PORT AND OCEAN ENGINEERING UNDER ARCTIC CONDITIONS
TECHNICAL UNIVERSITY OF NORWAY

SPECTRAL COMPOSITION OF MICROSEISMS AND THEIR RELATION TO SEA WAVES

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ABSTRACT

Studies of microseisms at Oulu in Finland were based on power spectra computed from the ordinary recordings of vertical long period seismographs. The relation of microseisms and sea waves were studied comparing the microseism spectra with corresponding sea wave spectra computed from the recordings at Årviksand near Tromsø. The sea wave data and spectra based on the recordings at some weather ships in the North Atlantic were also used. Microseisms at the same and double frequency of the corresponding sea waves were observed. The development storms were considered using series of successive microseism spectra.

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INTRODUCTION

Microseisms, continuous vibrations of the ground, are generally accepted to be connected with sea movements. Wiechert (14) suggests that microseisms are generated by the impact of surf against steep coastal areas and they should occur at the same periods as the sea waves. Bernard (1) found that microseism periods are half those of corresponding sea waves. This was theoretically explained by Longuet-Higgins (8). He points out that the interference of sea waves travelling in opposite directions causes variations in the pressure at the bottom of the sea. These variations are big enough, even in deep water areas, to cause generation of microseisms. This interference should appear on coastal areas due to incident and reflected waves, or on the open sea, when similar wave trains from different storm regions meet. The spectral studies made by Haubrich et al. (5) from seismic and ocean wave recordings near San Diego, California, show microseismic waves of frequency the same and double those of corresponding sea waves. They called these types of microseisms primary, and double frequency microseisms.

The origin of microseisms recorded at Fennoscandian stations is most often argued to be on the Norwegian sea and coast. According to Båth (2, 3) the coastal effect is the major cause of the generation of Scandinavian microseisms, but a cyclone effect also exists. Nesse (9, 10) attributes all microseisms recorded at Bergen to Norwegian surf. Nesse and Sellevoll (11) compared the periods of microseisms at Bergen to the sea waves recorded at Alnes and Ferkingstad. They found ratios slightly lower than 0.5.

The analysis of direction of approach of microseisms reported by Jensen (7) indicates that the majority of microseisms arrive from the direction of the Norwegian sea or coast to the stations at Copenhagen, Scoresbysund, Barentsburg, Murmansk and Wyborg. On the other hand, Greenland stations Nord, Ivigtut and Godhavn record microseisms from the direction of the North Atlantic ocean (6, 7). Microseisms from North Atlantic storms can also be recorded at Fennoscandian stations, too. There is, however, no full agreement as to whether these are generated on the open ocean, on its continental margin or when the oceanic swell interacts with the Norwegian coast. The latter possibility is pointed out by Šanto (12), who attributes all cases of microseisms with long periods and small amplitudes recorded during IGY at Uppsala and Kiruna to the distant swell running from storm centers toward the Norwegian coast. He gives, however, no observations whether such a swell really exists at the times in question.

OBSERVATIONS OF MICROSEISMS AND SEA

In this study microseisms of Oulu are compared with sea waves at the Norwegian sea. The correlation of microseisms and sea waves can be studied by visual measurements made from simultaneous seismograms and sea wave records. This is demonstrated in fig. 1, where the maximum microseism amplitudes and corresponding periods in January 1966 are presented at the Finnish seismograph stations KEV (Kevo), OUL (Oulu) and NUR (Nurmijärvi) together with sea wave maxima at Årviksand. The location of these stations are shown in the weather maps. In several storms the amplitudes of microseisms and sea waves increase nearly simultaneously, the periods of microseisms being about half of the sea wave period. Microseisms at the stations OUL and NUR correspond each other well. At station NUR, however, the amplitudes are often smaller and the periods longer than at OUL, as can be expected for longer source distances. The considerable differences of the KEV microseisms might be attributed to different geographical and geological conditions. All these seismograph stations are situated on the Pre-Cambrian bedrock, but station KEV lies nearest the Caledonian mountain chain and the Norwegian coast. The bedrock at station KEV consists of migmatic rocks close to the boundary of granulite massive. Stations OUL and KEV lay on the quarzitic schist.

SPECTRA OF MICROSEISMS AND SEA WAVES

In order to get more information about the relation of microseisms and sea waves, power spectra were computed from the recordings of microseisms at OUL and sea waves at Årviksand. Fig. 2 and fig. 3 show examples of these spectra during the storms 1966 January 19-20 and September 20-22. Microseism spectra are taken 12-16 hours later than corresponding sea wave spectra, but the problem of time lag is not dealt with in detail. Both microseism spectra and sea wave spectra were computed according to the method of Southworth (13). The sea wave recordings available limited the sample length to six minutes. Sampling interval was one second and maximum lag number 40. Thus for the resolution used in spectral analysis the errors in peak frequencies should be less than 6 mHz. In each microseism spectrum one can find a main maximum at frequencies higher than 130 mHz and a minor side maximum in frequency band 80-100 mHz. At nearly the same frequencies as the latter peak in microseism spectrum appears the main maximum of sea wave spectrum. The main maximum in microseism spectra occurs at frequencies which are nearly twice these peak frequencies.

