Timothy Smith, Ph.D.

Research Scientist

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Research Interests

Coupled Data Assimilation	Ocean Modeling	Open Source Software Development
Machine Learning	Uncertainty Quantification	High Performance Computing
Probabilistic Forecasting	Ice-Ocean Interactions	Observing System Design

Education

Ph.D. in Computational Science, Engineering, and Mathematics; December 2021
The University of Texas at Austin
Thesis: *Uncertainty Quantification of Ocean Driven Melting Under the Pine Island Ice Shelf*
Overall GPA: 3.96/4.00

M.S. in Computational Science, Engineering, and Mathematics; May 2017
The University of Texas at Austin
Overall GPA: 3.96/4.00

B.S. in Mechanical Engineering with High Honors; May 2014
Certificate in Scientific Computation
Thesis: *Modeling Coupled Photovoltaic Power Plants with Compressed Air Energy Storage in Texas*
The University of Texas at Austin
Overall GPA: 3.91/4.00

Research Experience

Research Scientist, December 2020 - present
Cooperative Institute for Research in Environmental Sciences (CIRES), CU Boulder
Physical Sciences Laboratory (PSL), NOAA Earth System Research Laboratories (ESRL)

Integrating neural networks with data assimilation to speed up and improve weather forecasting

Using machine learning to enable strongly coupled data assimilation capabilities

Graduate Research Assistant, August 2015 - December 2021
Oden Institute for Computational Engineering and Sciences; The University of Texas at Austin
Advisor: Dr. Patrick Heimbach

Developed computational framework for oceanographic uncertainty quantification

Evaluated ice shelf meltrate uncertainty reduction from sparse, in situ ocean observations

Developed and implemented anisotropic, nonstationary prior covariance model

Undergraduate Research Assistant, December 2011 - May 2014
Department of Mechanical Engineering; The University of Texas at Austin
Advisor: Dr. Mark Deinert

Developed Monte Carlo neutron transport model to better parameterize nuclear reaction rates

Implemented Monte Carlo radiation transport model in C for parameterization validation

Explored the potential solar energy cost reduction via positive feedback from economies of scale

Undergraduate Research Assistant, Summer 2013
Oden Institute for Computational Engineering and Sciences; The University of Texas at Austin
Advisor: Dr. Michael Sacks

Developed tetrahedral human heart model for mechanical deformation simulations

Established workflow for collaboration with Medtronic (industry partners)

Publications

Preprints and Ongoing Work

1. **Smith, T. A.**, Penny, S. G., Platt, J. A., & Chen, T.-C. (2023). Temporal Subsampling Diminishes Small Spatial Scales in Recurrent Neural Network Emulators of Geophysical Turbulence. *Submitted to JAMES*. Preprint: https://doi.org/10.48550/arXiv.2305.00100

2. Platt, J. A., Penny, S. G., **Smith, T. A.**, Chen, T.-C., & Abarbanel, H. D. I. (2023). Constraining Chaos: Enforcing dynamical invariants in the training of recurrent neural networks. arXiv. https://doi.org/10.48550/arXiv.2304.12865

3. **Smith, T. A.** A Practical Formulation for an Anisotropic and Nonstationary Matérn Class Correlation Operator. (2022). Preprint: https://www.essoar.org/doi/10.1002/essoar.10511974.1

4. Chen, T.-C., Penny, S. G., **Smith, T. A.**, and Platt, J. A. 'Next Generation' Reservoir Computing: an Empirical Data-Driven Expression of Dynamical Equations in Time-Stepping Form. Preprint: https://arxiv.org/abs/2201.05193.

5. Abernathey, R., Busecke, J., Banihirwe, A., Zhang, C., & **Smith, T.** Xgcm: a python package for analyzing data from general circulation models. *In review at the Journal of Open Source Software.*

Journal Articles

1. Platt, J. A., Penny, S. G., **Smith, T. A.**, Chen, T.-C., and Abarbanel, H. D. I. (2022). A systematic exploration of reservoir computing for forecasting complex spatiotemporal dynamics. *Neural Networks*, 153, 530–552. https://doi.org/10.1016/j.neunet.2022.06.025

2. Penny, S. G., **Smith, T. A.**, Chen, T.-C., Platt, J. A., Lin, H.-Y., Goodliff, M., and Abarbanel, H.D.I. (2022). Integrating Recurrent Neural Networks with Data Assimilation for Scalable Data-Driven State Estimation. *Journal of Advances in Modeling Earth Systems.* 14, e2021MS002843. https://doi.org/10.1029/2021MS002843

