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Overflow '73 - Evidence for atmospheric forcing of Arctic water overflow events

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Introduction

One of the central objectives of the ICES Expedition Overflow '73 is a study on the dynamics of the Arctic water overflow across the Greenland-Scotland Ridge. Despite numerous efforts it was mainly due to the lack of continuous records of currents or stratification parameters that neither the time scales nor the causes for the variability of the mass field were known from the previous investigations. Therefore extensive use of moored current and temperature sensors was made during Overflow '73. Figure 1 shows the distribution of instrumented arrays, which in general were recording simultaneously for a period of 4 weeks in August/September 1973.

This paper is intended to summarize observations of a major event in the flow field of the Iceland-Faroe Ridge which seems to be related to the atmospheric conditions at that time.

Description of an event in the flow field of the Iceland-Faroe Ridge

Figure 2 shows a record of current and temperature from a deep level on the arctic flank of the Iceland-Faroe Ridge. The coordinate system to compute current components has been aligned to the mean topography of the ridge with U' being normal and V' being parallel oriented. A low pass filter with a cut-off at 25 hours has been applied to eliminate the tidal signal. The dominant feature of the current record are persistent velocity fluctuations in the period-range of 2-5 days with an amplitude of 5-10 cm/sec (see also MEINCKE, 1974). This feature is contained similarily in all current meter records in the Iceland-Faroe area from the surface layer down to the bottom with vertically and horizontally varying phases. Although these 2-5 days fluctuations present an intriguing feature in itself, they will only be considered here as stationary phenomenon and the motion displayed in figure 2 is defined as being the "mean state" of the flow field for the purpose of this paper.

Figure 3 shows a record from a position on the crest of the central Iceland-Faroe Ridge. The instrument was located 150 m above the bottom (bottom depth 480 m) and, in contrast to figure 2, there is a very obvious deviation of the mean state for the current and the temperature as well. The onset of this deviation is found as dropping temperature on August 29, whereas in the current it occurs during September 31. The deviation in the current is strongest for the U'-component (normal to the ridge), starting with a negative sign, i.e. a southwesterly direction. After 2 days an opposite trend occurs, which finally leads to a northeasterly flow and rising temperatures. The total "event", as this deviation might be named, lasted for approximately 8 days. Its initial phase is considered to be an overflow-event, which advects Arctic water across the crest. Despite the current reversal during the event this process is at least partly irreversible, since observations during Overflow '73 revealed that the cold water (partly) remains on the southwestern flank of the ridge following completely different dynamics (MÜLLER et al, 1974). There are indications, especially from the temperature, that similar events may have occurred before the 20th of August and after the 12th of September at this position.

The second example of a current meter record with deviations from the mean state was chosen from a deep level at a position on the Atlantic flank of the Iceland-Faroe Ridge (Figure 4). Again an event is observed in the beginning of September, in this case however, with the strongest changes occurring in the V'-component, i.e. parallel to the isobaths. There is also an indication of related temperature changes. This record clearly covers another event, which took place before the 20th of August. It is different from the event at the beginning of September by having energy in both the U' and V'-components.

The examples presented in figures 2, 3 and 4 were chosen from a total of 26 current meter records presently available for the Iceland-Faroe Ridge area. The next two figures summarize the findings on the spatial distribution of the event observed during the end of

August/beginning of September. Figure 5 shows the vertical distribution of the event along a section normal to the Iceland-Faroe Ridge. It is found to be restricted to the surface layer on the Arctic side of the section. Proceeding across the ridge towards the Atlantic side the thickness of the layer influenced by the event is increasing. The maximum observed thickness is larger than 1100 m. The lower boundary of the hatched area in figure 5 shows a marked similarity to the distribution of isopycnals, which are underlying the graph. With the exception of the crest of the Iceland-Faroe Ridge, which is known to be a zone of considerable interfacial stress (MEINCKE, 1972), one might conclude from figure 5 that the occurrence of the event is linked to the presence of a high percentage of North Atlantic Water (see MEINCKE, 1974).

The onset of the event was observed to be vertically simultaneous. There are, however, distinct horizontal differences in the onset-time. They are shown in figure 6 in combination with the direction of the onset. The phase lines suggest a propagation of the onset from southwest towards northeast with a speed of approximately 2 m/sec. The direction of the onset is found to be parallel to the isobaths in slope regions north and south of the ridge and to be normal to the ridge in the crest zone. This directional distribution explains the observed differences in the magnitude of the temperature changes during the event. With the temperature gradients being normal to the ridge, the advective temperature changes are strongest in the crest zone, where the direction of the event and the temperature gradient coincide.

