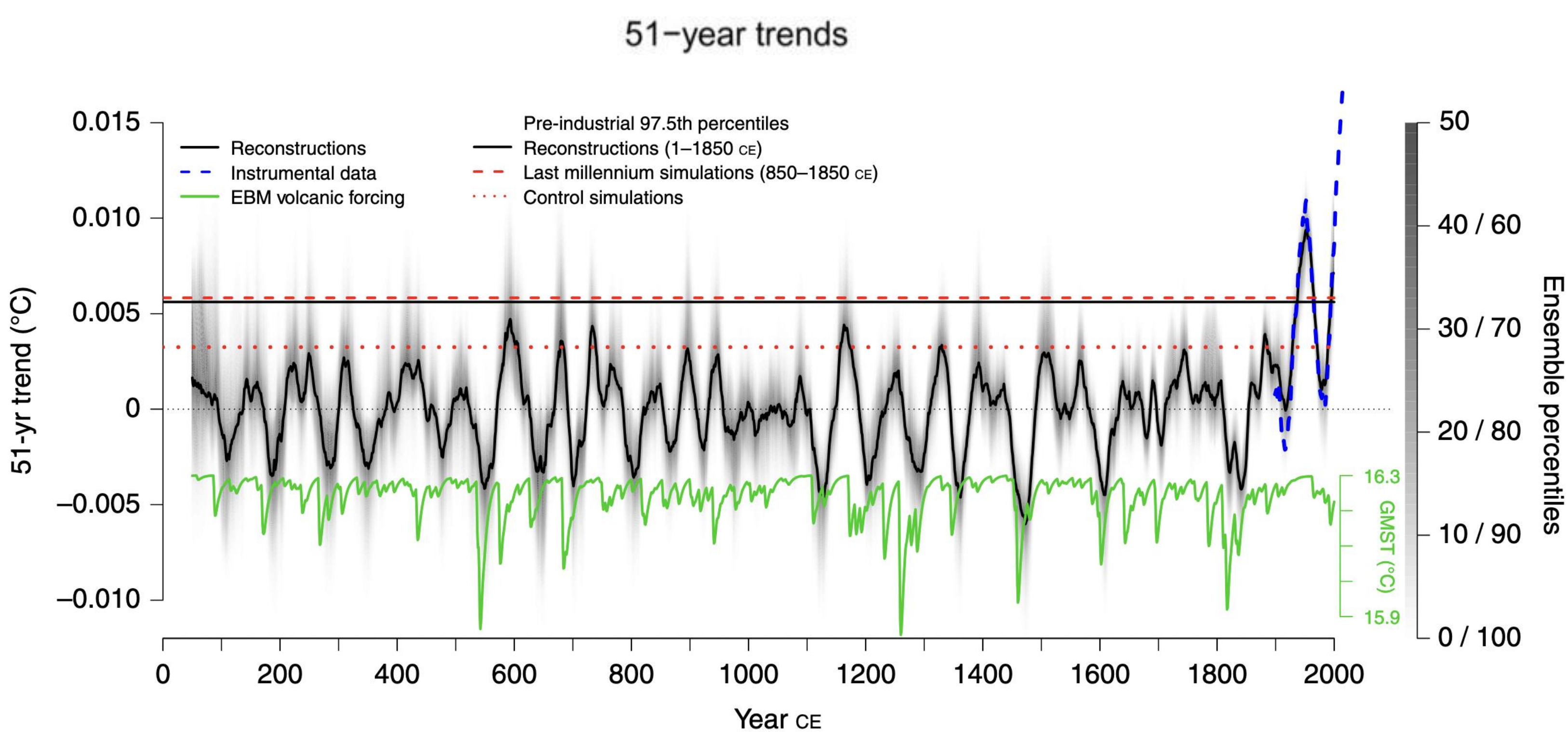
Benefits to overlapping, cross-disciplinary priorities

Daniel Sigman
Dept. of Geosciences
Princeton University

Jesse Farmer
School for the Environment
UMass Boston

- Why we need the past to gain insight into the future
- Why studies of millions-of-years-old material can provide insight into the near-term future
- Ocean drilling's implications for other disciplines and the near-term future: 1-2 examples
- Continuous paleoproxy development by multiple disciplines ensures new findings from continued ocean drilling
- Connections among paleoclimate, marine geology, and deep biosphere studies in ocean drilling

Instrumental data capture very little climate variation.



Article | Published: 24 July 2019

Consistent multidecadal variability in global temperature reconstructions and simulations over the Common Era

