PORT AND OCEAN ENGINEERING UNDER ARCTIC CONDITIONS
TECHNICAL UNIVERSITY OF NORWAY

THE INVESTIGATION OF LONG-WAVE PART OF SEA WAVE SPECTRUM

Dr. V.S. Bychkov, A.B. Leibo
Academy of Sciences
Moscow USSR

Abstract

In this report longperiod waves are examined. The periods of these waves are from some minutes to some hours. The movement of cyclone compared with the spectrum of these longperiod waves. It is shown that the reason for longperiod waves is the oscillations of atmospheric pressure. The spectrum of long waves correspond to typical oscillation spectra of atmospheric pressure set forth by Clark and Gossard.

The purpose of this paper is to study the so-called meteorological fluctuations of the sea surface.

By meteorological fluctuations we mean long period oscillations in the range of several minutes to several hours. Such division of the sea surface oscillation spectrum is justifiable because, generally speaking, its formation is indebted to various outer forces differing in their nature and in ways of energy transmission. Thus the most high-frequency part of the sea surface oscillation spectrum, wind waves; is caused by the wind blowing over the sea surface. Oscillations within the periods of about 30 sec to several minutes are probably due to the grouplike structure of sea wind waves. In this case the oscillations are not to be even considered as waves; they are rather more oscillations of the level underlying the wind waves, and do not possess certain specific features associated with the latter. (4)

The cause of meteorological oscillations is still not clear though such oscillations were observed by many scientists (2,5,6,10). Paper (8) deals with the study of oscillations of similar periods under the ice coat. The author gives estimates of the effect of the ice coat on the meteorological oscillations of the surface and suggests that the cause of their generation is the fluctuations of the atmospheric pressure in the region of the observations.

Hypotheses as to the generation of meteorological oscillations, if any have not been corroborated by natural observations. The authors of this paper believe that the long-period waves information collected and processed by them allows to state with confidence that the cause of meteorological oscillations is the fluctuations of pressure in cyclonic regions with periods close to those of meteorological oscillations of the sea surface.

The authors have processed data on sea surface oscillations measured with RW-9000 devices in the South-Kuril bay. Observations were carried out during two years or so from 1960 to 1962. The characteristic feature of meteorological oscillations is that they are constantly present within the sea surface oscillation spectrum and vary as the barometric situation changes. To be more exact, the great amplitude of oscillations within this interval of periods only occurs when a low pressure region is formed or propagated over the given area or the Pacific ocean in general (see Fig. 1).

In most simple cases, one can trace the interrelation between the depth of a cyclone, its distance to the point of registration and the amplitude of sea surface meteorological oscillations. The tentative study of the records showed that the amplitude of oscillations varies from 1-2 cm to 50 cm. To make a more thorough study of these oscillations the authors have constructed 30 spectra, each based on 1024 points with intervals equal to 30 sec. The quantization of ordinates constituted 1 mm. The choice of parameters like these is accounted for, firstly, by the fact that the processing of data was accomplished on BESM - 6 (Big electronic computer - 6) by the Furie method of quick transformation, and also by the fact that the instrument limited the choice of the interval of discreteness and quantization with the said parameters.

The authors deemed it their duty to give much care to the processing of data and the selection of a haphazard model as long as the problems of the resolution of spectra and the validity spectral peaks are the main ones in this investigation. The considerable 12-hour tide in the area of the observations accounted for the big trend in the record - the filter of the instrument did not exclude the tide entirely. The processing of records when a definite (big) trend is avaibable is not easy at all, and in the given case it was additionally complicated by the impossibility of applying standard filters. In fact, the commonly used Tuky filter would have sharply changed the true energy distribution

