

PRESENT STATE OF OCEAN OBSERVATIONS AND SERVICE IN VIETNAM

Le Dinh Mau^{1*}, Tran Hong Lam², Nguyen Manh Cuong³

¹*Institute of Oceanography-VAST*

²*Marine Hydrometeorological Center-MONRE*

³*Vietnam Maritime University*

*E-mail: ledinhmau.vnio@gmail.com

Received: 26-4-2015

ABSTRACT: *This paper presents the basic information on the present status of ocean observation and service in Vietnam with focus on the physical oceanography area. Study results show that in recent years, ocean observations of Vietnam have been equipped with a series of modern measured and analyzed instruments, especially at related offices of the Vietnam Academy of Science and Technology (VAST) and Ministry of Natural Resources and Environment (MONRE). The remarkable progress was to carry out the UAV (Unmanned Aerial Vehicle) program to observe oceanographic conditions in nearshore region by VAST from 2013. Earlier, from 2009 the MONRE carried out the program to establish a network of stations to observe waves and current characteristics in nearshore region by high frequency radar technology. However, the current status of ocean observations and services in Vietnam still has shortcomings in both manpower and equipment and the observations are mostly focused in the nearshore region. Services on oceanographic data are still less professional and public. For sustainable development of ocean observations and service, it is necessary to promote international cooperation projects on oceanography especially in the frame-work of IOC/WESTPAC cooperation.*

Keywords: *Observation, service, instruments, UAV, VAST, MONRE, IOC/WESTPAC.*

INTRODUCTION

Vietnam is a marine country located in the West of the East Sea and has 3,260 km coastline consisting of bays, harbours and more than 3,000 islands with various scales. Vietnam's sea is considered as an important gateway for international shipping. In addition, Vietnam's sea also contains a plenty of natural resources. The sea plays a vital role in Vietnam's economy, coastal area is the dwelling for over 20 million people of 28 provinces and cities. In recent years, annual marine economic activities in Vietnam have accounted for 30% of its GDP, contributing

50% to total value of Vietnam's export and created about 10 million jobs for people in coastal provinces. Basically, to promote the development of marine economy and satisfy the demands of marine resources exploitation, tasks of meteorological and oceanographic surveys are extremely essential and then to be used for scientific foundations to proposal of development strategies of marine economy. The fundamental surveys of meteorology and oceanography would help to improve forecast of dynamic changes in the sea and serve for construction of hydrostructures on sea, exploit marine resources ... Moreover, nowadays, under the impact of climate change phenomena

especially typhoon, storm surges ... Sustained ocean observations and service need to be considered as an essential element for Vietnam's economic development.

HISTORICAL BACKGROUND OF NATIONAL OBSERVATIONS AND SERVICES

Ocean observations and services of Vietnam can be divided into 3 stages:

From 1922 to 1954: Establishment of the IO at Nha Trang under colonial regime of France;

From 1954 to 1975: Period of separated country (North and South Vietnam);

From 1975 to present: Vietnam is a united country.

From 1922 to 1954 (French colonial regime)

The remarkable event was the establishment of the Institute of Oceanography in Nha Trang with name "Service des Pêche de l'Indochine" on September 14th, 1922. On January 1st, 1930, the name of "Service des Pêche de l'Indochine" was officially changed into the "Institut Océanographique de l'Indochine". At the beginning period, the IO was chiefly interested in biological problems and carried out a little oceanographic work. The outstanding result of this period was the establishment of the collection of marine bio-specimen in the East Sea. Its annual reports gave information on the activities of the Institute. Information on tides and tidal currents for that area was obtained from French hydrographic surveys. The tidal station system was constructed along the coast such as Hon Dau, Da Nang, Quy Nhon, Nha Trang, Vung Tau, and Kien Giang. The observed tidal data served for main harbors along Vietnam coast. These tidal stations are still the main tidal stations at present. In 1939 the marine observation station at Hoang Sa island was established by France and it was normally operated till 1974 by the South Vietnam Authority. The Hoang Sa marine station was recognized by the World Meteorological Organization (WMO). Some marine expeditions were carried out along Vietnamese

coast including the Gulf of Thailand and Tonkin, especially in Hoang Sa island region by vessel De Lanessan. From 1939 to 1954 marine observation work came to a standstill by the 2nd world war and the anti-French resistance war.

