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Model Verification of Transport Processes in the Barents and Kara Seas

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INTRODUCTION

Laboratory models at SINTEF have been used to simulate the transport routes of fish eggs and larver, heat, ice containing terrigenous materials and atmospheric deposition, oil and potential radioactive contaminants in the Barents and Kara seas (McClimans and Nilsen, 1993; McClimans et al, 1997). In general, the simulations have shown a very good correlation with field data in spite of the fact that local winds have not been used to force the model circulation. The most important forcing appears to be the inflowing Atlantic Water, for the deeper flows, and tides in the shallow regions. The results are valuable for environmental impact studies.

THE MODEL RESULTS

Fig. 1 shows the extent of the laboratory model of the Barents Sea. The general circulation pattern is taken from Loeng (1991). The circled letters on the figure refer to the following

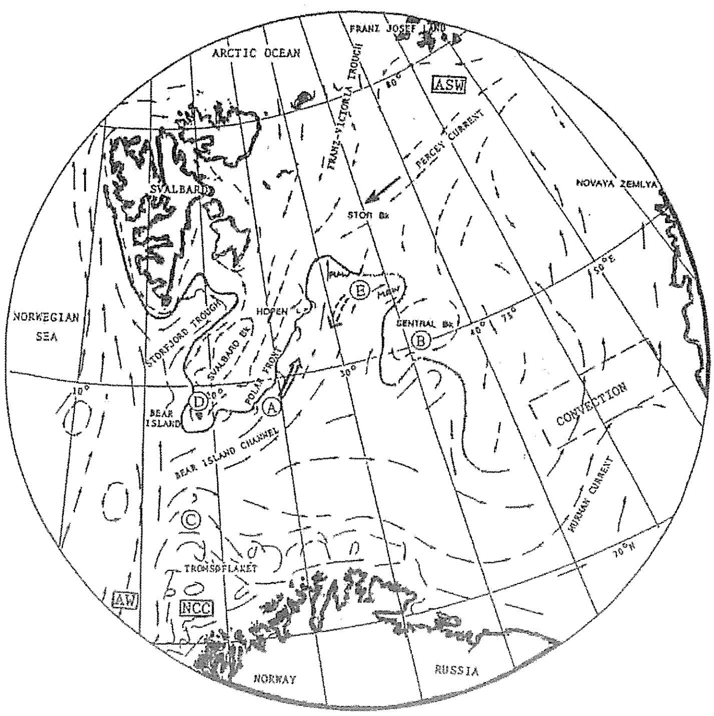

Figure 1. The geographical extent of the laboratory model of the Barents Sea. The circled letters refer to features which are discussed in the text.

transport processes which were simulated, and confirmed by field observations:

A - The warm core jet of inflowing Atlantic Water past Svalbard Bank pushes the marginal ice zone to the NE of Hopen, during the winter, and causes a sharp and persistent oceanic polar front with a rich fauna and fish production.

B - The anticyclonic circulation around the Central Bank shows the importance of topographic steering on the transport of drift ice and contaminants.

C - The mesoscale eddies within the spreading, buoyant coastal water enhance dispersion.

D - The tidally propelled residual current around Bear Island was discovered first in the laboratory model and confirmed by a satellite positioned drifter (Fig. 2). Average round times were 6 days in the model and 7 days in the field data. This has been used as a benchmark for developing fine resolution numerical models (Straume et al, 1994; Kowalik and Proshutinsky, 1995).

E - The dense bottom water produced by brine rejection during the freezing in the eastern Barents Sea flows west in the Bear Island Channel.

The laboratory model results were used to recommend a region with little throughflow for an oil-in-ice field experiment on Svalbard Bank (Sørstrøm, et al, 1993). The field results showed mesoscale eddies and weak throughflow in the region to the southeast of Hopen, and north of the April marginal ice zone, in agreement with the earlier model studies.

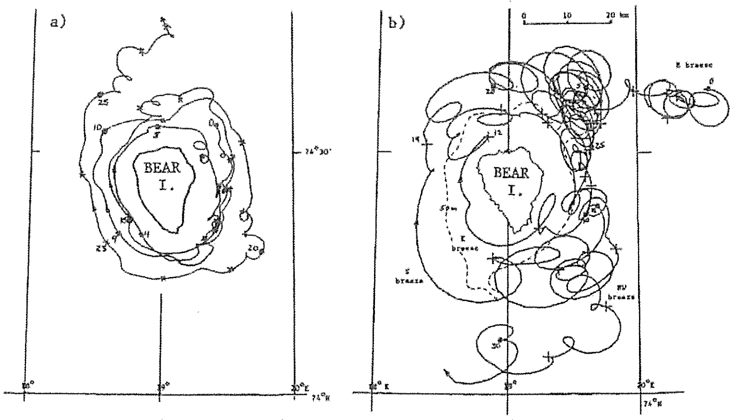

Figure 2. Currents around Bear Island: a) laboratory data and b) field data.

