Meteorological Measurements from WOCE Research Ships

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1. Introduction

1.1 Why the Data are Needed

Meteorological data from the WOCE ships would be of value for:

1. Initialization of atmospheric models;
2. As a source of accurate estimates of the basic meteorological variables (air temperature, humidity, *etc.*); *e.g.* for comparison to values from ships of opportunity, output from atmospheric forecast models, or for satellite validation;
3. To estimate the air-sea fluxes, *e.g.*, to verify climatology or model-derived flux values.

These uses, and the implications for measurement precision *etc.*, have been discussed in more detail in Taylor (1989). The greatest demand, in terms of the variables to be measured and the accuracy sought, is for the definition of the surface fluxes. Data adequate for that purpose will also be adequate for model initialization provided it is rapidly made available over GTS (Global Telecommunication System).

1.2 Role of WHP Ships

The ships participating in the WOCE program have the potential of being especially valuable platforms from which to make accurate *in situ* measurements of the basic observables – sea surface temperature, air temperature, wind velocity, barometric pressure, solar and longwave radiation, and humidity – and from which to make accurate estimates of the air-sea fluxes. They are attractive because: (1) they often travel paths through data sparse regions; (2) they are manned by crews, technicians and science parties with an interest in obtaining good meteorological data; and (3) their operating schedules permit their sensors and electronics to be returned periodically for calibration.

1.3 Summary of Accuracy Requirements

For routine measurement from ships the surface flux values will be obtained, using bulk formulae, from the basic meteorological observables. These are the sea surface temperature (T_s), air temperature (T_a), wind speed (U_w), wind direction (ϕ), barometric pressure (p_a), humidity (q_a) or dew point temperature (T_D) or wet bulb temperature (T_W), short wave radiation (SW), long wave radiation (LW), and precipitation rate. There should be care taken to minimize errors in the measurement of these basic observables, particularly systematic errors or biases that cannot be suppressed by averaging. The following accuracies should be sought:

Table of Accuracies

	Observable	Target Accuracy
Wind	Speed, U_w	larger of 2% or 0.2 m/s
	Direction, ϕ	2.8°
Temperatures	Air-sea temp. difference	0.5°C
	Air temp, T_a	0.25°C
	Sea surface temp, T_s	0.25°C
Humidity	Specific humidity, q_a	0.25 gkg^{-1}
	Relative humidity,RH	1.7%
	Dew point temp, T_D	0.3°C
Radiation	Net shortwave, SW↑↓	$10Wm^{-2}$
	Net longwave, LW↑↓	$10Wm^{-2}$
Other	Barometric pressure p_a	0.3 mb
	Precipitation	1 cm $month^{-1}$

1.4 Choice of Systems

The minimum requirement for WHP ships is to obtain meteorological data by one of two methods:

1. Automatic shipboard meteorological systems
2. Manual weather observations as performed on the Voluntary Observing Ships of the World Weather Watch (WWW).

For the reasons discussed below, it will often be desirable that both systems be used on WHP ships.

Automatic meteorological systems produce data suitable for verifications and flux estimation purposes, but the data will not be used for atmospheric model initialization, nor enter the standard climate data bases, unless it is coded into standard WMO codes and transmitted as a ship's weather message or recorded in a meteorological logbook. Some automatic meteorological systems are capable of formatting a WMO format message, either for transmission by the radio officer or for automatic transmission *via* satellite. IF such a system is **not** used, then arrangements must be made for the WHP ship to become VOS and submit standard ship reports.

Manual weather observations, transmitted to shore and hence over the Global Telecommunications System (GTS), are used for model initialization. Entered into a ship's Meteorological Logbook, the same data also eventually become part of the Marine Climate Database. It is because the World Weather Watch system of WMO has existing procedures to ensure that these data from WHP ships are utilized, that coded ship's meteorological messages are especially valuable. However, manual observations do not contain all the desired variables for model and ships satellite verification, and every effort should be made to equip WHP ships which take VOS observations with automatic meteorological systems.

2. Automatic Meteorological Systems

The functional definition of a suitable system should include:

a. A suite of calibrated, properly exposed meteorological sensors. This normally requires the use of two or three sensors for each variable to ensure good exposure for any relative wind direction. Calibration is required at frequent intervals (typically one to three months). The organization of a routine system for sensor maintenance and calibration should be an important part of the installation specifications.

b. A link to the ship's navigation system. The direction of the ship's head, and the ship's velocity through the water, are required to correct wind velocities.

c. Signal conditioning and transmission to the logging system. A particular problem for shipboard installations is to avoid interference from radio transmissions.

d. Sampling, time stamping, filtering and averaging of the data. Typically data may be sampled once per second or faster, and the processed values averaged over one or more minutes. The raw data should be recorded for possible post-cruise calibration corrections.

e. Conversion of the raw data to geophysical units. This may be performed either before recoding or on replay for data display. The correct calibration must be associated with each sensor despite, for example, the replacement of a sensor due to failure in the middle of a cruise.

f. Data recording. This must be reliable despite possible power fluctuations, *etc.*

g. Data display. Normally the scientific party on the ship requires a display of present data and also to be able to recover previously recorded data. This must be possible without compromising the data recording.

h. Transmission of the data to shore for system monitoring. If required this is normally accomplished through an ARGOS link.

i. Transmission of the data on the GTS for use by Meteorological Agencies. This requires that the data be quality controlled and that a correctly coded message be assembled.

