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Technical Report ECOM-2768

HAIL INCIDENCE IN THE TROPICS

by

E. M. Frisby

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Technical Report ECOM-2768

HAIL INCIDENCE IN THE TROPICS
PART II

by

E. M. Frisby

Atmospheric Physics Division
Atmospheric Sciences Laboratory

October 1966

DA Task No. 1V0-14501-B-53A-09

U. S. ARMY ELECTRONICS COMMAND

FORT MONMOUTH, NEW JERSEY

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HAIL INCIDENCE IN THE TROPICS
PART II

INTRODUCTION

Two studies have been made utilizing the data included in the four appendices to the original report of the same name.* The first study relates hailstorm frequency and station altitude; the second discusses hail regimes within the tropics.

DISCUSSION

Study Number 1

In temperate latitudes, hailstorm frequency has been observed to increase with altitude. The data presented in the appendices to the first report demonstrate a similar correlation at low latitudes, despite variations in the length of individual records and the inclusion of a number of "exceptions to the rule."

Monthly haildays, listed on pages 24 to 45 of Technical Report ECOM 02105-F, were summed and averaged to give an annual average number of hailstorms for each station. Annual averages were then plotted against station elevation (Fig. 1).

By courtesy of the Geography Branch, U. S. Army Natick Laboratories, who supplied many station elevations after the first report had gone to press, more data are shown in Fig. 1 than appear in the appendices to the original report.

The majority of stations in the tabulation are below 1200 meters and experience fewer than two haildays, on average, per year. The remainder, above 1200 meters, show a tendency to experience an average of three to eight haildays per year, or even more.

Study Number 2

Initially, hailstorm distribution graphs were drawn monthly for observation stations considered to be representative of the countries from which hail data were received (Figs. 2, 3, and 4). Next, composites of hail incidence were prepared for areas that appeared to experience about the same hail season.

*Technical Report ECOM-02105-F, "Hail Incidence in the Tropics," dated September 1966, prepared by Raven Industries, Inc., for the Atmospheric Sciences Laboratory, under Contract DA28-043 AMC-02105(E).

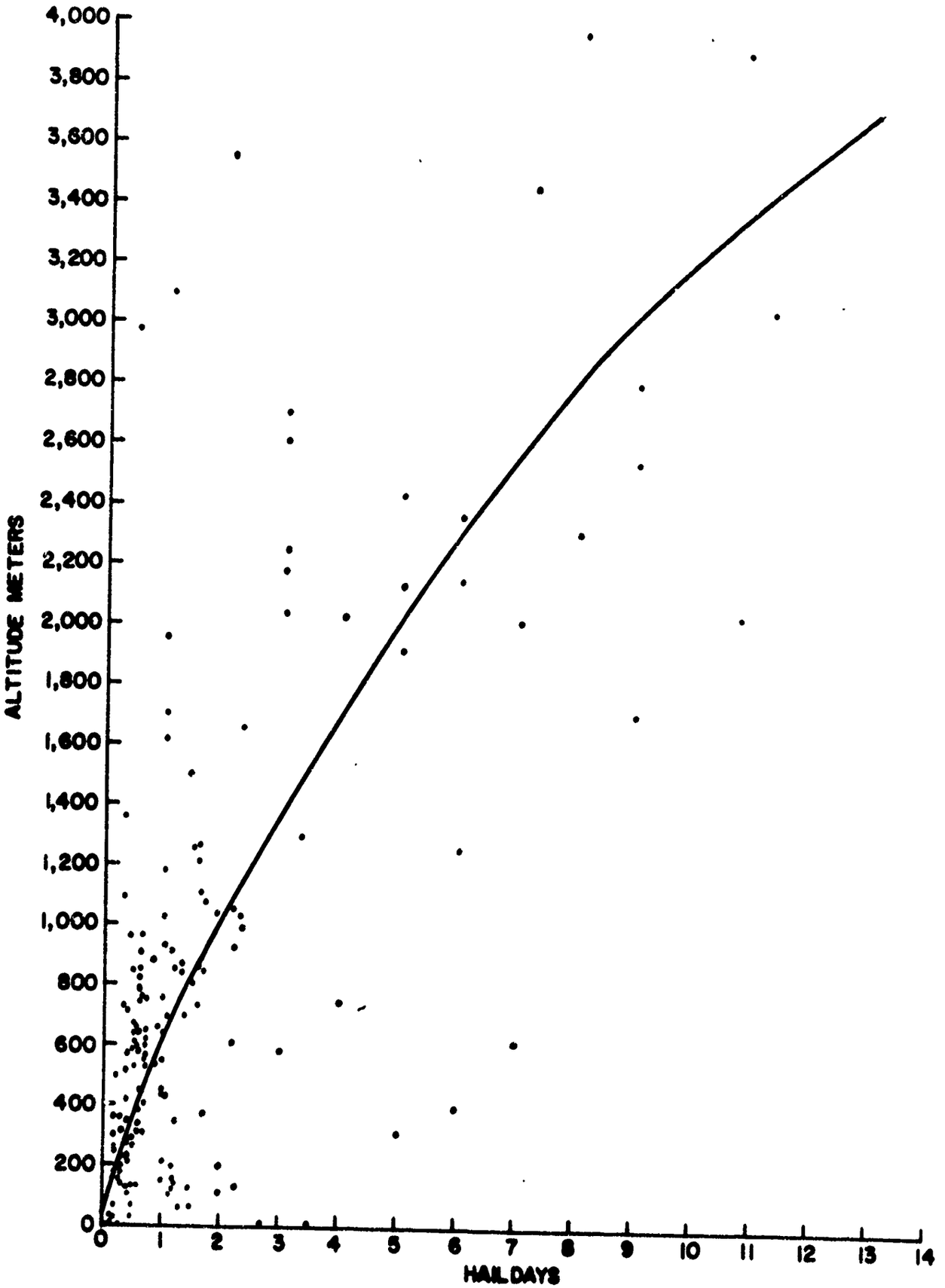
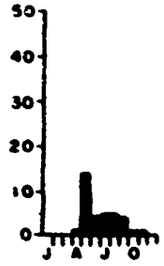


