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TEMPERATURE RELATIONS IN THE ADRIATIC SEA

TEMPERATURNI ODNOSI U JADRANSKOM MORU

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On the basis of a large amount of data collected so far in the Adriatic sea, an attempt is made here to review the state of temperature, its seasonal and long term variations and its possible relation to some inner and external

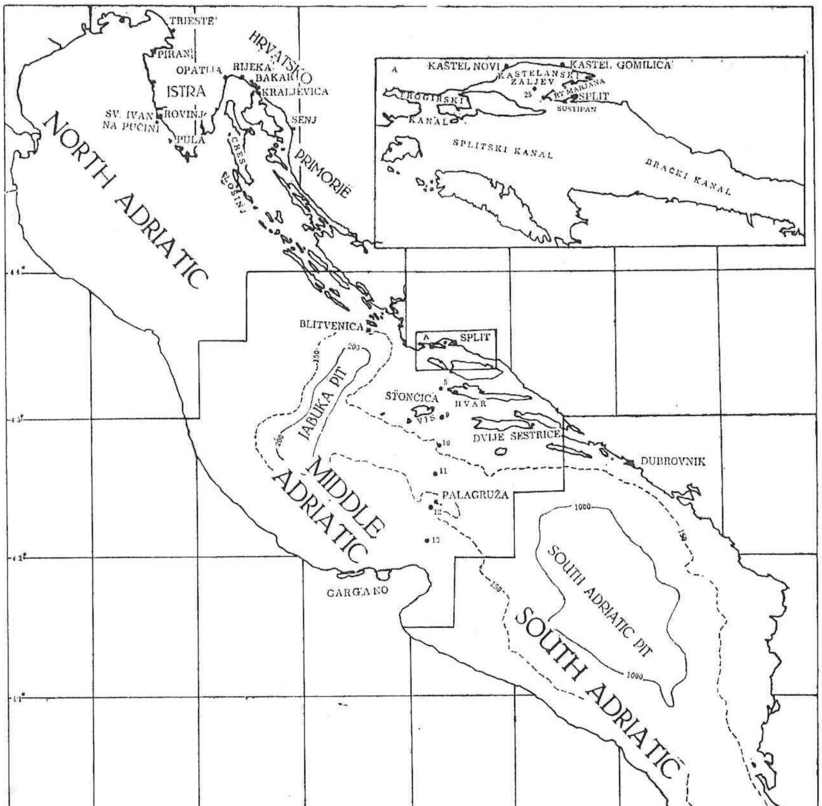

Fig. 1 Map of the coastal stations and those in the Split-Gargano profile and the division of the Adriatic to the northern, middle and southern as used in computer processing.

factors. The temperature structure of the coastal region and that of the open sea are separately dealt with. Owing to the abundance of the processed material, wich was collected during different periods with diffferent aims, the data are given in chapters representing different parts. Although these data are far from being complete it is hoped that they would be of use to those who need them for studying the related problems. However, as much data as available for illustrating the hydro-climatic conditions are given here.

1. SEA SURFACE TEMPERATURE ALONG THE EAST COAST

Besides the fifteen years' data of the sea temperature in Split that have been processed here, all other data collected so far during different periods from twenty coastal stations (mostly five years' series) have been considered. The stations from which the data have been processed are given in Fig. 1.

Buljan (1961) has analysed the data for Split up to 1954, and calculated the normal theoretical curve of the annual variation wich agrees well with the real curve.

a. Space Variations

Table 1

The average sea surface temperature for four typical months in ^{0}C (data according to the Nacionalna kom. 1958—1960 and Hidrometeorološki zavod, 1961—1963.)

	February (1958—1963)	May (1958—1963)	August (1958—1962)	November (1957—1962)
Piran	7.8	16.4	23.9	14.8
Sv. Ivan na pučini	9.3	16.4	24.0	16.0
Opatija	10.7	15.5	23.2	13.4
Kraljevica	8.7	15.0	22.0	13.6
Senj	10.2	14.8	20.3	14.8
Blitvenica	12.8	16.4	22.0	18.0
Kaštel Gomilica	11.2	17.4	24.3	15.6
Split, rt Marjana	11.3	17.9	23.7	16.8
Split, Sustipan	11.7	17.7	23.5	17.1
Hvar	12.6	17.5	23.0	18.5
Stončica	13.6	16.7	23.5	16.9
Palagruža	13.8	17.3	24.2	16.7
Dvije Sestrice	12.7	17.5	22.6	18.5
Dubrovnik	13.2	18.6	23.6	18.8

During W i n t e r the temperature of the coastal area of the north Adriatic is considerably lower than that of the south and a difference of about 6^0 C is observed (table 1). The lowest sea temperature has been found along the west coast of the Istra peninsula. One of the reasons for such a distribution of temperature in Winter is due to the latitudinal difference. Besides, there is the influence of the current system, which in Winter in the surface layer along the east coast brings Mediterranean warmer water resulting in the heightening of the horizontal temperature gradient. We are bound to believe that a still more important factor is the influence of the continentality which always affects the heightening of the extremes. The whole of the land locked Adriatic basin is shallower as we go towards north and as such the continental influence is also felt more in that direction. The same effect is reflected in the fact that the places less exposed to the influence of the open sea generally show lower temperatures. This is well illustrated by temperature structure at the Palagruža — Kaštela bay profile (12.8^0C to 12.0^0C) (table 2).

T a b l e 2

Average sea temperature in °C for March (1958—1963)

Palagruža	Stončica (Vis)	Hvar	Split	Kaštel Gomilica
13.8	13.5	12.7	12.1	12.0

Almost the same type of temperature difference can be seen in the area of Hrvatsko primorje (Croatia coast line) which shows the lowest temperature at Kraljevica as it is least exposed to the open sea influence.

The air temperature along the east coast of the Adriatic in the coldest month (January) varies from 4.1 to 9,2^0C (M a k j a n i ć, 1956). So the air temperatures vary less and are considerably lower than the sea temperatures. Favourable climatic influence of the Mediterranean water in the Adriatic is reflected in the course of the hibernal air isotherms which essentially deviate from the zonal course (M a k j a n i ć, op. cit.).

Another question arises here as to whether the great Winter horizontal gradient of the sea temperature (density) causes the Winter current system or whether it is conditioned by the current system. The stronger continentality of the north Adriatic and the horizontal temperature gradient caused by it seems to be of primary importance but the resulting current system seems to make the gradient itself even greater. This may be the reason for its greater prominence in Winter, when the current system is best defined. The influence of the wind and the distribution of air pressure above the East Mediterranean also should not be ignored here (Z o r e - A r m a n d a, 1968 and 1969).

In S p r i n g, the distribution of temperature is more uniform. The lowest temperature is found in the area of Hrvatsko Primorje and not along the west coast of Istra as during Winter. Senj shows the lowest temperature, whereas, the highest is shifted farther southwards (Dubrovnik) than in Winter (Palagruža).

In Summer the highest average temperature is found in August. Senj shows the lowest temperature as during Spring. It has been known since a long time that the sea temperature at Senj is comparatively low in Summer owing to the influence of the submarine springs which are also responsible for similar low temperature at Rijeka during the same season. The highest temperature is found in the mild Adriatic area (Kaštel Gomilica).

In Autumn, the temperature distribution shows the least regularity.

The lowest temperatures are found in Winter on the west coast of Istra, while during the other seasons they are found in Hrvatsko Primorje. The highest temperature is found in Winter in the places exposed to the influence of the open sea (Palagruža), in Spring it is in the south Adriatic, in Summer it is shifted to the mid Adriatic and in Autumn it occurs again in the south Adriatic.

In order to show to what extent the data in table 1 are representative, the average sea temperatures for four characteristic months collected for the longer time or in the earlier period are given in table 3. The date for the last century and Rovinj are according to Picotti and Vatova, 1942 and the data for Trieste are according to Polli, 1940 and Vatova, 1948.

Table 3

Average sea temperature (°C) for four typical months.

	February	May	August	November
Trieste (1934—39)	7.5	15.8	23.9	14.8
Rovinj (1920—44)	9.0	15.9	24.0	15.9
Pula (1882—95)	7.9	15.2	22.5	14.3
Rijeka (1868—73)	10.0	16.2	21.0	13.0
Kaštel Novi (1868—73)	12.1	17.9	22.1	16.8
Split, rt Marjana (1951—65)	11.0	17.5	23.6	16.6
Hvar (1868—73)	12.6	17.5	22.7	17.5
Kerkyra (1868—73)	12.9	19.4	24.4	19.1

A comparison of longer and shorter series for the same stations or from those stations which are geograficallly very close (e. g. Split, Rt Marjana in tables 1 and 3 or Rovinj in table 3 and Sv. Ivan na pučini in table 1) shows that five and six years' series are representative enough. On the other hand, a comaprison of the last century series with those of more recent data (e. g. Opatija in table 1 and Rijeka in table 3 or Kaštel Gomilica in table 1 and Kaštel Novi in table 3 and Hvar in tables 1 and 3) will show somewhat larger differences which are, however, negligible for most considerations. It is significant that the temperature data for the last century show a lower value in August than during the corresponding month in the recent years.

In order to get a better understanding of the differences between the north and middle Adriatic, two long series of temperature data from those areas, i. e. Rovinj and Split (table 4) are separately compared.

Table 4

Long term monthly average temperatures of the sea surface (^{0}C)

	Rovinj (1920—44)	Split (1951—65)	Difference
January	10.1	12.2	2.1
February	9.0	11.0	2.0
March	9.5	11.7	2.2
April	11.9	14.2	2.3
May	15.9	17.5	1.6
June	20.6	21.7	1.1
July	23.3	23.7	0.4
August	24.0	23.6	—0.4
September	22.1	22.0	—0.1
October	19.0	19.2	0.2
November	15.9	16.6	0.7
December	12.8	14.0	1.2
Annual average	16.2	17.3	1.1
Annual amplitude	15.0	12.7	2.7

The difference in the average multi-annual temperature between the two series is 1.1^{0}C. The temperature is generally higher in Split than in Rovinj, but is higher in Rovinj during Summer (August to September). The annual amplitude of the monthly differences amounts to 2.7^{0}C. If the average annual difference of temperature between Rovinj and Split (1.1^{0}C) is subtracted from the annual amplitude of the monthly differences in temperature, there is a difference of 1.6^{0}C, which might be considered as the numerical expression of the continentality of the north Adriatic as compared to the mid Adriatic.

It can be easily seen that such a relation of temperature has a direct influence on the dynamics of the basin: the curve of the monthly differences in the Rovinj — Split temperature and the Bakar — Senj sea level (Fig. 2) shows that the temperature distribution indirectly affects the system of flow.

The maximal positive difference in temperature between Rovinj and Split occurs in April, whereas the maximal negative difference is in August. If the influence of the distribution of salinity is not considered, we could expect in these two months in relation to the distribution of temperature the best marked gradient flow in the corresponding direction: ie. in April in the sense of the Winter regime and in August in the sense of the Summer regime. Judging by this characteristic, April behaves like a Winter month. But owing to the lack of direct observation of currents for all months, the above statement could not be proved at present. However, if the seasonal differences alone are taken into consideration (the four seasons are referred here) it may be seen that the differences of temperature between the north and mid Adriatic are greatest in Winter and the gradient flow is also best marked in the same season.

Another indication of the stronger continentality of the north Adriatic as compared to the mild Adriatic is the annual difference of temperature between the sea and air in Rovinj and Split. The multi-annual difference in average for Rovinj is 2.2^{0}C and that for Split 1.1^{0}C. This shows that the sea has o stronger thermic influence on the temperature of the air in Split than in Rovinj, ie. the maritime influence is much stronger in Split.

b. Seasonal Variations

The annual course of temperature of the sea at Split, Rt Marjana, according to a 15 years' average data (table 1A in the Appendix) shows a minimum temperature of 11,0 °C in February and a maximum of 23,7°C in July. The occurrence of the extremes of temperature after the Summer and Winter Solstices is a well known characteristic for the sea and air temperature of the maritime climate. The air temperature extremes are more pronounced than the sea temperature extremes so that the maximum of the multi-annual average monthly temperatures of the air is 1.4^{0}C higher and the minimum 3.0^{0}C lower than the corresponding extremes of the sea temperature (tables 1A and 2A in the Appendix).

The appearance of the extremes in the annual variation of the average monthly temperatures of the sea in Split is not constant every year. In the

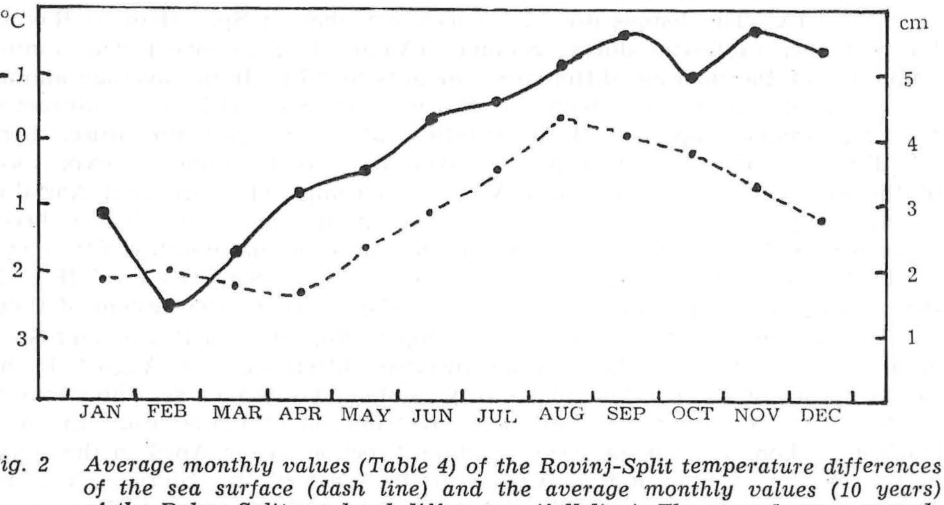

Fig. 2 Average monthly values (Table 4) of the Rovinj-Split temperature differences of the sea surface (dash line) and the average monthly values (10 years) of the Bakar-Split sea level differences (full line). The second curve according to the data from the Hidrografski institut, 1956—1966.

course of 15 years the average monthly temperature was the highest 10 times in July and 5 times in August (table 1A in the Appendix).