Atmospheric conditions in the Iceland-Scotland area

Time-series of sea surface pressure are shown in figure 7 for 5 stations in the Iceland-Scotland area. Besides shorter term fluctuations of 2-5 days duration two phases of distinct low pressure are encountered for the periods August 16-19 and August 31 to September 2, which also have been shown to be the periods of events in the current field. The occurrence of the pressure minima at the various positions suggests depressions moving through the area from southwest towards northeast, with a scale covering the Iceland-Scotland area. This view is supported by the mean absolute topographies of the 500 mb surfaces for August and September 1973, which are considered to be the steering level for the underlying atmospheric systems and which in fact show a southwest-northeast orientation throughout the period of the Overflow expedition and throughout the area between Iceland and Scotland. An estimate of the phase speed yields approximately 6 m/sec, which is not compatible to the estimate of 2 m/sec for the propagation of the current-event.

Discussion

So far we have described the occurrence of events in the flow field of the Iceland-Faroe Ridge and shown significant atmospheric depressions passing the area simultaneously. If the correlation between oceanographic and meteorological events is real, the large scale of the meteorological forcing should result in similar current events in the area outside the Iceland-Faroe Ridge. This is in fact the case, since the current records from the Faroe-Shetland Channel also show an event-type behaviour, especially in the beginning of September (DOOLEY, 1975, MEINCKE and DOOLEY, in prep.). This gives some confidence for the working hypothesis, that significant fluctuations of the current field in this area are induced by atmospheric disturbances.

While the analysis of this set of observations is presently going on with the aim of finding an adequate theoretical model to describe the fluctuations of the flow field, it has become obvious that the data set from the Overflow '73 - expedition provides a sufficient spatial coverage to describe events, the coverage in time, however, is completely insufficient, since the time scales involved are of the order of 2 weeks. To overcome this lack of data an observation programme was launched to supplement the Overflow data set. This project is called "MONA" (Monitoring the Overflow into the North Atlantic). At six critical positions along the Greenland-Scotland Ridge current meters were moored during summer 1975 (see figure 8). They will hopefully be recovered one year later and thus enable a statistically significant correlation between atmospheric depressions and flow-events.

<u>References</u>

1. DOOLEY, H.D. (1975): Features of Hydrography and Currents in the Faroe-Shetland Channel during Overflow '73. ICES, C.M. 1975 / C : 31, 10 pp mimeo.

2. MEINCKE, J. (1972): The hydrographic section along the Iceland-Faroe Ridge carried out by R.V. Anton Dohrn in 1957-1971.
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3. MEINCKE, J. (1974): Overflow '73 - Large-Scale Features of the Overflow across the Iceland-Faroe Ridge.
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4. MÜLLER, T.J., F. SCHOTT, G. SIEDLER, K.P. KOLTERMANN (1974): Observations of overflow on the Iceland-Faroe Ridge.
Meteor Forsch.-Ergebn. A, <u>15</u>, 49-55.

