Laure Zanna

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Research Interests: My research focuses on the role of the ocean in climate on local and global scales, through the analysis of observations and a hierarchy of simulations. My main interests lie in ocean physics and climate dynamics; predictability and prediction; uncertainty quantification; (stochastic) closures for ocean turbulence. In the past two years, I have worked on the physics of extreme surface temperatures and storm surges, estimates of global and regional ocean warming and sea level rise since the industrial revolution, machine learning for both data inference and turbulence parametrization in climate models, ocean ensemble simulations for probabilistic seasonal to decadal forecasts.
I am the lead PI of the NSF-NOAA Climate Process Team on Ocean Transport and Eddy Energy, and M^2LInES – an international effort to improve climate models with scientific machine learning. I also serves as an editor for the Journal of Climate, a member on the International CLIVAR Ocean Model Development Panel, and on the CESM Advisory Board. I am also a mentor at MPOWIR.

Professional Appointments

Present Affiliations

2020- Professor of Atmosphere/Ocean Science & Mathematics, **New York University, Courant Institute**, USA.

2019- Affiliated Faculty, **New York University, Center for Data Science**, USA.

2019- Visiting Professor, **University of Oxford**, Dept of Physics, UK.

Previous Affiliations

2019-2020 Associate Professor (tenured), **New York University**, Courant Institute, USA.

2011-2019 (tenured 07/2016) Associate Professor, prev. Univ. Lecturer, **University of Oxford**, Dept of Physics, UK. College affiliation: David Richards' Fellow, **Wadham College** (2018-2019); Fellow, **St Cross College** (2011-2018); Lecturer in Physics, **Christ Church College** (2014-2017).

2017-2018 Visiting Faculty, **Princeton University, AOS and GFDL**, USA.

2009-2011 James Martin Research Fellow, Oxford Martin School & Dept of Physics, **University of Oxford**, UK.

2009-2011 Junior Research Fellow, Balliol College. **University of Oxford**, UK.

Education

06/2009 PhD, **Harvard University**, Earth & Planetary Sciences. Adviser: Eli Tziperman.
Title: Optimal Excitation of Atlantic ocean circulation and implications for predictability.

09/2003 MSc, **Weizmann Institute of Science**, Environmental Sciences.

09/2001 BSc, **Tel Aviv University**, Geophysics, Atmospheric & Planetary Sciences. *Magna Cum Laude*.

Honors, Awards and Fellowships

2020 **Nicholas P. Fofonoff Award**, American Meteorological Society. Citation: *"For exceptional creativity in the development and application of new concepts in ocean and climate dynamics."*

2020 **Principal Lecturer**, Woods Hole Geophysical Fluid Dynamics Summer Program, Data-Driven GFD (postponed to 2022 due to COVID-19).

2020 **Distinguished PhD Visiting Scientist**, Department of Meteorology, University of Reading, UK.

2019 **Sigma Xi** Scientific Research Honor Society.

2017-2018 **Visiting Research Scientist Fellowship**, Princeton University, AOS and GFDL.

2009-2012 **James Martin Fellowship**, Oxford Martin School.

2009-2012 **Junior Research Fellowship**, Balliol College.

2008 **Outstanding Student Paper Award**, American Geophysical Union, Fall Meeting (AGU).

2005-2008 3 **Certificates of Distinction in Undergraduate Teaching**, Harvard University.

2006 **Young Scientist Outstanding Paper Award**, European Geosciences Union, General Assembly.

2005, 2006, 2007 **Bertram J. Cohn Fellowship for Environmental Studies**, Harvard University.

Funding

US

2021-2026 **NSF Science and Technology Center** - Learning the Earth with Artificial Intelligence and Physics. Led by Columbia University, with NYU, UC Irvine, Minnesota, teachers College ($25*M*).

2020-2025 **Schmidt Futures**, lead PI (other institutions: Princeton/GFDL, Columbia/LDEO, MIT, NCAR, IPSL, IGE Grenoble). M^2LInES - Multiscale Machine Learning In coupled Earth System Modeling, $10.3*M* ($3.2*M* to NYU).

2019-2022 **NSF PO**, PI (led by UCSD-Scripps). Collaborative Research: Transient response of regional sea level to Antarctic ice shelf fluxes, $1.1*M* ($464*K* to NYU).

2020-2021 **VoLo Foundation**, Predicting Extreme Events: Sea level Change along the Gulf of Mexico and US East Coast. $300*K*.

2020-2023 **NOAA CVP**, lead PI (other institutions: Arizona + GFDL). Drivers of Coastal Sea Level Change Along the Eastern US, $610*K* (550*K* to NYU).

2020-2023 **NOAA CVP**, co-PI (led by GMU). What sets the predictability timescales of SST and upper-ocean heat content in the Atlantic and Pacific basins?, $615*K* (60*K* to NYU).

