Uncertainty in the estimation of global and regional ocean heat content since 1970

Abhishek Savita[1,2,3,4]

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[2] Commonwealth Scientific and Industrial Research Origination (CSIRO)
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[4] Antarctic Climate and Ecosystems CRC, University of Tasmania

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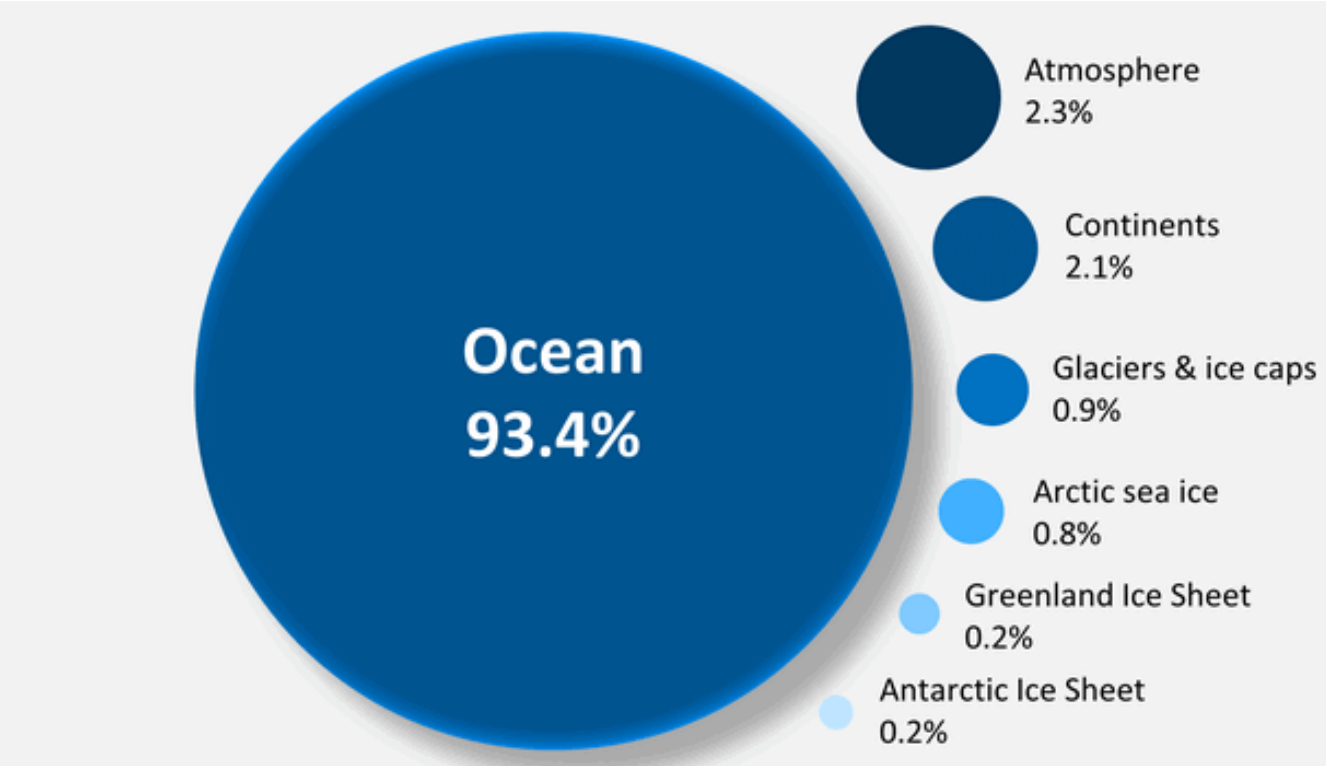
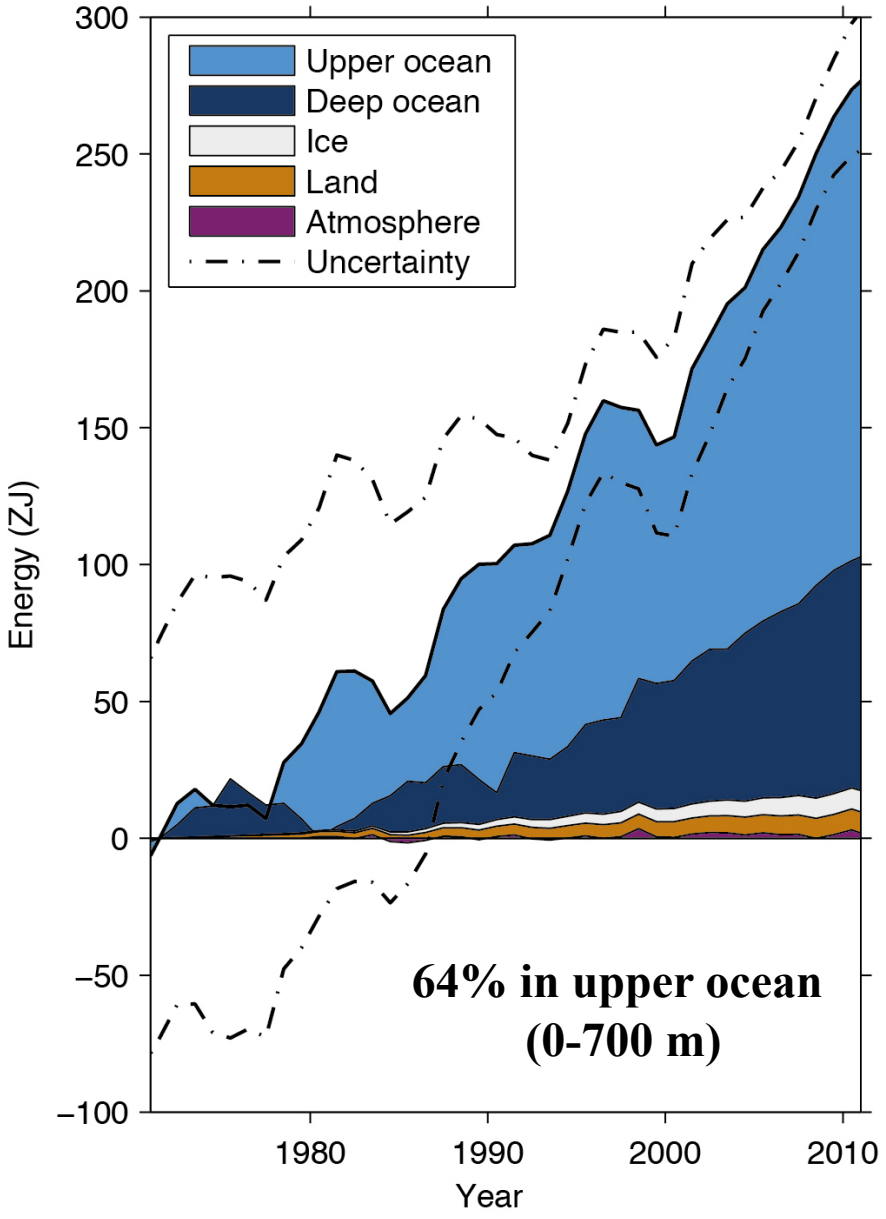
Why do we care about ocean warming?

Where is the human-induced heat stored in the Earth system?