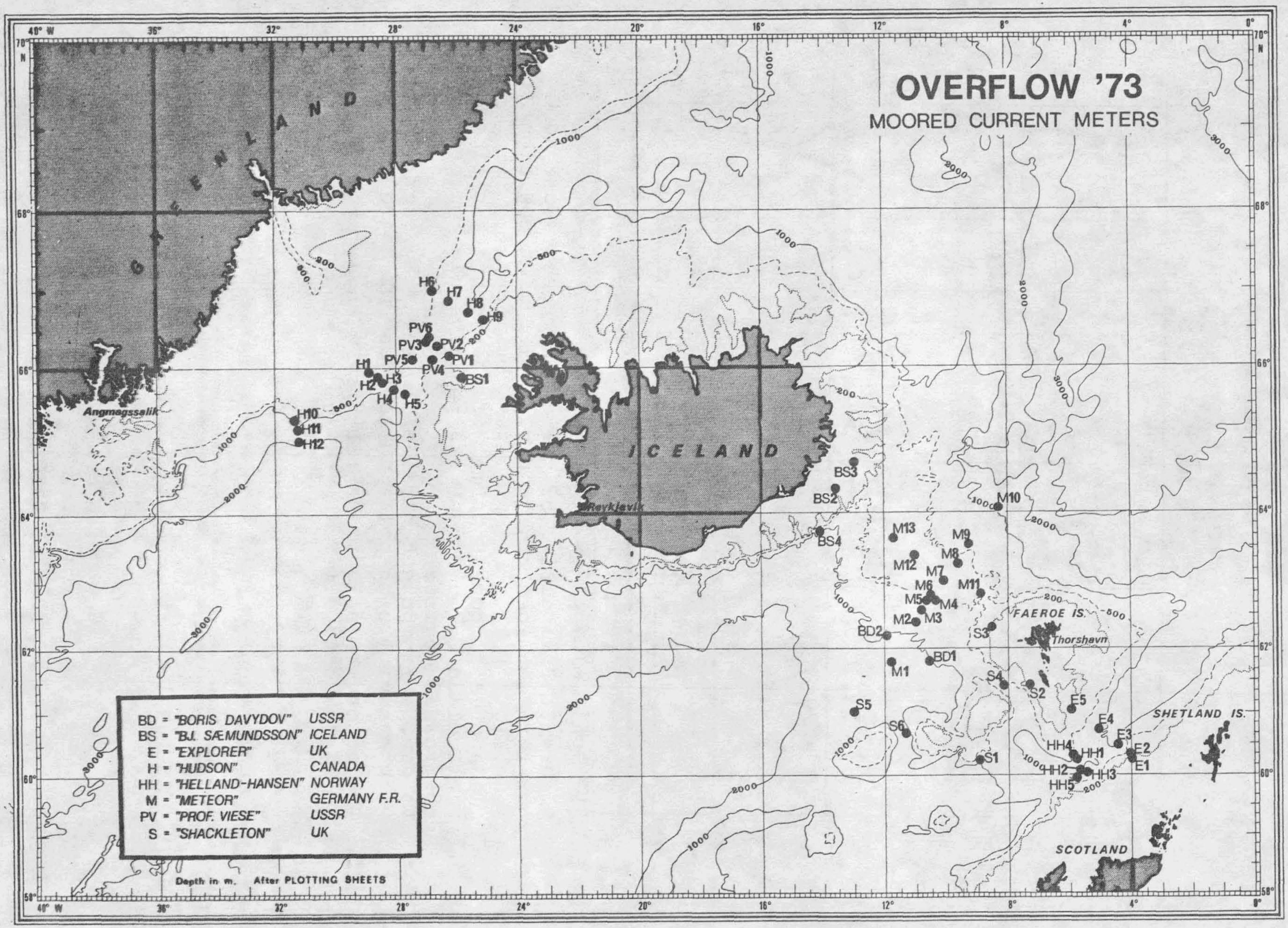

Figure 1: Map showing distribution of moored current meter arrays during "OVERFLOW"

