

The Seasonal Thermocline Affectivity by the Flow of Arvand River in Northwestern Part of the Persian Gulf

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Abstract:

The Persian Gulf is a water basin that is connected to Oman Sea and oceans through Strait of Hurmoz. This field is very important regarding the biological, fishery, military and navigation studies. Ebb and flow, wind, evaporation, light and precipitation occur there and are effective on thermocline formation. Furthermore, entrance of the flow of Arvand River into the northwestern part of Persian Gulf also affects this event considerably. According to the previous researches, Baroclinicity and stratification of the fluid column are two characteristics that seasonally occur in the Persian Gulf in a varying manner. In fact, the constitution of thermocline and the transfer of its axis regarding the space and time indicate turbulence activities and internal waves in the water environment. In this paper, constitution of thermocline and its affectivity by entrance of flow of Arvand River into the northwestern Persian Gulf are studied. The obtained results and their analysis in the area and the results of the measurements are compared against the results of a numerical model.

Keywords:

Persian Gulf, Thermocline, Baroclinicity, Arvand River

Introduction

If we consider the mechanism of the events as different factors in the sea environment, we could use these mechanisms in the analyses of their effects in the water basin. In Persian Gulf water, many investigations and measurements have been performed; including Mount Mitchel, 1992 research investigation in factors and this research has been performed on the basis of this measurement. Persian Gulf is an important strategic area in the Mid-East countries like Iran, Emirates, Oman and Qatar make use of this water field in areas such as navigation, fishery and commercial ties.

Thermocline separates from the two upper and lower layers by the severe temperature decrease like a substratum layer. The internal waves are created in this layer for various reasons which cause break due to the turbulence. The turbulence mixture happens in summer due to effective factors like; wind, ebb and flow, evaporation, light and the river entrance [11]. In the intersection of the two layers in the column of the sea water, the internal waves are displaced and transfer some of the turbulence kinetic energy [4].

The water with more salinity flows from the Persian Gulf to the district with 200 to 350 m depth of Oman Sea in the northeast of the Indian Ocean while the fresher water enters in to the Persian Gulf from the open sea and creates the salinity stratification [10]. The buoyancy flow of the mixed layer when the stratification of the fluid column is done leads to low scale

convection in this layer [8]. In shallow water, two factors make analysis of this issue difficult. First, the orbital movement made by the gravity surface waves creates a fluctuant border-lined layer.

Second, the geometry and topography of the bed are not pre recognized [2]. By Baroclinicity study and the convection of the internal wave in the fluid column, the thermocline expansion by the place and its relevance with the time is understood in Persian Gulf. Fengchao (2004) investigated the water circulation due to the water trade-off in the Strait of Hurmoz by modeling the mass transfer via Strait of Hurmoz (Kular; et, al, 2004) execute a 3- dimensional model for the shallow water of the Persian Gulf and simulated the composition and distribution trend of the internal waves thorough this Strait.

Determining the interdependence of internal waves with the thermocline expansion resulted from the tensions have been the main results of this research. The water flow of Arvand River in to the Persian Gulf is also one of the factors of thermocline formation via the stratification of the water column in the north of Persian Gulf and is considered in this study.

The area under study

The Persian Gulf is situated in [47-57] E, [24-30] N geographic area with 900 (km) * 300 (km) dimensions. In addition, Baroclinicity and turbulence exist in its northern part, since the flow entering from the river; the bed tension and wind have more effects in this part in comparison with the deep part of the Persian Gulf. In winter, we have denser water in the northern part of the Persian Gulf in comparison with the hotter southern and western parts [10]. The density stratification is resulted from the entrance the river and the precipitation in the Persian Gulf and the northern parts [8]. Figure (1) shows the area under study.



Figure 1. The aero picture of the entrance mouth of the flow of Arvand River into the Persian Gulf.

The Research Analysis Method:

Atmosphere plays an important role in water circulation and variation of physical parameters of sea water [10]. As we know, the entrance of the flow of Arvand River into the Persian Gulf in the northwestern part of the Gulf helps stratification of water column and as a result, the internal waves could be created. Of course, the density gradient all over the Persian Gulf and in summer indicates the thermocline constitution resulted from the heat factors and the stress of the wind in this season. The stress of the wind on the surface of open water is very effective in these processes.

