

# Mitch Bushuk

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Citizenship: Canadian

## Research Interests

Sea ice variability and predictability, polar oceanography, sea ice and coupled climate modeling, data assimilation, geophysical fluid dynamics, data analysis methods

## Education

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| 2010–2015 | PhD, Mathematics and Atmosphere-Ocean Science<br>Center for Atmosphere Ocean Science, Courant Institute of Mathematical Sciences,<br>New York University<br>PhD advisor: Dimitris Giannakis<br>Thesis: A Statistical and Dynamical Study of Arctic Sea-Ice Variability |
| 2005–2009 | Honours BSc, Mathematics and Physics joint specialist, University of Toronto   |

## Research Experience

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| 2017-present | Research Scientist (permanent), Geophysical Fluid Dynamics Laboratory, University Corporation for Atmospheric Research |
| 2017-present | Visiting Research Collaborator, Princeton University   |
| 2015-2017    | Postdoctoral Research Associate, Princeton University, Geophysical Fluid Dynamics Laboratory                           |
| 2010-2015    | Graduate Research Assistant, Courant Institute of Mathematical Sciences, New York University                           |
| 2007-2008    | Undergraduate Research Assistant, Department of Physics, University of Manitoba  |
| 2006         | Undergraduate Research Assistant, Department of Chemistry, University of Manitoba                                      |

## Publications

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|------|---|
| 2021 | Keen, A., E. Blockley, D. Bailey, J. Boldingh Debernard, M. Bushuk, S. Delhayé, D. Docquier, D. Feltham, F. Massonnet, S. O’Farrell, L. Ponsoni, J. Rodriguez, D. Schroeder, N. Swart, T. Toyoda, H. Tsujino, M. Vancoppenolle, and K. Wyser: An inter-comparison of the mass budget of the Arctic sea ice in CMIP6 models. <i>The Cryosphere</i> , 15, 951–982, doi: 10.5194/tc-15-951-2021. |
| 2021 | Zhang, Y., M. Bushuk, M. Winton, B. Hurlin, X. Yang, T. Delworth, and L. Jia: Assimilation of satellite-retrieved sea ice concentration and new prospects for September predictions of Arctic sea ice. <i>J. Climate</i> , 34, 2107–2126, doi: 10.1175/JCLI-D-20-0469.1.  |