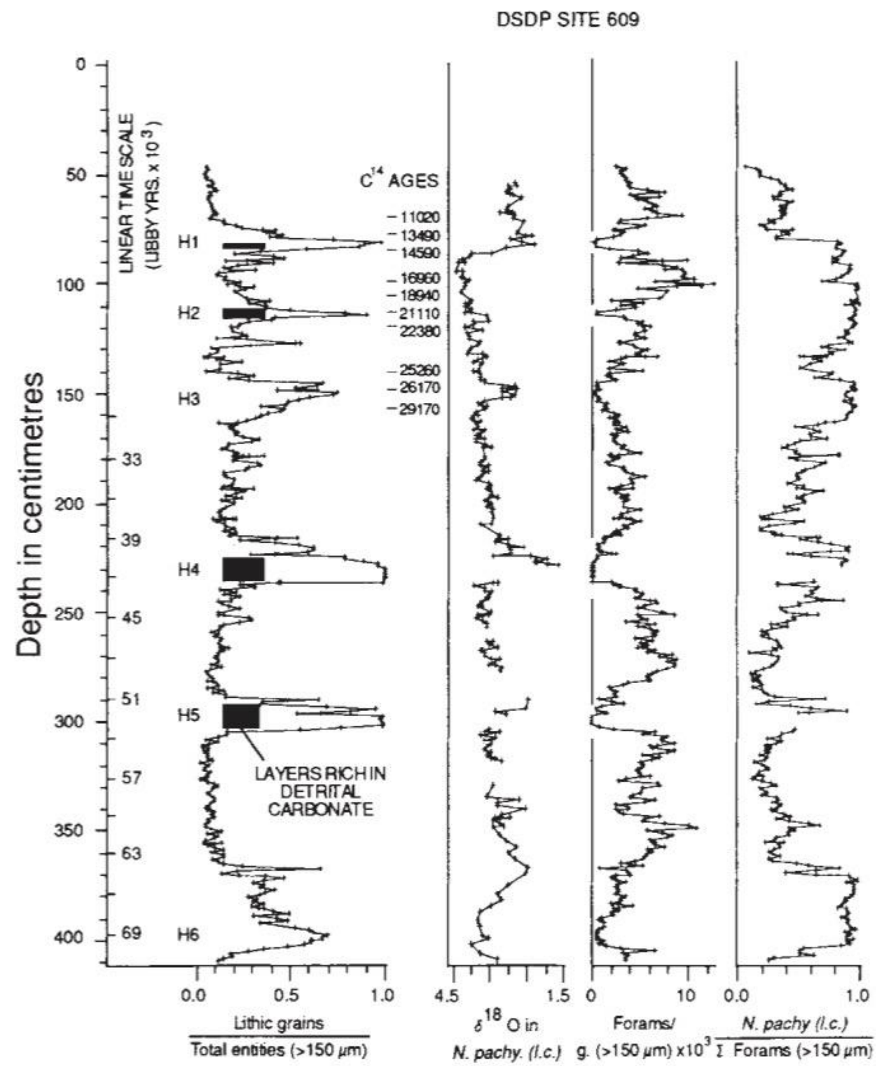
PAGES 2k Consortium

Pre-instrumental data have allowed us to look ahead of ongoing changes.

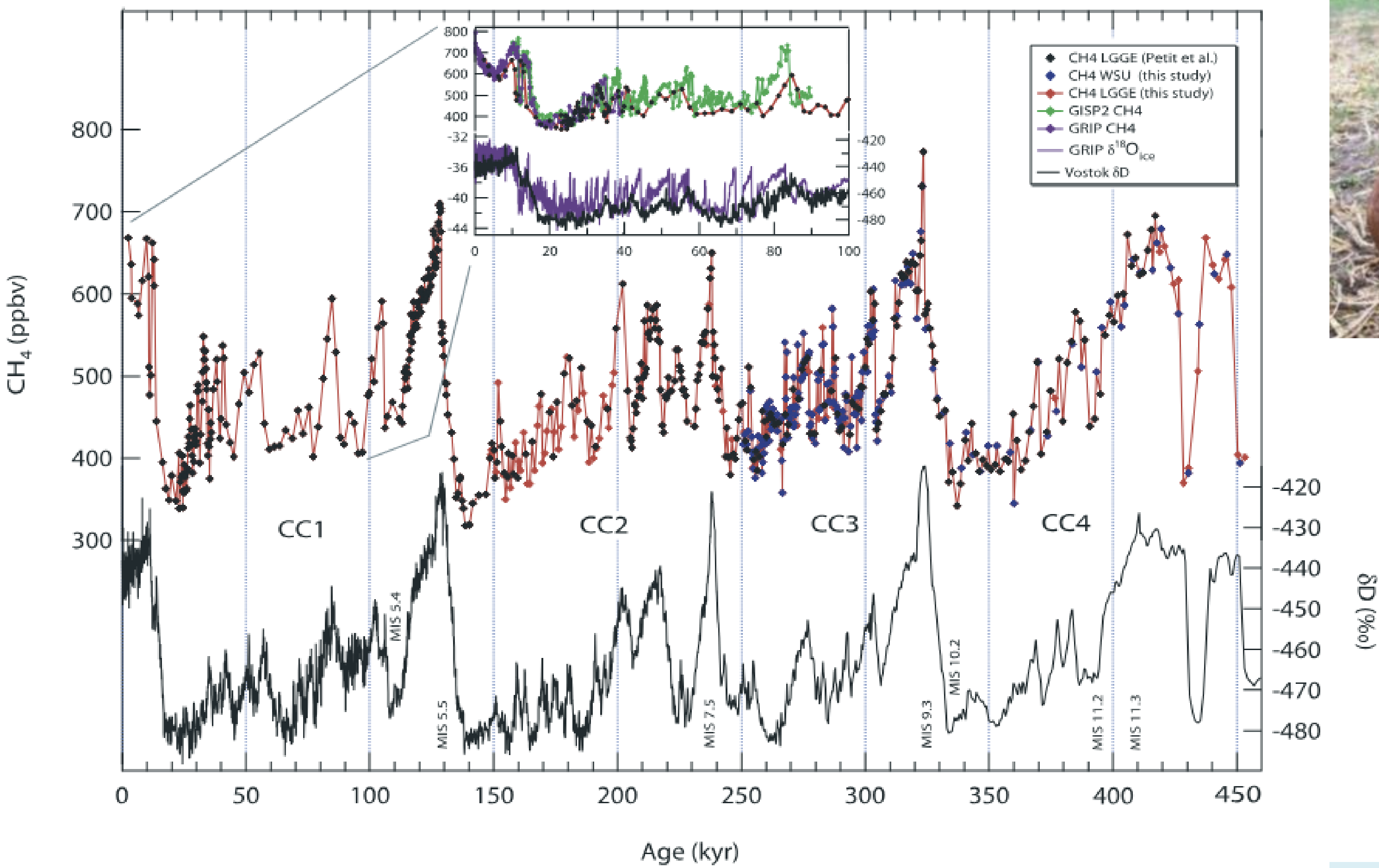
Evidence for massive discharges of icebergs into the North Atlantic ocean during the last glacial period

Gerard Bond*, Hartmut Heinrich†, Wallace Broecker*, Laurent Labeyrie‡, Jerry McManus*, John Andrews§, Sylvain Huon||, Ruediger Jantschik¶, Silke Clasen#, Christine Simet, Kathy Tedesco‡, Mieczyslawa Klas*, Georges Bonani†† & Susan Ivy**

