

Sensitivity of Global Upper Ocean Heat Content Estimates to Mapping Methods, XBT Bias Corrections, and Baseline Climatologies

T. Boyer¹, C. M. Domingues^{2,3,4}, S. Good⁵, G. C. Johnson⁶,
J. M. Lyman^{6,7}, M. Ishii⁸, V. Gouretski⁹, J. K. Willis¹⁰, J.
Antonov¹¹, S. Wijffels¹², J. A. Church¹³, R. Cowley¹², N.
Bindoff^{2,3,4,12}

XBT Science Workshop
October 5, 2016

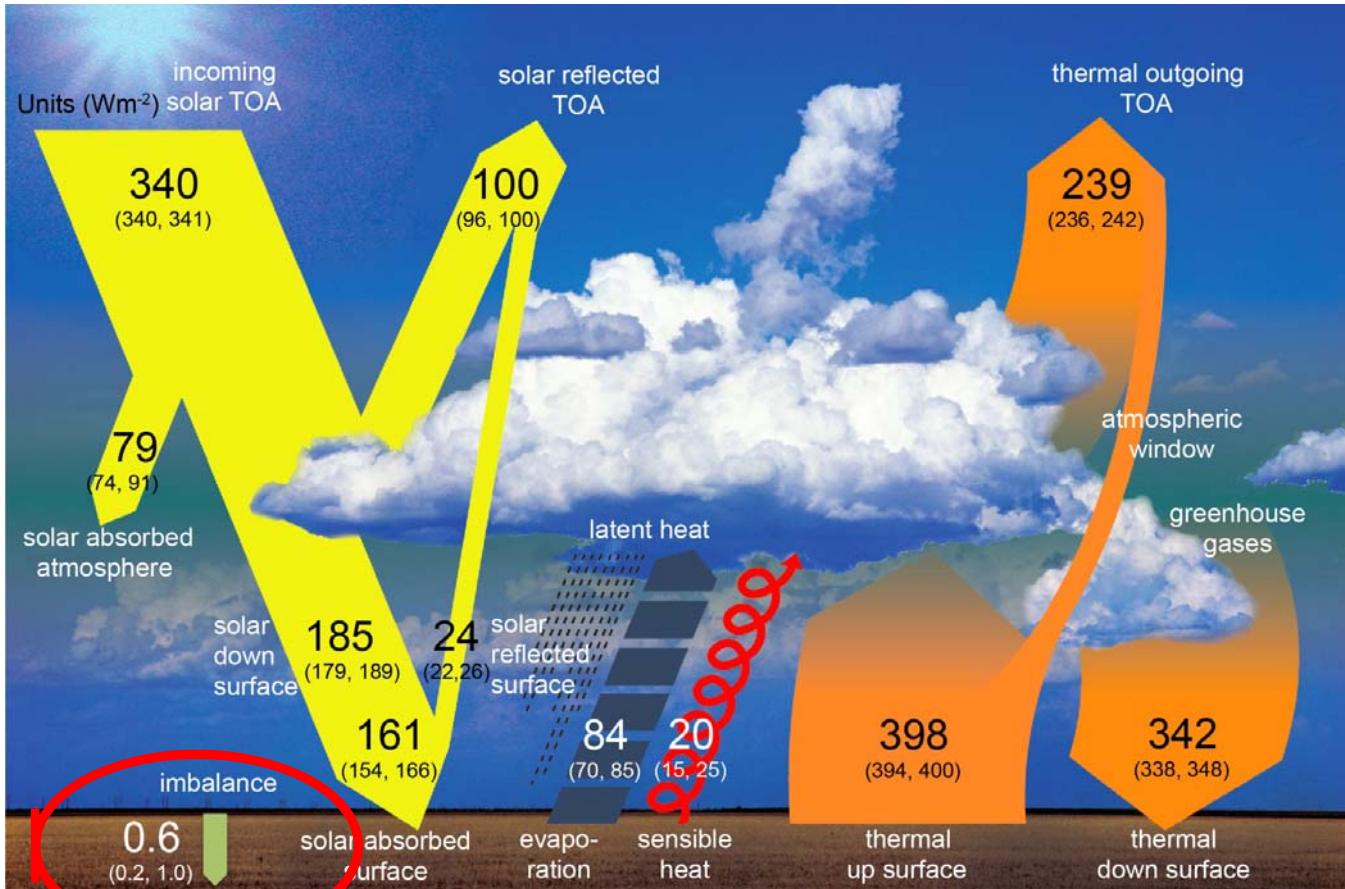
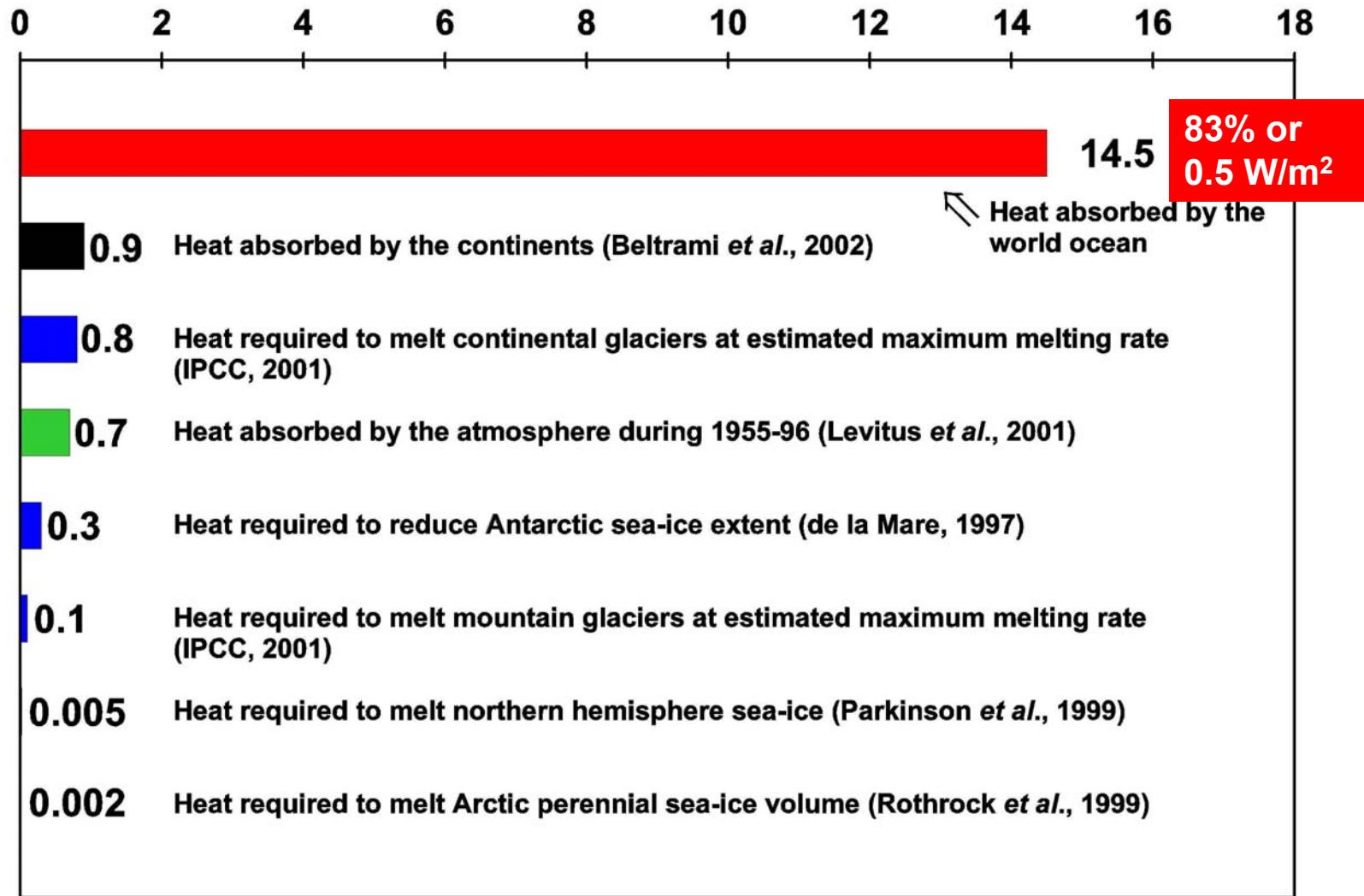


