

Elements



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THE NEWSLETTER OF THE CANADIAN GEOPHYSICAL UNION

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LE BULLETIN DE L'UNION GÉOPHYSIQUE CANADIENNE

President's Column

It has been a great pleasure to serve as President of the CGU over the last two years. The CGU meetings remain dynamic and exciting. We have a very talented executive, strong speakers and a wonderful group of students who are presenting advanced material and advancing science with their studies. We have seen significant development as a society over this period – it has been an honour to observe and be involved with this development. Several aspects of this development are useful to summarize at this time:

i) Initiation of the Canadian Societies for the Geophysical Sciences (CSGS), which is a society of societies, linking CGU with CMOS. We have now both formally approved the formation of CSGS with its first formal function being our joint conference at Ottawa in 2010. We are undertaking joint efforts to ensure support for our sciences and will engage in regularly timed joint meetings. The theme for Ottawa is Our Earth, Our Air, Our Water - Our Future, La Terre, l'air et l'eau: notre avenir. One can anticipate that this will be a very successful joint meeting, based upon the positive feedback we have received from our joint meeting in St. John's in 2007.

ii) Two new Sections in the CGU, 'Solid Earth' and 'Biogeosciences', have been proposed, have had initial meetings and are anticipated to become operational upon approval at the Annual General Meeting this May. This will transform CGU into an organization where most members have a sectional home.

iii) Formal structuring of how CGU organizes its meetings with the formation of a Scientific Programme Committee and Local Arrangements Committee. Rod Blais is serving as chair of the Scientific Programme Committee, while our LAC varies depending on who we are meeting with in a particular year.

iv) Application for Charitable Status with the Canadian Revenue Agency. When complete, this will permit CGU to issue tax receipts for donations and then through donations develop programs for good works such as scholarships and student support for meetings.

We have also made substantial progress in our accounting practices and have adopted a financial plan. We have deliberately subsidized recent meetings through invited speakers and travel bursaries to assist in the development of CGU – this investment has paid off in our new sections and the increased popularity and significance of our annual meeting. However, now it is time to ensure our long term sustainability with some fiscal restraint until the extent of our responsive growth becomes apparent.

CGU also will start addressing means to promote the involvement of women in geophysical sciences. We have large numbers of highly talented female students in CGU, but this level of interest is not reflected in our non-student membership and executive leadership. The first and only female member of the CGU executive is Kathy Young who joined in 2007. We therefore must make CGU a more welcoming society for female geophysical scientists throughout their careers. To assist in this, Katrina

Bennett and others have proposed a session to bring together women in the geosciences to share in the common experience of being a female scientist in Canada and beyond. The main goal of the session is to foster continued growth of the CGU female membership population, through mentoring young professionals, assisting students to engage with the community and creating a network of female students and non-students that may support each other in various ways. We hope that this session will be an annual event at CGU meetings and will be a positive development for all involved.

We have our Joint Assembly coming up in Toronto 24-27 May 2009 at the Metro Toronto Convention Centre, 255 Front Street West. The Joint Assembly brings CGU together with the American Geophysical Union, Geological Association of Canada, Mineralogical Association of Canada, and the International Association of Hydrogeologists – Canadian National Chapter, and so will be a large meeting with comprehensive sessions on the earth sciences. There are a large number of exciting sessions that have been proposed by CGU members for the Joint Assembly. The deadline for abstracts is **4 March at 2359 UT (GMT)** and so we are hoping for a strong CGU turnout for this meeting. Remember to register primarily as a CGU member so that CGU will benefit from your participation in the Joint Assembly.

CGU operates as an association because of the contributions from its individual members and the hard work of its executive. We are fortunate to have both strong contributors to our meetings and a hard working, talented executive. I would like to first recognize our Past President, Gary Jarvis, who, as President, initiated many of the achievements that have been recently

realised. His advice and wisdom have guided CGU for many years and his continued contributions to the developing Earth Science section are greatly appreciated. Spiros Pagiatakis has served admirably as our Vice President and has assumed responsibility for local arrangements at the upcoming meetings in both Toronto and Ottawa meetings. He would be a good President..... Kathy Young has done an astoundingly good job as Treasurer: she has improved our accounting methods considerably, developed a financial plan and developed CGU's application for charitable status. Masaki Hayashi is an extremely foresightful, active and competent Secretary to the CGU who runs the Secretariat, corresponds for the society and documents our meetings. His hard work and attention to detail have kept us running smoothly. Rod Blais has guided our scientific programme committee and local arrangements for a very successful meeting in Banff 2008 and for Toronto 2009. Ed Krebs edits our twice yearly newsletter, Hugh Geiger coordinates our awards and student awards processes, and Patrick Wu sets up our conference website for registration and abstract submission – all very time-intensive operations. CGU has two very active sections: Hydrology, with President Jim Buttle, and Geodesy, with President Marcelo Santos, along with the GAC Geophysics Division, chaired by Phillip McCausland. Thank you all for your commitment and contribution to the operation of the CGU. Those interested in joining the executive and contributing to the CGU through service are encouraged to talk to me or any executive member about how to become engaged.

It's been swell. Have fun and work hard.

John

J. Tuzo Wilson Medal – Call for Nominations

The Executive of the CGU solicits nominations for the J. Tuzo Wilson Medal – 2009. The Union makes this award annually to recognize outstanding contributions to Canadian geophysics. Factors taken into account in the selection process include excellence in scientific and/or technological research, instrument development, industrial applications and/or teaching.

If you would like to nominate a candidate, please contact Dr. Hugh Geiger, Chair of the CGU Awards Committee, Talisman Energy, Calgary AB (Email: HGEIGER@talisman-energy.com). At a minimum, the nomination should be supported by letters of recommendation from colleagues, a brief biographical sketch and a Curriculum Vitae. Nominations should be submitted by February 28, 2009. Additional details concerning the nomination process can be obtained from the Chair of the CGU Awards Committee.

L'exécutif de l'UGC vous invite à suggérer des candidats pour la médaille J. Tuzo Wilson – 2009. L'Union décerne la médaille chaque année "en reconnaissance d'une contribution remarquable à la géophysique canadienne". En choisissant parmi les candidats, on considère les accomplissements en recherches scientifique ou technologiques, aux développements d'instruments, aux applications industrielles et/ou à l'enseignement.

Si vous désirez suggérer un candidat pour cette médaille, s.v.p. contacter Dr. Hugh Geiger, Président du Comité des Prix d'Excellence, Talisman Energy (Email: HGEIGER@talisman-energy.com). Les nominations doivent être supportées de lettres de recommandation de collègues, d'un bref sommaire biographique et d'un Curriculum Vitae. Les nominations doivent être soumises avant le 28 février, 2009. Des détails additionnels concernant le processus de nomination peuvent être

obtenus en communiquant avec le Président du Comité des Prix d'Excellence de l'UGC.

Past Wilson Medallists

1978	J. Tuzo Wilson
1979	Roy O. Lindseth
1980	Larry W. Morley
1981	George D. Garland
1982	Jack A. Jacobs
1983	D. Ian Gough
1984	Ted Irving
1985	Harold O. Seigel
1986	Michael Rochester
1987	David Strangway
1988	Ernie Kanasewich
1989	Leonard S. Collett
1990	Gordon F. West

1991	Thomas Krogh
1992	R. Don Russell
1993	Alan E. Beck
1994	Michael J. Berry
1995	Charlotte Keen
1996	Petr Vaníček
1997	Chris Beaumont
1998	Ron M. Clowes
1999	David Dunlop
2000	Don Gray
2001	Roy Hyndman
2002	Doug Smylie
2003	Garry K.C. Clarke
2004	W.R. (Dick) Peltier
2005	Ted Evans
2006	Alan Jones
2007	Herb Dragert
2008	Ming-ko (Hok) Woo

CGU Young Scientist Award – Call for Nominations

The Executive of the CGU solicits nominations for the CGU Young Scientist Award – 2009. The CGU Young Scientist Awards recognize outstanding research contributions by young scientists who are members of the CGU. Both the quality and impact of research are considered. To be eligible for the award, the recipient must be within 10 years of obtaining their first Ph.D. or equivalent degree. The awards are made by the CGU Executive on the recommendations of a special committee struck for this purpose. The selection committee seeks formal written nominations from the membership, plus letters of support and a current curriculum vitae. Nominations for the CGU Young Scientist Awards may be submitted by CGU members at any time.

