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LOW FREQUENCY CURRENTS NORTH OF ROCKALL BANK

by

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ABSTRACT

Current measurements made in the period March - June 1979 near the 500 m isobath on the northern slope to Rockall Bank are presented. A fairly steady residual current flowing along the slope towards the east was found, which is inconsistent with previous deductions, based on geostrophic calculations, of a cyclonic vortex surrounding the bank.

The first half of the record was characterised by long period fluctuations (2 - 10 days) superimposed on the residual and this coincided with very stormy weather. There were at least two occasions in this period when partial exchange of Rockall Bank and ocean waters appeared probable, but attempts to relate those and other fluctuations to the local wind failed.

RESUMÉ

On présente des mesures de courant effectuées de mars à juin 1979 près de la courbe isobathe de 500 m sur la pente du nord vers le Banc de Rockall. On a trouvé un courant résiduel assey constant qui suivait la pente dans la direction de l'est, ce qui ne s'accorde pas avec les conclusions préalables, basées sur des calculs gé géostrophiques d'un tourbillon cyclonal entourant le banc. La première moitié du rapport se caractérisait notamment par des oscillations de longue durée (2 à 10 jours), superosées au courant résidual et cela coincidait avec un temps très orageux. Il y avait au moins deux occasions à cette époque où une èchange partielle entre les eaux du Banc de Rockall et celles de l'océan paraissait probable, mais des efforts pour établir un rapport entre ces fluctuations ainsique d'autres et le vent local n'ont abouti à rien.

INTRODUCTION

Strong slope currents at the edges of banks and continental shelves may provide an important containment mechanism for bank or shelf fisheries as well as a process whereby the larvae of fish species that are present on the slope, eg blue whiting may be rapidly transported away from their spawning grounds. The need for more research on slope currents was recently emphasised by Ellett, Dooley and Hill (1979). They considered specifically the rather ambiguous evidence for a north flowing slope current west of the British Isles

One feature that appears typical of slope currents is that they are unusually difficult to detect from descriptive oceanographic surveys. This may be because these currents are predominantely barotropic. Meincke (1971) was able to demonstrate slope currents surrounding the Great Meteor Seamount which flowed in such a direction that the shallow water was to the right of the current. He attributed the existence of this anticyclonic vortex to the doming of the density isolines due to intense mixing over the Seamount. Rockall Bank demonstrates a similar doming but Hill (1976) concluded that this Bank was contained by a cyclonic vortex, a view which was supported by the earlier findings of Ellett (1968) and Nansen (1913).

When considering the containment of Rockall Bank water all of the above evidence tends to be inconclusive. In particular it was not possible to assess the effects of the severe wind storms which frequent this region, neither was it possible to formulate the frequency of upwelling (Steele, Johnstone and Baird 1971) or cascading (Ellett 1968) at the edges of the Bank, processes which could reduce the residence time of water on the Bank.

It was against this background that the Marine Laboratory set out to quantify the strength of the Rockall Bank vortex by deploying current meter moorings on the Bank slope. The intention was to deploy three moorings at a depth of 550 m on the north, south and east slopes of the Bank. However it was only possible to deploy the northern mooring (186) which was located at 58°21'N 14°W in a depth of 534 m from 10 March - 1 July 1979 (Figure 1). Two current meters were deployed on this mooring at depths of 70 m (record 1861) and 470 m (record 1862). Unfortunately 1862 lost its impellor after 8 days deployment. Thus this paper will confine itself to a discussion of record 1861 drawing on direction data from 1862 where this is seen as necessary. During the 8 days of full data from both depths, residual currents near the surface were very slightly weaker, but of similar direction, to those at depth.

HYDROGRAPHIC BACKGROUND

Sections were worked on a north-south line through the mooring position on 20 May and 1 July 1979 (Figures 2(a) and (b)). The basic features were of weak gradients with temperature isolines rising slightly towards the Bank. Salinity on the Bank was slightly lower than in the adjacent ocean. The geostrophic currents calculated from such a mass distribution depict a westward surface flow along the slope of 5 - 10 cm s^{-1} assuming a zero surface at the bottom (Figures 2(c) and (d)). This is in conformity with Hill's (1976) postulate of a cyclonic vortex round Rockall Bank.