Table 1

Microseisms of OUL and sea waves of the Norwegian sea

	Microseisms		Sea waves
	Primary frequency	Frequency of the main maximum	Station, frequency of the main maximum (wave height)
1. Group			
a) 1965, Dec 18	75	157	Årviksand 75 mHz (0.4 m); Polar Front 77-91 mHz (9 m)
b) 1966, Dec 25	76	153	Ferkingstad 83 mHz (5.7 m)
c) 1967, Feb 06	63	136	Polar Front 67-77 mHz (7 m)
d) 1967, Feb 12	63	155	Årviksand 65 mHz (2.3 m)
2. Group			
a) 1963, Dec 06	88	175	Berlevåg 91 mHz (3.7 m); Polar Front 77-91 mHz (.6 m)
b) 1966, Sep 20	87	183	Årviksand 85 mHz (3.0 m)
c) 1966, Nov 29	93	195	Ferkingstad 95 mHz (4.7 m)
d) 1967, Oct 15	83	168	Polar Front 77-91 mHz (7 m)
3. Group			
a) 1966, Jan 19	83	203	Årviksand 83 mHz (3.3 m); Berlevåg 80 mHz (4.9 m)
b) 1966, Oct 02	108	227	Ferkingstad 111 mHz (3.3 m)
c) 1966, Nov 07	83	218	Ferkingstad 83 mHz (2.4 m)
d) 1967, Mar 08	75	210	Polar Front 91-111 mHz (4.5 m) Årviksand 63 mHz (0.2 m)

Table 2

Microseisms of OUL and ocean waves of North Atlantic

Date	Microseisms Primary frequency mHz	Double frequency mHz	Oceanic waves Frequency of the main maximum mHz	Weather ship
1966 Sep 06	55	118	55 (1	India
1966 Nov 16	58	125	52	Juliet
1967 Jan 23	60	117	55 (2	Alpha
1967 Feb 21	60	122	64	Juliet

(1 Ocean wave frequencies are obtained from the publication of Darbyshire and Okeke (4)

(2 Ocean wave spectrum on January 19

The development of successive spectra in fig. 3 shows considerable energy concentration at relatively narrow bands during the storm maximum. On the other hand broader sea wave spectra are accompanied by broader microseism spectra. More examples of microseism spectra with corresponding weather maps are shown in figures 4-6. The peak frequencies of the lower side maxima and main maxima are summed up in table 1. This table shows also the Norwegian sea wave frequencies observed at the weather ship station Polar Front (M) or at coastal stations Ferkingstad, Årviksand or Berlevåg. According to this table there is a good correspondence of primary microseism frequencies with frequencies of the Norwegian sea.

Besides these microseisms of Norwegian type our seismograph station sometimes records low frequency microseisms from North Atlantic storms. Fig. 7 shows microseism spectrum at OUL 1966 Nov 16

03 h together with simultaneous sea wave spectrum of North Atlantic waves at weather ship Juliet published by Darbyshire and Okeke (4). There is a good correspondence of peak frequencies of the North Atlantic sea waves and microseisms in this case. More examples of this correspondence are shown in table 2.

For better understanding of microseism sources at Fennoscandian area as well as for solving the problems of hindcasting and forecasting of microseisms and sea waves, it should be desirable to have more continuous registrations of the Norwegian sea available. A special value for both microseismic and oceanographic research on this field should have recording with seismometers placed on the bottom of the Sea.

