AN ARCHIVE OF UNDERWAY SURFACE METEOROLOGY DATA FROM WOCE

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INTRODUCTION

The World Ocean Circulation Experiment (WOCE) involved nearly 100 Research Vessels (R/Vs) and the participation of over 40 countries during a 10-year programme to measure the general circulation of the ocean, as well as to improve our understanding of the role of the ocean in climate. The WOCE planning process included the establishment of several distributed data centres to develop reporting methodologies and criteria for each observing system (centered primarily around measurement type) and to assemble and quality control all relevant WOCE data (WOCE International Project Office, 1997). A Data Assembly Center (DAC) for underway and moored surface meteorological data was established in the Center for Ocean-Atmospheric Prediction Studies (COAPS) at Florida State University (FSU) in support of WOCE. The mission of the FSU DAC is to collect, check, archive and distribute all surface meteorology data from the international R/Vs that participated in the WOCE programme as well as surface meteorological data from moored and drifting buoys deployed under WOCE. The FSU DAC has now established a unique archive of quality-reviewed surface meteorological data from WOCE cruises. The types of surface meteorology data processed include data from automated systems that record a wide variety of data at much higher frequencies that are not found in other data sets. We will highlight our assembly, quality-review, and management methodologies. The contents of the archive will be discussed as well as potential applications such as validating remotely-sensed data/products and identifying errors in atmospheric model fields over the ocean. Finally, questions regarding the incorporation of these data into the Comprehensive Ocean-Atmosphere Data Set (COADS) will be discussed.

DATA ASSEMBLY

Surface meteorological data were recorded during most WOCE cruises. Data reporting requirements were established for reporting WOCE surface meteorological data (e.g. Joyce and Corry, 1994), but were not widely followed. We relied on cruise reports to indicate whether meteorological data were routinely recorded. Data were then pursued through contact with scientists in charge of the cruise and/or through ship support groups at home institutions. Most data were obtained through exhaustive efforts using telephones, facsimilies, the post and the e-mail as contact means. The collection process has been very successful for nearly 70 per cent of the pre-1998 WOCE-specific data at FSU (Table 1). For a modest number of cruises no information has been forthcoming, even after several attempts to confirm reports of 'meteorological data recorded'. Data from some cruises were lost due to a variety of legacy problems such as file formats written by 'someone who no longer works for us', media degradation, etc. The collection of metadata on how the observations were recorded was equally important and includes instrument type (if any), installation height (depth) and other information. The metadata were equally difficult to obtain owing to a lack of reporting standards and difficulties in locating sources of knowledge about the instrument systems. Our experience indicates that reporting standards and requirements should be updated to reflect technological advances, particularly for automated systems. Additionally, these requirements should be more widely distributed to the research vessel community.

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Table 1—Data collection status at FSU DAC for surface meteorology. Entries reflect the number of segments (and percentage of the total number of segments). A segment is a subset of a cruise by one R/V and reflects the organization of data from cruises during the WOCE programme.

Date of WOCE cruises (years)	Number of WOCE cruise segments for which data are available at FSU DAC	Number of segments from previous column with high resolution (15 minute means or faster) data
pre-1989	6	0
1989	18	3
1990	35	10
1991	70	24
1992	81	32
1993	62	21
1994	73	36
1995	52	46
1996	12	12
1997	7	7
1998	2	2
Total	418	193 (47%)

The typical surface meteorological data set in the archive includes values for wind speed and direction, barometric pressure, humidity, air temperature, sea temperature, and for some installations, precipitation, and various radiation components. On some ships there may be more than one set of instruments. In this case, data from all instruments are included in the files. There are primarily two types of data in our archive. The first type are relatively low temporal resolution data that may be based on bridge observations. These observations are normally reported every several hours and are similar in nature to those found in COADS. We have focused especially on the second type of R/V data, i.e. those from automated instrument systems that record observations much more frequently. A typical automated system records one minute means of wind speed and direction, barometric pressure, humidity, air temperature, sea temperature, precipitation and short wave radiation (long-wave is optional), as well as several supporting variables. Examples of these automated systems are the IMET systems installed on several US platforms (Hosom *et al.*, 1995). Similar installations are found on ships from the UK, Germany, and Australia. Data from moored platforms are also becoming part of the archives, e.g. the WOCE Subduction Experiment had four moored buoys equipped with IMET systems for a two-year period.

