G03: General Geodesy

Conveners: Robert Kingdon[1], and Georgia Fotopoulos[2]

Co-chairs: Robert Kingdon[1], and Georgia Fotopoulos[2]

[1] Dept. of Geodesy and Geomatics Engineering, University of New Brunswick, Fredericton, NB, Canada E3B 5A3
Phone: 506-543-5143 E-mail: robert.kingdon@unb.ca
[2] Dept. of Geological Sciences and Geological Engineering, Queen's University, Kingston, ON K7L 3N6
Phone: 613-533-6639 E-mail: georgia.fotopoulos@queensu.ca

Session Description

This General Geodesy session is open to all aspects of geodesy not covered in other geodesy-related sessions, particularly, but not exclusively, related to geometric aspects. It includes contributions related to the state-of-the-art in geodetic measurements involving ground and space techniques individually (e.g., GNSS, VLBI) or in combinations (towards GGOS), and interpretation and application of geodetic results into investigations towards Earth rotation and polar motion, precise orbit determination, analysis, and prediction of processes involving the oceans, atmosphere and internal processes in the solid Earth. Contributions related to three-dimensional georeferencing and GNSS/INS/imaging for navigation, mapping and GIS applications are welcome.

Primary Affiliation: Geodesy

NOTE: THIS DOCUMENT CONTAINS INFORMATION FOR ALL SESSION SUB-SECTIONS. PRESENTER ABSTRACTS ARE FOUND AT THE END OF THE DOCUMENT.

SCHEDULE MAY BE SUBJECT TO CHANGE.

ORAL SESSION G03a

Chairs: Robert Kingdon and Georgia Fotopoulos **Room: ESB 2012**

Wednesday, May 31st

TIME	AUTHORS	TITLE
14:00	T. Nikolaidou and M. Santos	Effect of regional Numerical Weather Models on GNSS Positioning. A case study under non-standard atmospheric conditions
14:15	Ismael Foroughi, Robert Kingdon, Michael Sheng, Petr Vaníček and Marcelo Santos	Local spectral model of geoid-to-quasigeoid separation in North America
14:30	Yan Jiang, Simone Barani, John Cassidy, Roy Hyndman	Crustal Shortening in the Southern Canadian Rockies, Evidence from Geodesy and Seismology
14:45	Julie Elliott, Lucinda Leonard, Roy Hyndman, Yan Jiang, and Jeff Freymueller	Active Deformation in Alaska and Western Canada Observed with GPS
15:00	Joseph Henton, Andreas Rosenberger, Paul Collins, Ryan Key, Lisa Nykolaishen, Yuan Lu, Herb Dragert, Mark Caissy, Simon Banville Ken MacLeod, Nikola Vassilev, and François Lahaye	Development & Testing of a Low-Cost, Station-Based, Broad-Band, Real-Time Positioning Stream for Use in Earthquake & Tsunami Early Warning
15:15		

POSTER SESSION G03

Chairs: Robert Kingdon and Georgia Fotopoulos **Room: ESB Atrium**

Wednesday, May 31st

Poster No.	AUTHORS	TITLE
P01-G03	Yara Mohajerani, Isabella Velicogna, and Tyler Sutterley	Optimization of Spherical Cap Mascon Processing on the Ice Sheets for the GRACE and GRACE-FO Missions
P02-G03	John Crowley, Jianliang Huang, Goran Pavlic, and Marc Véronneau	Fewer stripes and more signals: a combined least-squares de-striping and statistical filter
P03-G03	Hojjat Kabirzadeh, Ricky Kao, Jeong Woo Kim, and Michael G. Sideris	Assessment of temporal gravity variations before large earthquakes in Western Canada
P04-G03	Theron Finley, Lucinda Leonard, Kristin Morell, Christine Regalla	Bending the Olympic Orocline: A neotectonic model of deformation in the northern Cascadia forearc

SUBMITTED ABSTRACTS

G03-01: Optimization of Spherical Cap Mascon Processing on the Ice Sheets for the GRACE and GRACE-FO Missions

Yara Mohajerani[1*], Isabella Velicogna[1,2], and Tyler Sutterley[1]

[1] University of California, Irvine, Earth System Science Dept., Irvine, CA, 92697-3100
Phone: 949-463-1944, E-mail: ymohajer@uci.edu
[2] Jet Propulsion Laboratory, CA 91109, USA

