Marie C. McGraw, PhD

Cooperative Institute for Research in the Atmosphere
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Current Position

08/2022 - present **Research Scientist I**
Cooperative Institute for Research in the Atmosphere (CIRA), Colorado State University, Fort Collins, CO, USA
Research topics: machine learning and tropical cyclone prediction, uncertainty quantification for machine learning in geosciences

Education

10/2015 - 03/2019 **Ph.D., Atmospheric Science**, Colorado State University, Fort Collins, CO, USA
Advisor: Elizabeth Barnes
Dissertation: "A Causal Discovery-Based Approach to Understanding Arctic-Midlatitude Dynamics"

06/2013 - 10/2015 **M.S., Atmospheric Science**, Colorado State University, Fort Collins, CO, USA
Advisor: Elizabeth Barnes
Thesis: "Seasonal Sensitivity of the Eddy-Driven Jet Response to Tropospheric Heating in an Atmospheric General Circulation Model"

09/2008 - 06/2012 **B.Sc., Mechanical Engineering**, Massachusetts Institute of Technology, Cambridge, MA, USA

Previous Research Experience

07/2021 - 07/2022 **Postdoctoral Research Associate**
Cooperative Institute for Research in the Atmosphere (CIRA), Colorado State University, Fort Collins, CO, USA
Research topics: machine learning and tropical cyclone prediction, uncertainty quantification for machine learning in geosciences

06/2019 - 06/2021 **Postdoctoral Research Associate**, University of Washington, Seattle, WA, USA
Department: Atmospheric Sciences
Research topics: sea ice forecasting, extreme sea ice loss
Advisor: Prof. Cecilia Bitz

06/2013 - 05/2019 **Graduate Research Assistant**, Colorado State University, Fort Collins, CO, USA
Department: Atmospheric Sciences
Research topics: atmospheric dynamics, climate modeling, causal discovery and atmospheric sciences, statistical modeling, extratropical-polar climate variability
Advisor: Prof. Elizabeth Barnes

Awards

2023 **Visiting scholar**, Data-Driven Atmospheric and Water Dynamics Group, University of Lausanne, Lausanne, Switzerland

Publications

Under Review

· Fernandez, M., E.A. Barnes, R.J. Barnes, M. DeMaria, **M. McGraw**, G. Chirokova, L. Lu: Predicting tropical cyclone track forecast errors using a probabilistic neural network. Submitted 07/2024 to *Artificial Intelligence in the Earth Systems.*

In Preparation

· Ganesh Sudheesh, S., F.I.-H. Tam, M.S. Gomez, **M. McGraw**, M. DeMaria, K. Musgrave, A. Gerhardus, J. Runge, and T. Beucler: Improving tropical cyclone intensity forecasting using causal discovery and machine learning methods. In preparation for submission to *Artificial Intelligence in the Earth Systems*, winter 2025.

Peer-Reviewed

14. V. Eyring, W.D. Collins, and coauthors (inc. **M. McGraw**) (2024): Pushing the Frontiers in Climate Modeling and Analysis with Machine Learning. *Nature Climate Change*, **14**, 916-928, `https://doi.org/10.1038/s41558-024-02095-y`.

13. McGovern, A., A. Bostrom, **M. McGraw**, R.J. Chase, D.J. Gagne II, I. Ebert-Uphoff, K. Musgrave, and A. Schumacher (2024): Identifying and Categorizing Bias in AI/ML for Earth Sciences, *Bull. Amer. Meteorol. Soc.*, **105**, `https://doi.org/10.1175/BAMS-D-23-0196.1`.

12. McGovern, A., and coauthors (inc. **M. McGraw**) (2023): Trustworthy artificial intelligence for environmental sciences: An innovative approach for summer school. *Bull. Amer. Meteorol. Soc.*, **104**, `https://doi.org/10.1175/BAMS-D-22-0225.1`.

11. Haynes, K., R. Lagerquist, **M. McGraw**, K. Musgrave, and I. Ebert-Uphoff (2023): Creating and evaluating uncertainty estimates with neural networks for environmental-science applications. *Artificial Intelligence for Earth Systems*, **1**, `https://doi.org/10.1175/AIES-D-22-0061.1`.

