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PERIODIC FLUCTUATIONS IN WIND, PRESSURE AND TEMPERATURE AT PORT HEDLAND

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ABSTRACT

Unusually regular and persistent fluctuations developed in a fresh NW wind at Port Hedland, on the northwest coast of Australia, on 9 November 1963.

Presumably the fluctuations were associated with the development of gravity waves on a sea breeze front below 1000 feet over Port Hedland. An estimate is made of the speed and direction of motion of the waves.

One year's records at Port Hedland and Broome, another station on the northwest coast, indicate that there, the occurrence of periodic fluctuations in surface wind are not unusual following the development or arrival of land or sea breezes or coastal fronts.

1. INTRODUCTION

Periodic fluctuations in autographic records of wind and pressure, associated with gravity waves, have been described and discussed theoretically by various authors including Goldie (1925), Pothecary (1954), and Gossard and Munk (1954). Such fluctuations have been observed in autographic records at Australian stations but probably few have been as pronounced as those recorded at Port Hedland (20° 23'S, 118° 37'E) on the afternoon of 9 November 1963 and the following night.

2. SYNOPTIC SITUATION AND OBSERVATIONS

The synoptic situation for 1300 WST 9 November 1963 is presented in Fig. 1. About 150 to 200 miles inland from the northwest coast of Australia, a trough of low pressure was orientated SW/NE with SW to WSW gradient flow along the coast. On the 1600 WST chart (not presented) N/NW sea breezes were in evidence at all coastal stations north of 21°S.

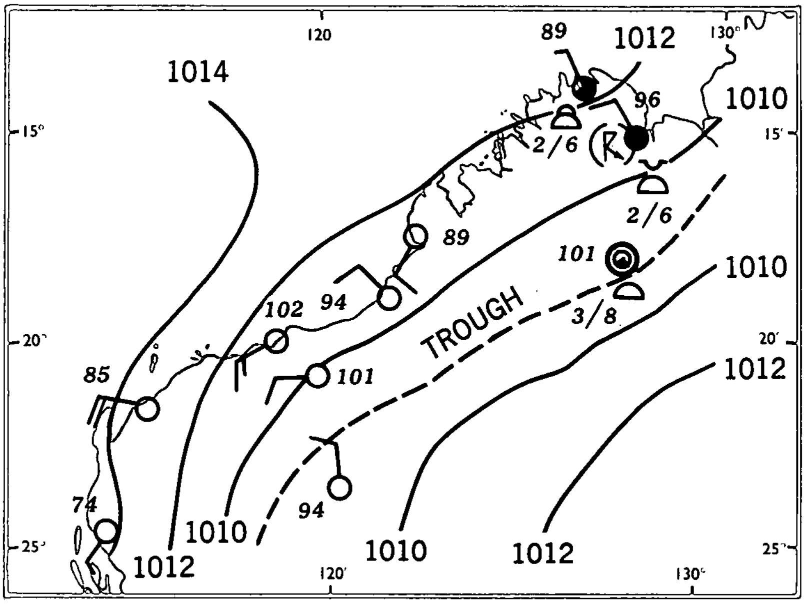

Fig. 1 M S L synoptic situation for 1300 WST 9 November 1963.

At Port Hedland the weather was practically cloudless throughout the day. Pothecary (1954) described waves initiated at a temperature discontinuity by a thunderstorm surge but in this case the nearest thunderstorm reported was at noon at Wyndham (15° 27'S, 128° 06'E) some 600 miles northeast of Port Hedland. At other stations within 300 miles of the coast no more than scattered large Cu was reported during the afternoon. No waves were recorded at Broome, about midway between Wyndham and Port Hedland.

Sections of the Port Hedland anemograph, barograph and thermograph charts covering the duration of the fluctuations are presented in Figures 2-4. The barograph record is from a weekly trace magnified for clarity. Temperature was not recorded from 1250 to 1500 WST, but from hourly observations it seems that the maximum temperature (104.8°F) occurred between 1400 and 1500 WST, the hour in which the fluctuations commenced.

