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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service

Monthly Climatological Charts of the Behavior of Fog and Low Stratus at Los Angeles International Airport

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Western Region

LAKE CITY,
UTAH

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U. S. DEPARTMENT OF COMMERCE
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MONTHLY CLIMATOLOGICAL CHARTS OF THE BEHAVIOR OF FOG
AND LOW STRATUS AT LOS ANGELES INTERNATIONAL AIRPORT

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TABLE OF CONTENTS

	<u>Page</u>
Abstract	1
Introduction	1
Development	2
Definitions	2
Examples of Interpreting the Charts	3
Applications	4
Concluding Remarks	8
Acknowledgments	9
References	9

LEGENDS FOR TABLE AND FIGURES

		<u>Page</u>
Table 1.	Symbols Used on Charts	10
Figure 1.	Average Number Days per Month of Fog (Top) and Low Stratus (Bottom) for Los Angeles International Airport, 1952 - 1962 and 1963 - 1971.	11
Figure 2.	Examples of Data Entries on Monthly and Seasonal Fog and Stratus Charts (See text for further explanation)	12
Figure 3.	Summer Low Stratus Chart	13
Figure 4.	Fall Low Stratus Chart	14
Figure 5.	Fall Fog Chart	15
Figure 6.	Winter Low Stratus Chart	16
Figure 7.	Winter Fog Chart	17
Figure 8.	Spring Low Stratus Chart	18
Figure 9.	Spring Fog Chart	19
Figure 10.	January Low Stratus Chart	20
Figure 11.	January Fog Chart	21
Figure 12.	February Low Stratus Chart	22
Figure 13.	February Fog Chart	23
Figure 14.	March Low Stratus Chart	24
Figure 15.	March Fog Chart	25
Figure 16.	April Low Stratus Chart	26
Figure 17.	April Fog Chart	27
Figure 18.	May Low Stratus Chart	28
Figure 19.	May Fog Chart	29
Figure 20.	June Low Stratus Chart	30

LEGENDS FOR TABLE AND FIGURES
(Continued)

		<u>Page</u>
Figure 21	June Fog Chart	31
Figure 22	July Low Stratus Chart	32
Figure 23	July Fog Chart	33
Figure 24	August Low Stratus Chart	34
Figure 25	August Fog Chart	35
Figure 26	September Low Stratus Chart	36
Figure 27	September Fog Chart	37
Figure 28	October Low Stratus Chart	38
Figure 29	October Fog Chart	39
Figure 30	November Low Stratus Chart	40
Figure 31	November Fog Chart	41
Figure 32	December Low Stratus Chart	42
Figure 33	December Fog Chart	43

MONTHLY CLIMATOLOGICAL CHARTS OF THE BEHAVIOR OF FOG AND LOW
STRATUS AT LOS ANGELES INTERNATIONAL AIRPORT

ABSTRACT

Coordinates of arrival time and ending time are used to chart the monthly climatology of fog as well as very low stratus clouds at Los Angeles International Airport. Nineteen years of record and special observations are charted by seasons and months in two categories: Fog (less than 200-foot ceiling and/or visibility less than 1/2 mile) and low stratus (ceilings 200 feet through 500 feet and visibilities of 1/2 mile or more). A variety of chart symbols are used for cloud or fog conditions to indicate the origin, how it subsequently changes to another category, its duration, and repetitions within categories. From the 24 monthly charts and 7 seasonal charts which are reproduced, patterns are discernible which should be useful to forecasters and flight operations personnel who have to make decisions about the immediate behavior of these marginal-type weather conditions. Some rather distinct patterns are apparent.

A comparison of fog frequency between the years 1952-1962 and 1963-1971 shows a significant reduction in fog in the recent period. This is tentatively attributed to extensive land development and expansion of the airport westward toward the ocean.

INTRODUCTION

Fog and stratus on the Southern California coast and at Los Angeles International Airport (LAX) have been abundantly documented by many authors. Only a few authors have attempted to derive parameters for objectively forecasting occurrence of fog or stratus, even though they occur, or the potential for their occurrence is present, on most nights of the year.

Even more difficult than a yes-no forecast of whether fog or stratus will occur is the forecast time of its arrival over the terminal. Very little has been written on this subject. The commonly practiced method of timing the event is "modified persistence". This is an evaluation of all available data in comparison with data from the previous day and the forecast trend of pressure systems, gradients, etc. Current data are used to modify the timing and cloud height of the previous day. The forecaster's experience includes variations due to synoptic patterns, seasons of the year, climatology, and many more specific parameters.

Graham (1952) developed an objective technique to predict the arrival time of warm-season stratus using a thickness value, a pressure gradient, and the Catalina Island Airport observation.

Gales (1962) used a pressure gradient and its 24-hour change in a study for fog forecasting, and Gales (1964) used the 1400Z and 1900Z dew-point temperatures in a similar study.

Keith (1957) developed a check list with numerically weighted items for forecasting clear sky, fog, or stratus at the terminal. The sum of the weighted numbers indicated the most probable forecast.

More recently, Eichelberger (1971) developed an objective technique for forecasting the Catalina Eddy using a coastal pressure gradient and the 500-millibar baroclinic vorticity forecast.

With these techniques, stratus forecasting has improved, but subtle parameter changes, often in conflicting directions, make stratus forecasting as much an art as a science.

This paper is concerned with use of fog and low-stratus climatology as an aid to the forecaster or airline flight-operations personnel who have to make decisions when fog has spread onto the airport, or is imminent. The climatology is only applicable to LAX.

DEVELOPMENT

Nineteen years of LAX hourly and special observations were examined for the presence of fog and low stratus. Each case of fog or stratus was charted separately according to time of beginning and ending. Storm conditions were not considered in the study. If it was raining at observation time or if rain had recently been reported, the observations were not considered. Thin broken or thin overcast sky condition was considered as a ceiling.

DEFINITIONS

These categories were arbitrarily selected for their application to aircraft operations:

FOG:	Ceiling \leq 100 ft.	and/or Visibility $<$ 1/2 mi
LOW STRATUS:	Ceiling = 200 to 500 ft	and Visibility \geq 1/2 mi
STRATUS:	Ceiling \geq 600 ft	and Visibility \geq 1/2 mi

Three basic symbols are used in the charting: \bullet , \times , \blacktriangle . Variations of the solid symbols are made by appending arrows. These symbols are intended to be logical, readable descriptions of the behavior of each fog or low stratus event. The symbol describes the recent history and subsequent behavior of the condition within its category. They are described in Table 1. In some cases repetitions can be traced between charts by the symbols.

The charts were plotted by months for both fog and low stratus as defined above. Because 19 years is a short period for monthly stratification of data, seasonal charts are also provided. Seasons were defined by similarity of behavior of fog or low stratus rather than by the calendar. Seasons vary in length from two to four months with a different grouping for fog and low stratus. There is no summer fog season chart, and July fog was not included in any season since it was dissimilar to adjacent months due to short fog durations.

Seasonal charts include only the initial symbols ▲, ×, ●, for a date and as such represent no redundancy of data, whereas monthly charts include open symbols for repetitions on a given date. To the casual observer this redundancy would tend to bias the data in favor of more events than actually occurred.

It is important for a study such as this to have observations all taken from the same location on the airport. Heat from the ground and low-level mechanical turbulence tend to lift the leading edge of the fog as it moves inland from the beach, which is about two miles west of the LAX observation site. Farther inland from the immediate coast, higher ceilings are likely to occur within the marine layer. To move the site westward would tend to increase the amount of data observed in the Fog Category as well as to lengthen the duration slightly. The observation site was moved westward 3/4 mile in June 1968. It is felt, however, that the basic presentation is still valid, although perhaps with a slight bias.

An additional factor of significant effect on the data is man-made changes to the environment over the years. Extensive suburban development of formerly agricultural areas, airport paving, building construction, and increased use of the airport and its facilities along with aircraft and motor vehicle emissions probably affect the amount and height of fog and low clouds observed. The westward move may compensate to some degree for the man-made effects.

Figure 1 shows a reduction in frequency of both fog and low stratus for most months since 1962, when airport activities were accelerating. This change in the climatology of fog and low stratus should not affect the validity of the charts, as these are to be used for forecasting arrival times and subsequent behavior of fog and low stratus, not the occurrence of these conditions.




EXAMPLES OF INTERPRETING THE CHARTS


Observations are plotted in two categories, fog and low stratus, using arrival time of the event as abscissa and the ending time of the event as ordinate (Figure 2). Fog ends when it lifts into the low stratus category, when it dissipates, or when it is advected away. In the case of fog lifting to low stratus, the ending time of the fog becomes the beginning time on the low stratus chart; and the reverse occurs when low stratus becomes fog.

Note that the time difference between beginning and ending of an event is the duration of the event. The zero-duration line is a diagonal across the chart upward to the right. All events of the same duration will fall on a line equidistant from the zero-duration line. Though not a chart coordinate, duration is a convenient parameter for comparing monthly patterns of behavior of the fog and low stratus.

Figure 2 shows several examples of fog entries. Note that the diagonal zero-duration line limits all data to the upper left-hand side of the chart. On monthly and seasonal charts the lower-right halves of the charts are deleted and the abscissa labels are placed along the diagonal for ease of reading.

The first example in Figure 2 shows an X on the 4-hour duration line. This indicates a fog began at 2345 GMT and ended at 0345 GMT. The fog did not repeat during that night according to the definition of the X-symbol (Table 1).

Another example (A) shows fog beginning at 0000 GMT and ending at 0100 GMT. The duration was one hour. The solid round symbol  indicates this to be the first fog entry of the date, and that it came from the lowering of low stratus to fog. It ended by lifting up to low stratus and repeated again at 0300 GMT by the lowering of stratus to fog (See A¹ in Figure 2). The open symbol  shows that the condition is a repetition of an earlier entry on the chart and also shows the fog ending by the visibility increasing to 1/2 mile or more at 0410 GMT. A second repetition (A²) is indicated by  at 0700 GMT when the visibility again decreased to less than 1/2 mile and/or the ceiling became zero or 100 feet, but not by lowering. This condition ended by lifting to low stratus near 0730 GMT. Letters with exponents are used to trace the particular case with subsequent repetitions. Not all cases are so lettered.

A third example has a solid triangular symbol  whose appendage indicates the fog came from the lowering of low stratus at 0400 GMT and it lifted back to low stratus at 0700 GMT. The solid triangle means this one event did not repeat in the fog category on this night. The triangle is used rather than the X symbol because of the change into the low stratus category.

APPLICATIONS

In practice the forecaster often has a difficult time describing the variable nature of the anticipated fog or stratus condition. It is hoped that he will find guidance in these charts for improvement of his forecasts. For example, he may not become concerned by report of a fog bank west of the airport at certain hours during a particular month if he checks the chart and find that fog did not move over the airport until some time later in the day; or that in some months or during evening hours, fog duration is never more than a few hours;

or sometimes the forecaster can state with confidence that a certain condition will (or will not) happen, because the 19-year climatology shows the event very frequently (or rarely) occurred at a certain hour in that particular month.

A flight dispatcher of an airline may find the time-behavior charts useful when he has to decide whether an airplane approaching LAX should go to an alternate airport, proceed to LAX, or take a chance on holding aloft in the area until the weather improves to landing conditions during a fog. Such decisions are always a calculated risk, but with the help of the time-behavior charts he has something factual upon which to base his decision. For example, in December it can be safely said that fog (ceiling below 200 feet and/or visibility less than 1/2 mile) is quite unlikely before 2330 GMT; or in March, if the airport is foggy at some time before 0800 GMT, the dispatcher should feel confident that the fog will not last over two hours and that the fog more likely will dissipate than lift. He might decide it unwise to pick up passengers from a flight that landed at a nearby alternate airport because of fog at LAX when the charts show a definite pattern of short-duration fogs (as in March), and that in less time than the bus ride the flight could fly into LAX after the fog lifts.

During changeable fog periods or marginal weather when the trend is uncertain, the time-behavior charts will give objective help to answer such questions as:

- How long is this condition likely to last?
- Now that it has ended, is it likely to repeat?
- How long before it may fog in again?
- Is the stratus likely to lower to fog, or will it stay as low stratus?

For several examples of applications of the data we will assume some representative conditions and follow through the charts to a reasonable forecast.

1. Given: March, ending of a period of dry offshore flow, no fog is reported over the water in the afternoon, but the sea breeze has increased coastal dew-point temperatures and pressure gradients are such that by other means (Gales, 1962, 1964) fog has been decided upon as the likely forecast for the coming night.

Procedure: Turn to the March Fog Chart or Spring Fogs and note that the majority of fogs prior to 0800 GMT (hereafter noted as 08Z) were caused by lowering of low stratus to the fog condition, and fog never lasted over two hours. Since no fog or clouds are over the water on this hypothetical afternoon, fog is most likely to come from either radiation (rare) or from later advection, but

not from the lowering of advected clouds. (This decision is largely from experience.) The charts indicate the arrival of below-limits fog to be unlikely earlier than 08Z to 10Z. The fog is not likely to be variable (allowing intermittent flight operations) since there are few open circles on the March Fog Chart. The ending time of the fog is usually by 17Z.

Forecast: LAX going below limits (below 2X1/2F) at 10Z and becoming operational between 15Z and 16Z through dissipation of the fog rather than from lifting into low stratus.

