Elements

Volume 35, Number 1 **Winter Issue** **March, 2017**

THE BULLETIN OF THE CANADIAN GEOPHYSICAL UNION

IN THIS ISSUE

LE BULLETIN DE L'UNION GÉOPHYSIQUE CANADIENNE

Message from the President

Dear CGU members,

Our annual scientific meeting is the highlight of the CGU year, and 2017 is no exception. I invite you to join the earth science community and in particular our CFASM colleagues on the beautiful campus of UBC at the end of May for an enjoyable and productive meeting.

But what about the rest of the year? To encourage more involvement from its members, the CGU is creating the new position of "Volunteer Coordinator". Please see the advertisement on page 3 of this issue. The Coordinator's main role will be to present you with several volunteer opportunities, for example contributing to the Elements newsletter or the website, or to organize events at students' conferences. Getting involved in the CGU is rewarding in itself and is a great way to give back to the community. As the outgoing President, I have tremendously enjoyed my time in the executive and I would like to thank everyone for their help and patience. I look forward to continue to be active in the CGU in a different way.

Sincerely,

Claire Samson, CGU President
Ph.D., P.Eng.

A strong CGU – UGC is a strong voice for Canadian geoscientists.

The CGU – UGC represents the interests of Canadian geoscientists in many ways, such as in organized scientific meetings, interactions with funding agencies, and in advocacy of the role of science in society and policy-making.

---

*Cover image for **Elements** flag courtesy of Fanny Larue, Université de Sherbrooke*

Upcoming Conferences

- **Western Snow Conference**, 85th Annual April 17-20, 2017, Boise, Idaho.
- **European Geosciences Union General Assembly 2017**, Apr 23 - 28, Vienna, Austria.
- **CGU-CSAFM Joint Meeting**, May 28 – May 31, 2017 in Vancouver, BC.
- **GAC-MAC Annual Meeting**, May 14 – 18, 2017 in Kingston, Ontario.
- **Eastern Snow Conference** June 6-8, 2017, University of Ottawa, Ottawa, Canada.
- **IAHS Scientific Assembly** July 9-15, 2017, Port Elizabeth, South Africa
- **IAG-IASPEI Joint Scientific Assembly** July 30 - August 4, 2017, Kobe, Japan
- **IAVCEI Scientific Assembly** August 14-18, 2017, Portland, OR, USA
- **IAPSO-IAMAS-IAGA Joint Scientific Assembly** August 27 - September 1, 2017, Cape Town, South Africa

Employment Opportunities

http://cgu-ugc.ca/jobs-and-opps/

Canadian Geophysical Union
Volunteer Coordinator

The Canadian Geophysical Union (CGU) welcomes expressions of interest for the newly-created position of "Volunteer Coordinator".

Responsibilities

- Identify activities in support of the CGU that could be held by volunteers (e.g. providing content for the CGU website, helping with the CGU booth at the annual meeting, organizing student networking events, etc.)
- Recruit volunteers and assign them to these various activities
- Assist and monitor the volunteers in the execution of their activities
- Report to the Board of Directors

The Volunteer coordinator will be appointed to the Board of Directors of the CGU. His/her mandate is for a duration of 2 years, starting at the annual meeting in Vancouver (28-31 May 2017).

If you are interested in this position, please send a letter of intent and your CV to **cgu@ucalgary.ca** at the latest on 30 April 2017. The position of volunteer coordinator is a non-remunerated position, open to full members of the CGU.

CGU - UGC Member Profiles

Student Member:

ATHINA PEIDOU, YORK UNIVERSITY

Where is home?
I am from Greece, from a small city called Katerini in North Greece.

What is your current position?
I am a PhD candidate at the Department of Earth and Space Science and Engineering at York University, working under the supervision of Dr. Spiros Pagiatakis.

What is your current research project?
We are working on the impact of higher atmospheric dynamics (space weather) on Low Earth Orbit satellites, with focus placed on satellite gravity missions.

What degree did you complete prior to starting this one, and where?
2016, MASc, Geological Engineering specializing in Geophysics, Queen's University, Canada
2014, Diplo. Eng., Geomatics Engineering, Aristotle University of Thessaloniki, Greece

What led you to join the CGU?
I think it is very important to interact with researchers across Canada. CGU is a common reference point for geoscientists in Canada. For this reason, I decided to get involved and join CGU.

What do you enjoy most about being a CGU student member? Is there anything more you'd like to see CGU do for student members?
CGU is a great opportunity to exchange research ideas. It would be great if student members from different sections could get together throughout the year, creating a platform that connects graduate students with each other.

What's your ultimate career goal?
I am a big believer of integrated geosciences. Ultimately, one of my biggest career goals is to cover a substantial segment of the geoscience spectrum, revealing unexpected synergies among disciplines that we would never think to be related.

What's your favourite activity outside of school/work?
Reading (Literature) and Basketball

Tell us something most people don't know about you.
When I was a kid, I used to collect compasses.

What are you currently reading that's not a scientific article?
The "Open Papers" by Odysseas Elytis and the "Only Daughter" by Anna Shoekstra.

CGU - UGC Member Profiles

Regular Member: DAVE EATON, UNIVERSITY OF CALGARY

Dave is a Professor in the Department of Geoscience at the University of Calgary, and holds the NSERC/Chevron Industrial Research Chair in Microseismic System Dynamics. He came to the UofC to take a position as Head of the Department of Geoscience in 2007, after a 10-year academic career at Western University and 3 years as a Research Scientist with the Geological Survey of Canada in Ottawa.

What's your favourite part of your job?

I can truthfully say that there are a multitude of exciting aspects of my job that get me out of bed early each day. I hold a research chair, which gives me more freedom to take a deep dive into research topics that I find challenging and important. My current research focus is induced seismicity, which are earthquakes triggered by human activities. I think of this as "applicable" research, rather than "applied", because it demands a balanced approach that includes both fundamental and applied elements. This may be a tired analogy, but I find the process of research to be reminiscent of a Sherlock Holmes investigation – it's all about gathering seemingly disconnected clues and then finding that creative spark that links them together. At the same time, I absolutely thrive on teaching and learning, which I believe goes hand-in-hand with research. The sense one gets at moment of collective epiphany in a classroom, when a group discussion brings everyone to a new level of understanding, is simply indescribable. Mentoring graduate students and postdoctoral researchers (or highly qualified personnel, in NSERC's vernacular) is incredibly rewarding as well. It's all about that proverbial moment when the trainee turns the table and begins to enlighten me. Recently I've started to take a lot of satisfaction in bringing together colleagues within ambitious team projects that aim for lofty scientific goals. All of this is not to say that an academic job is nirvana – like any position, it comes with its share of stress and drudgery – but on balance there are so many positive aspects that it's hard to pick a favourite.

Image: Riley Brandt, University of Calgary

DAVE EATON *continued*

Briefly describe your research program.
Together with my research group, we are tackling a diverse range of research problems. A central theme is induced seismicity caused by fluid injection, especially hydraulic fracturing used in unconventional oil and gas development. In order to address this topic, we are combining passive field experiments with seismic imaging, geological and geomechanical investigations and computer simulations. Our aim is to contribute to science-informed regulations and also to learn something fundamental about earthquake processes in plate interiors. This aspect of my research requires collaboration between academia, industry and government, and also provides a basis to reduce the environmental footprint of industry practices. Another very distinct component of my research focuses on the lithosphere asthenosphere boundary (LAB) beneath continents. This part of my research program uses a variety of seismological tools to image the crust and upper mantle, together with complementary types of data such as heat flow or magnetotelluric observations.

> "…It's all about that proverbial moment when the trainee turns the table and begins to enlighten me."

What led you to join CGU, and how long have you been a member? Did you start as a student member?
I first joined the CGU as a student, right after it formed through a merger of sections within the Canadian Association of Physicists (CAP) and the Geological Association of Canada (GAC). The first CGU talk that I gave was as a graduate student, at a CGU meeting in Saskatoon in about 1988. I got more involved in the CGU after I joined the Geological Survey of Canada, when I became a member of the Executive and ultimately president a little over a decade after I joined.

What's the biggest benefit to being a CGU member?
The CGU serves a number of very important functions that benefit all of its members. The annual meeting provides a focal point for the diverse geophysical community across Canada, of course, but occasional smaller meetings and regular communications also help to build an important sense of community. The CGU also performs various key behind-the-scenes functions that help to sustain Canada's position within the international geophysical community.

Where do you see CGU going in the future?
The world is changing with astonishing speed, with both positive and negative consequences. The CGU is on a trajectory to keep our community relevant in this changing world and to promote the geophysical sciences across many disciplines.

What's your favourite activity outside of work?
I really enjoy getting into the nearly Rocky Mountains in any season, especially the backcountry. This includes hiking, scrambling, skiing and snow shoeing.

What are you currently reading that's not a scientific article?
This is going to sound terribly nerdy: I'm currently reading A Short History of Nearly Everything by Bill Bryson. I'm really enjoying it.

CGU - UGC Biogeosciences Section :: Report

CARL MITCHELL, President

The Biogeosciences Section continues to have strong research dissemination and student engagement within the CGU.

The 2016 Joint Congress with CMOS was successful, with five biogeosciences sessions totaling 29 presentations. Students were the presenters on more than half of these. For the first time in a number of years, we required an extended abstract again as part of our annual student award competition. We received six very competitive submissions for the award. Kimberley Murray, who works with Professor Maria Strack at the University of Waterloo, was this year's winner for her submission "Controls on methane flux from a constructed fen in the Athabasca Oil Sands Region, Alberta." Our sincere thanks go to LiCOR, who sponsored the student award.

We also had a strong representation at the Eastern Student conference (held jointly with the Hydrology and Earth Surface Processes sections) at Guelph University in February, 2017. Our sincere thanks go out to Jackie Cockburn, Aaron Berg, John Lindsay and Wanhong Yang who organized this year's meeting.

The upcoming meeting in Vancouver is shaping up very nicely, with six biogeosciences sessions spanning microplastics to a very highly subscribed session on mine reclamation.

A number of executive positions were elected or continued at last spring's annual general meeting for the section. The current Biogeosciences Section executive includes:

Carl Mitchell, University of Toronto (President)
Murray Richardson, Carleton University (Vice-President)
Merrin Macrae, University of Waterloo (Past President)
Nora Casson, University of Winnipeg (Secretary)
Altaf Arain, McMaster University (Treasurer)
Maria Strack, University of Waterloo (Member-at-Large)
Britt Hall, University of Regina (Member-at-Large)
James Cober, University of Waterloo (Student Executive)

Adrienne Ducharme (MSc student at the University of Winnipeg) checks stream sampling equipment at the Experimental Lakes Area, near Kenora, Ontario.

Image submitted by Nora Casson.

CGU - UGC Biogeosciences Section :: Focus

Training undergraduate students in team science: the "LUGNuts" project

Osama Ahmed[1], Jeremy Leathers[2], Katy Nugent[1], Tyler Prentice[3], Matthew Sauer[4], Helen Baulch[1], Nora Casson[2], Rebecca North[4], Jason Venkiteswaran[3], and Colin Whitfield[1]

1 School of Environment and Sustainability & Global Institute for Water Security, University of Saskatchewan, Saskatoon, SK S7N 3H5
2 Department of Geography, University of Winnipeg, Winnipeg, MB R3B 2E9
3 Geography and Environmental Studies, Wilfrid Laurier University, Waterloo, ON N2L 3C5
4 School of Natural Resources, University of Missouri, Columbia, MO 65211

There is a recognized need to train students to conduct collaborative, interdisciplinary research in order to address complex environmental problems. While there are some programs (e.g. NSERC CREATE) that provide opportunities to train graduate students in collaborative science, there are fewer programs tailored for undergraduate students. The objective of our project – Linked UnderGraduate experiments on Nutrients (LUGNuts) – is to create a network of Honours thesis students working on a common project related to nutrient cycling in the environment. This project will expose the students to the joys and challenges of collaborating with a diverse group of scientists across institutions at an early career stage and give them a skill-set to approach large projects and will serve them well as they continue to graduate degrees. Mentorship by a group of academics beyond their home institution is a distinct benefit of our approach.

In this pilot year, students from Wilfrid Laurier University, the University of Winnipeg, the University of Saskatchewan and the University of Missouri conducted lab experiments to assess the impact of freeze-thaw cycles on the release of nutrients from riparian and wetland vegetation. Through bi-weekly videoconferences, the students designed a common field and lab protocol, developed a template to facilitate data sharing and analysis, offered each other advice based on their experiences at various stages of the research, wrote a collaborative literature review and are currently analyzing their results. While each student will write an individual thesis, they will also collaborate on a common manuscript that will aim to extrapolate from site-based results and examine geographic variability in the response of vegetation to freeze-thaw cycles. We are in the process of designing a project for next year. If you are interested in participating, please get in touch with one of the participating researchers. We also have a talk at the upcoming CGU conference in Session B02a in Vancouver.

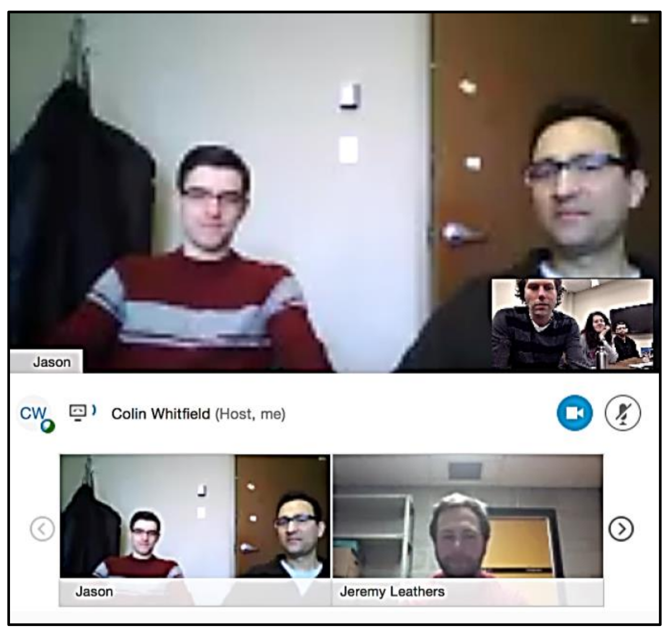


Image: LUGNuts Groupchat

CGU - UGC Solid Earth Section :: Report

PHIL MCCAUSLAND, President

The **CGU Solid Earth Section** has a number of events coming up in the next few months, involving CGU members and a wider range of Earth Scientists. Following the Section mandate, we seek to facilitate and promote Solid Earth Geophysics research, to encourage its timely communication, and to build links with other organizations that will help us achieve these goals.

Sponsorship of AESRC 2017

The Section has a mechanism for offering $500 sponsorship of regional meetings of any kind that promote Solid Earth geophysics. This year the Section again is sponsoring a geophysical session at the regional **Advances in Earth Sciences Research Conference**, which is organized by and for graduate students to showcase over two days their research and to network with peers and Earth Science organizations.

This year the meeting will take place on March 31- April 2 at Western University. The meeting will feature a range of geophysical contributions in a session sponsored by the Solid Earth Section.

Vancouver CGU-CSAFM Meeting

The Solid Earth Section is sponsoring five technical sessions at the meeting:

- Geophysical studies of structure and tectonics of the Canadian Cordillera
- The earthquake cycle: squaring the circle
- Recent trends in exploration geophysics
- Induced earthquakes: Source processes and hazard assessment
- Solid Earth Geophysics: General Contributions

The Section will also offer the eighth running of the **CGU-SES Best Student Presentation Award** at the annual meeting, to be determined amongst presenting student first-authors of Solid Earth geophysical posters and talks. This award is judged by volunteers (join us!) at the meeting and consists of a plaque and a cheque for $750.

We will also have an **election of officers for the SES Section Executive** at the annual meeting in Vancouver. A Nominating Committee has been struck (consisting of Past Presidents K. Tiampo and S. Butler as well as current President McCausland) to engage the Section membership in establishing a slate of candidates for the new 2017-2019 Executive. This process is underway now and you are invited to take part!

Finally, this is my last Report as Section President. It has been a blast over the past four years. I feel confident that the CGU and this Section are growing in useful ways, and are growing to provide key leadership in geophysics and Earth Sciences in Canada. I look forward to our future – with many new CGU members and old friends!

Cheers,

Dr. Phil J.A. McCausland,
President, CGU Solid Earth Section

PS – Check out our Section T-shirts!!

Bao, X., & Eaton, D. W. (2016). **Fault activation by hydraulic fracturing in western Canada.** *Science*, 354, 1406-1409.

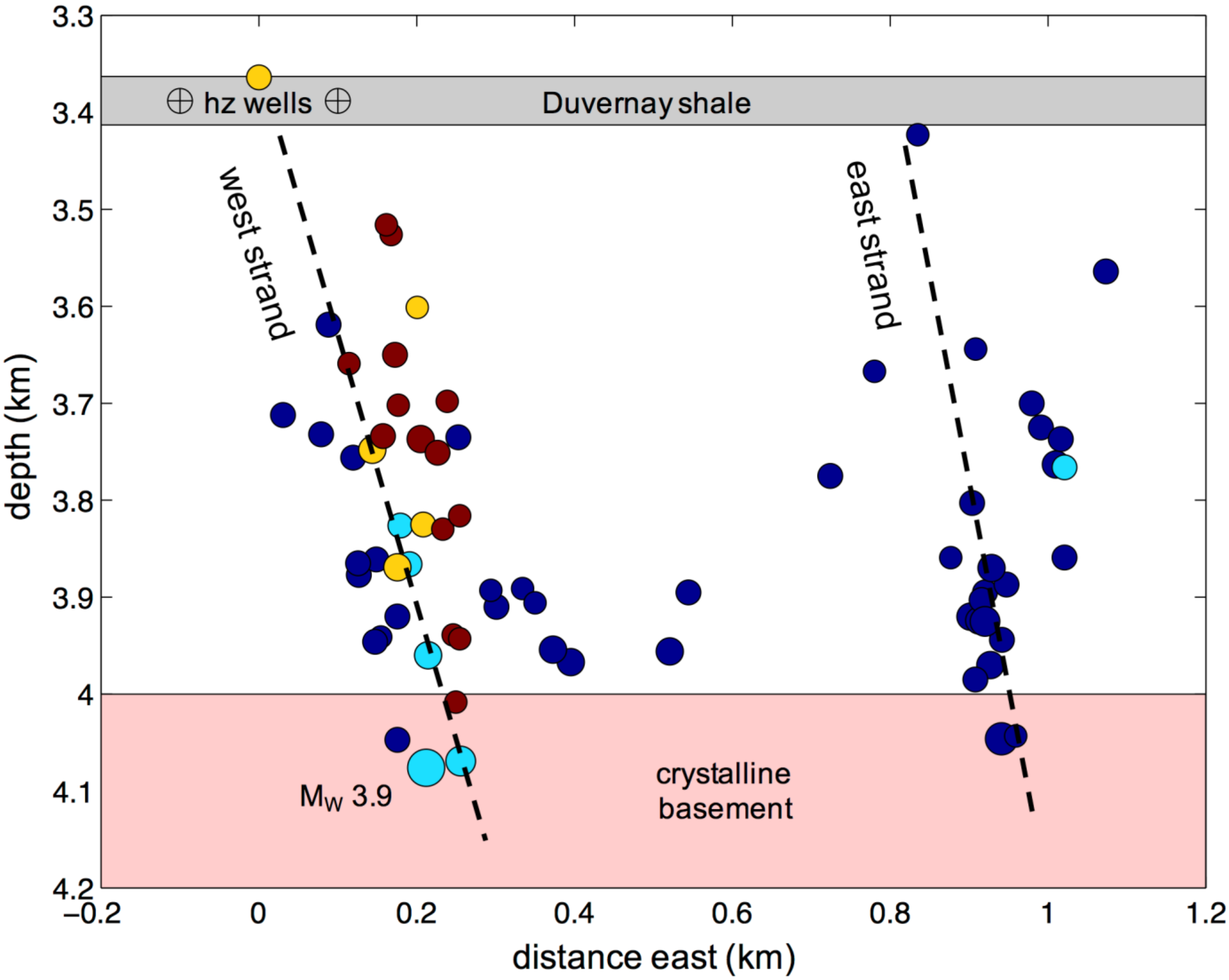


Figure: *Cross section through a seismicity cluster, showing east and west fault strands shown by dashed lines. Dark blue symbols show events that occurred during hydraulic fracturing in two horizontal (hz) wells. Other colours show post-treatment seismicity. Modified from Bao and Eaton (2016).*

CGU - UGC Solid Earth Section :: Research Highlight

Samsonov et al., (2016) **Fast subsidence in downtown of Seattle observed with satellite radar**, *Remote Sensing Applications: Society and Environment*, 4:179–187, 2016.

