

of these algorithms have shown promise in handling the problem's intrinsic difficulties, but new difficulties arise when the dimensions of the interferometric input data exceed the limits imposed by computer memory constraints. Similarly, new phase unwrapping strategies may be required when sheer data volumes necessitate greater computational throughput. These issues are especially important in the contexts of large-scale topographic mapping projects such as SRTM and the Alaska DEM Project. We propose a technique for applying the statistical-cost, network-flow phase unwrapping algorithm (SNAPHU) of Chen and Zebker (2001) to large data sets. That is, we introduce a methodology whereby a large interferogram is unwrapped as a set of several smaller tiles. The tiles are unwrapped individually and then further divided into independent, irregularly shaped reliable regions. The phase offsets of these reliable regions are then computed in a secondary optimization problem that seeks to maximize the probability of the full unwrapped solution, using the same statistical models as employed in the primary phase unwrapping stage. The technique therefore approximates a maximum *a posteriori* probability (MAP) unwrapped solution over the full-sized interferogram. The secondary optimization problem is solved through the use of a nonlinear network-flow solver. We examine the performance of this technique on a real interferometric data set, and we find that the technique is less prone to unwrapping artifacts than more simple tiling approaches.

**G22C MC: Hall D Tuesday 1330h**  
**General Geodesy**

**Presiding: J B Blair, NASA Goddard Space Flight Center; I M Vigo, University of Alicante**

**G22C-0224 1330h POSTER**

**Airborne Laser Swath Mapping: Results of Field Tests Conducted to Quantify the Effects of Different Ground Covers**

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Most scientific and engineering applications of Airborne Laser Swath Mapping (ALSM) require precisions and/or repeatabilities (relative accuracies) of several decimeters in the horizontal coordinates and a few to several centimeters in the vertical coordinates of the point measurements, or ultimately of surface features derived from the point measurements. Manufacturers generally use components consistent with this level of performance and laboratory calibration and testing results indicate that instrumental errors are within these bounds. However, field observations include additional sources of error that can vary significantly from project to project. Comparisons of results from an ALSM system operated by the University of Florida (Optech Model 1210) and ground survey values, on a point-by-point basis, and as profiles cut from Digital Elevation Models, consistently yield RMS differences of 30 to 50 cm in horizontal coordinates, and 4 to 8 cm in the vertical coordinates, for points on smooth bare surfaces such as pavements, roofs, and sand beaches. These numbers increase in steep or rugged terrain, and in areas covered with vegetation. Results from recent projects will be presented that illustrate the effects of different ground covers, including grass, row crops, marsh grasses, coastal mangroves, open pine and dense mixed forests. Examples illustrating the use of laser intensity values, multiple stops per pulse, and filtering algorithms, to minimize the degradation caused by ground cover, will also be presented.

**G22C-0225 1330h POSTER**

**Topographic Change Detection using Full-waveform Imaging Lidar**

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The capability of wide-footprint (i.e. 10 m or greater), full-waveform laser altimeters to penetrate beneath dense vegetation to directly measure the sub-canopy topography provides us with a unique capability for sensing topographic change in the presence of vegetation. We evaluate the feasibility of using a geolocated laser altimeter return waveform instead of individual elevation measurements to measure vertical elevation change within a laser footprint. The method, dubbed the return pulse correlation method, maximizes the shape similarity of near-coincident, vertically-geolocated laser return waveforms from two observation epochs as they are vertically-shifted relative to each other. First, we evaluate the inherent accuracy of the pulse correlation method using models and simulations under "bare-Earth" conditions. We then analyze the effects of vegetation and vegetation growth on the change detection capability. The use of this method, combined with order of magnitude improvements to laser altimeter swath widths (from 1 km to 10 km) and the potential for a future spaceborne imaging lidar, may provide sub-centimeter level relative change detection beneath vegetation to complement IFSAR's ability to make similar measurements in low or vegetation-free conditions.

**G22C-0226 1330h POSTER**

**Estimating Surface Slope and Roughness over the Greenland Ice Sheet Through Deconvolution of Laser Altimeter Waveforms**

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The Airborne Topography Laser Altimetry System (ATLAS) was flown at high altitude over the Greenland Ice Sheet in June 1993 in order to simulate the large footprint (65 m) of the Geoscience Laser Altimeter System (GLAS), providing the first laser altimeter waveforms ever collected over ice. Waveforms are of critical importance in laser altimetry since they contain information about surface roughness, surface slope (or equivalently instrument pointing direction) and atmospheric effects. These effects all act to broaden the laser return pulse, making it difficult to separate them. In principle, knowledge of two of the three effects permits determination of the last one.

