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Variations in the Norwegian coastal current off Arendal during 1975 and 1976

by

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ABSTRACT

Comparison between mean monthly freshwater discharges to Skagerrak, surface salinity and computed geostrophical volume transport through two sections off Arendal indicates a connection between variations in freshwater discharges and volume transports in the Norwegian coastal current in this area.

INTRODUCTION

Based on observations obtained by the International Skagerrak Expedition in summer 1966, Tomczak (1) presented in 1968 calculations of the exchange of different watermasses in Skagerrak (see map, fig. 1). Tomczaks results are based on calculations of the geostrophic current and are shown in Table 1.

These results indicate that there exist great variations in the volume transports of different watermasses.

Both wind and freshwater discharge from the Baltic and Norwegian coast have been cosidered as driving forces of the Norwegian Coastal Current (NCC). Without entering a discussion about which of these mechanisms is the most important, this paper intend to show that there is a connection between variations in the freshwater discharge to Skagerrak and variations of the volume transport of NCC in Skagerrak off Arendal.

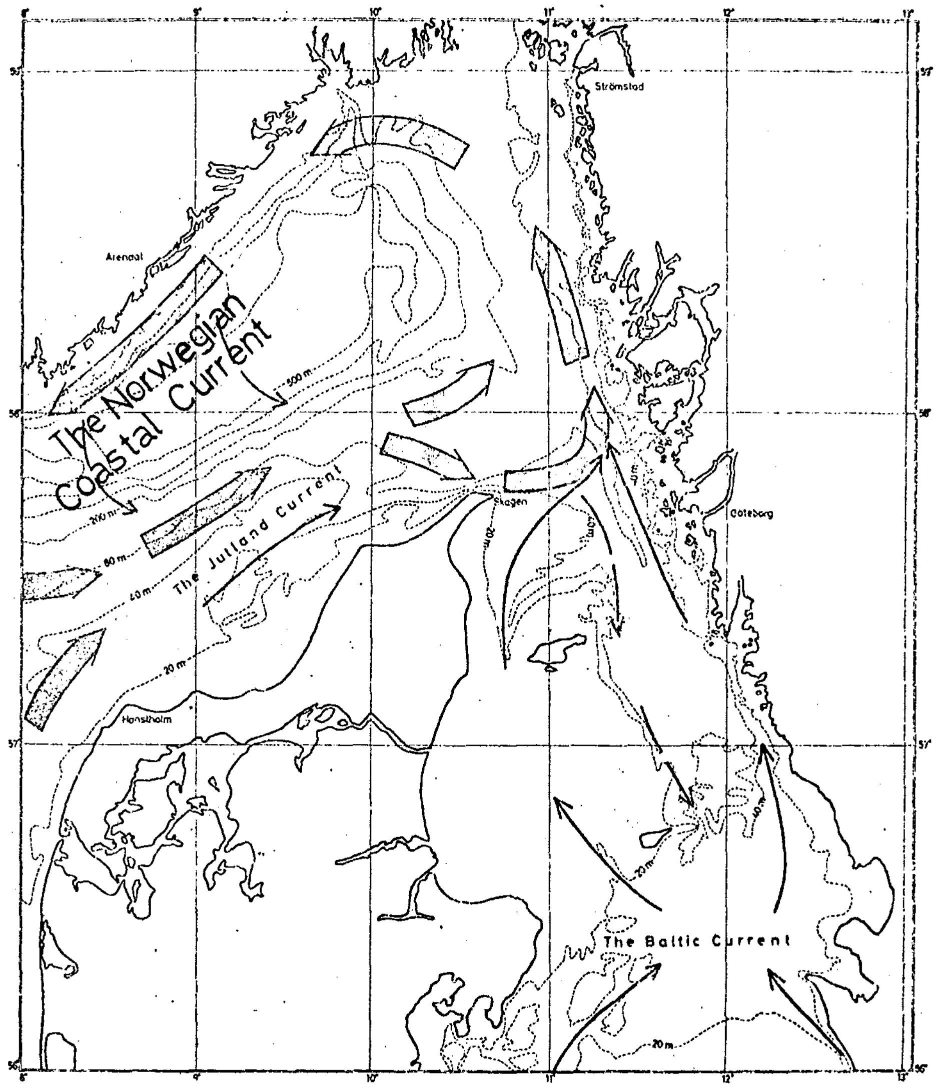

Fig. 1. Map over Skagerrak, showing the Baltic current, the Jutland current ant the Norwegian coastal current. (After Svansson 1975).