10. **McGraw, M.C.**, E. Blanchard-Wrigglesworth, R.P. Clancy, and C.M. Bitz (2022): Understanding the predictability of Arctic sea ice loss on subseasonal timescales. *J. Climate*, **35**, doi:10.1175/JCLI-D-21-0301.1.

9. Gonzalez, A.O., I. Ganguly, **M.C. McGraw**, and J. Larson (2022): Rapid dynamical evolution of ITCZ events over the east Pacific. *J. Climate*, **35**, doi:10.1175/JCLI-D-21-0216.1.

8. Clancy, R.P., C.M. Bitz, E. Blanchard-Wrigglesworth, **M.C. McGraw**, and S. M. Cavallo (2021): A cyclone-centered perspective on the drivers of asymmetric patterns in the atmosphere and sea ice during Arctic cyclones. *Journal of Climate*, **34**, doi:10.1175/JCLI-D-21-0093.1.

7. **McGraw, M.C.** and E.A. Barnes (2020): New Insights on Subseasonal Arctic-Midlatitude Causal Connections from a Regularized Regression Model. *Journal of Climate*, **33**, doi:10.1175/JCLI-D-19-0142.1.

6. **McGraw, M.C.**, C.F. Baggett, C. Liu, and B.D. Mundhenk (2019): Changes in Arctic moisture transport over the North Pacific associated with sea ice loss. *Climate Dynamics*, **54**, doi:10.1007/s00382-019-05011-9.

5. Samarasinghe, S., **M.C. McGraw**, E.A. Barnes, and I. Ebert-Uphoff (2019): A study of links between the Arctic and the midlatitude jet-streams using Granger and Pearl causality. *Environmetrics,* **30**, doi:10.1002/env.2540.

4. **McGraw, M.C.**, and E.A. Barnes (2018): Memory matters: A case for Granger causality in climate variability studies. *J. Climate*, **31,** doi:10.1175/JCLI-D-17-0334.1.

3. Woollings, T., E. Barnes, B. Hoskins, Y.-O. Kwon, R.W. Lee, C. Li, E. Madonna, **M. McGraw**, T. Parker, R. Rodrigues, C. Spensberger, K. Williams (2018): Daily to decadal modulation of jet variability. *J. Climate*, **31,** doi:10.1175/JCLI-D-17-0286.1.

2. **McGraw, M.C.**, E.A. Barnes, and C. Deser (2016): Reconciling the observed and modeled Southern Hemisphere circulation response to volcanic eruptions. *Geophys. Res. Lett.,* doi:10.1002/2016GL069835.

1. **McGraw, M.C.**, and E.A. Barnes (2016): Seasonal sensitivity of the eddy-driven jet to tropospheric heating in an idealized AGCM. *J. Climate*, **29,** doi:10.1175/JCLI-D-15-0723.1.

Other

· Sospreda-Alfonso, R., Exenberger, J., Dang, K., and **M.C. McGraw**: Statistical adjustment of decadal climate predictions using deep learning. *Tackling Climate Change with Machine Learning Workshop*, NeurIPS 2022.

· Samarasinghe, S., **M. McGraw,** E. Barnes, and I. Ebert-Uphoff (2017): A study of causal links between the Arctic and the midlatitude jet-streams. *Proceedings of the Seventh International Workshop on Climate Informatics (CI 2017), NCAR Technical Note NCAR/TN-536+PROC.*

Selected Presentations

Invited

2023 **Seminar**, ITU "AI for Good" Seminar Series, 03/2023. *AI for Tropical Meteorology: Challenges and Opportunities*. T. Beucler and **M.C. McGraw**.

2022 **Presentation**, Aspen Global Change Institute Workshop on Earth System Modeling with Machine Learning and Big Data, 06/2022. *Causality and Interpretability*. **McGraw, M.C.**, and I. Ebert-Uphoff.

Seminar, Data-Driven Atmospheric and Water Dynamics Group, University of Lausanne, Switzerland. *Machine learning and tropical cyclone forecasting.* **McGraw, M.C.**, K.D. Musgrave, and I. Ebert-Uphoff.