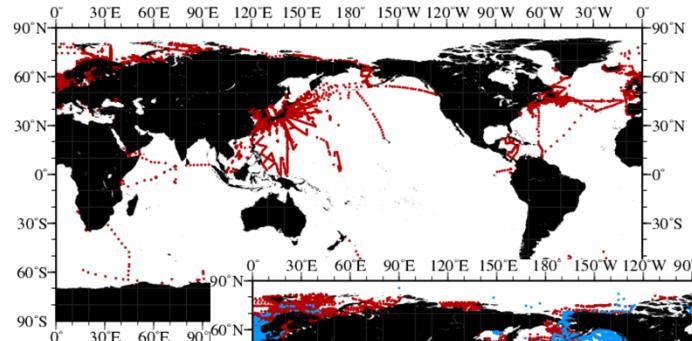
Figure 2.11: Global mean energy budget under present-day climate conditions. Numbers state magnitudes of the individual energy fluxes in W m^{-2} , adjusted within their uncertainty ranges to close the energy budgets. Numbers in parentheses attached to the energy fluxes cover the range of values in line with observational constraints. (Adapted from Wild et al., 2013.)

Hartmann, D.L., A.M.G. Klein Tank, M. Rusticucci, L.V. Alexander, S. Brönnimann, Y. Charabi, F.J. Dentener, E.J. Dlugokencky, D.R. Easterling, A. Kaplan, B.J. Soden, P.W. Thorne, M. Wild and P.M. Zhai, 2013: Observations: Atmosphere and Surface. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 159–254, doi:10.1017/CBO9781107415324.008

¹NOAA/United States National Centers for Environmental Information, Silver Spring, Maryland, USA, ²Institute for Marine and Antarctic Studies (IMAS), University of Tasmania (UTAS), Hobart, Tasmania, Australia , ³ Antarctic Climate and Ecosystems Cooperative Research Institute, Hobart, Tasmania, Australia, ⁴Australian Research Council's Centre of Excellence for Climate System Science, Hobart, Tasmania, Australia, ⁵Met Office, Exeter, Devon, United Kingdom, ⁶NOAA/Pacific Marine Environmental Laboratory, Seattle, Washington, USA, ⁷Joint Institute for Marine and Atmospheric Research, University of Hawai'i at Manoa, Honolulu, Hawai'i, USA, ⁸Meteorological Research Institute, Japan Meteorological Agency, Nagamine, Tsukuba, Ibaraki, Japan, ⁹University of Hamburg, Center for Earth System Research and Sustainability, CliSAP, Integrated Climate Data Center, ¹⁰Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA, ¹¹University Corporation for Atmospheric Research, Boulder, Colorado, USA, ¹²Commonwealth Scientific and Industrial Research Organization, Hobart, Tasmania.

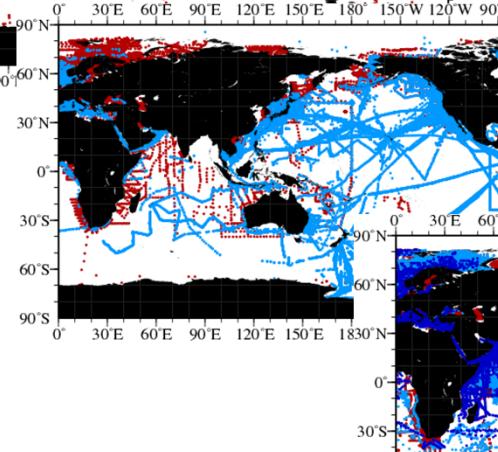
Changes in Earth's Heat Balance Components (10^{22} J)
During 1955-2003 (from Levitus, Antonov and Boyer, 2005, GRL)





