# The development of the new Hadley Centre Sea Ice and Sea-surface temperature dataset, HadISST2, to explore uncertainty in boundary forcing for reanalysis

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## Introduction

The Met Office Hadley Centre Sea-ice concentration and sea-surface temperature (SST) data set HadISST1, has been used in many hundreds of peer reviewed publications. HadISST2 aims to build on the successful elements of HadISST1, while making improvements in a number of key areas.

1. Improvements to source data sets. HadISST2 is based on version 2.5 of the International Comprehensive Ocean Atmosphere Data Set (ICOADS). Improved AVHRR data from the Pathfinder data set are being used, along with SST retrievals from the ATSR Reprocessing for Climate. Sea ice data sources have also been update and extended.

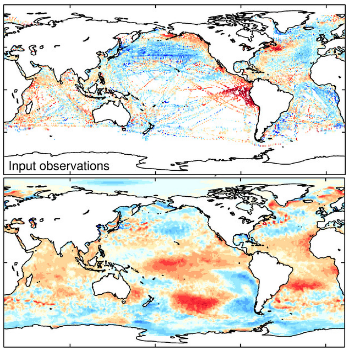
2. Bias corrections: comprehensive homogeneity adjustments are applied to the *in situ* SST, AVHRR SST and sea ice retrievals to correct for known biases in the data.

3. Improved reconstruction techniques. Previous data sets have focused on long-term homogeneity of the mean state, but have generally had inhomogeneous variance with more variance reconstructed in data rich periods. By drawing samples from the posterior distribution of the reconstructed SST, it is possible to reconstruct a greater and more consistent proportion of the variance.

4. Increased resolution: the base SST climatology is now 0.25°×0.25° and daily resolution allowing improved representation of high gradient features such as the Gulf Stream.

5. Uncertainties: HadISST2 will be presented as a set of realisations that explore the uncertainty range (see box at bottom left). Each realisation will have realistic spatial variability that is consistent with the known covariance structure of SST, the available observations and their uncertainties.

The challenge is to produce globally complete SST fields that are consistent with the available observations and their uncertainties, our understanding of the covariability of the fields and have realistic trends and variance at all time scales.




**(upper panel) *in situ* SST anomalies for June 1983 gridded at 1° latitude by 1° longitude resolution. Large areas of the southern hemisphere and tropical Pacific contain few observations however, certain patterns are clear, such as the strong El Niño event. Even in the northern hemisphere the fields tend to be affected by measurement errors which add white-noise. (lower panel) OSTIA SST anomalies for January 2010. The fields are globally complete and are shown here reduced to a 1° latitude by 1° longitude resolution.**

## In situ bias adjustments

*In situ* observations archived in the International Comprehensive Ocean Atmosphere Data Set were made using a variety of methods, principally by buckets of various kinds, measurements made at the engine room water inlet (ERI) and by drifting and moored buoys. Each of these methods introduces different systematic errors into the data and in order to combine them into a single homogeneous record it is necessary to make adjustments that minimise the effects of these biases.

To adjust the data and estimate the uncertainties three things are needed:

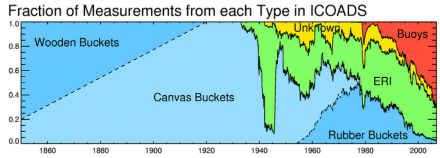
1. How each individual measurement was made
2. The systematic error associated with each measurement type
3. A method for combining 1 and 2.

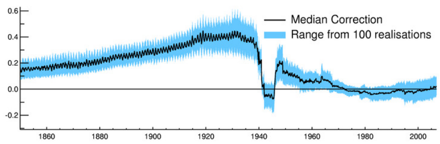
Each of these components introduces additional uncertainties. It is not clear, for example, how some observations were made. The systematic errors are known only approximately and there is no guarantee that the method chosen is absolutely correct. In order to estimate these uncertainties, assumptions in each component were varied within their plausible ranges. 100 different realisations of the adjustments were calculated and used to generate 100 different versions of the *in situ* data set.

