected for the influence of glacial isostatic adjustment, the average rate of secular sea level rise is determined to be 2.3 mm/year which is very close to the rate of 2.0 mm/year that has been determined on the basis of analysis of US East coast data. The time series from the individual gauges are sufficiently short, however, that no significant reduction in the RMS of the secular rates is achieved by the GIA correction procedure.

Investigation of decadal variability of sea level change using observational data and model results shows that the cumulative action of the wind-driven and thermohaline circulation may account for about 80% of sea level variance in the Arctic Ocean during 1950-1990. The most intriguing results were observed in the decade 1990-2000 during which time the rate of sea level rise was close to zero or became negative, contrary to the common expectation that the rate of sea level rise should increase uniformly as a consequence of global warming. This clearly warrants more detailed investigation.

G72A MCC: Hall C Sunday 1330h

New Results From GRACE and Other Gravity Missions Posters *(joint with H, OS)*

Presiding: **M M Watkins,** Jet Propulsion Laboratory**; B D Tapley,** University of Texas**; J M Wahr,** University of Colorado

G72A-0962 1330h POSTER

Geoid Anomalies due to Low-Viscosity Crustal Zones in Glacial Adjustment Models and Their Detectability by GOCE

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Glacial Isostatic Adjustment (GIA) due to late-Pleistocene Ice Age cycles has left clear imprints in various global and regional geodetic signatures. In GIA models these signatures are often modeled with an elastic crust/lithosphere as top layer in the earth model.

Seismic observations indicate the presence of low-viscosity ($10^{17} - 10^{18}$ $Pa \cdot s$) layers at various regions in the Earth's continental crust. In a recent study (Vermeersen, *Space Sci. Rev., in press*) it has been shown that such shallow low-viscosity layers can create high-harmonic patchlike geoid anomalies that should become observable by the Gravity field and steady-state Ocean Circulation Explorer (GOCE) satellite mission, scheduled to be launched in 2006: anomalies of 1 cm - 1 m for length scales of 100 - 1000 km.

In the present study, thickness, depth and viscosity of a low-viscosity crustal layer are varied and the variations in the resulting geoid anomalies are compared with the expected sensitivity of GOCE geoid data. A spherically symmetric analytical viscoelastic earth model is used, in combination with the pseudospectral method developed by Mitrovica and Peltier (1991) for self-consistently solving the sea-level equation up to high harmonics, to determine GIA-induced geoid anomalies due to Ice Age cycles based on the ICE-3G model of Tushingham and Peltier (1991). These modeling results on the discriminative power may help in identifying GIA-induced contributions in geoid anomaly maps.

G72A-0963 1330h POSTER

Gravity Fields from CHAMP Mission Data

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The CHAMP mission, launched in July 2000, is the first in a series of missions that will revolutionize our ability to model the Earth's geopotential. The CHAMP spacecraft is equipped for precision tracking by the Global Positioning System (GPS) and Satellite Laser Ranging (SLR) along with a precision accelerometer to provide measurements of the surface forces. Preliminary satellite-only geopotential solutions with only 30 days of CHAMP data are, by some criteria, as strong as solutions made from tracking data collected over the previous 30 years of the space age. Compared to EGM96, CHAMP makes notable contributions in regions where the terrestrial data (surface gravimetry and altimetry) were weak, for example in the polar regions, in the Amazon and the Himalayas. The CHAMP data allow us to separate the geoid from the dynamic ocean topography (DOT) up to at least degree 25 rather than just under degree 20 as in EGM96. We report on satellite-only and combination models that incorporate up to 100 days of CHAMP data as well as other satellite data. We report on our updated processing of the CHAMP tracking and accelerometer data and evaluate the performance of the geopotential models using a variety of tests.

G72A-0964 1330h POSTER

A Parana State Gravimetric Geoid, Brazil

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In geodesy, a geoid model is required to transform satellite-derived heights to physically meaningful heights based on the Earths gravity field, but it also has applications in geophysics and oceanography. Geoids models have been developed in many parts of the world, in particularly in North America an Europe. Recently, a project to determine the geoid in South America has been carried out. The purpose of this project was the determination of a regional gravimetric geoid in Parana State, Brazil. Gravity data were collected in Parana State and surroundings by different organizations since 1985 allowing the computation of a geoid. This study comprises: the preparation of terrestrial gravity and terrain data; the use of appropriate geodetic datum during gravity data reduction; the selection of the best fitting global geopotential model; the application of the gravimetric terrain corrections; the gridding of the gravity anomalies prior to geoid computation; and comparisons of a preliminary Parana State gravimetric geoid solution with geometrical control, provided by Global Positioning System (GPS) measurements in conjunction with leveling data.

