Use of WMO47 Metadata in a Global Flux Climatology

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Abstract

The SOC Flux Climatology (Josey et al., 1998) is unique in its use of Voluntary Observing Ship (VOS) metadata to improve the quality of ocean surface flux estimates obtained from merchant ship data within the Comprehensive Ocean-Atmosphere Data Set Release 1a (COADS, Woodruff et al. 1993). Corrections to the ship data combined two WMO-sponsored data sources: firstly the VOS Special Observing Project - North Atlantic (VSOP-NA) which identified errors in merchant ship weather observations and secondly the metadata collected by Port Meteorological Officers around the world and published annually by the WMO (WMO47, e.g. WMO 1994). The metadata were merged with COADS individual reports giving instrument types and heights for most VOS weather reports. These metadata allowed the identification of those reports that required correction following the recommendations of the VSOP-NA.

The resulting fluxes are now starting to be validated and the total heat flux from the SOC climatology agrees well with high quality research data from buoys where that is available.

1. Introduction

Climatological estimates of the ocean surface heat balance, climatologies, can be calculated from COADS. In past climatologies, global adjustments have been made to the flux fields to balance the global heat budget. Authors have justified these modifications as potentially compensating for the effect of ship measurement errors on the fluxes, and for uncertainties in the bulk formulae used to calculated the surface fluxes from the VOS reports.

The approach taken to balance the heat budget has been to appeal to external information to constrain the fluxes. For example, daSilva et al. (1994) used inverse analysis to simultaneously tune the COADS-based heat and fresh water fluxes to conform with oceanographic estimates of meridional heat and fresh water transports. This resulted in a 13% increase in the latent heat flux (with a compensatory increase in the precipitation to balance the fresh water transport) and a 8% decrease in the incoming solar flux. The sensible heat flux and the longwave flux were changed by smaller amounts. Even larger adjustments have been made in other studies.

Following the identification of sources of error in VOS data in the VSOP-NA project we were able to test whether the heat imbalance (about 30 Wm^{-2} excess heating of the ocean) found in VOS-derived flux climatologies is due to errors in the data. If the VSOP-NA corrections applied to the COADS data are similar in size to the global adjustments used by daSilva et al. (1994) then we might assume that the latter can be justified on the grounds of ship errors. If not, we will have to look for other methods of balancing the heat budget.

2. Correcting the VOS data

2.1 The metadata

The metadata for merchant ships in the Voluntary Observing Fleet have been published annually by the WMO since the 1950's (e.g. WMO 1994) and are available in electronic format from 1973 onwards. The metadata consist of, for each ship, the ship's name and callsign followed by a coded list of instrument types and heights. The instrument types for pressure, air and sea temperature and humidity are listed along with information about more specialized instrumentation installed on the ship. Anemometer heights are listed where the wind report is instrumental rather than a visual observation of sea state and also the height of the observing platform which we have used as a proxy for the height of air temperature and humidity measurement.

The ascii version of the metadata for the years 1973 to 1994 reformatted as part of the SOC flux climatology project can now be found on the Internet:

ftp://ftp.cdc.noaa.gov/Public/coads/metadata/wmo47

2.2 The ship corrections - VSOP-NA

The VSOP-NA (Kent et al. 1991, Kent and Taylor 1991) consisted of the detailed analysis of 2 years of meteorological reports from 46 ships selected because they reported regularly in the North Atlantic. Port Meteorological Officers gathered detailed information about the ships and the instruments carried. Photographs or plans of the ships and of the instrumentation sites were collected where possible along with information on observing practices. In addition extra fields were added to the ship's weather log to identify the conditions at the time of the observations.

The information from the logbooks, over 33 thousand records, was keyed into ASCII format by the Deutscher Wetterdienst in Hamburg. The reports were then merged with the output of a numerical weather prediction model by the UK Meteorological Office. The model was used to provide a consistent standard to allow ship reports separated in space and time to be compared.

