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WIND-DRIVEN VARIATIONS IN THE ATLANTIC INFLOW TO THE BARENTS SEA

by

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ABSTRACT

Results from a wind-driven homogeneous numerical current model for the Barents Sea are presented. The wind-driven fluctuations in the volume flux through the section between Fugløya and the Bear Island are computed for the period 1970–86. This time series shows a remarkable coincidence with measured temperature anomalies in the Kola section.

Reasons for and implications of this connection are discussed. In warm periods there is often low pressure over the central Barents Sea giving an increased Atlantic inflow. In colder periods the opposite effect occurs.

It is also suggested that these wind-driven fluctuations in the current may influence the transport of fish larvae. The east–west distribution of 0-group Arcto-Norwegian cod is discussed.

INTRODUCTION

The climate in the Barents Sea alternates between relatively warm and cold periods of duration 3 – 5 years. These fluctuations are described in (Midttun & Loeng 1987). Among the possible causes are variations in the intensity and/or temperature of the Atlantic inflow.

A measure for the intensity of the inflow is the volume transport through the Fugløya – Bear Island section. Based on current measurements in 1978, Blindheim (1989) calculated the inflow of Atlantic and Norwegian Coastal waters to 3.1 Sv and the outflow of Arctic water to 1.2 Sv. This leaves a net influx of approximately 2 Sv.

Part of the variations in this flux are caused by local meteorological conditions. Numerical models for the barotropic responce of the ocean to atmospheric forcing are well developed. Such a model for the Barents Sea is described in (Ådlandsvik 1989) with a brief review below. This model has been used for a long term simulation of this part of the flux.

Variations in the flow can also have a direct impact on the transport of biological material. Comparison of the flux values with the observed 0–grp. distributions of Arcto-Norwegian cod indicates a relation between increased inflow and easterly distribution.

THE MODEL

This section contains a brief description of the model, further details may be found in (Ådlandsvik 1989). The purpose of the model is to describe the response of the Barents Sea to the local atmospheric forcing. The model domain is shown in Fig. 1.

The driving forces are wind stress and atmospheric pressure taken from the Hindcast Archieve of the Norwegian Meteorological Institute (Eide *et al.* 1985). Other factors such as density differences, ice coverage, tidal forcing and background current at the open boundaries are neglected.

The model equations are the linear shallow water equations with vertical eddy viscosity, the continuity equation

$$\frac{\partial \eta}{\partial t} = -\nabla \cdot \int_{-H}^{0} \mathbf{u}\, dz$$

and the momentum equation

$$\frac{\partial \mathbf{u}}{\partial t} + f\mathbf{k} \times \mathbf{u} = -g\nabla\eta - \frac{1}{\rho}\nabla p_a + \frac{\partial}{\partial z}\left(\nu\frac{\partial \mathbf{u}}{\partial z}\right).$$

These equations are solved for the horizontal velocity field $\mathbf{u}$ and the surface elevation η. The atmospheric pressure is p_a while the wind stress enters through the boundary condition at the surface. The eddy viscosity term ν is prescribed.

The model is three-dimensional. Horizontally finite differences with a grid distance of 20 km are used. In the vertical direction finite differences are used with bottom following σ-coordinates. The numerical methods are similar to those applied by Davies (1985), in particular the scheme is explicit and uses a time splitting technique.

MODEL RESULTS

In this study the output data from the model is the computed volume flux every sixth hour through the section between Fugløya (70°40′N, 20°E) and Bjørnøya (the Bear Island) (74°15′N, 19°10′E). This section is marked with an "F" in Fig. 1. Since the mean Atlantic inflow is not considered in the model, the flux values should be viewed as fluctuations from this mean, in particular negative numbers represents a decreased inflow.

This flux is of course quite sensitive to the changing weather conditions. These short-time fluctuations are quite large, and may dominate the background inflow. For instance, in November 1979 the flux varied from −2.5 Sv to +5.8 Sv (Fig. 2). The mean for that month was 0.61 Sv and the standard deviation 1.6 Sv. The heavy line is a smoothed version given by a 5 day moving average. This curve varies between −1 and +2 Sv.

