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Analogy of Oceanological Processes on the North-West African Shelf

By

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Summary

Vertical temperature and salinity distribution curves including a large amount of information about state of medium, can be used for oceanological indexes of biological productivity.

With the help of statistical indexes of analogy we investigate the question of how vertical temperature and salinity distribution on curves for separate parts of the North-West African shelf are numerically similar (analogous) in different periods of time. Choosing definite gradations for analogy indexes, we establish the possibility of inertial prediction in some cases and the unsuitableness of taking inertia into account in other cases.

It is stated that vertical temperature distribution curves are more similar to each other for all indexes than vertical salinity distribution curves. For all curves the analogy in configuration is higher than in level.

Statistical conclusions obtained can find physical and partly fishery-biological explanation.

I. Introduction

One of the important problems of fishery oceanography is to find the reasons for variations of yields of important fishing grounds. This applies fully to the area of the North-West African Shelf.

However, the solution of this general problem consists of a number of separate problems; for instance, such as to draw schemes of biological productivity formation, to choose optimal environmental parameters, to study time-space variability of these parameters, and their prediction etc.

As this problem has not been throughly studied and corresponding observation materials are not available, this problem can not be quantitatively solved as a whole for the time being. However some separate questions may be answered in principle.

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II. The Aim of the Investigations

The whole complex of oceanological processes (interaction of water masses, water upwelling and sinking etc.) is likely to influence the formation of all the components of biological productivity. Therefore a more objective oceanological index cannot be the value of an element at any level but its distribution with depth. In fact the curve of vertical distribution of an oceanological element has a very large range of information: stratification of waters, presence of layers with extreme values etc. General combination or physico-statistically reliable choosing of these curves must significantly reflect the history of formation and the variability of oceanological conditions.

In the present work an attempt is made to find out the analogy of the vertical distribution curves of temperature and salinity by the statistical method, i.e., to determine how these oceanological indices can be quantitatively similar in different periods of time. At the same time the possibility of inertia prediction of the examined oceanological characters is indirectly cleared up. Thus, the phenomenon is predicted only by its previous state.

III. Materials of Observations

From the episodical observations on the North-West African Shelf available in AtlantNIRO the stations only were chosen where at the same position observations of water temperature and salinity down to 100 m were repeated several times. Such stations were Nos. 19 (φ = 28°10'N, λ = 13°50'W), 93 (φ = 21°12'N, λ = 17°28'W), 94 (φ = 21°24'N, λ = 17°26'W), 95 (φ = 21°34'N, λ = 17°27'W), 84 (φ = 20°47'N, λ = 17°42'W), 85 (φ = 20°47'N, λ = 18°05'W), 87 (φ = 20°47'N, λ = 19°31'W) (Fig. 1).

In Table I (left column, upper line) the observation on dates were marked for every station. As it is seen a number of observations for the stations Nos. 19, 84, 85, 87 has episodical and unsystematic character and consists of separate observations made on different days of different months and years. In the first approximation such data can characterize the long-term variations (inter-months, inter-years).

For the stations Nos. 93, 94, 95 all the observations are concentrated in the close time interval from December 21, 1965 to December 31, 1965 and reflect inter-diurnal variations. In order not to introduce subjectivity into the forms of vertical distribution curves, we used only observed values of temperature and salinity at the standard levels (0, 10, 30, 50, 75, 100 m for the station No.19 and 0, 10, 20, 30, 50, 75, 100 m for the rest) without interpolation for intermediate levels. Thus our initial material looked like rows of numeral values. The number of rows for each station is equal to the above mentioned number of standard levels. The number of columns for every station was defined by the collection of seasonal cases marked in Table 1.

IV. Methods of Investigation

The statistically small value of observations conducted in unequal periods of time permits to use modern mathematical apparatus for determination of space and time variability spectrum. We used indexes of analogy r,p,A, well-known in literature.

