Forcing models with flux anomalies, a proposed MIP (FAFMIP)

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Overview of presentation

Trying to understand, and isolate,
the role of the ocean in transient climate change

- Proposed MIP with coupled models – FAFMIP

Coupled integrations with prescribed 'overrides' of windstress, freshwater and heat fluxes acting at the sea-surface

- Some background

Review studies of ocean heat uptake using ocean-only models with prescribed heat flux 'overrides'

- Conclusions

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FAFMIP

- Assess spread of ocean model predictions of mean state and climate change of
  - Sea Level
  - AMOC
  - Heat uptake &
  - transient tracer and carbon uptake

CMIP6 experimental design

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Method

- Force coupled AOGC control runs with 'overrides'

  The 'over-rides' are common anomalous forcing patterns obtained as ensemble-means of '1%CO_2 minus control' CMIP5 calculations

- Proposed 'overrides' are:
  - surface wind stress
  - surface heat flux
  - surface freshwater flux
  - all of the above combined
  - geographically uniform heat flux anomaly

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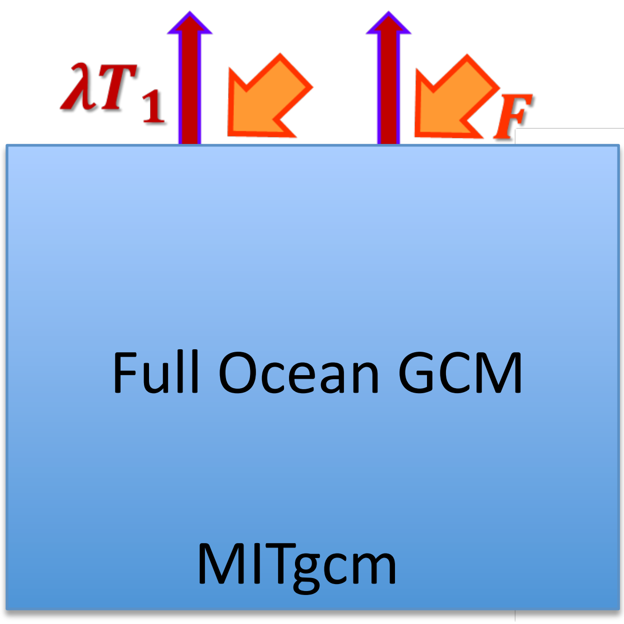
Example: ocean-only run under CORE-I forcing

Climate change experiment with a heat flux override:

- Abrupt, uniform surface forcing of F = 4 W/m^2 everywhere
- Spatially-invariant radiative feedback of $\lambda = 1\ Wm^{-2}K^{-1}$

Simplified representation of atmospheric climate feedbacks



Note:
Only surface heat fluxes are perturbed
No change in winds or E-P

Marshall et al, 2014: Climate Dynamics

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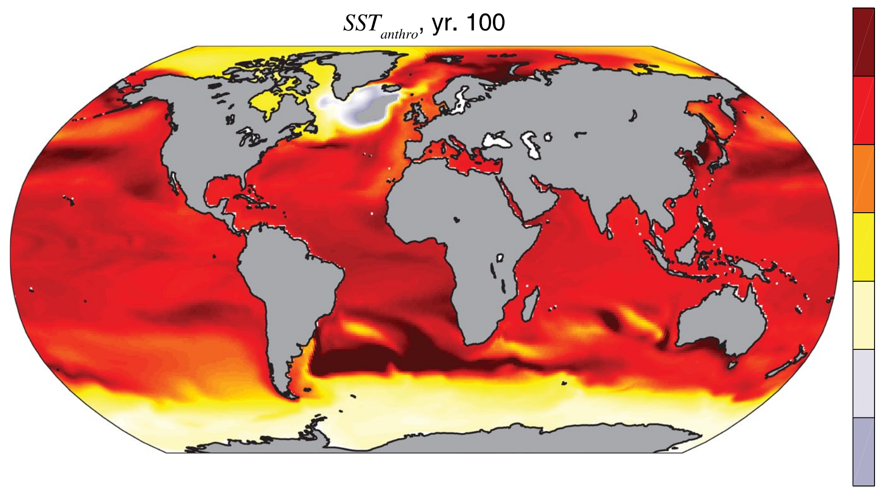
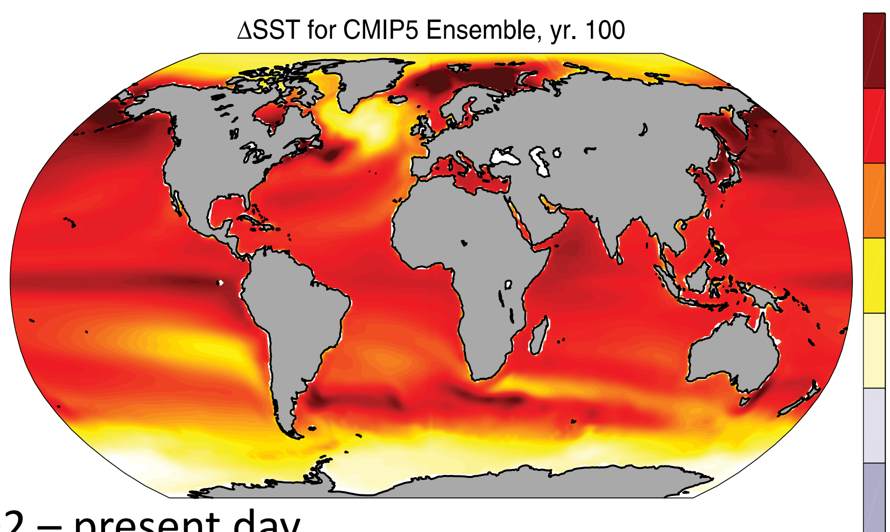
Temperature anomalies after 100y

