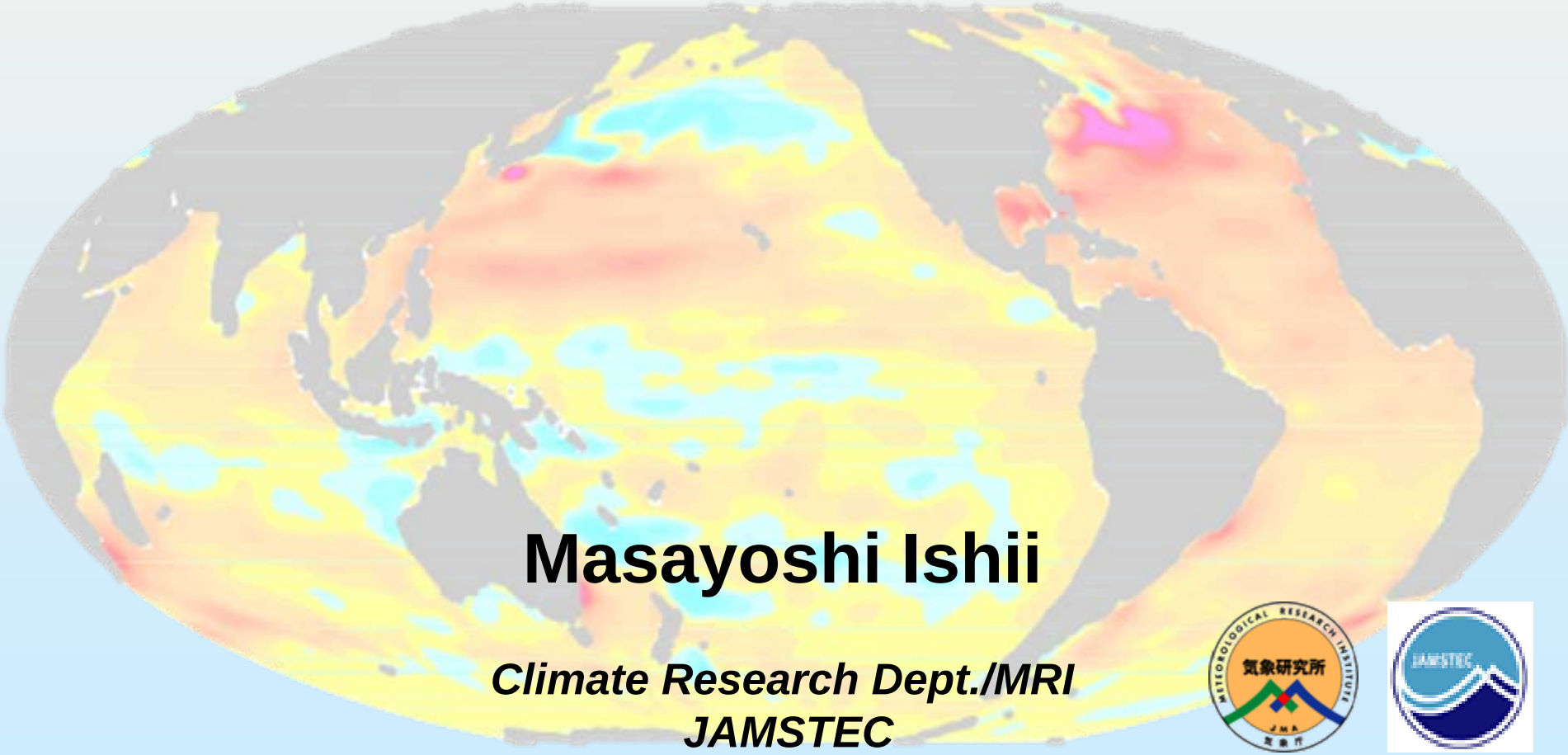
Reevaluation of historical ocean heat content variations with time-varying XBT and MBT depth bias corrections



Masayoshi Ishii

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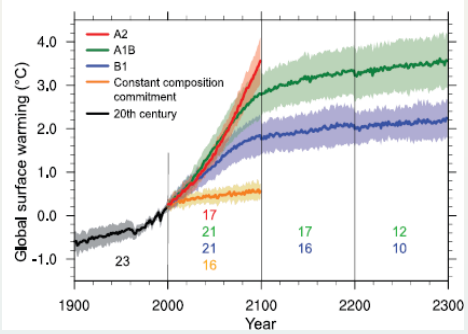
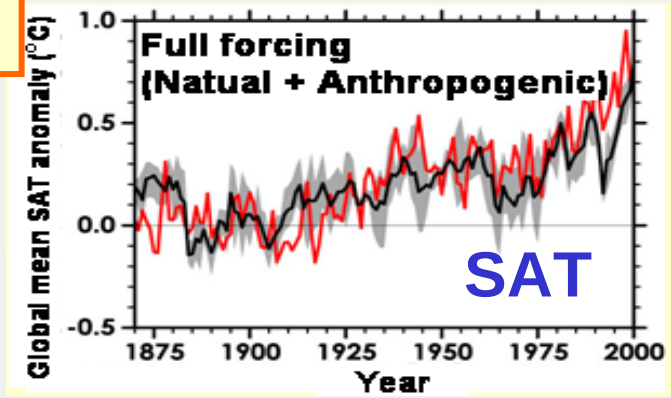
Outline

- Background
- XBT and MBT depth bias corrections
- What have been changed/affected by the corrections?
- Discussion on the XBT Meta data.
- How important the correction is in near-term climate predictions.
- Summary

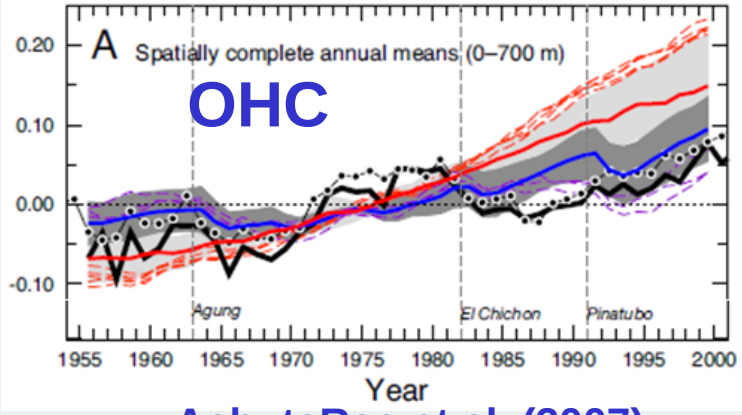
Background

IPCC AR4 2007





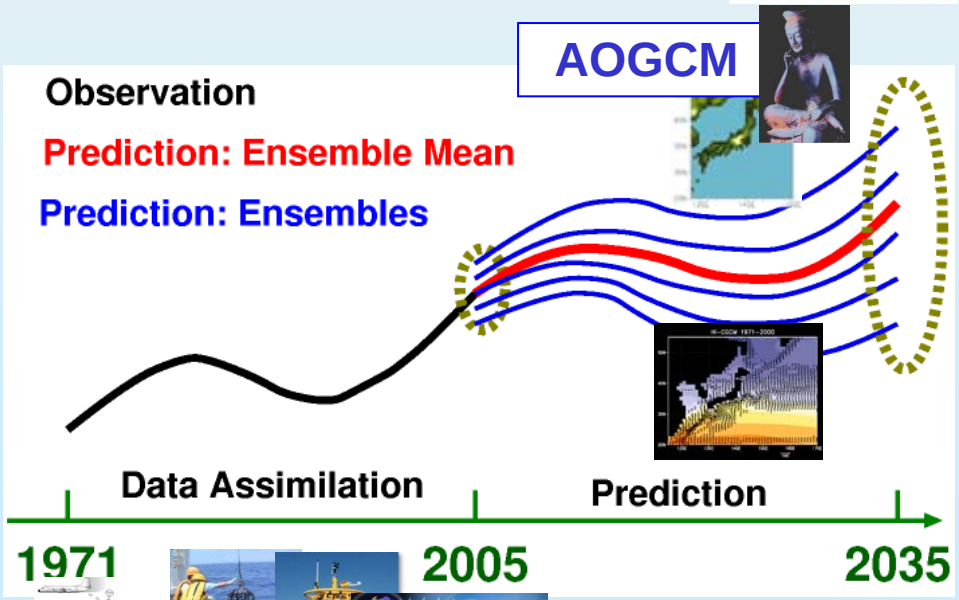
Nozawa et al. (2005)



AchutaRao et al. (2007)

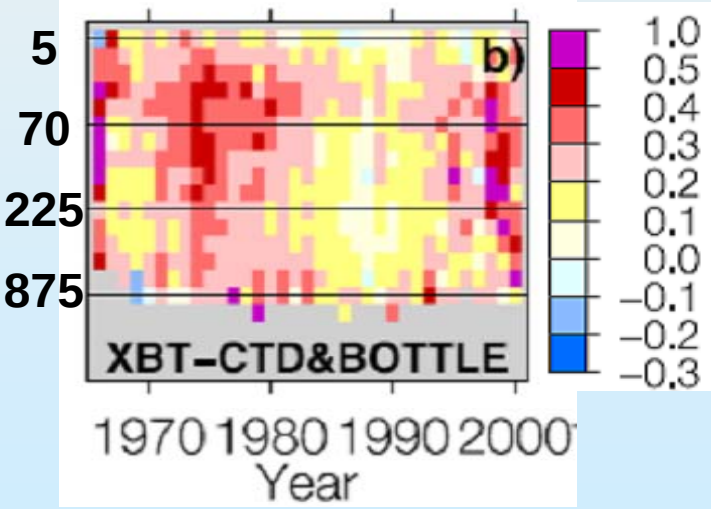
Japanese program for IPCC AR5 since 2007