The index of analogy r is the correlation coefficient for two seasonal rows. It ranges from +1 to -1. Positive values of r indicate direct analogy, and negative values inverse analogy. The correlation coefficient r serves as an index of analogy in configuration. In our case this index estimates similarity (analogy) in contours of curves of the vertical distribution of temperature and salinity and similarity of their forms.

The analogy index p is an index on level. It shows in what way the curves preserving their form change their number (absolute) characteristics. The estimation of p is made over the formula

$$p = 1 - \frac{\delta}{\delta max} \quad (1)$$

Here δ is the mean-square divergence of two curves,

δmax the maximum value of the mean-square divergences of two curves from the whole row, i.e. from the whole collection of curves for vertical distribution of an element for the given station.

Naturally the index p ranges from 0 to 1 and can have only positive values. There is complete analogy on the level $p = 1$ which occurs if $\delta = 0$. When there is no analogy then $\delta = \delta max$ and $p = 0$.

The index of analogy A is a general index of analogy with due regard to the variability of the similarity of curves along their configuration and level.

$$A = \frac{r + p}{2} \quad (2)$$

Variability limits for A are similar to those for r.

For each station r, p, A were calculated for every temporal case with all the following cases. The results are given in Table 1, where on the intersection of corresponding temporal cases three figures are shown: the upper figure is the value of r, the middle one the value of p, the lower one the value of A.

The higher the absolute values of indices, the more similar is the process. Preservation of high index values in time (with following cases) shows the statistical stability of the process, i.e., it is an evidence of the fact that the previous phenomenon with the given extent of accuracy is repeated in the subsequent time situations. The latter is possible only under inertia availability in the phenomenon to be investigated.

Let's assume that having an index of analogy equal to 0.75 and higher, the inertial prediction is principally possible. Thus on the basis of the preceding curve of the vertical distribution of an element it is possible to estimate the future curve without taking into account additional factors. If index values of analogy are within the limits of 0.50 to 0.74, then the inertia must be taken into account only as one of the arguments in the equation of regression. In this case inertia must be considered as an obligatory but insufficient factor for prediction of the vertical distribution curve.

Finally, if the index value of analogy is < 0.50 the process is so statistically unstable, that inertia should not be taken into account.

V. The Results of the Invesigations

The analysis of the results of calculation given in Table 1 will be treated for every index of analogy.

1. Index of analogy in configuration for the curves of vertical distribution of temperature.

For all examined cases $r \geq 0.50$, i.e., inertia must be taken into account. Moreover, 95% of the total number of values for r are higher than 0.75. That means that inertia can serve as the basis for prediction and only 5% of the total number of cases testify to the necessity of using other arguments. These are 5 cases for station No. 94, 3 cases for station No. 85 and 1 case for station No. 87.

The absence of inverse analogy is an evidence of the fact that the configuration of the curves of the vertical distribution of the temperature does not tend to be its reflection, and therefore its main features do not change into the reverse characters.

The highest analogy for curve configurations was marked at the most northern station, No. 19. It can have a physical basis, namely, that the shelf water in the north is more homogeneous (the Canarian current) than in the south (the Canarian current and the Equatorial counter-current). Besides that the atmospheric processes in the north are more constant (north-east trade-wind), but at the same time there are the equatorial depression and the summer monsoon region southward.

Analogy for stations Nos. 93, 94, 95 is not higher than for the other stations. On the total background of insignificant variability in configuration of vertical distribution curves of temperature the short-period (inter-daily) variability is likely to be compared with the long-period one.

2. Indication of Analogy in Configuration for Curves on Vertical Salinity Distribution

As a whole (76%) the statistical stability predominates, i.e., inertia should be taken into account. Thus in 68% of cases $r \geq 0.75$ and in 8% of cases $0.50 < r < 0.75$. So with a probability of 0.68 one can consider that it is possible to have inertial prediction for configuration of vertical salinity distribution curves.

In 40% of cases inverse analogy takes place. It demonstrates a significant (though not predominant) tendency of curves to take their mirror reflection. Physically it can be imagined as the processes of transition from maximum to minimum, changes of tendency to increase salinity with depths to inverse tendency etc.

