Coverage bias in the HadCRUT4 temperature series

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1. Abstract

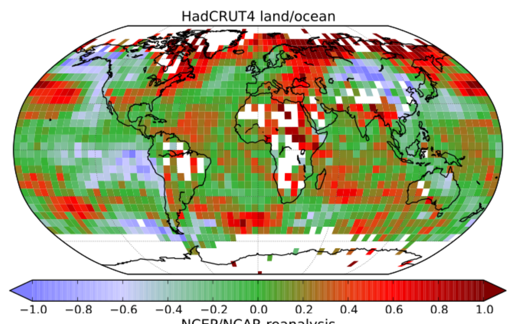
Incomplete global coverage is a potential source of bias in global temperature reconstructions. The widely used HadCRUT4 dataset covers about 84% of the globe over recent decades, with unsampled regions at the poles and over Africa.

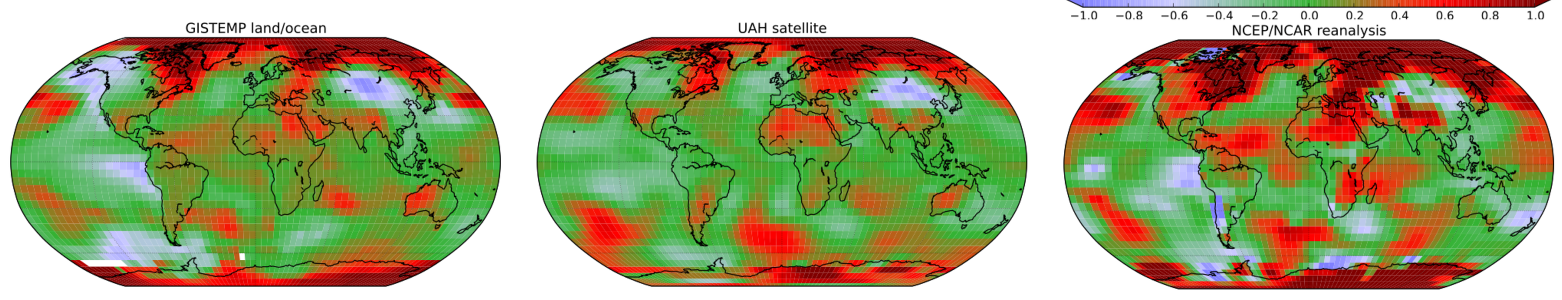
Two approaches for reconstructing global temperatures are explored, one based on an optimal interpolation algorithm and the other a hybrid method incorporating additional information from the satellite temperature record. The methods are validated on the basis of their skill at reconstructing omitted sets of observations.

The trend since 1997 in the hybrid reconstruction is two and a half times greater than in the HadCRUT4 data. Trends starting in 1997 or 1998 are maximally misleading with respect to the global trend.

