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THE NEWSLETTER OF THE CANADIAN GEOPHYSICAL UNION

IN THIS ISSUE

LE BULLETIN DE L'UNION GÉOPHYSIQUE CANADIENNE

President's Column

I want to thank you for the tremendous honour and privilege you have given me to serve as the new president of our outstanding Union. There have been eight great and unforgettable years since I started working with the CGU executive as a member of the local organizing committee of our annual meeting in Ottawa in 2001. Since then, I was very fortunate to have served under past presidents Terry Prowse, Dave Eaton, Phil Marsh, Gary Jarvis and John Pomeroy. Very tough to fill their shoes!

First and foremost, I wish to thank John Pomeroy for his dedication, hard work, and skillful leadership as President of the CGU for the past two years. During John's term, our Union took important new initiatives while consolidating many others. What stands out is the joint CGU-CMOS proposal for the creation of the *Canadian Societies for the Geophysical Sciences, CSGS*. Highly successful (scientifically) joint meetings with the Canadian Meteorological and Oceanographic Society (CMOS) in 2007 (St. John's), with the Canadian Geomorphology Research Group (CGRG) in 2008 (Banff) and with AGU and other Canadian Earth science associations and unions in 2009 (Toronto) paved the way for the promotion and strengthening of the vision and mission of the CSGS. CMOS and CGU have already endorsed the membership of the Canadian Society of Soil Sciences (CSSS) to CSGS. We are now feverishly preparing for next year's joint CMOS-CGU congress in Ottawa, the inaugural conference of CSGS!

CSGS must be seen as the main vehicle for active promotion of the Canadian Geophysical Sciences to NSERC, our primary research funding source. John Pomeroy was instrumental in maintaining and strengthening CGU's communication channels with NSERC, particularly during this period of the introduction of the new peer review structure for the Discovery Grants. CGU will continue to play its important role as a key stakeholder in the validation of different options for the new review process through CSGS. Whereas I'm confident that John will continue to provide his valuable insights and advice to the current executive regarding this important matter, it is the membership that must formulate and develop our positions. To this end, I encourage you all to be vigilant and never hesitate to contact any member of the executive with new ideas, suggestions, and initiatives.

CGU is moving towards a more flexible organizational structure that encourages and promotes the establishment of new Sections. At our latest Annual General Meeting in Toronto, two new sections, namely, Solid Earth and Biogeosciences, joined the existing Hydrology and Geodesy Sections. The new section structure is timely and comes to satisfy important needs in vital activity areas of our Union, while it encourages expansion in new directions and trends. The section structure is expected to enhance CGU's outreach, attract new members, facilitate the organization of workshops and invited lectures, define national projects, and consolidate cross-pollination among the different disciplines. I personally invite you to embrace the sections, show initiative and strong and active participation. And remember, you can be a member to more than one Section!

Our partnership with the National Research Council (NRC) in support of Canada's important affiliation with the International Union of Geodesy and Geophysics (IUGG) requires the submission of annual activity reports to NRC. We are grateful to the Chair of the Canadian National Committee of the IUGG (CNC-IUGG), Zoli Hajnal, for his immense efforts in compiling such annual reports that secure continued NRC financial support and maintain our membership to IUGG.

During John's term we revised and improved the awards criteria by moving towards a more uniform and integrated approach that substantially raises the prestige of the awards but requires a little more effort from everyone, awards committee and students, but …no pain, no gain! We are in the process of fine-tuning these criteria, as they have been in effect for only one year. Hugh Geiger (Talisman Energy) worked tirelessly and energetically not only to revise the criteria but administer the entire awards program, an onerous task indeed!

Nearly two years ago we started working towards changing the status of CGU to a charity organization. Moving forward in this direction has many advantages, but notably in the taxes we pay and the donations we may attract from organizations, industry and individuals. This is not an easy process because it requires detailed documentation of all CGU activities and particularly in the areas of awards, advancement of education, workshops, field trips for students, and others. In general, we need to demonstrate that our Union is non-profit and charitable in purpose within the meaning of the Income Tax Act. Although we have been refused this status, we are determined to continue our efforts. Kathy Young has taken the lead on this important initiative.

On a less happy note, the CGU executive at its latest meeting in May decided to increase the annual membership fees to $40 for regular members and to $20 for student members. This was not an easy decision, but recent increases in the cost of renting conference facilities, and the two consecutive annual deficits (in 2007 and 2008) dictated such a decision. As a consolation, I should mention that even with this small increase, the CGU still has by far the lowest membership fee among other Canadian scientific societies.

On behalf of all CGU members, I would like to warmly welcome Gail Atkinson (University of Western Ontario) as our new CGU Vice President, Kristy Tiampo (University of Western Ontario) as the first President of the Solid Earth Section, Nigel Roulet (McGill University) as the first President (Acting) of the Biogeosciences Section (see the related article in this issue of *Elements*) and Brian Branfireun (University of Toronto) as the new President of the Hydrology Section. I would like to sincerely thank Masaki Hayashi (Secretary), Marcelo Santos (President, Geodesy Section), Phil McCausland (Chair, GAC Geophysics Division), Hugh Geiger (Chair, Awards Committees), Rod Blais (Scientific Meetings Coordinator) and Ed Krebes (Newsletter Editor) for agreeing to continue their valued contribution to the CGU. I'm confident that the departing skilled and valuable member of the executive, Jim Buttle (Hydrology Section Past President), will continue to contribute with his valuable input and advice to the affairs of our Union.

See you next year at the joint CMOS-CGU Congress in Ottawa, May 31—June 4, 2010.

Spiros Pagiatakis

J. Tuzo Wilson Medal – Call for Nominations

The Executive of the CGU solicits nominations for the J. Tuzo Wilson Medal – 2010. The Union makes this award annually to recognize outstanding contributions to Canadian geophysics. Factors taken into account in the selection process include excellence in scientific and/or technological research, instrument development, industrial applications and/or teaching.

If you would like to nominate a candidate, please contact Dr. Hugh Geiger, Chair of the CGU Awards Committee, Talisman Energy, Calgary AB (Email: HGEIGER@talisman-energy.com). At a minimum, the nomination should be supported by letters of recommendation from colleagues, a brief biographical sketch and a Curriculum Vitae. Nominations should be submitted by February 28, 2010. 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 – 2010. 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. Hugh Geiger, Président du Comité des Prix d'Excellence, Talisman Energy (Email: HGEIGER@talisman-energy.com). Les nominations doivent être supportées de lettres de recommandation de colléques, d'un bref sommaire biographique et d'un Curriculum Vitae. Les nominations doivent être soumises avant le 28 février, 2010. Des détails additionnels concernant le processus de nomination peuvent être obtenus en communiquant avec le Président du Comité des Prix d'Excellence de l'UGC.

Past Wilson Medallists

1978	J. Tuzo Wilson
1979	Roy O. Lindseth
1980	Larry W. Morley
1981	George D. Garland
1982	Jack A. Jacobs
1983	D. Ian Gough
1984	Ted Irving
1985	Harold O. Seigel
1986	Michael Rochester
1987	David Strangway
1988	Ernie Kanasewich
1989	Leonard S. Collett
1990	Gordon F. West
1991	Thomas Krogh
1992	R. Don Russell
1993	Alan E. Beck
1994	Michael J. Berry
1995	Charlotte Keen
1996	Petr Vaníček
1997	Chris Beaumont
1998	Ron M. Clowes
1999	David Dunlop
2000	Don Gray
2001	Roy Hyndman
2002	Doug Smylie
2003	Garry K.C. Clarke
2004	W.R. (Dick) Peltier
2005	Ted Evans
2006	Alan Jones
2007	Herb Dragert
2008	Ming-ko (Hok) Woo
2009	Garth van der Kamp

CGU Young Scientist Award – Call for Nominations

The Executive of the CGU solicits nominations for the CGU Young Scientist Award – 2010. The CGU Young Scientist Awards recognize outstanding research contributions by young scientists who are members of the CGU. Both the quality and impact of research are considered. To be eligible for the award, the recipient must be within 10 years of obtaining their first Ph.D. or equivalent degree. The awards are made by the CGU Executive on the recommendations of a special committee struck for this purpose. The selection committee seeks formal written nominations from the membership, plus letters of support and a current curriculum vitae. Nominations for the CGU Young Scientist Awards may be submitted by CGU members at any time.

If you would like to nominate a candidate, please contact Dr. Hugh Geiger, Chair of the CGU Awards Committee, Talisman Energy, Calgary AB (Email: HGEIGER@talisman-energy.com). The nomination should be supported by three letters of recommendation from colleagues. Nominations should be submitted by February 28, 2010. 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 – 2010. 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 recommendations d'un comité spécial à cette fin. Le comité de sélection sollicite des nominations formelles par écrit des membres de l'UGC, accompagnées de lettres d'appui et d'un curriculum vitae à jour. Des nominations pour les Prix pour Jeunes Scientifiques de l'UGC peuvent être soumis en tout temps par les membres de l'UGC.

Si vous désirez suggérer un candidat pour cette médaille, s.v.p. contacter Dr. Hugh Geiger, Président du Comité des Prix d'Excellence, Talisman Energy, Calgary AB (Email: HGEIGER@talisman-energy.com). Les nominations doivent être supportées de trois lettres de recommandation de colléques. Les nominations doivent être soumises avant le 28 février, 2010. Des détails additionnels concernant le processus de nomination peuvent être obtenus en communiquant avec le Président du Comité des Prix d'Excellence de l'UGC.

Past Winners

2005	Shawn J. Marshall,	J. Michael Waddington
2006	No winner	
2007	No winner	
2008	Brian Branfireun,	Scott Lamoureux
2009	Gwenn Flowers,	Stephane Mazzotti

CGU Meritorious Service Award – Call for Nominations

The Executive of the CGU solicits nominations for the CGU Meritorious Service Award – 2010. The CGU Meritorious Service Award recognizes extraordinary and unselfish contributions to the operation and management of the Canadian Geophysical Union by a member of the CGU. All members of the CGU are eligible for this award, although the award is not normally given to someone who has received another major award (e.g. the J. Tuzo Wilson Medal). Nominations for the CGU Meritorious Service Award may be submitted by CGU members at any time. The award is made by the CGU Executive based on recommendations from the CGU Awards Committee, and is based on lifetime contributions to CGU activities.

If you would like to nominate a candidate, please contact Dr. Hugh Geiger, Chair of the CGU Awards Committee, Talisman Energy, Calgary AB (Email: HGEIGER@talisman-energy.com). The nomination should be supported by three letters of recommendation from colleagues. Nominations should be submitted by February 28, 2010. 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 – 2010. 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. Hugh Geiger, Président du Comité des Prix d'Excellence, Talisman Energy, Calgary AB (Email: HGEIGER@talisman-energy.com). Les nominations doivent être supportées de trois lettres de recommandation de colléques. Les nominations doivent être soumises avant le 28 février, 2010. Des détails additionnels concernant le processus de nomination peuvent être obtenus en communiquant avec le Président du Comité des Prix d'Excellence de l'UGC.

Past Winners

2004	Ron Kurtz
2005	Ted Glenn
2006	J.A. Rod Blais
2007	Ed Krebes
2008	Patrick Wu
2009	Gary Jarvis

2009 Joint Assembly Meeting in Toronto on May 24-27, 2009

Rod Blais

This Joint Assembly Meeting under the theme '**Meeting of the Americas**' was sponsored by the American Geophysical Union (AGU), the Geological Association of Canada (GAC), the Geochemical Society (GS), the International Association of Hydrogeologists – Canadian Chapter (IAH-CNC), the Mineralogical Association of Canada (MAC), the Society of Exploration Geophysicists (SEG) and the Canadian Geophysical Union (CGU). General participation was very good with 49 CGU students out of 755 students, and 99 CGU regular members out of 1883 registrants. It is worth noting that these CGU registration numbers amount to the largest Society participation after AGU. All scientific programs were held at the Metro Toronto Convention Centre and details can be found at the website www.jointassembly2009.ca and the AGU website www.agu.org/meetings/ja2009 .

The CGU Scientific Program included two sessions in **Geodesy**:

- Developing a North American Geoid to Serve as a Common Regional Vertical Datum;
- Advanced Geocomputations and Applications;

seven sessions in **Hydrology**:

- Binational Principles and Practices of Stream and Ecosystem Restoration;
- Advances in Cold Regions Hydrology (I and II);
- Recent Advances and Breakthroughs in the Use of Stable Water Isotopes as Tracers of Climate and Climate-Driven Hydrologic Change;
- Recent Advances in the Scientific Basis of

Water Resources Management;

- Thirty Years of Riparian Zone Hydrology and Biogeochemistry Research: Lessons Learned and Future Research Needs;
- Drought: Observations, Theories and Predictions;

three sessions in **Solid Earth**:

- Lithospheric Evolution of the Hudson Bay Region;
- Lunar Secular Evolution;
- Elastic and Inelastic Properties of Earth Materials Under High P-T Conditions;

one session in **Biogeosciences**:

- What is Biogeoscience?

and one general CGU poster session. In addition, there was a special one-hour session for the 2009 Woo Lecture in Hydrology.

Most of these CGU technical sessions had co-sponsors among the other participating Societies and also, a number of other sessions were co-sponsored by CGU. Such co-sponsorship greatly added interesting dimensions to the technical program.

