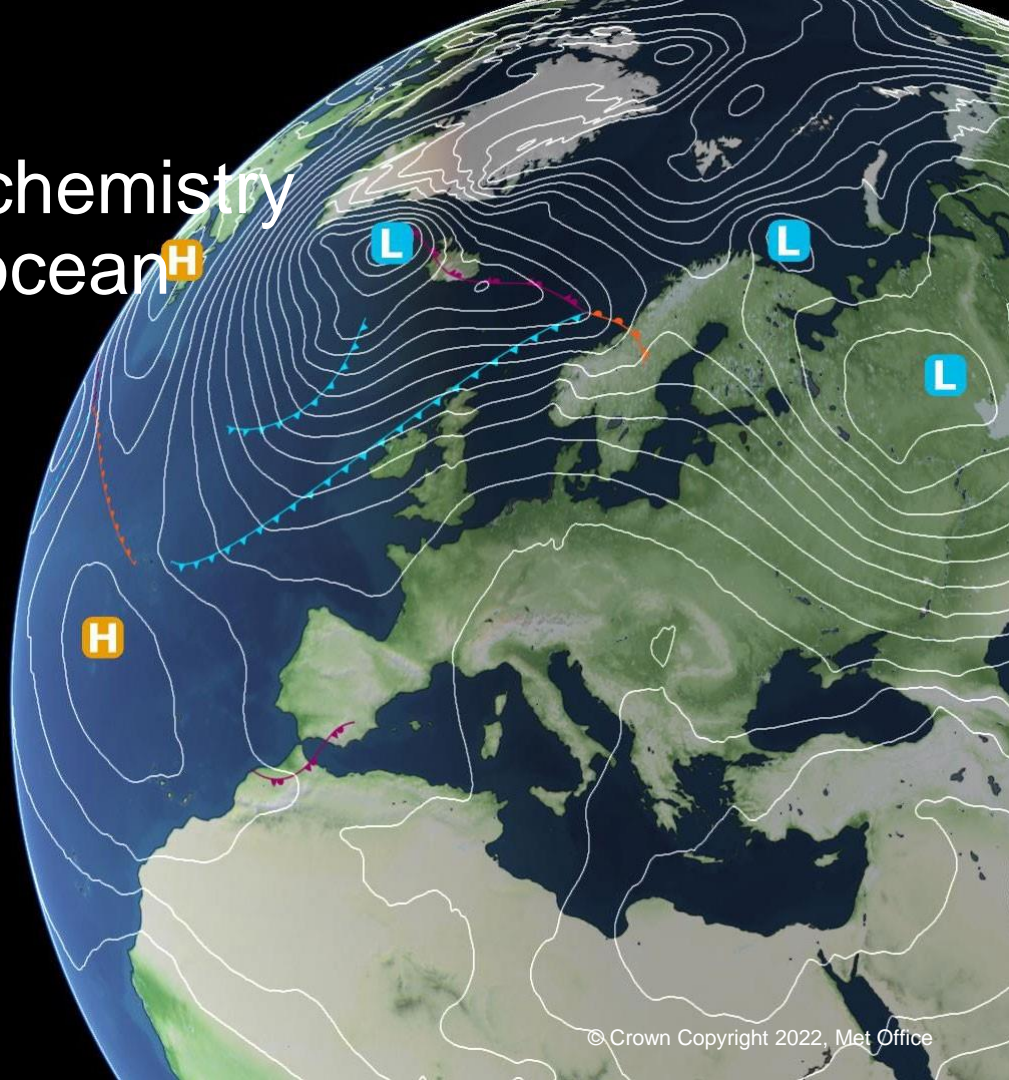


Two-way physics-biogeochemistry coupling constrained by ocean colour data assimilation