The absolute maximal annual temperatures are even more inconsistent as regards the time of their occurrence. In the 15 years' series of absolute maximal monthly temperatures of the sea (table 3A in the Appendix), the maximal annual values appeared 4 times in June once in June and September, 5 times in July and 5 times in August.

The appearance of the minimum temperature is comparatively more consistent than that of the maximum. In the course of 15 years under consideration, the average monthly temperature showed the minimum for 12 times in February, once in February and March, and twice in March. In the 15 years' series of absolute monthly minimal temperatures, the minimal annual value appeared twice in January, 7 times in February, and 6 times in March (table 4A in the Appendix).

The highest monthly average value of the sea temperature in the course of the 15 years was 25.5^{0}C (July 1953) and the lowest 9.9^{0}C (February 1963). The highest observed temperature in the same period was 28.6^{0}C (8th August 1952) and the lowest 7.5^{0}C (10th February 1963).

The annual course of the extreme temperatures near Split appears to be nearly parallel with the annual course of the average temperatures. The maximum difference between the medial and maximum values are found in Summer, whereas the minimum difference occurs in Autumn. There is a similar relation between the medial and minimum values and the greatest difference between the two occurs in Summer, whereas the least difference is seen in Autumn. It follows that the temperature of the sea surface oscillates least in Autumn.

At Split 48$^0/_0$ of the days have an average temperature higher than the multi-annual average. This is because the Summer extremes are high. From December to April all the days have their temperatures lower than the average multi-annual, whereas from June to September all the days show temperatures higher than the multi-annual average. Besides, from January to March all days show their average temperatures lower than the multi-annual average minimal value, whereas in July and August the average temperatures of all the days are higher than the multi-annual average maximum value. These relations are shown in table 5.

Table 5

Percentage of days having temperatures (according to 10 years' data):

A — higher than the average multi-annual sea temperature
B — higher than the average maximal sea temperature
C — lower than the average minimal sea temperature

	A	B	C
Jan.	0	0	100
Feb.	0	0	100
March	0	0	100
April	0	0	75
May	60	13	11
June	100	86	0
July	100	100	0
Aug.	100	100	0
Sept.	100	100	0
Oct.	85	24	0
Nov.	30	0	16
Dec.	0	0	80
Year	48	35	40

The occurrence of the extreme values of temperature in an annual course is not simulataneous at all the stations. Though it cannot be considered as a general role, it is characteristic of the places having a lower minimum to show extreme values earlier than in other places. The stations under the major influence of the open sea show less pronounced minima and their appearance is also at a later date. The date for the Split — Palagruža profile for 1959 are characteristic in this respect:

	Split (Rt Marjana)	Hvar	Vis	Palagruža
Minimum temp. in ^0C	9.9	11.6	13.0	12.8
Date of appearance	Feb. 11th	Feb. 17th	Feb. 13th to March 6th	March 25th

The curve of the average monthly values is characterised by faster warming up in Spring and slower cooling down in Autumn (Fig. 3). The warming up of the sea goes almost parallel with the warming up of the air, but the cooling down of the sea is rather slower compared to the cooling down of the air. This results in the autumnal temperature of the sea becoming considerably higher than that of the air, whereas in Spring the sea as well as the air show almost the same temperature. The period during which the air is warmer than the sea is shorter than the period when the sea is warmer than the air.

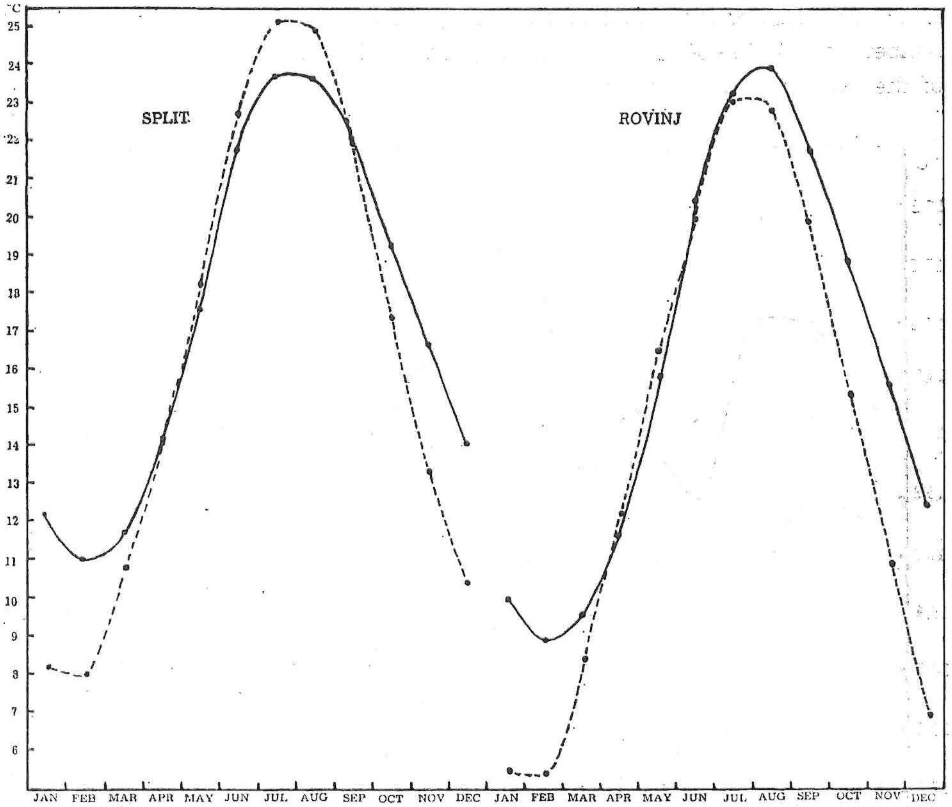

Fig. 3 *Long term average monthly temperatures of the air (dash line) and the sea surface (full line) for Rovinj and Split, Rt Marjana.*

If the sea-air temperature relation in Split is compared with that at Rovinj (Fig. 3) it is possible to find out the same reation during the period of warming up. However, in Summer at Rovinj the sea is warmer, whereas at Split the air is warmer. This is another consequence of the stronger continentality of the north Adriatic. In the period of cooling down, the temperature of the sea is higher than that of the air at both stations though the difference is greater at Rovinj. The sea is warmer at Rovinj during almost the whole year with the exception of April and May. In Split, the sea is cooler than the air from May to August.

c. Long Term Variations

A multi-annual course of the average annual temperatures of the sea in Split is represented in Fig. 4. The values vary from 16.8^0 to 17.8^{0}C and the general average comes to 17.3^{0}C (table 6). The average temperature of the sea is not only higher from that of the air by 1.1^{0}C, but the range of the average temperature of the air is approximately one and a half times higher than that of the temperature of the sea.

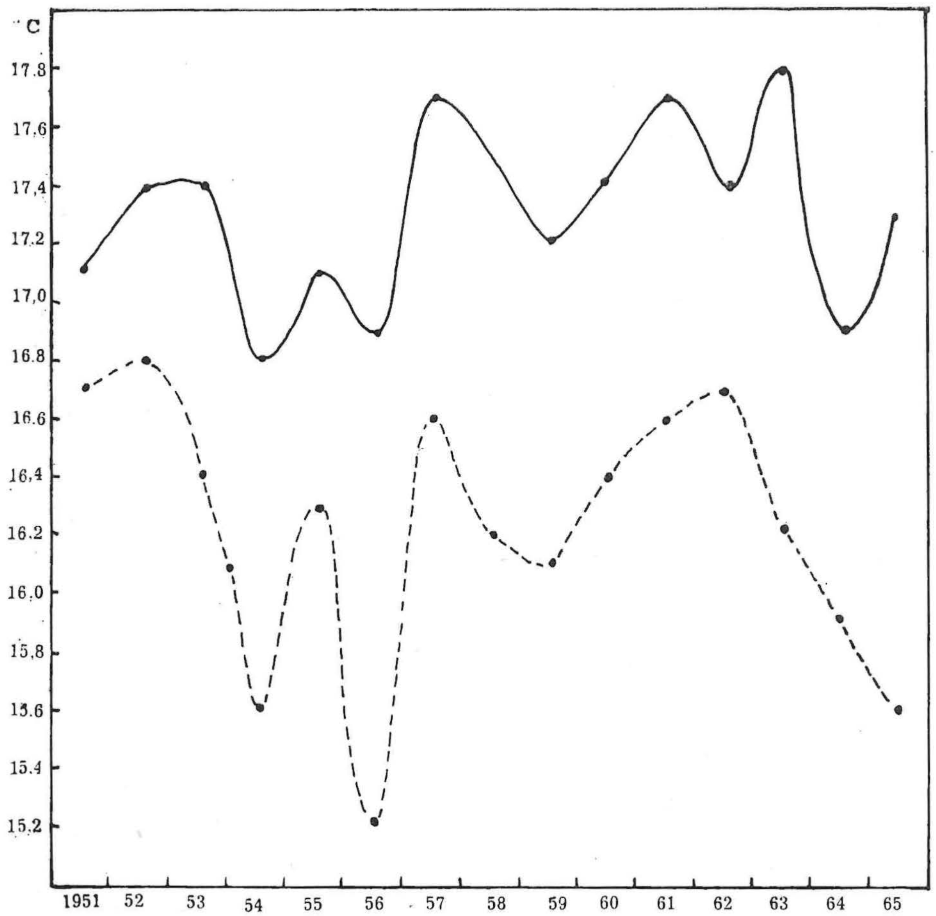

Fig. 4 *Average annual temperatures of the sea surface (full line) and the air (dash line) for Split, Rt Marjana.*

Table 6

Some annual and seasonal values of the temperatures of the sea and air for Split, Rt Marjana (^0C)

Year	Average air. temp.	Average sea temp.	Sea — air temp. diff.	Average sea temp. (Jan. Feb. March)	Average sea temp. (Jul. Aug. Sept.)	Maxim. sea temp.	Minim. sea temp.
1951	16.7	17.1	0.4	11.2	23.3	25.1	8.5
1952	16.8	17.4	0.6	11.6	23.7	28.6	10.1
1953	16.4	17·4	1.1	11.1	23.2	27.7	9.2
1954	15.6	16.8	1.2	11.2	22.9	27.1	9.2
1955	16·3	17.1	0.8	12.1	22.7	25.4	10.5
1956	15.2	16.9	1.7	10.9	23.8	27.5	8.4
1957	16.6	17·7	1.1	12.0	23.2	26.8	9.0
1958	16.2	17·5	1.3	11.8	23.3	27.4	10.2
1959	16.1	17.2	1.1	12.5	22.5	27·3	9.9
1960	16.4	17.4	1.0	12·0	22.5	25.9	8.5
1961	16.6	17.7	1.1	12.6	22.5	26·6	9.0
1962	16.7	17.4	0.7	11·6	23.7	27.6	9.6
1963	16.2	17.8	1.6	10.9	24.3	27·8	7.5
1964	15.9	16.9	1.0	11·9	22.0	26.3	8.1
1965	15.6	17.3	1.7	11.2	22.8	27·4	8.8
Average	16.22±1.0	17.31±0·5	1.09	11.64±0.9	23.09±1.2		

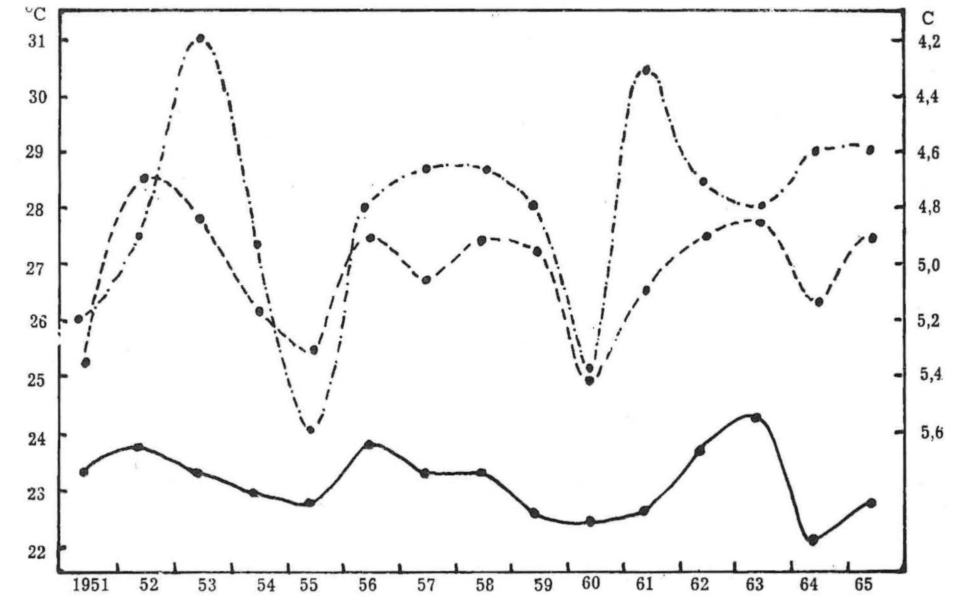

Fig. 5 *Maximum (dash line) and average summer temperatures (heavy full line) of the sea for Split, Rt Marjana and average annual cloudiness for Split (dash and dot line).*

The main factors that influence the formation of the sea surface temperature are radiation, evaporation and water advection, but the corresponding data for Split are not yet available. Besides, some other mateorological factors also influence the temperature of the sea which may be seen from the parallel long term fluctuations. The variation of the average annual cloudiness together with the maximal and median temperatures of the sea in Split is shown in Fig 5. It may be seen that less cloudiness brings about higher extremes and median Summer temperatures of the sea.

