Laure Zanna

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Research Interests: ocean dynamics and climate change; predictability and prediction of the climate system; uncertainty quantification; (stochastic) parameterization of ocean turbulence. *Tools*: Advanced analytical, numerical and statistical methods, a hierarchy of numerical models, and analysis of available observations.

Education

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

06/2009 MA by special resolution, **University of Oxford**.

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

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

Professional Appointments

09/2019- : **Associate Professor** (with tenure), New York University, Courant Institute, Dept of Mathematics, USA.

10/2011-: **Associate Professor** (prev. Univ. Lecturer), University of Oxford, Dept of Physics, UK **(tenured 07/2016)**.
09/2018-: **David Richards' Fellow & Tutor in Physics**, Wadham College.
2011-2018: Fellow, St Cross College.
2014-2017: Lecturer in Physics, Christ Church College.

2018- : **Visiting Academic**, New York University, Courant Institute, Dept of Mathematics, USA.

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

2009-2011: **James Martin Research Fellow**, Oxford Martin School &, Atmospheric, Oceanic & Planetary Physics, Dept of Physics, University of Oxford.

2009-2011: **Junior Research Fellow**, Balliol College.

2003-2009: **Graduate Research Assistant**, Earth & Planetary Sciences, Harvard University.

Awards and Fellowships

2017-2019: **International Exchange Grant**, Royal Society (with R. Abernathey, Columbia University).
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, 2006, 2007: **Bertram J. Cohn Fellowship for Environmental Studies**, Harvard University.
2006: **Young Scientist Outstanding Paper Award**, European Geosciences Union, General Assembly.
2005-2008: 3 **Certificates of Distinction in Undergraduate Teaching**, Harvard University.
2001: **Magna Cum Laude**, Tel Aviv University.

Selected Academic Service

External

2019: Guest Editor, **Oxford University Press**, Encyclopedia of Climate Science, Climate Dynamics: Theoretical Foundation, Focus Series on Parameterizations in Climate Models.

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

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

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

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

2013-: Examiner for 2 external (**Southampton University, Columbia University**) and 3 internal (**Oxford**) PhD/DPhil defences, and 1 MRes/MSc defence.

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

2018: Session organizer: **American Physical Society (APS) - GPC**, Los Angeles, *Multi-Scale Flows and Pathways in the Climate System*.

2017: Organizer, **Banff International Research Station**, Workshop on Transport in Unsteady Flow.

2011-2016: Peer Review College Member (Reviewer and Panel Member), **NERC**.

2016: Member of Scoping group on the Role of Southern Ocean in the Earth System, **Natural Environment Research Council (NERC)**.

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

2012, 2016: Convener and Chair, **Ocean Section IUGG** Conference on Mathematical Geophysics. Ocean processes: from small scale to global circulation.

2012, 2014: Session organizer: **AGU Ocean Sciences**, Salt Lake City 2012, *Oceanic Uptake of heat and greenhouse gases: dynamic and thermodynamic controls and inferences from tracers*; AGU Ocean Sciences, Hawaii, 2014 *North Atlantic ocean dynamics: from natural fluctuations to externally forced response*.

2011- : Judge for students presentations, **Ocean Modeling** 2011, 2012, 2014; **AGU** Ocean Sciences and Fall Meetings various dates since 2012; **AMS AOFD** 2017.

Service within Oxford

2016-: Assessor, Flows, Fluctuations & Complexity, Dept of Physics.

2018- : Governing body, Wadham College.

2018- : Academic Committee, Wadham College.

2018- : Nominating Committee, Wadham College.

2011- : Internal Examiner/Graduate Committee for 18 students, Dept of Physics.

2016-2017 : NERC Demand Management Decision Panel.

2012- 2018: Personnel Committee, Dept of Physics.

2014- 2017: Fellowship Committee, St Cross College.

2011- 2018: Governing body, St Cross College.

2012- 2016: Organizer, Atmospheric, Oceanic and Planetary Seminar Series, Dept of Physics.

2015: Invigilator, Physics of the Oceans & Atmospheres, Dept of Physics.

2010-2011: Organizer, Physical Oceanography & Climate Meetings, Dept of Physics and Earth Sciences.

2010-2011: Executive Committee, Balliol College.

2009-2011: Governing body, Balliol College.

Funding

2020-2021: **Simons Foundation**, Symposium on Multi-scale Physics.

