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Long period variability of currents in the Rockall Trough

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Abstract

Long term measurements of currents in the N. Rockall Trough have revealed a seasonal variation in current oscillations penetrating to depths of at least 1500 m. The dominant time scale in these oscillations is 15 days. The increase in energy is associated with the breakdown in stratification due to winter cooling and mixing. Isothermal layers have been observed to penetrate to greater than 600 m but not to the greatest depths at which the seasonal signal is observed.

Resume

Les mesures de courants de longue durée dans le basin de N. Rockall ont revelé une variation saisonnaire dans les oscillations de courant qui penetrent à une profondeur au moins de 1500 m. La periode dominante de ces oscillations est 15 jours. L'augmentation d'energie est associé avec la destruction du stratification par le mélangement et refroidissement en hiver. Les couches isothermales ont eté observes au profondeur de plus de 600 m mais pas dans les grandes profondeurs auquel le signal saisonnier a eté observé.

Introduction

The Rockall trough is a semi-enclosed basin with water depths between 1000 and 2000 m lying between Rockall Bank and the continental slope west of Scotland. Since the summer of 1978 the Institute of Oceanographic Sciences has been funded by the U.K. Department of Energy to carry out a series of current measurements at sites in the N. Rockall Trough. The positions of the current meter moorings and the local topographic features are shown in Fig. 1. Of the four sites (I1, 2, 3A and 4) at present occupied the most nearly continuous records are from I4 (nominal position 58° 50'N 11° 40'W) in water of 1800 m depth. This site is also the one farthest from and hence presumably least influenced by the surrounding banks and continental margins.

The individual current meter records have been calibrated, edited and used to produce a combined file sampled at a uniform 1 hr interval. A filtered version of this file from which energy at periods shorter than 2 days has been removed has been produced. Data gaps in the filtered time series have been filled by linear interpolation. The current meters used throughout this exercise are of the Aanderaa type and measure temperatures at each level and pressures at the uppermost current meter. Standard depths of observation were 200, 600, 1000 and 1500 m. All moorings were of subsurface design with the buoyancy at 150m, well below the depth of influence of surface wave activity.

A typical profile of temperature, salinity and density from near I4 is shown in fig. 2. The data are from thesummer of 1978. Below the seasonal thermocline is a homogeneous layer characterised by temperatures in the range 8 to 9°C and salinities from 35.20 to 35.26‰. Below 1000 m the stratification again increases until a more homogeneous deep water mass is approached below 1400 m (temperatures 4 to 5°C and salinities slightly below 35.0‰.

The current time series

The time series of filtered east and north velocity components at the four standard levels on mooring I4 are shown in fig. 3. The long data gap at the 600 m level is unfortunate but does not seriously affect the conclusions reached in this document. The times are given in days elapsed since 0000Z 1 January 1978 and the positions of July 1st 1978, January 1st 1979 and July 1st 1979 are marked. The maximum velocities are 80 and - 80 cm/sec. At the 200 m level there is a clear difference between the nature of both the east and north velocity components between January and July and for the remainder of the record. Large current extremes are seen and there are strong oscillations with periods of 20 days or so. The records at the two deepest levels also seem to exhibit this enhanced variability for the January to July period.

In order to quantify the changes in kinetic energy the spectra of currents have been computed for overlapping 60 day-long record segments at all levels and the mean energy in the frequency band from 3 to 30 days period has been calculated. The results of the computation are shown in fig. 4.

The kinetic energy is seen to increase during the late winter/early spring at all three levels with complete coverage. The most rapid increase in energy occurs during January at 200 m and during February at 1000 and 1500 m. The corresponding drop in energy is in June at 200 m but at the deeper levels it is less well marked and is spread over the period from April to June.