- An atmospheric disturbance creates an inertia wave.
- turbulence is resulted due to the stress of the internal waves.
- the lack of balance in the horizontal and vertical directions collapses the water column.

Also the internal waves have this ability and can transfer the energy needed for the turbulence formation and the annual salinity variations are observed in the coastal region [9]. The existence and distribution of the internal waves in this basin is distinguishable due to the effective factors according to the changes in temperature- gradient diagrams in the fluid column.

Figure (2) shows three main regions of summer thermocline composition in Persian Gulf according to the temperature profiles.

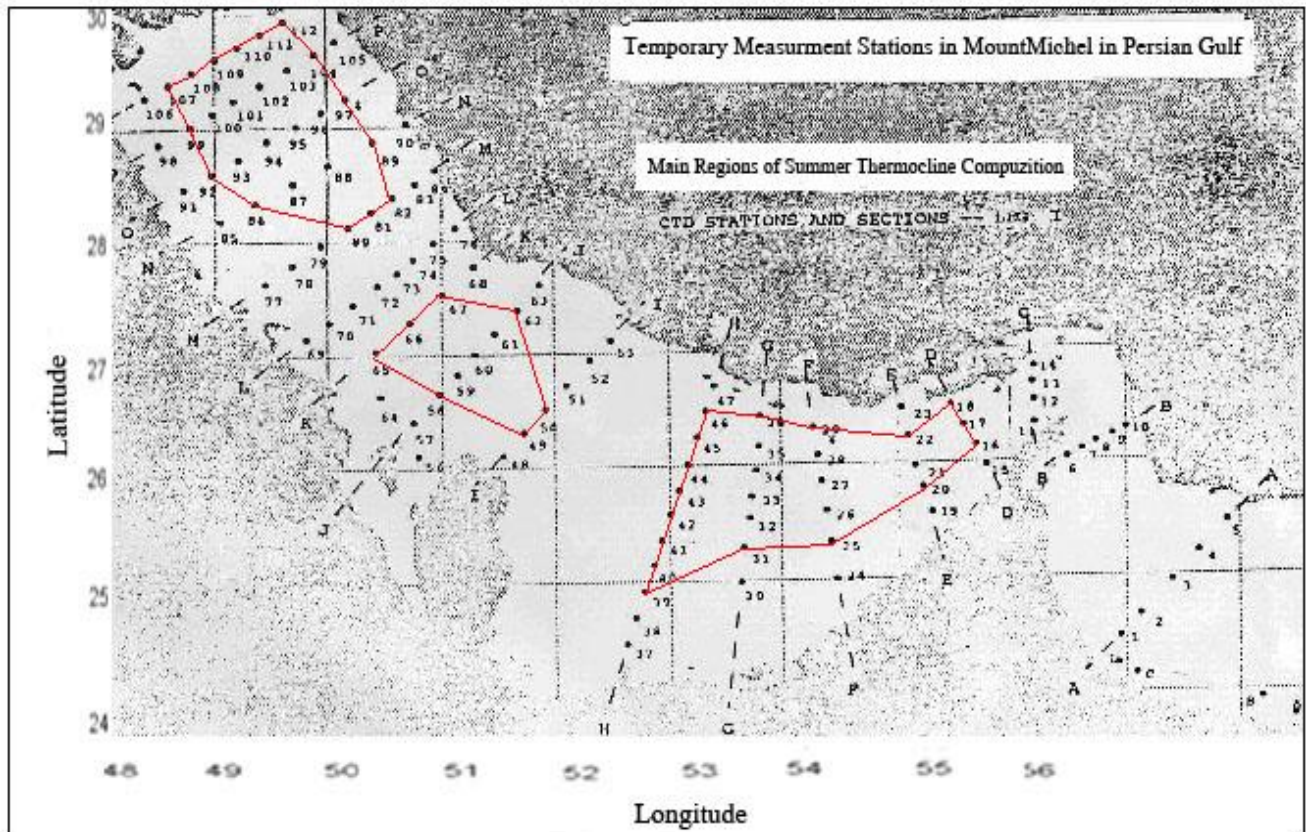


Figure2. Measurement stations in Persian Gulf with three main regions of summer thermocline composition.

