climate change initiative

→ CLIMATE MODELLING USER GROUP

WP3.9: Biophysical feedbacks in the global ocean

David Ford, Met Office

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cmug cci

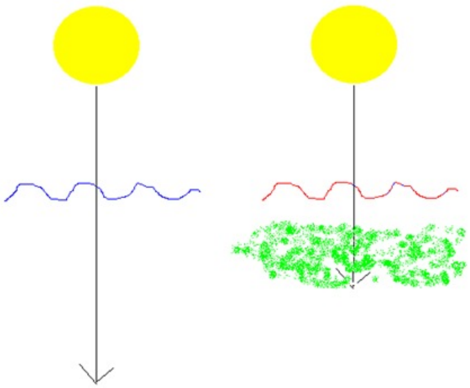
WP3.9: Biophysical feedbacks in the global ocean

1. Add feedback from biology to physics in global ocean model, constrained by CCI Ocean Colour, and assess impact using other marine ECVs.

2. Impact on air-sea CO_2 flux of including CCI Sea State data in flux parameterisation. [Bonus: impact of cool skin SST!]

WP3.9: Biophysical feedbacks in the global ocean

- Shortwave solar radiation (light) enters the ocean, heating the surface layers.
- Chlorophyll absorbs and scatters the light so it penetrates less deeply



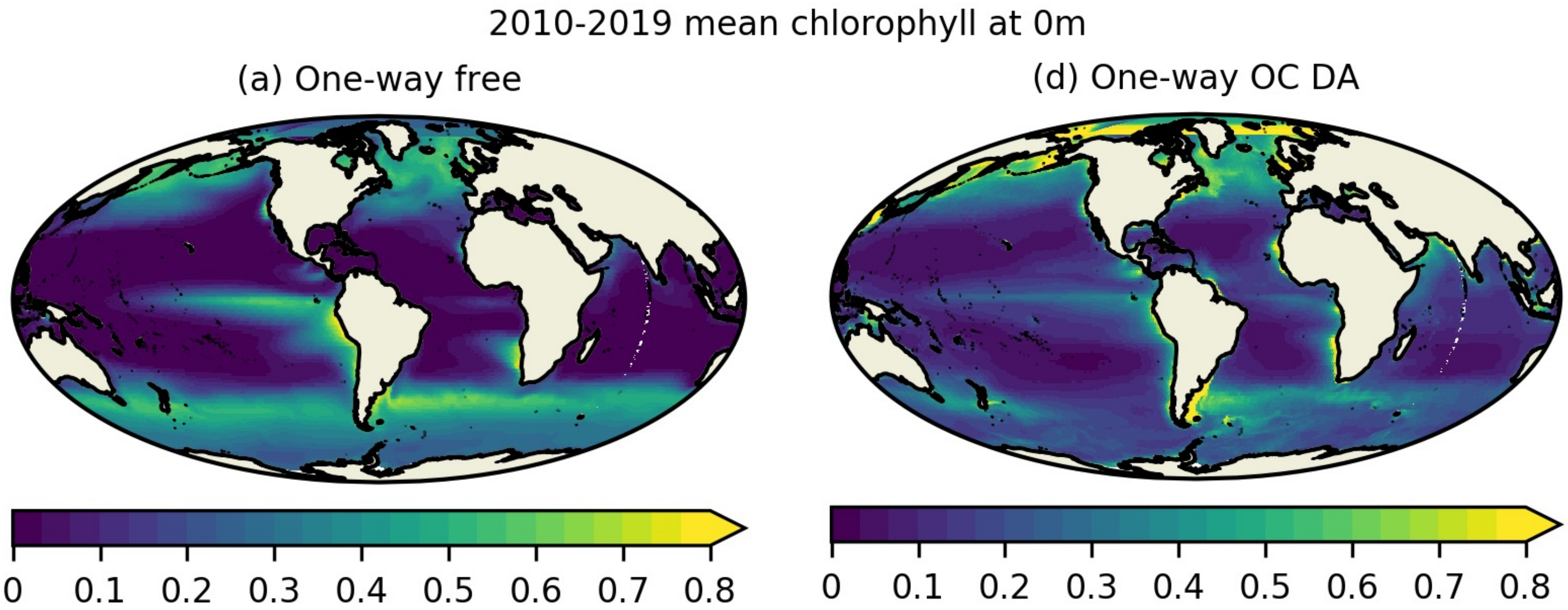
- UKESM1, like most models, does not include this coupling
- NEMO, the ocean physics component, assumes a constant chlorophyll value of 0.05 mg m^{-3} everywhere, representative of very clear waters
- We test this coupling with NEMO-CICE-MEDUSA and ocean colour data