The CGU technical program was assembled by the CGU Scientific Program Committee with special contributions from J. Henton (Geodesy), B. Branfireun (Hydrology), P. McCausland (Solid Earth) and E. Johnson (Biogeoscience). Their contributions were essential in this Joint Assembly Meeting and are greatly appreciated. The AGU Technical Program staff really ensured that everything went smoothly and special thanks go to S. Keeley, S. Grant and B. Weaver.

Our planned CGU-CMOS 2010 Meeting in Ottawa on May 31st – June 4th will obviously be quite different under the theme '**Our Earth, Our Air, Our Water, Our Future**'. Any suggestions for the Scientific Program are always welcome. More information is available at www.cmos.ca/Congress2010/ with the official Call for Session Proposals coming in mid-summer, and the Call for Papers in late September 2009.

Session Report: *Binational Principles and Practices of Stream and Ecosystem Restoration*

Peter Ashmore, University of Western Ontario; Sean Bennett, University at Buffalo; Joe Desloges, U. of Toronto

The science underlying the conservation, restoration and design of stream channels for geomorphic and ecological function has advanced considerably in the last decade. This session was convened to bring together ideas and examples of stream restoration theory and practice from Canada and the U.S. The session featured 10 oral presentations and 6 posters. Invited speakers were Alan Rabideau (Buffalo), Andrea Bradford (Guelph) and Paul Villard (Geomorphic Solutions). Papers covered the breadth of investigations from field based ecological analysis to experimental and numerical fluid dynamics, and from basin scale analysis and planning to the design and success of instream structures. The focus was on streams in the lower Great Lakes region where similar geomorphic and hydrologic conditions, and stream channel impacts, occur on both sides of the border. Experimental work on hydrodynamics and vegetation (e.g. papers by Bennett, Neary and Brooner et al) are refining both the understanding and approaches to modeling of vegetation effects as well as demonstrating ways in which this can be used to deliberately modify channel morphology in predictable ways and to assess the utility of riparian re-vegetation. There is now clear understanding of the need to understand the role of flow regime in channel morphology and habitat (e.g. papers by Bradford and Han and Endreny) and the way in which ecological flow assessments and subsurface flows need to be tied to geomorphology. There is continued work on the hydraulic design of stream improvement structures (Zhou and Endreny, and Jamieson et al.) especially in the face of limited evidence of ecological benefit (Whiteway and Biron). The importance of physical habitat and stream type is well-recognised and work on site-level effects and predictive relationships is building further detail and insight into regional effects (Quesnelle and Jones). This detailed understanding and regional context is being fed up into basin-scale objective assessment of stream dynamics (Ferencevic and Ashmore, Phillips) as well as conceptual and practical management and planning (Pushkar et al., Villard, Rabideau and Blersch, Rousseau and Biron). The science of stream system rehabilitation and the development of expertise will be greatly assisted by the development of interdisciplinary education such as that of the Ecosystem Restoration Through Interdisciplinary Exchange (ERIE) program at Buffalo (Rabideau) and by the kind of discussions and connections catalyzed by this session, extending into social and cultural realms and community engagement, in this area of environmental hydrology.

Session Report: *Advances in Measurement of Sediment Transport*

Marco Van De Wiel, University of Western Ontario

This session featured six talks, which were united in the common thread of the use of new remote sensing techniques to measure sediment transport, using visual, acoustic and magnetic sensors. Thematically, the talks were split evenly between aeolian and fluvial systems. First Cheryl McKenna-Neumann (Trent University) illustrated the potential of Particle Tracking Velocimetry in aeolian studies, showing high-resolution imagery of particle motion and interaction during saltation in wind tunnel experiments. Next, Irene Delgado-Fernandez (Guelph University), used repeat imagery from oblique cameras, in conjunction with anemometer measurements, to determine coastal dune sediment budgets over various temporal scales. In the final aeolian talk, S. Sutton (Trent University) conducted laboratory experiments to investigate avalanching on the lee slopes of dunes. Using a high-resolution laser scanner, he was able to reconstruct and analyse topographic change on the lee slope due to avalanching and reptation. The fluvial component of the session got started by Colin Rennie (University of Ottawa), who used Acoustic Doppler Current Profiling from a moving platform (i.e. a boat) to determine sediment bedload rates in the Fraser River. By subtracting the GPS obtained velocity of the platform from the Doppler sonar signal, the bedload transport rates were obtained. Uncertainty analysis on the results indicates different sources of uncertainty, depending on flow conditions. Next, Dan Parsons (University of Leeds, UK) gave an overview of the potential of Multi-bean Echo Sounder systems for imaging suspended load concentrations. Finally, Tim Argast (University of British Columbia) showed work in progress on the application of a new bar-shaped magnetic sensor, intended to overcome problems with existing in-situ magnetic devices for detecting bedload sediment transport.

Session Report: *Models of Catchment-Scale Sediment Transport*

Marco Van De Wiel, University of Western Ontario

This session featured six talks, all of which highlighted the complexity of catchment-scale sediment transport processes. First, Taylor Perron (Massachusetts Institute of Technology) analysed characteristic length scales in a landscape (e.g. spacing of first order valleys) using a numerical landscape evolution model. He showed that these characteristic length scales arise from the interaction between diffusive transport processes (e.g. hillslope creep) and advective transport processes (e.g. fluvial transport). Next, Tom Coulthard (University of Hull, UK) gave an overview of the abilities and limitations of numerical landscape evolution modelling, again highlighting process interactions, e.g. coupling fluvial and aeolian transport, and the complex dynamics that emerge from this. Lee Gordon (University at Buffalo), illustrated the use of physical modelling of rill network evolution, in a study which is aimed at better understanding the role of internal and external controls on drainage network development and landscape evolution. This balance between internal and external controls was also discussed by Marco Van De Wiel (University of Western Ontario), who traced the origins of highly variable sediment yields in a numerical landscape evolution simulations subjected to regular external forcing. Next, Faran Ali (University of Saskatchewan) showed that a simple empirical model of erosion and sediment yield gives good results the Upper Indus Basin, thereby providing a potential framework for modelling erosion in large ungauged basins. Finally, Hélène Lamarre (Université de Montréal), presenting her observations on bedload particle path-length in relation to morphological pool-riffle scale in natural rivers, reminded all the modellers that the real world is always more complex than the modelled world.

A poster session on Models and Measurement of Sediment Transport accompanied both the aforementioned sessions. Here, some very interesting work in progress was presented and we hope to see further developments of these researchers at future conferences.

The 2009 CGU J. Tuzo Wilson Medallist: Garth van der Kamp

Citation, by Masaki Hayashi

It is my great honour to introduce the 2009 J. Tuzo Wilson Medalist, Dr. Garth van der Kamp.

Hydrology is a prominent field of geophysics, as reflected in the fact that about one third of the CGU members identify themselves as hydrologists. However, many hydrologists tend to work on specialized subject areas that are not directly connected to broader fields of geophysics. Garth is an exceptional hydrologist, who has made outstanding contributions in remarkably diverse fields of geophysics including the poromechanical effects of earth tide, subsurface fluid flow under the ocean floor, perturbation of geothermal heat flow by groundwater movement, diffusion in low-permeability sediments, eco-hydrology of prairie wetlands, and groundwater sustainability. Some of his work dealt with fundamental theories of fluid flow, and others presented rigorous and innovative analyses of geophysical field data. The hallmark of his research is careful observation and rigorous analysis of physical phenomena, often using elegant but simple mathematical tools. When many of us face the immense pressure of 'publish or perish', he has maintained the principle to publish only those papers with significant results and only when he is satisfied with the quality of data and the rigor of analysis. It is this principle that earned him the respect from his peers in the international research community.

Garth arrived in Montreal in 1955 as a nine-year old boy in a Dutch immigrant family. The family eventually settled in Burnaby, BC and he attended the University of British Columbia majoring in physics. Garth always amazes me with his ability to spot the critical pieces in complex puzzles of geophysical phenomena. This may be due partly to his rigorous training as an experimental physicist. His first journal publication was on the plasma physics research he conducted as a M.Sc. student. For his Ph.D. research, however, he completely changed the research field to groundwater flow because he got tired of "spending hours and hours in the dark basement lab". This was very fortunate for the Canadian and international geophysics community. Working with Peter Carr he published his first hydrology-related paper in 1969, and then went to the Free University in Amsterdam and learned the theory of poromechanics from the pioneer in the field, Arnold Verruijt, and developed complex mathematical solutions describing the effects of tidal fluctuation on pore pressure.

After receiving his Ph.D. degree in 1973 and spending two years as a post-doctoral fellow at Environment Canada in Ottawa, he was hired by an engineering firm as the project hydrogeologist for a water supply project in Ghana, funded by Canadian International Development Agency. This is where he developed knowledge and interest in practical aspects of groundwater hydrology, and also met his future wife, Linda. Upon his return to Canada in 1980, he became a research associate professor at the University of Waterloo and resumed his work on poromechanics. He and John Gale published a seminal paper on the effects of earth tide and barometric fluctuations on fluid flow in 1983, which quickly became the international landmark. Later, Garth used similar approaches to understand the tidal responses and energy dissipation of fluid in seafloor boreholes for the Ocean Drilling Program, collaborating with Kelin Wang and Earl Davis from the Pacific Geoscience Centre.

Garth moved to Saskatoon in 1982 to work at the Saskatchewan Research Council and later at Environment Canada's National Hydrology Research Institute. He turned his attention to low-permeability glacial till that covers most of the Prairie Provinces. He and his graduate student, Kent Keller conducted careful field studies and published a series of papers, which demonstrated the roles played by often invisible fractures and thus advanced understanding of the groundwater flow in glacial till. After these papers, Garth and another graduate student, Vicki Remenda examined solute transport in unfractured glacial till and showed that the transport is dominated by molecular diffusion, consistent with the very slow fluid flow that was documented by the previous studies. Driven by the need to characterize the pore fluid and measure molecular diffusion coefficients in glacial till, Garth and his colleagues developed a new 'radial diffusion method' in 1996, which is now used by many researchers working on low-permeability materials around the world.

Garth's scientific interests expand well beyond the traditional realm of geophysics. He sees no disciplinary boundary between physical and biological science. In fact he considers plants and animals the essential component of the hydrologic cycle. He started a hydrological study of prairie wetlands in the early 1990's in St. Denis National Wildlife Area near Saskatoon, motivated by the need to understand the effects of wetland water regime on the population dynamics of waterfowl. Since this project had a very broad scope, Garth worked with a number of colleagues including Dave Rudolph, Malcolm Conly, and the late Bill Stolte, and Masaki Hayashi. They showed that the water balance of prairie wetlands is strongly influenced by the uptake of groundwater by the riparian vegetation, and that the existence of wetlands critically depends on the lateral inputs of snow-derived water from the surrounding uplands. In the last few years, his eco-hydrological interest has expanded to boreal peatlands and forest hydrology.

Garth takes great care in collecting high-quality field data, which resulted in several new data collection and interpretation methods that pushed the boundary of subsurface hydrology. For instance, he proposed a method to measure the hydraulic property of geological materials with extremely high permeability – so high that the water level in a well oscillates up and down when an instantaneous perturbation is introduced in the well. This method is now widely known as the van der Kamp method, and used by leading scientists around the world to understand a broad range of geophysical phenomena including the response of groundwater to earth quakes and the effects of subglacial water on glacier surge. In another case, he and Harm Maathuis noted that pore pressure fluctuation in extremely low-permeability formations is primarily governed by changes in total stress due to earth tide, barometric pressure, and the weight of soil water. Using meticulously collected field data and the poromechanical theory, he developed a method to detect changes in soil water storage averaged over a scale of hectares. This method is now called 'geological weighing lysimeter'. These examples clearly demonstrate the quality of Garth's research publications and their long-lasting and broad impacts on the international geophysical community.

As a research scientist working for provincial and federal government agencies, Garth contributed tremendously to the scientific understanding of water resources. He and his colleagues published numerous technical reports and advised policy makers and industrial sectors on practical issues related to the quantity and quality of groundwater. He is a much sought-after speaker in numerous workshops organized by watershed groups and local governments, because he is one of Canada's leading experts on water resources.

Garth's scientific curiosity and passion for 'figuring out' how nature works have been a steady source of encouragement for those who have been fortunate enough to be trained by him. He enjoys being out in the field so much that he often takes his family out to field sites to share his enthusiasm and passion. As an adjunct professor or as an external co-supervisor, he has trained many graduate students in Saskatchewan, Waterloo, and Calgary. All three of his Ph.D. students are now university professors (Kent Keller, Vicki Remenda, and Masaki Hayashi), and many of his M.Sc. students and trainees are working in environmental sectors. He is extremely generous with his time and intellect, but always challenges his students to probe deeper and find new ways to interpret the data. One thing I always remember is his advice to examine the meaning of outliers or noises that are inconsistent with the existing theory or model, as they often lead to a new discovery. The geological weighing lysimeter and the oscillating well, mentioned above, are excellent examples where noises in water level data turned out to contain important information.

He has been an active member of the CGU, who has worked tirelessly to integrate surface and subsurface hydrology in the CGU. In 1994, when I first attended the CGU annual meeting, there were very few, if any, hydrogeologists in the meeting other than Garth and I. After 15 years of efforts by Garth and others, we now have a sizable number of presentations integrating surface and subsurface hydrology at annual meetings.