Figure (3) shows the temperature mean in three main regions of summer thermocline composition in the Persian Gulf. In fact, after drawing the temperature profiles in the measurement stations in Mount Michel, three main regions (the north of Persian Gulf, the middle or deep part of Persian Gulf and near Strait of Hurmoz) , the thermocline constitution was made in the from of the above figure. By drawing the profiles of the temperature mean, salinity and density in the summer in three regions as you could see in below, the summer thermocline constitution is mainly observable in these regions, of course, according to the diagrams below, among the reasons of thermocline constitution in the summer in the northern area, we could name the north western winds and the entrance of Arvand river into the Persian Gulf and the region near the Strait of Hurmoz, the permanent water trade- off with Oman sea and the stratification of the water column in this part of Persian Gulf.

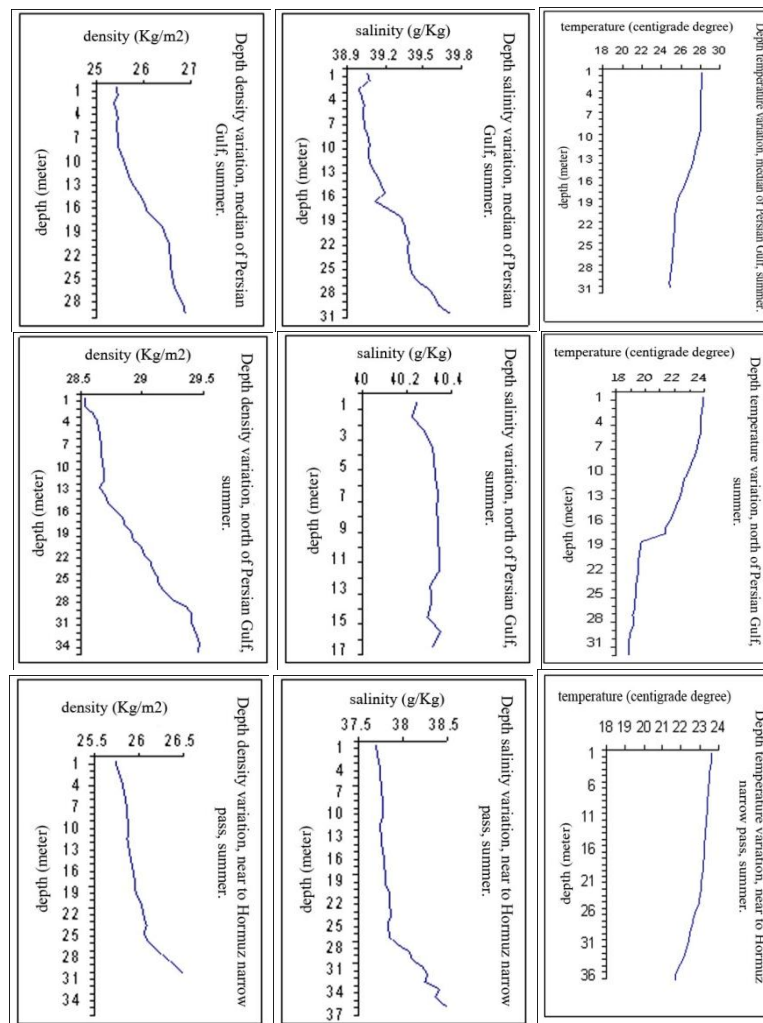


Figure 3. Depth density, salinity and temperature variation in the north, median and to Hurmoz in summer.

As we see in the above diagrams, density variation is increasingly with depth that shows seasonal thermocline making in the Persian Gulf and in the summer. So, interior waves along with seasonal changes in Persian Gulf can have a variable presence. However, unlike winter, that just in Hurmoz narrow pass, because of water continual exchanges between Persian Gulf and Oman sea and water pile layer formation, thermocline is making. In the summer you can see thermocline making all over the Persian Gulf that in other studies we gained the same results of thermocline making; But in general (based on depth temperature variation analysis in the measurement station in the Persian Gulf and in the two seasons of winter and summer) in the three parts: Northern, middle or near to Strait of Hurmoz thermocline formation is obviously seen and separable.

As we can see in the temperature variation diagram of Northern Persian Gulf, heat sudden decrease in the sub layer is because of Persian Gulf summer heat gradient; However because of Arvand river stream in this situation and the amount of cold water with 1.5 thickness and some deal low salinity made this heat fall to reach it's maximum (with respect to Persian Gulf and near to Strait of Hurmoz) and formation of this summer thermocline in the north west of Persian Gulf happens because of Arvand river stream in the Persian Gulf. In this diagram, in the confine depth 10 to 18 meters, the heat decreases from 22 to 18 and with a light incline that shows the effect of Arvand river stream in the Persian Gulf in this position and because

of water pile layer formation. Entrance of Arvand water in the north west of Gulf to this water confine is one of the reasons of inside Fluor pile layer formation and waves, and can help growing of turbulence [6].

