Drivers of subsurface Pacific cooling in ECCOv4r4

Anthony Meza
MIT/WHOI Joint Program in Oceanography

G. Jake Gebbie and Susan Wijffels
Woods Hole Oceanographic Institution

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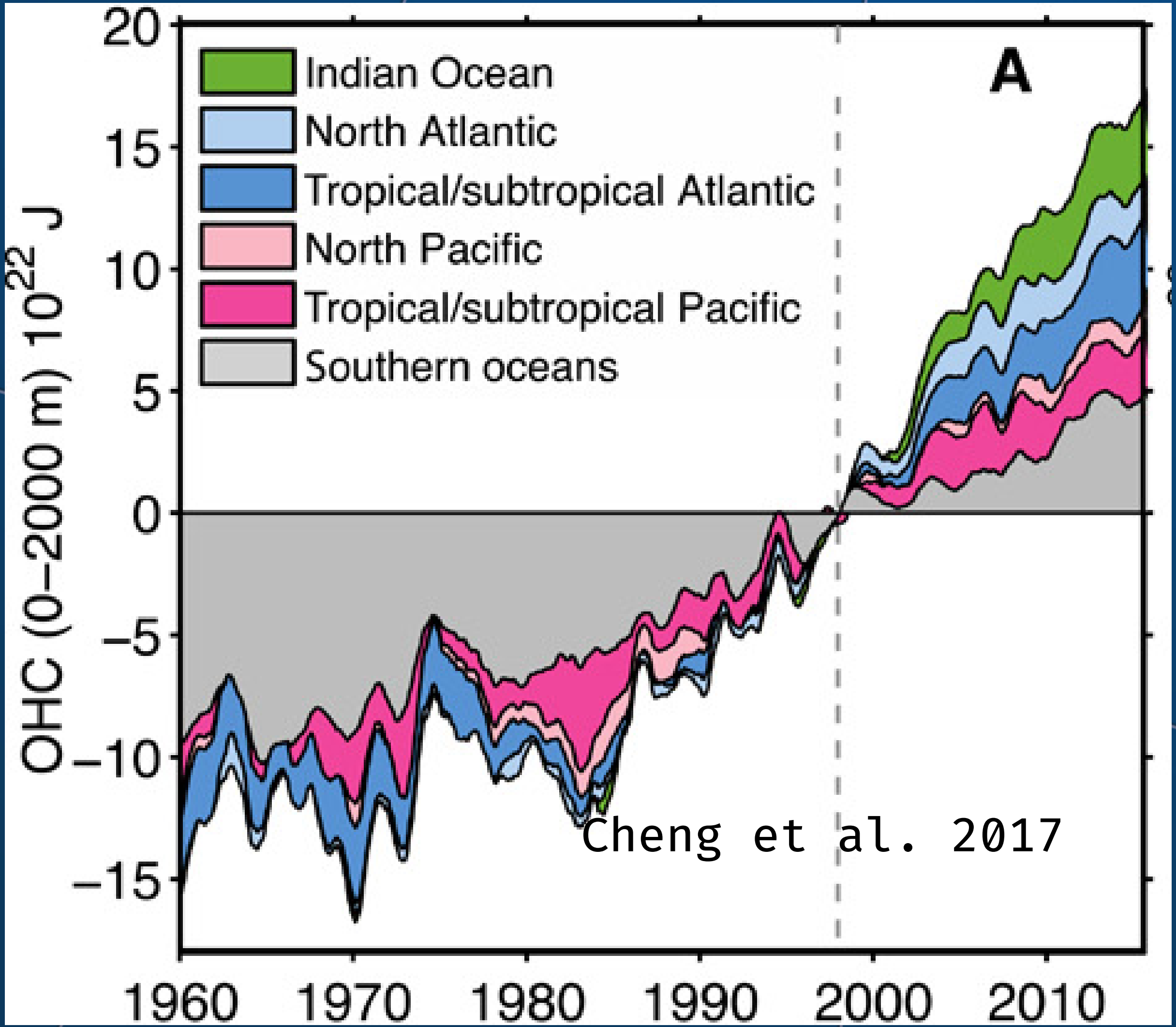
NASA Physical Oceanography program

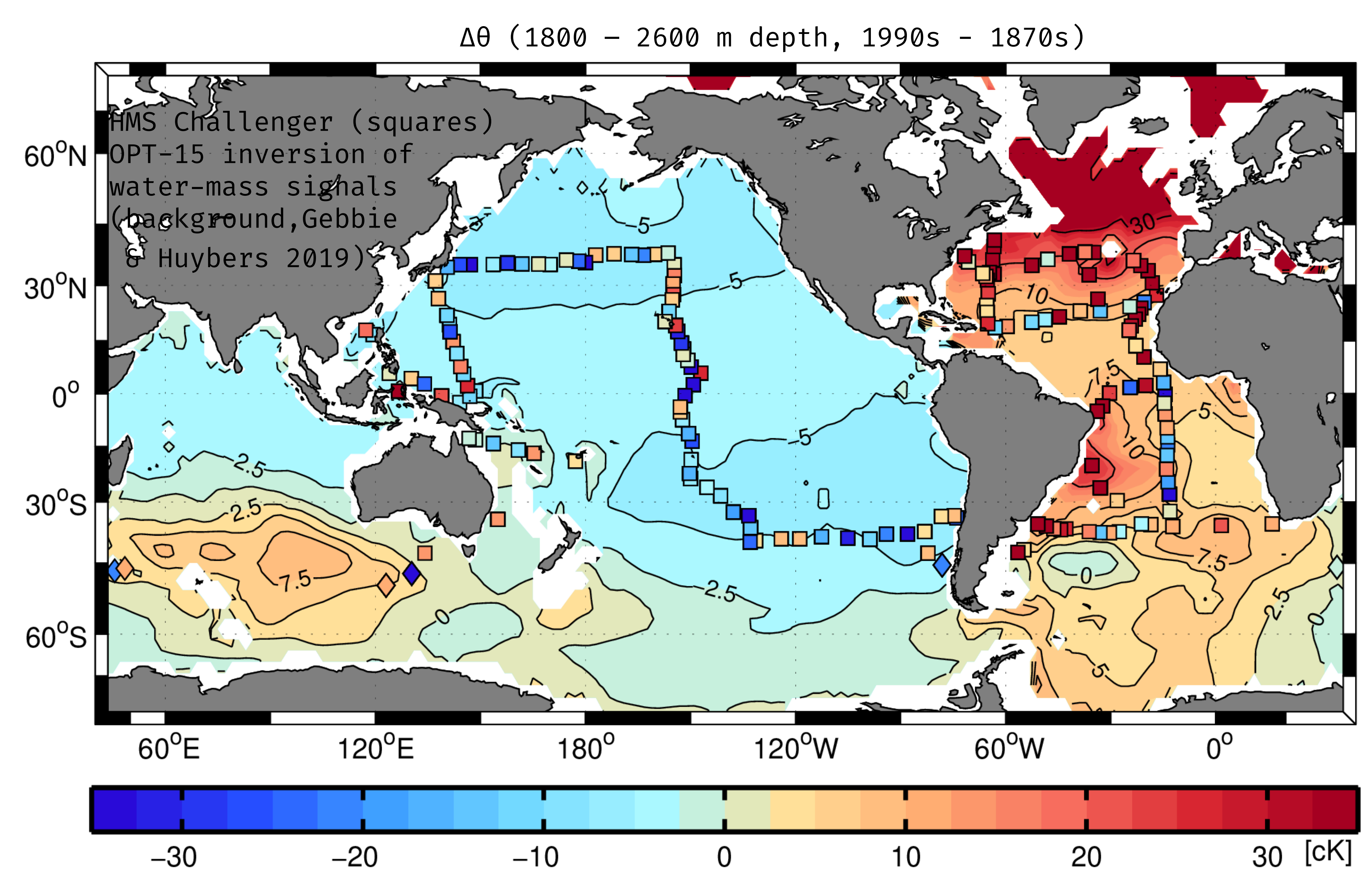
Johnson et al. (2016) infer an ocean heat uptake of 0.61 ± 0.09 W/m² above 1800 meters depth during the Argo era.



