A large-ensemble observational ocean temperature/heat content product and the application

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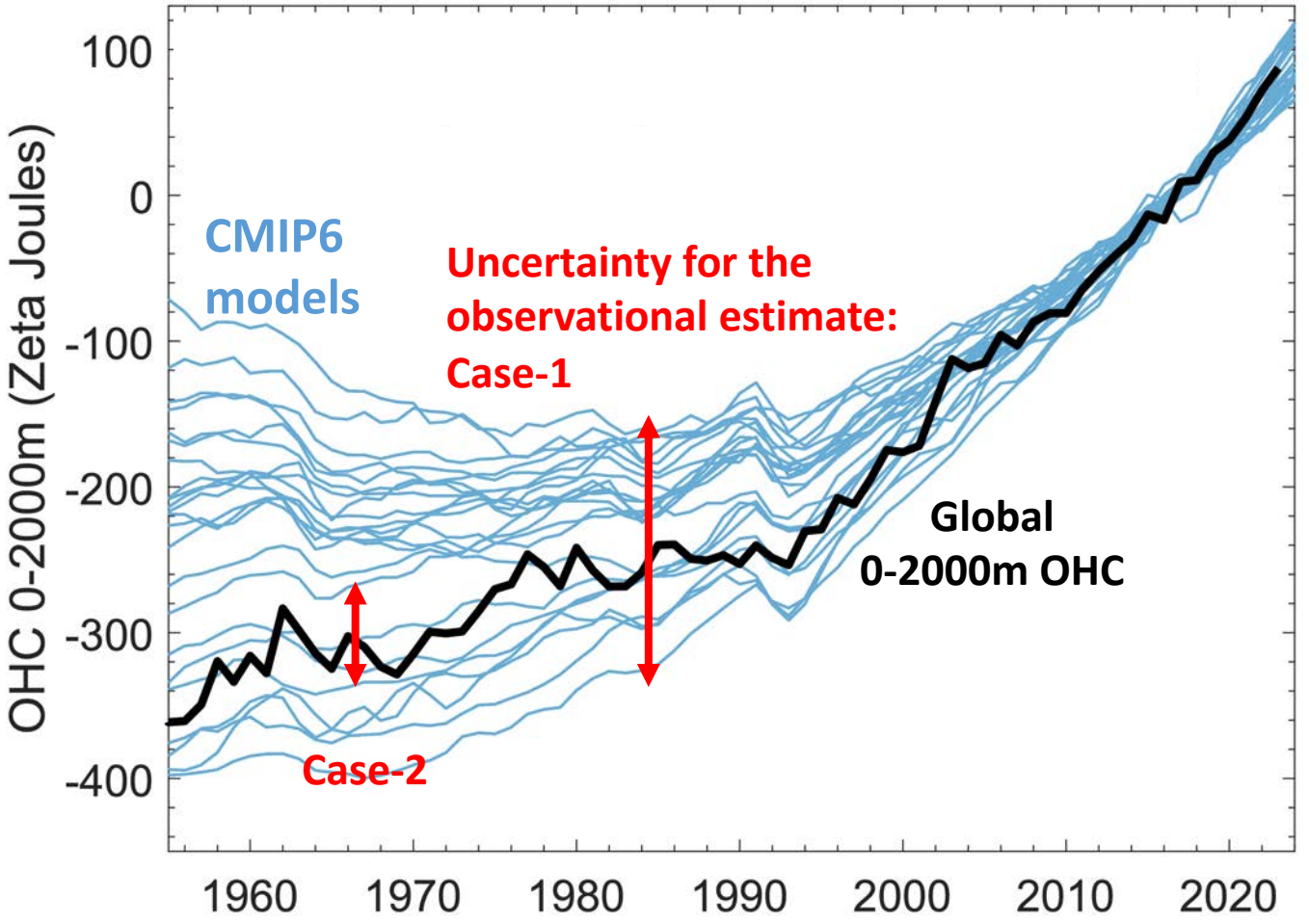
Observation Uncertainty

- A comprehensive uncertainty quantification for observational products and time series is critically needed for 1) Model-Obs comparison; 2) Refinement of the Observing System.

Assessment result:

