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including HadCRUT3 data set

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Development of the global surface temperature dataset HadCRUT3

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Executive Summary

We are producing an update to the historical surface temperature dataset HadCRUT, providing a comprehensive error model as well as a range of data and technical improvements.

We are using marine data and uncertainties from the new HadSST2 dataset. This provides better coverage, and assessments of marine uncertainties and biases.

We have added some extra stations to our land observations data-base. We have further improved this data-base by doing additional quality control.

We are producing comprehensive uncertainty estimates for the land data, including assessments of measurement and sampling error, and the effects of various biases. Together with the HadSST2 data, this gives us uncertainty estimates for the global data.

We have improved our methods for data blending and gridding, so we can make gridded datasets on any spatial resolution.

We are refining the statistical methods used for homogenising and averaging the gridded data. Testing these methods against pseudo-instrumental data derived from GCM results is allowing us to verify their capabilities and limitations.

1 Introduction

The historical surface temperature dataset HadCRUT [1, 2] is extensively used as a source of information on surface temperature trends and variability. One noteworthy use is the provision of time-series of global and hemispheric annual average temperatures. This dataset is produced through collaboration between the Hadley Centre, who provide the marine data expertise, and the Climatic Research Unit (CRU) at the University of East Anglia, who provide the land data and expertise.

Since the last update, which produced HadCRUT2 [2], important improvements have been made in the marine component of the dataset [3]. These include the use of additional observations, the development of comprehensive uncertainty estimates, and technical improvements that enable, for instance, the production of gridded fields at arbitrary resolution.

This document is a report on work to produce a new dataset version, HadCRUT3, which will extend the advances made in the marine data to the global dataset. The work is being managed in the Hadley Centre, but part of the work to be done needs expertise from CRU, so a contract has been placed with CRU to fund them to work on the project in collaboration with Hadley Centre staff.

2 Aims of the work

The work being done falls in five main areas:

- Improved land data: additional data, extra quality control.
- Comprehensive land error model: Add estimates of observation errors, extend existing sampling and bias uncertainty estimates to arbitrary grid resolutions.
- Flexible gridder: make gridded fields on any spatial resolution.
- Better land-sea blending: combine land and sea data in coastal grid-boxes in a way which uses our knowledge of the uncertainties for each data source.
- Better statistical processing: the gridded fields are refined using two important statistical processes:
 - Variance correction: removes the effect of the changing number of observing stations,
 - Optimum averaging: make global and hemispheric time-series from the gridded fields.

These processes will be checked for correctness, and simplified and refined where necessary.

The resulting dataset will be made available on the web, and the work will be published in time for the results to be available to the IPCC 4th assessment report.

3 Progress and plans

3.1 Improved land data

Some new station data has been added, mostly for stations in Mali and the Congo, Switzerland and Antarctica. Also a lot of quality control has been done. A comparison [4] of the CRU temperature data with the ERA-40 reanalysis found several areas where the station data was doubtful, and this was augmented by visual examination of individual station records looking for outliers. Many bad values were identified and either corrected or removed. A number of duplicate stations were found in the archive and these were rationalised. Also the station normals and standard deviations were regenerated and checked.

Figure 1 shows the locations of stations where changes have been made.

3.2 Flexible gridder

Earlier versions of HadCRUT [1, 2] were produced only on a 5x5 degree resolution. Recent work on marine datasets [3] has enabled us to produce them on any resolution; this is valuable for regional studies and for comparison with model results. We have developed the same functionality for gridding the land temperature, and so we can make HadCRUT3 gridded fields at any spatial resolution.

Figure 2 shows the land temperature anomalies for a sample month on the HadCM3 model grid. Figure 3 shows North American land temperature anomalies for the same month at the higher HadGEM1 resolution.

