Ian Grooms

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CURRENT POSITION

Associate Professor
Department of Applied Mathematics
University of Colorado, Boulder

PREPARATION

- **New York University**
  Postdoc at the Courant Institute of Mathematical Sciences, June 2011–May 2015
- **University of Colorado at Boulder**
  Ph.D. in Applied Mathematics, May 2011
- **College of William and Mary, Williamsburg, VA**
  B.S. in Mathematics, *summa cum laude*, May 2005

RESEARCH INTERESTS

- Ocean Modeling
- Data Assimilation
- Geophysical Fluid Dynamics

PUBLICATIONS

Student coauthors since 2016 underlined. Postdoc coauthors that I supervised denoted by an asterisk.*

Refereed Journal Articles

[59] N. Loose,* G. Marques, A. Adcroft, S. D. Bachman, S. Griffies, **I. Grooms**, R. Hallberg, and M. Jansen, "*Comparing two parameterizations for the restratification effect of mesoscale eddies in an isopycnal ocean model*" J. Adv. Model. Earth Sys. **15**:e2022MS003518-1–28, 2023.

[58] **I. Grooms**, "*Backscatter in energetically-constrained Leith parameterizations*" Ocean Modelling **186**:102265-1–15, 2023.

[57] N. Agarwal,* R. J. Small, F. O. Bryan, **I. Grooms**, and P. Pegion, "*Impact of stochastic ocean density corrections on air-sea flux variability*" Geophys. Res. Lett. **50**:e2023GL104248-1–12, 2023.

[56] **I. Grooms**, C. Renaud, Z. Stanley, and L. M. Yang, "*Analog ensemble data assimilation in a quasigeostrophic coupled model*" Q. J. Roy. Meteorol. Soc. **149**:1018–1037, 2023.

[55] **I. Grooms**, "*Two methods for data assimilation of wind direction*" Tellus A, **75**:145–158, 2023.

[54] N. Loose,* S. D. Bachman, **I. Grooms**, M. Jansen, "*Diagnosing scale-dependent energy cycles in a high-resolution isopycnal ocean model*" J. Phys. Oceanogr. **53**:157–176, 2023.

[53] **I. Grooms**, "*Limits on the Rate of Conversion of Potential to Kinetic Energy in Quasigeostrophic Turbulence*" Fluids **7**:276-1–14, 2022.

[52] **I. Grooms**, "*A comparison of nonlinear extensions to the ensemble Kalman filter*" Computat. Geosci. **26**:633-650, 2022.

[51] J. Kenigson,* A. Adcroft, S. D. Bachman, F. Castruccio, **I. Grooms**, P. Pegion, and Z. Stanley, "*Parameterizing the Impact of Unresolved Temperature Variability on the Large-Scale Density Field: Part 2. Modeling.*" J. Adv. Model. Earth Sys. **14**:e2021MS002844-1–17, 2022.

[50] N. Loose,* R. Abernathey, **I. Grooms**, J. Busecke, A. Guillaumin, E. Yankovsky, G. Marques, J. Steinberg, A.S. Ross, H. Khatri, S. D. Bachman, L. Zanna, and P. Martin, "*GCM-Filters: A Python Package for Diffusion-based Spatial Filtering of Gridded Data*" J. Open Source Software **7**:3947-1–4, 2022.

[49] L. M. Yang and **I. Grooms** "*Machine learning techniques to construct patched analog ensembles for data assimilation*" J. Comput. Phys. **443**:110532-1–17, 2021.

[48] **I. Grooms**, N. Loose,* R. Abernathey, J. M. Steinberg, S. D. Bachman, G. Marques, A. P. Guillaumin, E. Yankovsky, "*Diffusion-based smoothers for spatial filtering of gridded geophysical data*" J. Adv. Model. Earth Sys. **13**:e2021MS002552-1–24, 2021.

[47] Z. Stanley, **I. Grooms**, and W. Kleiber, "*Multivariate localization functions for strongly coupled data assimilation in the bivariate Lorenz '96 system*" Nonlin. Proc. Geophys. **21**:565–583, 2021.

[46] L. M. Yang, **I. Grooms**, and K. A. Julien, "*The Fidelity of Exponential and IMEX Integrators for Wave Turbulence: Introduction of a New Near-Minimax Integrating Factor Scheme.*" J. Comp. Phys. **434**:109992-1–21, 2021.