Temperature Data During Peak of Different Observing Systems

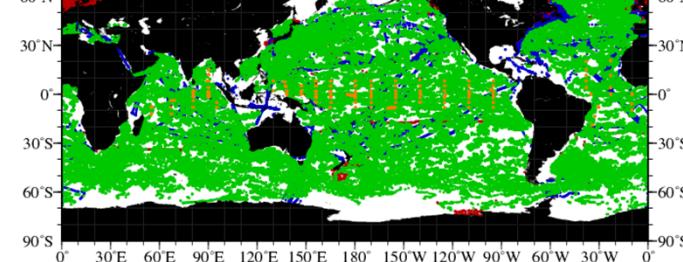
1934 : Nansen Cast



1960 : MBT



1985 : XBT

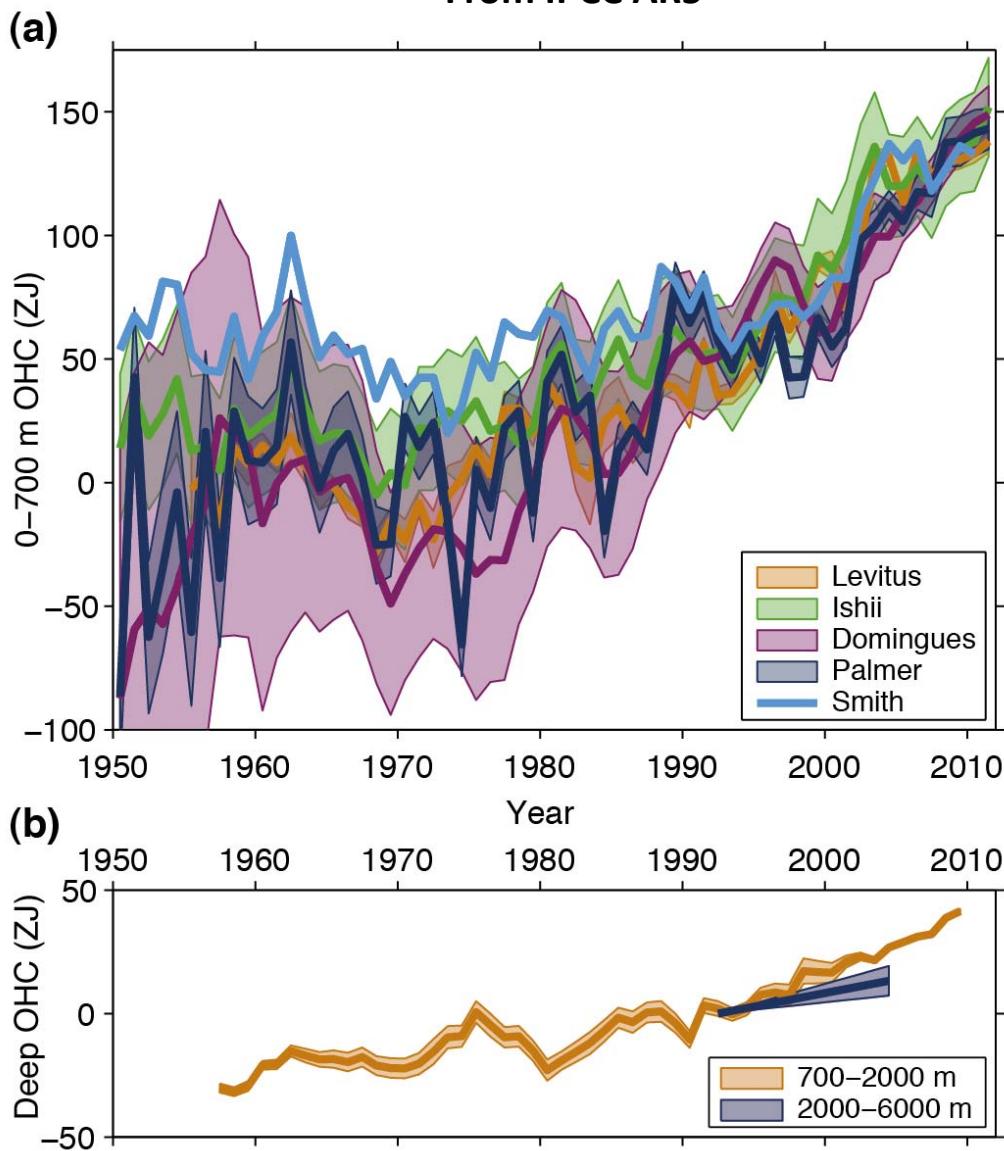


**2009 :
Argo**

Red=Nansen Cast /CTD[1890s/1964]
Light Blue=MBT [1939]
Dark Blue=XBT [1967]
Green=Argo float [2001]
Orange=Tropical buoy [1984]

Abraham, J. P., M. Baringer, N. L. Bindoff, T. Boyer, L. J. Cheng, J. A. Church, J. L. Conroy, C. M. Domingues, J. T. Fasullo, J. Gilson, G. Goni, S. A. Good, J. M. Gorman, V. Gouretski, M. Ishii, G. C. Johnson, S. Kizu, J. M. Lyman, A. M. Macdonald, W. J. Minkowycz, S. E. Moffitt, M. Palmer, A. Piola, F. Reseghetti, K. E. Trenberth, I. Velicogna, S. E. Wijffels, J. K. Willis: Monitoring systems of global ocean heat content and the implications for climate change, a review. - Review of Geophysics, Vol. 51, pp 450-483

From IPCC AR5



Sparse data leads to many methods to calculation of Ocean Heat Content

Josey, A. Kostianoy, C. Mauritzen, D. Roemmich, L.D. Talley and F. Wang, 2013: Observations: Ocean. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 255–316, doi:10.1017/CBO9781107415324.010.

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EN3: quality controlled subsurface ocean temperature and salinity data

Information about this dataset: a new version (EN4) is [now available](#). There will be no further updates to EN3.

Brief description of the dataset

The EN3 dataset consists of two products:

- Observed subsurface ocean temperature and salinity profiles with data quality information, and,
- Objective analyses formed from the profile data.

Data are available from 1950 to the present and there are separate files for each month. The sources of the data used to produce the most recent version of the EN3 dataset were [WODOS](#), [GTSPP](#), Argo and the [ASBO project](#). Please see the [data sources](#) page for more information (including details of the sources of the Arctic data collated by the ASBO project) and acknowledgements.

Obtaining the EN3 dataset

The current version of the EN3 dataset is EN3_v2a. This can be downloaded by following the link below:

[Download the current version of EN3](#)

The data can be obtained without charge for private study or scientific research, but please do read the [terms and conditions](#) before use. Some previous versions of the dataset are also available from the [download page](#).

More information

- [Description of file formats](#)
- [History of the dataset](#): Information about the origins of the dataset and the differences between versions.
- [Data sources and acknowledgements](#)
- [Description of quality tests and data processing](#): The data quality control checks and production of the objective analyses are described in Ingleby and Huddleston (2007). Although this documents EN2 (a previous release of the dataset), the data processing methodology remains broadly unchanged. The latest version of EN3 used a list of suspect Argo floats identified using altimetry data, which was downloaded from <http://fb.fremecfr.fremer/argo/etc/argo-as9-item13-AltimeterComparison/>. The method used to produce this list is described in Guinehut et al. (2009).
- Versions of the EN3_v2a profile data with time varying expendable bathythermograph (XBT) bias corrections are available from the [Download page](#).
- Files that enable the undoing of the cold water tapering of XBT corrections are provided for the latest dataset from the [Download EN3_v2a page](#).

Examples

The figures below show the most recent objective analysis fields minus a climatology for 1971–2000 (created from the EN2 objective analyses) averaged over the upper 725 m of ocean (corresponding to the top 24 levels of the analyses).

0 - 725 m average anomalies
12/2013



Dataset produced in collaboration with:



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References

When using the data set in a paper, the following is the correct citation to use (pdf file):
 Ingleby, B., and M. Huddleston, 2007: Quality control of ocean temperature and salinity profiles - historical and real-time data. *Journal of Marine Systems*, 65, 158-175
[10.1016/j.jmarsys.2005.11.019](https://doi.org/10.1016/j.jmarsys.2005.11.019)

The time varying XBT corrections are described in:
 Wijffels, S., J. Willis, C. M. Domingues, P. Barker, N. J. White, A. Gronell, K. Ridgway and J. A. Church, 2008, Changing expendable bathythermograph fall rates and their impact on estimates of thermosteric sea level rise, *Journal of Climate*, 21, 21, 5657-5672, DOI:10.1175/2008JCLI2290.1

The altimetry quality control methodology is described in:
 Guinehut, S., C. Coatanneau, A.-L. Dhondt, P.-Y. Le Traon and G. Larnicol, 2009. On the use of satellite altimeter data in Argo quality control, *Journal of Atmospheric and Oceanic Technology*, 26, 395-402, DOI: 10.1175/2008TECHO649.1

