Ali Ramadhan

Software & Machine Learning Engineer
Physicist · Climate Modeler

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Summary

I am a graduate researcher at MIT with 5 years of experience working at the intersection of climate modeling, software engineering, and machine learning.

I write code for next-generation climate models and use machine learning to improve the fidelity and compute cost. I am looking to apply my skill set in combining physical principles and machine learning to improve weather and climate predictions.

- **Software engineer** writing flexible user-friendly distributed GPU code with comprehensive test suites and documentation.
- **Applying machine learning** to design, train, and deploy AI powered models of ocean turbulence that improve climate models.
- **Computer modeler** developing next-generation ocean models for climate prediction with 18 peer-reviewed publications.

Research Work Experience

Massachusetts Institute of Technology　　Sep 2017 –
Department of Earth, Atmospheric, and Planetary Sciences
Graduate Research Assistant

- Developed a fast and flexible ocean model that runs on GPUs from scratch in Julia as part of the Climate Modeling Alliance.
- Trained data-driven models of turbulence to learn missing physics in climate models, outperforming operational turbulence models.
- Collaborated with scientists to accelerate research in ocean modeling and Bayesian inference for convection models using GPUs.
- Analyzed terabytes of satellite data to uncover signals of climate change, and communicated results in publications and conferences.

University of Waterloo　　Aug 2013 – Aug 2017
Department of Physics and Astronomy
Research Assistant

Developed a computational framework for creating movies of chemical reactions using nonlinear optimization and MATLAB. Independently conducted molecular physics experiments using ultrashort pulse lasers and at synchrotrons. Collaborated with engineers to weld microwires and synthesize graphene oxide gels using lasers.

Tokyo Metropolitan University　　Sep – Dec 2014
Department of Chemistry
Research Assistant

Developed a method to synthesize and control the end-caps of carbon chains (polyynes) using ultrashort laser pulses. Characterized polyyne samples using liquid chromatography.

Ontario Institute for Cancer Research　　Jan – Apr 2013
Informatics and Bio-Computing Program
Bioinformatics Specialist

Automated the processing of model organism genomic data sets for use by the cancer research community using Perl and Bash.

Education

2017– **Massachusetts Institute of Technology**
Doctor of Philosopy (Expected June 2023)
Earth, Atmospheric, and Planetary Sciences
Computational Science and Engineering
Thesis: Data-driven ocean modeling using neural differential equations

2017 **University of Waterloo**
Master of Science
Physics
Thesis: Molecular movies and geometry reconstruction using Coulomb explosion imaging

2016 **University of Waterloo**
Bachelor of Science
Physics with Joint Honours Mathematics
Graduating Dean's Honours List

Skills

Languages	Julia, Python, MATLAB, C, C++, LaTeX, Mathematica, R, HTML, CSS, Javascript, Bash, Perl, Java
Technical	CUDA, MPI, Flux.jl, PyTorch, Docker, Google Cloud, DigitalOcean, Buildkite, Django, git, Slurm, Linux, Windows
	Software development, Code review, Automated testing, GPU programming, Distributed computing, Data analysis, Performance optimization
Math	Scientific computing, differential equations, scientific machine learning, Bayesian statistics

Open Source Software

Oceananigans.jl
Led development of the first release and implemented features to turn it into an ocean model. Implemented support for GPUs with CUDA, and distributed computing with MPI. Built comprehensive test suites with custom CI pipelines and wrote extensive documentation.

Atmosfoolery.jl
Developed an idealized atmospheric model running on GPUs and implemented several validation tests.

Project Lovelace
Developed a website with scientific computing themed programming problems with automatic judging of submissions in Python, Javascript, C, and Julia.

