



ASIMET: Air Sea Interaction - METeorology

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IMET - Improved METeorology

Instrumentation

The ocean is critical to inter-decadal climate variability because of its ability to store and transport heat and fresh water and release them to the atmosphere through sensible and latent heat fluxes. Knowledge of various properties at the sea surface is essential to monitoring, understanding, and developing the ability to predict climate change. Vertical exchange across the air-sea interface of horizontal momentum and of buoyancy couples the ocean and atmosphere. The sea surface is the interface through which heat, fresh water, momentum, gases, and other quantities are exchanged. It is the bottom boundary of the atmosphere over approximately 70% of the earth's surface and the top surface of the very large oceanic reservoirs of heat and other properties. Observing this coupling is a fundamental need if we are to both understand ocean variability and its interrelation to climate. This requires the observation of surface wind velocity, humidity, air temperature, sea temperature, barometric pressure, incoming shortwave radiation, incoming longwave radiation and precipitation.

In planning for WOCE (World Ocean Circulation Experiment) it was recognized that moored buoys and ships would provide especially attractive platforms from which to make

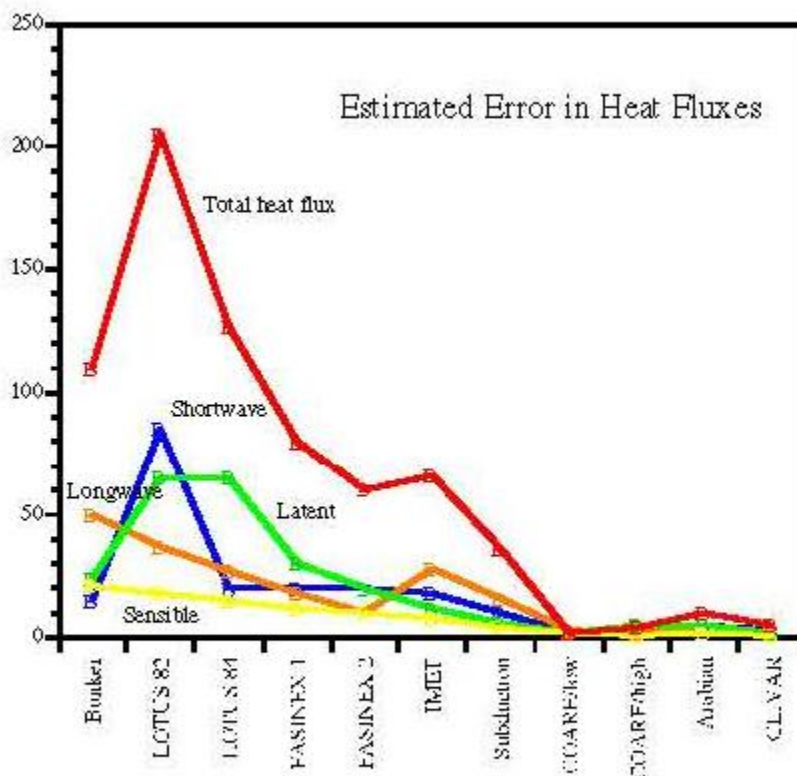
accurate in-situ measurements of the basic surface meteorological observable parameters required to investigate the air-sea fluxes of momentum, heat, and mass. Accuracy's of 10 Watts per meter squared were sought in estimates of the mean values (averaged over monthly and longer time scales) of each of the four components of the total heat flux (sensible, latent, shortwave, and longwave). Accuracy's of approximately 1 mm per day were sought in evaporation and precipitation.

WHOI (Woods Hole Oceanographic Institution) was funded to evaluate and choose sensors capable of meeting the WOCE goals and to develop the IMET system as a flexible data collection system. Each sensor was incorporated into a module with built-in intelligence that responds to polled commands from the central computer and data recording unit. Each module interfaces to an ADDB (addressable digital data bus) consisting of +12vdc power and RS485 serial ports. A key component of IMET accuracy is that the calibration constants are stored in the module so that the serial digital output is in calibrated units. The calibration constants from each unit are polled and stored on the data file with the data from a specific time period. Modules having non-linear algorithms will output both calibrated and raw data to permit later corrections.

IMET systems are now in use on eight UNOLS ships, six WHOI buoys, one USF (University of Southern Florida) buoy, one NOAA ship and the Rutgers University Field Station. These systems have proven themselves over the last eight years and now provide the baseline for climate quality data.

Data Accuracy

Traditionally, the bulk of surface marine observations have come from merchant ships. There have been numerous attempts to make use of these observations to map the air-sea fluxes and understand the ocean's role in climate. However, these shipboard observations have significant errors associated with the sensors, sensor placement, and flow disturbance. Furthermore, few ships are equipped to measure the shortwave and longwave radiative fluxes. Bunker, in his atlas of surface observations for the Atlantic, concluded that the error in the net heat flux developed using bulk formulae and merchant ship observations was in excess of 100 W m^{-2} (Figure 1).

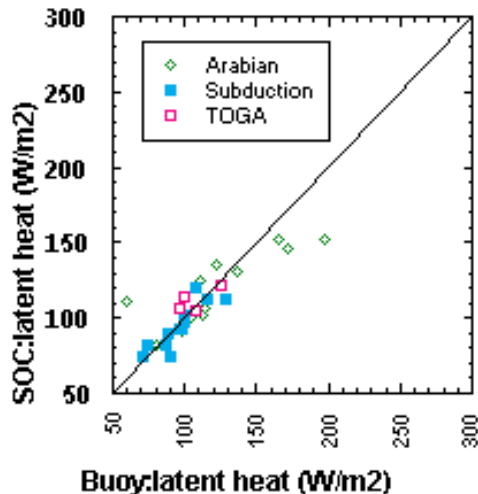


National agencies and researchers have turned to surface moorings in order to obtain time series of surface meteorology at fixed locations and to work toward observations that were both more complete and more accurate than those obtained on merchant ships. In the late 1970's and early 1980's, research oceanographers in the United States began to deploy surface buoys to investigate air-sea interaction. Error analysis of the sensor performance in the Long Term Upper Ocean Study (LOTUS)(Figure 1), which was conducted at 34 deg N, 70 deg W, was discouraging, as the measurement error in the net heat flux was found to be larger than the uncertainty Bunker assigned to his atlas data.