In Fig. 6 the variations of the average Winter temperature of the sea is shown. Besides, it is also possible to see the variations of a value which is a combination of the frequence of the cold NE Wind (bura) and the average

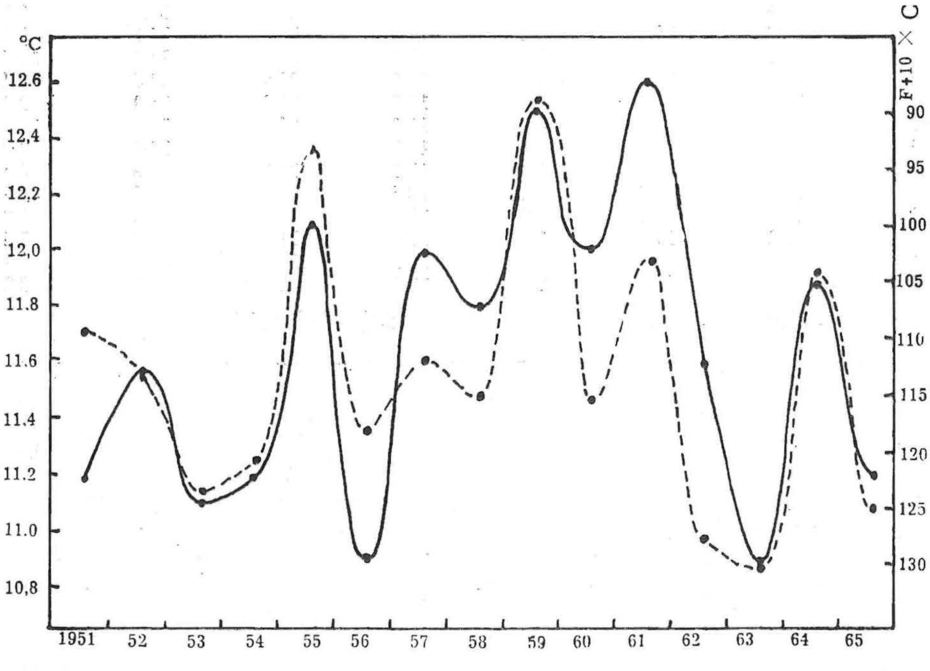

Fig. 6 *Average Winter (Jan., Feb., March) temperatures of the sea surface for Split, Rt Marjana (full line) and the superposed values of the NE wind frequency (F) and average cloudiness (10 × C_{winter}) for Winter (Jan., Feb., March) from the Hvar meteorological station (dash line) in the mid Adriatic.*

cloudiness in the mid Adriatic (Hvar) during winter. One cannot deny that these two factors together affect the temperature of the coastal sea to a large extent in the Winter season. It may be understood that cloudiness indicates the rate of the received insolation and hence its influence on the sea. During Winter the cold wind also plays an important part in reducing the temperature of the sea.

The temperature of the sea has of course a direct influence upon the temperature of air (Fig. 4). However, the very difference in the sea — air temperature undergoes multi-annual changes. These differences vary from 0.4 to 1.7°C (table 6). Twice in the course of 15 years the maximum difference is observed (1956 & 1965). If the sea is to represent the mare stable factor in these variations, the fluctuations in the differences in the sea — air temperature may be to a large extent assigned to the oscillation of the air temperature which is due to the greater or smaller influence of the continent. As the temperature of the air follows the temperature of the sea in the period of warming up, and as on the average the sea is always warmer than the air, continental influence would be further cooling down of the air, resulting from the stronger bursts of cold air masses. However, it is difficult to find satisfactory evidence for the bursts of cold air as »cold« here could not be taken in the absolute sense. The formation of cyclones in the west Mediterranean seems to be related to the bursts of the cold air

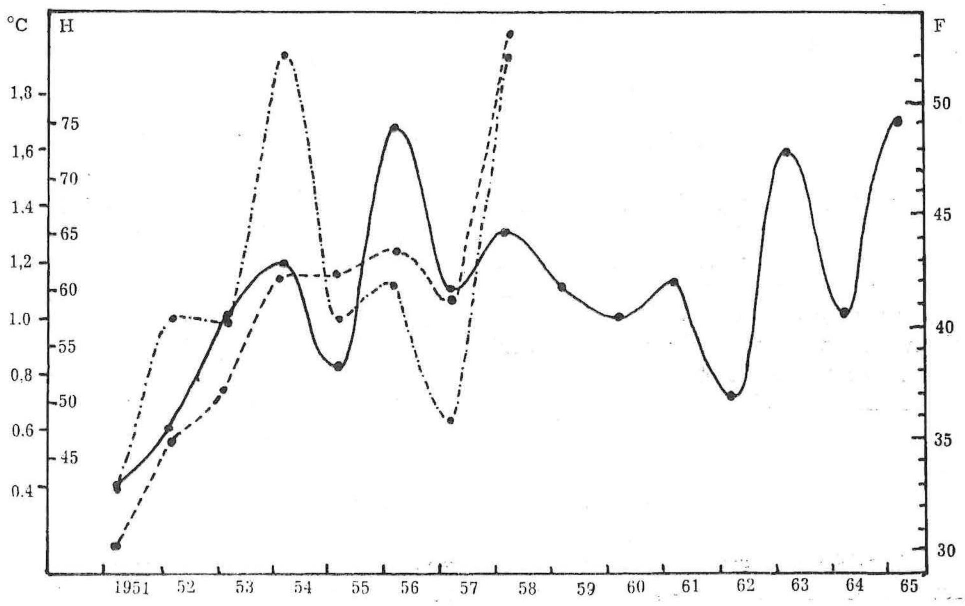

Fig. 7 Average annual sea surface and air temperature differences for Split, Rt Marjana (full line); total annual number of depressions (F) in the west Mediterranean area (dash line) and the number of hours (H) representing the period length from the beginning of cyclogenesis to the maximum development of depressions in the same area (dash and dot line).

masses (R a d i n o v i ć and L a l i ć, 1959). In Fig. 7 is given the variation of the annual number of depressions that passed along the west Mediterranean and the number of hours taken to reach their maximal intensity in the same area (according to R a d i n o v i ć and L a l i ć, op. cit.). In addition to this, the differences of the average annual temperatures of the air and sea in Split are shown. Along with the greater number of depressions or their longer period of development, there occurs a greater decline of the air temperature from that of the sea temperature. Even though the above relation looks little plausible at the first glance, it should be kept in mind that a greater number of depressions results in more bursts of the continental air to the Mediterranean. The cyclonic activity over Adriatic is related to such activity over the west Mediterranean and the part of the Adriatic is comprised in the corresponding data. So it follows that a greater decline of the temperature of the air from that of the sea means stronger continental influence upon the temperature of the air and so it shows its relation with the cyclonic activity. Therefore it could be concluded from the data of temperature differences between the sea and the air that in the years when these values were the highest, the cyclonic activity was more intense over the Adriatic (1956 and 1965).

From what has been said above, one can see how deep is the mutual thermic and dynamic dependence of the sea and the air especially if the phenomena over a larger area are considered.

2. TEMPERATURE OF THE OPEN SEA SURFACE

In this chapter the data collected before World War I (»NAJADE«, 1911—1914; »CICLOPE«, 1911—1914 and »VILLA VELEBITA«, 1913—1914), before the World War II (E r c e g o v i ć, 1934 and 1940) and those from more recent time (B u l j a n and M a r i n k o v i ć, 1956; Z o r e and Z u p a n 1960; B u l j a n and Z o r e - A r m a n d a, 1966.) have been used. Although there is abundant material, the conclusions arrived at could not be considered as final, as the data were not collected according to a uniform plan, which has also made the processing much more difficult.

a. Space Variations

In table 7 is given some data considering the average and extreme values for the whole year as well as for the different seasons.

Table 7

The average and extreme temperatures of the sea surface (^{0}C) for the Adriatic considering a total of 4928 observations.

Area	Sea temperature	Whole Year	Winter (Jan. Feb. March)	Spring (Apr. May June)	Summer (Jul. Aug. Sept.)	Autumn (Oct. Nov. Dec.)
The whole	Average	17.88	12.14	17.85	23.12	17.91
Adriatic	Maximal	28.8	16.2	25.9	28.8	24.7
	Minimal	4.1	4.1	10.1	13.8	7.3
North	Average	16.31	9.94	17.57	22.71	14.69
Adriatic	Maximal	28.8	14.0	24.0	28.8	17.8
	Minimal	4.1	4.1	10.1	19.1	7.3
Mid	Average	17.76	12.60	18.02	22.90	16.38
Adriatic	Maximal	28.2	16.2	24.7	28.2	22.7
	Minimal	8.1	8.5	11.6	13.8	8.1
South	Average	17.83	13.29	17.73	23.96	15.91
Adriatic	Maximal	27.1	16.2	25.9	27.1	20.7
	Minimal	9.1	9.1	12.5	20.0	9.7

For the requirement of table 7 and further statistical processing, the three areas of the Adriatic are separated as shown in Fig. 1. The limitations lie in the fact that the number of data for each area and the years providing the material are not the same.

According to table 7, the south Adriatic is the warmest at the surface, whereas north Adriatic is the coldest. The range of surface temperatures for the whole basin is 25^{0}C (4. 1 — 28.8). The general maximum and minimum appear in the north Adriatic, whereas they are lesser towards the south Adriatic. The reason for such a gradation is owing to the stronger continentality of the north Adriatic which has repeatedly been mentioned. The relation between the three parts of the basin vary during the different seasons. In Winter and Summer the south Adriatic shows the highest temperature, whereas the lowest is found in the northern part, which is the same relation as if taken the annual average values. In Spring and Autumn the sea surface is warmest in the mid Adriatic, whereas it is again coldest in the north Adriatic. The reason for such a distribution of temperature in the different seasons is probably due to the seasonal changes of the dynamics of the sea surface.

b. Seasonal Variations

The charts (Figs 8—11) showing the average temperature distribution of the sea surface for four months in the year representing the 4 seasons (February, May, August & November) are given according to the principle of Marsdens' distribution, with the difference that the smallest unit is a square degree. In spite of the limitations of the data, it is possible to deduce certain characteristics.

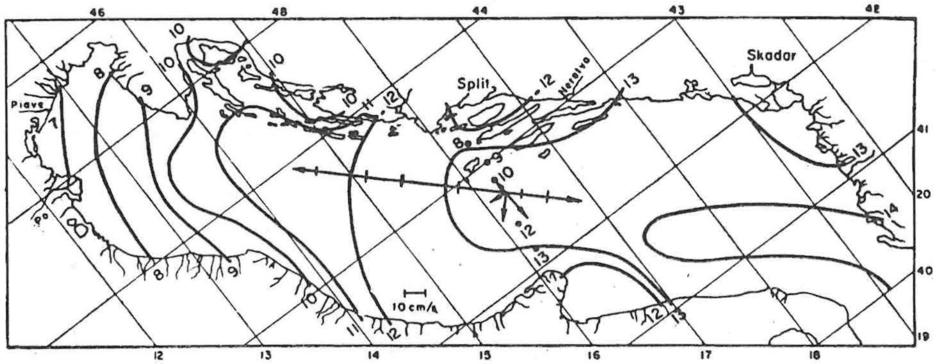

Fig. 8 *Average surface isotherms for February have been conctructed by means of the average value for every square degree and the values from coastal stations. The current rose for March for the mid Adriatic surface layer has been constructed from all the available data for stations 8, 9, 10, 12 and 13.*

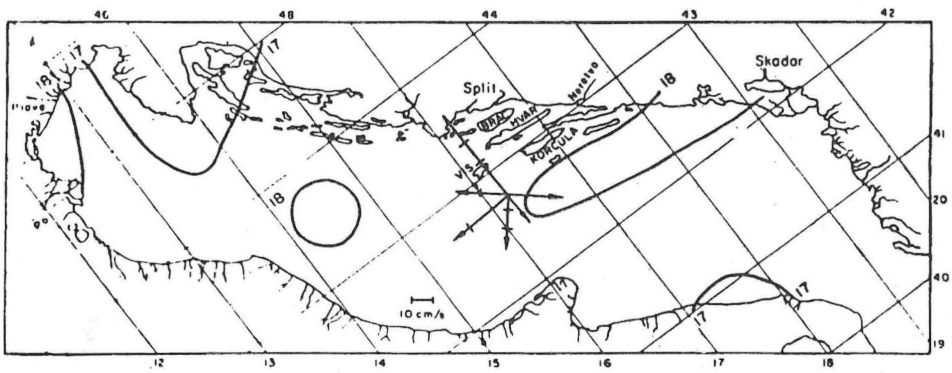

Fig. 9 Average isotherms for May and current rose for the mid Adriatic for June, both constructed as shown in Fig. 8.

