XUN [NICOLE] CAI

NSF Ocean Sciences Postdoctoral Fellow
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Research Interests

As a computational oceanographer and coastal ecosystem modeler, my research is driven by a central question: *How do **land–sea interactions** within the **dynamic transition zone**, from the coastal shelf to upland, shape and respond to climate change and other environmental stressors?* I integrate process-based numerical modeling, machine learning, and data-driven analysis to investigate tightly coupled physical and biogeochemical processes, with a focus on tidal dynamics, saltwater intrusion, carbon cycling, wetlands dynamics, and benthic-pelagic coupling.

Education

2022	Ph.D., Marine Science	William & Mary | Virginia Institute of Marine Science, VA
2018	M.S., Marine Science	William & Mary | Virginia Institute of Marine Science, VA
2015	B.S., Oceanography	Nanjing University, Nanjing, China

Career History

Aug. 2024 – present	**Yale University**, New Haven, CT *NSF Postdoctoral Research Fellow*, Yale School of the Environment Advisor: Peter Raymond
Aug. 2021 – Jul. 2024	**U.S. Environmental Protection Agency**, Annapolis, MD *ORISE Fellow*, Chesapeake Bay Program Office
Fall, 2017	**University of Oldenburg**, Oldenburg, Germany *Visiting Student* Host: Jörg-Olaf Wolff
Aug. 2015 – Jul. 2021	**William & Mary | VIMS**, Gloucester Point, VA *Graduate Research Assistant,* Department of Physical Sciences Advisors: Joseph Zhang, Jian Shen

Publications (mentee*)

Under review / In revision (first/second/others: 2/3/2)

[16] Yu, S., Li, X., Liu, J., Brunner, P., Yao, R., Yuan, B., **Cai, X.**, Yu, X., Effects of creek topology on salinization of coastal marsh due to storm surges. *Water Resources Research*.

[15] Teixeira, J.*, Mazzini, P., **Cai, X.**, Colombo, M., Qin, Q., Seeley, M., Zhang, Y., J., Distribution and Fate of Microplastics from the Chesapeake Bay to the Mid-Atlantic Bight: A Lagrangian Particle Tracking Approach. *Continental Shelf Research*.

[14] Qin, Q., **Cai, X.**, and Shen, J., Riverine Freshwater Connectivity Among Major Tributaries in a Large Estuary. *Water Resources Research*.

[13] Zhang, M.*, **Cai, X.**, Weston, N., Wu, Z., Giblin, A., Hunt, C., Tsao, S., Zhang, N., and Raymond, P., Spatiotemporal Modulation of Alkalinity and DIC Outwelling from Saltmarsh Porewater in New England's Largest Marsh Complex. *Journal of Geophysical Research: Biogeosciences*.

[12] Shen, J., **Cai, X.**, and Qin, Q., A Machine Learning Approach to Forecasting Saltwater Intrusion in the Chesapeake Bay and its Major Tributaries. *Water Resources Research*.

[11] **Cai, X.**, Qin, Q., Kirwan, M., Michael, H., Shen, J., Mach, K., and Raymond, P., Recognizing Salt Wave Events in Coastal Systems. *Geophysical Research Letters*. [preprint]

[10] **Cai, X.**, Qin, Q., Cui, L., Yang, X., Zhang, Y., J., and Shen, J., NAAC (v1.0): A Seamless Two-Decade Cross-Scale Simulation from the North American Atlantic Coast to Tidal Wetlands Using the 3D Unstructured-grid Model SCHISM (v5.11.0). *Geoscientific Model Development*. [preprint]

Peer-reviewed (first/second/others: 5/2/2)

[9] Tian, R., **Cai, X.**, Cerco, C., Zhang, Y., J., and Linker, L., Simulation of Benthic Microalgae Impacts on Water Quality in Shallow Water Systems, Corsica River, Chesapeake Bay. *Frontiers in Marine Science*. 2024.

[8] **Cai, X.**, Shen, J., Zhang, Y., J., Qin, Q., and Linker, L., Sea-level Rise Impacts on The Tidal Marshes and Estuarine Biogeochemical Processes. *Journal of Geophysical Research: Biogeosciences*. 2023.

[7] **Cai, X.**, Shen, J., Zhang, Y., J., Qin, Q., and Linker, L., The Roles of Tidal Marshes in the Estuarine Biochemical Processes: A Numerical Modeling Study. *Journal of Geophysical Research: Biogeosciences*. 2023.

