a deterministic-only perspective. In particular, it is explained how the process of minimizing the Euclidean norm of the adjusted residuals may generate a necessary and unavoidable increase of the Euclidean error norm for the computed parameters. For the purpose of preventing any possible misunderstanding, it should be noted that this paper does not represent a disagreement with the practice of applying the least-squares methodology for geodetic data processing. What is merely claimed here is that the optimality aspects that are typically associated with least-squares estimation techniques receive a more objective and careful treatment than is usually given to them.

G43A-03 1330h POSTER

Linear versus Non-Linear Least Squares Adjustment with Emphasis on the 3-D Coordinates Transformation Problem

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Different optimization procedures are employed to study one of the main geodetic problems, the three-dimensional coordinates transformation. Results are given for Egypt, where the old geodetic networks are related to the old Egyptian geodetic datum EGD of Helmert 1906, which is a non-geocentric regional datum. The paper's main objective is the transformation of geodetic control from the old EGD to the new WGS84 datum using different methods of non-linear least squares adjustment. 16 common stations are used in the computations of the seven transformation parameters. This is followed by the transformation of 23 stations using the transformation parameters determined from the nonlinear least squares algorithms. Five optimization methods have been tested for the solution of this problem. These methods are: Steepest Descent, Trust region, Gauss-Newton, Levenberg-Marquardt method, and traditional combined least squares adjustment with weighted observations. Conclusions and recommendations are given with respect to the suitability, accuracy and efficiency of each method.

G43A-04 1330h POSTER

STUDY OF EASTERN CANADIAN COASTAL SITE DISPLACEMENT DUE TO OCEAN TIDE LOADING USING A GPS NETWORK IN ATLANTIC CANADA

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The continuously operating GPS stations of The Princess of Acadia project, especially the Coast Guard station in Saint John, New Brunswick and the station Digby in Halifax, Nova Scotia, both of which lie in the proximity of highly turbulent waters of Bay of Fundy, are subjected to perpetual movements due to temporally oceanic water mass surface loading of the lithosphere by the ocean tides. If the affects of ocean tide loading are not taken into consideration they can affect high- accuracy positioning especially in the final solutions for height. It is proposed under this project that ocean tidal loading studies be carried out in the area using atleast 1 year of GPS data with varying data processing sessions. Time series would then be extracted from discrete 24-hour solutions for ocean tide loading studies. Data collection in this regard is already in progress and 3 hr and 24 hr solutions are being extracted, cleaned and processed using DIPOP 3.1 software. The role of the tropospheric delay and its effect on height estimates when ocean tide loading effects, whether modeled or ignored, would also be investigated.

G43A-05 1330h POSTER

REGIONAL COMPUTATION OF TEC USING A NEURAL NETWORK MODEL

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One of the main sources of errors of GPS measurements is the ionosphere refraction. As a dispersive medium, the ionosphere allow its influence to be computed by using dual frequency receivers. In the case of single frequency receivers it is necessary to use models that tell us how big the ionospheric refraction is. The GPS broadcast message carries parameters of this model, namely Klobuchar model. Dual frequency receivers allow to estimate the influence of ionosphere in the GPS signal by the computation of TEC (Total Electron Content) values, that have a direct relationship with the magnitude of the delay caused by the ionosphere. One alternative is to create a regional model based on a network of dual frequency receivers. In this case, the regional behaviour of ionosphere is modelled in a way that it is possible to estimate the TEC values into or near this region. This regional model can be based on polynomials, for example. In this work we will present a Neural Network-based model to the regional computation of TEC. The advantage of using a Neural Network is that it is not necessary to have a great knowledge on the behaviour of the modelled surface due to the adaptation capability of neural networks training process, that is an iterative adjust of the synaptic weights in function of residuals, using the training parameters. Therefore, the previous knowledge of the modelled phenomena is important to define what kind of and how many parameters are needed to train the neural network so that reasonable results are obtained from the estimations. We have used data from the GPS tracking network in Brazil, and we have tested the accuracy of the new model to all locations where there is a station, accessing the efficiency of the model everywhere. TEC values were computed for each station of the network. After that the training parameters data set for the test station was formed, with the TEC values of all others (all stations, except the test one). The Neural Network was trained with this parameters, and tested by computing the TEC for the test station. This assessment was carried out several times, one for each station of the network. Maps of the results of the estimations for the whole network will be shown.