In an attempt to define the evolution of the fluctuations as a function of time the spectral estimates have been plotted on a frequency/time plane in fig. 5. Spectral peaks at 200 m occur at periods of 7, 15 and 30 days but the 15 day energy is dominant and reaches a maximum in February. There is a hint at this level of a cascade of energy towards lower frequencies as time progresses. The 1000 m records show a significant peak only at 15 days during February. At 1500 m the energy in the 15-20 day band appears to persist for much of the year.

Discussions

The increased energy at all levels occurs during the winter months but also persists into the late spring and early summer. It does not then coincide exactly with the stormy winter period.

The combination of wind mixing and heat loss to the atmosphere produces very deep mixed layers in the upper part of the water column in the Rockall trough. The atlas of Robinson, Bauer and Schroeder (as yet unpublished) shows a mean depth of the convective layer in the Rockall trough in March in excess of 900 m. The development of this convective layer can be followed by the study of the temperatures recorded by the current meters. The loss of winter data at 600 m is particularly regrettable in this matter but at the nearby I3A mooring there are continuous temperature records through the winter period from the two shallow levels. These records show homogeneous water from the surface to at least 600 m from late January to mid March. There was however always a significant temperature difference between 600 and 1000 m. If we assume that there was a similar mixed layer development at I4 then the period when the mixed layer is at least 600 m deep corresponds to the time when the kinetic energy at all levels is increasing and that thereafter there is a general decrease in kinetic energy as the stratification is re-established.

The exact nature and time scale of the breakdown in stratification remain to be investigated and for this purpose the meteorological information extracted from the daily weather reports may be the only data source. It should be remembered that the winter 1978/9 was marked by anomalously low air temperatures over the U.K. The depth to which winter mixing penetrates may in fact be governed not solely by meteorological conditions but by the strength of the Mediterranean water influence on the water column at around 1000 m. Anomalously high temperatures at this level during the winter months could aid the penetration of the mixed layer to deeper levels.

Reference to fig. 3 illustrates that the motions are in general in phase in the upper 1000 m (there is a visual similarity between the records at the three upper levels) and this is borne out by the correlation matrices for the velocity components (Table 1) The 1500 m level is largely uncorrelated with the motions at higher levels (correlation coefficients < 0.3). The temperatures at this level are however more highly correlated to upper ocean temperatures (correlative coefficients ~ 0.45).

These results suggest that the motions which dominate the records are not wholly barotropic (correlations would be high throughout the water column) nor wholly baroclinic (correlations would change sign between the upper and lower points of the water column. A modal decomposition of the data and the computation of cross spectra between the time series at various levels have not yet been performed.

The dominant periodicity in the energetic periods of record ($\sim$ 15 days) is much longer than the synoptic periodicity of the meteorological forcing ($\sim$ 3-5 days) and is thus likely to be determined by the dimensions, stratification and bottom topography of the N. Rockall basin.

Both the minimum period for barotropic Rossby waves ($\sim$ 12 days) and the period of the internal seiche mode of the N. Rockall trough, assuming a diameter of the order of 200 km ($\sim$20 days) are of the same order as the observed oscillations. For both of these types of motion the horizontal wavelength would be large (of the order of, or greater than the basin diameter) and thus one would expect high correlations between different sites around the basin. This is not found (D.J. Webb Pers. Comm). Thus there remains a problem of interpretation of the cause of the dominant oscillatory motions.

TABLE 1

	T200	T600	T1000	T1500
T200	1.0	0.91	0.42	0.45
T600	0.91	1.00	0.49	0.61
T1000	0.42	0.49	1.00	0.45
T1500	0.45	0.61	0.45	1.00

	E/N200	E/N600	E/N1000	E/N1500
E/N 200	1.0/1.0	0.94/0.97	0.61/0.72	0.22/0.24
E/N 600	0.94/0.97	1.0/1.0	0.68/0.72	0.30/0.27
E/N 1000	0.61/0.72	0.68/0.72	1.0/1.0	0.15/0.08
E/N 1500	0.22/0.24	0.30/0.27	0.15/0.08	1.0/1.0

