

Voluntary Observing Ships: A Vital Marine Observing System in Decline

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Introduction

Shipboard marine meteorological observations extend back hundreds of years, and continue to form a critical component of the modern weather and climate observing system. Today, most of the participating ships are referred to as Voluntary Observing Ships (VOS), the VOS programme being managed by JCOMM¹. These observations benefit weather forecasters in real time and climate researchers in the longer term. VOS observations, along with meteorological information from buoys and a variety of other platforms are collated in the International Comprehensive Ocean-Atmosphere Data Set (ICOADS Worley et al. 2005, formerly COADS). ICOADS has been used in hundreds of published studies and remains the primary source for *in situ* surface marine meteorological information for climate research.

However Numerical Weather Prediction now relies more heavily on the information provided by satellites and drifting buoys. The sheer volume of information from these sources has played a part in recent improvements of weather forecasts, there are now ten times as many reports from buoys as from ships in ICOADS.

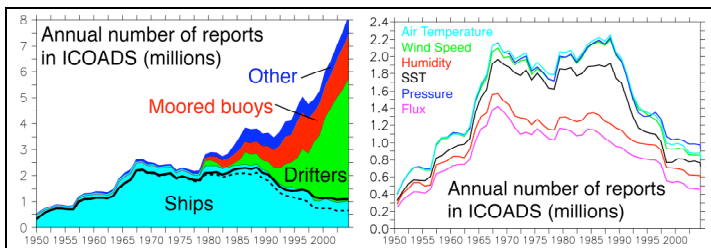


Figure 1: left: Shaded regions indicate annual number of reports from ICOADS for 1950 to 2004 by "platform type". Solid line indicates number of reports made 6-hourly, the dashed line the subset of 6-hourly reports from VOS. The increasing report numbers are largely from sources reporting hourly or more frequently; right: Number of 6-hourly reports (as Figure 1a) containing: sea surface temperature (SST), air temperature, humidity, pressure and wind speed and all of these variables ("Flux"). Note the change of vertical scale.

Recently several projects have significantly extended the availability of marine meteorological data going back as far as 1750, and improving the very data sparse periods due to the two World Wars. These include the Japan Meteorological Agency Kobe Collection Digitisation (Manabe 1999), tasks under the NOAA Climate Database Modernization Program (CDMP) and the European Union funded projects CLIWOC (García-Herrera 2005) and EMULATE (Ansell et al. 2006). However, it is important to note that significant resources are still required, but not currently identified, to incorporate these data into marine archives such as ICOADS (Woodruff et al. 2005).

Unfortunately the VOS observing system is now under

threat: the number of reports has dropped dramatically over the last decade (Figure 1) while the observation count from other sources has risen.

VOS in the Multi-platform Record

Whilst buoys and other Ocean Data Acquisition Systems (ODAS) provide increasing numbers of reports, VOS (and their predecessors) form the longest *in situ* record and, over much of the ocean, are our main or only source of air temperature, humidity, and pressure data.

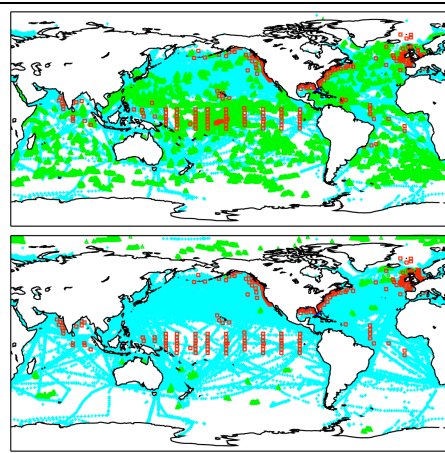


Figure 2: Distribution of SST (upper) and air temperature reports (lower) by platform type (VOS: light blue, drifters: green, moored buoys and platforms: red) in December 2004, the last available month of ICOADS.

This is illustrated in Figure 2. Although VOS coverage is not global, large areas are well sampled. While SST observations are supplemented by the drifting buoy and satellite network, away from the sparse and largely coastal, moored buoy network, only the VOS gives us the ability to estimate surface momentum, heat and freshwater air-sea exchange. Knowledge of these fluxes is vital to understanding the strengths and weaknesses of the atmospheric reanalyses (Kistler et al. 2001; Uppala et al. 2006; Sterl 2004) and satellite flux estimates (WGASF 2000).

