Optimum Interpolation Sea Surface Temperature Climate Data Record

1. Intent of This Document and POC

1a) This document is intended for users who wish to compare satellite derived observations with climate model output in the context of the CMIP/IPCC historical experiments. Users are not expected to be experts in satellite derived Earth system observational data. This document summarizes essential information needed for comparing this dataset to climate model output. References are provided at the end of this document to additional information.

Dataset File Name (as it appears on the ESGF):

--to be added once file is accepted-----

1b) Technical point of contact for this dataset:

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2. Data Field Description

CF variable name, units:	*Tos, Kelvin*
Spatial resolution:	*¼ ° (~25 km) rectangular grid*
Temporal resolution and extent:	*Daily and average monthly, 7/1981 – 12/2014*
Coverage:	*Global*

3. Data Origin

The daily NOAA Optimum Interpolation (OI) sea surface temperature (SST) is an analysis produced at 1/4° spatial resolution at the former National Climatic Data Center (NCDC), now part of the new National Centers for Environmental Information (NCEI). The dataset website is currently http://www.ncdc.noaa.gov/sst/. The daily OISST is based primarily on satellite data from the Advanced by High Resolution Radiometer (AVHRR), but also incorporates in situ observations (International Comprehensive Ocean Atmosphere Dataset described in Worley et al., 2005) and proxy SSTs computed from sea ice concentrations (details in Reynolds et al., 2007). The OI methodology combines these three input types to produce the analysis, which is a spatially complete but smoothed SST field.

The input datasets are prepared by first forming super-observations, using interpolation and averaging to place inputs on separate ¼ degree grids. For satellite SST data, separate daytime and nighttime grids are made, while for ice and for in situ data (ship and buoy separate), one grid is made per day.

Next, bias adjustments are made since the OI procedure requires unbiased inputs. A large-scale bias adjustment is applied to ship and satellite super-observations, on the assumption that buoys represent "sea truth". The ship data is adjusted to compensate for the nominal depth differences between buoy and ship measurements. The satellite data is adjusted to avoid gross errors (e.g., when volcanic aerosols are present). However, it should be noted that infrared instruments like AVHRR measure temperatures at the first few microns of the ocean surface, and tend to be slightly cooler than buoys that have thermistors located deeper. The satellite bias-adjustment procedure uses a set of pre-calculated 130 Empirical Orthogonal Teleconnection (EOT) functions or modes. Only the EOT modes supported by in situ data are used. But where there is insufficient or no in situ data (usually at high latitudes), the EOT bias correction may not be possible. To minimize this problem, a zonal correction based on the difference between satellite and in situ data is also computed and is applied if the EOT-based correction is not possible. The proxy SSTs computed from sea ice concentrations are very rough estimates and therefore not bias adjusted. An empirical equation is used to compute the proxy SSTs from gridded 7-day median sea ice concentrations. Proxy SSTs are estimated only at the sea ice margins where ice concentrations exceed 50%. The proxy SST is not allowed to be lower than the freezing point of seawater, -1.8 °C, but it should be noted that melting ice can produce fresher water, which may have a higher freezing point. More processing details can be found in Reynolds et al. (2007), with minor changes introduced in version 2 discussed in Reynolds (2009). See also http://www1.ncdc.noaa.gov/pub/data/sds/cdr/CDRs/Sea_Surface_Temperature_Optimum_Interpolation/AlgorithmDescription.pdf.

As discussed in the above references, reprocessed datasets are the preferred inputs to OISST because they are temporally more consistent than operational data. However, there may be a considerable time lag before reprocessed data become available, making operational (i.e. near real time) data the only option for routine updates to the daily analysis. Banzon et al. (2013) provides a list of the inputs to the daily OISST, and the differences with the precursor product, the 1° weekly OISST produced at National Centers for Environmental Prediction (Reynolds et al., 2002). For the reprocessed satellite SSTs, data from only one AVHRR instrument is used at a time, but when there is no more reprocessed data, then two current operational AVHRR satellites are used.

