Impact of observing systems on global Ocean Heat Content using Argo gridded dataset and SynObs Flagship OSEs

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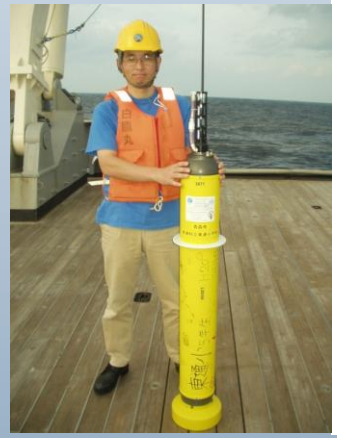
[1] JAMSTEC, [2] WPI AIMEC, [3] MRI, [4] Tokyo Univ.

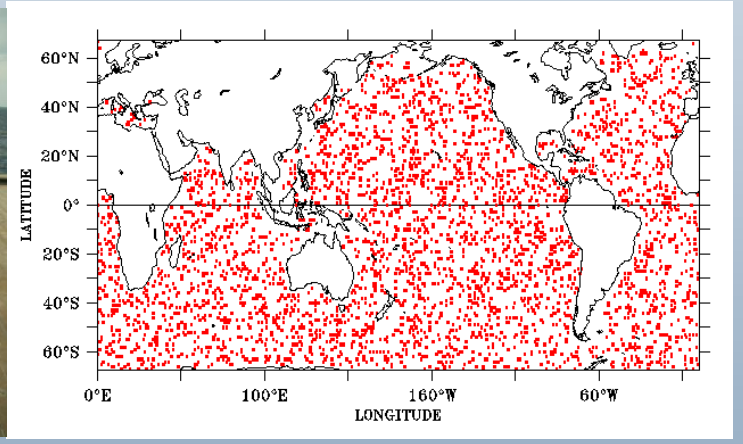


Introduction: Argo to OneArgo

Argo was born at the intersection of profiling floats and the scientific needs of climate change observation. The Argo started since 1999.

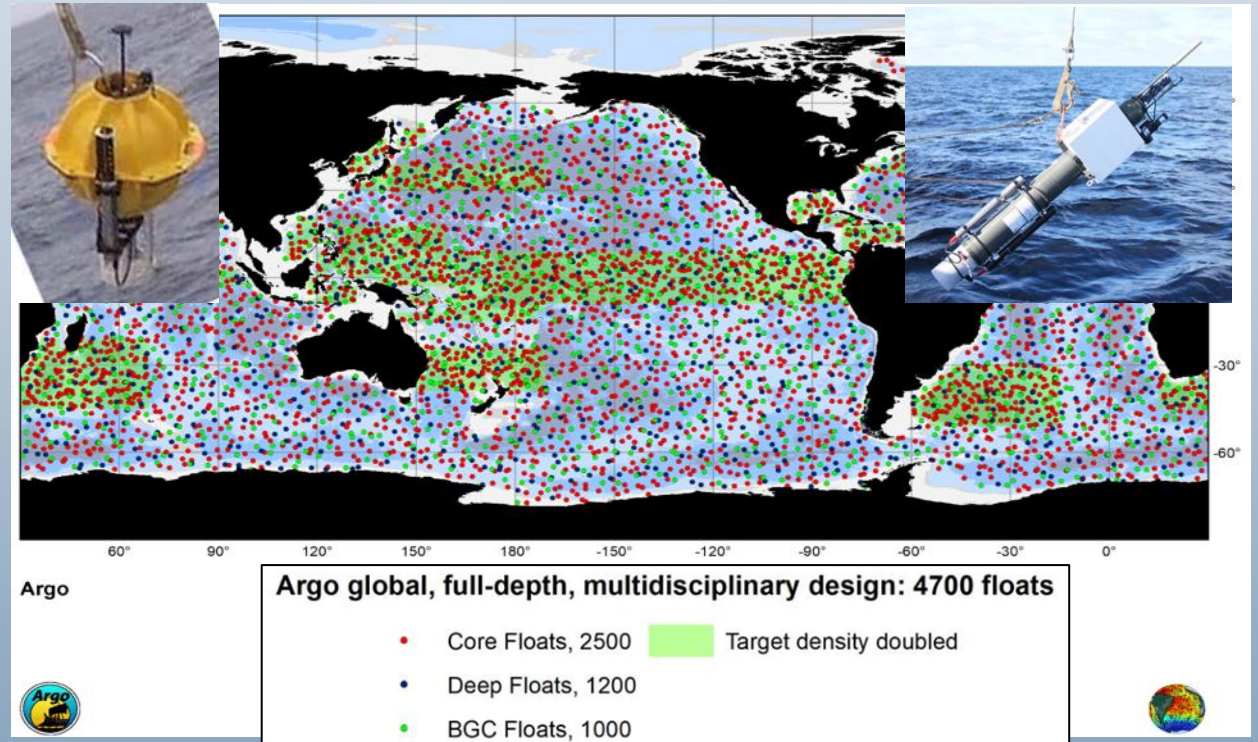
Original “Core” Design





Ocean observation network with 3000 profiling floats with physical parameters covering upper 2000m depth of ice-free open ocean (60N-60S).