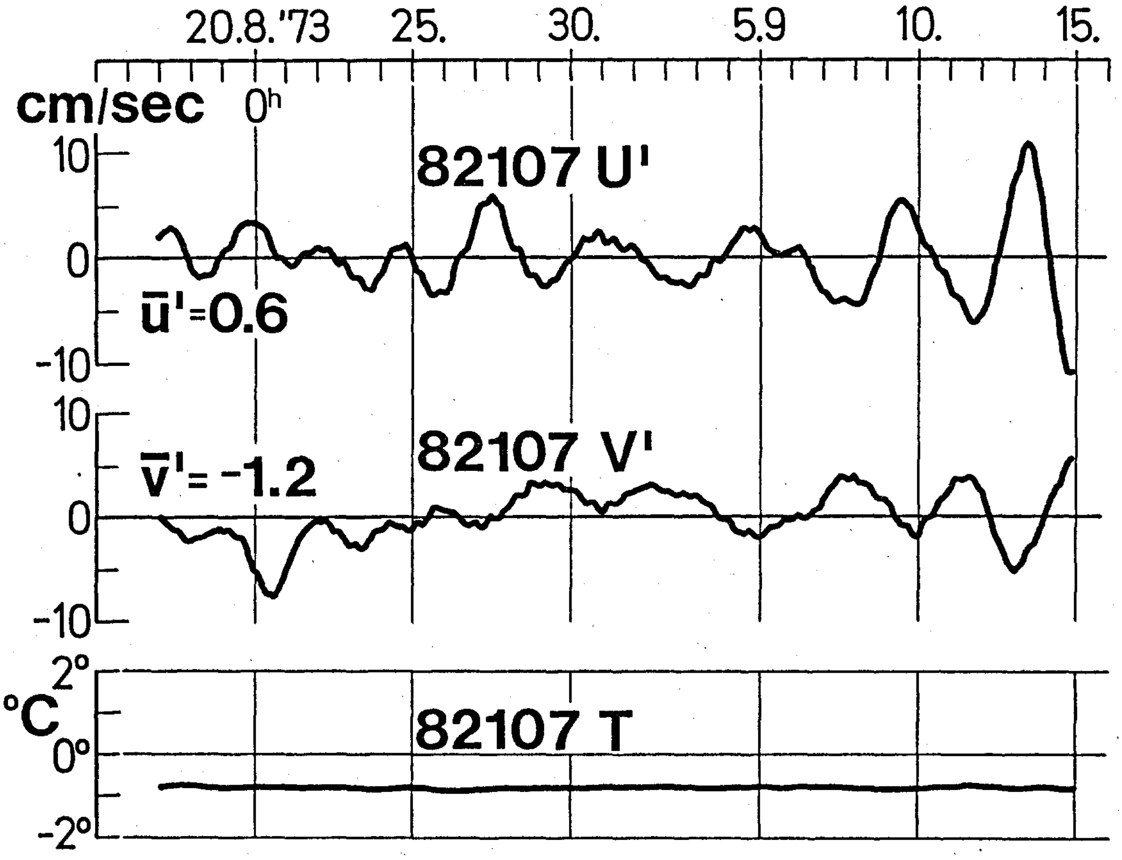

Figure 2: Time-series of current components and temperature obtained at a depth of 1129 m at position M10 (see Fig. 1)
U' denotes component normal to the mean crest line of the Iceland-Faroe Ridge with positive sign pointing towards 33 degrees
V' denotes component parallel to the mean crest line with positive sign pointing towards 302 degrees
The records are low pass filtered with a cutoff at 25 hours to eliminate the tidal signal

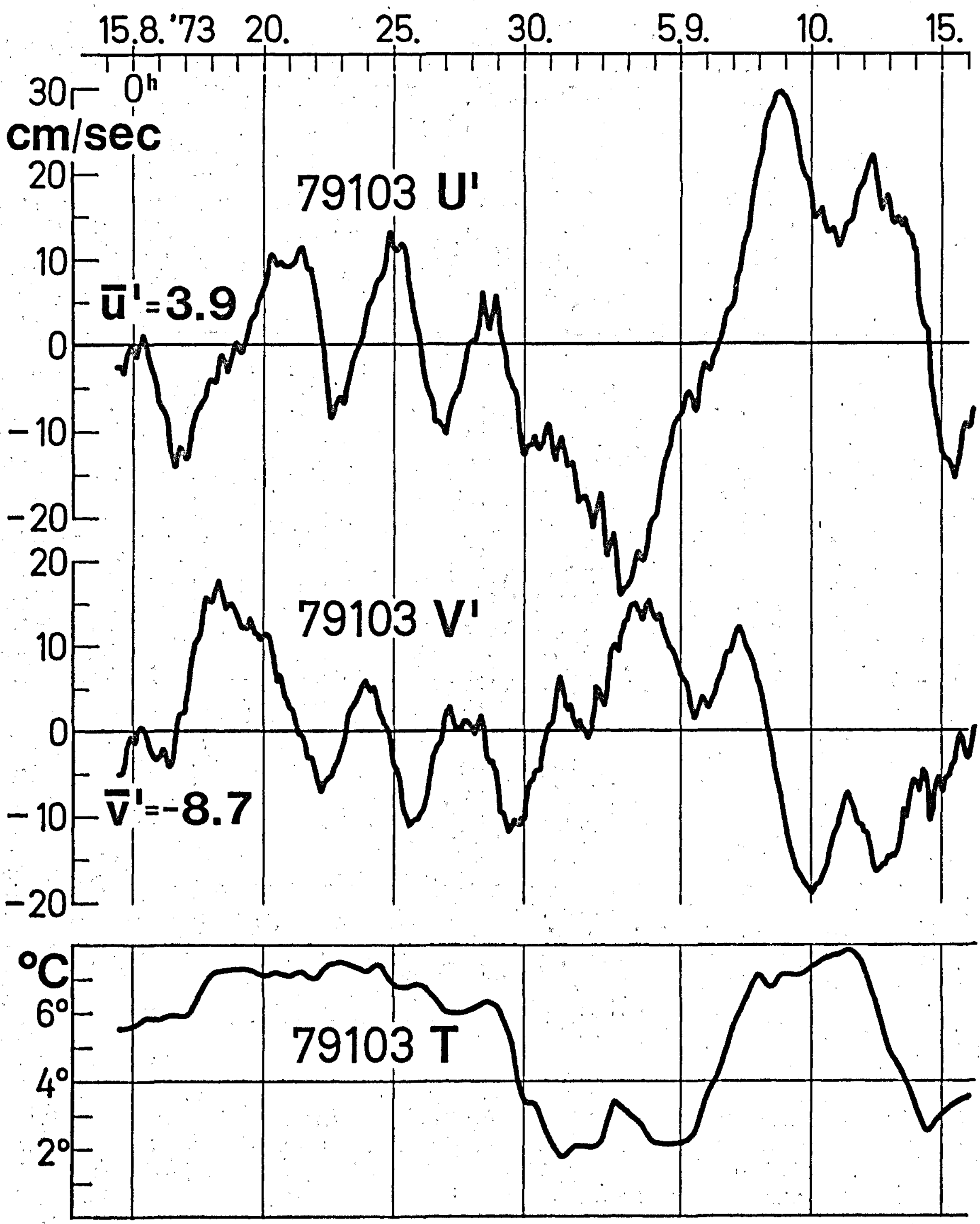

Figure 3: Time-series of current components and temperature obtained at a depth of 330 m at position M7 (see Fig. 1) For explanation see legend to Fig. 2