Previous studies to separate roughness and slope have been limited by the assumption of Gaussian return pulses and inaccurate knowledge of the outgoing pulse. We present a more general method which neither places restrictions on the temporal shape of the return pulse, nor requires knowledge of the outgoing pulse. We use the waveforms themselves to determine the impulse waveform of the instrument (which includes atmospheric broadening and instrument response), using simultaneous time domain deconvolution. For this purpose, we use several flight sections where the aircraft banked steeply over relatively smooth terrain, so that the contribution to broadening due to apparent slope dominates that due to surface roughness. With knowledge of the roll and pitch angles, we are able to extract the impulse function from the return waveforms. If the impulse function is accurately known when slope is known, roughness can be extracted by deconvolution, and we test this over parts of the ice sheet. In addition, this opens the possibility of extracting the waveform distortions due to forward scattering along the atmospheric path. This has important applications for processing GLAS waveforms whose output pulses will be recorded.

**G22C-0227 1330h POSTER**

**Validation of Large-Footprint Lidar Sub-Canopy Topography Measurements Beneath a Dense Tropical Forest**

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Large footprint (greater than 10 m wide) laser altimetry is a useful technique for mapping topography (including sub-canopy), canopy height and vertical structure in densely vegetated areas. In March 1998, the Laser Vegetation Imaging Sensor (LVIS), an airborne laser altimeter, mapped a ~800 km<sup>2</sup> area of Costa Rica including the La Selva Biological Station using 25 m-diameter footprints as part of the pre-launch activities of the Vegetation Canopy Lidar (VCL) Mission. To investigate the utility of the lidar technique for making sub-canopy topography measurements, the precision and accuracy of the LVIS elevation measurements from this mission are assessed. Crossover analysis using laser shots, whose recorded waveforms contain high amplitude reflections from the lowest reflecting surface, show a vertical precision of better than 1 m. Comparison of the LVIS elevations with coincident *in situ* ground elevation data reveals that the measurements are within ~1.5 m of each other on less than 3 degree slopes. Even on slopes of up to 30 degrees measurements are within ~5 m of each other. These are very encouraging results given that the forests of this region are some of the densest, most complex on Earth, and that mapping its sub-canopy topography is near-impossible using any other remote sensing technique. Given the similarity of the measurement processes of the LVIS and VCL systems, these results suggest that the topographic measurements made by the VCL will meet stated accuracy goals under the majority of measurement conditions.

**G22C-0228 1330h POSTER**

**International DORIS Service on web.**

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The International DORIS Service is on the way to be established. The dedicated web site (<http://ids.cls.fr>) is developed with two priorities : the DORIS system and its daily operation, the elements needed to initiate DORIS products generation and distribution.

General and technical DORIS information was initially available on the "about DORIS" topic. This topic is to be completed and moved to AVISO, the web site for ocean altimetry, DORIS being a main contributor to the Topex-Poseidon and Jason missions. In addition two FAQ on both DORIS and IDS schemes have been added. Information related to the system operation is obtained with a short delay thanks to a connection to SSALTO, the multi-mission orbitography and altimetry center. That way, information about system events such as satellite orbit maneuvers, changes in the instrument mode due to an incident - a single upset for example -, data gaps is available on line and regularly updated. Station history plots can be selected for each satellite, related to the whole network or to a given station. Performances of the preliminary orbits and the operational 2 days station network positioning are also shown.

Regarding DORIS data and products, the formats working group has discussed and proposed formats for preprocessed data, satellite ephemeris, station coordinates and associated times series. For each IDS Analysis Center, the web site gives its identification and its process strategy description in a standard form. As an experiment, present available products are satellite orbits and station network coordinates.