2019-2022 **NSF PO + NOAA**, lead PI (9 universities, 3 modeling centres). Climate Process Team: Ocean Transport and Eddy Energy, $2.8*M* ($782*K* to NYU).

UK

2017-2022 **NERC Large Grant**, PI. Transient tracer-based Investigation of Circulation and Thermal Ocean Change (TICTOC), £3,342,981.

2017-2020 **NERC**, Co-PI. Addressing the Grand Challenge of regional sea level change prediction (UKFAFMIP), £584,852.

2017-2019 **Royal Society, International Exchanges Scheme**, PI. Quantifying the Variability of Tracer Transport across the Gulf Stream. £11,830.00.

2014-2019 **NERC Directed**, Co-I. Summer: Testing Influences and Mechanisms for Europe, £764,189.

2014-2017 **NERC**, PI. Modelling the Ocean Circulation with Random Numbers, £301,109.

2012-2016 **NERC Directed**, Co-PI. Representing uncertainty in ocean observations and ocean model, for coupled ensemble data assimilation & ensemble extended-range prediction, £378,722.

2013-2017 **NOAA Earth System Science Program**, Co-PI. Variability, stochastic dynamics, and compensating model errors of the Atlantic Meridional Ocean Circulation in coupled IPCC models, $287,032.

2011-2014 **John Fell Fund**, PI. Dynamical Impacts of Unresolved Ocean Processes in Climate Models: Lessons from Stochastic Physics, £98,538.

2015-2016 **Met Office- Oxford Academic Partnership**, Undergraduate Research Experience Placement. PI, 2016: two proposals funded; 2015: one proposal funded, each for £2,000.

Publication List

* = first-author is a student or ** = postdoc supervised by LZ; underline = group member (student or postdoc).

All PDFs of published manuscripts are available at https://laurezanna.github.io/publication/.

Manuscripts Submitted for publication

[60] Newsom, Zanna, Khatiwala: Relating patterns of added and redistributed ocean warming. *Submitted*.

[59] Chemke, Zanna, Orbe, Sentman, Polvani. The future intensification of North Atlantic winter storms: the key role of dynamic ocean coupling. *Submitted to J of. Climate*.

Peer Reviewed Manuscripts Published/Accepted

2021

[58] Wang, Church, Zhang, Gregory, Zanna, Chen. Evaluation of the local sea-level budget at tide gauges since 1958. *GRL*, e2021GL094502.

[57]** Guillaumin, Zanna. Stochastic Deep Learning parameterization of Ocean Momentum Forcing. *JAMES*, https://doi.org/10.1029/2021MS002534

[56] Zanna, Bolton: Deep Learning for Ocean Subgrid Parameterizations. *Book Chapter* in "Deep learning for the Earth Sciences: A comprehensive approach to remote sensing, climate science and geosciences". Editors: Gustau Camps-Valls, Xiao Xiang Zhu, Devis Tuia, Markus Reichstein. *Wiley & Sons, inc., 2021*.

2020

[55] Couldrey, Gregory, Dias, Dobrohotoff, Domingues, Garuba, Griffies, Haak, Hu, Ishii, Jungclaus, Köhl, Marsland, Ojha, Saenko, Savita, Shao, Stammer, Suzuki, Todd, Zanna. What causes the spread of model projections of sea level change in response to greenhouse gas forcing? *Clim. Dyn.*, https://doi.org/10.1007/s00382-020-05471-4 .

[54] Hewitt, et al.: Resolving and Parameterising the Ocean Mesoscale in Earth System Models. *Current Climate Change Reports*, https://doi.org/10.1007/s40641-020-00164-w.

[53]** Newsom, Zanna, Khatiwala, Gregory: The influence of warming patterns on passive Ocean Heat Uptake. *GRL*, https://doi.org/10.1029/2020GL088429

[52]** Byrne, Zanna: Radiative effects of clouds and water vapor on an axisymmetric monsoon. *J. Climate*, https://doi.org/10.1175/JCLI-D-19-0974.1

[51] Zanna, Bolton: Data-driven Equation Discovery of Ocean Mesoscale Closures. *GRL*, https://doi.org/10.1029/2020GL088376.

[50]** Todd, Zanna, et al. Ocean-only FAFMIP: Understanding Regional Patterns of Ocean Heat Uptake and Dynamic Sea Level Change. *JAMES*, https://doi.org/10.1029/2019MS002027

[49] Frederikse, Landerer, Caron, Adhikari, Parkes, Humphrey, Dangendorf, Hogarth, Zanna, Cheng, Wu. The causes of sea-level rise since 1900. *Nature*, https://doi.org/10.1038/s41586-020-2591-3.

[48]* Bronselaer, Zanna: Heat and carbon coupling reveals ocean warming patterns due to circulation changes. *Nature*, https://doi.org/10.1038/s41586-020-2573-5.

