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THE NEWSLETTER OF THE CANADIAN GEOPHYSICAL UNION

IN THIS ISSUE

LE BULLETIN DE L'UNION GÉOPHYSIQUE CANADIENNE

President's Column

In this, my first column to the CGU membership as President, I would like to first extend my deepest gratitude to the Executive with whom I have served for the past two years. The two members whose roles are changing are deserving of special thanks. Gail Atkinson has been an important President for the CGU, creating numerous bridges among Canadian Geophysical Societies and has spearheaded the appointment of our Executive Director, Dr. Gordon Young. I look forward to keeping Gail close by as Past President. Spiros Pagiatakis officially moves out of the Past President role, however Past Presidents never really cease being Past Presidents and I am sure that we can look forward to Spiros' continued engagement in the business of CGU. On the theme of change, I am grateful to Claire Samson for assuming the Vice-President position, and the membership will certainly benefit from her insights and enthusiasm for the geophysical sciences in Canada. Thank-you Gail and Spyros, and welcome Claire.

It was a pleasure to see many of you at what was an excellent assembly in Saskatoon joint with CMOS and CWRA. I was particularly pleased that we were able to recognize so many superb student and faculty researchers with our Union and Section awards and scholarships. This years recipients are recognized in this edition of Elements. For its size, the CGU offers a very large number of prestigious and in some cases, high value awards. For faculty and government scientists, these awards are important career recognitions from a national society that are important metrics of achievement and impact both for the individual and for your department/institution. For students, a prize for your research presentation or a named scholarship in your field is not only financially rewarding, but has an impact on your developing CV that can lead to incredible future opportunities. That being said, one cannot be successful with awards and recognitions if one does not apply or is not nominated. I encourage you to nominate deserving colleagues for awards requiring them, such as the Union's Young Scientist and Tuzo Wilson Award. I strongly encourage students to make careful note of deadlines and commit the effort required to apply for our scholarships, and awards for posters and presentations. The returns on these modest investments in time may be career-long. Best wishes for the summer, and for many of you, your fieldwork.

Brian Branfireun

Message from the Executive Director

The Assembly in Saskatoon was a great success despite many government scientists being unable to attend. Joint meetings with partner organizations add breadth to the discussions and many new joint ventures and partnerships are the result.

Behind the scenes during the assembly there are many formal and informal business meetings. The Executive of CGU held its annual meeting which is supplemented by teleconferences during the year. Several important decisions were made during this meeting. Perhaps the most important relative to this newsletter is that, effective immediately, we will adopt an electronic only means of distribution. We hope that this will not inconvenience any members given that most now prefer on-line news and information. A second important decision relating to the awards is that the deadlines for application for several of the awards have been changed – the dates having been brought forward – please note the changes detailed later in this newsletter which will be put onto the CGU website.

Another important decision was taken during the Annual General Meeting of the CGU. As required by the Federal Government, CGU, as a not-for-profit corporation, must modify its bylaws in conformity with a set of new rules. A revised set of bylaws was presented to members during the AGU and unanimously adopted. These modifications, which will not change the functioning of the Union in any major way, will now be presented to Corporations Canada and, hopefully, accepted.

Gordon Young

J. Tuzo Wilson Medal – Call for Nominations

The Executive of the CGU solicits nominations for the J. Tuzo Wilson Medal – 2014. 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. Cherie J. Westbrook, Chair of the CGU Awards Committee, University of Saskatchewan (Email: cherie.westbrook@usask.ca). 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 December 23 2013**. 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 – 2014. L'Union décerne la médaille chaque année "en reconnaissance d'une contribution remarquable à la géophysique canadienne". En choisissant parmi les candidats, on considére 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. Cherie J. Westbrook, Président du Comité des Prix d'Excellence, Université de la Saskatchewan (Email: cherie.westbrook@usask.ca). 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 23 decembre, 2013**. 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.

Wilson Medalists

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	2006	Alan Jones
1999	David Dunlop	2007	Herb Dragert
2000	Don Gray	2008	Ming-ko (Hok) Woo
2001	Roy Hyndman	2009	Garth van der Kamp
2002	Doug Smylie	2010	Nigel Edwards
2003	Garry K.C. Clarke	2011	Fred Cook
2004	W.R. (Dick) Peltier	2012	Doug Oldenburg
2005	Ted Evans	2013	Zoltan Hajnal

CGU Young Scientist Award – Call for Nominations

The Executive of the CGU solicits nominations for the CGU Young Scientist Award – 2013. 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. Cherie J. Westbrook, Chair of the CGU Awards Committee, University of Saskatchewan (Email: cherie.westbrook@usask.ca). The nomination should be supported by three letters of recommendation from colleagues. **Nominations should be submitted by December 23 2013**. 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 – 2013. 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. Cherie J. Westbrook, Président du Comité des Prix d'Excellence, Université de la Saskatchewan (Email: cherie.westbrook@usask.ca). Les nominations doivent être supportées de trois lettres de recommandation de collègues. **Les nominations doivent être soumises avant le 23 decembre, 2013**. 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.

Winners

2005	Shawn J. Marshall, J. Michael Waddington
2006	No winner
2007	No winner
2008	Brian Branfireun, Scott Lamoureux
2009	Gwenn Flowers, Stephane Mazzotti
2010	Sean Carey
2011	Michael Riedel
2012	Brian Menounos
2013	Mathieu Dumberry and Brett Eaton

CGU Meritorious Service Award – Call for Nominations

The Executive of the CGU solicits nominations for the CGU Meritorious Service Award – 2013. 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. Cherie J. Westbrook, Chair of the CGU

Awards Committee, University of Saskatchewan (Email: cherie.westbrook@usask.ca). The nomination should be supported by three letters of recommendation from colleagues. Nominations should be submitted by **December 23 2013**. 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 – 2013. Le Prix pour Service Méritoire de l'UGC reconnait 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 recu 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 recommendations 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. Cherie J. Westbrook, Président du Comité des Prix d'Excellence, Université de la Saskatchewan (Email: cherie.westbrook@usask.ca). Les nominations doivent être supportées de trois lettres de recommandation de collègues. Les nominations doivent être soumises avant le 23 decembre, 2013. 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.

Winners

2004	Ron Kurtz
2005	Ted Glenn
2006	J.A.Rod Blais
2007	Ed Krebes
2008	Patrick Wu
2009	Garry Jarvis
2010	Zoltan Hajnal
2011	Masaki Hayashi
2012	Kathy Young
2013	Spiros Pagiatakis

The Stan Paterson Scholarship in Canadian Glaciology

The Executive of the CGU solicits nominations for the Stan Paterson Scholarship in Canadian Glaciology honoring Dr. Stan Paterson, a preeminent Canadian Glaciologist who has worked extensively on Canadian glaciers and is the author of the classic textbook The Physics of Glaciers. The scholarship is made possible by an endowment from Stan Paterson.

If you would like to nominate a candidate, please contact Dr. Cherie Westbrook, Chair of the CGU Awards Committee, University of Saskatchewan (Email: Cherie.westbrook@usask.ca). The nomination should be supported by two letters of recommendation. Nominations should be submitted by **October 29 2013**. Additional details concerning the nomination process can be obtained from the Chair of the CGU Awards Committee and from the CGU website http://www.cgu-ugc.ca/medal/StanPatersonAward.pdf

Award winner 2013 Ashley Dubnick

The 2013 CGU J. Tuzo Wilson Medallist: Zoltan Hajnal

Citation by Jim Merriam, University of Saskachewan

Ladies and gentlemen, it is my distinct pleasure to deliver the citation address for the award of the 2013 J. Tuzo Wilson Medal to Professor Zoltan Hajnal. Zoli emigrated from Hungary in the 1950's and almost immediately began a long association with his profession and the University of Saskatchewan by enrolling in Geophysical Engineering, receiving a B.E. in 1961 and an M.Sc. in 1963. His first work in seismology - he is best known as a seismologist - was his PhD from the University of Manitoba in 1970. That thesis involved cobbling together a long refraction and reflection seismic survey in western Canada. This was a mode that he would return to again with a profile across the Williston basin, conducted with one of his graduate students, as well as with the LITHOPROBE Trans-Hudson Orogen Transect.

Zoli is a seismologist with great range. He has performed some of the deepest seismic reflection surveys but has also extended the method to the shallowest depths. He is best known however for the many large-scale seismic investigations he has been involved with in Canada (CO-CRUST, LITHOPROBE) and internationally. He was co-leader, along with John Lewry, of the highly successful Trans–Hudson Orogen Transect, which changed the interpretation of the Trans Hudson Orogen. There is probably no other LITHOPROBE transect that resulted in such a comprehensive re-interpretation of the geology. That transect attracted a lot of attention from industry, and at Zoli's urging the Uranium industry, taking advantage of the LITHOPROBE presence of equipment and crew, funded a high resolution seismic survey in the Athabasca Basin. The application of the seismic method in minerals exploration was rare at that time, but that work resulted in the discovery of a new Uranium deposit and of course sustained interest by the industry in applying the seismic method. Autonomous seismic recorders were a key component of many large offset LITHOPROBE profiles. Zoli played a major role in writing the specifications for these instruments which were eventually made commercially available and are in use world-wide.

Zoli is an energetic and reliable collaborator. His LITHOPROBE successes testify to that. All of the support letters for the Wilson nomination praise his ability to attract and keep collaborators.

The CGU owes much to Zoli, he is a past president of the CGU, 1983-1985, and has served in many other capacities. It was during his term as president that the CGU resolved to become an independent scientific society. He and members of his group have been fixtures at CGU meetings for many years. There were three papers delivered in one session at this years meeting.

In the academic world citations are the currency, so I looked at Zoli's record. He has nearly one hundred refereed publications and there have been well over a thousand citations to those papers. For those familiar with the system, his 'H' index is a very respectable 23.

Zoli has been fortunate in attracting good graduate students. Good scientists always seem to attract good students. Through his connections with the geophysics community in Hungary (he was elected a member of the Hungarian Geophysical Society in 1996) he brought several high quality students to the University of Saskatchewan. These individuals are still making valuable contributions to geophysics in Canada and internationally.

I have already mentioned that he is a geophysics graduate of the UofS, so that program has been around for awhile, but it would be fair to say that during Zoli's tenure as professor it gained national recognition. Zoli and Don Gendzwill established the first geophysics field school in Canada. I don't think there is a geophysics program in Canada today that does not have a field school. Indeed, a field school is part of the requirements for registration as a professional geophysicist. At one time the field school was rumored to be the most expensive class at the University of Saskatchewan. Zoli fought hard to maintain it during the budget restrictions of the early nineties, a time when geophysics programs at larger, richer, universities were suspended. It is sometimes difficult to convince people of the value of faculty research to undergraduate programs, but Zoli's seismic adventures in the summer (to the Arctic, the Southern United States and all the many LITHOPROBE transects he participated in, especially the THOT) were a source of valuable experience for many of our students. Experiential learning is very popular now, but Zoli was there thirty years ago. I am sure all our graduates have fond memories of his classes. Was his (slight) accent a problem in the classroom? He famously and routinely responded to puzzled looks by saying "Am I speaking English folks?"

There are two aspects of Zoli's professional personality I should make you aware of. The first is his love for large explosions. This is exceeded only by his passion for battling bureaucracy. Many of you may remember the show Home Improvement from the nineties. The star's mantra was MORE POWER. In Zoli's case it would be MORE DYNAMITE. If you encourage him after dinner I am sure he can tell you some entertaining stories about his adventures with dynamite. I doubt any other Wilson medalist has had as many battles with bureaucrats as Zoli. Certainly they would not have had as many victories. I have an anecdote to relate that ties these two passions together, (more dynamite and fighting bureaucracy). I remember Zoli complaining to me once that he was having trouble getting a licence from the Saskatchewan government to set off a rather large explosion for a long offset refraction survey. Their rationale was that no one had ever been given permission to set off such a large explosion in Saskatchewan. Somehow Zoli managed to produce a Saskatchewan licence issued to him many years previously for an even larger explosion. How he managed to find that piece of paper in his office is another story, but no matter how old, or how long it has been since eyes have scanned it, if it is in there, Zoli somehow manages to find it. If I am lucky enough to give the citation for his next medal I would love to spend some time talking about his office.

Zoli, it was so easy to get the many letters of support that are required to back up a Wilson Medal nomination. The glowing terms that were used to describe your work and all your many accomplishments say much about the high regard that your colleagues have for you. Congratulations.

I would like to acknowledge Ron Clowes and Don White who did much of the work putting together the nomination. Thanks also to the many colleagues, collaborators and former students who wrote wonderful letters in support of the nomination.

Acceptance, by Zoltan Hajnal, University of Saskatchewan

Mr. President, Esteemed Colleagues, Ladies and Gentlemen,

I have the great pleasure of personally knowing most of the previous recipients of the Tuzo Wilson Medal. They all made outstanding intellectual contributions to the development and enhanced application of Canadian Geophysics. It is therefore, an immense honour to receive this most prestigious award of the Union. I am deeply privileged to join a special circle of distinguished colleagues.

Thank you Jim, for your extremely generous words. There are also anonymous individuals who are responsible for my nomination, others who have written letters of support on my behalf and the CGU awards committee who are responsible for selecting me. Please accept my sincere gratitude.

I am delighted to share this medal with my past and present, graduate students and research fellows. They shared with me, without serious objections, many of the ups and downs of numerous field programs. We had one of the smallest teams of the LITHOPROBE Transects, but through their dedication and extra efforts, we always successfully completed all the tasks. I have been blessed with exceptional young collaborators whose excellent contributions provided the major components to any of the successes we may have had.

Through the years, I had many exciting opportunities, all because I was extremely fortunate to receive unconditional support of many, benefitting from the sincere cutting-edge advice of several mentors. There is insufficient time to recognize all of them; however I have a few recollections to share, starting with Tuzo Wilson. The consequences of the disastrous outcome of the 1956 Hungarian Uprising brought a number of engineering students, some us in geophysics, from Sopron University, to Toronto. The Ontario Mining Association funded a special English language course for us. One of the most enthusiastic volunteers of the program was Professor Tuzo Wilson, who gave us a number of animated lectures. He discussed the dynamic progress of the plate tectonic principles and pointed out the importance in overcoming the old dogmas of Earth Sciences, quoting Bernard Shaw, *"Those who cannot change their minds cannot change anything"*. His informal approach toward us made us quickly realize the openness of the new world in which we were fortunate to find ourselves. He wanted to know as much as possible about us. We were guests at his cottage on several occasions, where he wanted to discuss the world behind the iron curtain. During our stay in Toronto, he was elected president of the IUGG and was asked to take a trip across the Soviet Union. We were delighted to help him do his homework for the visit to the dark other side of the world. It turned out that, beyond his exceptional understanding of tectonics, he was also an astute observer of humanity. When he returned from the trip, he again communicated with us, reporting that he now had a better grasp on the inhumane world found in the Soviet Union. He predicted that by the end of the twentieth century the Soviet Empire would fall apart. He was out only by nine years with his prediction. Not bad for a geophysicist temporarily indulging in the intricacies of political science.

My primary or only objective at the time was to complete my university education, and I investigated every geophysics program across the country. The just introduced new program at University of Saskatchewan suited most of my requirements including my level of finances. It turned out to be the best decision I could have made. Don Hall was my geophysics professor, with a diversity of interests and many projects. Conducting his resistivity survey programs, during summer breaks, brought my shaky financial status in order, and my undergraduate thesis on micro-gravity studies became our first publication in Geophysics. After completion of my M.Sc., Don departed to University of Manitoba and I joined the rank of exploration geophysicist with Chevron in Calgary. My wife, Vivian, was teaching in Bowness and we were expecting our first baby. We thought we were settled for the long run.

A letter from Don Hall turned our quiet world upside down. I was offered the management of the field program for the just initiated deep seismic studies at University of Manitoba, with compensation equivalent of my Chevron salary, and opportunity to pursue studies in a Ph.D. program. This turned out to be an ideal introduction into the field of lithospheric studies which changed my professional life to this day. Like Tuzo Wilson, Don did not have fear to search for the impossible. He encouraged me to design a data acquisition program to record deep crustal vertical reflections and search for converted waves, both of which, according to the gospel of the day, were theoretically possible but too weak to be practically observable. These were also the days of the late 1960s, and the arrival of the digital revolution in geophysics. We still had to record analog data, but we were able to gerrymander equipment to digitize the observations. Naturally I had to write all the programs from scratch to process the data. The beauty of all this adventure was that there were no experts to consult with on the entire campus, and very limited few anywhere. Consequently everything had to be worked out from basic fundamentals. In 1970, after five years, everything was working, the fun ended, money ran out, but I had my degree. The next step was to relocate the family.
There were interesting opportunities in industry, but they all were south of the border. As we were not very anxious to leave Canada, we responded positively to the call of the old Alma Mater, U of S. Here we are 43 years later, still in Saskatoon.

By joining the academic world I was also invited to join the COCRUST (Consortium for Continental Reconnaissance Using Seismic Techniques) a group of prominent crustal seismologists of Canada. It represented my dream coming through, as we were involved in seismic studies of the lithosphere, a continuation of the search of my Ph. D. program. Furthermore one of our major projects was in southern Saskatchewan. The group however quickly realized that to fulfill all our objectives, the program has to evolve into multidisciplinary investigations. After a number of intensive debates, LITHOPROBE was born. Several of the champions of this highly successful national program have been recognized by receiving this prestigious award, Ernie Kanasevich (1988), Mike Berry (1994), Charlotte Keen (1995), Chris Beaumont (1997), Ron Clowes (1998), Roy Hyndman (2001), and Fred Cook (2011). Shortly after the publications of the first set of comprehensive scientific results and realization of its organizational effectiveness, the program received international acclaim. It is still the fundamental template for planning and implementing of major geoscience research endeavors around the Globe. All phases of the LITHOPROBE investigation demanded comprehensive preparations and timely results, while the multi-disciplinary approach to final synthesis always generated positive outcomes.

