Notes on Changes to Heat Content Integrals between Levitus et al. (2009)* and September 2010 online version.

Ocean Climate Laboratory

National Oceanographic Data Center

*Levitus, S., J.I. Antonov, T.P. Boyer, R.A. Locarnini, H.E. Garcia, and A.V. Mishonov, 2009: Global Ocean Heat Content 1955-2008 in light of recently revealed instrumentation problems. Geophys. Res. Lett. , 36, L07608, doi:10.1029/2008GL037155.

Changes to heat content estimates are due to three factors

1. Changes due to data additions and data quality control, both at NODC and by originators. Substantial quality control has been carried out by the Argo community on the profiling floats, mainly to correct pressure offsets. A substantial amount of data for recent years has been added to the analysis.

2. Changes due to switch of our base climatology. The website and 2009 paper used an interim (L09) climatology (between WOA05 and WOA09) incorporating XBT corrections and a mean of five decadal climatologies to remove temporal bias. These changes were formally completed with additional data and quality control in WOA09.

3. Changes due to revised XBT bias calculations. With additional XBT and CTD data, the bias calculations were improved. This is an ongoing process, but as we receive less new data from earlier time periods, this recalculation will mostly affect more recent years.

The amount of change due to each element is detailed in the following slides.

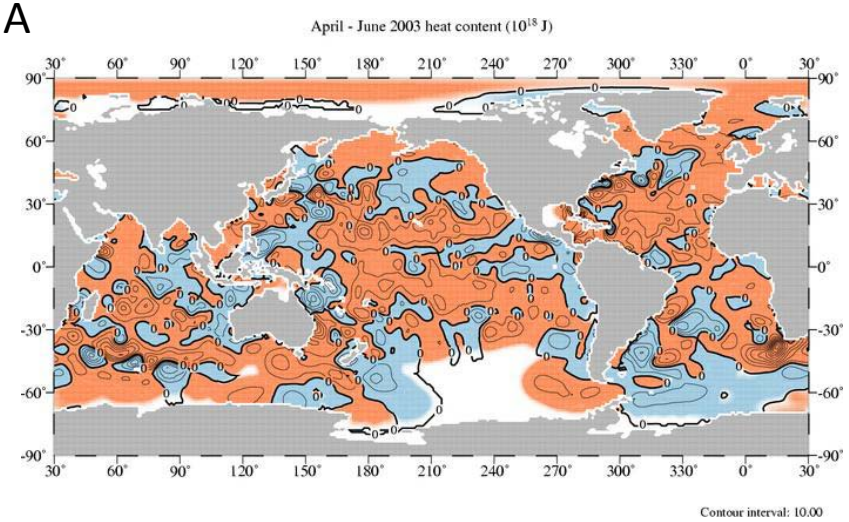
Heat content differences relative to Levitus *et al*. (2009).

- The next three figures show the difference due to each of the three changes relative to the published heat content for Apr.-Jun., 2003. 2003 was the last year with relatively small (< 0.5 x 10^{22}J) mean annual difference in heat content from published value.

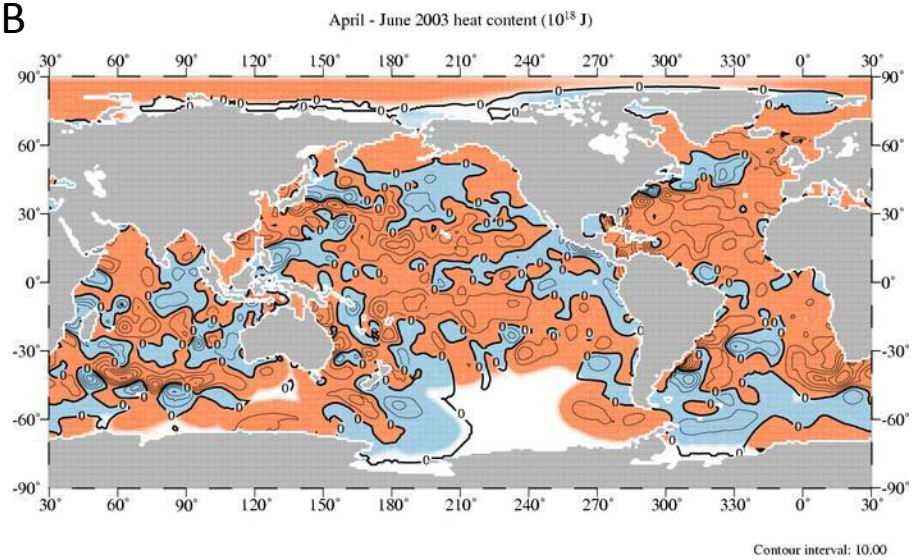
- The following three figures show the same differences, but for Jul.-Sep., 2004, the first year for which mean annual difference are relatively large (for 2004 published value is 2.0 x 10^{22}J greater than present value).

Changes due to additional/changed data, additional quality control

A



B



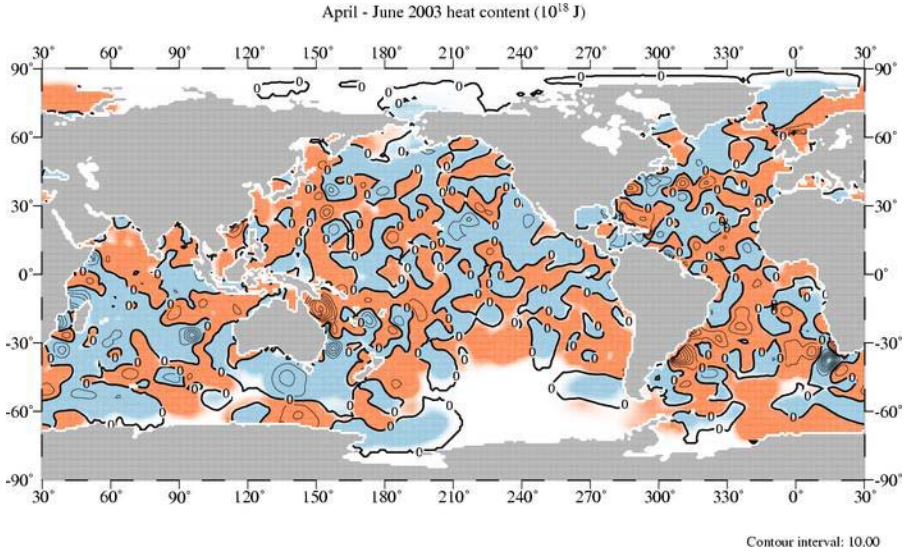
April –June Heat Content 2003

A) from Levitus *et al.* 2009 (L09): 9.69 x 10^{22} J globally integrated

B) current database (World Ocean Database, WOD updated through June, 2010), L09 climatologies, L09 XBT corrections: 10.40 x 10^{22} J, globally integrated