Teaching Experience

2022	**Staff and speaker**, First-Year Pre-Orientation Program: Discover Earth, Atmospheric, and Planetary Sciences, *MIT*
2019	**Kaufman Teaching Certificate Program**, Teaching + Learning Lab, *MIT*
2018	**Graduate Teaching Assistant**, Introduction to Weather Forecasting, *MIT*
2018	**Lecturer**, Joint Program on the Science & Policy of Global Change, Introduction to Climate Science, *MIT*
2016	**Graduate Teaching Assistant**, Thermal Physics, *University of Waterloo*
2016	**Drop-in Tutor (4×)**, Calculus II, *University of Waterloo*
2015	**Undergraduate Teaching Assistant**, Electricity & Magnetism I, *University of Waterloo*
2015	**Undergraduate Teaching Assistant**, Discrete Mathematics, *University of Waterloo*
2015	**Drop-in Tutor (2×)**, Electricity & Magnetism I, *University of Waterloo*
2014	**Drop-in Tutor**, Linear Algebra I, *University of Waterloo*
2014	**Undergraduate Teaching Assistant (2×)**, Physics I: Mechanics, *University of Waterloo*
2014	**Undergraduate Teaching Assistant (2×)**, Calculus II, *University of Waterloo*
2014	**Undergraduate Teaching Assistant**, Linear Algebra I, *University of Waterloo*
2015–17	**Head Tutor and Organizational Team Member**, Mathematics, *Frontier College (now called United for Literacy)*
2012–17	**Private Tutor**, Independent and through AccessAbility Services, *University of Waterloo*

Publications

PDF copies are available on my personal website (`aliramadhan.me`).

2023	**Capturing vertical mixing in the oceanic boundary layer using neural differential equations**, X. K. Lee, **A. Ramadhan**, J. C. Marshall, A. N. Souza, G. L. Wagner, U. Piterbarg, A. Hillier, R. Ferrari. In preparation.
	Capturing missing physics in climate model parameterizations using neural differential equations, **A. Ramadhan**, J. C. Marshall, A. N. Souza, X. K. Lee, U. Piterbarg, A. Hillier, G. L. Wagner, C. Rackauckas, C. Hill, J.-M. Campin, R. Ferrari. Submitted to *Journal of Advances in Modeling Earth Systems*.
	Divergent behavior of hydrothermal plumes in fresh versus salty icy ocean worlds, S. Bire, T. Mittal, W. Kang, **A. Ramadhan**, P. Tuckman, C. R. German, A. M. Thurnherr, J. C. Marshall. Submitted to *Journal of Geophysical Research: Planets*.
2022	**TOI-1075 b: A Dense, Massive, Ultra-short-period Hot Super-Earth Straddling the Radius Gap**, Z. Essack, A. Shporer, J. A. Burt, et al. (including **A. Ramadhan**) *The Astronomical Journal* **165**(2), 47.
	Observations of Upwelling and Downwelling Around Antarctica Mediated by Sea Ice, **A. Ramadhan**, J. Marshall, G. Meneghello, L. Illari, K. Speer. *Frontiers in Marine Science* **9**, 864808.
	Exploring Ocean Circulation on Icy Moons Heated From Below, S. Bire, W. Kang, **A. Ramadhan**, J.-M. Campin, J. Marshall. *Journal of Geophysical Research: Planets* **127**, e2021JE007025.
2021	**On the Settling Depth of Meltwater Escaping from beneath Antarctic Ice Shelves**, C. W. Arnscheidt, J. Marshall, P. Dutrieux, C. D. Rye, **A. Ramadhan**. *Journal of Physical Oceanography* **51**(7), 2257–2270.
	Near-Inertial Waves and Turbulence Driven by the Growth of Swell, G. L. Wagner, G. P. Chini, **A. Ramadhan**, B. Gallet, R. Ferrari. *Journal of Physical Oceanography* **51**(5), 1337–1351.
2020	**Uncertainty Quantification of Ocean Parameterizations: Application to the K-Profile-Parameterization for Penetrative Convection**, A. N. Souza, G. L. Wagner, **A. Ramadhan**, B. Allen, V. Churavy, J. Schloss, J. Campin, C. Hill, A. Edelman, J. Marshall, G. Flierl, R. Ferrari. *Journal of Advances in Modeling Earth Systems* **12**, e2020MS002108.
	Oceananigans.jl: Fast and friendly geophysical fluid dynamics on GPUs, **A. Ramadhan**, G. L. Wagner, C. Hill, J.-M. Campin, V. Churavy, T. Besard, A. Souza, A. Edelman, R. Ferrari, J. Marshall. *Journal of Open Source Software* **5**(53), 2018.