If you would like to nominate a candidate, please contact Dr. Hugh Geiger, Chair of the CGU Awards Committee, Talisman Energy, Calgary AB (Email: HGEIGER@talisman-energy.com). The nomination should be supported by three letters of recommendation from colleagues. Nominations should be submitted by February 28, 2009. Additional details concerning the nomination process can be obtained from the Chair of the CGU Awards Committee.

L'exécutif de l'UGC vous invite à suggérer des candidats pour le prix pour Jeune Scientifique de l'UGC – 2009. Les Prix pour Jeunes Scientifiques de l'UGC reconnaissent les contributions exceptionnelles de jeunes scientifiques qui sont membres de l'UGC. La qualité et

l'impact de la recherche sont considérés. Pour être éligible pour le prix, le scientifique doit avoir obtenu son premier Ph.D. ou degré équivalent au cours des dix dernières années. Les prix sont accordés par l'Exécutif de l'UGC sur recommandations d'un comité spécial à cette fin. Le comité de sélection sollicite des nominations formelles par écrit des membres de l'UGC, accompagnées de lettres d'appui et d'un curriculum vitae à jour. Des nominations pour les Prix pour Jeunes Scientifiques de l'UGC peuvent être soumis en tout temps par les membres de l'UGC.

Si vous désirez suggérer un candidat pour cette médaille, s.v.p. contacter Dr. Hugh Geiger, Président du Comité des Prix d'Excellence, Talisman Energy, Calgary AB (Email: HGEIGER@talisman-energy.com). Les nominations doivent être supportées de trois lettres de recommandation de collègues. Les nominations doivent être soumises avant le 28 février, 2009. Des détails additionnels concernant le processus de nomination peuvent être obtenus en communiquant avec le Président du Comité des Prix d'Excellence de l'UGC.

Past Winners

2005	Shawn J. Marshall, J. Michael Waddington
2006	No winner
2007	No winner
2008	Brian Branfireun, Scott Lamoureux

CGU Meritorious Service Award – Call for Nominations

The Executive of the CGU solicits nominations for the CGU Meritorious Service Award – 2009. The CGU Meritorious Service Award recognizes extraordinary and unselfish contributions to the operation and management of the Canadian Geophysical Union by a member of the CGU. All members of the CGU are eligible for this award, although the award is not normally given to someone who has received another major award (e.g. the J. Tuzo Wilson Medal). Nominations for the CGU Meritorious Service Award may be submitted by CGU members at any time. The award is made by the CGU Executive based on recommendations from the CGU Awards Committee, and is based on lifetime contributions to CGU activities.

If you would like to nominate a candidate, please contact Dr. Hugh Geiger, Chair of the CGU Awards Committee, Talisman Energy, Calgary AB (Email: HGEIGER@talisman-energy.com). The nomination should be supported by three letters of recommendation from colleagues. Nominations should be submitted by February 28, 2009. Additional details concerning the nomination process can be obtained from the Chair of the CGU Awards Committee.

L'exécutif de l'UGC vous invite à suggérer des candidats pour le Prix pour Service Méritoire de l'UGC – 2009. Le Prix pour Service Méritoire de l'UGC reconnaît les contributions extraordinaires et désintéressées à l'opération et à l'administration de l'Union Géophysique

Canadienne par un membre de l'UGC. Tous les membres de l'UGC sont éligibles pour ce prix, sauf que normalement, ce prix n'est pas donné à quelqu'un qui a reçu un autre prix important tel que la Médaille Tuzo Wilson. Des nominations pour le Prix pour Service Méritoire de l'UGC peuvent être soumises en tout temps par les membres de l'UGC. Le Prix est accordé par l'Exécutif de l'UGC sur recommandations du Comité des Prix de l'UGC, pour l'ensemble des contributions d'un membre aux activités de l'UGC.

Si vous désirez suggérer un candidat pour cette médaille, s.v.p. contacter Dr. Hugh Geiger, Président du Comité des Prix d'Excellence, Talisman Energy, Calgary AB (Email: HGEIGER@talisman-energy.com). Les nominations doivent être supportées de trois lettres de recommandation de collègues. Les nominations doivent être soumises avant le 28 février, 2009. Des détails additionnels concernant le processus de nomination peuvent être obtenus en communiquant avec le Président du Comité des Prix d'Excellence de l'UGC.

Past Winners

2004	Ron Kurtz
2005	Ted Glenn
2006	J.A. Rod Blais
2007	Ed Krebes
2008	Patrick Wu

CGU 2008 Young Scientist Awards

The winners of these awards were Brian Branfireun and Scott Lamoureux. The citation for Brian Branfireun, and Scott Lamoureux's acceptance speech, appear in the July 2008 issue of ELEMENTS. The citation for Scott Lamoureux, prepared by Hugh Geiger, appears below.

Scott Lamoureux's lifelong passion for the geosciences emerged as a young Arctic field assistant in the late 1980s. He has visited the north every summer since then, and focused both of his graduate theses on hydrologic, geomorphic, meteorological and sedimentary controls on Arctic lakes. Scott earned his PhD in 1998 at the University of Alberta and followed his research interests to the Department of Geography at Queen's University, first as a post-doctoral fellow and currently as an Associate Professor with a cross appointment to the School of Environmental Studies. Scott's achievements in geoscientific research are broad and extensive, encompassing the following four principal areas which are described in more detail below: 1) the conception, implementation and continued expansion of a multiyear, multidisciplinary research station on Melville Island in the Canadian High Arctic; 2) his involvement in

numerous national and international research initiatives; 3) a commitment to geoscientific education and development; and 4) a dedication to the dissemination of geoscientific knowledge and advancement.

In response to the absence of long-term monitoring data in the Canadian Arctic and the sensitivity of this region to climate change, Scott initiated a long-term environmental monitoring and field research project in 2003 at Cape Bounty, Melville Island, in the Canadian Arctic Archipelago. Initial studies focused on watershed hydrology, lake sedimentary processes and impacts on aquatic ecosystems. In the five years since, the project has expanded into a multi-disciplinary monitoring station encompassing a range of projects related to hydroclimatology, biogeochemistry, remote sensing, soil processes, and integrated sediment, nutrient and carbon flux monitoring. It is the most comprehensive monitoring

initiative in the Canadian Arctic to date. In 2007, the Cape Bounty project gained international attention by reporting unprecedented Arctic warming and landscape erosion that summer. In 2008, work at Cape Bounty will involve a diverse group of researchers and graduate students from eight universities and government agencies.

Scott is active in a number of national and international research projects. He is involved in two Canadian International Polar Year projects (including as a lead principal investigator for the Cape Bounty project), and is a Network Investigator for ArcticNet, a Network of Centres of Excellence of Canada. Internationally, Scott is the Vice-President of the International Association of Geomorphologists (IAG) Working Group on Sediment Budgets in Cold Regions (SEDIBUD). Scott is also working with researchers at Northern Arizona University, examining Holocene sediment records in southern Alaska to reconstruct glacier extent, ecology, lake productivity, and geomorphic processes. Most recently, Scott is involved in the Potrok Aike Maar Lake Sediment Archives Drilling Project (PASADO), a multinational effort to obtain paleoenvironmental reconstructions from Argentina's oldest lake.

Scott's growing reputation in national and international scientific pursuits is matched in his commitment to geoscientific education. In his eight years as a faculty member at Queen's he has supervised or co-supervised 16 undergraduate, graduate, and postdoctoral students and fellows, and is currently supervising 10 students and fellows. His graduate students are grateful for his superior mentorship, which extends well beyond the realms of field, laboratory and research project, and into long term career and professional development. He is highly respected as a teacher of numerous

undergraduate and graduate courses, and his enthusiasm for science and devotion to geoscientific research has inspired many students to pursue post-graduate degrees in the earth sciences. His commitment to education has recently expanded to elementary school children in Nunavut, where he is helping develop a geosciences education program as part of the International Polar Year initiative. Finally, Scott's aptitude for field work and technical skills have been invaluable to his students, from helping secure funding and carry out expensive northern fieldwork, to the development of new instruments for long term monitoring of sediment fluxes.

Scott's commitment to the dissemination of scientific knowledge is impressive. He has published three book chapters, and he and his students have published over 30 peer-reviewed articles in a wide range of scientific journals. He has personally shared his research across Canada and internationally through numerous invited lectures, keynote and plenary talks, and through participation in dozens of conferences. In addition, he has chaired, convened, and helped organize numerous scientific meetings. Scott has reviewed manuscripts for 18 scientific journals, and numerous book chapters and textbooks, and is currently the Newsletter Editor for the Canadian Geomorphological Research Group. Finally, his involvement in the Polar Continental Shelf Project Screening Committee and as Director of the Queen's Northern Studies Research Group demonstrate his commitment to giving others the opportunity to share scientific developments in the future.

