AN ARCHIVE OF UNDERWAY SURFACE METEOROLOGY DATA FROM WOCE

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1. INTRODUCTION

The World Ocean Circulation Experiment (WOCE) involved nearly 100 research vessels and participation from over 40 countries during a 10-year program to measure the general circulation of the ocean as well as improve our understanding of the role of the ocean in climate. The WOCE planning process included establishing several distributed data centers 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 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 (underway) surface meteorology data from international WOCE vessels and moored and drifting buoys. The FSU DAC has now established a unique archive of quality-reviewed surface meteorological data from WOCE cruises. The types of surface meteorological data processed includes data from automated systems that record a wide variety of data at much higher frequencies than 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 type of data into the COADS will be presented for discussion.

2. DATA ASSEMBLY

Surface meteorological data were recorded as part of 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 if 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 of contact through phone, fax, mail, and email. The collection process has been very successful with nearly 70% of the pre-1998 WOCE-specific data at FSU, Table 1. There are a modest number of cruises where no information has been forthcoming even after several attempts to confirm cruise reports of “meteorological data recorded”. Data from another set of cruises are lost due to a variety of legacy problems such as file formats written by “someone no longer working for us”, media degradation, etc. Collection of metadata about how the observations were recorded was equally important and includes instrument type (if any), installation height (depth), and other information. The metadata was equally difficult to obtain because there were no reporting standards and sources of knowledge about the instrument systems were difficult to locate. Our experience indicates that reporting standards and requirements should be updated to reflect technology advances particularly for automated systems. Additionally, these requirements should be more widely distributed to the research vessel community.

The typical surface meteorological data set in the archive includes 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 are relatively low temporal resolution data that may be based on bridge observations. These observations are nominally reported once every several hours and are similar to those found in COADS. We have focused especially on the second type of research vessel (RV) data, i.e., those from automated instrument systems recording observations much more frequently. A typical automated system records one minute means of wind speed and direction, barometric pressure, humidity, air and sea temperatures, precipitation and short wave radiation (long-wave is optional), as well as several supporting variables. Examples of these automated systems include IMET installed on several US platforms (Hosom et al., 1995). Similar systems are found on ships from the UK, Germany, and Australia. Data from moored platforms are also part of the archives, e.g. the WOCE Subduction Experiment had five moored buoys equipped with IMET systems for the 2-year duration.
Table 1. Data collection status at FSU DAC for surface meteorology. Entries reflect number of segments (and percentage of total number of segments). Note that little information is available for the final phase of the WOCE field program, 1996-1998.

<table>
<thead>
<tr>
<th>Year(s) of WOCE Cruises</th>
<th>Number of WOCE cruises recording surface meteorology data</th>
<th>Known high resolution (15 minute means or better) data sets</th>
</tr>
</thead>
<tbody>
<tr>
<td>pre-1989</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>1989</td>
<td>24</td>
<td>3</td>
</tr>
<tr>
<td>1990</td>
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<td>1997</td>
<td>22</td>
<td>12</td>
</tr>
<tr>
<td>1998</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>650</td>
<td>183 (28%)</td>
</tr>
</tbody>
</table>

3. QUALITY-CONTROL

The data were quality controlled through a series of statistical and graphical analyses tools in order to pinpoint problems with the data, (e.g. spurious data, time shifts, gaps, biases, and instrument drifts) which needed to be resolved with the upstream data supplier and/or flagged (Smith, et al., 1996). An example of the types of errors we found are spurious jumps in temperature and humidity data records of the research vessel Meteor, Figure 1 (from our QC reports, Smith, et al., 1996). We confirmed with the ship operator these are due to instrumentation mounted near the stacks such that during select periods where the orientation of the ship and wind align, 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 it may be present. Quality-control flags (including one for an interesting value) are included in the data files with explanations and descriptions of various data problems discussed in a Quality Control Report for each WOCE cruise.

4. DATA DISTRIBUTION

The data are accessible through a wide variety of distribution media (e.g. electronic network, magnetic media, interactive requests, printed reports, etc.) to the WOCE community. Documentation (i.e. metadata) regarding the observational data and the processing by the DAC likewise is available. Data for just under half of the WOCE cruises have been published on a series of CD-ROM's, Version 1 of the WOCE Global Data Set (WOCE Data Products Committee, 1998a; WOCE Data Products Committee, 1998b; WOCE Data Products Committee, 1998c), 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 via electronic (WWW/FTP) and CD-ROM media making this the largest uniformly formatted collection of surface meteorology data from research vessels.

5. UNIQUENESS

This data archive of underway surface meteorological data has several valuable attributes. The data are somewhat unique in that a relatively large portion are from automated instrument systems which records at rel-
Applications for 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 employed to validate other remotely sensed data. A report on this work will be presented at the CLIMAR conference. Other validation work with these data are underway and will address such issues 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 for some of the ships that have provided us data. Feedback of our quality-control review of the data has resulted in improved data recording practices, particularly for the wind reporting (Smith, et al., 1999). A paper presenting reporting requirements for winds will be presented at the CLIMAR conference.

Because these meteorological data are high resolution, air-sea fluxes can be more 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 to surface reanalysis products from NCEP. There are advantages to this approach. First the high-time resolution data from our archive produces more accurate flux estimates because we can average over the same six-hour time period as that represented in the reanalysis. Additionally, we can remove suspect data, make proper adjustments for measurement height, and observing method. As discussed previously, the data are somewhat independent and have distribution over wide ranges of latitude, longitude, and time. Such an analysis could be completed with individual ship reports from COADS, but given the large errors associated with COADS data and relatively high time resolution (averaging periods of seconds to minutes). This aspect has allowed a more rigorous quality-control review of the data and thus resulted in higher quality data. Additionally, the higher-resolution data permits additional applications to be considered that would not be possible (i.e. more difficult to complete) with ordinary reporting at synoptic hours. In our cursory review of data from several of the WOCE ships, much of their observations do not appear in COADS nor are they reported via the GTS. Certainly the high time-resolution data are not available in COADS or through usual sources. Some of the R/V's do report surface meteorological values at synoptic hours, but again the data from the automated systems are not typically reported. In cases where coincident data from both an automated system and from ordinary observations are reported for a single ship, the WOCE DAC data should by default considered to be of higher quality. Lastly, the high-quality metadata (instrument type, placement, and height) makes these data unique and valuable for climate studies.

6. APPLICATIONS

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the tremendous difficulties with gaining knowledge of how each ship observes and records the appropriate data, numerous questions would arise and compromise quantitative results. Another paper at CLIMAR will present findings of this evaluation of the NCEP reanalysis flux fields.

7. FUTURE PLANS AND DISCUSSION

Our WOCE center has focused on completing processing of data only from WOCE cruises. We have assembled a substantial collection of high-resolution surface meteorological data from non-WOCE cruises and transits from many of the same ships. We have begun processing these data for select ships with the best data and coverage during the WOCE period. Based on initial processing of some of these data, we estimate that we will expand our high-time resolution data volume for the selected ships by three-fold, Figure 2. These will provide additional surface flux data for a variety of studies. In relation to total volume of WOCE data, this would double the number of ship-days in our archive and increase our pool 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. Note that most of these additional cruises from this collection are in the Atlantic, and quite a few are 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, (the final composition and structure have yet to be completely defined). The question remains as to the inclusion of these data in COADS and other such data collections. Much work should precede this decision to address questions of representativeness.

8. ACKNOWLEDGEMENTS

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9. REFERENCES


