Collection of Marine Research Works, 2002, XII: 39-50

STUDY ON THE VARIATION OF THE VERTICAL STRUCTURE OF TEMPERATURE AND SALINITY AT THE REGIONS OF VIETNAMESE CONTINENTAL SHELF IN JUNES OF 2000 AND 2001

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ABSTRACT In this paper, on the basis of temperature and salinity data measured at the mooring stations in Vietnamese continental shelf in Junes of 2000 and 2001, some studied results on the variation of vertical structures of temperature and salinity are presented.

The vertical structures of temperature and salinity at the regions of Vietnamese continental shelf have different shapes and are influenced by specific dynamical conditions in different regions.

At the station Tr.LT1, the vertical structures of temperature and salinity have normal shape of coastal sea regions where the exchange of the water masses in deep layers is rather weak. At the stations Tr.LT8, Tr.LT14, Tr.LT20 and Tr.LT25, the vertical structures are influenced by water-mass exchange with the cold current system and upwelling phenomenon during the summer time in the western coastal zones of the East Sea (South China Sea).

NGHIEN CÖU SÖ BIEN ÑOI CUA CAU TRUC NHIET - MUOI THANG ÑÖNG TAI CAC VUNG BIEN THEM LUC ÑÒA VIET NAM TRONG THANG 6 NAM 2000 VA 2001

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TOM TAT Tren cô sô cac so lieu ño ñac ve nhiet muoi tai cac tram lien tuc ô cac vung them luc ñòa Viet Nam trong 6/2000 va 6/2001, ña tien hanh phan tích va so sanh sö bien ñoi cua cau truc nhiet - muoi thang ñöng. Ket qua nghien cöu cho thay rang: Sö bien ñoi cau truc nhiet - muoi thang ñöng tai tat ca cac tram co dang cau truc töông ñoi khac nhau, bieu thò sö anh höông bôi cac ñieu kien ñong löc ñac thu ô cac vung nghien cöu. Ô vung bien cua tram lien tuc Tr.LT1, cau truc thang ñöng nhiet - muoi co dang cau truc thong thöông nhö ô cac vung nöôc gan bô vôi sö trao ñoi nöôc nam ngang yeu ô cac tang sau. Con tai cac tram Tr.LT8, Tr.LT14, Tr.LT20, Tr.LT25, cau truc phan bo thang ñöng nhiet - muoi co dang bò anh höông ô töng möc ño khac nhau do sö trao ñoi nöôc nam ngang va thang ñöng vôi he dong chay lanh va hien töông nöôc troi trong thôi ky mua he ô cac vung bien bô tay Bien Ñong.

I. INTRODUCTION

In the framework of the National Project on Fundamental Investigation and Research on the Natural and Environmental Conditions of the East Sea (South China Sea) to serve the increasing requirements of national economy, two surveys in the coastal continental shelf regions of Vietnam were carried out in Junes of 2000 and 2001. The study on the variation of vertical structures on the basis of temperature and salinity data measured at 5 mooring stations has been conducted. The received results helped to understand the change of the vertical structure at different regions and their relation with specific dynamical conditions such as the cold current system and upwelling phenomenon in the western coastal zones of the East Sea.

II. USED DATA

In this paper, the temperature and salinity data measured at 5 mooring stations of coastal continental shelf of the provinces: Hai Phong (Tr.LT1), Quang Binh (Tr.LT8), Quang Nam (Tr.LT14), Binh Dinh (Tr.LT20) and Binh Thuan (Tr.LT25) (Fig. 1) were used. The data were measured by the temperature - salinity - depth recording instrument AST-500 of Japan with vertical resolution through 0.5m of depth. The data were very good for analyzing and comparing the variation of vertical structures of temperature and salinity in different sea regions. Some information about the mooring stations are given in table 1.