[6] Xiong, J., Shen, J., Qin, Q., Tomlinsom, M., Zhang, Y., **Cai, X.**, Ye, F., Cui, L., and Mulholland, M., Biophysical Interactions Control the Progression of Harmful Algal Blooms in Chesapeake Bay: A Novel Lagrangian Particle Tracking Model with Mixotrophic Growth and Vertical Migration. *Limnology and Oceanography Letters*. 2023.

[5] **Cai, X.**, Qin, Q., Shen, J., and Zhang, Y., J., Bifurcate Responses of Tidal Range to Sea-level Rise in Estuaries with Marsh Evolution. *Limnology and Oceanography Letters*. 2022.

[4] Tian, R., **Cai, X.**, Testa, J., Brady, D.C., Cerco, C., and Linker, L., Simulation of High-Frequency Dissolved Oxygen Dynamics in A Shallow Estuary, the Corsica River, Chesapeake Bay. *Frontiers in Marine Science*. 2022.

[3] Qin, Q., Shen, J., Tuckey, T.D., **Cai, X.**, and Xiong, J., Using Forward and Backward Particle Tracking Approaches to Analyze Impacts of a Water Intake on Ichthyoplankton Mortality in the Appomattox River. *Journal of Marine Science and Engineering*. 2022.

[2] **Cai, X.**, Shen, J., Zhang, Y., J., Qin, Q., Wang, Z., and Wang H., Impacts of Sea Level Rise on Hypoxia and Phytoplankton Production in Chesapeake Bay: Model Prediction and Assessment. *Journal of American Water Resources Association*. 2022.

[1] **Cai, X.**, Zhang, Y., J., Shen, J., Wang, H., Wang, Z., Qin, Q., and Ye, F., A Numerical Study of Hypoxia in Chesapeake Bay Using an Unstructured Grid Model: Validation and Sensitivity to Bathymetry Representation. *Journal of American Water Resources Association*. 2022.

Others

Graham, O., Griffiths, L., Munzer, K., Barbosa, C., **Cai, X.**, Ogashawara, I., Selak, I., Sun, X., Thellman, A., Engaging Beyond Academia: A Call to Act for Environmental Scientists. *Limnology and Oceanography Bulletin*. 2024.

Ignatoff P.[*], **Cai, X.**, Gadeken K., Baywide distribution of benthic ecological functions in the past decades in the Chesapeake Bay. 2023. [Dataset]

Awards

Aug. 2024	**NSF OCE Postdoctoral Fellow** (also see Grants and Proposals)
Nov. 2023	**William R. "Randy" Boggess Best Paper Award**, American Water Resources Association – "A Numerical Study of Hypoxia in Chesapeake Bay Using an Unstructured Grid Model: Validation and Sensitivity to Bathymetry Representation."
Mar. 2022	**Top Cited Article 2020-2021**, Journal of American Water Resources Association, Wiley – "A Numerical Study of Hypoxia in Chesapeake Bay Using an Unstructured Grid Model: Validation and Sensitivity to Bathymetry Representation."
May 2019	**Best Poster Award** at *Southeastern Virginia Marine Science Symposium*, Gloucester Point, VA – "Numerical Study of Impact of Submerged Aquatic Vegetation on Water Quality in Cache Slough Complex, Sacramento-San Joaquin Delta"

Grants and Proposals (funded in total: $599k)

Standard grants and fellowships

Submitted in Aug. 2025	NSF OCE Chemical Oceanography – "On-off Switch of Alkalinity Export from Tidal Marshes to the Coast"

PI: Peter Raymond (Yale); Role: investigator (responsible for proposal initiation and drafting; not officially listed as PI/Co-PI due to Yale eligibility policies)

2024 - 2026 NSF Ocean Sciences Postdoctoral Research Fellowships (OCE-PRF) – "Connections Between Tidal Flooding, Saltwater Intrusion, and Alkalinity Exports in Tidal Marsh Wetlands" ($351,926)

PI: **Xun Cai** (Yale); mentors: Peter Raymond (Yale), Holly Michael (U. Delaware), Sergio Fagherazzi (Boston U.)

