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Distribution characteristics of temperature, salinity, chlorophyll-*a*, and sound speed in the Da Nang and Quy Nhon waters

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Abstract
This paper presents some main characteristics of the distributions of temperature, salinity, chlorophyll-*a*, and sound speed, which were measured in the Da Nang and Quy Nhon waters in July, 2010. The CTD was deployed for measuring profiles of temperature and salinity at stations. The data showed that in the Da Nang water, concentration of chlorophyll-*a* ranged from 0.07 μg/l to 1.52 μg/l and decreased toward the offshore region. In the Quy Nhon water, concentration of chlorophyll-*a* varied from 0.05 μg/l to 1.43 μg/l. This concentration was quite small and homogenous from the surface to 28 m depth. The speed of sound in seawater was maximum with value of 1,543.8 m/s in the Da Nang transect while the water layer with the sudden change of sound speed was from 5 m to 10 m deep in nearshore region (from stations D1 to D4), and from 10 to 15 m deep in offshore region (in D5 and D6 stations). Its minimum value in the Da Nang transect is just 1,014 m/s in the bottom. In the Quy Nhon transect, the maximum value of sound speed in seawater was 1,545.2 m/s and the minimum value was 1,515.2 m/s. The nearshore sound velocity reaches its maximum in the surface layer down to 30 m deep and the offshore one is similar down to about 40 m deep, under which, the sound velocity declines steadily.

Keywords: Salinity, temperature, sound speed, Da Nang, Quy Nhon.

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INTRODUCTION

In the seawater, the transmissions of electromagnetic waves and light waves with different wavelengths are almost prevented, and the use of lasers to determine the depth of the seabed is also very limited. The use of sound waves for communication, detection of targets, mapping of the bottom, monitoring of the movement of submarines, tracking the attack of torpedoes, determination of the distance of resonated sound objects, looking for the ‘dark sound’ areas as a safe haven for submarines,... have been conducted since the early twentieth century, but the accuracy and effectiveness of this method have just been improved for a few decades as the completion of the research equipment has been raised [1, 2]. The research projects on the speed of sound in the sea in Centre of Vietnam have currently been limited. Therefore, study on the distribution of the temperature, salinity, and speed of sound aims to contribute to the general knowledge of marine science, also to solve the essential issues because of the domestic requirements. The Da Nang and Quy Nhon waters are important for both the water transportation activity and the national security. Therefore, study on the spatial distribution of the speed of sound has a great meaning to support economic development and national security.

MATERIALS AND METHODS

Data availability

The measured data of water temperature, salinity and chlorophyll-*a* from a survey conducted during 1/7/2010–7/7/2010 was used to investigate the distributions of the speed of sound and chlorophyll-*a* in the Da Nang and Quy Nhon waters under the cooperation between the Institute of Marine Environment and Resources (Vietnam Academy of Science and Technology) and the Hydrosphere Atmospheric Research Centre (Nagoya University, Japan) on “Drifting buoy observation along Vietnam coast in summer 2010”. The vertical profiles of temperature and salinity data in the Da Nang and Quy Nhon waters were measured by using a compact CTD with 0.1 m depth at six stations in each transect (figure 1 and table 1).

