Marine nitrogen fixers crucial for a dust-driven strengthening of the biological carbon pump

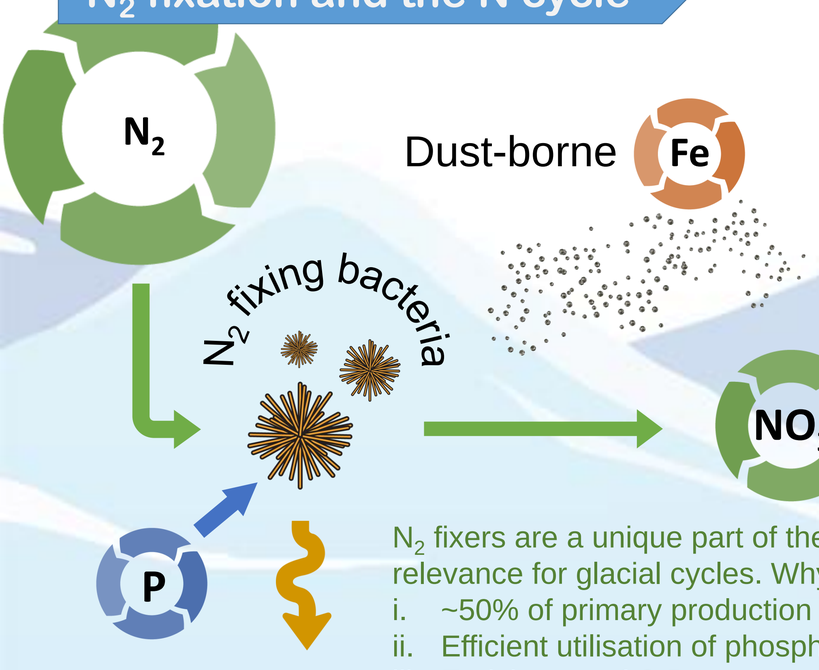
PJ Buchanan[1,2,3], RJ Matear[1,3], Z Chase[2], SJ Phipps[2], NL Bindoff[1,2,3]

1 CSIRO
2 UNIVERSITY of TASMANIA
3 ARC CENTRE OF EXCELLENCE FOR CLIMATE SYSTEM SCIENCE

We use a global ocean model to investigate the role of dinitrogen (N_2) fixation within the global carbon (C) cycle. We find that:

1. **N_2 fixation is ~25% (800 Pg C) of the biological C store** under preindustrial conditions.
2. **The biological C pump is severely limited without N_2 fixers** in its capacity to respond to increases in aeolian iron (Fe) supply.
3. **N_2 fixation and biological C pump are linearly related**, regardless of circulation, at ~0.5 ppm CO_2 per Tg N yr^{-1}.
4. **Magnitude of dust-driven increase in N_2 fixation (C) dependent on circulation: 7-17 ppm CO_2 (stratified–mixed ocean)**

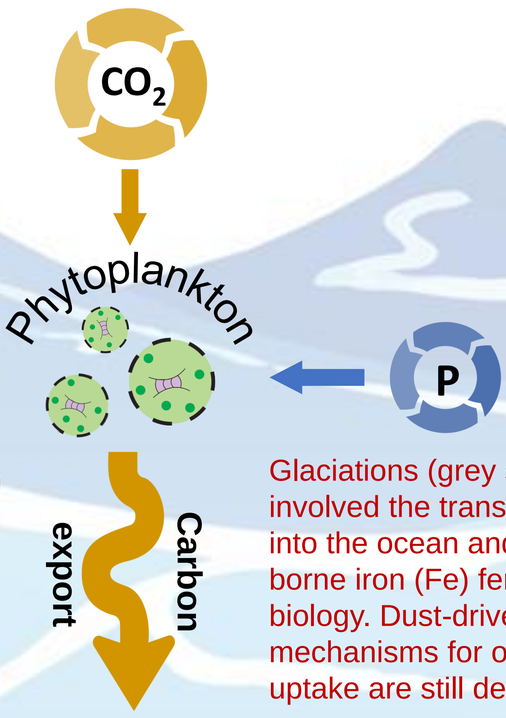
N_2 fixation and the N cycle



N_2 fixers are a unique part of the biological C pump with relevance for glacial cycles. Why?