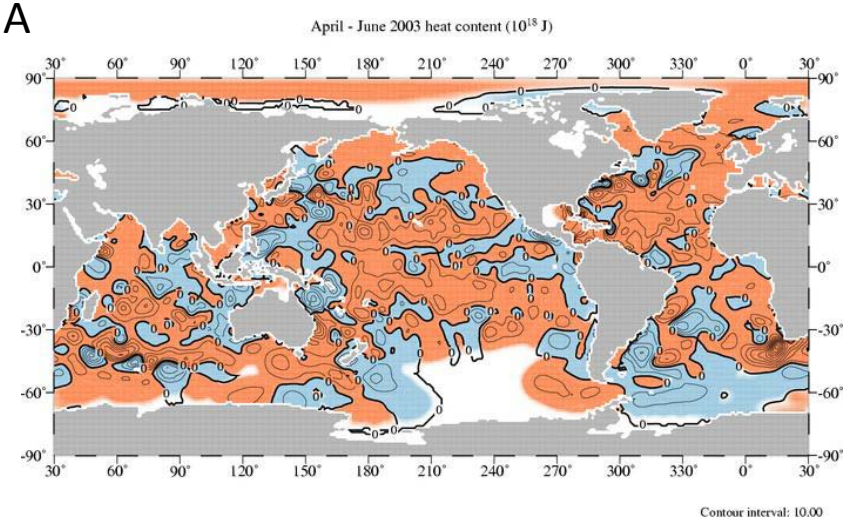
C) Difference (B-A)

C

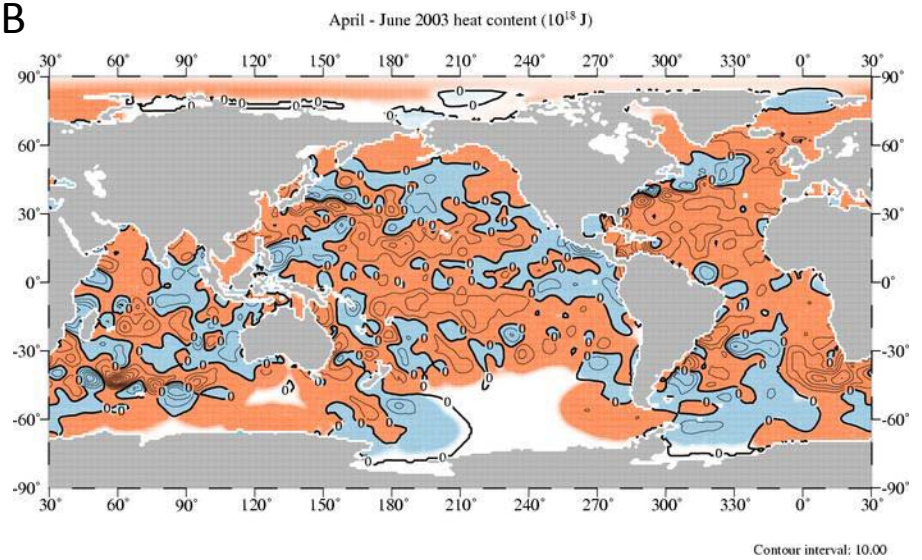


Additional changes due to change in base climatology

A



B



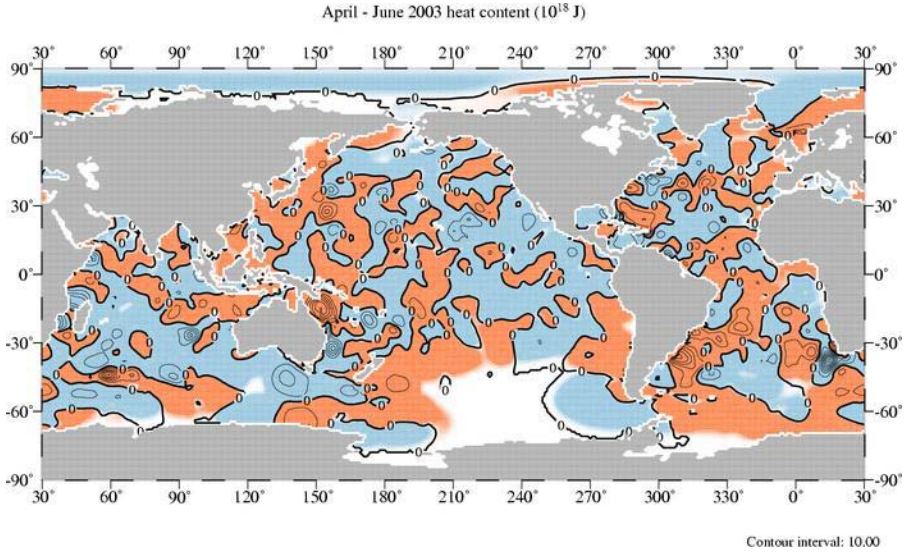
April –June Heat Content 2003

A) from Levitus *et al.* 2009 (L09): 9.69 x 10^{22} J globally integrated

B) current database (World Ocean Database, WOD updated through June, 2010), WOA09 climatologies, L09 XBT corrections: 9.27 x 10^{22} J, globally integrated

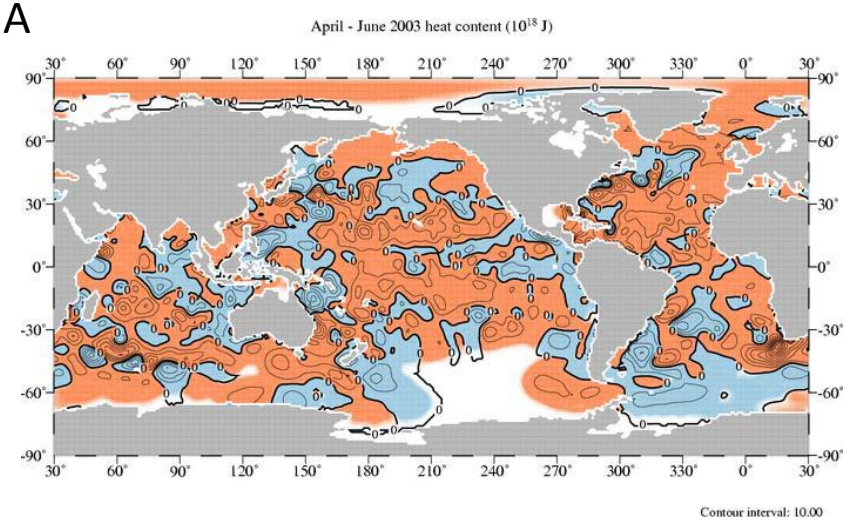
C) Difference (B-A)