Once daily radiosonde observations are made at about 0715 WST at Port Hedland. At 0715 WST on the 9th (see Fig. 5) the breakdown of the nocturnal surface inversion has occurred below 1000 mb. The sounding 24 hours later is practically the same as that for the 9th. Modifying the sounding for the 9th on the basis of the maximum surface temperature (40.5°C), a dry adiabatic lapse rate at the time of the maximum would have extended to 635 mb where an insignificant inversion of 0.5°C existed over a 10 mb layer. Upper winds covering the period of the fluctuations are given in Table 1.

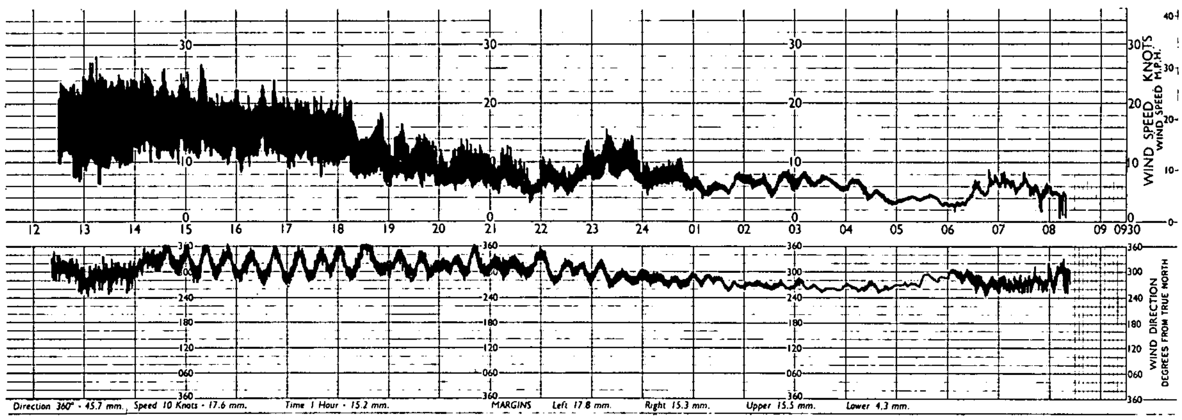

Fig. 2 Port Hedland anemograph record for 1300 WST 9 November to 0830 WST, 10 November 1963.

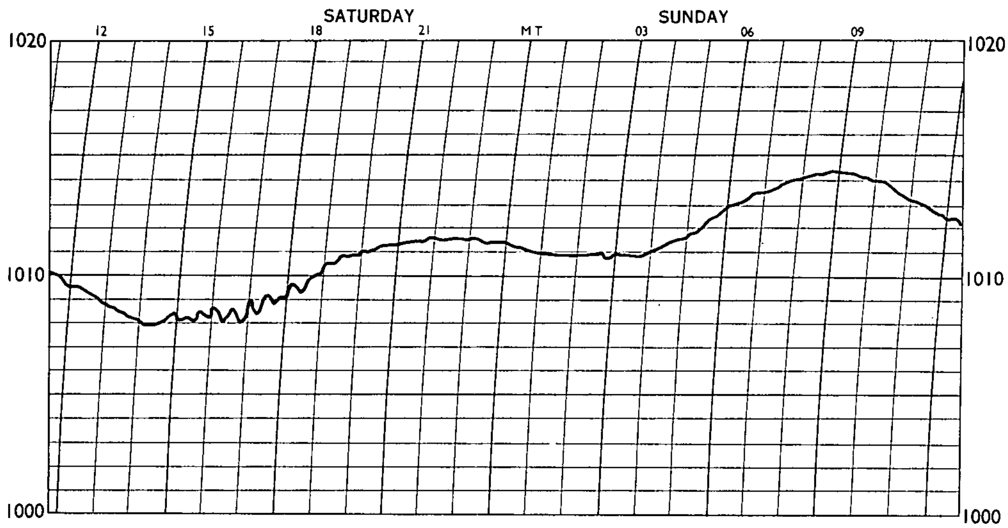

Fig. 3 Port Hedland barograph trace for 24 hours from 1200 WST 9 November 1963.

