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Big waves from polar lows?

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ABSTRACT

A simple theoretical model is used to analyse how a polar low can produce a severe sea condition. The predictions of the model are compared to data from records of polar lows that have passed in the proximity of the weather station A.M.I. (71.5° N, 19° E) during the period (1978–82), and wave records from the same location and period.

1. Introduction

Polar lows have a rather limited horizontal extent, l, of the order of 100 km. If they were more or less stationary, one would not expect very high waves even for extreme winds, due to the short fetch. For example, a wind of 35 m/s would produce a significant wave height of approximately 5.5 m over 100 km. Taking the motion of a polar low into account, a different picture emerges. One then realizes that at least the spectral component whose group velocity, c_g, are near the velocity, V, of the polar low, are going to stay in the enhanced wind-field for a long time. This phenomenon is known to wave modellers as group velocity quasi-resonance. It is known to be important in connection with moving hurricanes and tropical cyclones. For polar lows, we believe it may have an added significance due to the very limited horizontal dimension l.

In a "normal" self-similar spectral development (of the type observed during the JONSWAP project), the spectral peak has an accelerated motion. With increasing fetch, the peak period, T_p, becomes larger, and so does the corresponding group velocity. Is such a spectral development possible within a moving polar low? This and other questions are addressed in the present paper.

Starting with analysis of a very simple one-dimensional theoretical model (Section 2) we investigate the conditions under which an extended spectral development can take place within a polar low. By that we mean a "normal" self-similar development over a fetch considerably larger than l.

We find that the ratio V/U between the speed of the polar low, and the component of wind velocity in its direction of motion, is of critical importance. For $V/U < 0.25$, the motion is too slow to give considerable fetch enhancement. In the range $0.25 < V/U < 0.5$, there may be an extended development provided the enhanced wind field is not too compact. For $V/U > 0.5$, the polar low will mostly "outrun" the spectral development at an early stage. The predictions from the theoretical model are then compared to data (Section 3). We have used wave records from a wave rider at the weather station A.M.I. (71.5° N, 19° E), and looked for possible traces of polar lows that are believed to have passed in the proximity of A.M.I. (Wilhelmsen, 1985). Some laboratory data are also discussed. The data are in fair agreement with the predictions of the model. There is, however, a need for more detailed field data covering a larger area.

One prediction of the model is the possibility of an "anomalous" spectral development. In this case the polar low "outruns" the normal self-

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similar development at an early state, but a spectral window around the "resonance" frequency $\omega_0 = g/2V$ (where $c_g(\omega_0) = V$) continues to grow, giving a double-peaked spectrum. So far we have not found clear evidence for such a development in the field data.

2. Theoretical considerations

2.1. *Resonant fetch-enhancement due to travelling wind field*

In the following, we consider a rather simple-minded model of the wind field associated with a polar low. In a mean wind field of wind speed, U_0, there is a region of local enhancement (wind speed U) of dimension l, travelling at a speed V (see Fig. 1a). Since the dimension l is expected to be small compared to the extent of a "normal" storm, the strong winds associated with it would apparently have a comparatively small fetch. The conventional concept of fetch, however, is rather inappropriate here. What matters is the time spent by a wave in the enhanced wind field. That time is clearly frequency dependent, having a maximum around the frequency whose group velocity is equal to the travel velocity, V, of the polar low.

A frequency dependent fetch $F(\omega)$ can now be defined by

$$F(\omega) = \min\left\{ l \left| \frac{V}{c_g} - 1 \right|^{-1}, l_{\max} \right\}, \tag{1}$$

which is the distance the frequency component ω has travelled inside the enhanced wind field. Here $c_g = g/2\omega$ is the group velocity, and $l_{\max}$ is some limiting fetch (e.g., measuring the distance that a polar low is likely to travel along a fairly linear trajectory).

