

Carling Hay

carling.hay@bc.edu
www.carlinghay.com

EDUCATION

University of Toronto, Toronto, Canada **2012**

Ph.D., Physics

Thesis Title: *The Interaction of Ice Sheets with the Ocean and Atmosphere*

Advisors: Prof. G.W.K. Moore and Prof. Jerry X. Mitrovica

McGill University, Montréal, Canada **2006**

Bachelor of Science, with Great Distinction

Physics Major

PROFESSIONAL APPOINTMENTS

Assistant Professor **September 2017 – present**

Department of Earth and Environmental Sciences, Boston College

Postdoctoral Fellow **June 2012 – July 2015**

Department of Earth and Planetary Sciences, Harvard University

Postdoctoral Fellow **July 2014 – February 2017**

Department of Earth and Planetary Sciences, Rutgers University

Research Assistant **May – August 2005**

Department of Atmospheric and Oceanic Sciences, McGill University

Supervisor: Prof. Charles Lin

RESEARCH INTERESTS

My research involves the application of advanced statistical and geophysical modelling techniques to geological, historic, and space geodetic records of sea level in order to elucidate the connection between climate, ice sheet stability, and sea level over a broad range of time and spatial scales. I am particularly interested in understanding sea-level changes during periods of relative ice age warmth (e.g., interglacials, meltwater pulses), over the last 200 years of an industrial world, and into the next century and millennium.

SCHOLARSHIPS AND AWARDS

Ontario Graduate Scholarship in Science and Technology **2010 – 2011**

Ontario Graduate Scholarship **2009 – 2010**

Ontario Graduate Scholarship in Science and Technology
Dean's Honour List, McGill University

2007 – 2008
2004 – 2005

TECHNICAL SKILLS

- Matlab, R, Python, Fortran, and C.

FIELD WORK

Storm Studies in the Arctic (STAR)

October 2007

- A two-month field campaign to study severe Arctic storms, their hazardous conditions, and the ability of forecasters to predict them.
- Worked with a small group of graduate students preparing the scientific instruments for the field campaign in Iqaluit, Canada.

Greenland Flow Distortion Experiment (GFDex)

February – March 2007

- An International Polar Year project based out of Keflavik, Iceland that involved the use of the scientific research aircraft: the Facility for Airborne Atmospheric Measurements (FAAM).
- The campaign was designed to study how Greenland acts to distort airflow and determine the state of the atmosphere downwind of the topographic barrier.
- Prepared and led five graduate students in daily weather briefings.
- Worked with 30 scientists from four different universities to plan over 15 research flights.

TEACHING AND LEADERSHIP EXPERIENCE

Undergraduate Supervisor

September 2017 – present

Boston College, Chestnut Hill, MA, USA

- Supervisor of an undergraduate senior thesis in a project to reanalyze historical sea level in Alaska.
- The goal of the thesis is to partition the historical sources of regional and local sea level to ultimately improve local sea level projections for Native American communities in Alaska.

Graduate Supervisor

April 2016 – May 2017

Harvard University, Cambridge, MA, USA

- Supervisor of a MIT graduate student in a project to assess historical models of ocean dynamics and thermal expansion, with the goal of incorporating these models into statistical methodologies that analyze historical sea-level records.

Undergraduate Co-Supervisor

2012 – 2013

Harvard University, Cambridge, MA, USA

- Developed a research project for an undergraduate student to study the sea-level change associated with the artificial impoundment of water over the 20th century.
- Assisted the student with the conceptual and computational aspects of this project.

Lab Demonstrator, Department of Physics **2006 – 2010**
University of Toronto, Toronto, ON, Canada

- Taught first year physics and engineering undergraduate students introductory physics laboratory work and basic physics concepts.

COMMUNITY OUTREACH

Sea-Level Expert Witness **June 2016 – September 2016**
Conservation Law Foundation, Boston, MA

Boston Research Advisory Group **October 2015 – June 2016**
Climate-Ready Boston
 Tasked with developing an updated climate consensus report for the city of Boston.