C

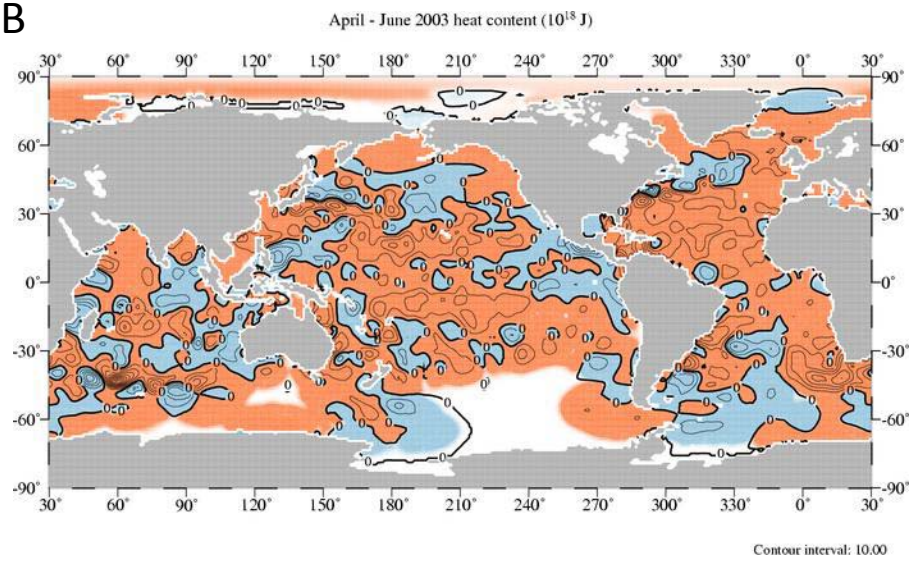


Additional changes due to changes in XBT bias correction

A



B



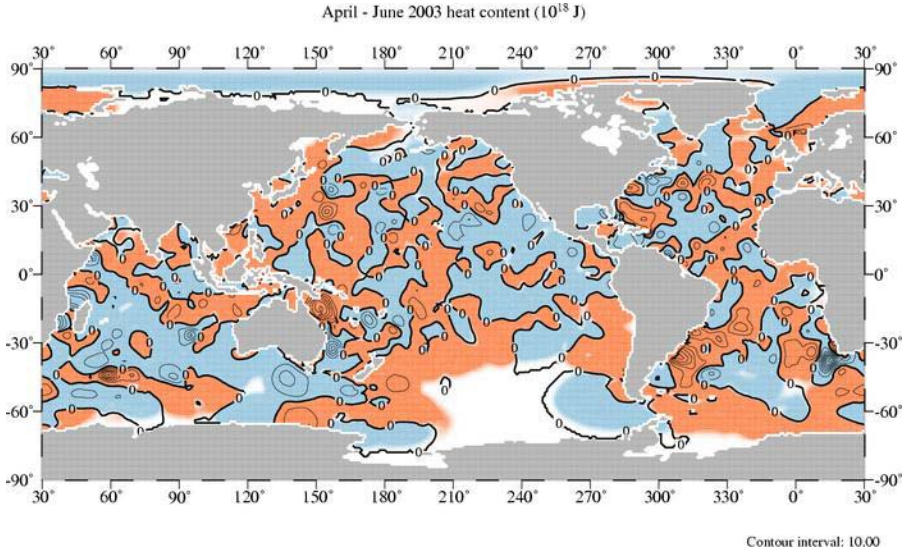
April –June Heat Content 2003

A) from Levitus *et al.* 2009 (L09): 9.69 x 10^{22} J globally integrated

B) current database (World Ocean Database, WOD updated through June, 2010), WOA09 climatologies, new XBT corrections: 9.98 x 10^{22} J, globally integrated

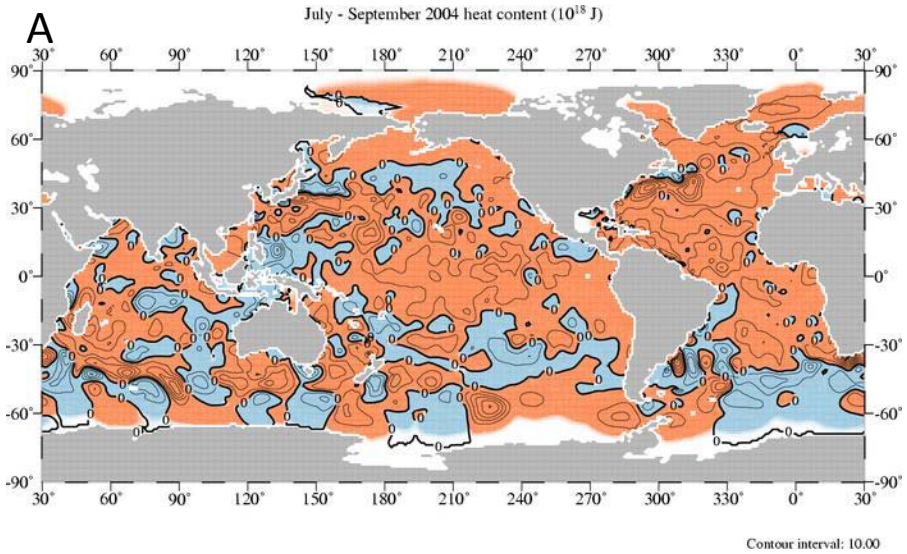
C) Difference (B-A)

C

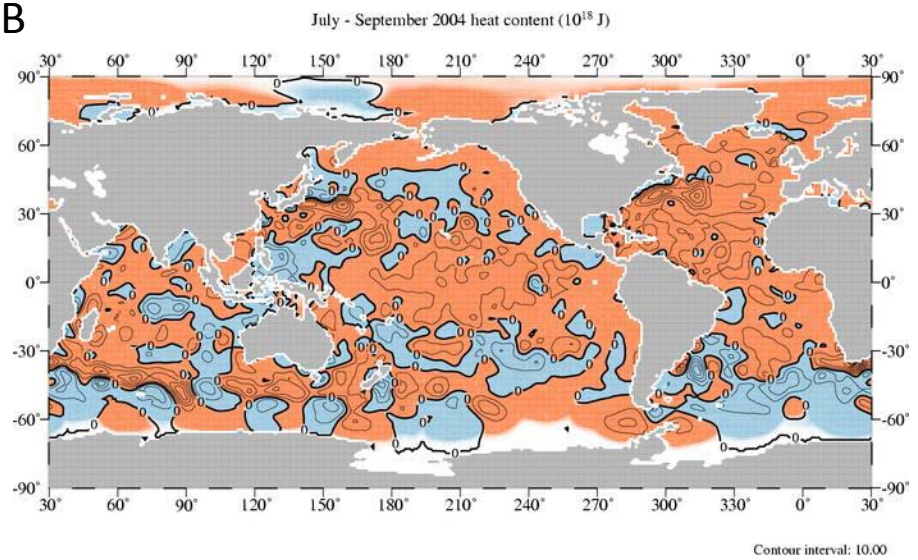


Changes due to additional/changed data, additional quality control

A



B



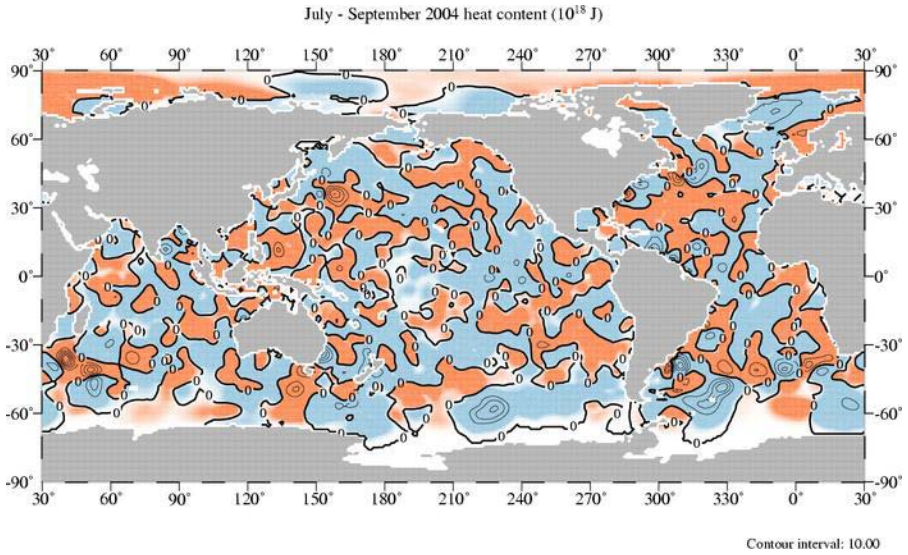
July –September Heat Content 2004

A) from Levitus *et al.* 2009 (L09): 13.00 x 10^{22} J globally integrated

B) current database (World Ocean Database, WOD updated through June, 2010), L09 climatologies, L09 XBT corrections: 11.25x 10^{22} J, globally integrated