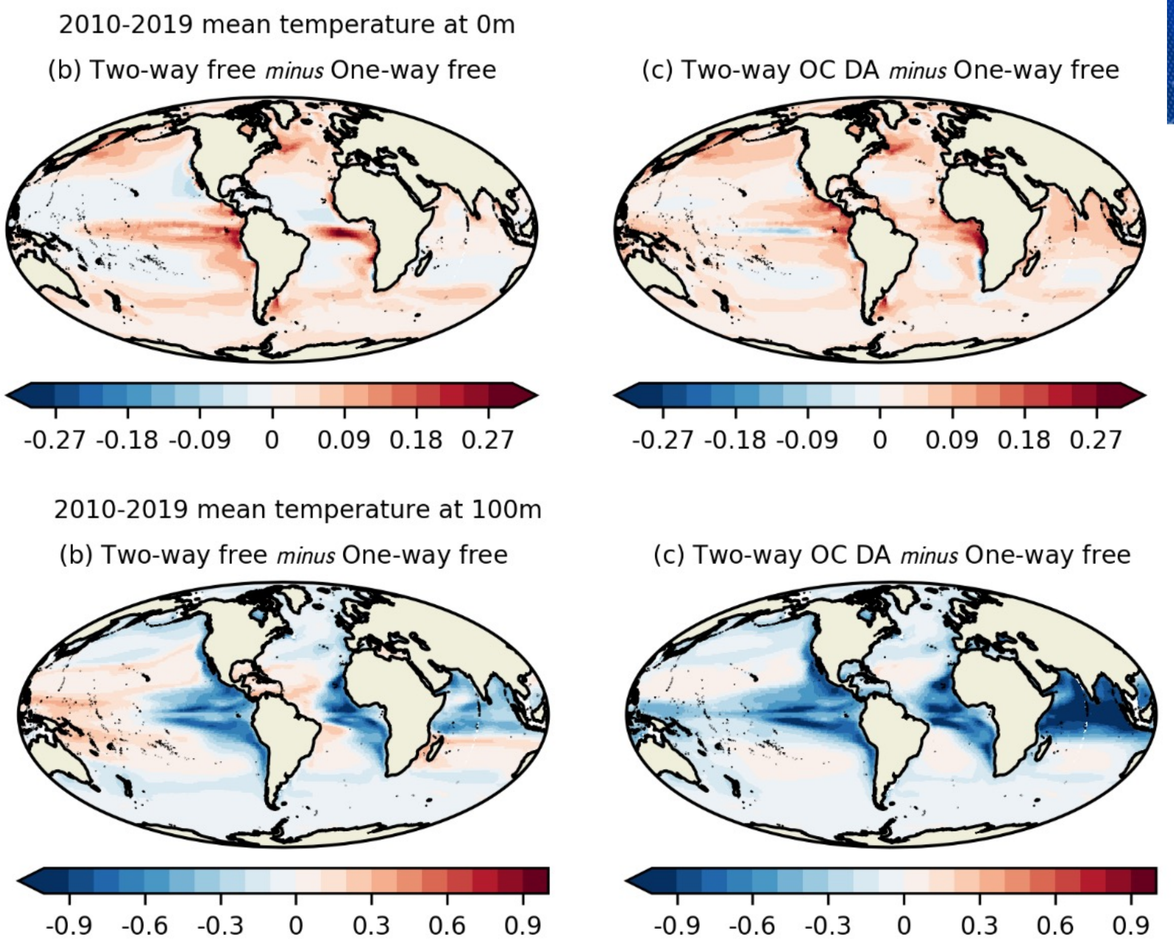
- Set of 10-year 1º runs from 2010-2019:

Name	Chlorophyll seen by NEMO	Assimilation
One-way free	Constant (0.05)	None
One-way OC DA	Constant (0.05)	Ocean colour
Two-way free	Varying (MEDUSA)	None
Two-way OC DA	Varying (MEDUSA)	Ocean colour

Identical physics (One-way free, One-way OC DA)

- (Also some 18-month 1/4º runs, and some sensitivity experiments where output from *Two-way OC DA* is used to constrain the light field of NEMO and/or MEDUSA while the biology remains unconstrained by assimilation. These are discussed in D3.1 but not shown today.)


2010-2019 mean chlorophyll at 0m
(a) One-way free
(d) One-way OC DA
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8


2010-2019 mean temperature at 0m
(b) Two-way free *minus* One-way free
(c) Two-way OC DA *minus* One-way free
-0.27 -0.18 -0.09 0 0.09 0.18 0.27
-0.27 -0.18 -0.09 0 0.09 0.18 0.27
2010-2019 mean temperature at 100m
(b) Two-way free *minus* One-way free
(c) Two-way OC DA *minus* One-way free
-0.9 -0.6 -0.3 0 0.3 0.6 0.9
-0.9 -0.6 -0.3 0 0.3 0.6 0.9