CURRENTS AT 1861

	Tidal						Residual		
	M_2 Ampl	phase	S_2 Ampl	phase	K_1/O_1 Ampl	phase	Mean cm s^{-1}	S.D.	Stability (%)
u	3.56	246	1.07	279	0.15	214	7.1	8.3	72
v	5.68	193	2.04	217	0.19	253	-1.9	2.9	

Table 1 Principal statistics for record 1861

Table 1 lists the principle statistics of tidal and residual currents for record 1861 (70 m). Clearly tidal currents were predominantly semi-diurnal with negligible currents at diurnal frequencies. Residual currents were on average larger than the tidal currents with the easterly directed residual being the dominant component. The mean flow was parallel to the local topography which is aligned towards 95°. The statistics show that there was some variability about the mean as illustrated in Figure 3 which is a time plot of the Godin low-pass filtered data, giving the tidally smoothed residual component of flow. Much low frequency energy was present in the early part of the record and for a three week period in early May there was a reversal in flow, thus reducing the overall mean. In much of the remainder of the record easterly residual currents were in excess of 15 cm s^{-1} and peaked at 30 cm s^{-1} on 30 March 1979. Current directions at 470 m (not shown) were very close to those of 70 m except during the period of flow reversal in May when directions at 470 m were westerly for a much shorter period. This would indicate that the stability of the easterly flow at depth was somewhat greater than at 70 m. There were short periods when there was a substantial component of flow normal to the Bank, in particular from 31 March - 4 April there was a flow of 6 cm s^{-1} directed towards the Bank and on 19/20 April there was a flow of similar magnitude but opposite in direction. The flow at 470 m appeared similarly perturbed at these times, indicating the possibility of exchange of bank and ocean waters. There was no obvious link between any of these events and wind.

EXAMINATION OF LOW FREQUENCY COMPONENTS OF FLOW

As already mentioned, Figure 3 demonstrates the presence of low frequency components of flow which disappeared towards the end of the record. Conditions at Rockall were extremely stormy until late May but thereafter it was much calmer and anticyclonic, suggesting a meterological link as a cause of these low frequency fluctuations. In order to investigate this possibility the coherence between components of wind velocity at Benbecula and currents was examined (Figure 4). Benbecula (Figure 1), in the Outer Hebrides, is the nearest weather reporting station at some 200 miles distance from Rockall. It was felt however that this should not present serious errors in the analysis as the pattern of weather was very similar over a wide area at this time.

Coherence between wind and currents was very poor, the only significant level being obtained for the u-component of current and v-component of wind (Figure 4) at a period of 83 hours. Figure 3 suggests however that low frequency currents exist at a variety of frequencies which varies with time, suggesting that this single significant coherence may be a statistical artefact rather than identifying a valid relation between wind and current. In order to examine this possibility in detail the time distribution of the low frequency variance of wind and current components was investigated using Fourier space-time plots (Woods 1975).

Figures 5 and 6 are such plots for the v component of wind and u component of current respectively. These are the same components as used in the coherence analysis in Figure 4. In these plots the Fourier components were computed from 512 hourly values, overlapped in such a way to produce 46 estimates at 2 day intervals. The contours give the distribution of variance in Fourier space-time. Peaks in wind variance (Figure 5) occur at periods of 80 hours and 170 hours in late March and mid May only, with very little variance from 5 - 15 April and after the 25 May. Figure 6 confirms the poor association between wind and currents, the distribution of current variance being poorly related to that of the wind. Until 25 May the long period variance (170 hours) shows a fairly uniform distribution but the only peak at 83 hours occurs very early in the record. There is also a pronounced peak at 57 hours in early April which coincides with an energy minimum in the wind. The only feature in the v-current component Fourier plot (not shown) coincides with this feature. From 26 April - 20 May the distribution of variances at periods >128 hours are very similar suggesting that at this time at least there is some coupling between wind and current. This is the period of westerly surface flow which resulted in a degree of baroclinicity and confirms the presence of a different regime influencing currents at 1861 in this period. Thus considering the complex time structure of the variance it is unlikely that computations involving the whole data set, such as presented Figure 4 could give a realistic result.