**The top panel shows the fractional contribution of different measurement methods to the global average. The central panel shows the global average of the estimated monthly adjustments and their uncertainties. The adjustments correlate with the measurement methods shown in the upper panel. This is particularly clear around the Second World War when the observing fleet was small and undergoing rapid change.**

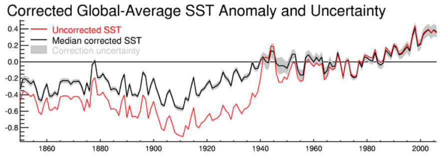
**The lower panel shows the global average SST both before (red) and after (black) adjustment. The grey area shows the uncertainty in the bias adjustments. There are other uncertainty components (not shown).**

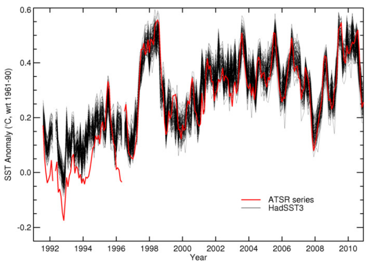
Fraction of Measurements from each Type in ICOADS



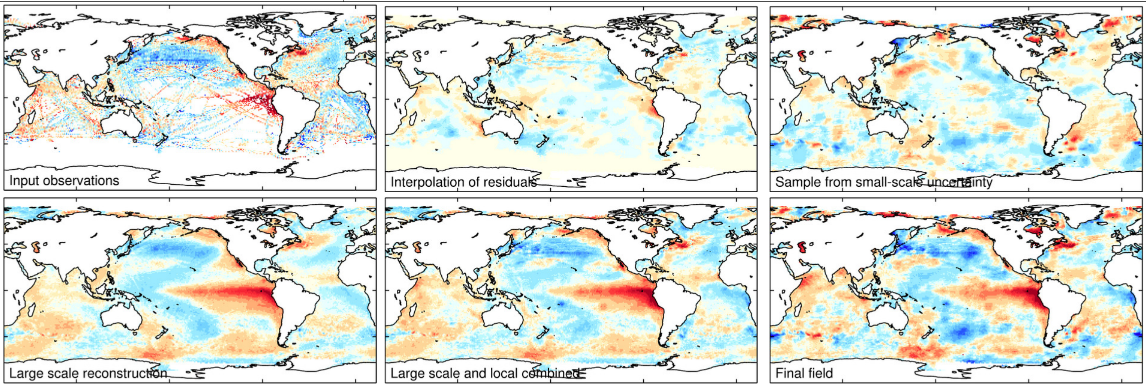

Corrected Global-Average SST Anomaly and Uncertainty




**Global average SST anomaly from HadSST3 ensemble (black) and ATSR Reprocessing for Climate (red).**

**Satellite data:** In order to combine satellite and *in situ* data it is necessary to first minimise the relative biases. For HadISST2 there are three principal SST data sources: ATSR (Along-track Scanning Radiometer), *in situ* data and AVHRR (Advanced Very High Resolution Radiometer). The ATSR and *in situ* data have been independently analysed and the bias adjustments applied to each largely remove relative biases between them (see figure above). Because of the greater reliability of the SSTs from the ATSR they are used to select realisations of the *in situ* data for the modern period. The AVHRR are less reliable, having particular problems with orbital drift and aerosol contamination, so the data are bias adjusted relative to the ATSR and *in situ* data. The resulting homogenised series are then combined according to their estimated uncertainties. Because of the greater spatial coverage, satellite data tend to dominate where they are available.

