The University of Oxford Department of Earth Sciences

EARTHSCIENCES

UNIVERSITY OF OXFORD

Mathematical and computational methods for Earth System Modelling

Supervisory Team	• **Prof. Samar Khatiwala** https://www.earth.ox.ac.uk/people/samar-khatiwala/ • **Prof. Cora Cartis** https://www.maths.ox.ac.uk/people/coralia.cartis
Key Words	**Oceanography, Marine Biogeochemistry, Climate, Scientific Computing, Mathematical Optimization, Numerical Analysis**

Description

Numerical models are one of the key tools for understanding the climate system and predicting its future evolution under anthropogenic forcing. However, as these models get more complex, they also become far more computationally expensive, limiting scientists' ability to perform simulations and make more effective use of them. It also increases the need to better calibrate the models against data. To addresses these challenges, one or more projects is available to develop novel mathematical and numerical techniques, and apply them to a range of problems in ocean and climate science. The ultimate goal is efficient and scalable software implementations that can be used in state-of-the-art climate models of the kind participating in the IPCC assessments.

The student(s) will be co-supervised by Profs. Samar Khatiwala in Earth Sciences and Cora Cartis in the Mathematical Institute. While the specific project will depend on the interests of the student, topics include: Newton-Krylov and vector sequence acceleration methods; fast PDE solvers; derivative-free parameter optimization; surrogate modelling and low rank approximations of complex systems via linear sketching; and machine learning. Of particular interest are applications to oceanography, marine biogeochemistry, and climate modelling, for example, ocean heat and carbon uptake, the ocean biological pump, and climate sensitivity.

Students with a strong first degree in natural sciences, mathematics, computer science or other engineering fields are encouraged to apply.

References & Further Reading

Anderson, D. G. (1965). Iterative procedures for nonlinear integral equations. *J. Assoc. Comput. Mach.*, https://doi.org/10.1145/321296.321305.

Khatiwala, S. (2008): Fast spin up of ocean biogeochemical models using matrix-free Newton-Krylov, *Ocean Modell.*, https://doi.org/10.1016/j.ocemod.2008.05.002.

Fang, H. and Y. Saad (2009). Two classes of multisecant methods for nonlinear acceleration. *Numer. Linear Algebra Appl.*, https://doi.org/10.1002/nla.617.

Woodruff, D. P. (2014): Sketching as a tool for numerical linear algebra, https://doi.org/10.48550/arXiv.1411.4357.

Brezinski et al. (2018). Shanks sequence transformations and Anderson acceleration. *SIAM Rev.*, https://doi.org/10.1137/17M1120725.

Cartis, C. et al. (2019): Improving the flexibility and robustness of model-based derivative-free optimization solvers, *ACM T. Math. Software*, https://doi.org/10.1145/3338517.

Khatiwala et al. (2019): Air-sea disequilibrium enhances ocean carbon storage during glacial periods, *Sci. Adv.*, https://doi.org/10.1126/sciadv.aaw4981.

d'Aspremont et al. (2021): Acceleration Methods, https://doi.org/10.48550/arXiv.2101.09545.

Khatiwala, S. (2022): Fast spin-up of radiocarbon and other geochemical tracers in ocean models, *J. Adv. Model. Earth Sys.*, https://doi.org/10.1002/essoar.10512611.1.

Further Information

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