Note that to extend the dataset, a "preliminary" OISST is computed every day, with 1-day latency, but is later replaced with the "final" product, after 2 weeks. The final computation produces a more stable product because steps that use a multi-day window centered on the day being processed have more data. In contrast, the preliminary version will have data for only the preceding days. The final is intended to replace the preliminary, so only the final is used in this Obs4MIPS dataset. Thus, if the user downloads the OISST in near-real time directly from the NCEI website, this preliminary version may not match the final product that is included here.

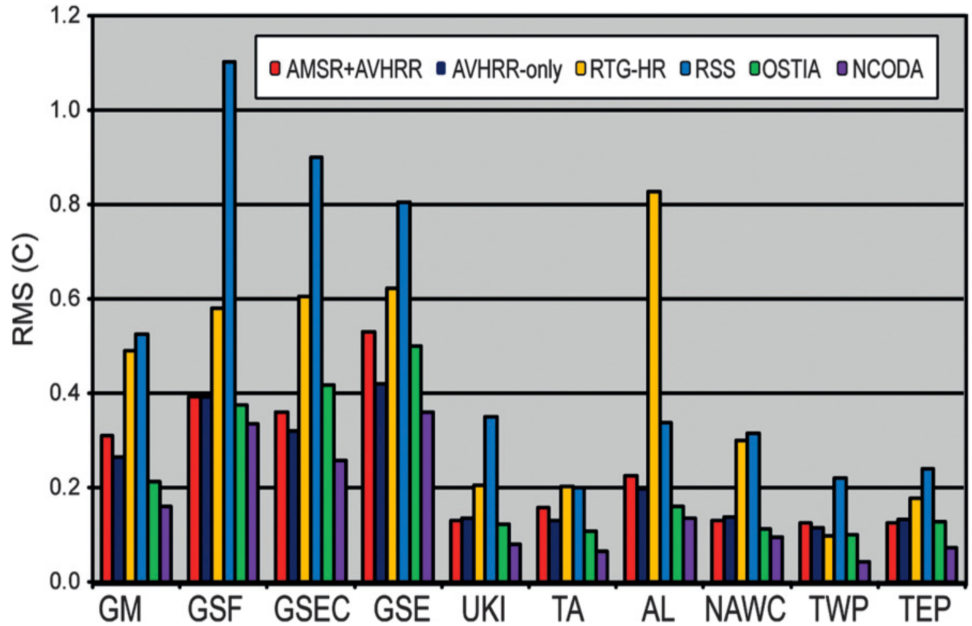
The monthly ¼° OISST fields provided are simple monthly averages of the gridded daily OISST.

4. Validation and Uncertainty Estimate

Satellite SSTs are the main input to OISST. For OISST, Level 3 AVHRR SSTs (Pathfinder version 5.0/5.1 algorithm; http://www.nodc.noaa.gov/SatelliteData/pathfinder4km/) are used up to December 2005. Although statistics are not available for the 5.0/5.1 algorithm, Kilpatrick et al. (2001) reported a reasonable global accuracy of the preceding version (0.02 ± 0.5°C relative to buoys). For the recent version 5.2 release, validation statistics are reported in http://www1.ncdc.noaa.gov/pub/data/sds/cdr/CDRs/Sea_Surface_Temperature_Pathfinder/AlgorithmDescription.pdf.