G72A-0965 1330h POSTER

First Recoveries of Water Storage Changes From GRACE

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Upon completion of the current commissioning phase, GRACE will begin delivering global estimates of the Earth's gravity field approximately every 30 days. After removing the atmospheric contribution, these gravity solutions can be inverted to determine changes in continental water storage, spatially averaged over regions of arbitrary shape and size. Recovering hydrologic signals with the exact averaging function for some region results in the inclusion of large satellite measurement errors. Approximate averaging kernels can be created which improve accuracy by reducing measurement errors. For example, with *a priori* estimates of measurement error and signal covariance matrices, one can construct an averaging kernel which minimizes the sum of the variances of the measurement and leakage errors. We construct optimal averaging kernels for continental regions, and examine the accuracy and resolution with which regionally averaged changes in water storage can be recovered from GRACE data.

G72A-0966 1330h POSTER

Multi-Resolution Representation and Estimation of the Gravity Field Using Spherical Wavelets

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In this paper, we explore the feasibility of the use of radially symmetric spherical wavelet functions (1) for the multi-resolution representation of the geopotential and (2) for the estimation of the wavelet-represented gravity field model using data from advanced gravity missions such as CHAMP, GRACE, and GOCE. The representation approach can be split into an expansion in terms of spherical harmonics for the long-wavelength components and a spherical wavelet expansion for the medium- and high-frequency components. This multi-resolution representation consists of a sum of detail signals and each detail signal is related to a certain frequency band and resolution step. Developed data compression methods can reduce the number of wavelet coefficients drastically. To satisfy several properties many eligible wavelet functions like the Abel-Poisson and the de la Vallee-Poussin wavelet have to be taken

into account. Preliminary results using CHAMP in-situ potential data for a spherical wavelet geopotential representation and for the gravity field estimation are presented. The development of this mathematical tool if successful, would have many advantages in the exploitation of highly accurate advanced gravity missions (i.e., GRACE) data for gravity field determination than the classical spherical harmonics approach.

G72A-0967 1330h POSTER

The Optimal Selection of GPS Double-Differenced Measurements for GRACE

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The GRACE mission currently generates approximately 150,000 GPS double-differenced measurements each day from a network of roughly fifty ground stations. The volume of data collected from these ground stations far exceeds the number of inter-satellite range measurements collected and processing these GPS measurements consumes the bulk of the computing time involved in estimating the gravity field. The GPS data only influence the recovery of the low to mid degree gravity signals, with most of the gravity signal being determined from the inter-satellite range measurements. The limited contribution of the GPS measurements, along with the significant computing time required to process them suggest that a strategy be developed by which only the minimal set of GPS measurements required be processed. The purpose of this study is to demonstrate that a reduced ground station network, combined with an optimal GPS parameterization, will provide a quality gravity field solution which satisfies the overall mission requirement with much greater processing efficiency

URL: http://www.csr.utexas.edu/grace/

G72A-0968 1330h POSTER

Assessment of the first static gravity field from GRACE in terms of surface ocean circulation

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GRACE's promise are monthly estimates of the Earth's gravity field, to degree 70 or more, for about 5 years. Being the first mission of its kind, preliminary versions of such fields need to be evaluated for reasonableness in various spectral bands and against a variety of data, including their effect on orbit computation, ocean circulation estimates, etc. Here we compare the difference between the geoid heights from one such preliminary field and the mean sea surface of Y.-M. Wang (2001), a measure of the time-averaged surface ocean currents, against output from the ECCO ocean model (which assimilates TOPEX altimetry), against various dynamic topographies derived from the Levitus (2001) hydrographic compilation, and against selected ADCP data.

G72A-0969 1330h POSTER

GRACE Orbit Deterimation for Gravity Field Recovery at CSR

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Determining the orbits of the GRACE satellites is an important aspect of the operational data processing for gravity field recovery. Precise orbits are required for data quality assessment and verification and finally as reference for the gravity field estimation step. Several stages are needed as part of the preparation for the gravity field solution. Using GPS tracking data, initial orbits are computed to produce model accelerometer and attitude data, edited tracking data and improved initial conditions. The model data are used to assess the performance of the accelerometer and star tracker as well as the quality of the measurements from these instruments. The tracking data are further edited to remove anomalous data. A final converged orbit is determined using the on-board accelerometer and attitude data along with the edited tracking data. Results of initial and final orbit fits for a period of data from April and May 2002 will be presented. Orbit quality metrics including GPS data residuals and SLR residuals will be presented. Improvement of the orbit fits due to an improved gravity field will be demonstrated. Using an initial GRACE derived gravity solution, an orbit accuracy at the few cm level is achieved.