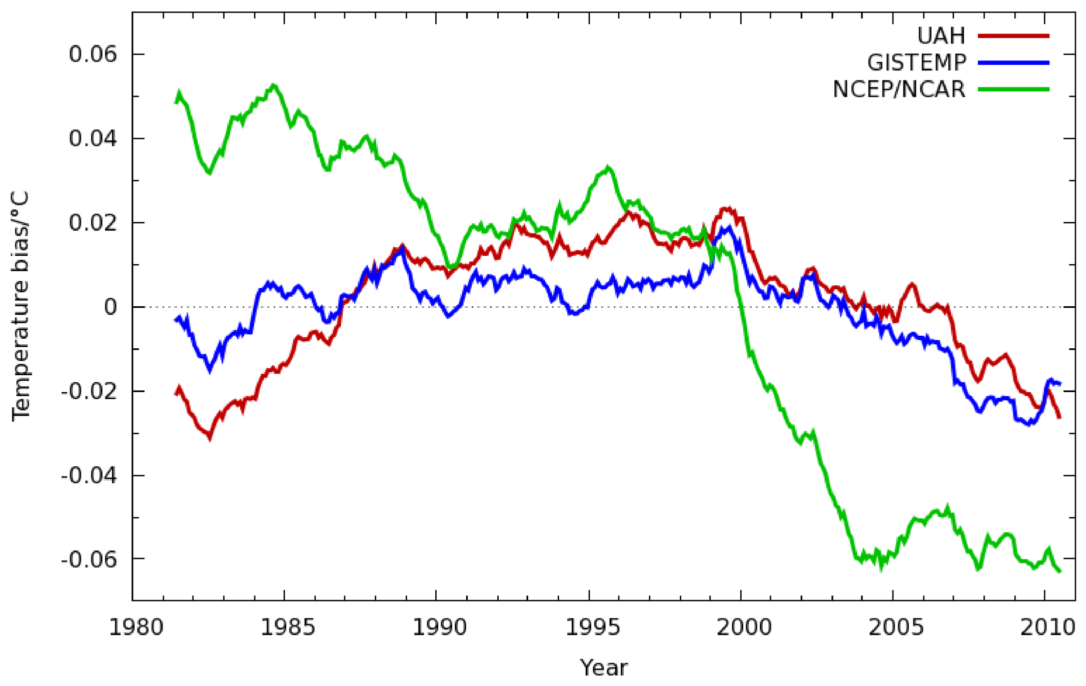
2. Background

The problem of coverage bias in the instrumental temperature record can be seen by comparison of 16 year trends in the HadCRUT4 data (Morice et al, 2013) with three other sources: GISTEMP (Hansen et al, 2010), the UAH satellite record (Spencer, 1990), and the NCEP/NCAR reanalysis (Kalnay et al 1996):





All the global series show extreme warming in the Arctic, which is largely missing in the HadCRUT4 record. An initial assessment of the resulting bias may be estimated by reducing the coverage of these three series to match HadCRUT4 and calculating how the loss of coverage biases the resulting global temperature estimate:



There is a significant warm bias around 1998, which transitions to a cool bias in recent years, although the reanalysis data differ in the details.

3. Methods

Two methods have been investigated:

- Optimal interpolation by 'kriging'. Ideally this would be conducted at a station level (Muller et al, 2012), but performing the calculation on the gridded data means that all the corrections in the HadCRUT4 data may be retained.
- A hybrid method using the UAH satellite data. The surface temperature data eliminates temporal inhomogeneities in the satellite data, while the satellite data provides proxy information about unobserved surface temperatures.

These approaches are described by the following two equations respectively:

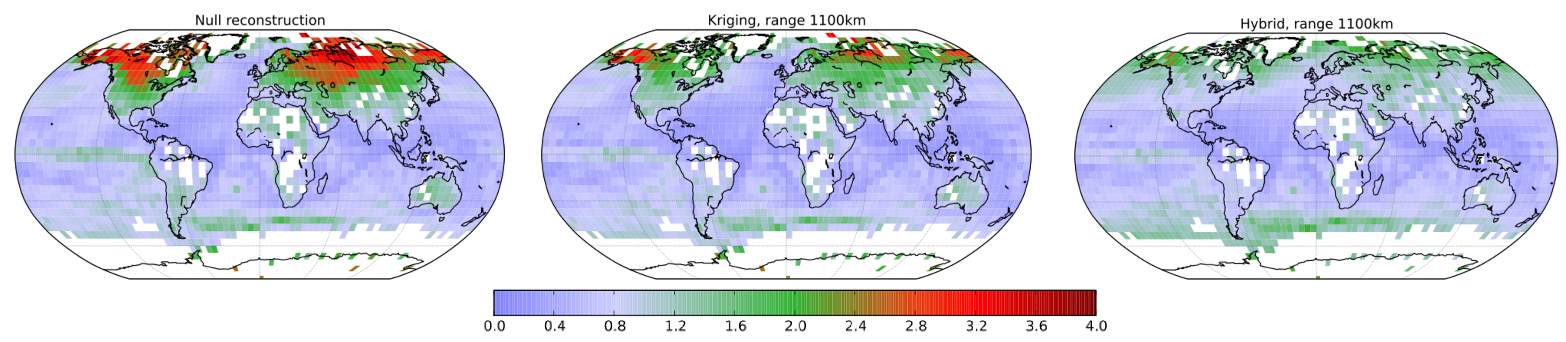
$$T^{krig}_x = \mathrm{krig}(\,T^{surf}\,)_x$$

$$T^{hybrid}_x = \mathrm{krig}(\,T^{surf} - sT^{sat}\,)_x + sT^{sat}_x$$

where s is a scale factor applied to the satellite data, determined by hold-out tests. The satellite data reduces the variation in the difference temperature field, which in turn reduces the uncertainty in the interpolation.