In Winter (Fig. 8) as in the case of the coastal temperatures, it is possible to see the greatest longitudinal gradient. The shape of the isotherms suggests the advection of warmer waters from the Ionian Sea. In Spring (Fig. 9) there are practically, no horizontal gradients. In Summer (Fig. 10) the west coast is somewhat warmer than the east coast. In Autumn (Fig. 11) there is difference between the north and south Adriatic ,in the former the west coast is warmer, whereas in the latter the east coast is warmer. Some of the characteristics of these charts of isotherms were explained by means of the known caracteristics of the system of currents in the mid Adriatic (Z o r e - A r m a n d a, 1966b). In Winter the NW inflowing current predominates (Fig. 8) and the shape of the isotherms is in accordance with it. Transversal flow predominates in this region in Spring and there is practically no longitudinal temperature gradient. In Summer the SE outflow is predominant and it is again reflected in the shape of isotherms in the mid Adriatic. In Autumn, the transverse flow predominates here again showing that there is no dynamic contact between

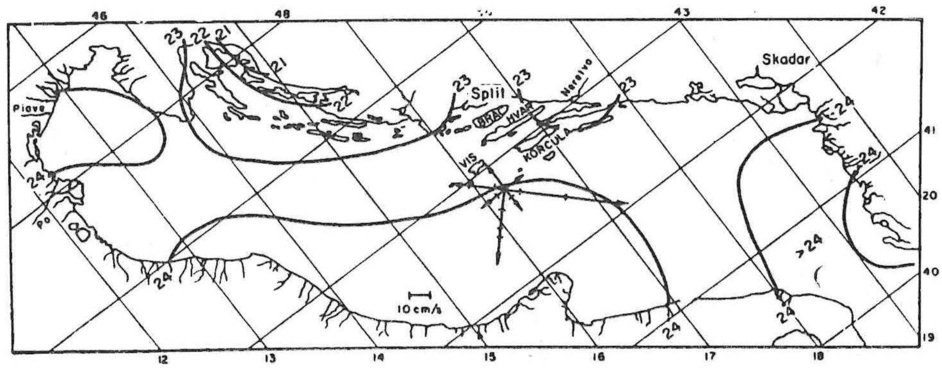

Fig. 10 Average isotherms for August and the current rofe for the mid Adriatic for Semptember, both constructed as shown in Fig 8.

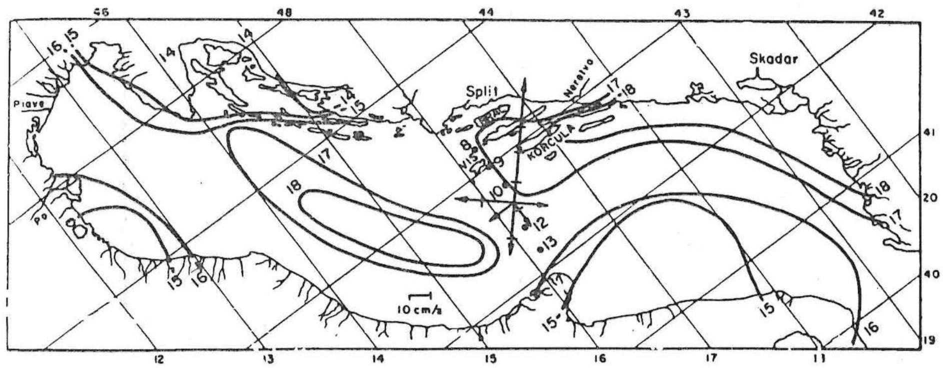

Fig. 11 Average isotherms for November and the current rose for the mid Adriatic for December, both constructed as shown in Fig. 8.

the north and south Adriatic. This is reflected in the shape of the isotherms which have not a uniform distribution. However, it may not be conclusively said whether the disappearance of the longitudinal gradient of temperature in the transititonal seasons (Spring and Autumn) is owing to the above described dynamic picture of the separation of the basin or whether the disappearance of the temperature (density) gradient causes the dinamyc separation. It is also difficult to establish as to whether the more pronounced longitudinal gradient of temperature during Summer and Winter is the result or cause of the dynamic relation of the whole basin (longitudinal current).

For getting a better understanding of the detailed seasonal distribution of temperature in the coastal area, a great amount of data from Kaštelanski

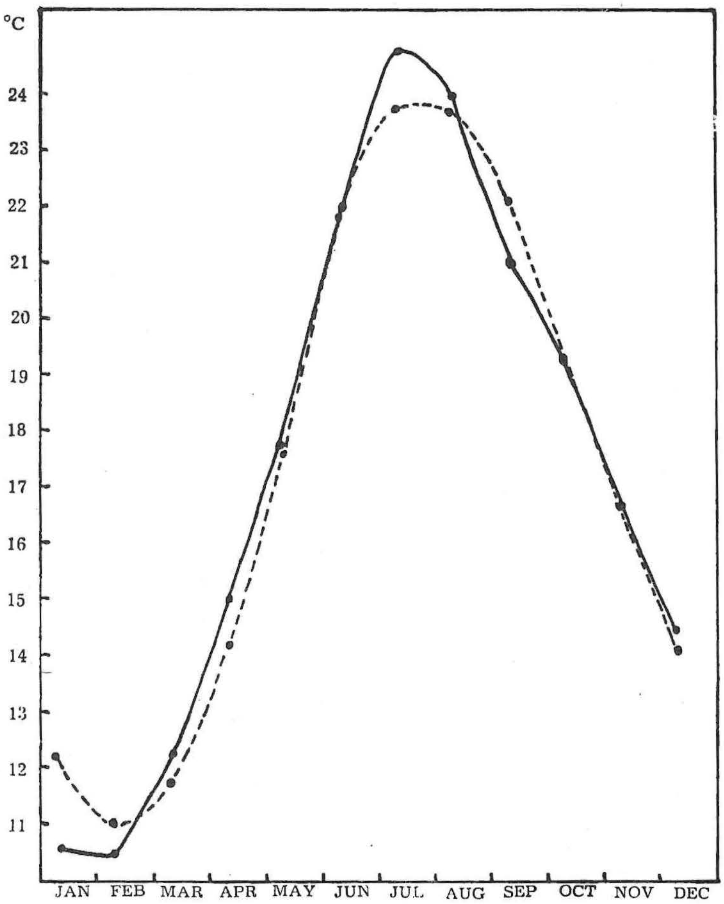

Fig. 12 Annual variations of the average monthly temperatures of the sea surface for Split, Rt Marjana (at the entrance to the Kaštelanski zaljev) (full line) and for the whole Kaštelanski zaljev (non coastal stations). (dash line).

zaljev (Kaštela Bay) have been considered. In Fig. 12 is shown the annual course of average monthly temperatures of the sea calculated from the data for a period of 17 years at several stations in the bay. Besides, the annual course of average monthly temperatures of the sea for Split, Rt Marjana is also given as this coastal station is situated at the entrance to the bay where it comunicates with the larger Splitski kanal (Split channel). The central part of the bay shows itself to be more continental than the coastal station at the entrance as it has lower temperature in Winter and higher in Summer. This may be the influence of the larger Split channel or of the Jadro river which flows into the bay at its eastern part ond carries comparatively warmer water in Winter and as a result the eastern part of the bay is generally warmer in that season.

The material for all 7 stations in the Kaštelanski zaljev — Gargano profile (stations 25, 8, 9, 10, 11, 12 and 13 — see Fig. 1) has also been processed according to seasons and is given in table 8.

Table 8

Average seasonal temperatures of the sea surface (^{0}C)

Station	Winter (Jan. Feb· March)	Spring (Apr. May June)	Summer (Jul. Aug. Sept.)	Autumn (Oct. Nov. Dec.)
25	10.98	18.48	23·07	16.49
8	13.85	17.71	22·60	17.94
9	13.65	17.82	23.29	18.29
10	13.79	19.55	23.63	17.17
11	14.02	19.01	23.57	16.77
12	13.68	18.02	23·31	15.59
13	13.17	18.57	23.41	15.50
Average	13.29	18.41	23·27	16.82

The minimum values for each season are underlined by a dash-line and the maximum ones by a full line.

The distribution of the maximum and minimum temperatures in the profile is different in the various seasons. But generally speaking the maximum temperature is usually found in the open sea, whereas the minimum is found near the land. Fig. 13 shows the distribution of average seasonal temperatures at the stations on the profile. In Winter, the minimum temperature is found along the east coast, though both coasts show temperatures lower than that of the open sea. The comparatively very low temperature of the sea in the Kaštela Bay might be due to the influence of the cold NE wind (bura) which has lesser influence on the west coast. The distribution of temperature in the profile is nearly regular. The shallower sea cools off easier in Winter whereas the open sea is under the influence of the advection of the warmer water from the south Adriatic and the Mediterranean. In Spring, the maximum temperature is again found in the middle of the profile (station 10) but at the stations close to the coast faster warming is noticed than at the adjoining stations. The minimum is found at station 8 near the Hvar Island and at the neighbouring station 9 near the Vis Island it is almost as low as at the previous station. A divergence in the system of the surface currents was noticed in that area in Spring (Zore-Armanda, 1966 b) which was brought into connection with the earlier noticed upwelling at station 9 (Buljan, 1965) which may be the reason for the comparatively low temperature there. Possibly a similar situation occurs in the Palagruža area (station 12). In Summer also a similar situation occurs and the reason may be due to the continuance of upwelling which was noticed earlier. However in Summer a greater difference in that respect is noticed between the east and west coasts. In Autumn the distribution of the temperatures in the profile is completely different and the lowest temperature is found along the Italian coast. This may also be accounted to the system of surface currents as there is water flow from the Italian coast towards the open sea in that season. This flow may cause upwelling along the coast. The SE wind (jugo) may also have some influence, as it predominates over the south and mid Adriatic in Autumn drifting the surface water off the west coast.

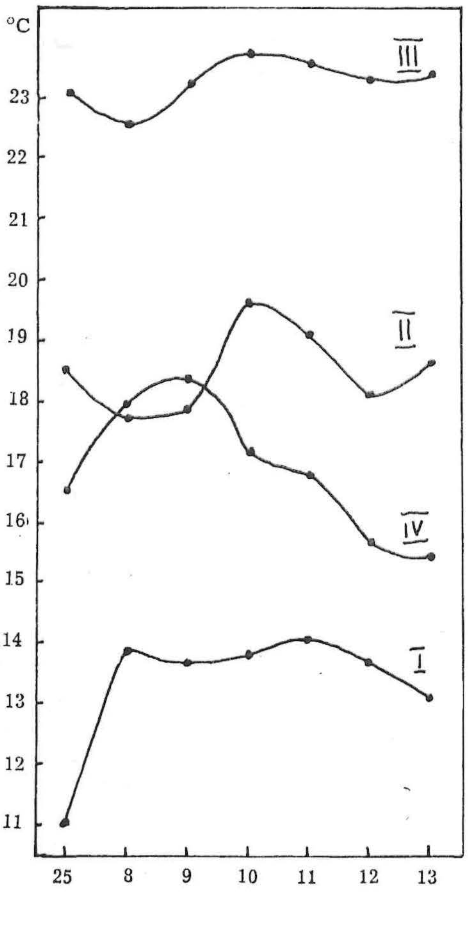

Fig. 13 Average seasonal temperature distribution for the sea surface in the Kaštelanski zaljev-Gargano profile (for stations 25 and 8 to 13 see Fig 1) for Winter (I), Spring (II), Summer (III) and Autumn (IV).

c. Long Term Variations

The results of the systematic long term observations of the NAJADE and CICLOPE expeditions have already shown that the temperature of the open sea is liable to strong multiannual changes (B u l j a n, 1957). A series of charts of the surface layer temperature distribution for the different years comprising

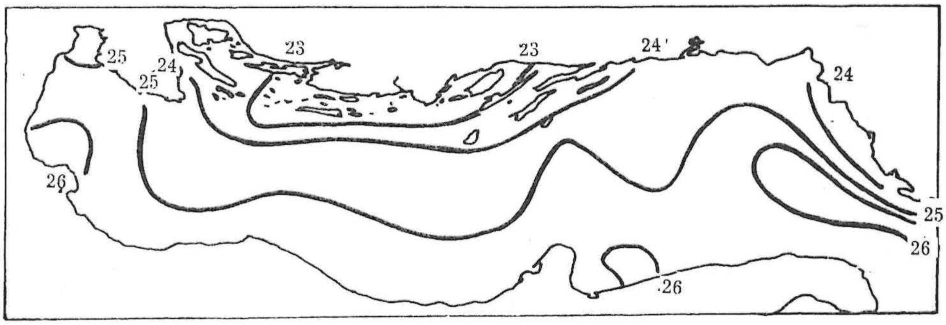

Fig. 14 Temperature distribution of the sea surface for August-September 1911 according to the data from the Najade and Ciclope expeditions.

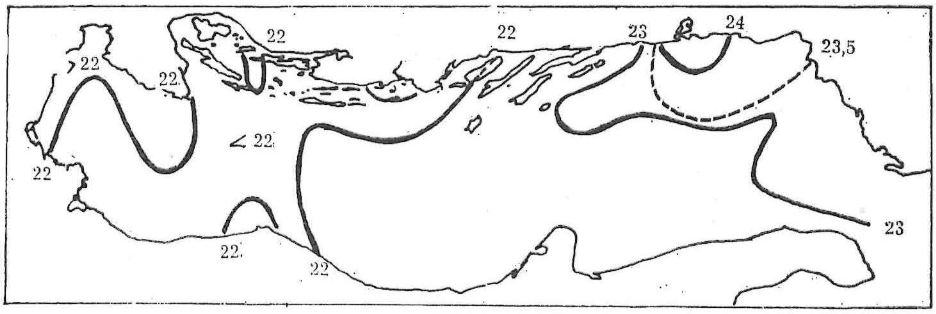

Fig. 15 Temperature distribution of the sea surface for August—September 1913 according to the data from the Najade and Ciclope expeditions.

the various seasons have been prepared (e. g. Z o r e, 1956). Of these, two charts for the Summer of 1911 and 1913 are given in Figs 14 and 15, to show the wide changes in the factor that has been considered.