KAKUSHIN



Ocean data

Historical XBT biases



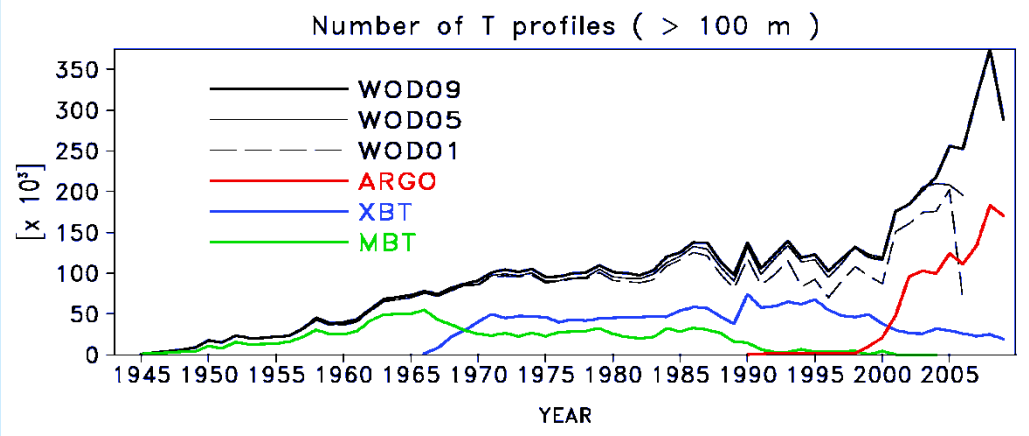
Gouretski and Koltermann (2007)

XBT and MBT depth bias corrections

Latest Historical Ocean Analysis

(Ishii et al. 2003, 2006, 2009)

- Objective analysis of monthly T & S by 3-dimensional variational minimization without a dynamical model
- 1 deg. X 1. deg, 28 levels above 3000 m depth, from 1945 to 2009.
- Observational data: WOD09, GTSPP, and GDAC Argo data (latest as of 11 Jan. 2010)
- Climatology: WOA05
- MBT & XBT depth bias corrections updated



MBT and XBT Depth Bias Corrections

XBT Depth Bias Model: $\delta d = Bt$

B: functions of year and probe type

t: elapsed time

Assuming that T biases are originated mainly from D bias.
Additional corrections to Hanawa et al (1995)

MBT Depth Bias Model: $\delta d = Cz^2 + Dz$

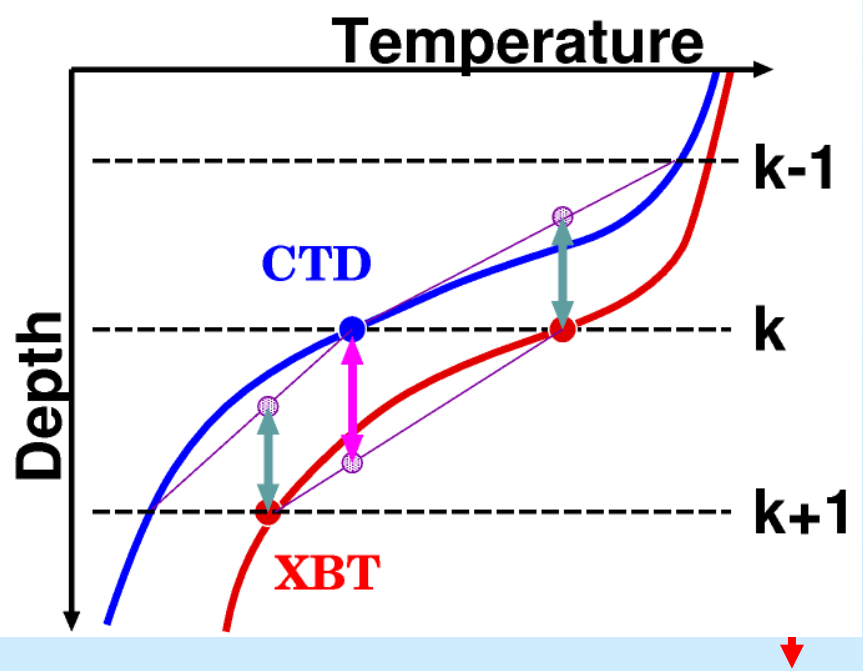
C, D: function of year

z: reported depth

Ishii and Kimoto (2009, JO)

Method

- **Box Averaging**; compute monthly box-averages individually for XBT and CTD-BOTTLE observations in WOD and GTSPP. Argo data are not used.
  - The box size: global 1 deg. X 1 deg., 10 m in the vertical (0-900m)
  - Averaging observed anomalies (relative to WOA climatology) rather than full temperature values.
- **Sampling**; collect depth differences for the same temperature values of XBT and CTD+BOTTLE at the same position in the same month.

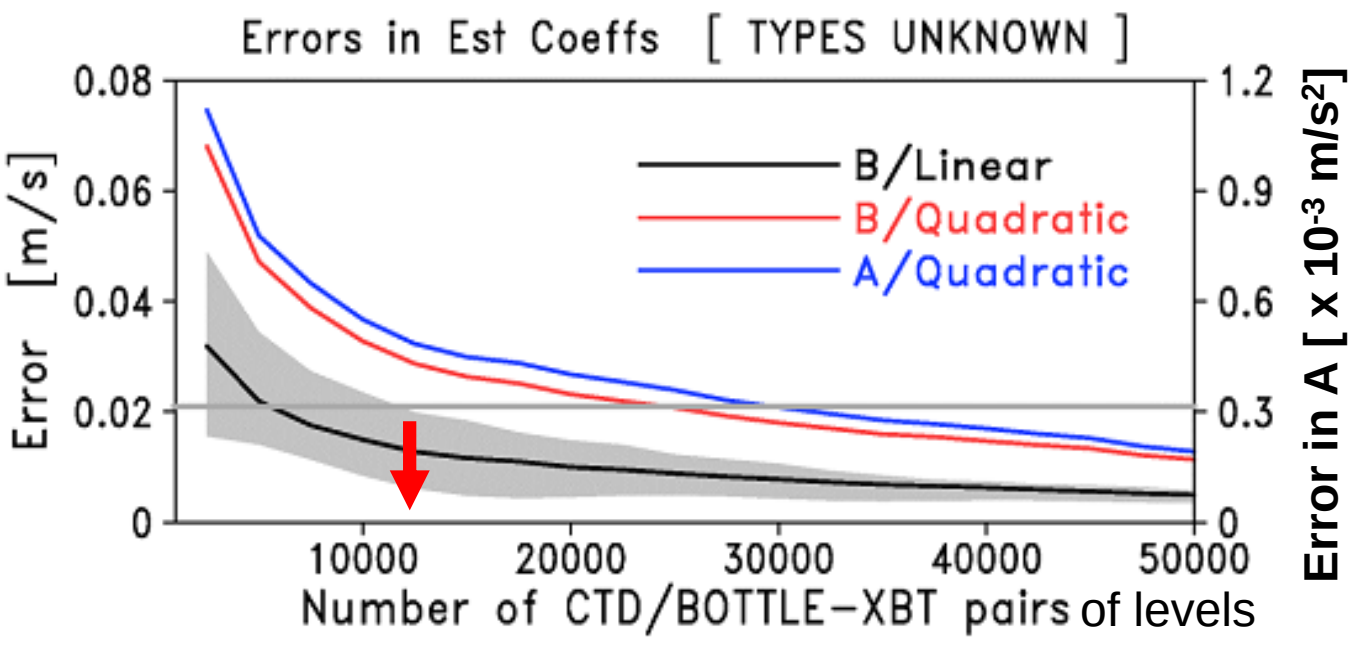


- ✓ Directly compared to CTD & BOTTLE
- ✓ Minimizing interpolation errors
- ✓ Minimizing sampling errors
- ✓ Accurate enough for practical uses.

- **Least squares fitting**; compute a coefficient of the linear bias model.

Method (2)

How many samples at least are required for accurate estimations?



Bootstrap test

0.02 m/s (B)

➔ 2m dep. err. at 700m

Depth Bias Model:

$$\delta d = Bt\ [+At^2]$$

When estimating yearly B's, collect samples nearest to each year enough to obtain B of error about 0.02m/s.

Probe-type-dependent Biases

Means over the whole period.

