

Muralikrishnan Gopalakrishnan Meena

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CURRENT AFFILIATION

Computational Scientist

Oak Ridge Leadership Computing Facility
Oak Ridge National Laboratory, Tennessee, USA

EDUCATION

University of California, Los Angeles, USA

January 2019 - June 2020

Ph.D., Mechanical Engineering, minor in Applied Mathematics
Dissertation: Network community-based analysis of complex vortical flows: Laminar & turbulent flows
Advisor: Prof. Kunihiko Taira

Florida State University, U.S.A

August 2015 - December 2018

Master of Science, Mechanical Engineering

Cochin University of Science & Technology, India

June 2010 - May 2014

Bachelor of Technology, Mechanical Engineering

RESEARCH AREAS OF INTEREST

Fluid Dynamics: • Turbulence • Atmospheric & oceanographic turbulence • Vortex interaction • Unsteady aerodynamics • Flow control

Data Science: • Network science (graph theory) • Machine learning (clustering, regression, classification, interpretability) • Reduced-order modeling

Biological Sciences: • Fungal community interactions & metabolic networks • Biomedical image reconstruction & segmentation

TECHNICAL SKILLS

Scientific Computing:

- *Machine learning & Data Science:* Packages - PyTorch (Python & C++ API, with multi-node GPU distributed data-parallel training & inference), TensorFlow (Keras), Scikit-learn, NetworkX, Matlab BCT for graphs; ML Models - mainly using MLP, ResNet, CNN, RNN, LSTM
- *CFD solvers:* DNS & LES solvers (based on immersed boundary method, finite difference & volume, spectral) in HPC environment; Basic user of OpenFOAM & ANSYS FLUENT
- *Parallel computation & HPC:* MPI, bash scripting, HPCToolkit for profiling (basic user), various HPC systems of US-DOE (OLCF-Summit, Andes), US-DOD (Gordon & Conrad), and academia (UCLA & FSU)
- *Performance portability:* Basic user of YAKL (github.com/mrnorman/YAKL) & HIP (including ROCm profiler & debugger)
- *Distributed version-control:* Git, Github

Programming Languages:

- Fortran, C++ (basic user of `gdb` & `valgrind` debuggers), Python (including Jupyter Lab), Matlab

Design:

- *Scientific modeling:* Solidworks, Pointwise
- *Visualization:* Python, MayaVi, Ncview, Matlab, Tecplot, ParaView, OmniGraffle, Draw.io

Last updated: May 12, 2023

WORK EXPERIENCE

Oak Ridge National Laboratory Computational Scientist	<i>March 2022 - Present</i>
Oak Ridge National Laboratory Postdoctoral Research Associate	<i>July 2020 - February 2022</i>
University of California, Los Angeles Graduate Research Assistant	<i>January 2019 - June 2020</i>
Florida State University Graduate Research Assistant Teaching Assistant: Numerical Methods for Engineers (Spring 2016, 2017)	<i>August 2015 - December 2018</i>

