Shikhar Rai

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Research Summary

Physical oceanographer focused on multiscale air-sea interactions. Combines theory, numerical modeling (e.g., ROMS-WRF, MOM6) with satellite/in-situ observations to investigate air-sea fluxes and turbulent dynamics.

Research Interests

Air-sea Interactions; Physical Oceanography; Turbulence; Geophysical Fluid Dynamics; Numerical Modeling; Machine Learning

Education

Ph.D. Mechanical Engineering Sep 2017 – Aug 2023
University of Rochester, NY
Thesis: *Scale Analysis of Wind Work on the Oceanic General Circulation*
Advisor: Dr. Hussein Aluie

B.E. Mechanical Engineering Oct 2010 – Feb 2015
Tribhuvan University, Nepal

Research Experience

Postdoctoral Investigator Aug 2023 – Present
Woods Hole Oceanographic Institution, MA

- Investigating multiscale air-sea interaction dynamics in the Tropical Pacific using coupled regional models (ROMS-WRF coupled with SCOAR).
- Using machine learning techniques (DBSCAN, Random-Forest, Deep-learning) to reconcile discrepancies between satellite and in-situ wind measurements (QuikSCAT, ASCAT, TAO array moorings).

Graduate Research Assistant Summers 2018, 2019
Los Alamos National Laboratory, NM

- Investigated the spatial scales of ocean surface wind forcing on mesoscale ocean dynamics using QuikSCAT observations and CESM/POP2 outputs.
- Modified and implemented analytical wind forcing and relative wind stress parameterizations in MOM6 for multiscale analysis of air-sea momentum fluxes.

Teaching Experience

- Fluid Dynamics of the Atmosphere and Ocean (TA Graduate course, Fall 2024, MIT-WHOI)
- Turbulence (TA Graduate course, Fall 2022, University of Rochester)
- Thermodynamics (TA Undergraduate course Spring 2018, University of Rochester)
- Solid Mechanics Lab (TA Undergraduate course, Fall 2017, University of Rochester)

Grants and Awards

- Awardee Participant, Physical Oceanography Dissertation Symposium (PODS) – 2024
- Travel Grant, US CLIVAR Air-Sea Workshop – 2023
- Travel Grant, SWOT FilaChange Workshop, Brown University – 2022
- Awardee Participant, Boulder Summer School in Condensed Matter Physics – 2022
- Merit Scholar, Rank 1 (out of ∼8000), Engineering Entrance Exam, T.U., Nepal – 2010

Service and Leadership

- Reviewer:
  - *Journal of Geophysical Research: Oceans*
  - *Journal of Physical Oceanography*
- Convener:
  - Session Convener: AGU Annual Meeting, Session AOS012 (2024)
  - Moderator: SWOT FilaChange Workshop, Brown University (2022)
- Leadership
  - Executive Committee:
    Junior Scientist Member-at-Large,
    APS Topical Group on Physics of Climate (2025–26)

Professional Associations

- American Physical Society
- American Geophysical Union

Industry Experience

CFD Engineer Feb 2017 – Jul 2017
Yokohama, Kanagawa, Japan

- Performed CFD simulations for parts and machinery used in natural gas plants.
- Relevant Skills: *HPC, Numerical Modelling, CFD, Parallel Computing*

CAD/CAE Engineer Nov 2014 – Feb 2017
E & T Nepal/ E & T Co. Japan
Sallaghari, Bhaktapur, Nepal/Utsunomiya, Tochigi, Japan

- Performed CFD simulations for automobile parts.
- Led the development and validation of the dynamic core in an in-house CFD solver.
- Relevant Skills: *C++, Numerical Modelling, Parallel Computing, CUDA, CAD, CFD*

Technical Skills

Machine Learning Frameworks: Scikit-learn, TensorFlow, PyTorch
Programming: Python, FORTRAN, C, C++, MATLAB
HPC: MPI, OpenMP, CUDA (C++), mpi4py, dask, xarray
Ocean/Atmosphere/Earth-System Modeling: ROMS, WRF, MOM6, CESM
CFD Tools: ANSYS Fluent, CFX, ICEM CFD
CAD Tools: CATIA, SolidWorks, AutoCAD