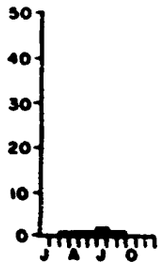
FIG. 1 AVERAGE ANNUAL NUMBER OF HAILDAYS

AREA NO.1 (FIG.1)

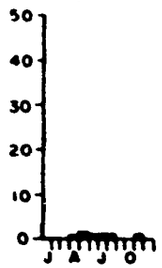
NO.5 JAMAICA. (WEST OF KINGSTON)
17°56'N 76°47'W (3)*
CASES (10 YEARS)



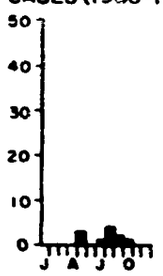
NO.6. MEXICO, TACUBAYA
19°24'N 99°12'W (2306)
MEANS



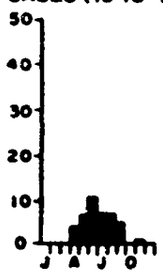
NO.6 MEXICO, TLAXIACO
17°16'N 97°41'W
MEANS



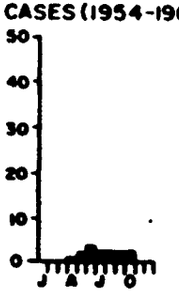
NO.7 COSTA RICA, EL COCO
09°39'N 84°13'W (920)
CASES (1960-1964)



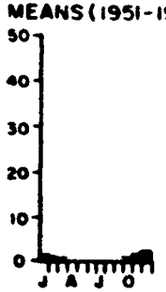
NO.8 HONDURAS, TONCONTIN
14°04'N 87°13'W (990)
CASES (1946-1963)



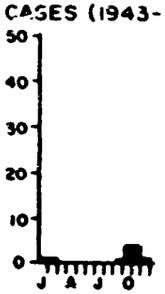
NO.8 HONDURAS, AMPALA
13°17'N 87°39'W (5)
CASES (1954-1960)



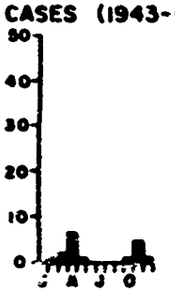
NO.10 ARGENTINE, LA GUIACA
22°06'S 65°36'W (3459)
MEANS (1951-1960)



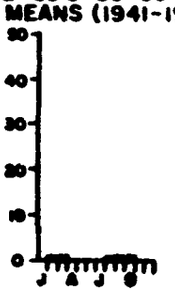
NO.11 BRAZIL, FORMOSA
15° 32'S 47°18'W (906)
CASES (1943-1960)



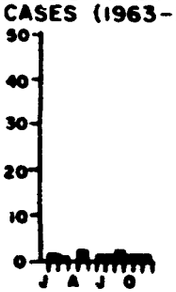
NO.11 BRAZIL, S. ANT. DE JESUS
12°58'S 39°16'W
CASES (1943-1960)