The Experiment: Yearly OHCA values can give a good measure of the Earths Energy Imbalance, but there are many sources of uncertainty in OHCA calculations. This study quantifies some of the uncertainties in OHCA estimation. The same data and quality control(ENv3.2a, <http://www.metoffice.gov.uk/hadobs/en3/> plus Argo data (Barker et al., 2008) were used throughout to eliminate data/quality control choice differences



Barker, P. M., J. R. Dunn, C. M. Domingues, and S. E. Wijffels, 2011: Pressure Sensor Drifts in Argo and Their Impacts. *J. Atmos. Oceanic Technol.*, **28**, 1036–1049.
 doi:<http://dx.doi.org/10.1175/2011JTECHO831.1>

Look at Uncertainties Due to:

- 1) Mapping method – differences due to technique for projecting irregular data to full geographic coverage, smoothing, etc.**
- 2) XBT bias corrections – the main ocean observing system 1970-2001, systematic biases with different published methods for correcting.**
- 3) baseline mean climatology – reference for anomalies; geographic, time period differences in chosen baselines**

Chosen study years are 1970-2008 and 1993-2008 (1970 near start of widespread use of XBT, 2008 is two years into the near-full global coverage of Argo floats, 1993 is the start of the altimeter era)

MAPPING METHODS

Name	Method description
DOM	Domingues et al. (2008)
LEV	Levitus et al. (2009)
ISH	Ishii et al. (2006)
WIL	Willis et al. (2004)
PMEL_M	Lyman and Johnson (2008)
PMEL_R	Lyman and Johnson (2008)
EN	Ingelby and Huddleson (2007)
GOU	Gouretski et al. (2012)

XBT Bias Corrections

Name	Description	Correction Type
W08	Wijffels et al. (2008)	depth
L09	Levitus et al. (2009)	temperature
I09	Ishii and Kimoto (2009)	depth
G11	Good (2011)	depth
GO12	Gouretski (2012)	depth + temperature
C13	Cowley et al. (2013)	depth + temperature