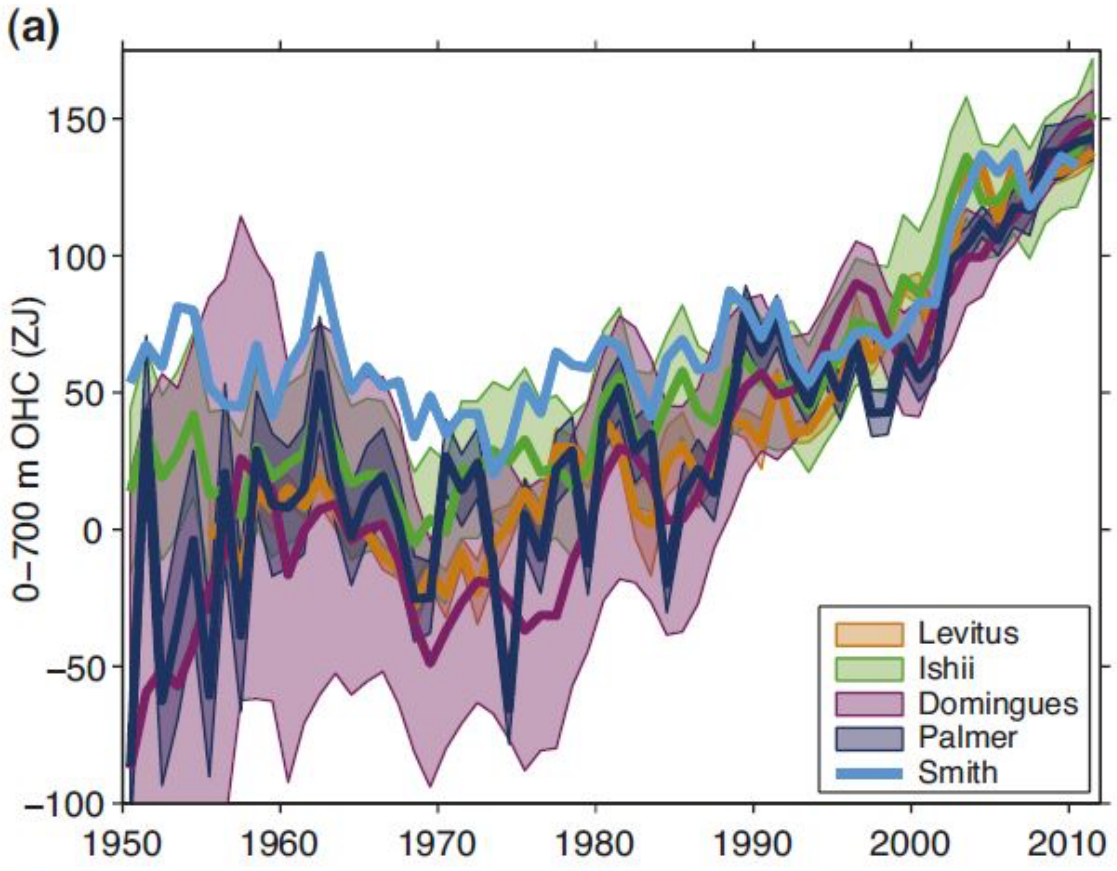
Bindoff et al. (2007 IPCC AR4)



Rhein et al. (2013, IPCC AR5)

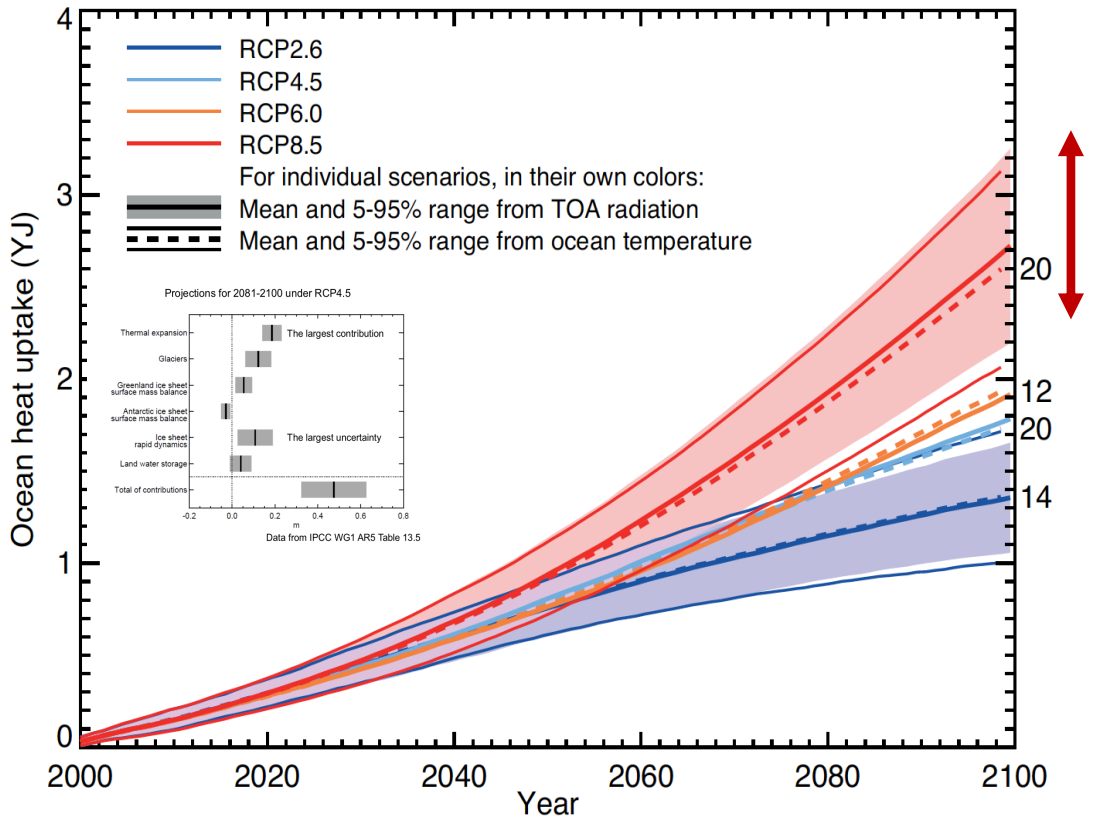
Uncertainty in the estimation of ocean warming

Observations



1 ZJ = 10^{21} J

CMIP5 models

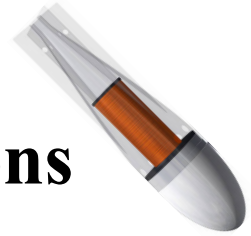


1 YJ = 10^{24} J

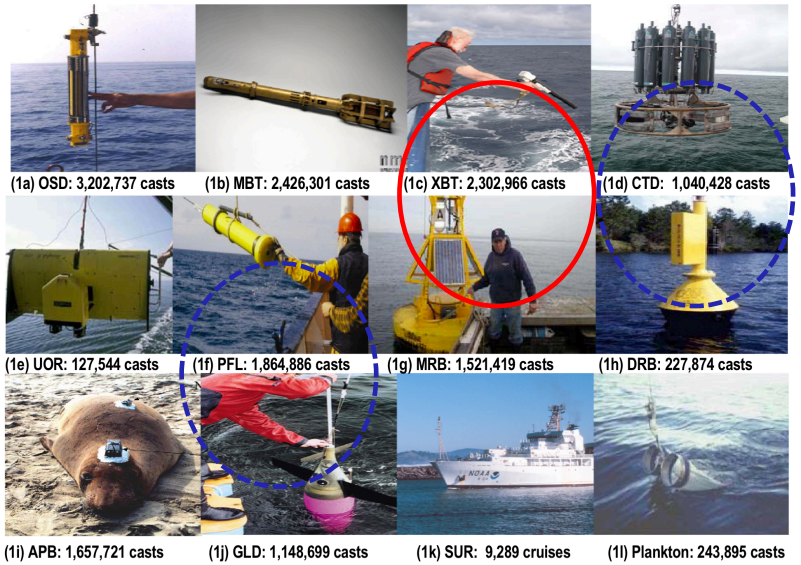
Church et al. (2013, IPCC AR5)

