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The Climate of Aldabra Atoll

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The climate of Aldabra Atoll

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Contents

Meteorological observations made by members of the expedition since August 1967 are the first to appear from Aldabra which cover a sufficient time span to merit analysis. Data for the period November 1967 to October 1968 are compared with marine derived parameters available from climatological atlases.

Aldabra experiences a 5- or 6-month wet season in most years and its climate may be classified as V_2/V_3. During midsummer 1967/8 a marked positive pressure anomaly was observed: this coincided with a 3-month failure of the monsoon. For 7 months of the year the southeast trade winds blow, with a constancy of more than 90%.

Summer maximum temperatures average 32 °C (90 °F) at the Settlement synoptic station, but this station is atypical for much of the atoll where maximum temperatures are about 3 °C lower. Winter minimum temperatures average 22 °C (72 °F). The annual pattern of temperature fluctuation for Picard compares most closely with the Comoro Islands. Summer maxima are identical with Diégo Suarez values; winter minima with the Seychelles. The highest and lowest shade temperatures recorded in the year were 36.3 °C (97.4 °F) and 19.5 °C (67.1 °F). The diurnal temperature range varies little throughout the year, averaging 6.5 °C, though extremes of 11 °C are occasionally recorded.

Lagoon water temperatures are tidally controlled. At springs mean values may exceed the local air shade temperature by more than 3 °C. This could lead to very high temperatures in the lagoon in summer, but the exact magnitude must be ascertained from future observations.

Sunshine measurements have not yet been made on the atoll. Calculations of probable monthly sunshine totals based on cloud observations show that October is clearly the sunniest month with a computed average of 8.6 h/day; January and April are least sunny, with 5.4 h/day. The annual total calculated for Aldabra (2400 h average; 2100 h 1967/8) is considerably at variance with regional values shown on world maps of climatology (indicating 1800 h). This can be resolved only by obtaining instrumental records from the island.

The mean annual rainfall of 670 mm (26.5 in) derived from 7 years records is strikingly lower than atlas predictions. It places Aldabra in the most arid sector of the western Indian Ocean. From 1950 to 1960 a sequence of pairs of wet and dry years can be discerned, with extreme yearly totals of 1200 and 350 mm (47 and 14 in). The monsoon may occasionally be as short as 2 months, and droughts of 3 months or more are recorded during the trades. In 1967/8 summer rainfall showed a continental-type bimodal distribution, though on average it shows a broad plateau tending towards a late summer maximum (cf. Lindi, Tanzania). In 1967/8, 42 % of the yearly rainfall fell on 5 days as violent showers with more than 40 mm (1.6 in).

Local climatic effects were investigated from an auxiliary meteorological station set up at Middle Camp, Passe Houareau. In October 1968 the mean trade-wind speed exceeded 9 m s^{-1} (19 knots) from 08h00 to 13h00; which indicates a tendency to underestimate its strength considerably when observing at Settlement. Appreciable east–west variation in rainfall totals occurred. It is this essential to evaluate any precipitation gradient which may exist during the monsoon, for rainfall totals from Picard may bear little relation to the southeastern region.

Analysis of autographic charts indicates that relative humidity varies from stable night values of around 93 % to minima of 70 % during early afternoon. In late September/October, values as low as 50 % have been recorded. A strongly semi-diurnal distribution of rainfall is shown by Dines tilting syphon raingauge charts, which correlates with the S_2 atmospheric tide. During the monsoon frequency of rain shows a pre-dawn maximum: during the trades a pre-dusk maximum, which is not typical of a truly oceanic atoll.

1. Introduction

The standard texts of Riehl (1954) and Roll (1965) provide a good background to tropical meteorology. Works restricted to the Indian Ocean have recently become available as a result of the International Indian Ocean Expedition's activities. These include a general survey of the climate (Ramage 1968*a*) and a meteorological atlas of the surface climate of 1963 and 1964 (Ramage, Miller & Jefferies 1968). Monthly meteorological charts of the Indian Ocean are published by both the British Meteorological Office (1959) and the Koninklijk Nederlands Meteorologisch Institut (1958): these provide 20-year averages for the major climatic phenomena. An environmental atlas for the western Indian Ocean and the Gulf of Aden is shortly to be published by the Director of Meteorology and Oceanographic Services (Naval). The development of synoptic disturbances affecting Aldabra and the neighbouring Indian Ocean region may be studied from the *Cartes Synoptiques quotidiennes* published by the Malagasy Republic (1967). Ramage (1968*b*) has reviewed the problems of analysing meteorological data from the Indian Ocean. On a wider scale the most significant recent advances in our understanding of tropical meteorology have come from Bjerknes (1966) who has noted the significance of equatorial anomalies of ocean temperature in controlling the atmospheric Hadley circulation; Gordon (1967), who has successfully applied a Lagrangian method of analysis; and Johnson (1969), who has described the value of the network of daily reports arriving from weather satellites. An Indian Ocean cyclone, dated as 29 October 1968, is illustrated (Johnson 1969, p. 59). Studies of tropical meteorology directly related to atolls have been published by Lavoie (1963) and Brier & Simpson (1969).

(*a*) *History of past climatic records on Aldabra*

Climatological records are scarce for the atolls of the Aldabra group. Assumption, having a history of human intervention in its guano exploitation, has better records than any of the other islands, but even here informaton is largely of rainfall, and temperature data are inadequate. In accounts of the late nineteenth- and early twentieth-century expeditions (Voeltzkow 1897; Fryer 1911) isolated rainfall totals appear, usually for the summer monsoon period. These indicated values of about 400 mm per month and suggested an annual total much higher than is now known to be the case. Continuous rainfall measurements were begun in 1949 but ceased in 1953. Even during this period there are several months devoid of data. After a gap of

5 years there are 2 complete years' records for 1958 and 1959, both of which were very dry years with less than 370 mm per year. Throughout this period there do not appear to have been kept any records of temperature, wind or pressure.

Following the mounting of the Royal Society Expedition to Aldabra in 1967 continuous weather records have been maintained from August of that year to the present time. Synoptic observations are made daily at 09h00 local time from the station situated at the Settlement on Ile Picard (9° 23′ S, 46° 12′ E), 3 m above mean sea-level on the lee side of the atoll, where considerable shelter is afforded by tall *Casuarina* trees and coconut palms. Auxiliary stations were established for short periods at more exposed sites in the eastern part of the atoll. J. Frazier set up a station on Dune Jean-Louis (9° 27′ S, 46° 23′ E) in the early part of 1968, in a site exposed to the maximum trade-wind force. His studies are being currently extended over a more prolonged period, and should provide a very valuable comparison with Ile Picard. Later in 1968, G. E. Farrow ran a station at Middle Camp, Passe Houareau (9° 22′ S, 46° 26′ E), likewise in a fully exposed situation.

The records from these two stations serve to demonstrate the perhaps atypically sheltered aspect of the synoptic reporting station at Settlement. In the discussion which follows it should be borne in mind that the Aldabran data refer to sheltered situations, and reflect the greatest degree of 'continental' influence likely to occur anywhere on the atoll.

(*b*) *The climatic classification of Aldabra*

Aldabra lies in the Savannah Belt, and is classed as V_2 by Troll and Paffen (in Landsberg, Lipmann, Paffen & Troll 1965). Such a tropical humid-summer climate should accordingly possess from 9 to 7 humid months and from 3 to 5 arid months, and be characterized by rain-green humid forest and humid grass-savannah. However, the observations so far accumulated on the atoll suggest that a 6-month rainy season is the norm, if anything erring towards a longer dry season. This would bring the climate more into line with a V_3 classification, defined by Troll and Paffen as a wet and dry tropical climate with from 7 to 5 humid months and from 5 to 7 arid months. Rainy green dry wood and dry savannah are diagnostic of this group. Certainly, the overall impression of the vegetation of Aldabra is more in keeping with V_3. Comparison of Aldabra with other more fully documented regions in the savannah belt suggests a marginal V_2/V_3 climate. The V_2 belt includes the Laccadives, the Mascarenes and Tromelin, and on the East African coast runs from Malindi in the north to Lindi in the south, where the V_3 belt starts. As will be seen later in the section on rainfall (§5*c*) the seasonal distribution for Aldabra compares most closely with Lindi and Diégo Suarez, both situated on Troll and Paffen's V_2/V_3 boundary.

2. Seasons, winds and pressure

Seasons in the tropics are largely governed by the migration of the subtropical high-pressure belts and the passage of the intervening equatorial trough. As the former migrate through 5° of latitude while the latter migrates through 20°, it follows that the belt dominated by the trades is much broader in winter than summer. During winter pressure is high over Aldabra, and the southeast trades blow strongly. Pressure is low during summer when the equatorial trough reaches its maximum southerly extent, normally centring about 5° S. During this period winds blow less strongly, from WNW: periods of calm and frequent wind changes occur. This is the monsoon. Heated air originating from the Indian and African continents is drawn anticlockwise around the equatorial trough: cyclonic disturbances bring very heavy showers. The precise timing of the trough's migration from one year to the next, and their regular passage of disturbances through it, cause much unpredictability in both the duration of the monsoon and the quantity of rain falling. On average the summer season extends from late November to April, the two transitional months often being ones with heavy rainfall.

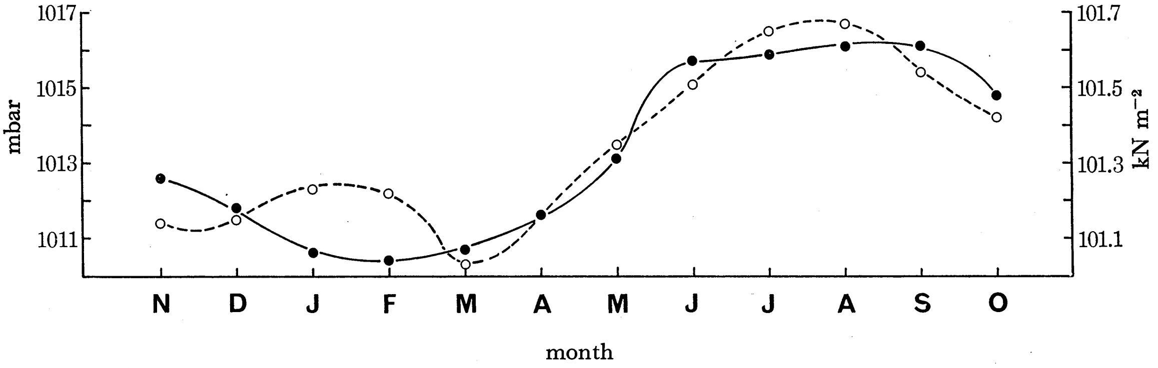

Figure 1. The annual fluctuation of atmospheric pressure over Aldabra. ●—●, 20-year average; ○---○, 1967/8. Twin troughs occurred in the summer of 1967/8; the intervening ridge marked a period of very stable, rainless weather. (Data from table 1.)

