# PART II

**CORRELATION** / 11

# CHAPTER 4 – CLIMATE

Contents





# CHAPTER 4 – CLIMATE

## *INTRODUCTION*

Central Mocambique is situated 19° south of the equator on the east coast of Africa at about 34° east longitude, and lies due west of Madagascar Island, from which it is separated by a 400 to 850 km wide strait, the Mocambique Channel. Madagascar Island is about 1 600 km in length and with a high mountain spine along its east coast it effectively blocks off the direct influences of the Indian Ocean. Almost the full length of Mocambique thus lies in the lee or shadow of Madagascar which causes far reaching climatic implications.

Apart from the local and regional climatic data personally collected, or recorded by stations, these notes on climatic processes are obtained mostly from Thompson (1965), Tyson (1969) and Griffiths (1972). Due to its geographical position, Central Mocambique, though lying directly in the path of the southeast trade wind belt, is close to the southern limits reached by the northeast monsoon in summer. The major determinants of climate in this region are therefore the zonal wind systems of both the Southern and Northern Hemispheres. The southeast trades are air masses blowing from the semi-permanent tropical high pressure centres of the South Indian Ocean. The monsoon system is an alternating macroscale air stream flow blowing in opposite directions in summer and winter. During the boreal winter, some of the air streams emenating from the Asian Continent traverse the northwestern Indian Ocean to the East Coast of Africa and pass south of the equator to Mocambique and Madagascar, where they contribute to precipitation processes or drying, depending on their trajectory. During the boreal summer the air streams are reversed. The southwest monsoon, of recurved Southern Hemisphere southeast trades, blows towards the Asian landmass from the equator and forms the major air mass contribution to Arabia, India and Burma at this time (see Fig 4.5).

In midsummer, tropical cyclones (hurricanes) move from east to west and are mostly intercepted by Madagascar. As the hurricane tracks recurve southwards, chiefly along the west coast of Madagascar or in mid-channel, drought conditions occur in Mocambique over the months of their greatest frequency (Fig 4.6 and pers. data). Conversely a hurricane track which approaches or crosses the Mocambique Coast causes floods.

Interrupting the interplay between two major zonal air flows, are invasions of temperate depressions moving from west to east and up the southern coast. In addition

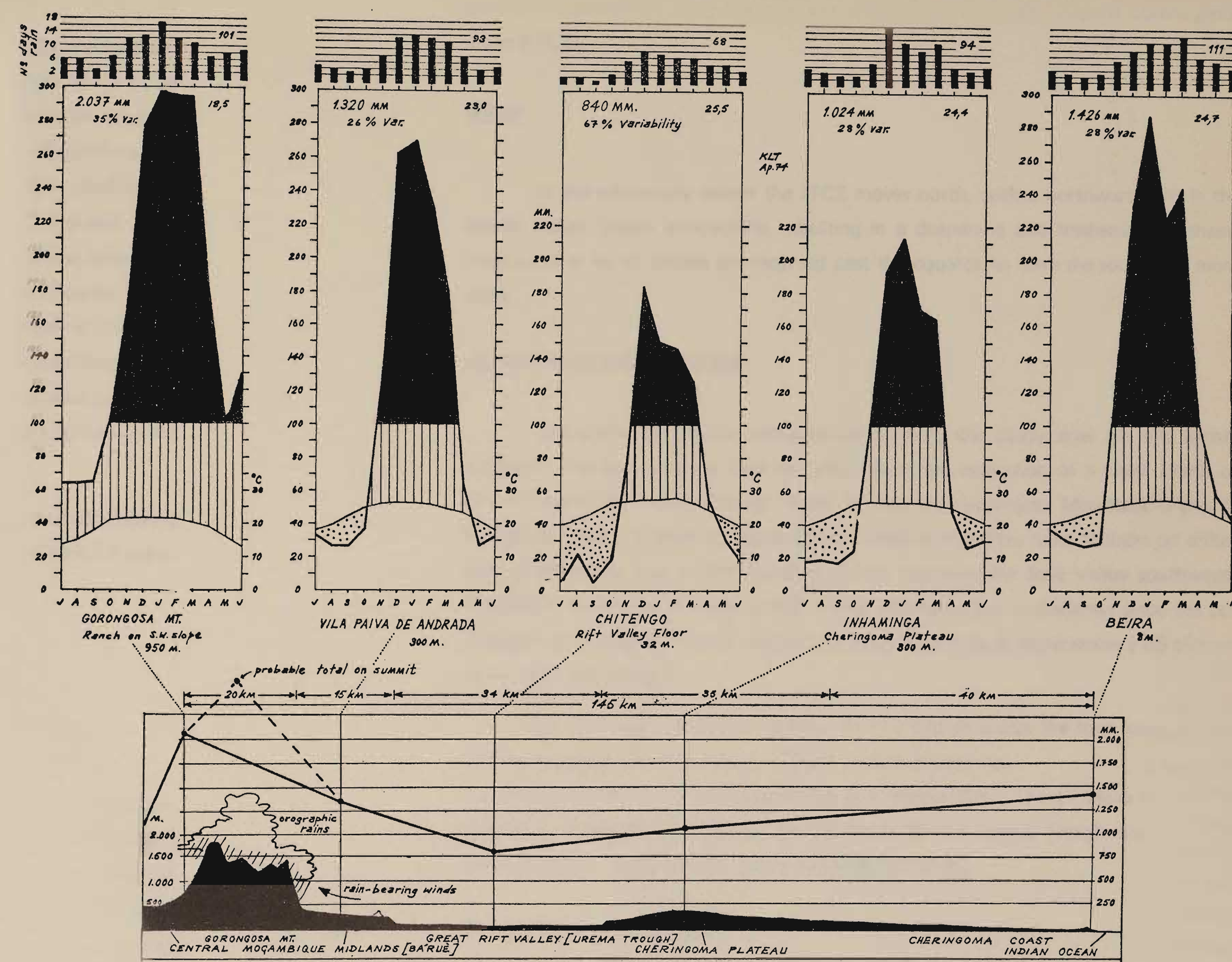



FIG 4.1 OROGRAPHIC & MARITIME CONTROL OF RAINFALL REGIMES IN THE GORONGOSA - CHERINGOMA REGION.

to these polar low pressure centres are equatorial low pressure troughs formed by recurved South Atlantic Anticyclone air, known as Congo air. This low pressure trough system penetrates southwards during the austral summer over the interior plateau of the subcontinent.

The tropical anticyclone centres do not occur vertically from ground level upward but are inclined westward with increasing height. Thus, at a height of 6 km the east coast cell is centred over South West Africa, this displacement causing an opposing flow of easterlies at the surface and of westerlies at 6 km. The persistence of the upper westerly geostrophic air stream is made conspicuous by the northeasterly anvil spread of cumulonimbus which develop on Gorongosa Mountain (Fig 4.9). Beneath these major wind systems are tertiary surface, diurnal air reversals of sea and land breeze circulations between the Eastern Great Escarpment and the Mocambique Channel, which are probably linked with similar centripetal flow form the western slopes of Madagascar. The nocturnal katabatic land breeze component is strongly developed throughout the year whenever clear skies occur. The sea breeze, or anabatic component, is due to deepening of the trade wind groundwards, from above the cold air drainage flow, in the mornings as the surface of the land heats up.

The interaction of the above air masses and their streamlines, produce a moving pattern of interacting anticyclone and cyclone centres which are responsible for either precipitation, or alternatively, drought.

## *SEASONAL CLIMATIC CONTROLS*

### *Summer*

In the southern summer the major determinants of climate in Central Mocambique are two anticyclone systems and two low pressure areas. The high pressure cells are those over the Asian landmass, and the other is situated midway between Africa and Australia and is known as the South Indian Ocean high. A low pressure cell (heat low) occurs over the interior of the sub-continent, or is associated with the Zambeze Valley. A persistent low pressure cell occurs over the Zambeze Delta, or seaward of it, extending at times from Beira to Pebane (as plotted on synoptic charts).

Part of the Asian air masses flowing south, as the northeast monsoon, maintain an oceanic trajectory and are thus moist. Another branch curves over the East Africa interior via Somalia and the Rift Valley heat lows to Central Mocambique, where they are very dry winds.

The northeast monsoon reaches its southern geographical limit in midsummer at about 16 to 17° S, and the southeast trades are then confined mostly south of the 18° latitude. The interface between these two air masses along an eastwest trough is generally regarded as being the southern position of the Inter-Tropical Convergence Zone (ITCZ).

### *Winter*

In the winter dry season the ITCZ moves north, with a northward shift in the South Indian Ocean anticyclone, resulting in a deepening and freshening southeast trade wind as its air masses are recurved past the equator to form the southwest monsoon.

## *CLIMATIC CLASSIFICATION*

The sector of Central Mocambique forming the study area all falls within Köppen's Tropical Savanna Climate (AW), with the exception of a small island of Warm Temperate Rainy Climate (CW) formed by Gorongosa Mountain (Faria & Goncalves 1968). Köppen's Steppe Climate (BS) is noted by these authors on either side of the study area in the Zambeze Valley and from the Save Valley southwards (Gazaland). However, analysis of Rift Valley data recorded at Chitengo since the publication of the above authors, shows that the Urema Trough experiences a BS climate in six years out of eight.

De Martonne's Index of Aridity (P/ (T+10)) separates the four main physiographic regions of the Gorongosa – Cheringoma transect into:
(1) Mountain (90%), (2) Midlands (41%), Rift Valley (23%), Coast Plateau (30%), and land-sea junction (41%). The high Aridity Index for the Urema Trough is of the same order as those in the Zambeze Valley and Gazaland areas.

## *CLIMATIC PARAMETERS*

As the various climatic components are summarized in diagrammatic form the relevant data and their seasonal relationships can be read from these. The longterm climatic features of the physiographic units in the Gorongosa – Cheringoma transect are depicted by comparative (Gaussen 1955) climatograms in Fig 4.1.

