Met Office Hadley Centre

Do you take three temperature data sets into the shower?

Not me, I use an optimal blend of sea surface temperature, night marine air temperature and land surface air temperature

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Global average temperature: a marriage of convenience

Data sets of global temperatures typically combine land surface air temperatures with sea-surface temperatures to get a near global assessment of near surface temperature change.

Sea-surface temperatures (SST) are used in place of the more obvious choice of marine air temperatures (MAT) because

1. There are more observations of SST.
2. The biases are more tractable.
3. SST is less variable, requiring fewer observations for a reliable estimate.

Of these three points, only the first is unquestionable. Recent work has shown that SST biases are an important source of uncertainty in assessing long term trends in all parts of the record.

The difference in variability between marine air temperature and sea-surface temperature reflects real physical differences between these variables. For some applications, using SST will lead to an underestimate of the variability. Data sets of temperatures such as NASA GISS, NOAA NCDC and HadCRUT have dealt with this in a variety of ways, typically by preferentially using land air temperatures where they are available.

A new data set is proposed which combines the strengths of the three component data sets – night marine air temperature (NMAT), sea-surface temperature (SST) and land surface air temperature (LSAT) – to give a dataset which better captures the variability in near surface air temperatures.

STEP 1: how similar are NMAT and SST?

Marine air temperature is not sea-surface temperature although there are good physical reasons for thinking that anomalies in NMAT will have similar anomalies to coincident SSTs. However, when there are strong temperature contrasts and the wind is blowing persistently, SST is not always a good predictor of NMAT.

Differences between grid box average NMAT (MOHMAT4N3) and SST (HadSTST3) anomalies were modelled as a Gaussian distribution with mean of zero and standard deviation, σ_{tot}. σ_{tot} is a sum of the actual variability (σ_{true}) and two measurement and sampling error terms (σ^2_{SST}/n_{SST} and σ^2_{NMAT}/n_{NMAT}) which depend on the number of SST and NMAT observations. A maximum likelihood estimator was used to assess the three contributions for each month.

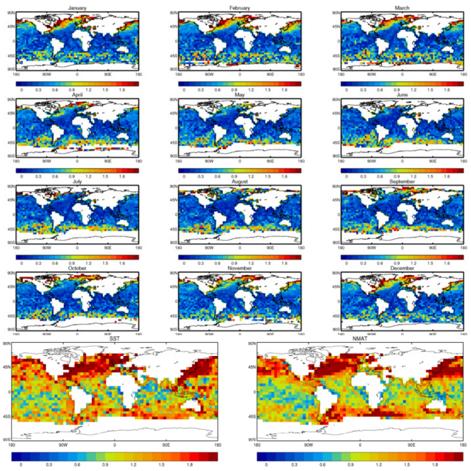

Figure 1: *First 12 panels show the standard deviation of true NMAT-SST anomaly differences (σ_{true}, ℃) for each month of the year. The lower two panels show the estimated uncertainties averaged over all 12 months for SST and NMAT grid-box anomalies (σ_{SST} and σ_{NMAT}, ℃) based on a single observation.*

In northern hemisphere winter months there can be large differences between SST and NMAT anomalies particularly downwind of continental land masses and in areas of sea ice. However, over the open oceans the differences are much smaller with SST and NMAT being more closely related.

The uncertainties of SST and NMAT are interesting. At high latitudes, NMAT is typically more variable than SST so the sampling uncertainties tend to be higher. However, at lower latitudes NMAT uncertainties are lower than SST uncertainties perhaps reflecting more reliable measurements

STEP 2: estimate uncertainties in parameters

To estimate the uncertainty in the fields of σ_{true}, the estimated parameters (σ_{true}, σ_{SST}, σ_{NMAT}) were used to create synthetic data from the same Gaussian model. The parameters were then re-estimated from the synthetic data. The process was repeated 100 times and the resulting scatter in the re-estimated parameters was used as an estimate of the uncertainty.

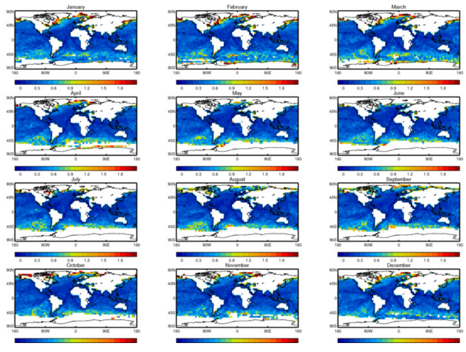

Figure 2: *12 panels showing the uncertainty (℃) in the standard deviation of true NMAT-SST anomaly differences (σ_{true}) for each month of the year.*

Uncertainties are largest in less well observed regions, and the effect of few observations is exacerbated in those regions where the NMAT-SST variability is largest. Nevertheless the uncertainties are generally smaller than the estimated variability. However, this does not account for uncertainty due to model mis-specification.