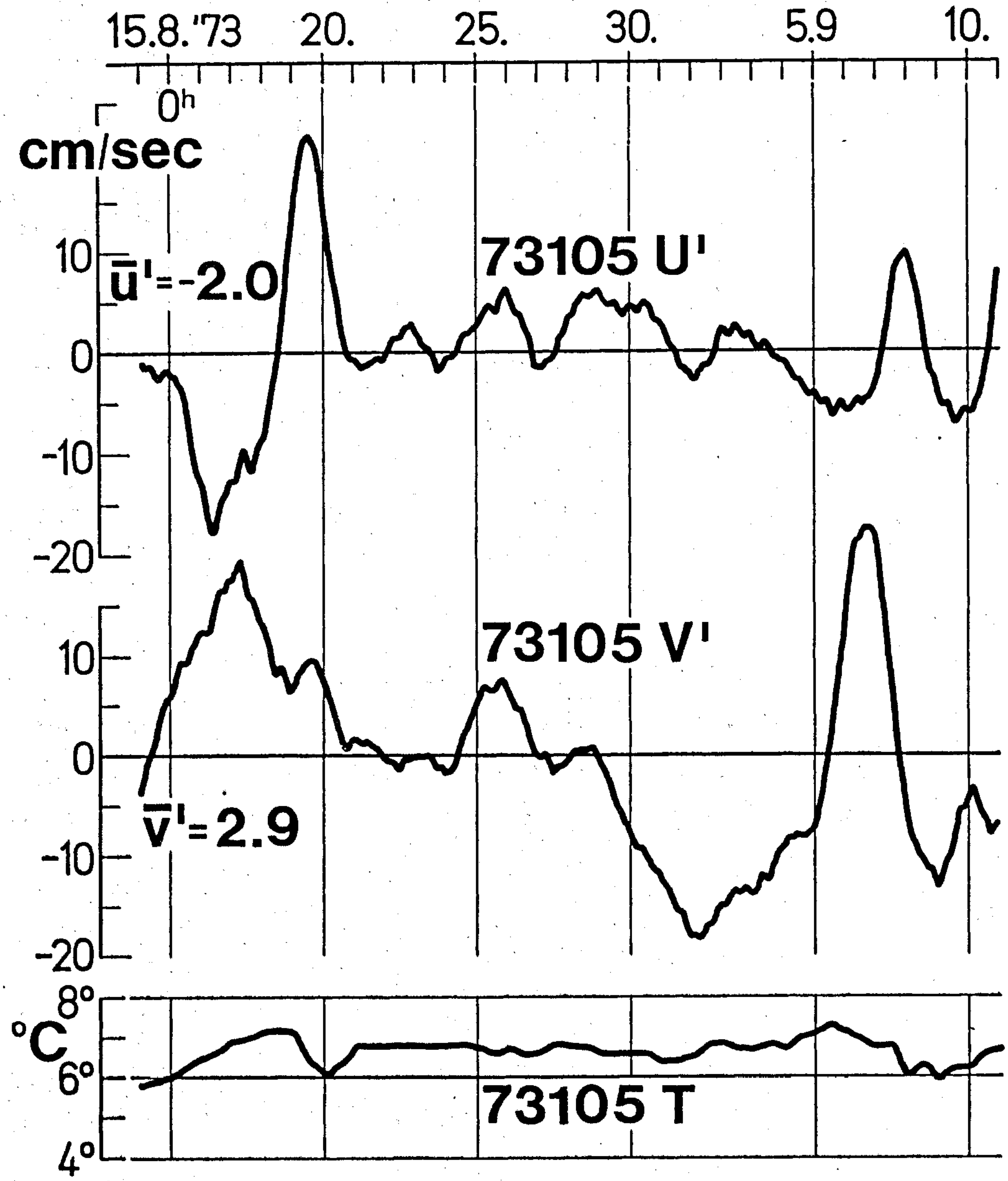

Figure 4: Time-series of current components and temperature obtained at a depth of 1143 m at position M1 (see Fig. 1)
For explanation see legend to Fig. 2

