Humidity Biases in Voluntary Observing Ship Observations

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1. Introduction

Humidity estimates over the oceans are important for the estimation of the surface heat fluxes and the validation of forecast and reanalysis models and data from satellites. The main source of in-situ humidity estimates over the oceans come from Voluntary Observing Ships (VOS). Typically VOS measure wet and dry bulb temperatures and the specific humidity is calculated using the psychometric formula. The wet and dry bulb thermometers are typically housed in either marine screens or whirling psychrometers, with a roughly even split between the two observing methods. Psychrometers are forcibly ventilated which ensures that the air flow over the sensors is adequate, even if the relative wind speed is low, or the sensor is not well sited. Marine screens rely on natural air flow, and observations may be biased if the screen is poorly exposed or the relative wind speed is low. Observations from psychrometers are there expected to provide better humidity estimates than the marine screens which may be biased high. Kent et al. (1993) developed a correction for these effects, new analysis shows this correction to give a poor estimate of the bias under high humidity conditions. A new correction is therefore proposed.

2. Data Sources

VOS observations for the period 1970 - 2006 from the Intenational Comprehensive Ocean-Atmosphere Data Set ICOADS (Worley et al., 2005) combined with measurement metadata (Kent et al., 2007) have been used. The ICOADS 3.5σ trimming limits have been applied to remove outliers and mis-positioned reports identified following Kent and Challenor (2006).

3. Previous Bias Corrections

Kent et al. (1993) compare dewpoint temperature observations from marine screens and sling psychrometers with the ouput of a NWP model as part of the VSOP-NA project (Kent et al., 1993). Based on this comparison, Kent et al (1993) show the screen humidity measurements to be biased high due to the inadequate ventilation of the wet bulb thermometers and propose a linear correction to the dew point measurements. This correction has then been applied to the screen observations used in the NOC Climatolgy (Josey et al., 1999; Grist and Josey, 2005). The correction applied to the screens is given by

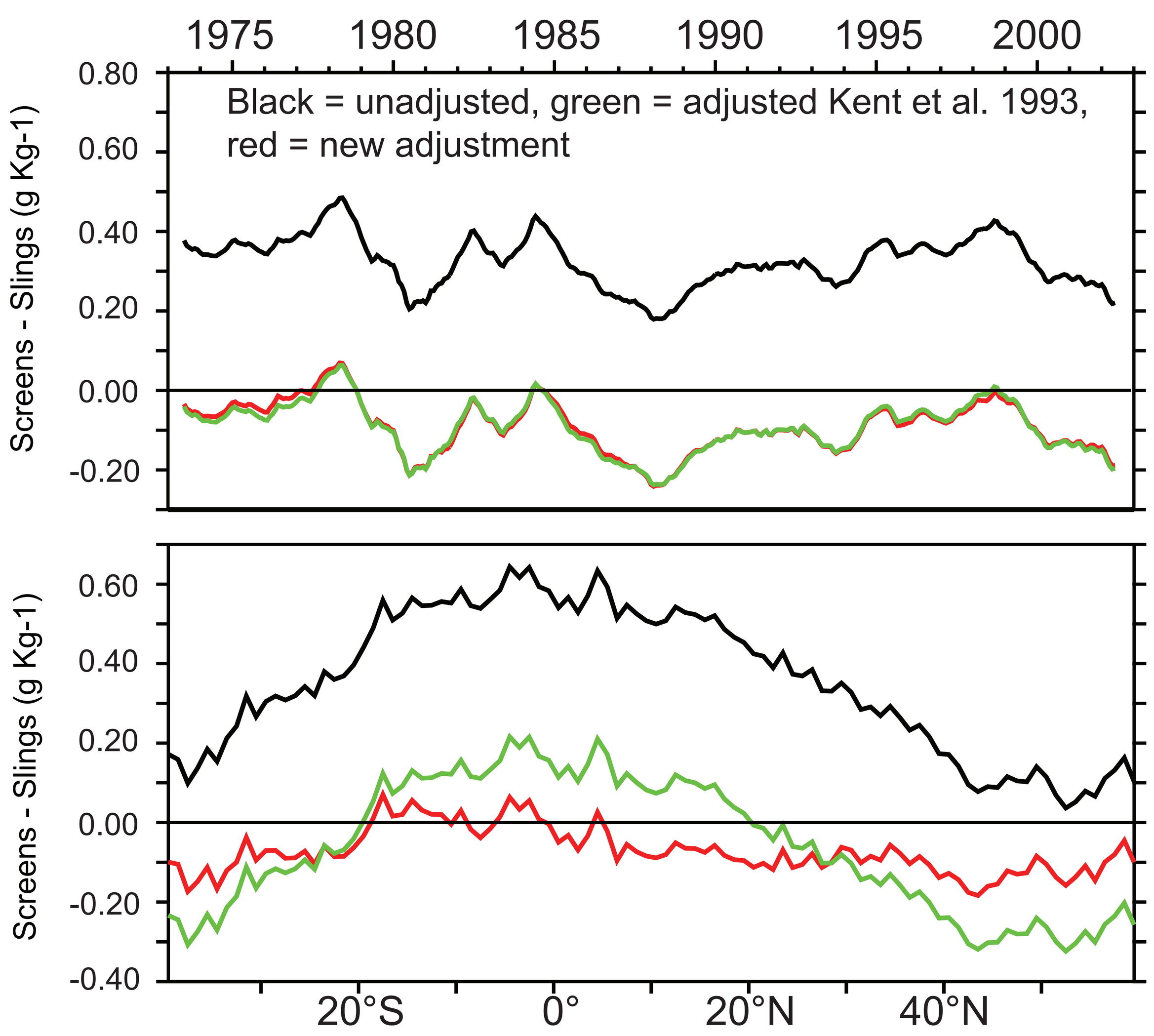
$$T_{dpt}^{cor} = 1.029 T_{dpt} - 1.080$$