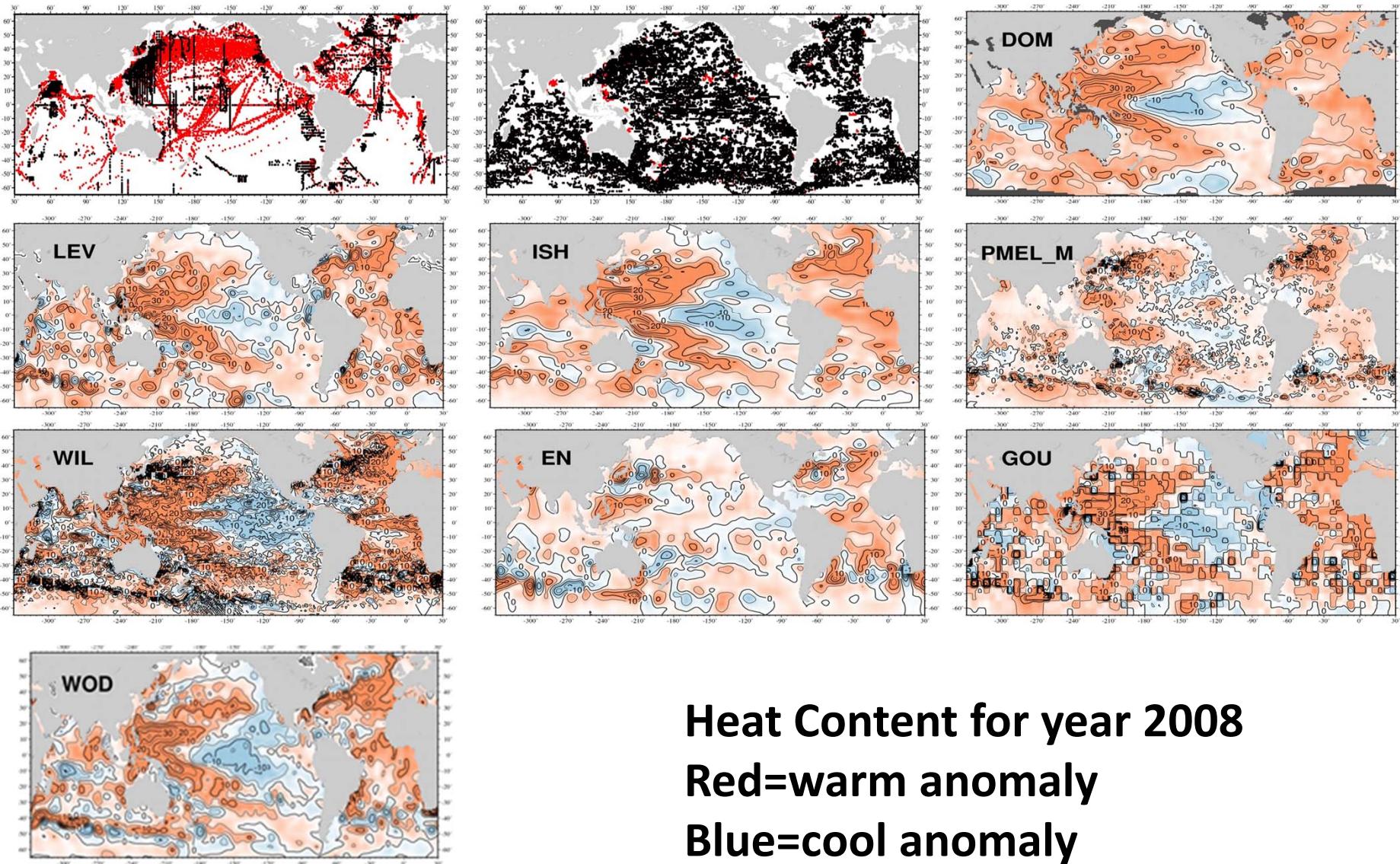
Baseline Climatologies

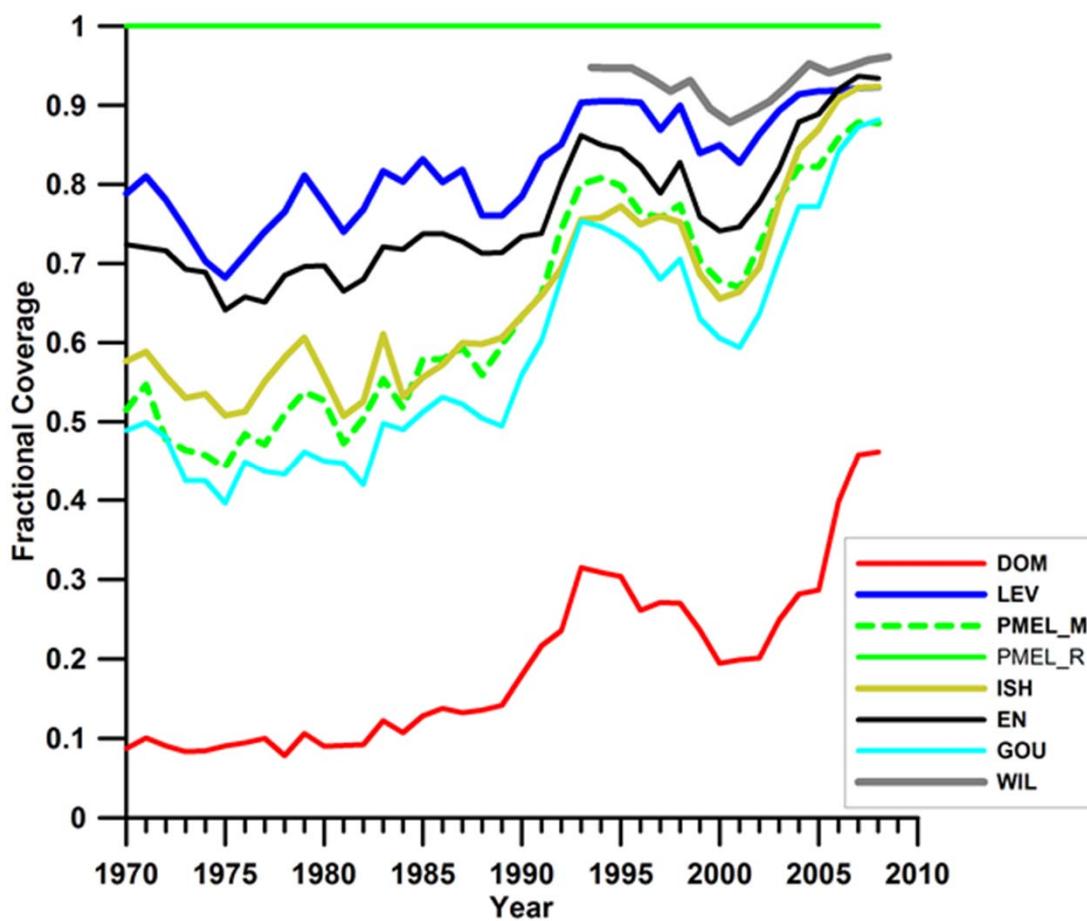
Name	Description	Data Used	Years
C1_H	Alory et al (2007)	Bottle, CTD, Argo	all
C2_H	Alory et al. (2007)	Same as C1_H plus XBT	all
C3_M	Locarnini et al. (2013)	All extant	2005-2012

References:

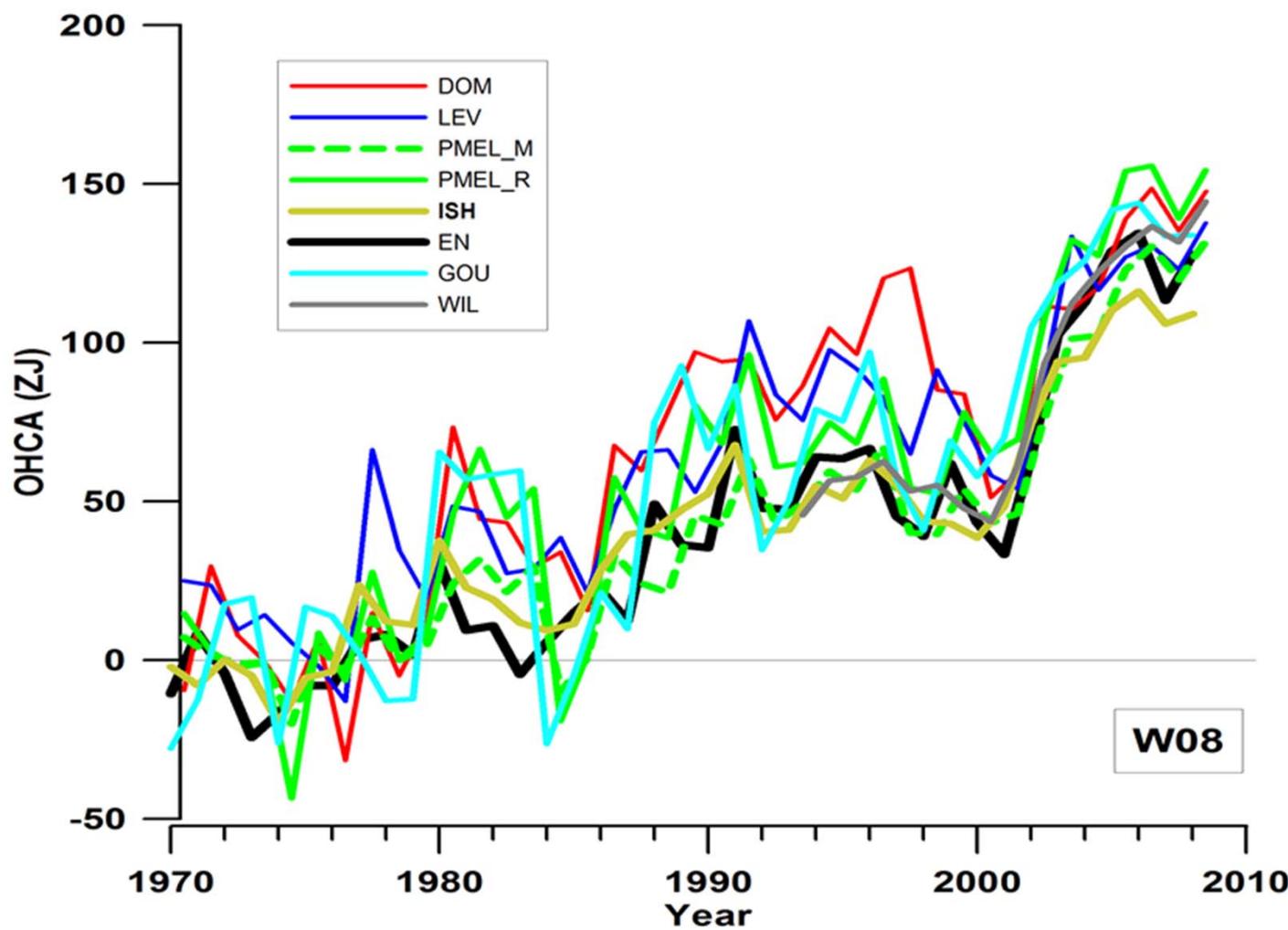
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1981 Data Distribution 2008 red= to 300m, black= to 700 m