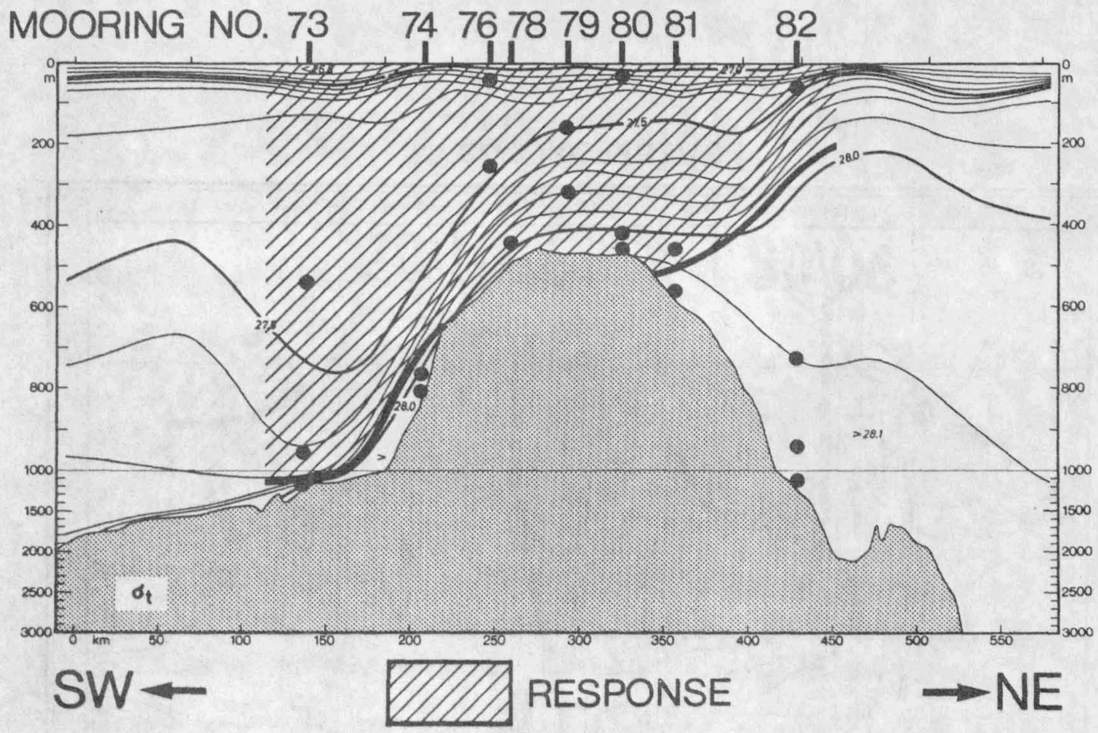

Figure 5: Vertical distribution of current response observed during August 29 to September 1 along line of current meter moorings M1 to M10 (see Fig. 1)
Black dots indicate positions of available records
Sigma-t lines are underlying the graph

