

Niraj Agarwal

Boulder, CO • 303.931.8747 • niraj.agarwal@colorado.edu • In: niraj-agarwal-37827572 • he/him • Indian

An Earth system modeling enthusiast with keen interests in multi-scale modeling of geophysical processes using advanced physics-based and data-driven methods, e.g., stochastics, ML/AI, and leveraging modern exascale computing resources to enable the development of high-fidelity next-generation coupled earth system model and strongly coupled data assimilation capability.

Education

Imperial College London

PhD Mathematics, Mathematics of Planet Earth, Centre for Doctoral Training (MPE CDT)
Thesis: “Statistical-Dynamical Analyses and Modelling of Multi-scale Ocean Variability”

London, UK
Sept 2018 - Feb 1, 2022

Imperial College London and University of Reading

Master of Research (MRes) in Mathematics of Planet Earth [with Distinction], MPE CDT
Dissertation: “Data-driven Reduced Order Modelling of Oceanic Variability”
Relevant Courses: Geophysical Fluid Dynamics, Advanced Numerical Methods, Uncertainty Quantification

London, UK
Sept 2017 – Sept 2018

Indian Institute of Technology (Indian School of Mines), Dhanbad

5 Year Integrated M.Tech., Mathematics and Computing [Department Rank:1, Gold Medal]
Dissertation: On the Application of Game Theory in Geophysical Inversion for Multi-Objective Optimization

Dhanbad, India
Aug 2010-May 14, 2015

Publications

- Slivinski, L. C., Whitaker, J. S., Frolov, S., Smith, T. A., & **Agarwal, N.** (2025). Assimilating observed surface pressure into ML weather prediction models. *Geophysical Research Letters*, 52, e2024GL114396. <https://doi.org/10.1029/2024GL114396>
- **Agarwal, N.**, Amrhein, D. E., & Grooms, I. (2025). Cross-attractor transforms: Improving forecasts by learning optimal maps between dynamical systems and imperfect models. *Geophysical Research Letters*, 52, e2024GL110472. <https://doi.org/10.1029/2024GL110472>
- Grooms, I., **Agarwal, N.**, Marques, G., Pegion, P. J., & Yassin, H. (2025). The stochastic GM + E closure: A framework for coupling stochastic backscatter with the Gent and McWilliams parameterization. *Journal of Advances in Modeling Earth Systems*, 17, e2024MS004560. <https://doi.org/10.1029/2024MS004560>
- **Agarwal, N.**, Small, R. J., Bryan, F. O., Grooms, I., & Pegion, P. J. (2023). Impact of stochastic ocean density corrections on air-sea flux variability. *Geophysical Research Letters*, 50, e2023GL104248. <https://doi.org/10.1029/2023GL104248>
- **Agarwal, N.**, Kondrashov, D., Dueben, P., Ryzhov, E., & Berloff, P. (2021). A comparison of data-driven approaches to build low-dimensional ocean models. *Journal of Advances in Modeling Earth Systems*, 13, e2021MS002537. <https://doi.org/10.1029/2021MS002537>
- **Agarwal, N.**, Ryzhov, E. A., Kondrashov, D., Berloff, P. (2021). Correlation-based flow decomposition and statistical analysis of the eddy forcing. *Journal of Fluid Mechanics*. 2021;924:A5. <https://doi.org/10.1017/jfm.2021.604>
- Ryzhov, E. A., Kondrashov, D., **Agarwal, N.**, McWilliams, J. C., and Berloff, P. (2020). On data-driven induction of the low-frequency variability in a coarse-resolution ocean model, *Ocean Modelling*, 153, 101664. <https://doi.org/10.1016/j.ocemod.2020.101664>
- Ryzhov, E. A., Kondrashov, D., **Agarwal, N.**, and Berloff, P. (2019). On data-driven augmentation of low-resolution ocean model dynamics, *Ocean Modelling*, 142, 101464. <https://doi.org/10.1016/j.ocemod.2019.101464>

Experience

University of Colorado Boulder/CIRES and NOAA Physical Sciences Lab

Postdoctoral Associate

Research Scientist - I

Research Scientist - II

Boulder, CO, USA
March 2022 – Feb 2024
March 2024 – April 2025
May 2025 – Present

- Investigated the impacts of a physics-based stochastic subgrid-scale parameterization for ocean density on air-sea flux variability in a comprehensive coupled climate model – CESM-MOM6 (published in GRL).

