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Microseisms of 28-29 December 1998

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Abstract

Microseism records taken at Menai, Anglesey, showed a very narrow frequency band centred on 0.125 Hz which appeared unchanged in frequency for over 24 hours. It was not found possible to relate this to any sea wave activity off the coast of the British Isles as this time. When, however, the North Atlantic Weather Charts were referred to, there were two strong storms, one off Newfoundland and one south of Iceland. The Newfoundland storm moved rapidly eastwards until it arrived at a point where it could be intercepted by waves coming from the Iceland storm which had been stationary. A wave prediction model was used to estimate the three dimensional frequency-direction spectra over the relevant areas. This showed that there was substantial interference caused by waves moving in opposite directions over a considerable area, from $15^0 - 25^0$ longitude and $45^0 - 50^0$ latitude. The wave interference effect could be measured by taking the product of the spectral densities at each end of all the azimuths involved. The results showed a strong correspondence with the observed microseism frequency spectra, giving a similar narrow band of unchanging frequency but with the double frequency being a little higher than the observed value of 0.125 Hz.

pp 295 - 314

1.0 Introduction

It has been known for a long time that there is a close connection between microseisms of frequency 1 to 10 Hz and sea waves caused by ocean storms. This was fist noticed by Wiechert (1905) and in 1945 Bernard found hat there was a two to one relationship between wave and microseism periods. A sound theoretical basis was given to the relationship by Longuet-Higgins (1950) who showed that when two wave trains of the same or nearly equal frequency meet head-on, there is a second order effect which has twice the wave frequency and does not vanish with increasing depth when the frequencies are equal and only very gradually when the frequencies are nearly equal. The resulting wave number would be he difference between the two primary wave numbers and so would be very small and correspond to a large wavelength which would be comparable with that of a seismic wave of the same frequency.

Such waves can occur because of three possible causes, (1) when waves get reflected off coast; (2) when a storm in mid-ocean moves in such a way that waves generated in the southern and northern parts can subsequently meet and (3) when waves from two different storms meet.

It is clear that the predominant effect is cause (1) as it was shown by Darbyshire (1998a, 1998b) that r.m.s amplitudes of sea waves recorded near Skomer Island off the coast of Pembrokeshire and the r.m.s. amplitudes of the vertical component microseisms recorded at Menai Bridge, Anglesey, every six hours for nearly six months showed a correlation of 79%. This correlation was quite remarkable as microseisms would correspond to the combined effect of waves spread over a wide area rather than at one point. The seismograph was a Willmore one with constant sensitivity from 0.1 to 1.0 Hz.

2.0 Microseisms of 28 – 30 December 1998

There were very large microseisms in December 1998. No wave records were available during this period and use had to be made of a wave prediction model due to the author and described by Elliott (1986). During this month, the correspondence between the predicted wave values and the microseism observations was on the whole satisfactory but there was some activity during the 28th to the 30th which could not be related to coastal waves predicted near the coast of Cornwall which was near the original recording site. Figure 1 shows a comparison of microseism r.m.s values and the corresponding values predicated for he waves. There are high coastal waves which reached a maximum at 26/12 0600 and had subsided by 28/12 and these were followed by another set which peaked at 29/12. The microseisms show corresponding peaks but also show a smaller rise in value between the two large ones. This does not appear at first sight to be very significant but it coincided with a very narrow band of frequencies which is shown in Figure 2 on the left, where the frequency spectra are shown every three hours from 28/10.30 to 29/0730. The narrow band of frequencies has a frequency round 0,125 Hz (8 secs.) and starts at 28/10.30 where it is mixed up with the remains of the first large storm and then it exists on is own until 28/19.30 and then gets mixed up with the forerunners of the second atom. The peak can, however, clearly identified throughout. It was not possible to relate this band to any coastal activity although further predictions were made for various points from Land's End to the Scottish coast. The band had the same frequency throughout and did not show the dispersive effect shown by coastal waves where the longer period waves are followed by the slower shorter period waves.

3. The Effect of wave interference

It was decided to investigate if there was any effect due to ocean wave interference due to (2) or (3). Two weather charts are shown in Figures 2 and 4. The first for 27/12 shows a strong storm to the south-west of Newfoundland, and another strong storm south of Iceland. The second chart for 28/18 shows that the Iceland storm is roughly the same position but weakened whilst the other storm has moved quickly across to centre between the longitudes of Greenland and Iceland and be in the right position to meet the high waves caused by the Iceland storm when it was at is strongest. It is clear that the winds in the north-eastern part of the southern storm would produce waves which would be running against those coming from the north.

It would be ideal to obtain by observation direction-frequency spectra for these waves but these are not available and it would be very difficult to obtain them as the wave heights in the southern storm reached heights of 18 metres. Use had then to make of the wave prediction model already mentioned. This has its limitations as it has never been tested for these conditions but it should be good enough to give some idea of the state of affairs.

The predicted spectra give the energies for each 2 seconds period and 22.5^0 direction to 18 seconds and 360^0, thus giving 63 estimates for one. For each period interval, the energy for 22.50 was multiplied by the one for 202.5^0 and so on until that for 180^0 was multiplied by that for 360^0. These were added together. This procedure was followed for all the period values and the total sum for all periods determined. It turned out that the interference effect was more marked for periods of 12 seconds and above. This procedure was followed from 28/00 to 30/06 for all the positions shown in Figures 5 to 14. The effect was very small at 28/00 but increased considerably at 28/06 when a value of 0.204 was found at 47.5^0N, 30^0W and the maximum values were found at 28/18 at 47.5^0N, 25^0W, 0.65 and there was a similar value at the same place at 29/00 and a value slightly less, 0.545 at 29/06. The effect gradually decreased until 30/00 when the maximum value was found at 52.5^0N and 30^0W and was 0.133. The energy values refer to the position at the south-eastern corner of the square.

Figure 16(a) shows the microseism energy values from 28/00 to 30/06 and Figure 16(b) shows the total sum of all the wave interference values for all the locations at each time as shown in Figures 5 to 14 and Figure 16(c) shows the predicted coastal wave energies for the same times. The wave energy shows a steady decrease from 28/00 to 29/00 but there is a smaller increase up to a maximum between 28/06 and 28/12. The wave interference values show a maximum at 28.18 falling gradually until 29/06 and 28/12. The wave interference values show a maximum at 28/18 falling gradually until 29/06 after which there is a sharper decrease. The wave interference effect does coincide approximately with the subsidiary maximum effect found with the microseism values.

The total energies over all the position were sub-divided again into period intervals, to obtain period spectra over all directions. These were converted to frequency spectra so that they could be directly compared with the microseism spectra. These are shown on the right side of Figure 2, the corresponding predicted wave spectra off Cornwall are shown at the same time by the broken line. The wave interference figures do give a narrow frequency at the right time but the frequency is slightly lower than that of the microseisms. The spectra on the right of Figure 2 have been referred to twice the sea wave frequency to facilitate comparison with the microseisms.

A better idea of the nature of the directional distribution can be obtained by using polar diagrams where the length of a line is proportional to the energy at the direction of the line. Such diagrams are shown in Figure 17 for 29/06 and 29/12 for 10 seconds, 12 seconds and 14 seconds for position 47.5^{0}N, 25^{0}W. It is seen that the maximum effect tends to be with the azimuth at $45^0 - 67.5^0$, that is, in the direction of the British Isles.

4.0 Conclusions

The occurrence of waves, caused by two different storms meeting each other caused microseisms which were recorded on a seismograph at Menai Bridge, Anglesey. The cross product of the energies for opposite directions for each period and direction interval was worked out from predicted wave spectra at various positions. The total sum of these values over all positions at a given time was compared with the microseisms energy at that time.

Acknowledgments

I wish to thank the Meteorological Office for permission to publish Figures 4 and 5. I also wish to thank the staff of the Unit for Coastal and Estuarine Studies, for much encouragement and advice during the preparation of this paper and in the investigation described.

