Meridional Sea Surface Temperature Gradients in the Southern Indian Ocean over the Last Glacial Cycle

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The Antarctic Circumpolar Current (ACC) and upwelling intensity

Background

- The **ACC flow** causes a net **equatorward Ekman transport** of surface water, which is **replaced by upwelled deep water masses**.
- **Sea surface temperatures (SST)** and **strength and position** influence **upwelling intensities and vertical mixing**.
- **Glacial-interglacial ACC changes** have been hypothesized, but **reconstructions remain ambiguous**[4, 5].

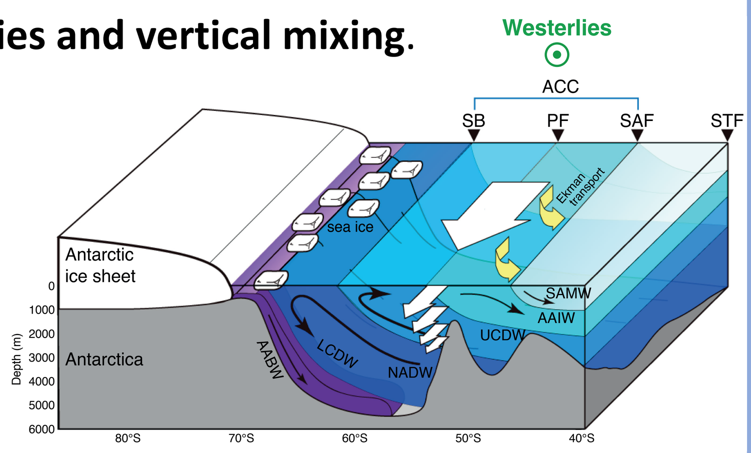


Figure 1. The ACC and upwelling dynamics in the Southern Ocean.

Research Questions

To better constrain **glacial-interglacial dynamics of the ACC** and their impact **on upwelling intensities** and, ultimately, **CO_2 sequestration**, we aim at addressing the following research questions:

- How much did SSTs vary over the last glacial cycle?
- Did the position and/or strength of the ACC vary?
- How may these changes have influenced atmospheric CO_2?

Take Home Message

- **Glacial-interglacial SST amplitudes** are about **8°C**. Lower SSTs **during glacials** may have **strongly reduced the air-sea buoyancy flux, impeding CO_2 outgassing**.
- **Reduced SST gradients during glacials** may indicate a **northward shift of the ACC**. This would have reduced upwelling intensities and CO_2 outgassing.
- **During the Holocene**, an increasing SST gradient may suggest a **strengthening in the ACC flow speed**, enhancing upwelling intensities and CO_2 outgassing.

What did we do?

Geographical Setting

We analyzed **two new sediment cores** close to the **Kerguelen Plateau** in the **Southern Indian Ocean** forming a **latitudinal transect across the ACC**.

- **SAZ: MD11-3357** (44°S, 80°E, 3349 m)
- **AZ: MD11-3353** (50°S, 68°E, 1568 m)