New “OneArgo” Design



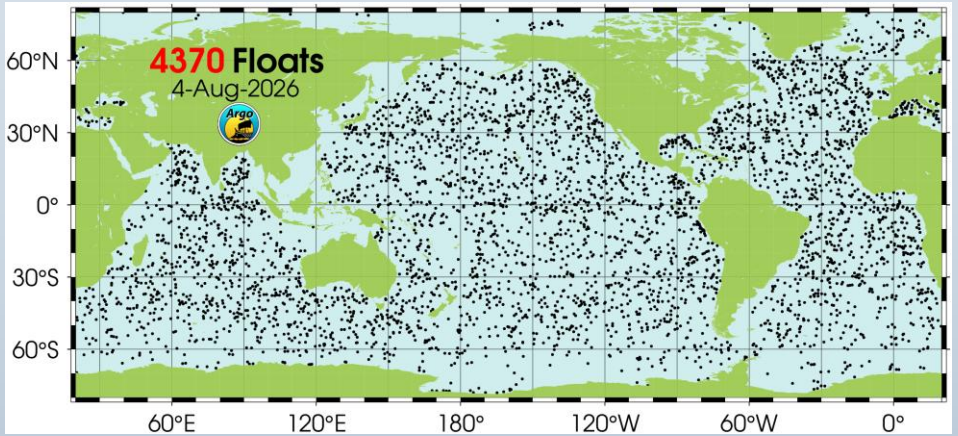
Full Depth (~6000m), Global (including polar) and multidisciplinary (bio-optics, oxygen, pH, nitrate)

Introduction: Ocean Heat Content and Research Purpose

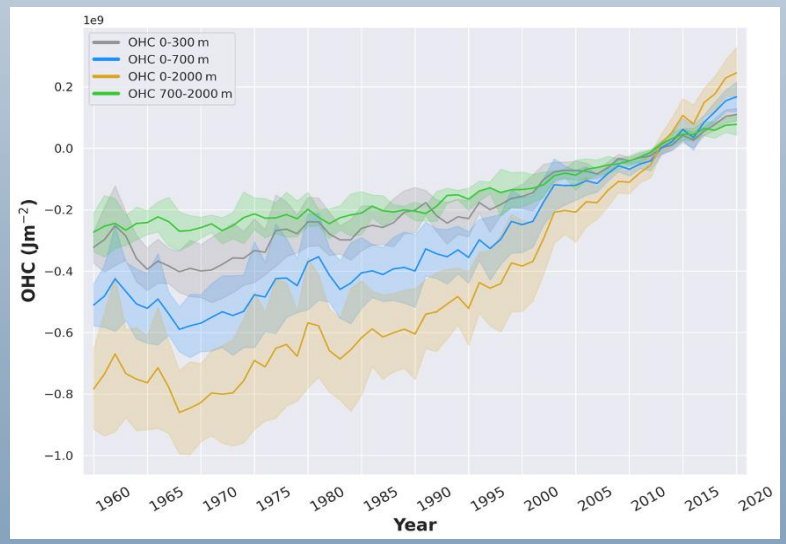
- Changes in ocean heat content (OHC) are one of the physical quantities used to estimate how much heat generated is stored, as a key factor in climate change in IPCC reports.
- With the expansion of the Argo, the accuracy of OHC estimation is expected to improve, and it has become possible to obtain detailed information in the spatial, temporal, and depth.

This study conducts the following analyses

- ➢ Identifying characteristics of OHC changes and trends by basin using objective analyses based on Argo data
- ➢ Using datasets from the Fragship OSEs, the interannual variations and trends in OHC are examined, evaluating the effectiveness of Argo



Global Argo array (Core; OceanOPS)



OHC trends w/ error (0-300, 0-700,0-2000, 700-2000db).
With the start of the 21st century and the increase in the amount of Argo float data, the error bars for OHC have become smaller, and its accuracy has improved.
(von Shuckmann et al.(2023))

DATA

MOAA GPV v2.0

The Argo gridded dataset “MOAA GPV” (Grid Point Value of the Monthly Objective Analysis using Argo data; Hosoda et al., 2008), developed by JAMSTEC, is constructed using optimal interpolation techniques and provides temperature and salinity fields down to 2000 dbar since January 2001.

The MOAA GPV employs 3D optimal interpolation (long × lat × time). Statistical parameters such as decorrelation radius and signal-to-noise ratio are prescribed as functions of latitude and depth.

https://www.jamstec.go.jp/argo_research/dataset/moaagpv/moaa_ja (en).html

	MOAA GPV V2.0
Method	3-D optimal interpolation (Lat x Lon x Time)
Analysis	Temperature and salinity on pressure surface
Area and depth	70.5N-70.5S, 179.5W-179.5E, 5~2000dbar, Including marginal seas
Resolution	1°×1°Horizontally, 66 levels vertically (Every 5 dbar in 5-100dbar, 25 dbar in 125-500dbar, 50 dbar in 550-2000dbar)
Period	Jan. 2001 ~, Monthly
Climatollogy for 1st guess	WOA13 (World Ocean Atlas 2013): Monthly climatology above 1500dbar, Seasonal climatology below 1500 dbar
Standard deviation	Annual mean standard deviation (WOA13)
Used params for OI	Temperature and salinity anomaly calculated from climatology
Decorrelation radius	Lat x Lon x Depth from White (1995) , 30 days for time window
Estimation error	The estimated error variance is the variance of the temperature and salinity minus the weight of the data. At an estimated point with zero data, the error variance is 1 and the estimated value is the climate value itself.

SynObs flagship OSEs

Collection of the data for the flagship OSEs

- Internationally coordinated **OSEs using multiple ocean reanalysis and prediction systems** with a common setting
  - **Observing System Experiment (OSE):** Reanalysis/prediction experiment to examine the sensitivity to observation data
- **To make robust evaluation** which does not depend on a particular system
- Results are stored as netCDF files in **the Japanese DTO on the JAMSTEC sever** and volunteer groups analyze observation impacts.