The Canadian Geophysical Union takes great pleasure in selecting Scott Lamoureux as a recipient of the 2008 CGU Young Scientist Award. Congratulations Scott!

News from the CGU Secretariat

At the CGU Secretariat in Calgary, we had a busy fall implementing the new on-line system for membership application and renewal. In previous years, new and returning members sent us the information by e-mail or regular mail. The information was entered manually to our database by the secretarial assistant, Kate Bentley, and credit card transaction processed manually by Conference Concept. The CGU Executive Committee decided earlier in 2008 to acquire an on-line system to streamline the registration process, which would benefit both the members (convenience!) and the CGU (improved efficiency and reduced cost). After some shopping around, we hired a Vancouver-based company, Active Network (also called Thriva), to implement our system because: 1) the company had successfully implemented an on-line registration system for a similar Canadian organization in 2007, and 2) the implementation cost was much less than what other companies quoted.

One drawback, however, is that the majority of Thriva's clients are organizations running sports camps and family events. As such, the Thriva system is not specifically designed for scientific organizations like the CGU. If you have already used the new on-line system, you might have noticed a few odd things such as the waiver form, which reads like a form for school summer camp. Please bear with us as we try to improve our system, and send us any comments or suggestions to cgu@ucalgary.ca.

Another thing we did this fall was to enhance the Job Posting page on our web site (www.cgu-ugc.ca/job/). If you visit this page, you will see a variety of student positions and employment opportunities. At the CGU Executive Meeting in September 2008, we set a formal policy regarding the web advertisement fee: free for student and postdoc positions, \$50 for university employment (e.g. professors and research technicians),

and \$200 for all other employment opportunities. The advertisement revenue will help us with our essential activities such as student travel support for the CGU meeting. If you are interested in posting an advertisement, please contact us by e-mail.

The CGU web master, Jun Mei, returned to Nanjing, China on December 31, 2008 with her husband, who completed two-year postdoctoral work in Calgary. During the past two years, she completely updated the CGU main web site and conference web site, and maintained their function. Her skill and pleasant smile will be sorely missed at the CGU Secretariat. The web sites will be

maintained by me with some help from Jun in China until a new web master is found.

We wish you a productive new year and look forward to seeing you at the Joint Assembly in Toronto. One more thing: if you have not renewed your 2009 membership, please renew now by going to www.cgu-ugc.ca/membership/how.html.

Masaki Hayashi
CGU Secretary



HYDROLOGY SECTION NEWS

CGU Hydrology Section Committee Reports 2008

Erosion and Sedimentation Committee

Chair: Peter Ashmore, Department of Geography, University of Western Ontario, London, ON, N6A 5C2
Email: pashmore@uwo.ca

Members: Dr. Dirk DeBoer, University of Saskatchewan, M. Conly, Environment Canada (CWS), Saskatoon, Dr. M. Church, University of British Columbia, Dr. A. Roy, Université de Montréal

Dirk DeBoer is Secretary of the IAHS-International Commission on Continental Erosion Secretary and ICCE Canadian Delegate

Objectives: the scientific advancement and practical application of knowledge of erosion, transport and deposition of sediment in fresh water systems - topic coverage similar to that of the IAHS Commissions on Continental Erosion some aspects of Water Quality.

- i) communication of current research via discussion, meetings, conferences and publications;
- ii) identification and promotion of high priority research topics in the Canadian context;
- iii) promotion and encouragement of the transfer of knowledge and technology in the field of interest.

Meetings & Activities

- Continued representation at CGU-HS sessions.
- Reciprocal membership arrangement and affiliation between CGU and Canadian Geomorphology Research Group has resulted in several sessions at other national conferences jointly between the two groups.
- Several sessions at 2008 CGU conference jointly with CGRG. Ashmore was a member of the program committee and helped coordinate sessions between the two organizations.
- Ashmore led the preparation of a summary of recent Canadian research in fluvial sedimentation for IAHS-CNC, with co-authors Pascale Biron (Concordia), Colin Rennie (Ottawa) and Brett Eaton (UBC). Now in press in CWRJ Journal.

Glaciers and Environment Committee

Chair: Michael N. Demuth, P. Eng., P. Geo., Head, Glaciology Section, Geological Survey of Canada, Natural Resources Canada, 601 Booth Street, Ottawa, ON K1A 0E8, Mike.Demuth@NRCan.GC.CA

Vice-Chair: Prof. Gwenn E. Flowers, Canada Research Chair, Glaciology, Simon Fraser University, gflowers@SFU.CA

Past-Chair: Prof. D. Scott Munro, University of Toronto

Advisory Members: Prof. Sarah Boon, University of Lethbridge; Prof. Gwenn E. Flowers, Simon Fraser University; Dr. Roy Koerner, Geological Survey of Canada; Prof. Shawn Marshall, University of Calgary; Prof. Brian Menounos, Univ. of Northern British Columbia; Prof. D. Scott Munro, University of Toronto; Prof. John W. Pomeroy, University of Saskatchewan; Jeffrey Schmok, P. Geo., Golder Associates Ltd.; Prof. Martin J. Sharp, University of Alberta.

Mandate and Objectives

- a. Assist the CGU and its executive in promoting glaciological research that is relevant to hydrological and environmental problems.
- b. Provide CGU members with information about glaciological research activity, and identify opportunities for collaboration among individuals and groups.
- c. Provide CGU members with information about the scope and extent of glaciological data, and promote efforts to improve accessibility to such data.
- d. Influence research development by establishing lines of communication with other working groups in snow and ice, such as the Cryospheric System (CRYSYS) to monitor global change in Canada and identify personnel training opportunities.
- e. Identify and promote opportunities for educating other members of the scientific community and the general public about glaciers and their role in the environment.

Meetings and Activities

- a. The Geological Survey of Canada's National Glaciology Program (NGP), co-supported by the Natural Resources Canada, Environment Canada and University partners continues to develop and operate an integrated monitoring and research program in the Canadian Arctic and western and northern Cordillera. Additional information pertaining to the *State and Evolution of Canada's Glaciers* can be found at: http://pathways.geosemantica.net/WSHome.aspx?ws=NGP_SECG%26locale=en-CA
- b. Mike Demuth, continues as Canadian National Correspondent to the World Glacier Monitoring Service and Canadian Co-ordinator, Global Terrestrial Network for Glaciers/WMO-GCOS.
- c. Simon Ommanney returns to assume the position of the Canadian National Correspondent to the International Glaciological Society. Periodic submissions to the IGS are made by the Correspondent, notifying the international glaciology community of Canadian work on snow and ice via the IGS publication ICE.
- d. David Burgess has been hired as a Cryosphere Remote Sensing Specialist at NRCan's Canada Centre for Remote Sensing and will, through NRCan's science

programs, be mentoring under Roy Koerner to operate the Arctic Islands ice cap mass balance observing work. In addition, he will be working with Mike Demuth on glacier remote sensing. Dave's hiring represents an important step forward in the continuation and recognition of Roy's labours and insights spanning some 50 years.

e. Mike Demuth, Gwenn Flowers, Roy Koerner, Shawn Marshall and Martin Sharp have appeared in recent Canadian Broadcasting Corporation television and radio programs that deal with global warming and ice cover loss in Arctic and Western Canada.

f. Sarah Boon and Shawn Marshall are co-convenors of CGU 2008: Hydrology and the Cryosphere

g. Scott Munro is Canadian Representative to IACS and National Organizing Committee member for MOCA-09: the Joint IAMAS-IAPSO-IACS Assembly, Montreal 2009.

Progress on Issues and Objectives

The NGP work, in linkage with the Cryospheric System (CRYSYS) program of Environment Canada, has been central to the objectives of this committee, where training in partnership with universities occurred through continued development of hydrometeorological research at NGP glacier mass balance sites in Western Canada, as well as through work in the Canadian Arctic. Despite the conclusion of the CRYSYS program, prospects for NGP-university linkages look brighter than ever, now that two new cryosphere research initiatives are underway: *Improved Processes and Parameterization for Prediction in Cold Regions* (IP3; John Pomeroy, P.I.) and *Western Canadian Cryospheric Network* (WC2N; Brian Menounos, P.I.). This signifies expanded opportunities for interaction among cryospheric scientists in Canada. We believe that this will raise the international profile of Canadian cryospheric research and do much to train new researchers to investigate the rapidly changing cryosphere.

