Computing has the potential to facilitate deeper degrees of collaboration within the context of the GGP. Through use cases which seek to identify core resonance effects at semi-diurnal periods (e.g., Lumb et al., AGU Monograph 72, 51-68, 1993) and earthquake activity, various opportunities for Grid-enabling the GGP are identified and prioritized. Because the High Energy Physics community has figured so significantly in the development of the World Wide Web and The Grid, a Grid-enabled GGP also has the potential to play a role in shaping the ongoing evolution of Grid Computing.

G34A-04 1615h

Numerical Modeling of Fold Structure Evolution

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Tectonic forces along thrust belts deform geological layers to produce folds and later faults when stresses exceed the failure stress. Evolution of such structures is influenced by several factors including composition and strength of geological layers, inhomogeneity in strength (vertical and horizontal), geometry of the layers, and boundary conditions. A comprehensive understanding of the influence of these factors on the development of folds and associated faulting is required to explain evolution of these structures over geological time scale. To achieve this understanding the finite element modeling technique is used. The study focuses on the effect of material strength and geometry of the layers on the development of fold structures and related faults. For a given boundary condition and geometry, it is observed that geological layers with low strength thickens without folding. In the case of high strength geological layers, folding is observed without significant thickening. When the layers and the decollement are horizontal, folding initiates in the middle of the unrestrained part of the layer. When a ramp is included in the decollement folding initiates at the ramp. In all the cases only one fold is produced except when vertical concentrated loads are applied that multiple folds are observed. When basal friction between decollement and the overlying layers is present, the layers thicken more and amplitude of the fold is less than when no friction is present. In the case of extreme folding cracks develop which may later evolve into faults, producing fault-bend folds.

G34A-05 1630h

Geoid determination in mountainous coastal regions from altimetry and gravimetry

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The paper presents numerical results for the solution of the altimetry-gravimetry boundary value problem along a mountainous coastline. The solution uses spherical Shanon wavelets based on the Abel-Poisson kernel and spherical pseudo-diffferential operators. The orthogonality of Shanon wavelets can be used for the numerical solution, overcoming some technical problems with generally non-orthogonal spherical wavelets. A numerical experiment has been conducted in the western coast of Canada and the US and the results have been compared with the geoid heights computed from gravity anomalies by applying 1D FFT spherical Stokes convolution with 50 km integration radius and with the most recent Canadian geoid (CGG2000). Significant effects of compatibility are expected in this mountainous coastal region. The smoothness effects on the solution are discussed and conclusions are drawn about the quality of the numerical solution obtained.

G34A-06 1645h

Error Analysis of Gravity and Bathymetry of the World's Oceans

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The National Geospatial-Intelligence Agency (NGA) has an ongoing massive collection and evaluation effort of terrain and gravimetric data to support navigation. This presentation will concentrate on the methods and findings of the data error analysis in ocean areas. NGA has devised a method of error analysis, which used differences between altimetry-derived gravity anomalies and its marine, submarine, and airborne survey gravity anomalies. Comparisons with both gridded and point gravity anomalies and how the results differ with respect to bathymetry, significant wave height, ice coverage, roughness, coast line variables, and the accuracy of the gravity anomalies will be presented. In recent years NGA has helped other geodesist design, test, and tune their procedures by comparing altimetry derived gravity anomaly sets in development using its data holding and analysis tools. This has resulted in significant overall improvement and dramatic improvement in the reduction of outliers (spikes), in shallow water areas, and in high frequency areas. Overall improvement and improvement in shallow water areas will be discussed. NGA has applied this same method of data analysis to bathymetric depths. It used comparisons of gridded bathymetry files derived from altimetry and ship soundings and from ship soundings alone with point depth soundings. There will be a discussion of how the results differ with respect to such variables as roughness, plus examples of how the analysis can be used to identify bad tracks in the point depth data. The results from the gravity anomaly analysis created certain expectations for the bathymetric results. There were some surprises. The results of using the two bathymetry grids will be discussed as well as the results using the two altimetry-derived grids (i.e. the gravity anomaly and depth grids). NGA is excited about methods of estimating bathymetry from a combination of satellite altimetry and ship depth soundings and in new developments in determining depths in shallow water using LIDAR or motion imagery. NGA looks forward to collaborating on improvements in the methods of computing bathymetry depths, as it did with improvements in methods of computing gravity anomalies. The presentation will conclude with a discussion of the advantages of using comparisons with point data, the complications introduced by using point data of varying quality, and what must be done to resolve the complications.

G34A-07 1700h

Goals and early results of The Princess of Acadia GPS Project

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The Princess of Acadia is an on-going GPS project in which a GPS receiver and meteorological station have been placed on-board the ferry the Princess of Acadia, which crosses the Bay of Fundy, in the Eastern coast of Canada, on a regular basis. A network of static continuous GPS receivers collocated with meteorological stations and tide gauges have also been installed. The project aims at studying high-accuracy GPS carrier phase relative positioning and navigation under variable weather environment, integration of vertical reference frames and local and tidal effects. This presentation will describe the project and its intended goals. Results will be presented coming from preliminary analysis of GPS data sets, tidal records and search for possible multipath signature in the GPS stations.

