UNIVERSITY OF TORONTO

2016 Connaught Summer Institute in Arctic Science: Atmosphere, Cryosphere, and Climate

July 18-22, 2016 • Nottasawaga Inn • Alliston, Ontario, Canada

Photo by Paul Loewen

Photos courtesy of NETCARE

Welcome to the Summer Institute!

The 2016 Connaught Summer Institute in Arctic Science: Atmosphere, Cryosphere, and Climate

The Connaught Summer Institute in Arctic Science: Atmosphere, Cryosphere, and Climate brings together students and scholars who are engaged in Arctic research, to provide an understanding of the Arctic climate and the processes that control it, and to establish an interdisciplinary forum in which they can discuss current challenges and identify emerging research opportunities in this area. The Summer Institute is supported by the University of Toronto's Connaught Fund and builds on the Summer School program developed by the NSERC CREATE Training Program in Arctic Atmospheric Science (CREATE-AAS).

The Summer Institute is affiliated with three networks funded by the Natural Sciences and Engineering Research Council of Canada (NSERC) Climate Change and Atmospheric Research (CCAR) program: Probing the Atmosphere of the High Arctic (PAHA), the Network on Climate and Aerosols (NETCARE), and the Canadian Sea Ice and Snow Evolution (CanSISE) Network, and with groups at the University of Toronto engaged in laboratory studies of chemistry at the air-ice/snow interface and paleo-reconstructions of Arctic environments. It spans the disciplines of physics, chemistry, earth sciences, geography, environmental science, and related areas, and encompasses the use of experimental, field observation, and modelling methodologies to study the Arctic region.

2011 CREATE-AAS Summer School

2012 CREATE-AAS Summer School

2013 CREATE-AAS Summer School

2014 Connaught Summer Institute

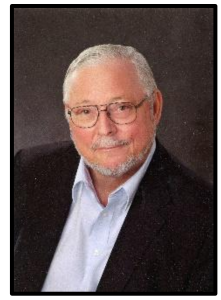
Program Website:

http://www.candac.ca/create/ss2016/summerschool2016.html

Summer Institute Speakers and Panelists

Peter Braesicke
is a Deputy Head of Institute and Group Leader for Interactions in the Atmospheric System (IAS), at Karlsruhe Institute of Technology. He obtained his PhD from the Free University of Berlin and has worked at the University of Cambridge. His current research addresses composition-climate interactions (including model development) and he teaches courses in climatology and theoretical meteorology.

Henry Buijs
is one of the original founders of Bomem in Quebec City, an internationally recognized high-technology company. He is currently Chief Technology Officer at ABB Inc. A scientist by profession, he has made extraordinary contributions to the field of Fourier transform infrared spectrometry and spectrometric analysis techniques.



Peter Calamai
worked for more than four decades in Canadian daily newspapers, as a news correspondent for the Southam newspapers, as editorial page editor of *The Ottawa Citizen* and national science reporter for *The Toronto Star*. He now is a communications consultant and freelance writer based in Ottawa. An adjunct journalism professor at Carleton University since 2001, Calamai is also a Fellow of the Institute for Science, Society and Policy at University of Ottawa.

Ray Clement
had a 30-year career with the Ontario Ministry of the Environment, working on high-profile environmental issues involving the detection of toxic chemicals in the environment. Ray has received major awards from the Chemical Institute of Canada and the American Chemical Society. He has taught at University of Waterloo, the University of Western Ontario, and Sheridan College, and has an interest in career consulting for students at all levels.

Brian Connor
is the Director of BC Consulting Limited in New Zealand, specializing in experimental spectroscopy, retrieval methods, error analysis, and instrument characterisation. He formerly worked as a Research Scientist at NASA Langley Research Center. He has contributed to several WMO/UNEP Ozone Assessments and is a member of the OCO-2 Science Team.

Chris Derksen
is a Research Scientist with the Climate Research Division of Environment and Climate Change Canada, and holds an adjunct faculty position with the Department of Geography and Environmental Management at the University of Waterloo. His research activities focus on remote sensing of terrestrial snow cover and sea ice and the use of satellite-derived datasets to identify interactions between the climate system and the cryosphere.

Summer Institute Speakers and Panelists *(continued)*

Sarah Finkelstein

is an Associate Professor in the Department of Earth Sciences at the University of Toronto. Dr Finkelstein's research interests and expertise include Quaternary paleoclimates in Arctic and sub-Arctic regions, landscape evolution and ecological change in response to long-term natural climate variability, northern wetlands, lake sediment records, Quaternary glacials and interglacials, and the impacts of recent climate warming on freshwater ecosystems.

John Fyfe

is a Senior Research Scientist at the Canadian Centre for Climate Modelling and Analysis, an Environment and Climate Change Canada laboratory. He is an internationally regarded climate scientist who has been recognized for his contributions in polar science, and for the awarding of the 2007 Nobel Peace Prize to the Intergovernmental Panel on Climate Change.

Gabrielle Gascon

is an atmospheric scientist with Environment and Climate Change Canada (ECCC). She works out of the Prediction Services Laboratory – West in Edmonton, Alberta. Her current work aims to improve ECCC's weather forecasting capabilities by developing new and innovative forecasting tools, as well as characterizing Arctic weather patterns using data from a meteorological supersite located in Iqaluit, Nunavut.

Dorothy Gordon

is a Certified Human Resources Professional (C.H.R.L) who has over 25 years of experience. She is currently a sought-after consultant applying her expertise within provincial and municipal sectors, where she has added tremendous value through the creation and implementation of best practices for her clients.

Patrick Hayes

is an Assistant Professor in the Department of Chemistry at Université de Montréal. His research uses a combination of field measurements and modeling to better understand the chemistry and sources of atmospheric aerosols.

Summer Institute Speakers and Panelists *(continued)*

Bob Holmes

is a science writer specializing in evolution, anthropology, genetics, and other biological subjects, and is author of more than 900 published articles. He has been a correspondent for *New Scientist* magazine since 1993, and was an editor for the magazine from 1999-2002. He has also written for *Science*, *US News & World Report*, *National Wildlife*, and other magazines.

Bill Simpson

is a Professor of Chemistry at the University of Alaska Fairbanks. His research develops and uses spectroscopy to study atmospheric chemistry, particularly in the Arctic. He studies how the changing Arctic climate affects the atmosphere, particularly how changes in sea ice affect production of atmospheric halogen radicals during the springtime. He has also worked on high-latitude pollution issues including urban particulate matter pollution and Arctic / Boreal greenhouse gas exchange.

Boyd Tolton

is the Chief Science Officer for Synodon Inc., based in Edmonton. Synodon provides remote sensing leak detection services primarily to the Oil & Gas pipeline industry. Tolton formerly was a project scientist with the MOPITT satellite program and an Assistant Professor in Physics at the University of Toronto.

Deborah Kigjugalik Webster

is an Inuit heritage researcher. For 20 years Deborah worked with the Prince of Wales Northern Heritage Centre (museum) in Yellowknife, Northwest Territories and Parks Canada as their Northern and New Parks archaeologist. She has served on heritage boards in Nunavut (Inuit Heritage Trust, Ittarnisalirijiit Katimajiit, Nunavut Historic Advisory Board, and Northern Heritage Society) and continues to be an advocate for her Inuit heritage.

Debra Wunch

is an Assistant Professor in the Department of Physics and the School of the Environment at the University of Toronto. After completing her PhD at UofT, she held postdoctoral and staff scientist positions at the California Institute of Technology, where she helped develop the Total Carbon Column Observing Network, the main ground-based validation network for the OCO-2 satellite mission.

Summer Institute Organizing Team

Kimberly Strong
is a Professor in the Department of Physics and inaugural Director of the University of Toronto's School of the Environment. Her research involves atmospheric remote sounding using ground-based, balloon-borne, and satellite instruments for studies of ozone chemistry, climate, and air quality. She is Deputy PI for PAHA, CREATE-AAS Training Program Director, and PI for the CSI.

Aubyn O'Grady
is the Connaught Summer Institute Coordinator and the Education and Outreach Facilitator for PAHA. She is currently pursuing a MA in education, and she has spent a number of years living in the Yukon, Canada, where she worked for the Tr'ondëk Hwëch'in First Nations Government and the Dawson City Music Festival.

Shannon Hicks
is the current Chair and social media manager of the CREATE/PAHA Trainees' Advisory Committee (TAC) and a first-year PhD student at the University of Western Ontario working with Dr. Bob Sica (University of Western Ontario) and Dr. Alexander Haefele (MeteoSwiss).

Connaught Summer Institute Co-Investigators

Jonathan Abbatt
Professor, Department of Chemistry
NETCARE Principal Investigator
www.chem.utoronto.ca/staff/ABBATT/default.htm

Jamie Donaldson
Professor, Department of Chemistry & Dept. of Physical and Environmental Sciences, U of Toronto Scarborough
www.chem.utoronto.ca/staff/DJD/

Sarah Finkelstein
Associate Professor,
Department |of Earth Sciences
http://www.es.utoronto.ca/people/facty/finkelstein-sarah/

Paul Kushner
Professor, Department of Physics
CanSISE Principal Investigator
pjk.atmosp.physics.utoronto.ca/

Jennifer Murphy
Associate Professor,
Department of Chemistry
www.chem.utoronto.ca/wp/murphygroup/

Kaley Walker
Associate Professor,
Department of Physics
http://www.atmosp.physics.utoronto.ca/~kwalker/

PAHA/PEARL/CANDAC Principal Investigator

James R. Drummond
Professor, Department of Physics and Atmospheric Science,
Dalhousie University
http://fizz.phys.dal.ca/~jrdrummond/

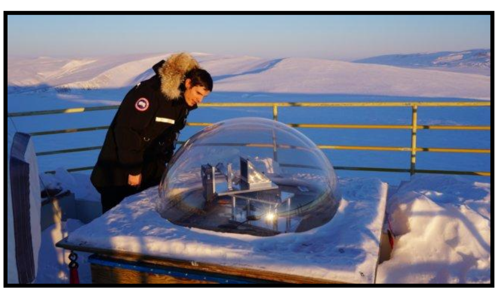
Summer Institute Students

	Name		Institution
1.	Yasmin AboEl-Fetouh	PhD	Université de Sherbrooke
2.	Whitney Bader	PDF	University of Toronto
3.	Ralf Bauer	PDF	University of Toronto
4.	Kristof Bognar	MSc	University of Toronto
5.	Brendan Byrne	PhD	University of Toronto
6.	Laurence Coursol	MSc	Université du Québec à Montréal
7.	April Dalton	PhD	University of Toronto
8.	Joan De Vera	PhD	University of Toronto
9.	Jing Feng	MSc	McGill University
10.	Sham Gamage	PhD	Western University
11.	Shannon Hicks	PhD	Western University
12.	Siraj ul Islam	PDF	University of Northern British Columbia
13.	Liviu Ivanescu	PhD	Université du Québec à Montréal
14.	Ali Jalali	PhD	Western University
15.	Paul Jeffrey	PhD	University of Toronto
16.	Allison Kolly	MSc	McGill University
17.	Kunna Li	MSc	University of Toronto
18.	Li Li	PDF	St. Mary's University
19.	Zhenhua Li	PDF	University of Saskatchewan
20.	Erik Lutsch	PhD	University of Toronto
21.	Sarah Murphy	PhD	Washington State University
22.	Ludovick Pelletier	MSc	Université du Québec à Montréal
23.	Keyvan Ranjbar	PhD	Université de Sherbrooke
24.	Ellen Reyes	MSc	University of Waterloo
25.	Sébastien Roche	PhD	University of Toronto
26.	Rodrigue Sandrin	MSc	University of Toronto
27.	Kanupria Seth	UG	University of Toronto
28.	Keegan Smith	MSc	Carleton University
29.	Chris Vail	MSc	University of New Brunswick
30.	Jeff VanKerkhove	PhD	Western University
31.	Dan Weaver	PhD	University of Toronto
32.	Charlie White	MSc	University of Toronto
33.	Xiaoyi Zhao	PhD	University of Toronto

Probing the Atmosphere of the High Arctic (PAHA) is an NSERC CCAR program that is using measurements from the Polar Environment Atmospheric Research Laboratory (PEARL) at Eureka, Nunavut and other Arctic stations, together with state-of-the-art analysis techniques, to probe the atmosphere of the Canadian High Arctic and analyze the causes of observed changes. The PAHA team is led by **Prof. James R. Drummond (Dalhousie)** and involves researchers at seven universities (Dalhousie, UofT, Western, Saskatchewan, Sherbrooke, York, UNB), and four divisions of Environment and Climate Change Canada, as well as international partners, including the NOAA Earth System Research Laboratory.

The PEARL facility was established in 2005 by the Canadian Network for the Detection of Atmospheric Change (CANDAC). It is located on the northern part of Ellesmere Island, in the vicinity of the Environment and Climate Change Canada Weather Station at Eureka, which is an important link in the support chain for PEARL. PEARL includes three facilities that are home to about 25 instruments being used to make measurements of the atmosphere from the ground to 100 km. The major site is the PEARL Ridge Lab, which was formerly Environment Canada's Arctic Stratospheric Ozone Observatory (AStrO), located at 80°N, 86°W, 610 m altitude. The building was constructed by Environment Canada in 1992, specifically to study stratospheric ozone. It is 15 km by road from Eureka and about 1,100 km from the North Pole.