List of Figures

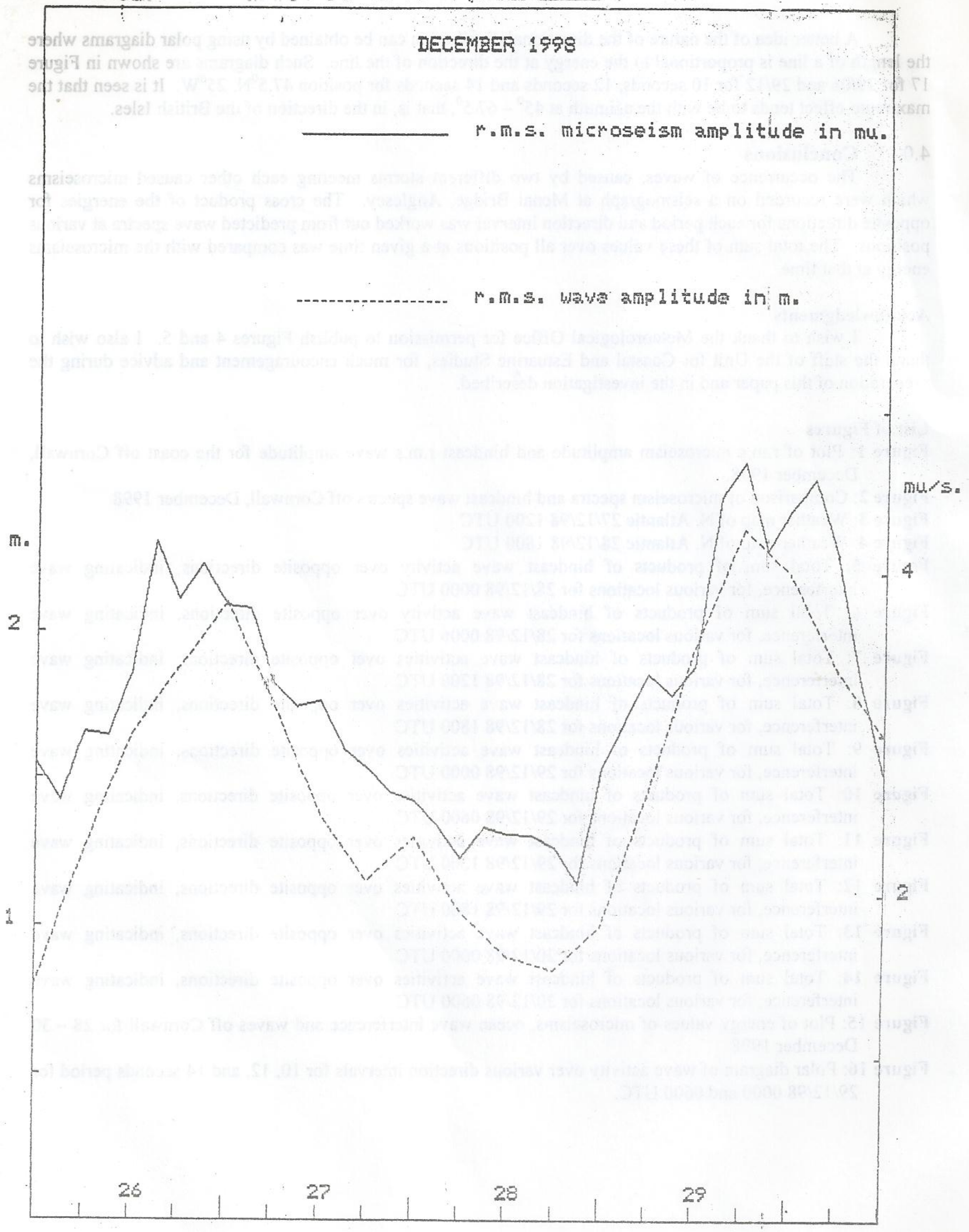


Figure 1 Plot of r.m.s. microseism amplitude and hindcast r.m.s. wave amplitude for the coast off Cornwall. December 1998.

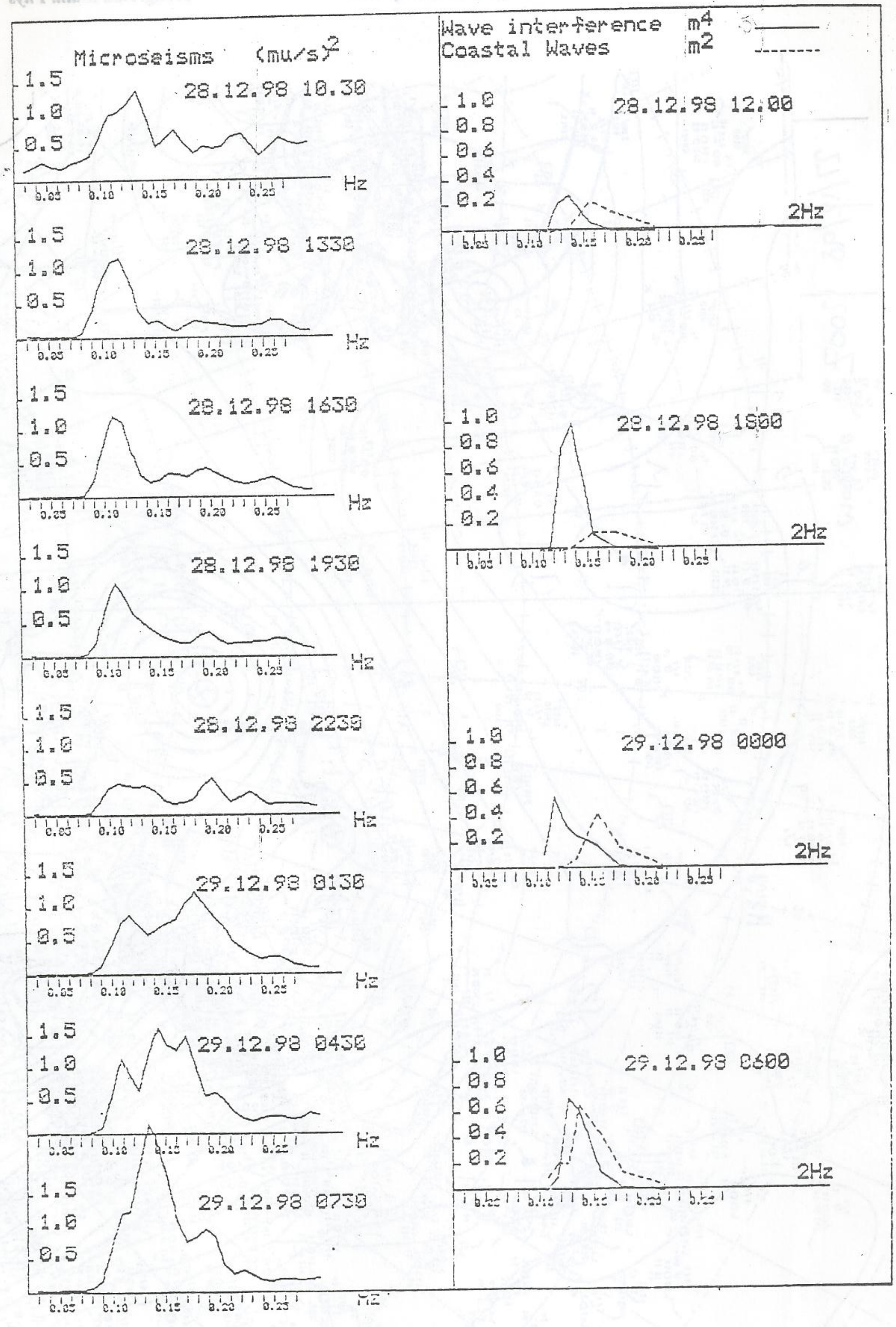


Figure 2. Comparison of microseism spectra and hindcast wave spectra off Cornwall.
DEC 1998