G41A CC: 220 C-E Thursday 0830h

Pleistocene Ice-Mass Change, Displacement and Gravity Change, and Their Interpretation With 3-D Earth Models I Posters *(joint with H, OS, S, T, C, GC, PP, SEDI)*

Presiding: **A Lambert,** Geological Survey of Canada**; P Wu,** University of Calgary

G41A-01 0830h POSTER

Glacial Isostatic Adjustment Observed using Historical Tide Gauge Records and Precise Relevelling Data in Eastern Canada

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In this paper, we employ historical tide gauge records and precise relevelling data in Eastern Canada to detect the glacial isostatic adjustment (GIA). The study region lies immediately outside of the Laurentide Ice covered area at the last glacial maximum. As the ice sheet began to decay, leading to the postglacial rebound of the crust in the Laurentide region, the forebulge began to collapse to supply the mass required to produce the uplift in the central region. Therefore, the geodetic data in this region primarily show the glacial isostatic submergence. The analysis of the tide gauge data set for the east coast is based upon monthly mean sea level linear trends. These are then treated using differencing method, in which the trend value at one gauge is considered as a point vertical velocity input and the rest of the records are differenced to cancel out the local variations of the sea level. Special attention is also paid to the contribution of other vertical movement effects such as sediment subsidence. Eustatic water rise is then removed from the records to obtain the postglacial rebound signal. Precise relevelled sections in Maritime Provinces are also used to compute the time variations of the regional tilt. We perform a preliminary comparison between the geodetic results and GIA models. The comparison is based on geodynamic interpretation of the observables in terms of the uncertain parameters in the GIA models, such as viscosity and lithospheric thickness. We then fit a vertical velocity surface in the form of a two dimensional algebraic polynomial over the sea level linear trends and levelling height difference differences. The results are presented in the form of a map for Maritime Provinces. We show that it provides useful constraints for the evaluation and/or refinement of postglacial rebound models. Keywords: Glacial isostatic adjustment, vertical crustal movement model, precise levelling data and tide gauges records

G41A-02 0830h POSTER

Glacial isostatic adjustment and recent sea-level change: The influence of Pleistocene ice sheet evolution on tide-gauge measurements

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The solution to the sea-level equation describing the redistribution of glacial melt water in the oceans is implemented in conjunction with the spectral-finite element method (Martinec, 2000) of modelling glacial-isostatic adjustment (GIA). The main feature of this method is that it solves the field equations governing GIA in the time domain, where a radially symmetric, self-gravitating, incompressible earth model consisting of a fluid core, a Maxwell-viscoelastic lower and upper mantle, and an elastic lithosphere has been adopted in the present study. The additional contribution to sea-level caused by the variation of the Earth's rotation due to the ice-water mass redistribution is deter-

mined by means of the Liouville equation. For predicting the GIA-induced sea-level change, three different global models of the Pleistocene deglaciation and several viscosity stratifications are used. We compare the predicted postglacial sea-level change induced by the Pleistocene deglaciation with a set of globally distributed sea-level index points and evaluate the acceptability of the underlying earth and ice models. The best-fitting models are employed to remove the GIA-induced contribution to the recent sea-level change recorded by a set of Fennoscandian tide-gauge stations. In future studies, the reduced tide-gauge trends may serve as a datum when studying the relation between recent ice-mass change and absolute sea-level rise. Martinec,Z., 2000. Spectral-finite element method approach to three-dimensional viscoelstic relaxation in a spherical earth. Geophys. J. Int., 142, 117-141.

G41A-03 0830h POSTER

Using Fuzzy-Set Classification to Analyse Sea-Level Indicators With Respect to Glacial-Isostatic Adjustment

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The intepretation of sea-level indicators (SLIs) in terms of glacial-isostatic adjustment (GIA) has usually been based on neighbouring SLIs grouped into a single sea-level curve, which is then assumed to represent the Holocene sea-level change in that region. In this method, the nominal height and age of a particular SLI are the only characteristics considered in the inference of the former sea-level height. However, only isolation basins yield a narrow range for sea level, whereas SLIs based on samples, such as flotsam, shells or peat, only allow the determination of an upper or lower bound or a range for it. To use also these types of sample properly, we have developed a classification scheme based on Fuzzy logic. After the defintion of appropriate membership functions, this method leads to a more systematic and realistic interpretation of the large amount of SLIs available. We apply this method to SLIs from several regions in Canada and demonstrate how it modifies the inference of GIA for a particular region and, thus, the determination of mantle viscosity.

G41A-04 0830h POSTER

A Reanalysis and Reinterpretation of Geodetic and Geomorphologic Evidence of Glacial-Isostatic Uplift in the Churchill Region, Manitoba

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We review the history of analyses of the tide-gauge record for Churchill, Manitoba, and advance 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. After that, the 'best' mean rate of relative sea-level rise 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, respectively. As an additional type of observation, the postglacial relative sea-level change obtained from paleo-shoreline evidence in the Churchill region is also included. 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 3×10^{20} Pa s and $> 5 \times 10^{21}$ Pa s, respectively.

