

POLYNYA NEAR THE STRAIT OF BALTIYSK IN THE VISTULA LAGOON OF THE BALTIC SEA

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ABSTRACT

Every year there is a polynya (an opening of water enclosed in ice) near the Strait of Baltiysk in the Vistula Lagoon of the Baltic Sea. 196 synthetic aperture radar (SAR) satellite images covered the period from 26 December 2010 to 06 March 2017 were analyzed, and on 76 of them polynya was detected. To find the main forcing factors of polynya's evolution we correlated its changing parameters with the basic characteristics - air temperature, wind and saline water intrusions according to sea level changes. We came to the conclusion that there may be even one more factor that can control the dynamics of the area of the polynya.

INTRODUCTION

The Vistula Lagoon is the second biggest shallow estuarine lagoon of the Baltic Sea separated from it by a narrow sand spit. The water exchange with the sea is achieved through the navigable Strait of Baltiysk (width 400 meters). The lagoon water has intermediate salinity of 3.5 PSU on average. Ice coverage of the lagoon is established practically every year. The main peculiarity is the existence of a stable polynya inside the lagoon near the Strait of Baltiysk (1,2).

METHODS AND MATERIALS

SAR images were obtained ENVISAT (European Space Agency - ESA); RADARSAT-1 (Canadian Space Agency - CSA); RADARSAT-2 (MacDonald, Dettwiler and Associates, Ltd. – MDA, Canada); Italian Space Agency (ASI) Cosmo-SkyMED-1,2,3,4; TerraSAR-X (German Aerospace Center - DLR) and SENTINEL-1A images (ESA). Ground rooting was made in the WGS 84, UTM zone 34N. The polynya was clearly limited in the North-East by the manmade islands in the navigable Strait of Baltiysk, in the North-West by the Northern and Southern malls of Hydroaviation harbour. Vectorization of the polynya's areas was done manually. Relative error of the "mouth click" was 1.6%, less than 10% and therefore not considered to be significant. Polynya's areas' estimation was performed by the analytical software of QGIS version 2.16.3. The values of daily air temperatures, wind direction and speed were taken from the archive www.rp5.ru according to the Kaliningrad weather station. Sea level data were received from the level gauge in Baltiysk.

RESULTS

The main characteristic feature of ice processes in the Vistula Lagoon is its variability, expressed in the repeated destruction of the stationary ice for the ice season, and in the presence of a stable polynya of different areas (from 6 to 38 square km), shapes (isometric with rounded, smooth, California borders, extruded outwards or into the Vistula Lagoon) and sizes (length from 0,3 km to 7 km, width from 0,6 to 10 km).

After correlation between the size of polynya areas and the daily average air temperature (clarifying the wind situation) the obvious tendency of increase or decrease of the polynya area with air

warming and cooling was found. But there were several time periods that don't fit into the overall picture.

To find some additional arguments the analysis of water level variations was made. But the comparison of the changes of the polynya area along the water level variations didn't demonstrate clear and obvious dependence. Only for the period 10.01.16 - 13.01.16 the area of the polynya grew with the increase of water level (by more than 20 cm per period, that illustrates the very intensive marine water inflow). Water level variations for other cases (increase or falling down) were of order of 10 cm and polynya didn't react on them identically.

To check the idea that polynya near the Baltiysk Strait indicates the area which is under permanent influence of the marine intrusions the proportions between areas covered by water (polynya) and ice using conventional "axis" from the Strait of Baltiysk through the Island Nasynoi towards the opposite bank of the lagoon along the steepest descent line of bathymetry were done. The unexpected result was that in many cases (and in average statistically) the landward side of the polynya is far inside the lagoon than the inner bar, which is formed by sedimentation of the marine sediments. This bar is bounded the area adjacent to the Strait of Baltiysk and indicate the zone of intensive inlet-outlet currents (3,4). Strictly speaking this fact shows that (a) inertia of inflowing mass of marine water is rather big and they penetrate more deeply in the lagoon area upper layers after overlapping the underwater inner bar, or (b) doesn't support the idea that polynya is formed exclusively by inflowing marine water.

CONCLUSIONS

We may suggest that in addition to air temperature, wind and saline water intrusions according to sea level changes some forth factor may finally control the polynya area. We may propose that it is surface waves coming from the sea through the Strait of Baltiysk. Initially we didn't consider them as it is known that the strait damps the surface waves very efficiently, and only the very long waves with small amplitude may pass through the strait (5). It seems that these waves are the crucial factor which nevertheless *ceteris paribus* (other things being equal) can control the dynamics of the polynya area.

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