Temperature and Iron Fertilization Dominate Glacial-Interglacial CO_2 Changes

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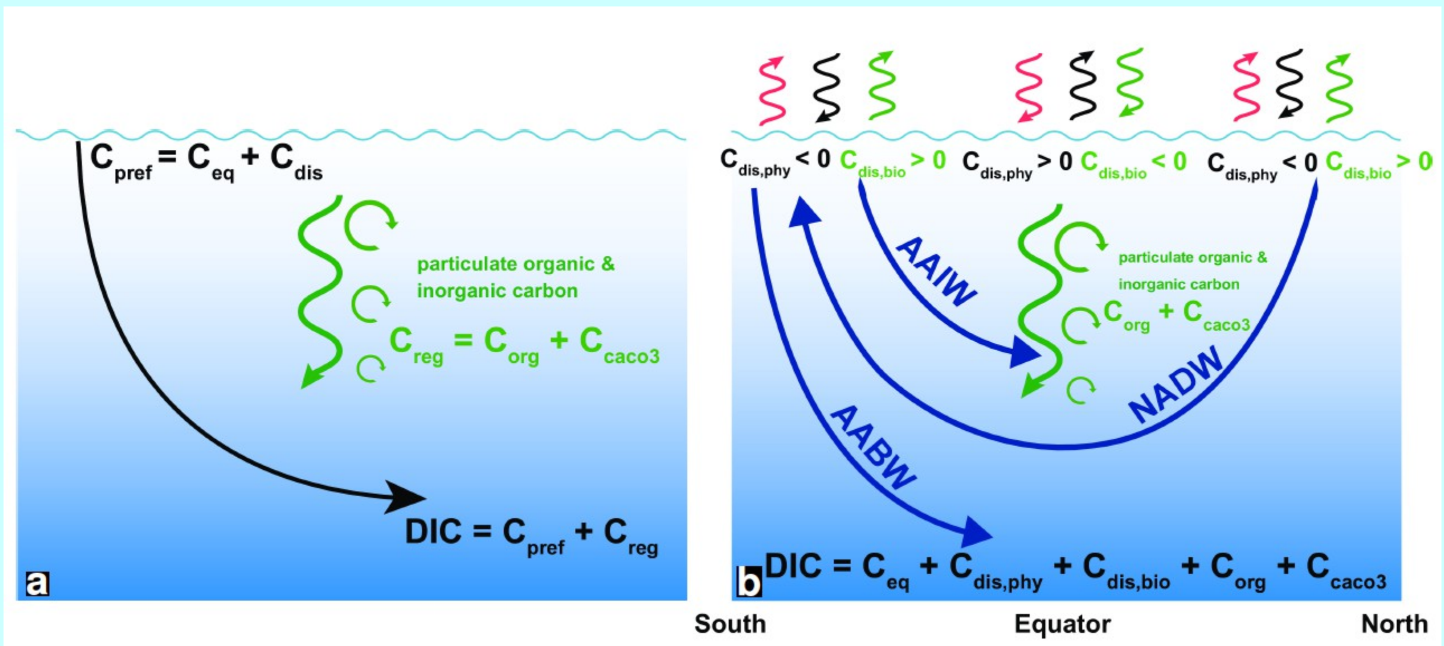
Motivation

Which processes caused the ocean to store more carbon during the LGM?