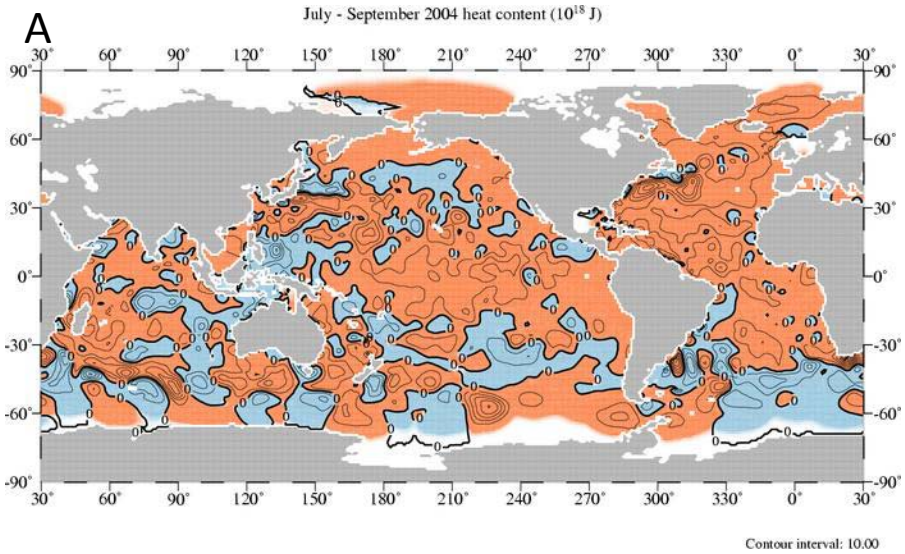
C) Difference (B-A)

C

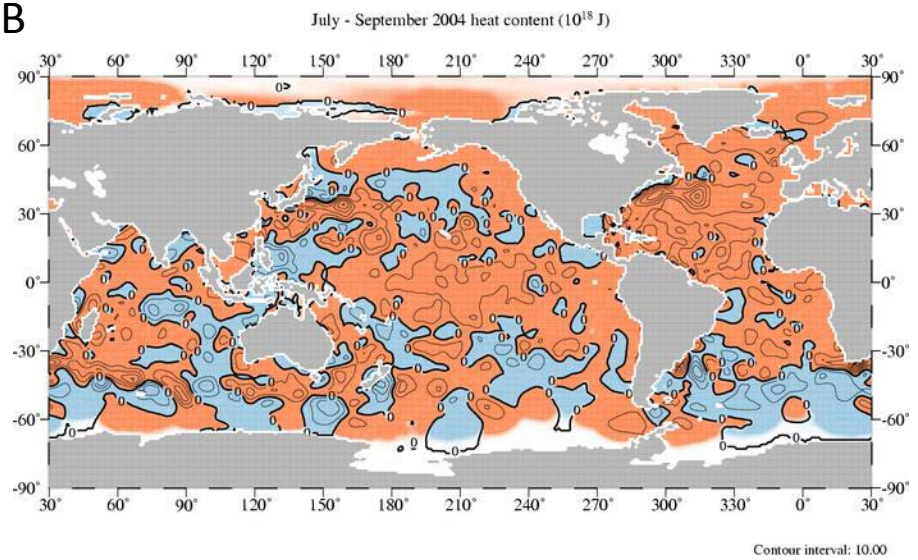


Additional changes due to change in base climatology

A



B



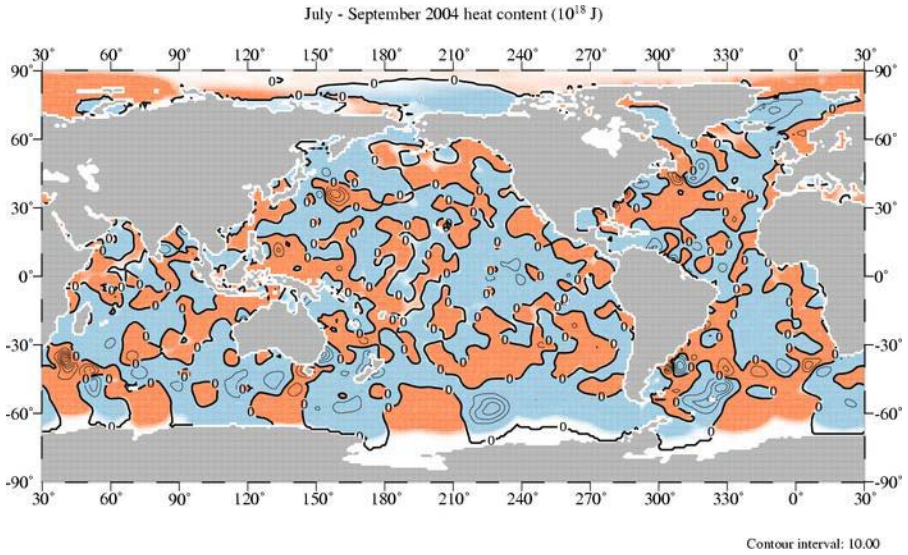
July –September Heat Content 2004

A) from L09: 13.00 x 10^{22} J globally integrated

B) current database, WOA09 climatologies, L09 XBT corrections: 10.41 x 10^{22} J, globally integrated

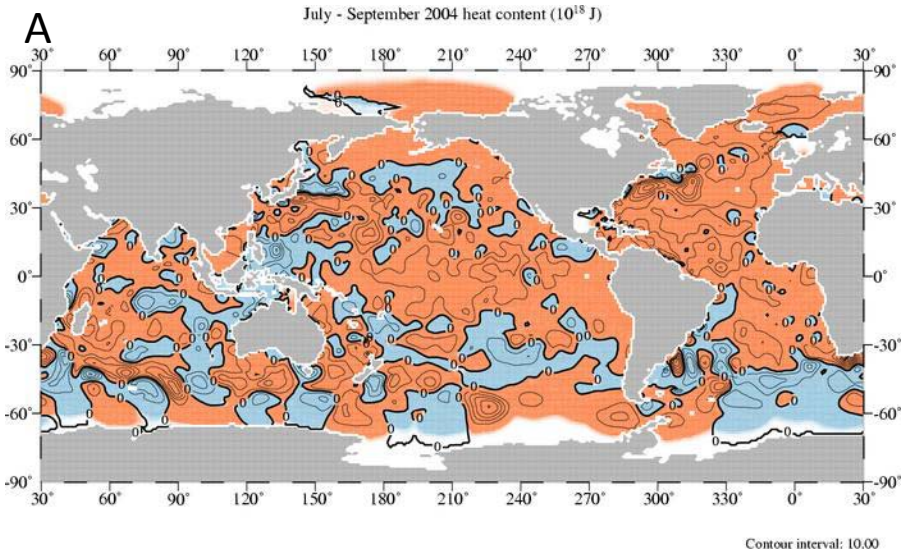
C) Difference (B-A)

