CO2 separation

18.04.2017

Prep list:
- Lauderdale paper
- Lauderdale slides
- Ncview control timmean
- Ncview hist timmean

CO2 separation

Aaron Spring

18.04.2017

Lauderdale et al. 2016

Key Points:

- We have developed a quantitative framework for diagnosing regional drivers of air-sea CO_2 fluxes
- Components can be evaluated in a model or can be derived from operational data, climatologies, and ocean state estimates
- Model CO_2 fluxes result from a balance between air-sea heat fluxes, biological activity, and disequilibrium

Quantifying the drivers of ocean-atmosphere CO_2 fluxes

Citation:
Lauderdale, J. M., S. Dutkiewicz, R. G. Williams, and M. J. Follows (2016), Quantifying the drivers of ocean-atmosphere CO_2 fluxes, *Global Biogeochem. Cycles*, *30*, doi:10.1002/2016GB005400.

Jonathan M. Lauderdale[1], Stephanie Dutkiewicz[1,2], Richard G. Williams[3], and Michael J. Follows[1]

[1]Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA, [2]Center for Global Change Science, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA, [3]Department of Earth, Ocean and Ecological Sciences, School of Environmental Science, University of Liverpool, Liverpool, Merseyside, UK

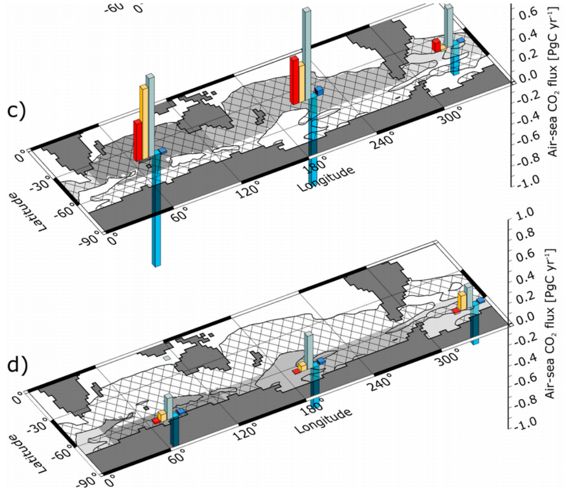
Assumption: steady state

	CO_2 flux driver:
$F_{CO_2} = \gamma_\theta \frac{F_{heat}}{\rho C_p}$	Heat flux
$+\frac{F_W}{\rho_{fw}}\left(\gamma_S \overline{S} + \gamma_{A_T}\overline{A_T} - \overline{C_T}\right)$	Freshwater flux
$-R_{C_T:P}\left(-\nabla\cdot(\vec{u}P) + \nabla\cdot(\kappa\nabla P)\right)\ h$	Organic matter sources and sinks
$-\frac{1}{2}R_{CaCO_3}R_{C_T:P}\left(-\nabla\cdot(\vec{u}P) + \nabla\cdot(\kappa\nabla P)\right)\ h$	Calcium carbonate sources and sinks
$+\left(-\nabla\cdot(\vec{u}C_{res}) + \nabla\cdot(\kappa\nabla C_{res})\right)\ h$	Transport of disequilibrium component

Table 2. Values of the Linear Solubility Coefficients Used in the Attribution of Saturated Carbon Changes[a]

Coefficient	Gradient	Units
γ_θ	−8.72	mmol C m^{-3} °C^{-1}
γ_S	−5.93	mmol C m^{-3} psu^{-1}
γ_{A_T}	0.81	mmol C (mmol eq)$^{-1}$