DISCUSSION

In the period March - June 1979 currents on the northern slope of Rockall Bank were topographically constrained with shallow water lying to the right. This current appears to be another example of a barotropic slope current as discussed by Ellett, Dooley and Hill (1979) and is also similar to that found by Meincke (1971) round the Great Meteor Seamount. Whether or not this easterly flow is part of an anticyclonic flow round the Bank must now await further observation, as was originally planned. Clearly however the cyclonic circulation which had previously been proposed by Ellett (1968) and Hill (1976) is not confirmed by the direct observation of current. Interpretation of the current distribution by means of geostrophy clearly gives erroneous results especially if the chosen zero reference level is within the water column. Such misleading conclusions have also been drawn in the investigation of slope currents in general and have arisen because these currents increase, rather than decrease, with depth.

Detailed time series analysis failed to yield information on the cause of the variability in currents. Energetic fluctuations with periods of several days were evident in both the current and wind time series, but these did not appear linked except during the current reversal period in mid-May. Fluctuations in the along-slope components were particularly marked at periods in excess of 50 hours, but the weaker fluctuations normal to the slope were mainly of shorter period and occurred before the end of April. Thus exchange of Rockall Bank water with the adjacent ocean waters is likely to be small. The driving mechanism for the along-slope fluctuations is not clear from the analysis presented here. Their virtual disappearance after the 25 May does however suggest a seasonal factor which may be related to the decrease in wind stress and the consequent build up of thermal stratification. Rotary spectra show that the very long period fluctuations are closely aligned to the topography and may be trapped waves generated by distant storms. At no time was it possible to directly relate either component of flow to meteorological events.

Finally, Table 1, Figure 3 and spectral analysis do not reveal evidence of the diurnal frequency trapped non-divergent waves predicted by Huthnance (1974).

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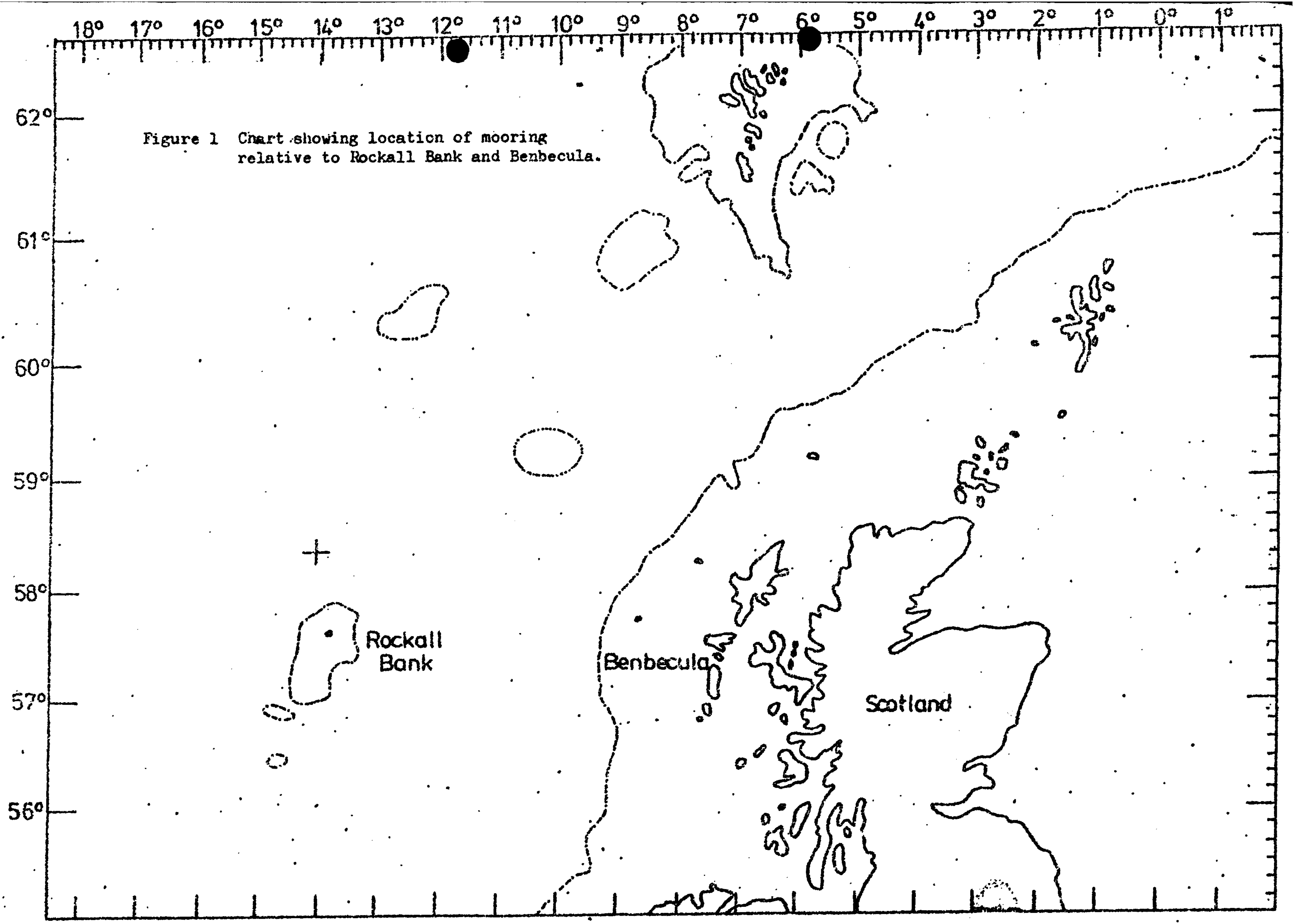