3. Indication of Analogy in Level for Vertical Temperature Distribution Curves

Inertial prediction ($p \geq 0.75$) can be applied in 10% of cases from the total number of calculated values for p. Inertia should be taken into account in altogether 48% of cases. Therefore statistical instability predominates (52%) in forming numeral values of vertical temperature distribution curves.

4. Index of Analogy in Level for Vertical Salinity Distribution Curves

Within the limits of the collection used, inertial prediction ($p \geq 0.75$) is impossible. Taking inertia into account as one of the arguments in the equation of connection ($0.50 < p < 0.75$) is suitable in 36% of cases. It means that statistical instability obviously predominates (64%) showing that inertia should not be taken into account for prediction of numeral values of vertical salinity distribution curves.

5. General Index of Analogy for Vertical Temperature Distribution Curves

Inertia prediction is possible in 32% of cases ($A \geq 0.75$). In 11% of cases inertia should not be taken into account ($A < 0.50$). So statistical stability of such order somewhat predominates (57% of cases), that inertia is suitable as one of the arguments in the general equation of relationship. ($0.50 < A < 0.75$).

It is natural that there is no inverse general analogy.

6. General Index of Analogy for Vertical Salinity Distribution Curves

Inverse analogy ($A < 0$) was recorded in 36% of cases. An in all cases with inverse analogy, it is not advisable to take inertia into account ($|A| < 0.50$). In 12% of cases inertial prediction is possible ($A \geq 0.75$) and in 28% of cases inertia was necessary as one of the arguments ($0.50 < A < 0.75$). So statistical instability predominates (60% of cases when $|A| < 0.50$) with clearly pronounced tendency for direct general analogy.

VI. Conclusions

1. Vertical temperature distribution curves are mutually more similar, as a whole, for all indexes than vertical salinity distribution curves. It can indicate that in the region of trade-wind circulation there is quasi-stability of thermal processes in the sea. At the same time the process of salinity formation at the depths is much more complicated and unstable as a result of great incongruousness of the factors in time stipulating the regime of salinity (evaporation, atmospheric precipitation, advection etc.).

2. The curves of vertical temperature and salinity distribution are more similar in configuration than in level. On the background of comparatively stable general contours of these curves (disposition of extremes, tendency etc.) there is great variability of numeral values of separate parameters of curves. Physically it can be compared with stability in stratification and in quantity of water mass, and with variability of intensity of thermocline, intensivity indexes of water masses etc. Fishery-biological significance of such a fact can have a reflection on locality of commercial stocks, their area within the limits of the observed area on one hand, and on difficult nature of behaviour and distribution of commercial fishing items (instability of optimal depths of commercial concentrations etc.) on the other hand.

3. In the paper the possibility of determination of the temperature and salinity vertical distribution parameters previous state is only found out with the working out the oceanological prediction methods. For putting into practice such possibility it is neccessary to obtain more qualitative material of the observations, i.e., statistically valid frequency of the observations with the given and constant discretion in time.

Table 1

Analogy of Vertical Temperature and Salinity Distribution Curves

1. Station No. 19. T°

	20.05.64	10.08.64	13.07.65	27.09.65	08.11.65	06.01.66
16.09. 1962	0.93 0.09 0.51	0.91 0.47 0.69	0.98 0.08 0.53	0.99 0.43 0.71	0.95 0.40 0.67	0.77 0.00 0.38
20.05. 1964		1.00 0.60 0.80	0.88 0.79 0.83	0.91 0.64 0.78	0.99 0.64 0.82	0.78 0.81 0.80
10.08. 1964			0.86 0.53 0.70	0.90 0.83 0.87	0.99 0.86 0.93	0.79 0.48 0.64
13.07. 1965				0.98 0.63 0.81	0.90 0.62 0.76	0.79 0.66 0.73
27.09. 1965					0.93 0.83 0.88	0.85 0.54 0.70
08.11. 1965						0.77 0.49 0.63

