Ocean-only FAFMIP: Understanding Regional Patterns of Ocean Heat Content and Dynamic Sea Level Change

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manuscript in review at JAMES, pre-print: https://doi.org/10.1002/essoar.10501557.1

CL4.5 Live Chat - 4 May 2020 08:30-10:15 CEST: https://meetingorganizer.copernicus.org/EGU2020/session/36739

NERC SCIENCE OF THE ENVIRONMENT

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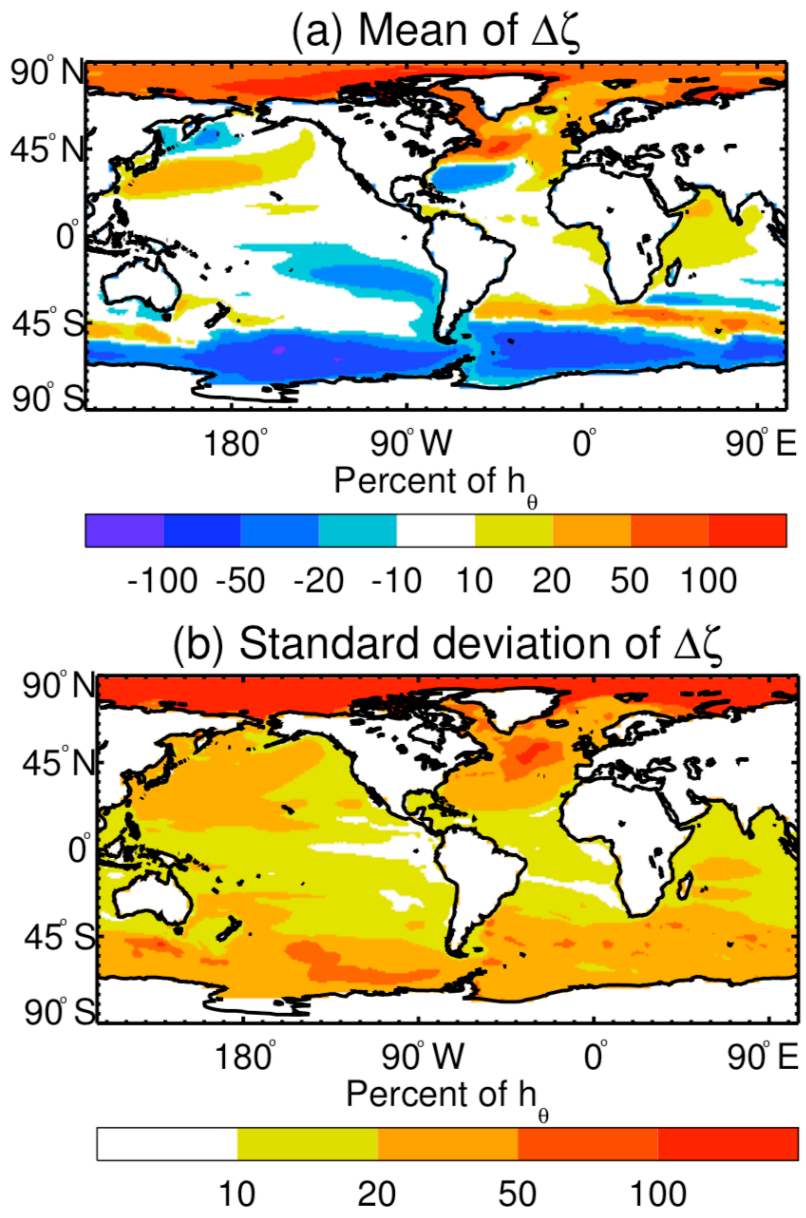
Introduction

Coupled (AOGCM) CMIP5 projections demonstrate a large uncertainty in dynamic sea level (DSL, ζ) and ocean heat content (OHC) change.

Uncertainty arises from the use of different ocean models and uncertainty in air-sea buoyancy and momentum flux changes.