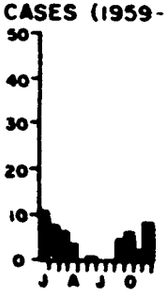
NO.12 PARAGUAY, PEDRO JUAN CABALLERO
22°35'S 55°39'W (614)
MEANS (1941-1960)



NO.13 ECUADOR, QUITO
00°08'S 78°29'W (2812)
CASES (1963-1964)



NO.14 PERU, CHUQUIBAMBILLA
14°47'S 70°43'W (3910)
CASES (1959-1963)

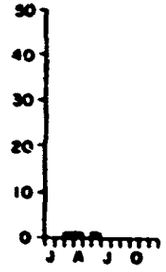


* = STATION ELEVATION IN METERS

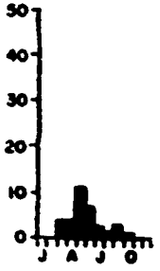
FIGURE 2.

AREA NO. II (FIG. 1)

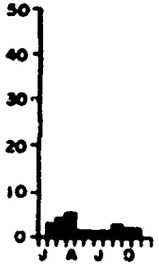
NO. 8 GHANA, HO
06°40'N 00°30'E (158)*
CASES (1949-1963)



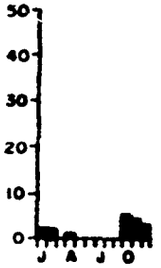
NO. 11 NIGERIA, JOS
09°52'N 08°54'E (1295)
CASES (1954-1963)



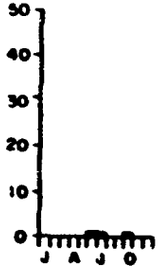
NO. 12 CAMEROUN, MEIGANGA
06°32'N 14°22'E (1027)
CASES (1951-1960)



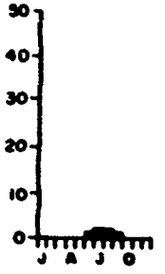
NO. 14 ANGOLA, SA DA BANDEIRA
14°56'S 13°34'E (1760)
MEANS (1931-1960)



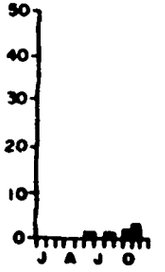
NO. 15 TCHAD, FT. ARCHAMBAULT
09°08'N 18°23'E (364)
CASES (1945-1962)



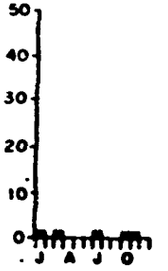
NO. 20 ETHIOPIA, ADDIS ABABA
09°00'N 38°44'E (2360)
MEANS (1957-1959)



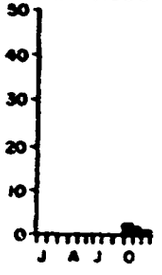
NO. 26 MOZAMBIQUE, MABOTE
22° 03'S 34°07'E (143)
CASES (1957-1963)



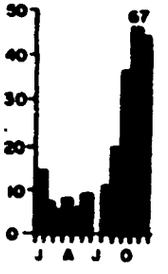
NO. 26 MOZAMBIQUE, MOCUBA
16°50'S 36°59'E (134)
CASES (1951-1960)



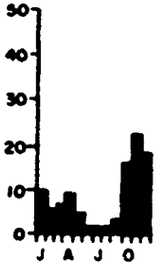
NO. 26 MOZAMBIQUE, FURACUNGO
14°54'S 33°36'E (1259)
CASES (1956-1959)



NO. 27 RHODESIA, (WHOLE)
MEANS (1957-1964)



NO. 29 MADAGASCAR, (WHOLE IS.)
MEANS (10 YEARS PERCENTAGED)



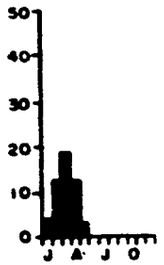
* = STATION ELEVATION IN METERS

FIGURE 3.

AREA III (FIG.1)

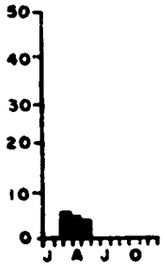
NO.2 INDIA, MADHYA PRADESH

CASES (1954-1958)



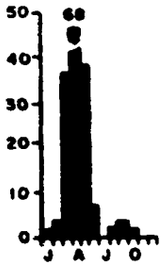
NO.2 INDIA, DECCAN

CASES (1954-1958)



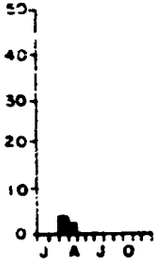
NO.2 EAST PAKISTAN

CASES (1951-1960)