Universal Differential Equations for Scientific Machine Learning, C. Rackauckas, Y. Ma, J. Martensen, C. Warner, K. Zubov, R. Supekar, D. Skinner, **A. Ramadhan**, A. Edelman. *arXiv:2001.04385v4 [cs.LG]*.

2017 **Molecular movies and geometry reconstruction using Coulomb explosion imaging**, **A. Ramadhan**. *Master's thesis*, University of Waterloo.

X-Ray Dosimetry During Low-Intensity Femtosecond Laser Ablation of Molybdenum in Ambient Conditions, M. J. Wesolowski, C. C. Scott, B. Wales, **A. Ramadhan**, S. Al-Tuairqi, S. N. Wanasundara, K. S. Karim, J. H. Sanderson, C. A. Wesolowski, P. S. Babyn. *IEEE Transactions on Nuclear Science* **64**(9), 2519–2522.

Synthesis of hydrogen- and methyl-capped long-chain polyynes by intense ultrashort laser pulse irradiation of toluene, **A. Ramadhan**, M. Wesolowski, T. Wakabayashi, H. Shiromaru, T. Fujino, T. Kodama, W. Duley, J. Sanderson *Carbon* **118**, 680–685.

2016 **Ultrafast molecular dynamics of dissociative ionization in OCS probed by soft X-ray synchrotron radiation**, **A. Ramadhan**, B. Wales, I. Gauthier, R. Karimi, M. MacDonald, L. Zuin, J. Sanderson *Journal of Physics B: Atomic, Molecular, and Optical Physics* **49**, 215602.

A Novel Femtosecond Laser-Assisted Method for the Synthesis of Reduced Graphene Oxide Gels and Thin Films with Tunable Properties, K. Ibrahim, M. Irannejad, M. Hajialamdari, **A. Ramadhan**, K. Musselman, J. Sanderson, M. Yavuz *Advanced Materials Interfaces* **3**, 1500864.

2014 **Ultrafast Light Interaction with Graphene Oxide Aqueous Solution**, K. Ibrahim, M. Irannejad, **A. Ramadhan**, W. Alayak, J. Sanderson, B. Cui, A. Brzezinski, M. Yavuz. *Proceedings of the 14th IEEE International Conference on Nanotechnology* 830–831.

Welding of Au Microwires by Femtosecond Laser Irradiation, N. Ly, M. Mayer, **A. Ramadhan**, and J. Sanderson. *Proceedings of the 14th IEEE International Conference on Nanotechnology* 146–149.

Coulomb imaging of the concerted and stepwise break up processes of OCS ions in intense femtosecond laser radiation, B. Wales, É. Bisson, R. Karimi, S. Beaulieu, **A. Ramadhan**, M. Giguère, Z. Long, W. Liu, J. Kieffer, F. Légaré, J. Sanderson. *Journal of Electron Spectroscopy and Related Phenomena* **195**, 332–336.

Presentations

2023 **Capturing missing physics in climate model parameterizations using neural differential equations**, *NASA-GISS Workshop on Climate Modeling using Machine Learning*, New York City, NY. (Oral)

2022 **Capturing missing physics in oceanic boundary layer turbulence using neural differential equations**, *2022 Ocean Sciences Meeting*, Virtual. (Oral)

Capturing missing physics in climate models using neural differential equations, *Society for Industrial and Applied Mathematics Seminar*, MIT, Cambridge, MA. (Oral)

2020 **Oceananigans.jl: Improving Climate Model Accuracy with Fast and Friendly Geophysical Fluid Dynamics on GPUs**, *International Conference for High Performance Computing, Networking, Storage and Analysis (SC2020)*, Virtual. (Poster)

2019 **Mathematical diseases in climate models and how to cure them**, *36th Chaos Communication Congress (36C3)*, Leipzig, Germany. (Oral)