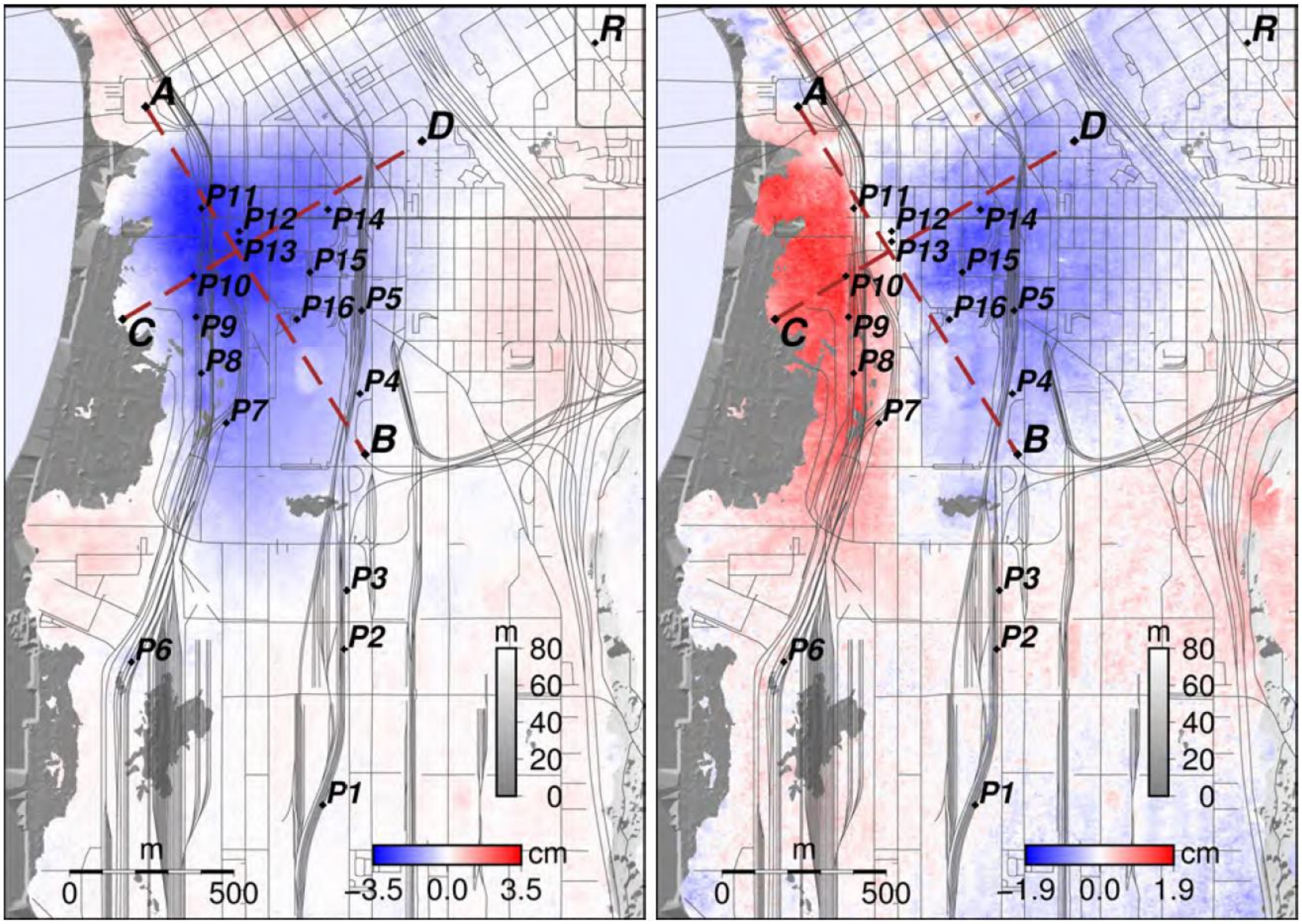


Figure: *Using RADARSAT2 DInSAR data to monitor infrastructure activities in urban areas. Cumulative vertical (left) and horizontal east-west (right) displacements, downtown Seattle, August 2014 through August 2015. From Samsonov et al. (2016).*

CGU - UGC Earth Surface Processes Section :: Focus

Announcing New Geomorphology Subcommittee for the Association of Professional Geoscientists of Ontario (APGO)

Image APGO

APGO has a new committee! The proposal for the new subcommittee was submitted by a group of members interested in better defining geomorphology within the practice of environmental geoscience. The proposal was first presented to APGO Council in November 2016 by Vice President Christine Vaillancourt, and the subcommittee chair was confirmed at the January 2017 council meeting. Ms. Vaillancourt is pleased to announce that Council has unanimously approved the formation of the new Geomorphology Subcommittee and recognises the great benefits of this new addition by offering more comprehensive guidance to current and future membership. The Council has approved APGO member Roger Phillips as the Chair of the new committee with the firm belief that his enthusiasm and numerous skills are key assets to the Council and the association as a whole.

Moving forward in 2017, the main objective of the subcommittee is to better define the practice of and qualifications for geomorphology as a geoscience under existing APGO policies, including the challenge of university programs that do not align with the Geoscientists Canada knowledge requirements. More generally, the subcommittee aims to help identify and mitigate the broader issues facing geoscience practitioners trained in physical geography and environmental science programs. The new subcommittee's activities will initially focus on outreach with universities, students, and industry stakeholders to develop recommendations for APGO Council and the Registration Committee. For more information or to receive updates regarding the Geomorphology Subcommittee's activities, please email: **geomorphology@apgo.net** (*from APGO Field Notes, submitted by Roger Phillips*)

Earth system observation from space platforms

E. Sinem Ince[1,2], Spiros Pagiatakis[1]

1 Department of Earth and Space Science and Engineering, Lassonde School of Engineering, York University, Toronto, Ontario, Canada
2 Helmholtz Centre Potsdam, GFZ German Research Centre for Geosciences, Section 1.2 Global Geomonitoring and Gravity Field, Telegrafenberg, Potsdam, Germany

The Gravity field and steady-state Ocean Circulation Explorer (GOCE) completed its mission in November 2013. Even though it was initially proposed and designed as a geodetic mission, GOCE data products have extensively been used in geophysical and space physics studies too.

Based on gradiometer principle, the six 3–axes accelerometers mounted onboard the centre of mass of the satellite measured both gravitational and non-gravitational accelerations along the satellite track. The gravitational accelerations separated from the non-gravitational accelerations made possible the estimation of the spatial derivatives of the Earth's gravitational potential from space for the first time and provided very high quality scientific data for geodesy, solid Earth and oceanography.

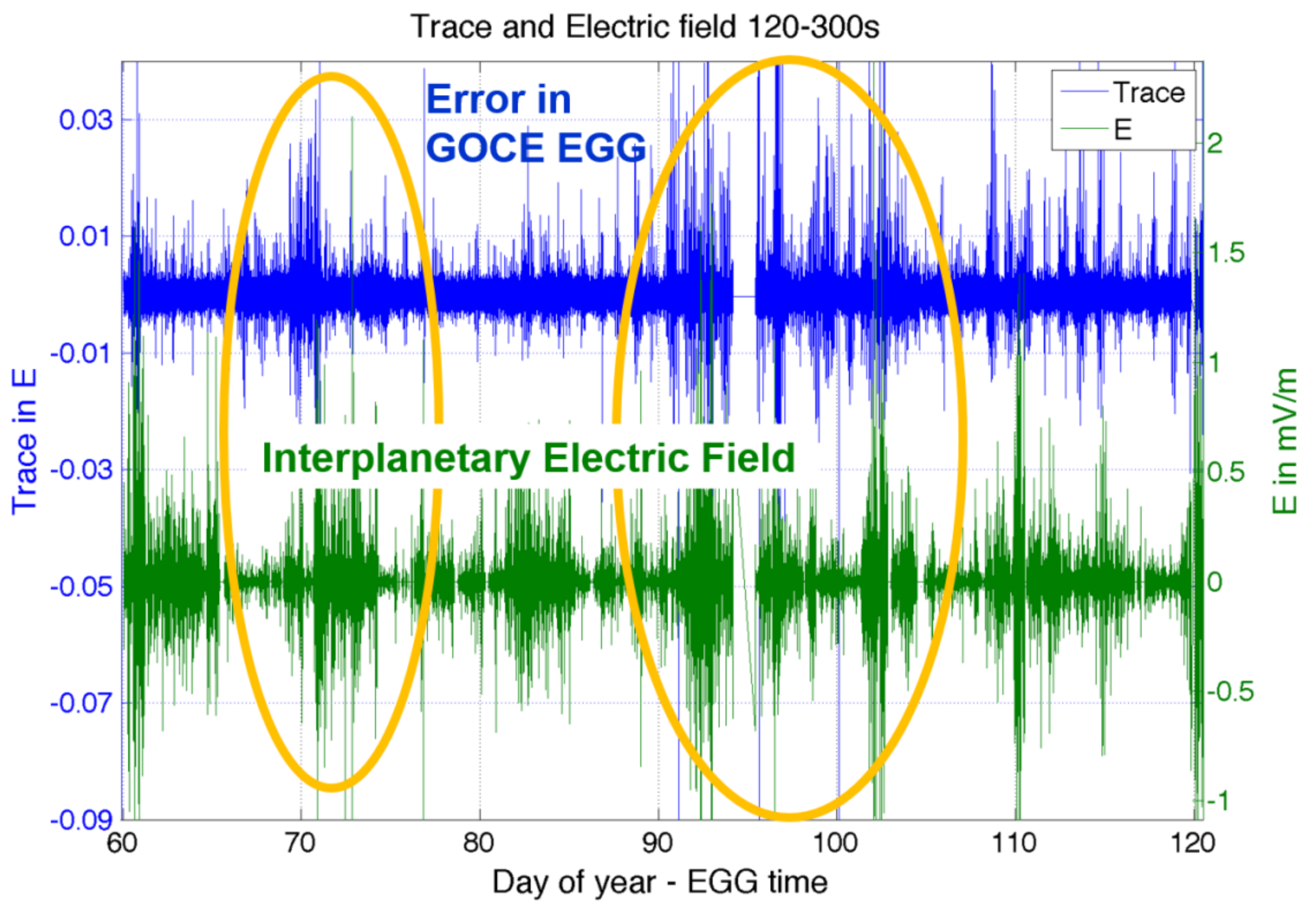


Figure 1a) Error in GOCE Gravitational gradients and Interplanetary Electric Field.

Moreover, the non-gravitational accelerations were used to retrieve thermospheric air density and neutral wind velocity profiles along the satellite track. Considering its almost tripled lifetime, GOCE contributed to both disciplines, geodesy and space physics enormously. Furthermore, there is still room for improvement of the GOCE products and European Space Agency has taken an action to reprocess the GOCE gradiometer data using proposed improved techniques.

Our analyses indicated that the noise level of the gravitational accelerations increased during geomagnetically active days (see also Fig.1a,b for the distribution of the errors in spatial and time domains) and degraded the quality of the gravitational products. In a recent publication, we analyzed the coherency between the error in the GOCE gravitational gradients and Poynting flux that is derived from equivalent ionospheric currents which represents the electromagnetic energy input into the satellite environment (Ince and Pagiatakis, 2016). The impact of this discovery is twofold. First, we showed that there is a causality of the gradiometer measurement errors and energy input into the satellite environment. This relationship was further used to understand and subsequently model the gradiometer measurement errors to improve the quality of GOCE measurements that in fact reduced the error by up to 30%. Second, our results showed that low earth orbiter (LEO) accelerometer measurements provide very useful information about the main characteristics of the ionosphere and its dynamics, e.g., neutral winds, equivalent ionospheric currents and Poynting flux (electromagnetic energy flux) which should be included in space physics research. Our results are encouraging for transdisciplinary research for understanding the Earth system and space environment further.

Ince, E.S. and Pagiatakis, S.D., 2016. Effects of space weather on GOCE electrostatic gravity gradiometer measurements. *Journal of Geodesy*, 90(12), pp.1389-1403.

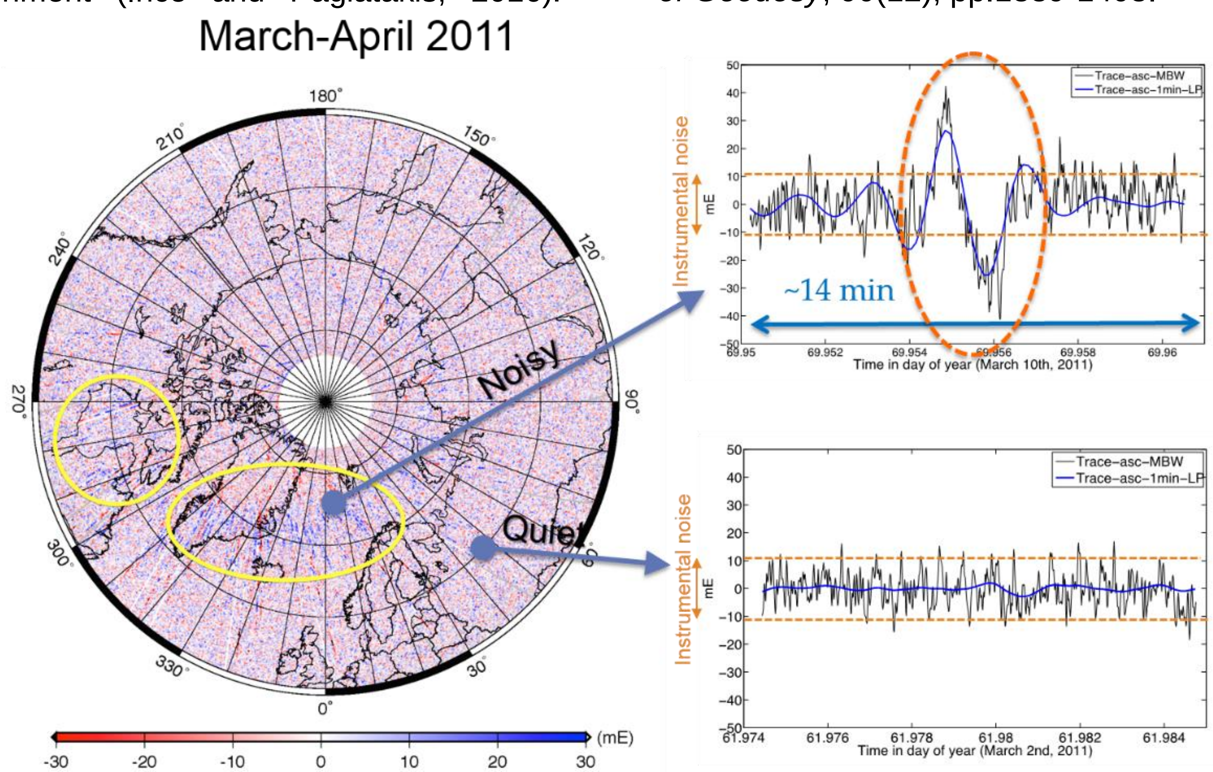


Figure 1b) Error distribution of GOCE Gravitational gradients over North Polar Region and its characteristics.

CGU - UGC Geodesy Section :: Research Highlight

Research and economic activity in the eastern Arctic and North Atlantic between 2003 and 2015

from Calvin Klatt

Director and Chief Geodesist, Canadian Geodetic Survey

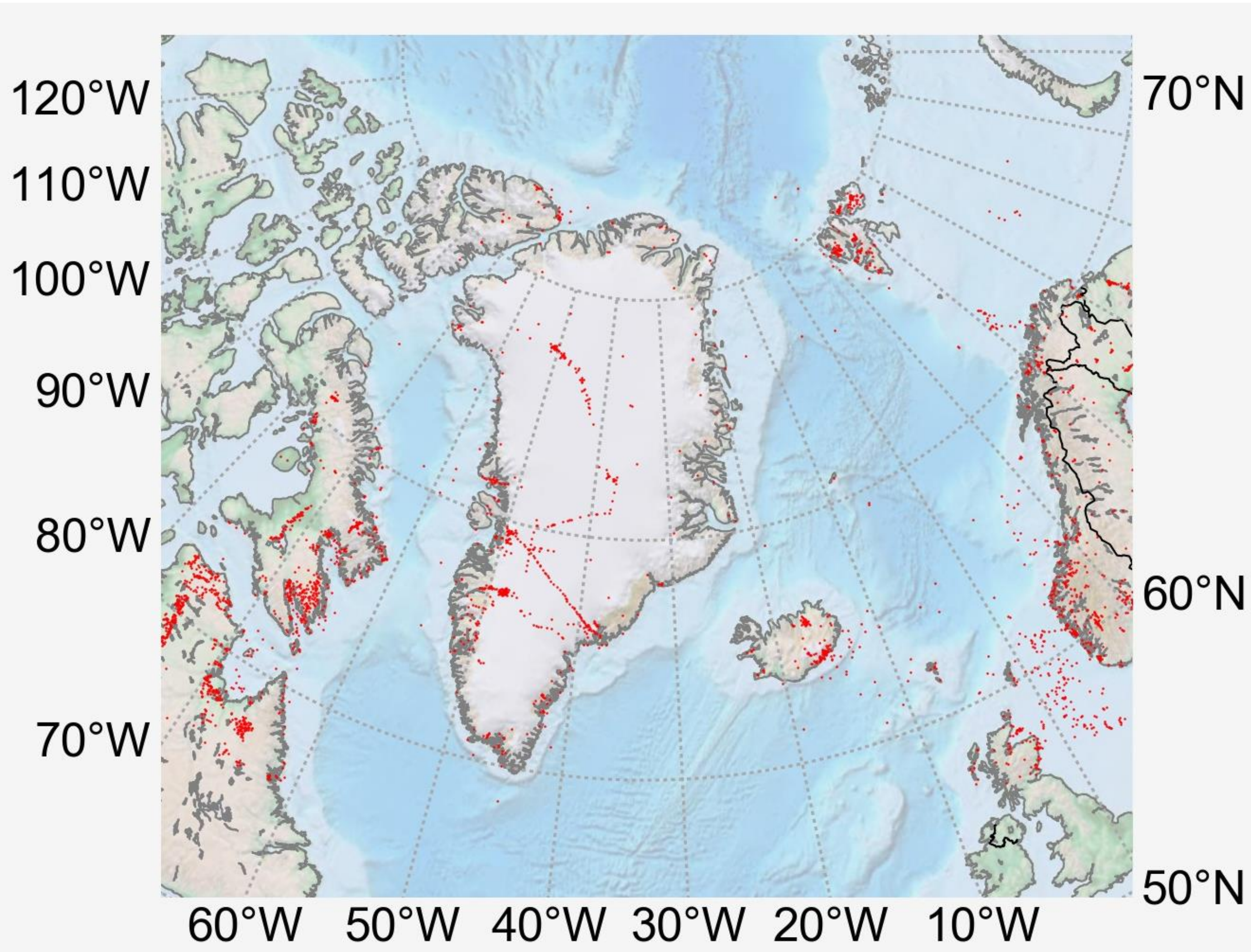


Figure: *GNSS files processed with the Geodetic Survey of Canada's CSRS-PPP service between 2003 and 2015 are depicted as red dots on a map of the eastern Arctic and North Atlantic, indicating vast continent-scale scientific efforts in the Arctic (Greenland particularly), environmental studies (in Quebec) as well as economic activity, including surveying of off-shore oil rigs. Note that the edges are not representative (west of 80, for example, is not plotted). Study to appear in the March 2017 issue of Geomatica.*

CGU - UGC Hydrology Section :: Report

DANIEL PETERS, President

The **Canadian Geophysical Union Hydrology Section (CGU-HS)** continued with a busy schedule of activities and initiatives over the past year. The CGU-HS was a prominent contributor to the **Joint Congress** of the Canadian Meteorological and Oceanography Society (CMOS) and CGU in Fredericton NB from May 29 to June 2 2016, where the attendance at lectures, workshops and our broad range of sessions was notable.

The annual Woo Lecture entitled "Recent advances in river temperature research and modeling "was presented by Dr. Daniel Cassie of Fisheries and Oceans Canada, Moncton NB. His talk focussed on the fundamental controls influencing the thermal behaviour of rivers, the spatial and temporal heterogeneity in river temperatures as well as relevant river heat exchange processes and modelling.

A healthy number of 9 special sessions made up the Hydrology program that comprised 65 oral and 40 poster presentations: Cold Regions and Hydrometeorology; Hydro-Climatic Extremes and Variability; Advances in Hydroecology in Canada; Urban Water in Canada; Hot and Hotter: Temperature as an indicator of environmental change and a tracer of hydrologic process; Oil Sands Reclamation; Applications of L-Band Microwave Remote Sensing in hydrological monitoring; Historical and Projected Changes in Hydroclimatological Extremes: Investigating the Roles of Teleconnection Signals and Climate Change; and General Hydrology sessions. In addition, the CGU HS supported “A Young Hydrologic Society” Workshop on the Sunday prior to the start of the Meeting.

The CGU-HS presides and adjudicates over three awards: The Campbell Scientific Award for Best Student Poster in Hydrology was awarded to graduate student Behrad Gharedaghloo, University of Waterloo; The D.M. Gray Award for Best Student Paper in Hydrology was awarded to graduate student Ryan Connon, Wilfrid Laurier; The D.M. Gray Scholarship (a Union award) was awarded to PhD Candidate Igor Pavlovskii, University of Calgary. As in previous years, competition was strong in all categories with many high-quality submissions.

The CGU-HS has several sub-committees on topics of interest to HS members: Committee on River Ice Processes and the Environment (CRIPE); Northern Research Basins Committee; Committee on Isotope Tracers; Hydroecology Committee, Urban Hydrology Committee; Canadian Young Hydrologic Society; and Committee on Hydro-climatic Impacts and Adaptation. Of note, the latter two committees were approved at the 2016 HS Annual General Meeting. Overall, the individual committees have specific objectives, but have a common goal of advancing scientific knowledge and application of research in their field. For more information on existing committees and/or creating a new committee, contact the committee chairs and/or the HS Member-at-

Large for Committees (Barret Kurylyk). HS Committee reports cab be found on the **CGU HS website**.

The CGU-HS continues to sponsor annual student meetings. The **2017 CGU Eastern Student Conference** student meeting was hosted by the Department of Geography at the University of Guelph on February 4th 2017. Approximately 100 attendees took-in 30 oral and 22 poster presentations throughout the day. The abstracts from the meeting are available as a **PDF from our meeting webpage**.

As in previous years, the CGU-HS has prepared a special issue of selected papers to be published in *Hydrological Processes* (HP). The issue was published in the Fall of 2016 and highlights 6 papers presented at the annual meetings held in Montreal QC in 2015 (May 3-7) and Banff AB in 2014 (May 4-7), as well as 5 from a CGU HS co-sponsored workshop on "Extreme Weather and Hydrology - Lessons Learned from the Western Canadian Floods of 2013 and Others" held in Canmore AB in February 2014. The preface the **HP Special Issue: Canadian Geophysical Union 2016** is now available. Once again, *Hydrological Processes* has agreed to host a special issue for papers presented at the 2016 meeting – papers were submitted last fall are currently undergoing peer review process for publication later in 2017.