3. Kostov, Y., Johnson, H., Marshall, D., Forget, G., Heimbach, P., Holliday, P., Li, F., Lozier, S., Pillar, H., & **Smith, T.** Contrasting sources of variability in subtropical and subpolar Atlantic overturning. *Nature Geosciences.* https://doi.org/10.1038/s41561-021-00759-4

4. Nguyen, A. T., Pillar, H., Ocaña, V., Bigdeli, A., **Smith, T. A.**, & Heimbach, P. (2021). The Arctic Subpolar gyre sTate Estimate (ASTE): Description and assessment of a data-constrained, dynamically consistent ocean-sea ice estimate for 2002–2017. *Journal of Advances in Modeling Earth Systems*, 13, e2020MS002398. https://doi.org/10.1029/2020MS002398

5. Laguë, M. M., Pietschnig, M., Ragen, S., **Smith, T. A.**, & Battisti, D. S. (2021). Terrestrial Evaporation and Global Climate: Lessons from Northland, a Planet with a Hemispheric Continent. *Journal of Climate*, 34(6), 2253-2276. https://doi.org/10.1175/JCLI-D-20-0452.1

6. Goldberg, D. N., **Smith, T. A.**, Narayanan, S. H. K., Heimbach, P., & Morlighem, M. (2020). Bathymetric Influences on Antarctic Ice-Shelf Melt Rates. Journal of Geophysical Research: Oceans, 125(11), e2020JC016370. https://doi.org/10.1029/2020JC016370

7. **Smith, T.** & Heimbach, P. (2019). Atmospheric Origins of Variability in the South Atlantic Meridional Overturning Circulation. Journal of Climate, 32(5), 1483–1500. https://doi.org/10.1175/JCLI-D-18-0311.1

8. Stoll, B. L., **Smith, T. A.**, & Deinert, M. R. (2013). Potential for rooftop photovoltaics in Tokyo to replace nuclear capacity. Environmental Research Letters, 8(1), 014042. https://doi.org/10.1088/1748-9326/8/1/014042

Peer Reviewed Conference Proceedings

1. Osborne, A. G., **Smith, T. A.**, & Deinert, M. R. (2013). Comparison of actinide production in traveling wave and pressurized water reactors. In Proceedings of GLOBAL 2013: International Nuclear Fuel Cycle Conference-Nuclear Energy at a Crossroads.

Selected Presentations

Oral Presentations

1. *Recurrent Neural Network Emulation for High Resolution Forecasting*. ECMWF-ESA Workshop on Machine Learning for Earth Observation and Prediction. Reading, UK. November 21-24, 2022.
2. *Toward Recurrent Neural Network Emulation of High Resolution Sea Surface Temperatures.* Ocean Sciences Meeting. Virtual Conference. February 24 - March 4, 2022.
3. *Quantifying uncertainties in ocean driven melting under the Pine Island ice shelf.* SIAM Conference on Mathematical and Computational Issues in the Geosciences. Virtual Conference. June 21-24, 2021.
4. `ecco_v4_py` *demo: analysis tools for the ECCO state estimate in python with xarray and dask.* ECCO Townhall, Ocean Sciences Meeting 2020. San Diego, California. February, 2020.
5. *Atmospheric origins of variability in the South Atlantic meridional overturning circulation.* Workshop on Sensitivity Analysis and Data Assimilation in Meteorology and Oceanography. Aveiro, Portugal. July, 2018.
6. *A dynamical reconstruction of AMOC variability at the mouth of the South Atlantic.* US AMOC Science Team Meeting. Santa Fe, New Mexico. May, 2017.

Poster Presentations

1. *Uncertainty Quantification of Ocean Driven Melting Under the Pine Island Ice Shelf, West Antarctica.* Invited Poster at Ocean Sciences Meeting. February - March, 2022. See it here.
2. *Atmospheric origins of variability in the South Atlantic meridional overturning circulation.* Ocean Sciences Meeting. February, 2020.
3. *Informing bathymetry through an ocean model.* Workshop on UQ for inverse problems in complex systems. Cambridge, UK. April, 2018.
4. *A dynamical reconstruction of AMOC variability at the mouth of the South Atlantic.* SIAM Conference on Mathematical and Computational Issues in the Geosciences. Erlangen, Germany. September, 2017.

