Coverage bias in the HadCRUT4 temperature series and its impact on recent temperature trends.
UPDATE
COBE-SST2 based land-ocean dataset

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November 7th, 2017

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This update document describes an new dataset created using the Cowtan and Way (2014) methodology version 2 (Cowtan *et al.*, 2015, supplement), but using the COBE-SST2 sea surface temperature data in place of HadSST3.

The HadSST3 dataset (Kennedy *et al.*, 2011) provides gridded temperature fields based on the ICOADS observational archive, using probably the most extensive analysis of the observation metadata to address inhomogenities in the data. However a recent unexplained drift in ship observations compared to free floating buoys and other sources (Hausfather *et al.*, 2017) has led to an apparent underestimation of 21st century temperature trends. As a result, HadSST3 shows slower warming over the past two decades than ERSSTv4/v5, which upweight the buoy data relative to the ship observations. However the ERSST records show hard-to-explain features in the earlier record, including a large warm spike during the second world war and unusual warmth in the 19th century inconsistent with the recorded use of wooden buckets (Folland and Parker, 1995).

The new COBE-SST2 dataset (Hirahara *et al.*, 2014) uses a similar if less complete metadata analysis to HadSST3 with very similar results (Kent *et al.*, 2016), except that it does not show the effect of the drift in ship observations since 2005 (Hausfather *et al.*, 2017). A reconstruction based on COBE-SST2 may therefore be useful for the evaluation of temperature trends over the purported "hiatus" period.

The reconstruction was produced as follows:

1. The COBE-SST2 data were upscaled from the original 1x1 degree grid to the 5x5 degree grid of HadCRUT4 by area weighted averaging in each 5x5 degree grid cell.

2. The sea surface temperatures were converted to anomalies using the 1961-1990 baseline of HadCRUT4.

3. The sea surface temperatures were extended to global coverage by Kriging following the method of (Cowtan and Way, 2014). The COBE-SST2 data are already infilled and so this step has almost no effect, however a small number of cells could potentially be missing values due to differences in the ice mask used in the two datasets. The variogram range from COBE-SST2 is overestimated due to smoothing, and so was set to the value of 860 km determined from the HadSST3 data.

4. The sea surface temperatures were then blended with the grid median of the HadCRUT4 land temperature ensemble. Following the approach of the update of 06/01/2014, a fixed monthly sea ice mask was used to avoid the bias introduced by cells changing from air to sea surface temeratures (Cowtan *et al.*, 2015). However given that the recent period is of primary interest for this dataset, the minimum sea ice mask was used in place of

the median sea ice mask, in the same manner as the short reconstructions described in the update of 05/02/2014.

The resulting gridded data and temperature series are available from the temperature series page under the name COBE2CRU. No uncertainty estimates are available for this dataset because they are contingent on the uncertainties in both the reconstruction and infilling in COBE-SST2. Updates to the COBE-SST2 data are currently irregular.

Discussion

IPCC AR5 WG1 box 9.2 included a discussion of temperature trends for the period 1998-2012, highlighting the trend in the HadCRUT4 dataset (the slowest warming of the major series) of 0.04°C/decade. The corresponding trend for the COBE2CRU blend is 0.13°C/decade. The low trend over the period has been the subject of many peer-reviewed papers (Lewandowsky *et al.*, 2015), however once the observational and methodological issues with the data are addressed the temperature trend is in no way exceptional in the context of long term variability in temperature trends.

The contributory factors to the difference in trend are broken down in Table 1. The HadCRUT4 trend reported in AR5 was based on version 4.1.1 of the HadCRUT4 and CRUTEM4 datasets. The CRUTEM4 weather station data fall into two classes - stations which are updated monthly, and stations which are updated periodically in new numbered versions, the latter group including many of the rapidly warming high latitude stations. New versions are released every 1-2 years. Global temperature estimates for months since the last version number increment tend to be biased low due to the missing high latitude stations. The release 4.1.1 data used in AR5 were incomplete from February 2012. Subsequent versions have introduced some additional stations in Asia, North America and Africa. The HadCRUT version 4.5.0 trend is therefore higher than for version 4.1.1 by about 0.01°C/decade.

The incomplete coverage of the observations mean that the HadCRUT4 summary statistics underestimate warming. A simple approach to this problem is the use of optimal averageing to weight each grid cell according to the independent information it provides (Kagan, 1997), which when used with the same variogram yields identical results to Cowtan and Way (2014). This results in a global trend which is about 0.05°C/decade higher than the HadCRUT4 summary statistics.

Separate reconstruction of the land and ocean temperature fields (i.e. the version 2 temperature reconstruction) yields similar a trend when using the minimum sea ice mask or a small increase of about 0.01°C/decade when using the median ice mask. The use of COBE-SST2 in place of HadSST3 leads to an increase in trend of about 0.03°C/decade in each case. The distributed version of the COBE-SST2 reconstruction uses the more conservative minimum ice mask.

Dataset	Trend (°C/decade)
HadCRUT4 4.1.1	0.04
HadCRUT4 4.5.0	0.05
Optimal averaging (C&Wv1)	0.10
Land-ocean reconstruction (C&Wv2)	0.10/0.11
Land-ocean with COBE-SST2	0.13/0.14

Table U1: Temperature trends for the period 1998-2012 as discussed in AR5 WG1 box 9.2, using different datasets and methodologies. Note: the two values for the land-ocean reconstructions are for the minimum and median ice masks respectively, which affect the amount of the Arctic for which air temperatures are used.

References

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