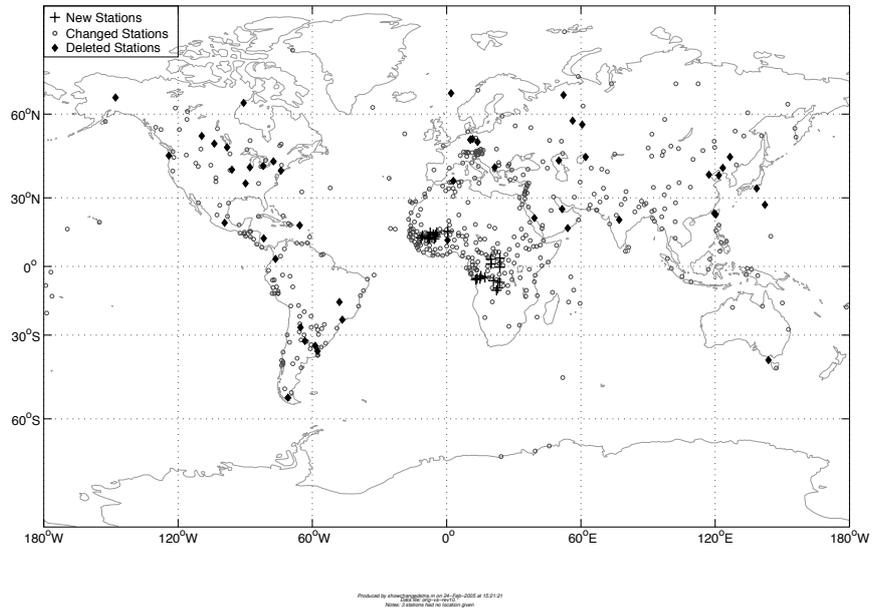


Figure 1: Improvements to the station data. (Plus signs are stations added, filled symbols stations deleted and hollow symbols stations edited).

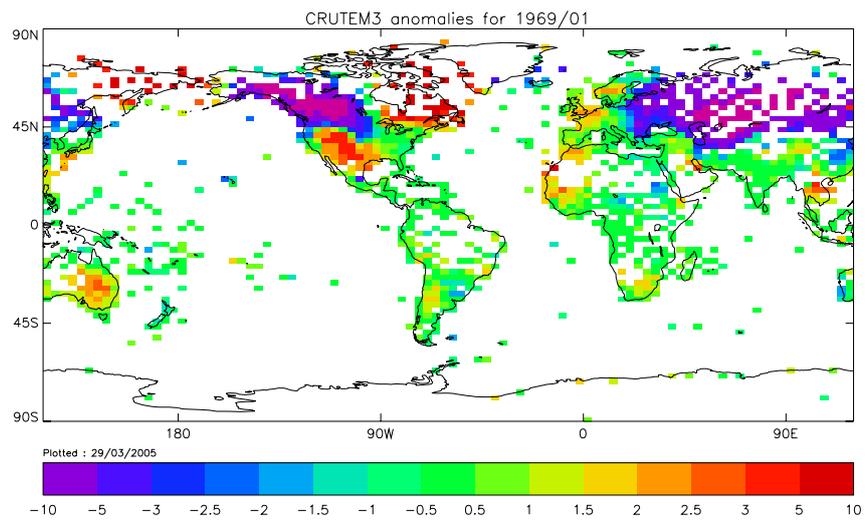


Figure 2: Land temperature anomalies (C) for January 1969 on the HadCM3 atmosphere grid

