Plan for a VOS-IMET Delayed Mode Data Center at the Florida State University

Shawn R. Smith, Mark A. Bourassa, and David M. Legler

COAPS Report 2000-04

COAPS

July 2000

Plan for a VOS-IMET Delayed Mode Data Center at the Florida State University

Shawn R. Smith, Mark A. Bourassa, and David M. Legler*

Center for Ocean Atmospheric Prediction Studies
The Florida State University
Tallahassee, FL 32306-2840

*Current affiliation:
U.S. CLIVAR Office
Washington, DC 20024

Final Technical Report for WHOI subcontract A100089 (FSU# 1338795-40)
COAPS Report 00-04

Monies provided by Office of Global Programs, NOAA

July 2000

1. Introduction

The development of the Improved Meteorology (IMET) system for marine meteorological observations (Hosom et al. 1995) has advanced automated weather observations on research vessels and fixed buoys. Throughout the late 1990s, several IMET systems were in operation on research vessels. Many of these IMET observations are included in the World Ocean Circulation Experiment (WOCE) Surface Meteorology Data Center (WOCE-MET) archive at the Florida State University (FSU) where they have undergone quality evaluation. The IMET system has proven its ability to provide high-temporal resolution meteorology observations under many atmospheric and oceanic conditions, and plans are now underway to expand the use of IMET systems to select vessels in the Volunteer Observing System (VOS) fleet. The expansion of the IMET installations to VOS will result in a significant increase in the number of observations requiring a revised strategy for the evaluation of these observations. In preparation for the VOS IMET system, this scale-up plan outlines changes to our quality evaluation and archival procedures as a first step to becoming the delayed-mode data center for the VOS IMET program. This plan will form the basis for a future funding proposal to begin scale-up operations.

The primary goal of the VOS IMET delayed-mode data center would be to create a value-added research quality archive of the high temporal resolution meteorological observations collected on the select VOS vessels. IMET observations from research vessels have proven to be ideal for the evaluation of satellite sensors (Bourassa et al. 1997) and global reanalysis products (Smith et al. 2001, Renfrew et al. 2000). In addition, IMET data are of interest for air-sea flux studies and global atmospheric and oceanic modeling. The expansion of IMET observations to VOS vessels will increase the volume of high temporal resolution data available to the scientific community. Prior to scientific application, the quality of the VOS IMET observations must be evaluated, and WOCE-MET has a wide range of IMET quality control (QC) experience that will be applied to the processing of VOS IMET observations.

The establishment of a VOS IMET observing program will create new challenges for data processing and archival. WOCE-MET's current quality processing uses both automated and visual data inspection. Experience gained through WOCE has shown both forms of data evaluation to be essential. Although visual inspection of vast data quantities under current methods is labor intensive, valuable insight into the operation of each IMET installation has been gained and will be necessary for new VOS IMET systems. The potential deployment of IMET system, each recording observations at a nominal one-minute interval, on 20 or more VOS vessels would tax our current QC system, so we plan to implement system wide changes to improve our quality processing. Past experience with visual data inspection has revealed several time-consuming checks that can be automated. Planned processing improvements include streamlining the raw data ingestion, improving automated flagging procedures, adding automated spike and step checks, and optimizing our visual inspection tool to allow the data quality evaluator (DQE) to assess more data in fewer man hours. The planned changes will allow more IMET data to be processed for each man hour of DQE time. In addition, advancements in our evaluation techniques will add further value to the delayed-mode VOS IMET observations.

2. Past experience

WOCE-MET was established in 1994 to collect, quality control, and archive underway meteorology data from WOCE sponsored cruises. Early in our history, we developed a QC system that ingests research vessel meteorology data into a common format and evaluates these observations using automated and visual techniques (Smith et al. 1996). The evaluation system was designed to ingest data collected over a wide range of temporal frequencies. Bridge (collected every 3 to 6 hours) and automated (collected as often as once a minute) weather data were evaluated using the same system. Through the years our work with research vessel data has expanded beyond WOCE and we currently maintain the largest international archive of quality reviewed underway meteorological observations.

Our quality evaluation philosophy is based on highlighting potential problems and unique features in the data stream by adding predefined flags to the data. Maintaining the original data content is one of our primary goals. Original data are removed from the final quality reviewed products only when identified problems are so severe as to render the data useless. Additional discussion of applied flags is provided in on-line quality control reports. Within the reports, recommendations are made regarding the use of flagged data. This flagging philosophy eliminates severely flawed data and places the decision for use of the remaining flagged data in the hands of the user. All original data are archived and available to interested users.

