Uncertainties in corrections applied to marine temperature data to account for changing measurement practices

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Outline

- Why are corrections necessary?
- SST then NMAT:
  - How are the corrections arrived at?
  - How do we calculate their uncertainty?
  - Results so far
- What are other uncertainties?
- Future plans and conclusions
Change in average ships’ deck height and consequent change in measured air temperature (see Rayner et al., 2003, JGR Atmospheres)
Global mean marine temperature: Uncorrected HadSST2 compared with corrected MOHMAT43N
Bucket correction strategy (1)

- The Folland and Parker (1995) corrections to SST are derived from a combination of the following information:
  - average speed of ships in any year, i.e. proportion of fast (7m/s) and slow (4m/s) ships
  - material of bucket used to take sea water sample, i.e. proportion of insulated (wooden) and uninsulated (canvas) buckets used
  - modelled quantities of heat lost from insulated and uninsulated buckets for fast and slow ships and climatological ambient conditions

- These quantities are known, or inferred, with some associated level of uncertainty
Bucket corrections, ICOADS & MOHSST
Bucket correction strategy (2)

- Determining the uncertainty in the input parameters we can calculate the uncertainty in the derived bucket corrections by Monte Carlo simulation, drawing each input parameter randomly from its possible distribution.
Determining uncertainty in inputs (1)

Uncertainty in speed of ships is obtained from literature cited in FP95. For each period cited, the standard error in average ships’ speed is \( \sim 0.2 \text{ m/s} \). This translates to an error in proportion of fast (or slow) ships of 0.07 (i.e. 7%).

\[
\sigma_{\text{prop_canvas}}^2 = (\sigma_{\text{speed}} \frac{d_{\text{prop}}}{d_{\text{speed}}})^2
\]
Determining uncertainty in inputs (2)

There are four basic correction fields for combinations of wooden and canvas buckets, fast and slow ships. We assume:

- there is no error in the modelled corrections for the wooden buckets.
- the uncertainty in the average canvas bucket correction fields stems mainly from the choice of integration time of the models, obtained by minimising the ratio of annual cycle to total variance in certain areas and periods. Fig16 of FP95 plots the spread of possible integration times for one model. From this we infer an error of $\sim13\%$ in integration time
- a linear relationship between integration time and correction field, leading to an error in the underlying
Determining uncertainty in inputs (3)

- Proportions of wooden vs canvas buckets are obtained by maximising the fit between corrected NMAT and SST in two regions of the tropics between 1856 and 1920.

- This fit depends on the first two inputs as the four basic correction fields are applied to the uncorrected SST according to:

  \[
  \text{SST}_{\text{corr}} = \text{SST}_{\text{uncor}} + p_c * p_f * f_c + p_w * p_f * f_w + p_c * p_s * s_c + p_w * p_s * s_w
  \]

- So, the fit is performed 1000 times, randomly varying the two canvas correction fields and the prop of fast ships (= 1 - prop slow ships) given their uncertainties.
Bucket correction uncertainties, 1860

January

April

July

October
Bucket correction uncertainties, 1940

January

April

July

October
Bucket corrections, ICOADS & MOHSST
Implied bucket correction (deg C) +/- 2 standard error
Combined uncertainty (one standard error) January 1860
Combined uncertainty (one standard error) January 1910
Combined uncertainty (one standard error) January 1940
Calculating the uncertainty in the deck height corrections for NMAT

\[ S_T^2 \equiv \left( S_H \frac{dT}{dH} \right)^2 + S_{(T_H-T_{16})}^2 \]

Where:

- \( S_H \) is the global annual height error
- \( dT/dH \) is the rate of change of temperature with height
- \( S_{(T_H-T_{16})} \) is the standard error in the temperature profile having been adjusted to be relative to 16 metres (average height in our reference period)
## Sources of deck height data

<table>
<thead>
<tr>
<th>Year(s)</th>
<th>Source</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1870, 1890, 1910 and 1930</td>
<td>UK log books</td>
<td>The uncertainty in the global representation has not been covered in the project.</td>
</tr>
<tr>
<td>1935-1939</td>
<td>UK data (Mike Jackson)</td>
<td>Globally representative</td>
</tr>
<tr>
<td>1966</td>
<td>WMO publication no. 47</td>
<td>Globally representative</td>
</tr>
<tr>
<td>1970 -1997</td>
<td>Liz Kent (SOC), her version of ICOADS cross-referenced ships callsigns to matching information in WMO no.47, where heights could be obtained.</td>
<td>Representative of the observing ships used to record NMAT</td>
</tr>
</tbody>
</table>
Global standard deviation of deck height (m), 1870-1997
Change in average ships’ deck height and consequent change in measured air temperature (see Rayner et al., 2003, JGR Atmospheres)
Error (degree C) in temperature profile owing to uncertainty in height

\[ \left( s_H \frac{dT}{dH} \right) \]
Temperature profile Standard error - adjusted to 16m
\[ s_T^2 \approx (s_H \frac{dT}{dH})^2 + s_{(T_H-T_{16})}^2 \]
Other sources of uncertainty not yet included (1)

- Geographical variation of deck height uncertainties
- Error in assumption of global representativeness of our earlier information on deck heights
- Corrections applied to NMAT to correct for the effects of non-standard measurement practises at certain times or in certain regions
- Include measurement and sampling error in NMAT data used to fit canvas/wooden proportions
Other sources of uncertainty not yet included (2)

- Work so far indicates a possible bias in the SST corrections, but this needs careful following up.
- This quantifies uncertainty in existing corrections - likely that corrections should be extended beyond 1941. [What is that odd behaviour in the late 1940s & 1950s?]
- Include uncertainties in reference values/heights/mixes to give errors for the actual SST or NMAT.
Summary

- We have started to quantify the uncertainties in corrections applied to SST and NMAT for changing measurement conditions/practices with time.
- Grid box uncertainties in deck height corrections are very small compared to measurement/sampling error.
- Uncertainties in bucket corrections are comparable to those used in Folland et al. 2001.
Global mean marine temperature: Uncorrected HadSST2 compared with corrected MOHMAT43N
From Smith and Reynolds (2002)

Fig. 4. (a) The 12 monthly coefficients, unsmoothed, and (b) the annual unsmoothed and smoothed coefficients. The coefficients are scaled by the annual and 60°S–60°N average of C, to give values with units of degrees Celsius.
FIG. 5. Annual-average bias corrections over the area 60°S–60°N for the SR corrections (heavy solid), FPK84 (light solid), and the FP95 corrections (dashed).
From Smith and Reynolds (2002)

1920s. Because of the sparsity of the data, we use both the bottle data and the NODC mechanical bathythermograph (MBT) data, which became available in the 1940s. The NODC-COADS bias correction is defined and averaged over the same region, and annually averaged. A three-point binomial smoother is applied to the time series, and the 1968–97 average difference is removed. Again, averaging is done only using biases collocated with NODC-COADS differences (Fig. 8a). Although the NODC COADS estimate is noisy with

**Fig. 7.** Annual cycle of bias corrections over the 1930–40 period, averaged over 25°–45°N, from estimates based on NODC bottle data and averages from collocated FP95 and SR corrections.

**Fig. 8.** Annual-average bias correction estimates averaged over 25°–45°N based on NODC data and average corrections from (a) collocated FP95 and SR and (b) the percent of 10° areas sampled by both NODC and COADS data.