2.1 Measurements Required

2.1.1 Wind Velocity

Normally at least two wind velocity sensors will be required to give good exposure for most relative wind directions, each sensor consisting of both speed and direction sensors, (*e.g.*, an anemometer and wind vane). The resulting measurements of wind speed relative to the ship must be recorded separately from data on the ships head and speed through the water, both of which are required at the same sampling rate and accuracy as the wind measurements.

2.1.2 Air Temperature

At least two measuring sites, to either side of the ship, are normally required. The sensor must be shielded from radiation in a well exposed 'Stevenson' screen or aspirated enclosure sited so that the effects of heat from the ship minimized.

2.1.3 Air Humidity

An adequate automatic humidity sensor remains to be demonstrated. Measurements using a wet bulb thermometer, colocated with the dry bulb measurement, will require careful sensor maintenance, (*i.e.*, clean wick, adequate reservoir).

2.1.4 Sea Surface Temperature

Ideally the sea temperature should be measured below the ocean surface skin, but above any diurnal thermocline, (*i.e.*, at about 10 cm depth). Such an approach considers the surface skin temperature to be a fluctuating quantity, determined by the instantaneous surface fluxes, which are, in turn, driven by the bulk air-sea temperature difference. Suitable SST sensors include hull contact sensors, trailing thermistors, and pumped thermosalinographs. However, the depth sampled will normally be deeper than the ideal case, and the water sampled will, in any case, have been disturbed by the ship.

2.1.5 Radiative Fluxes

Both downward longwave and shortwave fluxes should be measured by gimbal-mounted, upward-looking radiometers. Shadowing of shortwave radiometers can be corrected, to first order, by using more than one sensor. Correct siting of the longwave sensor is almost impossible on ships. The ideal position is the top of the tallest mast; however, the instrument cannot then be cleaned. The instrument may be contaminated by salt, engine exhaust deposits, and seagulls. Even from a clean sensor, the data will be contaminated if the engine exhaust plume is within the sensor field of view. A compromise sensor site must, therefore, be chosen for each ship.

2.1.6 Air Pressure

The device used should be connected to a suitable static head and incorporate averaging for ship heave, pitch, and roll.

2.1.7 Navigation

Ship's position must be available for each observation.

2.2 Examples of Meteorological Systems

To illustrate what is possible, SEAS, a basic system for preparing GTS reports and two systems which have been developed for use in WOCE are briefly summarized in Appendix 1. These last two are *"MultiMet"* developed by the Institute of Oceanographic Sciences Deacon Laboratory (IOSDL) in the U.K. and *IMET*, a new system of sensors and data loggers being developed in the U.S. Both the latter systems are capable of providing measurements for estimating the surface fluxes.

3. Manual Weather Observations

The observations should be obtained to at least the standard required of 'Selected Ships' under the Voluntary Observing Ships (VOS) programme of World Weather Watch (WMO 1983). Observations should be made at each of the main synoptic hours (00, 06, 12, 18 GMT) and every effort made to transmit the observations promptly (noting, however, that the standard cutoff is 12 hours, and reports up to 24 hours after observation are still accepted in some data-sparse areas such as the tropics). In addition to the standard VOS procedures improved documentation is required (section 5).

Details of the observational procedure are contained in Appendix 2, however, WHP ships which are to provide manual meteorological observations should become enroled through the Port Meteorological Officer (PMO) system as a VOS. Contact addresses for PMOs are provided in Appendix 3.

The standard instrumentation provided to a VOS depends on the recruiting agency; however, in almost all cases it would be possible to improve the instrumentation. This is particularly true on research ships where the choice of sensor sites and the ability to run cables is less inhibited than on merchant ships. However, use of non-standard instrumentation is likely to transfer the responsibility for maintenance from the meteorological agency to the science team. Where possible any changes should be negotiated with the responsible meteorological agency and clear provision made for servicing and calibration on a routine basis. Under those conditions, the use of instruments for wind velocity is highly desirable. Improvements for the measurement of air pressure, wet and dry bulb temperature and sea surface temperature should all be considered.

4. Additional Meteorological Observations

While the collection of data for the following variables is important for WOCE, the sampling opportunity provided by the WHP programme is either not essential or is not ideal. This data class includes some of the data required specifically for satellite verification or data required for regional flux studies. Although the collection of such data is not central to the WHP, efforts should be made to accommodate scientific groups wishing to obtain such data using WHP ships.

4.1 Wind Stress

Measurement of the wind stress using the dissipation technique is possible on a routine basis. Deployment of such systems is required for satellite verification, and would also be advantageous for model verification.

4.2 Sea Surface Temperature

Verification of satellite data requires the measurement of ocean skin temperature, that is the use of a downward-looking infrared radiometer.

4.3 Radiative Fluxes

Satellites measure the radiative fluxes at the top of the atmosphere, and algorithms have been developed to derive the ocean surface fluxes from these data. The observations for verification are very limited, particularly for longwave radiation. Additional radiation measurements should be encouraged.

4.4 Precipitation

The problems of precipitation measurement include difficult sensor siting and sampling errors due to the sporadic nature of tropic rainfall. However, some attempt should be made aimed at obtaining estimates to about 20% accuracy. For many ocean areas, even a crude estimate of precipitation period and intensity would represent an improvement on available observations.

5. Data Analysis and Archival

Manual observations obtained under the VOS scheme of WWW will have been transmitted to shore and entered into logbooks. In addition, improved documentation of the ships instrument fit defined for the VOS Special Observation Programme – North Atlantic (VSOP-NA) (WMO 1987) is required. These consist of improved documentation (detailed in Appendix 4), and should be submitted to the WHP Office in the form of a report for each ship operating within the WHP.

