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The fabrication and testing drifting buoys of marine data collection

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ABSTRACT

This paper presents the primary contents of successfully researching, designing and manufacturing drifting buoys to collect marine data to measure temperature, salinity, and ocean currents in surface layers. The paper presents the basic information about the structure, specifications, the buoys working as the laboratory results, and field tests of drift buoys at sea. The drifting buoy test results at the sea of Van Don - Quang Ninh area met the criteria of water-tightness, buoyancy, and balance; the ability to collect temperature and salinity data of the sensors; the ability to transmit and receive information from drifting buoy at sea to the central computer via a web server; operability of the parachute and the travel of the buoy. The buoy database management software is on the website at http://vnsea.vn. It manages the collected data in real-time, showing the parameters and their variables in space and time, the buoy's tracking on the Google map.

Keywords: Drift, buoy, East Vietnam Sea.

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BACKGROUND

Leonard de Vinci (1452–1519) made the earliest recorded drifting buoy measurements to measure the water velocity in the stream. A simple buoy comprised a weighted rod and buoyation bladder for drifting in the water. The buoy's downstream travel is measured after a particular time, and sufficient data were obtained to calculate the stream's discharge [1].

After that, drifting buoys continued to be developed and used in oceanography, mainly to measure currents. However, early techniques have needed help tracking the buoys [1].

When the TIROS-N satellite was launched at the end of 1978, this difficulty was resolved, and the possibility to operationally deploy large drifting buoy arrays at sea through the Argos system [1–3]. At present, the largest arrays of drifting buoys are deployed in the programs, such as the Tropical Ocean and Global Atmosphere (TOGA) program in the Southern Hemisphere continues to use the Argos system and provides data to operational and scientific users, economic activity, disaster prevention; The TOGA Program and World Ocean Circulation Experiment (WOCE) is part of World Climate Research (WCRP) to forecast climate and human influence to the climate. The program is also supported by the Intergovernmental Oceanographic Commission (IOC) of Unesco and the Scientific Commission for Ocean Research (SCOR) of ICSU [8]. Especially the ocean research programs of the US National Oceanic and Atmospheric Administration NOAA. According to statistical results on March 18, 2019, the arrays of drifting buoys of NOAA on the ocean, including a total number of 1346, to measure the sea surface temperature were 583, sea pressure: 753, salinity: 9 and wind: 1 [4].

Nowadays, the marine data collected from drifting buoys are increasingly widely used for investigation, forecasting and disaster prevention, resource management, and marine environmental protection [5, 6].

Drifting buoys for collecting marine data are increasingly widely used for investigation, forecasting and disaster prevention, resource management, and marine environmental protection [5, 6] because there are many preeminent features of drifting buoys that other marine data collection devices do not have, which are:

Drifting in the water stream, simultaneously measuring many oceanographic factors (waves, temperature, salinity, currents, etc.), can be used for many buoys for specific locations, creating the mobile station arrays of drifting buoys. The collected data is synchronous in time and space, so it is precious as input data for forecasting models and data assimilation.

The marine data collected by drifting buoys is in real-time and transmitted directly to the processing center; there is the possibility of collection in dangerous weather conditions that cannot be directly measured by humans, such as storms, monsoons, thunderstorms, and whirlwinds, serving safety warnings at sea.

The drifting buoys used to collect marine data in Vietnam are limited and have only been implemented in a few international cooperation projects [7]. The main reason is that we have been unable to manufacture the equipment and master the data transmission system, so the marine data collection cannot be secured. The proactive technology of designing and manufacturing drift buoys, marine investigation, and research equipment to serve domestic demands is urgent and has both scientific and practical significance.

Based on references to models and essential characteristics of drifting buoys that are used in Vietnam and published works in the world [8–14], the research team has successfully designed and manufactured the drifting buoys for measuring fundamental factors at marine surface layer including temperature, salinity, current speed, and direction. In the framework of this paper, the authors would like to introduce basic information about the structure, technical parameters, working process of the buoy, and test results of drifting buoys in the laboratory and at sea.

GENERAL INFORMATION ABOUT DRIFTING BUOY

Structure of drifting buoy

The buoy collecting marine data is made as a drifting buoy, which is water resistant, has a

balanced structure, withstands shocks, and moves along the water currents.