The fetch $F(\omega)$ is shown as a function of ω in Fig. 1b. The maximum fetch is around the "resonance" frequency, ω_0, where $c_g(\omega_0) = V$, i.e.,

$$\omega_0 = g/2V. \tag{2}$$

This resonant fetch enhancement is well-known to wave modellers (see SWAMP group report (1985)), called group velocity quasi-resonance. Its significance seems to have first been pointed out by Munk and Snodgrass (1957). For polar lows, the phenomenon may have a special significance in that a major contribution to a sea state may possibly be found in a fairly narrow frequency range around ω_0. On the other hand, one can argue that there may be time (or fetch) enough for the frequencies above ω_0 to develop, reach the spectral peak, and finally stabilize at a saturation level. That is a "normal" or self-similar spectral development of the kind demonstrated in the JONSWAP project (Hasselmann et al., 1973). In the next section we look into this possibility.

2.2. *Spectral evolution*

We have seen that a certain frequency band around the "resonance" frequency $g/2V$ has a long effective fetch. It is natural then to ask whether waves of higher frequency have time to grow such that the spectrum evolves in a self-similar manner like that observed during the JONSWAP project. If the answer to this question is positive, the evolution of the spectrum can be described by following the evolution of spectral parameters like the peak period T_p, and the significant wave height H_c. With increasing fetch, the peak period of the self-similar spectrum becomes larger. So does, of course, the corresponding group velocity. Thus the trajectory, or

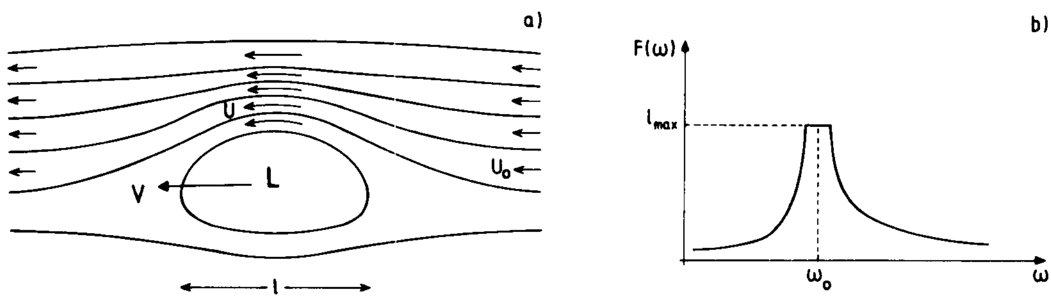

Fig. 1. (a) A simple model of a travelling low. (b) Frequency dependent fetch $F(\omega)$ versus frequency ω.

characteristic of such a spectrum is an "accelerated" one.

The question of whether a self-similar evolution is possible in connection with a polar low, is related to the question of whether the spectral trajectory, or characteristic, stays within the polar low for a fetch large compared to its dimension. The evolution of a self-similar spectrum is characterized in the simplest case by the way spectral parameters vary with fetch. This variation is determined empirically. We write

$$\frac{gH_c}{U^2} = e(x), \tag{3}$$

$$\frac{c_p}{U} = 2f(x), \tag{4}$$

where $x = gF/U^2$ is the non-dimensional fetch, U the wind speed at 10 m height, H_c the significant wave height, and c_p the phase velocity at the spectral peak. Hasselmann et al. (1973) proposed the following relations based on both laboratory and field data

$$e(x) = 1.6 \cdot 10^{-3} x^{1/2}, \tag{5}$$

$$f(x) = 0.023 x^{0.33}. \tag{6}$$

Phillips (1977) maintained that it is difficult to justify the use of laboratory data in obtaining (6). He suggested a relation based on field data alone, namely

$$f(x) = 0.045 x^{1/4}. \tag{7}$$

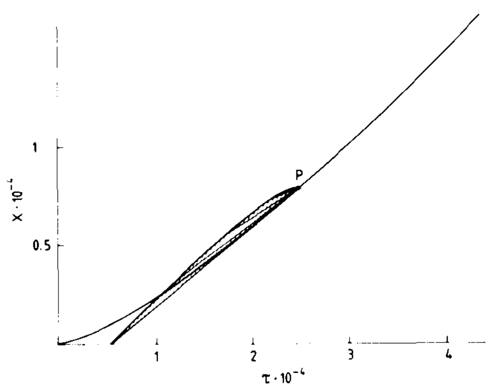

Fig. 2. Spectral characteristic (cf. eq. (9)). The shaded area is an estimate of the space-time domain which influences the spectrum at the point P on the characteristic.