OVERFLOW '73

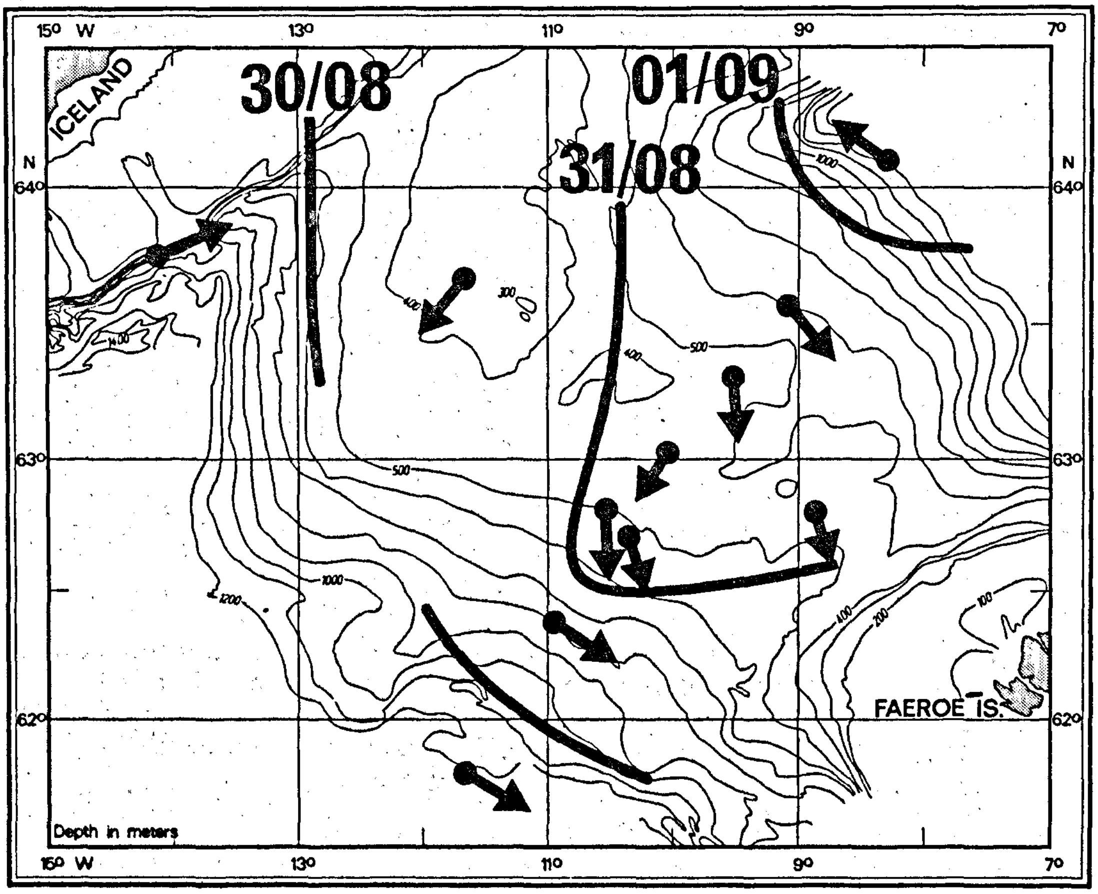

Figure 6: Horizontal distribution of date and direction for the onset of current response