One of the memorable benefits of our involvement in LITHOPROBE arose early in 2000 when I was asked to help organize a multi-nation lithospheric experiment in central Europe. Eventually with the help of Randy Keller from University of New Mexico, CELEBRATION 2000 (Central European Lithospheric Experiment Based Refraction), a huge active source lithospheric experiment, was launched with involvement of 14 countries, 28 institutions, approximately 1000 recording systems from Canada and USA, and 10 profiles, some of them 1500 km long. Publications are still coming out and many old tectonic models of the area are falling by the wayside. But ultimately, Ladies and Gentlemen the secret of all my success hinges on one step. One young woman from Dauphin, Manitoba decided to gamble against all parental advices and married this wild Hungarian revolutionist. After 50 years of marriage, she is still tolerating and sometimes encouraging my infatuation with geophysics. In the process, she taught me that in Canada you do not bring up kids with Eastern European iron discipline, although a love of soccer is allowed. The outcome has been very positive and our two children, Catherine and Zoltan Jr. join us today to celebrate. Nowadays a family subcommittee, with 5 Ph.D.'s (daughter-in-law included) proposes the possible solution to any problem, and then we unanimously accept Mother's advice. In closing, many thanks again to CGU for this honour and unforgettable event and I wish all of you comparable positive outcomes with your scientific adventures.

The 2013 CGU Young Scientist Award Winners: Mathieu Dumberry and Brett Eaton

Citation for Mathieu Dumberry by Micheal E. Evans, Maurico Sacchi, Douglas R. Schmitt, University of Alberta (presented by Douglas R. Schmitt)

The Canadian Geophysical Union, via the Young Scientist Award, recognizes outstanding research contributions by young scientists. Mathieu Dumberry is a young scientist who has made important contributions to the field of core dynamics and, therefore, we applaud this well deserved recognition.

Mathieu received a BSc in Physics from Université de Sherbrooke, in 1994, an MSc in Geophysics from UBC in 1998 and a PhD from Harvard in 2004. Mathieu held a postdoctoral fellowship at the University of Leeds from 2004 to 2007, and he became an Assistant Professor of Physics at the University of Alberta in 2008. His being awarded the "Zatman lecture" at the 11th symposium of SEDI (Study of the Earth's Deep Interior) in 2008 is evidence that his work is recognized internationally. He was also granted a highly competitive and prestigious Postdoctoral Fellowship of the Natural Environment Research Council of United Kingdom (NERC), 2004 – 2007.

Mathieu maintains the rich Canadian tradition of global leadership in geodynamics. His work primarily focuses on applying analytical methods to solving problems of the Earth's deep interior. His work heavily relies heavily on techniques of mathematical physics where he integrates rotational dynamics and magneto-hydrodynamics to elucidate electromagnetic coupling between the earth's inner core, the outer core, and the mantle.

It is important to point out that, before leaving Canada for doctoral studies and postdoctoral research positions, Dr. Dumberry received his basic academic training in institutions across Canada. This has given him a breadth of perspective that few are fortunate enough to share. He has worked at some of the best schools in the world for Geophysical studies and he maintains close links with these institutions. This results in a flow of researchers back and forth to Edmonton that helps to keep research in Geophysics healthy at the University of Alberta specifically, and by extension to all of Canada more generally.

We feel extremely fortunate to have attracted Mathieu back to work here in Canada. In addition to his strong record of research accomplishments, he is a valued colleague in the Geophysics group at the University of

L to r: Brian Branfireun, Mathieu Dumberry, Doug Schmitt

Alberta. He takes a keen interest in what the undergraduate and graduate students are doing and makes himself generously available to them. He always takes the time to participate in the student's social functions. With regards to teaching, he communicates effectively at all levels from first year introductory Geophysics to advanced graduate level Geodynamic theory. Proof of this lies in the strongly positive teaching evaluations he receives. Finally, he is a wonderful colleague to work with and helps to make the whole group run better. His current trajectory indicates that he will be one of the key Canadian Geophysical researchers of his generation who will assume the responsibility of maintaining Canada's strong reputation in solid earth Geophysics. We urge you to recognize his existing successes in order to help motivate him to make increasingly important contributions into the future.

On a personal note, we are proud that Mathieu is our colleague and that we have been able to attract him back to Canada; we are honoured to provide his citation for this award.

Acceptance by Mathieu Dumberry:

Many, many thanks to the CGU for this award. I will try to keep this very brief. I do not think any of us is doing science with the intention of winning awards. Yet, when you receive a prize like this one, it is an indication that your colleagues believe that your work is excellent. And this is the best possible reward. It means that all the hard days (and there are many) are worth plugging through, because the end product is well appreciated.

Science is not an individual sport. The number of people that have played a role in my career is too long to list here. But I can assure you that without the help and support from advisors, fellow students, postdocs and colleagues, I would not be standing here tonight.

To win a prize, you must first be nominated. I believe it is Woody Allen who said that half of life is just showing up. So on that note, I must thank my colleague Doug Schmidt for taking the time to put my nomination forward. As you know, my work is focused on the dynamics of deep planetary interiors. So you will all understand that I will proudly display this prize not on my mantle, but on my core!

Citation for Brett Eaton by Michael Church, Dan Moore and Graeme Wynn, University of British Columbia (presented by Dan Moore)

Dr. Eaton is a worthy recipient of the CGU Young Scientist Award for 2013, first of all on the basis of his fundamental contributions toward the resolution of one of the outstanding problems in Earth science – the form of river channels. This problem was first seriously essayed in the late 19th century by engineers seeking to design unlined irrigation canals (i.e., ones that would pass water without effecting net erosion of the sediments in which they were constructed, nor channel clogging deposition of sediment). Their solutions were entirely empirical. It was extended to river channels in the 1950s, but no theoretical progress was made. In ensuing decades various extremal principles (such as, that river channels 'maximize sediment transport') were put forward in an attempt to overcome the apparently under-defined nature of the problem. It remained for Dr. Eaton to finally place the problem on an entirely physical footing by adopting two principles: first, that the channel adjusts to pass the water and sediment load (independent, landscape-defined quantities) presented to it, and second, that the strength of the bank sediments is critical to determining the resultant channel form. The former is an important insight; the latter seems obvious but had not heretofore been incorporated into analysis because no one knew how to measure it. The result, worked out in his Ph.D. thesis, was the publication of "Rational regime model of alluvial channel morphology and response" (*ESPL* 29(4), 2004: 511-529: the secondary authors were his academic supervisors), which was awarded the 'best paper' prize of the British Society for Geomorphology in 2005.

Dr. Eaton has developed two exemplary lines of research from this foundational paper. First, the predictions of the theory (named the 'UBC Regime Model', UBCRM, later extended to the 'Reach Scale Channel Simulator', RSCS) were tested experimentally (beginning with work within his Ph.D. project, but continued after) (Eaton et al., 2006; Eaton and Church, 2009) and data of river channel form taken from the literature were shown to conform with the theory (Eaton and Church, 2007). Second, he has expanded and developed the bank strength criterion (originally worked on by R.G. Millar, one of his Ph.D. supervisors) in order to make it more tractable (Eaton, 2006; Eaton and Giles, 2009). Finally, he has shown that the UBCRM contains within it a rational explanation for the basic morphological form (single thread or compound) of river channels, a second classical problem that has defied rational solution for more than half a century.

With the RSCS in hand, Dr. Eaton is able to go on to tackle a wide range of problems concerning channel response to perturbations in the principal independent conditions – in the relatively short run, water and sediment supply. Accordingly, he has turned his attention to the response of a river channel to radical land surface change, exemplified by wildfire, and finding some counterintuitive results. It turns out that modification of the independent forcing conditions as the result of the fire is less important than the slow change in bank strength that accompanies root decay of burned trees over a period of years. This result emphasizes what Dr. Eaton' theory predicts, that the previously neglected bank condition is the single most sensitive determinant of channel form. Dr. Eaton has also applied his insight to the effect on the river of regime changes brought about by damming a river (as for hydro power generation). By playing a leading role in the NSERC Strategic Network HydroNet, he is bringing insight into river channel changes and consequent changes in aquatic habitat to a cooperating community of river scientists and ecologists seeking to understand the onsequences of manipulating flow and sediment delivery.

Dr. Eaton's recent work sustains his growing reputation as an original thinker and talented investigator of rivers. He has embarked on a series of studies to examine the role of large wood pieces in river channels – an important factor in small and intermediate scale channels in forested environments worldwide. Much like the problem of channel form (but more recently), this topic has been much described with little progress in understanding. Using reduced-scale experiments in a large stream tray as a source of critical observations, Dr. Eaton has elaborated a stochastic model of the process (Eaton et al., 2012; Eaton and Hassan, in preparation) that will generate a more comprehensive understanding of individual cases.

These substantive achievements, taken all together, demonstrate a more basic aspect of Dr. Eaton's worthiness to be named a CGU Young Scientist: his talents extend equally to field, experimental and theoretical work. This is a powerful combination of talents enjoyed by few individuals. Dr. Eaton's abilities in the field are demonstrated by the insight he has gained from his investigations of the McLure fire's effects on Fishtrap Creek in the interior of British Columbia – the inspiration for the work on fire-related channel changes – and from his work in HydroNet. His experimental expertise has been demonstrated in the experiments related to regime theory development and, more recently, in the clever use of model materials to study the effects of wood debris in stream channels, while his theoretical abilities are plainly evident in all his work, but principally in the development of the rational regime theory and exploration of its consequences.

Dr. Eaton's theorizing talent is particularly important in the field of geomorphology which, until relatively recently, has suffered from an absence of well-trained, geophysically oriented analysts. Dr. Eaton may be bracketed with the best few investigators in a new generation of geomorphological scientists who do possess the ability to formulate physically sound theory. These investigators would include Taylor Perron of the Massachusetts Institute of Technology, and Michael Lamb, of Caltech.

Dr.Eaton's leadership in his field is by no means limited to his own research accomplishments. He is a leader by virtue of his willingness to collaborate with colleagues and students, expanding their view at the same time as he develops his own insights. Moreover, he is already recognised as an outstanding teacher, having been voted so by the students in his department after only two years, and having been awarded the university's Killam Teaching Prize in only his sixth year in post. He espouses an approach to teaching that features the introduction and solution of problems, a strategy that teaches students to think creatively about the subject – surely a superior form of pedagogy. Dr. Eaton has also assumed a number of technical leadership roles in CGU and in the Association of Professional Engineers and Geoscientists of British Columbia.

We congratulate Dr. Eaton for his exemplary accomplishments to date, and are pleased to see them recognized formally through his selection to receive the CGU Young Scientist Award.

Acceptance by Brett Eaton:

L to r: Brian Branfireun, Brett Eaton, Dan Moore

I am deeply grateful to my colleagues who nominated me for the CGU Young Scientist award. Considering the academic achievements of my co-awardee, Dr. Mathieu Dumberry from the University of Alberta, and of the previous award winners, I am extremely honoured to have been chosen by the selection committee. Thinking about it, I am struck by the fact that the achievements recognized by this award are fundamentally intertwined with those of my mentors, my peers and my students. The path by which I arrived at this place looks incredibly precarious in hindsight, and there are a number of seemingly inconsequential decisions that have turned out to be momentous turning points. Often, there are people associated with those turning points, and they are probably unaware of the profound influence that they have had on me. There is not enough space here for me to mention all the ways in which my peers have enriched my professional life, nor to acknowledge the many joys and inspirations that come from working with my graduate students, all of whom have been fantastic academics and wonderful people. Suffice it to say that we form a community, one that I value and for which I am eternally grateful. I would like to recognize a few of the mentors that have profoundly influenced me, including Brian Branfireun, Michael Church, Brian Guy, Marwan Hassan, Michel Lapointe, Robert Millar, Dan Moore and Ellen Petticrew. Many of these people are former supervisors, others have acted as mentors in other capacities; all of them are tremendous individuals with incredible intellectual talents who have made critical contributions to by professional career. Thank you all.

The 2013 CGU Meritorious Service Award Winner: Spiros Pagiatakis

Citation by Masaki Hayashi, Rod Blais and Marcelo Santos

We are delighted to announce that the recipient of the CGU 2013 Meritorious Service Award is Professor Spiros Pagiatakis. Spiros presented his first paper at the 1982 CGU meeting as a graduate student. Since then he has been a very active member of the CGU and contributed immensely to the organization through his leadership roles.

Spiros received an undergraduate engineering degree from National Technical University of Athens in Greece, and M.Sc. and Ph.D. degrees in Geodesy and Geodynamics from the University of New Brunswick. His Ph.D. research was on the effects of ocean tide loading on earth surface displacement and gravity and he continued to carry out active research on geodynamics in global and regional/local scales, as observed by geodetic measurements such as Global Positioning System, Low Earth Orbiting Satellite mission, and Gravity Recovery and Climate Experiment mission.

He was a research scientist at what is now called Geodetic Survey Division of Natural Resources Canada for eight years, and served as the Head of the Gravity and Geodetic Network Section before he moved to York University in 2001. He is currently the Professor and the Associate Dean of Research and Graduate Studies in Lassonde School of Engineering at York University.

In 1997 the CGU initiated focus groups in several key research areas of solid earth geophysics, including the research group on geodesy, gravity, and geodynamics. Spiros served as the leader of this group and successfully organized special sessions on these topics in the 1998 annual meeting in Quebec City. This research group led to the establishment of the CGU Geodesy Section, in which Spiros served as the inaugural President, as well as a member of the CGU Executive Committee from 2002 to 2006. Spiros has been the key organizer of geodesy sessions at previous CGU annual meetings, and has promoted the Geodesy Section within the CGU and elsewhere. Spiros was very active in organizing meetings among Canadian geodesists that led to several collaborative research projects and research network proposals including GEOIDE and IPY. From 1999 to 2007, Spiros served as the Canadian National Representative to the International Association of Geodesy and a member of the Canadian National Committee for the International Union of Geodesy and Geophysics.

Spiros became the Vice President of the CGU in 2007, and served as the President from 2009 to 2011, and the Past President from 2011 to present. As the long-term serving member of the CGU Executive Committee, Spiros has made numerous major contributions to the CGU. As the President of the Union, he worked tirelessly to advance the objectives of the Union while strengthening the relationships with other scientific organizations on the national and international levels. The CGU and especially the Geodesy Section owe much to him for his many contributions over the past decade and half.

The CGU meritorious award expresses our appreciation for his many contributions to the Canadian geophysical sciences and the CGU. We are very delighted to present the 2013 Meritorious Service Award to Professor Spiros Pagiatakis. He is richly deserving of this honour.

L to r: Brian Branfireun, Spiros Pagiatakis, Masaki Hayashi

Acceptance by Spiros Pagiatakis, York University

Thank you Masaki, Rod and Marcelo for your kind and generous words about my contributions to our Union, our members and colleagues.

I'm honoured, I'm humbled, I'm privileged and touched to receive this award and join with pride the finest team of previous awardees who have contributed so much to CGU!

Sustained and significant contributions over many years cannot be achieved singlehandedly. I have been privileged to work with wonderful colleagues in the CGU executive, with the Geodesy Section and with all of you who have showed tremendous support and faithfulness in me to serve and lead this unique organisation. Without this unwavering support I wouldn't have achieved much. I promise to continue my services to CGU and remain devoted to its mandate in any capacity and as required. Thank you again for the great honour! My heartfelt appreciation to the CGU family for this extraordinary day!

The Stan Paterson Scholarship in Canadian Glaciology

Award Winner: Ashley Dubnick, University of Alberta, Edmonton

Acceptance:

I would like to send an enormous thank-you to Stan Paterson. It is a huge honour to receive an award from such a prominent scientist who has left a particularly strong imprint in the field of glaciology. As a student in glaciology, Stan Paterson's name seems to surface as often as the word glaciology itself. Stan's work has played a fundamental role in my understanding of these intriguing environments; his contributions and his generosity have proven to be incredibly important in fuelling my education. So thank-you Stan!

Of course my interest in glacier environments would have never transformed into such an intense fascination and scientifically intriguing journey without the support and guidance I have received from a particularly influential collection of individuals. The field of glaciology seems to be packed full of inspiring and generous people. Specifically, I would like to thank Martin Sharp who continually goes out of his way to provide me with remarkable opportunities – his mentorship, guidance, and generosity has truly made this what it is for me.

I'm sorry I'm not in Saskatoon to accept this award in person, but I figure there is no better place to be than in picturesque Narsarsuaq, Greenland, between an iceberg-filled fjord and a spectacular glacier spilling over the mountains from the Greenland Ice Sheet.

Report on the CMOS-CGU-CWRA Joint Congress in Saskatoon, May 26-30, 2013

Rod Blais

The first Joint Scientific Congress of the CMOS, CGU and CWRA was held on May 26-30, 2013, at the Teacher's Credit Union (TCU) Place in Saskatoon, Saskatchewan. The venue, the TCU Place, is located in the heart of downtown Saskatoon within walking distance of the beautiful South Saskatchewan River Valley. The Congress theme was "**Bridging Environmental Science, Policy and Resource Management**". General information can be found at the congress website www.cmos.ca/congress2013

Eight plenary speakers addressed the participants:

- **H. Wheater** (Un. of Sask.) on "Water Security in Western Canada: Science and Management Challenges";
- **T. Shepherd** (Un. of Reading) on "Understanding Uncertainty in Climate Models: Robustness of the Atmospheric Circulation Response to Climate Change";
- **W.R. Peltier** (Un. of Toronto) on "The Thermohaline Circulation of the Oceans: Impacts on Climate Variability and Change";
- **R. MacDonald** (IOS, DFO) on "Seasonal Ice in the Arctic Ocean is Vanishing – So, What Else is New?";
- **G. Rogers** (GSC) on "Earthquake and Tsunami Hazards on Canada's West Coast";
- **D. White** (GSC) on "The Aquistore Project: Commercial-Scale CO_2 Storage in a Saline Aquifer in Saskatchewan, Canada";
- **P. Myers** (Un. of Alberta) on "Freshwater Processes, Transport and Feedbacks between the Arctic and Sub-Polar North Atlantic Oceans";
- **J. Pomeroy** (Un. of Sask.) on "Regime Change in Canada: Hydrology's Response to Climate Change in Cold Regions".

A public lecture by **Ms. Paulette M. Fox** entitled "Linking Indigeneous Knowledge Systems with Science and Integrated Policy Development and Management Frameworks" was given on Tuesday, 28 May 2013. Brief biographies of those speakers and the Abstracts for those presentations can be found at the congress website.

