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SINAI CLOUD SEEDING POTENTIAL

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SINAI DEVELOPMENT STUDY - PHASE I

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EXECUTIVE SUMMARY

Sinai's climatic regimes -- precipitation, temperature, wind speed, and air mass circulation systems -- and natural geography provide generally favorable conditions for cloud seeding. However, the success of cloud seeding is dependent on the physics of the local cloud development systems,and because of the numerous potentially harmful side effects of cloud seeding (i.e., flooding, hail, and misplaced rainfall), a detailed analysis of Sinai's climatic and meteorological parameters must precede any recommendations.

Due to the scarcity of climatic data for Sinai, only the most general overview is possible at this time. The installation of a regional climatologic monitoring network will be the first step in ensuring a consistent pattern of data collection.

Recommendations are provided herein for the operational phases of any cloud seeding investigation and for the development of an appropriate climatologic station network.

1.0 INTRODUCTION

1.1 GENERAL CLIMATIC SETTING

The technology of cloud seeding is one of the largest applied fields of weather modification. Atmospheric resources, such as rain, are important to all sectoral development, especially agriculture. When natural precipitation is insufficient, rain can sometimes be stimulated by cloud seeding processes. This paper offers a preliminary analysis of the potential for cloud seeding in northern Sinai.

The northern Mediterranean coastal plain of Sinai includes large areas suitable for agriculture, but with insufficient rainfall. The majority of all precipitation in Sinai falls in this region, but its distribution over the area is not homogenous and shows a rapid increase toward the northeast corner. Cloud systems over the region generally include those types favorable for seeding. Hence, the application of seeding technology to these cloud systems may stimulate precipitation to help meet the water requirements for development.

Cloud seeding provides a means of modifying the precipitation process in some types of clouds. Conflicting reports on the effects of cloud seeding are due to site-specific variations in cloud-droplet spectra and ice crystal properties and concentrations.

1.2 HISTORICAL CLOUD SEEDING SUCCESS/FAILURE IN SIMILAR SETTINGS

There is some evidence that seeding certain subtropical convective cumulus clouds in winter can stimulate precipitation. Two experiments conducted by Israel on cloud systems similar to those in northern Sinai, from 1960 to 1967 and from 1969 to 1975, produced encouraging results. The first experiment yielded an overall result indicative of a 15 percent increase in rainfall. Results of the second experiment were sufficiently encouraging to conclude the experimental phase of seeding operations and to initiate an operational cloud seeding project in the study area.

Experiments in other areas have been undertaken to test the possibility of seeding warm clouds to increase precipitation. The analysis of two experiments conducted in India were inconclusive.

2.0 CLIMATIC FACTORS

The first meteorological observations in Sinai were made at El Arish in the early 1900's. In successive decades, the meteorological network was gradually increased but also was subject to major operational interruptions. Because of inconsistent monitoring, the climatological data sequences are of marginal utility. Table 2-1 shows the coordinates of the meteorological network stations, and Figure 2-1 shows the geographical sites.

Sinai can be divided into six climatic regions (Figure 2-2). The northern region, extending from the Mediterranean Sea inland to latitude 30^{0} 30' north, receives the maximum annual precipitation in Sinai and shows maximum cloudiness. Figure 2-3 shows the distribution of annual precipitation. Figure 2-4 depicts the mean monthly number of days with different sky cover at El Arish in the four seasons of the year (for 1966). Data from El Arish on total sky cover and number of days with rain are shown in Table 2-2. These data illustrate the potential of this region as a source for meeting the water requirements necessary for development.

The existing meteorological station network is sparse throughout Sinai. Existing meteorological data provide a general idea about the climatic regimes, but are insufficient to support the requirements of tourism, industrial, energy,and agricultural development projects.

2.1 METEOROLOGICAL DATA PROFILES

Sinai includes six climatic districts. By plotting the available climatic data for Sinai, a general profile of the climatic regimes can be obtained. Air temperature, surface wind, precipitation, and cloudiness are the most important meteorological parameters used to determine cloud seeding potential.

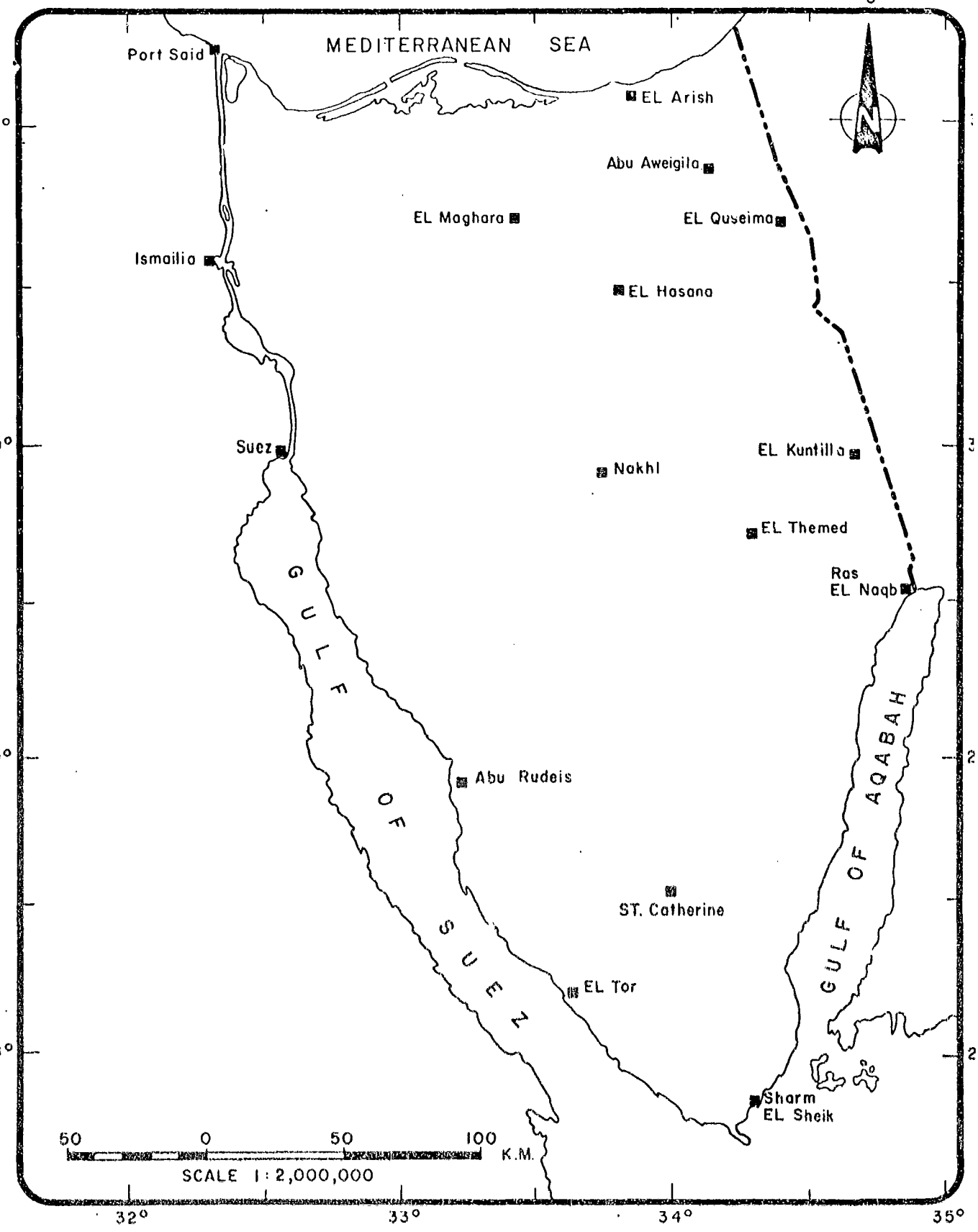
2.1.1 Annual Mean Daily Temperature Profiles

Figure 2-5 shows annual profiles of the available monthly values of mean daily temperature at selected stations in Sinai. These profiles reveal the following characteristics:

TABLE 2-1

Meteorological Station Coordinates In and Adjacent to Sinai for Which Data are Available

Climatic Region	Station	Years of Record	N. Latitude (Deg)	N. Latitude (Min)	E. Longitude (Deg)	E. Longitude (Min)	Elevation (Meters)
Northern	El Arish	1907 - 1914 1919 - 1934 1936 - 1967	31	07	33	46	15
	Rafah	1953 - 1956	31	16	34	14	67
	El Maghara	1966	30	35	33	20	323.5
	El Quseima	1938 - 1947 1953 - 1967	30	40	34	22	330
	Abu Aweigila	1940 - 1948	30	50	34	07	140
Plateau	El Hassana	1938 - 1947 1953 - 1961 1964 - 1967	30	28	33	48	250
	El Kuntilla	1933 - 1938 1944 - 1947 1953 - 1956 1958 - 1966	30	00	34	41	540
	Nakhl	1907 - 1914 1919 - 1921 1940 - 1947 1953 - 1954 1956 - 1967	33	44	29	85	406
	El Themed	1921 - 1947 1953 - 1966	29	40	34	22	616
	Ras El Naqb	1941 - 1947 1953 - 1967	29	36	34	52	760
Mountains	St Catherines	1934 - 1937	28	32	33	55	2,620
E. Canal	Port Said	1887 - 1934 1941 - 1975	31	16	32	17	1
	Ismailia	1886 - 1954 1964 - 1968	30	35	32	14	12.5
	Suez	1887 - 1934 1964 - 1973	29	52	32	28	2.5
Gulf of Suez	Abu Rudeis	1961 - 1967	28	53	33	11	18.9
	El Tor	1919 - 1967	28	14	33	37	2.7
Gulf of Aqaba	Sharm El Sheikh	1955	27	51	34	17	3.5



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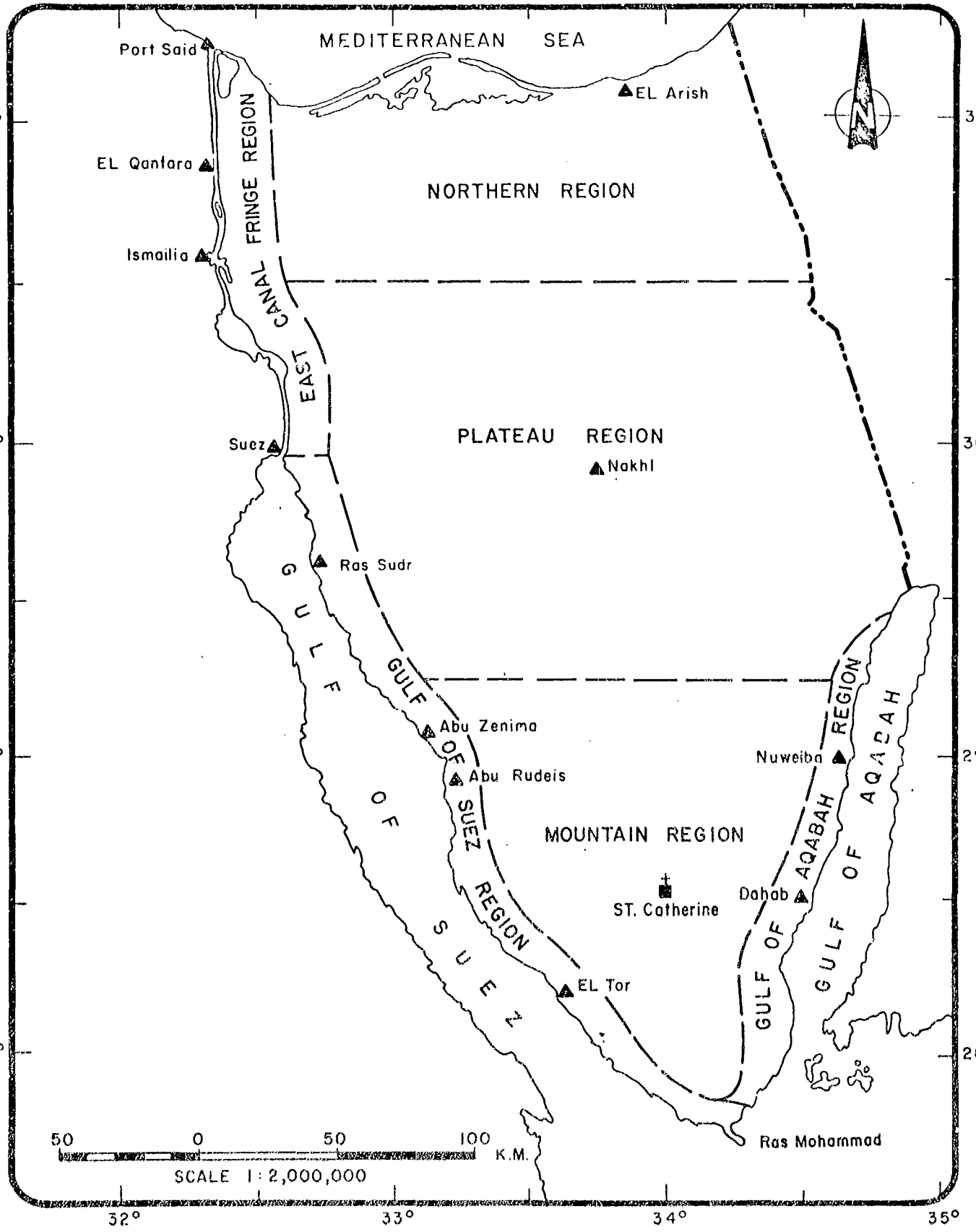
GEOGRAPHIC DISTRIBUTION OF METEOROLOGY STATIONS WITH AVAILABLE DATA