The long term course of temperature for the sea surface on the Hvar — Gargano profile (station 8 — 13) is represented in table 9. A summary of the data for all the six stations has been taken for calculating the average.

If we consider the long term course of average Winter temperatures, it may be seen that in the coastal regions (station Split, rt Marjana) it runs almost parallel to that in the open sea (Fig. 16). This fact helps us to predict the temperatures of the open sea from the known coastal temperatures. However ,there are a number of changes which are not parallel and the two series of values for particular years may be different. The components affecting the parallel changes are probably external factors which have an equal influence on the temperature of the coast as well as that of the open sea.

In the preciding chapter it has been shown that cloudiness and the cold NE wind (bura) are the main external factors that may affect the coast and open sea simultaneously (Fig. 6).

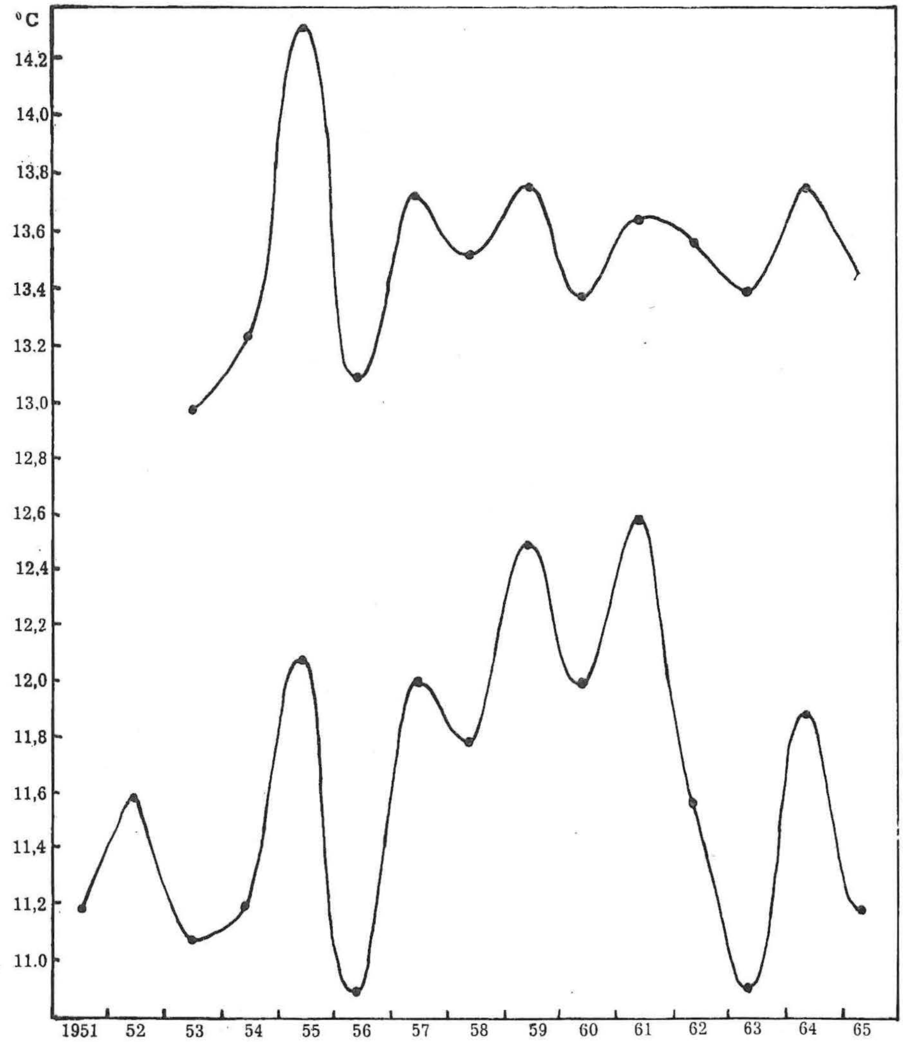

Fig. 16 Long term variation of the average Winter sea surface temperatures at Split, Rt Marjana station, (lower curve) and in the open mid Adriatic (upper curve) (stations 8 to 13, Fig. 1).

Table 9

Summary of the average temperature of the sea surface (⁰C) for stations 8 to 13 (mid Adriatic).

Year	Winter (Jan. Feb. March)	Spring (Apr. May June)	Summer (Jul. Aug. Sept.)	Autumn (Oct. Nov. Dec.)
1952	—	23.82	22.21	15.20
1953	12.97	16.10	23.78	18.70
1954	13.23	21.70	23.28	20.40
1955	14.36	14.34	—	—
1956	13.10	14.61	24.78	17.66
1957	13.76	20.71	21.92	15.48
1958	13.54	20.77	—	16.48
1959	13.79	19.47	21.62	16.45
1960	13.39	18.72	22.24	16.89
1961	13.68	17.53	22.22	17.47
1962	13.60	17.03	24.57	16.05
1963	13.40	18.40	23.47	19.28
1964	13.79	20.44	22.92	16.97
Average	13.55	18.74	23.00	17.25

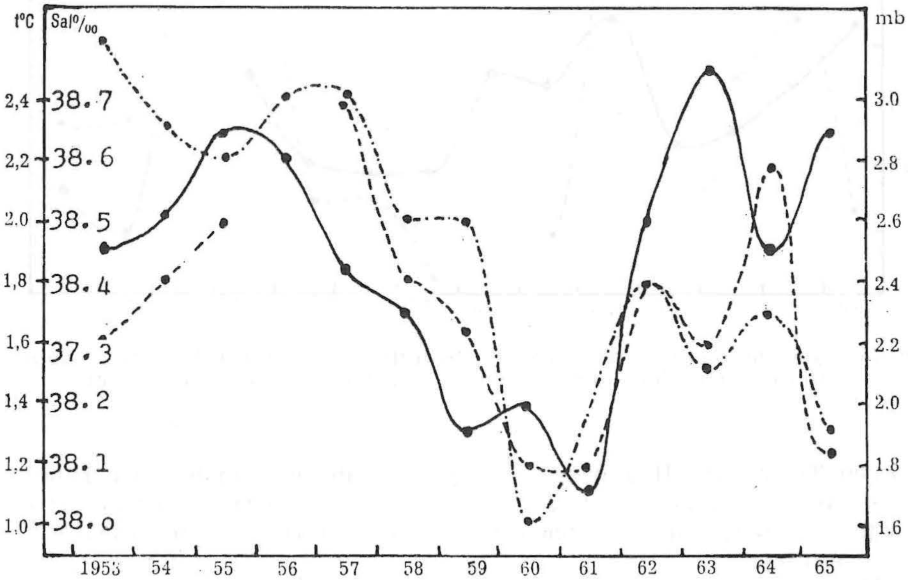

Fig. 17 Long term variations of the average Winter surface temperature differences of the coastal (Split, Rt Marjana) and open mid Adriatic (stations 8 to 13, Fig. 1) (full line); long term variation of the average Winter salinity of the open mid Adriatic (stations 8 to 13) (dash line) and the average annual Triest--Athens air pressure differences (dash and dot line). Data for this curve, from the U.S. Dpt. of Comm. *1951—1965.*

A factor which is not having an equal influence in the coastal area as well as in the open sea is probably the advection which is always stronger in the open sea. B u l j a n (1953) has shown that the variations in the intensity of the advection of the Mediterranean water is reflected in the fluctuations of salinity. Greater salinity is the indication of greater advection of the Mediterranean water. Fig. 17 shows the multiannual course of the average salinity in the Hvar — Gargano profile as well as the course of the annual difference in temperature between that profile and the coastal station, ie. $\bar{t}_{(8-13)} - \bar{t}_{\text{Rt Marjane}}$.

The striking resemblance of the above two curves substantiales the validity of the above reasoning. A discrepancy is observed only in 1963. The direct and indirect influences of the air pressure gradient on the current system of the Adriatic have already been pointed out (Z o r e - A r m a n d a, 1966 a and 1969). A greater air pressure gradient is related to a greater water advection. Fig. 17 also shows the average annual differences of air pressure

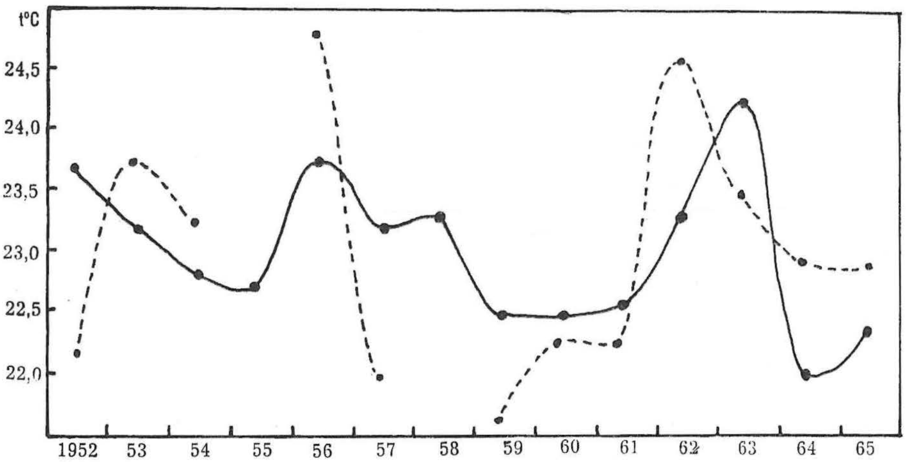

Fig. 18 Average Summer sea surface temperatures of the coastal station Split, Rt Marjana, (full line) and of the open sea, stations 8 to 13, (dash line).

between Trieste and Hvar where too the resemblance can be seen. However, the air pressure gradient affects a wider area and can be considered only as a part of more important phenomenon: the dynamics of the whole eastern Mediterranean.

The long term temperature variation of the coastal and open sea are much less parallel in Summer (Fig. 18). In this season the temperature varies more and these changes could not be easily understood as being effected by the particular factor.

One of the characteristics of the annual changes of temperature in Winter is that it varies in the first decimal only, whereas these changes are very great in trasitional seasons. Spring is most characteristic in that respect, as the variations amount to as much as 9,5^{0}C in a thirteen year's course. Besides, temperature variations in Spring shows no relation with the analagous variations in Summer and Winter. From this it may be concluded that during transitional seasons, local factors are more important in effecting the formation of the surface layer temperature. In Autumn, the annual temperature variation is somewhat less than in Spring (5°C). However, the annual variation in Autumn shows some analogous characteristics with that in Summer, which suggests that in Autumn this variation is, partially at least, a continuation of the temperature formed earlier in the Summer period.

3. VERTICAL TEMPERATURE VARIATION

The material used for writing the preceding chapter is used here also and so the limitations of data are valid here also. The meteorological data have been obtained by the courtesy of Hidrometeorološki zavod SRH, Zagreb.

a. The Adriatic

Along with the study of the water types of the Adriatic, their vertical distribution in the various seasons was also considered (Zore-Armanda, 1963 a). As each water type is characterised by a particular temperature, it follows that the vertical temperature arrangement depends on vertical distribution of water types. The defined types of water show the following temperature characteristics:

S Type = 11^{0}C; appears in the bottom layer.
M Type = 12°C; appears in the surface and intermediate layers.
A Type = 14°C; appears in the surface and intermediate layers.
J Type = 13^{0}C; appears in the intermediate and bottom layers.

The Summer surface water and the coastal waters have no defined characteristics as they continuously change. Te typical vertical arrangement of water types in the mid Adriatic in Winter is as follows:

Surface layer — M or A
Bottom layer — S

In the south Adriatic:

Surface layer — M or A
Bottom layer — J

The appearance of the particular water type in the surface layer depends upon the intensity of the advection of the Mediterranean water (A) into the Adriatic. It is worth mentioning that the surface layer comprises the intermediate layer in Winter and both have identical characteristics.

The typical vertical arrangement of water types in the mid Adriatic in Summer is as follows:

Surface layer	—	Summer surface water
Intermediate layer	—	A
Bottom layer	—	S

In the south Adriatic:

Surface layer	—	Summer surface water
Intermediary layer	—	A
Bottom layer	—	J

In Summer the surface layer is separated from the intermediate by a more or less pronounced thermocline. The lower limit of the thermocline (earlier defined according to T—S diagrams at about 40 m) is also the boundary between the two layers and it is never found constant at the same detph. The boundary between the intermediate and bottom layers is according to T—S diagrams at about 150 m in the mid Adriatic, and at about 400—500 m in the south Adriatic.

The vertical arrangement of temperature seen through the average values obtained from multiannual data will not be a direct reflection of the vertical distribution of water types as it changes in different years.

B u l j a n (1957) after a study of the multiannual variation of water temperature of the open Adriatic observed that in the period of stronger inflow of the Mediterranean water into the Adriatic (ingression) in Winter there occurs the warming up of the waters of the open south and mid Adriatic. He also noticed that in the same period the layer having the maximum temperature is located near the surface while the layer showing the minimum temperature is found at the bottom. With a weaker influence of the Mediterranean water, these layers show a reverse arrangement. Hence the average values do not reflect the dynamic characteristics of the basin, though they are helpful for some considerations. The average values are shown in table 10.

Table 10

Average annual and seasonal values of the sea temperatures (^{0}C) for the whole Adriatic and heat required for the warming up of separate layers.