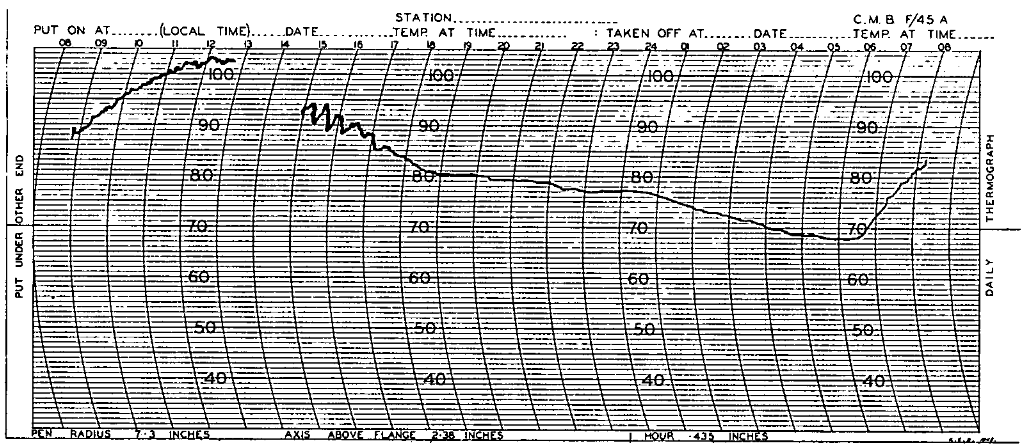

Fig. 4 Port Hedland thermograph record from 0850 WST 9 November to 0810 WST, 10 November 1963.

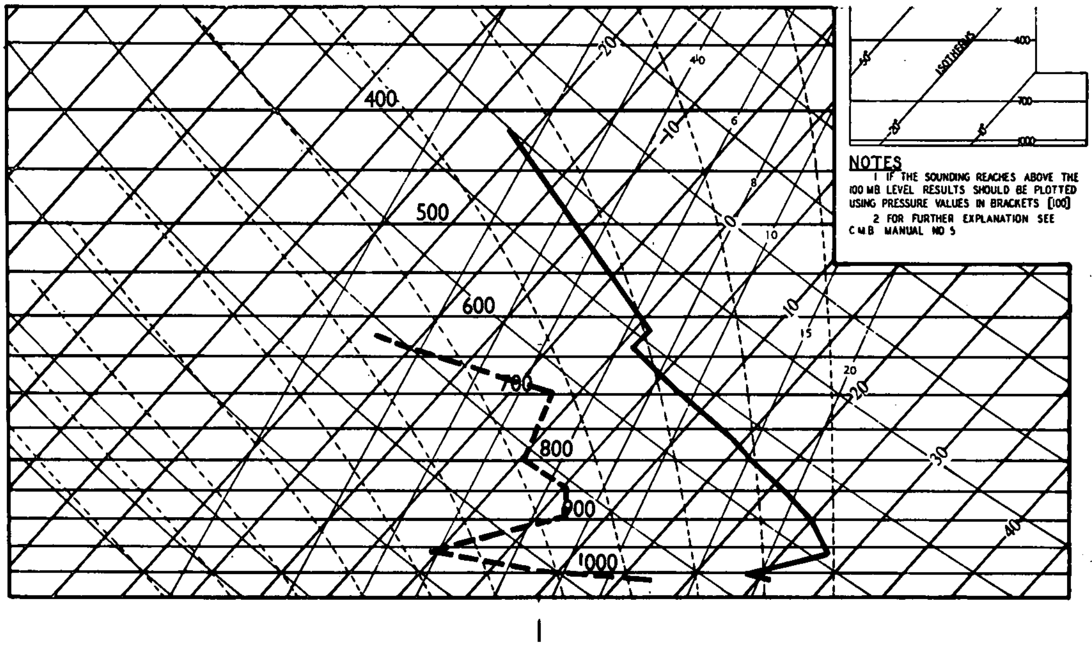

Fig. 5 Port Hedland radiosonde observation at 0715 WST 9 November 1963.