Table 1. Mean monthly atmospheric pressures/mbar

	1967/8†	20-year‡ average	difference from average
Nov.	1011.4	1012.6	−1.2
Dec.	1011.5	1011.8	−0.3
Jan.	1012.3	1010.6	+1.7
Feb.	1012.2	1010.4	+1.8
Mar.	1010.2	1010.7	−0.5
Apr.	1011.6	1011.6	0
May	1013.5	1013.1	+0.4
June	1015.1	1015.7	−0.6
July	1016.5	1015.9	+0.6
Aug.	1016.7	1016.1	+0.6
Sept.	1015.4	1016.1	−0.7
Oct.	1014.2	1014.8	−0.6

† 06h00 U.T. synoptic readings corrected for diurnal variation (−1.3 mbar) and altitude (−0.2 mbar) to give mean daily pressure.

‡ Mean daily pressure taken from *Environmental Atlas for the Western Indian Ocean and the Gulf of Aden* (Anonymous 1969).

(*a*) *Seasonal variation of pressure*

Figure 1 shows the annual variation of pressure for 1967/8 compared with the 20-year average derived from the *Environmental Atlas for the Western Indian Ocean and the Gulf of Aden* (1969). The average curve is obtained from marine observations; the 1967/8 curve from aneroid barograph traces recorded at Settlement, with appropriate height and diurnal corrections applied to obtain comparable mean daily pressures for each month. The monthly data are shown in table 1. Even allowing for hysteresis effects in the instrument and undue thickness of some lines on the barograph traces, which may cause individual synoptic readings to be as much as 0.5 mbar in error, the curves are significantly different, particularly in summer. Compared with the normal curve which possesses a broad trough centred about February, on average the wettest month, two troughs occurred; one relatively shallow, in November, when rain was heavy; the other much deeper, in March, again accompanied by heavy rain. In the intervening months pressure was 1.8 mbar higher than average, and rainfall negligible. It would appear that in 1967/8 the passage of the major low-pressure trough followed the variation of the Sun's zenithal latitude more closely than usual. Thus the predicted average annual pressure range of 5.6 mbar with a minimum of 1010.4 mbar in February and a maximum of 1016.1 mbar in August/September compares with an observed range of 6.5 mbar with a March minimum of 1010.2 mbar and a July/August maximum of 1016.7 mbar. The observed curve is markedly more symmetrical than the average. This slight difference is at least in part due to a terrestrial rather than a marine siting of the instrument.

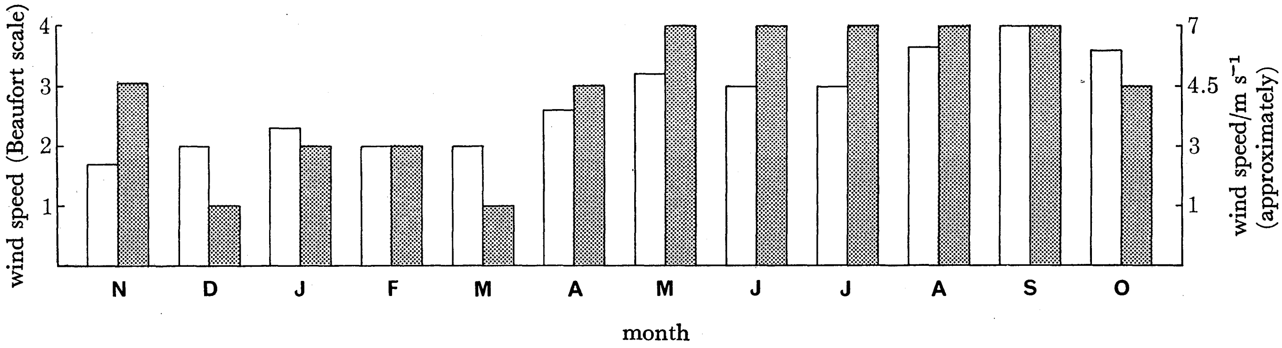

FIGURE 2. Observed wind speed for 1967/8 (unshaded) compared with the 20-year average for Aldabra (shaded). The persistent underestimation of trade-wind speed from the Settlement synoptic station is clear. (Data from table 2.)

(*b*) *Seasonal variation in wind speed*

Figure 2 compares the mean monthly 06h00 U.T. wind speed observed in 1967/8 at the sheltered Settlement station with the 20-year monthly average wind speeds (all observations). These, and all other averages concerning wind, are taken from the appropriate 5° latitude and longitude square on the *Monthly Meteorological Charts of the Indian Ocean* (1959). Because of the problem of isolating the differing effects of land and sea breezes at various points around the atoll this comparison should be limited strictly to sheltered sites on Ile Picard. Added error is also introduced by the distance of the 7.5° S/47.5° E square from Aldabra.

It is clear from figure 2 that even allowing for diurnal wind effects the wind speed during the trades was persistently underestimated. The apparent increase in strength during August, September and October is an artefact marking the change from phase IV to phase V in the expedition's personnel, and stresses the need for a less subjective analysis of wind speed. This should be possible from the Research Station, which occupies a much less sheltered site. Estimates of wind speed during the monsoon are more likely to be of the correct order of magnitude. In the 1967/8 season marked anomalies occur. The monsoon began about a month earlier than normal, so that instead of the usual ESE force three (*ca.* 4 m s^{-1}), winds were light and variable. A remarkably stable WNW airstream covered Aldabra during December and January, with faster winds than predicted, associated with the positive pressure anomaly described above. During the trades a continual force four (*ca.* 7 m s^{-1}) blows from May to September, diminishing to force three in the terminal months of April and October.

A more quantitative estimate of trade-wind speed is given in the section on local variation (§6*a*).

(*c*) *Constancy of surface wind direction*

Table 2 compares the predicted and observed constancy in wind direction. It is evident that a much higher constancy was observed than would have been expected from analysis of atlas records; except for November, which was irregular in many other aspects also. The very high constancy of the trade winds, as well as their speed relative to the variable monsoonal winds, fashions the shape of the atoll and determines the geomorphological characters of its coast. Regional variations in the shape of atolls may be controlled in part by trade-wind constancy, and their coastal phenomena by trade-wind speed. A study of the extent to which this hypothesis is valid may reveal patterns of anomalies which throw some light on the important question of Pleistocene and Recent climatic change. Certainly, it is probable that studies of intertidal zonation patterns on atolls may be closely correlated with trade-wind speed and constancy.

Table 2. Observed surface wind pattern for 1967/8 compared with the 20-year average

	dominant direction		mean speed (Beaufort scale)		constancy§ (%)	
	1967/8†	average‡	1967/8	average	1967/8	average
Nov.	—	ESE	1.7	3	40	41–60
Dec.	W/N	NE	2.0	1	97	0–20
Jan.	WNW	NW	2.3	2	87	21–40
Feb.	WNW	NW	2.0	2	68	21–40
Mar.	—	—	2.0	1	47	0–20
Apr.	SE	ESE	2.6	3	93	41–60
May	SE	SE	3.2	4	100	81–100
June	SE	SSE	3.0	4	97	81–100
July	SE	SE	3.0	4	100	81–100
Aug.	SE	SE	3.7	4	100	81–100
Sept.	SE	SE	4.0	4	97	81–100
Oct.	SE	SE	3.6	3	100	61–80

† 06h00 U.T. synoptic observations from Settlement.
‡ Twenty-year averages for all synoptic hours; taken from *Atlas of Monthly Meteorological Charts for Indian Ocean* (M.O. 519).
§ Constancy is defined as the percentage of all winds at the synoptic hour falling within 45° of arc centring on the dominant direction.

Figure 3 shows the seasonal pattern of wind speed, direction and constancy for various stations in the western Indian Ocean. In the duration of seasons Aldabra compares closely with Mayotte, though in winter the trades blow with far greater constancy than over the Comoros, where the continental influence of Madagascar creates variations in the local circulation. At Lindi on the Tanzanian coast the trades are more constant, but blow for a shorter season because of the greater monsoonal influence of the African continent: October and November are months of light and variable winds. Being more remote from continental influence, both Diégo Suarez and Agalega have a very protracted monsoon, the trades blowing for 10 months of the year. As these stations are near the centre of the trade-wind belt winds are very constant. The oceanic nature of the histograms for Aldabra and Agalega is readily apparent: of the six stations for which data are presented, only Agalega has a faster trade wind than Aldabra. The seasons in the Seychelles are of similar duration to those at Aldabra, but being nearer the doldrums winds are slower and blow with far less constancy. It would be instructive to establish whether reef zonation varies as greatly between Aldabra and Mahé as does the seasonal circulation.

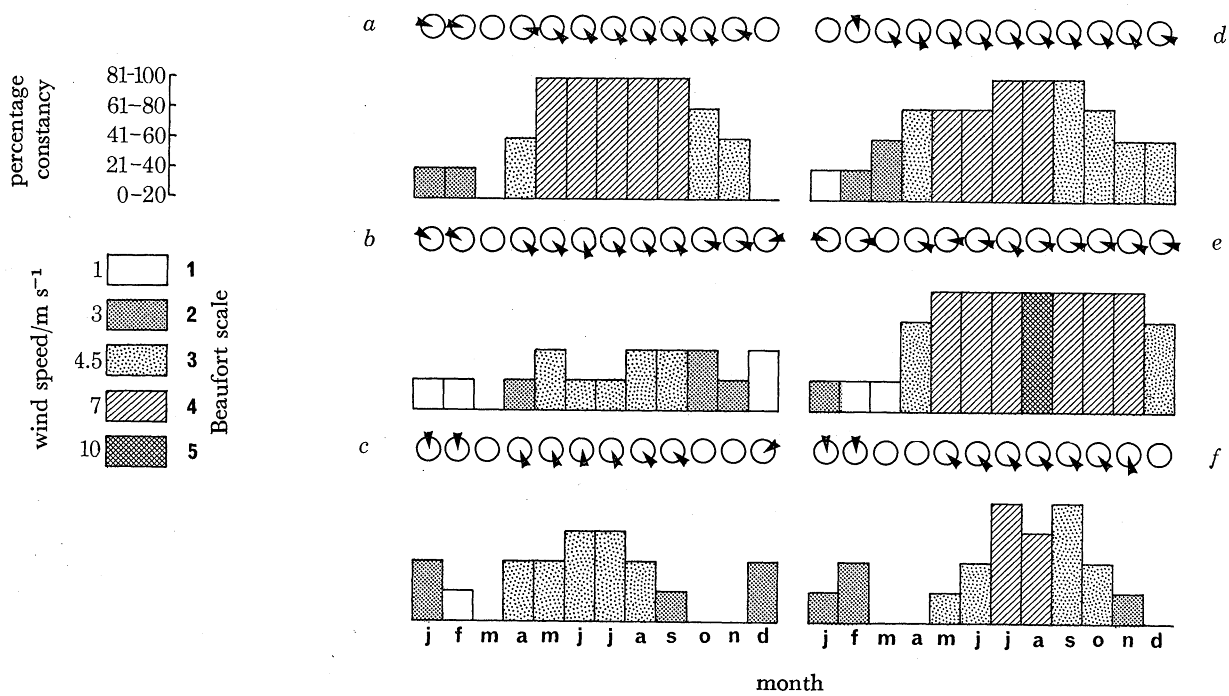

FIGURE 3. Duration of seasons, constancy and speed of wind, for six stations in the western Indian Ocean: *a*, Aldabra (9° 22′ S/46° 12′ E: 2.4 m); *b*, Dzaoudzi, Comoro Islands (12° 48′ S/45° 14′ E: 12 m); *c*, Lindi, Tanzania (10° 00′ S/39° 42′ E: 8 m); *d*, Diégo Suarez, Malagasy (12° 17′ S/49° 17′ E: 30 m); *e*, Agalega (10° 26′ S/56° 40′ E: 3 m); *f*, Port Victoria, Mahé (4° 37′ S/55° 27′ E: 4.5 m). (Data from R.S.E. records and M.O. 519.)

