Wind and Pressure Measurements in the Open Sea

Kuo-Ching Jao* Dong-Jiing Doong** Beng-Chun Lee*** Chia Chuen Kao* Mon-Shen Shi****

*Department of Hydraulic and Ocean Engineering, National Cheng Kung University, Tainan 70101, Taiwan, ROC
** Department of Marine Environmental Informatics, National Taiwan Ocean University, Keelung 20224, Taiwan, ROC
***Department of Environmental and Hazards-Resistant Design, Hufan University, Taipei 22301, Taiwan, ROC
****Coastal and Ocean Monitoring Center, National Cheng Kung University, Tainan 70101, Taiwan, ROC

Abstract - **The purpose of this paper is to introduce a new shipboard instrument for meteorological elements measurements in the open sea. Wind, Pressure, Temperature, humidity can be measured by this instrument. Since ship is navigating during the measurements, a calibration method for wind and pressure measurements is reported. This instrument has been installed on several cargo ships to observe the open sea data and transferred the data to local office in order to improve the marine weather forecasting accuracy.**

I. Introduction

Collecting meteorological data at open ocean locations is a challenging task but critical for high quality weather forecasting. Satellite observation is now often used. However, results from remote sensing still need in-situ measurements for calibration and verification. Data Buoy is therefore common used to measure the meteorological and oceanographic data in the coastal ocean or in the deep ocean. It did play an important role. However we are thinking if there are any cheap and easy ways for meteo-oceanographic data. Ships, Vessels are everywhere at any time in the open sea. If the ships can help to observe the ocean, it makes great advantages for understanding ocean as well as improving forecasting capability with the ocean. The international scheme by which ships plying the various oceans and seas of the world are recruited by meteorological services organizations for taking and transmitting meteorological observations is called the World Meteorological Organization (WMO) Voluntary Observing Ships' (VOS) scheme. From the very beginning, ships' meteorological observations were recognized as being essential for the provision of safety related meteorological services for ships at sea, as well as for climatological purposes At the present time, the contribution which VOS meteorological reports make to operational meteorology, to marine meteorological services and to global climate studies is unique and irreplaceable. During the past few decades, the increasing recognition of the role of the oceans in the global climate system has placed even greater emphasis on the importance of marine meteorological and oceanographical observing systems.

In the beginning of VOS scheme, mariners observed the oceanographic and meteorological elements subjectively and by experience. The data were not digitalized and transferred non-efficiency. Some year later, some commercial products were introduced. In this paper, we present a new Shipboard Meteo-Oceanographic Observation System (ShipMOS) based on latest technologies. The main difference compared to commercial products is that this instrument can storage raw data for advanced research requirements.

II. Shipboard Meteo-Oceanographic Observation System (ShipMOS)

In order to reduce the human's negligence, the present shipboard meteo-oceanographic observation system should be designed to an operational-free system. It must have the functions of energy self-supply, real-time data transmission and low malfunction capability. Figure 1 is the photo of the Shipboard Meteo-Oceanophic Observation System. Figure 2 shows the components of ShipMOS and its data flowchart. ShipMOS contains shipboard unit and ground unit. On the ship, the function of observation part is to measure the wind, pressure, humidity and temperature information. The on deck Information System Unit is installed in the ship's operation room in order to show the real time data on the screen as well as the forecasting weather charts which received from ground weather services organizations.

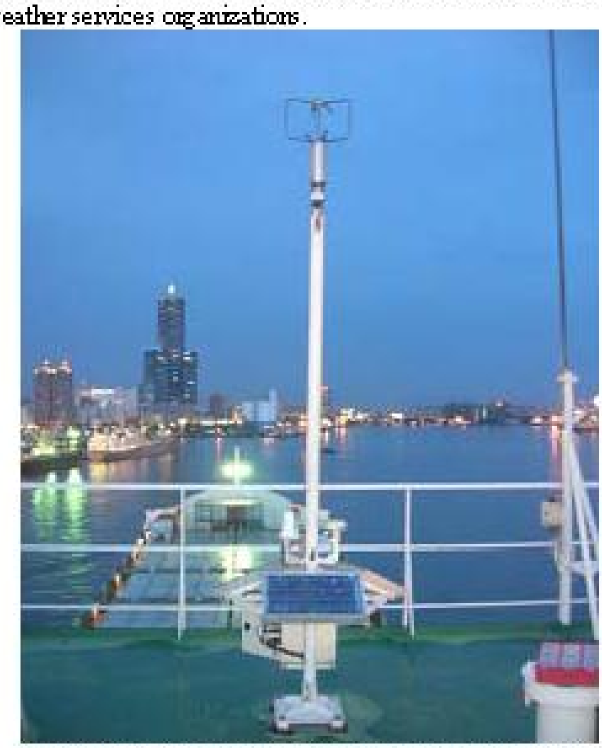

Fig. 1 The Shipboard Meteo-Oceanographic Observation System (ShipMOS)