The results of the VSOP-NA suggested that:

a) Sea surface temperature (SST) measurements made using engine intake thermometers were biased warm (Kent et al. 1993a). This correction could be applied for the log book reports which contain the method of SST measurement but for reports received by radio the method of SST measurement needs to be found from the WMO47 metadata.

b) Air temperature measurements were affected by solar radiation. The warm bias caused by the solar heating of the ship superstructure could be removed on average using a formula depending on the incoming solar radiation and the relative wind speed (Kent et al. 1993b). Both these parameters can be calculated from information in the normal weather report, no external metadata is required.

c) Humidity measurements were unaffected on average by solar heating (Kent and Taylor, 1996).

d) Humidity measurements from screens were biased high when compared with those from psychrometers, presumably due to their poorer ventilation. This bias could be removed on average by reducing the humidity from screens using an empirical formula (Kent et al. 1993a). The method of humidity measurement needs to be found from WMO47.

e) Height correction of instrument based wind speed measurements to 10 meters should be carried out to homogenize the wind data (Kent et al., 1993a). The height of the anemometer is contained in the WMO47 metadata.

2.3 Combining the data and metadata

The link between the COADS data and the WMO47 metadata is made using the ship callsign which is present in both datasets. Since a given call sign can be transferred from one ship to another, and because changes may occur in the metadata, the matching must be done on a year by year basis. For each ship meteorological report in COADS the WMO47 database was searched to find the metadata for the ship with the appropriate callsign in the particular year. About 10% extra reports were matched if reports unmatched with the correct year were checked with metadata for the following year, indicating there is sometimes a time lag between a ship being recruited to make weather reports and its details being collected for WMO47. Figure 1 shows the success rate for matching a report in COADS with the ship metadata.

The figure shows that although the number of reports in COADS has increased slightly over the period the number of reports from ships has declined. The deficit is made up from reports from fixed platforms and moored and drifting buoys. The composition of COADS is therefore very different towards the end of the 12-year period than at the beginning. This also leads to reduced spatial coverage as the data from platforms and buoys is usually restricted to fixed locations near the coast.

The matching rate increased from less than half the ship reports at the beginning of the period, largely due to the lack of callsign information in COADS to more than 80% by the end of 1992. The step increase in the match rate in 1982 is due to the inclusion of the ship callsign in WMO's format for exchange of ship logbook data at that time.

2.4 Use of the enhanced dataset: Beaufort Scale evaluation

The conversion of visual observations of sea state to wind speed data requires the use of a Beaufort equivalent scale to assign a wind speed to a Beaufort interval. Older scales, for example WMO1100 or CMMIV (WMO, 1970) used simultaneous observations of anemometer wind speed and sea state from a few selected sites or ships in