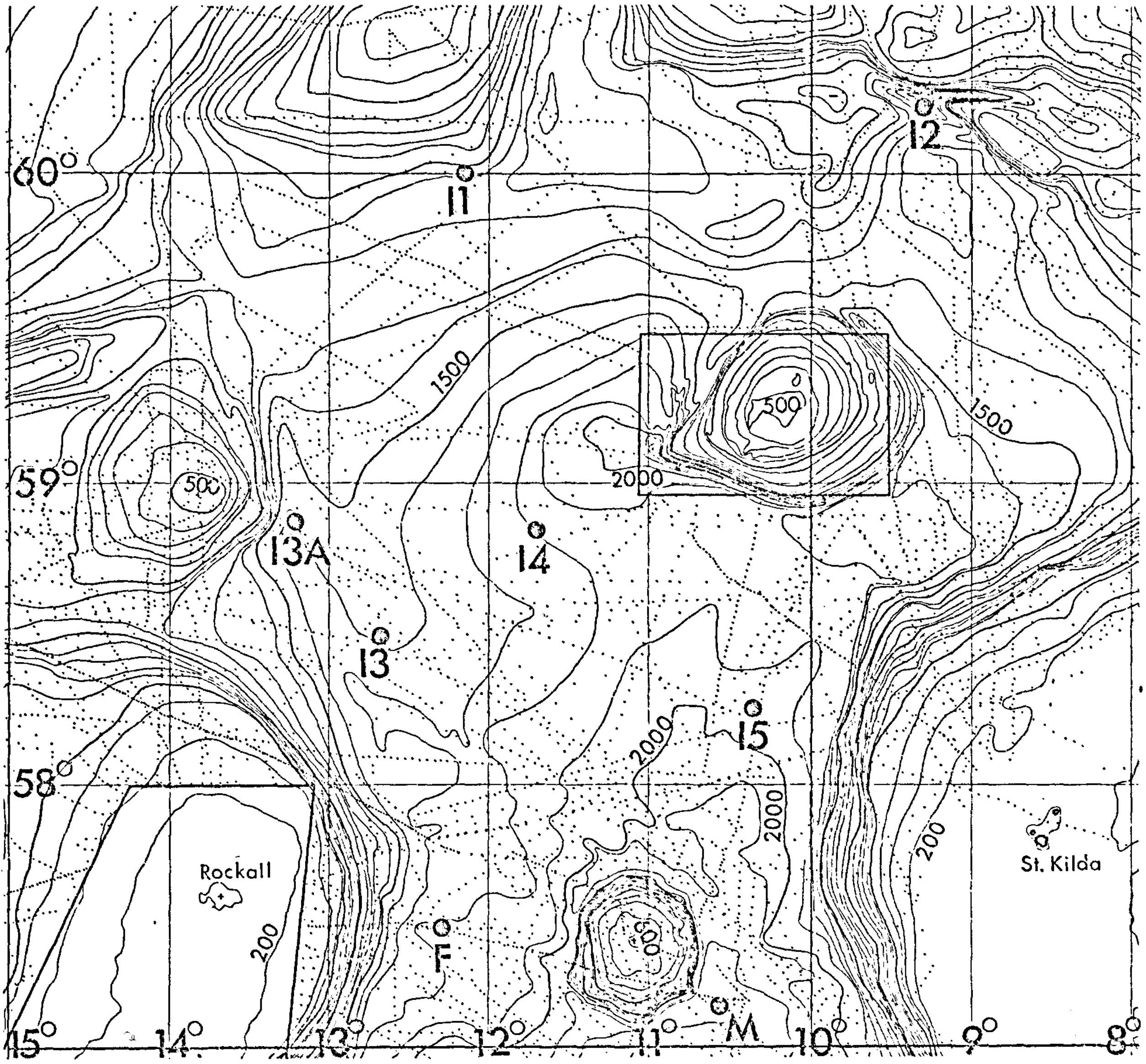

Fig. 1 Bathymetry of N. Rockall Trough

