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Outflow of Skagerrak water to the North Sea during the summer 1984

by

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ABSTRACT

This paper describes a situation from summer 1984 where low salinity water from the Skagerrak was flowing west and north and covered a significant part of the northern North Sea Plateau. This unusually Skagerrak water distribution is most likely caused by the prevailing winds.

INTRODUCTION

The outflow of low salinity water from the Skagerrak has an intermittent character. It alternates between a blocking and outbreak regime controlled by the prevailing winds. The first description of a Skagerrak water outbreak was presented by EGGVIN (1940). During February-March 1937 he was able to trace the movement of a cold water front along the Norwegian coast to about 62°N. Later, several authors presented observations off the Norwegian coast which they attributed to the same phenomenon (e.g. DEVOLD, 1972 and VINGER, 1978). AURE and SÆTRE (1981) revealed the generating mechanism of the Skagerrak water outbreaks, as well as features of their propagation and influence on the fjords of western Norway.

Usually, the low salinity water from the Skagerrak outbreaks propagates west and north along the Norwegian coast, and is subjected to short team lateral fluctuation due to variations in the wind field. More explicite, this feature appears in the summer when the vertical stratification is well developed and the outflowing water probably easy responds to the changes in wind.

The limitation of the coastal current is striking during the winter when the Atlantic inflow along the western slope of the Norwegian Trench reaches the surface and seems to act as a barrier for further displacement of coastal water to the west. During the summer this restriction is greatly reduced. However, the lateral movement is generally limited to the coastal current as described by LJØEN (1971) and also indicated by IVERSEN and LJØEN (1985).

Occasionally, however, it appears that water from the Skagerrak may leave the Norwegian coast and flow into the more offshore areas of the North Sea. LEE and RAMSTER (1973) observed a Skagerrak water outbreak to the central North Sea in approximate position N 57^{o}, E 5^{o} during August 1965. The present report will describe an apparently similar event during the summer of 1984.

DISTRIBUTION OF THE SKAGERRAK WATER IN JULY 1984

During the period 15 June - 1 August 1984 the Institute of Marin Research in Bergen covered most of the central and northern North Sea by a grid of CTD stations. The observations revealed that during this period outflow to the North Sea of low salinity Skagerrak water occurred. Figs 1-3 show the surface salinity distribution and the depths of the 33 isohaline for three different parts of the observation period.

As shown, low salinity water of Skagerrak origin is covering a significant part of the northern North Sea. Off the southern tip of Norway, the major part of the outflowing Skagerrak water has been flowing west and north over the northern North Sea Plateau. A minor part of the Skagerrak water seems to flow along the southwestern Norwegian coast. The maximum thickness of the low salinity layer, measured as the depth to the 33 isohaline, is about 20 m.

As the observation areas differ from one observation period to another, it is difficult to trace any time development of the phenomenon. For the overlapping areas, however, the distribution pattern of the Skagerrak water is approximately the same. An estimate of the volume of the low salinity water from the distribution in Fig. 2 reach $1 \cdot 10^{12}$ m^3 if an average thickness of 15 m is applied. This equal a mean Skagerrak outflow of $0.4 \cdot 10^6$ $m^3 \cdot s^{-1}$ during one month if mixing is not considered.

The major Skagerrak outbreak resulting in the distribution pattern of Figs. 1-3 have occurred previous to the first coverage (Fig. 1). In the following, reconstruction of the history of the event will be attempted.

DISCUSSION

AURE and SÆTRE (1981) have demonstrated that westerly winds over Skagerrak will retard or block the outflow and develop upwelling along the southern Norwegian coast. When the westerly wind stress is reduced, sudden outbreaks of Skagerrak water will happen. Easterly winds will intensify and affect the duration of the outbreaks.

The wind distribution off the southern Norwegian coast shows mainly northeasterly winds in May until around 10 June (Figs. 4-7). Later, the dominant winds were northwesterly, except for a shorter period around 10 July.