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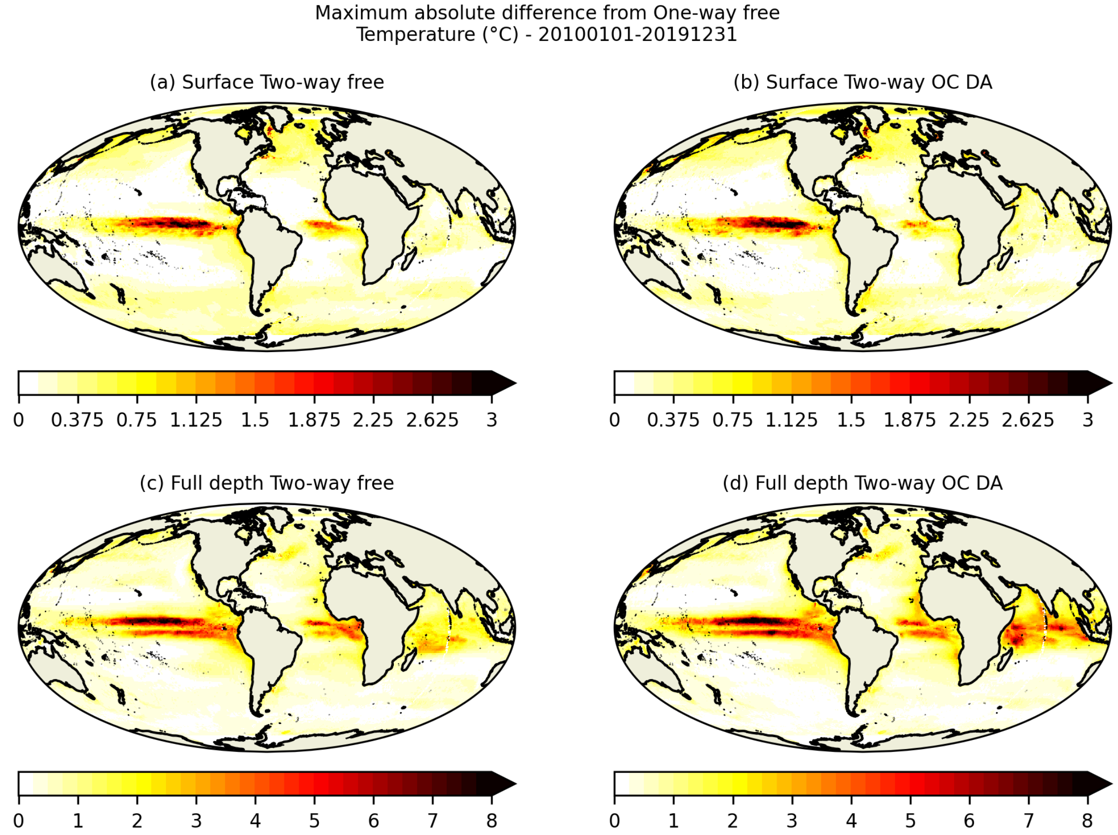
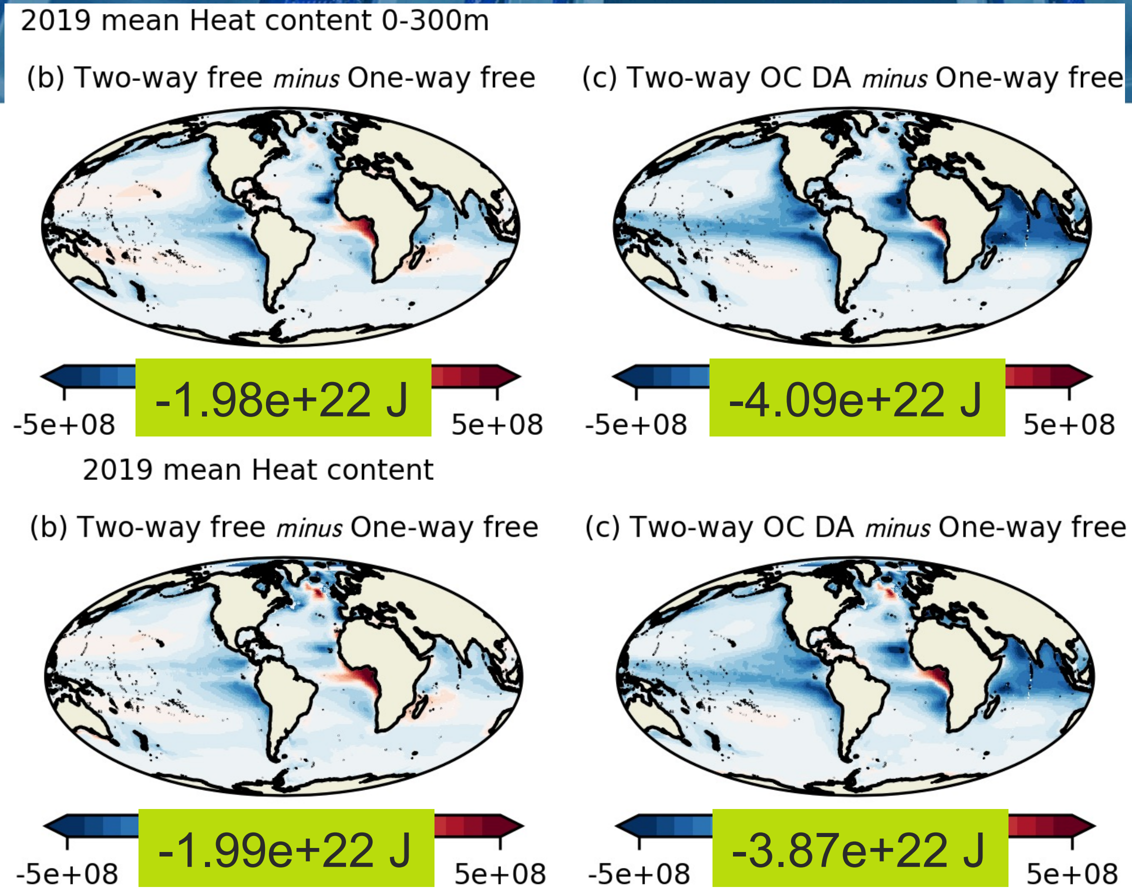