2. Given: March, the next night after the above example. Fog and low stratus are over the water and up to the coastline at forecast time (21Z). Pressure gradients are becoming more onshore toward the desert, indicating a trend toward low clouds with possible fog tonight. Day-time temperatures have been fairly warm and sunshine has warmed the ground.

Procedure: Since fog is along the shoreline and should move in with the sea breeze, the forecaster will find on the Spring Fog, Spring Low Stratus, or the two March charts that an arrival time earlier than 22Z is unlikely (Earliest onsets of stratus are about 2130Z; for fog, about 00Z); also, 00Z is a popular beginning time for low stratus. Low stratus is chosen because the warm ground will tend to lift the leading edge of the fog as it moves inland to the airport. However, the charts indicate that quite often a lowering-and-lifting pattern (X, Q) takes place in March with the duration in the low stratus category likely being less than four hours and in the fog category less than one hour during the time prior to about 09Z. Given the pressure gradient trend favoring low clouds, the forecaster may forecast something like the following:

Forecast: Marginal low stratus arriving at 00Z with short periods of fog (less than 2X1/2F) prior to 08Z or 10Z; then varying between low stratus and stratus above 500 feet (O). This was chosen because of the pressure gradient trend, and March charts show repeat conditions in the low stratus category are most often of this type (O) after 08Z. (The other choice for repetitions would be continuations between fog and low stratus (Q O) which was rejected because of the pressure gradient trend noted above.) After 14Z the forecast will be for higher stratus and continued lifting (O ▲).

Among the useful information derivable from the charts are:

1. Initial arrival time will rarely be earlier than that shown by the data toward the left side of the charts.
2. Normal ending times for the conditions will be found at the stratifying of the data near the top of the chart.

3. Variability during day or night will be indicated by the number and time-distribution of the open circles. (Caution: Some dates may be represented by several circles, thus lending some bias toward variability.)
4. Note the types of variability from the appendages (or lack of) on the symbols. Is it lifting-and lowering (⊙) or in-and-out (○) conditions?
5. Note the duration pattern, especially from the X and ▲ symbols, which are nonrepeating events during the night.
6. Compare the relative frequency of variable conditions (circles) with the one-time events X, ▲.
7. Compare the relative frequency of fog and low stratus conditions ending within their categories to the frequency of cases lifting to the next higher category. (Compare symbols without appendages to those with appendages.) For example, on the Fall Fog Chart, prior to 05Z, 31 of 35 initial onsets of fog were due to lowering from low stratus, while on the Winter Fog Chart, prior to 05Z, only 14 of 94 cases were due to the same action.
8. Compare seasonal distributions. Note that an early fog in winter may have a long duration, but spring and fall fogs forming prior to 08Z are mostly of short duration.
9. Use monthly charts in conjunction with seasonal charts for possible refinement, since there is a gradual transition between months as well as between seasons.
10. When the event has already begun, use the trend already established (lift-and-lower or in-and-out) to provide a clue as to which chart symbols to examine for future behavior.

As an example of application of the charts after an event has begun, assume it is an August evening at 02Z. A low stratus (M3 ⊕ 1F) moved over LAX from the west. The Summer Low Stratus Chart shows that (a) evening low stratus usually comes from the lowering of a higher stratus and returns to higher stratus (●, ▲); (b) at or near 02Z low stratus arriving without lowering (as assumed in our example) will, in reality much more often continue to lower to fog (⊙) than rise (●); (c) it has an almost equal chance to clear out, however, ●, X. Half of those fogs that clear out will not reappear as low stratus (X).

As to duration, the Summer Low Stratus Chart shows (a) the condition could last into the morning, but more likely (b) it will be variable (circles) and last less than two hours in this category. Looking at the Fall Fog Chart we are assured that (a) nearly every fog in the evening comes from lowering conditions and almost always lifts back up to low stratus (●, ▲); and (b) fog duration is usually under four hours and quite likely less than one hour if it begins between 03Z and

05Z. Additionally, fog repetitions are not common (circles) in August, but low stratus repetitions are common.

The forecaster's conclusion might be that the presently observed low stratus will lower to fog (below 2X1/2F) at about 03Z and lift up again to low stratus within an hour or so. Further conclusions about the behavior would depend upon trends of pressure and wind flow not specified in this example. However, the August Fog Chart gives about an even chance for a second appearance, probably around 10Z and lasting for several hours.

While these data are climatological and statistical, the forecaster can make the historical facts much more useful when incorporated with his knowledge of events transpiring at the moment and using this information with other objective aids to formulate his forecast.

The forecaster can examine the charts and form opinions or "rules" for each month, such as fog is rare at LAX before a certain hour in the afternoon; or fog almost always ends before some particular hour in the morning. Some months have a greater tendency for fogs to develop by lowering from a stratus condition (☉ or ☽) and ending by rising into a stratus condition (☼ or ☾). Other months are more prone to have ground fog without variability (X), while another month may be subject to great short-period variability (☉, ☽, ☼, ☾, ☉, ☽, ☼, ☾), and long duration fogs are rare.

It was found in working with the data that winter months tend to have low stratus for relatively short times, and that this condition is more often a transitory stage of a changing condition. Also, in spring the diurnal oscillation of ceiling height was greater than in other months. It was not unusual in April and May to have ceilings lower from 1000 feet to 300 feet during the night, a rather large change.

CONCLUDING REMARKS

The climatology of the behavior of fog and low stratus has been charted by months and seasons to give the meteorologist another tool in understanding and forecasting a rather common weather condition at LAX. Many years of observations from one location are necessary to make such a study representative. Future work similar to this could be made less complex by merging periods of brief changes having little or no operational significance. For example, lifting or lowering of fog or stratus for a period lasting only 10 minutes may be considered of little importance except for an aircraft in position for takeoff or already on a landing approach. Also, brief fluctuations between low-stratus and stratus ceilings are of little importance except when part of a trend.

Changes in fog climatology at LAX have taken place over the years.

Fog is less common in recent years, particularly in the warmer months. It is suggested that airport development by paving and construction of buildings, as well as increased utilization of the runways, has had a large influence in this change.

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The manuscript was reviewed by the Staff at Los Angeles Weather Service Forecast Office, and the preliminary draft was typed by Mrs. Frankie Latimer.

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TABLE 1. SYMBOLS USED ON CHARTS

BASIC SYMBOLS:

- ▲ A solid triangle indicates only one occurrence of the event on that day or night followed by a change in category as shown by the affixed arrows defined below.
- ○ A solid circle indicates more than one occurrence of the event on that day or night. Repetitions are shown by open circles. Arrows affixed to the symbols define changes.
- X Denotes only one occurrence of the event that day or night with no change in category.

CHART SYMBOLS

FOG* CHART

LOW STRATUS* CHART

X ● ○	Began and ended as fog.	Began and ended as low stratus.
▲↓ ●↓ ○↓	Lowered from low stratus and ended as fog.	Lowered from stratus* and ended as low stratus.
▲↓ ●↓ ○↓	Lowered to fog from low stratus and raised back up to low stratus.	Lowered from stratus and raised back up to stratus.
▲↑ ●↑ ○↑	Began as fog and lifted up to low stratus	Began as low stratus and lifted up to stratus.
▲↓ ●↓ ○↓	None	Stratus lowers to low stratus and then to fog
▲↑ ●↑ ○↑	None	Raised up from fog and then returns to fog
▲↑ ●↑ ○↑	None	Raised up from fog and ended as low stratus
▲↑ ●↑ ○↑	None	Raised up from fog and continues up to stratus
▲↓ ●↓ ○↓	None	Began as low stratus and lowers to fog.

*For definitions see page 2.

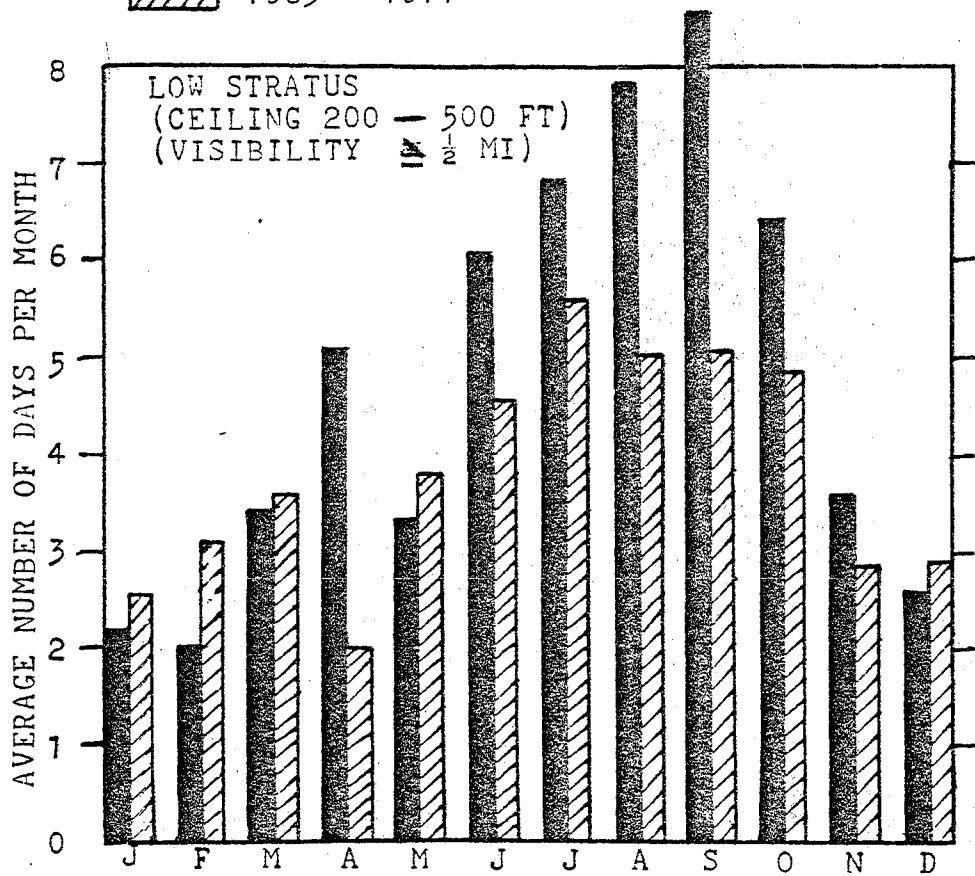
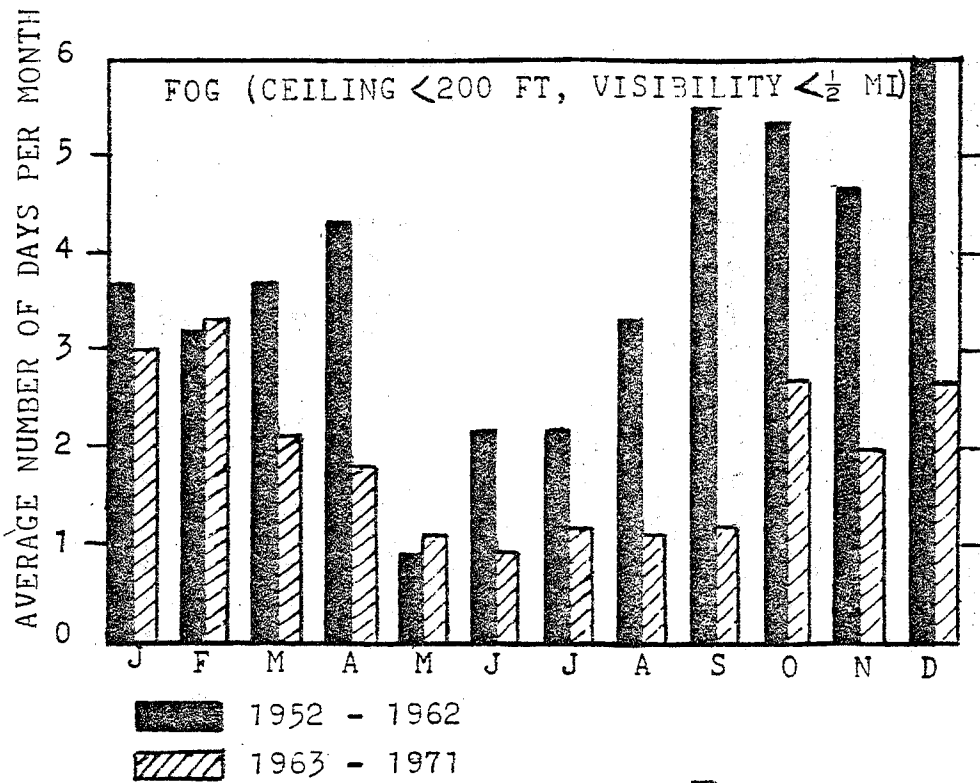


FIGURE 1. AVERAGE NUMBER DAYS PER MONTH OF FOG (TOP) AND LOW STRATUS (BOTTOM) FOR LOS ANGELES INTERNATIONAL AIRPORT, 1952 - 62 AND 1963 - 71.