Participation in this Joint Congress included some 109 CMOS registrants, 139 CGU registrants, 110 CWRA registrants, 218 other non-member registrants and a number of volunteers, teachers, etc., for a grand total of 687 participants. The CGU participation included 88 full members, 51 student members and many others classified as staff, volunteers, sponsors, etc..

A number of successful worshops were organized by CGU members: a 'Geoid Workshop' by M. Véronneau, a 'Geophysical High Pressure Research Workshop' by H. Mueller, a 'Finite Element Modeling Workshop' by S. Butler and an 'R Workshop' by D. Hutchison. Other workshops on climate and water related topics were obviously of special interest to many hydrologists. Again, more details can be found on the congress website.

The four CGU Sections were very well represented in the technical program with numerous multi-part sessions including two organized by Geodesy, seven by Hydrology, six by Biogeoscience and five by Solid Earth. A number of CMOS and CWRA technical sessions covered much common ground with Hydrology and Biogeoscience. Mathematics of Planet Earth (MOPE) also had a number of sessions with presentations of scientific interest to many CGU members. Everyone benefitted from the exchanges of ideas and discussions under the general theme of this Joint Congress.

Special thanks go to the very generous sponsors listed on the congress website and also, to the Pacific Institute for the Mathematical Sciences for supporting the MOPE technical sessions. All members of LAC and SPC (listed on the congress website) are to be sincerely thanked for their generous efforts over the past year to ensure the success of this Joint Congress of CMOS, CGU and CWRA. Comments and suggestions about such large joint CGU meetings are always welcome!

HYDROLOGY SECTION NEWS

Prepared by Sean Carey, President, CGU-Hydrology Section

CGU HYDROLOGY SECTION COMMITTEE REPORTS 2013

President's Report

The CGU Hydrology Section (CGU-HS) continues to be busy with a range of activities and initiatives. The CGU-HS was a prominent contributor to the Joint Congress of the CGU/CMOS/CWRA in Saskatoon. Attendance was strong and members contributed to a broad range of sessions. The annual Woo Lecture was presented by Philip Marsh from Environment Canada entitles "Arctic Hydrology: Complexities, Advances and Challenges". The talk highlighted in exceptional detail the past, present and potentially vexing future challenges of hydrology in cold regions. In addition, CGU-HS members John Pomeroy and Howard Wheater provided plenary presentations for the Joint Congress.

The CGU-HS presides and adjudicates over three awards. The D.M. Gray Award for Best Student Paper in Hydrology was awarded to Philip Harder (University of Saskatchewan) for the paper "Sensitivity of hydrological process simulations to precipitation phase differentiation". The Campbell Scientific Award for Best Student Poster in Hydrology was awarded to M.S.I. Kline (Western University) for the poster "Base and event-flow hydrologic and biogeochemical connectivity in a fen-stream transition in the central Hudson Bay Lowland". The D.M. Gray Scholarship (a Union award) was awarded to Scott Ketchison (University of Waterloo) for the proposal "The hydrology of a constructed watershed". Furthermore, the Shell Canada award for the Outstanding Student Poster Paper was won by Nadine Shatilla (McMaster University) for "The impact of surface mining on runoff timing and flow pathways, Elk Valley, British Columbia". There were many exceptional applicants in all categories and the CGU-HS encourages continued healthy submissions to the awards competition.

Once again, the CGU-HS published select papers in a special issue of Hydrological Processes. The issue was published 30 June and highlights eight papers presented at the 2012 meeting on a range of topics from wetlands to catchment classification. Once again, Hydrological Processes has agreed to host a special issue for papers presented at the 2013 meeting. A reminder that papers also presented in 2012 at the AGM are also eligible for the special issue. Manuscripts should be submitted via the normal online procedure by 31 August 2013. Additional details as to the special issue number will be provided soon.

The CGU-HS continues to sponsor annual student meetings. In the east, there was a joint meeting with the Biogeosciences section at Wilfrid Laurier University in early February. It was an excellent meeting with two sessions where many papers and posters were presented. While there was no Western meeting this year, in 2014 it will be hosted at the University of Saskatchewan. The 2014 CGU-HS eastern student meeting will be held at the University of Toronto.

Finally, there were some minor changes to the executive and a new slate was partly adopted for this year. There was agreement at the 2013 Annual General Meeting that terms of executive be staggered for continuity and the first student representative was selected. The 2013/2014 CGU-HS Executive and their length of term are:

Brian Branfireun (Past President - 1 year)
Sean Carey (President - 1 year)

William Quinton (Vice President - 1 year)
Daniel Peters (Secretary - 1 year)
Laura Brown (Treasurer - 2 years)
April James (Member at Large - 1 year)
Tim Duval (Member at Large - 2 years)
Colin McCarter (Student Representative - 1 year)

I wish to thank outgoing executive member Scott Lamoureux and Sarah Boon for their service on the executive.

Northern Research Basins Committee

Chair and Canadian Chief Delegate: Christopher Spence, Environment Canada, Saskatoon, SK.

The main activities of the CGU-HS Northern Basins Committee during the last year have focused on preparing for the 19th Northern Research Basins Symposium and Workshop in Alaska, August 11 – 17, 2013. The conference theme is **Water Resources: Developments in a Changing Environment.** Full details of the meeting and the proceedings can be found at www.19thnrb.com.

As outlined in the NRB Mandate and the Canadian NRB Terms of Reference, Canada can send delegates invited by the Canadian Chief Delegate (and approved by the CGU-HS Executive). The current proposed delegation represents a diversity of expertise relevant to the theme of the symposium and workshop. It is larger than the standard ten delegates, but some of the proposed delegates still require employer approval. Secondly, five of the delegates are students, important to ensure the long term viability of Canadian delegations to the NRB.

Name	**Affiliation**
Chris Spence	Environment Canada
Ric Janowicz	Yukon Territorial Government
Terry Prowse	Environment Canada
Kathy Young	York University
Ming-ko Woo	McMaster University
William Quinton	Wilfrid Laurier University
Rita Winkler	BC Ministry of Forests
Phil Marsh	Environment Canada
Roxanne Ahmed	University of Victoria
Allison Bawdon	University of Waterloo
Hayley Linton	University of Victoria
Brandi Newton	University of Victoria
Gillian Walker	University of Victoria

Canada continues to be responsible for the main NRB websites and NRB listserv; maintained through a contract with Laura Brown. These web sites: www.canadiannrb.com and www.northernresearchbasins.com contain information about the working group, the Canadian committee, past meetings, links to relevant websites, numerous photos, and the 19th NRB. Contact Chris Spence at chris.spence@ec.gc.ca for more information.

Committee on Isotopic Tracers

Committee members:

Jean Birks (Chair), Alberta Innovates- Technology Futures, University of Waterloo
Tom Edwards, University of Waterloo
John Gibson, Alberta Innovates- Technology Futures, University of Victoria (Past President IAHS International Commission on Tracers)
Claude Hillaire-Marcel, GEOTOP-UQAM
Bernhard Mayer, University of Calgary
Fred Michel, Carleton University

Tricia Stadnyk, University of Manitoba
Brent Wolfe, Wilfrid Laurier University

Background:

The CGU - HS Committee on Isotopic Tracers was established in 1997 to support and facilitate information exchange between isotope specialists and hydrologists both within Canada and internationally, and to address issues of importance to isotopic investigations including integration within broadly-based hydroscience research programs. Recognizing and supporting promising applications of isotopic tracers, promoting cooperative research, providing information resources, and articulating research and educational needs to government agencies, universities, and the general hydrology community are the fundamental aims of the Committee.

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 in the water survey, in understanding of precipitation processes and for regional, national and global networks that serve to build scientific capacity for tracer-based research. Some highlights from 2011-12 include:

The Water Survey of Canada, in cooperation with the University of Manitoba, University of Victoria, and Alberta Innovates Technology Futures, is supporting development of a national pilot network to demonstrate the value in systematic collection of river discharge and analysis for oxygen-18 and deuterium across Canada. Water sampling of several hundred key gauging stations is expected to commence in 2012-13. Further information can be obtained from John Gibson (jjgibson@uvic.ca).

An important precipitation isotope summary was published this year that explores the ability to model the spatial distribution of oxygen-18 isotopes in precipitation across Canada (Delavau et al. 2011). The paper utilizes the Canadian Network for Isotopes in Precipitation (CNIP) database. For more information contact Carly Delavau (umdelav0@cc.umanitoba.ca). Research on the isotopic labeling of precipitation in the arctic is being conducted by Fred Michel in collaboration with Dr. Feng at Dartmouth college in New Hampshire.

Jean Birks is leading the Canadian contribution to an International Atomic Energy Agency sponsored research program on “Use of Environmental Isotopes in Assessing Water Resources in Snow, Glacier, and Permafrost Dominated Areas under Changing Climatic Conditions”. In addition to describing the value of synoptic river surveys for large northern rivers (e.g. Yi et al. 2009), Canada is participating in a pilot study for testing the representativeness of snow lysimeters, snow cores, and Frisbee samplers. For more information contact Jean Birks (jean.birks@albertainnovates.ca).

Isotopic tracers methodology for estimating water yield to ungauged lakes has been incorporated within Environment Canada’s Oil Sands monitoring plan (see Environment Canada 2011). This strategy has previously been used by the Regional Aquatic Monitoring Program (RAMP) and by Environment Canada’s Acid Rain program to better understand site-specific hydrologic conditions across Canada (Gibson et al. 2010a,b). For more information contact John Gibson (jjgibson@uvic.ca) or Jean Birks (jean.birks@albertainnovates.ca).

Isotope tracers will be widely featured at the upcoming Goldschmidt Conference: Earth in Evolution to be held in Montreal during June 24-29 2012. Two sessions that will be convened by members of the isotope tracer committee including: 22c. Applications of emerging geochemical and isotopic analytical techniques for integrated water resource management and environmental monitoring, and 14e. New developments in understanding natural and anthropogenic water contaminants in the Athabasca oil sands region. Both sessions will highlight advances made in use of isotopic tracers. For more information contact Yi Yi (yiyi@uvic.ca).

Alberta Innovates Technology Futures and the Canadian Water Network are sponsoring an Oil Sands Water Research Colloquium on Surface and Groundwater Management in the Oil Sands Industry to be held June 6, 2012. The session will include discussion of isotopic and geochemical methods for fingerprinting water sources. For more information contact Jean Birks (jean.birks@albertainnovates.ca).

A special session will be held at the next Geological Society of America 2012 ANNUAL MEETING to be held in Charlotte, North Carolina, November 4-7 2012, co-sponsored by CGU committee on isotopic tracers, entitled "Biotracers, Mineralogical and Geochemical Properties of Circum-Arctic Sediment Sources and Runoff towards the Arctic Ocean (TS 123)". A large community is presently planning a drilling program in the Arctic Ocean in order to set up a robust geological history of the basin. One critical issue is to link detrital sediments to circum-Arctic sources using mineralogical, elemental and isotopic tracers as well as biotracers. Geoscientists with experience in surficial deposits, bedrock, major rivers and estuarine systems in surrounding lands, on ocean margin- and deep sediments are invited to contribute with reviews and new information about the mineralogy, geochemistry and biological/organic content of such potential sediment sources and their variability through time. Applications to issues such as changes in continental erosional rates and mechanisms are also welcome. For information contact Dennis Darby (ddarby@odu.edu) or Claude Hillaire-Marcel (chm@uqam.ca).

One important new research program underway is NSERC Discovery Frontiers Program: ADAPT: Arctic Development and Adaptation to Permafrost in Transition (PI Vincent; 2011-2016). This multidisciplinary and multi-faceted research program broadly addresses the fundamental research question: "What are the implications of rapid environmental change in Canada and the circumpolar North caused by thawing permafrost conditions?" Co-PI Brent Wolfe's (WLU) research will identify linkages among hydrological processes, limnological conditions and greenhouse gas exchange in thermokarst lakes. This is important because climate-driven alterations to lake-water balances (e.g., greater evaporation due to longer ice-free seasons, changes in precipitation regimes, accelerated permafrost thaw and more frequent lake drainage events) may influence limnological properties and hence greenhouse gas evasion rates. Research will utilize water isotope tracers and other approaches in present and past hydroecological studies of thermokarst lakes located in the subarctic discontinuous permafrost region in Nunavik and the continuous-discontinuous permafrost region in the western Hudson Bay Lowlands. For further information contact Brent Wolfe (bwolfe@wlu.ca)

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Recent publications in the field:

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Wolfe BB, EM Light, ML Macrae, RI Hall, K Eichel, S Jasechko, J White, L Fishback and TWD Edwards. 2011. Divergent hydrological responses to 20th century climate change in shallow tundra ponds, western Hudson Bay Lowlands. Geophysical Research Letters 38, L23402, doi:10.1029/2011GL049766.

Wolfe BB, TWD Edwards, RI Hall and JW Johnston. 2011. A 5200-year record of freshwater availability for regions in western North America fed by high-elevation runoff. Geophysical Research Letters 38, L11404, doi:10.1029/2011GL047599.

Yi, Y., Gibson, J.J., Cooper, L.W., McClelland, J.M, Holmes, R.M, Peterson, B., Isotopic signals (^{18}O, ^{2}H, ^{3}H) of six major rivers draining the Pan-Arctic watershed, Global Biogeochemical Cycles, 26, GB1027, doi: 10.1029/2011GB004159.

Recent graduate theses focused on isotopic tracers:

Chao, J. Major ion and stable isotope geochemistry of the Bow River, Alberta, Canada. MSc (Geoscience, University of Calgary.

Jasechko, S., 2011. Stable isotope mass balance of the North American Laurentian Great Lakes, M.Sc. Thesis (Earth Sciences Univ. Waterloo).

Light (Dobson) E. 2011. Characterizing the present and past hydrology of shallow ponds in the Churchill area using isotopic methods. MSc (Geography and Environmental Studies WLU). Recipient of Wilfrid Laurier University Gold Medal for Academic Excellence.

Proemse, B. C. Tracing Industrial Emissions in the Athabasca Oil Sands Region Using Stable Isotope Techniques. PhD (Geoscience, University of Calgary).

Tattrie, K., Groundwater surface water interactions in a wetland rich low relief Boreal environment. M.Sc. Thesis (Geography Univ. Victoria).

White J. 2011. Characterizing current and past hydroecological conditions in shallow tundra ponds of the Hudson Bay Lowlands. MSc (Biology Univ. Waterloo).

Wiklund J. 2012. Lakes of the Peace-Athabasca Delta: Controls on nutrients, chemistry, phytoplankton, epiphyton and deposition of polycyclic aromatic compounds (PACs). PhD (Biology Univ. Waterloo).

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), Sasakatoon
Dr. M. Church, University of British Columbia
Dr. A. Roy, University of Waterloo
Dirk DeBoer
IAHS-International Commission on Continental Erosion 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 of E&S topics at CGU-HS sessions.
• 2012 meeting includes sessions HRW 9 and 10,"Biogeomorphology- interactions between riparian ecosystems, aquatic ecosystems and stream channels" and "Fluvial responses to environmental change".
• Co-sponsor with CGRG of sessions R1 and R2: "Hypothesis-driven science: linking field observations to earth-surface processes" and "Advances in fluvial and glacial geomorphology".
• Reciprocal membership arrangement and affiliation between CGU and Canadian Geomorphology Research Group has resulted in sessions at other national conferences.
• Phil Owens (UNBC) is member of ICCE scientific committee for meeting in Chengdu "Erosion and sediment yields in the changing environment", October 2012.
• Mike Stone (Waterloo) is incoming ICCE President.
• Committee meeting at CGU 2012 conference will consider new leadership and members, and future directions for the Committee.

Canadian National Committee for IAHS (CNC-IAHS) – Annual Report 2013

Roles and objectives

- to promote and support hydrology as a geoscience within National and among International communities;
- to encourage and promote the collaboration between IAHS and Canadian scientific organisations and institutions;
- to encourage and promote the participation of Canadian scientists in IAHS and its activities;

- to initiate cooperative research and education programmes in hydrology with IAHS ;
- to respond, on behalf of Canada, to scientific requests from IAHS;
- to undertake the dissemination and transfer of information on IAHS-related activities among Canadian hydrologists;
- to seek and support the nomination of Canadian hydrologists to Executive positions of IAHS;
- to arrange the selection and nomination of National Representatives to IAHS, IAHS Commissions and Committees.

Current Executive

Senior Rep. and Chair	Dan Moore, UBC
Junior Rep. and Secretary	William Quinton, Wilfrid Laurier University
President, CGU-HS	Sean Carey, McMaster University
Vice-President, CGU-HS	William Quinton, Wilfrid Laurier University
CMOS Rep.	Pierre Gauthier
CWRA/CSHS Rep.	Wayne Jenkinson
CNC-IAH Rep.	Garth van der Kamp, Environment Canada
Member-at-large, CGU-HS	Masaki Hayashi, University of Calgary

Canadian National Representatives to IAHS Commissions

International Commission	Representative
Surface Water	Don Burn, Univ. of Waterloo
Groundwater	Masaki Hayashi, Univ. of Calgary
Water Quality	Brian Branfireun, Univ. of Western Ontario
Continental Erosion	Mike Stone, University of Waterloo
Coupled Land-Atmosphere Systems	Rich Petrone, Wilfrid Laurier Univ.
Remote Sensing	Al Pietroniro, Environment Canada
Water Resources Systems	Slobodan Simonovic, Univ. of Western Ontario
Snow and Ice Hydrology	Sean Carey, Carleton Univ.
Tracers	John Gibson, Alberta Research Council

Canadian Activities Related to IAHS

Canadians made substantial contributions to activities of several IAHS Commissions over the last year, in particular the International Commission on Tracers and the International Commission on Continental Erosion. See separate reports in this issue of Elements submitted by the CGU-HS Committees on Isotopic Tracers and Erosion and Sedimentation for details. Mike Stone takes up his Presidency of the International Commission on Continental Erosion in July 2013 and Gordon Young completes his Presidency of IAHS at the same time.