Future Meetings and Activities

Progress toward a collaborative Canadian glacier monitoring and research network, a need identified in the GSC Workshop (Ottawa, 2000) and promoted through the Canadian Government's Action Plan 2000, CSA GRIP and previous CRYSYS meetings, is expected to take on new life with the advent of IP3 and WC2N. Continued participation of the Canadian glacier research community in the CGU Annual Meeting is vital in this regard, so the Committee will look forward to continued organization of CGU-HS sessions on glaciological research, as well as to being influential at other meetings that provide opportunities to communicate the research efforts of our community. The forthcoming IAMAS/IAPSO/UCCS

joint assembly, the theme of which is *Our Warming Planet*, will provide an excellent opportunity to display Canadian cryospheric research findings just as the efforts of IP3 and WC2N are bearing fruit.

Other Business

The glacier inventory and the degree of change within what is still a large reservoir of land ice is a continuing matter of concern, particularly as it relates to water resource changes in Western Canada and flow to oceans aspects of water and ice discharges from the Canadian Arctic Islands. With new remote sensing tools (e.g., CryoSat2) coming on-line soon and the increasingly systematic use of repeat airborne laser terrain mapping surveys, water fluxes from Canada's large land ice reservoirs are currently being defined more comprehensively.

As noted at the final CRYSYS meeting, there is an urgent need to deal with issues related to archiving and sharing of data resources, a matter that could involve the Committee at some future date but which, for now, can be explored within IP3, WC2N and the NGP. As it concerns mass balance data, a new data portal under development within the aforementioned *State and Evolution of Canada's Glaciers* web Workspace will assist the sharing and utility of this much sought after data. The Workspace will also facilitate Canada's annual and biennial contributions to World Glacier Monitoring Service.

The Committee would like to work with other CGU-HS committees on defining research needs the cut across the themes of the Hydrology Section. There is much work to be done, for example, in the area of glacier river ecology and the eco-system services provided by the presence of glaciers. To this end, many of NGP's glacier observing and assessment efforts are conducted now in partnership with Parks Canada and their requirements to monitor ecological integrity under the Heritage Convention. The newest NGP glacier observing and assessment effort focuses on the glaciers of the Ragged Range in the NWT – glaciers that are part of the proposed expansion of Nahanni National Park. These observations and related analyses are co-delivered with NGP staff and have become part of the Park's formal EI monitoring program as of 2008.

CGU-HS Northern Research Basins Committee

The report from this committee appears in the July 2008 issue of ELEMENTS.

Committee on River Ice Processes and the Environment

Chair: Faye Hicks, PhD, PEng., FCSCE

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CRIFE Members:
Spyros Beltaos, Normand Bergeron,
Raymont Bourdages, Brian Burrell,
Shawn P. Clark, Evan Freisenhan, Joe
Groeneveld, Chris Katopodis, Chandra
Mahabir, Mike Morris

International Members:
Randi Pytte Asvall (Norway), Steven
Daly (United States), Mikko Huokuna
(Finland), Hung Tao Shen (IAHR)

Affiliate Members:
R W Carson, Kersi Davar, Terry
Prowse

About CRIFE:

CRIFE derived from a Working Group that was established in 1975 by the Associate Committee on Hydrology (ACH), itself funded by the National Research Council of Canada (NRCC). This working group evolved into a permanent Subcommittee of ACH in 1981. Severe budget cuts at NRCC forced the discontinuation of the associate committees in the early nineties. In 1995, the former River Ice Subcommittee of ACH joined the Canadian Geophysical Union, as a Committee of the Hydrology Section.

CRIPE Mandate and Objective:

Initially, the Committee's work focused on the hydraulic aspects of river ice phenomena, as a means of elucidating the effects of the ice cover on flow characteristics. This scope was gradually expanded to include additional issues of concern, such as ice formation, ice jams, winter operation of hydro-plants, environmental aspects of river ice, and climatic variability and change. The main objectives of the Committee are:

1. To identify specific high-priority topics for research and development and promote the undertaking of relevant research programs;
2. To facilitate information dissemination and exchange of ideas among practitioners, researchers, and resource managers; and
3. To encourage the incorporation of pertinent lectures or courses in undergraduate and graduate studies at Canadian Colleges and Universities.

Meetings and Activities:

One of the main Committee activities is the sponsorship of workshops and short courses and the publication of Proceedings. The first river ice workshop was held at Burlington, Ontario, in 1980, and the most recent workshops took place in Hanover, New Hampshire, in 2005 and Quebec City in 2007. Another ongoing activity is the initiation and leadership of Task Forces to work on specific problems and publish their findings. From time to time, the status of knowledge on particular topics is reviewed and research needs are identified. Liaison with river ice work abroad is maintained through formal and informal links.

14th Workshop, Quebec City, June 2007

The 14th Workshop of the Committee on River Ice Processes and the Environment was held in Quebec City in June 2007. A total of 40 papers and 12 posters were presented at the workshop. Topics covered included:

- Ice jam risk, impact, and mitigation
- River ice measurements and monitoring
- River ice modeling
- Special session on the St. Lawrence River
- Frazil ice
- Ice jam surges
- River ice ecology and fish habitat

The interest in topics of river ice ecology and fish habitat is building and attracts a new group of interested researchers. This area of research complements the topics of interest to CRIPE which have largely been focused on the physical aspects of river ice processes.

The workshop was hosted by INRS and the University of Laval. Brian Morse, Raymont Bourdages, and Yves Gauthier were co-chairs and David Godin and Hugo Drouin were workshop helpers. Their work is gratefully acknowledged.

Workshop Proceedings are freely available online at www.cripe.ca. Selected papers from the workshop have been expanded into full journal papers for a special issue of the Journal of Cold Regions Science and Technology.

2005 Gerard Medal

In 1992, the Committee established the Gerard Medal, to honour and remember the many contributions to river ice science by the late Professor Robert (Larry) Gerard who passed away in 1991. The Gerard Medal is awarded biennially to the author(s) of the best paper presented at the preceding River Ice Workshop.

The 2005 Gerard Medal was awarded to: M. Jasek, J. Marko, D. Fissel, M. Clarke, J. Buermans, and K. Paslawski for their paper entitled "*Instrument for Detecting Freeze-up, Mid-Winter and Break-up Ice Processes in Rivers*". The medals were awarded at the 2007 workshop in Quebec.

2006 Annual Meeting

CRIPE holds an annual administrative meeting and technical workshop in alternating years (between workshops). The 2006 meeting was held in Fredericton, NB, in conjunction with technical meetings for the Unified River Ice Breakup Model (URIBM).

2007 Annual Meeting

The 2007 annual meeting was held on June 23rd, 2007 in Quebec City, following the 14th CRIPE workshop. In addition to dealing with ongoing administrative and committee business, discussions were held on committee technical initiatives and membership renewal.

Following nominations by the committee at this meeting, the following new members have recently joined CRIPE, Dan Healy (AMEC Earth and Environmental) to the executive committee as secretary and the following committee members: Shawn Clark (University of Manitoba); Evan Friesenhan (Alberta Environment); Joe Groenveld (Hutch Consultants); and Mike Morris (Manitoba Hydro).

2008 Annual Meeting

The 2008 annual meeting was held on July 6th in Vancouver, British Columbia. The meeting precedes the 19th IAHR International Symposium on Ice. Topics covered at the meeting included:

- Planning for the upcoming workshop (2009)
- Status of current research publications and projects

19th IAHR International Symposium on Ice, Vancouver, British Columbia, July 2008:

CRIPE hosted the 19th IAHR Ice Symposium, which was held from July 6th to 11th, 2008, at the Coast Plaza Hotel in downtown Vancouver. Topics covered at the Symposium included:

- Environmental concerns in ice-infested water
- Ecology of ice covered waters
- River, lake, and reservoir ice engineering
- Formation and evolution of ice
- Navigation
- Ice/structure interaction
- Mechanics and physics of ice
- Ice management
- Mathematical and physical modeling
- Oil spills in ice-covered sea areas
- Climate change and ice conditions
- Break-up processes and river ice jams
- Freeze-up processes
- River and reservoir ice problems at hydroelectric facilities
- Frazil and anchor ice
- Instrumentation for measuring and monitoring river, sea, and lake ice
- Remote sensing of river, lake, and sea ice
- Ice related chemistry in lakes and tailings ponds

Martin Jasek deserves special mention for his efforts in organizing this event. For electronic proceedings visit www.cripe.ca/iahr-2008/.

15th Workshop on the Hydraulics of River Ice, St. John's, Newfoundland. 2009

The next Workshop of the Committee on River Ice Processes and the Environment will be held in St. John's Newfoundland, in June 2008. Visit the CRIPE website for updates and information (<http://www.cripe.ca>).