Table 1: Some information about mooring stations

Study regions	Symbol of stations	Measured time	Latitude	Longitude	Bottom depth (m)
Hai Phong	Tr.LT1	19 - 20/6/2000	20°08.182'	107°40.503'	33m
Quang Binh	Tr.LT8	10 -11/6/2000	17°14.432'	107°00.535'	31m
Quang Nam	Tr.LT14	4 - 5/6/2000	15°43.686'	108°43.537'	52m
Binh Dinh	Tr.LT20	16 - 25/6/2001	13°30.688'	109°22.423'	38m
Binh Thuan	Tr.LT25	13-15/6/2001	10°52.762'	108°48.752'	33m

III. STUDY RESULTS

The results of calculation of vertical structural characteristics of temperature and salinity at different mooring stations are given in table 2. The detailed information of each station is as follows:

1. At the mooring station Tr.LT1

At the mooring station Tr.LT1 (in the western sea region of Bach Long Vi island of Hai Phong city), the vertical structures of temperature and salinity have normal shape of coastal water regions where there are weak horizontal and vertical exchanges of water masses at the deep layers. The vertical structure is divided into three layers (Figs 2 & 3, Tab. 3): the surface

homogeneous layer with water thickness of nearly 10m with high average temperature and low average salinity; the deep homogeneous layer with water thickness of nearly 20m, the average temperature is 1°C lower and average salinity is 0.8 ‰ higher that of surface homogeneous layer; the seasonal thermocline layer has small thickness (4m) and big gradient of salinity (0.09‰/m). Study on variation of the diurnal oscillatory amplitudes and standard deviations of the temperature and salinity (Figs 4, 5, 6, and 7; Tab. 3) showed that they decreased rapidly and reached minimal values at the sea bottom because in deep layers there isn't horizontal exchange of water masses originated from different sea regions. In the surface homogeneous layer the variation of diurnal oscillatory amplitudes of temperature and salinity is higher than in other layers because there is a strong influence of tidal phenomenon in the exchange of coastal water masses.

Table 2: The vertical structural characteristics of temperature and salinity in different sea regions

Station	ht	hs	T.ht	S.hs	Zt	Zs	GradT	GradS	Dt	ds	T.dt	S.ds
Tr.LT1	6	7	28.90	32.25	4	5	0.15	0.090	21	20	28.10	33.05
Tr.LT8	5	6	27.60	32.53	22	17	0.20	0.007	6	8	23.00	32.70
Tr.LT14	10	11	28.00	32.60	26	29	0.18	0.015	14	12	22.80	33.40
Tr.LT20	9	9	28.40	33.50	30	29	0.15	0.017	-	-	-	-
Tr.LT25	10	11	28.70	33.00	19	16	0.14	0.028	7	9	26.10	33.55

Legend:

- ht and hs: thickness (m) of surface homogeneous layer of temperature and salinity.
- T.ht and S.hs: average temperature (°C) and salinity (‰) of ht and hs.
- Zt and Zs: thickness of seasonal thermocline and halocline (m).
- GradT, GradS: average gradients of temperature (°C/m) and salinity (‰/m) of seasonal thermocline and halocline.
- dt and ds: thickness (m) of deep homogeneous layer of temperature and salinity.
- T.dt and S.ds: average temperature and salinity of dt and ds.

2. At the mooring station Tr.LT8

The mooring station Tr.LT8 is in the coastal region of Quang Binh province. As it lies in the western coastal region of the mouth of Tonkin Gulf, where there are rather strong horizontal and vertical exchanges of the open sea and coastal water masses, beside that, a strong west wind flowing from the coast to the sea has been observed, therefore the vertical structure has another shape. The seasonal thermocline has a big thickness (nearly 17m). The average temperature and salinity of all water columns at this station are lower and higher, respectively, than at station Tr.LT1 (Figs 2, 3; Tab. 4). In addition to that, in this region the diurnal

oscillatory amplitudes and standard deviations of temperature and salinity had increased from the water surface to the depth of 10m, then decreased to the depth of 17m, increased again to the depth of 25m and after that decreased again to the sea bottom (Figs 4, 5, 6, 7; Tab. 4). On the basis of above results we can give some explanations about the formation of vertical structures of temperature and salinity. This is due to the influence of horizontal and vertical exchanges of water masses with the different temperature and salinity in the under surface layers.