XBT

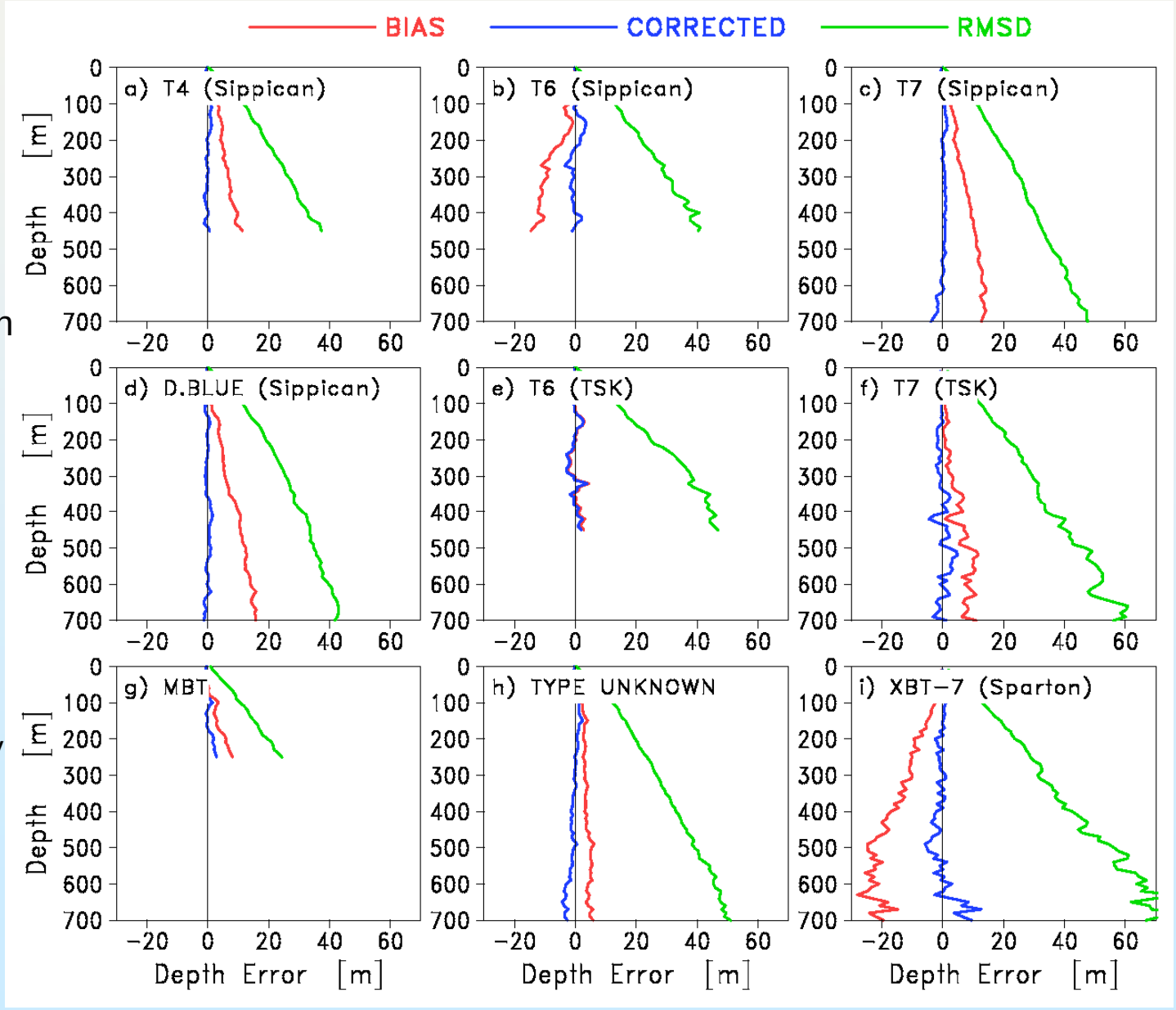
Manufacturer's dep.:

Sippican, TSK, Sparton

Probe-type dep.:

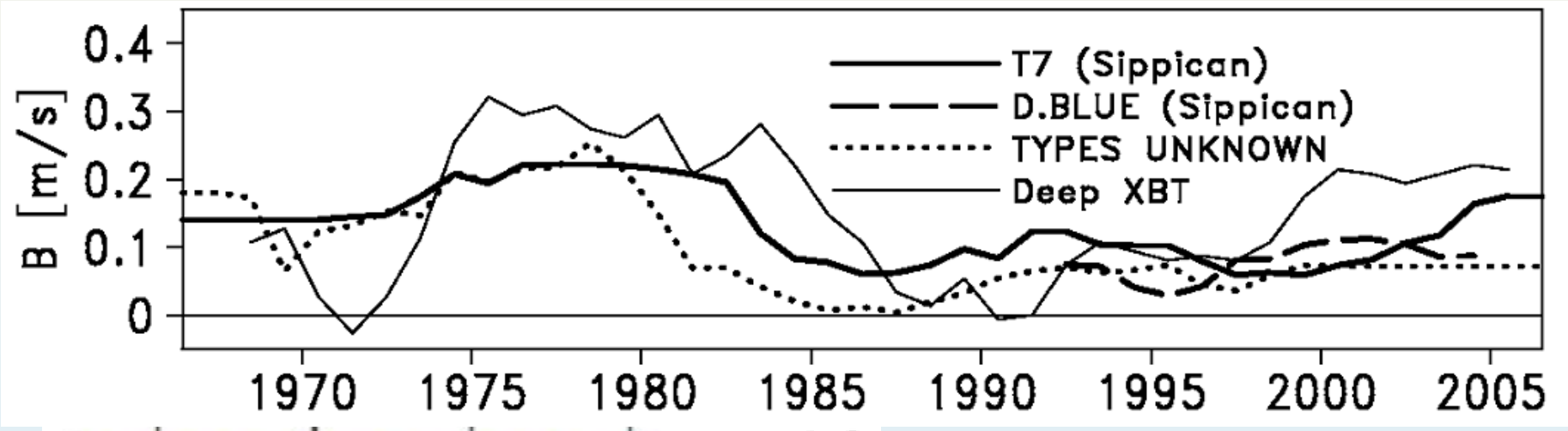
T4, T6, T7, Unknown

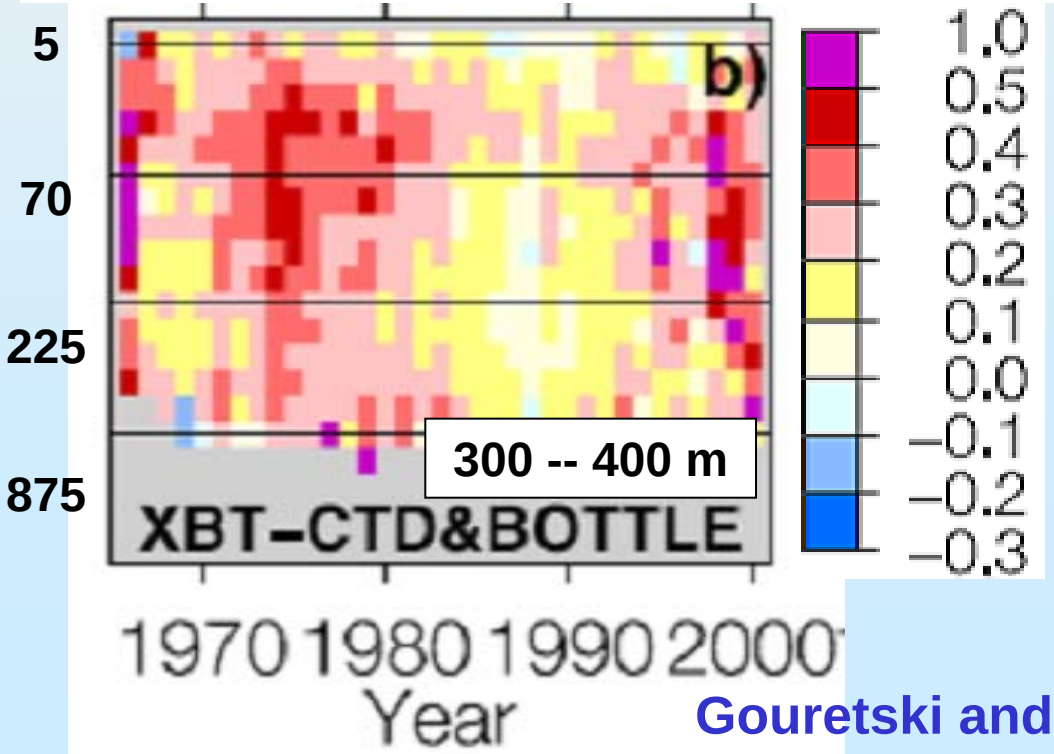
MBT



- Magnitudes of biases vary among types and manufacturer.
- Large RMSD, noisy
- The linear model is OK

Temporal changes in Bias





Depth Bias Model:

$$\delta d = Bt$$

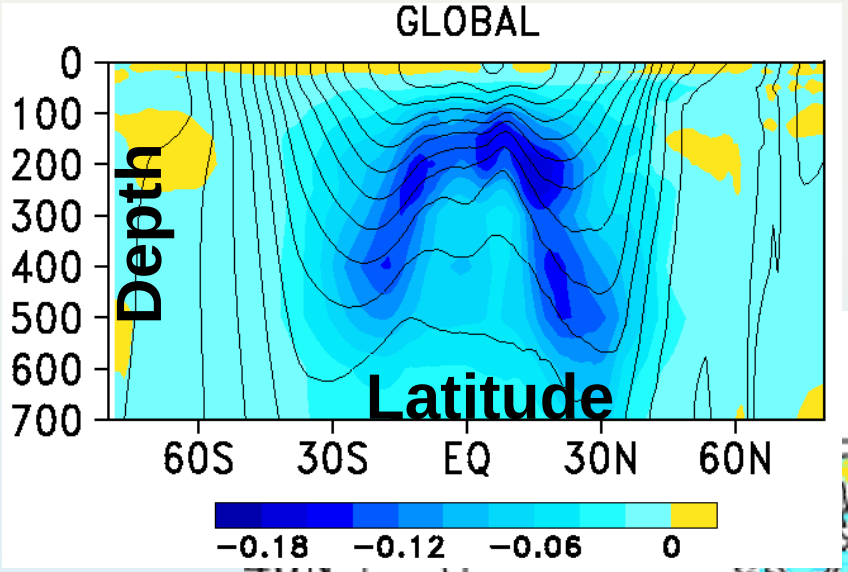
- temporal changes
- agree with Wijffels et al. (2008)
- agree with G&K (2007)

Gouretski and Koltermann (2007, GRL)

What have been changed/affected by the corrections?