Automatic observations should be processed to apply calibrations and to remove bad data points. A report detailing the data available, including details of instruments and their calibration should be submitted to the WHP Office. The report should include contact addresses and details of availability of the data.

6. References

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Appendix 1 Automatic Shipboard Meteorological Systems

This appendix describes three types of automatic or semi-automatic systems suitable for use on WHP ships.

A1.1 The NOAA SEAS System

The SEAS system is aimed at the preparation and transmission of a coded meteorological observation report over the GTS. In the basic implementation, the ship's officer manually reads wet and dry bulb thermometers situated in a screen or hand held psychrometer, reads the relative wind from an anemometer dial, and then enters these and other observations into a computer as prompted by the SEAS software. The computer codes the message and transmits it *via* GOES satellite to the GTS.

A1.2 The IOSDL MultiMet System

Birch and Pascal (1987) have described the hardware and software developed by the U.K. Institute of Oceanographic Sciences Deacon Laboratory for use on research ships, ships of opportunity, and moored buoys. MultiMet is an RCA 1802 microprocessor based data logger able to accept various inputs, sampling rates, and averaging intervals for various channels. Typically, analog, digital or frequency data can be accepted at 1 Hz for 50 seconds on up to 48 channels; data is recorded once per minute. Wind velocities are not vector-averaged, but wind direction measurements are specially sampled. The time base is provided by a real-time clock. Data is recorded on an EPROM logger in engineering units (frequency counts, volts, *etc.*). MultiMet is used with commercially available meteorological sensors. To minimize interference, signal conditioning is done as close to the meteorological sensors as possible. Good sensor exposure is achieved by using multiple sensors. Data display on board the ship is provided by a software package, MetMan (METeorological MANagement), running on a BBC microcomputer system. Communication between MultiMet and the BBC micro is RS423 link. Communication of the raw data to shore can be achieved *via* an ARGOS link inserted in the MultiMet logger. The system has been used on several research ships, and since 1987, on a continuous trial on the Ocean Weather Ship Cumulus.

A1.3 The WHOI IMET System

The IMET (Improved Meteorological Measurements, (a WOCE long-lead time development underway at WHOI) ship data logger/controller is a NEC APC-IV personal computer with optical disks (WORM) for on-board storage of all data, an ARGOS PTT for automatic data reporting, and flexible sampling/logging software. The sensor set will provide measurement of wind velocity, air temperature, sea temperature, barometric pressure, relative humidity, incoming shortwave radiation, incoming longwave radiation, and precipitation. Each sensor will be mated to a microprocessor based module that will perform some sampling tasks, convert the raw sensor output to engineering units, and send the data digitally over RS-485 link to the APC-IV data logger/controller. Each module will have stored in EPROM the calibration of the sensor; sensors will remain with the same module for their entire life. Air-sea fluxes will be computed on board (using Large and Pond stability dependent algorithms for momentum, sensible, and latent heat and computing net shortwave using an albedo look-up table and net longwave by estimating outgoing longwave with an improved graybody algorithm being developed by Dickey at USC). Raw data and original sampling rate (as fast as every minute for one year) fluxes will be stored on the optical disk; several-hour averaged surface variables and fluxes will be telemetered *via* ARGOS. ARGOS data should be monitored (and quality checked so it will qualify for distribution *via* GTS) and archived at an accessible (dial-up and/or Ethernet) data base; such a land-based data acquisition and archiving system is in operation at WHOI.

Based on tests to data (1990), a basic IMET sensor set has been chosen:

Variable	Sensor
Shortwave radiation	Eppley PSP
Longwave radiation	Eppley PIR, with USC/Foot (1986) modifications to thermopile, amplifier as above, extra channels of A/D to record dome and other temperatures.
Wind	R. M. Young wind monitor with 9-bit direction encoder attached to shaft instead of potentiometer; 12-bit compass in module, which does vector-averaging.
Air temperature	Thermistor or platinum RTD in multiplate shield.
Sea temperature	Thermistor or platinum RTD trailed as buoyant line.
Relative humidity	Vaisala sensor in multiplate shield. Vaisala air temperature also logged.
Barometric pressure	Paroscientific Digiquartz sensor with Gill port.
Precipitation	R. M. Young self-siphoning gauge.

A1.4 Comparison of SEAS, MultiMet, and IMET

The SEAS system is aimed only at preparing GTS messages. The disadvantage of using manually read sensors is that they must be safely accessible by the ship's officer under all weather conditions. This may result in poor instrument exposure. For use on the WOCE ships, remotely read instruments with good exposure are desirable. These should include air temperature, humidity, sea temperature, and wind velocity averaged over a suitable interval (*e.g.* 10 minutes); air pressure also is required. Thus, the SEAS system would have to be incremented so that it would become similar to, but more limited in sensing capability than the small ship IMET system described below. The SEAS software should be run for message coding.

The IOSDL MultiMet and the WHOI IMET systems have many similarities. Both use multiple sensors to ensure good exposure, and a dual processor system to ensure that sampling and recording continues uninterrupted on one system while the servicing of requests to display and process data initiated by the scientific crew is performed by the other system. For this the IOSDL system uses the MultiMet logger and a BBC computer; the WHOI system uses two NEC microcomputers, thus allowing some redundancy should one machine fail.

Many of the differences between IMET and MultiMet are due to the earlier design of the latter system. A new MultiMet system, now under development, is based on IBM PC/AT type microcomputers and will be more similar to IMET. It is also likely that the sensor suites will converge on a small number of sensor choices. Eventually the systems will require intercalibration to ensure a single homogeneous data set is collected during and after WOCE.