From 1954 to 1975 (Vietnam war period)

In South Vietnam: under war situation, the marine research programs in both sides of North and South Vietnam were limited. The main work was to carry out some small projects in the nearshore region and to maintain the operation of oceanographic stations, especially for tide gauge system. At that time, the IO in Nha Trang became a member of IOC/WESTPAC. Therefore, IO had an opportunity to join some international cooperation projects, especially NAGA (1959 - 1961), CSK (1965 - 1977) programs. The NAGA program was the international joint project on oceanography between USA-Vietnam-Thailand. The expedition had participation of Stranger vessel from Scripps Institute of Oceanography. NAGA program carried out 5 expedition cruises from 11/1959 to 2/1961 which covered the area between 4⁰N ÷ 16⁰N and extended to 250 miles offshore, 3,895 m water depth, including 6 transects from Da Nang to Ca Mau. Fig. 1 shows one of these expedition cruises.

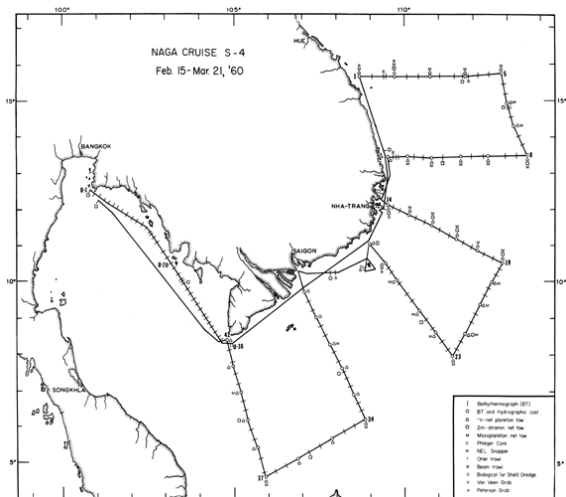


Fig. 1. NAGA cruise S4 from February to March 1960 (NAGA report)

The NAGA program collected a large oceanographic data on hydrodynamics, geology, biology, ecology and environment of South Vietnam waters. The main scientific reports of NAGA program were edited by Wyrcki, Robinson, and Faughn (NAGA report). In the period from 1968 to 1971 the offshore fishery program was carried out in the Vietnam continental shelf waters which was supported by FAO, USA and Holland with the participation of research vessels *Kyoshin Maru 52* and *Huu Nghi*. From 1965 to 1966 the U.S. research vessels *Rchoboth*, *Serano*, *Cable Enterprise* carried out the investigation into marine topography, acoustic structure in the East Sea.

In North Vietnam: Similar to South Vietnam, under Vietnam war condition the marine research programs in North Vietnam were also limited. The main marine research office was located in Hai Phong city named Marine Research Station which belonged to VAST, the other marine research office was the Marine Hydrometeorological Center which belonged to the Vietnam Hydro Meteorological Service. The main marine expeditions of this period were the international cooperation projects: Vietnam - China (1959 - 1962) and Vietnam - Russia (1960 - 1961). The investigated area was in the Gulf of Tonkin to collect the parameters on meteorohydrodynamics, geology, biology, ecology, environment, fishery resources. The vessels such as *Hai Dieu 1, 2, 3*; *Nam Ngu 228, 402*; *Hong Kong 1*; *Tue Ngu 219, 220, 306* from China were participants. The Vietnamese - Chinese joint marine expedition in the Gulf of Tonkin included two programs that were "Integrated expedition for the Gulf of Tonkin (1959 - 1962)" and "Expedition of the bottom fish resources in the Gulf of Tonkin (1959 - 1962)". Also, at that time (1960 - 1961) the Pacific Research Institute of Fisheries and Oceanography (TINRO) of Russia carried out the expedition on marine fishery in the Gulf of Tonkin. The results of joint programs between Vietnam - China, Vietnam - Russia provided the important data sources on marine conditions and fishery resources in the Gulf of Tonkin. The observing station system of these programs is shown in fig. 2.