3. Temperature

(*a*) *Seasonal variation in air temperature*

Figure 4 shows the average monthly screen maximum and minimum temperatures for 1967/8, recorded at the Settlement station on Aldabra. Summer maximum temperatures reach 32 °C (90 °F): winter minimum temperatures 22 °C (72 °F). The annual fluctuation in mean monthly temperature of 4 °C is considerably less than the mean diurnal variation of 6.5 °C. Table 3 summarizes the essential air temperature data, including monthly extreme values. The highest temperature recorded was 36.3 °C (97.4 °F): the lowest 19.5 °C (67.1 °F). The mean diurnal range of air temperature varies only slightly through the year, being marginally greater in summer when ranges up to 11 °C (20 °F) have been recorded.

Table 4 compares the temperature régime of Aldabra with other stations in the western Indian Ocean. Summer maximum temperatures are identical with those of Diégo Suarez, though the diurnal range is not as great on Aldabra. Winter maximum temperatures compare most closely with those in the Seychelles, although in this instance Aldabra has a considerably greater diurnal range. Despite slightly lower temperatures throughout the year, the annual pattern of temperature variation and the diurnal range of Mayotte in the Comoro Islands is very similar to Aldabra. Agalega and particularly Mahé are of a markedly more 'oceanic' régime, with more equable temperatures throughout the year. However, it is as well to stress again that the Aldabran data are recorded from a very sheltered station, and they may well more resemble the figures from Mahé when alternative records from more exposed sites around the atoll become available: (see §6*a* on local climatic effects).

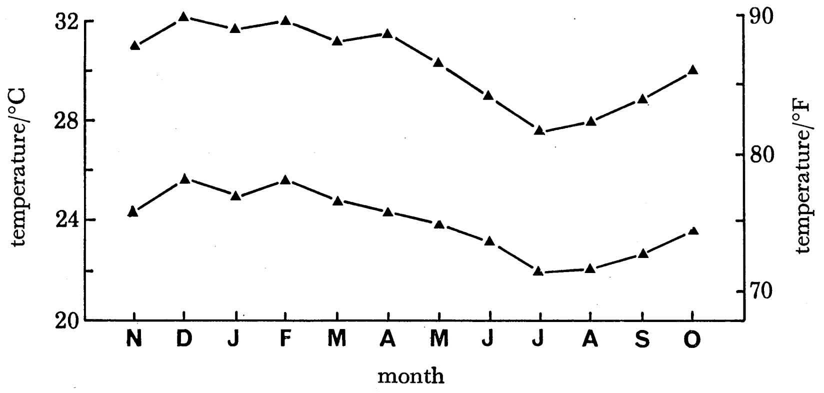

FIGURE 4. The seasonal fluctuation in maximum and minimum air temperatures at Settlement, Aldabra: 1967/8. (Data from table 3.)

TABLE 3. MEAN MONTHLY AND EXTREME AIR TEMPERATURES FOR 1967/8: RECORDED IN THE STEVENSON SCREEN AT SETTLEMENT

	average maximum		average minimum		highest maximum		lowest minimum		average diurnal range		greatest diurnal range	
	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
Nov.	30.9	87.6	24.3	75.8	33.4	92.2	22.5	72.5	6.6	11.8	9.6	17.0
Dec.	32.0	89.6	25.6	78.0	34.0	93.2	23.0	73.4	6.4	11.5	10.9	19.6
Jan.	31.6	88.8	24.9	76.8	36.3	97.4	21.6	70.8	6.7	12.0	10.0	18.0
Feb.	31.9	89.4	25.6	78.0	33.6	92.4	22.8	73.0	6.3	11.3	10.0	18.0
Mar.	31.1	88.0	24.7	76.3	32.9	91.2	23.1	73.5	6.4	11.6	8.7	15.7
Apr.	31.4	88.6	24.3	75.8	32.9	91.2	21.7	71.0	7.1	12.8	10.1	18.2
May	30.2	86.4	23.8	74.8	31.3	88.4	21.3	70.4	6.4	11.6	8.3	15.0
June	28.9	84.0	23.1	73.5	30.6	87.0	19.5	67.1	5.8	10.5	9.9	17.8
July	27.5	81.5	21.9	71.5	29.1	84.4	20.2	68.4	5.6	10.0	7.1	12.8
Aug.	27.9	82.2	22.0	71.6	28.5	83.3	19.6	67.2	5.9	10.6	7.7	14.0
Sept.	28.8	83.8	22.6	72.6	30.6	87.0	21.2	70.2	6.2	11.2	8.0	14.4
Oct.	29.9	85.8	23.5	74.2	30.7	87.2	22.0	71.6	6.4	11.6	7.8	14.2

TABLE 4. MEAN MONTHLY MAXIMUM AND MINIMUM AIR TEMPERATURES FOR STATIONS IN THE WESTERN INDIAN OCEAN: °C (°F)

	Aldabra		Comoro Islands		Lindi		Diégo Suarez		Agalega		Mahé	
	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.
Jan.	31.6 (89)	24.9 (77)	30.8 (87)	24.4 (76)	31.1 (88)	23.8 (75)	31.1 (88)	23.8 (75)	29.9 (86)	24.9 (77)	28.3 (83)	24.4 (76)
Feb.	31.6 (89)	25.5 (78)	30.8 (87)	24.4 (76)	31.1 (88)	23.3 (74)	31.6 (89)	23.8 (75)	30.8 (87)	24.9 (77)	28.8 (84)	24.9 (77)
Mar.	31.1 (88)	24.4 (76)	30.8 (87)	24.4 (76)	31.1 (88)	23.3 (74)	31.1 (88)	23.8 (75)	30.8 (87)	24.9 (77)	29.4 (85)	24.9 (77)
Apr.	31.6 (89)	24.4 (76)	30.8 (87)	24.4 (76)	31.1 (88)	22.7 (73)	31.1 (88)	23.8 (75)	30.8 (87)	24.9 (77)	29.9 (86)	24.9 (77)
May	29.9 (86)	23.8 (75)	28.8 (84)	23.8 (75)	30.8 (87)	21.1 (70)	31.1 (88)	23.3 (74)	29.4 (85)	24.9 (77)	29.4 (85)	24.9 (77)
June	28.8 (84)	23.3 (74)	27.2 (81)	22.7 (73)	30.8 (87)	19.4 (67)	29.4 (85)	21.6 (71)	28.8 (84)	23.8 (75)	28.3 (83)	24.9 (77)
July	27.2 (81)	21.6 (71)	26.6 (80)	21.6 (71)	29.9 (86)	18.8 (66)	28.8 (84)	20.5 (69)	28.3 (83)	23.8 (75)	27.2 (81)	23.8 (75)
Aug.	27.7 (82)	22.2 (72)	26.6 (80)	21.1 (70)	29.4 (85)	19.4 (67)	28.8 (84)	20.5 (69)	28.3 (83)	22.7 (73)	27.2 (81)	23.8 (75)
Sept.	28.8 (84)	22.7 (73)	28.3 (83)	21.6 (71)	29.4 (85)	19.9 (68)	28.8 (84)	21.1 (70)	28.3 (83)	22.7 (73)	27.7 (82)	24.4 (76)
Oct.	29.9 (86)	23.3 (74)	29.4 (85)	22.7 (73)	29.4 (85)	21.6 (71)	29.9 (86)	22.2 (72)	28.8 (84)	23.8 (75)	28.3 (83)	23.8 (75)
Nov.	31.1 (88)	24.4 (76)	31.1 (88)	23.8 (75)	30.8 (87)	23.3 (74)	31.1 (88)	23.3 (74)	29.9 (86)	24.4 (76)	28.8 (84)	23.8 (75)
Dec.	32.2 (90)	25.5 (78)	31.1 (88)	24.4 (76)	31.1 (88)	23.8 (75)	32.2 (90)	23.8 (75)	30.8 (87)	24.4 (76)	28.3 (83)	23.8 (75)
yearly average	29.9 (86)	23.8 (75)	29.4 (85)	23.3 (74)	30.8 (87)	21.6 (71)	30.8 (87)	22.7 (73)	29.4 (85)	24.4 (76)	28.3 (83)	24.4 (76)

Aldabran data from R.S.E. records; remaining data from M.O. 617 d (4) (Met. Office 1958).

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(*b*) *Seasonal variation in open ocean surface water temperature*

Mean monthly sea surface temperatures for 1963 and 1964 (table 5) taken in the vicinity of Aldabra during the International Indian Ocean Expedition (Miller & Jefferies 1967) are plotted on figure 5 and compared with 20-year averages. Unfortunately a simultaneous record of land temperatures is not available for Aldabra for the same period. Analysis of the Meteorological Office's Monthly Charts for the Indian Ocean shows that over the 20-year average period mean monthly air and sea temperatures are very close. A slight negative anomaly exists in February, March and April, when open ocean surface temperatures may rise 0.5 °C above mean air temperature. A positive anomaly of similar magnitude exists in September and October. These anomalies respectively coincide with the wettest and driest months of the Aldabran year (§5). In 1964 the mean March sea temperature of 29.3 °C was 1.3 °C higher than average: winter temperatures were near the normal 25.0 °C.

(*c*) *Seasonal variation in lagoon water temperature*

No simple relation between air and lagoon water temperatures has yet emerged. Figure 6 plots a month's parallel records for Middle Camp tide race point, Passe Houareau, for the

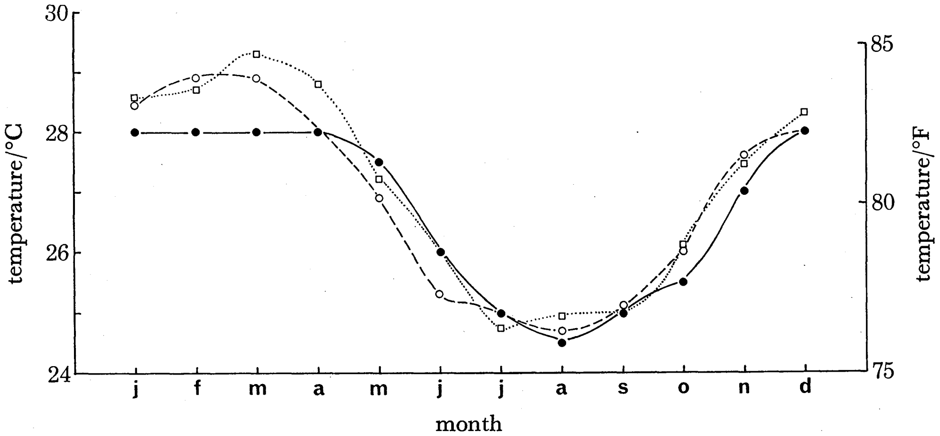

FIGURE 5. Seasonal variation in open ocean surface water temperatures: Aldabra. ●—●, 20-year average; ○–○, 1963; □····□, 1964. (Data from Miller & Jefferies 1967: table 5.)