[47] Chemke, Zanna, Polvani. Attribution of North Atlantic surface temperature. *Nature Comms*, 10.1038/s41467-020-15285-x.

[46] Yin, Griffies, Winton, Zhao, Zanna, 2020: Response of Storm-related Extreme Sea Level along the US Atlantic Coast to Combined Weather and Climate Forcing. *J. of Climate*, https://doi.org/10.1175/JCLI-D-19-0551.1.

[45] Sun, Eisenman, Zanna, Stewart, 2020. Surface constraints on the depth of the Atlantic Meridional Overturning Circulation: Southern Ocean vs North Atlantic. *J. of Climate*, https://doi.org/10.1175/JCLI-D-19-0546.1.

2019

[44]** O'Reilly, T. Woollings, L. Zanna, 2019. Assessing external and internal sources of Atlantic Multidecadal Variability using models, proxy data and early instrumental indices. *J. of Climate*, doi:10.1175/JCLI-D-19-0177.1.

[43]** O'Reilly, Woollings, Zanna and Weisheimer, 2019. An interdecadal shift of the extratropical ENSO teleconnection during boreal summer. *GRL*, doi:10.1029/2019GL084079.

[42] Carson, Lyu, Richter, Becker, Domingues, Han, Little, Zanna. Climate model uncertainty and trend detection of regional sea level projections in the open ocean and coastal zone. *Surveys in Geophysics*, doi:10.1007/s10712-019-09559-3.

[41] Ponte, et al: Ocean Obs' 2019: Towards comprehensive observing and modeling systems for monitoring and predicting regional to coastal sea level. *Frontiers in Marine Science*, doi: 10.3389/fmars.2019.00437.

[40]* Bolton, Abernathey, Zanna, 2019: Regional and temporal variability of lateral mixing in the North Atlantic. *JPO*, 49(10), 2601-2614, doi:10.1175/JPO-D-19-0042.1

[39]* Fraser, Palmer, Roberts, Wilson, Zanna, 2019: Predictability of Interannual Sea Level Variability in the North Atlantic. *Climate Dynamics*, doi:10.1007/s00382-019-04814-0.

[38] Rodrigues, Subramanian, Zanna, Berner, 2019. ENSO bimodality and extremes. *GRL*, DOI:10.1029/2019GL082270.

[37] Zanna, Khatiwala, Gregory, Ison, Heimbach, 2019: Global reconstruction of historical ocean heat storage and transport. *Proc. of the National Academy of Sciences*, 116 (4) 1126-1131, doi: 10.1073/pnas.1808838115. ***Link to press coverage***.

[36]* Bolton, Zanna, 2019: Applications of Deep Learning to Ocean Data Inference and Sub-Grid Parameterisation. *JAMES*, 11, doi: 10.1029/2018MS001472.

2018

[35]** Juricke, MacLeod, Weisheimer, Zanna, Palmer, 2018. Seasonal to annual ocean forecasting skill and the role of model and observational uncertainty. *QJRMS*, 144(715), 1947-1964.

[34]** O'Reilly, Zanna. The signature of oceanic processes on extratropical decadal SST anomalies. *GRL*, 45, 7719-7730.

[33] Zanna, Brankart, Huber, Penduff, Williams. Uncertainty and Scale Interactions in Ocean Ensembles: From Seasonal Forecasts to Multi-Decadal Climate Predictions. *QJRMS*, 145, 160-175, doi:10.1002/qj.3397.

[32] Faggiani Dias, Subramanian, Zanna, Miller: Remote and Local Influences in Forecasting Pacific SST: a Linear Inverse Model and a Multimodel Ensemble Study. *Clim. Dyn.*, pp 1-19; doi:10.1007/s00382-018-4323-z.

[31]* David, Zanna, Marshall, 2018. Eddy-mixing entropy as a measure of turbulent disorder in barotropic ocean jets. *J. of Stat. Mech.:Theory and Experiment*, 7, 073206.

[30]* O'Reilly, Woollings, Zanna and Weisheimer. The impact of tropical precipitation on summertime Euro-Atlantic circulation via a circumglobal wave-train. *J. Climate*, 31(16), 6481-6504.

[29] Bachman, Anstey, Zanna, The relationship between a deformation-based eddy parameterization and the LANS-α turbulence model. *Oc. Modelling,* doi:10.1016/j.ocemod.2018.04.007.

[28]* Bronselaer, Zanna, Munday, Lowe: Southern Ocean carbon-wind stress feedback. *Clim. Dyn.*, doi:10.1007/s00382-017-4041-y. ***Highlight in MITgcm news***.

[27] van Sebille et al.: Lagrangian ocean analysis: fundamentals and practices. *Oc. Modell.*, 121, 49-75, doi:10.1016/j.ocemod.2017.11.008.