Waiting list / unfunded NSF Earth Sciences Postdoctoral Fellowships (EAR-PF) – "Linkages Between Estuarine Hydrodynamics and Hydrological Drivers at the Coastal Critical Zone" ($180,000)

PI: **Xun Cai**; mentors: Holly Michael (U. Delaware), Matthew Kirwan (VIMS | W&M)

2021 - 2024 ORISE Fellowship, U.S. EPA, Chesapeake Bay Program Office – for development and application of numeric models to support to restore and maintain Chesapeake living resources from challenges of climate change, growth, and other impacts. ($205,740)

2020 - 2021 Commonwealth Coastal Research Fellowship, VIMS, VA – for dissertation research focus which strategically advances VIMS' advisory service to the Commonwealth of Virginia in areas such as water quality research, and management and resilience approaches. ($31,245)

Travel grants and others

Jun. 2024 CCRS Early Career Panel Funding Support, Chesapeake Research Consortium and NOAA, Annapolis, MD – for joining plenary session "Beyond 2025, the Early Career Panel" ($1,850)

May 2024 NSF Coastal Critical Zone Network Research Travel Award, for on-site research visit to NSF Coastal Critical Zone Network Cluster, U. Delaware, DE (~$3,000)

Mar. 2023 ECO-DAS XV Fellowship, Association for the Sciences of Limnology & Oceanography (ASLO) and National Science Foundation (NSF), Honolulu, HI ($3,337)

Apr. 2022 W&M Open Access Financial Assistance, for publication in L&O Letter – "Bifurcate Responses of Tidal Range to Sea-level Rise in Estuaries with Marsh Evolution" ($2,400)

Oct. 2021 Juliette B. & Carroll W. Owens, Sr. scholarship, VIMS, VA – for academic performance and progress in the Ph.D. Degree Program

May 2019 CSDMS scholarship at *Community Surface Dynamics Modeling System meeting 2019*, Boulder, CO – "Impact of Submerged Aquatic Vegetation on Water Quality in Cache Slough Complex, Sacramento-San Joaquin Delta: A Numerical Study" (~$1,000)

Mentoring and Teaching

Mentoring

May 2025 – present	Master student A. McGraw, U. Delaware, DE Thesis "Evaluating drivers of the marsh-upland boundary in salt marsh transition zones under the influence of sea level rise"
Apr. 2025 – present	Master student B. Garrioch, Yale, CT Hypothesis development, idea feedback, and draft review
Jul. 2024 – present	PhD student M. Zhang, Yale, CT Model practicing, idea investigation, and manuscript revising
2023 – 2025	Master student J. Teixeira, VIMS, VA Thesis "Distribution and fate of microplastics from the Chesapeake bay to the mid-Atlantic bight: a Lagrangian particle tracking approach"
Summer, 2023	Undergraduate intern P. Ignatoff, William & Mary, VA Design and conduct an 8-week research project "Revisit sediment diagenesis, bioturbation, and nutrient cycling"

Guest lectures

Jan. 2025	Capstone course: Society and the Sea Seminar at the East Carolina University – "Ocean salinity and estuarine circulations"
Oct. 2024	PhD level: Coastal Ecological Processes at the East Carolina University – "Role of submerged aquatic vegetation, tidal marsh, and mangrove in the coastal ecosystem"
Oct. 2024	Master level: Ocean Ecosystem Modeling at the University of Texas Rio Grande Valley – "Modeling complex ecosystems: integrating physical and biogeochemical processes" (*UTRGV is a Hispanic Serving Institution*)
Nov. 2023	Undergraduate level: Introduction to Environmental Science at the University of Texas Rio Grande Valley – "Water Quality Modeling, Climate Change, and Sea-level Rise"
Apr. 2019	Workshop: California Department of Water Resources, Sacramento, CA – "Introduction of SCHISM-ICM water quality model"

Presentations (mentee*)

Dec. 2025 (submitted)	Zhang, M.*, **Cai, X.**, Giblin, A., Weston, N., and Raymond, P., On-off Switch of Alkalinity Export from Tidal Marshes to the Coast. *AGU25*, New Orleans, LA