STEP 3: making a combined marine temperature series

To combine SST and NMAT a weighted average of the two gridded data sets was made. The weights were based on the uncertainties of the gridded values. The uncertainty of the SST fields (taken from HadSST3) were increased by the estimated variability of the SST-NMAT difference, giving a lower weight to SST particularly where it is likely to be a poor reflection of NMAT. The weights were chosen to minimise the uncertainty in the blended value.

Near continental margins, much greater weight will generally be given to NMAT unless observations are sparse. Over the open oceans the blend will be more evenly balanced between SST and NMAT.

STEP 4: combining land and sea

The combined marine data set was blended with land air temperatures using the estimated uncertainties of each.

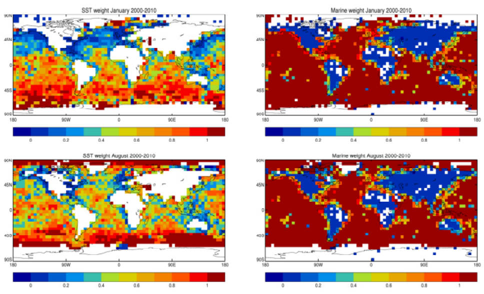

Figure 3: *Weights in the range 0 to 1 of gridbox average SSTs in the marine blend (left) and the weights of the marine blend in the final blend of marine and land data (right). The weights are the averages for the period 2000 to 2010. The top row shows the weights for January and the bottom row shows the weights for August.*

The SST data get relatively less weight in the northern hemisphere in winter and relatively greater weight where NMAT data are few. The NMAT data are most sparse in the southern hemisphere. In the summer the SST get a lower weight along continental margins, but a higher weight over central ocean areas.

The marine data generally get a higher weight than the land data except in grid boxes with few marine observations, with large numbers of land stations, or which have a large proportion of land

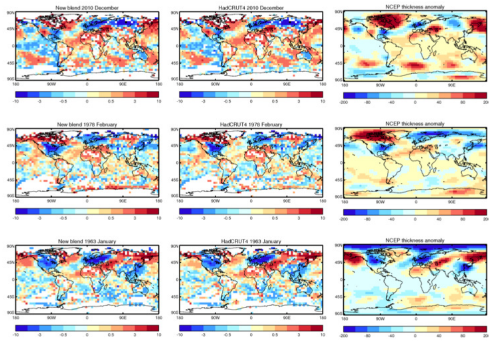

Figure 4: *Example months comparing surface temperature anomalies (relative to 1961-1990) from the new blend (left column) to HadCRUT4 (middle column) and fields of atmospheric thickness anomalies (right column) from the NCEP reanalysis.*

The continuity of the plumes of warm and cold air between land and ocean are more obvious in the new blend than in HadCRUT4 reflecting the inclusion of NMAT data. The areas of above and below average temperature correspond to areas of above and below average thickness respectively. In early years when there are fewer land stations, the use of NMAT in coastal areas can give a more accurate estimate of air temperature variability than SST alone.

Differences in global and regional time series

The data set can be used, as with any other global temperature data set to calculate derived quantities such as global and regional average temperatures.

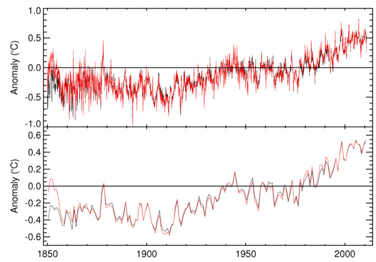

Figure 5: *Global average monthly (top) and annual (bottom) near-surface air temperature anomalies (relative to 1961-1990) from median HadCRUT4 (black) and from the new blend (red).*

The monthly variability at a global scale is very similar in the new blend. Variability is somewhat different at decadal time scales. Interestingly, the trend is lower in the period 1980 to 2012 than for HadCRUT4. However the new blend is cooler during the period 1945 to 1970. To what extent these differences reflect biases and to what extent they reflect actual physical differences is not clear. Large differences in the period 1850-1860 are due to day observations of marine air temperature being erroneously flagged as night observations.

NMAT-SST differences at other time scales

It is possible to repeat the analysis at other time scales than monthly. The standard-deviation of the differences of NMAT-SST anomalies was calculated for annual and decadal averages.

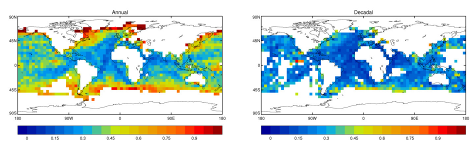

Figure 6: *Standard deviation (℃) of annual (left) and decadal (right) average differences between NMAT and SST anomalies.*

The variability at annual time scales is already much diminished from the variability at monthly time scales, and the decadal variability is lower again. The variability at decadal scales is approaching the uncertainty associated with bias adjustments suggesting that interpretation of decadal differences between NMAT and SST trends as reflections of actual variability should be tempered by an acknowledgement of the limitations of the observing system.

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