- **Climatology**
- **Time series of global mean OHC**

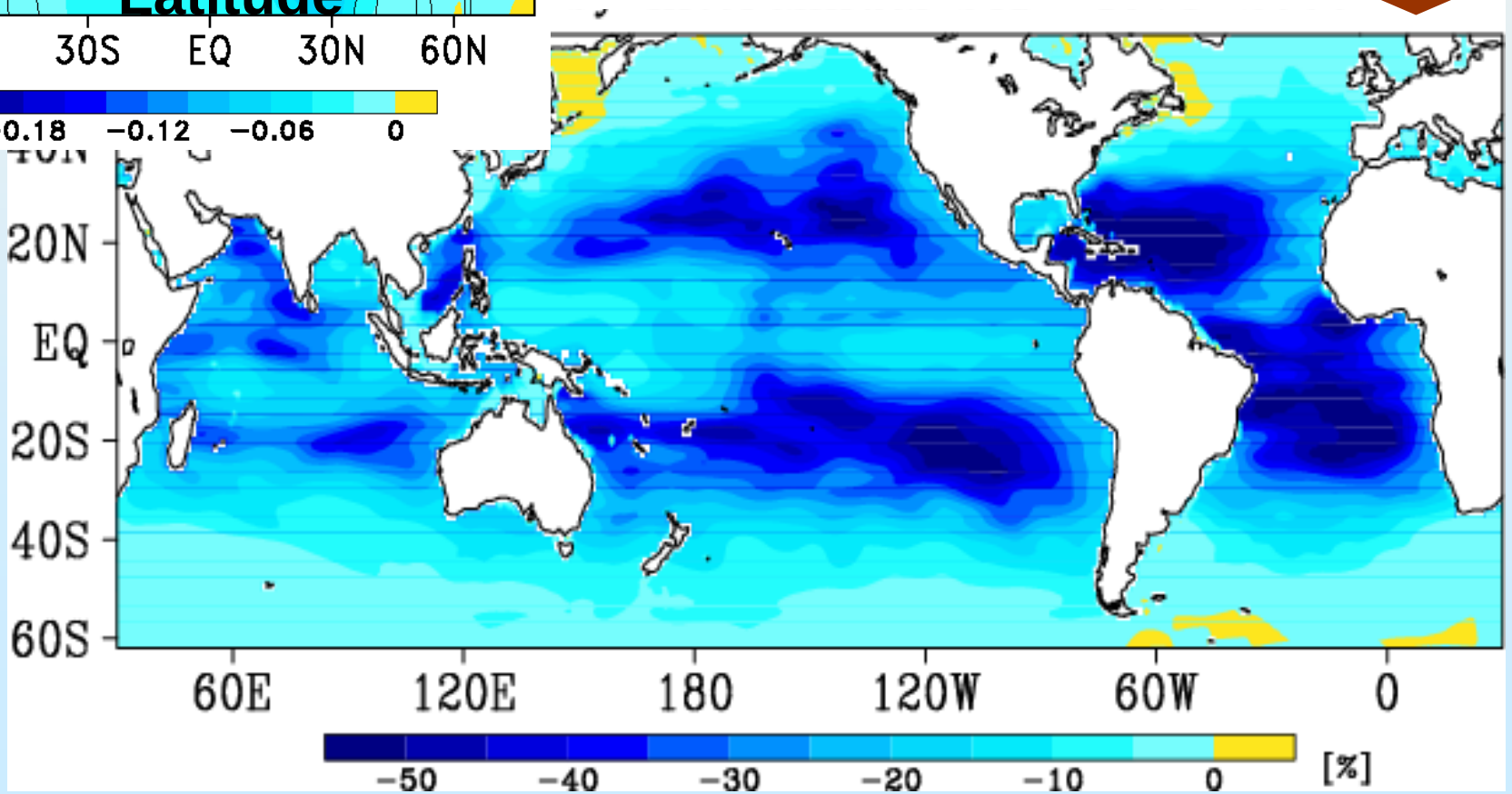
Spatial contrasts in Biases (1971-2000)



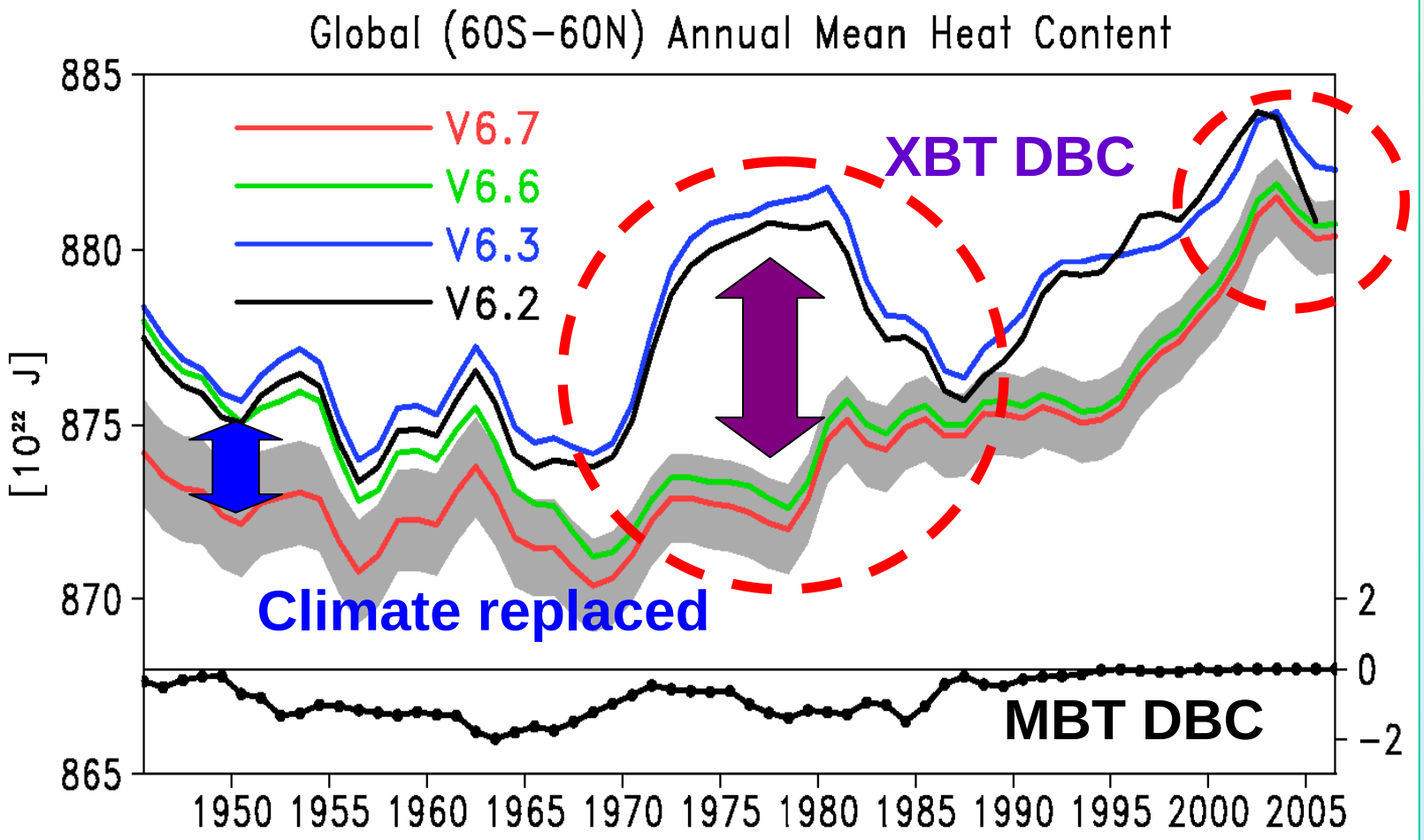
Zonal Mean Temp Diff.
w/ & w/o the Correction

Not sub-sampled but complete sampling of objective analysis for 1971-2000.

Diff. of OHC (0-700)
w/ & w/o the Correction



Ocean Heat Content (0-700m)



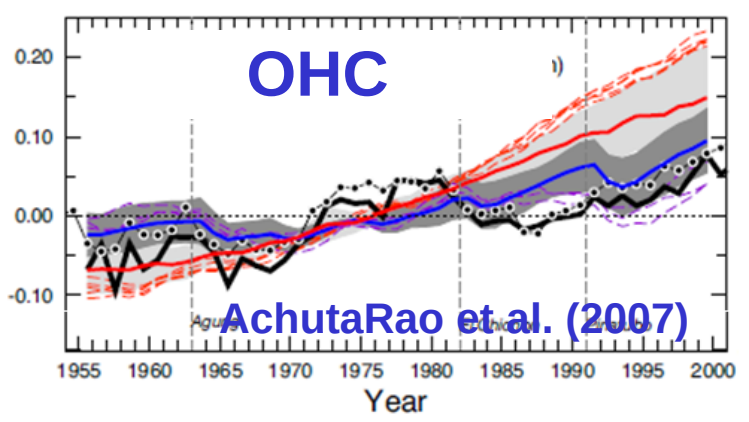
V6.2: WOA01, WOD01, W/O XBT and MBT DBCs
V6.3: WOA05, WOD05, W/O XBT and MBT DBCs
V6.6: WOA05, WOD05, W/ XBT and MBT DBCs
V6.7: WOA05, WOD05, W/ XBT and MBT DBCs, W/ V6.6 CLIMATE