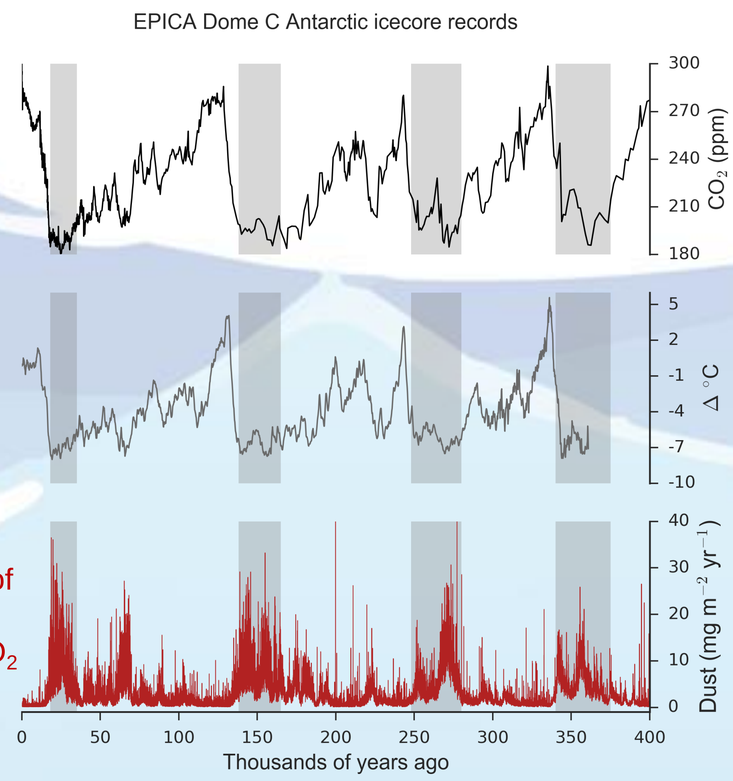
i. ~50% of primary production in N-poor waters.
ii. Efficient utilisation of phosphorus (P).
iii. Enrichment of C:P content of organic matter.
iv. Diverse and widespread between 40°S-40°N.
v. Highly sensitivity to aeolian Iron (Fe) supply.

Biological carbon pump



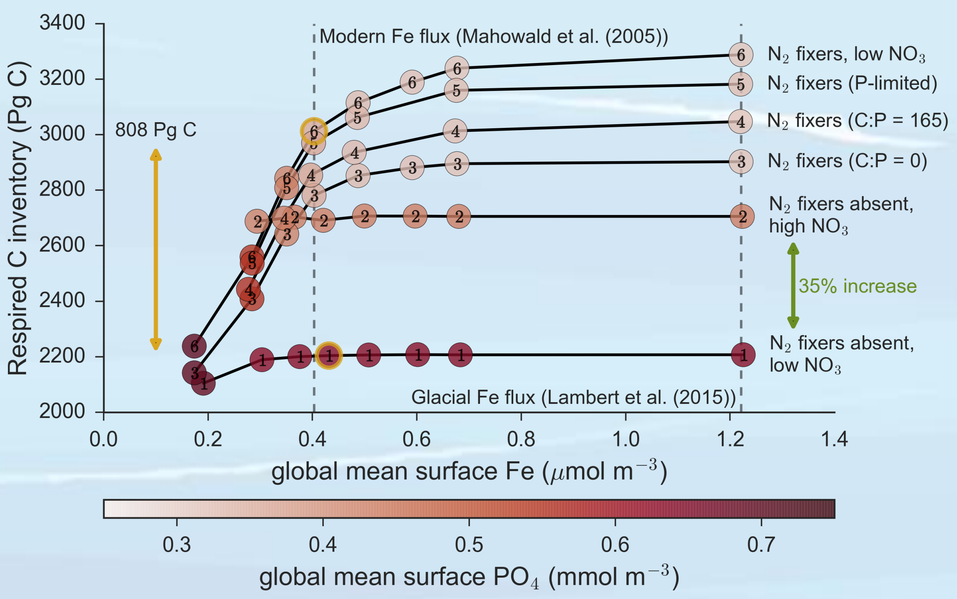
Glaciations (grey shading) involved the transfer of CO_2 into the ocean and dust-borne iron (Fe) fertilisation of biology. Dust-driven mechanisms for oceanic CO_2 uptake are still debated.