Volunteer, Science by the Pint **July 2014**
Cambridge, MA, USA

Volunteer, Science Rendezvous **2011 – 2012**
University of Toronto, Toronto, ON, Canada

INSTITUTIONAL ACTIVITIES

Boston College Read Aloud Program **September 2017 – present**
 Volunteer Reader.

McMullen Museum **September 2017 – present**
 Committee member for the *Indian Ocean World* exhibit.

PROFESSIONAL ACTIVITIES

External Peer Reviewer for grant proposals

- National Science Foundation (NSF) Physical Oceanography Program Grant [2015]

Journal Referee

- *Journal of Climate* [2015, 2017]
- *Current Climate Change Reports* [2015]
- *Nature Climate Change* [2015]
- *Nature* [2016]
- *Nature Communications* [2017]
- *Survey in Geophysics* [2016]
- *Climatic Change* [2016, 2017]

Team Member**Study of Environmental Arctic Change Land Ice Action Team** 2016-present

Tasked with identifying and facilitate the synthesis of scientific knowledge needed by stakeholders for better preparing for and understand sea level change.

Team Member**International Space Science Institute (ISSI)** 2017-present

12 person team tasked with assessing the performance of global mean sea level reconstructions from satellite altimetry, tide gauges, paleo-proxies and geophysical models.

Team Member**National Socio-Environmental Synthesis Center (SESYNC)** 2017-present

Member of the “Sea Level Rise and Migration” team.

PUBLIC ARTICLES

Hay, C. (2015). “Detective or Scientist? Fingerprinting the Ocean to Estimate Global Sea Level Rise”, (Feb. 6). *Union of Concerned Scientists*, <http://tinyurl.com/ptohdes>.

Hay, C. (2015). “Solving the puzzle of sea-level rise by reexamining the past”, (Feb. 16). *The Conversation*, <http://tinyurl.com/pmx76us>.

REPORTS

Climate Change and Sea Level Rise Projections for Boston. The Boston Research Advisory Group Report (June 1, 2016). <http://climateready.boston.gov/>

PUBLICATIONS IN PREPARATION

Ashe, E., Cahill, N., **Hay, C.**, Horton, B.P., Khan, N., Kemp, A., Parnell, A., and Kopp, R.E. (February 2018). Statistical modeling of rates and trends in sea level, QSR, *in prep.*

Hawley, W., **Hay, C.**, and Mitrovica, J. X. (June 2018). The sea-level implication of anthropogenic water impoundment over the last 100 years, *in prep.*

PUBLICATIONS SUBMITTED AND PUBLISHED

Horton, B.P., Kopp, R.E., Garner, A.J., **Hay, C.** Khan, N.S., Roy, K., Shaw, T.A. Mapping sea-level change in time, space and probability, *Annual Reviews*, *submitted*.