Case-1: CMIP6 models ok

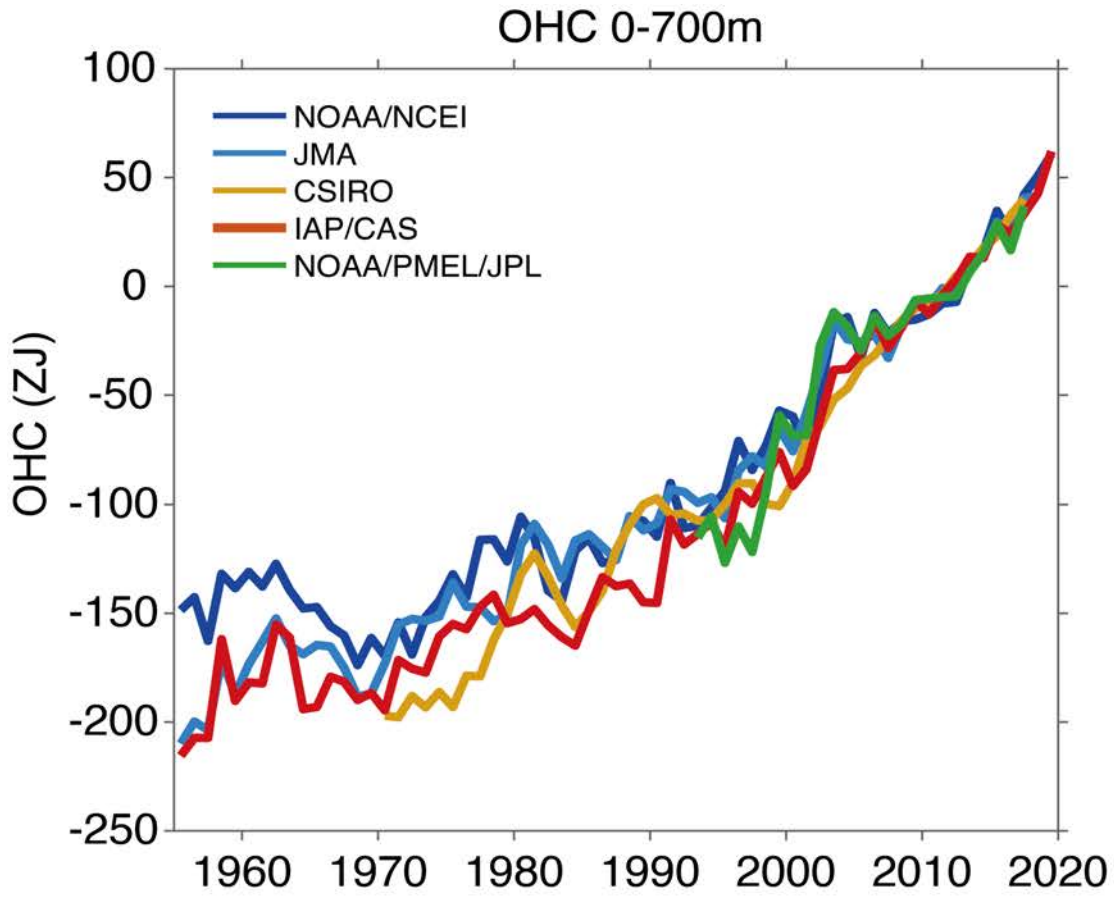
Case-2: CMIP6 models are really bad

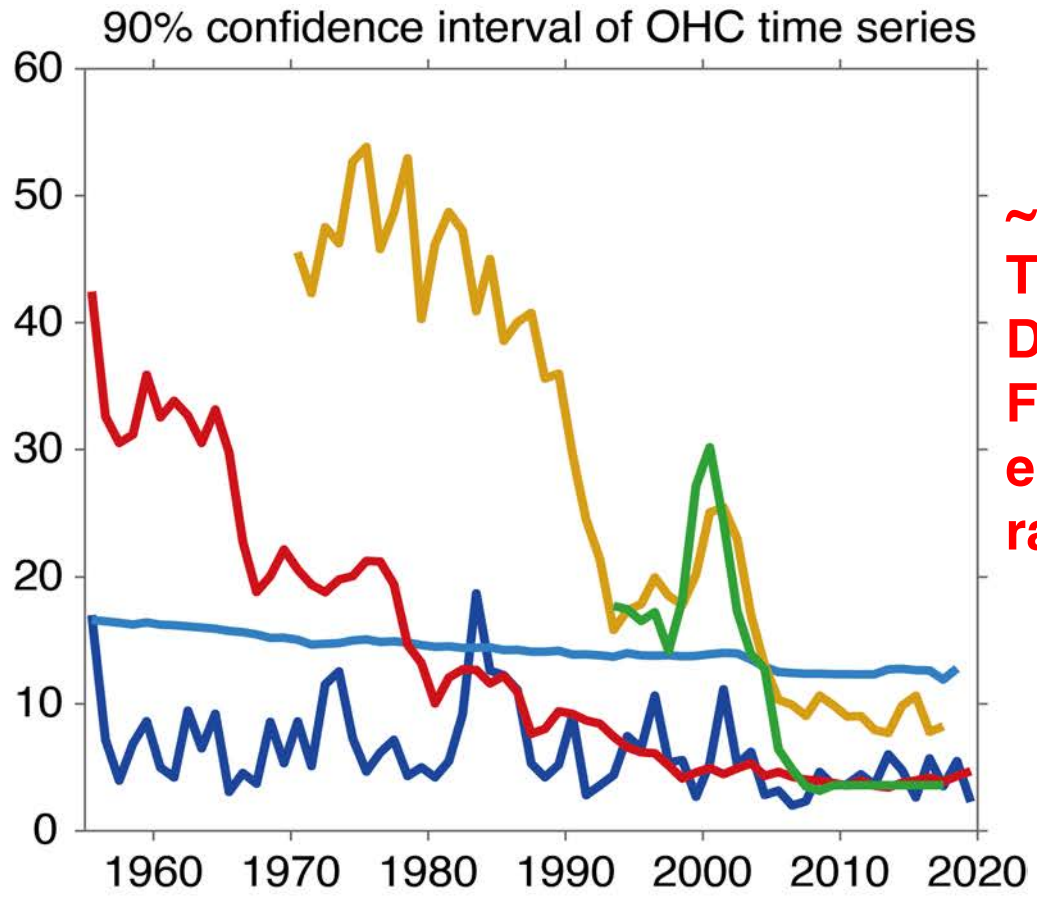


Observation Uncertainty

- A comprehensive uncertainty quantification is lacking

Need to know how big the uncertainty is? Where is the gap??

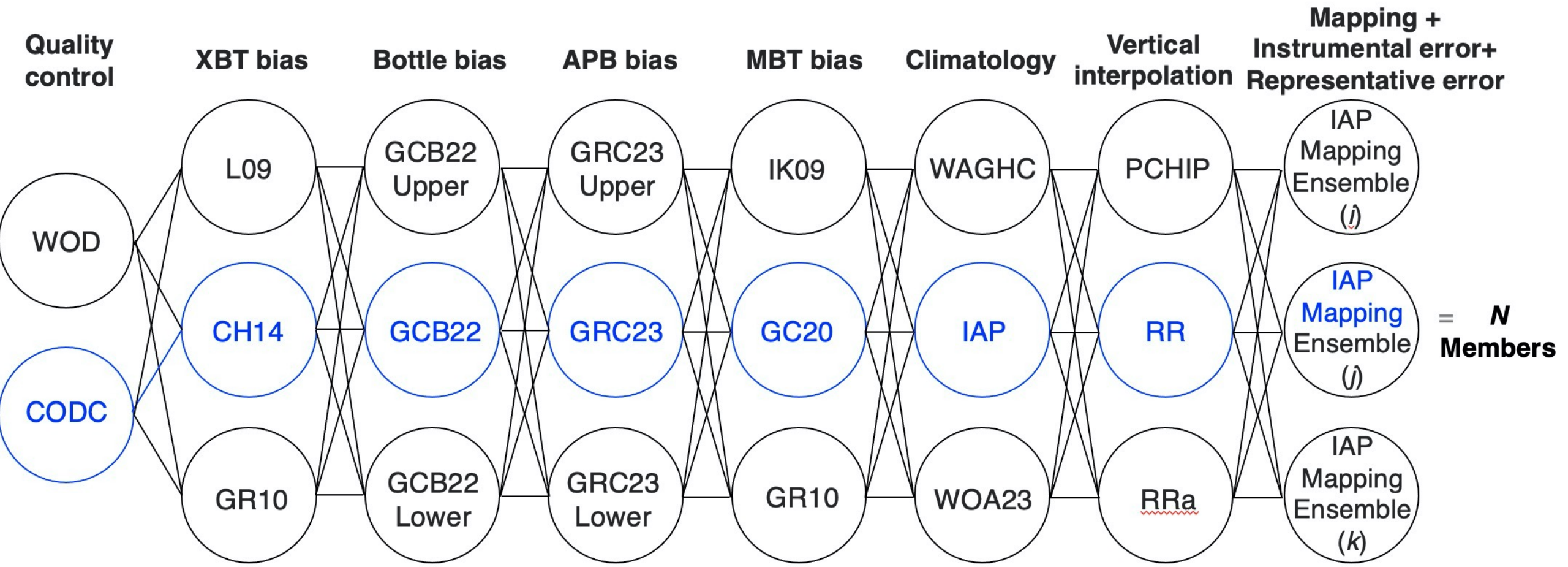




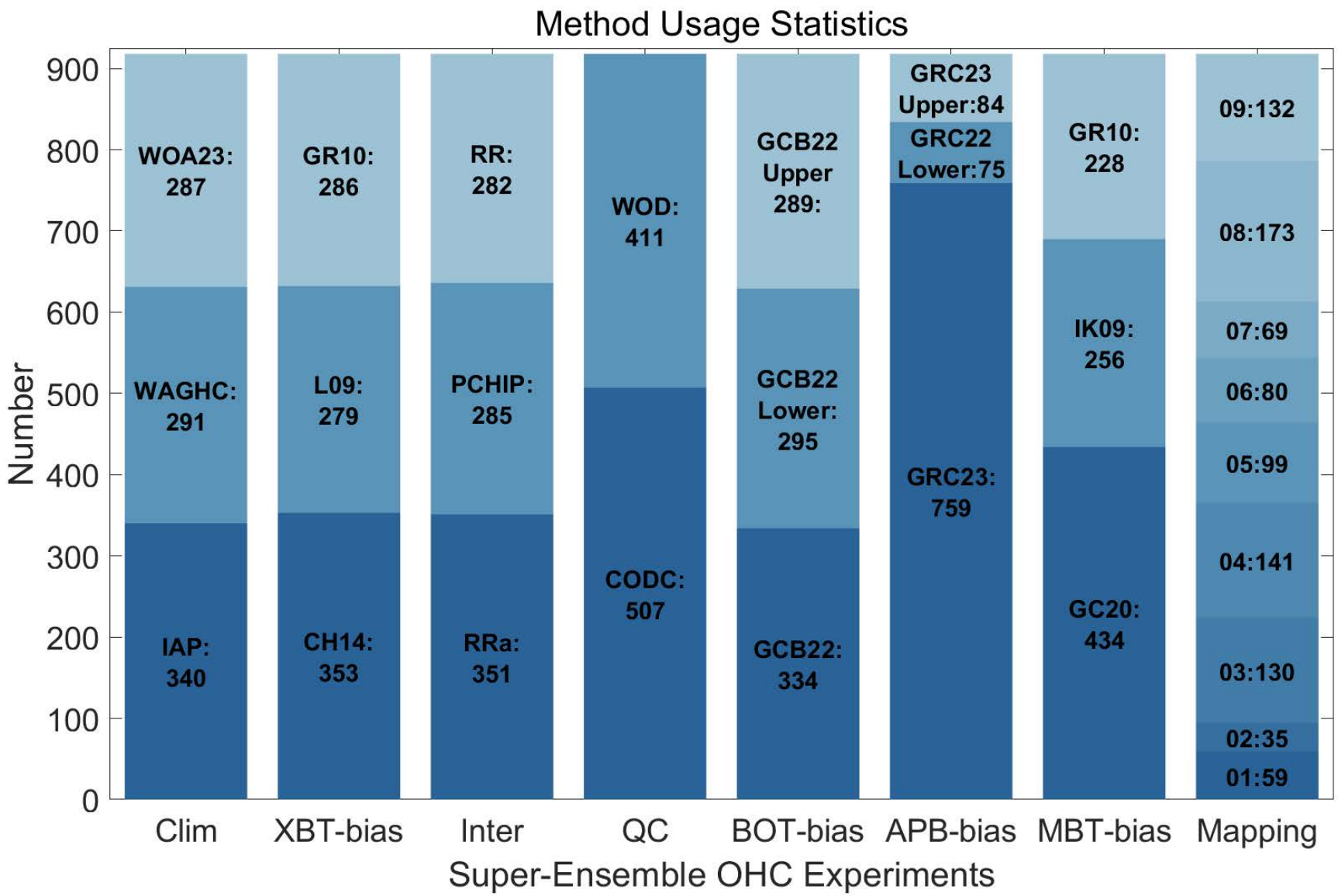
~10 Times Difference For their error range