Garth has generously volunteered his time and energy providing services to the scientific community. He has served as the treasurer of the CGU Hydrology Section, and is an executive member of the International Association of Hydrogelogists - Canadian National Chapter (IAH-CNC), and an Associate Editor of the journal Ground Water and the Canadian Water Resources Journal. He has also been very active in public outreach to promote earth science. He has given numerous seminars and presentations to the general public and at universities, and has regularly taught field courses for high-school science enrichment programs.

Garth's outstanding scientific achievements have been recognized by his peers around the world. In 2005, the IAH-CNC awarded him the Robert N. Farvolden Award to honour his outstanding contributions to the disciplines of earth science and engineering that emphasize the role or importance of groundwater. The rigor and quality of his research in diverse areas of geophysics, and his quality as a teacher and mentor is truly outstanding. He has served tirelessly for the CGU and other scientific societies, and has had significant influence on the development of environmental policies as a government research scientist.

Garth, on behalf of all of your former and present students and colleagues, I am highly privileged to have this opportunity to present this citation to honour your outstanding contribution to Canadian geophysics.

Acceptance, by Garth van der Kamp

Mr. President, colleagues, guests, friends:

Thank you Masaki for your generous remarks. To be awarded the Tuzo Wilson Medal of the Canadian Geophysical Union; that is something which I had never expected. And so a thank you to colleagues and friends who have so wonderfully shown their appreciation of the work we have enjoyed doing together.

The Canadian Geophysical Union is important to me. I look forward to its annual meetings as the occasions where I know I will meet with my peers in hydrology and geophysics from across Canada. I owe a special appreciation for those who organized the Hydrology Section of CGU in the early 1990's because it has functioned for me as a bridge between the groundwater and surface hydrology communities of Canada.

I also value highly the opportunities I have had to work with geophysical colleagues outside hydrology, many of whom I meet with at the CGU meetings. I have relished exploring the connections between hydrology and other branches of geophysics: gravity and groundwater with Tony Lambert, heat flow with Allan Judge and Allan Jessop, tidal energy dissipation with Kelin Wang and Earl Davis.

On such an occasion as this, one looks back and finds stories to tell. I can start with Tuzo Wilson's special lecture on plate tectonics at the University of BC in 1965. Dick Peltier, the 2004 Wilson recipient, was there. So was I, an undergraduate in physics, and I recall vividly the image of the parallel stripes of magnetization on the ocean floor that so amazingly demonstrated spreading at the mid-ocean ridges. In one short hour continental drift became part of my mental image of the globe.

But I had been sitting through too many lectures, writing endless notes, and the textbook variety of science was not exciting: a collection of facts to be learned. I came to Amsterdam, looking for a change and there I met with a much richer view of science through lectures on the history of science given by Professor Reijner Hooykaas. He described " in what variety of ways the human mind, with all its subjectivity and its capacity for self-deception, but also its piercing gifts of discovery, managed to come to terms with 'the whimsical tricks of nature'. Research in natural science was, I realized, a creative endeavour, a craft carried out by ordinary mortals such as me, and therefore could be enjoyed. And it was to be done with humility and integrity.

In Amsterdam I also fell in with art history students and sometimes accompanied them for site visits to the Rijksmuseum. While tourists streamed by, checking off famous paintings on their to-see lists, the professor kept us in front of one painting all morning, demonstrating that if a gifted artist spent years meticulously crafting the painting, then we could profitably spend a few hours exploring and enjoying its richness of meaning and composition. I learned that though I was surely no Rembrandt of science, I could at least take the time to be meticulous in reading and writing research papers.

My first experience of groundwater research was as a summer assistant with Peter Carr of the Geological Survey of Canada. He didn't send me home when he realized that I had never even heard of Darcy's law for groundwater flow. It worked out just fine because physics makes an excellent basis for groundwater theory. During my post-doctorate stint with Environment Canada there were many critical discussions of hydrology with Vit Klemes and Fred Morton. I may grumble about the foibles of my employer, Environment Canada, but the department still continues to provide opportunities for the pursuit of interesting questions.

Later, in Ghana, West Africa, I learned to appreciate the true importance of water while working on a large CIDA water supply project. As the project hydrogeologist, it fell to me to decide where new wells should be drilled to serve as many people as possible. Headmen from small isolated villages walked many miles to my house with a courtesy gift of a goat or a basket of eggs, to request a well. I still regret that I denied Charia a well, discovering after our drilling rigs had left the area that the villagers had cleared a road through miles of bush in the hope that we would come to drill in their tiny village.

Special thanks go to my wife Linda and my children for keeping me firmly in a healthy work-life balance. And after all, the best research ideas often come when one is least looking for them – while building a sandcastle on a sandbar in the river, or drowsing on the grass beneath an apple tree. Thank you to my parents, who encouraged us and taught us to look beyond conventional truths.

John Cherry and David Rudolph provided a connection to the groundwater research group at the University of Waterloo. It was a lifeline to new ideas and to graduate students, whom I hesitate to call students, because they soon became friends and colleagues: I think especially of Kent Keller, Vicky Remenda and Masaki Hayashi. Harm Maathuis has been a valued co-worker. Much of the really interesting data would not have been collected without Randy Schmidt's attention and technical skills. Jack Millar of the Canadian Wildlife Service persisted in collecting many years of water level data for prairie wetlands, in mud and cold and heat. I want in some way to dedicate the Wilson Award to all those who work carefully and patiently, perhaps with little recognition, in gathering more knowledge of the world around us.

Now I would like to take a wider view. Beyond the grasp of our equations and models there lies an endlessly intricate and beautiful world. The language of poetry is better suited for it. From Tim Lilburn, a Saskatchewan poet:

" ... to imagine [the world] caught in our phrases, is to know it without courtesy, and this is perhaps not to know it at all ....."

[Living in the world as if it were home, Cormorant, 1999]

Let me rephrase that: "To imagine [the world] caught in our [theories], is to know it without courtesy, and this is perhaps not to know it at all …..".

And we need to respect and cherish that world. Listen to Gerald Manley Hopkins, more than 100 years ago:

"What would the world be, once bereft
Of wet and of wildness? Let them be left,
O let them be left, wildness and wet;
Long live the weeds and the wilderness yet."

[Inversnaid]

Thank you.

Presentation of the Tuzo Wilson Medal. From left to right: Spiros Pagiatakis, Garth van der Kamp, Masaki Hayashi.

The 2009 CGU Young Scientist Award Winners:
Gwenn Flowers and Stephane Mazzotti

Gwenn Flowers is a rarely talented environmental earth scientist who is making outstanding contributions to our understanding of the dynamics of the terrestrial cryosphere—Earth's glaciers, ice caps and ice sheets. Her research focuses on the physics of water flow beneath ice sheets and on how the operation of the subglacial water system governs the processes that promote fast changes in ice flow and the catastrophic release of subglacial water.

Gwenn received the 1998 AGU Outstanding Student Paper in Hydrology and the 1999 D.M. Gray Award for Best Student Paper in Hydrology. In January 2005 Gwenn was appointed to the faculty of Simon Fraser University as the Canada Research Chair in Glaciology. As recognition of her excellence and promise, she received the 2006 Outstanding Young Scientist Award of the European Geosciences Union and is the first Canadian-based recipient of the 2008-2009 Marie Tharp Visiting Fellowships from the Earth Institute of Columbia University awarded each year to "women scientists on their way to becoming the best in their fields."

In terms of international reputation, the objective quality of her research contributions and her ultimate promise, she is one of our outstanding contributors. Gwenn Flowers is a highly deserving recipient of the Canadian Geophysical Union's Young Scientist Award.

Stephane Mazzotti is one of Canada's impressive young geoscientists, with great potential for future scientific achievements. He has already made exceptional contributions in earthquake hazard prediction and sea level change that are widely recognized internationally, and in addition are of critical importance to the needs of Canada and Canadians.

Stephane is currently a GSC Research Scientist at the Pacific Geoscience Centre, and Adjunct Associate Professor at the University of Victoria.

The most readily quantifiable measure of Stephane's exceptional scientific productivity is his 36 publications mainly in respected peer-reviewed international journals. The impact of these publications is demonstrated by close to 500 citations by others - an impressive number for a scientist who is only 10 years from his PhD. Stephane is a worthy recipient of the CGU Young Scientist Award.

CGU Awards Committee

The 2009 CGU Meritorious Service Award Winner: Gary Jarvis

Citation, by Julian Lowman

I am delighted to announce that the recipient of the 2009 CGU Meritorious Service Award is Dr. Gary Jarvis. Dr. Jarvis, or Gary, has been a member of the CGU since its founding in 1988, and has held several different positions on the Union's Executive Committee, including the Presidency. However, before summarizing his service and contributions to the CGU, I would like to recount some of Gary's scholarly achievements.

Gary graduated from the University of Toronto with a Bachelor of Science in Physics in 1971. He then went to the University of British Columbia and completed an MSc studying Glaciology in 1973 under the supervision of Dr. Garry Clarke. Following his MSc, Gary's focus turned to the Earth's interior. He was awarded a Commonwealth Scholarship, held at the University of Cambridge, in England, where he completed his PhD in 1978 under the supervision of Dr. Dan McKenzie, studying infinite Prandtl number compressible convection and its implications for convection in the Earth's mantle. In 1979 Gary returned to the University of Toronto as an NSERC postdoctoral fellow working with Dr. Richard Peltier. After his postdoctoral studies, Gary continued at the University of Toronto where he was awarded an NSERC University Research Fellowship, and became an Assistant Professor in the Department of Geology. In 1985, Gary moved to the Department of Earth and Atmospheric Science at York University where he was promoted to full Professor, in 1999. His service to York University has included holding the positions of Chair of the Department of Earth and Space Science and Engineering, Director of the Graduate Programme in Earth and Space Science, and Associate Dean (Academic Affairs). Gary's research interests lie in the fields of Global Geodynamics and Geophysical Fluid Dynamics and more specifically, mantle convection and lithosphere dynamics. Recognized for his expertise in these areas, he has published or co-published over 50 peer-reviewed research papers and book Chapters.

Gary's contributions to the promotion of Geophysics in Canada and his service to the Canadian Geophysical Union has seen him hold a number of key CGU posts. In 1994 he became the editor of the CGU newsletter *Elements*, a position that he undertook for 8 years. In 2003 Gary became Vice-President of the Union and from 2005-2007 he served as President. Since 2007 he has been serving on the CGU Executive Committee as Past-President.

Gary's 20 years of generous service to the success of our union clearly makes him most deserving of the CGU Meritorious Service Award and it is with great pleasure that I am able to announce that he now joins the list of distinguished recipients recognized for outstanding service to the CGU.

Acceptance, by Gary Jarvis

I am honoured to be this year's recipient of the *CGU's Meritorious Service Award*. I would like to thank those who initiated and supported my nomination, as well as the *CGU's Awards Committee* and *Executive Committee*. I would especially like to thank my former Masters supervisor, Garry Clarke [pictured here on the moraine covered terminus of Steele Glacier in 1973] – for getting me involved with the *CGU Executive* in 1994.

I think we always feel indebted to our first research supervisor, but doing field work together forms a special bond. So when Garry, as President of the *CGU*, called me - 21 years after this picture was taken - to ask a favour, I knew it would be hard to say no.

Garry and his executive had renamed the *CGU* newsletter from *The CGU Newsletter*, to *Elements* and had designed a new masthead and *CGU* logo for the front cover. Garry asked if I would join the Executive as the first editor of *Elements* for a two-year term. He admitted that I would probably be asked to serve a second 2-year term but there was not even the hint of a suggestion that the term might stretch to fifteen years.

In the past 15 years there have been a number of important developments and changes in the *CGU*. For me, the most satisfying has been the formation of the *CSGS*, the Canadian Societies for the Geophysical Sciences. The origins of the *CSGS* can be traced to Garry Clarke's President's message in my first issue of *Elements* [May 1995 – see below] in which Garry described how *NRC* - as the national *Adhering Member* of the *IUGG* - had chosen the *CGU* to be its scientific Partner. *NRC* pays Canada's annual fees to the *IUGG* (~ $18,000 CDN) and to 30 other international scientific unions. It also underwrites the costs of international meetings of the *IUGG* or any of its eight International Associations when their meetings are held in Canada (such as the joint *IACS-IAMAS-IAPSO* meeting being held in Montreal this summer). Garry's article notes that the Partnership Agreement with *NRC* will necessarily result in closer ties to *CMOS* and other scientific societies, in all fields encompassed by the *IUGG*.

Continuing this theme, Dave Eaton subsequently chaired a joint *CGU/CMOS* Fusion Committee, Phil Marsh arranged the second ever joint *CGU/CMOS* scientific meeting in St. John's, I initiated joint meetings of the Executive Committees of the *CGU* and *CMOS* during the St. John's meeting and John Pomeroy has brought the process to a successful completion this year with the signing of a joint agreement between the *CGU* and *CMOS* as the founding members of the new Canadian

Societies for the Geophysical Sciences (*CSGS*). This is the first step in formally grouping Canadian geophysical science societies together under one umbrella, comparable to the *IUGG*. The next society to join the *CSGS* will likely be the Canadian Society of Soil Science, and others will follow. An evolving *CSGS* will provide a collective voice for the Canadian geophysical sciences, at home and abroad. I encourage the new Executive to continue its work in coordinating the Geophysical sciences in Canada.