Machine Learning Course Certifications

- Machine Learning
  - Introduction to Supervised and Unsupervised learning, Logistic Regression, Neural Network, Support Vector Machine, Principal Component Analysis, K-Means Clustering, Random Forest Clustering
- Deep learning Specialization(5 courses)
  1. Neural Network and Deep Learning
  2. Improving Deep Neural Networks: Hyperparameter Tuning, Regularization and Optimization
  3. Structuring Machine Learning Projects
  4. Convolutional Neural Networks
  5. Sequence Model

Publications

[1] **Shikhar Rai**, J Thomas Farrar, Hussein Aluie. "Atmospheric wind energization of ocean weather". *Nature Communications* 16.1 (2025), p. 1172. DOI: 10.1038/s41467-025-56310-1.

[2] Hussein Aluie, **Shikhar Rai**, Hao Yin, Aarne Lees, Dongxiao Zhao, Stephen M Griffies, Alistair Adcroft, Jessica K Shang. "Effective drift velocity from turbulent transport by vorticity". *Physical Review Fluids* 7.10 (2022), p. 104601. DOI: 10.1103/PhysRevFluids.7.104601.

[3] **Shikhar Rai**, Matthew Hecht, Matthew Maltrud, Hussein Aluie. "Scale of oceanic eddy killing by wind from global satellite observations". *Science Advances* 7.28 (2021), eabf4920. DOI: 10.1126/sciadv.abf4920.

[4] Krishna Khanal, Hari P Neopane, **Shikhar Rai**, Manoj Thapa, Subendu Bhatt, Rajendra Shrestha. "A methodology for designing Francis runner blade to find minimum sediment erosion using CFD". *Renewable Energy* 87 (2016), pp. 307–316. DOI: 10.1016/j.renene.2015.10.023.

Pre-Prints:

[5] **Shikhar Rai**, Susan Wijffels, Hyodae Seo, J. Thomas Farrar, Tong Lee, Robert A. Weller. "Sampling Scale Mismatch Drives Discrepancies between Satellite and TAO Buoy Measurements of Ocean Surface Winds". *Authorea Preprints: Submitted to JGR:Oceans* (2025). DOI: 10.22541/essoar.176469127.71657349/v1.

[6] **Shikhar Rai**, Matthew W Hecht, Mathew E Maltrud, Hussein Aluie. "Scale-dependent air-sea mechanical coupling: resolution mismatch and spurious eddy-killing". *Authorea Preprints: Submitted to JAMES* (2023). DOI: 10.22541/essoar.167525271.13326232/v1.

Drafts Under Preparation:

[7] **Shikhar Rai**, Susan Wijffels, Hyodae Seo. "Multiscale Analysis of the Evolution of SST for Eastward Extension of the West Pacific Warm Pool". 2026.

Conference Presentations

Invited Talks:

[1] **Shikhar Rai**, Thomas J. Farrar, Hussein Aluie. "Atmospheric wind energization of ocean weather". *Observing Air-Sea Interactions Strategy (OASIS) Webinar Series*. 2025.

[2] **Shikhar Rai**, Matthew W. Hecht, Mathew E. Maltrud, Hussein Aluie. "Disproportionate Role of Small-Scale Winds On the Mesoscales and Spurious Eddy Killing from Resolution Mismatch". *Ocean DYnamics and Surface Exchange with the Atmosphere, Winds and Currents Webinar*. 2023.

Presentations:

[3] **Shikhar Rai**, Matthew W. Hecht, Mathew E. Maltrud, Hussein Aluie. "Scale Analysis of Wind Work on the Oceanic General Circulation". *Physical Oceanography Dissertation Symposium XIII, Lihue, Hawaii*. 2024.

[4] **Shikhar Rai**, Matthew W. Hecht, Mathew E. Maltrud, Hussein Aluie. "Modeling of Air-Sea Momentum Flux at the Mesoscales: Resolution Mismatch and Spurious Eddy-Killing". *Ocean Sciences Meeting, American Geophysical Union*. 2024.