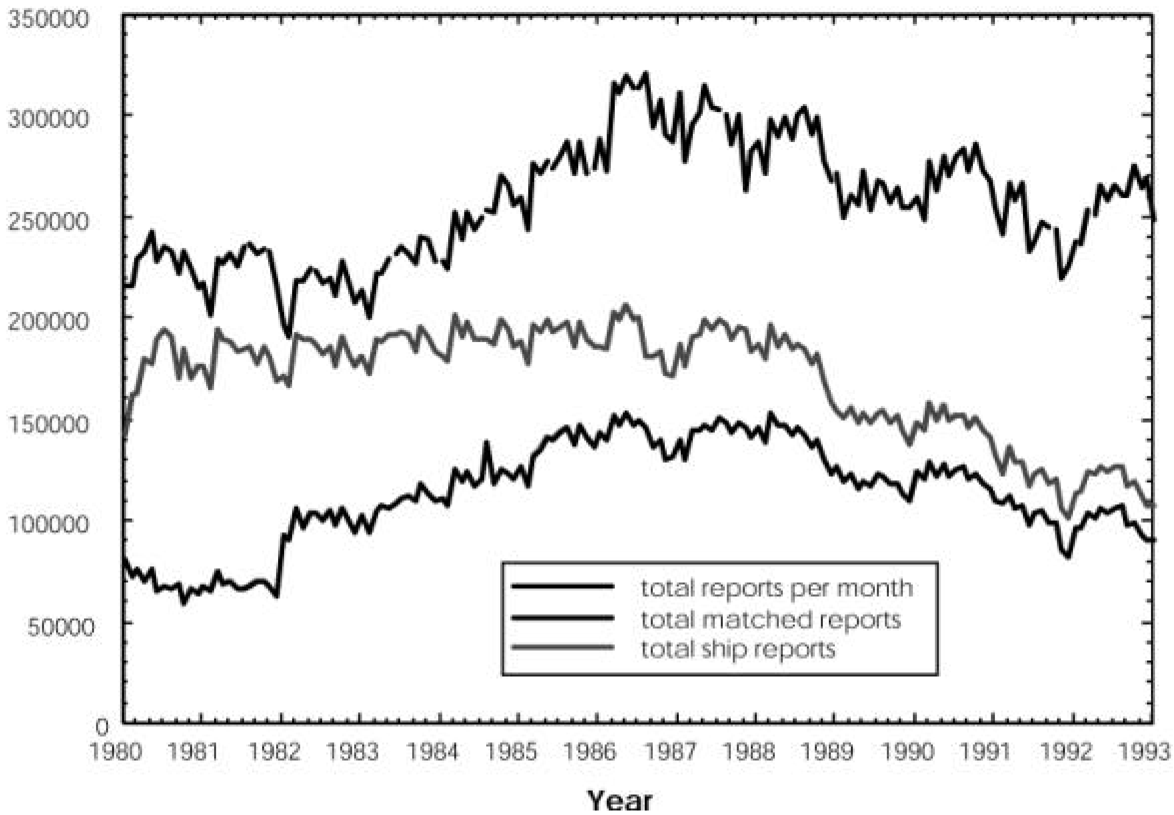

Figure 1: The number of reports per month in COADS Release 1a, top line. The number of reports from ships, centre line. The number of COADS reports for which metadata was found in WMO47, lower line.

their derivation. It is therefore not certain that these scales will work well with data from the VOS as a whole. This uncertainty led daSilva et al. (1995) to derive a Beaufort scale using data from COADS. However Lindau (1995) suggested that the uncertainty in VOS anemometer heights would cause error and compared anemometer measured Ocean Weather Ship winds of known height with VOS visual winds. The metadata-enhanced COADS has allowed us to determine the global distribution of anemometer heights.

It was already known that the Atlantic was dominated by visual wind reports (as many of the European Meteorological Services favor this method of observation) and that the Pacific was dominated by anemometer wind reports. Kent and Taylor (1997) show that the mean anemometer height in the North Pacific is greater than 30 meters over large areas; the Atlantic region reports come from lower anemometers, 20 to 25 meters on average. This is due to large Japanese ships with high anemometers dominating the reporting in the Pacific.

This large difference in anemometer height between the two ocean basins will lead to biases in the data if a uniform height correction is made to the wind data.

The merged dataset has also allowed us to use VOS anemometer winds corrected from known anemometer heights to directly compare VOS anemometer and visual winds (Kent and Taylor, 1996). The Lindau (1995) scale came out best in this comparison and is used in the SOC climatology. The daSilva et al. (1995) scale also performed well. The WMO1100 scale gave equivalent wind speeds which were too low at low wind speeds and slightly too high at high wind speeds. The CMMIV scale was found to be biased in the opposite sense, too high at low wind speeds and too low at high wind speeds.