In the following, we shall apply (5) and (7). It should be noted however, that these equations become invalid for very long fetches (for $x > 1.5 \cdot 10^4$ say) when $c_p > U$.

Using the dimensionless time $\tau = gt/U$, the "equation of motion" for the spectral peak, $dF/dt = c_{gp}$ becomes (c_{gp} = group velocity at the peak. Strictly speaking the directionally averaged group velocity should be used, which would amount to a slightly different coefficient in (7))

$$\frac{dx}{d\tau} = f(x). \tag{8}$$

The solutions of (8) are the x, τ characteristics of a self-similar spectrum characterized by the peak period. Using (7) the characteristic starting at the origin (see Fig. 2) is:

$$\tau = 29.63 x^{3/4}. \tag{9}$$

This is to be compared to the characteristics of the polar low. In dimensionless form they are given by

$$x = \frac{V}{U}\tau \quad \text{and} \quad x = \frac{V}{U}\tau - \frac{lg}{U^2}, \tag{10}$$

where l is the "length" of the polar low which we take to be the horizontal extent of the enhanced wind field in the direction of motion.

The question of how far a self-similar evolution of the wave spectrum can go on, seems to be related to the question of how far the spectral characteristic (9), starting at the front of the polar low, is contained between the polar low characteristics (10).

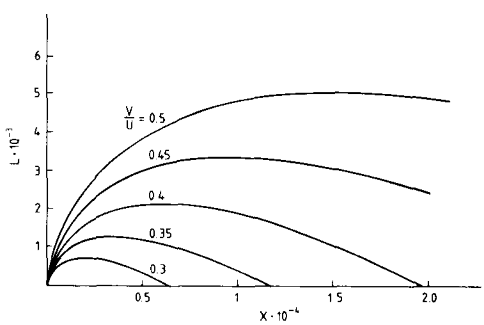

Fig. 3. Distance L, of spectral characteristic (eq. (9)) from the front of the polar low, as a function of fetch, x. (L and x are non-dimensional.)

The non-dimensional distance, L, that the spectral characteristic lags behind the front of the polar low, is obtained from (10) and (9) as

$$L\left(x, \frac{V}{U}\right) = 29.63 \frac{V}{U} x^{3/4} - x, \tag{11}$$

and L is shown in Fig. 3 as a function of x for some values of the ratio V/U. L has a maximum, L_0, at the fetch, x_0, where

$$L_0 = 8.13 \cdot 10^4 \left(\frac{V}{U}\right)^4 \quad \text{and} \quad x_0 = 2.44 \cdot 10^5 \left(\frac{V}{U}\right)^4. \tag{12}$$

The characteristic will finally leave through the front (where $L = 0$) at a fetch, $x_1 \equiv 3.16 x_0$. Note that the point of the characteristic with fetch x_0, is where its slope is V/U. The corresponding peak frequency is therefore the resonance frequency $\omega_0 = g/2V$.

If the dimensionless length, $\tilde{l} = lg/U^2$, of the polar low is larger than L_0, i.e.,

$$\tilde{l} > L_0, \qquad \text{or} \qquad l > 8.13 \cdot 10^4 \frac{V^4}{gU^2}, \tag{13}$$

the characteristic is contained by the polar low up to the point where it leaves through the front. We would therefore expect the spectral development to proceed past the resonance frequency, and eventually stop at the front, or at some maximum fetch $\tilde{l}_{max} = gl_{max}/U^2$. Beyond a fetch of x_1 ($= 3.16 x_0$, if this is less than l_{max}), there will be forerunners announcing the approach of the polar low.

If $\tilde{l} < L_0$, the characteristic leaves through the rear, and we would consequently expect the spectral development to halt there, before the peak has reached the resonance frequency. There does not seem to be any reason, however, why a spectral window around ω_0 should not continue to grow, as explained earlier, provided the wind velocity is larger than the phase velocity, i.e., $U > 2V$.