Report of the Forest Hydrology Sub-Committee of CGU-HS

Activities relevant to forest hydrology in Canada in 2007-08

Major activities related to forest hydrology revolved around the participation of Canadian forest hydrologists in a number of hydrology-related workshops:

1. Workshop on "Mountain Pine Beetle and Watershed Hydrology Workshop, Kelowna, July 2007. This workshop (158 participants) had 22 presentations on research from BC, Alberta and Colorado related to the impacts of the Mountain Pine Beetle (MPB) infestation on hydrology. Additional information can be found at: Redding, T.E. (Ed.). 2007. Mountain Pine Beetle and Watershed Hydrology: Preliminary Results of Research from BC, Alberta and Colorado (Workshop Handbook and Presentation Summaries). 60 p. http://www.forrex.org/program/water/mpb_hydrology.asp
2. Workshop on "Upper Penticton Creek Watershed Experiment", Kelowna, July 2007. This workshop had eight presentations on hydrology research being conducted as part of the Upper Penticton Creek Watershed Experiment. There were 105 participants at the workshop, and 16 participants on the field tour. Additional information can be found in: Redding, T.E. and Winkler, R.D. (Eds.). 2007. The Upper Penticton Creek Watershed Experiment: Results of a Paired Watershed Study Into the Effects of Forest Management on Water Resources (Workshop Handbook and Presentation Summaries). 22 p. Redding, T.E. 2007. The Upper Penticton Creek Watershed Experiment: Results of a Paired Watershed Study Into the Effects of Forest Management on Water Resources - Post-Workshop Evaluation Survey Summary and Results. FORREX Internal Report. 9 p.
3. Workshop on "Linking Trees and Water: A Fresh Perspective on Forest and Flood Hydrology", Kelowna, July 2007. This was a technical hydrology seminar presented by Younes Alila (UBC) on a new analysis method for examining watershed disturbance effects on peak flows. There were 44 participants.
4. Workshop on "Watershed Response to Fire", Kelowna, March 2008. Dan Moore and Brett Eaton (both UBC) ran a workshop on the Fishtrap Creek project in Kamloops. The goal of the project is to provide a better understanding of the mechanisms of hydrogeomorphic response to vegetation disturbance, specifically the McLure fire of 2003. The workshop was attended by about 40 people from government, industry and academia. More information can be found at: http://www.geog.ubc.ca/~beaton/Fishtrap/Overview_files/FishtrapBooklet.pdf
5. Workshop on "Hydrological Implications of Mountain Pine Beetle: Learning from Experience", Edmonton, October 2007. This workshop brought together hydrologists and other scientists from Canada and the United States with interests in the impacts of the MPB infestation on water resources. Speakers addressed the hydrological, assessment, management and regulatory aspects of the infestation. There were about 200 participants.

6. Hydrology Technical Field Tour, Prince George, September 2007.

The focus of the tour was riparian evaluation protocols and long-term harvest impacts. There were 34 participants. Another area of activity was the annual eastern and western graduate student conferences sponsored by the CGU-HS. The western conference was held on January 28, 2008 at the University of Saskatchewan and had 19 student presentations, some of which dealt with aspects of forest hydrology. The eastern conference was held on December 7-8, 2007 at the University of Waterloo, with 19 oral presentations and 11 poster presentations. A portion of these presentations dealt with aspects of forest hydrology.

These activities attest to the increasing importance being paid by governments, industry and academics to the role of hydrologic processes in Canada's varied forest landscapes, and to the need to understand how these processes may respond to natural and anthropogenic disturbance. Another important activity related to forest hydrology in Canada was a progress report on forest hydrology research in Canada for the period 2003-2007 that was been prepared by members of the Forest Hydrology subcommittee of CGU-HS. This report formed part of the overall report on progress in hydrology in Canada prepared by the Canadian National Committee for the International Association for Hydrological Sciences (CNC-IAHS), presented at the 2007 Quadrennial meeting of the International Union of Geodesy and Geophysics held in Perugia, Italy.

Committee on Isotope Tracers

Jean Birks (Chair), Alberta Research Council, University of Waterloo

Tom Edwards, University of Waterloo

John Gibson, Alberta Research Council, University of Victoria (President IAHS International Commission on Tracers)

Claude Hillaire-Marcel, GEOTOP-UQAM

Roy Krouse, University of Calgary

Fred Michel, Carleton University

Objectives and Activities

The long-term objectives of the committee are to:

- promote and advance the understanding and application of isotopic tracer techniques in hydrology and related sciences
- initiate and participate in research and education programs, maintain contact with relevant organizations, report on national and international research activities, information sources, isotope monitoring networks, and databases

- establish working groups and/or subcommittees to assess specific, high-priority topics for research, monitoring and/or development, and
- disseminate current research and important findings to the scientific community via discussion, meetings and conferences, and publications

Progress on Issues and Objectives:

Tracer committee members continue to be active in the promotion and advancement of the understanding and application of isotopic tracer techniques in hydrology and related sciences. Of particular interest are the application of isotope tracers for the evaluation of hydrological and hydroclimatic models and the organization of regional, national and global networks that serve to build scientific capacity for tracer-based research. Some highlights from 2007 are summarised below.

Activities supported, 2007

Isotope Tracer Committee supported meetings and workshops

- *HW1001* Isotope Tracing of Water Balance, Hydrodynamics, and Hydrological Processes, Perugia Italy.

The session included 28 presentations (19 talks, 9 posters) and lively discussions on the role of isotope tracers in a range of investigations including precipitation-runoff generation processes, tropical storms, lake dynamics and water balance, hydrograph separation, unsaturated zone, groundwater recharge, karst systems, geothermal systems, and regional hydrology. A range of tracer applications were presented including use of artificial tracers, CFCs, SF₆, stable isotopes of water, carbon, sulphur and nitrogen, and numerous radioisotopes including carbon-14, radon-222, chlorine-36, and tritium. One significant trend in the discipline is toward holistic integration of isotopes and other tracers within multi-faceted, multi-disciplinary water resources research programs. Participants included representatives from countries in all inhabited continents. The success of the session and the extent to which tracers have been incorporated within presentations in other sessions suggests that ICT serves a growing audience in the hydrological sciences.

- *HS2005 Water Quality and Sediment Behaviour of the Future: Predictions for the 21st Century*, sponsored by ICWQ, ICCE, ICGW, PUB and ICT
- Biosphere-Atmosphere Stable Isotope Network 2006 Pre-AGU Meeting, 10 Dec 2007, San Francisco, USA (Gibson J.J., invited presentation)

Other and ongoing committee activities:

- "Report on isotope hydrology in Canada 2002-2007" was prepared by Gibson and Birks (with contributions from B Mayer, JF Helie, WM Buhay, ID Clark, TWD Edwards, K Higuchi, L Huang, and D Chan)

to give an overview of recent progress in isotope tracer hydrology and related research.

- maintenance of the Tracer Committee web-site http://www.science.uwaterloo.ca/~jjgibson/gibson_files/isotope.html
- support of IAEA/WMO Global Network of Isotopes in Precipitation and Large Rivers Program
- liaison and support for expanding national isotope monitoring/science networks (Canada: Canadian Network for Isotopes in Precipitation, Manitoba Network for Isotopes in Precipitation, United States: USNetwork for Isotopes in Precipitation)
- participation in the IAEA CRP *Geostatistical analysis of spatial isotope variability to map the source of water for hydrology and climate studies* (Birks, SJ)

Planned activities, July 2008 – June 2008

Special session, Isotope tracers in hydrology, Hyderabad India, 6-13 September 2009.

CNIP Subcommittee:

Operation of CNIP continued during the past year, with sampling conducted by the Meteorological Service of Canada and analyses supplied by the Environmental Isotope Laboratory, University of Waterloo. The network consists of 19 stations distributed across Canada (spanning almost 40° of latitude and 70° of longitude) collecting weighted monthly precipitation samples for d¹⁸O and d²H analyses. This marks the first time that both the southern and northern regions of the country have been simultaneously sampled. Sampling of the southern stations was initiated in 1997 to supplement an existing informal arctic network (now formally incorporated in CNIP) resulting in a ten-year dataset for the entire country, including a complete El Niño/Southern Oscillation (ENSO) cycle. Detailed analysis of the complete monthly data series from the first ten years of CNIP operation (1997-2007) is underway.

GEODESY SECTION NEWS

Prepared by Marcelo Santos

These are news that provide a quick glance of Geodesy Section activities in 2008.