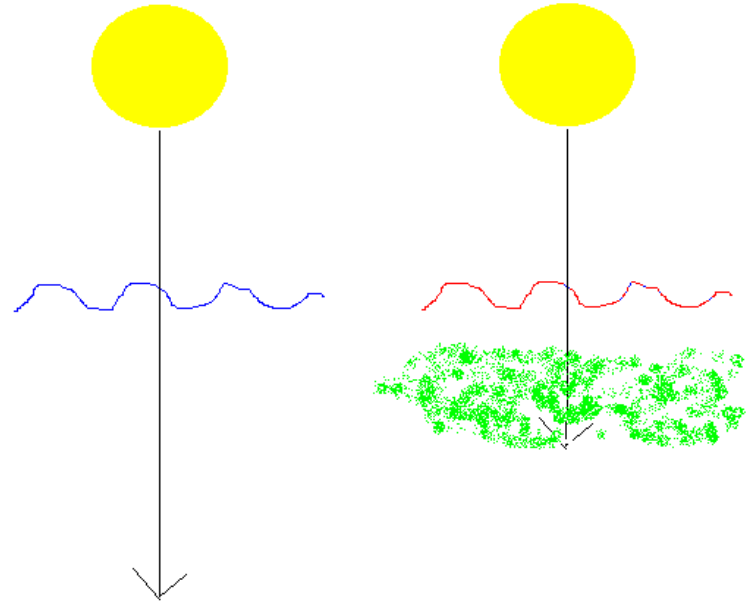
David Ford and Susan Kay

SynObs Kickoff, 16th November 2022



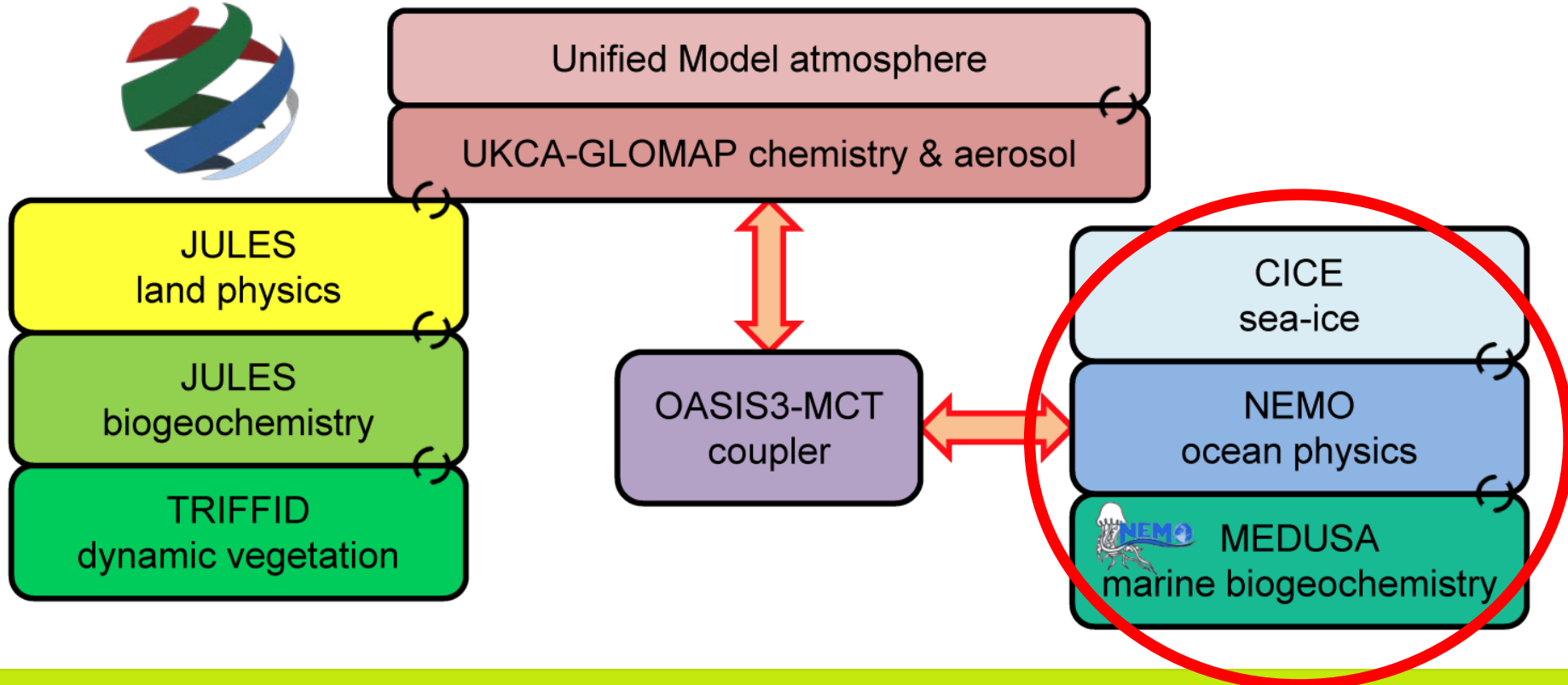
Background

- Shortwave solar radiation (light) enters the ocean, heating the surface layers.
- Chlorophyll (and sediment and gelbstoff in shelf seas) absorbs and scatters the light so it penetrates less deeply.
- Heating is concentrated nearer the surface, changing the physics.
- Long-established feedback but rarely included in models.