One fundamental difference between MultiMet and IMET concerns the conversion to geophysical quantities. The IOSDL system includes minimal signal conditioning at the sensors, performs the averaging, *etc.*, in the MultiMet logger, and records the uncalibrated data. This has the advantage for research use that different types of sensors can easily be attached to the MultiMet logger. However, a disadvantage for the use envisaged on the WOCE ships is that calibration information is stored separately from the data, that is, within the MetMan display system. Experience has shown that maintenance of several systems on different ships has necessitated great care to ensure correct calibrations are used for each sensor. To this end it has been necessary to invest significant effort in a database of sensor histories and calibrations.

In contrast, the IMET system uses modules attached to each sensor to individually calibrate, partially process, and perform signal conditioning. This ensures the use of the correct calibration and also minimizes the risk of corruption due to radio interference in transmitting the data to the logger. It has some advantage for installation on the WOCE ships.

A1.5 Recommended Installations

Taking as an example the IMET system, the recommended installation on the large vessels would include three sensor installations (port, starboard and bow mast) and a sensor suite designed to provide the best possible measurements of the surface variables. Two NEC APC-IV's would be used to provide redundancy and real-time access for the science party to the meteorological data. One APC-IV would carry on ARGOS telemetry and data logging at the standard rate and in the format to be provided by the other ships and buoys; the second APC-IV would be menu-driven and available to the science party and/or resident technician. The optical disks would be returned after one or more legs to be quality-checked and read into the data base. Also available for use on these ships would be a sensor suite designed for the best possible estimates of the air-sea fluxes (including towed SST sensor, infrared hygrometer and other relative humidity sensors, optical rain gauge, sonic anemometer). This additional sensor suite would be mounted for specific cruises where air-sea flux data would be of particular value, where intercomparisons would be run with the other sensors on board or where sensor development was being carried out.

Medium ships would carry two sensor sets (port and starboard), though on some ships good exposure might only be ensured through adding a third sensor set on a bow mast. One APC-IV, providing real time displays, data logging, and data telemetry *via* ARGOS would be used. The second APC-IV for redundancy and use by the science party would not be standard equipment; the Medium ships would typically be closer to home port than the Large ships, permitting easier replacement of failed equipment and making it easier for the science party to board their own APC-IV for their own data display purposes.

Small ships would have reduced sensor sets (two wind, humidity, and air temperature sensors as those are most sensitive to flow disturbance and heat contamination, but one of the other sensors) and one APC-IV for real time display, data logging, and data telemetry *via* ARGOS. Their areas of operation would presumably not be characterized by being data sparse.

Appendix 2 The WMO Voluntary Observing Ships' Scheme[1]

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1.1 Introduction

The international scheme by which ships plying the various oceans and seas of the world are recruited for taking and transmitting meteorological observations is called the "WMO Voluntary Observing Ships' Scheme". The forerunner of the scheme dates back as far as 1853, the year in which delegates of 10 maritime countries came together at a conference in Brussels, on the initiative of Matthew F. Maury, then director of the U.S. Navy Hydrographic Office, to discuss the establishment of a uniform system for the collection of meteorological and oceanographic data from the oceans and the use of these data for the benefit of shipping in return. In the present century, the system was recognized in the International Convention for the Safety of Life at Sea, which specified in Regulation 4 of Chapter V – Safety of navigation – that "The Contracting Governments undertake to encourage the collection of meteorological data by shops at sea and to arrange for their examination, dissemination and exchange in the manner most suitable for the purpose of aiding navigation."

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Note: The WMO Voluntary Observing Ships' Scheme is part of the Global Observing System of the World Weather Watch. Relevant standard and recommended practices and procedures are contained in Part III of the Manual on the Global Observing System (WMO-No. 544).

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1.2.2 Selected Ships

By definition, a selected ship station is a mobile ship station which is equipped with sufficient certified meteorological instruments for making observations and which transmits weather reports in the full SHIP code form. In addition, the observations are entered in meteorological logbooks. With respect to instrumentation, a selected ship should have at least a barometer (mercury or aneroid), a thermometer to measure sea-surface temperature (either by the bucket method or by other means), a psychrometer (for air temperature and humidity), a barograph and possibly an anemometer.

[1]Extracts from WMO, 1983, Guide to Meteorological Instruments and Methods of Observation. WMO 8, WMO Geneva. Part II, Chapter 1, The WMO Voluntary Observing Ships Scheme.

Selected ships constitute the large majority of voluntary observing ships. Table 1 shows the number of selected, supplementary and auxiliary ships during the years 1960-1979. Corresponding numbers for subsequent years are available in status reports, published by WMO, and in the International List of Selected Supplementary and Auxiliary Ships (WMO-No. 47).

