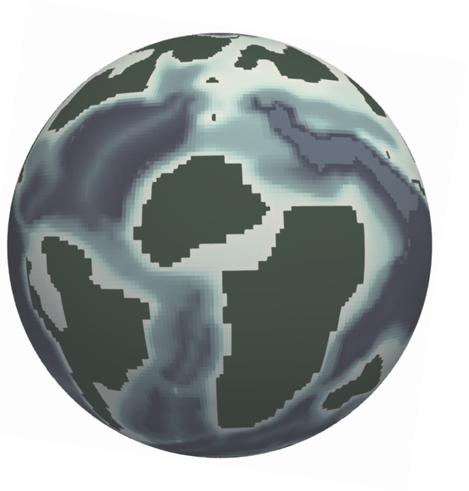
antasarr@uoregon.edu



An isotope enabled model perspective on late Cretaceous Sea Surface Temperatures

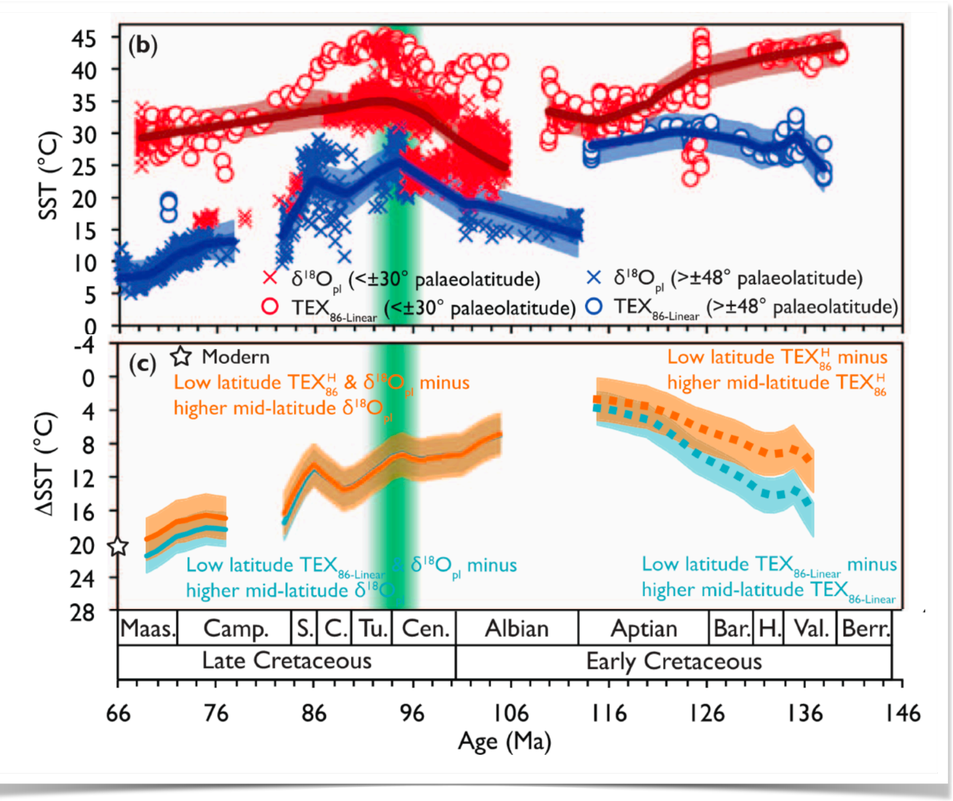
A-C. Sarr, C.J. Poulsen, E.L. Do

CESM Paleoclimate Working Group Meeting - February 26th 2024

UNIVERSITY OF OREGON

Extremely warm high latitudes during the Cenomanian-Turonian ?

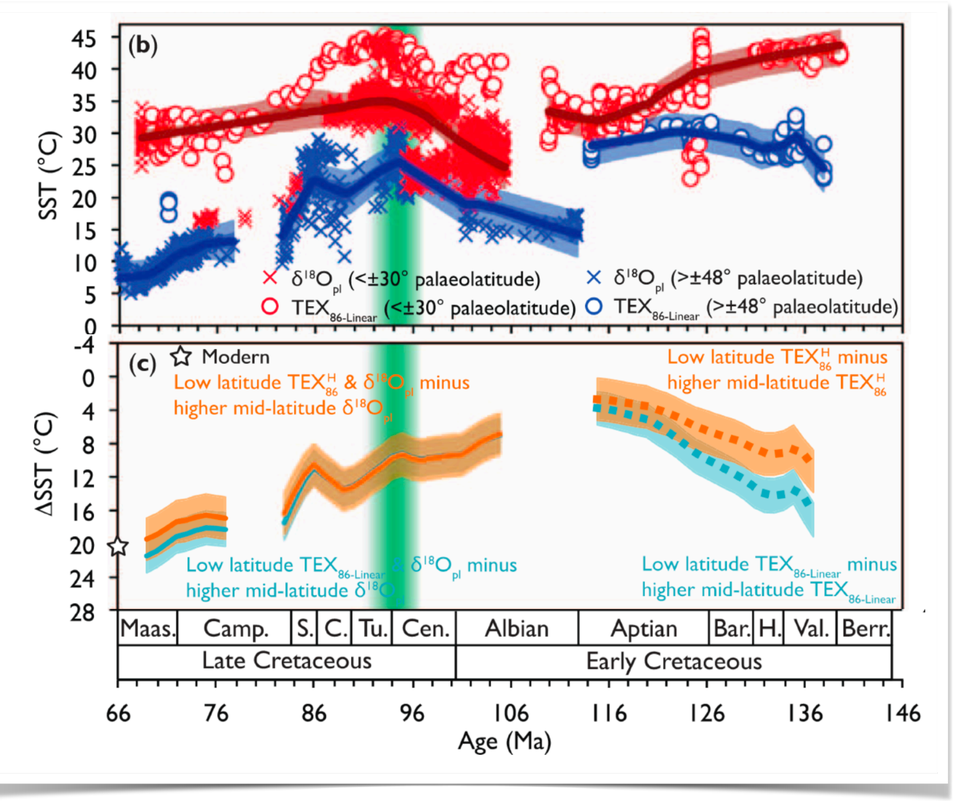
O'Brien et al. (2018)