The surface temperature at Lindesnes (Fig. 8A) show an increase from about 5.5^{o}C around 10 May to 16.5^{o}C around 10 June. The same tendency may be seen from the temperature and salinity variations in the surface layer at Holmane (Fig. 8B). From 10 May to beginning of June the salinity decrease from about 34^{o}/oo to 21.5^{o}/oo. The fixed hydrographic station at Lista (Fig. 9) also demonstrates that a major Skagerrak outbreak started around 10 May, transporting water of high temperature and low salinity out of the Skagerrak along the west coast of Norway. From about 10 June a upwelling situation occurred along the coast (Figs 8-9). Except for a few days around 10 July, the low salinity Skagerrak outflow water was not observed along the southwestern Norwegian coast during the period 10 June to the end of July.

The distribution of low salinity water in the central and northern North Sea in July 1984 may be caused by either a westward displacement of the Norwegian Coastal Current or by a direct input of Skagerrak water flowing westward off the southern tip of Norway. Due to the persistant northerly winds during summer a westward displacement of the Norwegian Coastal Current is frequently observed (e.g. IVERSEN and LJØEN, 1985). This is useally associated with an upwelling along the coast of western Norway. The seasonal lateral oscillation of the Norwegian Coastal Current, however, do hardly cross the Norwegian Trench into