Climatic studies requires longer time scales. The model was run for a period of 17 years, from 1970 to 1986. Monthly mean values are given by the thin curve in Fig. 3. Although the largest variations are removed, the data still give a chaotic impression. The values vary from −1.3 Sv in March 1979 to +1.6 Sv in February 1983. For the whole period the mean is 0.06 Sv and the standard deviation is 0.56 Sv. Compared with the estimated 2 Sv background inflow, these results indicate that the net effect of the local atmospheric forcing is small but variations are important.

Part of the variations may come from the seasonal cycle. Fig. 4 presents the mean and standard deviation for each month based on the years 1970–86. There is an increased inflow in autumn and winter and a decrease in spring and summer. The strongest inflow occurs in February with +0.5 Sv and the weakest in April with −0.18 Sv. The seasonal cycle is not very pronounced as indicated by the large standard deviations. It is interesting to note that the standard deviation also varies. This is probably caused by the more calm weather conditions during spring and summer.

To smooth the flux data, a one year moving average is applied to the monthly values, using the formula

$$f_{sm}(t) = \frac{1}{12}\Big(\tfrac{1}{2}f(t-6) + \sum_{i=-5}^{5} f(t+i) + \tfrac{1}{2}f(t+6)\Big).$$

In particular this removes the seasonal cycle. The smoothed curve is given by the heavy line in Fig. 3. A blown up version is presented in Fig. 5.

COMPARISON WITH OTHER DATA

The best available climatic time series from the Barents Sea is probably the Soviet temperature series from the Kola section (Bochkov 1982). This section lies along the 33°E meridian from 70°30′N to 72°30′N and is marked with a "K" in Fig. 1. The series contains monthly values for the temperature in the upper 200 m. For the years 1970–86 the mean temperature is 3.8°C with standard deviation 0.9°C. Using the same one year moving average to remove the seasonal cycle, one obtains the curve given in Fig. 6.

Fig. 7 gives the one year moving average of monthly values of air pressure at the point (22°47′E, 75°02′N) between the Bear Island and Hopen. These data are extracted from the Hindcast Archieve (Eide *et al.* 1985). For comparison the pressure axes is reversed. The mean pressure for the period 1970–86 is 1008.7 hPa with standard deviation 6.5 hPa.

These three time series show a high degree covariation. In the cold period 1976–81 the air pressure over the Barents Sea was relatively high and there were a decreased Atlantic inflow. In the warmer periods 1972–76 and 1982–84 the air pressure were lower and the inflow increased.

There seems to be a positive feedback mechanism involved. High pressure over the Barents Sea gives an anticyclonic contribution to the current system. Since the "entrance" to the Barents Sea is located in the south west corner, this current component counteracts the Atlantic inflow. With less heat coming into the Barents Sea, the temperature tends to decrease. The heat content of the Barents Sea in turn affects the pressure distribution in the atmosphere, in particular the position of the polar front. When the sea temperature is low the polar front is more frequently situated south of the Barents Sea, giving Arctic conditions with higher air pressure.

In periods with low pressure the opposite effects occur. Such a feedback mechanism influences the climatic fluctuations toward larger amplitude and lower frequency. The local weather conditions also influence the heat flux from the ocean to the atmosphere. It is interesting to see that Häkkinen & Cavalieri (1989) report high values for the heat loss in the very cold winter 1978–79. Studying both these processes it should be possible to quantify the influence of the local atmosphere on the climatic fluctuations in the Barents Sea.

DISTRIBUTION OF 0-GROUP COD

Larvae of Arcto-Norwegian cod are transported partly into the Barents Sea and partly to the area west of Spitsbergen. The amount of larvae reaching these areas varies greatly from one year to another as documented by the 0-grp. surveys (Anon. 1970–86). The larvae entering the Barents Sea will pass through the Fugløya–Bjørnøya section in June–July (S.Sundby pers. comm.).

The wind-driven flux in these months are given in Fig. 8. These data are combined with 0-grp. cod distribution data into the following table. The first row gives the successive years. The next row gives a subjective characterisation of the distribution based on the 0-grp. maps. Here E, W and A denotes easterly, westerly and average distribution respectively. The statements are inforced or weakened by a "+" or "−" respectively. the last row shows a similar index for the flow, with I and D denoting increased resp. decreased inflow.

