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NATURAL CHARACTERISTICS AND CLIMATIC CHANGES OF THE ADRIATIC SEA

PRIRODNA SVOJSTVA I KLIMATSKE PROMJENE U JADRANSKOM MORU

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Hydrographic description of the Adriatic presents notes on sea temperature and salinity and their variations. Density, transparency and oxygen distribution are also given in brief.

Water mass properties and their distribution are discussed as well as long-term variations of hydrographic conditions in connection with climatic changes.

Description of general circulation is based on geostrophic currents, topographic effects, water mass distribution and some numerical models. Wind-driven currents are mostly connected to bura wind. Different types of oscillatory movements are briefly described.

INTRODUCTION

Several topographic characteristics determine to a larger extent the continentality and in turn the oceanographic properties of the Adriatic Sea. It is an elongated landlocked basin. Its northern part is a shallow shelf. Open south and middle Adriatic are characterized by two pits: the Jabuka Pit (maximum depth 270 m) and the South Adriatic Pit (maximum depth 1233 m) separated by the Palagruža Sill. The Adriatic Sea is divided from the Ionian Sea by the Strait of Otranto with submarine sill at a depth of about 740 m. There are no islands on the western sandy shore, but a series of large and small ones lie off the eastern shore.

Meteorological conditions differ much during the year and so enhance the continental aspect of the Adriatic Sea. In winter, dominant are the NE wind bura (up to 50 m s^{-1}) and the SE wind jugo or sirocco. In summer, the most frequent are etesian winds of NW direction.

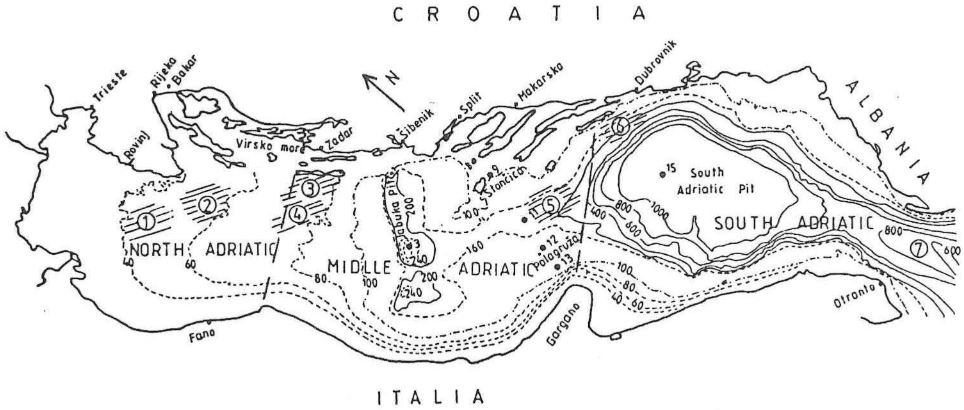

Fig. 1. Topographic chart of the Adriatic Sea. North, Middle and South Adriatic are separated schematically. Stations of the transect Splt-Gargano (over Palagruža Sill) are marked as well as areas relevant for statistical processing of sea water temperature and currents

Maximum precipitation occurs in late autumn and minimum in summer. Precipitation amounts are greater at inland stations (> 1000 mm $year^{-1}$) than at the open sea stations (~400 mm $year^{-1}$). Runoff of the river Po amounts to about 1500 m^{-3} s^{-1} being much higher after strong precipitation or snow melting. The input of all the other rivers along the coasts of Italy, Croatia and Albania, is comparable to the Po river runoff.

HYDROGRAPHIC DESCRIPTION

Considering ***temperature*** properties, the Adriatic is a temperate warm sea with rather high annual temperature variation (Buljan and Zore-Armanda, 1976). Extreme and mean temperatures for various localities are presented in Table 1.

The Table 1 proves the known fact that in winter, the southern Adriatic is about 8-10°C warmer than its central and northern parts. In other seasons the horizontal temperature distribution is more uniform. Generally, the open sea is warmer than the sea in the coastal area. At Split-Gargano transect the highest temperature occurs in the central part, the lowest surface temperature at the eastern coast and the lowest bottom temperature at the western coast. Systematically collected data in the Dalmatian coastal zone (Zore-Armanda *et al.*, 1991) show that going southward from Vir Sea to Dubrovnik annual mean temperature increases to almost 3° C from the surface down to 20 m depth.

The temperature generally decreases with depth. At 10-30 m the thermocline occurs in the warmer part of the year. The autumn isothermal layer in the southern Adriatic is recorded at 18-19°C.

Annual temperature variation is generally high (Fig.2). In the coastal area monthly temperature maximum appears in August lagging about a month behind maximum insolation. Minimum appears in February, two months after minimum insolation. About a month's lag of the extreme appearances is recorded from the open sea. At the Split-Gargano transect slight temperature drop appears at 20m depth in August indicating upwelling at the Palagruža Sill.