1. How much of the spread in DSL and OHC change is due to the use of different ocean models?

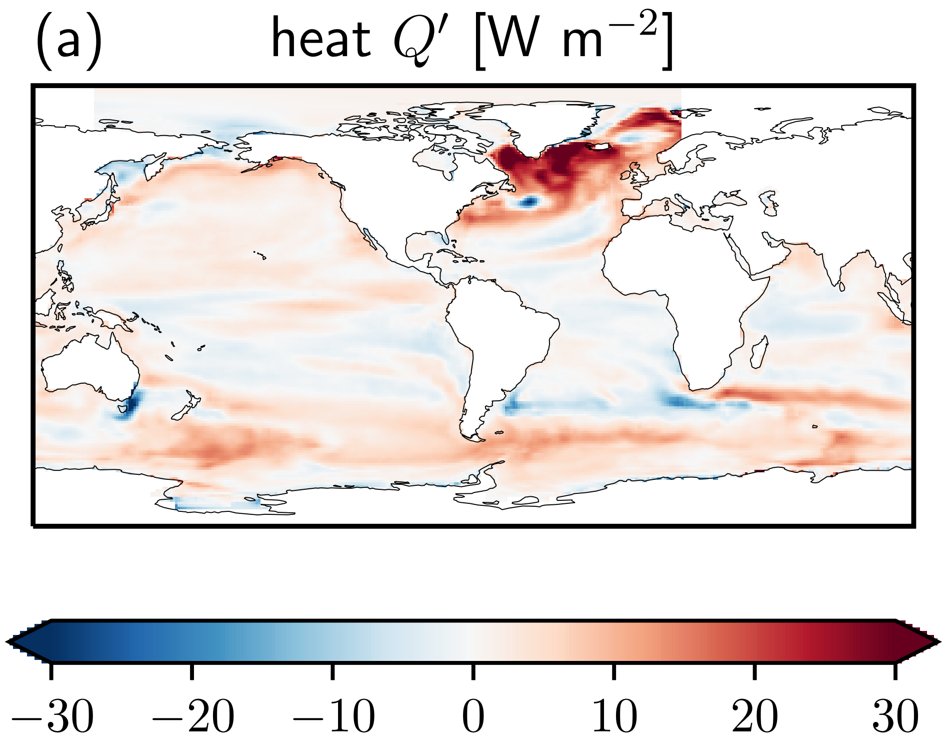
2. What is the effect of atmosphere feedbacks on ocean climate change?



(Gregory et al., 2016)

Surface Heat Flux Experiments

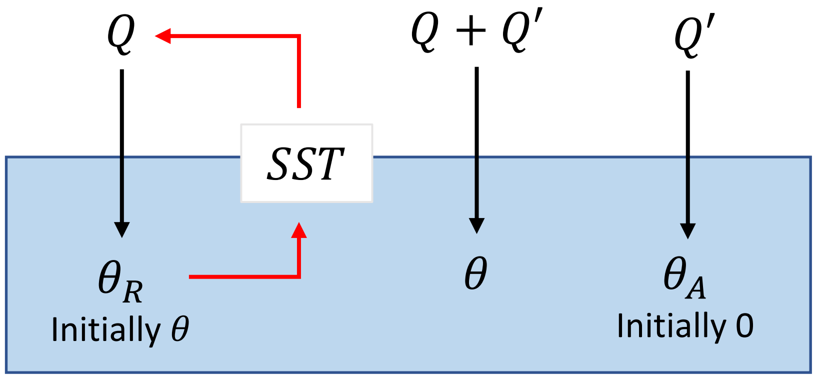
Perturbation: CMIP5 ensemble (13 member) mean 1pctCO2 yr 61-80 mean minus piControl mean 12 month climatology.



1) faf-heat (AOGCM, Method B)

(Banks & Gregory, 2006; Bouttes & Gregory, 2014; Gregory et al., 2016)

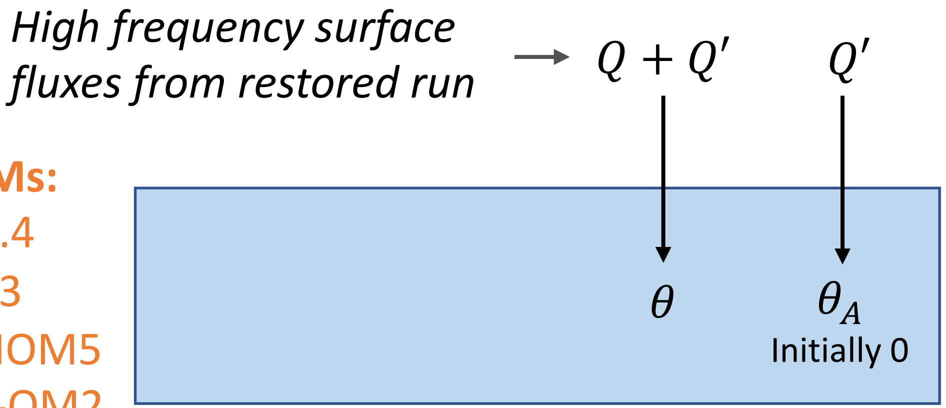
2*AOGCMs:
CanESM5
HadCM3



2) faf-heat-o (OGCM, Blaker Method)