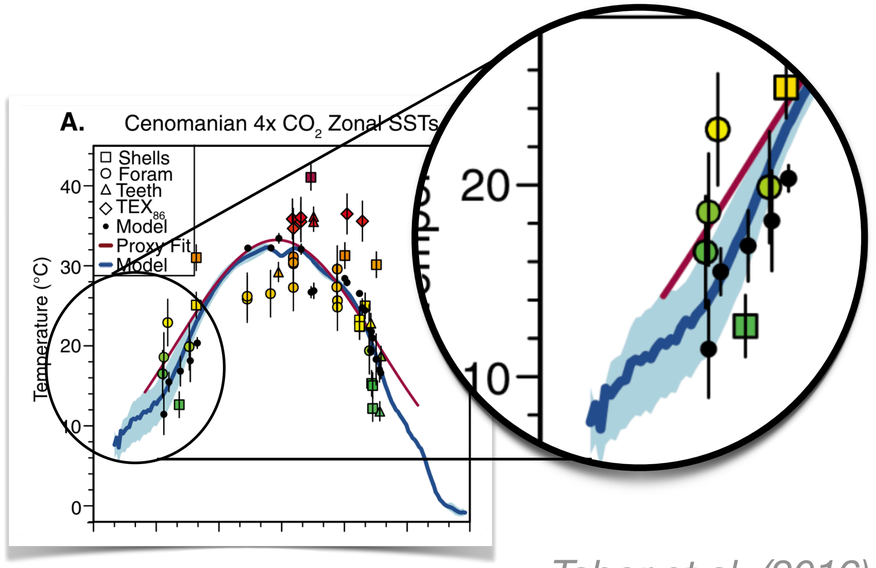
- Cenomanian-Turonian records suggest **extreme temperature** including at high latitudes (**up to 30°C,** Huber et al., 2018**).**
- Result in dampen meridional gradient of temperatures (5-10°C), lower than simulated gradients.

Extremely warm high latitudes during the Cenomanian-Turonian ?

O'Brien et al. (2018)

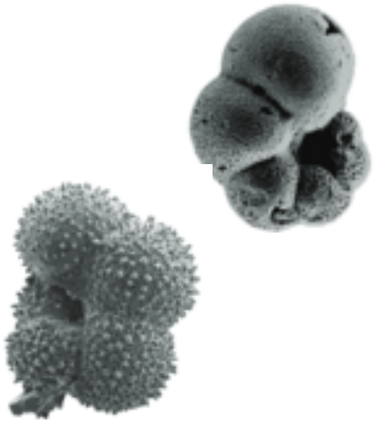


- CCSM4 is unable to reproduce such high temperature at SHLs, like many other models.



Tabor et al. (2016)

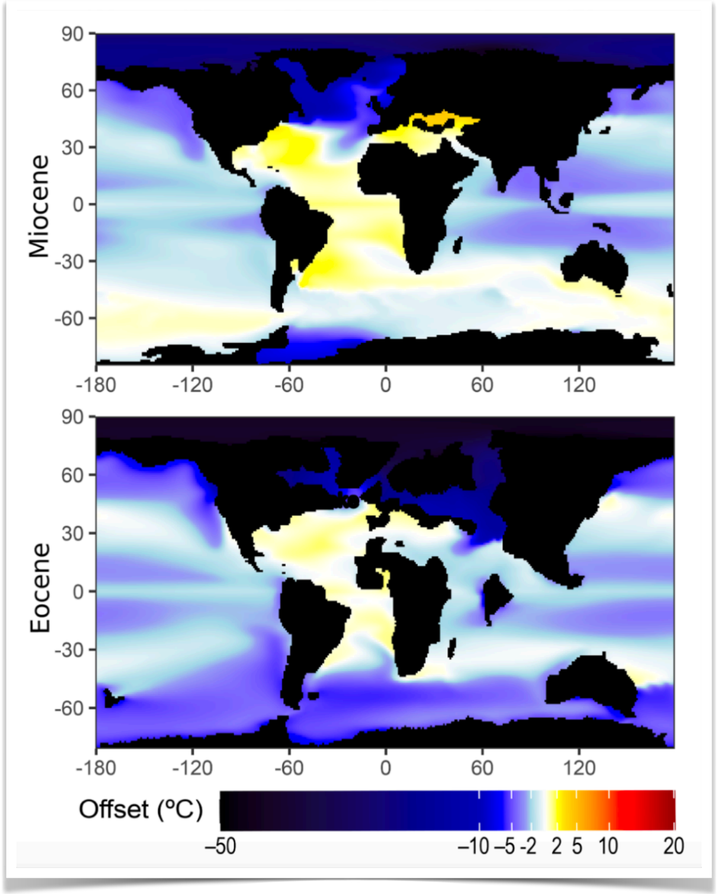
Revisiting $\delta^{18}Oc$ paleotemperature record



