Nutrient limitation in the subpolar north Pacific during glacial climates due to enhanced Pacific Meridional Overturning Circulation (PMOC)

J. W. B. RAE[1]*, R. WILLS[23], I. EISENMAN[4], W. GRAY[5], T. SCHNEIDER[2] AND B. TAYLOR[1]

[1]University of St Andrews, UK (*jwbr@st-andrews.ac.uk)
[2]ETH Zurich, Switzerland
[3]Caltech, Pasadena, USA
[4]Scripps Institution of Oceanography, La Jolla, USA
[5]UCSB, Santa Barbara, USA

The role of the North Pacific in glacial-interglacial CO_2 and climate change has been the subject of recent debate. A variety of geochemical proxies for ventilation (^{14}C, $\delta^{13}C$, redox indicators) suggest that during cold periods (glacial maxima and Heinrich stadials) the North Pacific saw more vigorous formation of intermediate waters, which perhaps even extended to the deep ocean during a brief interval of Heinrich Stadial 1. However paired nutrient utilisation and productivity proxies ($\delta^{15}N$, opal, biogenic Ba) indicate reduced nutrient supply to the surface North Pacific, and this has been used to argue for increased stratification in cold climates.

Here we show that these apparently contradictory observations may be reconciled by considering changes in nutrient supply to the subpolar North Pacific under enhanced PMOC (Pacific Meridional Overturning Circulation). We invoke an increase in exchange between the subtropical and subpolar gyres. This provides a source of high-salinity water to high latitudes, increasing surface water density and promoting intermediate water formation. As the nutrient concentrations of subtropical gyre waters are close to zero, an increase in cross-gyre exchange also causes a reduction in high latitude nutrient supply. Enhanced ventilation may cause further nutrient limitation by reducing the nutrient concentration of subsurface waters.

This scenario is supported by a variety of modelling approaches, including box models of salinity and nutrient budgets, and general circulation models. These GCM results indicate that cross-gyre exchange is increased in the presence of large ice sheets on North America, providing a link between enhanced ventilation and nutrient limitation in the North Pacific, and the Milankovitch forcing that ultimately drives the glacial cycles.