Through the years, WOCE-MET has gathered a wide knowledge of problems associated with automated weather system on vessels. Automated systems from 30 research vessels operating out of 10 countries have been evaluated. Some problem are common to many vessels (e.g., accurate true wind computation; Smith et al. 1999) while other problems are specific to a single instrument system or vessel deployment.

Our WOCE experience with the IMET system has focused on data from the *Knorr, Thomas G. Thompson, Melville,* and more recently the *Ronald Brown*. We have gained additional experience with IMET data from the *Roger Revelle, Polar Duke, Oceanus,* and *Atlantis* through our satellite wind validation studies (Bourassa et al. 1997). The overall quality of the WOCE IMET meteorological data was good with 7% of the approximately 17.5 million observations being flagged. Most of these flags were associated with problems in calculating the true winds (see Smith et al. 1999). Early deployments of the IMET system were plagued with major compass problems resulting in erroneous true winds. In addition, failure to record a gyrocompass heading and missing or poorly defined wind parameters resulted in a generally poor quality of the IMET true wind data. Communication between WOCE-MET and the IMET vessel operators resolved many of these problems and the quality of the wind data has greatly improved. At present some vessels still have problems reporting true winds from the IMET system, and more work is necessary to eliminate these problems. Additional problems with the IMET precipitation gauge and steps in the IMET atmospheric pressure data related to the ships motion were found and have yet to be resolved. We plan on working with the Woods Hole Oceanographic Institution (WHOI) and ship operators to identify and resolve these and other problems.

Completion of the funded pilot study for the VOS-IMET program, provided more knowledge of IMET systems. We evaluated the 1997 and 1998 IMET data from the NOAA vessel *Ronald Brown* and R/V *Roger Revelle* and reports for the *Ronald Brown* (Enloe et al. 2000) and *Roger Revelle* (Volkmer and Smith 2000) summarizing each vessel's data quality are available. The study revealed some problems that were noted in IMET systems evaluated earlier, and some that were specific to these vessels. True wind data from both the *Ronald Brown* and *Roger Revelle* showed signals of the ship's motion. Some were caused by erroneous input values for the true wind calculation (sensor failures, etc.), but most of the suspect wind data were deemed to be the result of flow distortion around the vessel. On the *Ronald Brown*, the severity of the flow distortion varied by cruise and likely resulted from changing arrangements of scientific cargo on the forward deck of the vessel. An example of the ship motion signal in wind data for the *Ronald Brown* was provided to NOAA Corps Operations for their evaluation. Both vessels also experienced severe problems with their precipitation gauges and steps in the atmospheric pressure data. The *Roger Revelle* was the first vessel with a bow mounted IMET system displaying temperature and relative humidity steps that are characteristic of the sensors being affected by the ship's exhaust plume. The potential for exhaust plume problems with bow mounted IMET sensors was confirmed by R. Payne (WHOI, personal communication, 2000). Investigation of these and other ship specific problems has been addressed with the vessel operators.

3. Planned activities

Our experience processing large volumes of automated marine observations has revealed several areas where our QC system can be improved to facilitate the future VOS IMET program. Necessary changes will include streamlining data ingestion into the system and more reliance on automated quality evaluation. We plan to maintain visual inspection of the VOS IMET data; however, several advancements in our technique will optimize DQE man-power. For the foreseeable future, we expect that visual inspection of all data will be essential to identify problems with new VOS IMET installations. In time, visual inspections may be reduced to spot evaluation, but should not be completely eliminated. The overall goal of the planned modifications is the efficient use of DQE man-hours and improved turnaround times for value-added, delayed-mode VOS IMET observations.

3.1 Data ingestion

Creation of a VOS-IMET delayed-mode archive will begin with the establishment of a data pipeline from the VOS-IMET vessels (VIVs) to the data archive. We expect that the VIVs will continue to log meteorological data at one minute intervals, and current plans have a sub-sample of these data being transmitted via satellite for real time evaluation by those maintaining the VOS IMET systems. The remaining one-minute data will be stored in onboard data loggers and will be retrieved from the vessels at roughly six month intervals (D. Hosom, personal communication, 2000). Once the IMET data are retrieved from the VIV, arrangements will be made to have the data forwarded to the delayed-mode archive.

Quality assessment of the delayed-mode IMET data will begin with the ingestion of the data into our automated QC system. The use of a standard file format to transfer the IMET data from the VIVs to FSU is essential to speed the processing of the data. Past experience has shown that a single vessel often provides data in multiple file formats, resulting in a time consuming process of converting these data to a standard file format. Planning for a comprehensive data logging format must be done well in advance and must include not only the meteorology data, but necessary metadata (Table 1). A standard VOS IMET data format, agreed upon by WHOI, the data center, and other parties involved in VOS IMET data collection, will ease the ingestion of VOS IMET data into our QC system. The result will be more valuable man hours for visual data inspection and a greatly reduced delay in quality processing.