Bond et al., 1992

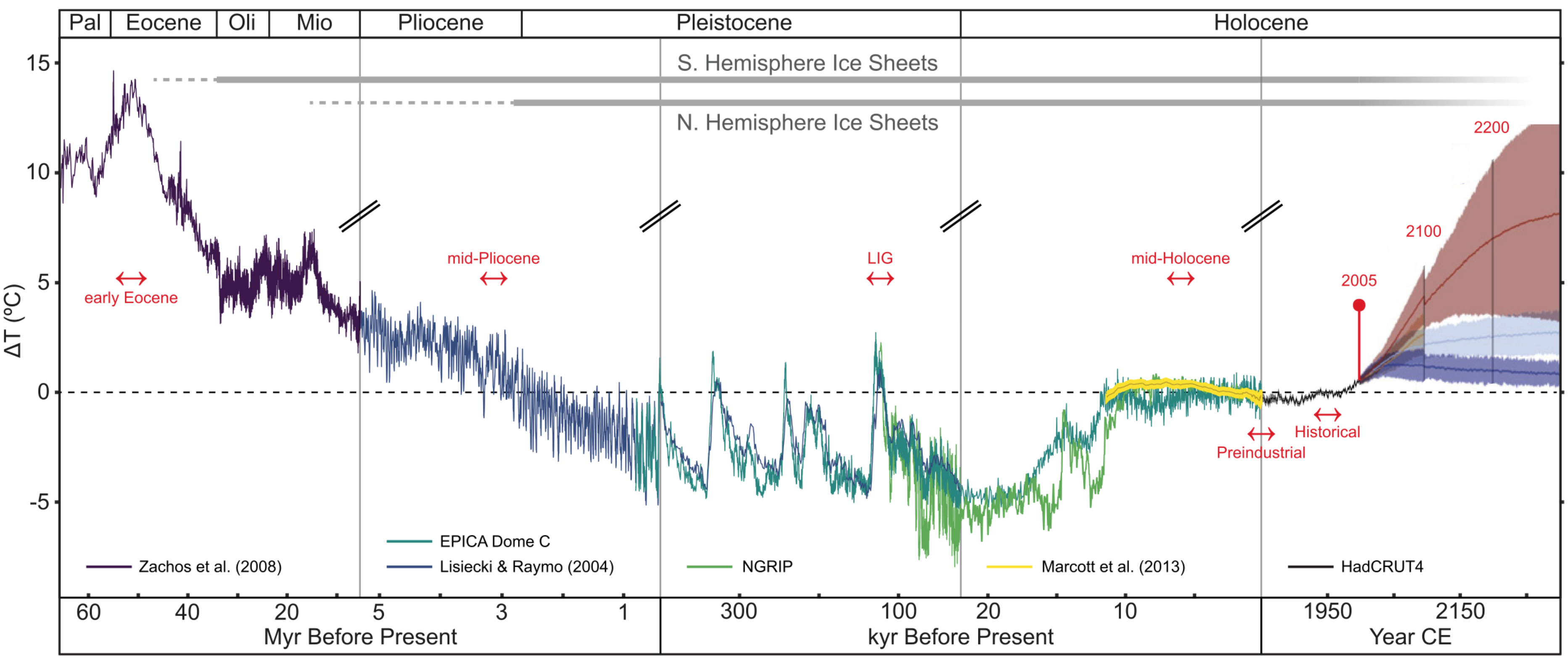


Knowledge of the past is an enduring check on arising hypotheses.



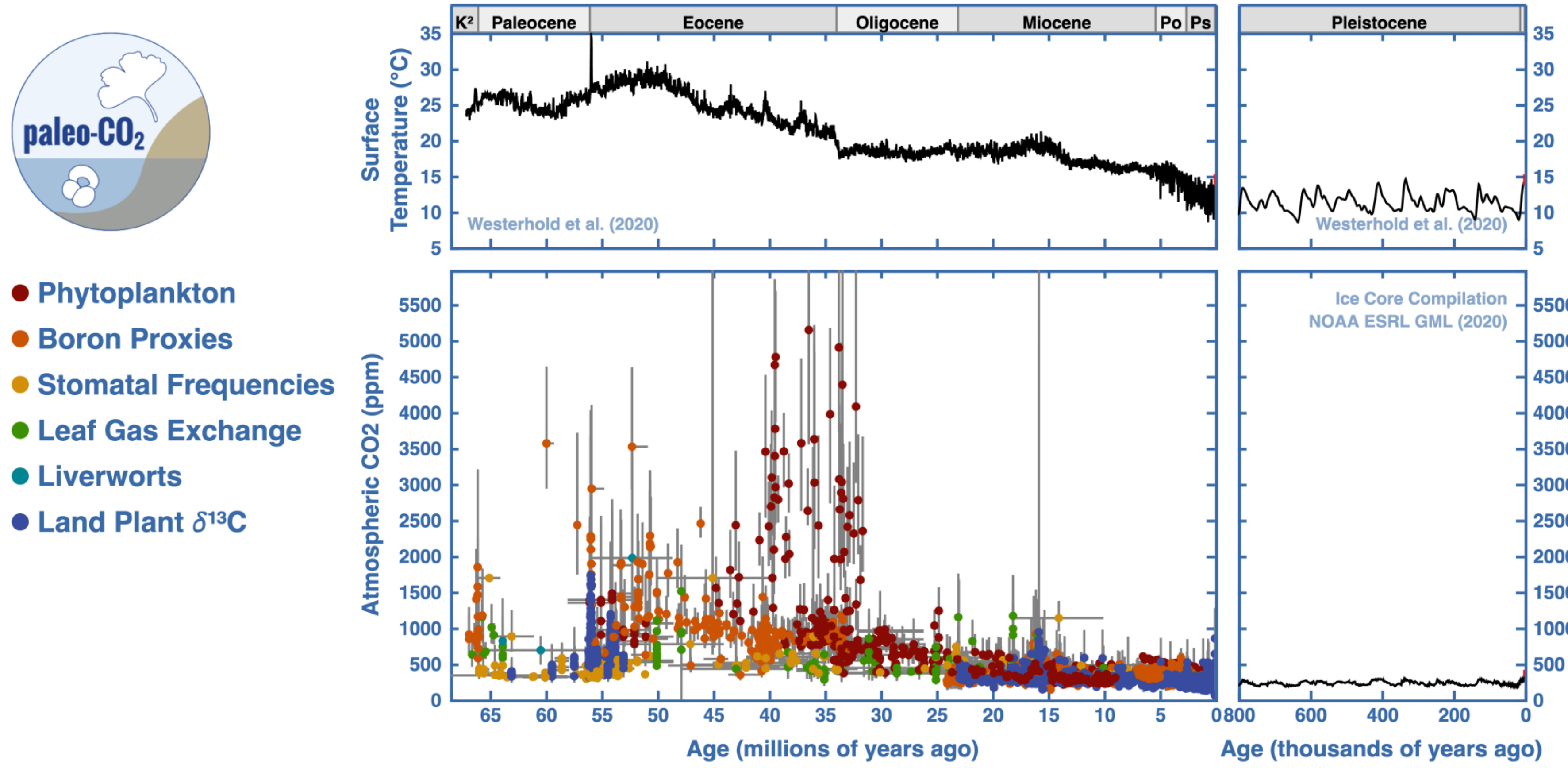
Delmotte et al., 2004

Comparable warm times are in the longer term past.