Because buoy data is one of the inputs to the daily OISST, and are the reference for the large-scale bias adjustments, then an evaluation of OISST relative to buoys cannot claim independence. However, the comparison is still instructive. Reynolds et al. (2010) evaluated the large-scale bias (relative to buoys in ten regions; Fig. 1b) for six SST analyses, including this product, for the years 2007-2008. Fig. 1a shows the RMS of the regional monthly biases (difference between monthly buoy and matching analysis averages) for the 24 months. The RMS was used so that the positive and negative biases do not cancel each other out, lowering the bias estimate. The OISST (referred to as AVHRR-only in Fig. 1a) performs at least as well as most other analyses, with RMS below 0.4 K, and in 6 regions, is below 0.2 K.

a)



b)

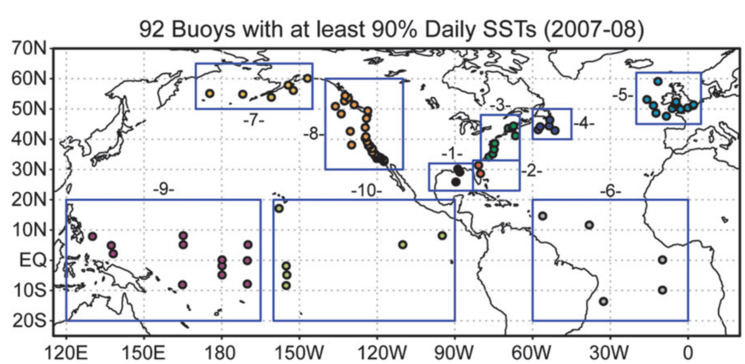


Figure 1. *a) Bias error relative to buoys of 6 SST analyses (listed in legend; AVHRR-only refers to the relevant OISST) in 10 regions. b) Regions in boxes showing buoy locations in circles: GM=Gulf of Mexiso, GSF=Gulf Stream Florida, GSEC=Gulf Stream East Coast, GSE=Gulf Stream Extension, UKI=United Kingdom/Ireland, TA=tropical Atlantic, AL=Aleutians, NAWC=North America West Coast, TWP=tropical west Pacific, TEP=tropical east Pacific. Figures from Reynolds et al (2010).*

Uncertainty fields are provided with the daily files. The standard error (Stderr), computed per gridpoint, represents the combination of two error estimates, the bias error and the combined random/sampling error. The random/sampling error estimate is based on the AVHRR-based OI analysis increment variance. The increment standard deviation (square root of the variance; Fig. 2) is largest in Western boundary current regions where mesoscale eddies are common, and smallest in the subtropical convergence areas and at high latitudes. This expected variance, by way of a multiplier term, is reduced when the OI uses more observations.

The bias error is assumed to be due to the satellite bias adjustment only, since satellite data overwhelm the other observations in coverage and frequency. The assumption is that the satellite bias error is related to the satellite EOT modes that could not be used (i.e., not supported by in situ data) plus a residual (due to the number of mode choices being limited to 130 so that the true bias is not fully estimated).

After the bias and the random/sampling variances are computed for each gridpoint, they are summed, on the assumption that they are independent, to get the total error variance. The total error (Stderr) reported in the netCDF file is the square root of this sum, and therefore is a standard deviation with units in °C. The pertinent equations and further details can be found in Reynolds et al. (2007), with some minor changes in Reynolds (2009).