ACKNOWLEDGEMENT

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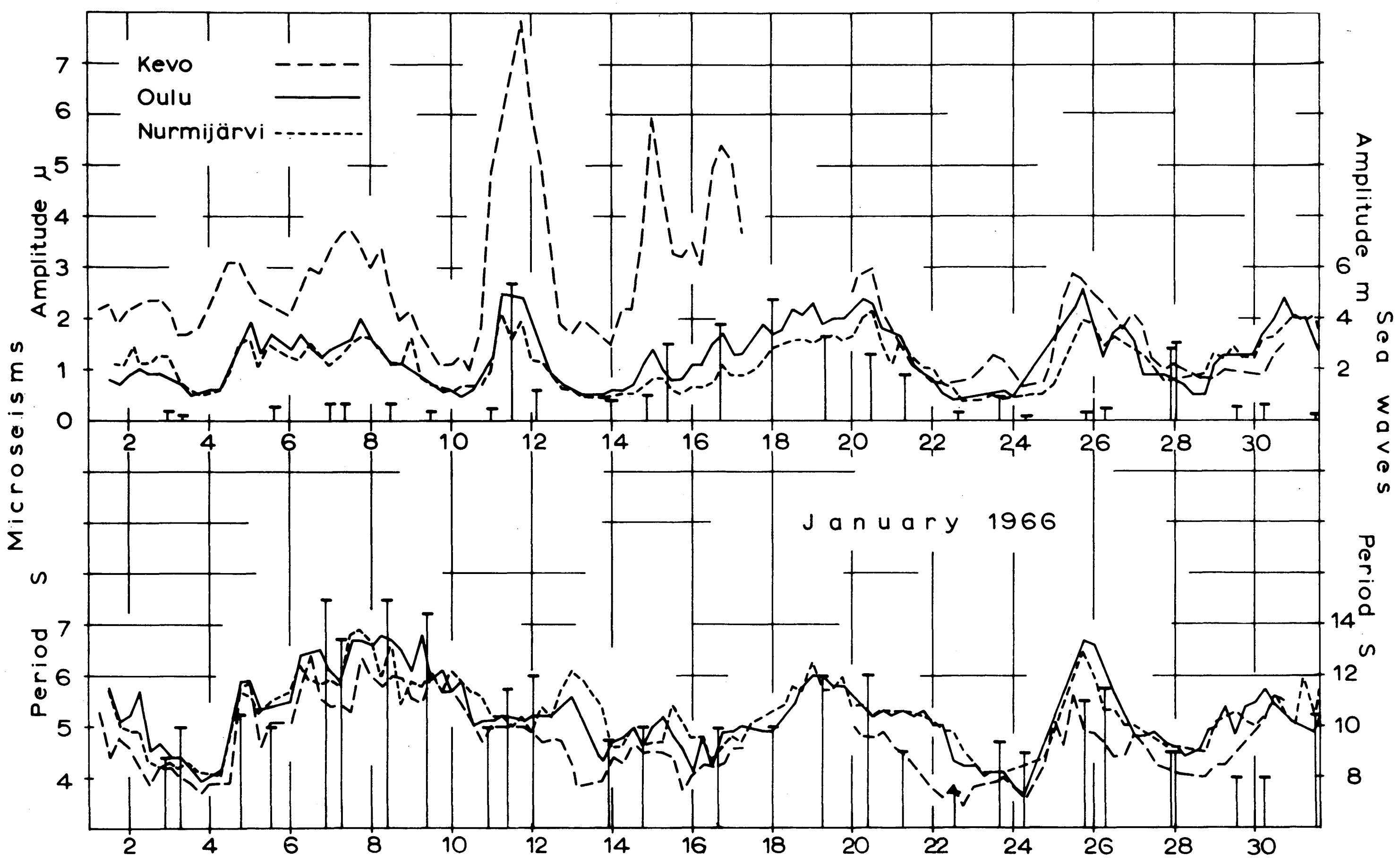


Fig. 1. Microseisms at Kevo, Oulu and Nurmijärvi. Max. wave heights and respective periods at Årviksand (vertical segments of lines).

