G24A-05 1630h

The effects of the definition of a stable Eurasian reference frame on geodetic velocity estimates along its boundaries

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The geodetic definition of a stable Eurasian reference frame has long suffered from having a disproportionate number of stations in its European portion and from the fact that the available stations east of the Ural mountains are all in, or close to, the central Asian deformation zone. This has affected, for example, the ITRF2000-Eurasia definition of Altamimi et al. (2002). Only recently this situation has changed with the availability of sufficiently long time-series of IGS stations in central and northern Siberia. These data has effectively been used by Calais et al. (2003) and Steblov et al. (2003). It has become evident that there is a systematic difference between the definition of a Eurasian reference frame from studies that include or exclude stations east of the Ural. The pole of rotation that explains the difference is located in Eastern Europe. The rate difference results in up to 4 mm/yr in Southeast Asia. All geodetic studies from the Mediterranean to Southeast Asia appear to use different definitions of stable Eurasia. We explore here the effects of adopting different definitions of Eurasia on the geodetic velocity estimates along Eurasia's southern margin, including Nubia, Arabia, India, and East- and Southeast Asia. We show that, compared to Nubia's motion relative to European stations, its motion relative to Eurasia is 12° more clockwise (CW) in the eastern Mediterranean and 20° more counter-clockwise (CCW) west of Gibraltar. Both solutions are significantly different form geologic estimates, but velocities in a Eurasian reference frame are noticeably closer to the geologic estimates than the velocities in a European definition. Bahrein (Arabia) moves 3° CW and 1 mm/yr faster relative to Eurasia than to a European defined Eurasia. The motion of Bangalore (southern India) could be 3 mm/yr slower and 2° CCW relative to a Eurasian fixed reference when only stations in Europe are used. At Shanghai and Singapore using only European stations would give a velocity 30° CW from a solution that includes Siberian stations. Other examples will be discussed as well. Finally, it is important to point out that any comparison with geologic plate motion models should be based on a geodetic definition of the Eurasian plate that includes Siberia stations, because the Artic Ridge (which is used in geologic plate motion estimates) extends to 120°E. Also, no-net-rotation (NNR) estimates of Eurasia based on geologic models should be avoided, because its definition is significantly different from geodetic estimates, largely as a result of the inclusion of the Asian deformation zones in the geologic NNR definition.

G24A-06 1645h

The Signatures of Tectonics and Glacial Isostatic Adjustment revealed by the Strain Rate in Europe

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Tectonics and Glacial Isostatic Adjustment (GIA) are simultaneously taken into account in order to quantitatively define their role on crustal deformation in Europe. A spherical finite element model, based on the thin viscous shell approach and suitable to predict tectonic deformation, and a spherical stratified viscoelastic Earth model, based on the normal mode approach to quantify the effects of GIA, are used to predict the intraplate deformation in Europe. Model predictions are compared with the geodetic strain rate obtained from ITRF2000 velocity solutions. Our results confirm that both geophysical processes influence intraplate deformation in Europe, with tectonics playing the leading role south of Potsdam, while GIA is the only mechanism north of Onsala. Both geophysical processes affect the deformation at intermediate latitudes,where the contributions to the deformation coming from tectonics and GIA are of the same magnitude and the combined tectonic plus GIA model succeeds to reproduce the eigendirections of the local predominantly SSW-NNE directed compression. The stiffening in the eastern European platform is crucial to shield the north-eastern regions from the compressional effects of Africa-Eurasia convergence and to allow SE-NW directed extension in Fennoscandia driven by GIA.

G33A CC: 516 B Wednesday 1330h

Observations of Glacial Isostatic Adjustment and Contemporary Ice-Ocean-Mantle Mass Redistribution I *(joint with H, OS, S, T, C, GC, PP, SEDI)*

Presiding: **H Scherneck,** Chalmers University of Technology**; J A Henton,** Natural Resources Canada**; A Capra,** University of Bologna