[45] **I. Grooms** and G. Robinson, "*A hybrid particle-ensemble Kalman filter for problems with medium nonlinearity*" PLoS ONE **16**:e0248266-1–20, 2021.

[44] J. D. Christopher, O. Doronina, D. Petrykowski, T. R. S. Hayden, C. Lapointe, N. T. Wimer, **I. Grooms**, G. B. Rieker, and P. E. Hamlington "*Flow parameter estimation using laser absorption spectroscopy and approximate Bayesian computation*" Exp. Fluids **62**:43-1–20, 2021.

[43] **I. Grooms**, "*Analog ensemble data assimilation and a method for constructing analogs with variational autoencoders*" Q. J. Roy. Meteorol. Soc. **147**:139–149, 2021.

[42] R. J. Small, A. K. DuVivier, D. B. Whitt, M. C. Long, **I. Grooms**, and W. G. Large, "*On the control of subantarctic stratification by the ocean circulation*" Climate Dynamics **56**:299–327, 2021.

[41] Z. Stanley, **I. Grooms**, W. Kleiber, S. D. Bachman, F. Castruccio, and A. Adcroft, "*Parameterizing the Impact of Unresolved Temperature Variability on the Large-Scale Density Field: Part 1. Theory.*" J. Adv. Model. Earth Sys. **12**:e2020MS002185-1–21, 2020.

[40] Z. Stanley, S. D. Bachman, and **I. Grooms**, "*Vertical structure of ocean mesoscale eddies with implications for parameterizations of tracer transport*" J. Adv. Model. Earth Sys. **12**:e2020MS002151-1–13, 2020.

[39] G. Robinson, **I. Grooms**, "*A fast tunable blurring algorithm for scattered data*" SIAM J. Sci. Comput. **42**:A2281–A2299, 2020.

[38] B. Pachev, J. P. Whitehead, G. Fantuzzi, **I. Grooms**, "*Rigorous bounds on the heat transport of rotating convection with Ekman pumping*" J. Math. Phys. **61**:023101-1–17, 2020.

[37] W. Barham, **I. Grooms**, "*On energy exchanges between eddies and the mean flow in quasigeostrophic turbulence*" J. Fluid Mech. **885**:1–19, 2020.

[36] M. Watwood, **I. Grooms**, K. Julien, and K. S. Smith, "*Energy-conserving Galerkin approximations for quasigeostrophic dynamics*" J. Comp. Phys. **388**:23–40, 2019.

[35] W. Barham and **I. Grooms**, "*Exact instantaneous optimals in the non-geostrophic Eady problem and the detrimental effects of discretization*" Theoretical and Computational Fluid Dynamics **33**:125–139, 2019.

[34] **I. Grooms** and W. Kleiber, "*Diagnosing, modeling, and testing a multiplicative stochastic Gent-McWilliams parameterization*" Ocean Modelling **133**:1–10, 2019.

[33] W. Barham and **I. Grooms** "*An eddifying Stommel model: Fast eddy effects in a two-box ocean*" Geophysical & Astrophysical Fluid Dynamics **113**:505-526, 2019.

[32] **I. Grooms** and K. A. Julien, "*Multiscale models in geophysical fluid dynamics*" Earth and Space Science **18**:668–675, 2018.

[31] J. D. Christopher, N. T. Wimer, C. Lapointe, T. R. S. Hayden, **I. Grooms**, G. B. Rieker, and P. E. Hamlington, "*Parameter estimation for complex thermal-fluid flows using approximate Bayesian computation*" Phys. Rev. Fluids **3**:10462-1–16, 2018.

[30] A. Chen, W. Barham, and **I. Grooms** "*Comparing eddy-permitting ocean model parameterizations via Lagrangian particle statistics in a quasigeostrophic setting*" Journal of Geophysical Research: Oceans **123**:5637–5651, 2018.

[29] G. Robinson, **I. Grooms**, and W. Kleiber "*Improving particle filter performance by smoothing observations*" Monthly Weather Review **146**:2433-2446, 2018.

[28] W. Barham, S. D. Bachman, and **I. Grooms** "*Some effects of horizontal discretization on linear baroclinic and symmetric instabilities*" Ocean Modelling **125**:106–116, 2018.

[27] **I. Grooms** "*Simulations of eddy kinetic energy transport in barotropic turbulence*" Phys. Rev. Fluids **2**:113801-1–18, 2017.