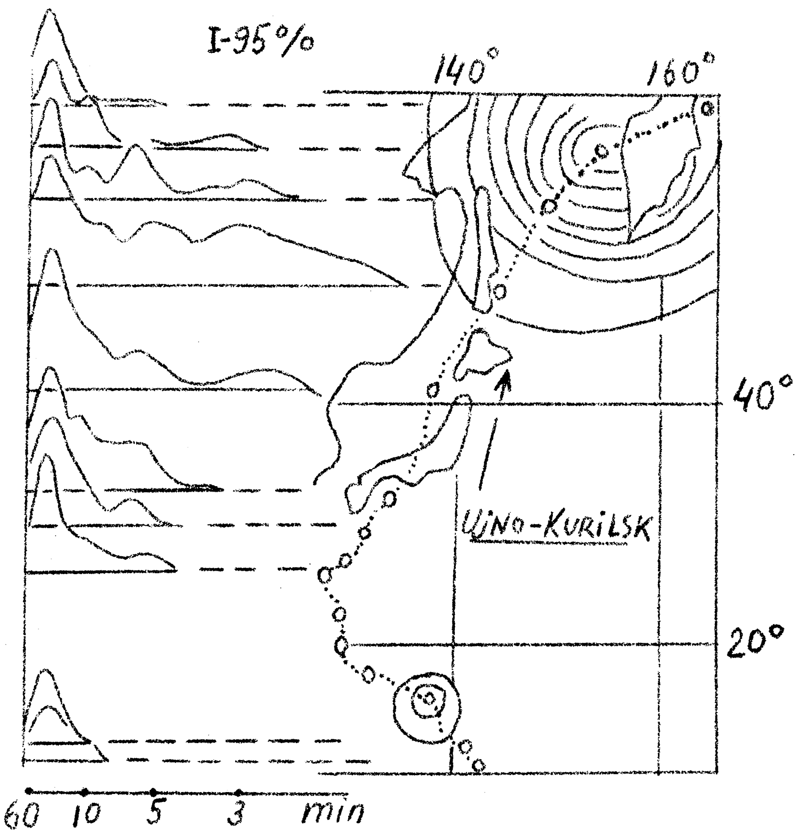

Fig.1. Schematic presentation of the "NANCY" typhoon position for 03.6.-18.IX.61.
The spectra are built in log scale in conventional units.
The presentation of the "NANCY" position was made by authors together with prof.Duvanin A.I. and dr. Monahov A.V.

according to frequencies that had been distorted by the instrument filter as it was. Filtration by means of the sliding mean was undesirable due to considerable by-product maximums in its frequency characteristics. All this has led to the necessity to design a filter that would meet the specific requirements of the present investigation. Such filter has been constructed, and it comprised 239 factors (coefficients).

The second problem to be solved was the choice of a haphazard model. The need in the probability approach is dictated first of all by the absence of more or less precise data pertaining to pressure fluctuations and also, probably, by undeterminability of the phenomena itself. The main difficulties in selecting a haphazard model are connected with great changes in oscillations of this part of the spectrum as the barometric situation varies, i.e., depending on time. At the same time there was no sense in deviating to a great extent from the commonly applied stationary haphazard model, since in this case we would have lost the hope to obtain any results from its use.

In general the problem was solved theoretically by Priestly in paper (7). And it is only the application of the results of paper (7) to the processing of oceanographic data that should be put as the merit of the authors in the techniques.

Having done the processing described, the authors came to the conclusion that spectra of sea surface meteorological oscillations obtained in different periods of time have some common features. All spectra, without exceptions, have a peak at the 30 min point. Many spectra show conspicuous peaks in the region of 20 and 13 min. The authors do not think that the reason for the 30 min peak is a shelf resonance since the rough approximation of the shelf and the solution of the shelf-oscillation problem (Fig.2) testify to the fact that such opinion is unreasonable.