QUALITY CONTROL

The data were quality controlled using a series of statistical and graphical analysis software tools to identify suspect data (e.g. spurious data, time shifts, gaps, biases and instrument drifts). Suspect data were brought to the attention of the upstream data supplier and flagged according to the nature of the identified problem or error (Smith *et al.*, 1996). Figure 1 shows that an example of the types of errors found were spurious jumps in temperature and humidity data records of the research vessel Meteor (from our QC reports, Smith *et al.*, 1996). We received confirmation from the ship operator that these errors are caused by instrumentation mounted near the stacks such that during select periods when the orientation of the ship and the wind are aligned, the warm moist conditions over the stack pollute downstream instruments. The subsequent errors in sensible heat flux for this case are 300 W m-2, thus demonstrating the importance of flagging suspect observations. Note that the high temporal resolution (reports every minute) of the data made it possible to confidently identify this problem. Comparable data from GTS and/or COADS (available each ~6 hours) would never indicate a problem even though one might be present. Quality control flags (including one for an interesting value, such as an extreme value verified through independent data) are included in the data files with explanations and descriptions of various data problems discussed in a quality control report that is written for each WOCE cruise.

DATA DISTRIBUTION

The WOCE community can access data through a wide variety of distribution media (e.g. electronic networks, magnetic media, interactive requests, printed

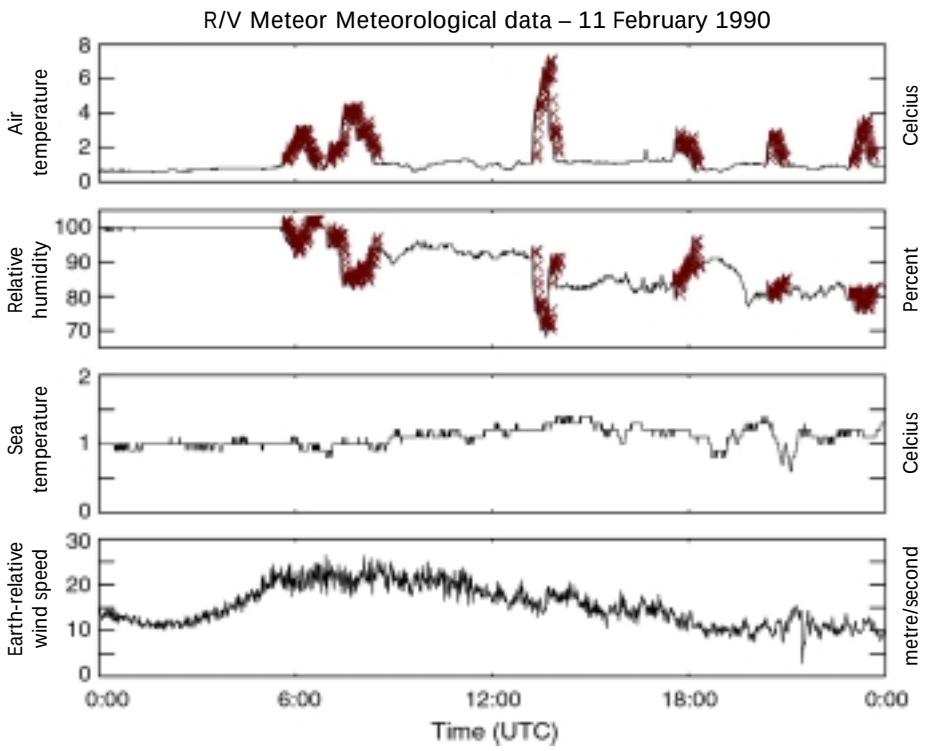

Figure 1—Underway data from the R/V Meteor with suspect data indicated by overlaid alphabetic code. Note that the Meteor was in the North Atlantic in February 1990.

reports, etc.). Documentation (i.e. metadata) on observational data and processing by DAC is also available. Data for just under half of the WOCE cruises have been published on a series of CD-ROMs, i.e. Version 2 of the WOCE Global Data Set (WOCE Data Products Committee, 2000*a,b*) (Figure 2). Updates are available on our web site (www.coaps.fsu.edu/WOCE). More complete versions of the WOCE Global Data Set will be produced. Although data from numerous WOCE cruises have yet to be delivered to FSU, to date nearly 50 million observations have been obtained, quality controlled and distributed through electronic (WWW/FTP) and CD-ROM media, thereby making this the largest uniformly formatted collection of surface meteorology data from research vessels.