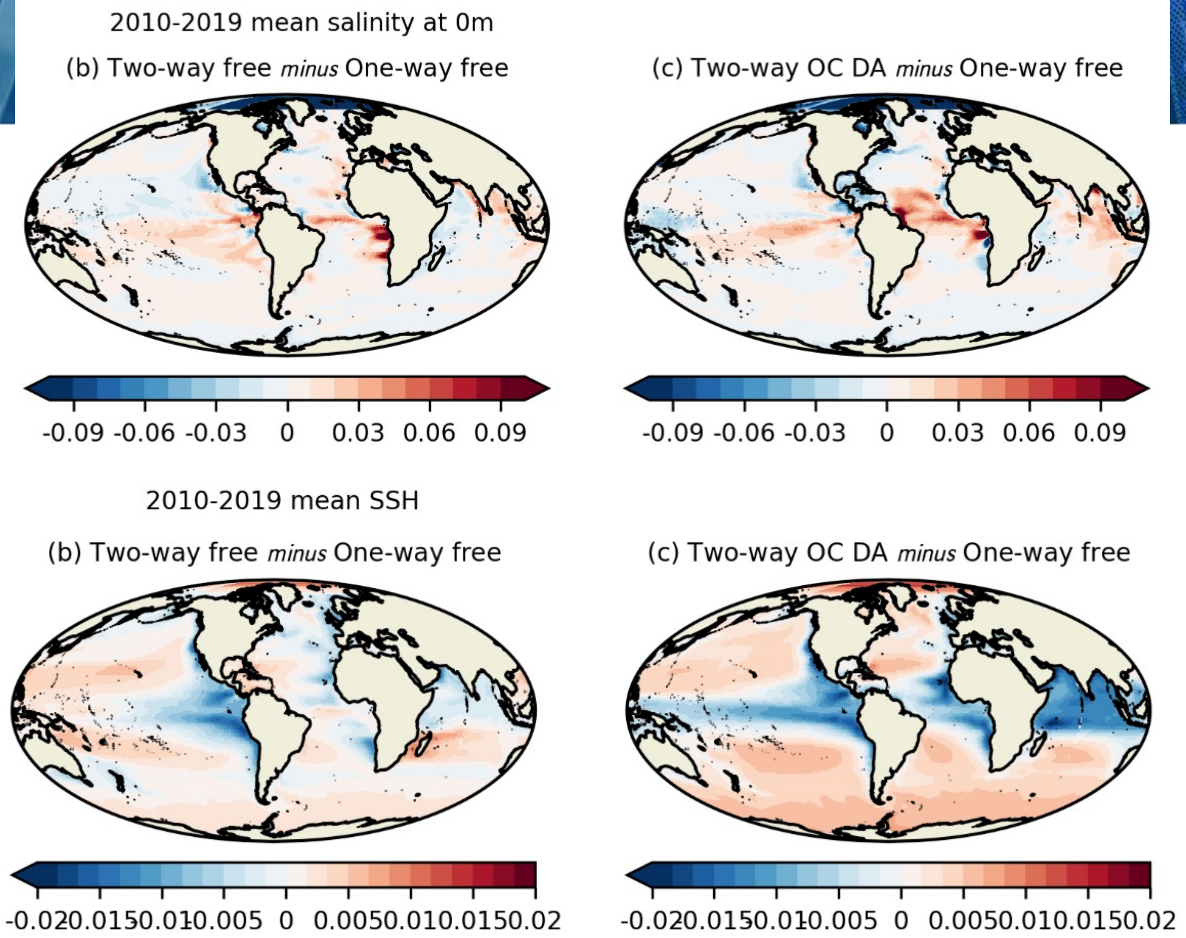
Max: 4.42°C

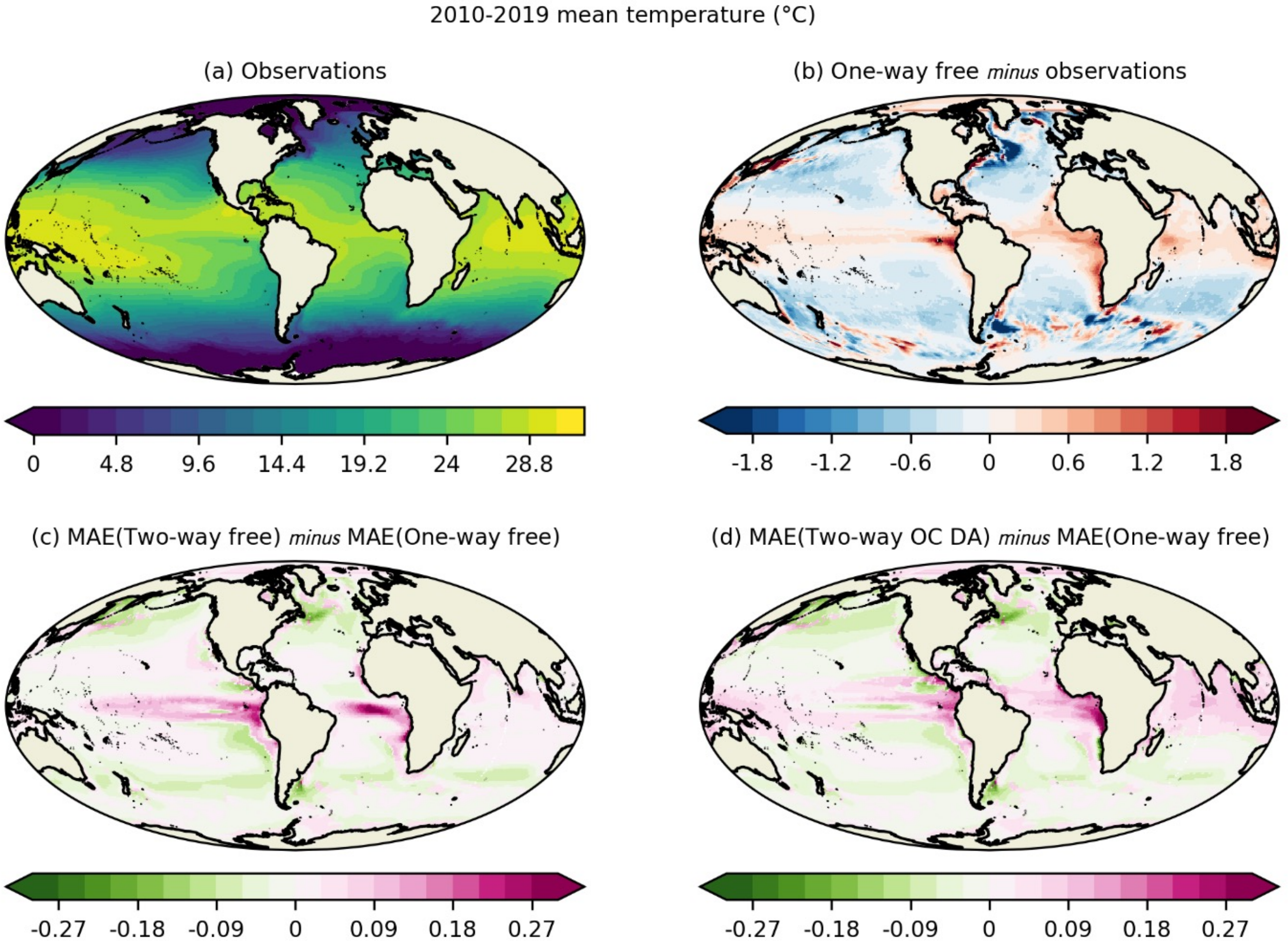
Max: 4.76°C

Max: 9.43°C

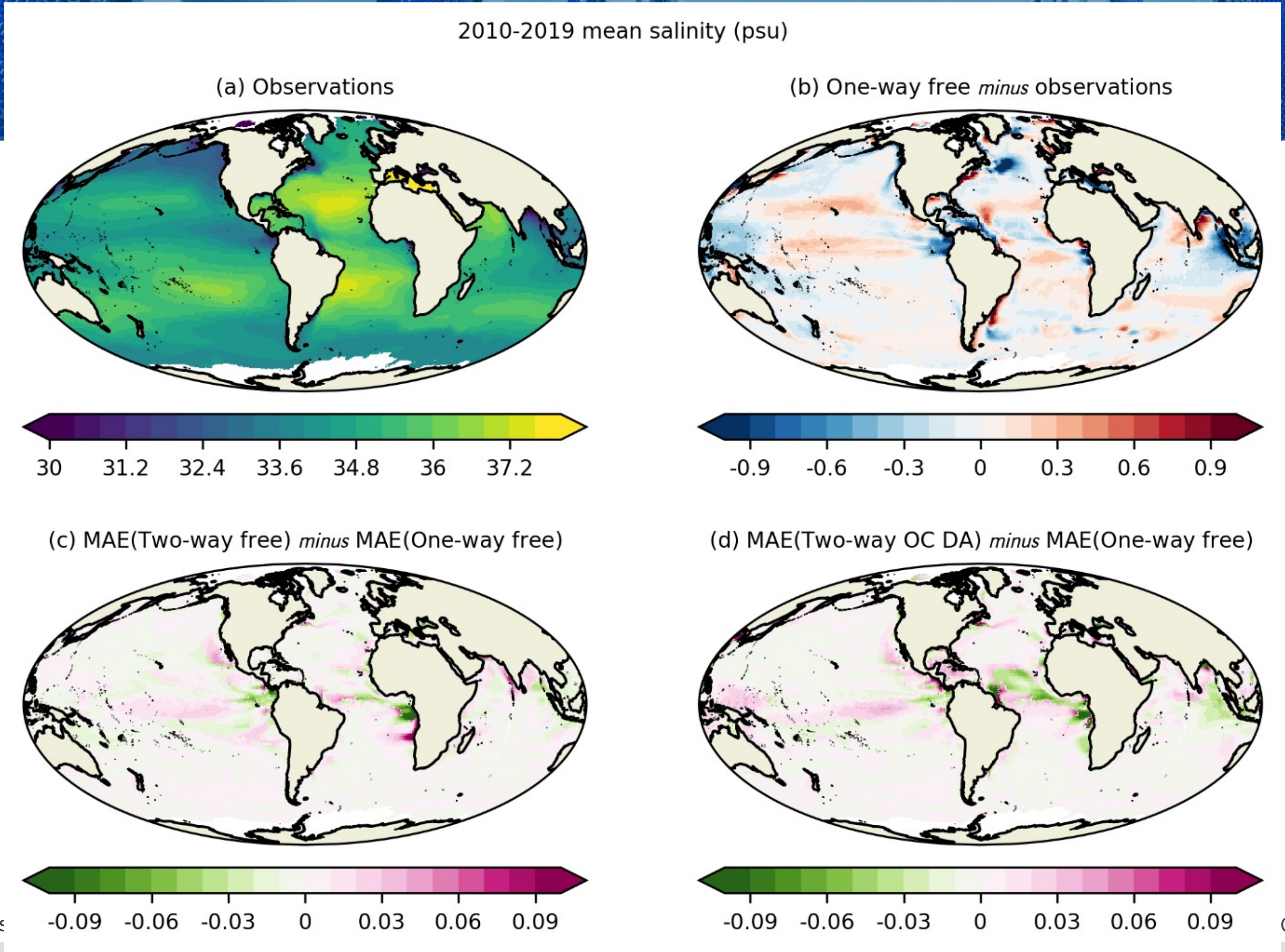
Max: 9.83°C


2019 mean Heat content 0-300m
(b) Two-way free minus One-way free
(c) Two-way OC DA minus One-way free
-5e+08
-1.98e+22 J
5e+08
-5e+08
-4.09e+22 J
5e+08
2019 mean Heat content
(b) Two-way free minus One-way free
(c) Two-way OC DA minus One-way free
-5e+08
-1.99e+22 J
5e+08
-5e+08
-3.87e+22 J
5e+08


2010-2019 mean salinity at 0m
(b) Two-way free *minus* One-way free
(c) Two-way OC DA *minus* One-way free
-0.09 -0.06 -0.03 0 0.03 0.06 0.09
-0.09 -0.06 -0.03 0 0.03 0.06 0.09
2010-2019 mean SSH
(b) Two-way free *minus* One-way free
(c) Two-way OC DA *minus* One-way free
-0.020.0150.010.005 0 0.0050.010.0150.02
-0.020.0150.010.005 0 0.0050.010.0150.02



2010-2019 mean temperature (°C)
(a) Observations
0
4.8
9.6
14.4
19.2
24
28.8
(b) One-way free *minus* observations
-1.8
-1.2
-0.6
0
0.6
1.2
1.8
(c) MAE(Two-way free) *minus* MAE(One-way free)
-0.27
-0.18
-0.09
0
0.09
0.18
0.27
(d) MAE(Two-way OC DA) *minus* MAE(One-way free)
-0.27
-0.18
-0.09
0
0.09
0.18
0.27


2010-2019 mean salinity (psu)
(a) Observations
30
31.2
32.4
33.6
34.8
36
37.2
(b) One-way free *minus* observations
-0.9
-0.6
-0.3
0
0.3
0.6
0.9
(c) MAE(Two-way free) *minus* MAE(One-way free)
-0.09
-0.06
-0.03
0
0.03
0.06
0.09
(d) MAE(Two-way OC DA) *minus* MAE(One-way free)
-0.09
-0.06
-0.03
0
0.03
0.06
0.09