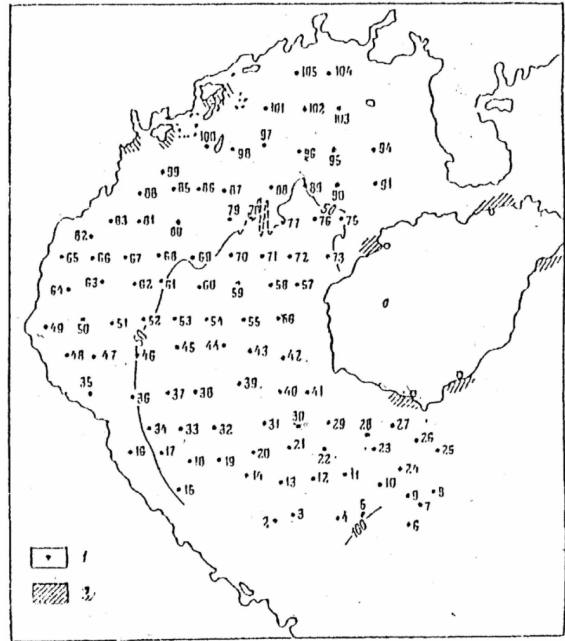


Fig. 2. Survey station system in the Gulf of Tonkin (Vietnamese - Chinese joint project: 1959 - 1962)

From 1975 to present (Vietnam is a united country)

National project on oceanography: From 1977 to present, each 5 years there has been a national program on marine research: 1977 - 1980, 1981 - 1985, 1986 - 1990, 1991 - 1995, 1996 - 2000, 2001 - 2005, 2005 - 2010, and 2011 - 2015. Most of these programs were carried out in the nearshore region which covered the meteorohydrodynamic processes, coastal erosion/deposition, environments, marine resources, integrated coastal management, marine hazard, upwelling phenomena ... The remarkable programs were [1-4].

National program on the integrated investigation in the nearshore region of Thuan Hai - Minh Hai (1977 - 1980). The purpose of this program was to provide the information on natural conditions and resources of study area including meteorohydro-dynamical features, geomorphology, biology and mineral resources;

National program on integrated investigation in the Vietnam continental waters

(Project 48-06/1981-1985) obtained the comprehensive information of natural conditions and resources of study area including meteo-hydro-dynamical features, geo-morphology, ecology, biology and mineral resources;

National program on integrated investigation in the Vietnamese waters (Project 48B/1986-1990) obtained the comprehensive information of natural conditions and resources of study area including meteo-hydro-dynamical features, geo-morphology, biology, social-economy ... for marine economic development policy;

National program (Project KT-03/1991-1996) concentrated on main oceanographical processes and applied oceanography such as hydro-litho-dynamic models, coastal erosion/deposition, shore protection measures;

The following were the national programs such as KHCN-06 (1996-2000); KC.09 (2001-2005, 2006-2010, 2011-2015). These programs have provided a huge data on natural conditions and resources of the Vietnamese waters.

In recent years, Vietnam Administration of Seas and Islands (VASI) has carried out the national program (Project 47) on marine science and technology activities for fundamental investigation and marine resources and environmental management. This program has provided an important data source on natural conditions and resources of Vietnam waters, especially for deep water region. In the period 2011 - 2015, VASI has prepared 14 technical standards for marine science and technology activities [4].

However, all of the above mentioned projects were limited by funding, therefore, the obtained scientific results were not comprehensive and still had shortcoming. Besides these programs, there have been several programs carried out by different authorities and international cooperation to investigate the natural conditions in the East Sea for petroleum exploration. The faculties of oceanography at some universities have carried out different projects on oceanography. Moreover, Vietnamese Navy has also carried out several

projects on marine hydrology for national defence purpose. These data sources have important role for understanding the oceanographic conditions of Vietnam waters.

International cooperation projects: This period had three remarkable joint projects.

Vietnam - Philippines project (1996 - 2008) carried out 4 marine expeditions along the transect Nha Trang - Manila: JOMSRE I (1996), JOMSRE II (2000), JOMSRE III (2005), JOMSRE IV (2008), observing different parameters such as meteo-hydrodynamics, biology, environment ...

Vietnam - German project (2003 - 2009): The first stage was to study the upwelling phenomenon in Southern Vietnam waters with the participation of vessel SONNE which carried out 8 cruises extending to water depth of about 3,000 m. It collected marine parameters such as meteo-hydrodynamics, biology, geology, ecology, environment in four seasons. The second stage was to study the interaction between Mekong river and upwelling water masses with 4 cruises for the period of low and high Mekong river discharges.

Vietnam - USA project (2013 - 2014) studied on the seasonal, annual variations of oceanographic processes in Southern Vietnam waters, observing of different parameters such as meteo-hydrodynamics, biology, environment ... The observed data would be compared to NAGA expedition data.

OVERVIEW OF NATIONAL OCEAN OBSERVING SYSTEM, SERVICES AND ASSOCIATED USERS

At present, in Vietnam the permanent ocean observation stations are managed by the Ministry of Natural Resources and Environment (MONRE) and VAST. But the financial source for observing stations of VAST is depends on MONRE.