$$T\ (°C) = 16.5 - 4.8\ (\delta^{18}Oc - \delta^{18}O_{sw} - 0.27)$$

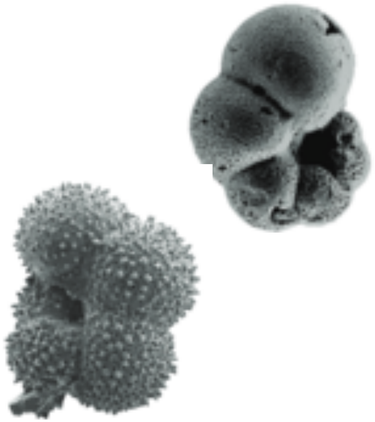
(Bemis et al., 1998)

- $\delta^{18}Oc$-based paleo-temperature suffers from uncertainty in estimating $\delta^{18}Osw$.
- Most of the studies assume a canonical value of -1.0 ‰ (ice-free world) or apply in addition a latitudinal correction based on present-day distribution.



Gaskell & Hull (2023)

Revisiting $\delta^{18}Oc$ paleotemperature record



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(Bemis et al., 1998)

PALEOCEANOGRAPHY, VOL. 18, NO. 2, 1031, doi:10.1029/2002PA000848, 2003

Extreme polar warmth during the Cretaceous greenhouse? Paradox of the late Turonian $\delta^{18}O$ record at Deep Sea Drilling Project Site 511

Karen L. Bice
Department of Geology and Geophysics, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, USA

Brian T. Huber
Department of Paleobiology, Smithsonian National Museum of Natural History, Washington, D. C., USA

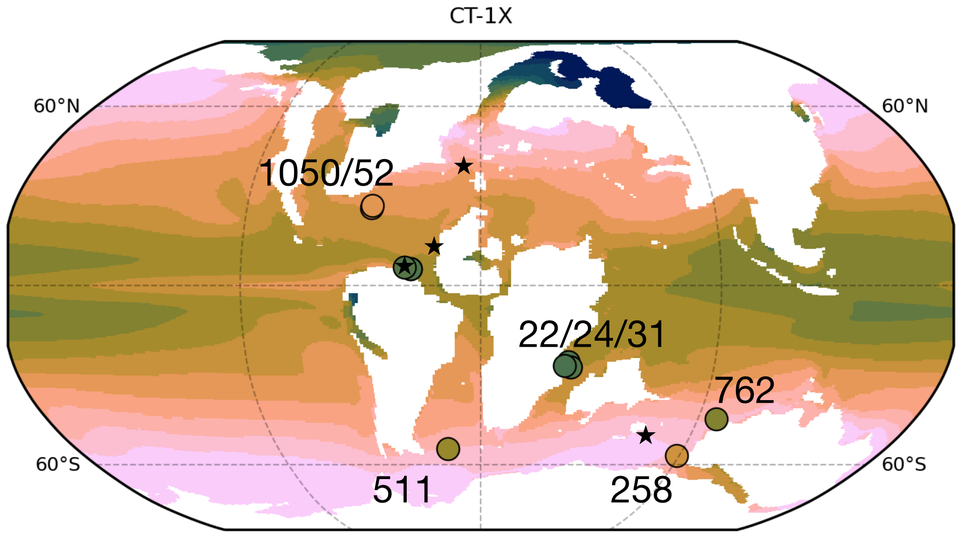
Richard D. Norris
Scripps Institution of Oceanography, University of California, San Diego, La Jolla, California, USA

- $\delta^{18}Oc$ measured at southern high latitudes (SHLs) sites like DSDP511 (Southern Atlantic, ~60°S) shows values as low as ~-4.5 ‰
- With standard $\delta^{18}Osw$ assumption this would suggest temperature of 27-30°C

✓ *Original publication questioned the validity of the temperature reconstructions (Bice et al., 2003)*

Note: -1.0 ‰ = ~4.8 °C

Simulation & proxy records



Isotope-enabled Ocean-atmosphere simulations (iCESM1.2)

- Cenomanian-Turonian setup (*Tabor et al., 2016, Ladant et al., 2020)*
- 1-, 3- and 6- times pre-industrial pCO_2

