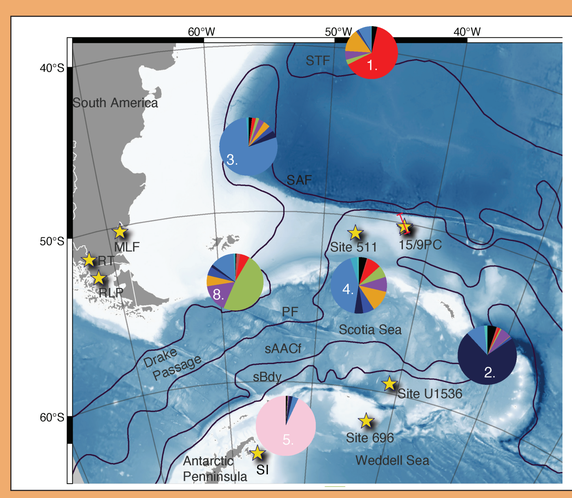
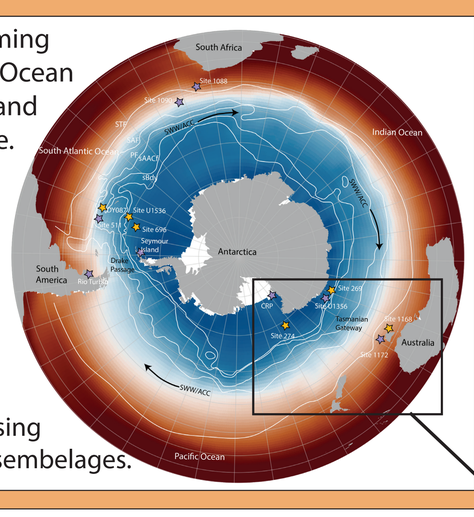
Stepwise Oligocene–Miocene breakdown of sub-polar gyres and strengthening of the Antarctic Circumpolar Current



We here elaborate on the nature and timing of the transition from Eocene Southern Ocean subpolar gyres to the onset of the ACC and consequences for ocean, climate and ice.

