Northwest Atlantic (NWA) Regional Climatology

Please note that this version of the regional climatology will be updated to include new data and improve the information section.

Overview: A set of analyzed temperature and salinity fields were computed for the Northwest Atlantic (NWA) domain to assess long-term climatological tendencies in this important region of the Atlantic Ocean. The set is comprised of the objectively analyzed temperature and salinity fields as well as some additional parameters that may be useful for applied climate studies. These additional parameters include simple statistical means, data distributions, standard deviations, standard errors of the mean, observed minus analyzed, and seasonal minus annual distributions for both temperature and salinity. These parameters were computed using all data available in the World Ocean Database that was released in 2013 (WOD13). The maps and data for the NWA are available for viewing and downloading. Since publication of the Climatological Atlas of the World Ocean (Levitus, 1982), objectively analyzed fields of essential oceanographic parameters, such as temperature, salinity and oxygen have been traditionally referred to as ocean climatologies.

After completion of all monthly analyses on all three horizontal grids (1°x1°, a 1/4°x1/4°, and 1/10°x1/10°), the seasonal and annual fields are computed. Annual and seasonal fields above 1500 m are calculated using the monthly fields. The monthly fields are computed by taking the average of six decadal monthly analyses from 1955 to 2012 (the last decade of 2005-2012 contains only eight years). Above 1500 m, the seasonal fields are computed at all depths by averaging the three months comprising each season (e.g., January, February and March for winter) and the annual mean fields are computed by averaging the four seasonal fields at all depths. Below 1500 m depth an annual analysis is defined as the mean of the four seasonal analyses and only annual and seasonal fields are shown (the monthly fields are not shown).

It is important to note that the high-resolution monthly temperature and salinity data coverage on the 1/10°x1/10° grid have more gaps than seasonal and annual fields computed from the monthly fields. In general, all high-resolution analyzed fields should be reviewed carefully before using them in critical mission applications. It is especially important when working with the high-resolution monthly fields. Users are advised to review the data distribution and statistical mean arrays before deciding whether to use the high-resolution analyzed temperature and salinity fields or their climatological means. Moreover, the monthly maps of objectively analyzed data on 1/10°x1/10° may show some too strong eddy-like irregularities in some regions due to interpolation and plotting combined. Although such cases are very few, more careful review of the fields with such occurrences is needed before using analyzed variables in research or applications.

Temperature and salinity climatologies are calculated separately. There are many more temperature data than salinity data. Even when there are salinity measurements, there are not always concurrent temperature measurements. As a result, when density is calculated from standard level climatologies of temperature and salinity, instabilities may result in the vertical density field. Appendices A and B in (Locarnini*et al.*, 2013) describe a method employed to minimally alter climatological temperature and salinity profiles to achieve a stable water column everywhere in the world ocean. All analyses shown in the NWA regional climatology have been performed using this stabilizing method.

Area: The NWA domain is encompassed between 80.0°W and 40.0°W longitudes and between 32.0°N and 65.0°N latitudes.

Temporal resolution:

A. All data from the WOD13 for the NWA domain were used to calculate six decadal climatologies within the following time periods: 1955-1964; 1965-1974; 1975-1984; 1985-1994; 1995-2004; 2005-2012. The all averaged decadal climatology was calculated by averaging six individual decades listed above (see World Ocean Database 2013 Introduction).
B. Each decadal climatology consists of
   a. *Annual* (computed as 12-months averages);
   b. *Seasonal*: Winter (Jan.-Mar.), Spring (Apr.-Jun.), Summer (Jul.-Sep.), Fall (Oct.-Dec.) computed as 3-months averages;
   c. *Monthly* fields (above 1500 m).

Spatial resolution:

a. *Annual*, *seasonal* and *monthly* fields are available on a 1°x1°, a 1/4°x1/4°, and a 1/10°x1/10° latitude/longitude grids.
b. *Monthly* fields are available only above 1500 m on all grids.

Vertical resolution:

a. All *annual* and *seasonal* fields were calculated from 0 to 5500 m depth on 102 standard levels;

b. All *monthly* fields were calculated from 0 to 1500 m on 57 standard levels.

Standard depth levels in the NWA regional climatology are the same as in the WOA13 (see Table 3 in the WOA13 documentation).

Objectives: Higher spatial resolutions – here the 1/10°x1/10° grid – provide major advantages in the areas where such resolutions are feasible and supported by data availability. The quality control on a higher-resolution grid reveals more outliers than an analysis on coarser grids. More importantly, with the significantly shorter radius of influence in the objective analysis procedure, the structure of the gridded fields is far better sustained, especially in regions with sharp gradients of the essential oceanographic parameter (temperature and salinity). Residual effect of quasi-stationary meanders and transient mesoscale eddies on climatological fields is clearly seen at 1/10°x1/10° resolution. They are better preserved in high-resolution climatological fields, which make them more valuable for ocean modeling and other applications.