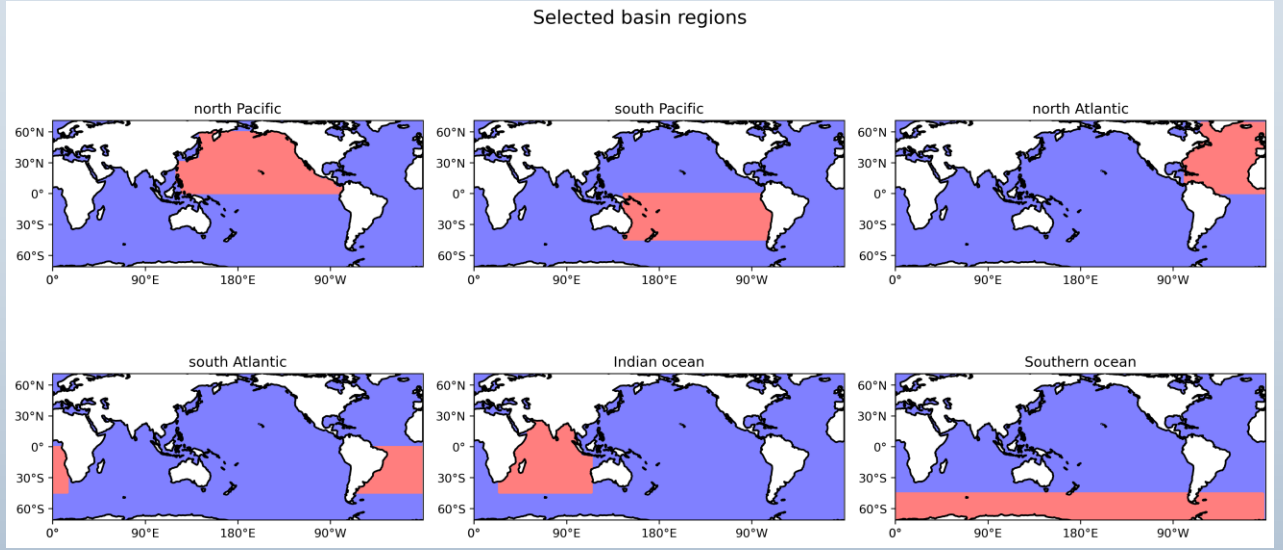
  https://www.jamstec.go.jp/jcope/distributions/SynObsDB/

➢ Data Collection for S2S Analysis (2003-2022)

System	Center	OSEs	Period	Provided Data
MOVE-G3A	JMA/MRI	CNTL, NoAlt, NoArgo, NoMoor, NoSST, HalfAlgo, Noinsitu, Free, SSTonly, **NoUSArgo**	2003-2022	Almost All
ORA6FP	ECMWF	CNTL, NoAlt, NoArgo, NoInsitu, NoSST, **NoMoor, Free, HalfArgo, NoSIC**	2003-2022	Only monthly data
GLORe	NOAA-CPC	CNTL, NoInsitu, Free, **NoArgo, HalfArgo, SSTonly, Oper**	2003-2022	Only monthly data

SETTINGS FOR ANALYSES

Analyses area:	
Global	70N-70S
N Pacific	EQ-50N、120E-80W
S Pacific	EQ-45S、150E-70W
N Atlantic	EQ-70N、80W-0
S Atlantic	EQ-45S、70W-20E
Indian Ocean	30N-45S、20E-110E
Southern Ocean	45S-70S



OHC Inventory (Pressure)
0-2000dbar
0-50dbar
0-300dbar
300-700dbar
700-2000dbar

OHC calculation:

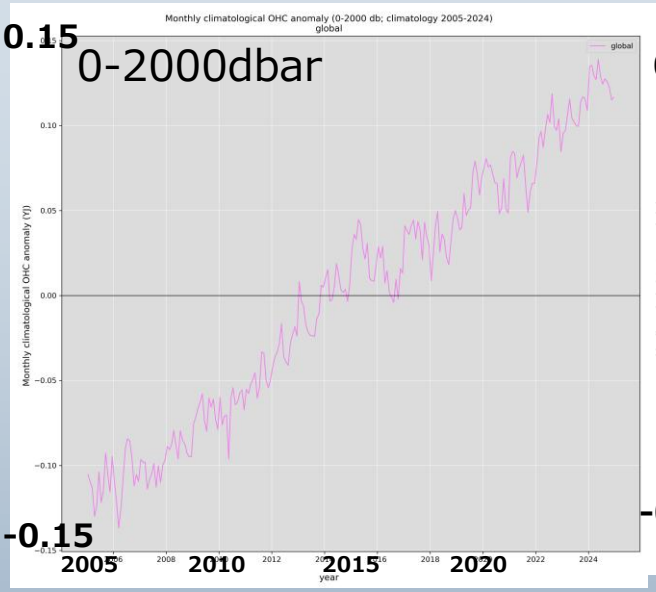
Based on the TEOS-10 formula, the OHC at each grid point (unit volume A) is calculated using the density ρ and specific heat C derived from the temperature (T).