Abstract
The GRACE mission has been providing time-variable gravity data crucial to studying the earth system since 2002, and the record will continue with the launch of the GRACE Follow-On (FO) mission. One way to obtain regional surface mass change estimates is fitting the GRACE data to regionally defined areas – "mascons" – in the harmonic domain. While previous studies using spherical cap mascons have considered uniform distributions, here we design a dynamic mascon configuration that can be optimized in both size and position based on the spatial pattern of signal to noise ratio for different regions. In this study we use Totten glacier in East Antarctica as an example to improve estimates of mass balance. Totten glacier, with most of its basin below sea level, has the largest discharge in all of East Antarctica, losing about 71 gigatonnes of mass per year to the ocean between 2003 and 2008. Therefore, it is crucially important to have continuous monitoring of this region. We show that our optimized GRACE-derived time-series agree well with independent estimates obtained from the Mass Budget method, combining measurements of ice velocity and thickness with surface mass balance models to estimate total mass balance. Our dynamic mascon approach allows for improved regional time-series, which can result in better quantification and understanding of changes in the cryosphere. [216 words]

Presentation type: Poster

G03-02: Effect of regional Numerical Weather Models on GNSS Positioning. A case study under non-standard atmospheric conditions

T. Nikolaidou[1], M. Santos[1]

[1] Department of Geodesy and Geomatics Engineering, University of New Brunswick, Fredericton, Canada. Contact Number: (506) 998 9749.
Email: *Thalia.Nikolaidou@unb.ca

Abstract
Mapping functions based on Numerical Weather Models (NWM) have been developed in the recent years to model tropospheric delay in Global Positioning System (GPS).Their limited accuracy however, requires the estimation of residual tropospheric delay for results of high accuracy.Correlation between the tropospheric delay, the receiver clock offset and the station height prolongs the time required for the solution to converge and impacts directly the accuracy of the results. Although observation in low elevation angles, help the parameters to de-correlate, they amplify the noise, are not always adequate and it is a highly demanding prerequisite for real-time applications.In this study, we applied tropospheric corrections proceeding from high resolution NWM in Precise Point Positioning (PPP), during cases of non-standard atmospheric conditions, in an attempt to acquire rapid and accurate positioning results. Although regional NWM have outperformed standard atmosphere parameters and global models, it is the first time they were compared against other NWM-derived corrections; such as the state-of-art Vienna Mapping Function 1 (VMF1) parameters.The results were assessed in terms of their formal errors, convergence time and station coordinate repeatability.Results shown minimal improvement in convergence time in “non-demanding” conditions, but “cm” height differences in kinematic mode and cases of tropospheric disturbances for specific sites. The quality of the corrections and the filter a-priori variance, are barometrical for the final solution. [221 words]

Presentation type: Oral Presentation

G03-03: Optimization of Spherical Cap Mascon Processing on the Ice Sheets for the GRACE and GRACE-FO Missions

Yara Mohajerani[1*], Isabella Velicogna[1,2], and Tyler Sutterley[1]

[1] University of California, Irvine, Earth System Science Dept., Irvine, CA, 92697-3100
Phone: 949-463-1944, E-mail: ymohajer@uci.edu
[2] Jet Propulsion Laboratory, CA 91109, USA

Abstract
The GRACE mission has been providing time-variable gravity data crucial to studying the earth system since 2002, and the record will continue with the launch of the GRACE Follow-On (FO) mission. One way to obtain regional surface mass change estimates is fitting the GRACE data to regionally defined areas – "mascons" – in the harmonic domain. While previous studies using spherical cap mascons have considered uniform distributions, here we design a dynamic mascon configuration that can be optimized in both size and position based on the spatial pattern of signal to noise ratio for different regions. In this study we use Totten glacier in East Antarctica as an example to improve estimates of mass balance. Totten glacier, with most of its basin below sea level, has the largest discharge in all of East Antarctica, losing about 71 gigatonnes of mass per year to the ocean between 2003 and 2008. Therefore, it is crucially important to have continuous monitoring of this region. We show that our optimized GRACE-derived time-series agree well with independent estimates obtained from the Mass Budget method, combining measurements of ice velocity and thickness with surface mass balance models to estimate total mass balance. Our dynamic mascon approach allows for improved regional time-series, which can result in better quantification and understanding of changes in the cryosphere. [216 words]

Presentation type: Poster

G03-04: Fewer stripes and more signals: a combined least-squares de-striping and statistical filter

John Crowley[1], Jianliang Huang[1], Goran Pavlic[1], and Marc Véronneau[1]