Table 1.1

Number of Ships Belonging to the Voluntary Observing Ships' Scheme

Year	Selected	Supplementary	Auxiliary	Total
1960	2.513	1.025		3.538
1961	2.802	952	14	3.768
1962	2.891	958	17	3.866
1963	3.205	1.017	18	4.240
1964	3.355	1.063	15	4.433
1966	3.494	1.085	122	4.701
1969	3.942	1.068	863	5.873
1970	4.102	1.234	996	6.362
1971	4.388	1.720	530	6.697
1972	4.485	1.802	571	6.858
1973	4.440	1.888	600	6.928
1974	4.481	1.951	620	7.052
1975	4.452	2.040	690	7.272
1976	4.442	2.095	719	7.256
1977	4.574	2.071	725	7.370
1978	4.589	1.742	704	7.035
1979	4.628	1.497	777	6.902
1980	4.775	1.643	902	7.320
1981	4.827	1.637	1034	7.498

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1.2.5 International List of Selected, Supplementary and Auxiliary Ships

Selected, supplementary and auxiliary ships constitute an important source of marine data which are used for various purposes all over the world. In analysing these data, Meteorological Services should be aware of the type of instrumentation on board a given ship, or the particular method of observation when several methods are generally in use. For this purpose, WMO has compiled an International List of Selected, Supplementary and Auxiliary Ships which is kept up to date through information supplied by Members and, for each ship, contains particulars such as:

- Name of ship;

- Call sign;
- Area or routes over which the ship normally plies;
- Type of barometer;
- Type of thermometer;
- Exposure of thermometer;
- Type of hygrometer or psychrometer;
- Exposure of hygrometer or psychrometer;
- Method of obtaining sea-surface temperature;
- Type of barograph;
- Various other meteorological instruments used aboard the ship;
- Types of radio equipment;
- Number of radio operators;
- Height, in metres, of the observing platform, measured from the mean water-line;
- Height, in metres, of the anemometer.

Regular updating of the International List of Selected, Supplementary and Auxiliary Ships is needed because of the frequent changes in the international merchant shipping fleet and also the changes in the recruitment of auxiliary ships in particular. As a rule, Members are required to provide to the WMO Secretariat before 1 March each year a complete list of their selected, supplementary and auxiliary ships which were in operation at the beginning of that year. This information could also be given in the form of amendments to the list valid for the preceding year.

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1.4 Meteorological Observations from Ships

1.4.1 Danger Messages

The *International Convention for the Safety of Life at Sea*, 1974, in its Regulation 2, Chapter V, concerning safety of navigation, specified that the master of every ship is bound to issue a danger message when a ship meets with objects or conditions which are of direct danger to navigation. As far as meteorological phenomena are concerned, danger messages should contain information on:

- Tropical cyclones (tropical storms) and their development;

- Winds of Force 10 or above on the Beaufort scale for which no storm warning has been received;
- Sub-freezing air temperatures associated with gale force winds causing severe ice accretion on super-structures;
- Sea ice or ice of land origin (*e.g.,* icebergs).

Details concerning the contents of danger messages and their transmission are described in Chapter V of the *International Convention for the Safety of Life at Sea.* The information given in these messages directly serves the safety of navigation. Those containing meteorological information are of vital importance to Meteorological Services for the preparation of weather and sea bulletins. For this purpose, ships should continue to supply this information and changes in weather conditions and repeat it in their regular observations.

1.4.2 Surface Observations

The observational requirements placed upon ship stations vary according to the category of vessel under the WMO Voluntary Observing Ships' Scheme. It is necessary to recognize these differing requirements.

1.4.2.1 Content of surface observations from ships

Observations taken on board a selected ship should consist of the following elements:

- Wind, direction and speed;
- Atmospheric pressure, tendency and characteristic;
- Air temperature;
- Humidity (dew point);
- Sea-surface temperature;
- Waves (direction, height, period);
- Visibility;
- Present and past weather;
- Clouds (amount, type and height of base);
- Ship's course and speed;
- Sea ice and/or ice accretion on board ship, when appropriate.

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1.4.2.2 Programme for surface observations on board ships

The basic programmes for making surface observations on board ships consists of the following procedures:

(a) Synoptic observations should be made at main standard times: 0000, 0600, 1200 and 1800 GMT. When additional observations are required they should be made at one or more of the intermediate standard times: 0300, 0900, 1500, and 2100 GMT;

(b) While taking observations, atmospheric pressure should be read at the exact standard time, the observation of other elements being made within the ten minutes preceding the standard time;

(c) When operational difficulties on board ship make it impracticable to make the synoptic observation at a main standard time, the actual time of observation should be as near as possible to the main standard times. In special cases, the observations may even be taken one full hour earlier than the main standard time, *i.e.,* at 2300, 0500, 1100 and 1700 GMT. This may arise, for example, when it is necessary to ensure transmission of a message to a coastal radio station before the radio officer goes off duty. In these cases, the actual time of observation should be indicated. It is, however, emphasized that these departures should be regarded only as exceptions;

(d) Observations should be made more frequently than at the main standard times, whenever storm conditions threaten or prevail;

(e) When sudden and dangerous weather developments are encountered, observations should be made for immediate transmission without regard to the standard times of observation;

(f) Special observations are made and transmitted if specifically requested for storm warnings, search and rescue or for other safety reasons;

(g) Supplementary observations when required for scientific studies should be made at intermediate standards times, subject to non-interference with navigation duties;

(h) When an observation is made at 0300, 0900, 1500 or 2100 GMT, in order to ensure its transmission to a coastal station, it is desirable that the observation at the next main standard time, *i.e.*, 0600, 1200, 1800 or 0000 GMT should be made for climatological purposes and if possible transmitted in accordance with normal procedures;

(i) Ships' officers should be encouraged to continue taking and reporting observations while the ships are in coastal waters, provided it does not interfere with their duties for the safety of navigation.

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1.4.6 Coding of Observations

Ships' observations are coded in the international meteorological codes published in the *Manual on Codes*, Volume I (WMO Publication No. 306). The various code forms are given code names which are sometimes included in the heading of the ship's report. In all cases, however, a 4-letter identification group in the form $M_iM_iM_jM_j$ is used (see code 2582, *Manual on Codes*, WMO No. 306). The identification groups are shown in Table 1.2.