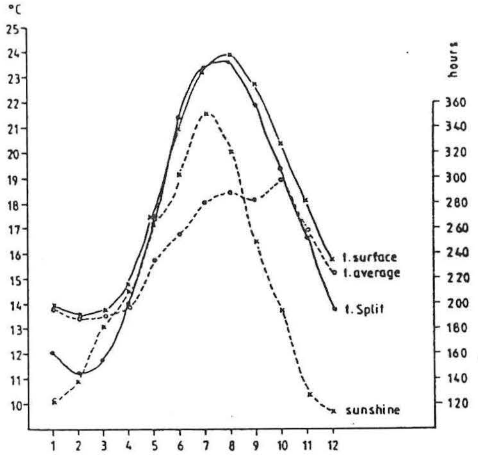

Fig. 2. Annual variation of the sea surface temperature at Split (Marjan Cape, 1951-1988); surface temperature at Split-Gargano transect (stations 8 - 13, 1952-1983); average temperature of the whole vertical layer (depths 0, 10, 20, 30, 50, 75, 100, 150 and 170 m) at the same transect; sunshine duration in Split (1951-1983). For data sources see Table 1)

Year-to-year temperature variations are also rather high (Fig.2). As a result of spectral analysis of monthly mean surface temperatures (Split, Marjan Cape) an extreme was recorded at the period of 33.3 months (2.8 years). The period of approximately three years is also clear in the oscillations of the sea surface temperature on Split-Gargano transect. Apart form that, the long-term variation of the open sea is mostly due to the uneven amount of the water exchange between the Adriatic and Eastern Mediterranean. The intensified impact of the Eastern Mediterranean may increase temperature of the open southern Adriatic by a few degrees (Zore-Armanda, 1969a). Long-term temperature variations at the Split-Gargano transect are least pronounced at 100 m and best pronounced at the surface and in the bottom layer.

Salinity of the Adriatic is relatively high. The largest part of its volume, i.e. its open southern part has salinities from 38.4 to 38.9 x 10^{-3}. In the northern parts and in the coastal zone, the salinity is lower and shows considerably greater annual variations. The lowest salinities are found close to the Po River mouth. In vertical distribution of the South Adriatic Pit surface, intermediate and bottom layers are clearly distinguished. Salinity is highest in the intermediate layer.

In the coastal zone the annual course shows two minima: in April-May and in December-January. First maximum occurs in February-March and second (higher) in July-August along the western coast and in September-October along the eastern coast. Annual salinity distribution on the Split-Gargano transect (Fig. 4) depends on the annual variation of the current system. Salinity maxima are farthest off the eastern coast in winter, approaching it gradually from spring to autumn (Zore-Armanda *et al.*, 1991).

Long-term salinity changes are due to the variable advection of the Eastern Mediterranean water which may be accounted for by the intensity of some climatic factors (Buljan and Zore-Armanda, 1976). In addition, the data from both the coastal and open middle and southern Adriatic, have shown constant salinity increase for the last decades (Fig.7). It is suggested to be due to the Aswan Dam erection and in that connection with the reduction of the fresh water inputs to the Eastern Mediterranean which influences the Adriatic. Some climatic factors, such as reduction of precipitation or evaporation increase, may also be responsible for gradual salinity increase, but so far they have not been identified.

Density of the Adriatic water is high, especially in the northern Adriatic in winter. Winter dense water sinks down to the deeper part of the Jabuka Pit (even though not every year). It also influences the southern Adriatic over the Palagruža Sill (Split -Gargano transect), density values being highest in its middle part. Annual variations of the central station at the Split-Gargano transect coincide with those at the South Adriatic Pit station and differ from the Jabuka Pit station suggesting that at the Split-Gargano transect the influence of the waters from the south is more intensive than that of the waters from the north.

In winter, almost vertical homogenization is present on the transversal transect Split-Gargano as distinct from summer stratification. However, on the longitudinal transect (Jabuka Pit, Palagruža Sill, South Adriatic Pit) stratification is permanently present being also more pronounced in summer. This shows that most probably

Table 1. Characteristic sea surface temperatures (in °C) after available sources Buljan and Zore-Armanda, 1966, 1979; Masselli *et al.*,1990, Picotti and Vatova 1943; Polli, 1950; Scaccini Cicatelli, 1957, 1965, 1970, 1975, Vatova, 1948; Zore-Armanda, 1969 a, Zore-Armanda *et al.* 1985, 1988, 1991). Areas 1 to 6 are marked in the Fig. 1

	Aps. max.	Aps. min.	Monthly max.	Monthly min.	General mean
TRIESTE (1934-1989)	29.2	3.2	26.5	4.7	15.6
ROVINJ (1920-1944)	27.7		25.4	6.7	16.2
FANO (1951-1989)			26.8	4.7	15.7
SPLIT (1951-1989)	28.6	7.5	25.5	9.4	16.0
OPEN ADRIATIC					
North	28.8	4.1			16.31
Middle	28.2	8.1			17.76
South	27.1	9.1			17.83
JABUKA PIT			24.60	13.23	17.91
SPLIT-GARGANO TRANSECT			23.82	13.61	18.20
SOUTH ADRIATIC PIT			23.00	13.42	19.19
Area 1	27.4	10.0			15.55
Area 3	27.4	10.0			17.83
Area 4	25.7	12.0			18.26
Area 5	26.6	13.0			18.21
Area 6	27.0	11.5			18.48