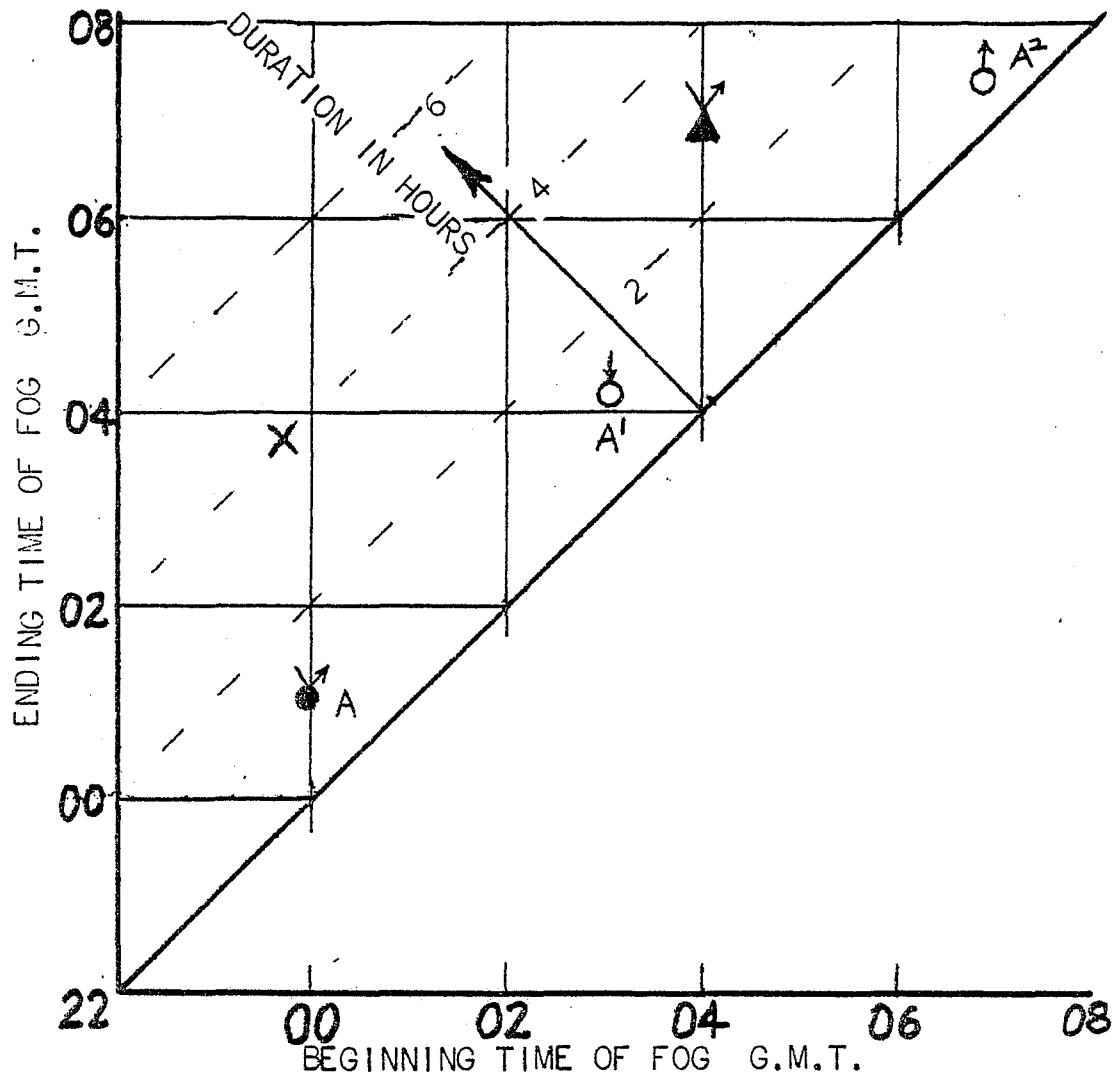


FIGURE 2. EXAMPLES OF DATA ENTRIES ON MONTHLY AND SEASONAL FOG AND STRATUS CHARTS (SEE TEXT FOR FURTHER EXPLANATION).