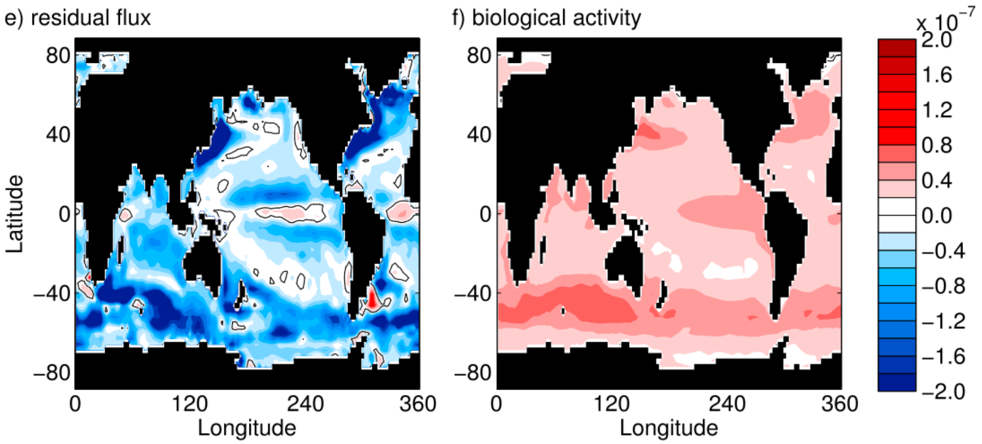
[a]Coefficients were empirically diagnosed by calculating C_{sat} over a range of values for temperature, salinity, or alkalinity while holding the others (including atmospheric CO_2) at surface mean values [*Lewis and Wallace*, 1998; *Goodwin and Lenton*, 2009; *Ito and Follows*, 2013] and finding the gradient by linear regression.

