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MULTIDECADAL CHANGES IN THE BALTIC MARINE ECOSYSTEM UNDER HYDROCLIMATOLOGICAL FORCING

by

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SUMMARY

The effect of the Earth rotation velocity and associated latitudinal migrations of the Azore anticyclone on the near-bottom salinity of the Baltic Sea is researched. It is stated that when the Earth rotation slows down, the Azore anticyclone migrates northwards, saline water is driven into the Danish Channels rising the sea level there and causing increase of saline water intrusion into the Baltic Sea. Near-bottom salinity in the Bornholm and Gdansk Deeps evidently increased in the years associated with the well-known El-Nino/ Southern Oscillation exhibited in the global scale. When the Earth rotation accelerates the Azore anticyclone migrates southwards, the sea level in the Danish Channels becomes lower and saline water intrusion into the Baltic Sea decreases. Besides, when the Earth rotation is slowing down the vertical component of the deforming force causes the raise of the sea level in the temperate latitudes in general and in the channel zone in particular which promotes saline water intrusion into the Baltic Sea.

INTRODUCTION

Revealing the mechanism of saline water intrusion into the Baltic Sea is an important problem still being the issue of the day. The amount of saline water intrusion being the component of the total salt balance in the Baltic Sea affects fish populations reproduction and abundance. The possibility to predict the trend of the Baltic water salinity reduction or increase is an important practical goal.

Saline water intrusion into the Baltic Sea occurs when the sea level at the northern boundary of Kattegat becomes higher that at the southern boundary. The most evident difference of the sea level in the Danish Channels may occur when Azore atmospheric center is strengthening and Island minimum becomes weaker and when the meridional component of the cyclonic activity is strengthening directly over the Baltic Sea. These processes create prerequisites for increasing saline water pressure upon the channel zone on the one hand and decreasing the Baltic Sea level (as a result of moistening reduction, evaporation increase, etc.) on the other hand.

To attain the effect of the ocean water drive into the Danish Channels the Azore anticyclone has to shift more northwards as compared to its usual location. This may occur under the impact of the horizontal component of the deforming force tangent to the sphere and directed towards the pole which appears when the Earth rotation velocity is slowing down. At the middle latitude of the Azore anticyclone location (35° N) this force is 1.6 g*cm/sec (Stovas, 1959). When the Earth rotation accelerates this force is directed to the equator. If the Earth rotation regime changes, the Azore anticyclone will migrate northward and southward of the usual location, while saline water intrusion into the Baltic Sea will become stronger or weaker. The purpose of this article is to verify the hypothesis proposed.

MATERIAL AND METHODS

The data on the Earth rotation regime may be considered valid from the moment of the atomic clock invention (1962). Therefore in this work the time series of average monthly data on deviations of the Earth rotation angular velocity (√) from 1962 to 1999. The deviations have been published in the monthly bulletins of the World Time Service. We obtained them at the Hydrometeorologic Center of the Russian Federation. The angular velocity deviations represent a difference between the actual and the mean angular velocity divided by the mean velocity. If required it is possible to apply the actual velocity instead of the deviations.

$$\omega = \sqrt{} * \omega \text{ mean} + \omega \text{ mean}$$

The estimated zonal gradients of the atmospheric pressure at the sea surface along 20°W meridian between 50° and 60° N were used in the work. This parameter characterizes the wind regime strength along the 55°N being the medial parallel of the Danish Channels. The pressure gradients were estimated on the basis of mapped mean monthly fields of the atmospheric pressure at the sea level over the Northern Atlantic Ocean during 1962- 1999.

The geographic center of the Azore anticyclone including the latitude of this atmospheric activity center was determined on the basis of the same maps. All these meteorological data are available in AtlantNIRO data base. The same data base includes also the data on near-bottom salinity of the Bornholm and Gdansk Deeps. The most complete data on salinity of the Bornholm Deep are available until 1985, while the data on salinity in the Gdansk Deep are used for the period from 198 1 to 1999.