Major sources of uncertainty

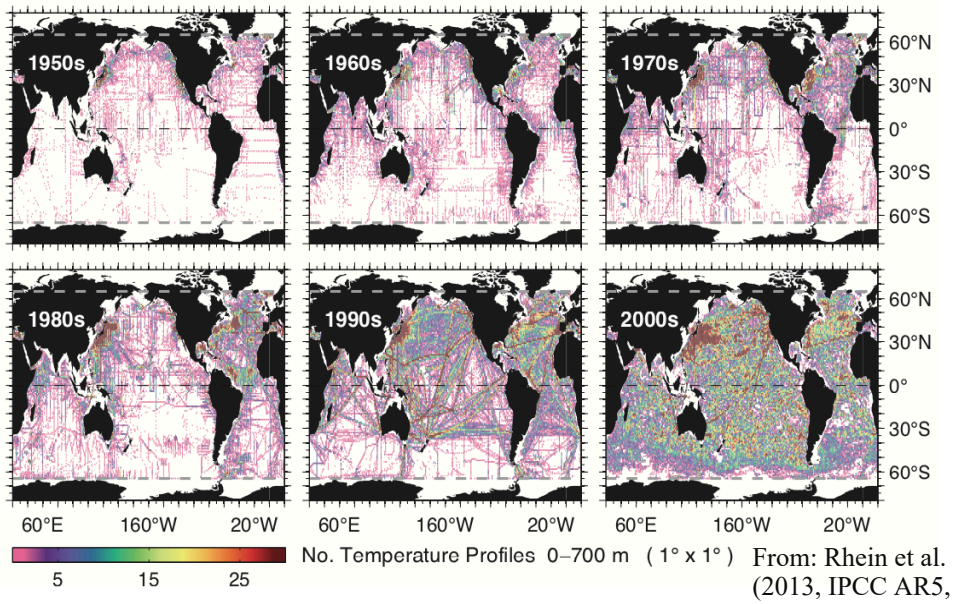
- ❑ Instrumental (XBT) bias corrections
- ❑ Mapping Methods
- ❑ Ocean mask definitions
- ❑ Quality/no. obs in global datasets
- ❑ Baseline climatologies



XBT= Expendable BathyThermograph

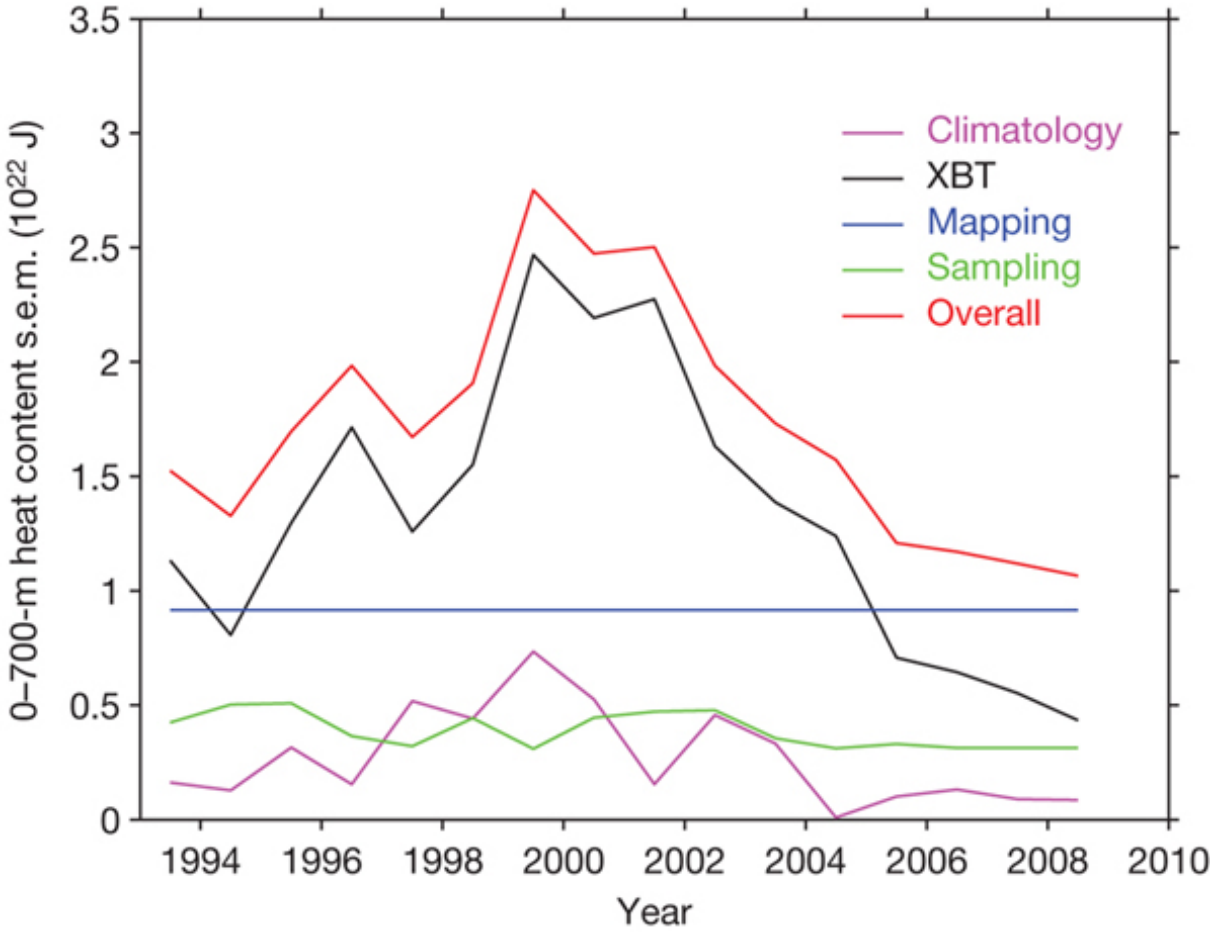


Courtesy: Tim Boyer



From: Rhein et al. (2013, IPCC AR5, suppl. material)

