Research and Data Management at the: NODC Ocean Climate Laboratory and WDC for Oceanography

Sydney Levitus
NODC/NOAA
Silver Spring, MD

and

WDC for Oceanography, Silver Spring,
part of the ICSU World Data System (WDS)

November 15, 2012
University of Maryland
Atmospheric and Oceanic Science Seminar

NODC Ocean Climate Lab. (OC5) staff

Sydney Levitus- OCL Director

FEDERAL EMPLOYEES:

1)	Tim Boyer	Oceanographer- OCL Team Leader
2)	Daphne Johnson	International Affairs/Physical Scientist
3)	Dr. Igor Smolyar	Oceanographer/International Affairs
4)	Olga Baranova	Physical Scientist/Programmer/Web work
5)	Dr. Ricardo Locarnini	Oceanographer
6)	Melissa Zweng	Oceanographer
7)	Chris Paver	Oceanographer
8)	Carla Forgy	Computer Clerk/QC of data
9)	Charlotte Sazama	WDC for Oceanography- (40% FTE)

8.4 Federal FTEs

CONTRACTORS:

10)	Dr. Alexey Mishonov	Oceanographer
11)	Alexandra Grodsky	Physical science technician, metadata quality control

UCAR VISITING SCIENTIST:

12)	Dr. John Antonov	Oceanographer (UCAR)

CICS scientist:

13)	James Reagan	Faculty Research Assistant (CICS)-Oceanographer

4 non-Federal FTEs

Also

Thanks to:

Dr. Hernan Garcia
Dr. Dan Seidov
Dr. Charles Sun
Melanie Hamilton
Matt Biddle

and other NODC staff for their contributions to data processing including the development of high-resolution climatologies.

FY12 publications

1) Helber, R. W. A. Birol Kara, J. G. Richman, M. R. Carnes, C. N. Barron, H. E. Hurlburt, and T. Boyer, 2012: Temperature versus salinity gradients below the ocean mixed layer J. Geophys. Res., 117, C05006, doi:10.1029/2011JC007382.

2) T. Boyer, S. Levitus, S. J. Antonov, J. Reagan, C. Schmid, and R. Locarnini, 2012: [Subsurface salinity] Global Oceans [in "State of the Climate in 2011"]. Bull. Amer. Meteor. Soc., 93 (7), S72-S75.

3) G. C. Johnson, J. M. Lyman, J. K. Willis, S. Levitus, T. Boyer, J. Antonov, and S. A. Good, 2012: [Ocean heat content] Global Oceans [in "State of the Climate in 2011"]. Bull. Amer. Meteor. Soc., 93 (7), S62-S64.

4) Levitus, S., 2012: The UNESCO/IOC/IODE "Global Oceanographic Data Archaeology and Rescue" (GODAR) and "World Ocean Database" projects. Data Sci. J., 11, 46-71,
published online at https://www.jstage.jst.go.jp/browse/dsj/11/0/_contents.

5) Gouretski,V. J. Kennedy, T. Boyer, and A. Köhl: 2012 Consistent near-surface ocean warming since 1900 in two largely independent observing networks. Geophys. Res. Lett., 39, L19606, doi:10.1029/2012GL052975.

6) Xue, Y., M. A. Balmaseda, T. Boyer, N. Ferry, S. Good, I. Ishikawa, A. Kumar, M. Rienecker, A. J. Rosati, and Y. Yin, 2013: A Comparative Analysis of Upper Ocean Heat Content Variability from an Ensemble of Operational Ocean Reanalyses. J. Clim., 6905-6929, doi:10.1175/JCLI-D-11-00542.1.

Recent Research on Ocean Heat Content

Levitus, S., J. I. Antonov, T. P. Boyer, O. K. Baranova, H. E. Garcia, R. A. Locarnini, A. V. Mishonov, J. R. Reagan, D. Seidov, E. S. Yarosh, M. M. Zweng, 2012: World Ocean heat content and thermosteric sea level change (0-2000 m) 1955-2010. *Geophys. Res. Lett*., 39, L10603, doi:10.1029/2012GL051106.

Building on earlier work:

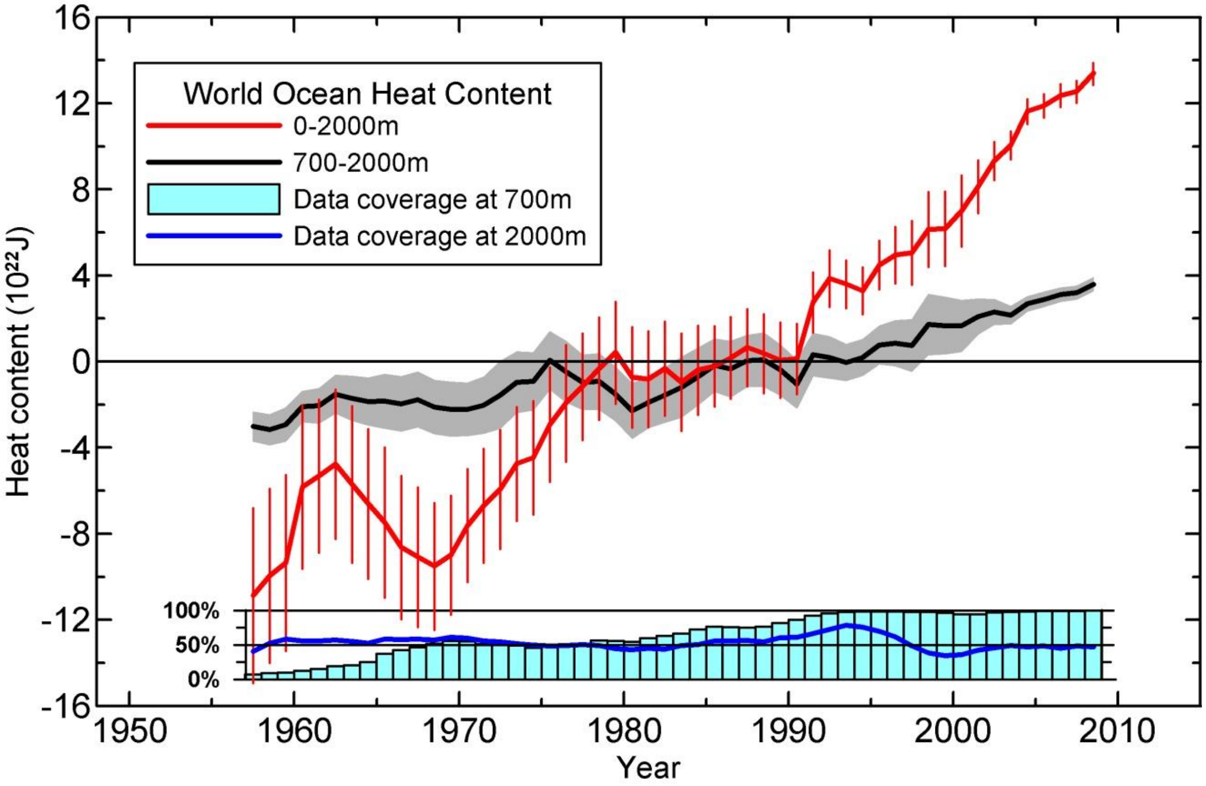
Levitus, S., J. Antonov, and T.P. Boyer, C. Stephens, 2000: Warming of the World Ocean. Science, 287, 2225-2229.

Levitus, S., Antonov, J. Wang, T. L. Delworth, K. W. Dixon, and A. J. Broccoli, 2001: Anthropogenic warming of earth's climate system. Science, 292, 267-270.

Levitus, S., J. I. Antonov, T. P. Boyer, 2005: Warming of the World Ocean, 1955-2003. Geophys. Res. Lett., L02604, doi:10.1029/2004GL021592.

Levitus, S., J. I. Antonov, T. P. Boyer, H. E. Garcia, R. A. Locarnini, 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.

World Ocean Heat Content (1955-2010) based on running pentads (5-year periods)



Levitus *et al.* (2012)

The 0-2000 m layer of the world ocean has warmed by ~ 0.09° C [24.0 ± 1.9x10^{22} J] in the 1955-2010 period.

30% of ocean warming for the 1955-2010 period occurred in the 700-2000 m layer

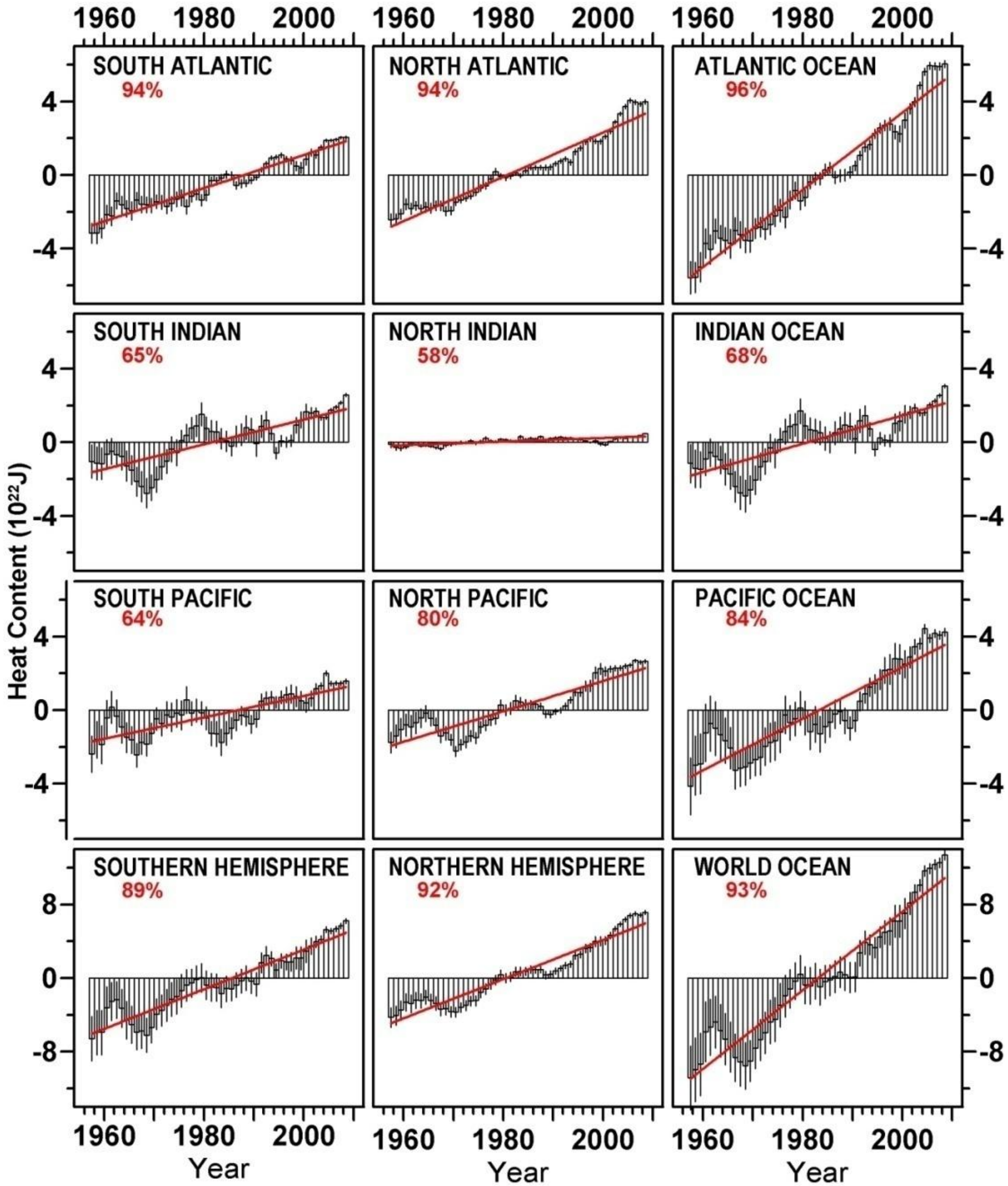
World Ocean heat content (10^{22} J) (1955-2010) for the 0-2000 m (red) and 700-2000 m (black) layers of the world ocean based on running pentadal (five-year) analyses. Reference period is 1955-2006.

Each pentadal estimate is plotted at the midpoint of the 5-year period. The vertical bars represent +/- 2.*S.E. about the pentadal estimate for the 0-2000 m estimates and the grey-shaded area represent +/- 2.*S.E. about the pentadal estimate for each 0-700 m estimate.

The light blue bar chart at the bottom represents the percentage of one-degree squares (globally) that have at least four pentadal one-degree square anomaly values used to compute one-degree square values at 700 m depth.

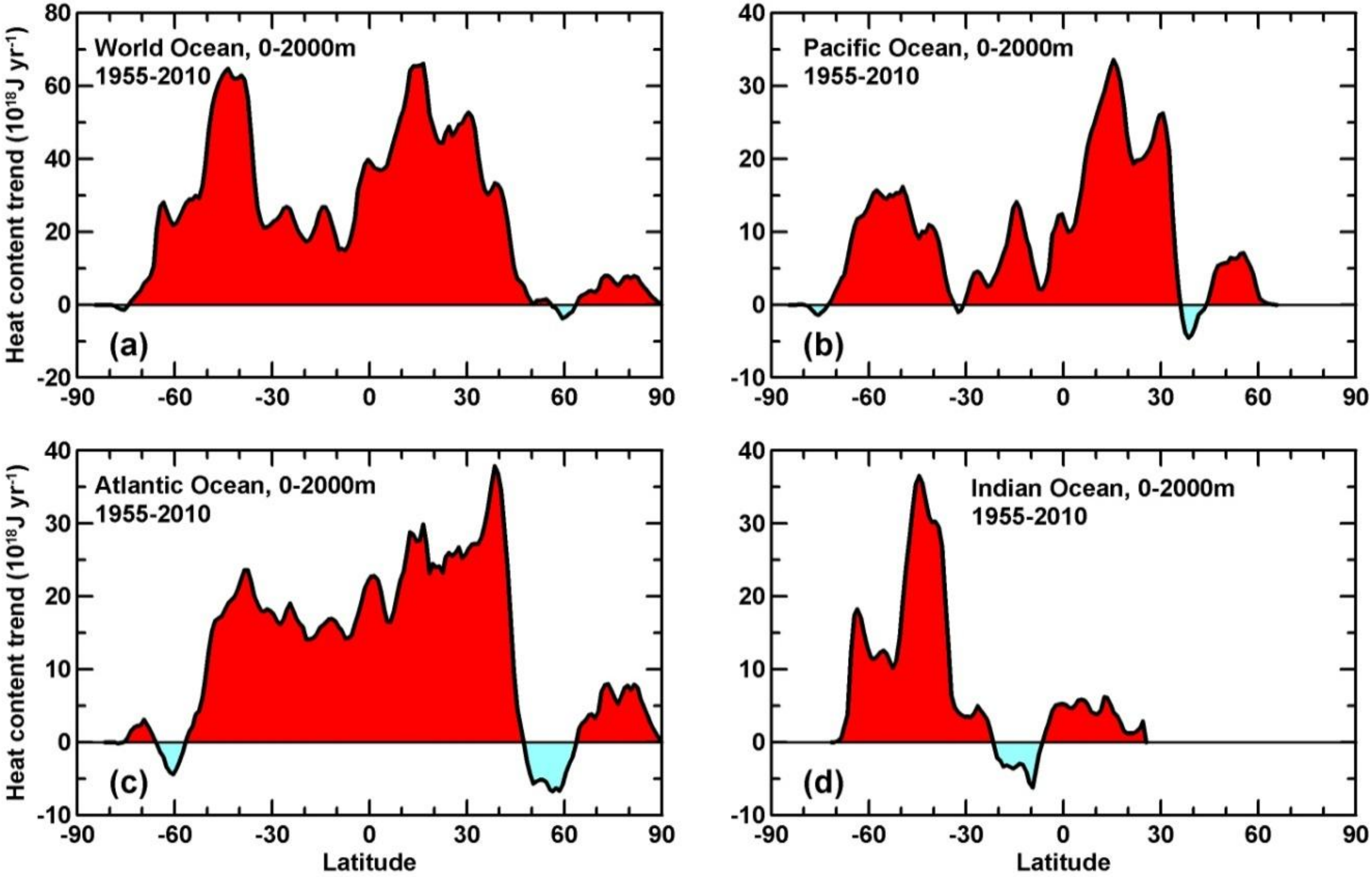
The dark blue line is the same quantity as for the bar chart but for 2000 m depth.