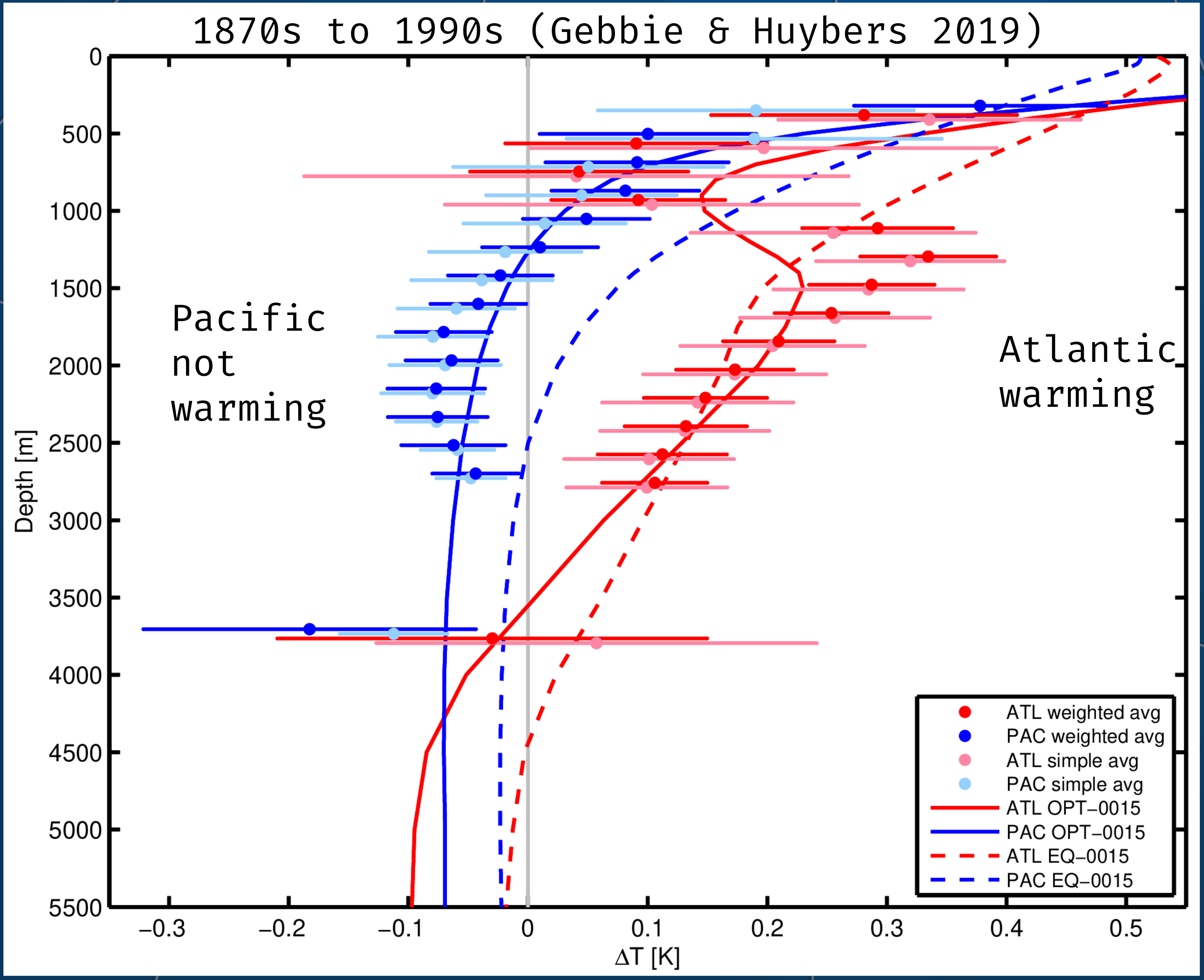
Cheng et al. 2017

How is the mid-depth ocean responding to surface conditions?

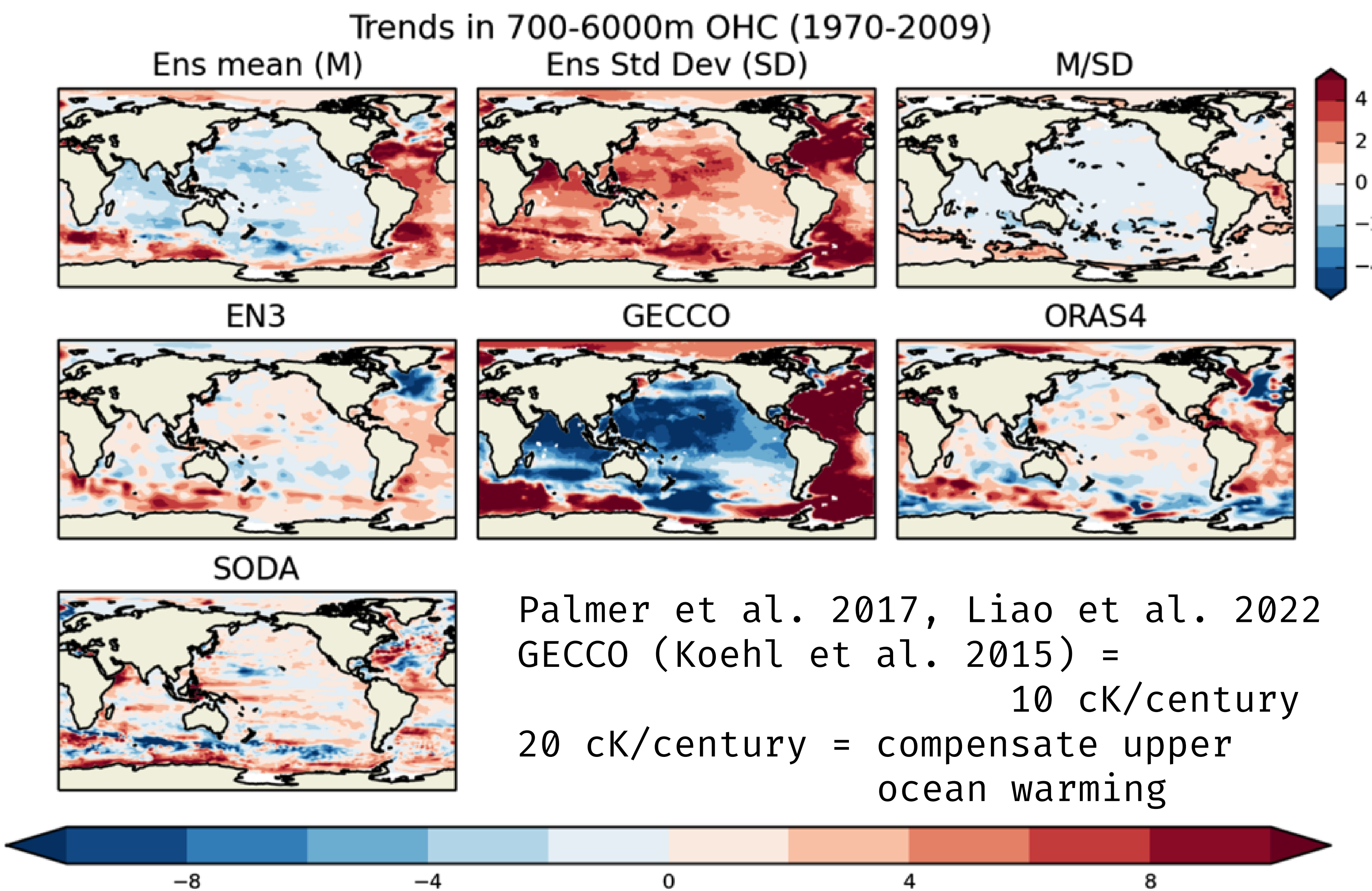
Historical temperature data indicate disparate responses to modern surface warming in the Atlantic vs. Pacific.