2. Station No. 93. T°

	21.12.65	23.12.65	27.12.65	28.12.65	29.12.65	30.12.	31.12
20.12. 1965	0.91 0.67 0.79	0.84 0.42 0.63	0.98 0.69 0.82	0.88 0.67 0.77	0.88 0.66 0.77	0.97 0.37 0.67	0.99 0.56 0.77
21.12. 1965		0.93 0.59 0.76	0.90 0.39 0.64	0.89 0.54 0.72	0.88 0.66 0.77	0.86 0.58 0.72	0.90 0.30 0.60
23.12. 1965			0.77 0.14 0.45	0.97 0.40 0.68	0.96 0.63 0.79	0.72 0.71 0.72	0.79 0.14 0.46
27.12. 1965				0.80 0.53 0.67	0.81 0.43 0.62	0.99 0.07 0.53	0.99 0.75 0.87
28.12. 1965					1.00 0.77 0.88	0.76 0.23 0.50	0.82 0.58 0.70
29.12. 1965						0.77 0.44 0.61	0.82 0.45 0.64
30.12. 1965							0.99 0.00 0.49

3.Station No. 94. T°

	21.12. 1965	23.12. 1965	24.12 1965	26.12. 1965	27.12. 1965	28.12. 1965	29.12. 1965	31.12. 1965
20.12. 1965	0.71 0.37 0.54	0.87 0.52 0.69	0.85 0.46 0.65	0.82 0.44 0.63	0.61 0.28 0.44	0.61 0.06 0.33	0.95 0.39 0.67	0.79 0.18 0.49
21.12. 1965		0.86 0.39 0.62	0.73 0.19 0.46	0.98 0.47 0.73	0.89 0.68 0.79	0.99 0.26 0.63	0.83 0.70 0.76	0.98 0.23 0.61
23.12. 1965			0.98 0.69 0.83	0.94 0.71 0.82	0.90 0.42 0.66	0.79 0.28 0.53	0.97 0.41 0.69	0.94 0.49 0.71
24.12. 1965				0.84 0.41 0.62	0.84 0.20 0.52	0.64 0.00 0.32	0.95 0.21 0.58	0.84 0.21 0.53
26.12. 1965					0.90 0.48 0.69	0.94 0.42 0.68	0.93 0.44 0.68	1.00 0.63 0.81
27.12. 1965						0.88 0.50 0.69	0.80 0.82 0.81	0.93 0.39 0.66
28.12. 1965							0.75 0.42 0.59	0.95 0.65 0.80
29.12. 1965								0.91 0.32 0.62

4. Station No. 95. T°

	21.12. 1965	23.12. 1965	24.12. 1965	26.12. 1965	29.12. 1965	31.12. 1965
20.12. 1965	0.96 0.89 0.93	0.94 0.50 0.72	0.89 0.28 0.58	0.74 0.45 0.60	0.93 0.07 0.50	0.97 0.70 0.84
21.12. 1965		0.84 0.41 0.63	0.76 0.17 0.47	0.58 0.36 0.47	0.99 0.00 0.50	0.90 0.61 0.75
23.12. 1965			0.99 0.63 0.81	0.78 0.68 0.73	0.78 0.48 0.63	0.95 0.78 0.87
24.12. 1965				0.81 0.55 0.68	0.69 0.26 0.47	0.93 0.49 0.71
26.12. 1965					0.52 0.32 0.42	0.86 0.68 0.77
29.12. 1965						0.85 0.34 0.60