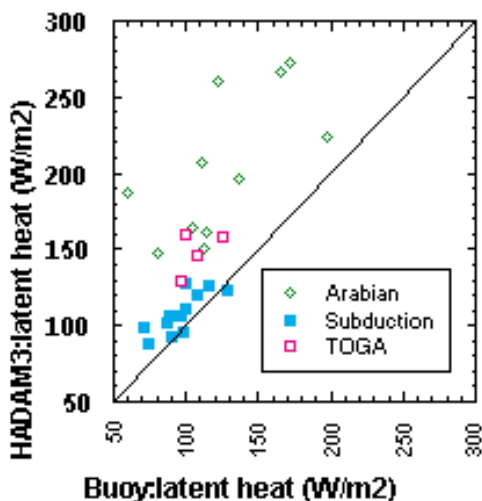
Work to improve buoy measurements continued in association with the ONR-supported Frontal Air-Sea Interaction Experiment (FASINEX), and significant, focussed support by the NSF as part of the World Ocean Circulation Experiment (WOCE) led to extensive sensor testing and development and to the design of the Improved Meteorological system (IMET). This work brought continued improvement. During the ONR-funded Subduction experiment, error in net heat flux was reduced to approximately 40 W m⁻² in monthly means. A major, international collaboration on flux sensors and algorithms and a specific focus on in-situ intercomparisons of methods and sensors during the TOGA Coupled Ocean-Atmosphere Response Experiment (COARE) led to another significant increase in accuracy. In part, the accuracy shown in Figure 1 for COARE results from the benefit of these dedicated in-situ intercomparisons. Further work continued in support of the ONR Arabian Sea experiment, and gains were made in reducing error due to radiative heating of sensors. Work on aspiration, on humidity sensors, on anemometer performance, and on radiation sensors continues; and these gains help make possible an accuracy approaching

that achieved in COARE even though in-situ intercomparisons are not being conducted.

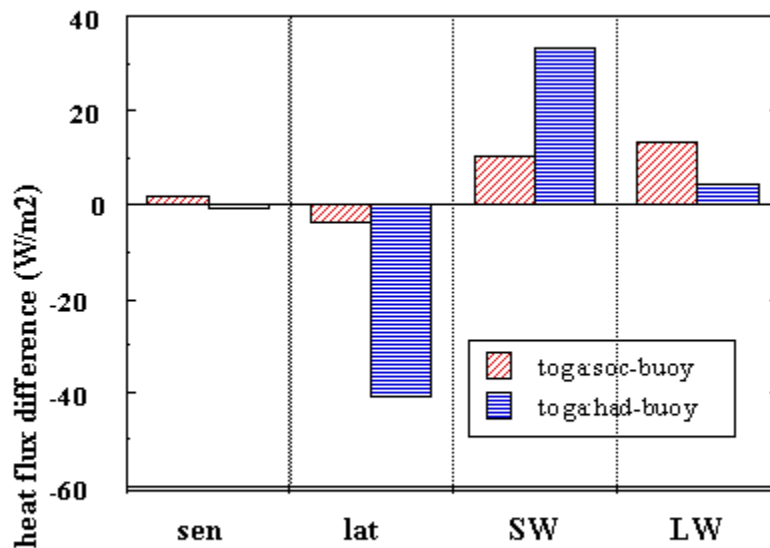
The time series of accurate surface meteorology and air-sea fluxes acquired by the buoys deployed in these experiments is now providing the means to examine the performance of atmospheric models, the accuracy of climatological data sets, the calibrations and performance of satellite sensors, and methods used to improve the data on Volunteer Observing Ships (VOS). For example, Taylor and Josey at the Southampton Oceanography Centre in the UK has worked to correct biases and errors in the data from the VOS; and comparisons between the buoy data and the SOC climatology verify that they have made significant improvement (Fig 2a).



In contrast, comparisons between the buoy data and numerical weather prediction models reveals problems with the surface meteorology and fluxes from the models (Figure 2b).



These problems may not be apparent in the net heat flux, as the heat flux components from the models can have biases that cancel. [Figure 3](#) shows that the latent and shortwave fluxes from the Hadley Centre model have biases of opposite sign.



High quality in-situ data is essential to validating models, remote sensing, and climatologies. Figure 4 uses one year of buoy data from the Arabian Sea to show how far off the net heat fluxes from the ECMWF, NCEP, and Hadley Centre models were. The model error approaches 100 W m^{-2} ; during the Southwest Monsoon the NCEP model had the wrong sign of the net heat flux.