Table 3: The diurnal average values (T.tb, S.tb), oscillatory amplitudes (ΔT, ΔS) and standard deviations (Stdev.T, Stdev.S) of temperature and salinity at station Tr.LT1 in June 2000

Depth (m)	T.tb (^{o}C)	S.tb (‰)	ΔT (^{o}C)	ΔS (‰)	Stdev.T (^{o}C)	Stdev.S (‰)
0	29.09	32.17	1.21	1.02	0.41	0.33
5	28.90	32.36	1.07	0.94	0.37	0.30
10	28.27	32.71	0.34	0.51	0.12	0.19
15	28.11	32.89	0.33	0.37	0.12	0.13
20	27.98	33.00	0.18	0.20	0.07	0.06
25	27.93	33.05	0.25	0.11	0.09	0.04
30	27.91	33.06	0.28	0.09	0.10	0.04

Table 4: The diurnal average values (T.tb, S.tb), oscillatory amplitudes (ΔT, ΔS) and standard deviations (Stdev.T, Stdev.S) of temperature and salinity at station Tr.LT8 in June 2000

Depth (m)	T.tb (^{o}C)	S.tb (‰)	ΔT (^{o}C)	ΔS (‰)	Stdev.T (^{o}C)	Stdev.S (‰)
0	27.64	32.53	1.34	0.37	0.52	0.15
5	27.52	32.54	1.22	0.33	0.49	0.12
10	26.19	32.71	2.07	0.22	0.79	0.09
15	25.08	32.83	0.62	0.05	0.20	0.02
20	24.33	32.75	0.87	0.17	0.26	0.07
25	23.41	32.70	1.13	0.12	0.42	0.04
30	23.12	32.71	0.55	0.06	0.21	0.02

3. At the mooring station Tr.LT14

At the mooring station Tr.LT14 (in the southern region of Cu Lao Cham Island of Quang Nam province), the vertical structures, diurnal oscillatory amplitudes and standard deviations of temperature and salinity had changed as the same as at the station Tr.LT8 (Figs 2, 3, 4, 5, 6, 7 and Tab. 5). At the stations Tr.LT8 and Tr.LT14 there is one water layer with slight high salinity under the surface layer. This layer is formed due to the salinity increase in the surface water caused by the evaporation process in the dry and hot climatic conditions. This water layer after increasing the salinity had sunk into the depths of 17m (Tr.LT8) and 25m (Tr.LT25).

Table 5: The diurnal average values (T.tb, S.tb), oscillatory amplitudes (ΔT, ΔS) and standard deviations (Stdev.T, Stdev.S) of temperature and salinity at station Tr.LT14 in June 2000

Depth (m)	T.tb (^{o}C)	S.tb (‰)	ΔT (^{o}C)	ΔS (‰)	Stdev.T (^{o}C)	Stdev.S ‰)
0	28.16	32.53	1.11	0.17	0.35	0.05
5	28.01	32.53	0.41	0.09	0.15	0.03
9	27.83	32.62	0.52	0.26	0.21	0.10
15	26.91	33.00	1.12	0.64	0.42	0.25
20	26.03	33.23	1.30	0.14	0.56	0.05
25	25.10	33.25	2.38	0.17	0.85	0.07
30	24.02	33.15	1.59	0.26	0.56	0.09
36	23.12	33.05	1.28	0.14	0.46	0.05
40	22.95	33.11	0.78	0.26	0.30	0.09
45	22.78	33.22	0.86	0.14	0.28	0.06
50	22.48	33.29	0.36	0.07	0.14	0.02