The Atlantic-Pacific difference is robust, but pressure-dependent biases in early thermometers make the inference of Pacific cooling uncertain.



The ensemble mean of ocean reanalyses also suggests cooling below 700 m, but is strongly influenced by a few products.



Palmer et al. 2017, Liao et al. 2022
GECCO (Koehl et al. 2015) = 10 cK/century
20 cK/century = compensate upper ocean warming

K m / yr (also Bagnell & Devries 2021)

Outline

1. Are there inter-ocean differences in the mid-depth ocean response of the ECCO version 4 release 4 state estimate, including Pacific cooling?

2. What drives mid-depth Pacific cooling in ECCO version 4 release 4?

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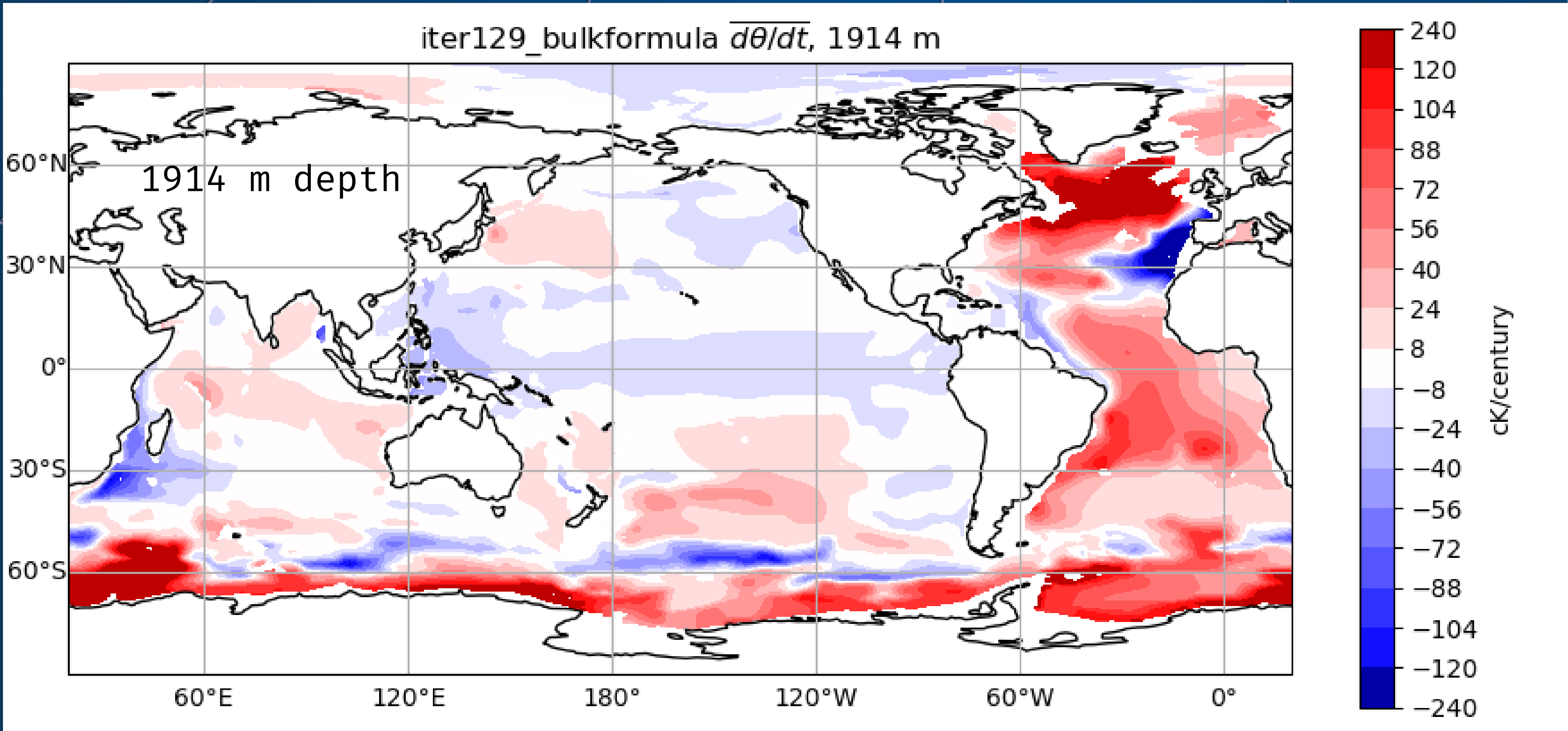
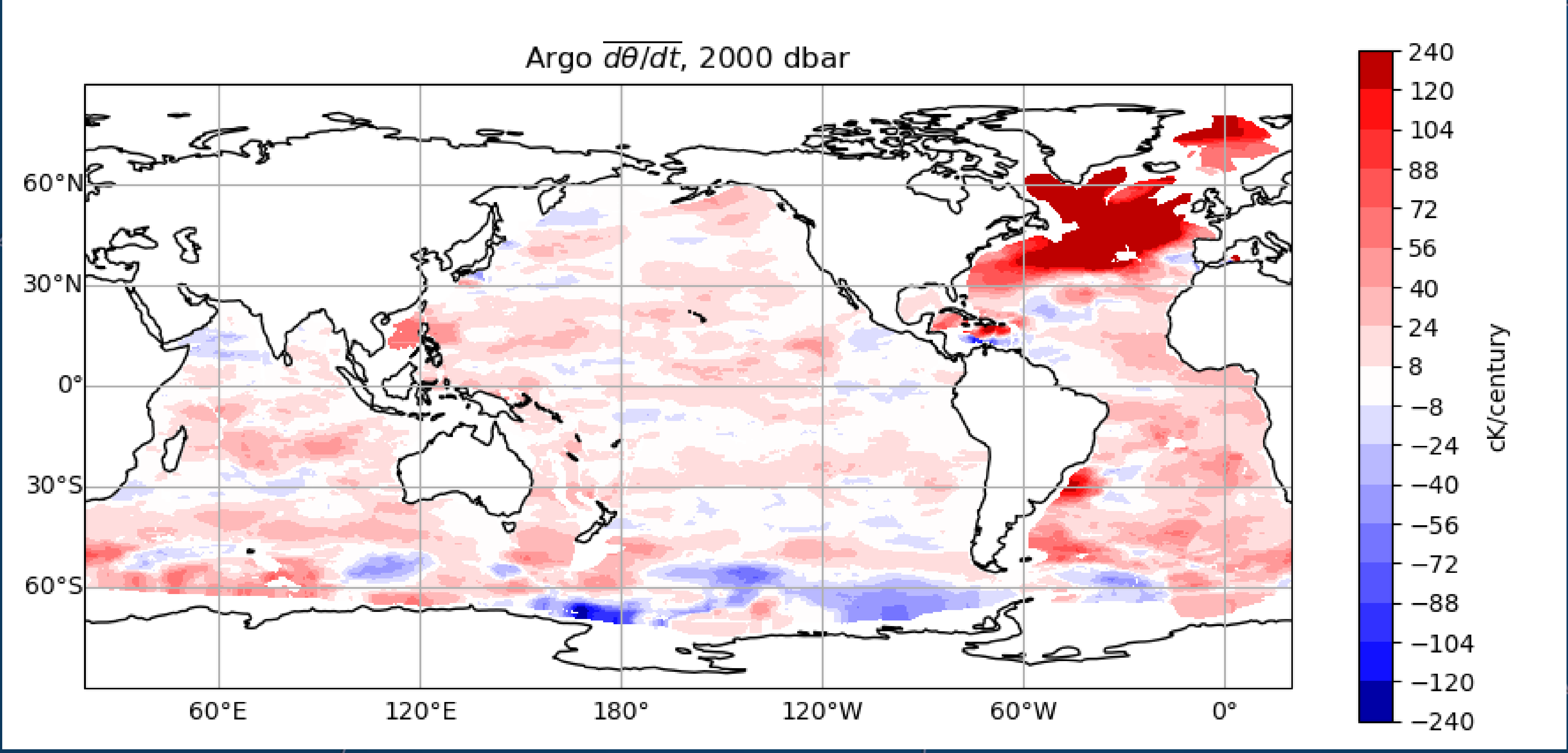
ECCO temperature trends for the years 2004-2018 indicate Atlantic warming and a weak Pacific signal.