Depth in m	Year (Whole)	Winter (Jan., Febr., March)	Spring (Apr., May, June)	Summer (Jul., Aug., Sept.)	Autumn (Oct. Nov. Dec.)	Ampl. (max-min)	Average for layer	Heat for warming up. cal/cm^2
0	17.88	12.14	17.85	23.12	17.91	10.98		
							10.99	5495
5	16.80	11.65	16.39	22.65	16.25	11.00		
							10.42	5210
10	16.77	11.95	16.05	21.78	16.53	9.83		
							7.96	7960
20	15.61	12.44	14.96	13.53	16.95	6.09		
							5.17	5170
30	14.84	12.37	14.34	16.31	16.62	4.25		
							4.48	4480
40	14.43	12.25	13.72	15.23	16.95	4.70		
							3.89	3890
50	14.28	13.03	13.74	14.63	16.11	3.08		
							2.65	6625
75	14.04	13.27	13.62	14.16	15.48	2.21		
							1.79	4475
100	13.79	13.27	13.55	13.86	14.63	1.36		
							0.96	4800
150	13.19	13.11	12.98	13.08	13.64	0.56		
							0.41	2050
200	13.01	13.01	12.99	12.89	13.15	0.26		
							0.26	2600
300	13.72	13.58	13.84	13.72	13.78	0.26		
							0.20	4000
500	13.45	13.42	13.53	13.39	13.50	0.14		
800	13.23	13.22	13.27	13.19	13.26			
1000	12.82	12.82	12.76	12.93	12.77			

The data in table 10 has been made use of for calculating approximately the heat budget for the Adriatic. According to Penzar (1960) the annual global radiation for Split (mid Adriatic) is 123861 cal/cm^2. This value is supposed to be representative enough for the whole basin. The total annual back radiation has been calculated by means of the average annual values of the sea surface temperatures (table 10) and the multiannual average values of relative humidity at the Hvar meteorological station ($u = 66\%$). This value is also considered to be representative owing to the central position of the station in the Adriatic and its location in the island. According to the nomogram from the modified Lönnquist's formula (Laevastu, 1960), the annual back radiation is calculated as 72576 cal/cm^2 when the sky is clear.

The reduction for cloudiness with the use of the average long term values for Hvar (C = 4) and the formula according to M ö l l e r (L a e v a s t u, op. cit.) ammounts to 21772 cal/cm^2 per year and so the corrected figure for back radiation comes tu 50804 cal/cm^2 per year.

The annual evaporation has been calculated from the absorbed (Q_s) and back (Q_b) radiations by means of the equation

$$E = \frac{Q_s - Q_b}{L\,(1 - R)}$$

where L stands for the latent heat of evaporation, and R for the so called B o w e n's ratio (S v e r d r u p et al. 1942). This is on the supposition that the whole of the Adriatic in an year's course does not use any heat for net warming (ie. the whole heat spent in warming is returned as back radiation) and that the heat received through the advection from the Mediterranean did not remain there. In order to calculate the R value the long term averages of the meteorological data for Hvar have again been considered (air t = 16,1^{0}C; air pressure = 1012 mb; water steam pressure = 12,7 mb; R = 0,16). Using these values the annual evaporation is estimated at 106 cm.

For finding out at least to some extent the seasonal variation of the evaporation the year is divided into two parts — the warming season (Spring and Summer — April to September) and the cooling season (Autumn and Winter — October to March). The total heat needed for warming of a water column of 1 cm^2 surface from 0 to 500 m is then calculated. The difference between the lowest and highest seasonal average values of temperature (table 10) is supposed to represent the figure for the total heating of water layer. The average temperature of each layer of water have been considered and the heat needed for heating has been calculated in cal/cm^2. The values for all layers up to the 500 m have been summed up for finding out the total energy required for the heating of the complete water column. The data reveal that the annual variation of temperature in the deeper layers is very insignificant. The total heat needed to warm up a water column from 0 — 500 m comes up to 56755 cal/cm^2. The greater part of this energy is used in the warming season ie. in Spring and Summer, when the water warms up from the lowest to the highest temperature in the upper 20 m deep layer. In the layer from 30 — 100 m heating takes place up to Autumn, i. e. for a third of an year longer. This accounts for the utilisation of about 2/3 of the total energy in this layer in the warming season. In deeper layers there is even greater phase shift (minimal temperature is found in Spring) so that only 1/2 of the total heat is used in the warming period. From the above calculation it follows that 43536 cal/cm^2 from the total heat needed for the maximum warming up of the whole layer is used in the warming season and the remaining 13218 cal/cm^2 is used in the cooling season. It is true that on the whole cooling in the water column takes place in the cooling season except rarely in the deeper layers. The calculation of the heat budget for warming and cooling seasons are shown below:

Table 11

Heat Budget Calculation

		Warming season Apr. to Sept.	Cooling season Oct. to March
		cal/cm²	cal/cm²
Radiation received Q_s		87602 +	36259 +
Water cooling Q_{t+}		—	56755 +
$Q_s + Q_{t+}$		87602 +	93014 +
Water heating Q_{t-}		43536 —	13219 —
Back radition Q_b		25745 —	23303 —
$Q_{t-} + Q_b$		69281 —	36522 —
Total received & released $Q_s + Q_{t+}$		87602 +	93014 +
Total given & spent without evaporation & convection $Q_b + Q_{t-}$		69281 —	36522 —
Heat for evaporation & convection		18321 +	56492 +
Long term average values for the Hvar meteoroolgical station used in calculating Q_b & R	Air temp.	21°C	11°C
	Cloudiness	3	5
	e	15.9 mb	9.5 mb
	p	1010 mb	1013 mb
	u	63%	68%
R		—0.1	0.37
Evaporation E		28 cm	70 cm

The annual evaporation calculated in this way comes to 98 cm compared to the previously calculated whole year evaporation of 106 cm (difference = = 8 cm). This is in good agreement considering the fact that these are rough calculations. Evaporation is 2 1/2 times greater during the cooling season than during the warming season.

By means of the annual value of evaporation it is possible to define the approximate E — P index. The rainfall data from the island stations are taken for geting the aproximate value of the rainfall for the Adriatic. The rainfall data from the coastal stations are not supposed to be representative as there is greater rainfall in the coast than in the sea owing to the air lifting. Though this is valid to same extent for the islands also, it is not considerable. On the other hand the question arises as to whether the coastal surplus of rainfall does not come back to the sea from submarine springs and short fresh water streams. The average annual rainfall for the four islands (Lošinj, Hvar, Vis, Palagruža) amounts to 70 cm (data according to M a k j a n i ć, 1956). The Po river gives 55 x 10^9 m^3 (V a t o v a, 1948), whereas the rest of the north Italian rivers altogether give 11.1 x 10^9 m^3 (according to U f f i c i o i d r o g r., 1963). The Yugoslav rivers give 34.2 x 10^9 m^3 (according to D u k i ć, 1960) and the Albanian rivers 36,4 x 10^9 m^3 (according to B o t i m I n s t i t u t i t H i d r o m e t. 1966). The remaining rivers have not been taken into account as they are comparatively poor in water supply. If the total river inflow is divided by the Adriatic superficies (according to R u b i ć, 1956, it comes to 138,595 x 10^6 m^2) the result shows that the Adriatic gets 84 cm per year from the river inflow. If that number is added to the total annual rainfall the result is 154 cm per year. If evaporation is substracted from the above figure we get 48 cm per year, i. e. 67 x 10^9 m^3 per year (od 56 cm per year equivalent to 78 x 10^9 m^3 cm if 98 cm is taken as the annual value of evaporation). Thus the Adriatic serves as a basin of dilution for the Mediterranean Sea. This phenomenon is supported by the surface salinity distribution of the Mediterranean. This is particularly true in Summer when the evaporation is low and the surface currents carry the less saline waters of the north Adriatic unto the Mediterranean and the more saline eastern water flows as compensatory current into the Adriatic in the intermediate layer.

Mosetti (1966—67) found that the total fresh water received in the north Adriatic in Summer is 1320 m^3/sec which amounts to 42 x 10^9 m^3/year. As the greatest part of the fresh water received in the Adriatic is in its northern section, the above stated values agree well.

For understanding the structure of table 10 one should bear in mind that it gives the summary of the data of the whole Adriatic including the two pits (Jabuka and the south Adriatic pit) and the shallow north Adriatic. In Winter a gradual increase of temperature from 5 up to the 150 m depth is observed; at 150 m and 200 m depths a somewhat lower temperature is found and after that the temperature increase again but becomes lowered again at 1000 m depth. The first decrease of temperature at 200 m is related to the Jabuka pit (bottom layer) and the second to the bottom layer of the south Adriatic pit. The common characteristic of the two pits is that the colder northern water advects into their bottom layers. It may be seen that the water advection in question comes from the north as the minimum temperature at 200 m is found in Summer, the Winter north Adriatic water having been taken about half a year to reach the Jabuka pit. This heavier and colder water in the bottom layer does not mix with that of the upper layers (Z o r e - A r m a n d a, 1963 a) resulting in the lower temperature values at these depths.

Spring warming can be felt up to 100 m depth and that of Summer up to 150 m depth. The cooling of the surface layer begins in Autumn while warming continues as we go deeper so that the maximum temperature for the season is found at 200 m depth. It follows that the warming up phase shifts for every 50 m depth for every season (three months). The warming up without retardation (i. e. the appearance of minimum in Winter and maximum in Summer) takes place in the layer up to 20 m depth. This depth is also characterised by the greatest thermocline. In this respect, this layer might be labeled as real surface layer; also characterised by some dynamic properties such es well-marked seasonal changes in the current system (Zore-Armanda, 1963 a). The layer from 30 — 100 m shows the minimum temperature in Winter and maximum in Autumn. The Summer thermocline diminishes the vertical mixing in that layer so that the water there warms to its maximum only when the autumnal cooling and water mixing take place. In Winter there is no phase shifting as the vertical mixing reaches the maximum. This layer could be to some extent identified with the intermediate layer (in the mid Adriatic only) and its characteristic is that it is in direct contact with the surface layer through vertical mixing. In deeper layers the annual variation of temperature is perhaps under a stronger influence of the vertical mixing which is also the main characteristic of this bottom layer.

Table 12

Extreme temperatures (°C) for different depths according to the data for the whole Adriatic.

Depth in m.	Minimum	Maximum	Amplitude
0	4.1	28.8	24.7
5	6.2	26.8	20.6
10	6.23	25.90	19.67
20	6.76	25.58	18.82
30	6.76	24.27	17.51
40	8.06	23.25	15.19
50	9.15	23.07	13.92
75	9.97	22.40	12.43
100	10.21	19.90	9.69
150	10.44	15.23	4.79
200	9.08	14.90	5.82
300	13.01	14.75	1.74
500	12.65	14.78	2.13
800	12.59	13.91	1.32
1000	12.55	13.95	1.40
Still deeper	12.54	13.40	0.86

The annual amplitude of the extreme temperatures, as may be seen from the table, constantly decreases with depth beginning from surface up to 150 m where it is 4,79°C. At 200 m the amplitude increases again owing to the lower minimum at that depth. This minimum is the result of the conditions in the bottom layer of the Jabuka pit into which during some Winters flows the cold north Adriatic water which remains there unmixed. The same phenomenon is reflected in table 10 which has already been described.

The absolute minimum of temperature shows the highest value at 300 m depth. This might be due to the influence of the dynamic effect of the intermediate layer which is under the influence of the Mediterranean intermediate water, i. e. the water type (A) having the highest temperature in the Adriatic (surface water excluded). This may also indicate that the center of the intermediate layer in the south Adriatic is at the above depth. Below 300 m depth the minimum temperature does not show any considerable change. The maximum temperature gradation is more constant and it decreases with depth with insignificant exeptions at 500 and 1000 m depths.

What has been said for table 10, that it gives only the summary of the data and not the dynamic characteristics of long term changes, applies to table 12 also. Certain consistencies in the vertical arrangement of the maximum and minimum temperature for different years was earlier noticed by Buljan, (1958).

b. North Adriatic

Table 13

Average annual and seasonal temperatures (^0C) and the vertical temperature gradient (t°C/10 m) rounded to 1/4 for the north Adriatic according to 3933 observations.

Depth in metres	Whole year		Winter (Jan. Feb. Mar.)		Spring (April May June)		Summer (July Aug. Sept.)		Autumn (Oct. Nov. Dec.)	
	Av. temp.	Grad.	Av. t.	Grad.	Av. t.	Grad.	Av. t.	Grad.	Av. t.	Grad.
0	16.31		9.94		17.57		22.71		14.69	
		1 1/2		1/4		3 3/4		—1/4		—1 1/2
5	15.58		9.81		15.71		22.94		15.50	
		1/2		—1/4		1		1 1/5		—1/4
10	15.39		9.91		14.79		22.13		15.63	
		1		—1/4		1		3 1/4		—1/4
20	14.40		10.20		13.72		18.86		15.97	
		3/4		—1/4		1/2		2 1/2		0
30	13.75		10.40		13.13		16.40		16.06	
		1/4		—1/4		1/4		1 1/4		—1/2
40	13.50		10.69		12.83		15.17		16.53	
		1/2		—1/4		1/2		1 1/2		1
50	12.99		10.87		12.22		13.66		15.51	
		1/2		0		1/4		1		1 1/2
75	11.37		10.84		11.49		11.50		11.76	
Average of absolute values		3/4		1/4		1		1 3/4		3/4

From the above table it may be seen that the vertical distribution of temperature in the area undergoes considerable seasonal changes. In Winter the water of this comparatively shallow basin (maximal depth about 90 m) is almost completely mixed and shows homogenous structure from surface to bottom. As a result the vertical gradients are the lowest in this season. The highest gradient of all the seasons is seen during Spring in the surface layer. In Summer, a somewhat lower gradient is seen in the layer 10—20 m and to some extent up to 30 m. Consequently, this depth may be considered as the lower limit of the thermocline in that area.