C

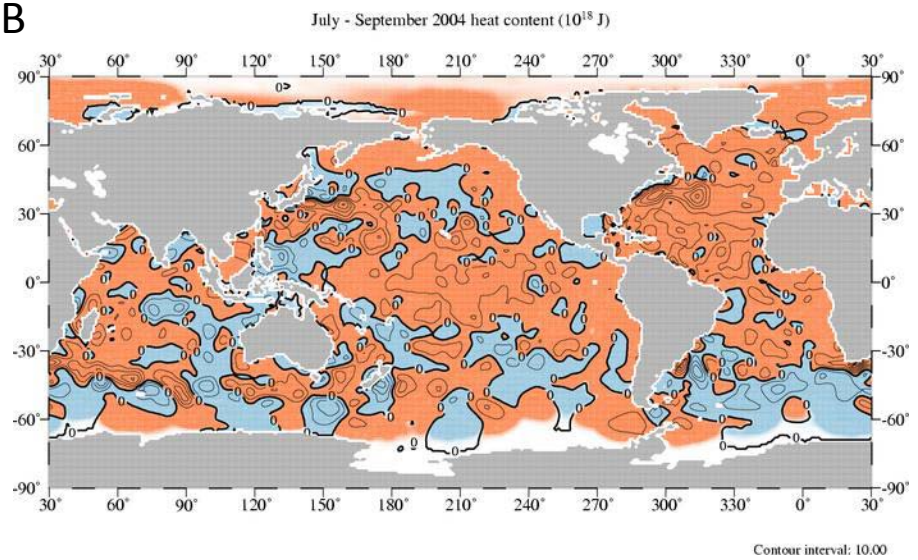


Additional changes due to changes in XBT bias correction

A



B



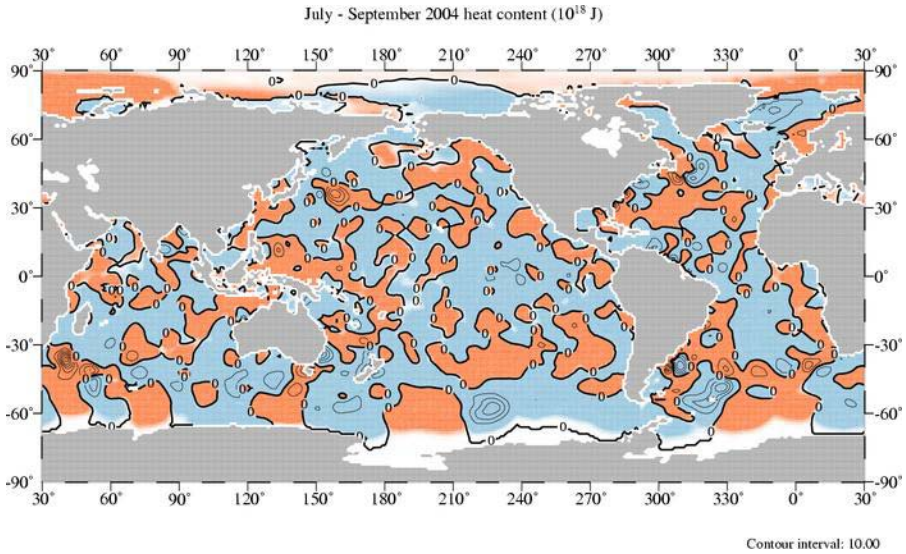
July –September Heat Content 2004

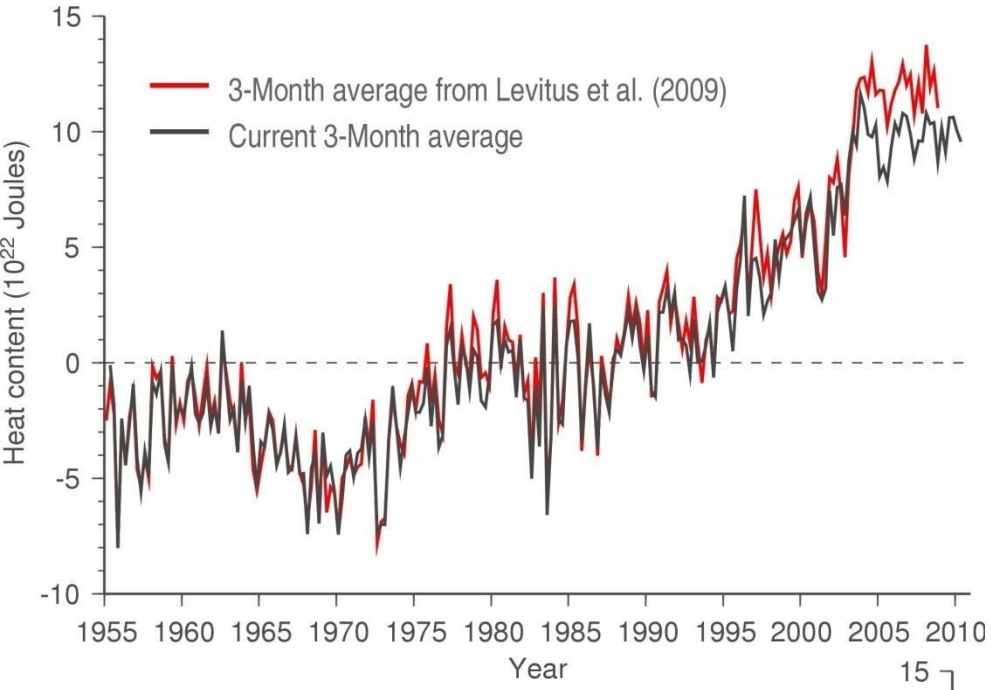
A) from L09: 13.00 x 10^{22} J globally integrated

B) current database, WOA09 climatologies, new XBT corrections, 10.06 x 10^{22} J, globally integrated)

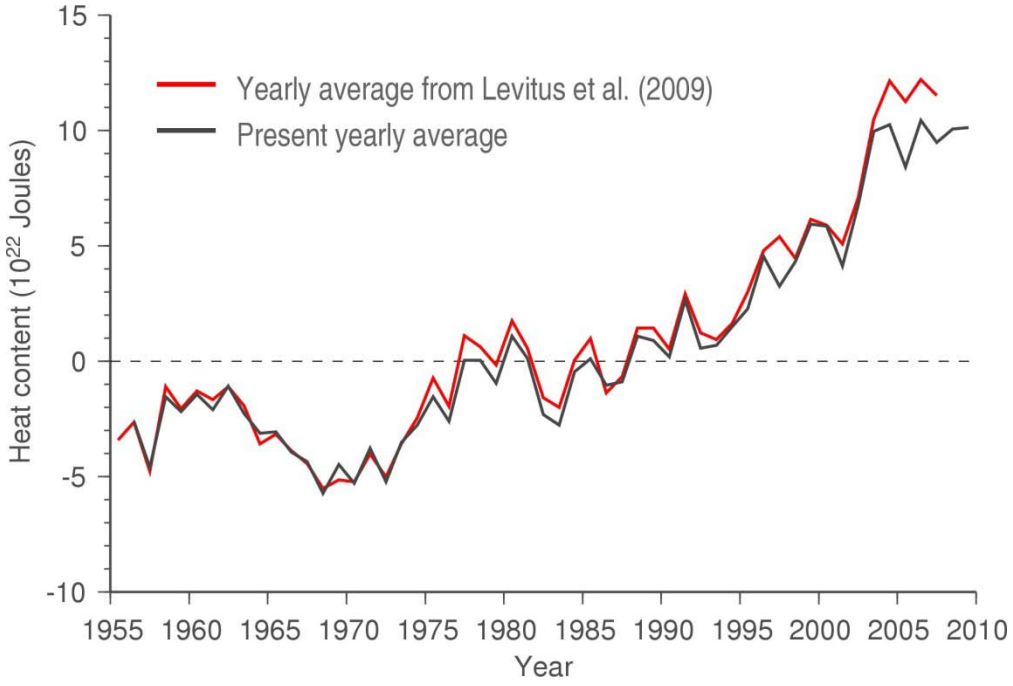
C) Difference (B-A)