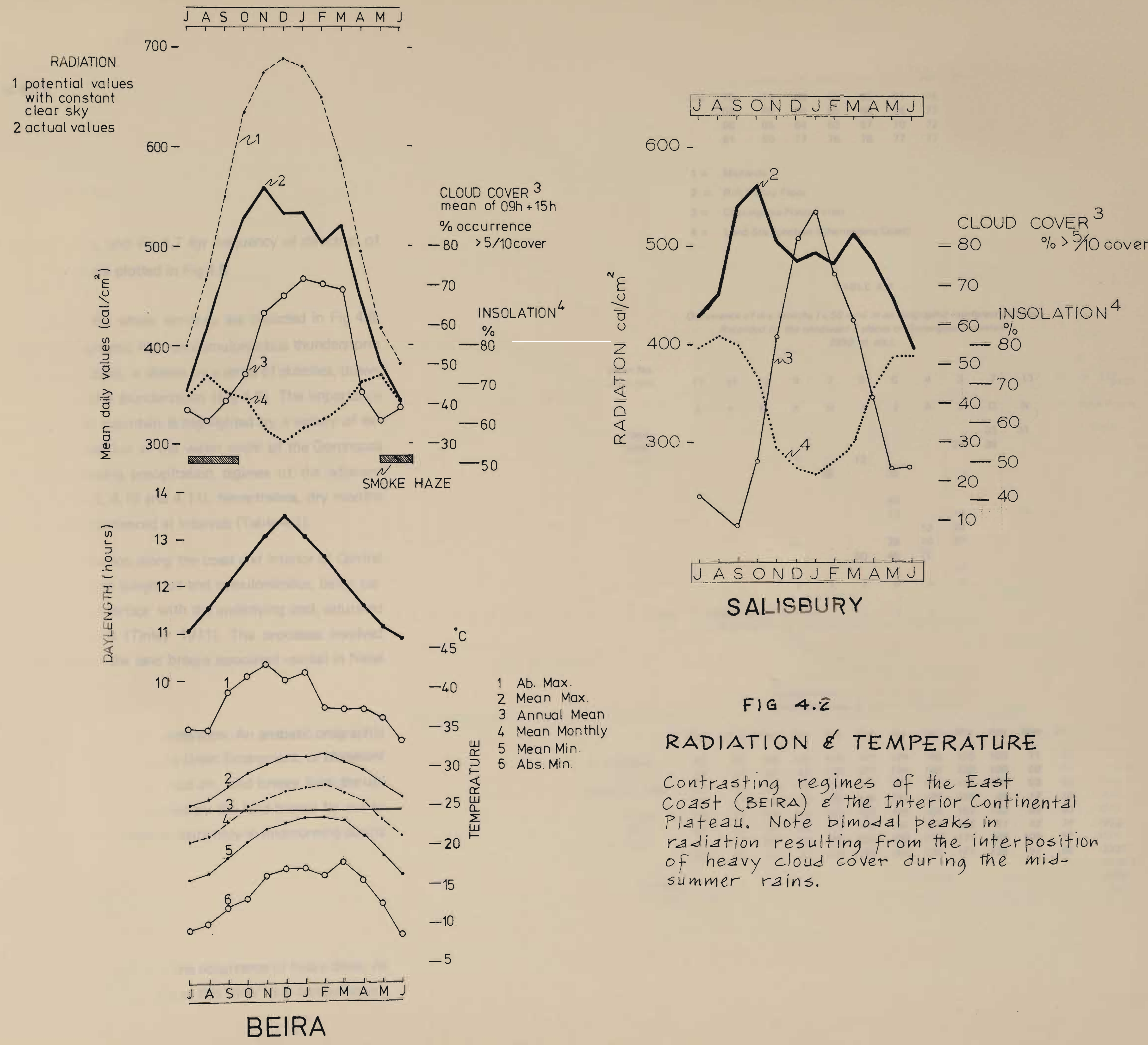



**FIG 4.2**

**RADIATION & TEMPERATURE**

Contrasting regimes of the East Coast (BEIRA) & the Interior Continental Plateau. Note bimodal peaks in radiation resulting from the interposition of heavy cloud cover during the mid-summer rains.

***Radiation, Insolation and Daylength:*** see Fig 4.2

***Temperature:*** see Figs 4.3 and 4.13

***Humidity:*** see Table 4.1

***Cloud Cover and Cloud Types:*** see Fig 4.4

***Wind:*** see Fig 4.5 for regional airstreams, and Fig 4.7 for frequency of direction of winds in the Rift Valley. Hurricane tracks are plotted in Fig 4.6

***Rainfall:*** The mean annual isohyets for the whole territory are depicted in Fig 4.8. The trigger effect of the Gorongosa orographic high on cumulonimbus thunderstorm development, or instability rains (***guti*** drizzle), is shown by a series of sketches, drawn at intervals on one day, of the growth of a thunderstorm (Fig 4.9). The importance of this feature on all life surrounding the mountain is highlighted by a variety of examples throughout the thesis. Its key position in the water cycle of the Gorongosa ecosystem is emphasized by the contrasting precipitation regimes of the adjacent Urema Rift Valley 15 km distant (Fig 4.1, 4.10 and 4.11). Nevertheless, dry months in the orographic rain forest climate are experienced at intervals (Table 4.2).

A characteristic feature of precipitation along the coast and interior of Central Mocambique is the occurence of rain, from congestus and cumulonimbus, being carried inland by the southeast trade on the interface with the underlying cool, saturated wedge of land breeze air flowing seawards (Tinley 1971). The processes involved appear to be similar to those described for the land breeze associated rainfall in Natal (Preston-Whyte 1970).

***Fog:*** Two quite different kinds of fog occur in the ecosystem. An anabatic orographic fog, or drizzle, which is known locally as ***guti*** along the Great Escarpment, or ***chiperoni*** in Zambezia and Malawi, and a low level nocturnal cool air, land breeze from the uplands to the sea (Fig 4.12). The katabatic fog is carried by the land breeze far out to sea over the Mocambique Channel, and often clears at Beira only in midmorning during winter (Tinley 1971).

***Guttation and Dew***

A notable feature in all physiographic units is the occurrence of heavy dews. As can be ascertained by direct observation, however, most of this "dew" is in fact guttation,

TABLE 4 1

*Relative Humidity % (Means)*

| | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 Vila Paiva de Andrada | 75 | 71 | 66 | 63 | 65 | 71 | 75 | 76 | 78 | 76 | 74 | 74 |
| 2 Vila Machado | 68 | 69 | 66 | 65 | 66 | 74 | 72 | 74 | 74 | 71 | 69 | 70 |
| 3 Inhaminga | 66 | 65 | 64 | 63 | 67 | 70 | 72 | 72 | 74 | 72 | 68 | 67 |
| 4 Beira | 81 | 80 | 77 | 76 | 76 | 77 | 77 | 78 | 78 | 78 | 78 | 80 |

1 = Midlands
2 = Rift Valley Floor
3 = Cheringoma Plateau crest
4 = Land-Sea Junction (Cheringoma Coast)

TABLE 4.2

*Occurrence of dry months (≤ 50 mm) in an orographic rainforest climate. Recorded on the windward S slopes of Gorongosa mountain (950 m alt.).*

| | J | F | M | A | M | J | J | A | S | O | N | D | total P/mm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean No. days rain | 17 | 14 | 13 | 9 | 7 | 9 | 6 | 4 | 3 | 7 | 13 | 15 | = 117 |
| 1963 | | | | | | | | | | 33 | 31 | | 2469 |
| 1964 | | | | | | | | | 20 | 38 | | | 1985 |
| 1965 | | | | 5 | | 13 | | | | | | | 1983 |
| 1966 | | | | | 38 | | 36 | | | | | | 2022 |
| 1967 | | | | | | | | | | | | | 2550 |
| 1968 | | | | | | | 43 | | | | | | 1804 |
| 1969 | | | | | | | 13 | | 18 | | 20 | | 2182 |
| 1970 | | | | | | | | 13 | 20 | | | | 1970 |
| 1971 | | | | 31 | | | 28 | 10 | 20 | | | | 1949 |
| 1972 | | | | | | 50 | 45 | 12 | | | | | 1871 |
| 1973 | | | | | | | | | 19 | | | | 2473 |
| Occurrence | | | | 2 | 1 | 2 | 5 | 3 | 5 | 2 | 2 | | |

April 1965 = lowest rainfall recorded.
July 1971 = end of month fire burnt out greater part of summit.

TABLE 4.3

*Evapotranspiration (mean values mm)*
*(from Gonçalves & Soares 1972: 485)*

| | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 Vila Paiva | 41 | 58 | 95 | 131 | 170 | 171 | 174 | 146 | 130 | 103 | 71 | 42 | 1332 * |
| | *37* | *42* | *47* | *53* | *129* | *171* | *174* | *146* | *130* | *100* | *50* | *37* | *1124 #* |
| 2 Vila Machado | 67 | 90 | 127 | 118 | 192 | 202 | 207 | 175 | 176 | 145 | 93 | 63 | 1655 |
| | *10* | *17* | *8* | *32* | *95* | *176* | *174* | *139* | *116* | *48* | *17* | *15* | *847* |
| 3 Inhaminga | 63 | 82 | 114 | 148 | 191 | 197 | 196 | 165 | 167 | 132 | 99 | 63 | 1617 |
| | *23* | *23* | *20* | *22* | *100* | *179* | *196* | *165* | *166* | *81* | *43* | *34* | *1052* |
| 4 Beira | 93 | 121 | 150 | 186 | 189 | 202 | 189 | 174 | 171 | 138 | 109 | 87 | 1809 |
| | *56* | *53* | *37* | *33* | *128* | *202* | *189* | *174* | *171* | *136* | *97* | *66* | *1342* |

1 = Midlands
2 = Rift Valley floor
3 = Cheringoma Plateau crest
4 = Land-Sea Junction (Cheringoma Coast)