Table I

Volume transport through the Kristiansand-Hanstholm section in m^3s^{-1}
(After Tomczak 1968)

Time	Norwegian Coastal Current	Jutland Current	Norwegian Trench	Total	Mean transport
22.-23.6 1966	-410	+54	+10	-346	
29.-30.6 1966	-500	+42	+65	-393	348
7.- 8.7 1966	-480	+19	+30	-431	
12.-14.7 1966	-355	+82	+40	-223	

(Positive values mean transport into Skagerrak
Negative " " " out of ")

Observations and discussion.

The monthly mean freshwater discharges to Skagerrak are shown in table II, which shows significant variations in the freshwater discharges. Maximum mean monthly runoff takes place in November, while minimum runoff takes place in September. There are also secondary maxima in February, May and August.

The variations in the freshwater discharges are causing variations in hydrographic conditions. Fig. 2 shows the monthly mean freshwater discharges and observed salinity at 2 m depth at a station 8 nautical miles off the Norwegian coast near Arendal. The correlation between the monthly mean freshwater discharge and the observed surface salinity is rather poor. For 1975 the correlation coefficient is found to be -0.54 and for 1976 -0.37. But a closer examination of figure 2 shows a rather good correlation between the variations in the runoff and the variations in the surface salinity. Increase in the runoff is usually followed by decreasing surface salinity and vice versa. Since shortterm variations are not

Table II

Mean freshwater discharge to Skagerrak

Month	Net from the Baltic 1) m^3s^{-1}	From the river Klara 2) m^3s^{-1}	From south-eastern Norway 3) m^3s^{-1}	Total m^3s^{-1}
Jan.	10903	604	560	12067
Feb.	22902	645	413	23960
Mar.	14861	641	485	15987
Apr.	20949	547	1466	21981
May	22031	447	3659	23944
Jun.	4861	332	3279	8472
Jul.	3700	302	2203	6207
Aug.	26437	392	1830	28659
Sep.	14930	471	1775	17176
Oct.	- 9223	506	1643	-7074
Nov.	32754	566	1350	34670
Dec.	15496	583	859	16938
Mean	15050	503	1627	17180