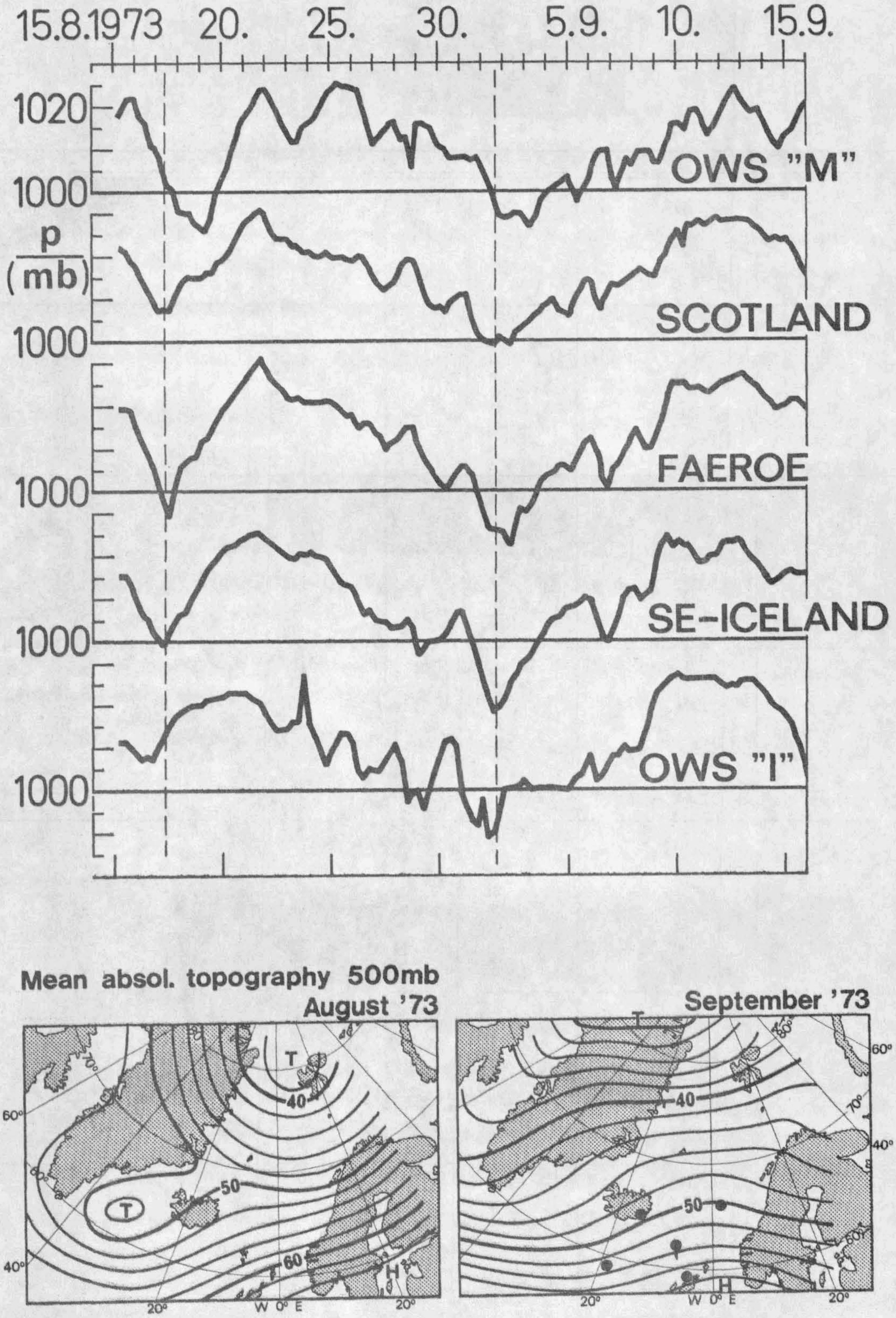

Figure 7: a) Time-series of atmospheric pressure for 5 locations in the Overflow-area (locations shown in lower right graph)
b) Mean absolute topography of 500 mb level given in geopotential dekameters

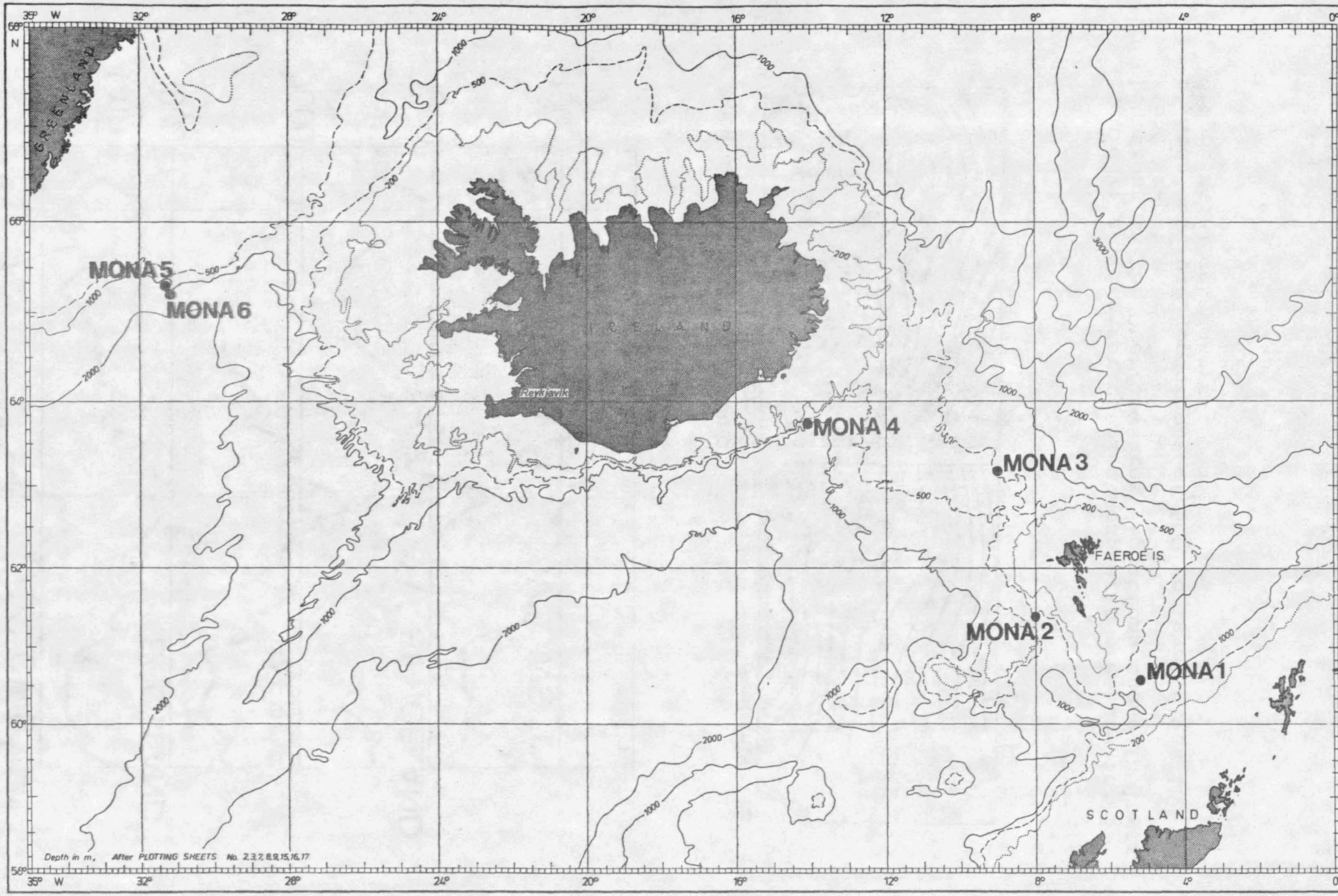

Figure 8: Distribution of current meters for a one year Monitoring the Overflow into the North Atlantic (MONA)