Fig. 5 Temperature perturbation after 100 years of an ocean-only calculation perturbed by a uniform downwelling flux at the ocean's surface.



Ocean-only run

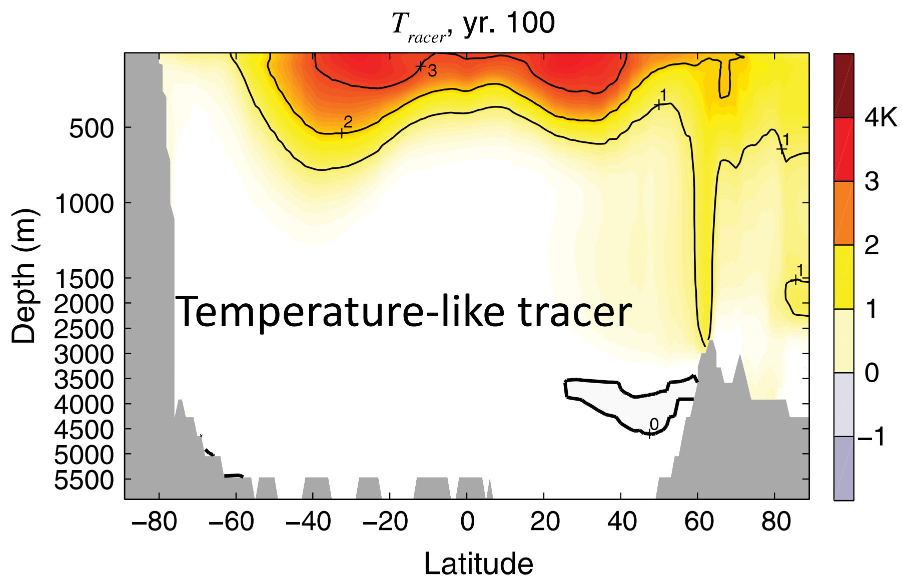


CMIP5 runs

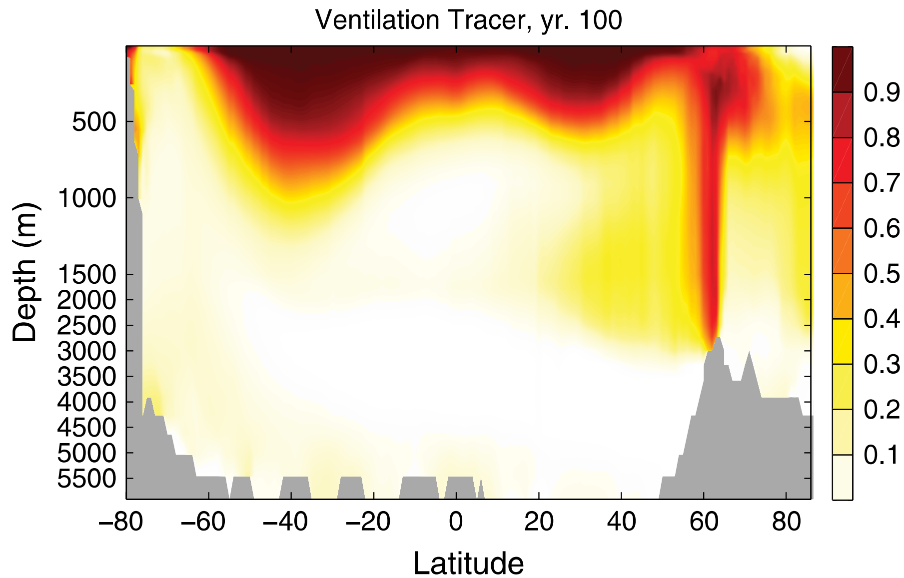
Marshall et al, 2014, Clim. Dyn.