NO.3 BURMA, YAMETHIN

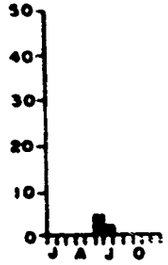
CASES (5 YEARS)



NO. 3 BURMA, LASHIO

22°58'N 97°51'E

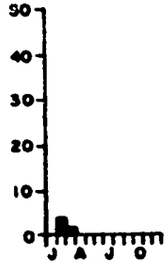
CASES (5 YEARS)



NO.3 BURMA, BHAMO

24°16'N 97°17'E

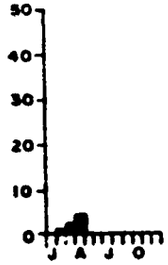
CASES (5 YEARS)



NO.5 THAILAND, CHIANGMAI

18°47'N 98°59'E

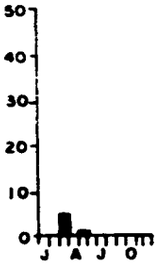
CASES (1951-1963)



NO.5 THAILAND, SAKON NAKHON

17°10'N 104°09'E

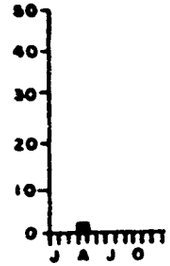
CASES (1944-1963)



NO. 5 THAILAND, BAGKOK

13°44'N 100°30'E

CASES (1944-1957)



NO. 10 NEW GUINEA, MT. HAGEN

05°51'S 144°09'E

CASES (7 YEARS)

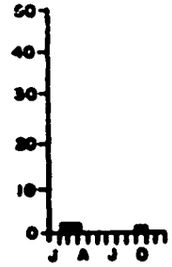


FIGURE 4.

A study of these composites made it possible to recognize three main hail regimes within the tropical band (Fig. 5). The areas within which the respective hail regimes operate are henceforth referred to as "zones" in order to differentiate them from the four "areas" of the earlier report.

Zone 1: Latitudes 10° to 23½° north of the equator, including areas of the Caribbean, Mexico, Central America, Africa, India, Asia, Hawaii, and the Philippines.

