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THE ATLANTIC INFLOW TO THE NORTH SEA AND THE SKAGERRAK INDICATED BY SURFACE OBSERVATIONS

by

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ABSTRACT

By means of surface observations of temperature and salinity along shipping routes across the North Sea it is shown that the Atlantic inflow along the western and southern edge of the Norwegian Channel seems to reach the surface during winter. This gives rise to a frontal zone of increased temperature along the route of the inflow. During summer a drop in surface temperature is detectable in the same zone, but the mechanism is probably different.

INTRODUCTION

The idea of an Atlantic inflow into the North Sea and the Skagerrak along the western edge of the Norwegian Channel was first put forward by Petterson and Ekman in 1891 (SVANSSON, 1965). It is usually considered as a subsurface flow (DOOLEY, 1974), and was partly confirmed by current measurements in 1961 (LJØEN, 1962).

The inflow can be traced northwards and westwards along the 200 m contour round the edge of the continental shelf (DOOLEY and MARTIN, 1969). In the Skagerrak the Atlantic water mixes with less saline water and flows out below the Norwegian Coastal Current (TOMCZAK, 1968).

More recently, further confirmation of the inflow by current measurement have been given by SÆTRE (1972) and by SÆTRE et al.(1975). Fig. 1 shows the approximate route of the inflow.

This Atlantic inflow is one of the most important contributors to the water balance of the North Sea. A discussion of the generating forces and possible seasonal variations has been given by SVANSSON (1965).

MATERIALS

In the early fifties the Institute of Marine Research in Bergen started a sampling program along some of the shipping routes across the North Sea. At fixed positions along the routes the temperature is measured at the intake of the cooling water to the engine. At the same time a water sample is taken for later analysis of salinity. The observation depth is approximately 4 m.

A sea thermograph is also installed at the cooling water intake thus giving a continous record of sea temperature at 4 m depth. A more comprehensive description of this instrument is given by EGGVIN (1940). Though these instruments today may look rather old-fashioned, they have proved to be reliable. By proper calibration it is possible to obtain an absolute accuracy of $\pm$ 0.1°C.

The table below gives a summary of the data available from this program.

SHIPPING ROUTE	STARTING YEAR	MONTHLY AVERAGE NUMBER OF SETS OF OBSERVATIONS	
		TEMPERATURE	SALINITY
Bergen-Newcastle	1952	12	6
Stavanger-Newcastle	1950	8	4
Kristiansand-Newcastle	1966	8	4
Stavanger-Rotterdam	1955	7	4

Monthly values for all the fixed positions for a mean year have been published by SÆTRE (1978).

Data from the mean year 1967-1976 have been used in this report. Some thermograph records from March 1969 are presented. In addition surface data from the fixed hydrographic section TORUNGEN - HIRTSHALS have been considered. This section is repeated at approximately monthly intervals, and a mean year for the period 1967-1976 has been calculated. Some hydrographic data from 1977 have also been consulted. Fig. 1 shows the location of the lines of observation.

RESULTS

Fig. 2 shows the average temperature in March and August along the lines of observation. During the winter there seems to be a zone of maximum temperature along the route of the Atlantic inflow. On the BERGEN - NEWCASTLE and STAVANGER - NEWCASTLE routes at 3°E and 4°E respectively, the maximum is less conspicuous than on the other routes. In the TORUNGEN - HIRTSHALS section there seems to be two maximum areas: one over the southern edge of the Norwegian Channel and another close to the Norwegian coast.

During August a slight drop in temperature is detectable on the BERGEN - NEWCASTLE route at about 3°E. Unfortunately the observations from STAVANGER - NEWCASTLE route are too scarce to be of any use. On the STAVANGER - ROTTERDAM and KRISTIANSAND - NEWCASTLE routes the drop in temperature is quite marked. In the TORUNGEN - HIRTSHALS section no such reduction of the surface temperature is observable. The decrease in temperature close to the coast during summer on the STAVANGER - ROTTERDAM route is due to local upwelling.

Fig. 3 shows the surface temperature and salinity during March 1977. A tongue of relatively warm and saline water is seen to penetrate into the Skagerrak.

Fig. 4 shows the temperature distribution in the UTSIRA section during March and July 1977. The core of Atlantic water over the western edge of the Norwegian Channel is noticeable in both sections. The upper figure clearly demonstrates the relationship between increased surface temperature over the western edge of the Norwegian Channel during winter and the Atlantic inflow to the Skagerrak. During this season the inflow seems to reach the surface. In summer the Atlantic core is covered by warmer water,mainly of coastal origin.

Figs. 5-8 show continuous records of surface layer temperature along the four shipping routes across the North Sea during March 1969. The number on each thermograph record indicates the date. In the area of the Atlantic inflow a pronounced increase in temperature is apparent in all the observations. The increase can occur very suddenly and amount to 4°C. As can be seen, the width, the shape and the location of the maximum temperature zone are subject to short-time variations. Apparent splitting up in branches or formation of eddies along the inflow also seems to occur.