70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
E	E-	E	E+	E	E+	E-	A	W+	W	W-	A	A	A	W	W	E
I	D-	D-	I-	D+	I+	I-	A	D+	D	D	I	I	I+	I	D+	A

The table seems to indicate that increased inflow is related to easterly distribution and vice-versa. The years 1974 and 1984 are the greatest misfits. It is not clear to what extent the distributions are affected by the variations in the inflow. As demonstrated above these variations are related to the temperature in the Barents Sea. Higher temperatures might give decreased mortality in the eastern part of the Barents Sea and therefore affect the distribution towards east.

Work is in progress to discretize the 0-grp. distributions. This will lead to a more objective measure of the east–west component. A more realistic model including the background current is planned. This will be used as basis for a transport model for cod eggs and larvae. In this way the impact of advection can be studied separately.

ACKNOWLEDGEMENTS

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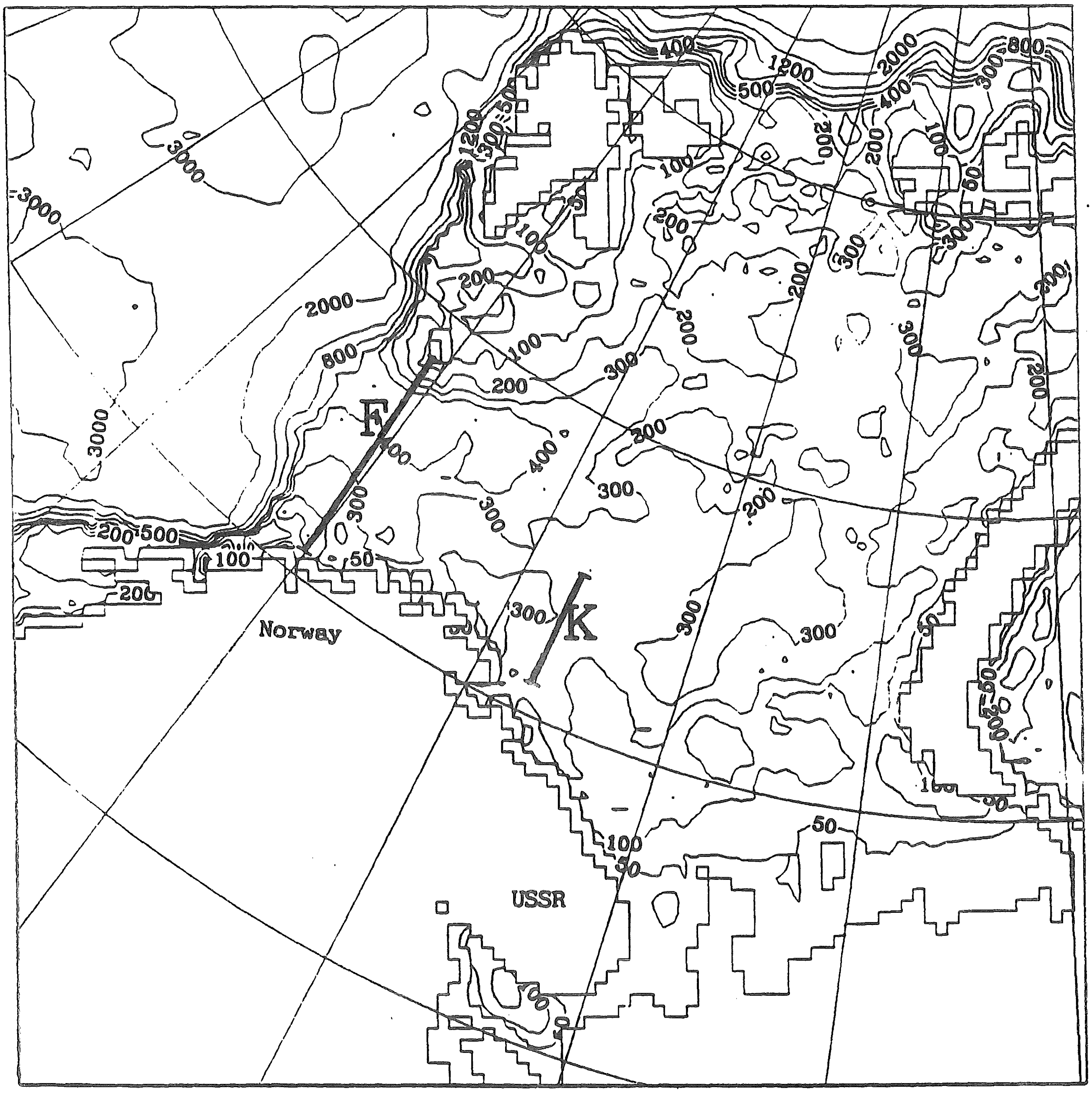