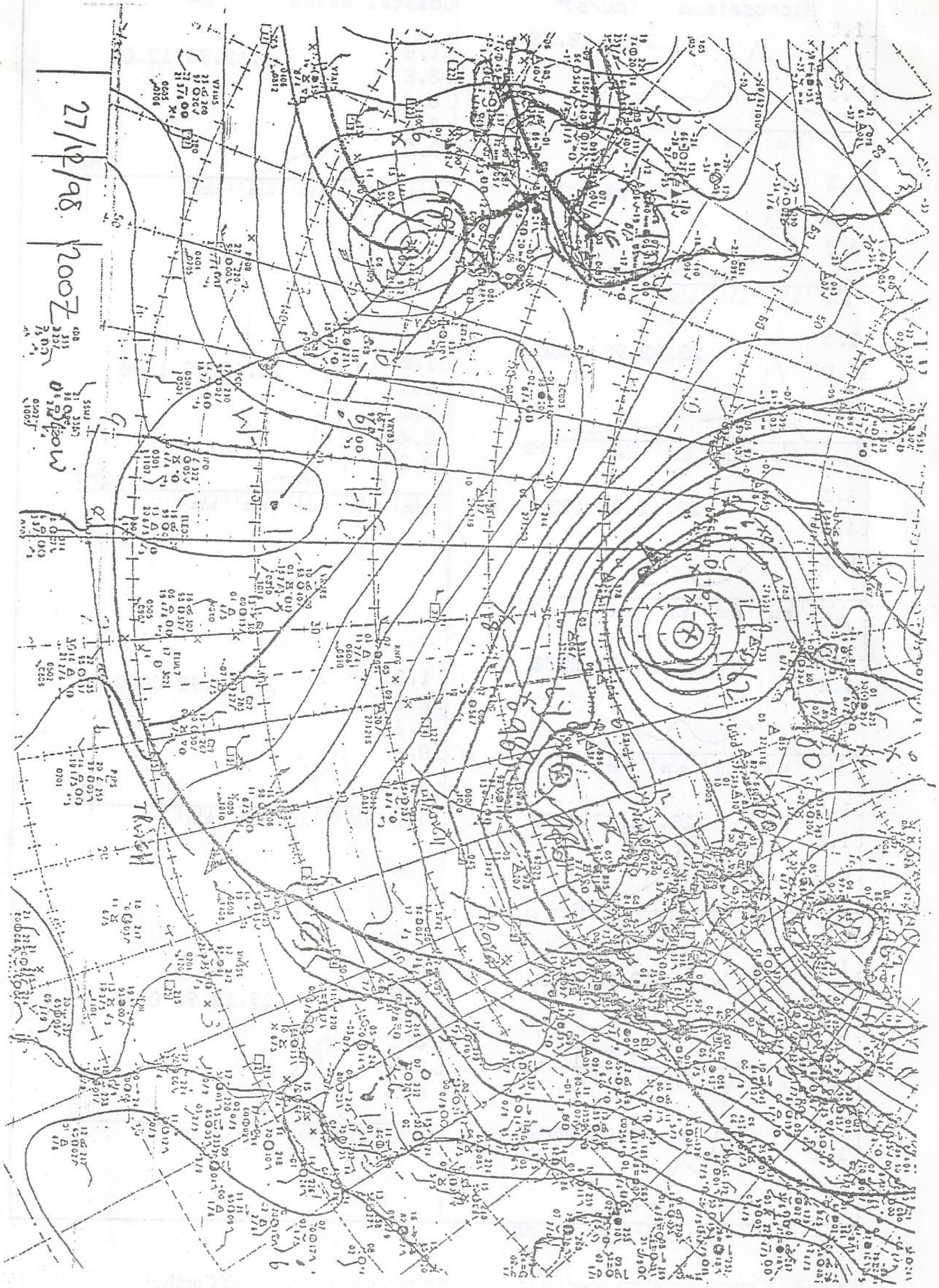


Figure 3. Weather Map of N.Atlantic. 27/12/98 1200 Z.

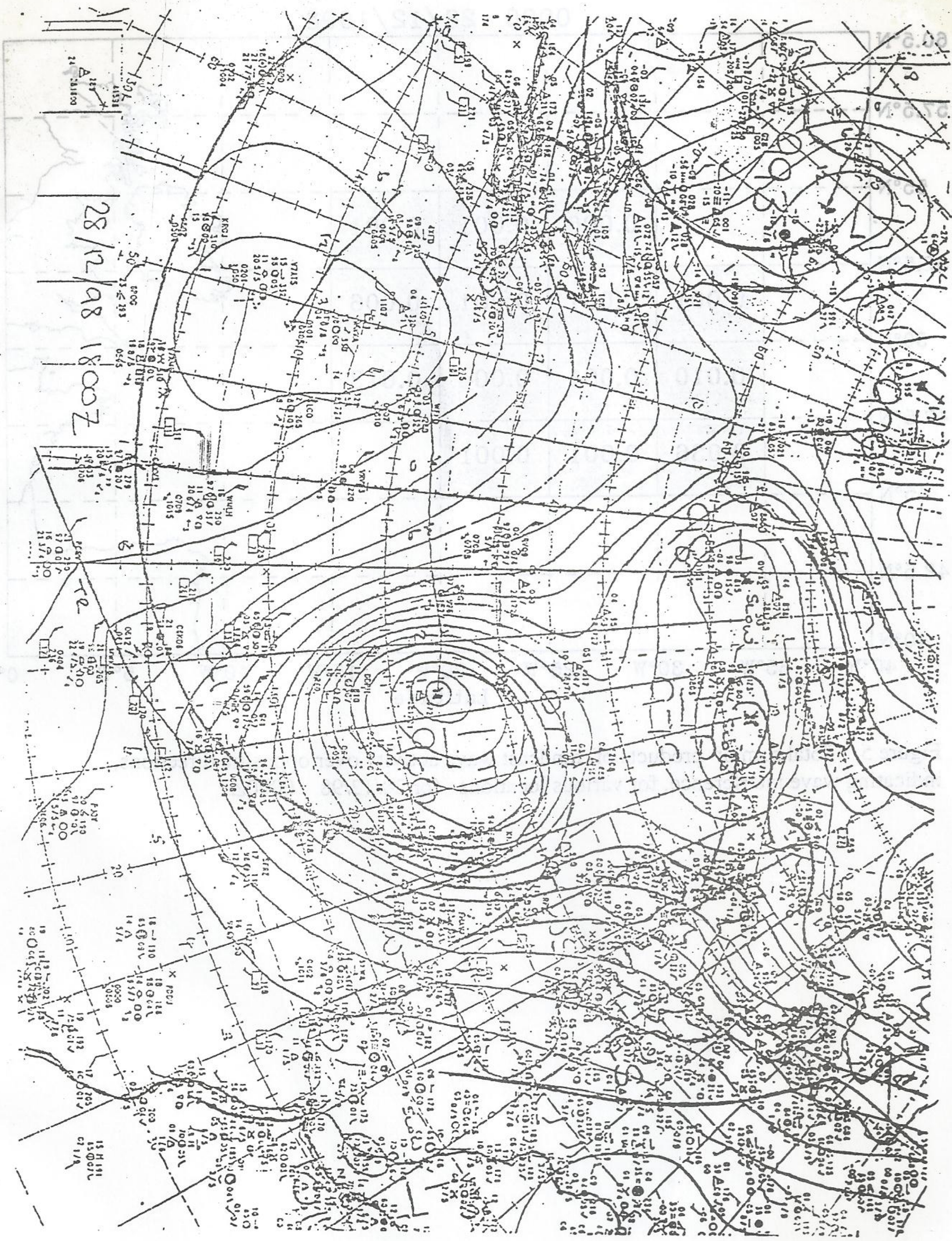


Figure 4. Weather Map of N.Atlantic 28/12/98 1800Z.

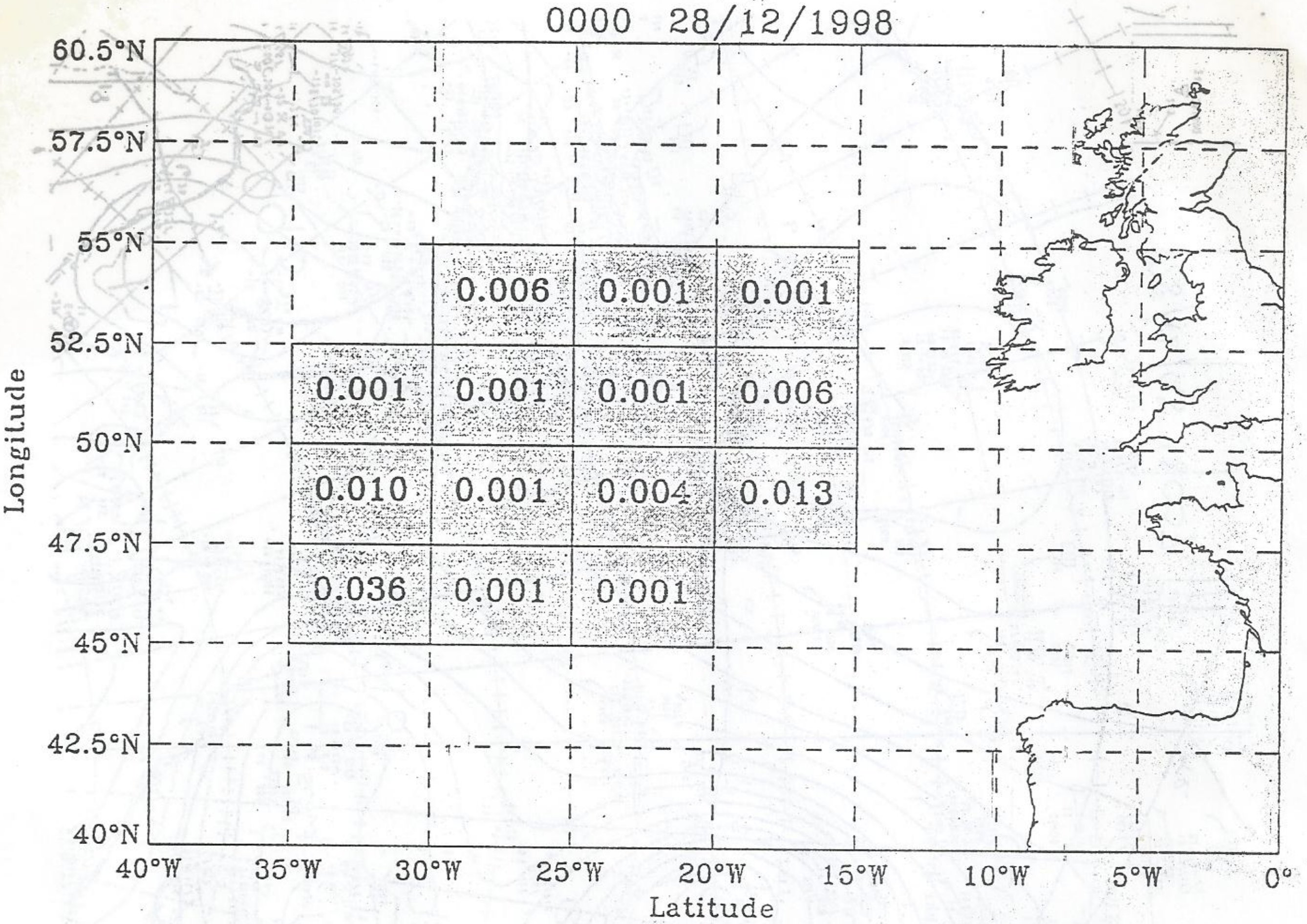


Figure 5. Total sum of products of hindcast wave activity over oppositie directions, indicating wave interference, for various locations for 28/12/98 0000Z.