34th Annual Meeting of the CGU, Banff, 11-14 May, 2008

A number of activities took place during the past CGU Meeting. We call attention to three in particular:

Geoid Workshop:

The 2008 Geoid Workshop had as a major topic the height reference system modernization in Canada. During the discussion, it was suggested that the International Association of Geodesy North-American Geoid Subcommittee should be officially and fully re-activated.

Geodesy Section Executive:

The Geodesy Section Executive for the 2008/2009 term was elected during the Annual General Assembly, and it is composed of: Marcelo Santos (president - UNB), Joe Henton (vice-president, NRCan), Georgia Fotopoulos (secretary, Toronto), Mohamed Elhabiby (treasurer, Calgary), Alex Braun (member-at-large, Calgary) and Patrick Wu (member-at-large, Calgary). The past-president is Spiros Pagiatakis (York).

Best Student Paper in Geodesy:

There were two winners of the “Best Student Paper in Geodesy”: Robert Kingdon (UNB) and Panagiotis

Vergados (York U). Their papers are, respectively: “A forward modelling approach for estimation of 3D density effects on geoidal heights,” and, “Bending angle retrieval algorithms using COSMIC mission observations.” Their papers appear below.

Special Issue in Geodesy of the Canadian Journal of Earth Sciences

A number of papers presented at the two Geodesy Section-sponsored sessions have been submitted to a Special Issue of the Canadian Journal of Earth Sciences, to be released in 2009. We expect to see the same happening from now on in every CGU Annual Meeting.

Geodesy Sessions at the 2009 Joint Meeting

We are all looking forward to the 2009 CGU Annual Meeting to be held in Toronto, 24-27 May. This meeting is special because it will be a joint meeting with the American Geophysical Union along with other Canadian sister organizations (GAC, IAH-CNC and MAC). There are a number of Geodesy related sessions in the preliminary program. Check on http://www.agu.org/meetings/ja09/program/scientific_session_search.php, and under Sponsor choose CGU or Geodesy for a list.

A forward modelling approach for estimation of 3D density effects on geoidal heights

Robert Kingdon¹, Petr Vaníček¹, Marcelo Santos¹

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Abstract

1. Introduction

The Stokes-Helmert scheme for geoid computation requires calculation of effects of topographical masses both as they exist in reality, and as masses condensed onto the geoid. The most comprehensive current evaluations of topographical effects in the Stokes-Helmert scheme account for terrain effects, use a spherical (rather than planar) approximation of topography, and incorporate 2-dimensional laterally varying models of topographical mass-density (e.g. Vaníček et al., 1999). A 2-dimensional mass-density model is used to approximate the Earth's real 3-dimensional density distribution because it is difficult and expensive to accurately determine the actual distribution of density within topography. We set aside the problem of determining exactly the real topographical mass-density distribution and instead seek an indication of how much accuracy is lost by using a 2-dimensional rather than 3-dimensional model of topodensity.

2. Method

We consider numerous hypothetical but realistic 3D mass-density distributions whose effect would not be accounted for in a 2D model. We have written a software program (Rad_Eff_Geoid) to apply forward modeling in each case to evaluate numerically the direct topographical effect (DTE), and the primary and secondary indirect topographical effects (PITE and SITE) of these masses. Our approach is a generalization of the work of Martinec (1998) dealing with topographical effects on geoid. Rather than repeat the mundane details of our approach, here we will provide an overview of the method emphasizing point of departure from approaches dealing with 2D models.

We consider any density distribution as a series of interfaces, whether these interfaces are drawn from

We apply analytical radial integration and numerical horizontal integration of the Newton kernel and its various derivatives to find the contribution of a 3D density distribution considered to represent the anomalous topographical density unaccounted for in a 2D model. Integration is performed over a limited spherical cap, with size determined by testing (normally no more than 3 degrees), to determine effects on gravity and gravity potential of the anomalous masses over a grid of points. The DTE on gravity, the PITE on gravity potential and geoidal height, and the SITE on geoidal potential are calculated in this way. Stokes integration of the DTE and SITE is then performed over a spherical cap of maximum size 6 degrees to determine the DTE and SITE on geoidal height.

3. Results and Discussion

To evaluate the accuracy of our software, we first consider simple shapes whose effects on gravity may be calculated analytically at specific points. Here we present one such example, a disc of anomalous density of 660 kg/m^3 , 30 km wide and 250 m thick, embedded at a depth of 1500 m in topography 2000 m thick. In a real world context, this might

represent a disc of basalt embedded in a sandstone.

The SITE resulting from this shape is negligible. The DTE on gravity, and the PITE on potential, are given in Figures 1a and 1b below. These and later figures show an arbitrary 1 degree by 1 degree region, centered on the anomalous mass whose effect they depict.

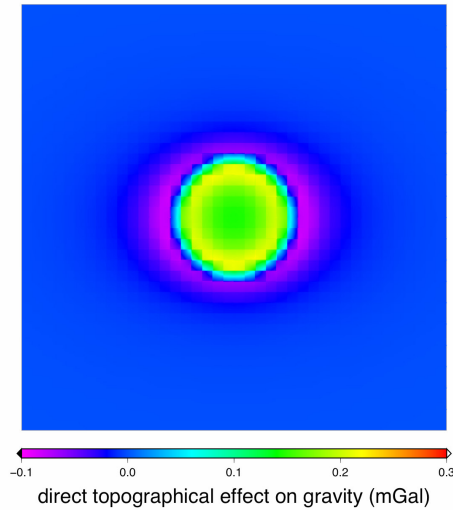


Figure 1a

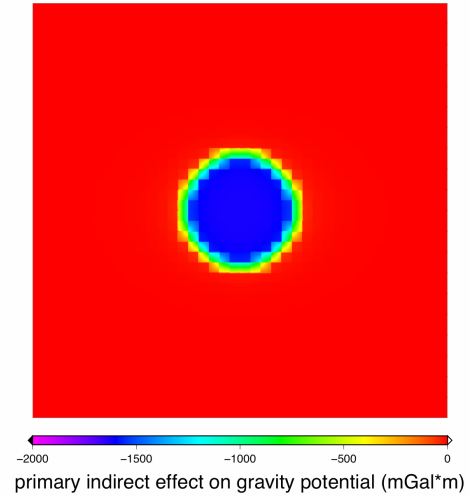


Figure 1b

For a computation point over the center of the disc, both of these effects may be calculated entirely analytically, without numerical integration. Figure 1a shows that this is not the maximum of the DTE, but has similar magnitude. Comparison with the analytical calculation at this point shows the error in our numerical approach. In this particular case our software calculates the DTE as 0.142 mGal, while an analytical determination yields 0.120 mGal (14.3 % error). Our software calculates the PITE as -1623 mGal*m, while the analytical result is -1716 mGal*m (5.4 % error). By performing the calculation with discs of various sizes and densities, we find no percent error greater than 15%, which we consider suitable for merely estimating whether the differences between 2D and 3D models are significant.

We further calculate effects on geoidal height corresponding to the DTE, PITE and SITE we have calculated. Again, the SITE is negligible. Results for the DTE and PITE are given in Figures 2a and 2b.

