Coverage bias in the HadCRUT4 temperature series and its impact on recent temperature trends.
UPDATE
Temperature reconstruction by domain: preliminary analysis

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1 Temperature reconstruction by domain: preliminary analysis

The land and ocean temperature fields show different behaviour and different levels of correlation with the satellite data. Ideally therefore the land and ocean data should be reconstructed separately and then blended, rather than reconstructing the blended data. This also avoids a potential bias caused by coastal cells which have only land data in one month and SST data in another.

The optimal scale factor s for the hybrid reconstruction is determined using the cross-validation test described in the main paper. The errors in the cross-validated reconstruction are given in Table (S1) for the land data and Table (S2) for the ocean data. At short ranges there is little differentiation, but the longer range tests suggest $s = 1.0$ for the land data and $s = 0.2$ for the oceans.

The geographical variation of s was also examined by comparing the surface and satellite time series for each grid cell. This approach provides additional geographical information but may be impacted by temporal inhomogeneities in the satellite data, in contrast to the methods employed in the rest of this work. The time series were therefore differenced to partially mitigate temporal inhomogenity. Linear regression was used to estimate the value of s required to fit the differenced satellite temperatures to the surface data in each cell. The results are shown in Figure (S1). Over land the value of s tends to be around 1, with slightly higher values in the continental interiors and lower values on non-icebound coastlines. For the oceans the optimal value of s is typically in the range 0.0 ... 0.3 apart from a few cells in the El Nino region. The results are consistent with the values estimated by the cross-validation test.

Vostok station (altitude 3500m) is the only inland Antartic station not in the satellite blind spot. Fitting the differenced temperature data for this station gives $s = 1.2$, and the satellite data predicts 67% of the variance in the surface observations. These values are typical for a continental interior and support the use of the satellite data even at high latitudes and altitudes.

As shown in the main paper, surface temperatures over sea ice are best reconstructed from land rather than SST data. However the changing sea ice coverage leads to a potential bias when working with anomalies, since the offset between the land and SST temperature anomalies is unknown. As a result when working with the HadCRUT data it is necessary to assume constant ice cover for any given month of the year. For this analysis ice masks representing the maximum, median and minimum ice over the period 1979 to 2012 were determined from the HadISST data (Rayner *et al.*, 2003). These were used to construct a combined land+ice mask.

The land temperature ensemble used in HadCRUT4 is not currently distributed, however the CRUTEM4 land data (Jones *et al.*, 2012) and HadSST3 ensemble median data (Kennedy *et al.*, 2011) can be used to assess the effect of reconstructing the global temperature field before or after blending the land and ocean data. The CRUTEM4 and HadSST3 datasets were first blended using a conventional land mask and reconstructed using the hybrid method with $s = 1.0$ following the reconstruction method employed in the main paper. Next hybrid reconstructions were performed for the land and ocean data using the satellite scales of $s = 1.0$ and $s = 0.2$ respectively. The separate reconstructions were then blended using the maximum, median, and minimum land+ice masks.

The resulting temperature series are shown in Figure (S2). The reconstruction from the blended data is a good approximation to the blend of the reconstructed land and ocean data. The choice of ice mask makes little difference - this is consistent with the observation that the largest bias arises in winter when the decline in ice extent is less pronounced.

References

Jones P, Lister D, Osborn T, Harpham C, Salmon M, Morice C. 2012. Hemispheric and large-scale land-surface air temperature variations: An extensive revision and an update to 2010. *J. Geophys. Res.* **117**(D5).

Kennedy J, Rayner N, Smith R, Parker D, Saunby M. 2011. Reassessing biases and other uncertainties in sea surface temperature observations measured in situ since 1850: 2. biases and homogenization. *J. Geophys. Res.* **116**(D14): D14 104.

Rayner N, Parker D, Horton E, Folland C, Alexander L, Rowell D, Kent E, Kaplan A. 2003. Global analyses of sea surface temperature, sea ice, and night marine air temperature since the late nineteenth century. *J. Geophys. Res.* **108**(D14).

Table S1: RMS difference between original and reconstructed cell temperatures calculated over all observed *land* cells when omitting one or more rows of data and reconstructing the central row from rows separated by the specified distance.

Method	RMS error in reconstruction (°C)		
	1 cell (550km)	2 cells (1100km)	3 cells (1650km)
Null	1.48	1.49	1.51
Krig	0.76	1.18	1.41
Hybrid 0.2	0.74	1.09	1.27
Hybrid 0.4	0.72	1.01	1.15
Hybrid 0.6	0.71	0.96	1.05
Hybrid 0.8	0.71	0.93	1.00
Hybrid 1.0	0.72	0.92	0.98
Hybrid 1.2	0.73	0.95	1.01
Hybrid 1.4	0.75	1.00	1.08

Table S2: RMS difference between original and reconstructed cell temperatures calculated over all observed *ocean* cells when omitting one or more rows of data and reconstructing the central row from rows separated by the specified distance.