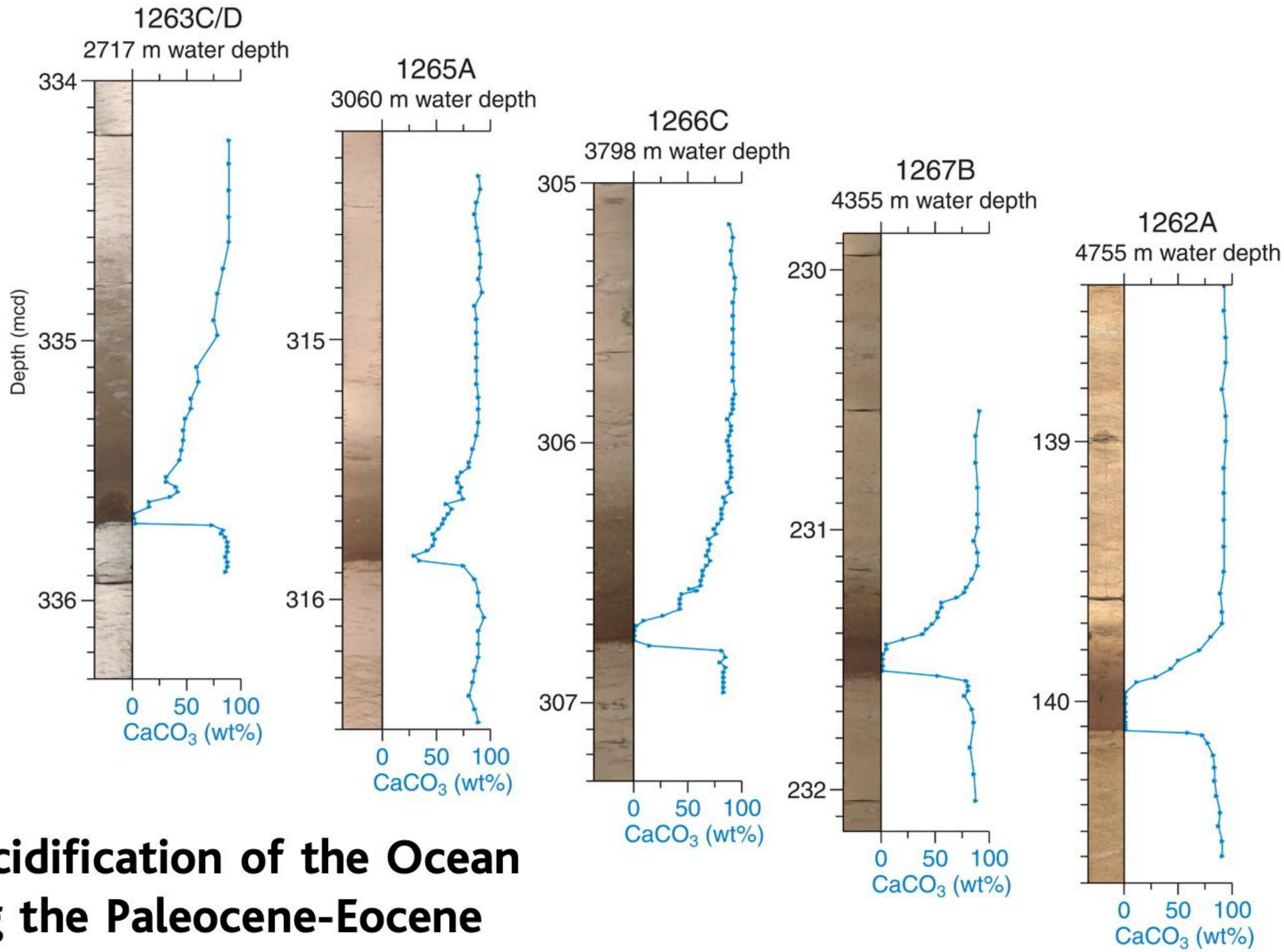
Burke et al., 2018

Secular changes provide "simple" information on climate's controls.



paleo-co2.org; Hönisch et al., in review

Rapid processes are recorded in deep time.

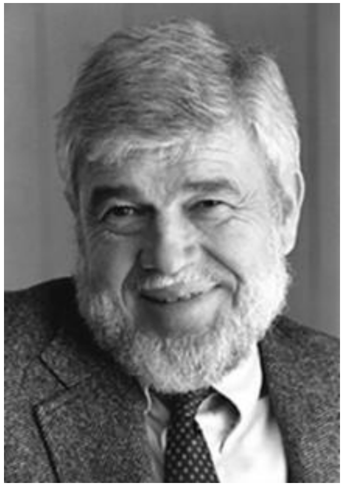


Rapid Acidification of the Ocean During the Paleocene-Eocene Thermal Maximum

James C. Zachos,[1*] Ursula Röhl,[2] Stephen A. Schellenberg,[3] Appy Sluijs,[4] David A. Hodell,[6] Daniel C. Kelly,[7] Ellen Thomas,[8,9] Micah Nicolo,[10] Isabella Raffi,[11] Lucas J. Lourens,[5] Heather McCarren,[1] Dick Kroon[12]