Fig. 1. The model domain with bathymetry. The Fugløya–Bjørnøya section is marked "F" and the Kola section "K".

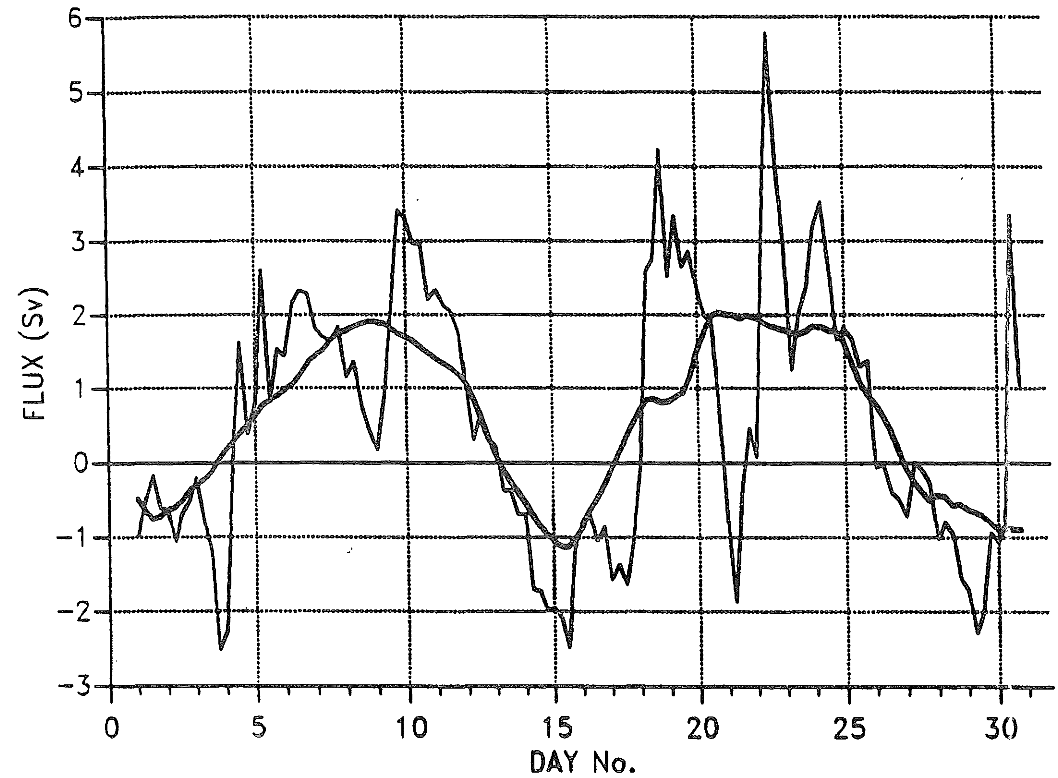

Fig. 2. Computed atmospherically driven volume flux through the Fugløya–Bjørnøya section in November 1979. The thin curve gives six-hourly values and the heavy curve is a moving five day average.