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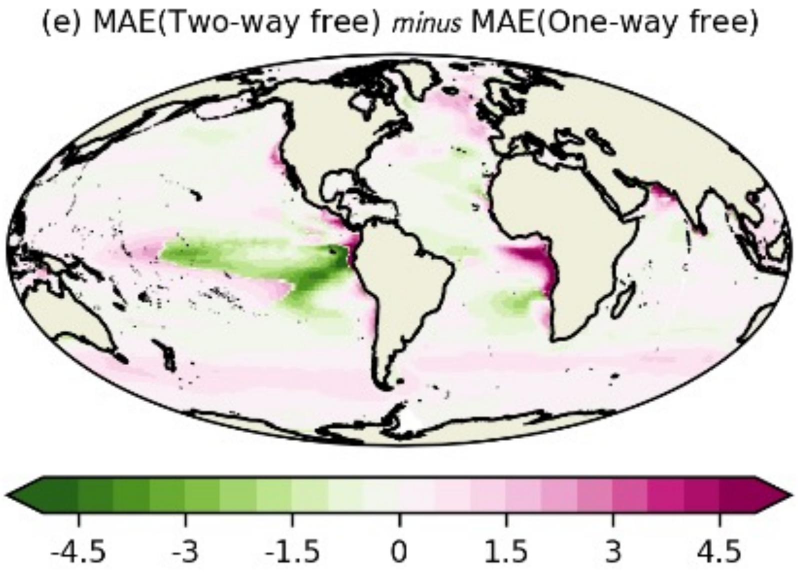
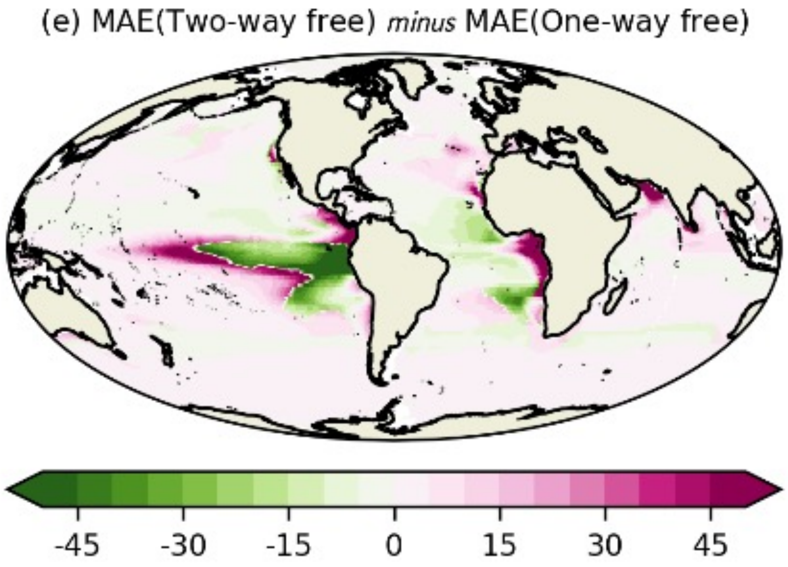
2010-2019 mean phytoplankton carbon



2010-2019 mean vertically integrated primary production



WP3.9: Biophysical feedbacks in the global ocean

- Summary (this part):
  - Implemented feedback in NEMO-CICE-MEDUSA (UKESM1 ocean)
  - Expected impact of (mostly) warming SST and cooling subsurface
  - Much regional variation
  - Including ocean colour assimilation strengthens feedback (in this model)
  - Validation against observations a mixed bag, but note the model was tuned without the feedback
  - Feedback important but model chlorophyll errors appreciable. Climate modellers may also wish to consider use of a satellite climatology

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- Air-sea CO_2 flux is calculated using:

  Flux = $k(\Delta CO_2)$

- where k is the transfer velocity and ΔCO_2 the air-sea CO_2 gradient
- Most models parameterise k as a function of wind speed only (Wanninkhof, 2014)
- Observations suggest sea state is important. Deike and Melville (2018) propose a parameterisation of k using significant wave height (H_s) as well as wind speed
- We test this parameterisation, using CCI Sea State data for H_s
- Use L3 daily H_s, defaulting to wind parameterisation where H_s not observed
- Three year run from 2010-2012 at 1/4º

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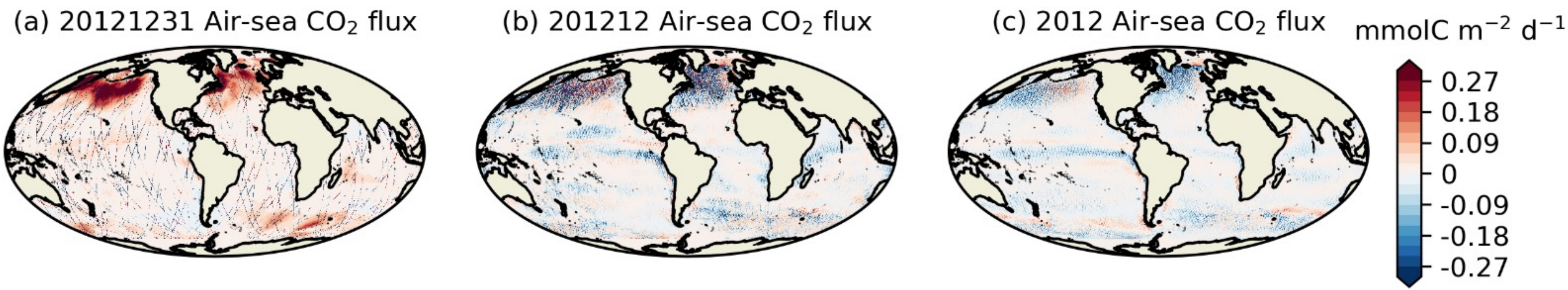
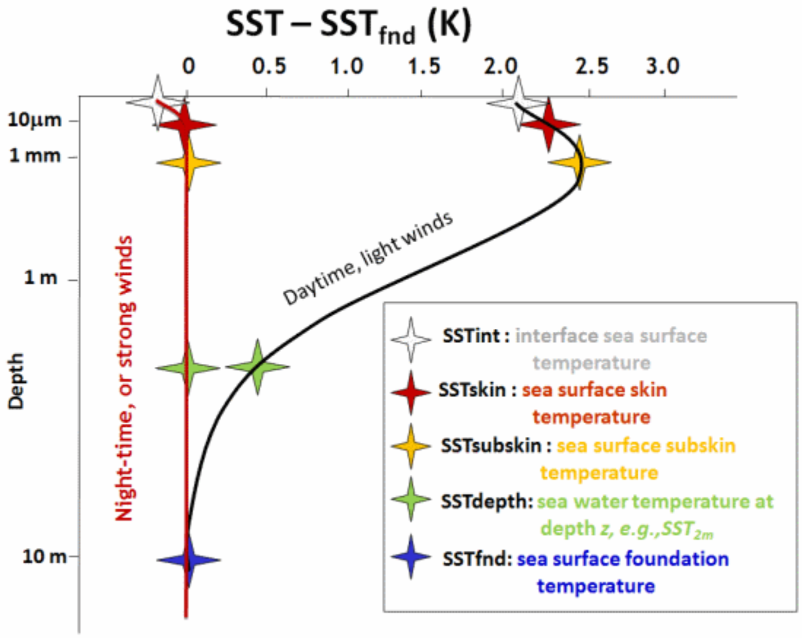


