Adrienne Hoarfrost

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Education

PhD in Marine Sciences, University of North Carolina at Chapel Hill. Advisor: Carol Arnosti ….....2018

MS in Marine Sciences, University of North Carolina at Chapel Hill. Advisor: Carol Arnosti……2015

AB in Biological Sciences (Geobiology concentration), Dartmouth College……..2011

Employment

Assistant Professor, Department of Marine Sciences, University of Georgia.....2022 - present

Chief Scientist and Co-founder, Fathom *(early stage ocean/climate-tech startup)*.....2022 - 2023

NASA Postdoctoral Fellow, Space Biology, NASA Ames Research Center.....2021 - 2022

Faculty, ML Lead, Frontier Development Lab 2021 Astronaut Health Challenge.....2021

Researcher, Frontier Development Lab 2020 Astronaut Health Challenge.....2020

NASA Postdoctoral Fellow, Astrobiology, Rutgers University.....2019 - 2021

Lab Technician, Harvard University. PI: Peter Girguis.....2011 - 2012

Publications

Li, K., Desai, R, Scott, R., Steele, J., Machado, M., Demharter, S., **Hoarfrost, A.**, Braun, J., Faardo, V., Sanders, L., and Costes, S. Explainable machine learning identifies multi-omics signatures of muscle response to spaceflight in mice (2023). *Accepted in npj Microgravity*.

Casaletto, J., Scott, R.T., Myrick, M., Mackintosh, G., Chok, H., Saravia-Butler, A., **Hoarfrost, A.,** Galazka, J., Sanders, L., Costes, S. (2023). Analyzing the relationship between gene expression and phenotype in space-flown mice using a causal inference machine learning ensemble. *Accepted in npj Microgravity*.

Sanders, L., Yang, J., Scott, R. T... **Hoarfrost**, A., et al. (2023). Beyond Low Earth Orbit: Biological Research, Artificial Intelligence, and Self-Driving Labs. *Nature Mach Intell. **5**, 208–219 (2023).* https://doi.org/10.1038/s42256-023-00618-4.

Scott, R. T., Antonsen, E., Sanders, L... **Hoarfrost**, A., et al. (2023). Beyond Low Earth Orbit: Precision Space Health, Monitoring, Artificial Intelligence, and Modeling. *Nature Mach Intell. **5**, 196–207,* https://doi.org/10.1038/s42256-023-00617-5.

Lloyd, C.C., Brown, S., Balmonte, J.P., **Hoarfrost, A.**, Ghobrial, S., Arnosti, C. (2023) Links between regional and depth patterns of microbial communities and enzyme activities in the western North Atlantic Ocean. *Marine Chemistry* 255, 104299. https://doi.org/10.1016/j.marchem.2023.104299.

Hoarfrost, A., Aptekmann, A., Farfañuk, G. et al. (2022). Deep learning of a bacterial and archaeal universal language of life enables transfer learning and illuminates microbial dark matter. *Nature Communications* 13, 2606. https://doi.org/10.1038/s41467-022-30070-8.

Lloyd CC, Brown S, Balmonte JP, **Hoarfrost** A, Ghobrial S, Arnosti C. (2022), Particles act as 'specialty centers' with expanded enzymatic function throughout the water column in the western North Atlantic. *Front Microbiol. 13:882333.* doi: 10.3389/fmicb.2022.882333.

Brown, S. A., Balmonte, J. P., **Hoarfrost**, A., Ghobrial, S., and Arnosti, C. (2022), Depth-related patterns in microbial community responses to complex organic matter in the western North Atlantic Ocean. *Biogeosciences*, *19, 5617–5631,* https://doi.org/10.5194/bg-19-5617-2022.