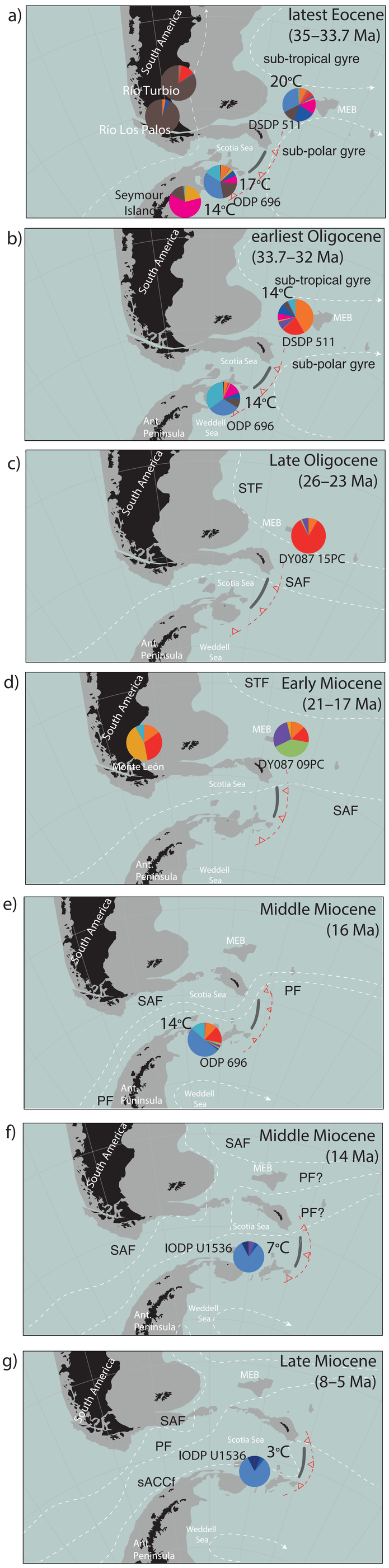
Approach: Dinocysts and TEX_{86}- SST

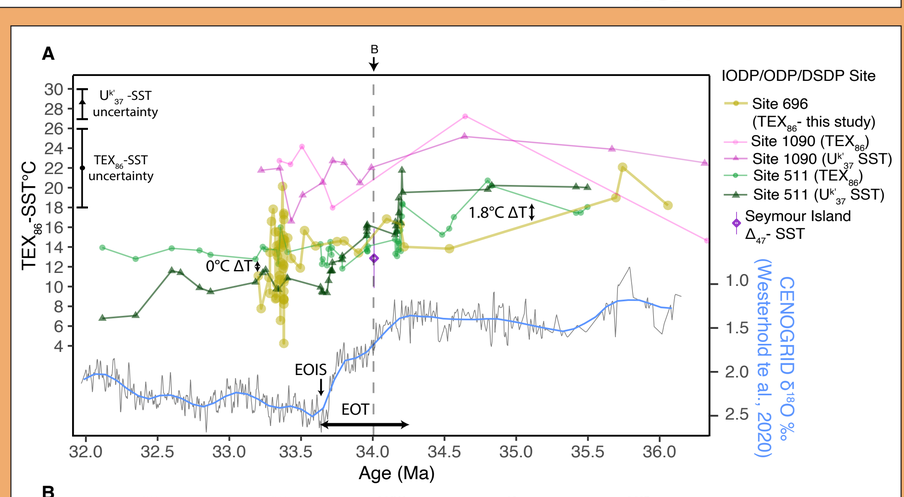
We reconstruct the latitudinal SST gradients, variability and position of ocean frontal systems and oceanic environmental conditions of the Southern Ocean from the Late Eocene until Late Miocene (37-5 Ma) using TEX_{86}-based SSTs and dinoflagellate cyst assembelages.

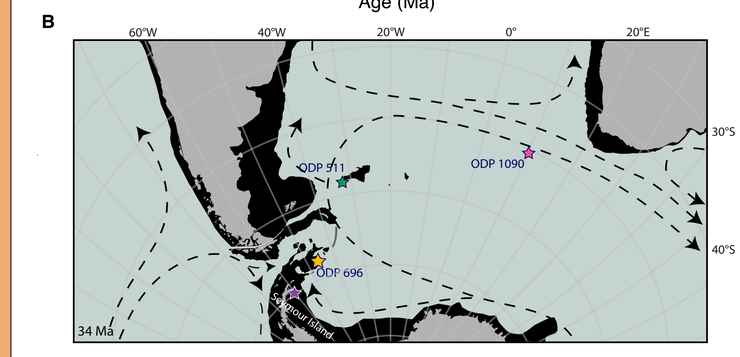


Frida S. Hoem, Adrián López-Quirós, Suzanna vd Lagemaat, Karlijn vd Broek, Johan Etourneau, Steve M. Bohaty, Claus-Dieter Hillenbrand, Robert Larter, Tim E. van Peer, Marie-Alexandrine Sicre, Carlota Escutia, Henk Brinkhuis, Francien Peterse, Francesca Sangiorgi and Peter K. Bijl

Universiteit Utrecht
erc European Research Council
IODP International Ocean Discovery Program
ORCID
@Frida_SH
@uu_oceanice
f.s.hoem@uu.nl