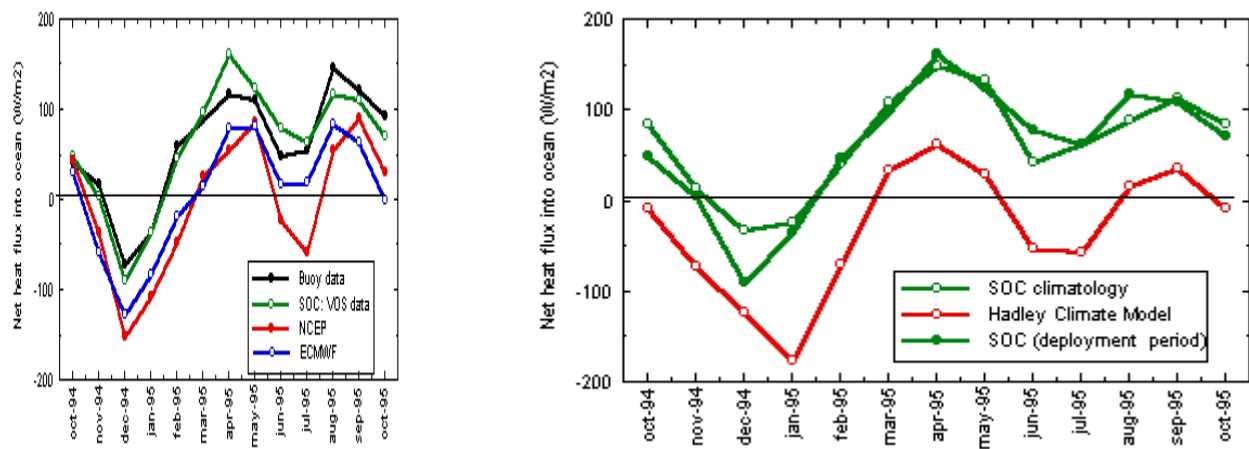


Figure 4, however, also presents a very encouraging result. The SOC developed VOS-based flux data at the buoy site and for the same time period agrees very well with the buoy data. Further such SOC and buoy comparisons indicate the need to make regional choices of the parameterizations used in the bulk formulae. There is both temporal and spatial variability in the fluxes due to things such as atmospheric aerosols that make high quality in-situ observations essential. Taylor's earlier work documented the benefits of a modest investment in understanding and improving the sensors in VOS. Thus, a strategy for moving toward greatly improved global surface meteorology and air-sea fluxes is to deploy surface moorings as flux reference sites and to field improved VOS systems to fill in the regions

around the reference sites. The flux reference sites provide the regional tie points, and the VOS calibrated by these sites provide the mapping capability.

VOS Climate Data Acquisition

Recently, the IMET technology has evolved into new modules designed for use on Volunteer Observing (VOS) ships. These new VOS-IMET are self-powered, self recording, stand alone units that also are able to communicate on the IMET Addressable-Digital-Data-Bus (ADDB). These units are being tested on VOS in cooperation with the SIO-VOS Group as part of a NOAA - OGP program. Currently installed sensor modules include the full flux suite including: Wind Speed and Direction, Relative Humidity and Air Temperature, Barometric Pressure, Precipitation, Shortwave Radiation, Longwave Radiation, and Sea Surface Temperature. These modules are housed in Grade 2 titanium, which provides economical, corrosion-free, rugged units. Mounting is accomplished by fiberglass channel and stainless steel latches that provides easy installation in a wide variety of ship configurations. The following figures shows the target platform for these systems - large commercial ships that make voluntary observations.

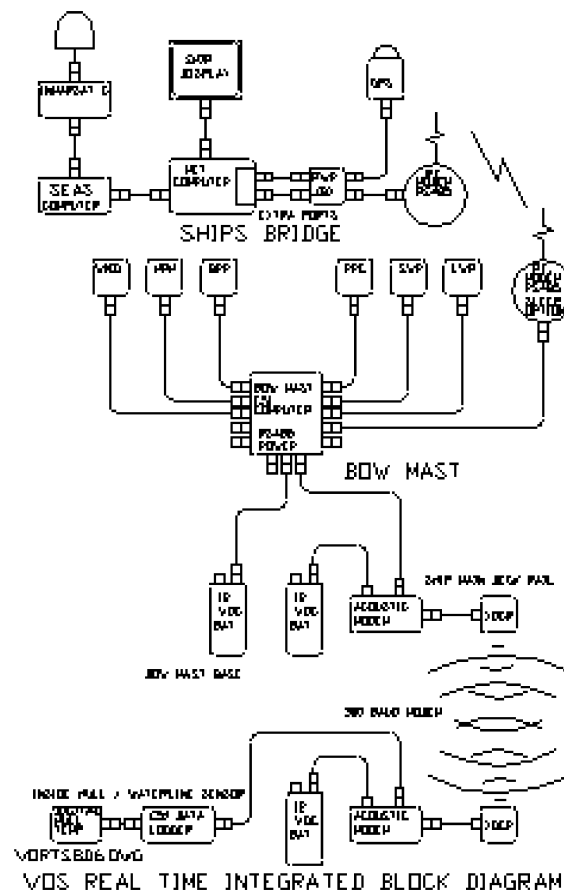


SeaLand ENTERPRISE and Bow Mast with IMET Modules at top.

One feature of the US VOS is that they are sold and change routes on a very regular basis. This has severe implications in that it is not feasible to run cables for system installations and it is normally not possible to obtain useable electrical power close to sensor mounting locations. One special problem is getting sea-surface temperature data from inside the hull of the ship at the waterline up to the rest of the modules. An acoustic modem has just been developed that uses the ships steel hull at the acoustic path for 20-baud data. The measurement system for a VOS therefore must be self-powered, self-recording and able to

communicate data to the bridge area for both ship use and satellite transmission. This means that the VOS climate observing system uses nearly the same components as a buoy climate observing system.

It is expected that the prototype climate observing system currently being tested on VOS will be available from commercial sources as an operational system. This new commercial system will provide the same data quality and data time resolution as modules used previously to establish better understanding of climate processes. This system or components from this system can provide the same performance from buoys and smaller ships. The following figure shows a block diagram of an IMET system for VOS real time use. On research ships with installed cables, the wireless devices (r.f. modem and acoustic modem) and battery packs may not be needed.



ASIMET Module Operations

The ASIMET main processor board (C51) operates in either RS232 or RS485 upon power up, depending on where power/comms is connected and the position of a jumper.

Getting Started

The following equipment should be available:

- Terminal (computer) with RS232 output set for 9600, N, 8, 1, running the terminal program (ProComm Plus), run with cap-locks on.

- Power supply with output of 12 vdc and capacity of 100 ma. Make sure that the polarity is correct otherwise there will be damage. It is recommended that there be a meter measuring the milliamps required in series with the module (3 ma to 6 ma is normal per module).
- RS232 to RS485 converter - Black Box Inc sells 2 converters that work well. The first is a PCMCIA /RS485 port (IC114A, \$199). This unit works well on laptops with PCMCIA slots but does not suppress the transmissions (you see two sets of what happens). The second is a standalone (IC108A, \$259). This unit works well on the bench.