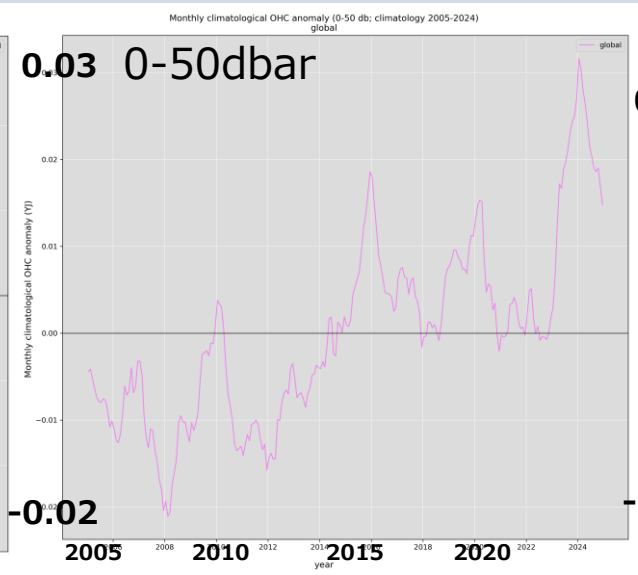
$$dOHC/dA = \rho CT$$

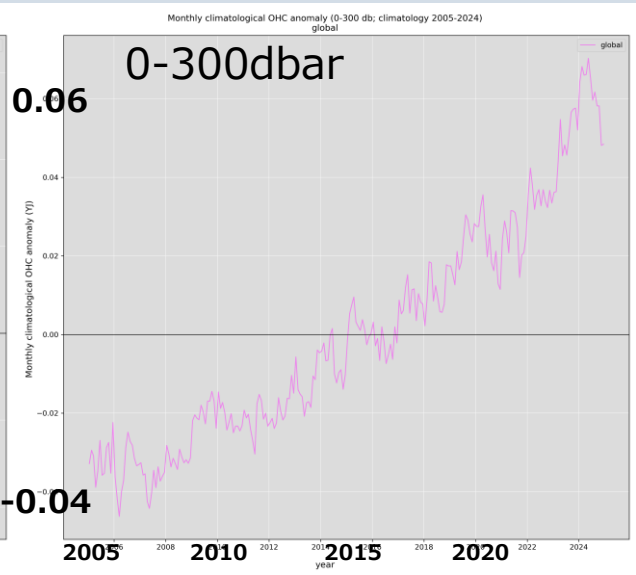
We perform a volume integral for each analysis region and analysis layer to calculate the OHC and its variations for each month.

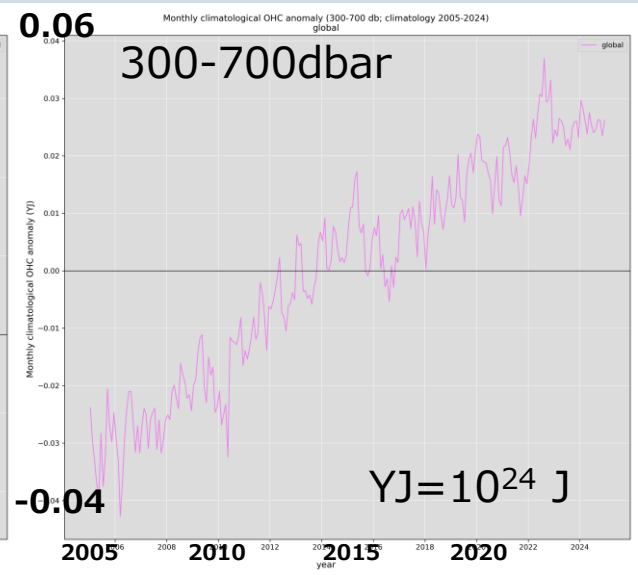
Global OHC variability (MOAA-GPV)

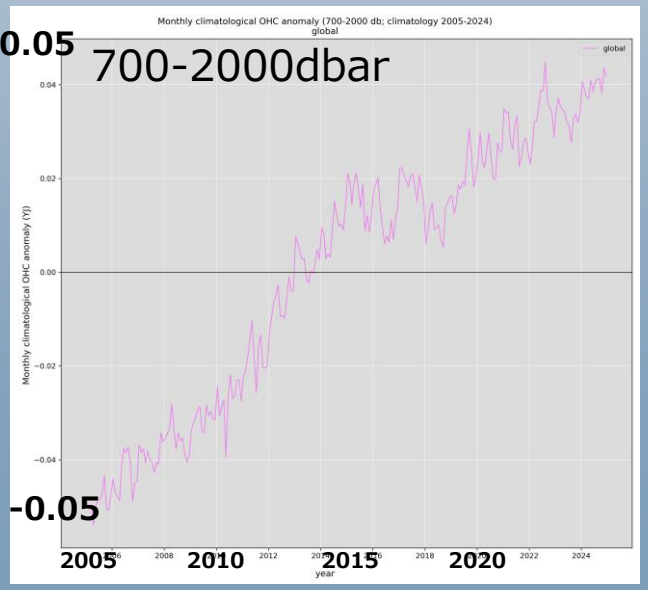
(Difference from monthly climatology in 2005-2024)