3.2 Automated quality processing

The automated quality processing currently in use by WOCE-MET is described in Smith et al. (1996). The system was designed to handle WOCE research vessel data recorded at one-minute to six-hourly intervals and to process ship, buoy, and land station data during TOGA-COARE. Allowances were made for multiple platform types and installation locations. A comprehensive data logging format for VOS IMET data will allow the entire automated quality process to be overhauled and optimized for the IMET data stream.

Table 1: Metadata necessary for scientific use of IMET observations. "All variables" implies both navigational (latitude, longitude, speed over ground and water, heading, and course) and meteorological (pressure, air and sea temperature, wind, moisture, radiation, and precipitation) parameters.

Metadata type	Measurement
Units	All variables
Averaging technique	All variables
Averaging period and center	All variables
Instrument height/depth	Pressure, air and sea temperature, winds, moisture
Instrument type	All variables
Instrument location on vessel	Pressure, air and sea temperature, winds, moisture, radiation, precipitation
Direction convention	Heading, course, winds

In addition to optimizing the automated QC, we plan to upgrade many of the current system's functions. For example, the current automated QC uses fixed range bounds to determine whether observed values are realistic. This method will be replaced with geographically dependent ranges that will reduce the overflagging of realistic values. For example, under the current system -10°C is used as a lower limit for air temperature. While this is reasonable in the tropics, when a vessel is near the Antarctic, air temperature routinely falls below this threshold and is flagged. At present, the DQE must manually remove these flags. We also plan to upgrade our QC of shortwave and longwave radiation to include variable dependent range checks and a comparison to a radiation climatology (where possible). Another potential change will be the addition of an "in port" flag to any data collected while the vessel is at the dock. In port data are typically not representative of open ocean conditions and should be screened out for many studies.

Previous quality evaluation of IMET and other automated systems has revealed a need for an automated method to identify spikes and steps in many observations. Spikes are common to most automated data. Steps in automated marine meteorology data are most often associated with changes in orientation or speed of the vessel. In many wind datasets, steps result from incorrect calculation of the true winds (Smith et al. 1999). Steps have also been noted in air temperature, humidity, and pressure data. These steps have been associated with changes in flow distortion related to ship maneuvers, and with airflow over the ship's exhaust stacks. Identification of spikes and steps is currently done by the DQE during visual data inspection and has proven to be the most time consuming part of our visual quality evaluation.

For the VOS IMET program, we plan to implement an automated technique to identify spikes and steps. Our new method examines changes in temporally coincident observations for a portion of the cruise, and determines statistical characteristics of the distribution of these changes. A threshold for excessive changes (i.e., spikes or steps) is objectively determined based on these statistics. This threshold will be determined every cruise or every week for each instrument, and therefore will be dependent on the ship operations and the equipment or cargo arrangement that influences the volume of air sampled by each instrument. The values that are flagged by this system are then identified as spikes or steps. Graphical and statistical methods can then be applied to determine if there are too frequent coincidence between the flagged data and changes ship speed, heading, or ship relative wind direction. These analyses allow for easy identification of errors in true wind calculation (including identification of the type of error) and some indication of large flow distortion errors (which is suspected with pressure and wind sensors). Graphics can easily identify the ship-relative wind directions for which the sampled air passes over (or too near) the stacks prior to being sampled. Identifying (and if possible correcting) these problems have been the most time consuming aspects of visual inspection. These improvements will greatly decrease the delay in processing the VOS-IMET observations. We will continue to use the knowledge gained from the visual inspection process to guide development of our automated quality control procedures.

3.3 Visual quality processing

WOCE-MET developed the Visual Data Assessment Tool (VIDAT) to work in conjunction with the automated quality processing system (Smith et al. 1996). After completing the automated processing, data flags are added, removed, or modified by the DQE using VIDAT. This is an essential, but labor intensive, step in the quality evaluation process. Although our experience with visual QC has identified problems that can be flagged using advanced automated techniques (see section 3.2), each new installation of an automated platform identifies new challenges for marine meteorological measurements. Therefore, implementation of a VOS IMET program will require some level of visual inspection into the foreseeable future. We plan to overhaul VIDAT to create a second generation visual editor that is optimized for automated (IMET type) data. The planned optimization will allow the DQE to visually inspect/flag significantly more data for each man-hour worked.

