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Geostrophic wind over Cape York Peninsula and pressure jumps around the Gulf of Carpentaria

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Surface pressure data for six Octobers (1978-1983) are used to calculate mean daily geostrophic wind over Cape York Peninsula. Barograms for Normanton, 30 km inland from the southeast corner of the Gulf of Carpentaria, and Mornington Mission, in the Gulf, are examined for marked nocturnal or early morning pressure jumps for the same period. Mean and standard deviation of the components of geostrophic wind, time of arrival of pressure jumps and their amplitude, and correlations between these, have been derived. These show some effect of the geostrophic wind on the formation and behaviour of pressure jumps, which are shown to be a very common phenomenon in October, and by no means always detectable with standard barographs.

Introduction

Since no detailed study has hitherto been made of the surface geostrophic wind in October over Cape York Peninsula, and since it turns out that this velocity is an important determinant for sea-breezes and bores alike, six years' October surface pressure data in the area have been inspected, and Bureau of Meteorology barograph records from two places (Normanton and Mornington Mission, on Mornington Island) examined for marked pressure jumps. An examination similar to the latter has been made by Neal et al. (1977) for five stations, but not related to detailed pressure gradients.

Geostrophic winds at daily intervals

These were derived objectively, as detailed below, from sea-level pressure measured at five stations, namely Normanton, Mornington Mission, Kowanyama, Cairns (for locations see Smith and Morton 1984, Fig. 1), and Thursday Island (10°35'S, 142°13'E) near the tip of the Peninsula. An experiment for one month, using another two stations (Cooktown and Weipa), suggested that these added little further information, and their use was abandoned. After trying 0900 h (EST*) and 1500 h data, it was decided that only the 0900 h data were suitable, both because, as 0900 h is the chief observing time, they were more frequently available, and because the diurnal heating (sea-breeze) effect on pressure is quite strong in the afternoon at places inland of the coast, such as Normanton, and this perturbs the pressure field markedly. This effect, if present, is much less pronounced at 0900 h. The 'morning glory' effect on the pressure serves to restore a nearly balanced condition.

For the purpose of assigning a geostrophic wind to a sea-breeze or bore event, it was assumed that the most relevant pressure gradient is that at 2100 h, and that this is, in unperturbed form, best approximated by a simple average of the preceding and following 0900 h geostrophic wind components, U and V. Here U is positive normal to the central axis of the Peninsula, which is oriented 349-169 degrees (i.e. U is the component from 079 degrees), and V is the component along the axis (i.e. from 349 degrees). On most days the geostrophic wind over the Peninsula is from the northeast, i.e. U and V are generally both positive; but in October, as described in Clarke (1983a, b) disturbances in the form of pressure troughs or cold fronts, usually oriented in a west to east or west-northwest to east-southeast direction, are known to move north over the Peninsula, interrupting the normal northeasterly geostrophic wind, and sometimes replacing it by a northwesterly, followed later by a fresh southeasterly one. The technique of computing the geostrophic wind from the surface pressure array consists of fitting a plane by least squares, from the slope of which geostrophic wind components U and V are readily computed. Clearly, this procedure gives reasonable results only when the pressure gradient is fairly uniform over the area of interest. With a synoptic-scale pressure trough lying across the Peninsula this condition is certainly not met, and in general the local geostrophic wind will differ, sometimes markedly, from the areal mean. The passage of a nocturnal pressure jump at Normanton, linked with a southern cold front, was noted on seven occasions in the six months of observations examined, but cold fronts at Normanton are not necessarily associated with pressure jumps. For example, the marked cold front, accompanied by a broad cloud shield and considerable rain (8.5 mm

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* 10 hours ahead of GMT.

at Normanton), moving north over Normanton on the afternoon of 3 October 1981, did not produce a sharp pressure jump there, although the temperature dropped to an unusually low 14 °C after the frontal passage. The cold outbreak and fresh winds accompanying this disturbance interrupted the normal sequence of nocturnal pressure jumps in the Peninsula-Gulf of Carpentaria area for four days (3 to 6 October).

Pressure jumps in the Gulf area

The barograms for 186 days from Normanton and 173 from Mornington Mission (some data were lost) were examined for marked nocturnal pressure jumps; the amplitude (A) and the time of occurrence (t) were logged, together with U and V (each the average of two 0900 h determinations). Means, standard deviations, and correlations were computed, and the surface winds in the field books inspected to find whether the pressure jumps were associated with a following east ('easterly jump') wind, or south ('southerly jump') wind. No marked jumps associated with a southerly disturbance were detected at Mornington Mission, although signs of frontal passages occur there as they do at Normanton; while seven were found at Normanton. The results of this statistical treatment are presented in Tables 1 and 2.

It will be noted that 69 per cent of October days had marked pressure jumps at either Normanton or Mornington Mission, that they had a mean magnitude of about 1 mb, were about equally frequent at both stations, and on less than half of the 69 per cent of days with easterly jumps they occurred at both places. The correlations show that at Normanton (but not at the island station) the amplitude of the jump is related negatively to U. At both places, the later the arrival time, the stronger the jump tends to be, while the closest relationship at both places is between strong geostrophic wind and early arrival of the jump.

