Annex IV

VOLUNTARY OBSERVING SHIPS (VOS) CLIMATE SUBSET PROJECT (VOSClim)

Objectives

The primary objective of the project is to provide a high-quality subset of marine meteorological data, with extensive associated metadata, to be available in both real time and delayed mode. Eventually, it is expected that the project will transform into a long-term, operational programme. Specifically, the project gives priority to the following parameters: wind direction and speed, sea level pressure, sea surface temperature, air temperature and humidity. Data from the project will be used: to input directly into air-sea flux computations, as part of coupled atmosphere-ocean climate models; to provide ground truth for calibrating satellite observations; and to provide a high-quality reference data set for possible re-calibration of observations from the entire VOS fleet. Requirements, rationale and scientific justification for the project are detailed below.

The VSOP-NA demonstrated clearly that the quality of measurements depends significantly on the types of instruments used, their exposures and the observing practices of shipboard personnel. It made a number of substantive recommendations in these areas which, if systematically implemented, would be expected to result in VOS observations of a quality appropriate to global climate studies. For logistic reasons, it is not realistic to expect full implementation to the entire global VOS. However, it is undoubtedly feasible for a limited subset of the VOS, and the primary goal of this project is therefore to effect such a limited implementation.

Scientific requirements and justification

1. The evolving requirements for Voluntary Observing Ship data

1.1 Introduction

For well over 100 years, the weather observations from merchant ships have been used to define our knowledge of the marine climate. This function continues within the Voluntary Observing Ships (VOS) programme as the Marine Climatological Summaries Scheme. However the main emphasis of the VOS programme has traditionally been the provision of data required for atmospheric weather forecasting. Today, the initialisation of numerical weather prediction models remains an important use of weather reports from the VOS. However recent trends, such as the increasing availability of data from satellite sensors, and the increased concern with regard to climate analysis and prediction, are making further requirements for data from the VOS.

That there is a growing need for higher quality data from a sub-set of the VOS has been identified by, *inter alia*, the Ocean Observing System Development Panel (OOSDP, 1995), the Ocean Observations Panel for Climate (OOPC, 1998), and the JSC/SCOR Working Group on Air Sea Fluxes (WGASF, 2000). The justification for improved surface meteorological data was also discussed in detail at the recent Conference on the Ocean Observing System for Climate (see paper by Taylor et al. 1999). Here we shall give examples of the requirements, the present state of the art and the potential improvements.

1.2 Examples of evolving requirements for VOS data

A. Satellite data verification

Satellite borne sensors are now used routinely for, for example, determining sea surface temperature (SST), sea waves, and surface wind velocity. Compared to *in situ* measurements, these remotely sensed data provide better spatial coverage of the global oceans. However the data are derived from empirical algorithms and a very limited number of individual sensors. In this respect, an important role for VOS data is the detection of biases in the remote sensed data due to instrument calibration changes or changing atmospheric transmission conditions. For example, the SST analyses produced by the US National Centers for Environmental Prediction (NCEP) are used at a number of operational weather forecasting centres including the ECMWF. The NCEP analyses (Reynolds and Smith, 1994) use SST data from satellite sensors that have been initially calibrated against drifting buoy data. VOS and buoy data are used to detect and correct biases in the satellite data caused, for example, by varying atmospheric aerosol loading due to volcanic eruptions. Without these real time bias corrections, errors of several tenths K or more can occur in satellite derived SST values (Reynolds, 1999). For satellite verification purposes the need is for a dataset of accurate data with known error characteristics.

B. Climate Change Studies

The VOS data are being increasingly used for climate change studies. Assembled into large data bases (such as the Comprehensive Ocean Atmosphere Data Set, COADS, Woodruff et al., 1993) the observations have been used, for example, to quantify global changes of sea and marine air temperature (Folland and Parker, 1995). Based on such studies, the recommendations of the Intergovernmental Panel on Climate Change (Houghton et al., 1990) have led to politically important international agreements such as the UN Framework Convention on Climate Change. However the detection of climate trends in the VOS data has only been possible following the careful correction, as far as is possible, of varying observational bias due to the changing methods of observation. For example sea temperature data have different bias errors depending on whether they were obtained using wooden buckets from sailing ships, canvas buckets from small steam ships, or engine room intake thermometers on large container ships. For the present, and for the future, it is important that we better document the observing practices that are used.