Previous findings

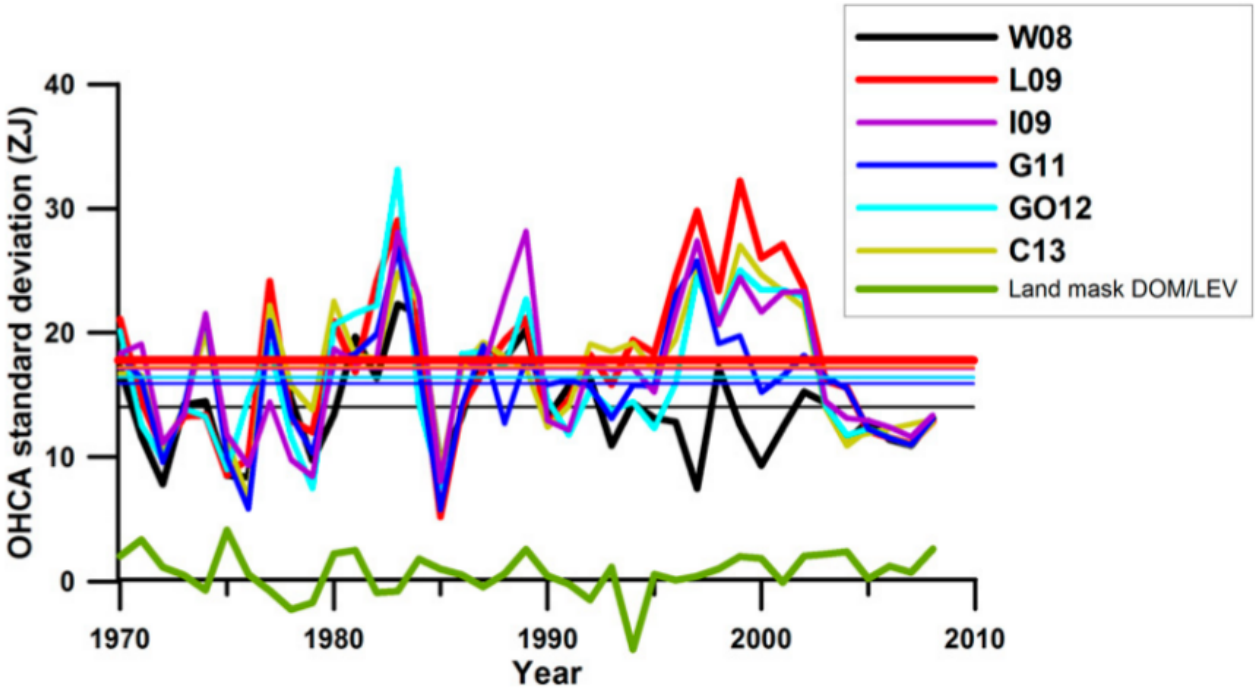


Lyman et al. (2010): Largest uncertainty due to choices for XBT bias correction

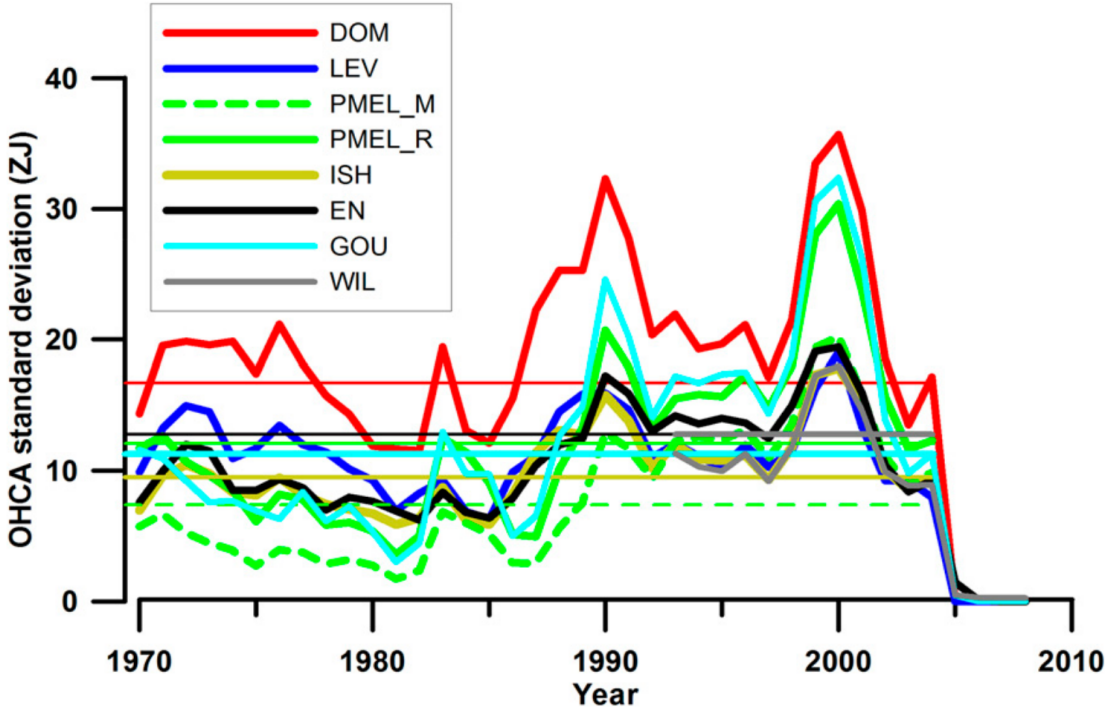
Limitations: not assessed with other mapping methods and only since 1993 (sparser obs. prior to 1993)

Previous findings*

Spread due to **mapping method**



Spread due to **XBT correction**



Boyer et al. (2016): On average, mapping method largest (17 ZJ) source of uncertainty and second largest is XBT (12 ZJ), since 1970 or 1993

* Based on an internationally-coordinated protocol (I will be using the same datasets from this protocol)

Gaps

- **Lyman et al. (2010) and Boyer et al. (2016) investigated uncertainty in OHCA estimates only at global scale. No basin to regional information.**

- **Boyer et al. (2016) did not fully consider uncertainty introduced by differences in ocean domain (land-ocean mask definition) to OHC estimates.**

Coordinated approach

ENACT3 v2a Bo, CTD, XBT data (1970-2004) + Argo data (2000-2008)

↓

6 XBT bias corrections | dataset versions
(W08, I09, L09, GD11,GK12 and CW13)

↓

1 baseline climatology to reference anomalies

↓

6 mapping methods | dataset versions
(DOM, LEV, I09, PMEL_M, EN, WIL)

↓

Yearly-average anomalies + same grid resolution (1^o x 1^o) + ocean mask (65N-65S)

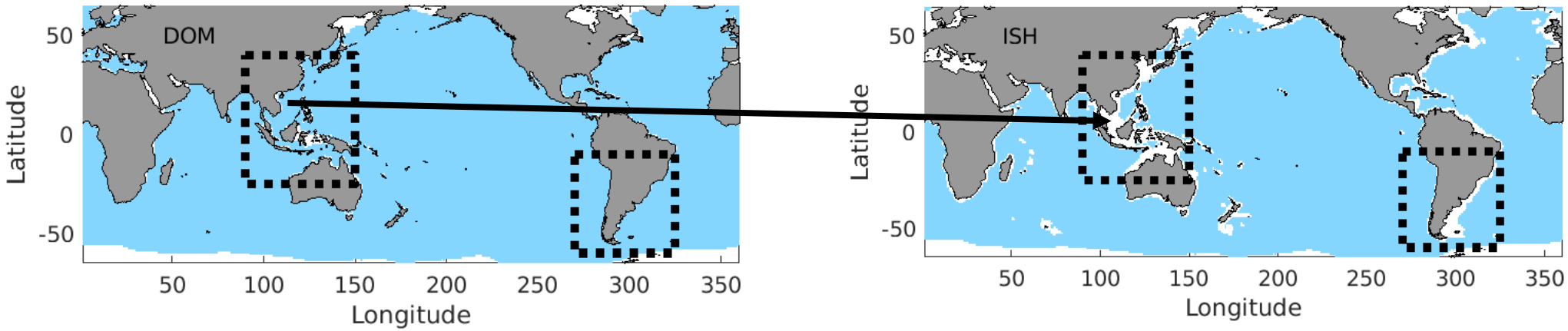
0-700 m =

0-300 m
+
300-700 m

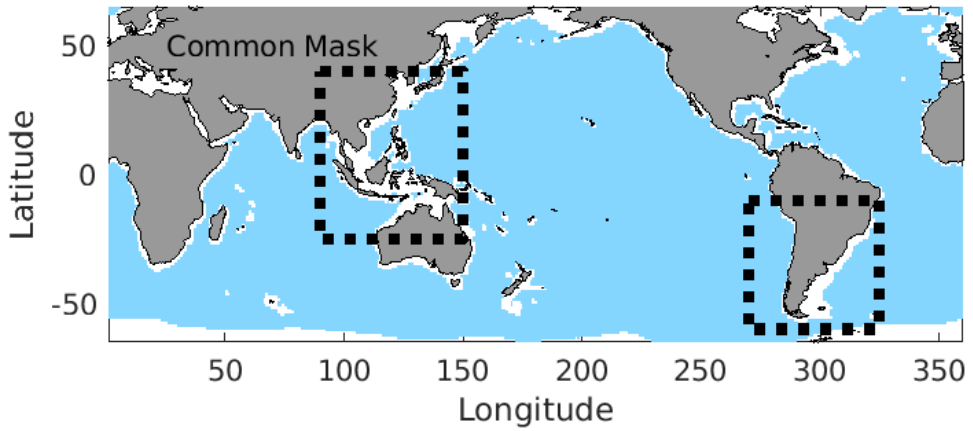
Ocean masks

- **Australia: ACECRC-CSIRO-IMAS/UTAS (DOM)**
- **Germany: Univ. Hamburg – Viktor Gouretski (GOU)**
- **Japan: MRI – Masayoshi Ishii (ISH)**
- **UK: Met Office - Simon Good (EN)**
- **US: NCEI/NOAA – Tim Boyer (LEV)**
- **US: JPL/PMEL/NOAA – John Lyman, Greg Johnson, Josh Willis (PMEL_M, PMEL_R, WIL)**