I will conclude by stating that it has been an honour and a privilege to work with my fellow colleagues on the CGU Executive Committee over the years. I thank them for their friendship, cooperation and self-less contributions which have made my experience on the Executive Committee so enjoyable.

I would also like to acknowledge the constant support and encouragement of my lovely wife, Helene, who adapted to my many trips for the CGU, Lithoprobe and my own research by becoming my constant travelling companion. This has made my business travel much more pleasurable and I thank her for that.

Finally, I again wish to thank the Canadian Geophysical Union for honouring me with this award.

Elements

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THE NEWSLETTER OF THE CANADIAN GEOPHYSICAL UNION

IN THIS ISSUE

LE BULLETIN DE L'UNION GÉOPHYSIQUE CANADIENNE

PRESIDENT'S COLUMN

As I discussed in a previous column, the CGU has been negotiating with the National Research Council to determine a satisfactory future for the Canadian National Committee for the International Union of Geodesy and Geophysics. With the next General Assembly of the IUGG scheduled for Boulder in July 1995, the uncertain status of the current CNC/IUGG had become a pressing concern. I am therefore pleased to report that in October 1994 we concluded an agreement with NRC that establishes the CGU as the new home for the CNC/IUGG and effectively transfers management responsibility from NRC to CGU.

The agreement affirms that the CGU is the "focus of the Canadian community working in the fields of geodesy and geophysics"; this accords fully with our own perception of the Union and with its stated goal: to serve as a national focus for the geophysical sciences in Canada. An important benefit to the CGU is that we shall necessarily be drawn toward closer interactions with companion societies such as the Canadian Meteorological and Oceanographic Society, the Geological Association of Canada, the Canadian Institute of Geomatics and the Canadian Association of Physicists, all of whom share our interest in strengthening the geophysical sciences. NRC will continue to pay the annual subscription fee to IUGG (roughly $14,000) and the CNC/IUGG will continue to function on a very small budget. Thus the financial implications for CGU should be negligible.

The CNC/IUGG will comprise 14 members, two representing each of the seven associations of IUGG. To refresh your memory, these associations are:

- IASPEI - International Association of Seismology & Physics of the Earth's Interior
- IAVCEI - International Association of Volcanology & Chemistry of the Earth's Interior
- IAG - International Association of Geodesy
- IAMAS - International Association of Meteorology & Atmospheric Science
- IAGA - International Association of Geomagnetism and Aeronomy
- IAHS - International Association of Hydrological Sciences
- IAPSO - International Association of Physical Sciences of the Ocean

The CGU will be responsible for appointing two members representing each of IASPEI and IAHS and one of the two members representing IAVCEI, IAG and IAGA; representatives to IAMAS and IAPSO will be appointed by CMOS. Because substantial communities of geophysical scientists are unaffiliated with CGU, one of our challenges is to be a sensitive manager of the CNC/IUGG. To ensure a smooth transition we have simply "adopted" the existing committee and will let current members of the CNC/IUGG complete their terms of service. Dr. Richard Langley of the Department of Survey Engineering, University of New Brunswick, has agreed to remain as chair until 1997 at which time he will be succeeded by an individual to be proposed by CMOS. Over the past few years we have witnessed NRC's dismantling of the network of associate committees and subcommittees that were originally created to mirror the structure of the associations and committees of IUGG. The individual merit of the various committees may have been uneven but certain of them played central roles in their areas of science. When, because of financial retrenchment within NRC, the lives of these committees terminated, no alternative institutions were ready to pick up the pieces. This was an unquestionable setback for Canadian science. Our agreement with NRC marks a new beginning and an opportunity to rebuild on a sounder basis.

-GARRY CLARKE

PRESIDENT'S COLUMN

As I discussed in a previous column, the CGU has been negotiating with the National Research Council to determine a satisfactory future for the Canadian National Committee for the International Union of Geodesy and Geophysics. With the next General Assembly of the IUGG scheduled for Boulder in July 1995, the uncertain status of the current CNC/IUGG had become a pressing concern. I am therefore pleased to report that in October 1994 we concluded an agreement with NRC that establishes the CGU as the new home for the CNC/IUGG and effectively transfers management responsibility from NRC to CGU.

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HYDROLOGY SECTION NEWS

CGU Hydrology Section Committee Reports, July 2009

Compiled by Sarah Boon

Erosion and Sedimentation Committee

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

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

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

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

i) communication of current research via discussion, meetings, conferences and publications;

ii) identification and promotion of high priority research topics in the Canadian context;

iii) promotion and encouragement of the transfer of knowledge and technology in the field of interest.

Meetings & Activities

- Continued representation at CGU-HS sessions.
- Reciprocal membership arrangement and affiliation between CGU and Canadian Geomorphology Research Group has resulted in several sessions at other national conferences jointly between the two groups, including several joint sessions at 2008 CGU conference (for the first time) including a full day special session on sediment transport and landform dynamics with several invited speakers. Ashmore was a member of the program committee and helped coordinate sessions between the two organizations.
- Ashmore led the preparation of a summary of recent Canadian research in fluvial sedimentation for IAHS-CNC, with co-authors Pascale Biron (Concordia), Colin Rennie (Ottawa) and Brett Eaton (UBC). Now in press in CWRA Journal.
- Active participation at Joint Meeting in Toronto (May 2009) including: CGU sponsored session on *Binational Principle and Practices in Stream Restoration*, and Hydrology section sessions on *Models and Measurement of Sediment Transport* and *Advances in Measurement of Sediment Transport*. Ashmore is participating (invited) in GAC session on fluvio-glacial sediment transport and landforms.
- We anticipate some renewal of Committee membership over the next 1-2 years to bring in active, new researchers interested in developing committee activities.

Glaciers and Environment Committee

Chair: Michael N. Demuth, P. Eng., P. Geo., Head, Glaciology Section, Geological Survey of Canada, Natural Resources Canada, 601 Booth Street, Ottawa, ON KIA 0E8, Mike.Demuth@NRCan.GC.CA
Vice-Chair: Gwenn E. Flowers, Canada Research Chair, Glaciology, Simon Fraser University, gflowers@SFU.CA
Past-Chair: D. Scott Munro, University of Toronto

Advisory Members: Sarah Boon, University of Lethbridge; Shawn Marshall, University of Calgary; Brian Menounos, Univ. of Northern British Columbia; D. Scott Munro, University of Toronto; John W. Pomeroy, University of Saskatchewan; Jeffrey Schmok, P. Geo., Golder Associates Ltd.; Martin J. Sharp, University of Alberta.

Mandate and Objectives

a. Assist the CGU and its executive in promoting glaciological research that is relevant to hydrological and environmental problems.

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

Meetings and Activities

(a) *Evolution of the Cold Water Collaborative*

In December of 2008 a landmark workshop organised by the Western Watershed Climate Research Collaborative and supported by various government, academic and private sector institutions concerned with water security, was held in Canmore, Alberta. The workshop process reviewed the status of water monitoring and modeling in western Canadian watersheds, and charted a course towards enabling sustainable observations and improved prediction, in particular as it concerns elevation biases in most observation series relevant to prediction at a number of scales.

As a mountain & Arctic watershed science, research and information group, it was proposed that a "Cold Water Collaborative" be formed that would, in part, serve the technical needs of the Western Water Stewardship Council. The WWSC identifies key inter-jurisdictional water issues and immediate work plan priorities needed to serving the common water resources management interests of western and provinces and adjacent northern territories.

Conceived as a user-driven scientific collaboration, the Cold Water Collaborative would develop, direct, harness and interpret science in support of the WWSC work plans. It is envisioned that the collaborative will be composed of already existing expertise and institutional capacity, including western and northern water and climate science initiatives that are presently collecting data or undertaking science for the public good. For further details please contact John.Pomeroy@ USask.CA or Robert Sanford at sandford@telusplanet.net

(b) *Interaction between the CFCAS research networks: Improved Processes, Parameterizations and Prediction in Cold Regions (IP3) and Western Canadian Cryospheric Network (WC2N)*

Several joint meetings between IP3 and WC2N have resulted in enhanced co-operation and opportunities for knowledge advancement and the training of HQP through these hydrologically thematic and regional research networks. In addition there has been the joint development of an Outreach Co-ordinator position that will serve to connect community and school groups with network members. For more information please see: http://www.usask.ca/ip3/

(c) "***State and Evolution of Canada's Glaciers" collaborative WWW Workspace and data portal at NRCan/GSC***

The State and Evolution of Canada's Glaciers initiative provides information and data products produced by the Federal Government's National Glacier-Climate Observing System (monitoring, assessment and data portal) and related freshwater vulnerability research in western and northern Canada.

The Glacier-Climate Observing System is delivered through an integrated monitoring and research collaborative comprised of Natural Resources Canada-Geological Survey of Canada (lead agency), Geomatics Canada-Canada Centre for Remote Sensing, Environment Canada-National Water Research Institute and Water Survey of Canada, Parks Canada Agency, C-CORE PolarView, and numerous academic partners.

An effort to renew access to basic data describing the mass balance of Canadian glaciers and ice caps is currently underway through the data portal of the State and Evolution of Canada's Glacier collaborative Workspace WWW site. At this time, the data comprise net mass balance time series for Canada's current reference network of mass balance glaciers. More detailed data on seasonal balances and specific variation by elevation are available through peer-to-peer collaboration. There is also a utility with which to submit new data on glacier fluctuations. These are compiled by the Canadian National Correspondent to the World Glacier Monitoring Service (WGMS) and periodically contributed to the WGMS on behalf of the observer/PI and Canada.

The Workspace also provides for the posting of announcements on new research results, publications and related events and news concerning Canadian glaciers. Please see: http://pathways.geosemantica.net/WSHome.aspx?ws=NGP_SECG&locale=en-CA

Other Correspondence:

(a) *Legal Status of Glaciers in Canada*

Numerous institutions across Canada concerning themselves with glaciers have been contacted by officials from Chile, asking whether glaciers had any specific legal status in Canada (viz. Argentina has declared glaciers as "protected").

Considerable discussion has been had internally and amongst Canadian institutions that perhaps the CGU-HS Committee on Glaciers and Environment consider developing a position paper that would investigate and clarify the status of glaciers in Canada as it concerns the legal and resource attributes of perennial snow and ice masses.

With the exception of their status in protected areas such as National Parks (which is clear), it would be instructive to convene a sub-committee comprised of technical, natural resource policy and legal experts to examine their disposition as it concerns private and crown lands, aspects of First Nations and jurisdictional limits concerning surface and sub-surface resources. Further it is worthy to examine to what extent, within practical human adaptation planning horizons, glaciers are to be considered a renewable resource. This has clear implications for regional energy mix considerations and carbon trade and cap.

(b) ***Citation of Canadian mass balance data***

There is a persistent problem arising whereby data collected and analysed by Canada's National Glacier-Climate Observing System (NG-COS) at NRCan/GSC is either not being cited or acknowledged; or reference is given to third-party compilations which: i) contain errors, and ii) do not acknowledge the PIs and institutions who work tirelessly to maintain long-term monitoring and assessment programs.

The co-ordinator of NG-COS has discussed this with the Director of the WGMS and other National co-ordinators, concluding that this lack of acknowledgment will only lead to the further decline of support for long-term mass balance study in member nations contributing to the UNFCCC process through WMO's Global Terrestrial Network for Glaciers (a component of the Global Climate Observing System).

These data culture concerns were also discussed during the inaugural Canadian meeting introducing the Global Cryosphere Watch initiative. Critical was the need to recognize the aspect of "reprocessing" in the data chain, and that periodic reassessments and reviews of past data may affect the provision of data according to academic or operational schedules.

In the lab and field:

(a) During 2008, several Journal Special Issues concerning the implication of glacier and cryosphere diminution on hydrology and eco-hydrology were published. Notably these international perspectives included some of the work conducted by numerous Canadian glaciologists and hydrologists:

(i) Terra Glacialis: Special Issue – Mountain Glaciers and Climate Changes of the Last Century (L. Bonardi, Editor)

(ii) Hydrological Processes 21(1): Special Issue – Hydrologic Effects of a Shrinking Cryosphere (T.D. Prowse, Editor)

(iii) Canadian Water Resources Journal 34(2): Recent Advances in Canadian Hydrology. (JW Pomeroy and RD Moore, Editors). Canadian Glacier Hydrology 2003-2007 (Boon, Flowers and Munro)

(b) Canadian International Polar Year project GLACIODYN, funded by NSERC's IPY program and focused on Arctic tidewater glacier response to climate change, is completing work this year. See http://people.uleth.ca/~sarah.boon/IPY_page for details.

(c) The Western Canadian Cryospheric Network (WC2N) has made significant advances on constructing contemporary glacier inventories for Alberta and British Columbia and conducting change detection studies relative to glacier morphometry and small glacier contribution to sea level rise.

(d) As part of WC2N, UBC researchers continue to define the effects of glacier contraction on streamflow regionally including studies of future contributions from glacierized catchments as glacier contraction continues.

(e) GSC Glaciology Section and NWRI have completed a detailed contemporary inventory of Rocky Mountain eastern slope glaciers (Nelson River System) and related inferred volume changes to streamflow volumes as a function of glacier cover fraction. This and related work points to small-glacier diminution dominating this leeward slope continental setting and evidence of declining streamflow contributions from glaciers in late summer.