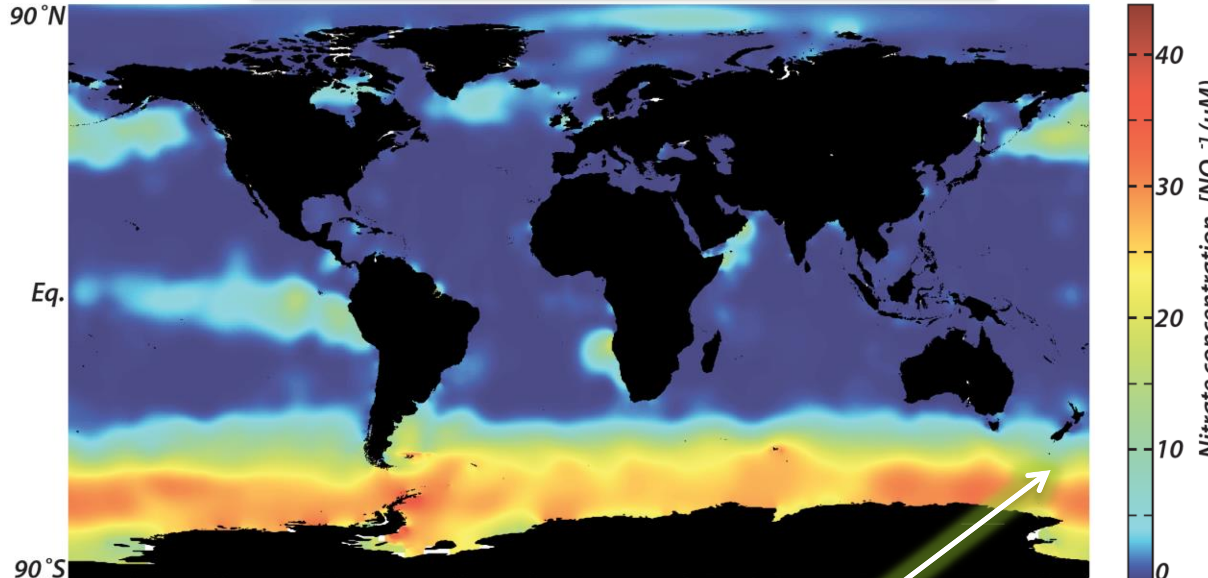
2005

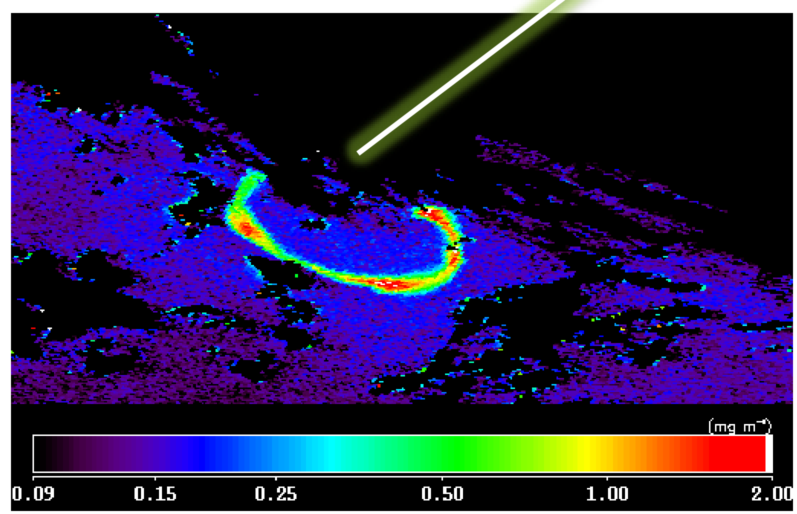
Iron in the ocean



John Martin (1935-1993)

unused nutrients at the surface





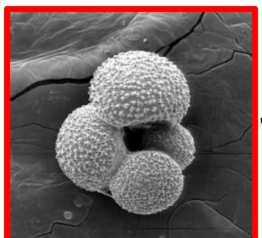
Phytoplankton bloom from iron release

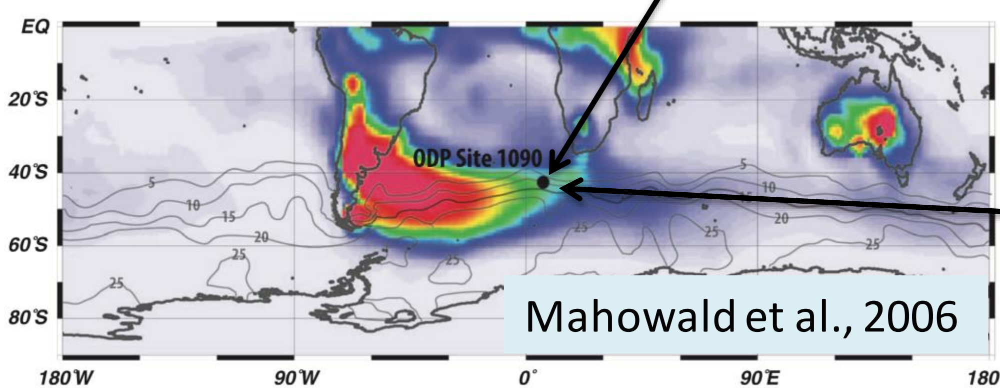
GLACIAL-INTERGLACIAL CO_2 CHANGE:
THE IRON HYPOTHESIS

John H. Martin

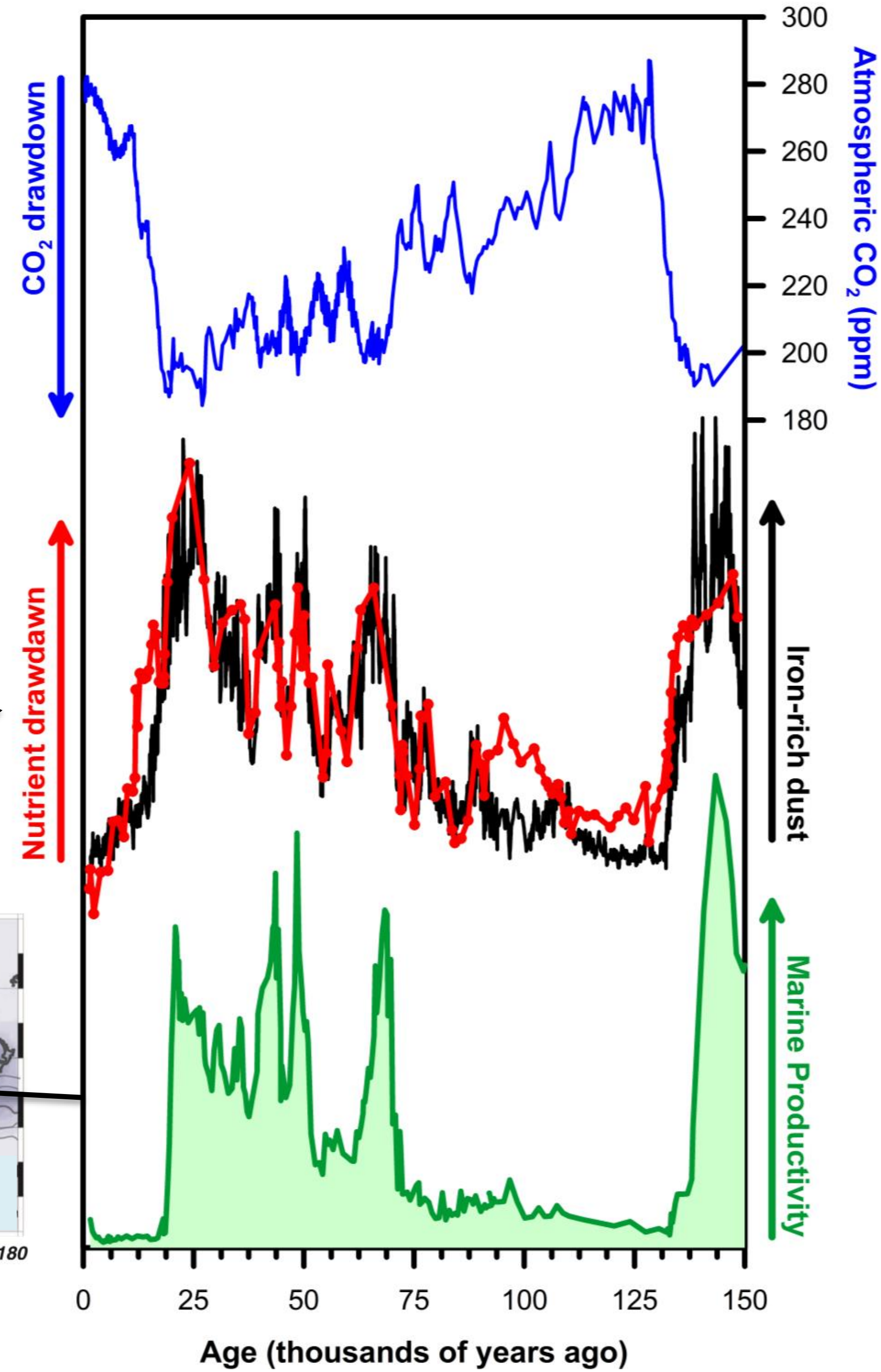
Moss Landing Marine Laboratories
Moss Landing, California