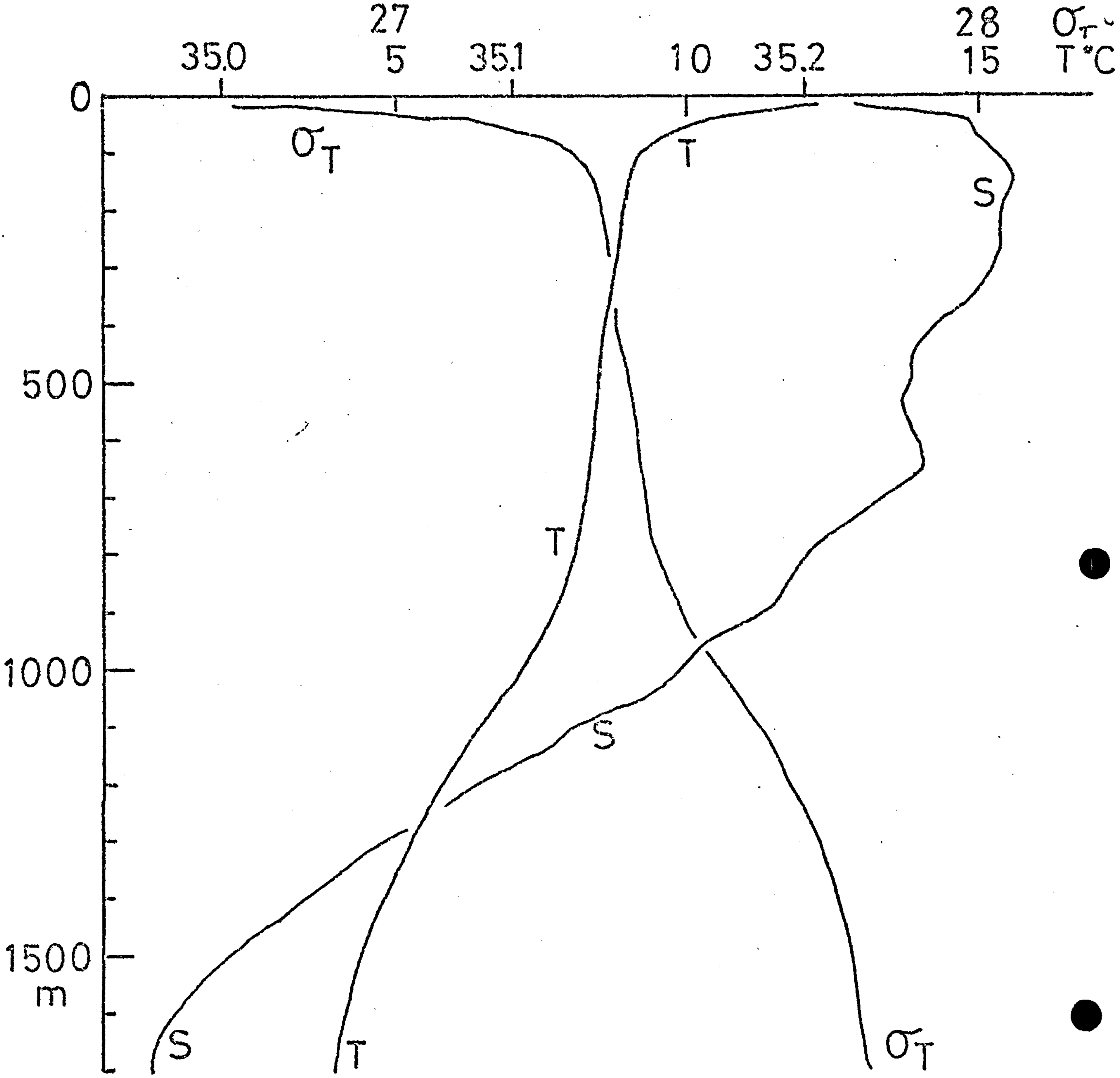

Fig. 2 Summer hydrographic data near I4