2019 **Seminar**, Department of Atmospheric Sciences, University of Washington, Seattle, WA. *Using causal discovery to explore Arctic-midlatitude dynamics.* **McGraw, M.C.**, and E.A. Barnes.

2018 **Seminar**, NCAR Climate Variability and Change group, Boulder, CO. *A causal discovery approach to Arctic-midlatitude dynamics.* **McGraw, M.C.**, and E.A. Barnes.

Submitted

2024 **36th AMS Conference on Hurricanes and Tropical Meteorology**, Long Beach, CA. *Applications of a Machine Learning Model for Estimating Tropical Cyclone Track and Intensity Forecast Uncertainty.* DeMaria, M., E.A. Barnes, M. Fernandez, R.J. Barnes, **M. McGraw**, G. Chirokova, L. Lu, P. Santos, and W.A. Hogsett.

36th AMS Conference on Hurricanes and Tropical Meteorology, Long Beach, CA. *Exploring Tropical Cyclone Structure and Evolution with AI-based Synthetic Passive Microwave Data*. **McGraw, M.C.**, K. Haynes, K.D. Musgrave, C.J. Slocum, I. Ebert-Uphoff, and J.A. Knaff.

36th AMS Conference on Hurricanes and Tropical Meteorology, Long Beach, CA. *TCBench: A Platform for the Data-Driven Prediction of Tropical Cyclones* (poster). Gomez, M.S., **M. McGraw**, L. Poulain-Auzeau, F. I. H. Tam, S.G. Sudheesh, S.J. Camargo, D.R. Chavas, Y. Cohen, and T. Beucler.

23rd AI Conference, AMS Annual Meeting, Baltimore, MD, USA. *Exploring Tropical Cyclone Structure and Evolution with AI-based Synthetic Passive Microwave Data* (poster). **McGraw, M.C.**, K. Haynes, K.D. Musgrave, I. Ebert-Uphoff, C.J. Slocum, and J.A. Knaff.

23rd AI Conference, AMS Annual Meeting, Baltimore, MD, USA. *Causal Feature Selection for Tropical Cyclone Intensity Forecasting.* Beucler, T.G., S. Ganesh Sudheesh, F. I.-H. Tam, M. S. Gomez, **M. McGraw**, M. DeMaria, K.D. Musgrave, A. Gerhardus, and J. Runge

2023 **22nd AI Conference, AMS Annual Meeting**, Denver, CO, USA. *What can machine learning methods tell us about the tropical cyclone intensity forecasting problem?* **McGraw, M.C.**, K.D. Musgrave, J.A. Knaff, C.J. Slocum, and I. Ebert-Uphoff.

22nd AI Conference, AMS Annual Meeting, Denver, CO, USA. *Using AI To quantify Uncertainty on Tropical Cyclogenesis.* Baldwin, M.R., C. Slocum, and **M. McGraw**.

22nd AI Conference, AMS Annual Meeting, Denver, CO, USA. *Creating and Evaluating Uncertainty Estimates with Neural Networks for Environmental-Science Applications.* Haynes, K., R. Lagerquist, **M. McGraw**, K. Musgrave, and I. Ebert-Uphoff.

22nd AI Conference, AMS Annual Meeting, Denver, CO, USA. *Classifying and Addressing Bias in AI/ML for the Earth Sciences.* McGovern, A., A. Bostrom, D.J. Gagne II, I. Ebert-Uphoff, K. Musgrave, **M. McGraw**, and R. Chase.

5th Special Symposium on Tropical Meteorology and Tropical Cyclones, AMS Annual Meeting, Denver, CO, USA. *A Machine Learning Model for Estimating Tropical Cyclone Track and Intensity Forecast Uncertainty.* DeMaria, M., E.A. Barnes, R.J. Barnes, **M. McGraw**, L. Lu, G. Chirokova, and S.N. Stevenson.