Canadians also made significant contributions to the final reporting phase of the IAHS PUB (Prediction in Ungauged Basins) initiative, resulting in the following publications:

Hrachowitz, M., Savenije, H.H.G., Blöschl, G., McDonnell, J.J., Sivapalan, M., Pomeroy, J.W., Arheimer, B., Blume, T., Clark, M.P., Ehret, U., Fenicia, F., Freer, J.E., Gelfan, A., Gupta, H.V., Hughes, D.A., Hut, R.W., Montanari, A., Pande, S., Tetzlaff, D., Troch, P.A., Uhlenbrook, S., Wagener, T., Winsemius, H.C., Woods, R.A., Zehe, E., and Cudennec, C., 2013. A decade of Predictions in Ungauged Basins (PUB)—a review. *Hydrological Sciences Journal*, 58 (6), doi: 10.1080/02626667.2013.803183.

Moore, R.D., Woods, R.A. and Boyle, D.P. 2013. Putting PUB into practice in mountainous areas. *Streamline Watershed Management Bulletin* 15(2), 12–21.

Pomeroy, J.W., C. Spence, and P.H. Whitfield [ed]. 2013. Putting Predictions in Ungauged Basins into Practice: Proceedings of the Predictions in Ungauged Basins Workshop. Canmore, Alberta. May 2011. Canadian Water Resources Association and International Association of Hydrological Sciences.

GEODESY SECTION NEWS

Prepared by Joe Henton, President, CGU Geodesy Section

The 1st Joint Scientific Congress of the CMOS, CGU and CWRA took place from May 26th to 30th 2013 in Saskatoon, Saskatchewan and proved to be an excellent assembly with numerous stimulating topics and presentations. On behalf of the Geodesy Section (GS) I would like to thank the Local Arrangements Committee and the Scientific Program Committee for organizing an outstanding meeting. Although the number of contributions self-identified as geodesy-related was more limited than in recent years, the breadth of the geodetic sciences was well-demonstrated in the GS sessions. In particular we would like to applaud the contribution of Sinem Ince of York University. Her paper *"Spectral Characteristics of GOCE Level 1b Gradiometer Data"* was the well-deserved winner of this year's CGU Geodesy Section's Student Award. Furthermore it was fulfilling that importance of geodetic techniques was highlighted throughout various other scientific and plenary talks. This was also a milestone year for our community as 15th Annual Canadian Geoid Workshop was held during the Joint Assembly in Saskatoon.

Specific to the activities of the section, the most significant topic discussed at the GS meetings related to our finances – in particular how can our section use its resources to better support GS-affiliated students? With the support of Spiros Pagiatakis, we plan to poll the section membership for ideas in the upcoming months. Hopefully we can then begin to implement some of your feedback in time for our next CGU meeting in Banff. Additionally we'll note that this was not an election year for the Geodesy Section (GS) and the section Executive remains unchanged. However new opportunities on the GS Executive will be opening and we invite all of the members to consider serving on future executives.

Finally I would like to introduce a "Geodetic Corner" where we plan to use the CGU newsletter to highlight topical information from and/or for the Canadian geodetic community. Our first note (below) outlines the definition of the new vertical datum for Canada – timely because this was a focus of the 15th Canadian Geoid Workshop held in Saskatoon. I hope that we'll have upcoming notes related to (1) the geodetic monitoring response to the M7.7 Haida Gwaii earthquake - Canada's second largest recorded earthquake; (2) the VMF1 service from Department of Geodesy and Geomatics Engineering at the University of New Brunswick – a service providing geodetic-quality corrections to the signal propagation delays caused by the troposphere; and (3) news from the "GNSS Precise Point Positioning Workshop: Reaching Full Potential" – a meeting held in Ottawa (12-14 June 2013) to discuss the state-of-the-art as well as future developments for PPP technology.

Geodetic Corner: A new vertical datum for Canada

by Marc Véronneau & Jianliang Huang

For more than a century, the levelling technique has been serving well Canada in realizing and maintaining its vertical datum through a network of some 90,000 benchmarks anchored to the ground and stable structures. Despite this large number of benchmarks, the coverage remains fairly sparse in southern Canada, outside urban areas, and basically inexistent in northern Canada. A substantial number of these benchmarks have disappeared or can be considered unstable. Nevertheless levelling remains the most precise technique to determine locally height differences. However, it is inefficient and costly when surveying a country as large as Canada.

Global Navigation Satellite Systems (GNSS) such as GPS offer an efficient and precise alternative for height determination at any location globally. These heights are referenced to an ellipsoid, which is a simple mathematical representation of the Earth that, unfortunately, does not provide meaningful reference for elevations. A geoid model, the separation between the ellipsoid and the geoid, allows the transformation from these ellipsoidal heights to orthometric heights that are referenced to the mean sea level and compatible with levelling-derived heights.

With the release of the Canadian Geodetic Vertical Datum of 2013 (CGVD2013) in November 2013, Canada will now define its vertical datum by an equipotential surface (geoid) and realize it by a geoid model covering entirely North America. This modernization of the vertical datum will replace the levelling- and benchmark-construct CGVD28. Natural Resources Canada (NRCan) will not maintain the federal benchmarks anymore, but will continue to publish their elevations during the transition period. In addition, the levelling networks will be readjusted using legacy data to publish elevation in CGVD2013.

Officially, the access to CGVD2013 will be trough GNSS positioning. CGVD2013 is a more precise datum than CGVD28 which contains which distortions ranging from approximately -0.65 to 0.55 m nationally.

BIOGEOSCIENCES SECTION NEWS

Prepared by Merrin Macrae and Brett Eaton

The 2013 CMOS/CGU/CWRA Congress in Saskatoon was a successful meeting. The Biogeosciences Section (BGS) hosted four sessions for oral presentations and three sessions for poster presentations. Of the 32 presentations and 10 posters, 16 were lead by students. We also had a strong representation at the Eastern Student conference (held jointly with the Hydrology section) at Wilfrid Laurier University in February, 2013. We are looking forward to another great year next year!

Brett Eaton (President) and Merrin Macrae (Vice-President) will continue their service for another year, as will Members-at-Large, Mark Johnson and Tim Duval, Carl Mitchell (Secretary) and Altaf Arain (Treasurer). We are actively seeking new board members for 2014.

Priorities and Membership Growth:
As noted in 2012, our goal over the next few years is to significantly increase both membership and attendance at CGU meetings. We plan to accomplish this by targeting key groups/topics each year, which will be tied to the focus of the annual meetings. In 2014 (Banff, AB), the CGU meeting will be held jointly with the CSSS. This will provide an opportunity to host some exciting joint sessions, particularly in the areas of agricultural runoff quality, and greenhouse gas emissions from agricultural or wetland soils. We are also seeking potential sessions to be held with other CGU sections such as HS in 2014 and at future meetings. As usual, the BGS session accepts all submissions related to the subject area of "Biogeosciences". We invite members of the CGU community to provide suggestions for potential speakers to invite to this meeting, and please consider hosting a special session related to this general subject area. We are also seeking a Plenary speaker for the 2014 meeting. Please provide suggestions for potential speakers.

Student Involvement:
Two awards were given to students in the BGS section this year. The award for best oral presentation, went to Colin McCarter of the University of Waterloo for his presentation titled: " The hydrology of the Bois-des-bel peatland restoration: Hydrological properties retarding restoration." The award for best poster went to Kristine Haynes of the University of Toronto for her poster titled: "Precipitation input and antecedent soil moisture effects on mercury mobility in soil laboratory experiments with an enriched stable isotope tracer". Every year, the BGS section provides student awards at CGU annual meetings for oral and poster presentations. Please encourage your students to apply for these awards!

Student membership in the BGS section has grown significantly over the past few years, with student presentations now constituting nearly half of all BS presentations at the 2013 meeting. The BGS section will continue to recruit student members at meetings through a Mentorship Dinner and other social programs at future meetings. This provides our students with valuable contact time with possible mentors, and facilitates overall mentorship, collaboration opportunities and networking. We hope that our members will consider volunteering to have dinner with a student (or small group of students) at future CGU meetings. Please contact us if you are willing to be a part of this initiative. We will likely be contacting many of you!
The 2014 meeting of the Eastern Student Conference will be held jointly (BGS/HS) at the University of Toronto (tentatively on the downtown campus).

SOLID EARTH SECTION NEWS

Prepared by Phil McCausland, President, CGU Solid Earth Section

Elements has recorded the activities of the new CGU Solid Earth Section for the past four years. From these reports, one can find that the fledgling Solid Earth Section underwent an initial rapid growth of membership and Annual meeting-related activities within the CGU. The Section is now entering a time of consolidation within the CGU and the beginning of activites outside of the Annual meeting. As the incoming Section President and as the former Secretary from those formative first four years, I will attempt to give a sense of what I think is happening during this time of transition and what might lie ahead.

As with past years, the Section sponsored several sessions at the 2013 CGU-CMOS-CWRA Annual meeting in Saskatoon, including CO_2 sequestration, developments in assessing seismic hazards, rock physics, high pressure mineral physics, geophysical imaging and the structure of North America's lithosphere. Two well-attended workshops were also sponsored by the Section: Use of commercial finite element modelling packages in Solid Earth geophysics (Sam Butler, University of Saskatchewan) and Geophysical high pressure research in conjunction with synchrotron radiation – a hands-on workshop (Hans Mueller, GFZ Potsdam), taking advantage of the nearby Canadian Light Source synchrotron hosted at the University of Saskatchewan.

At the Saskatoon CGU-CMOS-CWRA meeting, the Section once again had a competition for the best Student presentation in Solid Earth geophysics. The winner this year is Amin Baharvand Ahmadi (PhD candidate at the University of Saskatchewan) whose excellent oral presentation entitled, "Time-lapse amplitude variations with Angle (AVA) in vertical seismic profiles during CO_2 flooding of Weyburn reservoir" was deemed by our judges to be the best of the Solid Earth geophysics presentations. Congratulations Amin! The Award consists of a mounted plaque along with a cheque from the CGU Solid Earth Section for $750.

As hinted above, the Section indeed had an election of Officers for the 2013-2015 Executive at the Annual meeting, with the following results:
President: Phil McCausland (Western University)
Vice President: Julian Lowman (University of Toronto at Scarborough)
Treasurer: Andrew Frederiksen (University of Manitoba)
Secretary: Karen Assatourians (Western University)
Member-at-Large: Hans Mueller (GFZ Potsdam)
Member-at-Large: -vacant- but subsequently Hadi Ghofrani (Western University) offered to take part and was appointed by the Executive, pending an election in 2014.
Past President: Sam Butler (University of Saskatchewan)

I would like to take this opportunity to thank Sam Butler for taking on the busy President's role for the past two-year term, and for his continued involvement and advice in Solid Earth affairs as the new Past President. Sam replaces Kristy Tiampo (Western) who was the first President and has now moved on from the Executive altogether –thanks Kristy! Claire Samson has also moved on from her previous role as Section Vice President to become the Vice President for the CGU. Congratulations, Claire! A big thank you is also in order for the newly-elected Executive members who have freshly joined or variously moved into new positions. …We have our work cut out!

From the top, I mentioned that the Solid Earth Section is entering a form of transition period. This is to be expected as we leave behind the `fledgling' stage, having now established a Solid Earth Student Award as well as consistently sponsoring five or more Solid Earth theme sessions at the Annual meeting. The Section and the CGU as a whole have, however, had a softening of membership numbers in this past year, suggesting that the Canadian Geophysical Union is also in transition. Indeed, this has become a difficult time for geophysical sciences in Canada, with tightened Federal budgets threatening the operation of key facilities and the employment of researchers. At the same time, a realignment of existing

Federal policies and programs is leading to diminishing opportunities for geophysicists to take part in research travel and meetings, or even to fund research programs and infrastructure without demonstrable industrial linkage. The effect of these changes upon geophysical sciences in Canada is difficult to quantify, but at minimum represents a new, more challenging context within which to pursue research.

Fostering research is the core rationale of the CGU Solid Earth Section, as drawn from its bylaws: “Solid Earth geophysics is the science concerned with the properties of and the physical processes acting upon the Earth’s crust, mantle and core, throughout Earth’s history. The Solid Earth Section shall address itself to these questions within the context of all Earth sciences and will seek fruitful collaborations with other Union Sections and scientific organizations having allied interests.” We have an essential role to play in facilitating the communication of Solid Earth geophysics research at meetings, fostering the development of young researchers as well as celebrating research breakthroughs and career achievements. The Solid Earth Section also has a contribution to make in articulating these developments in geophysical research to a wider public audience. This latter function does not explicitly foster “research” but is nonetheless becoming more important as a potential means of redefining the public context within which policy decisions are made.

Moving to activities outside of our Annual meeting, the Solid Earth Section for the first time sponsored a graduate student research meeting, the Advances in Earth Sciences Research Conference (AESRC), in March 2013 as part of a new initiative to support student research and to promote the CGU Solid Earth Section amongst new researchers. The AESRC meeting had 70 participants from across southern Ontario and was hosted over three days at Western University, with participants from the University of Ottawa, Carleton University, Queen’s and other institutions. Proposals from the organizers of upcoming Solid Earth geophysics-related graduate student meetings or workshops for funded sponsorship from the Solid Earth Section are welcome at any time and will be assessed by the Executive on a case-by-case basis.

More information on this new initiative, the Solid Earth Section Executive, past Student Award winners and other details are available on the CGU Solid Earth website, at: http://www.cgu-ugc.ca/SESection/index.htm

Looking ahead to the next Annual meeting, it will return to Banff, Alberta once more before a longer spell away in other venues in coming years. Next year’s meeting is to be held jointly with the Canadian Soil Science Society and the Mantle Convection workshop. This 2014 meeting promises to have an enlarged Solid Earth component, given that the Mantle Convection workshop will likely add upwards of 200 people to the meeting. Please note that the Solid Earth Section is looking to generate good session proposals over the next few months that will reflect the breadth of Solid Earth geophysics research, complementing the Mantle Convection workshop!

Best regards,

Phil McCausland
President, CGU Solid Earth Section

CGU 2012 Best Student Paper Award Winners

A number of awards were presented in recognition of outstanding performance in scientific research and presentation by students. Each of the awards comes with a monetary prize. The awards were announced and presented at the Awards Banquet at the recent 2013 CGU-CMOS-CWRA Joint Meeting in Saskatoon. To be considered for an award, the student must be the first author and presenter of the paper (visit http://www.cgu-ugc.ca for details).

CGU Best Student Paper (all fields of geophysics – oral presentations):
Winner: Kristine Haynes (University of Toronto, Scarborough)
Co-author Carl P.J. Mitchell
"Hydrological Controls on Mercury Mobility and Transport from a Forested Hillslope during Spring Snowmelt"

Shell Canada Outstanding Student Poster Paper:
Winner: Nadine Shatilla (McMaster University)
"The impact of surface mining on runoff timing and flow pathways, Elk Valley, British Columbia"

Chevron Canada Outstanding Student Paper in Seismology (oral or poster):
Winner: Subbarao Yelisetti (University of Victoria)
Co-author George Spence
"Seismic velocity and attenuation structure beneath the Vancouver Island continental shelf using frequency domain visco-acoustic full waveform inversion of multichannel seismic data"

D. M. Gray Award for Best Student Paper in Hydrology (oral presentation):
Winner: Phillip Harder (University of Saskatchewan)
Co-author: John W Pomeroy
"Sensitivity of hydrological process simulations to precipitation phase differentiation"

D. M. Gray Scholarship in hydrology:
Winner: Scott Ketchison (U Waterloo)

Campbell Scientific Award for Best Student Poster in Hydrology:
Winner: M.S.I. Kline (University of Western Ontario)
Co-author, B.A. Branfireun
"Base and event-flow hydrologic and biogeochemical connectivity in a fen-stream transition in the central Hudson Bay Lowland"

Geodesy Section Award for Best Student Paper in Geodetic Research & Education (oral presentation):
Winner: E. Sinem Ince (York University)
Co-author: S. D. Pagiatakis
Spectral Characteristics of GOCE Level 1b Gradiometer Data

CGU Solid Earth Section 2013 Student Best Paper award
Winner: Amin Baharvand Ahmandi (R) is congratulated by Solid Earth Section Past President Dr. Sam Butler at the University of Saskatchewan. PhD candidate Ahmandi's presentation at the Saskatoon meeting was entitled, "Time-lapse amplitude variations with Angle (AVA) in vertical seismic profiles during CO2 flooding of Weyburn reservoir."

CGU Best Student Paper (all fields of geophysics)

Hydrological Controls on Mercury Mobility and Transport from a Forested Hillslope during Spring Snowmelt

Kristine M. Haynes[1, 2] and Carl P.J. Mitchell[1, 2]*
[1]University of Toronto Scarborough, Department of Physical and Environmental Sciences
[2]University of Toronto, Department of Geography **Presenting Author: k.haynes@utoronto.ca*

Abstract

Upland systems play an important role in conveying atmospherically-deposited mercury (Hg) to downstream wetlands and water bodies. Understanding the influence of different and/or changing hydrological conditions on Hg mobility is critical because of poorly understood potential effects due to climate change and because of the toxicological threats of Hg to human and wildlife populations. Two complementary studies were conducted to assess the role of hydrological processes in controlling Hg mobility and transport in forested upland environments. First, a field study compared runoff and Hg fluxes from three replicate hillslope plots throughout two contrasting spring snowmelt periods. Second, a microcosm laboratory study involved the application of an enriched stable Hg isotope tracer to intact, foam-encased soil cores in order to investigate the relative influences of soil moisture and precipitation on Hg mobility. Collectively, these studies suggest that inter-annual variability in hydrology including winter snowpack depth, volume of runoff and antecedent soil moisture during the spring snowmelt period significantly influenced the magnitude and timing of hillslope Hg fluxes. Given the likelihood of decreasing snow accumulation in the study region of north-central Minnesota due to climate change, greater fluxes of contemporarily deposited (new) Hg may be flushed from upland environments via preferential flowpaths in dry soils during storm events. Enhanced fluxes of new Hg, which is likely more bioavailable for methylation, may lead to increased methylmercury production in downstream aquatic ecosystems and potentially enhance Hg availability for biotic uptake.

Introduction

Mercury (Hg) is a potent neurotoxin with severe toxicological and teratological effects on both vulnerable human and wildlife populations (Mergler et al. 2007; Scheuhammer et al. 2007). Spring snowmelt has been demonstrated to be an important period of Hg export from watersheds; contributing a large portion of the annual Hg flux (Mitchell et al. 2008a). The large pulse of Hg to receiving aquatic systems, in association with such solutes as dissolved organic carbon (DOC), sulphate and other ions known to stimulate methylmercury (MeHg) production, may contribute to enhanced availability of MeHg and biotic uptake (Jeremiason et al. 2006; Mitchell et al. 2008b). Despite the important role hydrological processes play in controlling Hg mobility, minimal research has been conducted to explore the relative controls of certain hydrological factors, such as antecedent soil moisture, on Hg transport in upland soils. The impact of global climate change on snowpack accumulation and volume of spring runoff, and subsequent influence on Hg and solute mobility and transport has not been examined.