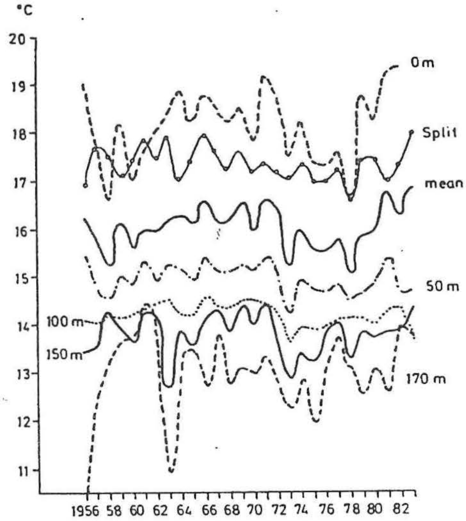

Fig. 3. Year-to-year variation of the sea surface temperature at Split (Marjan Cape) and at Split-Gargano transect (stations 8 - 13) for different depths and average of the vertical layer. For data sources see Table 1.

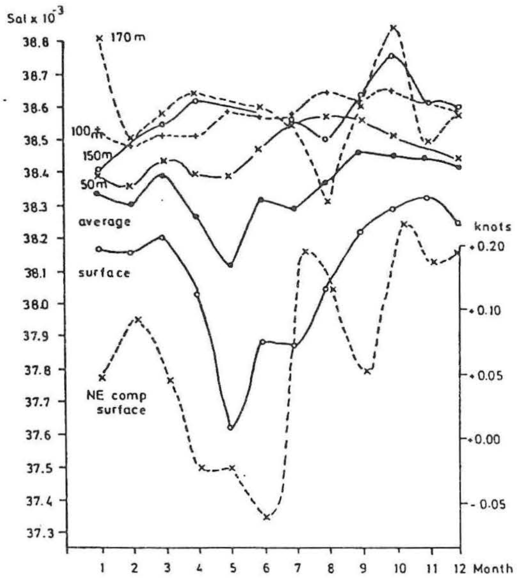

Fig. 4. Annual variation (monthly means 1952-1983) of salinity at Split-Gargano transect (stations 8-13)for different depths and vertical average (depths 0,50,100,150 and 170 m); annual variation of the NE surface flow component (1956-1979) at station 9 (Stončica) at the same transect. For data sources see Table 1.

longitudinal flow prevails in the Adriatic, particularly in deeper layers.

The waters of the open south Adriatic have the highest ***transparency*** (Tešić and Vučak, 1976). During the year the lowest values are found in autumn, rather low values in winter and an increase in spring and summer.

For the last decades constant decrease of transparency has appeared most probably due to the eutrophication of the Adriatic waters. It was recorded as early as in the 1962-1970 period (Buljan and Zore-Armanda, 1979). The next decade (1971-1983) shows further transparency decrease both in the coastal and open waters.

Table 2. Average transparency (Secchi disc in m) for different stations in two periods (data sources in Table 1)

	Station					
Period	9	11	12	13	3	15
1962-1970	26.2	27.0	26.6	23.3	25.7	29.3
1971-1983	24.9	25.2	24.2	21.8	25.2	26.1

The Adriatic waters are in general rich in oxygen content enriching in ***oxygen*** the adjacent Mediterranean waters. At Split-Gargano transect the 100 % isopleth could descend bellow 50 m during the warmer part of the year (Zore-Armanda *et al.*, 1991). Long-term variation in oxygen content at Split-Gargano transect (Fig. 5) shows a trend of decrease at 100 m depth which may also be indicative of the eutrophication of the open Adriatic. However, from 1971 on a trend of increase in oxygen content at 30 m depth, that is in the thermocline zone can also be noticed as a result of the same process. Similar processes have been recorded from the northern Adriatic (Benović *et al.*, 1987).

WATER MASS PROPERTIES AND CLIMATIC CHANGES

The Adriatic Sea is considered to be a site of deep water formation for the entire Eastern Mediterranean (Pollak, 1951; Zore-Armanda, 1963; Ovchinnikov *et al.*, 1985). This is due to the fact that the Adriatic is one of two northernmost basins of the Eastern Mediterranean. The other is the Black Sea which does not exert a distinctive influence due to the different hydrologic properties and

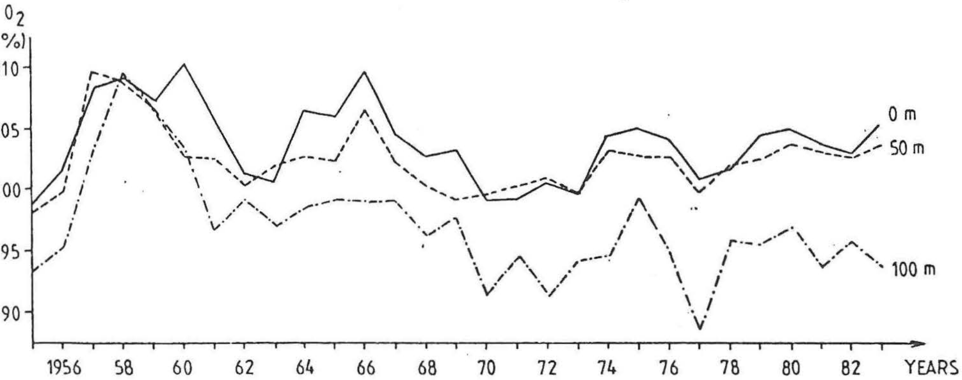

Fig. 5. Year-to-year variation (annual means) of oxygen saturation for stations (8-13) at Split-Gargano transect for three depths (after Zore-Armanda *et al.*, 1987)