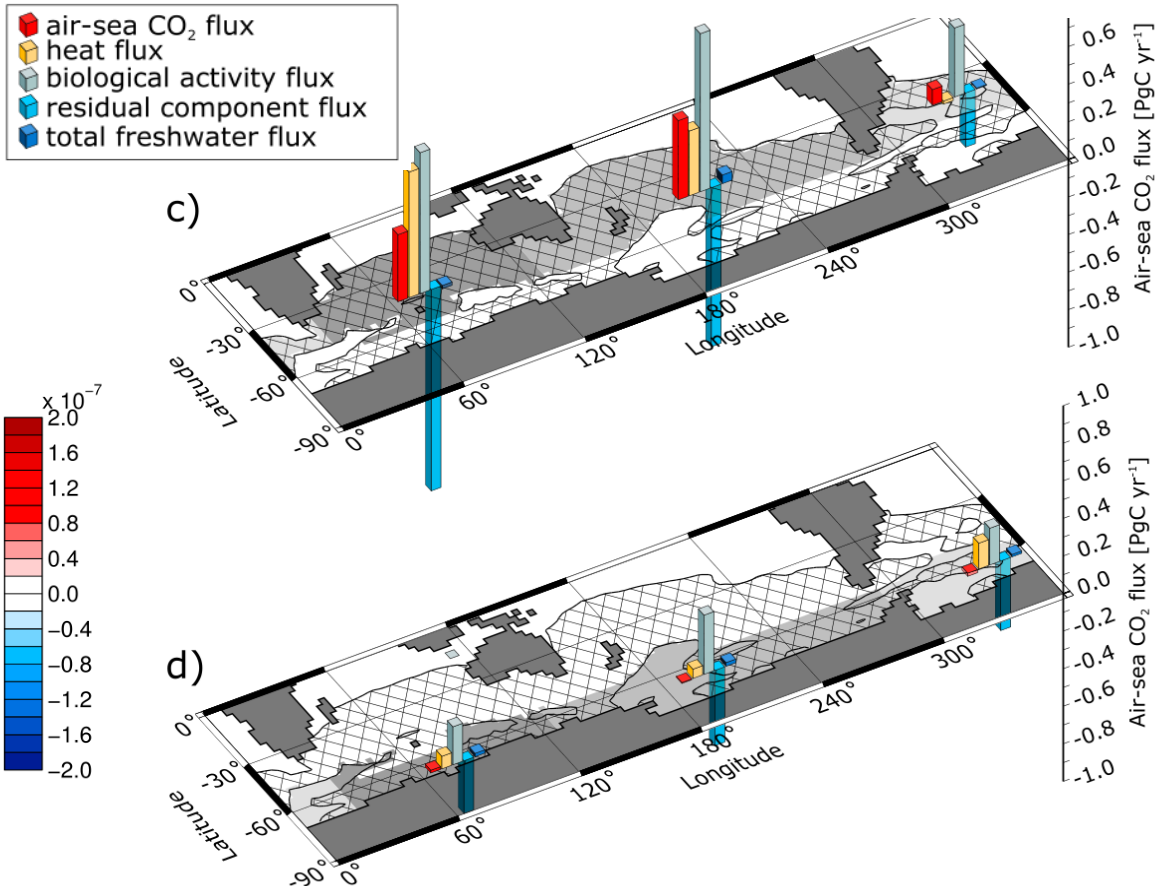


negative CO2flux = outgassing!

What can we learn from this?

- Fresh water: alkalinity flux and dilution flux cancel out
- Bio and residual are largest contributors, but depend on each other by definition





Adaptation to my large ensemble runs

- Goal: identify drivers of CO2 variability

aoflnhwo: net heat flux over water

pem: water flux to ocean [m/s]

$$F_{CO_2} = \gamma_\theta \frac{F_{heat}}{\rho C_p} + \frac{F_W}{\rho_{fw}} \left(\gamma_S \overline{S} + \gamma_{A_T} \overline{A_T} - \overline{C_T} \right)$$

CO$_2$ flux driver:

Heat flux

Freshwater flux

- (caex90+coex90) biology

+ change in ensmean co2flux since 1870 climate change

+ residual circulation

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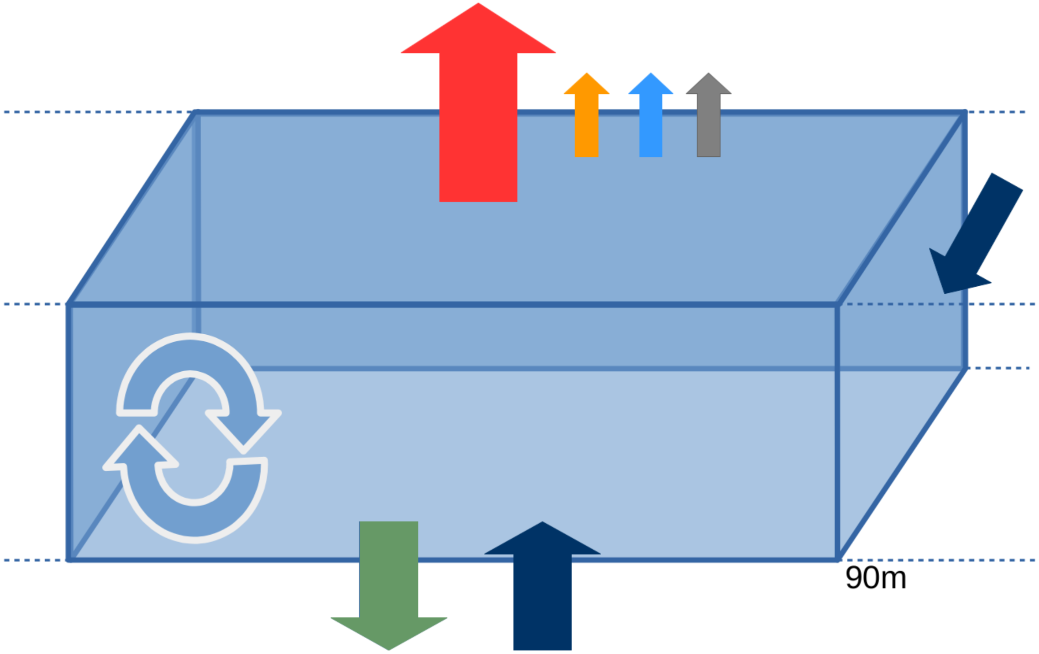