Evidences for the large OHC reduction in the 1970s

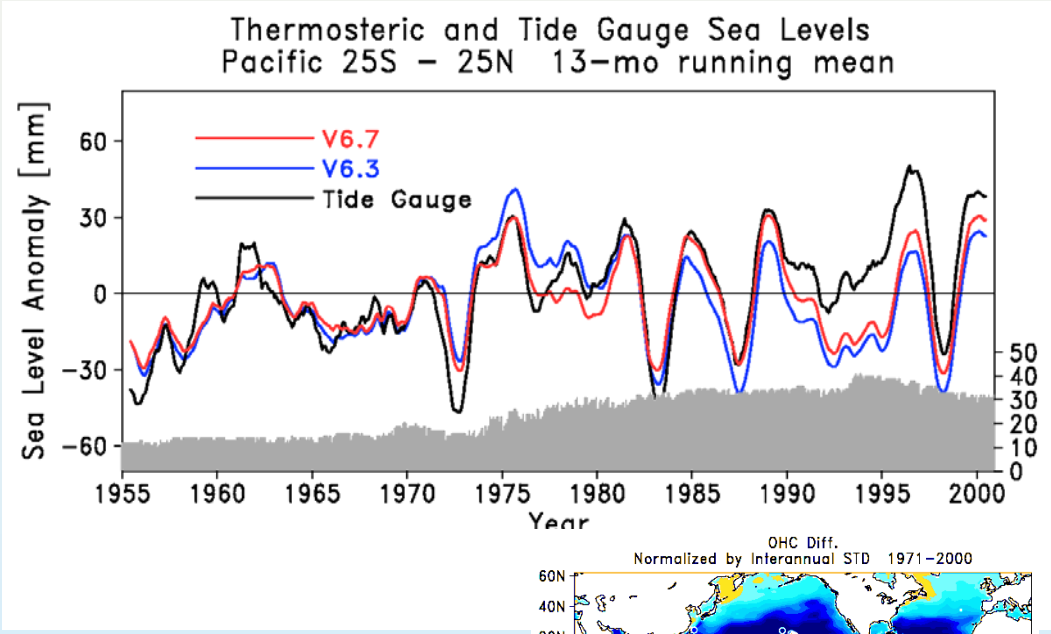
Ishii and Kimoto (2009)

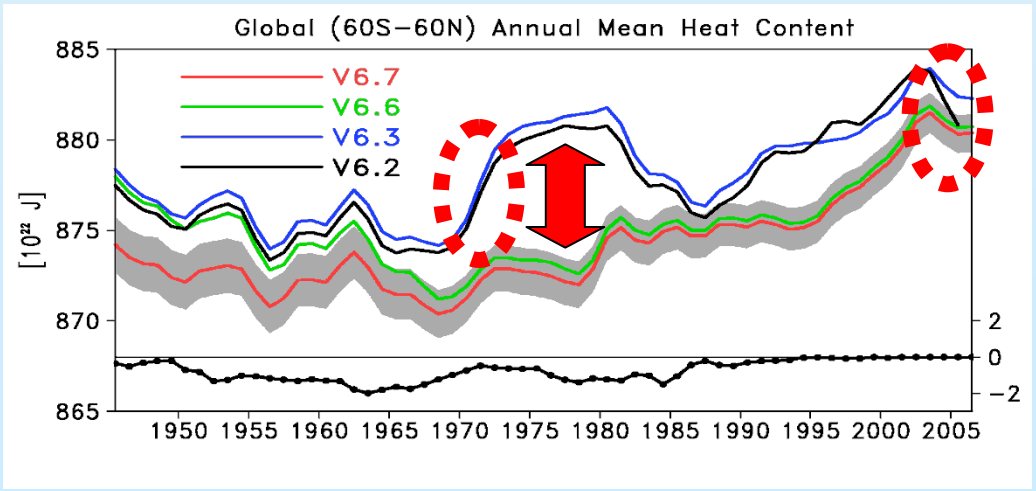
Circumstantial, not crucial

vs. AOGCM



vs. Tide Guages





Abnormal 2-year OHC Change

2004-05: -4x10^{22} J

1972-73: +4x10^{22} J

Recent OHC Changes Verified with Argo

- **Recent Argo data may not be contaminated severe errors or biases.**

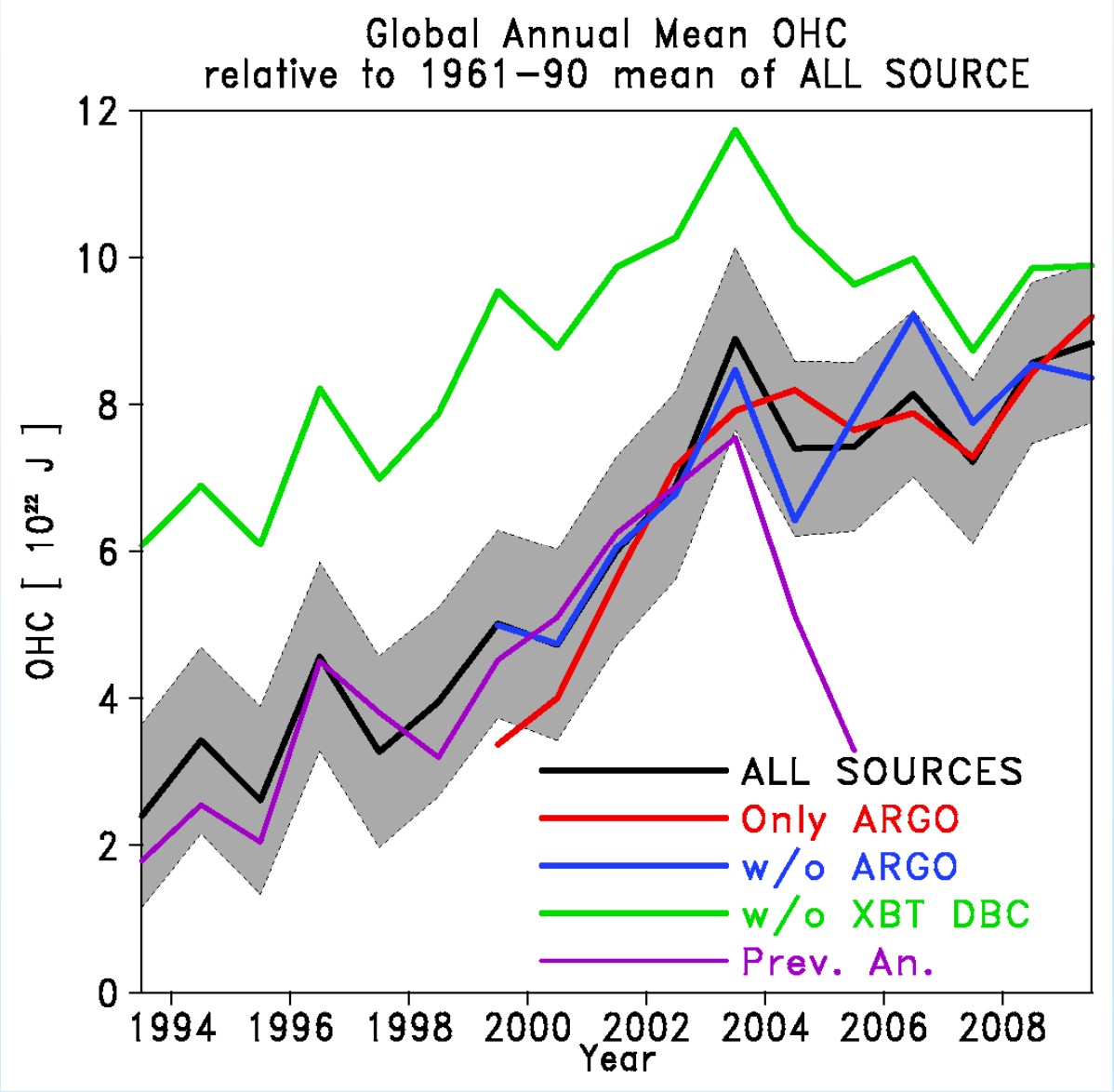
  w/ Argo vs. w/o Argo

- **XBT bias correction is very necessary for agreement with Argo data. Recall that Argo is not used in constructing XBT bias formula.**