One-factor variance analysis according to the scheme described in (Hiks, 1967) was applied for probabilistic assessment of one factor dependence on another. The well-known correlation analysis was used to get quantitative assessment of the relation between a predictor and a predictant.

The most significant advection of saline water in the Baltic Sea were observed from October to March, i.e. in the period of the most evident migrations of the Azores anticyclone. Therefore, prior to the correlation analysis, the data on the Earth rotation acceleration ($\partial\omega/\partial t$), fluctuations of the Azore anticyclone latitude ($\varphi°$), variability of the atmospheric pressure gradient (A grad) and near-bottom salinity in the Bornholm Deep were averaged for the cool season of the year from October to March. In assessment of the relation between the Earth rotation angular velocity deviations ($\sqrt{}$) and near-bottom salinity of the Gdansk Deep the values averaged for the year were used.

The most close relation between these parameters in the area was obtained when the time series of salinity data were shifted to 2 years backwards relative to the time scale of the Earth rotation angular velocity deviations.

RESULTS AND DISCUSSION

At the beginning of this research the one-factor variance analysis was carried out to obtain the probability assessment of dependence between salinity variability in the near-bottom layer of the Bornholm Deep and fluctuations of the atmospheric pressure gradient along 20°W meridian between 50" and 60° N. The results show that the atmospheric pressure gradient fluctuations affect salinity variability at the probability level exceeding 0.99.

At the next stage of researches the closeness of relation between 4 parameters – one of them is a planetary and a global parameter (the Earth rotation acceleration), and three other are local ones: latitude of the Azore anticyclone location, the atmospheric pressure gradient along 20°W meridian between 50" and 60° N (the North-Eastern Atlantic Ocean) and salinity of the Bornholm Deep near-bottom layer (the Baltic Sea.) – were assessed by means of the correlation analysis. The results of the correlation analysis revealed that all linear correlation coefficients are significant as they exceed the estimate of the natural supply ($r = 0.5$). The atmospheric pressure gradient is most closely related to the Azore anticyclone latitude ($r = 0.8$). Salinity variability in the near-bottom layer of the Bornholm Deep is more closely ($r = -0.72$) related to the Earth rotation acceleration than to the Azore anticyclone latitude ($r = 0.53$) and to atmospheric pressure gradient ($r = 0.56$). In our case the global factor appeared more efficient as a predictor than the regional ones. The Azore anticyclone migrations are related to direction variability of the deforming force horizontal component appearing at the Earth rotation acceleration and slowing down.

The process of the sea level raising in the Danish Channels and saline water intrusion into the Baltic Sea is related to the intrusion of driven ocean water into the Channels when the deforming force horizontal component is directed northwards during the Earth rotation slowing down. In addition, during the Earth rotation slowing down the sea level raises at the temperate latitudes of the Atlantic Ocean (Stovas, 1959) in general and in the Danish Channels in particular under the impact of the deforming force vertical component.

Thus, the efficiency of the Earth rotation acceleration as the predictor is explained by availability of two mechanisms of the sea level modulation in the Danish Channels: intrusion of driven ocean water caused by the horizontal component and rotation tides cause by the vertical component of the deforming force.

Fig.1 shows that saline water intrusion into the Baltic Sea occurred in the years of well-known El-Nino / Southern Oscillation (ENSO): 1965, 1969/70, 1972/73, 1976 and 1982183.

ENS0 events at the low latitudes of the Pacific Ocean and saline water intrusions into the Baltic Sea are associated with the same global phenomenon – the Earth rotation slowing down.

In addition to relatively short (from 6-7 to 12-15 months) and irregular strong fluctuations of the Earth rotation velocity, typical to ENS0 events, the gradual and long-term fluctuations occur in the Earth rotation regime.