Iron fertilization in the Subantarctic during ice ages



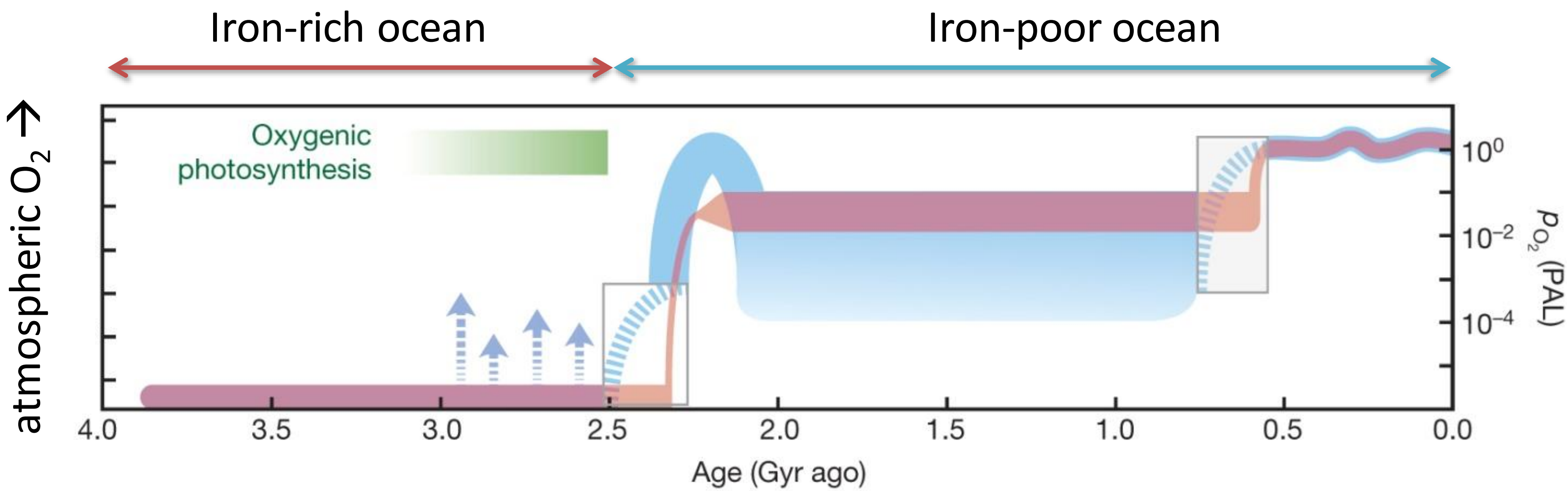


Mahowald et al., 2006



Martinez-Garcia et al., 2014

Broader implications



Origins of life and atmospheric O_2 billions of years ago → Atmospheric CO_2, climate, and life now

Point of comparison for proposals of purposeful iron fertilization

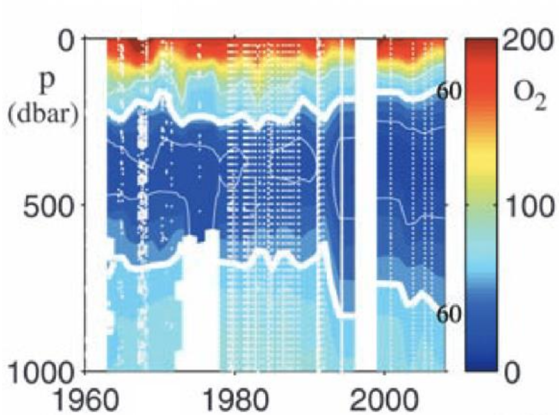
Lyons et al., 2014

Oxygen-deficient zones and global warming

Expanding Oxygen-Minimum Zones in the Tropical Oceans

Lothar Stramma,[1*] Gregory C. Johnson,[2] Janet Sprintall,[3] Volker Mohrholz[4]