The Zero Altitude PEARL Auxiliary Laboratory (ØPAL) is located at sea level at the outer perimeter of the Weather Station proper, and was added to expand the range of scientific research into the very lowest layers of the atmosphere. A third facility, the Surface and Atmospheric Flux, Irradiance and Radiation Extension (SAFIRE) is located away from all structures, for measurements of the undisturbed terrain, about 5 km from the Weather Station.



PAHA is utilizing data from PEARL under three major themes: Composition Measurements (led by Kim Strong), Polar Night (led by Bob Sica), and Satellite Validation (led by Kaley Walker). The first involves studies of the changing composition of the Arctic atmosphere, including greenhouse gases related to the carbon cycle; ozone and related species; biomass burning and continental influence on the Arctic; and clouds, aerosols and precipitation. The Polar Night theme is addressing the immense differences between polar day and polar night; there is a dearth of field measurements during the four months of darkness, which uniquely shapes the atmospheric environment in ways that are still not fully understood. PEARL is a highly desirable site for satellite validation, being in a "sweet-spot" for polar-orbiting satellite overpasses, and so the Satellite Validation theme is making use of PEARL data to establish the accuracy and reliability of Arctic measurements made by instruments on numerous satellite missions. PAHA is also affiliated with international initiatives, including the Network for Detection of Atmospheric Composition Change, the Total Carbon Column Observing Network, the MUSICA water vapour network, and the Aerosol Robotic Network.

All photos by Erik Lutsch

NETCARE (Network on Climate and Aerosols: Addressing Key Uncertainties in Remote Canadian Environments) is an NSERC CCAR program comprised of researchers from ten Canadian universities (Toronto, UBC, UQAM, Waterloo, UQAR, Laval, Dalhousie, Calgary, Sherbrooke, Victoria) and five partner institutions (Environment and Climate Change Canada, Fisheries and Oceans Canada, Alfred Wegener Institute, Max Planck Institute, Johannes Gutenberg University). NETCARE is one of seven networks funded under the NSERC CCAR program and is led by **Prof. Jonathan Abbatt (University of Toronto)**.

NETCARE has been configured around four research activities that address key uncertainties in the field. The first three are focused on specific aerosol-climate connections that remain poorly characterized, and will be addressed through a variety of observational approaches. The fourth activity integrates the results from Activities 1-3, approaching the subject from a comprehensive modeling perspective so as to provide a broad assessment of aerosol climate effects.

Activity 1: Carbonaceous Aerosol
Activity 2: Ice Cloud Formation and Impacts
Activity 3: Ocean-Atmosphere Interactions
Activity 4: Implications of Measurements on Simulations of Atmospheric Processes and Climate

NETCARE includes both modeling and field work activities. For example, the summer of 2014 was a particularly active field season for NETCARE, with large-scale field work occurring in the Arctic. Ten NETCARE scientists were on board the Canadian Coast Guard Service Amundsen, a research icebreaker, studying atmospheric and oceanic composition throughout the central Arctic. The campaign is being repeated in summer 2016 with a more extensive instrumentation complement.

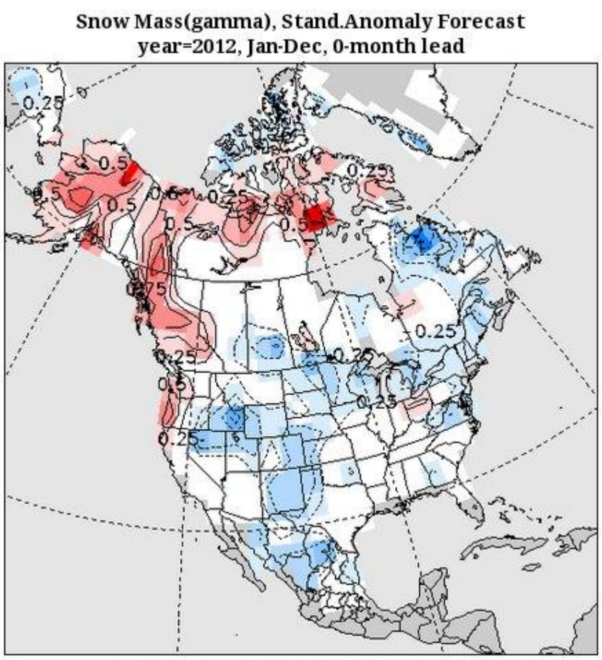
In addition to the Amundsen campaigns, aircraft campaigns (on the German POLAR6 aircraft) were conducted in July 2014 based out of Resolute Bay, Nunavut, aiming to assess the different roles that oceanic input and long range transport play in driving atmospheric composition. As well a campaign was held in spring 2015 in a pan-Arctic sense, to study Arctic Haze.

CanSISE

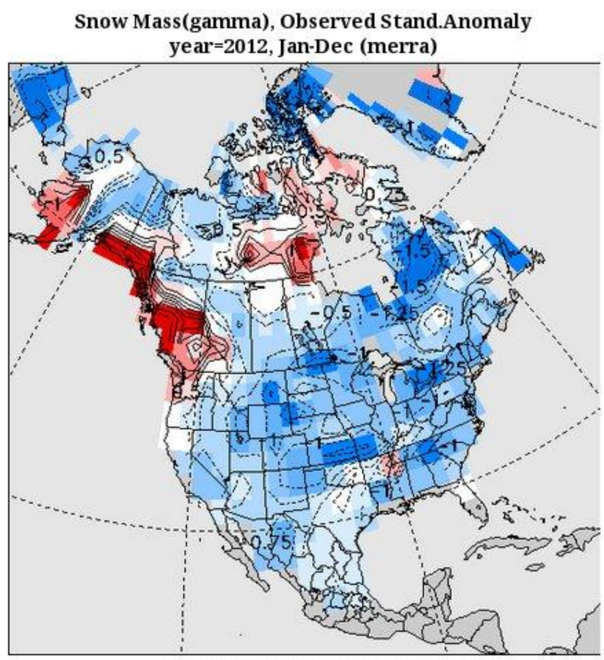
Canadian Sea Ice and Snow Evolution Network

The Canadian Sea Ice and Snow Evolution (CanSISE) Network seeks to advance our ability to predict Arctic sea ice and snow in Canada's sub-Arctic, alpine, and seasonally snow-covered regions. It aims to exploit advances in climate observations and climate modelling that allow us to forecast these quantities over seasons, years, and even decades. The CanSISE Network is also seeking to understand and exploit the role that Northern Hemisphere snow and sea ice processes play in climate variability and climate change. The CanSISE Network is a collaborative partnership between researchers from eight Canadian universities (UofT, York, McGill, Victoria, Guelph, Waterloo, UBC, UNBC) and three partner organizations (the Climate Research Division of Environment and Climate Change Canada, the Canadian Ice Service, and the Pacific Climate Impacts Consortium). To a unique degree, CanSISE is bringing together university and government researchers with climate modelling and observational expertise. CanSISE is funded under the NSERC CCAR program and is led by **Prof. Paul Kushner (University of Toronto)**.

The CanSISE Network has three Research Areas focussed on (A) prediction, (B) climate change detection and attribution, and (C) process studies related to snow and sea ice and their roles in climate. Each of these research areas has an associated series of collaborative projects whose outcomes are tied to the project's four Deliverables, which represent concrete targets for the Network to complete over its 5-year duration.



12-season calibrated ensemble mean standardized anomaly forecast.



Observed standardized anomaly.

Our thanks to the University of Toronto Connaught Fund for supporting this Summer Institute, and to NSERC for its support through the Climate Change and Atmospheric Research (CCAR) Program and the Collaborative Research and Training Experience (CREATE) Program.

We would also like to acknowledge the following for their additional support of our three networks:

PAHA/CANDAC

Aboriginal Affairs and Northern Development Canada, the Arctic Research Infrastructure Fund, Atlantic Innovation Fund/Nova Scotia Research and Innovation Trust, Canadian Foundation for Climate and Atmospheric Science, Canada Foundation for Innovation, Canadian Space Agency, Dalhousie University, Environment and Climate Change Canada, Government of Canada International Polar Year, NSERC, the Northern Scientific Training Program, Ontario Innovation Trust, Ontario Research Fund, Polar Continental Shelf Program, the US Study of Environmental Arctic Change (SEARCH) and the University of Toronto.

NETCARE

Environment and Climate Change Canada, Fisheries and Oceans Canada, Alfred Wegener Institute, ArcticNet National Centre of Excellence, and the Surface Ocean-Lower Atmosphere Study (SOLAS) program.

CanSISE

Environment and Climate Change Canada: Atmospheric Science and Technology Division, Canadian Climate Centre for Modelling and Analysis, Canadian Ice Service, and the Pacific Climate Impacts Consortium.

PAHA/CANDAC: http://www.candac.ca

NETCARE: http://www.netcare-project.ca

CanSISE: http://www.cansise.ca/
@CanSISE https://twitter.com/CanSISE

CREATE-AAS: http://www.candac.ca/create/
@CREATEArcticSci https://twitter.com/CREATEArcticSci
/CANDAC http://www.facebook.com/groups/CANDAC/
CREATE Arctic Science Blog http://createarcticscience.wordpress.com/

Summer Institute Sponsor

We would also like to thank ABB for its additional sponsorship of the Connaught Summer Institute.

2016 Connaught Summer Institute in Arctic Science: Atmosphere, Cryosphere, and Climate

Nottawasaga Inn, Alliston, Ontario
July 18-22, 2016

Thank-you to ABB for sponsoring the Summer Institute

http://new.abb.com/ca

http://new.abb.com/products/measurement-products/analytical

2016 Connaught Summer Institute Program

Day 1: Monday July 18, 2016

Lectures will be held in room 2 and posters will be on display in room 1 on the ground floor.
Poster boards will be set up on Monday morning and posters can be hung in room 1 any time after arrival.
Please refer to page 25 for poster room layout, including individual poster locations.
The Welcoming Icebreaker begins at 8:30 PM at the lower patio, with the Starlight Lounge as the alternate location in case of rain. See page 22 for indoor map.

Time	Activity	Speaker/Organizer	Topic
10:00 – ~11:30	Chartered bus departs Holiday Inn (280 Bloor Street West, Toronto, ON) for the Nottawasaga Inn. Please be there and ready to leave promptly at **9:45 AM**.		
11:30 – 12:00	Arrival and check-in at Nottawasaga Inn (6015 Ontario 89, Alliston, ON)		
12:00 – 1:30	Lunch (Riverview Dining Room)		
1:30 – 1:45	Welcoming remarks	Kimberly Strong	Introduction
1:45-1:55		Shannon Hicks	Remarks from the CREATE/PAHA Trainees' Advisory Committee (TAC)
1:55-2:00		Yasmin AboEl-Fetouh	Overview of the Career Panel
2:00 – 3:45	Jamboree	All attendees	Speaker and Student Jamboree (two minutes and one slide per attendee)
3:45 – 4:15	Coffee break		
4:15 – 5:00	Lecture A	Peter Braesicke (1/3)	Composition-climate interactions: introduction
5:00 – 5:45	Lecture B	Patrick Hayes (1/2)	Arctic aerosols: what are they and where do they come from?
5:45 – 6:30	Lecture C	Deborah Webster (1/3)	Inuit heritage
6:30 – 6:35	Icebreaker introduction	CREATE/PAHA TAC	
6:35 – 7:00	Free time (except for poster judges – they will meet in room 2 for a short discussion)		
7:00	Dinner (Riverview Dining Room)		
8:30	Welcoming Icebreaker	CREATE/PAHA Trainees' Advisory Committee	

Day 2: Tuesday July 19, 2016

Lectures will be held in room 2 and posters will be on display in room 1 on the ground floor.
Please stay near your poster for your assigned presentation times during the Poster Session.
Note that awards will be given to the best posters on Thursday evening after the last lecture.
Judges will be evaluating your poster during your assigned presentation times.
Outdoor recreational activities will take place on field 2 (see map on page 23) beginning at 8:30 PM.

Time	Activity	Speaker/Organizer	Topic
7:00 – 9:00	Breakfast (Riverview Dining Room)		
9:00 – 9:45	Lecture A	Chris Derksen (1/3)	Terrestrial snow and the global climate system
9:45 – 10:30	Lecture B	John Fyfe (1/3)	Influence of internal variability on Arctic sea ice trends
10:30 – 11:00	Coffee break		
11:00 – 12:30	Poster Session	All attendees	
12:30 – 1:30	Lunch (Riverview Dining Room)		
1:30 – 3:00	Free time		
3:00 – 3:45	Lecture C	Debra Wunch (1/1)	The role of the Arctic and Boreal region in the global carbon cycle
3:45 – 4:30	Lecture D	Patrick Hayes (2/2)	Aerosols and climate: the big climate impact of small particles
4:30 – 5:00	Coffee break		
5:00 – 5:45	Lecture E	Brian Connor (1/1)	Measurements of ClO in the Antarctic stratosphere
5:45 – 6:30	Lecture F	Bill Simpson (1/2)	Arctic oxidation chemistry
6:30 – 7:00	Free time		
7:00	Dinner (Riverview Dining Room)		
8:30	Free time & optional outdoor recreational activity	All attendees	Outdoor sports (soccer, volleyball, ultimate frisbee, horseshoes)

Day 3: Wednesday July 20, 2016

Lectures will be held in room 2 and posters will be on display in room 1 on the ground floor.
We will take a group photograph today during the afternoon break or after lecture G.
The Career Panel will take place in room 2 at 8:00 PM after dinner.