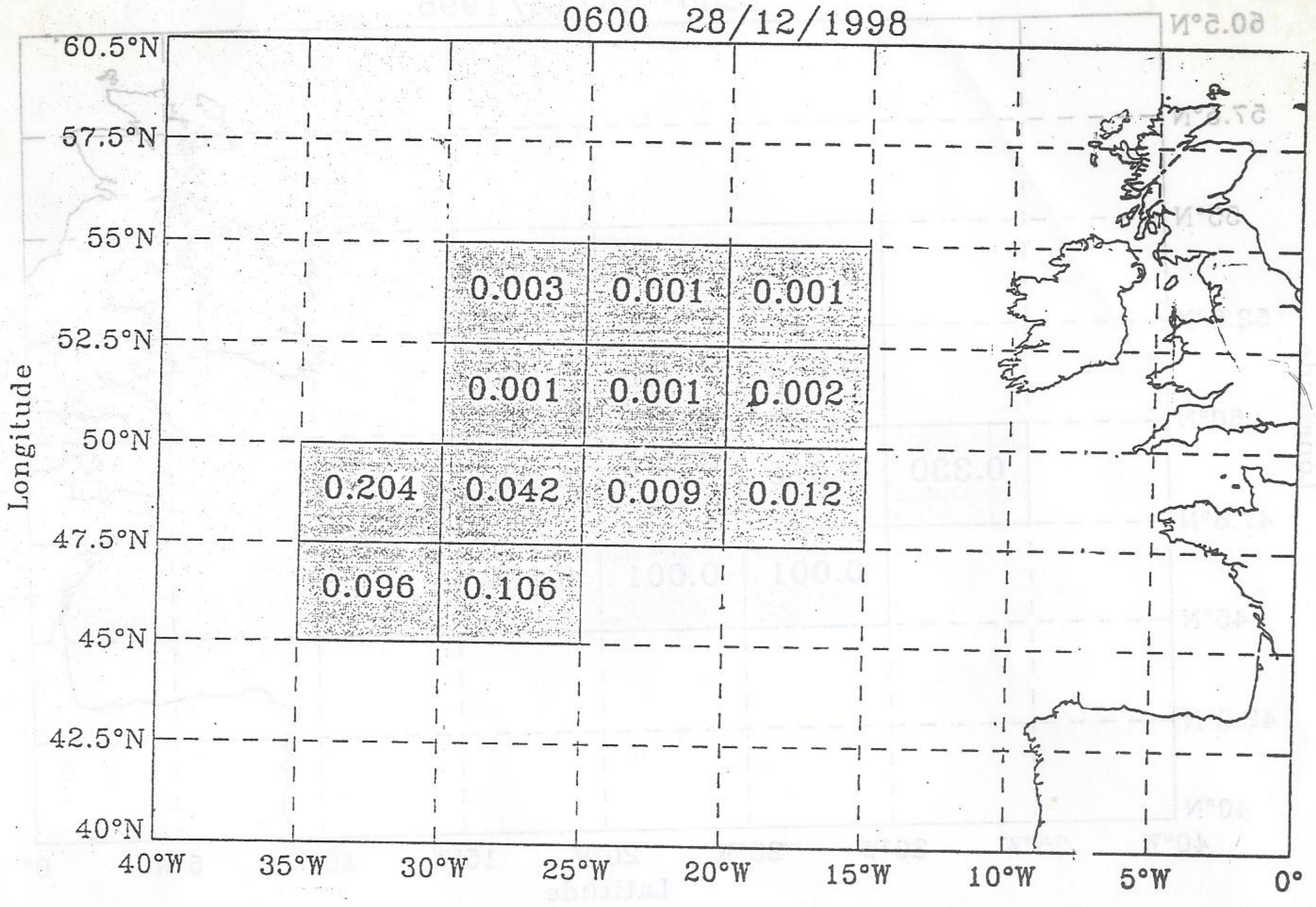


Figure 6. Total sum of products of hindcast wave activity over opposite directions, indicating wave interference, for various locations for 28/12/98 0006Z.

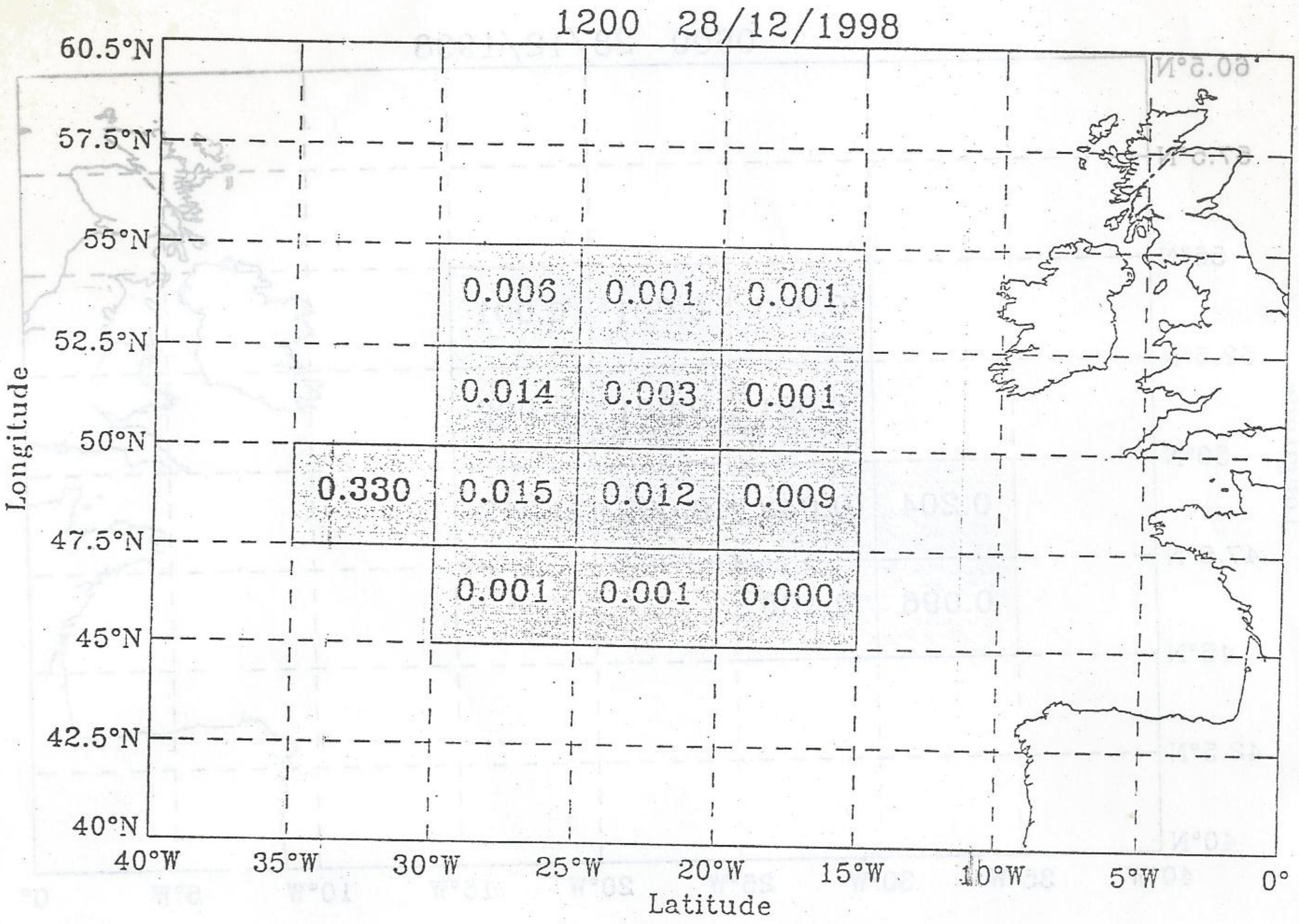


Figure 7. Total sum of products of hindcast wave activity over opposite directions, indicating wave interference, for various locations for 28/12.98 1200Z.

