A multi-model study on Southern Ocean CO₂ uptake and the role of the biological carbon pump in the 21st century


**Models**

- **MAREM/CMIP5 models**
  - Atmospheric CO₂ according to RCP8.5 scenario
  - five fully coupled and three ocean-ice-ecosystem models
  - models differ widely in mixed layer depth (MLD) definitions

- **two additional RECoM2 simulations**
  - CONST: with constant preindustrial atmospheric CO₂ * changing climate
  - RCP85: with constant climate and increasing atm CO₂

- **Box model**
  - Prognostics: DIC and ALK concentration and CO₂ flux.
  - Forcing: output from RECoM2 RCP8.5 simulation, averaged over periods 2012-2031 and 2081-2100 as forcing: prescribed temperature, salinity, deep DIC and ALK, export as gross primary production (GPP) minus respiration minus remineralization, sea ice area. Wind speed from MIROCS to calculate Ekman transport and up-/ downwelling from mass balance. Atmospheric CO₂ from RCP8.5

**Results**

Multi-model mean CO₂ flux (positive into ocean). Regions 44-58°S and south of 58°S will contribute more to Southern Ocean (south of 30°S) CO₂ flux in the future due to larger impact of biology at high Revelle factor (Hauck & Völker, 2015) and increase in export. The larger uptake in the south limits uptake in the north (northward Ekman transport).

**Conclusions**

No agreement among models whether system south of 44°S will be controlled by SAM or warming signal. In the temperate region 30-44°S the warming signal with shallower mixed layer depths dominates.

The largest impact on future CO₂ uptake is by the atmospheric CO₂ increase.

Roles of biology. Increase of biologically-driven CO₂ uptake until 2100 and twice as large (not shown) as F_NPP increase due to increased export production before interaction between biology and Revelle factor (Hauck & Völker, 2015, GRL).

Without biology red/orange bars: Southern Ocean would be source of CO₂ to the atmosphere.

**Possible scenarios for export production and CO₂ flux**

- Shallow MLD: more light (less nutrients) less NPP and export enhanced summer CO₂ uptake
- Deeper MLD: less light (more nutrients) less NPP and export reduced summer CO₂ uptake

**Motivation**

- Which signal will be dominant in the future?
- What does that mean for export production?
- And how will that translate into CO₂ flux?

**Causes for export production changes**

1. No model agreement on dominance of SAM or global warming signal, but agreement on increase of export in spring or summer in the region south of 58°S
2. No model agreement on dominance of SAM or global warming signal, no agreement on sign of export change in the region 44-58°S
3. Model agreement on dominance of global warming signal, nutrient-driven decrease of export production in the region 30-44°S

**Global warming signal**

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**SAM signal**

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**Figure**

- Export production (PgC month⁻¹)
- (A) Export production (PgC month⁻¹)
- (B) MLD (m)
- (C) Nutrient limitation (%)