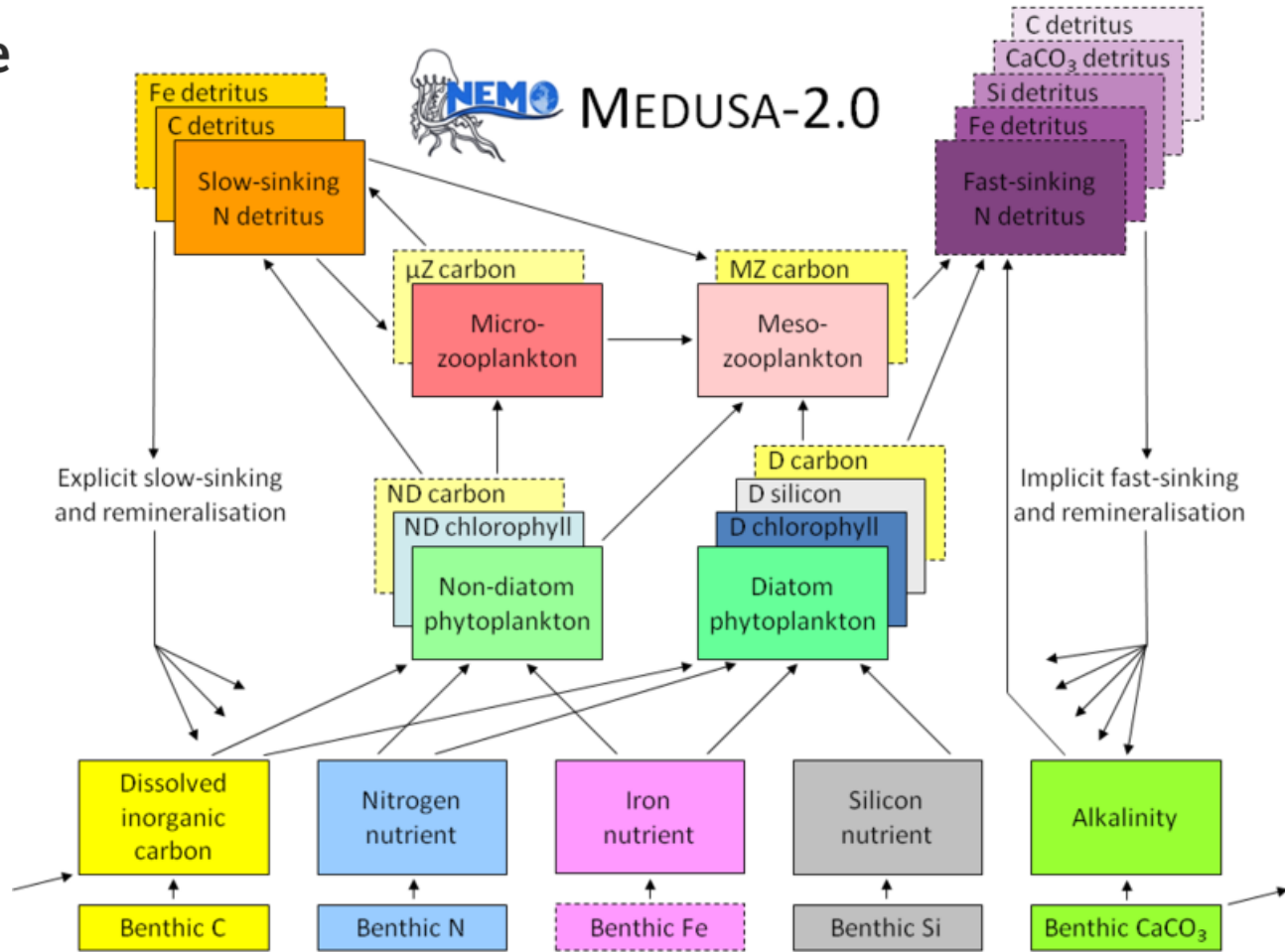


Met Office UK Earth System Model 1 (UKESM1)



- In UKESM1, NEMO uses “RGB” scheme of Lengaigne et al. (2007)
- Visible light split into:
 - Red (600-700 nm)
 - Green (500-600 nm)
 - Blue (400-500 nm)
- Chlorophyll-dependent attenuation coefficient for each waveband
- Constant chlorophyll of 0.05 mg m^{-3} (clear waters)
- But what if chlorophyll came from a coupled biogeochemical model instead, maybe assimilating chlorophyll from ocean colour?

NEMO MEDUSA-2.0





ocean colour
cci



Copernicus Sentinel-3. Credit: ESA/ATG Medialab

Experiments

- Set of ocean-only runs from 2010-2019
- 1° global NEMO-CICE-MEDUSA (ocean components of UKESM1)
- ERA5 atmospheric forcing

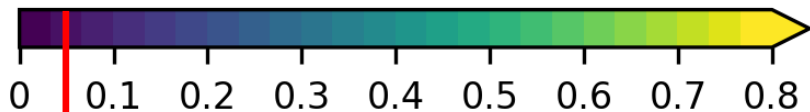
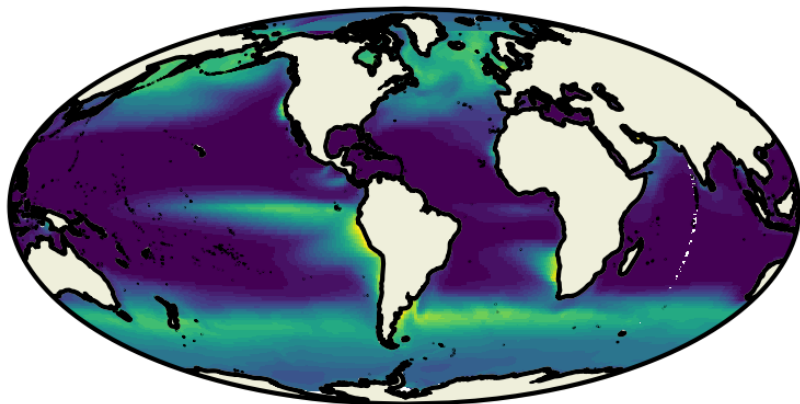
Name	Chlorophyll seen by NEMO	Assimilation
One-way free	Constant (0.05)	None
One-way OC DA	Constant (0.05)	Ocean colour
Two-way free	Varying (MEDUSA)	None
Two-way OC DA	Varying (MEDUSA)	Ocean colour

Identical physics

- (Also some 18-month 1/4° 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)