Materials and methods

In this study, we analyze summer thermocline formation against winter. Flow and ebb, evaporation, wind, sunshine and Hurmoz narrow pass entrance streams from Oman Sea and Arvand River to Persian Gulf in the North West, are of the most popular stands and problems available in the zone. Depth data provided from national center of oceanography (ETOPO2 data) are used and because of any same level topography, zone uneven bed and the important effect of those streams, these data became tabulate lightly. In the figure (4), Persian Gulf topography diagram is presented, to have a more understanding of the zone topography which is studied in this research.

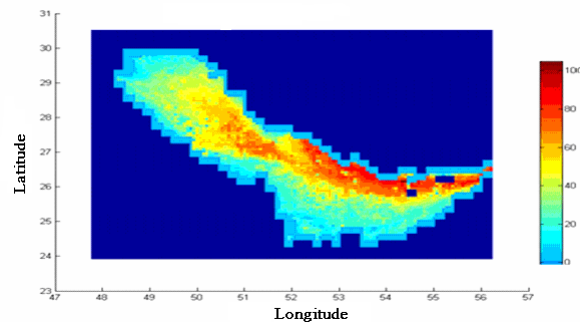


Figure 4. Persian Gulf topography

Beside, to analysis the formation of summer thermocline, depth variation diagram of these two quantities in two seasons in index stations of 16, 52, 80, 93 and 103 are as following.

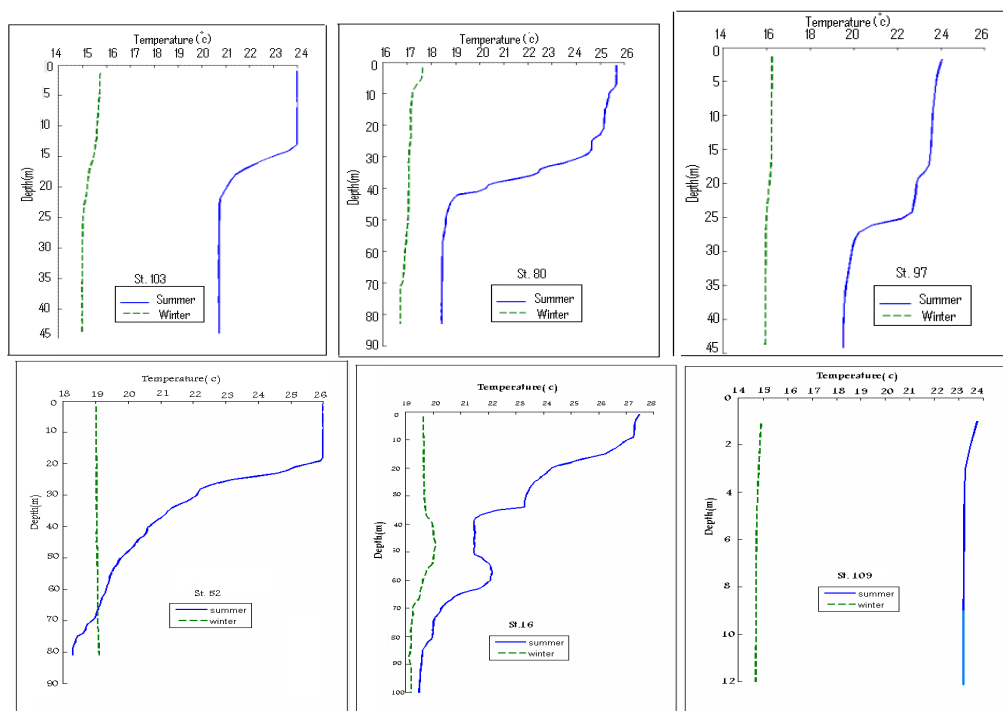


Figure 5. Temperature variation with depth in some Persian Gulf measurement stations in the summer and winter.