Changes were made to the executive and a new slate was adopted for this year. The 2016/2017 CGU-HS Executive are:

President: Daniel Peters (Environment Canada) daniel.peters@ec.gc.ca

Vice President: Claire Oswald (Ryerson University) coswald@ryerson.ca

Past President: Bill Quinton (Wilfrid Laurier University) wquinton@wlu.ca

Secretary: Andrew Ireson (University of Saskatchewan) andrew.ireson@usask.ca

Treasurer: Genevieve Ali (University of Manitoba) Genevieve.Ali@umanitoba.ca

Member-at-Large (Committees): Barret Kurylyk (University of Calgary) bkurylyk@gmail.com

Member-at-Large (Awards): Peter Whittington (Western University) whittington.pete@gmail.com

Student representative: Casey Beel (Queen's University) 15cb29@queensu.ca

In the last year, Canadians were active in several International Association of Hydrological Sciences (IAHS) Commissions and as National Correspondents:

ICCE, Continental Erosion

President, Michael Stone, University of Waterloo mstone@uwaterloo.ca

ICCLAS, Coupled Land-Atmosphere Systems

Vice President, Rich Petrone, Wilfrid Laurier University rpetrone@wlu.ca

ICRS, Remote Sensing

Vice President, Chris Hopkinson, University of Lethbridge c.hopkinson@uleth.ca

IAHS National Representatives

Rich Petrone, Wilfrid Laurier University rpetrone@wlu.ca

Genevieve Ali, University of Manitoba Genevieve.Ali@ad.umanitoba.ca

Finally, the HS Executive looks forward to seeing you at the 2017 annual meeting in Vancouver BC.

CGU - UGC Hydrology Section :: Research Highlight

Comparison of commonly-used microwave radiative transfer models for snow remote sensing

from Alain Royer, Professeur
Centre d'applications et de recherches en télédétection (CARTEL) et Centre d'Études Nordiques du Québec
Université de Sherbrooke

Figure:** Photo montage of field campaign at Umiujaq, Nunavik, Canada last winter (March 2016) for validation of microwave satellite retrieval algorithm for snow monitoring. Sub-sets include photos of my students: Fanny Larue, PhD , Olivier St-Jean-Rondeau, M.Sc. and Alex Roy, post-doctoral fellow, all at the Université de Sherbrooke. Royer et al. (2017). Remote Sensing of Environment, 190, 247–259,* ***http://dx.doi.org/10.1016/j.rse.2016.12.020

Special Section

CMOS-CGU 2016 Joint Scientific Congress Highlights

For our 2016 annual meeting, the CGU had a Joint Scientific Congress with CMOS (Canadian Meteorological and Oceanographic Society), held in Fredericton, NB from 29 May – 2 June, 2016. This marked the return of the CGU to Fredericton fully 37 years after the last CGU meeting there, in 1979!

Held downtown at the Fredericton Convention Center with some events across the street at The Crown Plaza, the four-day meeting featured 58 technical sessions, six special sessions, eight plenary lectures and a general public lecture, arranged around the meeting theme "Monitoring of and Adapting to Extreme Events and Long-Term Variations." In all, the Joint Congress attracted 550 registered participants with 469 abstract contributions, of which ~35% were from CGU members.

This 2016 Joint Congress was ably organized by a Local Arrangements Committee chaired by Prof. William Ward (UNB) and Prof. Marcelo Santos (UNB), aided by many volunteers! The Scientific Program Committee was led by Dr. Paul Yang (Environment Canada) with key CGU representation by Dr. Karl Butler (UNB).

The pages that follow contain highlights from the CMOS-CGU 2016 Joint Congress, focusing on the CGU Awards (J.Tuzo Wilson Medal, Young Scientist Award, and many student Awards) and their celebration at the Annual Banquet.

*(with files from Marcelo Santos, Gordon Young, Kristy Tiampo and **CMOS**)*

CMOS-CGU 2016 Joint Scientific Congress Highlights

Public Lecture

George Porter (NB Power) "The Future of the Mactaquac Generating Station"

Plenary Lectures

Kumiko Azetsu-Scott (Bedford Institute of Oceanography) "Ocean acidification in the Arctic"
Alex Hay (Dalhousie University) "Dynamic adjustment of the seabed to wave-current forcing in the nearshore"
Kevin E. Trenberth (National Center for Atmospheric Research) "Insights into Earth's energy imbalance from multiple sources"
Michel Jean (Director General, Canadian Centre for Meteorological and Environmental Prediction) "Big data, Social Media, Crowd Sourcing and the Evolution of the Meteorological Enterprise"
Dan Hutt (Defence R&D Canada) "Underwater sensing for Canadian defence"
Fiona Darbyshire (Université du Québec à Montréal) "Illuminating the structure of the North American continent: advances in broadband seismology"
Gordon McBean (President, International Council for Science and Western University) "Weather, Climate and Ocean Sciences for a Sustainable Future Earth"
David Risk (St. Francis Xavier University) "Non-growing season greenhouse gas production in high-latitude soils"

Marcelo Santos (left), introducing Public Lecturer George Porter (NB Power). On right, Plenary Speaker Gordon McBean (President, ICSU) addresses the Joint Congress.

CMOS-CGU 2016 Joint Scientific Congress Highlights

CGU 2016 Annual Banquet and Awards, at The Crowne Plaza Hotel, Fredericton, NB

Major Union Awards

J. Tuzo Wilson Medal: **Gail M. Atkinson**, Western University
Young Scientist Award: **Scott Jasechko**, University of Calgary
Stan Paterson Scholarship in Canadian Glaciology: **Laura Thomson**, U Ottawa
Don Gray Scholarship in Canadian Hydrology:
Igor Pavlovskii, University of Calgary

CGU Best Student Paper Awards

CGU Best Student Paper Award (oral): **Kelly Biagi**, McMaster University
Chevron Canada Outstanding Student Paper in Seismology: **Mitch Grace**, UNB
Shell Canada Best Student Poster Award: **Katelyn Lutes**, University of Waterloo
Biogeosciences LiCor Best Student Paper Award:
Kimberly Murray, University of Waterloo
Best Student Paper in Geodesy Award: **Ismael Foroughi**, UNB
D.M.Gray Award for Best Student Paper in Hydrology **Ryan Connon**, Wilfrid Laurier
Campbell Scientific Award for Best Student Poster in Hydrology:
Behrad Gharedaghloo, University of Waterloo
Solid Earth Best Student Paper Award:
Andrew Gagnon-Nandram, Queens University

CGU awards three Union level awards annually: The internationally-recognized J. Tuzo Wilson Medal, the Young Scientist Award and the Meritorious Service Award. Deadline for submission of all three is December 12 of the year prior to the CGU Annual Scientific Meeting.

Do the right thing! Nominate your colleagues for these Major CGU Awards!

The 2016 CGU J. Tuzo Wilson Medal
Gail M. Atkinson, Western University

Nomination by Hadi Ghofrani, Western University
(nomination presented by Dr. Karen Assatourians, Western University)

I am pleased to nominate Professor Gail M. Atkinson for the J. Tuzo Wilson Medal. Dr. Assatourians and Professor Motazedian, both Members of the Canadian Geophysical Union, are co-nominators. This letter includes a brief summary of scientific contributions and is supported by four international referees, and six national referees. The referees are highly accomplished and published scientists with extensive experience on national and international committees.

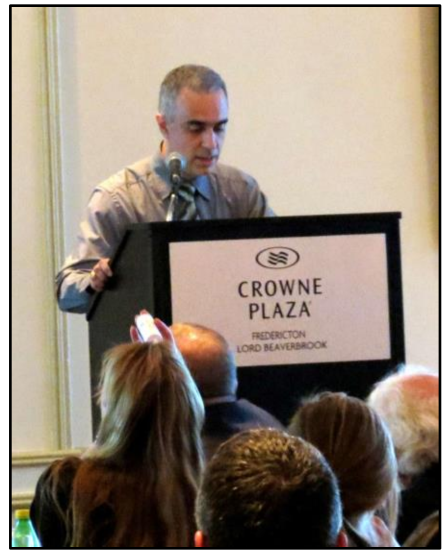
Synopsis

Scholarship: Dr. Atkinson has published 174 articles in peer-reviewed national and international journals, (please consult her CV). Total citations are 3526 according to the Web of Knowledge Database (WKD) and 6500 according to the GoogleScholar Database (GSD). Her two most quoted papers have 314 and 307 citations (WKD) and 538 and 584 according to the GSD. She has 11 (WKD) or 19 papers (GSD) with over 100 citations. The WKD database indicates an h-factor of 37 whereas the GSD indicates an h-factor of 43.

Leadership: Dr. Atkinson is an engineering seismologist specializing in (i) engineering ground motion; (ii) earthquake source and attenuation processes; (iii) seismic hazard analysis; and (iv) seismological processes in eastern North America. Dr. Atkinson is, or has been:

- Responsible for seismic hazard analyses for major engineering projects in Canada, the US and overseas and is active on Canadian code committees developing seismic design regulations;

Dr. Gail Atkinson (centre) with Dr. Karen Assatourians (left) and Dr. Claire Samson, President, CGU



- Project leader of the $10 million POLARIS project funded by Canadian Foundation for Innovation;
- Director of Ottawa-Carleton Earthquake Engineering Research Centre, 2000-2004; -President, Seismological Society of America, 2001-2003;
- Associate Editor, Bull. Seism. Soc. Am., Advisory Committee, Southern California Earthquake Center (and NSF National Science Center), 2005-2013;
- Chair (SCEC Advisory Council), 2014-2016;
- Scientific Management Committee, NSERC Canadian Seismic Risk Network, 2008-2013;
- President of the CGU, 2011-2013.

Honours and Awards:

- NSERC/TransAlta/Nanometrics Industrial Research Chair in Hazards from Induced Seismicity, 2014-present;
- Elected to the Royal Society of Canada, 2015;
- NSERC Accelerator Award, 2007-2010 and 2012-2015;
- Bayer Canada “Science for a Better Life” Award, for innovative work in Earthquake Protection, 2013;
- Canada Research Chair (Tier 1) in Earthquake Ground Motions, Univ. of Western Ontario, 2007- 2014;
- Keynote Lecturer: 15th World Conf. Earthq. Eng., Lisbon, Portugal, Sept. 2012; Canadian Nuclear Safety Comm. Conf. on Soul-Structure Interaction, Ottawa 2010; Australian National Earthquake Engineering Conference, 2006; World Conference on Earthquake Engineering, 2004; Canadian Geophysical Union Meeting, 2002; Geotechnical Society of Canada, 2000;

- Benjamin Meaker Lecturer, Institute for Advance Studies, Bristol, U.K. 2001;
- William B. Joyner Memorial Lecturer, 2007 (Seism. Soc. America/ Earthquake Engineering Research Institute);
- Premier’s Research Excellence Award, 2002-2007;
- Jesuit Seismological Association Award for Contributions in Observational Seismology, Eastern Section, SSA, 2003;
- NSERC Women’s Faculty Award, 1995-2000.

2016 J. Tuzo Wilson Medal Acceptance by Gail M. Atkinson

It is indeed an honour and a privilege to accept the J. Tuzo Wilson award from the Canadian Geophysical Union. I draw a theme for my remarks from Tuzo Wilson himself, who once said: "Beneath all the wealth of detail in a geological map lies an elegant, orderly simplicity." I hope Tuzo would not mind if I take the liberty to transform this into a seismological quote: Beneath all the wealth of detail in a seismogram lies an elegant, orderly simplicity. In my career as a seismologist, I have tried to find the order and simplicity that must underlie every seismic signal, ultimately lending it the shape and amplitude that we observe. As my career has been spent on the interface between seismology and engineering, my objectives in this regard have had a practical focus – I aim to characterize ground motions in a way that allows structures to be designed to withstand them. Particular engineering challenges have tended to provide the inspiration for new directions along the way.

> "In my career as a seismologist, I have tried to find the order and simplicity that must underlie every seismic signal, ultimately lending it the shape and amplitude that we observe."

I consider myself very fortunate to have been able to pursue such an interesting and rewarding career. I am often asked how I came to be interested in seismology. I must admit it was mostly through a series of lucky accidents, involving very little deliberation and even less wisdom. I did not set out as a child to be a seismologist. Though I do recall having some aspirations to be a mad scientist. In particular, my first clearly recollected career goal, from about the age of 10, was to invent a special belt or backpack that would allow the wearer to fly through the air like a bird. It is probably just as well that I never succeeded in this goal, otherwise the world today would likely be plagued by people trying to text and fly at the same time.

By the end of high school, I had a more practical goal - to become a chemist! But as a first year university student, I discovered that I did not like the formality of chemistry labs. They seemed too much like cooking, but under adverse conditions involving overly-prescriptive recipes, lab coats, safety glasses, fume hoods and so on – whereas I prefer cooking with wine. On the other hand, I found physics labs quite entertaining. I also enrolled in first-year geology, not out of interest, but as a way of avoiding biology – I knew I did

not like biology, because I did not like the biology teacher I had in high school. From this combination of ill-formulated decisions, my career path in geophysics was firmly set. My subsequent focus in engineering seismology was also prompted by a string of seemingly-random fortuitous circumstances that followed in the wake of looking for a part-time job to help finance my university studies and lifestyle habits. In the interests of time I will spare you the details. Suffice it to say that a few jobs, a few degrees and a few forks in the road later, I found myself a specialist in engineering seismology, not to mention a great admirer of stochastic processes. Perhaps because of this experience, I tend to look at processes in both seismology and life through this lens. Yes, we strive to understand the underlying system, which must have the orderly, deterministic simplicity that Tuzo Wilson so admired.

But this order is overlain by stochastic processes that obscure our vision of how the earth, or indeed the universe, works its magic. These stochastic processes, though often frustrating, are strangely beautiful and have their own internal order.

I have concluded that it is difficult to predict how things will turn out, and that what may initially appear as a setback may turn out to be an advantage in disguise. I have developed a healthy respect for Plan B, and I believe that although much of the universe reveals itself through science, there is also such a thing as good luck.

I have been especially lucky in my associations with others. The most rewarding aspect of my career has been collaborating with talented students and colleagues. There are too many to name – but among my former students, now my colleagues, I have been continuously inspired by Karen Assatourians, Hadi Ghofrani, and Dariush Motazedian and each of whom has touched me with their wisdom in a unique way. I have been enriched by interactions with academic colleagues at both Carleton and Western Universities. I also owe much to collaborations with my colleague David Boore at the U.S. Geological Survey in Menlo Park – we have had such a long-standing and fruitful collaboration that many American seismologists are firmly convinced that I am a native Californian. But finally, my greatest fortune was to marry that man over there. My husband, Glenn Greig, has been my love, my joy and my rock - and a trusted collaborator in the great venture of raising two marvelous children, who are now charting their own semi-random journeys through life. One could ask for no greater fortune.

– **Gail M. Atkinson, J. Tuzo Wilson Medallist**

The 2016 CGU Young Scientist Award
Scott Jasechko, University of Calgary

Nomination by J.J.McDonnell, University of Saskatchewan

(Nomination presented by Daniel Peters)

It is a pleasure to present the CGU Young Scientist award to Dr. Scott Jasechko, University of Calgary. Scott is a terrific young Canadian scholar in the hydrological sciences. Despite his current Assistant Professor rank and limited years since his PhD degree, Scott has rocketed forward to become a global leader in isotope hydrology. He has shaken the foundations of the global hydrology community with his 2012 Nature paper on transpiration component of total ET (for which, AGU awarded him the Horton Research Grant for best PhD proposal in hydrology). That paper ushered in a fundamentally new way to come at the calculation of the global water balance; a 2015 paper in Nature showing widespread occurrence of ecohydrological separation whereby plants use water not seen in streamflow; a paper two weeks ago in Nature (Geoscience) on global groundwater ages (featured prominently on CBC and other national news outlets), and now, this week, the acceptance of yet another Nature (Geosciences) paper on global streamflow and the role of young water. I know of few people in hydrology, at any career stage, making this sort of impact. Of course, these high profile papers are in addition to his many important disciplinary papers focused mechanisms and processes to back-up his global scale assessments (e.g. his WRR paper last year on the pronounced seasonality of groundwater recharge—stunning work and itself gaining significant citation). All this work maps clearly to his overarching research question concerning the global hydrologic cycle.

His MSc advisor, John Gibson from the University of Victoria notes in his support letter that “the impact of Scott’s work places him among the leaders in his field. His work is influential”. William Schlesinger, James B. Duke Professor of Biogeochemistry (Emeritus) and member of the US National Academy of Sciences and former President of the Ecological

Society of America states “The impact of Scott’s work far exceeds that of other young scientists and places him among the leaders in his field. His work is influential”. Finally, Jim Kirchner, Professor at ETH Zurich and former Director of WSL states that “Scott is one of the most promising isotope hydrologists of his generation.”

Others have recognized Scott’s research excellence. Only one year out of his PhD, he’s been invited to the world’s top universities to give talks—Stanford; Rutgers, UC London, University of Arizona and University of Washington. The upcoming AGU Chapman Conference on Tropical Ecohydrology in Cuenca, Ecuador will feature Scott as one of only 6 or so speakers at the meeting. This is remarkable as Scott’s many papers focus on ice age water, cold regions processes! Yet, his work cuts across all environments; all scales; all environmental disciplines. Scott is practicing interdisciplinary science at the very highest level and these esteem indicators certainly back this up.

Remarkably, with all this success and attention, Scott remains incredibly humble and grounded. He is a selfless giver of time to shortcourses (here in Saskatoon and in the Caribbean) where he has helped countless students in the developing world. His social media presence is aimed squarely at poverty reduction through water research. His PhD advisor, Zackary Sharp notes in his support letter that “(Scott) is truly passionate about water and humanity. He is in this line of work because he cares about our planet and wants to help find solutions. He is keenly aware of water shortages and unsafe drinking water and wants to combine his scientific expertise with policy in order to make things better”.

In short, Scott Jasechko is an exceptionally collegial, self-effacing and simply delightful and inspiring colleague. Canada can celebrate this brain-gain and this CGU award is an early acknowledgement of his tremendous contribution as he continues to propel forward at the University of Calgary. He is indeed, a rare Canadian who exhibits a rare level of accomplishment in Canadian hydrology.

Acceptance by Scott Jasechko, University of Calgary

Thank you to Claire Samson and Gordon Young for your leadership and care for this vital organization and the community that it brings together. Thank you to Kristy Tiampo and all who devoted their time to the CGU Awards Committee.

I am deeply grateful to Jeffrey McDonnell, Tom Edwards, Peter Fawcett, John Gibson, Tom Gleeson, Jim Kirchner and Zachary Sharp for your guidance and support. You challenged me and showed me how to succeed. Thank you. I hope that I can create similar opportunities for others, the same way that each of you has for me.

The CGU is vital to research and to discovery in Canada and internationally. This community is a welcoming home of discovery for so many. It is an all-important platform for early career scientists to present hard-earned results and to cheer on research completed by colleagues.

I am deeply grateful to receive this award. I look forward to doing my best to contributing to the work ethic, support and camaraderie of the Canadian Geophysical Union community for years to come.

– **Scott Jasechko, 2016 CGU Young Scientist**

Stan Paterson Scholarship in Canadian Glaciology
Laura Thomson, University of Ottawa

The **Stan Paterson Scholarship in Canadian Glaciology** honours Dr. Stan Paterson (May 20, 1924 – October 8, 2013), a preeminent Canadian Glaciologist who worked extensively on glaciers in the Canadian High Arctic and Rocky Mountains and authored the classic textbook *The Physics of Glaciers*, now in its fourth edition.

The scholarship is made possible by an endowment from Stan Paterson, and is valued at $2,500. The application deadline is December 1st of the year prior to the annual meeting of the CGU.

Laura Thomson, 2016 recipient, with Dr. Claire Samson, CGU President

Don Gray Scholarship in Canadian Hydrology
Igor Pavlovskii, University of Calgary

The **Don Gray Scholarship in Canadian Hydrology** is a $2,500 scholarship made possible by a donation from the Gray family, and is awarded at the annual meeting of the CGU.

All doctoral candidates studying in the broad field of hydrology at a Canadian University are eligible. Applicants must be registered in a full-time, thesis-based doctoral program, and be within their first 24 months of study at the time of application, by December 1st of the year prior to the annual meeting of the CGU.

D.M. (Don) Gray (1929-2005) is known as the 'father of Canadian hydrology,' who chaired the Division of Hydrology at the University of Saskatchewan from 1965 to 2001. He mentored over 68 graduate students and produced over 132 publications. Don was instrumental in forming the **CGU Hydrology Section** in 1993.