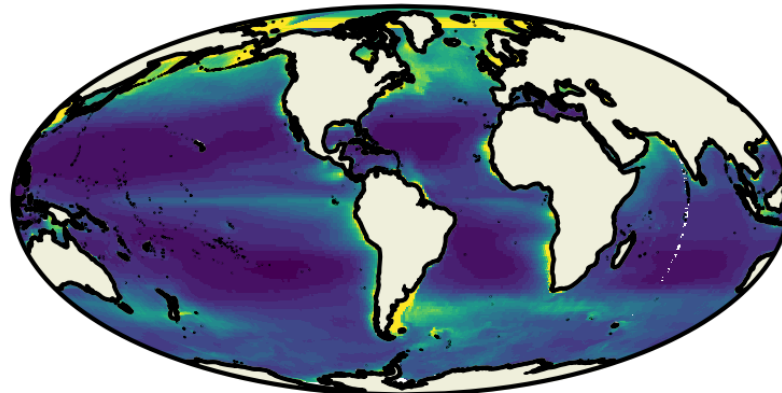
Results

(a) One-way free



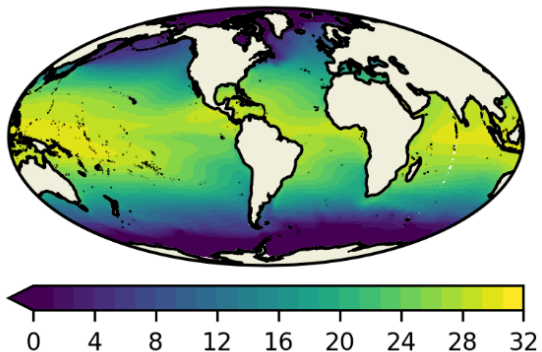
Constant used by NEMO

(d) One-way OC DA



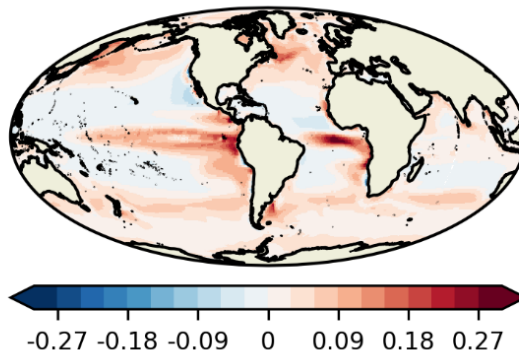
Constant used by NEMO

(a) One-way free

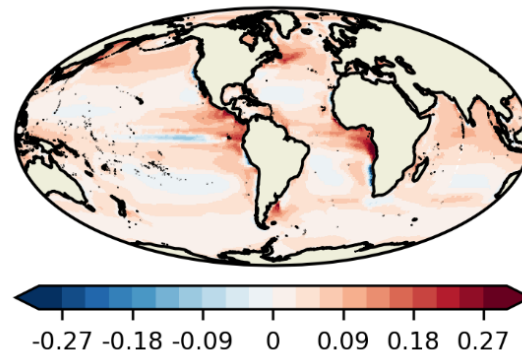


2010-2019 mean temperature at 0m

(b) Two-way free *minus* One-way free

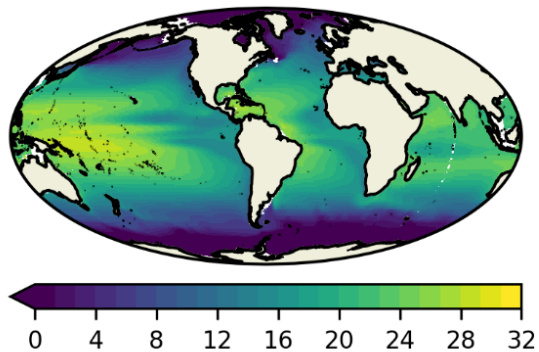


(c) Two-way OC DA *minus* One-way free

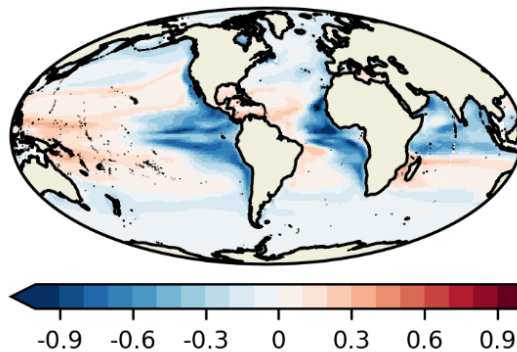


2010-2019 mean temperature at 100m

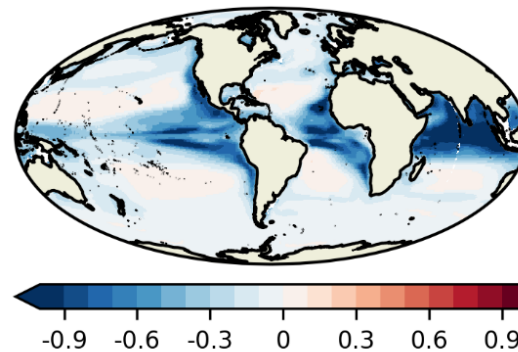
(a) One-way free



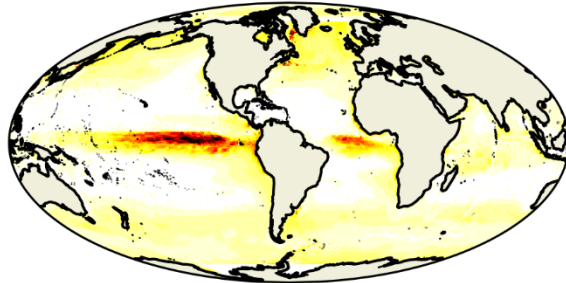
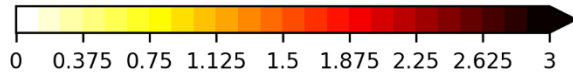
(b) Two-way free *minus* One-way free