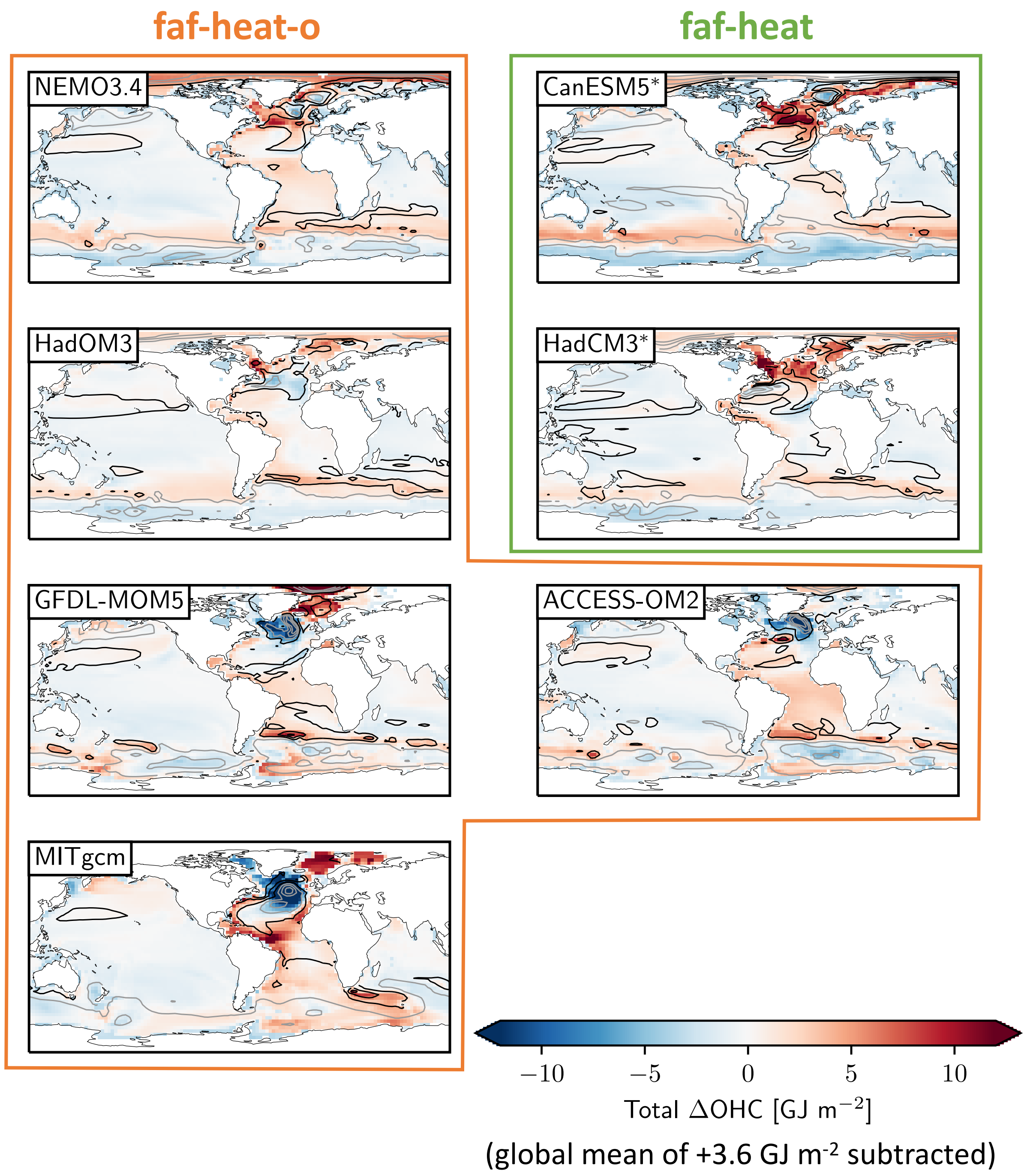
(Marshall et al., 2015; Zika et al., 2018)