G33A-01 1330h INVITED

Global Inverse Approach to ice Mass Variations Using Data Combination

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Ice mass balance, sea level rise, and post-glacial rebound (PGR) are all manifestations either directly or indirectly of mass and thermal variations in the volatile cryosphere and hydrosphere of the Earth with multiple spatiotemporal scales. The southern hemisphere is especially important because of its huge ice mass reservoir. The coupling of multi-processes with various parameters makes their separate determination extremely difficult. On the other hand, surface mass variations leave many significant geodetic and geological signatures that are now being accurately measured and documented. A global simultaneous inversion of data combination offers exciting opportunities to unravel the complex processes collectively and objectively with statistical rigor. Gravity data from satellite laser ranging (SLR) and CHAMP/GRACE missions, satellite altimetry, and GPS deformation measurements will aid in providing a description of the short period variations having elastic Earth response with unprecedented global coverage, accuracy and resolution. Remarkable agreements have been found for annual n=1 and low degree zonal surface mass variations between SLR and inverse GPS results. For secular present-day variation and PGR, our analyses indicate that the combination of GRACE and ice altimetry may allow for separation of their signatures. For example, assuming that GRACE and Icesat perform to full expectation, and that the "compaction error" is smooth, the mean Antarctic present-day ice mass balance can be determined to about 4 mm/yr, corresponding to an error of 0.1 mm/yr in its contribution to sea-level change. A further combination with relative sea-level (RSL) history can significantly improve parameter separation and enhance temporal resolving power. Global and targeted regional GPS data are also complimentary for long-wavelength improvement and spatial coverage.

G33A-02 1345h

Separating GIA and Water Mass Redistribution Combining satellite and in situ Measurements:Preliminary Results From GRACE.

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Recent satellite missions provide new and valuable information to better understand the complex ice-ocean-Earth system. We present a method to combine satellite measurements with other in situ measurements and independent information. The final goal of this methodology will be to use all possible available observations to separate the contributions of time-variable accumulation, glacial isostatic adjustment and ice mass change. We will examine how to optimally combine time variable gravity from GRACE, altimeter measurements from ICEsat/GLAS, GPS measurements of vertical velocity, ice core measurements of compaction through time, radar-derived estimates of snow density, and InSAR estimates of height change. We will discuss the strengths and limitations of combining these different data sets, including complexities in estimating compaction trend using ice cores collected before the final epoch of satellite measurement, and how estimates of precipitation fields from Global Circulation Models may improve estimates of ice mass trend and GIA.

G33A-03 1400h INVITED

Direct constraints on GIA motion in North America using GPS

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We use continuous and episodic Global Positioning System (GPS) data to measure the movement caused by glacial isostatic adjustment (GIA) due to glacial unloading in eastern North America. At present it is challenging to quantify GIA motion in North American due to the limited number of continuous GPS sites (CGPS) in and around Hudson Bay, the area of maximum glacial loading. Episodic GPS (EGPS) sites provide a low cost and higher density alternative, but often have large errors, especially in the vertical. However, the large vertical signal due to GIA (>10mm/yr) in the area of maximum uplift permits this motion to be resolved, even with EGPS data. We present data from 130 CGPS sites throughout North America and almost 100 EGPS sites of the Canadian Base Network (CBN). The CBN sites are located across central and southern Canada and have been episodically occupied between 1994 and 2002. We detect a coherent pattern of vertical motions around the area of maximum glacial loading, Hudson Bay. The observed velocities are initially large and upward, and decrease southward from Hudson Bay to zero, delineating the hinge line near the Great Lakes. The position of the hinge line is in agreement with some numerical GIA predictions. The horizontal residual velocities after removing the motion of the rigid North American plate also show a consistent, but more complex pattern than the vertical velocities. In particular we observe larger than expected motions on the east side of the Canadian Rocky Mountains, possibly reflecting larger ice loads and/or changes in mantle viscosity. We believe that this velocity field provides the first comprehensive direct description of GIA motion and can be used to constrain GIA model predictions.

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G33A-04 1415h

New GPS and Raised Shoreline Measurements of Rapid Uplift in Southern Alaska.

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Five years of campaign-style GPS observations at 74 sites indicate uplift rates of 10 - 32 mm/yr over a large area of southern Alaska. Studies of raised shorelines at 27 sites throughout the region show rapid sea level changes, consistent with the distribution and magnitude of the GPS determined uplift rates. Dendrochronology of 14 of these shorelines gives the onset of uplift at 1850 to 1880 AD. Two of the shoreline study sites show 5.5 m of sea level change since then, in Dundas Bay and Upper Lynn Canal, and the remaining 25 shoreline sites describe a pattern of smoothly decreasing uplift with increasing distance away from Glacier Bay. Both the raised shorelines and the GPS data indicate greatest uplift surrounding areas of post-Little Ice Age (LIA) deglaciation. Using a combination of independent studies, geomorphic indicators and historical observations of the ice extent in Glacier Bay, we have built a model of LIA expansion and retreat of the Glacier Bay Icefield. Total ice volume lost in Glacier Bay since 1750 AD is on the order of 2500 km^3, with ice thickness changes up to 1.5 km. We will present viscoelastic rebound models using this ice load model, and combined with ice models based on airborne laser altimetry of present day ice loss. Earth models that invoke a 50 km thick elastic crust over a 100 km thick asthenospheric layer with viscosity of 1 x 10^{19} Pa s can