Nov. 2025 (submitted)	**Cai, X.**, Qin, Q., Kirwan, M., Michael, H., Shen, J., Mach, K., and Raymond, P., Recognizing salt wave events in coastal systems. *Coastal & Estuarine Research Federation (CERF) 2025*, Richmond, VA
Nov. 2025 (submitted)	Shen, J., **Cai, X.**, Qin, Q., Forecasting saltwater intrusion in Chesapeake Bay and its major tributaries: a machine learning approach. *Coastal & Estuarine Research Federation (CERF) 2025*, Richmond, VA
Nov. 2025 (submitted)	Zhang, M.*, **Cai, X.**, Weston, N., Giblin, A., and Raymond, P., Spatial and temporal variabilities of carbonate chemistry driven by porewater exchange in a saltmarsh-dominated estuary. *Coastal & Estuarine Research Federation (CERF) 2025*, Richmond, VA
Nov. 2025 (submitted)	Qin, Q., Ruiz, E., Chettanawanit K., and **Cai, X.**, Multi-decadal tidal range trends near coastal marshes across U.S. estuarine systems. *Coastal & Estuarine Research Federation (CERF) 2025*, Richmond, VA
May 2025 (invited)	**Cai, X.**, Coastal Saltwater Intrusion: From Long-Term Trends to Episodic Variability. *NSF Coastal Critical Zone* project meeting, virtual
Dec. 2024	Teixeira, J.*, Mazzini, P., **Cai, X.**, Qin, Q., and Zhang, Y., J., Distribution and fate of microplastics from estuarine sources in the Mid-Atlantic Bight: a lagrangian particle tracking approach. Oral presentation at *AGU24*, Washington DC
Dec. 2024	Zhang, M.*, **Cai, X.**, Weston, N., Wu, Z., Giblin, A., Hunt, C., Tsao, S., Zhang, N., and Raymond, P., Unveiling the spatial and temporal variabilities of carbonate chemistry driven by porewater exchange in a saltmarsh-dominated estuary. Poster presentation at *AGU24*, Washington DC
Dec. 2024	Movahedi, N., Zheng, L., **Cai, X.**, Tian, R., Linker, L., Skarke, A., and Heiss, J., A nested hydrodynamic modeling approach for simulating realistic pressures along estuarine bedforms. Poster presentation at *AGU24*, Washington DC
Dec. 2024	Griesel, M., Movahedi, N., Zheng, L., **Cai, X.**, Tian, R., Linker, L., Skarke, A., and Heiss, J., Benthic exchange in large estuaries: The role of alternating tidal currents and surface water salinity oscillations. Poster presentation at *AGU24*, Washington DC
Jun. 2024	Qin, Q., Shen, J., **Cai, X.**, Wang, Z., and St-Laurent, P., The transport and retention conditions in the middle-lower Rappahannock River. Oral presentation at *Chesapeake Bay Symposium,* Annapolis, MD
May 2024 (invited)	**Cai, X.**, Coastal Environment Facing Climate Change: Insights from Computational Methods. *Delaware Environmental Institute and the Coastal Critical Zone Network*, Newark, DE
Mar. 2024 (invited)	**Cai, X.**, Coastal Environment Facing Climate Change: Insights from Computational Methods. *Old Dominion University Ocean & Earth Sciences Department Spring Seminar Series*, Norfolk, VA

Feb. 2024	**Cai, X.**, Shen, J., Zhang, Y., J., Qin, Q., and Linker, L., Impacts of sea-level rise on the tidal marshes and estuarine biogeochemical processes. Poster presentation at *Ocean Sciences Meeting 2024*, New Orleans, LA
Feb. 2024	Qin, Q., **Cai, X.**, and Shen, J., Freshwater Connectivity Between Major Subestuaries in Chesapeake Bay. Oral presentation at *Ocean Sciences Meeting 2024*, New Orleans, LA
Nov. 2023	**Cai, X.**, Shen, J., Zhang, Y., J., Qin, Q., and Linker, L., Impacts of sea-level rise on the tidal marshes and estuarine biogeochemical processes. Oral presentation at *Coastal & Estuarine Research Federation (CERF) 2023* Portland, OR
May 2023	**Cai, X.**, Shen, J., Zhang, Y., J., Qin, Q., and Linker, L., Impacts of sea-level rise on the tidal marshes and estuarine biogeochemical processes. Oral presentation at *International Society for Ecological Modelling Global Conference*, Toronto, Canada
Jun. 2022	**Cai, X.**, Shen, J., Zhang, Y., J., Qin, Q., and Linker, L., Impacts of sea-level rise on the material exchange between tidal marshes and the estuary. Oral presentation at *Chesapeake Bay Symposium,* Annapolis, MD
Jun. 2022	**Cai, X.**, Linker, L., Shen, J., Zhang, Y., J., Qin, Q., Xiong, J., and Tian, R., Development of a Next-Generation Tributary Model in the tidal James River. Oral presentation at *Chesapeake Bay Symposium,* Annapolis, MD
Jun. 2020	**Cai, X.**, Shen, J., Zhang, Y., J., Qin, Q., Wang, Z., and Wang H., Impacts of Sea-level Rise on Hypoxia and Phytoplankton Production in Chesapeake Bay: Model Validation and Assessment. Oral presentation at *Chesapeake Bay Symposium,* virtual
Nov. 2019	**Cai, X.**, Shen, J., Zhang, Y., J., Qin, Q., Wang, Z., and Wang H., Numerical Simulation of Impacts from Sea-level Rise on Hypoxia in Chesapeake Bay Using an Unstructured Grid Model: Validation and Assessment. Oral presentation at *Coastal & Estuarine Research Federation (CERF) 2019*, Mobile, AL
Nov. 2017	Qin, Q., Shen, J., and **Cai, X.**, The contribution of phytoplankton to primary production dynamics in shallow areas of York River, VA. Oral presentation at *Coastal & Estuarine Research Federation (CERF) 2017*, Providence, RI
Jun. 2016	Wang, Z., **Cai, X.**, and Wang H., Effect of pH on nutrients release and algal bloom in the Back River, Upper Chesapeake Bay. Poster presentation at *Chesapeake Bay Symposium, 2016*, Williamsburg, VA

