Glacial-Interglacial Changes in Export Production of the Southern Ocean

Karen E. Kohfeld[1], Zanna Chase[2], Robert F. Anderson[3]

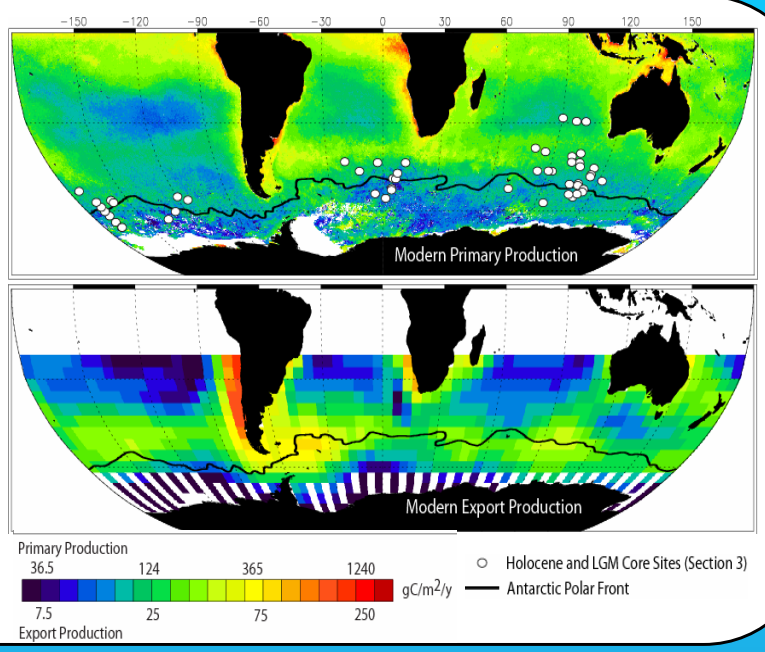
[1]Max Plank Institute for Biogeochemistry, Jena, Germany (kek@bgc-jena.mpg.de); [2]Monterey Bay Aquarium Research Institute, Monteray Bay, CA, USA (zanna@mbari.org); [3]Lamont-Doherty Earth Observatory, Palisades, NY, USA (boba@ldeo.columbia.edu)

1. Motivation and Modern Conditions

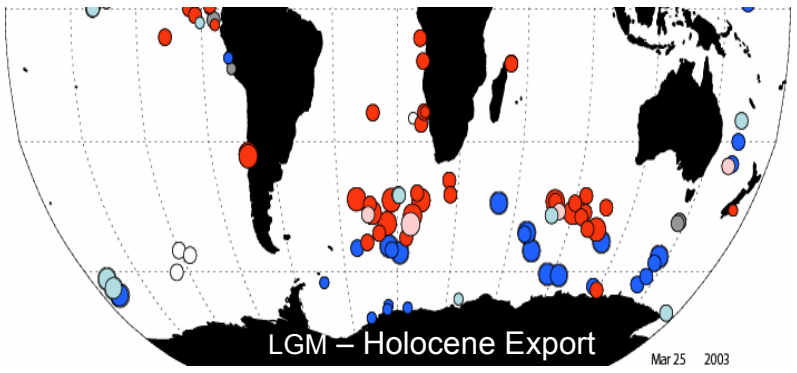
Changes in biological pump efficiency via export of biogenic matter from the surface to the deep sea (**export production**) has been proposed as an important factor controlling atmospheric CO_2.[1-4] The Southern Ocean holds ~90% of the global inventory of unused surface water nutrients and so has the greatest potential for drawing down atmospheric CO_2. Fertilization of marine biota by iron from dust is one mechanism proposed to increase export production in the Southern Ocean during glacial periods.[5]

Here we:
•show glacial-interglacial changes in export production in the Southern Ocean,
•quantify intrabasinal differences opal burial rates, and
•relate these differences to changes in lithogenic fluxes in these basins.