TABLE 5. MEAN MONTHLY OPEN OCEAN SURFACE WATER TEMPERATURES FOR ALDABRA: 1963, 1964 COMPARED WITH AVERAGE

(Calculated from Miller & Jefferies 1967)

	20-year average		1963		1964	
	°C	°F	°C	°F	°C	°F
Jan.	28.0	82.4	28.4	83.2	28.5	83.3
Feb.	28.0	82.4	28.9	84.0	28.7	83.7
Mar.	28.0	82.4	28.9	84.0	29.3	84.8
Apr.	28.0	82.4	28.0	82.4	28.8	83.8
May	27.5	81.5	26.9	80.3	27.2	81.0
June	26.0	78.8	25.3	77.5	26.0	78.8
July	25.0	77.0	25.0	77.0	24.7	76.5
Aug.	24.5	76.2	24.7	76.5	24.9	76.8
Sept.	25.0	77.0	25.1	77.2	25.0	77.0
Oct.	25.5	77.8	26.0	78.8	26.0	78.8
Nov.	27.0	80.5	27.6	81.7	27.4	81.3
Dec.	28.0	82.4	28.0	82.4	28.3	83.0

period September/October 1968. In late September lagoon temperatures are only slightly more elevated than the mean air temperature. In late October, however, the difference may amount to 2.5 °C. It would thus appear that during the winter months mean air temperatures may be taken as a reasonable approximation to mean lagoon temperatures, but that as summer is approached temperatures rise at a greater rate in the lagoon than in the Stevenson Screen. Superimposed on this seasonal fluctuation is a short period tidally controlled temperature cycle. This cycle does not possess a symmetrical 14-day pattern, but is markedly asymmetrical, being a reflexion of the time at which local low water occurs. It is very noticeable on figure 6

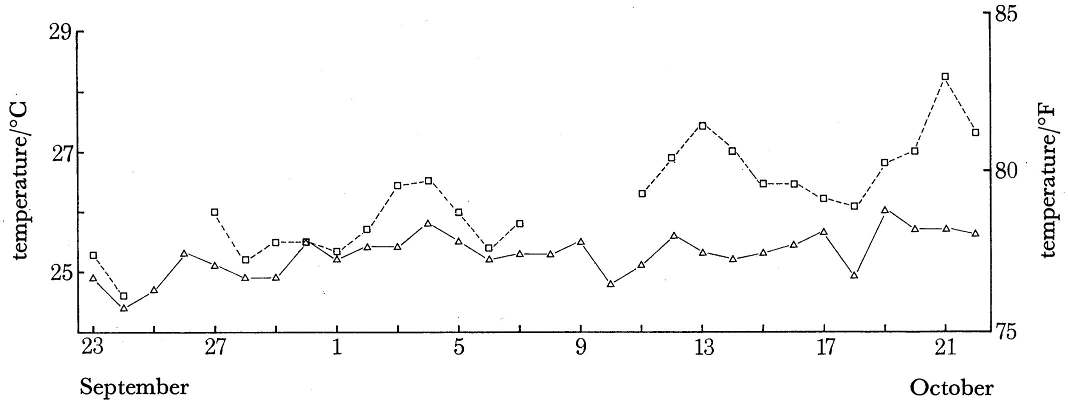

FIGURE 6. Lagoon and air temperatures for Passe Houareau, Aldabra: late 1968. △—△, Mean air shade temperature; □--□, mean lagoon water temperature. The cyclic nature of the lagoon curve is tidally controlled.

that where low water falls after dusk mean lagoon water temperatures are either identical with mean screen values (as on 30 September and 1 October) or else approach them more closely than at any other time in the cycle (17 October). The peaks in lagoon temperature on 4 and 21 October coincide with the occurrence of low water at noon. The marked peak centring around 13 October is not easily understood without an acquaintance of the peculiar nature of the tides in Passe Houareau (Farrow & Brander, this volume, p. 93). It is caused by the local cycle of extreme low water, which although amounting to only about 6 or 7 cm below mean low water is sufficient when taken over the vast areas of platform to affect markedly the heat balance in the lagoon.

Extrapolation on the basis of only one month's observations is hazardous, but the data clearly indicate that when additional allowance is made for tidal influences on temperature fluctuation, maximum lagoon temperatures in summer may well exceed 35 °C. On 21 October, when low tide occurred at noon, a maximum of 31 °C was recorded in the lagoon compared with 27 °C in the screen. Were a similar excess to occur in January on the occasion of the highest screen temperature (36 °C) a lagoon temperature of 40 °C would not be unexpected. In view of the siting of the Passe Houareau lagoon thermometer in a region of great tidal current activity it seems that more tranquil areas might experience greater temperature excesses than those recorded above. Because of the implications in terms of the temperature tolerance of lagoonal invertebrates it is manifestly essential to conduct a similar series of observations on lagoon temperature during the summer, if possible selecting sites with varying flow régimes.

4. Sunshine and cloud

No sunshine records are available for Aldabra. Estimates can however be prepared from cloud observations, using the formula

$$S = T\,(8-C)/8,$$

where S, mean sunshine hours; T, maximum possible hours; C, mean cloudiness in oktas.† Mean cloud values for all synoptic reporting hours over a 20-year period are available from Atlas records (Meteorological Office 1959): 06h00 U.T. observations are also available for the period 1967/8. Sunshine figures obtained from such cloud data are subject to a very wide margin of error since all categories of cloud, high, medium and low, are included in the okta value quoted. Thus a veil of cirrostratus completely covering the celestial dome would record as 8 oktas, though almost certainly the sun would be shining with sufficient intensity to record a trace on a Stokes pattern sunshine recorder. Estimates of total sunshine are therefore likely to err seriously on the low side when such situations prevail: in November 1968, for example, cirrostratus veiled the celestial dome for much of the month.

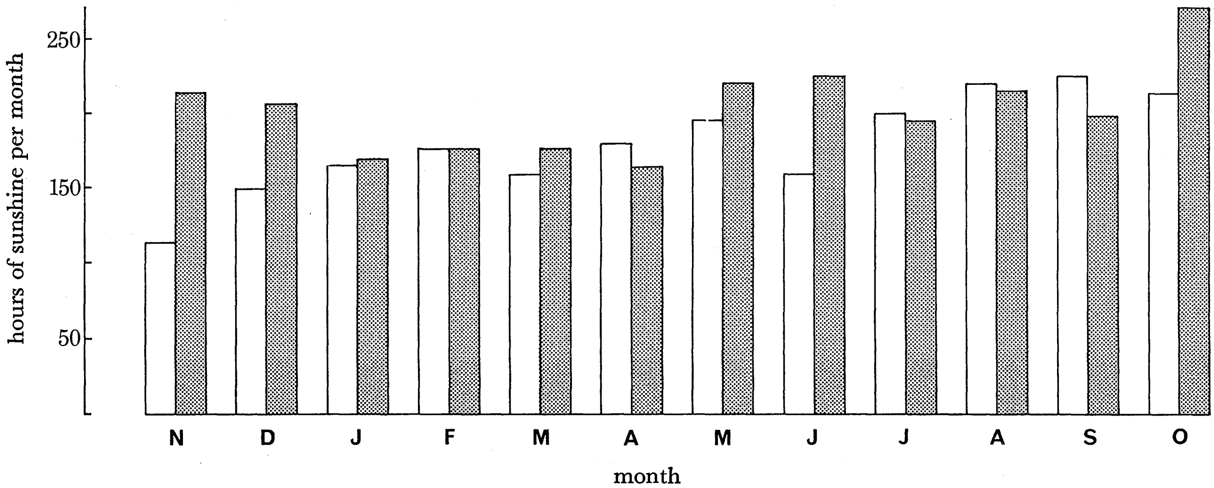

Figure 7. Calculated monthly sunshine totals for Aldabra, based on cloud observations: 1967/8 (unshaded) compared with 20-year average (shaded). (Data from table 6.)

The data presented in table 6 and plotted on figure 7 should be viewed with these limitations in mind. October appears to be the sunniest month by a large margin, with an estimated total of 270 h, or 8.6 h/day; over 1 h/day more than the next sunniest month June. Summer is substantially less sunny, with January and April both having over 100 h less sunshine per month than October. Figure 7 shows the marked fall-off in probable hours of sunshine per day during the monsoon. Figure 8 presents an alternative more qualitative plot of the data in terms of cloud density.

Although the data for 1967/8 are so limited as to be only semi-quantitative at best, they at least give a gross pattern of sunshine distribution consistent with the average overall picture. Most months have totals close enough for differences to be of no consequence, but the months of November 1967 and June 1968 appear anomalous. An estimated total of only 110 h sunshine

† Meteorological term meaning 'eighth': thus a cloudiness of 5 oktas means the sky is five-eighths covered by cloud.

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in November 1967 contrasts with the 20-year average of 210 h, and stresses the early arrival of the monsoon in that year. The predicted June 1968 total of 150 h is very low for the trades season and does not correlate with abnormal rainfall which followed in July.

The average annual total of 2400 h sunshine computed for Aldabra is strongly at variance with the 1800 h shown on map 3 of Landsberg *et al.* (1965), although the same method was used for both estimates. It would seem that the isohel gradient is perhaps less steep off Mombasa than is indicated on Landsberg's map. The desirability of establishing this instrumentally is obvious. The distribution of global and net radiation over the Indian Ocean has been discussed by Mani, Chacko, Krishnamurthy & Desikan (1967): the average cloud cover in the tropics has been evaluated by Sadler (1968) from satellite observations. An atlas of Indian Ocean clouds has also been recently published (Bunker & Chaffee, 1968).

The available evidence on the local development of cloud caused by the convective effect of the atoll rim is discussed in section §6*b*.

Table 6. Computed monthly sunshine totals for Aldabra based on cloud observations

	cloud (oktas)		sunshine (h) monthly totals		sunshine (h) mean hours/day	
	1967/8†	average‡	1967/8	average	1967/8	average
Nov.	5.5	3.3	113	212	3.8	7.0
Dec.	4.8	3.6	149	206	4.8	6.6
Jan.	4.5	4.4	165	169	5.2	5.4
Feb.	3.8	3.8	176	176	6.3	6.3
Mar.	4.8	4.2	149	176	4.8	5.7
Apr.	4.0	4.4	180	162	6.0	5.4
May	3.8	3.3	195	220	6.3	7.1
June	4.7	3.0	149	225	5.0	7.5
July	3.7	3.8	200	195	6.4	6.3
Aug.	3.3	3.4	220	215	7.0	6.8
Sept.	3.0	3.6	225	198	7.5	6.6
Oct.	3.5	2.2	213	270	6.7	8.6
yearly total			2134	2414	—	—
average monthly total			178	201	—	—

† 06h00 U.T. synoptic observations at Settlement.
‡ Twenty year average for observations at all synoptic hours; taken from *Atlas of Monthly Meteorological Charts for Indian Ocean* (M.O. 519).