Time series (1955-2010) of ocean heat content (10^{22}J) for the 0-2000 m layer



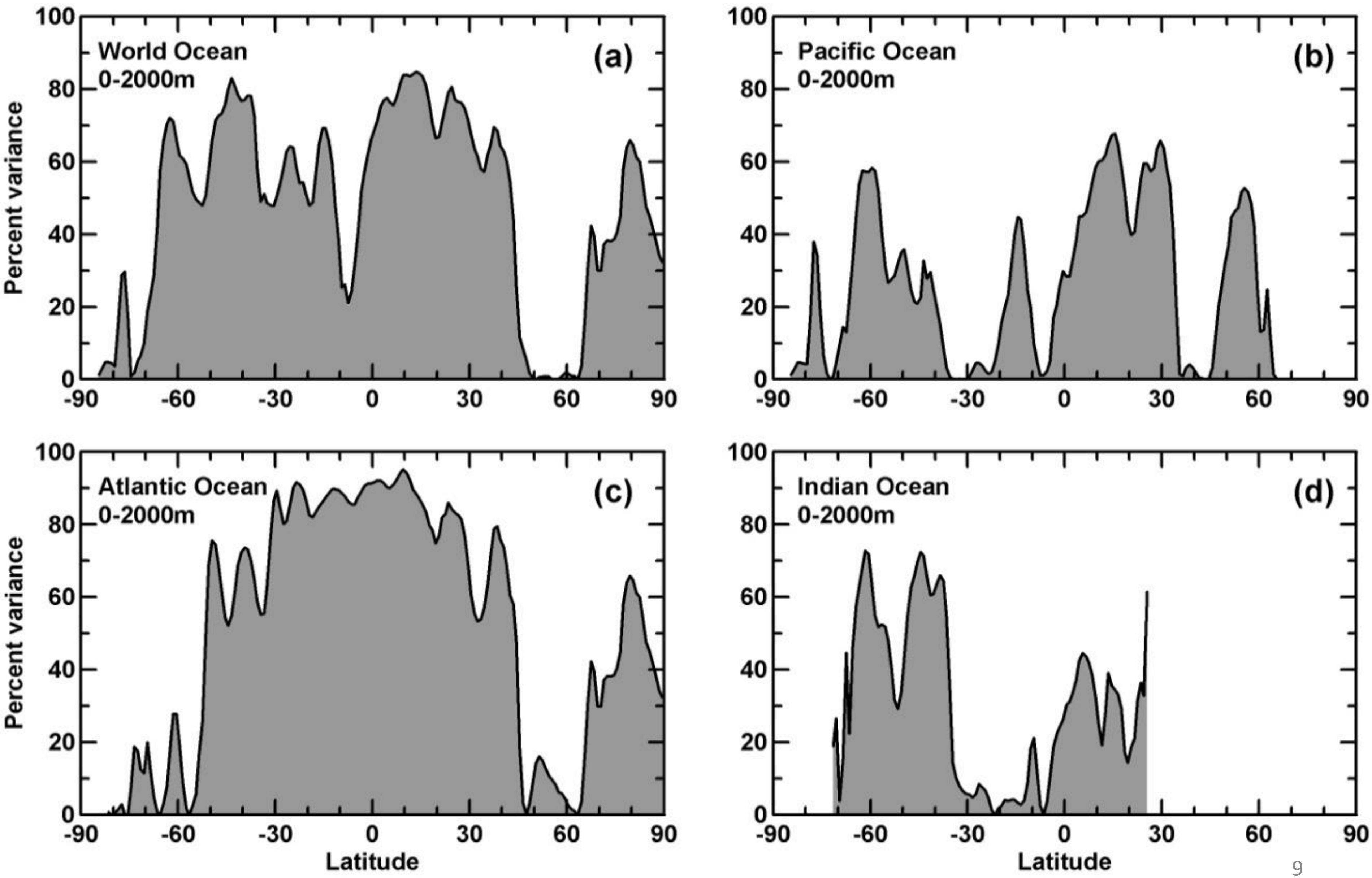
Time series of ocean heat content (10^{22}J) for the 0-2000 m layer for the major ocean basins based on running pentadal analyses.
Each pentadal estimate is plotted at the midpoint of the 5-year period. The vertical bars represent +/- 2.*S.E. about the pentadal estimate.
The linear trend line and the percent variance accounted for by the linear trend are shown in red on each panel. Reference period is 1955-2006.

Linear trend (10^{18} J yr^{-1}) (1955-1959) to (2006-2010) of zonally integrated ocean heat content as function of latitude for the 0-2000 m layer.

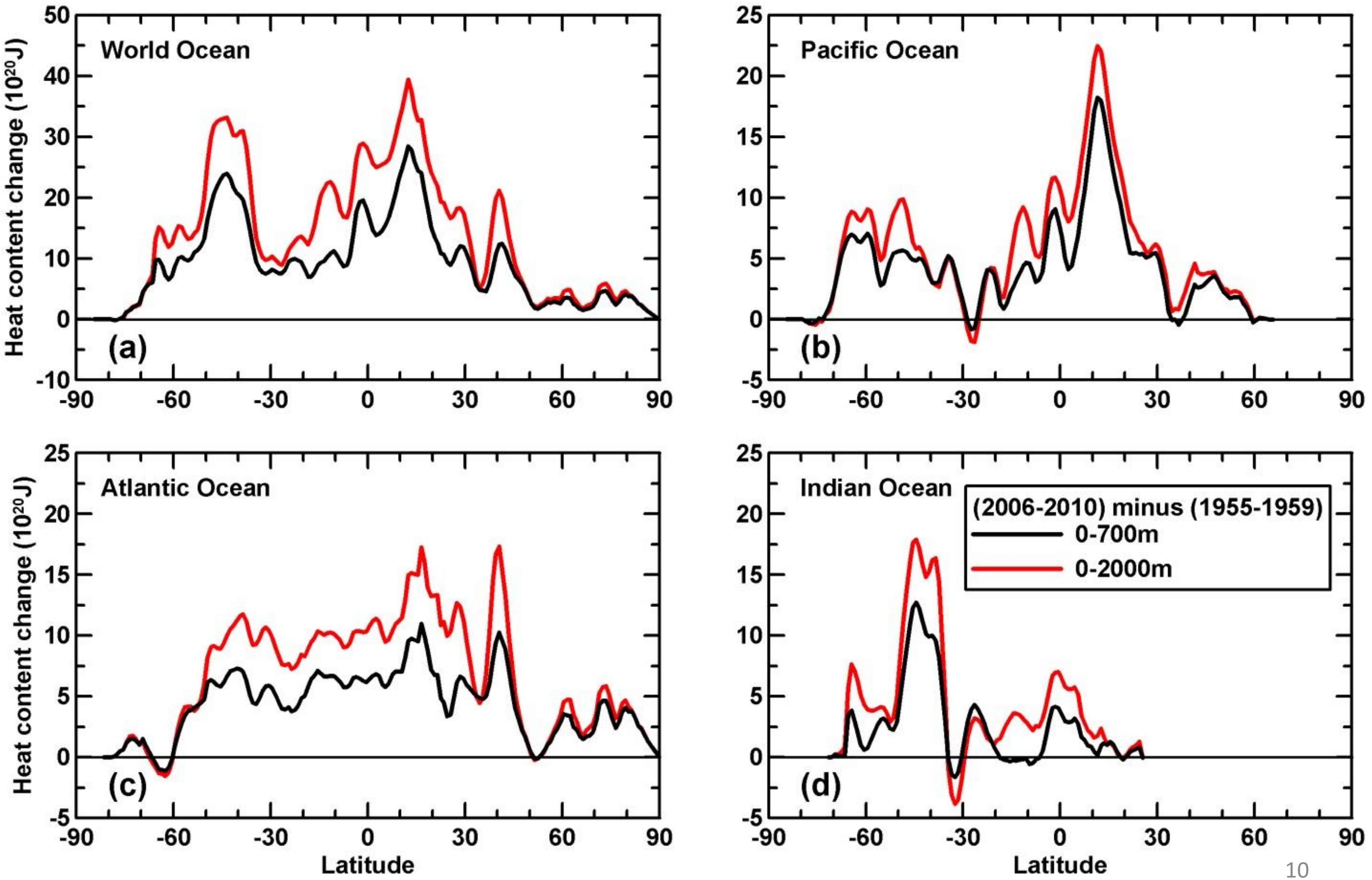


Red indicates a positive trend and blue a negative trend.

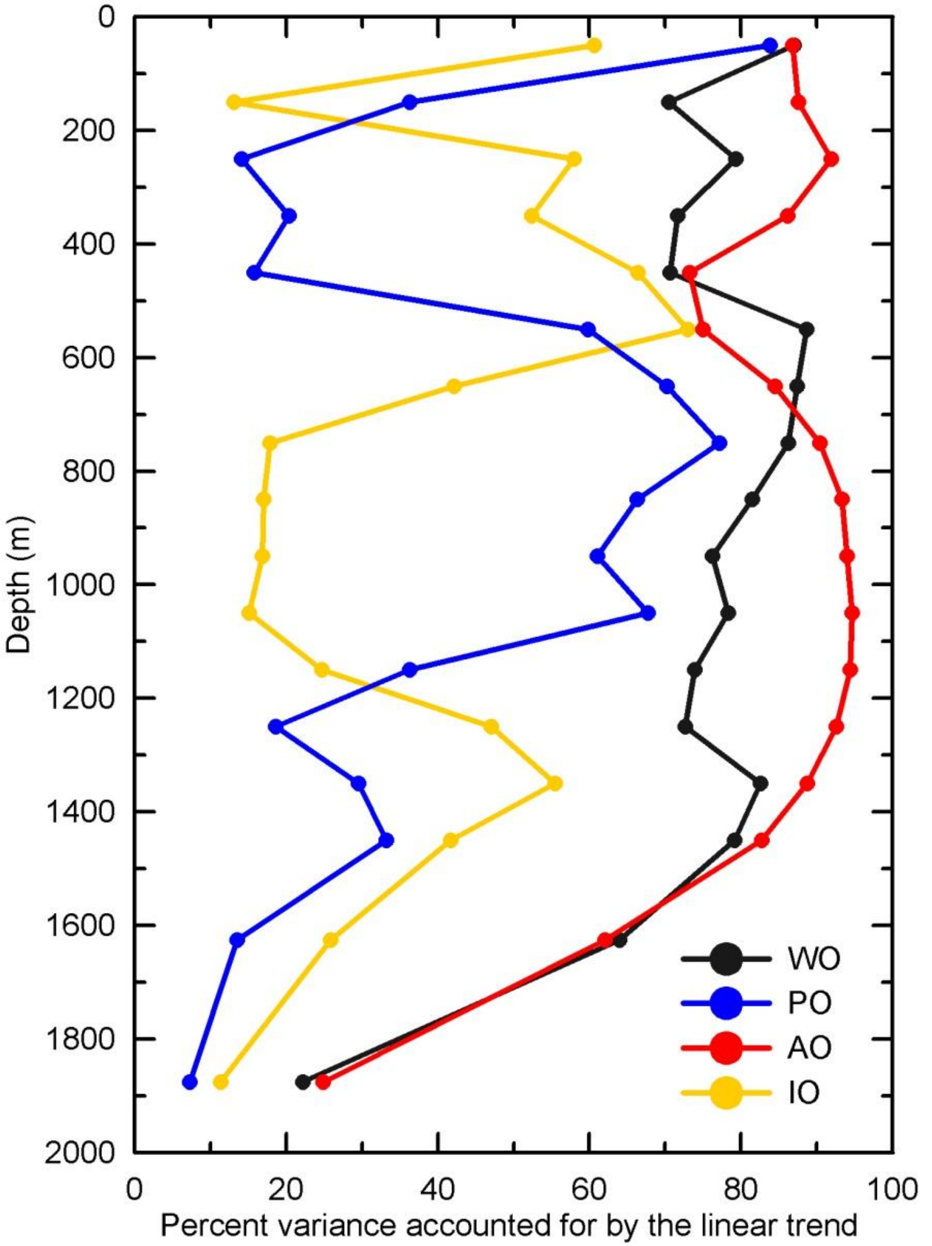
Percent variance accounted for by the linear trend of zonally integrated ocean heat content (0-2000 m layer) as a function of latitude for individual ocean basins



Zonal integral of the difference (2006-2010) minus (1955-1959) in OHC700 and OHC2000 for the World, Pacific, Atlantic, and Indian oceans as function of latitude. Units of all curves are 10^{20} J.

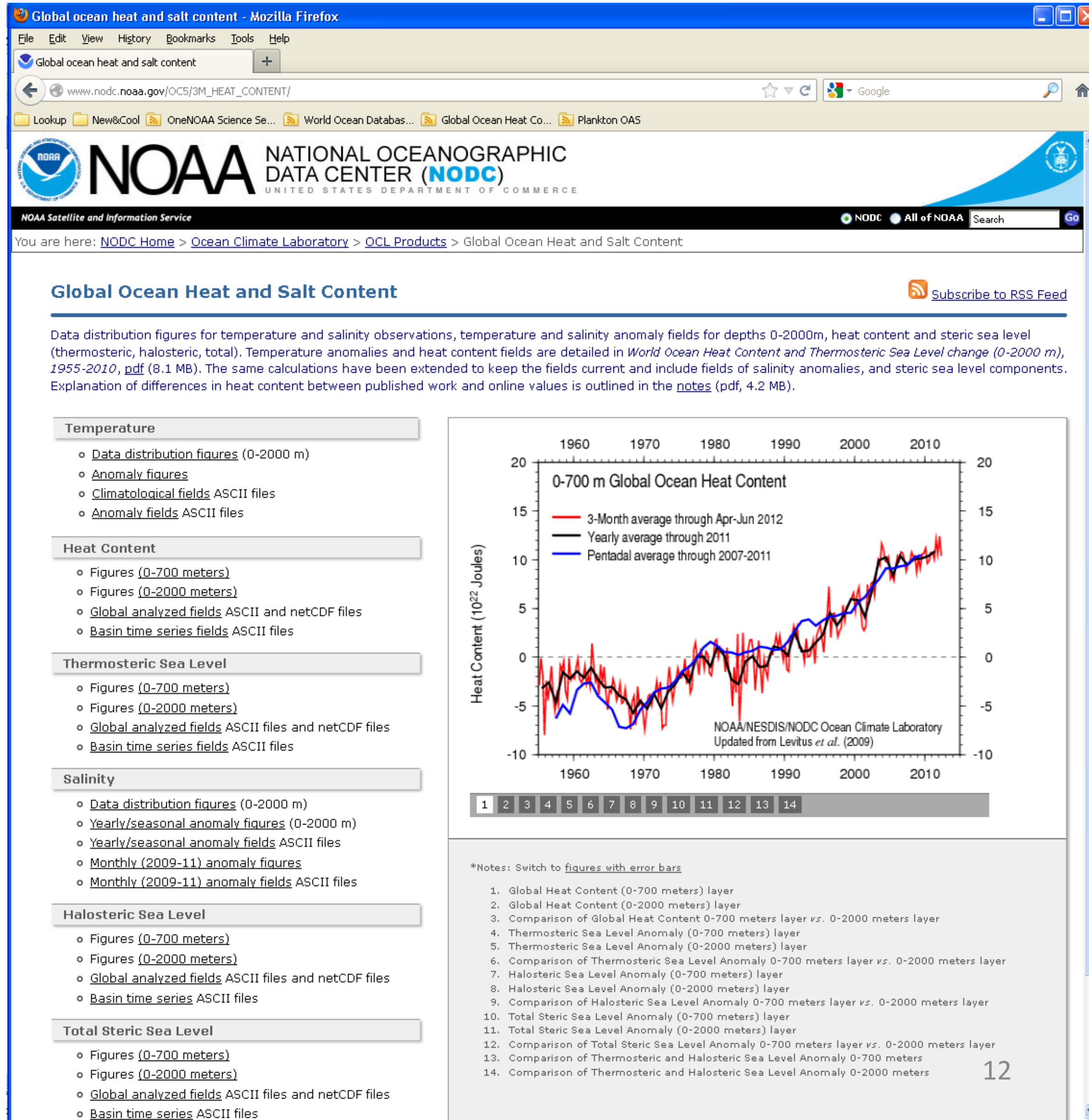


Percent variance accounted for by the linear trend of ocean heat content by 100 m-layers for 1955-2010 for individual ocean basins



What are some of our products that are available online?

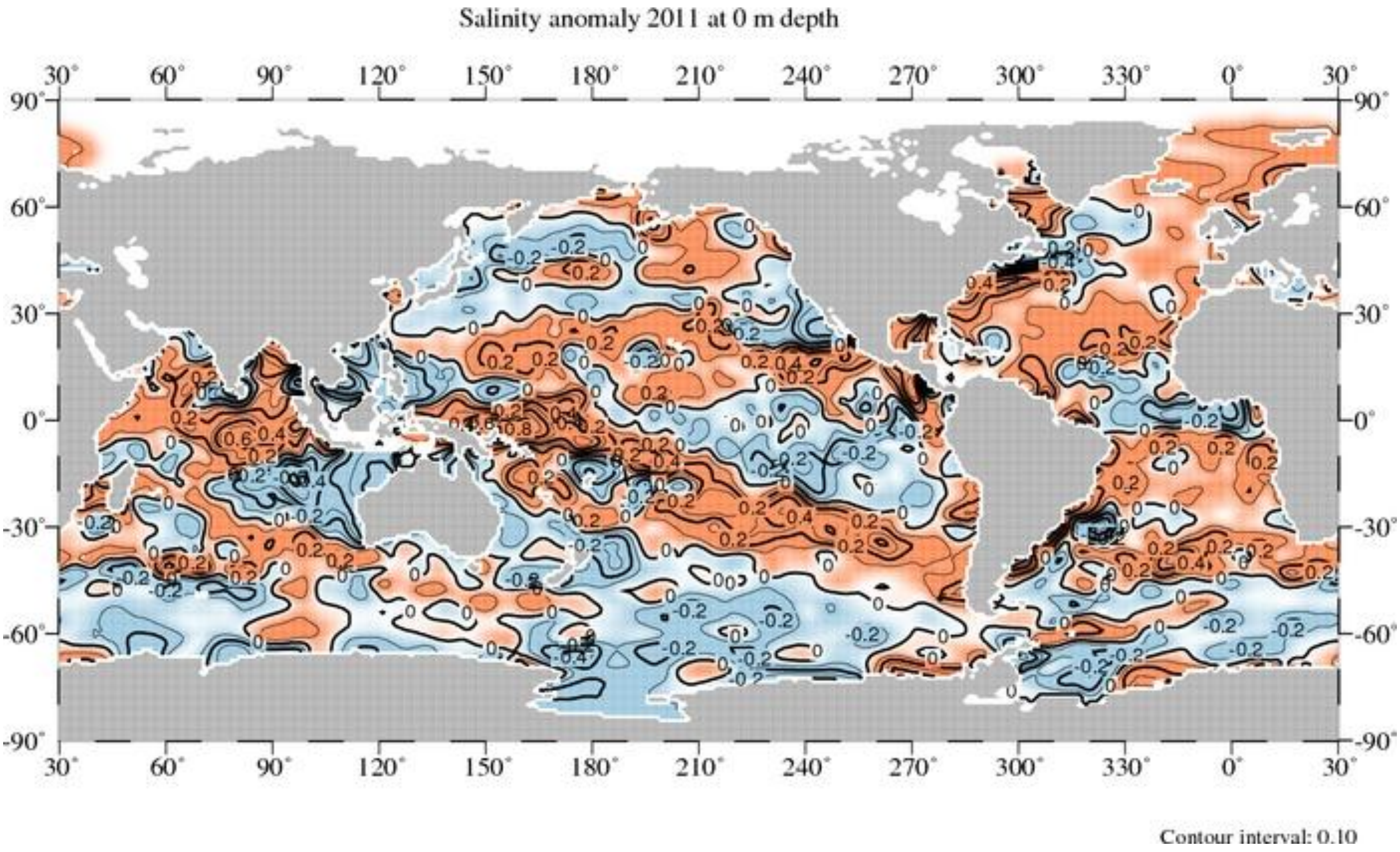
World Ocean T anomalies, S anomalies, Heat Content, and Steric Components of sea level change, (0-700 m, 0-2000 m) updated every 3 months.