Oceananigans.jl: Fast and friendly high-resolution ocean process modeling for long-range climate prediction, *13th Graduate Climate Conference*, Woods Hole, MA. (Treasurer, session chair, and poster)

Constraining the Position of the Antarctic Divergence and Ascertaining its Effects on Antarctic Land Ice Loss Using Observations, *27th International Union of Geodesy and Geophysics (IUGG) General Assembly*, Montréal, QC, Canada. (Oral)

Reducing the error bars on climate and ocean predictions, *MIT Stephen A. Schwarzman College of Computing Launch*, Cambridge, MA. (Poster)

2018	**Reducing the error bars on climate predictions**, *Society for Industrial and Applied Mathematics Seminar*, MIT, Cambridge, MA. (Oral)
2016	**Comparing Coulomb explosion dynamics of multiply charged OCS after ionization by soft X-rays and few cycle femtosecond laser pulses**, *Photonics North 2016*, Québec City, QC, Canada. (Oral)
2015	**Reconstructing Molecular Geometries of Small Molecules using Coulomb Explosion Imaging**, *Compute Ontario Research Day*, Kitchener, ON, Canada. (Oral)
	Dissociative ionization dynamics of the OCS molecule induced by soft X-rays, *Canadian Light Source 18th Annual Users' Meeting*, Saskatoon, SK, Canada. (Poster)
2014	**Coulomb Explosion Imaging and Polyyne Production in Toluene using Femtosecond Laser Pulses**, *Kindai University Physical Chemistry Colloqium*, Osaka, Japan. (Invited seminar)
	Imaging of Structure in the OCS^{6+} molecule using intense variable pulse length 7–200 fs laser pulses, *Photonics North 2014*, Montréal, QC, Canada. (Oral)
2013	**Coulomb Explosion Imaging of CO_2 and OCS in Intense Femtosecond Laser Radiation**, *Canadian Undergraduate Physics Conference 2013*, Hamilton, ON, Canada. (Oral)

Activities

Graduate Climate Conference
2019
Treasurer
- Secured conference funding from several institutional sources. Co-chaired the oceanography session.
- Distributed travel funding to attendees in need and processed local and international reimbursements.

Frontier College (now United for Literacy)
2015 – 2017
Head Tutor, Organizational Team Member
- Worked with local schools to develop new educational math programs and games for students in grades 4–8.
- Tutored middle and high-school students one-on-one in math, science, and English for two nights a week.

University of Waterloo Science Endowment Fund
2014 – 2016
Physics Representative
- Represented and advocated for the Physics Department at council meetings to ensure funding of equipment.
- Voted on funding requests taking endowment fund policies and undergraduate interests into consideration.

University of Waterloo Cooking Club
2012 – 2016
Founder, President (5×)
- Founded a club for students who enjoy cooking to meet and to teach other students how to cook.
- Led a team of 12–25 executive members as president to plan events, recruit members, and ensure smooth club operation.
- Planned and hosted cooking classes, competitions, potlucks, bake sales, BBQ's, restaurant outings, and field trips. Many events were highly attended (50–100) and members consistently rated our classes highly.

Awards

2017	**Praecis Presidential Graduate Fellowship**, Massachusetts Institute of Technology
	Jule Charney Prize, Program in Atmospheres, Oceans, & Climate, MIT
2016	**Alexander Graham Bell Graduate Scholarship**, Natural Sciences and Engineering Research Council of Canada
	President's Graduate Scholarship, University of Waterloo
	Marie Curie Award, Department of Physics and Astronomy, University of Waterloo
	Dean's Honours List (7×), Faculty of Science, University of Waterloo
2015	**Undergraduate Student Research Award**, Natural Sciences and Engineering Research Council of Canada
2014	**Xerox Research Centre of Canada Award for Excellence in Oral Communication**, University of Waterloo
2013	**Undergraduate Student Research Award**, Natural Sciences and Engineering Research Council of Canada
2011	**Merit Scholarship**, University of Waterloo