C

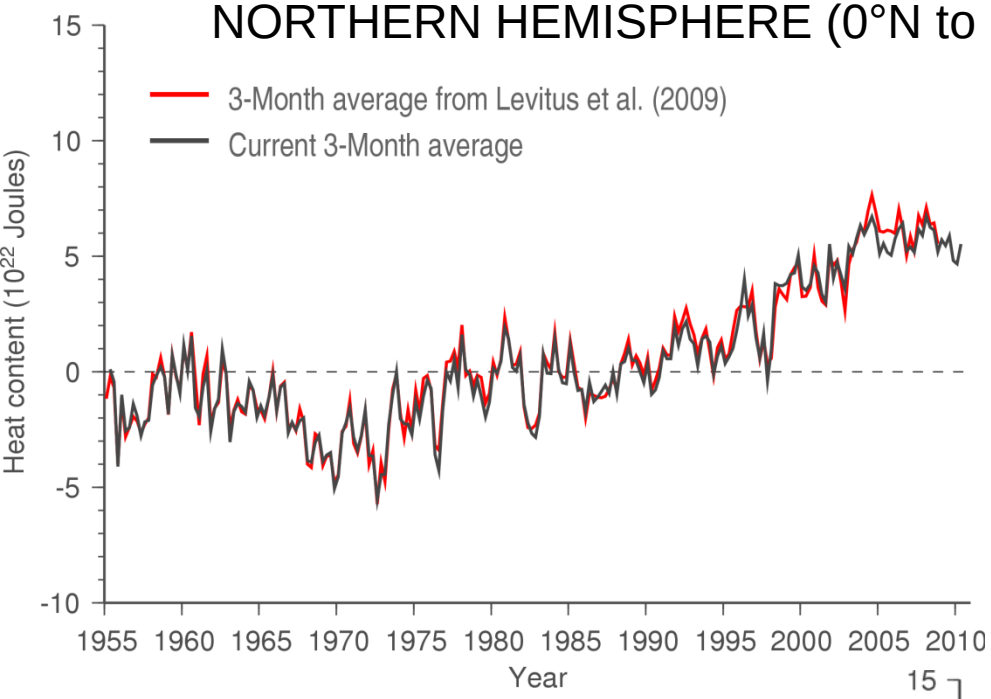




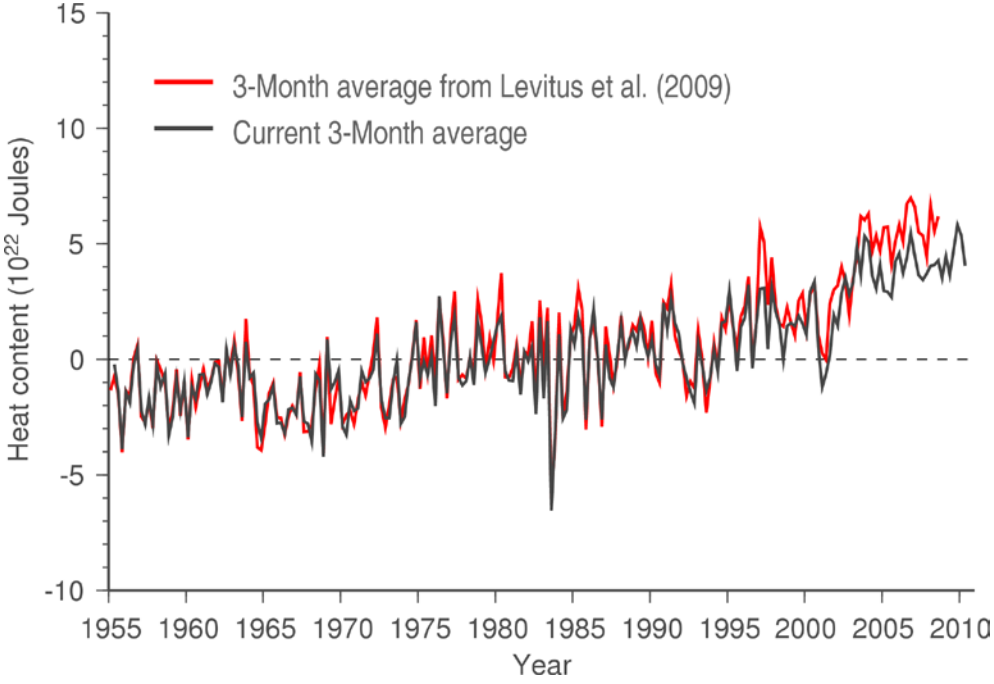
Difference between published global heat content integrals and present calculations (Globally integrated, 0-700m January-March1955 to April-June 2010)



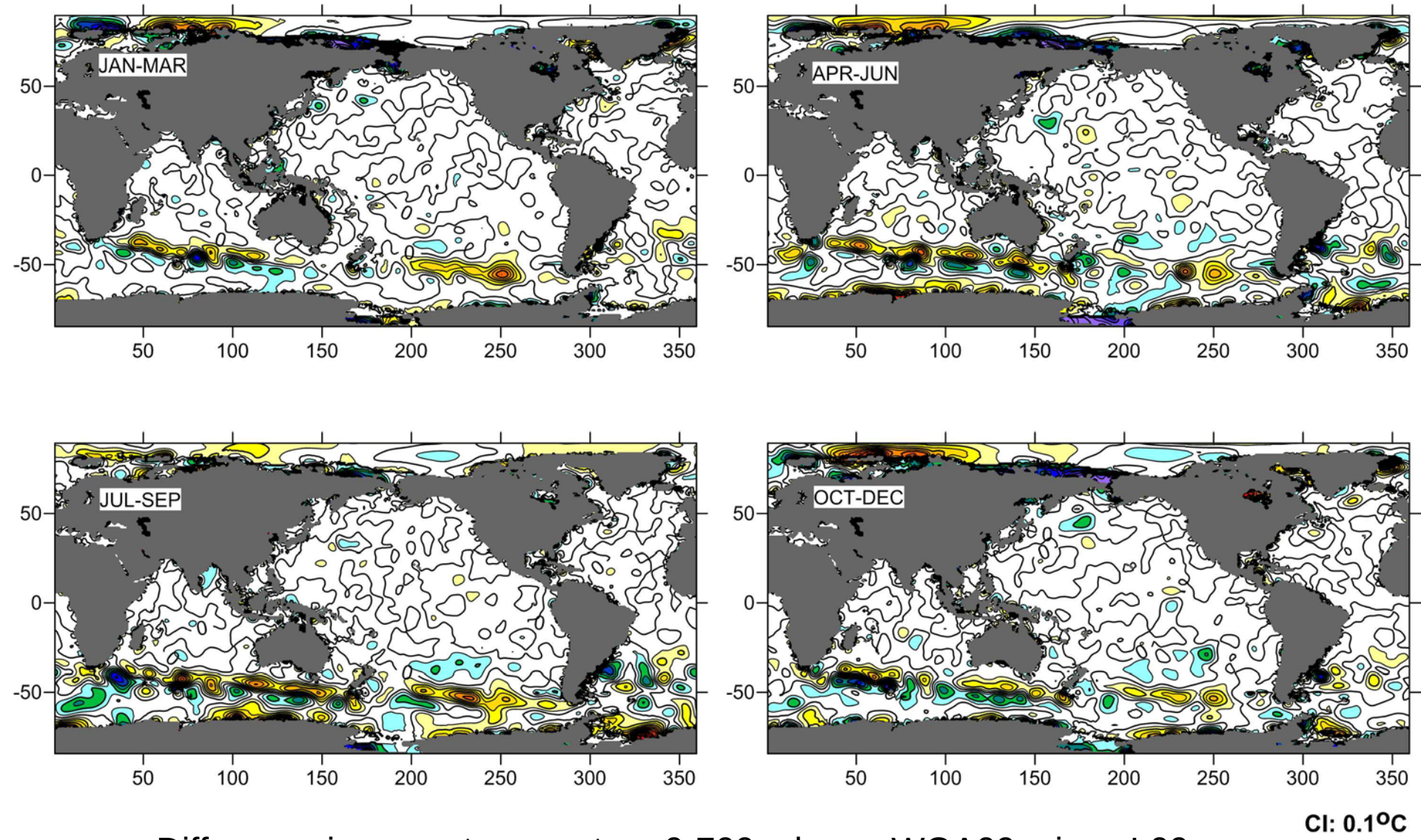
NORTHERN HEMISPHERE (0°N to 90°N)