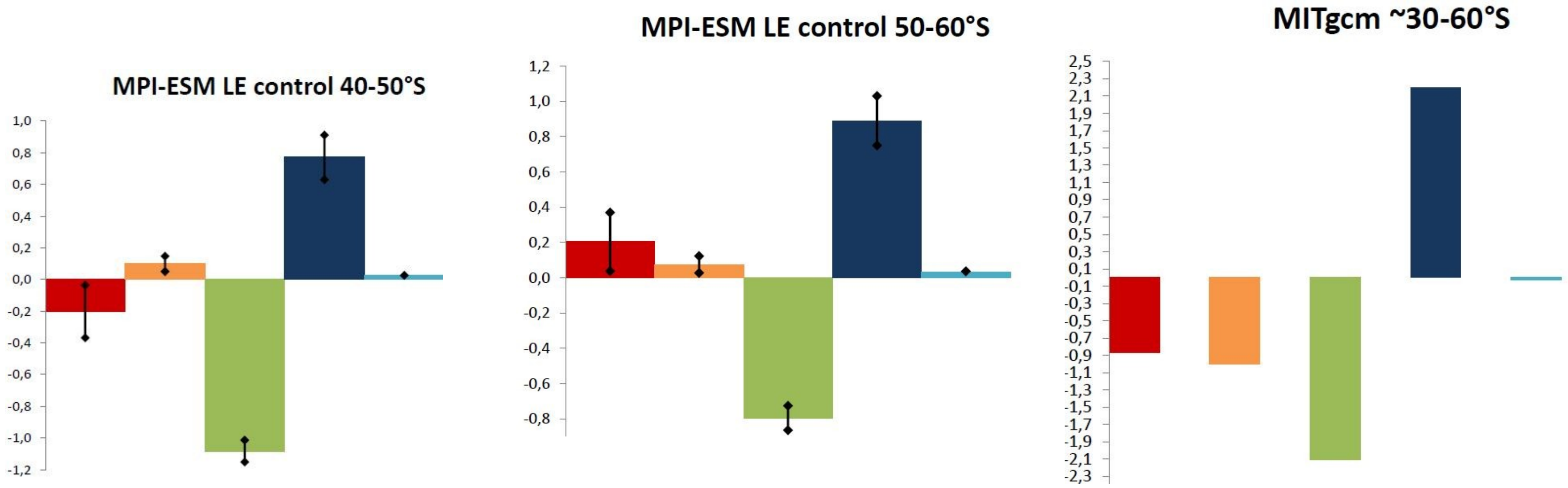
CO$_2$flux=heatflux+freshwater+biology+climate change+residual circulation

positive CO2flux = outgassing!