completely attribute the rapid uplift of southern Alaska as due to post-LIA ice loss.

G33A-05 1430h

BIFROST project: Reprocessing six years of continuous GPS observations and inference of three-dimensional deformation in Fennoscandia

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New solutions are presented from 2000 days of continuous GPS obtained in the permanent networks in Fennoscandia. The period encompasses a prolongated phase of stable observation conditions after January 1998. Several significant improvements have led to narrower uncertainties and lower systematic errors in the new solutions compared to our previous results. Elevation cutoff was lowered to 10 degrees, only sporadically were antenna bias parameters required, and parallel solutions were produced with different softwares and different strategies. We used GAMIT and GIPSY/OASIS-II, the latter in point positioning mode both with and without ambiguity fixing. The new results confirm earlier findings of maximum discrepancies between GIA models and observations in northern Finland. The reason may be related to overestimated ice thickness and glaciation period in the north. In general, the new solutions are more coherent in the velocity field as some of the perturbations could be avoided. We compare GPS rates with sea level rates from tide gauge observations and with model computations.

G33A-06 1445h INVITED

Forward and Inverse Modelling of GPS Observations of Fennoscandian GIA

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Project BIFROST (Baseline Inferences for Fennoscandian Rebound Observations Sea Level and Tectonics) was initiated in 1993 to directly measure the present-day, 3-D crustal deformation field in Fennoscandia [*Johansson et al., JGR,* **107**, *2002; Milne et al., Science,* **291**, *2001*]. A dense array of continuously operating GPS (Global Positioning System) receivers was deployed between 1993 and 1997 to achieve this objective. The BIFROST GPS network is composed of two sub-networks, the Swedish SWEPOS^{TM} network and the Finnish FinnRef^{TM} network which, together, provide a relatively uniform and broad spatial sampling of crustal motion in Sweden and Finland. We shall present results from both forward and inverse modelling analyses of the BIFROST data. In particular, we shall focus on the implications of the results for constraining sub-surface viscosity structure and the deglaciation history of the most recent Fennoscandian ice sheet. We shall also discuss the residual signal in the context of limitations of the earth and ice components of the GIA model as well as a regional neotectonic signal.

G33A-07 1520h INVITED

Past and Present Deglaciation Effects on Ongoing Sea Level Changes

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The observed global sea-level rise has many components, notably including thermal expansion of the oceans and the ongoing signal from cryospheric mass variations. The latter includes variations of the solid Earth and the sea surface caused by both past and present changes in glaciers and ice sheets. Separating the relative contributions from these and other sources is difficult. One method is to use geographic variations, or 'fingerprints', in both sea level (as measured by tide gauges) and sea surface (as observed from TOPEX/Poseidon and Jason) [Mitrovica et al., 2001, Plag and Jüttner, 2001] to estimate the relative weighting of the individual sources. As an example, local geographic variations in sea level caused by the ongoing mass imbalance of the Alaskan and Patagonian glaciers can be quite large, over 1 cm/yr [Tamisiea et al., 2003]. However, these signals may be contaminated by local effects associated with previous Late Holocene glacial fluctuations. In contrast, the predicted sea surface variation in the same regions is insensitive (to within 10%) to this aspect of the loading history. In this talk we demonstrate that measurements of sea surface (geoid) variations in the vicinity of small glacier systems provide a remarkably robust (i.e., uncontaminated) measure of the ongoing mass balance of these systems. In addition, we present bounds on the contribution to the sea surface change, from local to global scale, arising from the Late Pleistocene glacial fluctuations; this range is based on numerical calculations generated from a plausible suite of ice sheet and Earth models.