DISCUSSION AND SUMMARY

The winter situation

During this season the Norwegian Coastal Water is confined to a deep and narrow wedge along the Norwegian coast. The Atlantic inflow along the western and southern edge of the Norwegian Channel seems to reach the surface and give rise to a zone of increased surface temperature along the route of the inflow as demonstrated by Figs. 3 and 4. In the Skagerrak, however, the flow deepens (TOMCZAK, 1968). As seen in Figs. 5-8, the structure of this zone is subject to short-time variations which most likely are due to meteorological alterations. The maximum lateral displacement of the zone seems to be 40-50 km. The bathymetrical constraint on the flow appears to be less on the BERGEN - NEWCASTLE and STAVANGER - NEWCASTLE routes than further south and east. As a result of this larger lateral oscillation, the maximum zone indicated by the mean values in Fig. 2 is less marked along these routes.

The surface salinity distribution in Fig. 3 indicates that a rise in salinity should also be expected in the maximum temperature zone.

In the mean salinity values such an increase is not observed except in the TORUNGEN - HIRTSHALS section, as seen in Fig. 9. This probably means that the tongue-like salinity distribution in Fig. 3 is not a typical winter situation. During winter the Atlantic water is found over the western edge of the Norwegian Channel as well as in the central northern North Sea. The inflow in the Norwegian Channel involves a reduction of the residence time of the Atlantic water in this area and thus gives rise to a zone of maximum temperature, but not necessarily to increased salinity. In the Skagerrak, however, a rise of surface salinity in the area of the Atlantic inflow should be expected. The horizontal salinity gradient seems to have its highest values in the vicinity of the maximum temperature zone, as indicated by Fig. 9.

The summer situation

During this season the Norwegian Coastal Water moves seaward and the Atlantic inflow is covered by warmer and less saline water. The lower part of Fig. 4 demonstrates this. The inflow during this season attains more the character of a subsurface flow. As seen in Fig. 2 there is a drop in the mean temperature in the same zone where an increase in winter temperature is observed. The drop is most marked on the STAVANGER - ROTTERDAM route. Due to the strong stratification of the upper water masses in the area during summer, it is hard to believe this reduction in surface temperature to be a result of vertical mixing with the Atlantic water below. Two possible explanations suggest themselves:

The boundary between the inflowing Atlantic water and the northgoing current along the Norwegian coast seems to be very sharp and the horizontal shear stress considerable. Dynamic processes along the boundary surface may be responsible for the drop in surface temperature.

The coastline between Kristiansand and Stavanger is the area where wind-induced upwelling is observed most frequently along the Norwegian coast. Using data from the Joint Skagerrak Expedition 1966, LJØEN (1971) has showed that variation in the wind field commonly occurring in the summer can create zones of divergence approximately parallel to the coast. The location of some of these divergence zones seems to be more or less constant, and they result in reduced surface temperature.

These mechanisms are not necessarily independant.

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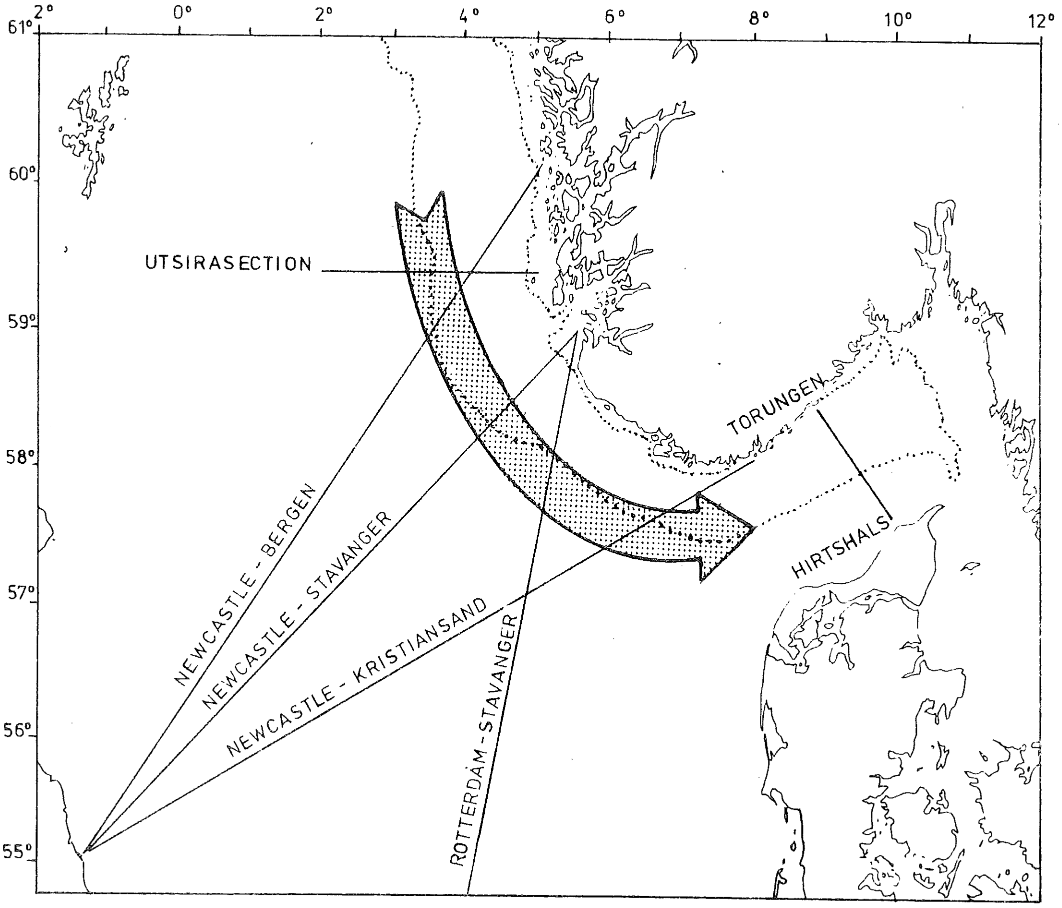

Fig. 1 Location of the lines of observation.