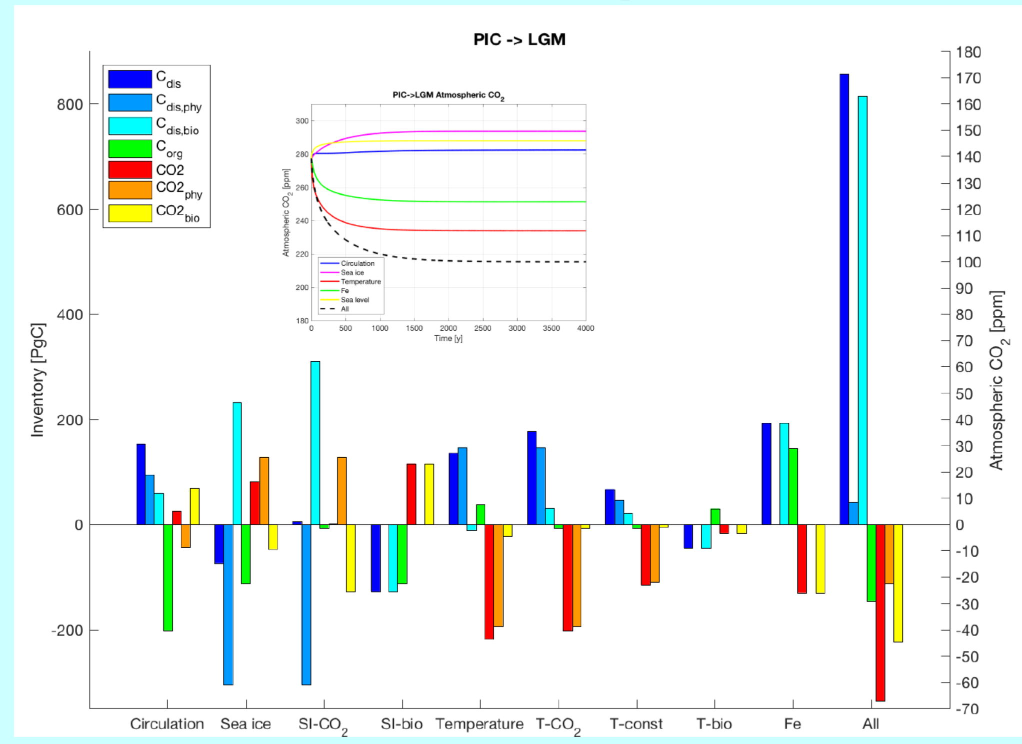
Method 1: Modeling Ocean Carbon Storage (Khatiwala et al. 2019)

Use data-constrained model (Muglia et al. 2018) of the LGM and Transport Matrix Method (TMM, Khatiwala 2007) to quantify carbon components precisely (we do not use the AOU approximation, which doesn't work). This model fits LGM $\delta^{13}C$, $\delta^{15}N$ and radiocarbon data and features a weak and shallow AMOC and enhanced iron fertilization in the Southern Ocean (Muglia et al., 2018). Total ΔCO_2 = 67 – 87 ppm. Sea ice and circulation changes are not important for CO_2.

