Greenland-Iceland-Norwegian Seas Regional Climatology version 2 (GINS RC v2)

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

Overview:

Since the 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. The *World Ocean Atlas 2013* (WOA13), which is the most recent version of the World Ocean climatology (Locarnini *et al*, 2013; Zweng *et al*, 2013), was compiled using data from the *World Ocean Database 2013* (WOD13; Boyer *et al*, 2013). The WOD13 and WOA13 are available on-line. All NCEI regional climatologies are descendants of the WOA and derived from WOD. The *GINS regional climatology versions 2 (GINS RC v2)* is derived from WOD13 (Boyer *et al*, 2013).

The *GINS RC v2* is a set of six decadal mean fields for temperature and salinity within the 50°N and 85°N and 45°W to 15°E domain comprising the Greenland, Iceland, and Norwegian Seas and adjacent areas of the northern North Atlantic and Arctic Ocean. The six decadal climatologies of temperature and salinity use all data available in WOD13 from 1955 to 2012. There are five 10-year (1955-1964, 1965-1974, 1975-1984, 1985-1994, and 1995-2004) climatologies and an 8-year (2005-2012) climatology that were calculated for annual, seasonal, and monthly time periods. Seasons are as follows: Winter (January-March), Spring (April-June), Summer (July-September), and Fall (October-December). Additionally, there is a 58-year climatology defined as "all averaged decades," which was computed by averaging all six decadal climatologies and represents the long-term mean state of the ocean in the GINS region.

Decadal climatologies included in the *GINS RC v2* are comprised of the objectively analyzed temperature and salinity fields and some additional parameters that may be useful for applied ocean 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. The maps and data from the GINS RC v2 are available for viewing and downloading. This is the first quality-controlled regional climatology of the GINS region with 1/10°x1/10° spatial resolution and seasonal temporal resolution for both temperature and salinity for six consecutive decades.

The procedure of computing annual and seasonal temperature and salinity is as follows: The monthly fields are computed by taking the average of six decadal monthly analyses from 1955-1964 to 2005-2012 (the last decade of 2005-2012 contains only eight years). From the sea surface to 1500 m depth, 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 on all grids (the monthly fields on all three grids are not shown). Annual, seasonal, and monthly fields for the six individual decades are presented on the 1°x1° and 1/4°x1/4° grids, with the annual and seasonal fields also available on a 1/10°x1/10°. For the aggregated ocean climate state between 1955 and 2012 (i.e., the 'all averaged decades'), annual, seasonal and monthly fields are shown for all three resolutions.

Higher spatial resolution grids provide major advantages in areas where such resolutions are feasible and supported by data availability (Seidov *et al*, 2016). The quality control on a higher-resolution grid reveals more outliers than on coarser resolution grids. More importantly, with the significantly shorter radius of influence in the objective analysis procedure (see Table 1), the structure of the gridded fields are far better sustained, especially in regions with sharp gradients of the essential oceanographic parameter (*i.e.*, temperature, salinity, *etc.*). In subpolar latitudes, mesoscale elements of hydrographic fields can be more clearly seen on the maps with 1/10°x1/10° resolution. They are better preserved in the generated climatological fields, which makes high-resolution climatologies more valuable for ocean modeling and for ocean climate change analysis (Seidov *et al*, 2017).

There is another product, closely related to the *GINS RC v2*, called the *Climatological Atlas of the Nordic Seas and Northern North Atlantic* (Korablev *et al*, 2014). It was published by NOAA's National Centers for Environmental Information (NCEI) within the NCEI International Atlases Series and overlaps the GINS regional climatology domain. Both regional climatologies have annual and monthly decadal temperature and salinity fields with 1/4°x1/4° resolution built using WOD13. However, because the methodologies for building the climatologies and the dates that they cover are substantially different, these two regional climatology products are complimentary to one another rather than simply overlapping. Additionally, the GINS RC v2 includes annual, seasonal and monthly temperature and salinity fields compiled on 1°x1° and annual and seasonal fields on the 1/10°x1/10° grid, while the Climatological Atlas of the Nordic Seas and Northern North Atlantic provides oxygen and density fields on 1/4°x1/4° grid. The new version of the *GINS RC v2* allows using the two GINS regional climatology products side-by-side in a wide range of applications which helps add to a better understanding of ocean variability in the GINS and adjacent regions. Two sets of climatologies covering almost the same region for overlapping time period - the Atlas analysis extends from 1900 to 2012, while *GINS RC v2* covers time period from 1955 to 2012 - offers a unique opportunity not only to conduct a wide range of regional ocean climate change studies but also to cross-verify the results thus improving the overall reliability of the research.

It is important to note that the high-resolution monthly temperature and salinity data coverage on the 1/10°x1/10° grid has more gaps than seasonal and annual. In general, all high-resolution analyzed fields should be reviewed carefully before using them in critical mission applications. 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 irregularities which are too strong in some regions with fewer profiles (more data gaps) and are, in our view, artefacts caused by interpolation and plotting. Although there are not too many of such cases, more careful review of the fields with such occurrences is recommended.

Area:
The area encompassed is from 45°W to 15°E longitudes and from 50°N to 84.5°N latitudes.

Temporal resolution:

1. All data from the WOD13 for the GINS 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 climatology was calculated by averaging the six individual decades listed above (see World Ocean Database 2013 Introduction).
2. Each decadal climatology consists of
   - Annual (computed as 12-month averages);
   - Seasonal: Winter (Jan.-Mar.), Spring (Apr.-Jun.), Summer (Jul.-Sep.), Fall (Oct.-Dec.) computed as 3-month averages;
   - Monthly fields.

Spatial resolution:

1. Annual and seasonal fields are available on 1°x1°, 1/4°x1/4°, and 1/10°x1/10° geographic grids.
2. Monthly fields are available on the 1°x1° and 1/4°x1/4° grids for all decades; on the 1/10°x1/10° grid, monthly fields are available for the averaged decades only.

Vertical resolution:

1. All annual and seasonal fields were calculated from 0 to 4000 m depth on 87 standard levels (from the sea surface to the maximum depth in the GINs part of the domain);
2. All monthly fields were calculated from 0 to 1500 m depth on 57 standard levels.

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

Additional fields:
In addition to climatological objectively analyzed fields, fields of statistical means, standard deviation, standard error, data distribution, observed minus analyzed, and differences of seasonal fields from the annual climatological mean, are also available.

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

Data used:
All data from WOD13 within the GINS area from 1955 to 2012 were used to generate the GINS decadal climatologies. The description of datasets used can be found in World Ocean Database 2013 Introduction.

Bathymetry used:
For all three grid resolutions, mean depth values at the center of a grid square under its 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 regarding high-resolution climatological calculations can be found in *Boyer et al.*, 2005.

Table 1:
Radii of influence for the objective analysis procedure, including the 1/10° grid resolution. Table has been updated from (Boyer *et al.*, 2005).

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 presented in a comma separated value (csv) format which gives latitude and longitude of the center of each grid box with the value at each depth in that grid box. Data are also provided in an ArcGIS compatible shape-format and in netCDF format.

References:

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