A Large Ensemble Approach

- Ocean heat content / Temperature uncertainty quantification



A Large Ensemble Approach

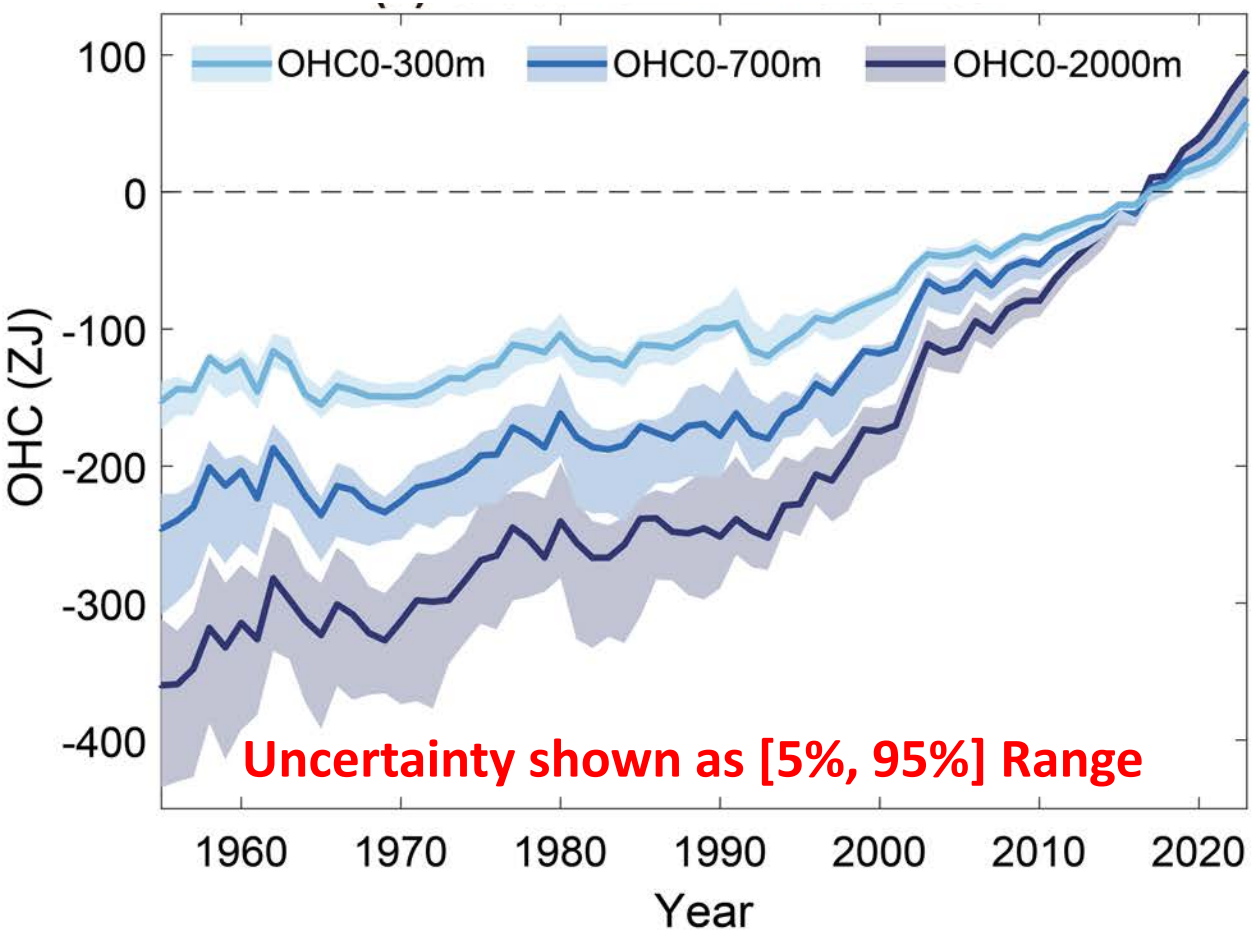


- 900 Ensemble Members!
- 12 ZFLOPs CPU times
- 70 TB memory

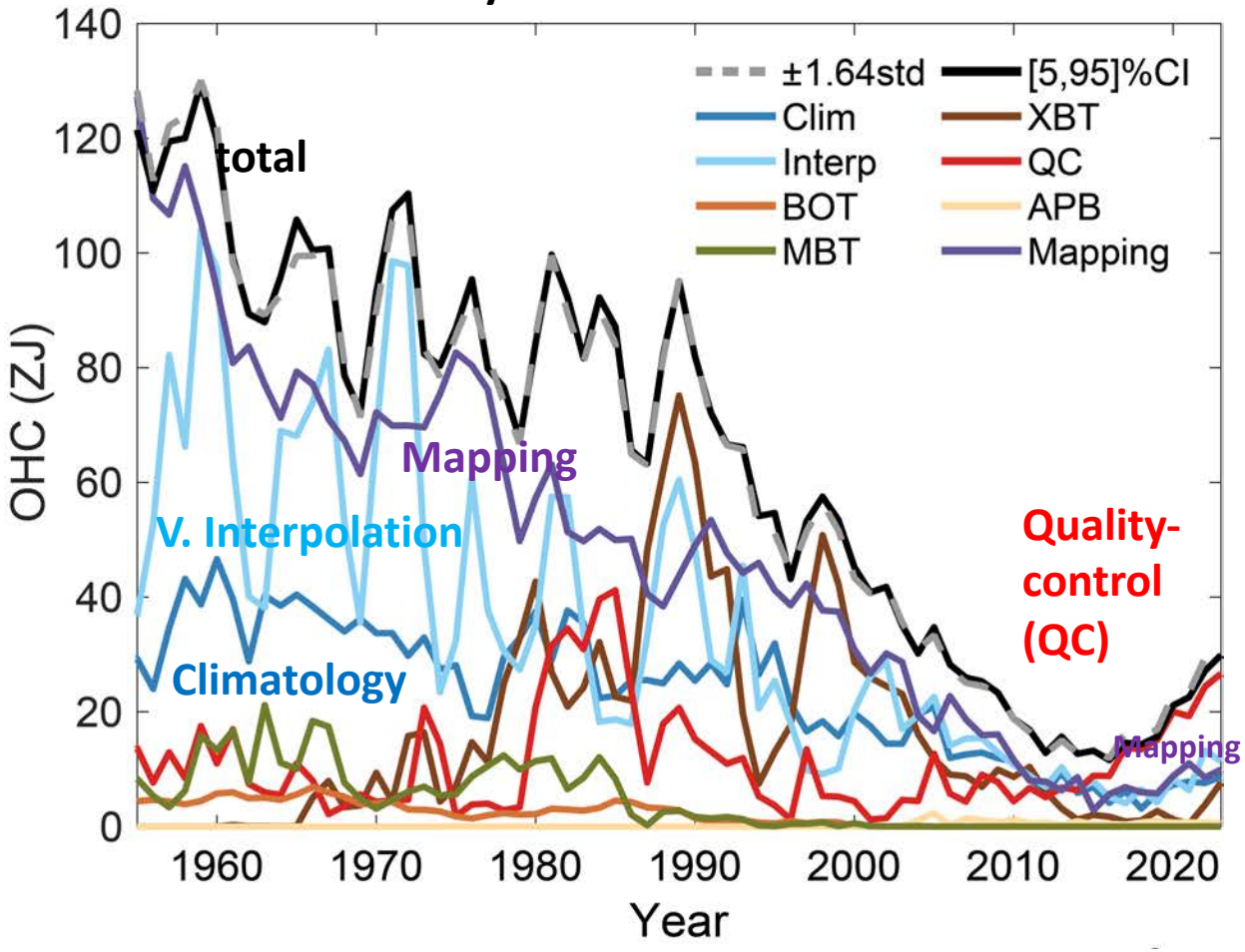
Results: OHC annual mean

- Total uncertainty: reduced from ~120 ZJ (~1960) to 20~30 ZJ (2010-2023)
- QC: largest error source for now; mapping/sampling: largest before ~2010