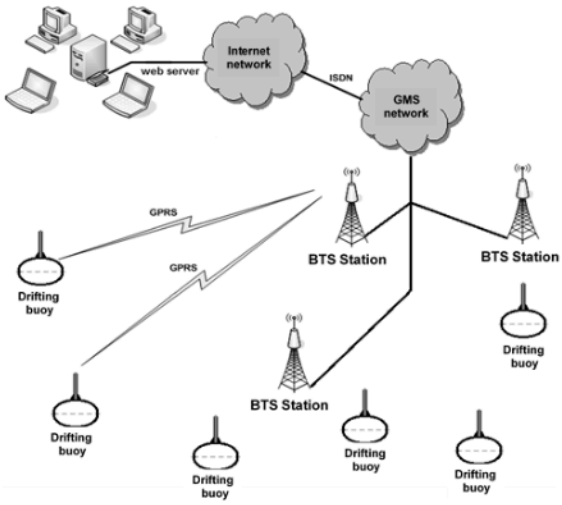

Figure 1. Communication connection system of drifting buoys

The shape of the buoy is spherical, about 40 cm in diameter. Inside the buoy shell are fitted devices such as a central data processing control block and sensor for measurement of marine data and GPS for identifying the position of buoys and their journey tracks, transmitting the information and data that were collected, and operating status of the buoy to the central computer system via GSM/GPRS network or satellite (Figure 1). Collected information will be processed by database management software on the Web.

The basic structure of a drifting buoy consists of 5 main parts (Figure 2), which include:

(1) The buoy contains functional blocks that ensure watertightness and operation in all weather conditions.

(2) Transceiver mounted setup on top, inside the buoy, include GPS Antenna and GSM/GPRS Antenna

(3) Central microcontroller block.

(4) The Alkaline battery is the power source for the operation of the drifting buoy.

(5) Sensors for measuring the temperature and salinity of marine surface layers are mounted on the bottom of the buoy.

In addition, there is software running on the Web platform for database management of the drifting buoy, the http://http protocol at the central computer to directly access information from the buoy and make requests according to user purposes.

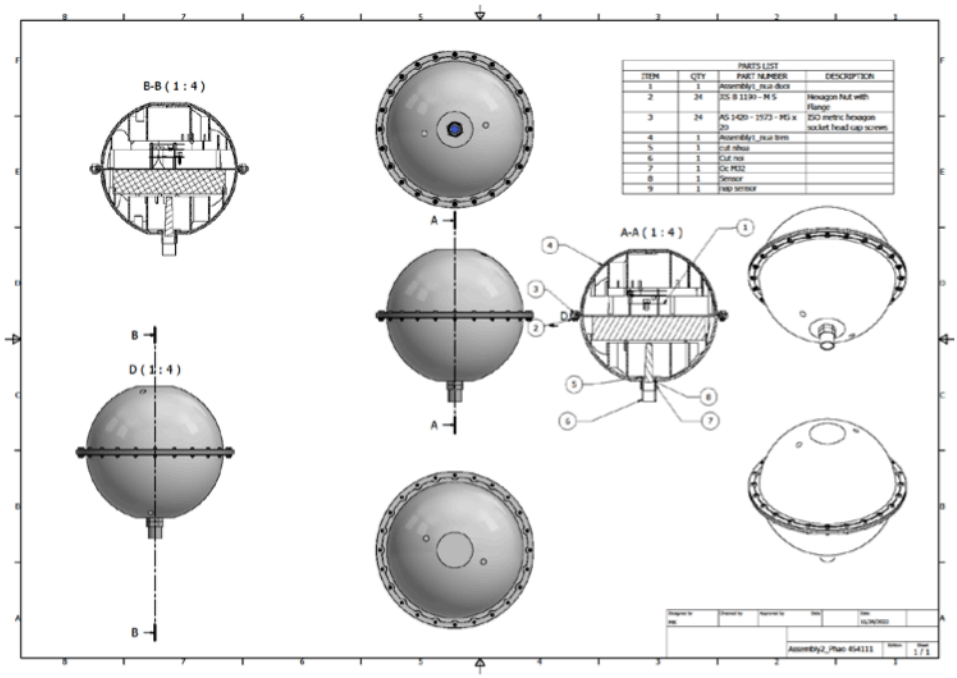

Figure 2. Technical drawing of the drifting buoy structure

When working, the drifting buoy will collect sea data such as salinity, temperature, and contact GPS data to determine the position and calculate the speed and direction of movement of the buoy in real-time. These parameters are updated on the Webserver with the address http://vnsea.vn. The database management software will process, calculate the collected data, and display it on the Google map (Figure 3).