* Potential
\# Actual

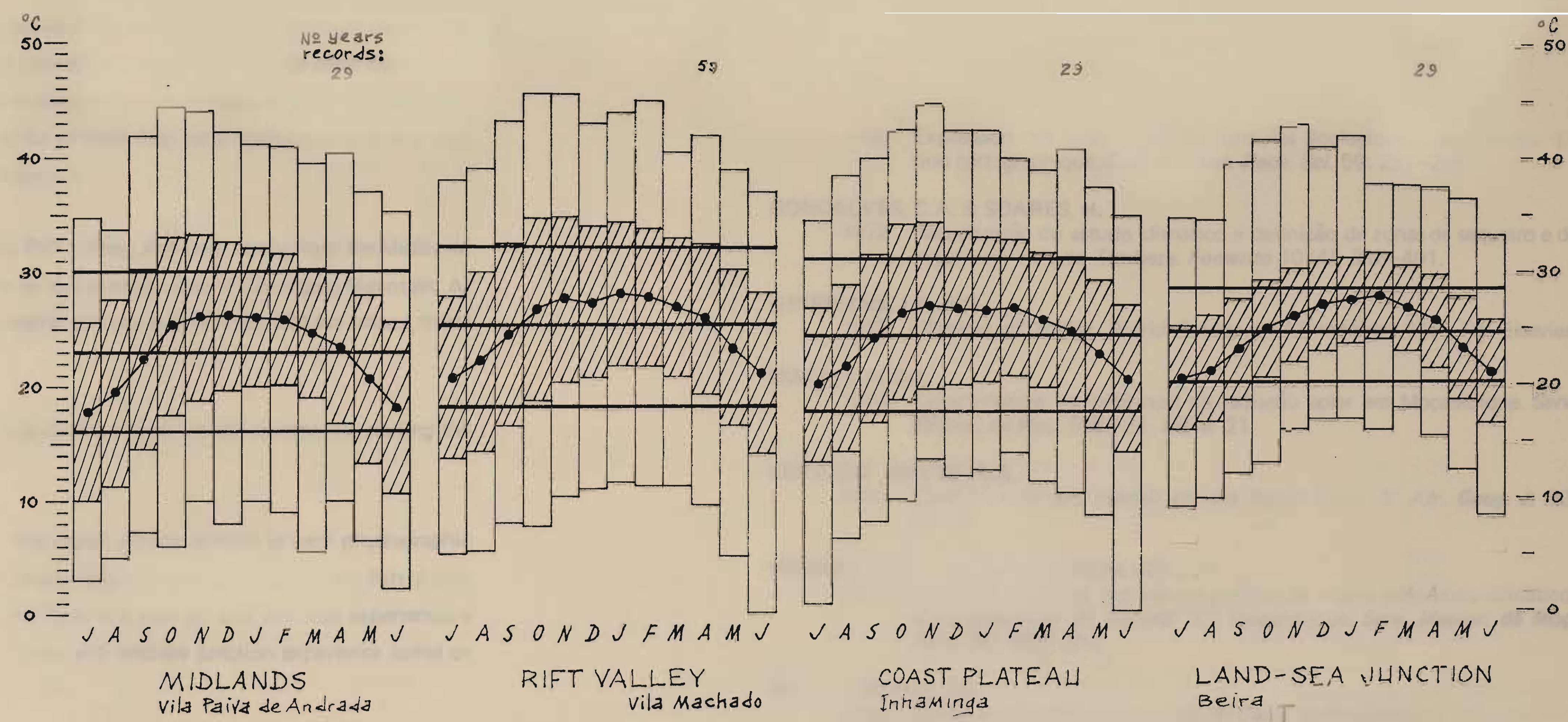



FIG 4.3 TEMPERATURE REGIMES OF EACH PHYSIOGRAPHIC UNIT °C

that moisture exuded by plants at specialized pores termed hydathodes. This occurs when soil moisture is near field capacity at night or in the early morning when no evapotranspiration is taking place. The conditions under which guttation takes place are generally favourable for dew formation, but guttation continues in conditions unfavourable to the formation of dew.

It is significant that the abrupt termination of valley fog occurrence in September (Fig 4.12) is associated with the termination of guttation (soil moisture depletion). The spring thermal changes and wind intensity patterns may also be contributary factors, but light valley fog occurs again in midsummer on cloudless nights, thus the pumping out of soil moisture by plants may be of more than local significance and may contribute directly to katabatic fog development.

*Frost:* No frost is recorded from the Rift Valley, and only rarely from the Midlands. There are no records of its incidence on the summit areas of Gorongosa Mountain. At Inyanga (Rhodes Estate), at a comparable altitude and latitude 120 km inland, frosts are recorded only in June and July.

*Evaporation:* Actual and potential evapotranspiration for the transect (excluding the mountain) are presented in Table 4.3.

*The Seasons:* Fig 4.13 summarizes the march of the seasons in each physiographic unit. Due to cold air drainage of the nocturnal land breeze component, the Rift Valley trough, which lies at right angles to the flow, is a cold air sink and thus experiences a mild midwinter period. The coast plateau and land-sea junction experience torrid or hot thermal conditions throughout the year.



## REFERENCES / CLIMATE


BUNKER, A.F. & CHAFFEE, M.
1969 ***Tropical Indian Ocean Clouds.*** Honolulu, East-West International Indian Ocean Expedition Meteor. Monographs No 4. Centre Press.

CORREIA, M.M.
1968 Aspectos aeronauticos das condições climáticas do Aeroporto de Sacadura Cabral (Beira). ***Serv. Meteor. de Moç.*** SMM 44, Mem 42.
1970 Nebulosidade total na Beira. ***Serv. Meteor. de Moç.*** SMM 65, MEM 60.

GAUSSEN, H.
1955 Expression des milieux par des formules écologiques: leur representation cartographique. ***Coll. Int. Nat. Rech. Sci.*** 59: 257–269

GONCALVES, C.A. & SOARES, H.
1972 Actualização do estudo climático e definição de zonas de sequeiro e de regadio no Vale do Zambeze. ***Fomento*** 10 (4): 313–491.

GRIFFITHS, J.F. (ed).
1972 ***Climates of Africa.*** World Survey of Climatology Vol. 10. Elsevier.

MATA, L.A. DA
1966 Caracterı́sticas da incidencia da radiação solar em Moçambique. ***Serv. Meteor. de Moç.*** SMM 23 , MEM 21.

PRESTON–WHYTE, R.A.
1970 Land breezes and rainfall on the Natal Coast. ***S. Afr. Geog. J.*** 52: 38–43.

ROCHA FARIA, J.M. DA & GONCALVES, C.A.
1968 Cartas de isopletas dos valores médios de alguns elementos climáticos e da classificão de Köppen em Moçambique. ***Serv. Meteor. de Moç.*** SMM 38, MEM 36.

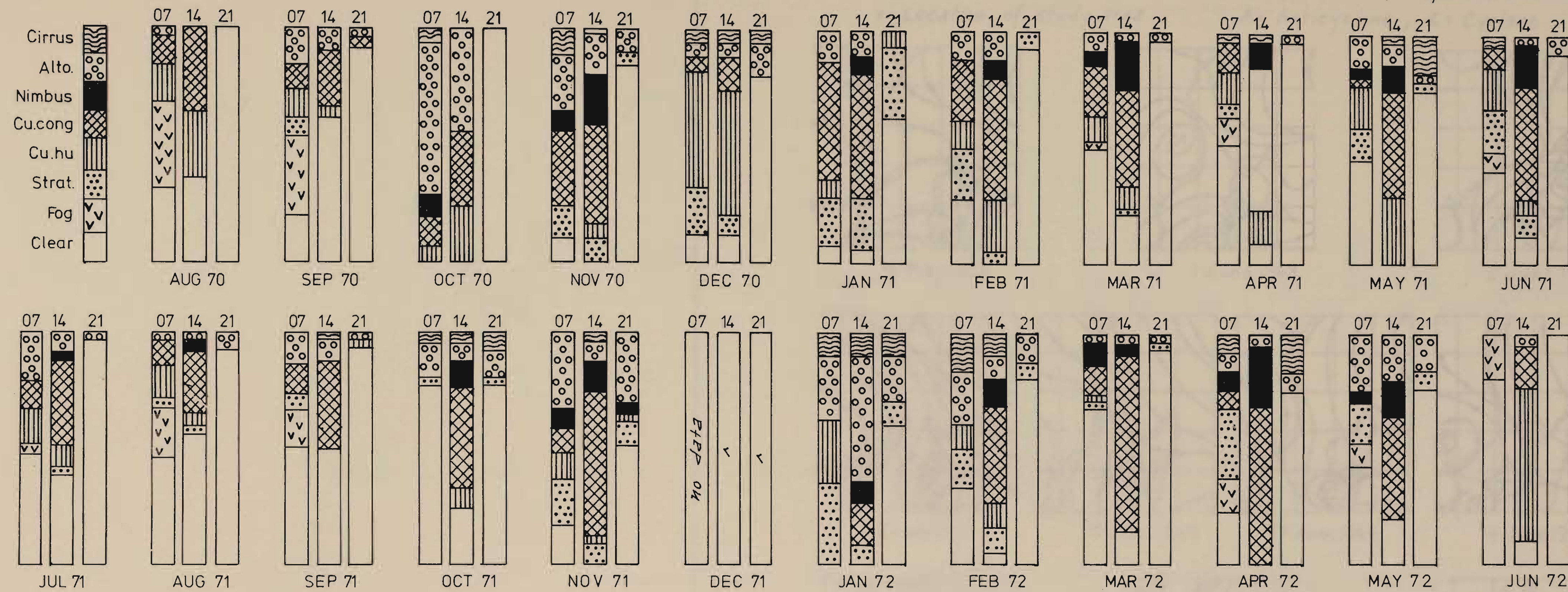
ROSA, J. MARIA DA
1969 Ciclones e depressões tropicais do Canal de Moçambique. ***Serv. Meteor. de Moç.*** SMM 54, MEM 52.

THOMPSON, B.W.
1965 ***The Climate of Africa.*** Oxford University Press, London.

