

Limited Role of Export Production in Glacial-Interglacial CO₂ Cycles?

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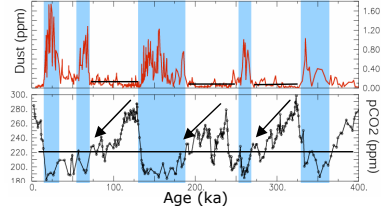
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1. Motivation

Observations from Vostok ice core¹:

- High dust associated with peak glacial periods
- High dust ONLY occurs AFTER atmospheric CO₂ drops below 220 ppm
- Initial ~50 ppm drawdown occurs at LOW dust levels



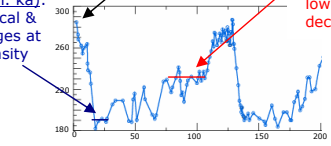
What is the impact of marine carbon export and iron fertilization on CO₂ at different dust input levels?

We examine marine export production proxies from three time periods:

Last Glacial Maximum (LGM, 19-23 cal. ka):
Physical, chemical & biological changes at maximum intensity

"Today"

Marine Isotope Stage 5a-d: atmospheric dust low, but CO₂ already decreased by 50 ppm.



2. Data

Paleo-export data compiled for 145 deep-sea cores²:

Ten paleo-export proxies used to assess relative changes in export production:

- Opal (SiO₂)
- Calcium Carbonate (CaCO₃)
- Organic Carbon
- Biomarkers (C37 Alkenones)
- ¹⁰Be
- ²³¹Pa
- Barite
- Authigenic Uranium
- Authigenic Cadmium
- Benthic Foraminiferal Fluxes

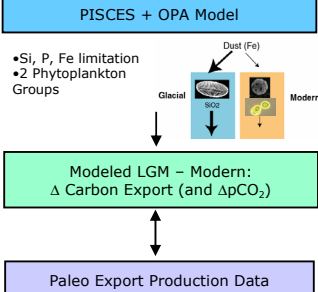
Confidence in data ranked for each core, based on (from highest to lowest for each category):

- **Age Model Type:**
Radiocarbon dating (AMS)
Oxygen Isotope Stratigraphy
Lithogenic Correlation
- **Type of Flux Measurement:**
Constant Flux Normalization (230Th)
Mass Accumulation Rates
Sediment Concentration
- **Number and % agreement of proxies in core**

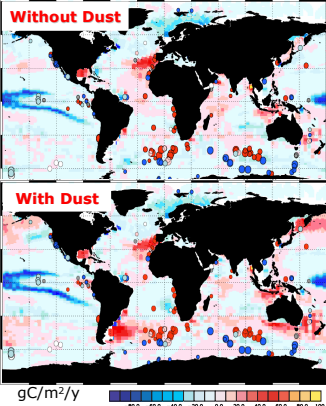
4. Discussion

Simulated contribution of dust to atmospheric CO₂ changes:

An ocean biogeochemistry model³ was forced with LGM-Modern changes in temperature, sea ice, circulation, and dust⁴. Results were compared with paleodata (right).



LGM-Modern Changes in Carbon Export



Conclusions:

- Dust fertilization is required to reproduce export production patterns, particularly in the Southern Ocean.
- Combining temperature, sea ice, circulation and dust changes only results in a 30 ppm drawdown of atmospheric CO₂, 15 ppm of which is attributed to the dust effect.
- This result is in line with results from other simulations^{5,6}, and is reasonable giving the timing of increased dust concentrations relative to CO₂ in the Vostok ice core.
- The small role of ocean biology suggests that other physical or chemical processes must be responsible for the first 50 ppm drawdown of atmospheric CO₂.

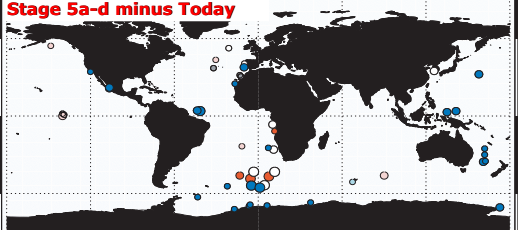
5. References

¹Petit, J. R. et al. Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. *Nature* **399**, 439-436 (1999). ²Kohfeld, K. E. & Le Quéré, C. Limited role of marine biological export in glacial-interglacial CO₂ cycles. (in prep, 2003). ³Aumont, D., Waeber Reimer, E., Blain, S. & Monfray, P. An ecosystem model of the global ocean including Fe, Si, P co-limitations. *Global Biogeochemical Cycles* (in press). ⁴Bopp, L., Kohfeld, K. E., Le Quéré, C. & Aumont, D. Dust impact on marine biota and atmospheric CO₂ during glacial periods. *Paleoceanography* (revised). ⁵Archer, D., Wingham, A., Lea, D. & Mahowald, N. What caused the glacial/interglacial atmospheric pCO₂ cycles? *Reviews of Geophysics* **38**, 159-189 (2000). ⁶Watson, A. J., Bakker, D. C. E., Ridgwell, A. J., Boyd, P. W. & Law, C. S. Effect of iron supply on Southern Ocean CO₂ uptake and implications for glacial atmospheric CO₂. *Nature* **407**, 730-734 (2000).

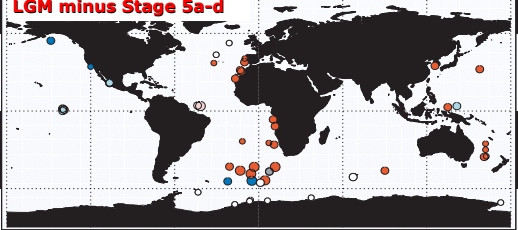
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3. Results

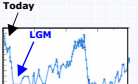
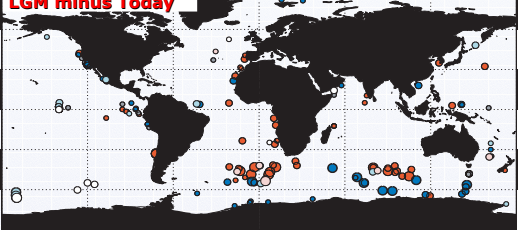
Stage 5a-d minus Today



LGM minus Stage 5a-d



LGM minus Today



Key:
Change in Export
● lower
○ slightly lower
○ no change
○ slightly higher
● higher
● ambiguous
Data Confidence
○ high
○ medium
○ low

The first 50 ppm of atm CO₂ drawdown not caused by an increase in export production.

- W. Pacific and S. Ocean (S. of 50°S) show uniformly lower export at Stage 5a-d compared with today (top), suggesting that if anything export was reduced 80-100,000 years ago.
- Export was for the most part enhanced at the LGM compared with Stage 5a-d (middle) and today (bottom). The major exception is south of 50°S, where export had already reached minimum levels by Stage 5a-d.