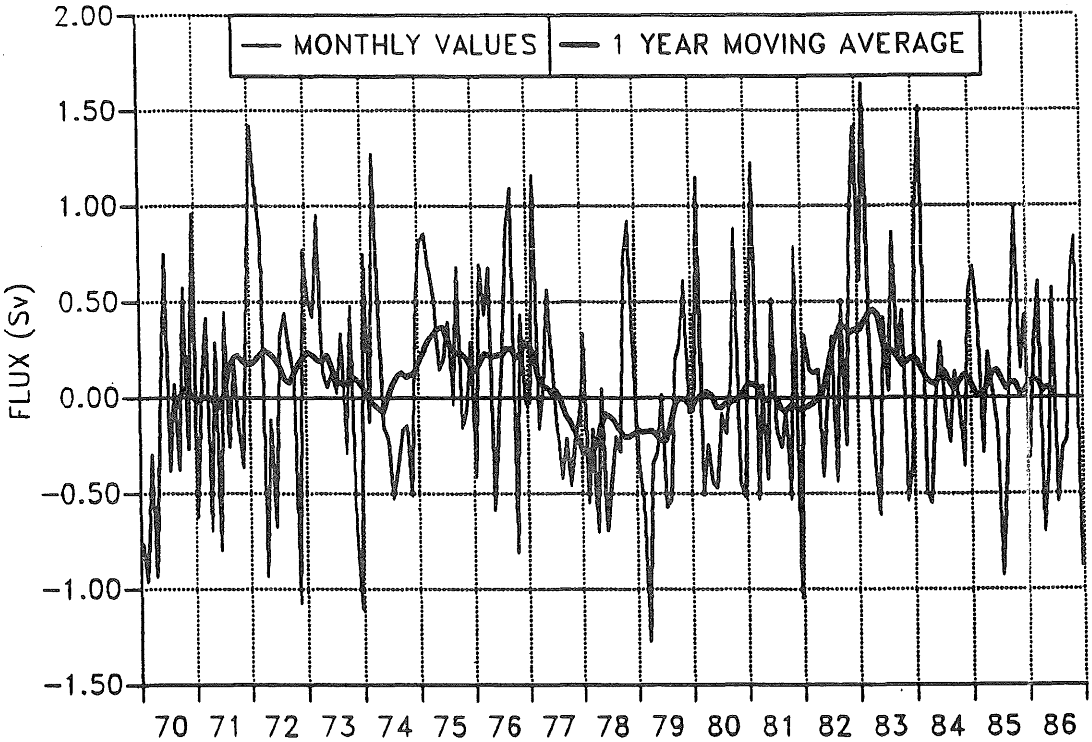

Fig. 3. Computed atmospherically driven volume flux through the Fugløya–Bjørnøya section in the period 1970–86. The thin curve gives monthly mean values and the heavy curve is a moving one year average.