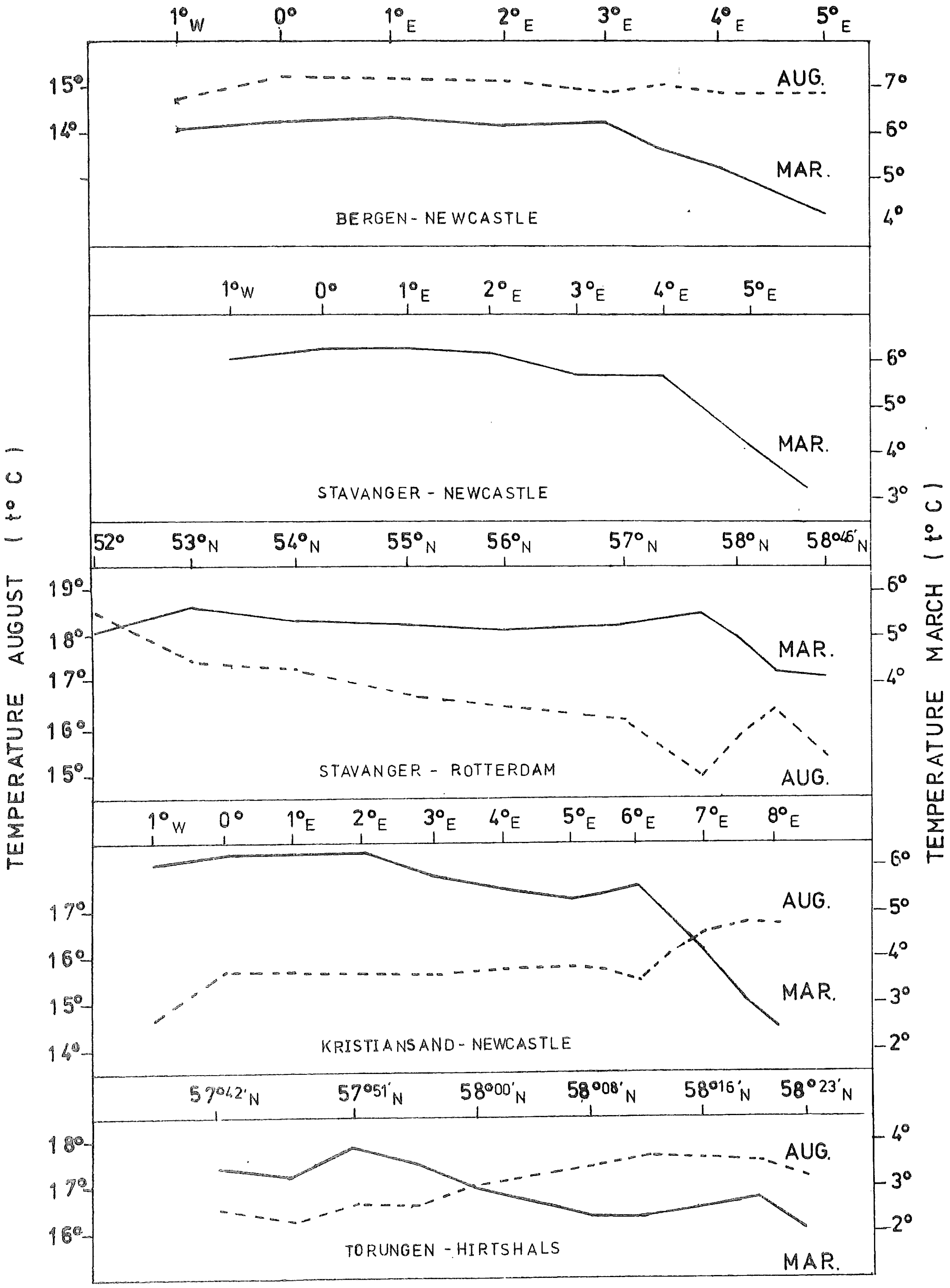

Fig. 2 Average temperature in March and August for the mean year 1967 - 1976.