3. Results

3.1 Effect of the VSOP-NA corrections

The effect of the corrections described in Sections 2.2 and 2.4 on the flux fields can now be determined (for a full description of the corrected climatological fields see Josey et al., 1998). As an example we shall take the latent heat flux. Figure 2 shows the effect of the VSOP-NA corrections, the individual height corrections (as opposed to a single assumed height of 25 meters for anemometer winds) and the visual scale of Lindau (1995) on the latent heat flux in January 1990.

The latent heat flux is reduced in the North Pacific, in some regions by more than 15 Wm^{-2}. This is due to the correction to SST from engine intakes. The SST is reduced in these cases, which reduces the saturation humidity at the sea surface and hence the sea-air humidity difference resulting in a decrease in the latent heat flux. An additional, but smaller, decrease in the latent heat flux in this region arises from the use of individual anemometer heights. In contrast the correction to the screen humidities decreases the air humidity, hence increasing the sea-air humidity difference and leading to an increase in the latent heat flux.

It is largely this effect which leads to the increased latent heat flux values over much of the Atlantic where most of the screen measured humidities are reported.

The effect of the solar radiation correction to the air temperature only affects the calculation of stability and the effects on the latent heat flux are therefore small. A larger effect of this correction is seen in the sensible heat flux field (not shown). The overall effect of the individual height corrections and the Lindau (1995) scale is patchy.

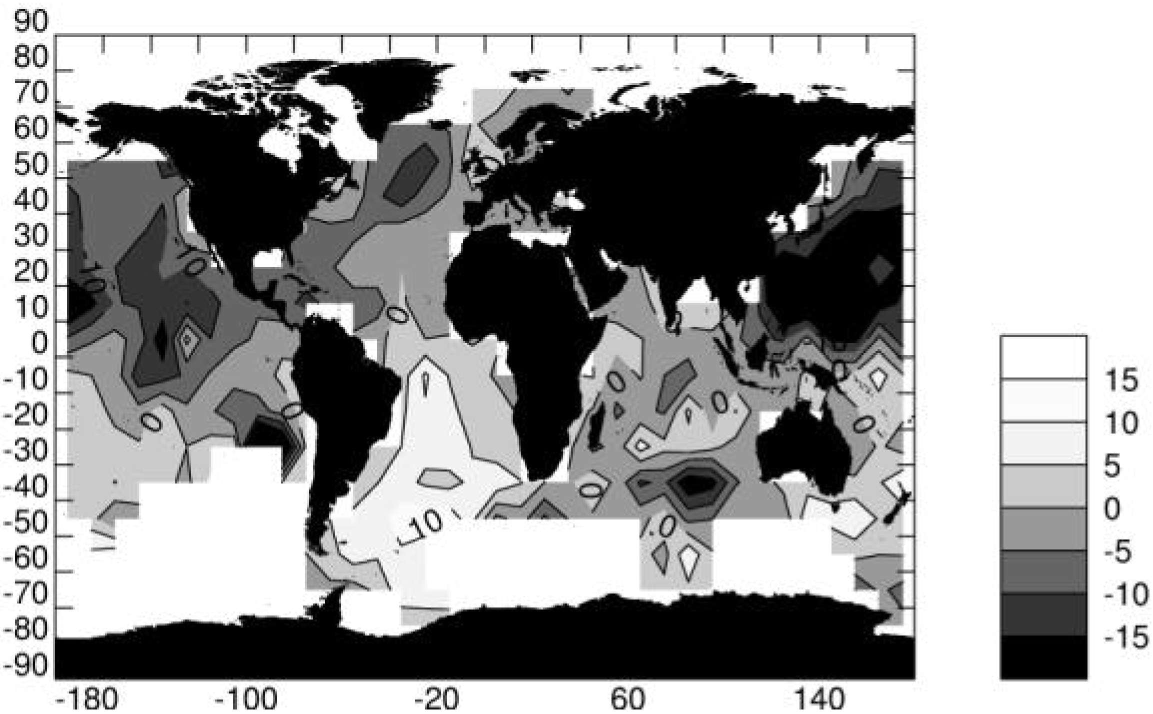

Figure 2: The effect of corrections applied to the VOS data on the latent heat flux. Differences are plotted in Wm^{-2} and a negative difference represents a decrease in the heat loss from the ocean due to corrections.