**G22C-0229 1330h POSTER**

**A Fuzzy Logic Study of Weighting Scheme for Satellite-Laser-Ranging Global Tracking Network**

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In satellite-laser-ranging (SLR) data processing, oftentimes the weighting scheme of station observations is subjective or even quasi-arbitrary, and a somewhat arbitrary cutoff of say, 1m is applied prior to the data processing. This practice leaves something to be decided in terms of making optimal use of the available data. We intend to improve the situation by applying fuzzy-logic techniques in the editing and weighting of the data in an objective way. Many authors (e.g., Katja Heine (2001) and others in the Proceedings of the First International Symposium on Robust Statistics and Fuzzy Techniques in Geodesy and GIS) have demonstrated the potential utility of the fuzzy logic methods in geodetic problems.

The aim of this work is to test a fuzzy logic method as a tool to provide a reliable criteria for weighting scheme for satellite-laser-ranging (SLR) station observations, seeking to optimize their contribution to the precise orbit determination (POD) problem. The data regarding the stations were provided by the International Laser Ranging Service, NASA/CDDIS provided the satellite data for testing the method. The software for processing the data is GEODYN II provided by NASA/GSFC. Factors to be considered in the fuzzy-logic clustering are: the total number of LAGEOS passes during the past 12 months, the stability measure of short and long term biases, the percentage of LAGEOS normal points that were accepted in CSR weekly LAGEOS analysis, and the RMS uncertainty of the station coordinates. Fuzzy logic statistical method allows classifying the stations through a clear membership degree to each station group. This membership degree translates into a suitable weight to be assigned to observations from each station in the global solution. The first tests carried out show improvements in the RMS of the global POD solution as well as individual stations, to within a few millimeters. We expect further work would lead to further improvements.

**G22C-0230 1330h POSTER****Comparison of Atmospheric Parameters from VLBI, GPS and WVR at the KSP Geodetic Network**Ryuichi ICHIKAWA<sup>1</sup> (+81-299-84-7142;richi@crl.go.jp); Yasuhiro KOYAMA<sup>1</sup>; mamoru SEKIDO<sup>1</sup>; Hiroshi OHKUBO<sup>1</sup>; Hiro OHSAKI<sup>1</sup>; Tetsuro KONDO<sup>1</sup>; Jun AMAGAI<sup>2</sup>; Hitoshi KUCHI<sup>2</sup>; Taizoh YOSHINO<sup>2</sup>; Fujinobu TAKAHASHI<sup>2</sup><sup>1</sup>Kashima Space Research Center, Communications Research Laboratory, 893-1 Hirai, Kashima 314-0012, Japan<sup>2</sup>Communications Research Laboratory, 4-2-1 Nukuiikita, Koganei 184-8795, Japan

A precise geodetic measurement called Key Stone Project (KSP) has been carried out around the Tokyo metropolitan area by the Communications Research Laboratory (CRL), using three modern space techniques: very long baseline interferometry (VLBI), satellite laser ranging (SLR), and global positioning system (GPS). One of the main objectives of the KSP is to monitor regional deformation and strain accumulation in the plate boundary region of the Kanto district. The VLBI measurements have spanned the last four years and indicate that the Miura and Tateyama sites are moving with respect to Kashima at velocities of 17.0 and 20.9 mm/year toward the NNW, respectively. These velocities obtained by the VLBI measurements agree well with those obtained by the GPS measurements. Moreover, extraordinary drifts in both VLBI and GPS measurements after the end of June 2000, namely the baseline length between Kashima and Tateyama were shortened by about 5 cm in two months. Similar displacements at four GPS sites (Katsuura, Kyonan, Miura, and Tateyama) of GEONET by the Geographical Survey Institute (GSI) were also detected. According to the inversion using half-infinite elastic model, the crustal deformation at Tateyama is caused by a dike intrusion at about 3 km depth and co-seismic offsets between the Izu islands. On the other hand, it is difficult to determine the epoch of the rate change based on the day-to-day solutions of the baseline length since tropospheric delay significantly degrades the precision of GPS and VLBI. We are now comparing estimated atmospheric parameters (equivalent zenith wet delay and linear horizontal delay gradients) derived from an independent analysis of simultaneous VLBI, GPS and water vapor radiometer (WVR) observations during the last two years. We find estimated weighted RMS differences below the 10 millimeter level and correlation coefficients more than 0.8 for the zenith wet delays derived from GPS and WVR. However, RMS differences

between the zenith wet delays derived from VLBI and those from WVR are more than 50 millimeters. In addition, the agreement for the estimated horizontal delay gradients from these three techniques is less clear.