The settings for this are as follows (* indicates the default):

- XW1ADCE *
- W8B-C2-wire
- W15A-B * RTS/CD enabled
- W5A-B * RTS/CTS delay normal
- W9RTS/TCS delayC*0 msec
- W17D0.7 msec time driver remains enabled after a low-to-hi transition
- W16B * 0.1 msec Turnaround delay
- S1OUT * Normal
- S2OFF *RS-485 receiver Unterminated
- S3OFF *Line Bias Off
- TB1term 1, RxB+ (connect to 3, Tx, B+) to the +485 (orange)
- term 2, RxA- (connect to 4, Tx, A-) to the -485 (brown)
- term 3TxB+
- term 4TxA-
- Connector to power / comms - see drawing of connector / cables next page. Use Molex connectors - (03-06-1044 male shell, 03-06-2044 female shell, 02-06-5103 female pins, and 02-06-6103 male pins. HTR1719C tool required).
- Module C51 mode configuration. The C51 board is placed into the desired mode upon power up based on the input connector used and the position of jumper JP1. Refer to the drawing of the board for the proper configuration. The unit must be opened up to make this change.

A module should always be powered up and communicated with on the bench prior to connection in a system or when checking operation and trouble shooting. Make sure that the +12 Vdc is connected to the proper connector pin, and that the terminal is running at the proper protocol (9600, N, 8, 1). The current drawn should be in the 3 to 6 milli amps range depending on the module.

Communications

ASIMET (like IMET) has a communications protocol based on the SAIL (Serial ASCII Interface Loop) protocol developed at Oregon State University. The module is interrogated with the following format (always with capital letters):

prefix 3 char TYPE 2 char SN command suffix

i.e.: # XXX nnX

TYPE of:

- BPR = Barometric Pressure
- HRH = Relative Humidity / Air Temperature
- LWR = Longwave Radiation
- PRC = Precipitation
- SST = Sea Surface Temperature
- SWR = Shortwave Radiation
- WND = Wind Speed and Direction

2 char SN of 01, 02, 03 etc

command suffix of:

- A = Address acknowledge
- C = Output calibrated
- H = help
- I = ID information
- L = Calibration header Info
- T = Test data (usually 1 sec rate)
- U = EEPROM Update mode
- (requires password of "OK")

Operation

1. With terminal running at (9600, N, 8, 1) , the power set at 12 vdc, perform the following sequence, in the RS232 mode without the 232/485 converter.

Send:#WND01A Receive:**WND01**<cr><lf><etx>

2. With terminal running at (9600, N, 8, 1) , the power set at 12 vdc, perform the following sequence, in the RS485 mode and with the 232/485 converter.

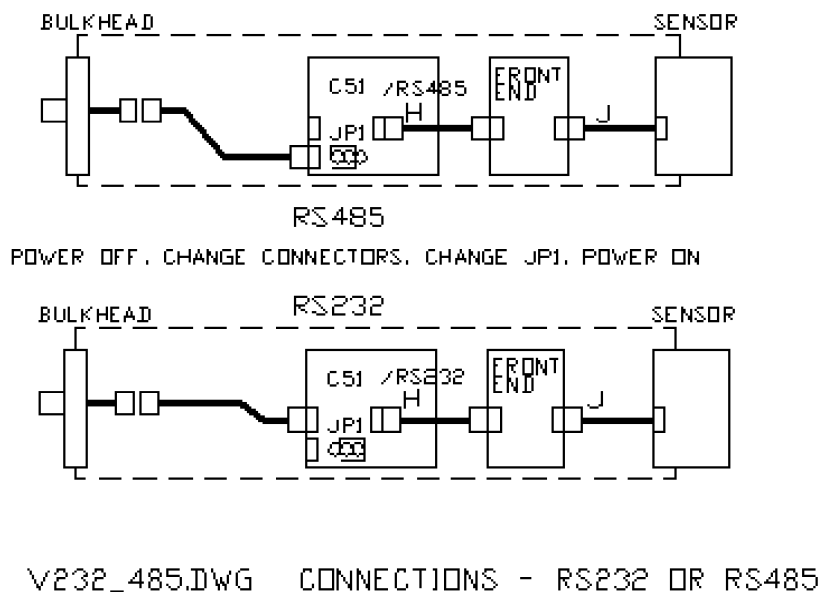
Send:#WND01A Receive:**WND01**<cr><lf><etx>

3. When the module responds with the address acknowledge in both modes, communications have been established. Send the help command:

Send:#WND01H Receive:(**Help Menu**)

Send each command as indicated by the help menu to understand the operation and the data format of the output data. The "I" command will provide detailed information on the data output formats.

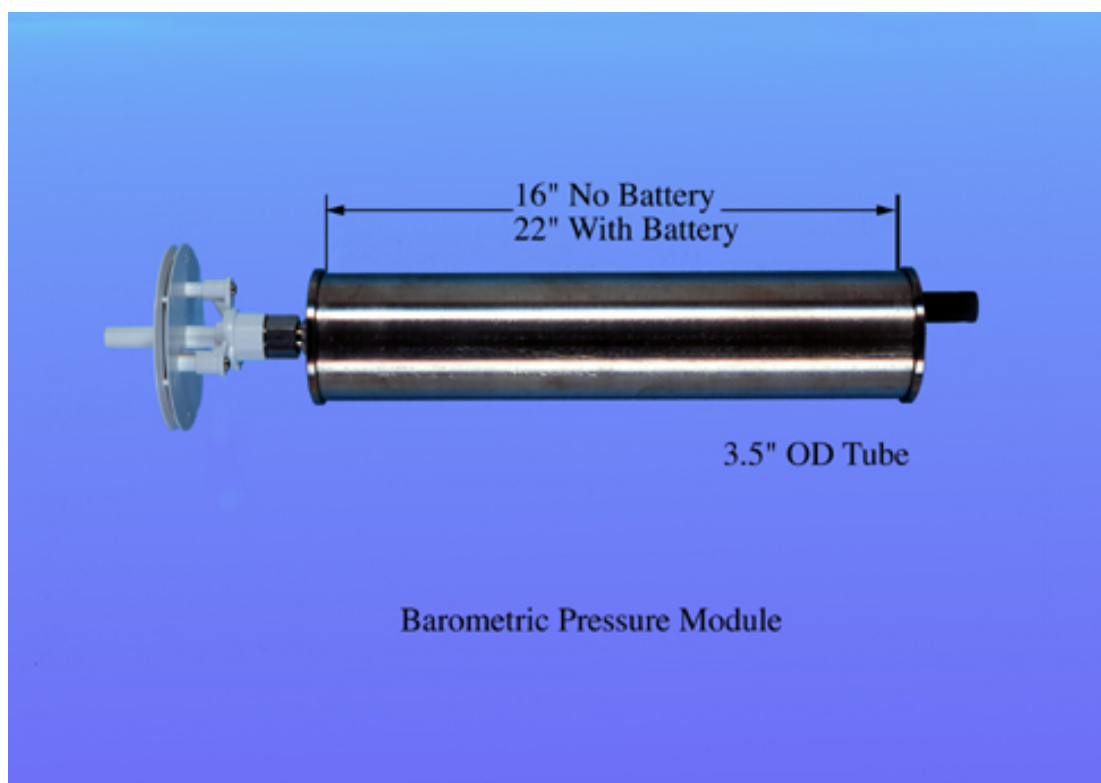
The following figure shows the RS232 vs RS485 configuration jumpers inside of a module.