Global OHC and its uncertainty

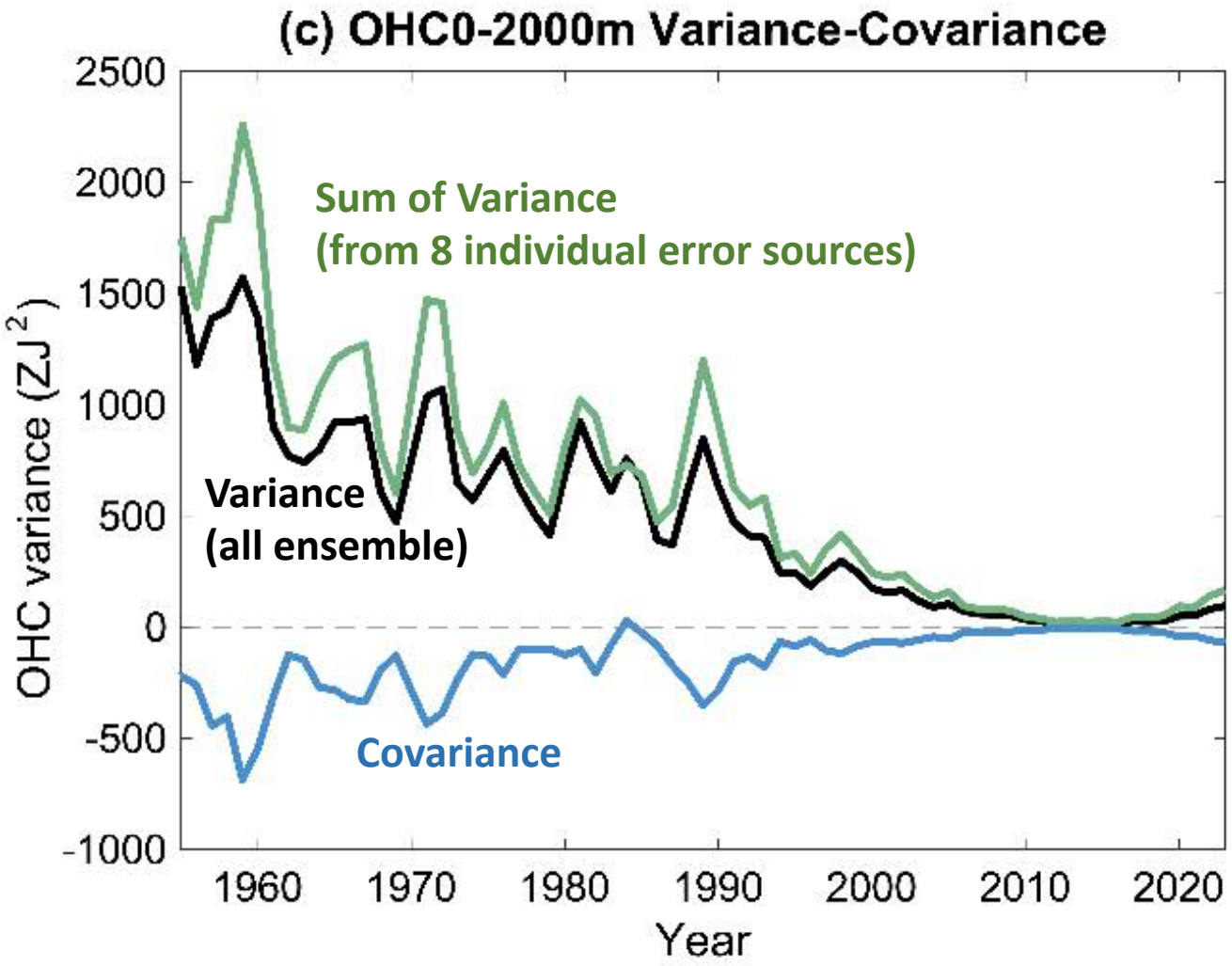


Uncertainty: total and each error source

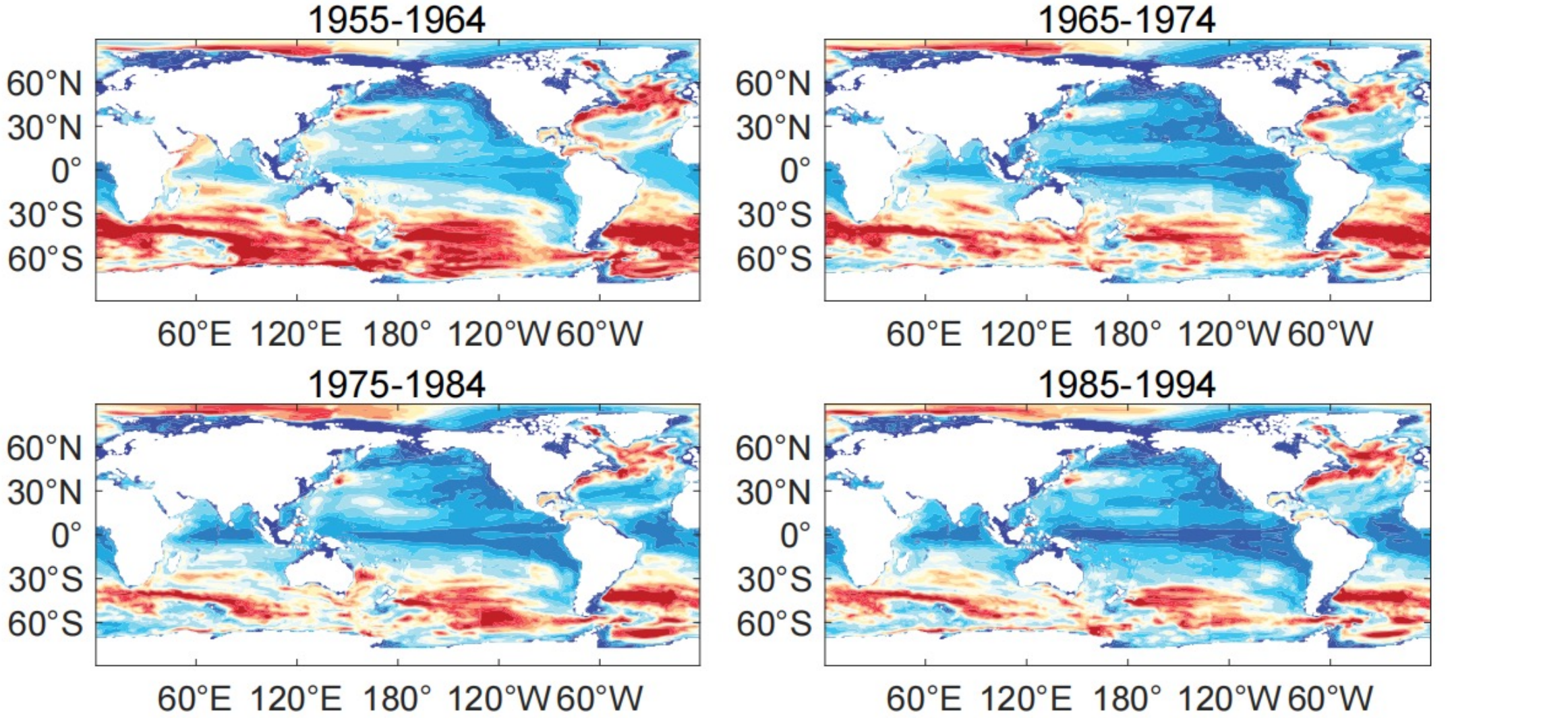


Results: OHC annual mean

- Different error sources are not independent

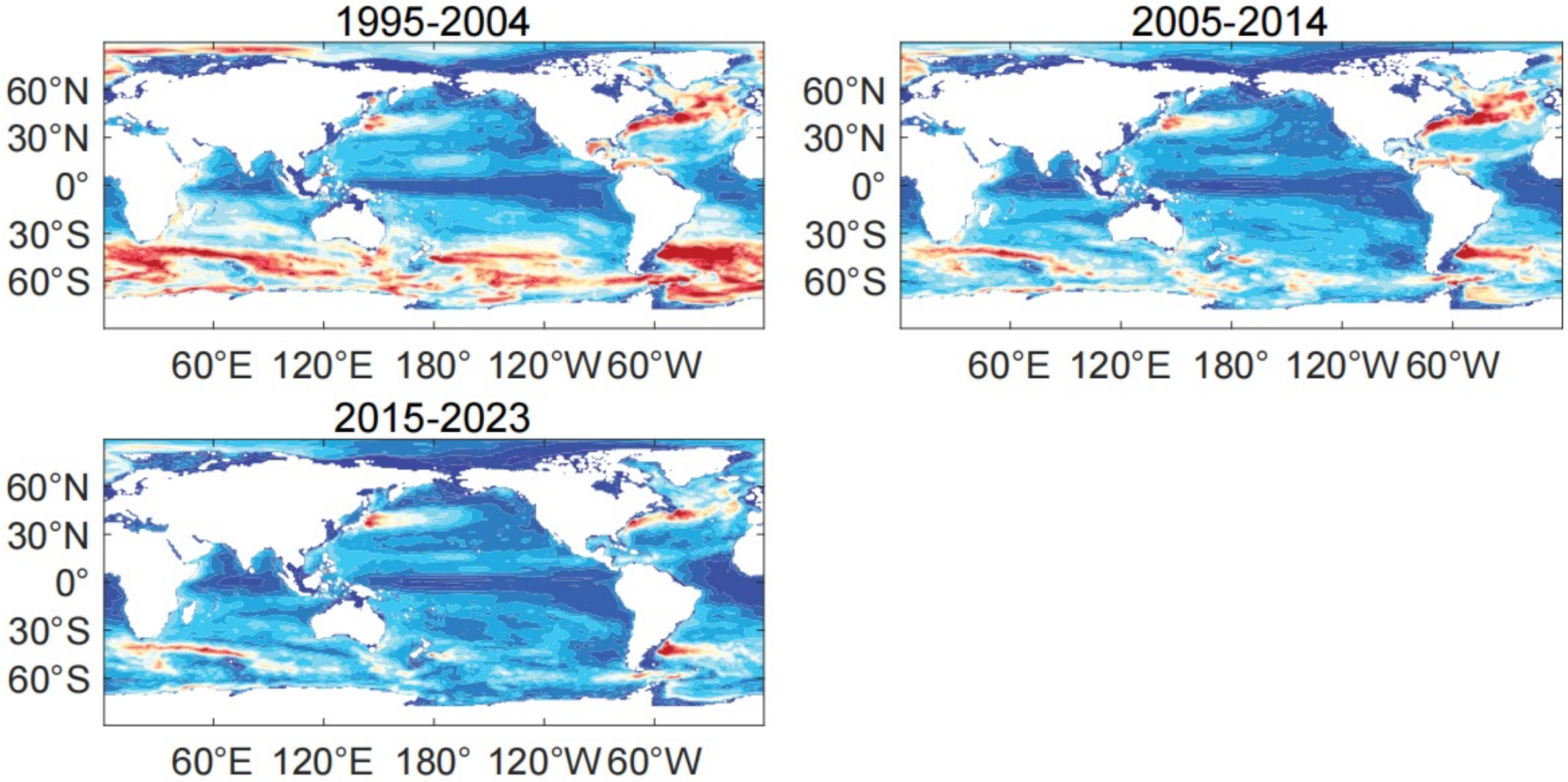


Results: OHC annual mean, regional