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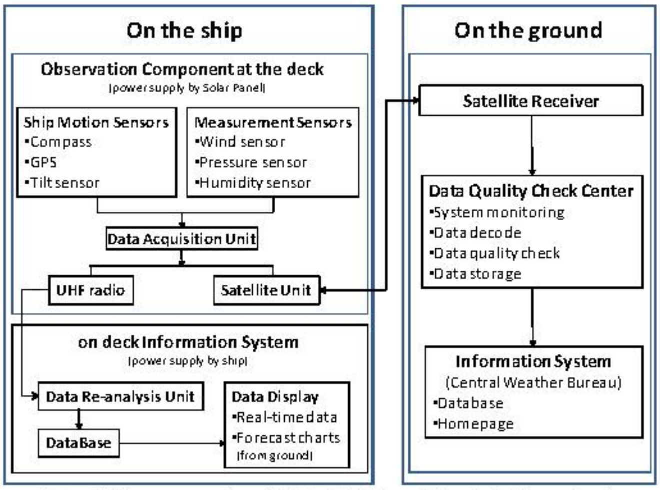

Fig. 2 Components of ShipMOS and its data flowchart

Figure 3 shows the interface of the information system. This information system can be installed on the ship as well as in the office on the ground. The captain and the operator on the ground can know the ship location, ship speed, ship heading direction, wind speed, direction, gust, pressure, humidity and temperature. By this information system, captain can also receive weather forecast chart that delivered from weather services.

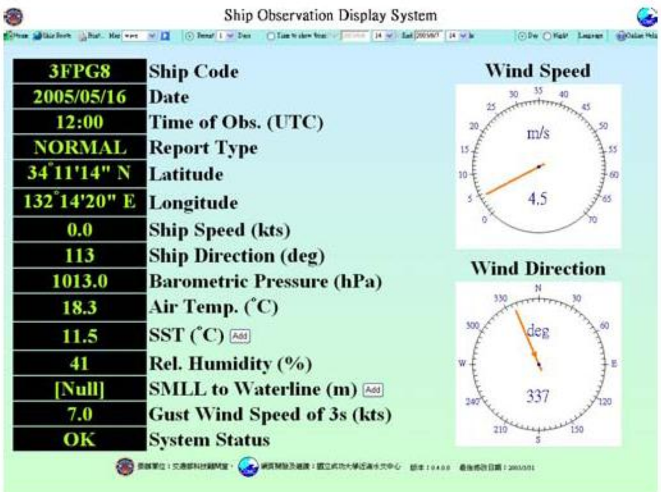

Fig. 3 The interface of ShipMOS's information system

III. Calibrations

Figure 2 shows that ShipMOS contains a ship motion sensor and the compass. These devices are going to know the ship motion (incl. moving speed, heading, heave, pitch and roll) in order to calibrate the measured data since they are detected on a moving ship. Table 1 shows the sensors within the ShipMOS and their measuring ranges and resolutions. From the regular output of wind sensor, the wind speed is the value against the ship motion, therefore the true wind speed (against ground) has to be estimated by vector calculation referring to the data of ship moving speed, heading direction and the true north direction given by compass.

Table 1 Sensors and their resolutions with ShipMOS

items	Measuring range	resolution
Wind speed	0~50m/s	0.1m/s
Wind direction	Azimuth:0~360deg Elevation: -60~60deg	1deg 0.1deg
Pressure	800~1,100hPa	0.1hPa
Humidity	0~100%	1.0%
Air temperature	-40~+60℃	0.1℃
compass	0~360deg	±1.5deg

For the calibration of air pressure, it is necessary to calibrate the measuring pressure to sea surface pressure (z=0) in order to have standard values. The pressure calibration processes contain three parts. They are latitude gravity calibration, height gravity calibration and height/temperature calibration. The modified pressure (B_n) after latitude gravity calibration can be estimated by Eq.(1) and Eq.(2).