Individual module data and configuration are in the following pages.

ASIMet Module Specifications: Barometric Pressure

An AIR (Atmospheric Instrumentation Research Inc.) model S2B sensor was selected for barometric pressure measurement. The sensor provides output of calibrated engineering units in ASCII (parallel) for direct input to the processor board. A sample is collected from the ARI sensor every several seconds. Each sample is calibrated in the ARI barometer and is internally averaged from 10 samples taken over the previous second. A Gill static pressure port is used to minimize errors due to the wind blowing over the exposed sensor port.

**Specifications:****Sensor:**

Range: 850 to 1050 mb
Resolution: 0.1 mb
Accuracy: 1 mb

Physical:

Housing diameter: 89 mm (3.5")
Housing length: 419mm (16.5")
Overall length: 517 mm (20.4")
Weight: 13 kg (6 pounds)

Electrical:

+12 vdc to +15 vdc with 2.5 ma average current

Communications:

RS485 or RS232 (9600, N, 8, 1) IMET format

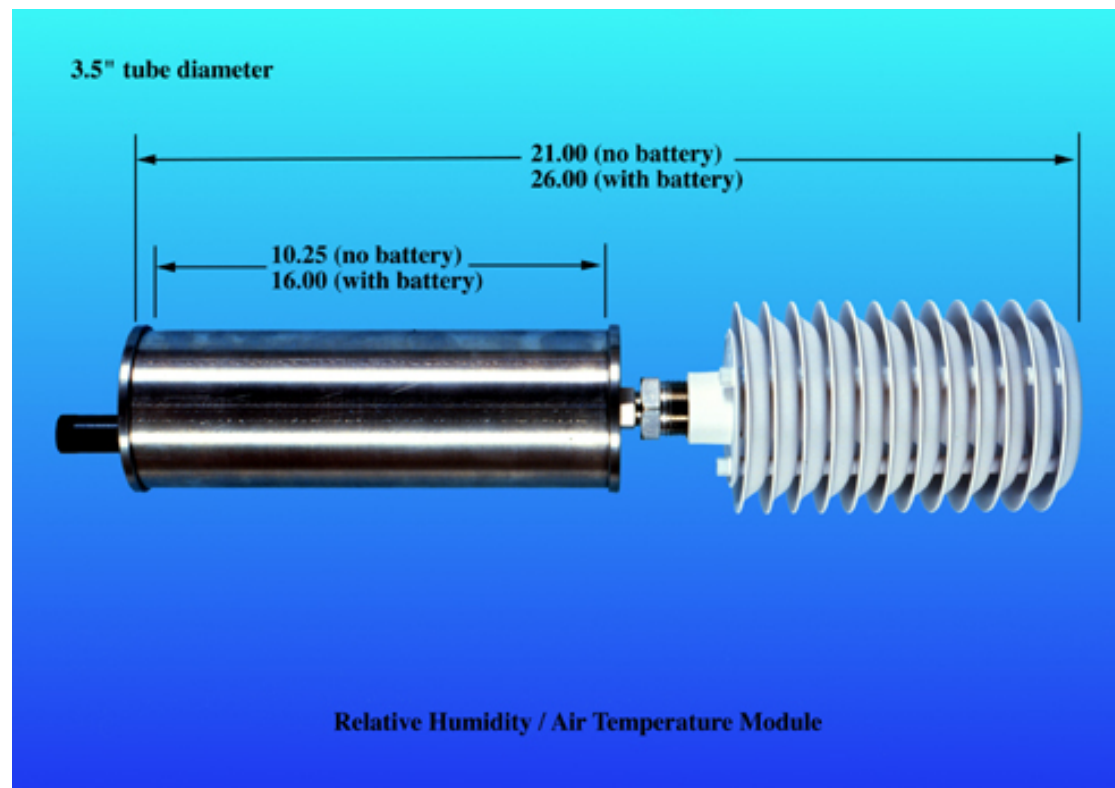
Calibration:

Calibration is checked using a lab standard electronic barometer and the bias is adjusted as required. If

unable to adjust the bias, the unit is returned to the manufacturer for complete calibration. Calibration constants are stored in the EEPROM.

ASIMET Module Specifications: Relative Humidity / Air Temperature

Relative humidity measurements are made with a Rotronic MP-101A sensor. To meet the environmental needs of buoys and ships, the sensor is packaged in a custom housing which is more rugged than the standard housing and with high pressure water seals. The sensor electronics is conformal coated and the sensor housing is packed with a desiccant. The humidity-temperature probe provides analog outputs of 0 to 1.0 volts DC for humidity (0 to 100% rh): and 0 to 1.0 volts DC for temperature (- 40 to +60 deg C). These signals are amplified and converted to digital in the module. One set of measurements are made every minute and calibrated via a fourth order polynomial for RH% and degrees C. This set of measurements is returned when polled. This probe is placed inside a modified R.M. Young multi-plate radiation shield for standard use. This modified shield has wider plate spacing and a hydrophobic coating on the plates to provide a more accurate measurement.