FIGURE 2-1



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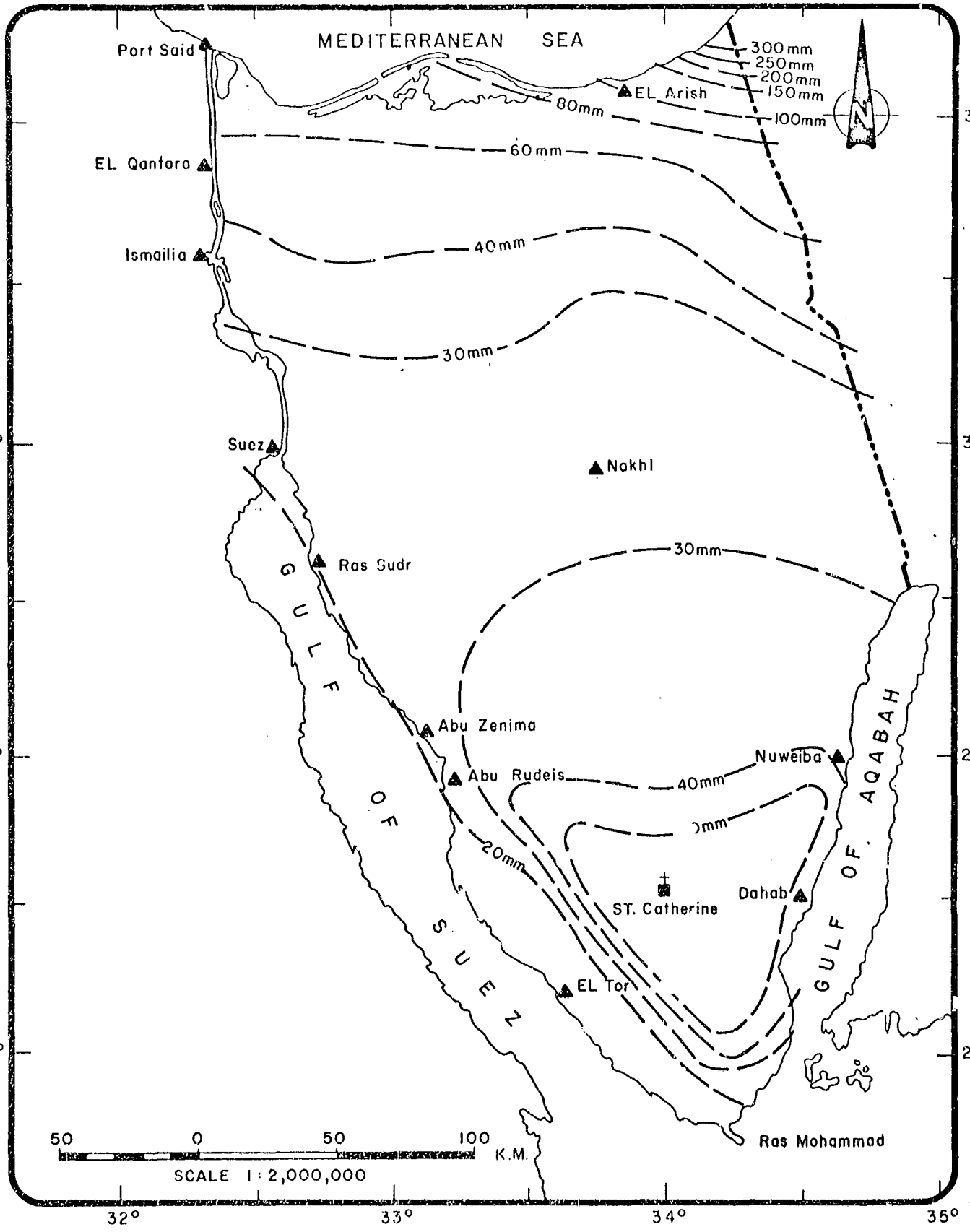
CLIMATIC REGIONS OF SINAI

FIGURE 2-2



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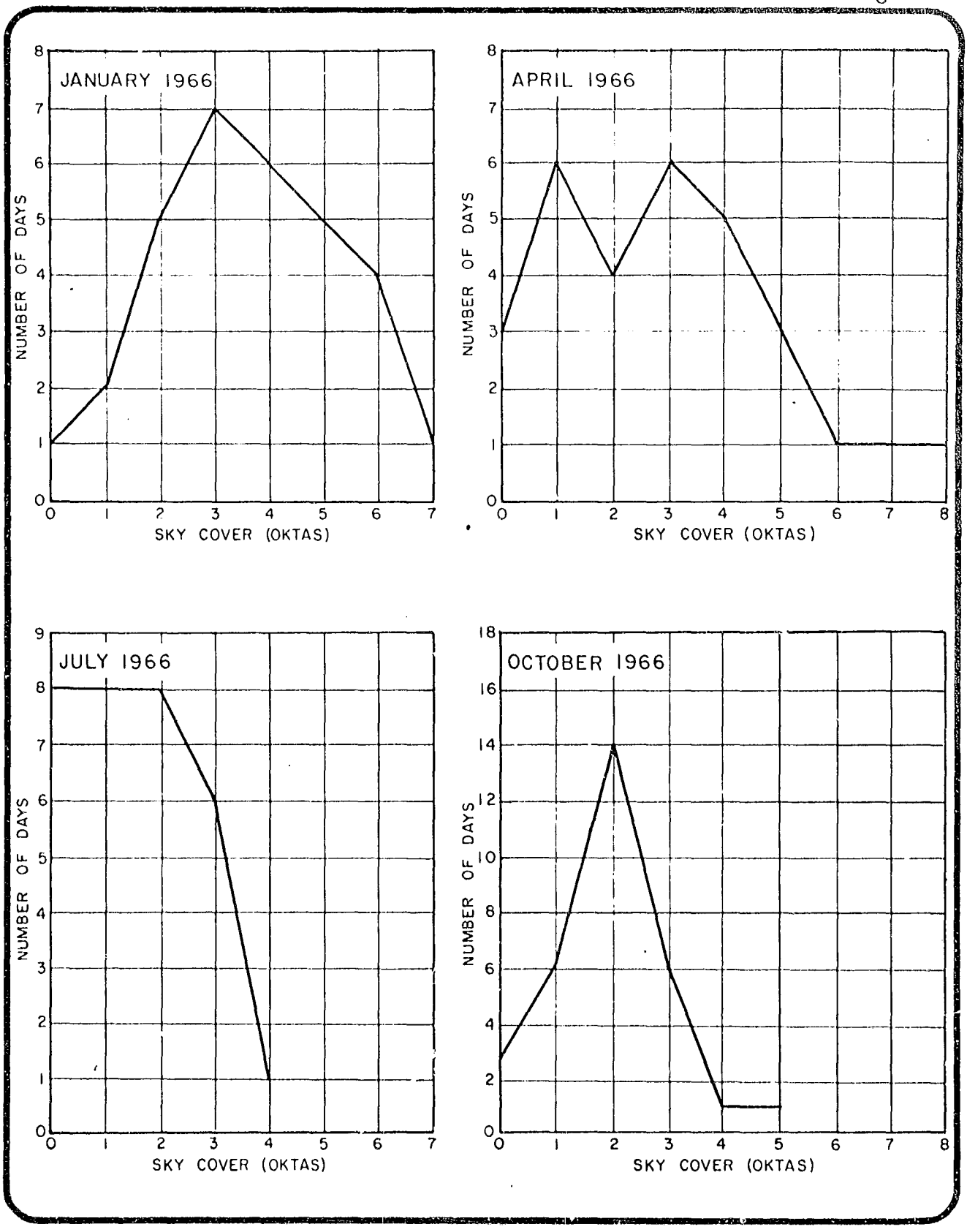
ISOHYETS OF PRECIPITATION IN SINAI

FIGURE 2-3



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MEAN MONTHLY NUMBER OF DAYS
WITH SKY COVER AT EL ARISH

FIGURE 2-4

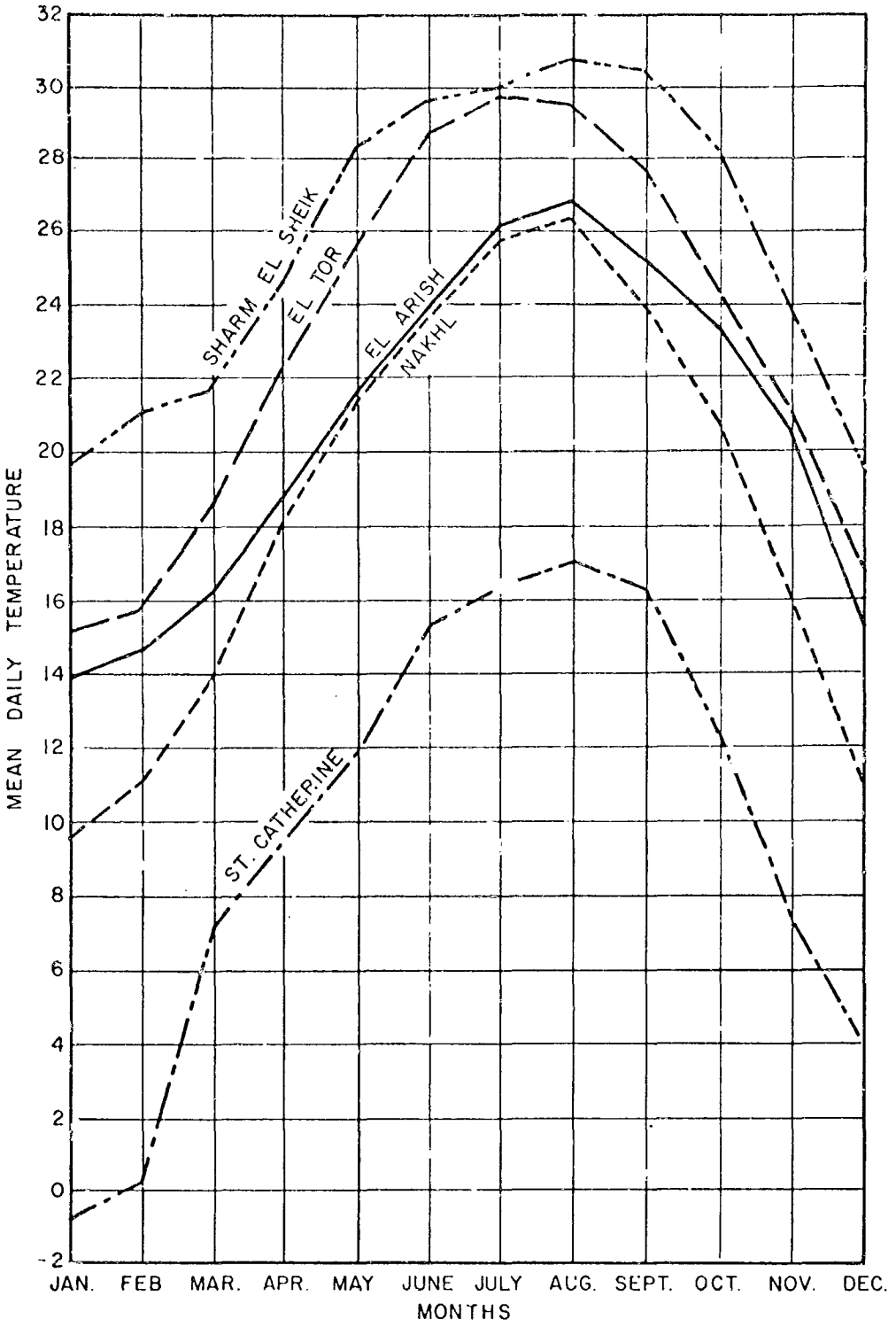
TABLE 2-2

Total Sky Cover at Fixed Hours, Frequency of Days with Specified Ranges of Sky Cover, and Rainfall Data for El Arish

Month	Total Sky Cover (oktas)[a]							Number of Days with Rain[b]			Rainfall (mm)
	0000	0600	1200	1800	Number of Days with Sky Cover			0.1 (mm)	1.0 (mm)	100 (mm)	
					2/8	3/8-5/8	6/8				
January	3.1	3.5	3.8	3.2	7.7	19.2	4.1	4.6	3.4	1.1	20.3
February	3.3	4.2	3.8	3.4	6.4	19.2	3.1	4.5	3.1	1.3	17.1
March	3.3	3.6	3.4	3.2	7.9	20.0	3.1	4.3	3.0	0.1	12.8
April	3.3	3.7	3.2	3.1	6.7	21.2	2.1	1.1	0.7	0.2	6.1
May	2.4	3.7	2.0	2.2	14.5	16.0	0.5	0.7	0.6	0.1	3.2
June	1.7	2.5	0.5	1.2	20.5	9.3	0.2	0.0	0.0	0.0	
July	2.1	2.7	0.4	1.5	20.2	10.8	0.0	0.0	0.0	0.0	0.0
August	2.5	3.3	0.5	1.3	16.7	14.1	0.2	0.1	0.1	0.0	0.2
September	2.8	3.5	1.3	2.0	12.2	18.6	0.2	0.1	0.1	0.1	0.6
October	2.8	4.3	2.3	2.4	9.	21.6	1.3	1.0	0.6	0.1	6.0
November	2.8	4.3	3.0	2.7	10.7	16.8	2.5	3.7	2.6	0.1	16.2
December	3.0	4.8	3.4	3.0	10.0	17.2	3.8	4.7	3.4	0.7	22.2
TOTAL	2.8	3.7	2.3	2.4	11.9	17.0	1.8	24.8	17.6	3.8	104.7

[a]1964 to 1975.