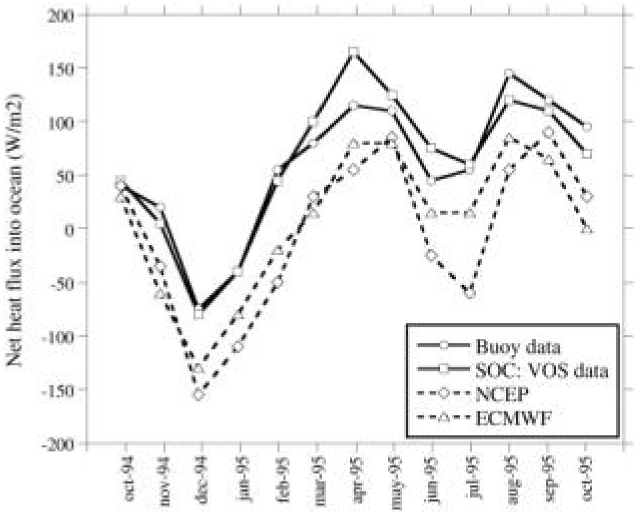

Figure 3: Comparison of monthly mean total heat flux data from a research buoy (Woods Hole IMET system; Weller et al., 1997) with monthly mean total heat flux from the SOC climatology for the same period. Also shown are total heat flux data from the numerical weather prediction models of NCEP and ECMWF which in this region agree much less well with buoy data than do the SOC data. (Adapted from Weller et al., 1998.)

The effect of the ship corrections on the latent heat flux is thus complex and regional, and has little correlation with the magnitude of the latent heat flux. This implies that a global increase of latent heat flux in order to match the fluxes with the ocean heat transport estimates cannot be justified on the grounds of errors in the ship data.

3.2 Example of heat flux validation

The surface fluxes in the climatology require validation against independent data. An example of this is shown in Figure 3 in which the total heat flux from the climatology is compared with data from a research buoy in the Arabian Sea (Weller et al., 1998).

The buoy and the climatology agree well; this is particularly pleasing as the region is not well sampled in COADS.

The agreement between the buoy and the SOC total heat flux is seen to be much better than the agreement between the buoy and two commonly used numerical weather forecast models; those of ECMWF and NCEP. In addition, the authors found that the adjusted fluxes of daSilva et al. (1994) gave a poorer representation of the heat exchange in this region; again suggesting that global adjustments are not appropriate. (Although the daSilva et al. (1994) fluxes cover a different period than the SOC fluxes, analysis of the SOC fluxes suggested that the period of the buoy deployment is climatologically typical.) Comparisons have been carried out with independent data in other regions and preliminary results from these analyses suggests that, in general, global adjustments to the fluxes will worsen the agreement.

4. Conclusions

The use of metadata with a global dataset has enabled the correction of certain errors in ship's meteorological reports. A good success rate for the matching of reports with the correct instrument information was achieved: over two thirds of the ship reports were merged with metadata. The metadata were required to apply the results of the VSOP-NA project to COADS to remove biases from the data. The corrected data were used to calculate heat fluxes from COADS and resulted in flux estimates which differed from previous estimates. For example the latent heat loss from the ocean was decreased by up to 15 Wm^2 in the North Pacific but increased in the South Atlantic.

The SOC flux fields calculated from the corrected COADS data compare well with co-incident data from research quality buoys. These results suggest that global adjustments of the flux fields are not appropriate and that the heat budget should be balanced by local adjustments to the flux fields, for example in the data sparse southern oceans (see Josey et al., 1998 for discussion). Further comparison with other data is however required.

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