So far, we implicitly assumed that containment of a characteristic inside the polar low (with a constant wind U), is a sufficient condition for the corresponding spectral development to take place. One might worry that the space-time limitations of the region of constant wind might somehow be felt, even when the characteristic is still inside. Obviously the spectrum at each point, P, consists of waves that came from somewhere else. One can associate with this point a basin of "production", or "influence". This can be estimated by prescribing a lifespan to each spectral component. If this is taken to be the time required to bring that particular component to the spectral peak (with the same wind U), the basin of production is readily constructed as shown in Fig. 2. Due to the so-called overshoot phenomenon, this would seem to be an overestimate of the region having an influence on the spectrum at P. It appears that the main effect of such a region of influence is to limit the development on characteristics turning near the rear end of the polar low, in such a way that the peak frequency would not progress much further than ω_0.

So far, we have considered only one characteristic. If a more representative collection of the characteristics entering the polar low is drawn, the cases $L_0 < \tilde{l}$ and $L_0 > \tilde{l}$ appear as qualitatively different.

The case $L_0 > \tilde{l}$, exemplified in Fig. 4a, is the easiest to interpret. The development of a self-similar spectrum comes to a halt as the characteristics leave through the rear. In the reference frame of the polar low a steady state for this part of the spectrum occurs above the characteristic starting at the origin (which is the first one to traverse the polar low).

The case $L_0 < \tilde{l}$, exemplified in Fig. 4b, is harder to interpret. Between the characteristic starting at the origin, and the caustic (generated by the characteristics starting at the front) there is a domain, D, where three characteristics cross at each point, with three corresponding sets of values of the spectral parameters. If the value of the peak frequency $\omega_p(x, \tau)$ is taken as a vertical distance above the x, τ-plane, the surface generated has a fold whose horizontal projection is D. When a more sophisticated parametric model is used, like the one proposed by Hasselmann et al. (1976), the problem of multiple valued spectral parameters seems to persist. (We solved their eq. (6.3) for our model of a polar low, and got pretty much the same picture with a folded surface for ω_p.) The problem, as it seems, cannot be completely solved within the context of a parametric model. If a conserved quantity had been known, a "shock fitting procedure" (see Whitham (1974)) might be applied. It seems plausible to us, however, that along the front face of the region D, a rather strong interaction takes

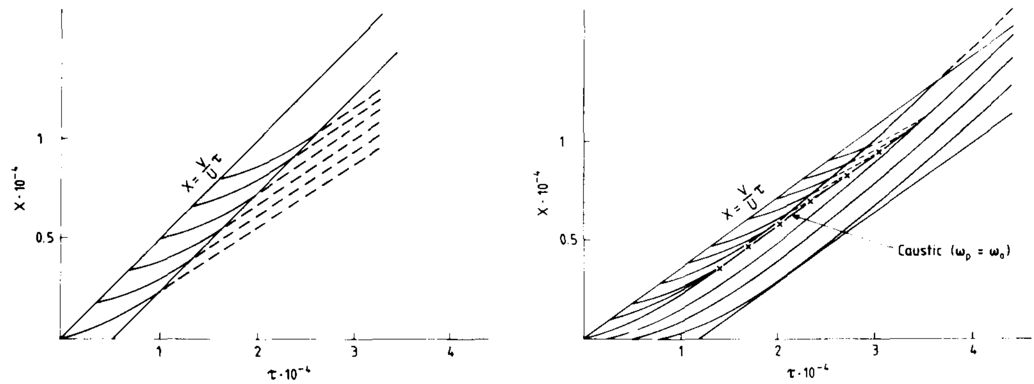

Fig. 4. Spectral characteristics relative to the model of a polar low, for two different sets of relevant parameters. (a) $L_0 > \tilde{l}\,(V/U = 0.5$ and $\tilde{l} = 2.5 \cdot 10^3)$. The spectral development is outrun by the polar low. (b) $L_0 < \tilde{l}\,(V/U = 0.36$ and $\tilde{l} = 4.2 \cdot 10^3)$. The spectral development proceeds past the resonance frequency ω_0, and produces forerunners for fetches larger than x_1.

place involving nonlinear transfer and breaking, resulting in the restoring of the universal spectral shape with peak frequency near the lowest one of the interacting spectra. On a somewhat slower scale (see Hasselmann et al. (1976)) the energy level would adjust so that the eqs. (3) and (5) would be compatible with (4) and (7) (implying that the total wave energy, $\varepsilon \propto \omega_p^{-4}$, or if eq. (6) had been chosen, $\varepsilon \propto \omega_p^{-10/3}$). Whether this latter adjustment can take place on the space- and timescales of a polar low is not clear. For our purpose, looking for a very rough estimate, we shall proceed to consider the "oldest" or most developed characteristics to dominate throughout the region of overlap, using (3) for an estimate of wave height.