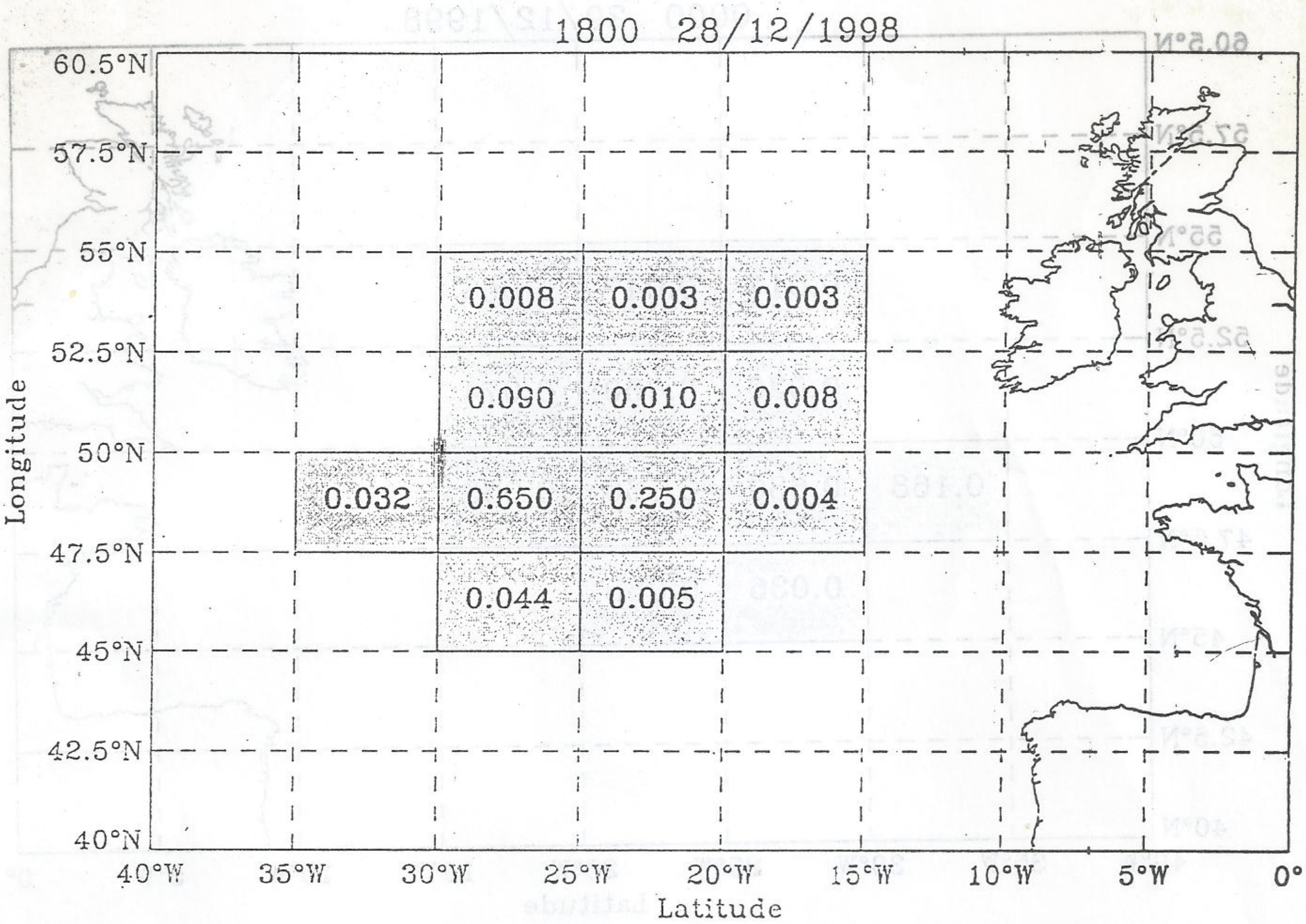


Figure 8. Total sum of products of hindcast wave activity over opposite directions, indicating wave interference, for various locations for 28/12/98 1800Z.

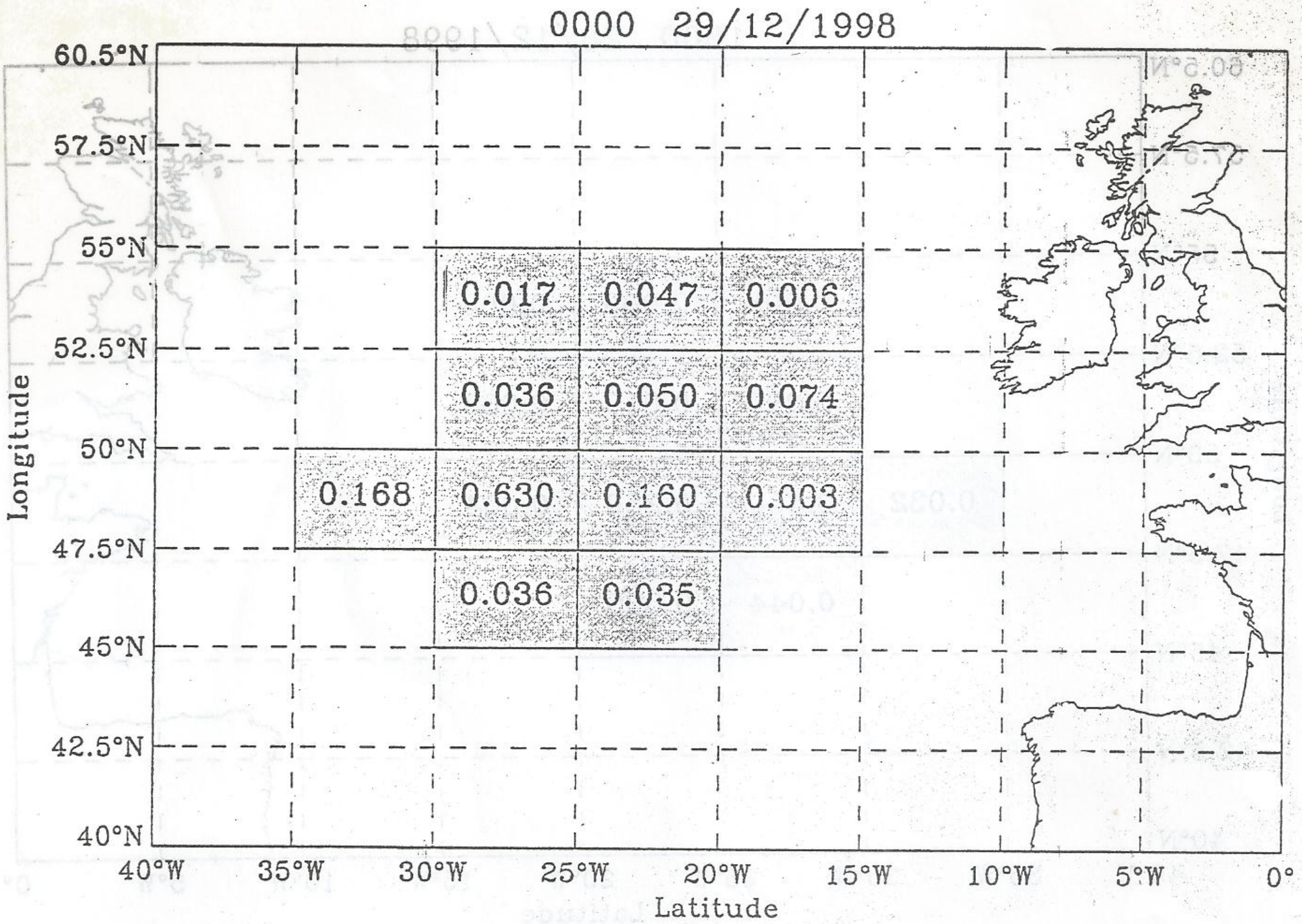


Figure 9. Total sum of products of hindcast wave activity over opposite directions, indicating wave interference, for various locations for 29/12/98 0000Z.