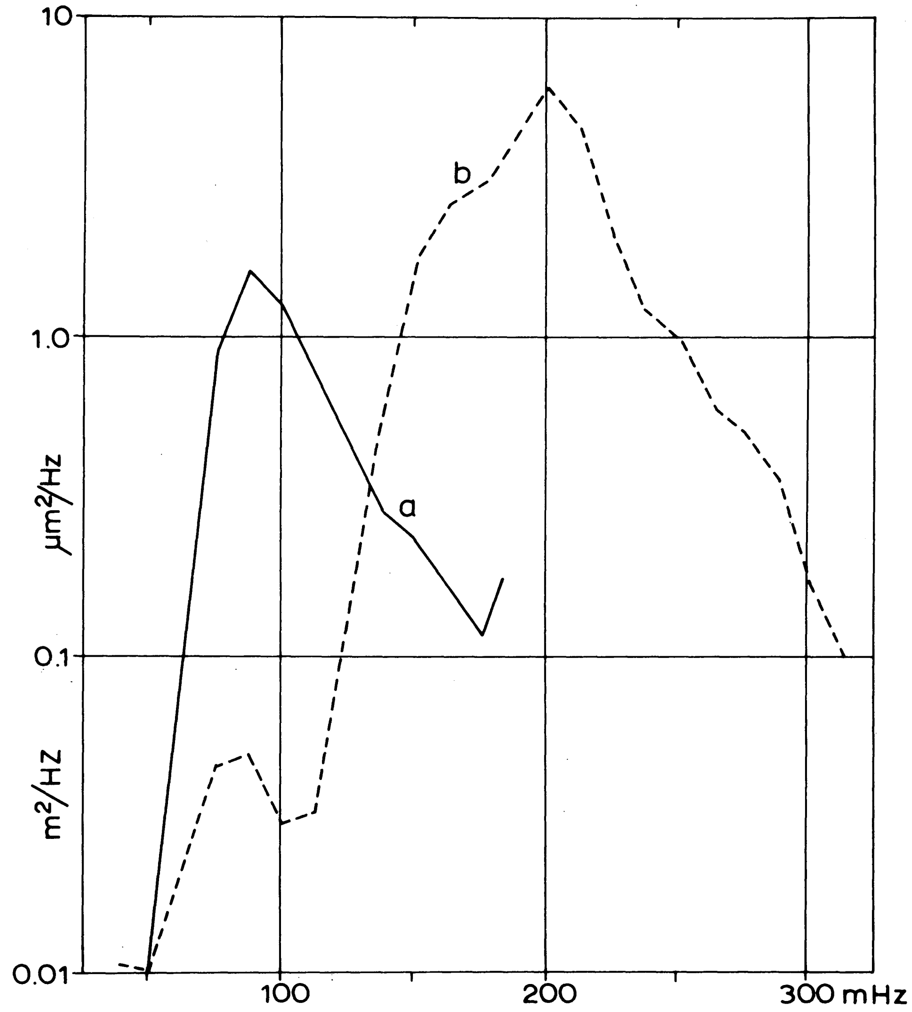


Fig. 2. Sea wave spectrum of Årviksand 1966 Jan 19 at 12 h and microseism spectrum of Oulu jan 20 at 04 h.

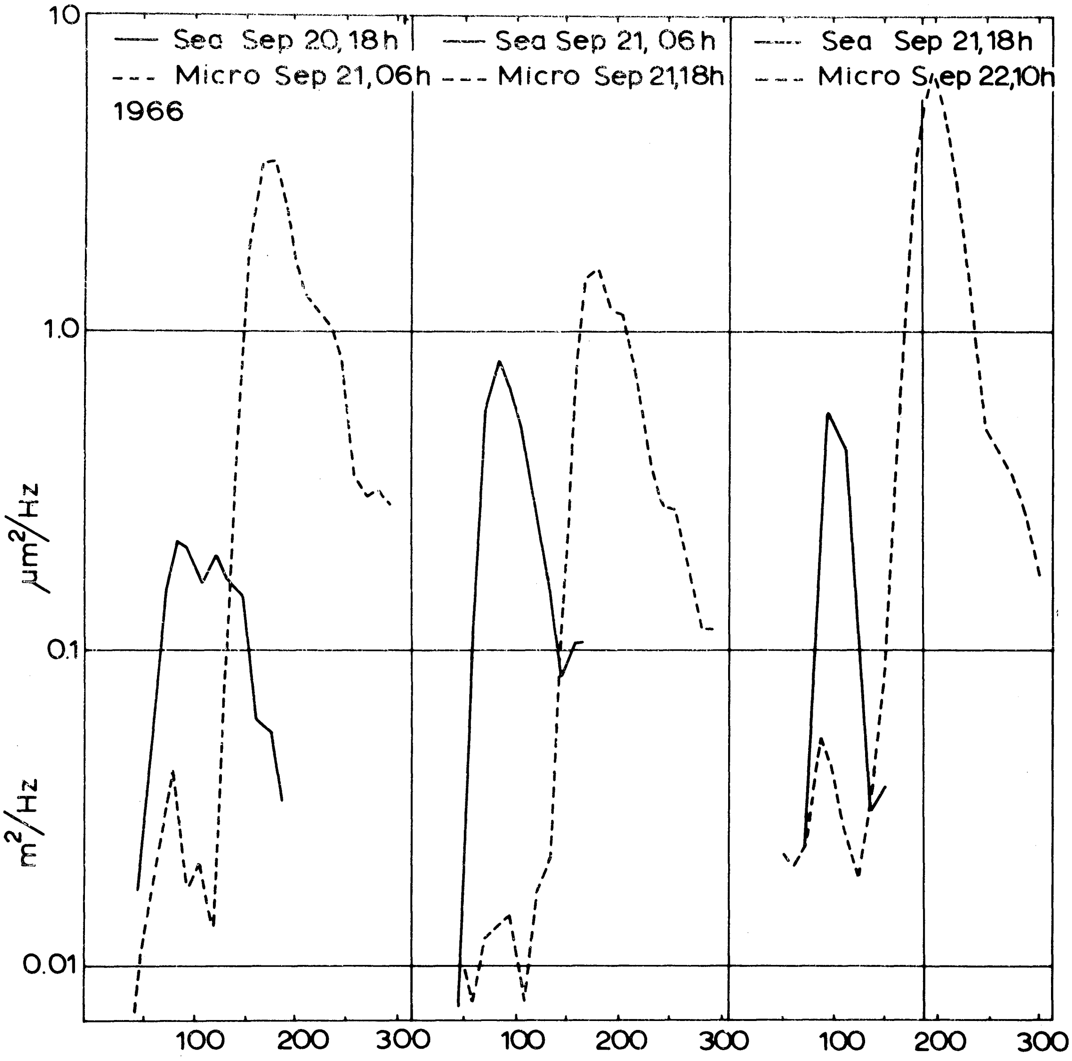


Fig. 3. Successive spectra of sea waves from Årviksand and corresponding microseism spectra of OUL during the storm 1966 Sep 20 - 22.