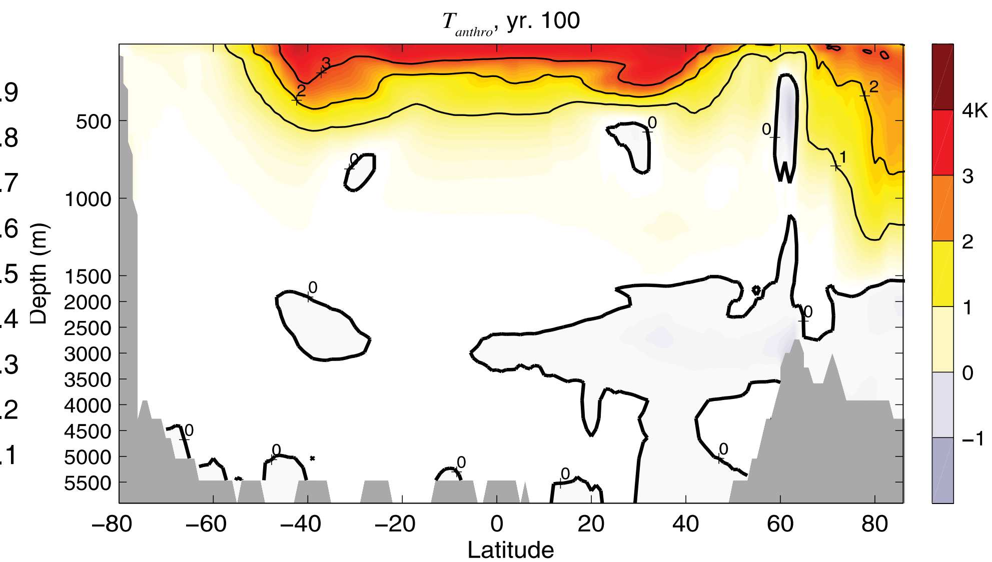
SST change in expt 4xCO_2 – present day

Latitude



Strong similarity between anthropogenic temperature and transient tracer in CMIP5





Marshall et al, 2014, Clim. Dyn.