**G22C-0231 1330h POSTER****Determination of Ionospheric Parameters by Geodetic VLBI**Harald Schuh<sup>1</sup> (+43/1-58801-12860; hschuh@luna.tuwien.ac.at)Thomas Hobiger<sup>1</sup> (thobiger@luna.tuwien.ac.at)Johannes Boehm<sup>1</sup> (jboehm@luna.tuwien.ac.at)<sup>1</sup>Institute of Geodesy and Geophysics, Vienna University of Technology, Gusshausstr. 27-29., Wien 1040, Austria

In geodetic VLBI the observations are performed at two frequencies (2.3 and 8.4 GHz) in order to correct for the ionospheric delay. This also allows to get information about the total electron content (TEC) of the ionosphere from VLBI observables. Due to the large frequency separation the accuracy of the individual VLBI TEC measurement is higher than that of GPS. Various VLBI sessions of the CORE-A network were used to determine the TEC. The results were compared with TEC measurements obtained from GPS within IGS. A very good agreement can be observed, in particular for baselines longer than 1000km. The TEC measurements allow to derive ionospheric maps for areas with dense VLBI networks, e.g. over Europe. For that purpose the EUROPE VLBI sessions were used with 7-10 stations observing simultaneously.

**G22C-0232 1330h POSTER****GPS Tropospheric Modeling for SAR Interferometry: are Small GPS Networks Useful?**Simon C Edwards<sup>1</sup> (44-191-222-6445;S.C.Edwards@ncl.ac.uk); Peter J Clarke<sup>1</sup>; Geoffrey Blewitt<sup>1,2</sup>; Geoff Wadge<sup>3</sup>; Peter W Webley<sup>3</sup>; Richard M Bingley<sup>4</sup>; Alan H Dodson<sup>4</sup>; Samantha J Waugh<sup>4</sup><sup>1</sup>Department of Geomatics, University of Newcastle upon Tyne, Newcastle NE1 7RU, United Kingdom<sup>2</sup>Seismological Laboratory, University of Nevada, Reno, Mail Stop 178, Reno, NV 89557-0088, United States<sup>3</sup>Earth Systems Science Centre, University of Reading, Whiteknights, Reading RG6 6AL, United Kingdom<sup>4</sup>Institute for Engineering Surveying and Satellite Geodesy, Nottingham University, Nottingham NG7 2RD, United Kingdom

Artifacts caused by changes in tropospheric microwave delay are a common source of error in SAR interferometry. In regions of moderate to high topography, this error can amount to as much as four ERS fringes (~10 cm). Static GPS geodesy offers the possibility to calibrate this microwave delay, but the efficacy of this technique is not established. We have tested this method using data from a temporary 14-receiver GPS network established on Mt Etna (Sicily) and from the permanent BARGEN network in the Yucca Mountain area of Nevada.

We processed the data using JPL's GIPSY-OASIS II precise point positioning software and abstracted the time series of total tropospheric zenith delay at each site. Next, we estimated coefficients of various polynomial models of zenith delay as a function of position and altitude using a singular value decomposition linear least-squares method. In the Mt Etna region, a simple one-dimensional model as a function of altitude (two parameters), using as few as two well-distributed GPS sites, can typically describe 60-70% of the tropospheric variability in the area of the SAR scene. A more complicated three-dimensional model (up to ten parameters), using up to ten GPS sites, increases this figure marginally, to around 75%.

We conclude that a simple empirical model can be successful in removing tropospheric artifacts, and that the advantages of a more complicated model, using a denser network, are marginal. With many deforming regions now containing permanent GPS networks, this method offers interesting possibilities even where the GPS data are sparsely distributed.

**G22C-0233 1330h POSTER****Permanent GPS Network in Greenland.**Per Knudsen<sup>1</sup> (45-35875318; pk@kms.dk)Mette M Weber<sup>1</sup> (45-35875752; mmw@kms.dk)<sup>1</sup>National Survey and Cadastre - Denmark, Rentemestervej 8, Copenhagen 2400, Denmark

The National Survey and Cadastre - Denmark (KMS) is responsible for the geodetic definition and reference network in Greenland. Permanent GPS plays an important role in the monitoring and maintenance of the geodetic network. Furthermore, KMS supports the international GPS infrastructure by supporting IGS. KMS has established a new permanent GPS station THU2 in Thule, Greenland in 1999 to have a back up station for the old IGS station THU1. Now THU2 is a high quality and high performance station and accepted for the IGS LEO network. Besides the GPS stations in Thule, KMS is also running a permanent GPS station in Illoqqortoormiut on the east coast of Greenland, and in the fall 2001 a new permanent station is established in Qaqortoq in southern Greenland. Furthermore, University of Colorado operates the IGS station Kellyville in Kangerlussuaq on the west coast and a station in Kulusuk on the east coast.