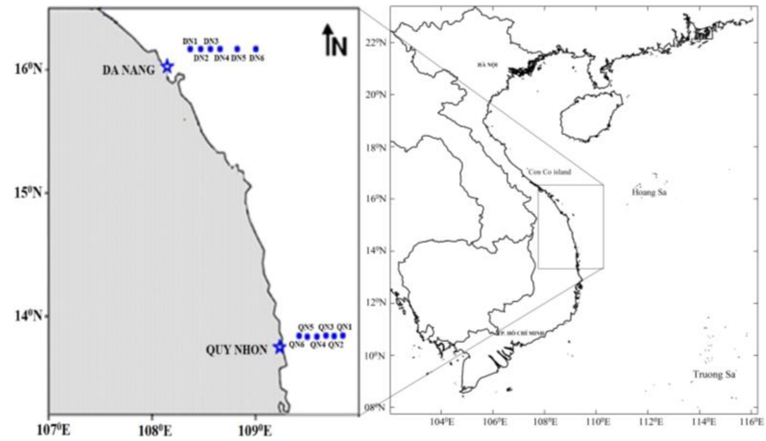


Figure 1. Map of stations in the Da Nang and Quy Nhon waters

Table 1. Location of six stations in the Da Nang and Quy Nhon waters

No.	Da Nang		Quy Nhon	
	Latitude (N)	Longitude (E)	Latitude (N)	Longitude (E)
1	$16^{o}10'00''$	$108^{o}22'00''$	$13^{o}50'00''$	$109^{o}30'00''$
2	$16^{o}10'00''$	$108^{o}28'00''$	$13^{o}50'30''$	$109^{o}25'24''$
3	$16^{o}10'00''$	$108^{o}34'00''$	$13^{o}50'00''$	$109^{o}40'00''$
4	$16^{o}10'00''$	$108^{o}39'30''$	$13^{o}50'24''$	$109^{o}35'19''$
5	$16^{o}10'00''$	$108^{o}49'30''$	$13^{o}50'00''$	$109^{o}50'00''$
6	$16^{o}10'00''$	$109^{o}00'00''$	$13^{o}50'30''$	$109^{o}45'36''$

Sound speed computation

The speed of sound in the seawater depends on the temperature (T), salinity (S), and hydrostatic pressure (P) of seawater. The intimate relationship is expressed as the following formula:

$$C = C_o + \Delta C_T + \Delta C_S + \Delta C_P + \Delta C_{TSP}$$

Where: C_o: Standard sound speed; ΔC_T, ΔC_S, ΔC_P: The correction due to the effects of temperature, salinity, hydrostatic pressure; ΔC_{TSP}: The correction due to the coincidental effect of temperature, salinity, hydrostatic pressure. Hydrostatic pressure, however, is a function of depth, so it is possible to calculate the sound speed in water through the parameters of temperature, salinity and depth.

There are several methods to compute the speed of the sound in the sea. In this study, we used the equation given by Mackenzie (1981) [3] which represents the speed of sound in seawater as a *function* of salinity, temperature and depth.

$$C = 1,448.96 + 4.591T - 5,304\times10^{-2}T^2 + 2.347\times10^{-4}T^3 + 1.340(S-35)$$
$$+1.630\times10^{-2}D + 1.675\times10^{-7}D^2 - 1.025\times10^{-2}T(S-35) - 7.139\times10^{-13}TD^3$$

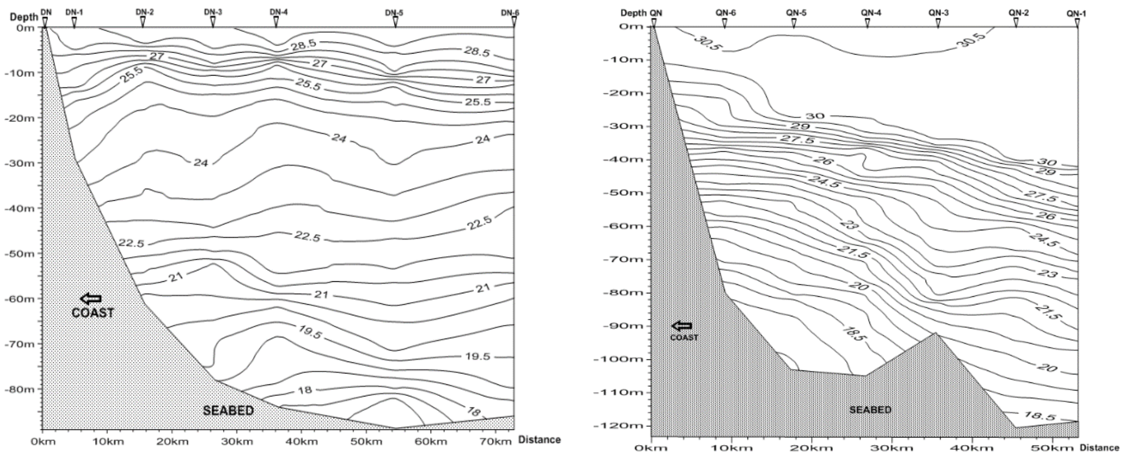
Where: T: Sea water temperature (^{o}C); S: Sea water salinity (‰); D: The depth of water layer (m).

The above equation gave accurate results in temperature range of 2–30^{o}C, salinity of 25–40‰, depth of 0–8,000 m [4].