the northern North Sea plateau. Figs. 1-3 clearly indicate that the low salinity water in this area is caused by a direct input from the Skagerrak. The front of the Skagerrak water have moved north to about 60^{o}30'N. The Skagerrak water thus have travelled about 500 km during 30 days which equals a frontal speed of about 20 cm/s. This is in accordance with the frontal speeds in the Norwegian Coastal Current (EGGVIN, 1940, AURE and SÆTRE, 1981) during major Skagerrak water outbreaks.

During the period 10 May to 10 June, when the outflowing Skagerrak water was close to the coast of Norway, the winds were mainly northeasterly (Figs. 4-7). From 10 June northwesterly winds dominated which probably have forced the outflowing water westwards. The water then have propagated north over the shallow North Sea Plateau to about N60°30'. The mechanism resulting in a distribution seen in Figs. 1-3 is probably rather complicated. Further studies using all available data from the period including satellite image will be attempted in order to reveal the generating forces.

A similar phenomenon as that of the summer of 1984 has not previously been observed. This does not necessarily mean that the event are extremely rare. In the mean summer situation presented by LJØEN (1980) a tongue of Skagerrak water penetrating westward may clearly be seen.

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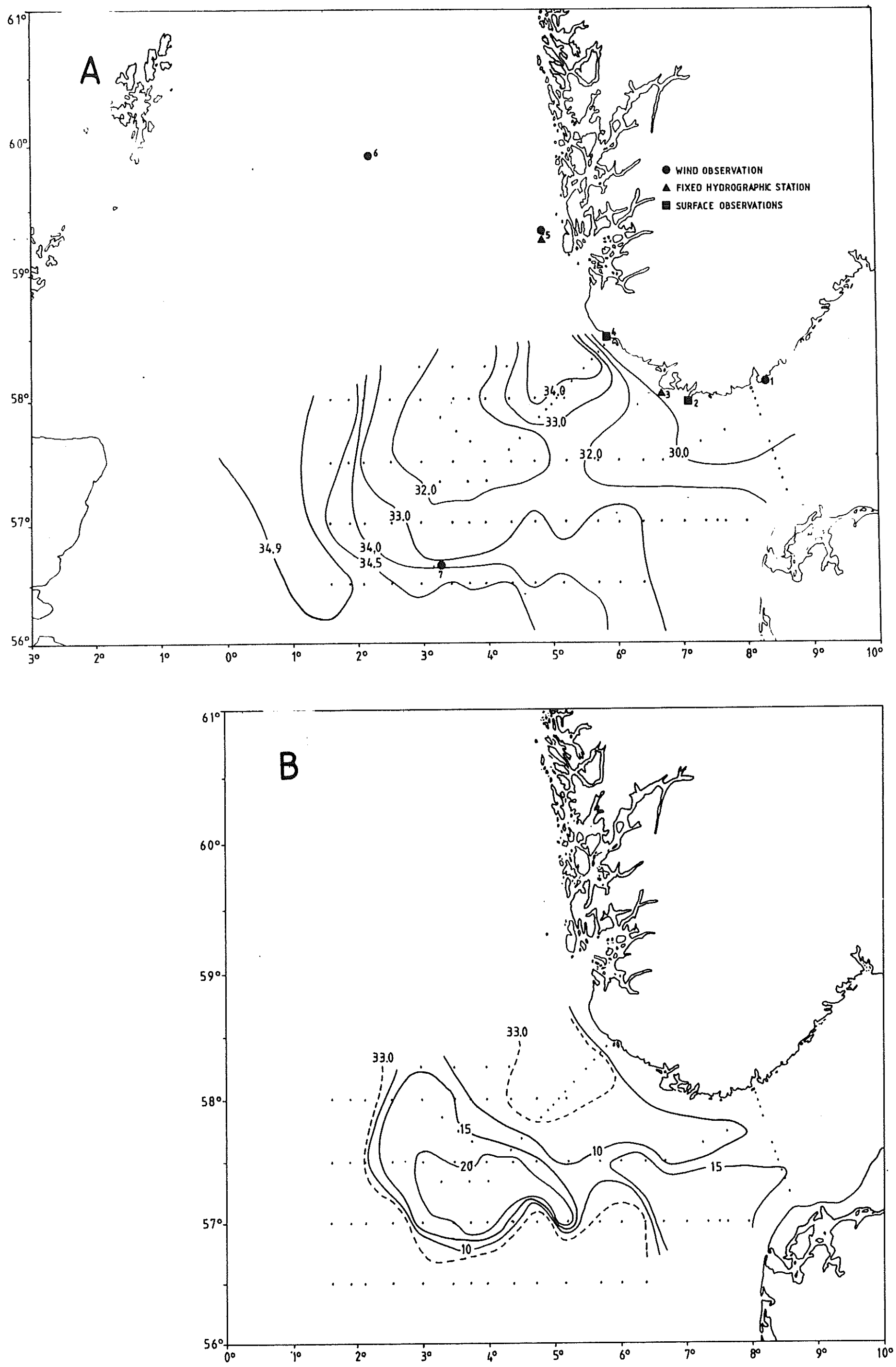