Honors and Awards

- **Certificate of Recognition,** UT Austin SIAM Student Chapter. 2018.
- **Poster Presentation Award,** SIAM Conference for Mathematical and Computational Issues in the Geosciences. September, 2017
- **Professional Development Award for Travel,** UT Office of Graduate Studies. Fall, 2017.
- **CSEM Fellowship,** Oden Institute, UT Austin. 2014 - 2018
- **Graham F. Carey Undergraduate Scholarship in Computational Science,** Oden Institute, UT Austin. 2014
- **Fuel Cycle Research Award,** US DOE Office of Fuel Cycle Technologies. 2013
- **Nuclear Energy University Program Scholarship,** US DOE Integrated University Program. 2012

- **Undergraduate Research Fellowship,** UT Austin, 2012

Teaching Experience, Service, and Leadership Roles

Teaching

- **Computing Mentor,** Significant Opportunities in Atmospheric Research and Science (SOARS). May - July, 2022.

  Assisting protégé with computing needs, mostly establishing a consistent and efficient, python-based workflow for analyzing atmospheric data and model output.
- **Instructor and Co-Organizer,** ECCO Summer School. May, 2019.

  Presented Jupyter notebook tutorials, demonstrating ECCO state estimate analysis in python

  Taught students to use Git and GitHub

  Organized computational resources for remote analysis via the Texas Advanced Computing Center
- **Mentor,** for Andrew Xiao (undergraduate), UT Austin. Spring, 2019.

  Mentored undergraduate student during his final thesis project, titled:

  Comparing Volumetric Transport from the Arctic with Estimated Transport using ECCO and ASTE
- **Teaching Assistant,** Descriptive Physical Oceanography, UT Austin. Spring, 2019.

  Presented lecture and provided course notes on air-sea interactions at undergraduate & graduate level
- **K-12 Outreach Tutor & Committee Chair,** Tau Beta Pi Engineering Honor Society. 2013-2014.

  Tutored students in high school mathematics

  Organized supplemental Saturday tutoring sessions
- **Undergraduate Tutor,** Mechanical Engineering, UT Austin. 2011-2012.

  Tutored undergraduate level thermodynamics, fluid mechanics, dynamics, & computational methods

Professional Service and Leadership

- **Reviewer:** Artificial Intelligence for the Earth Systems, Journal of Advances in Modeling Earth Systems, Quarterly Journal of the Royal Meteorological Society, Journal of Climate, Frontiers in Oceanography
- **Co-Organizer,** Texas Applied Mathematics and Engineering Symposium. September, 2017.

  Helped organize and run a 3 day, student led conference, initiated by the UT Austin Chapter of SIAM
- **Industry Liaison,** UT Austin Chapter of SIAM. 2016-2018.

  Invited speakers from industry and national laboratories to give talks aimed at graduate students

  Organized one-on-one meetings between representatives and students

Outreach and Volunteering

- **Zero Waste Volunteer,** Oden Institute, UT Austin. January 2020 - January 2021.

  Co-leading institute initiative to curtail landfill waste, implement composting, and reduce carbon footprint
- **Volunteer,** UT Girl Day. February, 2020.

  Organized and demonstrated Arctic-Ocean themed scientific experiments for girls in grades K-12

Coursework and Summer Schools

Selected Graduate Coursework

Mathematics: Variational Methods for Inverse Problems, Functional Analysis, Multiscale Modeling, Statistical Estimation Theory

Computational Science: Parallel Algorithms, Validation and Uncertainty Quantification in Computational Models, Numerical Methods for Differential Equations

Fluid Mechanics & Oceanography: Dynamics of Turbulent Flows, Fluid Dynamics of the Atmosphere and Ocean, Computational Ocean Modeling, Observational Physical Oceanography

Summer Schools

Advanced Climate Dynamics Course, September 2018

Global Ocean Data Assimilation Experiment (GODAE) Ocean View International School, October 2017

Statistical and Applied Mathematical Sciences Institute (SAMSI) Optimization Summer School, August 2016

Software Contributions and Computational Skills

Selected Software Contributions

- **ecco_v4_py**: python package for analyzing ECCOv4 output with xarray, dask, xgcm, & xmitgcm
- **MITgcm**: general circulation model largely for oceanographic applications in Fortran
- **xgcm**: python package for analyzing general circulation model output
- **xmitgcm**: python package to read MITgcm binary output to xarray
- **sparc**: educational tool for solving the sparse page rank problem in C++ on multicore (KNL) architecture

Computational Skills

Python, with experience using Dask for parallel computing, CuPy for GPU acceleration, & xarray because it's more fun to use than raw NumPy

Fortran, C/C++ with experience using MPI and OpenMP

Git/Mercurial, LaTeX, Matlab

Check out my Git and GitHub tutorial slides for a recent team meeting here