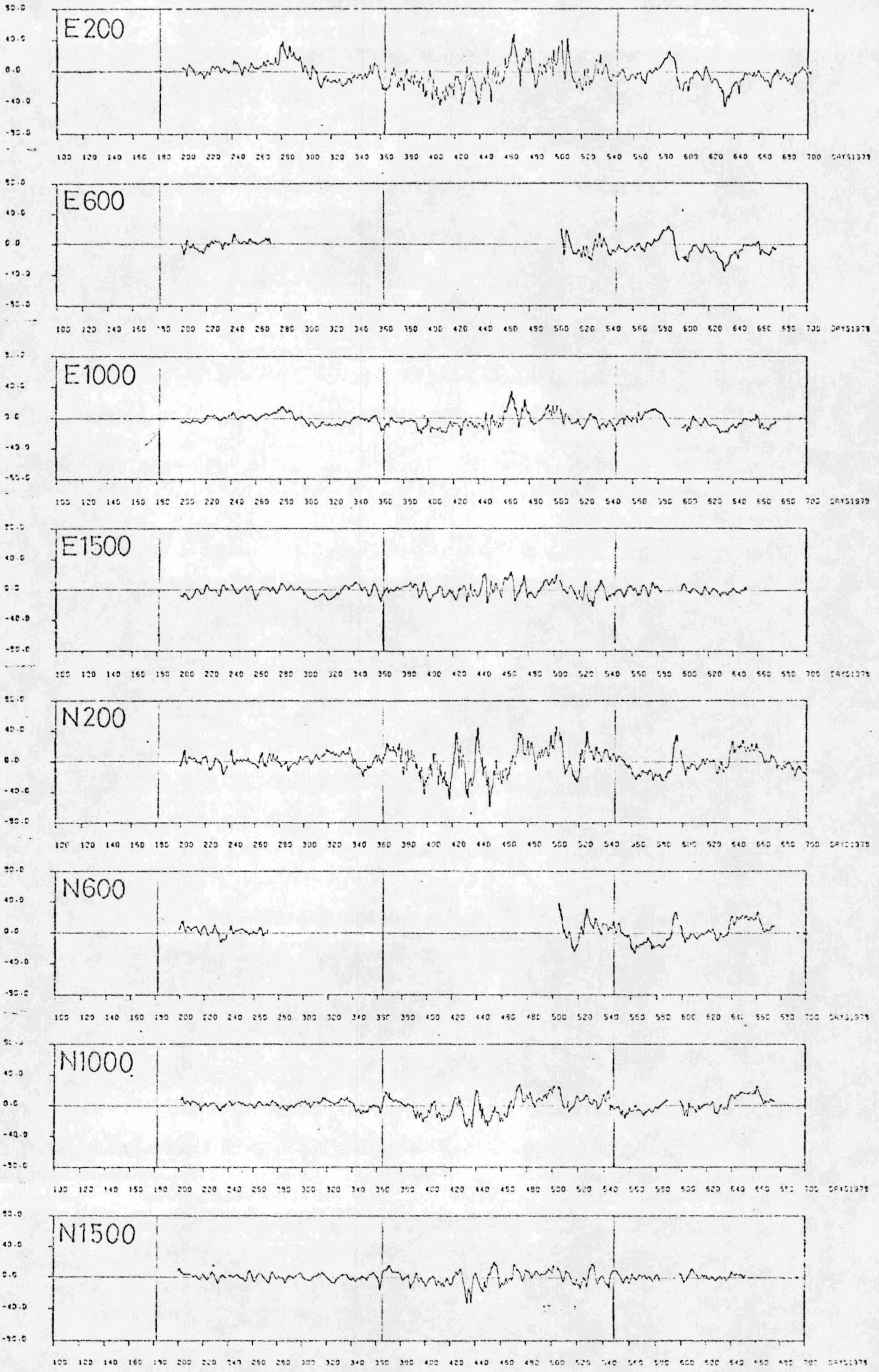

Fig. 3 Time series of velocity components from I4.