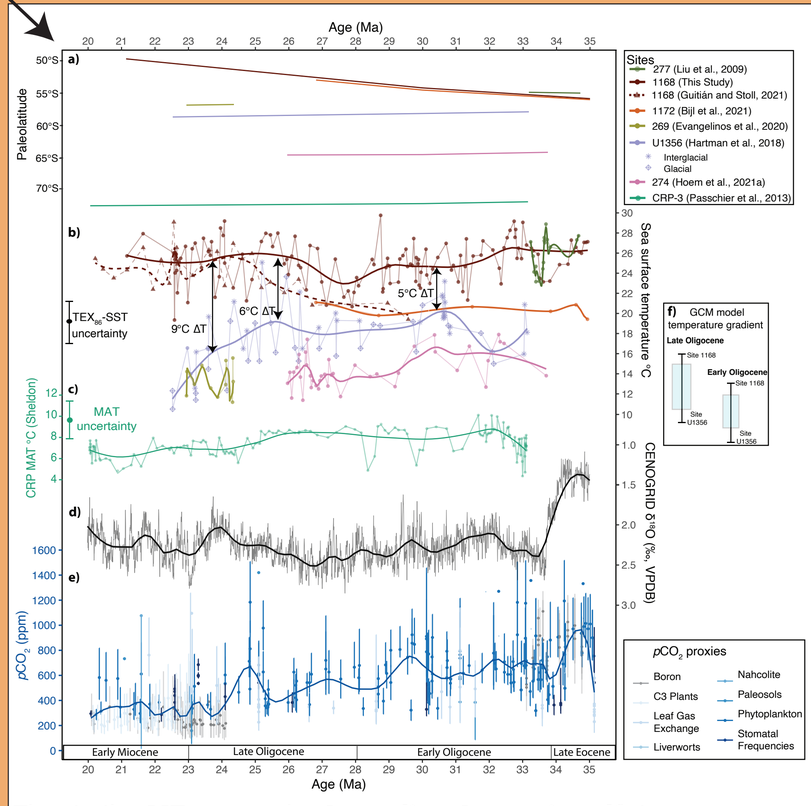






South Atlantic Late Eocene - Oligocene

The similar SSTs and dinocyst assemblages at Sites 696 and 511 in the Late Eocene–Early Oligocene South Atlantic indicates a persistent subpolar gyre circulation, which relies on absence of strong throughflow across the Drake Passage. In the Late Oligocene, all cold water/Antarctic endemic dinocysts are replaced by warm water affiliated species suggesting breakdown of the dominant gyral circulation.



The similar SSTs across the **Australian-Antarctic gulf** sites during the Late Eocene–Early Oligocene (37-27 Ma) indicate the presence of robust subpolar gyral circulations after the onset of Antarctic glaciation. In the Late Oligocene Antarctic-proximal sites progressively cooled, increasing the SST gradient in the Australian-Antarctic gulf (>9°C) indicating a weakened gyral circulation.
The timing of Antarctic-proximal cooling coincided with sedimentary and kinmatic reconstructions of Drake Passage deepening after 26 Ma. Matching ocean model experiments demonstrating that Drake Passage deepening weakened gyral circulation, enhanced thermal isolation and cooled Antarctic proximal waters.