PUBLICATION

Google Scholar: scholar.google.com/citations?user=2yNLfcsAAAAJhl=en

Peer-reviewed Articles

1. M. R. Norman, C. Eldred, and **M. Gopalakrishnan Meena**, “Investigating inherent numerical stabilization for the moist, compressible, non-hydrostatic Euler equations on collocated grids”, *in review*, 2023
2. **M. Gopalakrishnan Meena**, M. R. Norman, D. M. Hall, and M. S. Pritchard, “Surrogate modeling of subgrid-scale effects in idealized atmospheric flows: A deep learned approach using high-resolution simulation data,” *in review*, 2023 (preprint)
3. **M. Gopalakrishnan Meena**, M. J. Lane, J. Tannous, A. A. Carrell, P. E. Abraham, R. J. Giannone, J-M Ané, N. P. Keller, J. L. Labbé, D. Kainer, D. A. Jacobson, and T. A. Rush, “A light into the fungal metabolomic abyss: Network analysis for revealing relationships between exogenous compounds & their outputs”, *in review*, 2022 (preprint)
4. T.A. Rush, J. Tannous, M.J. Lane, **M. Gopalakrishnan Meena**, A. Carrell, J.J. Golan, M. T. Drott, S. Cottaz, S. Fort, J.M. Ané, N.P. Keller, D. A. Pelletier, D.A. Jacobson, D. Kainer, P. Abraham, R.J. Giannone, J.L. Labbé, “Lipo-chitooligosaccharides induce specialized fungal metabolite profiles that modulate bacterial growth”, *mSystems*, 7 (6), e01052-22, 2022 (link)
5. T. A. Rush, H. K. Shrestha, **M. Gopalakrishnan Meena**, M. K. Spangler, J. C. Ellis, J. L. Labbé, and P. Abraham, “Bioprospecting Trichoderma: A systematic roadmap to screen genomes and natural products for biocontrol applications”, *Frontiers in Fungal Biology*, 2:716511, 2021 (link)
6. S. Mahajan, L. S. Passarella, F. M. Hoffman, **M. Gopalakrishnan Meena**, and M. Xu, “Assessing teleconnections-induced predictability of regional water cycle on seasonal to decadal timescales using machine learning approaches”, *DOE BER AI4ESP*, No. AI4ESP1086, 2021 (link)
7. **M. Gopalakrishnan Meena** and K. Taira, “Identifying vortical network connectors for turbulent flow modification”, *Journal of Fluid Mechanics*, 915, A10, 2021 (link)
8. C.-A. Yeh, **M. Gopalakrishnan Meena**, and K. Taira, “Network broadcast analysis and control of turbulent flows”, *Journal of Fluid Mechanics*, 910, A15, 2021 (link)
9. Z. Bai, N. B. Erichson, **M. Gopalakrishnan Meena**, K. Taira, and S. L. Brunton, “Randomized methods to characterize large-scale vortical flow network”, *PLOS One*, 14(11), e0225265, 2019 (link)
10. **M. Gopalakrishnan Meena**, A. G. Nair, and K. Taira, “Network community-based model reduction for vortical flows”, *Physical Review E*, 97, 063103, 2018 (link)
11. **M. Gopalakrishnan Meena**, K. Taira, and K. Asai, “Airfoil wake modification with Gurney flap at low-Reynolds number”, *AIAA Journal*, 56(4), 1348-1359, 2018 (link)

Peer-reviewed Conference Proceedings

1. **M. Gopalakrishnan Meena**, A. K. Ziabari, S. V. Venkatakrishnan, I. R. Lyngaas, M. R. Norman, B. Joo, T. L. Beck, C. A. Bouman, A. J. Kapadia, and X. Wang, “Physics guided machine learning for multi-material decomposition of tissues from dual-energy CT scans of simulated breast models with calcifications,” *High Performance Computing for Imaging Conference at Electronic Imaging Symposium*, San Francisco, CA,