5*OGCMs:
NEMO3.4
HadOM3
GFDL-MOM5
ACCESS-OM2
MITgcm

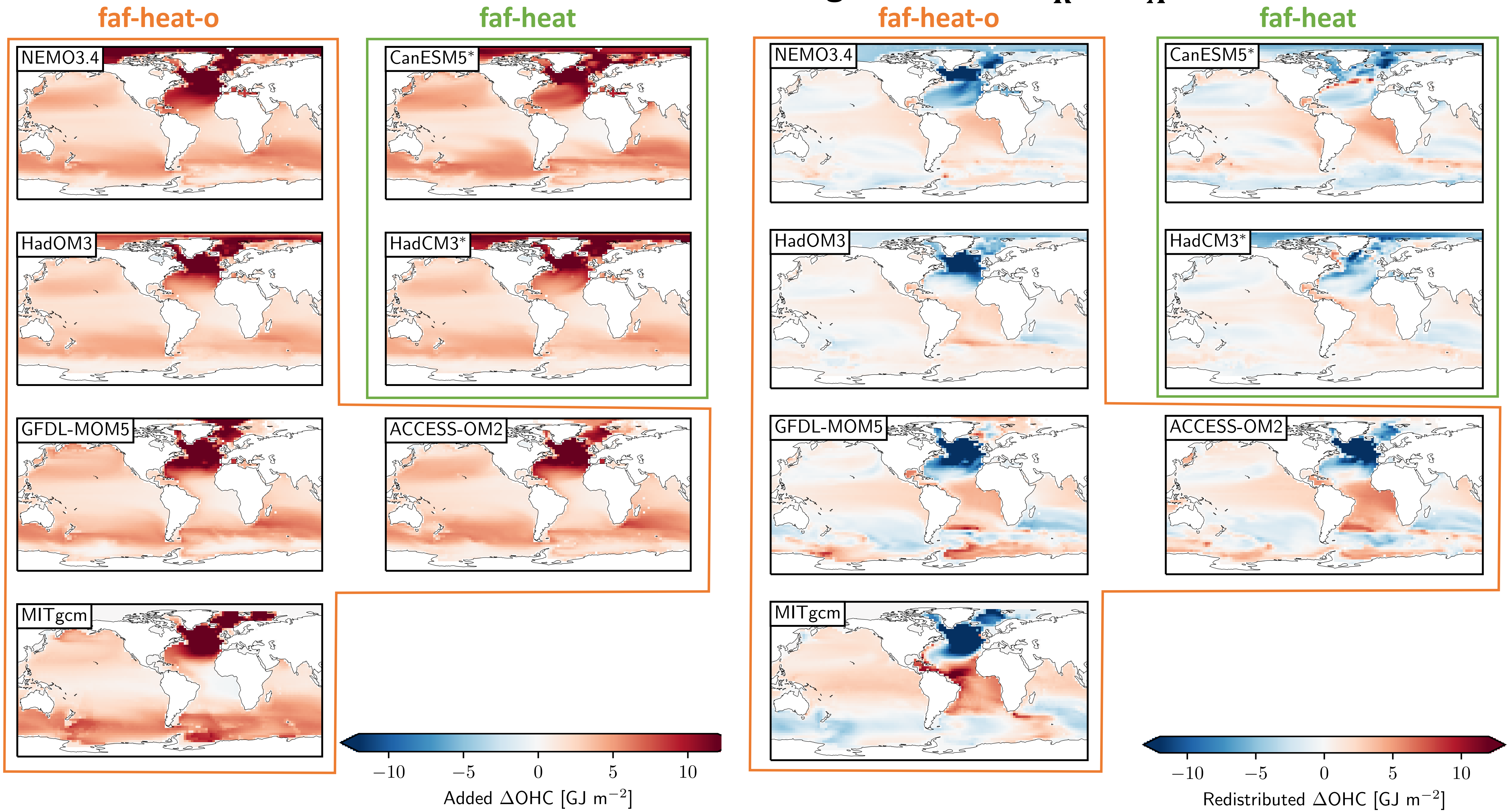


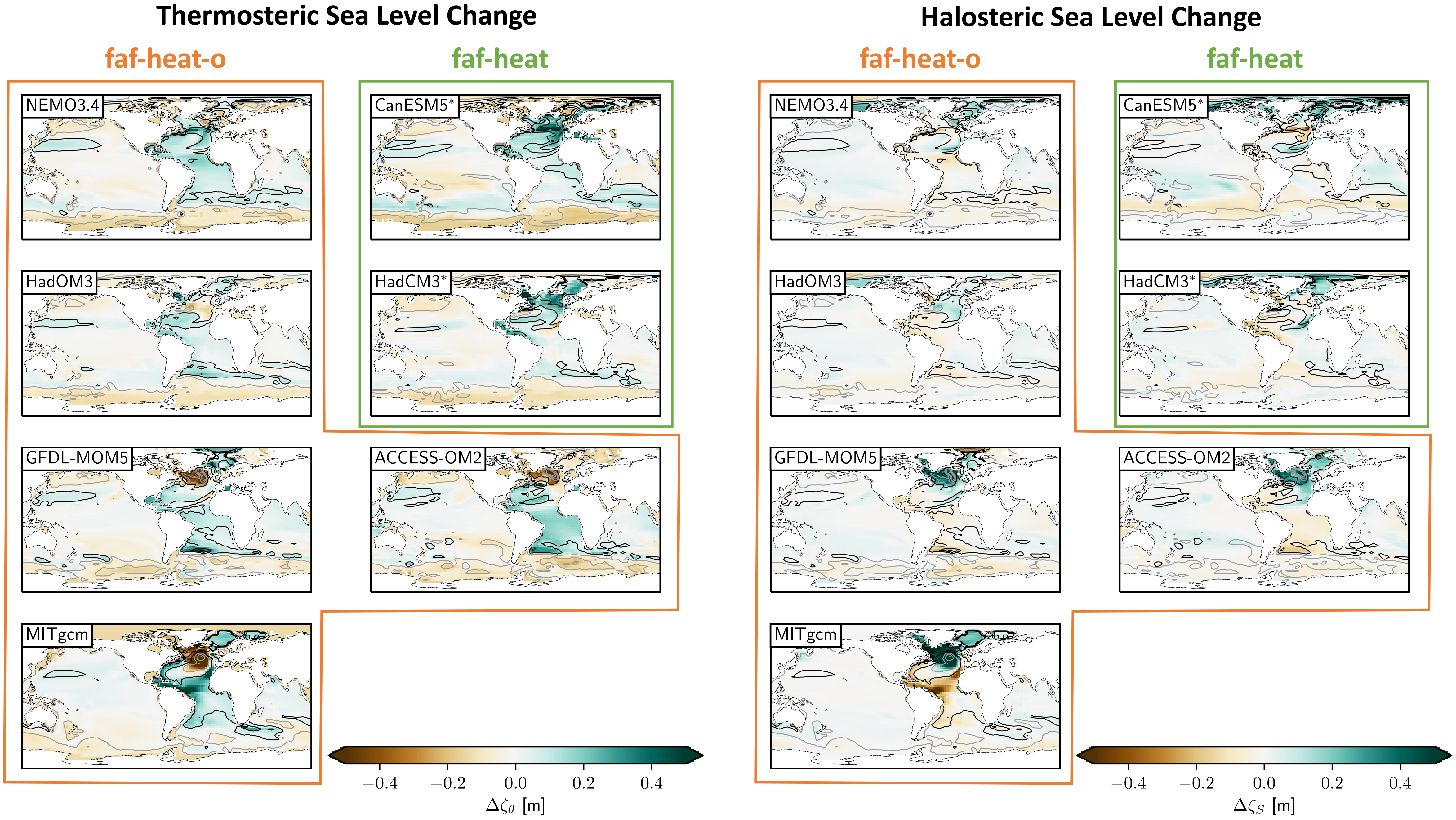
Ocean Heat Content Change

- Large <u>disagreement</u> over warming/cooling of mid to high latitude North Atlantic.
- Greater <u>agreement</u> for Southern Ocean meridional pattern.
- AOGCMs indicate more warming in North Atlantic relative to OGCMs.
    - ➢ AO-feedback amplifies warming.