Fig. 3 shows the surface transport routes in the laboratory model of the Kara Sea (McClimans et al, 1997). The circled letters on the figure refer to the following processes:

A - The northwestern flow of the river plumes and the long residence times in the Kara Sea.

B - A return current of seawater to the mixing region in the estuaries at 10-15 m depth.

C - Several circulation patterns to the east of Novaya Zemlya.

D - The western outflow in the northern part of the Kara Strait is primarily composed of water that flows into the Kara Sea in the southern two-thirds of the passage.

E - Internal tides to the east of the Kara Strait with amplitudes up to 15 m can lift deeper water over the sill.

The above results have been confirmed by several sets of field data (see, e. g. Burenkov et al, 1995 and Johnson et al, 1997). The western and northern flow of the river plumes was noted first by Fridtjof Nansen in 1893 and the two-way flow in the Kara Strait has been known since early in this century (Pavlov et al, 1993). However, the recirculation path of the coastal water through the Kara Strait appears to be a new result which has been verified only in part, due to a lack of field data. The model simulations show that the currents to the east of Novaya Zemlya, where there are several ocean dump sites for radioactive wastes, are divided into many counter-rotating regions, unlike the throughflow depicted by, e.g., Pavlov et al (1993), based on sparse, historical data. This suggests that the transport of contaminants from the Kara Sea to the fish habitats in the southeastern Barents Sea is less than earlier assumed.

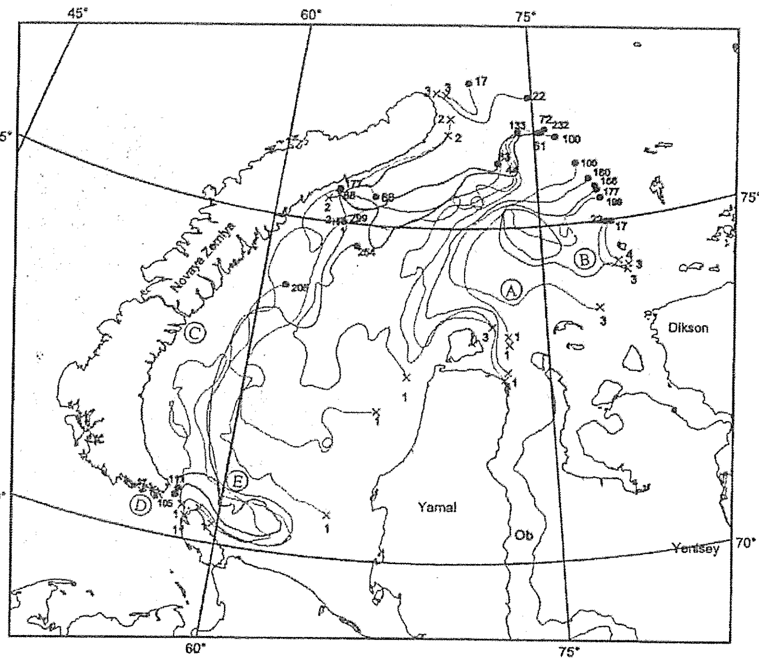

Figure 3. Surface particle paths from the laboratory simulation of the ocean circulation in the Kara Sea. Numbers at the crosses denote start season (1 = Jan-Mar, 2 = Apr-June, etc), and numbers at the dots give the number of (simulated) days of travel. The circled letters refer to features discussed in the text.

CONCLUSIONS AND DISCUSSION

The laboratory model results have been sufficiently validated to field data to give us faith that the details are also correct. For example, the average currents around Bear Island agree to within 15% of the field data. A general agreement to within 25% is common, as long as the local winds do not give a significant forcing. Effects of the persistent winter southerlies over the Kara Sea were apparent in the high, late winter surface salinities observed to the north of the Ob and Yenisei estuaries. The model results improved our understanding of the governing physical processes. We conclude that topography and the earth's rotation are the most important steering agents, that the deeper currents are forced predominantly by the inflow of Atlantic Water, and that the currents in the shallow regions are driven mostly by the tides, in the absence of strong, persistent winds. Concerning the boundary forcing conditions, the Atlantic Water inflow is the least known. For this reason, we have developed an algorithm for computing its variability, based on coastal water level measurements (McClimans, 1993).

The model results are useful not only to evaluate the spreading and dilution of contaminants, but knowledge of the strong, narrow jets along the slopes is valuable for evaluating the safety of operations. We also have many examples of laboratory simulations as surrogate realisations which can be used as benchmarks for the development of numerical models. These can include local winds, and chemical and thermodynamic processes, which are not simulated in the lab.

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