Fig. 1. Sea surface salinity, A and depth of 33 isohaline, B from the first observation period. (June 27 - July 11). Dots: grid of CTD stations, broken lines: intersection between sea surface and the 33 isohaline. Wind observations: 1. Oksøy, 5. Utsira, 6. Frigg oilfield, 7. Ekofisk oilfield. Fixed hydrographic stations: 3. Lista, 5. Utsira. Surface observations: 2. Lindesnes, 4. Holmane.

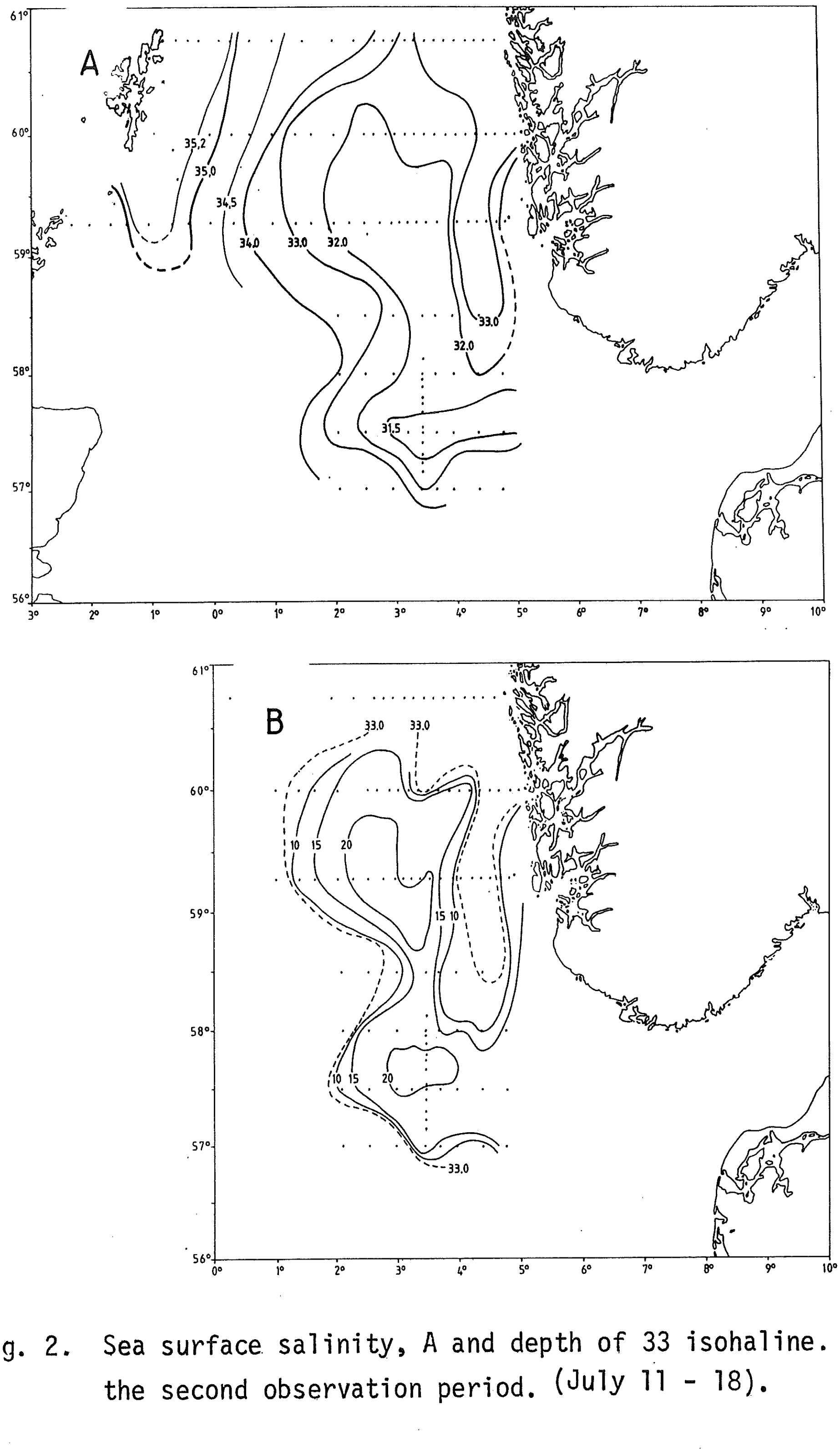

Fig. 2. Sea surface salinity, A and depth of 33 isohaline. B from the second observation period. (July 11 - 18).