Sea state run
minus
control run

- Air-sea CO_2 flux is calculated using:

  Flux = $k(\Delta CO_2)$

- where k is the transfer velocity and ΔCO_2 the air-sea CO_2 gradient
- Sea surface pCO_2 is a function of SST. But SST can be defined many ways…
- Typically use model top-box temperature (average over top 1m), but should more accurately use cooler skin SST



https://www.ghrsst.org/ghrsst-data-services/products/

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- In observations, this has been shown to make a significant difference to ocean carbon uptake:

Article | Open Access | Published: 04 September 2020

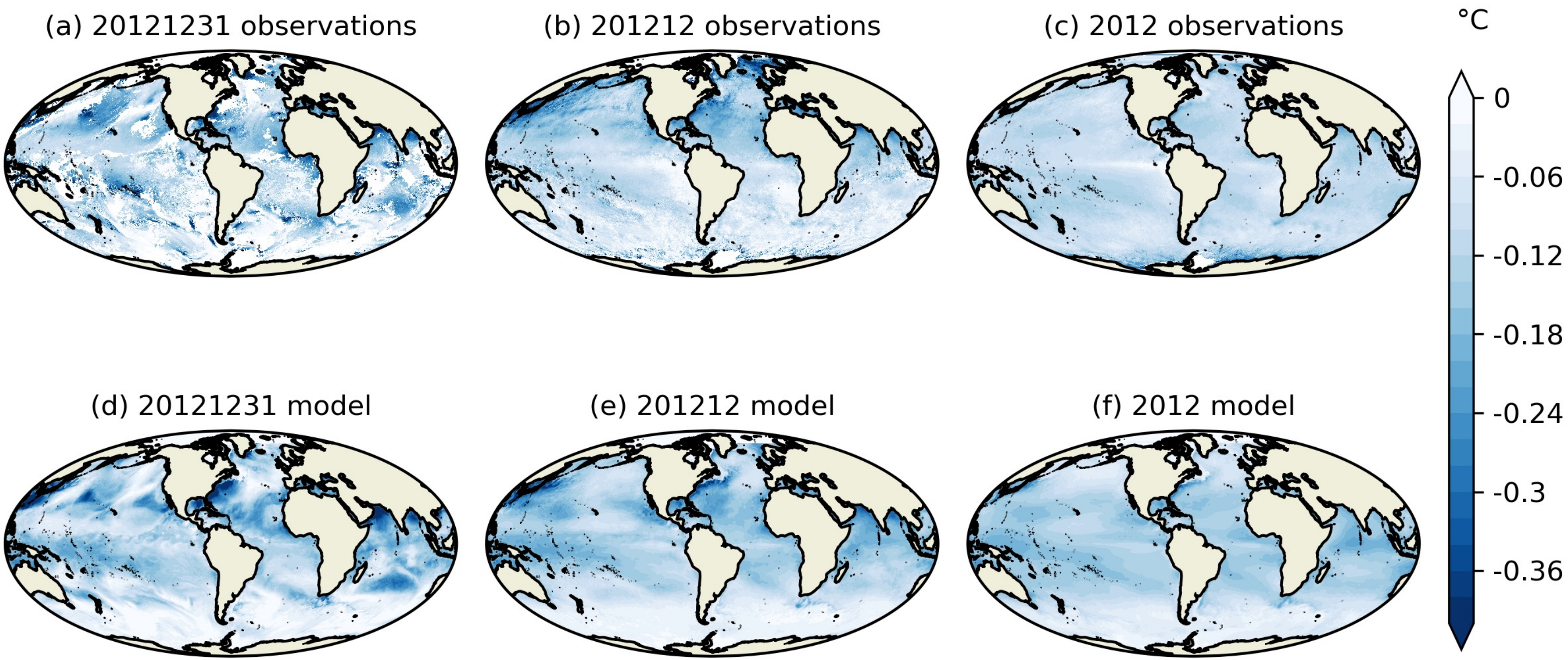
Revised estimates of ocean-atmosphere CO_2 flux are consistent with ocean carbon inventory

Andrew J. Watson, Ute Schuster, Jamie D. Shutler, Thomas Holding, Ian G. C. Ashton, Peter Landschützer, David K. Woolf & Lonneke Goddijn-Murphy

Nature Communications **11**, Article number: 4422 (2020) | Cite this article

- Probably not as important in models, but this seems never to have been tested
- Test using diurnal skin SST model implemented in NEMO by While et al. (2017)

Skin SST minus SST at depth



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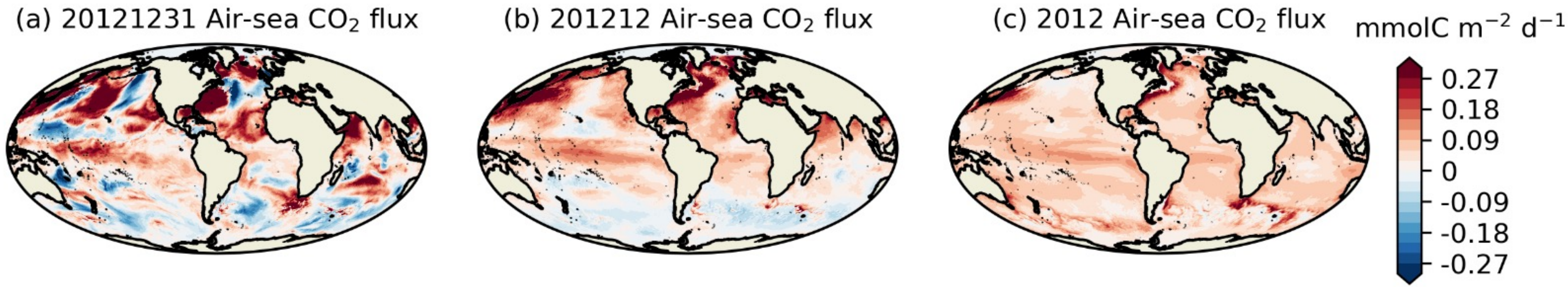