Specifications:

Relative Humidity Range - 0 to 100%

Accuracy (77 deg) +/- 2%RH

Resolution 0.1% RH

Long Term Stability, 1% RH or better over one year

Sensor Protection, MF25 membrane filter

RM Young modified shield

TemperatureRange - -20 deg to +55 deg C

Accuracy 0.1 deg C (if full temp calibration, 0.05 deg

Resolution 0.01 deg C

Physical -Housing diameter is 89 mm (3.5")

Housing height is 267mm (10.5")

Overall height is 535mm (21")

Weight is 13kg (6 pounds)

Rotronic sensor mounted in passive shield.

Electrical:

+12vdc to +15vdc with 2.5 milliamps average current.

Communications:

RS485 or RS232 (9600, N, 8, 1) IMET format.

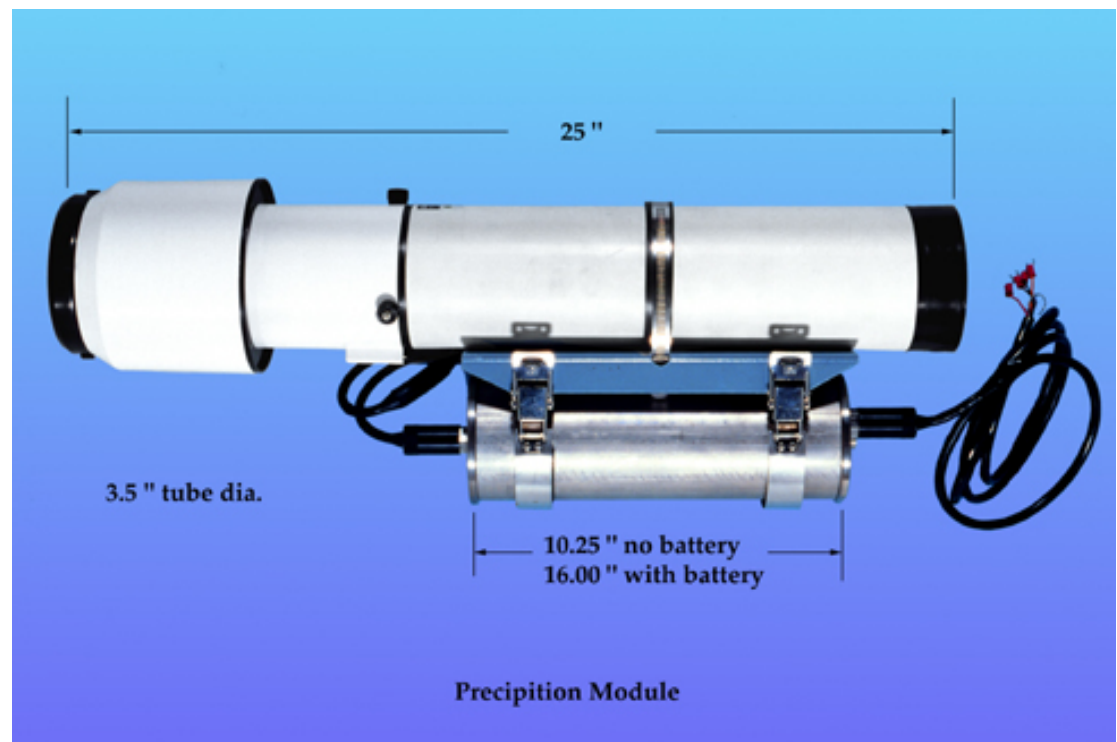
Calibration:

Relative humidity is calibrated over a humidity range of 25 to 95 % RH in a special test chamber with stability to 0.1% RH. The dew point standard has an accuracy of 0.1 deg C and is traceable to NIST.

Temperature is calibrated over a range of 1 to 35 degrees C in a water bath with a resolution of 0.001 degrees C and an accuracy of 0.005 degrees C.

ASIMET Module Specification: Precipitation

Rainfall is measured by an R.M. Young model 050201 self-syphoning rain gauge. This sensor uses a capacitive measurement technique to measure the volume of rain water deposited inside a collection chamber. It automatically empties in about 20 seconds when the chamber is full. The output of the sensor is 0 to 5 Vdc which represents 0 to 50 mm of rainfall in the gauge. The sensor is sampled once each minute and the level output. Rain rate is calculated based on average of the last 5 (one minute) samples. The total rainfall for the last hour is also calculated.

**Specifications:****Sensor:**

R.M. Young Self-syphoning rain gauge
0 to 50 mm, with a resolution of 0.1 mm
20 second drain time
Catchment collection area is 100.0 cm² (15.5 in²)
Catchment outside diameter 140 mm (5.5 ")

Physical:

Electronics housing diameter: 89 mm (3.5")
Electronics housing length: 267mm (10.5")
Overall height: 650 mm (25.5")