This expected result lends credence to the concept of mean geostrophic wind over the Peninsula controlling, to some degree, the bore-producing

Table 1. Mean and standard deviation of U,V,A, t for I: occasions when a pronounced pressure jump occurred at either or both of Normanton and Mornington Mission; for II: occasions when such a pressure jump occurred at both places; for III: occasions with southerly pressure jumps at Normanton; and for IV: occasions with no easterly pressure jumps at either place. n is the number of observations, and f the frequency of occurrence (per cent). Time is in hours and minutes EST.

	I		II		III		IV
	Norm'n	M M	Norm'n	M M	Norm'n	M M	
n (days)	89	86	55		7	0	54
f (per cent)	49	51	32		4	0	31
Mean U (m s^{-1})	7.3	7.6	7.9		2.4	—	5.8
SD of U (m s^{-1})	2.6	3.0	2.3		3.3	—	4.3
Mean V (m s^{-1})	6.7	6.9	7.0		2.8	—	3.8
SD of V(m s^{-1})	2.2	2.2	2.1		3.3	—	4.3
Mean A (mb)	0.96	0.92	0.98	0.97	1.00	0	0
SD of A (mb)	0.34	0.40	0.32	0.44	0.39	0	0
Mean t (hr, min)	0305	0607	0241	0616	0206	—	—
SD of t (min)	106	82	96	69	169	—	—

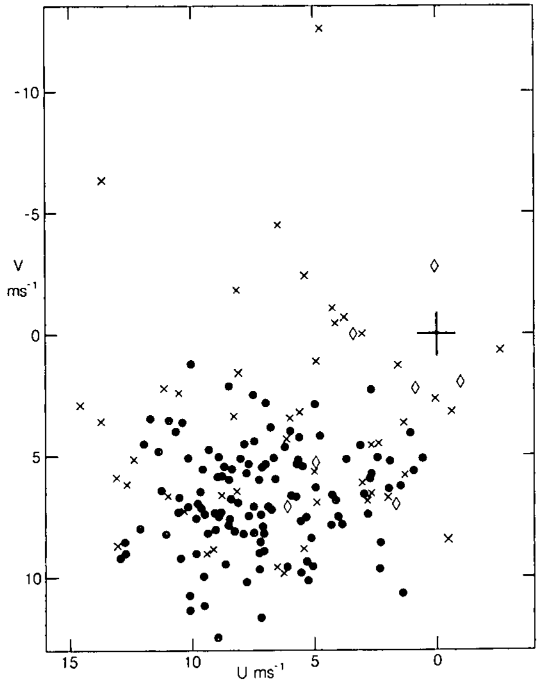
Table 2. Correlation coefficients (r), with confidence level in per cent (C), between amplitude (A), time of arrival (t) of pressure jumps and components of geostrophic wind (U and V) for I: occasions when the pressure jumps occurred at either or both of Normanton and Mornington Mission; and II: occasions when the jumps occurred at both places.

	I				II			
correlands	Normanton		Mornington		Normanton		Mornington	
	r	C	r	C	r	C	r	C
A, t	0.16	87	0.19	93	0.14	<80	0.21	89
A, U	-0.20	95	0.11	-	-0.24	93	0.06	-
A, V	0.08	-	0.00	-	0.13	<80	-0.06	-
t, U	-0.42	>99	-0.15	82	-0.41	>99	-0.21	89
t, V	-0.23	97	-0.12	<80	-0.11	-	-0.10	-

processes, although the rather low correlations, especially at Mornington Island on the western margin of the network, suggest that other determinants may be more important. Among them will be the spatial variation of geostrophic wind and, obviously, cloudiness over the Peninsula during the preceding day, for this largely controls the solar input, and thus the amount of available potential energy created during the day. This in turn largely determines the strength of the sea-breezes and resultant pressure jumps or bores. The investigation of cloudiness and bore production has not been explicitly addressed. It could be attempted, with sufficient satellite data coverage, by averaging the cloudiness over the relevant part of the Peninsula, and estimating its effect on the surface radiation balance.

The association between 2100 h geostrophic wind and pressure jumps is shown in Fig. 1, in which the occurrence of easterly and southerly jumps at either Normanton or Mornington Mission, and no detectable jumps at all, is plotted in geostrophic wind space. It can be seen that occurrences of easterly pressure jumps lie within an ellipse whose axes extend from about U = 0 to about U = 13 m s^{-1}, and from V = 1 to about V = 12 m s^{-1}. About 80 per cent of days falling within this ellipse were classified as having marked pressure jumps, while the eleven per cent of days lying outside it are characterised by a disturbed synoptic situation and no marked easterly jumps, although southerly ones may occur at Normanton and other coastal areas. The relatively frequent occurrence of jumps at Mornington Island unaccompanied by detected jumps on the Peninsula probably reflects non-uniformity in the controlling factors. No significant differences in the mean geostrophic winds for such cases could be found. In Clarke (1984) it is shown by numerical modelling that with sufficiently strong U the bore producing the jump may be formed offshore.