Comparing Lauderdale to pi-control

NCL plots: normal view or ncview live

Comparing Lauderdale to pi-control



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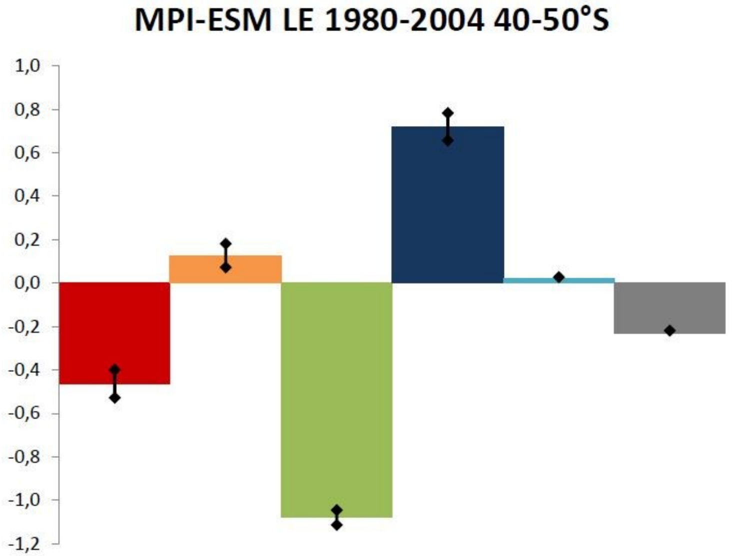
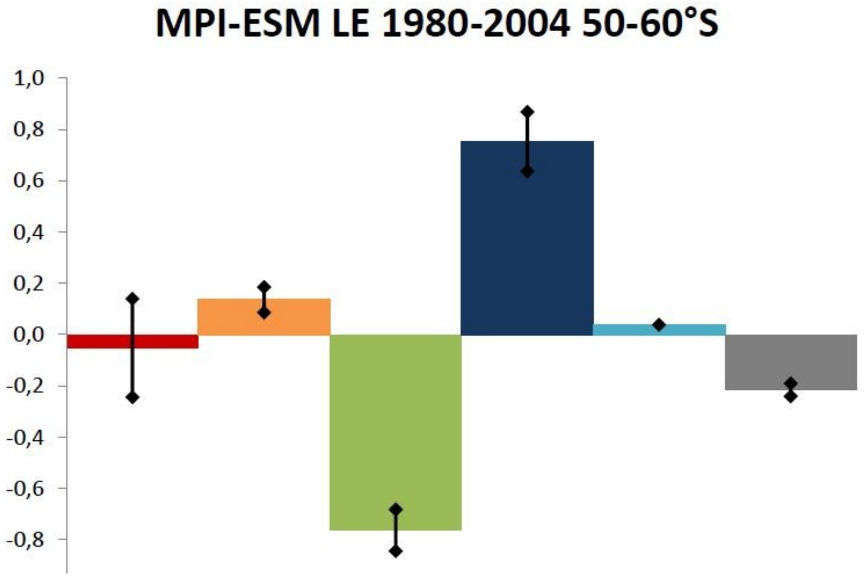
My results 1980-2004



40-50°S	positive carbon sink trend		negative carbon sink trend		MPI-ESM LE
	PgC/8yrs	% contribution	PgC/8yrs	% contribution	PgC/yr
CO_2 flux	-0.15	100	-0.03	100	-0.46±0.06
heat flux	-0.04	25	0.12	-366	0.13±0.06
fresh water	0.01	-4	-0.01	27	0.02±0.00
biology	0.03	-19	-0.07	197	1.09±0.03
climate change	-0.03	17	-0.01	16	-0.23±0.01
circulation	-0.12	83	-0.08	225	0.72±0.06



50-60°S	positive carbon sink trend		negative carbon sink trend		MPI-ESM LE
	PgC/8yrs	% contribution	PgC/8yrs	% contribution	PgC/yr
CO_2 flux	-0.43	100	0.58	100	-0.05±0.19
heat flux	-0.04	9	0.06	11	0.14±0.05
fresh water	-0.00	1	0.00	1	0.04±0.00
biology	-0.17	39	0.17	30	-0.76±0.08
climate change	-0.06	13	-0.01	-2	-0.22±0.02
circulation	-0.17	38	0.35	60	0.75±0.12

Table 1: The trends of CO_2 flux and its contributions for the zonal band of 50-60°S indicate circulation as the most variable contribution

Limitations

- Thermal pump via heat flux and not SST
  - Cooling SST trends (m178) can have negative trend in CO_2 flux contribution due to heat flux, but should be positive (thermal)
- I tried bio=fddtdic-co2flux, but too high values