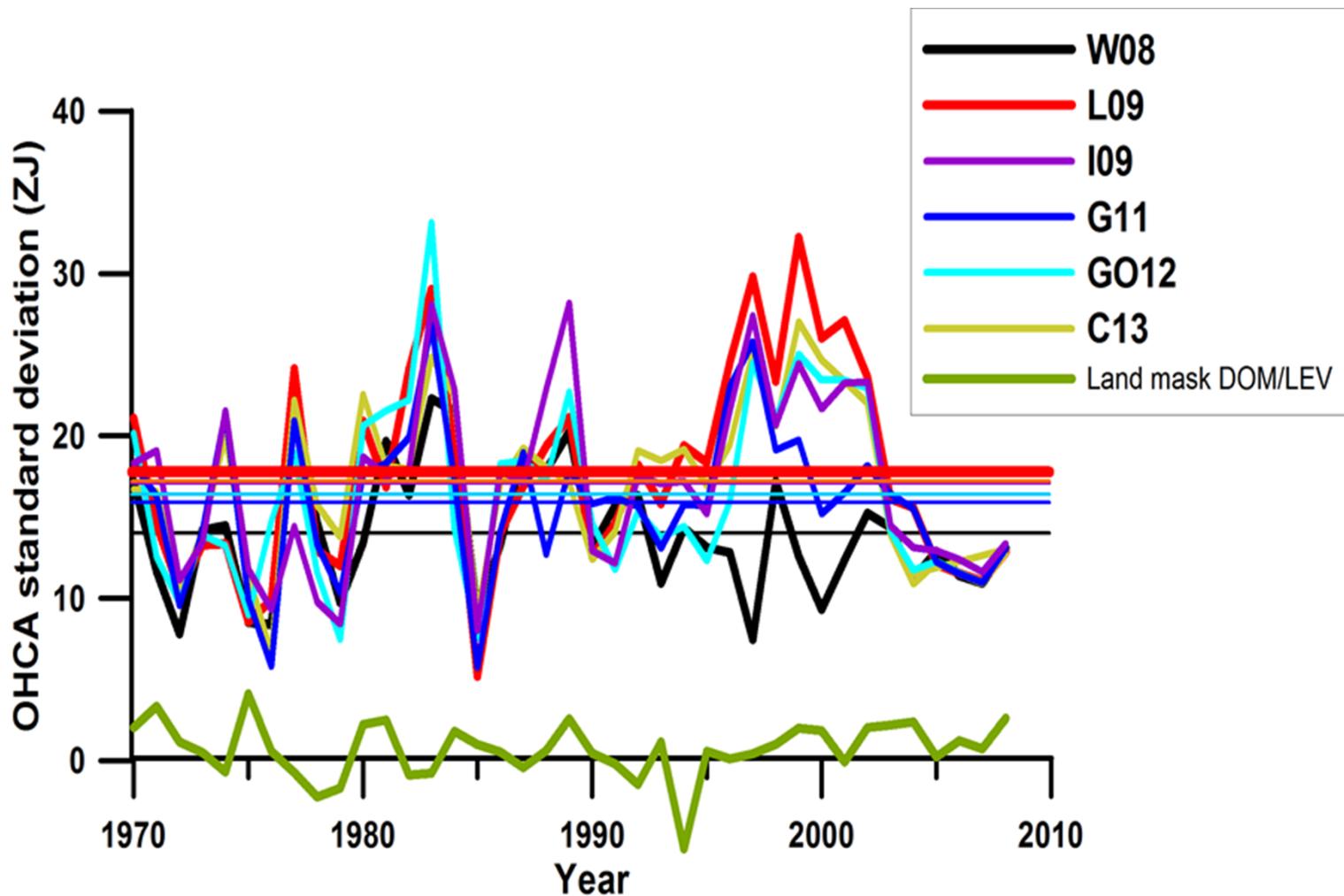




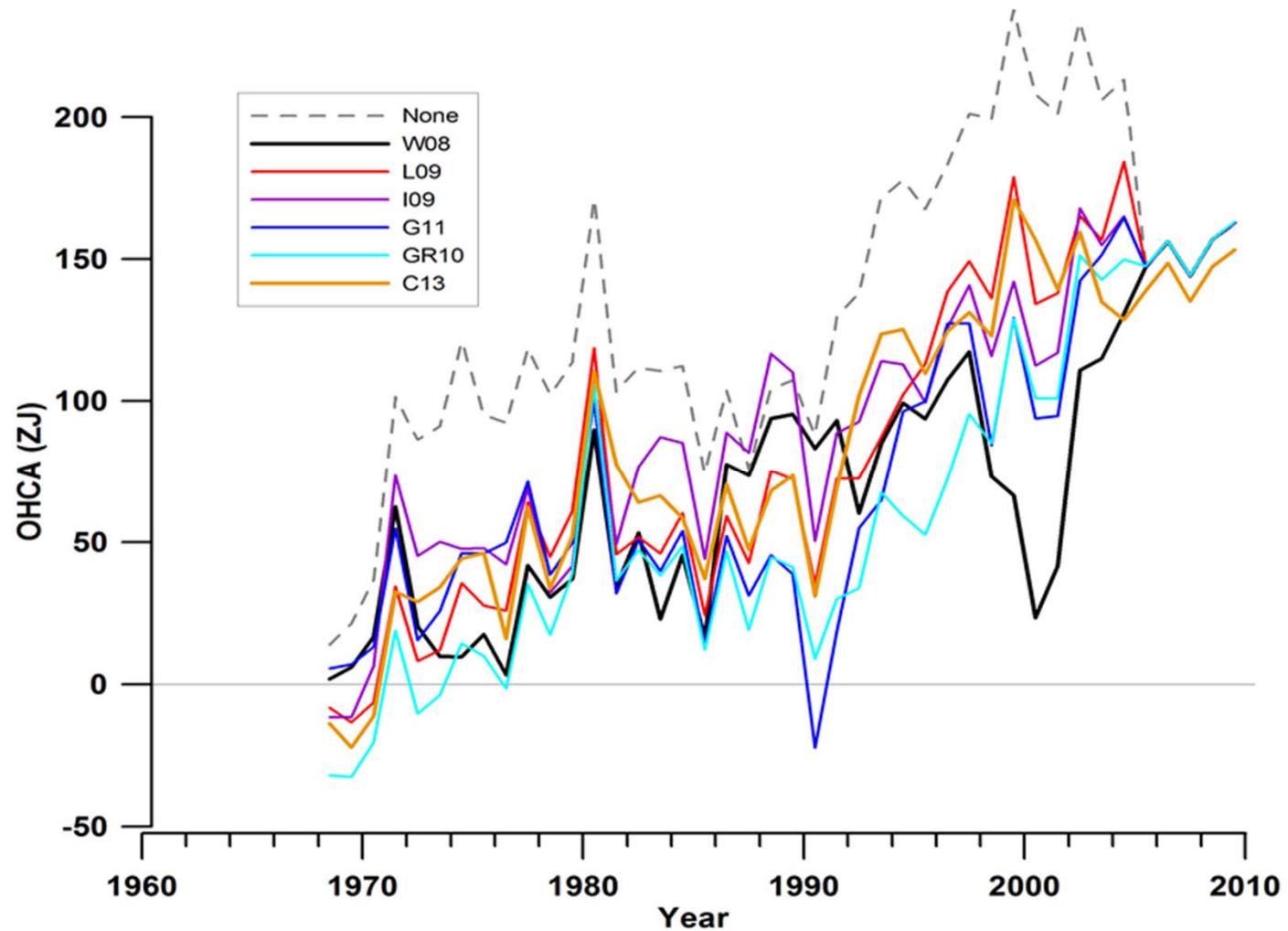
Fractional Coverage: Data distribution within mapping radii