[1] Canadian Geodetic Survey, SGB, Natural Resources Canada, Ottawa, ON, K1A 0Y7
Phone: 343-292-6752, E-mail: john.crowley@canada.ca

Abstract
The Gravity Recovery and Climate Experiment mission (GRACE) has been measuring variations in the Earth's gravitational field since 2002. Changes in groundwater, melting glaciers, ocean circulation, and large deformations associated with post glacial rebound, continental tectonics and earthquakes all produce signals that can be detected and monitored. However, these signals tend to be contaminated by errors that manifest themselves as north-south elongated linear features, often called 'stripes'. Many procedures have been proposed to remove the erroneous stripes and often build on either the decorrelation method of Swenson and Wahr (2006) or the statistical filter of Davis et al. (2008). While both methods offer substantial improvement to the GRACE level 2 data products, the former is known for removing real signals while the latter is not entirely effective in removing all stripes in the monthly solutions. In this paper, we use a least-squares method that combines the two approaches by taking into account correlations between spherical harmonics (of equal order and parity) while simultaneously fitting a simple temporal model to each coefficient. We demonstrate that the method is more effective at removing stripes while at the same time preserving real signals, in particular with north-south orientation (e.g. Greenland).

Presentation type: Poster

G03-05: Local spectral model of geoid-to-quasigeoid separation in North America

Ismael Foroughi*, Robert Kingdon, Michael Sheng, Petr Vaníček and Marcelo Santos

Department of Geodesy and Geomatics, University of New Brunswick, Fredericton, Canada.
Corresponding author: Ismael Foroughi; phone No.: (506)-998 9664. Email: I.foroughi@unb.ca

Abstract
The coefficients of Earth gravitational models can directly be used to model the quasigeoid over the world's ocean and land areas. However, if the geoid is required, topographic corrections (terrain roughness and topographic density variation) need to be applied over continents. These corrections are often ignored in global studies, assuming that gravitational contribution of topography mainly affects the higher frequency spectrum of gravitational field. This assumption is disputed in this paper, for the case of the North American continent. The proposed numerical method utilizes forward modelling of topographic masses above the geoid and indirect gravimetric modelling of the masses below the geoid. The EGM2008 gravity model, the Earth2014 topographic model (including ice thickness and lake masses), and the CRUST1.0 crustal density model is used here to compute the contribution of a topographic mass-density distribution on $2.5' * 2.5'$ grid points in the North American continent ($25 < \varphi < 85$ and $-160 < \lambda < -25$). The maximum resolution of global models (degree/order 2160) is used. The differences between gravitational potential computed at the surface of the Earth and on the geoid are used to analyze the correction coefficients to EGM2008 for the quasigeoid-to-geoid separation. The resulting potential coefficients are used to compute the differences between normal and rigorous orthometric heights in north America. The total difference varies between $-0.20m$ and 3.4m , with the maximum corresponding to western mountainous areas. The maximum contribution of masses above the geoid is from topographic masses with average density (0.5m). The CRUST1.0 model is limited only to degree/order 360, and the maximum contribution of sediments and bedrocks is only a few centimeters. [261 words]

Presentation type: Oral Presentation

G03-06: Assessment of temporal gravity variations before large earthquakes in Western Canada

Hojjat Kabirzadeh, Ricky Kao, Jeong Woo Kim, and Michael G. Sideris

Department of Geomatics Engineering, University of Calgary, AB, T2N 1N4
Phone: 403-210-6833 E-mail: hkabirza@ucalgary.ca

Abstract
The Cascadia Subduction Zone (CSZ) of northeast Pacific is an active tectonic area where the Juan de Fuca Plate is diving beneath the North American Plate at a mean horizontal velocity of 40 mm/yr. The iGrav001 superconducting gravimeter (SG) was installed in July 13th, 2012 at the Pacific Geoscience Center (PGC), in Sidney, Vancouver Island, BC, in order to monitor tectonic activities in Western Canada. During the iGrav's mission, the nearest and largest recorded seismic event was Haida Gwaii earthquake (Mw 7.7), which occurred offshore at 03:04:09 UTC on October 28, 2012 at a 15 km depth in the Queen Charlotte Fault (QCF) area. The other large seismic effect on the gravity signal was associated with the Southeastern Alaska Craig earthquake (Mw 7.5), which occurred on January 5, 2013 at 08:58:19 UTC at a depth of 10 km. The processed gravity signal of the iGrav001 indicates that the gravity strength experienced a sharp drop followed by a significant increase of 20-30 nm/s^2 magnitude during 2-3 weeks before both earthquakes. This behavior had been detected in connection with several historical earthquakes, using gravity observations of superconducting gravimeters installed at Fairbanks, Alaska and several other stations in California. The results suggest that more investigations are still required for recognition of micro-gravimetric anomalies as earthquake precursors.