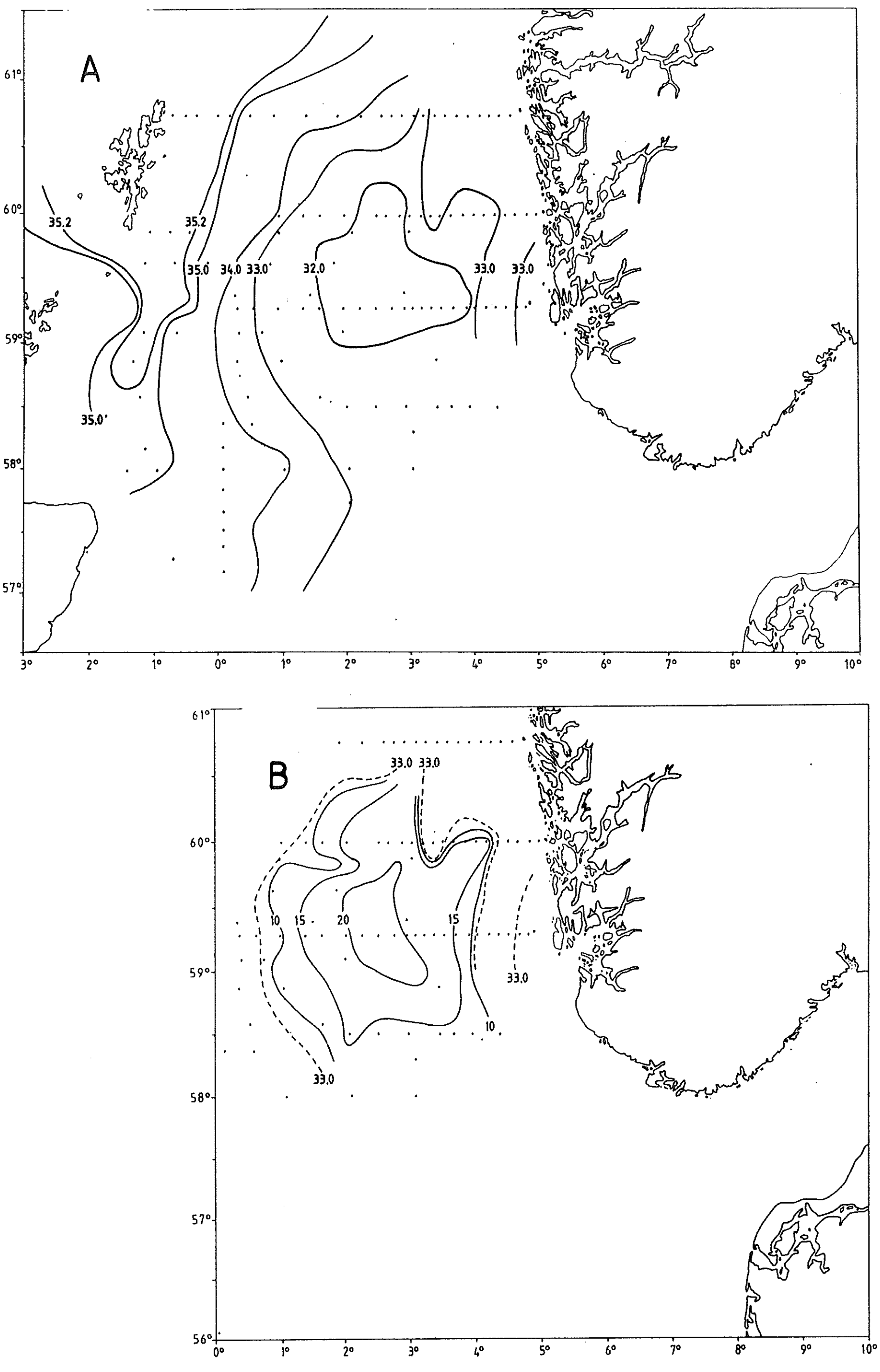

Fig. 3. Sea surface salinity, A and depth of 33 isohaline, B from the third observation period. (July 21 - 31).

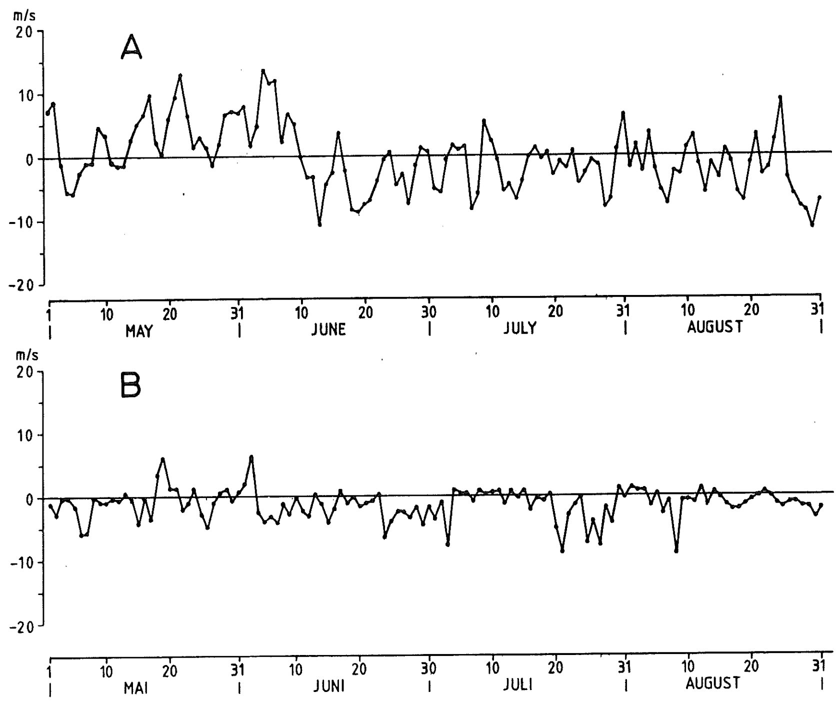

Fig. 4. Wind observations at Oksøy (1):
A. Long shore component (NE-SW) B. Normal to the coast (NW-SE).