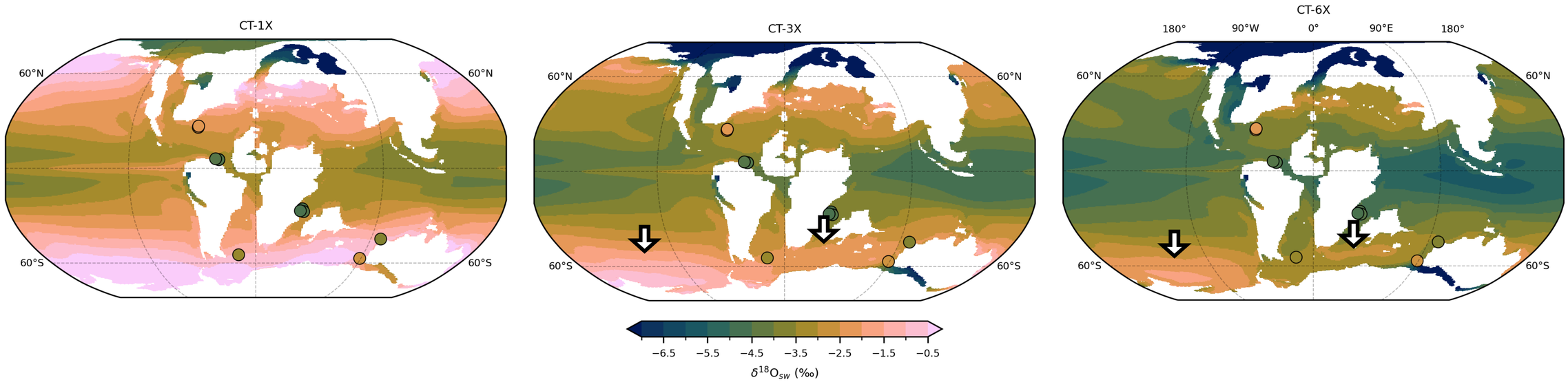
Planktonic foraminifera $\delta^{18}Oc$ records (89.5 to 100.5 Ma)

Good to excellent preservation

- *O'Brien et al. (2018)*
- *Huber et al. (2018) - SHLs sites*

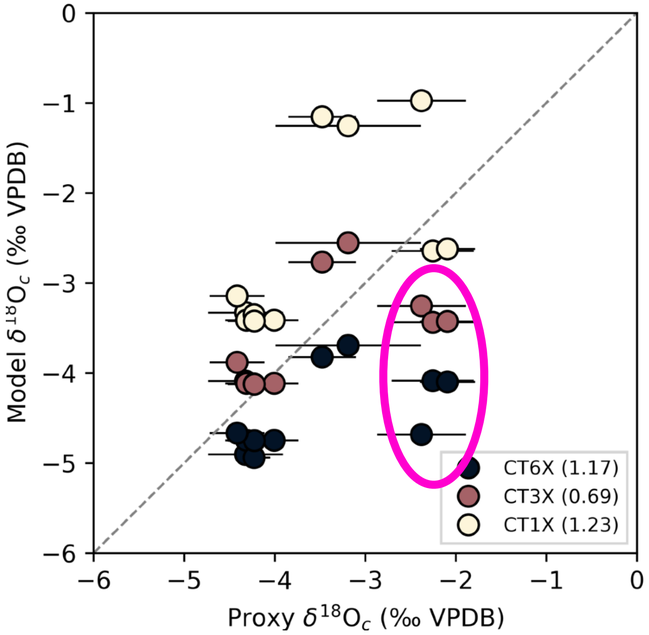
Simulated $\delta^{18}Oc$

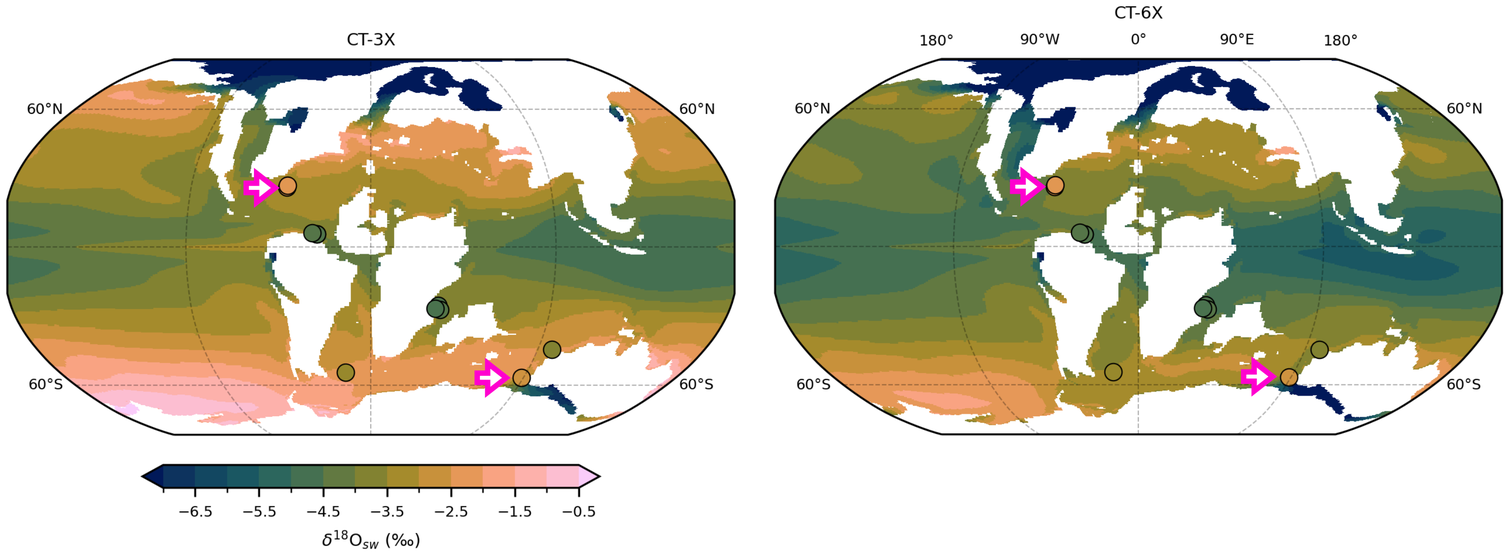
T (°C) = 16.5 – 4.8 ($\delta^{18}Oc$ - $\delta^{18}O_{sw}$ - 0.27)
(Bemis et al., 1998)