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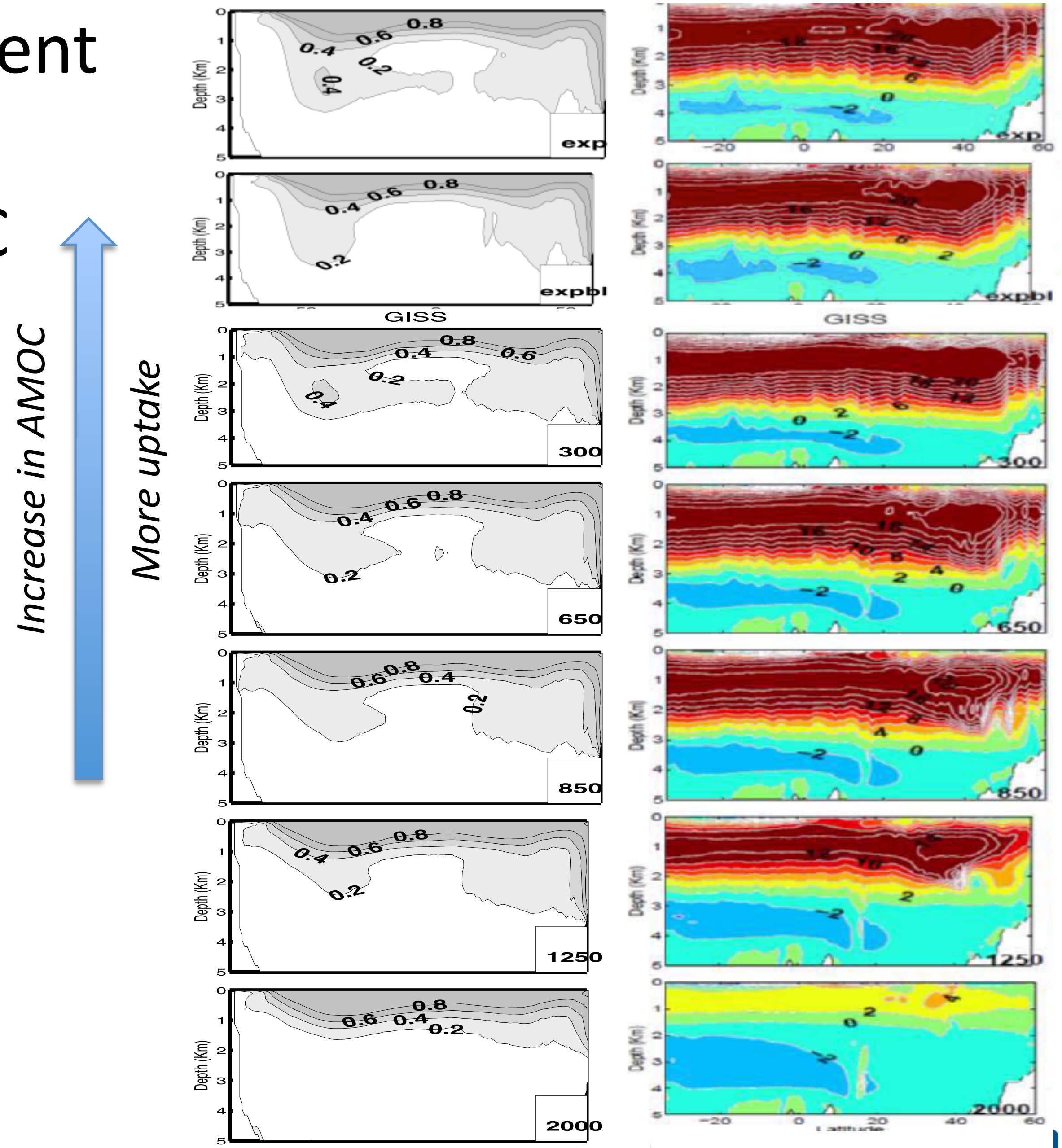
Sensitivity of transient tracer uptake to strength of MOC

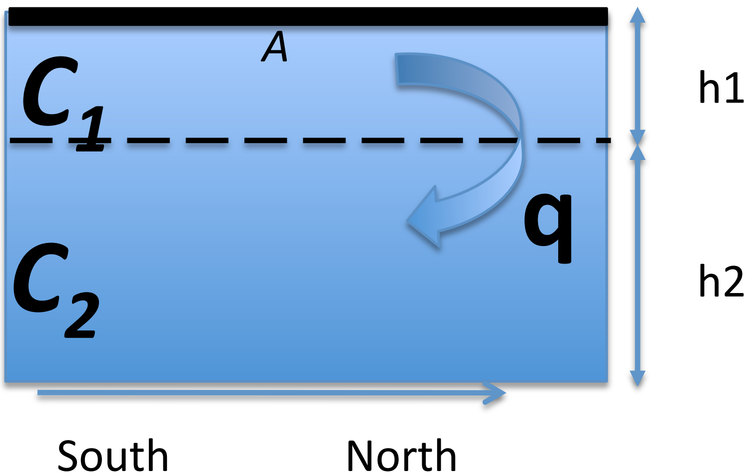
- Experiments with CORE-I forcing and transient tracer
- Vary AMOC in two different models: GISS and MIT