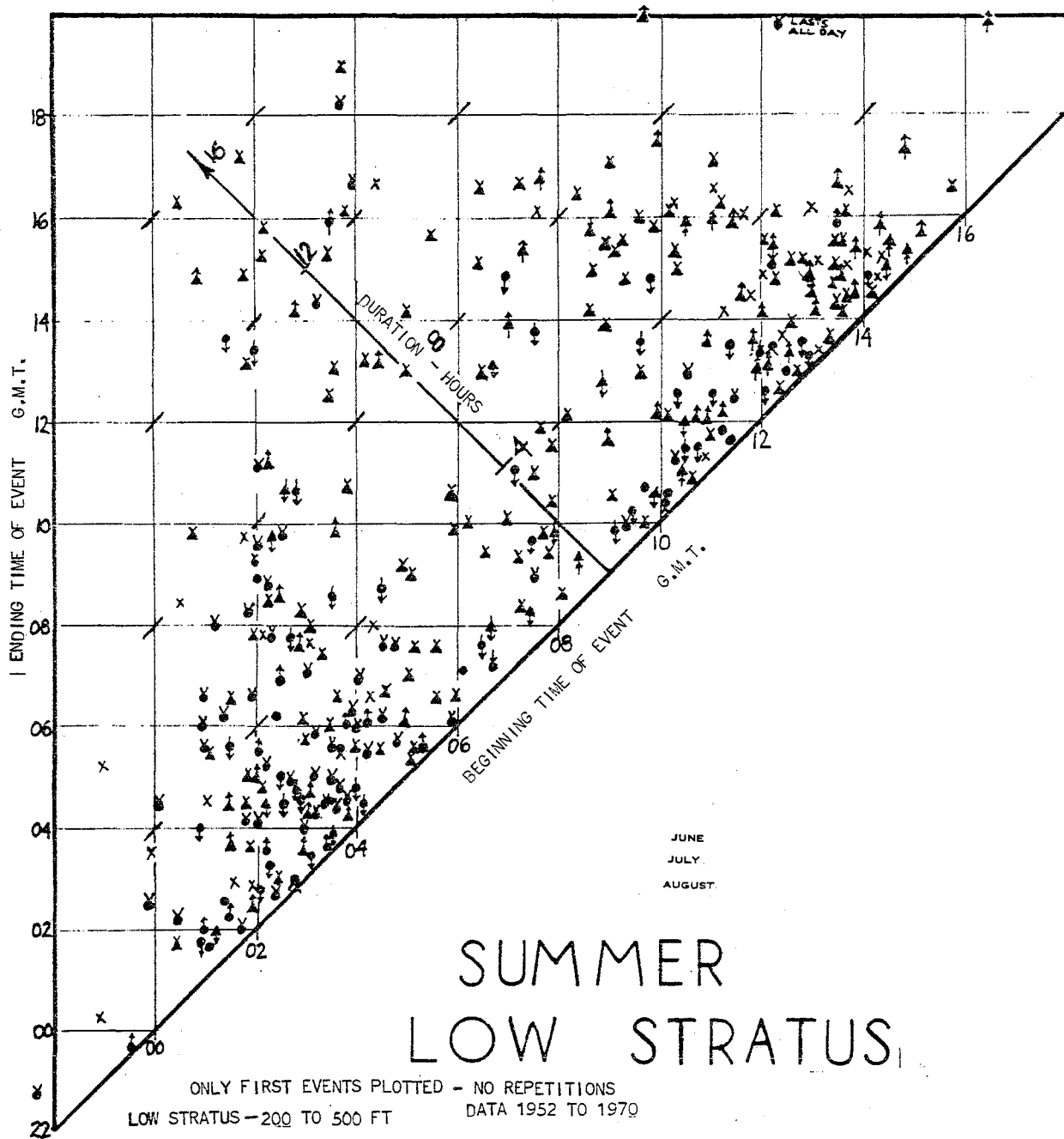


FIGURE 3

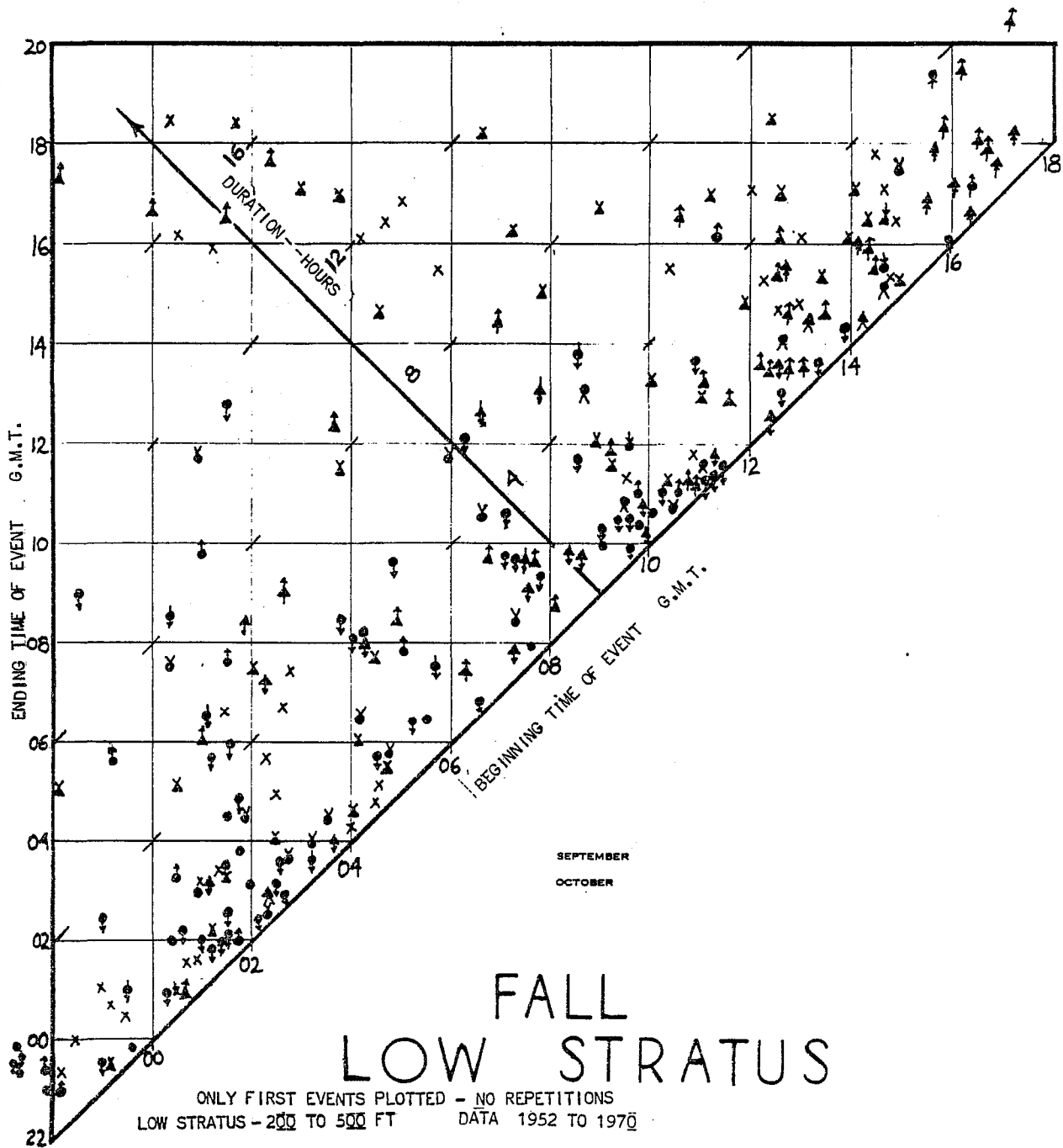


FIGURE 4

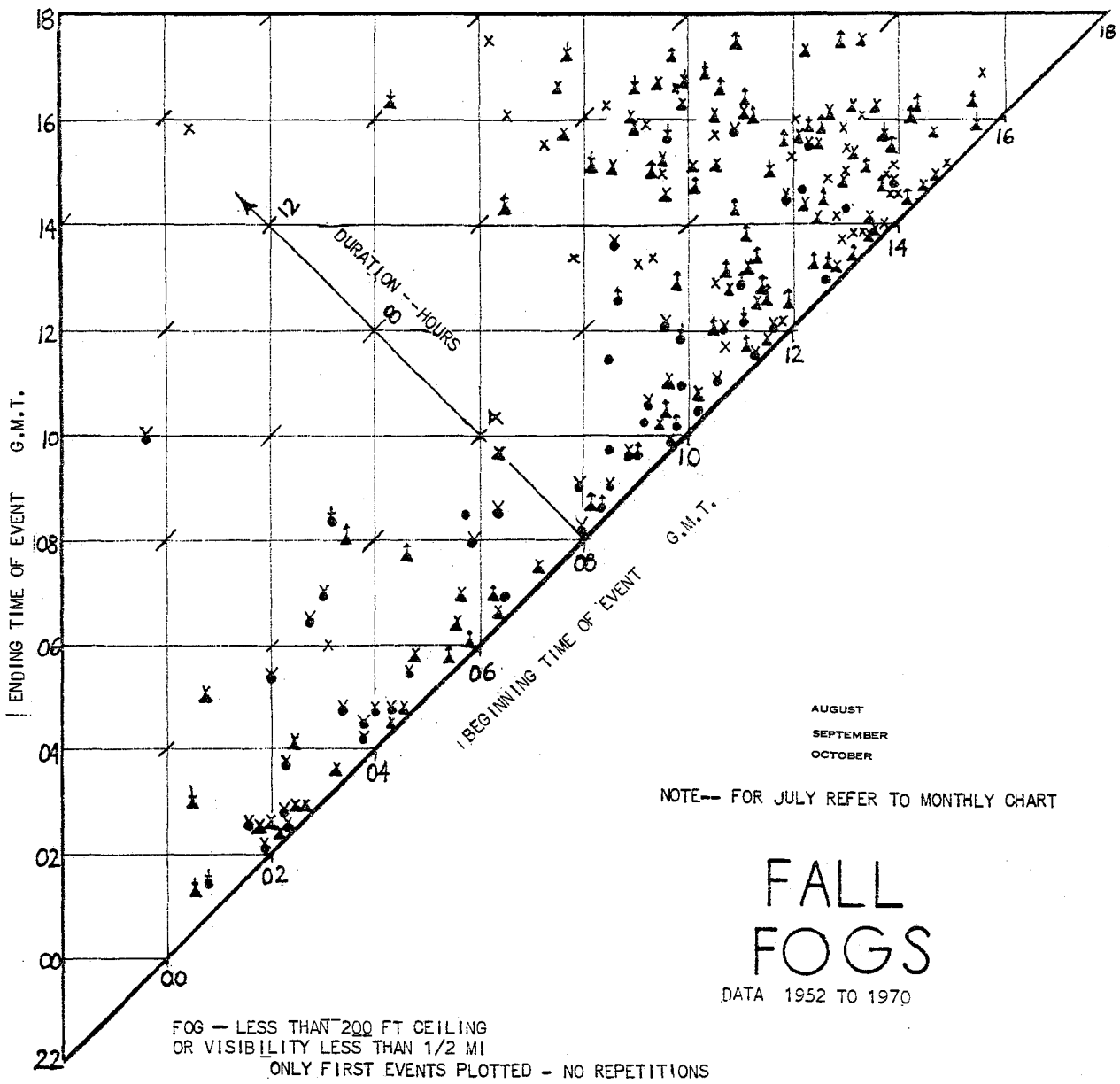
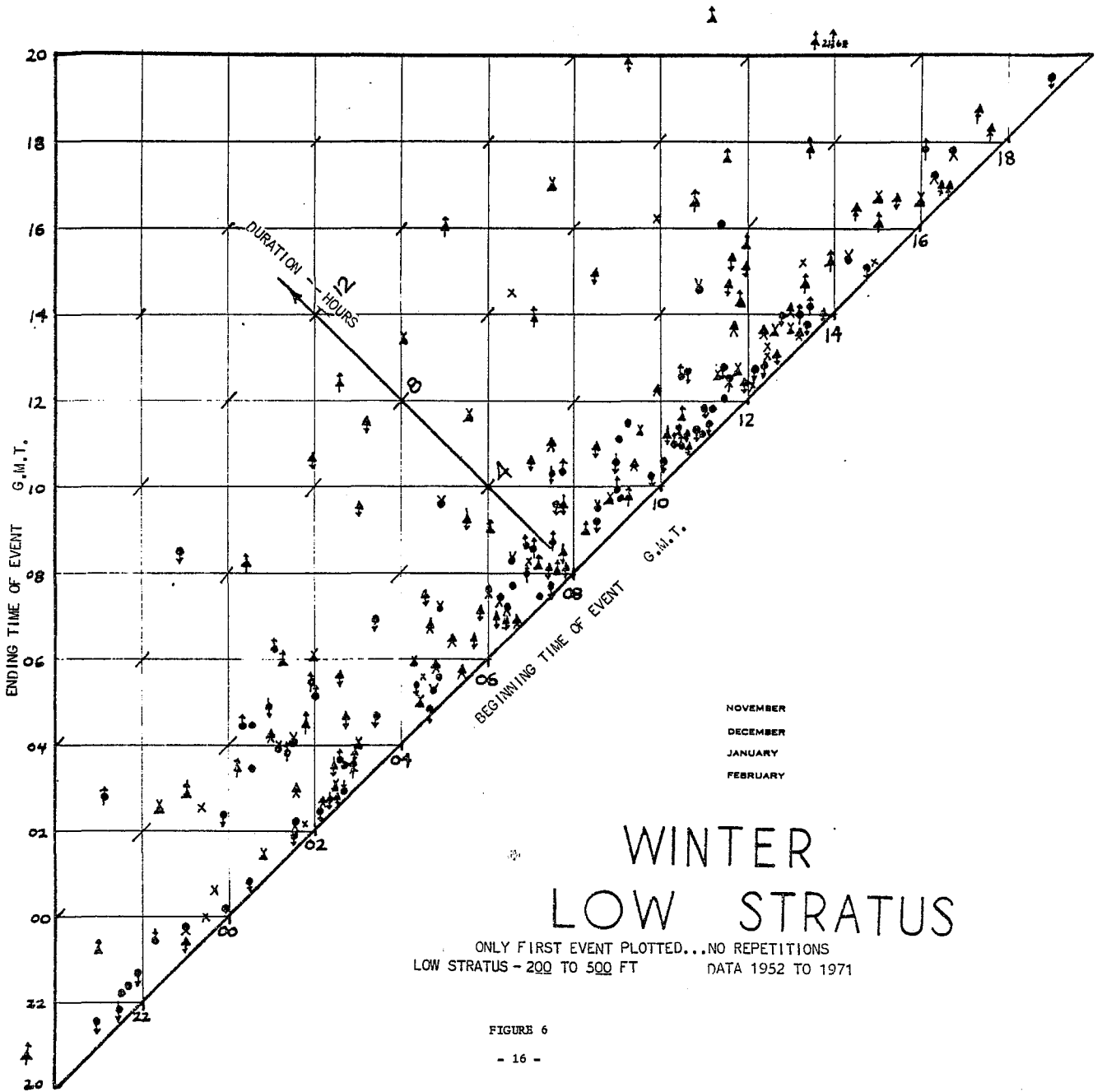