Zone 2: Latitudes 10° north to 10° south of the equator, comprising equatorial sections of South America, Africa, and Indonesia.

Zone 3: Latitudes 10° to 23½° south of the equator, including sections of South America, Africa, Madagascar, Northern Australia, and Polynesia (Fig. 4).

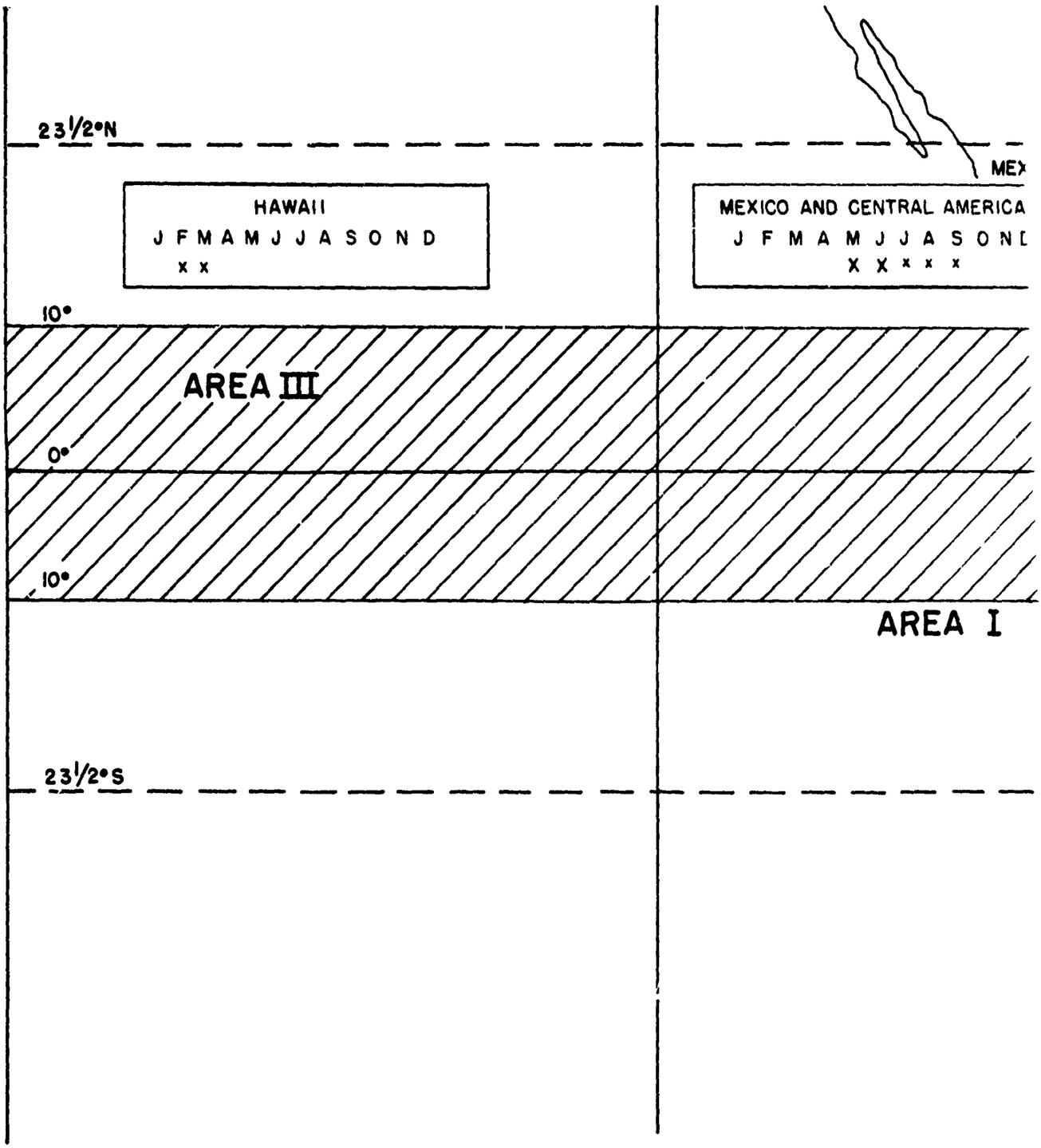
In Zones 1 and 3, hail is a feature principally of the spring months and in most instances of the relatively dry season preceding summer rains. In the Northern Hemisphere (Zone 1), the months involved are usually February to May. In the Southern Hemisphere (Zone 3), they are September to December. In Zone 2, however, the equatorial zone between Zones 1 and 3, hail appears to have at least two seasons and in some cases to occur intermittently throughout the year, e.g., Ecuador and Peru, Nigeria Cameroun, and Western Kenya. These are general statements, subject to considerable modification from place to place and year to year. Moreover, the boundaries between the zones must be regarded as transitional areas rather than narrow lines.