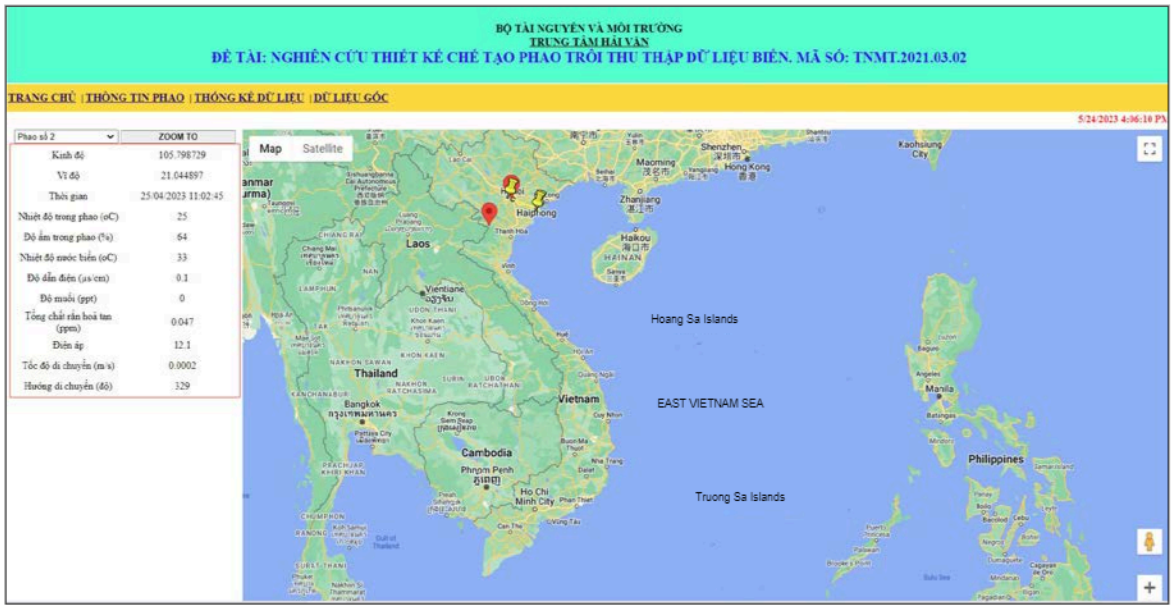

Figure 3. Information of the drifting buoy which is displayed on the googlemap background of the Web page

Specifications of drifting buoy

Temperature measurement range: 0–50°C;
Salinity measurement range: 5–60‰;
Conductivity measurement range: 0–2,000 µS/cm; 0.0–200.0 mS/cm;
Total dissolved solids measurement range: 0–133,000‰.
Buoy position: coordinates obtained from GPS;
Movement speed of buoy: 0–5 m/s;
Direction of movement of buoy: 0–360°;
Ambient humidity: 100%;
Ambient temperature: 5–60°C;
Real-time data format: dd/mm/yy, h:m:s;
Continuous operation time: 3 months;
Alkaline battery 12 V.

Operation process of the main function block of the buoy

Operation of the central microcontroller block

The central control block is designed using a 32-bit ARM chip STM32F103xx of ST. The control circuit is designed based on high-performance low voltage. The integrated circuit with NXP PCF8583 real-time chip, RS485 communication interface, AT24C128 external memory (16Kbytes), integrated with 1Wires, I2C, RS sensor communication standards,...

Hardware modules are bidirectionally connected with the chip made from the central control block. The main task of the block is to control the general operation of the buoy according to the original principle and initial design with the following main functions:

Receive GPS satellite positioning signal ($GPGGA or $GPRMC message format in NMEA0183).

According to the user's settings, set up the working mode of the buoy, such as the test settings, the rest mode, and the continuous working mode.

Receive and process data from sensors measuring salinity, temperature, position, and time of transmitting signals from buoys.

Store initial setting parameters, real-time collected data, and calculate time parameters.