- Co-developed, implemented and analyzed “Cross-Attractor Transformations (CATs)”: a novel scalable machine learning approach to optimize earth system predictions using biased/incomplete models (published in GRL with a GRL commentary on it).
- Performed experiments in MOM6 to quantify the impacts of energy backscatter and other stochastic physics (e.g., ePBL, SPPT) schemes on ensemble statistics in S2S global forecasts (in collaboration with NOAA-PSL).
- Helped with the training of GraphCast, in-house at NOAA-PSL using the REPLAY reanalysis dataset.
- Leading a research effort on the development of a fully-coupled earth system emulator possessing all major earth system components – i.e., atmosphere, ocean, land, and sea ice – like NOAA’s Global Forecast System (GFS) with an aim to accelerate and improve earth system forecasts on medium to extended-range time scales. This also includes proposing stochastic extensions of the AI-based earth system emulators to improve extreme events predictions.

Goethe University

Research Associate

Frankfurt, Germany

Aug 2021 – Feb 2022

- Served as part of the multi-institutional project DataWave for the processing and data-driven emulation of Multi-Scale Gravity Wave Model (MS-GWaM) outcomes for orographic gravity wave drag.
- Proposed and implemented the theory for achieving Fourier transform of fields discretized on anisotropic grids, e.g., those in the German Weather Service model ICON, for their advance postprocessing and analysis.

King Abdullah University of Science and Technology (KAUST)

Graduate Student Researcher

Jeddah, Saudi Arabia

Feb 2017 - June 2017

- Investigated recurring earthquakes from specific sources in Tanzania to understand the underlying subsurface geology and locate active faults.
- Implemented time-series-based methods for seismic data analysis and used template matching algorithm for identifying the repeating earthquakes, followed by their physical interpretations.

National Institute of Oceanography, Goa

Project Assistant-II

Dona Paula, Goa, India

March 2016 – Jan 2017

- Developed a novel image-processing-based method to modify the loss function used in Full Waveform Inversion (FWI) of seismic data.
- Demonstrated steeper model convergence using the revised algorithm even for a poor initial guess of the model parameters.

Personal Sabbatical – Unpaid Internship and Personal Development

Tiruchirapalli and Delhi, India

May 2015 – Feb 2016

- Completed an unpaid internship with a data science startup, Fiind, based in Trichy, India, to explore data scientist responsibilities and gain insights into building a startup from the ground up.
- Collaborated with college friends to establish a startup that provides on-demand laundry services delivered to customers' doorsteps. We approached several investors to secure funding for developing the hardware backend and mobile application, but we were ultimately unsuccessful.
- Gained familiarity with the requirements of Android app development and pursued relevant training on Coursera to develop the necessary coding skills for bringing the mobile application of our intended startup to fruition.
- Enhanced my software engineering skills further through the online platform "GeeksforGeeks" and interviewed with several tech companies to seek job opportunities within their research and development departments.

Summer Schools, Internships, and Trainings

MPE CDT Virtual Summer School

Participant, Principal Instructor: Henk Dijkstra, Utrecht University

Sept 29 - Oct 27, 2020

Online

- Weekly lectures delivered on the topics covering dynamical systems, ocean and atmospheric dynamics, climate, and machine learning. The lectures were supplemented by mini practical assignments with a short group presentation at the end.

- The scheduled 10-week research internship at the UK Met Office got cancelled due to Covid restrictions.

National Institute of Oceanography, Goa

Summer Intern, Supervisor: Pawan Dewangan

May 20 - July 21, 2014

Dona Paula, Goa, India

- Worked towards estimating the power of GPU in seismic data processing.
- Developed a CUDA (with C) code for FFT and demonstrated a processing speed up of approx. 15x for the available GPU configuration.

National Geophysical Research Institute, Hyderabad

Summer Research Intern, Supervisor: Mrinal K. Sen

May 3 - July 4, 2013

Dec 4, 2013 - Jan 6, 2014

- Research work done on the introduction of Game Theory into geophysical inversion.
- Devised loss functions based on Cooperative, Non-Cooperative and Modified Game Theory concepts and developed codes to integrate them into the existing inversion routines.
- Also developed a C code for quantum particle swarm optimization and showed its efficacy over the binary version for a 2D inversion problem.