Time	Activity	Speaker/Organizer	Topic
7:00 – 9:00	Breakfast (Riverview Dining Room)		
9:00 – 9:45	Lecture A	John Fyfe (2/3)	Natural and human drivers of Arctic temperature and sea ice changes
9:45 – 10:30	Lecture B	Deborah Webster (2/3)	Conducting archaeological projects in Nunavut
10:30 – 11:00	Coffee break		
11:00 – 11:45	Lecture C	Peter Braesicke (2/3)	Composition-climate interactions: the recent past
11:45 – 12:30	Lecture D	Ray Clement (1/1)	The search for zero: How low can we go and what does it mean?
12:30 – 1:30	Lunch (Riverview Dining Room)		
1:30 – 3:00	Free time		
3:00 – 3:45	Lecture E	Henry Buijs (1/1)	Instrumentation for the accurate and sensitive remote sensing of the atmosphere
3:45 – 4:30	Lecture F	Boyd Tolton (1/1)	Remote sensing leak detection in the oil & gas industry
4:30 – 5:00	Coffee break and group photograph		
5:00 – 6:30	Lecture G	Bob Holmes & Peter Calamai	Science journalism
6:30 – 7:00	Free time		
7:00 – 8:00	Dinner (Riverview Dining Room)		
8:00 – 9:30	Career Panel	Henry Buijs Ray Clement Sarah Finkelstein Gabrielle Gascon Boyd Tolton	Moderated by Yasmin AboEl-Fetouh

Day 4: Thursday July 21, 2016

Lectures will be held in room 2 and posters will be on display in room 1 on the ground floor. Indoor recreational activities (mini-golf) will take place in Sports and Leisure Dome 2 (see map on page 23) beginning at 8:30 PM.

Time	Activity	Speaker/Organizer	Topic
7:00 – 9:00	Breakfast (Riverview Dining Room)		
9:00 – 9:45	Lecture A	Chris Derksen (2/3)	Observations of Arctic snow: from snowpits to satellites
9:45 – 10:30	Lecture B	Gabrielle Gascon (1/1)	Understanding and monitoring Arctic weather using Iqaluit Supersite meteorological observations
10:30 – 11:00	Coffee break		
11:00 – 11:45	Lecture C	Sarah Finkelstein (1/1)	Proxy-based reconstructions of Arctic paleoclimate
11:45 – 12:30	Lecture D	Peter Braesicke (3/3)	Composition-climate interactions: what will the future bring?
12:30 – 1:30	Lunch (Riverview Dining Room)		
1:30 – 3:00	Free time (except for poster judges – they will meet in room 2 at 1:30 to decide on poster awards)		
3:00 – 4:30	Workshop I	Dorothy Gordon (1/1)	Career development workshop: How to find your Superpower within to help you land your dream job
4:30 – 5:00	Coffee break		
5:00 – 5:45	Lecture E	John Fyfe (3/3)	Arctic sea ice decline in the global context
5:45- 6:30	Lecture F	Bill Simpson (2/2)	Arctic tropospheric chemistry and climate
6:30 – 7:00	Poster Awards	Poster judges	The posters awards will be announced
7:00	Dinner (Riverview Dining Room)		
8:30	Free time & optional indoor recreational activity	All attendees	Mini-golf

Day 5: Friday July 22, 2016

Lectures will be held in room 2. Please remove your poster from room 1 before lunch on Friday.
Please check out by 11 AM; you may want to check out in the morning before lectures begin at 9 AM.
The front desk can store your luggage until departure.

Time	Activity	Speaker/Organizer	Topic
7:00 – 9:00	Breakfast (Riverview Dining Room)		
9:00 – 9:45	Lecture A	Chris Derksen (3/3)	Climate models and snow: predictions and projections
9:45 – 10:30	Lecture B	Deborah Webster (3/3)	Arctic archaeology and oral tradition
10:30 – 11:00	Coffee break		
11:00 – 12:30	Workshop II	Bob Holmes (2/2)	Science writing workshop
12:30 – 1:00	Closing Session	CREATE/PAHA Trainees' Advisory Committee	Summer Institute survey and closing remarks
1:00 – 2:00	Lunch (Riverview Dining Room)		
2:00	Depart Nottawasaga Inn for Toronto. Please be ready to leave at **2:00 PM** – meet in the front lobby.		
~3:30	Arrive at the Holiday Inn (280 Bloor Street West)		

Jamboree (2:00-3:45, Monday, July 18 in Room 2)

Requests

The slides are in alphabetical order by last name beginning with speakers followed by students. Please refer below to find your presentation slot and be prepared to begin when the person before you finishes. You will be given two minutes to introduce yourself and your research. Please be courteous to the next speaker and keep to time. Please excuse any formatting errors that may have occurred in compiling the slides into one presentation.

Organizers

1. Kimberly Strong
2. Aubyn O'Grady

Speakers and Panelists

1. Peter Braesicke
2. Brian Connor
3. Chris Derksen
4. John Fyfe
5. Patrick Hayes
6. Bob Holmes
7. Boyd Tolton
8. Deborah Kigjugalik Webster

Kim Strong will introduce absent speakers:

9. Henry Buijs
10. Peter Calamai
11. Ray Clement
12. Sarah Finkelstein
13. Gabrielle Gascon
14. Dorothy Gordon
15. Bill Simpson
16. Debra Wunch

Jamboree *(continued)*

Students

1. Yasmin AboEl-Fetouh (PhD, Université de Sherbrooke)
2. Whitney Bader (PDF, University of Toronto)
3. Ralf Bauer (PDF, University of Toronto)
4. Kristof Bognar (MSc, University of Toronto)
5. Brendan Byrne (PhD, University of Toronto)
6. Laurence Coursol (MSc, Université du Québec à Montréal)
7. April Dalton (PhD, University of Toronto)
8. Joan De Vera (PhD, University of Toronto)
9. Jing Feng (MSc, McGill University)
10. Sham Gamage (PhD, Western University)
11. Shannon Hicks (PhD, Western University)
12. Siraj ul Islam (PDF, University of Northern British Columbia)
13. Liviu Ivanescu PhD, Université du Québec à Montréal)
14. Ali Jalali (PhD, Western University)
15. Paul Jeffrey (PhD, University of Toronto)
16. Allison Kolly (MSc, McGill University)
17. Kunna Li (MSc, University of Toronto)
18. Li Li (PDF, St. Mary’s University)
19. Zhenhua Li (PDF, University of Saskatchewan)
20. Erik Lutsch (PhD, University of Toronto)
21. Sarah Murphy (PhD, Washington State University)
22. Ludovick Pelletier (MSc, Université du Québec à Montréal)
23. Keyvan Ranjbar (PhD, Université de Sherbrooke)
24. Ellen Reyes (MSc, University of Waterloo)
25. Sébastien Roche (PhD, University of Toronto)
26. Rodrigue Sandrin (MSc, University of Toronto)
27. Kanupria Seth (UG, University of Toronto)
28. Keegan Smith (MSc, Carleton University)
29. Chris Vail (MSc, University of New Brunswick)
30. Jeff VanKerkhove (PhD, Western University)
31. Dan Weaver (PhD, University of Toronto)
32. Charlie White (MSc, University of Toronto)
33. Xiaoyi Zhao (PhD, University of Toronto)

Career Panel (8:00-9:30 PM, Weds, July 20 in Room 2)

The Career Panel will take place after supper on Wednesday, July 20 from 8:00 to 9:30 PM and will be moderated by Yasmin AboEl-Fetouh from the CREATE/PAHA Trainees' Advisory Committee. This event provides an opportunity for Summer Institute attendees to gain insight into future career paths. This panel of successful science professionals represents a range of job opportunities available to science graduates. The session will begin with a short introduction by each panelist, and proceed into a question and answer session.

Students are encouraged to think about their professional goals and anticipated career paths, and what questions they might ask during the Career Panel session to help inform or inspire their future job-seeking efforts. A question-submission box will be provided in room 1 during the week to enable students to anonymously submit their questions in writing ahead of time, if they wish to do so. The panel (or specific panelist) will be asked these questions during the session by the moderator. Students may also ask questions directly during the session.

Panelists

Henry Buijs
(industry)
Co-founder of Bomem,
Chief Technology Officer
at ABB Inc.

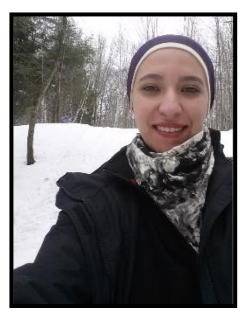
Ray Clement
(government)
EnviroAnalysis, former
Senior Research Scientist, Ontario
Ministry of the Environment

Sarah Finkestein
(academia)
Associate Professor,
Department of Earth Sciences,
University of Toronto

Gabrielle Gascon
(government)
Physical Sciences Specialist,
Environment and Climate
Change Canada

Boyd Tolton
(industry)
Chief Science Officer,
Synodon

Yasmin AboEl-Fetouh
(moderator)
PhD Student,
Université de Sherbrooke



Suggested Readings and Websites

Peter Braesicke: https://www.imk-asf.kit.edu/english/staff_1638.php

Henry Buijs: http://new.abb.com/ca
Suggested viewing: http://www.ace.uwaterloo.ca/ (The ACE website at U of Waterloo has many very good papers related to ACE measurements. Look for papers about ground-breaking new observations of the upper atmosphere.)

Peter Calamai: https://carleton.ca/sjc/profile/calamai-peter/
http://www.sciencemediacentre.ca/

Ray Clement: http://www.enviroanalysis.ca/about
https://www.ontario.ca/page/ministry-environment-and-climate-change

Brian Connor: Nedoluha et al., 20 Years of ClO Measurements in the Antarctic Lower Stratosphere, Atmos. Chem. Phys. Discuss., doi:10.5194/acp-2016-188, in review, 2016

Chris Derksen: https://www.ec.gc.ca/sc-cs/default.asp?lang=En&n=DE007646-1
Suggested readings:
Callaghan et al., The changing face of Arctic snow cover: A synthesis of observed and projected changes. Ambio. 40:17–31, 2011.
Sturm, M., J. Holmgren, and G. Liston, A seasonal snow cover classification system for local to global applications. Journal of Climate. 8: 1261-1283, 1995.
Mudryk, L., C. Derksen, P. Kushner, and R. Brown, Characterization of Northern Hemisphere snow water equivalent datasets, 1981–2010. Journal of Climate. 28: 8037-8051, 2015.

Sarah Finkelstein: http://www.es.utoronto.ca/people/faculty/finkelstein-sarah/
Suggested reading: Miller et al., PALEOCLIMATE | Paleoclimate History of the Arctic. Encyclopedia of Quaternary Science (Second Edition). Amsterdam: Elsevier, 113-125, 2013.

John Fyfe: http://www.cccma.ec.gc.ca/

Gabrielle Gascon: https://www.researchgate.net/profile/Gabrielle_Gascon

Dorothy Gordon: https://ca.linkedin.com/in/dgordonhrprofessional

Patrick Hayes: https://sites.google.com/site/hayesgroupatmontreal/home
Suggested viewing: http://earthobservatory.nasa.gov/Features/Aerosols/ (This NASA website is a good introduction to aerosols.)