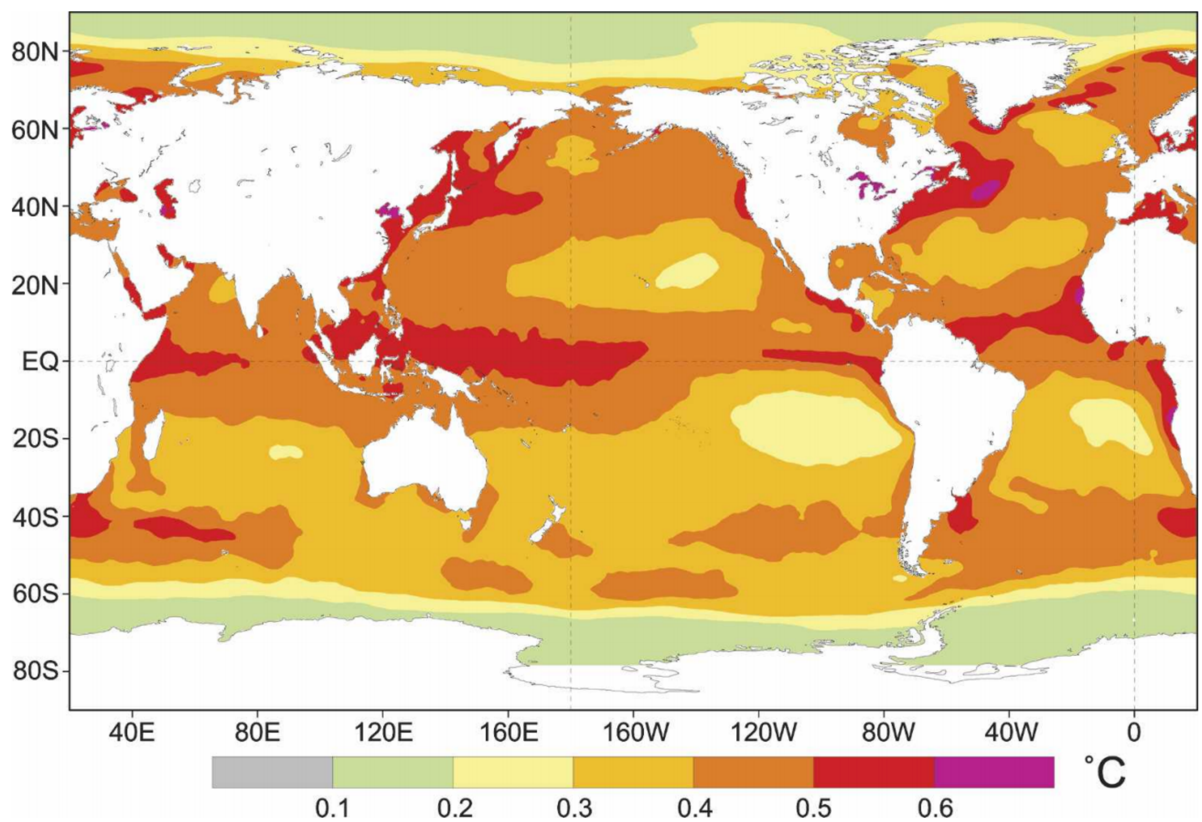


Figure 2. *The SST increment standard deviation represents the maximum possible random/sampling error per gridpoint, and is reduced when more observations are used in the OISST. Figure from Reynolds et al (2007).*

For the monthly files, the standard deviation values written to the output file Stddev variable are per-grid-cell standard deviations over each month associated with the means of the daily OISST fields. In addition, since a daily Stderr variable is also available, a per-grid-cell calculation of the means of the collected uncertainty values is performed, and the grid of means is then written to the monthly Stderr variable. This simple mean of the daily Stderr significantly overestimates the monthly uncertainty if the errors were assumed to be completely uncorrelated (no systematic component). But given that there is very likely a small systematic component to the total uncertainty, then is probably only a slight overestimate of the true error.

5. Considerations for Model-Observation Comparisons

There are biases in each of the input datasets. The bias correction scheme discussed in Section 2 is not perfect, but seeks to compensate for platform differences and to minimize the very large AVHRR error due to the Mt. Pinatubo and El Chichon eruptions.

By definition, the daily analysis is a smoothed field, made by combining observations made at different times of day and at different distances from the gridpoint center, representing different spatial scales. Therefore, an analysis will not agree perfectly with single observations. Users are encouraged to understand the trade-offs in using an analysis by also making comparisons to observations. Because it is effectively a filtered product, the analysis may not capture extremes or match locally collected data, but it will provide a best estimate for each day.