Fig. 1 Occurrence of easterly pressure jumps (dots), southerly pressure jumps (diamonds), and no pressure jumps (crosses) at Normanton and Mornington Mission, plotted against the geostrophic wind vector, for each October day from 1978 to 1983.



It is relevant to note the inadequacy of the available barograph traces to detect all the pressure effects observed in the Gulf area. In Clarke (1983b) we showed (Fig. 4) a recording of rate of change of surface pressure obtained at Karumba by A. Samah, then of La Trobe University, during October 1980. Many more such records were obtained, spanning the period 4 to 19 October of that year, and these reveal the high frequency of occurrence of pressure jumps and waves in the early morning. In the list of days of occurrence of pressure jumps at Normanton (30 km southeast of Karumba) prepared for the current investigation, no marked jump was recorded on eight days during the period covered by Samah's observations, although the geostrophic wind, located on Fig. 1, suggested that there should have been jumps on each of these days. Figure 2, depicting the rate of change of pressure traces recorded by the La Trobe University system (Jones and Forbes 1962; Essex and Love 1978; Samah 1981), shows that there were indeed well-defined pressure jumps at Karumba on each of the eight days in question, although the Bureau's barograph at Normanton was not sensitive enough to record them. The Normanton barogram for the period 3 to 6 October 1980 is included in the figure. Thus pressure jumps in the area bordering the Gulf are evidently much commoner than examination of standard barograph records would suggest, and it is likely that many of the crosses in Fig. 1, indicating 'no pressure jump', at least within the domain 0 < U < 13, 1 < V < 12 m s^{-1}, should be replaced by a symbol meaning 'weak pressure jump'.

It should also be observed that close examination of the surface pressure observations used in determining U and V illustrate the difficulties of obtaining regular, timely, and accurate data from amateur observers in remote areas where supervision is rare. The result is to throw considerable and incalculable variance into the estimates of geostrophic wind, which in any case varies markedly both spatially and temporally, and has had to be assumed uniform and constant for a day at a time.

Conclusions

Pressure jumps, usually followed by wavelike fluctuations, and almost certainly due to interaction of opposing sea-breeze gravity currents, are very common in the nocturnal atmosphere of western

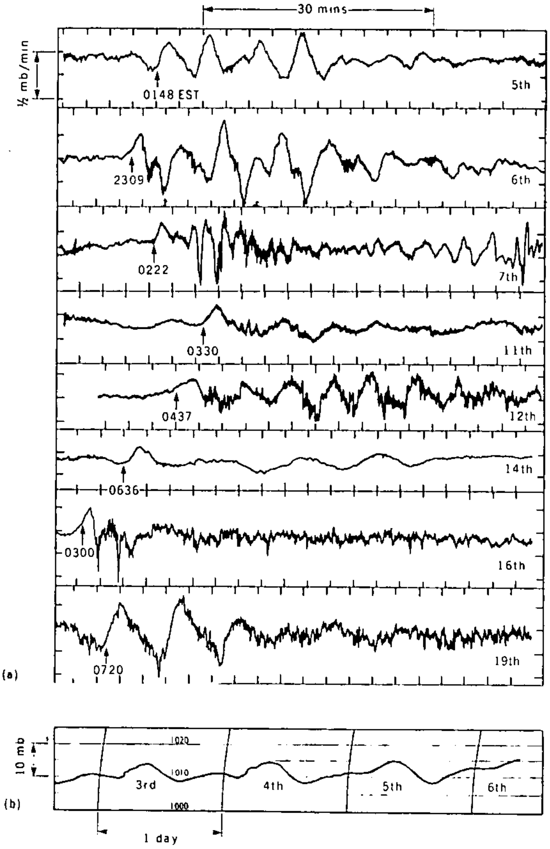


Fig. 2 (a) High quality records of rate of change of pressure at Karumba for eight pressure jump events in October 1980, not detected by the standard barograph at Normanton. These traces were obtained from microbarographs of the kind used in the LaTrobe University system. These instruments measure rate of change of pressure as distinct from actual pressure measured by normal Bureau of Meteorology barographs.
(b) Four-days record by the Normanton barograph in October 1980, included for comparison with (a).

Cape York Peninsula and the Gulf of Carpentaria in October. Most come from the east-northeast, the direction of the eastern coast of the Peninsula, and they apparently occur on well over 70 per cent of days in some part of the morning glory zone. These days are those relatively unaffected by synoptic-scale disturbances. On a minority of days, perhaps about four per cent along the southern shores of the Gulf, jumps come from a southerly direction, and probably signal the interaction of a southern front with the sea-breeze preconditioned nocturnal boundary layer about the coast. The lack of observed southerly jumps at Mornington Island is attributable to the lack of a suitable sea-breeze conditioned boundary layer there, in such situations.

A determining factor in the occurrence and behaviour of easterly pressure jumps has been shown, despite the difficulties, to be the strength and direction of the geostrophic wind. The presence of a widespread cloud shield must be a strong inhibiting factor, but this is relatively rare in October and has not been investigated.

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