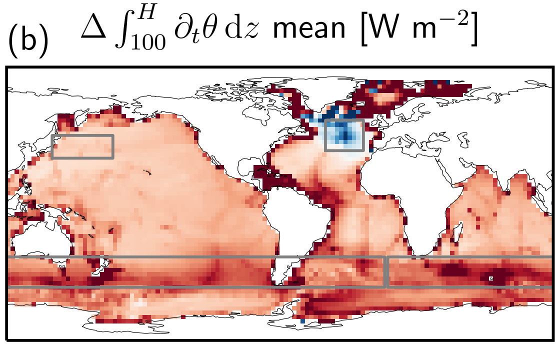


Added vs. Redistributed Ocean Heat Content Change: $\theta = \theta_R + \theta_A$




Thermosteric Sea Level Change
Halosteric Sea Level Change
faf-heat-o
faf-heat
NEMO3.4
CanESM5*
HadOM3
HadCM3*
GFDL-MOM5
ACCESS-OM2
MITgcm
−0.4
−0.2
0.0
0.2
0.4
$\Delta\zeta_\theta$ [m]
$\Delta\zeta_S$ [m]

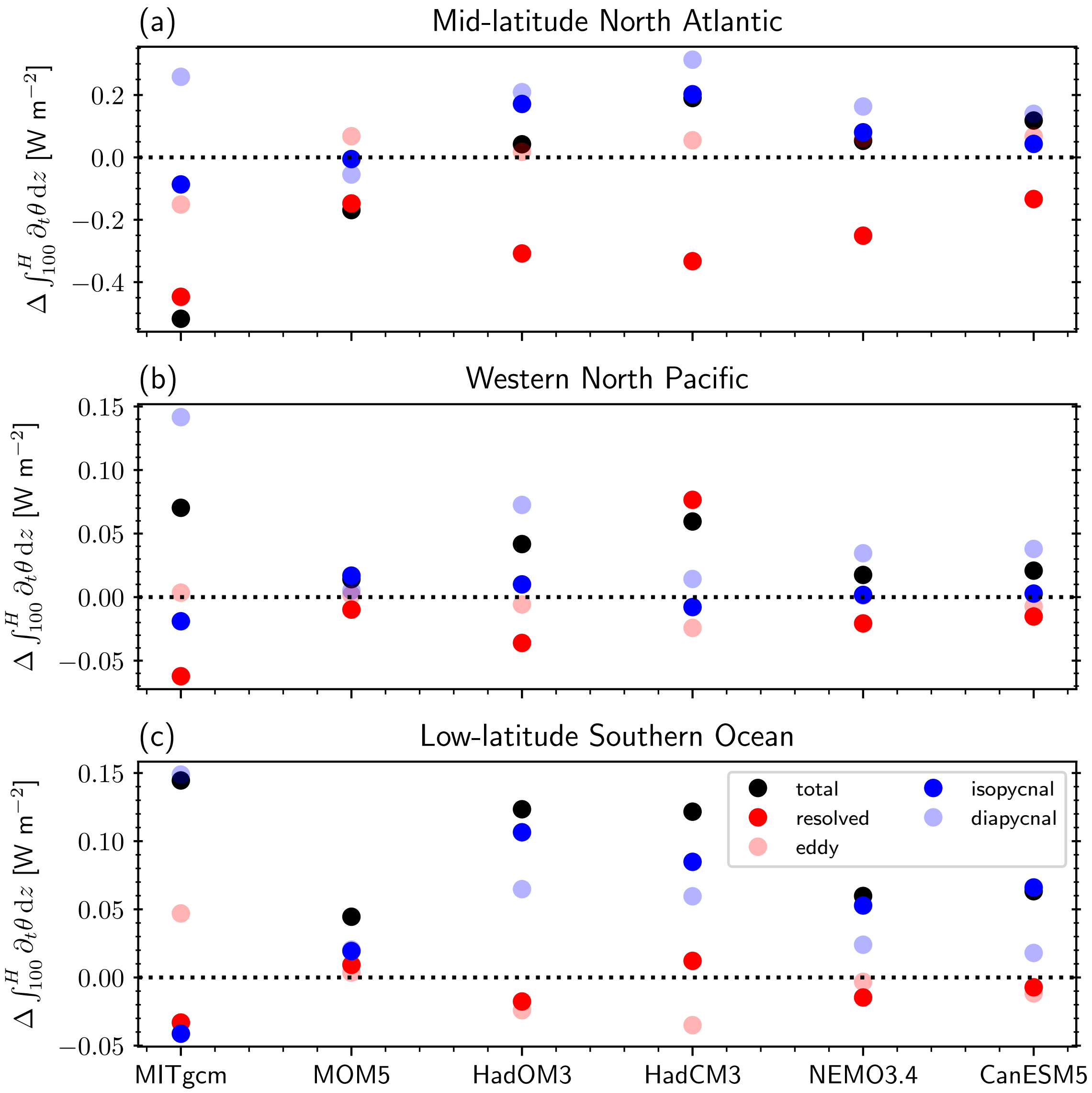
ΔOHC processes



Consider the heat budget:

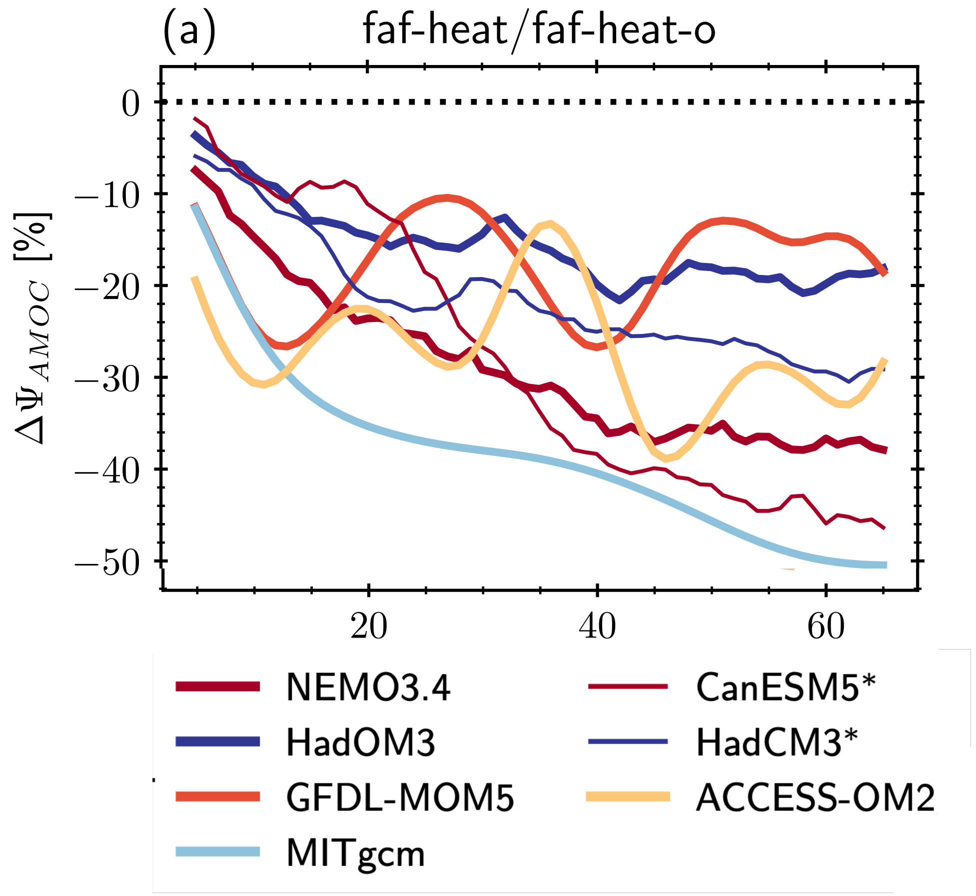
$$\partial_t \theta = \partial_t \theta_{resolved} + \partial_t \theta_{eddy} + \partial_t \theta_{isopycnal} + \partial_t \theta_{diapycnal}$$

- Mainly cooling due to <u>residual circulation</u> ($\partial_t \theta_{resolved} + \partial_t \theta_{eddy}$) change in North Atlantic
- <u>Contrasting</u> processes in HadOM3/HadCM3 in Pacific.
- Mainly <u>diffusive</u> processes in Southern Ocean.