[b]1959 to 1967.



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MEAN TEMPERATURE PROFILE
AT SELECTED STATIONS IN SINAI

FIGURE 2-5

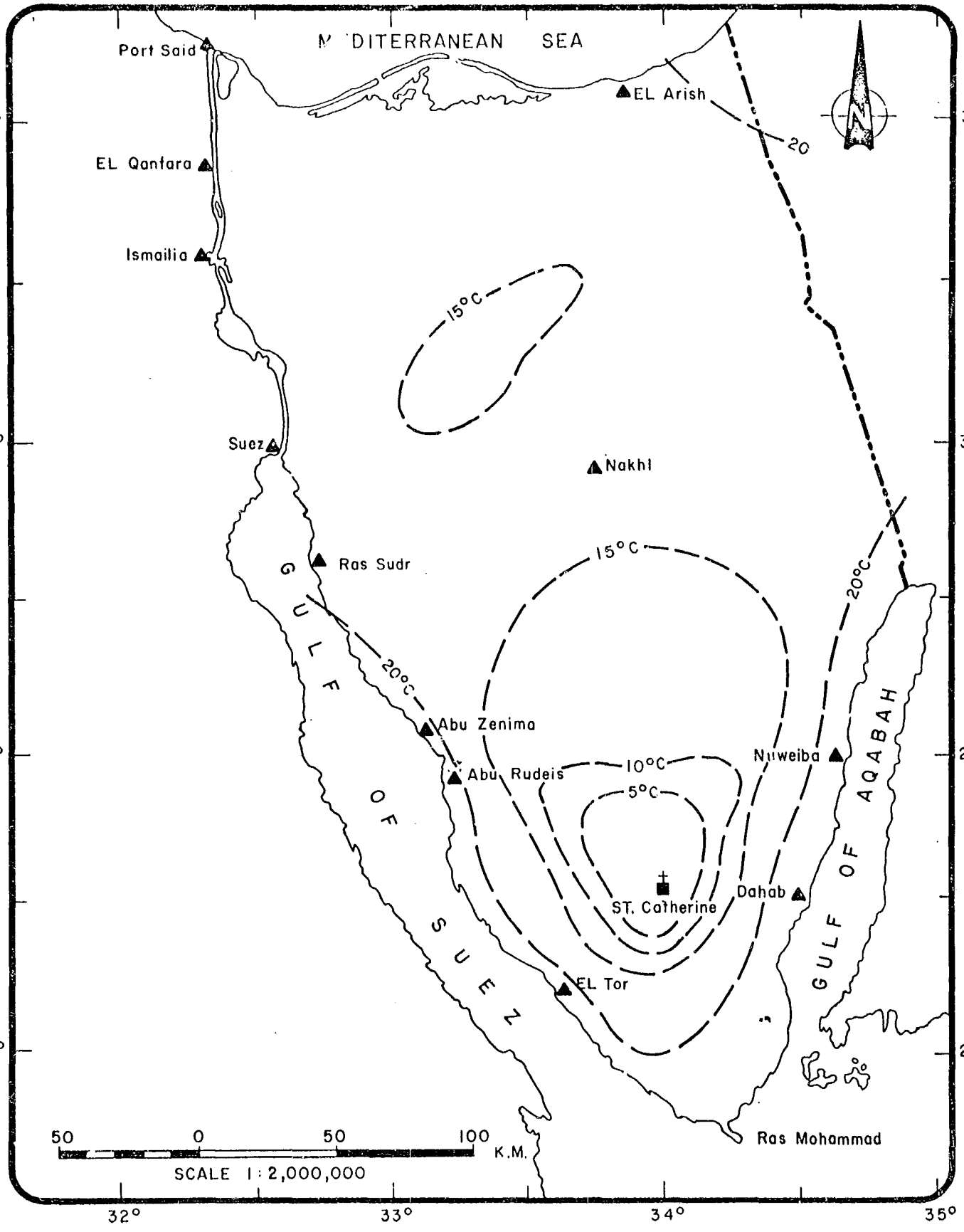
- Maximum temperatures in the summer months of June, July, and August; lowest temperatures in the winter months of November, December, January, and February.
- A gradual decrease in temperature southward from El Arish on the Mediterranean coast to Nakhl in the interior and on to the southern mountainous region at St Catherine's; also a marked increase in temperature along both the Gulf of Suez and the Gulf of Aqabah.

Figures 2-6 and 2-7 show the distribution of the monthly values of maximum temperatures over Sinai in January and July, respectively. These figures illustrate the regional temperature isotherms that form a closed deep center of cooling over the mountainous region and another shallow center of cooling over the interior plateau, together with latitudinal increases in both the Gulf of Suez and the Gulf of Aqabah southward.

2.1.2 Monthly and Seasonal Surface Wind Roses

There is even less surface wind data for Sinai than temperature and precipitation data. Based on data from 1959 to 1966, it has been possible to draw wind roses for El Arish. Figures 2-8 through 2-11 show the monthly wind roses for the winter, spring, summer and autumn months and summary seasonal wind roses. These wind roses depict monthly and seasonal wind features with respect to direction and velocity:

- Prevalence of winds blowing from the south in winter.
- Prevalence of winds blowing from the north in summer.
- Equal frequencies of prevalence of winds from the south and north in the transitional spring and autumn season.
- Winds in summer and transitional seasons do not normally exceed 27 knots in velocity, with the majority falling within the range of 1 to 10 knots.
- In the winter season, particularly in February, surface wind velocity exceeds 27 knots, with a very small percentage frequency ($<$ 1 percent) of occurrence.
- Calms are more frequent in spring and summer seasons ($\approx$18 percent), while the frequency of light variable winds (velocity $<$ 1 knot) ranges from 3 to 5 percent per season.



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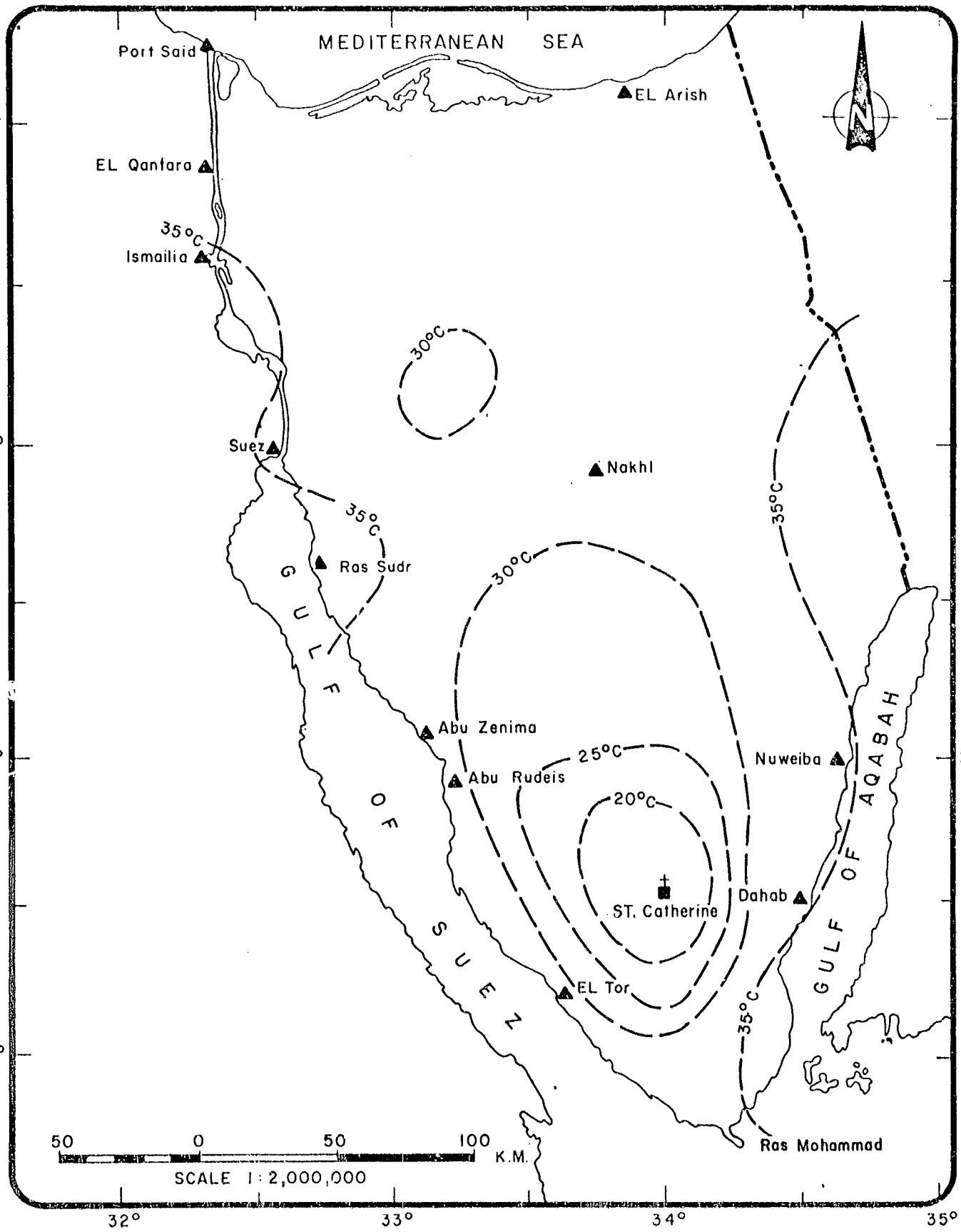
ISOTHERMS OF MEAN MONTHLY VALUES OF MAXIMUM TEMPERATURE OVER SINAI (JANUARY)

FIGURE 2-6



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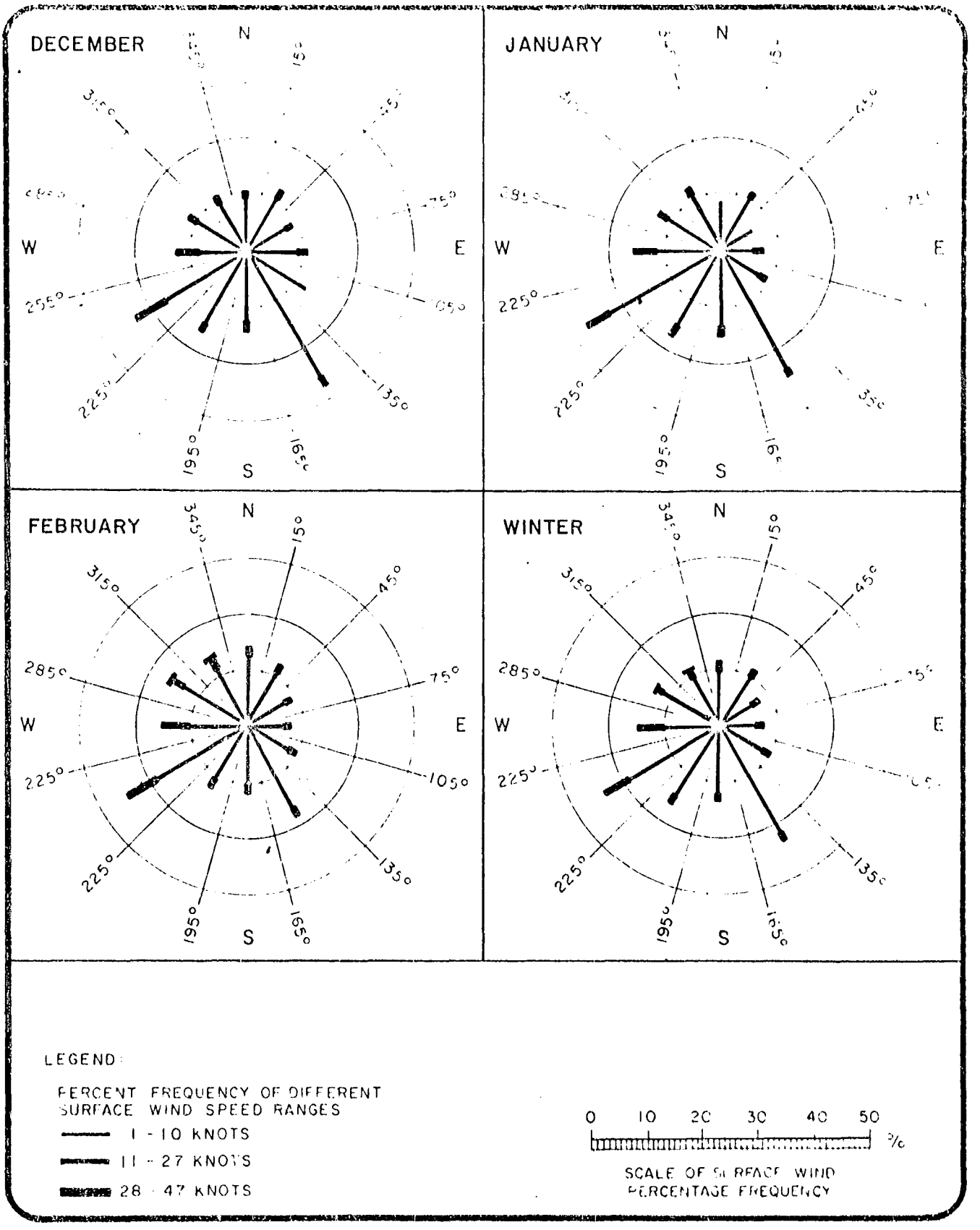
ISOTHERMS OF MEAN MONTHLY VALUES OF MAXIMUM TEMPERATURE OVER SINAI (JULY)