Figure 1 Chart showing location of mooring relative to Rockall Bank and Benbecula.

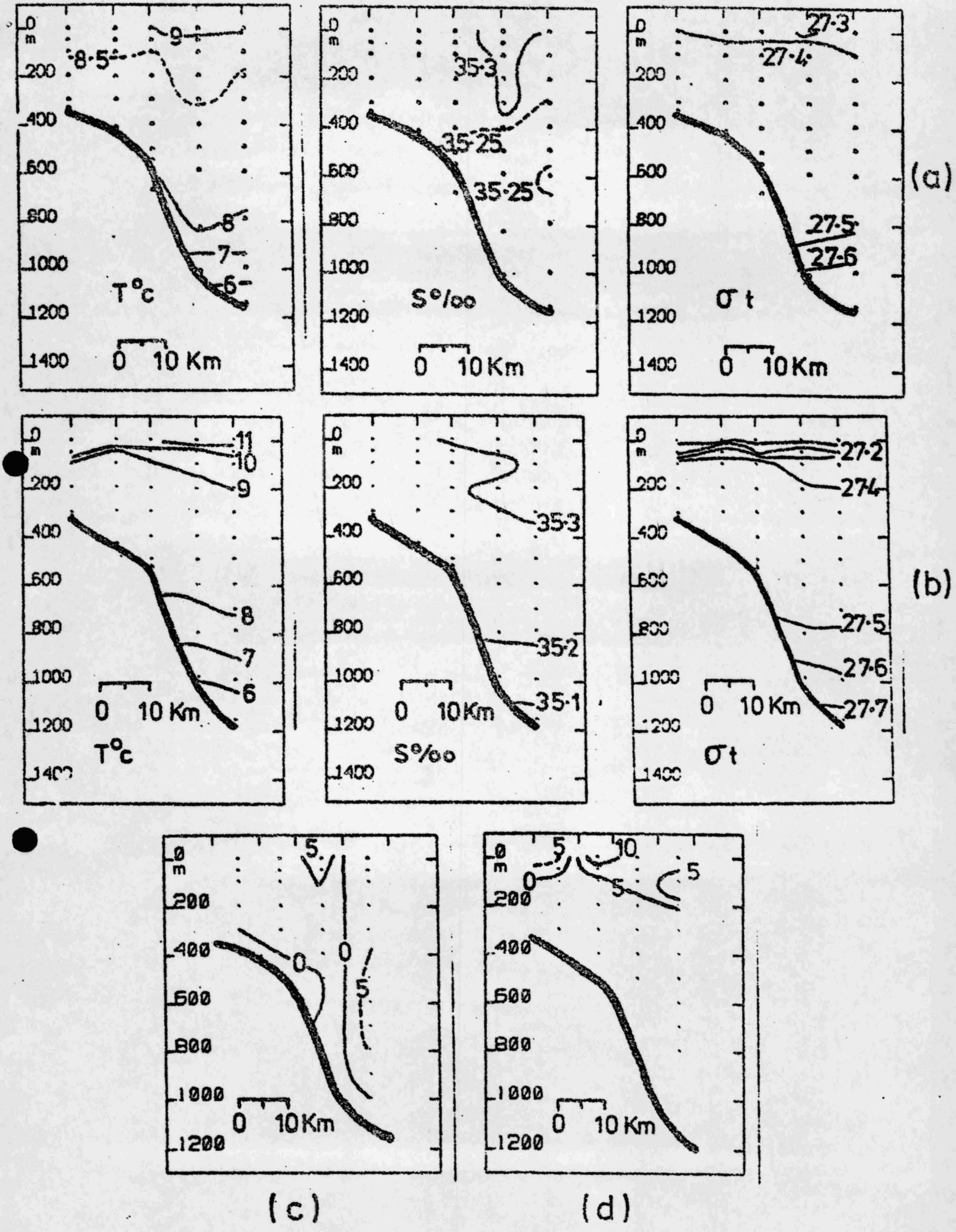
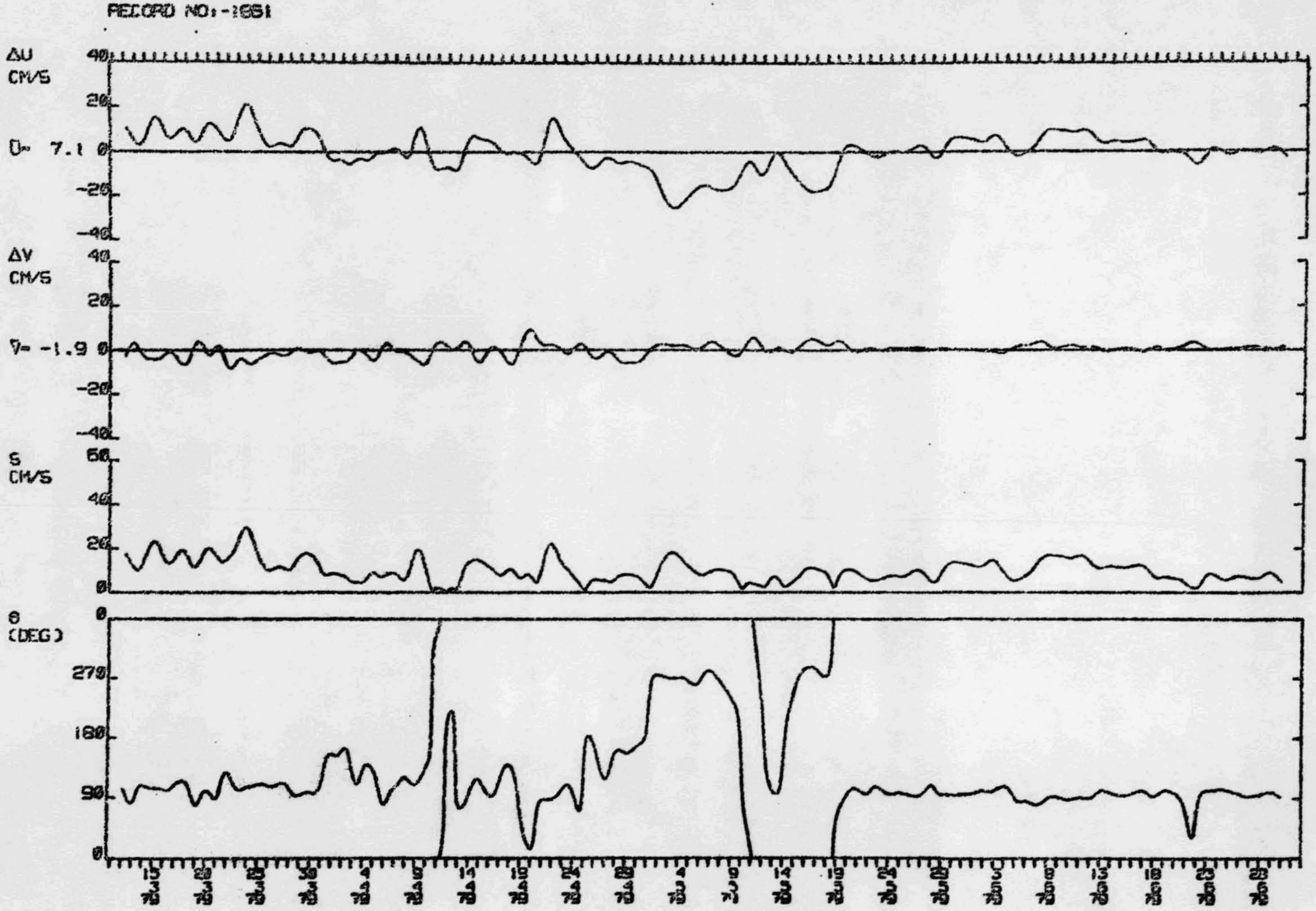