1)Wyrtki 1954

2)UNESCO 1969

3)Tollan 1976

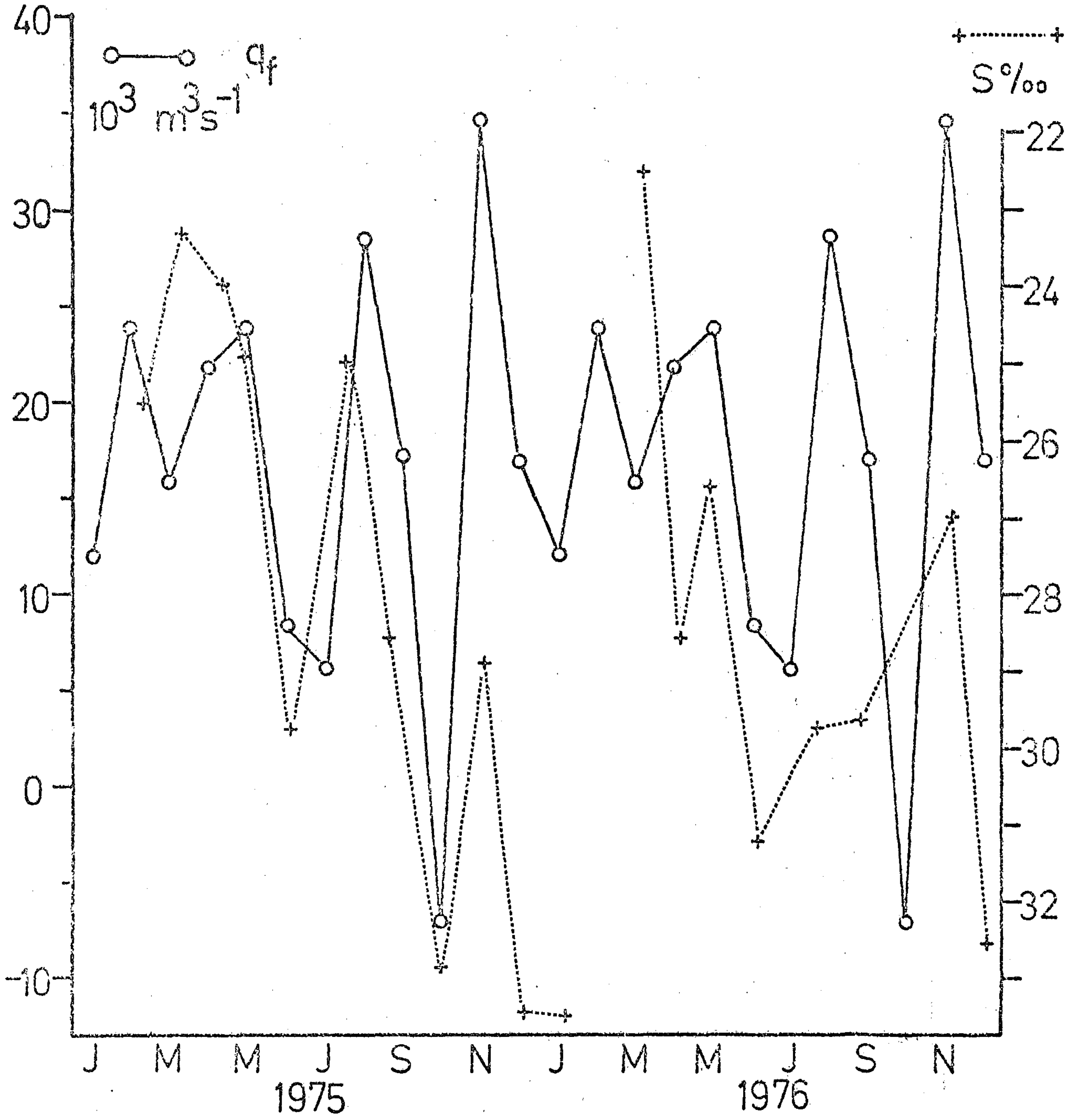

Fig. 2. Monthly mean freshwater discharges to Skagerrak (q_f) and surface salinity (S).

found in the deeper layers off the Norwegian coast in Skagerrak (see Ljøen and Svansson (2)), this indicates that shortterm variations in the hydrographic conditions due to variations in the runoff are restricted to the surface layers. If such variations affect the density gradients, then the geostrophic volume transport through sections in the area is also affected. In order to investigate such effects, hydrographic measurements have been carried out in two sections near Arendal since 1975. (Danielssen and Iversen (3)). The distance between the sections is 17 nautical miles, and the outermost station at each section is taken 15 n.m. off the coast. From the data collected in 1975 and 1976, geostrophic volume transport through the sections have been computed. The main problem of all such computations is to find the depth of no horizontal motion (zero layer). Svansson (4) warns strongly against assuming no motion near the bottom, because this may lead to results which do not agree with observations of other hydrographic properties.

Tomczak (1) assumed that the depth of no motion was to be found in the layer(s) where the vertical density gradient had a minimum, and also the horizontal density gradients between neighbouring stations reached a minimum. This method was tried on the present data, but the results were very often meaningless. Instead a method first proposed by Tully (5) has been used. This method, which usually gives a depth of no motion just above or in the upper part of a deep layer with relative uniform salinity, has been found to give good agreement between direct current measurements and geostrophic calculations in the outer part of the Oslofjord (Dahl (6)). The method has also the advantage that it is easily programmable for computers. The results of the geostrophic calculations, using the method proposed by Tully, are given in Fig. 3, which shows the mean value of the geostrophic volume transport through the two sections above the level of no motion, and observed salinity at 2 m 8 n.m. off the coast.