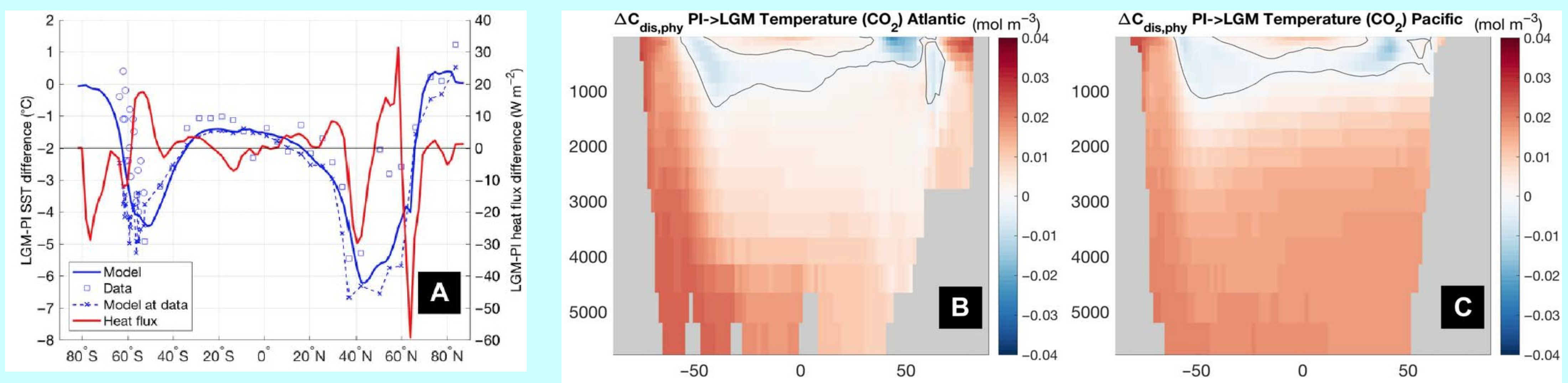
Theory



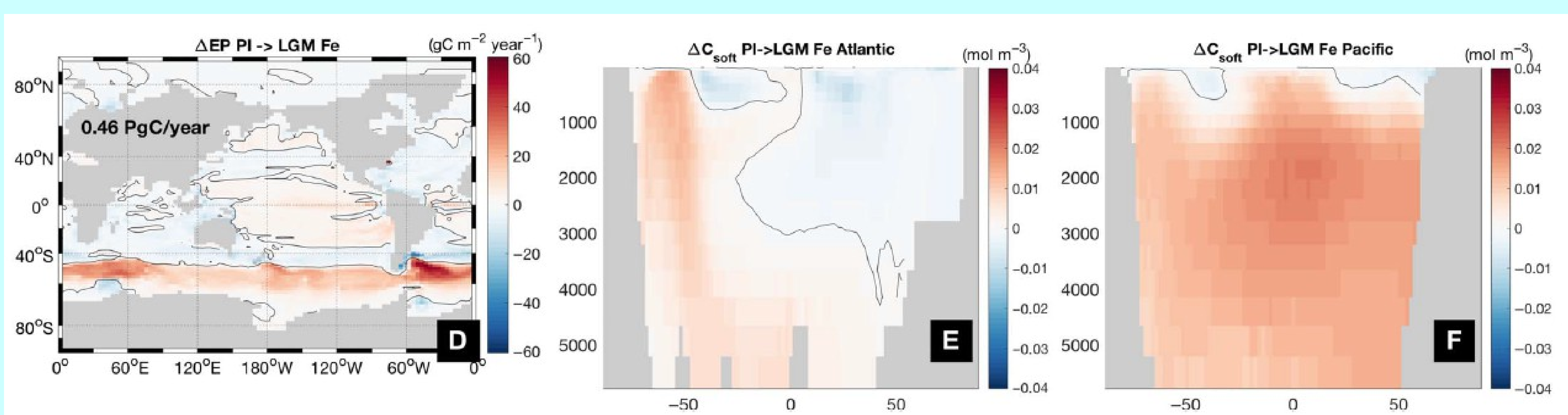
Perturbation Experiments

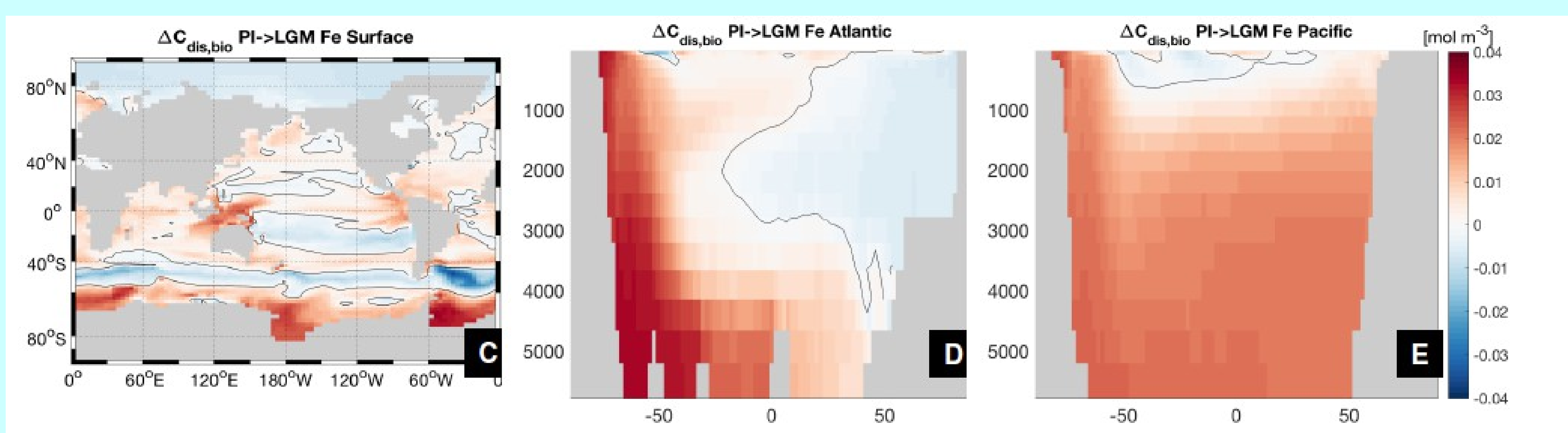


Temperature (44-45 ppm)



Iron Fertilization (26-39 ppm)