2017

[26]** Kjellsson, Zanna, 2017: Spectral Fluxes of Kinetic Energy in Global Ocean Models and the Impact of Horizontal Resolution. *Fluids*, 2(3), 45, doi: 10.3390/fluids2030045

[25] Zanna, Porta Mana, Anstey, David, Bolton, 2017: Scale-Aware Deterministic and Stochastic Parametrizations of Eddy-Mean Flow Interaction. *Oc. Modell.*, 111, 66-80, doi:10.1016/j.ocemod.2017.01.004

[24]** Juricke, Palmer, Zanna, 2017: Stochastic parametrizations of sub-grid scale ocean variability: Impacts on low frequency variability. *J. Climate*, 30(13), 4997-5019, doi:10.1175/JCLI-D-16-0539.1

[23]** Anstey, Zanna, 2017: Deformation-based parametrization of ocean mesoscale eddies. *Oc. Modell.*, 112, 99-111, doi:10.1016/j.ocemod.2017.02.004

[22]* David, Marshall, Zanna, 2017: The statistical nature of turbulent barotropic ocean jets. *Oc. Modell.*, 113, 34-49, doi:10.1016/j.ocemod.2017.03.008

[21]** O'Reilly, Woollings, Zanna, 2017: The dynamical and thermodynamical influences of the Atlantic Multidecadal Oscillation on continental climate. *J. Climate*, doi:10.1175/JCLI-D-16-0345.1 .

[20]** Huber, Zanna, 2017: Drivers of uncertainty in simulated ocean circulation and heat uptake. *GRL*, 44, 1402-1413, doi:10.1002/2016GL071587.

[19] Grooms, Zanna, 2017: Statistical Parameterization of Mesoscale Eddies. *Oc. Modelling*, 113, 30-33, doi:10.1016/j.ocemod.2017.03.007.

[18]* Huddart, Subramanian, Zanna, Palmer, 2017: Seasonal and Decadal forecasts of Atlantic SST using a Linear Inverse Model: *Clim. Dyn.*, DOI: 10.1007/s00382-016-3375-1.

2016

[17]* Bronselaer, Zanna, Munday, Lowe, 2016: The Influence of Southern Ocean Winds on the North Atlantic Carbon Sink. *Global Biogeochem. Cycles*, 30, 844-858.

[16]** O'Reilly, Huber, Woollings, Zanna, 2016: The signature of low frequency oceanic forcing in the Atlantic Multidecadal Oscillation, 2016. *GRL*, 43, 2810-2818. ***Research Spotlight: Eos, 97, doi:10.1029/2016EO050997***.

[15] MacMartin, Zanna, Tziperman, 2016: Suppression of AMOC variability at increased CO_2. *J. Climate*, 29, 11, 4155-4164, doi:10.1175/JCLI-D-15-0533.1.

[14]* Andrejczuk, Cooper, Juricke, Palmer, Weisheimer, Zanna, 2016: Oceanic stochastic parametrizations in a seasonal forecast system. *Mon. Wea. Rev.*, 144, 5, 1867-1875, doi:10.1175/MWR-D-15-0245.1.

2014-2015

[13]** Cooper, Zanna, 2015: Optimisation of an idealised ocean model: stochastic parameterisation of sub-grid eddies. *Oc. Modell.*, 88 (0), 38-53.

[12] Marshall, Zanna, 2014: A Conceptual Model of Ocean Heat Uptake under Climate Change. *J. Climate*, 27, 8444-8465.

[11]** Porta Mana, Zanna, 2014: Toward a Stochastic Parameterization of Ocean Mesoscale Eddies. *Oc. Modell.*, 79, 1-20.

2013

[10] Wilson, Horsburgh, Williams, Flowerdew, Zanna, 2013: Tide-Surge Adjoint Modelling: A New Technique to Understand Forecast Uncertainty. *JGR-Oceans*, 118 (10), 5092-5108.

[9] MacMartin, Tziperman, Zanna, 2013: Frequency-domain Multi-model Analysis of the Response of Atlantic Meridional Overturning Circulation to Surface Forcing. *J. Climate*, 26, 21, 8323-8340.

[8] Palmer, Zanna, 2013: Singular Vectors, Predictability and Ensemble Forecasting for Weather and Climate. **Invited Contrib.**. Special issue: Lyapunov analysis: from dynamical systems theory to applications, *J. Physics A*, 46, 254018.

2012

[7] Zanna, 2012: Forecast Skill & Predictability of Observed Atlantic Sea Surface Temperatures. *J. Climate*, 25, 14, 5047-5056.

[6] Zanna, Heimbach, Moore, Tziperman, 2012: Upper Ocean Singular Vectors of the North Atlantic Ocean with Implications for Linear Predictability and Variability. *Q.J.R.M.S*, 138, 500-513.

2010-2011

[5] Zanna, Heimbach, Moore Tziperman, 2011: Optimal Excitation of Interannual Atlantic Meridional Overturning Circulation Variability. *J. Climate*, 24, 2, 413-427.