Temperature variation against depth in some of summer and winter measurement stations of Persian Gulf. In the temperature – depth diagrams and in summer not with standing winter, we can outcome temperature breaking in sub layers because of thermocline formation. However, depth – salinity diagrams in these stations and in two seasons of summer and winter are presented in the appendix part of this study.

In two seasons of summer and winter in some temperature and salinity measurement stations based on measured data ROPME in 1991, the geographic situation of these analyzing stations are alike table 1. In fact, via these analysis, temperature and salinity popularization (based on crewman) has done to all over the Persian Gulf, and the summer and winter temperature and salinity resulted from this popularization will be study.

Table 1. Geographic situation of 29 temperature and salinity popularization station of Persian Gulf in summer and winter.

Station #	Depth (meter)	Latitude	Longitude
16	133	2609.960	5550.660
17	54	2619.890	5543.260
20	56	2546.780	5518.110
22	108	2610.670	5503.360
26	36	2531.350	5436.790
28	91	2602.270	5435.690
31	37	2511.500	5347.000
34	80	2552.390	5352.280
40	49	2514.700	5248.700
42	46	2534.050	5257.820
45	113	2614.700	5322.830
50	62	2627.050	5155.260
52	110	2654.390	5221.590
60	21	2656.170	5118.380
62	56	2717.470	5143.610
65	78	2709.780	5544.020
67	90	2730.510	5110.850
71	79	2723.190	5014.000
73	115	2738.540	5036.500
78	49	2745.970	4943.550
81	61.5	2807.000	5020.000
86	39	2814.160	4930.180
88	76	2837.310	5006.110
93	67	2847.330	4913.470
95	70	2856.200	4937.960
100	35.5	2910.600	4859.800
102	30	2912.400	4929.600
108	22	2932.500	4856.000
110	10.5	2945.570	4925.560

In the figure 6, research study zone with highlighting summer index thermocline specifying station and salinity and temperature popularization station to all over the Persian Gulf is presented.

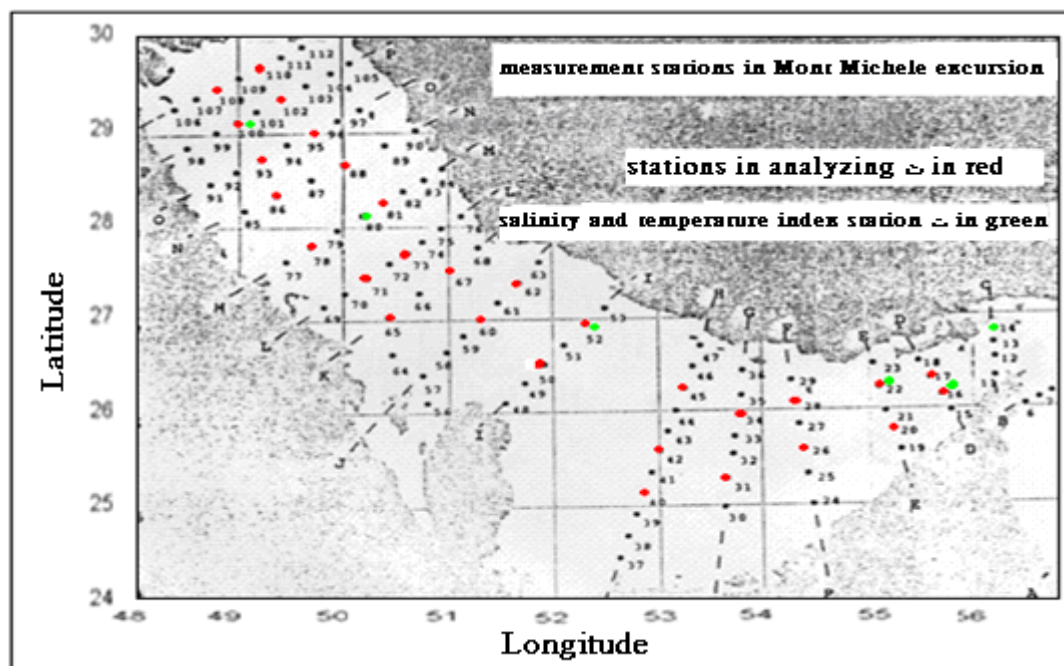
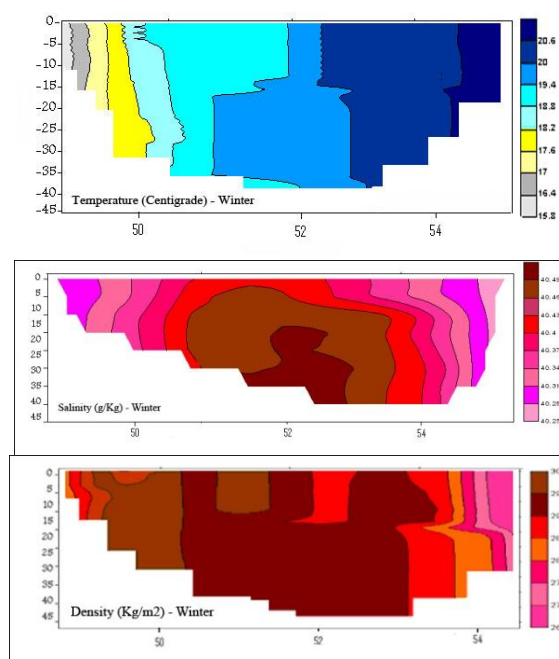