Bob Holmes: http://bobholmes.org/about-us/

Bill Simpson: http://www.uaf.edu/chem/simpson

Kimberly Strong: http://www.atmosp.physics.utoronto.ca/people/strong/strong.html

Boyd Tolton: http://www.synodon.com

Deborah Kigjugalik Webster: http://www.cbc.ca/news/canada/north/inuit-special-constable-nunavut-deborah-webster-1.3528764

Debra Wunch: https://sites.physics.utoronto.ca/debrawunch

Nottawasaga Inn Facilities

Complimentary with Accommodations

25 metre indoor swimming pool
100ft waterslide
Squash & racquetball courts
Fully-equipped fitness centre
Sauna & Whirlpool
(Available during scheduled times. Age and ability restrictions may apply)

Seasonal

Outdoor swimming pool
Bocce
Volleyball
Horseshoes
Nature/jogging trail

Pay-As-You-Play Activities

45 holes of golf on 2 courses
Private golf lessons (CPGA certified instructors)
(Call main pro shop for rates & tee-off times - (705) 435-5504)

Centre Ice Arena
2 NHL-size ice surfaces

Jungle Quest
Indoor 18 hole miniature golf
($5. per person)

Games Room
Video arcade and billiards tables

Tennis
3 indoor courts
(call the Sports & LeisureDome for rates & availability - (705) 435-5502)

Aerobics, Aquafit, Fitness Classes, Swim Lessons
(call the Sports & LeisureDome for rates & availability - (705) 435-5502)

Massage Therapy
(rates starting at $45. Call the Sports & LeisureDome - (705) 435-5502)

Esthetician - (705) 435-8829

Hair Salon - (705) 435-4570

Starlite Lounge

Located on the 3rd floor, east wing
Monday to Saturday: 3pm - 12am
Sunday: 4pm - 11pm

Sports & LeisureDome

Hours of Operation

Monday to Thursday
Facility: 6:30am - 10:00pm
Fitness Club: 6:30am - 9:30pm
Pool & Sauna: 7:00am - 9:30pm
Waterslide: 8:00pm - 9:00pm

Friday
Facility: 6:30am - 11:00pm
Fitness Club: 6:30am - 10:30pm
Pool & Sauna: 7:00am - 10:00pm
Waterslide: 5:00pm - 9:30pm

Saturday
Facility: 8:00am - 11:00pm
Fitness Club, Pool, Sauna: 8:00am - 10:00pm
Waterslide: 10:00am - 12:00pm, 1:00pm - 5:00pm, 8:00pm - 9:00pm

Sunday
Facility: 9:00am - 9:00pm
Fitness Club, Pool, Sauna: 9:00am - 8:00pm
Waterslide: 10:00am - 12:00pm, 6:30pm - 8:00pm
(Hours of operation may change seasonally)

Riverview Dining Room

Breakfast Buffet: 7:00am - 10:00am
Lunch Buffet: 11:30am - 1:30pm
Sunday Brunch: 10:30am - 1:30pm

Dinner (Table d'hôte)
Monday - Thursday: 6:00pm - 9:00pm
Friday & Saturday: 5:30 - 9:30pm
Sunday: - 5:30pm - 9:00pm
(A buffet dinner may be substituted for menu options during certain holiday periods)

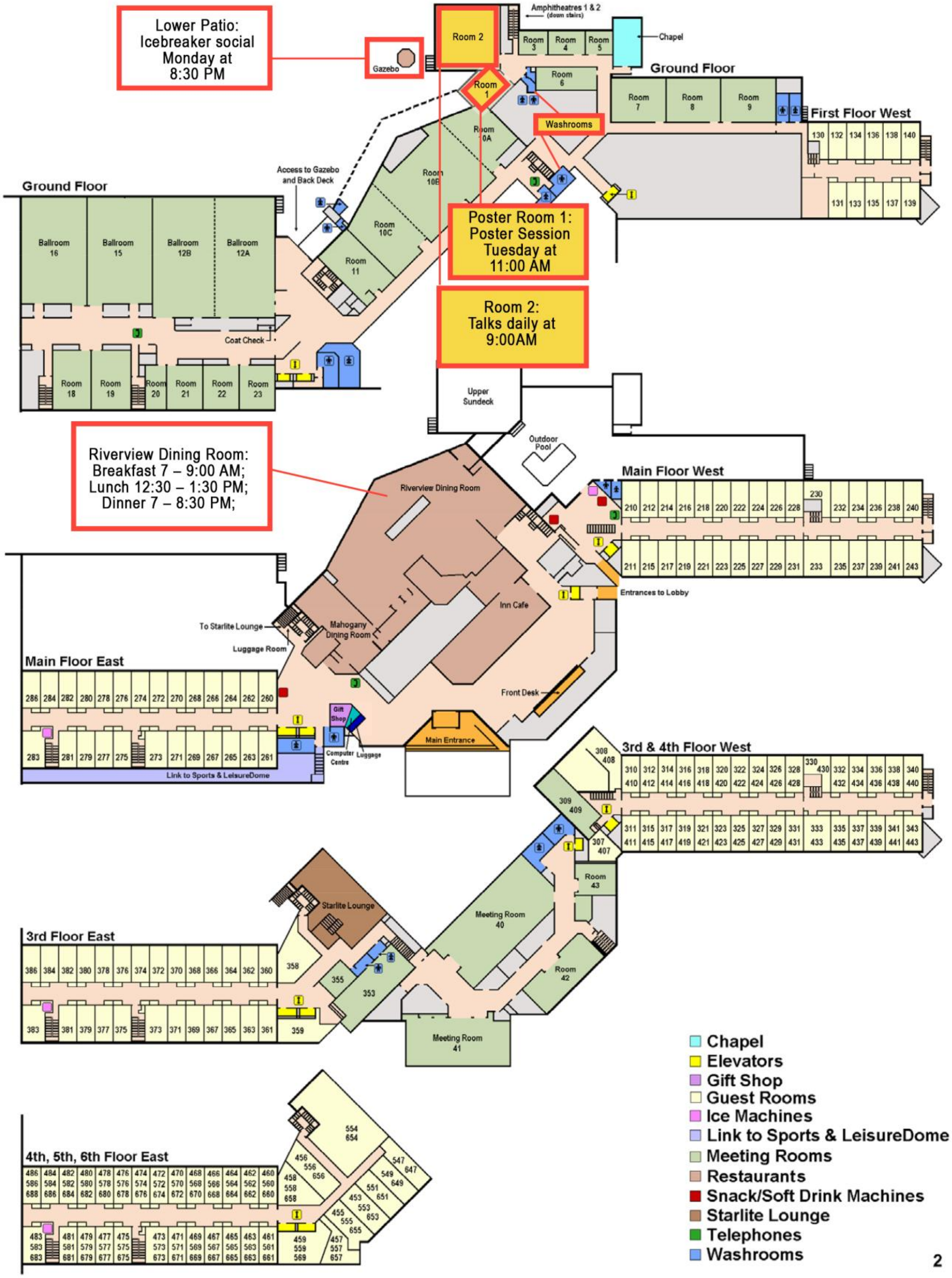
Mahogany Room

Monday - Thursday: 6:00pm - 9:00pm
Friday & Saturday: 5:30 - 9:30pm
Closed Sundays & Holidays
(Smart-casual dress code in effect for Mahogany Room)

Inn Café

Monday - Thursday: 10:00pm - 10:00pm
Friday & Saturday: 10:00am - 11:00pm
Sunday: - 9:00pm - 10:00pm

Nottawasaga Inn Maps



Nottawasaga Inn Maps

Poster Session (11:00-12:30, Tuesday, July 19, Room 1)

Posters will be displayed in room 1 from Monday through Friday morning. Poster boards will be set up on Monday morning. Please mount your posters in the locations indicated on the next page sometime on Monday. Please stay near your poster for your assigned session on Tuesday, as judges will be visiting during that time. Note that awards will be given to the best posters during the awards ceremony before dinner on Thursday. Please take down your poster before lunch on Friday.

Poster judges:

Peter Braesicke
Chris Derksen
John Fyfe
Patrick Hayes
Bob Holmes
Boyd Tolton

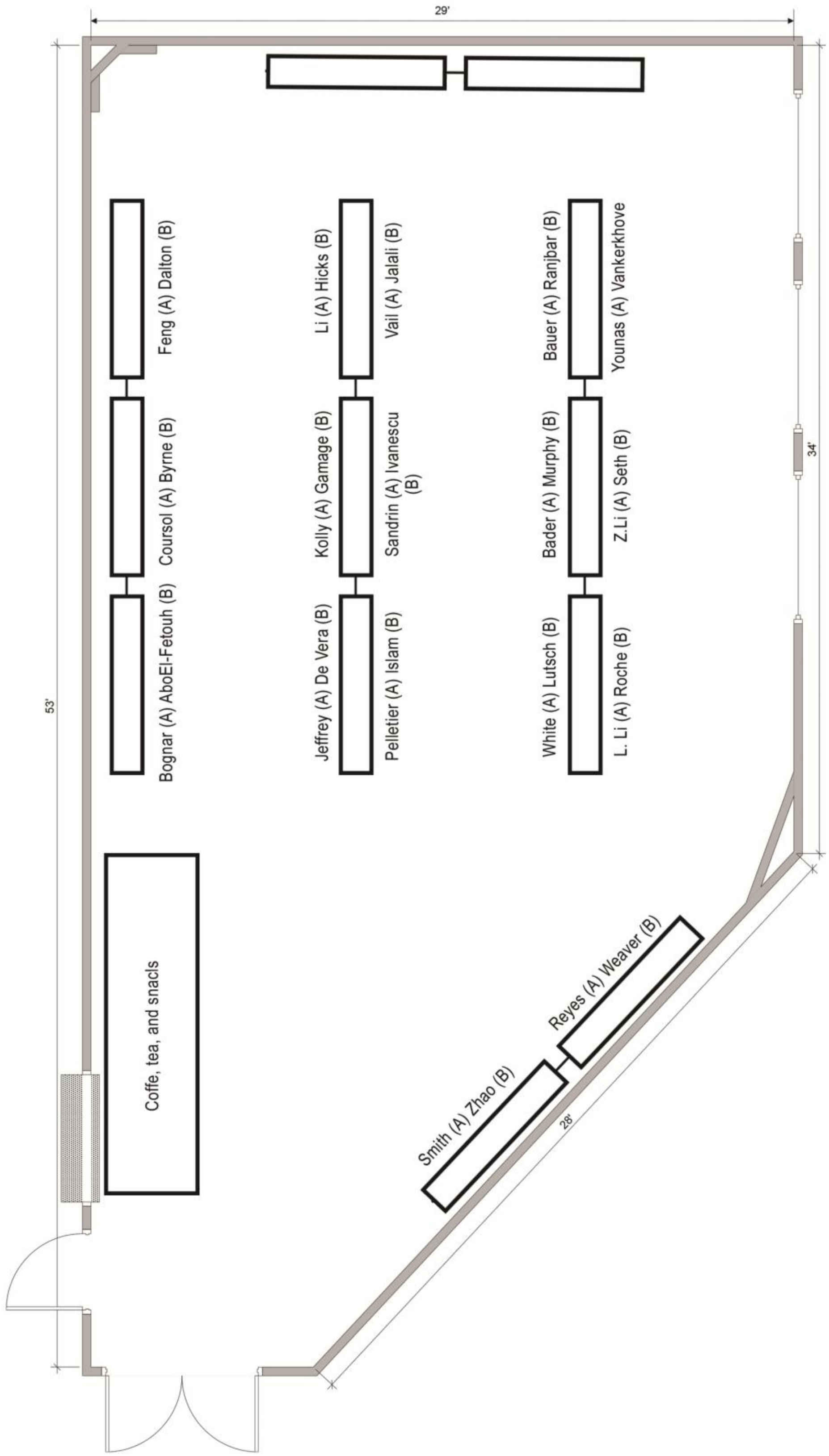
Session A (11:00 – 11:45 AM):

Kristof Bognar (MSc)
Laurence Coursol (MSc)
Jing Feng (MSc)
Allison Kolly (MSc)
Kunna Li (MSc)
Ludovick Pelletier (MSc)
Ellen Reyes (MSc)
Rodrigue Sandrin (MSc)
Keegan Smith (MSc)
Chris Vail (MSc)
Charlie White (MSc)
Whitney Bader (PDF)
Ralf Bauer (PDF)
Siraj ul Islam (PDF)
Li Li (PDF)
Zhenhua Li (PDF)

Session B (11:45 – 12:30 PM):

Yasmin AboEl-Fetouh (PhD)
Brendan Byrne (PhD)
April Dalton (PhD)
Joan De Vera (PhD)
Sham Gamage (PhD)
Shannon Hicks (PhD)
Liviu Ivanescu (PhD)
Ali Jalali (PhD)
Paul Jeffrey (PhD)
Erik Lutsch (PhD)
Sarah Murphy (PhD)
Keyvan Ranjbar (PhD)
Sébastien Roche (PhD)
Kanupria Seth (UG)
Jeff VanKerkhove (PhD)
Dan Weaver (PhD)
Xiaoyi Zhao (PhD)

Poster Room Layout (Room 1)



Poster Abstracts

Climatological-scale variation of the fine mode aerosol optical depth and effective radius over Eureka and Ny Alessund, Spitsbergen

Yasmin Aboel Fetouh[1] and N.T. O'Neill[1]

[1]Centre d'Applications et de Recherches en Télédétection, Université de Sherbrooke, Sherbrooke, Canada

The Arctic atmosphere and Arctic climate is affected by different types of aerosols that usually originate from southern latitudes. High pollution concentrations during late winter and early spring result in what is known as the Arctic haze; a mixture of ozone precursors and different kinds of aerosols such as sulfate and black carbon. The optical and radiative forcing effects of aerosols change with particle size and particle nature. The fine mode effective radius, and the fine mode optical depth are robust retrieval parameters that together, represent the source of the greater part of aerosol optical variations. At Eureka we have been using starphotometer and lidar data to develop the solid beginnings of an aerosol polar winter optical climatology. Ny Alesund, Spitsbergen is a ground-based measuring station in the European Arctic for which we have another, more extensive, starphotometer optical climatology (2002 to the present). These two data sets are being used to investigate the climatological scale variations of fine mode optical depth and effective radius over Eureka and Ny Alesund; some preliminary results will be presented.