[4] Zanna, Heimbach, Moore, Tziperman, 2010: The Role of Ocean Dynamics in the Optimal Growth of Tropical SST Anomalies. *J. Phys. Ocean.*, 40, 5, 983-1003.

2005-2008

[3] Tziperman, Zanna, Penland, 2008: Non normal Thermohaline Circulation Dynamics in a Coupled Ocean-Atmosphere GCM. *J. Phys. Ocean.*, 38, 3, 588-604.

[2] Zanna, Tziperman, 2008: Optimal Surface Excitation of the Thermohaline Circulation. *J. Phys. Ocean.*, 38, 8, 1820-1830.

[1] Zanna, Tziperman, 2005: Non normal Amplification of the Thermohaline Circulation. *J. Phys. Ocean.*, 35, 9, 1593-1605.

Grey Literature

Yuval, Pritchard, Gentine, Zanna, and Fan, 2021: Call for papers on machine learning and Earth system modeling, Eos, 102, https://doi.org/10.1029/2021EO160820.

Zanna, Bachman, Jansen, 2020: Energizing Turbulence Closures in Ocean Models. Variations/Exchange Clivar, doi:10.5065/g8w0-fy32.

Zanna and Gebbie, 2019: New Ocean Heat Content Histories, RealClimate.org http://www.realclimate.org/index.php/archives/2019/01/new-ocean-heat-content-histories/.

Zanna, 2012. Ocean Model Uncertainty in Climate Prediction. *ECMWF Proceedings, Workshop on Representing model uncertainty and error in numerical weather and climate prediction models*.

Zanna, 2009. Optimal excitation of Atlantic Ocean variability and implications for predictability. Harvard University, PhD Thesis.

Mentoring & Teaching

Supervision ($^+$ = co-advised with)

PhD Students:

2021- Adam Subel

2020- Aurora Basinski

2020- Andrew Brettin

2018- Matthias Aengenheyster ($^+$ M. Allen, J. Gregory)

Graduated: 2020 Thomas Bolton (won best prize for 2nd yr PhD research report, best retreat talk 2018; best talk at AMS AOFD 2019); 2018 Robert Fraser, now Data Scientist; 2017: Tomos David ($^+$ D. Marshall), now postdoc at Oxford; 2015: Ben Bronselaer, now postdoc at Princeton/GFDL.

Postdoctoral Scholars:

2021- Abigail Bodner (Simons Junior Fellow), Fabrizio Falasca, Andrew Ross, Ziwei Li, Pavel Perezhogin

2020- Elizabeth Yankovsky

2019- Emily Newsom; Arthur Guillaumin

2018- Mike Byrne (Marie Curie Fellow)

2018-2019: Alex Todd; 2015- 2019 Chris O'Reilly ($^+$ T. Woollings); 2016- 2017: Joakim Kjellsson; 2015-2017: Stephan Juricke ($^+$ T. Palmer), now researcher at Bremen Univ.; 2015-2016: Markus Huber (funded by a S-NSF fellowship); 2014-2015: James Anstey, now permanent researcher at CCCma; 2012-2015: Fenwick Cooper ($^+$ T. Palmer), now postdoc at Oxford; 2011-2013: Mirek Andrejczuk ($^+$ T. Palmer), now permanent researcher at UK-Met Office; 2011-2013: Luca Porta Mana, now researcher at the Kavli Institute.

MPhys Students (= senior thesis): (*=*won a prize for best project in Atmospheric, Oceanic and Planetary Physics*). 2016-2017: Jonny Ison, Kirill Mikhaylov. 2014-2015: Thomas Bolton*. 2013-2014: Andrew Bailey*; Michael Walker*. 2013: Tomos David. 2012: Shaomin Cai. 2011: Brodie Pearson.

Teaching Activities

2020-present *Lecturer*, **Courant Institute, NYU**; Fundamentals of Atmosphere and Ocean dynamics (undergrad, 2019, 2020, 2021); Machine Learning for Atmosphere/Ocean/Climate Science (grad, 2019); Ocean Dynamics (grad, 2020).

2010-2019: *Lecturer and College Tutor*, **University of Oxford**: 2013-2019 *Lecturer*, Physics of the Oceans & Atmospheres (undergrad); 2014-2019 *Lecturer*, Climate Dynamics and Variability (grad); 2016-2019 *Lecturer*, Advanced Math and Numerical Methods (grad); 2010-2019 *College Tutor* (undergrad): Mechanics & Special Relativity, Circuit Theory & Electromagnetism, Flows, Fluctuations & Complexity (Nonlinear Dynamics, Chaos, Stochastic Processes, Biophysics).

2009 *Invited Lecturer*: **Joint UW-MIT-Bjerknes** Advanced Climate Dynamics Course, Bergen, Norway; **MIT** Course on Adjoint methods: from large scale optimization to climate modeling.