FIGURE 5



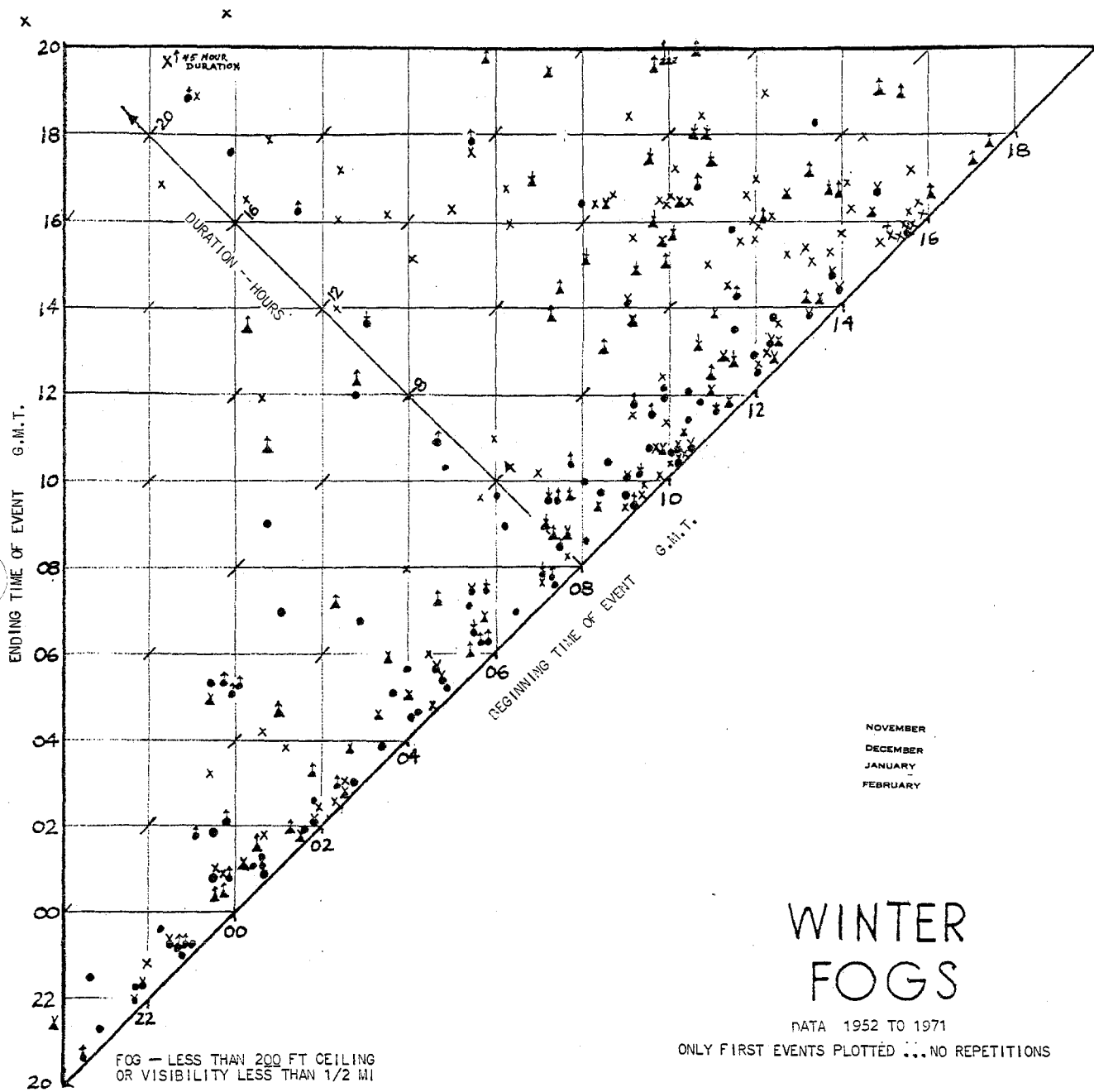


FIGURE 7

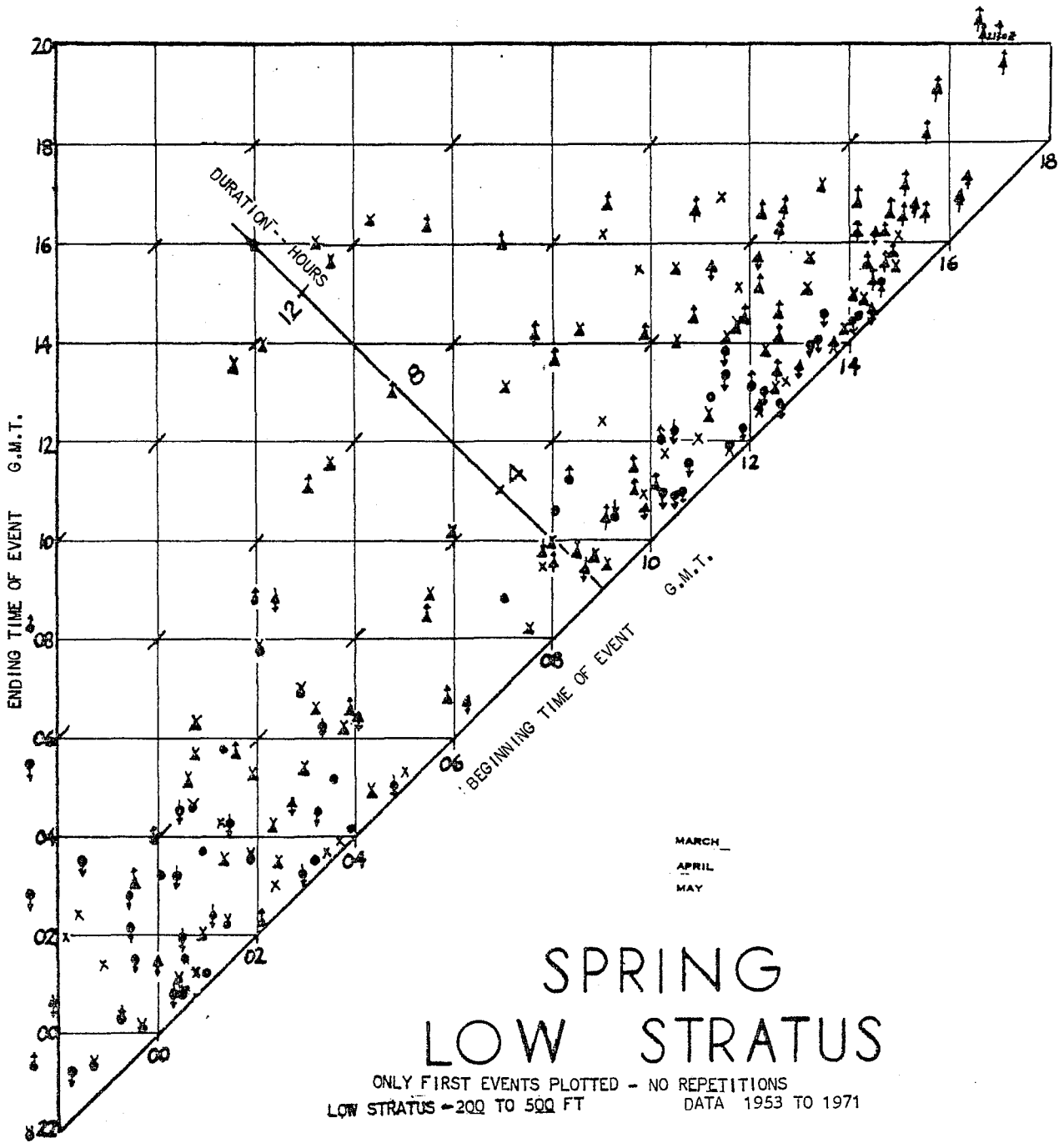


FIGURE 8

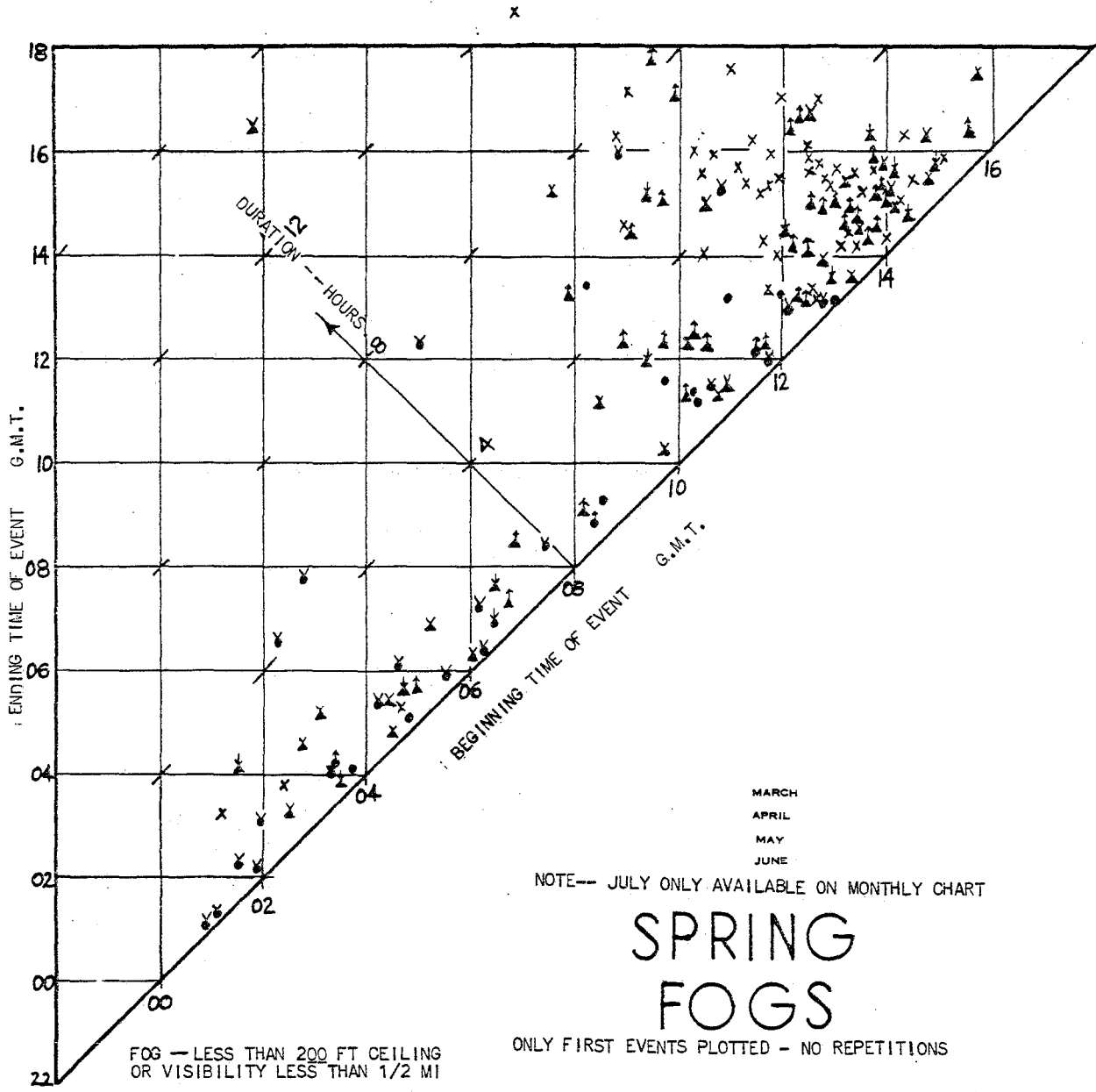
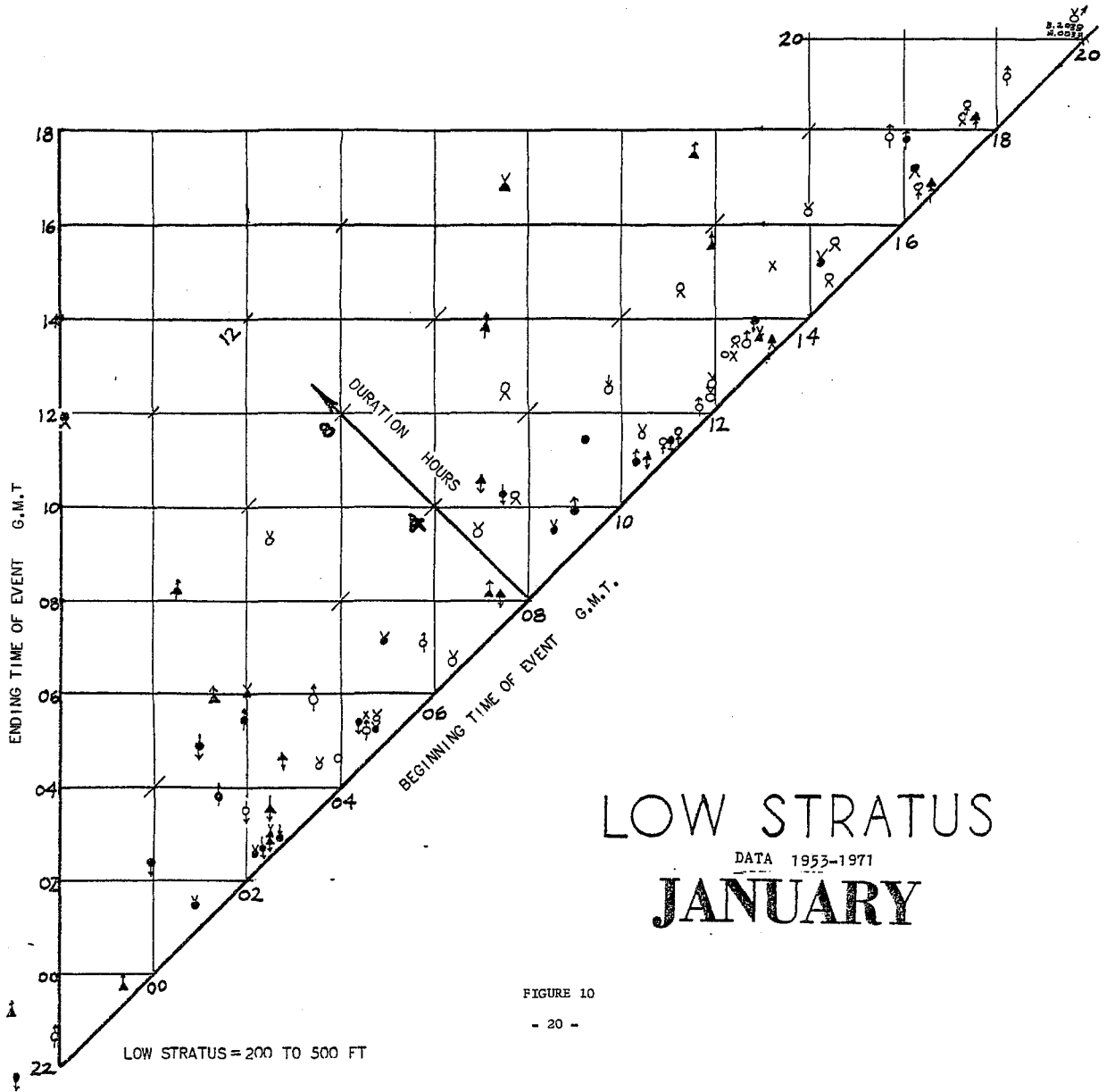