G43A-06 1330h POSTER

Parallel 2D and 3D Prestack Depth Migration Using Recursive Kirchhoff Wavefield Extrapolation

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Recursive Kirchhoff wavefield extrapolation in the space-frequency domain can be thought of as a simple convolutional filter that calculates a single output point at depth z+dz using a weighted summation of all input points within the extrapolator aperture at depth z. The desired velocity values for the extrapolator are the ones that provide the best approximation of the true phase (propagation time) of the seismic wavefield between the input points and the output point. Recursive Kirchhoff extrapolators can be designed to handle lateral variations in velocity in a number of ways: a PSPI-type (phase shift plus interpolation) extrapolator uses only the velocity at the output point, a NSPS-type (nonstationary phase shift) extrapolator uses the velocities at the input points; a SNPS-type (symmetric nonstationary phase shift) extrapolator incorporates two extrapolation steps of dz/2 where the first step uses the velocities at the input points (NSPS-type) and the second step uses the velocity at the output point (PSPI-type); while the Weyl-type extrapolator uses an average of the velocities between each input point and the output point. Here, we introduce the PAVG-type (slowness averaged) extrapolator, which uses velocity values calculated by an average of slowness along straight raypaths between each input point and the output point. Parallel 2D and 3D prestack depth migration algorithms have been coded in both MATLAB and C and tested on a small Linux cluster. A simple synthetic with a lateral step in velocity shows that the PAVG Kirchhoff extrapolator is very close to the exact desired response. Tests using the 2D Marmousi synthetic data set suggest that the extrapolator behaviour is only one of many considerations that must be addressed for accurate depth imaging. Other important considerations include preprocessing, aperture size, taper width, extrapolator stability, and imaging condition.

G43A-07 1330h POSTER

Earth Science Data Grid System

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The Earth Science Data Grid System (ESDGS) is a software system in support of earth science data storage and access. It is built upon the Storage Resource Broker (SRB) data grid technology. We have developed a complete data grid system consistent of SRB server providing users uniform access to diverse storage resources in a heterogeneous computing environment and metadata catalog server (MCAT) managing the metadata associated with data set, users, and resources. We also develop the earth science application metadata; geospatial, temporal, and content-based indexing; and some other tools. In this paper, we will describe software architecture and components of the data grid system, and use a practical example in support of storage and access of rainfall data from the Tropical Rainfall Measuring Mission (TRMM) to illustrate its functionality and features.

G43A-08 1330h POSTER

On Detecting Shallow Mass Anomalies With Ground and Airborne Gradiometry by Filtering Techniques

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Shallow mass anomalies, such as voids and other significant density contrasts, generate distinct gravitational gradient signals within the background gradient field of the Earth. These signals attenuate rapidly with survey altitude of an airborne gradiometer whose resolving capability is further affected by flight velocity and measurement noise. The prospects of new highly sensitive gradiometers enhance the possibility of detecting such anomalous sources if careful data filtering techniques are carried out. We have developed a matched filter whose weighting coefficients basically enhance the signal-to-noise ratio (SNR) for detection of small gradient signals contained in geological background noise. Results from simulations are compared to similar detection procedures using the Wiener filter. An airborne survey is simulated based on the power spectral density (PSD) model for gravitational gradients, derived from EGM96, 1'x1' mean gravity anomaly data, and 30"x30" elevation data over an area of moderately rough gravitational signal strength. Instrument noise characteristics are based on a range of sensitivities of current and future gradiometers. The study evaluates the filtering options and trade-offs in measuring different gradient tensor components in order to assess the capability to detect subsurface density contrasts by ground and airborne surveys.