4. At the mooring station Tr.LT20

At the mooring station Tr.LT20 (in the coastal region of Binh Dinh province), the vertical structures of temperature and salinity decreased and increased respectively from the surface to the bottom. The vertical structure in this region can be divided into two main layers: the surface homogeneous layer with the water thickness of nearly 8m and the deep thermocline with the thickness of 30m and small gradients of temperature and salinity (Figs 2, 3, 4, 5, 6, 7 and Tab. 6). This specific vertical structure shape is observed in the coastal upwelling region and caused by strong influence of the south - west monsoon wind and cold current system in the western coastal zone of the East Sea. Study on the diurnal oscillatory amplitudes of temperature and salinity also showed that they increased rapidly from the

surface to the sea bottom. In the sea bottom the temperature and the salinity reached to the maximal values of 5.08°C and 0.87‰ respectively. This is due to the strong horizontal water exchanges at deep water layers that had caused vertical movements of waters from the sea bottom to the surface (Figs 4, 5, 6, 7 and Tab. 6).

Table 6: The diurnal average values (T.tb, S.tb), oscillatory amplitudes (ΔT, ΔS) and standard deviations (Stdev.T, Stdev.S) of temperature and salinity at station Tr.LT20 in June 2001

Depth (m)	T.tb (°C)	S.tb (‰)	ΔT (°C)	ΔS (‰)	Stdev.T (°C)	Stdev.S (‰)
0	28.42	33.26	1.33	0.34	0.31	0.14
5	28.33	33.24	1.23	0.56	0.26	0.11
10	28.09	33.28	1.97	0.45	0.38	0.10
15	27.45	33.36	3.49	0.52	0.75	0.09
20	26.51	33.45	3.79	0.60	0.98	0.10
25	25.72	33.52	4.60	0.56	1.02	0.10
30	25.00	33.60	5.65	0.67	1.06	0.12
35	24.18	33.68	6.04	0.87	1.04	0.18
38	23.76	33.75	5.08	0.87	1.07	0.19

5. At the mooring station Tr.LT25

At the mooring station Tr.LT25 (in the coastal region of Binh Thuan province), the vertical structure is divided into three layers: the surface homogeneous layer with the water thickness of nearly 11m, the average temperature and salinity with the values of 28.70°C and 33‰ respectively; the seasonal thermocline with the thickness of 17m and the gradients of temperature (0.14°C/m) and salinity (0.028‰/m); the deep homogeneous layer with water thickness of nearly 8m, average temperature of 26.10°C and average salinity of 33.55‰ (Figs 2 and 3; Tab. 7). The diurnal oscillatory amplitudes of the temperature and salinity had increased to the depth of 20m, then decreased again to the sea bottom. In the layer of 20m the diurnal oscillatory amplitudes of temperature and salinity had reached to the values of 2.70°C and 0.53‰ respectively (Figs 4, 5; Tab. 7). The variation of the standard deviations of the temperature and salinity had the same law as the diurnal oscillatory amplitudes (Figs 6, 7; Tab. 7). On the basis of above results, it is possible to estimate the important role of vertical movements of deep waters in the formation of vertical structure of the temperature and salinity. In comparison with the studied results of former publications on the hydrological and dynamical

conditions in upwelling region of Binh Thuan and Ninh Thuan provinces [1, 2, 3, 4, 5], it is understood that the sea region at station Tr.LT25 had characteristics of the vertical structures of temperature and salinity as the same as in the upwelling water edge region.

Table 7: The diurnal average values (T.tb, S.tb), oscillatory amplitudes (ΔT, ΔS) and standard deviations (Stdev.T, Stdev.S) of temperature and salinity at station Tr.LT25 in June 2001

Depth (m)	T.tb (^oC)	S.tb (‰)	ΔT (^oC)	ΔS (‰)	Stdev.T (^oC)	Stdev.S (‰)
0	28.81	33.00	0.84	0.20	0.30	0.07
5	28.83	33.02	0.82	0.19	0.28	0.06
10	28.79	33.02	0.86	0.20	0.31	0.06
15	28.31	33.11	1.93	0.46	0.63	0.14
20	27.45	33.27	2.73	0.54	0.93	0.17
25	26.45	33.48	1.59	0.28	0.47	0.09
30	26.10	33.54	0.55	0.09	0.17	0.03
34	26.03	33.55	0.46	0.08	0.13	0.02