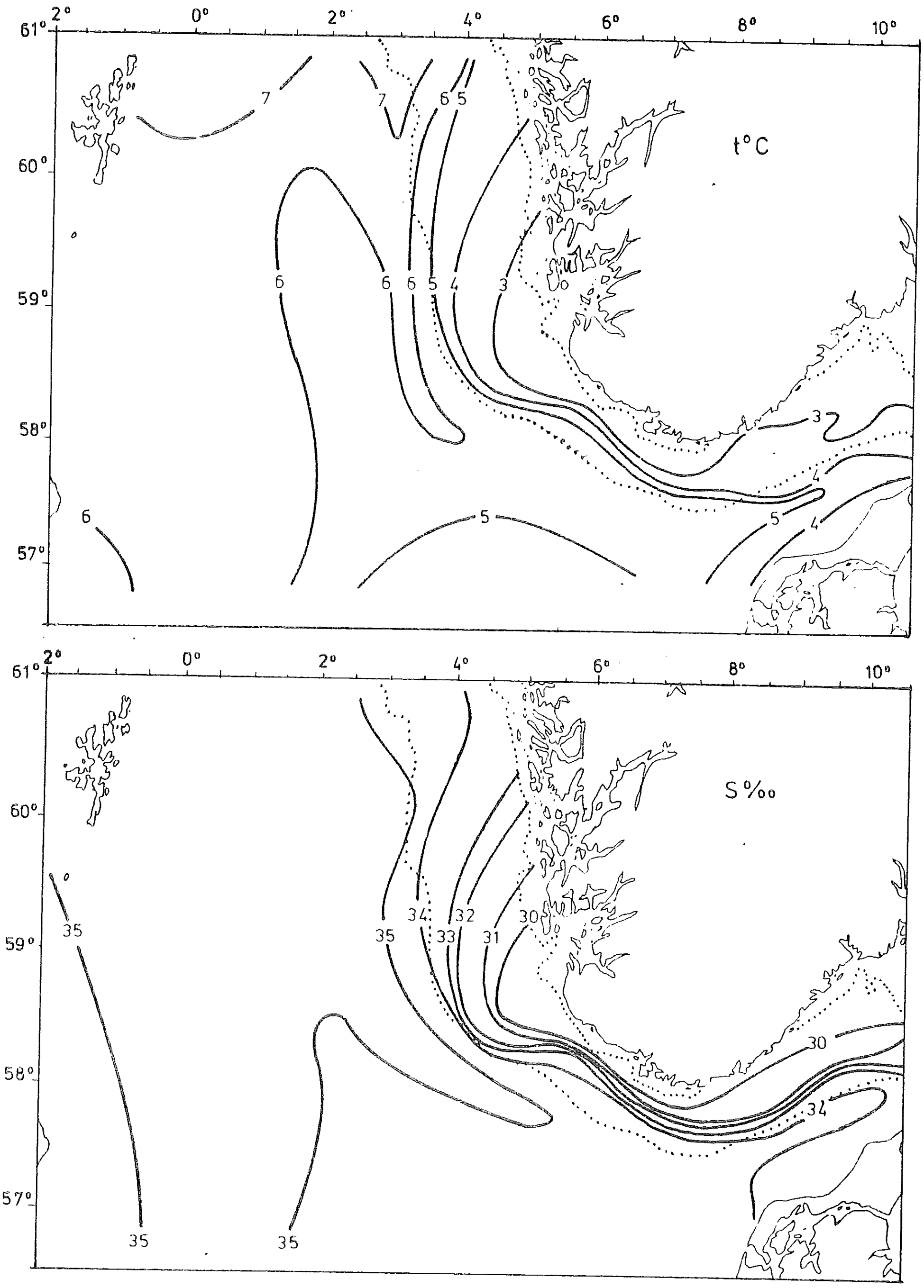

Fig. 3 Distribution of surface temperature and salinity - March 1977 (After ANON, 1977).