5. Station No. 84. T°

	01.07. 1963	02.08. 1963	09.02. 1964	17.07. 1965	08.10. 1965	03.11. 1965	12.12. 1965	09.04. 1966
04.06 1963	0.94 0.85 0.89	0.89 0.12 0.50	1.00 0.66 0.83	0.88 0.10 0.49	0.98 0.30 0.64	0.90 0.42 0.66	0.83 0.61 0.73	0.98 0.88 0.93
01.07 1963		0.92 0.24 0.58	0.94 0.77 0.86	0.86 0.23 0.54	0.96 0.43 0.70	0.99 0.56 0.78	0.83 0.72 0.78	0.90 0.74 0.82
02.08 1963			0.90 0.41 0.66	0.89 0.75 0.82	0.87 0.69 0.78	0.86 0.61 0.74	0.97 0.48 0.72	0.92 0.00 0.46
09.02 1964				0.91 0.41 0.66	0.98 0.62 0.80	0.90 0.70 0.80	0.86 0.77 0.82	0.99 0.56 0.77
17.07 1965					0.88 0.69 0.78	0.79 0.56 0.68	0.94 0.45 0.69	0.93 0.00 0.47
08.10 1965						0.95 0.80 0.87	0.81 0.59 0.70	0.95 0.19 0.57
03.11 1965							0.76 0.69 0.73	0.84 0.31 0.57
12.12 1965								0.90 0.50 0.70

6. Station No. 84. S ‰

	01.07. 1963	02.08. 1963	09.02. 1964	08.10. 1965	12.12. 1965
04.06 1963	0.87 0.52 0.70	-0.84 0.49 -0.17	0.93 0.70 0.82	0.89 0.45 0.68	0.83 0.63 0.73
01.07 1963		-0.47 0.30 -0.08	0.69 0.25 0.47	0.69 0.00 0.34	0.48 0.21 0.35
02.08 1963			-0.93 0.39 -0.27	-0.86 0.27 -0.30	-0.98 0.58 -0.20
09.02 1964				0.98 0.72 0.85	0.90 0.71 0.80
08.10 1965					0.80 0.58 0.69

7. Station No. 85. T°

	01.07. 1963	02.08. 1963	17.07. 1965	08.10. 1965	03.11. 1965	12.12. 1965
04.06 1963	0.95 0.33 0.64	0.68 0.36 0.52	0.94 0.61 0.78	0.99 0.00 0.50	0.98 0.55 0.77	0.94 0.61 0.78
01.07 1963		0.54 0.57 0.56	0.85 0.52 0.69	0.91 0.50 0.71	0.97 0.75 0.86	0.93 0.53 0.73
02.08 1963			0.83 0.51 0.67	0.75 0.29 0.52	0.66 0.62 0.64	0.79 0.55 0.67
17.07 1965				0.98 0.76 0.87	0.97 0.20 0.58	0.98 0.77 0.87
08.10 1965					0.96 0.39 0.68	0.94 0.73 0.83
03.11 1965						0.96 0.32 0.64

8. Station No. 85. S ‰

	01.07. 1963	02.08. 1963	08.10 1965	12.12. 1965
04.06 1963	0.10 0.52 0.31	-0.14 0.16 0.01	0.12 0.06 0.08	-0.12 0.00 -0.06
01.07 1963		-0.92 0.32 -0.30	0.94 0.27 0.61	0.94 0.28 0.61
02.08 1963			-0.77 0.45 -0.16	-0.91 0.23 -0.34
08.10 1965				0.79 0.70 0.74

9. Station No. 87. T°

	01.07. 1963	02.08. 1963	17.07. 1965	08.10. 1965	03.11. 1965	12.12. 1965
04.06 1963	0.93 0.84 0.89	0.75 0.06 0.41	0.83 0.28 0.55	0.93 0.07 0.50	0.86 0.53 0.69	0.96 0.70 0.83
01.07 1963		0.94 0.10 0.52	0.97 0.24 0.60	0.97 0.00 0.48	0.98 0.60 0.79	0.86 0.59 0.72
02.08 1963			0.99 0.53 0.76	0.88 0.27 0.57	0.97 0.46 0.72	0.67 0.13 0.40
17.07 1965				0.92 0.63 0.77	0.99 0.44 0.71	0.74 0.46 0.60
08.10 1965					0.96 0.19 0.57	0.82 0.30 0.55
03.11 1965						0.75 0.45 0.60