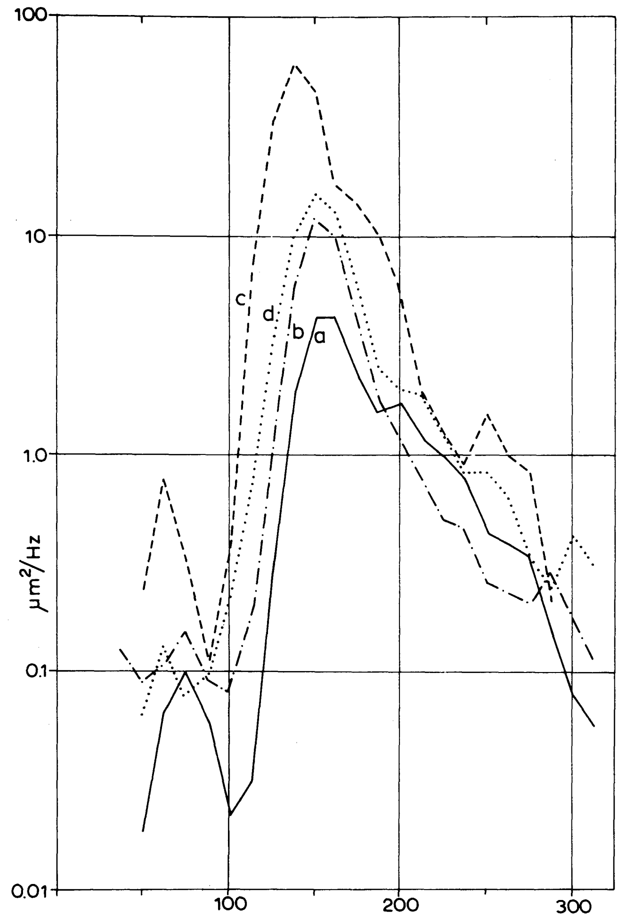


Fig. 4a. Microseism spectra of OUL, 1. group
a) 1965 Dec 19, 03 h 54
b) 1966 Dec 25, 18 h 27
c) 1967 Feb 07, 06 h 22
d) 1967 Feb 13, 16 h 15.

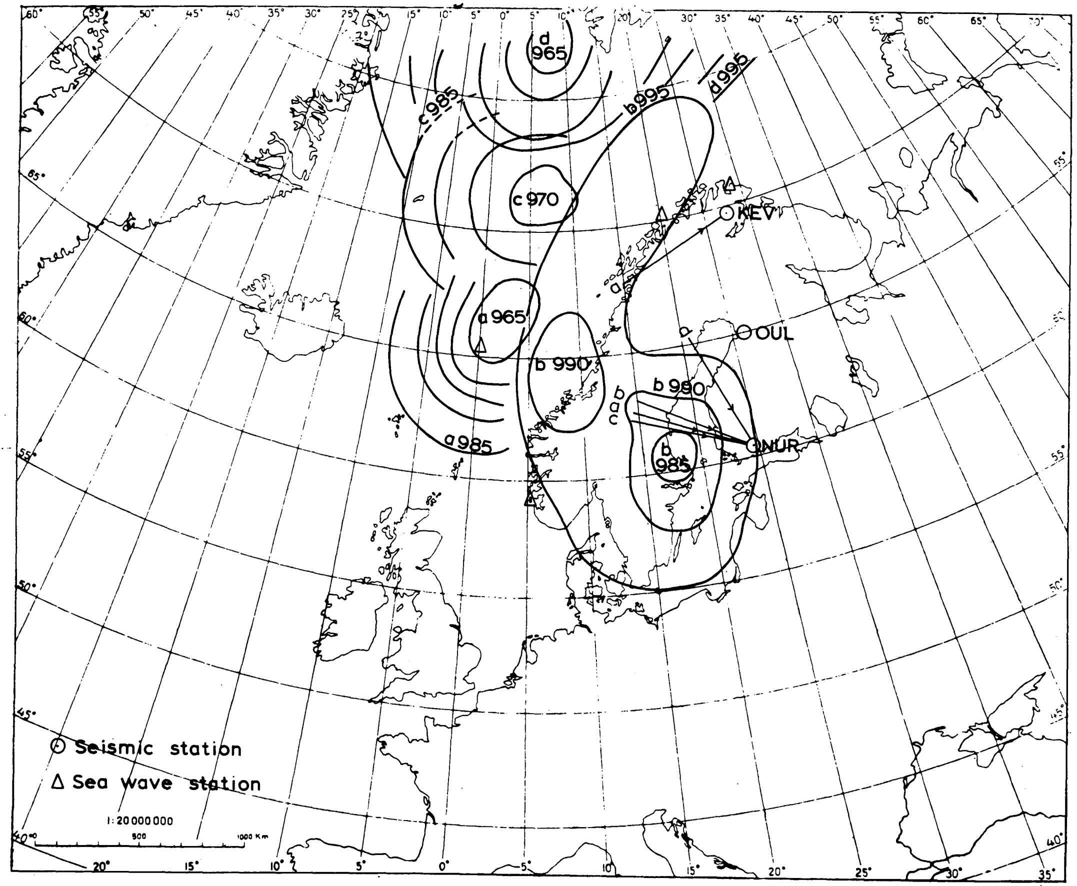
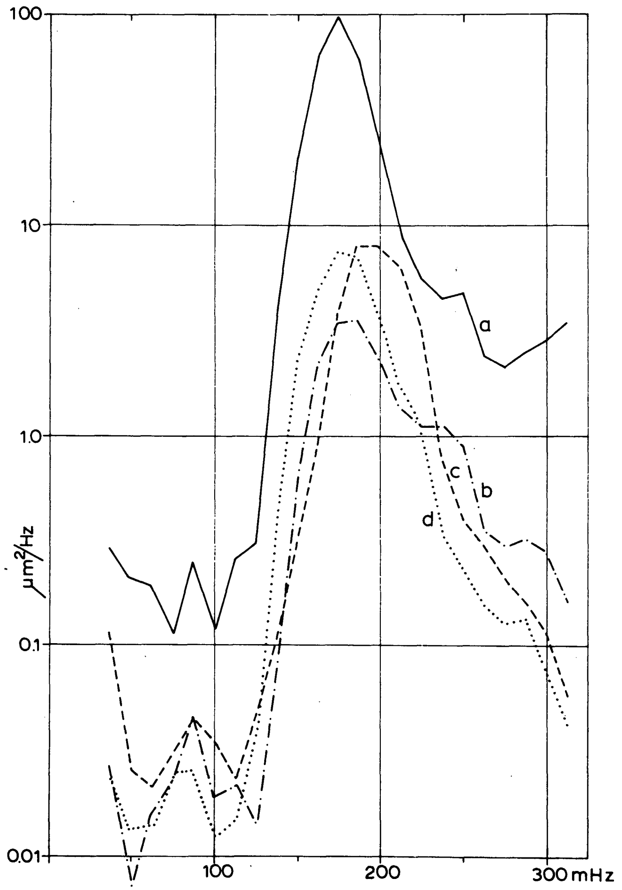