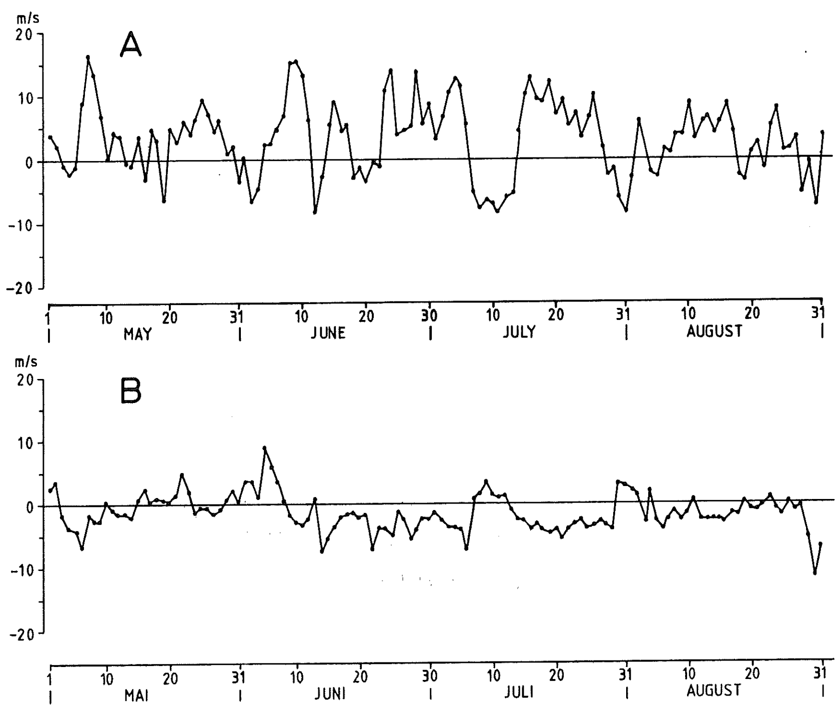

Fig. 5. Wind observations at Utsira (5):
A. Long shore component (N-S) B. Normal to the coast (E-W).

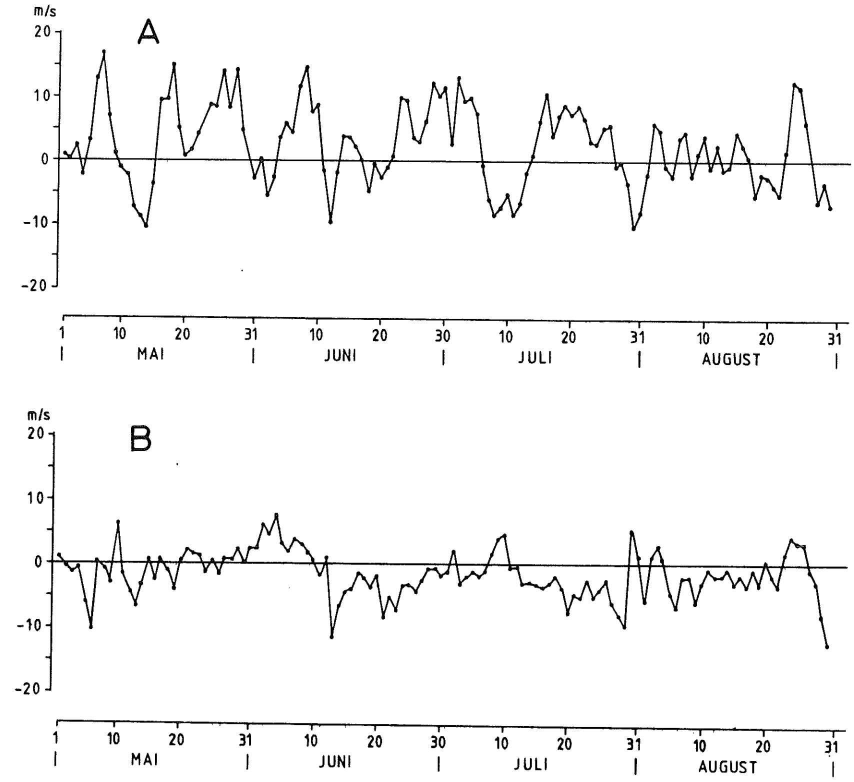

Fig. 6. Wind observations at Frigg (6):
A. N-S component B. E-W component.