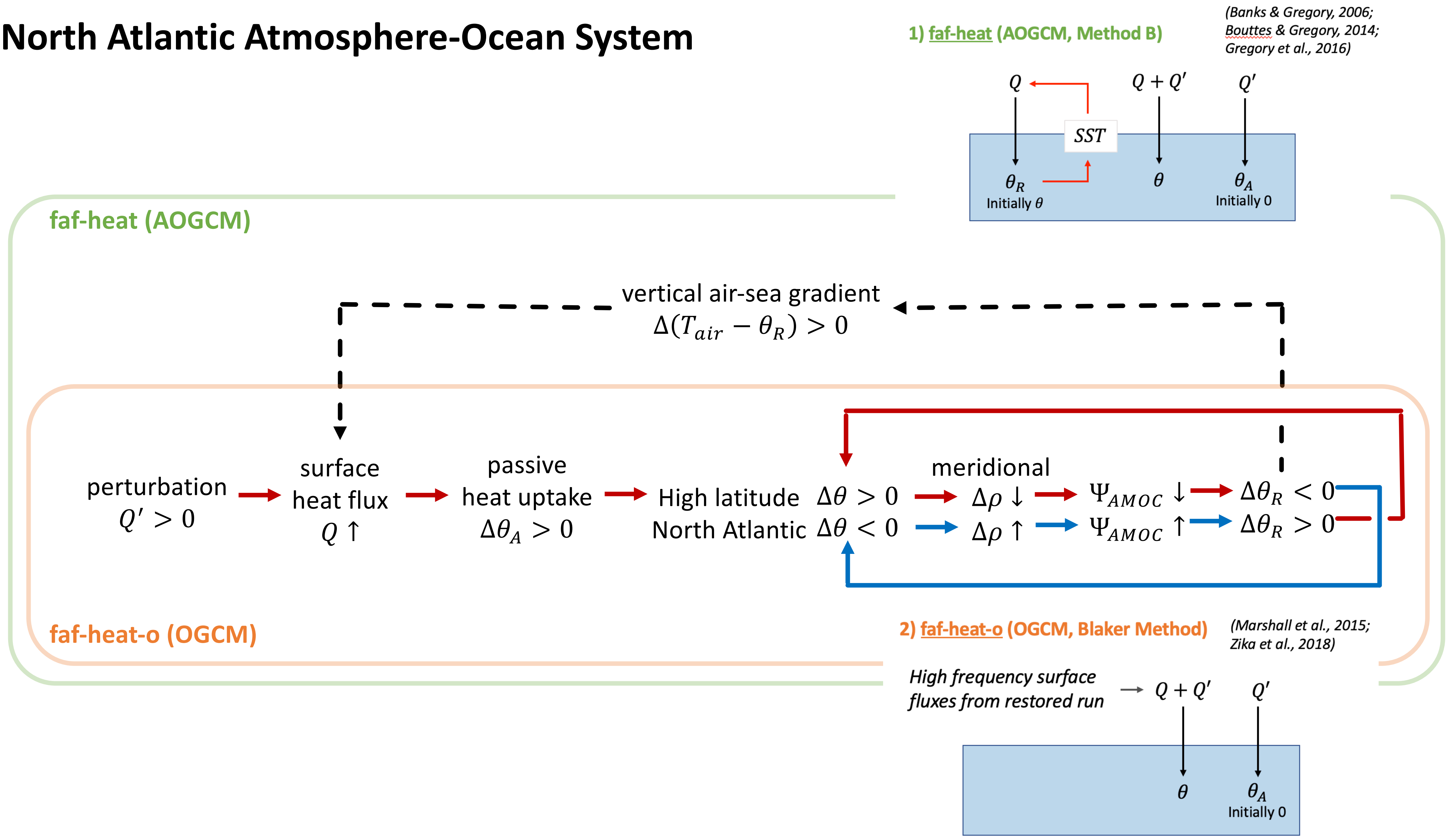


AMOC Change

- Large <u>spread</u> (20-50% weakening) in relative AMOC change after 70 years.
- AMOC weakening amplified by ~10% in AOGCMs relative to OGCMs.
    - ➢ AO-feedback increases AMOC weakening
- MITgcm is an outlier: 21 Sv control and -11 Sv change.



North Atlantic Atmosphere-Ocean System



Summary

1) Large spread in ΔOHC and $\Delta\zeta$ from prescribing the same surface heat flux perturbation to different OGCMs.

   - ➢ Structural and background state differences alone contribute a large spread in ocean sensitivity to boundary condition changes.

   - ➢ Little agreement on which processes dominate ΔOHC on regional scales.

   - ➢ Large spread in both thermosteric and halosteric contributions to $\Delta\zeta$, consistent with Couldrey et al. (in rev.)

2) FAFMIP Method B introduces an AO-feedback which amplifies $\Delta\Psi_{AMOC}$ weakening by ~10%

   - ➢ Mitigated by the negative AMOC-θ-surface heat flux feedback

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