IV. CONCLUSIONS

Finally, a summary on the studied results could be given as following: beside the station Tr.LT1, where the vertical structures of temperature and salinity had the normal shapes of the coastal water regions, the vertical structures at other stations: Tr.LT8, Tr.LT14, Tr.LT20, Tr.LT25 had the shapes influenced in different levels by the horizontal and vertical water exchanges. At these stations there were big water thickness of seasonal thermocline, the diurnal oscillatory amplitudes have increased in the depth. These conclusions are correspondent with the studied results, which were published before in the different papers.

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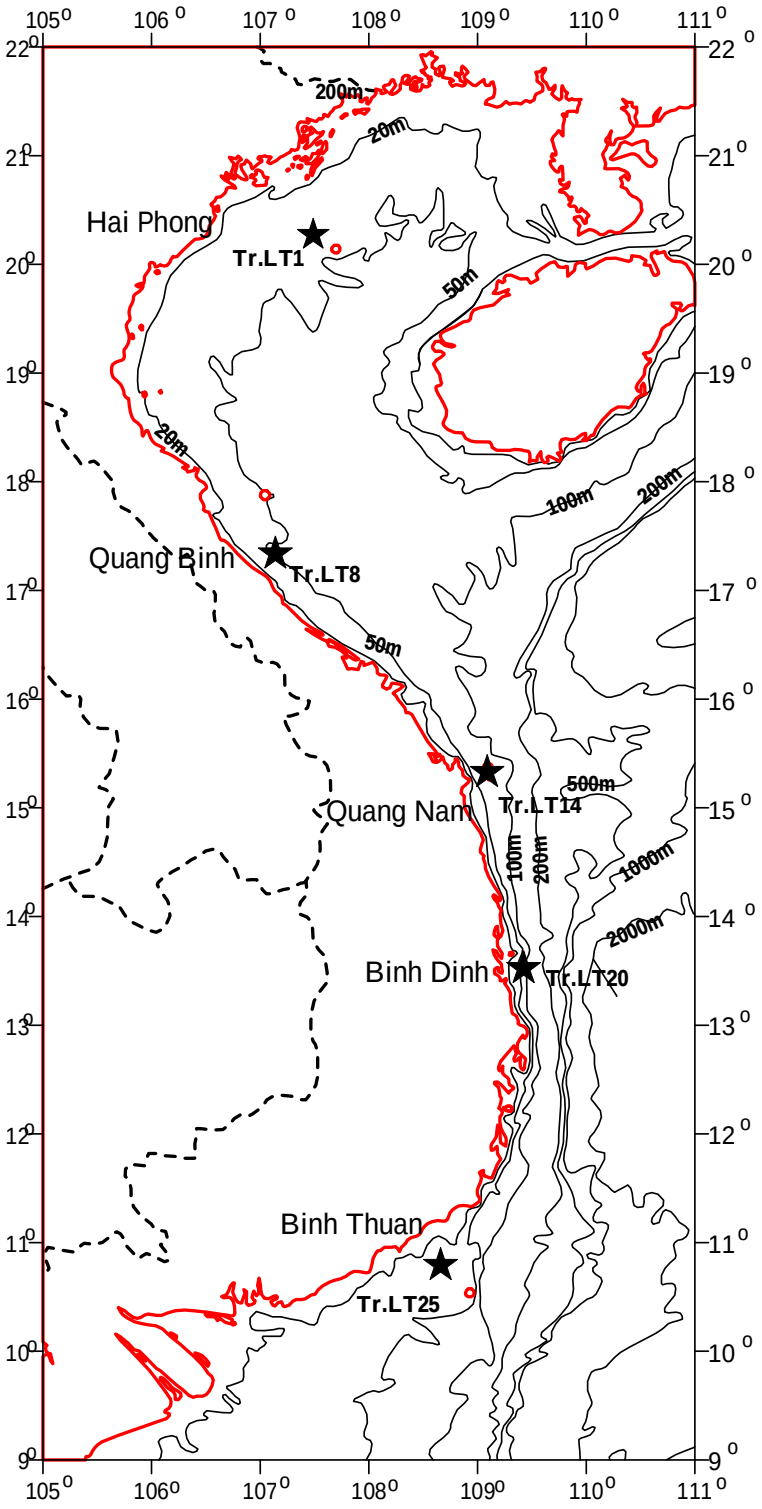