Fig. 2 presents inter-annual variability of the Earth rotation velocity deviations and salinity in the near-bottom layer of the Gdansk Deep from 198 1 to 1996. The input data were smoothed with the moving 3-year averaging to reject short-term fluctuations. The salinity curve is shifted 2 years back relative to the time scale of the Earth rotation velocity deviations. On this assumption the maximum close relation was observed between parameters shown in the figure ($r = -0.87$). This figure shows that the pattern of relation between the Earth rotation velocity and near-bottom salinity variations revealed during irregular fluctuations of the Earth rotation regime is preserved also during long-term fluctuations, i.e. water salinity increase associates to the Earth rotation slowing down, while water salinity reduction – to the Earth rotation acceleration.

Thus, the proposed hypothetic mechanism of the ocean saline water intrusion into the Baltic Sea has been confirmed.

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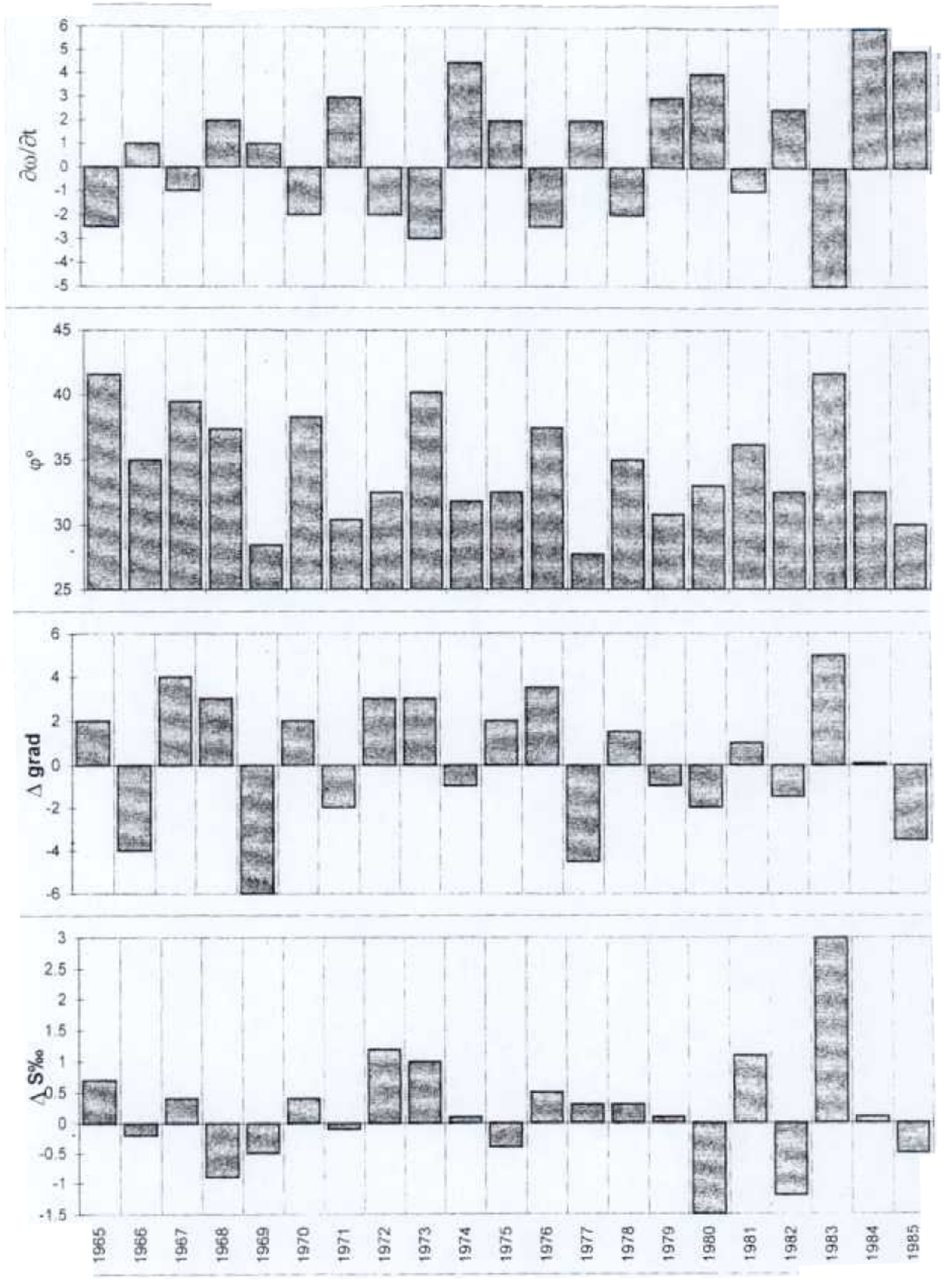