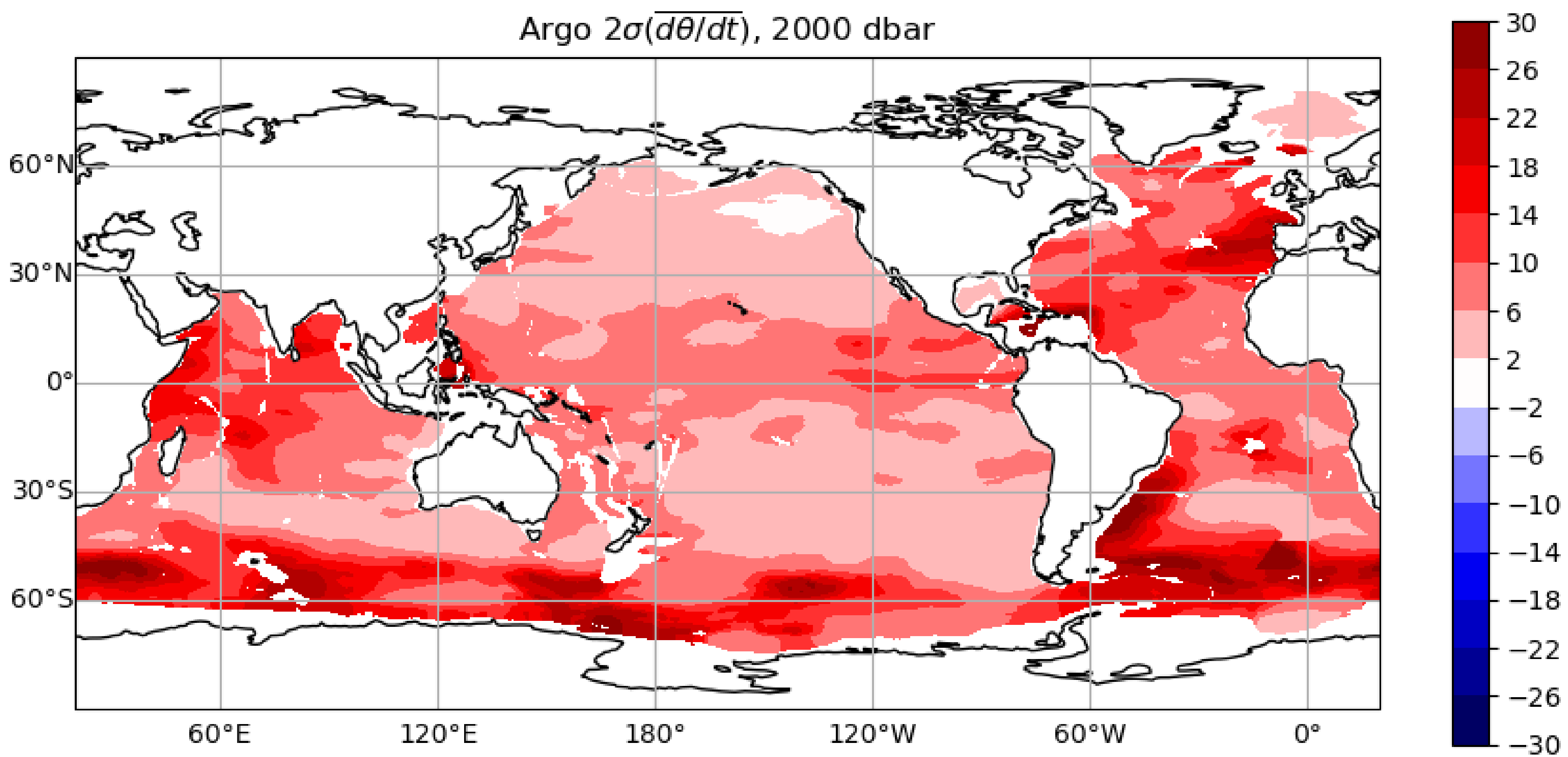
This latest ECCO version has less cooling than the GECCO state estimate.

Temperature trends derived from 16 years of Argo floats also show North Atlantic warming and a weak Pacific signal.