Heavy methane to explain the unexplained recent methane growth?

Whitney Bader[1], K. Strong[1], and K. Walker[1]

[1]Department of Physics, University of Toronto, Toronto, ON, M5S 1A7, Canada

Methane (CH_4) is the second most important greenhouse gas emitted by human activities in the Earth's atmosphere. Although it is roughly 200 times less abundant than carbon dioxide, it is a 28 times more potent greenhouse gas. Approximately one-fifth of the changes in the Earth's balance energy caused by human-linked greenhouse gases since the beginning of industrialization (~1750) is due to methane. Methane is emitted by both natural sources and human activities. Indeed, methane can be emitted to the atmosphere through coal mining, oil and gas exploitation, rice cultures, domestic ruminant animals, biomass burning, waste management, wetlands, termites, methane hydrates and ocean. In the atmosphere, methane is mainly destroyed by the radical hydroxyl, also called the detergent of the atmosphere, and therefore plays a major role on the oxidizing capacity of the atmosphere. Since the beginning of the industrialization, atmospheric methane concentrations have increased by 260% to reach 1824 pbb in 2013. From the 1980s until the beginning of the 1990s, atmospheric methane was significantly on the rise, then stabilized during 1999-2006 to rise again afterwards. To this day, the source or sink responsible of this latter increase remains unexplained.

Through each emission process, heavy molecules of methane (with one additional neutron either on a carbon or on one hydrogen atom) are emitted along methane ($^{12}CH_4$). The main heavy molecules of methane, called isotopologues ($^{13}CH_4$ and CH_3D), are respectively ~110 and ~60 000 times less abundant than methane. Despite their small abundances, they give crucial information on the concentration of methane in the atmosphere and its evolution. Indeed, both isotopologues are emitted with specific emission ratio depending on the emission sources. Determining isotopic ratio of atmospheric methane is therefore a unique tracer of its budget.

Validating satellite measurements over the Canadian high Arctic

Ralf Bauer[1], K. A. Walker[1,2], S. Conway[1], K. Strong[1], C. D. Boone[2], and P. F. Bernath[3,4]

[1]University of Toronto, Toronto, Canada
[2]University of Waterloo, Waterloo, Canada
[3]Old Dominion University, Norfolk VA, USA
[4]University of York, York, United Kingdom

In the high Arctic, a snowy world home to animals like the Arctic wolf and the Arctic hare, human settlements are rare. Yet, determined scientists can be found working in research stations to learn more about what is happening to our atmosphere. For example, PEARL (Polar Environment Atmospheric Research Laboratory) is such a research facility and is located in the Canadian high Arctic. There is much to learn, as the climate in the Arctic is warming – much faster than where most Canadians and U.S. citizens live. Furthermore, while the ozone hole seems like a problem from a long time ago, it still appears every year. Researchers take great care in monitoring the emissions that harm the ozone layer, which shields us from harmful UV-radiation that can cause skin cancer.

One cannot just build these types of research stations equipped with instruments and well-trained scientists all over the world, that would be much too expensive. If you want a complete picture of the whole globe, space is the answer. Man-made satellites orbit the Earth, where they quietly provide all kinds of services to us down below. There are communication satellites, satellites for navigation purposes, satellites that send and receive TV programs, among others. Some satellites however, measure what is in the Earth's atmosphere – in a similar way to what is done at the Arctic research station PEARL mentioned above. Due to their position, these can monitor the whole planet!

Yet, measuring the atmosphere with a satellite is a complicated manner. You need to always check whether what you measure is correct. One way to do it is to compare it with measurements taken from the ground, like those collected by the researchers at the Arctic station. These types of comparisons are what my work is about. Please, feel free to have a look at my poster to learn how well one particular satellite measured substances harmful to the ozone layer in comparison to what the scientists in the Arctic also measured. Where they seeing the same things?

A bromine explosion event, as seen by ground based spectrometers at Eureka

Kristof Bognar[1]

[1]Department of Physics, University of Toronto, Toronto, Canada

Ozone in the atmosphere is important not only because it reduces the amount of UV radiation reaching the surface, but also because it is a potent greenhouse gas. Accurate information on the processes affecting ozone concentrations is essential to understand the changes the global climate is facing today. In the Arctic winter, the long months of darkness and strong stratospheric winds create an isolated atmosphere that gives rise to unique ozone chemistry. Just like in the Antarctic, chlorine is trapped in the polar stratosphere. When the sun returns in the spring, chlorine breaks down ozone via reactions activated by sunlight. Ozone is also present – in smaller quantities – near the ground in the Arctic. In the springtime, periodic increases in the concentrations of bromine (an element chemically similar to chlorine and commonly found in sea salt) give rise to often complete destruction of near surface ozone. How exactly the bromine enters the atmosphere, how the bromine levels are maintained, and how these so called bromine explosions evolve are questions yet to be answered satisfactorily.

To study ozone and related chemistry, the University of Toronto installed two Ground Based Spectrometers (GBS) in the High Arctic, in Eureka, Nunavut. These instruments, looking straight up to the sky, can derive information about atmospheric components using a technique called Differential Optical Absorption Spectroscopy. When the sun is near the horizon, its rays pass through more of the atmosphere than when the sun is high in the sky. Taking the ratio of the spectra at noon and twilight thus leaves behind the signature of the extra absorption by atmospheric components (ozone, nitrogen dioxide, chlorine and bromine compounds) during twilight hours. If the instruments are pointed at an angle instead of straight up, information on the vertical distribution of gases (mainly bromine oxide) can also be obtained.

I will present observations of a bromine explosion event in March 2016, detected by one of the GBSs at Eureka. While stratospheric ozone remained unaffected, near surface ozone (as measured by other instruments in Eureka) has disappeared for nearly a week. Satellite observations show that bromine was not transported into the region, indicating relatively local release. Exploring the atmospheric conditions before and during the event might shed light on the uncertain origins of atmospheric bromine, and give some insight into the conditions required for bromine explosions to unfold.

Sensitivity of CO_2 flux inversions to the temporal and spatial distribution of observations

Brendan Byrne[1]

[1]Department of Physics, University of Toronto, Toronto, Canada

Inverse modeling of regional CO_2 sources and sinks is sensitive to the observational coverage of the observing network. Here we use the GEOS-Chem adjoint model to examine the sensitivity of observations to surface fluxes of CO_2 for data from the surface in-situ network, the Total Carbon Column Observing Network (TCCON), the Greenhouse Gases Observing Satellite (GOSAT), and the Orbiting Carbon Observatory (OCO-2). We find that OCO-2 has the highest sensitivity to surface fluxes throughout the tropics and southern hemisphere, while surface observations have the highest sensitivity to surface fluxes in the northern extratropics. We perform Observing System Simulation Experiments (OSSEs) to examine how differences in sensitivities influence the ability to recover surface fluxes. In particular, we examine the impact of the spatiotemporal coverage of the different observing systems on the ability of the inversion analyses to recover the timing and amplitude of the seasonal cycle of the surface fluxes.

Using far infrared satellite observations for data assimilation in polar regions

Laurence Coursol [1], Q. Libois[1], P. Gauthier[1], and J.-P. Blanchet[1]

[1]Department of Earth and Atmospheric Sciences, UQAM, Montréal, QC, Canada

Data assimilation optimally combines numerical weather predictions and huge amounts of observations to provide the best weather prevision. In this context, most available observations come from satellites measurements and a large majority of these measurements are taken in the thermal infrared, by satellites such as AIRS and IASI. However, the thermal infrared constitutes only half of the Earth's emission spectrum, the other half being the far infrared, ranging from 15 to 50 μm. The last satellite measurements in the far infrared region were taken more than 40 years ago by Russian and American spacecrafts. Recently, a number of theoretical studies have shown the added-value of far infrared observations for remote sensing of water vapor and clouds, especially in dry and cold regions. More practical studies have evaluated the performances of virtual interferometers similar to AIRS and IASI but with a spectral coverage extending to the far infrared and concluded that the added-value depends on the sensitivity of the sensors. Here, we focus on a different kind of instrument capable of measuring the far infrared, namely radiometers. This study serves as a basis for the development of the future satellite mission TICFIRE (Thin Ice Clouds in Far IR Experiment) and shows the added-value of far infrared radiometry in polar regions and in particular at Eureka, NU. To do so, the analysis error, error after assimilating data, will be used and compared to the prevision error of the numerical weather prediction system. We show that for the troposphere, assimilating 9 channels of TICFIRE has the same effect on reducing the analysis error as assimilating 85 of AIRS channels.

Investigating the Missinaibi Formation, Hudson Bay Lowlands, Canada: implications for ice sheet paleogeography and paleoclimate

April S. Dalton[1] and Sarah A. Finkelstein[1]
With collaborators: Peter J. Barnett[2], Minna Väliranta[3], and Steven L. Forman[4]

[1]Department of Earth Sciences, University of Toronto, Toronto, Canada (aprils.dalton@mail.utoronto.ca)
[2]Department of Earth Sciences, Laurentian University, Sudbury, Canada
[3]Department of Environmental Sciences, University of Helsinki, Finland
[4]Department of Geology, Baylor University, Waco, TX, United States

Understanding the dynamics of ancient and modern ice sheets is important for developing and testing Earth System Models, which are used to predict future climates. However, evidence of past glaciations is often difficult to find owing to glacial erosion, a process whereby the most recent glacier erodes all evidence of previous glaciation. One way to understand the position of previous ice sheets is to study geological records from the previously glaciated region. However, such records are rare and often poorly preserved. The Missinaibi Formation is a unique, ancient, non-glacial deposit which pre-dates the most recent glacial flow, and is located in the Hudson Bay Lowlands, Canada. Since the Hudson Bay Lowlands are positioned near the growing center of many Pleistocene ice sheets, the age of this deposit can help inform about the presence or absence of regional ice sheets over time and can be used to address unresolved questions about the dynamism of the ice-sheet margin during the Pleistocene and the sensitivity of peri-glacial ecosystems to paleoenvironmental change. However, until now, attempts at dating the Missinaibi Formation have been hindered by unsuitable dating material. Our compilation of new and previously published chronological data suggests that this deposit may date to Marine Isotope Stage 3 (ca. 57,000 to ca. 29,000 yr BP; n = 20 radiocarbon dates; 4 thermoluminescence dates, 3 optically stimulated luminescence dates), which means that the position of the ice sheet margin had shifted, leaving this region ice-free during that time. These results have important implications for calibrating and refining Earth System Models since previous models of the ice sheet margin during that time had constrained it to Southern Ontario, which is 700 km to the south of the HBL. In addition to being an important record for constraining the extent of paleo ice sheets, the Missinaibi Formation represents a rare record of Pleistocene paleoenvironments. Results from the Ridge Site, which was dated to MIS 3, suggest that a boreal and wetland-type conditions similar to present-day prevailed throughout the Pleistocene in the HBL, as shown through plant macro-remains and pollen grains of *Pinus* (pine), *Picea* (spruce), *Alnus* (alder), *Betula* (birch), Cyperaceae (sedge), and spores of *Sphagnum* (peat moss). These plant remains can be used to quantitatively reconstruct temperature and precipitation using transfer functions. The results from the Ridge Site suggest that temperatures during MIS 3 were similar to present-day, but precipitation may have been lower during this interstadial time. Thus, we propose that paleo-climates inferred from Missinaibi Formation pollen assemblages may be used to help support chronological determinations.

Role of aerosols in understanding movement of contaminants in the Arctic

Joan De Vera[1], P. Chandan[1], A. Steffen[2], W. Landing[3], and B. Bergquist[1]

[1]Department of Earth Sciences, University of Toronto, Canada
[2]Air Quality Research Division, Science and Technology Branch, Environment Canada
[3]Department of Oceanography, Florida State University, U.S.A.

Trace elements such as iron (Fe), zinc (Zn), copper (Cu) and lead (Pb) play a critical role in the ocean because they act as nutrients and toxins to marine organisms. Trace elements and their isotopes can also be used as tracers to understand ocean processes such as the carbon cycle, anthropogenic contaminant transport and ocean circulation. However, their distribution and role are not well understood across many parts of the oceans. To bridge this gap, an international collaborative effort called GEOTRACES has been established to understand the role of trace elements in the world's ocean systems. My research is part of this broader program to study the cycling of Fe and Pb in the Canadian Arctic Ocean. Iron is an important marine micronutrient and in low concentration, it can limit primary production in the ocean. Because of its role in primary productivity, Fe is considered a key factor in understanding carbon cycling and ocean ecosystems. Lead concentrations and its isotopes can be used as tracers to study particulate contamination and ocean circulation and mixing.

In the first part of this research, we are focusing on aerosols because they could be significant sources of metals to seawater and to the Arctic. However, since the extent of dissolution in seawater determines the amount of metals (e.g., Fe) available for biological uptake, we are doing aerosol dissolution experiment. To do this, the aerosols were subjected to weak acid leach designed to extract the maximum amount of metal available for dissolution and thus to organisms. Aerosols can also reveal the recent sources of contamination in the Arctic as different Pb sources have different Pb isotope signatures.