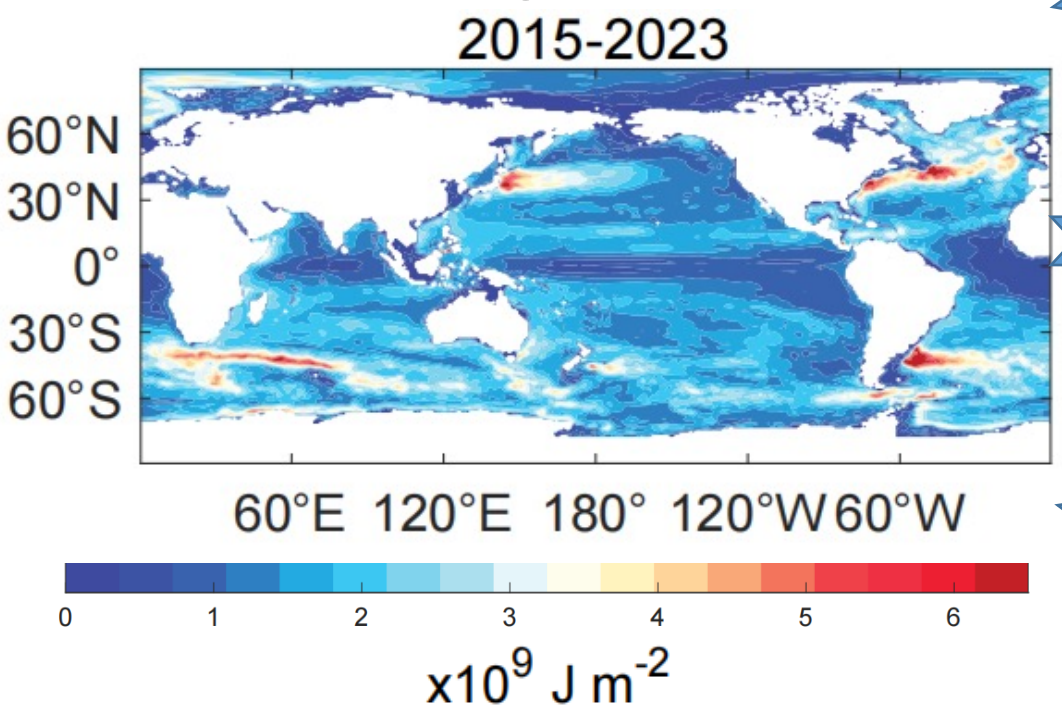
Uncertainty shown as [5%, 95%] Range

Results: OHC annual mean, regional

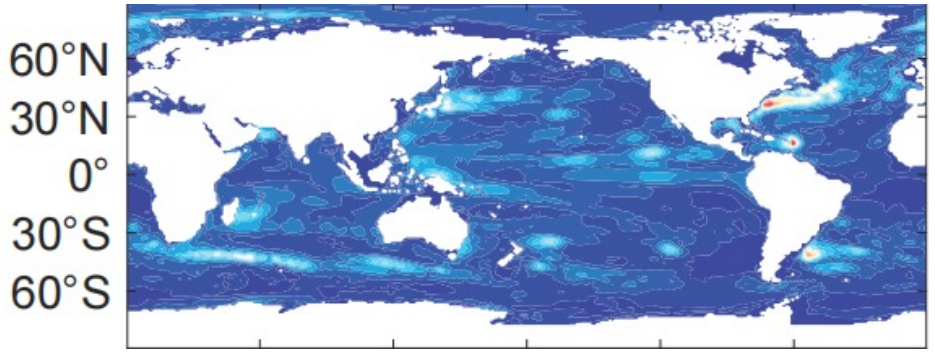


Results: OHC annual mean, regional

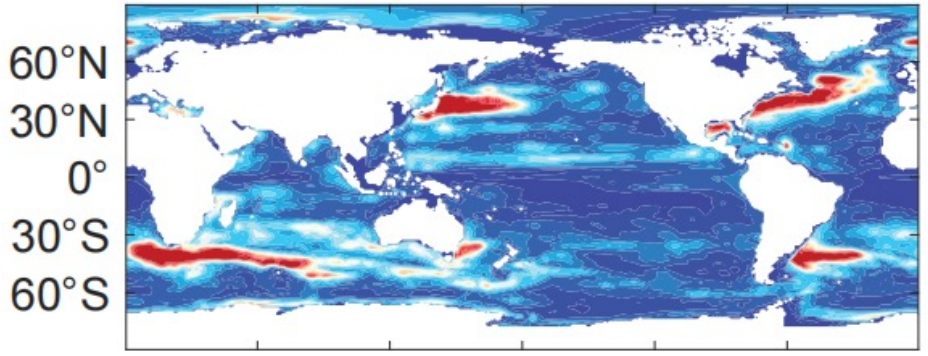
Total uncertainty



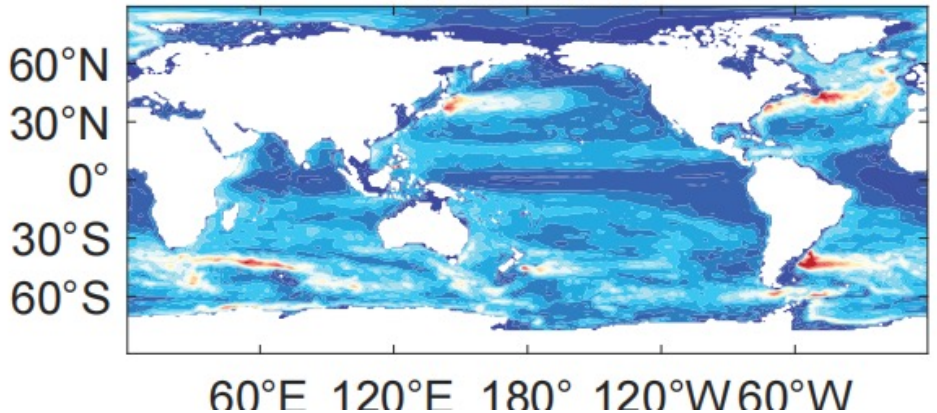