RESULTS AND DISCUSSION

Temperature and salt structures

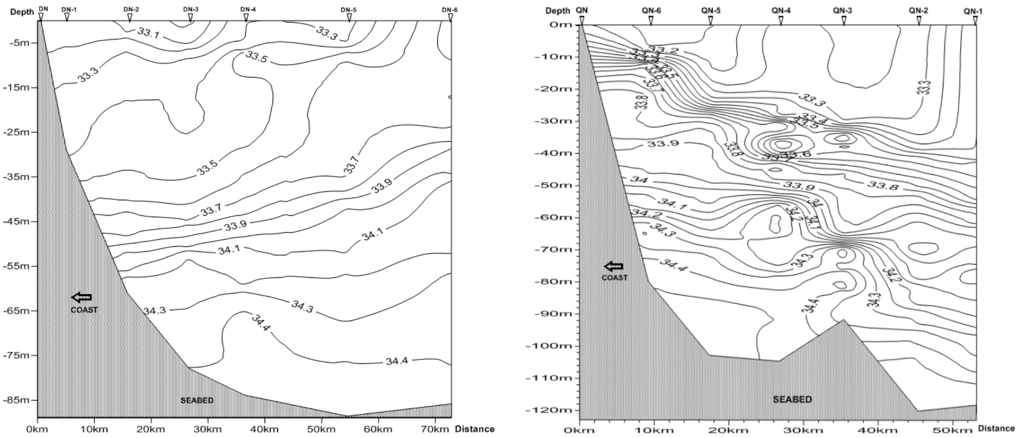
The Central Vietnam's water is deep region with a large transparency, open sea, and the water is exchanged directly with the offshore region, so structure of temperature - salinity should be presented as the case study in the offshore region. In the Da Nang transect, thickness of surface mixed layer was approximately 5 m. The salinity from 5 m to 20 m depth in coastal areas was well mixed. In the Quy Nhon transect, the temperature tends to rise gradually from the nearshore to offshore regions and to decrease from the surface to the bottom. The homogeneous layer of surface temperature in offshore area is down from 0 m to a depth of 35–40 m while this exists only at a depth of about 5–10 m in coastal areas. The homogeneous layer is followed by the mixed layer of the temperature with a trend to decrease gradually in depth (fig. 2).



a) Da Nang b) Quy Nhon

Figure 2. Vertical distributions of temperature (^{o}C) along Da Nang and Quy Nhon transects

The homogeneous salinity layer has also the distribution rules similar to that of the homogeneous temperature layer. The mixed layer in salinity, however, was quite complicated (especially in coastal areas, stations QN-3 and QN-2), with the dramatic fluctuation in depths of 30–40 m and 70–90 m. In the period of the prevailing Southwest monsoon and resulting upwelling in July on the Southwest coast of Vietnam, the water mass transport of the southwest surface water invades the southern sea on the latitude of 9^o North. There is a presence of the denatured winter - summer water mass in the offshore water. That is disturbance and the rise of the maximum salinity in Quy Nhon coast (fig. 3).

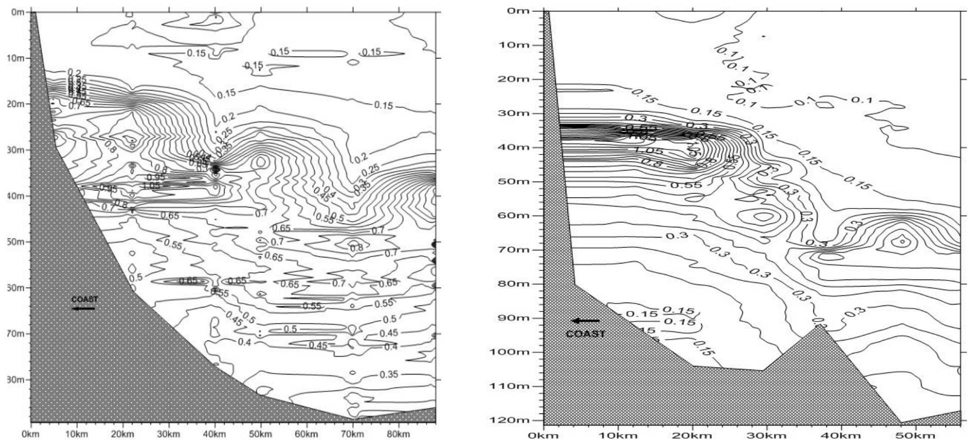


a) Da Nang b) Quy Nhon

Figure 3. Vertical distribution of salinity (S‰) at Da Nang and Quy Nhon transects