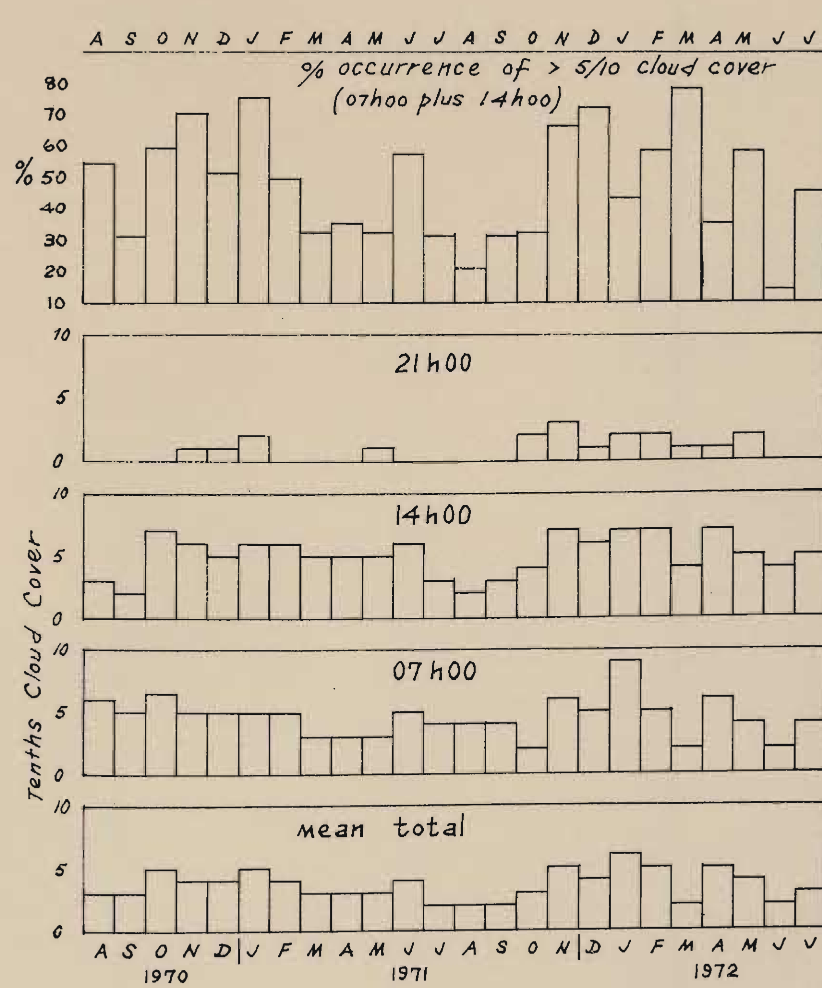
TINLEY, K.L.
1971 Determinants of coastal conservation : Dynamics and diversity of the environment as exemplified by the Mocambique Coast. In: ***Nature Conservation as a form of land use.*** Proceedings SARCCUS Symposium, Govt. Printer, Pretoria. pp. 125–163.

TYSON, P.D.
1969 Atmospheric circulation and precipitation over South Africa. University of the Witwatersrand. ***Environ. Studies Occ. Paper*** No. 2.

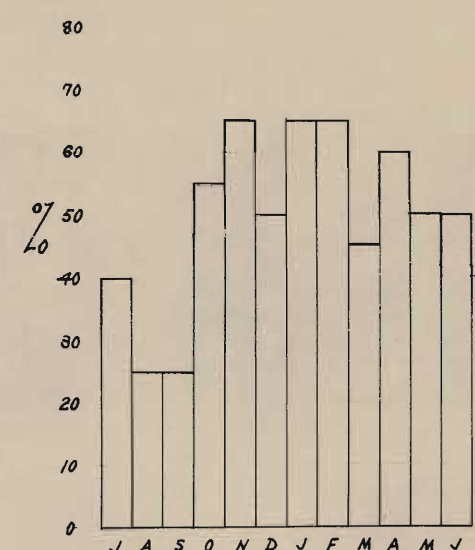
MONTHLY PERCENT OF CLOUD TYPES RECORDED ABOVE THE UREMA RIFT VALLEY (over a 2 year period at 07h00, 14h00, 21h00) pers. data




# FIG 4.4
## CLOUD COVER SEQUENCES OVER THE RIFT VALLEY.




Cloud cover variations over a 2 year period above the Mocambique sector of the Great Rift Valley. (pers. data)




Percent cloud cover recorded above Rift Valley (mean of 14h00 readings over a two year period).

Chitengo, Urema Trough sector of Great Rift Valley.

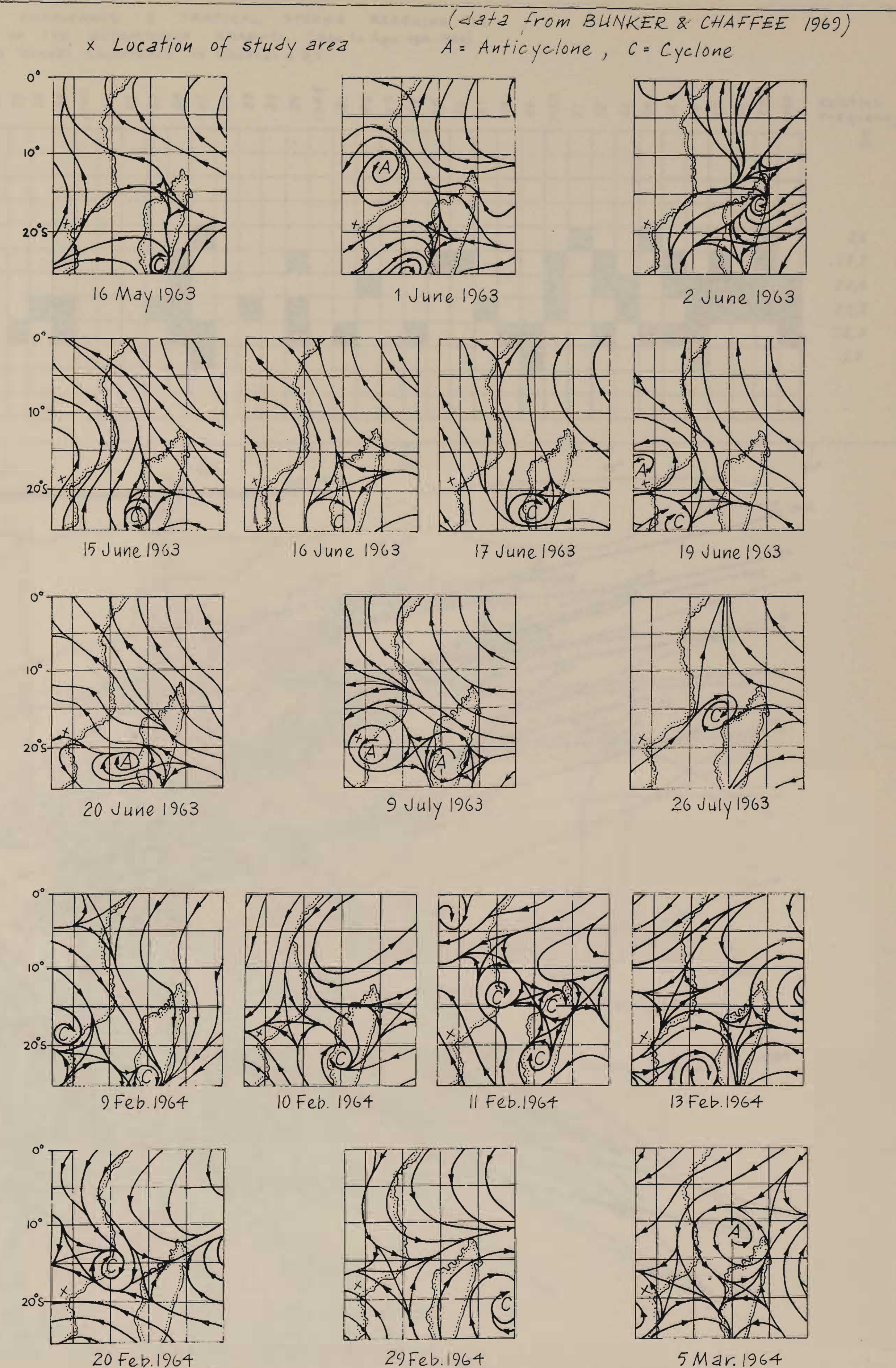
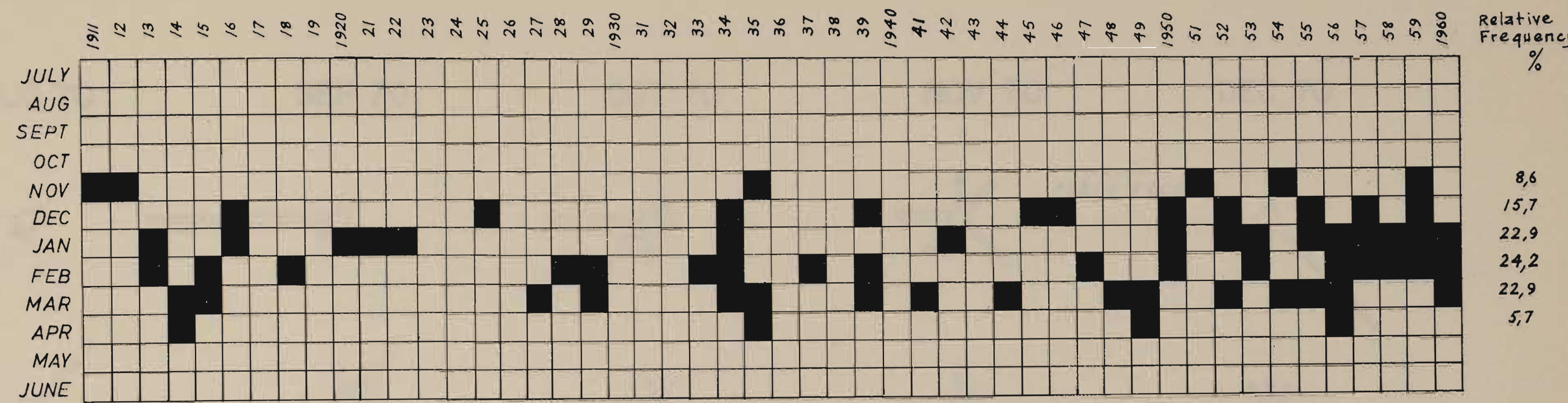
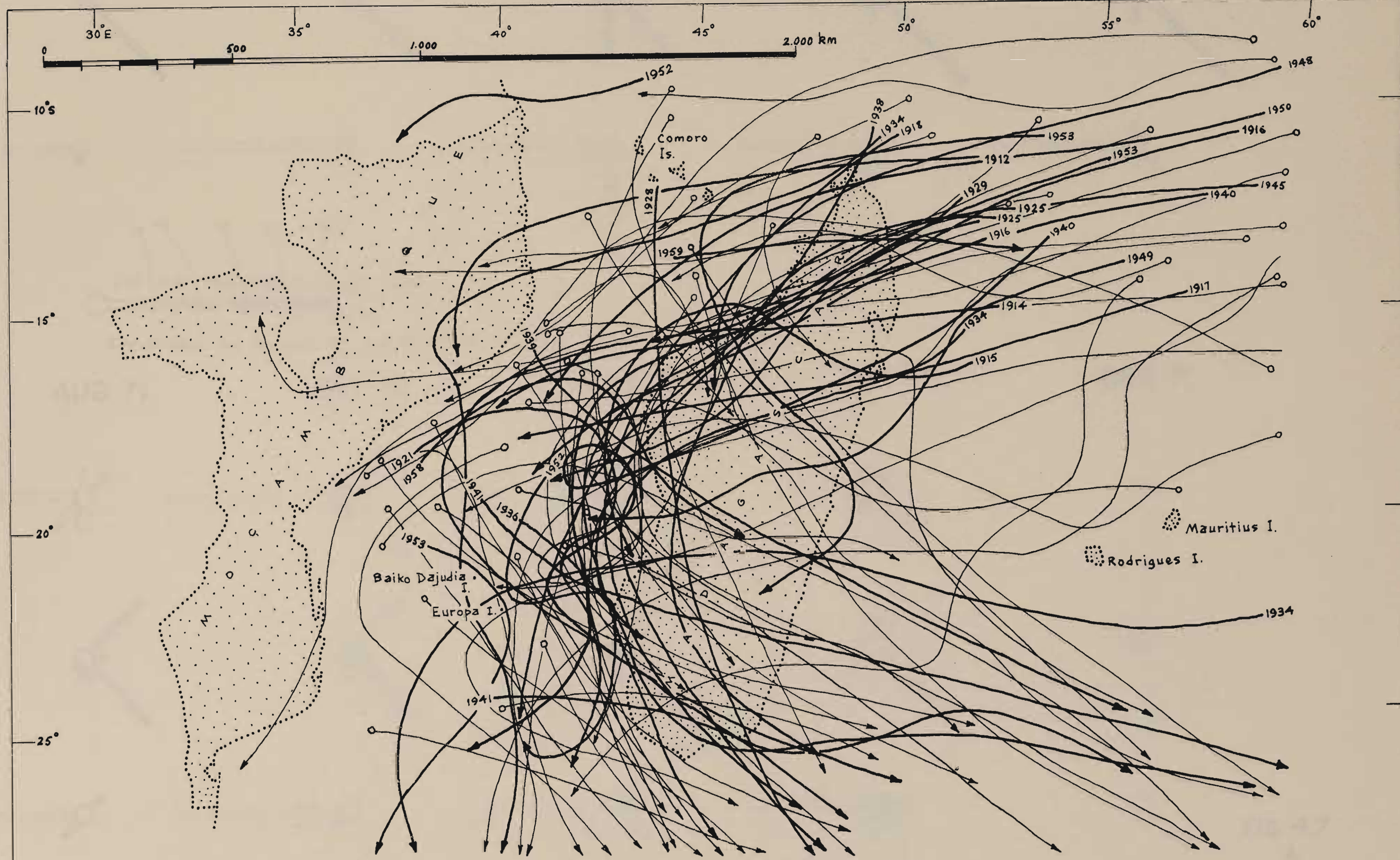