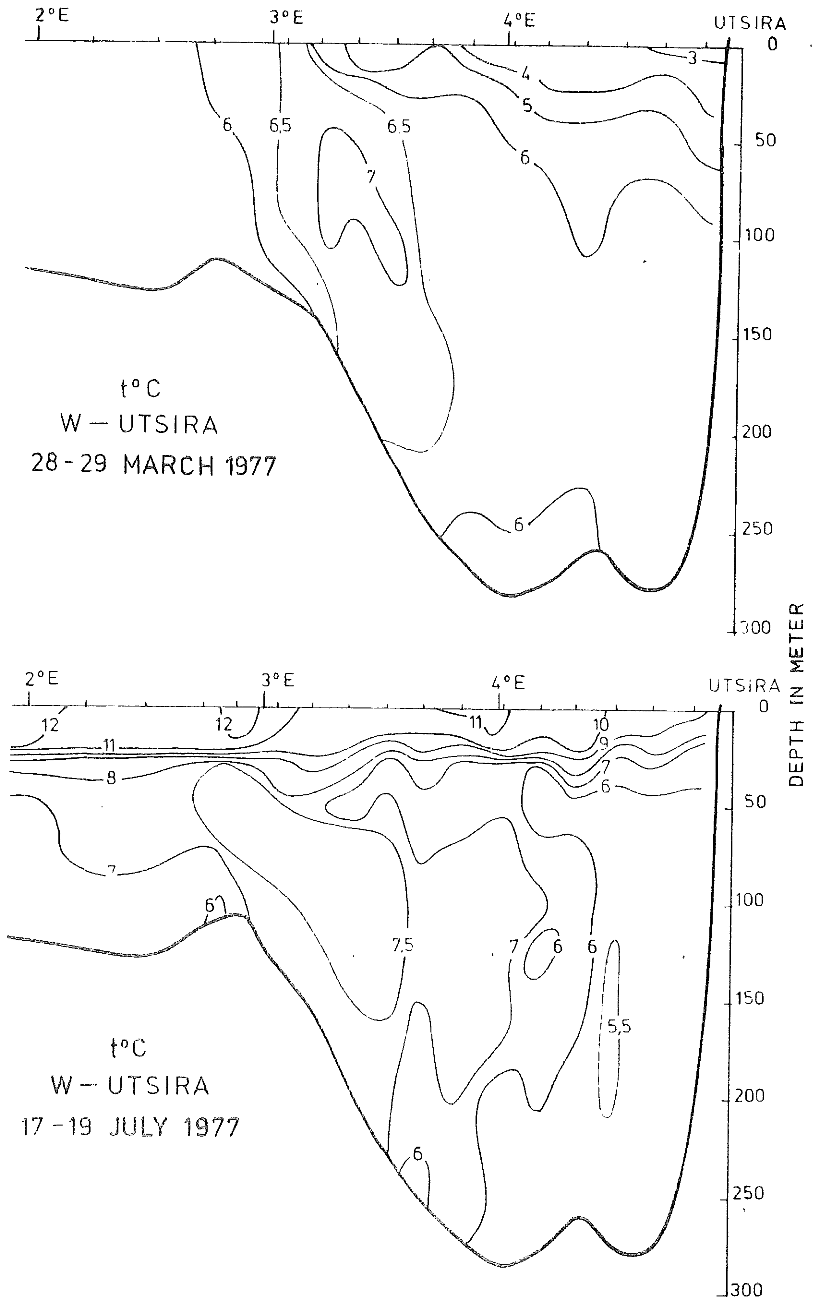

Fig. 4 Vertical distribution of temperature in the Utsira section in March and July 1977.

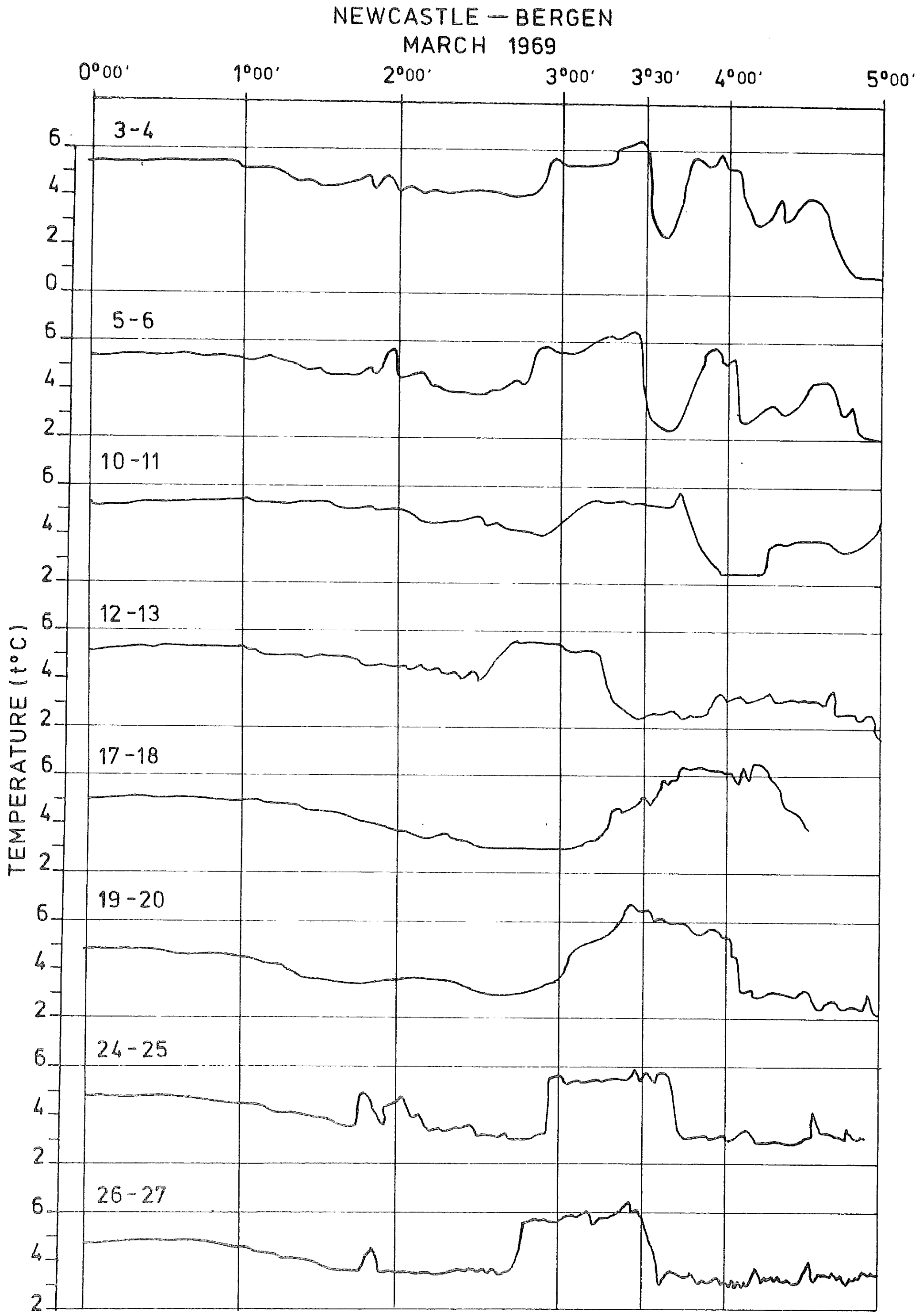

Fig. 5 Thermograph records along the BERGEN - NEWCASTLE line - March 1969.