Improvements to VIDAT will include streamlined file handling, multivariate flagging, and improved zoom capabilities. At present, the file handling is rather cumbersome with the DQE having to load each file in turn. Improvements will allow the DQE to load multiple days of data through fewer keystrokes. In addition, VIDAT currently allows only one variable in one file to be flagged at one time. Improvements are planned to allow multiple variables over the same time range to be flagged. This will simplify flagging for the DQE when related variables (e.g., temperature and relative humidity) experience a problem. Changes are also planned to allow the DQE to flag the data for multiple days at one time. These are just some of the advancements that are planned as a result of WOCE-METs experience with automated marine data. With the planned improvements, we initially expect that all VIV data will be visually inspected by the delayed-mode data center. As the VIV fleet grows, our procedure will have to undergo periodic modifications to keep up with an ever increasing volume of IMET data.

3.4 Communication and Archival

The acquisition and quality evaluation of the VOS IMET data are only two of the roles of the delayed-mode data center. As WOCE-MET has done in the past, we plan to provide active feedback to those maintaining the VOS IMET systems, informing them of potential problems. Once a substantial database of VIV data exists, we may be able to provide insight into design changes or new instrument selection for future IMET vessels. Active feedback can only be provided through dialog established between the delayed-mode archive, the persons responsible for inspecting the real time data, and the VOS IMET instrument technicians. The primary goal of this dialog is to identify the source of problematic data and expedite system repairs/modifications.

The final step in the creation of the VOS IMET delayed-mode data center is to establish an archive of research quality observations. Our strategy will be to provide data quality reports and the quality reviewed IMET data via an on-line media source. Our current system takes advantage of the world wide web and ftp to allow continuous access to all processed data. A database of all VOS IMET cruises will be maintained and the potential for search capabilities will be explored. Distribution on other digital media will also be possible. Long-term archival strategies will be discussed and planned with the IMET VOS team to insure the viability of the data into the future.

4. Conclusion

The data center at COAPS has developed a wide range of experience with IMET and other automated marine weather systems. We are well qualified and willing to provide the service of evaluating VOS IMET observations once collection begins. Plans for the establishment of a delayed-mode VOS IMET archive and some of the necessary improvements to our evaluation procedures have been outlined. Working with other groups involved in the VOS IMET program we will develop a streamlined system to ingest VOS IMET data and evaluate its quality using improved automated and visual techniques. Planned improvements will result in a man-hour efficient evaluation system that will create value-added VOS IMET observations. The result, through feedback with VOS IMET technicians and scientists, will be higher quality marine meteorological observations that will be suitable for many research applications.

5. Acknowledgments

Funding for this plan and the quality evaluation of the NOAA vessel *Ronald Brown* and R/V *Roger Revelle* was provided by the NOAA Office of Global Programs through a subcontract (A100089) with the Woods Hole Oceanographic Institute.

References

Bourassa, M. A., M. H. Freilich, D. M. Legler, W. T. Liu, and J. J. O'Brien, 1997: Wind observations from new satellite and research vessels agree. *EOS Trans. of Amer. Geophys. Union*, **78**, 597 & 602.

Enloe, J., J. Lovell, and S. R. Smith, 2000: *Ronald H. Brown* IMET data quality control report: 1997 and 1998. RVSMDC Report 00-04, Research Vessel Surface Meteorology Data Center, COAPS, Florida State University, Tallahassee, Florida, 32306-2840, USA, 7pp.

Hosom, D.S., R.A. Weller, R.E. Payne, and K.E. Prada, 1995: The IMET (Improved Meteorology) ship and buoy systems. *J. Atmos. Oceanic Technol.*, **12**, 527-540.

Renfrew, I. A., G. W. K. Moore, P. S. Guest, and K. Bumke, 2000: A comparison of surface-layer, surface heat flux, and surface momentum flux observations over the Labrador Sea with ECMWF analyses and NCEP reanalyses. *J. Phys. Oceanogr.*, submitted.

Smith, S.R., C. Harvey, and D.M. Legler, 1996: Handbook of quality control procedures and methods for surface meteorology data. WOCE Report 141/96, COAPS Report 96-1, WOCE Data Assembly Center, COAPS, Florida State University, Tallahassee, Florida, 32306-2840, USA, 56pp.

Smith, S.R., M.A. Bourassa, and R.J. Sharp, 1999: Establishing more truth in true winds. *J. Atmos. Oceanic Technol.*, **16**, 939-952.

Smith, S.R., D.M. Legler, and K.Verzone, 2001: Assessment of NCEP reanalysis flux fields using high quality meteorological data from WOCE vessels. *J. Climate*, submitted.

Volkmer, L., and S. R. Smith, 2000: *Roger Revelle* IMET data quality control report: 1997 and 1998. RVSMDC Report 00-03, Research Vessel Surface Meteorology Data Center, COAPS, Florida State University, Tallahassee, Florida, 32306-2840, USA, 12pp.