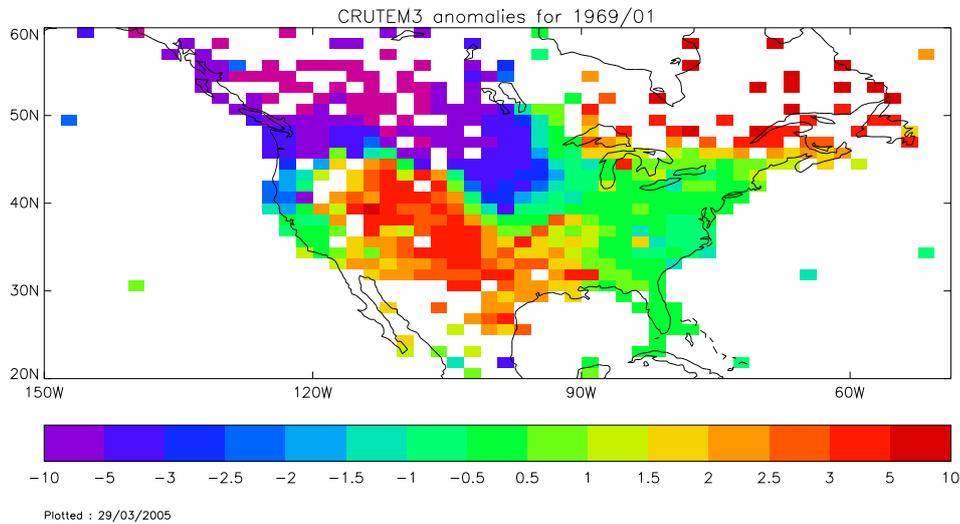


Figure 3: North American land temperature anomalies (C) for January 1969 on the HadGEM1 atmosphere grid

3.3 Comprehensive land error model

There are three different sorts of uncertainty to be considered:

- Uncertainties in the station data:
 - Measurement error: following [5] we estimate this as 0.04C on monthly average temperatures.
 - Uncertainty in homogenisation corrections: we are estimating this by examining records of corrections performed at CRU, and by examining differences between corrected and uncorrected data provided by the Austrian and Canadian national met. services.
 - Uncertainty in the climatologies: this is only important where station data is incomplete over the climatology period; we are estimating it by exploring the effect of removing data from stations with complete coverage.
- Uncertainties in the gridded fields:
 - Effects of the station uncertainties: the combined effect of the uncertainties described above.
 - Sampling error: we are adapting the methods of [6] to work on a flexible grid.
- Uncertainties in the bias corrections. Following [5], we are considering two bias corrections: instrument exposure changes and urbanisation. we are adapting the methods of [5] to work on a flexible grid.

We have not yet made final estimates of all the uncertainty components, but we expect the sampling error to dominate the uncertainties of monthly gridded fields. Figure 4 shows the estimated sampling errors for the gridded fields of figure 3

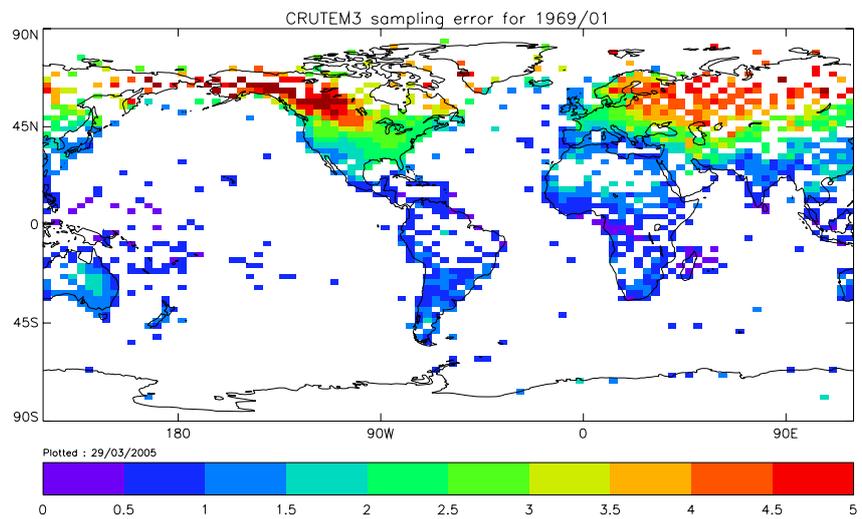


Figure 4: Temperature anomaly sampling errors (C) for January 1969 on the HadCM3 atmosphere grid