- 2021 Zhang, L., T. Delworth, W. Cooke, H. Goosse, M. Bushuk, Y. Morioka, X. Yang: The dependence of internal multidecadal variability in the Southern Ocean on the ocean background mean state. *J. Climate*, 34, 1061–1080, doi: 10.1175/JCLI-D-20-0049.1.
- 2021 Luo, R., Q. Ding, Z. Wu, I. Baxter, M. Bushuk, Y. Huang, X. Dong: Summertime atmosphere-sea ice coupling in the Arctic simulated by CMIP5/6 models: Importance of large scale circulation. *Clim. Dyn.*, 1-19, doi: 10.1007/s00382-020-05543-5.
- 2020 Lu, F., M. J. Harrison, A. Rosati, T. Delworth, X. Yang, W. F. Cooke, C. McHugh, N. C. Johnson, L. Jia, M. Bushuk, Y. Zhang, A. Adcroft: GFDL’s SPEAR seasonal prediction system: ocean data assimilation (ODA), ocean tendency adjustment (OTA) and coupled initialization. *J. Adv. Model. Earth Syst.*, 12, 1-36, doi: 10.1029/2019MS001895.
- 2020 Bushuk, M., M. Winton, D. B. Bonan, E. Blanchard-Wrigglesworth, T. Delworth: A mechanism for the Arctic sea ice spring predictability barrier. *Geophys. Res. Lett.*, 47, 1-13, doi: 10.1029/2020GL088335.
- 2020 Sea-Ice Model Intercomparison Project Community (incl. M. Bushuk): Arctic Sea Ice in CMIP6. *Geophys. Res. Lett.*, 47, 1-11, doi: 10.1029/2019GL086749.
- 2020 Holland, M. M., M. Bushuk, A. Jahn, A. Roberts: Integrating Models and Observations to Better Predict a Changing Arctic Sea Ice Cover. *Arctic Report Card 2020*, 123–129, 10.25923/bx13-ja71.
- 2020 Delworth, T., W. Cooke, A. Adcroft, M. Bushuk, J-H Chen, P. Ginoux, R. Gudgel, R. Hallberg, L. Harris, M. Harrison, N. Johnson, S. Kapnick, S-J Lin, F. Lu, S. Malyshev, P. C. Milly, H. Murakami, V. Naik, S. Pascale, D. Paynter, A. Rosati, M. D. Schwarzkopf, E. Shevliakova, S. Underwood, A. Wittenberg, B. Xiang, X. Yang, F. Zeng, H. Zhang, L. Zhang, M. Zhao: SPEAR—the next generation GFDL modeling system for seasonal to multidecadal prediction and projection. *J. Adv. Model. Earth Syst.*, 12, 1-36, doi: 10.1029/2019MS001895.
- 2019 Adcroft, A., W. Anderson, C. Blanton, M. Bushuk, C. O. Dufour, J. P. Dunne, S. M. Griffies, R. W. Hallberg, M. J. Harrison, I. Held, M. F. Jansen, J. John, J. P. Krasting, A. Langenhorst, S. Legg, Z. Liang, C. McHugh, A. Radhakrishnan, B. G. Reichl, T. Rosati, B. L. Samuels, A. Shao, R. Stouffer, M. Winton, A. T. Wittenberg, B. Xiang, N. Zadeh, R. Zhang: The GFDL Global Ocean and Sea Ice Model OM4.0: Model Description and Simulation Features. *J. Adv. Model. Earth Syst.*, 11, 1-45, doi: 10.1029/2019MS001726.
- 2019 Held, I. M. Held, H. Guo, A. Adcroft, J. P. Dunne, L. W. Horowitz, J. Krasting, E. Shevliakova, M. Winton, M. Zhao, M. Bushuk, A. T. Wittenberg, B. Wyman, B. Xiang, R. Zhang, W. Anderson, V. Balaji, L. Donner, K. Dunne, J. Durachta, P. Gauthier, P. Ginoux, J.-C. Golaz, S.M. Griffies, R. Hallberg, L. Harris, M. Harrison, W. Hurlin, J. John, P. Lin, S. J. Lin, S. Malyshev, R. Menzel, P.C.D. Milly, Y. Ming, V. Naik, D. Paynter, F. Paulot, V. Ramaswamy, B. Reichl, T. Robinson, A. Rosati, C. Seman, L. Silvers, S. Underwood, N. Zadeh: Structure and Performance of GFDL’s CM4.0 Climate Model. *J. Adv. Model. Earth Syst.*, 11, 1-37, doi: 10.1029/2019MS001829.
- 2019 Bushuk, M., X. Yang, M. Winton, R. Msadek, M. Harrison, A. Rosati, and R. Gudgel: The value of sustained ocean observations for sea-ice predictions in the Barents Sea. *J. Climate*, 32, 7017-7035, doi: 10.1175/JCLI-D-19-0179.1.
- 2019 Bushuk, M., D. M. Holland, T. P. Stanton, A. A. Stern and C. Gray: Ice Scallops: A laboratory investigation of the ice-water interface. *J. Fluid Mech.*, 873, 942-976, doi: 10.1017/jfm.2019.398.