Original masks



Common mask



- Australia: ACECRC-CSIRO-IMAS/UTAS **(DOM)**
- Germany: Univ. Hamburg – Viktor Gouretski **(GOU)**
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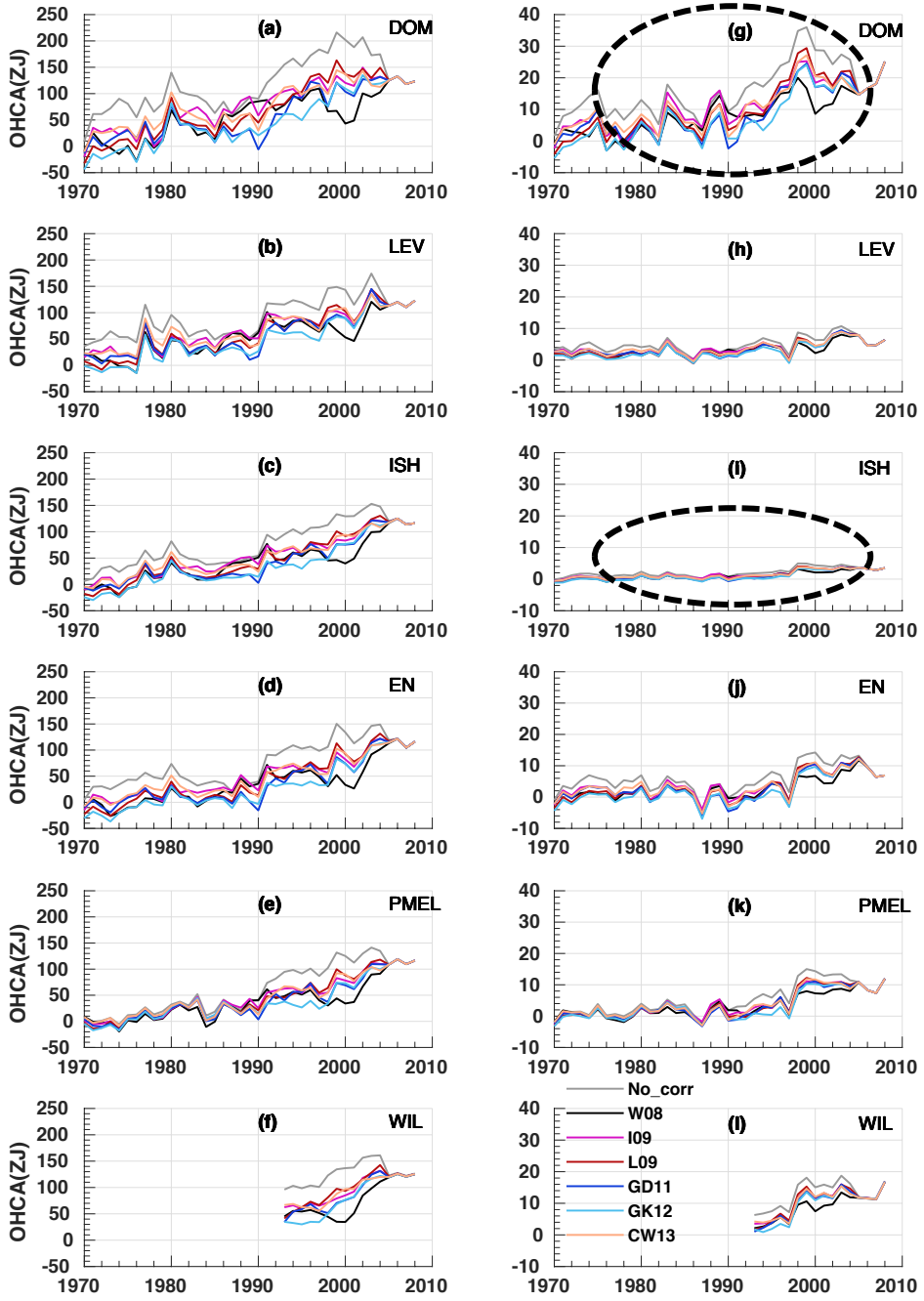
Savita et al., in Prep.



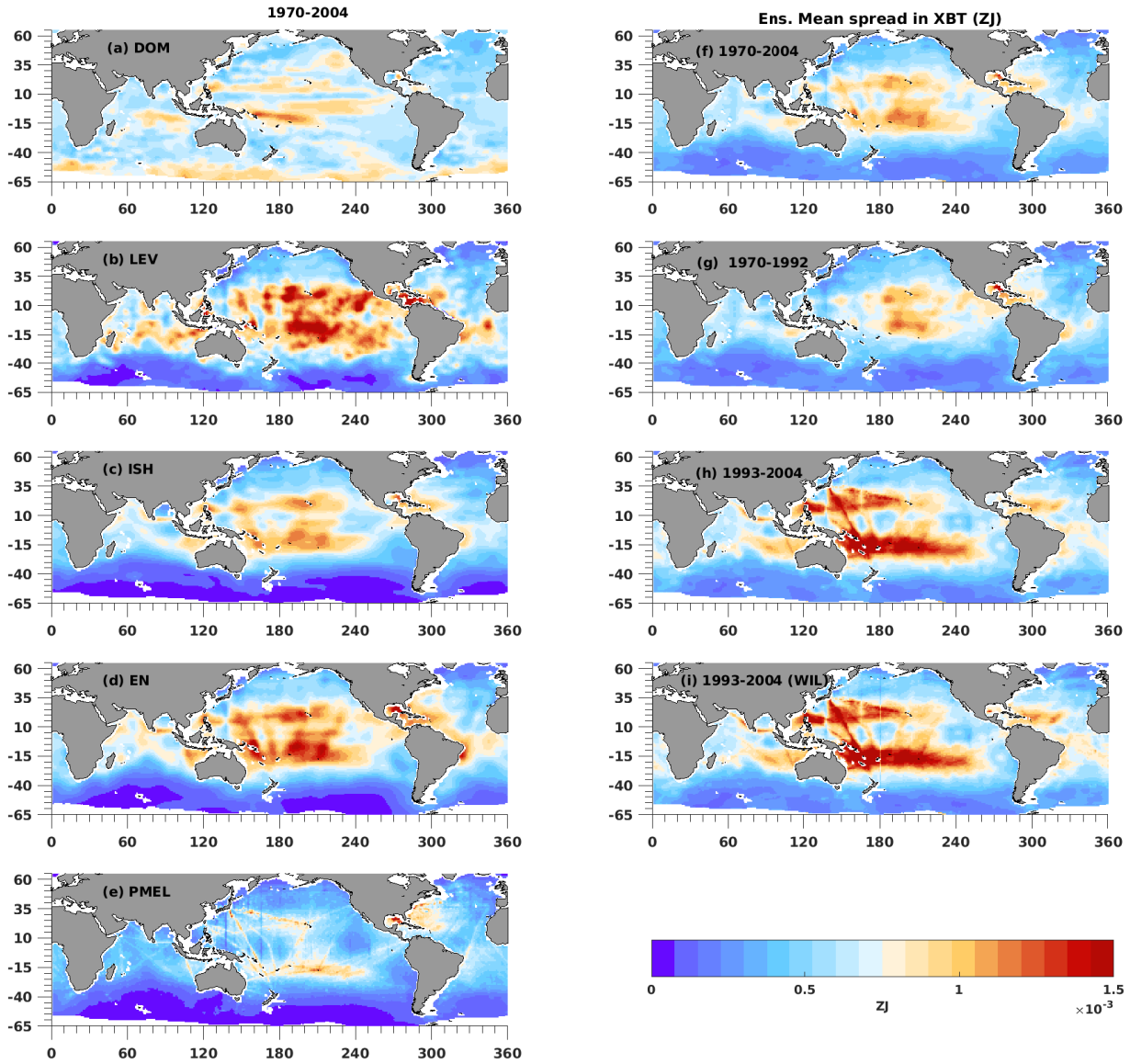
Global OHCA time series per mapping method for each XBT correction (color)