2.3. *Discussion*

Our rough model of wave production by a polar low, seems to indicate that two qualitatively different scenarios may develop depending on the ratio V/U, and the horizontal extent of the low:

If $L_0 < \tilde{l}$, the spectral development proceeds past the resonance frequency, ω_0, and the development finally outruns the polar low giving forerunners at fetches beyond $x_1 = 3.16 x_0$.

If $L_0 > \tilde{l}$, the normal spectral development is outrun by the polar low. On the other hand, there does not seem to be any reason why a spectral window around ω_0 should not continue to develop provided $U > 2V$.

Carstens (1985) and Lønnseth and Torsethaugen (1985) have investigated the effect of a travelling wind field experimentally. They let a mobile wind field (produced by fans) move along a 260 m long wave channel. The equivalent wind velocity, U, at 10 m was approximately 10 m/s. The length of the wind field (15% variation around the mean value $U = 10$ m/s) is approximately 12 m. Their report gives detailed data for two runs with travelling velocities 0.6 m/s and 0.7 m/s, respectively.

For the case $V = 0.6$ m/s, they find large waves (near breaking) in the rear half of the wind field with frequency approximately ω_0 $(= 8.2\ \mathrm{s}^{-1})$. These are preceded by longer waves extending out in front where there is no wind. These forerunners are first observed at their station 2 having a fetch $x \simeq 12.5$. This should be compared to $x_1 \simeq 10$ where the first characteristic is supposed to leave through the front.

For the case $V = 0.7$ m/s, they still find large waves (near breaking) in the rear half of the wind field. The frequency of these waves $(\approx 7.6\ \mathrm{s}^{-1})$ is higher than ω_0 $(\approx 7\ \mathrm{s}^{-1})$. Towards the front of the wind field, however, one also finds quite large waves of frequency $\approx \omega_0$. In front of the wind field no waves are found. The description above sounds rather like that of the two situations depicted in Fig. 4b and 4a. Whether we are going to have one or the other depends on whether the condition (13) is satisfied or not. Dealing with a laboratory experiment the formula (6) is supposed to be better than (7) (see Phillips (1977)). If it is chosen as a basis for calculating a criterion, we find instead of (13) the relation

$$l > 4.11 \cdot 10^4 \frac{V^3}{gU}.$$

Substituting the experimental parameters, we find for $V = 0.6$ that $l > 9$ m, and for $V = 0.7$, we find that $l > 14$ m are the appropriate conditions for the case of Fig. 4b to occur. With $l = 12$ m, we see that there is fair agreement between the experimental findings of Carstens (1985) and Lønnseth and Torsethaugen (1985) and our simple-minded theoretical considerations.

To be able to give a more detailed discussion, realistic values for the relevant parameters should be considered. We concentrate on polar lows with high winds, in the range 20–35 m/s. Judging from rectilinear parts of the tracks given by Wilhelmsen (1985) it would seem that $l_{max} \sim 500$–800 km. Fedor (1984) estimated the horizontal extent of polar lows to be in the range 200–500 km. We take, rather arbitrarily, the length, l, of the enhanced wind field (in the direction of motion) to be half of that. In dimensionless form we have:

$$\tilde{l}_{max} \equiv \frac{g l_{max}}{U^2} \sim 0.4 \cdot 10^4 - 1.5 \cdot 10^4,$$

and

$$\tilde{l} = \frac{gl}{U^2} \sim 0.8 \cdot 10^3 - 6 \cdot 10^3.$$

Here we have taken into consideration that for fetches larger than $\sim 1.5 \cdot 10^4$, the eqs. (5) and (7) are no longer valid, as the spectrum is saturating ($c_p > U$).