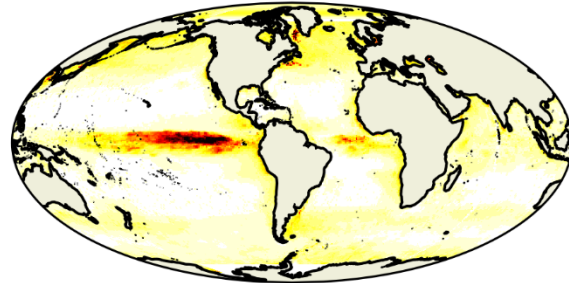
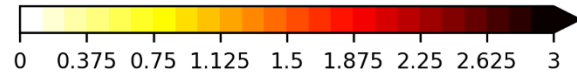
(c) Two-way OC DA *minus* One-way free



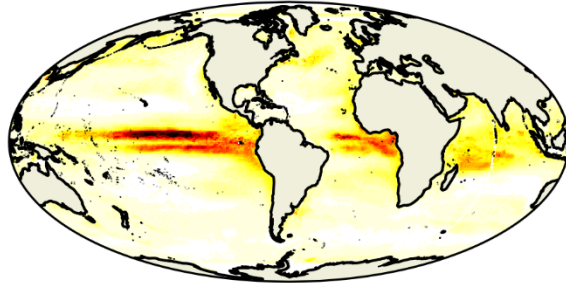
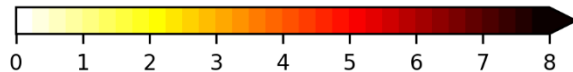
(a) Surface Two-way free

Max:
4.42°C

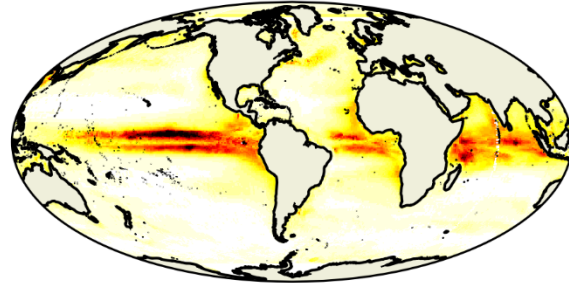
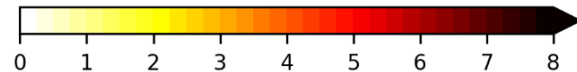
(b) Surface Two-way OC DA