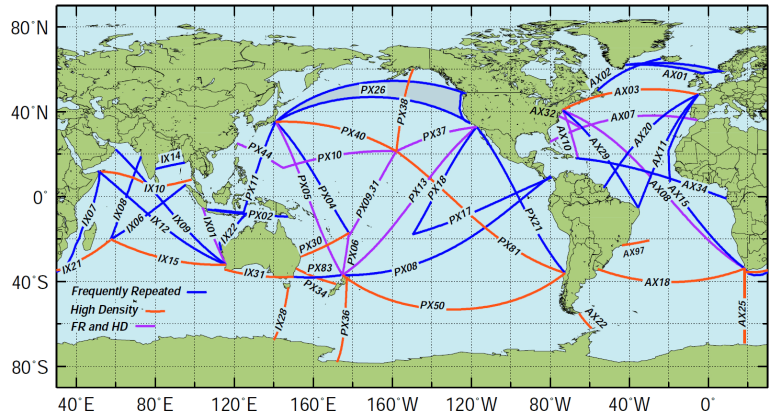
Difference = Individual Mask minus Common Mask

- DOM has the largest mask difference
- ISH has the smallest mask difference
- (~2-13% total OHC change)
- Differences vary with time and also depend on XBT correction.

XBT bias corrections

Regional spread due to XBT bias correction





- Largest XBT spread in the Pacific ocean, confined 30N-30S.
- Spread largest during 1993-2004 than 1970-1992

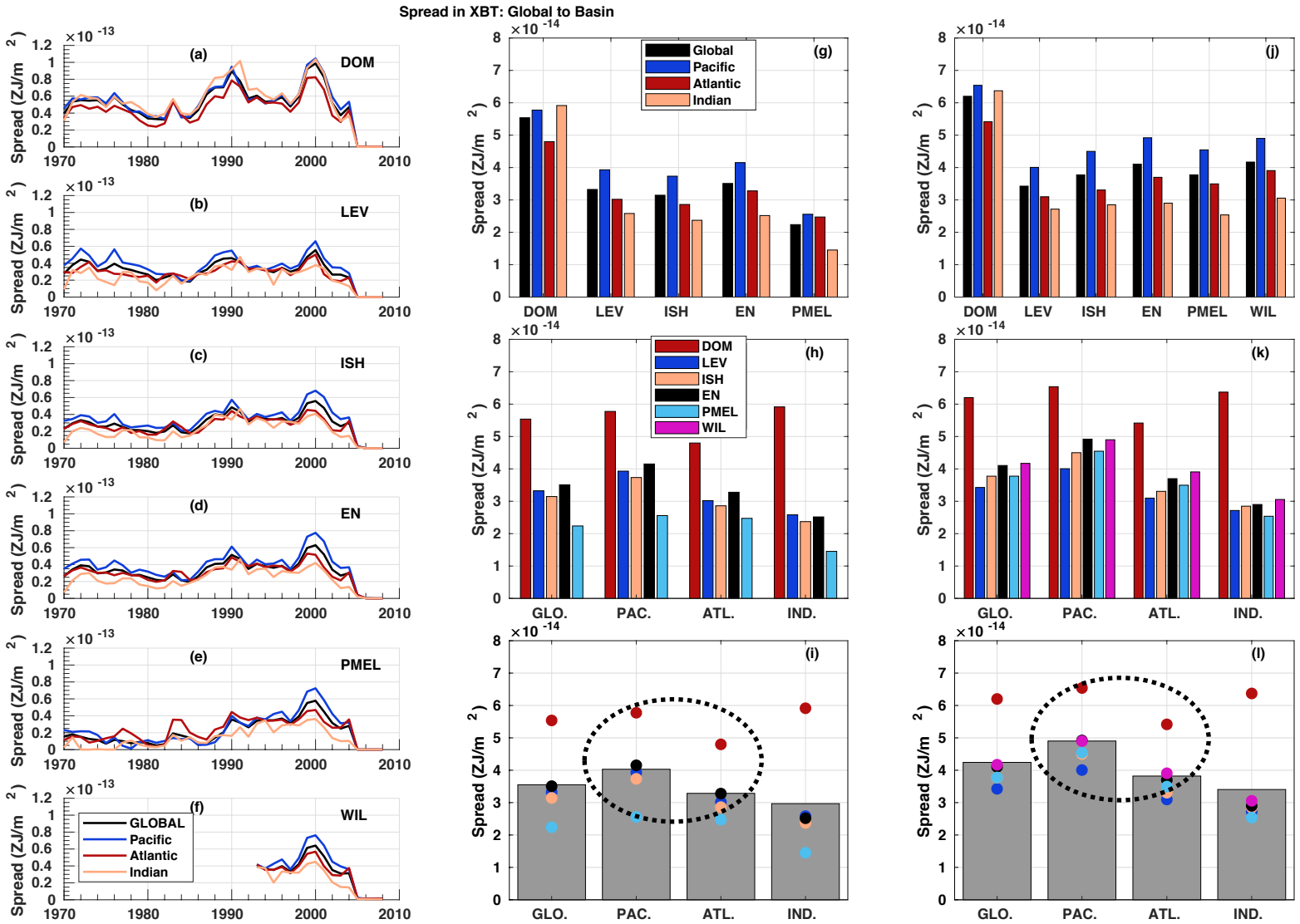
Why? (speculations)

- More differences in XBT bias corrections
- Larger no. deep xbt profiles (depth integration)
- More stratified water column in 1993-2004

There are visible differences for individual mappings: left column

Savita et al., in Prep.