www.nodc.noaa.gov

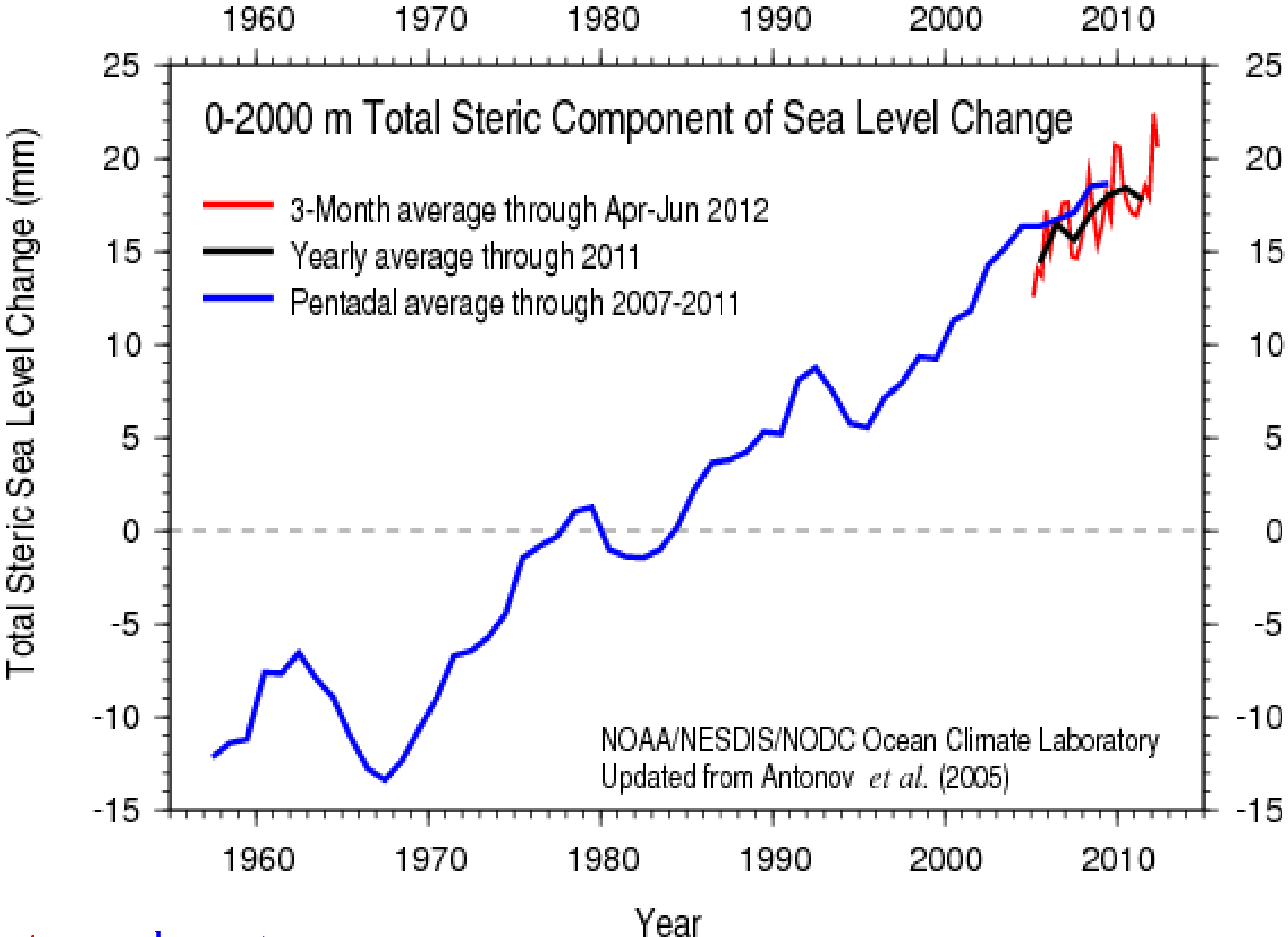
Web page developed by Olga Baranova and Tim Boyer

Annual salinity anomaly at z = 0. for 2011



Online at www.nodc.noaa.gov

0- 2000 m steric component of sea level change



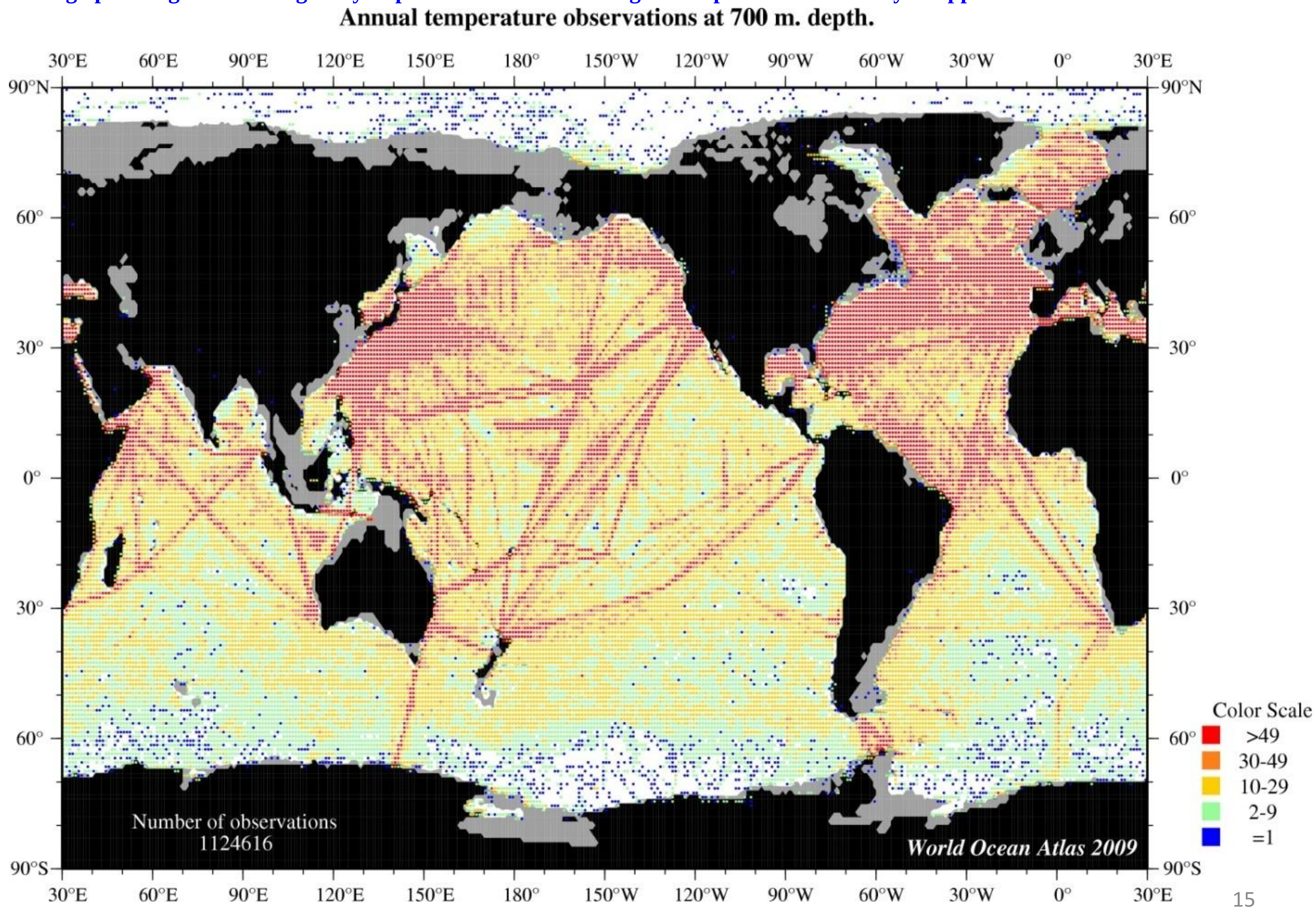
Online at www.nodc.noaa.gov

It is the thermosteric component of sea level change that is the main contributor to the total change.

Halosteric component can be very important regionally.

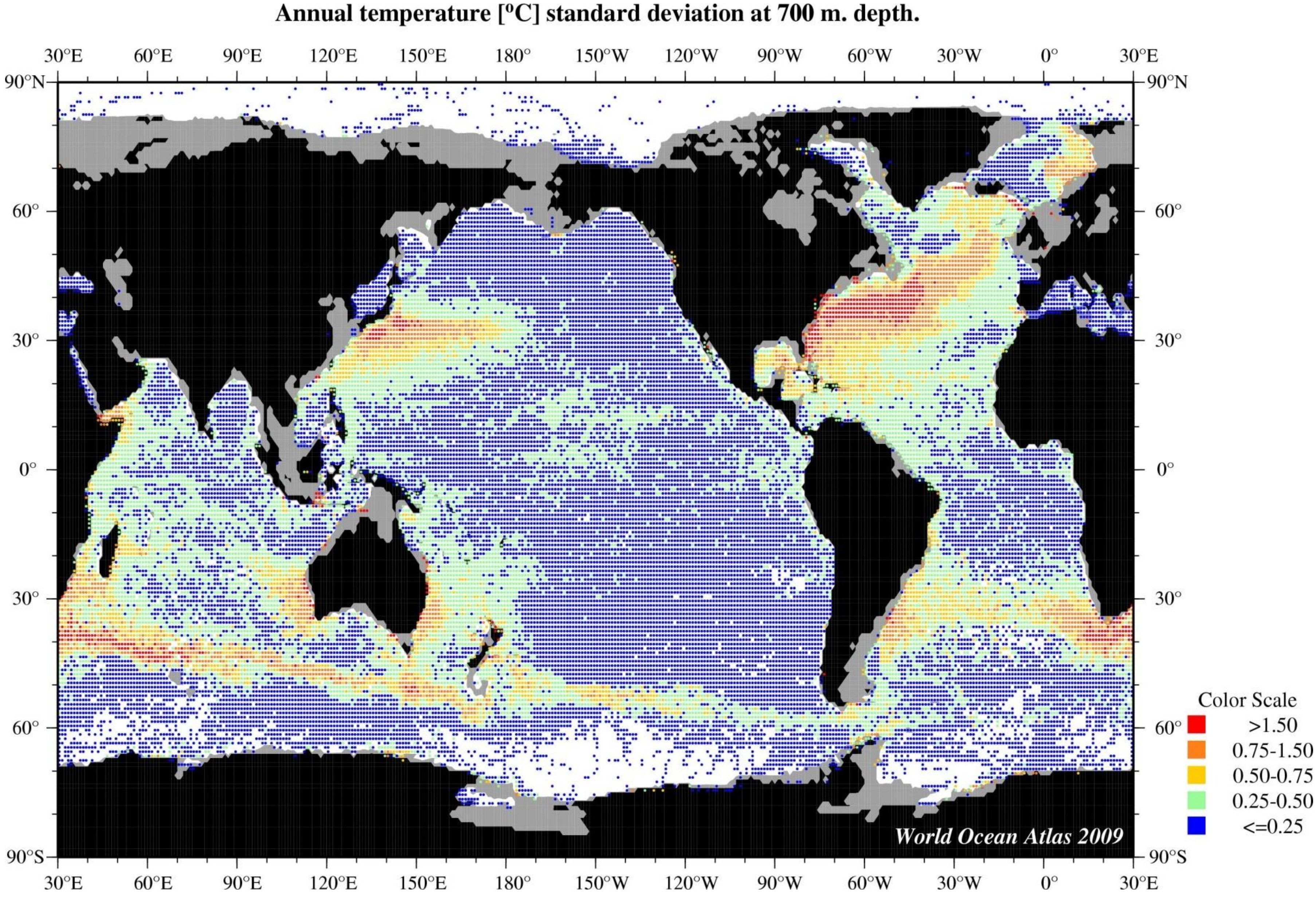
Distribution of all temperature observations used in this study at 700 m depth

Argo profiling floats have greatly improved ocean monitoring of Temperature & Salinity in upper 2000 db of the world ocean



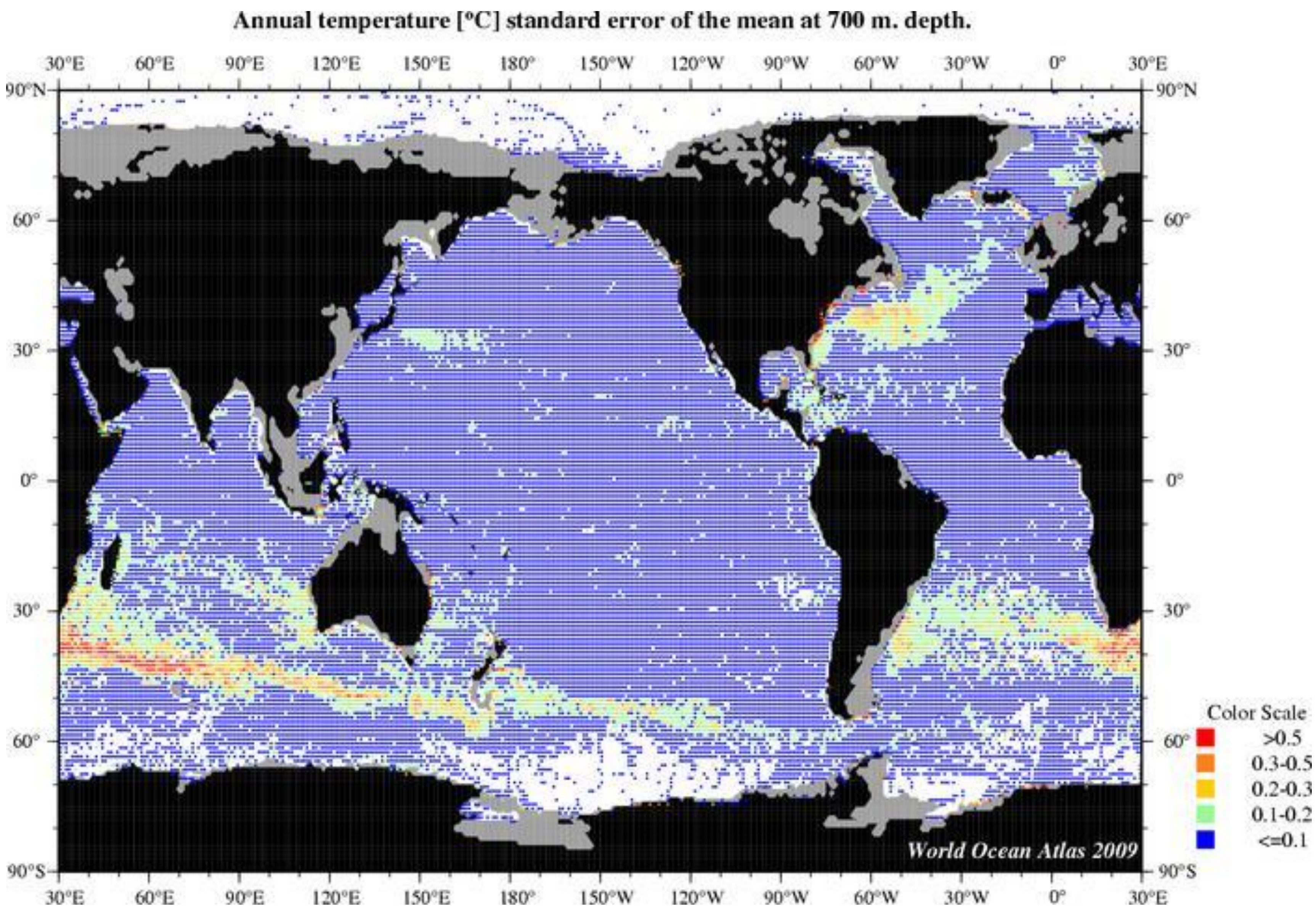
From Locarnini *et al.* (2010). Atlas is available online at www.nodc.noaa.gov

All-data temperature standard deviation (°C) at 700 m depth



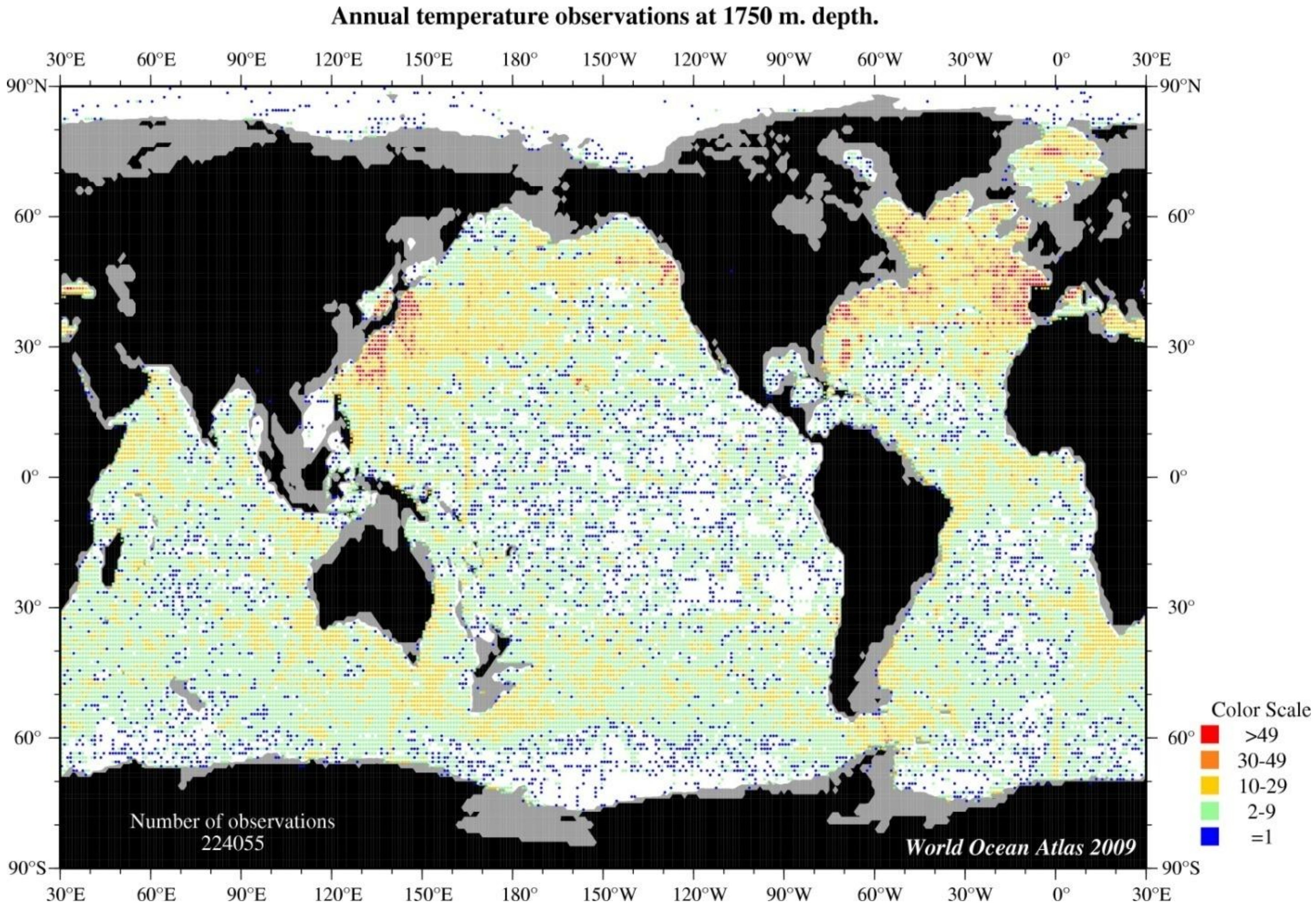
From Locarnini *et al*. (2010)