Where T_{dpt}^{cor} gives the corrected dewpoint temperature and T_{dpt} the observed dewpoint temperature.

4. Estimating the Biases

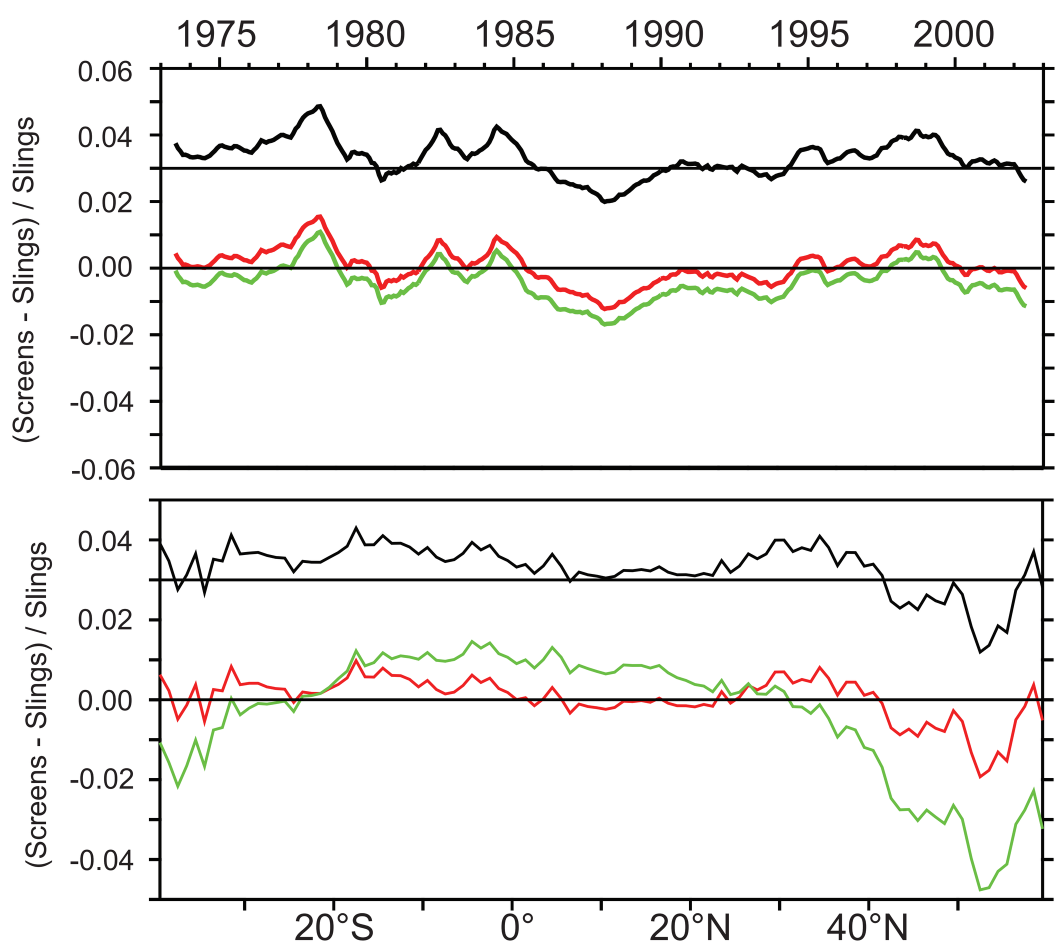
Humidity observations made using sling psychrometers are forcibly ventilated and as a result expected to contain much smaller biases compared to observations from marine screens. Hence, as a first approximation, assuming the psychrometer observations to be unbiased we can estimate the bias in screen observations to be the difference between the two observing methods.