$$g_{\phi 0} = 980{,}616\left(1 - 0.0026373\cos 2\phi + 0.0000059\cos^2 2\phi\right) \quad (1)$$

$$B_n = B_1 + B_1\left(\frac{g_{\phi 0}}{g_n} - 1\right) \quad (2)$$

Where g_n is the standard gravity; $g_{\phi 0}$ is the sea surface gravity at latitude ϕ degree; B_1 is the measuring pressure. Then, Eq. (3) and Eq. (4) are applied to execute the height gravity calibration.

$$g_{\phi H} = g_{\phi 0} - 0.0003086\ H + 0.0001118\ (H - H') \quad (3)$$

$$B_n = B_\phi + B_\phi\left(\frac{g_{\phi H}}{g_n} - 1\right) \quad (4)$$

Where H is the height of measurement; H' is the average height at the area by 150 cm radius; $g_{\phi H}$ is the gravity at latitude ϕ and height H; g_n and $g_{\phi 0}$ have the same definition as above. In addition, the calibrated pressure on height and temperature can be estimated by Eq. (5), as shown below.

$$h = 18400(1 + \alpha t)\log_{10}\frac{B_0}{B} \quad (5)$$

Where h is the height of measurement; t is thetemperature; α is the gas constant (α= 1/273); B is the measuring pressure and B_0 is the sea surface pressure.

Figure 4 shows the performance of the pressure calibrated using above formula. In the figure, blue line is the calibrated

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pressure which original measured from the ShipMOS installed on Fishery Ship No.1. The green line is the local sea surface pressure measured at a weather station at Keelung. They have very good agreement representing the correctness of pressure calibration of ShipMOS.

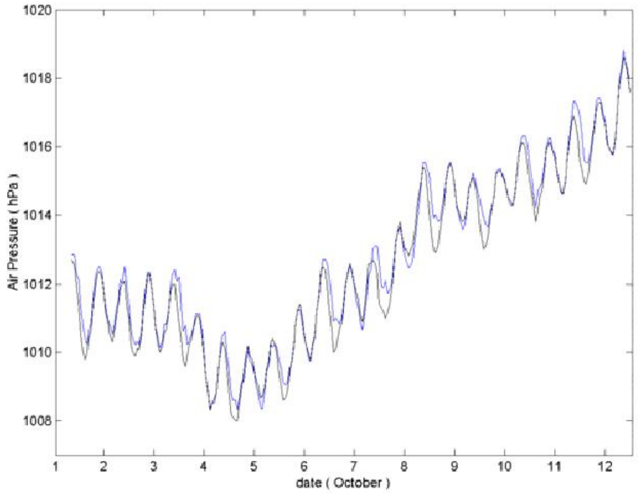

Fig. 4 ShipMOS measured pressure calibration result(blue line) compared to local sea surface measurement (green line)

IV. Measurements

Three ShipMOSs have been installed on cargo ships or research vessels for operational testing since 2004. They are listed in table 2. The measuring interval is 1 hr or 2 hr, depending the requirements of the ship owner. Until the end of 2007, the average observation successful rate of these operational ShipMOS is 82%. One reason of this value is not so satisfied is due to the failure of data transmission by Iridium satellite. This has to be improved in the future. On the ShipMOS, a three axis acoustic wind sensor is installed to measure wind stress. These data is useful to study the air-sea interaction. Two ShipMOSs were installed on two commercial cargo ships named Li-Lei ship and Han-Ming Ship respectively. They navigate between countries or locations in Asia, such as Taiwan, Japan, Hongkong, Vietnam and so on. From figure 5 to figure 9 show some routes of these ships and their observation during their cruises. For example, Li-Lei ship navigated from Taiwan to HongKong and then went to Japan via Taiwan. In this cruise, the observation successful rate is 99%. The lowest sea surface pressure observed was 1000.8hPa and the max. gust wind is 22.4 kts. These data were transferred to Central Weather Bureau (CWB) in Taiwan in real-time. The data collection center of CWB checks the data and puts into worthy data into their weather chart, such as in figure 10. This much increases the accuracy of marine weather forecasting.