[26] J. B. Weiss and **I. Grooms** "*Assimilation of ocean sea-surface height observations of mesoscale eddies*" Chaos **27**:126803-1–8 2017.

[25] **I. Grooms** and L. Zanna "*A note on 'Towards a stochastic parameterization of ocean mesoscale eddies'*" Ocean Modelling **113**:30–33, 2017.

[24] **I. Grooms** "*A Gaussian-product stochastic Gent-McWilliams parameterization*" Ocean Modelling **106**:27-43, 2016.

[23] **I. Grooms** and L.-P. Nadeau "*The effects of mesoscale atmosphere-ocean coupling on the quasigeostrophic double gyre*" Fluids **1**:34-1–14, 2016.

[22] D. Nieves, **I. Grooms**, K. Julien, and J. B. Weiss "*Investigations of nonhydrostatic, stably stratified and rapidly rotating flows*" J. Fluid Mech. **801**:430–458, 2016.

[21] C. B. Rocha, W. R. Young, and **I. Grooms** "*On Galerkin approximations for the quasigeostrophic equations*" J. Phys. Oceanogr. **46**:125-139, 2016.

[20] **I. Grooms** "*A computational study of turbulent kinetic energy transport in barotropic turbulence on the f-plane*" Phys. Fluids **27**:101701-1–7, 2015.

[19] **I. Grooms** and Y. Lee "*A framework for variational data assimilation with superparameterization*" Nonlin. Proc. Geophys. **22**:601–611, 2015.

[18] **I. Grooms**, Y. Lee, and A. J. Majda "*Ensemble filtering and low resolution model error: Covariance inflation, stochastic parameterization, and model numerics*," Mon. Weather Rev. **143**:3912–3924, 2015.

[17] **I. Grooms**, Y. Lee, and A. J. Majda "*Numerical Schemes for Stochastic Backscatter in the Inverse Cascade of Quasigeostrophic Turbulence*," Multiscale Modeling & Simulation **13**:1001–1021, 2015.

[16] **I. Grooms** "*Submesoscale Baroclinic Instability in the Balance Equations*," J. Fluid Mech. **762**:256–272, 2015.

[15] **I. Grooms**, A. J. Majda, and K. S. Smith "*Stochastic Superparameterization in a Quasigeostrophic Model of the Antarctic Circumpolar Current*," Ocean Modelling **85**:1–15, 2015.

[14] **I. Grooms** and J. P. Whitehead "*Bounds on Heat Transport in Rapidly Rotating Rayleigh-Bénard Convection*," Nonlinearity **28**:29–41, 2015.

[13] **I. Grooms** "*Asymptotic Behavior of Heat Transport for a Class of Exact Solutions in Rotating Rayleigh-Bénard Convection*," Geophys. Astrophys. Fluid Dyn **109**:145-158, 2015.

[12] **I. Grooms**, Y. Lee, and A. J. Majda "*Ensemble Kalman Filters for Dynamical Systems with Unresolved Turbulence*," J. Comp. Phys. **273**:435–452, 2014.

[11] **I. Grooms** and A. J. Majda "*Stochastic Superparameterization in Quasigeostrophic Turbulence*," J. Comp. Phys. **271**:78–98, 2014.

[10] A. J. Majda and **I. Grooms** "*New Perspectives on Superparameterization for Geophysical Turbulence*," J. Comp. Phys. **271**:60–77, 2014.

[9] **I. Grooms** and A. J. Majda "*Stochastic Superparameterization in a One-Dimensional Model for Wave-Turbulence*," Commun. Math. Sci. **12**:509–525, 2014.

[8] **I. Grooms**, L.-P. Nadeau, and K. S. Smith "*Mesoscale Eddy Energy Locality in an Idealized Ocean Model*," J. Phys. Oceanogr. **43**1911–1923, 2013.

[7] **I. Grooms** and A. J. Majda "*Efficient Stochastic Superparameterization for Geophysical Turbulence*," Proc. Nat. Acad. Sci. USA **110**:201302548-1–6, 2013.

[6] **I. Grooms**, K. S. Smith, and A. J. Majda "*Multiscale Models for Synoptic-Mesoscale Interactions in the Ocean*," Dyn. Atmos. Oceans **58**:95–107, 2012.