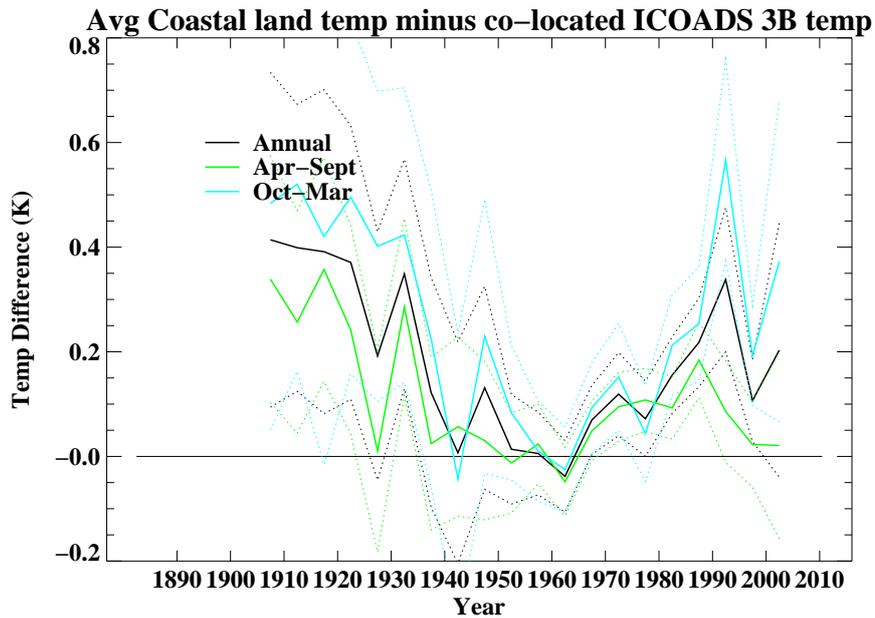


Figure 5: Global mean land-sea temperature difference in coastal and island grid boxes

3.4 Better land-sea blending

Previous versions of HadCRUT blend land and sea data in coastal and island grid-boxes by weighting the land and sea values by the area fraction of land and sea respectively, with a constraint that the land fraction cannot be greater than 75% or less than 25%, to prevent either data-source being swamped by the other.

The optimum way to average two values is to scale them according to their uncertainties, so that the more reliable value has a higher weighting than the less reliable. As we have full uncertainty estimates for both the land and sea gridded data we will make HadCRUT3 by blending the components like this.

To get further insight into the uncertainties in the blended dataset it is useful to look at the differences between land and sea data in coastal and island grid-boxes. Figure 5 gives time-series of global average land-sea differences, which show interesting structure. The land-sea differences are larger than the uncertainties would suggest, and have trends. We believe that these trends are caused by uncorrected biases in the land and sea data sets. We don't propose to pursue this further as part of the HadCRUT3 work, but such comparisons may be useful in future work on land and marine temperature bias estimation.

3.5 Better statistical processing

3.5.1 Variance correction

Because the number of observations on which they are based varies, grid-box and larger scale temperatures based on observational data have a standard deviation that varies through time. Most analyses of the data do not allow for this effect, so we need to correct the data to behave as if the number of observations were