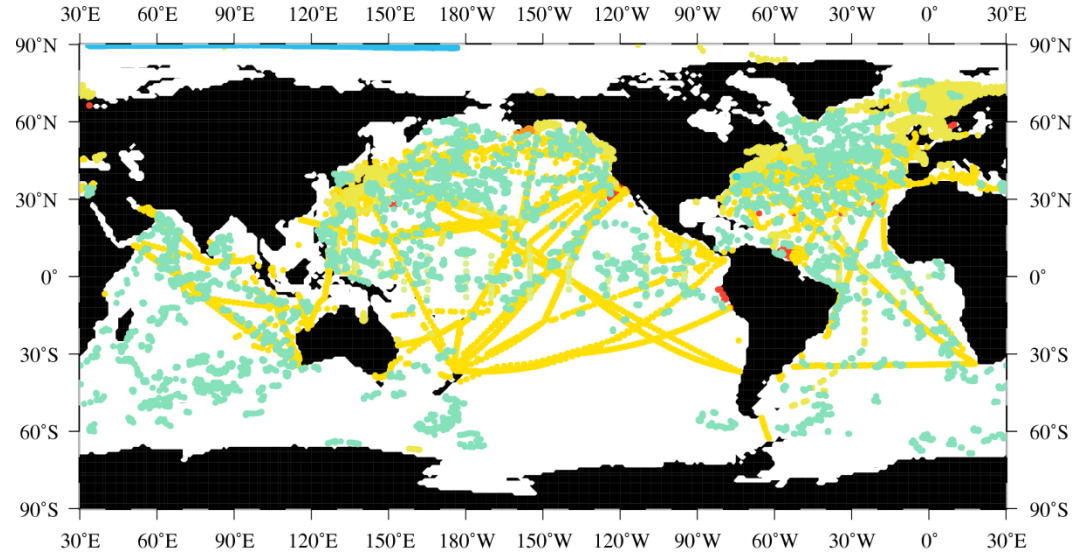
SOUTHERN HEMISPHERE (90S° to 0°S)



Difference between published global heat content integrals and present calculations (Globally integrated, 0-700 m, January-March 1955 to April-June 2010)

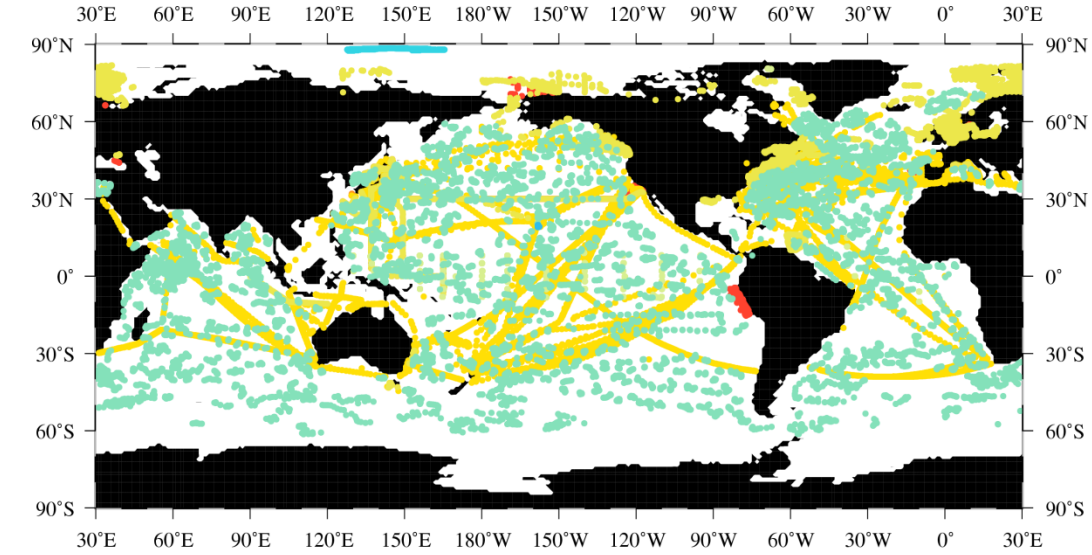


Difference in mean temperature 0-700m layer: WOA09 minus L09
Green/Blue=negative, Yellow/Red=positive, White= < 0.1°C difference
Contour interval=0.1°C



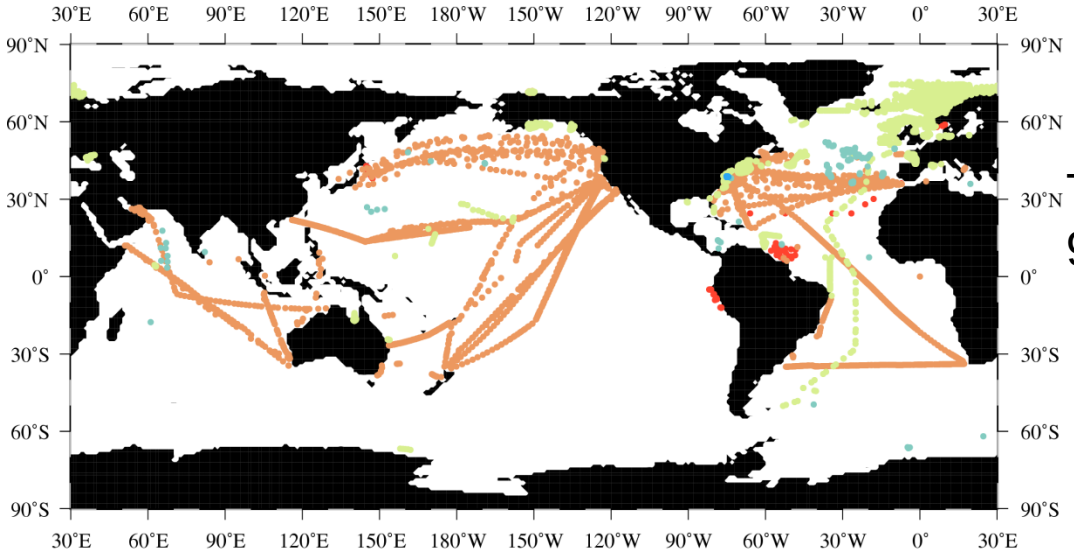
Temperature profiles: Apr-Jun, 2003
32,138 total profiles