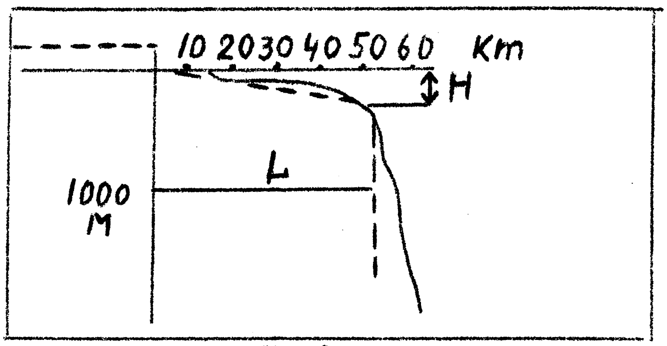

Fig. 2.

The authors are rather inclined to the hypothesis stating the presence of such typical peaks within the air pressure fluctuation spectrum. The comparison of the air pressure fluctuation spectrum with that of sea surface meteorological oscillations is to the credit of such a hypothesis. Such spectra were built by Clark (1) and Gossard (3) and are shown in Fig.3.

According to Clark such air pressure fluctuations are indebted with their generation to stable waves occuring on the inversion layers in the atmosphere during heavy wind. As for the energy transmission in this range of periods from the atmosphere to the sea surface it does not cause any doubts. The main part here is certainly played by dynamic processes. The hypothesis of a statical

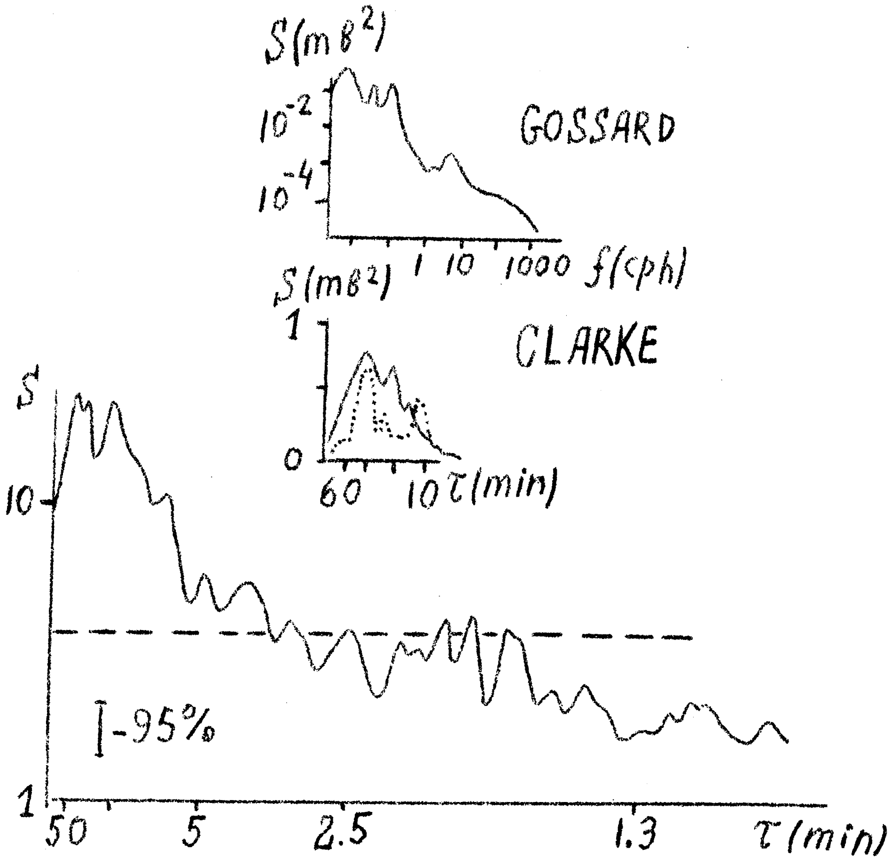

Fig.3. Above are depicted the air pressure oscillations spectra by Clark and Gossard.

Below are shown the spectrum of typical meteorological oscillations of the sea surface; the horizontal line designates the level of the normal white noise.

