River loop and natural ocean outgassing

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Partition between land and ocean key to assess impacts and carbon-climate feedbacks
Natural carbon flows introduce large uncertainties in ocean/land partition and global carbon budget

Challenge to constrain natural flows of carbon

Atmospheric growth rate

River loop

Land
Vulnerable sink?

Ocean
Acidification and ecosystems?
Constraint on natural ocean/river carbon flux: north/south asymmetry & river loop contribution

Mismatch up to 1 PgC/y in ocean sink between estimates
Le Quéré et al., 2018

Uncertainties in river loop
0.45 ± 0.18 PgC/y (Jacobson et al., 2007)
0.75 ± 100% PgC/y (Regnier et al. 2013; Bauer et al, 2013)
Hemispheric asymmetry quantifies north/south imbalance in ocean/river fluxes

Hemispheric asymmetry

\[ A = \frac{T_{20N} + T_{20S}}{2} \]
Carbon north-south transport scales with heat transport

Heat asymmetry explains 60% of differences in carbon transport
Heat + Bio pump asymmetry explain 85% of carbon transport

1) Models biased low in heat and carbon transports
2) Southward carbon transport = 0.30 to 0.75 PgC/y

Heat fluxes (Large and Yeager, 2009)
Atmospheric data (Resplandy et al., 2016)
Hydrography (Ganachaud and Wunsch, 2003)

Resplandy et al., Nat Geo 2018

OCB Working Group on Carbon Gaps
Heat constraint on carbon transport

- Estimates agree within large uncertainties but systematic differences in north-south balance
- Ocean inversions incompatible with heat constraint
- Stronger river loop improve match to heat constraint
- Implies strong outgassing of CO$_2$ offsets uptake in the South

Resplandy et al., Nat Geo 2018
SOCCOM float data suggests stronger winter outgassing in Southern Ocean

Winter pCO$_2$-based air-sea CO$_2$ flux

SOCAT database only

SOCAT database + SOCCOM floats

Adding SOCCOM float data reduces annual uptake by 0.4 PgC/y

OCB Working Group on Carbon Gaps

Bushinsky et al, 2019
Constraints on river loop including recent research on estuaries, coastal vegetation and shelves

Top-down ocean heat
Resplandy et al 2018

Bottom-up estimate
Jacobson et al 2007

Revised bottom-up estimate
Regnier, Resplandy and Ciais in prep
Multiple line of evidence support large natural carbon flow to the ocean leading to a natural outgassing of 0.7 PgC/y

- Top down heat constraint
- Stronger winter outgassing in the Southern Ocean
- Revised bottom up estimates of estuaries including carbon fixation by coastal vegetation

Influence partition between land/ocean sink and understanding of carbon feedbacks