All-data temperature standard error of the mean (°C) at 700 m depth



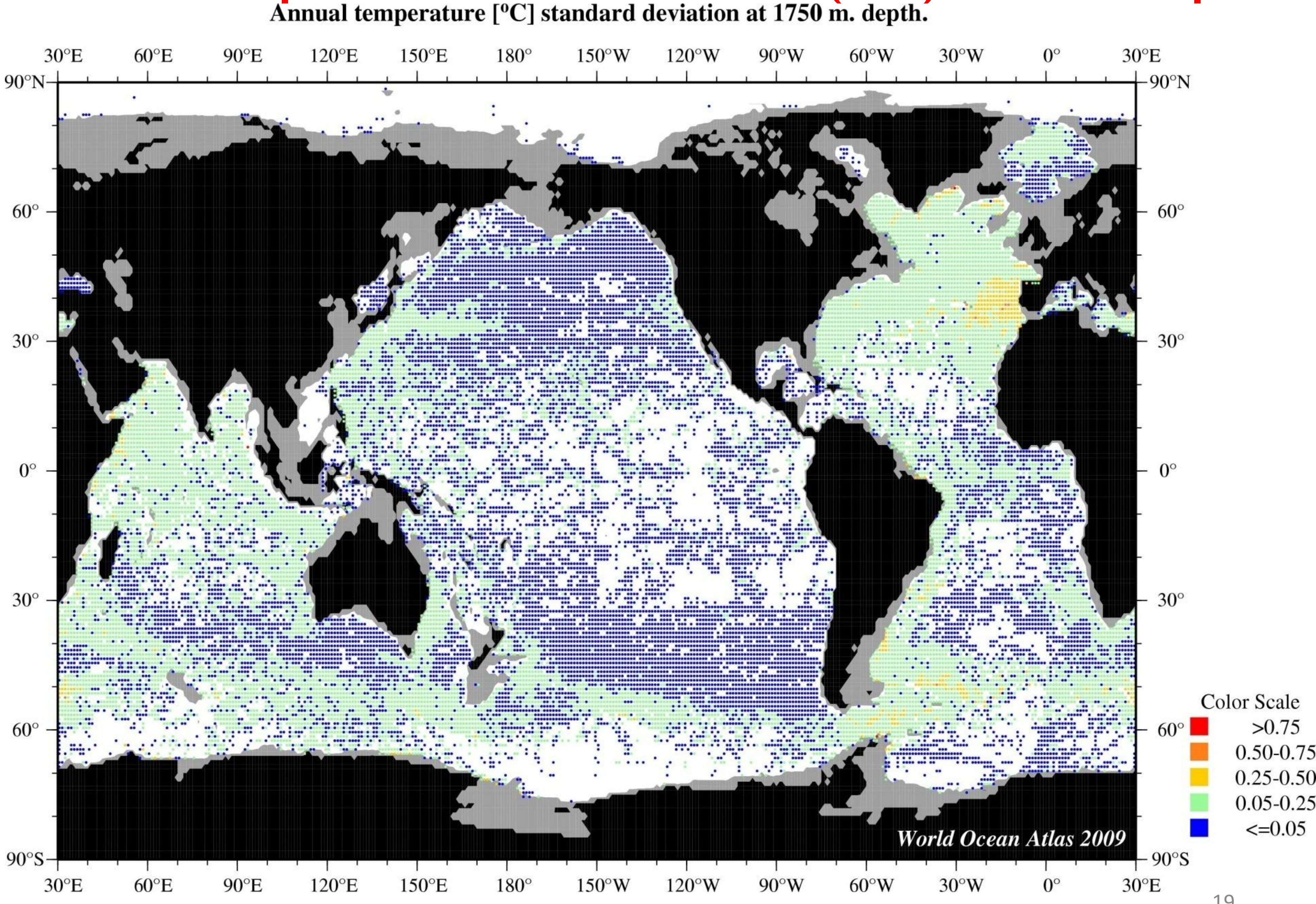
From Locarnini *et al*. (2010)

Distribution of all temperature observations at 1750 m depth



From Locarnini *et al*. (2010)

All-data temperature standard deviation (° C) at 1750 m depth



From Locarnini *et al.* (2010)

Data Management

Extended vertical resolution (EVR) is being introduced for WOD & WOA & other products such as regional climatologies.

WOD profiles will be available at 103 standard depth level between the surface and 5500 m depth as compared to 33 levels in previous works and WOA analyses will be performed at these same 103 levels (Boyer *et al.* (2013)).

1) Every 5 m for 0-100 m layer

2) Every 25 m for 100-500 m layer

3) Every 50 m for 500-2000 m layer

4) Every 100 m for 2000-5500 m layer

5) Actually can extend down to 9,000 m depth.

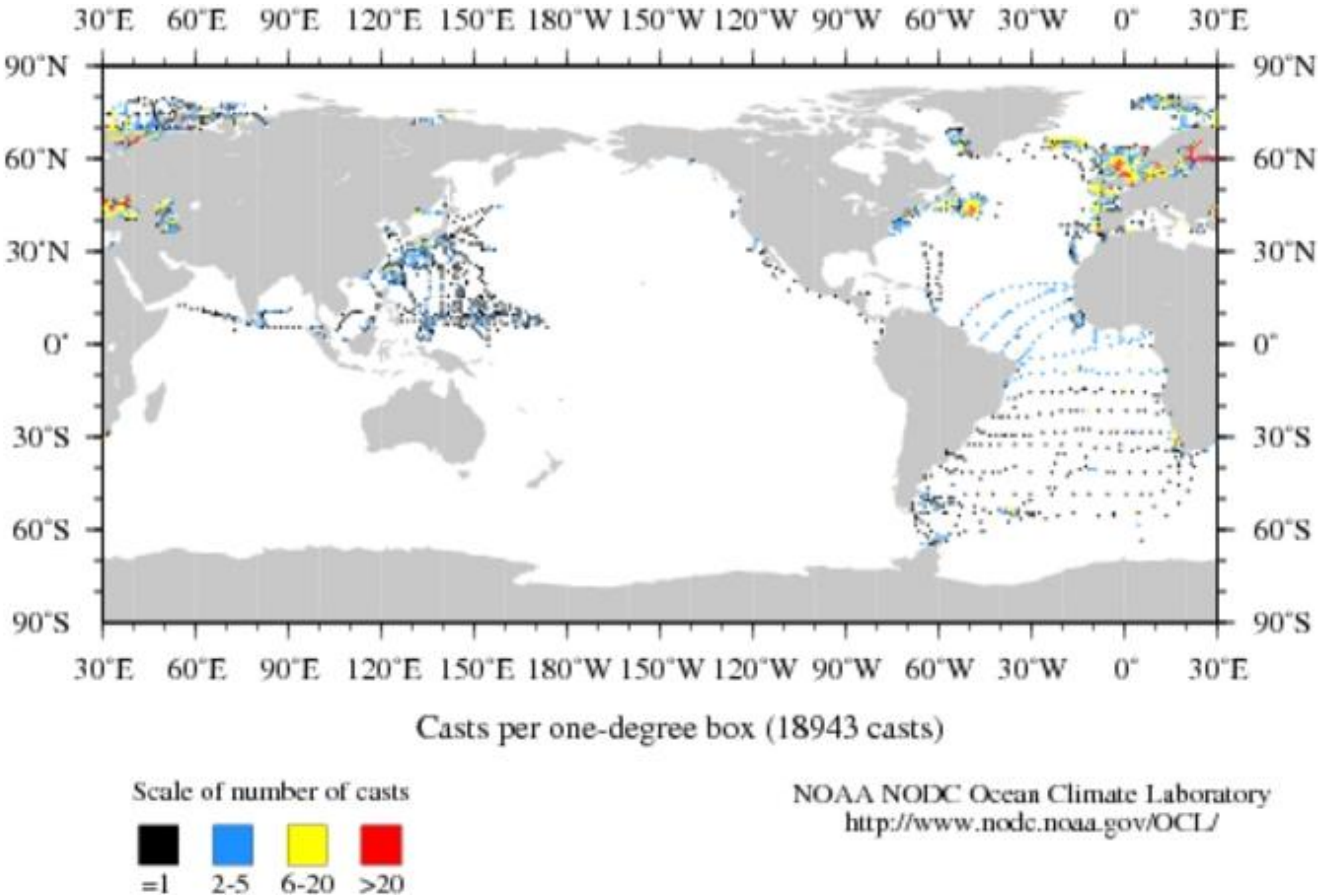
***GODAR*, *ICOADS*, *etc*. are no longer funded by the NOAA/CPO office but they live!**

IOC/IODE

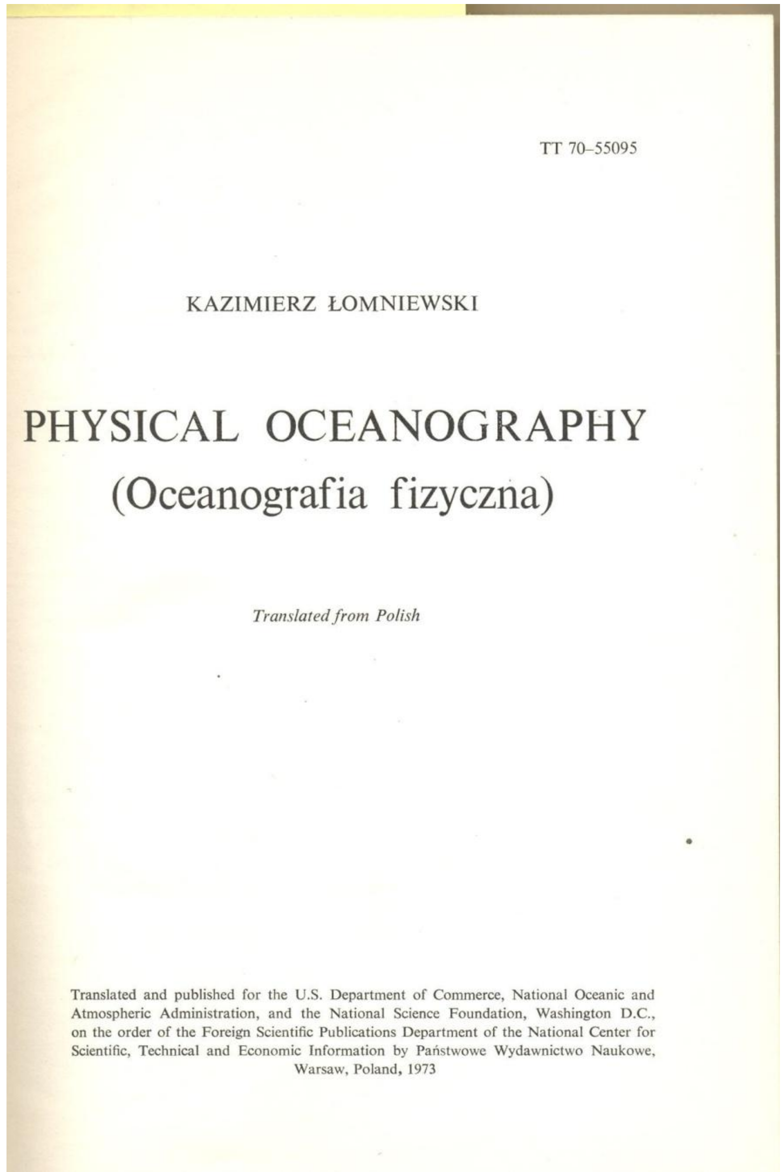
***Global Oceanographic Data Archaeology and Rescue* project.**

What follows is a recent example of GODAR activity.

WOD09 Ocean Station Data locations, 1925-1927, all countries



Polish oceanography textbook, found in a Wash., D.C. bookstore- Translated into English by D.O.C. / NOAA



TT 70–55095

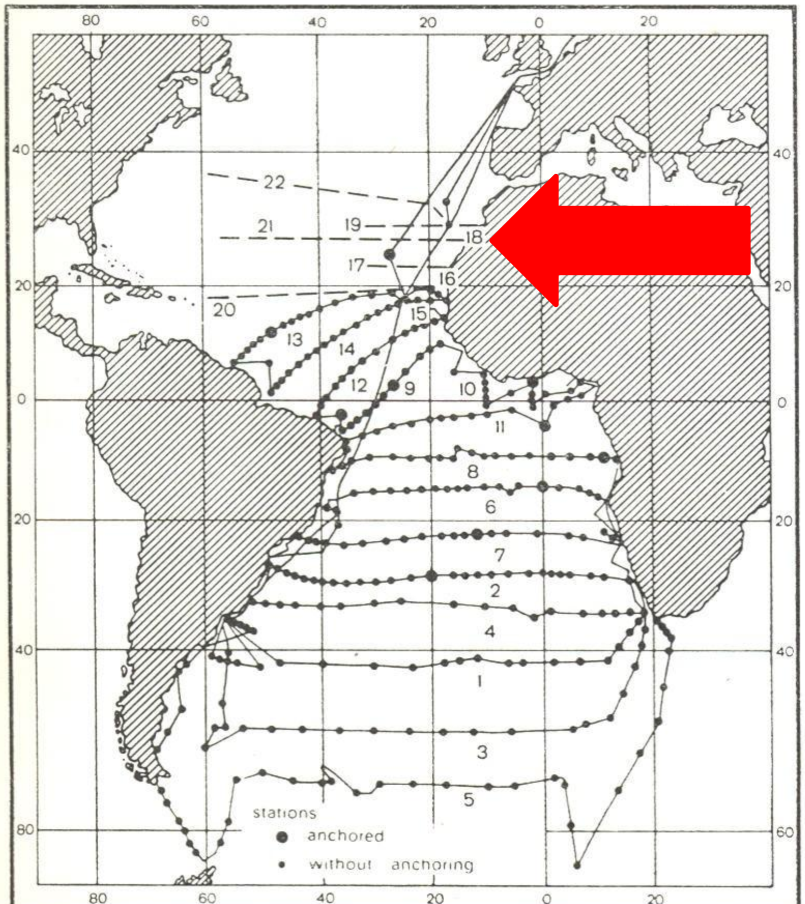
KAZIMIERZ ŁOMNIEWSKI

PHYSICAL OCEANOGRAPHY
(Oceanografia fizyczna)

Translated from Polish

Translated and published for the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, and the National Science Foundation, Washington D.C., on the order of the Foreign Scientific Publications Department of the National Center for Scientific, Technical and Economic Information by Państwowe Wydawnictwo Naukowe, Warsaw, Poland, 1973

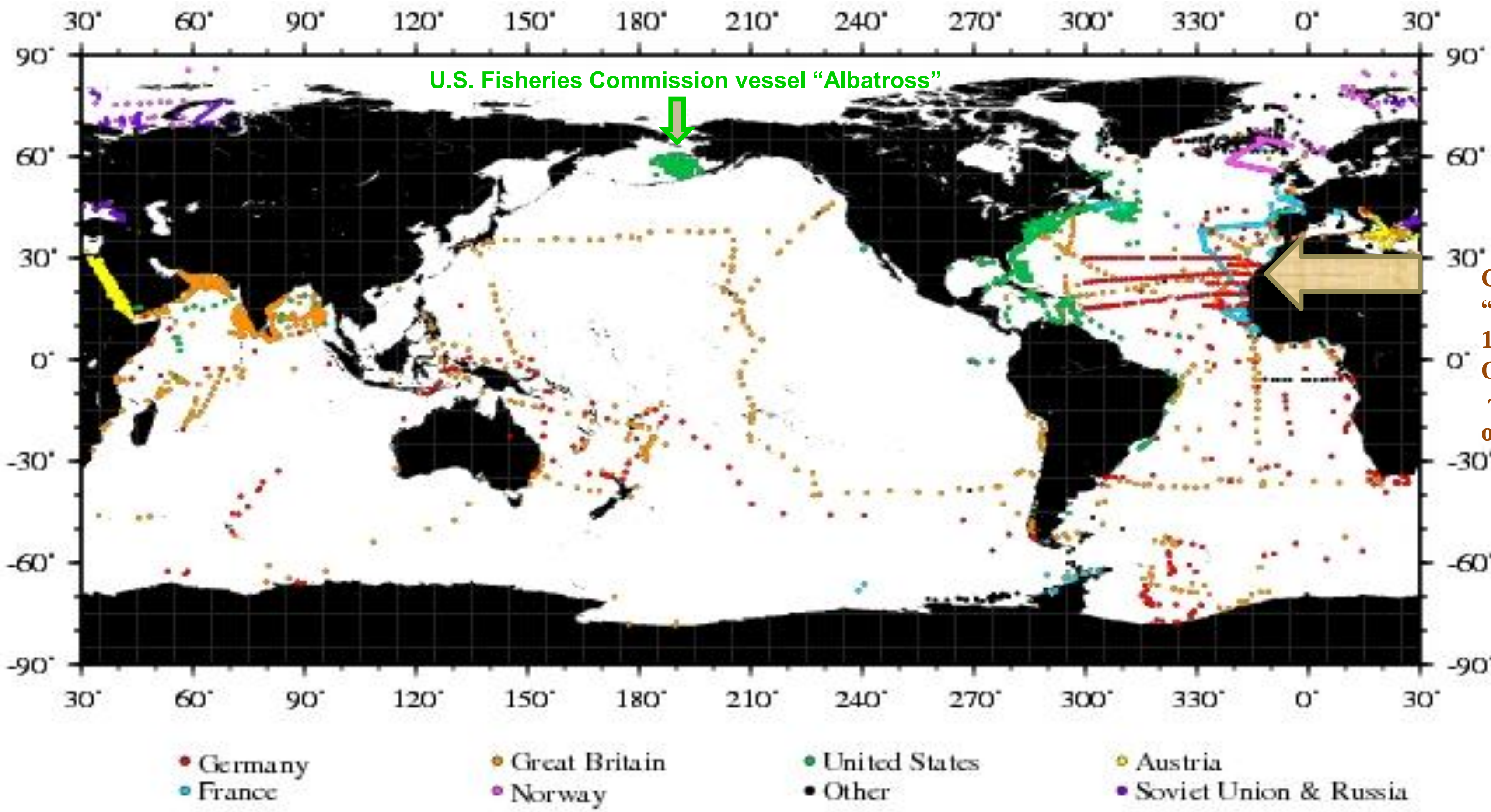
From the Polish textbook written by K. Lomniewski- “Physical Oceanography”