The spectrum of sea surface meteorological oscillations and the pressure fluctuations spectrum by Gossard are built in log scale in conventional units.

change of the level seems to us unreasonable (the law of reverse barometer), since in that case one had to suppose 30 min pressure oscillations in the point with an amplitude of about 10 mb. In case of the dynamic process of energy transmission the amplitude of meteorological oscillations would depend to a great extent on the dimensions of the oscillating area, too.

In this connection the authors deem it to be of interest to compare the spectra of meteooscillations with the synoptical situation in respective periods of time. Fig.1, 4 gives a schematical view of the spectra of such oscillations.

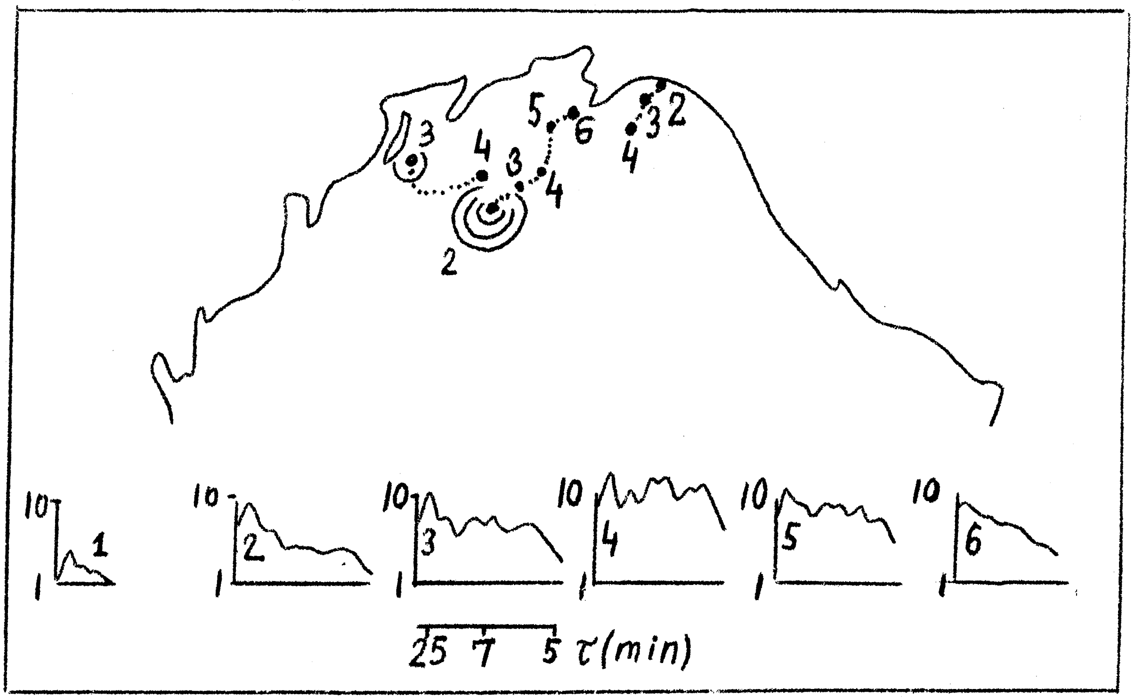

Fig.4. Schematic presentation of cyclone positions for 26.II.61-4.III.61. The Spectra are built in log scale in conventional units.

The spectra contain peaks having probability of 0,95 from the standpoint of the semistationary process model used by the authors. The 6-hour interval of processing is also the result of the model applied.

One can easily see the following laws governing the formation of the surface meteooscillation spectrum. Within the interval of meteooscillations from 5 min to 1 hour the spectra have 30 min peaks which rise with the decrease of the distance from the centre of the cyclone to the point of observation, as well as with the deepening of the cyclone (see Fig.1,4). As to the high-frequency part of the spectrum, it exceeds the level of the white noise provided the cyclonic region is over the point of observations, which is in turn to the credit of the hypothesis stating that oscillations of this range are formed as the result of a group-like structure of wind waves.