FIGURE 2-7



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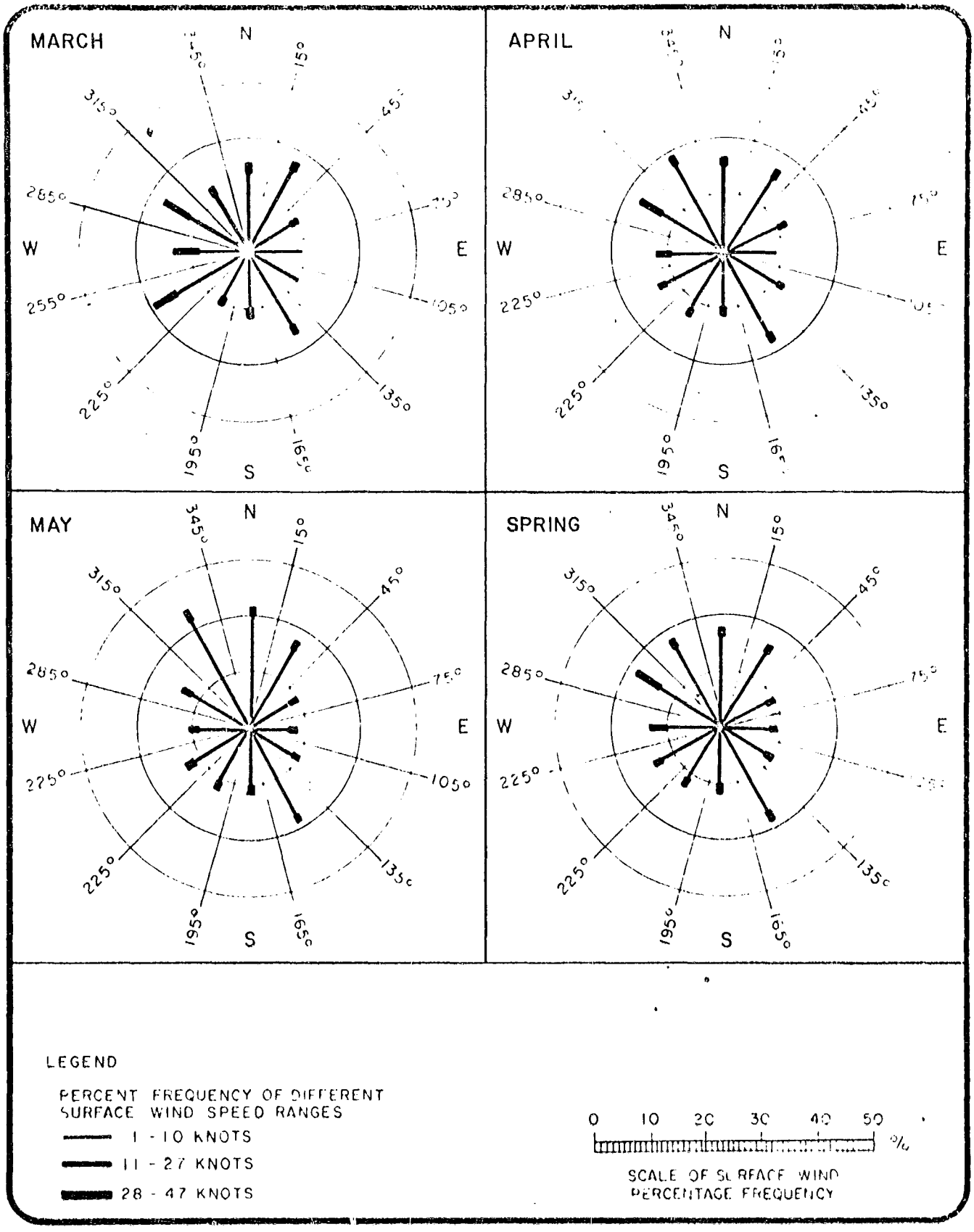
SURFACE WIND ROSES FOR WINTER EL ARISH (1959-1966)

FIGURE 2-8



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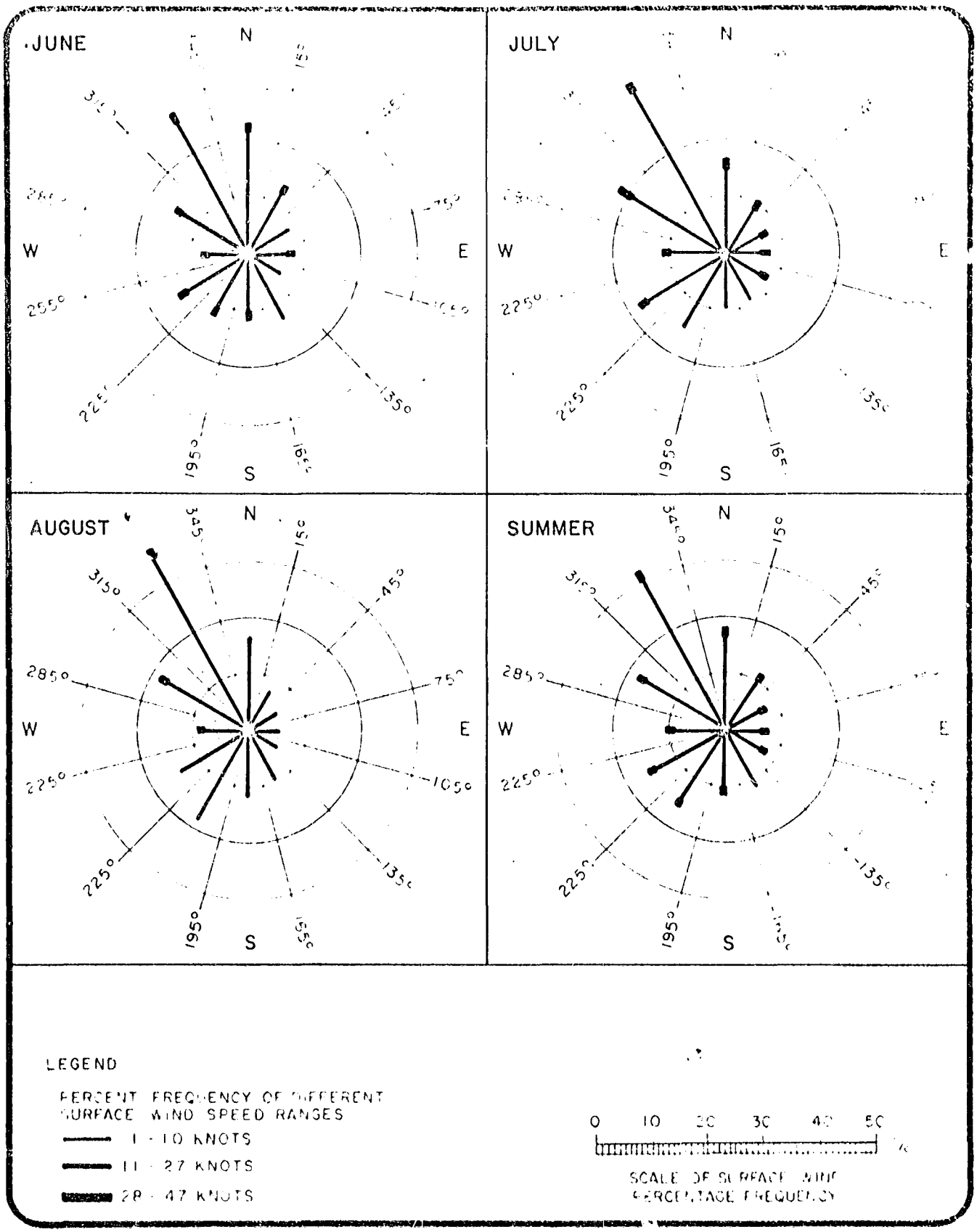
SURFACE WIND ROSES FOR SPRING
EL ARISH (1959 - 1966)

FIGURE 2-9



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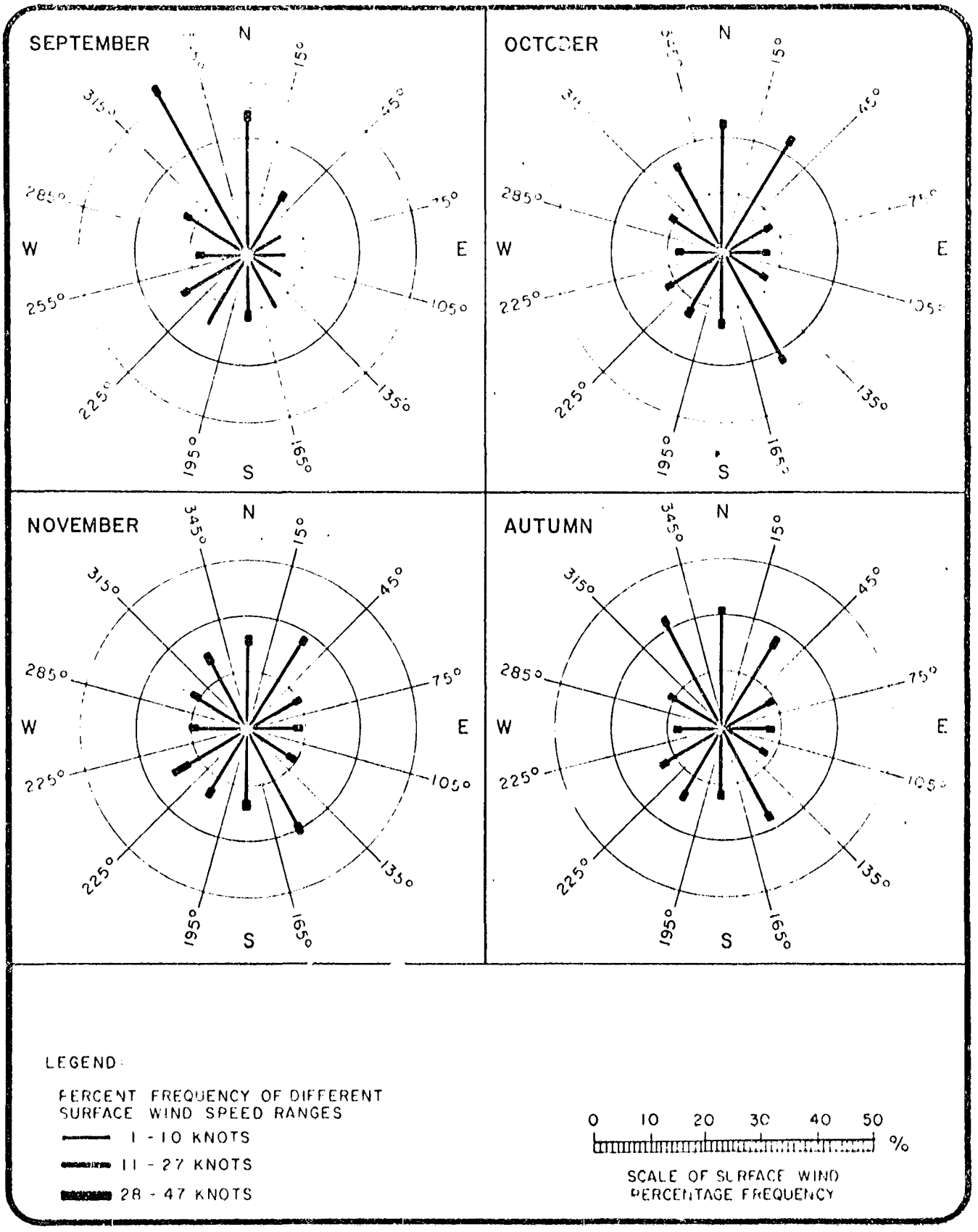
SURFACE WIND ROSES FOR SUMMER
EL ARISH (1959-1966)

FIGURE 2-10



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SURFACE WIND ROSES FOR AUTUMN EL ARISH (1959-1966)

FIGURE 2-11

2.1.3 Total Precipitation - Seasonal and Annual Profiles

Precipitation over Sinai is another important meteorological factor. Available observations of precipitation over Sinai are used in this study to estimate relevant parameters and to plot precipitation profiles. A more detailed profile analysis would require a better meteorological network.