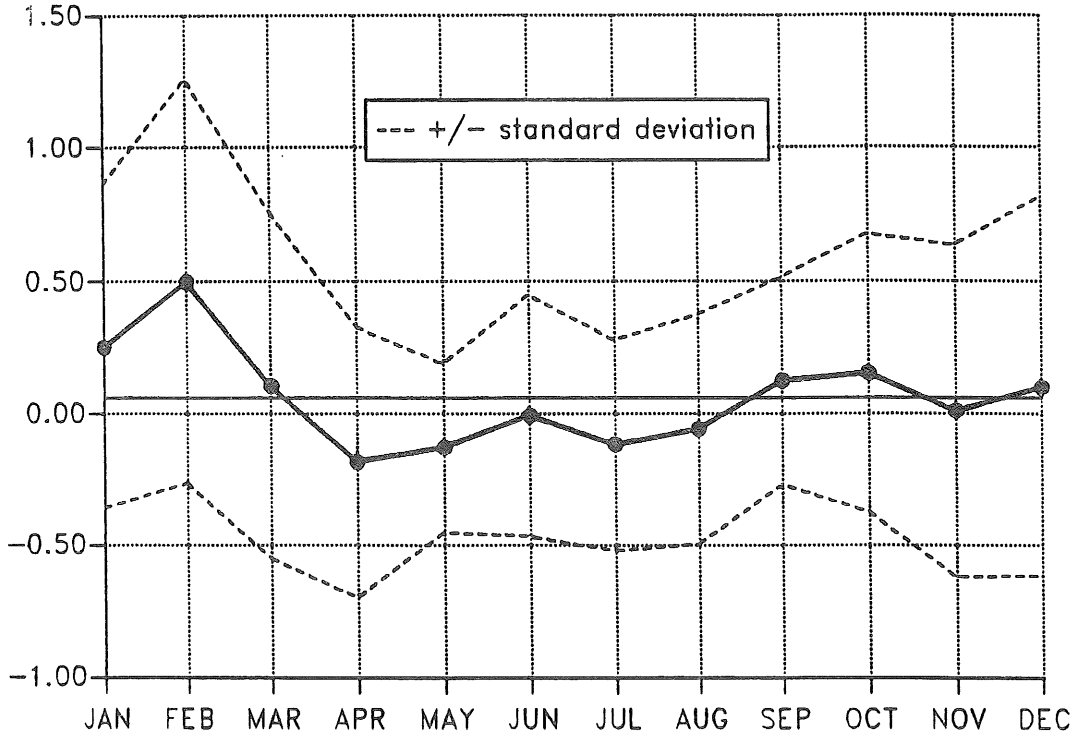

Fig. 4. The seasonal cycle in the computed atmospherically driven volume flux through the Fugløya–Bjørnøya section, based on the years 1970–86. The dotted line represents ± one standard deviation.

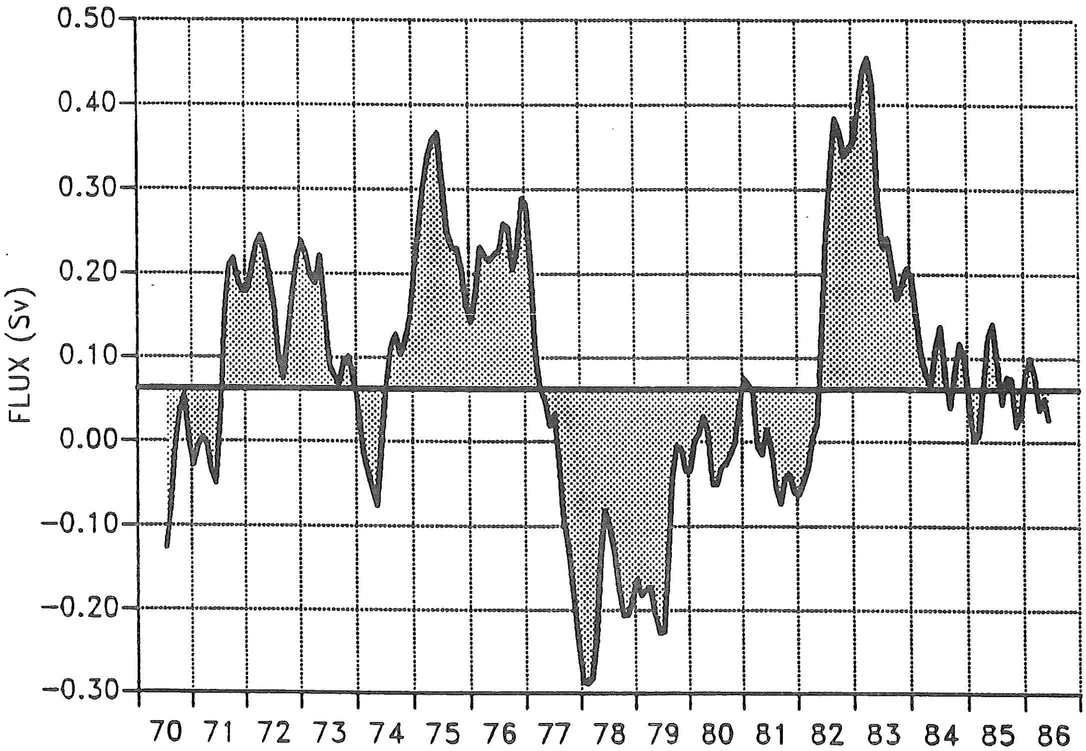

Fig. 5. The moving one year average of monthly values of computed atmospherically driven volume flux through the Fugløya–Bjørnøya section, 1970–86.