- $\delta^{18}Oc$ distribution have a latitudinal pattern with more negative value in the tropics and enriched values at high latitude
- Southern Atlantic-Indian ocean basins have more depleted value than adjacent Pacific basin

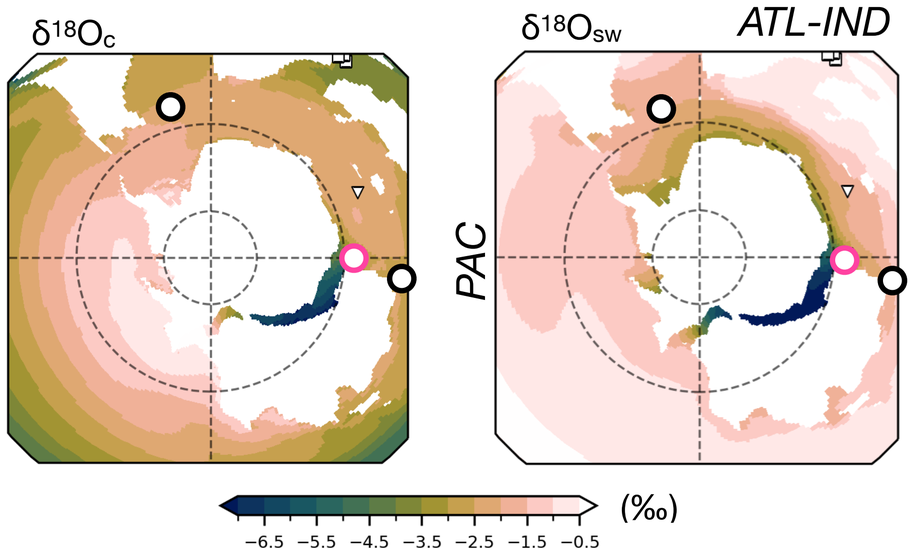
δ^{18}Oc model-data fit

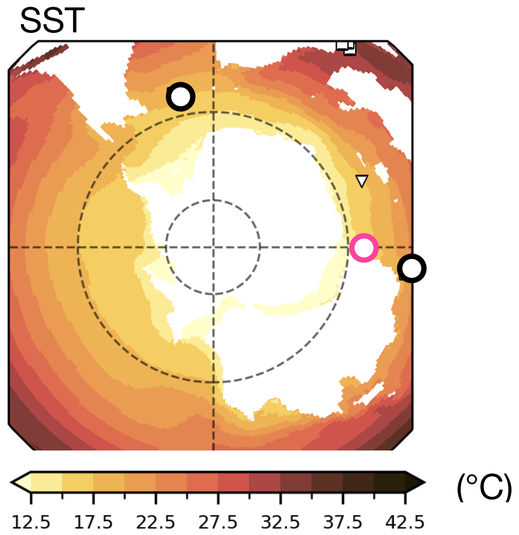


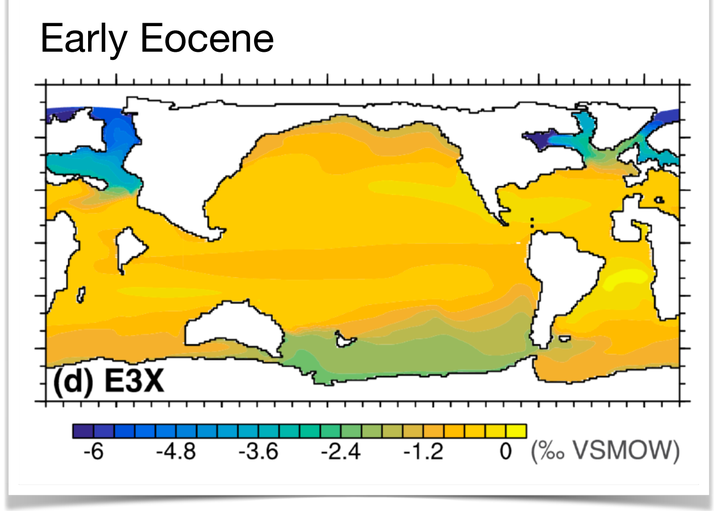


- 3x CO_2 simulation is the best fit with data
- Some sites (Central ATL and SW Australia) have a strong discrepancy with any of the simulations