Table 1. 2

Code name	Identification group(s)	Content of the code
SHIP	BBXX	Surface report from a sea station

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1.5 Meteorological Instrumentation On Board Ships

1.5.1 General

Full guidance upon the basic meteorological instruments suitable for use on board ships making observations under the Voluntary Observing Ships' Scheme, together with advice upon methods of observation, is provided in the *Guide to Meteorological Instrument and Observing Practices* (WMO-No. 8) Chapter 17, Marine observations.

Experience over several years has indicated that certain features of the present instrumentation fitted to ships require constant attention. The following comments emphasize those aspects to which special care should be given and are fully complementary to the general guidance in the above-mentioned Guide.

1.5.2 Instruments Measuring Atmospheric Pressure

In practice the proper installation and operation of mercury barometers at sea has proved very difficult, and mercury barometers are now rarely installed on board ships. The use of precision aneroid barometers on the other hand does not give rise to similar problems. However, because of the zero drift to which these instruments are liable, frequent checking against standard barometers is necessary in order to ensure proper continuous operation. The zero drift of aneroids currently in use is seldom continuous, the instrument correction remaining stable for a rather long period of time, then suddenly dropping to another level. Checking procedures should therefore continue routinely even if the correction has remained stable for some time. This checking should be carried out by a PMO whenever possible, preferably at intervals not exceeding six months. To obtain accurate pressure readings, a static pressure head should be fitted to ensure proper ventilation.

On board small vessels the reduction of the pressure reading to MSL [Marine Surface Layer] may be carried out by the addition of a given reduction constant, or simply by correcting the reading of the scale to give pressure at MSL directly. When the elevation of the barometer varies significantly with the loading of the ship, the use of different reduction constant has to be considered. If the barometer elevation is great, air temperature may also have to be taken into consideration when preparing reduction tables. At all times the limit of accuracy of the applied reduction should be kept within 0.2 hPa.

Barographs used on board ships should be supplied with an efficient built-in damping device and the instrument should be mounted on shock-absorbing material (to minimize the risk of the pen arm swinging off the chart) in an athwart-ship position where it is least likely to be affected by concussion, vibration or movement of the ship. The best results are generally obtained from a position as close as possible to the centre of flotation.

1.5.3 Instruments Measuring Wind Speed and Direction

In order that wind reports from ships equipped with instruments could be comparable with estimated winds and wind reports from land stations, anemometer readings have to be averaged over 10 minutes. It is difficult to estimate 10-minute means by watching the dial of an anemometer. An overestimation of more than 10% is not uncommon. It is, therefore, preferable that the instrument readout used for reporting wind velocities in WMO codes be automatically averaged over 10 minutes. If such readouts are not available, careful instructions should be given in order to avoid overestimation.

Due to the flow distortion caused by superstructure, masts and spars, the site of the anemometer sensor has to be carefully selected. Studies are in progress to establish an international standard procedure for the reduction of readings to the meteorological standard of 10 m.

Any anemometer mounted on a ship measures the movement of air relative to the ship. Considering that an observer on board a modern merchant vessel in calm conditions, may read a "wind speed" equivalent to Beaufort 5 at the anemometer, the importance of a correct calculation of the true wind must never be neglected. For computing true wind from relative wind and ship's speed and course it is advisable to draw a simple vector diagram or to use tables. Special sliderules and hand computers are also available.

1.5.4 Instruments Measuring Temperature and Humidity

Measurement of temperature and humidity in a single fixed screen has been regarded generally as unsatisfactory on board ships, largely due to the influence of the many and varied artificial sources of heat. The use of sling or aspirated psychrometers exposed in the fresh airstream at the windward side of the bridge has normally been recommended.

Automated observing stations or distant-reading thermometers and hygrometers, which may be employed, require a fixed exposure. Such equipment should be sited in a well-ventilated screen with good radiation protection and placed as far away from any artificial source of heat as practicable. It is advisable to compare the readings with standard psychrometer observations at the windward side of the bridge at regular intervals, particularly when new types of equipment are introduced.

1.5.5 Instruments Measuring Sea Temperature

It is important that the temperature of the uppermost thin film of water (measured by infra-red radiometers) should be distinguished from the temperature of the underlying mixed layer. It is the representative temperature of the mixed layer which should be reported by voluntary observing ships.

The "bucket" instrument method is the simplest and probably the most effective method of sampling this mixed layer, but unfortunately the method can only be used on board small vessels moving slowly. A number of methods an instruments are described in Chapter 17 of the WMO *Guide to Meteorological Instrument and Observing Practices* (WMO-No. 8). Recently, proposals for the reference or calibration of instruments and for a standard depth of measurement have become available. These suggest that in general the sensor should be placed as far forward as practicable, and if possible, forward of any outlets. A depth of 2 metres below the water line for sensors of the "limpet" type has been proposed.

1.6 Clearance of Meteorological Reports from Ships

1.6.1 General

As a rule, observations from meteorological stations, whether from land or sea stations, are collected as quickly as possible to permit their immediate use at national meteorological centres. When international exchange is involved, meteorological observations from ships should be collected and disseminated over the Global Telecommunication System (GTS) channels as expeditiously as possible so that they can be received at other centres, as a reasonable objective, within two hours after the time of observation. Three main operations have to be carried out in succession within this time interval, namely:

(a) Transmission of the report from ship to shore;

(b) Transmission from the coastal radio station to the national meteorological center;

(c) Dissemination over the GTS.