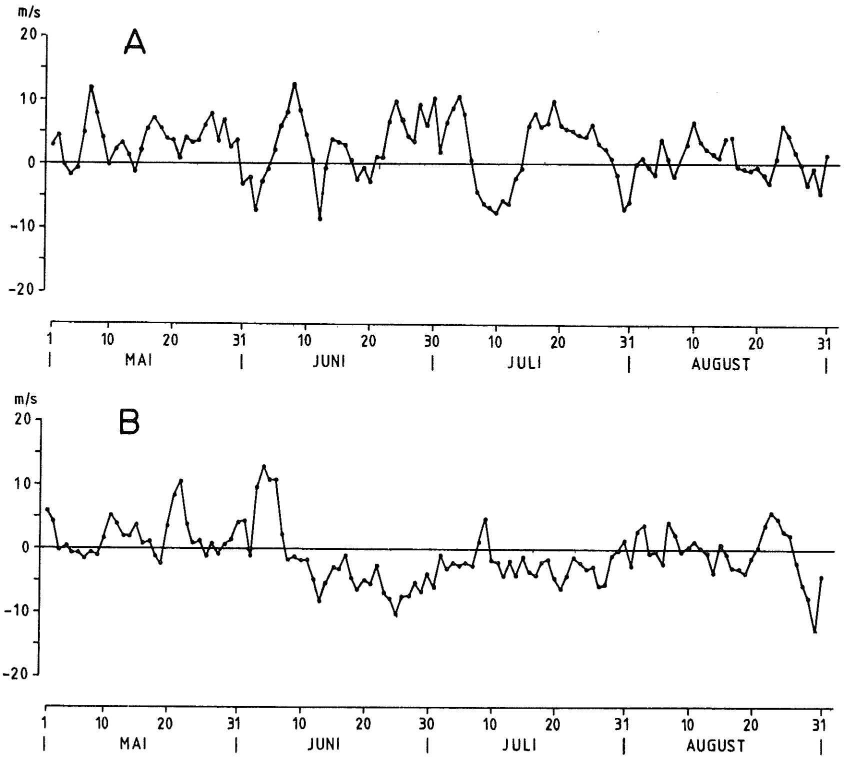

Fig. 7. Wind observations at Ekofisk (7):
A. N-S component B. E-W component.