Figure 2 Vertical profiles of temperature, salinity and density (σt) on a north-south line through mooring on: (a) 20 May 1979; and (b) 1 July 1979 Computed geostrophic currents with bottom reference level are shown in: (c) for 20 May 1979; and (d) 1 July 1979.

Figure 5 Time series plot of record 1861



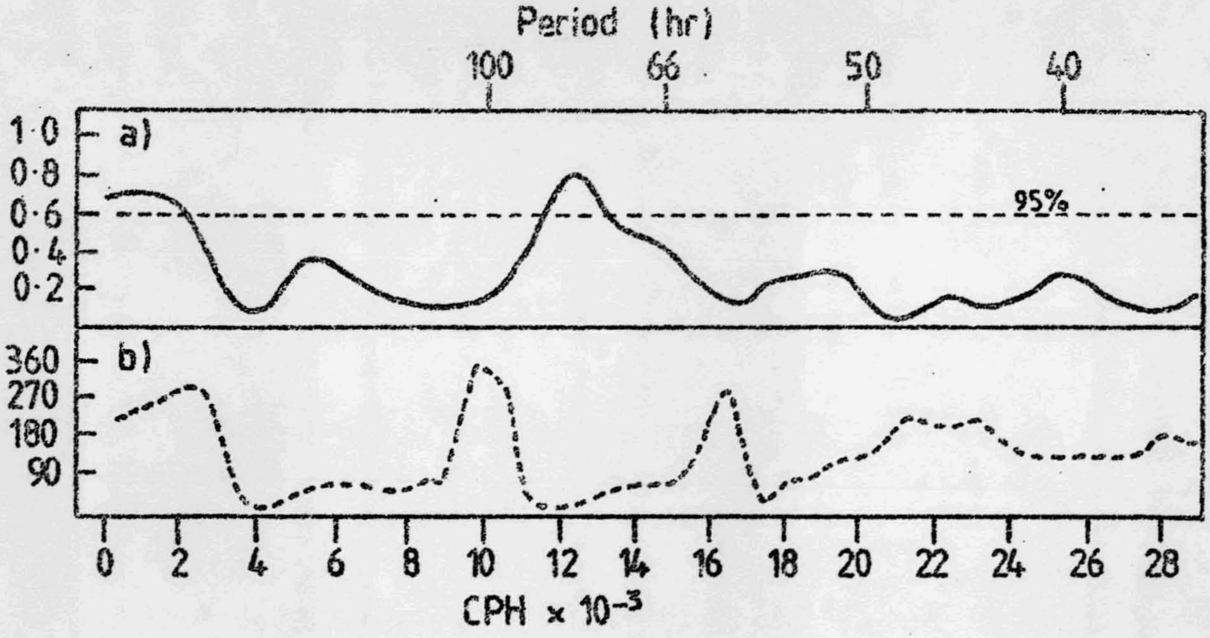


Figure 4 Squared coherence (a) and phase (b) of low frequency u-component of current with v-component of wind stress.