Romanou et al, in prep



Ventilation tracer **AMOC**

Simple model of tracer uptake



$$Ah_2 \frac{\partial C_2}{\partial t} - q(C_1 - C_2) = 0$$

$$C_2 = C_1(1 - e^{-\gamma t}) \quad \text{where } \gamma = \frac{q}{Ah_2}$$

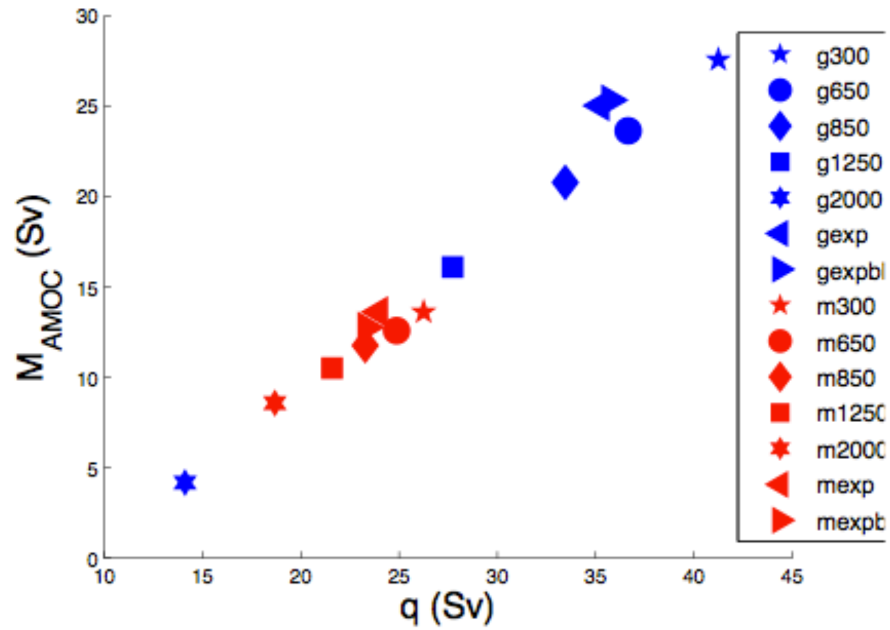


FIGURE 4. Predicted q vs strength of the AMOC. q= slope*100m*Area(initially)/Inv(initially)/1e6 (Sv).

Romanou et al, in prep

$$Inventory = Ah_2C_2 = C_1qt$$ (in the limit that $\gamma t \ll 1$)

Simple model suggests that the tracer inventory increases linearly at a rate set by the overturning strength

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Heat uptake varies with AMOC in CMIP5 models

Depth where 80% of the heat uptake occurs

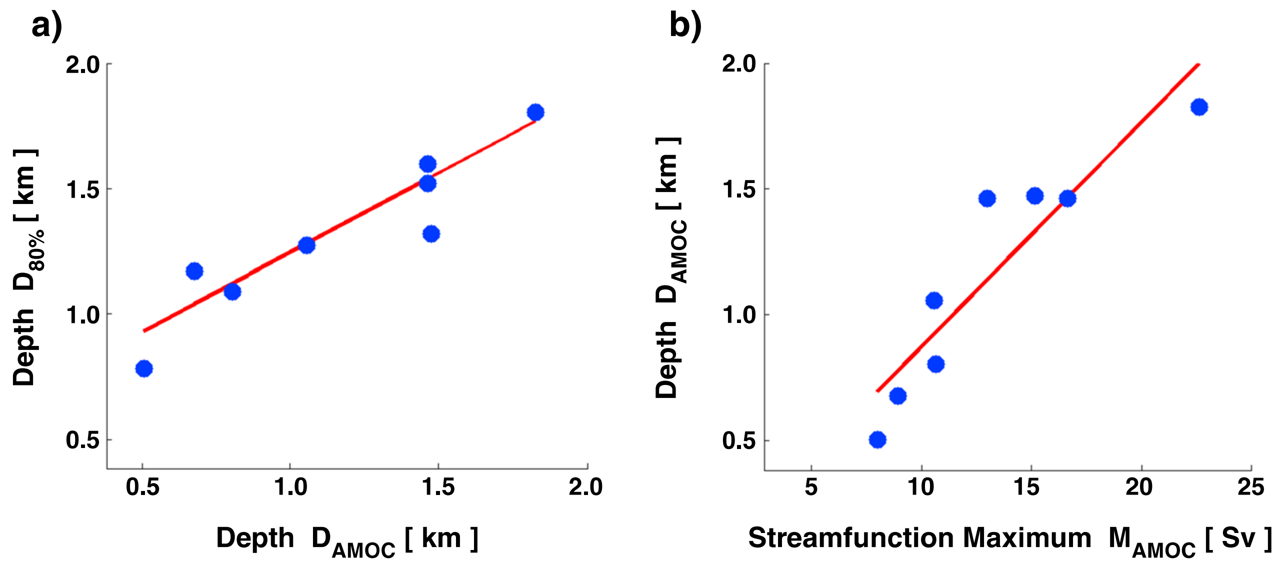

Figure 3. (a) Correlation between $D_{80\%}$ and D_{AMOC} ($R = 0.93$, p value $p < 0.01$); (b) Correlation between D_{AMOC} and M_{AMOC} ($R = 0.92$, p value $p < 0.01$).

Kostov et al 2014, GRL

Concluding remarks

- FAFMIP will use AOGCMs, and a variety of 'override' forcings (heat, salt, wind)
- Coupled models are needed to represent climate feedbacks appropriately
- In ocean-only models, progress can be made using a simple air-sea feedback parameter λ
- Ocean's MOC plays a central role in setting patterns and rates of heat and tracer uptake


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