Patterns of $\delta^{18}O_{sw}$



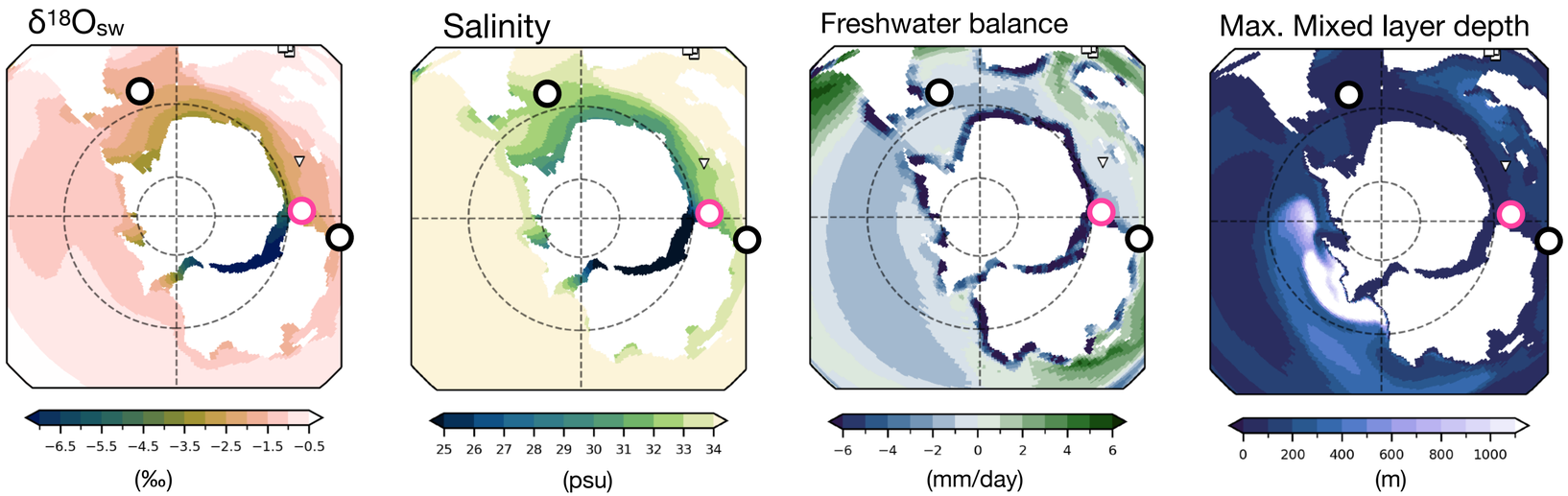


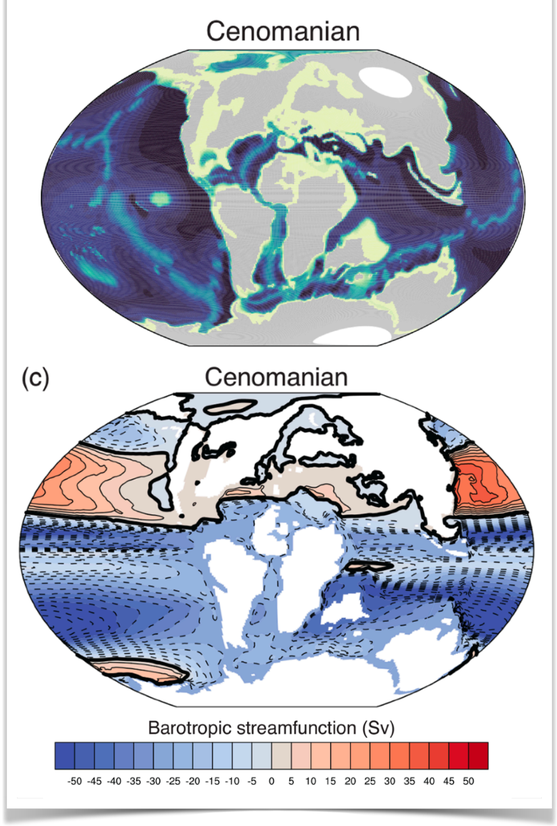


Zhu et al., 2020

- $\delta^{18}O_{sw}$ range -9.0 to -1.5 ‰ in the Atlantic-Indian part of Southern Ocean
- Depleted $\delta^{18}O_{sw}$ might explain depleted $\delta^{18}O_c$ without requiring extreme SHLs temperatures
- Difference in paleogeography configuration can be responsible for important difference in $\delta^{18}O_{sw}$ distribution