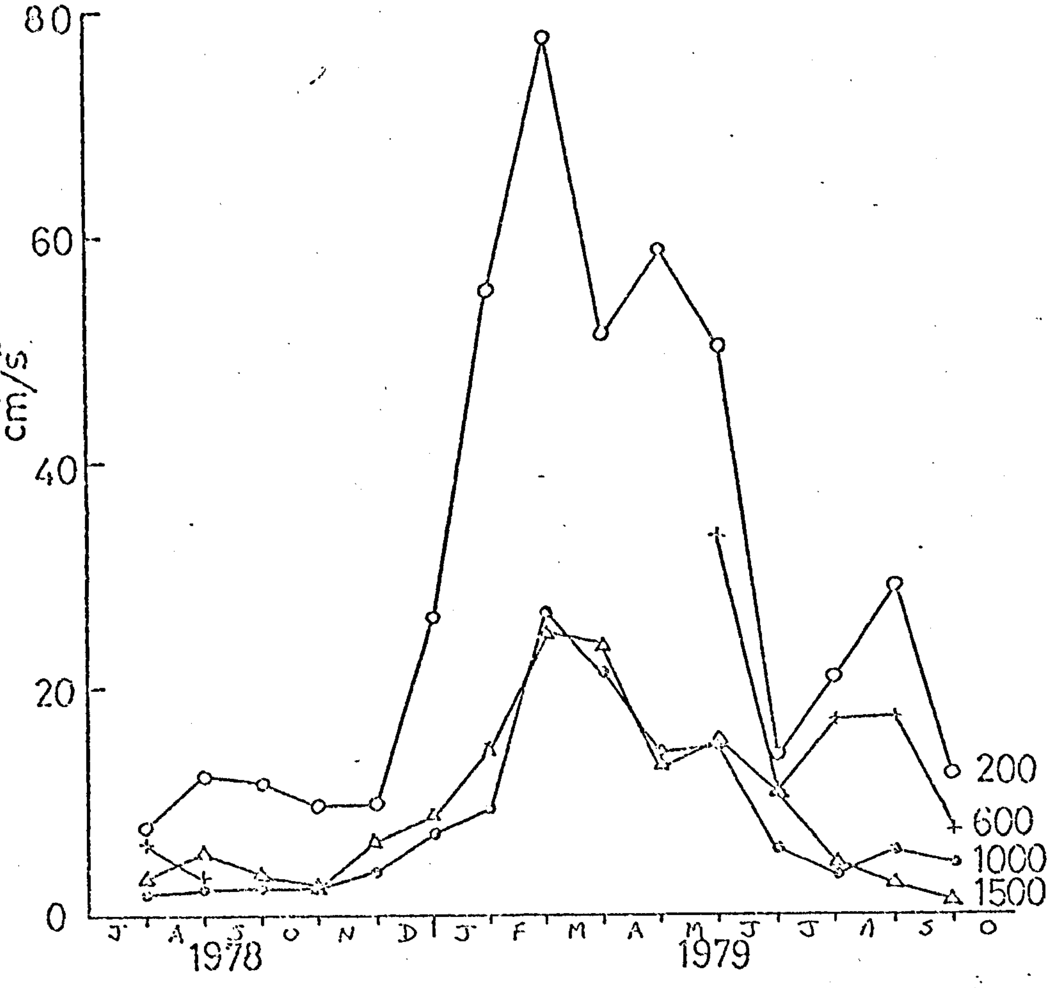

Fig. 4 Kinetic energy in frequency band from 3 to 30 days

o 200m + 600m ◦ 1000m △ 1500m