(f) GSC Glaciology Section has engaged PCA mountain block and northern bioregion National Parks in regards to developing glacier indicator measures for Ecosystem Integrity Monitoring and State of the Park Reporting. GSC, Jasper, Banff and Yoho Parks will be installing mass balance programs on the Athabasca, Saskatchewan and Yoho Glaciers to augment current work by the GSC at Peyto and Ram River. Laser altimetry will continue to feature in these measurements through GSC collaboration with C-CLEAR and NASA-Wallops. In some cases the expanded activity in the mountain block Parks involves partnerships with academic investigators (e.g., Illecillewaet Neve, Glacier/Mount Revelstoke National Park and the University of Calgary).

(g) GSC Glaciology Section with support from PCA Nahanni National Park Reserve has completed a detailed inventory of glaciers in the Greater Nahanni Ecosystem and with it conducted change detection and glacier morphometric studies spanning LIAmax-1949-1982-1999-2008. The changing influence of glacier cover on flows in the Flat and S. Nahanni Rivers will be studied using WSC-RHBN historical streamflow data and a hydrological model.

Details pertaining to these and other advances can be found under the *Announcements* link of the NRCan Pathways Collaborative Workspace "*State and Evolution of Canada's Glaciers*":

http://pathways.geosemantica.net/

Northern Research Basins Committee

Chair and Canadian Chief Delegate: Kathy L. Young, Geography Department, York University

One of the main activities of the CGU-HS Northern Basins Committee during the last year has been the organization of the 17th NRB meeting. Canada will be hosting the 17th International Northern Research Basins (NRB) Symposium & Workshop in the Eastern Canadian Arctic **August 12-18, 2009.** The symposium/workshop will be held on an Inuit owned expedition ship which will travel from Iqaluit to Pangnirtung and then onto Kuujjuaq. The conference theme is **Managing Hydrological Uncertainty in High Latitude Environments**. Planned sessions include: *Prediction of Precipitation in Ungauged Northern Basins*; *Northern Lake Systems*; *Hydrology & Ocean Interactions*, *Climate, Cryosphere, Hydrosphere* and *Arctic Hydrology & Uncertainty*. The 17th NRB has invited two guest speakers: Dr. Larry Hinzman, International Arctic Research Institute, University of Alaska, Fairbanks, and Dr. Robbie Macdonald, Department of Fisheries & Oceans, Environment Canada. The 17th NRB delegation will also meet with community members in Iqaluit and Kuujjuaq and will hold an Open House/Workshop in the hamlet of Pangnirtung. Similar to previous NRB meeting, time will be set aside for field trips and cultural events. To date we have 60 scientists registered from **ALL** circumpolar countries and about 10 guests making this one of the biggest NRB meetings. Full details of the meeting can be found at www.northernresarchbasins.com/17NRB

As outlined in the NRB Mandate and the Canadian NRB terms of Reference, the Canadian participation in the NRB meeting is limited to 10 delegates appointed by the Canadian Chief Delegate (and approved by the CGU-HS Executive) to represent Canadian interest in the hydrology of northern areas. Given that Canada is hosting this event in 2009, it is also allowed to invite other Canadian scientists as observers and their names and affiliation can be found on the website posted above. The Canadian Chief Delegate to the 17th NRB meeting will be Kathy Young, York U. Chris Spence, Environment Canada will be the Deputy Chief Delegate. While a slate of 10 Canadian Delegates was submitted to the CGU-HS for approval in Jan.'09, only nine have since registered, and they are as follows:

Dr. Terry Prowse, University of Victoria: cold regions hydrology with special focus on river ice, lake ice and snow. Terry also holds a Canada Research Chair.
Dr. Chris Spence, NWRI: sub-arctic hydrology and Deputy Delegate, Canadian NRB
Mr. Richard Janowicz, Yukon Gov't: cold regions hydrology and operational water resources, member of the 17th NRB organizing committee
Dr. Kathy L. Young, York University: high arctic environments and Chief Delegate, Canadian NRB
Dr. Scott Lamoureux, Queen's University: watershed hydrology and geomorphology, high arctic environments, P.I. of an ArcticNet project.
Dr. Faye Hicks, Water Resources Engineering, University of Alberta: northern river ice jams and break-up. Faye is a Full Professor and engineer. She was recently involved in the MAGS project.
Dr. Michael (Mike) Demuth, Glaciology, NRCan: Head of Glaciology, NRCan, glacier mass balance, Northern Canada climate change and human impacts.
Dr. Sean Carey, Carleton University: runoff processes in sub-arctic environments, member of the 17th NRB organizing committee
Dr. William (Bill) Quinton, Wilfrid Laurier University: sub-arctic hydrology. Bill holds a Canada Research Chair, and is a member of the 17th NRB organizing committee

Information about Canadian NRB activities can be found at www.canadiannrb.com or contact Kathy L. Young for more details: klyoung@yorku.ca.

Forest Hydrology Committee

Major activities related to forest hydrology in 2008-2009 revolved around the participation of Canadian forest hydrologists in a number of hydrology-related workshops:

1. Discussion Session: Potential Effects of Climate Change on Watershed Processes, Cranbrook, BC, October 8, 2008. A discussion session was organized by the BC MFR (Robin Pike) to gather experts to discuss potential climate change implications on watershed processes. This meeting was part of the BC MFR's Future Forest Ecosystems Initiative (FFEI), and was attended by around 20 watershed scientists.

2. Field workshop at Cotton Creek Experimental Watershed, Cranbrook, BC, October 9, 2008. The aim of the workshop was to present results to date on the effects of forest harvesting on watershed processes. The workshop was attended by industry, government and private sector consultants, with 34 total participants.

3. Workshop on "Mountain Pine Beetle and Water Management", June 2, 2009, Kelowna, BC. This workshop (102 participants) had 11 presentations and a panel discussion on topics related to implications of the current MPB infestation for water providers in BC. The workshop handbook will be available on the FORREX website (www.forrex.org) in July, and a summary article will be published in Streamline (http://www.forrex.org/publications/streamline/streamline.asp) in Fall 2009.

4. Workshop on "Wildfire and Watershed Hydrology", June 3-4, 2009, Kelowna, BC. This workshop (105 participants) had 23 presentations and a panel discussion on topics related to recent process and mitigation research on wildfire effects on hydrology and geomorphology. The workshop handbook will be available on the FORREX website (www.forrex.org) in July, and a summary article will be published in Streamline (http://www.forrex.org/publications/streamline/streamline.asp) in Fall 2009.

Another area of activity was the annual western and eastern graduate student conferences sponsored by the CGU-HS. The western conference was sponsored by the University of Lethbridge and was held on January 31, 2009 at the new Alberta Water and Environmental Science building. The meeting was attended by 36 students, with 20 oral presentations and 1 poster presentation, some of which dealt with aspects of forest hydrology. The eastern conference was sponsored by the University of Toronto and was held on December 6, 2008 at the Frost Centre in Minden, ON. The meeting was attended by 25 students, with 14 oral presentations and 6 poster presentations, some of which involved research into forest hydrological processes and properties.

Canadian National Committee for the IAHS Prediction in Ungauged Basins Initiative (CNC-PUB)

Chair: Christopher Spence, Environment Canada, Saskatoon, SK S7N 3H5, chris.spence @ec.gc.ca
Vice Chair: Paul Whitfield, Environment Canada, Vancouver, BC V6C 3S5, paul.whitfield@ec.gc.ca
CWRA Members at Large: Taha Ouarda, Institut national de la recherche scientifique, Québec
Al Pietroniro, Environment Canada, Saskatoon, SK
CGU-HS Members at Large: John Pomeroy, Centre for Hydrology, University of Saskatchewan (CGU-HS)
Robert Metcalfe, Renewable Energy Section, Ontario Ministry of Natural Resources

Objective and Roles

The objective of CNC-PUB is to coordinate and communicate IAHS's PUB program in Canada.

The roles of the CNC-PUB are defined as follows:

- Liaising with water resource managers and government agencies in the development of programs supportive of the PUB initiative,
- Supporting PUB working group implementation and funding in Canada,
- Supporting outreach of working group scientific progress,
- Encouraging technology transfer from working groups,
- Reporting to CGU-HS and CSHS on Canadian PUB activities and
- Reporting to IAHS on Canadian PUB activities through CNC-IAHS and the PUB SSG.

Progress on Issues and Objectives

The Improved Processes, Parameterization and Prediction in Cold Regions (IP3) initiative is into its final year of funding by the Canadian Foundation for Climate and Atmospheric Sciences. IP3 is registered as a cold regions working group with the international PUB initiative (http://pub.iwmi.org/UI/Images/PUB_WG16_IP3%20in%20Cold%20Regions.pdf). More information on IP3 specifically can be found at www.usask.ca/ip3.

In support of the Canadian water resource community and PUB working group 17, Low Stream Flows and Hydrologic Drought, the proceedings of a prediction of low flows workshop held in Québec City at INRS_ETE in April 2007 were published in the Canadian Water Resources Journal in June 2008. The special issue provided the latest information on low flows practice and research, especially as it pertains to predictions in ungauged basins. The workshop themes included measuring low flows, regional processes of low flow, low flows in practice, predictive approaches, and the future of low flow research.

The Benchmark Assessment of Predictions in Ungauged Catchments is currently in progress. It will contain a review of the current state of hydrological predictions in the absence of data, addressing where we are now, what we have achieved in the past 4 years, and what are the challenges for the remaining years.

An invited paper on Canadian progress with the PUB initiative was presented at the AGU in December 2008.

Future Meetings and Activities

There are some who wish to continue pursing a model intercomparison project as was proposed at the 2007 IUGG. Progress has been slow within CNC-PUB to pursue this idea within Canada, but the Canadian community, especially the practicing hydrologists, has been keen. One possibility is to apply for an NSERC strategic workshop grant to help our community design a research plan.

Some effort should be made to consolidate Canada's contributions to the PUB initiative as we enter the last few years of the programme.

CGU-HS Prairie Student Conference, January 2009

Sarah Boon

On 30-31 January 2009, the University of Lethbridge's Department of Geography hosted the eighth annual Canadian Geophysical Union-Hydrology Section (CGU-HS) Prairie Student Conference. This was our first time hosting this event, and it was a great success. Twenty-one graduate students from the Universities of Alberta, Calgary, Saskatchewan, and Lethbridge presented talks outlining their research, with an additional fifteen students and nine faculty attending. The conference was held in our new Water and Environmental Science Building, with views of the (windy) southern Alberta coulees. Conference funding was provided by the University of Lethbridge (NSERC), and the Canadian Geophysical Union-Hydrology Section. Thanks to Katie Burles, Ryan MacDonald, Mike Nemeth, Viet Blahaut and Dave Dixon for assisting with conference organization. See you all next year at the University of Alberta!

GEODESY SECTION NEWS

Prepared by Marcelo Santos

Joint Assembly, Toronto, May 2009:

A number of activities took place during the past CGU Meeting. As many as 8 geodesy-related sessions took place during the Joint Assembly, including those sponsored by the AGU. And, as usual, there were the meetings of the Executive and the Annual General Meeting.

Best Student Paper in Geodesy:

The winner of the "Best Student Paper in Geodesy" was Vidya Renganathan (University of Calgary, with the paper "Arctic Sea Ice Freeboard Heights from ICESat Laser Altimetry."

Special Issue in Geodesy of the Canadian Journal of Earth Sciences:

A number of papers presented at the two Geodesy Section-sponsored sessions in the 2008 CGU Assembly have been selected to be part of a Special Issue of the Canadian Journal of Earth Sciences, which is about to be released.

SOLID EARTH SECTION NEWS

Prepared by Phil McCausland

After more than a year of development the Solid Earth Section of the CGU has now been formed, as of the Toronto Joint meeting in May. The Solid Earth Section executive was also elected at our first Section meeting in Toronto. We now invite the participation of all CGU members who have interests in Solid Earth geophysics, as outlined below.

Rationale:

The CGU Solid Earth Section is intended to create within the CGU a more organized representation of many areas of geophysics not addressed by the existing Sections and to provide essential support for the growth of Solid Earth geophysics research in Canada, including greater participation in meetings and in other scientific, outreach or public policy initiatives. The Solid Earth Section may also provide the CGU with a useful means of keeping in contact with organizations bearing related interests, such as the GAC and the CSEG.

The scope of Solid Earth geophysics is taken to include "classical" geophysics and other research areas including:

- Tectonophysics
- Seismology
- Mantle and core geodynamics
- High P mineralogy; experimentation & theory
- Potential fields
- Geomagnetism & Paleomagnetism
- Heat flow

An immediate role for the new Section is to help develop the scientific programme for the upcoming Ottawa 2010 meeting! Please contact Sam Butler (Section VP) at the address below for more information or to make suggestions.

Membership and Officers:

Joining the Solid Earth Section is easily done during your upcoming CGU membership renewal. A website is being developed for the Section. By all means contact any of the officers (below) if you have questions or suggestions to offer on the new Solid Earth Section.