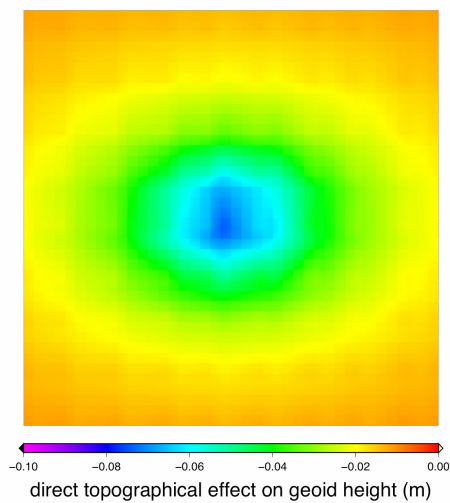


Figure 2a

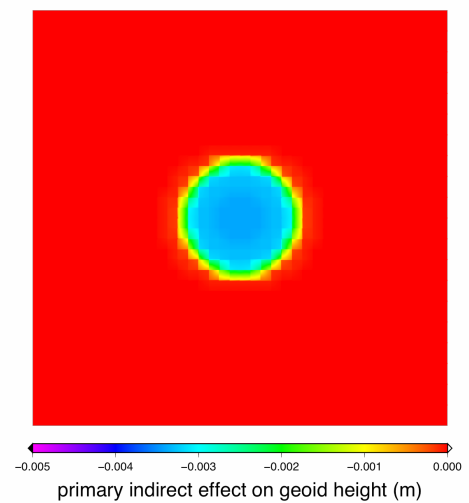
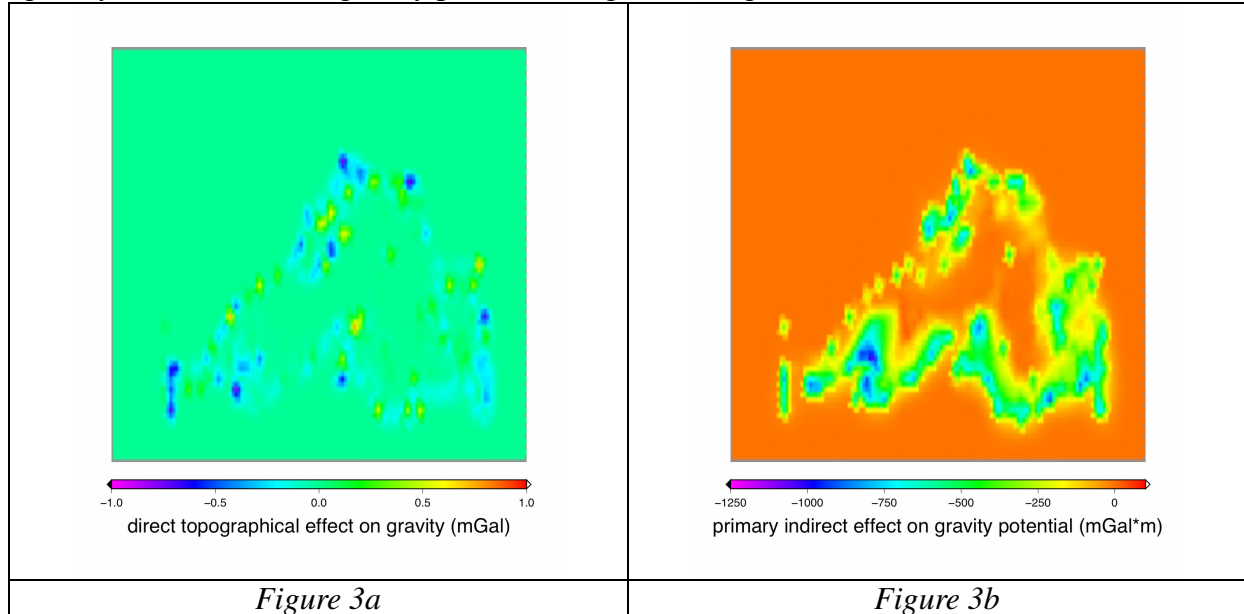


Figure 2b

Figure 2a indicates a minimum DTE of -7.1 cm, and Figure 2b a minimum PITE of -0.3 cm. As expected, the PITE is an order of magnitude smaller than the DTE. The magnitudes indicate however that for a realistic density distribution the contributions not accounted for in a 2D topodensity model may reach centimeters in magnitude.

We have further extended our software to deal with more complex density distributions, to estimate effects in more realistic situations. As an example application, we consider radial density effects over Lake Superior. We assume that a laterally varying model has already been applied based on the extent of the lake surface. Thus radial density effects will mainly be significant near to shore, since in areas where the lake bottom is deeper than the geoid there is no radial density variation within topography. Our results for the DTE on gravity and the PITE on gravity potential are given in Figures 3a and 3b.



We see that while effects of lake waters are relatively small, they are still significant. The DTE reaches -0.99 mGal and the PITE -1190 mGal*m in the most extreme areas.

4. Conclusions

We have created a method for calculating the DTE, PITE and SITE resulting from masses neglected in 2-dimensional models of topographical density. Our results are within roughly 15% error of values determined through an entirely analytical calculation. We find that the differences between geoidal heights calculated using 2-dimensional and 3-dimensional models might be on the order of centimeters, based on realistic simulations. While the software we have developed would allow implementation of a 3-dimensional model, we lack sufficient information on the radial topographical density distribution to apply it in such a way. In the future we will attempt through various simulations to determine how often 2-dimensional models are insufficient and to identify characteristics of such situations.

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Bending angle retrieval algorithms using COSMIC mission observations

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1. Introduction

COSMIC Data Analysis & Archive Centre (CDAAC) provides post-processed and real time data and derived products such as, raw GPS and orbit determination data, and neutral atmosphere and ionosphere observation files. The scientific foundation of the Constellation Observing System for Meteorology, Ionosphere & Climate (COSMIC) is the Radio Occultation (RO) (limb sounding) technique used to study planetary atmospheres. RO involves tracking of L1 and L2 pseudo-range and carrier phase data transmitted from Global Positioning System (GPS) satellites using receivers on Low Earth Orbiting (LEO) satellites (e.g. CHAMP, GRACE and COSMIC). RO takes place in the occultation plane, which is defined by the two position vectors to GPS and LEO satellites with respect to a geocentric coordinate system. Satellite RO observation data are primarily used for retrieving atmospheric parameters such as, atmospheric temperature, pressure and relative humidity for weather, climate, and space weather research and forecasting, but also for applications in geodesy and gravity research (Hajj, *et al.*, 2002). The ultimate objective of this study is to investigate the impact of higher order ionosphere contributions to the retrieval of atmospheric refractivity. We employ COSMIC raw excess phase delays as well as GPS and COSMIC position and velocity vectors.

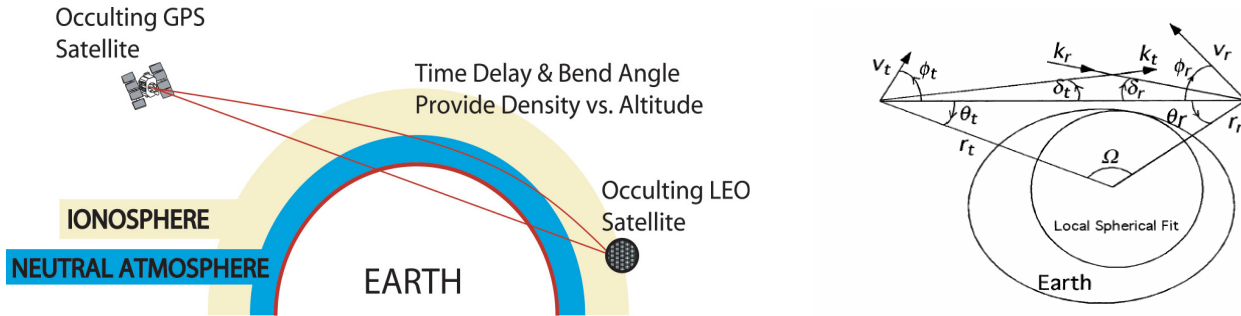


Fig. 1. Schematic of radio occultation geometry. Signal (red line) transmitted by the occulting GPS and received by the LEO satellite is refracted by the neutral atmosphere (in blue) and the ionosphere (in yellow) (left graph) (courtesy of ©2008 UCAR). Occultation geometry defining the velocity and position vectors and the angles involved (right graph)

2. Method

In previous work (e.g., Hajj, *et al.*, 2002), the GPS-LEO occultation technique has been described, from which bending angle profiles can be calculated. Figure 2 demonstrates step-by-step the procedure followed by the CDAAC team to calculate bending angle profiles. We adopt their approach to model and present preliminary results using near real-time observational data from the COSMIC mission in 2008. The first step is to understand how the RO works.

Initially, the L1 and L2 excess Doppler frequency shifts are obtained by differentiating consecutive measured excess phase delays divided by the time between the measurements (Fig. 2; left-side boxes). Next, the satellite elevation angles, and the velocity projections on the occultation plane of both LEO and GPS satellites are calculated given their velocity and position vector components in the X, Y and Z directions in the Geocentric Celestial Reference System (GCRS) (Fig. 2; middle boxes).