- 2019 Bonan, D., M. Bushuk, and M. Winton: A spring barrier for regional predictions of Arctic sea ice. *Geophys. Res. Lett.*, 46, 1-11, doi: 10.1029/2019GL082947.
- 2019 Ding, Q., A. Schweiger, M. L'Heureux, E. J. Steig, D. S. Battisti, N. C. Johnson, E. Blanchard Wrigglesworth, S. Po-Chedley, Q. Zhang, K. Harnos, M. Bushuk, B. Markle, I. Baxter: Fingerprints of internal drivers of Arctic sea ice loss in observations and model simulations. *Nature Geoscience*, 12(1), 28, doi: 10.1038/s41561-018-0256-8.
- 2018 Bushuk, M., R. Msadek, M. Winton, G. Vecchi, X. Yang, A. Rosati, R. Gudgel: Regional Arctic sea-ice prediction: Potential versus operational seasonal forecast skill. *Clim. Dyn.*, 1–23, doi: 10.1007/s00382-018-4288-y
- 2018 Blanchard-Wrigglesworth, E. and M. Bushuk: Robustness of Arctic sea-ice predictability in GCMs. *Clim. Dyn.*, 1–12, doi: 10.1007/s00382-018-4461-3
- 2017 Bushuk, M., R. Msadek, M. Winton, G. Vecchi, R. Gudgel, A. Rosati, X. Yang: Skillful regional prediction of Arctic sea ice on seasonal timescales. *Geophys. Res. Lett.*, 44, 4953–4964, doi: 10.1002/2017GL073155.
- 2017 Bushuk, M. and D. Giannakis: The seasonality and interannual variability of Arctic sea-ice reemergence. *J. Climate*, 30, 4657–4676, doi: 10.1175/JCLI-D-16-0549.1.
- 2017 Shean, D., K. Christianson, K. Larson, S. Ligtenberg, I. Joughin, B. Smith, C. Stevens, D. Holland, M. Bushuk: GPS-derived estimates of surface mass balance and ocean-induced basal melt for Pine Island Glacier ice shelf, Antarctica. *The Cryosphere*, 11, 2655–2674, doi: 10.5194/tc-2016-288.
- 2017 Bushuk, M., R. Msadek, M. Winton, G. Vecchi, R. Gudgel, A. Rosati, X. Yang: Summer enhancement of Arctic sea-ice volume anomalies in the September-ice zone. *J. Climate*, 30, 2341–2362, doi: 10.1175/JCLI-D-16-0470.1.
- 2016 Christianson, K., M. Bushuk, P. Dutrioux, B. Parizek, I. Joughin, R. Alley, D. Shean, P. Abrahamsen, S. Anandakrishnan, K. Heywood, T. Kim, S. Lee, K. Nicholls, T. Stanton, M. Truffer, B. Webber, A. Jenkins, S. Jacobs, R. Bindshadler, D. Holland: Sensitivity of Pine Island Glacier to observed ocean forcing. *Geophys. Res. Lett.*, 43, 10817–10825, doi: 10.1002/2016GL070500.
- 2015 Bushuk, M. and D. Giannakis, 2015: Sea-ice reemergence in a model hierarchy. *Geophys. Res. Lett.*, 42, 5337–5345, doi: 10.1002/2015GL063972.
- 2015 Bushuk, M., D. Giannakis, and A. J. Majda, 2015: Arctic sea-ice reemergence: The role of large-scale oceanic and atmospheric variability. *J. Climate*, 28, 5477–5509, doi: 10.1175/JCLI-D-14-00354.1.
- 2014 Bushuk, M., D. Giannakis, and A. J. Majda, 2014: Reemergence mechanisms for North Pacific sea ice revealed through nonlinear Laplacian spectral analysis. *J. Climate*, 27, 6265–6287, doi: 10.1175/JCLI-D-13-00256.1.

### Submitted/In Preparation

- Submitted Zhang, G., H. Murakami, W. F. Cooke, Z. Wang, L. Jia, F. Lu, X. Yang, T. L. Delworth, A. T. Wittenberg, M. J. Harrison, M. Bushuk, C. McHugh, N. C. Johnson, S. B. Kapnick, K.-C. Tseng, and L. Zhang: Seasonal predictability of baroclinic wave activity: Toward predicting risks of extratropical extremes. Submitted to *Nature Geoscience*.