- January 15-19, 2023 (Selected for **Conference Best Paper Award** and **Symposium Highlights Session**)
(link)
2. N. L. Hickmon, et al., “Artificial Intelligence for Earth System Predictability (AI4ESP) Workshop Report (Section: Knowledge Discovery and Statistical Learning)”, No. ANL-22/54. Argonne National Laboratory, Argonne, IL (United States), 2022. (link)
 3. **M. Gopalakrishnan Meena**, M. R. Norman, and D. M. Hall, “Subgrid-scale surrogate modeling of idealized atmospheric flows: A deep learned approach using high-resolution simulation data,” 12th International Symposium on Turbulence and Shear Flow Phenomena, Osaka, Japan, July 19 - 22 (Online), 2022 (TSFP 12 229) (link)
 4. M. R. Norman and **M. Gopalakrishnan Meena**, “Confident, adaptable, and robust machine learning to augment traditional modeling and simulation,” Position Papers for the ASCR Workshop on Reimagining Codesign, USDOE Office of Science (United States), 2021 (link)
 5. **M. Gopalakrishnan Meena** and K. Taira, “Characterizing influential networked structures in isotropic turbulence,” 11th International Symposium on Turbulence and Shear Flow Phenomena, Southampton, UK, July 30 - Aug. 2, 2019 (TSFP 11 235) (link)
 6. **M. Gopalakrishnan Meena**, K. Taira, and K. Asai, “Low Reynolds number wake modification using a Gurney flap,” 55th AIAA Aerospace Sciences Meeting, Grapevine, TX, Jan. 9-13, 2017 (AIAA 2017-0543) (link)
 7. **M. Gopalakrishnan Meena**, A. Anandakrishnan, and M. A. Kavumcheril. “Numerical study on heat transfer and fluid flow in pin fin-dimple channels with fillet on dimple edge”, ASME Gas Turbine India Conference, New Delhi, India, Dec. 15-17, 2014 (GTINDIA2014-8103) (link)

PRESENTATIONS

Underlined: Invited presentation

1. **M. Gopalakrishnan Meena**, “Physics-guided machine learning for image-based multi-material decomposition from dual-energy CT scans,” Multimodal and Multi-scale Bioimaging for Biomedical and Bioenergy Research, NSLS-II, CFN & LBMS Users’ Meeting (virtual), Brookhaven National Laboratory, NY, April 24-28, 2023
2. **M. Gopalakrishnan Meena**, “Physics guided machine learning for image-based multi-material decomposition from dual-energy CT scans,” Advancing Medical Care through Discovery in the Physical Sciences: Radiation Detection, Joint DOE/NIH Workshop, Thomas Jefferson National Accelerator Facility, VA, March 15-17, 2023
3. **M. Gopalakrishnan Meena**, A. Simin, J. J. Riley, and S. M. de Bruyn Kops, “A machine learning approach for second moment closure modeling of stably stratified turbulence,” APS March Meeting, Las Vegas, NV, March 5-10, 2023
4. **M. Gopalakrishnan Meena**, “Data-driven surrogate modeling of turbulent flows in the atmosphere and ocean,” Mathematics in Computation (MiC) seminar series, Oak Ridge National Laboratory, February 9, 2023
5. **M. Gopalakrishnan Meena**, A. K. Ziabari, S. V. Venkatakrisnan, I. R. Lyngaas, M. R. Norman, B. Joo, T. L. Beck, C. A. Bouman, A. J. Kapadia, and X. Wang, “Physics guided machine learning for multi-material decomposition of tissues from dual-energy CT scans of simulated breast models with calcifications,” High Performance Computing for Imaging Conference at Electronic Imaging Symposium, San Francisco, CA, January 15-19, 2023 (Selected for **Conference Best Paper Award** and **Symposium Highlights Session**)
6. M. R. Norman and **M. Gopalakrishnan Meena**, “Machine learned surrogate model for subgrid-scale effects in 3-D stratified Kelvin-Helmholtz turbulence using the miniWeatherML app”, AGU Fall Meeting, Chicago, IL, December 12-16, 2022 (NG22B-0359)
7. **M. Gopalakrishnan Meena**, M. R. Norman, and D. M. Hall, “Subgrid-scale surrogate modeling of idealized atmospheric flows: A deep learned approach using high-resolution simulation data,” 12th International Symposium on Turbulence and Shear Flow Phenomena, Osaka, Japan, July 19 - 22 (Online), 2022 (TSFP 12 229)