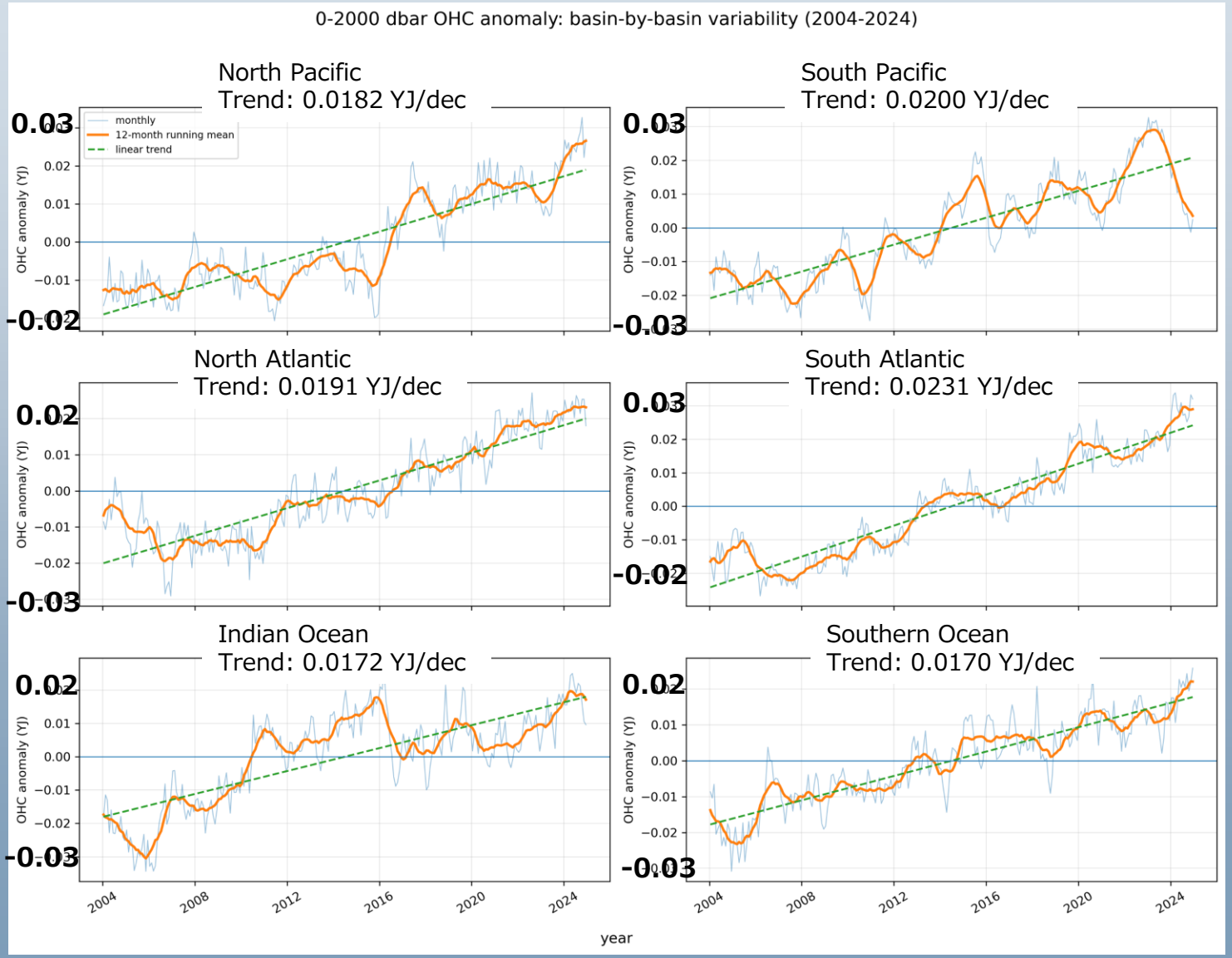


- The linear trend of OHC in 0-2000dbar is approximately 0.02 YJ/decade.
- Regarding interannual variability, ENSO-related fluctuations appear in the 0–50 dbar, while a linear warming trend becomes clearly evident at depths greater than 300 dbar.
- At depths greater than 300–700dbar, the trend is largely synchronized and closely resembles the pattern observed in 0-2000dbar.

OHC TREND IN EACH BASIN (MOAA-GPV)

(Difference from monthly climatology in 2005-2024)

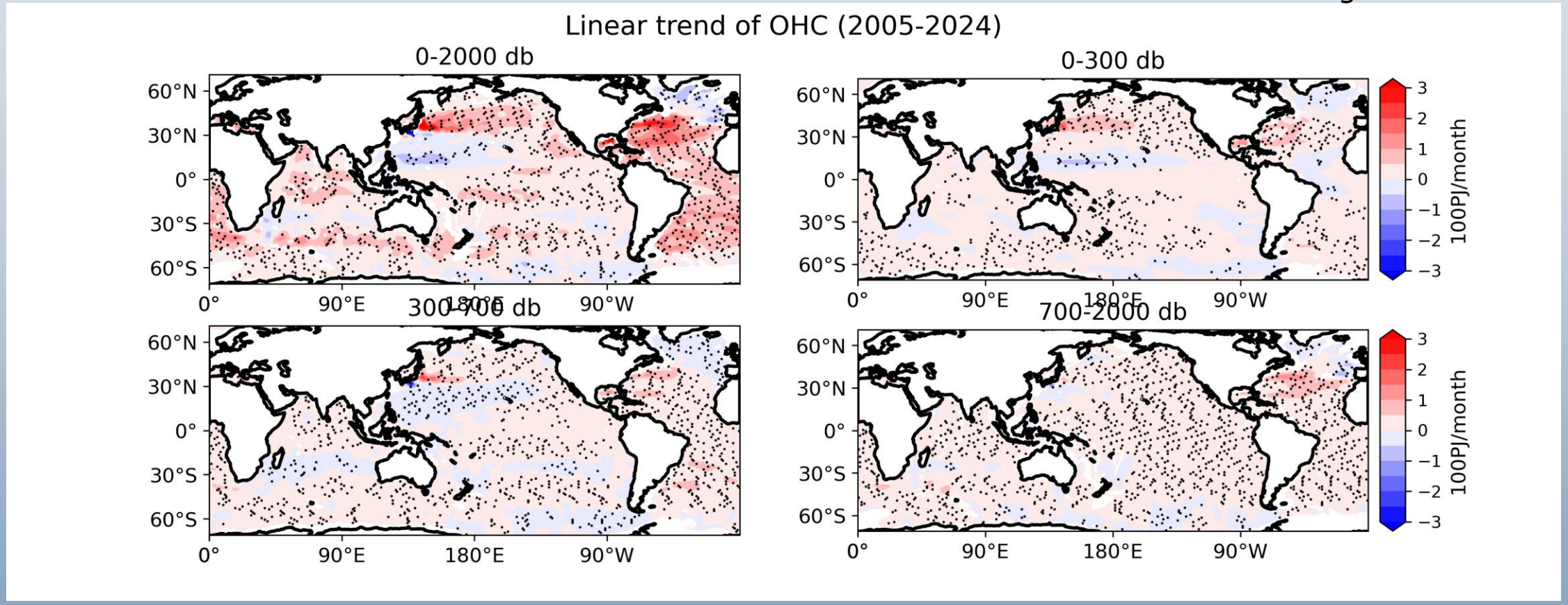
YJ=10^{24} J



- Differences in variability are observed among ocean basins, with higher variability in the North and South Pacific and the Indian Ocean (a detailed analysis is not provided here).
- In the North and South Pacific, fluctuations synchronized with ENSO are observed.
- The values of linear trends vary slightly depending on the ocean region (0.017~0.231 YJ/decade).