2004-2008 *Teaching Fellow*, **Harvard University**: Climate & Physical Oceanography (undergrad/grad); The Atmosphere (undergrad); Ordinary and Partial Differential Equations (undergrad/grad); Nonlinear Dynamical Systems (undergrad/grad).

1999-2002 *Special Educator, Teacher and Tutor,* **Balfour High School**, Mathematics.

2015, 2016 *Organizer and Speaker*, **University of Oxford**, Atmospheric Physics Research Experience Day for NERC Doctoral Training Program incoming graduate students.

Selected Academic Service

External activities (Current)

2023 Co-organizer, **Simons Foundation**, Symposium on Multi-scale Physics: Theoretical Astrophysics to Climate Science.

2021-2022 Member, Scientific Organizing Committee, US Clivar. Workshop on the Pattern Effect: Coupling of SST patterns, radiative feedbacks, and climate sensitivity (May 2022).

2021 Co-director **Kavli Institute for Theoretical Physics** Program and conference on Machine Learning and the Physics of Climate.

2021 Advisory Board Member, NSF CSSI Collaboration **CSSI Collaboration**.

07/2021- **National Academies of Sciences, Engineering, and Medicine**'s Workshop Planning Committee Member on Machine Learning and Artificial Intelligence to Advance Earth System Science.

06/2021- **NOAA C&GC Postdoctoral Fellowship**, Steering Committee Member.

01/2021- Chair-Elect (10/2021-), Member (01/21-10/21), Oceanic Research Awards Committee **American Meteorological Society**.

10/2020- **CESM** Advisory Board Member.

10/2020- **NSF AI Institute AI2ES** External Advisory Board Member.

02/2020- Ocean Model Development Panel Member, **CLIVAR**.

09/2019- Member of the Working Group on Emerging Data Science Tools for Climate, **US CLIVAR**.

11/2019- Editor, Journal of Climate, **American Meteorological Society**.

09/2019- Mentor, **MPOWIR** (Mentoring Physical Oceanography Women to Increase Retention) + Invited Senior Scientist, Patullo Conference 2021.

09/2019- Steering Committee Member, **FAFMIP** (Flux-anomaly-forced model intercomparison project, CMIP6).

2006- **Reviewer**, *Proposals*: National Academies, NSF, NOAA, NERC, ISF, Irish Research Council, KAUST/ CRG. *Articles*: J. of Climate, J. Phys. Ocean., Nature, Science, GRL, JAMES, Clim. Dyn., Ocean Modelling, J. of Phys. A, ERL, Q. J. Roy. Met. Soc., Phil. Trans. of the Royal Society. *Books*: SIAM, Cambridge University Press.

Past Activities

2017- 2020 Schmidt Science Fellowship Panel Member, **Schmidt Futures**, Earth Sciences.

2020 Co-organizer, **Columbia University**, Machine Learning in Science & Engineering, Environmental Science.

2017 Co-organizer, **Banff International Research Station**, Workshop on Transport in Unsteady Flow.

2018 Panel Member, **National Academies of Sciences, Engineering, and Medicine**, Gulf Research Program.

2011-2016 Member of Scoping group on the Role of Southern Ocean in the Earth System, 2016, **Natural Environment Research Council (NERC)** Peer Review College Member (Reviewer and Panel Member), **NERC**, 2011-16.

2015-2016 Expert Panel Member, **Belmont Forum & Joint Programming Initiative**.
Connecting Climate Knowledge for Europe, Climate predictability & inter-regional linkages.

2018-2019 Committee Member, Lorenz Lecture Award, **American Geophysical Union**, Nonlinear Geophysics.

2014-2018 International Scientific Council Member, **European Institute for Marine Studies (IUEM)**, Brest.

2012-2020 Co-organizer at AGU, EGU, Ocean Science: **AGU Fall Meeting 2020**, *Machine Learning for Weather & Climate Modelling*; **EGU 2020**, *Chaotic variability and modelling uncertainties in the ocean: towards probabilistic oceanography*; **AGU Ocean Sciences 2020**, *Ocean Transport and Eddy Energy*; **AGU Fall Meeting 2019**, *Machine Learning for Climate Modelling*; **American Physical Society - GPC 2018**, *Multi-Scale Flows & Pathways in the Climate System*; **AGU Ocean Sciences 2014**, *North Atlantic ocean dynamics: from natural fluctuations to externally forced response*; **AGU Ocean Sciences 2012**, *Oceanic Uptake of heat and greenhouse gases: dynamic and thermodynamic controls and inferences from tracers*.

2013-20 Examiner for 5 external (**Columbia University, Imperial College London, Southampton University, University of Grenoble**) & 4 internal (**Oxford**) PhD/ DPhil, and 1 MRes/MSc.

Service within NYU

2021- Lead, Climate Faculty Cluster Hire Initiative.

2021- Faculty Steering Committee, NYU's All-University Climate Change Initiative.