Figure 2-12 shows the total seasonal precipitation in the winter, spring, and autumn at the seven meteorological stations -- Rafah, El Arish, El Maghara, Nakhl, Saint Catherine's, El Tor, and Sharm El Sheikh. The following are general characteristics of precipitation over Sinai:

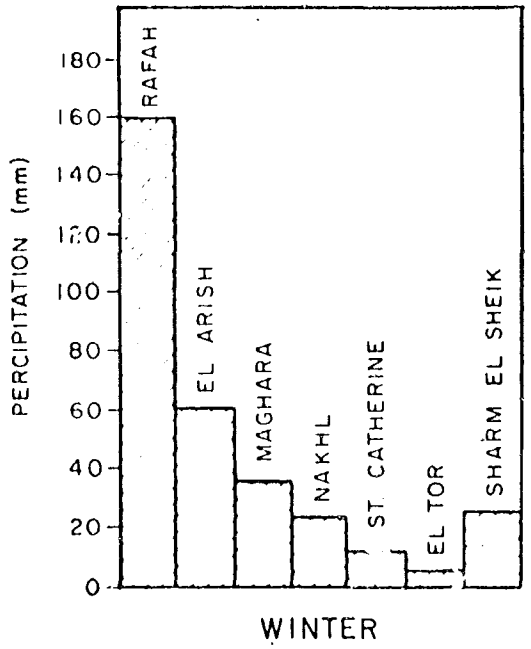
- Total seasonal precipitation is highest over the northern region.
- Total seasonal precipitation decreases gradually southward; the Gulfs of Suez and Aqabah receive only a few millimeters of rain.
- Total seasonal precipitation over the northern district increases gradually northeastward and attains a maximum at Rafah.
- The summer season is completely dry throughout Sinai.

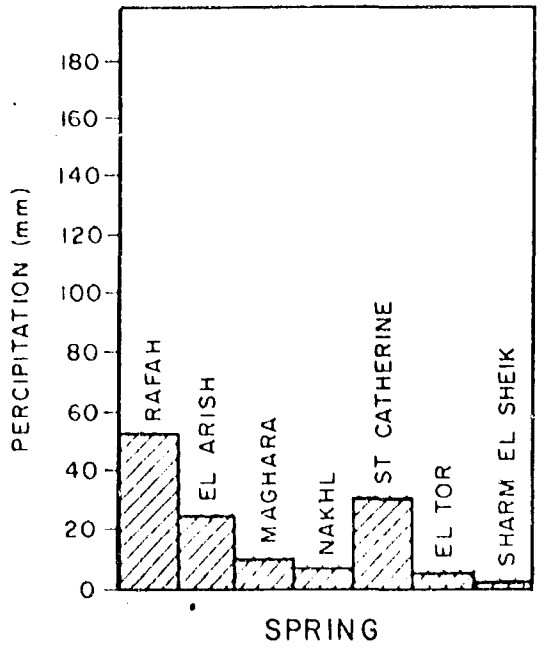
The regional isohyets for Sinai were presented in Figure 2-3. The data on cloudiness are insufficient to provide any insight into cloud patterns, types, or paths. The number of potentially laden clouds that pass over Sinai without precipitating cannot be estimated.

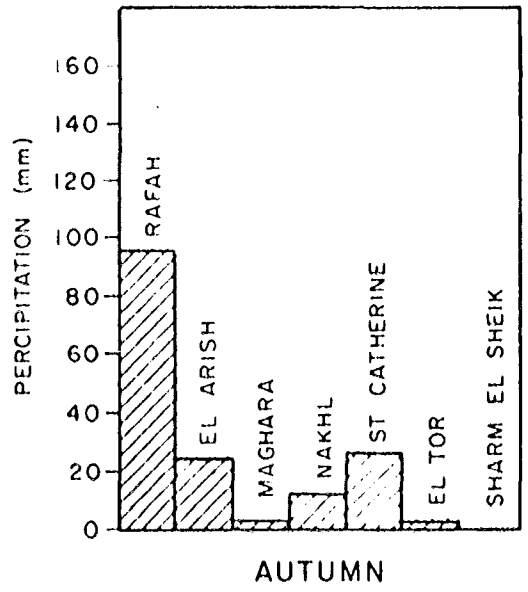
2.1.4 Seasonal Upper Wind Profiles

Upper air data over Sinai are of great importance to all developmental sectors affected by weather. Weather conditions are caused by various physical and dynamic processes, both near the earth's surface and in the atmosphere. Hence, data about meteorological elements in the upper atmosphere complete a three-dimensional picture of the atmospheric distribution system. Information on the source and atmospheric characteristics of the upper air masses is necessary to understand the various processes applicable to cloud seeding.

The upper air meteorological network over Egypt comprises three air stations -- at Mersa Matruh, Helwan, and Aswan. There are no upper air







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SEASONAL PROFILES OF PRECIPITATION IN SINAI

FIGURE 2-12

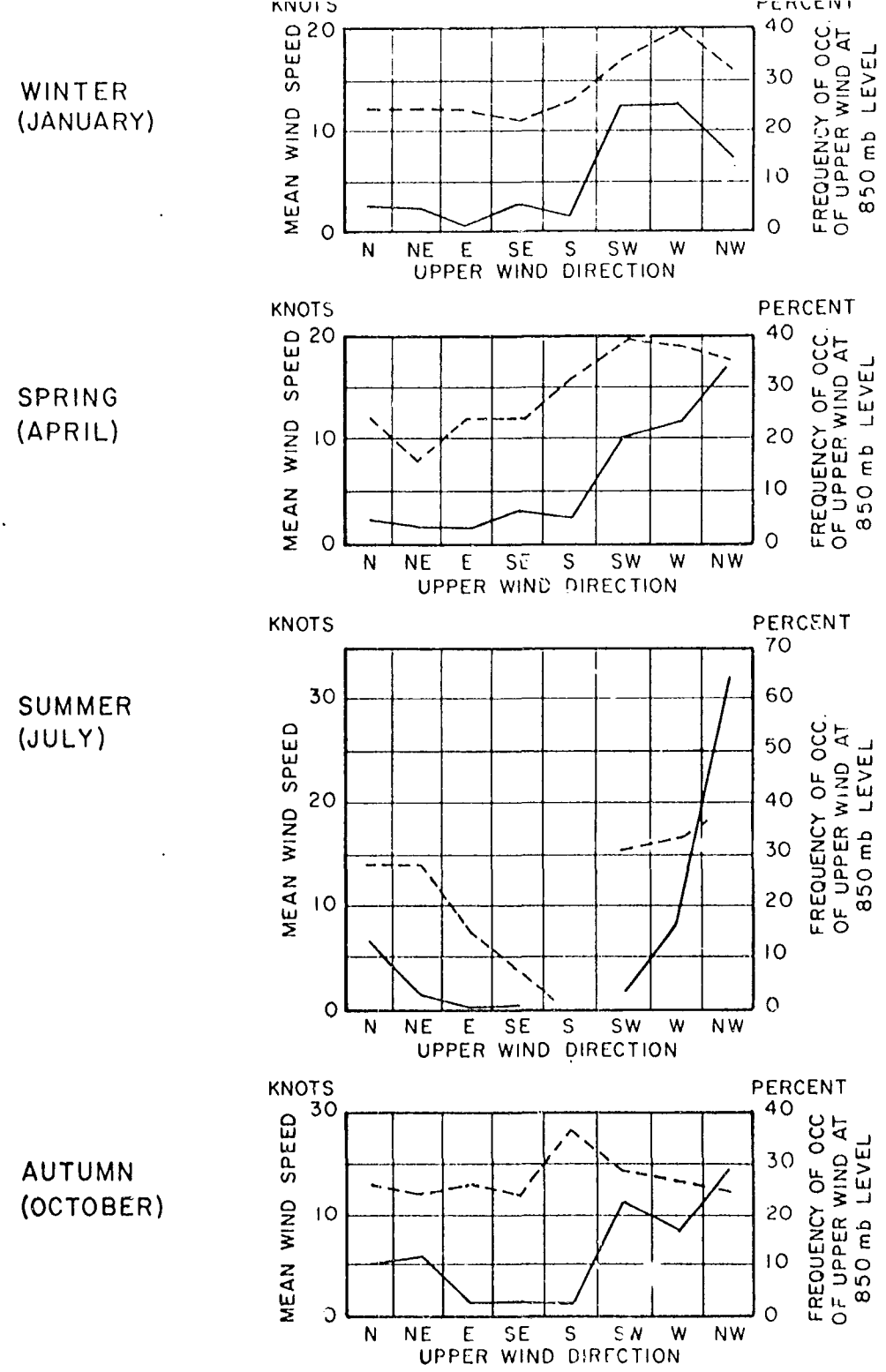
stations in Sinai. The existing network fails to provide detailed upper air data for Sinai. Before much advancement can be made toward investigating cloud seeding opportunities in Sinai, it is imperative that a well developed meteorological network, including upper air stations, be established.

In an attempt to provide some idea of the upper air flow pattern across Sinai, data from the available stations were extrapolated. This extrapolation was based on available upper air observations at Mersa Matruh (1956-1975) and Heïwan (1961-1975) and on extensive experience derived from synoptic analysis and forecasting techniques in Egypt during the last 40 years. Seasonal wind profiles at the 850-, 700-, and 500-millibar (mb) levels were prepared. They can be regarded as a crude estimate and general summary of the persistence and intensity of upper wind regimes over Sinai.

Figures 2-13, 2-14, and 2-15 demonstrate the upper wind profiles (their persistence and velocity) at the 850-, 700- and 500-millibar levels, respectively, for the northern climatic region. Each group of figures includes the four seasonal regimes as summarized in winter, spring, summer, and autumn.

At the 850-millibar level, southwesterly winds are most frequent in summer and less frequent during the transitional seasons. At the 700-millibar level, southwesterly winds are most frequent in the winter and transitional seasons, and northwesterly winds are most frequent in the summer. At the 500-millibar level, southwesterly winds are frequent in all seasons, and northwesterly winds are present during the winter and transitional seasons.

Upper wind velocities at the 850-millibar level usually do not exceed 20 knots. At the 700-millibar level during the summer and autumn seasons, winds are normally below 20 knots. On the other hand, upper winds at the 700-millibar level during winter and spring range from 20 to 35 knots. The prevailing upper winds at the 500-millibar level range from 30 to 45 knots in the winter and spring seasons and do not exceed 25 knots in summer and autumn.