OHC linear trend map (MOAA-GPV)

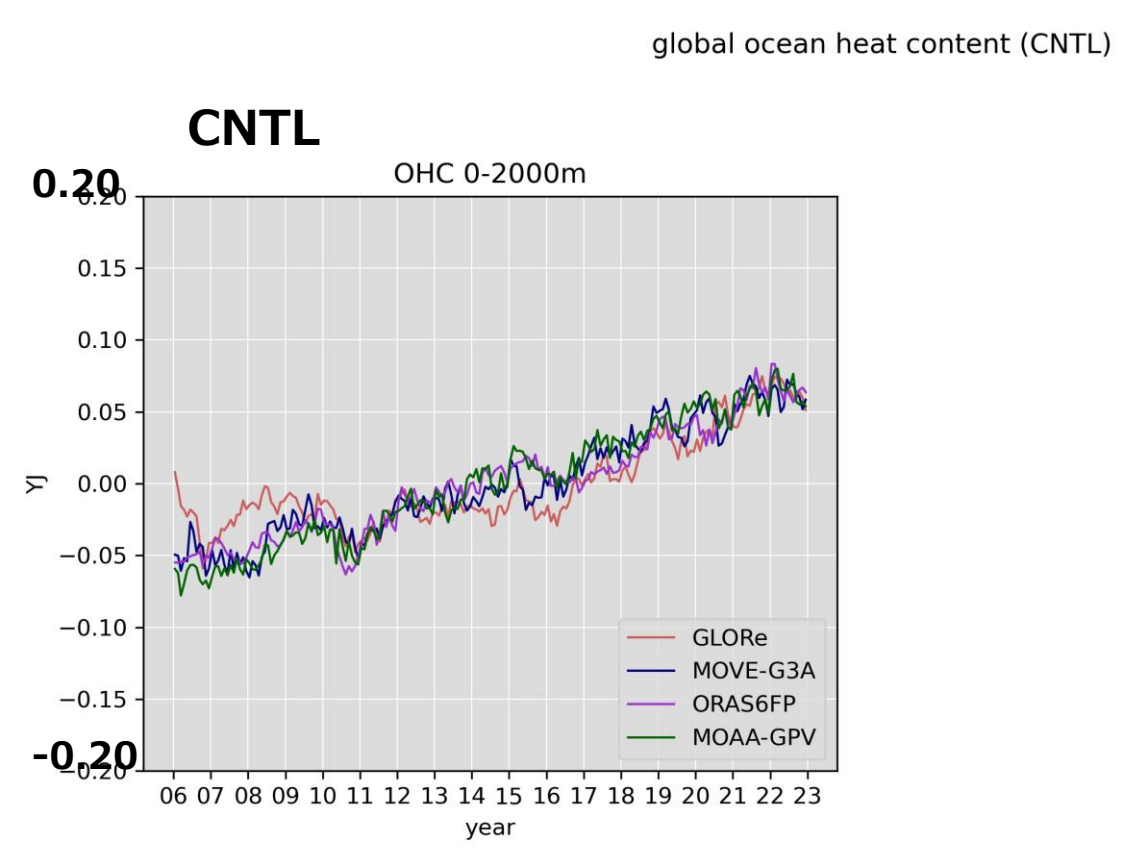
(Trend is calculated in 2005-2024)
Dot means 95% significance area