The THU2 station replaces THU1, which has not been operating since April 2001. For more than one year the two GPS stations have been running simultaneously and the link between them is analyzed. Also coordinate time series for both stations are computed and analyzed. The analysis of the data shows a high accuracy link between the two stations determined to the millimeter level.

**G22C-0234 1330h POSTER****GPS and Communications Technology Development at the UNAVCO Boulder Facility**Victoria Andreatta<sup>1</sup> (303-497-8050;victoria@unavco.ucar.edu); Mike Jackson<sup>1</sup> (303-497-8008; mikej@unavco.ucar.edu); Chuck Meertens (303-497-8011; chuckm@unavco.ucar.edu); Oivind Ruud (303-497-8030; ruud@unavco.ucar.edu); Warren Gallahar (303-497-8016; warren@unavco.ucar.edu); Karl Feaux (303-497-8037; kfeaux@unavco.ucar.edu); Lou Estey (303-497-8036; lou@unavco.ucar.edu); Bjorn Johns (303-497-8034; bjorn@unavco.ucar.edu); Shad O'Neal (303-497-8041; shad@unavco.ucar.edu); Lynette Laffea (303-497-8033; laffea@unavco.ucar.edu)<sup>1</sup>UNAVCO/CAR, 3340 Mitchell Ln., Boulder, CO 80301, United States

The UNAVCO Boulder Facility has a long history of GPS and data communications development and testing activities. These include receiver and antenna testing, evaluating data communications alternatives, and hardware and software development. In this paper we discuss testing of new GPS receivers and antennas including the Trimble 4700, 5700, Zepher antenna, the Ashtech micro Z receiver with geodetic antenna, the impact of antenna domes on measurement accuracy, and evaluation of techniques for in-situ multipath measurement and mitigation. Hardware testing and development includes new data communications techniques such as VSAT and TDMA strategies using Freewave radios, and the development of a low power PC104 data collection computer for DC based permanent stations, seismic, and single frequency applications. Software testing and development includes BINEX data streaming format, JStream software for stream collection, and the Facility support for the EGADS/SHARC data download software.

**G22C-0235 1330h POSTER****GPS Measurements in Order to Improve the Accuracy of GPS at Mountain Areas**Mikio Satomura<sup>1</sup> (81-54-238-4945; samsato@ipc.shizuoka.ac.jp)Makiko Nishikori<sup>2</sup> (81-3-5711-5344; nishikori@gps.hzs.co.jp)Seichi Shimada<sup>3</sup> (81-298-51-1611; shimada@bosai.go.jp)<sup>1</sup>Faculty of Science, Shizuoka University, 836 Oya, Shizuoka 422-8529, Japan<sup>2</sup>Hitachi Zosen Information Systems Co., Ltd., 7-37-10 Nishikamata, Ohta-ku, Tokyo 144-8601, Japan<sup>3</sup>National Research Institute for Earth and Disaster Prevention, 3-1 Tennodai, Tsukuba 305-0006, Japan

It has been pointed out that GPS observation in mountain areas is usually less accurate than that in flat areas, especially in the vertical component, when the height difference among observation sites is large. It is thought that the decrease of accuracy is caused by insufficient corrections for tropospheric delay of the GPS microwave.

In order to investigate the difference of tropospheric delays at sites located on high mountains and those at valleys, and furthermore to improve the accuracy of GPS observation in mountain areas, we have repeated

GPS measurements since September 1997 at Yamainudan (about 1400 m above sea level) near the top of Mt. Sobatsubu in the Southern Alps of Japan. Their data were processed with the data at four stations of surrounding valleys (300 - 400 m) by using GAMIT, to investigate the relation of the coordinates obtained and tropospheric zenith delays.

There is a negative correlation between the difference of tropospheric zenith delay and height difference between Yamainudan and a site at valley. These results scarcely change when a mapping function used or meteorological data are changed.