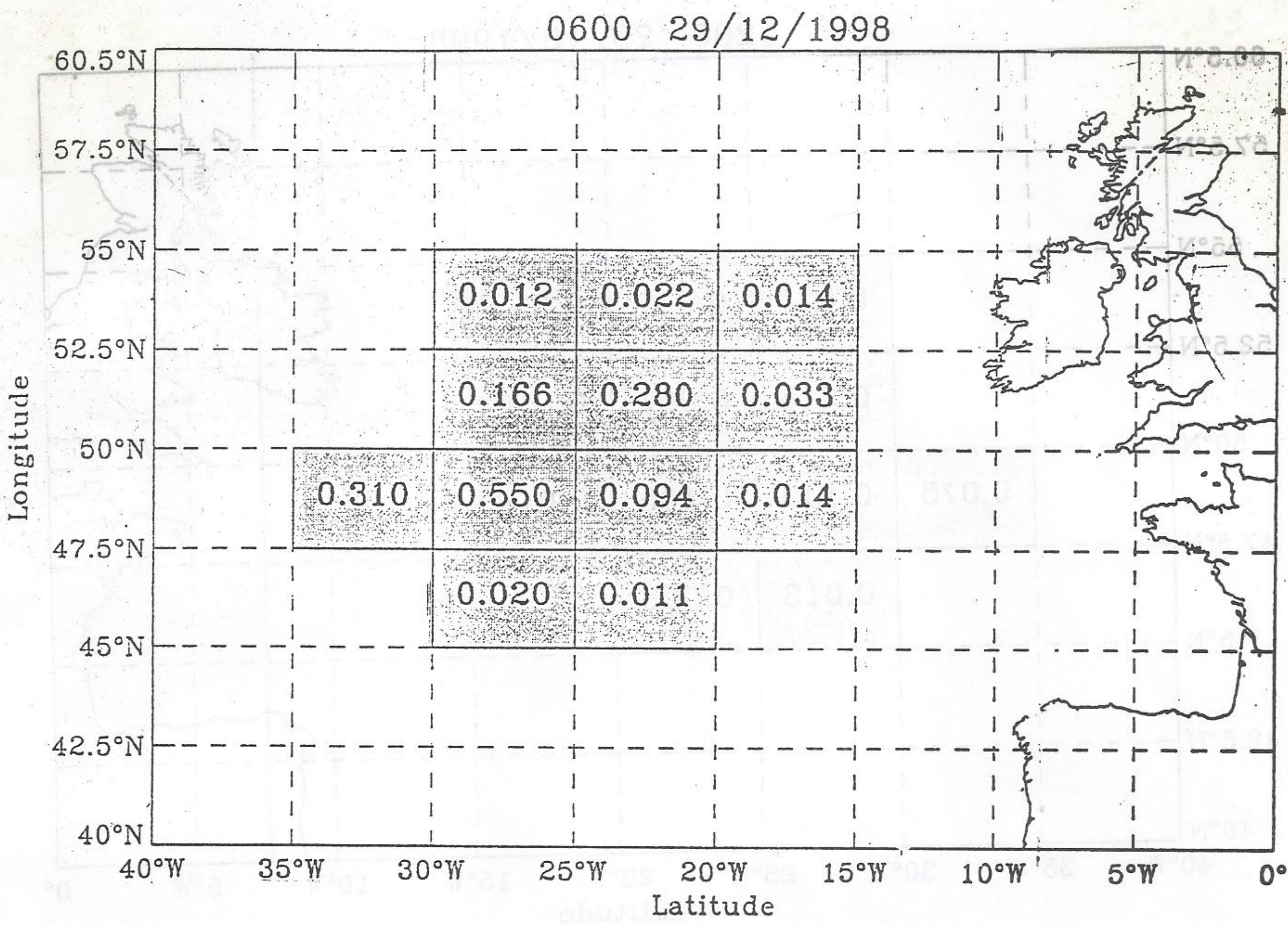


Figure 10. Total sum of products of hindcast wave activity over opposite directions, indicating wave interference, for various locations for 29/12/98 0006Z.

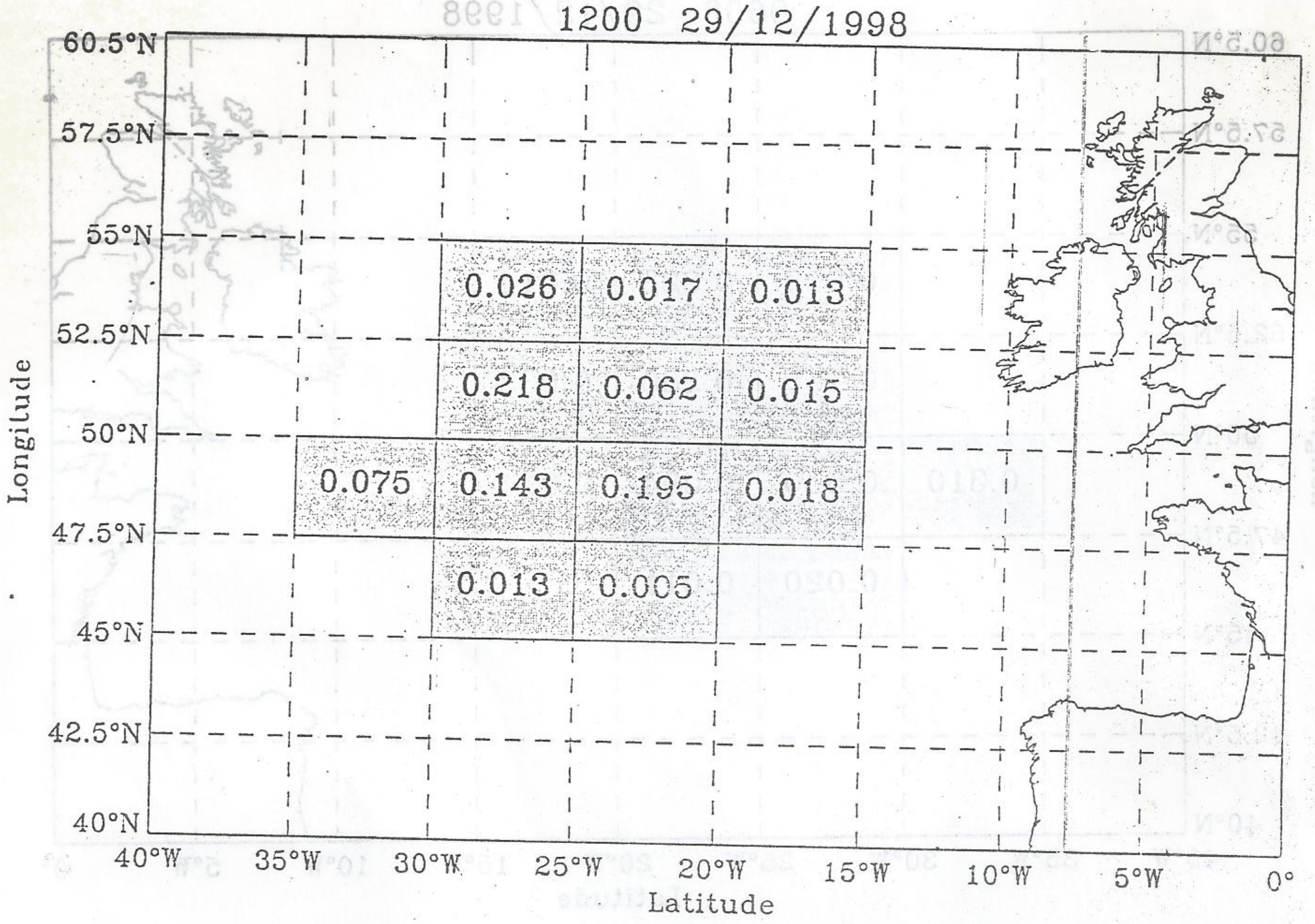


Figure 11. Total sum of products of hindcast wave activity over opposite directions, indicating wave interference, for various locations for 29/12/98 1200Z.