Vertical Interpolation



Quality Control



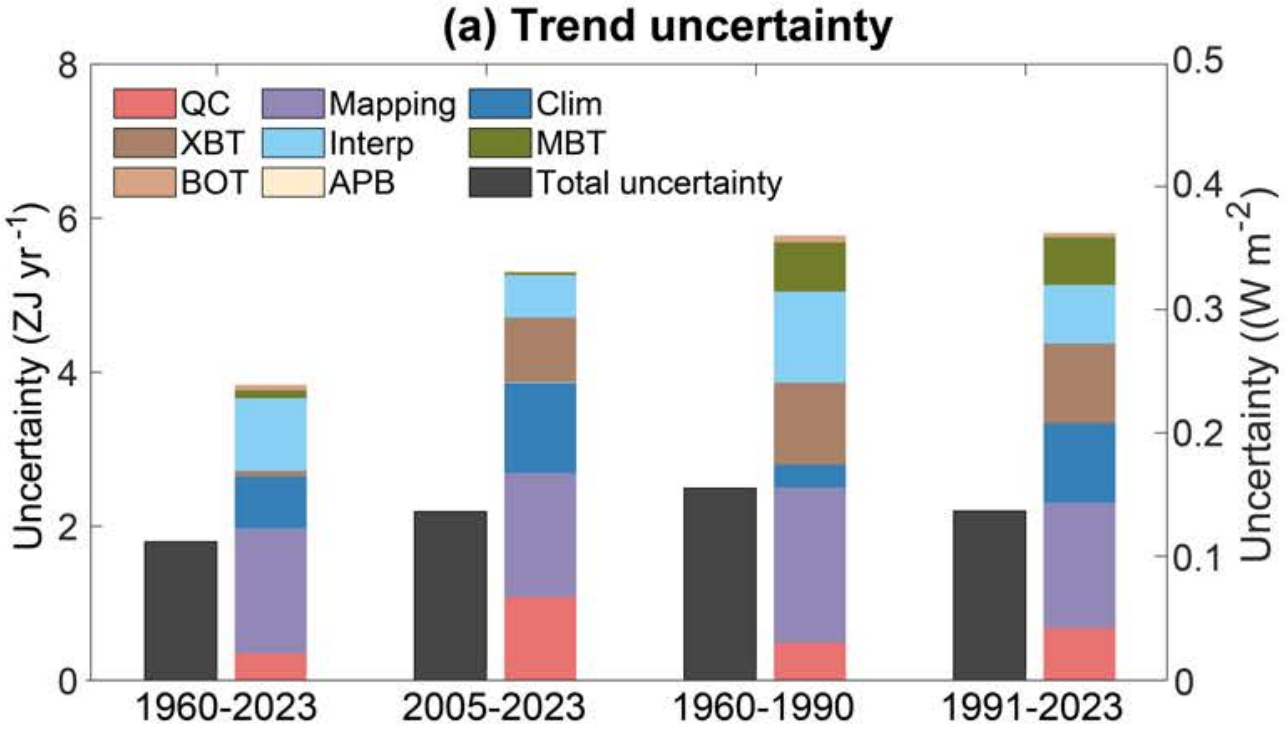
Mapping/ Sampling

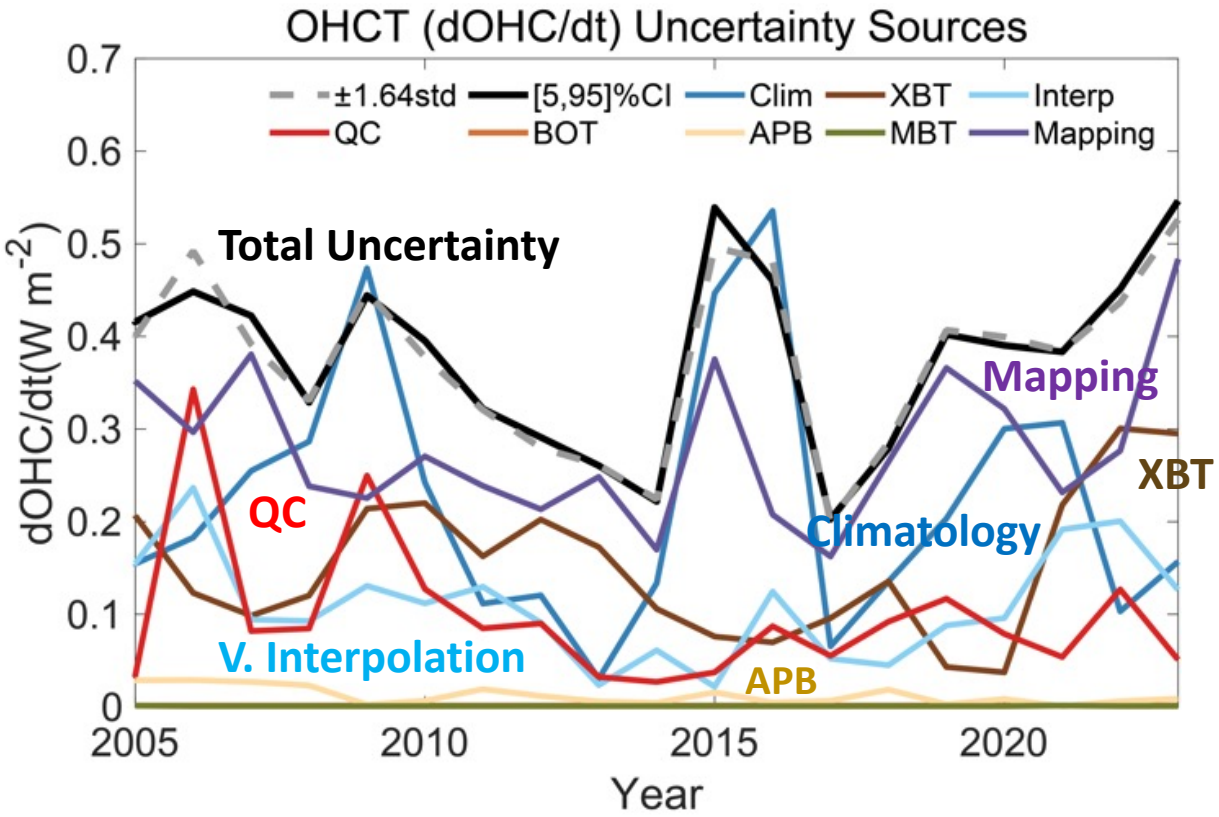


Uncertainty shown as [5%, 95%] Range

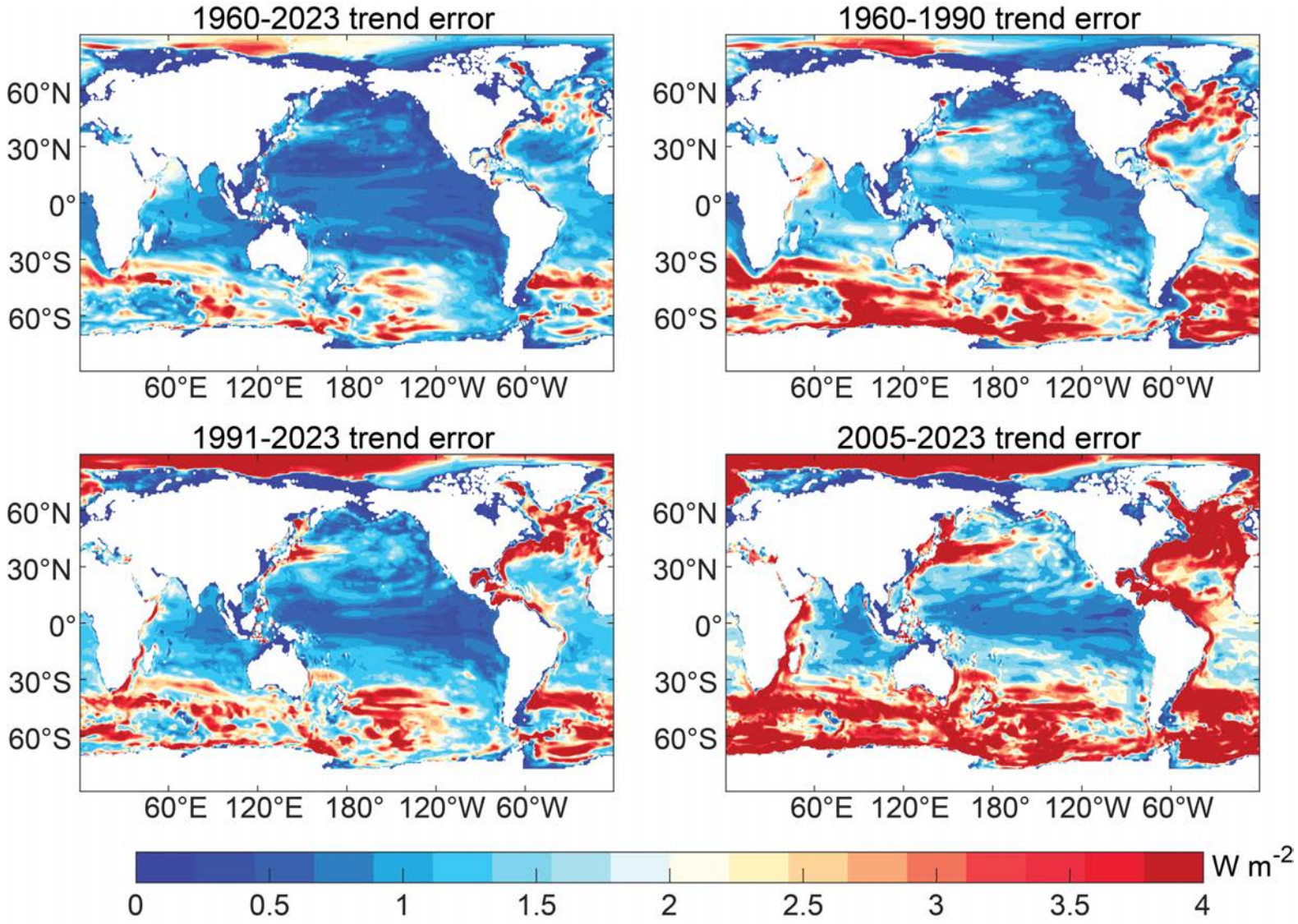
Results: OHC trend and variability uncertainty