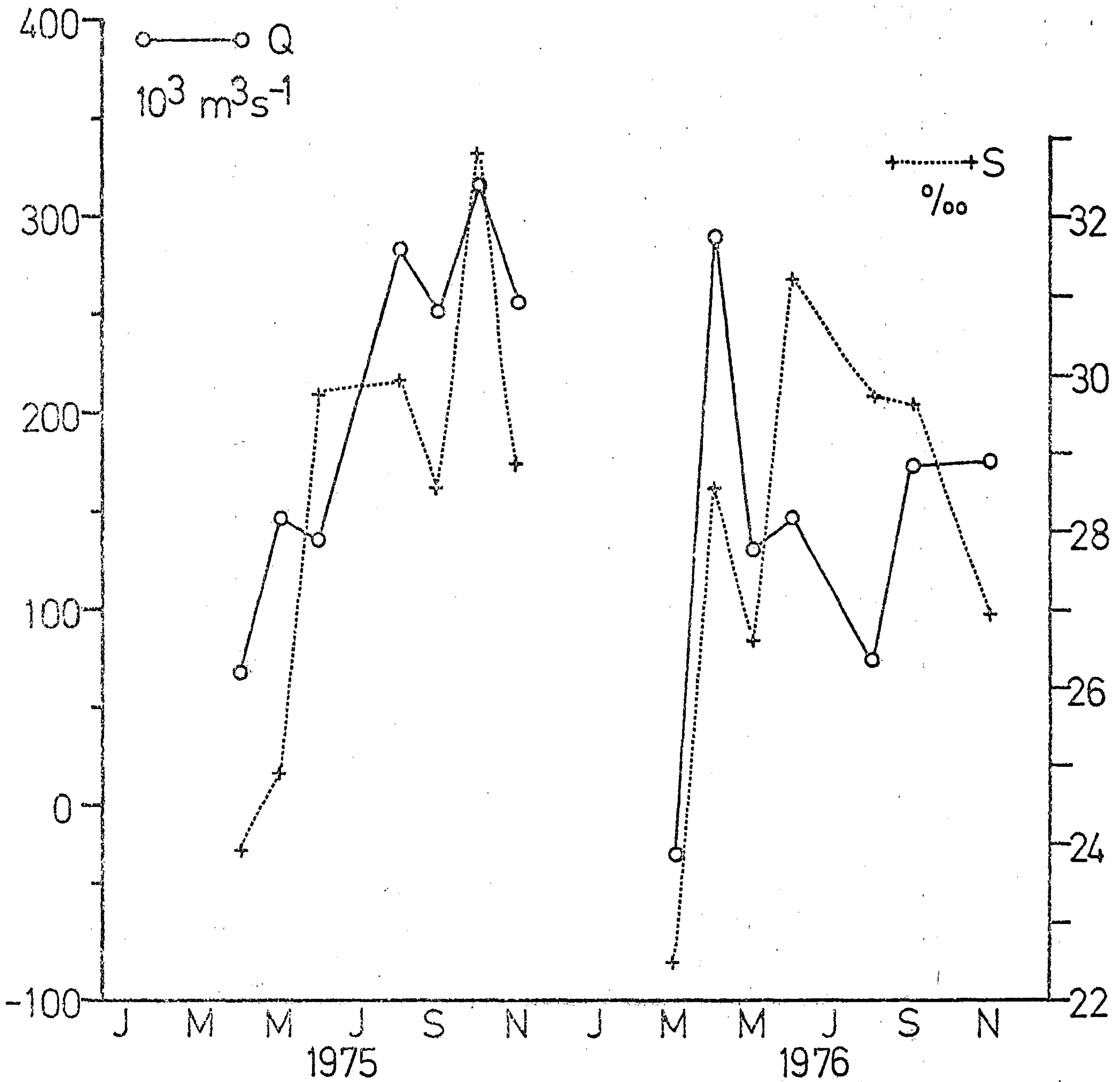

Fig. 3. Mean geostrophic volume transport (Q) and surface salinity (S)

The correlation coefficient between the geostrophic volume transport and the surface salinity for the observations during 1975 and 1976 is found to be 0.51. Figure 3 shows that increasing surface salinity usually is followed by increasing volume transport and vice versa. Bearing fig. 2 in mind this indicates that increased freshwater discharge to Skagerrak usually is followed by decreased volume transport in the NCC and vice versa.

The immediate consequence of changes in the runoff to fjords and coastal areas is a change in the density gradients Thorpe (7) has shown by experiments that if the Richardson number

$$R_i = \frac{g}{\rho} \frac{\frac{\partial \rho}{\partial z}}{(\frac{\partial u}{\partial z})^2}$$

where ρ is the density, u is the horizontal velocity and g is the acceleration due to gravity, becomes larger than 0.2, then turbulence due to horizontal shear flow will not develop. If the vertical density gradients become too large, then the impact of increased runoff will be restricted to a shallower layer than would be the case if the R_i-number was lower than 0.2, because the density gradients act against development of vertical turbulence.

It is beyond the scope of this paper to discuss problems associated with vertical transfer of mass and momentum due to turbulence and the geostrophical response to such transfer, but the effect of such phenomenas are important to understand the variations in the volume transport in a coastal current.