Missing “Meteor” ship data from the 1930s (sections 15-21)

Fig. 7. Profiles of the “Meteor” in Southern Atlantic in the years 1925–1927 (1–14) and additionally in the years 1937–1938 (15–21)

Ocean Station Data archived stored in (East) Germany that survived WWII that were recently rescued from paper records (1868-1945)

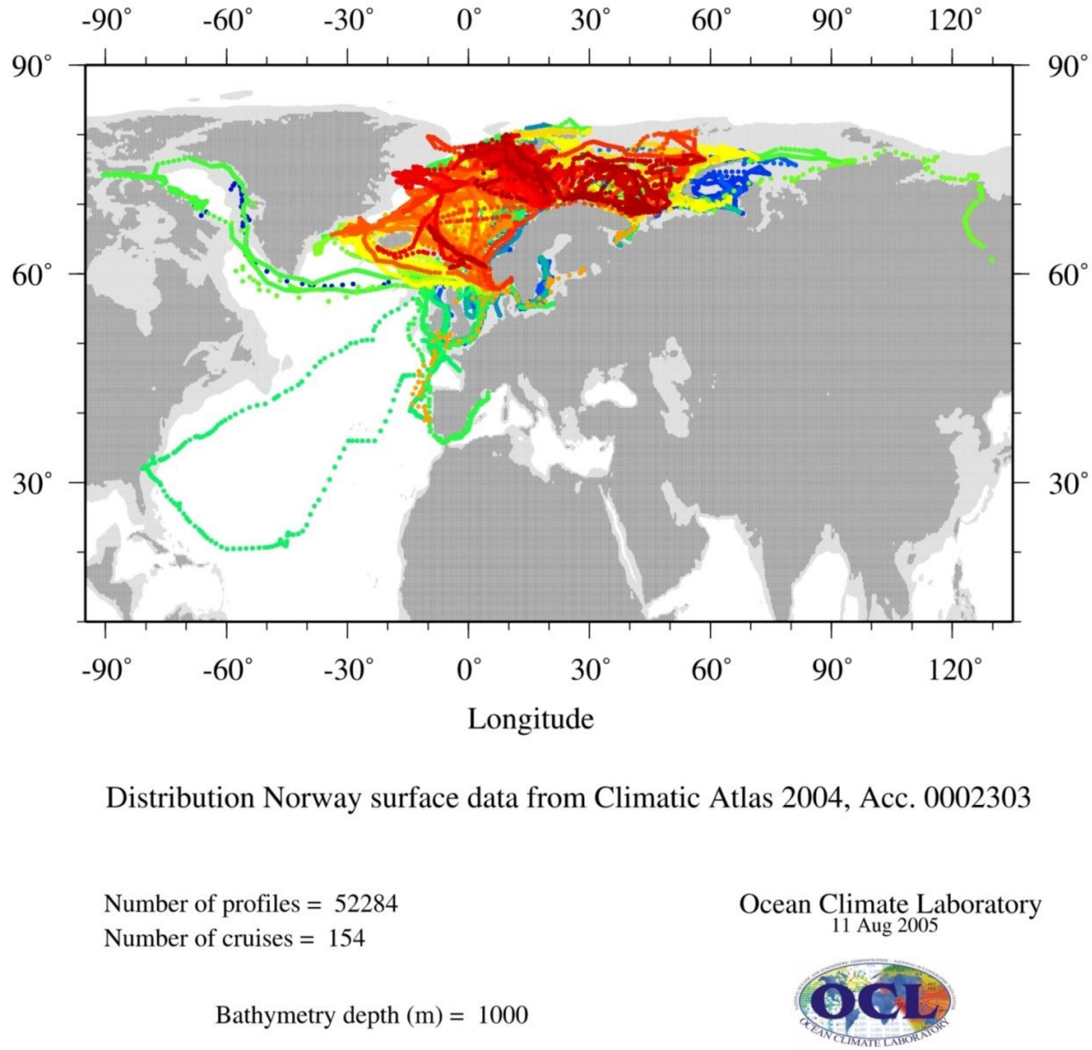


German ship "Meteor" data 1937-38. Observations to ~500 m depth only.

Number of casts = 5,016   Observation dates: June 1868 – May 1945

Contribution to the IOC GODAR project by the BSH
(Bundesamt fuer Seeschifffahrt und Hydrographic of the Deutsches Ozeanographisches Datenzentrum-
Federal Maritime and Hydrographic German Oceanographic Data Centre)

Norwegian surface-only data in WOD09



European countries are now making much more of their data available in a timely manner, *e.g.*, ICES countries formerly had a 10 year "hold" on their data. This "hold" has ended.

But some countries, *e.g.*, India, People's Republic of China, … are still not very forthcoming with their ocean data, or at least certain types of ocean data. This could be for military, economic reasons (fisheries), or …

Past, Present, and Future

1)

The scientific community has found great value in the WOD.

WOD and products based on WOD (e.g., WOA) have been cited ~ 400 times per year for the last 12 years.

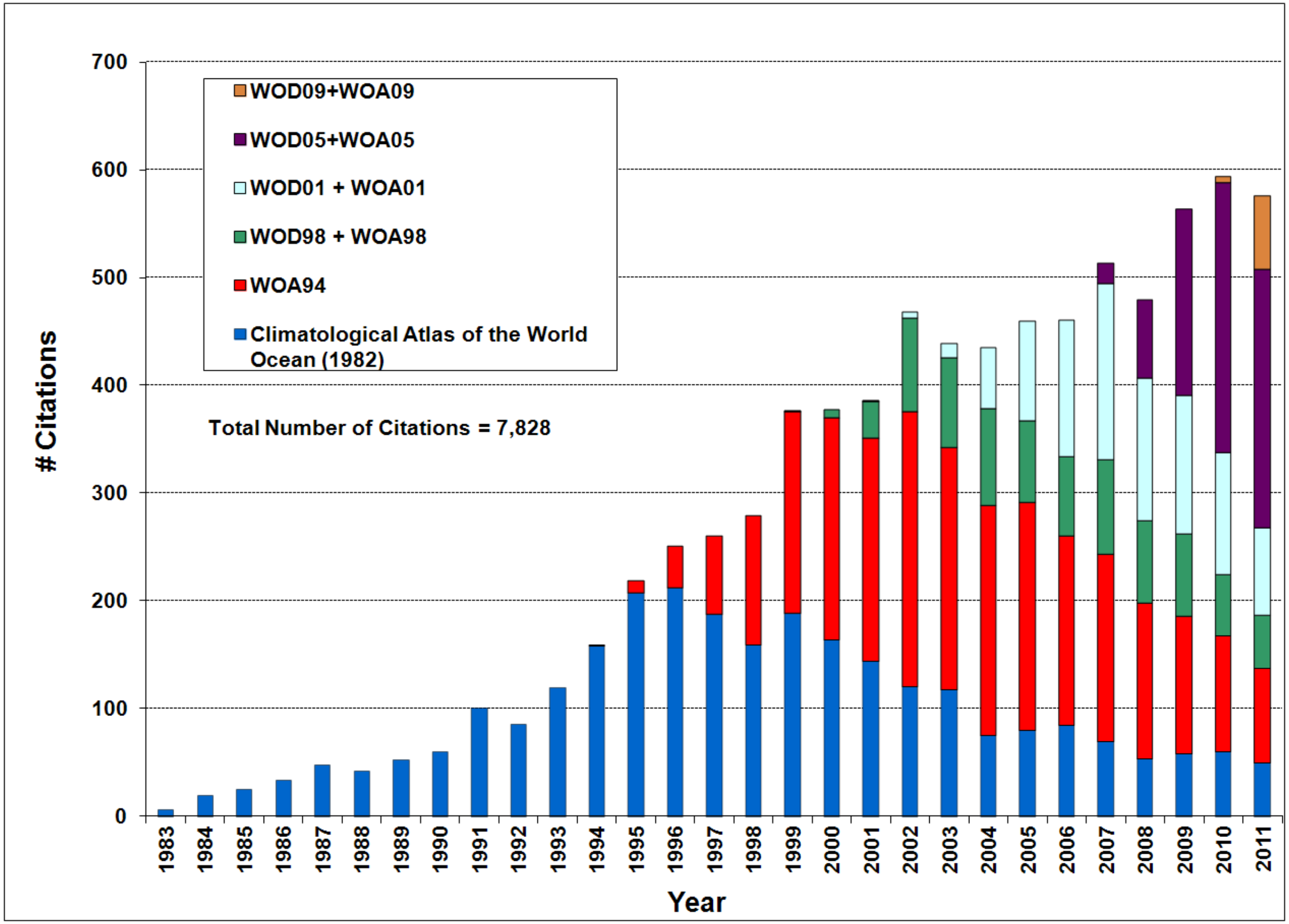
2)

WOD continues to grow.

3) Extended vertical resolution is being introduced.

WOD profiles and WOA analyses will be performed at 103 standard depth level between the surface and 5500 m depth as compared to 33 levels in previous works.

Utility of NODC/WDC profile data as indicated by citations to NODC atlases in the scientific literature



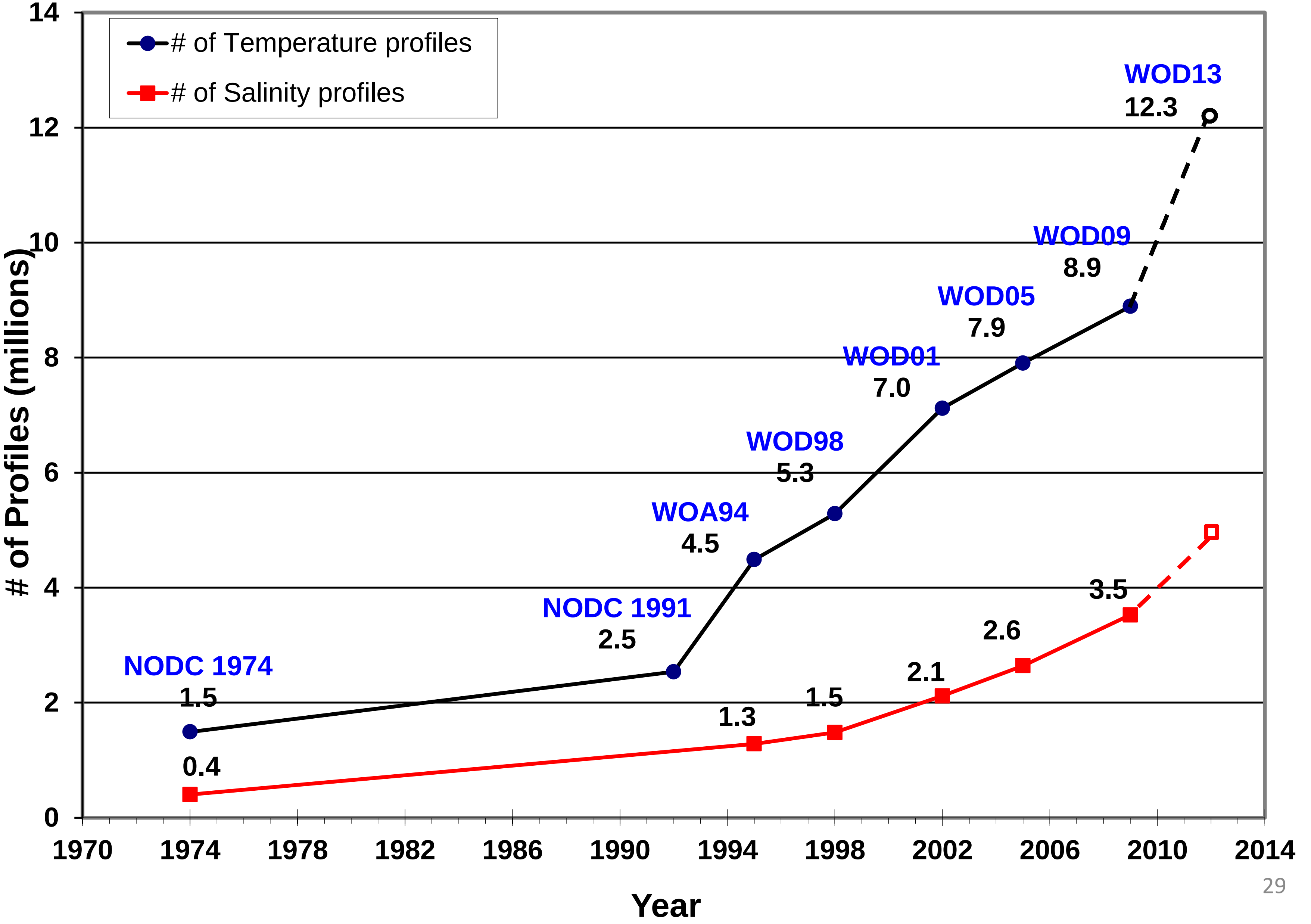
1) The *World Ocean Database* (WOD) is the world's largest collection of ocean profile-plankton data available internationally without restriction. All data are quality-controlled and in one format.

2) The "archive" is the originators data as received at NODC/WDC which are copied to disk.

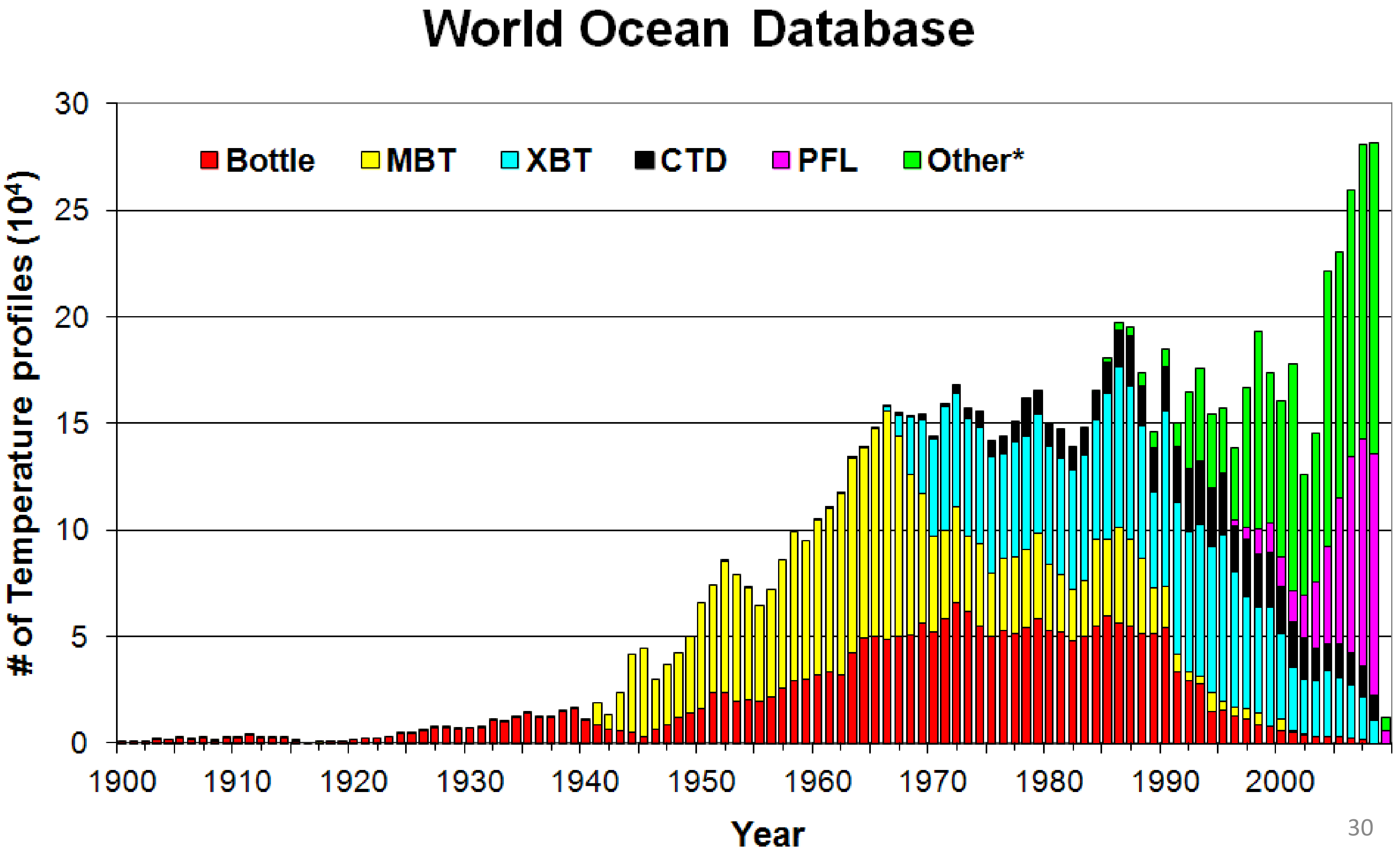
3) Not all data that scientists submit to NODC/WDC are put into the WOD, *e.g.*, amino acids, …

*Based on a search of the ISI *Scientific Citation Index* as of March 2012.

Growth of the *World Ocean Database*



WOD by Instrument Type as of 6/19/12



Why do we need to proceed to "Extended Vertical Resolution"?