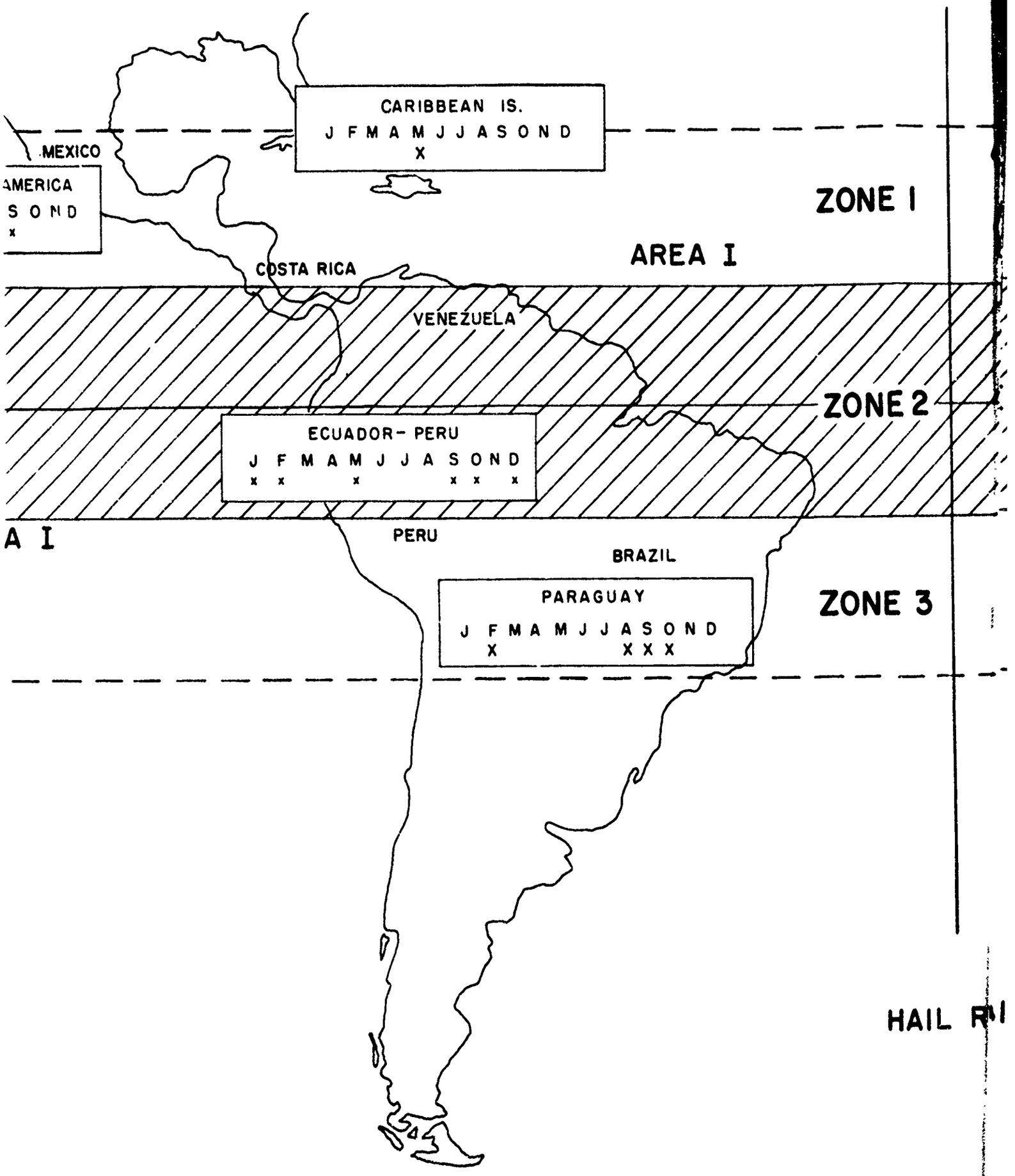
CONCLUSIONS

Conclusions that may be drawn from two corollaries to the first report on "Hail incidence in the tropics" are as follows:

1. Hailstorm incidence increases with altitude in tropical as in temperate latitudes.

2. Tropical and equatorial hail regimes correspond latitudinally though not necessarily seasonally, with the rainfall regimes of the same areas; e.g., in the tropics per se, the hail season precedes the season of most rain.


23 1/2°N
HAWAII
J F M A M J J A S O N D
x x
MEX
MEXICO AND CENTRAL AMERICA
J F M A M J J A S O N D
X X x x x
10°
AREA III
0°
10°
AREA I
23 1/2°S


CARIBBEAN IS.
J F M A M J J A S O N D
X
MEXICO
AMERICA
S O N D
X
ZONE 1
AREA I
COSTA RICA
VENEZUELA
ZONE 2
ECUADOR- PERU
J F M A M J J A S O N D
X X X X X X
A I
PERU
BRAZIL
PARAGUAY
J F M A M J J A S O N D
X X X X
ZONE 3
HAIL R

AREA II

WEST AFRICA
J F M A M J J A S O N D
x x x

TCHAD

SUDAN

SAUDI ARABIA

ETHIOPIA

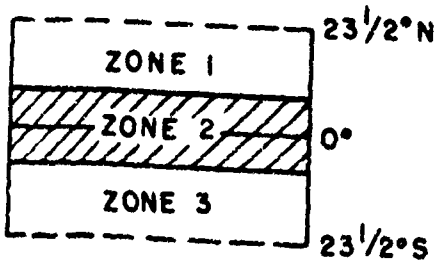
WEST KENYA
J F M A M J J A S O N D
x x X x