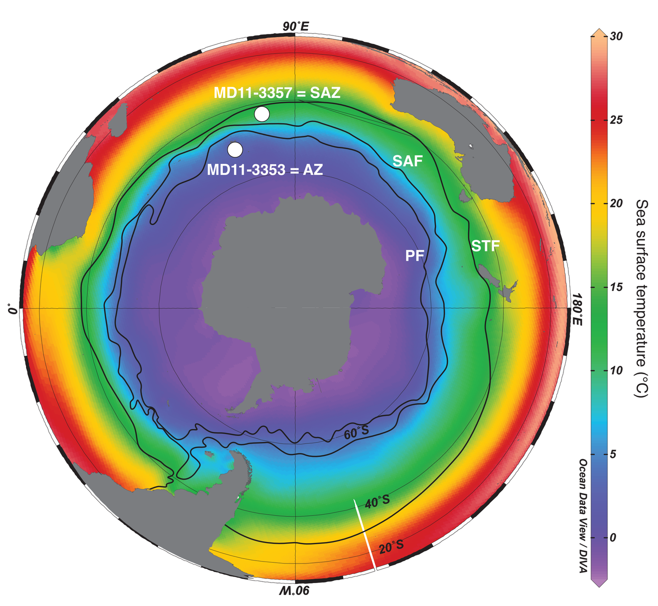
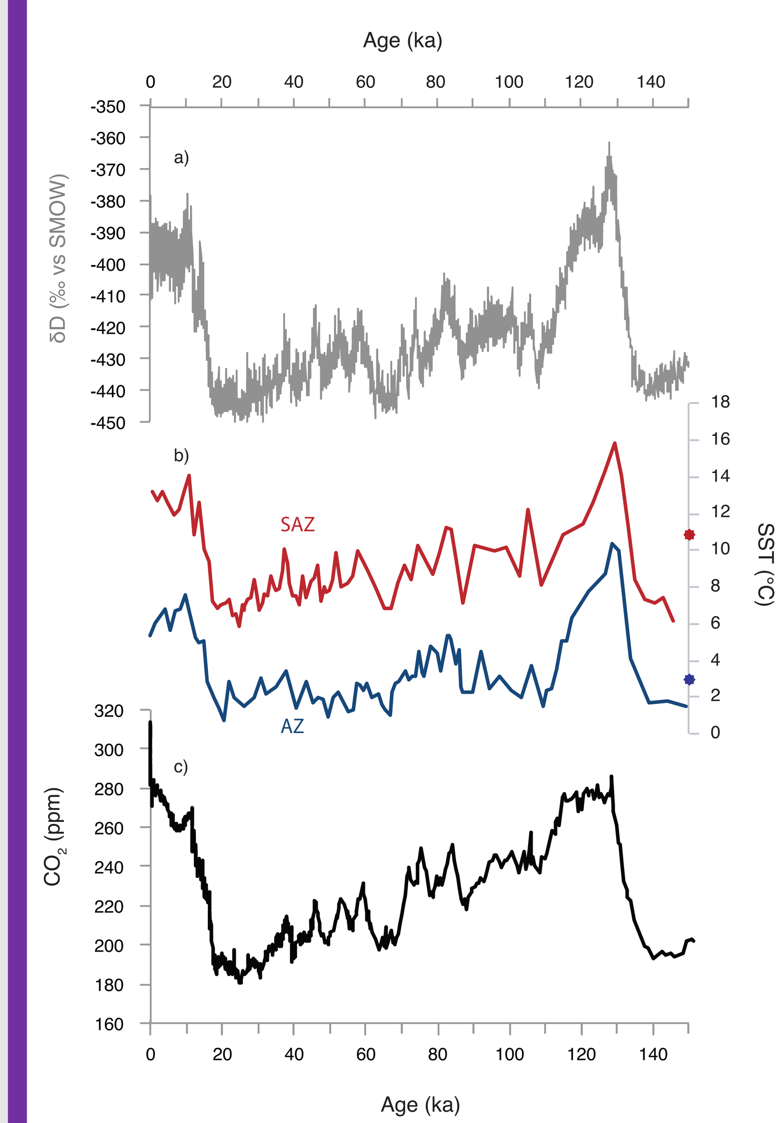


Figure 2. Austral summer sea surface temperatures, oceanic fronts, and core locations.

Methods

- **SSTs were** reconstructed based on (GDGT-based) **TEX^{86}_{L}**-index and **calibrated for low temperatures** after Kim et al. (2012)[7].
- **Meridional SST gradients** were determined by **resampling the downcore records** on a 2.5 ka resolution.
- **Age models** were determined by **aligning** the newly generated SST records to the deuterium **ice core data from Antarctica**[8].