G33A-08 1535h

A Bayesian Calibrated Deglacial History for the North American Ice Complex

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Past deglacial ice-sheet reconstructions have generally relied upon discipline-specific constraints with no attention to the determination of objective confidence intervals. Reconstructions based on geophysical inversion of relative sea-level (RSL) data have the advantage of large sets of proxy data but lack constraints from ice-mechanics. Conversely reconstructions based on dynamical ice-sheet models are glaciologically self-consistent, but are dependent on poorly constrained climate forcings and sub-glacial processes. As an example of a much more constrained methodology, we present a high-resolution glaciologically-self-consistent deglacial history for the North American ice complex calibrated against a large set of RSL and geodetic data. The history is derived from ensemble-based analyses using the 3D University of Toronto glacial systems model and a new high-resolution ice-margin chronology derived from geological and geomorphological observations. Isostatic response is computed with the VM2 viscosity structure. Bayesian calibration of the model is carried out using Markov Chain Monte Carlo methods in combination with neural networks trained to model results. The calibration provides a posterior distribution for model parameters (and thereby modelled glacial histories) given the observational data sets that thereby also takes into account data uncertainty. Incorporation of a surface drainage solver offers the possibility of adding strandline and lake shoreline tilt data to the constraint and/or validation data sets. Comparison against the current version of the ICE-5G deglacial load history will also be presented to elucidate the impact of glaciological self-consistency on inferred load chronologies.

URL: http://www.atmosp.physics.utoronto.ca/people/lev/glacmov.html

G33A-09 1550h

Understanding the Dynamic Neotectonic System in Antarctica

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Feedbacks and interactions between components of the earth system are fundamental to polar geodynamic processes. The Antarctic Neotectonics (ANTEC) group has developed a vision for a major interdisciplinary program to investigate linkages between neotectonic processes in Antarctica, focused on understanding 1) how the stress/strain regimes of the lithosphere respond to changing ice mass loads; 2) how glacial isostatic adjustment and the tectono-thermal structure of the lithosphere influence modern ice sheet dynamics; 3) how tectonic motions and magmatism are linked with fluctuations of the Antarctic ice sheets through the Cenozoic; and 4) how evolving continental-scale paleogeography, volcanism, and erosion/sedimentation influence climate change. A primary focus to address these science goals is achieving continental-scale deployments of remote geodetic and geophysical observatories across the continental interior. Developing technologies are beginning to allow observatory operation through the polar night, due to advances in power sources and data storage capacity. Continued development in these areas, as well as in communications technologies to allow data transfer from remote stations, is required. Ground-based experiments must be integrated with campaigns by spaceborne instruments, to discriminate cryosphere mass flux signals from neotectonic activity. Coordination of ground-based observatory deployments with ongoing efforts to develop airborne geophysical platforms and new drilling systems will facilitate mapping and sampling unknown subglacial terrain and the earth's deep interior. Promising new areas of investigation to understand how surface processes are linked with tectonism in polar environments lie in application of new mapping technologies (LIDAR, ice-penetrating radar), new chronological tools, and assimilation of new surface information into modeling. If we can meet the logistical and funding challenges of instrumenting the Antarctic interior on a grand scale, we will reap a wealth of data that will serve as the foundation for monitoring our dynamic physical environment far into the future. The SCAR-ANTEC group is convening symposia and workshops to coordinate international efforts to achieve these goals.

G33A-10 1605h

Antarctic VLNDEF Network for Regional Deformation Control in Absolute Reference Frame: Problems and Possible Solution.

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VLNDEF (Victoria Land Network for DEFormationn control) Geodetic Program addresses the crustal deformation control of the Northern Victoria Land (Antarctica) by means of geodetic GPS measurements. The project is within the activity of GIANT (Geodetic Infrastructure of Antarctica) SCAR Program and was established within the actions of ANTEC (ANTarctic NeoTECtonics) Group of Specialists. During 1999-2000 and 2000-2001 Italian expeditions a network of 27 stations was established and completely surveyed over an area extending from the southernmost points at 70 degrees latitude south to the Oates Coast region at 76S, corresponding to a wideness of 700 km along the south-north and 300 km in the west to east directions. The average distance between stations is about of 70-80 km. During the field activities in the 2002-03 expedition the whole network was surveyed. During those expeditions long time sessions of connection between VLNDEF and TAMDEF networks performed. TAMDEF is a USA NSF program for crustal deformation control on southern Victoria Land. The dataset has been processed using different package such as Bernese and Gipsy in order to compare solutions and fix the better approach for the transition between reference frame. The first solution was initially constrained in the ITRF97 solution using the TNB1 GPS permanent station coordinate provided by the SCAR GPS Epoch solution. The approach to crustal deformation determination is relevant in terms of relative regional deformation, among the network stations, and the absolute

deformation study, through the connection to international reference frame. Particularly important is the study of for VLNDEF in order to integrated evaluation with other continental and regional networks, as SCAR GPS Epoch and TAMDEF.Some aspects related to the data processing in the Antarctic region and the use of the ITRF2000 as reference frame will be discussed in the paper in addition to the analysis of the deformation in the area.