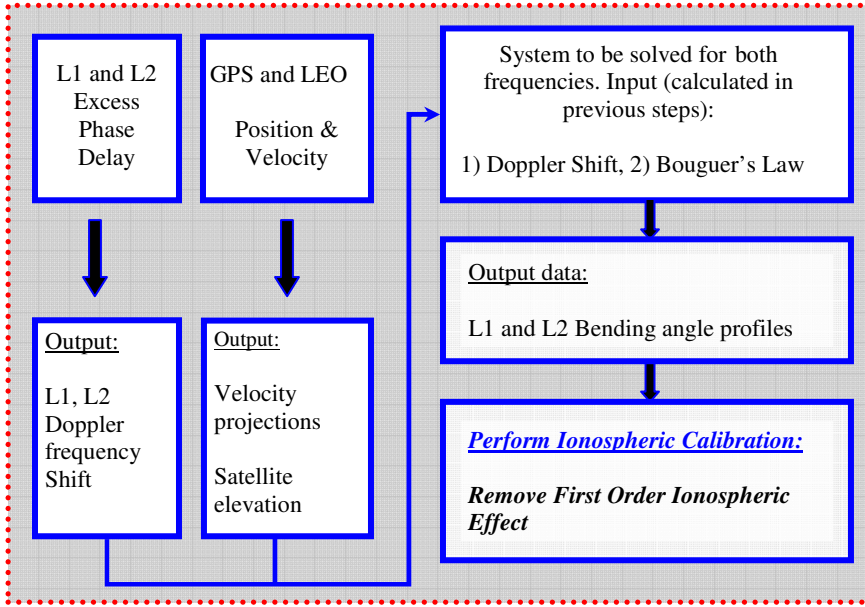


Fig. 2. Methodology followed for the calculation of L1 and L2 bending angle profiles. Blue-Italic-bold text indicates the research area of our focus.

The output products of the previous steps are used as input parameters in a non-homogeneous, non-linear system of equations given in Hajj et. al., (2002) for the estimation of L1 and L2 bending angle profiles. The system to be solved consists of two equations: a) the Doppler frequency shift and b) Snell's Law for spherical media (Bouguer's formula) (Fig. 2; top, right-side box), as shown below:

$$\frac{d\gamma}{dt} = (v_i \cos(\varphi_i - \delta_i) - v_r \cos(\varphi_r - \delta_r)) - (v_i \cos \varphi_i - v_r \cos \varphi_r),$$

$$r_i n_i \sin(\theta_i + \delta_i) = r_r n_r \sin(\theta_r + \delta_r),$$

where $d\gamma/dt$ is the excess atmospheric Doppler shift derived by differencing the Doppler shift observed in the presence of the atmosphere and the Doppler shift that would be observed for the same transmitter-receiver geometry in the absence of the atmosphere. The velocity and position vectors of both GPS and LEO satellites as well as the angles involved are shown in Fig. 1 (right-graph). The angles δ_i , δ_r are determined by simultaneously solving the system of the two equations above using Newton's method, and the bending angle is $\alpha = \delta_i + \delta_r$. The first order ionospheric correction can be realized through a linear combination of the derived bending angle profiles (e.g. Kursinski, et al., 2000, Hajj, et al., 2002). Although first order ionospheric corrections can account for the major part of the ionosphere, residual terms of higher order still affect the results and their significance is mentioned briefly in the conclusions.

3. Preliminary results and discussion

The excess atmospheric Doppler shift on the occulted signals between COSMIC – GPS16 starting at 2008/03/06 – 00:04 UT and COSMIC – GPS03 starting at 2006/04/21 – 19:19 UT are shown in Fig. 3. Figure 3 (left graphs) demonstrates the linear relationship between atmospheric Doppler and occultation time, peaking at about 160 m/s and 65 m/s, respectively. These case studies aim at demonstrating the effect of Doppler shift “jump” which sometimes is observed in the COSMIC measurement datasets. Figure 3 (left graphs; bottom) presents a case of a 25m/s “jump” in the Doppler shift during the 55 and 65s of the occultation (case of COSMIC – GPS03), which may be attributed to GPS signal loss (Hajj et. al., 2002). The COSMIC – GPS16 case study appears to be following a linear relationship from the beginning until the end of the occultation. Figure 3 (right graphs) shows the comparison between the derived bending angles (dots) and the observation data (solid line). The asymptotic miss distance - defined as the closest distance of the signal-ray from the centre of the Earth - is plotted against the bending angle (rad) in a linear-log graph to demonstrate their exponential relationship. Our calculations show very good agreement with the observations below the 6,430km asymptotic miss distance. Above 6,430km, (upper stratosphere/lower mesosphere) the GPS signal has to be corrected for higher order ionospheric terms to achieve better agreement. The small perturbations on the atmospheric Doppler (Fig. 3, left graph) after 55s, are responsible for the scattered behaviour of the bending angle profile.

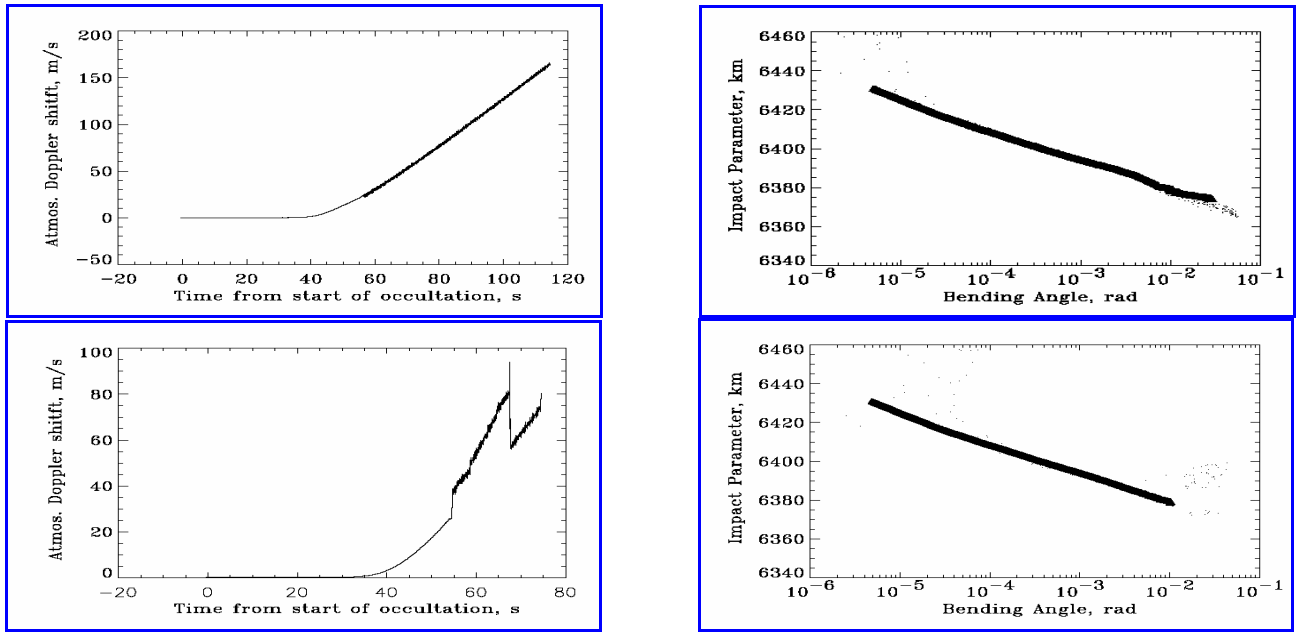


Fig. 3. Atmospheric Doppler shift (left graphs). Bending angle profile as a function of the asymptote miss distance (right graphs); the thick-solid-black line represents COSMIC observational data, and the dotted-grey line shows the retrieved bending angles.

It is worth mentioning that the retrieved bending angle profiles examined in this paper show a “jump” in the lower part of the atmosphere (below ~6,385km) similar to the “jump” shown in the Doppler shift. However, this behaviour is not shown in the results presented by the CDAAC team. Instead, the CDAAC bending angle profile seems to follow a rather exponential behaviour. Numerous COSMIC observational datasets (not shown here) have been processed showing a slight disagreement both, in the altitude and the number of observation points (see Fig. 3; left panel). The altitude difference may be attributed to a coordinate transformation from the Geocentric Celestial Reference System (GCRS) to the Earth Fixed reference frame, and to the ellipsoidal shape of the Earth, which still need to be implemented in our method. The difference, however, in the number of the observation points can be attributed to the CDAAC using constraints on the bending angle profiles to an exponential climatological model rejecting those observations that do not meet certain criteria; a speculation which seems to be supported by the results presented in Fig. 3 (bottom left).

4. Conclusions

It has been suggested that higher order ionospheric terms can enable more accurate positioning of LEO using line-of-sight carrier-phase measurements (e.g. *Hoque and Jakowski, 2007*) and hence, more accurate bending angle estimation. On these grounds, focus is currently being placed on developing a technique for the removal of second order ionospheric effects. The Earth’s magnetic field is being introduced into the mathematical formalism of higher order ionospheric terms, which we now have to account for. The results produced with our technique will be compared against COSMIC observational data for validation purposes. Upon achieving higher precision by accounting second order ionospheric terms, this research will provide the basis for a new data set of atmospheric parameters.

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Submissions should be sent to the Editor:

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