conditions for water exchange with adjacent basins. The landlocked position of the Adriatic and consequently a strong winter cooling produce strong vertical convection. The shelf area of the northern Adriatic, the Jabuka Pit and the South Adriatic Pit are considered as sites where different water types are formed. Meteorological conditions favourable for the water mass formation are cold and dry outbreaks during the winter time when bura blows. Three water types of the Adriatic origin were identified (Zore-Armanda, 1963). North Adriatic Water (S-type) with temperature of 11°C, salinity of 38.5 ppt and σt of 29.52, Middle Adriatic Water (M-type) with temperature of 12°C, salinity of 38.2 ppt and σt of 29.09 and South Adriatic Water (J-type) with temperature of 13°C, salinity of 38.6 ppt and σt of 29.09. The last values may be now somewhat higher due to constant salinity increase in the middle and southern Adriatic in the last decades.

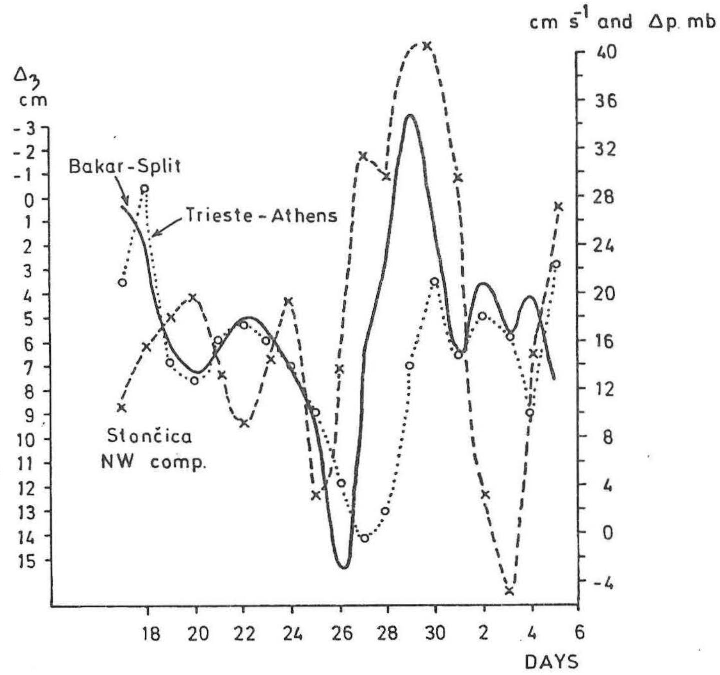

Fig. 6. Daily means of the surface NW current component at Stončica (station 9) from November 17 to December 5, 1978; daily differences between the sea level at Bakar and Split; daily air pressure difference between Trieste and Athens (after Zore-Armanda *et al.*, 1991)

Due to its high density North Adriatic Water (S-type), fills up the Jabuka Pit and only occasionally spreads over the Palagruža Sill into the South Adriatic Pit. A theoretical study (Hendershott and Rizzoli, 1976) shows the development of the cyclonic gyre in the northern Adriatic in winter driven by horizontal density gradient between the dense water in the central part of the basin and the fresh water coastal runoff. On the other hand, the frontal zone in the northern Adriatic, which separates water affected by fresh water runoff from the North Italian rivers and water influenced by advection from the south, is the site of convergence and sinking of water (Fig.10) and so may function as a site of formation of dense North Adriatic Water (Zore-Armanda and Gačić, 1978).

M-type water is formed in the area of the Jabuka Pit when there is no intensive northwestward flow i.e. in the period of low inflow of the Mediterranean water into the Adriatic.

J-type water originates from the South Adriatic Pit under the conditions similar to those that prevail when M-type is formed. Due to its high density this water spreads into the bottom layer of the Eastern Mediterranean. After Ovchinnikov *et al.*, 1985, this water formation takes place in the centre of the cyclonic gyre during the period of the strongest cooling. Water formation processes have time scales of several days and length scales of few tens of miles. Another possibility is that it is formed in the region of the Otranto Strait where denser Adriatic water is forced to sink down and mix with intermediate Mediterranean water (Zore-Armanda, 1974).

The fourth water type, not being of the Adriatic origin, is A-type formed in the Levantine basin. This water experiences a salinity decrease on its way towards the Adriatic and then eventually spreads through the Otranto Strait into the Adriatic.