High-vertical-resolution data are being submitted in ever increasing amounts Including:

profiling floats,

gliders, } **Relatively new instruments**

underway CTDs,

XBTs,

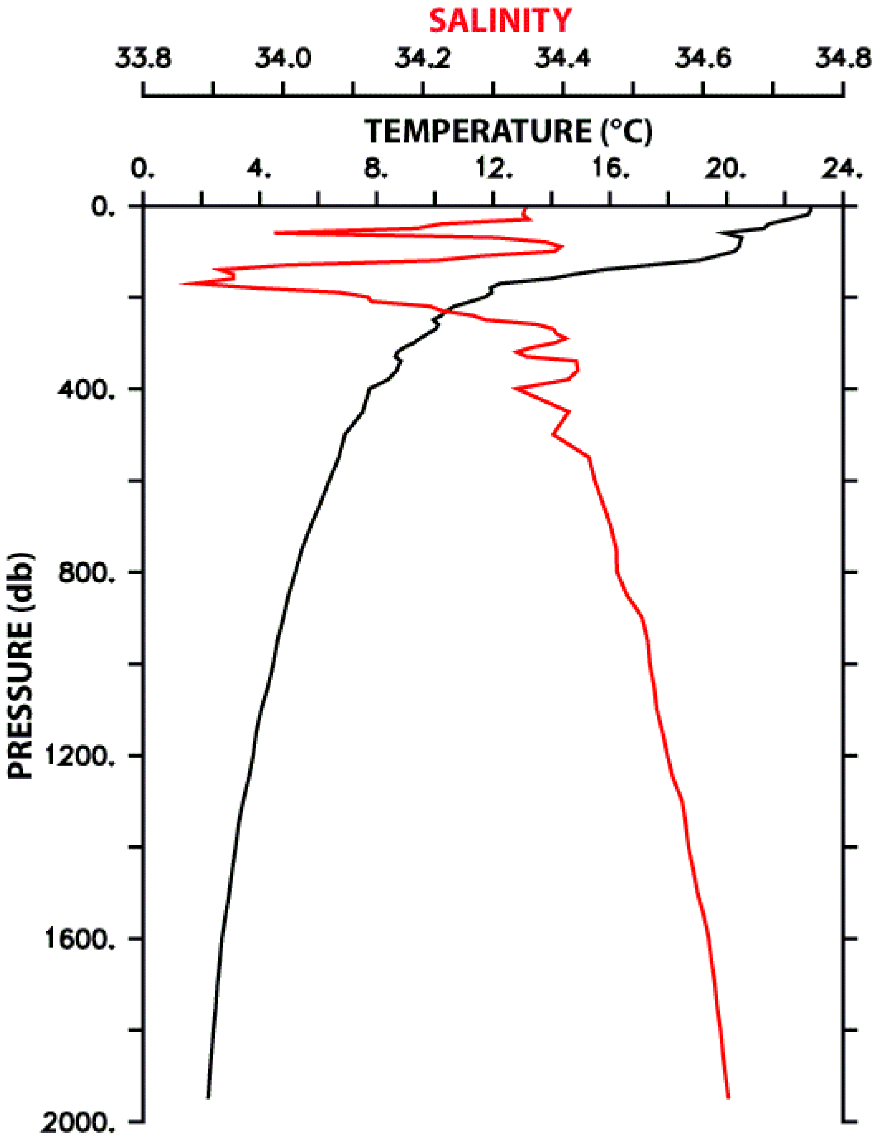
XCTDs

CTDs.

This will allow the scientific community to better understand the physics of the ocean and improve model initial and boundary conditions,

***e.g.*, better resolve smaller scales associated with sill depths, channels, *etc*.**

Argo profile from the subtropical N. Atlantic courtesy of Steve Riser, U.W.



Need to resolve and understand the physics of smaller-scale phenomena than we have in the past.

Regional climatologies-

all with Extended Vertical Resolution (EVR)

http://www.nodc.noaa.gov/OC5/regional_climate/

Tim Boyer leads Regional Climatology work at NODC:

1) Oceanographic Atlas of the East Asian Seas

2)Gulf of Mexico Regional Climatology

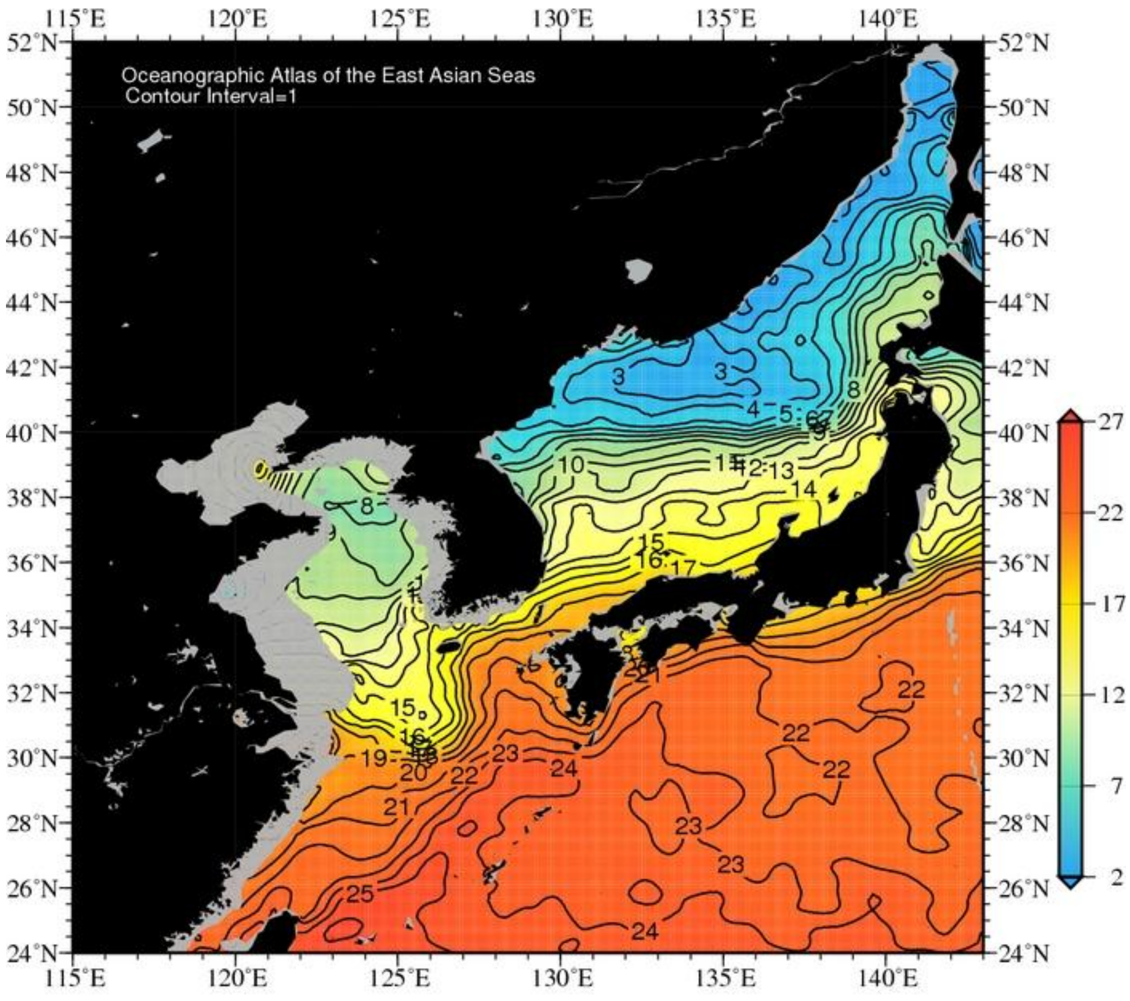
3) Arctic Regional Climatology.

With contributions from other NODC staff.

Oceanographic Atlas of the East Asian Seas

"Extended vertical resolution" compared to earlier products

Annual temperature (° C) at 45 m depth, C.I. = 1.0 ° C, Grid spacing = 0.1° lat-lon



Annual temperature [ºC] at 45 m. depth (tenth-degree grid)

Done jointly with Republic of Korea:

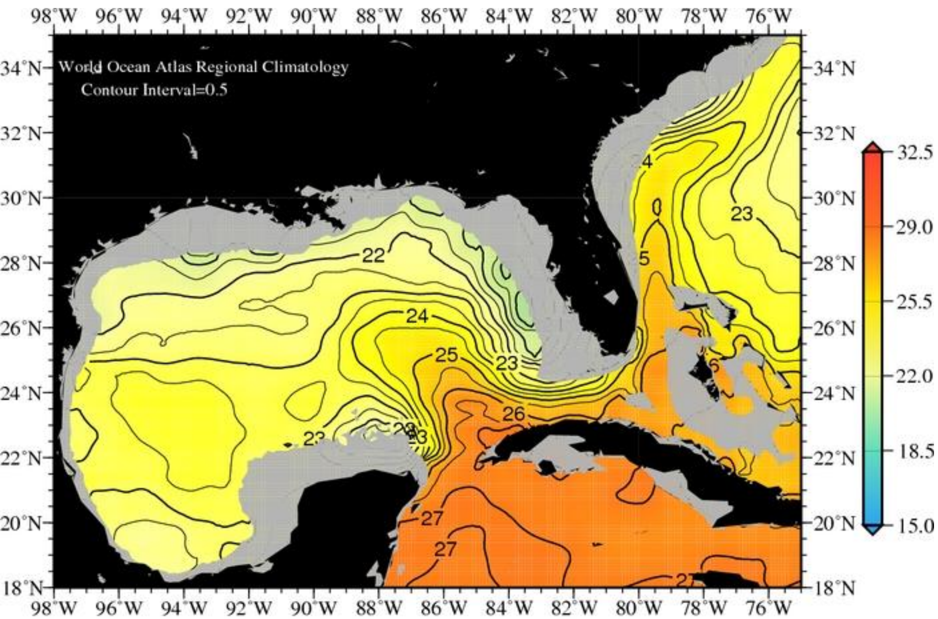
Daphne Johnson (NODC) &
Dr. Joon-Soo Lee (Korea)

Online at http://www.nodc.noaa.gov/OC5/regional_climate/

World Ocean Atlas regional climatology- GoM preliminary
“Extended vertical resolution” compared to earlier products

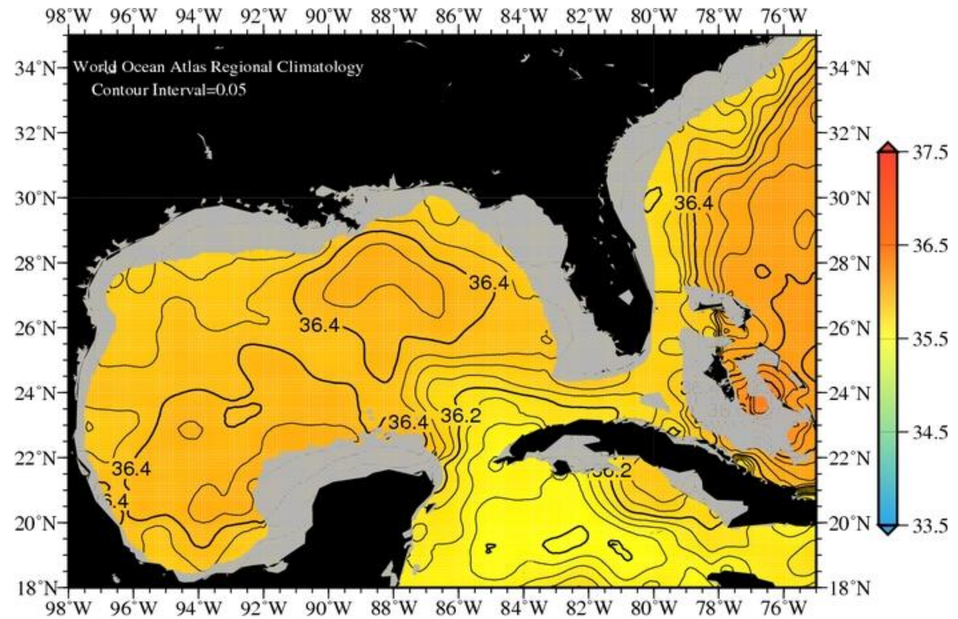
z = 60 m depth, Grid = 0.1° lat-lon

Annual mean temperature (° C), C.I.=0.5



Annual temperature [°C] at 60 m. depth (tenth-degree grid)

Annual mean salinity (pss), C.I. = 0.05



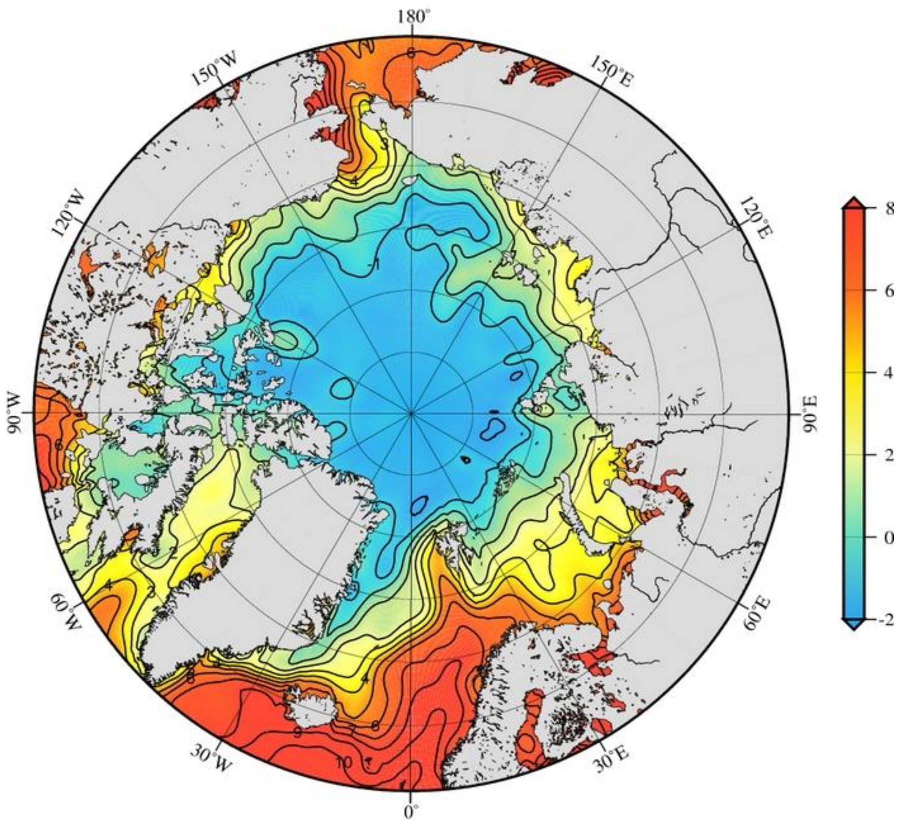
Annual salinity [PSS] at 60 m. depth (tenth-degree grid)

Online at http://www.nodc.noaa.gov/OC5/regional_climate/

Arctic Ocean T,S Climatologies (z = 0., 0.25° grid)

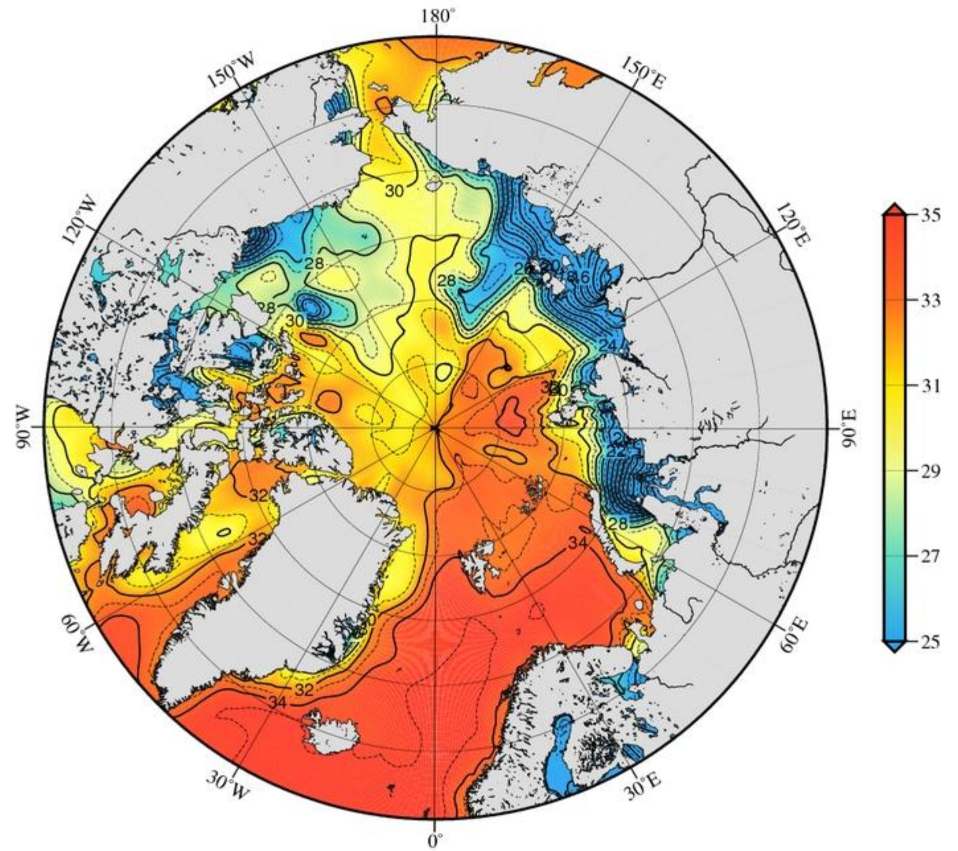
"Extended vertical resolution" compared to earlier products

Temperature (° C), z = 0., C.I.= 1., Grid = 0.25°



Annual temperature [°C] at the surface (quarter-degree grid)