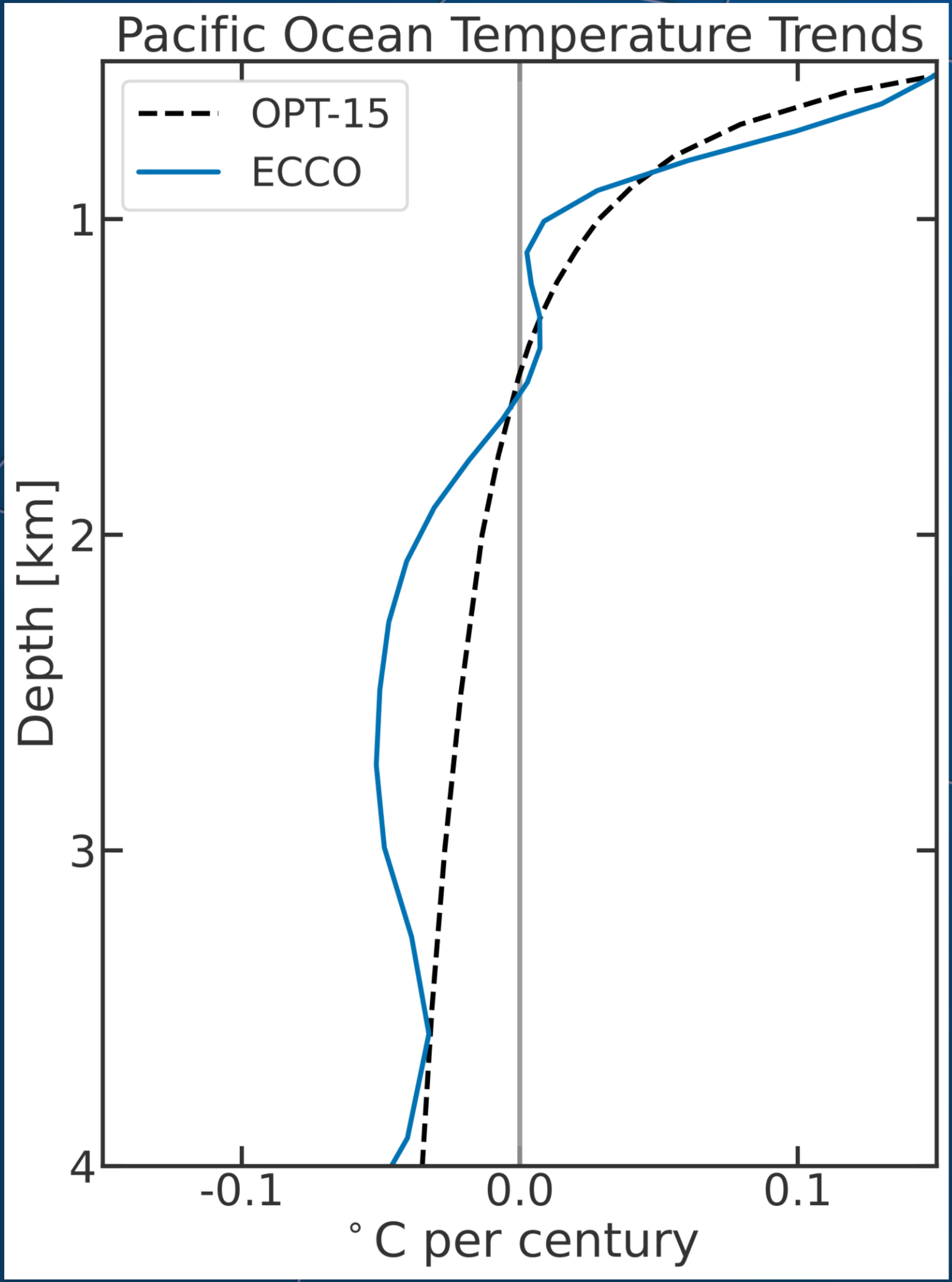


South Atlantic and Southern Ocean warming is not as evident in the Argo analysis.

Temperature trends derived from 16 years of Argo data are often not significant at the 95% confidence level.



Uncertainty from Argo analysis approaches 10 cK/century (Note: colorbar shift from previous slides)



Vertical structure of temperature trends in ECCO v4r4 (iteration 129) in line with prediction from propagating pre-industrial climate signals (OPT-15, Gebbie & Huybers 2019).

Outline

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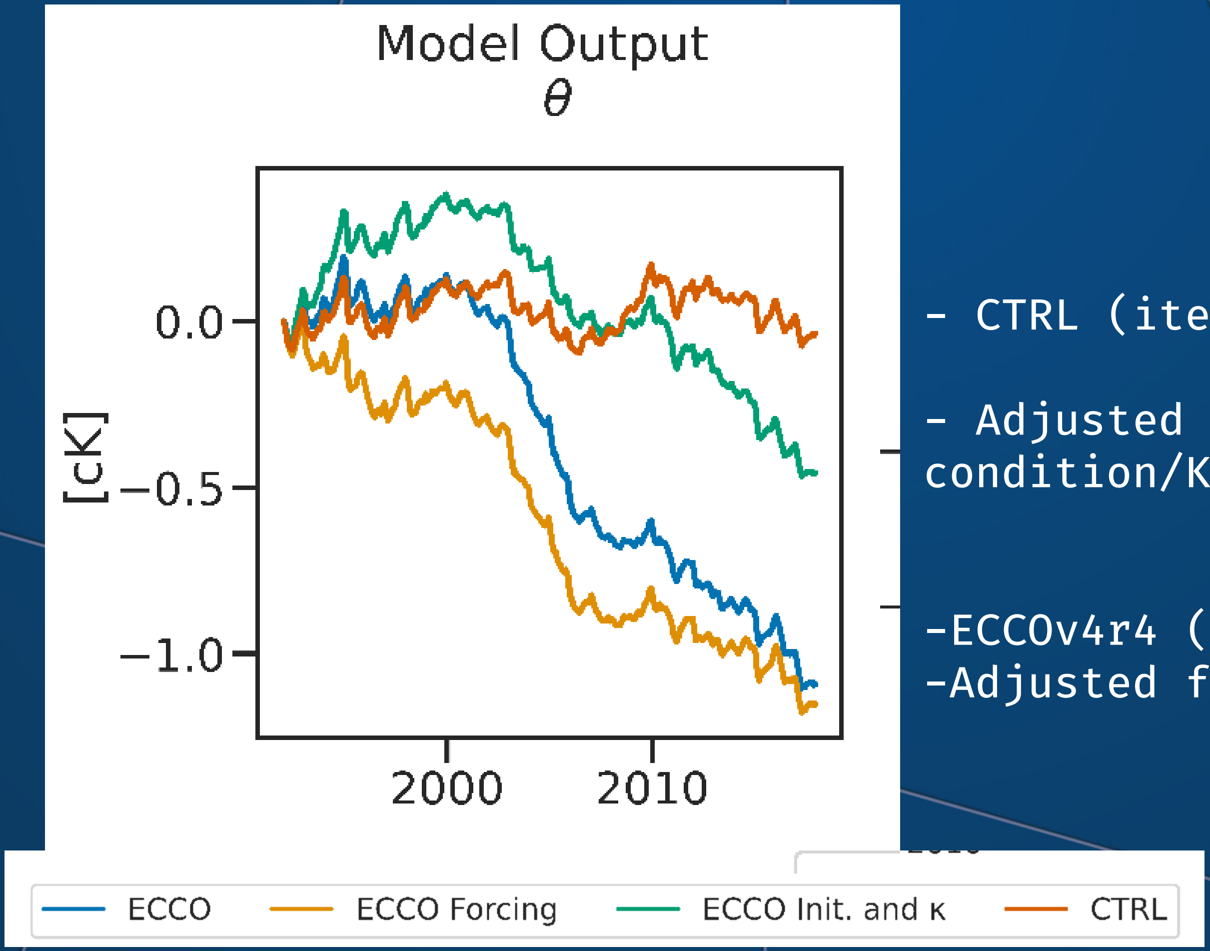
Approach

Case study: ECCO Version 4 Release 4
(Forget et al. 2015, Fukumori et al. 2019)

	Scenario	Best Fit Boundary?	Best Fit Initial Condition?
Best Fit ->	Iteration 129	Yes	Yes
First Guess ->	Iteration 0	No	No
K_z also adj. →	Unadjusted surface	No	Yes
	Unadjusted initial cond.	Yes	No