The Adriatic Sea shows considerable year-to-year variations of oceanographic parameters which are evident, in the first place, from the volume of A water present in the Adriatic. Stronger water inflow is easily seen from the salinity increase (Buljan, 1953) and can be explained by the long-term variations of meteorological parameters (Zore-Armanda, 1969 b; 1974). Changes of baric field over the North Atlantic, Europe and Mediterranean Sea dictate the cyclonic activity over the Adriatic and determine the amount of bottom water formed in the region. This leads to the variability of the exchange rate between the Adriatic and the Eastern Mediterranean. On the other hand, it also influences the level of the air pressure gradients that in turn directly act upon the water exchange between the Adriatic and Ionian Sea. Sea level slope is related to air pressure gradients, particularly if sufficiently distant locations are observed. This seems to be due to the way of water exchange between two adjacent seas through a strait. A simple model (Toulany and Garret, 1984) shows that the sea level slope is geostrophically balanced through a strait, so that the difference in sea level between two adjacent seas at the opposite sides of a strait causes corresponding fluctuations in the current field. The results of 20-day current measurements at Stončica (station 9) in autumn 1978 compared to daily differences in the sea level between Trieste and Athens show good agreement (Fig.6). The flow is represented by longitudinal (NW) component of the surface current owing to prevalently vertical homogeneity in the current field.

On the longer time scales the sea level slope is affected by some other processes, such as heat exchange with the atmosphere, fresh water inflow and horizontal sea density gradients, but again the air pressure gradients show very important influence on the sea level slope, longitudinal flow and salinity (Fig. 7). High correlation between the alongshore sea level slope and air pressure gradients at time scale longer than a day and shorter than seasonal was shown in the paper by Lascaratos and Gačić, 1990.

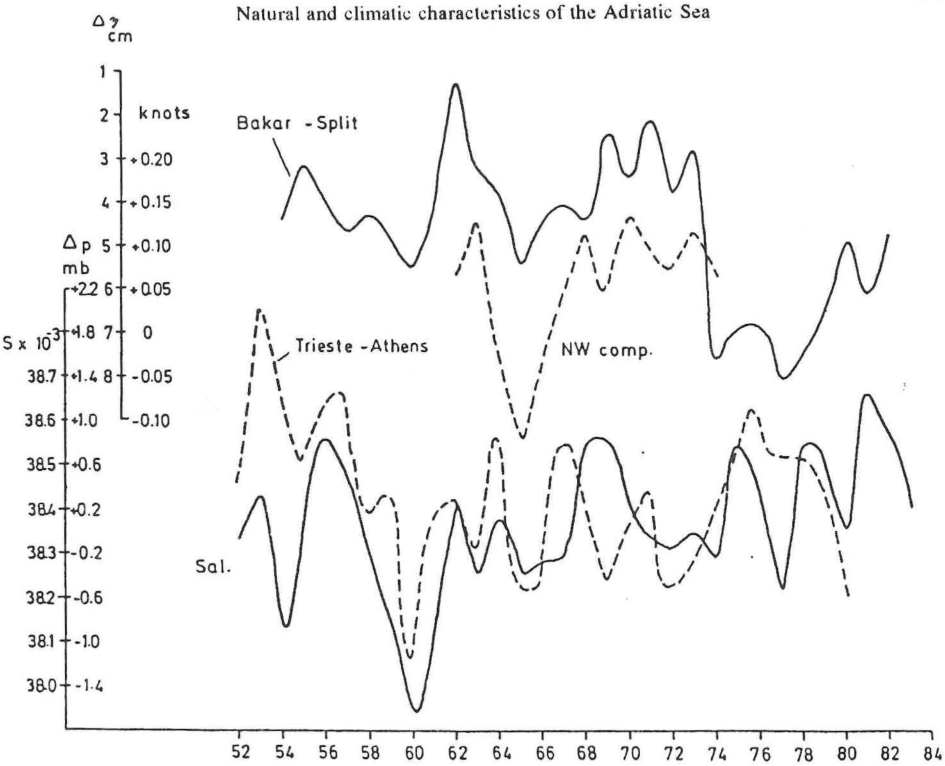

Fig.7. Annual means of NW component of the surface flow at Stončica (station 9), sea-level differences between Bakar and Split, air pressure differences between Trieste and Athens and mean salinity at Split-Gargano transect (stations 8-13 and depths 0, 50, 100, 150 and 170 m considered) after Zore-Armanda *et al.*, 1991

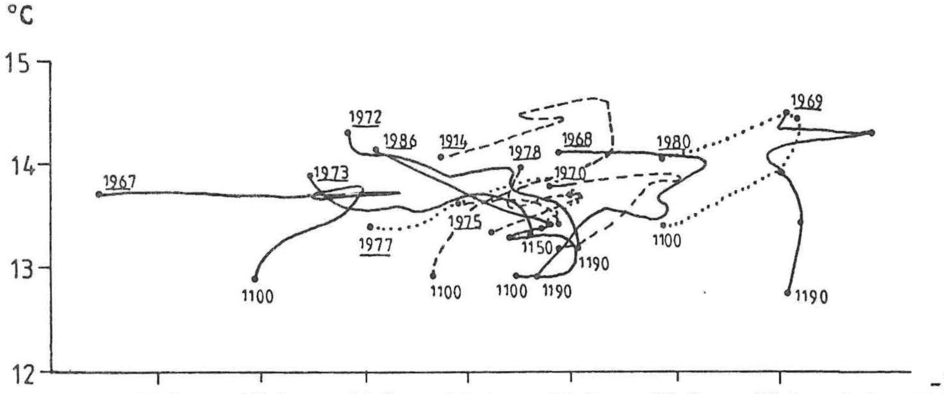

Fig. 8. T-S diagram for the South Adriatic Pit for 12 winters. Years are underlined and the greatest depths marked on each curve