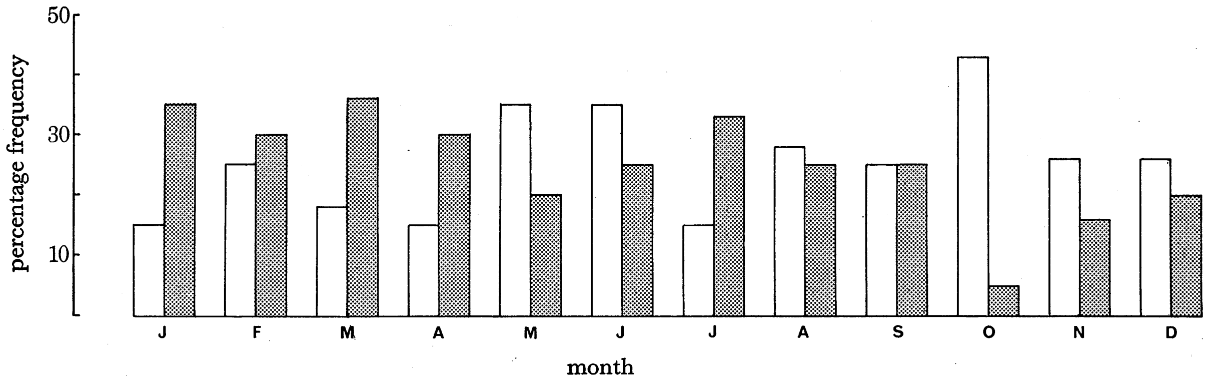

Figure 8. Seasonal variation in the frequency per month of bright (up to one-quarter of sky cloudy: 0 to 2 oktas) and overcast (sky seven-eighths to completely cloudy: 7 or 8 oktas) days at Aldabra, taken from atlas records (M.O. 519). Overcast days shaded.

5. Rainfall

Table 7 presents all the available monthly rainfall totals for Aldabra. Because of missed observations during certain months of some years only four annual totals are known. However, mean monthly totals span 6 or 7 years' records. The mean annual total of 673 mm (26.5 in) is strikingly lower than existing atlas predictions (e.g. *Times Atlas* 1967). If median values are considered, the total is lowered still further to 556 mm (21.9 in). The atoll of Aldabra is evidently situated in the most arid sector of the western Indian Ocean. In spite of the inadequate number of years' records compared with the desirable minimum of twenty, it is probably unlikely that future records will drastically raise the mean annual rainfall, since both very wet and very dry years are represented in the records (figure 9).

Table 7. Monthly rainfall totals for Aldabra: 1949–68

	1949		1950		1951		1952		1953		1958		1959		1967†/8	
	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in
n.	—	—	95	3.74	92	3.65	160	6.30	—	—	92	3.61	102	4.03	5	0.20
b.	—	—	219	8.65	60	2.35	306	12.05	—	—	101	3.98	199	7.87	28	1.11
ar.	—	—	423	16.63	—	—	29	1.15	54	2.15	40	1.56	6	0.23	150	5.92
r.	—	—	272	10.68	221	8.70	250	9.85	67	2.64	36	1.41	1	0.02	144	5.70
ay	—	—	6	0.25	46	1.80	13	0.50	30	1.19	2	0.07	0	0	28	1.09
ne	2	0.07	24	0.95	—	—	18	0.70	38	1.50	2	0.09	1	0.02	38	1.50
y	26	1.05	0	0	13	0.50	4	0.15	—	—	9	0.35	1	0.05	71	2.78
g.	0	0	16	0.64	32	1.29	0	0	—	—	8	0.31	4	0.17	15	0.58
pt.	0	0	37	1.45	0	0	—	—	—	—	4	0.17	4	0.16	10	0.38
t.	0	0	10	0.40	7	0.28	—	—	—	—	2	0.10	0	0	7	0.29
v.	13	0.50	23	0.90	70	2.66	—	—	—	—	45	1.74	19	0.73	163†	6.42†
c.	57	2.24	67	2.62	—	—	—	—	—	—	40	1.57	12	0.46	9†	0.33†
al	—	—	1192	46.91	—	—	—	—	—	—	381	14.96	349	13.74	668	26.30

† Data for 1967/8 from R.S.E. records: remaining data from East African Meteorological Department (unpublished).

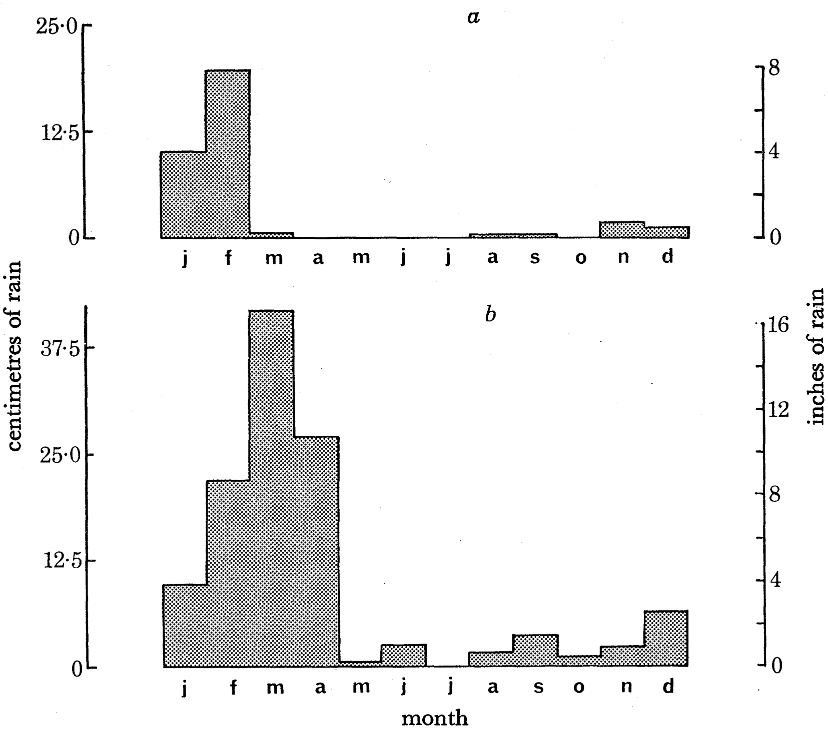

Figure 9. Seasonal distribution of rainfall on Aldabra for the driest ((*a*) 1959: 34.8 cm) and wettest ((*b*) 1950: 119 cm) years so far on record. (Data from East African Meteorological Department, unpublished: table 7.)

(a) Variability of rainfall totals

The variability of rainfall both in total from year to year and in monthly distribution is extreme. The wettest and driest years so far on record were 1950 and 1959. The monthly total of 423 mm (16.63 in) for March 1950 is considerably in excess of the total for the whole of 1959 (figure 9). In any year, however, the beginning and end of the monsoon is usually sharply defined. In 1958/9 rainfall was effectively limited to January and February: in 1949/50 the season extended from December until April, with a single mode in March. The season 1967/8 so far appears to have been unique for an oceanic island in the possession of a marked bimodal rainfall distribution during the summer monsoon (figure 10*b*), normally characteristic of continental stations (cf. 20-year average curve for Entebbe; Riehl 1954, figure 3.8, p. 81). January 1968 was the driest month of the year with 18 times less rainfall than average.

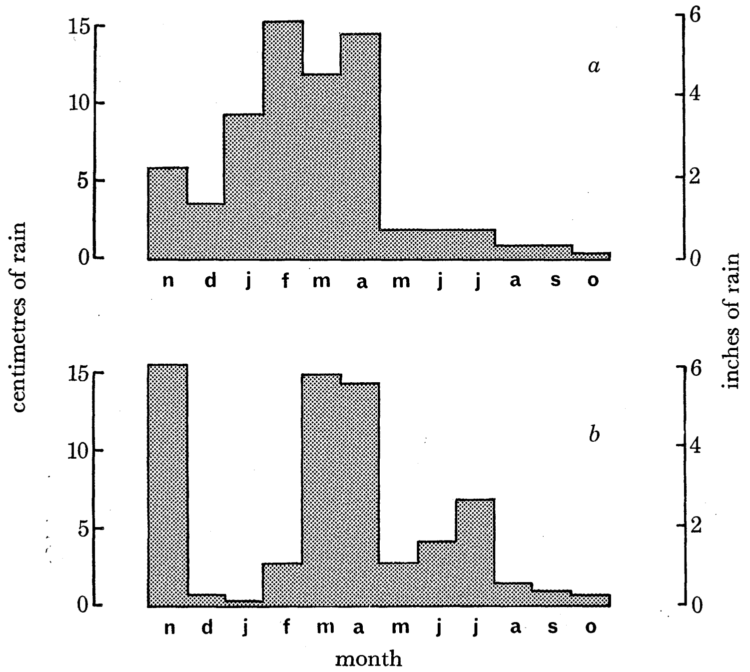

FIGURE 10. The seasonal distribution of rainfall on Aldabra: (*a*) during 1967/8, compared with (*b*) the 7-year average. The bimodal summer distribution is characteristic of continental stations (such as Entebbe). (Data from table 7.)

The trades season is generally arid. No rain fell, for example, for the 3 months of August, September, October 1949. The average curve (figure 10*a*) shows a gradual diminution through the season to only 5 mm (0.2 in) in October. The normal quota for the 6-month May to October trades season is 11 % of the annual rainfall total. Even in this period considerable variation may be shown from year to year. Thus only 15 mm (0.6 in) of rain fell in the 8-month trades season of 1959 compared with over 103 mm (4.0 in) in June and July 1968 (cf. figures 9*a* and 10*b*).

(b) Seasonal variability in rainfall intensity

Data on the average amounts of rain falling per rain-day each month are only available for the season 1967/8; which, as has been discussed above, was atypical. Table 8 shows that throughout the year rainfall intensity varied from an average of 21 mm per rain-day in April to 1 mm in December, January and August. Nearly half a month's total (44 %) is accounted for in the amount falling on the rainiest day. In April 80 mm (3.1 in) fell in one day, representing 54 % of the monthly total. Of the total annual rainfall 42 % fell on 5 days as rainstorms with 24 h accumulations of more than 40 mm (1.6 in).

If the months of August, September and October 1968 are taken to approximate the average rainfall conditions during the trades it would appear that what little rain there is has little permanent effect. Strong winds (figure 3) and clear skies (figures 7, 8) would rapidly evaporate the 1 or 2 mm falling per rain-day. The data suggest that in at least 5 years out of 6 winter rainfall is negligible, being unlikely to affect permanently the water balance on the atoll.