Therefore, the overall objective of this research was to directly couple an in-depth understanding of hillslope hydrological processes in a watershed to the mobilization of Hg stored in upland soils. Firstly, this research used hydrological and Hg biogeochemical monitoring over two contrasting spring snowmelt seasons as a means of quantifying the effect of smaller and later snowpack development, and variable volumes of spring runoff on the mobility and transport of Hg. Second, an enriched stable Hg isotope was applied to intact soil columns taken from the field site and subjected to similar soil moisture and precipitation levels observed during the two spring melts in order to determine the relative controls of these hydrological factors on Hg mobility in soil.

Study Site

This study was conducted on the north-facing hillslope (mean slope = 10°) of watershed S7 within the Marcell Experimental Forest (MEF) in north-central Minnesota (47° 31’ 21” N, 93° 28’ 7” W). The upland overstory vegetation in the S7 watershed is predominately comprised of sugar maple (*Acer saccharum*), quaking aspen (*Populus tremuloides*) and balsam poplar (*Populus balsamifera*). Runoff is predominantly via shallow lateral interflow within sandy soil, above a low-permeability silty-till horizon. Upland runoff drains into an adjacent peatland. The climate at the MEF is characterized as sub-humid continental, with an average daily temperature of 4.2°C (average temperatures of 13.9°C during the months of April to September and -5.6°C for the months of October to March). Typical annual precipitation for the MEF is approximately 780 mm.

Methods

Hydrological flows, Hg and solute mobility were compared between the spring snowmelt period following the winter of 2009-2010 (snow water equivalent (SWE) = 48 mm) to the greater snow accumulation for 2010-2011 winter (SWE = 98 mm). Three replicate, forested hillslope plots (S7A, B and C) were delineated in the upland with a shallow subsurface runoff trench equipped with digital flow datalogging in each plot. Teflon-coated snow lysimeters (2010-2011 winter only) were also installed in each plot, as well as an array of wells to monitor snow meltwaters and upland water tables, respectively. Runoff samples were collected daily during spring snowmelt in 2010 and 2011 from each of the three replicate plots, in addition to snow meltwaters and well waters, and were analyzed for total Hg (THg) and dissolved organic carbon (DOC).

Intact soil cores (15 cm deep, 10 cm diameter) were collected in the upland of the S7 watershed using a soil corer. Each core was encased in expandable polyurethane spray foam insulation using a tube form to avoid wall-effects during the experiments. The soil core microcosm experiments were conducted in a full factorial design in which the two controlled variables (antecedent soil moisture and amount of hydrological input) incorporated both a low and high treatment level with three replicate cores per treatment combination. For precipitation input, the low and high levels were 50 mm and 100 mm, respectively, selected in order to mimic natural snowpack SWE observed in the field study described above. The low antecedent soil moisture treatment level was designed to simulate the 65 mm of available soil water in the surface 45 cm of soil recorded in fall 2009 prior to the 2010 winter, while the high antecedent soil moisture treatment level was represented by field capacity. Antecedent moisture was altered immediately prior to conducting each experiment. For each antecedent moisture treatment level, a control experiment was also performed in which no further input was added to each core following isotope addition to determine the level to which the isotope was transported as a baseline prior to meltwater addition. 90 µg of enriched stable ^{199}Hg isotope (~3X ambient THg load) was applied to the soil surface via a Teflon 'sieve' delivery vessel. A rainfall simulator and pump was then used to deliver the prescribed snowmelt input treatments to the core surface. Outflow was collected from each core in 50 mL intervals, which was analyzed for THg (both excess total ^{199}Hg and ambient) and DOC. Soil cores were sampled in 3 cm sections and analyzed for THg (excess total ^{199}Hg and ambient).

Results

Overall, hydrological conditions were very different between the 2010 and 2011 snowmelt periods. The 2010 snowmelt period had less snow (48 mm SWE), drier antecedent moisture conditions (65 mm soil water in upper 45 cm soil), more soil frost (279 mm mean thickness), and an earlier onset of melt (March 11, 2010). Approximately twice as much snow (98 mm SWE), 30% wetter conditions (84 mm soil water), and practically no soil frost (patchy with maximum depth of 50 mm) were observed prior to the 2011 snowmelt, which began on April 1, 2011. The 2010 spring melt yielded a total of 22 ± 5 mm of runoff, while approximately 2.8 times more runoff was observed for the 2011 spring melt (61 ± 17 mm). Significant differences in the melt patterns between the two snowmelt periods were observed. The hydrograph for 2010 showed two distinct peaks in runoff; the first of which can be attributed to snowmelt with the second peak the result of melting soil frost (Figure 1). Evidence of the melting of soil frost was also observed in the sudden and considerable increase in the perched water table positions in the lower-slope wells around March 27, which peaked on April 2, 2010 in S7A and S7B (simultaneously with runoff), while water tables in S7C remained elevated throughout the month of April (data not shown). From best estimates of the observed runoff peaks in 2010, the snowmelt runoff response accounted for approximately 72% of the total spring runoff with the remaining 28% due to the melting of soil frost. In comparison, the hydrograph for the 2011 spring melt had only a single peak of flow associated with snowmelt runoff, with no distinct frost melt (Figure 1).

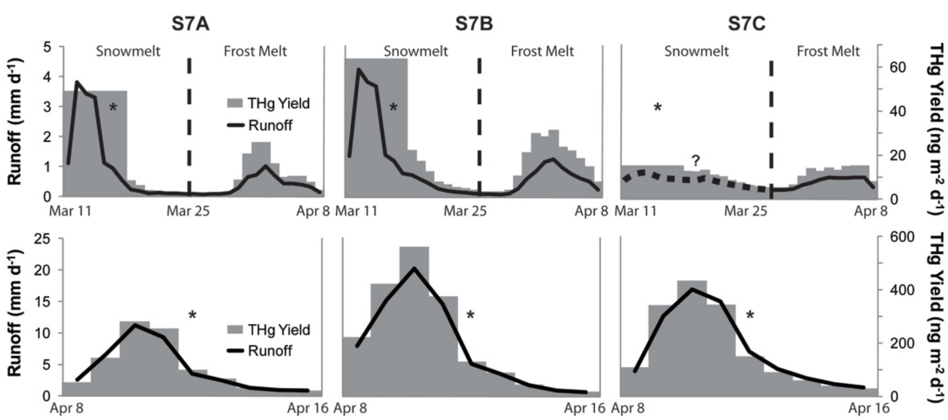

Figure 1: Daily runoff and THg yield in replicate S7 plots A, B and C for both the spring melt of 2010 and 2011 (note differences in scale). Runoff data for Mar11-Mar17, 2010 based on empirical model. * = last day of snow present on the ground. Dashed line in 2010 S7C due to poor agreement with empirical model.

The 2011 snowmelt period resulted in an approximately 2.8 times greater THg yield (1479 ng m^{-2}) than the 2010 snowmelt (524 ng m^{-2}) (Figure 2). Similarly, the 2011 spring melt yielded approximately 2.7 times more DOC per square metre (1292 mg m^{-2}) than the 2010 melt period (483 mg m^{-2}). For the spring 2010 melt period, melting of soil frost accounted for approximately 30% of the total THg flux. These proportions in inter-annual flux differences

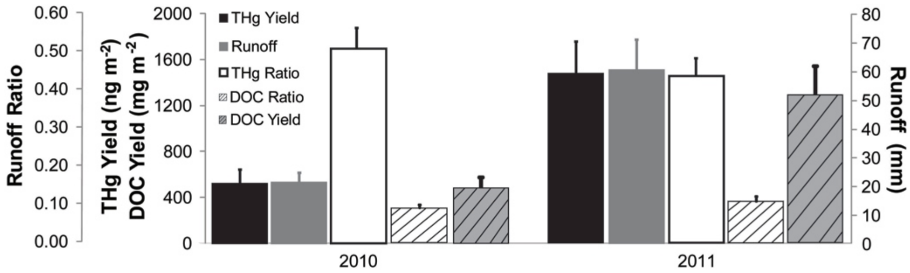

Figure 2: Inter-annual comparison of runoff, THg and DOC yields, and THg and DOC runoff ratios (source/sink functions). Error bars represent standard error.

were nearly identical to the differences in inter-annual runoff.

For the laboratory experiment, less than 0.5% (range of 0.03 – 0.38%) of the added 90 µg of the ^{199}Hg tracer was present in the total outflow collected across all treatments combinations. The highest excess (tracer) total ^{199}Hg outflow load occurred in the low soil moisture – high precipitation input (LH) experiments (mean total load = 341 ng; Figure 3).
The LH outflow excess total ^{199}Hg load was significantly greater than that of any of the other treatment combinations. The second largest excess total ^{199}Hg outflow load was observed in the low moisture – low input (LL) experiments. There was not a statistically significant difference ($p < 0.05$; ANOVA analysis with Tukey post-

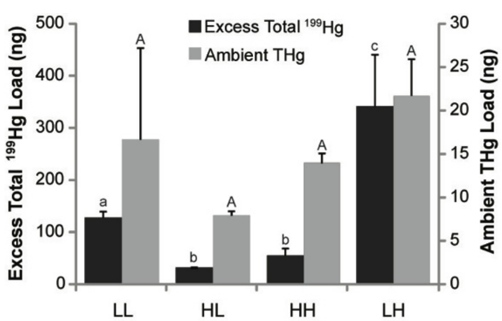

Figure 3: Excess (tracer) total ^{199}Hg and ambient THg outflow loads (ng) for all hydrological treatment combinations. Error bars represent standard deviation and lower-case letters represent significant differences for excess total ^{199}Hg, while upper-case letters represent significant differences for ambient THg.

hoc test) between the tracer outflow loads resulting from the two high soil moisture treatments (HH and HL). Both of these treatments were significantly less in outflow excess total ^{199}Hg than those resulting from the low moisture treatments ($p < 0.0001$) regardless of the level of precipitation input (Figure 3). Similarly, the outflow excess total ^{199}Hg loads resulting from the high input treatments exceeded the low input treatments at both levels of soil moisture ($p = 0.001$). The total ambient THg loads followed the same general pattern by treatment as the excess total ^{199}Hg loads (Figure 3). However, no significant differences in outflow ambient THg were present among any of the treatment combinations ($p = 0.07$).

According to the results of a factorial ANOVA, both antecedent soil moisture ($p < 0.0001$) and the volume of precipitation input ($p = 0.001$) were significant controls on excess total ^{199}Hg transport and mobility through soil. The lack of interaction ($p = 0.16$) between these hydrological variables suggested that these controls on excess total ^{199}Hg mobility acted independent of one another, in an additive manner. Neither antecedent soil moisture (although close to significance at $p = 0.06$) nor the volume of precipitation input ($p = 0.18$) exerted a strong influence on the mobility of ambient THg mobility.

Discussion

With enhanced snow accumulation and subsequently greater magnitude of snowmelt runoff, upland THg yield was proportionally increased. Total Hg, DOC, and water yields all increased by the same proportion following the winter with greater snow accumulation, suggesting strongly that inter-annual differences in upland THg and DOC export are predominately flow-driven in this landscape. The tendency of Hg fluxes to increase with flow has previously been observed during high-flow events such as spring snowmelt and high-intensity rain events, particularly at the watershed scale (Bishop et al. 1995; Scherbatskoy et al. 1998; Lee et al. 2000). By taking into account the inter-annual differences in runoff when considering the observed differences in THg, effectively normalizing the inter-annual variation for flow, no difference in THg export existed between the two years; despite very large differences in hydrology. It is therefore likely that the mobility of Hg in this system does not change significantly with depth or with antecedent moisture, as observed at this scale. As THg export appears to be controlled by flow, increases in winter snow accumulation in certain regions due to climate change would significantly enhance the flux of Hg being delivered to ecologically-sensitive downstream ecosystems. Conversely, as global climate change is forecasted to diminish snow accumulation in northern Minnesota (Mohseni and Stefan 2001), as well as many other regions in North America (Moore and McKendry 1996), overall spring THg export to downstream water bodies would be expected to proportionally diminish with flow.

The timing at which this reduced THg flux is released from forested upland systems may be critical when considering the potential effects of global warming on Hg methylation and bioaccumulation. Soil frost may play an important role in transporting a significant portion of the spring Hg flux following winters with minimal snow accumulation. In this study the considerable THg flux as a result of frost melt occurred nearly three weeks after the onset of snowmelt and more than two weeks after the disappearance of the snowpack. By significantly delaying a large portion of upland THg export later into the spring, thick frost development due to a lack of insulating snow cover (Hardy et al. 2001) may have deleterious effects to downstream aquatic organisms. In conjunction with rising Hg methylation rates that might be expected with warmer temperatures (Gilmour et al. 1992) during the spring season, the augmented contribution of THg as well as solutes such as DOC later into the presumably warmer spring season may act to enhance Hg methylation in downstream wetlands (Mitchell et al. 2009). This enhanced methylation has the potential to increase the bioavailability of Hg for biotic uptake.

The results of the laboratory study suggest that both antecedent soil moisture and the volume of precipitation input were instrumental in controlling new, contemporary Hg mobility in soil. As there was no observed interaction between these factors, it can be concluded that these hydrological variables act independently of one another, in an additive manner. However, old, legacy Hg was not significantly influenced by either soil moisture or precipitation input; similar to what we observed in our field study. The ability to distinguish how new Hg mobility was enhanced with larger precipitation events as well as from initially drier soils was a particularly significant finding that could only have been determined using isotope tracers. This result suggests that more extreme precipitation events among otherwise drier conditions could significantly affect the mobilization of Hg from upland environments and its subsequent transport to downstream wetlands and water bodies.

Conclusions

Inter-annual variability in hydrology including winter snowpack depth, volume of runoff and antecedent soil moisture during the spring snowmelt period significantly influenced the magnitude and timing of hillslope Hg fluxes, as evidenced by the results of these two complementary studies. As global climate change is likely to diminish precipitation, particularly snow accumulation, in the Midwestern states including the study area of north-central Minnesota (Mohseni and Stefan 2001), soil moisture may be similarly impacted. With global warming, a greater proportion of new, contemporary Hg may be flushed from upland environments during high-flow events such as spring snowmelt as soils become increasingly dry. It has been suggested that new Hg is more reactive in the environment than legacy Hg in terms of methylation (Hintelmann et al. 2002). Greater fluxes of new Hg to downstream receiving wetlands and water bodies may result in enhanced MeHg production and greater Hg availability for biotic uptake. This research also observed the melting of soil frost to be important in transporting approximately 30% of the overall hillslope Hg load later into the spring season following the winter with less snow accumulation. When considering that lower antecedent soil moisture may coincide with low snow years, as was observed in this research, the melting of soil frost may in fact contribute a large flux of new, reactive Hg to receiving wetlands later into the spring. Given the important linkages between Hg in runoff and downstream bioaccumulation, accounting for the hydrological controls on Hg mobility provides insight into potential hydroclimatic-biogeochemical feedbacks that could affect the timing and magnitude of Hg inputs into aquatic systems.

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Chevron Canada Outstanding Student Paper in Seismology

Seismic velocity and attenuation structure beneath the Vancouver Island continental shelf using frequency domain visco-acoustic full waveform inversion of multichannel seismic data

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Summary

In structures with steep dips and high degree of lateral variation, conventional seismic data processing and tomography are inadequate to obtain high-resolution velocity and attenuation models. Hence we apply frequency domain visco-acoustic full waveform inversion – a first application to marine multichannel seismic reflection data on the continental shelf off Vancouver Island. The primary objectives are (i) to obtain detailed seismic velocity and attenuation structure of sediments within the Tofino fore-arc basin, and (ii) to understand the relationship with underlying accreted terranes such as the Crescent terrane and the Pacific Rim terrane. The waveform inversion velocities match reasonably well with the sonic velocities from three exploration wells on the shelf, down to the maximum modelled depth of ~ 2km. A prominent low velocity zone at a depth of 800-900 m was observed over a lateral distance of ~10 km. Possible interpretations include: (a) lithology changes associated with a high porosity layer, (b) fluid over-pressure, and (c) over-pressured gas in this potential hydrocarbon environment. This low velocity zone, and other localized low velocity zones are associated with high values of attenuation, defined as the inverse of quality factor (Q). Attenuation values as high as 0.03-0.06 are observed at depths below 1 km, which probably indicates increased clay content and the presence of mineralized fluids. The results also throw light on the likely occurrence of accreted terranes such as the Eocene volcanic Crescent terrane and the Mesozoic marine sedimentary Pacific Rim terrane at depth.

Introduction

At the Northern Cascadia margin off Vancouver Island, the Juan de Fuca plate is subducting beneath the North American plate at a convergence rate of 46 mm/year. As a result, sediments are scraped off from the down going plate and attached to the continental plate to form the accretionary wedge (Hyndman et al., 1990). In southernmost Vancouver Island, major westerly trending faults partition the crust into two narrow zones – the Pacific Rim terrane and the Crecent terrane, which were accreted to the margin in late Eocene time, between 55 and 42 Ma ago (Hyndman et al., 1990). The Tofino forearc basin has a maximum width of about 60 km and a length of ~ 200 km (Figure 1) on the Vancouver Island continental shelf and contains up to 4 km of sedimentary rocks, which lie above the accretionary wedge basement, the ocean basaltic Crescent terrane and the marine sedimentary Pacific Rim terrane (Shouldice, 1971). It comprises Paleogene and Neogene clastic rocks that have been penetrated by six exploratory wells (Figure 1) that penetrate up to 3 km of Miocene to Recent mudstones and minor sandstones. Eocene sediments/volcanics were also encountered in four of these wells (Shouldice, 1971; Narayan, 2003). Tomographic results from a recent study (Hayward and Calvert, 2007) suggest that sediment deposition increased more rapidly in the later half of the Tofino basin history.