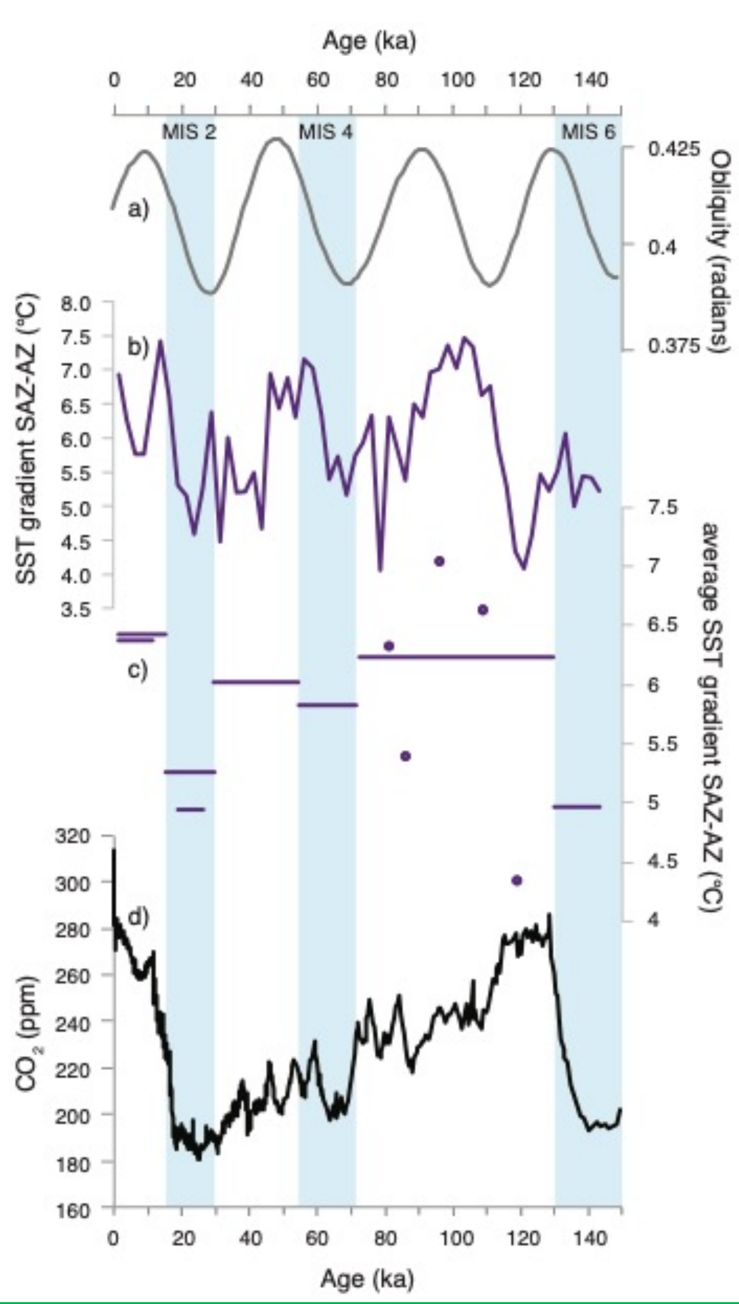
SST reconstructions



- Both **SST records** show **well defined glacial-interglacial** temperature oscillations, allowing for **robust intercomparison**.
- **Core top SST values are ±2°C** lower than modern annual mean SST (dots on y-axis). This argues for **a bias** in our reconstruction **towards summer SST**, when productivity is highest.
- **SST reconstruction** and **atmospheric CO_2** concentration[8] show a **high correlation**. Again, this, suggests a **strong influence of Southern Ocean SST** on CO_2 outgassing due **to changes in the air-sea buoyancy flux**.