Fig. 4b. Cyclone centers in cases of fig 4a. The arrows show direction of microseism approach measured by the method of Jensen.



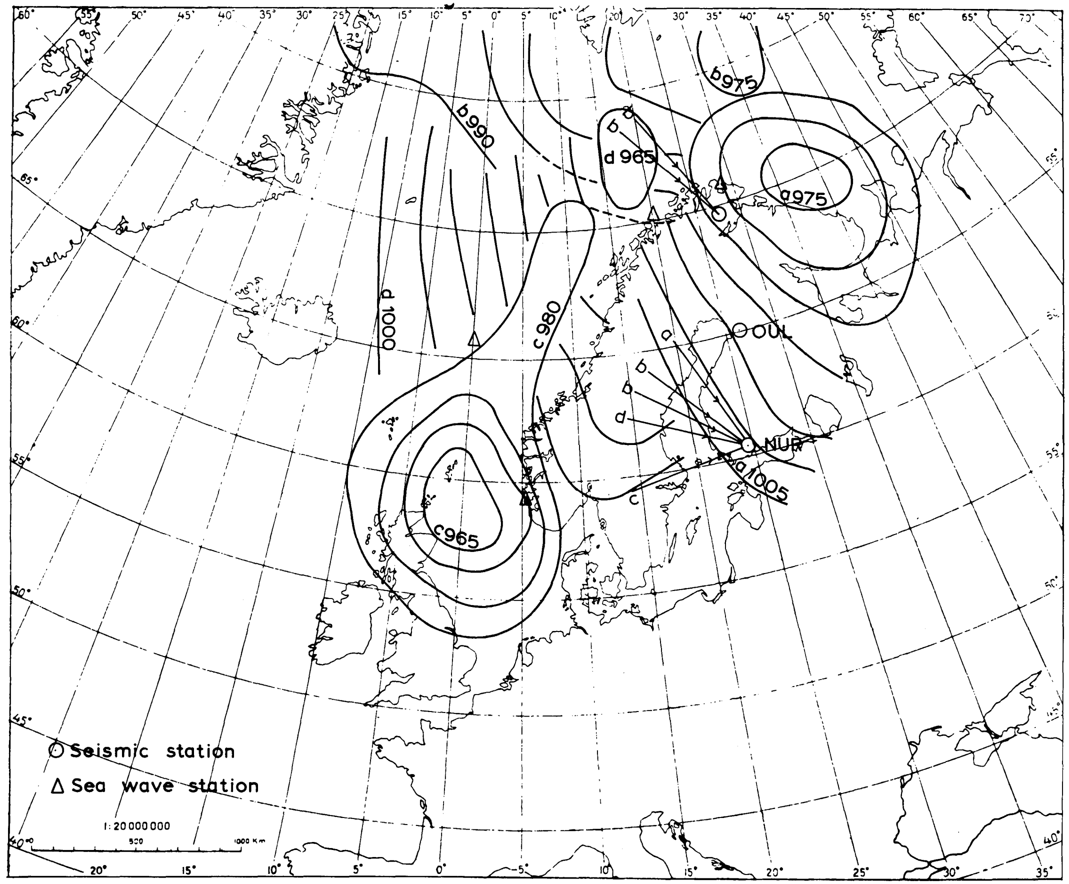
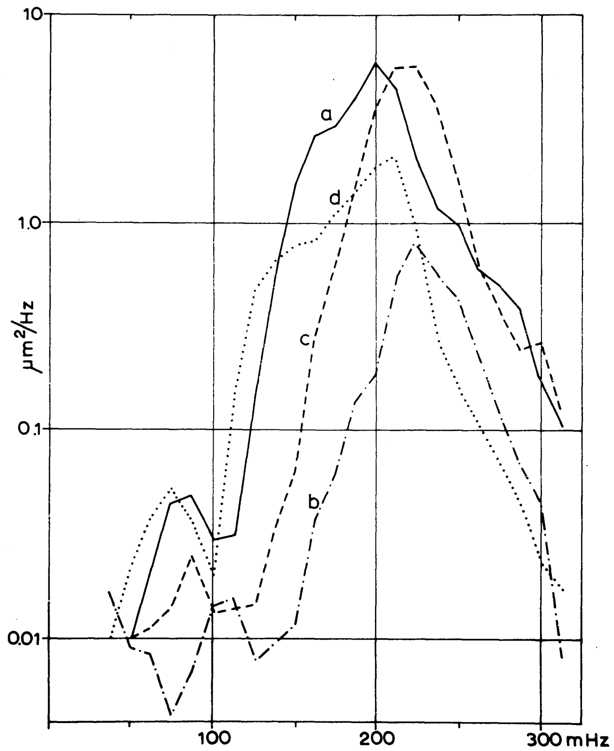