Fig. 1: Coordinates of the mooring stations in the studied area

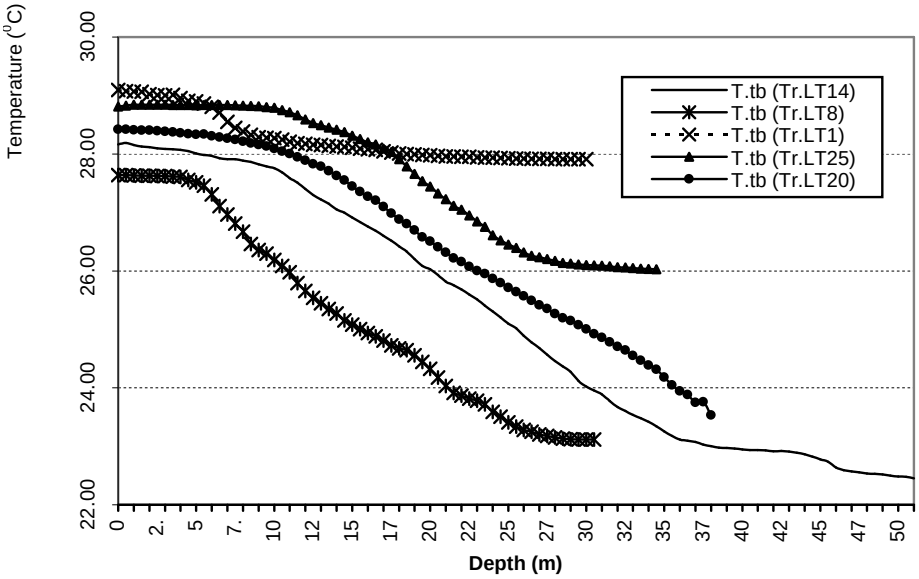

Fig. 2: The diurnal average tempratures in the sea regions of Vietnamese shelf in Junes of 2000 and 2001

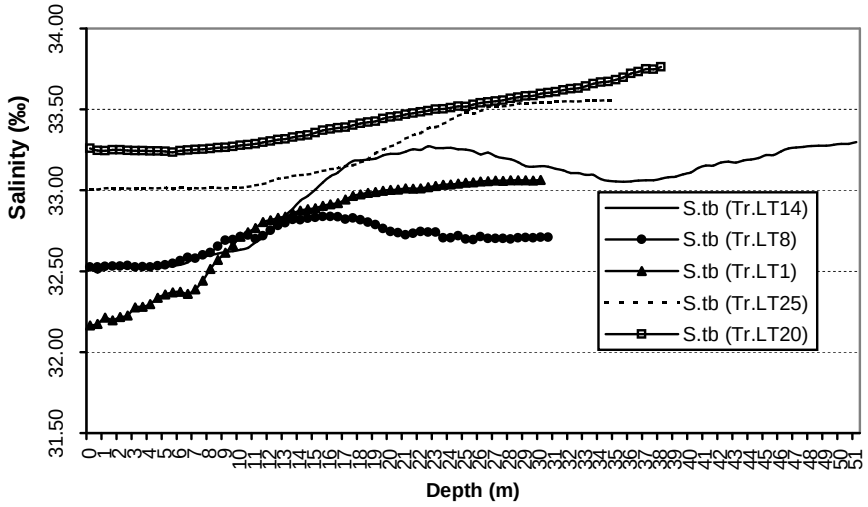

Fig. 3: The diurnal average salinity in the sea regions of Vietnamese shelf in Junes of 2000 and 2001