8. **M. Gopalakrishnan Meena**, M. J. Lane , J. Tannous , T. A. Rush, “Predicting production of known, putative, and unknown microbial metabolites through network analysis,” 31st Fungal Genetics Conference, March 15-20, 2022 (Biotechnology-331V)
9. **M. Gopalakrishnan Meena**, “Data-driven modeling of turbulent flows: Approaches using graph theory & AI,” *Data Sciences & Machine Intelligence Group Seminar*, Pacific Northwest National Laboratory, March 7, 2022
10. **M. Gopalakrishnan Meena**, M. R. Norman, and D. M. Hall, “Subgrid-scale surrogate modeling of cloud-like flows: An AI-based approach using high-resolution simulation data,” AMS 102nd Annual Meeting, Virtual Conference, January 23-27, 2022 (paper # 13A.5)
11. **M. Gopalakrishnan Meena**, M. R. Norman, and D. M. Hall, “A deep learned subgrid-scale surrogate model for cloud-like flows from high-resolution simulation data,” AGU Fall Meeting, Virtual Conference, December 13-17, 2021 (A15E-1689)
12. C.-A. Yeh, **M. Gopalakrishnan Meena**, and K. Taira, “Network-based resolvent analysis for modification of isotropic turbulence,” 25th International Congress of Theoretical and Applied Mechanics, Milan, Italy, Aug. 2021
13. T. A. Rush, H. K. Shrestha, **M. Gopalakrishnan Meena**, M. K. Spangler, J. C. Ellis, J. Labbé, and P. E. Abraham, “Bioprospecting Trichoderma: A systematic roadmap to screen genomes and natural products for biocontrol applications”, 9th Annual Oak Ridge Postdoctoral Association Research Symposium, July 29, 2021
14. M. R. Norman, C. Eldred, I. Lyngaas, **M. Gopalakrishnan Meena**, K. Pressel, M. Taylor, “Recent Developments for a New Cloud Resolving Model on the A-Grid,” *PDEs on the Sphere*, Virtual Meeting, May 17-21, 2021
15. M. R. Norman, C. Eldred, W. Hannah, I. Lyngaas, **M. Gopalakrishnan Meena**, K. Pressel, M. Taylor, X. Yuan, “Developing a New Cloud Resolving Model for the E3SM-MMF ECP AD Project,” *ECP Annual Meeting*, Virtual Meeting, April 12-16, 2021
16. **M. Gopalakrishnan Meena**, “Identifying vortical network connectors for turbulent flow modification,” *Network Science for Fluid Mechanics Seminar Series*, Virtual Seminar Series, March 19, 2021
17. M. R. Norman and **M. Gopalakrishnan Meena**, “Confident, adaptable, and robust machine learning to augment traditional modeling and simulation,” *ASCR Workshop on Reimagining Codesign*, Virtual Workshop, Mar. 16-18, 2021
18. C.-A. Yeh, **M. Gopalakrishnan Meena**, and K. Taira, “Network broadcast mode analysis and control of 2D decaying isotropic turbulence,” *SIAM Conference on Computational Science and Engineering*, Virtual Conference, Mar.1-5, 2021 (MS275)
19. **M. Gopalakrishnan Meena** and K. Taira, “Modeling and modifying fluid flows using network-community-based techniques: laminar and turbulent flows,” *SIAM Conference on Computational Science and Engineering*, Virtual Conference, Mar.1-5, 2021 (MS190)
20. **M. Gopalakrishnan Meena** and M. R. Norman, “Towards a Deep Learned Subgrid-scale Surrogate Model for Cloud Resolving Models from High-resolution Simulation Data,” AMS 101st Annual Meeting, Virtual Conference, January 10-15, 2021 (paper # 6.9)
21. **M. Gopalakrishnan Meena** and M. R. Norman, “Towards a deep learned subgrid-scale surrogate model for stratified turbulence from high-resolution simulation data,” AGU Fall Meeting, Virtual Conference, December 1-17, 2020 (A068-0013)
22. T. A. Rush, **M. Gopalakrishnan Meena**, J. Tannous, P. Abraham, R. Giannone, and J. Labbé, “Lipo-chitoooligosaccharides (LCOs) are biotic stress factors in *Aspergillus fumigatus*,” *14th Annual Vanderbilt Postdoctoral Association Symposium*, virtual symposium, October 29, 2020
23. **M. Gopalakrishnan Meena** and K. Taira, “Network-based identification of influential structures to modify turbulent flows,” *Network Science for Fluid Dynamics*, virtual workshop, June 24-25, 2020
24. C.-A. Yeh, **M. Gopalakrishnan Meena**, and K. Taira “Broadcasting Mode Analysis for Turbulent Flow Modification,” *Network Science for Fluid Dynamics*, virtual workshop, June 24-25, 2020