Table 8. Intensity of rainfall on Aldabra: 1967/8

	monthly total		no. of rain days (0.1 mm<)	no. of wet days (1.0 mm<)	no. of very wet days (10.0 mm<)	greatest in one day		% of monthly total falling in one day	average amount of rain per rain day
	mm	in				mm	in		mm
Nov.	163.1	6.42	14	12	3	69.1	2.72	42	12
Dec.	8.5	0.33	6	4	0	3.0	0.12	36	1
Jan.	5.0	0.20	5	2	0	2.8	0.11	55	1
Feb.	28.0	1.11	9	6	1	14.0	0.55	50	3
Mar.	150.1	5.92	18	16	3	51.0	2.01	34	8
Apr.	144.0	5.70	7	6	2	80.0	3.15	54	21
May	27.6	1.09	9	7	0	7.3	0.28	26	3
June	38.1	1.50	11	7	1	20.9	0.83	55	3
July	70.7	2.78	13	12	2	24.5	0.95	34	5
Aug.	14.8	0.58	11	4	0	5.6	0.24	41	1
Sept.	9.7	0.38	6	4	0	3.7	0.15	39	2
Oct.	7.3	0.29	3	2	0	4.9	0.19	66	2

Table 9. Monthly rainfall averages for stations in the western Indian Ocean

	Aldabra		Comoro Islands		Lindi		Diégo Suarez		Agalega		Mahé	
	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in
Jan.	91	3.6	297	11.7	145	5.7	269	10.6	249	9.8	386	15.2
Feb.	152	6.0	208	8.2	117	4.6	241	9.5	193	7.6	266	10.5
Mar.	117	4.6	193	7.6	170	6.7	193	7.6	158	6.2	233	9.2
Apr.	142	5.6	94	3.7	173	6.8	56	2.2	155	6.1	182	7.2
May	18	0.7	36	1.4	38	1.5	7	0.3	142	5.6	170	6.7
June	18	0.7	13	0.5	10	0.4	5	0.2	91	3.6	101	4.0
July	18	0.7	5	0.2	7	0.3	5	0.2	99	3.9	83	3.3
Aug.	10	0.4	10	0.4	5	0.2	7	0.3	76	3.0	68	2.7
Sept.	10	0.4	15	0.6	13	0.5	7	0.3	81	3.2	129	5.1
Oct.	5	0.2	33	1.3	15	0.6	18	0.7	120	4.7	155	6.1
Nov.	56	2.2	74	2.9	53	2.1	28	1.1	107	4.2	230	9.1
Dec.	36	1.4	117	4.6	150	5.9	147	5.8	206	8.1	336	13.4
total	673	26.5	1093	43.1	897	35.3	983	38.7	1676	66.0	2350	92.5

Data other than for Aldabra obtained from M.O. 617d (4).

(c) *Seasonal rainfall patterns in the western Indian Ocean*

Long-period monthly rainfall averages are tabulated in table 9 for the same stations as in figure 3. In each region an effort was made to select stations as close to sea-level as possible, and with minimal orographic effects. For a comparison of seasonal patterns and variability strictly limited to sea-level reef islands reference should be made to Stoddart (1970). The histograms for Agalega, Dzaoudzi and Mahé (figure 11) are of similar type, possessing symmetrical

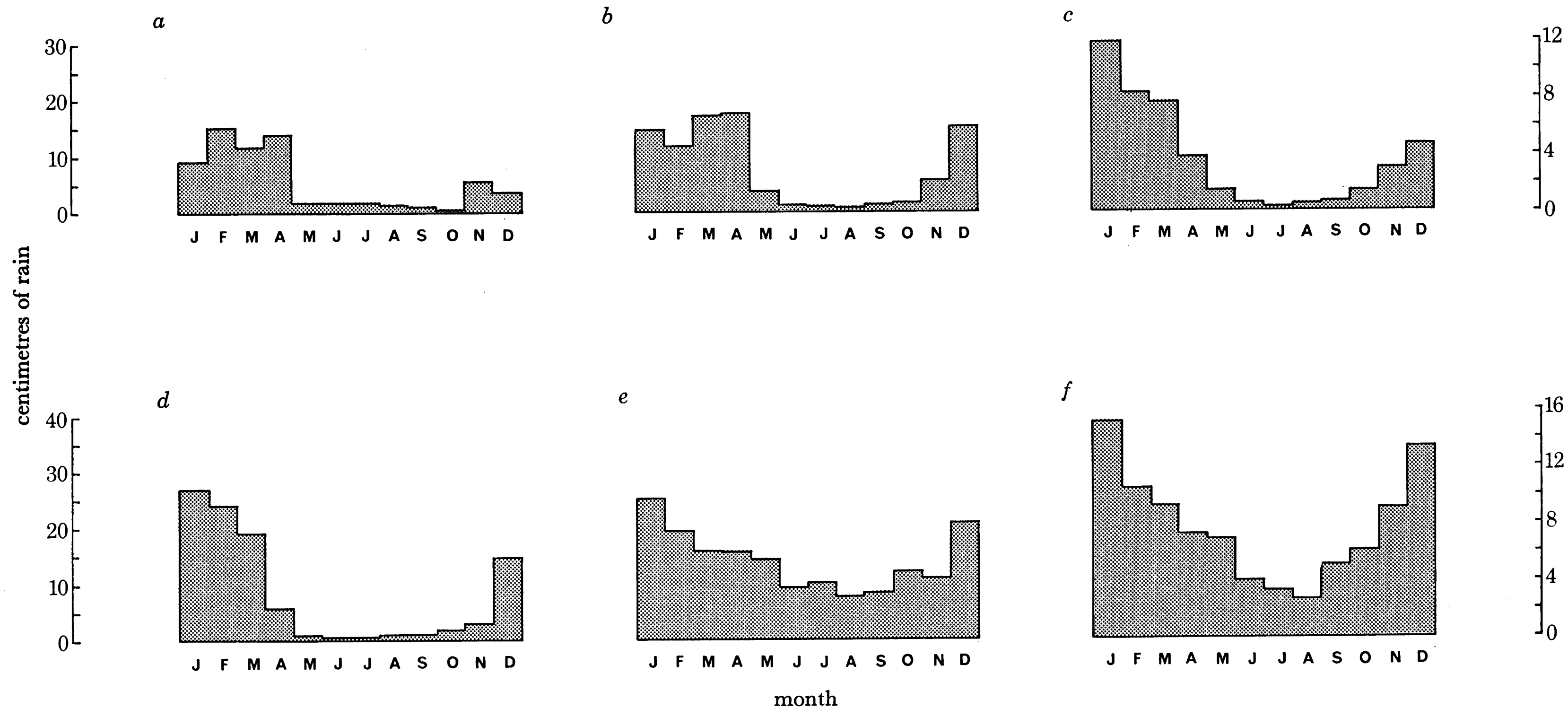

Figure 11. Seasonal distribution of rainfall in the western Indian Ocean; stations as in figure 3: *a*, Aldabra (7 years); *b*, Lindi (21 years); *c*, Dzaoudzi (15 years); *d*, Diégo Suarez (31 years); *e*, Agalega (20 years); *f*, Mahé (64 years). (Data from table 9.)

profiles with no clear boundary between rainy and dry seasons. At Mahé and Agalega the whole year is rainy, but at Dzaoudzi a 4-month interruption occurs during the trades season. All three are classed as V_1 type climates by Lipmann, Troll & Paffen (in Landsberg *et al.* 1965) and should accordingly possess from 12 to 9 humid months. Dzaoudzi, from the length of its dry season, clearly belongs to V_2. The profile for Diégo Suarez is similar to that of Mayotte, but with a clearer separation of wet and dry seasons as at Aldabra and Lindi, and a longer dry season. Diégo Suarez and Lindi, although of identical pattern in the trades season, possess radically different profiles during the monsoon. Of the stations shown on figure 11 all have clear January rainfall maxima with the exception of Aldabra and Lindi, which have a broader, plateau-like distribution tending towards a late summer maximum. Although it must be admitted that future years' records may change the shape of the Aldabran histogram (possibly, for example, removing the bimodality by a strengthened December total) it should be noted that even after 21 years' records at Lindi the profile shows no increased tendency towards symmetry. In this respect then, continental influence on the distribution of summer rainfall on Aldabra is clear. This continental influence is occasionally sufficiently strong for a bimodal rainfall distribution to occur (see above, p. 80).

According to the data presented in figure 11 there are clear grounds for classifying Aldabra as of transitional V_2/V_3 climate, along with Lindi and Diégo Suarez, while Dzaoudzi in the Comoros is clearly V_1/V_2.

6. Diurnal and local climatic effects

One of the most striking features of the geomorphology of Aldabra is the concentration of platin, and permanent reservoirs of fresh water, in the south eastern sector of the atoll. It is clearly a matter for further study to determine the extent to which the rainfall values for Picard are applicable in this region. In view of the size of the atoll appreciable differences may be expected.

A preliminary attempt was made in September and October 1968 to estimate the likely range of local climatic effects. A Stevenson screen was set up at Middle Camp, Passe Houareau, in a situation fully exposed to the trade-winds; a raingauge was erected; and wind speeds measured every hour during daylight with a hand-held anemometer. Over the 32-day period of study the most striking differences observed were in maximum air temperature and wind speed. Although rain did not always fall on the same days as at Picard, the rainfall totals were almost identical. It is unfortunate that the data are for the driest part of the year: a similar study during the monsoon might give more significant results.

(a) *Local variation in air temperature and wind speed*

Figure 12 compares maximum and minimum air temperatures for Passe Houareau and Picard. Maximum temperatures average nearly 3 °C lower, and minima slightly higher than at Picard. This underlines clearly the effect of the full speed of the trades. Such values must be typical for most of the lagoon, certainly for the northern shore. The level of wind speed which brings about this reduction in the diurnal temperature range from 6.3 to 3.6 °C is indicated on figure 13. This plots the hour-by-hour wind speed averaged for the 32-day period. Following a rapid rise after dawn a speed of 9 m s^{-1} (19 knots) was sustained from 08h00 to 13h00, after which it falls in linear fashion to 7 m s^{-1} (13 knots) at 18h00. It is difficult to establish the relative contributions of land or sea breeze effects and barometric winds of the type described by Stolov (1955) from such a curve as this.

The southeast coast of the atoll experiences a considerable sea breeze. This reinforces the trade wind to produce winds of gale force in the dune complexes. A substantial land breeze is often noticeable at Settlement during the hours preceding sunrise. During the first week of August 1968 squally winds gusting to force 7 (*ca.* 15 m s^{-1}) were repeatedly experienced.

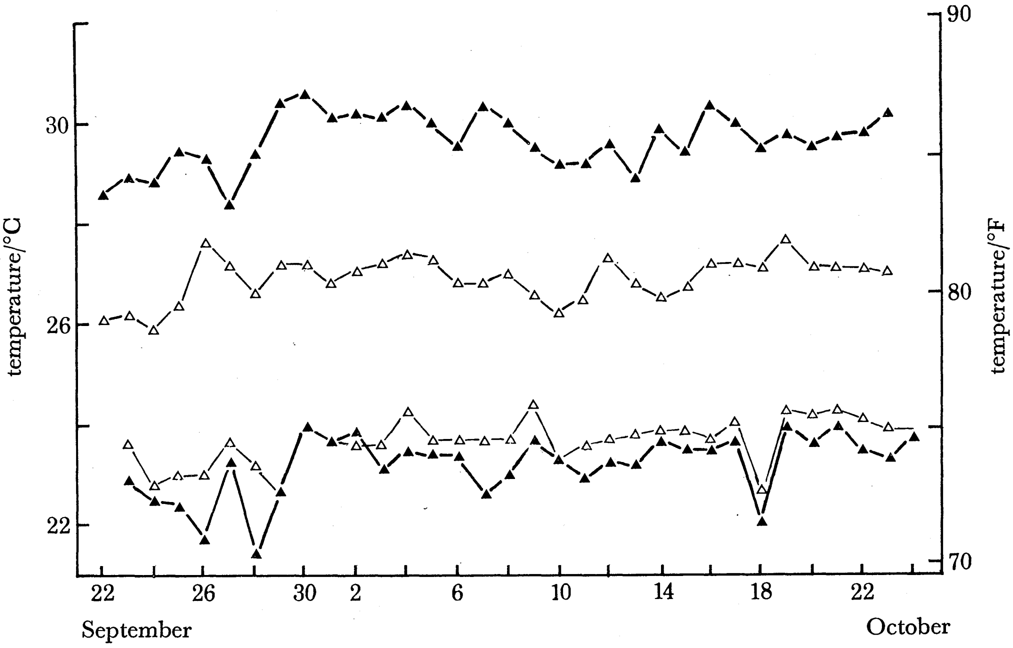

FIGURE 12. Comparison of maximum and minimum air temperatures between Picard (▲—▲) and Passe Houareau (△—△) for the period 22 September to 23 October 1968.