President: Kristy Tiampo (Western) ktiampo@uwo.ca
V-President: Sam Butler (U Sask) sam.butler@usask.ca
Treasurer: Julian Lowman (U Toronto)
lowman@utsc.utoronto.ca
Secretary: Phil McCausland (Western) pmccausl@uwo.ca
Members-at-Large:
Hans Mueller (GFZ-Potsdam) hjmuel@gfz-potsdam.de
Mahmoud Abd El-Gelil (York) mahmoud@yorku.ca

Yours,
Phil McCausland, Secretary, CGU Solid Earth Section

BIOGEOSCIENCES SECTION NEWS

Prepared by Nigel Roulet

At the CGU Annual General Meeting in Toronto in May a new Biogeosciences section was approved. The following day a short meeting of the new section was held and at that time is was decided the membership of the CGU should be polled to determine who was interested in being affiliated with the Biogeosciences section. This was suggested because the small group that assembled was uncomfortable about selecting a slate of officers for the section without wider representation or advanced notice. So if you are interested in being affiliated with the Biogeosciences section, please send a short e-mail to nigel.roulet@mcgill.ca by mid-September 2009. Remember you can be affiliated with more than one section so an interest in the Biogeosciences does not affect your status with another section with which you are already affiliated.

Based on the response by those CGU members who affiliate with the Biogeosciences, a temporary set of officers for the section will be recommended and put to the affiliated members for approval. This slate of officers will be interim officers and the first full election of officers will occur at the 2010 CGU meeting in Ottawa next spring.

However, the most important task for the new Biogeosciences Section for the coming year is to organize a series of sessions for the 2010 CGU meeting which will be held in conjunction with the annual meeting of the Canadian Meteorological and Oceanographic Society (CMOS). A joint meeting of the CGU and CMOS provides several good opportunities for collaborative sessions around the Biogeosciences. If you have suggestions for Biogeosciences sessions at the next annual meeting please forward them to Nigel Roulet. We can then begin to put these together to ensure we have a good representation at the meeting. Joint sessions with other Sections of the CGU are also encouraged.

Nigel Roulet
McGill University
Acting Un-president of the CGU Biogeosciences Section

CGU 2009 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 2009 Joint Assembly in Toronto. 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). The winners are listed below. The abstracts for the Shell Canada, CGU Best Student Paper, and Geodesy Awards appear below. The abstracts for the D.M. Gray and Campbell Scientific Awards will appear in the January 2010 issue of ELEMENTS.

The CGU component of the Organizing Committee of the Congress and the CGU Executive Committee would like to sincerely thank all the judges of the student papers for their careful evaluations of the student presentations.

CGU Best Student Paper Award (all fields of geophysics – oral presentation):

Winner: Nicholas J. Kinar (University of Saskatchewan). Acoustic observation of snowpack physical properties (co-author: J. Pomeroy).

Honourable Mention: Kevin Garroway (Dalhousie University). A desktop GIS approach to topographic mapping of surface saturation (co-authors: C. Hopkinson, R. Jamieson, J. Boxall).

Honourable Mention: X.J. (May) Guan (University of Saskatchewan). Spatiotemporal interaction of near-surface soil moisture content and frost table depth in a discontinuous permafrost environment (co-authors: C. Spence, C. Westbrook).

Honourable Mention: Vidyavathy Renganathan (University of Calgary). Arctic sea ice freeboard heights from ICESat laser altimetry (co-authors: A. Braun, H. Skourup, R. Forsberg).

Honourable Mention: Xueyang Yu (University of Western Ontario). Melting of Fe-Si Alloys up to 14 GPa (co-author: R. Secco).

Shell Canada Outstanding Student Poster Paper:

Co-winner: Sheri Molnar (University of Victoria). 3D ground motion in the Georgia Basin region of SW British Columbia for intra-slab earthquake scenarios. (co-authors: J.F. Cassidy, S.E. Dosso, K. Olsen).

Co-winner: Angela Schlesinger (University of Victoria). A study of gas hydrates with ocean-bottom-seismometer data on the east coast of Canada (co-authors: D. Mosher, J. Cullen, K. Louden, G. Spence, R. Hyndman).

D.M. Gray Award for Best Student Paper in Hydrology (oral presentation):

Winner: Claire J. Oswald (University of Toronto at Mississauga). Hydrologic connectivity and runoff response in the METAALICUS catchment (co-author: Brian A. Branfireun).

Campbell Scientific Award for Best Student Poster in Hydrology:

Winner: Scott J. Ketcheson (University of Waterloo), Ecohydrological processes in cutover peatlands: the impact of peatland restoration on the site hydrology and water balance of an abandoned block-cut bog in Quebec (co-author: J.S. Price).

Geodesy Award for Best Student Paper in Geodetic Research & Education (oral presentation):
Winner: V. Renganathan (University of Calgary). Arctic sea ice freeboard heights from ICESat laser altimetry (co-authors: A. Braun, H. Skourup, R. Forsberg).

3D Ground Motion in the Georgia Basin Region of SW British Columbia for Intra-slab Earthquake Scenarios

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[2]Natural Resources Canada, PO Box 6000, Sidney, BC, V8L 4B2, Canada
[3]San Diego State Univ., Dept. of Geological Sciences, 5500 Campanile Dr., San Diego, CA, 92182-1020, U.S.A.
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We investigate long-period (> 2 s) ground motions in the Georgia basin region of SW British Columbia (BC) for intra-slab earthquake scenarios using 3D finite-difference simulations of viscoelastic wave propagation. The Georgia basin is a site of concentrated deep (25-80 km) Juan de Fuca plate seismicity in a region with over 2 million inhabitants and vital economic facilities. Earthquake waves are altered by 3D basin structure due to the generation of surface waves and S-wave focusing at the basin edges. To validate our simulation, synthetic surface waveforms are compared with 32 strong- and weak-motion recordings of the 2001 Mw 6.8 Nisqually earthquake spanning from Puget Sound, Washington, to southern BC. To investigate intra-slab earthquake scenarios we initiate the Nisqually-model source in six different locations beneath the NW-SE trending Georgia basin. The largest ground motions always occur NW of the source location, so the peak ground velocity pattern alters dramatically with source location. In all cases, ground motion is amplified at the edges of the basin due to S-wave focusing, as well as along a NE-SW velocity contrast that runs beneath the city of Vancouver. In greater Vancouver, the largest simulated ground motions (100 cm/s) occur for sources located beneath the SE portion of the basin.

A Study of Gas Hydrates With Ocean-Bottom-Seismometer Data on the East Coast of Canada

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Email: schlesin@uvic.ca, dmosher@nrcan.gc.ca, jcullen@dal.ca, keith.louden@dal.ca, gspence@uvic.ca, rhyndman@nrcan.gc.ca

A number of BSR locations have been identified along the Scotian Slope from geophysical evidence, but as yet none have been confirmed to contain gas hydrate through direct sampling. Studies near the Mohican Channel (200 km offshore Halifax) show the BSR is around 450 ms below sea floor with a possible underlying low- velocity zone (indicative of free gas in the sediments). Models with hydrate as part of the sediment frame give hydrate concentrations of 2-6 % and free gas concentrations of less than 1% (LeBlanc et al., 2007). In a joint project between the Geological Survey of Canada and the Dalhousie University, 19 ocean-bottom- seismometers (OBS) were deployed in 2006 to study the geophysical structure of the Mohican Channel BSR. In this area, a clear BSR beneath the channel and in its levee disappears in a direction away from the channel and parallel to slope. This observation may be related to fining of sediments distal to the channel levee, but there are no direct samples in this zone to confirm this hypothesis. Fining of sediment may restrict vertical fluid flow by reducing permeability, as well as reducing pore spaces available for hydrate formation. Wide-angle reflection and refraction data are used to ascertain the thickness of the sub-BSR low-velocity zone as a function of position on the seismic transect away from the Mohican Channel, and to use these thicknesses to calculate the variation in upward fluid flow along slope. Preliminary results show refractions with apparent velocities of 1850 to 1900 m/s for a depth range of 350 to 600 mbsf. However, initial traveltime inversions using refractions and wide-angle reflections indicate no significant low-velocity zone below the BSR. Furthermore, there appears to be no strong lateral velocity contrast between regions with and without BSR observations. Further use of S-wave arrivals from the geophone components may provide additional constraints on hydrate and gas distribution and help to characterize fault patterns.

Acoustic Observation of Snowpack Physical Properties

Nicholas J. Kinar (n.kinar@usask.ca), Centre for Hydrology, University of Saskatchewan, Saskatoon, SK Canada S7N 5C8, Session C02-Remote Sensing and Modeling of Snowpack Processes

Summary

Sound waves produced by a loudspeaker situated above the surface of a snowpack have been used to determine Snow Water Equivalent (SWE). Digital signal processing of reflections from the sound wave travelling in the pore spaces of the snowpack allowed for the determination of SWE. The possibility of determining additional physical properties of the snowpack has been considered. This paper presents a novel algorithm for determining the physical, thermal, and structural parameters of snow by acoustics. The algorithm was tested on synthetic data. Although the Biot theory of sound propagation through porous media has been widely applied in seismology to model the amplitude displacements created by the propagation of P-waves and S-waves through layered sediment, it cannot model the pressure disturbances of a wave in the pore spaces of a porous medium. The numerical solution of a modified acoustic wave equation was used to model the acoustic-to-seismic coupling of an air-borne pressure wave into the porous snow medium. The theory of the acoustic algorithm presented in this paper has the potential to be used for the continuous monitoring of the physical properties of snow.

Introduction

During the last century, snow scientists have been measuring the physical properties of snow by the use of invasive techniques which require the presence of a human operator. The most widely-used measurement methods involve the use of a snow sampling tube or the creation of a snowpit. Along with concomitant measurements of snow depth, these methods are used to determine snow density and Snow Water Equivalent (SWE) by gravimetric sampling (Goodison et al., 1981).

SWE is an estimate of the depth of water which results from the melting of the snowpack at a given sampling point (Pomeroy and Gray, 1995). Landscape-scale measurements of SWE can be used to provide inputs to mathematical models of climate and weather, and can also be used to gauge the amount of water entering rivers and streams after the snow ablation season (Pomeroy et al., 2007). Given the current need to ensure the availability of fresh water resources, measurement of SWE has been of increasing societal and scientific importance.

A series of recent papers have proposed the concept of a measurement system which can be used to non-invasively measure SWE (Kinar and Pomeroy, 2007; Kinar and Pomeroy, 2008a; Kinar and Pomeroy, 2008b; Kinar and Pomeroy, 2009). The measurement system is comprised of a loudspeaker and a microphone situated above the snow surface (Figure 1). The input of a source signal to the loudspeaker creates a pressure wave in the air above the surface of the snowpack. The pressure wave propagates toward the surface of the snowpack, and is transferred to the pore spaces of the snow medium by acoustic-to-seismic coupling. Because the pore spaces in the snowpack are mostly interconnected (Buser, 1986), the sound wave propagates until there is a change in acoustic impedance, which causes reflections. The reflections travel back across the snow surface and are detected by a microphone located at an offset distance from the loudspeaker.

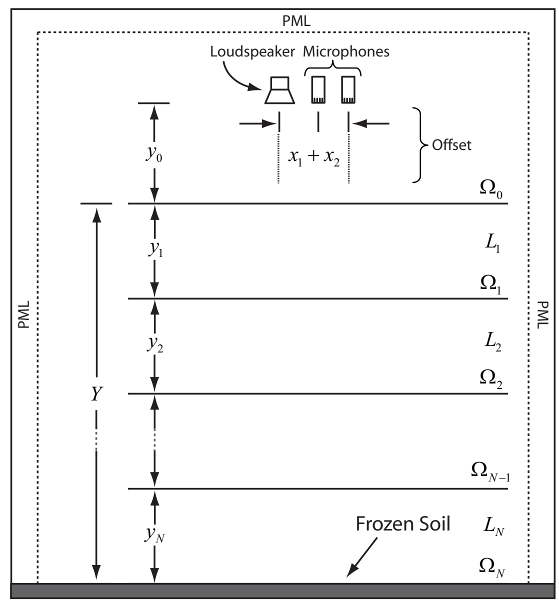

Figure 1: Diagram of the snowpack system. Previous research only used one microphone. The model presented in this paper uses two microphones at a combined offset distance of $x_1 + x_2$. The total depth of the snowpack is Y, and the depth of an individual layer L_k in the snowpack is denoted by y_k. An interface between the layers is denoted by Ω_k. The computational domain is bounded by a PML and a layer of frozen soil.

Initial research (Kinar and Pomeroy, 2007) used a source signal which was frequency-swept between 20 Hz and 20 kHz. A deconvolution algorithm was used to determine the reflection response, which was then related to a depth-integrated estimate of SWE. Reflection events had to be manually picked, thereby requiring a human operator to examine and interpret the processed signals.

Later research (Kinar and Pomeroy, 2008a; Kinar and Pomeroy, 2008b; Kinar and Pomeroy, 2009) used a Maximum Length Sequence (MLS) as the source signal. The acoustic response from the snowpack was recorded, and an algorithm was used to recursively determine the depth-integrated SWE from the impulse response. Although the algorithm was able to automatically pick reflection events, human intervention was still required to enter the snow depth to constrain the model solutions.

This paper extends the previous work by proposing an algorithm which is able to autonomously determine SWE. Testing of this algorithm on synthetic data showed that a sampling system comprised of more than one microphone situated at spatial offset to the loudspeaker can be used to determine a wide number of physical parameters of the snowpack.

Theory

Biot Theory

The Biot theory has been successfully used to model the propagation of seismic waves through porous media. Some of this research has focused on snow as a porous medium (Albert, 1993; Johnson, 1982).