- Hay, C.**, Creveling, J. R., Hagen, C. J., Maloof, A., and Huybers, P. Assessing the robustness of chemostratigraphic correlations, *Geology*, *submitted*.
- Shakun, J.D., Corbett, L.B., Bierman, P.R., Underwood, K., Rizzo, D.M., Zimmerman, S.R., Caffee, M.W., Naish, T., Golledge, N.R., **Hay, C.** Minimal East Antarctic Ice Sheet retreat onto land during the past 8 million years. *Nature*, *submitted*.
- Piecuch, C.G., Huybers, P., **Hay, C.**, Little, C.M., Mitrovica, J.X., Ponte, R.M., and M.P. Tingley. Origin of spatial variation in United States East Coast sea level trends during 1900–2016, *Nature*, *submitted*.
- Polyak, V. J., Onac, B. P., Fornós, J. J., Asmerom, Y., **Hay, C.**, Dorale, J. A., Ginés, J., Tuccimei, P., Ginés, A. (2017) Highly resolved MIS 5e sea level in the Western Mediterranean Sea, *Nature Geoscience* (In review).
- Mitrovica, J. X., **Hay, C.**, Kopp, R. E., Harig, C., Latychev, K., (2017) Quantifying the Sensitivity of Sea Level Change in Coastal Localities to the Geometry of Polar Ice Mass Flux. *Journal of Climate* doi.org/10.1175/JCLI-D-17-0465.1.
- Kopp, R. E., DeConto, R. M., Bader, D., Horton, R. M., **Hay, C.**, Kulp, S., Oppenheimer, M., Pollard, D., Strauss, B. H. (2017). Implications of ice-shelf hydrofracturing and ice cliff collapse mechanisms for sea-level projections, *Earth's Future*, **5**, 1217-1233. doi:10.1002/2017EF000663.
- Hay, C.**, Morrow, E., Kopp, R. E., and J. X. Mitrovica (2017). On the robustness of Bayesian fingerprinting estimates of global sea-level change, *Journal of Climate*, **30**, 3025-3038.
- Hay, C.**, Lau, H., Gomez, N., Austermann, J., Powell, E., Mitrovica, J. X., Latychev, K., and D. Wiens (2017). Sea-level fingerprints in a region of complex Earth structure: The case of WAIS, *Journal of Climate*, **30**, 1881-1892.
- Hay, C.**, Mitrovica, J. X., Kopp, R. E., Huybers P., and R. B. Alley (2016). Earth rotation changes since -500BC driven by ice mass variations, *Earth and Planetary Science Letters*, **448**, 115-121.
- Tsuji, L.J.S., Daradich, A., Gomez, N., **Hay, C.**, and J.X. Mitrovica (2016). Sea level change in the western James Bay region of sub-Arctic Ontario: Implications for Treaty No. 9, *Arctic*, **69**, 99-107.
- Kopp, R. E., Kemp, A. C., Bittermann, K., Horton, B. P., Donnelly, J. P., Gehrels, W. R., **Hay, C.**, Mitrovica, J. X., Morrow, E., and S. Rahmstorf (2016) Temperature-driven global sea-level variability in the Common Era, *PNAS*, **113**, E1434-E1441.
- Mitrovica, J. X., **Hay, C.**, Morrow, E., Kopp, R. E., Dumberry, M., and S. Stanley (2015). Reconciling past changes in Earth rotation with 20th century global sea-level rise: resolving Munk's enigma, *Science Advances*, **1**, e1500679.
- Kopp, R. E., **Hay, C.**, Little, C. M., and J. X. Mitrovica (2015). Geographic variability of sea-level change, *Current Climate Change Reports*, **1**, 192-204.

Hay, C., Morrow, E., Kopp, R.E., and J.X. Mitrovica (2015). Probabilistic reanalysis of 20th century sea-level rise. *Nature*, **517**, 481-484.

Creveling, J.R., Mitrovica, J.X., **Hay, C.**, Austermann, J., and R.E. Kopp (2015). Revisiting tectonic corrections applied to pleistocene sea-level highstands. *Quaternary Science Reviews*, **111**, 72-80.

Hay, C., Mitrovica, J. X., Gomez, N., Creveling, J. R., Austermann, J., and R. E. Kopp (2014). The sea-level fingerprints of ice-sheet collapse during interglacial periods. *Quaternary Science Reviews*, **87**, 60-69.

Hay, C., Morrow, E., Kopp, R. E., and J. X. Mitrovica (2013). Estimating the sources of global sea level rise with data assimilation techniques. *Proceedings of the National Academy of Science*, **110**, 3692-3699.

Mitrovica, J. X., Gomez, N., Morrow, E., **Hay, C.**, Latychev, K., and M.E. Tamisiea (2011). On the robustness of predictions of sea-level fingerprints, *Geophysical Journal International*, **187**, 729-742.

Kopp, R. E., Mitrovica, J. X., Griffies, S. M., Yin, J., **Hay, C.**, and R. J. Stouffer (2010). The impact of Greenland melt on regional sea level: a partially coupled analysis of dynamic and static equilibrium effects in idealized water-hosing experiments. *Climatic Change*, **103**, 619-625.

