# Sea Surface Temperature

## 1 Describe the physical, chemical, or biological measurements upon which this indicator is based. Are these measurements widely accepted as scientifically and technically valid? Explain.

This sea surface temperature (SST) indicator, developed by the National Climatic Data Center (NCDC) of the National Oceanic and Atmospheric Administration (NOAA), describes the long-term variability and change in global mean SST for the period from 1880 to 2009. The indicator is based on in situ instrumental measurements of water temperature. When paired with appropriate screening criteria and bias correction algorithms (see response to Question 3), in situ records provide a reliable long-term record of temperature.

## 2 Describe the sampling design and/or monitoring plan used to collect the data over time and space. Is it based on sound scientific principles? Explain.

A summary of the relative availability, coverage, accuracy, and biases of different measurement methods is provided in Reynolds et al. (2002). In situ data have been compiled as part of NOAA's International Comprehensive Ocean-Atmosphere Data Set (ICOADS), release #2 (Slutz et al., 2002). The long-term sampling was not based on scientific sampling design, but was gathered by "ships of opportunity" and other ad hoc records. Records are particularly sparse or problematic prior to the 20$^{th}$ century and during the two World Wars. Since about 1955, the in situ sampling became more systematic and measurement methods have continued to improve. SST observations from drifting and moored buoys were first used in the late 1970s. Buoy observations became more plentiful following the start of the Tropical Ocean Global Atmosphere (TOGA) program in 1985. Locations have been designed to fill in data gaps where ship observations are sparse.

## 3 Describe the conceptual model used to transform these measurements into an indicator. Is this model widely accepted as a scientifically sound representation of the phenomenon it indicates? Explain.

This indicator is based on the extended reconstructed sea surface temperature (ERSST) data set, a reconstruction of historical SST based on in situ data. The reconstruction has undergone several stages of development and refinement; this indicator is based on the most recent release, version #3b (ERSST.v3b).

This reconstruction involves filtering and blending data sets that use alternative measurement methods and include redundancies in space and time. Because of these redundancies, this reconstruction is able to fill spatial and temporal data gaps and correct for biases in the different measurement techniques (e.g., uninsulated buckets, intakes near warm engines, uneven spatial coverage). Thus, the combined set of measurements is stronger than any single set.

Reconstruction methods are documented in more detail by Smith et al. (2008). Smith and Reynolds (2005) discuss and analyze the similarities and differences among various reconstructions, showing that the results are generally consistent. For example, the long-term average change obtained by this method is very similar to those of the "unanalyzed" measurements and reconstructions discussed by Rayner et al. (2003).

This indicator shows the extended reconstructed data as anomalies, or differences, from a baseline "climate normal." In this case, the climate normal was defined to be the average SST from 1971 to 2000.

Figure 1 also provides 95 percent confidence intervals for the data. These intervals were calculated from the sample variance, which was provided with the data set. For each year, the square root of the variance (the standard error) was multiplied by two, and this value was added to or subtracted from the reported anomaly to define the upper and lower confidence bounds, respectively. Assuming a normal distribution, the probability that the true value is within two standard errors of the reported value is approximately 95 percent.

## 4 What documentation clearly and completely describes the underlying sampling and analytical procedures used?

Sampling and analytical procedures are documented in several publications that can be accessed online.

In terms of data collection, NOAA has documented the measurement, compilation, quality assurance, editing, and analysis for the ICOADS sea surface data set at: http://icoads.noaa.gov/publications.html. Additional information on the compilation, data screening, reconstruction, and error analysis of the reconstructed SST data can be found at: www.ncdc.noaa.gov/oa/climate/research/sst/ersstv3.php.

## 5 To what extent is the complete data set accessible, including metadata, data-dictionaries, and embedded definitions? Are there confidentiality issues that may limit accessibility to the complete data set?