  w/ DBC vs. w/o DBC vs. only Argo

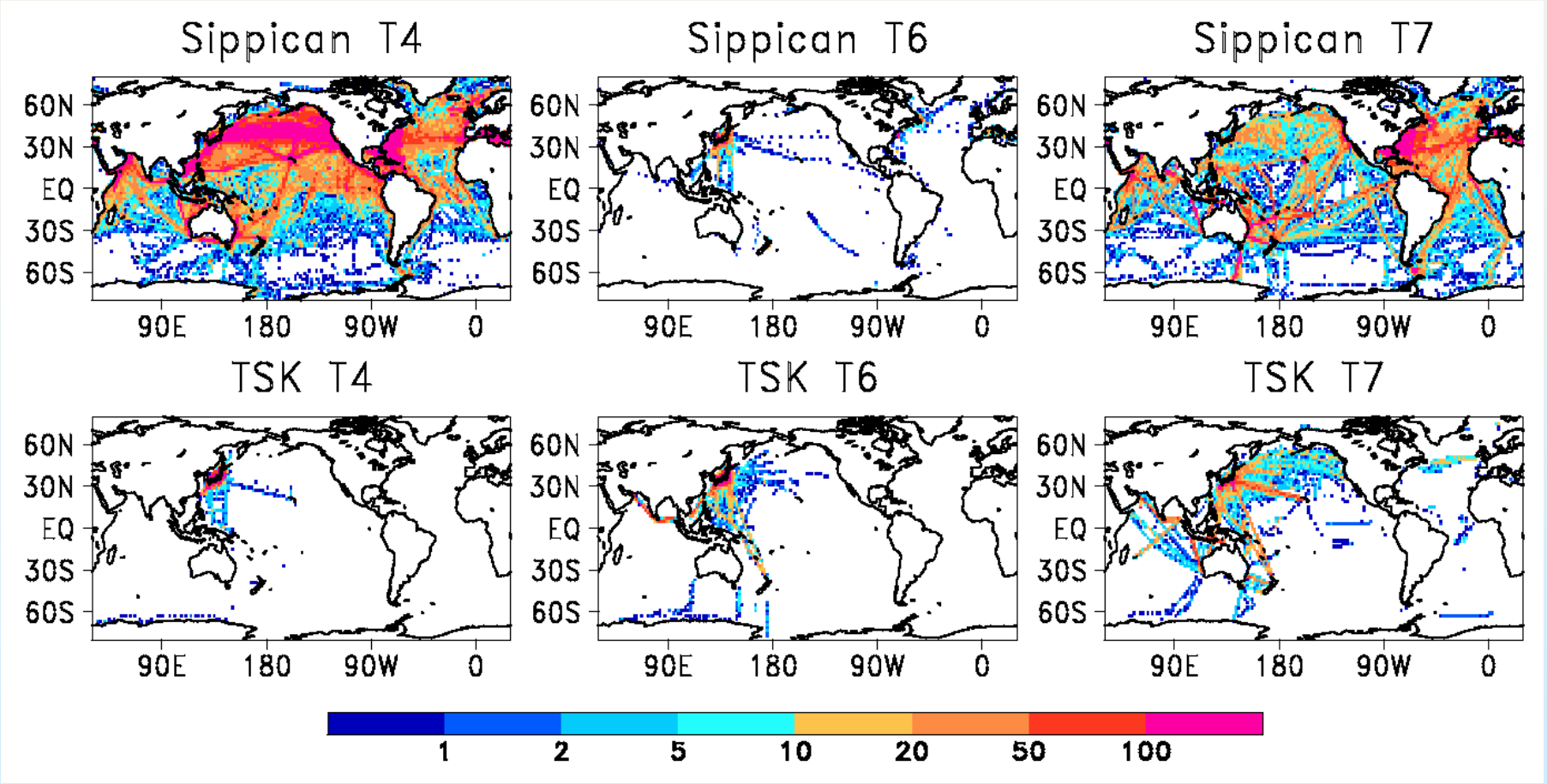
- **XBT biases partly contributed artificial ocean cooling after 2003 (Ishii and Kimoto 2009).**

  w/o DBC vs prev. an.



Discussion on the XBT meta data

XBT data distribution



Unit: number of XBT obs. for 1966-2009 in 2 deg. x 2 deg. boxes.

Data of minor XBT type are localized and XBT biases depend on type and manufacturer

➔ The correction equations for individual types are needed.

Meta data (type, manufacturer) are known for half of XBT data

➔ Add more. Need to update?

XBT meta data --- Japanese case ---

- Which XBT type and manufacturer can be attributed to each observation?

  ➔ all known probably, and those of JMSDF as well.

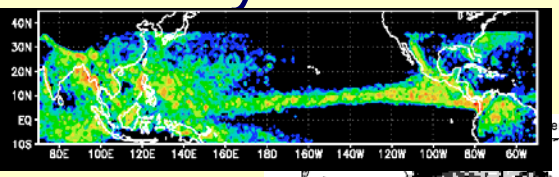
- What lot number of XBT can be attributed to each observation?

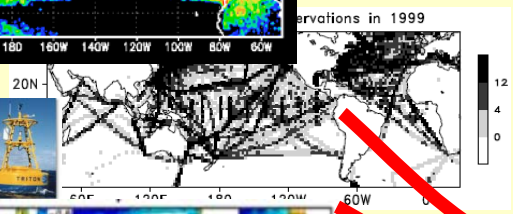
  ➔ known only for observations made after the mid 1990s at major agencies/institutes.

How important the correction is in near-term climate predictions.

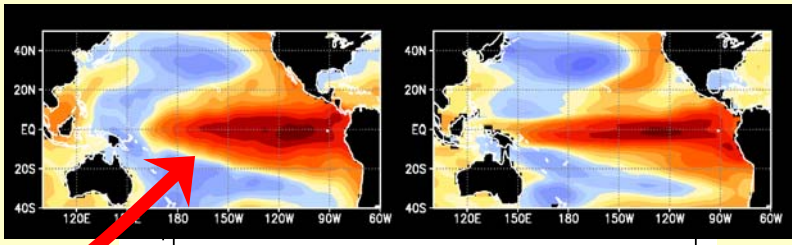
SPAM

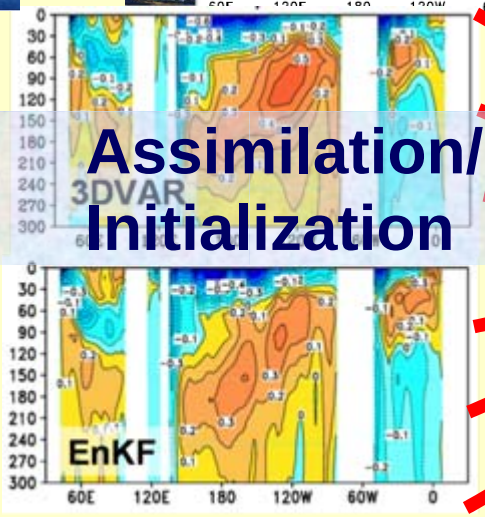
System for Prediction and Assimilation by MIROC





Data

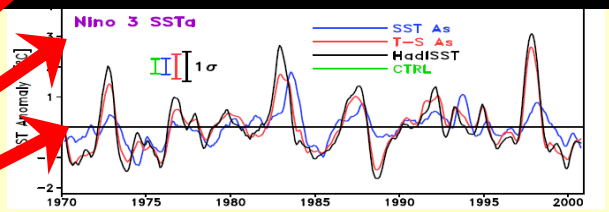




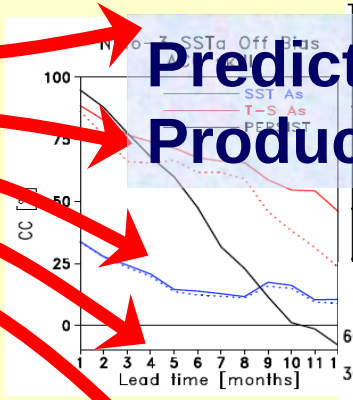
Assimilation/ Initialization

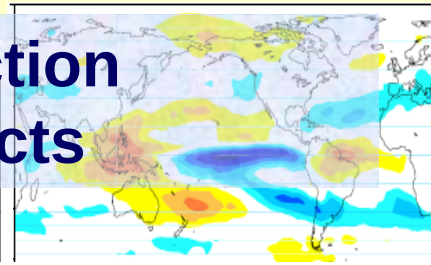
Data Assimilation

AOGCM MIROC

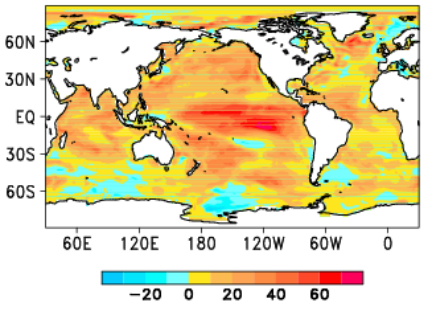


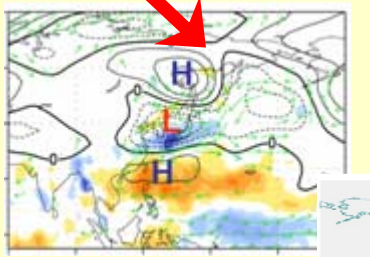
Prediction Products

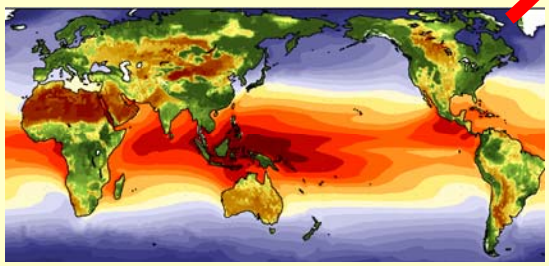




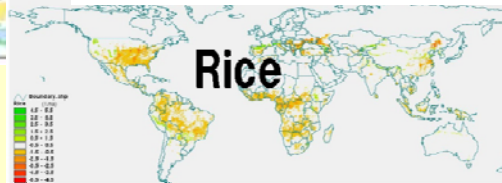
T–S As 6–mo lead







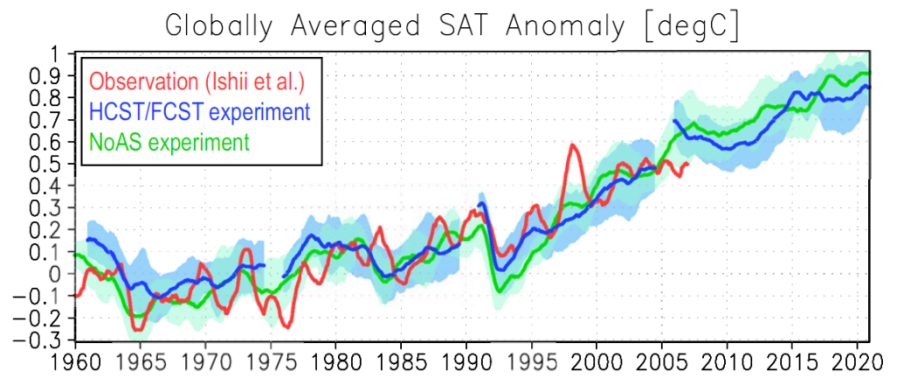
Coupled climate model MIROC



Decadal Predictability? – case of PDO

Mochizuki et al. (2010, PNAS)