Fig. 1. Inter-annual variations of the Earth rotation angular velocity ($\partial\omega/\partial t$), the Azore anticyclone width ($\varphi°$), deviations of atmospheric pressure gradient at the sea level between 50° and 60°N and 20°W (Δ grad) and salinity fluctuations in the near-bottom layer of the Bornholm Deep (ΔS‰).

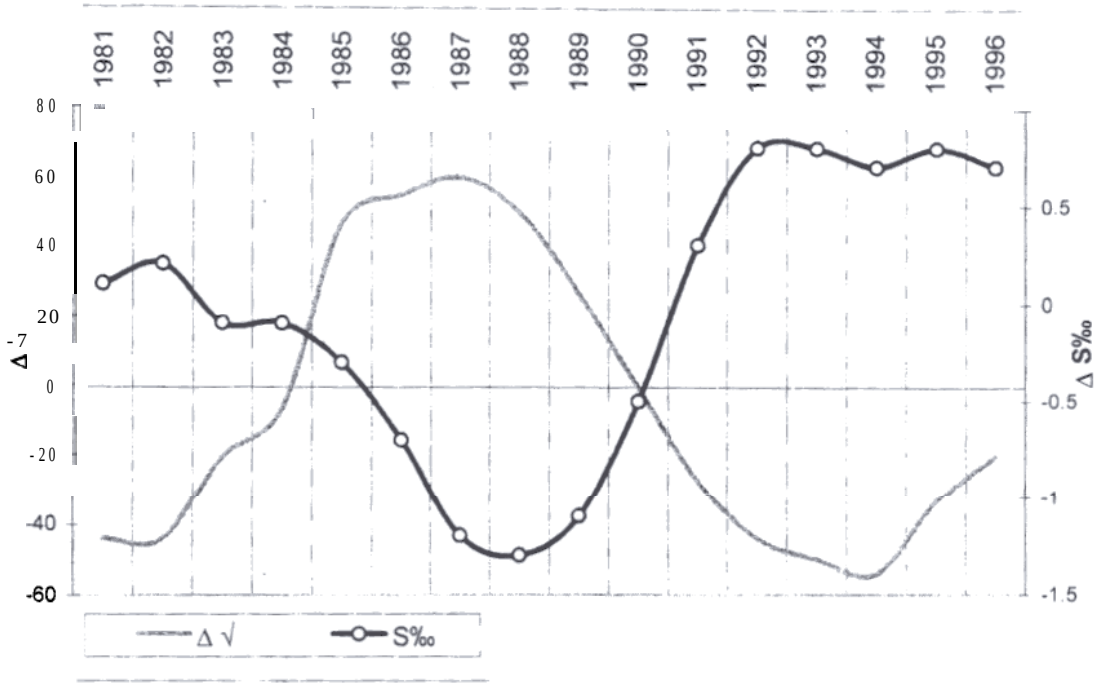

Fig. 2. Inter-annual variations of the Earth rotation deviations ($\Delta\sqrt{}$) and salinity in the near-bottom layer of the Gdansk Deep.