This extended reconstruction of SST, called ERSST.v3b, was recently described in Smith et al. (2008). NCDC provides access to monthly and annual SST and error data from this reconstruction, as well as a mapping utility that allows the user to calculate average anomalies over time and space (NOAA, 2010b). EPA used global data (all latitudes), which can be downloaded from: ftp://eclipse.ncdc.noaa.gov/pub/ersstv3b/pdo. Specifically, EPA used the ASCII text file "aravg.ann.ocean.90S.90N.asc," which includes annual anomalies and sample variance.

The ERSST.v3b reconstruction is based on in situ measurements that are available free from an online database (NOAA, 2010a).

## 6 Are the descriptions of the study or survey design clear, complete, and sufficient to enable the study or survey to be reproduced? Explain.

Yes. NOAA has provided sufficient documentation of processing algorithms to allow full reproduction of SST figures from the raw data.

## 7 To what extent are the procedures for quality assurance and quality control of the data documented and accessible?

Thorough documentation of the quality assurance and quality control (QA/QC) methods and results is available in the technical references for ERSST.v3b at NOAA's NCDC (www.ncdc.noaa.gov/oa/climate/research/sst/ersstv3.php).

## 8 What statistical methods, if any, have been used to generalize or portray data beyond the time or spatial locations where measurements were made (e.g., statistical survey inference, no generalization is possible)? Are these methods scientifically appropriate?

This SST reconstruction (ERSST.v3b) was created by blending several data sets together. Locations have been combined to report a global total, based on scientifically valid techniques for averaging over areas. Daily and monthly records have been averaged to find annual anomalies.

No attempt was made to project data beyond the period in which measurements were collected.

## 9 What uncertainty measurements or estimates are available for the indicator and/or the underlying data set?

The extended reconstruction data set includes a sample variance for each year, which is associated with the biases and errors in the measurements and treatments of the data. This sample variance was used to calculate a 95 percent confidence interval, which is provided as part of the indicator (see Figure 1), so that the user can understand the impact of uncertainty on any conclusions that might be drawn from the time series.

Uncertainty measurements are also available for some of the underlying data. For example, several articles have been published about uncertainties in ICOADS in situ data; these publications are available from: www.noc.soton.ac.uk/JRD/MET/coads.php.

## 10 To what extent do uncertainty and variability impact the conclusions that can be inferred from the data and the utility of the indicator?

Presenting the data at a global and annual scale reduces the uncertainty and variability inherent in SST measurements, and therefore, the overall reconstruction is considered to be a good representation of global SST. As Figure 1 shows, even when a 95 percent confidence interval is applied, the indicator still demonstrates statistically significant changes in SST. A comparison by Smith and Reynolds (2005) found that other similar reconstructions using alternative methods yield consistent results, albeit with narrower uncertainty estimates. Hence, the indicator presented here may be more conservative than alternative methods.

## 11 Describe any limitations or gaps in the data that may mislead a user about fundamental trends in the indicator over space or over the time period for which data are available.

Limitations to this indicator include the following:

1. Because this indicator tracks SST at a global scale, the data cannot be used to analyze local or regional trends.
2. Due to denser sampling and improvements in sample design and measurement techniques, newer data have more certainty than older data. The earlier trends shown by this indicator are less precise due to lower sampling frequency and less precise sampling methods.
3. The geographic resolution is coarse for ecosystem analyses, but reflects long-term and global changes as well as variability.
4. The reconstruction methods used to create this indicator remove almost all random "noise" in the data. However, the anomalies are also damped when and where data are too sparse for a reliable reconstruction. The 95 percent confidence interval reflects this "damping" effect as well as uncertainty caused by possible biases in the observations.
5. The 95 percent confidence interval is wider than other methods for long-term reconstructions; in mean SSTs, this interval tends to dampen anomalies.
6. Data screening results in loss of many observations at latitudes higher than 60 degrees north or south. Although the effects of screening at high latitudes are extremely small on the global average, the main effect is to lessen anomalies and widen the confidence intervals.

## 12 References

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