Igor Pavlovskii, 2016 recipient

CGU Best Student Paper Awards - 2016

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

Kelly Biagi, McMaster University

"Understanding the hydrochemical evolution and patterns of a constructed wetland in the Athabasca oil sands region, Canada"

Shell Outstanding Student Poster Paper

Katelyn Lutes, University of Waterloo

"Biofuel production using willow (Salix spp.): influence of nitrogen fertilizer on soil CO_2 and N_2O emissions"

Chevron Canada Outstanding Student Paper in Seismology

Mitch Grace, University of New Brunswick

"Imaging Sediment Thickness and Stratigraphy Beneath the Mactaquac Headpond by Acoustic Sub-bottom Imaging"

Mitch Grace (left), Claire Samson (CGU President)

CGU Best Student Paper Awards - 2016

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

Ryan Connon

Wilfrid Laurier University

"Active layer and talik dynamics of a permafrost cored peat plateau"

Campbell Scientific Award for Best Student Poster in Hydrology

Behrad Gharedaghloo

University of Waterloo

"Micro-scale characterization of peat hydraulic properties using pore network modeling and X-RAY computed tomography"

Daniel Peters (CGU Hydrology Section President, left), Behrad Gharedaghloo, Claire Samson (CGU President , right)

Best Student Paper in Geodesy Award

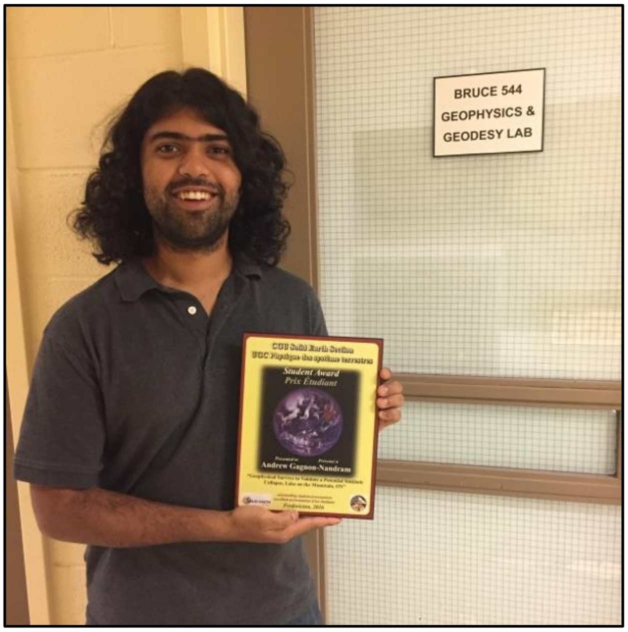
Ismael Foroughi

University of New Brunswick

"Harmonic downward continuation of scattered point gravity anomalies to mean anomalies on a mesh on the geoid"

Joe Henton (CGU Geodesy Section President, left), Ismael Foroughi, Claire Samson (CGU President , right)

CGU Best Student Paper Awards - 2016



Solid Earth Section Best Student Paper Award

Andrew Gagnon-Nandram
Queens University

"Geophysical surveys to validate a potential sinkhole collapse, Lake on the Mountain, ON."

Biogeosciences Best Student Paper Award

Kimberly Murray
University of Waterloo

"Controls on methane flux from a constructed fen in the Athabasca Oil Sands Region, Alberta"

Carl Mitchell (CGU Biogeosciences Section President, left), Kimberly Murray, Claire Samson (CGU President , right)

GOING TO VANCOUVER? GO FOR STUDENT BEST PAPER AWARDS!

Now is the time to prepare and submit your extended abstracts for student paper awards at the **CGU-CSAFM Joint Annual Scientific Meeting in Vancouver.** See the **CGU - UGC website** for details.

CGU Best Student Paper (all fields of geophysics – oral presentation) 2016

Kelly Biagi, McMaster University

Understanding the hydrochemical evolution and patterns of a constructed wetland in the Athabasca oil sands region, Canada.

Biagi, K.[1*], Oswald, C.[2], Carey, S. K.[1] & Nicholls, E.[1]
[1]School of Geography and Earth Sciences, McMaster University. [2]Department of Geography, Ryerson University.
*Corresponding Author - Phone: 905-902-6362, Email: biagikm@mcmaster.ca

Abstract

Bitumen extraction in the Athabasca oil sands causes significant landscape disturbance of wetland-forest ecosystems, which now require reclamation as required by Albert legislation. Although wetlands dominated the pre-disturbance landscape, reclamation has largely focused on upland-forested ecosystems. Syncrude Canada Ltd. has constructed a unique 52 hectare upland-wetland system, the Sandhill Fen Watershed (SFW), which is a highly managed system. A pump/drain system was installed during construction to provide freshwater and inhibit salinization from the underlying waste materials which are characterized by elevated electrical conductivity (EC) and Na^+ and Cl^- concentrations. *The objective of this research is to understand the evolution and hydrochemical responses of the SFW three years post construction by examining variations in the sources, flow pathways and major chemical transformations of water within the SFW.* EC, major ions and stable isotopes were collected using a combination of high frequency and discrete surface and pore water sampling from 2013-2015. Results indicate that the high activity of both inflow and outflow pumps in 2013 kept the overall EC relatively low, with most wetland sites <1000 µS/cm. Most water classified as Ca-HCO_3 or Ca-SO_4 in 2013 with Na^+ concentrations <250 mg/L. With limited pump activity in 2014 and 2015, the overall EC and ion concentrations increased considerably with many sites in the wetland exceeding 1000 µS/cm. Although most sites classified as Ca-SO_4, the most notable change was the presence of several Na^+ "hotspots" in SFW, where water classified as Na-SO_4 and Na^+ concentrations reached as high as 886 mg/L. These results provide evidence of upward movement of Na^+ from the underlying waste materials and subsequent seepage into these "hotspots" with limited pump activity. Pumps remained mostly inactive throughout 2015 and data show a continued increase in EC (850-5500 µS/cm) and ion concentrations where Na^+ "hotspots" are more pronounced.

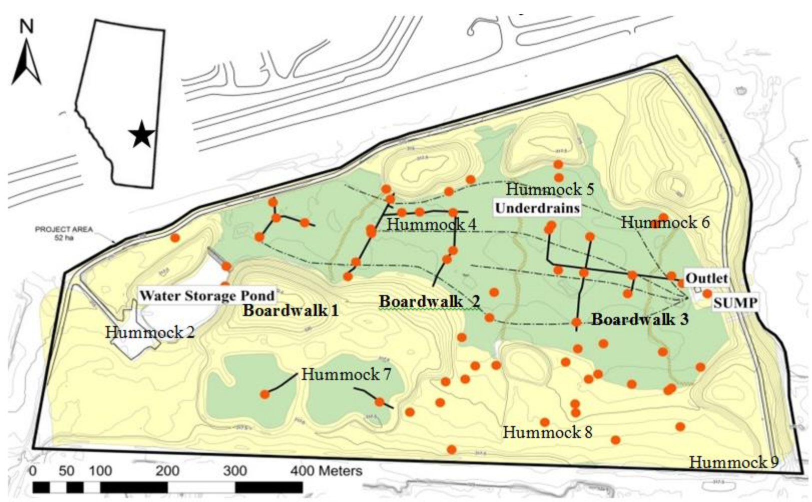


Figure 1. Design of SFW. Dashed lines represent underdrains. Coloured dots represent surface & pore water sampling sites.

Introduction

The Peace River Oil Sands, the Athabasca Oil Sands and the Cold Lake Oil Sands in Alberta, Canada make up some of the world's largest oil sand deposits which cover ~140,200 km^2 of the province. Open-pit surface mining makes up the majority of bitumen extraction in the

Athabasca oil sands region (AOSR)[1], which has resulted in significant disturbance and permanent alteration of over 700 km^2 of Boreal forest and wetland ecosystems, as these landscape surfaces are completely removed. Although reclamation of these disturbed landscapes is required by Alberta legislation, much of the efforts to date have focused on forested ecosystems even though peat-forming wetlands dominated the pre-disturbance landscape. Wetland-peatland reclamation presents many challenges as they are complex ecosystems that take thousands of years to develop naturally[2], and in this region are susceptible to salinization[3,4]. Excessive salts are ubiquitous in the AOSR as a result of 1) natural marine shale sediments and saline aquifers that are disturbed and incorporated into reclamation material[5–7], 2) the use of caustic hot water in (NaOH) in bitumen recovery, and 3) the addition of gypsum ($CaSO_4$) to decrease the volume of fine tailings[8,9], all of which form a waste material referred to as composite tailings (CT) and oil sands process water (OSPW), which is characterized by elevated electrical conductivity (EC) and salts. Most of the concern surrounding the CT and OSPW is the high concentrations of Na^+ due to its occurrence in reclamation materials and consequent negative ecological effects[10].

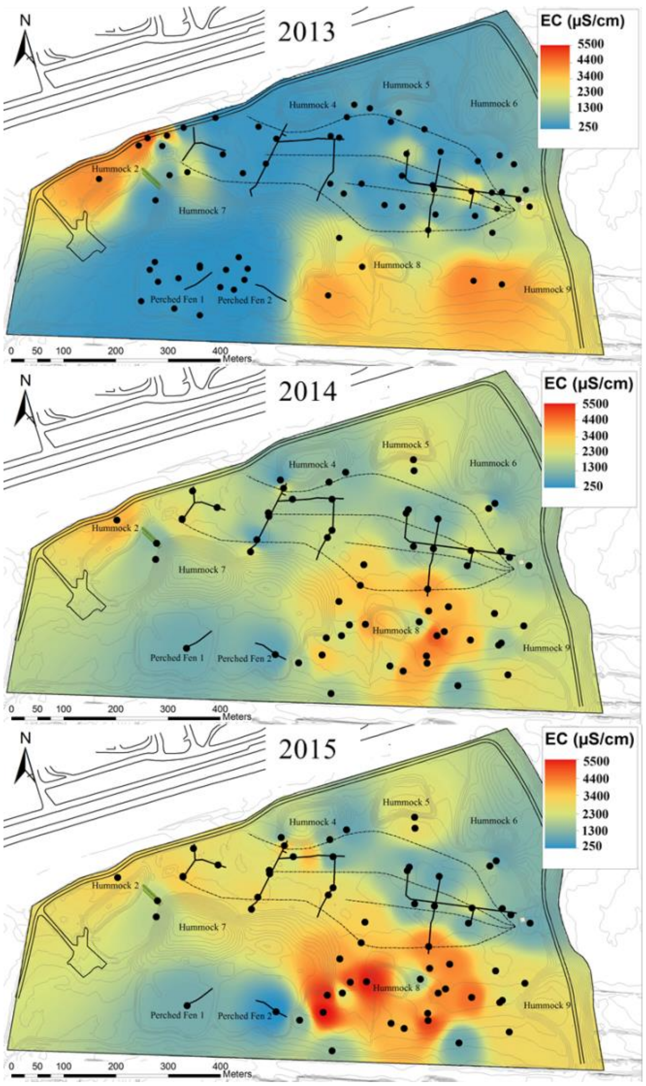


Figure 2. EC (µS/cm) patterns from 2013 - 2015.

Wetland-peatland reclamation in the AOSR will involve the complete reconstruction of these systems with no benchmarks or previous knowledge of such methods in this region. Wetlands have been identified as keystone ecosystems within the region due to the variety of ecosystem function they provide[11] such as water storage and transmission[12], peat formation, carbon storage[13], nutrient transport and biodiversity. Not only will constructed wetlands have to mimic these important functions, but will also have to limit salinization from the underlying waste materials. Syncrude Canada Limited (SCL) and Suncor Energy are the first companies to attempt wetland-peatland creation within the AOSR, which vary considerably in design[14,15]. The focus of this study is on the Sandhill Fen Watershed (SFW) constructed by SCL and aims to understand the evolution and hydrochemical responses of the SFW three years post construction by examining variations in the sources, flow pathways and major chemical transformations of water within the SFW.

Study Site

The SFW, located ~50 km north of Fort McMurray, is 52 ha and comprises of a 17 ha lowland-wetland area as well as a drier upland area with constructed hummocks (Figure 1). The SFW is underlain by 35 m of CT, followed by 10 m of tailings sand that acts as a structural cap, followed by 0.5 m of clay to provide mineral soil and attenuate upward migration of salts from the CT layer and lastly, 0.5 m of peat material to provide organic soil, both of which were only placed in the lowlands. The hummocks are constructed of tailings sand and topped with 0.1 – 0.5 m of

Pleistocene fluvial sand (Pf Sand). The SFW is a highly managed system and has four important engineered components that were installed largely in part to limit salinization from the underlying waste[15]: the water storage pond (WSP), underdrains, outlet pond (OP) and SUMP (Figure 1). In addition to precipitation, freshwater is supplied to the WSP from an artificial source (Mildred Lake Reservoir) which gradually flows east towards the OP where surface drainage is enhanced through a spillbox and weir in addition to the underdrain system that underlies the majority of the lowlands. When open, the underdrains induce a downward hydraulic gradient as well as transport any OSPW that has migrated upward from depth to the SUMP before it can interact at the surface. The SUMP collects the surface and near-surface water as well as the underdrain water, before it is collectively pumped out of the SFW[15].

Methods

Methodologically, this research focused on distributed and high frequency sampling of surface and near-surface water within the SFW. Distributed sampling included biweekly surface and pore water samples from >20 locations and were analyzed for major chemical ions as well as stable oxygen and hydrogen isotopes. Isotope data were supplemented with a previously developed Local Meteoric Water Line for SCL's Mildred Lake Base Mine as well as several site-side source waters[16]. In addition, continuous measurements of water level and EC were recorded with transducers at 10 well locations to map salinity variability in response to environmental changes. The critical difference to highlight between the summers of 2013, 2014 and 2015 is the variation in pump activity. In 2013, SFW was highly managed with frequent activity of the inflow and outflow pumps and open underdrains. In 2014 and 2015 both the inflow and outflow pumps were largely off and the underdrains closed, with the exception of a single ~56hr outflow pumping event in 2015.

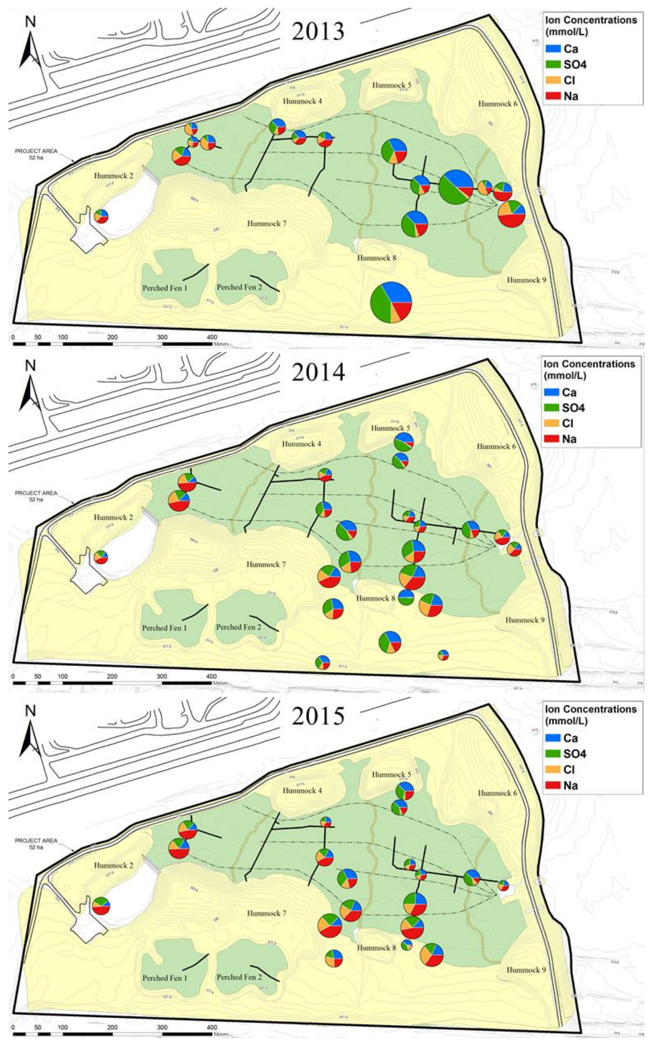


Figure 3. Major ion concentrations (mmol/L). Na^+ "hotspots" outlined in black.

Results

Pumping regimes varied substantially over the past three years, which resulted in notable differences in the hydrochemistry within the SFW. The SFW was highly managed in 2013, as total inflow and outflow amounted to ~809 mm and ~883 mm, respectively which exceeds the annual precipitation by almost two-fold. Data indicate that the combination of freshwater input, outflow flushing and open underdrains in 2013 kept overall EC within the SFW relatively low, with most lowland sites <1000 µS/cm (Figure 2). The uplands do not directly benefit from the freshwater input and had a higher EC than the lowlands. Major ion concentrations in general were lower in 2013 (Figure 3) and most water was classified as $Ca\text{-}HCO_3$ or $Ca\text{-}SO_4$ dominant. Na^+ and Cl^- concentrations were highest exclusively in the OP and SUMP reaching as high as 847 mg/L and

521 mg/L respectively. With minimal management in 2014 and consequently limited freshwater input (~14 mm) and outflow flushing (~17 mm), the overall salinity of the SFW increased considerably and EC at most sites in lowlands exceeded 1000 µS/cm. Na^+, Ca^{+2}, Cl^-, and SO_4^{-2} concentrations also increased at all sampling sites, with generally higher concentrations in the uplands. Most sites still classified as Ca-SO_4-dominant however, several Na^+ "hotspots" along the base of the southern hummocks (#2, 7 and 8) emerged (Figure 3), where water samples classified as Na-SO_4 dominant and had Na^+ and Cl^- concentrations as high as 886 mg/L and 672 mg/L, respectively. Unlike Na^+ and Cl^-, Ca^{+2} and SO_4^{-2} increased relatively consistently across the SFW with no "hotspots" of extreme increase. In addition to the high Na^+ and Cl^- concentrations, isotope data identified that water at the observed "hotspots" is sourced from the underlying CT and OSPW. Pumps remained inactive throughout 2015 with the exception of a single ~56 hr outflow pumping event equating to ~54 mm. EC continued to increase in 2015, where most sites in the lowlands exceeded 2000 µS/cm. Major ion concentrations also continued to increase throughout the SFW and "hotspots" remained pronounced (Figure 3), where Na^+ and Cl^- concentrations reached as high as 744 mg/L and 659mg/L respectively. The single pumping event in 2015 resulted in a slight EC decrease in the lowlands, while major ion concentrations remained relatively constant or slightly increased throughout the lowlands.

Discussion

The CT and OSPW that underlie the SFW create a strong concentration and salinity gradient with surface materials, providing the means for significant upward diffusion of salts[17]. However, with the combination of inflow supply of freshwater, open underdrains and frequent activity of outflow of SUMP water in 2013, the overall salinity was minimized as evident from the relatively low EC and ion concentrations across the SFW. This high degree of pump activity in 2013 resulted in a highly variable water table, EC and ion concentrations throughout the summer. The overall salinity and ion concentrations increased in 2014 and 2015 as a result of reduced pump activity and closure of the underdrains, which eliminated the induced downward hydraulic gradient. As a result, the SFW was not consistently flushed which enhanced the accumulation of ions and elevated EC. This limited pump activity in 2014 and 2015 resulted in a slow decline of the water table and a gradual increase in EC over the summer which is more similar to a natural wetland. Ion concentrations also continuously increased throughout the summer as a result of accumulation and evapo-concentration[3]. The appearance of the Na^+ "hotspots" in 2014 and continued presence in 2015, along with the isotope data provide evidence of upward transport of OSPW and subsequent seepage from the southern hummocks with a decrease in pump activity. Overall, OSPW likely diffuses upwards from the CT layer that underlies the SFW, which is then transported via advection as it moves horizontally in the tailings sand cap in the direction of groundwater flow (northeast). Once this water reaches the southern hummocks where the clay liner is absent, it seeps through the Pf sand at the base of the hummocks and consequently reaches the surface where salts are slowly transported via diffusion through the relatively stagnant surface waters. Additionally, the slightly elevated Na^+ concentrations in the lowlands in 2014 and 2015 may be a result of some slow diffusion of OSPW occurring through the clay layer and into the peat in the lowlands, as the induced downward hydraulic gradient was eliminated. Although a slight decrease in EC was observed in the lowlands as a result of the outflow pumping event in 2015, the duration of the event was insufficient to lower the EC across the SFW. Ion concentrations were also expected to decrease in response to pumping however, it was not enough to flush the system completely and a slight increase in Na^+, Ca^{+2}, Cl^- and SO_4^{-2} was observed which may be explained by advection of high ion concentrated waters from other areas such as boardwalk 1.

Conclusions

Current mining activities may continue for many decades as Alberta has over 170 billion barrels of proven oil reserves[18], and will therefore continue to produce significant quantities of CT and OSPW which will underlie reclaimed landscapes as a method of containment and storage. Improved understanding of the engineered watersheds within the oil sands region requires quantification of how and where water and chemicals move throughout the constructed landscape particularly because of the potential for contamination from the waste materials that underlie reclaimed ecosystems, particularly with respect to Na^+. Variations in pump activity had a strong control and influence on the hydrochemistry and source waters. With limited pump activity, "hotspots" of OSPW emerge at the border between the lowlands and the hummocks where the extent of the clay liner ends. Continual or increased prevalence of high Na^+ may be detrimental to the ecological success and may require more extensive pumping to limit salinization. In addition to results presented here, continued hydrological monitoring of the SFW will provide the building blocks for future wetland construction in the AOSR.

References

1. Government of Alberta. Oil Sands - The Resource. (2012). at <http://www.oilsands.alberta.ca/FactSheets/Resource_FSht_June_2012_Online.pdf>
2. Price, J. S., McLaren, R. G. & Rudolph, D. L. Landscape restoration after oil sands mining: conceptual design and hydrological modelling for fen reconstruction. *Int. J. Mining, Reclam. Environ.* **24,** 109–123 (2010).
3. Trites, M. & Bayley, S. E. Vegetation communities in continental boreal wetlands along a salinity gradient: Implications for oil sands mining reclamation. *Aquat. Bot.* **91,** 27–39 (2009).
4. Renault, S., Lait, C., Zwiazek, J. MacKinnon, M. Effect of high salinity tailings waters produced from gypsum treatment of oil sands tailings on plants of the boreal forest. *Envl. Pol.* **102,** 177–184 (1998).
5. Kessler, S., Barbour, S. L., van Rees, K. C. J. & Dobchuk, B. S. Salinization of soil over saline-sodic overburden from the oil sands in Alberta. *Can. J. Soil Sci.* **90,** 637–647 (2010).
6. Leung, S. S., MacKinnon, M. D. & Smith, R. E. H. The ecological effects of naphthenic acids and salts on phytoplankton from the Athabasca oil sands region. *Aquat. Toxicol.* **62,** 11–26 (2003).
7. Lord, E. R. F. & Isaac, B. a. a. Geotechnical investigations of dredged overburden at the Syncrude oil sand mine in northern Alberta, Canada. *Can. Geotech. J.* **26,** 132–153 (1989).
8. Chalaturnyk, R. J., Scott, D. J. & Özüm, B. Management of Oil Sands Tailings. *Pet. Sci. Technol.* **20,** 1025–1046 (2002).
9. Matthews, J. G., Shaw, W. H., MacKinnon, M. D. & Cuddy, R. G. Development of Composite Tailings Technology at Syncrude. *Int. J. Surf. Mining, Reclam. Environ.* **16,** 24–39 (2002).
10. MacKinnon, M. D. & Boerger, H. Description of two treatment methods for detoxifying oil sands tailings pond water. *Water Qual. Res. J. Canada* **21,** 496–512 (1986).
11. Ferone, J. M. & Devito, K. J. Shallow groundwater-surface water interactions in pond-peatland complexes along a Boreal Plains topographic gradient. *J. Hydrol.* **292,** 75–95 (2004).
12. Devito, K., Mendoza, C. & Qualizza, C. *Conceptualizing water movement in the Boreal Plains. Implications for watershed reconstruction.* (2012).
13. Vitt, D. H. in *Boreal peatland ecosystems* 9–24 (2006).
14. Daly, C. *et al.* in *Restoration and Reclamation of Boreal Ecosystems: Attaining Sustainable Development* 179 – 198 (Cambridge University Press, 2012).
15. Wytrykush, Vitt, Mckenna & Vassov. in *Restoration and Reclamation of Boreal Ecosystems - Attaining Sustainable Development* 161–178 (Cambridge University Press, 2012).
16. Baer, T. J. An evaluation of the use of water isotopes to track water movement through oil sands closure landforms. (University of Saskatchewan, 2014).
17. Fraser, C., Roulet, N. & Lafleur, M. Groundwater flow patterns in a large peatland. *J. Hydrol.* **246,** 142–154 (2001).
18. Energy Resources Conservation Board. *Alberta's Energy Reserves 2007 & Supply/Demand* (2009).