CONGO

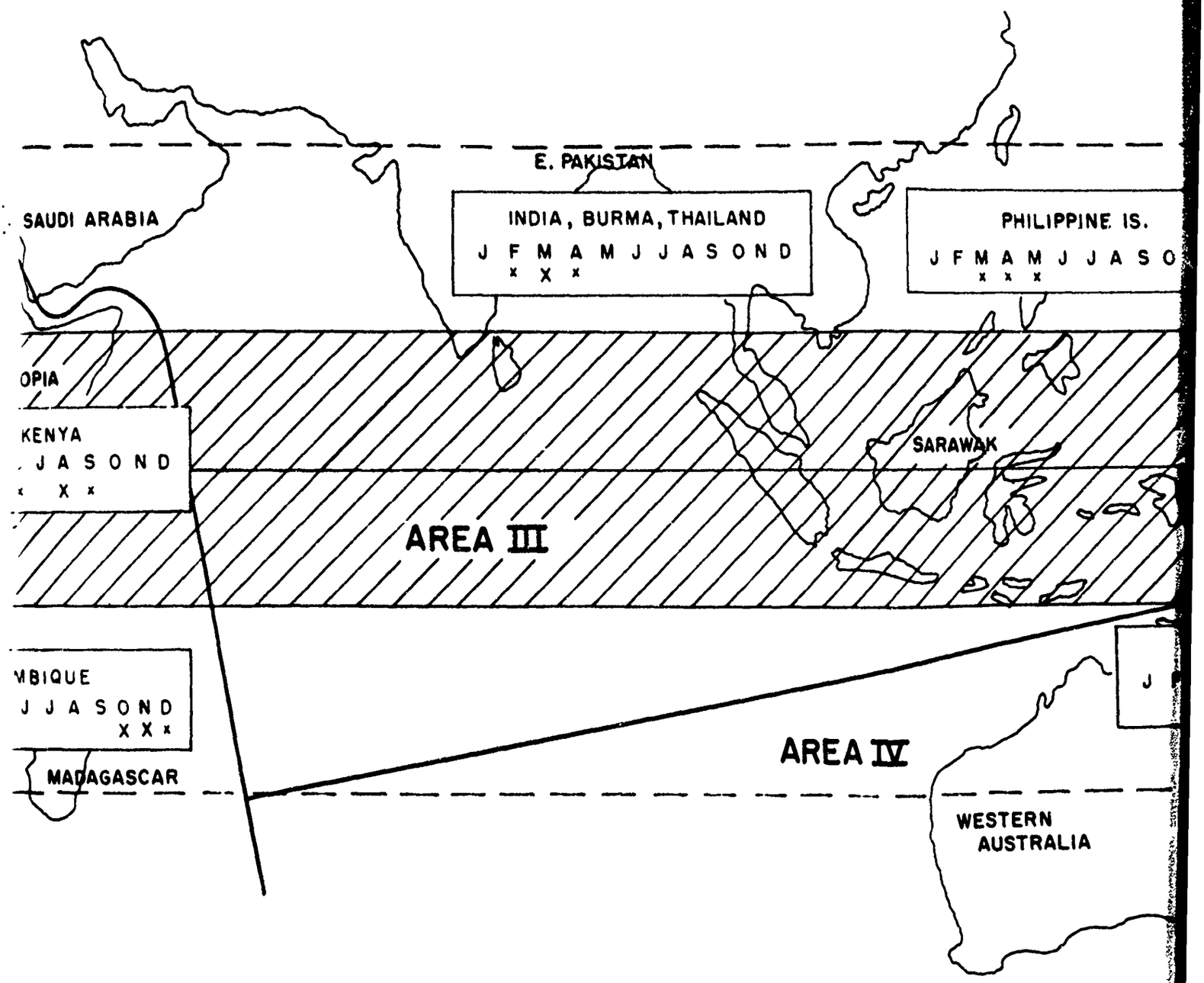
ANGOLA - RHODESIA
J F M A M J J A S O N D
X X

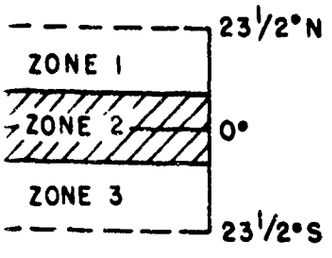
MOZAMBIQUE
J F M A M J J A S O N D
X X x

MADAGASCAR



L REGIMES


E. PAKISTAN
SAUDI ARABIA
INDIA, BURMA, THAILAND
J F M A M J J A S O N D
x X x
PHILIPPINE IS.
J F M A M J J A S O
x x x
OPIA
KENYA
J A S O N D
x X x
SARAWAK
AREA III
MBIQUE
J J A S O N D
X X x
MADAGASCAR
J
AREA IV
WESTERN
AUSTRALIA