FIG 4.5 Examples of surface streamlines over Mocambique & Madagascar. These show the close interplay of the macroscale air masses across the equator in the development & movement of anticyclonic & cyclonic processes.

OCCURRENCE OF HURRICANES & TROPICAL STORMS REACHING THE WESTERN HALF OF THE MOÇAMBIQUE CHANNEL. (Nov. to Apr. 1911-1960)
Mean annual occurrence in Channel = 3,1




THE PATTERN OF HURRICANE TRACKS & TROPICAL STORMS OVER THE MOÇAMBIQUE – MADAGASCAR REGION OF THE SOUTHWEST INDIAN OCEAN (November to April, 1911-1960).

FIG 4.6

Hurricanes or Near-hurricane strength 1950
Tropical Storms of medium to low intensity

[storm track traces & occurrences from J. Maria da Rosa 1969]

KLT

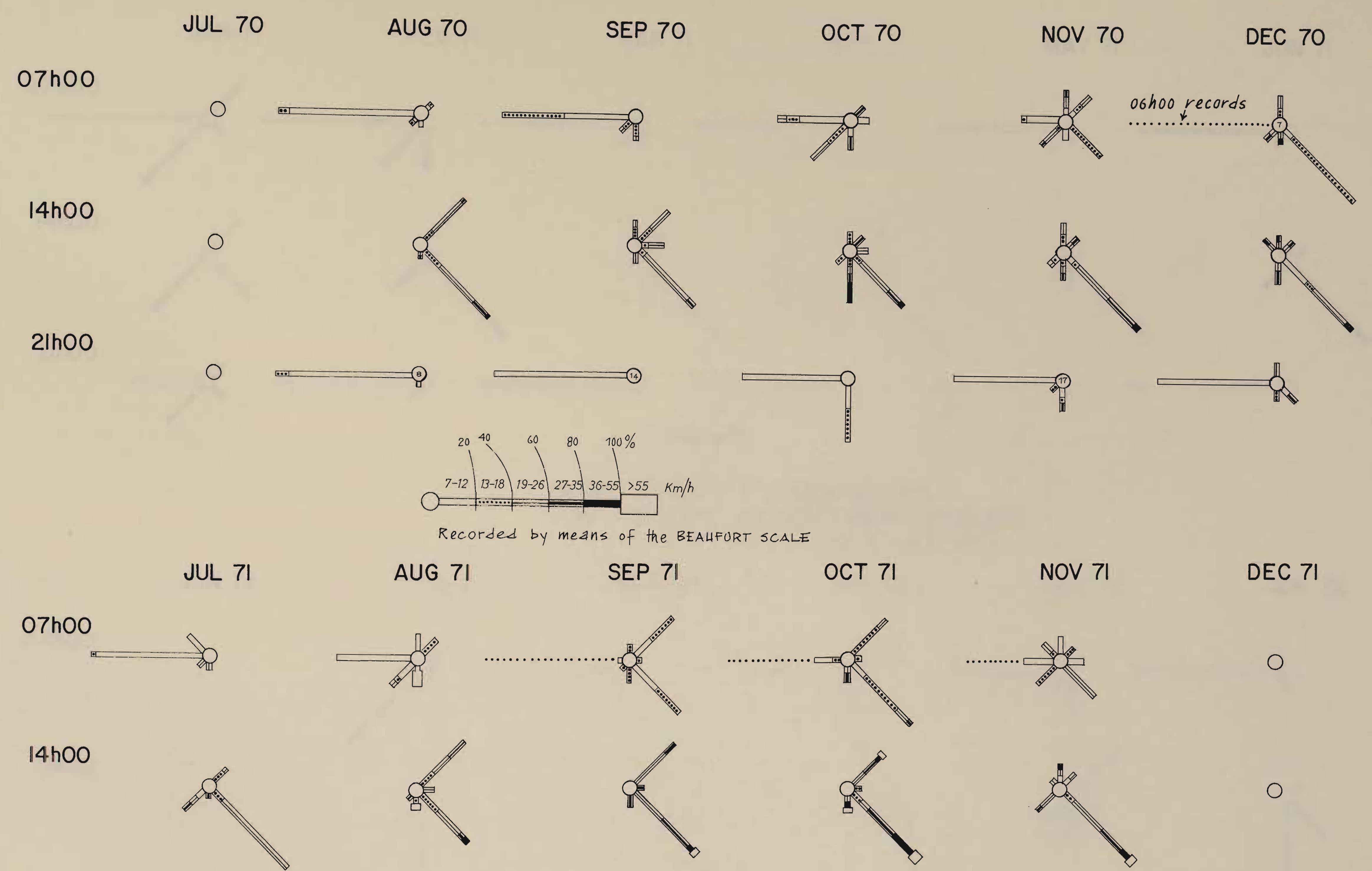

JUL 70
AUG 70
SEP 70
OCT 70
NOV 70
DEC 70
07h00
14h00
21h00
06h00 records
20
40
60
80
100 %
7-12
13-18
19-26
27-35
36-55
>55
Km/h
Recorded by means of the BEAUFORT SCALE
JUL 71
AUG 71
SEP 71
OCT 71
NOV 71
DEC 71
07h00
14h00
21h00

FIG 4.7
A

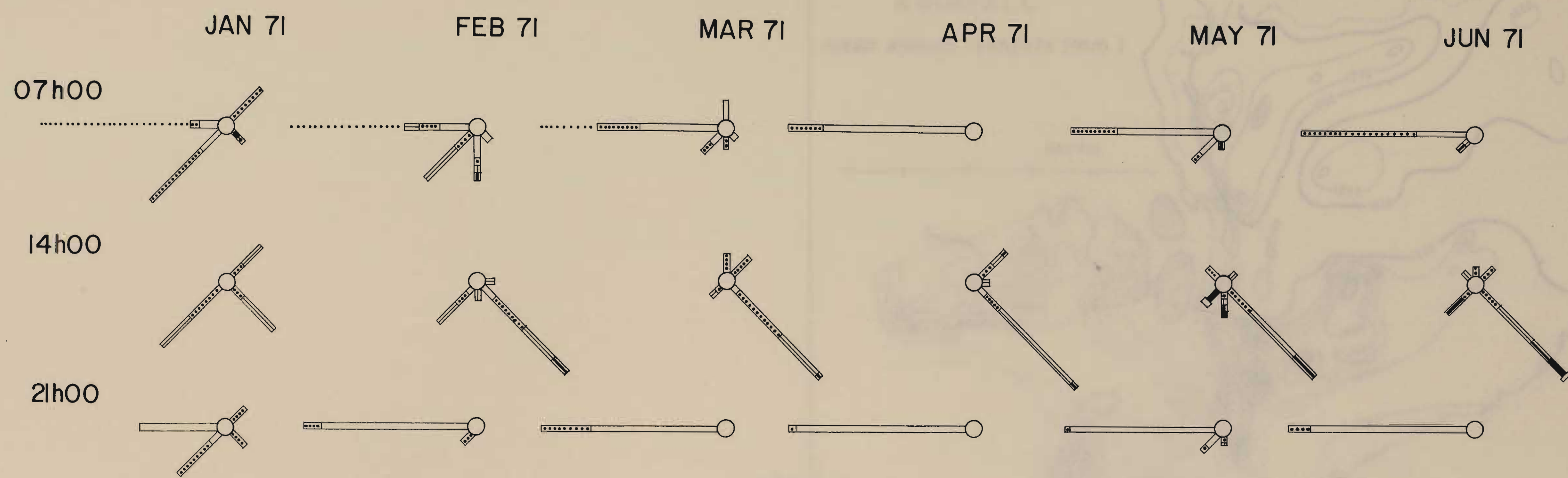



FIG 4.7

WIND DIRECTION FREQUENCIES
FOR THE RIFT VALLEY (UREMA TROUGH).
(recorded over a 2 year period pers. data)