Chlorophyll-*a*

In the Da Nang water, chlorophyll-*a* varies between 0.07 μg/l and 1.52 μg/l, chlorophyll-*a* decreases from shore to offshore water. According to vertical distribution, chlorophyll-*a* increases from the surface down to a depth of about 40–45 m, then decreases with depth. The class that has the strongest variation of chlorophyll-*a* (mutative class) is from 12 m to 22 m depth in coastal areas and from 32 m to 42 m in the offshore area. In the surface layer from 0–12 m in coastal areas and 0–25 m in the offshore area, chlorophyll-*a* is relatively homogenous and less variable. At a depth of 40–45 m, chlorophyll-*a* reaches a maximum value (fig. 4a).



a) Da Nang b) Quy Nhon

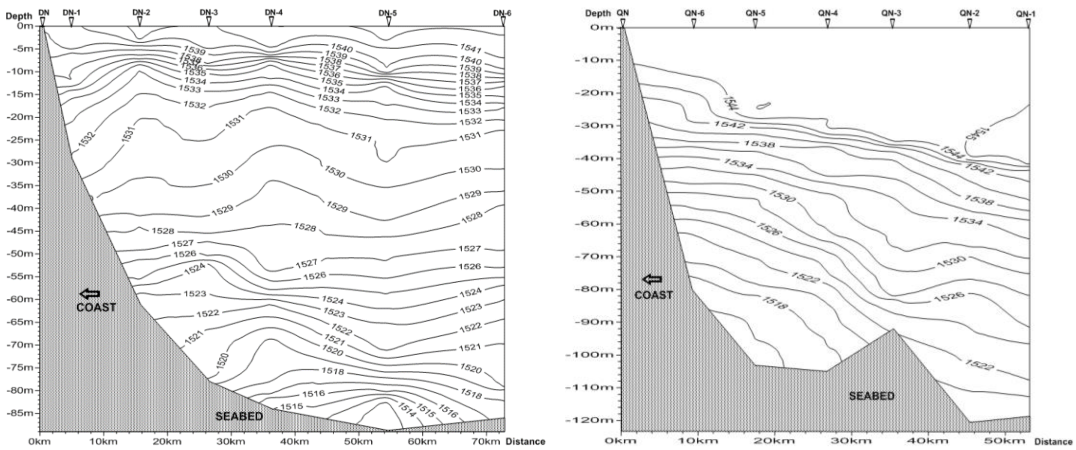
Figure 4. Vertical chlorophyl-*a* distribution (μg/l) according to depth

In the Quy Nhon water, chlorophyll-*a* changes from 0.05 μg/l to 1.43 μg/l, chlorophyll-*a* decreases from shore to offshore water. In coastal areas (about 26 km away from the coast), chlorophyll-*a* increases from the surface down to 40 m depth, then reduces gradually with depth. From the surface layer to a depth of about 28 m, chlorophyll-*a* is fairly small and homogenous. The mutative class lies at a depth of 40–50 m. In the place 30 km from shore to the offshore region, chlorophyll-*a* tends to rise gradually with depth. The layer where chlorophyll-*a* has the most significant change (mutative layer) is located at a depth of about 60–70 m, however gradient of chlorophyll-*a* is smaller than the variability in the coastal region (fig. 4b).

Acoustic velocity distribution

There are four types of sound rays: plus refraction (type I), minus refraction (type II), the transition of minus refraction from the upper layer to the plus refraction in the underlying layer (type III) and the underground (type IV) [5, 6].