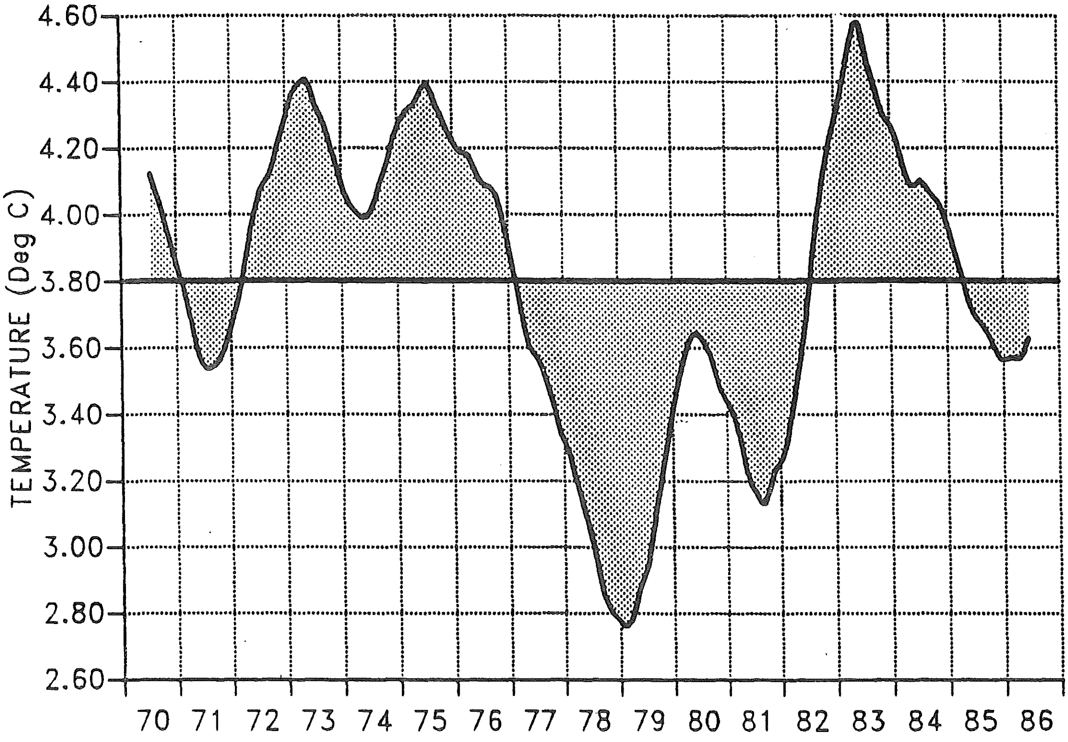

Fig. 6. The moving one year average of monthly temperature values from the Kola section, 1970-86.