Table 1. Port Hedland Upper Winds (deg/kt)

	Hour (WST) and Date			
Height (ft)	0700 9th	1300 9th	1900 9th	0100 10th
Surface	250/10	300/17	340/10	270/08
1,000	241/13	282/14	280/17	264/23
2,000	251/22	270/12	262/22	246/23
3,000	260/21	275/18	263/19	254/25
5,000	310/17	294/17	273/17	250/19
10,000	330/32	331/25	313/15	317/26
15,000	310/19	320/25	290/14	330/24
20,000	280/28	-	260/19	310/17

The normal direction of the sea breeze at Port Hedland is from NW. As the upper winds in Table 1 are mean values over 1000 ft layers it is not possible to determine the precise height of the top of the sea breeze, but the observations suggest that it was below 1000 ft at 1900 WST.

3. THE WAVE MOTION

Pothecary, following Goldie (1925), has discussed features of waves on a discontinuity between two superimposed streams in an incompressible fluid. With a lower stream of depth h, density ρ and mean velocity $\underset{\sim}{U}$ (mean speed U) flowing over a rigid surface and assuming that the upper stream is unlimited in depth and that the length of the waves is large compared with the height of the discontinuity

$$\Delta p_s = \frac{\rho a}{h} (U \cos\beta - V)^2 \qquad \ldots (1)$$

$$\Delta U_s = \frac{a}{h}(U \cos\beta - V) \qquad \ldots (2)$$

where Δp_s is the amplitude of the surface variation of pressure,

ΔU_s the amplitude of the surface variation of wind speed,

a the amplitude of the wave motion on the discontinuity,

β the angle between the mean surface wind and the direction of travel of the waves,

and V the speed of the waves relative to the ground.

From (1) and (2)

$$U \cos\beta - V = \frac{\Delta p_s}{\rho \Delta U_s} \qquad \ldots (3)$$

Gassard and Munk (1954) give a relation (their equation (1)) from which the direction of $U \cos\beta - V$ can be obtained. $U \cos\beta - V$ is directed in the direction of the orbital wind at the time of the maximum pressure.

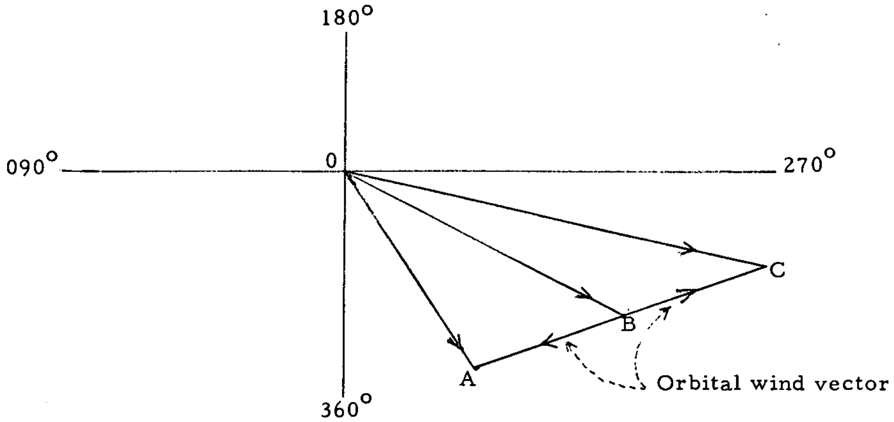

Fig. 6. Example of orbital winds (see text).