- 1960-2023 trend: Mapping > Vertical interpolation method > Climatology choice
- 2005-2023 trend: Mapping > QC > Climatology choice
- Annual dOHC/dt, 2020-2023: Mapping > XBT bias > vertical interpolation



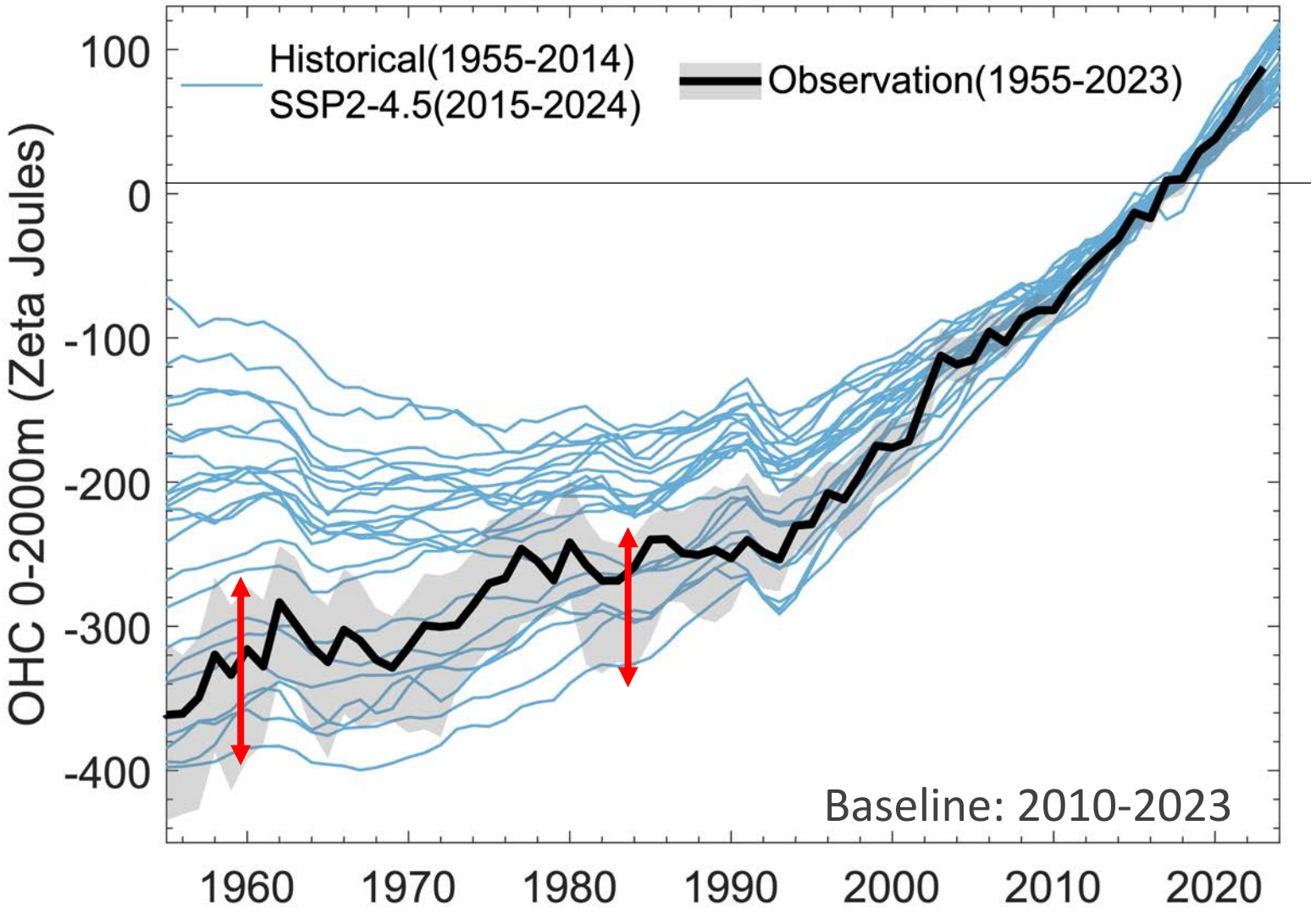


Results: OHC trend uncertainty, regional



- The critical regions to estimate the OHC trend are the **polar regions** and the **boundary current regions**.
- The **Atlantic and Southern Oceans have** higher uncertainty than the Pacific and Indian Oceans, characterized by high variability and trends.

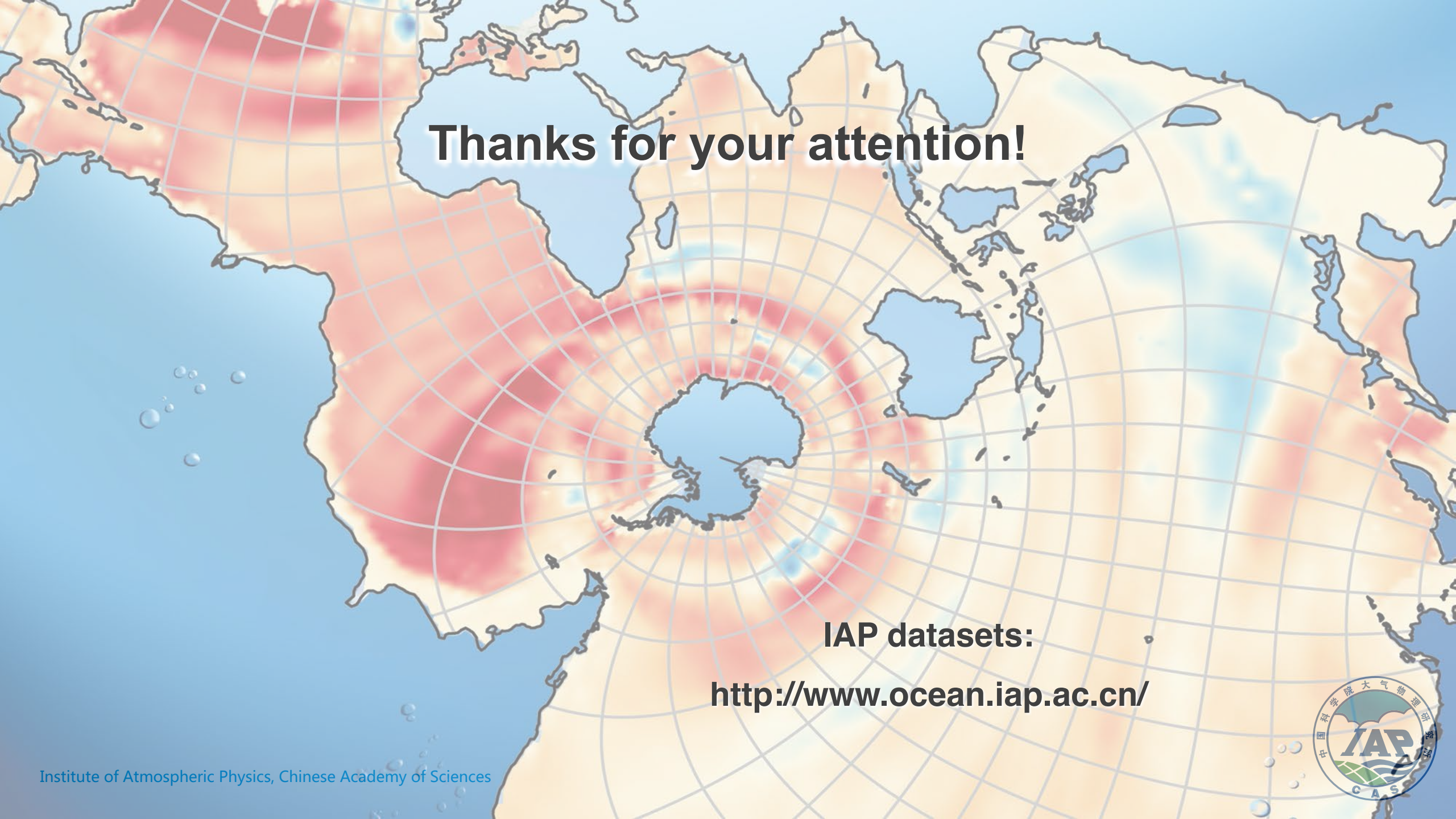
Results: OHC Model-Obs inter-comparison



- Among **22** CMIP6 models, **7** fall in the [5%-95%] observational range and are consistent with observations.