Technical Strengths

Programming Languages: C, C++, Python, Shell scripting, FORTRAN

Parallel Programming: Basics of CUDA, MPI

Databases: DBMS, MySQL, Microsoft SQL, NCO

Softwares & OS: MATLAB, Microsoft Office Suite, Windows 7, Linux

AI4NWP relevant skills: Algorithm Design and Analysis, Machine Learning, Data Assimilation for higher dimensional systems, Version Control toolkits (e.g., Git), Numerical Methods and Analysis, Accelerator and Program transformation library JAX, Deep Learning and Optimization libraries like Tensorflow, Haiku, and Optax, Efficient data handling using, e.g., xarray, and Data handling in netCDF and cloud-optimized zarr formats.

Scholarships, Awards, Grants and recognitions

- Travel and accommodation support from the University of Oxford, UK, and German Climate Computing Center, Hamburg, Germany, for workshop/hackathon attendance.
- Mathematics of Planet Earth Center for Doctoral Training (MPE CDT) Best M.Res. Project Award, 2018.
- MPE CDT international studentship award for 2017-21 (1 out of 26 international applicants selected). MPE CDT is an innovative 1+3 year fully-funded M.Res + PhD program run jointly by Imperial College London and the University of Reading, UK.
- Scholarship for Higher Education (SHE)” from 2010-2012 : A component of the ‘Innovation in Science Pursuit for Inspired Research (INSPIRE)’ implemented by the Department of Science Technology (DST), New Delhi, India.
- All India Rank in Top 1.75% of IIT-JEE (Joint Entrance Examination)-2010 among a total examinee of 485,571.
- Awarded a computational grant as co-PI for the project “Scaling transformer neural networks for skillful and reliable weather, S2S, and climate modeling” by Argonne Leadership Computing Facility. The grant provides us with 250,000 node hours on the Polaris and 200,000 node hours on the Frontier supercomputer.
- Granted early promotion to Research Scientist II from Research Scientist I recognizing the significant scientific contributions during the tenure.
- The GRL paper on Cross-Attractor Transforms (CATs) is spotlighted by Steve J Penny in a GRL commentary, highlighting its originality, novelty, and strong theoretical foundation, dating back to 1960s. Link to the commentary: <https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2025GL116465>.

Synergistic and Outreach Activities

- Regular referee for high-quality peer-reviewed journal, such as GRL, JAMES, Nature Scientific Reports, AIES.
- Poster presentations at AGU 2022; PICO presentation at EGU 2021. Abstract accepted for AMS 2025.
- Active participation in the ML workshop in weather and climate predictions (Sept 2-5, 2019) at University of Oxford, UK; the TRR energy transfers in oceans and atmosphere workshop (April 2-4, 2019) at the university of Potsdam, Germany; and in the Hamburg COMMODORE conference (Jan 28-31, 2020).
- Participation in Hackathon participation at ECMWF, Imperial College London (Stochastic Transport in the Upper Ocean Dynamics (STUOD) themed), and ESiWACE-DYAMOND meeting in Mainz, Germany.
- Full length research talks at Imperial College London, US Naval Research Lab (Stennis), CU Boulder, NOAA,

Goethe University.

- Introductory Artificial Intelligence seminar for year 8 school kids in Reading, UK.

References

- Dan Amrhein, Scientist I, National Centre for Atmospheric Research (NCAR), Boulder, CO, USA
Tel: +1-303-497-1363, Email: damrhein@ucar.edu
- Ian Grooms, Associate Professor, University of Colorado Boulder, CO, USA
Tel: +1-303-492-4668, Email: ian.grooms@colorado.edu
- Peter Dueben, Head of Earth System Modeling Section, ECMWF, Bonn, Germany
Tel. +44-(0)-118-9499784, Email: peter.dueben@ecmwf.int
- Phil Pegion, Director, Modeling and Data Assimilation Division, NOAA Physical Sciences Laboratory, CO, USA
Tel. +1-443-486-8707, Email: philip.pegion@noaa.gov