Here, we apply frequency domain visco-acoustic full waveform inversion to marine multichannel seismic reflection data on the Vancouver Island continental shelf. The primary objective of this work is to further the study of the upper part of the Tofino basin by quantitatively imaging its structure. Multichannel data used in this study, collected in 1989 by Geological Survey of Canada (Spence et al., 1991), contains dominant frequency of 10 - 35 Hz with a limited maximum offset of ~ 3.6 km.

Waveform tomography method

The success of waveform inversion strongly depends on the accuracy of the starting model and proper data preconditioning, as well as the presence of low frequencies and large offsets in the data. Starting velocity model in this study was constructed using travel time inversion (TTI). For TTI, we used two techniques: ray tracing using a block model (Zelt and Smith, 1992) initially, and then first arrival seismic tomography using a grid model (Zelt and Barton, 1998). Smoothed starting model used in this work is shown in Figure 3a, which produced modelled travel times that are within ½ cycle of the observed travel times. We used the 2-D frequency domain visco-acoustic waveform tomography approach (Pratt, 1999) to obtain seismic velocity and attenuation structures. During the inversion, starting velocity model is updated by iteratively minimizing the misfit between the forward modeled data and the field data. The gradient is computed by multiplying the forward propagated wavefield with the back-propagated data residual.

We followed a waveform inversion strategy similar to that of Takam Takougang and Calvert (2011). Prior to inversion, data preconditioning included low-pass filtering (up to 15 Hz), amplitude scaling to match modelled data with field data and time windowing (up to 2 s). Initial source wavelet was obtained from source inversion using starting velocity model and a spike wavelet. Inversion was applied for frequencies between 6-14 hz with 0.4 hz interval and five iterations per frequency. We used a homogeneous attenuation model with a grid spacing of 12.5 m. Both amplitude and phase of the source function were updated at each iteration step. Gradient was filtered in the wave number domain using 2D-band pass filter in both horizontal and vertical directions.

Waveform inversion is applied, initially to obtain velocity model. Later, using this velocity model, we simultaneously inverted for velocity and attenuation models. A common offset gather derived using this final velocity model is shown in figure 2(b), for offset 3308 m. Raw common offset gather for the same offset is shown in figure 2(a). Clearly, there is a high degree of similarity between the raw data and the predicted data. An anticlinal structure near trace number 55 and a shallow sub-basin between trace number 60 and 120 is well imaged.

lower than the surrounding velocities at similar depths. LVZ is observed between ~ 600 – 1000 m below seafloor (mbsf) and extends up to ~ 10 km in length. LVZ is not observed in the previous studies (Hayward and Calvert, 2007) due to resolution limits imposed by conventional processing and tomography. We speculate that the LVZ is probably a consequence of high pore pressures arising from fluid expulsion from accretionary wedge sediments beneath the Tofino basin (Calvert & Clowes 1991). Alternatively, the LVZ could be due to over-pressured gas in this potential hydrocarbon environment (Shouldice, 1971). Lithology changes associated with a high porosity layer could also cause the observed LVZ.

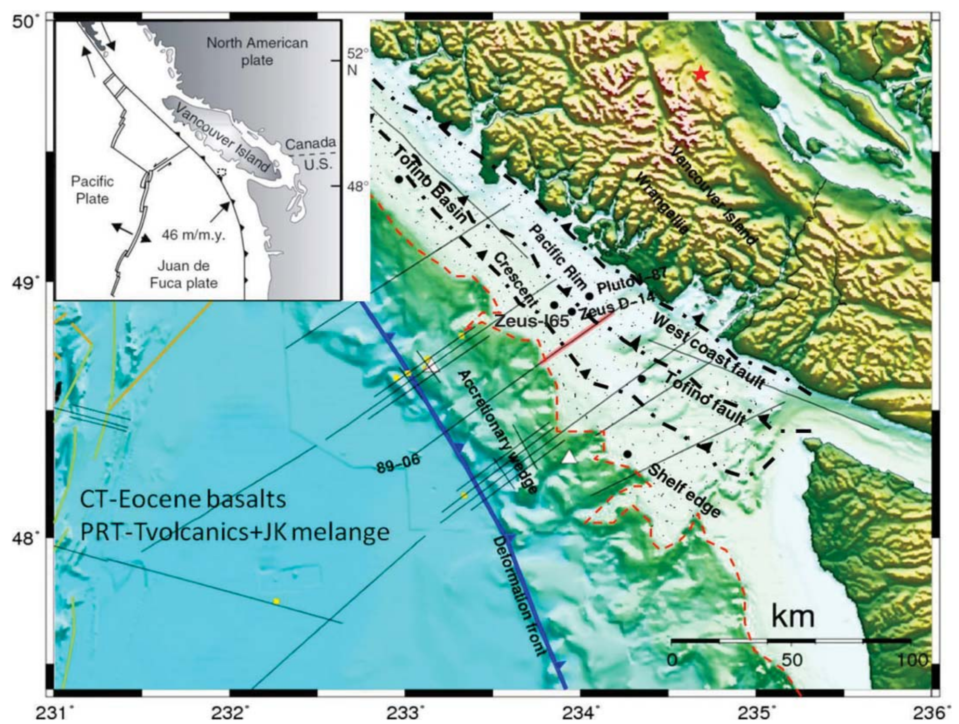

Figure 1: *Location of the Tofino basin (dotted fill). Black lines indicate the location of the seismic reflection profiles. Thick red line is used in the present study (CT-Crescent terrane; PRT-Pacific Rim terrane; Solid circles- well locations).*

Results and discussion

I. Velocity structure

a) Low-velocity zone (LVZ): The most prominent feature of the final velocity model (Figure 3b) is the low velocity zone in the southwestern portion of the line. It is observed within the accretionary prism sediments of the Tofino basin. The sediment velocities in this zone are ~ 200 m/s

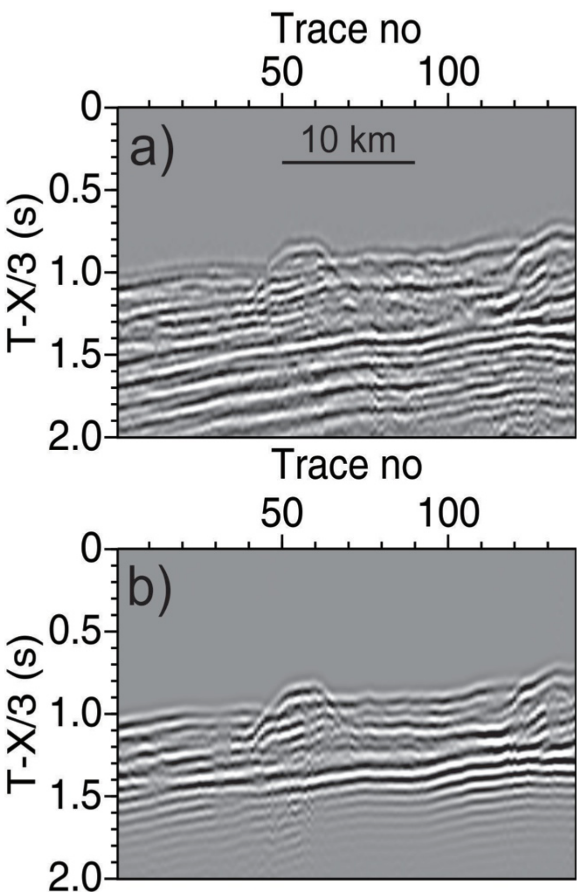

Figure 2: (a) Raw common offset gather low pass filtered to 14 Hz at offset 3308 m. Trace spacing is 250 m. (b) Common offset gather from visco-acoustic fullwaveform inversion. A high degree of similarity exists between raw and modeled data, particularly in the shallow sediment section above 1.5 s.

b) Crescent terrane: A high velocity feature occurs between ~12-18 km, over which seismic velocities rapidly increase sharply from 2000 m/s to 2500 m/s at 750 m depth and then uniformly to 5000 m/s at 2000 m depth (Figure 3b). This is interpreted as the shallowest occurrence of volcanic Crescent terrane. The location of Crescent terrane beneath the shelf is also marked by a magnetic high (Spence et al., 1991). An anticlinal fold or diapiric feature (between 17 – 22 km model distance, Figure 3d) is observed ~2-3 km landward of the shallowest Crescent terrane, and is likely associated with the landward dipping Tofino fault that forms the top boundary of Crescent terrane.

c) Pacific Rim terrane: Sediment velocities within the shallow shelf generally increase landwards (Figure 3b). This landward increase may be associated with the general compressional environment at the time of emplacement of the Crescent and Pacific Rim terranes. As a specific example, velocities in the northeastern portion of the model (between 32-38 km model distance) are about ~ 600 m/s higher than average velocities just to the west. This may be associated with a possible deeper transition to the Pacific Rim terrane.

II. Comparision with drill hole data

Sonic log velocities from three of the wells (Zeus-I65, Zeus-D14 and Pluto-I87) were used in the present study to compare with velocities from waveform inversion models. Zeus-I65 was drilled on an anticline and penetrated through the top of the Crescent terrane, Zeus-D14 was drilled on the flank of an anticline and penetrated through volcanics, while Pluto-I87 was drilled on an anticlinal structure and penetrated through a thin gas-bearing sand at depth. However, these wells were projected onto our line by 18 km, 10 km and 11 km, respectively. Highly smoothed log velocities are assigned velocity uncertainities of ±200 m/s, ±100 m/s and ±150 m/s for Zeus-I65, Zeus-D14 and Pluto-I87 velocities, respectively. Results indicate that waveform inversion velocities match reasonably well with the sonic log velocities (Figure 4), down to the maximum modelled depth of ~ 2km.

III. Attenuation structure

Seismic attenuation is defined as the inverse of quality factor (Q). Seismic waves propagating into basement structures are strongly attenuated due to heterogeneity and mode conversion effects, which are not included in the inversion (Figure 2b, 3c and 3d). Hence the match between the raw data and predicted data is less accurate at depths below 1.5 s. The low velocity zone indicated in the above section, and other localized low velocity zones are associated with high values of attenuation. Some of these zones are close to faults or folds and the low velocity and high attenuation may be due to elevated fracture porosity. Attenuation values as high as 0.03-0.06 are observed at depths below 1 km, which probably indicates increased clay content and the presence of mineralized fluids (Malinowski et al., 2011). In the mid-shelf region where an anticlinal structure was observed, shallow high velocities (3-5 km/s) coupled with high attenuation values (> 0.03) were observed at depths below ~ 1 km. These high velocity and high attenuation (low Q) values indicate the presence of Crescent volcanics. Alternatively, the high attenuation may also be due to scattering and elastic effects that are not included in the visco-acoustic inversion. The landward-dipping Tofino fault that separates the Crescent terrane from Pacific Rim terrane (Figure 1) is tentatively identified as a thin layer with high attenuation values (Figure 3c).

Conclusions

The application of waveform tomography to seismic reflection data from the Tofino basin has enabled the identification of a prominent low velocity zone in the basin sediment section. As well, the results provide clues about the structure and subsurface location of Crescent and Pacific Rim terranes. Extracted 1d-velocity profiles from the final model match very well with the available sonic log velocities. This study shows that with proper data preconditioning and a good inversion strategy, waveform tomography of relatively short offset streamer data can be used to image shallow geological features. Velocity and inelastic attenuation models derived in this study may provide background or regional seismic trends that are useful to hydrocarbon exploration industry for planning of possible new seismic exploration in Tofino basin.

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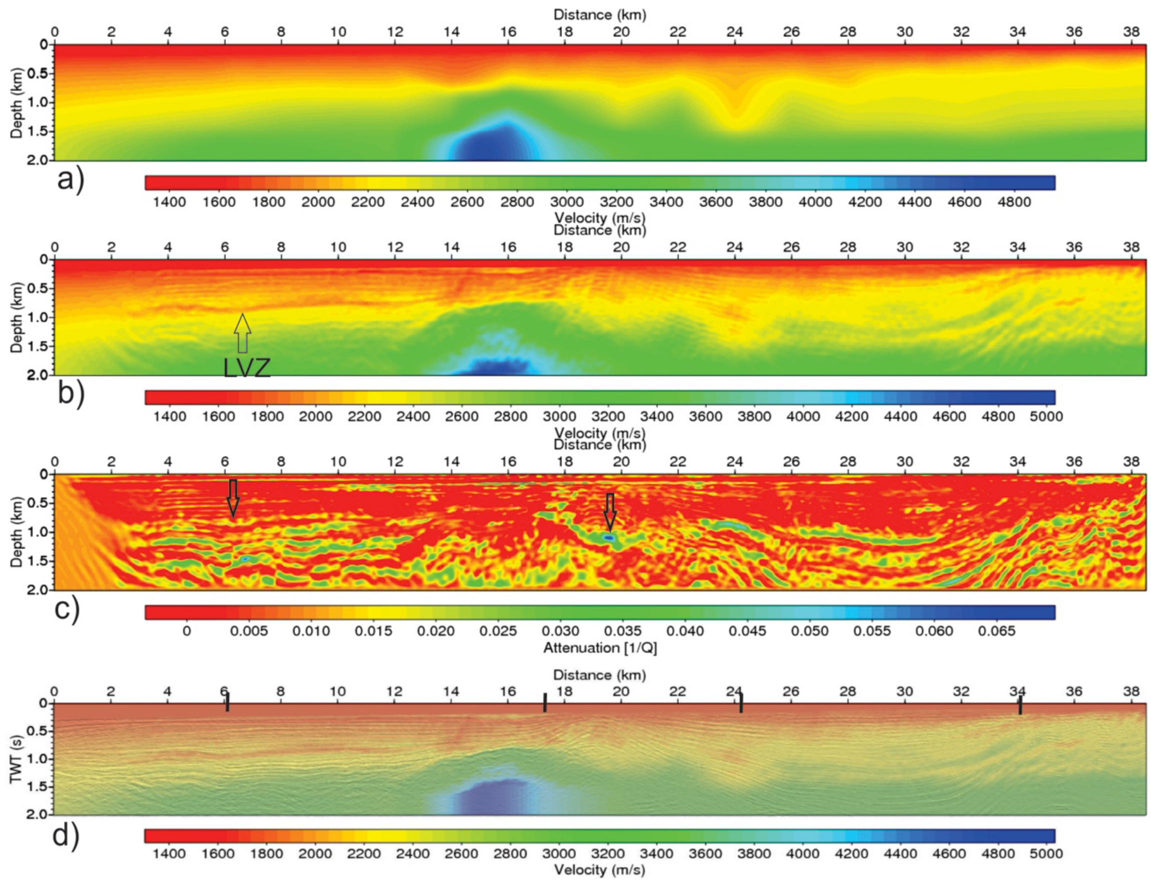

Figure 3: a) Smoothed starting model from travel time inversion, b) final velocity model after 6 – 14 hz inversion, c) attenuation model after 6-14 Hz inversion. Black arrows indicate the location of the LVZ and Tofino fault, respectively and d) final velocity model superimposed on migrated seismic section. Black tick lines indicate the location of 1D-velocity profiles shown in figure 4.

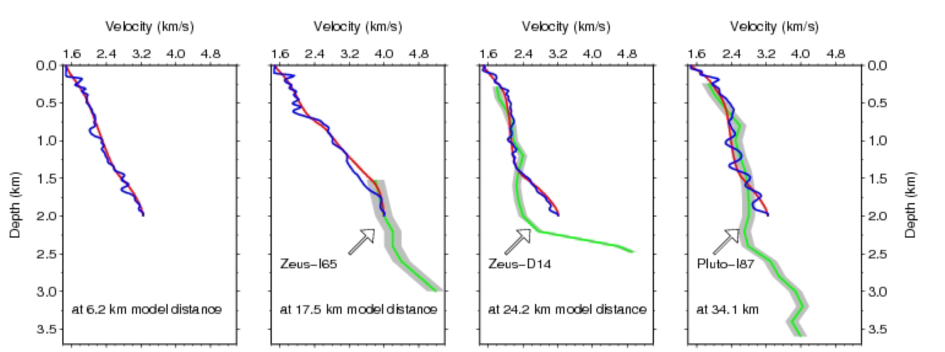

Figure 4: 1D-velocity profiles through starting model (red) and final model (blue) along with sonic log velcoties (green). Uncertainty in sonic log velocities indicated in gray. Location of the 1D velocity profiles is shown in figure 3d.

D. M. Gray Award for Best Student Paper in Hydrology

Sensitivity of hydrological process simulations to precipitation phase differentiation

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Abstract

A wide variety of precipitation phase differentiation algorithms are used to simulate cold region hydrological processes. Many of these algorithms are based upon calibrated empirical relationships with air temperature, for which there is uncertainty in their basic reliability and the spatial and temporal transferability of calibrated parameters. In order to estimate the uncertainty associated with employing various relationships, hydrological processes were calculated using a flexible, modular, hydrological modelling platform with various phase differentiation algorithm options. Streamflow discharge, rainfall/total precipitation ratio, local runoff and snow accumulation were calculated using the UBC model double temperature threshold, a physically based psychrometric energy balance method and the commonly used single air temperature threshold algorithms. Intercomparison of the hydrological responses of the differing algorithms highlighted differences between air temperature based and psychrometric methods. Overall uncertainty of hydrological processes, as established with simulating a wide range of temperature methods, reached 19% for rain ratio, 75% for discharge, 131% for runoff and 41% of snow water equivalent. Temporally, the range of temperature methods showed that snow cover duration, snow free date and peak discharge date could vary by up to 36, 16 and 10 days respectively. The greatest hydrological uncertainty due to precipitation phase algorithms was found at sub-alpine and sub-arctic headwater basins and the least uncertainty was found for the prairie headwater basin.

Introduction

There is no standard approach used by hydrological models to differentiate precipitation phase. Early work in this area by Auer (1974) showed a transition from snowfall to rainfall corresponding to air temperatures ranging from 0°C to 6°C. Consequently precipitation phase determination techniques for hydrology have focused on relating phase to daily averages of air temperature or sometimes dewpoint temperature measured at weather stations. Most of these relationships are empirical relationships to single, or double, air temperature thresholds which fall within the bounds of Auer's (1974) observations and are not physically based (Harder and Pomeroy, 2013) or spatially transferable (Marks *et al.,* 2013). The physical basis of precipitation phase is the hydrometeor temperature which is primarily a function of the psychrometric equation (Stewart, 1992). Harder and Pomeroy (2013) used this to accurately estimate phase using estimates of heat and mass transfer to the hydrometeor. The uncertainty that various phase determination algorithms introduce into hydrological modelling has not been quantified. The overall objective of the paper is therefore to evaluate the uncertainty that different precipitation phase differentiation methods introduce to hydrological modelling, specifically in assessing point and basin scale hydrological processes.