G43B CC: 220 C-E Thursday 1330h

Heights and Geoid Modeling: North America I Posters *(joint with OS, T, SEDI)*

Presiding: **D R Roman,** U.S. National Geodetic Survey; **M Veronneau,** Geodetic Survey Division, National Resources Canada

G43B-01 1330h POSTER

Gravity and Geoid in Canada

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The presentation, based upon my involvement over more than four decades with the application of gravity data to some problems of geodesy, consists of two parts: 1. It will show the progress of gravity surveys in Canada based upon the mission mandated by the Dominion Observatory. The surveys started in 1902 with the pendulum measurements, later adding some local Eötvös torsion balance determination and continued from 1945 with the much faster gravity measurements. During the presentation the point distributions, prepared for each decade, and also the relevant data set for the various gravimetric geoid for Canada [1972, 1988, 1995] will be shown. 2. In the 1960s, with the increasing availability of gravity data, the computation of gravimetric deflections and/or geoid determination became a top priority of the Gravity Division of the Observatory. The first computer implementation for gravimetric deflections of the vertical computations were carried out in the early 60s, complemented with terrain corrections computations based on digital elevation data. Parallel to the development of the practical

evaluation of the gravimetric geoid, a number of associated problems were also tackled [terrain correction by digital computers, high degree spherical harmonics expansion of surface gravity, various 3-dimensional gravity modeling, etc.]. The first gravimetric geoid for Canada, and the refinements which became possible with the availability of more and more data will be shown and discussed briefly.

G43B-02 1330h POSTER

Values of a Correction to Helmert Orthometric Heights Resulting from Terrain Roughness

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The poster will present results of the calculation of the effect of terrain roughness on orthometric height, and the resulting corrections to Helmert orthometric height. The computation is done using three approaches: the Mader approach, the Neithammer approach and the U.N.B. approach. The results of these computations indicate the the U.N.B. method is the most effective for computation of the correction to Helmert orthometric height. The poster gives some indication of the magnitude of the terrain roughness effect, showing that it has an effect on orthometric heights of up to 26 cm in a test area in the Rocky Mountains. It should be understood that a significant part of this correction is balanced out by the effect of the gravity disturbance generated by the geoid.

G43B-03 1330h POSTER

MEAN GRAVITY ALONG THE PLUMBLINE

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The mean value of gravity along the plumbline between the earth surface and the geoid depends on the mass density distribution within the earth and the shape of the earth. Since the actual gravity along the plumbline cannot be measured, the mean value of gravity has to be computed from the gravity observed at the physical surface of the earth. This can be realized by reducing the observed gravity according to some accepted physical model. To evaluate the mean gravity, the actual gravity is decomposed into the normal gravity, geoid-generated gravity disturbance and the gravitational attraction of topographical and atmospheric masses. The mean normal gravity is defined according to Somigliana-Pizzeti's theory of the normal gravity field. The mean geoid-generated gravity disturbance is obtained by applying the Dirichlet's boundary value problem into the theorem of integral mean. The mean values of gravity generated by topographical and atmospheric masses are computed as the mean linear potential gradient