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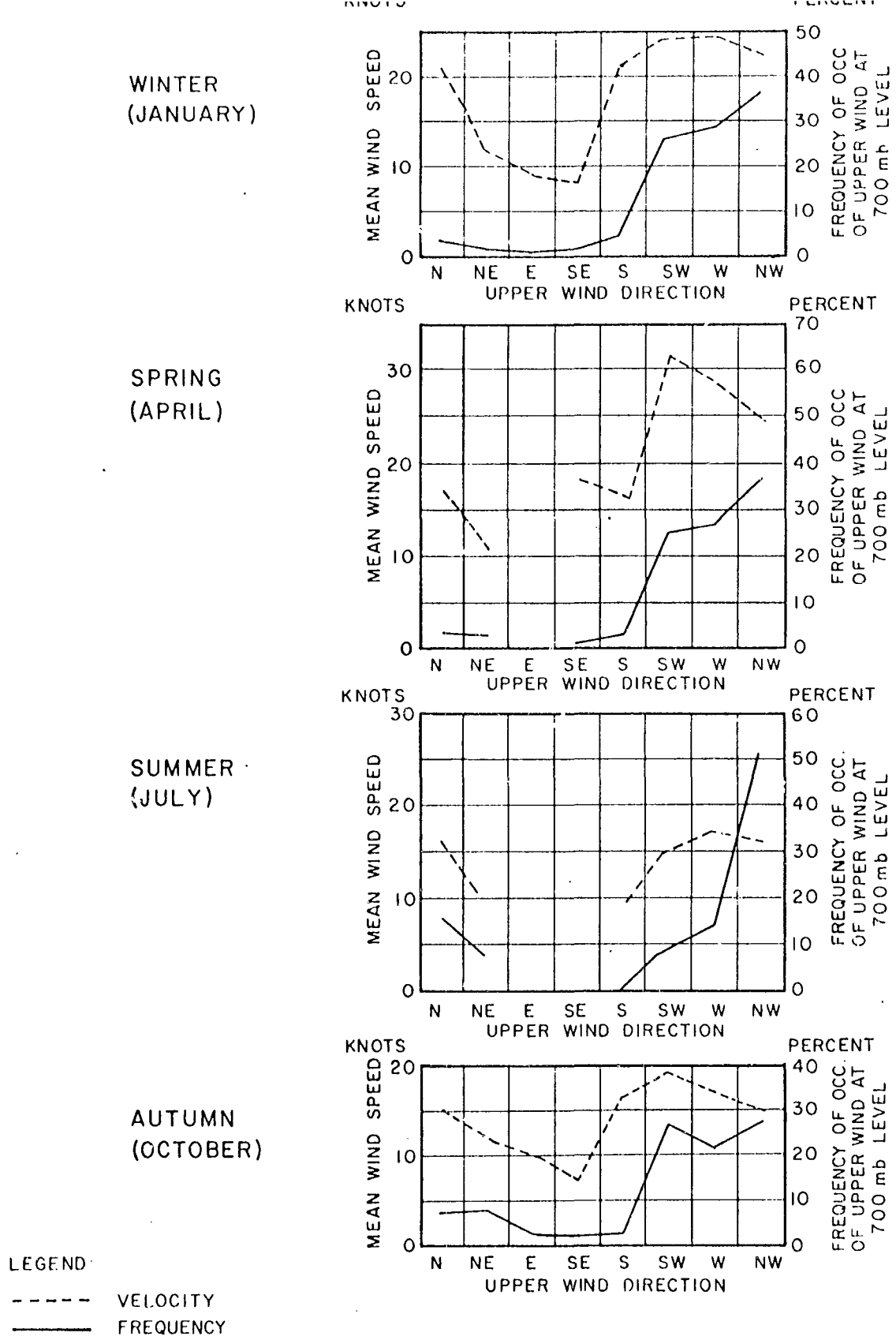
ESTIMATED SEASONAL UPPER WIND SUMMARIES AT THE 850 mb LEVEL FOR NORTH SINAI

FIGURE 2-13



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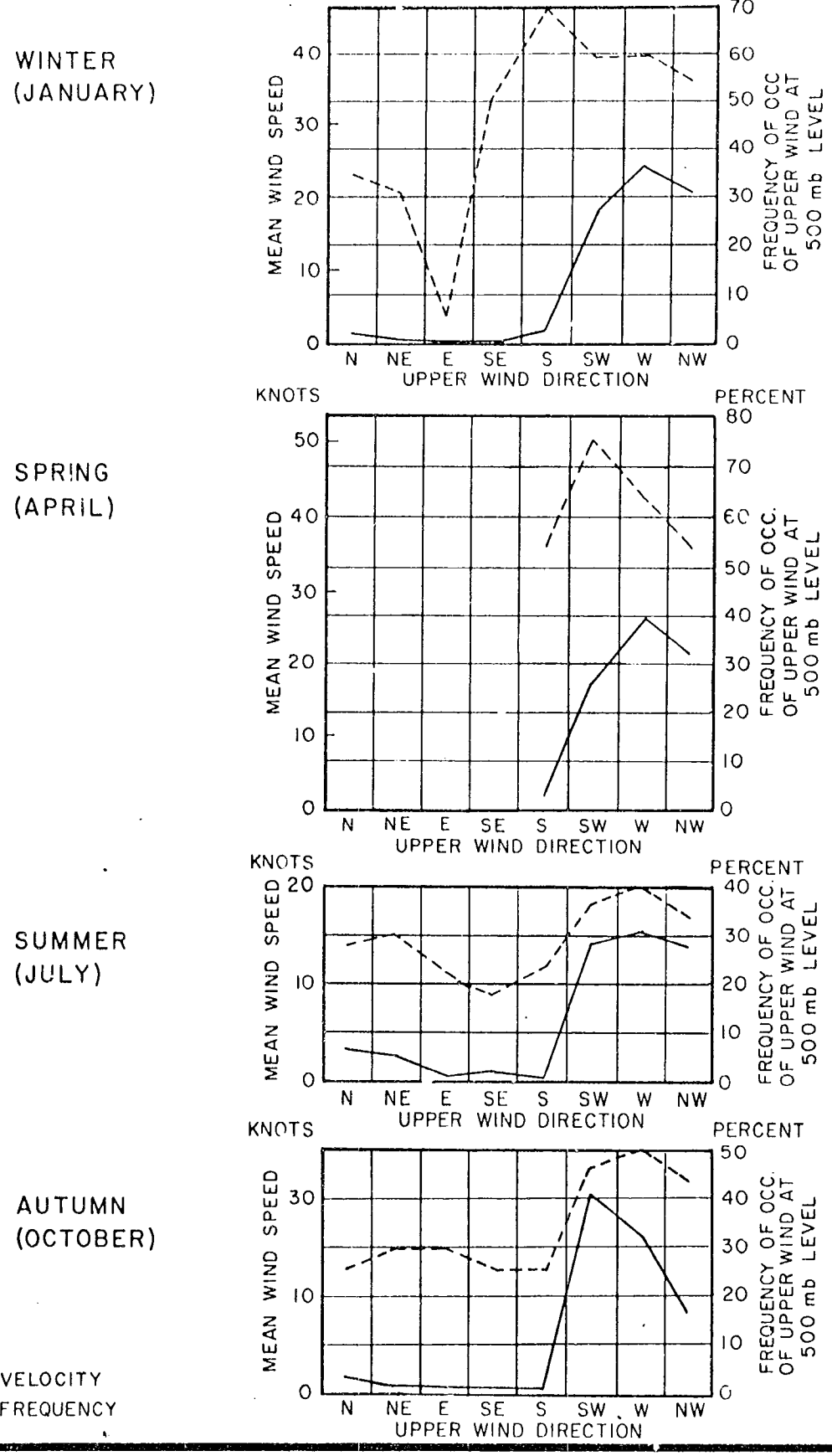
ESTIMATED SEASONAL UPPER WIND SUMMARIES AT THE 700 mb LEVEL FOR NORTH SINAI

FIGURE 2-14



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ESTIMATED SEASONAL UPPER WIND SUMMARIES AT THE 500 mb LEVEL FOR NORTH SINAI

FIGURE 2-15

2.2 PRECIPITATION-TRIGGERING MECHANISMS

Water vapor in the atmosphere must change into water droplets or ice crystals before a cloud can appear. Water droplets form on condensation nuclei, while ice crystals develop on ice nuclei (freezing nuclei). These cloud particles grow to the stage where precipitation can occur (water droplets or ice crystals), as explained in the following sections.

2.2.1 Coalescence

The process by which cloud vapor becomes rain drops is triggered by the direct collision and coalescence of water droplets. Droplets carried upward by ascending currents fall relative to their size and the rising air columns. Very small droplets ($< 18\mu$) are unable to collide with one another. When the radius of a droplet is greater than 18μ, collision occurs.

Collision and coalescence are necessary for the development of precipitation from warm clouds. The temperature of the clouds must be above $0^{o}C$, and they must be comprised entirely of water droplets.

2.2.2 Bergeron Process

This process is concerned with the initial growth of ice crystals. Growth by the direct deposition or transfer from water vapor to ice may be rapid while the ice crystal is small. However, because of expended latent heat , the growth ratio decreases as the ice crystal becomes larger.

2.2.3 Accretion Process

Ice crystals also grow appreciably by collision with supercooled droplets. This leads to the freezing of water on the surface of the ice crystal.

The Bergeron and accretion processes are necessary for the development of precipitation from cold clouds. Ice crystals in these clouds may grow by the direct change of water vapor to ice (the deposition Bergeron process), by the freezing of the supercooled water droplets (accretion process), or by a combination of these processes.

In Sinai, cloud systems develop in winter and to a lesser extent in spring and autumn. A large portion of these clouds are below $0^{o}C$ and, accordingly, the clouds are supercooled to an appreciable height.

Cloud seeding introduces an artificial stimulant to trigger the initial condensation of water vapor. Bringing cloud particles (cloud water droplets or ice crystals) to the stage where precipitation can occur over Sinai will require a complete set of both upper air and surface observations in the northern region, the area of maximum cloudiness. A careful analysis of meteorological data and microphysical cloud parameters will be required prior to embarking on a cloud seeding program.

2.2.4 Air Masses Over Sinai

Air masses over Sinai have different source regions -- with the central parts of Asia as the main source of continental polar air masses, and the North Atlantic as the source of maritime polar air masses. Precipitation-triggering mechanisms in these air masses are frontal or upper air instability.

Continental polar air masses reaching Sinai in winter, early spring, and late autumn undergo a marked modification according to their tracks. In late spring and early autumn, continental tropical air masses undergo less modification, and maritime polar air masses, originating over the North Atlantic, undergo a very marked modification before moving across Sinai. When they follow the upper air Mediterranean track, these air masses normally lose their maritime characteristics before hitting the Sinai coast and, therefore, carry less moisture.

During early autumn, maritime tropical air masses originating over the Arabian Sea occasionally invade the southeast Mediterranean corner and are characterized by much cloudiness and thunderstorm activity, either when they undergo uplifting by orography or when they contact cold pools (fronts) in the upper atmosphere (upper air instability).

2.2.5 Orography

Orography plays a large part in the formation of climatic districts in Sinai. Sinai can be classified broadly into the following orographic regions:

- The northern region, extending from the Mediterranean southward to a latitude of 30° 30' north, increases in height gradually up to approximately 500 meters.
- The plateau region, starting from latitude 30° 30' north and extending south to latitude 29° 30' north, has an elevation above mean sea level that ranges from 500 to 1,500 meters.
- The mountainous region, from latitude 29° 30' north and extending south to Ras Mohammad, has elevations exceeding 1,500 meters -- with many high ridges and mountaintops. Its elevation decreases gradually to the broad coastal strips of the Gulf of Suez and the Red Sea and slopes abruptly to the narrow coastal strip along the Gulf of Aqabah.

Occasionally during the fall season, the eastern parts of the plateau and mountainous regions act as triggering mechanisms to lift humid maritime tropical air masses moving north along the Red Sea. The resulting clouds are associated with a few autumnal thunderstorms and small amounts of precipitation. In winter and during seasonal transitions, the western parts of these regions also act as a triggering mechanism in lifting warm tropical air masses, thereby giving rise to medium height clouds and rain; scattered thunder cells occasionally develop. However, because of the lack of comprehensive data, it cannot be determined whether cloud seeding efforts on these clouds would be productive.

2.2.6 Thermals

Convection currents lift surface air layers upward as they are heated. These rising masses of warm air are referred to as thermals. Convection currents are responsible for the formation of cumulus clouds. During the winter, spring, and autumn seasons, convection clouds may sometimes reach levels where ice crystals form, and may therefore be favorable hosts for seeding.

3.0 REVIEW OF CLOUD SEEDING TECHNOLOGY

From our present state of knowledge about weather modification and its applied technology, cloud seeding appears to be one of the most promising fields for practical benefits. Although cloud seeding experiments are being carried out in different parts of the world, the results cannot be applied unilaterally to the meteorological mechanisms of Sinai. Sites differ with respect to cloud types and vertical structure and the natural geography of the earth's surface. The most applicable of the cloud seeding experiments are those based on supercooled clouds or warm clouds.

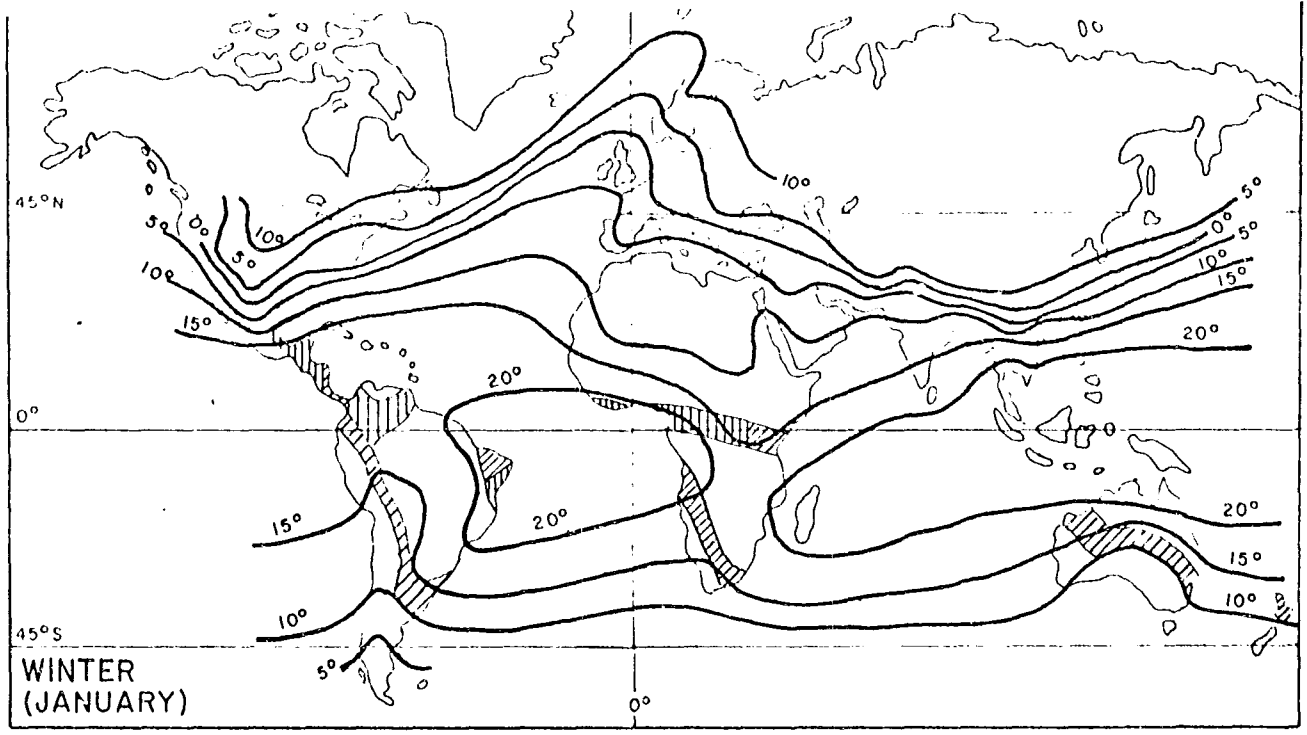
It has been demonstrated that the seeding of supercooled clouds with dry ice, silver iodide, and other nucleants generates the formation of ice crystals, providing a means of modifying the precipitation process. Also, experiments in the subtropics have tested the possibility of seeding warm clouds with hygroscopic particles or water droplets.