Global/ Basin spread due to XBT bias correction by mapping

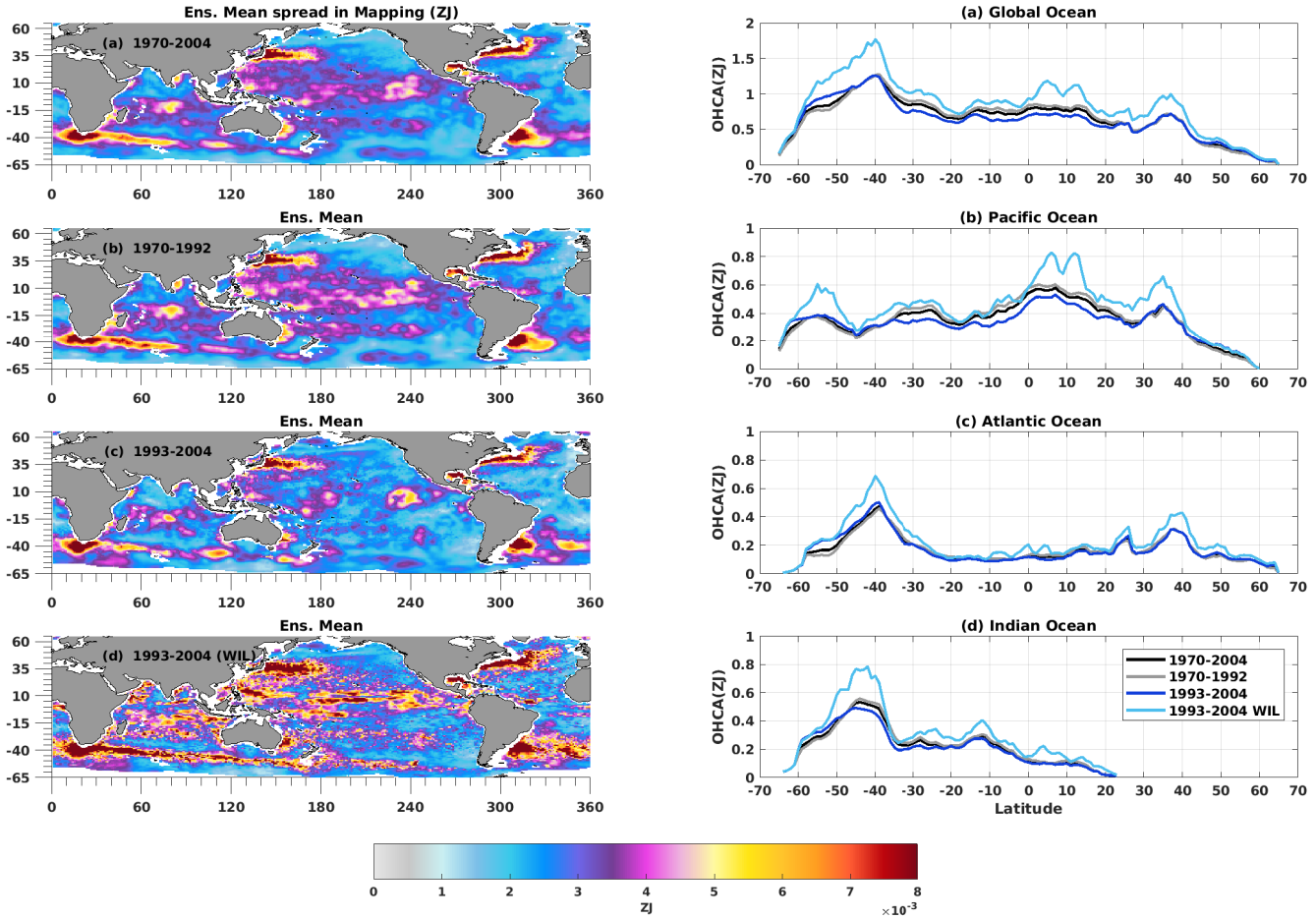


- DOM mapping has largest and PMEL has lowest XBT spread for each basin
- Overall XBT spread is largest in the pacific per m^2 followed by Atlantic Ocean
- XBT spread is larger during 1993-2004 than 1970-2004 for each mapping and each basin

Savita et al., in Prep.

Mapping methods

Regional spread due to mapping method



- **Largest spread in eddy energetic/frontal regions**

  Why? Aliasing eddy-variability in different ways depending on mapping method? Where no data?

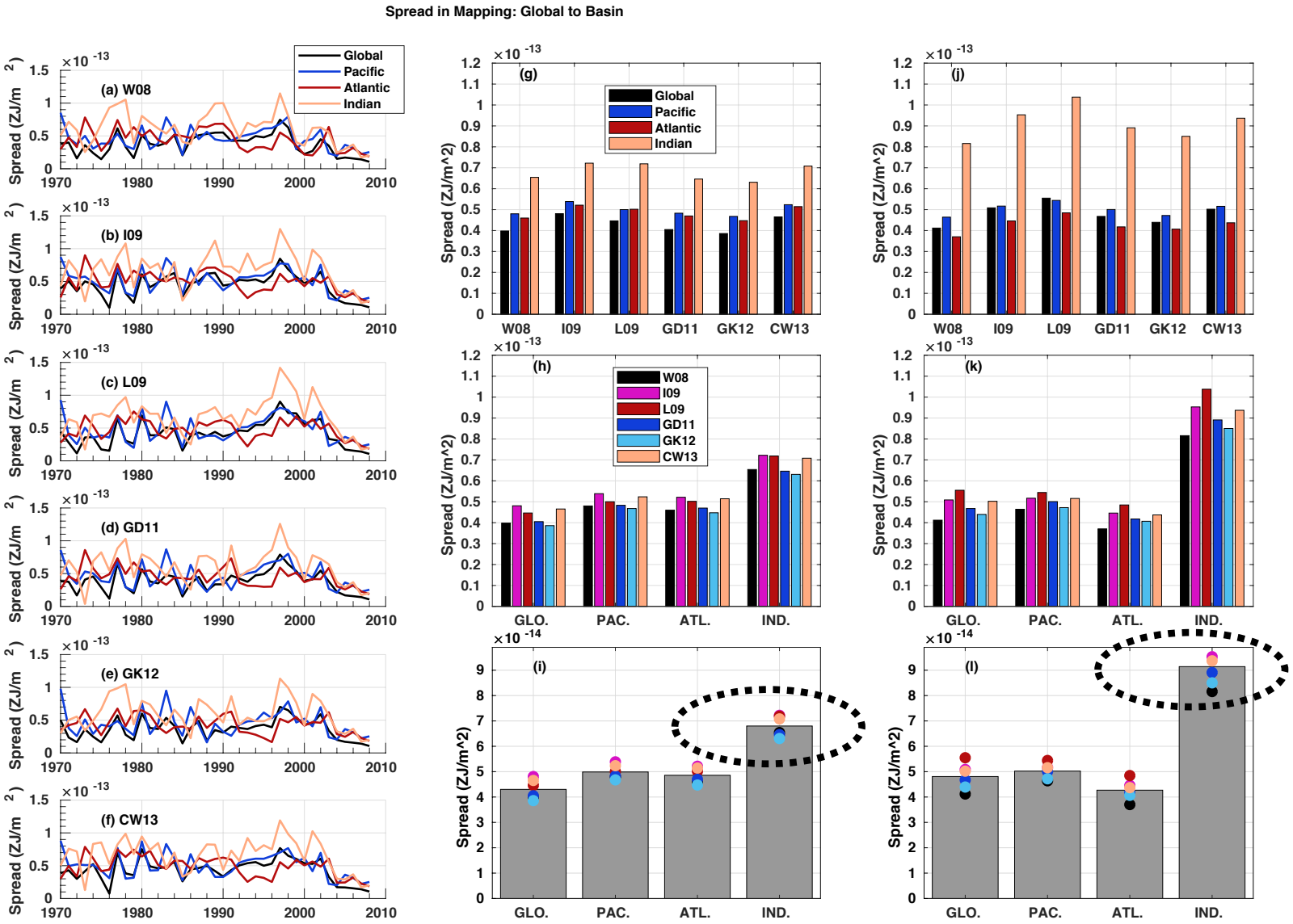
- **Spread enhanced when including WIL mapping (1993-2004)**

- Why? WIL map is the richest in eddy features?

No visible differences in regional patterns for individual XBT bias corrections.

Savita et al., in Prep.

Global/Basin mapping due to XBT bias correction by XBT



- Mapping spread reduced since 2004 for each XBT correction
- Overall mapping spread is largest per m^2 in the Indian followed by Pacific Ocean
- mapping spread is larger during 1993-2004 than 1970-2004
- Mapping spread is independent of XBT correction used

SUMMARY - KEY MESSAGES

1970-2004

Domain	Common mask Impact	Largest Spread due to XBT Corrections	Largest Spread due to Mapping Methods
Global	Under/Over estimate **up to 2-13% global** OHC change over 1970-2004		
Ocean Basin		**Pacific Ocean per m^2 (ensemble mean)**	**Indian Ocean per m^2 (ensemble)**
Regional (Grid Point)		30°N-30°S (Pacific) 1970-2004 < 1993-2004	**Energetic ocean regions** (mesoscale eddy variability)

- XBT community? (larger impact/stratification)
- Mapping community? (higher "noise" variability)
- User community (inc. reanalyses)? Largest uncertainties in OHC estimates?