The Biot theory assumes that the porous medium is comprised of a skeletal frame which is completely saturated with a fluid. When the Biot theory is applied to snow, the skeletal frame is considered to be comprised of snow crystals, and the fluid saturating the pore spaces is air at a fixed temperature and pressure. Three types of seismic waves are assumed to propagate through the porous material. A P-wave and an S-wave propagate through the skeletal frame, whereas a P-wave propagates through the pore spaces. This particular version of the model is referred to as the "classical Biot theory."

Although of great use to seismologists studying the dynamics of a seismic impulse through a layered sedimentary rock medium, the classical Biot theory can only calculate the amplitude displacements caused by the propagating waves. These calculated displacements can be directly related to actual measurements of ground movement by examination of signals recorded from geophones. However, such a measurement approach is unsuitable when using a microphone situated above the snow surface. Microphones measure pressure fluctuations, and not amplitude displacements.

Because a gas is incapable of shear motion, the reflection response captured by a microphone situated in the air above the surface of the snowpack will be comprised of pressure waves. Moreover, the amplitude of the P-wave which propagates through the skeletal frame is orders of magnitude less than the amplitude of the P-wave which propagates through the pore spaces of the snow (Albert, 2001). This implies that only the P-wave which propagates through the pore spaces of the snowpack will be detected by the microphones.

The Modified Acoustic Wave Equation

The coupled differential equations of the Biot theory can be used to derive a version of the acoustic wave equation which models the propagation of the P-wave through the pore spaces of a porous medium (Pierce, 2007):

$$\nabla^2 \mathbf{p} - \frac{1}{c^2}\frac{\partial^2 p}{\partial t^2} = \frac{-\tau}{c^2}\frac{\partial^3 p}{\partial t^3} \qquad (1)$$

In Equation (1), $\mathbf{p}$ is the pressure vector, c (m s^{-1}) is the speed of the sound wave in the pore spaces of the medium; p (Pascal) is the magnitude of the pressure vector; and τ (seconds) is a time constant which modifies the acoustic wave equation for a porous medium. Because the speed of the pressure wave through the porous medium is dependent on the frequency of the sound source, the time constant ensures that this behavior is properly modeled. Consequently, the pressure wave will also be attenuated. When $\tau = 0$, Equation (1) is reduced to the ordinary acoustic wave equation.

Synthetic Signal Generation

The proposed experimental setup used to measure the physical properties of snow is shown in Figure 1. This setup defines the boundary conditions of the numerical model which was used to generate synthetic data to test the numerical inversion algorithms.

In Figure 1, a moving-coil loudspeaker is situated above the snow surface. The horn of the loudspeaker points toward the surface of the snowpack. The source signal produced by the loudspeaker was chosen as an acoustic MLS sequence (Borish and Angell, 1983; Rife and Vanderkooy, 1989).

The properties of the MLS sequence allows for: (1) determination of the reflection response of the snowpack within a short (~1 second) period of time, despite the presence of environmental sources of noise; and (2) the source signal can be adequately reproduced by the loudspeaker, which has a non-linear frequency response. The acoustic MLS sequence has been used with success by Kinar and Pomeroy (2009) to determine the impulse response of the snowpack, and it is also used in this study to demonstrate the applicability of the new signal processing algorithm.

Situated at an offset distance x_1 (meters) from the loudspeaker is a microphone which faces the snow surface. Situated at another offset distance x_2 (meters) from the first microphone is a second microphone. Both microphones are assumed to have a nearly flat frequency response over the audible frequency range (20 Hz to 20 kHz). The microphones are also assumed to be onmi-directional electret microphones with a sensitivity response of -35 dB. These parameters are representative of microphones that are commercially available.

The setup shown in Figure 1 was discretized on a two-dimensional finite-element grid. The spacing of cells comprising the regular grid was $\Delta x = \Delta y = 1$ mm. The pressure p calculated for every timestep was considered to be situated at the centre of each grid cell. The cells comprising the bodies of the loudspeaker and each microphone were assigned Dirichlet boundary conditions with $p = 0$ at each time step. The boundary at the bottom of the snowpack was assumed to be a layer of frozen soil, whereas the top and sides of the computational domain were assumed to extend infinitely in the respective directions.

Initial discretization and solving of Equation (1) using finite-difference techniques revealed that the modified acoustic wave equation is not numerically stable. To ensure numerical stability, the third derivative was replaced by an equivalent expression comprised of mixed partial derivatives:

$$c^2\left[\frac{\partial^2 p}{\partial x^2}+\frac{\partial^2 p}{\partial x^2}\right]=-\tau c^2\left[\frac{\partial^3 p}{\partial t\partial x^2}+\frac{\partial^3 p}{\partial t\partial y^2}\right]+\frac{\partial^2 p}{\partial t^2} \quad (2)$$

To implement the infinite boundary conditions on three sides of the computational domain, perfectly matched layer (PML) absorbing boundary conditions were added to Equation (2). The PML is a layer of grid cells which surround the boundaries of the computational grid. This layer reduces numerical reflections at a boundary, and allows for the modeling of a wave which continues propagating past the extent of the computational domain (Komatitsch and Tromp, 2003).

To apply the PML, Equation (2) was split into a system of five coupled partial differential equations (PDEs), given as Equation (3) to Equation (7). After some algebraic transformations, the inverse Fourier transform was applied to eliminate imaginary numbers and the angular frequency ω variable used in the PML transformation. The system of PDEs was then discretized using a finite-difference stencil and solved by numerical methods. This allowed for the generation of synthetic traces $s_1[t]$ and $s_2[t]$ captured at two offset distances by the two microphones. The synthetic traces are represented in computer memory as two vectors consisting of 1×10^6 floating point numbers, which correspond to a 1 second signal duration taken at a sampling frequency of 1 MHz.

$$\frac{\partial a_x}{\partial t}=c^2\frac{\partial p}{\partial x}-a_x\sigma_x[x] \quad (3)$$

$$\frac{\partial a_y}{\partial t}=c^2\frac{\partial p}{\partial y}-a_y\sigma_y[y] \quad (4)$$

$$\begin{aligned}&\frac{\partial p}{\partial t}\left(1+\frac{\partial b}{\partial t}\right)\left(1+\frac{\partial c}{\partial t}\right)=\\&\left[\frac{\partial a_x}{\partial x}\left(1+\frac{\partial c}{\partial t}\right)+\frac{\partial a_y}{\partial y}\left(1+\frac{\partial b}{\partial t}\right)\right]\\&+\tau\left[\frac{\partial^2 a_x}{\partial t\partial x}\left(1+\frac{\partial c}{\partial t}\right)+\frac{\partial^2 a_y}{\partial t\partial y}\left(1+\frac{\partial b}{\partial t}\right)\right]\end{aligned} \quad (5)$$

$$\frac{\partial b}{\partial t}=\sigma_x[x] \quad (6)$$

$$\frac{\partial c}{\partial t}=\sigma_y[y] \quad (7)$$

Signal Processing Model

The synthetic data was used to determine the physical parameters of a modified version of the Biot theory. To determine the impulse response of the snowpack, the Fast Hadamard Transform (FHT) was applied to vectors $s_1[t]$ and $s_2[t]$ to generate the vectors $H_1[t]$ and $H_2[t]$. When an MLS signal is provided as an input to a linear system, the correlation of the output signal with the input MLS is the impulse response of the system (Borish and Angell, 1983; Rife and Vanderkooy, 1989). The impulse response is similar to the response of the snowpack if the source signal was produced by an implosive seismic source.

By taking the cross-spectrum $\psi[\omega]$ between $H_1[t]$ and $H_2[t]$, the speed of the sound wave in the snowpack at a given discrete depth y (meters) was determined. The cross-spectrum also allowed for the determination of speed-frequency and speed-attenuation relationship curves. Details on the signal processing flow to determine pressure wave speeds in a layered porous medium have been given in the literature (Bautista and Stoll, 1995; Stoll et al., 1994a; Stoll et al., 1994b; Stoll et al., 1991).

By non-linear fitting, the speed-frequency and speed-attenuation curves were used to determine the parameters of a modified version of the Biot model. The model was evaluated for the complex phase velocity $v_k=c_k+\psi_k$, where c_k is the speed (m s^{-1}) at a given depth beneath the snow surface, and ψ_k (dB s^{-1}) is the attenuation coefficient.

Modified Biot Model

The Biot equations presented by Stoll (1989) are used in the context of this paper to model the phase velocity c_k and the attenuation ψ_k of sound in snow. These particular equations were chosen because they are useful in determining the parameters of interest (Stoll, 1989):

$$\nabla^2(Ce-M\xi)=\frac{\partial^2}{\partial t^2}(\rho_f e-m\xi)-\frac{\eta}{k}\frac{\delta\xi}{\delta t} \quad (8)$$

$$\nabla^2(He-C\xi)=\frac{\partial^2}{\partial t^2}(\rho e-\rho_f\xi) \quad (9)$$

$$e=e_x+e_y+e_z=\operatorname{div}(\mathbf{u}) \quad (10)$$

$$\xi=\phi\operatorname{div}(\mathbf{u}-\mathbf{U}) \quad (11)$$

$$C=\frac{K_r(K_r-K_b)}{D-K_b} \quad (12)$$

$$M=\frac{K_r^2}{D-K_b} \quad (13)$$

$$m=\alpha\rho_f/\phi \quad (14)$$

$$H = \frac{(K_r - K_b)^2}{D - K_b} + K_b + \frac{4}{3}\mu \qquad (15)$$

$$D = K_r(1 + \phi G - \phi) \qquad (16)$$

$$G = K_r / K_f \qquad (17)$$

Equation (8) above describes the movement of the fluid in the pore spaces of the medium, whereas Equation (9) describes the movement of the porous frame. Both Equation (8) and Equation (9) are a coupled system of differential equations. When a sound wave propagates through a snowpack, the displacement of the frame is $\mathbf{u}$ and the fluid displacement is $\mathbf{U}$. Both $\mathbf{u}$ and $\mathbf{U}$ are vector quantities. As defined by Biot, the volumetric strain of the frame is denoted by e, which is equal to the divergence $\operatorname{div}(\mathbf{u})$ of the frame displacement. Scalar e is a measure of the change in volume of the frame which occurs due to the shear force of the pressure wave. Volumetric strain components parallel to the $\{\hat{\mathbf{x}}, \hat{\mathbf{y}}, \hat{\mathbf{z}}\}$ axes are the scalar quantities $\{e_x, e_y, e_z\}$. The corresponding volumetric increment of fluid in the pore spaces of the frame is given by $\boldsymbol{\xi}$. The apparent mass increase of the porous material is given by m, which is calculated from the tortuosity α, fluid density ρ_f, and porosity ϕ. The parameter m accounts for the apparent increase in the mass of the porous material due to air disrupted by the acoustic pressure wave. The total density of the porous framework and the fluid is given by ρ. The dynamic viscosity of the fluid saturating the pore spaces is η. Dynamic viscosity is a measure of the flow resistance of the fluid. The bulk modulus of particles comprising the frame is given by K_r, the total bulk modulus of the frame is K_b, and the bulk modulus of the fluid saturating the pore spaces is K_f.

Equations (8) to (17) were modified to describe the presence of two phases of fluid in the pore spaces of the snowpack. The technique followed here is similar to the mixture theory approach, which considers total volume as being comprised of fractional volumes of the constituents (Morland et al., 1990). The mixture theory approach is used in models of snowpack evolution to manage the complexity of natural snowcovers. If the volume fraction of air, liquid water and snow are known, these parameters can be used directly in the snowpack evolution model. To use the mixture theory in the context of the Biot theory, the following substitutions are made:

$$\rho = \rho_r(1 - \phi) + \rho_f s_w \phi \qquad (18)$$

$$\phi = \frac{\phi_e}{(1 - s_{wi})} \qquad (19)$$

$$s_e = \frac{s_w - s_{wi}}{1 - s_{wi}} \qquad (20)$$

$$k = \frac{k_w}{s_e^n} \qquad (21)$$

$$K_f = K_f^* \qquad (22)$$

Equations (18) to (22) have been successfully used to model melt water movement through snow (Colbeck, 1978; Colbeck, 1982). Models of snowpack evolution use these equations to calculate the mass flux of water during runoff. The effective density ρ of the snow medium is considered to be a sum of densities contributed from the snow and water. The density of the grains comprising the frame is ρ_r, and the saturation as a pore volume fraction is s_w. The density of water is given by ρ_f. When the pore spaces of the snowpack are partially saturated with water, the porosity of the mixture is considered to be the effective porosity ϕ_e. The fraction of irreducible water content in the porous snow medium is s_{wi}. This refers to the amount of water that cannot be removed from the pore spaces. The saturations $\{s_w, s_{wi}\}$ are used to calculate the effective saturation s_e. Equation (21) calculates the effective permeability k from the water-saturated permeability k_w and s_e^n, where $n \in \mathbb{R}$ is a real number. The bulk modulus K_f^* is assumed to be the effective bulk modulus of the air and liquid mixture which saturates the pore spaces of the snow.

The Jackson-Black model of thermal conductivity is intended for application to a porous medium which is comprised of sand-like grains bonded together by an adhesive fluid (Jackson and Black, 1983). The model has been used to explain the results of snow thermal properties measurements (Liu and Si, 2008).