C. Climate Research and Climate Prediction

Coupled numerical models of the atmosphere and ocean are increasingly being used for climate research and climate change prediction. Because the time and space scales for circulation features in the atmosphere and the ocean are very different, the ocean surface is an important interface for model verification. The simulated air-sea fluxes of heat, water and momentum must be shown to be realistic if there is to be confidence in the model predictions. At present the uncertainty in our knowledge of these surface fluxes is of a similar order to the spread in the model predictions (WGASF, 2000). Partly this is due to the limitations of the parameterisation formulae used to calculate the fluxes. Verification of the model predictions of near surface meteorological variables (air temperature, humidity, SST etc.) against high quality *in situ* observations from moored "flux" buoys and specially selected VOS is required (e.g. Send et al. 1999, Taylor et al. 1999a).

2. The State-of-the-Art for VOS observations

2.1 What is needed?

These relatively new applications for VOS data imply a need to minimise the errors present in the observations. For example, 10 Wm^{-2} is often quoted as a target accuracy for determining the heat fluxes; it is about 10% of the typical interannual variability of the wintertime turbulent heat fluxes in mid to high latitudes. To achieve such accuracy implies that the basic meteorological fields are known to about ±0.2°C for the SST, dry and wet bulb temperatures (or about 0.3 g/kg for specific humidity) and that the winds be estimated to ±10% or better, say about 0.5 m/s. These are stringent requirements which we do not expect to be met by an individual VOS observation. Enough observations must be averaged to reduce the errors to the required level. The more accurate the individual VOS observations, the less averaging will be needed. Nor is averaging alone enough; corrections must also be applied for the systematic errors in the data set.

In terms of the longer term ocean heat balance even an accuracy of 10 Wm^{-2} is not adequate. A flux of 10 Wm^{-2} over one year would, if stored in the top 500m of the ocean, heat that entire layer by about 0.15°C. Temperature changes on a decadal timescale are at most a few tenths of a degree (e.g. Parilla et al., 1994) so the global mean heat budget must balance to better than a few Wm^{-2}. It is unlikely that such accuracy will ever be achieved using VOS data either alone, or combined with other data sources. Thus the calculated flux fields must be adjusted, using "inverse analysis", to satisfy various integral constraints. Inverse analysis techniques rely on detailed knowledge of the error characteristics of the data; information which is poorly known at present for the VOS data set. Thus there is an urgent need to better define the accuracy of VOS data.

2.2 What is presently achieved?

To attempt to quantify the random error in VOS observations, Kent et al. (1999) determined the root-mean-square (rms) error for VOS reports of the basic meteorological variables. Table 1 shows the minimum, maximum and mean error values for individual ship observations calculated for 30° x 30° areas of the global ocean. It is obvious that individual ship observations can not achieve the desired accuracy and that the average of many observations is needed. For example, to reduce a typical temperature error of 1.4C to the desired 0.2C requires some 50 independent observations; more when natural variability is taken into account. Sufficient observations are obtained for adequate monthly mean values in well-sampled regions like the North Atlantic but in data sparse regions acceptable accuracy cannot be achieved.

The Voluntary Observing Ship Special Observing Programme - North Atlantic project, VSOP-NA (Kent et al., 1993a), was an attempt to determine the systematic errors in VOS data. For a subset of 46 VOS, the instrumentation used was documented (Kent & Taylor, 1991), and extra information included with each report. The output from an atmospheric forecast model was used as a common standard for comparison. The results were analysed according to instrument type and exposure, ship size and nationality and other factors, and relative biases were determined. For example it was found that SST values from engine intake thermometers were biased warm compared to other methods (Kent et al. 1993a), and that daytime air temperatures were too warm due to solar heating (Kent et al. 1993b). It could be shown that the dew point temperature was not biased by the latter error (Kent and Taylor, 1996) but, compared to aspirated psychrometer readings, the dew point was biased high when obtained from fixed thermometer screens.