Climate Research Requirements: Quality vs. Quantity

The quality of meteorological observations from VOS is often questioned. Indeed some ship reports are of poor quality, and the use of observations ranging as far back as the 18th century raises important homogeneity questions. However many reports are made with care by experienced observers and contribute to an extremely valuable multi-century record of surface conditions over the ocean. VOS observations are actually better characterised than many other data sources, including reanalysis model output, many satellite products and ODAS (for which historical metadata are sparse and have not yet been carefully organized internationally). There is a long history of research quantifying bias and uncertainty in VOS data, examples for wind speed and SST are reviewed by Kent and Taylor (1997, 2006). Recently information on the methods of measurement and observation heights for VOS originally published by the WMO for operational use have been made available to the research community (Kent et al. 2006). These digital metadata, dating back to 1973, allow improved

¹ Joint World Meteorological Organisation (WMO)/Intergovernmental Oceanographic Commission Technical Commission for Oceanography and Marine Meteorology

characterisation of marine meteorological reports and are already finding use in a wide range of applications. Further insight will come when a CDMIP digitisation project extends this metadata record back to 1955.

Recent analysis has shown that VOS data have improved in quality over the last 30 years (Kent and Berry 2005). However our knowledge of meteorological variables over the ocean has actually declined with the number of reports. This is compounded by the increasing number of higher-resolution observations from shipboard Automatic Weather Systems, as well as ODAS. Gathering hourly observations is useful, for example to define the diurnal cycle, but successive observations are highly correlated and therefore give less information about the global climate than the same number of, say, six hourly observations.

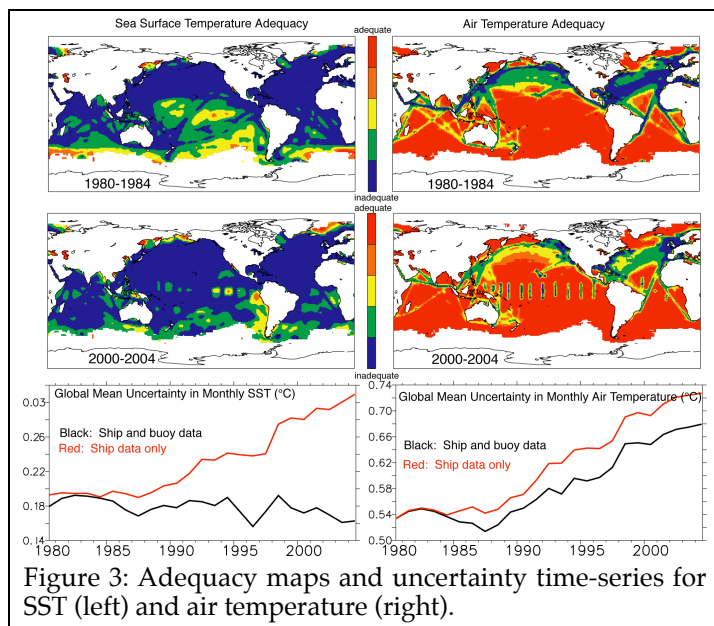


Figure 3: Adequacy maps and uncertainty time-series for SST (left) and air temperature (right).

Figure 3 compares estimates of the uncertainty in SST and air temperature for the early 1980s and 2000s. The contouring has been designed to highlight regions of adequate (blue) and inadequate (red) data coverage based on a particular observational need - in this case the ability to estimate monthly mean, 5° area surface heat exchange to an accuracy of 10 Wm^{-2} or better (WGASF 2000). Using this measure of adequacy, SST turns out to be generally well sampled and sampling has improved over time due to additional data from drifting buoys. In contrast, for air temperature there has been no such improvement in sampling and with the exception of the Tropical buoy arrays the marine air temperature is less well known than it was 20 years ago. The time series show the impact of moored and drifting buoy observations on the global accuracy of the *in situ* record and illustrate our reliance on ship observations for air temperature information (and by implication, for other variables such as humidity).

It should be remembered that every application has its own adequacy requirement. Our conclusion here, that sampling for SST is not a major problem, will not hold for other applications calling either for higher resolution SST fields or with a greater sensitivity to SST accuracy.

ICOADS Products and Applications

As the data themselves become better understood and characterised we can use more sophisticated methods of dataset construction, for example optimal interpolation (OI). Figure 4 shows an example of one day's air temperature field for the North Atlantic calculated from VOS data only with a comparison to surface air temperature from the ERA40 reanalysis (Uppala et al. 2006). Much of the North Atlantic is relatively well sampled by the ships. It is clear that the *in situ* data shows a lot of smaller scale detail than ERA40. Some of the small scale structure may be due to noise, but we expect further research to show that the ships, at least in some regions, can provide higher resolution data than the reanalyses. The accompanying uncertainty estimates mean that we can easily identify regions where we have confidence in the *in situ* estimates.