Table 2 Data of operational ShipMOS ships

	Observation period	△t	Data amount	Observation successful rate
Li-Lei Ship	2004/11/22~	2hr	6484	87%
Fishery Ship No.1	2006/5/18~	1hr	4457	84%
Han-Ming Ship	2005/11/4	2hr	2728	74%

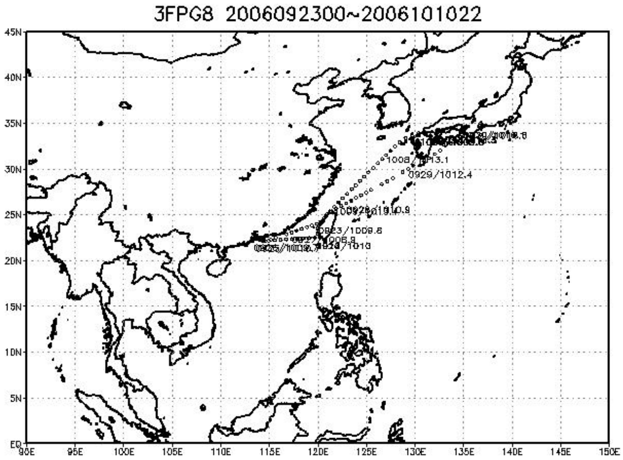

Fig. 5 Lilei ship's route to HongKong and Japan and its measurements in Sep/Oct, 2006 (18 days)

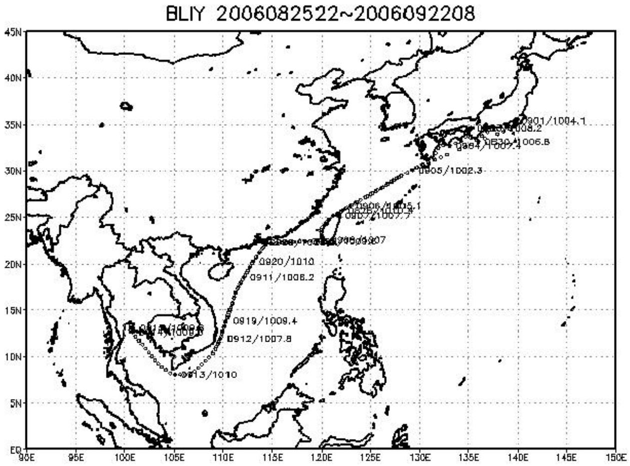

Fig. 6 Lilei ship's route to Vietnam and Japan and its measurements in Aug/Sep, 2006 (27 days)

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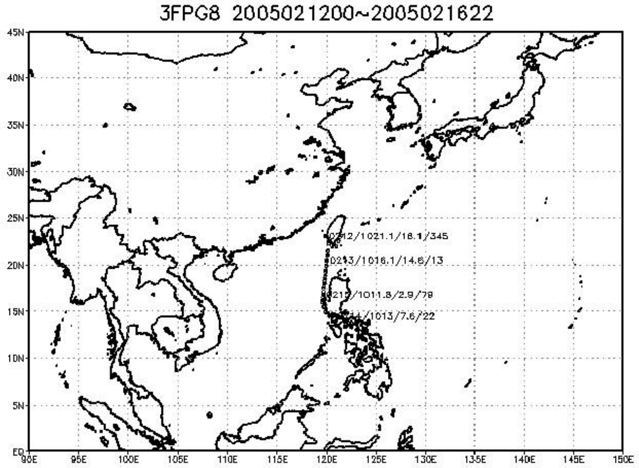

Fig. 7 Lilei ship's route to Phillips and its measurements in Feb, 2005 (5 days)

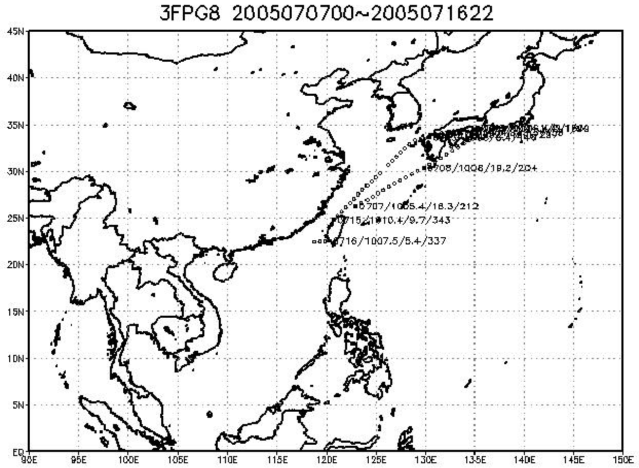

Fig. 8 Lilei ship's route to Japan and its measurements in Jul, 2005 (9 days)