Summary

- “Observation” is not perfect (it is an estimate of the actual world); it does have uncertainty caused by many sources of error. A quantification of observational uncertainty is critically needed.
- A Large-ensemble approach (~900 members) is proposed to quantify Ocean Temperature (0-2000m) and OHC estimate uncertainty, accounting for 9 known error sources (8 groups).
- Uncertainty can be estimated globally/regionally, for annual (monthly) mean, trend, variability, etc.
- This Large-ensemble approach is a useful tool for 1) Model-Obs inter-comparison; 2) observation system evaluation and gap identification.



Institute of Atmospheric Physics, Chinese Academy of Sciences

International Quality-controlled Ocean Database
IQuOD "Mission Statement"

To **maximize the quality, consistency, and completeness** of the long-term global subsurface ocean temperature (and salinity) database

The power of IQuOD: Ability to pull together the expertise from the international research community (producers/users) and to focus that combined effort into a single "best" dataset.

I Q u O D

www.iquod.org

5. Uncertainty estimate/assignment

Instrumental uncertainty (IQuOD)

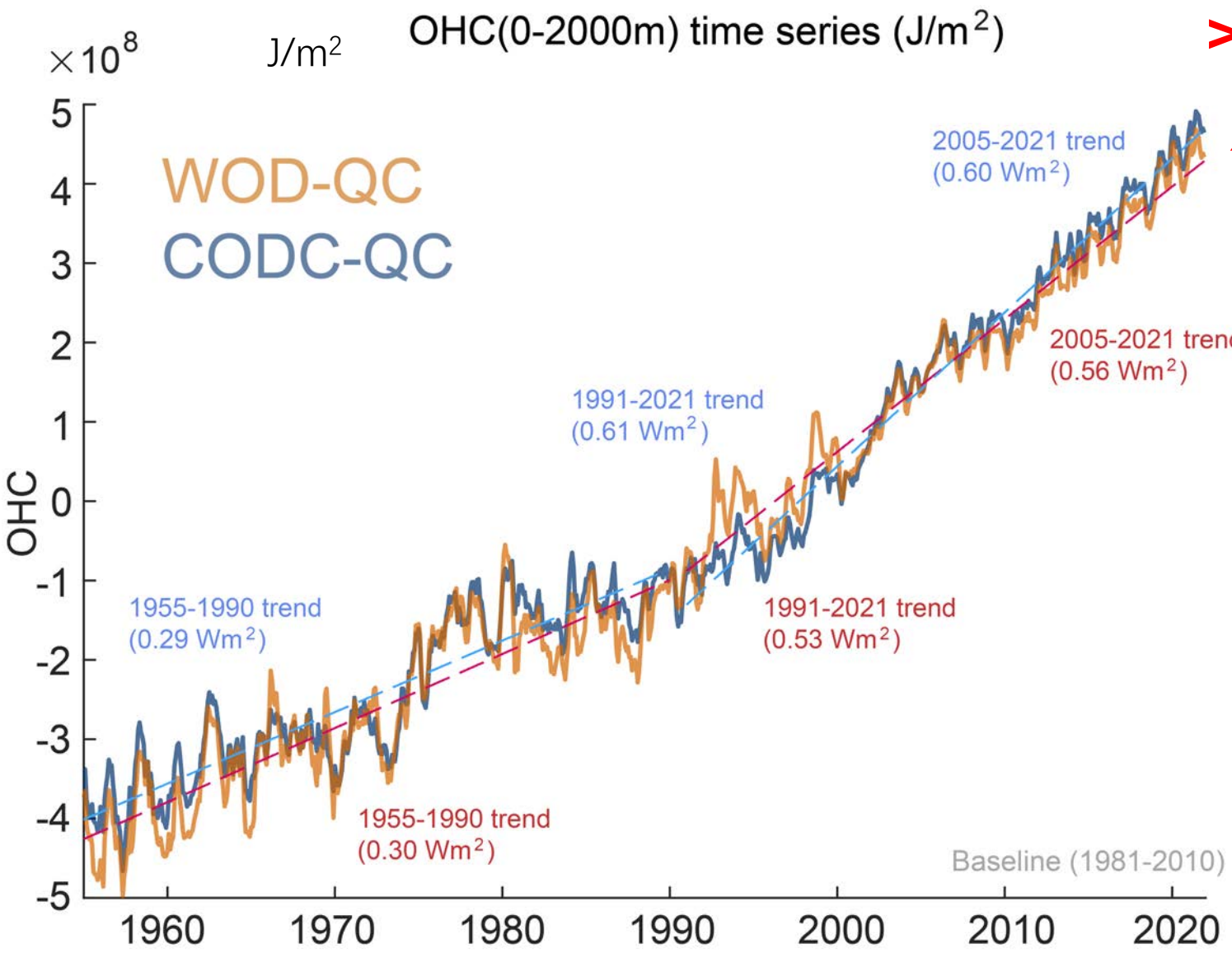
- IQuOD v0.1 (2018) release contains 'Type B' measurement uncertainties determined from **manufacturer specifications** and other publications.

Uncertainty budget templates and **a code base with sample calculations** for uncertainty budgets will be published.

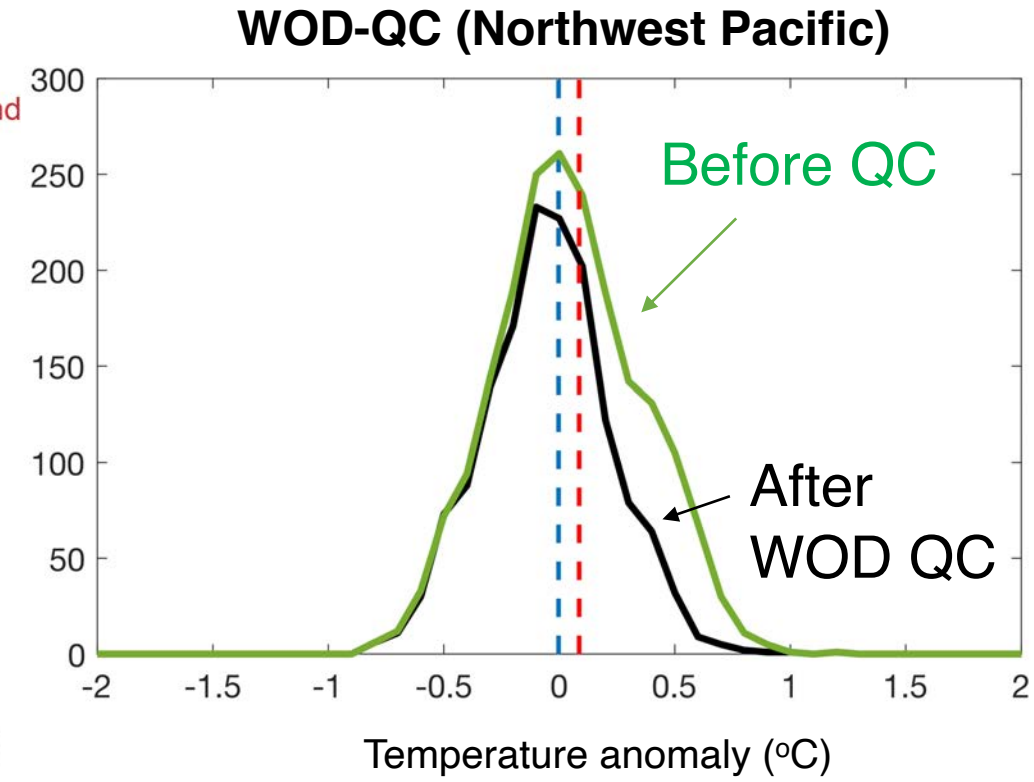
Instrument type	Temperature (°C)	Depth/Pressure	Approx. First Year of Routine Use
Bottle/reversing thermometer	0.02	5%	1900
Conductivity-Temperature-Depth (CTD) uncalibrated and calibration status unknown	0.01	0.08%	1964
CTD calibrated	0.002	0.015%	1964
CTD animal mounted	0.005	-	2004
Glider	0.002	-	2002
Profiling floats (pre-Argo)	0.005	-	1994
Profiling floats (Argo***)	0.002	2.4 dbar	2000
Expendable Bathythermograph (XBT) Sippican manufacturer	0.1	<=230 m: 4.6 m; >230 m: 2%	1967
Mechanical Bathythermograph (MBT)	0.3	3%	1938

Uncertainty estimates for a selection of instrumentation in the WOD as described in Cowley et al, 2021. See https://www.iquod.org/specifications.html for full information.

Results: QC impact



>8% trend difference!



Tan et al. 2023 Deep-Sea Research I

Results: QC impact

Eddy-rich regions are critical

2005-2020 mean Difference between WOD-QC and CODC-QC OHC (0-2000m)