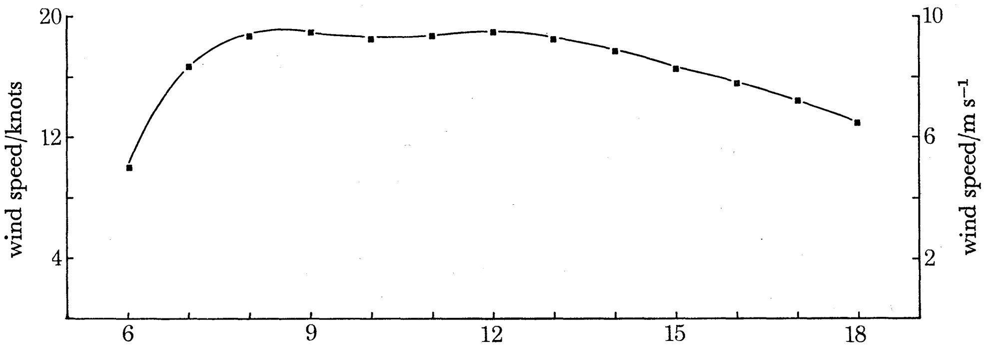

FIGURE 13. Trade-wind strength during the hours of daylight during the period 22 September to 23 October 1968; average curve based on 372 hand-held anemometer observations from Middle Camp, Passe Houareau.

(*b*) *Local variation in sunshine*

No direct measurements of sunshine have so far been undertaken on the atoll. Calculations of probable sunshine hours over the year have been derived from recorded cloud amounts (see §4). These amounts refer either to oceanic records, or to 06h00 U.T. observations at Settlement. Both may be without relevance for large parts of the island.

Convective effects caused by the land rim of the atoll very commonly reveal themselves in the presence of long cloud streets. Cumulus streets covering Polymnie and the western end of Ile Malabar may be seen frequently from the head of Grande Passe, while skies are cloudless over the whole of the lagoon. Similarly, a great horseshoe of cloud extending around the eastern part of Grande Terre (South Island) may be seen from Point Malabar. On the basis of visual estimates of sunshine from July to November at many points around the atoll it would seem that the Cinq Cases region was the sunniest, as may be expected from the strong trade effect on convective cumulus development. Along the northern rim of the atoll during September/October simultaneous cloud observations at 06h00 U.T. showed that the eastern end of Ile Malabar was on average 1 okta more cloudy than Picard. However, in view of the limited vista from the Settlement recording station it is wise to regard this result as tentative, pointing perhaps to the need for further more detailed study. If the same relation exists in summer between incident wind and sunshine then the Cinq Cases region would become the cloudiest, and also probably the wettest part of the atoll.

Table 10. Rainfall variation between Passe Houareau and Picard: 22 September to 24 October 1968

	surface wind at 06h00 U.T.		rainfall (mm)	
	Picard	Passe Houareau	Picard	Passe Houareau
24 Sept.	SE 4	SE 5	—	tr.
27	SSW 3	SSW 4	0.5	0.2
28	SE 4	ESE 5	3.7	8.0
30	E 4	ESE 5	0.1	0.2
4 Oct.	ESE 2	E'S 6	—	tr.
6	SE 3	SE 5	—	0.1
8	SE 4	SE 5	—	tr.
12	SE 3	SE 4	2.0	0.1
13	ESE 4	SE 6	—	tr.
14	ESE 4	SE 4	—	tr.
15	ESE 4	SE 5	0.4	tr.
17	SE 4	SE 5	4.9	3.4
mean wind speed	3.6	5.0	total 10.6	12.0

(c) *Local variation in rainfall*

During the trades slight changes in surface wind direction frequently bring rain. When the wind veers SSW following a period of calm, as on 5 and 27 September, the ensuing rain is heavier at the eastern end of the island. When convective showers fall without a change of wind direction they are invariably heavier on Picard. Such showers are very common late in the season, but generally fall about 5 to 8 km offshore in a westerly rather than northwesterly direction because of the upward rotation of the wind belt.

Comparative rainfall totals for Passe Houareau and Picard during September/October are shown in table 10. For more insight into the geomorphological variation between the southeastern and northwestern parts of the atoll it would be of great value to obtain simultaneous rainfall measurements for Cinq Cases or Takamaka and Picard.

(d) *Diurnal and semi-diurnal variation in atmospheric pressure*

The regularity of the barograph trace from day to day on Aldabra is a most striking phenomenon to the visiting scientist from the temperate zones. Figure 14 compares curves for times

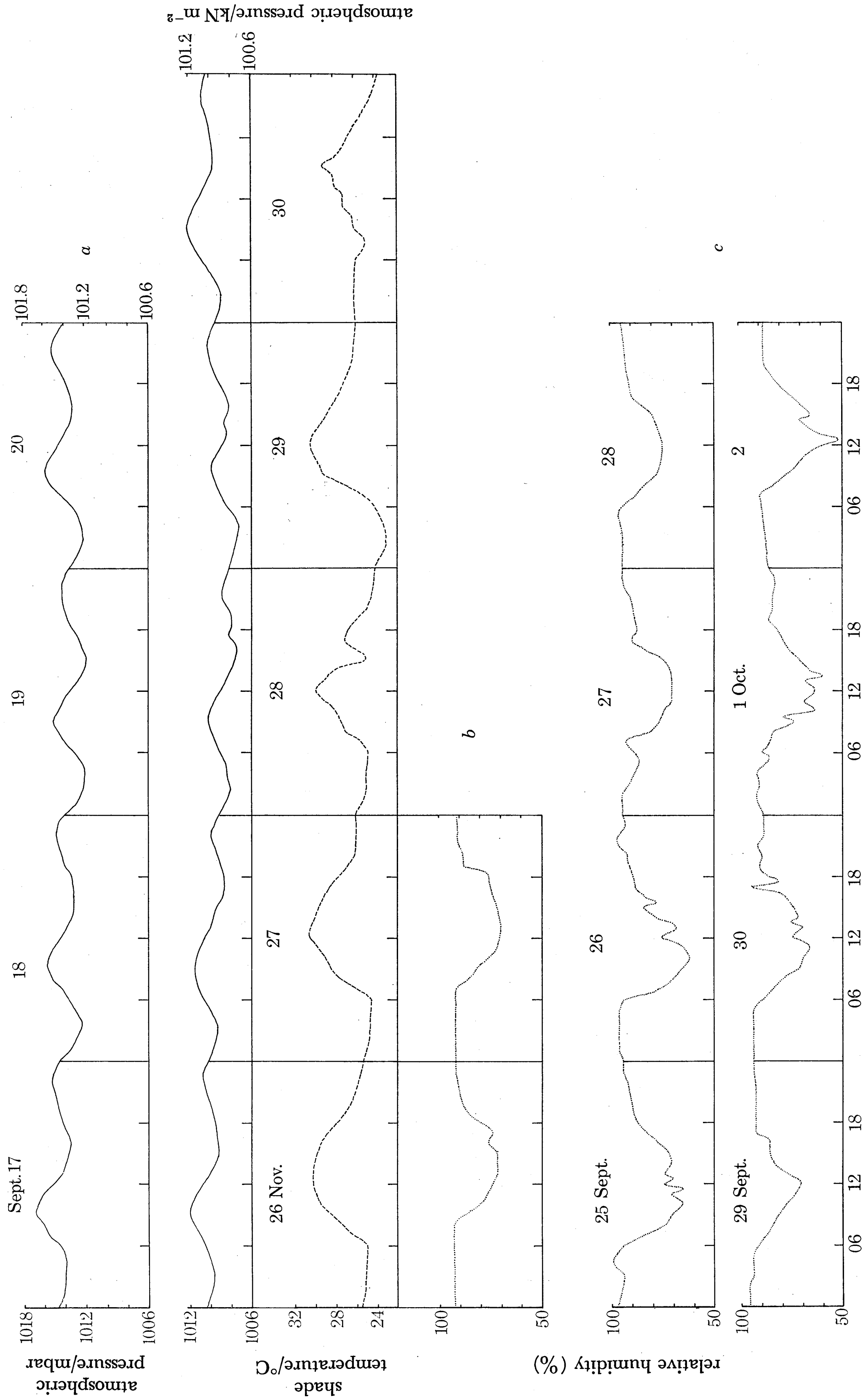

Figure 14. Autographic records of dirunal variations in: atmospheric pressure (solid line); air temperature (dashed line); relative humidity (dotted line).

of the year with large and small daily variation. The semidiurnal atmospheric solar tidal oscillation (the S_2 wave) is well shown on both curves. Atmospheric tides at the atoll station of Wake Island have recently been studied by Kiser, Carpenter & Brier (1963). Brier (1967) has shown that the S_2 amplitude correlates with lunar gravitational tides in beat fashion. Large amplitudes occur when S_2 is in phase, and small amplitudes when S_2 is out of phase with the lunar tide. Processing of tropical weather observations is beginning to show that synoptic-scale disturbances are more likely to develop when the S_2 wave has a large amplitude (Brier & Carpenter 1967). A careful check should be made in future climatological observations on Aldabra on the incidence of synoptic disturbances in relation to atmospheric/lunar tidal periodicities.

(*e*) *Diurnal variation in air temperature and relative humidity*

The bimetallic thermograph at the Settlement station was found to be incorrectly calibrated over much of the year. A correctly calibrated trace is shown on figure 14*b*: it shows on one trace the variability characteristic of late November 1968, during the transition from trades to monsoon. Profiles for 26, 27 and 29 November are characteristic of sunny days and show the typical asymmetrical curve, with lowest temperature at sunrise. The profile for 28 November reveals the effect of a sudden backing of the wind through north at midday to WNW in mid-afternoon: that for 30 November the effect of more prolonged overcast conditions, with the temperature maximum delayed until 15h00. Usually the maximum temperature occurs at exactly midday (as in the previous 4 days' records).

Hair hygrograph traces for 26 and 27 November are illustrated beneath the thermograph record (figure 14*b*). A very stable night-time humidity of around 93 % is common throughout the greater part of the year. This normally falls to values of about 70 % in early afternoon. Figure 14*c* shows the trace for the least humid part of the year, when on 2 October 1968 a relative humidity of only 52 % was recorded shortly after midday.