We now want to discuss the conditions for an extended spectral development to take place. By that we understand a development over a fetch considerably larger than l, which we take to mean larger than $3l$. According to (3) and (5) this represents an increase in H_c more than 70%, relative to a stationary polar low of the same wind and dimension. A necessary condition for this to happen is the relation (13), $\tilde{l} > L_0$ (this is seen from the fact that $x_0 = 3L_0$). It means that an extended development in the above sense is one that proceeds at least to the point where the resonance frequency, ω_0, is at the spectral peak. Other necessary conditions are that $V/U < 0.5$ (when $V/U > 0.5$, then $x_0 > 1.5 \cdot 10^4$), and $V/U > 0.25$ (when $V < 0.25$, then the fetch $x_1 = 3.16 x_0$ where the characteristic (9) leaves through the front is less than $3\tilde{l}$).

When an extended spectral development takes place, the effective fetch is between x_0 and x_1. To get a rough idea of the wave height to be expected, we use the empirical formula (3), (5), which gives

$$H_c(x_0) \simeq 0.8 V^2/g, \qquad H_c(x_1) \simeq 1.4 V^2/g. \qquad (14)$$

We note that the results are independent of U. (If we choose formula (6) instead of (7), we find a weak dependence $U^{1/6}$.) How far the spectral development proceeds, does of course depend in U.

In Table 1, we list $H_c(x_0)$ and $H_c(x_1)$ for some values of V.

For $V > 13$ m/s, the condition (13) is only satisfied for $U > 35$ m/s. For $V > 10$ m/s, U must be larger than 35 m/s, for $U^2 x_1/g$ to be less than 800 km.

In summary, the conditions for an extended spectral development to take place are:

- the polar low trajectory must have a straight part, l_{max}, considerably larger than the horizontal extent, l, of the enhanced wind field;
- the ratio V/U, where U is the component of the enhanced wind velocity in the direction of motion of the polar low, should satisfy

  $$0.25 < V/U < 0.5;$$

- the length l should satisfy the condition (13) ($\tilde{l} > L_0$).

Table 1. *Estimates of H_c at non-dimensional fetches x_0, and x_1 for different values of the velocity V of the polar low*

V (m/s)	7	8	9	10	11	12	13
$H_c(x_0)$ (m)	4	5.2	6.5	8	9.8	11.6	13.6
$H_c(x_1)$ (m)	7	9	11.3	14			

Under these conditions, a rough estimate of the significant wave height at the end of the development is

$$H_c = \min\{H_c(\tilde{l}_{max}), 1.4V^2/g\}, \quad (15)$$

where $\tilde{l}_{max} = gl_{max}/U^2$ and $H_c(x)$ is given through (3) and (5).

When the condition (13) is not satisfied, the normal spectral development stops before the spectral peak, ω_p, has reached the resonance frequency, ω_0. A spectral window, $\Delta\omega$, around ω_0 should continue to grow, however, provided $U > 2V$. This may result in a double-peaked spectrum if ω_p is outside that window ($\Delta\omega \sim \omega_0 l/l_{max}$). Such an anomalous development would not be noticed by a purely parametric wave model. The spectral energy around ω_0 will probably grow more slowly than by a normal development, so that it will take a fetch longer than x_0 to produce a wave height comparable to $0.8V^2/g$ (see eq. (14)). This is because the nonlinear transfer of energy across the spectral peak is believed to be the reason why the exponential growth on the front face of a normal spectrum is considerably larger than that expected if direct input from the wind was the cause (see Hasselmann et al. (1973)). Under an anomalous development there is still some nonlinear transfer from the normal part of the spectrum. It is, however, taking place over a longer range in frequency, and is therefore less effective.

In Table 2 below we list some combination of parameter values for polar lows that we would expect to give an anomalous development.

3. A comparison with data

In Section 2, we have presented a rather simple-minded theoretical model in order to obtain some understanding of the physical mechanisms behind the influence of a polar low on the wave conditions. We have compared this model to a laboratory experiment and found it to give fair agreement. Whether such a large scale laboratory experiment is representative of oceanic conditions is perhaps arguable. We therefore want to compare the model with actual field data.