Units: Temperature units are °C. Salinity is unitless on the Practical Salinity Scale-1978.

Data: All data from WOD13 were used to generate the NWA mean and decadal climatologies. The description of employed datasets can be found in World Ocean Database 2013 Introduction.

Bathymetry: For all three grid resolutions, mean depth values at the center of a grid square with the respective resolution were extracted from the ETOPO2 World Ocean bathymetry.

Methods: The methods of calculating mean climatological fields are described in details in the following publications: Temperature: Locarnini *et al.*, 2013, Salinity: Zweng *et al.*, 2013.

Additional details on high-resolution climatological calculations can be found in Boyer *et al.*, 2005.

The updated table from (Boyer *et al.*, 2005), including the 1/10° grid resolution, provides radii of influence for the analysis procedure as:

Pass	1° radius of influence	1/4° radius of influence	1/10° radius of influence
1	892 km	321 km	253 km
2	669 km	267 km	198 km
3	446 km	214 km	154 km

Data formats:
Data are distributed in several formats:

a. Comma Separated Values (CSV) format which gives latitudes and longitudes of the center of a grid box and the value at each depth in that grid box;
b. ArcGIS shape-file format;
c. netCDF format.

Most of the procedures used for generating the NWA, Arctic (Boyer *et al.*, 2012) and GINS (Seidov *et al.*, 2013) regional climatologies are similar. A pilot study using the Arctic Regional Climatology has been recently published in a special issue of the Progress in Oceanography (Seidov *et al.*, 2015).

References:

Boyer, T., S. Levitus, H. Garcia, R. A. Locarnini, C. Stephens, J. Antonov, 2005: *Objective analyses of annual, seasonal, and monthly temperature and salinity for the world ocean on a 0.25 degree grid*. Int. J. Clim., 25, 931-945.

Boyer, T. P., J. I. Antonov, O. K. Baranova, C. Coleman, H. E. Garcia, A. Grodsky, D. R. Johnson, R. A. Locarnini, A. V. Mishonov,T. D. O'Brien, C. R. Paver, J. R. Reagan, D. Seidov, I. V. Smolyar, M. M. Zweng, 2013: *World Ocean Database 2013*. Sydney Levitus, Ed.; Alexey Mishonov, Technical Ed.; NOAA Atlas NESDIS 72, 209 pp.

Boyer, T.P., O.K. Baranova, M. Biddle, D.R. Johnson, A.V. Mishonov, C. Paver, D. Seidov and M. Zweng, 2012: *Arctic Regional Climatology*, Regional Climatology Team, NOAA/NCEI (www.nodc.noaa.gov/OC5/regional_climate/arctic).

Levitus, S., 1982: *Climatological Atlas of the World Ocean*, NOAA Professional Paper 13, U.S. Gov. Printing Office, Rockville, M.D., 190 pp.

Locarnini, R. A., A. V. Mishonov, J. I. Antonov, T. P. Boyer, H. E. Garcia, O. K. Baranova, M. M. Zweng, C. R. Paver, J. R. Reagan, D. R. Johnson, M. Hamilton, and D. Seidov, 2013: *World Ocean Atlas 2013, Volume 1: Temperature.* S. Levitus, Ed., A. Mishonov Technical Ed.; NOAA Atlas NESDIS 73, 40 pp.

Seidov, D., O.K. Baranova, M. Biddle, T.P. Boyer, D.R. Johnson, A.V. Mishonov, C. Paver and M. Zweng, 2013: *Greenland-Iceland-Norwegian Seas Regional Climatology*, Regional Climatology Team, NOAA/NCEI (www.nodc.noaa.gov/OC5/regional_climate/gin-seas-climate).

Seidov, D., J. I. Antonov, K. M. Arzayus, O. K. Baranova, M. Biddle, T. P. Boyer, D. R. Johnson, A. V. Mishonov, C. Paver and M. M. Zweng, 2015: *Oceanography North of 60°N from World Ocean Database*, Progress in Oceanography, v 132, p. 153-173; doi:10.1016/j.pocean.2014.02.

Zweng, M. M, J. R. Reagan, J. I. Antonov, R. A. Locarnini, A. V. Mishonov, T. P. Boyer, H. E. Garcia, O. K. Baranova, D. R. Johnson, D. Seidov and M. M. Biddle, 2013: *World Ocean Atlas 2013, Volume 2: Salinity.* S. Levitus, Ed., A. Mishonov Technical Ed.; NOAA Atlas NESDIS 74, 39 pp.