G43B-04 1330h POSTER

An Assessment of Global Digital Terrain Models Over Canada

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A variety of digital terrain models (DTMs) are nowadays available for use by the international scientific community. In terms of geodetic applications, such models are especially important for precise Stokesian geoid determinations, for geophysical and geodynamical studies related to the isostatic behaviour of the Earth's crust, and also for the development of realistic synthetic representations for the Earth's external gravitational field. However, the problem of which DTM should be chosen for such studies, as well as in other related applications of geo-sciences and engineering, is not a trivial question to answer. That is because most of the available global DTMs differ significantly in terms of their original data sources and their production technique, their accuracy and resolution levels and their actual spatial coverage. Furthermore, additional problems may arise from the fact that the accuracy characteristics within each DTM are not really homogeneous over the total coverage area, but they rather exhibit a spatially dependent behaviour which is often strongly correlated with the terrain morphology. Among the freely available DTMs covering Canada, the recently released SRTM30 model is of special interest for geodetic applications since it is based on the interferometric data gathered during NASA's Shuttle Radar Topography Mission (SRTM). The SRTM used space-borne radar interferometry sensors to produce a near global digital terrain model. The final SRTM30 model is thus primarily generated by a set of data which is consistent and of uniform quality over the entire coverage area. This is usually not the case for other global DTMs which are typically generated by merging existing topographic and/or cartographic data sources with varying (and often questionable) quality levels. This paper presents an initial assessment of the SRTM30 terrain model with respect to some other well known DTMs that are often used in practice, namely ETOPO2, GTOPO30 and the Canadian Digital Elevation Data (CDED) sets. The aforementioned models are evaluated and assessed through a statistical intercomparison over various test areas representing typical Canadian landforms (e.g., mountain ranges along the Rockies in western Canada, flatter regions in the eastern Canada). A type of absolute comparison for all these models is also performed using as reference the orthometric, ellipsoidal and geoid height values at a set of nearly 1930 geodetic leveling benchmarks distributed throughout Canada.

G43B-05 1330h POSTER

Modern GPS Positioning Tools for Geoscientists

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This presentation is intended to review the GPS positioning tools available to Geoscientists who may not be experts in Geodesy or for those who would like a review of the tools available. A growing list of tools for positioning has created opportunities for the geoscientist to obtain global position information in the field with unprecedented ease and accuracy. Rapid technological change, combined with the variety of different means of augmenting GPS has caused confusion for selecting the optimum methodology for obtaining a desired accuracy. This talk will review the positioning technologies and provide the necessary background to help the user identify which tool is most appropriate for their application. Beginning with the use of GPS for geometric positioning we will review the accuracy expected from basic broadcast GPS through to augmentation techniques, both real-time and post processing, using Canadian examples. The relationship between the NAD83, NAD83 (CSRS or NSRS), WGS84 and ITRF reference frames will be discussed. The determination of physical heights from GPS will follow. This determination relies on the use of mathematical models giving the sea-level (or similar) height. Two model types will be discussed; models intended to precisely represent the Geoid, and models that provide heights compatible with published height datums (incorporating any distortions that exist in these official datums). The presentation will be complemented by a Natural Resources Canada Geodesy booth, which will provide demonstrations of two GPS augmentation tools: CDGPS, a real-time GPS correction service and Precise Point Positioning (PPP), an Internet post-processing tool. Demonstrations of an online tool for physical height determination will also be provided.

URL: http://www.geod.nrcan.gc.ca/

G43C CC: 516 A Thursday 1330h

New Sensors of Our Planet: Modern Geodesy and New Insights in Earth Science II *(joint with OS, P, S, T, C, GC)*

Presiding: **N Sneeuw,** University of Calgary**; H Dragert,** Geological Survey of Canada

G43C-01 1330h INVITED

Terrestrial Gravimetry and the Development of Absolute Gravimeters

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By extending the reach of our hands and quickening the response of our eyes, measurement methods and instrumental capabilities have driven and made possible much of scientific progress. By the middle of the nineteenth century, measurement capabilities for g had reached a precision of 1 in 10^6 and an accuracy of 1 in 10^5. Over the past 40 years, instruments have evolved to the point where measurements can be made at the parts in 10^9 level of precision and, in the case of absolute instruments, accuracy. In this talk, reasons will be given for this remarkable progress (4 orders of magnitude improvement in 40 years) in our ability to measure g. In the context of this session's title, "New Sensors of Our Planet," our recent—probably for one of us (JF) the last—development of a truly portable absolute gravimeter will be described. This small and portable absolute instrument drops a test mass 200 times a second while keeping the center of mass of the apparatus fixed—to avoid recoil effects—during the entire measurement cycle. The capabilities of this μgal-accuracy instrument will be demonstrated.

G

G43C-02 1350h

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

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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