[5] Mehrnoush Kharghani, Benjamin Storer, **Shikhar Rai**, Hussein Aluie. "Mass Transport By Oceanic Mesoscale Eddies". *American Physical Society, Division of Fluid Dynamics, Annual Meeting*. 2023.

[6] Abdus Samad, Benjamin Storer, **Shikhar Rai**, Hussein Aluie. "Investigating mechanism underlying the North Atlantic Oscillation". *American Physical Society, Division of Fluid Dynamics, Annual Meeting*. 2023.

[7] Hussein Aluie, Michele Buzzicotti, Stephen Griffies, Matthew Hecht, Hemant Khatri, Matthew Maltrud, **Shikhar Rai**, Mahmoud Sadek, Benjamin Storer, Geoffrey Vallis. "Disentangling the Oceanic General Circulation". *American Physical Society, Division of Fluid Dynamics, Annual Meeting*. 2022.

[8] **Shikhar Rai**, Matthew Hecht, Matthew Maltrud, Hussein Aluie. "Scale of Eddy Killing from Global Satellite Observations". *FilaChange Surface Water and Ocean Topography, AdAC Consortium*. 2022.

[9] **Shikhar Rai**, Matthew Hecht, Matthew Maltrud, Hussein Aluie. "Oceanic Eddy-killing by Wind from Global Satellite Observations". *Ocean Sciences Meeting, American Geophysical Union*. 2022.

[10] **Shikhar Rai**, Hao Yin, Hussein Aluie, Aarne Lees, Dongxiao Zhao, Stephen Griffies, Jessica Shang. "Effective Drift Velocity from Turbulent Transport by Vorticity in Compressible Turbulence". *American Physical Society, Division of Fluid Dynamics, Annual Meeting*. 2022.

[11] Hussein Aluie, **Shikhar Rai**, Matthew Hecht, Matthew Maltrud. "Oceanic Eddy-killing by Wind from Global Satellite Observations". *American Physical Society, Division of Fluid Dynamics, Annual Meeting*. 2021.

Posters:

[12] **Shikhar Rai**, Thomas J. Farrar, Hussein Aluie. "The theory of wind work on ocean mesoscales". *American Geophysical Union, Annual Meeting*. Dec. 2025.

[13] **Shikhar Rai**, Susan Anne Wijffels, Hyodae Seo, Thomas J. Farrar, Tong Lee, Robert A Weller. "Small-scale wind structures likely drive most buoy and scatterometer disagreements: reconciling two ways to track ocean surface winds". *American Geophysical Union, Annual Meeting*. Dec. 2025.

[14] **Shikhar Rai**, Susan Anne Wijffels, Hyodae Seo. "Data-driven approach in investigating the differences in wind measurement in the Tropical Pacific between buoys and QuikSCAT". *Wyrtki Symposium, Honolulu, Hawaii*. Mar. 2025.

[15] **Shikhar Rai**, Susan Anne Wijffels, Hyodae Seo. "Data-driven approach in investigating the differences in wind measurement in the Tropical Pacific between buoys and QuikSCAT". *American Geophysical Union, Annual Meeting*. 2024.

[16] **Shikhar Rai**, Matthew W. Hecht, Mathew E. Maltrud, Hussein Aluie. "Wind-driven Ocean: Atmospheric Scales Forcing the Ocean Circulation and Damping its Eddies". *American Geophysical Union, Fall Meeting*. 2022.

[17] **Shikhar Rai**, Matthew Hecht, Mathew Maltrud, Hussein Aluie. "Oceanic Eddy-killing by Wind from Global Satellite Observations". *American Geophysical Union, Fall Meeting*. 2021.

[18] **Shikhar Rai**, Matthew W. Hecht, Mathew E. Maltrud, Hussein Aluie. "Wind Forcing and Eddy Killing in the Global Ocean". *Ocean Sciences Meeting, American Geophysical Union*. 2020.

[19] **Shikhar Rai**, Mahmoud M. Sadek, Mathew Maltrud, Matthew W. Hecht, Geoffrey K. Vallis, Hussein Aluie. "Direct and Indirect Wind Driving of the Ocean". *22nd Conference on Atmospheric and Oceanic Fluid Dynamics, American Meteorological Society*. 2019.