2019- Appointment Committee, Dept of Mathematics, Courant Institute.

2019- PhD Advisory Group, Center for Data Science.

Selected Service within Oxford

2010-2019 **Dept of Physics**: Assessor for Flows, Fluctuations & Complexity (2016-19); Invigilator for Physics of the Oceans & Atmospheres (2015-16); Internal Examiner for 18 students (2011-19); Personnel Committee (2012-18); Parking Committee (2017-18); Organizer for Atmospheric, Oceanic and Planetary Seminar Series (2011-2019); Organizer for Physical Oceanography & Climate Meetings (2010-2011).

2018-2019 **Wadham College**: Governing body; Academic Committee; Nominating Committee.

2016-2017 **Mathematical, Physical, Engineering & Life Sciences Division**: NERC Demand Management Decision Panel.

Presentations (as first author only)

Invited Departmental Seminars (69 since 2009):

2021: Caltech (CLiMA); U. of Toronto (Physics); Harvard Widely Applied Math; Harvard (Institute for Applied Computational Science); CU Boulder (Applied Math); Stanford (Earth Sciences); NYU (Tandon); U of Oxford (Physics).

2020: MIT (EAPS), U of Rhode Island (Oceanography); CSU (Atmospheric Science); GISS (Sea Level Seminar); Univ of Reading (Met Dept as part of Distinguished PhD visitor scientist);

2019: Georgia Tech (Earth Sciences); Columbia University (Applied Math + Climate); Brown University (Earth Sciences); Univ of Reading (Met Dept); University of Southampton; IGE Grenoble.

2018: Caltech; Flatiron Institute/Simons Foundation; UW; NYU/Courant (APM); Harvard; U. Chicago; UCSD/Scripps; NCAR.

2017: Lamont Doherty Earth Observatory - LDEO (colloquium); GFDL; Columbia University/LDEO (Ocean and Climate); NYU/Courant (CAOS); George Mason University; U. of Edinburgh; U. of Reading.

2016: ANU; U. Tasmania; U. of Copenhagen; Imperial College London (Physics); Leeds.

2014: UCLA; Caltech; Scripps Institute of Oceanography; British Antarctic Survey; UCL; NOC/Southampton; Weizmann Institute of Science; Tel Aviv University.

2013: Imperial College London (Math); Harvard; MIT; U. of Cambridge (DAMTP); Hebrew University of Jerusalem; Weizmann Institute of Science; Reading.

2012: LPO/IFREMER Brest; New York University; U. of Hamburg/Max Planck Institute of Meteorology.

before 2012: Imperial College London (Physics); U. of Reading; U. of Oxford; U. Cambridge (Earth Sciences); European Centre for Medium-Range Weather Forecast; Proudman Oceanographic Laboratory, Liverpool; U. of East Anglia; National Oceanography Centre, Southampton; MIT; Columbia University/LDEO; Princeton/GFDL; Tel Aviv University; Beer Sheva University.

Invited Workshops and Conferences (63 Invited since 2009):

Upcoming: Aspen Workshop on Machine Learning and Climate Science; AGU Fall 2021 (2 talks) AI4ESP Workshop DOE NeurIPS ML for Physical Sciences

2021: The science of global sea-level projections: progress, challenges and future directions (London), *Understanding past and future ocean warming*; UN AI For Good: Accelerating Climate Science with AI, *AI for Oceans: Improving Climate Predictions*; KITP Public Lecture, *The Oceans in a Warming Climate* ; NOAA workshop on leveraging AI in Environmental Sciences, *AI for Oceans?*; Climate and Carbon feedback workshop (UK), *Elucidating the relationship between carbon emissions and ocean warming*; NYU Climate Connections, *The Oceans in a Warming Climate* IMSI Confronting climate change (Chicago), *Understanding past and future ocean warming: from theory to modeling*; Eddy - Mean Flow and Waves (Hamburg), *Ocean transport and eddy energy: Climate Process Team*; Scaling Cascades for Complex Systems (Berlin, plenary), *Blending Machine Learning and Physics to improve climate model*; SIAM Mathematical & Computational Issues in the Geosciences (Milano), *Remarks and Presentation: Machine Learning for Physics-discovery and Climate Modelling*; One World Mathematics of Climate (webinar), *Climate Modeling in the Age of Machine Learning* ; SIAM Annual Meeting (Spokane, plenary), *Machine Learning for Multi-Scale Systems: From Turbulence to Climate Prediction*; Data Science Coast To Coast DSC2C *Blending Machine Learning and Physics to Improve Climate Models*; AI4Climate (Paris) *Climate Modeling in the Age of Machine Learning* ; CESM workshop: Machine Learning Working Group *Machine Learning Methods for Ocean Models*; CESM Ocean Model Working Group meeting *Introduction to the CPT* and *Discovering equations for eddy parametrizations from data*;