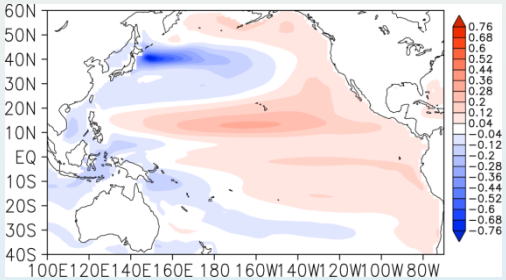
Global SAT



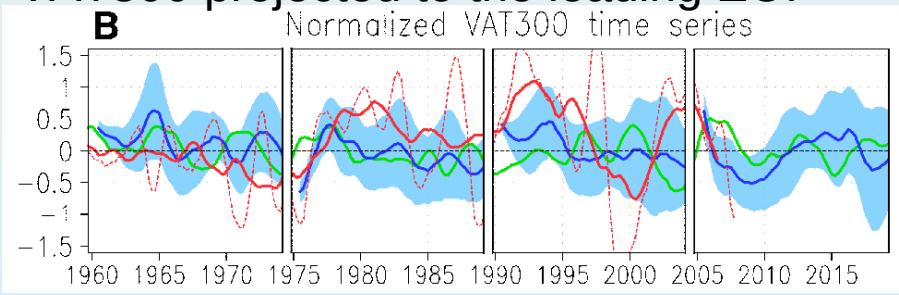
– 10-ens. prediction

– 14.5y-lead predictions from 7 initial dates every 5 years from 1960 to 2000.

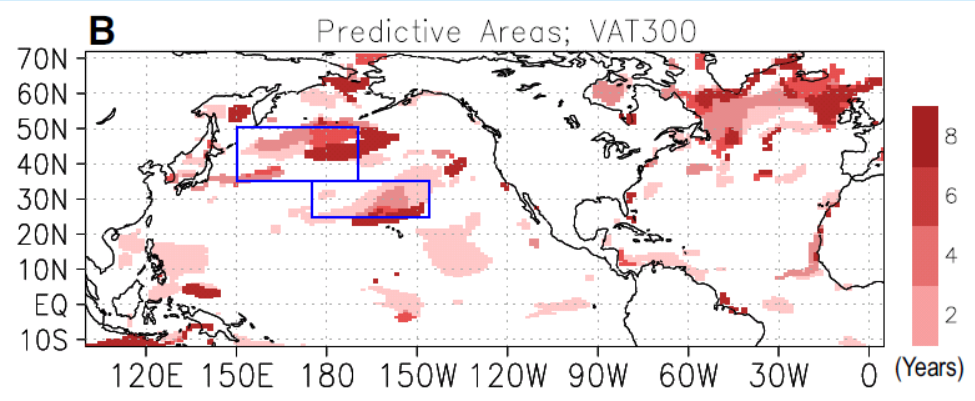
– 25.5y-lead prediction from 2005

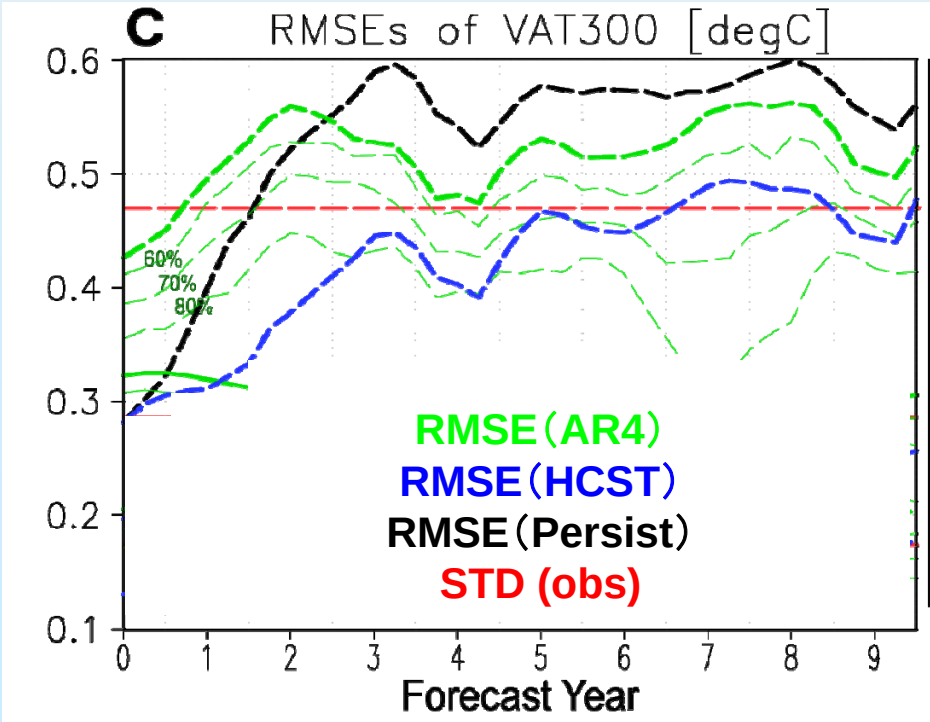


VAT300 projected to the leading EOF



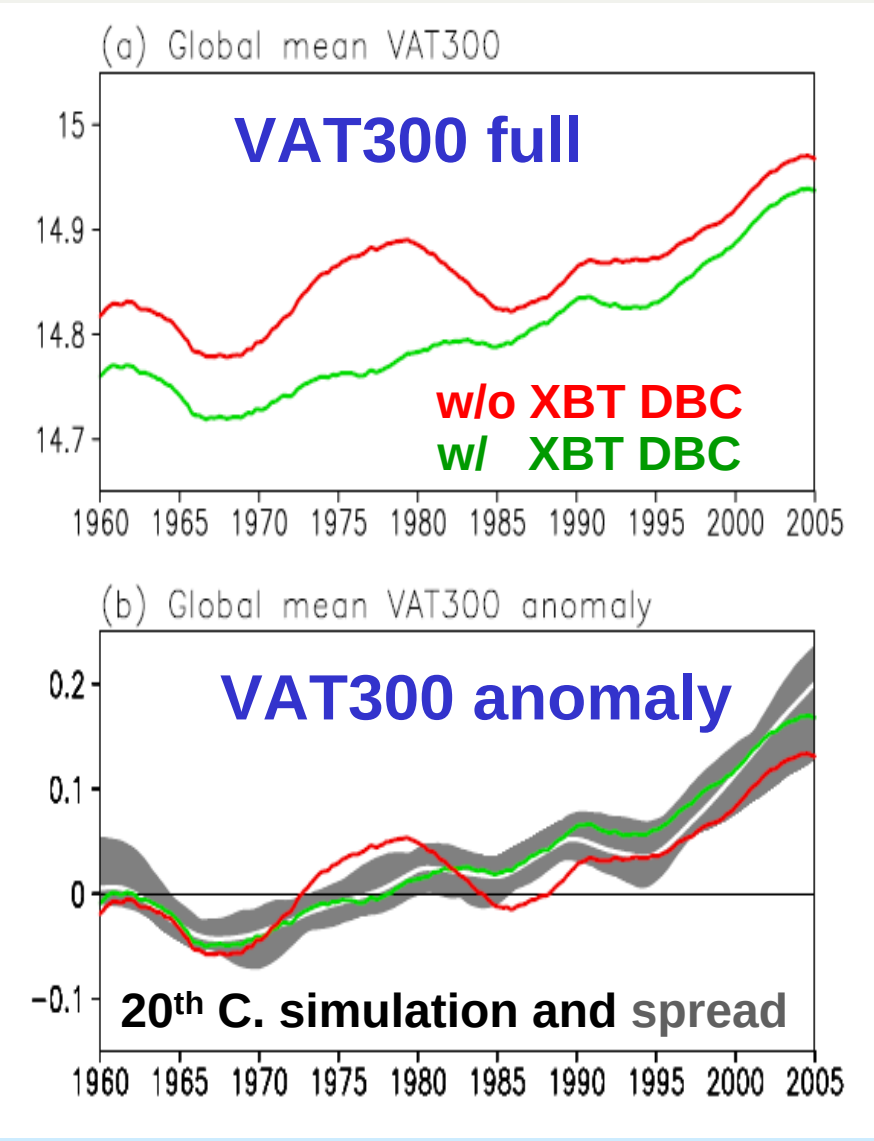
VAT300 (5-yr mean) predictability (in years)