Salinity (pss) , z = 0., C.I.=1., Grid = 0.25°



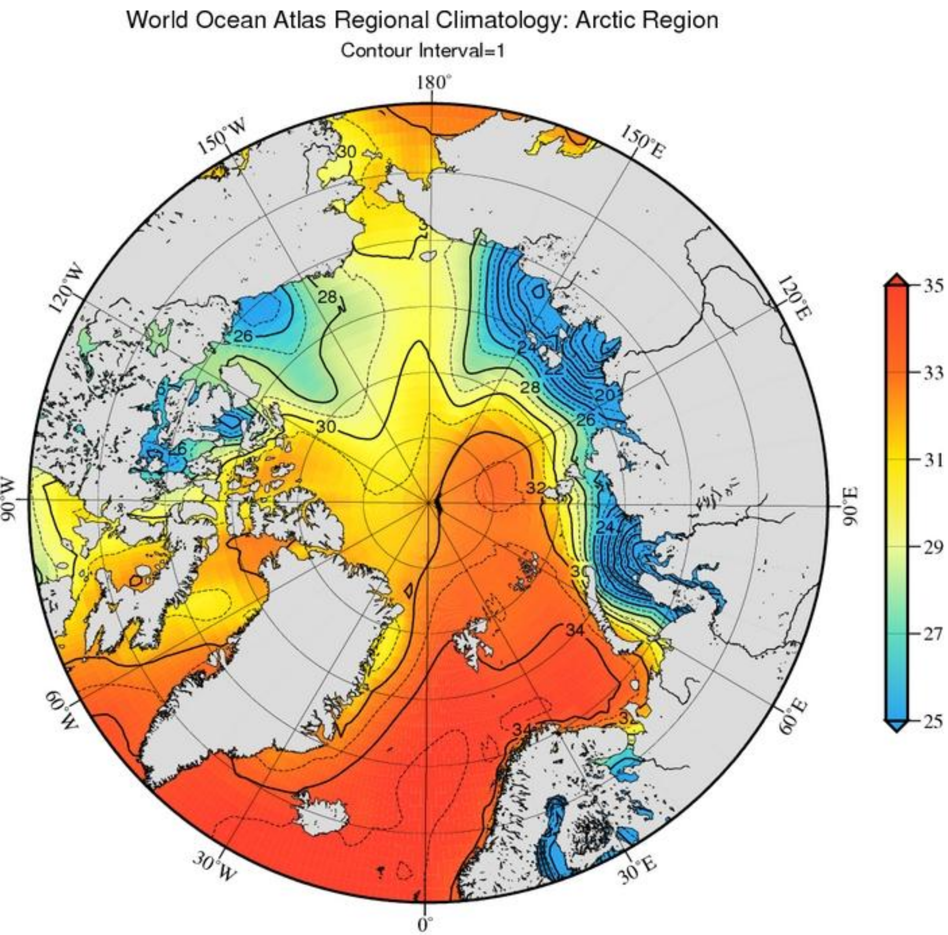
Annual salinity [PSS] at the surface (quarter-degree grid)

Online at http://www.nodc.noaa.gov/OC5/regional_climate/

Arctic Ocean Climatology

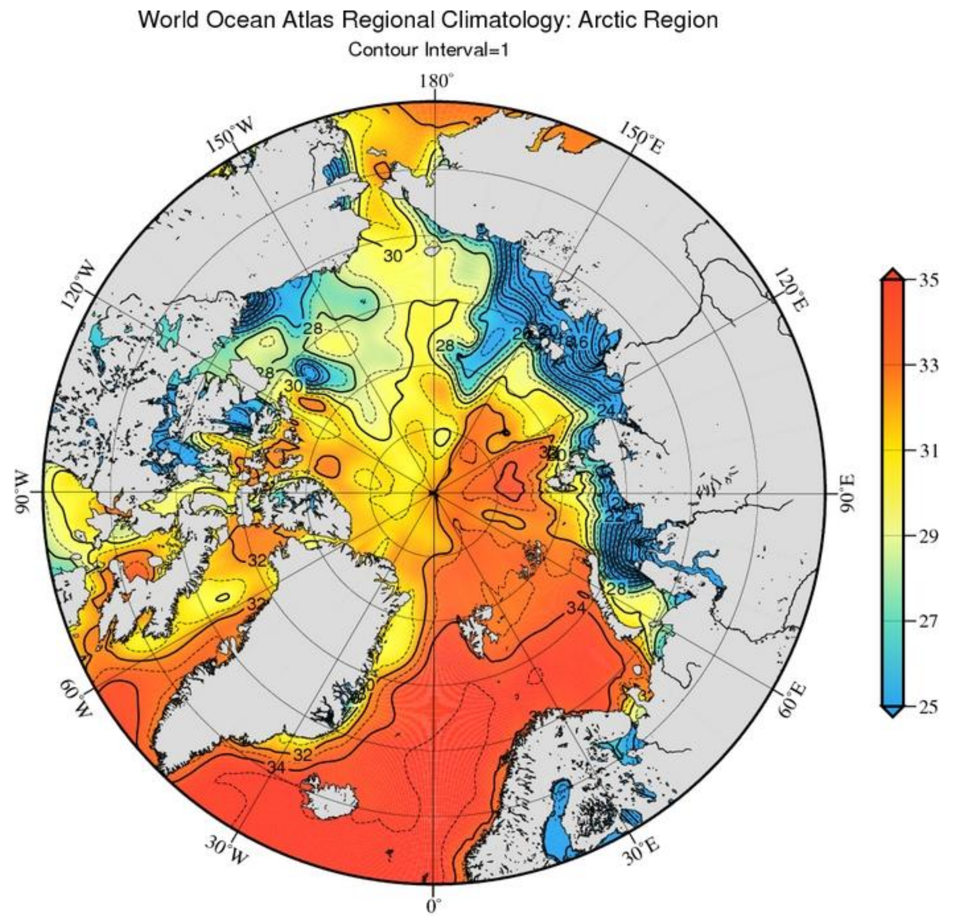
(Comparison of salinity on a 1° and 0.25 ° grid)

Annual mean <u>Salinity</u> (° C) at z = 0.0 m,
C.I.=1.0 , grid = 1.0° Lat-Lon



Annual salinity [PSS] at the surface (one-degree grid)

Annual mean <u>Salinity</u> (° C) at z = 0.0 m,
C.I.=1.0, grid = 0.25 ° Lat-Lon

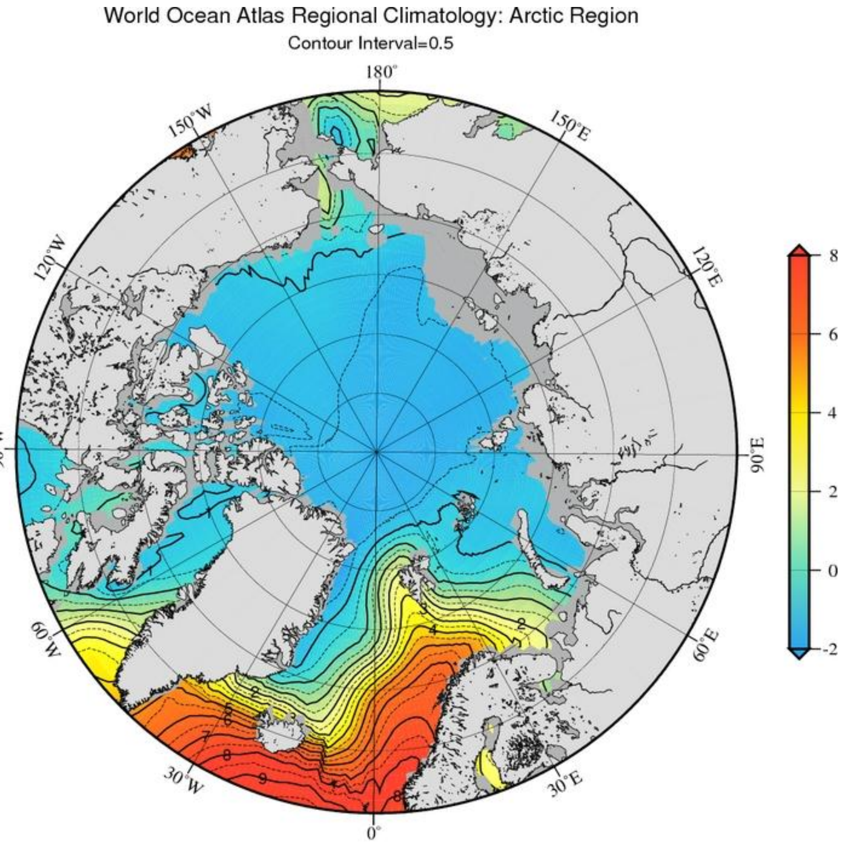


Annual salinity [PSS] at the surface (quarter-degree grid)

Arctic Ocean Climatology

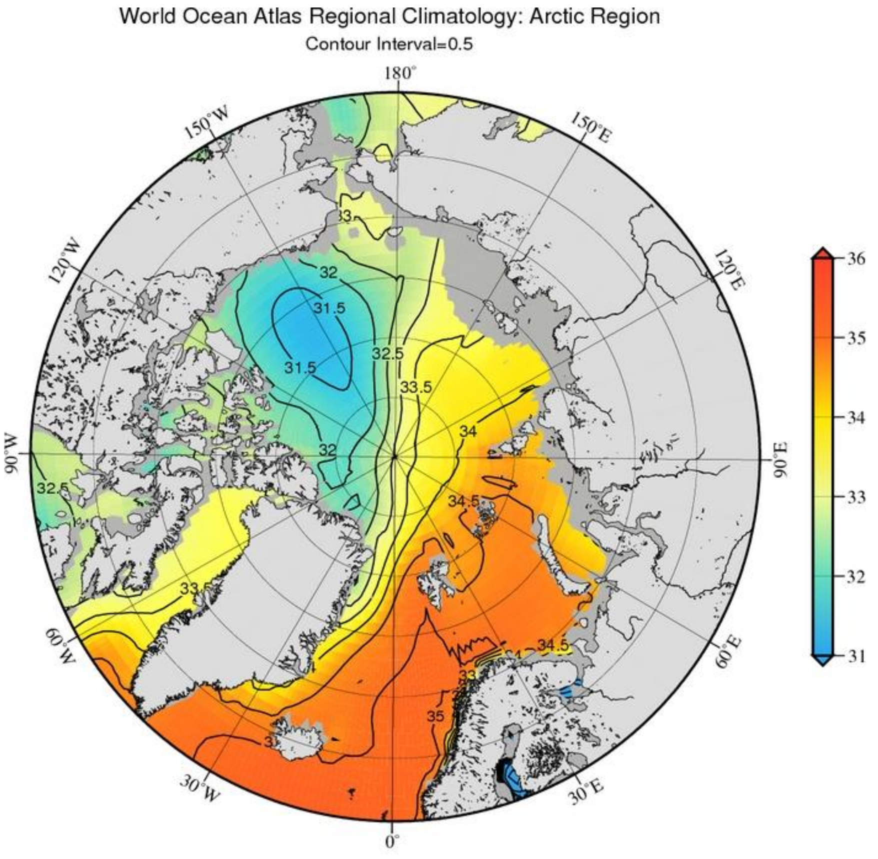
"Extended vertical resolution" (EVR) compared to earlier products

Annual mean Temperature (° C) at z = 60 m, C.I.=0.5



Annual temperature [°C] at 60 m. depth (one-degree grid)

Annual mean Salinity (pss) at z = 60 m, C.I.=0.5



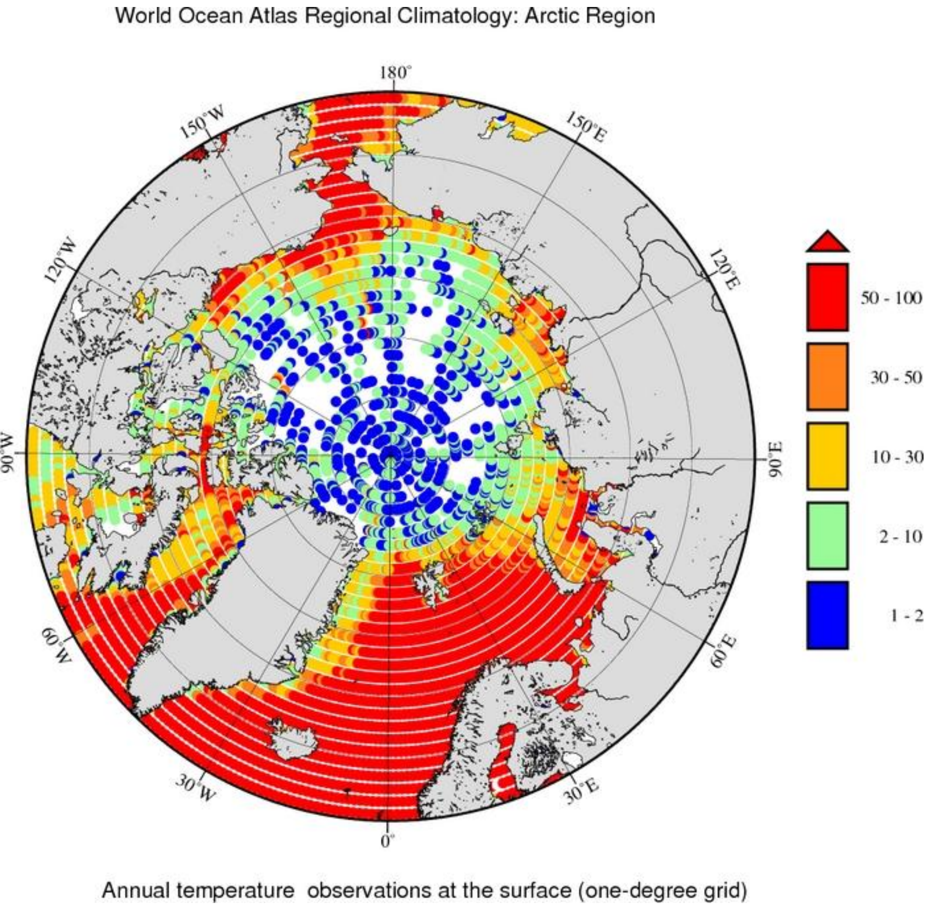
Annual salinity [PSS] at 60 m. depth (one-degree grid)

http://www.nodc.noaa.gov/OC5/regional_climate/

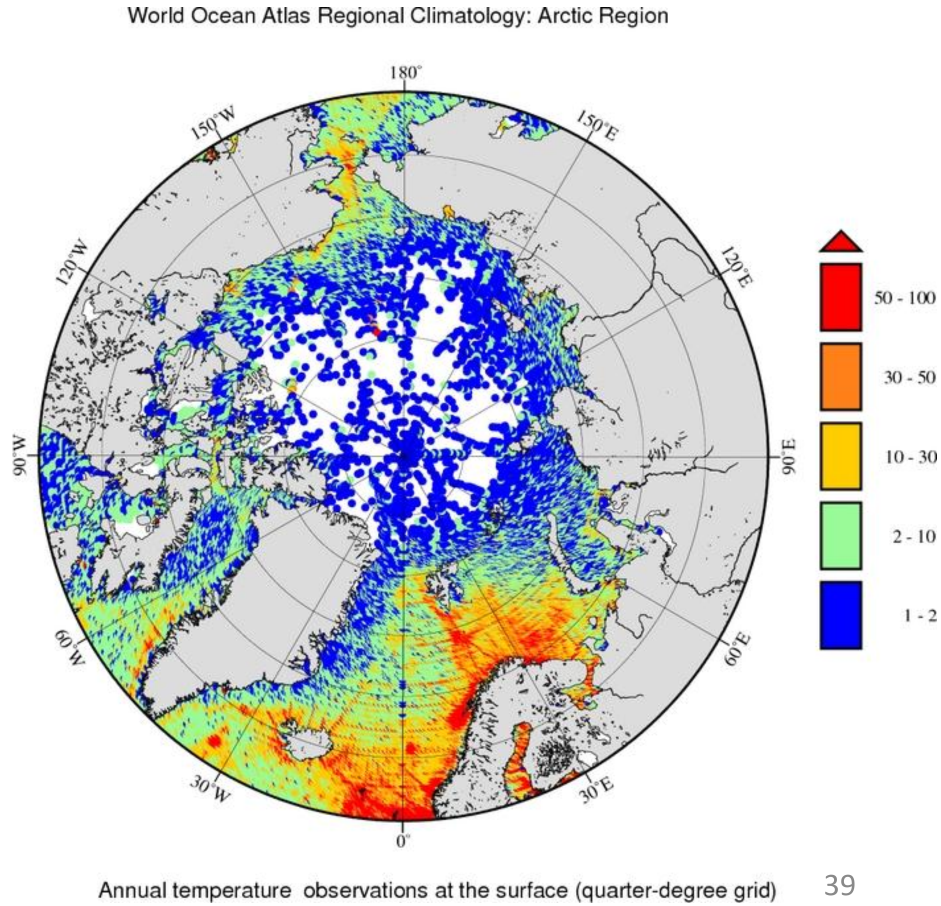
Statistics are provided, not just objectively analyzed fields

observations, mean, St. Dev., St. Error of the Mean

Number of Temperature observations by 1° squares for all-data observations.



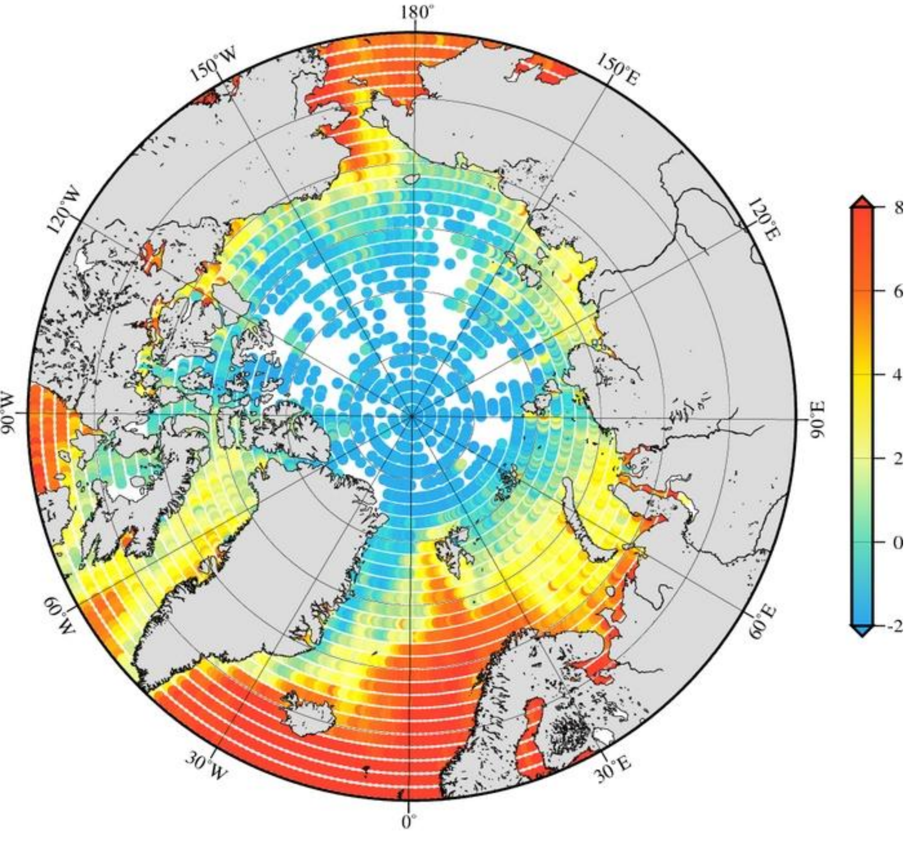
Number of Temperature observations by 1/4° squares for all-data observations.



