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Flaw polynyas as a source of long-distance connections in climate system

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Flaw polynyas are significant areas of open water and young ice (with thickness up to 30sm), polynyas are stable in time, and formed between fast ice and drift ice in the winter period (November-May) along coast of Arctic ocean. Flaw polynyas are formed under action of dynamic processes practically along of all fast ice. Separate polynyas are pulled on hundreds (up to 1000km) kilometers, their width reaches, sometimes, hundreds kilometers. In one region they open seldom, on short time, and do not achieve the big horizontal development. In other areas the probability of their occurrence is extremely great, time of existence reaches months, and the area could be significant (up to 100 000 square kilometers). Flaw polynyas represent a unique natural phenomenon where we could find processes of various spatial and time scales. Uniqueness of existence of a phenomenon of open water in the Arctic during the winter is determined by features of hydrodynamics and atmospheric circulation (by wind mainly).

Polynyas are significant sources of heat, from ocean to atmosphere. Heat transport could exceed 500W/m2 (Lemke, 2001). Through heat transport polynyas could influence on atmosphere, they can strengthen baroclinity of atmospheric synoptic gyres and well-developed polynya frequently causing regeneration of cyclones. In some cases cyclones stopped over the polynya. Reorganization of atmosphere structure in area of polynya, heat and mass exchange in polynya could lead to development of cyclone over polynya. Cyclone forms in its forward part area of positive anomalies of temperatures and in a rear part - area of negative anomalies of temperature. Besides in rear

part of cyclone area of a high pressure appears.

For revealing episodes of cyclogenesis in area of flaw polynyas we used the 6-hour data on trajectories of cyclones from climatic data file on trajectories of cyclones of Northern hemisphere for the period with 1948 for 2000 (this dataset was created on the basis of data processing of NCEP/NCAR reanalysis data under prof.S.Gulev supervising in Laboratory of interaction of Ocean and Atmosphere of P.P.Shirshov Institut of Oceanology, Moscow (Zolina and Gulev, 2002; Gulev, Zolina, Grigoriev, 2001)). Investigation of this dataset has revealed their significant dependence of cyclones on a development of flaw polynyas. Cyclones in area of development of flaw polynyas in the winter period provides effective transport of heat to high latitudes, on the one hand, and carrying out of cold air masses in area of midlatitudes, on the other hand. In arctic regions is formed significant areas concerning with relatively high temperatures and, accordingly, relatively low pressure areas. In midlatitudes the return picture is observed - formation of areas with relatively low temperatures and a high pressure is observed. Thus, development of flaw polynyas initiates formation of a positive phase of Arctic Oscillation (AO).

Cooling of surface water masses, formation of young ice and brine rejection initiate convection and formation of “cold halocline” layer and shelf water masses. Well-known, that the basic source of new ice for the Arctic basin are shelf arctic seas. As has shown in papers (Zaharov, 1996) up to 70 % of volume of new ice of the seas of the Siberian shelf are produced in flaw polynyas of the appropriate seas. Conclusions of Zakharov concern to 1960-70th to years of 20th century. According to investigations of A.Popov (Popov, 2000), these years repeatability and the areas polynyas in the seas of the Siberian shelf were minimal. From 1970th to 1990th there was a significant increase as areas, and repeatability of episodes of existence polynyas. Sizes of repeatability have increased from 30-60 % up to 80-100 %, i.e. many polynyas went from the category incidental went in a class of constant polynyas. Thus the area of many polynyas has increased in 2-5 times. Calculations of new ice production were executed by method described by S.Martin and D.J.Cavaliery (Martin, Cavalieri, 1989; Cavalieri, Martin, 1994). We found, that ice production of polynyas, at their significant development can exceed in 2-3 times ice production of all sea surface (excluding flaw polynyas), calculated without taking into account carrying out of ice.

Further the most part of new ice is involved in system of superficial currents of Arctic Ocean and taken out in the Arctic basin. In process of promotion in the Arctic basin new ice pass numerous seasonal cycles of increase and thawing. Nevertheless, receipt of the big volume of new ice from Siberian shelf area, should create significant indignations in climatic system. And the climatic signal caused by formation of the big volume of new ice in polynyas is shown twice. First, it occurs at the period of direct

formation of ice, owing to an intensification energy and mass exchange between ocean and an atmosphere. In the second, here arise, so-called long-distance connections in climatic system. Formation of ice in polynyas is accompanied by genesis of new water weights. Ice and the formed water are involved in system of currents of Arctic Ocean. After numerous seasonal cycles of increase and thawing, through the certain time named “reaching time”, this ice will arrive through Fram Strait in the Euro-Arctic seas. Big volume of the ice which has arrived from places of origin and in Fram Strait will be significant enough. Thus, ice transfers a climatic signal to area of the origin in the Euro-Arctic seas and further to Northern Atlantic. Carrying out of significant volumes of ice to Greenland Sea and Northern Atlantic stimulates occurrence here significant anomalies thermohaline characteristics. That in turn influences a mode of convective processes, results in an aggravation polar and sub-polar hydrofronts and as consequence results in an intensification of system of currents Gulf Stream - North Atlantic - Norwegian. Alongside with it, there is an aggravation of atmospheric fronts. Apparently, the similar script of development of events can be used for an explanation of a phenomenon of substantial growth of temperature of the Atlantic waters, marked in 1990th years of 20th century and the beginning of 21th century. Using the received time series of ice production, we investigated influence of flaw polynyas on formation of long-distance connections and feedback in climatic system of Northern hemisphere. In particular, crosscorrelation analysis of sizes of volumes of the ice formed in polynyas of Kara sea and thermohaline characteristics of waters of Greenland sea, has allowed to prove, that reduction of salinity of superficial waters Jan-Mayen current and salinity of waters of the Greenland gyre by horizon of 200 m in the summer period comes in 2-4 years after increase of Kara sea, and the increase of temperature of the Atlantic waters in area West Spitsbergen current comes in 2-3 years after increase of ice production in polynyas Kara sea. All above described processes result in strengthening to macrocirculation picture, characterized by “W” macrocirculation index (according to (Girs, 1970)). It seems there are preconditions for reduction of an NAO index. Processes, describing by “W” index characterized by rather insignificant development of the Icelandic minimum of atmosphere pressure, on all hemisphere baric formations zone displacement prevail of continent are formed area of positive anomalies of temperature of air, and in Arctic regions - negative. Cyclones from system of the Icelandic depression are displaced in east direction in a zone of midlatitudes, thus occurs oppression of arctic flaw polynyas. Thus, the negative phase of AO is formed. As shown in paper “Influence of flaw polynyas on formation of anomalies of ice cover in the arctic seas at the end of 20th - the beginning of 21th centuries” (Popov, 2007), in 2005-2007 in the Arctic basin was observed minimal area of sea ice for all history of observation. These time polynyas was extremely developed, and huge amount of young ice was produced. Melting of this ice in the summer period

should result to significant freshening of superficial waters and to formation climatically significant anomaly of salinity in Northern Atlantic. Thus, in conformity with the author's concept, in 2-3 years we can expect essential reorganization of large-scale atmospheric circulation and, as consequence, the beginning of formation of a negative phase of Arctic Oscillation. To a negative phase of AO, there corresponds downturn of temperature and increase pressure in Arctic regions. We could expect increase of the areas of sea ice, both in the Arctic shelf seas, and in the central Arctic basin in 2-3 years.

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