G41A-05 0830h POSTER

Viscoelastic Relation of Multi-layered Half-space Models

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The response of viscoelastic (VE) half-space models to time dependent surface loading was analyzed using both a semi-analytical and numerical approachs. The models solved were (1) an elastic layer resting on a VE half-space and (2) a three layer lithosphere, containing a crustal low viscosity zone, resting on a half-space mantle. First, the corresponding elastic problems were solved using Propagator Matrix methods (an exact analytical approach) or shooting methods (using an ODE solver). Then, the Correspondence Principle was employed to transform the elastic solutions into their corresponding VE solutions for a given model rheology. The Correspondence Principle involves inverting the Laplace Transform of the time domain solution using the calculus of residues. In the first model, a comparison was made between Maxwell and Burgers Body rheologies for the VE half space. The poles were investigated to determine their characteristics in the wavenumber domain and under what conditions they have imaginary parts. In the second model, the effects of the crustal low viscosity zone on the ratio of the vertical to horizontal displacements was investigated in an attempt to reconcile the difference between observations and current model predictions.

G41B CC: 220 C-E Thursday 0830h

Observations of Glacial Isostatic Adjustment and Contemporary Ice-Ocean-Mantle Mass Redistribution II Posters *(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

G41B-01 0830h POSTER

Observing Fennoscandian Geoid Change

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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 an extension of 1750 by 1000 km with the major axis oriented approximately northeast. Maximum uplift (1 cm/yr) is observed in the northern part of the Bothnian Bay, reducing to less than 1 mm/yr at the western coastline of Norway Denmark and Baltic countries. Existing time series of relative and absolute gravity for a few sites and GIA model calculations indicate an annual gravity change of -2 μgal/yr in the central uplift area. 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 eexpected to peak at 0.6 mm/yr may be determined by gravimetric satellite missions. Cross-validation of the space and terrestrial observations will play a central role in the project. 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 (by the University of Hannover, the Finnish Geodetic Institute, and the Agricultural University of Norway) 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 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.

G41B-02 0830h POSTER

Absolute Gravity and Global Positioning System Measurements of Glacial Isostatic Adjustment in Eastern Canada

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The Nouveau Quebec-Labrador region was the site of one of the major ice domes of the Laurentide Ice Sheet and is currently experiencing postglacial rebound. For this region the highest observed uplift rates are in the vicinity of James Bay through to southwestern Labrador; the rates then decrease to the south and towards the coastal Atlantic margins. High-precision geodetic observations are providing a useful and accurate method of measuring the pattern and rates of contemporary uplift in this area. In order to monitor the temporal variations in gravitational potential resulting from regional glacial isostatic adjustment, an array of absolute gravity (AG) sites have been established in northern Quebec. Acquired in late 1985, the JILA-2 absolute gravimeter operates by using the free-fall method. This instrument has been continually upgraded since its acquisition with new computer control, new lasers, GPS clock, new timing electronics, and ancillary equipment. These upgrades were necessary in order to make it more efficient, field-worthy, lighter and easier to use. Indeed for the sites of the James Bay/Nouvelle Quebec Region, JILA-2 is generally operated within a tent in an often challenging environment. Absolute-gravity field stations are all co-located with sites of the Canadian Base Network (CBN). Initiated in 1994, the CBN is a network of pillar monuments with forced-centering plates for Global Positioning System (GPS) receiver antennae. Accurately positioned three-dimensionally with GPS, the CBN can serve as a monitoring network for deformation studies of the Canadian landmass. Issues such as mass redistribution or changes in density contrasts within the Earth may be better addressed by monitoring positional changes (*i.e.*, primarily height changes) and integrating these observations with gravitational variations. The comparison of the temporal rate of change of gravity with the GPS height rate is thus highly desirable. Recent velocity estimates based on both the multiple-epoch GPS network surveys as well as the preliminary results from absolute-gravity trends indicate regional uplift. These preliminary results also exhibit general agreement among the uplift rates for GPS radial velocities, gravity trends, and predictions of vertical crustal motion from postglacial rebound models. Finally, in order to densify the array of AG stations and facilitate comparisons with GPS-determined rates, planning is now underway for the occupation of all suitable CBN sites with an A-10 (*Micro-g Solutions*) absolute gravimeter.

G41B-03 0830h POSTER

Geoid-height Change and Vertical Crustal Motion due to Present and Past Glacial Changes in Antarctica

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We present results based on forward modelling of signatures related to present and past variations of the Antarctic Ice Sheet. Our calculations are organized according to the time scale of the ice-mass change. First, we implement seasonal and secular ice-mass imbalances acting on an elastic earth. Then, the elastic earth is replaced by a viscoelastic earth, and the glacial-isostatic adjustment due to global Pleistocene deglaciation scenarios is calculated. We predict the resulting geoid-height change and vertical crustal motion for Antarctica and discuss whether the signals generated are sufficiently large to be detected by the GRACE satellite

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