Current status of ocean observations and service at VAST

VAST has managed some institutions which have been studying oceanography:

Institute of Mechanics: studying marine mechanical processes;

Institute of Geography: studying meteorological processes related to ocean;

Institute of Geology: studying geological processes related to ocean.

And there are three institutions specializing in marine sciences:

Institute of Oceanography (IO) located in Nha Trang city;

Institute of Marine Resources and Environment located in Hai Phong city;

Institute of Marine Geology and Geophysics located in Hanoi city.

IO has three support units:

Marine Monitoring Station (for Southern Vietnam waters);

Research Vessel NCB - 95 (operation within water depth of 50 m);

Oceanographic Database (VODC).

Current status of ocean observations and service at VAST:

Annually VAST has a scientific program on marine research, with duration of project being about 2 years and with a limited amount of finance for each. However, marine related institutions of VAST often get different projects on marine science from different levels such as national, international.

VAST has 3 environmental monitoring programs in Northern, Central and Southern Vietnam coasts. These programs have been carrying out the seasonal monitoring on coastal water quality such as current, T-S, DO, COD, BOD, and Chl-a, ... at fixed stations along the coast and nearshore islands. VAST also has 5 permanent observation stations located in Hai Phong, Nam Dinh, Dong Hoi, Nha Trang and Can Gio (Ho Chi Minh city). At these stations the daily measure of the sea water quality such as T-S, DO, COD, BOD, Chl-a, ... and nearshore wave observation at Nam Dinh station and hourly measure of tide at Nha Trang have been provided (fig.3).

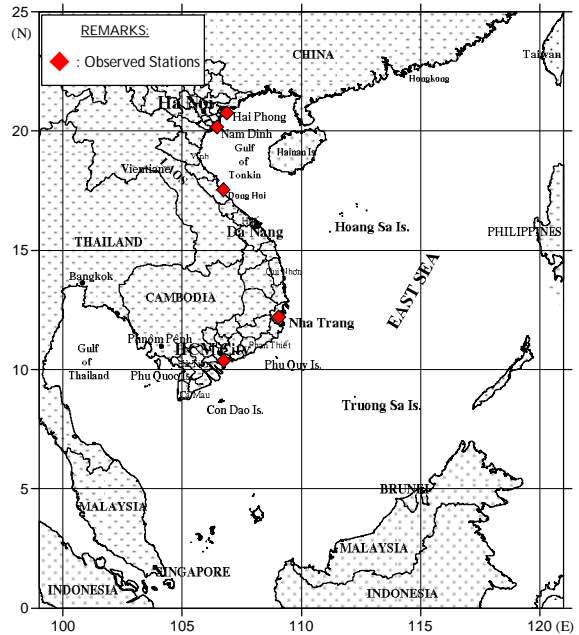


Fig. 3. Permanent marine observing stations of VAST

From 2013, VAST carried out the UAV program to serve the marine observation campaigns. This project has been carried out by the IO. The UVA models AV.UAV.S1, AV.UAV.S2 are equipped with different cameras to observe the marine hydrology, biology, ecology, environment conditions in the coastal region (extending to approximately 100 km offshore), and coastline changes ... (fig. 4).



Fig. 4. The UVA models AV.UAV.S1, AV.UAV.S2 at Nha Trang Coast (5/2013)

Current status of ocean observations and service at MONRE

At present MONRE has some offices related to marine research that are National Center for Hydrology and Meteorology and Vietnam Administration of Seas and Islands (VASI). The VASI has Institute of Marine Management and Center for Oceanography. The vessel Nghien Cuu Bien belongs to the Center for Oceanography. This vessel can operate in the coastal and offshore region of Vietnam Sea.

A network of coastal and island stations for meteorological and oceanographic observation includes 17 fixed stations which were built from 1910 in Northern Vietnam and 1980s in Central and Southern Vietnam. At these stations the meteorological and oceanographic factors have been observed and recorded such as:

Meteorological factors: wind, air temperature, humidity, precipitation, visibility, fog ...

Oceanographic factors: wave, sea level, sea temperature, salinity ...