Conclusions

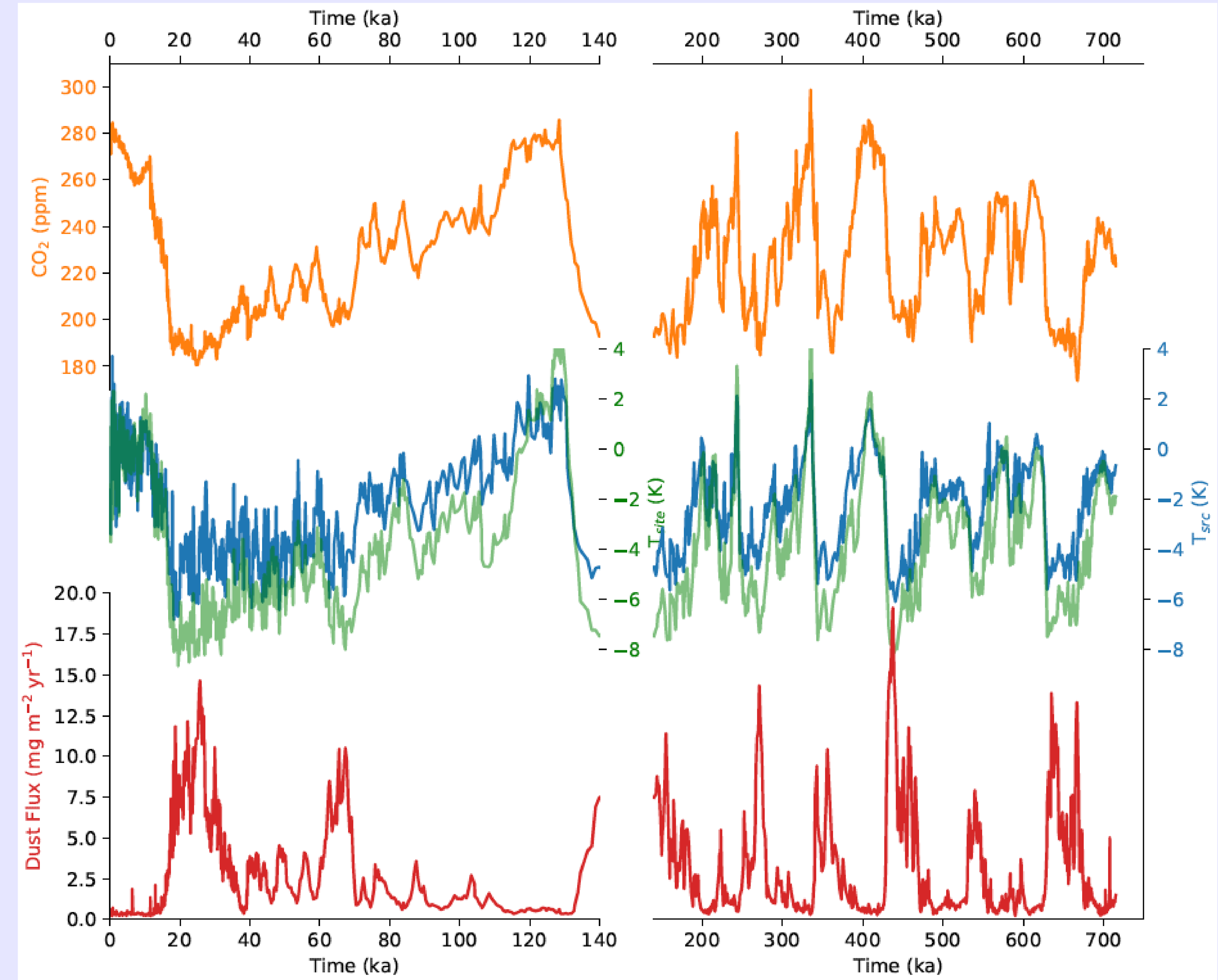
- Temperature and iron fertilization are the dominant drivers of glacial-interglacial ocean carbon storage and CO_2 changes
- Disequilibrium effects amplify both temperature ($C_{dis,phy}$) and iron ($C_{dis,bio}$) effects
- Circulation and sea ice effects are minor due to opposing effects on different carbon components

References

- Khatiwala, S., A. Schmittner, and J. Muglia (2019), Air-sea disequilibrium enhances ocean carbon storage during glacial periods, Science Advances, 5(6), doi: 10.1126/sciadv.aaw4981.
- Muglia, J., Skinner, L. C. & Schmittner, A. Weak overturning circulation and high Southern Ocean nutrient utilization maximized glacial ocean carbon. Earth and Planet. Sci. Lett. 496 (2018).