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

2017-2022: **NERC - Large Grant**, Oxford 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.

2014-2018: **NERC - Directed**, Co-I. Summer: Testing Influences and Mechanisms for Europe (SummerTIME), £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 the ocean model, for coupled ensemble data assimilation and 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 OUP 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.

Mentoring & Teaching

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

DPhil (=PhD) Students:

Apr 2018-: Matthias Aengenheyster ($^+$ J. Gregory)

Apr 2016-: Thomas Bolton (won best prize for 2nd yr PhD research report, and best retreat talk 2018)

Previously: 2013-2018: **Robert Fraser**, now Data Scientist; 2013-2017: **Tomos David** ($^+$ D. Marshall), now postdoc at Oxford; 2011-2015: **Ben Bronselaer**, now postdoc at Princeton/GFDL.

Postdoctoral Scholars:

2019- : Emily Newsom

2018- : Mike Byrne (Marie Curie Fellow)

2018- : Alex Todd

Previously: 2015- 2018: **Chris O'Reilly** ($^+$ T. Woollings), now postdoc at Oxford; 2016- 2017: **Joakim Kjellsson**, now researcher at Univ. of Kiel; 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.

Summer Students: Alex Gyoffry, Arnaud de Larturiere, Benjamin Huddart, Twm Jonathan, Andrey Orkney.

College Graduate Supervision (St Cross, Christ Church, Wadham): I act or acted as College supervisor for about 15 students in Physics, Earth Sciences, Engineering, Materials, Genomic Medicine & Statistics, Musculoskeletal Sciences, Physiology, Anatomy & Genetics, Organic Chemistry, Life Sciences, Healthcare Innovation, Bioscience.

Teaching Activities

2010-present: *Lecturer and College Tutor*, **University of Oxford**

2013-present: *Lecturer*, Physics of the Oceans & Atmospheres (undergrad).

2014-present: *Lecturer*, Climate Dynamics and Variability (grad).

2016-present: *Lecturer*, Advanced Math and Numerical Methods (grad).

2010-present: *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.

Presentations (as first author only)

Invited Departmental Seminars (54 since 2009):

2019: Univ of Reading (Met Dept). *upcoming:* University of Southampton.

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 (41 Invited since 2009):

Upcoming: Physics and Mathematics of Turbulent Flows at Different Scales (Les Houches); Sources and Sinks of Ocean Mesoscale Eddy Energy US CLIVAR (Florida); International FAFMIP workshop (Reading); EGU, Sea level: Past, Present, Future (Vienna); ORCHESTRA workshop (UK); Equadiff 2019 minisymposium (Leiden).

2019: Physical Society Club (London); Rotating Fluids (UCL)

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 27 since 2009): Model Hierarchies Workshop, Princeton 2016; AGU Ocean Sciences 2018, 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 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.

2018- : 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*.

Publication List

A total of 37 published papers, with 31 as lead author or led by team members supervised by LZ.

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

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

Manuscripts Submitted for publication

[44] Rodrigues, Subramanian, Zanna, Berner, 2019. ENSO bimodality and extremes. *GRL*.

[43]* Bolton, Abernathey, Zanna, 2019: Regional and temporal variability of lateral mixing in the North Atlantic. *JPO, Minor Revisions*.

[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, Submitted*.

[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, Submitted.*

[40]* Fraser, Palmer, Roberts, Wilson, Zanna: Predictability of Interannual Sea Level Variability in the North Atlantic. *Climate Dynamics, Minor Revisions.*

[39] Chemke, Zanna, Abernathey, Polvani. Emergence of an anthropogenic signal in the North Atlantic warming hole. *Submitted*.

[38]* Bronselaer, Zanna: Future ocean climate change amplified and mitigated by circulation changes. *Submitted*.

Peer Reviewed Manuscripts Published/Accepted

2019

[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), pp.1947-1964..

[34]* O'Reilly, Zanna. The signature of oceanic processes on extratropical decadal SST anomalies. *GRL*, 45, 77197730.

[33] Zanna, Brankart, Huber, Penduff, Williams. Uncertainty and Scale Interactions in Ocean Ensembles: From Seasonal Forecasts to Multi-Decadal Climate Predictions. *QJRMS*, https://doi.org/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.org/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.*, 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*, 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, 14021413, 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.

2015

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

2014

[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

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.