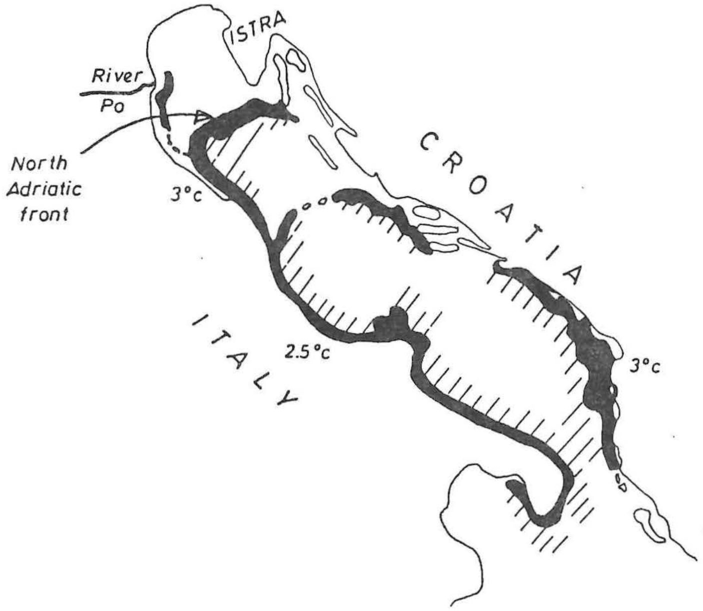

Fig. 9. Mean horizontal thermal structure at the sea surface from satellite images for one winter month (February 1981) after SATMER. Shaded areas are frontal zones. Numbers denote horizontal temperature differences per 5 km

In the surface layer of the Otranto Strait area denser Adriatic water encounters lighter Ionian water. That is why it sinks and mixes with more saline intermediate A water. The upper layer of mixed water proceeds from Otranto area into the Adriatic where it mixes with different Adriatic waters and forms South Adriatic J water. In some particular climatic periods, in sense of the statements mentioned, the unmixed A-water enters the Adriatic and fills a large volume of that sea (Fig. 8), as in years 1969 and 1980.

The water types mentioned are not formed in the coastal area. In the narrow coastal region the stratification persists throughout the year. Coastal waters are separated from the open sea waters by semipermanent front extending parallel to the coast (Fig. 9). The distance between front and shoreline varies on the seasonal time scale (Zore-Armanda, 1983). Coastal area is affected by different heating intensity, fresh water runoff and specific dynamics.

Fresh water runoff is considered as one of the important driving forces for the near-shore circulation along the Italian coast (Malanotte Rizzoli and Bergamasco, 1983). Along the eastern coast wind forces the water to move upslope generating the exchange of water between the coastal areas and open sea (Gačić, 1982). In the northern Adriatic the orientation of the coastal front depends on the frequency of bura wind. During strong bura blowing a two-gyre circulation system is formed (Fig. 10), the fresh water from the Po River spreads throughout the interior of the northern Adriatic and front extends zonally. The front is parallel to the Italian coastline when the wind blows from other directions and then major part of the Po River water flows southward along the Italian coast (Zore-Armanda and Gačić, 1987).

CIRCULATION

The Adriatic currents are generally weak (Table 3). Another characteristic is rather high dispersion of directions. The relation between the kinetic energy of fluctuations and mean flow may be instructive in that matter.

Surface circulation of the Adriatic may be approximated by a cyclonic gyre with northwest incoming flow along the eastern coast and returning southwest outgoing flow along the western cost. Geopotential topographies show that in winter the inflowing current is dominant, in summer the outgoing current, and in spring and autumn such differences between the coasts disappear, whereas transversal currents are more important (Zore, 1956). Such seasonal variations of surface circulation have been qualitatively explained by different density gradients that develop in the Adriatic Sea during the year.

Basically, the streamlines follow bottom contours. Approaching a submarine sill, i.e. a topographic barrier, the streamlines show disturbances such as simple deflections, wavelike patterns or meanders. A simple analytical model tried to describe the mechanism of the topographic effect on a current field (Zore-Armanda and Bone, 1987).