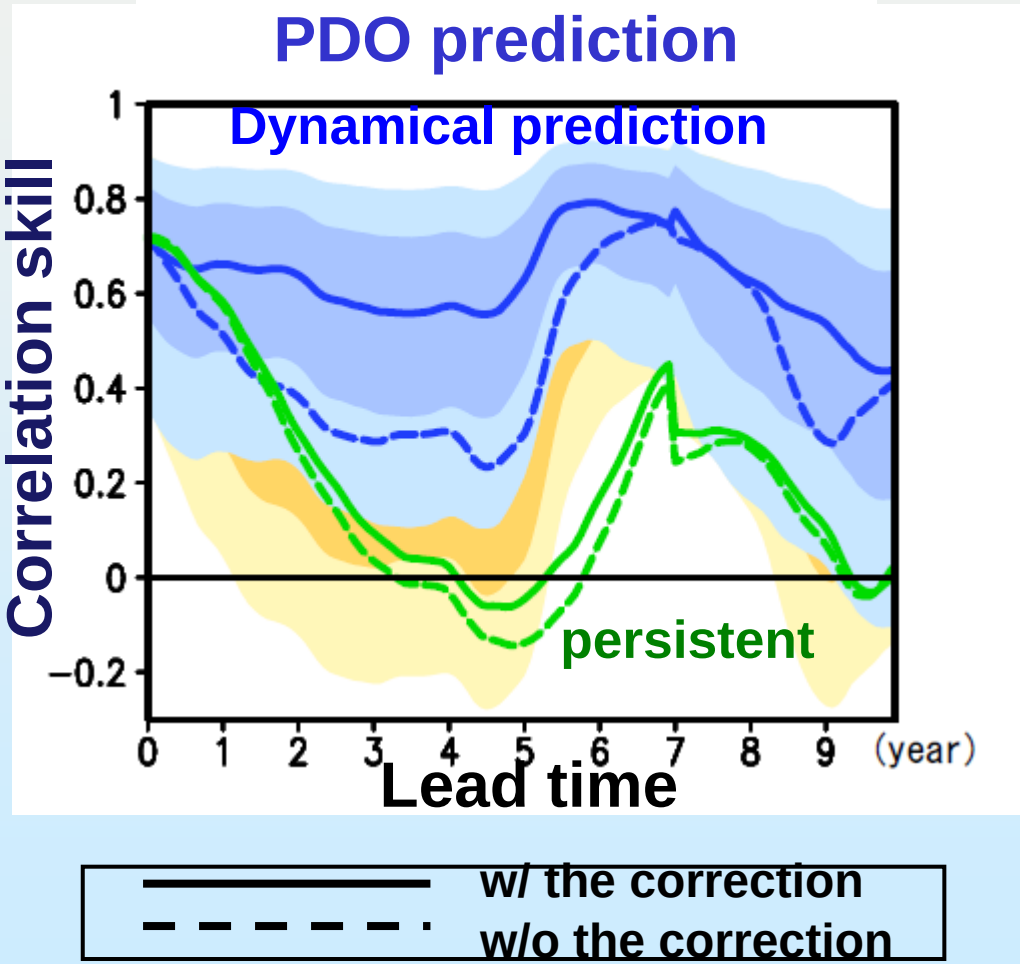


Impacts of XBT DBC on Decadal Prediction

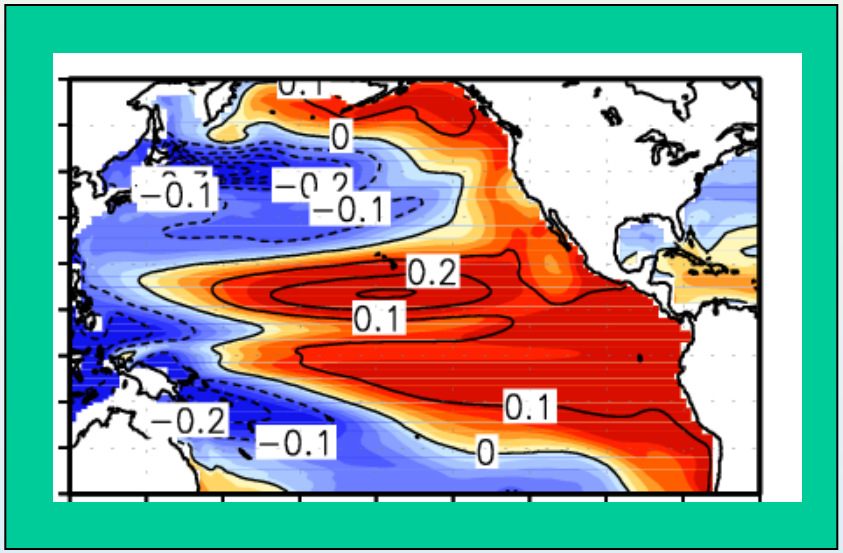
Yasunaka et al. (2010, submitted)



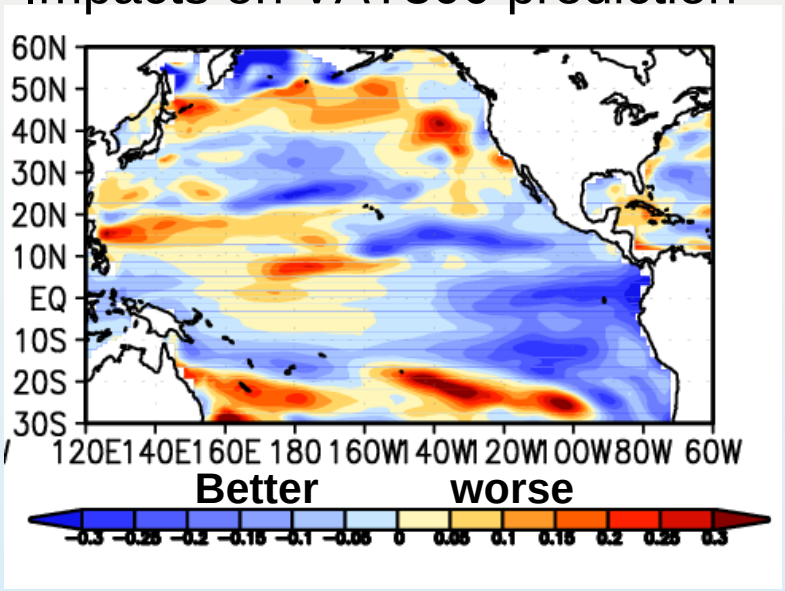
– 10-ens. predictions from 10 initial dates every 5 years from 1961 to 2006.
– 10y-lead predictions



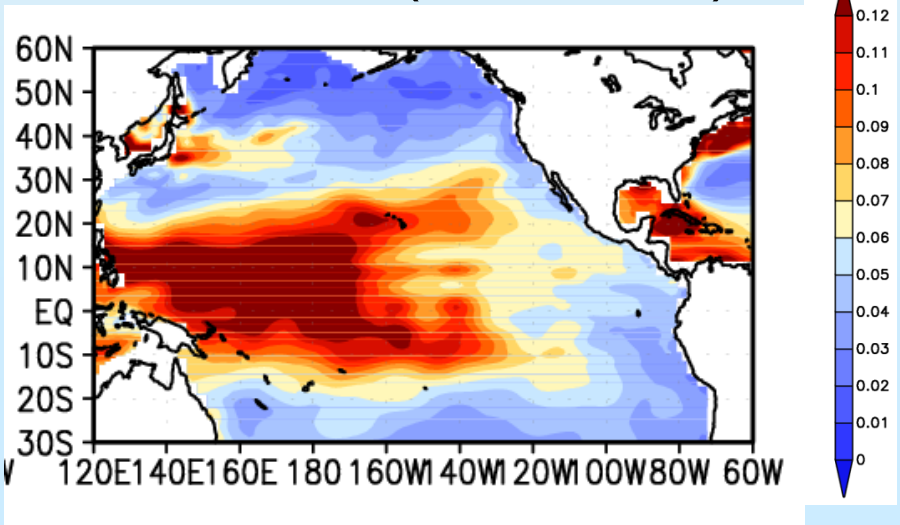
Impacts of XBT DBC on Decadal Prediction (2)



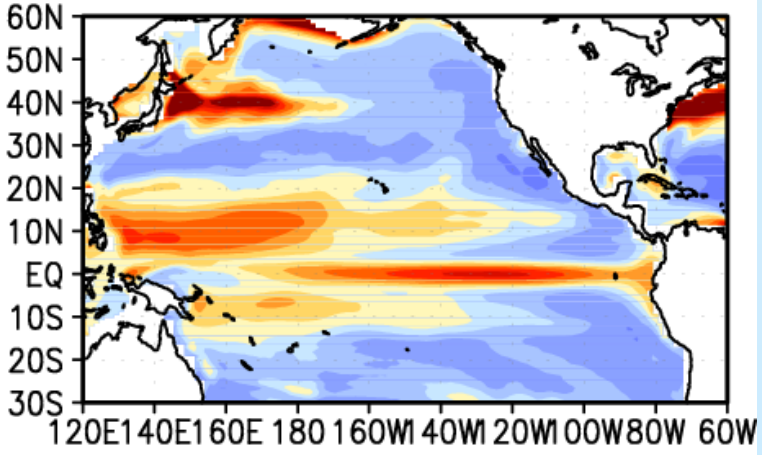
Impacts on VAT300 prediction



VAT300 RMSD (off mean diff)



VAT300 RMSD Assimilation



Summary

- We have introduced XBT and MBT depth bias corrections to the historical ocean temperature analysis, expecting that the positive temperature biases are caused by biases in depths given by XBT drop rate equations.
- Owing to the corrections, there appear cooling in global mean OHC since the late 1960s, and it is prominent in the 1970s. Recent ocean cooling became insignificant (partly thanks to discarding erroneous Argo data).
- The cooling due to the correction is significant on a climatological time scale in low latitudes, where the major thermocline locates at great depths. The temperature climatology used in the temperature analysis should be replaced by a new one with the XBT and MBT depth bias corrections.
- For the near term climate prediction with a coupled model, the ocean initialization is relatively important. According to an model experiment, the model initialized with bias-corrected XBT data produced better PDO predictions than that with uncorrected data.
- XBT biases should be defined individually for XBT types and manufacturers.
- Meta data related to XBT observations should be collected under an international collaboration.