The microcontroller block operation process and the buoy's hardware modules, Methods of implementation, and technical criteria for measurement and testing were introduced in the article "Investigation and design of drift buoy system applied in ocean environment data collection" [15].

Operation of data management software

The data management software of the drifting buoy includes four essential components:

Transmission of data from the buoy to the center web server using http or https protocol;

Collection and processing of data at the center by using Webserver;

Store parameters of buoys data collected from sensors;

Website monitoring, data statistics and display, and impact as needed.

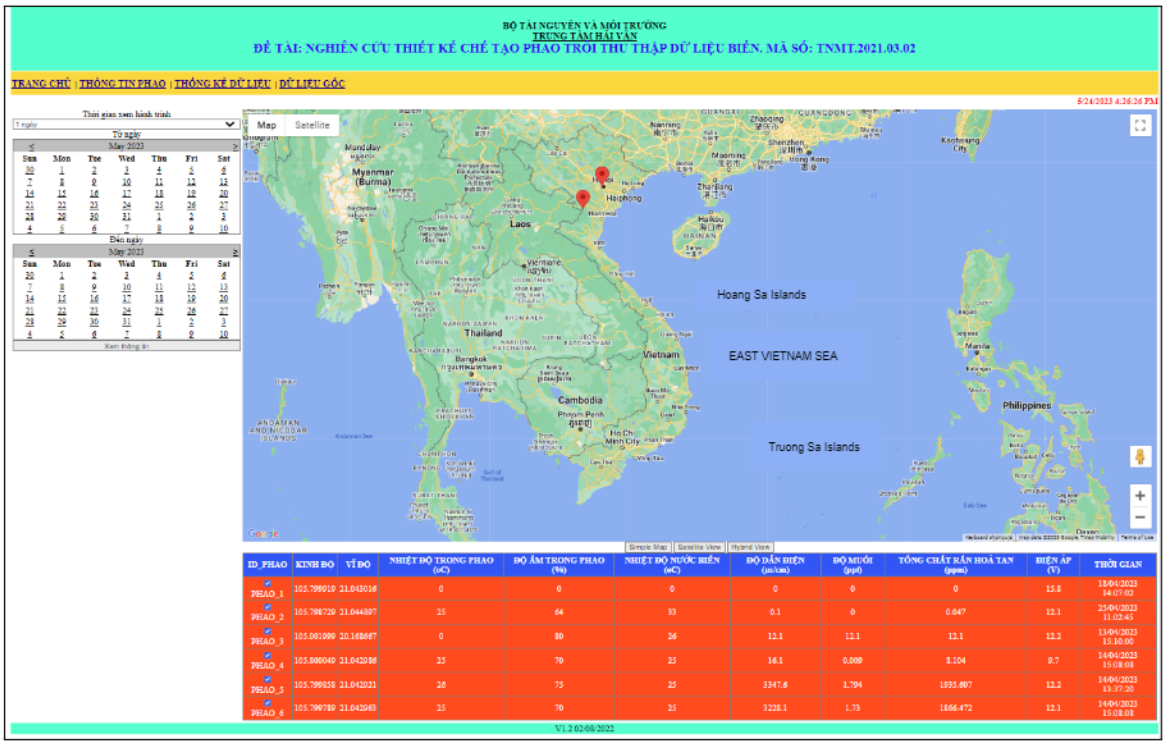

Figure 4. The parameters of the drifting buoys are displayed on the Web

The center for managing the database of drifting buoys includes computers connected to the Internet, decentralized and access accounts, and maintaining a two-way communication channel to serve the management and operation of the online buoys. The watchman channel is responsible for detecting the request to log in or re-login the system of the buoys starting to work or just restoring lines of communication. Depending on the corresponding operating mode, the software will activate the broadcast to send data update requests to the online buoys (send to all or only a group with higher priority). In there:

Managing and updating databases, including:

Registered buoy database: the buoys must be registered with the Center before participating in the management system. Each buoy will be assigned a unique identification code;

Digital chart database: Contains information about the geographical coordinates of Vietnam's sea;

Buoy operation database: Stores information about the parameters of the buoy that has been and is active for an optional period.

User interface: Allows operating the system in different modes:

Install and initialize system parameters depending on actual conditions: for example, the level of automation of the system (automatic, semi-automatic, manual) and management level (complete management or priority management of each buoy group)

Display information of the entire buoy: Display a panorama, show details of a buoy;

Distributing notices unexpected operating orders.