Drivers of cooling for North Pacific (2-3 km depth) control volume:



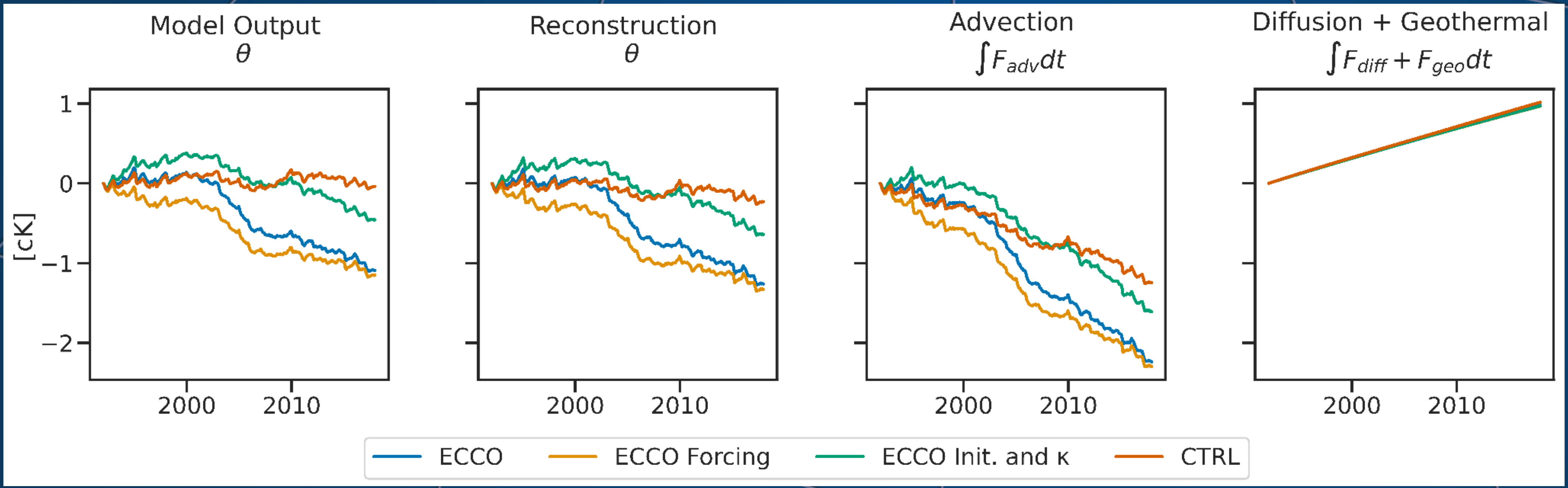
- CTRL (iteration 0)

- Adjusted initial condition/K

-ECCOv4r4 (iteration 129)
-Adjusted forcing

Cooling:
- not solely due to use of MIT GCM
- contributed by adjustments to surface forcing AND initial conditions/diffusivity

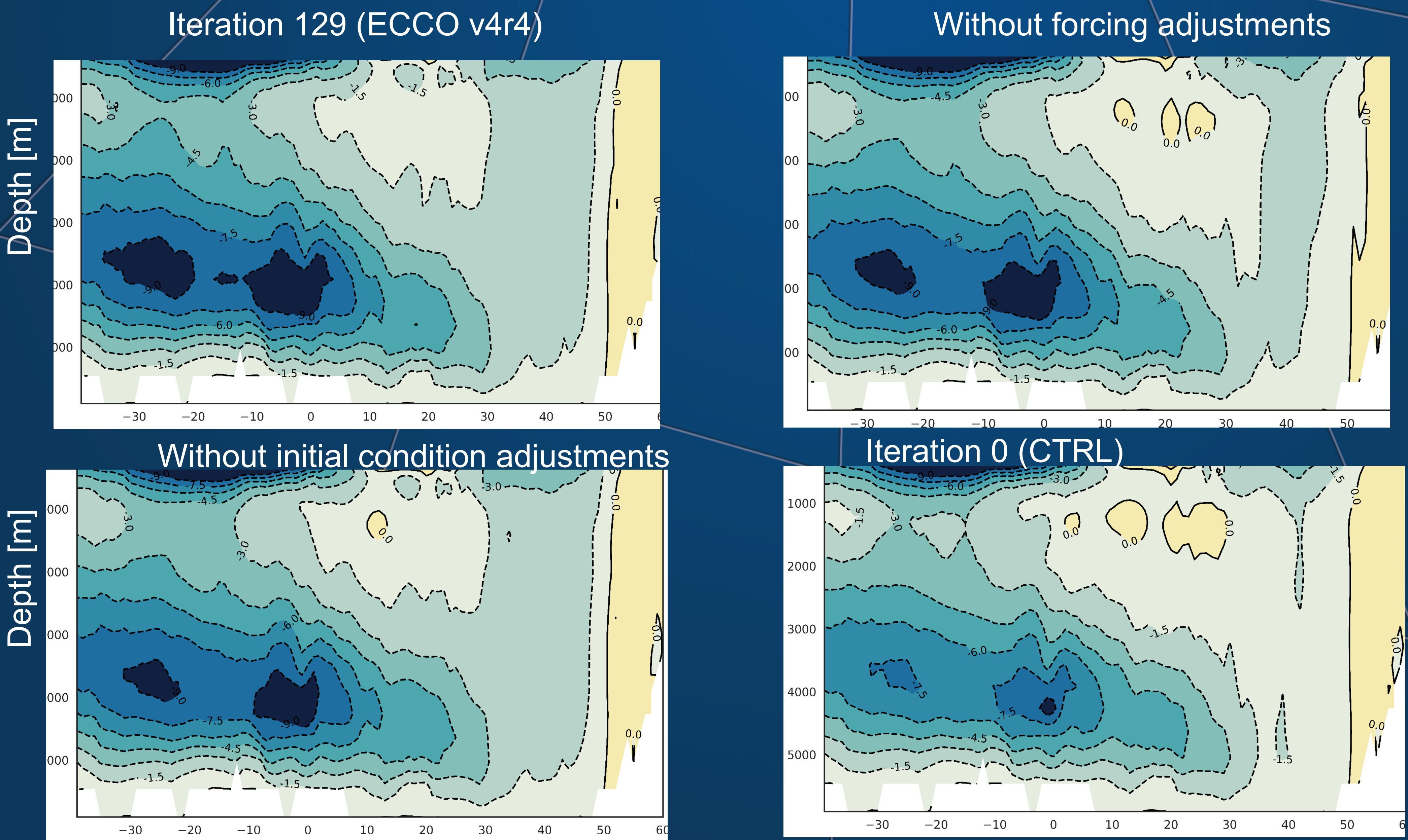
Drivers of cooling for North Pacific (2-3 km depth) control volume:



Cooling indicates advective-diffusive disequilibrium.

Vertical and horizontal advection of cold abyssal waters in ECCO v4r4 not balanced by turbulent diffusive processes.

Dynamic response of abyssal overturning to surface forcing responsible for heave-induced cooling.