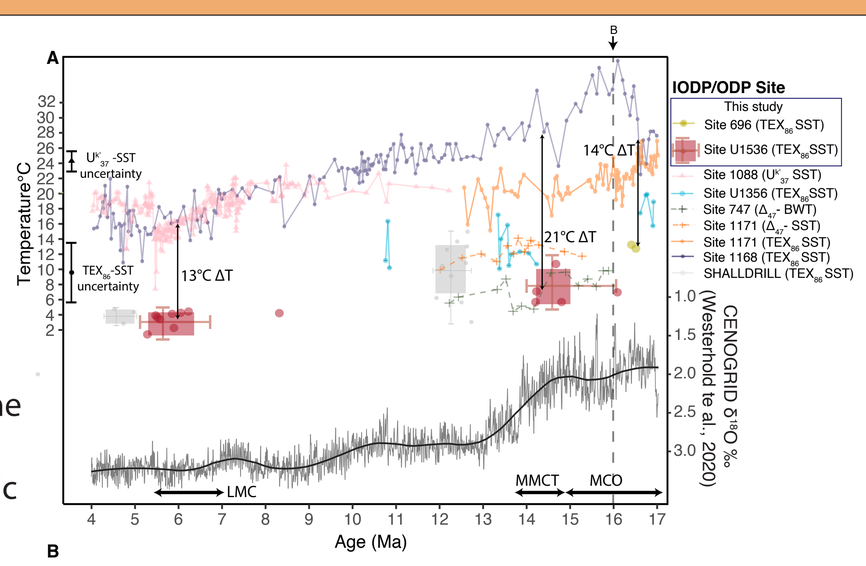
South Atlantic Miocene

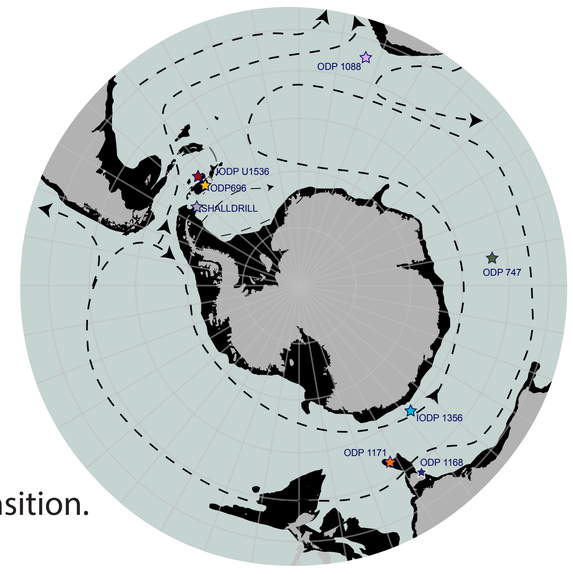
By the early Miocene dinocyst assemblages show the Subtropical Front moved northwards, possibly linked to a strenghtening ACC throughflow.
We have no South Atlantic SST records between the early Oligocene and middle Miocene.

The relatively high abundance warm-oligotropic dinocyst assemblages and temperate SSTs (14°C) during the Miocene Climatic Optimum (16 Ma) indicate that the Subantarctic front was located closer to Antarctica, either due to tectonic configurations or polaward shift in westerlies.

During the Middle Miocene Climatic Transition (14 Ma) oligotrophic, warmer water indicative dinocysts are replaced by protoperidinioid dinocysts indicative of cold, sea-ice-influenced Antarctic-proximal surface water conditions. Meanwhile SSTs drop from 14°C to 7–5°C. This is consistent with the drop in atmospheric CO_2 (below 300 ppm) and increase in benthic foraminifera $\delta^{18}O$, indicating global cooling conditions and/or increasing ice volume.

The southern South Atlantic was the coldest region in the Southern Ocean with perennial sea ice and likely the main deep water formation location after the Middle Miocene Climatic Transition.





CONCLUSION

Although time and geographic coverage are sparse, our SST and dinocyst data show the stepwise breakdown of subpolar gyres and the transition into the modern-like oceanographic regime with the development of strong frontal systems, latitudinal gradients, perennial sea ice and deep-water formation. We demonstrate, with modelling and geological data, that while climate and ice volume changes determine the strength of latitudinal SST gradients and position of ocean fronts on orbital time scales, gateway configurations play a large role in long-term trends.

Reference data: TEX_{86}-SST records: Site U1356 (Miocene: Sangiorgi et al., 2018, Oligocene: Hartman et al., 2018), Site 1168 (Miocene; Hou et al., 2022, Oligocene: Hoem et al., 2022), Site 1171 (Leutert et al., 2020), Site 277 (Liu et al., 2009), Site 269 (Evangelinos et al., 2020). $U^{K'}_{37}$- SST data: Site 1088 (Herbert et al., 2016), Site 1090 (Lie et al., 2009), Site 511 (Houben et al., 2019). terrestrial temperature from the Cape Roberts Project (CRP; Passchier et al., 2013). Dinocyst data: Site 511 and 696 (Houben et al., 2019), Seymour Island (Douglas et al., 2014), Rio Los Palos (Bijl et al.,2021), Rio Turbio (Guerstein et al., 2014), Monte León Formation (Parras et al., 2020).
Clumped isotope: bottom water temperature (BWT) data from Site 747 (Leutert et al., 2021), SST from Site 1171 (Leutert et al., 2020) and SST from Seymour Island (Douglas et al., 2014).
Benthic foraminiferal $\delta^{18}O$ compilation; CENOGRID (Westerhold et al., 2020). CO_2 compilation from https://www.paleo-co2.org (Hoenisch, 2021). High resolution ocean model (Sauermilch et al., 2021).