Method	RMS error in reconstruction (°C)		
	1 cell (550km)	2 cells (1100km)	3 cells (1650km)
Null	0.76	0.76	0.77
Krig	0.62	0.72	0.76
Hybrid 0.2	0.62	0.71	0.74
Hybrid 0.4	0.62	0.72	0.75
Hybrid 0.6	0.63	0.75	0.80
Hybrid 0.8	0.64	0.79	0.87
Hybrid 1.0	0.65	0.85	0.96
Hybrid 1.2	0.66	0.91	1.07
Hybrid 1.4	0.68	0.98	1.18

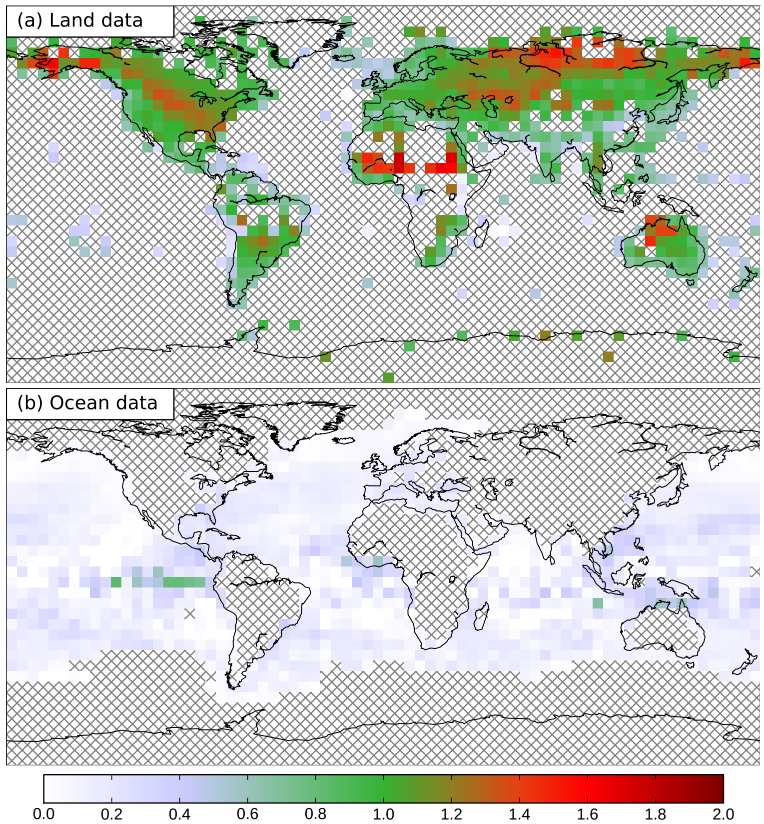

Figure S1: Geographical variation in s evaluated using first-differenced time series in each cell for land and ocean data.

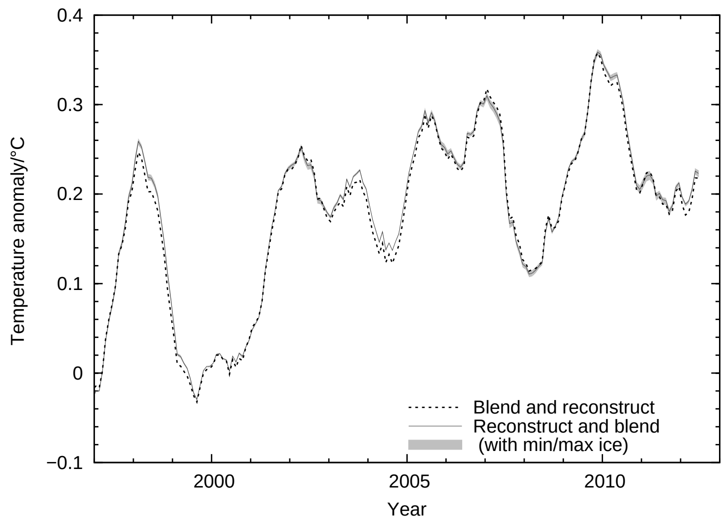

Figure S2: Temperature anomaly comparison of the reconstruction from the blended data against blends of the separate land and ocean reconstructions using maximum, median and minimum land+ice masks.