6. Instrument Overview

The OISST code does not perform any satellite retrievals, relying on other data producers to provide infrared SSTs and the microwave sea ice concentrations, both from a series of sensors. The Advanced Very High Resolution Radiometer (AVHRR) series is the source of SSTs. A summary of the AVHRR series and how the instrument evolved can be found in many publications, such as Hutchison and Cracknell (2006), who also provide historical context by comparing with existing and future meteorological satellites. Technical documentation is available online http://www1.ncdc.noaa.gov/pub/data/satellite/publications/podguides/. For the period that the Pathfinder version 5.0/5.1 algorithm was used up to 2005, the schedule of the individual AVHRRs is listed in http://www.nodc.noaa.gov/SatelliteData/pathfinder4km/. From 2007 onward, the analysis uses AVHRR SSTs processed using the Navy algorithm (May et al., 2001), and any change in individual sensors is posted at the OISST website (http://www.ncdc.noaa.gov/oisst/).

Sea ice concentrations are obtained from passive microwave instruments. Ice data derived using the NASA Team Algorithm (Cavalieri et al., 1999; http://nsidc.org/) are used up to 2004. From 2005 onward, the operational NCEP sea ice analysis (Grumbine, 1997; http://polar.ncep.noaa.gov/seaice/) is used. Descriptions of the instruments are provided at the two websites and references therein.

7. References

Primary references:

Reynolds, R. W., T. M. Smith, C. Liu, D. B. Chelton, K. S. Casey and M. G. Schlax, 2007:Daily High-resolution Blended Analyses for sea surface temperature. J. Climate, 20, 5473-5496.

Reynolds, R. W., 2009: What's New in Version 2. OISST Webpage.

Background and related references:

Viva F. Banzon, Richard W. Reynolds, Diane Stokes, and Yan Xue, 2014: A 1/4°-Spatial-Resolution Daily Sea Surface Temperature Climatology Based on a Blended Satellite and in situ Analysis. *J. Climate*, **27**, 8221–8228.

doi: http://dx.doi.org/10.1175/JCLI-D-14-00293.1

Cavalieri, D. J., C. L. Parkinson, P. Gloersen, and H. Zwally. 1996, updated yearly. *Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data*. Boulder, Colorado USA: NASA DAAC at the National Snow and Ice Data Center. http://nsidc.org/data/nsidc-0051.html.

Cavalieri, D. J., C. l. Parkinson, P. Gloersen, J. C. Comiso, and H. J. Zwally. 1999. Deriving Long-term Time Series of Sea Ice Cover from Satellite Passive-Microwave Multisensor Data Sets. *Journal of Geophysical Research* 104(7): 15,803-15,814.

Hutchison, K. D. and A. P. Cracknell, 2006. Visible Infrared Imager Radiometer Suite: A New Operational Cloud Imager. Taylor & Francis, Boca Raton, FL. 256pp.

Kilpatrick, K. A., G. P. Podesta, and R. Evans, 2001: Overview of the NOAA/NASA advanced very high resolution radiometer Pathfinder algorithm for sea surface temperature and associated matchup database. J. Geophys. Res., 106, 9179–9198.

Reynolds, R.W., C. L. Gentemann and G. K. Corlett, 2010: Evaluation of AATSR and TMI Satellite SST Data. J. Climate, 23, 152-165.

Reynolds, R. W., and D. B. Chelton, 2010: Comparisons of daily sea surface temperature analyses for 2007-08. J. Climate, 23. 3545-3562.

Reynolds, R. W., N. A. Rayner, T. M. Smith, D. C. Stokes and W. Wang, 2002: An improved in situ and satellite SST analysis for climate. J. Climate, 15, 1609-1625.

Worley, S.J., S.D. Woodruff, R.W. Reynolds, S.J. Lubker, and N. Lott, 2005: ICOADS Release 2.1 data and products. *Int. J. Climatol. (CLIMAR-II Special Issue)*, **25**, 823-842 (DOI: 10.1002/joc.1166).

8. Dataset and Document Revision History

Rev 0 – 7 January 2015 - This is a new document/dataset, referring to Version 2 of the Optimum Interpolation Sea Surface Temperature CDR data set.