In the initial set of measurements done on samples collected in the Arctic from 2013 to 2015, we found that the extent of Pb dissolution ranges from 82% to 93%. Analysis of other suite of metals (V, Cr, Cu, Zn and Cd) also showed above 50% dissolution. The high dissolution rate indicates that these aerosols are non-mineral in origin and therefore may have come from human activities and/or biomass burning. This can be confirmed by measuring the Pb isotopic ratios. Further analyses will analyze leachates for Fe as well. Previous studies of anthropogenic aerosols have shown high levels of Fe dissolution and thus we might find the same. As the current study is indicating that the Arctic aerosols have originated from human activities, the Pb isotopes can also be utilized to further reveal the sources of contaminants to the Arctic. Also, since we can potentially measure significant concentrations of Pb in the ocean coming from aerosols, we can use Pb isotope ratios to understand how Fe and Pb are distributed in the water column. Finally, since the dominant Pb sources change over time, the different water layers is expected to have different isotopic signatures that can be used to better understand the mixing time and circulation pattern of the Arctic Ocean.

Cloud-assisted retrieval of stratospheric water vapor from nadir view satellite measurements

Jing Feng[1] and Y. Huang[1]

[1]Department of Atmospheric & Oceanic Sciences, McGill University, Montreal, Canada

Water vapor in dry atmospheric environments is of great importance for weather and climate. For example, despite of its scarcity, stratospheric water vapor is an important atmospheric component that can greatly influence climate change, due to its radiative and chemical impacts. Recent studies suggest that stratospheric water vapor may have strong relations to surface climate change and stratospheric ozone loss, highlighting the need of improved monitoring of stratospheric water vapor. However, the retrieval of stratospheric water vapor is known to be challenging. Satellite nadir view radiance measurements usually do not have sufficient sensitivity to the low concentration of stratospheric water vapor while limb view measurements have large sampling footprints, making small scale water vapor hard to be detected.

This study tests the feasibility of retrieving the stratospheric water vapor in the presence of dense upper tropospheric clouds, which block the radiance emission and obscuration of the lower atmosphere for stratospheric retrieval. This investigation uses synthetic satellite radiance simulated from atmospheric profiles using a radiative transfer model, MODTRAN, and adopts a widely-used optimal estimation method [Rodgers 2000] that iteratively retrieve the stratospheric temperature and humidity.

We find the quality of retrieval results depends on several factors. High spectral resolution and low level of measurement noise are especially beneficial to the retrieval accuracy, while the position and amplitude of moistening also affect how well the retrieval can reproduce the truth profile. Nevertheless, it is possible to achieve a satisfactory retrieval accuracy for moistening occurring in lower stratosphere.

RALMO Rotational Raman Temperature Retrieval: Traditional Method and First Steps Towards The Application of Optimal Estimation Method (OEM) Retrieval

S. Mahagammulla Gamage[1], A. Haefele[1,2], and R.J. Sica[1]

[1]Department of Physics and Astronomy, The University of Western Ontario, London, Canada
[2]Federal Office of Meteorology and Climatology MeteoSwiss, Payerne, Switzerland

Raman---scatter lidars provide atmospheric temperature measurements with higher spatial and temporal resolution compared to the other traditional temperature measuring techniques such as radiosondes. In 1972 John Conney, first introduced temperature retrieval from lidar Rotational Raman (RR) backscatter signals that is also known as the traditional method [1]. The traditional method of retrieving RR temperature from lidar measurements is based on the ratio of the two pure RR signals [2].

The objective of this study is to retrieve atmospheric temperature using the traditional method and the Optimal Estimation Method (OEM) for the lidar measurements from Raman Lidar for Meteorological Observations (RALMO) located in Payerne, Switzerland (46 480 N, 6 560 E). The OEM is the most recent method of retrieving atmospheric aerosol, water vapor and temperature from lidar data used by the lidar community. The OEM is an inverse method, which estimates the most likely solution from solution space, and its associated covariance matrix of a set of retrieval parameters using a forward model based which includes the physics of the measurement including sensor characteristics [3].

For the first time a forward model is proposed to retrieve the Rotational Raman
(RR) temperatures using the OEM and it was used to create synthetic data. Applying the traditional retrieval method to the synthetic data produced temperature values with in ±4 K uncertainty with the radiosonde temperature measurements from ground to 15 km in altitude. In future the forward model will be tested using the synthetic data and later on the OEM will be applied to the RALMO measurements.

Key Words: Raman Lidar, OEM, Pure Rotational Raman Temperature, Radiosonde

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A Multi-year Water Vapour Mixing Ratio Climatology using the MeteoSwiss RAman Lidar for Meteorological Observation (RALMO), Step 1: Lidar Calibration, A Different Approach

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The last seven months have seen record-breaking high temperatures around the world, and unfortunately the trend will likely continue. As the effects of global climate change are becoming increasingly apparent, so is the importance of monitoring our atmosphere. The atmosphere is what allows the existence of life on Earth, and the best way in which to protect it is to understand it and how human development influences it. One of the methods by which scientists can study the atmosphere is by studying water vapour trends and climatologies (an average picture of the atmosphere in time and altitude). Water vapour is the most significant greenhouse gas, and thus it is important to understand the quantity of the water vapour and its location in the atmosphere in order to understand how it interacts with anthropogenic, or human-induced, processes. Analyzing trends allows us to project the future evolution of the atmosphere, and consequently, the global climate. Climatologies provide an average "map" of the atmosphere over time and allow us to see what the water vapour content at any altitude for any given day might be. The more measurements we obtain, the better average and the more detailed trend can be created.

My PhD thesis involves working with a lidar (laser - radar) that has operated for almost 9 years. I will be working with a large data set, with extremely high time resolution. The primary goal of my thesis is to produce a climatology of the water vapour located above the Swiss RALMO lidar, located at the MeteoSwiss station in Payerne. I will be expanding on the work done by *Sica and Haefele 2016* and use the Optimal Estimation Method (OEM) to produce the water vapour climatology. Unlike traditional water vapour retrieval methods, the OEM provides a detailed error budget and quantifies the valid altitude ranges of our water vapour retrieval. The initial OEM procedure involves constraining the parameter space by providing an initial guess of the problem's parameters, including the lidar calibration constant. The focus of this poster will be the process by which we derive the lidar constant for our lidar system. We compare only the air masses sampled by both the calibration radiosonde and the lidar by calculating the trajectories of each air mass. This is a more robust calibration method as it ensures that the radiosonde and the lidar are measuring the same water vapour sources and we aren't introducing water vapour biases into our climatologies and trends. This methodology seems to have a significant effect on the lidar profile, and improves the correlation between the lidar and the radiosonde. Further work will involve doing a complete statistical analysis of the differences between my method and the traditional method.

Quantification of uncertainties in modelling the present and projected hydrology of the Fraser River Basin, British Columbia

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While the advance in computational power and the ongoing developments in hydrological modelling have increased the significance of hydrologic simulations, the issue of adequately addressing the associated uncertainty remains challenging. There is a growing need for proper estimation of uncertainties associated with models and the observations required to drive and evaluate model outputs. This study focuses on the quantification of predictive uncertainties in the hydrology of the Fraser River Basin (FRB) of British Columbia (BC), using the Variable Infiltration Capacity (VIC) model forced with four different gridded climate data sets. Uncertainties are quantified at different stages starting with the driving datasets and model parameters. Furthermore, uncertainties are investigated in the projected hydrological response of the FRB using VIC simulations forced by statistically-downscaled forcing datasets of Global Climate Model (GCM) runs.

Systematic differences in the simulated runoff are identified by comparing VIC simulations driven with different input datasets. High uncertainty corresponding to selection of forcing data is seen for the datasets with greater precipitation difference especially in mountainous sub-regions of FRB. Parametric uncertainty in the VIC calibration process, reflecting the inability to specify exact values of model parameters due to finite length, are evaluated with two different models setups. Choice of the initial parameter range during the calibration process is found to plays a crucial role in defining the model hydrological response for FRB. Comparing the coarse and high resolution A wide range of projected changes in FRB hydrograph is seen for different sets of driving GCMs owing to their internal variability in temperature and precipitation.

Challenges in operating an Arctic telescope

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The Earth weather engine is fueled on the polar cold and on the equator heat. The pristine polar atmosphere is fragile and the pollution can easily unbalance the global climate. Our atmospheric observing facility is in a surreal world, at the Eureka Weather Station (80°N, 86°W), one of the coldest places in the High Arctic winter, but hottest during summer, making it the garden spot of the Arctic. The purpose is to observe during the night the attenuation of the starlight by the arctic atmospheric pollutants and clouds. We describe our nine-year experience and the specific technical and environmental challenges we had to overcome while operating a telescope in the High Arctic.

Evaluation of Temperature Retrieval Techniques Using PCL Rayleigh Scattering Temperature Climatology

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Various instruments have been used to measure atmosphere parameter variability including: satellites, weather balloons, rocketsondes, radars and lidars (laser – radars). Taking measurements of the middle atmosphere is difficult as it is beyond the range of aircrafts and balloons. Among these systems, lidars provide high temporal and vertical resolution making them suitable to study the dynamics of the middle atmosphere.

Rayleigh-scatter lidar measurements are commonly used to develop temperature climatologies for the stratosphere, mesosphere, and lower thermosphere. Rayleigh and Raman scatter measurements from The University of Western Ontario Purple Crow Lidar (PCL) have been used to develop temperature climatologies for the range between 30 to 110 km using data from 1994 to 2013. Temperature retrievals from Rayleigh-scattering lidar measurements have been performed using analytical methods which just estimate statistical uncertainty. However, a new numerical method has many advantages over the other technique. Different temperature retrieval methods have been used to generate the PCL temperature climatology, including the analytical method and the numerical method. This presentation will compare the different temperature retrieval techniques and will present the merit of the numerical technique over the analytical.

Global Trends in Water Vapor as Measured by ACE-FTS

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Many people view water vapor as relatively harmless. Possibly annoying if it's a hot day made worse by humidity, but hearing that the quantity of water vapor in the stratosphere and mesosphere is changing seems inconsequential. But in truth stratospheric water vapor plays a large role in climate forcing, a process by which one of the many effects is a change in surface temperature, and increases in water vapor are tied to increases in surface warming. A 2010 study by atmospheric chemist Dr. Susan Solomon and her collaborators found that over a similar period of time increases in stratospheric water vapor led to a climate forcing approximately two-thirds as great as that caused by carbon dioxide (Solomon *et al.* 2010). Many factors contribute to changes in stratospheric water vapor, including the season and surface temperatures, and given the magnitude of temperature changes that result it is thus important to analyze these trends for use in climate forecasting.

An important tool for evaluating water vapor trends is currently orbiting 650km above the surface of the Earth. This would be the Atmospheric Chemistry Experiment Fourier Transform Spectrometer (ACE-FTS), an instrument capable of measuring different gases that are present in low quantities in the atmosphere. Since its launch in May 2003 the Canadian satellite SCISAT-1, also called ACE, has been orbiting the Earth 15 times per day and measuring from 85°N to 85°S on a yearly basis. ACE-FTS makes trace gas measurements using a technique known as solar occultation; during sunrise and sunset as viewed by ACE, it makes measurements of the light passing through the atmosphere at multiple heights. As this light passes through the atmosphere part of it is absorbed by gases, with different gases able to absorb light at different parts of the spectrum of light. Thus the amount of light absorbed at a given altitude for a particular section of the spectrum of sunlight can be used to evaluate the quantity of a trace gas present there. A series of these vertical measurements are made covering from approximately 10km to 100km above the Earth's surface, and together they yield vertical profiles of the quantities of particular gases. ACE-FTS is able to measure the quantities of over three dozen atmospheric gases, including the focus of this work: water vapor.

Diagnosing the sign of Cloud Radiative Feedback

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When attempting to diagnose the climate sensitivity, clouds are the cause of much uncertainty as they are highly variable. Due to the large uncertainty that clouds provide, there exists a discrepancy between many authors on the sign and magnitute of cloud radiative feedback (CRF). For example, Dessler (2013) shows that models predict a very strong, positive feedback response in the central Pacific which is not present in observations. To better understand these discrepancies we are using radiation data from the CERES satellite and ERAi data to look at the most recent El Nino event. By looking at temperature and humidity anomalies in the central Pacific which are associated with this event, and using radiative kernels, we can calculate the radiative effect.