Glacial cycles and dust



N_2 fixers enable C storage as Fe supply increases.

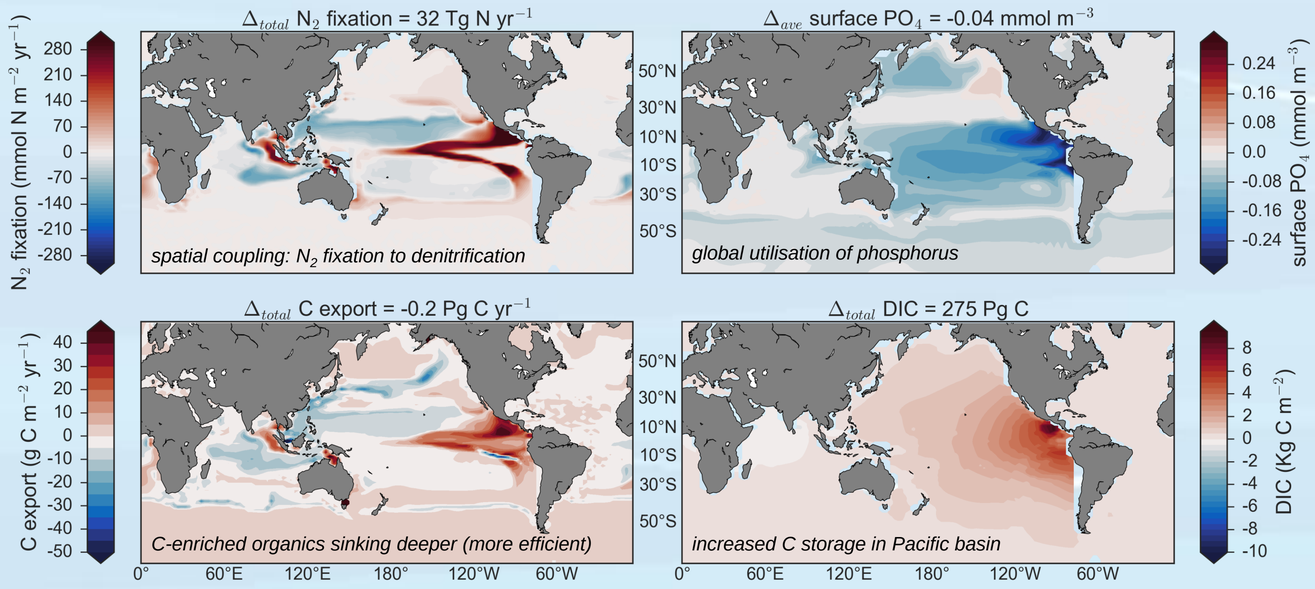
Regardless of how they were represented, N_2 fixers were essential for an Fe-induced strengthening of the biological C pump going from low to high Fe supply.



Points 1 and 2

Why? A closer look at how N_2 fixers increase respired C.

Biogeochemical changes associated with glacial minus modern aeolian Fe supply.



Do physical conditions matter?

Four very different circulations. More sluggish, colder and stratified from GFDL$_{PI}$ → Mk3L$_{PI}$ → HadGEM$_{PI}$ → Mk3L$_{LGM}$

Points 3 and 4

Two answers with implications for biological CO_2 drawdown.

No: more N_2 fixation always increases respired C (left) and absorbs CO_2 (right).
Yes: physical delivery of P controls magnitude of increase in N_2 fixation as Fe becomes less limiting in the global marine ecosystem. P ultimate limiting nutrient.