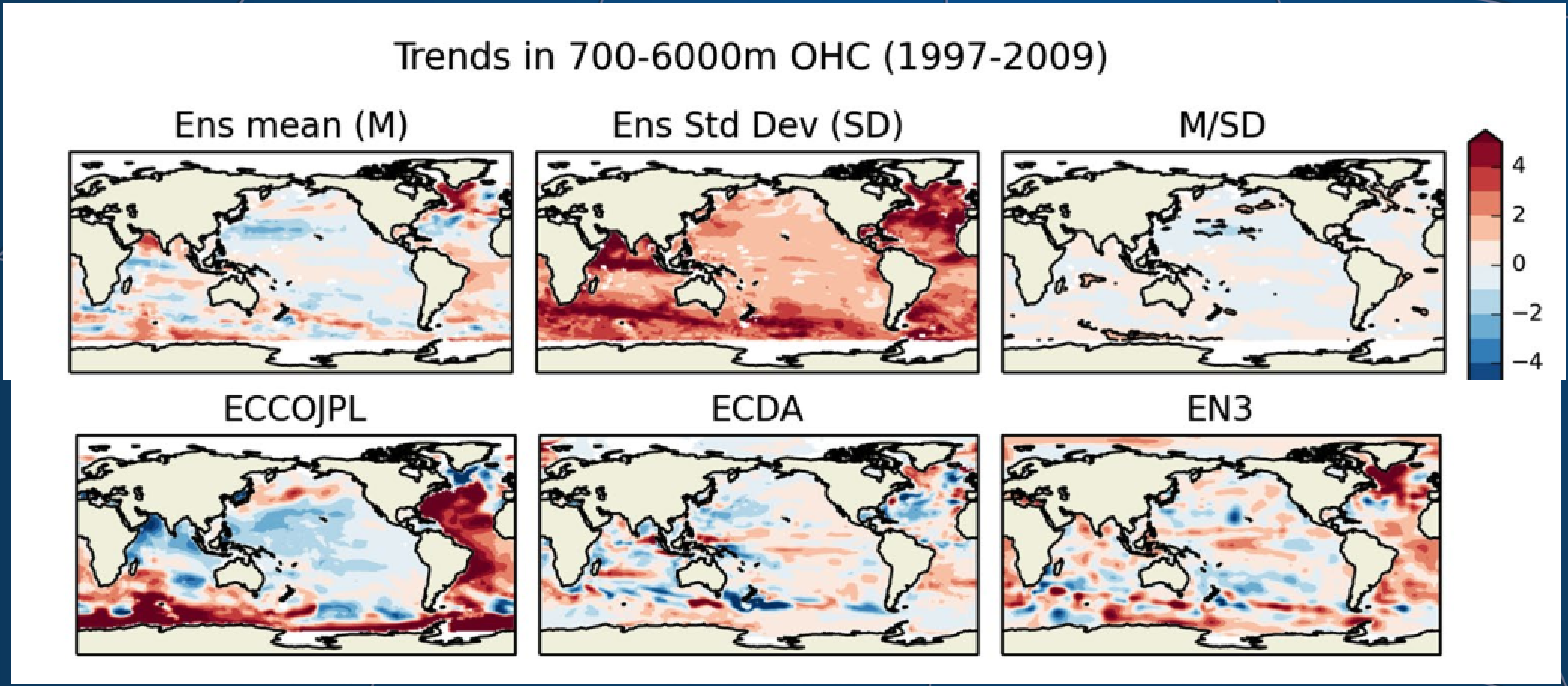
Summary

Mid-depth ocean heat content trends appear to continue the century-long signal of greater warming in the Atlantic compared to Pacific.

The ECCOv4r4 state estimate indicates Pacific cooling that is not present in the first-guess model simulation, suggesting that observations contain this signal.

Subsurface Pacific cooling in ECCOv4r4 due to:
1) Isopycnal heave from the abyssal overturning circulation,
2) Propagation of abyssal water-mass signals

Multiple ocean reanalyses have Pacific cooling trends from 1997-2009, including other products based on the MIT General Circulation Model.



Cooling at a rate of 20 cK/century in the deep ocean would completely compensate the upper ocean warming.

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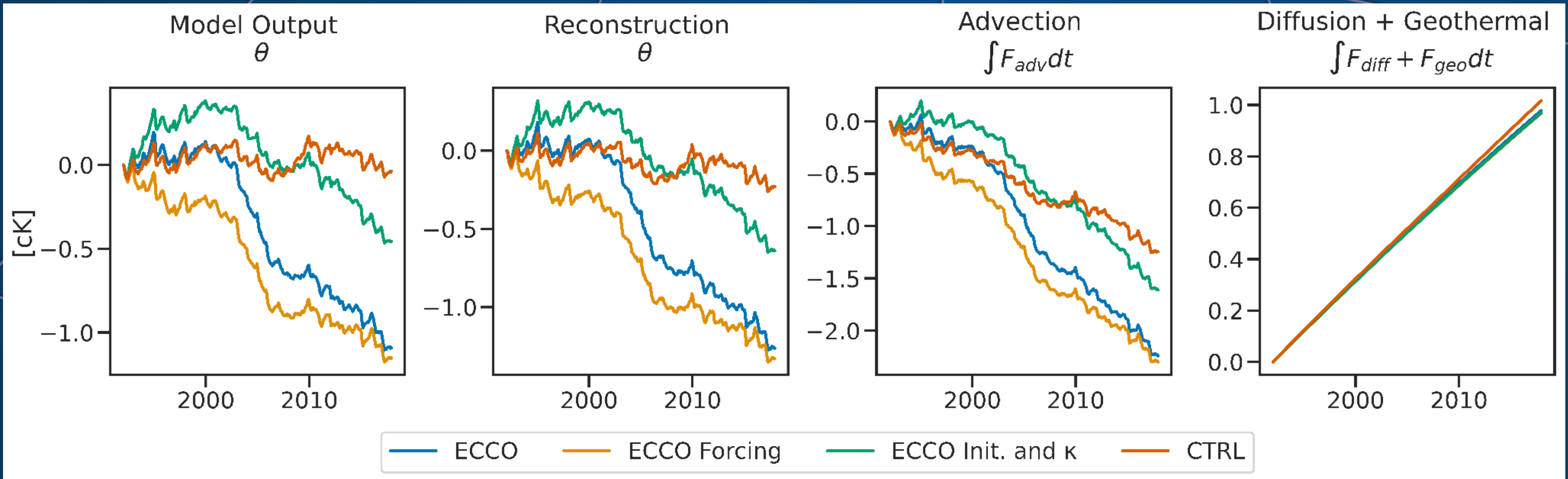
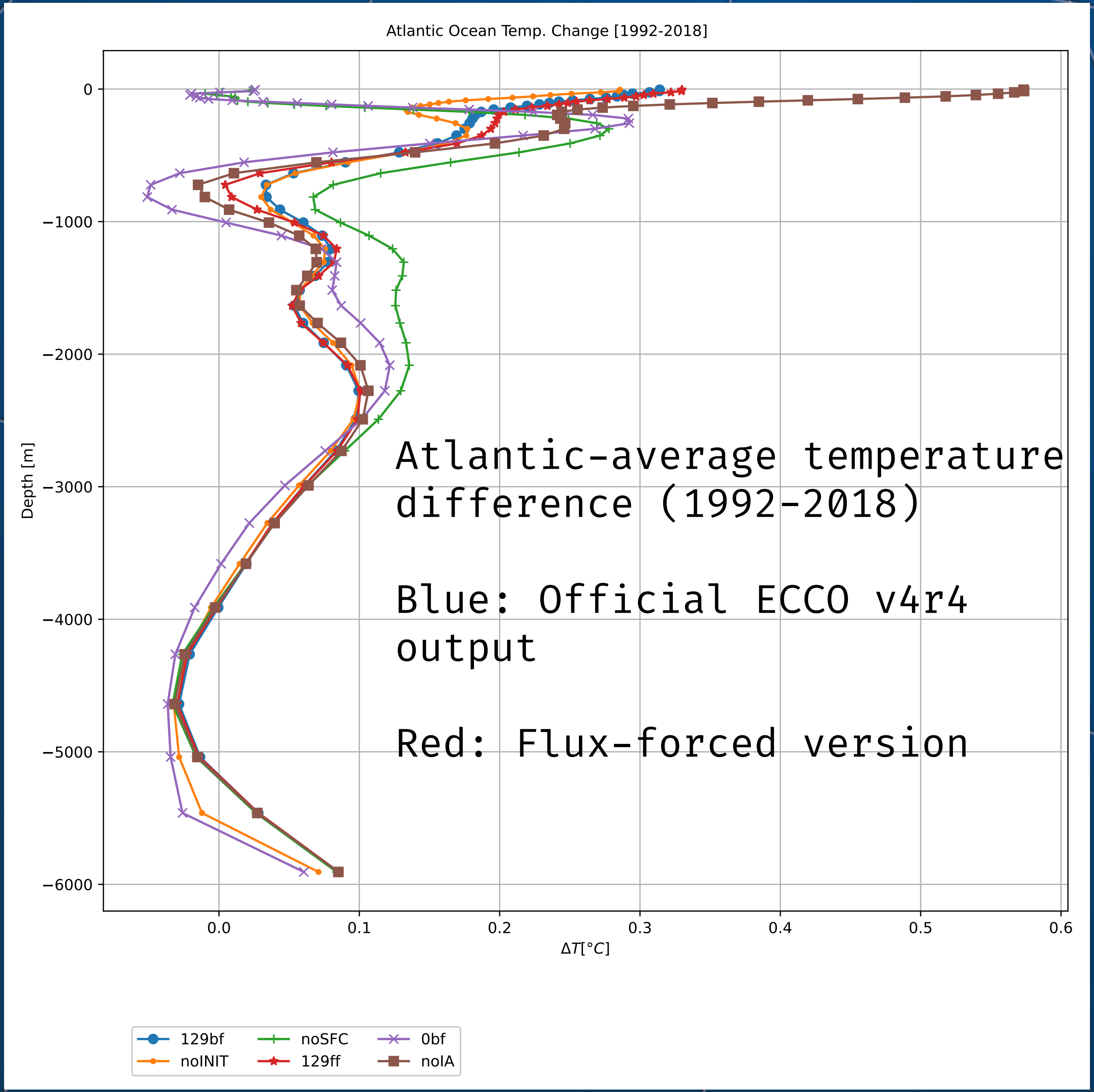