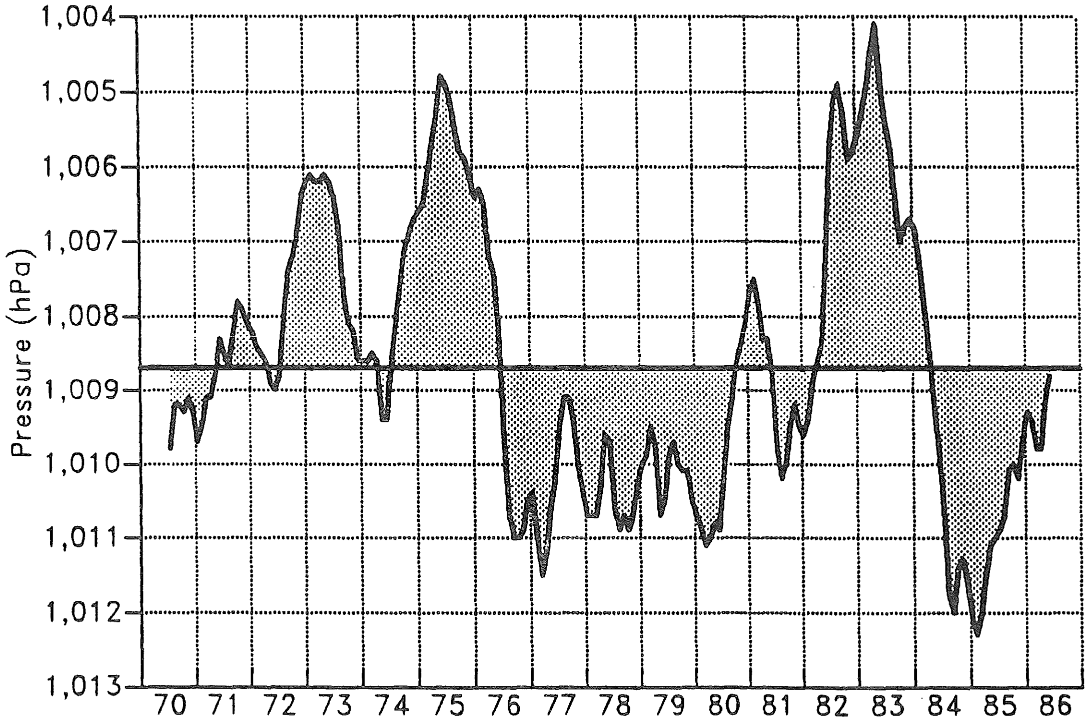

Fig. 7. The moving one year average of monthly values of air pressure at (22°47′E, 75°02′N), 1970-86.

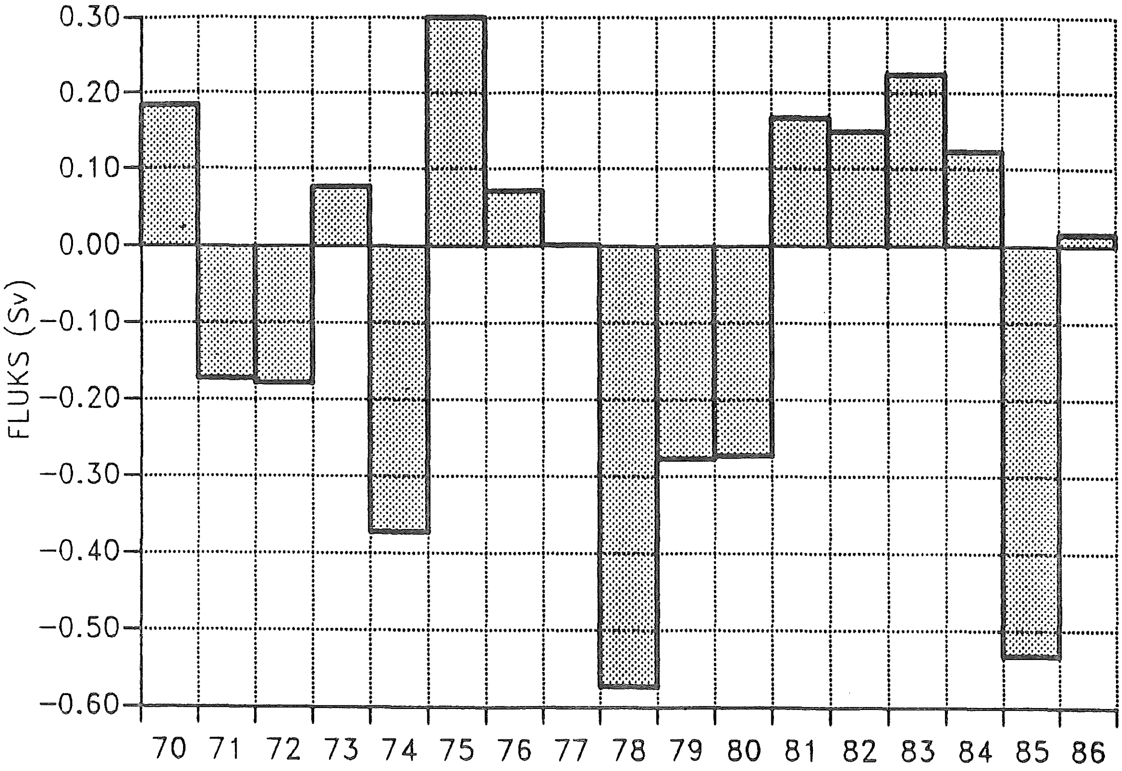

Fig. 8. Computed atmospherically driven volume flux through the Fugløya–Bjørnøya section averaged over the months June–July, 1970–86.