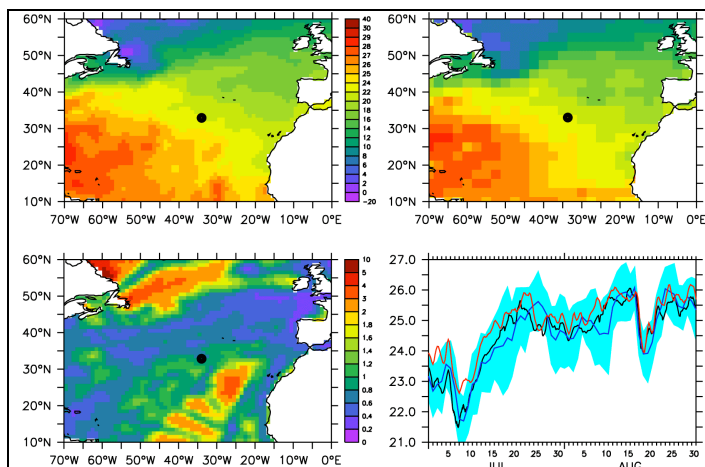


Figure 4: air temperature ($^\circ\text{C}$) on 10th July 1992 from VOS observations (top left), and ERA 40 (top right) its uncertainty from VOS (lower left), and comparison with research-quality buoy data at 33°N , 34°W in 1992 (Moyer and Weller, 1997) (black: buoy; blue: VOS; red: ERA40; all $^\circ\text{C}$).

One of the strengths of the multi-variate ship record is that we can calculate estimates of air-sea exchange from the reports. Figure 5 shows an example of the latent heat flux for 1990, again in the North Atlantic, calculated from ship data only (black with estimated uncertainty range in grey), the OAFflux product (red) and the NCEP1 reanalysis (green). There is qualitative agreement between these three estimates, and the periods of high

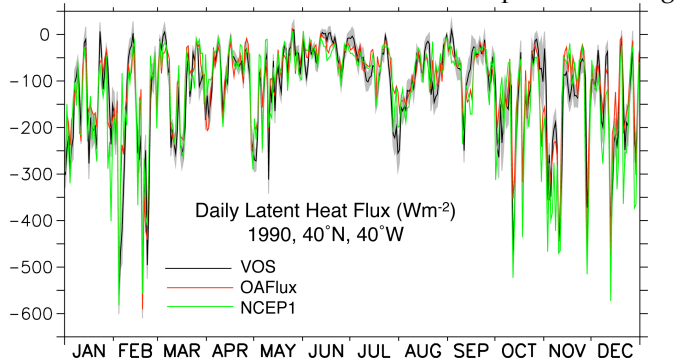


Figure 5: Comparison of daily latent heat flux estimates at 40°N , 40°W from VOS, OAFflux (Yu et al., 2004) and NCEP1 Reanalysis (Kistler et al. 2001).

and low evaporation are well captured by all. However closer inspection reveals significant differences between the estimates, falling well outside the uncertainty estimates (which are only available for the *in situ* data). This shows that in many ocean regions we can use the *in situ* flux estimates not only to validate model and satellite flux fields in the monthly mean, but also on the daily timescale.

Applications for ICOADS reports and derived products

Recent workshops have brought together scientists with diverse interests (e.g. Kent et al. 2006). ICOADS has a wide range of applications, including:

- International assessments of climate change (e.g., IPCC).
- Providing broad-scale context for process studies.
- To confront and understand atmospheric reanalyses.
- Multi-decadal analysis of air-sea interaction.
- Validation of the satellite and pre-instrumental proxy records.
- Data assimilation and model validation.
- Others applications such as fisheries, changes in coastal geological features, global anthropogenic emissions from ships (see Worley et al. 2005).

Outlook

As the number of ship reports declines, our ability to generate useful marine meteorological fields and surface fluxes diminishes.

Reversing the decline in the ship observations will require finding new resources, despite increasingly tight national and international budgets. In support of such efforts, it will be critical to review and define user requirements for a wide range of applications and to make adequacy assessments using those requirements. The support systems for the ships (for example the Port Meteorological Officer network) are also declining and will require bolstering if we are to maintain the quality of observations from VOS.

New observation sources such as automated systems on VOS and the integration of research vessels into the observing system through, for example, the Shipboard Automated Meteorological and Oceanographic System Initiative (SAMOS: <http://samos.coaps.fsu.edu/html/>) may prove part of the answer. But any transition must be well-planned and address the homogeneity requirements of climate assessments. It is clear that to characterise the marine atmosphere, to even the same standards as 20 years ago, requires the maintenance of a more distributed system than that which we now have. ODAS are not presently the answer as moored buoys cannot monitor the global ocean, and drifters do not meet our multi-variate accuracy requirements. The VOS have served us well and should be recognised as making a valuable and ongoing contribution to the marine record. We must ensure that this contribution is maintained and enhanced until we are sure that any candidate systems to replace the VOS fulfil the Global Climate Observing System Monitoring Principles (GCOS, 2003).

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