Methodology

The Cold Regions Hydrological Model (CRHM) was used to assess the uncertainty of various precipitation phase differentiation methods on hydrological processes. CRHM is a physically based modular hydrological modeling platform based on decades of integrated research on cold region hydrological processes in Western and Northern Canada (Pomeroy *et al.,* 2007). Process representation spans the hydrological continuum of the region including blowing, snow interception, sublimation, snowmelt, infiltration into frozen soils, hillslope water movement over permafrost, actual evaporation, radiation exchange to complex surfaces, soil moisture balances and streamflow routing. The physical basis of the model makes it useful for assessing the uncertainty of improvements in hydrological process algorithms.

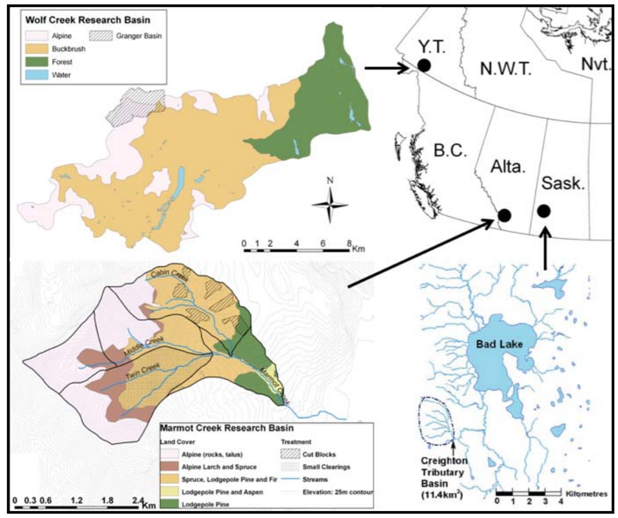

Figure 1: Research Basins showing land cover and location in Western Canada

The uncertainty of precipitation phase methods in hydrological models was assessed with previously developed and tested CRHM models from Western Canada and include:

- **Marmot Creek Research Basin 2006-2011** (MC: Fang *et al.,* 2013): is a small Canadian Rockies headwater basin in the Kananaskis Valley, Alberta. The 9.6 km^2 basin varies between exposed alpine ridges, alpine meadows and sub alpine and montane forests. The climate is dominated by long mild winters, snowy springs and cool wet summers.
- **Wolf Creek 1994-2002** (WC: Pomeroy *et al.,* 2010): is located in the Upper Yukon River Basin near Whitehorse, Yukon. The basin, ~179 km^2, is typical of sub-arctic mountain headwaters. The basin incudes alpine tundra, subalpine taiga and boreal forest. The climate is cold and sub-humid.
- **Granger Basin 1999-2001** (GB: MacDonald *et al*., 2009): is a small (8 km^2) alpine sub-basin of WC.
- **Bad Lake 1974-1975** (BL: Pomeroy *et al.,* 2007): Creighton tributary (11.4 km^2) of BL, an internally drained basin near Totnes in southwestern Saskatchewan, Canada, represents a typical small agricultural Canadian prairies basin. The climate is semi-arid with extreme temperatures.

In CRHM a double threshold approach was previously used to define the ratio of rain to total precipitation (rain ratio) with user defined temperature thresholds (Tsnow: all precipitation as snow and Train: all precipitation as rain) and a linearly interpolated mixed phase transition zone. The specific phase differentiation methods implemented in CRHM included a static threshold (0°C: T0), double threshold using parameters given by Pipes and Quick (1977) (0.6°C and 3.6°C: PQ) and the psychrometric method from Harder and Pomeroy (2013) (PSY). Methods are visualised (Fig. 2) as rain ratio versus air temperature; as PSY is a psychrometric function the visualization

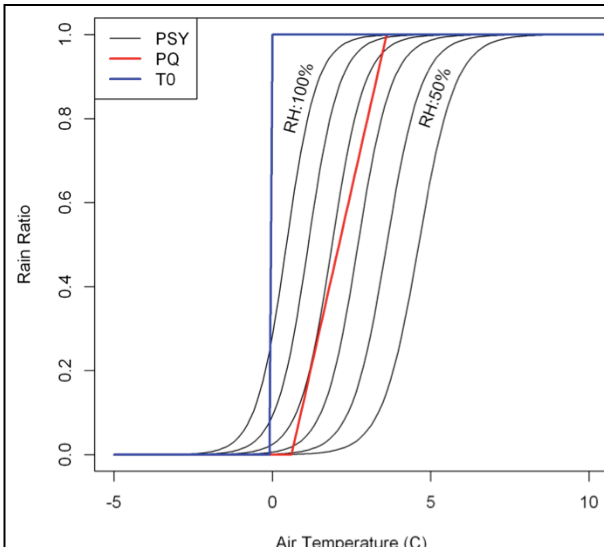

Figure 2: Precipitation phase methods as rain ratio versus air temperature.

includes rain ratio for various relative humidities.

To quantify the uncertainty of air temperature based methods all permutations of Tsnow (0°C to 1°C) and Train (0°C to 6°C) parameters for every 0.5°C interval, for a total of 36 combinations, were used to run CRHM. This range in parameters corresponds to the transition range reported by Auer (1974). The normalized uncertainty of the temperature methods, hereafter overall uncertainty, is calculated as follows:

$$overall\ uncertainity = \frac{mean(Max\ values - Min\ values)}{mean(PSY\ values)}$$

Output analysed included: monthly total discharge (basins) or runoff (points), rain ratio and daily snow water equivalent and peak annual discharge (basins). Temporal indices of snow cover duration, snow free day and date of discharge peak (basins) were also analysed with overall uncertainty determined to be the difference between maximum and minimum values. The PSY method is used as a reference as it is physically based and has been shown to be more accurate than air temperature methods in identifying precipitation phase (Harder and Pomeroy, 2013). MC was used to assess performance of the model to simulate snow water equivalent on the point scale and discharge on the basin scale. MC point models spanned forest clearings (Upper Clearing: UC), forests (Upper Forest: UF), alpine ridegtops (Fisera Ridgetop: FR) and treeline forests (Fisera Forest: FO).

Results/ Discussion

The greatest uncertainty in quantifying phase as a monthly rain ratio (Fig. 3) was observed at MC, GB and WC. MC has a moderate climate where the majority of precipitation occurs near the transition range, and thus uncertainty in phase is important much of the year. In contrast GB and WC temperatures are near the transition range, and thus more uncertain phase, from spring through fall, but not in winter. BL, with its climatic extremes, experiences temperature near the transition range, and thus uncertain phase, only in spring and fall. MC, GB and WC are in mountains where elevational gradients of temperature increase the probability, and thus

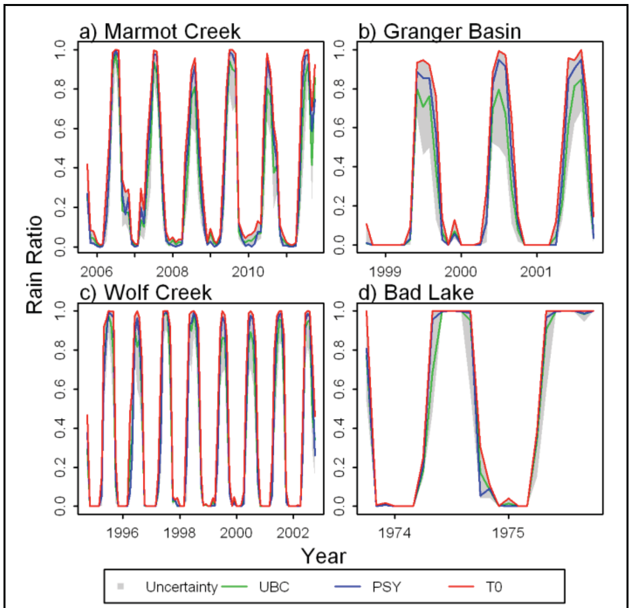

Figure 3: Monthly rain ratio for basins. Overall uncertainty (grey area) is overlain by PQ (green), PSY (blue) and T0 (red) methods.

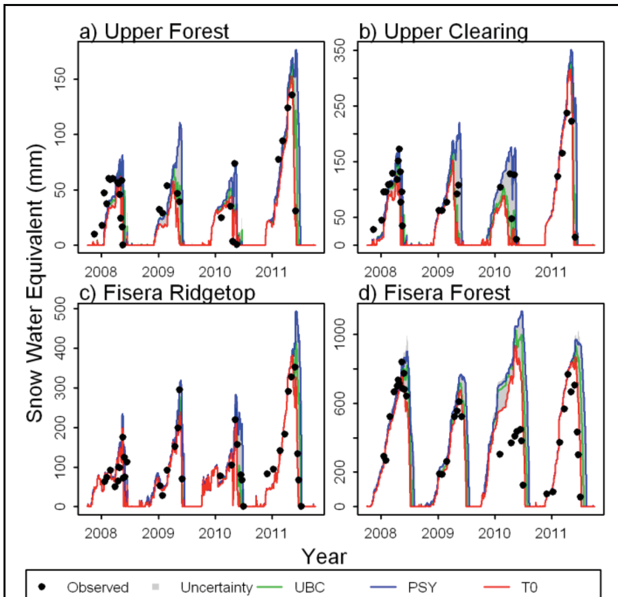

Figure 4: Daily MC snow water equivalent. Overall uncertainty (grey area) is overlain by PQ (green), PSY (blue) and T0 (red) methods with snow survey observations (black dots).

uncertainty in phase, of mixed phase events when temperature is near the transition range. The uncertainty due to the elevation-phase relationship is further observed when comparing high and low elevation points at MC. Warmer temperatures at lower elevations in winter mean that precipitation often occurs near the transition range where there is greater uncertainty in rain ratio. In addition to varying phase, the amount of precipitation can vary due to wind induced undercatch of snowfall. Correction within CRHM results in average annual differences of total precipitation of 20 and 12 mm between PQ and T0 methods for MC and BL respectively.

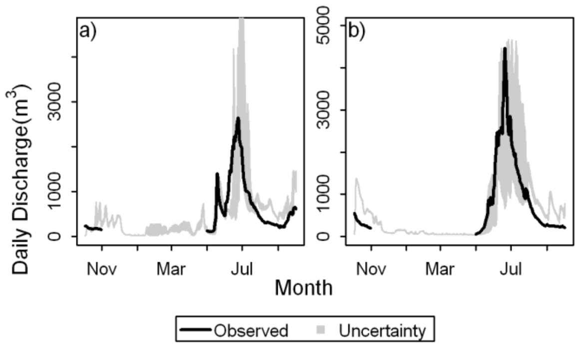

Figure 5: Marmot Creek observed discharge relative to modeled air temperature method uncertainty for water years 2010 and 2011

The uncertainty of phase algorithms propagates through the model and results in large differences in overall uncertainty between basins associated with snow water equivalent and discharge simulations (Table 1). Monthly runoff and discharge have the highest uncertainty relative to other variables. Uncertainty in discharge was greatest at GB, likely due to the high variability of streamflows in this small basin. Snow water equivalent estimates follow rain ratio patterns and display the greatest uncertainty at MC and the least uncertainty at BL.

The relationship between PSY, T0 and PQ for snow water equivalent reveals how the seasonality of precipitation introduces sensitivity to phase estimation methods. T0 estimated less snowfall, leading to less snow water equivalent; PQ did the opposite. In contrast PSY, which estimates less snow than PQ, estimates higher snow water equivalent than PQ. PSY considers both temperature and humidity thus the higher relative humidity of winter will correspond to precipitation being identified as snow at lower air temperatures than PQ will identify and at higher air temperatures than PQ will identify in the lower humidity months of summer. PQ produces more and greater runoff events than PSY in the warmer summer months.

Table 1: Overall Uncertainty

Variable	**Units**	**Points**				**Basin**			
		UC	UF	RT	FO	MC	GB	WC	BL
Rain ratio	% PSY	**20.2**	18.5	17.2	17.9	18.3	**18.6**	16.4	10.5
Runoff/Discharge	%PSY	116	**131**	107	127	28.9	**75.2**	28.9	42.6
Snow Water Equivalent	%PSY	**40.5**	38.7	28.3	29.1	**34.7**	20	9.5	8.4
Peak Discharge	%PSY					46.9	**81.5**	74.5	11.7
Snow Free day	Days	**25.5**	20.2	15.5	20.8	**16.2**	5.7	11.4	-2
Snow Cover duration	Days	**35.8**	30.5	28.2	35.2	24.8	16.3	**35.2**	3
Peak Discharge Day	Days					7	**10**	5.9	0

The algorithms that considered mixed phase (whether empirical or physically based) performed better than T0 at simulating snow water equivalent in a clearing (Fig. 4). T0 performed best for windswept or forested sites, where blowing and intercepted snow processes are important. These sites are difficult to model though so it cannot be concluded that T0 is the best method. The increase in uncertainty associated with considering additional processes masks improvements in performance by using a more accurate phase method. CRHM, Figure 5, has some trouble in estimating the hydrograph correctly at Marmot Creek as it tends to overestimate streamflow response to small snowmelt or rainfall events and underestimate the main snowmelt event. In general, PSY estimates the most discharge followed closely by T0 and finally PQ. Thus the methods which estimate the most snowfall will lead to greater discharge. In this case model structure leads to an overestimation of all methods in estimating discharge making it difficult to properly assess the performance of the different methods.

Conclusions

Many methods have been used in hydrological modelling to differentiate precipitation phase and this study compares the hydrological uncertainty and sensitivity of a selection of these methods over a variety of basins and scales. Uncertainty between basins was largely a function of climate and topography. The most sensitive basins were small alpine basins that had most precipitation occurring in the long phase transition uncertainty period. In contrast the prairie basin had little precipitation in its short phase transition uncertainty period and so showed the least uncertainty to variations in phase methods. Statistical assessment of the performance of the point scale snow water equivalent simulations could not identify a method to be consistently better than the rest with T0 performing better in some situations. Assessment of the simulated seasonal discharge at MC showed no method outperforming the others due to overriding model errors. The uncertainty of precipitation phase methods in hydrological modelling has been underappreciated in the literature and constitutes a significant source of potential error that varies between basins. This error has large implications on the performance of many aspects of hydrological models in cold regions.

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Campbell Scientific Award for Best Student Poster in Hydrology

Base and event-flow hydrologic and biogeochemical connectivity in a fen-stream transition in the central Hudson Bay Lowland

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Introduction:

The hydrological and biogeochemical role of riparian areas of the Hudson James Bay Lowlands (HJBL) the world's second largest peatland complex (Riley, 2011), are unknown. The riparian areas of second order and higher streams are drier, have taller trees, and have less soil organic matter than the surrounding bogs and fens. These differences have important implications for the near stream hydrology. While the term riparian is widely applied to areas directly adjacent to any waterbody, particularly rivers, most definitions of riparian also state or imply that these areas are wetter than the surrounding upland (National Research Council, 2002). In the low gradient, peatland dominated environment of the HJBL, this relationship is inverted, with riparian areas that are drier and steeper than the fens that drain into them. In terrestrial environments, riparian areas can be defined as the gradient between terrestrial and aquatic ecosystems and have unique hydrological, geomorphological and ecological roles in many landscapes (Gregory, 1991). Riparian areas in the HJBL are expected to play similarly unique and important roles, however the functioning of riparian areas in this landscape is poorly understood and conceptual models developed in upland watersheds may not transfer well. As part of a broader assessment of the hydrology and biogeochemistry of the HJBL, this study sought to clarify the influence of the riparian zone on the connectivity between a fen and a second order stream, and to quantify the flux of water and solutes (specifically dissolved organic carbon (DOC) and methylmercury (MeHg)) between the fen and the stream.

Study Site:

The study site is located within the watershed of the Nayshkootayaow River a tributary of the Attawapiskat River. It is ~12km from the DeBeers Victor Diamond Mine, located at approximately (52.83 N, 83.93 W), in the central James Bay Lowlands of the subarctic region. This landscape is dominated by peatlands, with ~2m of peat accumulation in most areas with the exception of the riparian zones. The gradient from fen to denser riparian forest begins approximately 400-500m away from the stream. The research was focused within the riparian forest of a ~1km reach of Tributary 5, a second order stream that joins the Nayshkootayaow and ultimately flows to the Attawapiskat River.

Methods:

Field reconnaissance revealed the presence of small rivulets/soil pipes in the riparian zone, and we hypothesized that these were an important connection between the fen and the stream. To measure the fluxes of water from these outlets, v-notch weir boxes and flumes were installed and fitted with pressure transducers that recorded water levels at 10 minute intervals. Wells installed in the fen were sampled for water chemistry and isotopes on a weekly basis, with more intensive sampling later in the season. Outlets were sampled on an event basis to capture important stormflow solute dynamics including methylmercury (MeHg) (e.g. Babiarz et al. 1998). This represents the first event-flow sampling of MeHg in this environment. The water samples were analyzed for major ions, water isotopes, DOC, and a subset for MeHg and Total mercury (THg).

Results

Hydrology

Tributary 5 is incised down through the peatland into the marine sediments, exposing low permeability sediments close to the surface. Since there is only a thin organic layer overlying these sediments, most of the flow of water seems to be in the form of localized surface and subsurface drainage; small rivulets and both ephemeral and perennial soil pipes. As shown by Figure 1, discharge from the soil pipes is dominated by storm events in the mid to late fall when antecedent conditions are wet. Earlier storms show much more muted responses. Four major multiple day storm events with total precipitation greater than 15 mm can be identified, labeled 1,2,3,4 on the figure, these have total rainfalls of 15.7, 33.5, 61.2, and 37.4 mm respectively. In pipe B these events produce peak discharges of 0.2, 0.6, 1.9 and 7.2 l/s respectively. Baseflow discharge preceding these events is typically at least an order of magnitude less than the peak discharge.