The figures to the right show the differences between specific humidity estimates from the two methods averaged monthly on a 1° grid (black). The top plot shows the differences averaged globally between 40 S and 60 N with a 12 month running mean filter applied. The bottom plot shows the differences averaged zonally and in time. Both figures show the screen observations to be biased high compared to psychrometers, with the differences greatest in the tropics, peaking around 0.60 g Kg^{-1}, and decreasing towards the higher latitudes. Averaged globally, the biases vary by ±0.10 g Kg^{-1} from one month to the next and the mean bias across all months is 0.31 g Kg^{-1}.



The plots below show the biases as a fraction of the psychrometer specific humidity observations (black). Again, the top plot shows the biases averaged globally between 40 S and 60 N and the bottom plot the zonally averaged values. In both plots the screen observations overestimate the specific humidity by approximately 3%, with the overestimate relatively constant both zonally and in time.

5. A New Bias Correction?



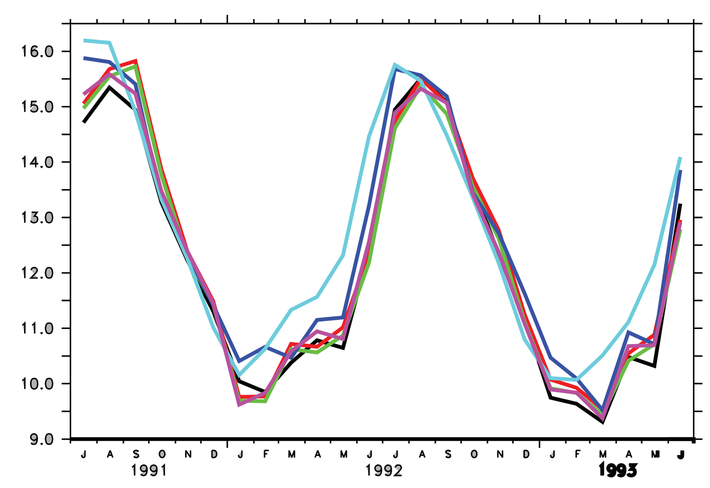
The results suggest a bias correction equal to 3 % of the specific humidity would a good first approximation for screen observations. The plots above and to the left also show residual biases after they have been corrected using the bias correction of Kent et al (1993) (green) and after reducing the screen observations by 3% (red). Averaged globally, there is little to distinguish between the two corrections with mean residual biases of -0.09 g Kg^{-1}.

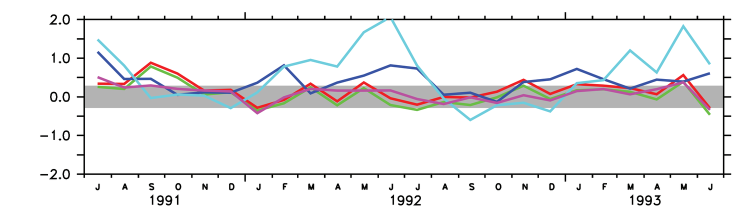
Averaged zonally, the differences between the two corrections are more evident. At high latitudes the old correction over corrects by up to 0.32 g Kg^{-1}. At low latitudes the correction under corrects by up to 0.22 g Kg^{-1}. In contrast, the new correction over corrects slightly over most latitudes, reaching a maximum over correction of 0.18 g Kg^{-1} around 40 N. Between 20 S and 0 N the new correction slightly underestimates the bias by 0.07 g Kg^{-1}.

Overall, reducing the screen specific humidities observations by 3% brings them into better agreement with sling psychrometer observations than either the uncorrected observations or observations corrected using Kent et al (1993). Global humidity estimates based on all available observations are reduced by 0.15 g Kg^{-1} when the new bias correction is applied.

6. Comparison to other sources

The plots below show a comparison of humidity estimates from the new NOC surface flux data set (see poster by Berry and Kent), corrected for observing height and with the new bias correction applied, with other gridded humidity datasets. The datasets are compared during the deployment of the Woods Hole Oceanographic Institution (WHOI) Subduction Array in the Northeast Atlantic. The black line shows the humidity from the Northwest mooring and colours indicate NOCv2.0 (green, unadjusted in red), NCEP1 (light blue), HOAPS3 (dark blue) and purple (WHOI OAFlux).