Shell Outstanding Student Poster Paper 2016
Katelyn Lutes, University of Waterloo

Biofuel production using willow (Salix spp.): influence of nitrogen fertilizer on soil CO2 and N2O emissions

Lutes, Katelyn Oelbermann, Maren Thevathasan, Naresh V. Gordon, Andrew M.
University of Waterloo *klutes01@gmail.com*

Willow (Salix spp.) grown in short-rotation coppice systems on marginal lands, are an effective biofuel option to provide ecosystem services, including carbon (C) sequestration. Nitrogen (N) fertilizer application is a common management practice in these systems as it increases aboveground woody biomass production and maintains soil productivity. However, it also affects soil C and N transformations, which can lead to greater soil-derived CO2 and N2O emissions. The objective of this study was to examine the effect of N fertilizer addition on greenhouse gas emissions in short-rotation willow biomass plantations, and relate these findings to soil temperature, moisture and NH4+ and NO3- concentrations.Two willow clones [*S. miyabeana* (SX67), *S. dasyclados* (SV1)] were evaluated for CO2-C and N2O-N emissions, and soil chemical characteristics in a split-plot design with fertilized and unfertilized treatments in Guelph, Ontario. Mean CO2-C emissions from SV1 and SX67 ranged from 72 to 91 mg CO2-C m-2 h-1 in fertilized treatments, and from 63 to 105 mg CO2-C m-2 h-1 in unfertilized treatments, respectively. Carbon dioxide emissions were strongly affected by seasonal temperature and moisture variability and availability of soil organic C. Nitrous oxide emissions, and NO3- and NH4+ soil concentrations increased immediately following fertilizer application. Elevated N2O-N emissions persisted for approximately month. Mean N2O-N emissions from SV1 and SX67 from fertilized treatments ranged from 22 to 26 ?g N2O-N m-2 h-1 and was significantly higher than emissions from unfertilized treatments, which ranged from 16 to 17 ?g N2O-N m-2 h-1. There was no significant difference between N2O-N emissions from clones SV1 and SX67, and N2O-N emissions were weakly correlated to soil temperature and moisture. Results indicated that N2O emissions were more strongly affected by inorganic N fertilizer application than fluctuations in soil moisture and temperature associated with seasonal changes.

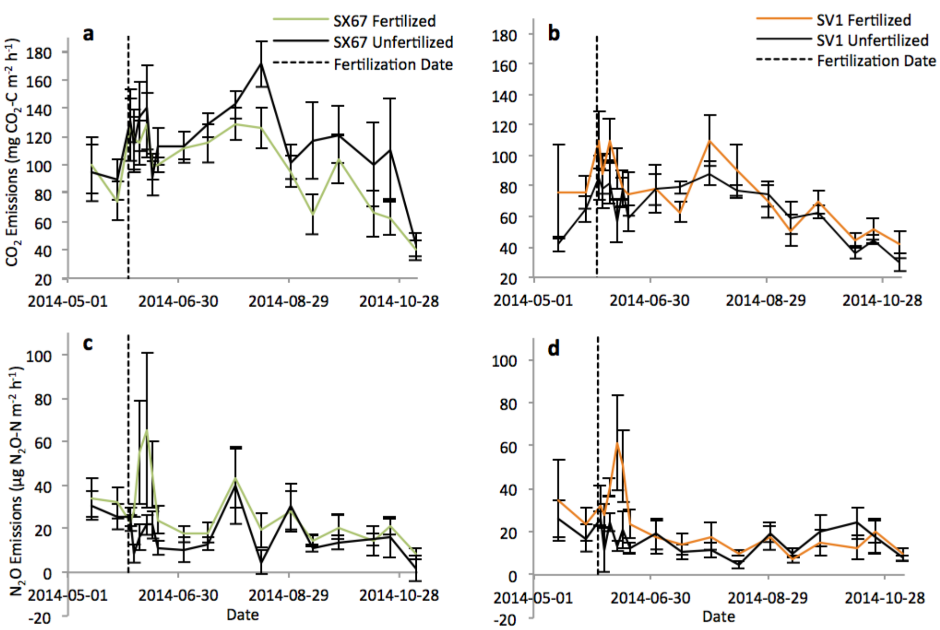


Figure Carbon dioxide emissions (CO_2-C m^{-2} h^{-1}) from willow clones Salix miyabeana [SX67] (**a**) and S. dasycloados [SV1] (**b**), and N_2O emissions (N_2O-N m^{-2} h^{-1}) from clone SX67 (**c**) and SV1 (**d**) from fertilized and unfertilized willow biomass plantations in Guelph, Ontario

D.M. Gray Award: Best Student Paper in Hydrology (oral presentation) 2016
Ryan Connon, Wilfrid Laurier University

Active layer and talik dynamics of a permafrost cored peat plateau

RF Connon1*, É Devoie2 & WL Quinton1
1 Cold Regions Research Centre, Wilfrid Laurier University, 75 University Ave W Waterloo, ON
*Corresponding Author: rconnon@wlu.ca
2 Department of Civil and Environmental Engineering, University of Waterloo, 200 University Ave W Waterloo, ON

Abstract:

The presence of a talik (perennially thawed feature in a permafrost environment) below the active layer (ground that freezes and thaws annually) has important hydrologic and thermal implications as taliks can provide an active flowpath throughout the year. As taliks do not freeze over winter, they should be distinguished separately from the active layer. In areas of discontinuous permafrost where taliks are prevalent, measuring end of season thaw depth should not be considered a proxy for active layer thickness. At a site in the southern Northwest Territories, Canada, we measured active layer thickness and talik thickness across an ice-cored peat plateau in 2015 and 2016. In both years the average thickness of the active layer was 35 cm and 41 cm respectively, whereas talik thickness was 80 cm and 99 cm. The talik extended the entire width of the plateau and provides a year-round hydrological connection between a flat bog and a channel fen. The presence of a talik will increase the rate of permafrost thaw as it allows for greater advection of energy through this feature. As the active layer thaws in the spring, a two-layered flow system develops as snowmelt water flows over the frozen portion of the active layer of plateaus into adjacent wetlands, and stored water from the plateau is also routed through the unfrozen, saturated talik. This two-layered system continues until the entire active layer thaws. Flow through the talik is limited by the low hydraulic conductivity of deep peat (~ 3.5 m day-1), but as it persists throughout the year it amounts to ~10% of total runoff from the plateau.

Introduction:

The active layer, defined as the 'top layer of ground subject to annual thawing and freezing in areas underlain by permafrost' (ACGR, 1988), is conceptualized as the layer of soil where most hydrological processes occur. Runoff typically occurs in the thawed portion of the active layer, above the underlying frozen ground (Carey and Woo, 1999; Wright et al., 2008) as the saturated hydraulic conductivity of unfrozen soil is orders of magnitude higher than frozen soil. As the majority of hydrological processes occur within the active layer, changes in active layer thickness will have important hydrological consequences, and thus should be monitored (see Brown et al., 2008).

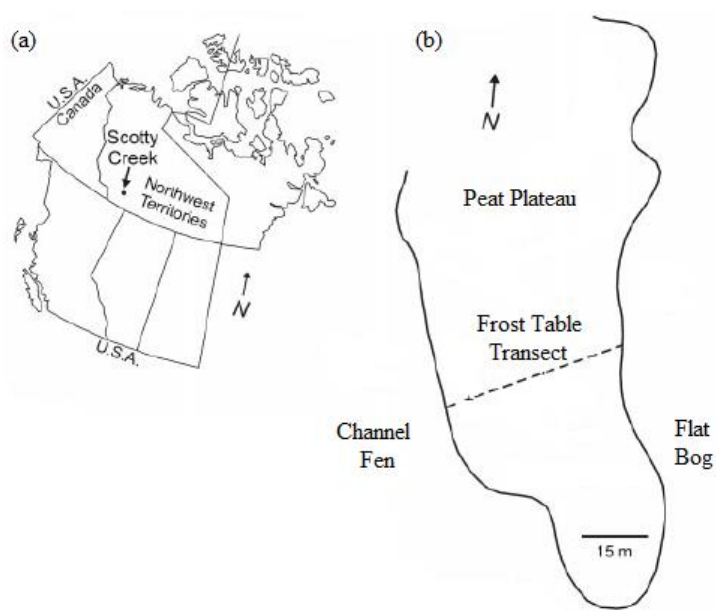


Figure 1: (a) Location of SCRB; (b) planar view of study plateau. Modified from Wright *et al*. (2008)

In areas of ice-rich permafrost, a large amount of energy is required to satisfy latent heat requirements to thaw the frozen active layer. Conversely, the ground must also lose an equivalent amount of energy to re-freeze the active layer over winter. The amount of energy the ground loses over-winter is controlled primarily by the timing and magnitude of snowfall, as snow is a very effective thermal insulator (Williams and Smith, 1989). The thickness of the active layer is thus governed by whichever process (thawing or freezing) is least able to penetrate the ground. In areas of continuous permafrost, seasonally thawed ground typically refreezes entirely, and consequently, the maximum thaw depth defines the active layer thickness. However, in areas where the mean annual temperature approaches 0°C, it is necessary to measure both freezing and thawing depths when determining active layer thickness. If insufficient energy is lost over winter such that a complete refreezing of the active layer does not occur, a talik forms between the active layer and the underlying permafrost. Depending on soil moisture conditions and water table location, this layer may or may not be saturated. A series of consecutive warm summers and/or winters may allow the talik to grow to a thickness such that complete refreezing of the soil above permafrost may not be possible over one winter.

Accordingly, we caution that measurements of maximum (i.e. end of summer) thaw depth should not be taken as the active layer thickness. The Circumpolar Active Layer Monitoring (CALM) program protocol states that active layer thickness can be measured by 'late-season mechanical probing' of the ground (Brown et al., 2008, p. 169). This incorrectly assumes that the entire depth of ground above permafrost completely refreezes over winter, an assumption that yields errors in energy balance calculations, particularly concerning phase changes. This assumption also incorrectly implies that hydrological processes are relatively dormant for a period of time when the ground is assumed to be entirely frozen and does not account for the possibility of a talik. Unfortunately, the freezing depth is much more difficult to measure than the thaw depth, and as such it is rarely reported.

When S.W. Muller (1947) first presented the term 'active layer', he also proposed that the term 'suprapermafrost layer' be used to describe the 'combined thickness of ground above the permafrost consisting of the active layer and talik' (Muller, 1947 p. 11). We recommend that the term 'suprapermafrost layer thickness' be used in place of 'active layer thickness' when depth to permafrost table measurements are taken at the end of the thaw season, but not corroborated with measurements of the maximum penetration of the freezing front.

Permafrost cored features such as peat plateaus are typically thought to inhibit the transmission of subsurface water beneath the thawed portion of the active layer due to the very low hydraulic conductivity of frozen, saturated peat. The current conceptual understanding of hillslope runoff from these plateaus is that runoff only occurs in the thawed portion of the active layer (Wright et al., 2008). The presence of a talik may provide an additional runoff pathway on hillslopes and allow for the transmission of water between wetlands throughout the year. The objectives of this study are two-fold: 1) to document the hydrological function of a perennially-thawed talik; and 2) to show that the thickness of the active layer at our study site is governed by the depth of re-freeze over winter and not by the maximum summer thaw depth.

Study Site:

The study was conducted at the Scotty Creek Research Basin (SCRB), located about 50 km south of Fort Simpson, NT (Figure 1a). The study site is dominated by thick peat deposits (>2 m) overlying a clay rich glacial till of low hydraulic conductivity. Permafrost occupies ~40% of the basin and exclusively takes the form of treed peat plateaus that rise about 1m above surrounding wetlands (ch annel fens and flat bogs). The associated hydraulic gradient directs runoff from the plateaus and into the adjacent wetlands (Wright et al., 2008). Channel fens transmit water to the basin outlet (Hayashi et al., 2004), while flat bogs can either act as storage features or route water to the channel fens through a fill-and-spill process dependent on antecedent moisture conditions

(Connon et al., 2015). Ongoing data collection has been occurring since 1999 at a study plateau. The plateau is flanked by a channel fen on one side and a flat bog on the other (Figure 1b). Substantial lateral and vertical thawing of permafrost at the study plateau has been observed since monitoring began (Figure 2).

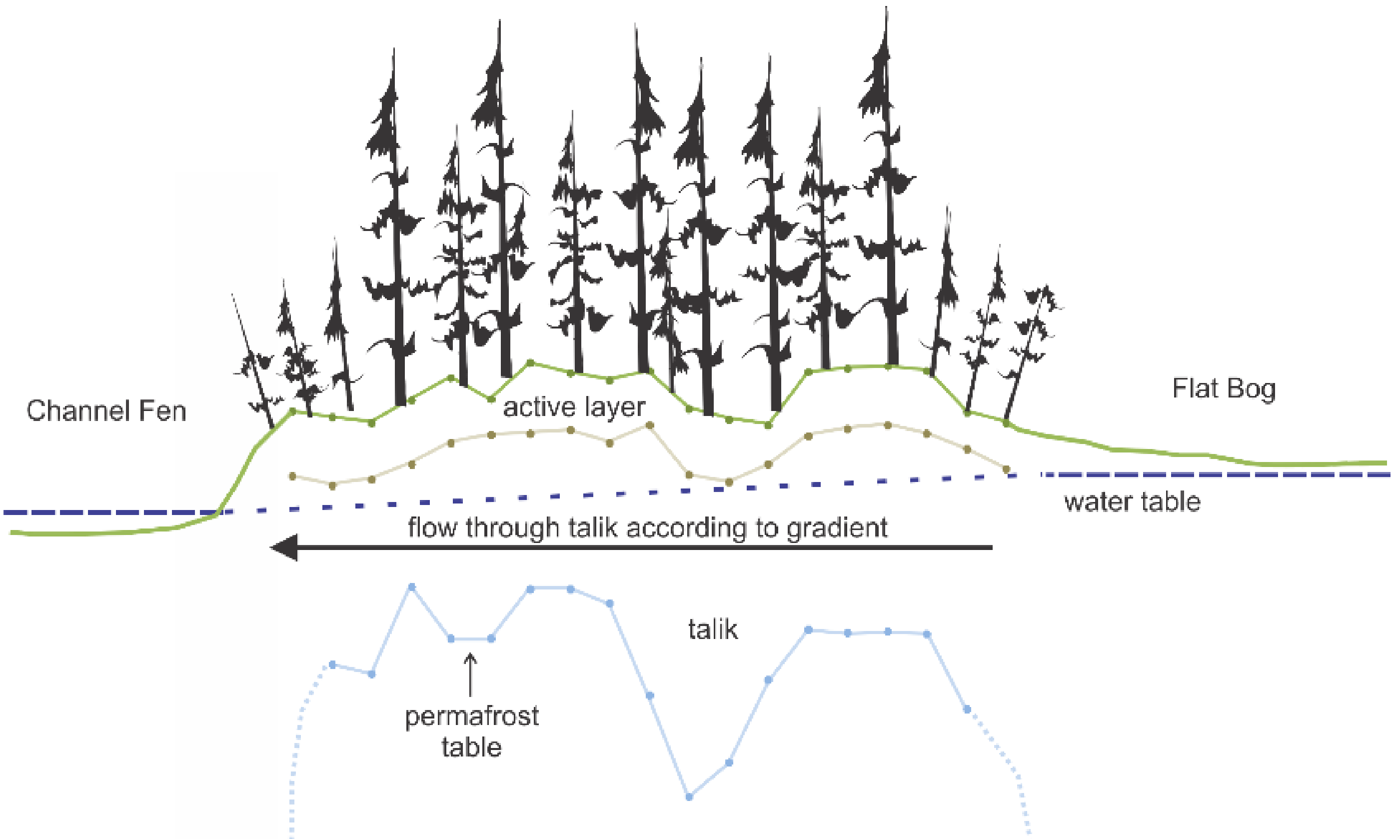


Figure 2: Cross section of study plateau indicating thickness of the active layer in and underlying talik. Each dot indicates measurement location. Data shown is from 2014/2015.

Methods:

End of summer (late August) measurements of permafrost table depth have been taken at the study plateau since 1999. These measurements have been taken annually along a transect at 1 m intervals, permitting 19 measurement points in 2014 and 2015. This allows for measurement of both lateral and vertical permafrost thaw. In 2015, weekly measurements of the depth to the frost table (top boundary of the frozen and saturated soil) were taken to quantify the progression of thaw. Typical downward progression of the frost table averages about 0.5-1 cm day-1. When a sudden increase (i.e. more than 30 cm) in depth to frost table was observed it was assumed that this was the boundary of seasonal re-freeze and that the measured frost table was now below a talik. In 2016, end of winter (early April) measurements of maximum re-freeze depth were taken by using a hand ice auger to drill through the frozen soil until the unfrozen talik was reached. The boundary between frozen and unfrozen soil was clear and this depth was measured and recorded as active layer thickness.

Thermistors and water content meters are installed at 10 cm increments in the soil to quantify temperature and liquid water content at different depths. Additionally, in 2016, the temperature of the talik was also measured using a handheld digital thermometer. Total pressure transducers were installed in the bog and fen adjacent to the plateau to calculate a hydraulic gradient between the two features. The hydraulic conductivity of the peat in the talik is assumed to be 3.5 m day-1 (Quinton et al., 2008, M. Braverman unpublished data). Although there was only one transect, it is assumed that the talik thickness calculated on the transect is representative of the entire 75 m length of the plateau. Total flux through the plateau was then calculated using Darcy's law.

Results:

The average thaw depth measured at the end of summer was 115 cm in 2014 and 135 cm in 2015, while for the same points, the average refreeze depth was 35 cm in 2015 and 41 cm in 2016. In both years, the thaw depth was ~3 times greater than the depth of re-freeze, indicating a talik with a thickness of ~1 m (Fig. 2). The thickness of the talik and has increased each year since measurements began, while the width of the plateau has decreased as the permafrost core thaws laterally (Fig. 3). Ground thaw, driven by the vertical heat flux from the ground surface, is augmented by advection of energy via water moving from the bog to the fen. Both continuous and discrete temperature measurements indicate that the talik is isothermal at -0.2°C, the freezing point depression measured at this site (Quinton and Baltzer, 2013). Liquid volumetric soil moisture at 50 cm depth (deepest soil moisture sensor) was 0.8, indicating that the soil was fully saturated with liquid water throughout winter. The total flux of water draining through the talik and into the fen is 47 mm yr-1, accounting for about 10% of total average runoff (520 mm yr-1) from the plateau (data from Quinton and Baltzer, 2013).

Given the thickness of the talik, it is highly unlikely that enough energy could be removed from the suprapermafrost layer to freeze it entirely. Given current climate conditions in the study region, once a talik expands vertically to the point where complete refreezing in winter is no longer possible, thaw of the underlying permafrost is inevitable, owing to the presence of liquid water on the permafrost table throughout the year.