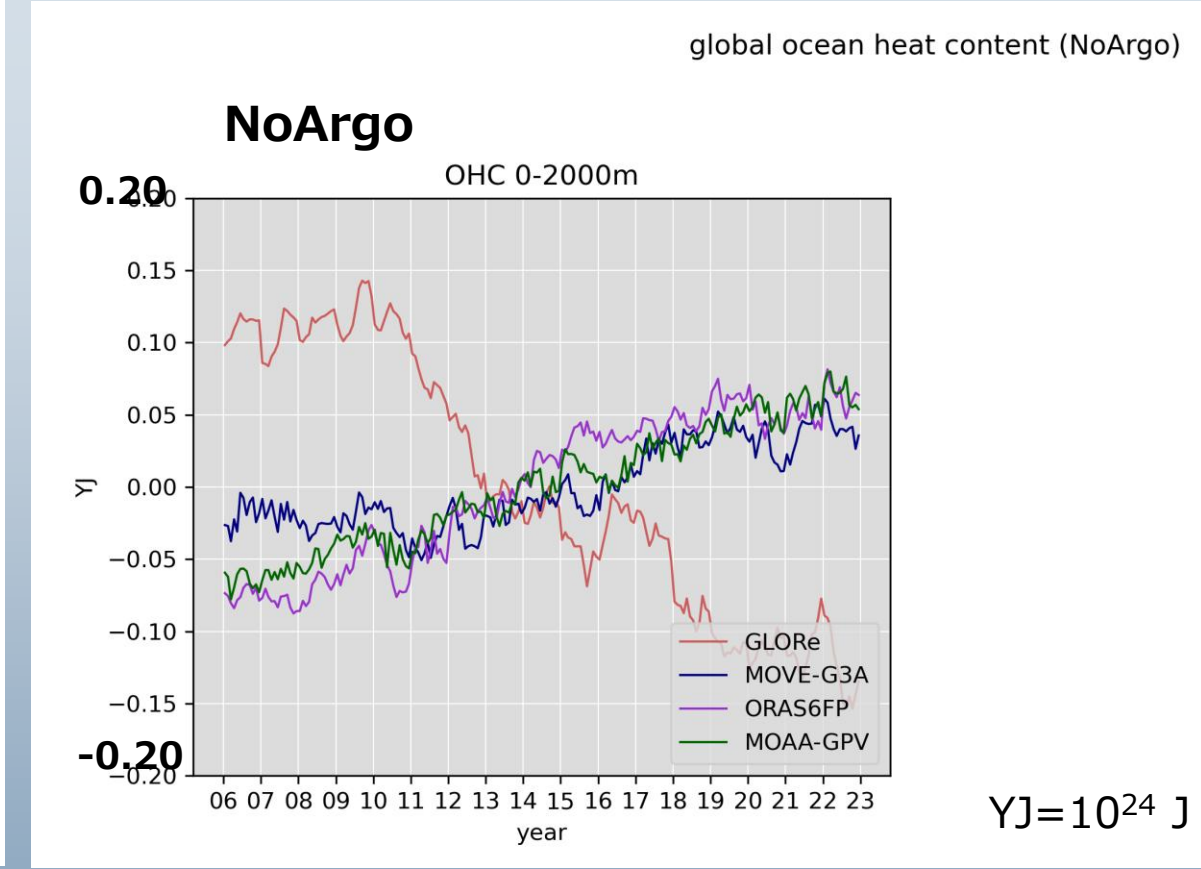


- In the OHC trend from 0 to 2,000 dbar, strong signals are primarily observed in mid-latitudes.
- These signals are mainly driven by the thermocline (0–300, 300–700 dbar).
- In the Atlantic, positive trends are widely observed, while in the Pacific and Indian Oceans, negative and positive trends are distributed following the ocean circulation patterns.

OHC trend in Flagship OSEs (0-2000dbar)

(Difference from monthly climatology (2006-2024))

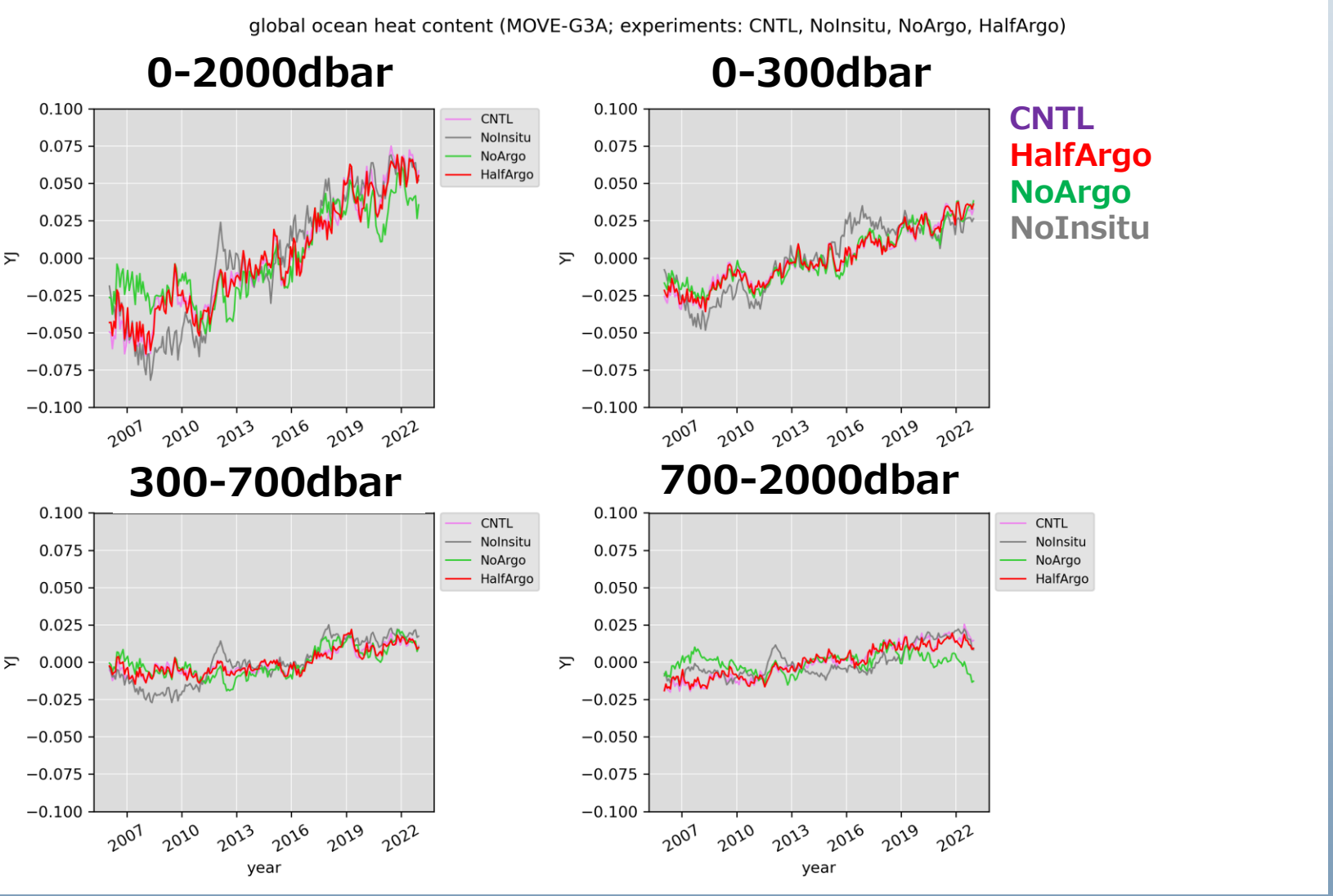




YJ=10^{24} J

- Including observational data (e.g., Argo), reducing the variability among the models and tends to be closer to the observational OHC.
- Without Argo data (NoArgo), the variability is significant; it becomes even greater—demonstrating the effectiveness of Argo.
- Without in-situ ocean observations, the variability increases even further (not shown here).