The meteorological situation for 03 hours 28.61-4.61 is more complicated, therefore in this case (see Fig.4) it is more difficult to trace the changes in spectra depending on the position of cyclones, though in general the laws, noted for a more simple case (see Fig.1) can be found here too. Let us consider in more detail Fig.4. In this Fig.4 each period of observation is associated with several cyclonic regions propagating along the trajectories shown on the Fig.4 by points. On February 26.1961, there were no cyclonic regions over the Pacific Ocean, and Fig.4 shows that during this period no considerable oscillations of the surface were observed and the spectrum is entirely below the level of the white noise.

It is remarkable that the shape of the spectrum is in generally is not changed and the 30 min peak is present. On February 26.2. 1961 the cyclone formed over the water area in the north-eastern part of the Ocean. The law registered by us when observing the typhoon "NANCY" also revealed here the increase in spectrum energy in the region of the previously noted and constantly observed peak for 30 sec. On March 1, 1961 a second cyclone formed which then deepend and extended to the north. This cyclone reached the maximum depth on March 2, 1961. At that same time the spectral energy of sea surface oscillations reached its maximum on all the periods studied up to 2 min. The energy of the high-frequency part of the spectrum becomes equal to that of low-frequency one. In this more complicated, as was already mentioned, case compared with the investigation of the "NANCY" typhoon, it is hard to explain the latter result, because at the very same time another cyclone, though more weak, was over the point of observations. The authors are inclined to think that, as it was the case with the previous example ("NANCY" typhoon) the oscillations in the high-frequency-region in this case were caused by the cyclone that was over the point of observations at that moment.

In conclusion we should like to say that the authors have been interested in long waves not so much due to their theoretical significance, as their practical aspects.

Long waves are the cause of breakdowns in normal work in a number of ports of the globe due to the fact that they cause strong currents in port entries, and are responsible for the appearance of the socalled 'Range action'. Therefore the investigation of the causes of their generation may contribute to the problem of securing continuous work of dockers.

Since, as it was shown, sea surface oscillations are associated with a barometric situation over the sea area, one may expect to obtain some information on cyclones and their movement from the observations of long sea waves. The work by Mank (5) in which location of storms by forerunners of swell was determined exactly enough, says in favour of the latter.

This technique, where applied to meteorological oscillations, would ensure forecasting in good time.

References

1. Clarke R.F. Pressure oscillations and fall-out down draughts. Quart. J.Roy.Meteorol.Soc.1962, 88, IV378.
2. Van Dorn W. G., Donn W.F. Long waves Ann.Internat.Geophys.Year 1969, 46, 46-60.
3. Gossard E.E. Spectra of atmospheric scalars. I.Geophys.Res. 65 (10) 3339-3351, 1960.
4. Longuet-Higgins and Stewart R.W. Radiation stress and mass transport in gravity waves with application to surf beats, J.Fluid Mech.13, N 4, 481-504, 1962.
5. Munk W.H. Long ocean waves, Sea Vol. 1. New-York-London, Interscience, 1962, 647-663.
6. Munk W.H., Snodgrass F.E., Tucker M.I., Spectra of low-frequency ocean waves 1959 Bull.Scripps.Inst.Oceanogr. 7(4) 283-362.
7. Priestley M.I. Evolutionary spectra and non-stationary processes. J.Roy.Statist.Soc.Ser.B, Vol.27, N 2, 1965, London.
8. Sergeev V.M. Experiment of the study of sea long period waves. The letters of University of Leningrad N 309, 1961.
9. Snodgrass F.E. and other, Propagations of ocean swell across the Pacific. Phil.Trans.Roy.Soc.,Vol.A259, pp.431-497, 1966.
10. Snodgrass F.E., Munk W.H. and Tucker M.I. Offshore recording of low-frequency ocean waves. Trans.Amer.Geophys.Un. 39, 114-120, 1958.