G33A-11 1620h

Neotectonic Crustal Motions in the Antarctic Interior Measured by the TAMDEF GPS Network

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The Transantarctic Mountain Deformation (TAMDEF) GPS network has been constructed over Victoria Land, Antarctica. After new station deployments in 2003, the TAMDEF network extends 670 km north-south and 400 km east-west. The network crosses gradients in predicted vertical motion due to glacial-isostatic rebound and spans the Terror Rift in the western Ross Sea, where faulting reaches the seafloor and volcanism is active, suggesting modern rift activity. The network now includes 6 remote stations designed to operate continuously, surrounded by 26 campaign sites. The continuous stations will provide strong control for the campaign measurements and will more rigorously constrain vertical bedrock motions. The network of campaign sites allows a broad region to be monitored for horizontal motions. The first campaign sites were installed in 1996 and the continuous stations were added to the network between1999 and 2003. Measurements from the first 7 years of monitoring document east-northeastward horizontal motion of stations on islands within Terror Rift with respect to stations along the inland flank of the Transantarctic Mountains, which are used to approximate a stable 'cratonic' reference frame for interior Antarctica. The rate of extension is about 4mm per year. Although a component of this motion may be due to glacial isostatic adjustment, modeling suggests that the horizontal motion is also due to tectonic opening of the Terror Rift. The horizontal relative motion direction is perpendicular to faults that cut the seafloor mapped from marine seismic data, compatible with modern tectonic activity in the rift.

G33A-12 1635h

Crust and Upper Mantle Seismological Model of Transantarctic Mountains from TAMSEIS

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The large 2-D geometry of the Transantarctic Mountain Seismic Experiment (TAMSEIS) allows for charactering the East Antarctic crust and upper mantle deep into the interior. This array consists of three subarrays that 1) traverse 370km from McMurdo across the Transantarctic Mountains with 20 km spacing, 2) traverse perpendicular to the first sub-array with spacing of 80km running 1400 km inland from Terra Nova, and 3) extend along the coastline at 80km spacing. The 43 seismic stations are used to examine the Antarctic lithosphere with better resolution and extent than any previous experiment. Using a niching genetic algorithm (NGA is a guided search method) we are able to invert both receiver functions and surface wave phase velocities simultaneously. As the two data sets are complimentary they increase the uniqueness of the solutions and reduce need for a priori information. Additionally the NGA allows us to implement ice layers with known thickness and velocity without adversely affecting the inversion. This method produces a variety of 1-D models representing structures underlying TAMSEIS stations. By analyzing these 1-D structures together, we produce 2-D cross sections. From the 2-D cross sections we construct a 3-D model representing the crust and uppermost mantle from the Ross Sea to 1400 km within the East Antarctic plate. The resultant models indicate several structural variations from the Ross Sea to the East Antarctic Ice Plateau. 1) The East Antarctic crust thins through the Transantarctic Mountains from 40 km to 20 km at the Ross Sea, coinciding with uplift. 2) The Ross Sea crust and upper mantle are largely different from those observed beneath East Antarctica. The Ross Sea Moho is not only shallower than that of East Antarctica, but the underlying mantle is seismically much slower. 3) The East Antarctic crust is homogeneous for a large lateral extent. These observations may suggest a buoyant load underlying the West Antarctic Rift System, and a coincident response from the colder, older, and more brittle East Antarctic plate.

