Key Biomes: Southern Ocean

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Key concepts

• The circulation of the Southern Ocean controls air-sea CO$_2$ exchange; Southern Ocean is a net sink for atmospheric CO$_2$

• Approximately 40% of the anthropogenic carbon in the global ocean entered via the Southern Ocean

• Recent changes in the circulation of the Southern Ocean may have changed its ability to absorb CO$_2$ from the atmosphere
Southern Ocean sea-air CO$_2$ exchange

- South of 50°S, Southern Ocean is a source of CO$_2$ to the atmosphere
- North of 50°S, strong sink for CO$_2$
- 50°S is location of Antarctic Circumpolar Current (ACC)
- CO$_2$ fluxes are strongly linked to circulation of Southern Ocean – why?

\[ \text{mol C m}^{-2} \text{yr}^{-1} \]
Wind stress imparts momentum

[dyn cm$^{-2}$]
Idealized Southern Ocean circulation

modified from Speer et al. (2000)
Spinning up the Southern Ocean

Courtesy of Ryan Abernathy
Dissolved Inorganic Carbon

![Graph showing dissolved inorganic carbon distribution](image-url)
Circulation and carbon fluxes

modified from Speer et al. (2000)
Southern Ocean is a sink for atmospheric CO$_2$

Median annual sea-air CO$_2$ flux, 1990-2009, 44$^\circ$S-75$^\circ$S

Sea-air CO$_2$ flux (Pg C yr$^{-1}$)

- observations (Wanninkhof et al. 2013)
- atmospheric inversions (Peylin et al. 2013)
- ocean inversions (Gruber et al. 2009)
- ocean biogeochemical models

data from Lenton et al. (2013)
Anthropogenic CO$_2$

modified from Sarmiento and Gruber (2002)
Anthropogenic CO$_2$ storage

Sabine et al. (2004)
Importance of Southern Ocean

Total anthropogenic CO$_2$ inventory, 2008

data from Khatiwala et al. (2009)
Historical evolution of CO$_2$ exchange
Historical evolution of CO$_2$ exchange.
A recent change in the sink strength?

Lovenduski et al. (2008)
Underlying causes of change

Lovenduski et al. (2008)
Future scenarios

Source: PCMDI, NCAR CCSM SRESA1B scenario

- Wind stress
- Precipitation
- Surface temperature
- Ice fraction

(2090-2099) - (2000-2009)
What will the future bring?

Lovenduski and Ito (2009)
What happened in the past?

Toggweiler et al. (2006)
The end!