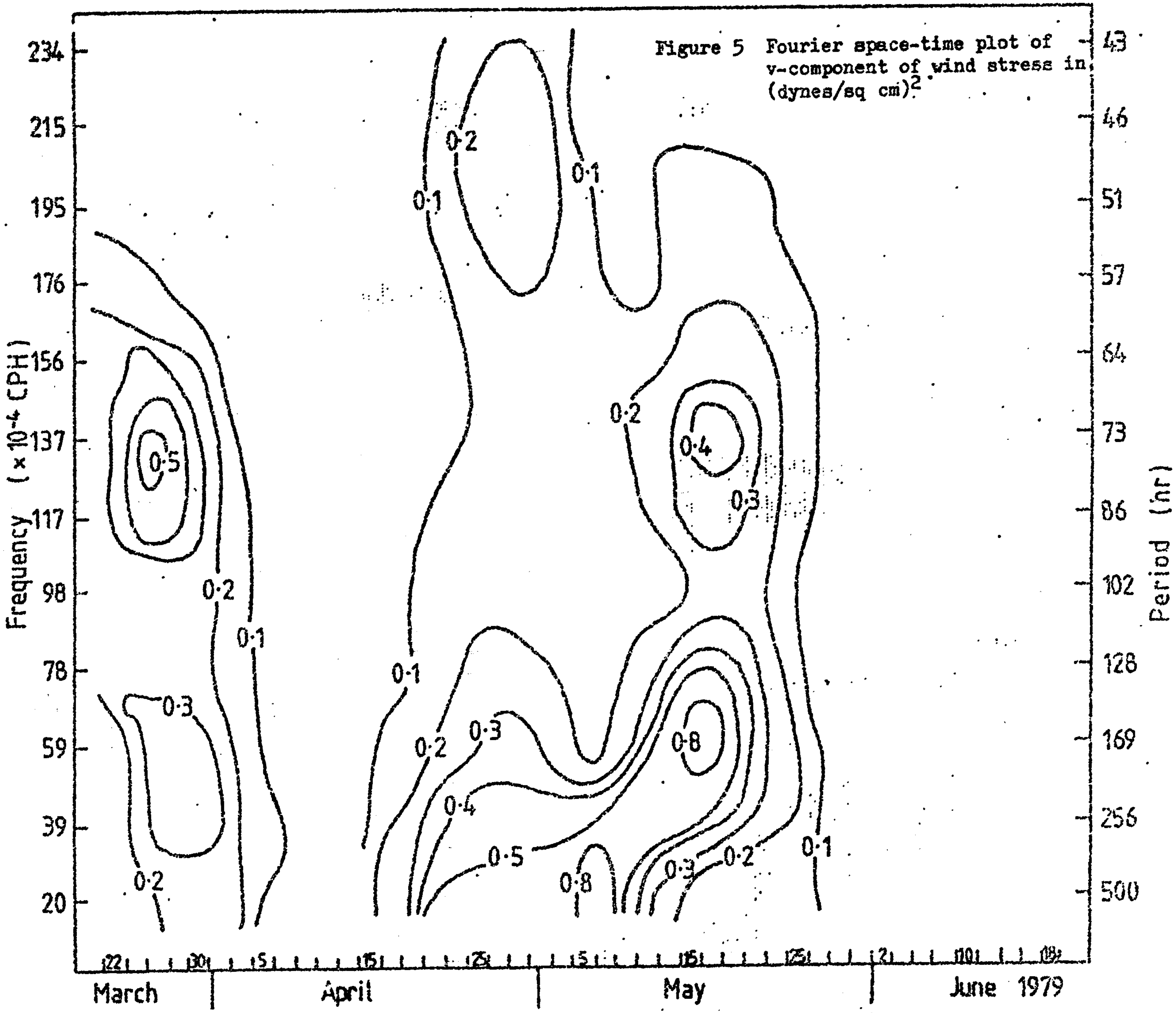


Figure 5 Fourier space-time plot of v-component of wind stress in (dynes/sq cm)^2