Submitted	Bushuk, M., M. Winton, F. A. Haumann, T. Delworth, F. Lu, Y. Zhang, L. Jia, L. Zhang, W. Cooke, M. Harrison, B. Hurlin, N. C. Johnson, S. Kapnick, C. McHugh, H. Murakami, A. Rosati, K.-C. Tseng, A. T. Wittenberg, X. Yang, F. Zeng: Seasonal prediction and predictability of regional Antarctic sea ice. Submitted to <i>J. Climate</i> .
Submitted	Tseng, K.-C., N. C. Johnson, S. B. Kapnick, T. L. Delworth, F. Lu, W. F. Cooke, A. T. Wittenberg, A. Rosati, L. Zhang, C. McHugh, X. Yang, M. Harrison, F. Zeng, G. Zhang, H. Murakami, M. Bushuk, L. Jia: Skillful Seasonal to Multiseasonal Prediction of Atmospheric Rivers over Western North America. Submitted to <i>NPJ climate and atmospheric science</i> .
Submitted	Pauling, A., M. Bushuk, C. Bitz: Robust inter-hemispheric asymmetry in the response to symmetric volcanic forcing in model large ensembles. Submitted to <i>Geophys. Res. Lett.</i> .

## Teaching Experience

Spring 2021	Guest Lecturer, Oceans, Atmosphere, and Climate, Princeton University
Fall 2020	Guest Lecturer, Introduction to Physical Oceanography, Princeton University
Fall 2019	Guest Lecturer, Introduction to Physical Oceanography, Princeton University
Fall 2018	Guest Lecturer, Introduction to Physical Oceanography, Princeton University
Fall 2017	Guest Lecturer, Introduction to Physical Oceanography, Princeton University
Fall 2016	Guest Lecturer, Introduction to Physical Oceanography, Princeton University
Spring 2014	Teaching Assistant, Math for Economics III, New York University
Fall 2013	Teaching Assistant, Math for Economics II, New York University
Spring 2013	Teaching Assistant, Math for Economics I, New York University
Fall 2012	Teaching Assistant, Calculus I, New York University

## Student/Postdoctoral Research Mentoring

2018-present	Yongfei Zhang, Postdoctoral Research Fellow, Princeton University and GFDL
2021-present	Joseph Fogarty, Princeton University, PhD Committee Member
2019	Xinyang Yang, New York University, External PhD Committee Member
Summer 2019	Alex DiNovi, High School Research Internship Program, GFDL
Summer 2018	David Bonan, Hollings Undergraduate Internship Program, GFDL
Summer 2013	Brandon Wabah, New York University Abu Dhabi undergraduate summer research program, NYU

## Student Career Mentoring

2020-2021	Rosalie Cormier, University of Toronto Physics Mentorship Program
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2019-2020	Kathleen Zhao, University of Toronto Physics Mentorship Program
2018-2019	Rees Hughes, University of Toronto Physics Mentorship Program
2017-2018	Yanzheng Shen, University of Toronto Physics Mentorship Program
2016-2017	Bryce Wu, University of Toronto Physics Mentorship Program
2015-2016	Subin Kim, University of Toronto Physics Mentorship Program

## Field Experience

2013	Pine Island Glacier, Antarctica: GPS and seismic data collection, maintenance of automatic weather station
2011 & 2012	Jakobshavn and Sermilik fjords, Greenland: conductivity-temperature-depth (CTD) ocean data, deployment and retrieval of ocean moorings, xCTD probes, and GPS devices.

## Laboratory Experience

2012 & 2013	Cold Regions Research and Engineering Laboratory, New Hampshire: Designed and performed experiments to study ice scallops. Measured flow, ice geometry and heat fluxes using PIV, LIDAR, and fast thermistors.
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## Professional Service

- Member of AMS Polar Meteorology and Oceanography Committee (01/2016–present)
- Reviewer for Annals of Glaciology, Climate Dynamics, The Cryosphere, Eos, Environmental Research Letters, Geophysical Research Letters, IPCC Sixth Assessment Report, Journal of Geophysical Research - Atmospheres, Journal of Geophysical Research - Oceans, Journal of Climate, Journal of Glaciology, Journal of Fluid Mechanics, Nature Scientific Reports, Polar Geography, Quarterly Journal of the Royal Meteorological Society, Swiss Data Science Center, Weather and Forecasting
- Member of AGU, AMS
- GFDL Diversity, Equity, and Inclusion Committee Member (02/2021–present)
- GFDL Impacts Working Group Committee Member (05/2018–present)
- GFDL Formal seminar co-ordinator (2018–19, 2019–20)
- GFDL Employee Association President (2019)
- GFDL Employee Association Vice President (2018)