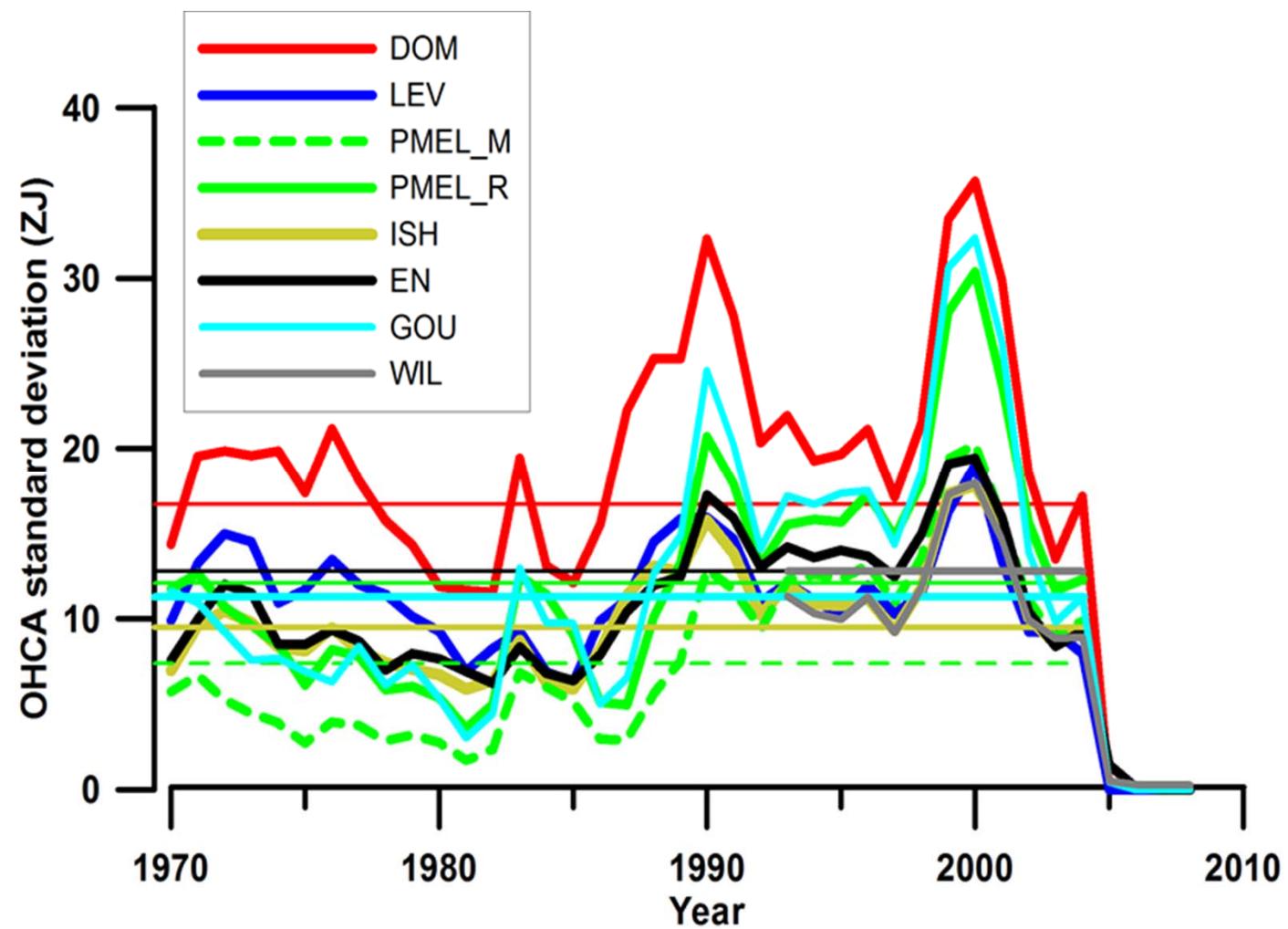
Difference due to mapping method: W08 XBT correction, C1_H Baseline Climatology



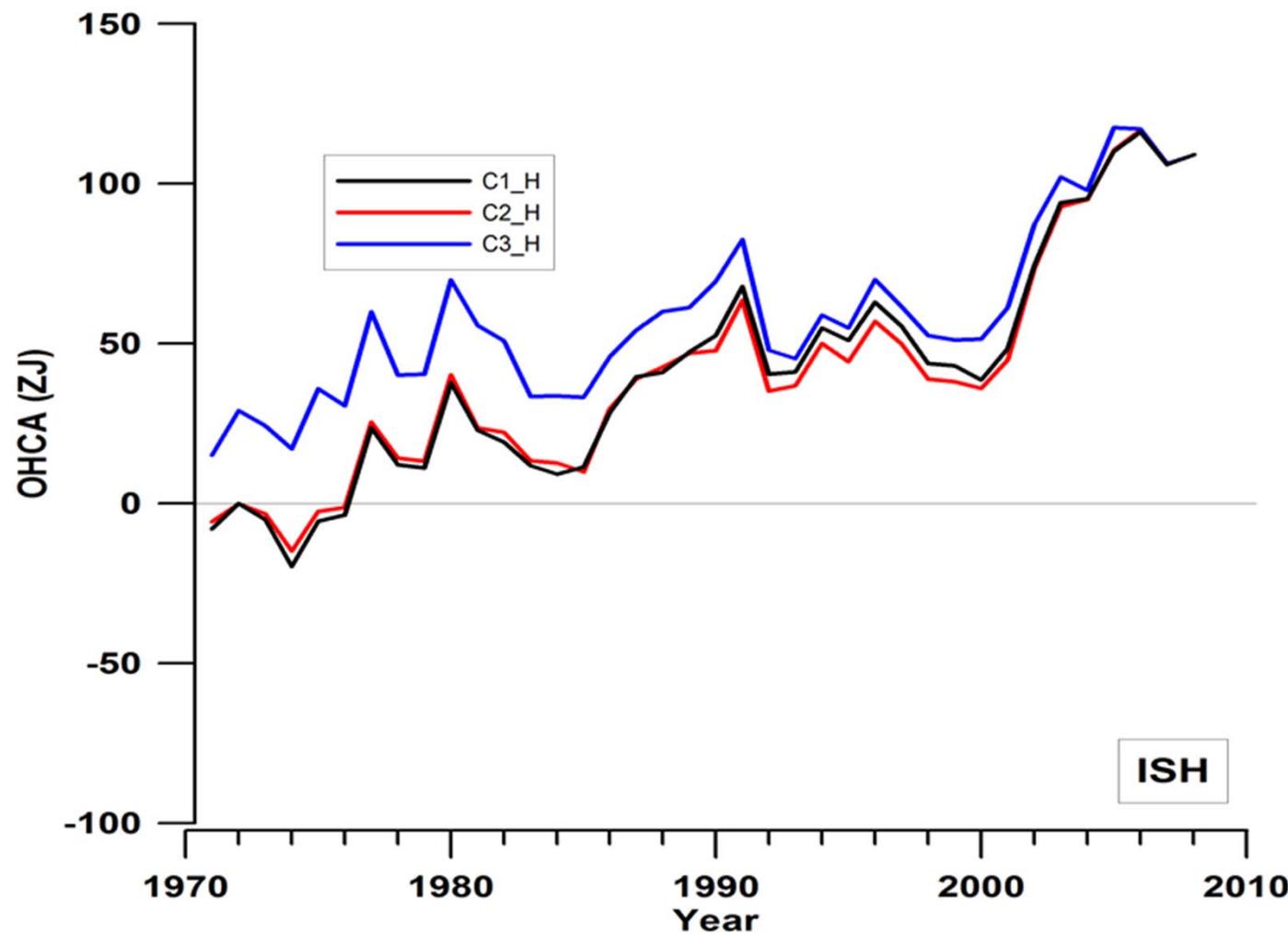
Standard Deviation for each Year due to mapping method (for different XBT corrections)