O'Donoghue, O.*, Duckworth*, P.*, Scheibenreif, L.*, Ughi, G.*, Khezeli, K., **Hoarfrost, A.**, Budd, S., Chia, N., Foley, P., Mackintosh, G., Kalantari, J., Soboczenski, F., Sanders, L. Invariant Risk Minimisation for Cross-Organism Inference: Substituting Mouse Data for Human Data in Human Risk Factor Discovery (2021)*. Machine Learning 4 Health at NeurIPS 2021, arXiv:2111.07348 (* indicates equal contribution of the authors)*

Budd, S.*, Blaas, A.*, **Hoarfrost, A.***, Khezeli, K.*, D'Silva, K., Soboczenski, F., Mackintosh, G., Chia, N., Kalantari, J. (2021), Prototyping CRISP: A Causal Relation and Inference Search Platform. *IEEE LifeTech Proc.,* pp. 517-521. doi: 10.1109/LifeTech52111.2021.9391819.

El Abd, H., Bromberg, Y., **Hoarfrost, A.**, Lenz, T.L., Franke, A., Wendorff, M. (2020), Amino Acid Encoding for Deep Learning Applications. *BMC Bioinf. 21:235*, doi: 10.1186/s12859-020-03546-x.

LaRowe, D., Arndt, S., Bradley, J., Estes, E., **Hoarfrost, A.**, Lang, S., Lloyd, K., Mahmoudi, N., Orsi, W., Shah Walter, S., Steen, A., Zhao, L. (2020), The fate of organic carbon in marine sediments – new insights from recent data and analysis. *Ear. Sci. Rev. doi:10.1016/j.earscirev.2020.103146.*

Hoarfrost, A., Nayfach, S., Ladau, J., Yooseph, S., Arnosti, C., Dupont, C. L., Pollard, K. S. (2020), Global ecotypes in the ubiquitous marine SAR86 clade. *ISME Journal. 14:178-188, doi: 10.1038/s41396-019-0516-7.*

Hoarfrost, A., Brown, N., Brown, C.T., Arnosti, C. (2019), Sequencing data discovery with MetaSeek. *Bioinformatics*, *btz499*, doi:10.1093/bioinformatics/btz499.

Hoarfrost, A., Balmonte, J.P., Ghobrial, S., Ziervogel, K., Bane, J., Gawarkiewicz G., Arnosti, C. (2019), Gulf Stream ring water intrusion on the Mid-Atlantic Bight continental shelf break affects microbially driven carbon cycling. *Front. Mar. Sci. 6(394),* doi:10.3389/fmars.2019.00394.

Balmonte, J.P., Buckley, A., **Hoarfrost, A.**, Ghobrial, S., Ziervogel, K., Teske, A., Arnosti, C. (2018), Community structural differences shape microbial responses to high molecular weight organic matter. *Environ. Microbiol. 21 (2), 557-571.* doi:10.1111/1462-2920.14485.

Hoarfrost, A., and Arnosti, C. (2017), Heterotrophic extracellular enzymatic activities in the Atlantic Ocean follow patterns across spatial and depth regimes, *Front. Mar. Sci*., 4, 200, doi:10.3389/fmars.2017.00200.

Hoarfrost, A., Snider, R., Arnosti, C. (2017), Improved measurement of extracellular enzymatic activities in subsurface sediments using competitive desorption treatment, *Front. Earth Sci., 5(13)*, 13. doi:10.3389/feart.2017.00013.

Adams, M. M., **Hoarfrost, A.**, Bose, A., Joye, S. B., Girguis P. R. (2013), Anaerobic oxidation of short-chain alkanes in hydrothermal sediments: potential influences on sulfur cycling and microbial diversity, *Front. Microbiol., 4(110),* doi:10.3389/fmicb.2013.00110.

Other Publications (not peer-reviewed)

Arnosti, C., **Hoarfrost, A.**, Balmonte, JP, Lloyd, C., Brown, S., Ghobrial, S. (2023), Empirical definition of the Mad Buckets Magic Number – a guide for seagoing scientists. *Limnology and Oceanography Bulletin*, https://doi.org/10.1002/lob.10577.