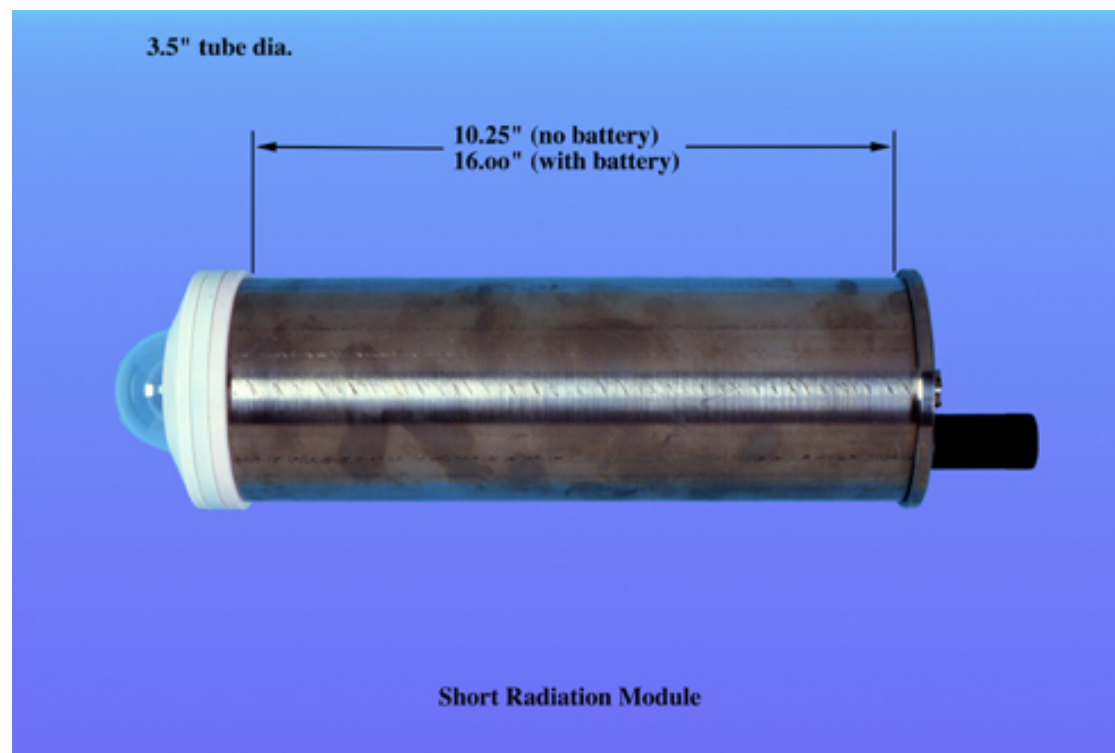
Overall weight: 12 lbs

Calibration:

Recalibrate by adding successive known volumes of water. Perform gain adjustment and calibration of the module electronics. Calibration constants are stored in the EEPROM.

ASIMET Module Specifications: Shortwave Radiation

Shortwave radiation is measured with a modified Eppley Precision Spectral Pyranometer (PSP) mounted on an aluminum base which provides a reference mass for the PSP. The aluminum base is mounted to a PVC endcap for thermal isolation from the module housing. The sensor uses a temperature compensated thermopile. It provides an output voltage proportional to incident short wave solar radiation (0.3 to 5.0 micro meters). Sensitivity is approximately 9 microvolts per watt, per meter squared, and has a temperature dependence of +/- 1% over the range of -20 to +40 degrees C. A set of sample is collected, calibrated via a fourth order polynomial, and averaged for the return measurement.

**Specifications:**

Sensor:

Sensitivity approx 9 microvolts per W/M²

Temperature Dependence +/- 1% from -20 to +40 deg C
Linearity is +/- 0.5% from 0 to 1400 watts/meter squared
Response time is 1 sec
Sensor is Eppley PSP.

Physical:

Housing diameter is 89 mm (3.5")
Housing height is 267mm (10.5")
Overall height is 310mm (12.25")
Weight is 13kg (6 pounds)

Electrical:

+12vdc to +15vdc with 2 milliamps average current.

Communications:

RS485 or RS232 (9600, N, 8, 1) with standard IMET format.

Calibration:

The sensor is calibrated outside in sunlight against a secondary standard (March to October). If this is not possible, the sensor is returned to Eppley for complete calibration. The gain adjustment and calibration of the sensor electronics are made separately. Combined calibration constants are stored in the unit EEPROM.

ASIMET Module Specification: Sea Surface Temperature

A platinum resistance thermometer (PRT) was chosen for sea surface temperature measurement. PRTs have a positive temperature coefficient, are highly stable over long periods of time, and have a very low hysteresis. The electronics consists of an analog front end and an ultra low-power micro processor unit for conversion to a digital signal. The analog front-end uses an Anderson circuit that provides a low noise interface to the PRT that uses a constant current source through the series combination of the PRT and two precision resistors. The resistors are set at the -10 deg C and +20 deg C values of the PRT. Since the measurements are always made relative to the reference resistors, electronic drift is compensated for and an accuracy of 5 milli degrees C with a resolution of one milli-degree C is achieved over a range of -10 to +45 deg C. The sensor is mounted in a PVC housing that is attached inside the ship hull at the water line. This

conforms to the configuration that has provided excellent results from the U.K. Meteorological Office sensors used on VOS ships.

Note that this system can also be used for air temperature with a PRT mounted in a standard 6" probe. For very accurate air temperature measurements, an aspirated shield (R.M. Young) is recommended since the R.M. Young static shield introduces errors in direct sun and with low wind speeds independent of the sensor used. The aspirator uses about 0.5 amps at 12 vdc and is only suitable on a buoy with solar panels or for limited time.



Specifications:

Sensor:

Electronics: 1000 ohm PRT with low noise
Anderson Circuit interface.
Accuracy: 0.005 deg C
Resolution: 0.001 deg C

Physical:

Data recorder housing diameter is 89 mm (3.5")
Recorder housing length is 267mm (10.5")
Weight is 13kg (6 pounds)
Sensor housing is 1490mm (5.875") diameter x
89mm (3.5") high.
Electrical:

+12vdc to +15vdc with 2.5 milliamps average current.