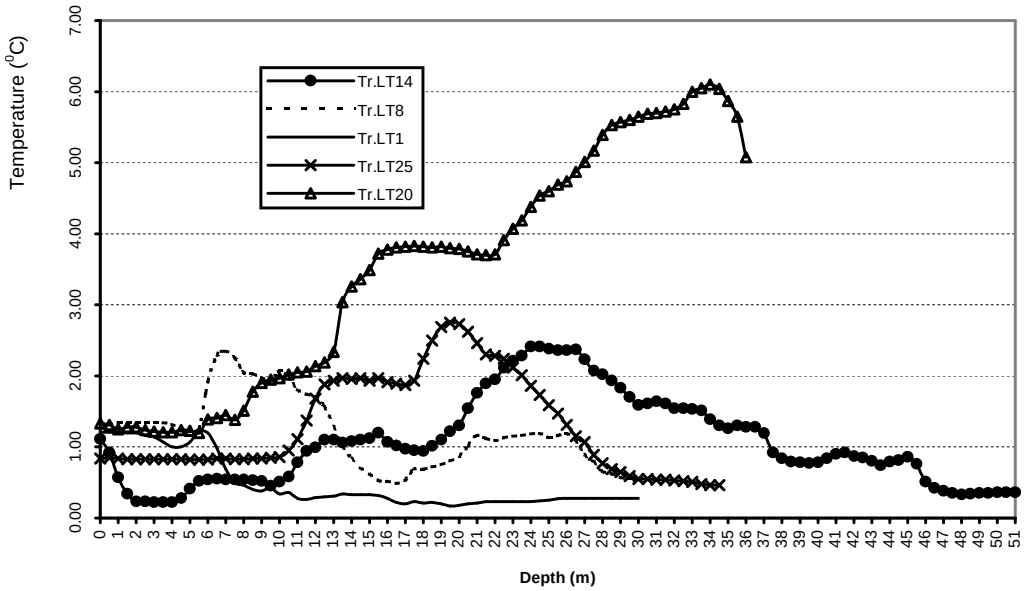

Fig. 4: The diurnal oscillatory amplitudes of temperature in the sea regions of Vietnamese shelf in Junes of 2000 and 2001

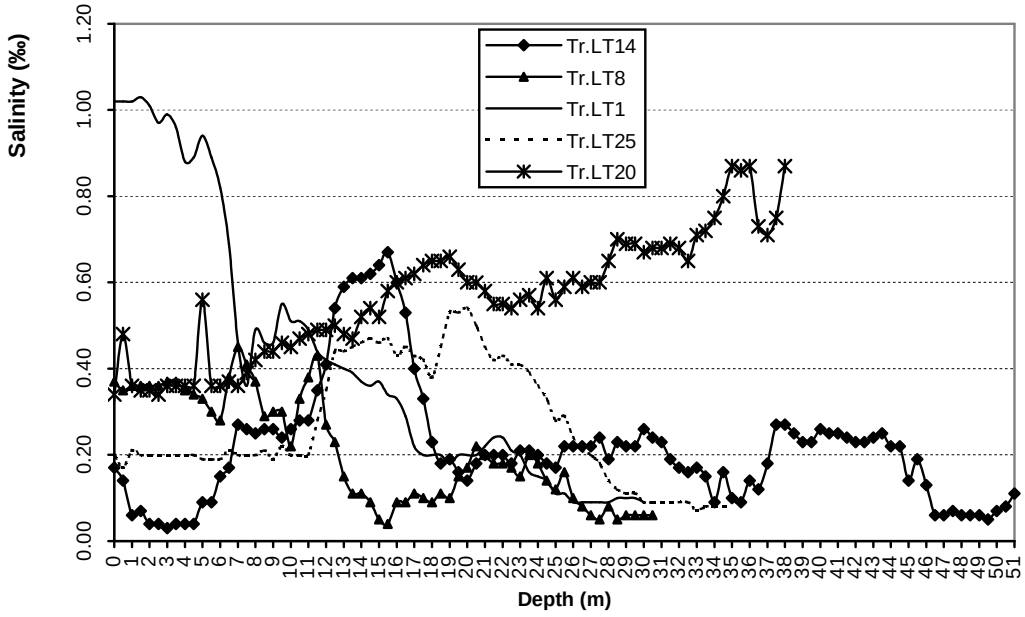

Fig. 5: The diurnal oscillatory amplitudes of salinity in the sea regions of Vietnamese shelf in Junes of 2000 and 2001