The first operation in (a) implies that contact is established between the ship's radio station and a particular coastal radio station. The choice of the coastal radio station must be such that the ship report reaches the meteorological centres directly concerned within the required time interval. A world-wide scheme has been developed to meet this objective.

Courses of action to be taken on board ship in order to send a meteorological report to what is called the "nearest convenient coastal radio station" are described in the following paragraphs.; What happens to the meteorological report after it has been received at a coastal radio station is the subject of operations (b) and (c) above.

1.6.2 Transmission of the Report from Ship to Shore

Weather reports from mobile ship stations should be transmitted to a coastal radio station as soon as possible after the time of observation; hence the meteorological report, as soon as it is made on board ship, should be handed to the ship's radio officer without delay so that it can be cleared to shore as rapidly as possible. Procedures for the transmission of weather reports form mobile ship stations to designated coastal radio stations are given in the WMO —em Manual on the Global Telecommunication System, (WMO-No. 386) Volume I, Part I.

For ready reference, the relevant procedures are reproduced below.

"Weather reports from mobile ship stations should (without special request) be transmitted from the ship to the nearest coastal radio station situated in the zone in which the ship is navigating.

If it is difficult, due to radio propagation conditions or other circumstances, to contact promptly the nearest radio station in the zone in which the ship is navigating, the weather messages should be cleared by applying the following procedures in the order given below:

(a) Transmission to any other coastal radio station in the zone in which the ship is navigating;

(b) Transmission to any coastal radio station in an adjacent zone within the same region;

(c) Transmission to any coastal radio station in any other zone within the same region;

(d) Transmission to a coastal radio station in an adjacent zone in a neighboring region, or, failing that, to any other station in a neighboring region;

(e) Transmission to another ship or an ocean weather station with the function or willing to act as a relay station.

...]

1.6.5 Procedures for Addressing Ships' Weather Reports

The meteorological report which is transmitted to the coastal radio station contacted by the ship's radio officer must carry the address of the corresponding National Meteorological Centre. Addresses which should be used are given, together with the names of the corresponding coastal radio station, in WMO Publication No. 9, Volume D, Part B. According to WMO recommendations, the address should include as the first word the five-letter abbreviation "METEO".

According to ITU regulations, meteorological radiotelegrams from ships are entitled to a transmission priority and a special reduced rate of charge. The abbreviation "OBS" shall be included as a service paid indicator before the address in ships' weather messages to secure appropriate handling of messages at the coastal stations. In addition, according to WMO regulations, the abbreviation "OBS" is also used in the original call from the ships to the coastal stations in order to secure the appropriate priority of answer from the coastal station.

Ships should not be asked to send the same meteorological report to more than one address. However, in ocean regions where shipping is less dense and where weather and sea bulletins for shipping are not regularly broadcast, ships are requested to interchange their meteorological reports by radio. In these regions, when radio contact with shore stations is difficult ships could ask other ships to relay their meteorological reports.

Members must provide their mobile sea stations with details of procedures for addressing and routing reports in the different sea areas.

1.6.6 Transmission of Delayed Reports

Observations made at any of the standard time – 0000, 0600, 1200 and 1800 GMT – should be transmitted even after a period of delay after the time of observations and:

(a) In most parts of the world they should be transmitted up to 12 hours after the time of observation if it is not possible to do so earlier;

(b) In the southern hemisphere and other areas where few ships' weather reports are available they should be transmitted up to 24 hours after the time of observation.

It is important that this procedures be followed even if an observation for a more recent time is also being transmitted. In bringing this procedure to the attention of ships' personnel, Members should explain the value of late reports for Meteorological Services and the consequent feed-back for improved forecasts and warnings for shipping.

...]

[...

1.8 Meteorological Logbooks for Ships

1.8.1 Layout

The recording of observations in a meteorological logbook is obligatory for selected and supplementary ships and is recommended for auxiliary ships. They layout of logbooks is a national responsibility. Generally, the order of parameters recorded in the logbook follows the order of elements in the SHIP code form. Thus, the logbook can be used both for recording the synoptic weather report which is to be transmitted and to include in the same format additional information required for climatological purposes. For the latter use, the entries are subsequently transferred on to standardized 80-column punch-card or magnetic tape.

Logbooks should contain clear instructions for entering observations. Code books should also be provided, along with logbooks, for ready reference and to correct wrong entries as necessary. It is useful to mark in the logbook those columns which are earmarked for entries to be transmitted as part of the weather report. In some national logbooks, these columns are lightly shaded or colored and in others they are inserted in a special frame. Also, space is often provided in logbooks to enter the various readings used to compute a meteorological element such as air pressure reduced to sea-level, or actual wind derived from a measured apparent wind and the ship's movement. This will enable a check of the computations carried out on board ship for subsequent quality control of the data during processing for climatological purposes.

The size of a meteorological logbook is usually such as to permit the entries for four days on one sheet, that is, 16 observations made at the four main standard times. Ships should be requested to return the completed logsheets soon after completion of the ocean voyage to the Meteorological Service (or PMO) which has recruited the ship. Shipments of completed logsheets should cover periods generally not extending over more than three months. Sheets thus returned should contain information regarding the ship, the instruments used and other details of a general nature. Appropriate space should be provided on the sheet for these entries. If an incentive programme exists in the country where the ship has been recruited, the general information should include the name of the master, the observers and the radio officer.

1.8.2 Supply and Return

To facilitate the supply of meteorological logbooks to ships which do not regularly visit their home ports, port meteorological officers in various ports keep a stock of logbooks fo different National Services. In addition, port meteorological officers may also keep stocks of observing and coding instructions in languages of other countries for supply to ships which may require them.