The average lower limit of the thermocline is determined in a different way also. This is by finding out the depth for each series of measurements (accordino to the N a j a d e data) and then the average is calculated. The lower limit determined in this way also showed the same detph (30 m).

If the annual average values are considered, it may be seen that the vertical gradient is always positive. It is also positive through the whole layer in Spring when the warming up begins. In Winter the gradient is negative through with the exception of the surface layer, where some warming already begins. In the same way, the surface layer begins to cool down in Summer. However, while the vertical gradient is positive throughout the depth in Spring, in Autumn it is negative only in the layer up to 40 m. The positive gradients (Spring, Summer) are generally higher than the negative ones (Autumn, Winter), and as a result the gradient is always positive in the annual average value, i.e. the temperature in the lower layers is lower on average. In Summer, stratification is the most pronounced and so the average gradient is the highest in that season.

The long term changes in the vertical arrangement depend upon the change of the outer factors and dynamics. These relations were qualitatively understood to a certain extent, when the distribution of the defined water types in particular years was studied (Z o r e - A r m a n d a, 1963 a).

c. Mid Adriatic

For 13 years temperature measurements were made in Split at the surface and a depth of 2 m.

Table 14

Split, Rt Marjana; average monthly temperatures of the sea (°C), 1953—1965

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Surface	12.2	11.0	11.7	14.2	17.5	21.7	23.7	23.6	22.0	19.2	16.7	14.0
2 m	12.3	11.2	11.8	14.0	17.2	21.1	23.2	23.3	21.8	19.3	16.8	14.3
Difference	—0.1	—0.2	—0.1	0.2	0.3	0.6	0.5	0.3	0.2	—0.1	—0.1	—0.3

The temperatures at the two levels differ so that the annual extremes are a slightly lesser at 2 m depth. This difference in temperatures is greater in Summer (weaker mixing). There is no temperature difference in October which is the month of the strongest vertical mixing. From November to February the temperature at 2 m depth is sligthly higher than at the surface. The annual course of the temperature differences at the surface and at 2 m depth is very simmetrical. In Autumn only the difference is slightly less than in Spring. This is because the water mixing in the period of warming is weaker than in the period of cooling.

Buljan (1965) studied the vertical distribution of sea temperature at the control station (9) in the middle Adriatic (Stončica near Island Vis). On the basis of 6 to 12 year's data he has constructed a typical graph of the vertical temperature distribution in the course of an year. According to this graph »the first four and the last two months of the year show no gradients, whereas a thermocline sets up at the begining of May. It becomes more pronounced till September and then begins to disappear by the lowering of the isotherm of 10°C to the bottom (100 m). Homothermy (17°C) reaches the bottom by the end of November. The winter cooling down decreases the temperature of the water column for another 4°C till the end of March«. The above graph shows the possibility of upwelling in Summer.

The average values (annual and seasonal temperature) and the vertical temperature gradients have been calculated for the mid Adriatic also.

Table 15

Average annual and seasonal temperatures (°C) and vertical gradients (t°C/10 m) rounded to 1/4 for the mid Adriatic according to 9427 observations.

Depth in metres	Whole year		Winter (Jan. Feb. Mar.)		Spring (April May June)		Summer (July Aug. Sept.)		Autumn (Oct. Nov. Dec.)	
	Av. temp.	Grad.	Av. t.	Grad.	Av. t.	Grad.	Av. t.	Grad.	Av. t.	Grad.
0	17.76		12.60		18.02		22.90		16.38	
		1		0		2 1/2		2 1/4		—1 1/4
5	17.34		12.56		16.81		21.78		16.98	
		1/4		—1/4		1		1 1/2		—3/4
10	17.17		12.63		16.26		21.00		17.31	
		1 1/4		—1/2		1		3		—1/4
20	15.87		13.06		15.15		17.89		17.62	
		1/2		0		1/2		2		1/4
30	15.25		13.13		14.66		16.00		17.33	
		1/2		1/4		3/4		3/4		0
40	14.77		13.00		13.97		15.19		17.28	
		1/4		—1/2		0		1/2		3/4
50	14.54		13.37		13.93		14.81		16.60	
		1/4		0		0		1/4		1/4
75	14.21		13.35		13.72		14.32		15.90	
		1/4		0		1/4		1/4		1/2
100	13.69		13.04		13.33		13.74		14.84	
		1/4		0		1/4		1/4		1/4
150	12.76		12.84		12.52		12.45		13.34	
		1/4		1/4		1/4		1/4		1/2
200	11.42		11.97		11.26		11.02		11.14	

The mid Adriatic is warmer than the north in the upper layers during all the seasons, especially in Winter. In Summer the difference is less and at 5 and 10 m depths the north Adriatic is even warmer than the south.

In Winter the vertical gradients are more irregularly distributed in the mid Adriatic than in the north. Besides, there appears a positive gradient in the bottom layer during this season, which shows that it is not comprised in the vertical mixing except perhaps to a very small degree. The temperature of the bottom layer is conditioned by the water advection from the north Adriatic. As the lowest temperature in the bottom layer (150 and 200 m) is found in Summer it may be deduced that it took about half an year for the north Adriatic Winter water to rich the Jabuka pit. This corresponds to the current velocity of ca. 2 cm/sec which seems to be very convincing. The average resultant current velocity in the bottom layer of the middle Adriatic is ca. 9 cm/sec (Z o r e - A r m a n d a, 1966 c) but this is derived from currents in all directions and need not agree close with the above figure.

In Spring the greatest vertical temperature gradient is seen in the surface layer as in the north Adriatic, the difference being that in the mid Adriatic it is lower than in the north. In Summer the maximum gradient is again between 10 and 20 m but the lowest thermocline limit could be located at 30 m. In this respect it is necessary to distinguish the data for the coastal area from those for the open sea. The lowest thermocline limit for Summer is calculated to be 20 m for the coastal area (Kaštelanski zaljev and Trogirski kanal according to the data by B u l j a n and Z o r e - A r m a n d a, 1966). However, in Summer there often occurs such a situation in the coastal area that there is a great gradient from the surface to the bottom and any thermocline is out of question. If we exclude the data from the coastal stations in calculating the depth of the thermocline of the mid Adriatic, the lower limit in Summer may be fixed at 35 m.

There is no phase shift in the annual variation of temperature in the upper 20 m and so in this respect the mid Adriatic behaves like the whole Adriatic.

In the layer from 30 to 100 m the maximum temperature appears as late as in Autumn. As already pointed out, this layer in the mid Adriatic approximately coincides with the intermediate layer, which is dynamically defined with the NW inflowing current and with interchanging influence of the A (Mediterranean) and J (south Adriatic) waters.

In the bottom layer the maximum temperature appears in Winter and the minimum in Summer. The temperature of this layer is under the influence of advection from the north Adriatic and not by the mixing up with the upper layers.

d. South Adriatic

Table 16

Average annual and seasonal temperatures (°C) and vertical gradients (t°C/10 m) rounded to 1/4 for the south Adriatic according to 4468 observations.

Depth in metres	Whole year		Winter (Jan. Feb. Mar.)		Spring (April May June)		Summer (July Aug. Sept.)		Autumn (Oct. Nov. Dec.)	
	Av. temp.	Grad.	Av. t.	Grad.	Av. t.	Grad.	Av. t.	Grad.	Av. t.	Grad.
0	17.83		13.29		17.73		23.96		15.91	
		0		1/4		1		—1/4		—1/4
5	17.83		13.21		17.15		24.10		16.08	
		1/2		—1/2		—1/2		1 3/4		1/4
10	17.61		13.48		17.41		23.27		15.73	
		1 1/4		0		1 1/2		3 1/2		0
20	16.29		13.51		15.96		19.68		15.70	
		1		0		3/4		2 3/4		—1 4
30	15.29		13.51		15.11		16.87		15.92	
		1/4		—1/4		1/4		1 1/4		—1/2
40	15.09		13.75		14.80		15.58		16.48	
		1/4		—1/4		1/4		1 1/4		—1/2
50	14.61		13.78		14.44		14.90		15.39	
		0		0		0		1/4		1/4
75	14.34		13.82		14.20		14.38		15.07	
		1/4		0		0		0		1/4
100	14.00		13.74		13.98		14.02		14.30	
		0		0		0		0		0
150	13.89		13.73		13.78		13.95		14.07	
		0		0		0		0		0
200	13.75		13.58		13.73		13.82		13.90	
		0		0		0		0		0
300	13.72		13.58		13.72		13.72		13.78	
		0		0		0		0		0
500	13.45		13.42		13.53		13.39		13.50	
		0		0		0		0		0
800	13.23		13.22		13.27		13.19		13.26	
		0		0		0		0		0
1000	12.82		12.82		12.76		12.93		12.77	
		0		0		0		0		0
Bottom	12.76		12.75		12.77		12.79		12.74	

The vertical distribution of the average annual temperatures in the south Adriatic is different from that of the mid Adriatic. In the surface layer there is no gradient and it disappears in smaller depth as the bottom layer is warmer.

The surface layer in the south Adriatic reaches somewhat deeper. The lower limit of the thermocline may be considered as 40 m according to table 16 and also according to the separate average calculated in the same way as for other areas.

The greater depth of the surface layer of the south Adriatic is also due to some other properties too. For example, there is no phase shift in the appearance of the maximum in the annual course of temperature variations up to 30 m depth, whereas it is found here in Summer.

In the annual course, the appearance of the maximum temperature from 40 to 300 m is one season late (Autumn), but the minimum is in Winter. As was interpreted for the mid Adriatic, this layer would correspond to the intermediate layer. However, the exact lower limit of the layer has not been ascertained as we have no data for the depths between 300 and 500 m. The analysis of the T—S diagram shows the lower limit of the layer as between 400 and 500 m (Zore-Armanda, 1963 a).

Summary

All the available temperature data of the Adriatic sea collected so far have been statistically dealt with.

The first chapter deals with the analysis of the temperature data of the sea surface along the east coast collected from 22 stations. The considerable difference in temperature observed between the north and the rest of the Adriatic is suggested as due to the greater continental effect in the former region. The influence of certain meteorological elements like cloudiness and cold wind on the sea temperature is also shown.

The higher values of air — sea temperature difference are found when the influence of the land on the air temperature is stronger, ie. when there is a stronger penetration of the cold continental air over the Adriatic.

The second chapter deals with the temperature of the open sea surface. Seasonal temperature fluctutations have been presented by means of charts of average distribution for four characteristic months. Some characteristics of these charts have been explained by means of the known properties of the current system. In the mid Adriatic transverse profile (Kaštelanski zaljev — Gargano) during Spring and Summer the minimum temperatures appear near the islands Hvar, Vis and Palagruža. It is pointed out that this might be related to the water divergence and upwelling at those places. In Autumn the lowest temperature in the profile is found along the west coast and in Winter along the east coast. This has also been connected with the system of currents and the wind influence (jugo and bura respectively) and their possible resultant water upwelling. The long term variations of the differences between the temperature of the open and coastal sea have been assigned to the influence of advection which is more prominent in the open sea. The Trieste — Hvar air pressure difference also shows a parallel course indicating the cause of the advection intensity fluctuations.

In the third chapter, the vertical temperature distribution is given. The average values calculated for the whole Adriatic are used in a preliminary calculation of the evaporation of the Adriatic in the warm and cold periods of the year (28 and 70 cm respectively). The lower limit of the thermocline for the north, middle (coastal as well as open) and south Adriatic has been

calculated and it is found to vary from 20 to 40 m. In the layer up to the thermocline the maximum temperature appears in Summer and the minimum in Winter. The intermediate layer is characterised by the phase shift in the reaching of the maximum, which occurs in Autumn. The lower limit of this layer is at 100 m in the mid Adriatic, whereas it is at 300 m in the south. This layer can be to some extent identified with the previously dynamically identified intermediate layer which is characterised by water advection from the Mediterranean. The temperature of the bottom layer is not influenced by the mixing with the upper layers; it is rather under the influence of the advection of the heavy Winter water from the north Adriatic. In the north Adriatic the vertical temperature gradient is greatest in the surface layer and appears in Spring, whereas in the mid and south Adriatic it is highest below the surface and appears in Summer.