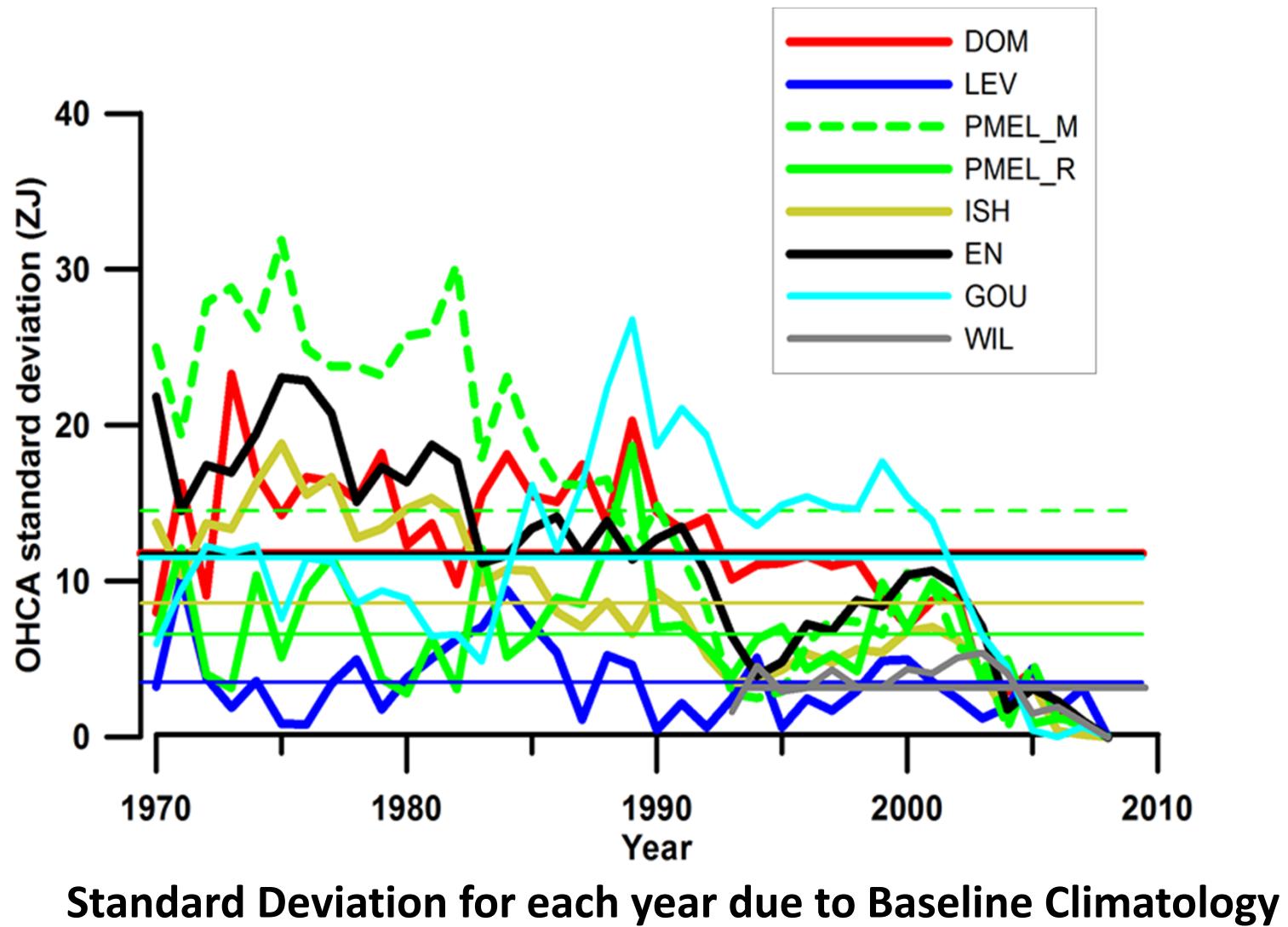
XBT Bias Correction Differences: DOM mapping method C1_H baseline



Standard deviation for each year due to XBT bias correction



Differences due to Baseline Climatology Used (normalized to year 2008):
ISH mapping method, W08 XBT correction



Name	Mapping Method	XBT bias correction	Baseline Climatology
DOM	16.5 (17.1) ZJ	16.7 (18.9) ZJ	11.8 (7.1) ZJ
LEV	16.5 (17.1) ZJ	11.1 (10.4) ZJ	3.5 (2.7) ZJ
PMEL_M	16.5 (17.1) ZJ	7.4 (11.5) ZJ	14.5 (4.7) ZJ
PMEL_R	16.5 (17.1) ZJ	12.1 (15.3) ZJ	6.6 (4.9) ZJ
ISH	16.5 (17.1) ZJ	9.5 (10.5) ZJ	8.6 (3.9) ZJ
EN	16.5 (17.1) ZJ	12.8 (15.1) ZJ	11.8 (5.6) ZJ
GOU	16.5 (17.1) ZJ	11.3 (15.2) ZJ	11.5 (9.8) ZJ
WIL	* (17.1) ZJ	* (12.8) ZJ	* (3.1) ZJ
Average	16.5 (17.1) ZJ	11.6 (12.2) ZJ	9.8 (5.2) ZJ

Summary of Uncertainties:

For perspective – Average Ocean Heat Content Anomaly over the 1970-2008 period is ~80 ZJ
 Average year to year increase in ocean heat content is ~4 ZJ

Conclusions: From an XBT Science Team Perspective

Larger uncertainty due to mapping method than due to XBT bias correction, with baseline climatology uncertainty smaller in most cases.

The XBT bias uncertainty can be lessened as a consensus in the XBT community coalesces around a single correction or at least a set of recommendations for best corrections, and an adoption in the Ocean Heat Content community