4. Validation

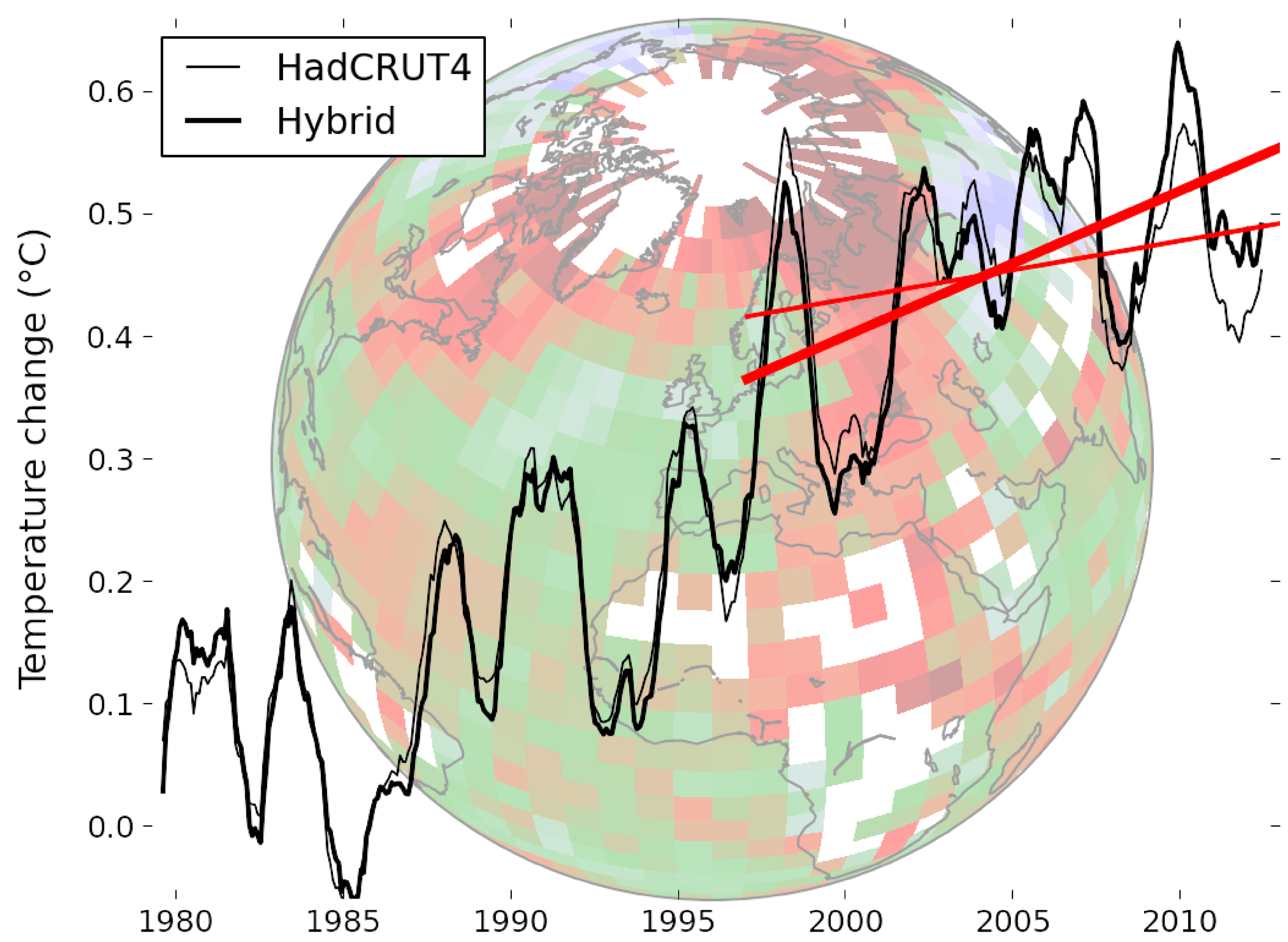
The methods were tested against a null reconstruction (with omitted cells set to the global mean), reconstructing each row of the map from data at least 2 rows distant. Kriging is effective for sea surface temperatures, but the hybrid method is better over land:



The skill of the methods in reconstructing omitted cells in a 1100km band around the edge of the unobserved regions was also tested for the period 2005-2012.

Method	Bias/ºC	Error/ºC
Null	-0.027	0.074
Kriging	-0.026	0.064
Hybrid	-0.003	0.033

5. Results



The trend on the period 1997-2013 in the hybrid reconstruction is 2½ times the trend in the original data. Trends starting in 1997/1998 are maximally misleading with respect to the global temperature trend.

This has implications both for public understanding (given the wide reporting of 15-16 year temperature trends in the media) and for research into recent temperature trends.

6. Discussion.

The biggest contribution to coverage bias comes from the Arctic, as does the biggest uncertainty in this result. The cross-validation results show that temperature extrapolation across land-ocean boundaries is problematic. However, given that the Arctic is largely land-bounded and ice-covered, there are no nearby sea surface temperatures (SSTs) to extrapolate. As a result, extrapolation of the merged land-ocean data implicitly treats the central Arctic as land.

Arctic weather stations are all coastal, and winter sea ice significantly insulates the atmosphere from the ocean, so there is some justification for extrapolation from the land stations. Ideally this assumption should be tested against observational or model data.

References:

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