Sanders, L., Scott, R. T., Costes, S... **Hoarfrost,** A., et al (2021). Machine Learning, Artificial Intelligence and Data Modeling for the Next Decade of Space Biology Research and Astronaut Health Support. *White Paper Submitted to the 2023-2032 Decadal Survey Committee on Biological and Physical Sciences in Space.*

External Funding

NASA Postdoctoral Fellowship 2019 - 2022

Project Title: *Linking Life and Earth with Deep Transfer Learning*
Amount Awarded: $350,000 (approx.)
Role: lead PI

Microsoft AI For Earth Grant 2020 - 2021

Project Title: *The Universal Language of Life – Leveraging Deep Transfer Learning to Model the Biogeosphere*
Amount Awarded: $5000
Role: sole PI

Royster Society of Fellows Dissertation Completion Fellowship 2018

Project Title: *Linking Environmental and Microbial Processes from Community to Global Scales*
Amount Awarded: $21,000
Role: lead PI

Deep Carbon Observatory Deep Life Modeling and Visualization Graduate Fellowship 2016 - 2017

Project Title: *Using Machine Learning to Predict Global-Scale Patterns in Microbial Communities and Carbon-Cycling Activities*
Amount Awarded: $27,000
Role: lead PI

Center for Dark Energy Biosphere Investigations Graduate Fellowship 2014 - 2016

Project Title: *Investigating Microbial Activities Driving Organic Matter Transformations in the Deep Subsurface*
Amount Awarded: $65,000
Role: lead PI

Pending and in-prep Funding (UGA)

UGA Interdisciplinary Seed Grant (pending) - Building Quantitative, Scalable, Whole-Ecosystem Monitoring Capabilities for 'Blue Carbon' Ecosystems in Georgia and Beyond
PIs: **Adrienne Hoarfrost (PI)**, Anna Harper (Co-I), Gengchen Mai (Co-I), Aditya Mishra (Co-I), Jimmy Nelson (Co-I), Jaclyn Saunders (Co-I)
Budget Requested: $149,975

UGA Interdisciplinary Seed Grant (pending) - Revealing the Hidden Potential in 'Microbial Dark Matter': An AI-Powered Open-set Method for Functional Inference
PIs: Jin Sun (PI), **Adrienne Hoarfrost (Co-I)**
Budget Requested: $58,647

DOE ARPA-E (pending) – Identifying Biological and Environmental Mechanisms Driving Commercial Viability of Rare Earth Element Extraction in Sugar Kelp with a Machine Learning Mechanistic Discovery Approach
PIs: **Adrienne Hoarfrost (PI)**, Jaclyn Saunders (Co-I), Rishi Masalia (Co-I).
Budget Requested: $1,067,262

Google Research Scholar Award (pending) – Revealing the Hidden Potential in 'Microbial Dark Matter' from Genes to Ecosystems: AI-driven exploration from novel functional characterization to complex community phenotypes driving the global carbon cycle
PIs: **Adrienne Hoarfrost (PI)**
Award Amount: $60,000

UGA Interdisciplinary Seed Grant (pending) - Environmental AI: Detecting the patterns that rule microbial elemental cycling
PIs: Christof Meile (PI), **Adrienne Hoarfrost (Co-I)**, Jaclyn Saunders (Co-I)
Budget Requested: $144,908

UGA Interdisciplinary Seed Grant (pending) - A Multimodal Foundation Model for Various Geospatial, Environmental, and Agricultural tasks
PIs: Gengchen Mai (PI), Tianming Liu (Co-I), Ninghao Liu (Co-I), Jin Sun (Co-I), Xiaobai Angela Yao (Co-I), Lan Mu (Co-I), James Marshall Shepherd (Co-I), Deepak Mishra (Co-I), Gabriel J Kooperman (Co-I), Anna Harper (Co-I), Lilong Chai (Co-I), Guoyu Lu (Co-I), **Adrienne Hoarfrost (Co-I)**, Adam T. Greer (Co-I), Sheng Li (Co-I), Changying Li (Co-I)
Budget Requested: $149,990

NSF BIO (in prep, planned submission Dec 2023) – High-throughput functional characterization of biological processes driving metabolic networks enabled by deep learning of protein-compound interactions
PIs: **Adrienne Hoarfrost (PI)**, Mary Ann Moran (Co-I)

NASA Habitable Worlds (in prep, Letter of Intent submitted Nov 2023) – Characterizing biological interactions with known and out-of-distribution environments using generative AI and coupled metagenome-geochemical graph learning
PIs: **Adrienne Hoarfrost (PI)**