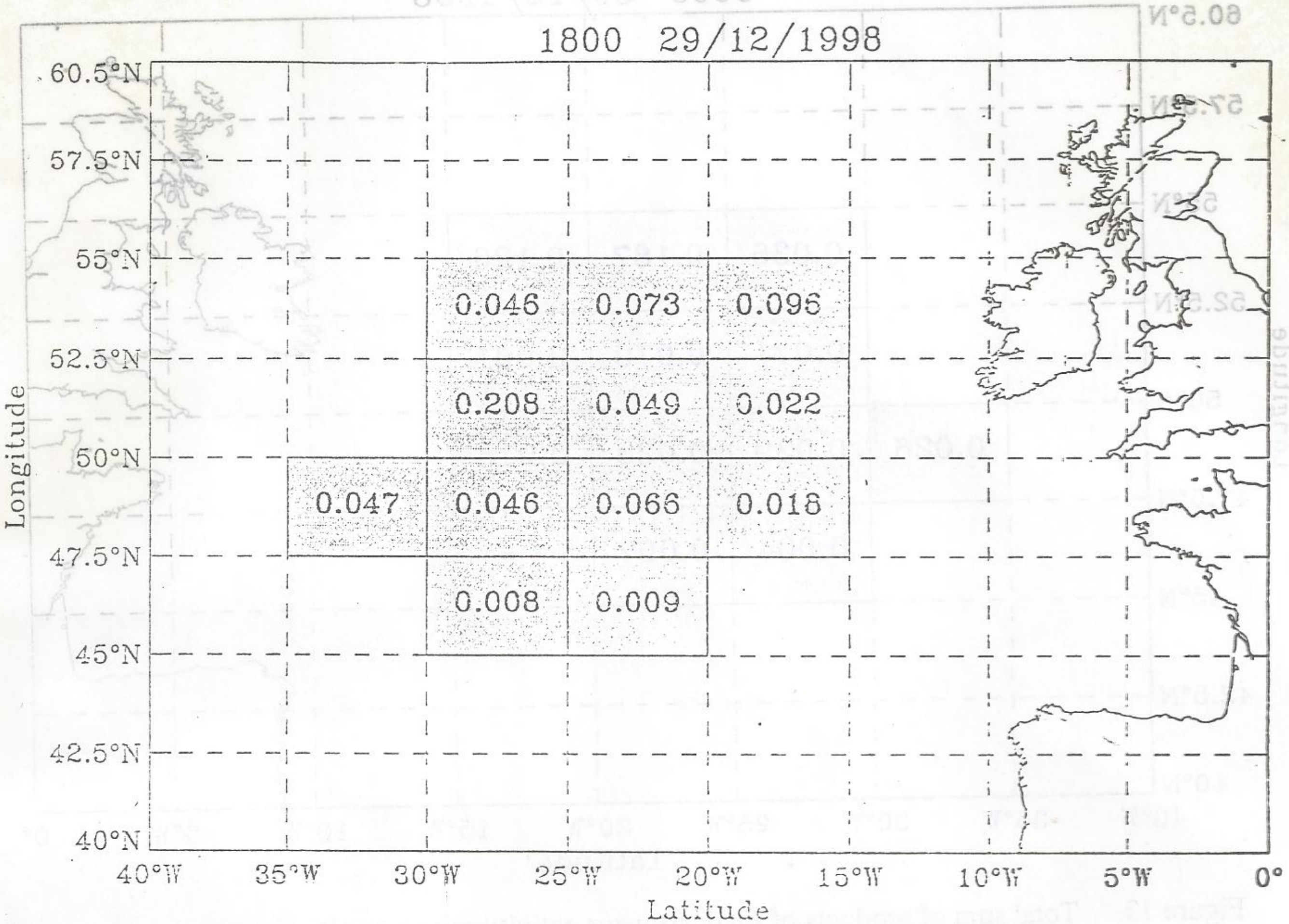


Figure 12 Total sum of products of hindcast wave activity over opposite directions, indicating wave interference, for various locations for 29/12/98 1800Z.

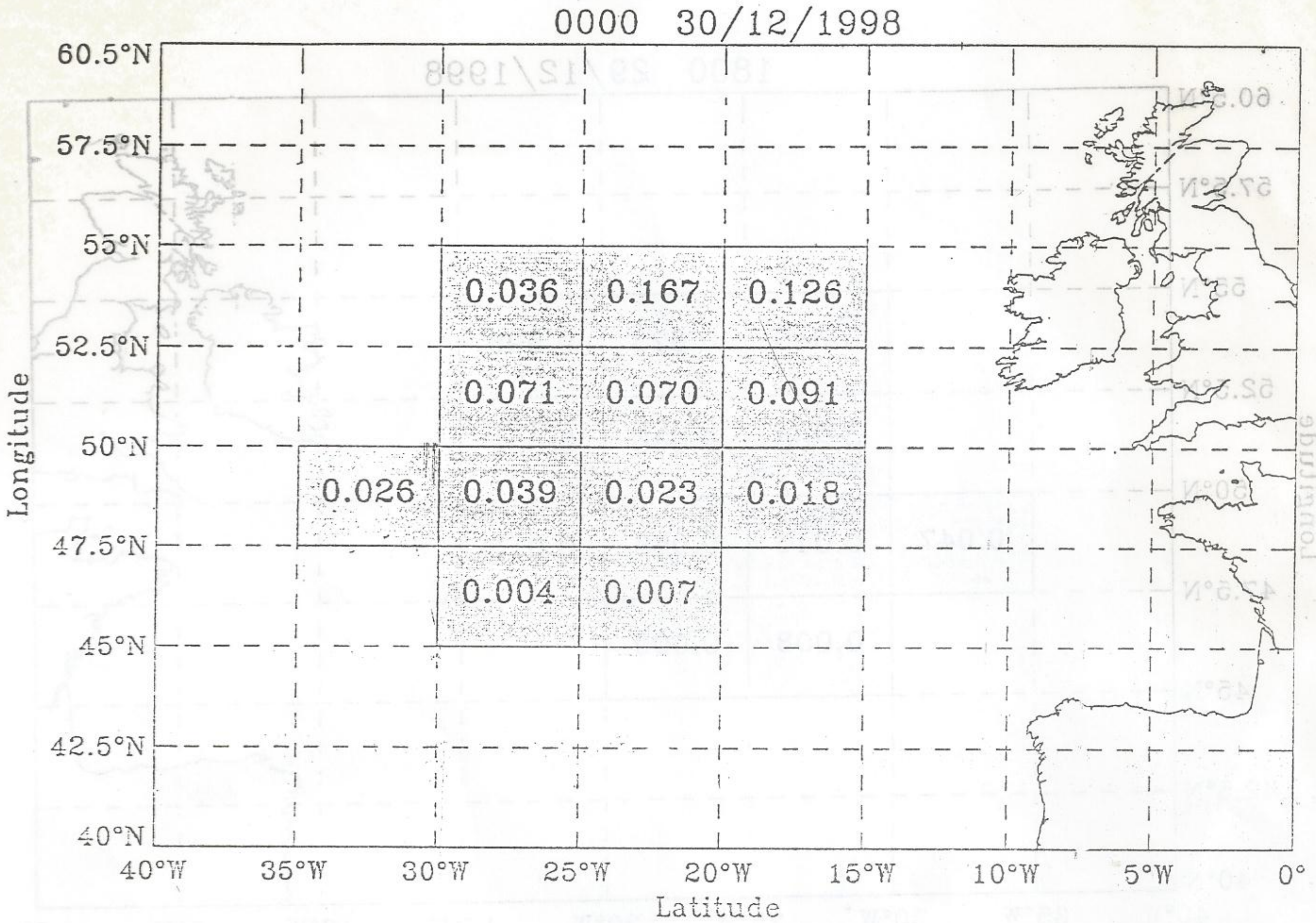


Figure 13. Total sum of products of hindcast wave activity over opposite directions, indicating wave interference, for various locations for 30/12/98 0000Z.