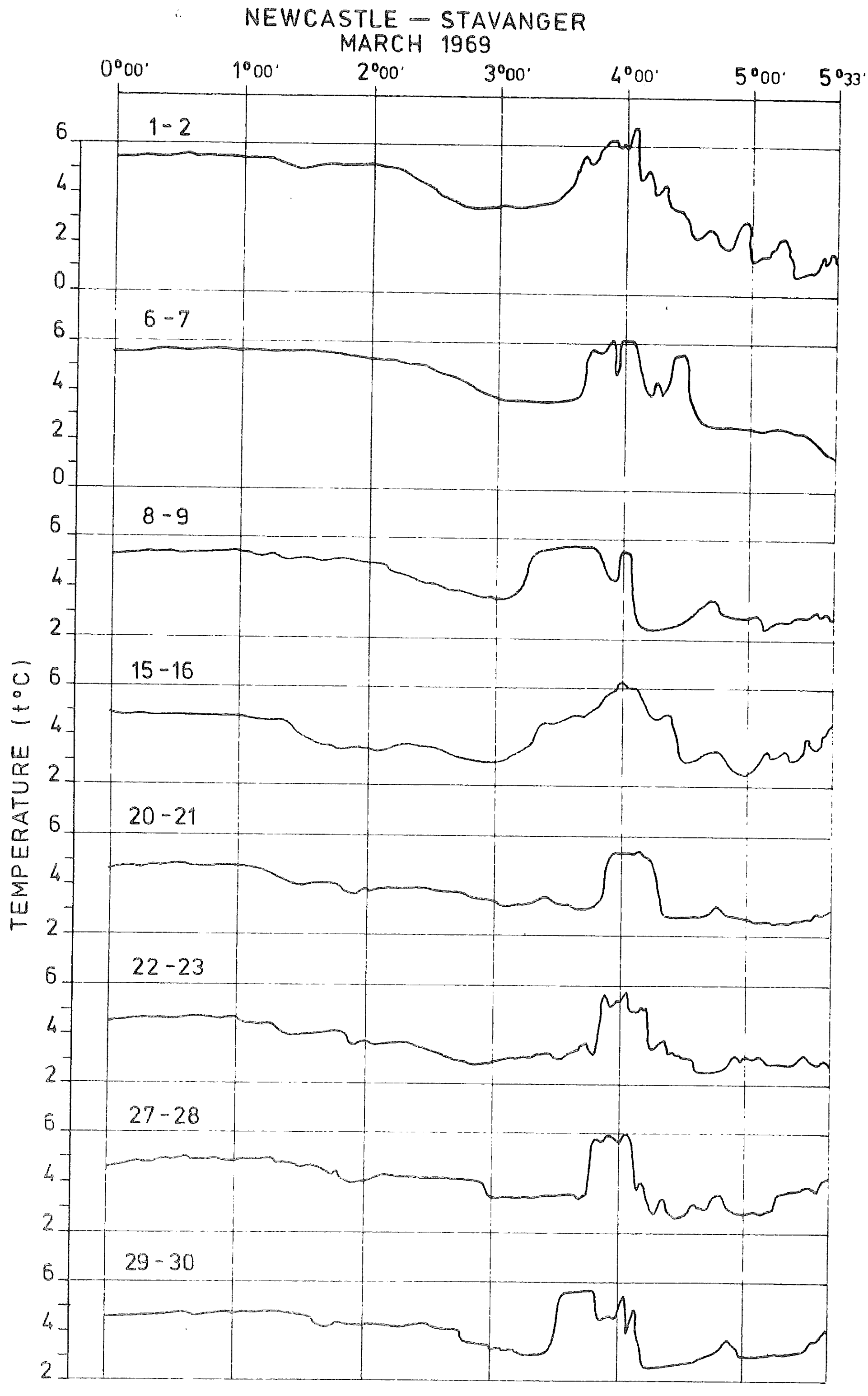

Fig. 6 Thermograph records along the STAVANGER - NEWCASTLE line - March 1969.