Completed logsheets are generally considered the property of the national Meteorological Service which has recruited the ship for the purpose of meteorological observing.

As they contain the results of work done on a voluntary basis, they should be kept for a sufficient number of years to permit examination of the original entries.

Ships' officers often include questions on coding matters or on any special phenomena observed by them in the "remarks" column of the logbook. Response to these questions is important, as this falls within the same spirit of maintaining interest in meteorological work. Some countries have instituted special periodicals for meteorological observers on board their ships in which these questions are discussed and explained.

1.9 Port Meteorological Officers

In recruiting voluntary observing ships and assisting them in their meteorological work, direct contact with ships' officers is often needed to provide them with instructive material and other documents, to inspect meteorological instruments on board ships, to collect back the logbooks of observations and, on an initial check, take such corrective action as is possible by personal contact. For this purpose, port meteorological officers having maritime experience should be appointed at main ports (recommended procedure in WMO Technical Regulations).

Port meteorological officers are representatives of the Meteorological Service of the country as far as the local contact with maritime authorities is concerned. The role of the voluntary system of ships' observations often depends on the initiative displayed by these officers. They are in a good position to discuss with ships' officers any problems they have encountered and offer suggestions, bring to their attention any changes in procedures that may have taken place and give them the latest information which they may desire. Opportunity should also be taken to explain various meteorological and/or oceanographic programmes whenever observations are specially needed from ships.

...]

[...

1.10 Incentive Programme for Voluntary Observing Ships

In recognition of the valuable work done by ships' officers in taking and transmitting meteorological observations and as an incentive to maintain the high standard of the observations, many maritime countries have established a national award or certificate system. These systems vary greatly from country to country; in some countries the ships receive the awards, while in other countries awards are made to the masters or navigation and radio officers individually. Sometimes recognition for the meteorological work done on board ships is given in the form of books, charts and other documents presented to the ship.

Members are encouraged to continue the practice of issuing national awards or certificates to selected, supplementary and auxiliary ships recruited by them or to the ships' personnel, as a sign of their participation in the WMO Voluntary Observing Ships' Scheme.

Appendix 3 Contact Addresses for the Voluntary Observing Ship System of the World Weather Watch

The following contacts would be able to give details of recruitment to the VOS system.

Country	Contact
Canada	Chief, Data Acquisition (Atlantic Region) Atmospheric Environment Service 1496 Bedford Highway Bedford, Nova Scotia B4A 1E5 **Canada**
France	Chef de la Subdivision Prévision Marine Service Central D'Exploitation de la Meteorologie 2 Avenue Rapp 75340 Paris Cedex 07 **France**
Germany	Deutscher Wetterdienst Seewetteramt Bernhard-Nocht Strasse 76 D-2000 Hamburg 4 **Germany**
Japan	Marine Meteorological Division Japan Meteorological Agency 1-3-4, Otemachi, Chiyoda-ku Tokyo 100 **Japan**
Netherlands	Royal Netherlands Meteorological Institute Postbus 201 3730 AE De Bilt **Netherlands**
U.K.	Meteorological Office Meto 1 a(1) Eastern Road Annexe Bracknell Berkshire RG1 2UR **UK**
U.S.A.	Marine Observations Programme Leader National Oceanic and Atmospheric Administration National Weather Service 8060 13th Street, Room 721 Silver Spring, Maryland 20901 USA
Other Countries - Contact the National Meteorological Agency or...	Chief Ocean Affairs Division World Weather Watch Department WMO, Case postale No. 5 CH-1211 Geneva 20 **Switzerland**

Appendix 4 Information Required on First Reconnaissance[2]

This information will be obtained by PMOs and, for those ships selected, be forwarded to the archival centre for re-distribution in summary form to all participating services.

Air Temperature

a. Type of screen or housing;

b. Type of thermometer and make;

c. Method of estimating humidity, giving type and make of instrument used (could include sling psychrometer);

d. Measurement location of thermometers on board ship.

Sea-surface Temperature

a. Method of measurement, *e.g.,* bucket, engine room intake, hull sensor, trailing thermistor or any other;

b. Type of thermometer used;

c. For non-bucket, location of instrument, *e.g.* distance inboard or depth below reference level;

d. If a bucket is used, details of type and insulation;

e. For bucket, agreed location of measurement. Also need location of nearby engine room and other discharges.

Wind

a. Type of anemometer used, including whether fixed or portable;

b. Location of anemometer and height above reference level;

c. Averaging time used for windspeed;

d. Units used in measuring windspeed;

e. Is a correction applied for ship's speed and direction; if yes, give details of method;

f. How is the ship's instantaneous speed measured.

[2]WMO, 1987. Implementation Co-Ordination Meeting for the Ocean Observing System Development Programme Pilot Study on a High Quality Voluntary Observing Ships' Subset. De Bilt Netherlands, 21-23 Sept 1987 (available from WWW Marine Branch, Geneva)

Pressure

a. Type of barometer/barograph;

b. Location and height above reference level;

c. Height of pressure head above reference level (if P.H. fitted).

NOTES:

1. Ideally, the location of instruments should be marked on ship's drawings, in addition to detailed written descriptions of such locations by the PMOs. The descriptions should also give details of any permanent structural features which will affect the observation, *e.g.* water outfalls, airflow obstructions, air conditioning vents, *etc.*

2. The reference level must be clearly specified. Particular reference level used may be a matter of national practice. The reference level must be a fixed point on the ship, *e.g.* main deck, loading line marked on ship's hull, *etc.*