The website http://vnsea.vn displays information about buoys and collected parameters fully updated in real-time (Figure 4). In it, general information about the buoys in operation at the time of access, including buoy number, coordinates, the real-time temperature in buoy, humidity in the buoy, sea temperature and salinity, conductivity, total dissolved solids, battery voltage, travel velocity, direction of tracking.

TESTING DRIFTING BUOY IN THE LABORATORY

After the buoy has completed hardware and software testing, it is integrated with modules, packaged, and labeled for the buoy. Information on the label includes the Name of the buoy: Drifting buoy collecting marine data; Name and address of the agency: Hai Van Center, No. 8 Phao Dai Lang, Dong Da, Hanoi; the Phone number, Model, serial number, and code (ID). Each buoy is assigned a unique code (ID) for management on the Webserver (Fig. 5).

Figure 5. Each buoy is labeled with information, code and ID

Next, the buoy was tested in the Tropical Endurance Laboratory of the Vietnam - Russia Tropical Institute, issued a certificate of assurance of testing conditions at sea with water tightness criteria: 5dbars; heat-humidity: 60°C and 100% respectively; vibration: peak acceleration (A) - $5g_n$, corresponding width of the nominal pulse (D) - 30 ms.

The sensor for measuring sea water temperature and salinity integrated on the buoy has a model C4E, manufactured by Ponsel/Aqualabo, is 100% new, and has a quality inspection certificate.

TESTING THE DRIFTING BUOYS AT SEA

Purpose, requirements and location of buoy testing at sea

Purpose of request:

Checking the water tightness, buoyancy, and balance of drifting buoys;

Checking the operation of the buoy parachute;

Checking the buoy's ability to receive and transmit information of drifting buoys at sea to the central computer via webserver http://vnsea.vn;

Checking the working status of sensors measuring the seawater temperature and salinity;

Checking the buoy's moving speed and compairing it with the marine surface current speed.

Test location: The buoy was tested at sea in the Bai Tu Long Bay - Quang Ninh province on July 14, 2023

Weather conditions: strong sunshine, wind speed of about 1.5 m/s, wind direction SSE; Small wave height of 0.25 m, tidewater height of about 2.0 m in tide rising time.

Equipment for testing:

The buoy is number ID2;

Infinity-EM self-recording flow meter (Model AEM-USB-0596);

CTD meter: ASTD151-ALC-R02.

Results of buoy testing at sea

After releasing the buoy into the sea, the buoy ensures water tightness, buoyancy, and balance (Fig. 6). The temperature and salinity measurement by sensors that work well, the GPS signal transceiver system transmits a regular and complete to the webserver in real-time with a frequency of 6 minutes per time. The data management software processed the collected data, displayed the position and path of the buoy on the Google map (Fig. 7), and displayed all the information from the buoy (Fig. 8).

Figure 6. Set up the buoy and equipment to measure temperature and salinity, at sea of Van Don - Quang Ninh

The parameters collected from the buoy are compared with those measured by CTD and flow meter to estimate the reliability of the sensors as well as the ability to move the drifting buoy with the sea flow. The comparison results are shown in Tables 1 and 2. Table 1 shows that, for sea water temperature, the value measured by the CTD meter is smaller than the data collected

from the buoy; the smallest value is 0.3°C, and the largest is 1.4°C (only one value), but most of the remaining values are less than 0.7°C. For surface seawater salinity, the value measured by the CTD meter is larger than the value collected from the buoy, the largest difference is 2,605‰, and the remaining values are mostly smaller from 1,400‰ to 1,900‰.