Career Development, Service, and Outreach

2021 –present	Reviewer for *Geology, Journal of Advances in Modeling Earth Systems, Journal of American Water Resources Association, Journal of Geophysical Research: Biogeosciences, Limnology and Oceanography, Marine Pollution Bulletin, Ocean Modeling, Ocean Science,* and USGS Colleague Review.

2025	Participant at American Geophysical Union's (AGU) LANDInG Postdoctoral Research Fellows Program (PRFP) as NSF-funded Postdoctoral Fellowship awardee
2025	Participant at *Mentoring Physical Oceanography Women to Increase Retention (MPOWIR)* mentorship program
2024	Mentor at *Women in Coastal Geoscience and Engineering (WICGE)* mentorship program
Jun. 2024	Panelist at plenary session "Beyond 2025, the Early Career Panel" at *Chesapeake Community Research Symposium 2024*.
Jun. 2024	Session convener at *Chesapeake Community Research Symposium 2024* – "Exploring the Linkage Between the Tidal Marsh Dynamics and the Key Processes in the Chesapeake Bay" (session proposal accepted).
May 2024	Participation at *Scientific and Technical Advisory Committee (STAC) workshop* titled 'CBP Climate Change Modeling III: Post-2025 decisions.'
2019 –2022	VIMS Ombudsperson – Peer mentor and confidential resource for graduate students to promote conflict resolution for problems that arise in the university setting.
Aug. 2019	Oral presentation at *A Scientist Walks into A Bar – Grad Student Edition* – "To Save the Fish by Removing Seagrass?"

Professional Skills

Numerical modeling	Semi-implicit Cross-scale Hydroscience Integrated System Model (SCHISM); Integrated Compartment Model (ICM) multi-dimensional water quality model; Sediment Flux Model; Tidal Marsh Model; Submerged Aquatic Vegetation Model; Benthic Algae Model; Benthic Feeder Model; Bioturbation Model; Sediment Transport Model; Wind Wave Model; Watershed and Airshed Coupling; Groundwater model HydroGeoSphere
Data analysis and machine learning	Harmonic Analysis, Empirical Mode Decomposition (EMD), Regressions, Decision Tree, Classification and Regression Trees (CART), Generalized Linear Models (GLM), Generalized Additive Model (GAM), Random Forest, Neural Network, Empirical Orthogonal Function (EOF), Mann-Kendall (MK) test
Programing languages	Fortran, Matlab, Python, HTML, Perl, C, Git, and R
Software	SMS, ArcGIS, CorelDRAW, STELLA
Operating system	Unix for high-performance computing (HPC)

Field Experience and Research Cruises

May 2024	On-site visit to NSF Coastal Critical Zone Network Cluster sites on the Delmarva Peninsula, 1 day.
Oct. 2017	RV HEINCKE HE498, CTD profiling at North Sea, 7 days.
Sep. 2017	Fish tagging cruise at Sacramento-San Joaquin delta, 1 day.