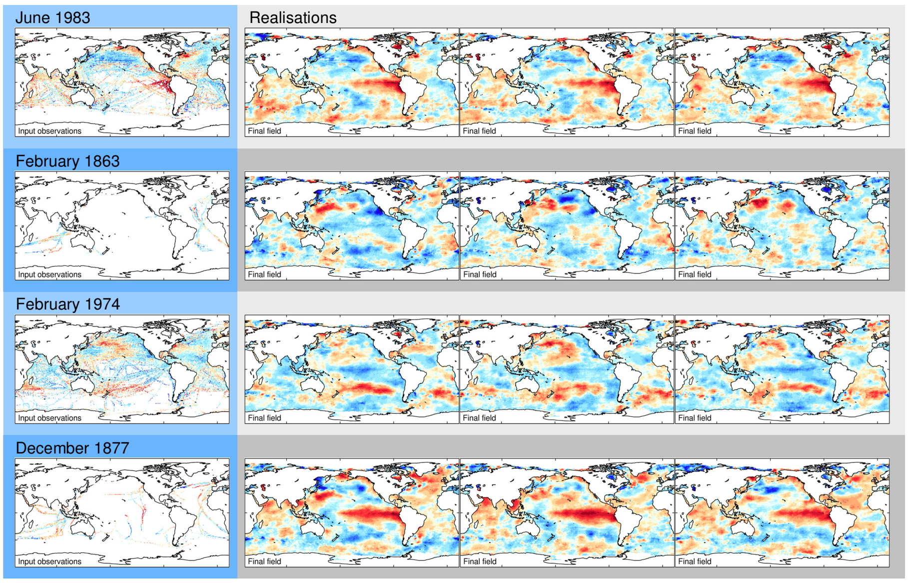



**Step 1 Large scale reconstruction :** The upper panel shows the *in situ* observations for June 1983. The lower panel shows a single sample drawn from the posterior distribution of the large scale reconstruction. The large scale reconstruction uses 70 Empirical Orthogonal Functions that are estimated using an iterative method (Ilin and Kaplan, 2009) from the combined *in situ* and satellite data from 1850 to 2010. This one step procedure captures the long-term trend in the data without additional processing. Reconstructions for other months can be found at the bottom of the poster.

**Step 2 Small scale reconstruction :** The large scale reconstruction is subtracted from the *in situ* observations and a local optimal interpolation (OI) method is used to create a small-scale analysis of the residuals (upper panel). The OI scheme uses three parameters to build a local covariance matrix (two orthogonal length scales and the angle of the principal axis from the line of longitude) as in Karspeck et al. (2011 QJRMS). The OI solution is then added to the large scale reconstruction (lower panel). Note that in areas with few observations the best-estimate OI gives very smooth fields.

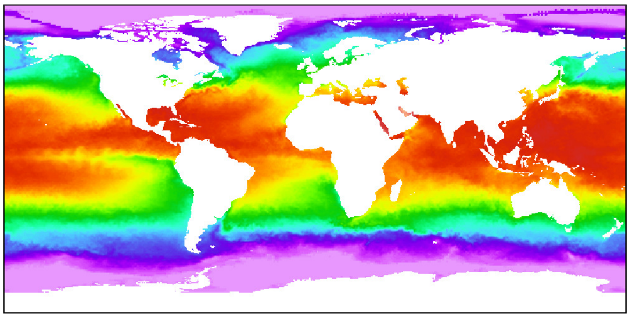
**Step 3 Local variance:** In the final stage a sample is drawn from the local covariance structure (top panel) scaled by the uncertainty. This ensures spatial homogeneity of the variance.

The process is repeated many times for each month allowing representative distributions to be built up. Some examples are shown at the bottom of the poster. In each case independent samples were drawn at each stage of the reconstruction. Where observations are plentiful, much of the between-sample variance comes from the local reconstruction.




## Increased Resolution

The base SST climatology has been revisited and is now daily and 0.25 degree resolution in both latitude and longitude. This allows improved quality control and calculation of anomalies particularly in areas where SST gradients are high, such as the Gulf Stream and other western boundary currents, or where there is a strong seasonal cycle. The 1 degree resolution pentad and monthly reconstructions are interpolated to 0.25 degree daily resolution using a conservative interpolation technique which preserves the temporal and area averages. The interpolated reconstruction is then added on to the high resolution climatology. The resulting high resolution fields are then blended, using the Poisson blending technique, with SSTs estimated from the sea-ice concentrations.



**Above: An example field of actual SST based on the pentad analysis (from September 2007) is shown above. It combines the high-coverage SST retrievals from the AVHRR instrument with the lower-coverage but higher-quality AATSR SST retrievals in a way that is homogeneous with the longer instrumental record. Remaining gaps are filled using the estimated covariance structure learned from over 150 years of SST observations.**

**Left: Multiple realisations of the reconstructed fields are produced that are consistent with the available observations, the uncertainties in those observations and our best understanding of the covariance relationships between SSTs at different locations.**

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