Fig. 5a. Microseism spectra of OUL, 2. group
a) 1963 Dec 07, 12 h 12
b) 1966 Sep 21, 05 h 57
c) 1966 Nov 30, 03 h 11
d) 1967 Oct 15, 23 h 57.

Fig. 5b. Cyclone centers in the cases of fig. 5a.



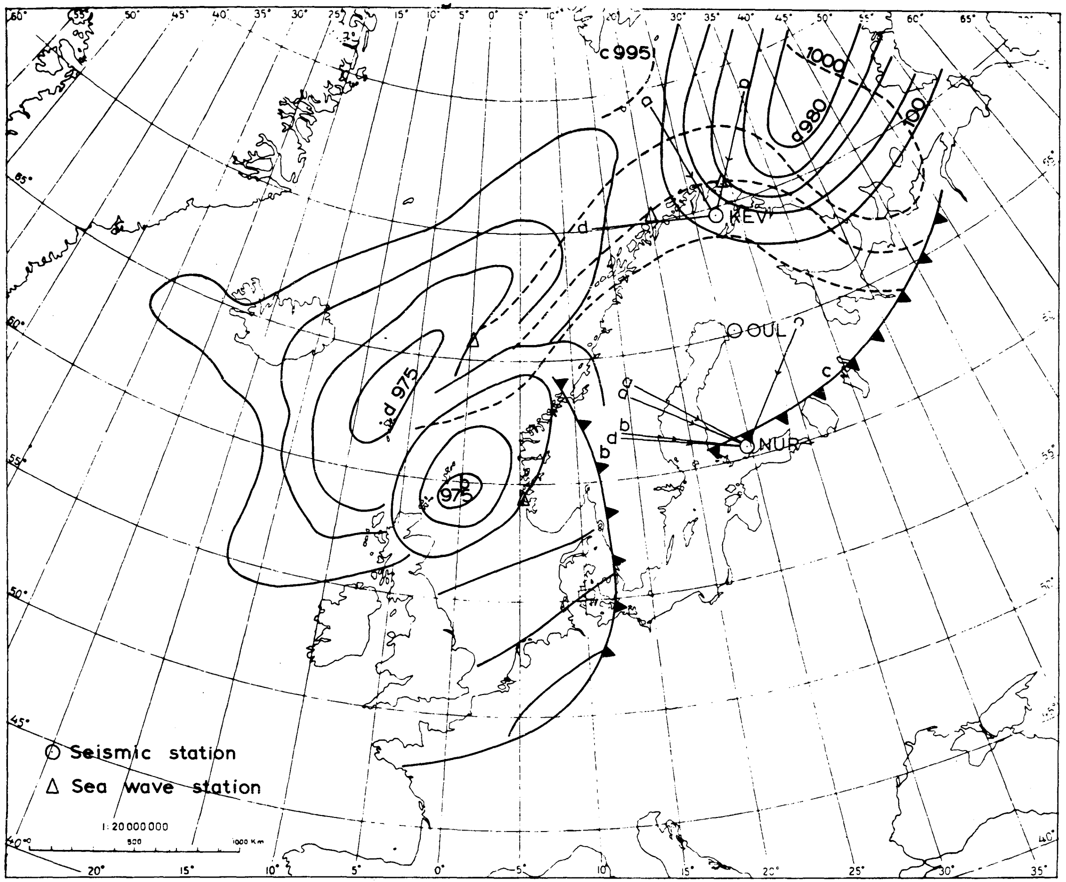


Fig. 6a. Microseism spectra of OUL, 3. group
a) 1966 Jan 20, 04 h 00
b) 1966 Oct 02, 11 h 16 (sample length 3 minutes)
c) 1966 Nov 07, 15 h 18
d) 1967 Mar 08, 08 h 08.