Effectiveness of Argo data for OHC trend (MOVE-G3A)

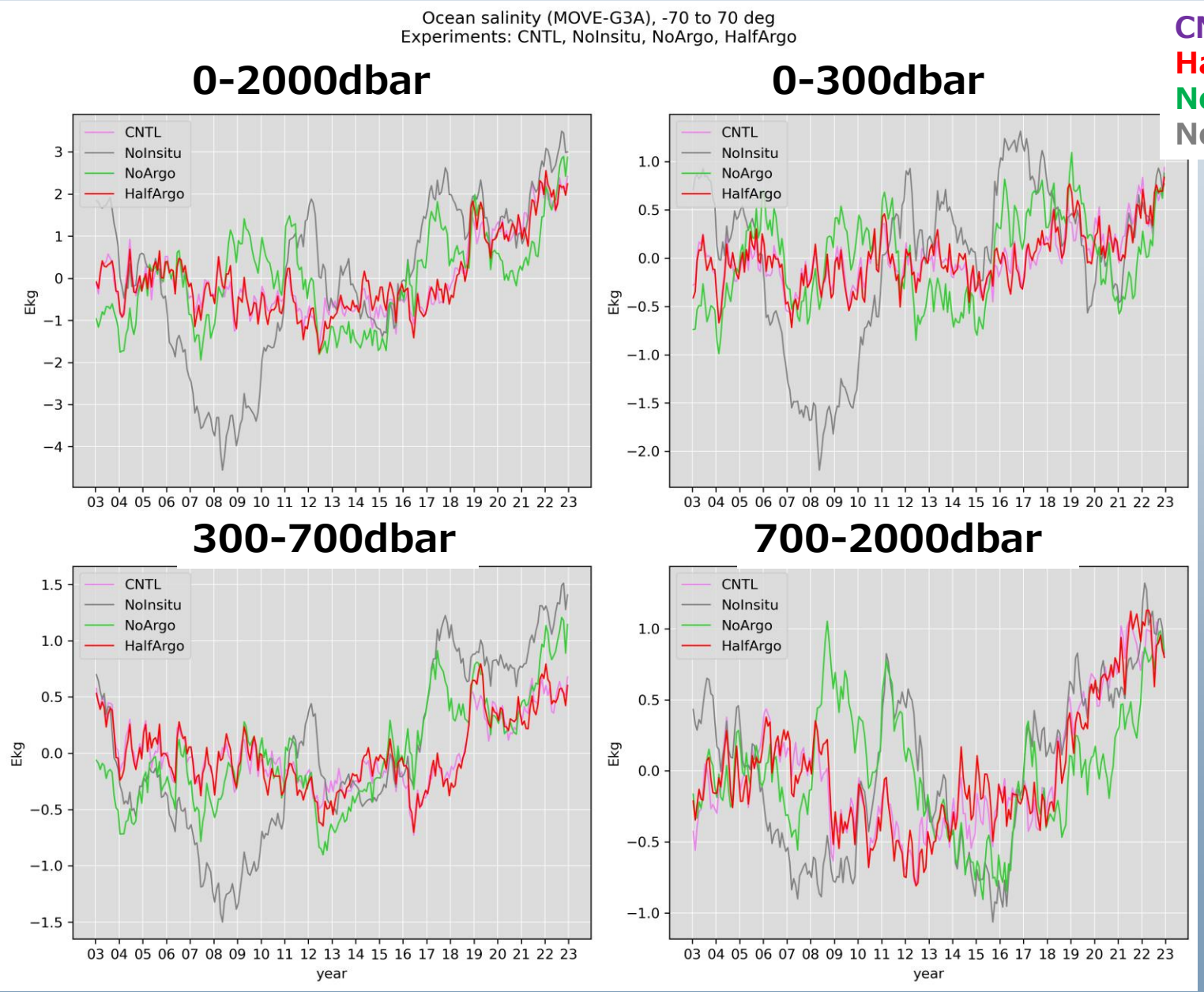


- Based on the "NoInstu" (no observation data) and “NoArgo” (absence of Argo), the “CNTL” (presence Argo) and “HalfArgo” (half of Argo) are closer to MOAA-GPV observational data.

- The difference between the "HalfArgo" and "CNTL“(Full Argo) is smaller; this indicates that comprehensive ocean data is essential for estimating OHC.

Effectiveness of Argo data for OSC (salinity) trend (MOVE-G3A)

E kg=10^{18} kg



- "CNTL" follows the OSC variability to MOAA-GPV (not shown here), and the linear trends are unclear.
- As with OHC, the existence of in-situ observational data and Argo data significantly affects the reproducibility of the OSC variation.
- The effectiveness of Argo is more pronounced as depth increases, in comparison to "CNTL" with "HalfArgo".

Summary

- Using high-density spatio-temporal observation data from Argo, it has become possible to calculate OHC variations by ocean basin and by depth.
- The variability in OHC trends based on each assimilation model depends on the availability of Argo data, demonstrating the usefulness of Argo.
- In the experiments of the Flagship OSEs, a slight dependence on the observation data is shown, while the difference between Argo and Half-Argo was not significant. The OHC does not show a strong dependence on Argo float density.
- By continuing high-resolution observations using instruments such as Argo, it will be possible to estimate detailed OHC, OSC and other parameters, and to evaluate and forecast them through data assimilation.