Renfrew, I.A., Moore, G.W.K., Jristjansson, J.E., Olafsson, H., Gray, S.L., Petersen, G.N., Bovis, K., Brown, P.R.A., Fore, I., Haine, T., **Hay, C.**, Irvine, E.A., Lawrence, A., Ohigashi, T., Outten, S., Pickart, R.S., Shapiro, M., Sproson D., Swinbank, R., Woolley, A., and S. Zhang (2008). The Greenland flow distortion experiment, *Bulletin of the American Meteorological Society*, **88**, 1307-1324.

Hanesiak, J., Stewart, R., Taylor, P., Moore, G.W.K., Barber, D., McBean, G., Strapp, W., Wolde, M., Goodson, R., Hudson, E., Hudak, D., Scott, J., Liu, G., Gilligan, J., Biswas, S., Dyck, R., Fargey, S., Field, R., Gascon, G., Gordon, M., Greene, H., **Hay, C.**, Henson, W., Hochheim, K., Laplante, A., Melzer, M.A., and S. Zhang (2008). Storm studies in the Arctic: The meteorological field project, *Bulletin of the American Meteorological Society*, **91**, 47-68.

PRESENTATIONS

Invited:

Hay, C., "Projecting sea level through the 21st century". Coastal and Estuarine Research Federation Biennial Conference, Providence, R.I., USA. November 2017.

- Hay, C.**, “Fingerprinting the oceans: Solving the mystery of historical sea level”, Dept. of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM, USA. September 2016.
- Hay, C.**, “Fingerprinting the Sources of Recent Sea-Level Change”, Centre for Research in Earth and Space Science, York University, Toronto, Ontario, Canada. February 2016.
- Hay, C.**, Morrow, E., Kopp, R.E., and J.X. Mitrovica, “A Reassessment of 20th Century Global Sea-Level Change”. American Geophysical Union Annual Meeting, San Francisco, USA. December 2015.
- Hay, C.**, Morrow, E., Kopp, R.E., and J.X. Mitrovica, “Probabilistic Estimates of Global Mean Sea Level and its Underlying Processes”. American Geophysical Union Annual Meeting, San Francisco, USA. December 2015.
- Hay, C.**, “Fingerprinting the oceans: A probabilistic assessment of 20th century sea-level change”, Dept. of Geosciences, Princeton University, Princeton, NJ, USA. November 2015.
- Hay, C.**, “A new probabilistic estimate of global and local sea levels over the 20th century”, Geological Society of America Annual Meeting, Baltimore, MD, USA. November 2015.
- Hay, C.**, “Understanding the present by revisiting the past: Fingerprinting the sources of global sea-level rise”, Lamont-Doherty Earth Observatory, Columbia University, NY, USA. March 2015.
- Hay, C.**, “Revisiting the past: Fingerprinting the sources of 20th century global sea-level rise”, Dept. of Earth & Environmental Sciences, Boston College, MA, USA. February 2015.
- Hay, C.**, Morrow, E., Kopp, R.E., and J.X. Mitrovica, “A revised estimate of 20th century global mean sea level”. American Geophysical Union Annual Meeting, San Francisco, USA. December 2014.
- Mitrovica, J.X., **Hay, C.**, Kopp, R.E., and E. Morrow, “The sea-level fingerprints of global change”, American Geophysical Union Annual Meeting, San Francisco, USA. December 2014.
- Hay, C.**, Mitrovica, J.X., Gomez, N., Creveling, J.R., Austermann, J., and R.E. Kopp. “The sea-level fingerprints of ice-sheet collapse during interglacial periods”, American Geophysical Union Annual Meeting, San Francisco, USA. December 2013.
- Kopp, R.E., **Hay, C.**, and J.X. Mitrovica. “Quantifying uncertainty in the level, rates, and sources of interglacial sea-level change”, American Geophysical Union Annual Meeting, San Francisco, USA. December 2013.