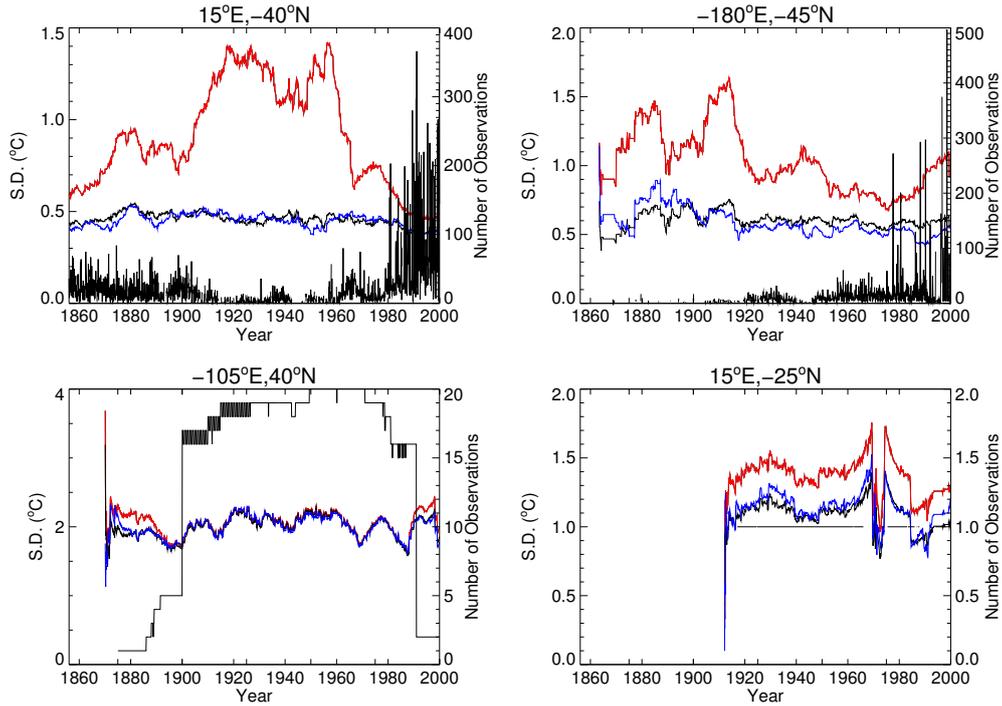


Figure 6: Effects of variance correction on grid-box standard deviation series for 4 sample locations. Shown are uncorrected SD (red), corrected SD (blue), actual SD (black); also shown is the number of observations

constant. Methods for this ‘variance correction’ have been developed for previous versions of HadCRUT [7] but doubts have been expressed over their suitability, so we want to test and perhaps simplify them.

We are testing this statistical method using a similar technique to the ‘pseudo-proxy’ method recently used to investigate statistical problems in paleo-climate reconstruction [8]. We have taken surface temperature data from an All-Forcings HadCM3 run, degraded it by removing data where we have no observations, and added noise to mimic the noise expected in HadCRUT. This gives us a ‘pseudo-instrumental’ dataset, where each grid-box shows variance fluctuations of the kind seen in the instrumental data. If we apply our variance correction methods to this dataset, and they work correctly, we should recover the original model data. So by comparing the corrected pseudo-instrumental data with the model data we can test the effectiveness of our statistical processing.

The results of this test are encouraging, the correction process introduces no biases into the temperature trends, and makes a good job of removing the artificial variance fluctuations. Reconstructed variances are very close to the original variances, the change in variance is typically a reduction of up to 50%, to within a few % of the correct value.

Figure 6 shows the results of this test in four sample grid-boxes (2 sea and 2 land). The time-series of standard deviation from the original model data is the black curve, the uncorrected pseudo-instrumental data gives the red curve, and the variance corrected pseudo-instrumental data the blue curve.

3.5.2 Optimum averaging

Instrumental datasets have incomplete global coverage, especially in the 19th and early 20th centuries. In spite of this, we want to make estimates of global and regional temperature anomalies. We do this by optimum averaging (OA) [5], a process which first estimates the local covariability of the data, and then

uses this covariance information to estimate values for regions with missing data, and so their contribution to the global average. We intend to test this process also on the pseudo-instrumental data: if the OA method is working, the OA of the pseudo-instrumental data will be the close to the simple average of the (spatially complete) model data. So we will be able to check that the OA technique is not introducing biases.

4 Summary

We are making good progress towards the production of an updated version of the global historical surface temperature dataset HadCRUT. This new version will be based on improved observational data, will have comprehensive error estimates, and will have associated local and global average time-series that are produced using fully tested methods.

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