Max:
4.76°C

(c) Full depth Two-way free

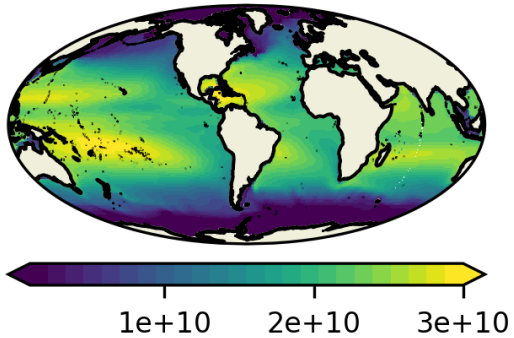
Max:
9.43°C

(d) Full depth Two-way OC DA

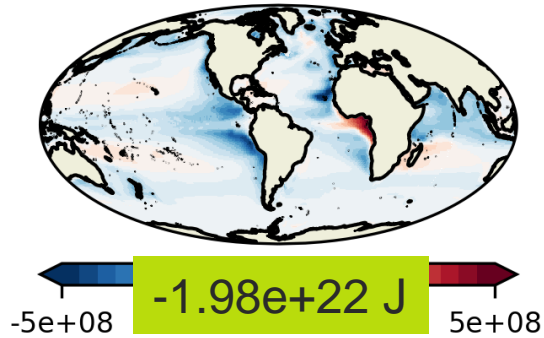
Max:
9.83°C

2019 mean Heat content 0-300m

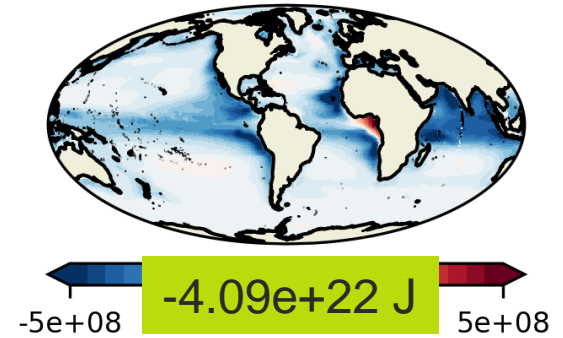
(a) One-way free



(b) Two-way free *minus* One-way free

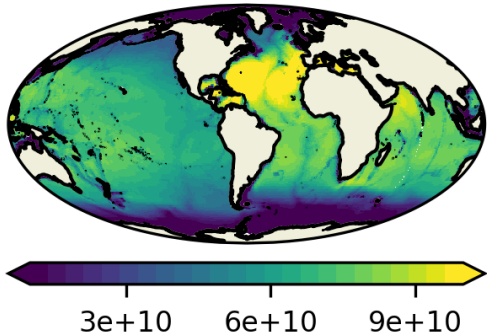


(c) Two-way OC DA *minus* One-way free

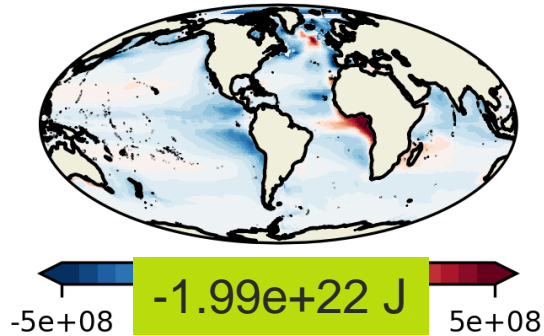


2019 mean Heat content

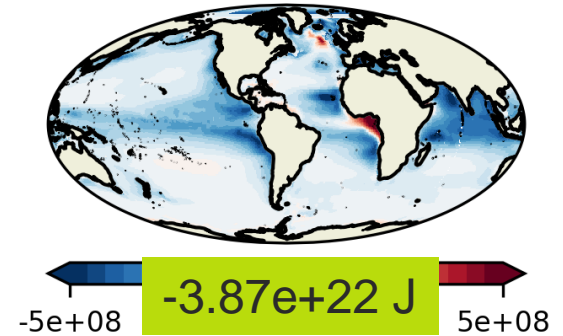
(a) One-way free



(b) Two-way free *minus* One-way free

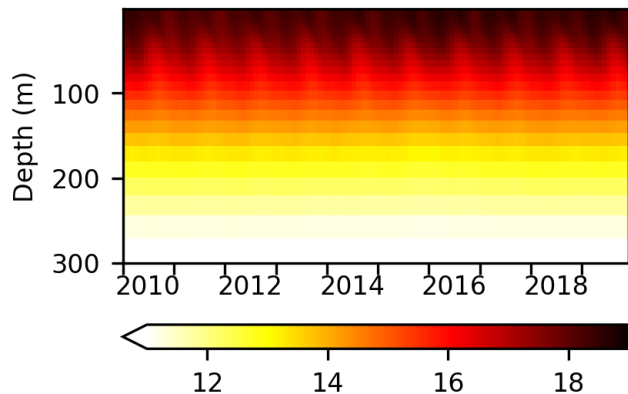
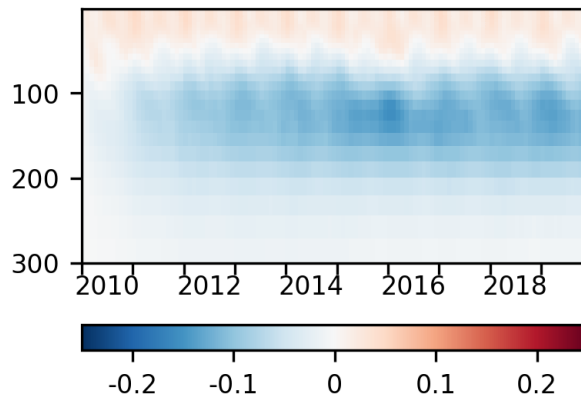
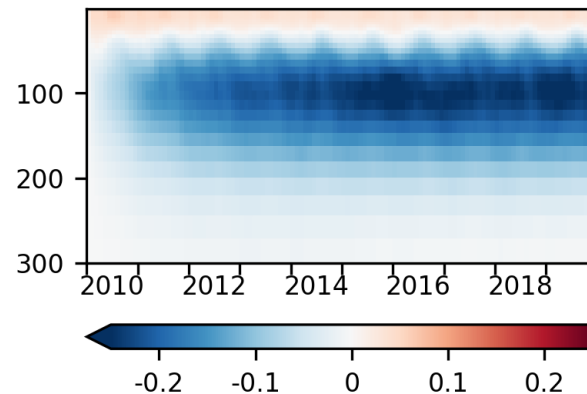


(c) Two-way OC DA *minus* One-way free



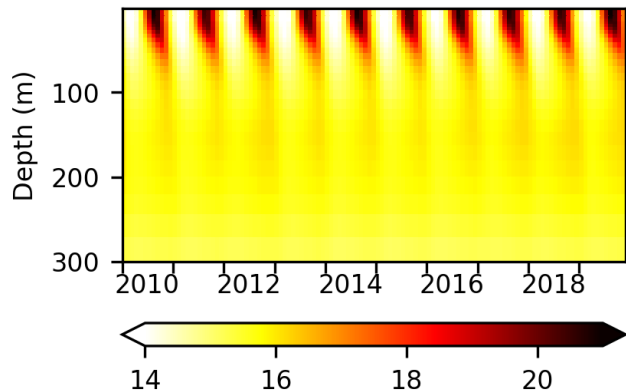
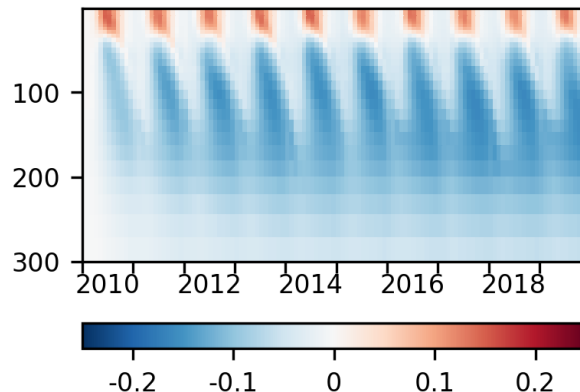
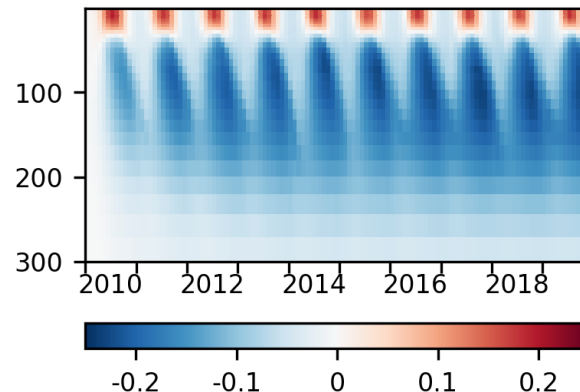
Global Ocean monthly mean temperature (°C)