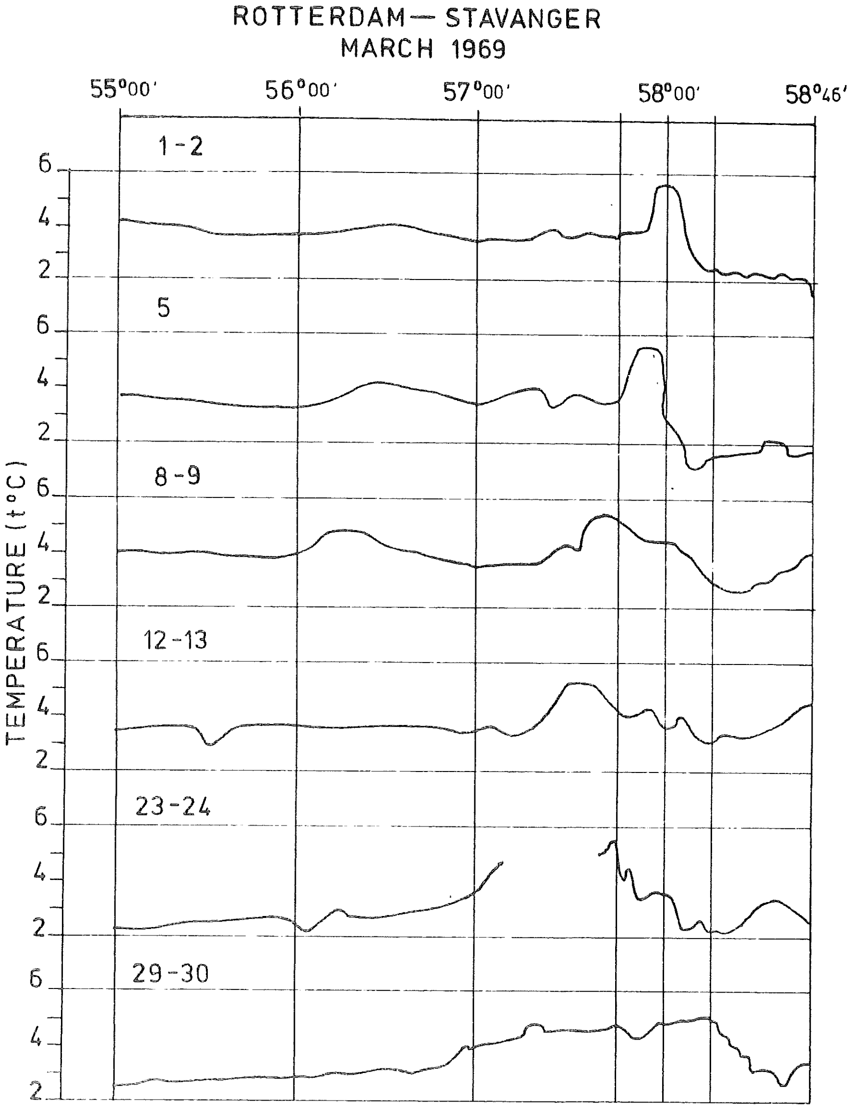

Fig. 7 Thermograph records along the STAVANGER - ROTTERDAM line - March 1969.