The interpretation of the winter circulation pattern has been partially supported by numerical modelling results (Hendershott and Rizzoli, 1976). It has been shown that the outbreaks of cold, dry Eurasian air over the Adriatic Sea result in rapid evaporation and strong heat fluxes. The horizontal density gradients induced plus coastal river runoff of fresh water have been capable of driving a cyclonic flow in the northern Adriatic. Malanotte Rizzoli and Bergamasco (1983) modeled the summer circulation of the northern Adriatic which may be modified by two separate circulation cells and is of thermohaline origin where Po River runoff is of primary importance. Baroclinic simulation in the model by Djenidi *et al.*, 1987, gives similar results. Two-gyre current system in the northern Adriatic has been repeatedly proved by direct measurements (e.g.Zore-Armanda and Vučak, 1984) for

Following the T-S diagram analysis, three levels could be clearly distinguished in vertical distribution of currents (Zore-Armanda, 1963). The depth of 20 to 40 m separates the surface from the intermediate layer. The intermediate layer descends to

Table 3. Characteristic speeds for some coastal and open sea areas after available sources (Zore-Armanda et al., 1979, 1985, 1988; Ferentinos and Kastanos ,1988). Areas 1 to 7 are marked in Fig 1.

Area	Depth (m)	Mean speed cm s^{-1}	Max speed cm s^{1}	Kinetic energy	
				fluctuations 0.1 J m^{-3}	mean flow 0.1 J m^{-3}
Coastal area					
Virsko more	surface	13	61		
Zadar	surface	8	49		
Kaštela Bay (Split)	surface	11	44		
Dubrovnik	surface	11	43		
Open sea areas					
1	surface	11	59	90.6	0.7
	25	9	58	69.3	0.7
	40	6	37	26.9	0.2
2	surface	15	66	144.3	4.5
	30	9	56	51.7	5.1
	50	7	46	37.5	1.8
3	surface	16	52	174.7	21.1
	30	5	44	42.1	1.4
	60	2	35	16.4	0.5
4	surface	23	58	18.1	9.1
	30	6	50	44.1	1.8
	70	5	48	25.7	0.5
5	surface	14	59	143.1	22.6
	100	6	40	47.0	1.2
	170	5	28	34.0	4.8
6	surface	28	74	308.7	54.5
	90	7	30	30.1	16.6
	200	6	36	48.3	12.9
	275	3	25	10.5	3.2
7	50	19	60		
	100	13	36		
	500	5	10		

about 200 to 400 m in the middle and southern Adriatic. The NW flow prevails in this layer throughout the year. In summer this flow may be understood as compensatory to the surface flow. In winter, the same flow occurs both in the surface and intermediate layer and is compensated by the outgoing SE flow in the bottom layer. As already mentioned, the flow intensity in the intermediate layer and the quantity of the Eastern Mediterranean water entering the Adriatic in this layer vary considerably from one year to another. These variations depend on some climatic factors. Otherwise, the NW flow in the intermediate layer is most consistent. Its frequency in the area of Palagruža Sill amounts to 30-50 % (Buljan and Zore-Armanda, 1976). The outflow prevails in the bottom layer. Winter dense water from the northern Adriatic flows into the bottom layer of the Jabuka Pit, then further to the deep southern Adriatic. Spreading over the Otranto Strait this water affects the bottom layer of the whole Eastern Mediterranean.

Bura wind induces the most pronounced, although transient, contribution to the northern Adriatic current field. Three dimensional model (Kuzmić *et al.*, 1985;

Orlić *et al.*, 1986) demonstrated the controlling influence of both topography and wind-stress curl. The speeds of wind-forced currents amount up to 50 cm s^{-1} for winds of about 10 m s^{-1}. The sea lags only slightly behind the wind. Stravisi (1977) formulated a two-dimensional model of bura-forced circulation in the northernmost part of the Adriatic showing the development of the cyclonic flow. Malanotte Rizzoli and Bergamasco (1983), simulating wind-driven currents concluded that wind-driven circulation is secondary under average, standard meteorological conditions, but it can become dominant when strong bura can increase the current speeds for an order of magnitude with respect to seasonal, thermohaline values.

Along the eastern coast, south of Istria, currents are often related to the bura, which reflects on frequent appearance of the W surface current direction (Zore-Armanda *et al.*, 1979) followed by upwelling. Mean circulation in most of the semiclosed basins is dictated by prevalent winds, since the fresh water inflow is rather small. The Kaštela Bay was repeatedly investigated in that respect (Zore-Armanda, 1980). The types of horizontal and vertical circulation differ depending on the wind direction. The influence of stratification on the wind-forced circulation has also been shown in some areas, such as the channel Virsko more near Zadar (Zore-Armanda and nda and Gačić, 1987, Dadić, 1984). Under stratified conditions alongshore wind induces horizontal circulation without bottom compensatory current, and in the

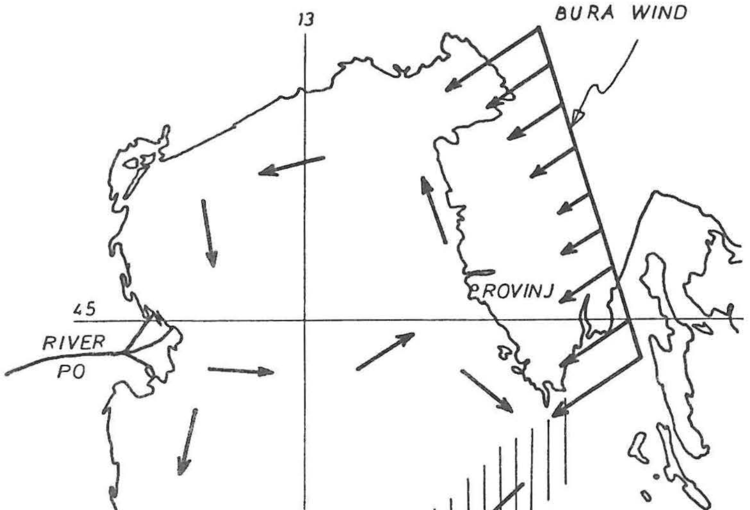

Fig. 10. Schematic representation of the bura wind field and water circulation in the northern Adriatic with position of the frontal zone indicated by hatching (after Zore-Arma