25. **M. Gopalakrishnan Meena** and K. Taira, “Network-based identification of influential structures to modify turbulent flows,” *72th Annual Meeting of the APS Division of Fluid Dynamics*, Seattle, WA, Nov. 23-26, 2019 (H10.00010)
26. C.-A. Yeh, **M. Gopalakrishnan Meena**, and K. Taira, “Time-evolving network analysis of two-dimensional turbulence,” IUTAM Symposium on Laminar-Turbulent Transition, London, UK, Sep. 2-6, 2019
27. **M. Gopalakrishnan Meena** and K. Taira, “Characterizing influential networked structures in isotropic turbulence,” 11th International Symposium on Turbulence and Shear Flow Phenomena, Southampton, UK, July 30 - Aug. 2, 2019 (TSFP 11 235)
28. **M. Gopalakrishnan Meena** and K. Taira, “Characterizing three-dimensional homogenous isotropic turbulence network”, *SoCal Fluids XIII*, UC Santa Barbara, 20 April, 2019
29. Z. Bai, N. B. Erichson, **M. Gopalakrishnan Meena**, K. Taira, and S. L. Brunton, “Sparse and randomized sampling methods for scalable turbulent flow networks,” *71th Annual Meeting of the APS Division of Fluid Dynamics*, Atlanta, GA, Nov. 18-20, 2018 (G01.00004)
30. **M. Gopalakrishnan Meena** and K. Taira, “High-dimensional turbulence network characterization and modeling”, *NetSci Conference*, Paris, France, June 13-15, 2018 (140)
31. K. Taira, **M. Gopalakrishnan Meena**, and A. G. Nair, “Community-based model reduction of unsteady vortical flows”, *NetSci Conference*, Paris, France, June 13-15, 2018 (135)
32. **M. Gopalakrishnan Meena**, A. G. Nair, and K. Taira, “Vortex network community based reduced-order force model,” *70th Annual Meeting of the APS Division of Fluid Dynamics*, Denver, CO, Nov. 19-21, 2017 (M1.00005)
33. **M. Gopalakrishnan Meena**, A. G. Nair, and K. Taira, “Network representation and analysis of bluff body wake,” *SIAM Conference on Computational Science and Engineering*, Atlanta, GA, Feb. 27-Mar. 3, 2017 (MS110)
34. **M. Gopalakrishnan Meena**, K. Taira, and K. Asai, “Low Reynolds number wake modification using a Gurney flap,” *55th AIAA Aerospace Sciences Meeting*, Grapevine, TX, Jan. 9-13, 2017 (AIAA 2017-0543)
35. A. G. Nair, **M. Gopalakrishnan Meena**, and K. Taira, “Vortical and modal network analysis of unsteady cylinder wake,” *69th Annual Meeting of the APS Division of Fluid Dynamics*, Portland, OR, Nov. 20-22, 2016 (E8.00004)
36. **M. Gopalakrishnan Meena**, A. Anandkrishnan, and M. A. Kavumcheril. “Numerical study on heat transfer and fluid flow in pin fin-dimple channels with fillet on dimple edge”, ASME Gas Turbine India Conference, New Delhi, India, Dec. 15-17, 2014 (GTINDIA2014-8103)