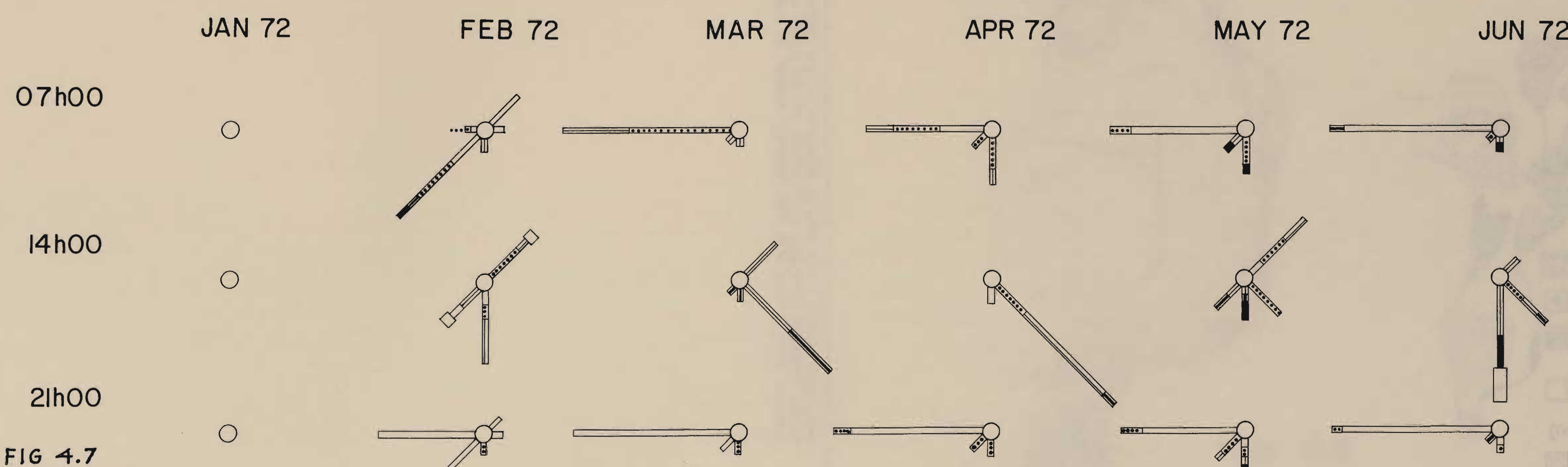



FIG 4.7
B

isohyets from latest map (1974, unpubl) drawn by the Met. Serv. of Moçambique. Modified & corrected by K.L.Tinley to fit topographic-vegetation units & the isohyet patterns of the adjacent territories.

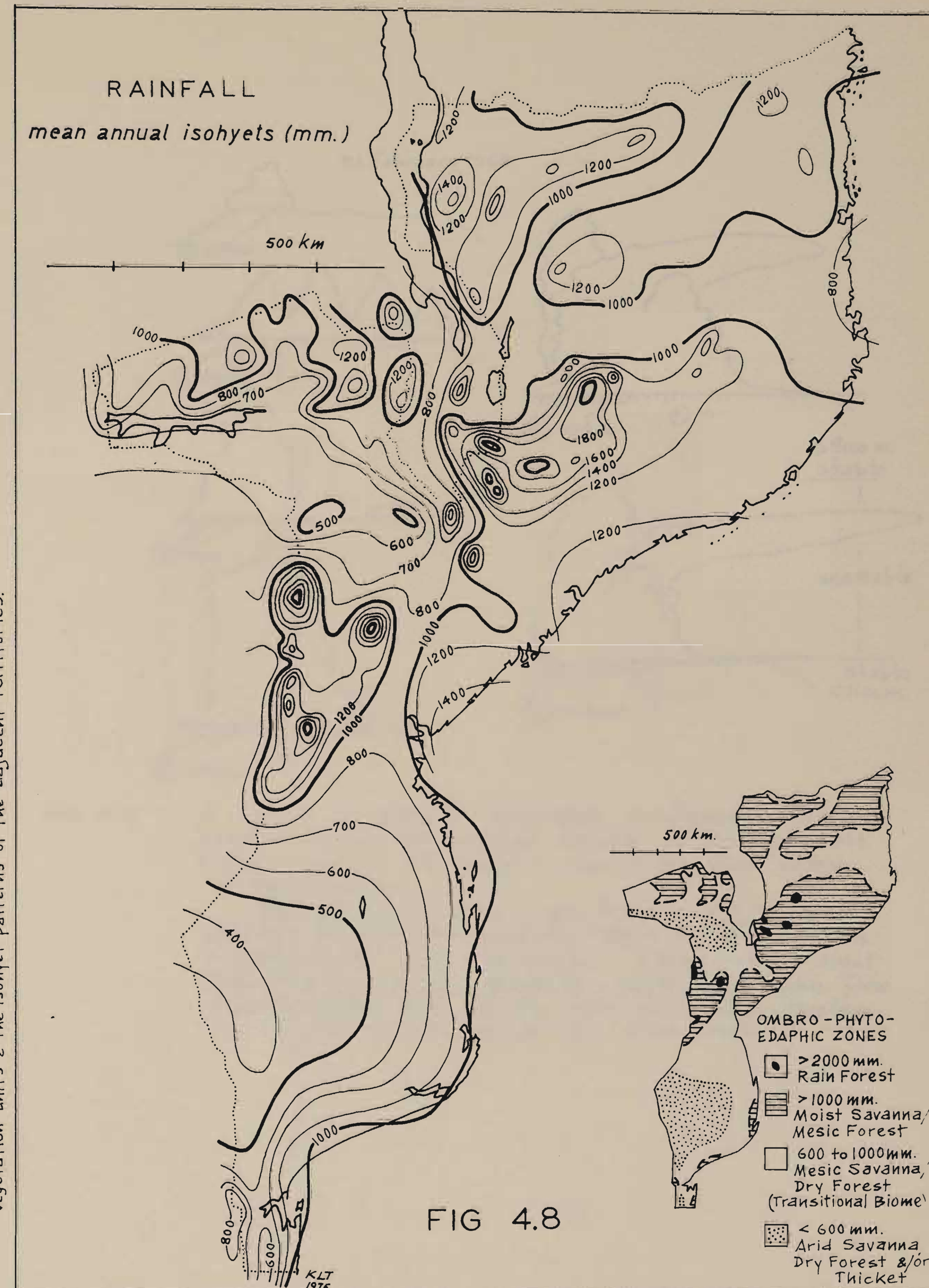



FIG 4.8

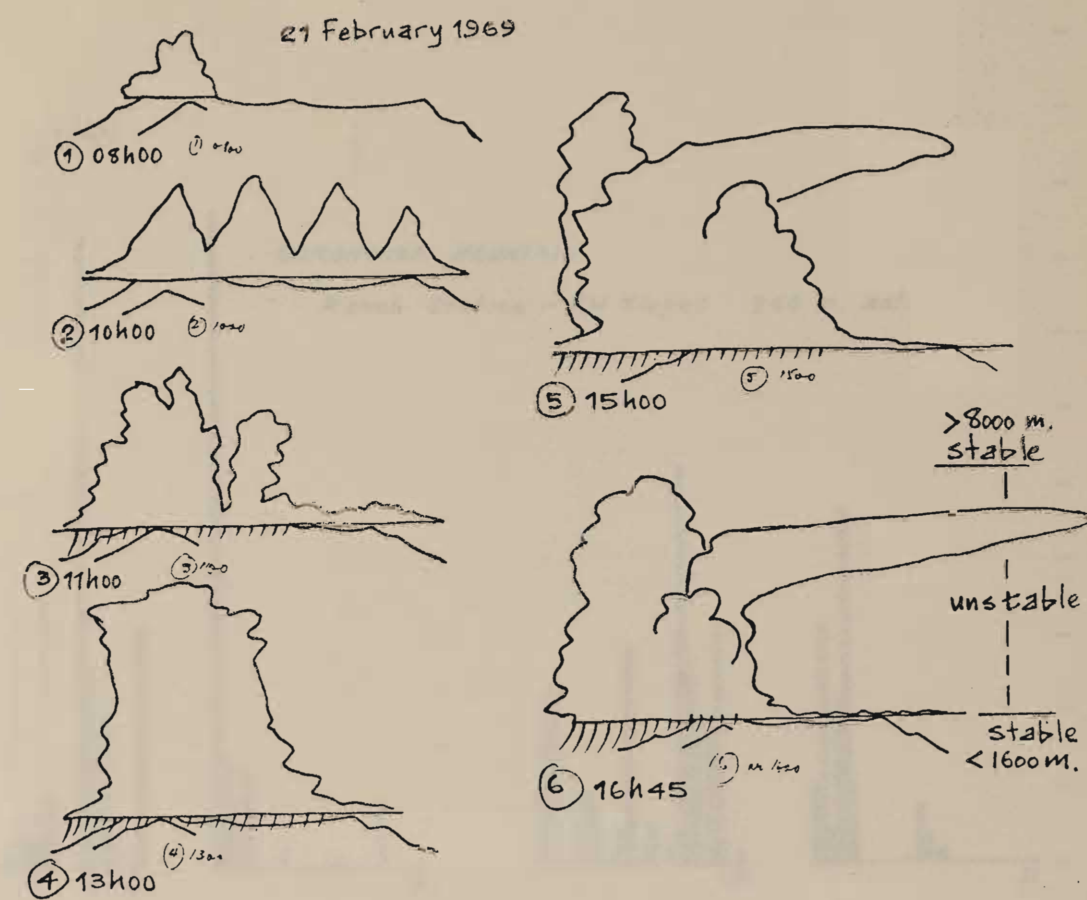



FIG 4.9 A typical example of orographic cumulonimbus rain development over the isolated massif of Gorongosa Mt. (1863 m. asl.) on the western edge of the Rift Valley in Mocambique.