Skin SST run minus control run

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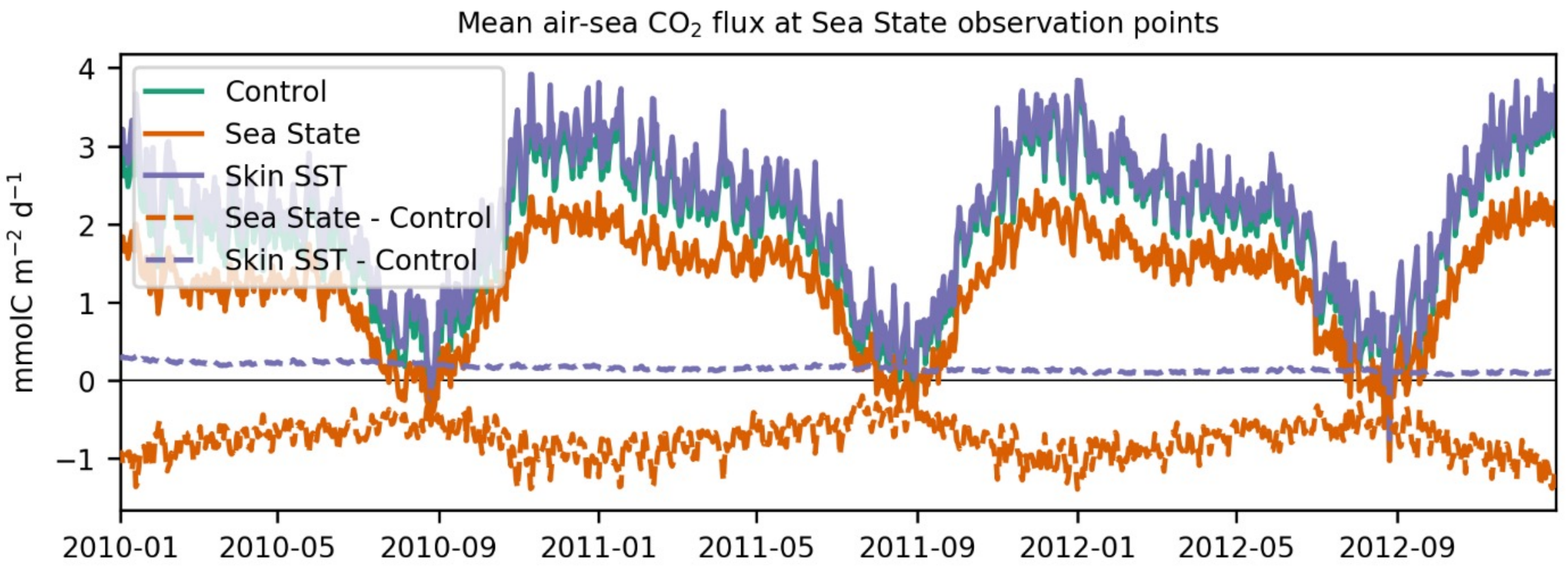

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- Summary (this part):
  - Air-sea CO_2 flux sensitive to inclusion of sea state data in parameterisation, recommend this is investigated further
  - Also a sensitivity to use of skin SST
  - Longer runs (outside CMUG, by Andrea Rochner at University of Exeter) suggest global mean flux converges over time, but seasonal (hemispheric) variability remains altered

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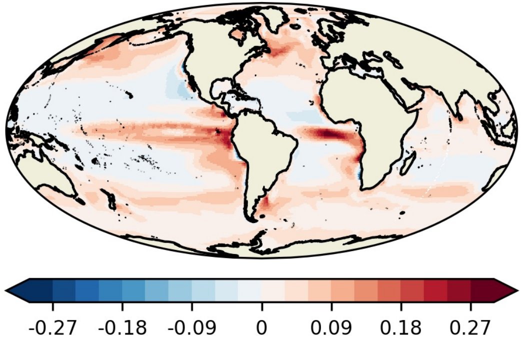
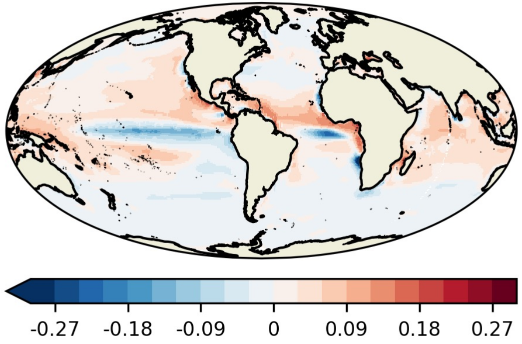
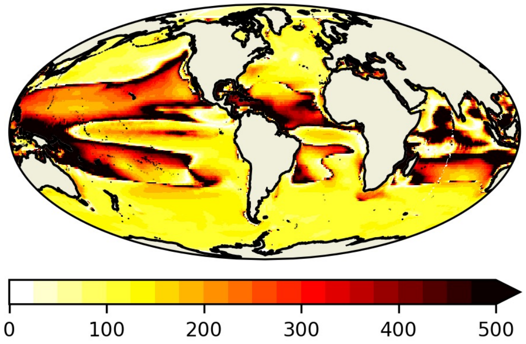
2010-2019 mean temperature at 0m

Two-way free *minus* One-way free



Two-way DA *minus* Two-way free





Relative magnitude of the change in SST associated with uncertainty in model chlorophyll, compared with the overall change introduced by two-way coupling.

$$\frac{|(\text{Two-way DA} - \text{Two-way free}) - (\text{Two-way free} - \text{One-way free})|}{|(\text{Two-way free} - \text{One-way free})|} \times 100$$