Teaching

Marine Biology (MARS3450), UGA Department of Marine Sciences	Fall 2023
Graduate Teaching Assistant (UNC): Energy Flow in the Environment and Society	2013
Graduate Teaching Assistant (UNC): Marine Physiological Ecology	2013
Graduate Teaching Assistant (UNC): The Marine Environment	2012
Undergraduate Lab Teaching Assistant (Dartmouth): Genetics	2009

Mentorship

Damián Santiago-Sosa, PhD student, University of Georgia 2023 -
- *Metagenome-level embedding model training and validation in the wet-lab*

Ratish Jha, MS student, University of Georgia 2023 -
- *Transformer based AI foundation model for environmental sequences*

Soumya Bharadwaj, MS student, University of Georgia 2023 -
- *AI-based reference-free functional annotation tool for 'microbial dark matter'*

Vatsal Thakkar, MS student, University of Georgia 2023 -
- *Multi-modal learning on omics data and natural language*

Preeti Chatterjee, MS student, University of Georgia 2023 -
- *Representative metagenome benchmark datasets from public data*

PI to 2 PhD rotation students, University of Georgia Fall 2023
- *Functional analysis and wet-lab characterization of marine microbial dark matter*

Henok Hagos, Undergraduate Honors Research Student Spring 2023
- *Exploring cyanobacterial potential for biomining applications*

Committee Member to 3 doctoral students, 1 MS student (UGA) 2023 -

Mentor to 5 interns (NASA), 4 undergraduates (Rutgers & UNC) 2013 - 2022

Mentor to 2 high school interns, Harvard University 2011 - 2012

Leadership

Ocean Visions Expert Database, member 2024 -

Southeast Regional Node Leader, Ocean Carbon Biogeochemistry marine carbon dioxide removal (OCB mCDR) working group 2023 -

Entrepreneurship & Scientific Mentor, BlueSwell Startup Incubator 2023 -

Scientific Advisor, Frontier Development Lab MED exploratory team 2023

Subgroup Leader, NASA AI/ML AWG 'Self-Driving Labs' Interest Group 2023

Contributor, Ocean Visions "Microalgae for Ocean CDR" Roadmap 2022

Challenge Owner, Mondial de Mer Ocean Hackathon, San Francisco, USA 2021

Subject Matter Expert & moderator, NASA AI for Space Biology Workshop 2021

Census of Deep Life Metadata Standards Working Group 2017 - 2018

Honors & Awards

Sigma Xi Scientific Research Honor Society Member 2023 -

1st place Regional, 3rd place Global winner, Mondial de Mer Ocean Hackathon 2021

IEEE LifeTech 2021 Outstanding Paper Award 2021

International Union of Crystallography Travel Award 2018

UNC Graduate Student Mentor Award 2016

UNC Graduate and Professional Student Federation Travel Award 2013

Richter Memorial Fund Recipient for Independent Research 2010

Barr 1968 Memorial Scholarship for accomplishment in the sciences and performing arts 2009

Service

UGA Marine Science Dept Promotion & Tenure Guideline Review Committee 2023 - 2024

UGA Statistics Dept Faculty Search Committee, External Member 2022 - 2023

Reviewer for proposals and manuscripts at: NSF, NASA NPP, NSF Antarctic & Polar Programs, Nature Communications, Science Advances, Marine Chemistry 2017 -

Selected Community Outreach

Subject Matter Expert, NASA Space Apps COVID-19 Challenge	2020
Science Advisor for the children's book *Where the Wild Microbes Grow*	2015
President, Graduate Action Group, UNC-Chapel Hill Dept. of Marine Sciences	2014 - 2015
Science Judge, Blue Heron Bowl, Raleigh, NC	2014
Senator and Finance Committee member, Graduate and Professional Student Federation Senate, UNC-Chapel Hill	2013 - 2014

Field Experience

R/V *Endeavor*, North Atlantic. Effects of organic carbon source and community on carbon cycling activities.	2016
R/V *Endeavor*, Mid Atlantic Bight. Impacts of ring water intrusions on microbial enzymatic activities.	2015
R/V *Knorr*, South Atlantic. Latitudinal and depth-driven patterns in heterotrophic functional capacities.	2013
R/V *Atlantis*, Juan de Fuca Ridge. Expedition with the Alvin submarine to study microbial hydrocarbon and sulfur cycling in hydrothermal vent ecosystems.	2010

Invited Talks

Keynote Speaker, *Deep Learning Gateways to Illuminating the Functional Potential and Ecosystem Impacts of Microbial Communities*, AI in Bioinformatics Symposium, Athens, GA, Oct 2023.