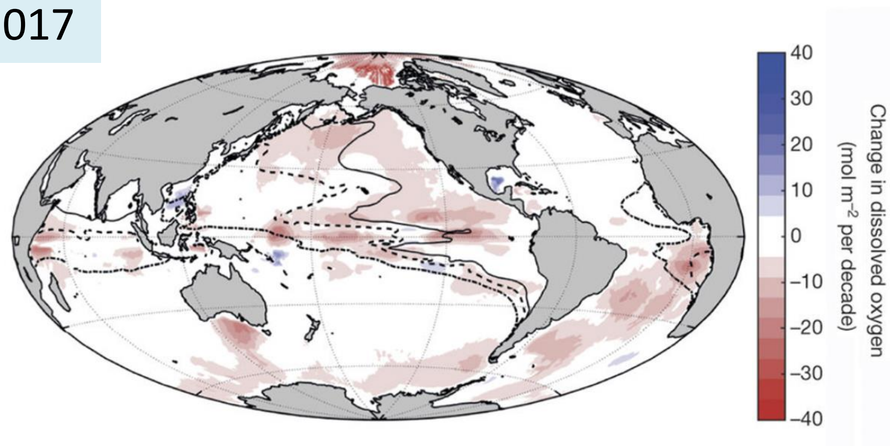
2008



Decline in global oceanic oxygen content during the past five decades

Sunke Schmidtko[1], Lothar Stramma[1] & Martin Visbeck[1,2]

2017

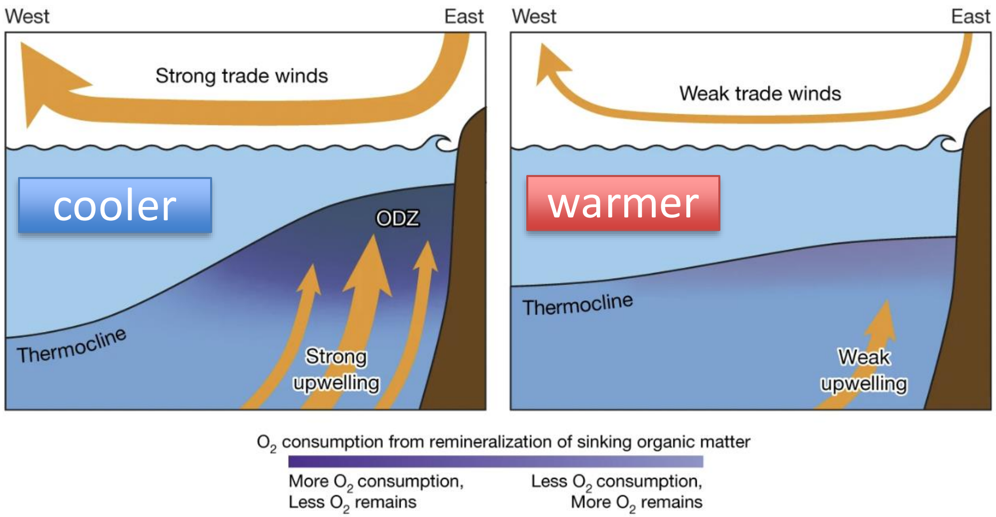


Oceans suffocating as huge dead zones quadruple since 1950, scientists warn

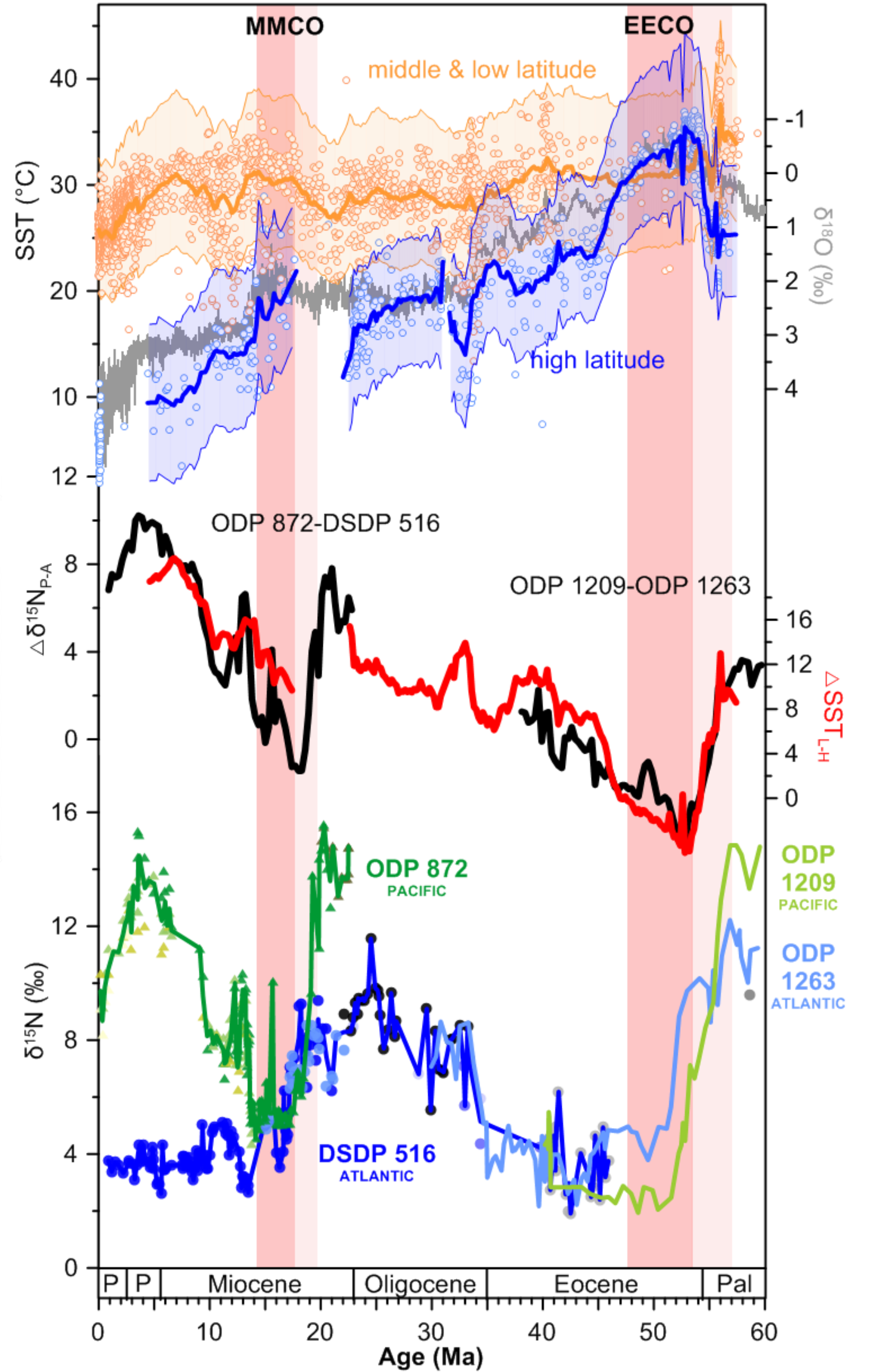
Areas starved of oxygen in open ocean and by coasts have soared in recent decades, risking dire consequences for marine life and humanity