Today, maximum levels of primary production occur near the Subtropical Front (STF; ~40°S) with maximum export production 10° further south.[6,7] Phytoplankton near the STF are mostly small cells easily recycled by grazers, leaving little organic matter for export. South of the Antarctic Polar Front (APF), large diatoms dominate and are less efficiently recycled, leading to greater proportions of exported organic matter. Similar levels of export production occur in all sectors, although zonal variability in export production occurs within each sector. [8]



2. Export Production at the LGM



During the LGM, export production was less than today south of the APF (see map in Section 1 for APF location). Export production was greater than today in the zone between the APF and the STF. The zone of maximum export was north of its present position, but overall export production during the LGM was not significantly greater than today. [9,10]

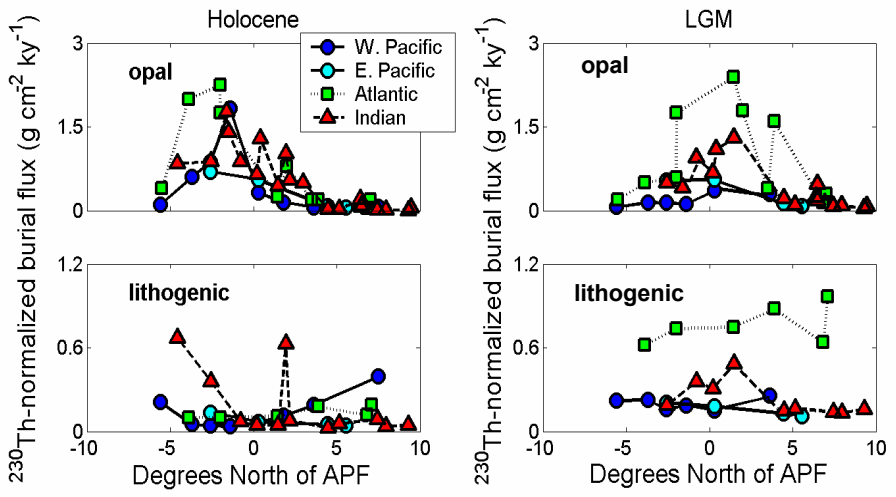
Changes in export production were determined in marine cores using the consensus of relative fluxes of nine different paleo-export production indicators, including opal, calcium carbonate, organic carbon, biomarkers (C37 alkenones), ^{10}Be, ^{231}Pa, barite, authigenic uranium and cadmium, and benthic foraminifera.[9,10]

3. Opal and Lithogenic Burial Rates

Today, maximum opal burial rates are located just south of the APF, consistent with the position of maximum export production. Similar maximum opal burial rates are found in each sector during the Holocene, although zonal variability in export production is manifest in opal burial. For example, opal accumulation rates in the SE Pacific are less than in the SW Pacific.

During the LGM maximum opal burial rates were located north of the APF, consistent with the northward position of maximum export production. Unlike today, there was a substantial zonal gradient in opal burial (export production) during the LGM, with highest rates in the Atlantic sector and smallest in the Pacific sector.[11]

A similar pattern (Atlantic > Indian > Pacific) is seen in the accumulation rate of lithogenic material during the LGM, suggesting that regional variability in the supply of iron may have contributed to regional variability in export production.[11]



4. Summary

1) The zone of maximum productivity during the LGM was north of its present position: North of the APF productivity was greater during the LGM than during the Holocene, whereas south of the APF the reverse was true.

2) Productivity of the glacial Southern Ocean was not much greater than today. The sediment record argues against a massive increase in productivity due to Fe fertilization.

3) Diatom productivity is similar today in all sectors, but varied among sectors during the LGM. Differentiation among sectors during the LGM may reflect a zonal gradient in Fe sources, with maximum inputs to the Atlantic, just east (downwind) of Patagonia, and minimum inputs to the Pacific.

4) The northward shift in maximum diatom productivity during the LGM may reflect inhibition of diatom growth south of the APF by increased sea ice cover,[12] allowing silicic acid upwelled south of the APF to reach surface waters north of the APF, much as occurs for nitrate today.[13]

References

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Acknowledgements

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