

Western boundary currents and the deglacial expansion of marine life

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Key words:	Physical oceanography, palaeoceanography, climate change, connectivity, dispersal, model
Research theme(s):	• Oceanography, Climate and Palaeoenvironment
Eligible courses for this project:	• DPhil in Earth Sciences (3-4 years) • Interdisciplinary Life and Environmental Science Landscape Award (ILES LA) • Intelligent Earth (UKRI CDT)

Overview

Western boundary currents (WBCs) of subtropical gyres transport warm water poleward, elevating surface temperatures above typical values for their latitude. With temperature being the main control on the distribution of marine life, it is no coincidence that the highest latitude occurrences of many tropical marine species (such as corals) are found in western boundary currents. As well as warm water, subtropical WBCs also facilitate poleward transport of larvae for many types of marine life (fig. 1), providing a mechanism by which tropical species can reach subtropical and temperate seas.

20,000 years ago, the planet was in the depths of the last glacial period and was therefore rather chilly. As a result, the ranges of warm-water species were limited to lower latitudes than they are found at today. When the ocean warmed after the end of the last glacial (deglaciation), marine organisms would have been able to expand poleward. For many species, they must have achieved this by dispersing in ocean currents such as WBCs.

However, we have little understanding of how marine population connectivity may have been different during the last glacial period and subsequent deglaciation versus the present. Oceanographic modelling of the Kuroshio (WBC of the North Pacific Subtropical Gyre) suggests poleward transport may have been as strong or stronger than the present (e.g. Vogt-Vincent and Mitarai, 2020; Yang et al., 2022, fig. 2) while geochemical evidence suggests the Gulf Stream (WBC of the North Atlantic Subtropical Gyre) may have weakened (Lynch-Stieglitz et al., 1999). WBC strength is not the only relevant factor for past marine connectivity: lower sea level during the last glacial may have changed WBC proximity to the coast, altering the likelihood of marine larvae entering or leaving WBCs in the first place.

Reconstructing the path and strength of WBCs over the past 20,000 years and quantifying the impact on marine connectivity through larval dispersal will help us to understand how marine organisms repopulated subtropical and temperate seas after the last glacial period. The warming accompanying deglaciation was the most recent example of rapid global climate change before the Anthropocene, so this will in turn help us predict how the ocean and marine life may respond to ongoing and future anthropogenic climate change.

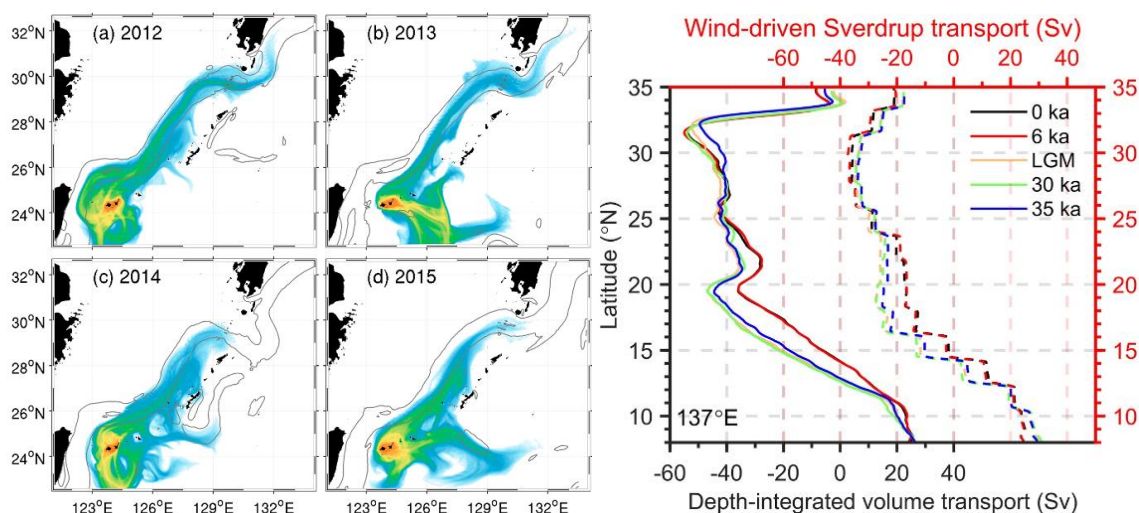


Figure 1 (left) Simulations of poleward larval dispersal through the Kuroshio. Figure from Uchiyama et al., 2018. **Figure 2 (right)** Volume transport of the North Pacific Subtropical Gyre versus latitude from 35,000 years ago to the present based on an ocean model (Yang et al., 2022).

Methodology

You will run regional palaeoceanographic models (e.g. using NEMO or ClimaOcean.jl) for the NW Atlantic and/or NW Pacific under bathymetric and climate boundary conditions from the last glacial to the present. After assessing the realism of your simulations using palaeoceanographic proxy data, you will run larval dispersal simulations to investigate how marine connectivity may have changed throughout deglaciation. Depending on your progress and interests, further research directions could involve investigating how changes in tides under lower sea level may have affected boundary currents as associated transport. Alternatively, with international collaborators, it may be possible to investigate whether past changes in marine connectivity have affected contemporary population genetic structure.

Timeline

Year 1: Training and rotation projects (ILES/Intelligent Earth).

Years 2 and 3: Running palaeoceanographic models, assessing models against proxy data, running dispersal simulations and investigating how connectivity and network structure responded to deglacial climate change.

Year 4: Deep-dive into tides, evolution, or other areas of interest. Completing papers, presenting at conferences, thesis write-up.

Training & Skills

The student will be provided training as required in physical oceanography, palaeoceanography, and hydrodynamic modelling. Depending on student interests, further

training and/or collaborators may be introduced into the project (e.g. population genetics). A strong quantitative background (ideally physical oceanography, physics, mathematics, engineering, or similar) is strongly desirable for this project but specialist knowledge of oceanography or palaeoceanography is not essential.

References & Further Reading

Lynch-Stieglitz, J., Curry, W. B., & Slowey, N. (1999). Weaker gulf stream in the Florida Straits during the last glacial maximum. *Nature*, 402(6762), 644–648.

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Uchiyama, Y., Sachika Odani, Kashima, M., Kamidaira, Y., & Mitarai, S. (2018). Influences of the Kuroshio on interisland remote connectivity of corals across the Nansei Archipelago in the East China Sea. *Journal Of Geophysical Research: Oceans*, 123(12), 9245–9265.

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Vogt-Vincent, N. S., & Mitarai, S. (2020). A persistent Kuroshio in the glacial East China Sea and implications for coral paleobiogeography. *Paleoceanography and Paleoclimatology*, 35(7). <https://doi.org/10.1029/2020pa003902>

Yang, H., Guo, X., Miyazawa, Y., Varlamov, S. M., Abe-Ouchi, A., & Chan, W. Le. (2022). Changes in the Kuroshio path, surface velocity and transport during the last 35,000 years. *Geophysical Research Letters*, 49(4). <https://doi.org/10.1029/2021gl097250>

Further Information

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