The groundlevel wind was from the SE Trades off the sea (from the observer toward the mountain) with a condensation level at c. 1.600 m. Above this at about 6000 - 8000 m was the opposing SW/W geostrophic flow from the upper level of the same anticyclone system centred over the Kunene at the 6 km level.

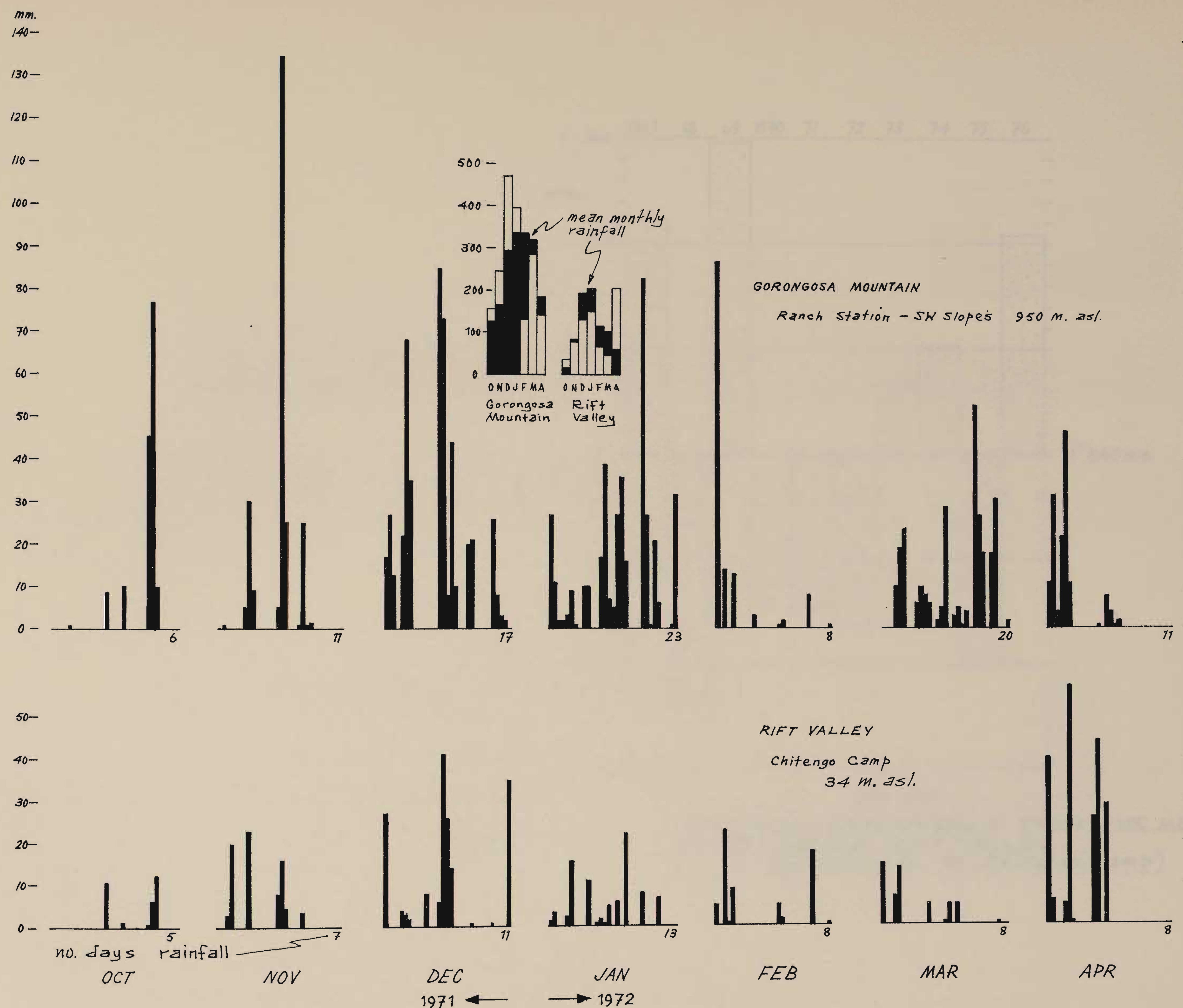



FIG 4.10

DAILY SUMMER RAINFALL COMPARISONS BETWEEN GORONGOSA MOUNTAIN & THE ADJACENT UREMA RIFT VALLEY.

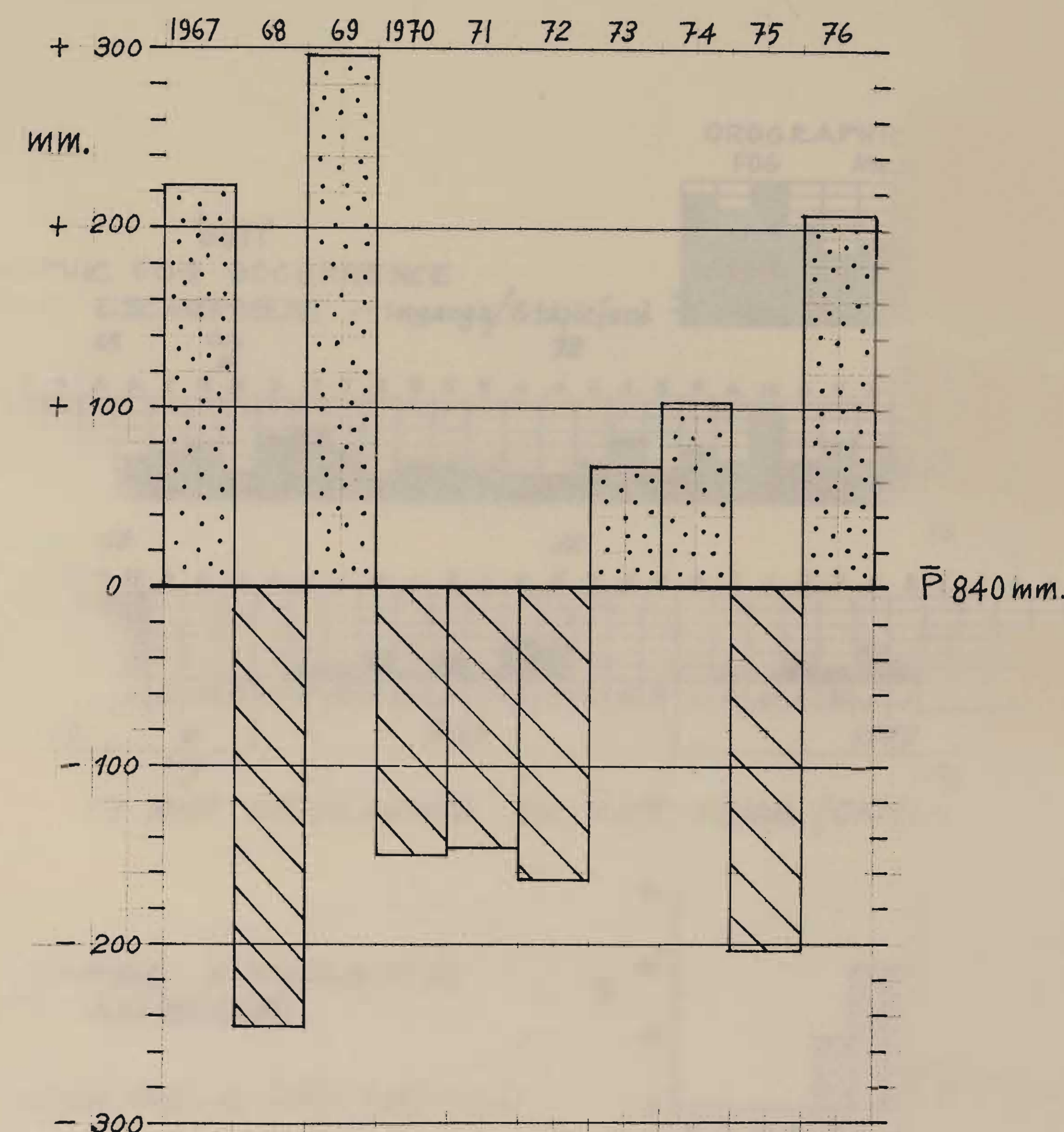
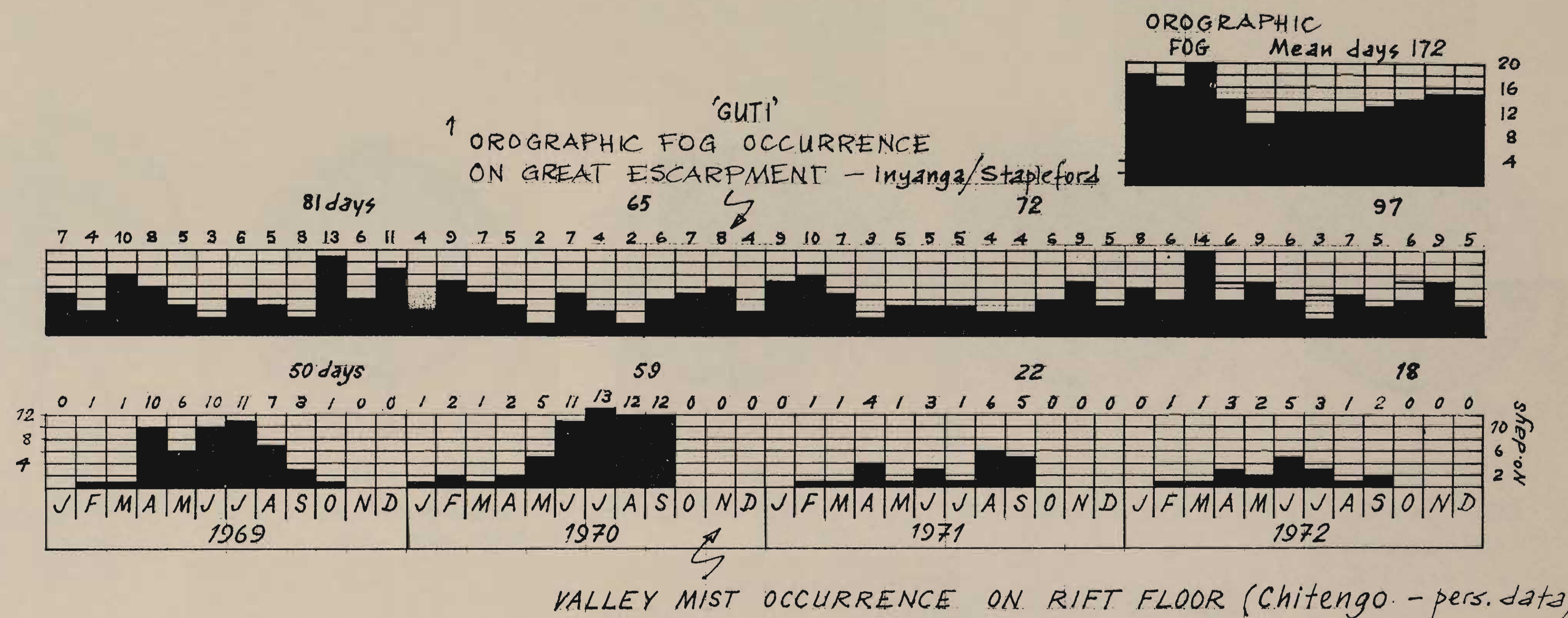
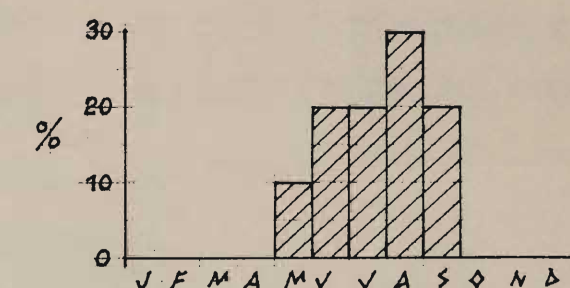