2020: The Institute for Mathematical and Statistical Innovation (IMSI Chicago, plenary) *Blending physics and machine learning to improve climate projections*; The National Academies, Climate and Weather (webinar) *Predicting Weather and Climate*. NASA GISS Sea Level Rise Seminar (webinar) *Understanding past and future patterns of ocean warming* Workshop on Knowledge Guided Machine Learning (KGML) (webinar) *Blending machine learning and physics for climate modeling*

2019: AGU fall meeting (San Francisco) *Discovering Novel Eddy Parameterisations with Machine Learning*; Simons Foundation - Universality: Turbulence Across Vast Scales (New York) *Scale-aware ocean turbulence closures for climate models*; CLIVAR Summit *Machine learning for Ocean Modelling: parametrizations, numerical algorithms and model error revisited*; ORCHESTRA workshop (UK) *Reconstructing 150 years of ocean warming*; Equadiff 2019 minisymposium (Leiden) *Deep Learning for Ocean Data Inference and Turbulence Parameterisation* ; Sources and Sinks of Ocean Mesoscale Eddy Energy US CLIVAR (Florida) *Energizing Turbulence Closures in Ocean Models*; International FAFMIP workshop (Reading) *Ocean Stratification as an emergent constraint for ocean heat uptake*; EGU, Sea level: Past, Present, Future (Vienna) *A Global Reconstruction of Ocean Heat Storage and Transport with Implications for Thermosteric Sea Level* ; Physical Society Club (London) *The Physics of the Oceans in a Warming Climate*; Rotating Fluids (UCL) *Energizing turbulence closures in ocean models*;

2018: Machine Learning in Climate; Regional Atlantic Circulation and Global Change (Bremen, keynote); AGU fall meeting (DC); US AMOC/RAPID (Miami); AIMS Conference on Dynamical Systems (Taipei); Caltech - ESM Workshop; AGU Ocean Sciences (Portland); Understanding the relationship between coastal sea level and large-scale ocean circulation (ISSI, Bern); Oceans in Weather and Climate (Exeter, OiWC2018).

2017: ECMWF Annual Seminar on Ensemble Prediction; Intrinsic & Forced Ocean Variability Workshop; Max Planck Institute for the Physics of Complex Systems; Banff International Research Station for Mathematical Innovation and Discovery; MFO Oberwolfach Research Institute for Mathematics.

2016: Data Analysis and Modeling in Earth Sciences; Uncertainty Quantification SIAM (The Society for Industrial and Applied Mathematics).

2015: Future Lagrangian Ocean Modeling; ICIAM Beijing; Turbulence Days; Europe Dynamics Days; Workshop on Stochastic Physics in Climate; Theoretical Advances in Planetary Flow and Climate Dynamics; Met Office Academic Partnership; Ice2Ice (keynote).

2014: AGU Fall Meeting; ClimathNet (plenary).

2013: AGU Fall Meeting; The Institute of Mathematics and its Applications (IMA) Workshop on Stochastic Modeling of the Oceans and Atmosphere.

2012: AGU Fall Meeting; European Space Agency (ESA) workshop on model uncertainty.

before 2012: Workshop on Representing Model Uncertainty in Weather and Climate Prediction (2011), EGU General Assembly (2009); Advanced Climate Dynamics Course (2009).

Selected Contributed Presentations (total 30 since 2009): CESM OMD NCAR 2020 *Eddy Energetics CPT*; Model Hierarchies Workshop, Princeton 2016; AGU Ocean Sciences 2020 *Machine learning for inference and parametrization of ocean turbulence*, 2018 *Air-sea coupling and predictability of North Atlantic Ocean variability*, 2016, 2014, 2012; Workshop on Energy transfers in the atmosphere and in the ocean 2016, 2015; RAPID/ US AMOC annual meeting 2015, 2013; Latsis Symposium on Climate Dynamics 2014; AGU Fall Meeting 2020 *Heat and carbon coupling reveals ocean warming due to ocean circulation changes*, 2019 *Ocean Heat Uptake Efficiency, Ocean Stratification and Transient Climate Change*, 2013, 2012; American Met. Soc. AOFD 2013, 2017; APS General Meeting 2013.

Selected Outreach, College & Alumni Activities

1992- : Various activities and tutoring for middle- and high-school students (in France, Israel, USA and UK) with learning disabilities and/or from disadvantaged backgrounds.

2020: NYU Alumni Week, *AI for Climate*.

2018-2019 : Access to Excellence (students age 12 to 17), Wadham College.

2019: Wadham Cross-college Symposium: Disruption, *Ocean Physics & Climate Change*.

2017: Foundation Fellows Event, Wadham College, *Sea Level Rise*.

2015: Atmospheric Physics Alumni Event, Royal Society, *Oceans in Climate Change*.

2016: Oxford Physics Society, *Physics of Climate Change*.

2013: Oxford Alumni Weekend, *The Oceans in a Warming Climate*.