homogeneous situation well developed vertical circulation is formed. On the contrary, under stratified conditions bura induces vertical recirculation (offshore in the surface layer with upwelling) and horizontal gyres in the homogeneous situation.

OSCILLATORY MOVEMENTS

Although the Adriatic tides have relatively low amplitudes, they are higher than elsewhere in the Mediterranean. Amplitudes increase northward. Diurnal inequalities are well marked, and tides are of mixed type. Syzygial tides in the southern and northern Adriatic are opposite in phase which led to the conclusion that semi diurnal constituent could be described as a standing wave (Defant, 1914; Sterneck, 1919). Owing to the fact that a free oscillation of the basin of nearly the same period (~11 to 12 h) was also found, the idea arose of the presence of forced and eigen oscillation resonances. The diurnal tide constituent is, however, in phase in the whole basin. Besides the presence of the diurnal tide constituent there is also a free oscillation with the similar period (~ 22 h) and corresponding resonance. The nodal line of this free oscillation is in the Otranto Strait and therefore the amplitudes increas going northward. Average annual tidal amplitudes range from 11 to 33 cm. Current vectors generally follow elliptical path (Cavallini, 1985; Bone, 1988). The major axes of tidal ellipses are aligned with the shoreline, and current vectors more often turn counterclockwise in the coastal region. In the open sea surface layer current vectors turn counterclockwise, and in the bottom layer clockwise. Tidal currents have maximum speeds of few cm s^{-1} .

Wind pulses induce the whole spectrum of free oscillations in addition to those already mentioned. Seiches were investigated for many basins along the eastern coast (see reviews by Buljan and Zore-Armanda, 1976; Franco *et al.*, 1982). Typical periods range from few minutes to few hours and amplitudes from 5 to 20 cm.

Inertia-period (~ 17 h) motions are better pronounced in the open Adriatic than close to the coasts (Accerboni *et al.*,1981; Gačić and Vučak,1982;Orlić, 1987). Significant energy maxima appear in the current spectra in summer. Oscillations last for a few days and coincide with transients of wind field above the Adriatic. Inertia-period currents accounted for about 10 to 30 % of the total current variance depending on the position of stations towards the open sea. The clockwise current vector rotations were opposed in phase across the thermocline.

Along the Croatian coast local wind forces oscillations at the time scale of seven to ten days (Gačić, 1980; 1982; 1983). In semiclosed basins or in the nearshore region within the internal radius of deformation (~ 10 km), surface currents generated by the local wind are in downwind direction. If the wind has an onshore component the compensatory flow will be developed in the bottom layer. Under stratified conditions, bura induces an offshore surface transport and consequently the upwelling. As a consequence of the upward motion of isopycnal surfaces, alongshore baroclinic motions are generated under stratified conditions.

CONCLUSIONS

Most distinguished characteristics of the Adriatic Sea are large annual and year-to-year fluctuations of its basic oceanographic properties giving to this sea clearly an continental aspect. Extremes of the sea-surface temperature embrace large range from 3 to 29 °C. Salinity ranges are not less important, though minimum is difficult to define due to rivers influence in the coastal zone. Currents have generally low speeds and many various directions. Fluctuations of different parameters depend, in the first place, on some climatic factors over the Mediterranean and therefrom on the level of water exchange between the Adriatic and the Eastern Mediterranean. Three year periods in fluctuations of surface temperature and salinity were also observed. In addition, the man-made impact on some oceanographic properties has become clear for the past two decades.

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PRIRODNA SVOJSTVA I KLIMATSKE PROMJENE U JADRANSKOM MORU

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KRATKI SADRŽAJ

Iznesen je pregled osnovnih oceanografskih karakteristika Jadranskog mora. Ukazano je na njihove znatne sezonske i višegodišnje fluktuacije. Primjerice, raspon površinskih temperatura mora kreće se od 3 do 29° C. Rasponi saliniteta su također veliki, ali ih je teže numerički izraziti, jer minimumi ovise o udaljenosti od ušća rijeka. Struje imaju općenito male brzine, a njihov smjer je vrlo promjenljiv. Fluktuacije raznih parametara su prvenstveno prouzročene klimatskim faktorima, koji djeluju iznad Mediterana, a koji utječu na intenzitet izmjene vode između Jadrana i istočnog Mediterana. Uočen je i trogodišnji period u promjenama površinskih temperatura i slanosti. U posljednja 2 desetljeća uočljiv je i utjecaj čovjekovih aktivnosti na razna svojstva mora.