2022 **Tackling Climate Change with Machine Learning Workshop, NeurIPS 2022**, remote. *Statistical adjustment of decadal climate predictions using deep learning.* Sospreda-Alfonso, R., Exenberger, J., Dang, K., and **M.C. McGraw** (spotlight presentation).

35th AMS Conference on Hurricanes and Tropical Meteorology, New Orleans, LA, USA. *What can machine learning tell us about the tropical cyclone intensity forecasting problem?* **McGraw, M.C.**, K.D. Musgrave, J.A. Knaff, C.J. Slocum, and I. Ebert-Uphoff.

2021 **European Geophysical Union Annual Meeting**, Vienna, Austria. *Drivers of the spatial pattern of Arctic sea ice response to Arctic cyclones.* Clancy, R.P., C.M. Bitz, E. Blanchard-Wrigglesworth, and **M.C. McGraw**.

34th AMS Conference on Hurricanes and Tropical Meteorology, remote. *Causal links between eastern Pacific ITCZ shifts and boundary layer dynamics.* Gonzalez, A.O., I. Ganguly, and **M.C. McGraw**.

2020 **American Geophysical Union Annual Meeting**, remote. *Extreme sea ice loss on subseasonal timescales in S2S forecast models* (poster). **McGraw, M.C.**, E. Blanchard-Wrigglesworth, R.P. Clancy, and C.M. Bitz.

American Geophysical Union Annual Meeting, remote. *Causal links between eastern Pacific ITCZ shifts and boundary layer dynamics.* Gonzalez, A.O., I. Ganguly, and **M.C. McGraw**.

American Geophysical Union Annual Meeting, remote. *Drivers of the spatial pattern of Arctic sea ice response to Arctic cyclones.* Clancy, R.P., C.M. Bitz, E. Blanchard-Wrigglesworth, and **M.C. McGraw**.

2019 **American Geophysical Union Annual Meeting**, San Francisco, CA. *Evaluating very rapid sea ice loss events in dynamical model forecasts* (poster). **McGraw, M.C.**, E. Blanchard-Wrigglesworth, R.P. Clancy, and C.M. Bitz.

2018 **American Geophysical Union Annual Meeting**, Washington, DC. *Using causal discovery to explore Arctic-midlatitude dynamics.* **McGraw, M.C.**, and E.A. Barnes.

NCAR Climate Variability and Change Working Group Meeting, Boulder, CO. *Causal discovery and midlatitude jet variability.* **McGraw, M.C.**, and E.A. Barnes.

2017 **American Geophysical Union Annual Meeting**, New Orleans, LA. *Revisiting causal links between the Arctic and midlatitudes.* **McGraw, M.C.**, and E.A. Barnes.

7th International Workshop on Climate Informatics, Boulder, CO. *A study of causal links between the Arctic and the midlatitude jet-streams* (spotlight presentation). Samarasinghe, S., **M.C. McGraw**, E.A. Barnes, and I. Ebert-Uphoff (co-first author with S. Samarasinghe).

21st AMS Conference on Atmospheric and Oceanic Fluid Dynamics, Portland, OR. *Causal links between the Arctic and the midlatitude jets.* **McGraw, M.C.**, and E.A. Barnes.

21st AMS Conference on Atmospheric and Oceanic Fluid Dynamics, Portland, OR. *Multi-scale response of moisture flux to projected sea ice loss* (poster). **McGraw, M.C.**, C.F. Baggett, C. Liu, B.D. Mundhenk, and E.A. Barnes.

NCAR Climate Variability and Change Working Group Meeting, Boulder, CO. *Comparing lagged regression and Granger causality in climate science.* **McGraw, M.C.**, and E.A. Barnes.

2016 **American Geophysical Union Annual Meeting**, San Francisco, CA. *Comparing the forced response to volcanic eruptions against internal variability in climate models* (poster). **McGraw, M.C.**, and E.A. Barnes.

SPARC Dynamical Variability Workshop, Helsinki, Finland. *Understanding the forced response to volcanic eruptions in climate models within the context of internal variability.* **McGraw, M.C.**, and E.A. Barnes.

NCAR Climate Variability and Change Working Group Meeting, Boulder, CO. *Understanding the forced response to volcanic eruptions in climate models.* **McGraw, M.C.**, and E.A. Barnes.