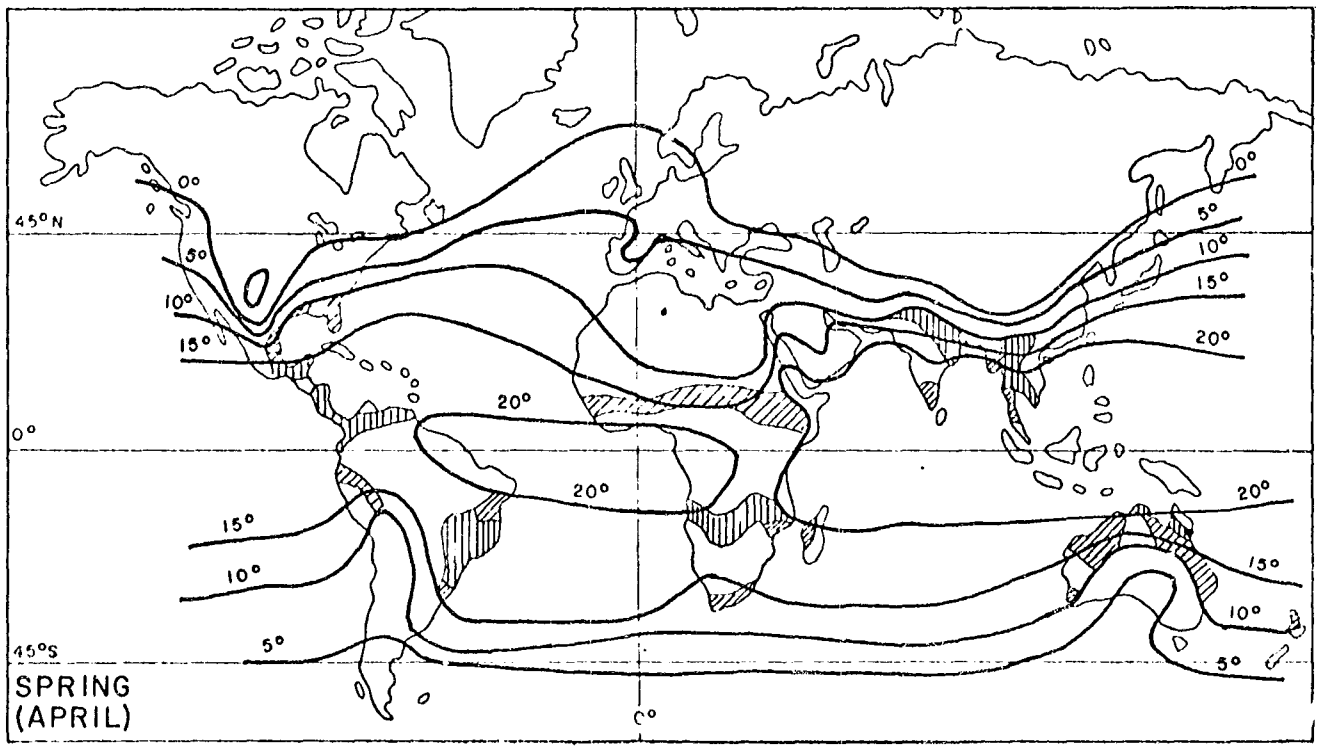
3.1 FAVORABLE CLIMATIC ZONES

There is some theoretical and experimental support that precipitation from convection clouds can be initiated by a process of coalescence in the liquid phase, before the appearance of ice crystals, if the temperature at the cloud base exceeds $10^{o}C$ and if the hygroscopic nuclei of appropriate mass are present in the air entering the clouds. Using these assumptions, F.M. Fourier (WMO Report No. 443 , 1976) classified the world into climatic zones favorable for cloud seeding with hygroscopic nuclei. Figures 3-1 and 3-2 show the approximate regions of the world and in what seasons the above criteria are likely to be satisfied. From these charts, the southeast corner of the Mediterranean appears to be within the favorable area for cloud seeding during winter and seasonal transitions.

3.2 EXPERIENCE IN THE MIDDLE EAST

The two cloud seeding experiments carried out by Israel (Section 1.2) are the only two experiments conducted in the southeast corner of the Mediterranean, in an area similar to northern Sinai.





REFERENCE:
FURNIER, F.M.; 1976;
W.M.O. REPORT NO.443.

LEGEND:
AREAS WITH MONTHLY RAINFALL 25-100 mm
AREAS WITH ANNUAL RAINFALL < 1000 mm
5° CLOUD BASE TEMPERATURE

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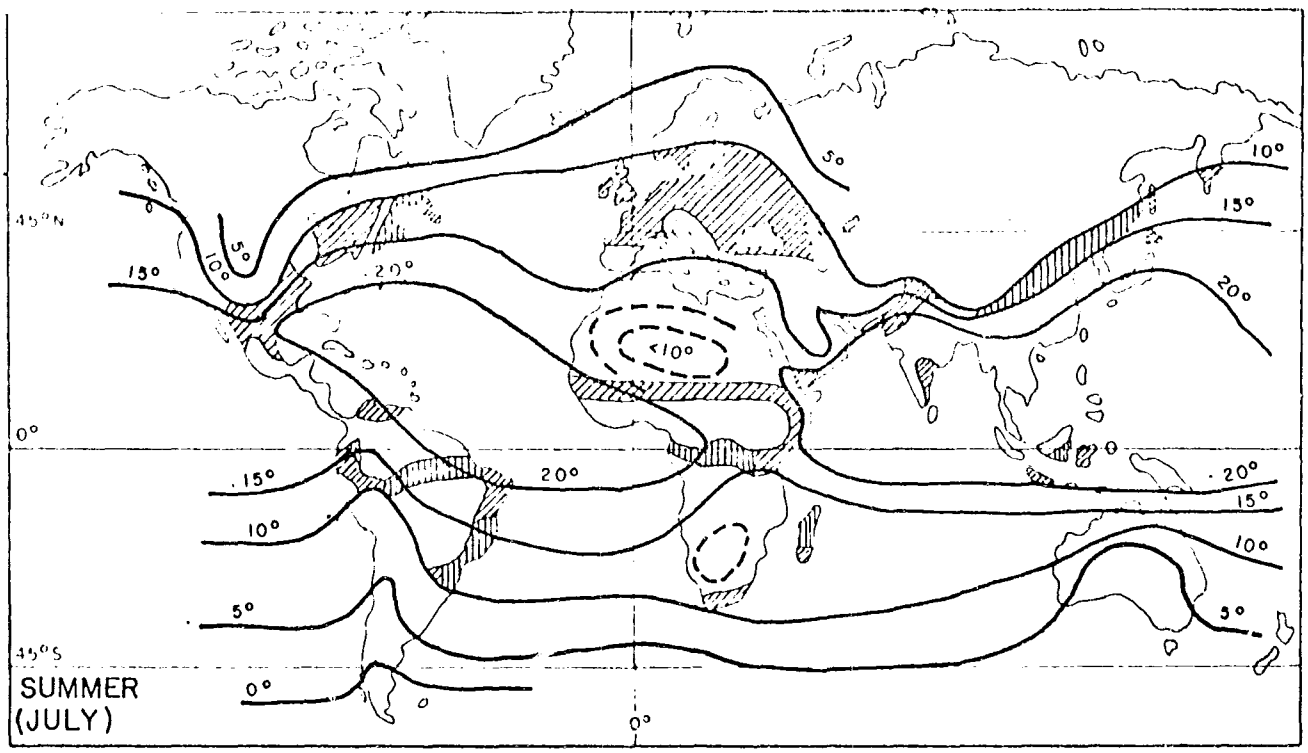
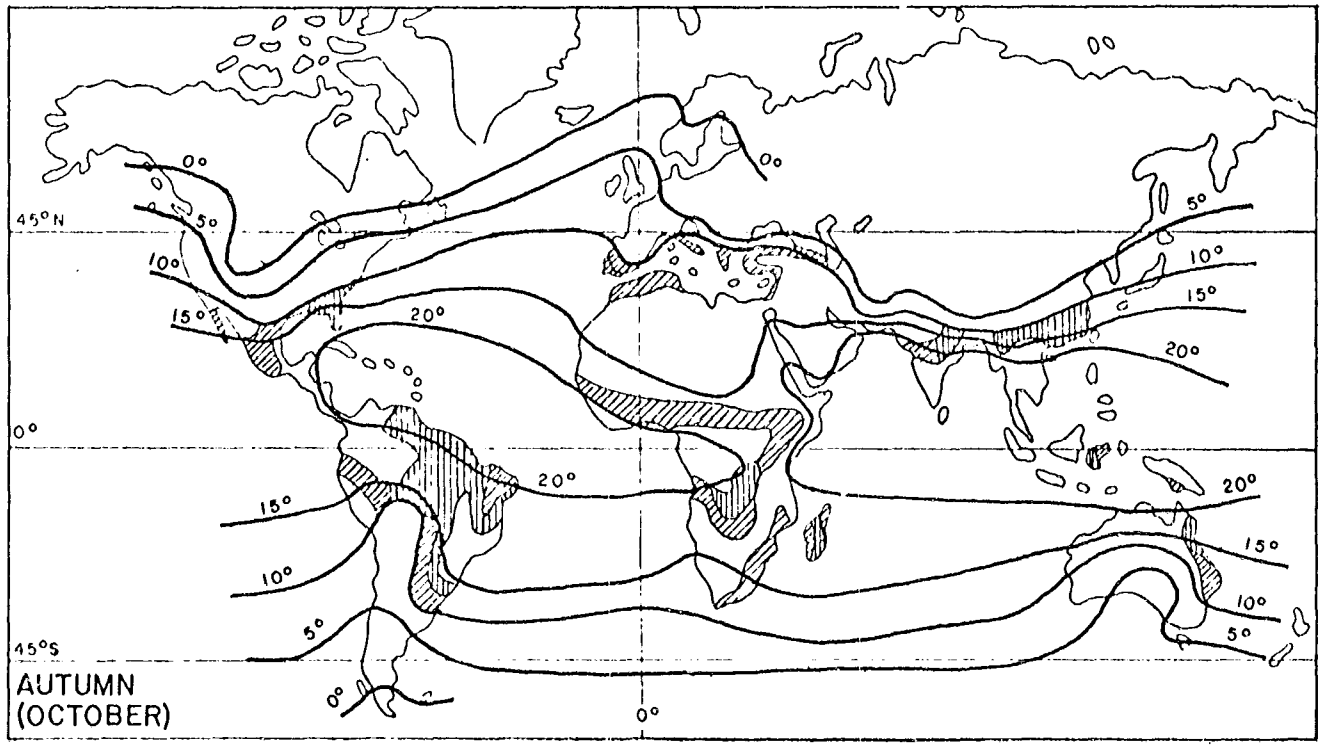
FAVORABLE GLOBAL AREAS FOR CLOUD SEEDINGS (WINTER AND SPRING)

FIGURE 3-1





REFERENCE:
FURNIER, F.M.; 1976;
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LEGEND:
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AREAS WITH ANNUAL RAINFALL < 1000mm
5° CLOUD BASE TEMPERATURE

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FAVORABLE GLOBAL AREAS FOR CLOUD SEEDINGS (SUMMER AND AUTUMN)

FIGURE 3-2

These experiments were launched to explore the possibility of rainfall enhancement in the catchment area of Lake Tiberias. This lake is Israel's main water reservoir, where water is pumped to the more arid south.

