Detection of a weakening Southern Ocean carbon sink

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Thanks to
Galen McKinley and Amanda Fay
University of Wisconsin - Madison
Evolution of Southern Ocean CO$_2$ exchange
Evolution of Southern Ocean CO$_2$ exchange
Saturation of the CO$_2$ sink

adapted from Lovenduski et al. (2008)
Mechanism

CO₂ outgassing

wind

ψ_eul

ψ_edd

biological production

Zonal-mean DIC (mmol m⁻³)
Corroborating model results

<table>
<thead>
<tr>
<th>Model</th>
<th>Reference</th>
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<tbody>
<tr>
<td>Bern3D</td>
<td>Tschumi et al. 2008</td>
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<tr>
<td>CCSM/CESM</td>
<td>Lovenduski et al. 2007</td>
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<td></td>
<td>Wang and Moore 2012</td>
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<td>Lovenduski et al. 2013</td>
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<td>CSIRO</td>
<td>Lenton et al. 2007</td>
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<td>IPSL</td>
<td>LeQuéré et al. 2007</td>
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<td>Lenton et al. 2009</td>
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<td>LOVECLIM</td>
<td>Menviel et al. 2008</td>
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<td>MITgcm</td>
<td>Lovenduski and Ito 2009</td>
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<td></td>
<td>Hauck et al. 2013</td>
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<td>Lauderdale et al. 2013</td>
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<td>NASA GISS</td>
<td>Romanou et al. 2013</td>
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<td>UVic</td>
<td>Zickfeld et al. 2007</td>
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<td>Swart et al. 2014</td>
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A note on language

steady sink
A note on language

weakening sink
A note on language

variable sink

Southern Ocean Sea-Air CO2 flux (PgC yr⁻¹)
Observed wintertime pCO$_2$ changes 1986-2010

Change in surface ocean pCO$_2$

<table>
<thead>
<tr>
<th>Temperature Range</th>
<th>pCO$_2$ Change (μatm decade$^{-1}$)</th>
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</thead>
<tbody>
<tr>
<td>0.8-1.5°C</td>
<td>15-20</td>
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<tr>
<td>1.5-2.5°C</td>
<td>15-20</td>
</tr>
<tr>
<td>2.5-3.5°C</td>
<td>20-25</td>
</tr>
<tr>
<td>3.5-4.5°C</td>
<td>25-30</td>
</tr>
<tr>
<td>4.5-5.5°C</td>
<td>25-30</td>
</tr>
</tbody>
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Change in atmospheric pCO$_2$

Data from Takahashi et al. (2012)
Trend in $p\text{CO}_2^{oc}$ vs. $p\text{CO}_2^{atm}$ trend

Fay and McKinley (2013)
Research questions

1. Are CO$_2$ flux trends affected by the choice of start/end year or season?

2. Does the observational sampling introduce biases into the $\Delta$pCO$_2$ trends?

3. Do we have enough observational data to detect a weakening CO$_2$ sink?
Does the start/end year matter?

CO$_2$ flux trend, SO-SPSS

simulated period

observed period

Lovenduski et al. (in review, GBC)
Is the CO$_2$ flux trend larger in winter?

annual CO$_2$ flux trend

winter CO$_2$ flux trend

Lovenduski et al. (in review, GBC)
Do we have observational biases?

$\Delta pCO_2$ trend, SO-SPSS

full model

model sampled as observed

observed

Lovenduski et al. (in review, GBC)
Do we have observational biases?

\[ \Delta pCO_2 \text{ trend, SO-ICE} \]

Lovenduski et al. (in review, GBC)
Do we have enough data?

Required length of time series

Years of data available

Lovenduski et al. (in review, GBC)
Conclusions

1. Are CO$_2$ flux trends affected by the choice of start/end year or season?
   Start/end year: Yes.
   Season: Not significantly.
2. Does the observational sampling introduce biases into the ΔpCO$_2$ trends?
   In SO-SPSS: Only slightly.
   In SO-ICE: Yes, but also model bias.
3. Do we have enough observational data to detect a weakening CO$_2$ sink?
   No, but one promising route to detection is data from the Drake Passage time series.