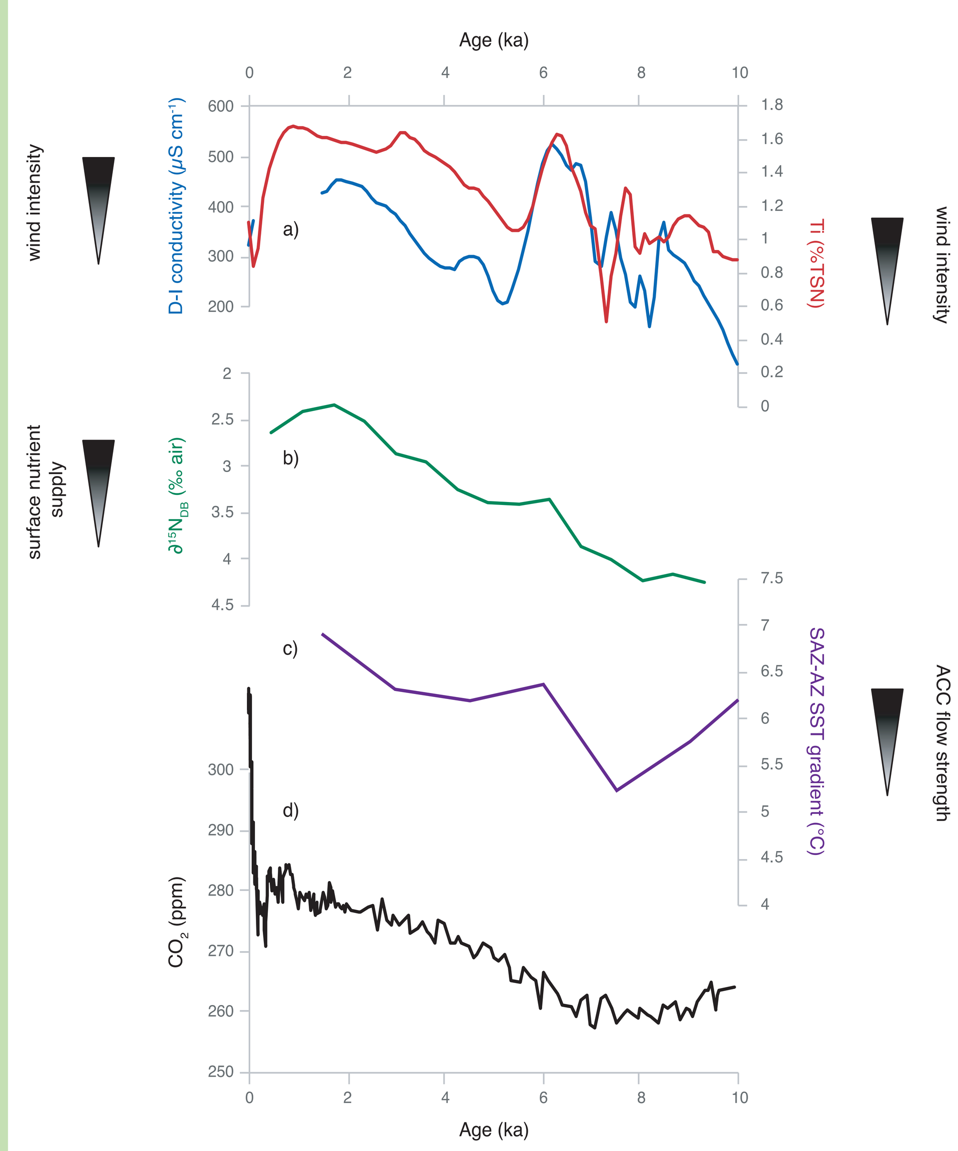
ACC shifts vs changes in the ACC strength

Frontal shifts over glacial–interglacials



- Without **paleosalinity** reconstructions, we **cannot** make any assumptions about **flow speed changes during cold periods**. SST gradient changes over glacial-interglacials are interpreted as a **signal of shifting fronts**.
- **Obliquity** may have had a **strong impact** in modulating the SST gradient.
- **Reduced SST gradients** during **cold periods** may suggest a **northward shift** of the ACC, **reducing upwelling intensities**.
- During the **MIS 5e**, **the smallest SST gradient** together with high SSTs argues for **a drastic southward shift of the ACC**, possibly enhancing upwelling.
- These **ACC dynamics** may have an important **influence on CO_2 outgassing**.

Strengthening of the ACC during the Holocene



- During the **Holocene**, **density** is mainly **driven by temperature. SST gradients** are interpreted as **ACC flow speed changes**.
- Wind strength reconstruction from the **Southern Ocean** indicate **intensifying westerlies over the Holocene**[9].
- **Nitrogen isotope reconstructions** at our AZ core location suggest **enhanced nutrient supply over the Holocene**[10].
- Together with an **increasing SST gradient** over the Holocene, this argues for a **stronger ACC flow speed**, leading to more upwelling.
- This argues for a **crucial role of ACC strength on CO_2 release** to the atmosphere.

References

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