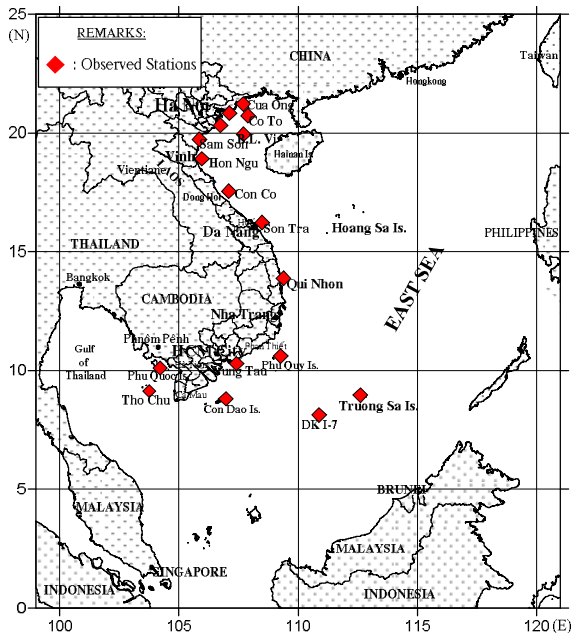


Fig. 5. Current scheme of Vietnam Marine meteorological and oceanographic stations [Managed by the Center for Oceanography]

In recent years, observation equipment has been modernized and automated by Vietnam

Government. Additional devices for 16 meteorological and oceanographic stations (fig. 5) have been equipped including: 11 sensors to measure wind (direction, speed), 10 doppler sensors to measure wave, 8 sensors of buoy and digital type to measure sea water level and 6 sensors to measure sea level by pressure, sensors to measure air temperature, humidity, precipitation, solar radiation, evaporation. These have improved the accuracy of measured data of meteorological and oceanographic factors at coastal areas. However, the distribution of these stations is not suitable. Namely, the density of station in Northern Vietnam is too thick, whereas that in Central and Southern areas is too sparse. Therefore, observed data don't satisfy the demand of scientists to forecast ocean weather, especially for dangerous disaster conditions such as storms, flood ...

From 2009 the Center for Oceanography has installed equipment to measure wave and current by high frequency radar system (4.3 - 5.4 MHz) at three stations at Quang Binh, Ha Tinh and Hai Phong provinces (fig. 6).

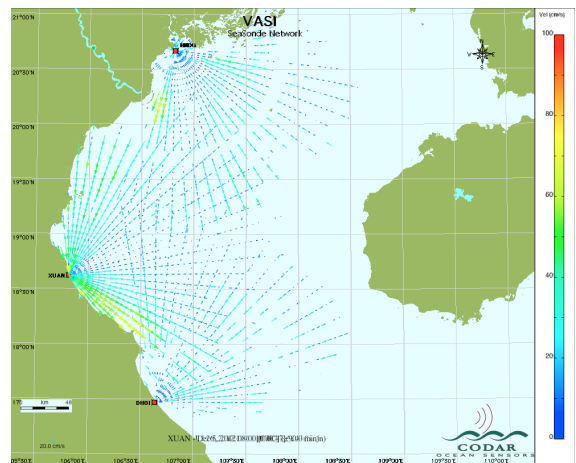


Fig. 6. Scheme of the marine radar stations in Western coast of the Gulf of Tonkin

The central station at Hanoi controls and manages the transmission and reception of signal from 3 stations based on installed softwares in a server which has automatically received data with frequency of 24/24 h in a day. The central station has also been equipped

with data combination software between radar stations, software of data analysis, creation of grids and inter-extrapolation of missed data at cells; software of 2 dimensional current prediction at surface; software of movie creation of 2 dimensional current field; Codar Leeway software for prediction of drift objects for next 12 hours (24 hours) serving for rescue on the sea.

The specification of Hai Phong radar station is as follows: range of surface current measurement of 200 km, range of wave measurement of above 20 km, using low energy which is supplied from battery charged by solar cells. The data are transferred each hour (24/24 h) in a day from this station to central station in Hanoi through satellite by internet;

Ha Tinh and Quang Binh radar stations' specifications are as follows: range of surface current measurement of above 300 km, range of wave measurement of above 20 km. The data are transferred each hour (24/24 h) in a day from these stations to central station in Hanoi through high speed internet (ADSL).

Up to now, these radar stations have started running and have initially collected data of sea surface state such as wave and current serving for the development of economy and society at marine area in Tonkin gulf, the main functions of these stations can be summarized as follows:

Measuring wave and current in all dangerous weather conditions. Forecasting surface current for next 24 hours and warning for next 48 hours in all dangerous weather

conditions (storms and low depression conditions, strong monsoon condition ...). Using radar data as input for numerical models to adjust parameters in predictions of current and waves in coastal area, improve the accuracy of marine forecast; predicting sea state in dangerous marine weather conditions.