Deep Learning Gateways to Illuminating the Functional Potential and Ecosystem Impacts of Microbial Communities. UGA Department of Statistics Seminar Series, Athens, GA, Oct 2023.

Invited Panelist, *Opportunities and Risks for AI in Climate*, Georgia Climate Conference, Athens, GA, May 2023.

Institute for AI GradFIRST Seminar, Athens, GA, Apr 2023.

Active Learning and Self-Driving Labs. NASA AI/ML Analysis Working Group, Virtual, Feb 2023.

Empowering AI-Driven Insights into Biological Complexity: for life on Earth, in space, and in our search for life on other planets. NASA Ames Research Center, Moffett Field, CA, USA, Sep 2022.

Empowering AI-Driven Insights into Biological Complexity: for life on Earth, in space, and in our search for life on other planets. NASA AI/ML Working Group, Virtual, Sep 2022.

Empowering AI-Driven Insights into Biological Complexity. University of Georgia Athens, Virtual, Feb 2022.

Empowering AI-Driven Insights into Biological Complexity. Rutgers University, Virtual, Sep 2021.

Learning the Biological 'Language of Life': Capturing High Complexity with Limited Data. NASA Artificial Intelligence and Modeling for Space Biology Workshop, Virtual, June 2021.

Empowering Data-Intensive Discovery and Deep Learning-Driven Insights to Capture Biological Complexity in the Biogeosphere. Woods Hole Oceanographic Institution, Virtual, April 2021.

Empowering AI-Driven Insights of Biological Complexity and Open Science for Space Biology. NASA Ames, Virtual, March 2021.

Capturing the complexity of the bio-geosphere with deep transfer learning. NASA Postdoctoral Program Site Visit, Virtual, July 2020.

Capturing the complexity of the bio-geosphere with deep transfer learning. ENIGMA Symposium, Virtual, June 2020.

Modeling the complexity of the bio-geosphere with deep transfer learning. ENIGMA Symposium, New Brunswick, NJ, May 2019.

Linking environmental and microbial processes from community to global scales. Royster Fellow Interdisciplinary Seminar, Chapel Hill, NC, Oct 2018.

From data discovery to data-driven discovery: leveraging sequencing data integration for insights into global microbial biogeography. Rutgers University, New Brunswick, NJ, May 2018.

Data discovery => data-driven discovery. Deep Life Modeling and Visualization Workshop, Tempe, AZ, Mar 2018.

Opportunities and challenges facing deep learning for subsurface microbiology in the era of data-intensive bioinformatics. Microorganisms and Organic Carbon in the Marine Subsurface Workshop, Knoxville, TN, Mar 2018.

Sequence data discovery with MetaSeek. University of California Davis, Davis, CA, July 2017.

Sequence data discovery with MetaSeek. Deep Carbon Observatory Deep Life Community Meeting, Edinburgh, Scotland, Mar 2017.

Global-scale patterns in microbial communities and functions using machine learning. Deep Life Modeling and Visualization Workshop, Ascona, Switzerland, Mar 2016.

Contributed Presentations

Hoarfrost, A. *Deep learning gateways to illuminating the functional potential and ecosystem function of 'microbial dark matter'.* Association for the Sciences of Limnology and Oceanography Annual Meeting, Palma de Mallorca, Spain, June 2023.

Hoarfrost, A., Aptekmann, A., Farfanuk, G., Falkowski, P., Bromberg, Y. *Illuminating the Microbial Dark Matter Driving Energy Transformations in the Environment with a Universal Language of Life*. Goldschmidt Annual Conference, Virtual, July 2021.