FIGURE 9

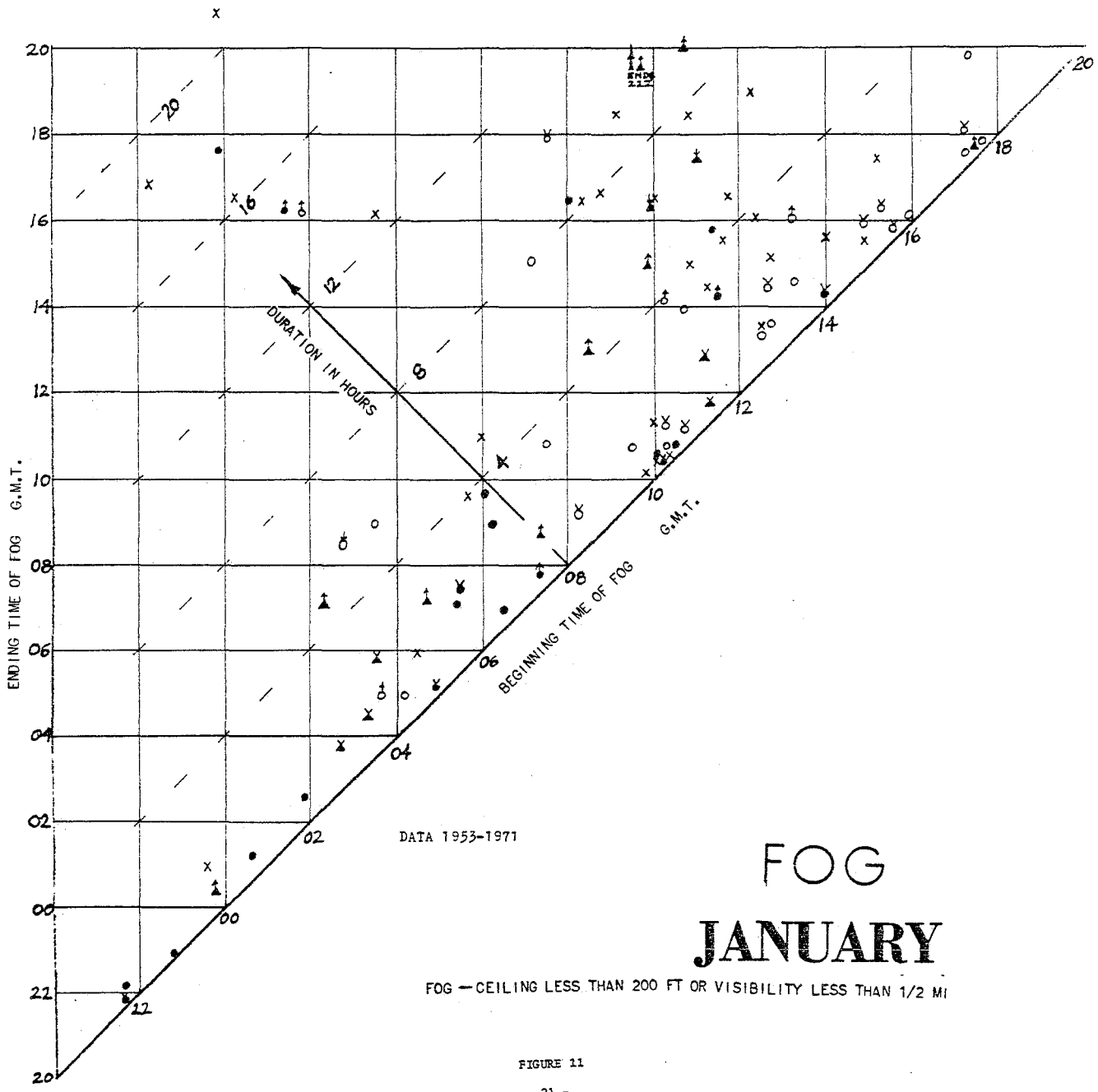


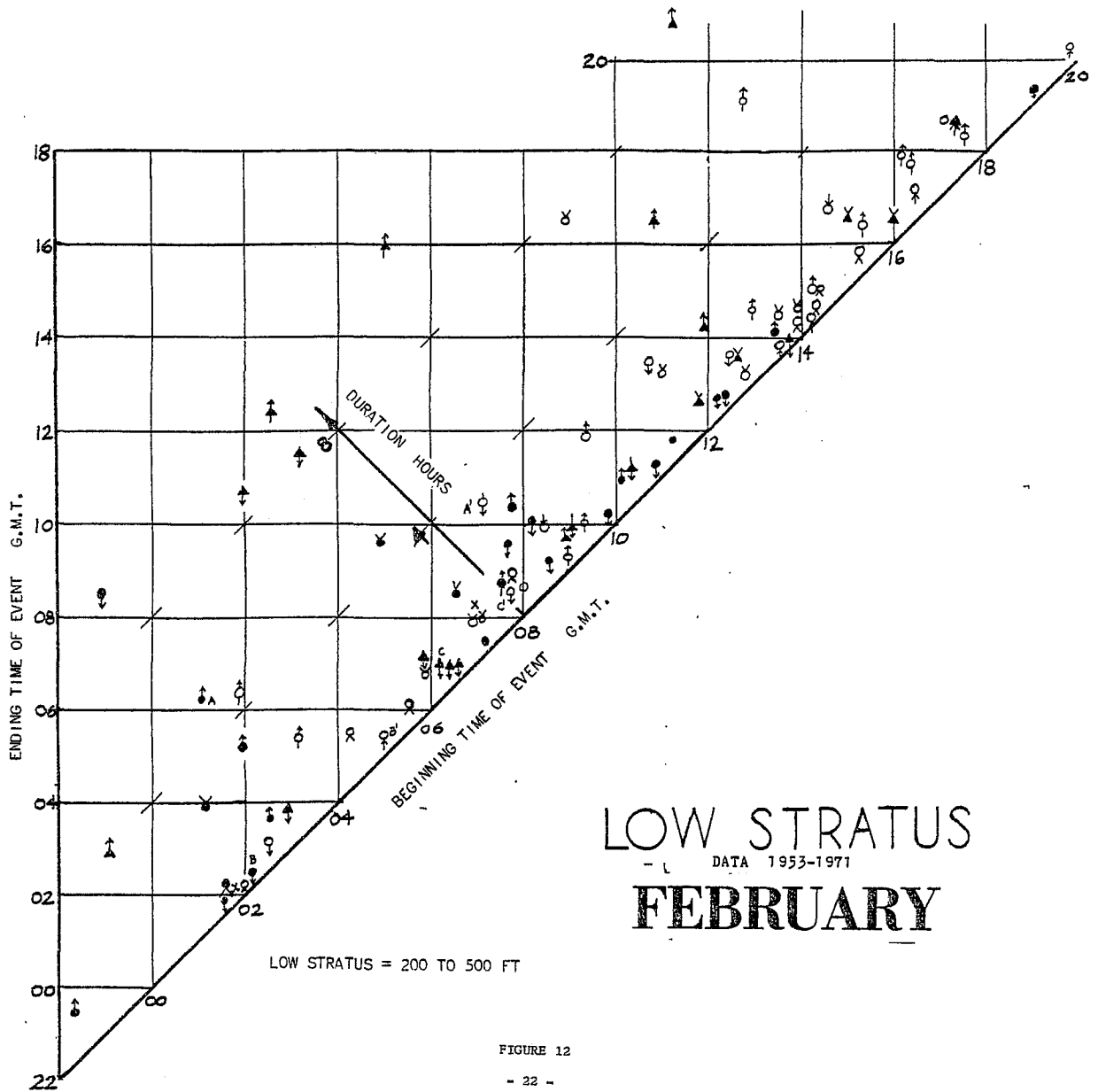
LOW STRATUS

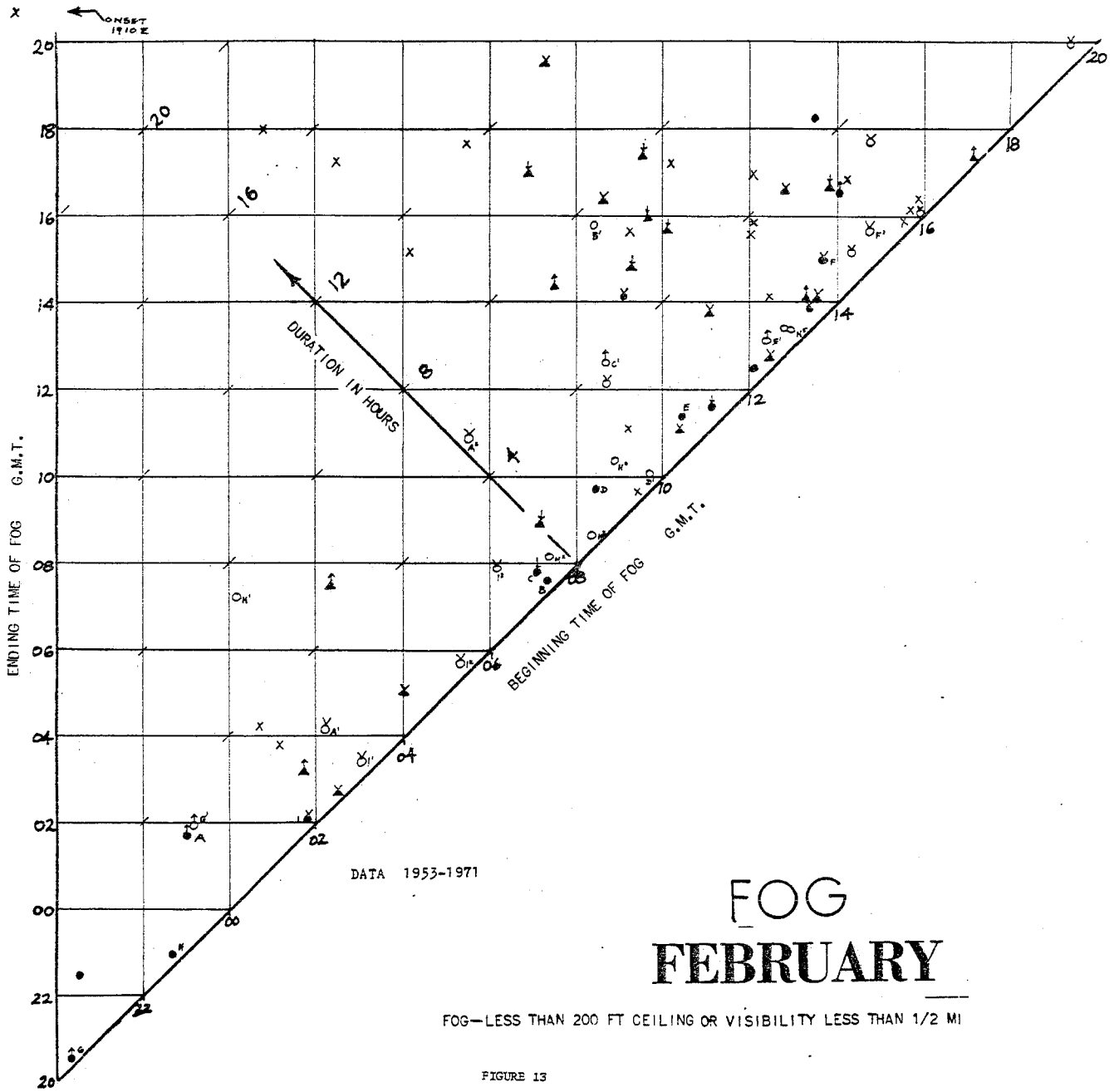
DATA 1953-1971

JANUARY

FIGURE 10
- 20 -







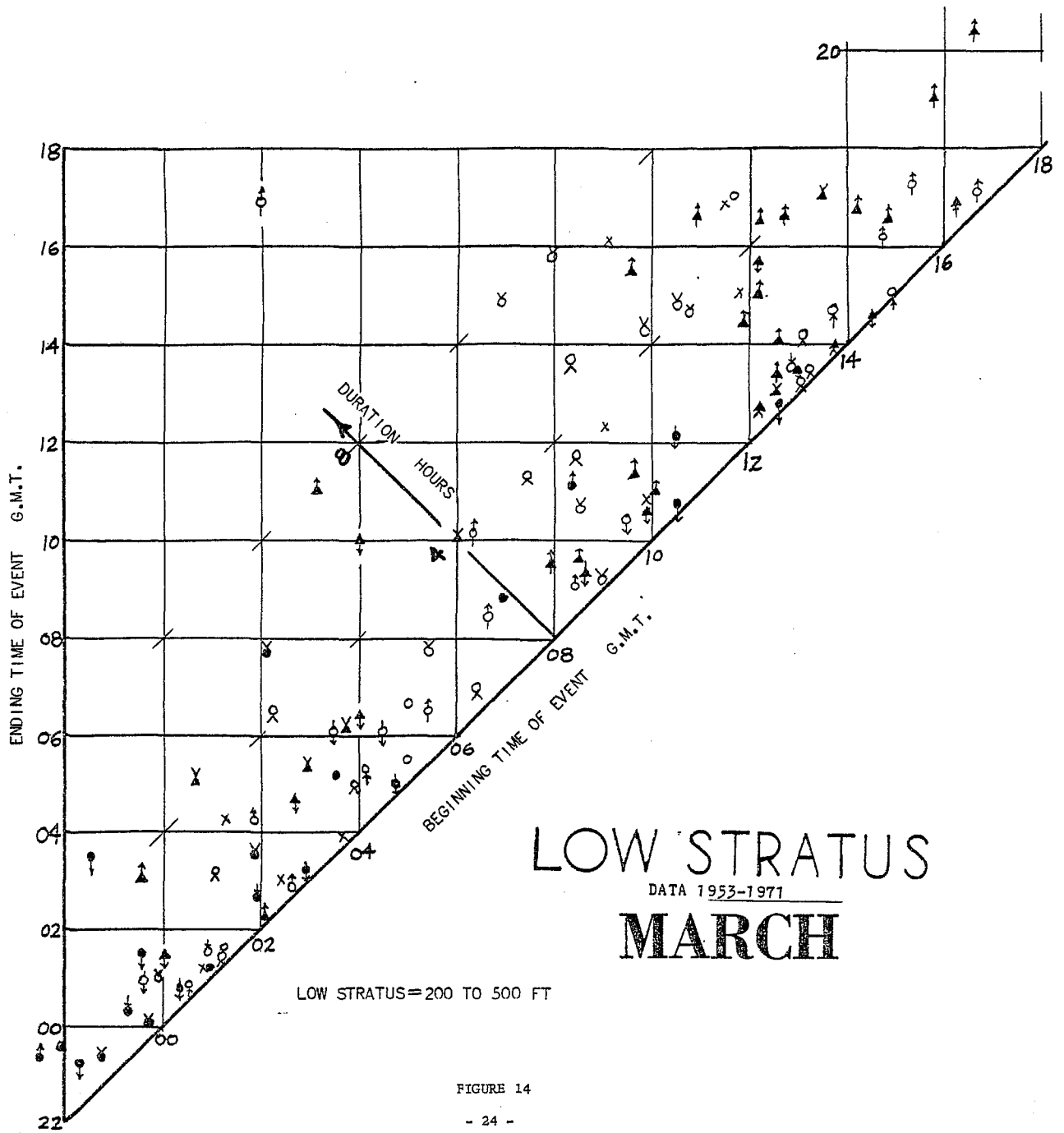
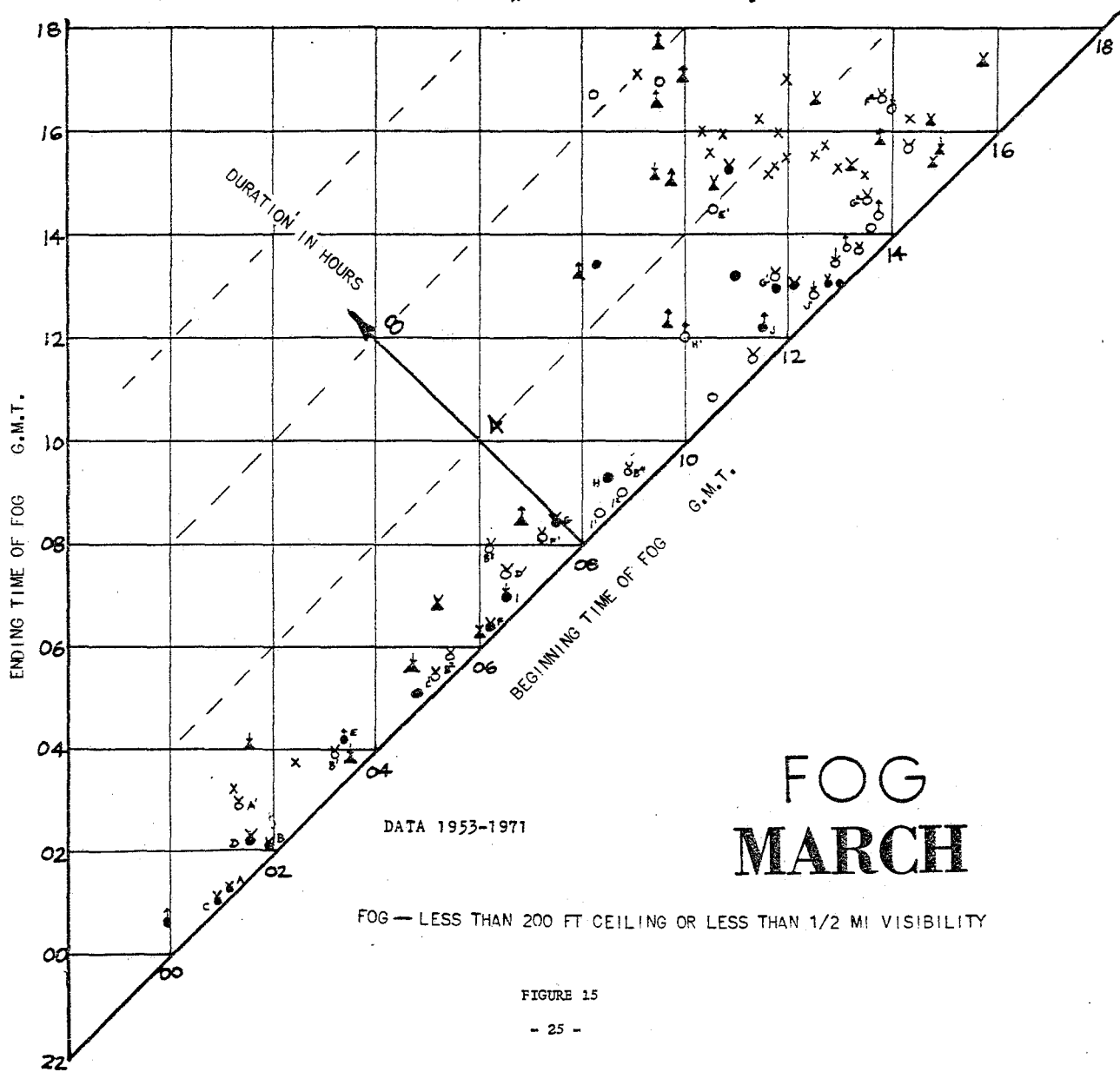
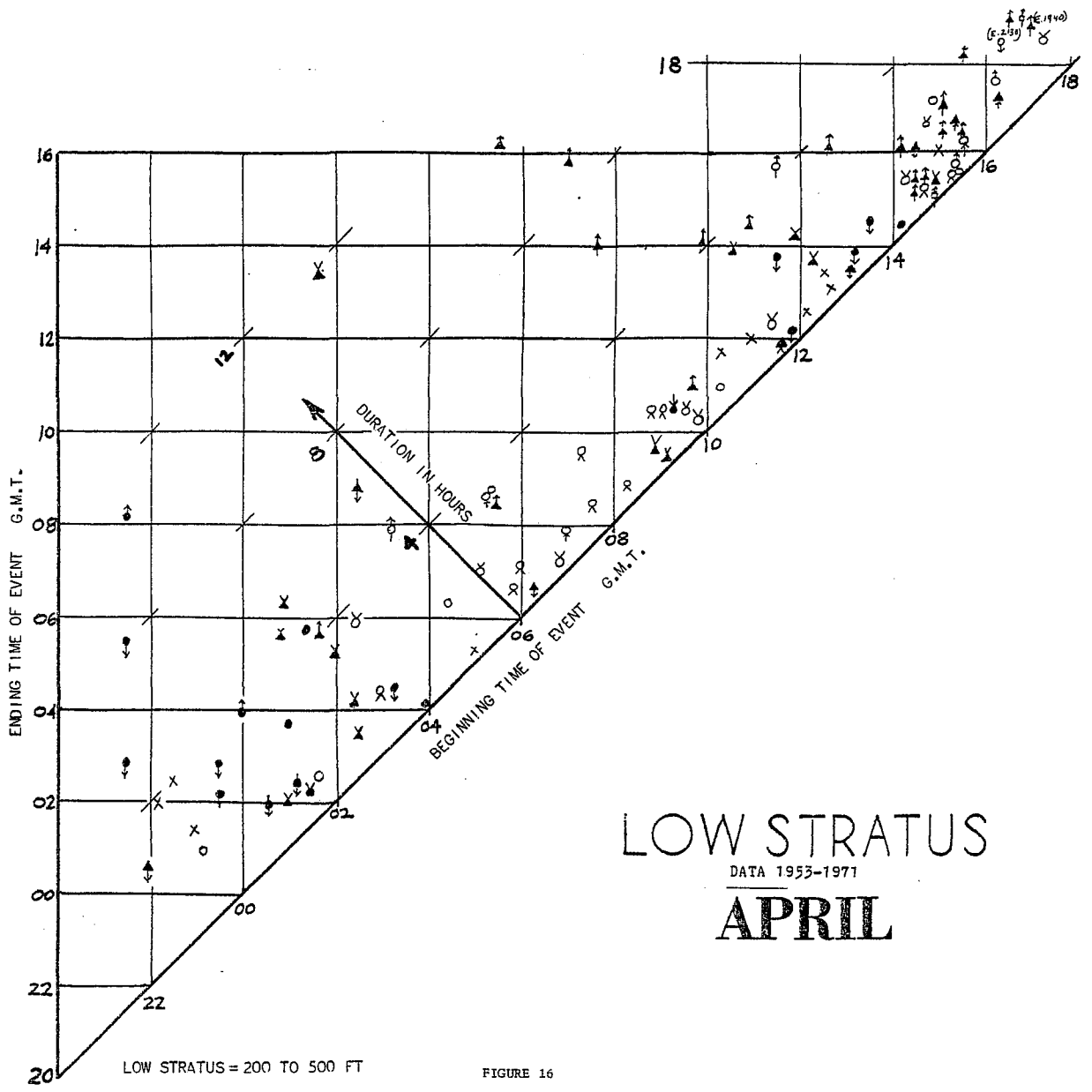