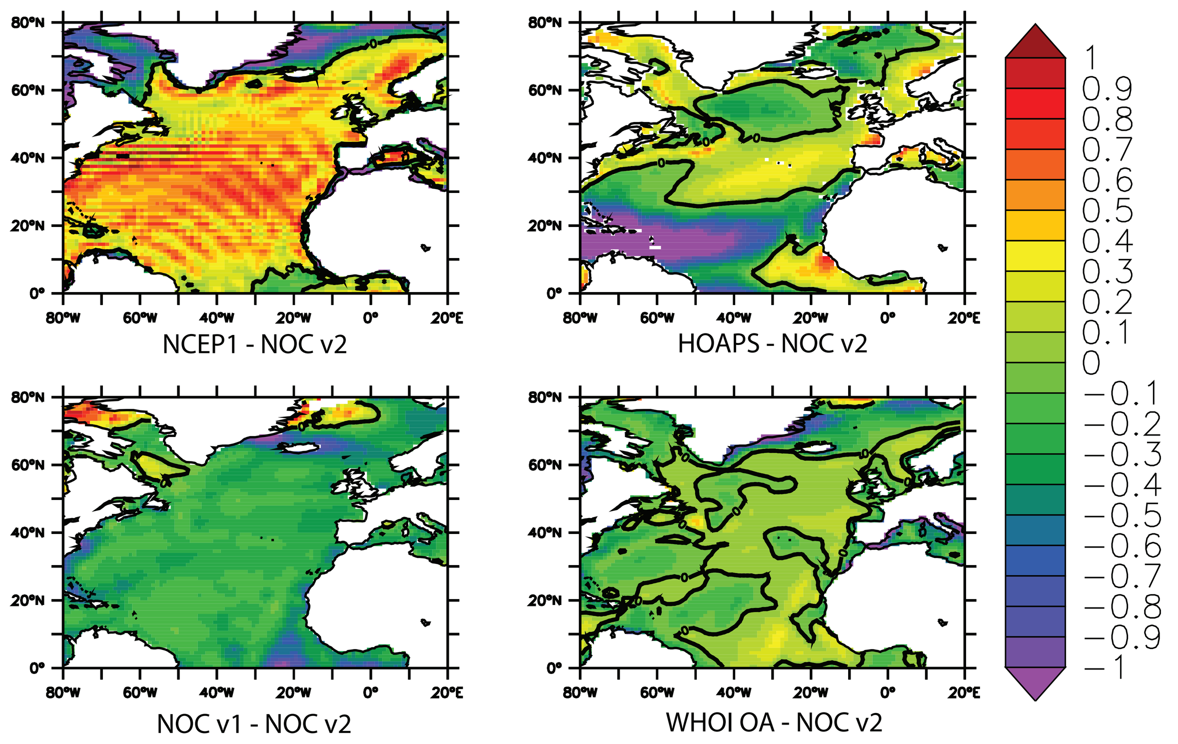




The plots show time series of monthly mean humidity (right) and differences from the buoy (above) for each data source. The NOCSv2.0 humidity is 0.06 g Kg^{-1} higher than the buoy (0.18 Kg^{-1} before adjustment). The grey band shows the NOCS uncertainty estimate. Other biases from the buoy are OAFlux: 0.08, HOAPS3 0.41 and NCEP 0.55 Kg^{-1}.

Residual biases for the NOCv2.0 humdity at the other subduction buoy sites are slightly, higher, ranging from 0.04 to 0.52 Kg^{-1}. In each case agreement is improved by adjustment. More research is required to see whether the psychrometer humidities also need adjustment as was suggested as a possibility by Kent et al. (1993).

The maps below show the differences (g Kg^{-1}) averaged over time for each of the comparisons with a zero contour line. The large differences between the HOAPS3 estimates and the new dataset are clearly visible, with HOAPS3 significantly lower in regions of high cloud amounts and heavy rainfall such as the Inter Tropical Convergence Zone. The higher humidity estimates from NCEP1 are also clearly visible with positive differences over much of the North Atlantic. The differences between the new data set and NOC v1.1a are fairly uniform over the North Atlantic with differences of the order -0.2 g Kg^{-1}. The OAFlux humidities show small differences scattered around zero.



7. Summary and Conclusions

- Humidity observations from marine screens have been shown to be biased high (0.3 g Kg^{-1} averaged globally) compared to sling psychrometers.
- Two different bias corrections have been examined which both reduce the globally averaged bias to -0.09 g Kg^{-1} and bring the observations into better agreement with the psychrometer observations
- However, the correction of Kent et al (1993) under (over) estimates the bias at high (low) specific humidity values
- Overall, the new correction performs better over all latitudes and gives the best agreement with psychrometer observations
- Global humidity estimates are reduced by 0.15 g Kg^{-1} when all available observations are used and the new bias correction applied.
- A new gridded humidity dataset (NOCv2.0), using VOS observations and bias corrected, is compared to other humidity products over the North Atlantic.

References

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