Hoarfrost, A., Blaas, A., Budd, S., Khezeli, K., Chia, N., D'Silva, K., Gal, Y., Mackintosh, G., Soboczenski, F., Kalantari, J. *Prototyping CRISP: A Causal Research and Inference Search Platform.* 2021 NASA Human Research Program Investigators' Workshop, Virtual, Feb 2021.

Hoarfrost, A., Bromberg, Y. *The universal language of life – leveraging deep transfer learning to model the biogeosphere.* Goldschmidt Annual Conference, Virtual, June 2020.

Hoarfrost, A., Brown, N., Brown, C.T., Arnosti, C., Bromberg, Y. *Data discovery, integration, and deep learning for the bio-geosphere.* Astrobiology Science Conference, Bellevue, WA, June 2019.

Hoarfrost, A., Brown, N., Brown, C.T., Arnosti, C. *Sequencing data discovery and integration with MetaSeek: enabling data-driven discovery linking the biosphere and geosphere*. Earth in 4D: Deep-time Data Driven Discovery and the Evolution of Earth Workshop, Washington, DC, June 2018.

Hoarfrost, A., Nayfach, S., Ladau, J., Arnosti, C., Yooseph, S., Dupont, C., Pollard, K. *Predicting global functional and phylogenetic distributions of SAR86*. Ocean Sciences Meeting, Portland, OR, Feb 2018.

Hoarfrost, A., Brown, N., Brown, C.T., Arnosti, C. *Discovery and integration of ocean sequencing data with MetaSeek*. Ocean Sciences Meeting, Portland, OR, Feb 2018.

Hoarfrost, A., Brown, N., Arnosti, C. *Sequencing data discovery and integration for Earth system science with MetaSeek*. American Geophysical Union Annual Meeting, New Orleans, LA, Dec 2017.

Hoarfrost, A., Brown, N., Brown, C. T., Arnosti, C. *MetaSeek: A sequencing data discovery platform*. Deep Carbon Observatory International Meeting, Edinburgh, Scotland, Mar 2017.

Hoarfrost, A., Balmonte, J.P., Ziervogel, K., Ghobrial, S., Gawarkiewicz, G., Arnosti, C. *Strong effects of a shelfbreak jet on microbial enzyme activities*. Ocean Sciences Meeting, New Orleans, LA, Feb 2016.

Hoarfrost, A., Snider, R., Arnosti, C. *Microbial degradation of organic carbon in the diverse sediments of Guaymas Basin*. American Geophysical Union Annual Meeting, San Francisco, CA, Dec 2015.

Hoarfrost, A., Arnosti, C. *Patterns in heterotrophic extracellular enzymatic activity across geospatial regimes*. Gordon Research Conference on Chemical Oceanography, Holderness, NH, July 2015.

Hoarfrost, A., Arnosti, C. *Microbial extracellular enzymatic hydrolysis of organic carbon along depth and latitudinal gradients in the South Atlantic*. Association for the Sciences of Limnology and Oceanography Annual Meeting, Barcelona, Spain, Feb 2015.

Hoarfrost, A., Couper, L., Arnosti, C. *Pour some sugar on me: extracellular enzymatic hydrolysis of high-molecular-weight polysaccharides in sapropelic and non-sapropelic subsurface sediments*. American Geophysical Union Annual Meeting, San Francisco, CA, Dec 2014.

Hoarfrost, A., Couper, L., Arnosti, C. *Extracellular enzymatic hydrolysis of high-molecular-weight organic carbon in sapropelic and non-sapropelic subsurface sediments*. Center for Dark Energy Biosphere Investigations Annual Meeting, Marina, CA, Oct 2014.

Hoarfrost, A., Couper, L., Arnosti, C. *Investigating microbial activities driving organic matter transformations in the deep subsurface*. Deep Carbon Observatory Summer School, Big Sky, MT, July 2014.

Hoarfrost, A., Arnosti, C. *Investigating microbial activities driving organic matter transformations in the deep subsurface*. Center for Dark Energy Biosphere Investigations Annual Meeting, Marina, CA, Oct 2013.