Figure 6. Persian Gulf consists of measurement stations

To compare thermocline formation in summer vise versa winter in the study zone, thermometers, density and salinity in two seasons with measurement data resulted from analysis of parameters of 29 popularize station to allover the Persian Gulf in the latitude segment and along the Arvand driver – Strait of Hurmoz axis areas following.



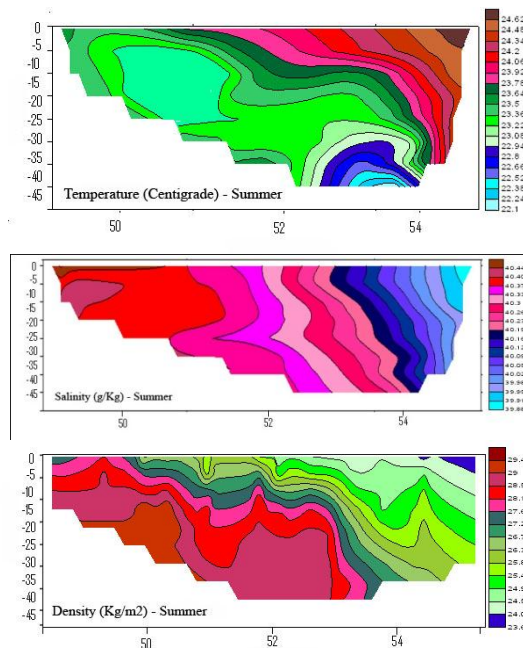


Figure 7. Contours of the temperature, density and salinity meter along Arvand River – Hurmoz Strait where all the vertical axes are depth (meter) and horizontal ones are longitude.

As we see in the above meters, a considerable gradient in temperature, density and salinity is not seen in the winter. As in the Stephen and Bower (2002) because of more vapors and less depth in the beaches of Arabic countries of the Persian Gulf zone, there is higher salinity. The other interesting point that is obvious in these meters is that there is partly low salinity and temperature in Iran beaches that is because of Arvand stream entrance to Persian Gulf and less temperature. Whereas in the salinity and temperature meters in summer (especially temperature) graduation is in the sub layer that will cause to summer thermocline formation and in fact thermocline expansion and formation from winter to summer will happen. However, in two cold and hot seasons of year, temperature graduation in the west part of this phenomenon section is presented that will cause to Arvand river entrance and effect on temperature graduation in this zone. Also in the contours of temperature and density, and in the both seasons of summer and winter in the north west of Persian Gulf, there is less temperature and density; this point shows the entrance of colder Arvand river stream into the Persian Gulf. That will cause to layer formation of Fluor pile in this zone and at last effect on summer thermocline formation in the north of Persian Gulf.

The out come of six months digital model performance POM that is based on inconsequent solving of low depth water 3 dimension equations with the method of C Arakavwa and Boussinesque access and also use of border qualification by saying 3 meters beach depth around the study zone, salinity and temperature meters that is compared with the figure 7. By using the amounts of monthly arrange, stopping the shining, evaporation, wind blow, entrance of Arvand river stream to the Gulf from the north west side and also Dobby from the Oman sea side via Strait of Hurmoz from winter until summer, in this six months of the year,

POM code has done and in the salinity and temperature of five minuets time steps is in dimensions $11 \times 100 \times 126$ for the study Zone at last, temperature and salinity meters that are from the model performance in phenomena profile along with Arvand river axis to Strait of Hurmoz are resulted as following.