Table 1 - RMS Error Estimates: The uncertainty quoted in the mean error is derived from the weighted sum of the error variances (from Kent et al. 1999)

Observed Field	RMS Error:		
	Min.	Max.	Mean
Surface Wind Speed (m/s)	1.3	2.8	2.1 ± 0.2
Pressure (mb)	1.2	7.1	2.3 ± 0.2
Air Temperature (°C)	0.8	3.3	1.4 ± 0.1
Sea Surface Temperature (°C)	0.4	2.8	1.5 ± 0.1
Specific Humidity (g/kg)	0.6	1.8	1.1 ± 0.2

Some of the VOS in the VSOP-NA project reported anemometer estimated, relative wind speed in addition to the calculated true wind speed. Kent et al. (1991) showed that a major cause of error was the calculation of the true wind speed. Only 50% of the reported winds were within 1 m/s of the correct value, 30% of the reports were more than 2.5 m/s incorrect. For wind direction, only 70% were within ±10° of the correct direction and 13% were outside ±50°. These were large, needless errors which significantly degraded the quality of the anemometer winds. A similar conclusion was reached by Gulev (1999). Preliminary results from a questionnaire distributed to 300 ships' officers showed that only 27% of them used the correct method to compute true wind. The problem is not confined to VOS observations. A majority of the wind data sets obtained from research ships during the World Ocean Circulation Experiment showed errors in obtaining true wind values (Smith et al., 1999).

2.3 How can the situation be improved?

Consider as an example, wind velocity. The typical rms error for a wind speed observation shown in Table 1 (about 2.1 m/s) was achieved after instrumental observations had been corrected for the height of the anemometer above the sea surface (using data from the List of Selected Ships, "WMO47") and the visual observations corrected using the Lindau (1995) version of the Beaufort scale. For the observations as reported, the errors were nearly 20% greater - about 2.5 m/s. Alone, this change in mean accuracy decreases the number of observations required to obtain a reliable mean by a factor of 2/3rds. The quality of the anemometer winds can be further improved by using an automated method of true wind calculation such as the TurboWin system developed at KNMI. The effect on the anemometer measurements of the air-flow disturbance around the ships' hull and superstructure can be investigated using computational fluid dynamics (CFD) modelling of the airflow (Yelland et al., 1998). While it would be impracticable to model all the VOS, it is believed that typical values for the resulting error can be estimated given knowledge of the anemometer position and the overall geometry of the ship (Taylor et al. 1999b).

Similarly for the other observed variables correction schemes can be devised. For example, air temperature errors due to daytime heating of the ship depend on the solar radiation and the relative wind speed (Kent et al. 1993b). Josey et al., (1999) found that correcting the various known biases changed the climatological monthly mean heat flux by around ±15 Wm^{-2} varying with area and season. For climate studies these represent significant changes.

3. Conclusions

Most of the potential improvements discussed above require detailed, accurate documentation on the methods of observation. Some of this information is available in the List of Selected Ships (WMO47) which should be augmented with information similar to that collected for the ships which participated in the VSOP-NA. Improved meta-data with regard to the ship and observing practices, and improved quality control of the observations, are the initial priorities for the VOS Climate project. Other desirable enhancements to the VOS system include increased use of automatic coding, and improved instrumentation. These are being introduced on an increasing number of VOS, and future implementation on the ships participating in the VOS climate subset should be anticipated.

The successful implementation of the VOS Climate project will represent an important contribution to the Ocean Observing System for Climate as defined by the OOSDP (1995) and the OOPC (1998).

4. References

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EXTRA INFORMATION WITH EACH OBSERVATION

Ship parameters

Code 1	ss	Instantaneous ship's speed in knots at time of observation
Code 2	DD	Ship's heading in tens of degrees true
Code 3	LL	Maximum height in metres of deck cargo above summer maximum load line
Code 4	hh	Departure of summer maximum load line from actual sea level (m)

Wind

Code 5	ff	Relative speed in knots or m/s (in conformity with wind code indicator)
Code 6	DD	Relative wind direction in tens of degrees (00 to 36) off the bow.

This information will be included in Section 2 of the SHIP code, in optional groups to be introduced after the ICE groups. The groups will be prefixed by CLIM, and will be of the form 1ssDD 2LLhh 3ffDD, to be extended as required.