Table 2. *Examples of polar low parameters expected to produce anomalous spectral development*

U (m/s)	V (m/s)	V/U	l (km)	l_{max} (km)
40	14	0.35	<200	>600
35	14	0.4	<260	>800
25	10	0.4	<130	>400

Among the polar lows reported by Wilhelmsen (1985), we have selected 8 cases, where the polar low has allegedly passed in the proximity of the weather station A.M.I. (71.5° N, 19° E). We have looked for possible traces of these passages in the wave records, as recorded by a wave rider at A.M.I. In four cases (13 April 79, 2 December 80, 13 December 82, and 14 December 82) V/U was greater than 0.5, and no significant change in wave condition (as given by the wave parameters H_c, H_{max} and T_p), was found near the time of passage. In the remaining four cases, the parameters were such that V/U was in the range 0.35–0.4. The condition (13) would be satisfied for all but one (17 February 78) of the cases if $l > 100$ km. In all 4 cases, increasing wave parameters H_c, H_{max} and T_p were registered around the arrival of the polar low (as interpreted from the increase in wind speed given by the wind records at the same station). This phase of increase lasted for a period from 3 to 7 hours. In three of these instances (23 January 78, 14 January 80, and 10 June 80), the increase was fairly small, although the peak period moved up to (10 June 80), and beyond (24 January 78, 14 January 80) the "resonance" period $4\pi V/g$. The most spectacular event was found to be the one associated with the polar low of 17 February 78. Compared to the other three it had higher wind and a longer fetch, l_{max}. In the following we consider that event in some more detail.

3.1. Passage of a polar low 17–18 February 1978

The meteorological aspects of the polar low 17–18 February 78 have been described by Wilhelmsen (1985). The low originated in the Barents Sea around (72° N, 40° E), and moved east towards A.M.I. (71.5° N, 19° E). It passed A.M.I. and reached the coast of Troms 3 hours later. The wind speed, U, was estimated in the range 25–28 m/s, and the speed of the low, V, to be 10 m/s. Processed records from the wave rider at A.M.I. for the period 17–18 February 78 were

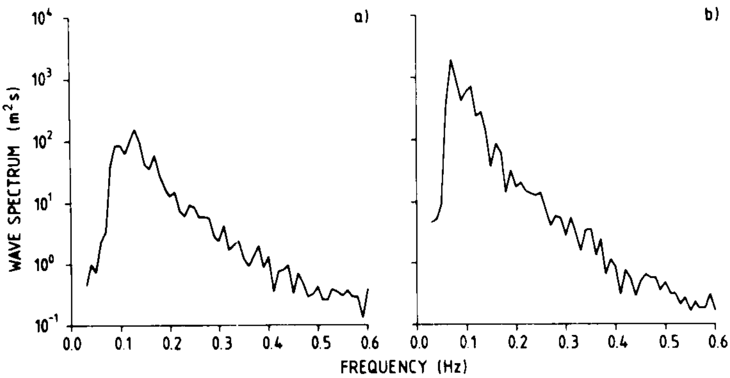

Fig. 5. Wave spectra from A.M.I. (71.5°N, 19°E) 17 February 1978. (a) 13.48 GMT ($H_c = 3.9$ m, $H_{max} = 7$ m, $T_p = 7.5$ s). (b) 19.47 GMT ($H_c = 9.3$ m, $H_{max} = 16$ m, $T_p = 14.2$ s). (Data provided by Continental Shelf and Petroleum Technological Institute, Trondheim.)

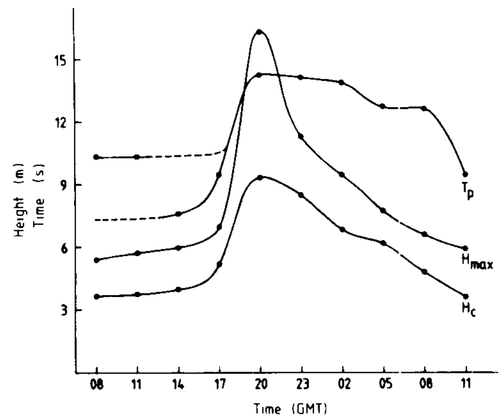

Fig. 6. Evolution of the wave parameters, T_p, H_c and H_{max} at A.M.I. 17–18 February 1978.