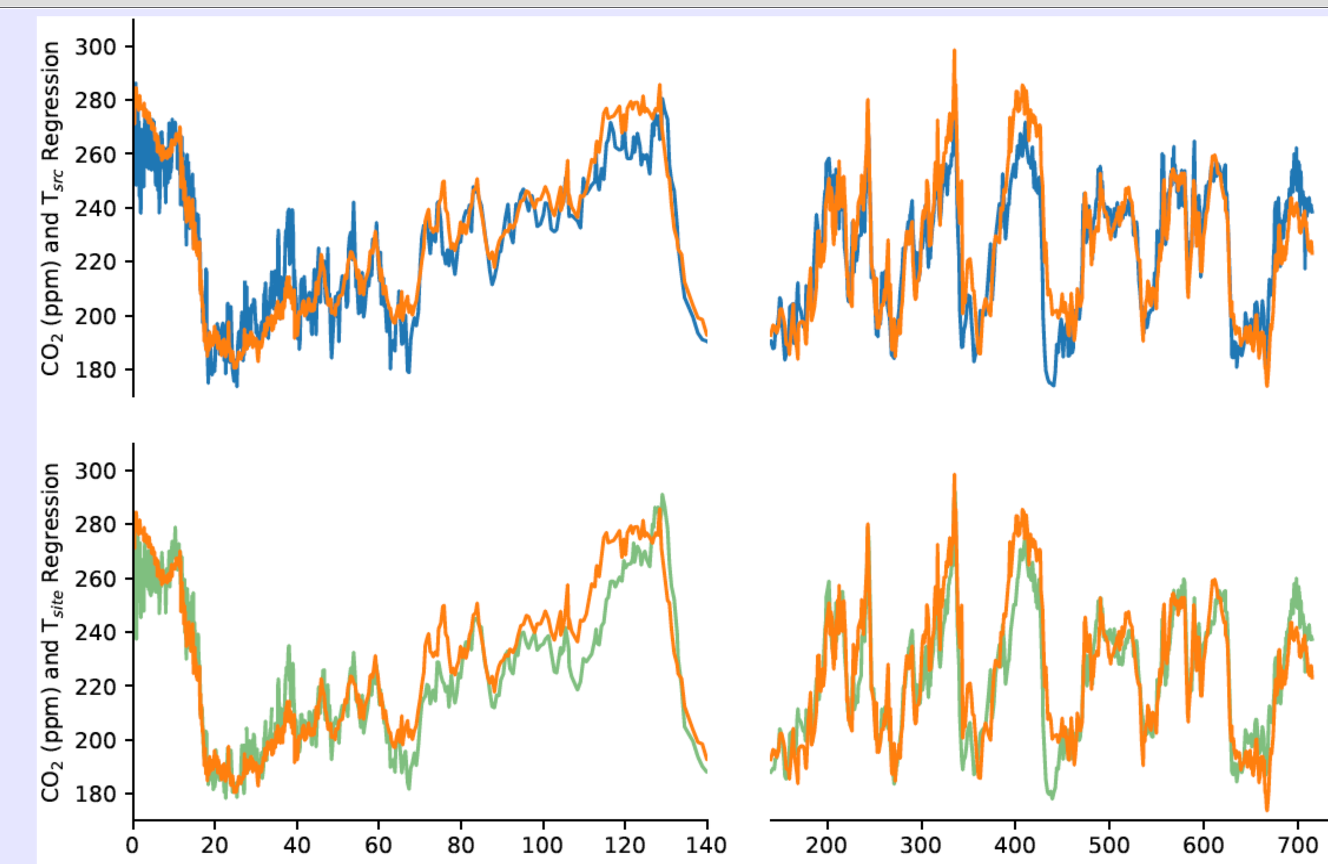
Method 2: Timeseries Analysis

Use Antarctic ice-core data with source (T_{src}) and site (T_{site}) temperature reconstructions (Uemura et al. 2018) and CO_2 on same timescale (AICC2012).



Multiple Linear Regression: $CO_2 = a + b*T + c*ln(dust\ flux)$

T	a	b	c	r^2	σ	RMSE	ΔCO_2 (ppm) LGM-LH T	ΔCO_2 (ppm) LGM-LH dust
T_{src}	253±0.6	7.1±0.2	-12±0.4	0.82	11.8	12.3	**-38.5**	**-33.9**
	269±0.5	12.5±0.2	0	0.71	15.2			
T_{site}	253±0.6	6.5±0.2	-8.2±0.5	0.85	10.9	11.8	**-47.8**	**-26.1**
	269±0.5	10.9±0.1	0	0.82	15.6			



Acknowledgements

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