# Niraj Agarwal

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An Earth system modeling enthusiast with keen interests in multi-scale modeling of oceanic and atmosphere geophysical processes using advanced white- and block-box methods, e.g., stochastic modeling, ML/AI, and leveraging modern exascale compute capabilities to contribute to the development of high-fidelity next-generation coupled earth system models.

## Education

**Imperial College London** — London, UK
PhD Mathematics, Mathematics of Planet Earth, Centre for Doctoral Training (MPE CDT) — Sept 2018 - Feb 1, 2022
Thesis: "Statistical-Dynamical Analyses and Modelling of Multi-scale Ocean Variability"

**Imperial College London and University of Reading** — London, UK
Master of Research (MRes) in Mathematics of Planet Earth [with Distinction], MPE CDT — Sept 2017 – Sept 2018
Dissertation: "Data-driven Reduced Order Modelling of Oceanic Variability"
Relevant Courses: Geophysical Fluid Dynamics, Advanced Numerical Methods, Uncertainty Quantification

**Indian Institute of Technology (Indian School of Mines), Dhanbad** — Dhanbad, India
5 Year Integrated M.Tech., Mathematics and Computing [Department Rank:1, Gold Medal] — Aug 2010-May 14, 2015
Dissertation: On the Application of Game Theory in Geophysical Inversion for Multi-Objective Optimization

## Publications

- N Agarwal, D Amrhein, and I Grooms, Cross-attractor transformations (CATs): A novel machine learning framework to reduce forecast error in the presence of model bias, Manuscript under review, Geophysical Research Letters, 2024.
- I. Grooms, N. Agarwal, G. Marques, P. J. Pegion, and H. Yassin, The Stochastic GM+E closure: A framework for coupling stochastic backscatter with the Gent and McWilliams Parameterization, Manuscript under review, Journal of Advances in Modeling Earth Systems, 2024.
- Niraj Agarwal, R. Justin Small, Frank O. Bryan, Ian Grooms, and Philip J. Pegion, Impact of stochastic ocean density corrections on air-sea flux variability, Geophysical Research Letters 50, e2023GL104248 (2023).
- N Agarwal, Kondrashov, P Dueben, EA Ryzhov, and P Berloff, A comparison of data- driven approaches to build low-dimensional ocean models, Journal of Advances in Modeling Earth Systems 13, e2021MS002537 (2021).
- N Agarwal, EA Ryzhov, D Kondrashov, and P Berloff, Correlation-based flow decomposition and statistical analysis of the eddy forcing, Journal of Fluid Mechanics 924, A5 (2021).
- EA Ryzhov, D Kondrashov, N Agarwal, JC McWilliams, and P Berloff, On data-driven induction of the low-frequency variability in a coarse-resolution ocean model, Ocean Modelling 153, 101664 (2020).
- EA Ryzhov, D Kondrashov, N Agarwal, and PS Berloff, On data-driven augmentation of low-resolution ocean model dynamics, Ocean Modelling 142, 101464 (2019).

## Experience

**University of Colorado Boulder/CIRES and NOAA Physical Sciences Lab** — Boulder, CO, USA
**Postdoctoral Associate** — March 2022 – Feb 2024
**Research Scientist - I** — March 2024 - 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 (manuscript under prep.).
- Performing 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).
- Engaged in training the AI weather emulator, GraphCast, in-house at NOAA-PSL using the REPLAY reanalysis dataset and proposing its stochastic and coupled (atmosphere-ocean-sea ice) extensions.

**Goethe University** Frankfurt, Germany
Research Associate 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)** Jeddah, Saudi Arabia
Graduate Student Researcher 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** Dona Paula, Goa, India
Project Assistant-II 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.

## Summer Schools, Internships, and Trainings

**MPE CDT Virtual Summer School** Sept 29 - Oct 27, 2020
Participant, Principal Instructor: Henk Dijkstra, Utrecht University 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** May 20 - July 21, 2014
Summer Intern, Supervisor: Pawan Dewangan 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** May 3 - July 4, 2013
Summer Research Intern, Supervisor: Mrinal K. Sen 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 Modi ed 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), Ocean Modeling, Data-driven Modeling, Theory of Chaotic Dynamical Systems, Numerical Methods and Analysis.

## Scholarships and Awards

- 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.

## Synergistic and Outreach Activities

- Regular referee for high-quality peer-reviewed journal, such as JAMES, Nature Scientific Reports, AIES.
- Poster presentations at AGU 2022; PICO presentation at EGU 2021.
- 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.