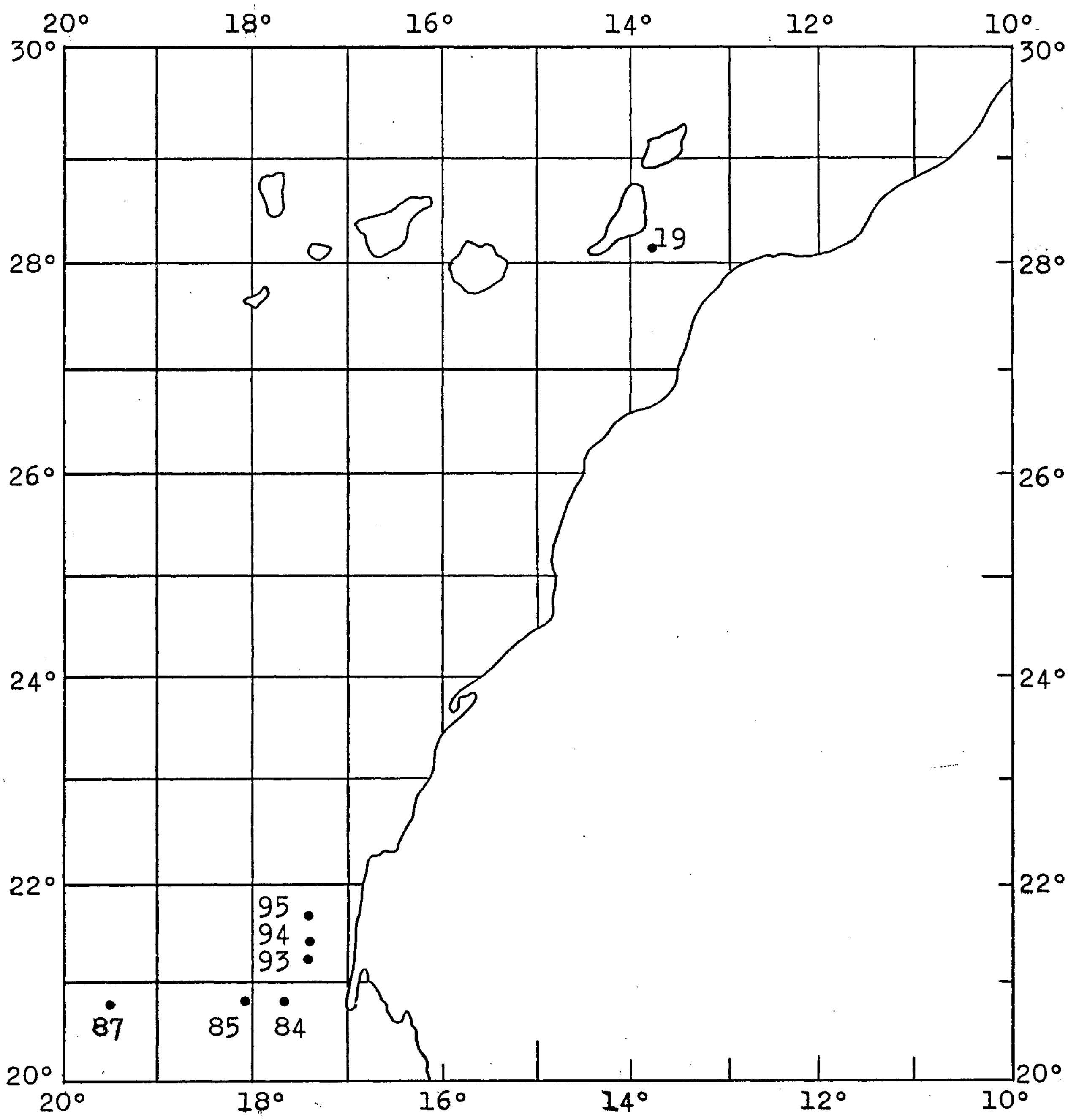

Fig. 1 Position of stations used for calculation of analogy.