Tristan Montoya

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EDUCATION

Doctor of Philosophy, Aerospace Science and Engineering — September 2018 – June 2024
University of Toronto — *Toronto, Canada*

Thesis: Provably stable discontinuous spectral-element methods with the summation-by-parts property: Unified matrix analysis and efficient tensor-product formulations on curved simplices

Advisor: David Zingg

Bachelor of Engineering, Mechanical Engineering — September 2014 – June 2018
Carleton University — *Ottawa, Canada*

Capstone project: Performance analysis and numerical optimization of a supercritical carbon dioxide Brayton cycle

CURRENT POSITION

Postdoctoral Researcher, Department of Mathematics and Computer Science — January 2024 – Present
University of Cologne — *Cologne, Germany*

Project: Robust split-form and entropy-stable discontinuous spectral-element methods for the ICON-DG atmospheric dynamical core; collaboration with the Deutscher Wetterdienst (DWD) and German Aerospace Center (DLR) as part of the "Smarter" module of the WarmWorld project for kilometre-scale climate predictions at exascale, which is funded by the German Federal Ministry of Education and Research (BMBF)

Advisor: Gregor Gassner

RESEARCH INTERESTS

Numerical analysis and scientific computing focused on nonlinear hyperbolic and advection-dominated systems of partial differential equations with applications in geophysical fluid dynamics; specific topics include robust structure-preserving high-order methods using summation-by-parts operators, dynamical core development for weather and climate models using discontinuous Galerkin and spectral-element methods, dynamical systems and control-theoretic approaches to adaptive simulations, data-driven methods for subgrid-scale parametrization, open-source scientific software development, and efficient implementation on modern high-performance computing systems

PUBLICATIONS IN PEER-REVIEWED JOURNALS

T. Montoya and D. W. Zingg, Efficient entropy-stable discontinuous spectral-element methods using tensor-product summation-by-parts operators on triangles and tetrahedra. *Journal of Computational Physics* 516, article no. 113360, 2024.

T. Montoya and D. W. Zingg, Efficient tensor-product spectral-element operators with the summation-by-parts property on curved triangles and tetrahedra. *SIAM Journal on Scientific Computing* 46(4), pp. A2270–A2297, 2024.

T. Montoya and D. W. Zingg, A unifying algebraic framework for discontinuous Galerkin and flux reconstruction methods based on the summation-by-parts property. *Journal of Scientific Computing* 92(3), article no. 87, 2022.

PUBLICATIONS IN CONFERENCE PROCEEDINGS

T. Montoya* and D. W. Zingg, Stable and conservative high-order methods on triangular elements using tensor-product summation-by-parts operators. *11^{th} International Conference on Computational Fluid Dynamics*, Maui, United States, July 2022. **Awarded best student paper**.

CONFERENCE PRESENTATIONS (EXCLUDING ABOVE PROCEEDINGS)

T. Montoya* and D. W. Zingg, Efficient entropy-stable discontinuous spectral-element methods in collapsed coordinates for hyperbolic systems on curved triangular and tetrahedral meshes. *Canadian Applied and Industrial Mathematics Society Annual Meeting*, Kingston, Canada, June 2024.

T. Montoya* and D. W. Zingg, Efficient entropy-stable tensor-product spectral-element methods on simplices. *9^{th} European Congress on Computational Methods in Applied Sciences and Engineering*, Lisbon, Portugal, June 2024.

T. Montoya* and D. W. Zingg, Efficient tensor-product spectral-element methods with the summation-by-parts property on triangles and tetrahedra. *SIAM Conference on Computational Science and Engineering*, Amsterdam, Netherlands, February 2023.

T. Montoya* and D. W. Zingg, Unified analysis of discontinuous Galerkin and flux reconstruction methods based on the summation-by-parts property. *International Conference on Spectral and High-Order Methods* (online), July 2021.

T. Montoya* and D. W. Zingg, Unified analysis of high-order methods based on the summation-by-parts property: Application to discontinuous Galerkin and flux reconstruction discretizations. *SIAM Conference on Computational Science and Engineering* (online), March 2021.

INVITED TALKS

T. Montoya,* An entropy-stable discontinuous spectral-element method for the spherical shallow water equations in covariant form. University of Waterloo Numerical Analysis and Scientific Computing Seminar, Waterloo, Canada, February 2025.

T. Montoya, A. M. Rueda-Ramírez, G. J. Gassner, J. Markert,* M. Baldauf, and D. Reinert, ICON-DG: Gearing up the ICON model with smarter discretizations. *WarmWorld General Assembly*, Bremerhaven, Germany, October 2024.

T. Montoya* and D. W. Zingg, Provably stable tensor-product discontinuous spectral-element methods on triangular and tetrahedral unstructured grids. Ansys, Inc. (online), July 2024.

T. Montoya* and D. W. Zingg, Entropy-stable tensor-product discontinuous spectral-element methods on curved triangles and tetrahedra. Rice University (online), March 2024.

T. Montoya* and D. W. Zingg, Efficient and robust spectral-element methods on triangles using tensor-product summation-by-parts operators. *NASA Advanced Modeling and Simulation Seminar Series* (online), October 2022.

T. Montoya* and S. Nadarajah, Robust deformation of unstructured grids. Bombardier Aerospace, Montréal, Canada, August 2016.

OTHER APPOINTMENTS

Visiting Researcher, Department of Mechanical Engineering — August 2022
National University of Singapore — *Singapore*
Project: Koopman operator approaches to data-driven stability analysis of numerical methods
Advisor: Gianmarco Mengaldo

Undergraduate Researcher, Institute for Aerospace Studies — May 2017 – August 2017
University of Toronto — *Toronto, Canada*
Projects: Optimization of finite-difference operators with the summation-by-parts property on non-uniform nodal distributions; comparison of continuation methods for steady aerodynamic flows
Advisor: David Zingg

*Presenting author.

