Empirical orthogonal function (EOF) analysis of temperature-salinity field in a small semienclosed bay (Kastela Bay)

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ABSTRACT An EOF analysis has been applied to the temperature and salinity data sets collected on a bi-weekly basis from a dense station network in the Kaštela Bay (Adriatic Sea, Yugoslavia) during the period 1953/54. Vertical EOF's have been determined at two stations in the Bay inlet, one station in its centre and one station in the shallowest part next to the mouth of the River Jadro inflowing into the Bay. The EOF analysis of temperature-salinity fields in the horizontal plane has been done at the surface and depths of 10 and 20 meters. Time-varying amplitudes of the most important horizontal and vertical modes of salinity have been correlated with the wind and water level data of the River Jadro integrated over consecutive time intervals prior to sampling dates (from one to eight days). Fresh water inflow contains strong seasonal signal which has been removed by subtracting daily values of the water level from the respective ten-year monthly means. Horizontal and vertical salinity modes have also been correlated between themselves. Horizontal temperature distribution is almost entirely represented by the first EOF which subtracts more than 98% of the total variance. Its time dependence shows that it is induced by the seasonal heating and cooling resulting in a simultaneous temperature increase or decrease over the entire Bay area. The percentage of the temperature variance explained by the first vertical EOF depends on the station depth; the deeper the station is the smaller is the percentage of the variance explained by the first mode. The first vertical mode as the first horizontal one represents seasonal temperature changes. Second vertical temperature EOF displays a zero-crossing at the thermocline depth and represents out-of-phase oscillations of the surface temperature with respect to that of thelayer below thermocline. Horizontal salinity decomposition in the surface layer results in the first mode explaining about 82% of the total variance. It represents in-phase salinity changes over the entire Bay. The second mode explains about 8% of the total variance and is related to those salinity changes which are out-of-phase in the shallow eastern part with respect to the Bay inlet and its centre. Similar distribution of the variance between different horizontal modes is evident at the depth of 20 meters while at 10 m depth almost 95% of the variance is contained in the first EOF. Vertical decomposition of salinity shows different behaviour from the temperature; the first mode represents the smallest portion of the total variance at the shallowest station near the river mouth. This is the consequence of the strong two-layer estuarine type of circulation in this portion of the Bay. Going towards the Bay inlet the percentage of the variance explained by the first EOF increases. The second vertical salinity EOF has again one zero-crossing which is situated closer to the surface than the zero-crossing of the second temperature EOF. This is probably due to the halocline being shallower than the thermocline. The second vertical EOF's of both salinity and temperature have largest time variations during the halo-/thermocline generation and destruction processes. The local wind averaged over three to six days prior to sampling dates is highly correlated with salinity changes represented by the first mode in the surface and bottom layers. In intermediate layer correlation is lower showing that wind induces vertically two layer circulation pattern. This is also supported by a relatively high correlation between the wind data and second vertical salinity mode while the correlation with the first vertical mode is rather poor. The two-layer vertical circulation pattern in the Bay is also generated by the fresh water inflow. A high correlation is evidenced between the river water level and first horizontal EOF's at the surface and 20 m depth. Also there exists a statistically significant correlation between the river water level and the second vertical mode at all stations except at the station next to the river mouth. In that relatively shallow part of the Bay (depth ≅ 10 m) the first vertical mode is closely related to the river water level showing that the fresh water influence at the surface, is rather quickly spread over the whole water column. The north wind component averaged over a week period seems to be responsible for the existence of the surface pattern of salinity changes which are out-of-phase in the shallow part of the Bay with respect to the Bay inlet and its centre. Therefore, it can be concluded that temperature changes in the Bay of Kaštela are mostly induced by the seasonal heating. On the other hand, salinity variations are due to the two-layer water exchange induced by the local wind forcing and by the river water inflow.

On the structure of inertia-period oscillations in the Adriatic Sea

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Oscillations of the inertia period have been detected in the Adriatic Sea during various summers. It has been found that these oscillations are manifested by considerable thermocline movements and current-vector rotations that change their phase across the thermocline. The oscillations have been modelled as transverse internal seiches in a rotating rectangular channel (Orlić, 1987).

Both empirical and theoretical approaches have had their shortcomings. The main drawback of various data sets collected in the Adriatic Sea has been the lack of synopticity, whereas the modelling of inertia-period oscillations has been limited to two dimensions. Logical next step then is to extend measurements to a network of synoptic stations, and to build a three-dimensional model. Here, an experiment, which has been inspired by the first of these goals, will be described.

The experiment has been carried out in the Northern Adriatic during May-June and August-September 1987. In the first part of the experiment currents and hydrographic data were measured at three stations along a profile parallel with the Yugoslav coast; in the second part same parameters were measured at three stations along a profile perpendicular to the coast (Fig. 1). Simultaneous meteorological data were available from the nearby coastal stations.

Preliminary analysis of the data shows that inertia-period oscillations were well developed during May and June (variance of band-passed current time series amounted to 356.9 cm^2/s^2 at station 107 and depth 6 m), whereas they almost disappeared during August and September 1987 (variance at the same station and depth went down to 27.9 cm^2/s^2). Comparison with the concurrent meteorological data shows that first two decades of September 1987 were very quiescent, without major perturbations in the wind field, and consequently no oscillations could be generated in the sea. Exceptionality of September 1987 manifested itself also in low-passed sea surface temperatures, which increased during the greater part of the month.

The inertia-period oscillations were characterized by current variations being smaller along the coasts than farther offshore, and by temperature variations which diminished with the offshore distance. Variances of band-passed time series clearly illustrate the point:

CURRENTS	TEMPERATURES
STATION 007 (8 m): 170.9 cm^2/s^2	STATION 107 A (7 m): 0.0365 $(^{\circ}C)^2$
STATION 107 (6 m): 356.9 cm^2/s^2	STATION 107 (6 m): 0.0053 $(^{\circ}C)^2$
STATION 209 (8 m): 329.3 cm^2/s^2,	STATION 107 B (4 m): 0.0018 $(^{\circ}C)^2$.

Along the vertical, temperature variations were greater at intermediate levels than close to the surface or bottom, pointing to the dominance of the first baroclinic mode.

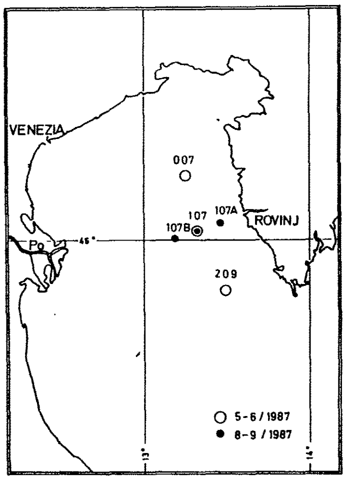

Fig. 1. Positions of sampling stations.

It can be seen that the structure of inertia-period oscillations in the Adriatic Sea is three-dimensional. Consequently, these oscillations, which have up to now been simulated as a two-dimensional phenomenon, should more realistically be interpreted in terms of internal Poincaré-type modes of the basin. An attempt should therefore be made to compute such modes for the Adriatic Sea, probably along the lines suggested by Schwab (1977).

References

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Schwab D.J. (1977): Internal free oscillations in Lake Ontario. Limnology and Oceanography 22, 700 - 708.