Predicting the trajectory of drift objects at sea. From measured data of 2D current field and wave, Codar Leeway modelling can closely specify the location of missing boat or ship after drifting period. These sources of information will help the application of result in searching and rescuing boat and human on sea.

Supporting the monitoring task in environment protection such as predicting oil spill and detecting the origin of oil track to determine causes ... Forecasting oil spill on the sea, helping the managers to give policies of resolution to this problem, supporting fishery. Building the current map (Atlas) for serving the planning of constructions at sea and integrated management in the coastal area.

DATA MANAGEMENT AND COMMUNICATION

IO-VAST manages the National Oceanographic Museum & Aquarium. In the museum nearly 20,000 specimens of marine and fresh water species from Asia and the East Sea region from 1922 and an aquarium system have been collected for research and tourism (fig. 7).



Fig. 7. National Oceanographic Museum & Aquarium at IO-VAST

Vietnam Oceanographic Data Center (VODC for PC) belongs to IO (fig. 8a) and was established in 1997. The domain of study is from 99°E to 125°E; and from 5°S to 25°N. VODC collects, analyses, stores and exchanges oceanographic data from different projects in Vietnam and in the world. The objectives of VODC are:

- Exchanging oceanographic data;
- Providing clients with oceanographic data;
- Tourism;
- Updating of the database.

Interface of VODC is shown in fig. 8b.

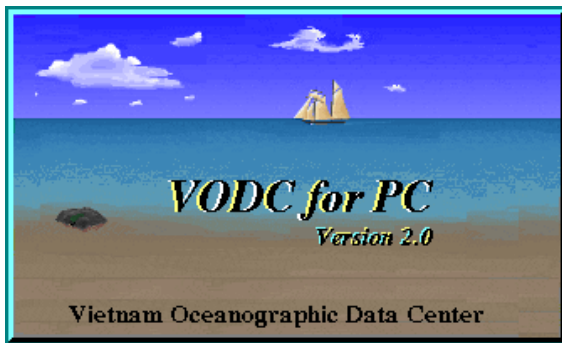


Fig. 8a. VODC for PC at the IO



Fig. 8b. Interface of VODC

Fig. 9 shows the distribution of DO data on the East Sea (1929 - 2002) including 8,150 stations, the number of data of DO is 55,169.

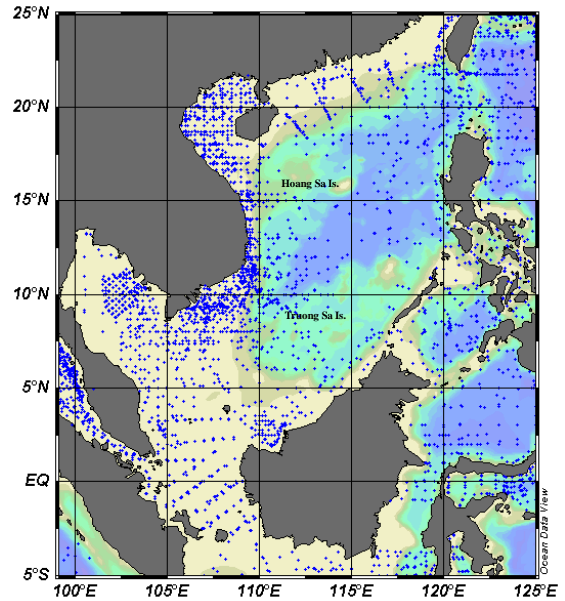


Fig. 9. Distribution of sampling stations for DO in the East Sea (1929 - 2002)

The MONRE has a center for oceanographic data. These stored data can be transferred by the supplying data contract.

At present, the national oceanographic database has been increasing the data exchange with different countries and organizations in the world, especially the Comprehensive Ocean Atmosphere Data Set (COADS). The COADS is the data source which was integrated from NCAR-ERI-NOAA-NCDC and CIRES. The oceanographic data of Japan (JODC) has been becoming the important marine data source for Vietnam [3, 4].

However, the current status of ocean observations and services in Vietnam still has shortcomings such as:

The number of permanent ocean observing stations is limited. The distribution of observed stations is not equal. Observed parameters at each station are limited and not comprehensive. Observation instruments is too limited and underdeveloped. Especially, there is still lack of mooring station system in offshore region.