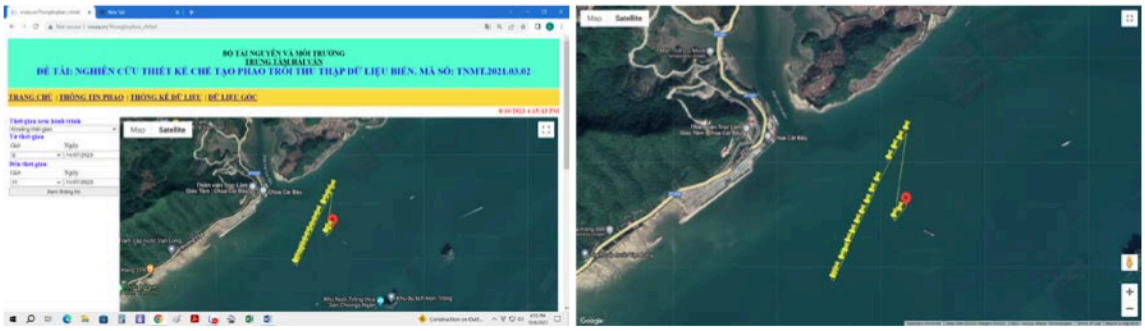

Figure 7. Location and tracking of drifting buoy from 9:59 am to 11:36 am on July 14, 2023 at sea of Van Don - Quang Ninh

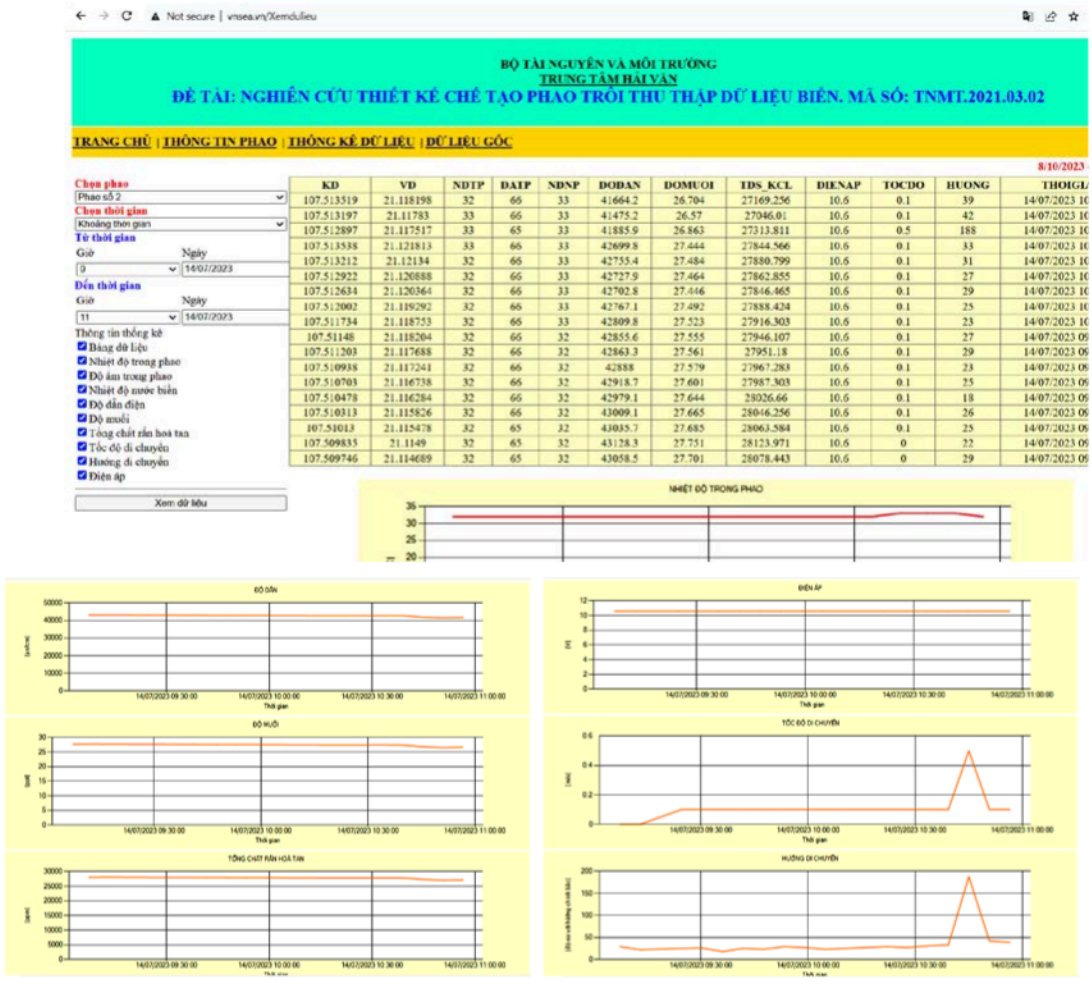

Figure 8. The data obtained from the drifting buoy is displayed on the Webserver

Table 1. Data collected on seawater temperature and salinity of buoys and CTD mater from 9:59 AM to 11:36 AM on July 14, 2023 at sea of Van Don - Quang Ninh