Presentation type: Poster

G03-07: Bending the Olympic Orocline: A neotectonic model of deformation in the northern Cascadia forearc

Theron Finley[1*], Lucinda Leonard[1], Kristin Morell[1], Christine Regalla[2]

[1]School of Earth and Ocean Sciences, University of Victoria, Victoria, BC, V8W 3P6
Phone: (250) 516-8939, E-mail: tfinley@uvic.ca
[2]Department of Earth and Environment, Boston University, Boston, MA, 02215

Abstract
Paleomagnetic vectors from the Eocene-age Crescent-Siletz Terrane are consistently parallel to its curving strike on the Olympic Peninsula and southern Vancouver Island. The paleomagnetic data imply that the terrane was previously straight, and subsequently bent around a vertical axis to form an orocline. This suggests that at least some deformation in the Cascadia forearc is inelastic, and may be accommodated permanently on crustal faults, rather than being entirely restored during the next megathrust earthquake. Paleoseismic investigations have shown that many faults in the forearc are indeed active and pose a significant hazard to the region, but the faults are arranged in a complex network, and the patterns of deformation are not well understood. We compare contemporary rotation rates derived from geodetic networks to those inferred from paleomagnetic data, and find a close spatial correlation between the two, with an axis of rotation centred on the Olympic Peninsula. We suggest that the "Olympic Orocline" is bending in real time due to margin-parallel compression of the forearc, and that movement on crustal faults in the region might be better understood and predicted when placed in this conceptual framework. The paleomagnetic data indicate rotation rates of ~0.5°/Myr on each limb of the orocline, while the GPS rates are slightly higher. To test whether this disparity is due to the strong signal of elastic deformation driven by interseismic locking of the Cascadia megathrust, we subtract the velocity field predicted by a geophysically-constrained dislocation model of the subduction zone from the vectors recorded at GPS stations. The residual velocity and rotation fields are discordant with permanent deformation recorded by paleomagnetic data, which indicates that current dislocation models may not properly account for long-term inelastic strain. [280 words]

Presentation type: Poster

G03-08: Crustal Shortening in the Southern Canadian Rockies, Evidence from Geodesy and Seismology

Yan Jiang[1], Simone Barani[2], John Cassidy[1,3], Roy Hyndman[1,3]

[1] Geological Survey of Canada - Sidney, P.O. Box 6000, 9860 West Saanich Road, Sidney, BC, V8L 4B2, Canada. Phone: 250-363-6352, E-mail: yan.jiang@canada.ca
[2] University of Genoa, Viale Benedetto XV 5, 16132, Genoa, Italy
[3] School of Earth and Ocean Sciences, University of Victoria, Victoria, BC, Canada V8W 3P6.

Abstract:
The Canadian Rockies are the eastern boundary of the Canadian Cordillera. This region has a complex deformation history related to a series of subduction events and associated magmatism, glacier and inter-glacier cycles, and terrane collisions. In this study, we use geodetic and seismic data to investigate current deformation in the southern Canadian Rockies, and derive the associated strain rate map. We processed available GPS data in the study area, and calculated geodetic strain rate. Current geodetic strain rate show rapid shortening between Banff and Calgary, the strain rate decrease rapidly to the east of the Rocky Mountain. Our results suggest active deformation of the southern Canadian Rockies. Using available earthquake catalogue, we derive seismic strain rate map that based on earthquake recurrence relations. We compare the two strain rate end products from two difference data sets. The geodetic strain rate is an order of magnitude larger than the seismic strain rate. The discrepancy show either incompleteness of the earthquake catalogue due to short observation history and sparse distribution of seismic stations, or that the accumulated geodetic strain is to be released by future aseismic events. The observed high geodetic strain rates are concentrated in the Canadian Rockies. We propose that the detached upper crust due to high heat flow in the lower crust transmits strain from distant Cascadia subduction zone to the Canadian Rockies is responsible for the observed crustal shortening. (231 Word)

Presentation Type: Oral Presentation

G03-09: Development & Testing of a Low-Cost, Station-Based, Broad-Band, Real-Time Positioning Stream for Use in Earthquake & Tsunami Early Warning