## Research Grants

- 2019–2021: NOAA Climate Program Office’s Modeling, Analysis, Prediction, and Projection (MAPP). “Sea ice variability over the Pacific sector of the Arctic Ocean driven by atmospheric

circulation changes: Developing a process-based understanding of biases in CMIP6 models”, \$199,193, Co-PI role (lead PI: Qinghua Ding, University of California, Santa Barbara).

- 2018–2020: ExxonMobil Research and Engineering, EM09125.A1.TO12. “Novel data assimilation techniques for seasonal Arctic sea-ice prediction”, \$208,444, Co-PI role.
- 2018–2021: NOAA Climate Program Office’s Modeling, Analysis, Prediction, and Projection (MAPP). “Advancing understanding of Arctic sea ice variability and diagnostic predictability in ESMs with regional-to-global-scale process-oriented evaluation”, \$508,420, Unfunded collaborator role (lead PI: Cecilia Bitz, University of Washington).
- 2018–2022: Office of Naval Research, Multidisciplinary University Research Initiative (MURI). “Mathematics and Data Science for Improved Modeling and Prediction of Arctic Sea Ice”, Unfunded collaborator role (lead PI: Dimitris Giannakis, New York University).
- 2019–2022: University of Bristol. “Snow Blanket: Exploring the critical role of snow on Arctic sea ice for new state-of-the-art NASA & ESA satellite missions”, International Partner role (lead PI: Jack Landy, University of Bristol).

## Academic Awards

2015-2017	Princeton AOS Postdoctoral Fellowship
2014	Moses A. Greenfield Research Prize for outstanding interdisciplinary studies by a current student, New York University
2011-2014	NSERC Postgraduate Scholarship, Doctoral level
2010-2011	NSERC Canadian Graduate Scholarship, Master’s Level (Declined and accepted Postgraduate Scholarship, Master’s level, for study abroad)
2010-2015	New York University MacCracken Graduate Scholarship
2005-2009	University of Toronto National Scholarship
2008-2009	3T0 M&P and Associates Scholarship, University of Toronto
2008-2009	Coxeter Scholarship in Mathematics, University of Toronto
2008-2009	Dickson JA and CP Scholarship, University of Toronto
2008-2009	Reuben Wells Leonard Scholarship in the Physical Sciences, University of Toronto
2007-2008	NSERC Undergraduate Student Research Award
2007-2008	William R. Hossack Memorial Scholarship in Mathematics and Physics, University of Toronto
2007-2008	3T0 M&P and Associates Scholarship, University of Toronto
2007-2008	Reuben Wells Leonard Scholarship in the Physical Sciences, University of Toronto
2007-2008	William Mulock Prize in Mathematics and Physics, University of Toronto
2006-2007	NSERC Undergraduate Student Research Award
2006-2007	C.L. Burton Scholarship in Mathematics and Physics, University of Toronto
2005	Governor General’s Medal, Glenlawn Collegiate Institute
2005	Whitey Howard Memorial Scholarship

## Invited Seminar Talks

Feb 10, 2021	US CLIVAR PPAI Webinar Series (virtual seminar)
Oct 21, 2020	Polar Oceans Seminar Series, British Antarctic Survey (virtual seminar)
Oct 3, 2019	SEAS Colloquium in Climate Science, Columbia University
Sep 20, 2019	Applied and Computational Math Seminar, University of Wisconsin-Madison
Apr 15, 2019	AOS/PEI/GEO Climate Seminar Series, Princeton University
Apr 4, 2017	Research Seminar, Météo France and CNRM
Nov 16, 2016	Research Seminar, University of Manitoba
Nov 9, 2016	Research Seminar, GFDL
Oct 12, 2016	CAOS Colloquium, Courant Institute, NYU
Feb 5, 2015	Atmosphere Ocean Climate Dynamics Seminar, Yale
Jan 7, 2015	Sack Lunch Seminar, MIT
Dec 9, 2014	Research Seminar, GFDL
Oct 8, 2014	Topics in Atmospheric and Oceanic Sciences Seminar, Stony Brook University