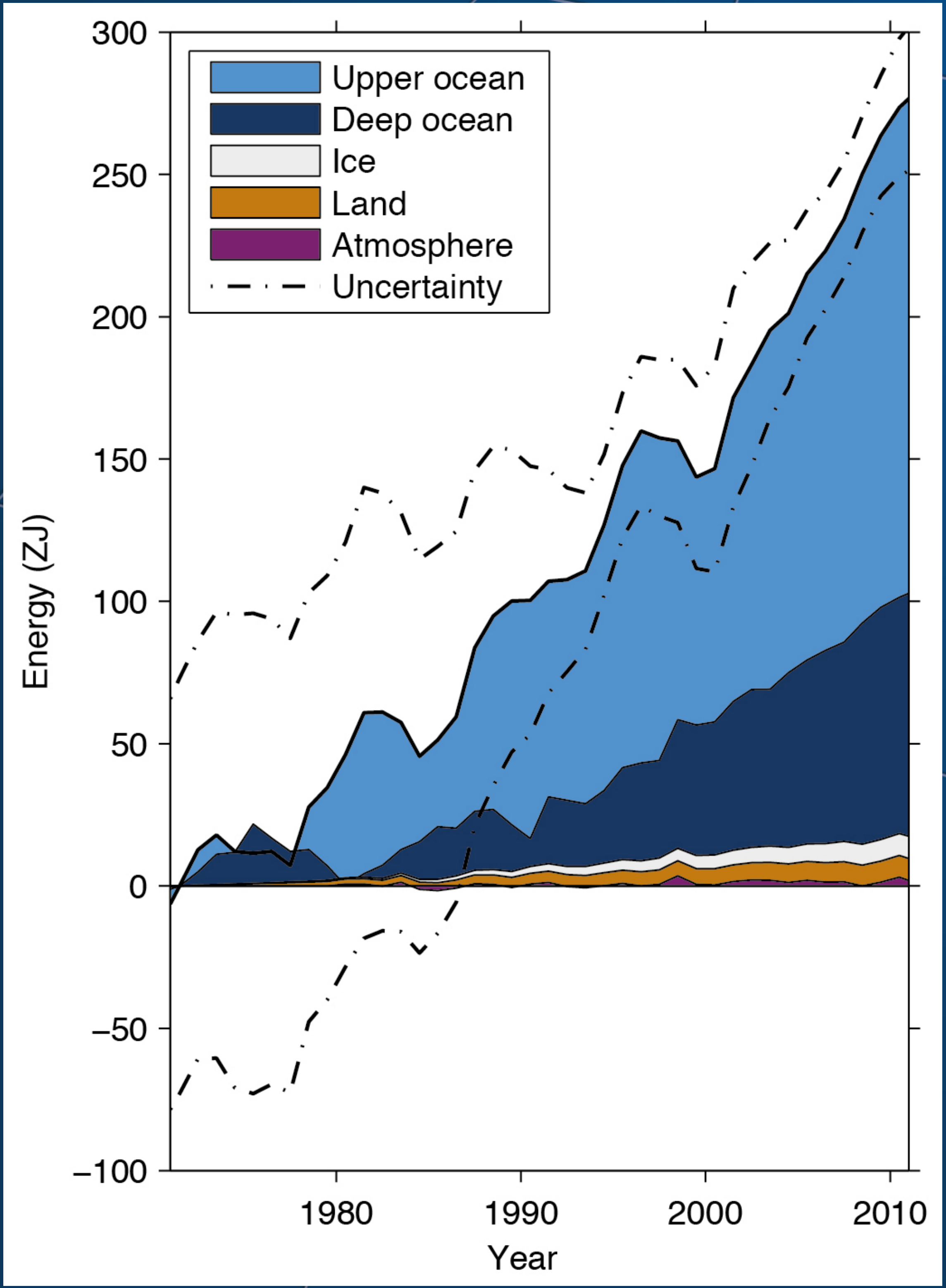
Cooling:
- not solely due to use of MIT GCM
- indicates advective-diffusive disequilibrium
- contributed by adjustments to surface forcing

AND

initial conditions/diffusivity

The Atlantic Ocean warms, but warming holes exist at depths with southern source waters.





Ocean heat uptake is our best hope at reconstructing the planetary energy imbalance.

About 90% of excess radiative energy after 1955 is stored in the ocean.
(Myrhe et al. 2012)

Heave-induced signal of cooling dominates over water-mass signal in North Pacific in ECCOv4r4 iteration 129.