2015 **SPARC Storm Tracks Workshop**, Grindelwald, Switzerland. *Seasonal sensitivity of the eddy-driven jet to tropospheric heating in an idealized AGCM* (poster). **McGraw, M.C.**, and E.A. Barnes.

20th AMS Conference on Atmospheric and Oceanic Fluid Dynamics, Minneapolis, MN. *Seasonal sensitivity of the eddy-driven jet to tropospheric heating in a simple model* (poster). **McGraw, M.C.**, and E.A. Barnes.

Teaching, Mentoring, Outreach, & Service

2024 Program Committee Member for "Tackling Climate Change with Machine Learning" Workshop at the 2024 Conference on Neural Information Processing Systems (NeurIPS)

Co-chair for session "AI Advances in Tropical Meteorology: Tropical Cyclones, Sub-Seasonal Phenomena, and More" at the 23rd Annual AMS AI Conference

2023 Participated in a review panel for the NSF Office of Advanced Cyberinfrastructure in FY2023

Mentor for CIRA/ATS Mentoring Pods program (Colorado State University)

Co-chair for sessions "Exploring the Black Box of Machine Learning in Atmospheric Science" I and II at the 22nd Annual AMS AI Conference

2022 Mentor for ClimateChangeAI Summer School

Co-supervisor for NOAA Hollings Scholar Marshall Baldwin (University of Oklahoma)

Guest lecturer, "Uncertainty Quantification and Machine Learning", AI2ES Summer School on Trustworthy AI

Assistant Instructor, Trustworthy AI Hackathon, AI2ES Summer School on Trustworthy AI

2019-2021 Postdoc representative, Department of Atmospheric Sciences Colloquium Committee, University of Washington

Member, Diversity, Equity, and Inclusion Committee, University of Washington

2014-2018 Graduate teaching assistant, *Objective Analysis for Atmospheric Sciences*, spring 2018. Colorado State University

Graduate teaching assistant, *Atmospheric Dynamics I*, fall 2015. Colorado State University

Co-mentor for REU intern Julia Shates (now a Ph.D. student at the University of Wisconsin)

Reviewer: *Journal of Climate*, *Geophysical Research Letters*, *Nature Climate Change*, *Weather and Climate Dynamics*, *Journal of Geophysical Research: Atmosphere*, *Earth System Dynamics*, *Quart. J. Roy. Meteorol. Soc*, *Weather and Forecasting*, *Bull. Amer. Meteorol. Soc.*, *Nature Communications*; ad-hoc reviewer for the National Science Foundation.

Workshops, Tutorials, & Summer Schools

2024 **6th NOAA Workshop on Leveraging AI in Environmental Sciences**, Boulder, CO.

2023 **Front Range Tropical Cyclone Workshop**, Boulder, CO.

5th NOAA Workshop on Leveraging AI in Environmental Sciences, virtual.

2022 **Front Range Tropical Cyclone Workshop**, Fort Collins, CO.

4th NOAA Workshop on Leveraging AI in Environmental Sciences, virtual.

Trustworthy Artificial Intelligence for Environmental Science Summer School, virtual.

Aspen Global Change Institute Workshop on Earth System Modeling with Machine Learning and Big Data, Aspen, CO. Travel funded.

2021 **3rd NOAA Workshop on Leveraging AI in Environmental Sciences**, virtual.

Trustworthy Artificial Intelligence for Environmental Science Summer School, virtual.

2019 **CMIP6 Hackathon**, Boulder, CO. Travel funded.

2018 **8th International Workshop on Climate Informatics**, Boulder, CO.

CESM Polar Modeling Workshop, Boulder, CO. Travel funded.

2017 **7th International Workshop on Climate Informatics**, Boulder, CO.

2016 **NCAR Community Earth System Model Tutorial**, Boulder, CO. Travel funded.

SPARC Dynamical Variability Workshop, Helsinki, Finland. Travel funded.

2015 **SPARC Storm Tracks Workshop**, Grindelwald, Switzerland. Travel funded.