My results 1980-2005 ensmean

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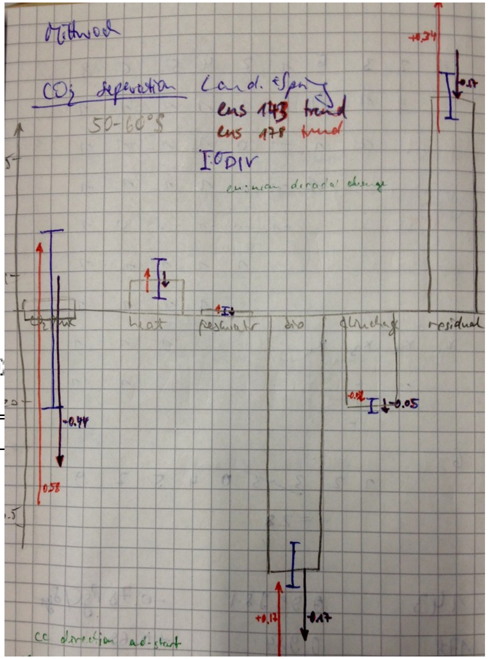

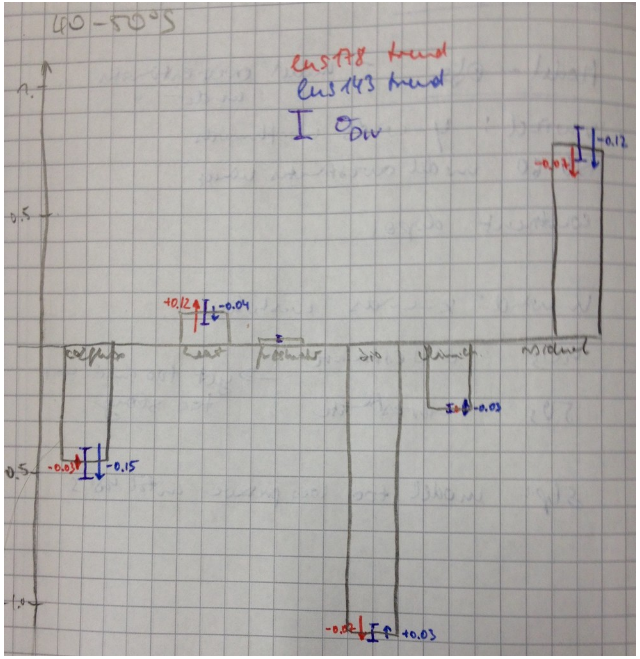

Heat refers to net air-sea radiative heat flux:
Positive carbon sink trend: SST warming
Negative carbon sink trend: SST cooling

Lauderdale et al. 2016 input

- Text

Key Points:

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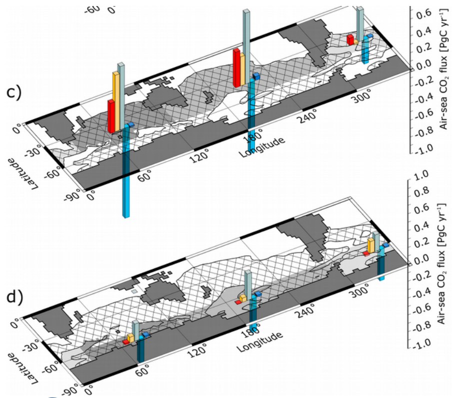

Quantifying the drivers of ocean-atmosphere CO_2 fluxes

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$$
\begin{aligned}
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&+ \frac{F_W}{\rho_{fw}} \left(\gamma_S \overline{S} + \gamma_{A_T} \overline{A_T} - \overline{C_T} \right) \\
&- R_{C_T:P} \left(-\nabla \cdot (\vec{u}P) + \nabla \cdot (\kappa \nabla P) \right) \ h \\
&- \tfrac{1}{2} R_{CaCO_3} R_{C_T:P} \left(-\nabla \cdot (\vec{u}P) + \nabla \cdot (\kappa \nabla P) \right) \ h \\
&+ \left(-\nabla \cdot (\vec{u}C_{res}) + \nabla \cdot (\kappa \nabla C_{res}) \right) \ h
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CO_2 flux driver:
Heat flux
Freshwater flux
Organic matter sources and sinks
Calcium carbonate sources and sinks
Transport of disequilibrium component

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