Through the chart of the acoustic velocity distribution in Da Nang transect (figure 5a), sound velocity reaches its maximum in the surface layer (from surface to a depth of about 17 m) and fluctuates in the range from 1,544 m/s to 1,545 m/s. The vertical gradient of sound velocity in the surface layer is small, and averaged vertical gradient of sound is about 0.03 at the station DN-2 and about 0.17 at the station DN-6. From the surface, the sound velocity experiences a significant reduction and this is called the mixed layer of sound velocity, at about 5–10 m depth in the coastal area (stations DN-1, DN-4), and at the depth from 10 m to 15 m in the offshore water (stations DN-5, DN-6). In this layer, the sound velocity declines sharply, the vertical gradient of velocity reaches the average value of about 1.31 at the station DN-2 and about 0.96 at the station DN-6. Below this layer, the sound velocity decreases gradually with depth, attains the average value of 0.21 at the station DN-2 and 0.25 at the station DN-6. The contours of sound velocity in the surface layer has the distribution similar to the distribution of the sine function, this can be explained by the reflection mechanism of the rays: When the sound beam passed down the layers to the mixed heat-salt layer, it would be reflected to the sea surface where it would be reflected back again to the water environment. In general, the sound velocity tends to be declined with the depth and to be homogeneous horizontally. However, in offshore area, the mixed layer of the sound velocity is deeper than that in the coastal areas.



a) Da Nang b) Quy Nhon

Figure 5. The vertical distribution of sound velocity

In Quy Nhon transect, it is clearly seen that the sound velocity tends to fall gradually from the surface to the bottom and descends from the offshore to nearshore regions corresponding to depth. At the depth of about 40 m (station QN-1, figure 5b) in the offshore area, there is a zone in which the sound velocity reaches the maximum value (1,545.23 m/s), the minimum value of sound velocity across the cross-transect is 1,515.19 m/s at a depth of 103 m at station QN-5. The maximum velocity exists from the sea surface to a depth of about 30 m in coastal areas, and from the surface to a depth of about 40 m in the offshore water. In this layer, the sound velocity is relatively uniform but below this layer it is the mixed layer which has the rapid decline of sound velocity. From the surface to the depth of the mixed layer, the sound velocity tends to increase slightly with vertical gradient value (0.017). On the other hand, it begins to collapse with vertical gradient value (0.35) from the mixed layer to the bottom. From the sea laws about changing the vertical sound velocity, the refraction of the rays on this cross-transect belongs to the refracting type III (a type of refraction which occurs when the sound velocity increases in the surface layer and decreases from the lower boundary of this layer to the bottom).

CONCLUSIONS

With the data availability, the vertical distribution data of temperature and salinity (*T-S*) is still limited in Vietnam. In this investigation, analyzing and calculating the monitoring data have initially given the picture of *T-S* structure and the vertical distribution of sound velocity. The distribution characteristics of *T-S* structure and the sound velocity in July, 2010 are affected by the Southwest monsoon and water circulation. In the studied zone, Da Nang and Quy Nhon waters, the maximum of the sound velocity exists from the surface layer to a depth of about 30 m and 40 m in the coastal and offshore areas, respectively. The sound speed is quite homogeneous in this layer and would be declined rapidly in lower levels.

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REFERENCES

[1] Tran Anh Tu, Le Duc Cuong, Do Trong Binh, Akihiko Morimoto, Tetsuo Yanagi, 2011. The structure of temperature-salinity and speed of sound in seawater in Da Nang - Quy Nhon area. *Proceedings of Workshop "International Cooperation on Investigation and Research of Marine Natural Resource and Environment", Hanoi & Ha Long - Vietnam, September 15–17th, 2011*. pp. 243–250.

[2] Tran Anh Tu, Le Duc Cuong, Pham Hai An, 2013. New results on temperature-salinity vertical structure in water of Hai Phong coastal area. *Proceedings of VAST - IRD Symposium on Marine Science, Hai Phong - Vietnam, November 28–29th, 2013*. pp. 283–288.

[3] Mackenzie, K. V., 1981. Nine-term equation for sound speed in the oceans. *The Journal of the Acoustical Society of America*, *70*(3), 807–812. https://doi.org/10.1121/1.386920.

[4] JFE Alec Co., LTD, 2008. Calibration Sheet the Compact-CTD (ASTD687).

[5] Pham Van Thuc, 2004. The sound velocity field in the upwelling zone in the South Central Vietnam. *Vietnam Journal of Marine Science and Technology*, *4*(1), 23–24.

[6] Nguyen Ba Xuan, 2008. The structure and distribution characteristics of the seasonal average sound velocity in sea areas of Vietnam. *Final report of projects of the Vietnam Academy of Science and Technology*.