Most of survey campaigns and measuring instruments are only suitable for nearshore

region (with depth ≤ 50 m). And almost all measuring instruments have not been periodically verified by users.

Remote-sensing data on oceanography is still limited;

Information exchange of collected data between different related institutions is limited;

Services on oceanographic data are still less professional and public.

PERSPECTIVES OF OCEAN OBSERVATION AND SERVICE DEVELOPMENT IN VIETNAM

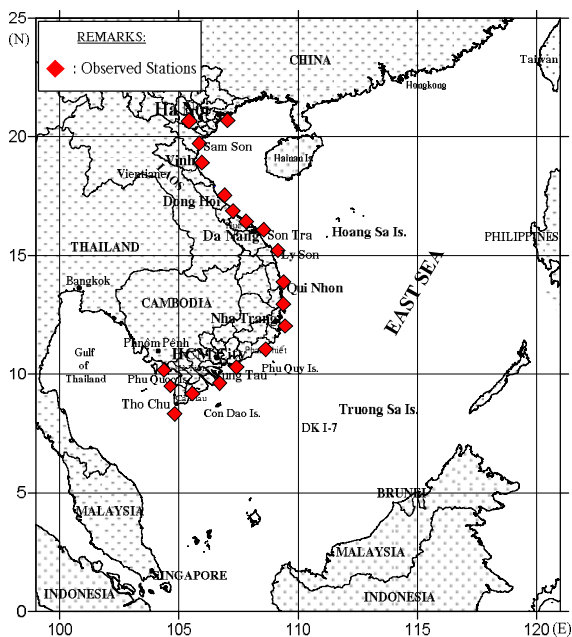


Fig. 10. Perspective on marine radar in Vietnam until 2020

According to the perspective of future observation in Vietnam for 2025 and Vietnam's policy from 2014 to 2020, 15 HF radar stations will be built to measure waves and current which serves for the development of economy in Vietnam coastal area. The ranges of wave and current measurement are above 30 km and 300 km respectively.

From 2014 to 2025, Vietnam will construct more than 27 stations to observe marine resources and marine environment. From 2014 - 2016 (stage I) 9 stations will be installed in

Northern Vietnam waters. From 2017 - 2020 (stage II) 10 stations will be installed in Central Vietnam waters. From 2021 - 2025 (stage III) 8 stations will be installed in Southern Vietnam waters (fig. 10, 11).

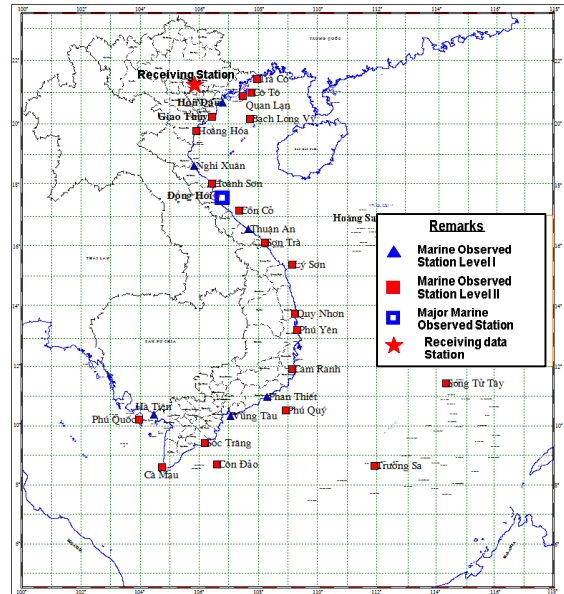


Fig. 11. System of observation stations of marine resource and environment for 2014 - 2025 period

The observed parameters at each station are as follows:

Automatically measuring wind, air pressure, air temperature, precipitation, visibility, solar radiation.

Installing oceanographic stations to observe factors: sea level, wave, current, sea temperature, salinity, pH, DO.

Observing and sampling chemical characteristics of marine water, including: As, Cd, Cr, Pb, Hg, Zn, Cu, Mn; NO_2^- , NO_3^- , NH_4^{3-} , PO_4^{3-} , total P, SiO_3^{2-} .

System transmits signal through satellite internet, high speed internet (ADSL), GPRS, GSM ... Frequency of transfer is at each hour (24/24 h) in a day.

CONCLUSIONS

At present, ocean observations and services in Vietnam still have shortcomings in both manpower and equipment and mostly serve for nearshore region. Public access on oceanographic data is still limited and not professional.