Statistics are provided, not just objectively analyzed fields

Observed 1° square means of all-data annual temperature observations at z = 0.

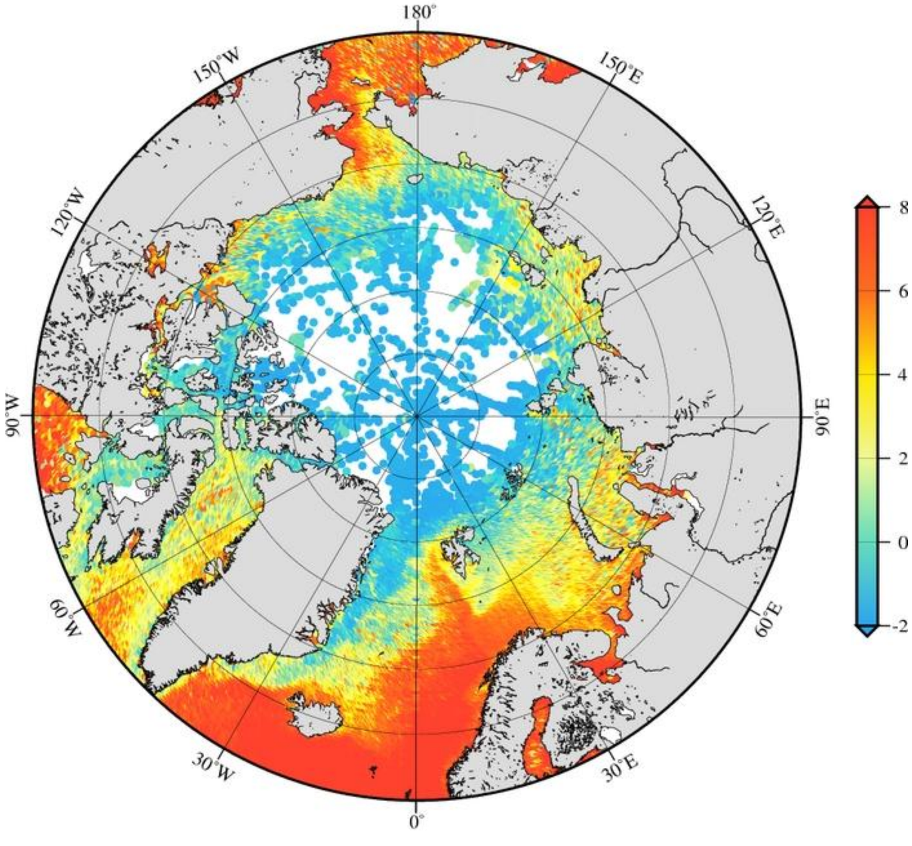
World Ocean Atlas Regional Climatology: Arctic Region



Annual temperature [ºC] at the surface (one-degree grid)

Observed 1/4° square means of all-data annual temperature observations at z = 0.

World Ocean Atlas Regional Climatology: Arctic Region

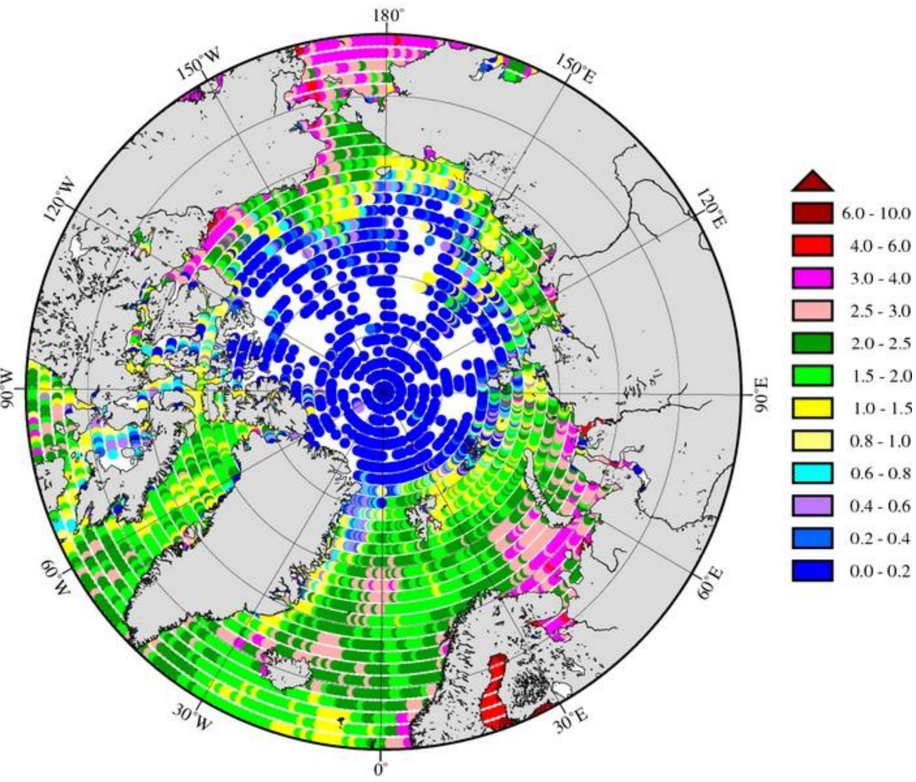


Annual temperature [ºC] at the surface (quarter-degree grid)

Standard deviation (° C) at z = 0.0

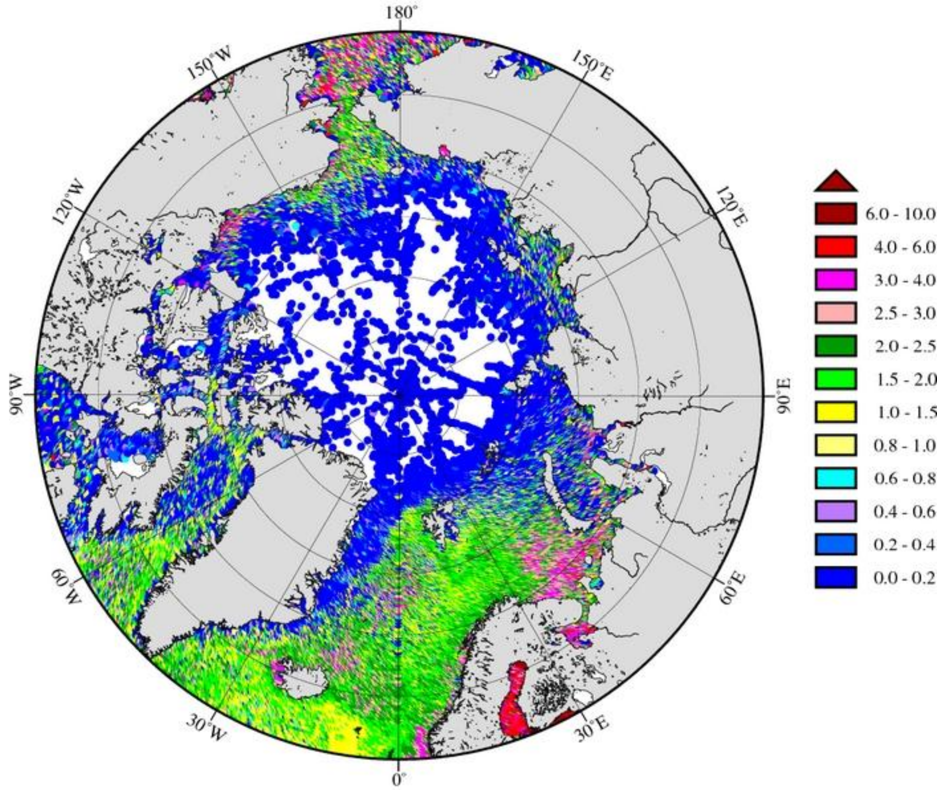
1° grid | **1/4° grid**

World Ocean Atlas Regional Climatology: Arctic Region



Annual temperature [°C] standard deviation at the surface (one-degree grid)
Maximum Standard Deviation = 7.69

World Ocean Atlas Regional Climatology: Arctic Region



Annual temperature [°C] standard deviation at the surface (quarter-degree grid)
Maximum Standard Deviation = 9.68

Why do we need to keep building ocean profile databases?

There are many scientific reasons that you all know,
e.g., provide Initial Conditions and B.C.s for computer models, fisheries research, quantify the role of the ocean as part of earth's climate system, model verification, *etc*.

However, the Deep-Water Horizon incident strongly illustrated, yet again, that we need all available data in a common ocean profile database, *e.g.*, *World Ocean Database,* as soon as possible.

Response by the U.S. scientific community to requests for historical data from the Gulf of Mexico (GoM) was excellent, everyone recognized this was a national emergency. They provided NODC with much historical data from the GoM that we did not previously have.

But *once an incident occurs, it is almost too late to begin collecting the historical data that will be of use to scientists involved in short-term forecasting, mitigation, etc.*

Older data will still be useful for long-term studies and in the event of another incident somewhere, but we emphasize it takes time to process these data *etc*.

New ocean monitoring technologies

1) Profiling floats that extend to depths as deep as 6 km and measure T & S.

U.S.A. (6 km) , Japan (4 km), France (3.5 km).
Also SBE is developing improved sensors (this is my understanding).

2) Gliders that extend to depths as deep as 6 km.

Already demonstrated by Prof. Charlie Eriksen & colleagues at U. Wash.

Further development is ongoing.

3) Underway CTDs.

Vertical depth extent (0-1 km) depends on the speed of the ship at time of deployment. Maximum depth is 2 km with ship at rest.

Being sold and used.

These instruments will greatly improve monitoring of the world ocean for weather forecasting, climate assessments, fisheries research,….

International Ocean Data Exchange

Many of the results shown today are due to international cooperation in oceanographic data exchange under the auspices of:

1)

the International Ocean Data and Information Exchange (IODE) committee

of the

Intergovernmental Oceanographic Commission (IOC)

and

3)
the International Council of Science (ICSU) World Data System (WDS) (WDCs of the WDS)

The Future

NODC has a 31% budget cut this year (FY13)

Immediate future:

1)WOD13-EVR & WOA13-EVR will be produced & distributed (at least online)

2)Seasonal updates of WOD will continue for now

Further out:

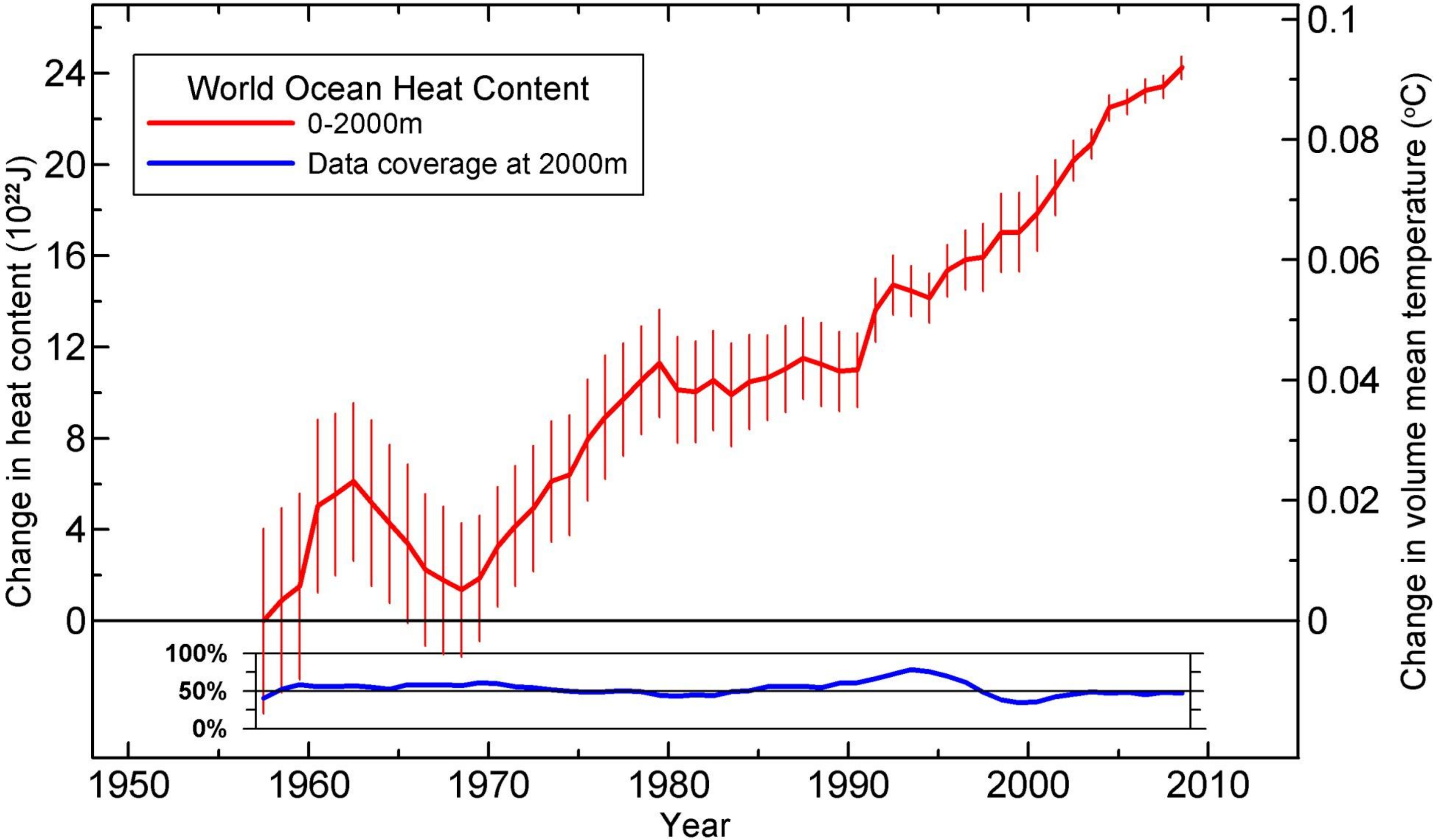
1)The OCL may merge with the NODC Marine Data Stewardship Division

2)NOAA may merge its' 3 data centers together but no move of staff is involved, just reorganization, cross-data center divisions?

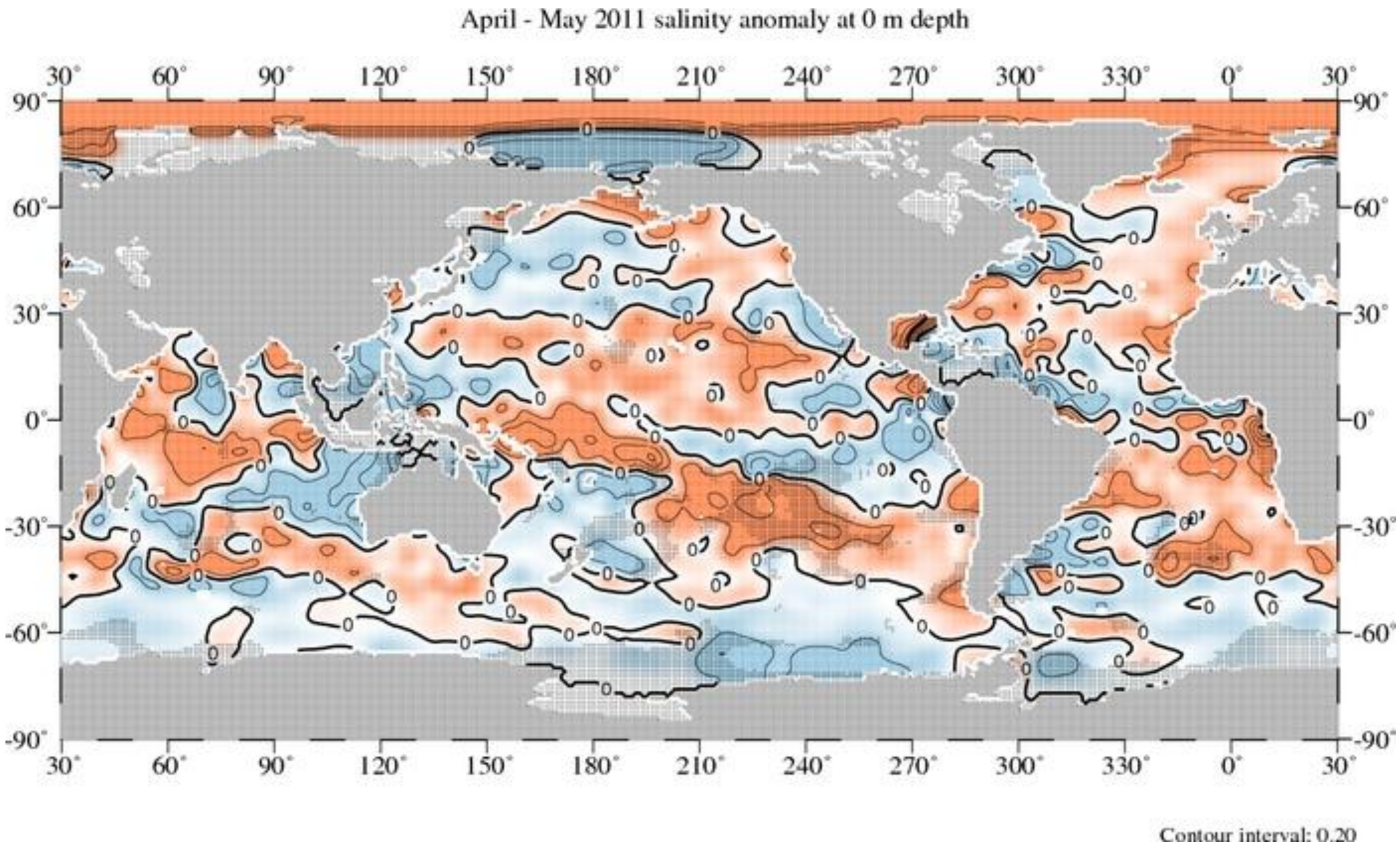
i) National Oceanographic Data Center
ii) National Climatic Data Center
iii) National Geophysical Data Center

Thank you.

World Ocean Heat Content (1955-2010) based on running pentads (5-year periods)



Seasonal salinity anomaly Apr-Jul 2011



T anomaly, S anomaly, OHC, & components of steric sea level fields are updated online every 3 months, annually, and by pentads (5-year) at (www.nodc.noaa.gov).