Communications:

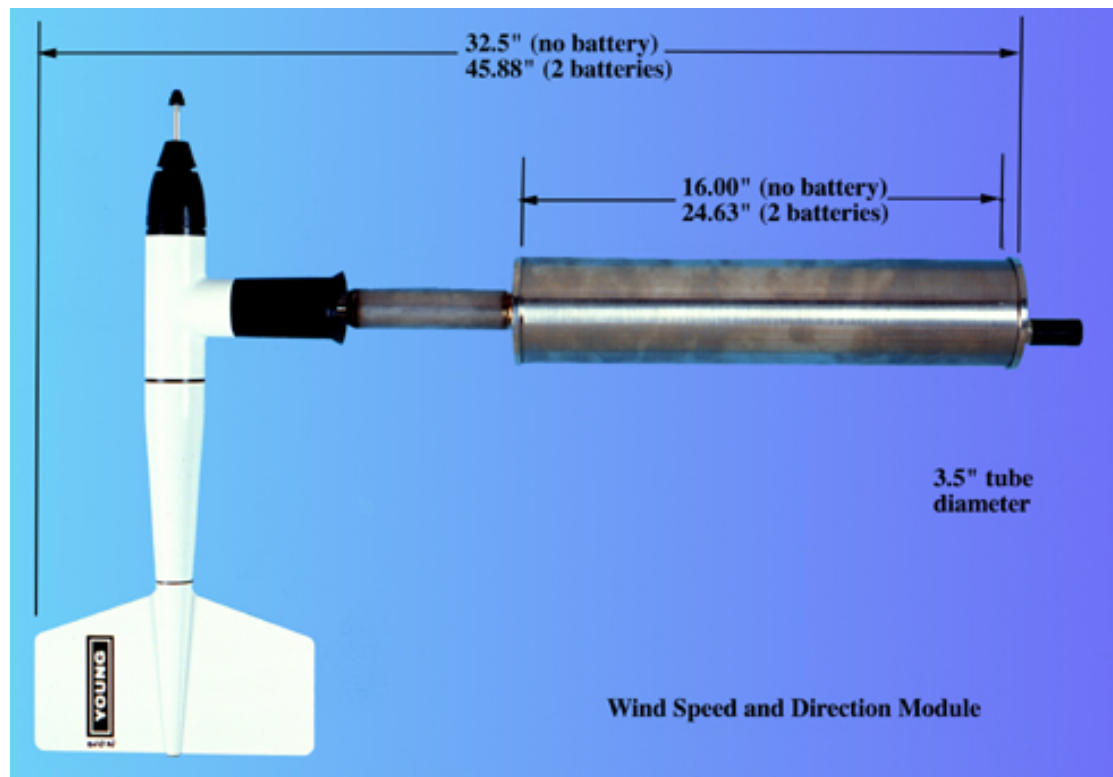
RS485 or RS232 with standard IMET format.

Calibration:

Perform a liquid bath calibration over the nominal range of 0 to 35 deg C. the calibration bath and temperature standard are stable and accurate to better than 1 mK.

ASIMET Module Specification: Wind

Wind speed and direction are measured with a modified R.M. Young model 05103 wind monitor. This sensor was selected because of its proven record. It uses a propeller to measure wind speed. The standard vane potentiometer is removed and the vane shaft extended down and coupled with an absolute angle encoder for a full 360 degrees of measurement. A magnetometer compass is used to provide the north reference for use on buoys. This is can be disabled for use on ships (ships gyro and external GPS are then used to compute true wind speed in the data recorder). The propeller generates 3 pulses per revolution which has a calibration of 0.297 meters of wind per revolution. The pulses are amplified and counted over a 5 second period providing scalar wind speed. The vane position is measured once per second and the compass measured once each 5 seconds. This provides a scalar wind speed and direction every 5 seconds that is then vector averaged over the normal one minute sample period. The maximum and minimum wind speeds during the one minute time are also reported for wind gust information.

**Specifications:****Speed:**

0 to 60 meters/second, propeller with a 0.098 meters/second per hertz, with 3 pulses/propeller revolution.

Direction:

Vane encoder has a resolution and accuracy of 0.01 degrees. The compass has an accuracy of 2 degrees and a resolution of 1 degree. There is a full 360 degrees of range with no deadband.

Physical:

Housing diameter is 89 mm (3.5")
Overall housing height is 380mm (15")
Overall height is 760mm (30")
Propeller is 178mm (7")
Weight is 17.6kg (8 pounds)

Electrical:

+12vdc to +15vdc, with 6 milliamps average current.

Communications:

RS485 or RS232 (9600, N, 8, 1) with standard IMET format.

Calibration:

The propeller bearings are replaced (on re-calibrations) and the speed checked at several standard speeds using the R.M.Young calibration unit. Operation of the vane encoder and compass is checked by rotating the module and vane slowly through 360 degrees with confirmation of indicated directions for at least two known directions in each quadrant. Vane alignment is checked and adjusted as required.

Cost Summary For ASIMET Modules

Updated January 2000

The following is an approved cost list for ASIMET modules fabricated at WHOI with the point of acceptance at Woods Hole, MA. WHOI is a non-profit research and educational organization and all purchase orders are on a best efforts basis. The design is subject to change without notice. The listed costs include materials, shop time, fabrication labor and engineering support labor.

Costs for repairs are not included and any repair required will be charged at the time of repair. WHOI fee is 15% for non-government organizations. Shipping, agents fees, taxes, and any export costs are the responsibility of the purchaser. Shipping containers are required but prices are not included. If the purchaser does not have a Massachusetts tax exempt number, then the state tax adds 5% to the final cost.

Estimated delivery time is 5 to 6 months ARO (since no parts are inventoried, purchased and machined parts can only be started after an order is received). A purchase order should be sent to:

Attn: David Hosom, MS#30
Account: 1-05-520365.00 (ASIMET Module Fabrication)
Woods Hole Oceanographic Institution
Woods Hole, MA 02543

Item	Description	Cost	Q=1	Q=3	Total
			Calibration	Calibration	W/WHOI fee

1	Relative Humidity/Air Temp	6,425	765	345	\$8,270
2	Barometric Pressure	5,675	195	145	6,750
3	Wind Speed/Direction	7,325	270	270	8,735
4	Wind S/D (no compass)	6,625	270	270	7,930
5	Precipitation	6,585	185	105	7,785
6	Shortwave Radiation	7,215	415	415	8,775
7	Ship Sea Temp (hull mount)	6,290	675	345	8,010
8	Longwave Radiatio	8,230	995	995	10,610
9	Mounting Bracket	350	n/a	n/a	402
10	Buoy Low Power Logger	7,590	n/a	n/a	8,730
11	Battery (15v, 98ah /logger)	200	n/a	n/a	230

For additional information contact: D. Hosom (phone 508-289-2666, fax 508- 457-2165, or email dhosom@whoi.edu Since September 1998, prices are slightly up due to labor.