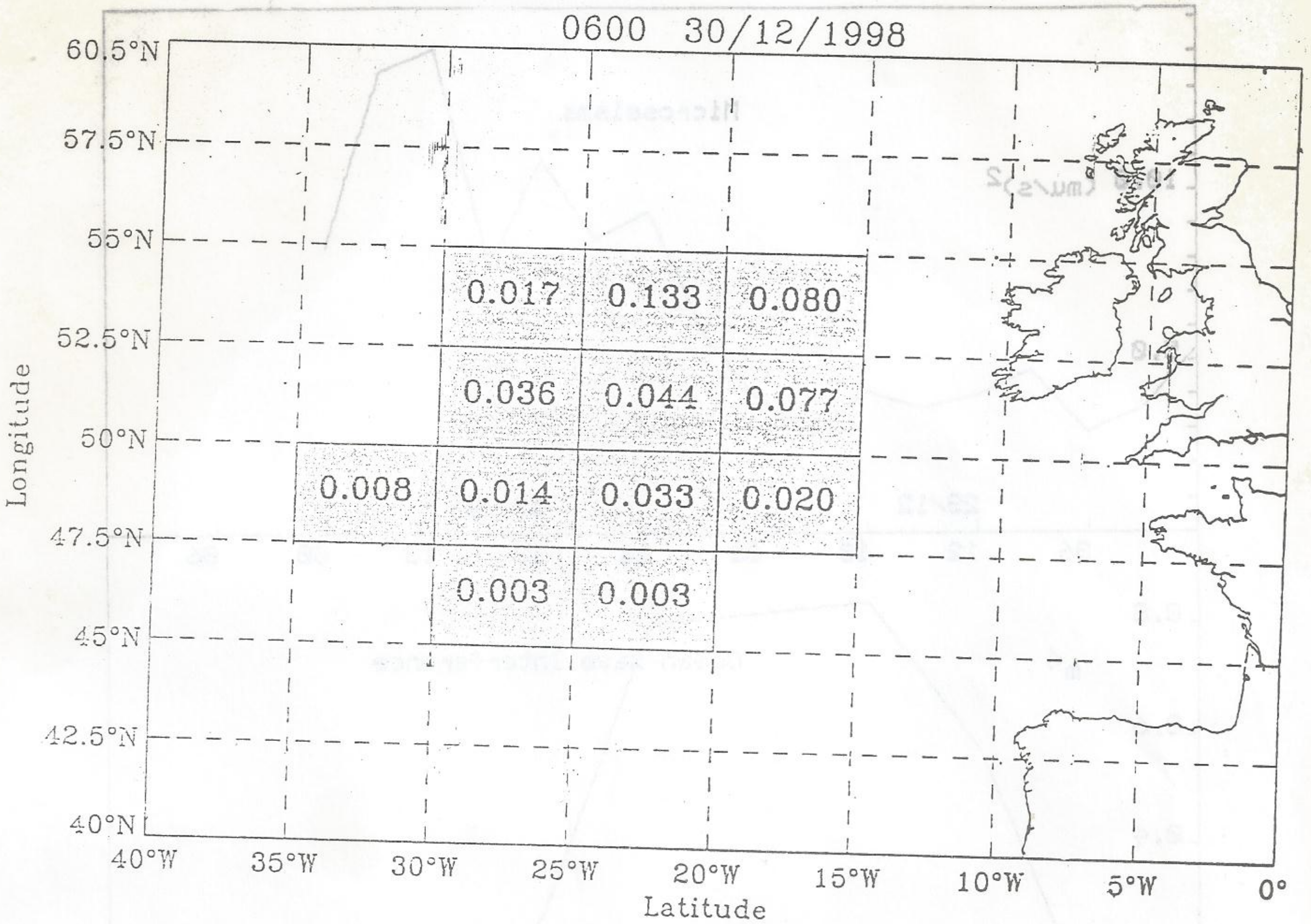
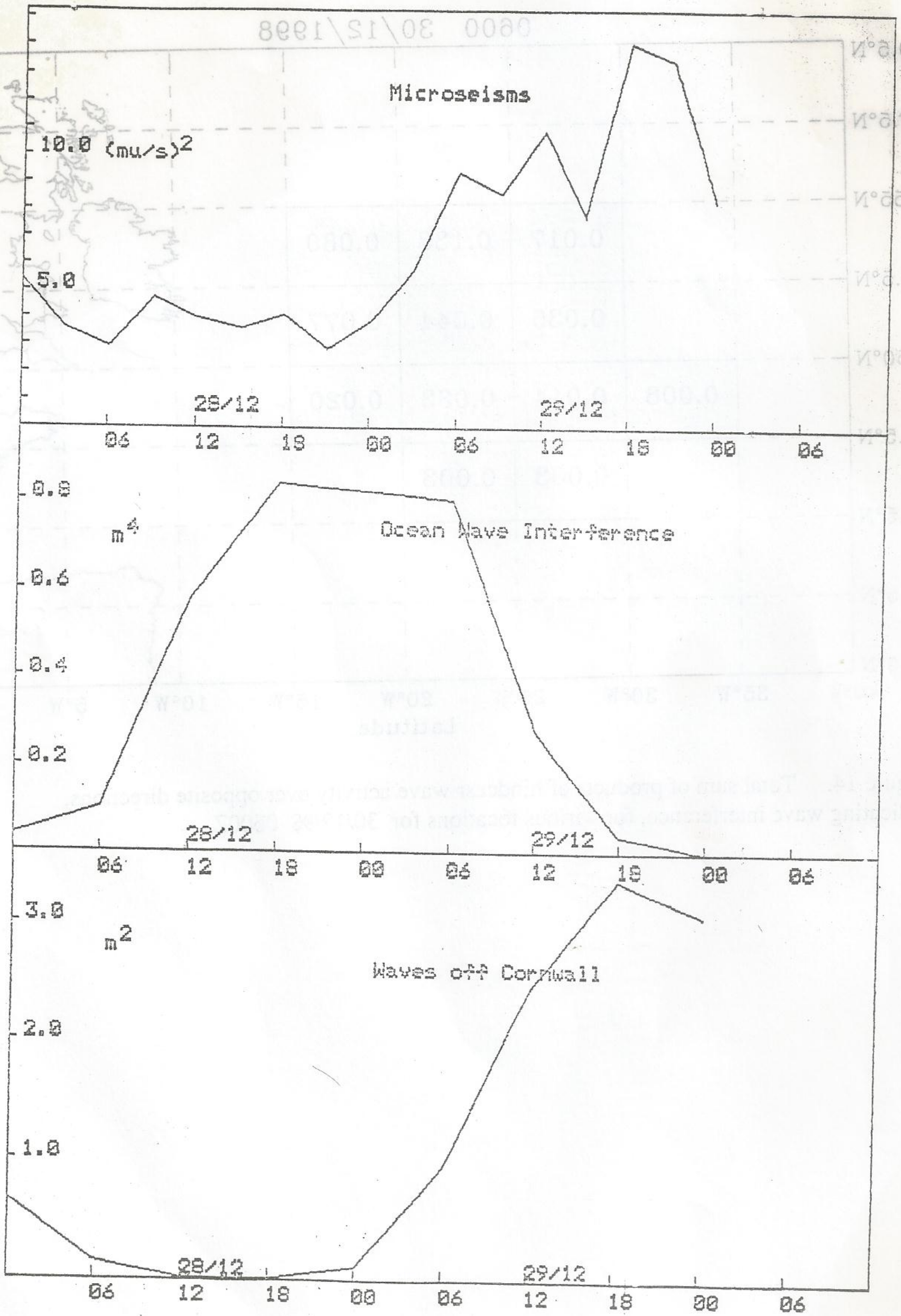


Figure 14. Total sum of products of hindcasr wave activity over opposite directions, indicating wave interference, for various locations for 30/12/98 0600Z.

Figure 15. Plot of energy values of microseisms, ocean wave interference and waves off Cornwall for 28-30 December 1998.



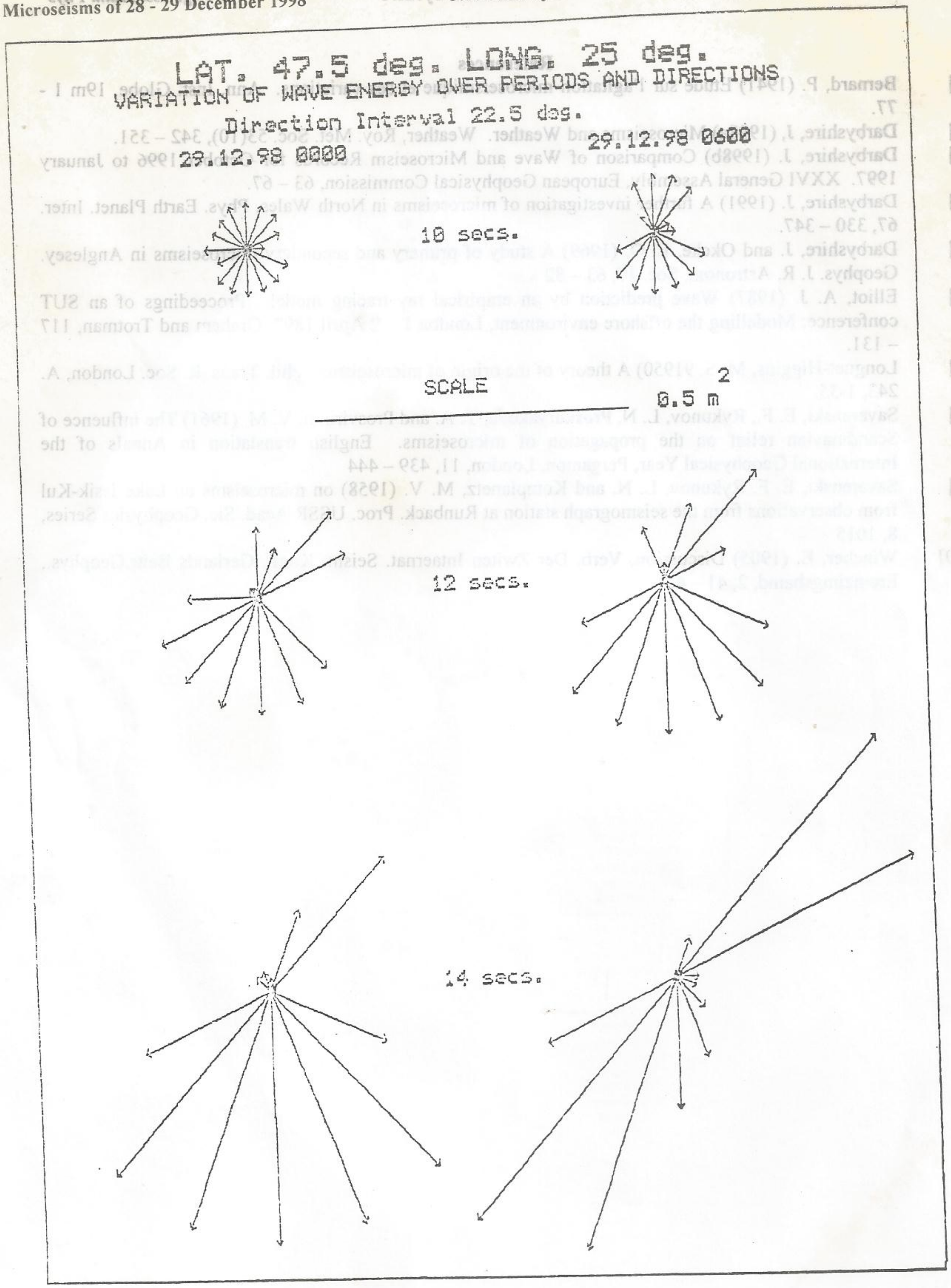


Figure 16 Polar diagram of wave activity over various direction intervals for 10,12, and 14 seconds period for 2912/98 0000 and 0600Z.

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