One-way free

Two-way free *minus* One-way freeTwo-way OC DA *minus* One-way free

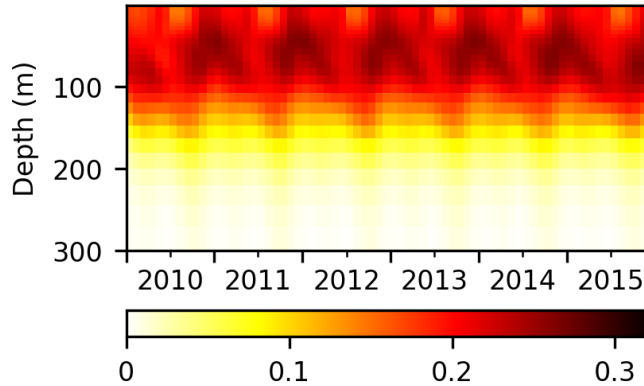
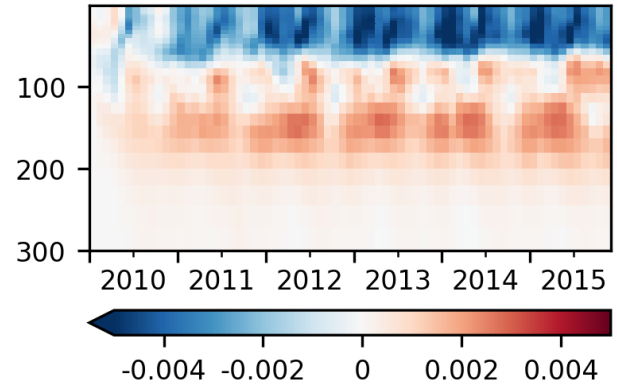
North Atlantic monthly mean temperature ($^{\circ}\text{C}$)

One-way free

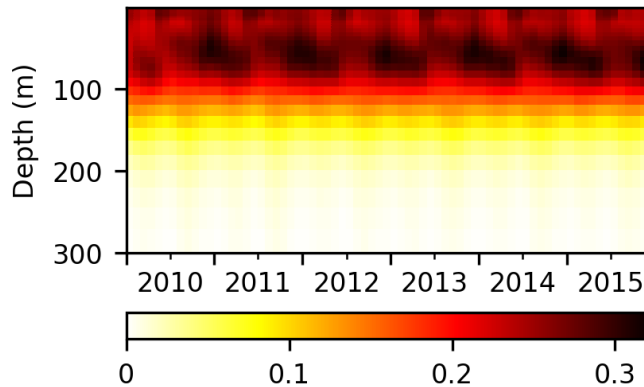
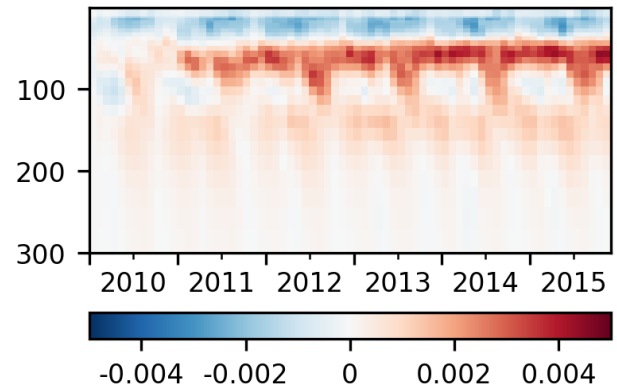
Two-way free *minus* One-way freeTwo-way OC DA *minus* One-way free

Global Ocean monthly mean chlorophyll (mg m^{-3})

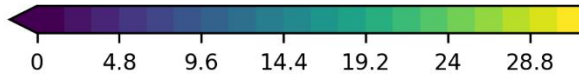
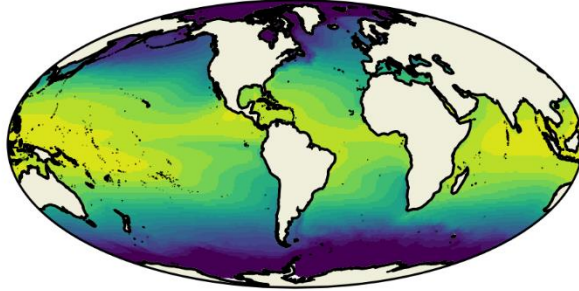
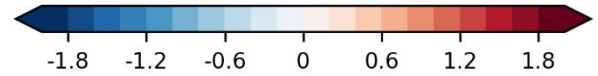
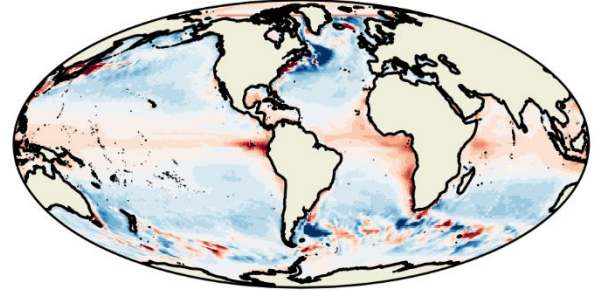
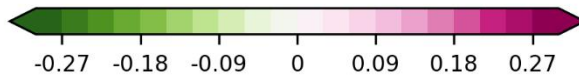
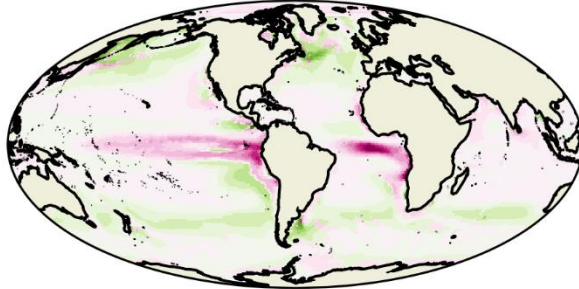
One-way free