We also processed some GPS data obtained by the Geographical Survey Institute (GEONET data) in the mountain areas. In this case, we can see a positive correlation between the difference of tropospheric zenith delay and height difference. This correlation may be caused by the load of snow on the mountain areas.

G22C-0236 1330h POSTER

**Bistatic Synthetic-Aperture Imaging Using GPS Reflections**

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We present results of a program to create SAR-like images using GPS reflected signals. This technique can be used as a relatively inexpensive remote-sensing tool. Imaging resolution as a function of geometry and antenna characteristics will be presented. Imaging data were recorded over Lake Casitas, near Santa Barbara, CA, over a nearby shoreline, and over the open ocean using a Cessna 310 flying at 10000 elevation. The GPS signals were collected using an open-loop recorder operating at 20 MHz, and were processed using a software GPS receiver. The receiver output is further processed by a custom SAR-like processor to form images in the forward scattering direction.

G22C-0237 1330h POSTER

**Geopotential Coefficients Derived From GPS/GLONASS Orbits**

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The Center for Orbit Determination in Europe (CODE) has been involved in the processing of combined GPS/GLONASS data during the International GLONASS Experiment (IGEX). Precise GLONASS orbits were computed with an accuracy better than 20 cm for a time span of almost two years. Due to the uncertain development of the GLONASS system after the IGEX campaign, CODE put emphasis on the investigation of the available GLONASS orbit series (and their comparison with GPS orbits), rather than generating precise GLONASS orbits on a routine basis.

The orbit series were analyzed using a program called SORBTD. Introducing the satellite's positions as pseudo-observations, the program is capable of fitting orbital arcs through these positions by means of numerical integration. For the presented study, the program was enhanced to be capable of estimating selected parameters of the Earth's gravity field. In addition, a program for combining these geopotential coefficients on normal-equation level was developed.

A sensitivity study of the GPS and GLONASS orbits with respect to the geopotential coefficients is the first part of our analysis and answers the question what kind of gravity signal may be found in the orbits of GPS and GLONASS satellites. The correlations between the geopotential coefficients and the correlations of the geopotential coefficients with other estimated orbit parameters are the crucial issue in this context. In particular, correlations of the gravity parameters with Solar radiation pressure parameters have to be studied. The orbital periods of the GPS satellites are in deep 2:1 resonance with the rotation period of the Earth. Therefore, resonance effects of the satellite motion with terms of the geopotential occur and influence the estimation of these parameters. The results stemming from GPS are compared with results stemming from the GLONASS system: Differences caused by different revolution periods, different inclination angles of the orbital planes, and different behavior with respect to the Y-bias are analyzed. Furthermore, the influence of different arc-lengths on the estimated parameters is studied and first time-series of the corresponding parameters are presented.

G22C-0238 1330h POSTER

**The M2 ocean tide loading wave in Alaska: Vertical and horizontal displacements, modeled and observed**

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Crustal deformations caused by surface load due to ocean tides are strongly dependent on the surface load closest to the observing site. In order to correctly model this ocean loading effect near irregular coastal areas, a high-resolution coastline is required. A test is carried out using two GPS sites located in Alaska, where the ocean tide loading effect is large and consequently observed easily by relative positioning with GPS. The selected sites are FAIR (Fairbanks) and CH13 (located on an island that separates Prince William Sound from the Gulf of Alaska). Processing hourly baseline solutions between FAIR and CH13 during a period of 49 days yields a significant ocean tide loading effect. The M2 ocean tide wave in the Gulf of Alaska has very large amplitude. Although the horizontal M2 ocean tide loading amplitude in general is only about 1/4 of the vertical M2 ocean tide loading amplitude, thus, even the differential horizontal M2 ocean tide loading displacements are measurable using differential GPS (DGPS). When using the GOT99.2 ocean tide model and taking the coastal structure into account, the predicted differential vertical M2 amplitude and Greenwich phase lag due to ocean tide loading are 19.29 mm and 110.23 degrees, respectively, while GPS measurements yield 23.21 mm and 85.11 degrees. Similarly the predicted differential horizontal M2 amplitude and Greenwich phase lag (in the north-south direction) are 4.51 mm and -77.01 degrees, while GPS yields 5.52 mm and -78.00 degrees. Only the north-south component of the differential horizontal M2 ocean tide loading wave is considered, because the east-west component is too small for the processed baseline and not detectable using DGPS.