Patterns of $\delta^{18}O_{sw}$

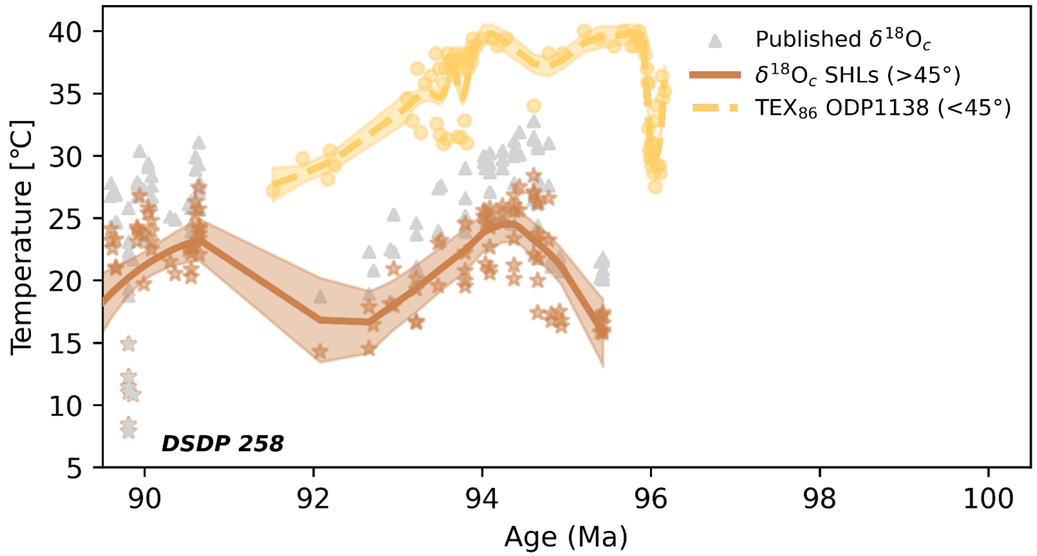




Ladant et al., 2020

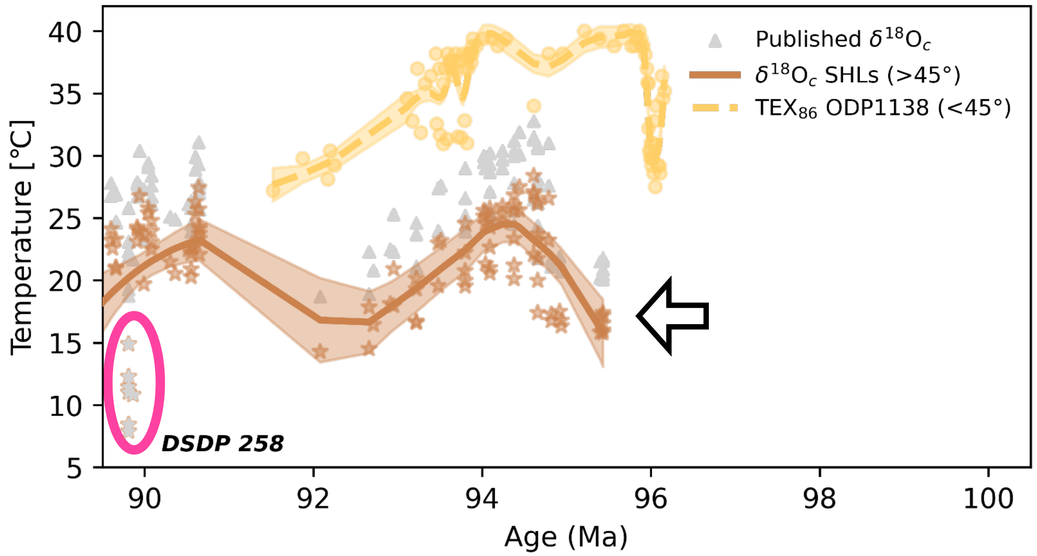
- Large input of depleted $\delta^{18}O$ water from runoff in the Southern Ocean
- Atlantic and Indian basins of SO are isolated from the global circulation, so this freshwater supply is not well mixed
- Mixing happens in the Pacific basin, explaining less depleted $\delta^{18}O_{sw}$ at this location