Marine economy plays the most important role in the country development. Therefore, marine research must be developed. Firstly, the ocean observations and services must be enhanced by means of upgrades of manpower in oceanography and by international cooperation in training program. Modern observation and analysis instruments should be equipped, including vessel and mooring station system for marine investigation in the open sea.

Information exchange of oceanographic data between different national and international institutions should be improved. Public access on oceanographic data should also be enhanced. International cooperation projects on oceanography must be promoted, especially in the framework of IOC/WESTPACT.

Acknowledgements: The authors gratefully acknowledge all colleagues for their kind help and encouragement throughout the preparation of this paper.

REFERENCES

1. *Lê Đức Tố (Chủ biên), 2003. Biển Đông. Tập I: Giới thiệu về Biển Đông. Chương trình biển Quốc gia: KH-CN (1996 - 2000). Nxb. Đại học Quốc gia Hà Nội. 454 tr.*
2. *Phạm Văn Ninh (Chủ biên), 2003. Biển Đông. Tập II: Khí tượng, thủy văn, động lực biển. Chương trình điều tra nghiên cứu biển cấp Nhà nước: KH-CN 06 (1996 - 2000). Nxb. Đại học Quốc gia Hà Nội, 565 tr.*
3. *Dương Ngọc Hải (Chủ biên), 2011. Tình hình nghiên cứu khoa học công nghệ biển hiện nay và định hướng nghiên cứu trong giai đoạn tới. Báo cáo khoa học tại Hội nghị khoa học và công nghệ biển toàn quốc lần thứ V, Quyển 1, Tổng quát. Nxb. Khoa học tự nhiên và Công nghệ. Hà Nội, Tr. 1-63.*
4. *Nguyễn Văn Cư, 2011. Một số vấn đề về hoạt động khoa học - công nghệ phục vụ quản lý nhà nước tổng hợp và thống nhất về biển và hải đảo. Báo cáo khoa học tại Hội nghị khoa học và công nghệ biển toàn quốc lần thứ V, Quyển 1, Tổng quát. Nxb. Khoa học tự nhiên và Công nghệ. Hà Nội, Tr. 64-73.*

HIỆN TRẠNG QUAN TRẮC VÀ DỊCH VỤ HẢI DƯƠNG HỌC TẠI VIỆT NAM

Lê Đình Mậu¹, Trần Hồng Lam², Nguyễn Mạnh Cường³

¹*Viện Hải dương học-Viện Hàn lâm Khoa học và Công nghệ Việt Nam*

²*Trung tâm Khí tượng thủy văn biển-Bộ Tài nguyên và Môi trường*

³*Trường Đại học Hàng hải Việt Nam*

TÓM TẮT: Bài báo trình bày những thông tin cơ bản về hiện trạng quan trắc và dịch vụ hải dương học tại Việt Nam trong những năm gần đây, nhất là trong lĩnh vực hải dương học vật lý. Kết quả nghiên cứu cho thấy, trong những năm gần đây, quan trắc hải dương học đã được trang bị nhiều thiết bị đo đạc và phân tích hiện đại, nhất là tại Viện Hàn lâm Khoa học và Công nghệ Việt Nam (VAST) và Bộ Tài nguyên và Môi trường (MONRE). Nổi bật nhất là dự án sử dụng máy bay không người lái (UAV) nhằm quan trắc các đặc trưng hải dương học ven bờ do VAST tiến hành từ

năm 2013. Trước đó, năm 2009 Bộ Tài nguyên và Môi trường tiến hành dự án thiết lập hệ thống trạm quan trắc sóng và dòng chảy ven bờ bằng công nghệ radar với tần số cao. Tuy nhiên, hiện nay công tác quan trắc hải dương học và dịch vụ tại Việt Nam còn nhiều bất cập cả về nguồn nhân lực và trang thiết bị, các trạm quan trắc tập trung chủ yếu tại dải ven bờ. Dịch vụ dữ liệu hải dương học vẫn còn thiếu chuyên nghiệp và đại chúng. Để phát triển bền vững công tác quan trắc và dịch vụ hải dương học cần thiết phải tăng cường hợp tác quốc tế, đặc biệt trong khuôn khổ của Ủy ban liên chính phủ về hải dương học khu vực Tây Thái bình dương (IOC/WESTPAC).

Từ khóa: *Quan trắc, dịch vụ, thiết bị, UAV, VAST, MONRE, IOC/WESTPAC.*