Joseph Henton[1], Andreas Rosenberger[2], Paul Collins[3], Ryan Key[4], Lisa Nykolaishen[5], Yuan Lu[5], Herb Dragert[5], Mark Caissy[3], Simon Banville[3] Ken MacLeod[3], Nikola Vassilev[3], and François Lahaye[3]

[1] Natural Resources Canada, Canadian Geodetic Survey (Sidney, BC)
Phone: 250-363-6658, E-mail: joe.henton@canada.ca
[2] Arescon Ltd (Sidney, BC)
[3] Natural Resources Canada, Canadian Geodetic Survey (Ottawa, ON)
[4] Ocean Networks Canada, University of Victoria (Victoria, BC)
[5] Natural Resources Canada, Geological Survey of Canada – Pacific (Sidney, BC)

Abstract
High-rate low-latency Global Navigation Satellite System (GNSS) data are being utilized for real-time (RT) applications focused on disaster mitigation, including tsunami early warning. RT-GNSS complements other geophysical monitoring (*i.e.*, accelerometer) networks to improve the robust assessment and reporting of hazards. Given the tectonic setting of Canada's west coast, megathrust earthquakes (M_w>8) are the primary targets for immediate identification, since the tsunamis they generate will strike the coast within 15 to 20 min. However, large (6.0<M<7.5) normal or strike-slip earthquakes when occurring within the ocean plate offshore could be mistakenly identified as large-scale tsunami-genic events and need to be discriminated from subduction thrust ruptures in order to avoid tsunami "false alarms" and unwarranted mitigation responses. To facilitate testing of distributed (on-site) analyses and integration with other local sensors, Natural Resources Canada's Canadian Geodetic Survey (CGS) has implemented real-time GNSS processing on a low power, Linux platform. Currently three RT-time positioning streams may be executed locally: precise point positioning (PPP) with integer ambiguity resolution and 'float' PPP (both using RT clock and orbit correction streams) as well as fully autonomous single point positioning using broadcast orbits. To test both RT-GNSS derived coordinate streams (rather than velocity) in a controlled experiment, a mechanical system is used to drive the GNSS antenna along a circular path while keeping its orientation direction fixed. A strong-motion accelerometer (SMA) located beneath (co-axial to) the GNSS antenna is operated simultaneously. RT-GNSS position streams and SMA observations are recorded independently in order to produce suitable data sets to evaluate algorithms to fuse GNSS and SMA data streams. The reliability (amplitude and period accuracy) and noise characteristics of the currently available (and, possibly, developmental) RT-GNSS streams are evaluated.

Presentation type: Oral or Poster (Either is acceptable).

G03-10: Active Deformation in Alaska and Western Canada Observed with GPS

Julie Elliott[1], Lucinda Leonard[2], Roy Hyndman[2,3], Yan Jiang[3], and Jeff Freymueller[4]

[1] Dept. Earth, Atmospheric, and Planetary Sciences, Purdue University, West Lafayette, IN
Phone: 509-961-3568 E-mail: julieelliott@purdue.edu
[2] School of Earth and Ocean Sciences, University of Victoria, Victoria, BC V8W 2Y2
[3] Pacific Geoscience Centre, Geological Survey of Canada, Sidney, BC V8L 4B2
[4] Geophysical Institute, University of Alaska Fairbanks, Fairbanks, AK 99775

The idea that the tectonics of the northeastern Pacific is defined by relatively discrete deformation along the boundary between the Pacific and North American plates has given way to a picture of broadly distributed deformation. This is in part due to a number of studies and initiatives in recent years that have greatly expanded the density of GPS data throughout the region. We present an updated GPS velocity field for Alaska and northwestern Canada as well as a new, integrated tectonic block model for the region. Rather than discrete plate boundaries, we observe zones of concentrated deformation where the majority of the relative plate motion is accommodated. Within these zones, there are major fault systems, such as the Fairweather-Queen Charlotte transform and the Aleutian megathrust, where most of the deformation occurs along a main structure, but often motion is instead partitioned across multiple faults, such as the fold-and-thrust belt of the eastern St. Elias orogen. Some regions, such as central Alaska south of the Denali fault and the area south of Glacier Bay, appear to move as coherent blocks. Other regions, such as the area surrounding the collisional front of the Yakutat block, are best described as zones of internal deformation. Strain is transferred far inboard, either by diffuse deformation or along fault systems such as the Denali fault, and outboard of the main zones of deformation.

Presentation type: Oral