URL: http://epsc.wustl.edu/seismology/jfisher/

G33A-13 1650h

Lateral viscosity variations beneath Antarctica and their implications on regional rebound motions and seismotectonics

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In this paper, the potential contributions to present-day crustal motions and seismicity from glacially-induced Pleistocene ice mass changes in Antarctica are assessed by considering different combinations of ice and earth models. Due to the uncertainties in reconstructing the late-Pleistocene ice-sheet distributions in Antarctica, three ice models that encompass a wide range of plausible scenarios are considered. Two different earth models are used to describe the viscoelastic response of the bedrock: In the first one, mantle viscosity varies with depth only. In the second model, three-dimensional viscosity variations inferred from seismic tomography are included, with East Antarctica underlain by a stiff cratonic root and the upper mantle underneath West Antarctica being relatively weak. The results show that predicted present-day crustal motions depend strongly on the ice model chosen, with vertical motions focused around former ice domes. The horizontal motions are greatly affected by earth rheology, as the flow goes from the stiff East Antarctic cratonic root to the weaker West Antarctic mantle. Fault stability is predicted over much of Antarctica today, indicating that the seismically quite state is probably due to the presence of the thick ice. At the site of the 1998 Balleny Island Earthquake (Mw=8.1), the induced fracture stresses are relatively small by comparison, and interestingly become more prone to stress failure when a three-dimensional earth model is assumed.

G34A CC: 519 A Wednesday 1530h

Computations in Geodesy and Geosciences I *(joint with OS, GC)*

Presiding: **R Blais,** University of Calgary**; M Soofi,** University of Calgary

G34A-01 1530h

Modeling Uncertainties in Flood Predictions due to Climate Change

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Classical estimation theory and parametric modeling assume that the hydrologic system structure exhibits stationary behaviour over the entire collection of system observations. However, hydro-meteorological processes are subject to both nonlinear and nonhomogeneous adaptations due to climate change and other variabilities. Previous studies have shown that the variability of daily rainfall causes considerable uncertainty in flood hydrograph simulation. Therefore, in this paper, two approaches, estimation theory and parametric modeling are used to (1) describe the structure of extreme daily rainfall and (2) track error propagation from rainfall data into simulated flood hydrograph. A new approach that uses a Kalman filter to track patterns of hydrologic system behavior under different rainfall inputs and over different periods under greenhouse gas forcings is developed. The methodology incorporates bootstrap resampling and Monte Carlo modeling to simulate different scenarios of hydrologic inputs into HEC-1 flood prediction model to generate potentially realizable flood hydrographs for a medium sized watershed in southwestern Alberta. Preliminary studies indicate that uncertainties in rainfall input can result into about 100% increase or 20% reduction in the 200 year flood.

G34A-02 1545h

Estimating Density Contrast From Global Geopotential Fields

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Each succeeding global geopotential model has provided an increasingly accurate representation of the Earth's potential on the sphere. From these models, the quasi-spherical surface known as the geoid is defined. It is an equipotential surface and represents all mass variations within the Earth. If one could interpret a model's spectrum in terms of plausible depths to anomalous bodies or layers, one could estimate the probable density variations that contribute to that portion of the measured field, and thus to the geoid. It has been known since the early nineteenth century that any Newtonian potential V on an equipotential surface could be represented outside that surface by a layer of density given by the normal derivative of V. Recently, this was used to represent all of the mass within and beneath the mantle to create a realistic model of the Earth's gravity field. This presentation will extend the surface density contrast model by describing a method to use the knowledge of the Earth's potential to estimate possible density contrast variations within the mantle. An indication of why the spectrum has been subdivided, and what density variations will result, will be given.

G34A-03 1600h

Towards Grid-Enabling the Global Geodynamics Project

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The Global Geodynamics Project (GGP) allows Earth scientists to access a network of globally distributed superconducting gravimeters (SGs). By establishing standards around SG instrumentation and data, in concert with various bilateral agreements, the GGP ensures scientific and organizational integrity. Now in its second phase, the GGP is proactively engaging non-traditional disciplines - i.e., those outside the tidal gravimetry community. Although GGP has generated interest with geodynamicists, seismologists, and others, there are practicalities which inhibit engangement by these 'non-specialists'. For example, to geodynamicists and seismologists, tidal, atmospheric, hydrologic and oceanic signals are all unwanted. This means that the processed GGP Data must undergo further, nontrivial reductions before it is useful for geodynamic and seismic purposes. The requirement to correlate data in time and space presents another example. Currently this is a manually intensive process that requires geodynamicists and seismologists to specify temporal (e.g., a period of time, an event in time) and/or spatial (e.g., global, regional, specific instruments) specifics to allow for further analysis. These and other examples suggest infrastructural opportunities for further enabling GGP scientists. With decided emphasis on Virtual Organizations, open standards and qualities of experience, Grid

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