G72A-0970 1330h POSTER

Ocean Bottom Pressure from GRACE — Utility & Validation

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The GRACE satellites were launched in March 2002, and will measure the gravity field of the Earth. Each month for 5 years they will produce a monthly-averaged gravity estimate sensitive to mass changes equivalent to a cylinder of water about 500 km in diameter and 1 mm in height (0.001 dbar in pressure). Month to month, the main source of geoid changes is the redistribution of water mass in the hydrosphere. Over the ocean, the time-varying gravity field can be interpreted as the fluctuating part of the ocean bottom pressure. This will be the first time such measurements are made from space, and because of the complexity of deriving gravity changes from the satellite-to-satellite tracking data, it will be beneficial to have some in-situ data against which these observations can be compared. The issue discussed here is how to compare such GRACE bottom pressure estimates to in-situ bottom pressure recorder data for the purposes of providing groundtruth for the former. The presence of short spatial-scale variability in ocean bottom pressure requires enough bottom pressure recorders be deployed in an area so their average achieves an accuracy comparable to 0.001 dbar on monthly scales. Short time-period variability in ocean bottom pressure brings up an additional issue of aliasing in the GRACE signal, which requires a combination of one month of the gravity data to produce an estimate of the geoid. We will discuss the planned deployment of an array of bottom pressure recorders to provide an ocean-based, in-situ dataset to validate the time-varying component of the GRACE observations. The location of the proposed array is an area around 16°N in the subtropical North Atlantic Ocean, and is the location of an on-going study of the meridional overturning circulation called the Meridional Overturning Variability Experiment (MOVE). This location was selected by virtue of having suitable bottom pressure signal, one that is dominated by large spatial-scale variability on monthly and longer timescales, and is the site of an on-going climatological observation program. Other opportunities to provide groundtruth observations to compare against the GRACE measurements will also be discussed.

The interpretation and utility of the GRACE observations over the oceans will be presented. We describe a method of using those gravity measurements to estimate temporal variations in deep ocean currents. We examine the probable accuracy of the current estimates by constructing synthetic GRACE data, based in part on output from an ocean general circulation model. We ignore the possible contamination caused by short-period gravity signals aliasing into the 30-day solutions. We conclude that in the absence of aliasing, GRACE should be able to recover the 30-day variability of mid-latitude currents at 2 km depth. Additionally, a method for combining satellite altimetry observations with satellite measurements of the Earth's time-varying gravity to give improved estimates of the ocean's heat content will be illustrated. It is found that the inclusion of bottom pressure improves the ocean heat storage estimates. The improvement comes from a better estimation of the steric sea surface using a combination of sea surface height and bottom pressure than over using sea surface height alone.

G72A-0971 1330h POSTER

Progress in the Ground Calibration of GRACE data.

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The calibration / validation of GRACE data is being actively pursued using a ground array of superconducting gravimeters in Europe. This is a project that will be ongoing for a number of years as the improvements to the processing of both satellite and ground-based data are realized. For example, the atmospheric corrections using a 3-D model have been shown to be important to the GRACE mission, and are only now being developed for gravity applications. We continue to analyze the ground-based mean gravity field over Europe from the GGP project, this time for more cent epoch that overlaps with the time window of the CHAMP mission. Previous results have been extended to show that the accuracy of the mean field recovery is at the microgal level. This will provide an interesting comparison with the accuracy of the actual GRACE data that will be presented in this session.

G11A MCC: 123 Monday 0830h

Geodesy at the Solid-Fluid Interface I

(joint with A, H, OS)

Presiding: **R S Gross,** Jet Propulsion Laboratory**; C R Wilson,** University of Texas at Austin

G11A-01 0830h

Inversion of Solid Earth's Varying Shape 1: Global Mean Sea Level Variations

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We develop a spectral approach to invert for the redistribution of mass on the Earth's surface given precise global geodetic measurements of the solid Earth's geometrical shape. We use the elastic load Love number formalism to characterize the redistributed mass as a truncated spherical harmonic expansion on an epoch-by-epoch basis. Integration of the resulting mass distribution over oceanic areas gives us an estimate of ocean-continent mass exchange, and hence the non-steric (mass) component of changes in global mean relative sea level.

We apply this theory to study the contribution of seasonal inter-hemispheric (degree-1) mass transfer to global mean sea level, using weekly GPS station coordinates of the global IGS network after removal of secular motions [Blewitt et al., 2001]. Our inversion yields a seasonal ocean-continent mass exchange with annual amplitude of $(2.9 \pm 0.3) \times 10^{15}$ kg and maximum ocean mass on 25 August. Semi-annual mass exchange takes place with amplitude $(3.6 \pm 2.6) \times 10^{14}$ kg such that the maximum ocean mass increase, in Northern Hemisphere spring, occurs more rapidly than the maximum ocean mass decrease later in the year (consistent with run-off data).

Our estimate of the annual amplitude of global mean relative sea level is therefore 8.0 ± 0.8 mm. Comparison with satellite altimetry, which measures geocentric sea level, requires a small correction for the average deformation of the ocean floor that is consistent with the total loading [Blewitt and Clarke, this meeting], which results in an annual amplitude of global mean geocentric sea level of 7.6 ± 0.7 mm. Results from TOPEX/POSEIDON corrected for steric effects are in the range 7.1 mm to 9.5 mm with maximum sea level occurring between 12 September and 24 September. Assuming the large steric corrections (of order 5 mm in amplitude, half the total effect) are correct, this good agreement between our result and that of altimetric methods implies that seasonal inter-hemispheric mass transfer is indeed the dominant driving mechanism for seasonal change in sea level. In contrast, hydrological models of global mean sea level differ by up to a factor of three between themselves and from geodetic results.

G11A-02 0845h

Inversion of Solid Earths Varying Shape 2: Using Self-Consistency to Infer Static Ocean Topography

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