(*f*) *Diurnal and semi-diurnal variation in rainfall*

On the majority of atolls cloud and rainfall amounts reach a maximum during the hours of darkness (Lavoie 1963); the same situation as that prevailing over the open sea (Kraus 1963). The available year's records for Aldabra, analysed hour-by-hour from Dines tilting syphon rain-gauge charts for November 1967 to October 1968, do not show this unequivocally. They rather show a very strong semi-diurnal variation of the type recently described by Brier (1965) and more rigorously analysed by Brier & Simpson (1969). Figure 15 shows the frequency of occurrence of rain through the 24 h. During the monsoon (*a*) a broad maximum is observed immediately before dawn. During the trades (*b*) the curve is conspicuously bimodal with a clear maximum in late afternoon. The curve for the whole year (*c*) is bimodal, but with the pre-dawn peak slightly greater than the pre-dusk one. Observational analyses by Kiser *et al.* (1963) and Malkus (1964) have indicated that the late afternoon maximum is normally much weaker. This is certainly the case on Aldabra when rainfall *amounts* are considered, especially during the monsoon (figure 16*a*), though in the trades the morning peak has shifted to 08h00 (*b*). The resulting histogram of rainfall totals, hour-by-hour, for the whole year (*c*) is, however, of comparable proportions to that for frequency (figure 15*c*), but has the clearer morning maximum which has been observed in comparable studies (Kiser *et al.* 1963).

The critical factor in the verification of a relationship between rainfall peaks and the S_2 atmospheric tide is confirmation of a post-midnight suppression of rainfall. A suppression immediately after midday could be explained by other processes, such as sea breeze and land effects (Holle 1968). However, neither radiative nor sea–air exchange hypotheses can explain a post-midnight suppression, which is strikingly seen on figure 16*a*, *c*. The histogram for the Aldabran trades (figure 16*b*) has a striking irregularity from 01h00 to 02h00 caused by two synoptic-scale disturbances which occurred on 20 May and 19 June, when 6.3 and 11.4 mm of rain fell. In dealing with mean daily marches of weather variables such interaction of land–sea and atmospheric–lunar tidal effects with synoptic disturbances cannot be subtracted, and

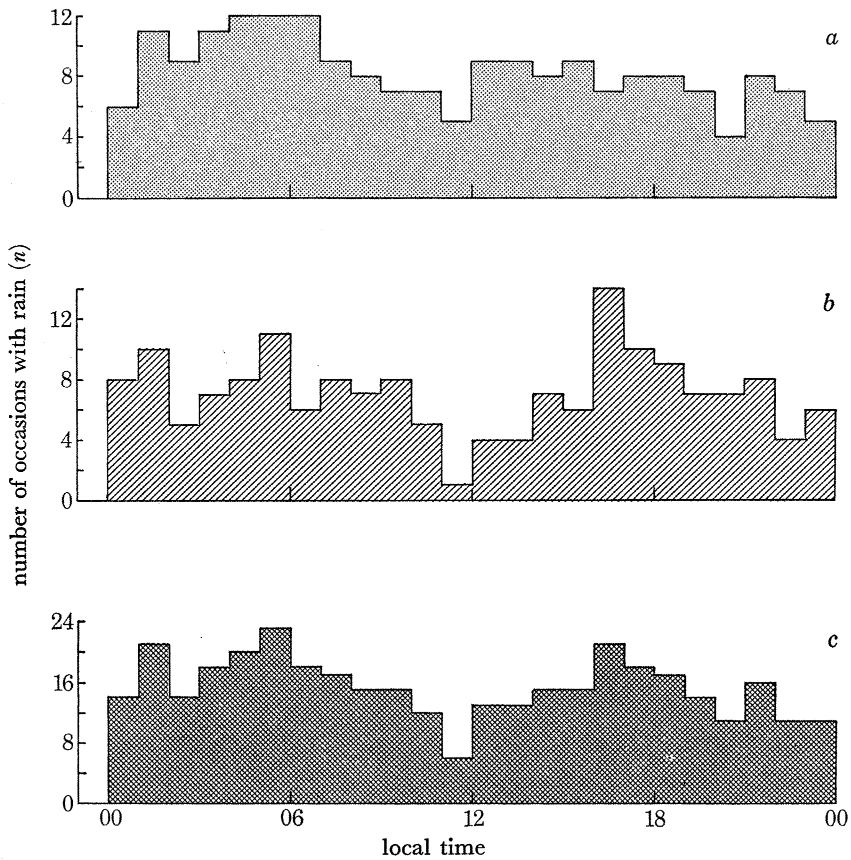

FIGURE 15. Diurnal variation in the frequency of rain falling at Settlement, Aldabra for: *a*, Monsoon (November 1967 to April 1968); *b*, Trades (May to October 1968); *c*, whole year. (Data from Dines tilting syphon rain-gauge charts.)

only by processing many years' records can these be eliminated satisfactorily. Brier & Simpson (1969) used 12 years for the atoll Wake Island and 70 years for Djakarta. Comparison of the Aldabran curves with these two contrasted tropical stations is instructive. Wake Island (19.29° N/166.65° E) is a truly oceanic atoll approximately 6.5 by 5 km: it lies in the northeast trade belt throughout the year. The mean annual rainfall of 94 cm is 27 cm greater than that of Aldabra. The curve for the frequency of occurrence of rain on Wake Island (Brier & Simpson 1969, figure 5, p. 126) shows a clear 05h00 maximum. The analogous curve for Aldabra (figure 15*b*) shows a 17h00 maximum, but not such a strong one as that for Djakarta (Brier & Simpson, figure 4, p. 125). It is clear then that Aldabra does not in this respect function as a truly oceanic atoll.

The midday suppression of rainfall during the trades is very striking on Aldabra (figures 15*b*, 16*b*). This does not imply, however, that cloud is also suppressed around noon. On the contrary, during the September/October observation period at Passe Houareau cumulus development showed a marked midday peak, the result of a pronounced 'heated island' effect. Malkus (1964) has suggested that midday island-produced clouds are less likely to precipitate because of the rise in cloud base level which results from the heating.

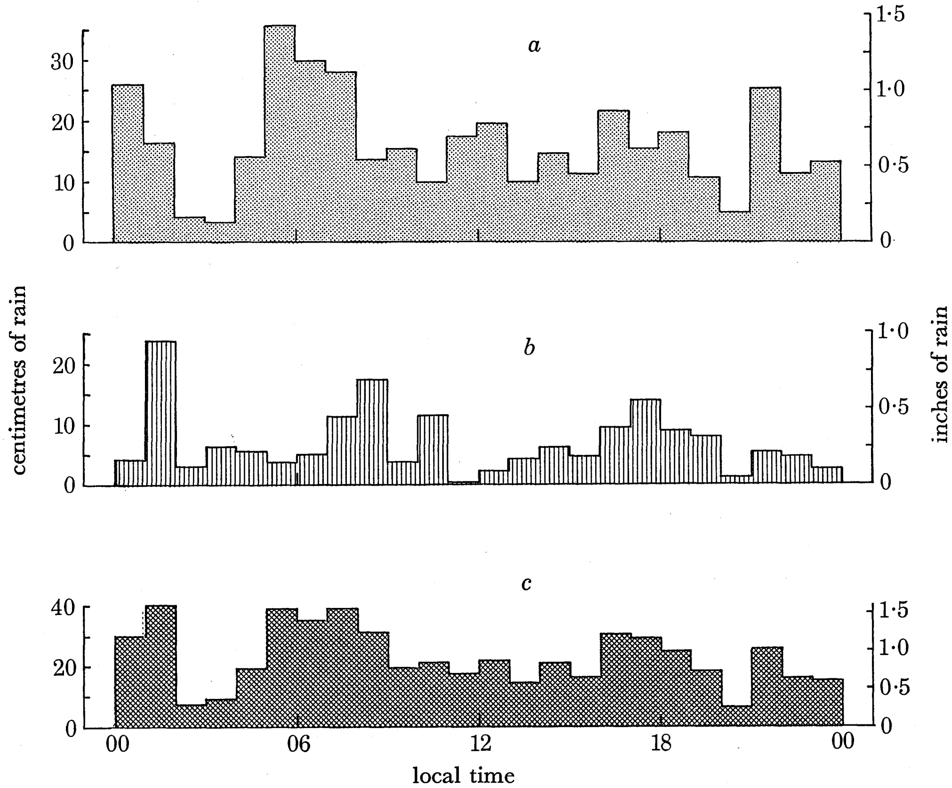

FIGURE 16. Diurnal variation in the amount of rain falling at Settlement, Aldabra; for: *a*, Monsoon (November 1967 to April 1968); *b*, Trades (May to October 1968); *c*, whole year. (Data from Dines tilting syphon rain-gauge charts.)

7. CONCLUSIONS

This paper has demonstrated the extremely sheltered aspect of the Settlement meteorological station, which supplies data atypical for much of the atoll. When the new research station is set up it will provide more widely applicable values, since it is situated in a more typically exposed position. Two major deficiencies in existing records will be remedied by the superior instrumental cover of the new station. The first concerns wind speed, and here continuous autographic anemometer recording will ensure an accurate assessment of, particularly, trade-wind speed. The second concerns sunshine. Here the data provided by a sunshine recorder will not only settle the discrepancy between atlas predictions and calculations based on cloud observations, but also provide much-needed quantification of diurnal variations in sunshine throughout the year.

Future climatological investigations on Aldabra are being focused on evaluation of local climate, the standard of reference being the synoptic observations at the research station. Two major programmes are dealing with local variation in rainfall and lagoon temperatures.

An investigation into the magnitude of any southeast to northwest rainfall gradient across the atoll is to be carried out, covering at least the whole of the monsoon. This will enable the diurnal distribution to be compared, in addition to monthly totals. The results from such a study as this may provide the key to an understanding of geomorphological variation around the atoll.

As part of the programme on the hydrology of the atoll, it is planned to record sea temperatures for open ocean, platform and lagoon environments. Preliminary experiments in Passe Houareau have demonstrated a tidal periodicity in lagoon temperatures. These suggest that values near the tolerance limits of many benthic invertebrates may be obtained at spring tides on clear summer days. Quantification of monsoon extremes of temperature will be achieved from integrated data for lagoonal regions of varying flow régime and tidal amplitude.

The maintenance of climatic records on Aldabra has only been possible by the sacrifice of successive members of the various phases of the Expedition, and to every synoptic observer a measure of considerable gratitude is due. During subsequent analysis of the records, and in obtaining long period averages for the western Indian Ocean I have received much assistance from the Meteorological Office, which is a pleasure to acknowledge. The Royal Society is also grateful to the Meteorological Office for the loan of instruments for use at Aldabra. Mr R. F. M. Hay kindly drew my attention to unpublished rainfall totals for Aldabra and gave me the benefit of his wide experience of marine climatology. Mr W. S. S. Stubley has shown great interest in the Expedition's monthly returns, and willingly made available relevant autographic charts. I am also indebted to him for discussions on the change in site of the synoptic station on Aldabra. Dr D. R. Stoddart has provided advice and encouragement at various stages in the course of the work, and made available his reef island rainfall data and map for the Indian Ocean.

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