The impact of Quasi-Biennial Oscillation (QBO) and vertical resolution on dynamics and chemistry in Canadian Middle Atmosphere Model (CMAM)

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The quasi-biennial oscillation (QBO) is an oscillation in the winds in the tropical stratosphere. Although it is confined to the tropics, it influences the whole stratosphere by modulating the effects of waves in the extratropics. Most models are incapable of simulating the QBO because it requires high vertical resolution to simulate the tropical waves that produce the QBO. Recently, the resolution of a version of the Canadian Middle Atmosphere Model (CMAM), with stratospheric chemistry, has been increased and the dynamics adjusted to simulate a QBO. Increasing the vertical resolution and producing a QBO will influence the dynamics and the chemistry in the model stratosphere. In this project we are trying to understand the impact of increased vertical resolution and the QBO on the stratosphere and troposphere in CMAM. To understand the impact of the changes in the model, we are using three different simulations: a low resolution model run without the QBO, a high resolution run without the QBO, and a high resolution run with the QBO. We are analyzing the vertical structures of different dynamical and chemical variables in order to understand how the general structure of the stratosphere and the exchange of air between the troposphere and the stratosphere, which determines the distribution of the gases in the stratosphere and troposphere, are influenced by the QBO and increased vertical resolution. We are especially interested in understanding the influence of the QBO on tropospheric ozone, which is a harmful pollutant and a greenhouse gas.

Measurements of Ozone from OP-FTIR in Halifax, Canada

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Ozone is toxic to humans because it can oxidize biological tissues. Open-path Fourier transform infrared (OP-FTIR) spectroscopy provides a real-time, effective and visual measurement to Ozone. Different from the ultra-violet (UV) method, infrared light is safe to human, especially in open path applications. Over the past year, a mobile OP-FTIR spectrometer was set up at different locations at Halifax, Nova Scotia, included downtown, harbour, highway, university campus and coastal forest for various measurement purposes of trace gases. The path length was varied from tens meters to hundreds meters, which depended on the terrain conditions. Batch of measured spectra were processed and retrieved by professional tools: MATLAB and MALT, to derive the concentration of Ozone, and plot it in time series. Details of retrievals, such as spectral range, interfering gas compounds, and retrieval parameters will be presented. The correlation between Ozone and its precursor NO at busy traffic conditions will be discussed. Finally, the overall concentrations of Ozone measured outdoors will be plotted and compared with the data from an in-situ station of National Air Pollution Surveillance Program (NAPS).

Polar Vortex and Circulation Patterns of Persistent Cold Events in Central-Eastern North America

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The circulation patterns for persistent cold winter weather events for eastern US and Canada (95°W-65°W, 32°N-52°N) are investigated using NCEP Reanalysis data from 1948 to 2014. The criteria for the persistent cold events are: 1.The three day averaged temperature anomalies for the regional average over eastern US and Canada are below 10th percentile; 2. Such extreme "cold spells" last at least 10 days. The circulation patterns and underlying oceanic condition associated with these cold events are examined closely to find common factors that are preludes of these events. The circulation anomaly patterns of these events are categorized based on the El Nino-Southern Oscillation (ENSO) indices, Pacific Decadal Oscillation (PDO), Arctic Oscillation (AO) indices, and stratospheric polar vortex characteristics. The differences of in tropic convections and stationary wave pattern variation during cold events under the former mentioned climate indices are investigated. Cold events associated with strong tropospheric polar vortex (AO>1) tend to associate with strong tropical convections in the Maritime Continent, whereas those with weak polar vortex (AO<1) tend to associate with weaker convections in the Maritime Continent and stronger tropical convections center near dateline.

Detection of Wildfire Pollution Across Canada: From the High Arctic to Toronto and to the East in Halifax

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Boreal forests in Canada, United States and Russia contribute to significant episodes of wildfires in the summer months. Wildfires are a natural process where the frequency and intensity is strongly influenced by climate. In recent years there has been several major wildfires that burned for extended periods over a large spatial range. In August 2010, unseasonably high temperatures and drought lead to extreme wildfires that burned in central Russia with smoke and ash from these fires greatly affecting air-quality in urban areas like Moscow. In 2014, the Northwest Territories experienced an exceptional wildfire season. Large areas of boreal forest burned near Great Slave Lake in July and August 2014 and the pollution was detected throughout Canada from the High Arctic at Eureka, Nunavut, to Toronto, Ontario and Halifax, Nova Scotia. Most recently, in May 2016, an early start to the boreal wildfire season began with fires near the town of Fort McMurray, Alberta, displacing over 80,000 residents from their homes. Major wildfires such as these have brought attention to the destructive nature of wildfires and awareness of the potential increase in magnitude with climate change.

Not only do wildfires have impact on air-quality and human health, they are also a significant source of atmospheric pollution in the form of trace gases. Globally, wildfire emissions may rival those of man-made sources. A large number of trace gases are emitted from wildfires in various abundances with lifetimes ranging from several hours to months, which makes quantifying the effects of wildfire pollution difficult. The emission of trace gases from wildfires influence the chemistry of the atmosphere and as a result may have a considerable impact on air-quality, climate and biodiversity in sensitive ecosystems such as the Arctic.

The use of Fourier Transform infrared (FTIR) spectroscopic measurements at Eureka, Toronto and Halifax to investigate the long range transport of wildfire pollution from the 2014 Northwest Territories fires will be presented. In particular, FTIR measurements of carbon monoxide (CO), a long-lived species, is used as a tracer of the smoke plume to identify long-range transport to each site. FTIR measurements of ammonia (NH_3), a short-lived species, at Eureka identify boreal wildfires as a source of NH_3 in the Arctic, while FTIR measurements of NH_3 at Toronto allow for a 48 hr NH_3 lifetime to be estimated. The detection of NH_3 at both Eureka and Toronto illustrate that wildfire emissions of NH_3 may influence a greater spatial range than previously thought. Satellite observations and transport model results provide further insight to the long-range transport of boreal wildfire pollution in Canada.

A Preliminary Case Study of Cloud Radiative Forcing During the N-ICE2015 Experiment

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The Norwegian Young Sea Ice (N-ICE2015) experiment took place on a Norwegian ice breaker frozen into newly formed sea ice in the Arctic Ocean. The ship and surrounding camp flowed with the ice from January to June 2015 while taking atmospheric measurements over the young sea ice. The primary objective of this experiment was to understand the role that young sea ice plays in atmosphere and ice dynamics. Instruments deployed on this ship included a MicroPulse Lidar (MPL) from the U.S. Atmospheric Radiation Measurement (ARM) program, a Vaisala Ceilometer, Kipp and Zonen shortwave and longwave radiometers, and a Campbell Scientific Eddy-Covariance system. These instruments determined the amount of radiative energy and turbulent flux reaching and being emitted from the ice surface near the ship. The radiation balance calculations were used in conjunction with the cloud occurrence, height, depth, and phase information retrieved from the MPL and ceilometer to determine cloud radiative forcing. Determining this relationship gives details about the influence of different cloud types on the melt and formation of sea ice. Cloud characteristics differed as winter transitioned into spring. Early in the experiment, clouds were generally found higher in the atmosphere. As the experiment entered the spring season clouds formed closer to the surface. Latent heat fluxes throughout the experiment were negligible while sensible heat fluxes were significant. Information from this study will be used to improve the Polar Weather Research and Forecasting model's predictions of cloud cover and atmospheric conditions over the Arctic Ocean.

Far Infrared Radiometer campaign at Eureka

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Ice clouds and water vapour play an important role in the Arctic weather and climate system. They strongly affect the radiative budget of the atmosphere, especially through the polar night. Remote sensing observations from CALIPSO and CloudSat satellites over the Arctic have revealed the existence of two types of thin ice clouds (TIC). The first type, TIC-1, is characterized by a high concentration of small ice crystals. On the other hand, TIC-2 are characterized by a low concentration of larger precipitating ice crystals. The formation processes of the two types of TICs is not well understood. To allow further studies, a new passive remote sensing technique is needed to make the distinction between the two types of TICs.

In this poster, we show preliminary results of a new instrument prototype, the Far InfraRed Radiometer (FIRR) located at Eureka (ØPAL) to measure the radiance emitted by the clouds and the atmosphere in the infrared spectrum, from 8 to 50 μm. This spectral region is really sensitive to the water vapour content and the effective diameter of ice crystals. By comparing these measurements with a millimeter cloud radar (MMCR), a stellar photometer and the CANDAC RMR Lidar (CRL), we analyse some interesting cases to see the sensitivity of the FIRR to cloud properties and to the water vapour total column.

Polar winter sea-salt events over and near Ny Alesund, Spitsbergen

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The effects of aerosols are acknowledged by the Intergovernmental Panel on Climate Change (IPCC) to be the greatest uncertainty in the climate change radiation budget. Furthermore because of the surface-atmosphere system conditions observed in Polar Regions, climate change effects are magnified over the Arctic. Typically, Arctic aerosols can be categorized into anthropogenic and natural aerosols. Natural aerosols include black carbon (BC) and brown carbon (BrC) aerosols[1], volcanic aerosols (sub-micron sulphates[2] and super-micron ash), dust[3] (typically super micron), sea-salt[4], non-sea-salt sulphates (nss-sulphates) and type Ib polar stratospheric clouds (PSCs[5]). We will present some examples of potential polar winter sea salt events over and near Ny Alesund, Spitsbergen. A combination of starphotometry data, satellite based CALIOP (lidar) data and volumetric NaCl concentration measurements were employed to detect and characterize fine mode aerosol events during time periods when we believed that this type of aerosol was likely present. In addition, we employed the simulations of the GEOS-Chem chemical transport model to help guide our search for this type of aerosol and, in general, to better understand the dynamics of sea salt transport to the high Arctic.

[1] The most apparent intrusion of such aerosols in the Arctic comes from biomass burning in the south
[2] from the condensation of volcanic-emitted SO2 gas
[3] generally from wind erosion over Chinese deserts but also from local, summertime erosion in the Arctic
[4] generated by high winds over open oceanic waters
[5] These large, fine mode aerosols are generally formed from volcanic sulphates that make their way into the stratosphere.

Assessing Mercury Risks for the Optimization of Nutrient Benefits from Wild-harvested Fish Consumption in the Northwest Territories, Canada

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The consumption of fish, often rich in essential nutrients, promotes health in humans; however, methylmercury, a contaminant in fish, may pose health risks. To better understand these risks and benefits, total mercury (HgT), selenium (Se) content, and omega-3 fatty acid (*n*-3 FA) composition within the muscle tissues of fish from three lakes in the Northwest Territories were characterized. Thereafter, a probabilistic optimization software (Crystal Ball's OptQuest) was utilized to inform dietary recommendations that mitigate risks of Hg exposure.

Average HgT levels ranged from 0.057 mg kg^{-1} (Cisco) to 0.551 mg kg^{-1} (Northern Pike), while average *n*-3 FAs levels ranged from 101 mg/100 g (Burbot) to 1,689 mg/100 g (Lake Trout). In contrast, average Se concentrations were relatively similar among species. Interestingly, fish HgT covaried with the nutrient content for Lake Trout, Northern Pike, Walleye, Lake Whitefish, and Cisco. These analyses indicated that Lake Whitefish, Cisco, and Longnose Sucker had the highest nutrient levels relative to HgT content. For the OptQuest model, the term best solutions refers to the optimum food choices that maximize nutrient intake, while also limiting Hg's toxicological reference values (TRVs). To achieve nutritional adequacy for *n*-3 and Se intake, respectively, the total amount of fish within the best solutions for women of child-bearing age were 546 and 1,359 g/week and the general population were 851 and 1,848 g/week. The models indicated that the consumption of Burbot, Cisco, Lake Whitefish, and Longnose Suckers would most help people achieve nutritional adequacy without exceeding the Hg TRV.

The nutrient:Hg ratios and OptQuest model approaches that were utilized to determine the optimal food choices that achieve nutritional sufficiency without exceeding the Hg TRV yielded different answers. Future research will be necessary to determine which of these approaches yield the most useful information that balance nutrient benefits and contaminant risks.

GFIT2 : CO_2 profile retrievals

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To mitigate global warming and climate change, the recent Kyoto Protocol's Conference of the Parties (COP21), in Paris, set a target goal of limiting the global mean temperature rise to 1.5°C above pre-industrial levels. To achieve this goal, countries need to commit to policies to monitor and reduce their emissions of greenhouse gases (GHGs). Reduction plans require a capacity to estimate sources and sinks of GHGs, and to better understand the carbon cycle to make predictions regarding future climate change. Networks of instruments observing the atmospheric composition are a critical part of this process.

The Total Carbon Column Observing Network (TCCON) is composed of high resolution ground-based Fourier transform spectrometers. They can retrieve, with high precision, the column-averaged dry mole fraction of CO_2 (XCO_2), and other trace gases, from solar absorption spectra. Retrievals combine observations with our a priori knowledge of the atmospheric concentrations of a trace gas to produce a best estimate of those concentrations. TCCON observations are used to validate the less precise satellite observations. A column of trace gas is the total amount of molecules, per surface area, between the source of radiation and a detector.
Variations in XCO2 are partly driven by local surface fluxes of CO_2, and partly by transport from remote locations. Even though XCO_2 observations are precise, they lack information on the vertical distribution of CO_2 in the atmosphere. Local surface fluxes and vertical mixing have a larger impact on the CO_2 concentrations near the surface, in the planetary boundary layer. Transport from remote locations has a larger impact on CO_2 concentrations at higher altitudes, in the free troposphere. It is thus expected that vertical profiles of CO_2, instead of total columns, can improve the constraints on the distribution of carbon fluxes.