Undergraduate Researcher, Department of Mechanical Engineering May 2016 – August 2016
McGill University *Montréal, Canada*
Project: Robust deformation of unstructured grids using radial basis functions and linear elasticity
Advisor: Siva Nadarajah

Undergraduate Researcher, Department of Mechanical and Aerospace Engineering May 2015 – August 2015
Carleton University *Ottawa, Canada*
Projects: Optimal estimation of uncertain parameters in computer models of welding processes; novel interpolation techniques for stress and strain tensor fields using quaternions
Advisor: John Goldak

AWARDS AND SCHOLARSHIPS

Best Student Paper, International Conference on Computational Fluid Dynamics	2022
Ontario Graduate Scholarship	2019 – 2020, 2022 – 2023
Kenneth Molson Fellowship	2021 – 2022, 2022 – 2023
Queen Elizabeth II Graduate Scholarship in Science and Technology	2020 – 2021, 2021 – 2022
Douglas Patton Hogg Memorial Award	2021
NSERC Canada Graduate Scholarship - Master's	2018 – 2019
University Medal (highest academic standing of any Bachelor of Engineering graduate)	2018
Canadian Society for Mechanical Engineering Gold Medal	2018
Rajesh Ahluwalia Memorial Scholarship	2017 – 2018
NSERC Undergraduate Student Research Award	2015, 2017
McGill University Summer Undergraduate Research in Engineering Award	2016
Allan Buchanan Undergraduate Scholarship	2015 – 2016
Deans' Honour List	2014 – 2018
Faculty Scholarship	2014 – 2018

SUPERVISION OF GRADUATE AND UNDERGRADUATE RESEARCH

Paula Weiß, Master of Science thesis student August 2024 – Present
University of Cologne (Co-supervised with Gregor Gassner and Benedict Geihe) *Cologne, Germany*
Project: High-order vertical discretizations for nonhydrostatic atmospheric models

Fabian Höck, Master of Science thesis student April 2024 – Present
University of Cologne (Co-supervised with Gregor Gassner and Benedict Geihe) *Cologne, Germany*
Project: Discontinuous Galerkin methods for moist atmospheric flows with rain

Ruilin (Jerry) Bai, Bachelor of Applied Science student intern September 2020 – December 2020
University of Toronto (Co-supervised with David Zingg) *Toronto, Canada*
Project: Optimization of summation-by-parts operators for minimal solution error

Yewon Lee, Bachelor of Applied Science student intern May 2019 – August 2019
University of Toronto (Co-supervised with David Zingg and Masayuki Yano) *Toronto, Canada*
Project: Comparative evaluation of energy- and entropy-stable discontinuous Galerkin and summation-by-parts methods

TEACHING

Scientific Computing: Introduction to the Simulation of Atmospheric Flows (14722.0023) April 2024 – July 2024
University of Cologne *Cologne, Germany*
Assisted in the development and delivery of a new graduate-level course on modern numerical methods for atmospheric dynamics; contributed to curriculum design and preparation of lecture notes, and was responsible for the creation and supervision of the final project, in which students implement a discontinuous Galerkin solver for the spherical shallow water equations and assess its effectiveness for a series of standard atmospheric test problems

OPEN-SOURCE SOFTWARE CONTRIBUTIONS AS PRINCIPAL DEVELOPER

TrixiAtmo.jl https://github.com/trixi-framework/TrixiAtmo.jl

Julia package extending the Trixi.jl numerical framework for conservation laws to enable the solution of atmospheric flow problems using a high-order discontinuous spectral-element dynamical core

StableSpectralElements.jl https://github.com/tristanmontoya/StableSpectralElements.jl

Julia framework for energy-stable and entropy-stable discontinuous spectral-element methods on general element types based on multidimensional and tensor-product formulations; emphasis on dispatched strategies for matrix-based and matrix-free operator evaluation

GHOST: Generalized High-Order Solver Toolbox https://github.com/tristanmontoya/GHOST

Python implementation of discontinuous Galerkin and flux reconstruction schemes in one or two spatial dimensions with various design choices

OTHER OPEN-SOURCE SOFTWARE CONTRIBUTIONS

Trixi.jl https://github.com/trixi-framework/Trixi.jl

Modified mesh data type to enable the solution of partial differential equations on surfaces

NodesAndModes.jl https://github.com/jlchan/NodesAndModes.jl

Added high-order symmetric quadrature rules on triangular and tetrahedral elements

SERVICE

Lab Representative, Computational Aerodynamics — December 2021 – June 2024
Centre for Computational Science and Engineering — *Toronto, Canada*

Member of the student organizing committee for an interdepartmental group of researchers at the University of Toronto across various disciplines of computational science and engineering

Editor, Physics and Mathematics Section — June 2022 – March 2024
Canadian Science Fair Journal — https://csfjournal.com/

Volunteer editor and mentor for an open-access online publication showcasing science projects by children and youth at primary and secondary schools across Canada

TECHNICAL SKILLS

Programming languages	Julia, Python (NumPy/SciPy), C, C++, MATLAB, Fortran, LaTeX
Development tools	Unix shell, Git, GNU Make, Anaconda, Jupyter Notebook, VS Code, Vim, Emacs, Slurm

OTHER ACTIVITIES

Music (performing guitarist/bassist), cycling, alpine skiing (former ski instructor), non-fiction reading

CITIZENSHIP

Canada, France