If during the fluctuations the end points of the surface wind vector trace out the line AC and OB is the mean wind vector, then BC and BA are defined as the orbital wind vectors (see Fig. 6). $U \cos\beta - V$ will be directed along BC or BA according to whether the positive pressure oscillation occurs with wind OC or wind OA.

In the period 1500-1830 WST, when the waves were most pronounced, the core of the surface wind direction record oscillated between 340° and 290° with a mean velocity U of 315°/15 kt. The maximum positive pressure change occurred when the wind direction was 290°, so from a hodograph plot the appropriate orbital wind direction is approximately 230°. In this case β is then 85°.

Taking the mean temperature of the lower air as 31°C, $\rho = 1.16 \times 10^3$ gm m^{-3}, and from the autographic records

$$2\Delta p_s \simeq 0.6 \text{ mb} = 0.6 \times 10^5 \text{ gm m}^{-1} \text{ sec}^{-2}$$

$$2\Delta U_s \simeq 14 \text{ kt} \simeq 7 \text{ m sec}^{-1}$$

Then from equation (3)

$$U \cos\beta - V = 7.4 \text{ m sec}^{-1} = 15 \text{ kt.}$$

But $U \cos\beta \simeq 1$ kt. The waves therefore were moving relative to the earth's surface with a velocity of 050°/14 kt. This direction is parallel to the normal orientation of the sea breeze boundary.

The length λ of the waves is given by

$$\lambda = TV \qquad \ldots (4)$$

where T is the period. Between 1500 and 1830 WST the average period is 26 min so λ is approximately 6 n. mi. or 11 km. Also from equation (2) the amplitude a of the waves is 7h/15, i.e. approximately half the height of the discontinuity. However, the observational data do not give the height precisely although the 1900 WST winds (measured over 1000 ft layers) suggest it is below 1000ft.

After 1830 WST the pressure oscillation becomes too small to apply the relations given above. Although the sea breeze was replaced by "gradient" flow after 2300 WST, weak oscillations persisted until 0700 WST the next day. Perhaps the wave motion was transferred to the surface inversion which developed during the night, the wave motion ceasing with the breakdown of the surface inversion after 0700 WST. This seems more likely than the possibility of the wave motion being associated with the very weak inversion at 640 mb.

4. DISTRIBUTION OF FLUCTUATIONS BY MONTH AND THE SYNOPTIC SITUATION

One year's records at Port Hedland and Broome (17° 57'S 122° 13'E) were examined for the occurrence of other cases of periodic fluctuations in the surface wind.

At Port Hedland in 1962 there was only one case and at Broome in 1963 four cases of fluctuations approaching the regularity of those in the case discussed above.

The total number of cases, including moderately regular and slight fluctuations, is given in Table 2.

Table 2. Number of cases of periodic fluctuations in surface wind in one year at Port Hedland (1962) and Broome (1963).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Port Hedland	4	2	1	0	0	1	1	2	2	1	4	8	26
Broome	2	1	2	3	0	0	2	1	2	6	1	4	24

In all cases the mean wind speed during the fluctuations was 12 knots (3 cases) or less.

Although the individual synoptic situations were not examined, study of the autographic records indicates that most cases of fluctuations occurred following the development or arrival of a land or sea breeze, a coastal front or, in winter, a cold front. The classification is given in Table 3.

Table 3. Classification of situations in which periodic fluctuations occurred.

	Following or with			No change in wind direction
	Sea Breeze	Land Breeze	Coastal or cold front	
Port Hedland	3	9	8 *	6
Broome	13	5	3	3

* one following a thunderstorm

5. CONCLUSION

Although periodic fluctuations in surface wind are not unusual on the northwest coast of Australia following the development or arrival of a sea or land breeze or a coastal front, the fluctuations recorded on 9 November 1963, following the development of sea breeze, were unusual in their persistence and regularity and in the strength of the wind during the fluctuations.

REFERENCES

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