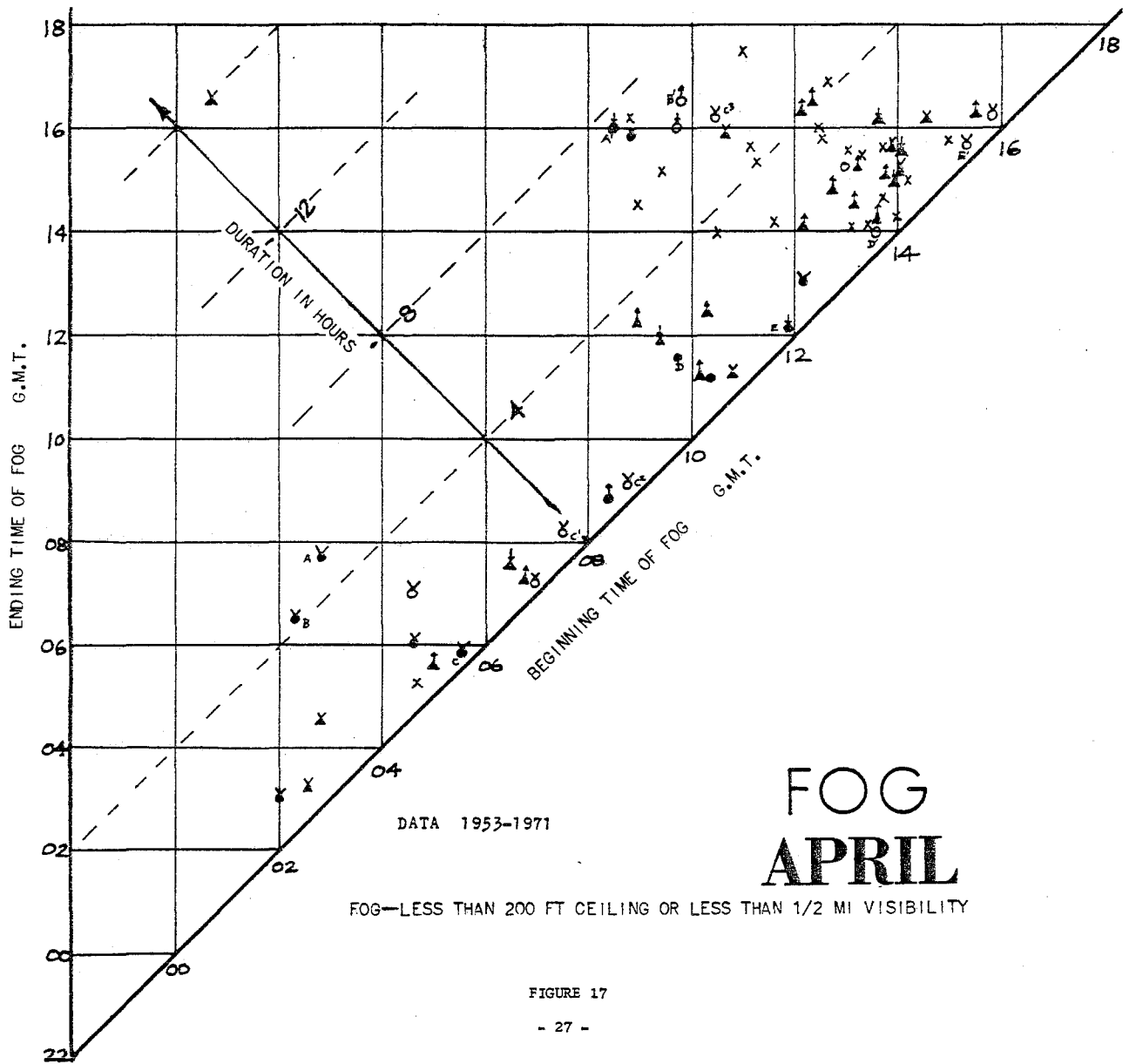
FIGURE 14





LOW STRATUS
 DATA 1953-1971
APRIL

FIGURE 16



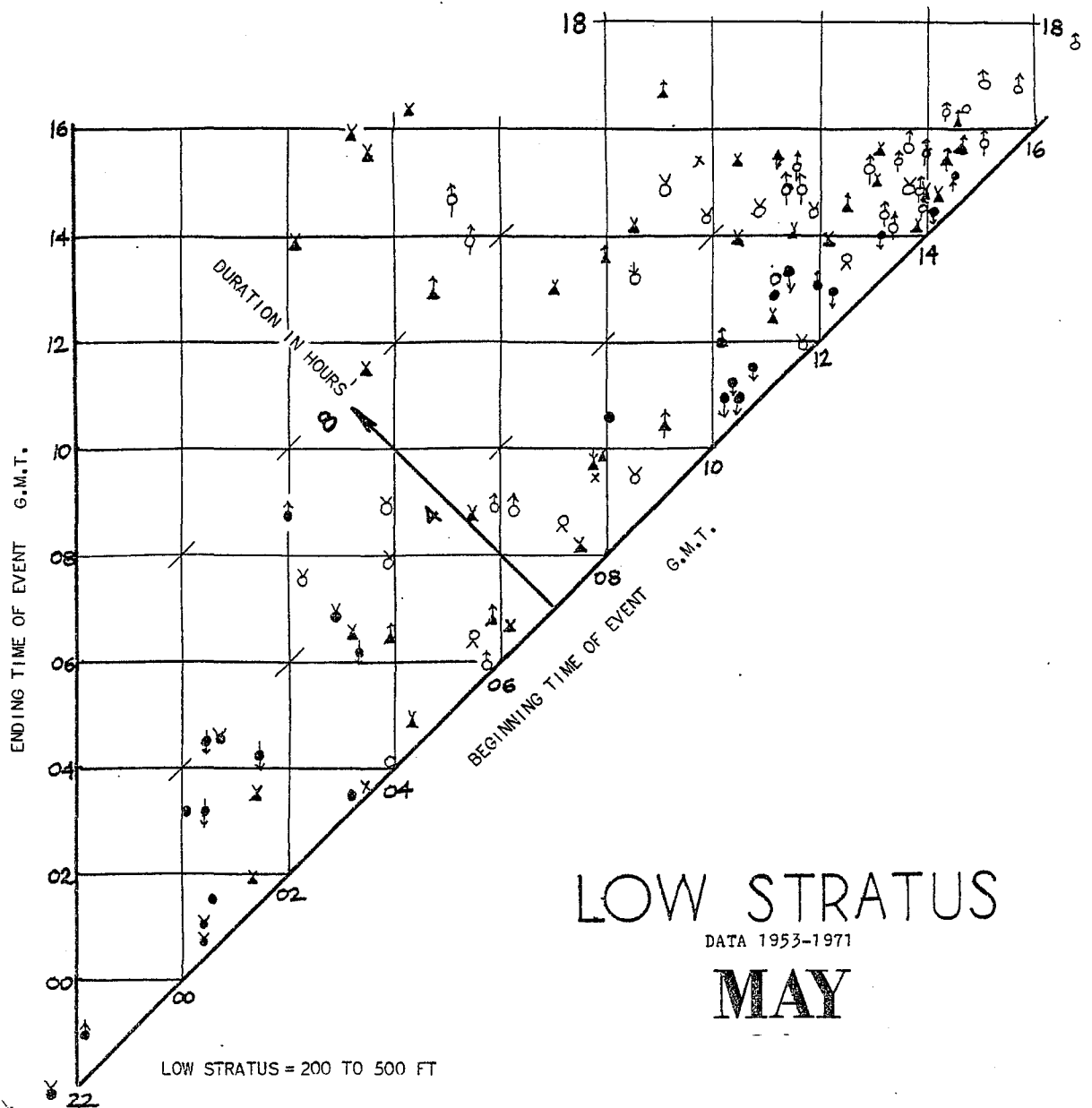
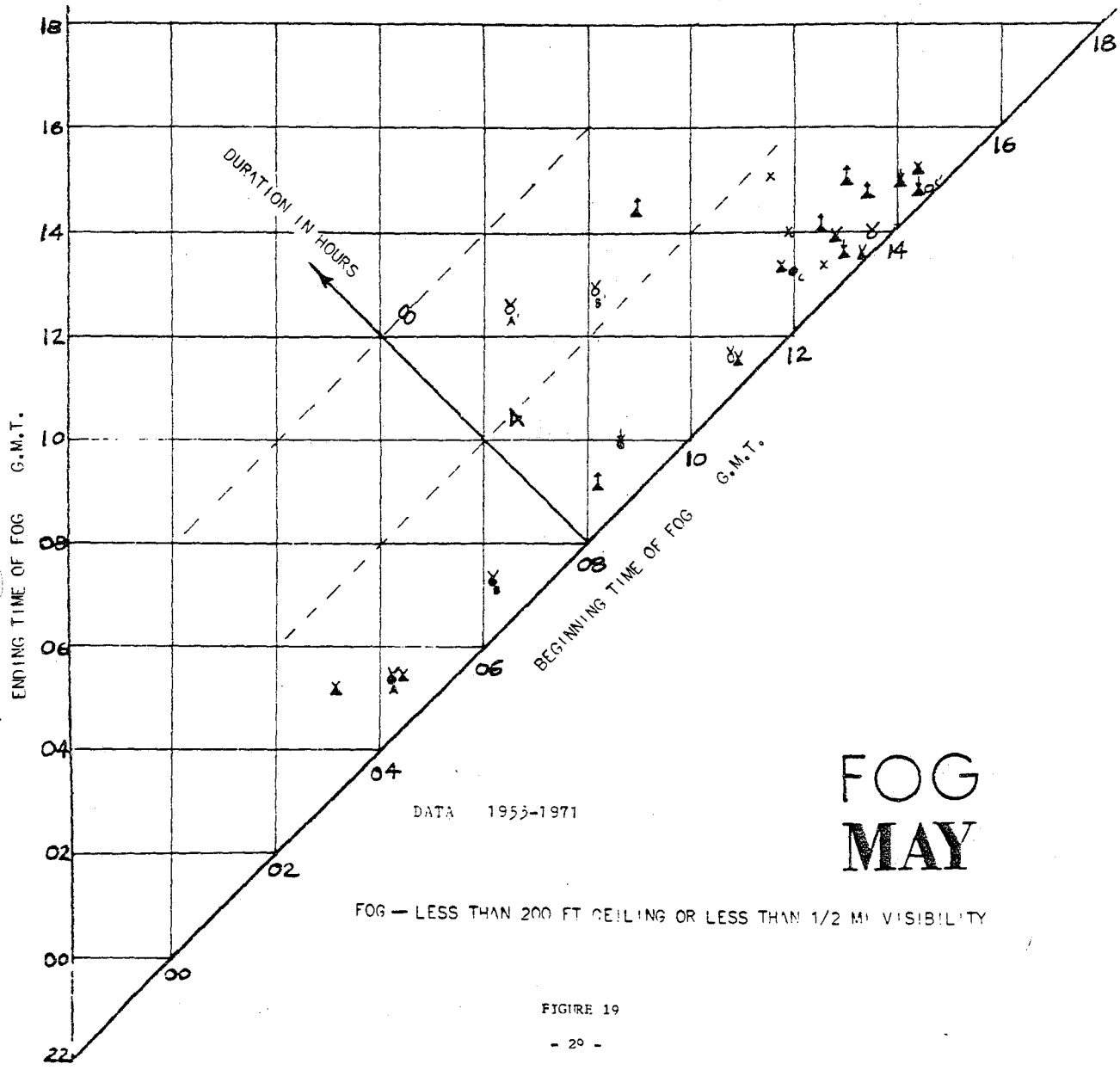


