Annual Progress Report 2024-2025

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This report outlines my research progress and updates during the academic year 2024–2025, made possible through the generous support of the Shida Scholarship.

Research

As a fourth-year Ph.D. candidate, I have continued my research in hydrology, a field of water science, under the guidance of Dr. Hilary McMillan and Dr. Kelly Caylor. My work focuses on the role of soil moisture in water cycles to advance flood and drought modeling. Soil holds a critical water resource, storing about 8.5 times the water of rivers[1] and supplying 74% of the water for food production[2]. Soil moisture replenishes groundwater, regulates air humidity, and supports vegetation growth, making it a key driver of the water, energy, and carbon cycles. Despite its importance, soil moisture remains an overlooked variable; most hydrologic models are rarely evaluated for their accuracy in representing soil moisture conditions. This oversight stems from our lack of theoretical frameworks to extract meaningful information from heterogeneous patterns in observed soil moisture. Consequently, soil moisture state continues to be a major complication of flood and drought predictions. My research addresses this issue by identifying temporal patterns in soil moisture that represent water storage and transport dynamics. By focusing on these dynamics, rather than mere moisture values, this approach aims to elucidate the spatial organization of underlying ecohydrological processes and reveal fundamental scaling laws governing soil moisture distribution.

My work in 2022-2024 demonstrated that soil moisture drying patterns contain valuable information about ecosystem water consumption under drought conditions. In my current project, I am investigating whether similar patterns of water regulation strategies can be observed between satellite and field-sensor measurements. In 2024-2025, I dedicated my time primarily to developing the research plan, improving the analytical algorithm, and curating data. Unlike the previous version that analyzed individual drydown events, the enhanced algorithm can now aggregate multiple events, improving its robustness, interpretability, and predictability of future conditions. With these preparations now complete, I will dedicate 2025-2026 to investigating spatial heterogeneity, its controlling factors, and scaling; I plan to complete my research and graduate by Summer 2026.

Additionally, I've been on another project as a research assistant to Dr. Hilary McMillan, investigating global patterns of hydrologic processes. This research utilizes an open-source hydroclimatic dataset comprising more than 7,000 watersheds to map hydrologic processes.

These findings will be valuable for model selection—determining which hydrologic model types best suit specific environmental conditions. We are currently finalizing a paper targeted for submission by Summer 2025.

Publication

Many research projects (both my own and collaborative) over the past few years have come to fruition around the same time this year!

Araki, R., Ogden, F. L., & McMillan, H. K. (2025). Testing Soil Moisture Performance Measures in the Conceptual-Functional Equivalent to the WRF-Hydro National Water Model. Journal of the American Water Resources Association, 61(1), e70002. https://doi.org/10.1111/1752-1688.70002

– This is the first chapter of my Ph.D. thesis, examining the utility of soil moisture data for model parameter tuning. This is the paper where I first independently developed the hypothesis. While the results weren't outstanding—showing that soil moisture data neither improves nor deteriorates river flow prediction—this work deepened my theoretical understanding and established multiple collaborative relationships.

Frame, J. M., Araki, R., Bhuiyan, S. A., Bindas, T., Rapp, J., Bolotin, L., et al. (2025). Machine learning for a heterogeneous water modeling framework. Journal of the American Water Resources Association, 61(1). https://doi.org/10.1111/1752-1688.70000

– This publication emerged from the internship at the National Water Center in Alabama in Summer 2023. The paper proposes promising machine learning schemes that could expand the capability of the operational US National Water Model.

McMillan, H., Araki, R., Bolotin, L., Kim, D.-H., Coxon, G., Clark, M., & Seibert, J. (2025). Global patterns in observed hydrologic processes. Nature Water. https://doi.org/10.1038/s44221-025-00407-w

– I have been a research assistant on this project for more than six years since 2019. It's an ambitious effort to uncover global patterns in hydrologic processes (how water moves and is stored across the land-atmosphere continuum) using a novel and original approach (combining literature review and meta-analysis). It was an invaluable learning experience for me to observe my advisor's approach and the entire research process, and this publication on Nature Water!

Palmer, T., Biggs, T., Araki, R., Bagheri, K., Davani, H., Downing, R., et al. (2025). Quantifying sources, sinks and mitigation of macroplastic and other river debris: A trash balance model. Earth's Future, 13(3). https://doi.org/10.1029/2024ef005677

– During 2021-2022, I was monitoring trash remobilization before and after storms in the San Diego River, conducting weekly assessments with undergraduate students (which was really fun!). This resulting paper proposes optimal strategies for mitigating plastic pollution flowing from the San Diego River into the Pacific Ocean.

Teaching

The personal highlight of the Year 2024-2025 was teaching—I served as the instructor of record for an upper-division undergraduate course "Environmental Hydrology," meaning that I taught the entire course and handled grading myself, with my name appearing on the school system as the lecturer. It was extremely intimidating for me to teach in my second language for 15 weeks, twice a week, to 30 students, and most terrifyingly, without any prior teaching experience. However, thanks to my advisors, friends, and extremely polite and sweet undergraduate students, it turned out to be one of my best experiences. I received great feedback from students that they enjoyed the class and learned a lot. Many of them developed a genuine interest in hydrology, and currently pursuing further studies and internships related to environmental conservation and water management.

Visit to Washington, D.C.

The largest Earth Science conference, the American Geophysical Union Meeting, is held in different cities every year. Fortunately, the 2024 meeting took place in D.C.! This coincidence allowed me to visit Kyodai Collaborative Headquarters last December. Thanks to arrangements by Ms. Rika Okayama, I had multiple opportunities to talk to Kyodai alumni—from a Year-End house party, to a 1-on-1 meeting with Dr. Kuno at Evermay, as well as a visit to Dr. Takamatsu at the World Bank. The conversations during these meetings were truly inspiring and enlightening, and I departed D.C. with a heart full of appreciation and motivation.

After January 2025
The field of earth science in 2025 has been profoundly impacted by recent administrative changes. Since January, we've witnessed unprecedented shifts: NOAA, the agency responsible for weather forecasting and observation critical to public safety, has laid off 20% of its workforce and faces imminent shutdowns of its data servers and research centers. Princeton University, home to climate research and Nobel Laureate Dr. Shukuro Manabe's work, is also in peril of shutting down. The new screening of research proposals containing "banned words" – including "climate change," "environmental justice," and even "women"–looms.

As I face these challenges, I find myself questioning the impact we are making. Maybe they're right—science can feel powerless when climate change is happening but we still lack the technology to stop it. But wait—am I gaslighting myself here? The role of science has never been more critical, especially in upholding safety standards. While research alone may not "solve" global warming issues, scientists still have the great capability to have conversations with multiple organizations to help us adapt and prepare for extreme weather events. Perhaps public outreach and education are the way around or forward. Empowering the next generation with knowledge about water science—like those wonderful students I had the chance to teach—reminds me why this work matters. Though my thoughts are scattered, one (unfortunate) thing is certain: I must prepare to navigate a challenging job market as I begin my search this fall. Whatever path I take, I want my work to remain not only personal but impactful.

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Reference
1. Oki, T. & Kanae, S. Global hydrological cycles and world water resources. Science 313, 1068–1072 (2006).
2. Falkenmark, M. & Rockström, J. The new blue and green water paradigm: Breaking new ground for water resources planning and management. J. Water Resour. Plan. Manag. 132, 129–132 (2006).