  Ocean Mask (shallow areas/global) + XBT (Pacific) + Mapping (Indian)

Thank you

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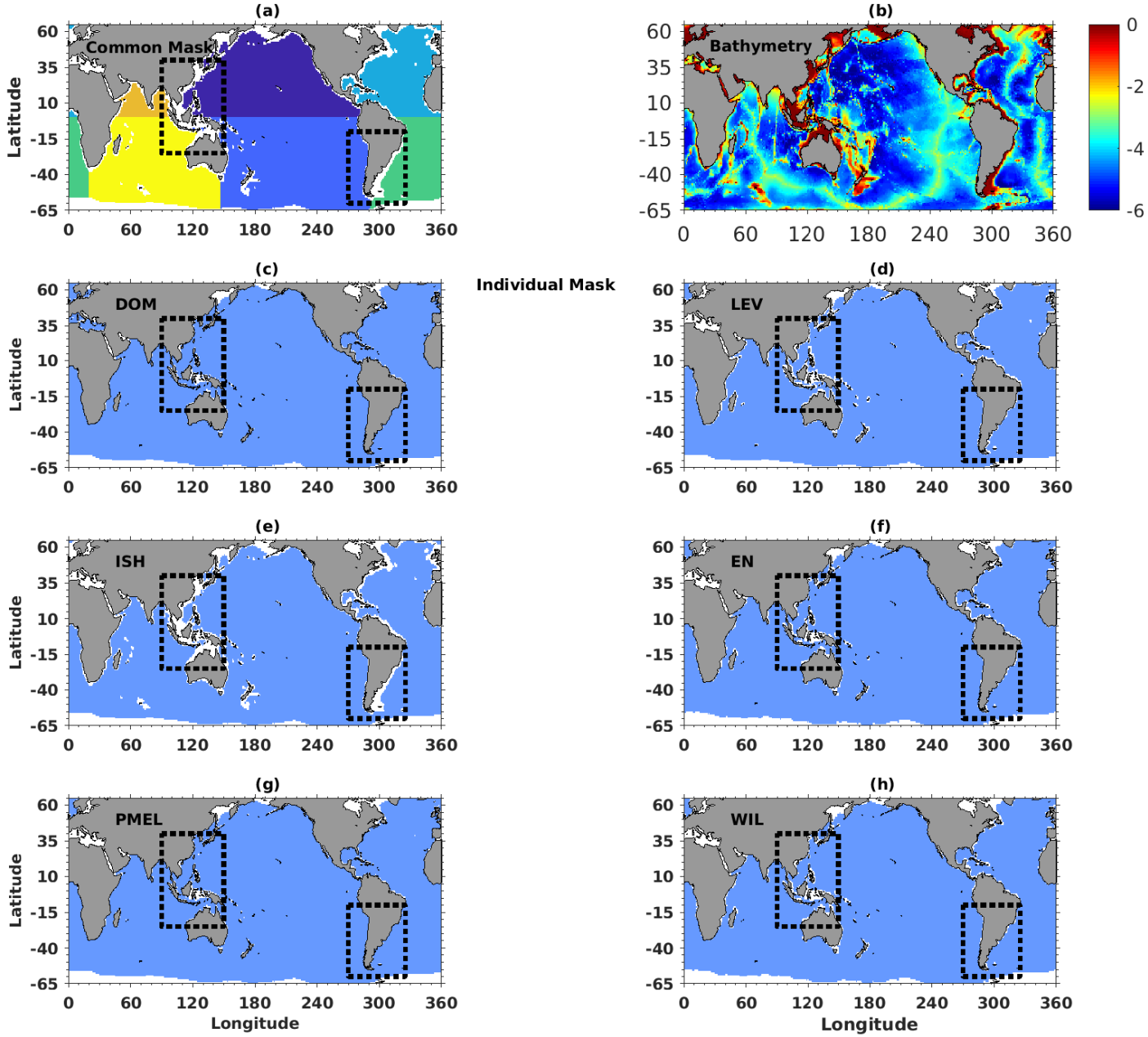
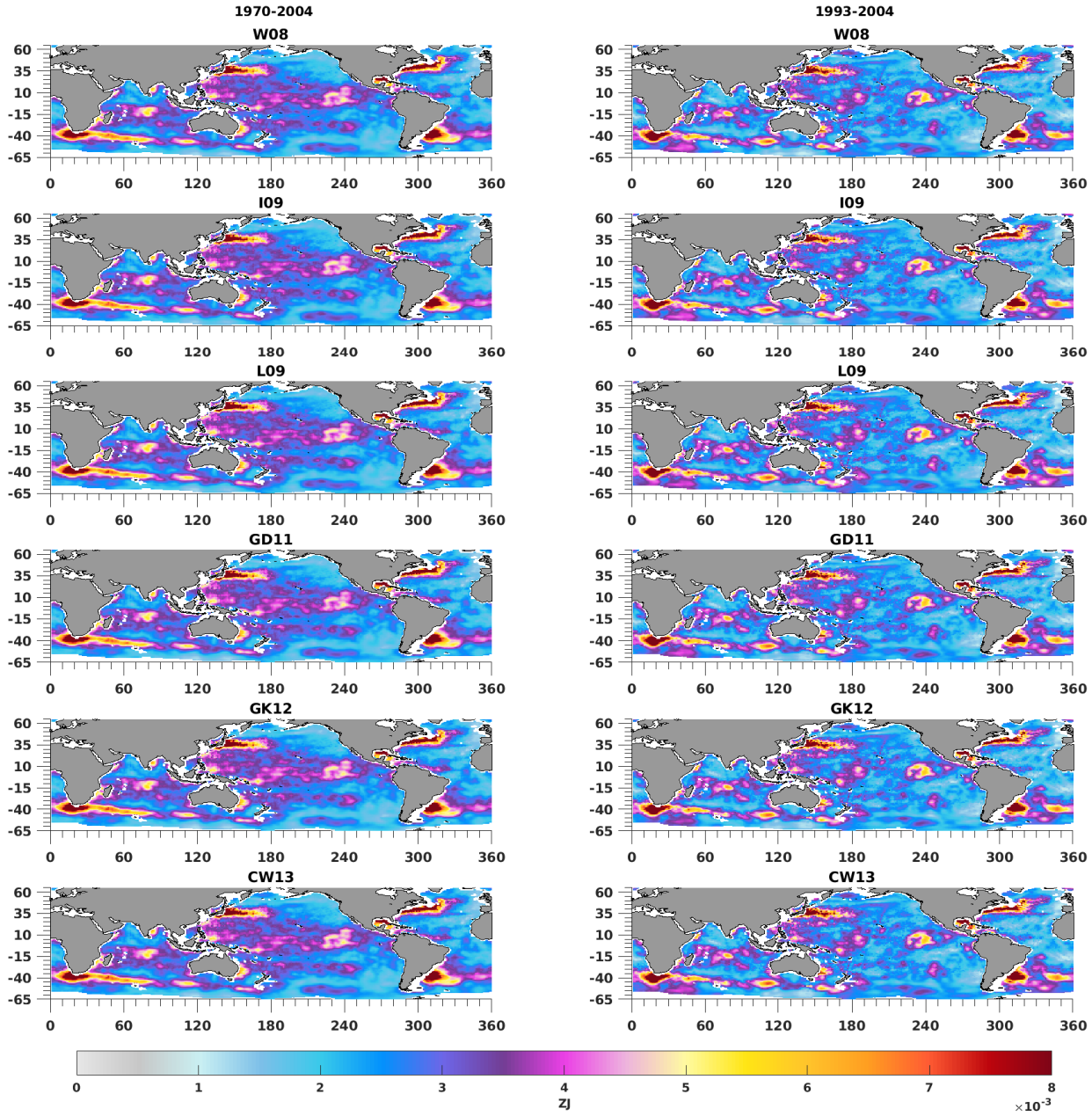
Additional figures


(a)
Common Mask
(b)
Bathymetry
0
-2
-4
-6
Individual Mask
(c)
DOM
(d)
LEV
(e)
ISH
(f)
EN
(g)
PMEL
(h)
WIL
Latitude
Longitude
60
35
10
-15
-40
-65
0
60
120
180
240
300
360


1970-2004
1993-2004
W08
I09
L09
GD11
GK12
CW13
60
35
10
-15
-40
-65
0
60
120
180
240
300
360
0
1
2
3
4
5
6
7
8
ZJ
×10-3