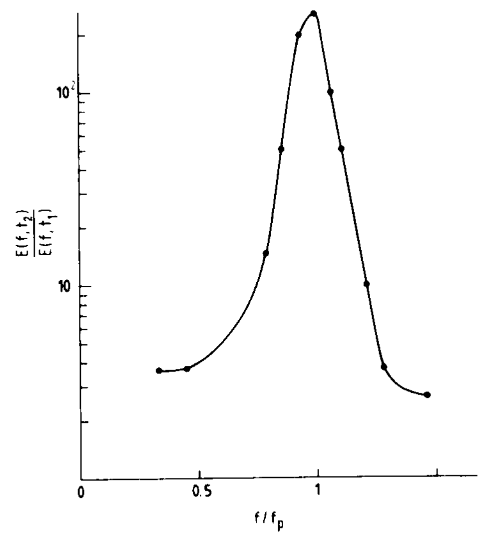

Fig. 7. Relative spectral growth between 16.48 GMT (t_1), and 19.45 GMT (t_2), 17 February 1978 at A.M.I. ($f_p = (14.2)^{-1}$ Hz).

made available to us by IKU (Continental Shelf and Petroleum Technology Institute).

The two spectra shown in Fig. 5 are: (a) before the polar low arrives (at 13.48 GMT), and (b) at (or near) the peak of the event (at 19.47 GMT). The peak period T_p at 13.48 GMT is 7.5 s. There is, however, a rather flat plateau between the periods 7.5 s and 11.4 s. By the arrival of the polar low the peak period changes to 14.2 s (wavelength 315 m).

The evolution of some wave parameters is shown in Fig. 6. Remarkable is the steep rise, especially between 17.00–20.00 GMT. From the frequency spectra it is possible to estimate the relative growth of spectral energy for this period. This is shown in Fig. 7 and demonstrates how the largest growth has taken place in a rather narrow band around the frequency $f_p = (14.2)^{-1}$ Hz. In terms of H_c the increase is from 5 to 9 m, and for H_{max} the corresponding numbers are 7 and 16 m.

For comparison with the theoretical model, we use the following numbers: $U = 25$–28 m/s, $V = 10$ m/s, $l_{max} = 650$ km. To estimate l is rather difficult. If the wind data at A.M.I. is used, measuring the time that the wind was within 15% of the peak value, and multiplying by $V = 10$ m/s, we get roughly $l = 250$ km. The condition (13),

Table 3. *Estimates of T_p and H_c for the polar low 17 February 1978, at the position of A.M.I. (71.5°N, 19°E)*

U (m/s)	H_c (m)	T_p (s)
25	8.6	14.4
28	9.6	15.3

which for $U = 25$ m/s is $l > 133$ km, and for $U = 28$ m/s, is $l > 105$ km, is probably well satisfied. The ratio V/U is in the range 0.4–0.36, so that the spectrum has not outrun the polar low (for the given V and U it would take a fetch, l_{max}, of 1000 km for the spectral peak to overtake the polar low). With the velocity $V = 10$ m/s, the "resonance" period is 12.8 s.

We can now use (3), (4), (5) and (7) to give an estimate of T_p and H_c at A.M.I. (with a fetch 650 km) (see Table 3).

This should be compared to the measured values of $T_p = 14.2$ s and $H_c = 9.3$ m.

3.2. *Conclusions*

It seems that the data we have considered, both from laboratory and field, tend to support the simple one-dimensional theoretical model of Section 2, both qualitatively, and to some extent quantitatively. More data is of course needed to see whether the predictions from the model are reliable. So far we have not seen a case with anomalous (double-peaked) spectral development. Only in the laboratory experiment have we seen a case where the wind field is outrun by the spectrum. Clearly there is a need for more detailed field data, especially data covering a larger area. It is possible that a combination of SAR, altimeter, and scatterometer data from the coming European Remote Sensing Satellite (ERS 1), can give a closer look on the effects of a polar low on the sea surface.

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