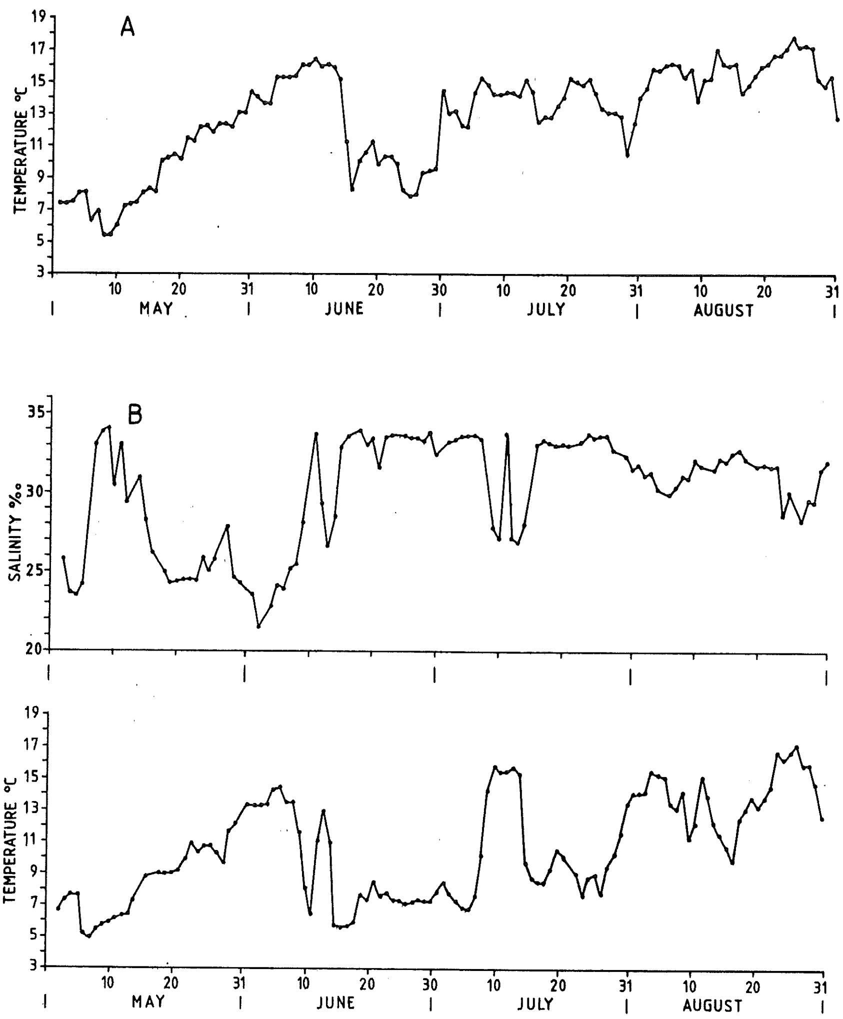

Fig. 8. Surface observations:

A. Temperature at Lindesnes (2)

B. Salinity and temperature at Holmane (4).

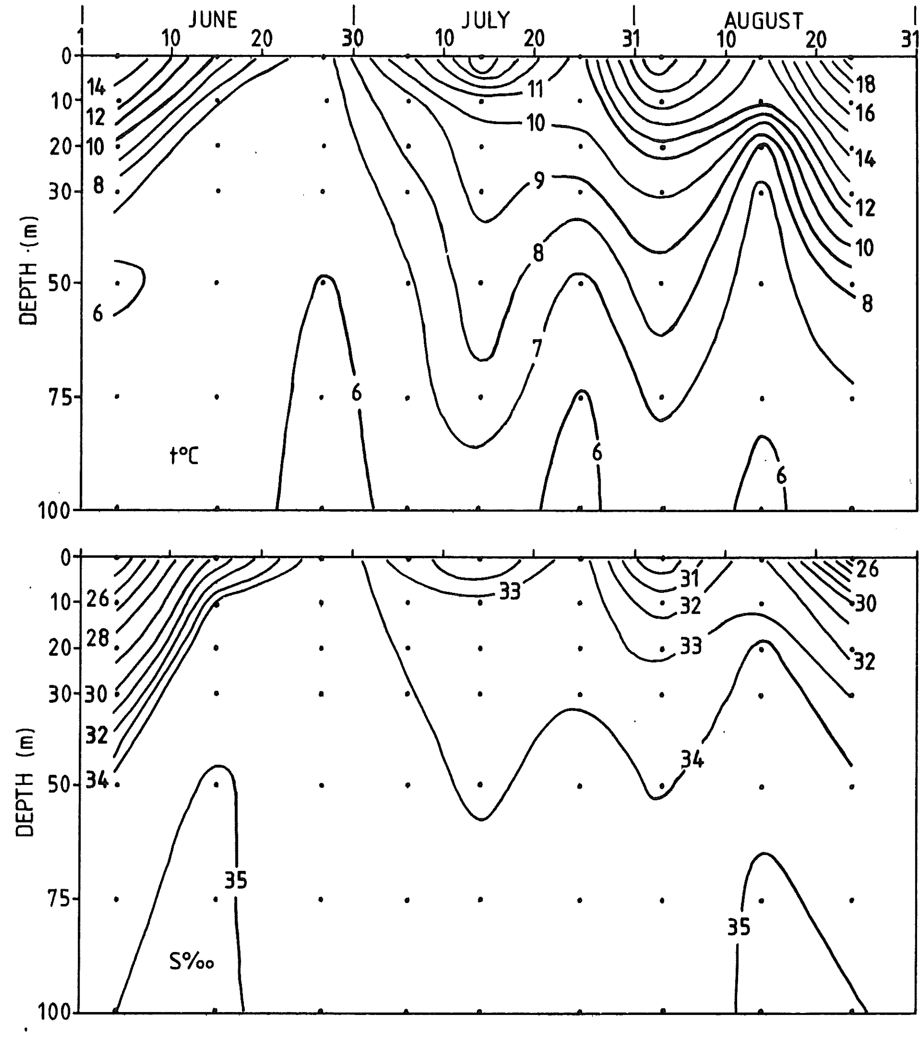

Fig. 9. Isoplet diagram of temperature and salinity at Lista (3).