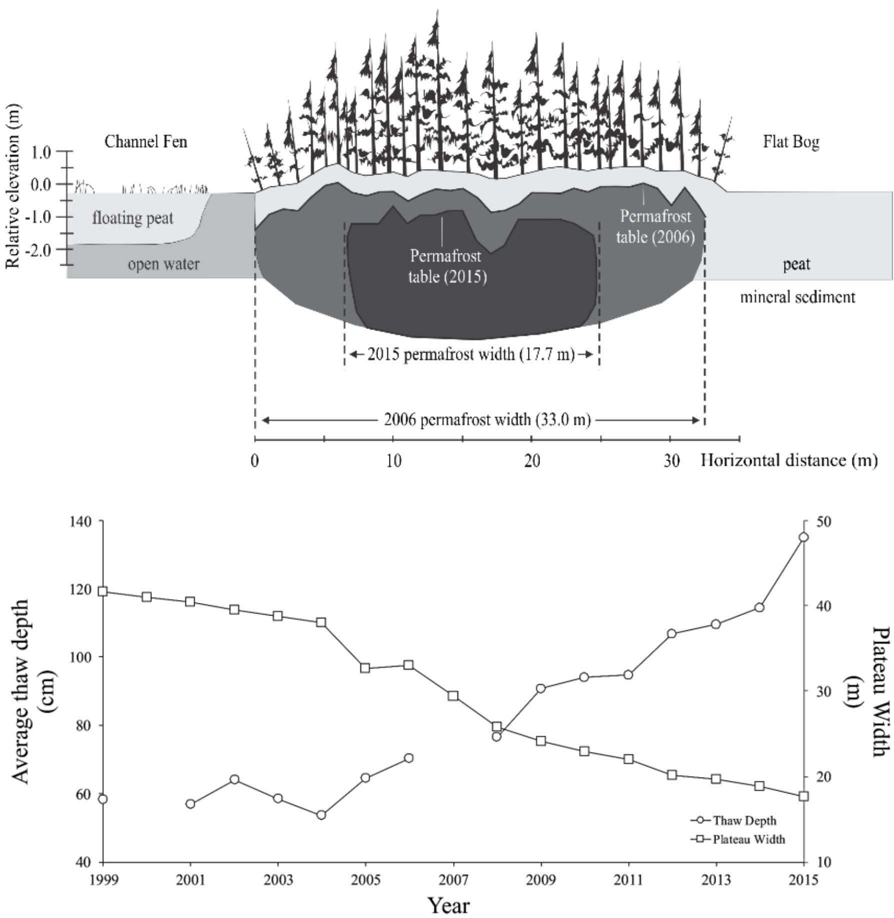


Figure 3: (a) Cross section of study plateau showing lateral and vertical thaw since 2006; (b) Changes in plateau width and thaw depth since 1999

Discussion:

Hillslope runoff from a permafrost cored peat plateau as first described by Wright et al. (2008) indicates that runoff is restricted to the thawed portion of the active layer. Combining the results of the current study with that of Wright et al. (2008) suggests a two-layered runoff system where both the talik and thawed portion of the active layer convey subsurface runoff. Although not the primary runoff mechanism, flow through the talik should not be excluded from runoff measurements. Using isotope tracers, Hayashi et al. (2008) found that less than half the runoff from the SCRB was derived from snowmelt (event) water. Other studies (i.e. Gibson et al., 1993; Carey et al., 2012) using isotope tracers have found similar results in discontinuous permafrost terrains. These studies found that 'old' water dominated the hydrographs; the presence of taliks would provide a flowpath allowing for this old water to reach the drainage network.

Many studies (i.e. Akerman and Johansson, 2008; Xue et al., 2008) have reported a trend of a thickening active layer in climates where the mean annual temperature is close to 0°C but do not report the depth of refreeze. It is important that researchers do not incorrectly assume that the thaw depth measured at the end of the thaw period is a measure of the thickness of the active layer. We show this assumption to be erroneous, and it is important to distinguish the thickness of the suprapermafrost layer and the thickness of the active layer if the suprapermafrost layer does not entirely re-freeze over winter. Therefore, researchers should be cognoscente of the fact that end of season thaw depths may not be indicative of active layer thickness (Muller, 1947; ACGR, 1988), especially in areas of discontinuous and sporadic permafrost.

We suggest that climate warming leads not to active layer thickening as commonly discussed in the literature, but to active layer thinning, considering that the largest temperature increases in Canada's North have occurred over winter (Vincent et al., 2015). A thinner active layer would allow for more rapid thawing of the underlying permafrost, as thawing of the active layer would be completed earlier in the season, permitting more energy to penetrate through to the permafrost. These processes must be properly conceptualized and parameterized in order to better understand and predict the response of such systems to climate warming.

Permafrost thaw is very rapid in the zone of discontinuous permafrost (Kwong and Gan, 1994; Quinton et al., 2011) where permafrost is thin (<10m), relatively warm (>-1.5°C), and subject to both lateral and vertical thaw. Permafrost thaw changes the routing and storage of water within a basin (St. Jacques and Sauchyn, 2009; Connon et al., 2014). If a thinner active layer facilitates more rapid permafrost thaw, the coupled hydrological changes will also occur more rapidly than expected. It is important to identify the point at which thinning of the active layer may be expected, as this would indicate a threshold at which permafrost thaw will become more rapid.

Conclusions:

In permafrost regions where taliks have developed, active layer thickness should be measured by the maximum extent of the freezing front, not by the thaw depth at the end of summer. In these areas, a thinning of the active layer is predicted in response to a warming climate. We propose that the term 'suprapermafrost layer' originally suggested by Muller (1947) be reincorporated into the current nomenclature to refer to the end of summer thaw depths when re-freeze depths are not known. The presence of a talik provides an additional flowpath that can transport water to the drainage network year-round. Taliks also allow for lateral advection of energy, providing an additional energy source that may thaw underlying permafrost, and as such should be documented and included in runoff measurements and models to accurately represent the system.

References:

Akerman, J., Johansson, M. 2008. 'Thawing permafrost and thicker active layers in sub-arctic Sweden'. Permafrost and Periglac. Process. 19, 279-292.

Associate Committee on Geotechnical Research (ACGR). 1988. 'Glossary of Permafrost and Related Ground-Ice Terms'..National Reasearch Council of Canada, Associate Committee on Gentechnial Research, TM: 142

Brown, J., Hinkel, K, Nelson F. 2008. 'The circumpolar active layer monitoring (calm) program: Research designs and initial results'. Polar Geography. 24:3, 166-258.

Carey, S., Woo, M. 1999. ‘Hydrology of two slopes in subarctic Yukon, Canada’. Hydrol. Process. 13, 2549-2562

Carey, S., Boucher, J., Duarte, C. 2012. Inferring groundwater contributions and pathways to streamflow during snowmelt over multiple years in a discontinuous permafrost subarctic environment. Hydrogeo. J. 21, 67-77.

Connon, R., Quinton, W, Craig, J., Hayashi, M. 2014. ‘Changing hydrologic connectivity due to permafrost thaw in the lower Liard River valley, NWT, Canada’. Hydrol. Process. 28, 4163-4178.

Connon, R., Quinton, W., Craig, J., Hanisch, J., Sonnentag, O. 2015. ‘The hydrology of interconnected bog complexes in discontinuous permafrost terrains’. Hydrol. Process. 29, 3831-3847

Gibson, J., Edwards, T, Prowse, T. 1993. ‘Runoff generation in a high boreal wetland in northern Canada’. Nordic Hydrology. 24, 213-224.

Hayashi, M., Quinton, W., Pietroniro, A., Gibson, J. 2004. ‘Hydrologic functions of wetlands in a discontinuous permafrost basin indicated by isotopic and chemical signatures’. J. Hydrol. 296, 81-97

Kwong, J., Gan T. 1994. ‘Northward migration of permafrost along the Mackenzie highway and climatic warming’. Climatic Change. 26, 399-419

Muller, S. 1947. Permafrost or permanently frozen ground and related engineering problems. Edwards, Ann Arbor, p. 231.

Quinton, W., Hayashi, M., Carey, S. 2008. ‘Pore hydraulic conductivity in cold regions and its relation to pore size geometry’. Hydrol Process. 22, 2829-2837.

Quinton, W., Hayashi, M., Chasmer, L. 2011. ‘Permafrost-thaw induced land-cover change in the Canadian subarctic: implications for water resources’. Hydrol. Process. 25, 152-158.

Quinton, W, Baltzer, J. 2012. ‘The active-layer hydrology of a peat plateau with thawing permafrost (Scotty Creek, Canada)’. Hydrogeo. J. 21, 201-220.

St. Jacques, JM., Sauchyn, D. 2009. ‘Increasing winter baseflow and mean annual streamflow from possible permafrost thawing in the Northwest Territories, Canada’. J. Geophys. Res. 36, L01401.

Vincent, L., Zhang, X., Brown, R., Feng, Y., Mekis, E., Milewska, E., Wan, H., Wang, X. 2015. Observed trends in Canada’s climate and influence of low-frequency variability modes. Journal of Climate. 28, 4545-4560

Williams, P., Smith M. 1989. The frozen earth: Fundamentals of geocryology, Cambridge University Press, Cambridge, p.306.

Wright, N., Quinton, W., Hayashi, M. 2008. ‘Hillslope runoff from an ice-cored peat plateau in a discontinuous permafrost basin, Northwest Territories, Canada’. Hydrol. Process. 22, 2816-2828.

Xue, X., Guo, J., Han, B., Sun, Q., Liu, L. 2008. ‘The effect of climate warming and permafrost thaw on desertification in the Qinghai-Tibetan Plateau. Geomorphology. 108, 182-190.

Chevron Canada Outstanding Student Paper in Seismology
Mitch Grace, University of New Brunswick

Imaging Sediment Thickness and Stratigraphy Beneath the Mactaquac Headpond by Acoustic Sub-bottom Imaging

Grace, Mitch; Butler, Karl; Simpkin, Peter; Yamazaki, Gordon
Department of Earth Sciences, University of New Brunswick, Fredericton, NB
mitch.grace@unb.ca

The Mactaquac Hydroelectric Generating Station, located on the Saint John River in New Brunswick, Canada, is reaching the end of its life due to deterioration of the concrete structures. As part of the Mactaquac Aquatic Ecosystem Study, designed to inform a decision on the future of the dam, sediment in the headpond is being examined. The focus of this sub-study lies in (i)

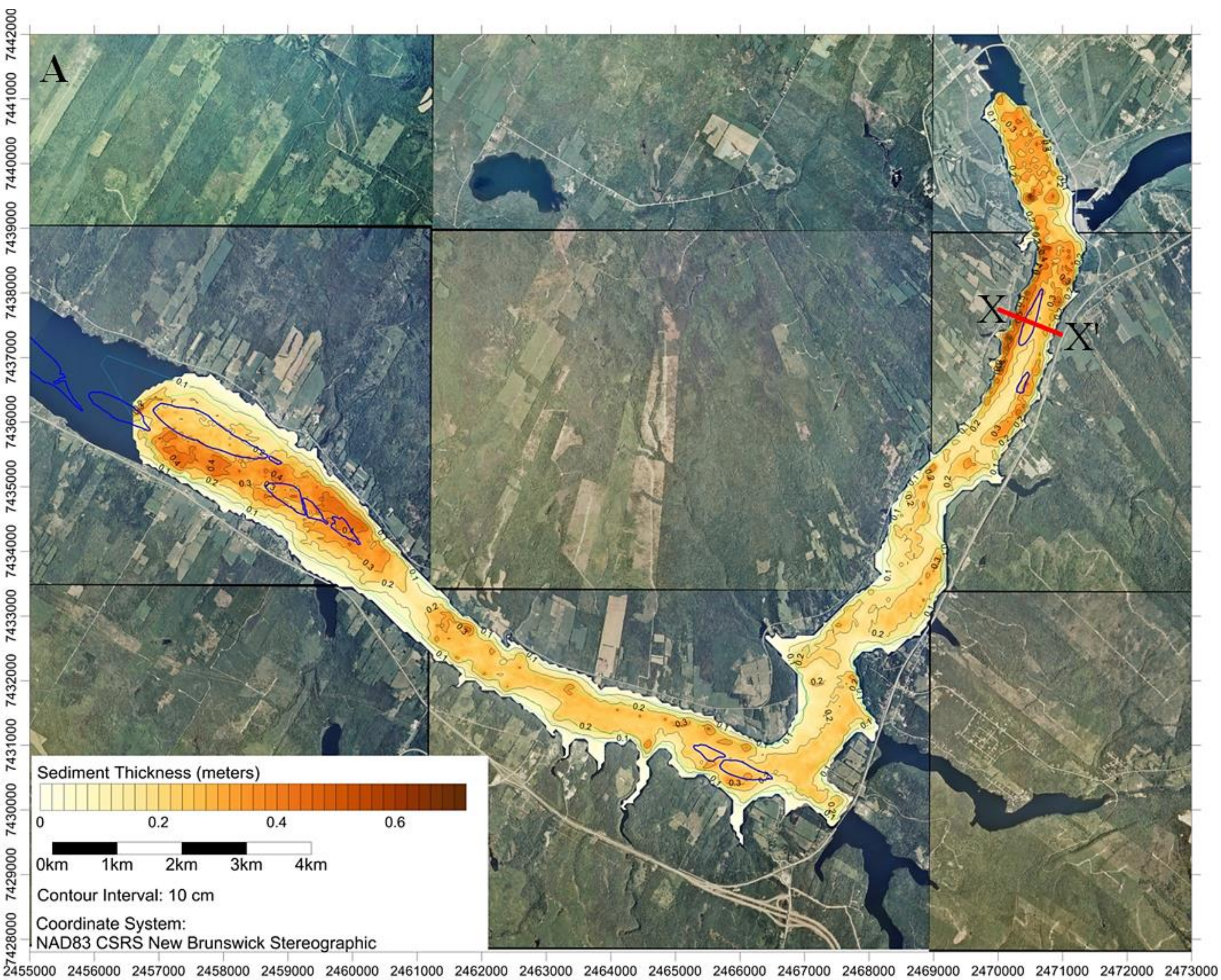


Figure A Map of post-inundation sediment thickness between Mactaquac and Bear Island. Seistec profile X – X' location is indicated and profile is shown in Figure B.

mapping the thickness of sediments that have accumulated since inundation in 1968, and (ii) imaging the deeper glacial and post-glacial stratigraphy.Acoustic sub-bottom profiling surveys were completed during the summers of 2014 and 2015. The initial 3.5 kHz chirp sonar survey proved ineffective, lacking in both resolution and depth of the penetration. A follow-up survey employing a surface towed catamaran supporting a boomer based Seistec high resolution sediment profiler provided better results, resolving sediment layers as thin as about 15 cm, and yielding coherent reflections from the deeper Holocene sediments.Post-inundation sediments in the lowermost 25 km of the headpond, between the dam and Bear Island, are interpreted to be less than 40 cm thick, except in a few areas. They appear to be thickest in deep water areas overlying the pre-inundation riverbed. In the ~15 km stretch from north of Bear Island to Nackawic, the presence of gas in the uppermost sediments severely limits sub-bottom penetration and our ability to interpret sediment thicknesses. Profiles acquired in the ~40 km reach from just north of Nackawic to Woodstock show a strong, positive water bottom reflection and little to no sub-bottom penetration, indication the absence of soft post-inundation sediment.

A recently completed coring program will aid in constraining sediment thickness estimates.Deeper reflections in profiles acquired between the dam and Bear Island reveal a buried channel extending up to 20 m below the water bottom with infill consisting of glacial to post-glacial sediments; these include a finely laminated unit interpreted to be clay-silt and a possible esker - similar to stratigraphy found 20 - 40 km downriver at Fredericton.

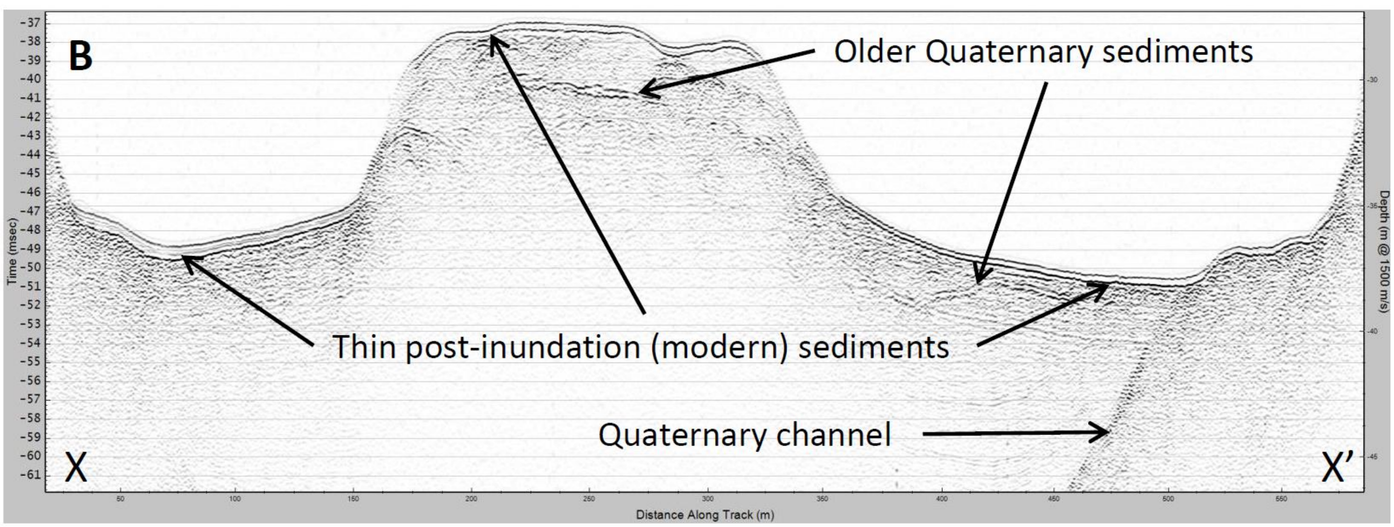


Figure B One of the Seistec profiles showing the variability in post-inundation sediment thickness across Snowshoe Island (line X – X' labeled in red on Figure A), as well as deeper reflections from the older (glacial and post-glacial) Quaternary stratigraphy beneath the river.

Campbell Scientific Award for Best Student Poster in Hydrology 2016
Behrad Gharedaghloo, University of Waterloo

Micro-scale characterization of peat hydraulic properties using pore network modeling and X-RAY computed tomography

Behrad Gharedaghloo1*, Fereidoun Rezanezhad2, Jonathan Price1
1-Department of Geography and Environmental Management, University of Waterloo, Waterloo, Canada
2-Department of Earth and Environmental Sciences, University of Waterloo, Waterloo, Canada
* Corresponding Author: Phone: 519-888-4567 ext. 35397, Email: bghareda@uwaterloo.ca

ABSTRACT

Peat soils have complex pore structures that contain open, dead-end pores and pores that are closed or partially closed. This distinct physical property influences the hydraulic properties (i.e., flow and transport) in peat. Despite widespread interest in micro-pore scale modeling of fluid flow and solute transport in different types of porous media, there are no similar studies on organic soils such as peat. In this study, we extracted pore network structures using the pore space information obtained from 3D X-ray computed tomography (CT) images of peat soil. The pore network information was used to simulate the hydraulic conductivity and solute transport properties of peat using a pore-network modeling approach. Horizontal and vertical hydraulic conductivity of peat and the anisotropy ratio were calculated. Numerical results showed that peat hydraulic conductivity drops 50 folds from 2 to 11 cm depth, comparable to results of previous studies conducted on the same peat. Solute transport simulations were done on the same networks using different pore velocities. Dispersivity was estimated to be ~3mm, comparable measured values in similar peat types. Single phase flow and solute transport results indicate that our micro-scale pore characterization of peat using pore network modeling is realistic. This

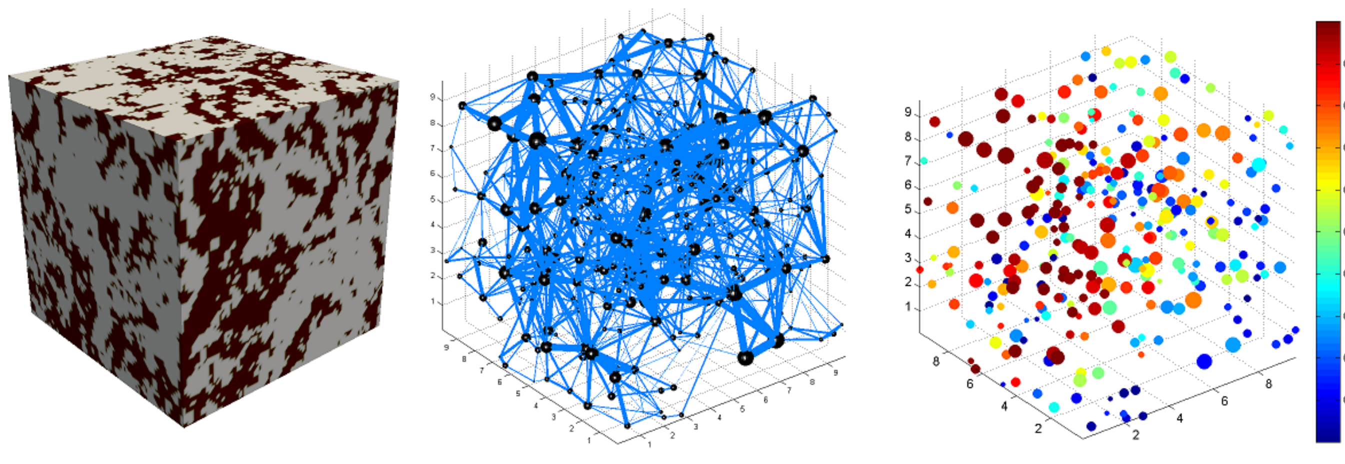


Figure 1: Left: 1x1x1cm micro CT imaging data for 2 cm depth peat -dark color and white color, respectively, represent matrix and pore space. Middle: equivalent pore-throat network obtained using network extraction code - black circles represent pores and blue cylinders are throats. Right: C/C_0 in individual pores after 1 pore volume of injection.

approach provides a tool to better understand how hydraulic conductivity and solute transport of peat soils are controlled by its pore size distribution and network structure.

INTRODUCTION

Pore scale numerical simulations of water saturated flow have been done in several studies in ordered and disordered lattices representing media including sandstones, carbonate rocks, etc. (Bakke & Øren, 1997). However this has not been done on organic soils such as peat. Pore network solute transport numerical simulations have also been successfully done on ordered lattices representing uniform pore spaces such as Berea sand or glass beads (Bijeljic et al., 2004; Raoof & Hassanizadeh, 2013). However, no solute transport numerical simulation has been done using irregular shaped and disordered lattices. X-ray CT imaging techniques used to characterize the pore network of poorly decomposed Sphagnum dominated peat (Quinton et al., 2009; Rezanezhad et al., 2009; Rezanezhad et al., 2010), showed the reduction of hydraulic conductivity with depth was related to pore-size distribution. In this study, the same 3D CT X-ray images of peat were used to extract disordered lattices for flow and solute transport studies. The objective is to develop a numerical simulation model of flow and solute transport on the extracted lattices, to determine the variations of flow and solute transport properties with depth. This approach can answer questions not easily determined using experimental methods to measure flow and transport parameters. For example, it realistically represents the adsorption of solute onto peat pore surface, as well as its absorption into inactive pores and dead end spaces; estimates of dispersivity based on experimental measurements lumps these. This model provides a base for further understanding complex processes governing flow and transport in peat, such as how and why hydraulic conductivity changes due to peat decomposition or due to accumulation of biomass in pore spaces.