## Conference Presentations\*

\*These presentations are talks, unless specified as poster

Jan 21, 2021	Sea Ice Outlook Contributors Forum, Virtual Meeting
Dec 16, 2020	AGU Fall Meeting, Virtual Meeting
Aug 27, 2020	Sea Ice MURI Workshop, Virtual Meeting
Jun 17, 2020	IARPC Joint Arctic Observing Systems and Modeling Sub-Team Meeting, Virtual Meeting
Feb 19, 2020	AGU Ocean Sciences Meeting, San Diego
Dec 10, 2019	AGU Fall Meeting, San Francisco
Oct 30, 2019	GFDL External Lab Review, Princeton
Oct 11, 2019	Sea Ice MURI Workshop, NYU
Aug 20, 2019	IGS Sea Ice Symposium, Winnipeg, Canada
May 21, 2019	Polar AMS Conference, Boulder
Apr 25, 2019	Polar Prediction Workshop, University of Oklahoma
Dec 12, 2018	AGU Fall Meeting, Washington, D.C.
Sept 20, 2018	International Conference on Seasonal to Decadal Prediction, Boulder
Sept 14, 2018	SIAM Conference on Mathematics of Planet Earth, Philadelphia
Jun 22, 2018	Polar2018 Meeting, Davos, Switzerland
May 7, 2018	Polar Prediction Workshop, McGill University

Dec 11, 2017	AGU Fall Meeting, New Orleans
Nov 2, 2017	GFDL Science Symposium, Princeton
July 13, 2017	Sea Ice Workshop, University of Washington, Seattle
June 26, 2017	Arctic Modeling Workshop, NASA, Washington, D.C.
June 6, 2017	Canadian Meteorological and Oceanographic Society Congress, Toronto
June 4, 2017	Canadian Snow and Sea Ice Evolution Network (CanSISE) Workshop, Toronto
Mar 27, 2017	Polar Predictability Workshop, Alfred Wegener Institute
Feb 1, 2017	GFDL Poster Expo, Princeton (poster)
Jan 26, 2017	AMS Annual Meeting, Seattle
Nov 2, 2016	FAMOS Meeting, Woods Hole Oceanographic Institution (poster)
May 5, 2016	Polar Prediction Workshop, Lamont Doherty Earth Observatory
Feb 3, 2016	Sea Ice Forecasting Workshop, NCAR
Jan 28, 2016	MURI Workshop, NYU
Dec 18, 2015	AGU Fall Meeting, San Francisco (poster)
Nov 20, 2015	Regional Climate Symposium, Rutgers University (poster)
Apr 9, 2015	Polar Predictability Workshop, University of Reading
Dec 18, 2014	AGU Fall Meeting, San Francisco
Jan 20, 2014	MURI Workshop, NYU
July 12, 2013	SIAM Annual Meeting, San Diego.
June 6, 2013	AOS Days, Johns Hopkins University
May 26, 2013	Sea Level Rise Meeting, NYU Abu Dhabi
Aug 16, 2012	Greenland Summer School, Tasiilaq, Greenland
Mar 14, 2012	Sea Level Rise Meeting, NYU Abu Dhabi
Nov 11, 2011	Graduate Student Symposium, Princeton (poster)
July 26, 2011	Greenland Summer School, Illulisat, Greenland.
June 21, 2011	AOS Days, MIT

## Outreach Events

2020	Webinar presentation on sea ice physics to Undergraduate Physical Oceanography class at Rider University, NJ
2019	Climate change presentation to retirement community at Greenbriar at Whittingham, Monroe Township, NJ
2019	Skype presentation on climate change to grade 5/6 students at Island Lakes school in Winnipeg, Manitoba
2019	Presentation on climate change to grade 7/8 students at French American School, Princeton, NJ