The Guardian, 2018
Breitberg et al., 2018

Past warm periods: Reduced open ocean suboxia



Hess et al., 2023



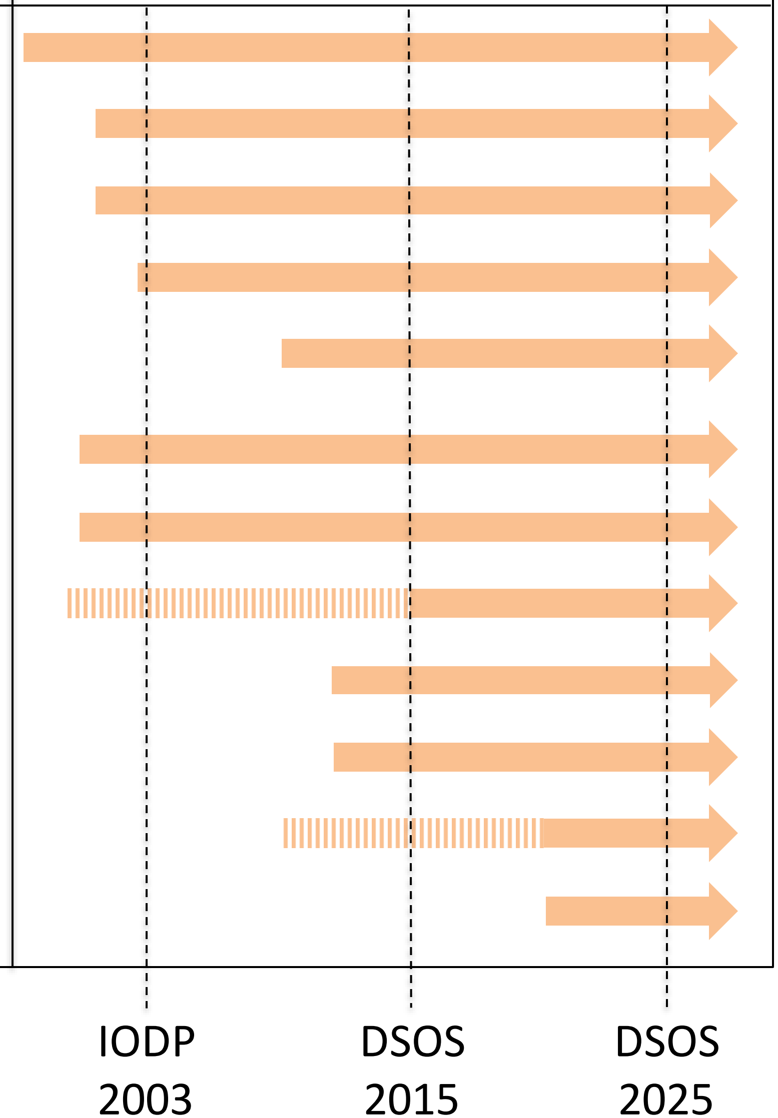
Auderset et al., 2022

Proxies for a growing list of environmental processes

Parameter	Tools
Temperature	$\delta^{18}O$, biomarkers (U^{K}_{37}, TEX_{86}), cation ratios (Mg/Ca, Sr/Ca, Li/Mg), Δ_{47}, pore waters, microfossil assemblages
Sea level/ice volume on land	$\delta^{18}O$ deconvolution (with T proxy), basin $\delta^{18}O$, porewater $\delta^{18}O$, U/Th dating
Ocean circulation	$\delta^{18}O$/density, $\delta^{18}O$ budget, εNd, radiocarbon, $\delta^{13}C$, $^{231}Pa/^{230}Th$, grain size
Sea ice extent	Microfossil assemblages (diatoms, foraminifera), biomarkers (IP_{25}), $\delta^{18}O$ differencing
Seawater composition	$\delta^{44}Ca$, $\delta^{26}Mg$, $\delta^{41}K$, $\delta^{7}Li$, $^{87}Sr/^{86}Sr$, $^{187}Os/^{188}Os$, ε_{Nd}, $\delta^{30}Si$, $\delta^{34}S$, pore water and fluid inclusions
CO_2 system	$\delta^{11}B$, B/Ca, $\delta^{13}C$ of biomarkers and other organics (ε_p), dissolution index, carbonate accumulation rate
Dissolved oxygen	$\Delta\delta^{13}C$, $\delta^{15}N$, redox-sensitive element concentrations (e.g., I, Cd, Mo, V, U, Zn, Cu) and isotopes (e.g., S, Fe, Tl, Mo, V, U), biomarker preservation
Biological productivity	^{230}Th-,^{3}He-normalized fluxes of biogenic materials (opal, organic carbon, carbonate), biogenic Ba, U, Cd, $^{231}Pa/^{230}Th$, $^{10}Be/^{230}Th$, microfossil assemblages
Surface and deep nutrients	Bioactive element ratios to Ca (Cd, Ba, Zn) and isotope ratios (e.g., $\delta^{15}N$, $\delta^{30}Si$, Ge/Si, $\delta^{114}Cd$, $\delta^{66}Zn$, $\delta^{138}Ba$, $\delta^{60}Ni$, $\delta^{53}Cr$)
Land inputs and conditions	Dust composition and chemistry, pollen, phytoliths, clay chemistry, n-alkane concentration and isotopes ($\delta^{13}C$, δD)
Ecological conditions	Trophic level and symbiosis (amino acid isotopes, size-specific carbonate $\delta^{13}C$, fossil-bound $\delta^{15}N$)

Ongoing proxy development ensures new findings from continued sediment coring.

Parameter	Tool	Development Timeline
Temperature	Carbonate $\delta^{18}O$	
	Alkenones (U^{k}_{37})	
	Mg/Ca	
	GDGTs (TEX_{86})	
	Clumped Isotopes (Δ_{47})	
Dissolved oxygen	Redox element conc.	
	Bulk sediment $\delta^{15}N$	
	$\Delta\delta^{13}C$	
	$\delta^{53}Cr$	
	I/Ca	
	Fossil-bound $\delta^{15}N$	
	$\varepsilon^{205}Tl$	



Growing symbioses among paleoclimate, marine geology+geophysics, and deep biosphere

Drill, baby, drill!