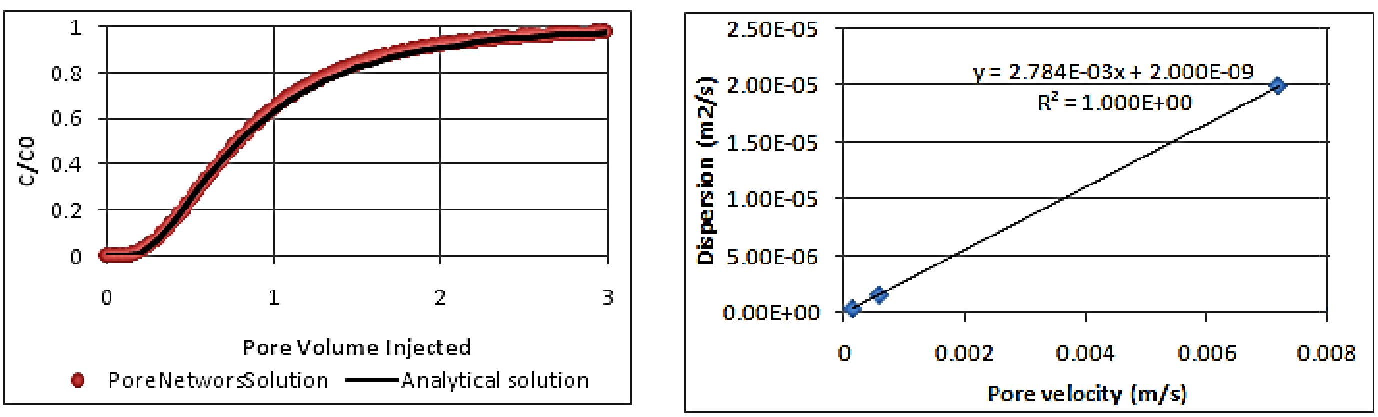


Figure 2: Left: Numerical solution and exact solution of solute transport through the pore network extracted for 2cm deep peat; Right: Variation of dispersion with pore velocity and obtained dispersivity value for the same network.

METHODOLOGY

Seven 3D cubes with a dimension of 1cm a side were cut from digitized micro CT data (Figure 1-left); from increasing depths ranging from 2 to 11 cm. The equivalent pore network lattice (Figure 1-middle) of the pore spacewas extracted for each cube using a well-known pore network extraction code (Dong & Blunt, 2009). The code uses micro CT data and reports the spatial distribution of pores, throats, their connectivity, shape, size, length, hydraulic radius and volume. Saturated water flow through each network was then simulated in both horizontal and vertical directions, resulting in estimates of horizontal (Kh) and vertical (Kv) hydraulic conductivities. To do this, the pore pressure was obtained by solving mass conservation at every pore within the network. A simplified form of the Navier-Stokes equation correlates pressure gradient and the flow rate in individual throats located between two pores. Knowing the flow rate and cube dimension, the hydraulic conductivity of peat was calculated (see Valvatne & Blunt, 2004 for details). The pore/throat shape and dimension information, along with the calculated flow rate data were then used to simulate unsteady-state solute transport through the peat pore network, for four selected depths. A numerical solution scheme (Qin & Hassanizadeh, 2015) was used to solve solute transport equations and to obtain the spatial and temporal variations of solute concentration within the network (Figure 1-right). Concentration of solute at the out-flowing stream is recorded as the solute breakthrough curve. The breakthrough data were matched using the Ogata-Banks exact solution, and the corresponding dispersion value was determined through curve matching (Figure 2-left). The solute transport simulation was done at three different flow rates and Peclet numbers to obtain the variation of dispersion with pore velocity. Finally the dispersivity value, which is a property of the porous medium, was calculated by linear regression of dispersion against pore-water velocity (Figure 2-right).

RESULTS AND DISCUSSION

Hydraulic conductivity was determined to decrease from 8.7 x 10-3 to 1.6 x 10-4 m/s between 2- 11 cm depth (Table 1). This 50-fold reduction in the hydraulic conductivity is consistent with laboratory observations of the same peat (Rezanezhad et al., 2010; Quinton et al., 2008). Kv and Kh values were similar, suggesting peat was anisotropic. Dispersivity was ~3 mm (Figure 2), similar to values obtained experimentally on Sphagnum dominated peat (Hoag & Price, 1997).

Table 1: Variation of KH, Kv and dispersivity values versus depth

Depth	2 cm	3 cm	5 cm	6 cm	9 cm	10 cm	11 cm
Kh (m/s)	8.69E-03	7.77E-03	2.71E-03	3.38E-03	1.95E-03	5.61E-04	1.58E-04
Kv (m/s)	8.31E-03	7.17E-03	3.05E-03	3.90E-03	1.89E-03	5.39E-04	1.46E-04
Dispersivity (m)	2.79E-03	-	3.66E-03	-	2.08E-03	2.07E-03	-

CONCLUSION

Modeled peat hydraulic conductivity declined with increasing depth similar to experimental observations (Rezanezhad et al. 2009). Dispersivity was calculated to be ~3mm, comparable to values reported in a previous solute transport study in Sphagnum-dominated peat. Our study illustrates how the pore size distribution and pore network structure of peat controls hydraulic conductivity and solute transport. This approach will be used to better understand how changes to the pore network geometry caused by decomposition or clogging with mobile particulates affect flow and transport.

REFERENCES

Bakke, S. and Øren, P.E., 1997. '3-D pore-scale modelling of sandstones and flow simulations in the pore networks', SPE Journal, 2, 136-149.

Bijeljic, B., Muggeridge, A.H. and Blunt, M.J., 2004. 'Pore-scale modeling of longitudinal dispersion', Water Resources Research, 40.

Dong, H. and Blunt, M.J., 2009. 'Pore-network extraction from micro-computerized-tomography images', Physical Review E, 80, 036307.

Hoag, R.S. and Price, J.S., 1997. 'The effects of matrix diffusion on solute transport and retardation in undisturbed peat in laboratory columns', Journal of Contaminant Hydrology, 28, 193-205.

Qin, C.Z. and Hassanizadeh, S.M., 2015. 'Pore-Network Modeling of Solute Transport and Biofilm Growth in Porous Media', Transport in Porous Media,110, 345-367.

Quinton, W.L., Elliot, T., Price, J.S., Rezanezhad, F. and Heck, R., 2009. 'Measuring physical and hydraulic properties of peat from X-ray tomography', Geoderma, 153, 269-277.

Quinton, W.L., Hayashi, M. and Carey, S.K., 2008. 'Peat hydraulic conductivity in cold regions and its relation to pore size and geometry', Hydrological Processes, 22, 2829-2837.

Raoof, A. and Hassanizadeh, S.M., 2013. 'Saturation-dependent solute dispersivity in porous media: pore-scale processes', Water Resources Research, 49, 1943-1951.

Rezanezhad, F., Quinton, W.L., Price, J.S., Elrick, D., Elliot, T.R. and Heck, R.J., 2009. 'Examining the effect of pore size distribution and shape on flow through unsaturated peat using computer tomography', Hydrol. Earth Syst. Sci., 13, 1993-2002

Rezanezhad, F., Quinton, W.L., Price, J.S., Elliot, T.R., Elrick, D. and Shook, K.R., 2010. 'Influence of pore size and geometry on peat unsaturated hydraulic conductivity computed from 3D computed tomography image analysis', Hydrol. Process. 24, 2983–2994.

Valvatne, P.H. and Blunt, M.J., 2004. 'Predictive pore-scale modeling of two-phase flow in mixed wet media', Water Resources Research. 40, W07406**.**

Best Student Paper in Geodesy Award
Ismael Foroughi, University of New Brunswick

Harmonic downward continuation of scattered point gravity anomalies to mean anomalies on a mesh on the geoid

Foroughi, Ismael; Vaníek, Petr; Novák, Pavel; William Kingdon, Robert; Goli, Mehdi; Sheng, Michael; Santos, Marcelo
Department of Geodesy and Geomatics, University of New Brunswick, Fredericton, Canada
i.foroughi@unb.ca

Harmonic downward continuation (DC) of ground gravity anomalies to produce input values required in the geodetic boundary-value problem, is perhaps the most challenging step in geoid determination. An inverse of discretized Poissons integral has typically been used to continue point Helmerts gravity anomalies from the surface of the Earth down to their mean values on a regular coordinate mesh on the geoid. The matrix of a system of linear equations, resulting from discretized Poissons integral, is badly numerically conditioned if either the discretization step on the geoid is too small or the surface points have high elevations. The numerical conditionality of the problem is measured by the condition number of the matrix of the resulting linear equations. Different discretization and rastering techniques, such as mean to mean or point to point, as well as different iterative processes for inverting the Poisson matrix have been applied to improve conditionality of the problem. A point to mean transform has been more of interest as such a set up would be the most physically meaningful of all possible options. Inherently, the DC is a high pass filtering technique, yet, we should be really interested in the mean gravity values on the geoid. In the ideal case the DC of scattered observations at the Earth surface should be combined with the prediction process, whereby the resulting downward continued values would be produced on a regular coordinate mesh, ready for numerical integration. It is the purpose of this study, to discuss the combination of the DC with the prediction on a regular mesh on the geoid. We wish to transfer the scattered points from topography down to mean points on a raster on the geoid, to deteriorate the frequency information contained in the observation data as little as possible.The least-squares technique (LST) was tested for continuing scattered Helmerts gravity anomalies in the Auvergne area down to 1*1 arc-min mesh on the geoid. Results show that due the poor conditionality of the 3-D matrix of normal equations, the desired accuracy cannot be obtained without some regularization. For evaluation of this approach, EGM2008 up to full degree/order of 2190 was used to generate both synthetic scattered gravity anomalies on topography and mesh mean gravity anomalies on the geoid. Numerical results of the evaluation will be provided.

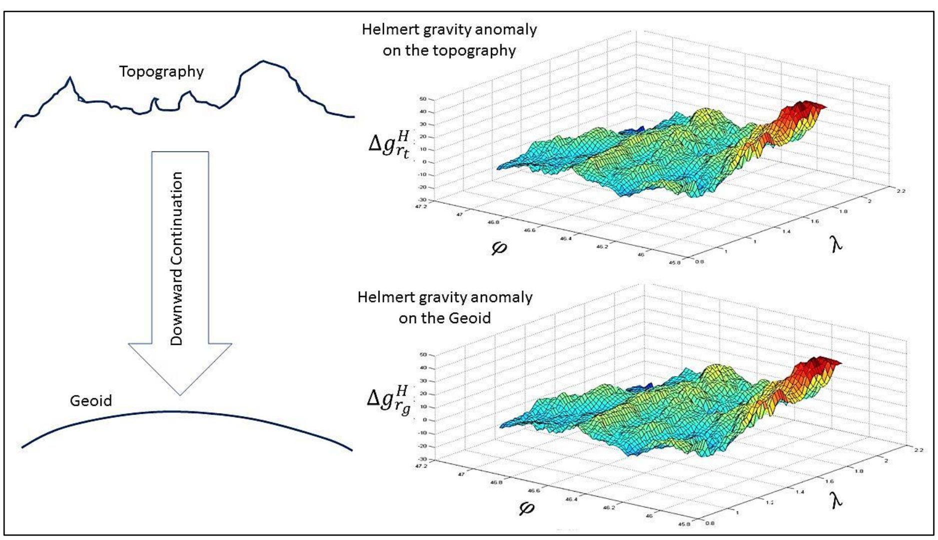


Figure: Downward Continuation process

Solid Earth Section Best Student Paper Award 2016
Andrew Gagnon-Nandram, Queen's University

Geophysical surveys to validate a potential sinkhole collapse, Lake on the Mountain, ON.

Gagnon-Nandram, Andrew & Braun, Alexander
Department of Geological Sciences and Geological Engineering, Queen's University

Lake on the Mountain, located in Prince Edward County, Ontario, has been a mystery to researchers and locals alike for decades. The 35 m deep lake is located precipitously close to the edge of a 62 m high cliff overlooking the Bay of Quinte. How the lake has existed at this elevation without draining into the bay below is not known, nor is it completely understood how the lake was originally formed. The accepted hypothesis is that it was formed by a large Quaternary sinkhole collapse, though significant evidence to support this claim does not exist. The lake is emplaced in Ordovician carbonates, which would make a sinkhole collapse a plausible explanation.

The objective of this project is to provide validation to support a hypothesis of the lake's formation, through the collection and analysis of geophysical survey data, as well as water temperature and conductivity measurements.

An electromagnetic survey using a Max-Min and EM-31 horizontal loop system was undertaken in order to identify groundwater inflow channels. This survey showed no lateral anomalies in the conductivity profile, which may indicate that these inflow channels are not present. In addition, the temperature and conductivity measurements of the water column indicate that the lake is very strongly stratified in temperature and in chemistry at a depth of approximately 7 m. Though not unexpected for a lake of this size and shape, this does suggest that there is not a significant groundwater flux occurring at depth in the lake.

Figure: Andrew Gagnon-Nandram (right) and field assistants preparing for a ground penetrating radar survey on the frozen surface of Lake on the Mountain, Ontario, in March, 2015

A Ground Penetrating Radar (GPR) survey was performed from the frozen lake surface using a MALA ProEx 100 MHz instrument. An acoustic survey was also performed from a canoe platform, using a Knudsen Pinger Echosounder. The GPR and acoustic surveys were performed in order to acquire a more detailed bathymetric image of the lake bottom surface, in addition to imaging the thickness and stratification of sediment layers. The acoustic profiles of the lake bottom bedrock identified several vertical structures that appear to be solutionally enlarged fractures, which are typical bedrock features that occur in epikarst environments. The acoustic data also shows that the deep lake basin is elongated and linear, and strikes parallel to a set of normal faults present in the area. This indicates that the lake may be situated over a fault zone, which would have provided fractures to accelerate karst development.

The identification of epikarst bedrock features, as well as a possible fault zone under Lake on the Mountain support the hypothesis that the lake was formed from a karst sinkhole collapse.

Biogeosciences Best Student Paper Award 2016
Kimberly Murray, University of Waterloo

Controls on methane flux from a constructed fen in the Athabasca Oil Sands Region, Alberta

K.R Murray*, and M. Strack
Department of Geography and Environmental Management, University of Waterloo, 200 University Avenue West, Waterloo, ON, Canada N2L 3G1
*Corresponding author: Email: *k7murray@uwaterloo.ca*

Abstract
Recently, fen construction projects on post-open pit mines in northeastern Alberta have been attempted as a reclamation strategy to reintroduce peatlands into the region where industry disturbs a substantial amount of wetland ecosystems. In this study methane (CH_4) flux and controls on flux from a constructed fen and two natural reference sites in northeastern Alberta were considered in an effort to better understand functionality of the constructed fen. Methane release was found to be lower at the constructed fen compared to the reference poor fen, but similar to the reference saline fen. Further analysis also revealed similarities in environmental variables measured between the constructed and saline fen. Statistical results suggest that a thorough understanding of biogeochemistry, peat properties, hydrology, and vegetation is necessary to understand CH_4 flux at the recently reclaimed constructed fen compared to natural reference sites. A clear statement of reclamation goals is required to understand how CH_4 emissions from constructed fen ecosystems relate to reclamation success.

Introduction

Open pit mining activities associated with the extraction of oil sand ore is a common land-use in the Athabasca Oil Sands deposit around Fort McMurray, Alberta. Mining in this area disturbs landscapes which were predominantly peatlands (Vitt et al., 1996). The Alberta Government requires reclamation of a portion of mined landscapes to wetland ecosystems with "equivalent capability" of pre-disturbed land (OSWWG, 2000). As peatlands act to sequester carbon and have a high capacity to store water, it is advantageous to restore disturbed areas to peatlands where possible (Price et al., 2010). Fens are the dominant peatland type near Fort McMurray and recently the construction of fen peatlands on post-open pit mined landscapes have been attempted (Daly et al., 2012). It has been predicted that the functionality of constructed fen systems may not align with natural sites, given that fen creation results in unique hydrology and water chemistry conditions, causing the eventual development of novel ecosystems (Nwaishi et al., 2015). Ongoing monitoring to understand how these potential novel systems function should consider carbon dynamics, comparing results to natural reference ecosystems.

Although natural peatlands act to sequester carbon through the flux of carbon dioxide (CO_2) overall, the incomplete decomposition of organic matter in waterlogged soils over thousands of years results in a loss of the greenhouse gas methane (CH_4) from undisturbed peatlands to the atmosphere in the order of 30 Tg (1 Tg = 10^{12} g) CH_4 annually (Frolking et al., 2011). Controls on CH_4 dynamics from peatlands include vegetation type, vegetation productivity, water table depth, soil temperature, and peat geochemistry (Lai, 2009).

Information on the controls on CH_4 flux at a constructed fen compared to reference ecosystems is beneficial to understand functionality of the reclaimed fen and to make recommendations to future projects. The primary objective of this study is to determine controls on CH_4 flux over a growing season from similar vegetation treatments at a constructed fen and two reference fens in northeastern Alberta with a focus on two vascular species planted at the constructed fen *(Carex aquatilis* and *Juncus balticus)* and including a consideration of moss presence.

Study Sites

The study was conducted at three different study sites located within 30 km of Fort McMurray, Alberta (Fig 1). The constructed fen (CF) site, which was completed in 2013, was a ~3 ha fen within a 32 ha watershed. It included an upland area made up of tailings sands with high hydraulic conductivity (Price et al., 2010). Two meters of donor peat was placed on a layer of petroleum coke at the base of the slopes. Donor peat was collected from a dewatered peatland and stored for two years before being transported to the reclamation site for construction (Nwaishi et al., 2015). Vegetation was planted on the site with a randomized split-plot vegetation design to test vegetation establishment (A. Borkenhagen, unpublished). Specifically, for this study seedling plantation (Cooper and Macdonald, 2001) of two vascular species, moss layer transfer (Rochefort and Campeau, 2002), and bare control areas were considered. Treatments at the CF included four replicates of plots across the site in each treatment: 1) *Carex aquatilis*, 2) *Juncus balticus*, 3) *Carex aquatilis* and moss, 4) *Juncus balticus* and moss, 5) bare, and 6) moss. Two natural reference sites were also considered for this study. One reference site was a saline fen (SF) influenced by saline groundwater (Wells and Price, 2015). At SF treatments included four replicates each in areas dominated by *Juncus balticus* and bare areas. A final study site was a poor fen (PF) surrounded by upland coniferous forests and dominated by a *Sphagnum* carpet. At this site four replicates of both moss, and *Carex aquatilis* and moss treatments were considered.

Fig 1. Study site locations near Fort McMurray, Alberta. *Source:* Google Earth

Methods

Flux measurements were made 10 times from May 16-September 3, 2015 using the closed chamber method (Alm et al., 2007). Briefly, CH_4 flux was measured using opaque chambers (0.108 m^3) placed on metal collars, with gas samples (20mL) extracted four times over a 35-minute interval and subsequently analyzed via gas chromatography. Flux was determined from the linear change in concentration over time. Measurements of gross ecosystem productivity (GEP) were made using a clear chamber connected to an infrared gas analyzer in full light conditions (photosynthetically active radiation >1000 µmol m^{-2} s^{-1}). Water table depth (WT) was measured with ~1 m PVC standpipe adjacent to each plot (diameter 0.05 m). Soil temperature at 0.10 m depth (Temp10) was measured with a thermocouple probe inserted into the peat. To better understand redox reactive ions in pore water, plant root simulator (PRS)™ probes (Western Ag Innovations Inc., Saskatoon, SK) were buried at 0.20 m depth adjacent to each plot for 14 days. PRS probes included a 10 cm^2 resin membrane which measured ion supply in soil solution. Finally, aboveground biomass was sampled using a 0.2 x 0.6 m quadrat placed adjacent to the flux sampling plots. All biomass in the quadrat was cut at the soil surface and transported to the laboratory where it was dried at 60˚C for 72 hours and weighed.

To determine differences in CH_4 flux between sites and treatments across the growing season a one-way ANOVA with repeated measures that accounted for date was used, with a pairwise t-test with adjusted p-values using the holm method. Principal component analysis (PCA) was applied to seasonal average CH_4 flux and environmental data to understand variance in data across sites. To understand controls on CH_4 flux, Pearson correlation and multiple linear regression analysis were applied to seasonal average flux and environmental data. Environmental controls included in analysis were WT, Temp10, GEP, aboveground biomass, and redox reactive ions sulfur (S), ammonium (NH4), iron (Fe), and manganese (Mn). Data were log transformed to meet normality and variance conditions, and a significance of α=0.05 was used. The statistical program R 3.2.4. (R Core Team, 2016) was used for all statistical analysis.

Results

Growing season CH_4 flux from the PF (23.9 mg CH_4 m^{-2} d^{-1}) was significantly higher compared to the SF (4.4 mg CH_4 m^{-2} d^{-1}) and CF (4.0 mg CH_4 m^{-2} d^{-1}; $F_{9,241}$=2.6, p=0.007; Fig 2). Considering seasonal averages at all treatments in the study, *Juncus balticus* plots at the CF had significantly higher CH_4 flux compared to bare plots at the CF, and the two treatments at the PF, *Carex aquatilis* and moss and moss only, had significantly higher flux compared to all other treatments ($F_{2,33}$=28.5, p<0.001; Fig 2).