ALL DATA



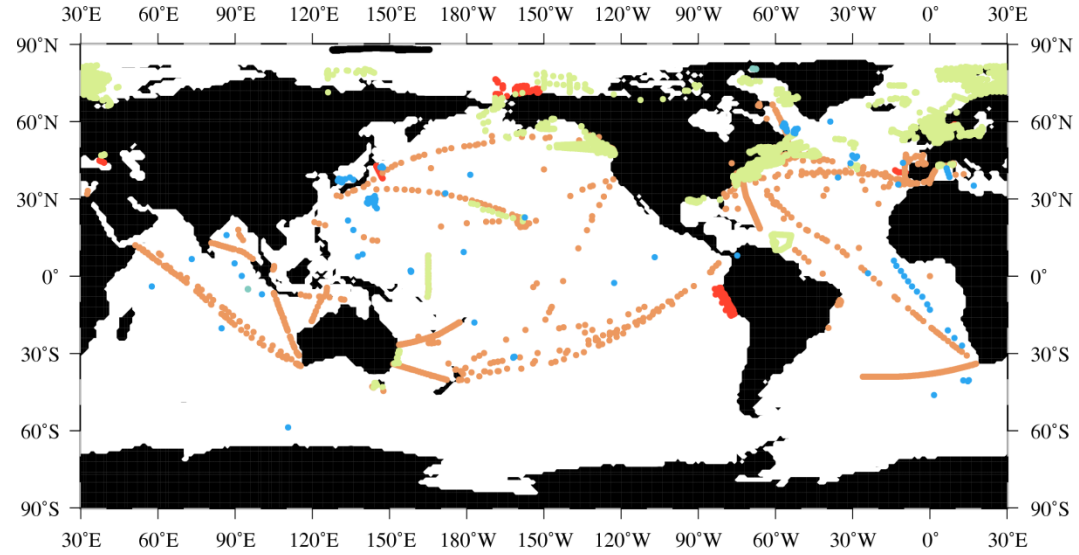
Temperature profiles: Jul-Sep, 2004
36,352 total profiles

Red=bottle,
Orange/Yellow=CTD/XBT/moored buoy
Green=Argo floats
Blue=Drifting buoys



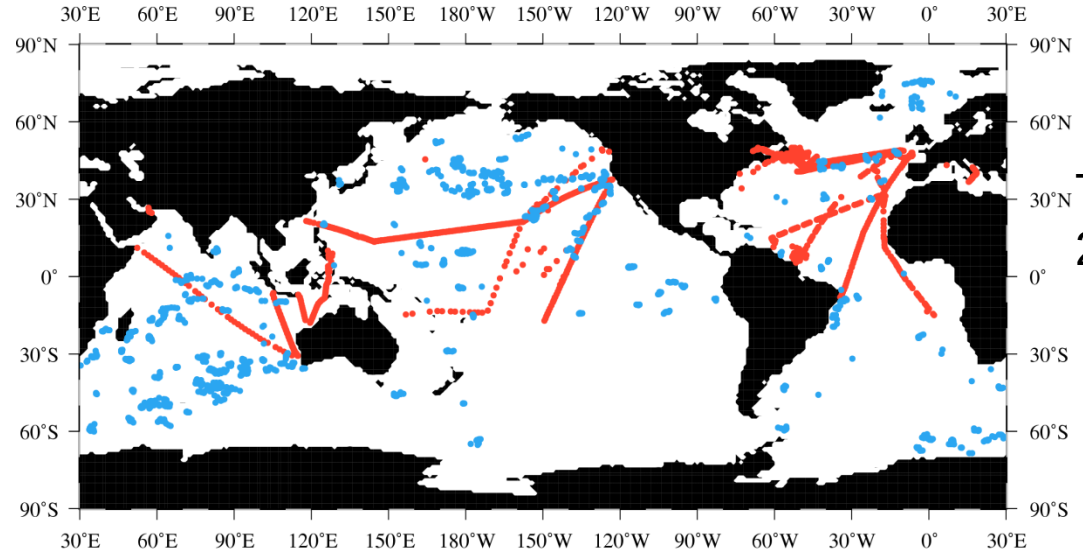
Temperature profiles: Apr-Jun, 2003
9,356 new profiles

NEW DATA
Since L09



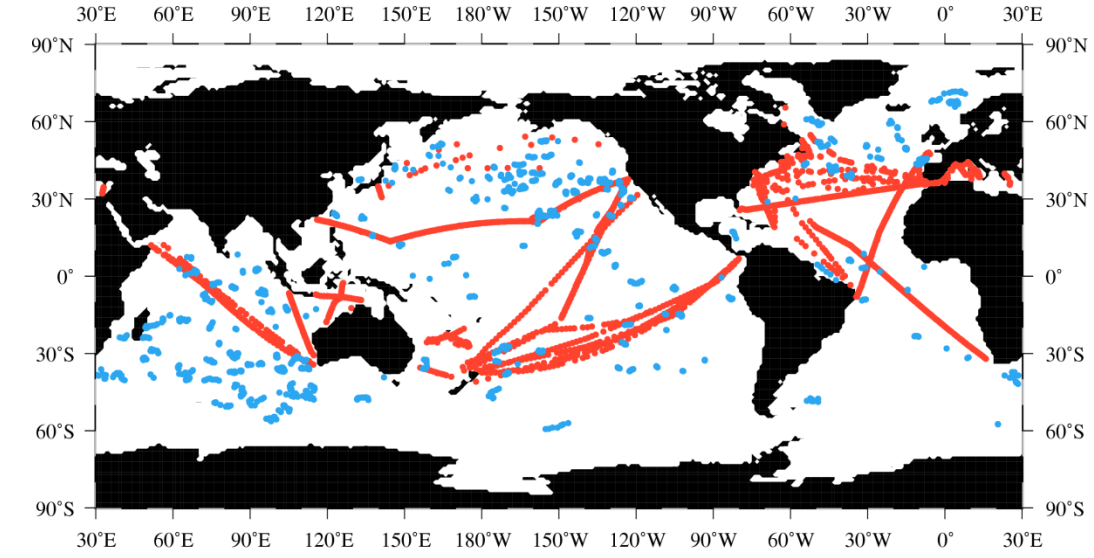
Temperature profiles: Jul-Sep, 2004
9,078 new profiles

Red=bottle,
Orange=XBT
Green=CTD
Blue=Argo floats
Black=Drifting buoys



Temperature profiles: Apr-Jun, 2003
2,800 changed profiles

CHANGED DATA Since L09



Temperature profiles: Jul-Sep, 2004
3,907 changed profiles

Red=XBT,
Blue=Argo floats

Notes on Data Distributions

- Many CTD/bottle data do not come to NODC within 3 months. Many do not come at all.

- Changes to XBT data are usually replacement of real-time data with full profile delayed-mode data, including delayed-mode quality control.

- Changes to Argo profiles are mostly pressure adjustments applied during delayed-mode quality control.

- For Apr-Jun, 2003, mean pressure adj. is 2.9 ± 2.1 db

- For Jul-Sep, 2004, mean pressure adj. is 3.5 ± 2.5 db

Notes on Heat Content differences: published to present

- **Mean difference between seasonal integrals for 1955-2008: 0.51 ± 0.12 x 10^{22}J**

- **For period 1955-2003: 0.33 ± 0.07 x 10^{22}J**
- **For period 2004-2008: 2.17 ± 0.04 x 10^{22}J**

- **Largest differences 2004-2008 in the Southern Hemisphere, where consistent data collection begins ~2004.**

- **Major factor in differences is new/changed data, updated quality control**

- **Questions to be answered: Are quality control differences related to Argo delayed-mode quality control, NODC handling of data, or both?**

Questions or comments: Please send to

OCL.help@noaa.gov