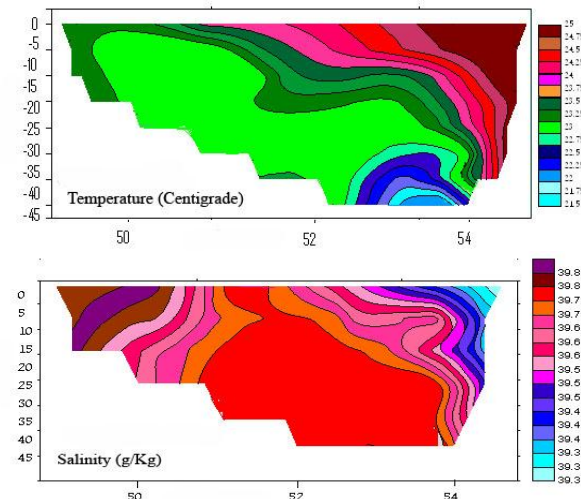


Figure 8. Temperature and Salinity contours along Arvand River- Hurmoz Strait in summer resulted from running POM code.

As we see in the above salinity and temperature contours, salinity and temperature gradient can be seen obviously in the longitudinal profile of eastern that is because of cold and sweet entrance of Arvand River to Persian Gulf. As we know, obvious gradient in temperature and because of the known density of summer thermocline formation.

As we see in the above temperature development contours, there is an obvious gradient in the depth Zone of 10 to 20 meters. This result is based on the realities in thermocline based on temperature measurement in figure 7. Therefore, it results in summer thermocline formation and its mutation from winter to summer. However in the thermocline which is resulted from POM code six months performance, in the zone of Arvand River stream entrance to Persian Gulf, there is partly less temperature, and like this gained contours, based on measurements, temperature gradient in the north west of Persian Gulf is obvious that courses in summer thermocline formation and is based on measurements. In fact, entrance of Arvand river stream in the west of Persian Gulf Hurmoz in the east of Persian Gulf is of the most important reasons of temperature gradient in these two parts (based on there search, Abde Ellah, 2009) thermocline formation, is because of fluid pile layer formation and the entrance of river stream to perish an Gulf and sea. However, because of the high amounts of income water from Oman Sea in Strait of Hurmoz to Persian Gulf, temperature gradient in Strait of Hurmoz is in the both seasons, while in the head point of Arvand, temperature gradient, especially in summer, causes to thermocline formation.

Discussion

Based on several measurements from temperature, salinity and density parameters in Persian Gulf and according to the gained results in analytical study and digital modulation about Persian Gulf, formation of summer thermocline vice versa winter proofed. According to the gained data of this research with respect to density and temperature contours in summer, temperature gradient in sub layer results in summer thermocline formation. However, in Strait of Hurmoz because of water constant exchange between Omen Sea and Persian Gulf, and as a result of fluor pile taxonomy, in the both seasons of winter and summer thermocline in formed. From winter to summer, thermocline expansion is happened from the Strait of Hurmoz toward Persian Gulf North West beaches: in a way that thermocline is formed allover the Persian Gulf in summer. It means the amount of stresses in this season is in away that high wind prevention decrease and shining heat decrease is

forming in the thermocline sub layer by surveying of gained outcome from measurements and also code performance, temperature gradient in the north west of Persian Gulf because of Arvand river stream entrance and less temperature can be seen in this Zone. Therefore, Arvand river entrance results in fluency on water pile layer formation in the north of Gulf and summer thermocline formation. At last, in the north west of Persian Gulf, inside waves and turbulence along with summer temperature gradient is presented due to the Arvand river stream.

Conclusion

1. Arvand river stream entrance to Persian Gulf in the North West part causes in temperature gradate for water sub layer, and Thermocline formation.
2. In the meters of temperature in the part of near to Iran beaches and around Arvand entrance in Persian Gulf produced of measurement and also as a product of model performance, less temperature can be seen.
3. As a result of orthogonal temperature gradate intensification in summer vice versa winter; summer thermocline is formed in Persian Gulf.
4. Thermocline in Strait of Hurmoz is forming because of water constant exchanges between Persian Gulf and Oman Sea in the seasons, winter and summer.
5. Baroclinisty effect and Fluor pile classification in Persian Gulf causes to turbulence and inside wave expansion in summer.

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