My research consists in continuing the development of GFIT2, a new retrieval algorithm to retrieve profiles of CO_2 for TCCON. Instead of applying a single scaling factor to our a priori knowledge of the CO_2 profile, a scaling factor is retrieved for each atmospheric level. Spectral residuals can introduce variations in the retrieved profiles and special care must be taken to isolate useful information from systematic residuals.

Trend analysis of atmospheric trace gases over Toronto during the past 15 years

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The Network for the Detection of Atmospheric Composition Change (NDACC) is a world-wide network of stations that observe Atmospheric composition for decades. Trend analysis on atmospheric composition can show its evolution and can be used to estimate future impacts on climate change.

As part of the NDACC Network, the University of Toronto Atmospheric Observatory (TAO) is used to measure the amount of nine different tropospheric and stratospheric trace gases on a daily basis since 2001. This is done using a Fourier Transform InfraRed (FTIR) Spectrometer, a ground-based instrument that measures the absorption of solar radiation to determine atmospheric composition of C_2H_6, CH_4, CO, HCl, HCN, HF, N_2O and O_3. This large dataset can be used to conduct studies of urban pollution and mid-latitude atmospheric chemistry and is also used for satellite data validation.

The goal of this poster is to present a trend analysis technique that can be used on the acquired data. It also presents the bootstrap resampling method used to obtain the 95% confidence level on the trend. Results indicate that some of the gases (CO, O_3) are decreasing, whereas some others (CH_4 and C_2H_6) are increasing, highlighting the increase of oil and natural gas extraction in north America the past years.

Overview of the University of Toronto Atmospheric Observatory, and investigation of atmospheric temperatures and trace gas concentrations in Toronto

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The University of Toronto Atmospheric Observatory (TAO), established in 2001, houses several instruments including a Brewer ozone spectrophotometer, a weather station, UV-visible spectrometers (as guest instruments), and our primary instrument – a high-resolution Fourier transform infrared (FTIR) spectrometer, coupled to a heliostat (solar tracker). These instruments measure various atmospheric properties, including ozone columns, other trace gas concentrations, UV radiation, and basic weather parameters. The FTIR spectrometer measures solar absorption spectra, from which the concentration of many atmospheric trace gases can be retrieved in a vertical column of air over Toronto, including important tropospheric gases – ozone (O_3), carbon monoxide (CO), methane (CH_4), ethane (C_2H_6), hydrogen cyanide (HCN), nitrous oxide (N_2O), as well as gases of importance in stratospheric chemistry – ozone (O_3), hydrogen fluoride (HF) and hydrogen chloride (HCl).

Several of these gases are important indicators of urban atmospheric pollution, which has been an increasing global concern ever since the industrial revolution. In the past 10 years, the world has witnessed temperatures soaring up to record-breaking heights, and the rate of increase of the Earth's surface temperature has nearly doubled in the past 50 years. In Canada, pollutants that pose a serious health risk include ozone, nitrogen oxides and carbon monoxide. It is important to keep track of these gases for recording their trends over time, and for analysis of their links with global warming.

The FTIR spectrometer and the weather station at TAO operate daily. Since May 2016, I have been recording measurements with the FTIR spectrometer and helping with its operation and maintenance when needed. This study will present concentration of trace gases from 2002 to 2015, to show long-term trends and seasonal cycles. Weather station measurements of the outside atmospheric temperature in Toronto from 2002 to mid-2016 will also be shown. Please see my poster for these plots and for the time-trends that they reveal.

Terrain modeling of snow accumulation near Iqaluit, Nunavut

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Snow is the most important input to freshwater systems in most of the Arctic. In Iqaluit, NU, snowfall is a greater source of water than rainfall annually. Water is stored in winter snow for up to 9 months, releasing a season's worth of water in a "pulse", called the spring freshet. After freshet, river flows recede rapidly due to limited inputs from groundwater. Predicting freshet flow, and thus peak annual water supply for freshwater ecosystems and community reservoirs, relies on an estimate of the snow water equivalent (SWE) stored in a watershed, as well as a prediction of snow melt rate.

The goal of this research project is to predict the end-of-winter SWE accumulation for the Apex River, which drains 58 km^2 and provides the secondary water supply for the city of Iqaluit. Snowfall on southern Baffin Island is usually associated with moderate-to-high winds, and the rough terrain, devoid of tall vegetation, allow strong wind flow during frequent winter storms. Blowing snow is suspended in the lower atmosphere, reducing visibility and creating a hazard for aviation or travel on the land, before depositing downwind in drifts when wind decelerates. Thus, interaction between terrain and wind is the primary determinant of snow distribution here.

The models employed in this project use digital terrain analysis, correlating SWE measurements with variables such as slope gradient and curvature. A 1-m-resolution digital elevation map of the area was used for terrain analysis, while weather data came from both Environment Canada records at Iqaluit Airport, and from a remote weather station established in 2015. Observations of snow depth, density, and structure were made during snowmobile-based traverses conducted in April and May of 2015 and 2016. These traverses were conducted in partnership with Nunavut Arctic College's Environmental Technology Program (ETP), with students learning the basic techniques of snow hydrology during the work.

Two models were used: a "cluster analysis" (CA) model, which identified terrain categories statistically, and a "residual analysis" (RA) model, which identified categories based on local variation in slope and elevation. Both models indicated that accumulation regimes differed by terrain feature – ridges and wide valley floors accumulated limited snow, while slopes accumulated the most. The RA model further segmented slopes into "windward/leeward" and "local high/low", where high, windward-facing slopes had limited accumulation, while low, leeward slopes accumulated almost twice the watershed average. Average SWE for the whole watershed was estimated at 22.6 and 23.3 cm based on CA and RA model categories, respectively – similar to the unmodeled estimate of 24.3 cm. Variance in drift depth increased for categories with deeper accumulation, so increased sampling of "drift zones" can enhance model certainty. Future work will employ 3D wind transport simulations to further improve prediction.

Climatology of Gravity Wave Activity over Eureka, Nunavut using the PASI

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There is an amazingly large amount of dynamical motion responsible for moving energy around in the atmosphere. This poster will present the research used to detect a particular type of motion known as gravity waves and their relevant parameters using images taken by the Polar Environmental Atmospheric Research Laboratory (PEARL) All Sky Imager (PASI). The PASI has been operating since November 2007 at PEARL in Eureka, Nunavut with images being taken on average every 45 seconds during the long polar night. The technique used in this research is a time efficient automated approach which examines the images and determines if there are gravity waves present and what their parameters are.

PASI is a CCD imager that uses optical filters to view six different airglow emissions. Airglow is a naturally occurring layer of the atmosphere roughly 90km above the surface that emits faint visible and infrared light that is created from chemical reactions. The filter of primary interest in this research isolates the hydroxyl airglow emission (at 720-910nm with a notch at 865nm to eliminate emissions from molecular oxygen). PASI cycles through the different filters when it operates with the hydroxyl filter interleaved between the different filters in the observation sequence.

The gravity wave parameters that are highlighted in this research are: the horizontal and vertical wavelengths, intrinsic period, propagation direction and intrinsic phase speed. In each image, occurrences of these waves are described in terms of their horizontal spatial frequency (as known as the wavenumber) and phase. Phase information is determined from consecutive images that contain wave signatures with similar horizontal wavenumbers. The vertical wavelength is determined from the horizontal wavelength, the buoyancy frequency (referred to as the Brunt–Väisälä frequency) that is determined from Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instrument or from the extended Canadian Middle Atmosphere Model (CMAM) and the background wind speed using the co-located E-Region Wind Interferometer (ERWIN) instrument. The Brunt–Väisälä frequency is the frequency that a parcel of air will oscillate vertically if the parcel has been moved from an equilibrium position.

The observed gravity wave parameters will be presented as seasonal variations for the horizontal and vertical wavelengths, intrinsic period and intrinsic speed and monthly variations in the wave direction.

Characterizing the Purple Crow Lidar Water Vapour Lidar to investigate potential sources of bias

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The Purple Crow Lidar (PCL) is a large aperture lidar, capable of retrieving water vapor profiles and temperatures up to the thermosphere. A comparison campaign with the NASA/GSFC ALVICE mobile lidar in the spring of 2012 showed PCL water vapor measurements were consistently larger than those of ALVICE in the lower stratosphere, prompting an investigation to characterize the system. The investigation looks into how changes to the data processing approach, as well as applying additional instrumental corrections, would affect the water vapor mixing ratio. We also look into a retrieval of the mixing ratio using optimal estimation method (OEM), which should provide greater insight into the associated data processing parameters and uncertainties.

TCCON vs. MUSICA: Can the carbon-focused network measure atmospheric water vapour accurately?

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Intuitively, people understand humidity impacts temperature. Hot summer days feel more uncomfortable when the humidity is high. Humans are less able to cool themselves by evaporating sweat off their skin under humid conditions, so we are more affected by the heat. Humidity can also directly impact temperatures by trapping heat. This is particularly true in the Polar Regions, where humidity is very low. Because of its potent heat-trapping abilities, water vapour is the most important greenhouse gas on Earth. Changes in temperature and humidity cause changes in the water cycle, creating droughts, floods, and shifts in weather. Monitoring water vapour is important for understanding our changing climate and how it will impact society. Measuring water vapour is not easy. The amount of water vapour in the air can change quickly throughout a day, change substantially from winter to summer, and change significantly if observing tropical or polar sites. It is difficult to fine-tune instruments to accurately measure water vapour under such a wide range of conditions. Many different techniques are being developed to meet this challenge.

Water vapour measurements are especially valuable if information about isotopes are recovered. Isotopes are slightly different versions of the same molecule, which differ because of the number of neutrons their atoms contain. Water exists in a variety of isotopes, such as the standard H_2O and the less common HDO (which has one extra neutron on a hydrogen atom). As air moves, it loses heavier isotopes more than lighter isotopes. The ratio of isotopes can tell us about the history of the air.

While it focuses on measuring atmospheric gases like CO_2 and methane, the Total Carbon Column Observing Network (TCCON) also produces H_2O and HDO products at sites across the planet. However, the accuracy of these measurements remains unclear. This study compares TCCON measurements of water vapour (and the ratio between H_2O and HDO) with measurements of known accuracy to assess their reliability and accuracy. These reference measurements were taken by the same spectrometers at several globally-distributed sites, but using a technique designed specifically for water vapour (the well-validated MUSICA product). Results suggest that – with more work on the part of researchers - the TCCON measurements can indeed contribute to investigations of the water cycle and atmospheric dynamics.

Identification of patterns in the global atmospheric circulation preceding extreme heat and ozone events

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Extremely hot temperatures and high ozone concentrations at the Earth's surface can cause humans to become ill, sometimes fatally, and damage crops and other vegetation. Forecasting of these extreme events could be improved by finding global-scale patterns in the atmosphere that commonly occur well in advance.

In this work, historical records from North American ozone and temperature monitoring stations are examined to find the dates and locations of past extreme events. A new statistical algorithm is used to divide the stations into a small number of groups that are likely to experience high heat or ozone levels on the same days. The algorithm shows that these groups of stations lie within large geographical regions, like the Southeast United States or the West Coast. These divisions are useful because the causes of extreme events may differ between regions. For example, the emissions from vegetation in the densely forested U.S. Appalachians react to produce ozone, and do so at a higher rate when temperatures are high, meaning that extreme temperatures and ozone levels will tend to coincide. Meanwhile, mountainous regions with less vegetation are more likely to be subjected to ozone transported downward from the upper troposphere and lower stratosphere, regardless of temperature variations.

For each region, the state of the global atmosphere in the days and weeks before each extreme event is examined. By averaging these states and applying mathematical techniques (Fourier transform analysis), prominent patterns that consistently occur are made to emerge. It is argued that because these patterns evolve more slowly than typical weather patterns, they may be used to predict future ozone and temperature extremes.

Accuracy, precision, and temperature dependence of Pandora total ozone measurements estimated from a comparison with the Brewer triad in Toronto

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This study evaluates the performance of the recently developed Pandora spectrometer by comparing it with the Brewer reference triad. The Brewer triad was established by Environment and Climate Change Canada (ECCC) at Toronto in the 1980s. The triad is used to calibrate Brewer instruments around the world, ensuring high quality total ozone column measurements. To reduce stray light, the double Brewer instrument was introduced in 1992, and a new reference triad of double Brewers is also operational at Toronto. Since 2013, ECCC has deployed two Pandora spectrometers co-located with the old and new Brewer triads, making it possible to study the performance of these three generations of ozone monitoring instruments. The statistical analysis of column ozone data records from these Brewer and Pandora instruments indicates that the random uncertainty for Brewer is below 0.6%, while that for Pandora is below 0.4%. However, there are a 1% seasonal difference and a 3% bias between the standard Pandora and Brewer total column ozone data, which are related to the temperature dependence and difference in ozone cross sections. A statistical model was developed to remove this seasonal difference and bias. It was based on the daily temperature profiles from the European Centre for Medium-Range Weather Forecasts (ECMWF) Interim data over Toronto and ozone records from the six instruments of the Brewer reference triads. When the statistical model was used to correct Pandora data, the seasonal difference was reduced to 0.25% and the bias was reduced to 0.04%.

End of Program