Time	CTD mater: ASTD151-ALC-R02		Drifting buoy No 02 (ID2)		Difference between CTD and Drifting buoy	
	Temperature (°C)	Salinity (‰)	Temperature (°C)	Salinity (‰)	Temperature (°C)	Salinity (‰)
9 h 59	32	29.069	32	27.555	0.3	1.514
10 h 04	32	29.189	33	27.523	0.7	1.666
10 h 10	32	29.154	33	27.492	0.7	1.662
10 h 22	32	28.974	33	27.446	0.7	1.528
10 h 27	32	29.137	33	27.464	0.7	1.673
10 h 33	32	28.912	33	27.484	0.7	1.428
10 h 39	32	28.813	33	27.444	1.0	1.369
10 h 45	32	28.793	33	26.863	1.4	1.93
10 h 50	32	29.175	33	26.57	0.8	2.605
10 h 56	32	29.152	33	26.704	0.7	2.448
11 h 02	32	29.172	33	27.339	0.8	1.833
11 h 13	32	29.149	33	27.328	0.7	1.821
11 h 19	32	29.148	33	27.302	0.7	1.846
11 h 25	32	29.099	33	27.314	0.7	1.785
11 h 31	32	29.09	33	27.312	0.7	1.778
11 h 36	32	28.956	33	27.32	0.7	1.636

Table 2. Data on speed and direction of drifting buoys movement and speed and direction of sea current from 09:59 to 11:36 on July 14, 2023 at sea of Van Don - Quang Ninh

Time	Infinity-EM flow meter (AEM-USB-0596)		Drifting buoy No 02 (ID2)		Difference between flow meter and Drifting buoy
	Speed (m/s)	Direction (degree)	Speed (m/s)	Direction (degree)	Speed (m/s)
9 h 59	0.1	34	0.1	27	0.0
10 h 04	0.1	46	0.1	23	0.0
10 h 10	0.1	46	0.1	25	0.0
10 h 22	0.1	46	0.1	29	0.0
10 h 27	0.1	46	0.1	27	0.0
10 h 33	0.2	51	0.1	31	0.1
10 h 39	0.1	45	0.1	33	0.1
10 h 45	0.1	42	0.1	40	0.1
10 h 50	0.1	47	0.1	42	0.0
10 h 56	0.1	50	0.1	39	0.0
11 h 02	0.1	43	0.1	42	0.0
11 h 13	0.1	29	0.1	40	0.0
11 h 19	0.2	39	0.1	42	0.1
11 h 25	0.1	64	0.1	40	0.0
11 h 31	0.1	44	0.1	40	0.0
11 h 36	0.2	36	0.1	42	0.1

The flow speed measured by the Infinity-EM recorder (Model AEM-USB-0596) is almost similar to the moving speed of the buoy. Table 2 shows that, on a total of 16 measured values, only 3 values measured by the current meter have a difference of 0.1 m/s compared to the moving speed of the buoy. The flow direction measured by the current meter and the direction of drifting buoy movement is in the Northeast. Specifically, the flow direction measured by the current meter is in the range of 29–64°, and the direction of the drifting buoy moving is in the range of 23–42°, showing that the speed and direction of drifting buoy movement are relatively consistent with the speed and direction of the flow.

CONCLUSION

The test results of drifting buoys at sea have met the purpose and requirements set out in terms of watertightness, buoyancy, and balance; the ability to collect temperature and salinity data of the sensors; the buoy's ability to receive and transmit information at sea to the central computer via webserver http://vnsea.vn; operability of the parachute and the travel of the buoy.

The above results have proved that we can ultimately master the technology of manufacturing drift buoys to collect marine data while open up the direction of developing technology for manufacturing marine survey and investigation equipment. For drifting buoys to become a common device for marine data collection and investigation to work well in all waters of Vietnam, drift buoys must be supported to transmit signals directly via Iridium satellites, with additional measuring sensors and other factors according to actual requirements, and upgrade the software and data center of drift buoys.

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