The Jackson-Black model relates the effective thermal conductivity κ of the porous medium to the thermal conductivity of the frame κ_b, the thermal conductivity of the water κ_w and the thermal conductivity of the air κ_a (Zhang et al., 2006):

$$\kappa = \kappa_b \left\{ C_1 + \frac{C_2^2}{C_2 + (1 - s_w)\phi(\kappa_b / \kappa_w - 1)} + \frac{C_3^2}{C_3 + s_w \phi(\kappa_b / \kappa_a - 1)} \right\} \qquad (23)$$

The coefficients $\{C_1, C_2, C_3\}$ are empirically determined, and as such, the constraint is $C_1 + C_2 + C_3 \approx 1$. Equation (23) takes into consideration the possibility of low levels of water saturation in the pore spaces ($s_w \to 0$), an effect which becomes important when modeling dry snow. The effective thermal conductivity of snow was related to the heat flux by Fourier's Law (Mellor, 1977; Sturm et al., 1997).

Conclusions

- The results of this study demonstrated that the new inversion algorithm was able to determine the physical, thermal, and structural parameters of a snowpack.
- A modified version of the acoustic wave equation was able to model the propagation of an acoustic pressure wave through the pore spaces of the snowpack without calculating for amplitude displacements.
- The ability to non-invasively measure the physical parameters of the snowpack with an appropriate sampling system has wide-ranging implications in the environmental sciences. A potential application for this type of sampling may be found in an electronic avalanche warning system, where the physical parameters of the snowpack are used to drive a model used to predict avalanche activity.
- The relatively low cost of electronics used to create an acoustic sampling system may be less expensive than the use of radar in studies of snowpack stratigraphy.

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Arctic sea ice freeboard heights from ICESat laser altimetry

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Introduction

Arctic sea ice extent has been decreasing at a rate of about 10% per decade, since the earliest satellite observations in 1979. This decline is mainly attributed to climate change and variability. The effect of climate change is more pronounced in the Arctic because of the ice-albedo feedback effect which accelerates the melting process.

Sea ice cover plays an important role in the Earth climate system because, i) it controls the ice-albedo feedback mechanism that amplifies the climate response at high latitude regions. ii) growth (melt) rate affects the salt (freshwater) flux from sea ice that is significant to global ocean circulation and deep water formation. iii) due to relatively thin ice floating on the deep ocean, it interacts with winds and ocean currents. Resulting sea ice dynamics and circulation are responsible for the ice and freshwater transport in (and export from) the Arctic Ocean. iv) sea ice alters the surface heat and mass budget in the Arctic Ocean, which greatly depend on ice thickness. Clearly, sea ice processes span a wide range of scales from micrometer to thousands of kilometres and a wide range of disciplines. Despite about 200 years of research and observations, the evolution of sea ice and its position in the climate system is not completely understood. Therefore, the prediction of the future climate is unreliable. More observations are required for small- and large-scale processes at longer and continuous time-series. But, field campaigns in the Arctic are challenging due to the complex extreme environment and its inaccessibility. Hence, remote sensing techniques are crucial as they can provide global homogeneous coverage and continuous time-series.

Motivation and Objective

In order to understand the changing Arctic sea ice cover, the change in sea ice *volume* must be known (both extent and thickness). Sea ice thickness is an important parameter that moderates the heat exchange between the ocean and the atmosphere which affects the Earth's climate. The objective of this study is to measure Arctic sea ice freeboard heights from satellite laser altimetry data (ICESat - NASA's Ice, Cloud, and Elevation Satellite) and models of geoid (EIGEN-GL04), ocean tides (AOTIM-5), and mean dynamic topography.

Sea Ice Freeboard from Altimetry

NASA’s ICESat was launched in January, 2003. The primary objective of this laser altimetry mission is to measure the ice sheet elevations changes over Greenland and Antarctica and the secondary objective is to provide sea ice thickness distribution over the polar oceans (Schutz et al., 2005). The Geoscience Laser Altimeter System (GLAS) onboard ICESat has a ~ 70 m footprint, ~ 170 m track spacing, and 40 Hz pulse rate. ICESat operates in a 91-day repeat cycle and provides near-global coverage, up to 86 N.

Sea ice freeboard is the height of the sea ice surface above the sea level. A satellite laser altimeter measures the snow surface height or the sea ice surface height with respect to a reference ellipsoid depending on the physical properties of the overlying snow layer. Thus, by measuring the sea surface height (with respect to the same reference ellipsoid), snow/sea ice freeboard can be directly derived from laser altimetry.

The basic equation for sea ice freeboard height estimation from laser altimetry data products is,

$F = E - N - T - MDT - S - IBE - e$,

where, F is sea ice freeboard, E is ellipsoidal height of snow surface, N is geoid height, T is ocean tides, MDT is permanent mean dynamic topography, S is snow thickness, IBE is inverse barometric effect correction, e contains the errors in each measurement.

Ellipsoidal height (E) - The ICESat sea ice altimetry data products contain snow surface heights with respect to the Topex/Poseidon reference ellipsoid (E). They are converted into snow surface heights with respect to the WGS-84 ellipsoid, by subtracting 70 cm. This transformation is accurate to about 1 cm due to latitude depending changes of the 70 cm bias.

Geoid (N) - Recent gravity missions GRACE and CHAMP, terrestrial, airborne and ship-borne gravimetry data have significantly improved the geoid models. Best available geoid models have been reported as ArcGP (Forsberg and Kenyon, 2004) and EIGEN-GL04c (Forste et al., 2005) in Forsberg et al. (2007). In this study, EIGEN-GL04c model will be used to estimate N for every ICESat footprint.

Mean dynamic topography (MDT) – The Arctic Ocean exhibits spatial, seasonal and inter-annual variations in MDT. Current models are not consistent in predicting the MDT for the Arctic Ocean and show large differences on the order of tens of centimeters (Forsberg et al., 2007). In this study, a MDT model from University of Washington will be used for freeboard estimation. Also, freeboard will be estimated without the MDT correction.

Inverse barometric correction (IBE) - Sea level pressure varies in the Arctic Ocean at time scales between few hours to decades, due to changes in wind and atmospheric circulation. The response of the ocean and sea ice surface to changes in sea level pressure is known as the inverse barometric effect. It can be corrected using a simple linear equation described in Kwok et al. (2006). The sea level pressure values for each ICESat footprint are obtained by linearly interpolating the 6-hourly NCEP/NCAR reanalysis products provided by the NOAA-ESRL PSD Climate Diagnostics Center Branch, Boulder Colorado.

Ocean tides (T) - Global and regional tide models (CSR 4.0, GOT 00.2, TPXO 6.2, AOTIM-5 (Padman and Erofeeva, 2004)) were evaluated to determine the best model that represents the ocean tides in the Arctic Ocean. Sea ice cover has a damping effect on the ocean tide amplitudes and a phase lag of the co-tidal lines. Current ocean tide models only assimilate data from tide gauge records and altimetry data over open ocean and only during the summer months. In other words, the models are constrained by observations which do not include the sea ice-tide interactions. Consequently, tide models perform less accurately in the presence of sea ice. In order to identify how the performance decreases and if there is a measurable effect, a number of coastal tide gauges records in the Arctic Ocean were compared with tide models. This work is published in Forsberg et al. (2007). It was concluded that the AOTIM-5 model is the best model in the Arctic Ocean as it best predicts the tidal amplitudes in most constituents. Thus, this model will be used to correct the ICESat footprints for the effects of ocean tides. Loading tides are already corrected in the ICESat sea ice altimetry data products using GOT 00.2. AOTIM-5 model was not replaced because the difference between the models for loading tide is not significant.

Snow thickness (S) - Snow depth must be known to convert snow freeboard height into sea ice freeboard height. Besides, the snow-loading on sea ice must be known in order to apply hydrostatic equilibrium assumptions and estimate the sea ice thickness from freeboard height. The future mission Cryosat-2 will carry a radar altimeter, therefore, will be able to directly measure the height of the snow-ice interface above reference ellipsoid in dry snow conditions. Co-incident ICESat and Cryosat-2 foot-prints have the potential to provide snow thickness data, in cold and dry conditions. In this study, only the snow freeboard heights will be derived.

Results and Discussion

Sea ice freeboard results from ICESat data (GLAS 13, release 28) for mission phases from 2003 to 2008 were derived. Figure 1 shows the sea ice freeboard map in the Arctic during October 2003, where only the geoid and ocean tides were removed from the snow surface height. In the final presentation, results of freeboard heights which will also include corrections for inverse barometric effect and mean dynamic topography will be presented.

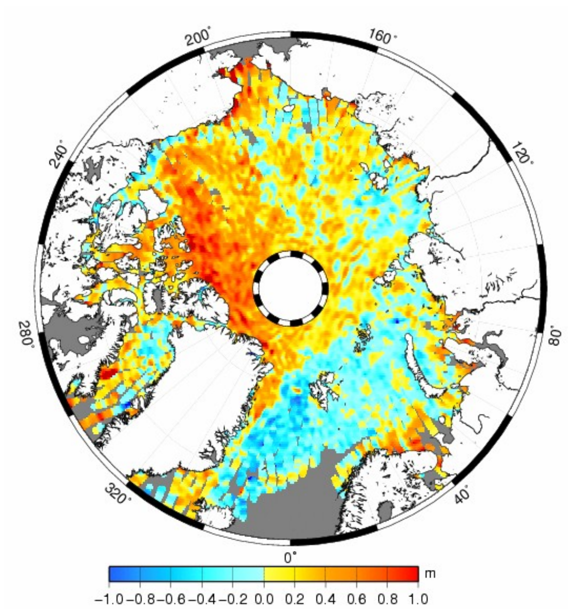

Figure 1: Sea ice freeboard height (October 2003) estimated from ICESat GLA13 release 28, AOTIM-5 tidel model and EIGEN-GL04c geoid model.

Summary

In summary, sea ice freeboard heights are estimated from ICESat by combining various models of the geoid, ocean tides and mean dynamic topography. Current limitations in this method are the lack of information on the depth of the overlying snow layer and the uncertainties in the oceanographic models. Mean dynamic topography models are expected to improve with the launch of GOCE. In the future, sea ice freeboard will be converted into sea ice thickness using physical properties of sea ice under hydrostatic equilibrium assumptions.

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Canadian Geophysical Union **Financial Statement 2005-2008**

Kathy Young (treasurer)

	Year Ended December 31 **2008**	**2007** restated*	**2006**	**2005** HS**
REVENUES				
Annual scientific meeting	-	-	15,066	10,253
Membership dues	3,709	4,222	4,149	4,914
Grants	4,500	4,500	4,000	4,000
Interest Income	2,836	2,529	2,188	768
Advertising	1,450	-	-	-
Other			1,260	1,509
	12,495	**11,251**	**26,663**	**21,444**
EXPENSES				
Annual Scientific Meeting	-	-	19,499	11,936
Annual Scientific Meeting - Net	9,004	18,772	-	-
Awards	500	800	2000	2,000
Executive travel	3,365	970	1,483	-
Program allocations	3,025	-	-	-
Miscellaneous	2,397	2,507	1,064	1,143
Newsletter - Elements	3,598	2,920	2,081	5,622
Professional fees	2,777	1,750	1,750	2,484
Publications	9,866	-	-	-
Secretariat	5,035	5,822	2,500	5,893
Website	1,810	-	-	-
	41,377	**33,541**	**30,327**	**29,078**
DEFICIENCY OF REVENUES OVER EXPENSES FROM OPERATIONS	(28,882)	(22,290)	(3,664)	(7,634)
Hydrology Section - Net	(2,513)	(1,306)	(593)	(523)
DEFICIENCY OF REVENUES OVER EXPENSES	(31,395)	(23,596)	(4,257)	(8,157)
Net assets at beginning of year	117,564	141,160	145,417	153,574
NET ASSETS AT END OF YEAR	**$ 86,169**	**$ 117,564**	**$ 141,160**	**$ 145,417**

**The comparative financial statements for 2007 have been restated to reflect an additional $12,523 in expenses relating to the 2007 Annual Scientific Meeting that were paid in 2008.*

*** Beginning in 2005, the Hydrology Section is included in the financial statements of the Canadian Geophysical Union. This change has been accounted for retroactively in the prior year financial statements with an increase in expenses of $675, an increase in opening net assets of $14,566 and an increase in cash of $13,891*

Canadian Geophysical Union **Financial Position 2005-2008**

Kathy Young (treasurer)

	Year Ended December 31 2008	2007 restated*	2006	2005 HS**
ASSETS				
CURRENT ASSETS				
Cash	$ 17,441	32,360	65,563	94,441
Investments	65,988	97,953	70,653	48,500
Amounts receivable	1,356	1,283	6,211	567
Prepaid Medals	3,484	3,996	4,504	3,910
	$ 88,269	$ 135,592	$ 144,913	$ 147,418
LIABILITIES AND NET ASSETS				
CURRENT LIABILITIES				
Accounts payable and accrued liabilities	$ 2,100	$ 18,028	$ 3,753	$ 2,001
NET ASSETS	**86,169**	**117,564**	**141,160**	**145,417**
	$ 88,269	$ 135,592	$ 144,913	$ 147,418

**The comparative financial statements for 2007 have been restated to reflect an additional $12,523 in expenses relating to the 2007 Annual Scientific Meeting that were paid in 2008.*

*** Beginning in 2005, the Hydrology Section is included in the financial statements of the Canadian Geophysical Union. This change has been accounted for retroactively in the prior year financial statements with an increase in expenses of $675, an increase in opening net assets of $14,566 and an increase in cash of $13,891*

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Submissions should be sent to the Editor:

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Electronic submission is encouraged.

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