[5] K. Julien, A. Rubio, **I. Grooms**, and E. Knobloch "*Statistical and Physical Balances in Low Rossby Number Rayleigh-Bénard Convection*," Geophys. Astrophys. Fluid Dyn. **106**:392–428, 2012.

[4] **I. Grooms**, K. Julien, and B. Fox-Kemper "*On the Interactions Between Planetary Geostrophy and Mesoscale Eddies*," Dyn. Atmos. Oceans **51**:109–136, 2011.

[3] **I. Grooms** and K. Julien, "*Linearly Implicit Methods for Nonlinear PDEs with Linear Dispersion and Dissipation*," J. Comp. Phys. **230**:3630–3650, 2011.

[2] **I. Grooms**, K. Julien, J. B. Weiss, and E. Knobloch, "*Model of Convective Taylor Columns in Rotating Rayleigh-Bénard Convection*," Phys. Rev. Lett. **104**:224501-1–4, June 2010. **Cover Article**

[1] **I. Grooms**, R. M. Lewis, and M. W. Trosset, "*Molecular Embedding via a Second Order Dissimilarity Parameterized Approach*," SIAM J. Sci. Comp. **31**:2733–2756, 2009.

Conference Proceedings, Non-Refereed

[4] O. Doronina, C. Towery, J. Christopher, **I. Grooms**, and P. E. Hamlington "*Turbulence Model Development Using Markov Chain Monte Carlo Approximate Bayesian Computation*" AIAA SciTech Forum, 13 pages, 2019.

[3] J. Christopher, D. Petrykowski, T. Hayden, C. Lapointe, N. Wimer, S. Nigam, **I. Grooms**, P. Hamlington, and G. Rieker,"*Parameter Estimation using Wavelength Modulation Spectroscopy Temperature Measurements and Approximate Bayesian Computation*," in Light, Energy and the Environment 2018 (E2, FTS,

HISE, SOLAR, SSL), OSA Technical Digest (Optical Society of America, 2018), paper EM3A.5, 2 pages, 2018.

[2] J. Christopher, C. Lapointe, N. Wimer, T. Hayden, **I. Grooms**, G.B. Rieker, and P.E. Hamlington "*Parameter Estimation for a Turbulent Buoyant Jet with Rotating Cylinder Using Approximate Bayesian Computation*" 23rd AIAA Computational Fluid Dynamics Conference, 18 pages, 2017.

[1] J. Christopher, C. Lapointe, N. Wimer, T. Hayden, **I. Grooms**, G.B. Rieker, and P.E. Hamlington "*Parameter Estimation for a Turbulent Buoyant Jet Using Approximate Bayesian Computation*" 55th AIAA Aerospace Sciences Meeting, 18 pages, 2017.

Gray Literature, Non-Refereed

[1] **I. Grooms** "*Mesoscale Eddy Energy Transport*" Special Joint Edition of US CLIVAR Variations and CLIVAR Exchanges, 2020.

Research Software

- My publicly-available research code and documentation of my contributions to other public software is available on my github account `github.com/iangrooms`
- I am a lead developer of `gcm-filters`, a Python package for spatial filtering of gridded geophysical data.

TEACHING

- Linear Algebra with Statistical Applications, APPM 5720, Fall 2019 & 2020
- Numerical Linear Algebra, APPM 5620, Spring 2018, 2020, 2022
- Numerical Analysis 1, APPM/MATH 5600, Fall 2017 & 2018
- Data assimilation for high-dimensional dynamical systems, APPM 4/5510, Fall 2016, 2019, 2021, 2023
- Modeling in Applied Mathematics, APPM 4/5380, Fall 2021
- Matrix Methods and Applications, APPM 3310, Spring 2016–2018, 2020, 2021, 2023 & Fall 2018, 2020
- Calculus 2 for Engineers, APPM 1360, Summer 2007, Fall 2015, 2023 & Spring 2019

AWARDS AND HONORS

- **Turcotte Award** "to recognize an outstanding dissertation by a recent graduate that contributes directly to nonlinear geophysics." Nonlinear Geophysics section of the American Geophysical Union, 2011
- **William and Mary Prize in Mathematics**, 2005

PROFESSIONAL MEMBERSHIPS

I am a lifetime member of:

- The Society for Industrial and Applied Mathematics (SIAM)
- The American Geophysical Union (AGU)