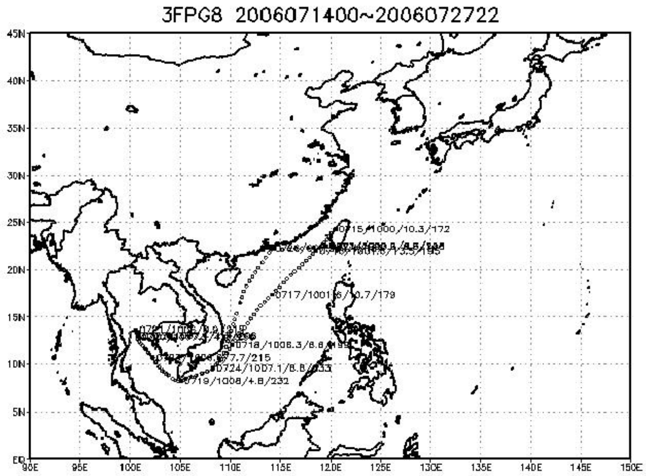

Fig. 9 Lilei ship's route to HongKong and Vietnam and its measurements in Jul, 2006 (14 days)

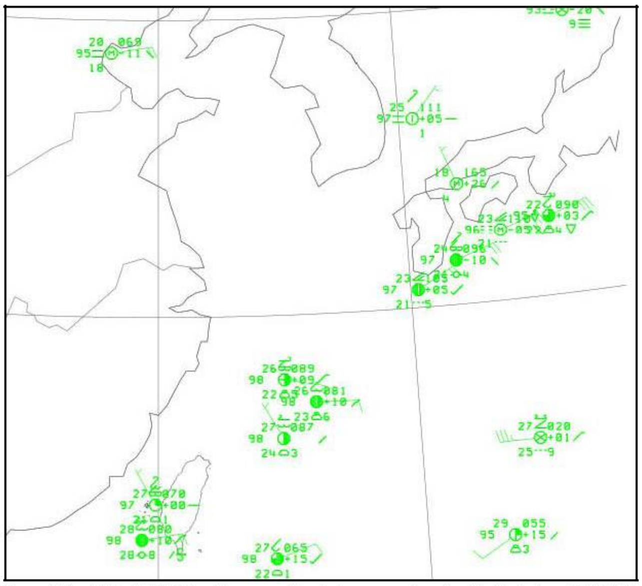

Fig. 10 ShipMOS observed data are included into CWB's weather chart

In 2005, there are several typhoon raised in Pacific Asia area. During the typhoons, some of the ships which install ShipMOS were in the sea. Typhoon data were therefore observed. They are listed in table 3. The max. gust wind observed was 57.5 kts during typhoon Sanhu in August 2005. ShipMOS still worked well under this server weather condition. This proof the robust of ShipMOS.

Table 3 Observed extreme meteorological elements during typhoons by ShipMOS

Typhoon name	time	Lowest pressure (hpa)	gust wind (kts)	Max. mean wind speed (kts)
Haitang	2005/7/16～20	993.4	38.3	37.3
Masa	2005/8/03～06	995.3	38.1	35.8
Sanhu	2005/8/11～13	993.6	57.5	38.9
Taili	2005/8/30～01	992.7	44.3	38.6
Kanu	2005/9/09～11	999.7	28.9	23.1
Dairei	2005/9/21～23	999.7	23.9	23.9
Longwang	2005/9/30～03	1007.7	27	24.1

V. Conclusions

ShipMOS was developed in the university research center. It is not a commercial instrument. In additional to observe the meteo-oceanographic elements on the moving ships in the open sea (to achieve the requirements of VOS), ShipMOS can

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obtain much open sea data for ocean research such as air-sea interaction. This is very difficult obtained before. ShipMOS can measure air temperature, air pressure, humidity, gust wind, mean wind speed, direction as well as ship motion. The power is self-sufficiency by combining solar panel and batteries. The data can be real-time transmitted to the land control office by satellite transmission unit. ShipMOS is modularized design therefore any sensors can be mounted onto it. ShipMOS has been installed in three ships which navigate in Asian countries for testing. Wind and pressure data observed on the ships are calibrated into ground based data. From the data received from these ships, they show good quality. These data have been used for marine weather forecasting runs.

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