URL: <http://research.kms.dk/~sak>

G22C-0239 1330h POSTER

**A Variational Principle for the Calculation of Core Modes Directly in the Displacement Field**

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We present a new functional for the variational calculation of core modes expressed directly in the vector displacement field. The Earth's outer core is a rotating, compressible, self-gravitating, stratified fluid, contained within the elastic spherical boundaries of the shell and inner core. The calculation of its long period modes of oscillation is a challenging problem first solved by Smylie et al (1992) using a variational principle based on the scalar generalized potential. While the accurate computations this formulation affords led to the detection of the three translational modes of oscillation of the inner core in the spectra of superconducting gravimeter observations (Smylie, Francis and Merriam, 2001), it is a complicated formulation and leads to a lambda matrix problem of degree eight, even in the case of small non-neutral stratification. The functional presented here gives the displacement field directly and leads to only a quadratic eigenvalue problem for arbitrary non-neutral stratification. It is easily converted to a linear problem of twice the dimension opening the possibility of computing all eigenvalues and eigenvectors below a given degree of spatial complexity, and the construction of a catalogue of core modes.

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**Study of Downward Continuation Methods for Geoid Modeling in the Canadian Rocky Mountains**

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The Stokes-Helmert approach for geoid modeling requires that the Helmert gravity anomalies be given on the co-geoid. Two approaches are proposed to derive the Helmert gravity anomalies on the co-geoid. The first one, hereafter 'the UNB approach' (Vaníček et al., 1996), consists of evaluating the Condensed Topographic Effects (CTE) on the Earth's surface then continuing the Helmert anomalies downward to the co-geoid. The second one, hereafter 'the GSD approach' (Véronneau, 2001), reverses the order, i.e., continuing the refined Bouguer gravity anomalies downward to the co-geoid followed by evaluating the CTE on the co-geoid. In theory, both approaches should produce identical Helmert gravity anomalies on the co-geoid, consequently identical geoid models.

This study aims to develop the Downward Continuation (DC) methods for both the UNB and GSD approaches in order to generate similar geoid models within the error budget. The Poisson integral is used for the determination of the DC from the Earth's surface to the co-geoid. The DC for the UNB approach is sensitive to roughness of topography. When using a 2' by 2' Digital Elevation Model (DEM) to represent the mean topography, the DC ranges from 0.4 m to 1.8 m with a mean of 1.2 m. While the DC ranges from 0.2 m to 1.0 m with a mean of 0.7 m when using a smoother DEM with a 5' by 5' resolution. However, the sum of the DC and CTE does not significantly change when using either DEM. It ranges from 0.0 m to 0.2 m with a mean of 0.1 m. On the other hand, the DC for the GSD approach is sensitive to the radius of the integration cap. It increases by about 50% from 1 arc-degree cap and 2 arc-degree cap. The increment of the DC shows a dominant long wavelength feature. The DC of the Helmert gravity anomalies can be compared to those of refined Bouguer anomalies by removing the contribution of the DC from the CTE. Numerical results indicate that the short-wavelength component of the DC is similar between the two approaches. Further investigation is currently in progress with respect to the contribution of the long wavelengths in the DC.

Finally, geoid models, which include the DC (short wavelengths only), agree slightly better with the GPS/Levelling geoid. The contribution of the short wavelengths can reach approximately 20 cm in the Canadian Rocky Mountains.

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**Geodynamic Motion at European SLR Sites**

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The twenty year (1980-2000) time series of the positions at Satellite Laser Ranging (SLR) sites tracking the LAGEOS I satellite (launched May, 1976) contain signals with periods between hours and years, as well as the long-term effects of crustal movements or post-glacial rebound. Improved temporal sampling from a second similar satellite, LAGEOS II (launched Oct. 1992), aids in the separation of the geophysical from the SLR instrumental effects better than would be possible from LAGEOS I data analysis alone. Since these satellites are at the same altitude, but in different inclination orbits, the effect of some of the orbital errors on the analysis is also eliminated. During the past two decades the advances in overall system accuracy, in conjunction with improved satellite, Earth, and orbit perturbation modeling, now enable these observations to reveal a variety of features in geocentric position in time. Both the horizontal and the vertical components of station velocity can be determined to better than one mm/year at a majority of the European SLR sites. This facilitates the use of the European SLR sites to geodetically connect regional and local positioning networks monitoring sea level change in a geocentric reference frame.