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Atmospheric Circulation Patterns Inducing Coastal Upwelling in the Baltic Sea

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Abstract : This study is meant as a contribution to the research of the upwelling phenomenon, which is one of the most pronounced examples of the sea-atmosphere coupling. The aim is to confirm the atmospheric forcing of the sea waters circulation and sea surface temperature along the variously oriented Baltic Sea coasts and to find out macroscale and regional circulation patterns triggering upwelling along different sections of this relatively small and semi-closed sea basin. The mean daily sea surface temperature data from the summer seasons (June–August) of the years 1982–2017 made the basis for the detection of upwelling cases. For the atmospheric part of the analysis, monthly indices of the Northern Hemisphere macroscale circulation patterns were used. Besides, in order to identify the local direction of airflow, the daily zonal and meridional regional circulation indices were constructed and introduced to the analysis. Finally, daily regional circulation patterns over the Baltic Sea region were distinguished by applying the principal component analysis to the gridded mean daily sea level pressure data. Within the Baltic Sea, upwelling is the most frequent along the zonally oriented northern coast of the Gulf of Finland, southern coasts of Sweden, and along the middle part of the western Gulf of Bothnia coast. Among the macroscale circulation patterns, the Scandinavian type (SCAND), with a primary circulation center located over Scandinavia, has the strongest impact on the horizontal flow of surface sea waters in the Baltic Sea, which triggers upwelling. An anticyclone center over Scandinavia in the positive phase of SCAND enhances the eastern airflow, which increases upwelling frequency along southeastern Baltic coasts. It was proved in the study that the zonal circulation has a stronger impact on upwelling occurrence than the meridional one, and it could increase/decrease a chance of upwelling formation by more than 70% in some coastal sections. Positive and negative phases of six distinguished regional daily circulation patterns made 12 different synoptic situations which were analyzed in the terms of their influence on the upwelling formation. Each of them revealed some impact on the frequency of upwelling in some coastal section of the Baltic Sea; however, two kinds of synoptic situations seemed to have the strongest influence, namely, the first kind representing pressure patterns enhancing the zonal flow and the second kind representing synoptic patterns with a cyclone/anticyclone centers over southern Scandinavia. Upwelling occurrence appeared to be particularly strongly reliant on the atmospheric conditions in some specific coastal sections, namely: the Gulf of Finland, the south eastern Baltic coasts (Polish and Latvian-Lithuanian section), and the western part of the Gulf of Bothnia. Concluding, it can be stated that atmospheric conditions strongly control the occurrence of upwelling within the Baltic Sea basin. Both local and macroscale circulation patterns expressed by the location of the pressure centers influence the frequency of this phenomenon; however, the impact strength varies, depending on the coastal region. Acknowledgment: This research was funded by the National Science Centre, Poland, grant number 2016/21/B/ST10/01440.
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