APPENDIX

Table 1A

Average monthly and annual sea surface temperatures (°C) for
Split, rt Marjana

Year	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
1951	11.9	10.5	11.2	13,6	17.1	22,7	23.7	23.0	23.1	18.7	16.7	13.6	17.1
1952	12.6	10.9	11.2	16.2	17.5	22,1	24.0	24.7	22.4	19.0	15.0	12.9	17.4
1953	11.2	10.4	11.6	14.8	17.6	21,6	25.5	23,3	20.8	19.7	17.3	15.4	17.4
1954	11.5	10.3	11.9	13.8	16.3	22.5	24.0	22.8	22.0	17.5	15.2	12.9	16.8
1955	12.1	11.8	12.2	13.5	17.8	20.4	23.4	22.7	22.1	19.2	16.7	14.0	17.1
1956	12.6	10.1	10.1	12.9	16.5	20,6	23.6	25,2	22.5	19.2	16.1	13.3	16.9
1957	12.2	11.4	12.5	14.5	18.0	22.4	23.9	23.6	22.2	20.0	17.2	13.2	17.7
1958	12.3	11,8	11.2	12.8	18.9	21,1	23.7	24.3	21.9	20.1	16.7	14.9	17,5
1959	12,7	11.6	13.3	14.6	17.9	21.9	23.6	23.3	20.5	17.9	15.4	13.8	17,2
1960	12.0	11.6	12.3	15.1	17.4	21.5	22.8	23.1	21.6	19.5	17.2	14.8	17.4
1961	12.8	12.0	13.1	15.6	17.4	21.9	23,2	22.9	21.3	20.1	17.2	15.1	17,7
1962	12,8	11.1	10.8	14.1	17.5	20.6	23.0	24.6	23.3	20.2	17.1	13.8	17,4
1963	11.7	9.9	10.9	14.1	18.5	22.4	24.7	24.6	23.6	20.0	18.0	14.8	17.8
1964	12.3	11.6	12.0	14.6	17.5	22.4	22.3	22,2	21.4	17.7	15.4	13.1	16,9
1965	12.5	10.7	11.3	13.5	16.3	20.9	23.8	23.6	21.1	19.8	17.3	14.1	17.3
Average	12.2	11.0	11.7	14.2	17.5	21.7	23.7	23.6	22.0	19.2	16.6	14.0	17.3

Table 2A

Average monthly and annual air temperatures (°C) for
Split, rt Marjana

Year	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
1951	(8.5)	(8,0)	11,2	14,4	18,1	23,6	25.6	25.5	23.6	16.7	14.7	11.3	16.7
1952	8.9	8,2	10,2	15,0	18.7	24.5	27.3	27.0	22.5	17.0	12.0	10.3	16.8
1953	7.6	7.8	10,5	15,5	19.5	22.1	26.2	24.7	21.7	18.6	12.5	11.0	16.4
1954	5.3	6,7	12.0	13,1	16.8	23.5	24.4	24.4	22.5	16,3	12.3	10.8	15.6
1955	10.6	10,0	10.4	13.0	18.4	22.4	25.0	23.8	21,1	17.4	11.8	11.2	16.3
1956	8.9	3,2	8.3	13.3	18.0	20.5	24.7	26.6	22,7	16.7	12.0	8.6	15.2
1957	8.4	10.5	11.2	14.7	17.4	24.3	25.0	24.6	20.9	18.0	13.4	10.4	16.6
1958	9.5	9.8	7.5	11.8	20.3	22.3	24.6	25.4	21.4	17.5	14.1	10.5	16.2
1959	7.9	8.8	12.5	14.0	17.9	22.0	26.0	23.7	19.8	15.8	13.4	11.8	16.1
1960	8,7	9.6	11.4	14.2	17.8	22.3	23.2	24.3	18.6	18.9	14.4	12.5	16.4
1961	8.4	9.5	12.4	16.2	17.6	23.0	24.6	24.5	22,9	18.2	13.3	9.2	16.6
1962	9.4	7.5	(13.9)	14.4	18.3	21.7	25.0	27.4	22.1	18.8	13.2	8.3	16.7
1963	5,4	6.7	9.5	15.1	19.2	23,0	25.7	24.7	22,0	17.6	16.2	9.5	16.2
1964	6.9	(8.7)	10.9	14.1	18.1	23.1	24.7	23.6	21,0	16.6	13.1	10.1	15.9
1965	9.2	4.8	10.8	12.5	17.1	21.4	24.5	23.2	20.4	16.9	13.6	10.7	15.6
Average	8.2	8.0	10.8	14.1	18.2	22.6	25.1	24.9	21.5	17.4	13.3	10.4	16.2

Table 3A

Maximal monthly and annual sea surface temperatures (°C) for Split, rt Marjana

Year	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1951	12.7	12.70	12.6	14.5	19.6	25.1	25.0	24.0	25.1	20.1	17.9	15.5	25.1
1952	14.1	11.5	11.8	20.3	18.6	24.4	25.4	28.6	25.1	21.4	17.4	14.4	28.6
1953	12.3	11.7	13.9	17.3	22.6	26.1	27.7	25.5	23.9	22.9	18.9	16.5	27.7
1954	13.1	11.8	13.7	15.9	21.5	27.1	26.0	25.8	24.7	20.2	16.9	14.6	27.1
1955	13.2	12.7	15.2	16.9	19.6	23.2	25.4	24.8	24.7	20.3	17.8	15.8	25.4
1956	13.7	12.5	12.1	14.9	23.7	23.4	27.4	27.5	25.8	21.8	18.2	14.8	27.5
1957	14.2	12.0	15.2	17.4	21.2	26.5	26.8	25.5	23.9	21.3	19.3	16.4	26.8
1958	13.1	13.1	12.9	15.0	24.0	24.6	25.7	27.4	23.0	21.9	18.1	16.3	27.4
1959	14.7	13.8	14.6	16.9	21.2	25.9	27.3	25.2	22.8	19.3	16.9	15.4	27.3
1960	13.6	13.3	13.8	19.5	21.6	23.4	24.8	25.0	24.2	21.1	19.3	15.9	25.0
1961	15.0	13.4	14.5	17.8	21.3	26.6	25.0	26.2	22.9	22.0	19.3	17.2	26.6
1962	14.4	12.1	11.7	20.6	21.4	25.2	27.2	27.6	25.8	22.3	19.3	16.5	27.6
1963	13.4	10.7	12.2	18.4	23.0	26.5	27.8	27.1	24.9	22.0	18.8	17.0	27.8
1964	14.1	12.3	13.2	17.0	21.7	26.3	25.5	23.9	24.2	19.8	17.0	15.2	26.3
1965	13.8	13.1	13.4	15.6	19.5	27.4	26.2	27.2	22.6	22.5	18.7	15.8	27.4

Table 4A

Minimal monthly and annual sea surface temperatures (°C) for
Split, rt Marjana

Year	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1951	10.1	8.6	8.5	12.5	15.6	20.1	21.8	21.9	21.5	17.9	15.7	12.0	8.5
1952	11.5	10.1	10.5	12.3	16.2	19.1	21.8	23.8	20.0	17.7	13.6	11.0	10.1
1953	9.6	9.2	10.2	12.6	14.9	18.1	23.3	20.3	19.3	18.2	16.1	13.0	9.2
1954	9.4	9.2	10.2	12.4	14.0	19.1	22.1	20.4	19.2	16.2	13.0	10.4	9.2
1955	10.6	11.1	10.5	11.9	14.7	16.7	21.3	20.8	20.5	17.2	14.9	12.0	10.5
1956	10.4	8.9	8.4	10.3	13.5	18.8	21.0	23.4	20.4	18.0	13.9	11.4	8.4
1957	10.1	10.4	9.0	12.2	15.4	19.4	21.6	21.2	20.9	18.1	14.0	12.9	9.0
1958	10.5	10.4	10.2	11.1	13.2	18.6	21.3	22.0	20.6	17.6	14.9	12.3	10.2
1959	11.2	9.9	12.2	13.3	14.9	19.0	20.6	21.2	19.0	16.8	14.2	11.5	9.9
1960	8.5	10.4	11.0	12.5	13.8	17.5	21.0	22.0	19.5	17.2	15.2	13.2	8.5
1961	10.8	9.0	10.9	13.2	15.3	19.2	22.0	20.0	20.0	17.7	16.0	13.3	9.0
1962	11.3	9.6	9.8	11.3	14.0	17.3	19.3	22.7	20.3	19.0	14.0	12.7	9.6
1963	9.5	7.5	9.2	11.3	15.4	19.0	22.2	22.4	21.2	18.0	17.0	11.2	7.5
1964	8.1	10.4	10.5	12.8	15.1	19.0	20.2	20.5	18.1	16.1	14.4	9.0	8.1
1965	10.5	9.1	8.8	11.6	14.3	17.8	21.2	20.9	20.5	18.1	15.5	12.8	8.8

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TEMPERATURNI ODNOSI U JADRANSKOM MORU

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KRATAK SADRŽAJ

Statistički su obrađeni svi do sada sabrani podaci o temperaturi mora u Jadranu.

U prvom poglavlju je prikazana temperatura površine mora uz istočnu obalu, te je za tu svrhu iskorišten materijal sa 22 obalne postaje, ali je svestranije obrađena postaja Split, na rtu Marjana. Prikazan je raspored temperatura u različitim sezonama. Upozoreno je na značajne razlike u temperaturi koje uzrokuje veća kontinentalnost sjevernog u odnosu prema srednjem i južnom Jadranu. Godišnji hod temperature u Splitu prikazan je s pomoću niza klimatskih karakteristika. Isti niz je iskorišten za prikaz višegodišnjih promjena. Pokazano je kako neki meterološki elementi utječu na temperaturu mora, što je vidljivo iz paralelnih višegodišnjih fluktuacija. Vidljiv je paralelan hod naoblake i maksimalnih i srednjih ljetnih temperatura mora. Zimi uz naoblaku na formiranje temperature utječe i hladan vjetar — bura.

Razmotren je i višegodišnji hod razlika temperatura između morâ i zraka u Splitu. Pokazano je da više vrijednost te razlike nastaje kada je uticaj kopna na temperaturu zraka veći, a to znači kada nastane veći prodor hladnog kontinentalnog zraka nad Jadran. Kao mjera za te prodore je uzet broj i razvijenost depresija nad zapadnim Mediteranom, pa je pokazano da se uz veću razliku temperature između mora i zraka pojavljuje veći broj depresija i da se one duže razvijaju.

U drugom poglavlju je prikazana temperatura površine otvorenog mora za cijeli Jadran, te za njegov sjeverni, srednji i južni dio. Date su statističke karakteristike prema velikom broju podataka. Sezonske fluktuacije prikazane su s pomoću srednjih karata izoterma za 4 karakteristična mjeseca. Neke od karakteristika tih karata protumačene su s pomoću poznatih svojstava sistema strujanja u srednjem Jadranu. Kao karakterističan za obalno područje, obrađen je velik niz podataka iz Kaštelanskog zaljeva. Dalje su izračunati sezonski srednjaci za 7 postaja profila Kaštelanski zaljev — Gargano u srednjem Jadranu, te su analizirane prilike na tom profilu. U proljeće i ljeti se minimalne temperature pojavljuju kod otoka Hvara, Visa i Palagruže, pa je pokazano da bi to moglo biti u vezi s divergencijom i dizanjem vode na tim mjestima, kako je

već prije bilo uočeno na području otoka Visa. U jeseni je najniža temperatura uz talijansku obalu, a zimi uz istočnu obalu. To je dovedeno u vezu sa sistemom struja i djelovanjem vjetra (juga ili bure) i mogućnošću dizanja vode (upwelling) s tim u vezi. Dizanje vode kod otoka u proljetnom i ljetnom razdoblju bilo bi također u vezi sa sistemom strujanja.

Višegodišnji hod temperature studiran je prema podacima s istog profila, samo su za tu svrhu oni uzeti sumarno za sve postaje. Najprije je pokazan paralelizam u višegodišnjem hodu temperatura na otvorenom moru i uz obalu. Očito do neke mjere djeluju isti faktori na formiranje dviju temperatura, a to su vjerojatno vanjski faktori, donekle opisani u poglavlju koje tretira temperaturu obalnog područja. Razlike između temperature otvorenog mora i obalnog područja pripisane su utjecaju advekcije, koja je sigurno puno intenzivnija na otvorenom moru. Za dokaz takvog shvaćanja prikazan je paralelan višegodišnji hod tih razlika temperature i srednjeg saliniteta otvorenog mora. Od ranije je, naime, poznato, da je srednji salinitet u tom području pokazatelj intenziteta advekcije mediteranske vode. Paralelan višegodišnji hod ima i razlika tlaka zraka Trst — Hvar, što ukazuje i na uzrok fluktuacija u intenzitetu advekcije.

U trećem poglavlju je prikazan vertikalni raspored temperature. Iz svih raspoloživih podataka izračunati su srednjaci za sve dubine i to za cijeli, te za sjeverni, srednji i južni Jadran. Ti podaci su poslužili za preliminiran proračun evaporacije Jadrana u toplom i hladnom razdoblju godine, (28 i 70 cm), te za približnu bilancu P—E. Dalje je izračunata srednja donja granica termokline za sjeverni Jadran, za obalno područje i otvoreno more srednjeg Jadrana, te za južni Jadran i ona se kreće od 20 do 40 m dubine. U godišnjem hodu temperatura ističu se tri sloja. U površinskom sloju je maksimum temperature ljeti, a minimum zimi. Donja granica tog sloja se poklapa s donjom granicom termokline. Intermedijarni sloj je karakteriziran pomakom u fazi u nastupanju maksimuma, koji se pojavljuje u jesen. U srednjem Jadranu je donja granica toga sloja na 100, a u južnom na 300 m. Taj sloj se donekle može poistovjetiti s ranije dinamički definiranim intermedijarnim slojem, karakteriziranim advekcijom mediteranske vode. Temperatura pridnenog sloja nije pod utjecajem miješanja u gornjim slojevima· nego više pod utjecajem advekcije teške zimske vode iz sjevernog Jadrana. To vrijedi osobito za pridneni sloj Jabučke kotline, a u manjoj mjeri za južni Jadran. Za sva područja i sezone izračunati su i vertikalni gradijenti temperature. U sjevernom Jadranu vertikalni je gradijent najveći u površinskom sloju u proljeće, a u srednjem i sjevernom Jadranu ispod površine ljeti. Uzevši u obzir godišnje srednjake, vertikalni gradijenti su skroz pozitivni. Oni su još u cijelom sloju pozitivni u sjevernom Jadranu u proljeće, a u srednjem Jadranu u proljeće i ljeti.

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