UNIQUENESS

This data archive of underway surface meteorological data has several valuable attributes. Much of the data are unique in that they originate from automated instrument systems that record observations at a relatively high time resolution (averaging periods of seconds to minutes) and are not reported via the GTS. The high-frequency recording aspect allows a more rigorous quality control review of the data and thus results in data with a higher level of quality. Additionally, the higher resolution data enables additional applications to be considered that would not be possible (i.e. more difficult to complete) with ordinary reporting at synoptic hours. In our review of data from several of the WOCE R/Vs, many observations do not appear in the COADS; neither are they reported via the GTS. High time resolution data are certainly not available in COADS or through other sources. Some R/Vs do report surface meteorological values at synoptic hours, but again the data from automated systems are not typically reported. In cases where coincident data from both automated systems and ordinary observations are reported for a single ship, the WOCE DAC data should by default be considered to be of a higher quality. Lastly, the high-quality metadata (instrument type, placement and height) make these data unique and valuable for climate studies.

APPLICATIONS

The applications of these data are varied. Process-oriented studies often require coincidental measurements of the water column as well as the surface air-sea fluxes. Some of the surface meteorological data are used to validate NSCAT surface winds (Bourassa *et al.*, 1997) and will be used to validate other remotely sensed data. Other validation work with these data is underway and will address issues

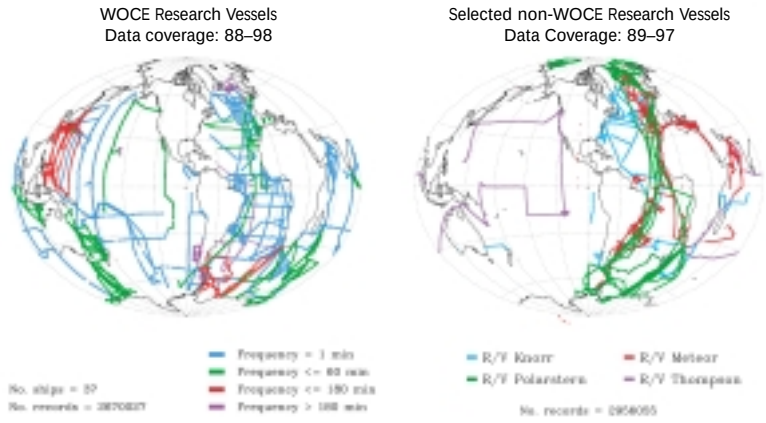

Figure 2—(left) Coverage of FSU DAC archive as of May 1998. Shades indicate temporal frequency of data recordings. (right) Coverage from non-WOCE data to be processed in the future. Shades indicate respective research vessels. All data on this plot are recorded at greater than 5-minute frequency.

such as optimal averaging times for recording anemometers so that remotely-sensed and in situ winds can be blended.

We have taken an active role in improving the reporting standards of some of the ships that have provided us with data. Feedback from our quality control review of the data has led to improved data recording practices, particularly for wind reporting (Smith *et al.*, 1999).

Because these meteorological data are high resolution, air-sea fluxes can be computed more confidently and with more accuracy. Consequently, we are developing methodologies to use the DAC data as an independent means for validating surface meteorology and flux products. We have begun to compare select WOCE surface meteorology observations from our DAC with surface reanalysis products from NCEP. There are certain advantages to this approach. First, the high time resolution data from our archive produce more accurate flux estimates because we can average over the same six-hour time period that is represented in the reanalysis. Additionally, we can remove suspect data and make proper adjustments to height measurements and observing methods. As previously discussed, many of the WOCE data are independent of the data stream used as input for reanalysis. These data were observed over a relatively wide range of locations; they consequently represent a wider distribution of environmental conditions under which the reanalysis and other flux products may be evaluated. Such an analysis could be completed with individual ship reports from COADS, but given the substantial errors associated with COADS data and the tremendous difficulties in gaining knowledge of how each ship observes and records these data, numerous questions would arise and compromise quantitative results (Smith *et al.*, 2001).

FUTURE PLANS AND DISCUSSIONS

Our WOCE centre has focused on completing the processing of data only from WOCE cruises. We have assembled a substantial collection of high time resolution surface meteorological data from non-WOCE cruises from many of the same ships. We have started to process these data for selected ships with the best data and coverage during the WOCE period. On the basis of the initial processing of some of these data, we estimate that we will expand our high time resolution data volume for the selected ships by nearly three million observations (Figure 2). These will provide additional surface flux data for a variety of studies. Additionally, they will increase our pool of WOCE high time resolution data for potential matches to evaluate flux products by three-fold. These additional data will also supplement the general pool of in situ data for other purposes such as remote sensor validation. It should be noted that most of the additional cruises from this collection are in the Atlantic, with quite a few being from rarely sampled regions of the Southern Hemisphere.

All of our data will be made available to NODC for final archiving. Additionally, these (and all other relevant) WOCE data are being melded into a single WOCE Global Data Resource (its final composition and structure have yet to be completely defined). Questions remain concerning the inclusion of these data in COADS and other such data collections. Much work should precede this decision to address questions of representativeness.

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