Two-way free *minus* One-way free

One-way OC DA

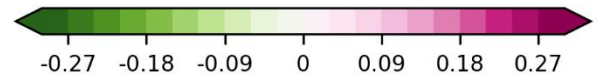
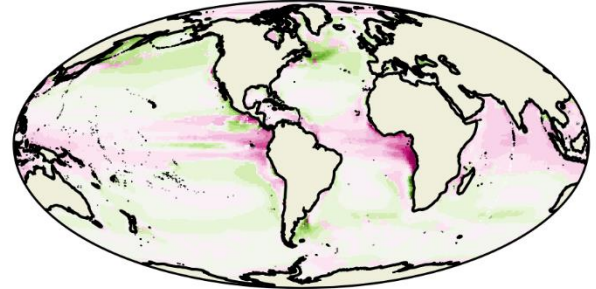
Two-way OC DA *minus* One-way OC DA

(a) Observations

(b) One-way free *minus* observations(c) MAE(Two-way free) *minus* MAE(One-way free)

Better

Worse

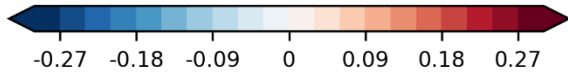
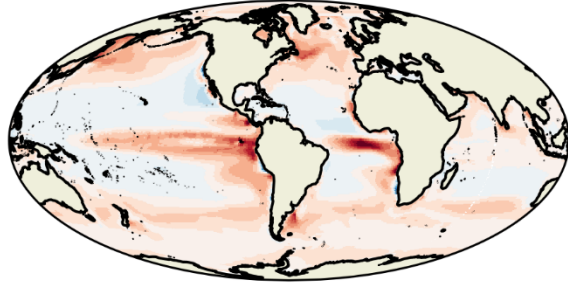
(d) MAE(Two-way OC DA) *minus* MAE(One-way free)

Better

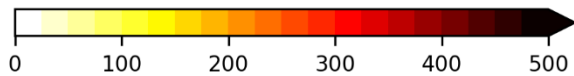
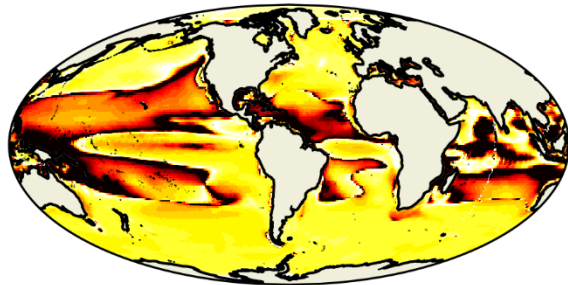
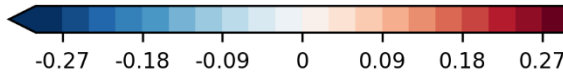
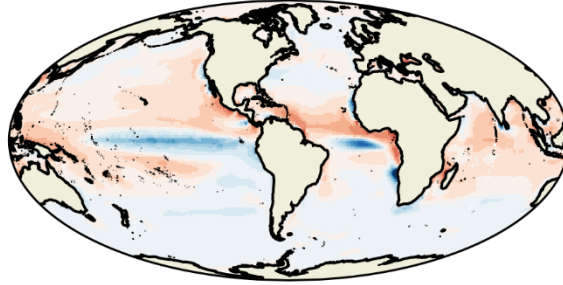
Worse

2010-2019 mean temperature at 0m

Two-way free *minus* One-way free



Two-way DA *minus* Two-way free



Relative change in SST due to assimilation compared to change due to coupling

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

Summary

- Implemented two-way coupling between NEMO and MEDUSA
- Impact of two-way coupling consistent with theory and could be significant, e.g. for ocean heat content
- Much regional and seasonal variation
- Magnitude of change in SST due to uncertainties in model chlorophyll comparable to change due to coupling
- Use of input chlorophyll climatology a potential compromise



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
Ocean Modelling

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The impact of ocean biogeochemistry on physics and its consequences for modelling shelf seas

Jozef Skákala ^{a, b}  , Jorn Bruggeman ^a, David Ford ^c, Sarah Wakelin ^d, Anil Akpınar ^d, Tom Hull ^{e, f}, Jan Kaiser ^f, Benjamin R. Loveday ^g, Enda O’Dea ^c, Charlotte A.J. Williams ^d, Stefano Ciavatta ^{a, b}

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