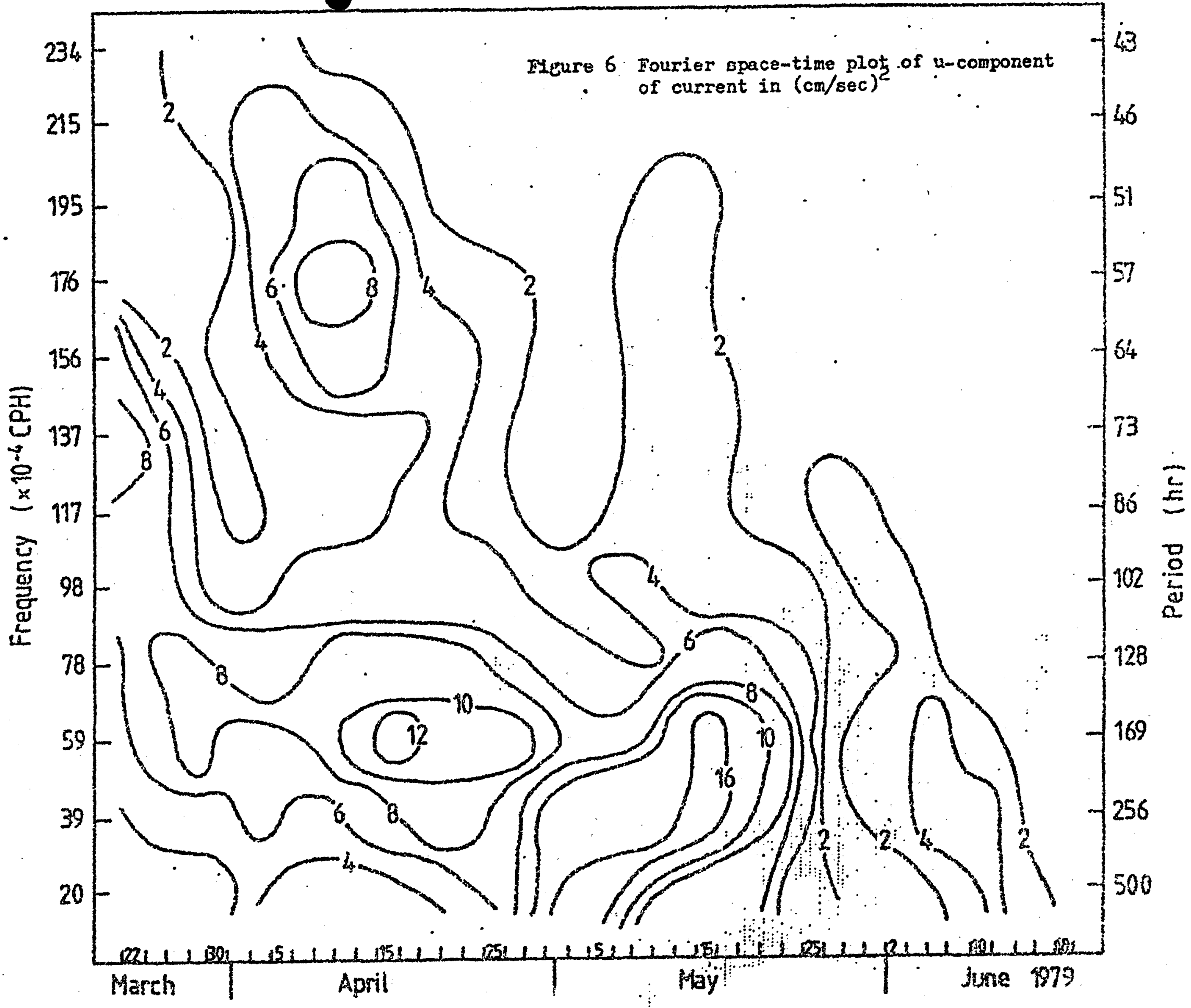


Figure 6 Fourier space-time plot of u-component of current in $(cm/sec)^2$