Dissertations

Transfrontal exchange of mass and heat in the region of the Arctic front

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Ph. D. thesis in physical oceanography supervised by Professor Jan Piechura.

The thesis by Waldemar Walczowski, a research scientist in the Hydrodynamics Department of the Institute of Oceanology PAS, was completed under the supervision of Professor Jan Piechura. It offers a new approach to an extremely difficult scientific problem concerning the complex processes governing the exchange of mass and heat in the Arctic region.

The introductory paragraphs draw attention to the formative function of the high latitudes in the global climate and briefly characterise the European sector of the Arctic seas. The meteorological conditions, and the heat exchange processes between the sea and atmosphere are described comprehensively. The circulation of water masses and the location of hydrological fronts are discussed, and the relevant water balance equations are included. An up-to-date classification of water masses is presented together with their physical properties.

The author of this extensive thesis has participated in several oceanographic expeditions to polar seas and has collected a vast amount of empirical material, which he has verified scrupulously and comprehensively analysed using statistical methods. This material served as a foundation for the hypothesis suggesting that mesoscale eddies at high latitudes are the major mechanism of transfrontal transport of heat and salt from the Atlantic Ocean across to the Arctic side of the front. The system under investigation is extremely complex owing to the quantitatively and qualitatively diversified forms of energy and mass exchange within the interrelated environments of the atmosphere, sea and cryosphere.

There is a detailed description of the dynamics of the fronts on a climatic scale, which includes the equations of motion and continuity, as well as the criteria for defining macroscale processes, their time scale, and the total

energy of the turbulence. The main types of flow and flow instability criteria, including the horizontal scale parameters, are also presented. This approach has enabled the author to:

(a) discern the principal levels of exchange from mesoscale through fine structure to the molecular level;

(b) to obtain valuable information on the length of the front and the frequency of eddies hiving off from the front;

(c) to calculate the salt and heat content of such eddies.

Such a comprehensive description of the mechanism functioning in the frontal zone is a considerable innovation as regards eddy dynamics, sources of turbulence and the problems of potential and relative vortices. The significance of sea floor topography on eddy location is emphasised, as this aspect tends to have been ignored by other authors. To compare the *in situ* results with the computed ones,

- formulas were applied to enable the flow on the warm and cool sides of the front to be calculated and the baroclinic geostrophic transport to be evaluated;
- calculations were performed on a 2-layer model to obtain information on the front wavelength and the duration of eddy formation.

A large part of the thesis deals with transfrontal transport. The author considers the problem beginning with the content of salt and heat in a single eddy, considerably modifying some literature-based methodological elements and models in so doing. The modifications of eddy geometry simplified the calculations but very probably did not influence the accuracy of the results. Among other things, the results show that every eddy that crosses the Arctic front en route to the Greenland Sea transports a quantity of salt sufficient to form a deep-water volume three times as large as its own capacity!

Intrusions, internal waves, salt fingers, convection and Kelvin-Helmholtz instability are some of the microscale phenomena causing fluctuations of the salinity and temperature fields which the author discusses. He focuses mainly on isopycnal intrusions and attributes considerable significance to lateral intrusions in salt and heat transport. He presents an original method for calculating the speed of intrusion propagation, based on the assumption that any salinity change within the ceiling layer of the intrusion is governed by double diffusion.

It must be stressed that Waldemar Walczowski has undertaken a difficult subject for his project, which required several expeditions to the Arctic. He presents a well-documented and clear picture of the Arctic front region

with its multiple and complex dynamic structures. The results of the computations of the transfrontal transport of heat and mass by eddies and lateral intrusions must be regarded as a significant scientific achievement. The aesthetic presentation of the thesis is also worth mentioning: the graphics of the numerous figures and charts are original and in many cases innovative, and are characterised by meticulous attention to detail.

Jerzy Cyberski