Eigenvalues from the PCA analysis revealed the first three principal components to be important (eigenvalues >1), and explain 73.3% of the data variance (Fig 3). The PCA indicated strong clustering based on sites, with PF plots grouped along PC1. Pearson correlation between average seasonal environmental variables across all three sites revealed S, NH4, and Fe to be significantly correlated to CH_4 flux (Table 1), consistent with the PCA results which found Fe and NH4 to be highly correlated to PC1 (Fig 3). Multiple linear regression with the highest coefficient of determination included WT, S (log transformed), Fe (log transformed), NH4 (log transformed), biomass, and Temp10 as independent variables ($F_{6,33}$ = 4.2, p=0.039, R^2 *(adj)* = 0.73). This

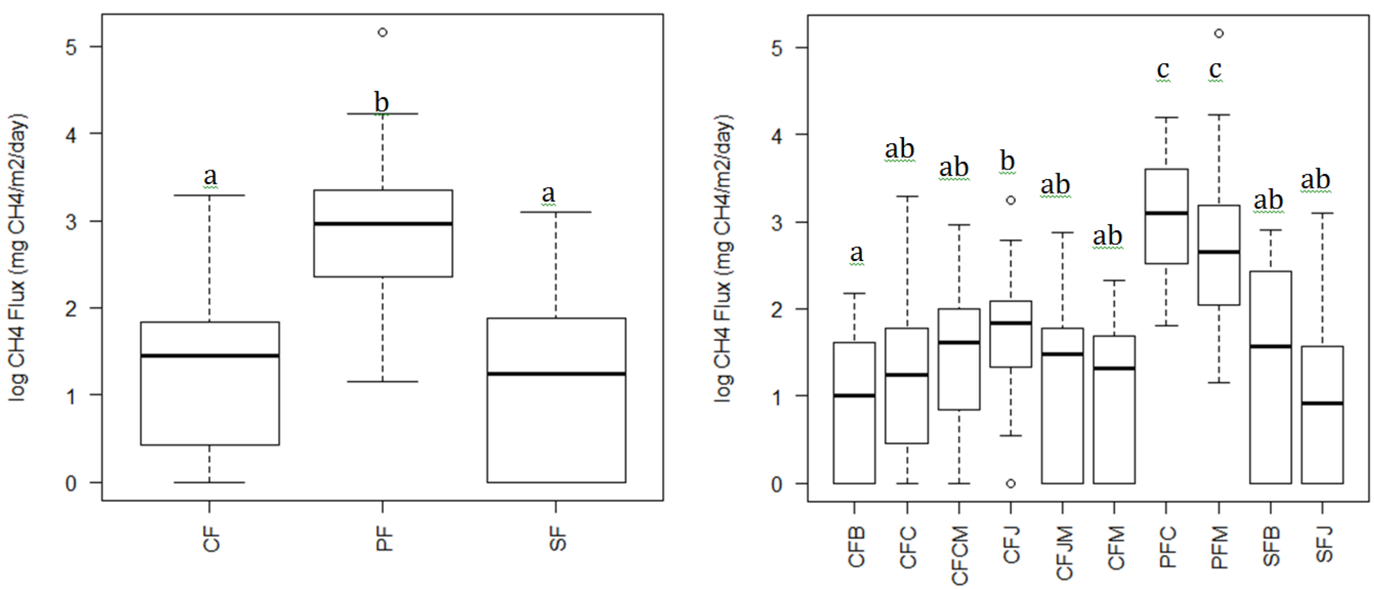


Fig 2. Methane flux at the constructed fen (CF), poor fen (PF), and saline fen (SF; left). Methane flux at treatments CF bare (CFB), CF Carex (CFC), CF Carex + moss (CFCM), CF Juncus (CFJ), CF Juncus + moss (CFJM), CF moss (CFM), PF Carex + moss (PFCM), PF moss (PFM), SF bare (SFB), and SF Juncus (SFJ; right). Letters indicate significant differences between sites and treatments.

regression also included treatment (CF bare, PF moss, etc.) as an interactive term with variables S (log transformed) and NH4 (log transformed).

Discussion

Average 2015 CH_4 flux values from the CF and SF sites in this study were substantially lower than values reported from other fen sites in the region, while the value from the PF was in a similar range. For instance, Long et al. (2010) reported average emissions of 32 mg CH_4 m^{-2} d^{-1} over a growing season in Alberta using eddy covariance. Lower CH_4 emissions from both CF and SF were expected, associated with a pre-existing knowledge of high sulphate values at both sites (Wells, 2015). Sulphate is known to inhibit CH_4 flux, as it is the last terminal electron acceptor to be energetically favoured in competition for substrates necessary for CH_4 production (Bridgham et al., 2013).

No prominent treatment effect was revealed from CH_4 fluxes between the CF and SF (Fig 2). Only the CF bare plots were found to have significantly lower flux compared to the CF *Juncus balticus* plots. This likely indicates that the *Juncus balticus* plants were wicking CH_4 to the atmosphere through aerenchymous tissues (Whalen, 2005). Ström et al. (2005) found a species-specific effect of vascular plants on CH_4 emissions, where *Juncus* species emitted less CH_4 compared to *Carex* species. While no evidence of differences in CH_4 emissions between vascular species were found in the present study, low flux values at both CF and SF made it challenging to parse apart a vegetation influence on the flux.

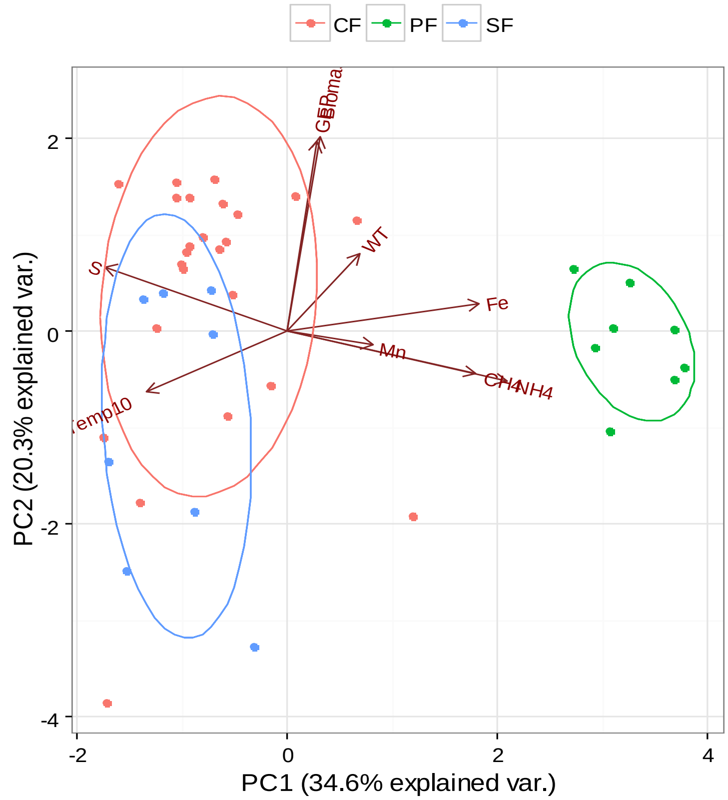


Fig 3. Principal component analysis of seasonal average methane flux and environmental controls (water table depth (WT), temperature at 10cm below surface (temp10), gross ecosystem productivity (GEP), aboveground vegetation biomass (Biomass), soil water iron (Fe), ammonium (NH4), manganese (Mn), and sulfur (S)) measured at the constructed fen (CF), poor fen (PF), and saline fen (SF).

The PCA results revealed variance between sites in CH_4 and environmental variables measured, with plots from CF and SF clustering closer together compared to the PF. This indicates that, at this early stage post-reclamation, the CF is functioning more similarly from a biogeochemistry stance to a saline natural site compared to a poor fen. The Pearson Correlation and multiple linear regression results highlighted the importance of the redox reactive ions in explaining CH_4 flux (Table 1). The PF had higher NH_4 and Fe values compared to the other sites (results not shown). Positive correlation between CH_4 and both NH4 and Fe (Table 1) indicated that biogeochemistry at the PF was more conducive to CH_4 production compared to the other sites (Bridgham, 2013). Results from the regression analysis, which included six environmental controls on CH_4 flux, suggests that explaining CH_4 emissions from a reclaimed fen requires in-depth knowledge of plot-scale ecohydrological conditions.

Conclusions

In this study differences in CH_4 flux and environmental variables, particularly biogeochemistry, were found between a constructed fen and poor fen in the area, indicating constructed fens do not function similar to poor fens dominant in the area shortly after reclamation. However, similarities in flux and controls were found between a constructed fen and a saline fen in the area. As CH_4 is a strong greenhouse gas, low CH_4 flux from a constructed fen may actually be seen as beneficial in future fen creation projects by reducing greenhouse gas emissions, despite apparent differences in functionality between constructed fens and poor fens. Ultimately clear statement of reclamation goals (e.g., greenhouse gas sink vs. similar biogeochemical function as natural fens) will be required to determine how CH_4 flux and its controls relate to the success of constructed fen projects, particularly over the long-term.

Table 1. Pearson correlation between seasonal average environmental variable and log CH_4 flux across the constructed fen, poor fen, and saline fen. Refer to Fig 3 for descriptions of variables.

Variable	Correlation	*p*-value
WT	-0.037	0.818
Temp10	-0.250	0.120
GEP	0.030	0.854
Biomass	-0.188	0.245
logS	-0.624	**<0.001**
logNH4	0.635	**<0.001**
logFe	0.419	**0.007**
logMn	0.209	0.195

Bold indicates a significant results $p<0.05$
S, NH4, Fe, and Mn were log transformed

References

Alm, J., Shurpali, N.J., Tuittila, E.-S., Laurila, T., Maljanen, M., Saarnio, S., and Minkkinen, K. 2007. Methods for determining emission factors for the use of peat and peatlands-flux measurement and modeling. Boreal Environ. Res 12: 85–100.

Bridgham, S.D., Cadillo-Quiroz, H., Keller J.K., and Zhuang, Q. 2013. Methane emissions from wetlands: Biogeochemical, microbial, and modeling perspectives from local to global scales." Global Change Biol 19: 1325–46.

Cooper, D.J., and MacDonald, L.H. 2000. Restoring the vegetation of mined peatlands in the southern Rocky Mountains of Colorado, USA. Restoration Ecology 8: 103-111.

Daly, C., Price, J., Rezanezhad, F., Pouliot, R., Rochefort, L., and Graf, M.D. 2012. Initiatives in oil sand reclamation: considerations for building a fen peatland in post mined oil sands landscape. In Restoration and Reclamation of Boreal Ecosystems, New York, NY: Cambridge University Press.

Frolking, S., Talbot, J., Jones, M.C., Treat, C.C., Kauffman, J.B., Tuittila, E.-S., and Roulet, N. 2011. Peatlands in the Earth's 21st century climate system. Environ. Rev. 19: 371–396.

Google earth. V 7.1.5.1557. (April 9, 2013). Fort McMurray, Alberta, Canada. 473357.39 m E, 6294340.35 m N, elevation 3495, eye alt 146km. https://www.google.com/earth/ [April 13, 2016].

Lai, D.Y.F. 2009. Methane Dynamics in Northern Peatlands: A Review. Pedosphere 19: 409-421.

Long, K.D., Flanagan, L.B., and Cai, T. 2010. Diurnal and seasonal variation in methane emissions in a northern Canadian peatland measured by eddy covariance. Global Change Biol. 16: 2420–2435.

Nwaishi, F., Petrone, R.M., Price, J.S., Ketcheson, S.J., Slawson, R., and Andersen, R. 2015. Impacts of donor-peat management practices on the functional characteristics of a constructed fen. Ecological Engineering 81: 471-480.

Oil Sands Wetlands Working Group (OSWWG). 2000*. Guidelines for Wetland Establishment on Reclaimed Oil Sands Leases*. Chymko, N. (ed). Alberta Environment. Environmental Services Publication No. T/517.

Price, J. S., McLaren, R. G., Rudolph, D. L. 2010. Landscape restoration after oil sands mining: conceptual design and hydrological modelling for fen reconstruction. International Journal of Mining, Reclamation and Environment 24: 109–123.

R Core Team. 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available: **http://www.R-project.org/**.

Quinty, F., and Rochefort, L. 2003. *Peatland Restoration Guide,* 2nd edn. Canadian Sphagnum Peat Moss Association and New Brunswick Department of Natural Resources and Energy.

Ström, L., Mastepanov, M., and Christensen, T.R. 2005. Species-specific effects of vascular plants on carbon turnover and methane emissions from wetlands. Biogeochemistry 751: 65-82.

Wells, C.M., and Price, J.S. 2015. A hydrologic assessment of a saline-spring fen in the Athabasca oil sands region, Alberta, Canada–a potential analogue for oil sands reclamation. Hydrological Processes 29: 4533-4548.

Whalen, S.C. 2005. Biogeochemistry to methane gas exchange between natural wetlands and the atmosphere. Environmental Engineering Science 22: 73-94.

Vitt, D. 2006. Functional Characteristics and Indicators of Boreal Peatlands. Ecological Studies 188: 9-23.

Recent Papers of Interest

- Bao, X., & Eaton, D. W. (2016). Fault activation by hydraulic fracturing in western Canada. *Science*, 354, 1406-1409
- Ince, E.S. and Pagiatakis, S.D. (2016). Effects of space weather on GOCE electrostatic gravity gradiometer measurements. *Journal of Geodesy*, 90(12), pp.1389-1403.
- Samsonov, S.V., Tiampo, K.F., Feng, W. (2016) Fast subsidence in downtown of Seattle observed with satellite radar, *Remote Sensing Applications: Society and Environment*, 4:179–187, doi:10.1016/j.rsase.2016.10.001
- Royer A., A. Roy, B. Montpetit, O. Saint-Jean-Rondeau, G. Picard, L. Brucker and A. Langlois (2017). Comparison of commonly-used microwave radiative transfer models for snow remote sensing. *Remote Sensing of Environment*, 190, 247–259, doi.org/10.1016/j.rse.2016.12.020
- Alinia, H.S., Tiampo, K.F., James, T.S. (2017) GPS coordinate time series measurements in Ontario and Quebec, Canada, *Journal of Geodesy*, doi:10.1007/s00190-016-0987-5
- Kropivnitskaya, Y., Tiampo, K.F., Qin, J., Bauer, M.A. (2016) Real-time earthquake intensity estimation using streaming data analysis of social and physical sensors, *Pure and Applied Geophysics*, doi:10.1007/s00024-016-1417-6
- Shirzaie, M., Ellsworth, W., Tiampo, K., González, P., Manga, M. (2016) Surface uplift and time-dependent seismic hazard due to fluid-injection in eastern Texas, *Science*, 353 (6306), doi:10.1126/science.aag0262
- Samson, C., Mah, J., Haltigin, T., Holladay, S., Ralchenko, M., Pollard, W., Monteiro Santos, F.A. 2017. Combined electromagnetic geophysical mapping at Arctic perennial saline springs: potential applications for the detection of water in the shallow subsurface of Mars. Advances in Space Research; doi: 10.1016/j.asr.2017.02.016.
- Blanchard, J.A., Ernst, R.E., and Samson, C. 2017. Gravity and magnetic modelling of layered mafic-ultramafic intrusions in large igneous province plume centre regions; Case studies from the 1.27 Ga Mackenzie, 1.38 Ga Kunene-Kibaran, 0.06 Ga Deccan, and 0.13-0.08 Ga High Arctic events. Canadian Journal of Earth Sciences, 54(3): 290-310; doi:10.1139/cjes-2016-0132.
- Harris, K., White, D., Melanson, D., Samson, C., and Daley, T. 2016. Feasibility of time-lapse VSP monitoring at the Aquistore CO2 storage site using a

distributed acoustic sensing system. International Journal of Greenhouse Gas Control, 50: 248-260; doi: 10.1016/j.ijggc.2016.04.016.

- Lai, P., and Samson, C. 2016. Applications of mesh parameterization and deformation for unwrapping 3D images of rock tunnels. Tunnelling and Underground Space Technology, 58: 109-119; doi: 10.1016/j.tust.2016.04.009.
- Wood, A., Cook, I., Doyle, B., Cunningham, M., and Samson, C. 2016. Experimental aeromagnetic survey using an unmanned air system. The Leading Edge, 35(3): 270-273; doi: 10.1190/tle35030270.1.
- Mah, J., McKinnon, S., Samson, C., and Thibodeau, D. 2016. Wire mesh filtering in 3D image data of rock faces. Tunnelling and Underground Space Technology, 52: 111-118; doi: 10.1016/j.tust.2015.11.005.

Contributors in this issue

We thank: Kelly Biagi, Katelyn Lutes, Mitch Grace, Ryan Connon, Behrad Gharedaghloo, Ismael Foroughi, Andrew Gagnon-Nandram, Kimberly Murray, Athina Peidou, Gordon Young, David Eaton, Daniel Peters, Phil McCausland, Alain Royer, Calvin Klatt, Sinem Ince, Claire Samson, Kristy Tiampo, Carl Mitchell, Nora Casson, Fanny Larue, Osama Ahmed, Roger Phillips, Marcelo Santos, Gail Atkinson, Hadi Ghofrani, J.J.McDonnell, Scott Jasechko

NB Kitchen Party by the Calithumpians at the CMOS-CGU Post Banquet, Fredericton May 2016

Canadian Geophysical Union :: CGU-UGC Executive and Sections

CGU-UGC BOARD OF DIRECTORS

President: Claire Samson (Carleton University) claire.samson@carleton.ca
Vice President: Richard Petrone (University of Waterloo) rich.petrone@uwaterloo.ca
Past President: Brian Branfireun (University of Western Ontario) bbranfir@uwo.ca
Secretary: Jeffrey McKenzie (McGill University) jeffrey.mckenzie@mcgill.ca
Treasurer: Laura Brown (University of Toronto Mississauga) lc.brown@utoronto.ca
Awards Chair: Kristy Tiampo (Western University) ktiampo@uwo.ca

Executive Director: Gordon Young (Wilfrid Laurier University) gordonyoung_wwap@yahoo.com

BIOGEOSCIENCES

President: Carl Mitchell (University of Toronto Scarborough) carl.mitchell@utoronto.ca
Vice President: Murray Richardson (Carleton University) murray_richardson@carleton.ca
Past President: Merrin Macrae (University of Waterloo) mmacrae@uwaterloo.ca
Secretary: Nora Casson (University of Winnipeg) n.casson@uwinnipeg.ca
Treasurer: Altaf Arain (McMaster University) arainm@mcmaster.ca
Member-at-Large: Britt Hall (University of Regina) britt.hall@uregina.ca
Member-at-Large: Maria Strack (University of Waterloo) mstrack@uwaterloo.ca
Student Member: James Cober (University of Waterloo) jrcober@uwaterloo.ca

EARTH SURFACE PROCESSES

President: Chris Hugenholtz (University of Calgary) chhugenh@ucalgary.ca
Vice President: Jaclyn Cockburn (University of Guelph) jcockbur@uoguelph.ca
Past President: Peter Ashmore (University of Western Ontario) pashmore@uwo.ca
Secretary-Treasurer: Roger Phillips (Western University) roger.phillips@uwo.ca
Member-at-Large: Patrick Lajeunesse (Laval) Patrick.Lajeunesse@ggr.ulaval.ca
Member-at-Large: Étienne Godin (Université de Montréal) etienne.godin.1@umontreal.ca
Student Representative: Sarah Peirce (University of Western Ontario) speirce@uwo.ca

GEODESY

President: Jeong Woo Kim (University of Calgary) jw.kim@ucalgary.ca
Vice-President: Georgia Fotopoulos (Queen's University) georgia.fotopoulos@queensu.ca
Past President: Joe Henton (Natural Resources Canada) Joe.Henton@NRCan-RNCan.gc.ca
Secretary: Robert Kingdon (University of New Brunswick) robert.kingdon@unb.ca
Treasurer: Elena Rangelova (University of Calgary) evrangel@ucalgary.ca
Member-at-Large: Hojjat Kabirzadeh (University of Calgary) hkabirza@ucalgary.ca
Member-at-Large: Ismael Foroughi (University of New Brunswick) i.foroughi@unb.ca
Student Member: Athina Peidou (York University) peidou@yorku.ca

HYDROLOGY

President: Daniel Peters (Environment Canada) daniel.peters@ec.gc.ca
Vice President: Claire Oswald (Ryerson University) coswald@ryerson.ca
Past President: Bill Quinton (Wilfrid Laurier University) wquinton@wlu.ca
Secretary: Andrew Ireson (University of Saskatchewan) andrew.ireson@usask.ca
Treasurer: Genevieve Ali (University of Manitoba) Genevieve.Ali@umanitoba.ca
Member-at-Large (Committees): Barret Kurylyk (University of Calgary) bkurylyk@gmail.com

Member-at-Large (Awards): Peter Whittington (Western University) whittington.pete@gmail.com
Student Representative: Casey Beel (Queen's University) 15cb29@queensu.ca

SOLID EARTH

President: Phil McCausland (Western University) pmccausl@uwo.ca
Vice-President: Julian Lowman (University of Toronto Scarborough) lowman@utsc.utoronto.ca
Past President: Sam Butler (University of Saskatchewan) sam.butler@usask.ca
Secretary: Claire Currie (University of Alberta) claire.currie@ualberta.ca
Treasurer: Andrew Frederiksen (University of Manitoba) andrew.frederiksen@umanitoba.ca
Member-at-Large: Behnam Seyed-Mahmoud (University of Lethbridge) behnam.seyed@uleth.ca
Member-at-Large: Yajing Liu (McGill University) yajing.liu@mcgill.ca

GAC GEOPHYSICS DIVISION

President: Ian Ferguson (University of Manitoba) Ij.Ferguson@umanitoba.ca

Editor's Note:

ELEMENTS, the Bulletin for the Canadian Geophysical Union, is published on the **CGU website** and distributed to all CGU members twice each year; one Summer issue and one Winter issue. We welcome submissions regarding geophysical meeting and workshop announcements or summaries, awards, accomplishments, news and images of interest.

Advertisements for employment opportunities in geophysics and for commercial concerns will be included for a nominal charge (contact the **Editor** for rates). Text notices of student and post-doctoral fellowship positions available will be included free of charge.

Submissions should be sent to the Interim Editor:

Phil McCausland,
Department of Earth Sciences,
Western University, 1151 Richmond St., London ON, N6A 5B7
Telephone: 519 661-2111 x-88008
Email: **pmccausl@uwo.ca**

CGU WEB SITE ADDRESS: http://www.cgu-ugc.ca