FIG 4.11

RAINFALL DEPARTURES FROM THE MEAN IN THE UREMA RIFT VALLEY.
(as recorded at Chitengo Camp)



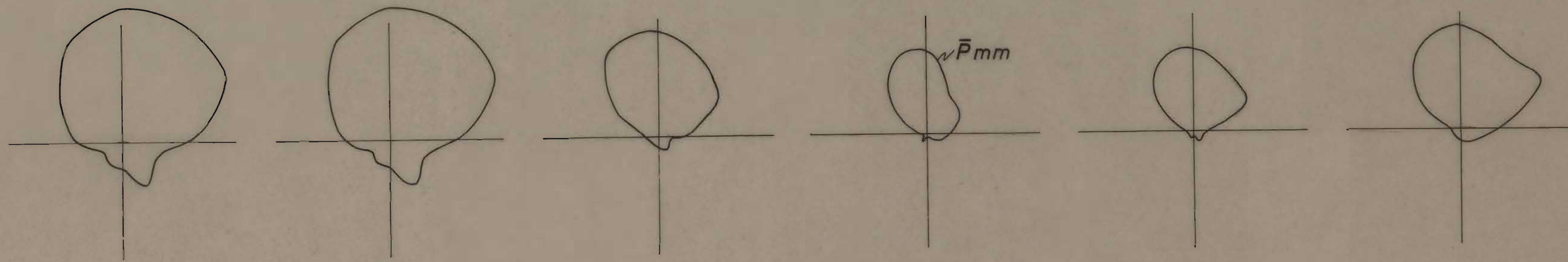
Frequency of katabic fog at Beira[2]

**FIG 4.12**

**OCCURRENCE OF OROGRAPHIC & KATABATIC FOG IN CENTRAL MOCAMBIQUE.**

1 data from Rhodesian Meteorological Dept. (Salisbury)

2 data from CORREIA (1968)


P̄mm

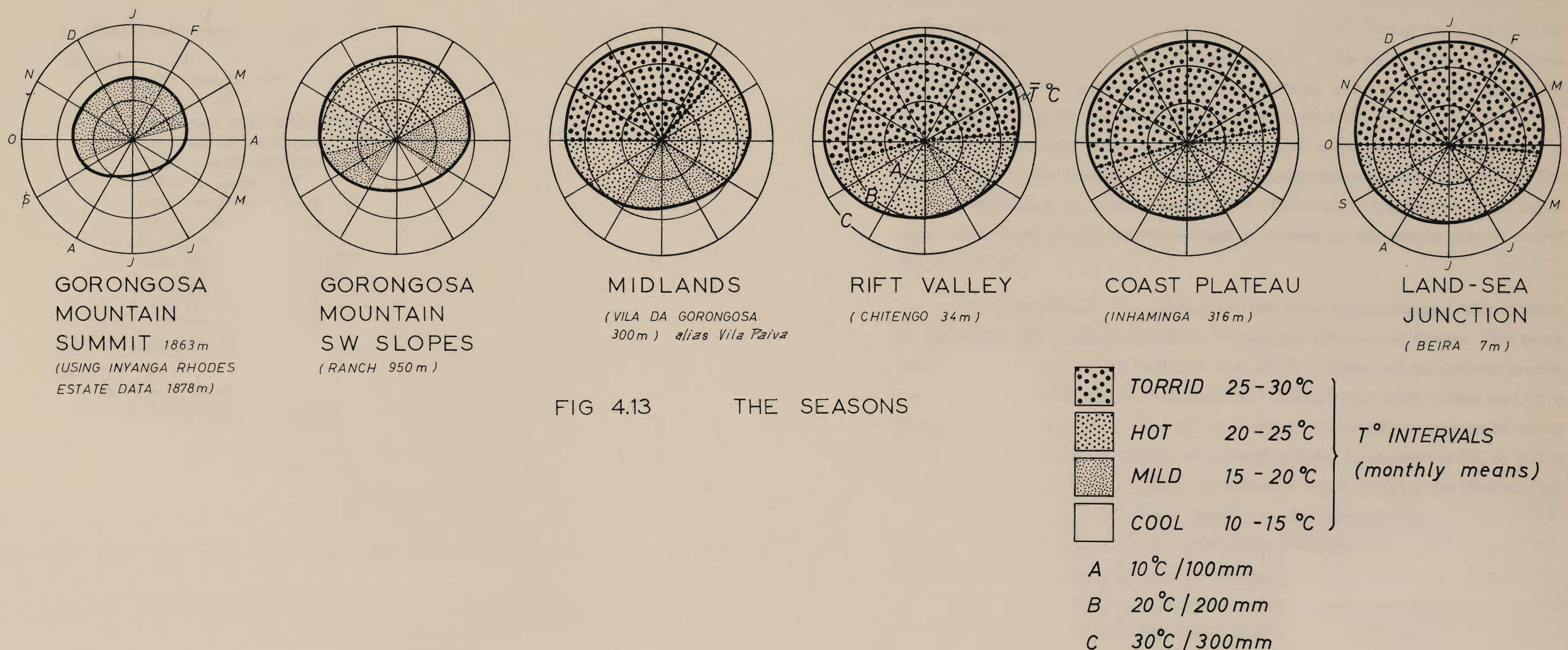



FIG 4.13 THE SEASONS

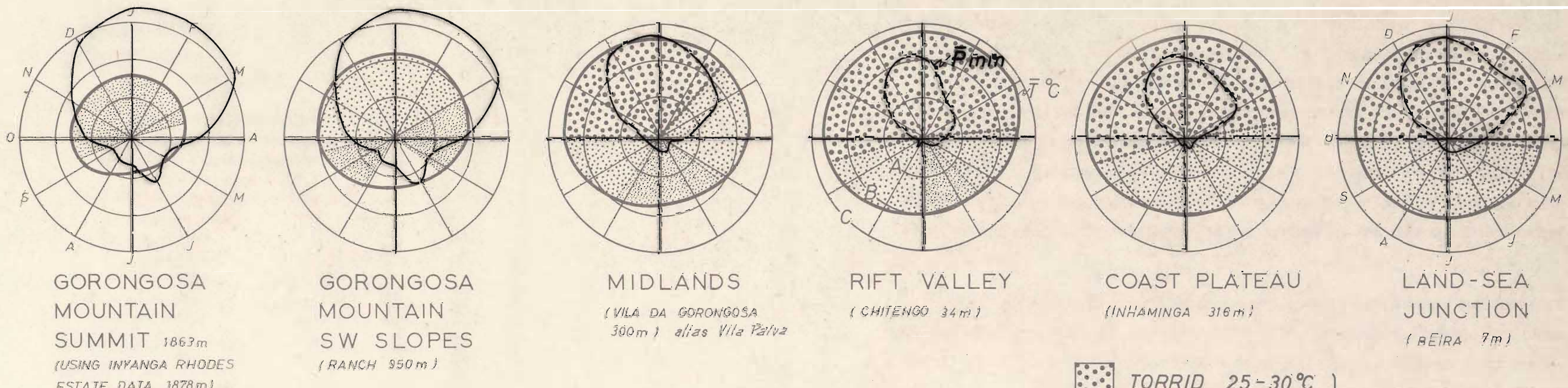



FIG 4.13 THE SEASONS

| | | | |
|---|---|---|---|
| TORRID | 25 - 30 °C | | |
| HOT | 20 - 25 °C | T° INTERVALS | (monthly means) |
| MILD | 15 - 20 °C | | |
| COOL | 10 - 15 °C | | |

A 10°C / 100mm

B 20°C / 200mm

C 30°C / 300mm