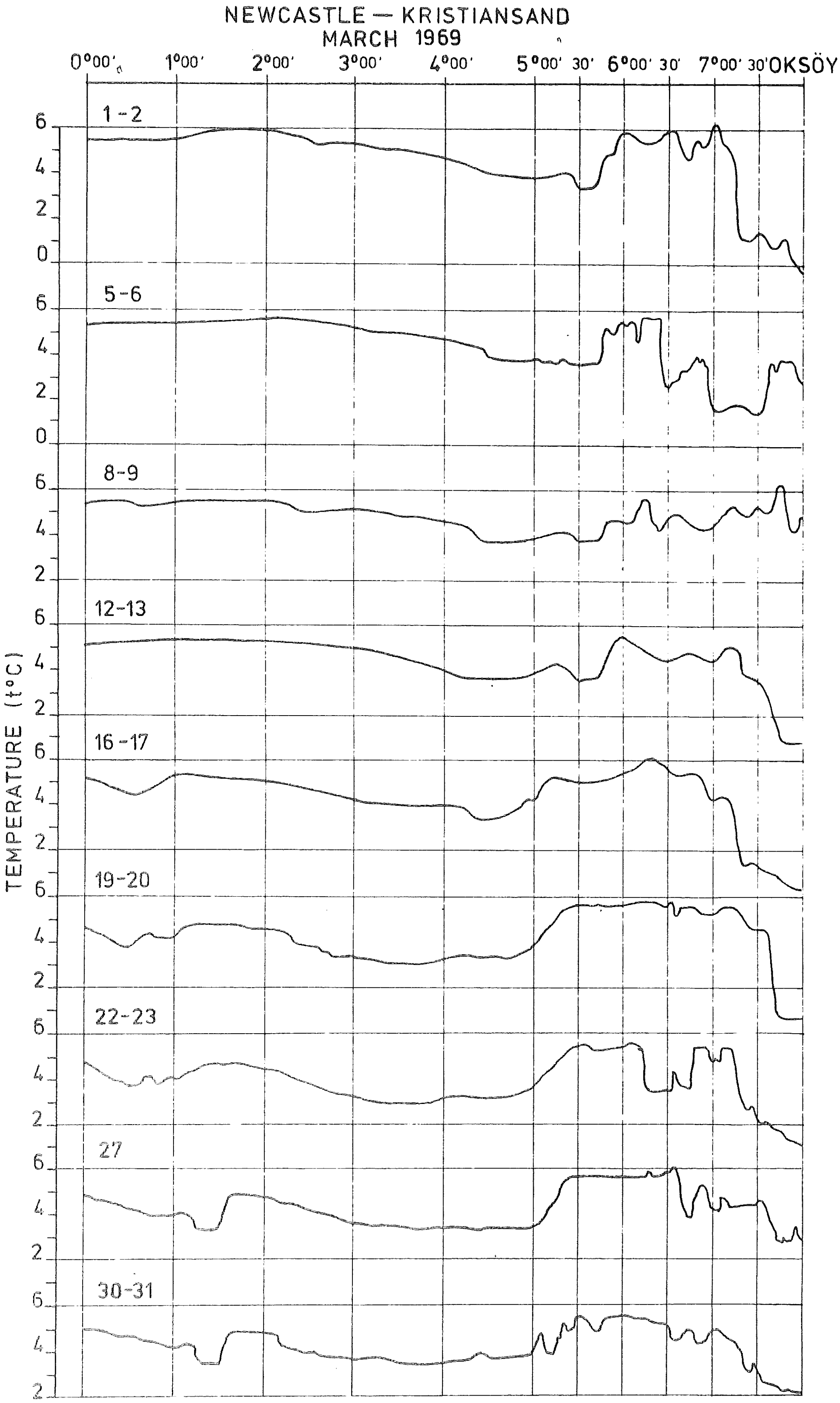

Fig. 8 Thermograph records along the KRISTIANSAND - NEWCASTLE line - March 1969.

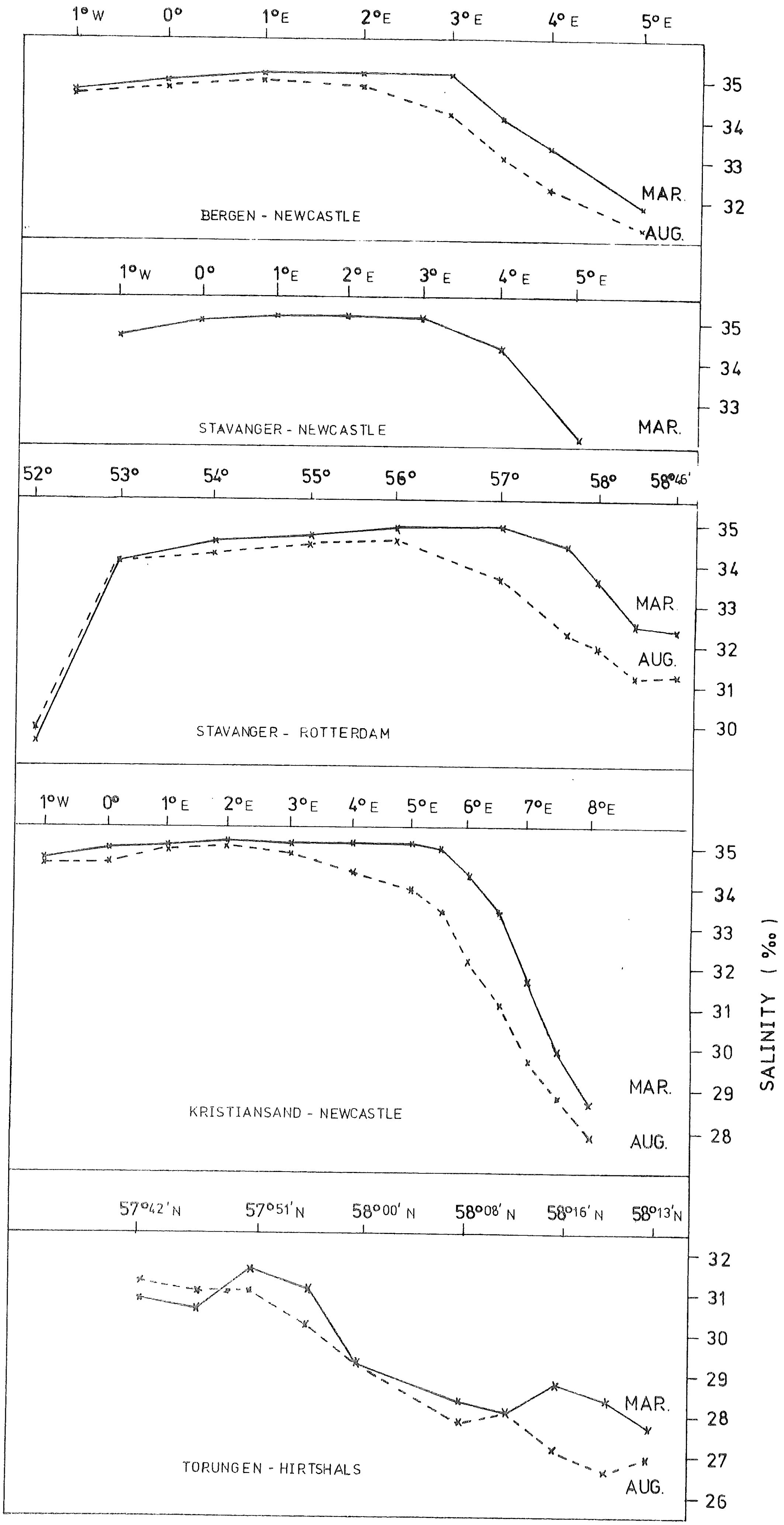

Fig. 9 Average salinity in March and August for the mean year 1967 - 1976.