PROFESSIONAL & COMMUNITY SERVICES

Journal & Proposal Referee

- Journal of Fluid Mechanics • AIAA Journal • International Journal of Heat and Fluid Flow
- Physica D • Physics Letters A • IEEE Access • Journal of Applied Meteorology and Climatology
- Partial Differential Equations in Applied Mathematics • Progress in Computational Fluid Dynamics
- DOE’s INCITE - Computational Readiness • ORNL Director’s Discretionary Allocation
- NASA - Early Stage Innovations

Workshop Organization

- APS March Meeting, March 2022: Session chair - “Fluids II” (march.aps.org/)
- High Performance Computing for Imaging Conference at Electronic Imaging Symposium, January, 2023: Session chair - “AI Methods for Imaging” (www.imaging.org/Site/IST/Conferences/EI/EI2023/EI2023.aspx)
- AMS Annual Meeting, January 2022: (1) Session chair - “AI in Weather and Climate Modeling: Bridging the Gap Between Theoretical Advances and Production Use” and (2) Session co-chair for 2 sessions (annual.ametsoc.org/index.cfm/2022/)

- AGU Fall Meeting, December 2021: Session chair - “AI in Weather and Climate Modeling: From Theoretical Advances to Operational Use” (www.agu.org/Fall-Meeting)
- Network Science for Fluid Mechanics Seminar Series (virtual), once every month, Nov. 2020 - present: Organizer (with Aditya Nair and Kunihiro Taira) (sites.google.com/g.ucla.edu/nsfm/)

Training Events

- Mentor at GPU Hackathons (www.gpuhackathons.org)
 1. OLCF Hackathon, October 18, 25-27, 2021 (Team 3d3n_h4ck3r2)
 2. Princeton Hackathon, June 2, 8-10, 2021 (Team SLEAP)
- AI tutorial at OpenACC Summit 2022: M. R. Norman and M. Gopalakrishnan Meena, “Exploring Neural Network Surrogate Models with miniWeatherML”

Student mentoring

- 2022 - Andrew Simin, M.S. independent study (University of Massachusetts Amherst) “Modeling parameterized system of ODEs using machine learning”
- 2017 - Tyler Pilet, NSF-REU student (Florida State University) “System identification of bubble collapse model”

Outreach & Volunteering

- Youth Outreach in STEM, Knoxville TN (www.yostem.org) (2021 - present)
- Oak Ridge Computer Science Girls, Oak Ridge TN (www.orcsgirls.org) (2021 - present)
- Buck Lake Elementary School, Tallahassee FL (2016, 2017)
- FSU AME Building Open House for the public, Tallahassee FL (2016, 2017)

Honors/Awards/Recognition

- 2023 - **Best Paper Award at the High Performance Computing for Imaging Conference at the 2023 Electronic Imaging Symposium** for the paper titled: M. Gopalakrishnan Meena et al., “Physics guided machine learning for multi-material decomposition of tissues from dual-energy CT scans of simulated breast models with calcifications”. Also selected for **Symposium Highlights Session**.
- 2022 - **ORNL, UT-Battelle Supplemental Performance Award** for recognition of extraordinary accomplishment, exceeding expectations, rising above unforeseen challenges and going the extra mile to advance ORNL’s missions. The highest standards of performance and significance of the work make the SPA a rare achievement in one’s career at ORNL.
- 2022 - **Winner of the 2022 American Association of Physicists in Medicine (AAPM) Grand challenge: Truth-Based CT Reconstruction Challenge** (<https://www.aapm.org/GrandChallenge/TrueCT>). Press release at ORNL: <https://www.olcf.ornl.gov/2022/08/15/ornlpurdue-team-wins-ct-imaging-competition/>
- 2021 - **Invention disclosure sponsored by ORNL, UT-Battelle**: M. Gopalakrishnan Meena, M. J. Lane, J. Tannous, T. A. Rush, “Using bipartite networks to determine interactions between analytes and chemical treatments”, 2021 (provisional patent application filed)