The first experiment yielded an overall result indicative of rainfall increases of about 15 percent due to seeding. Moreover, the "interior" sectors of the target area, 25 to 30 kilometers from the line of seeding, showed increases of about 20 percent.

3.2.1 Cloud Types

The seeding was carried out in clouds on rainy days (days with 0.1 millimeters of rain). Clouds were of the continental cumulus form, with a strong vertical structure. Their bases ranged from 8° to $9^{o}C$, and their tops ranged from 13,000 feet and temperatures of $-13^{o}C$ to 23,000 feet and temperatures of $-25^{o}C$. The clouds were therefore partly warm and partly supercooled. In Sinai, during some seasons, cloud systems are similar to those over Israel.

3.2.2 Artificial Triggering Methods

The conversion of ice crystals to solid precipitation particles (graupels), rather than collision coalescence, was the dominant rain-forming mechanism on the majority of rainy days in these experiments.

Clouds with tops ranging from -12° to $115^{o}C$ characteristically had a deficiency of precipitation particles. Clouds with tops warmer than $-12^{o}C$ proved to be totally deficient of such particles.

In Sinai, the definition of appropriate seedable clouds can be defined only after microphysical studies of cloud structure. Such studies should be undertaken during the experimental phase of the cloud seeding project (Phase II of the recommendations).

4.0 ANALYSIS OF CLOUD SEEDING POSSIBILITIES FOR SINAI

Detailed analysis of the general climate and climatic factors in Sinai and review of cloud seeding technology in the Middle East indicate that the northern district of Sinai has the most favorable weather for cloud seeding.

This region of Sinai is the area with the largest annual rainfall and cloudiness. Rainfall along the district increases gradually toward the northeast corner and ranges from 50 millimeters in the west to 300 millimeters in Rafah. North Sinai is also within the favorable area of the world classification for cloud seeding. The encouraging results of the Israeli cloud seeding experiments indicate that favorable results might also be expected from similar efforts in Sinai. However, until additional data are acquired for this study area, no firm recommendations for cloud seeding can be made , nor can any estimate be made for the amount of additional precipitation which might result from cloud seeding.

The existing rainfall data in Sinai are inadequate to give a detailed rainfall profile for Sinai districts, particularly in the northern region. Accordingly, a well developed dense rainfall network is urgently needed, and a complete, updated meteorological network to measure wind parameters, temperature, precipitation, evaporation, and upper air currents is required to augment the existing stations. In addition, a condensed rainfall network is needed specifically for evaluating seeding efforts in the northern Sinai region.

4.1 RECOMMENDATIONS

Cloud seeding is a highly technical and scientific field. Detailed studies are needed in both the planning and experimental stages before any routine operational plan can be developed. Cloud seeding is not merely the deployment of microscopic nuclei into cloud systems. Extreme care must be exercised to ensure that such problems as misplaced precipitation, flooding, or destructive hail will not occur (or at least not occur in areas where they can cause damage).

The planning stage includes two phases of detailed studies for the northern district of Sinai:

- Phase I: Provides clear and specific knowledge about the potential for cloud seeding in the northern region and establishes specific requirements for practicing this technology.
- Phase II: Provides specific knowledge about cloud seeding technology and its application in Sinai in an experimental stage.

4.1.1 Phase I

- Collection of all available observational data on rain and cloudiness in the northern district.
- Preparation of maps and profiles depicting orography and plant cover for the northern district.
- Selection of the most favorable areas for cloud seeding in the northern region.
- Selection of the total area of interest, including catchment areas, target areas, and control areas, and marking lines of seeding in the northern district.
- Determination of requirements for the spatial deployment of a rainfall network in the area to specifically serve the cloud seeding experiments.

4.1.2 Phase II

Phase II recommendations are designed to provide experience in the experimental application of cloud seeding technology in the northern region of Sinai.

- Purchase and establishment of a specific automatic dense rainfall network for cloud seeding.
- A detailed study report on cloud seeding technology and its application in the study area.
- A study report on types of experiments in cloud seeding to be carried out in the northern district with special reference to:
  - Description of each type of experiment
  - Material requirements (equipment, aircraft, generators, etc.)

- Different steps in each experiment
- Total cost estimates
- Laboratories and institutions analyzing results
- A general plan for a precipitation enhancement experiment and evaluation.

Additionally, international standards control the application of cloud seeding in any country. The following are requirements based on these international agreements:

- Designation of a national body responsible for undertaking cloud seeding experiments.
- Designation of one or more developed countries, also conducting cloud seeding experiments, to provide advice, assistance, and cooperation.
- The initial assistance of WMO in receiving full documentation on cloud seeding technology.

None of the above cloud seeding program efforts, however, should be undertaken until a complete meteorological network has been established in Sinai and several years of data have been collected and analyzed.

4.2 COSTS

The following are rough cost estimates (in U.S. dollars) for each phase of the cloud seeding program.

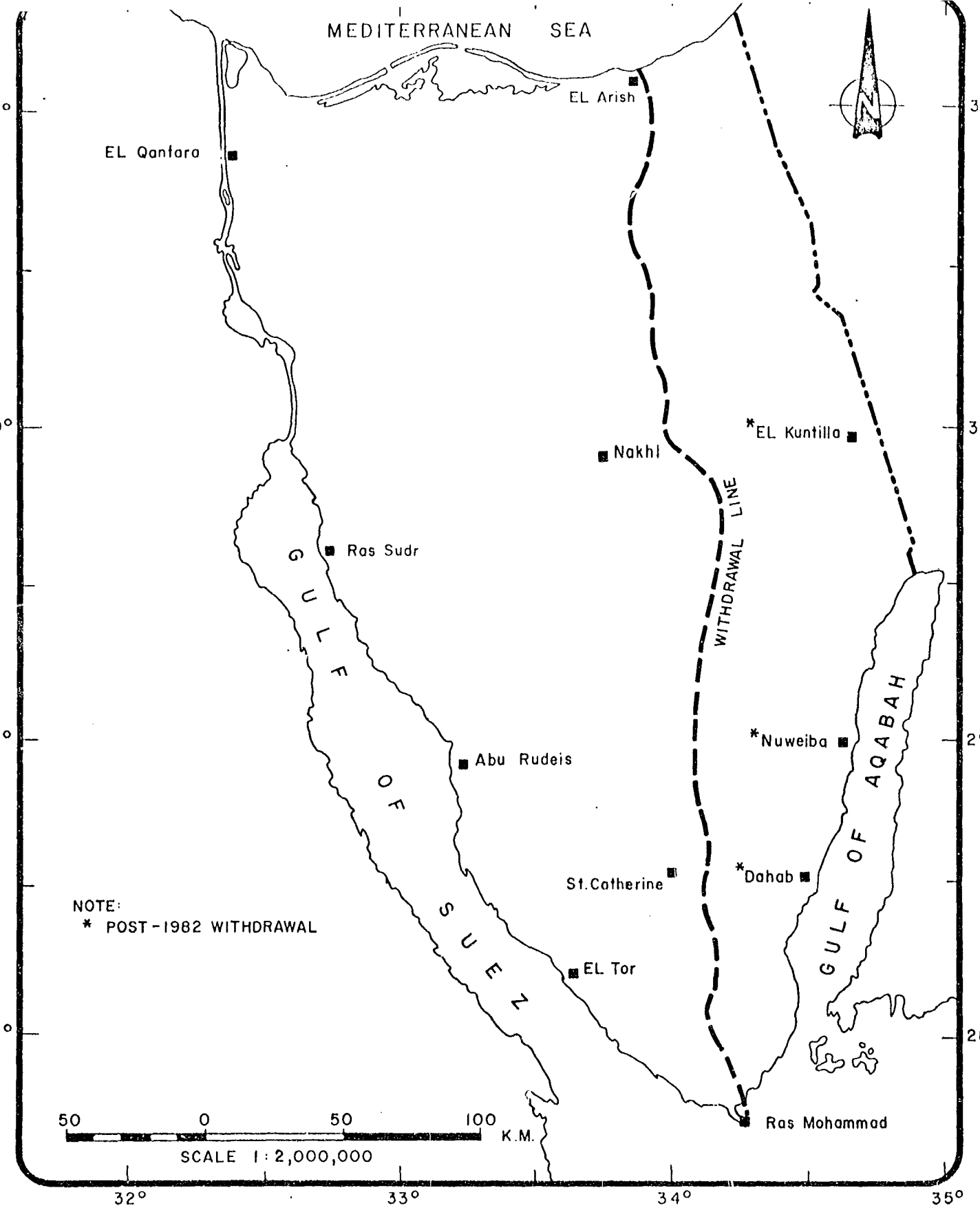
• Phase I	Meteorological consulting firm	
	- Labor costs	$ 60,000
	- International travel	5,000
	- Operating costs in Egypt	8,000
	- Stateside project costs	2,000
	- Egyptian project personnel	12,000
	SUBTOTAL	87,000
	Fee	8,700
	TOTAL	$ 95,700
• Phase II	Implementation	$ 2,000,000
	Fee	200,000
	TOTAL	$2,200,000

5.0 ADDITIONAL DATA NEEDS

As indicated previously, there is a serious lack of meteorological and climatological data for Sinai, and the existing meteorological station network fails to meet the requirements of development projects. These data are critical to the planning of many types of development projects, including tourism, industry, energy, and agriculture. It is therefore clear that the existing meteorological station network requires completion, expansion, and upgrading to meet the increasingly urgent data requirements.

The expansion and upgrading of the existing meteorological station network and the establishment of meteorological upper air stations in Sinai can be achieved only by formulating a joint project between the Egyptian Meteorological Authority (EMA) and another organization having experience in the deployment and operation of data acquisition systems and in the analysis of climatic data. Figure 5-1 shows the recommended sites for an automatic telemetry meteorologic data collection network necessary to meet the future development needs of Sinai.

Cost estimates are provided in Tables 5-1, 5-2, and 5-3 for three aspects of the complete meteorological network. Table 5-4 shows the primary station locations and associated system parameters. Until such time as a program to fully investigate cloud seeding meteorological parameters is undertaken, an accurate estimate of the number of requisite basin area rainfall stations and their locations cannot be determined.



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PROPOSED METEOROLOGICAL DATA TELEMETRY STATIONS

FIGURE 5-1

TABLE 5-1

Costs for Complete Short- and Long-Term Meteorological Network (Telemetered)

Item	Cost
Labor costs	$1,130,000
International travel	140,000
Operation costs in Egypt	330,000
Stateside project costs	15,000
U.S. purchased equipment	1,660,000
Egypt project personnel	63,000
TOTAL	$3,338,000*

* Eight stations as listed in Table 5-4. Costs for surface stations at Dahab, Nuweiba, and El Kuntilla after total Israeli withdrawal would increase the cost by approximately $300,000.

TABLE 5-2

Costs for Each Short-Term Agro-Meteorological Station

Item	Cost
Labor costs	$37,000
International travel	10,000
Operation costs in Egypt	11,000
Stateside project costs	2,000
U.S. purchased equipment	22,000
Egyptian project personnel	3,000
Egypt purchased equipment	3,000
SUBTOTAL	88,000
Fee	8,000
TOTAL	$96,000*

* Obviously, if several stations are set up at the same time, a considerable cost savings for travel and living expenses can be achieved (e.g., each additional station would cost approximately $65,000).

TABLE 5-3

Costs for Rainfall Stations (Phase II and Forward)

Item	Cost
Labor costs	$37,000
International travel	10,000
Operation costs in Egypt	11,000
Stateside project costs	2,000
U.S. purchased equipment	13,000
Egyptian project personnel	3,000
Egypt purchased equipment	2,000
SUBTOTAL	78,000
Fee	7,800
TOTAL	$85 800*

* Costs provided are for a first station. Each additional station could be installed for approximately $30,000. The above station costs include collection of wind speed and direction data, important but not essential for each station.

Equipment for each station recording rainfall only would cost approximately $5,000. Time and expenses for each rainfall only station would also be less.

TABLE 5-4

Station Locations/System Parameters

Climatological Parameters	El Arish	El Qantara	Ras El Sudr	Abu Rudeis	El Tor	Ras Mohammad	St. Catherine's	Nakhl
Surface meteorology[a]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Air quality[b]	Yes	No	No	Yes	Yes	No	No	No
Upper air meteorology[c]	Yes	No	No	No	Yes	No	No	No
Development Activities								
Agriculture	Yes	Yes	Yes	Yes	Yes	No	No	Yes
Tourism	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	No	No	No
Energy	Yes	No	Yes	Yes	Yes	No	No	No

[a]Surface meteorology: wind speed, wind direction, temperature, relative humidity, solar insolation, precipitation, evaporation, sigma theta, atmospheric pressure.

[b]Air quality: sulfur dioxide, nitrogen oxide, ozone, carbon monoxide, total suspended particulates.

[c]Upper air meteorology: wind speed, wind direction, relative humidity, pressure.

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5. Prof. Dr. Mohamed Saad El-Din Harb, Personal Communication, unpublished notes.