23 1/2°N
ZONE 1
ZONE 2
0°
ZONE 3
23 1/2°S

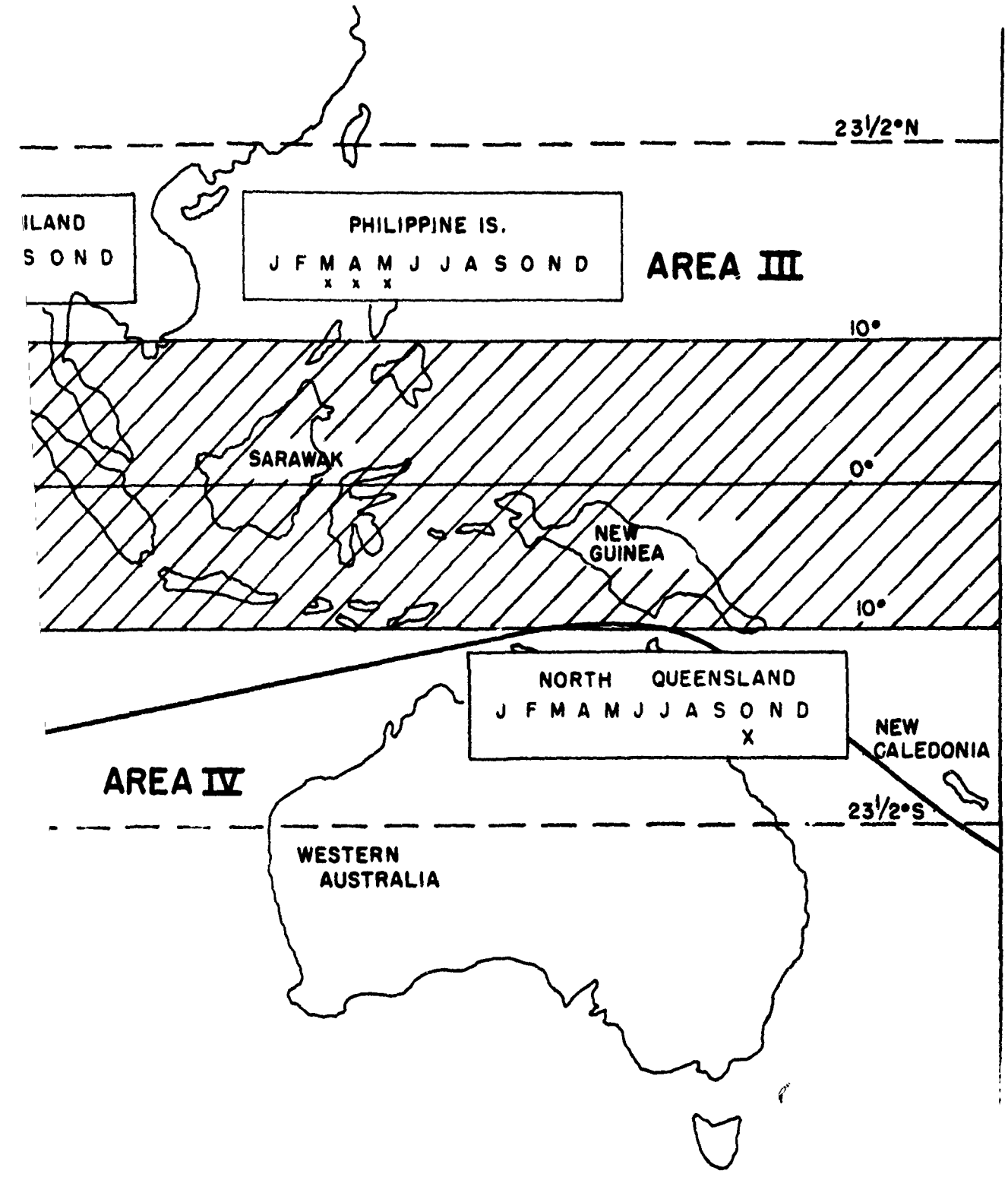

23½°N
ILAND
S O N D
PHILIPPINE IS.
J F M A M J J A S O N D
x x x
AREA III
10°
SARAWAK
0°
NEW
GUINEA
10°
NORTH QUEENSLAND
J F M A M J J A S O N D
X
NEW
CALEDONIA
AREA IV
23½°S
WESTERN
AUSTRALIA

FIGURE 5.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY *(Corporate author)*

U. S. Army Electronics Command
Fort Monmouth, New Jersey

2a REPORT SECURITY CLASSIFICATION

UNCLASSIFIED

2b GROUP

3 REPORT TITLE

Hail Incidence in the Tropics

4 DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Technical Report

5 AUTHOR(S) *(Last name, first name, initial)*

Frisby, E. M.

6. REPORT DATE	7a TOTAL NO OF PAGES	7b NO OF REFS
October 1966	7	0

8a. CONTRACT OR GRANT NO.	9a ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO. 1V0-14501-B-53A	ECOM-2768
c. Task No. -09	9b OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d	

10. AVAILABILITY/LIMITATION NOTICES

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

11. SUPPLEMENTARY NOTES	12 SPONSORING MILITARY ACTIVITY
	U. S. Army Electronics Command (AMSEL-BL-AP) Fort Monmouth, New Jersey 07703

13. ABSTRACT

Two studies have been made utilizing the data included in the four appendices to the original report with the same title. (~~Technical Report ECOM-02105-F~~, "Hail Incidence in the Tropics," dated September 1966, prepared by Raven Industries, Inc., for the Atmospheric Sciences Laboratory, under Contract DA28-043 AMC-02105(E)). The first study relates hailstorm frequency and station altitude; the second discusses hail regimes within the tropics.

DD FORM 1 JAN 64 1473

UNCLASSIFIED

Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Hailstorm frequency **Hail regimes**						

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