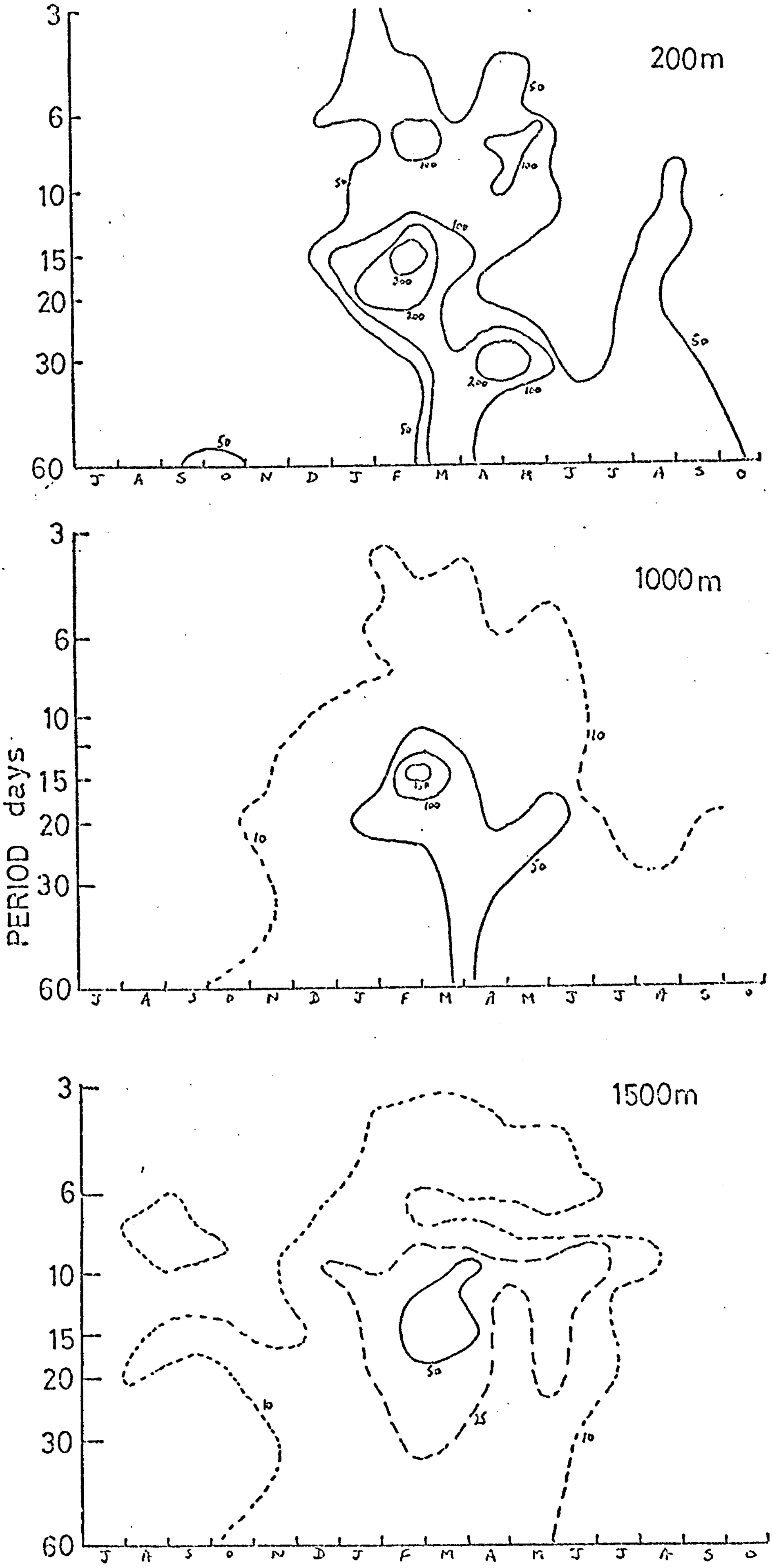

Fig. 5 Development of velocity spectra from July 1978 to October 1979