Adjusted temperature estimates

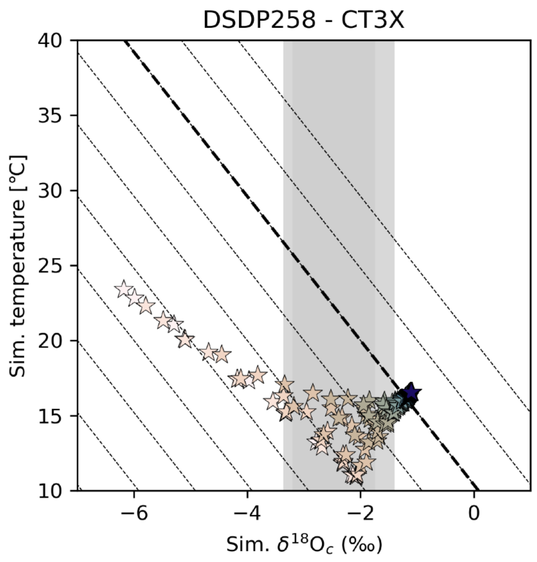


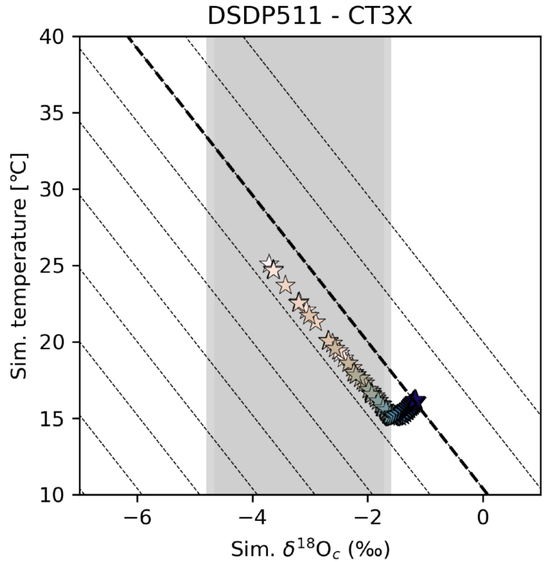
- SHLs adjusted temperature are on average 7°C lower than published estimates

Adjusted temperature estimates

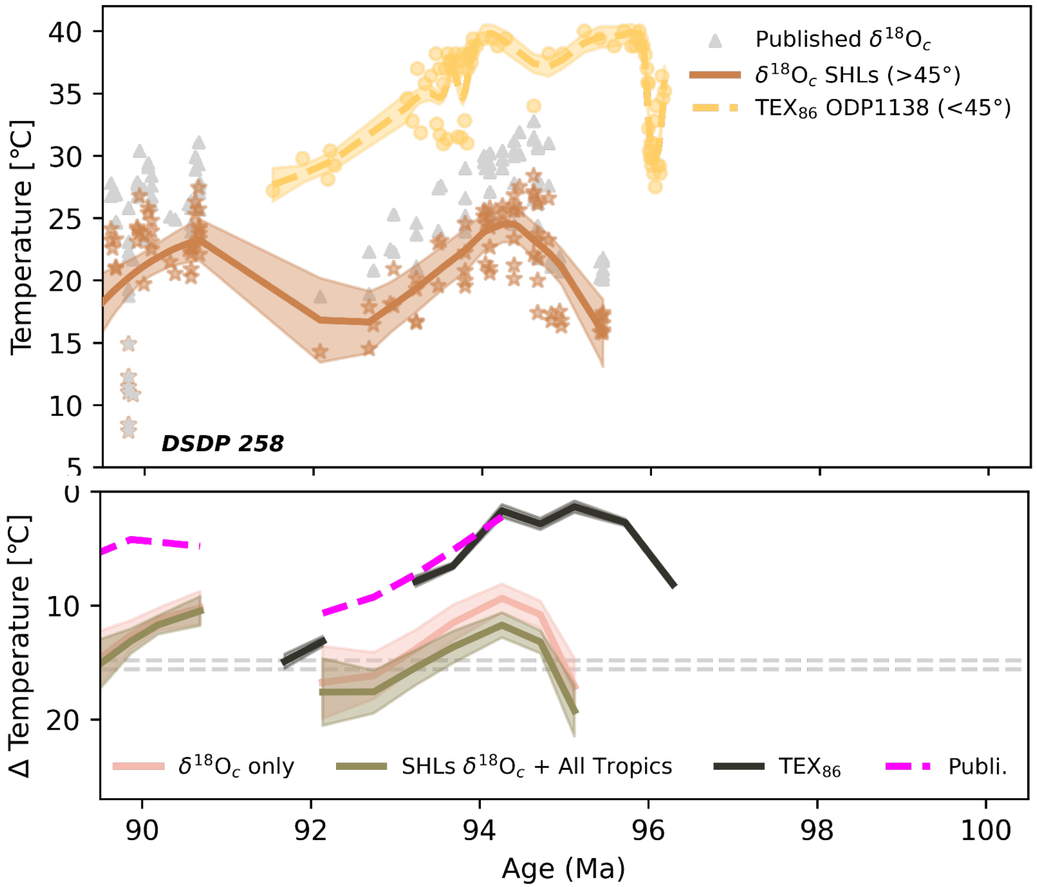


- SHLs adjusted temperature are on average 7°C lower than published estimates
- DSDP258 site likely not record surface temperature





Adjusted temperature estimates



- Using adjusted temperature estimates increase latitudinal gradient estimates for the Cenomanian-Turonian
- The adjusted temperature gradient is closer to simulated gradient.
- Close to Gaskell *et al.* (2022) gradient estimate (15°C)

antasarr@uoregon.edu

Conclusion

- Peculiar Southern ocean configuration during the Cenomanian-Turonian likely have resulted to non-normal conditions and more depleted δ^{18}Osw.
- SHLs paleo-temperature were lower (18-24°C) than initially assumed (27-30°C).
- Latitudinal gradient are therefore higher than initial publication assumed.
- Model-data fit is improved but some inconsistencies still exist.
- Limitation : paucity of the record / need to understand better foraminifera ecology and how it impacts data interpretation.