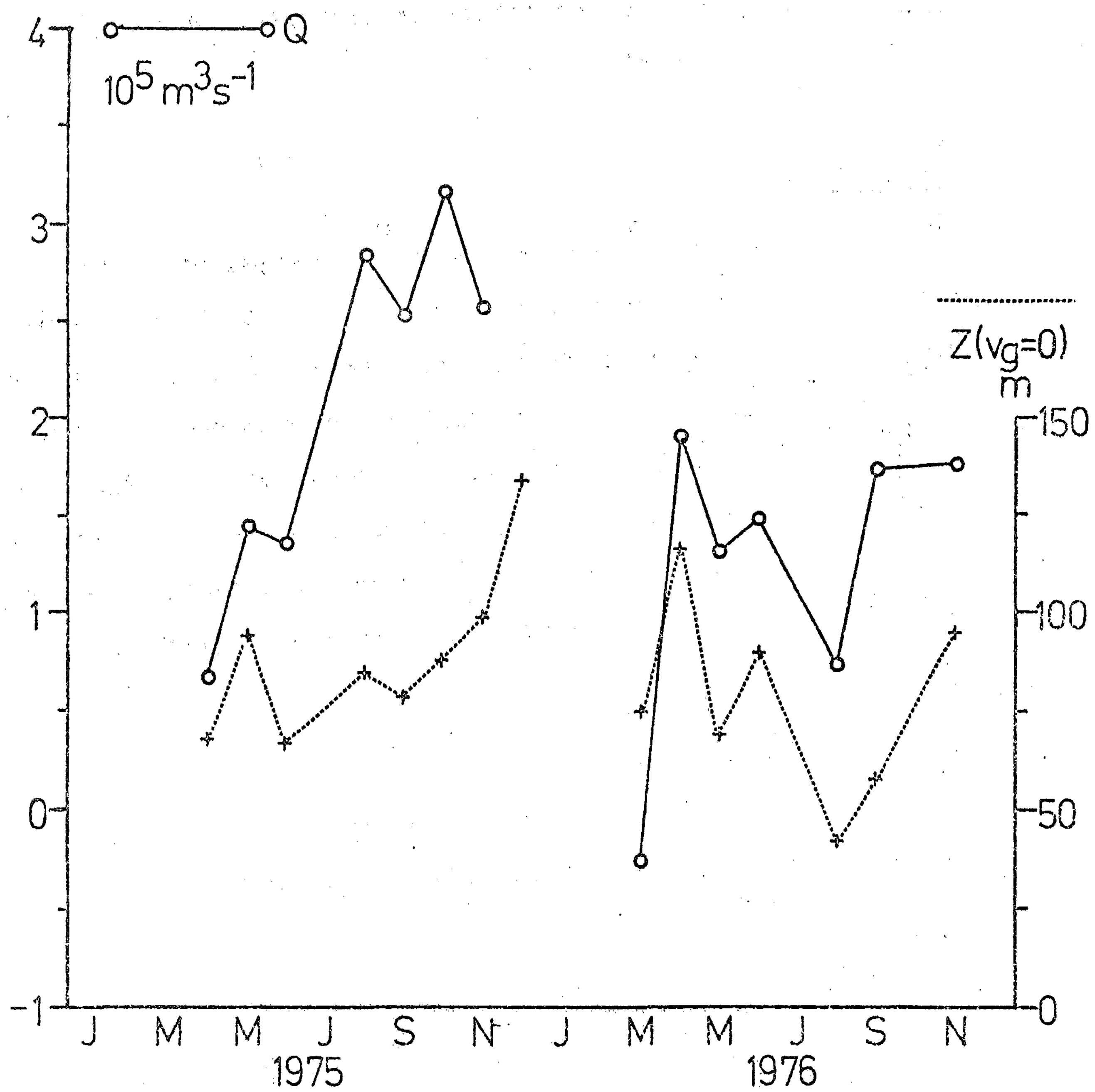

Fig. 4. Mean geostrophic volume transport (Q) and depth of layer of no motion ($Z(v_g) = 0$).

Fig. 4 shows the geostrophic transport (already shown in fig. 3) and the depth of the layer of no motion. This figure shows that increased volume transport usually is associated with increased depth of the layer of no motion, and vice versa. Comparison of figure 4 with figures 2 and 3 indicates that the depth of the layer of no motion is connected to the magnitude of the freshwater discharge.

CONCLUSION

The variations in the volume transport in the Norwegian Coastal Current off Arendal seem to be dependent upon the freshwater discharges to Skagerrak in such a way that increased freshwater discharge will reduce the vertical turbulence so that the coastal current will be restricted to shallower depths. Decreased freshwater discharges weaken the vertical density gradients, so that the vertical turbulence increase, and the coastal current may extend to greater depths.

ACKNOWLEDGEMENT

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