Kopp, R.E., **Hay, C.**, Morrow, E., Mitrovica, J.X., Horton, B., and A. Kemp, "Sea-level variability in tide-gauge and geological records: An empirical Bayesian analysis", American Geophysical Union Annual Meeting, San Francisco, USA. December 2013.

Hay, C. "Fingerprinting polar ice mass variations: A new formalism for estimating the sources of global sea level rise". Dept. of Earth and Planetary Sciences, Rutgers University, New Jersey, USA. October 2012.

Hay, C., Mitrovica, J. X., Morrow, E., and N. Gomez. "The fingerprinting of global sea level change", International Polar Year Meeting 2012, Montreal, Canada. April 2012.

Hay, C., Mitrovica, J. X., Kopp, R., Griffies, S., Yin, J., and R. Stouffer. "Detecting the sea-level fingerprint of polar ice mass changes", WCRP/IOC Workshop on Regional Sea Level Change, Paris, France. February 2011.

Kopp, R.E., Mitrovica, J.X., Griffies, S.M., Yin, J., **Hay, C.**, and R.J. Stouffer, "Dynamic and static equilibrium effects of Greenland ice sheet melt: An assessment of partially-coupled idealized water hosing experiments", American Geophysical Union Annual Meeting, San Francisco, California, USA. December 2010.

Other:

Hay, C., Creveling J.R., and P. Huybers, "Assessing the statistical robustness of inter- and intra-basinal carbon isotope chemostratigraphic correlation". American Geophysical Union Annual Meeting, San Francisco, USA. December 2016.

Hay, C., Morrow, E., Kopp, R.E., and J.X. Mitrovica, "Two probabilistic methods for attributing the sources of sea-level rise from sparse tide gauge records". American Geophysical Union Annual Meeting, San Francisco, USA. December 2014.

Hawley, W. B., **Hay, C.**, and J. X. Mitrovica. "The effects of artificially impounded water on tide gauge measurements of sea level over the last century", American Geophysical Union Annual Meeting, San Francisco, USA. December 2013.

Morrow, E., **Hay, C.**, Kopp, R. E., and J. X. Mitrovica. "Fingerprint-based estimates of polar ice sheet mass change: The application of a Kalman smoother to identify ice melt contributions to 20th century sea level change", American Geophysical Union Annual Meeting, San Francisco, USA. December 2012.

Hay, C., Morrow, E., Kopp, R., and J. X. Mitrovica. "Sea level fingerprinting of polar ice mass variations: A new formalism for estimating the sources of global sea level change", Ocean Sciences Meeting, Salt Lake City, USA. February 2012.

Hay, C., Morrow, E., Kopp, R., and J. X. Mitrovica. "Detecting the sea-level fingerprint of polar ice mass changes: Testing a new method for estimating the sources of

- global sea level change”, American Geophysical Union Annual Meeting, San Francisco, USA. December 2011.
- Hay, C.**, Mitrovica, J. X., Kopp, R. E., Griffies, S., Yin, J., and R. Stouffer. “Detecting the sea-level fingerprint of polar ice mass changes”, American Geophysical Union Annual Meeting, San Francisco, USA. December 2010.
- Hay, C.**, and G.W.K. Moore, “A case study of a Greenland lee cyclogenesis event and the subsequent spawning of a tip jet”, American Meteorological Society Annual Meeting, Phoenix, Arizona, USA. January 2009.
- Hay, C.**, and G.W.K. Moore, “Flying into the eye of a polar low”, Arctic Change Conference, Quebec City, Quebec, Canada. December 2008.
- Hay, C.**, Moore, G.W.K., and R.S. Pickart. “Case study of a Greenland tip jet”, Canadian Meteorological and Oceanographic Society Congress, Kelowna, B.C., Canada. May 2008.
- Hay, C.**, and G.W.K. Moore, “Greenland tip jet: November 2004”, Polar Dynamics Conference, Bergen, Norway. August 2007.