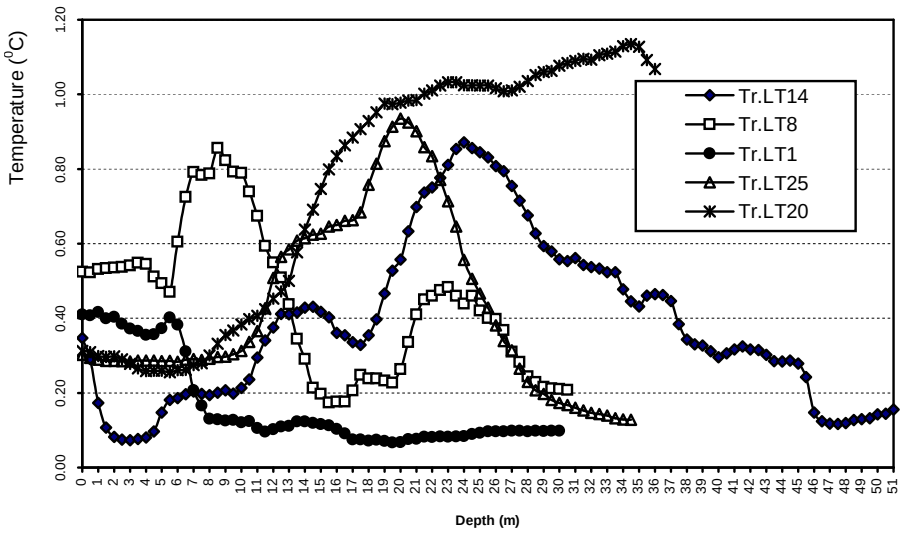

Fig. 6: The standard deviations of temperature in the sea regions of Vietnamese shelf in Junes of 2000 and 2001

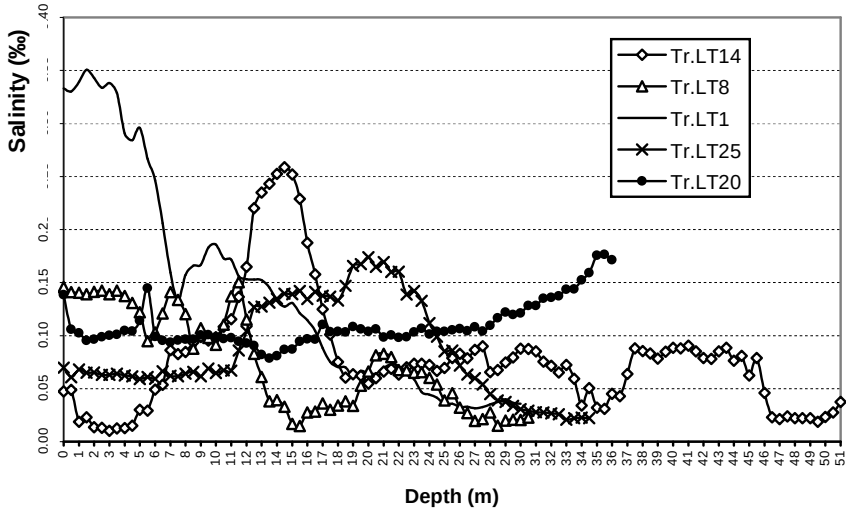

Fig. 7: The standard deviations of salinity in sea regions of Vietnamese shelf in Junes of 2000 and 2001