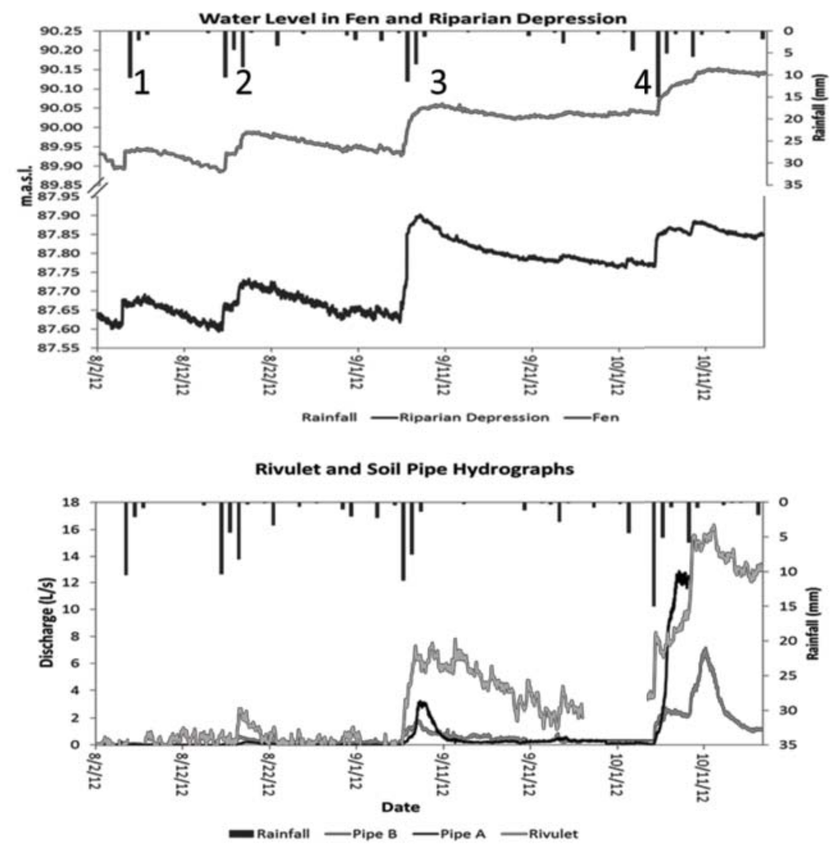

Figure 1: Compares event response in the fen, riparian area and the outlets. Illustrates how much more hydrologically responsive the outlets and the riparian area are compared to the fen.

Biogeochemistry:

Water chemistry results show that pore water and surface waters in the riparian area are significantly more enriched in DOC and MeHg than in the adjacent fen. Median concentration of DOC in the riparian zone and adjacent fen are 24 and 9 mg/L, respectively. Methylmercury concentrations in the riparian area are an order of magnitude higher than in the fen (0.27 and 0.02 ng/L respectively). Dissolved organic carbon concentrations show a very consistent spatial pattern among the discharge points, with pipes tending to have higher DOC concentrations than the larger, more connected rivulet. This pattern is preserved during storm events. MeHg concentrations vary more with flow than DOC, and show less consistent spatial patterns. For example the MeHg concentration in the rivulet increased from 0.06 ng/L, under baseflow conditions on August 28 to 0.51 ng/L at the beginning of a storm event on September 6, suggesting an important near stream flushing process.

Discussion:

Hydrology: The rivulets and soil pipes concentrate the delivery of water and solutes from the extensive peatlands that dominate the landscape to point discharges along the banks of the stream. As Woo and diCenzo (1988) found in the southern HJBL, pipeflow is a significant contributor to run-off in this environment. Furthermore the pipes and rivulets are more hydrologically responsive to storm events than the fen (Figure 1), indicating that at times they respond independently from the broader hydrologic system. Near stream depression storage may serve to lengthen residence time of the water, and facilitate mixing with the less chemically dilute riparian water. The runoff response of the outlets appears to reflect the availability of storage in the fen and riparian area and is strongly dependent on antecedent conditions. This makes the later fall storm events the most important contribution to discharge during the period monitored, since even significant storm events in the late summer will only produce a minimal response in terms of pipe and rivulet flow due to a much larger storage deficit in both the fen and riparian zone. Under dry conditions the riparian area appears to dampen the event response of the fen, but satisfaction of the storage deficit in the riparian area results in an amplified storm response in the outlets compared to the fen.
Biogeochemistry: While the initial objective was to quantify the delivery of DOC and MeHg from the fen to the adjacent stream, the research revealed that the near stream environment is itself a significant contributor of both DOC and MeHg to surface water. Although the fen dominates the landscape, the riparian area is a more important source of solutes to the stream, and the hydrology of the riparian zone controls the timing of their delivery. Storm events seem to have more impact on MeHg concentrations than they do on DOC concentrations; although DOC does not appear to be source-limited, MeHg exhibits a flushing effect, making storm events very important for delivering MeHg to the stream. The nearly ubiquitous occurrence of this fen-riparian forest- stream hydrogeomorphology suggests that the findings here may have regional implications.

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Geodesy Section Award for Best Student Paper in Geodetic Research & Education

Spectral Characteristics of GOCE Level 1b Gradiometer Data

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Abstract
Recent studies on the gravity field determination focus on GOCE-based data and global gravity field models. It is known that GOCE data are capable of improving the knowledge of the Earth's gravitational field in some specific spectral domain. However, there are different characteristics of GOCE-derived datasets which are not completely known yet. In this study, two-month GOCE Level 1b gradiometer derived data sets in different directions are investigated in the frequency domain in order to identify the spectral components of the Electrostatic Gravity Gradiometer (EGG) Level 1b data which represent the calibrated common- and differential-mode accelerations and gravity gradients in our case study. The outcome of this study is expected to help us understand the processing stages and models involved in the development of final products of GOCE data, such as spherical harmonic coefficients, global geopotential models and regional geoid models from raw measurements and introduce innovative improvements.
Keywords: GOCE, gradiometer, accelerations, gravity gradients

Introduction
The Gravity field and steady-state Ocean Circulation Explorer (GOCE) mission was launched on March 17, 2009. The objective of the GOCE mission is to model the Earth's static gravity field with an accuracy of 1 cm in geoid heights and 1 mGal in gravity anomalies at a spatial resolution of 100 km (Drinkwater et al., 2007). In order to solely observe the Earth's static gravitational field, the influence of all other gravitational and non-gravitational accelerations should be eliminated or measured and compensated. The measurement of these effects is generally retrieved by using accelerometer observations onboard the satellite. For the previous gravity missions, CHAMP and GRACE, the accelerometers were mounted precisely at the center of the mass (COM) of the satellite. Therefore, the accelerometer, which is rigidly tied to the COM, would sense the non-gravitational forces only (Hoffmann-Wellenhof and Moritz, 2005). In addition to this concept, the core instrument making GOCE special is the Electrostatic Gravity Gradiometer (EGG) which is almost perfectly positioned at the COM. EGG consists of 3 accelerometer pairs which are placed on three mutually orthogonal axes (Fig. 1). The three axes (of the Gradiometer Reference Frame-GRF) can be expressed as X-axis, along track of the satellite, Y-axis, cross track and Z-axis, along the gravitational plumb line. The distance between the accelerometer couples (A14, A25, and A36) is about 50 cm and the distance between the center of the gradiometer and center of each individual accelerometer is about 25 cm. This causes accelerometers to be affected by the gravitational forces differently from each other and helps map the Earth's gravitational field in detail.

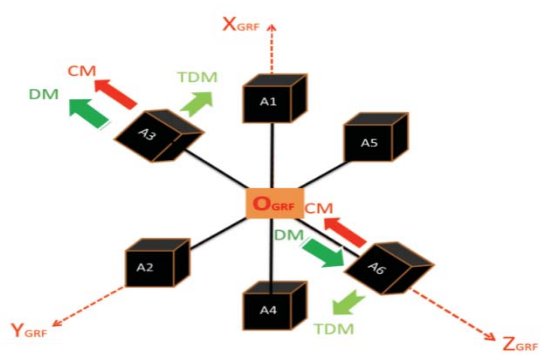

Fig. 1: Configuration of the accelerometers and the axes of the GRF.

Methodology
Data processing and development of the global gravity field models are as important as the development of the mission, its launch and monitoring. Comprehensive investigations are needed both, on the instruments used onboard and ground,

communication between these two as well as the methodologies applied in the data processing. The three datasets investigated in this study are common- and differential-mode (CM and DM) accelerations and gravity gradients collected during March and April, 2011. Previous studies (see Stummer et al., 2012) focused on the GOCE EGG measurement bandwidth (5 to 100 mHz) whereas we focus on the lower frequency components (1 to 2.10^{-4} mHz) in order to complement the investigations.

The CM accelerations are of non-gravitational origin acting on the satellite, such as air-drag and solar radiation pressure and these measurements are used in the drag-free control. DM can be defined as the mode where the CM is rejected and the DM accelerations arise from gravitational sources and from angular accelerations of the satellite. The CM and DM accelerations can be expressed by Eqs. (1) and (2), respectively, where *n* and *m* represent the ID number of the accelerometers (cf., Fig. 1) and *i* indicates the measurement direction, X, Y, and Z.

$$a_{c,n,m,i} = \frac{1}{2}(a_{n,i} + a_{m,i}) \qquad (1)$$

$$a_{d,n,m,i} = \frac{1}{2}(a_{n,i} - a_{m,i}) \qquad (2)$$

The CM and DM accelerations should be separated from each other very clearly. In other words, CM should not affect the DM measurements. However, due to small gradiometer imperfections, CMs can leak into DMs which is taken into consideration during the gradiometer calibration process and data processing. These imperfections are due to the scale factor applied in the retrieval of the accelerations, misalignments of the accelerometers and non-orthogonality of the accelerometer axes. More information on the calibration procedure can be found in Mayrhofer, 2008; Siemes et al., 2012 and Stummer et al., 2012.

The main outcome of the GOCE mission is the gravity gradients and they are derived from DM accelerations (Bouman et al., 2004, ESA 2006, and Stummer et al., 2012) by using:

$$\mathbf{a}_d = \mathbf{V} + \mathbf{\Omega}^2 + \dot{\mathbf{\Omega}}, \qquad (3)$$

where $\mathbf{V}$ is the gravity gradient tensor, $\mathbf{\Omega}^2$ is the centrifugal acceleration due to the rotation of the satellite about its COM and $\dot{\mathbf{\Omega}}$ is the acceleration due to the satellite angular acceleration.

Results

Our preliminary spectral investigations of the CM and DM accelerations and each individual gravity gradient tensor component in all three directions (not shown here) show that orbital and semi-orbital periods are the common spectral characteristics of the EGG data. It is also observed that there are different characteristics of different components in various directions. Moreover, there are various unknown non-gravitational sources affecting the accelerations in the Y direction, which made us focus our study on the components of Y-axis which are derived from the accelerometer pair 2 and 5 (A25). It is worth mentioning here that the most accurate CM and DM accelerations on the Y-axis can only be retrieved from A25 pair due to the configuration of the ultra- and less-sensitive axes of the accelerometers. The V_{yy} component is important as it is one of the diagonal tensor elements and used in the development of its trace ($V_{xx}+V_{yy}+V_{zz}$) (see ESA, 2006). The trace of the gradient tensor is a very useful quantity to check the instrument performance and data quality. Fig. 2 shows the V_{yy} component derived from the DM observations during March and April, 2011. One can notice that V_{yy} shows an increasing error during the two months and has gaps.

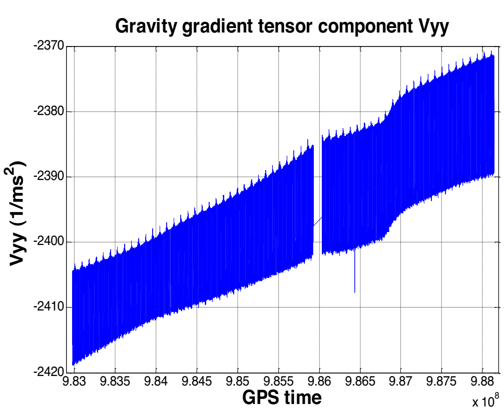

Fig. 2: Vyy collected during March-April, 2011.

Geographic positions of ascending tracks of the CM and DM accelerations and V_{yy} gravity gradients filtered and decimated to 10 seconds interval are shown in Figs. 3, 4 and 5, respectively. One can notice that there are some signatures displayed in Fig 3. Some of these signatures are related to the atmospheric dynamics over the specific regions. The DM accelerations obtained for the same period are displayed in Fig. 4. Similar signatures are observed around the same regions in both, CM and DM acceleration data along the meridian of 120°E, the region below Australia and over auroral regions in the north. The results shown in this paper indicate that there is a coupling between the CM and DM accelerations which needs to be resolved. Previous studies also suggested that there is a wind effect in the North and South Pole, auroral ovals, and ionospheric turbulences around the magnetic equator (Peterseim et al., 2011). Our further analyses suggest that the reasons of these clear signals shown in Fig.3 are most probably related with the magnetic field of the Earth (see Finlay et al., 2010).
The V_{yy} gravity gradients derived for the same period are shown in Fig. 5. In Figs. 4 and 5, it is possible to see that there are some other common characteristics. These components show a strong pattern along the longitudes and show a change in the magnitude from equator to the Polar Regions. These effects are related to the shape of the Earth and can be expressed by the effect of the second zonal term, J_2.

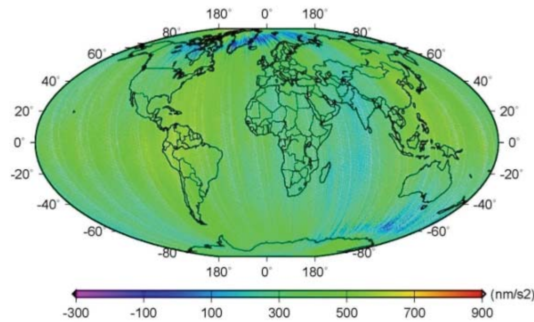

Fig. 3: CM accelerations, March-April, 2011.

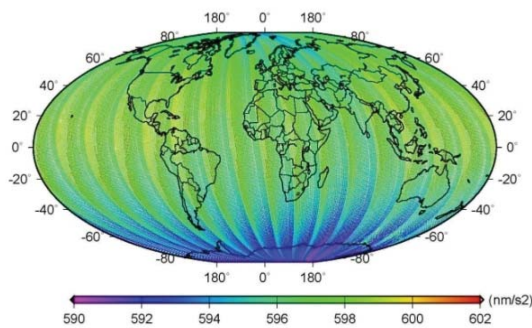

Fig. 4: DM accelerations, March- April, 2011.

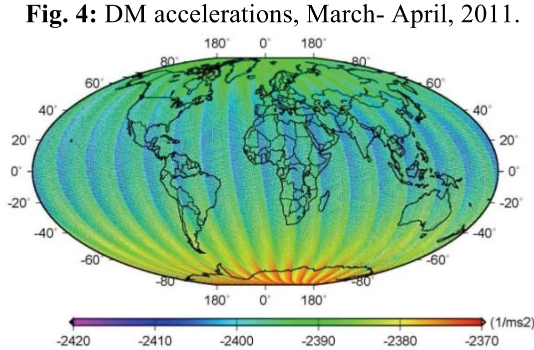

Fig. 5: V_{yy}, March- April, 2011.

Spectral analyses performed on the same datasets show that the orbital (~5386s) and semi-orbital periods (~2691s) are dominating spectral characteristics of the gravitational and non-gravitational accelerations as well as of the gravity gradients. The power spectral densities (PSD) of the three datasets are shown in Fig 6. The PSD of the CM accelerations is higher than the one of the DM accelerations. This is not true for the other axes, X and Z. It is worth mentioning that the ion thruster

assembly of GOCE keeps the mission drag free in the X direction; however, these effects of the drag compensation are not applied to the cross-track components (see Fig. 3).
The PSDs of DM acceleration and V_{yy} are at about the same level for the higher frequencies whereas, the difference increases for the lower frequency components. This might be an indication that the effect of the centrifugal acceleration is higher for the lower frequency components. The dominating components detected (see peaks in Fig. 6) are summarized in Table 1. It is noted that our results are consistent with the investigations of simulated GOCE data given in Bobojc, 2008.

Table 1: Spectral components of the EGG data.

Data	Period (s)	Source
CM	5386, 5067, 4784, 2778, 2691, and 1346	Non-gravitational sources
DM	5386 and 2691	Gravitation of other planets, geopotential
Vyy	5386, and 2691	

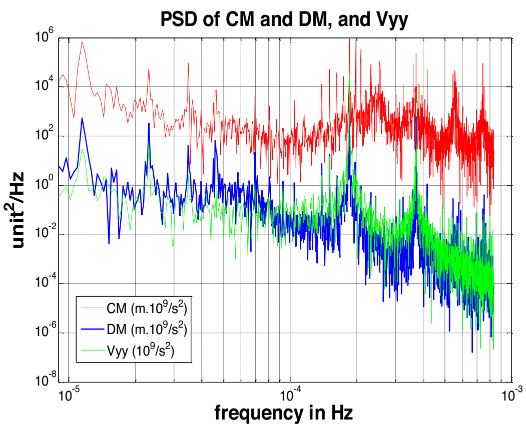

Fig. 6: PSDs of CM and DM accelerations and V_{yy}.

Discussions and Future Work

Our ultimate goal is to develop improved regional static geoid models from GOCE Level 1b data. A combination of well treated satellite observations with accurate regional terrestrial gravity data may lead to accurate regional geoid models.
The aim of this study was to understand and identify the characteristics of GOCE EGG derived Level 1b datasets. Spectral analyses show that the orbital and semi-orbital periods of GOCE dominate other spectral components. These two periodicities can be related to the gravitational attraction due the ellipticity of the Earth. Other periodicities, still to be investigated, contribute to higher frequency characteristics of the gravitational field.
It is observed that the CM accelerations are affected by atmospheric dynamics and the geomagnetic field, which leak into the DM accelerations due to the insufficient calibration parameters. The results indicate that a revision of the determination of the calibration parameters is necessary.
Further studies on the CM and DM accelerations and gravity gradients will be performed by comparing with the datasets obtained for other epochs (2 month length) and also with global gravitational models developed from other gravity missions, such as GRACE. Moreover, comparison between the ascending and descending ground tracks will be studied in order to investigate the systematic differences between the two which might be useful for the improvement of the data processing.
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