Fig. 6b. Cyclone centers in the cases of fig. 6a.

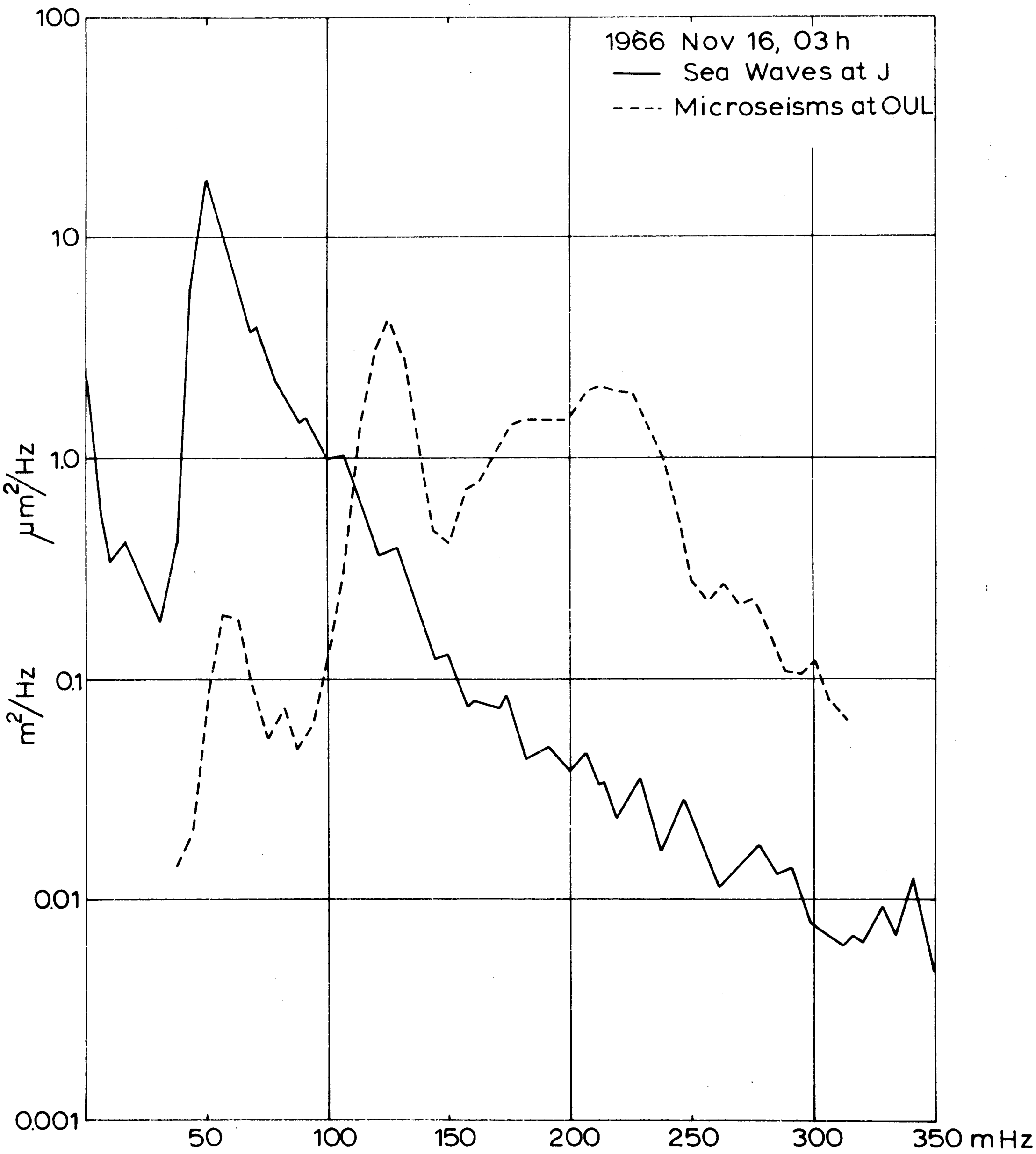


Fig. 7. Microseism spectrum of OUL 1966 Nov 16, 03 h (sample length, 18 minutes, maximum lag number 80) and simultaneous sea wave spectrum of station Juliet. Ocean wave spectrum is redrawn from the publication of Darbyshire and Okeke (1969).