FIGURE 18

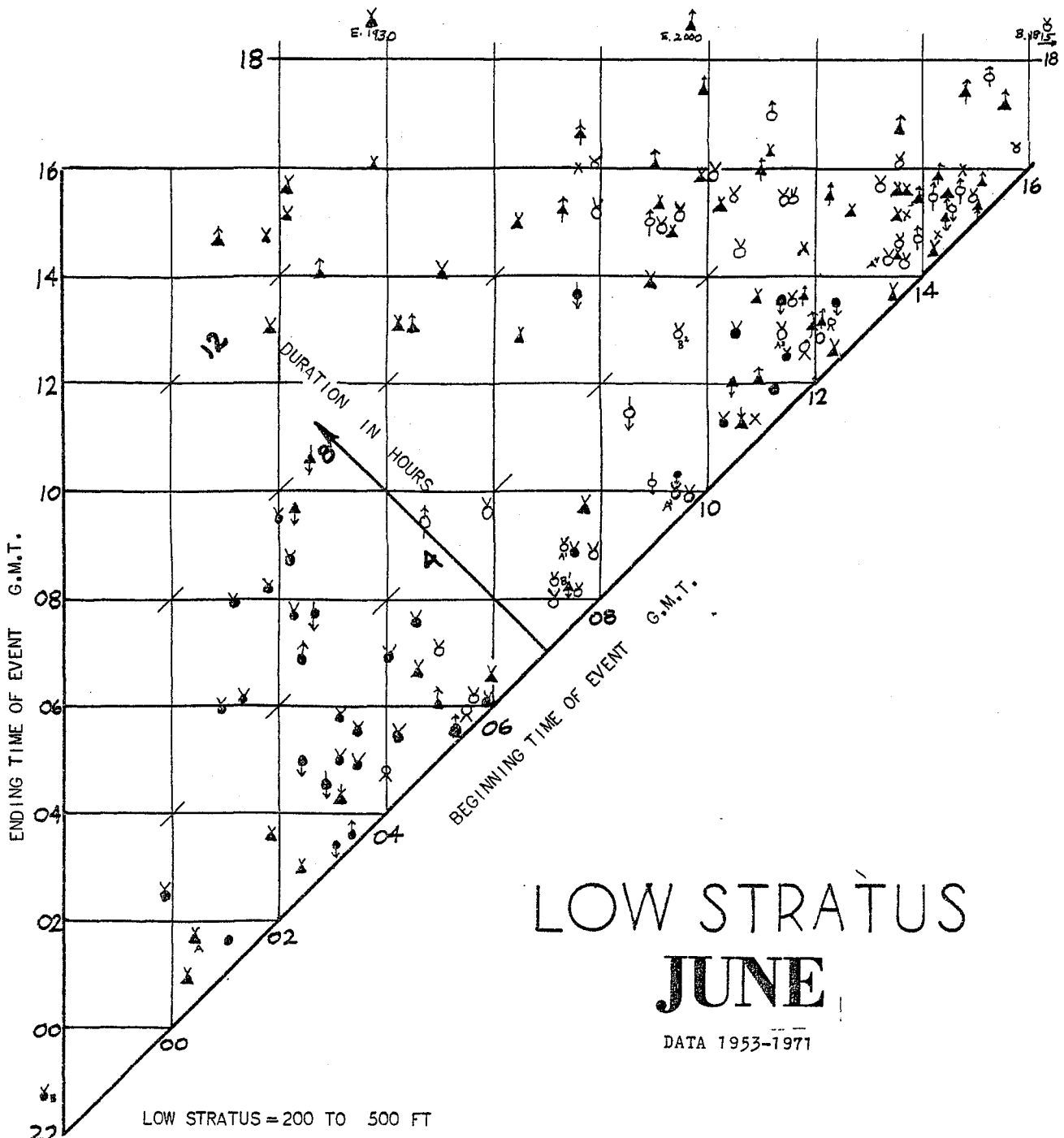


FOG MAY

DATA 1953-1971

FOG - LESS THAN 200 FT CEILING OR LESS THAN 1/2 MI VISIBILITY

FIGURE 19



X

FIGURE 20

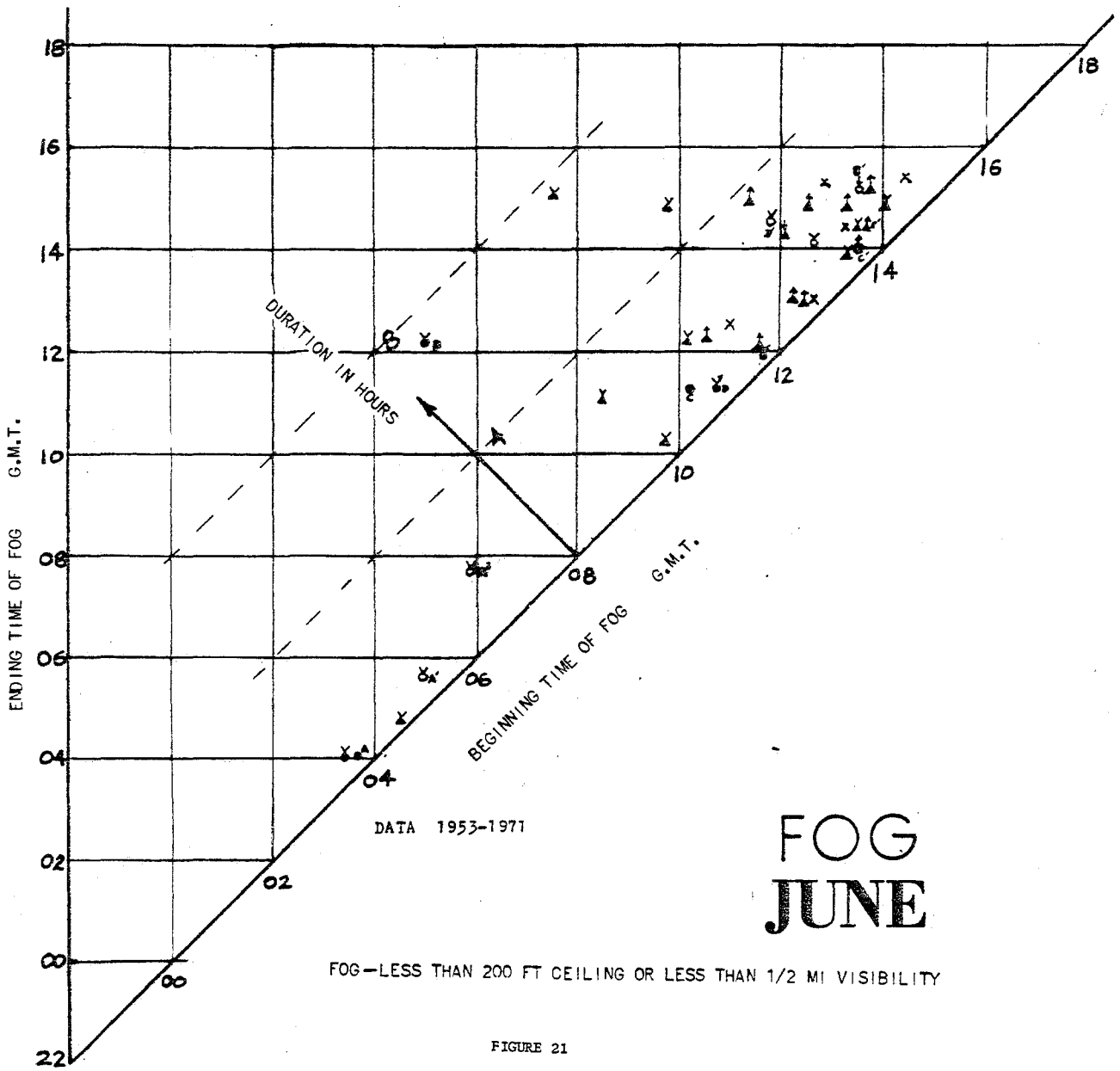


FIGURE 21

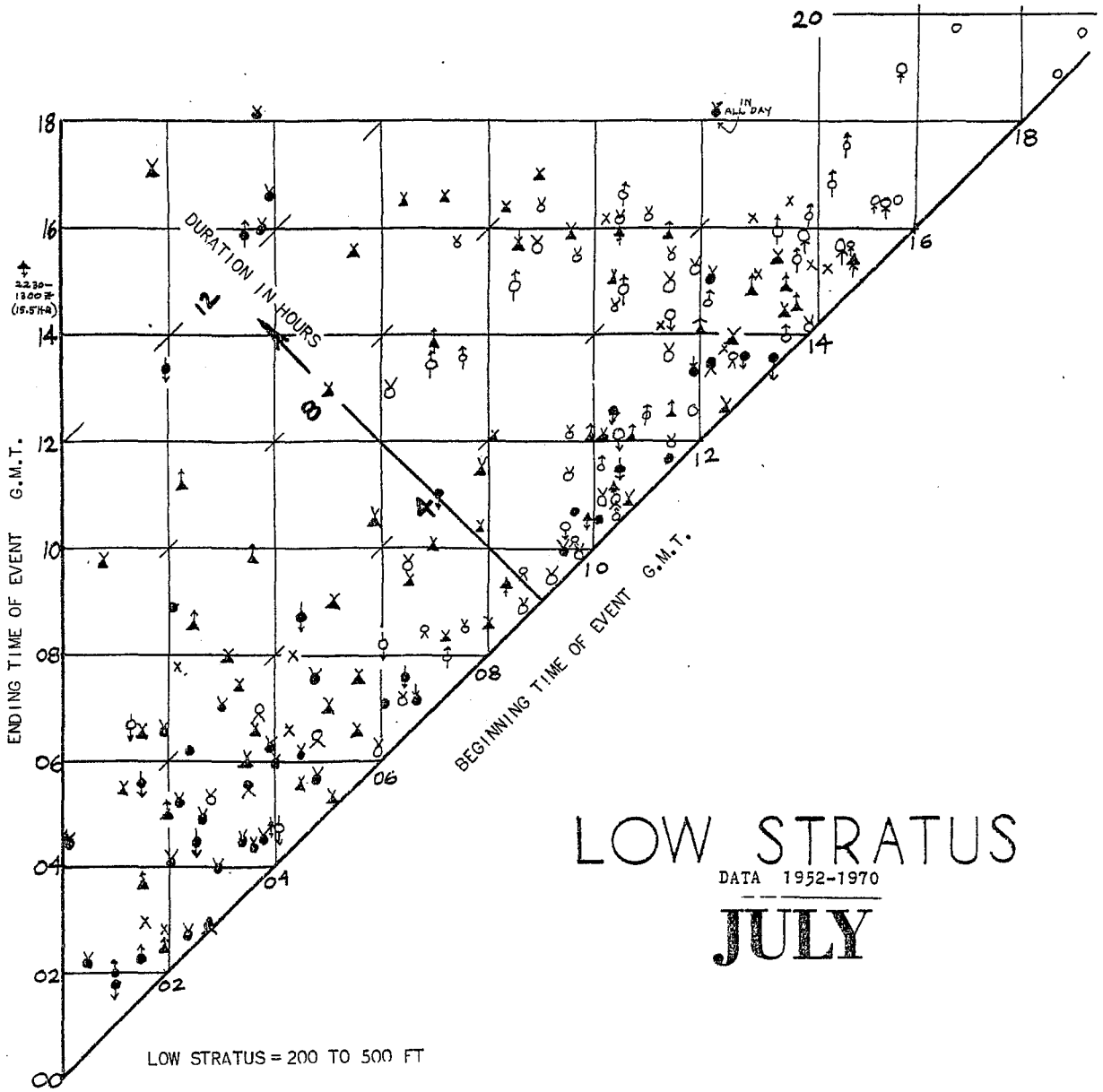
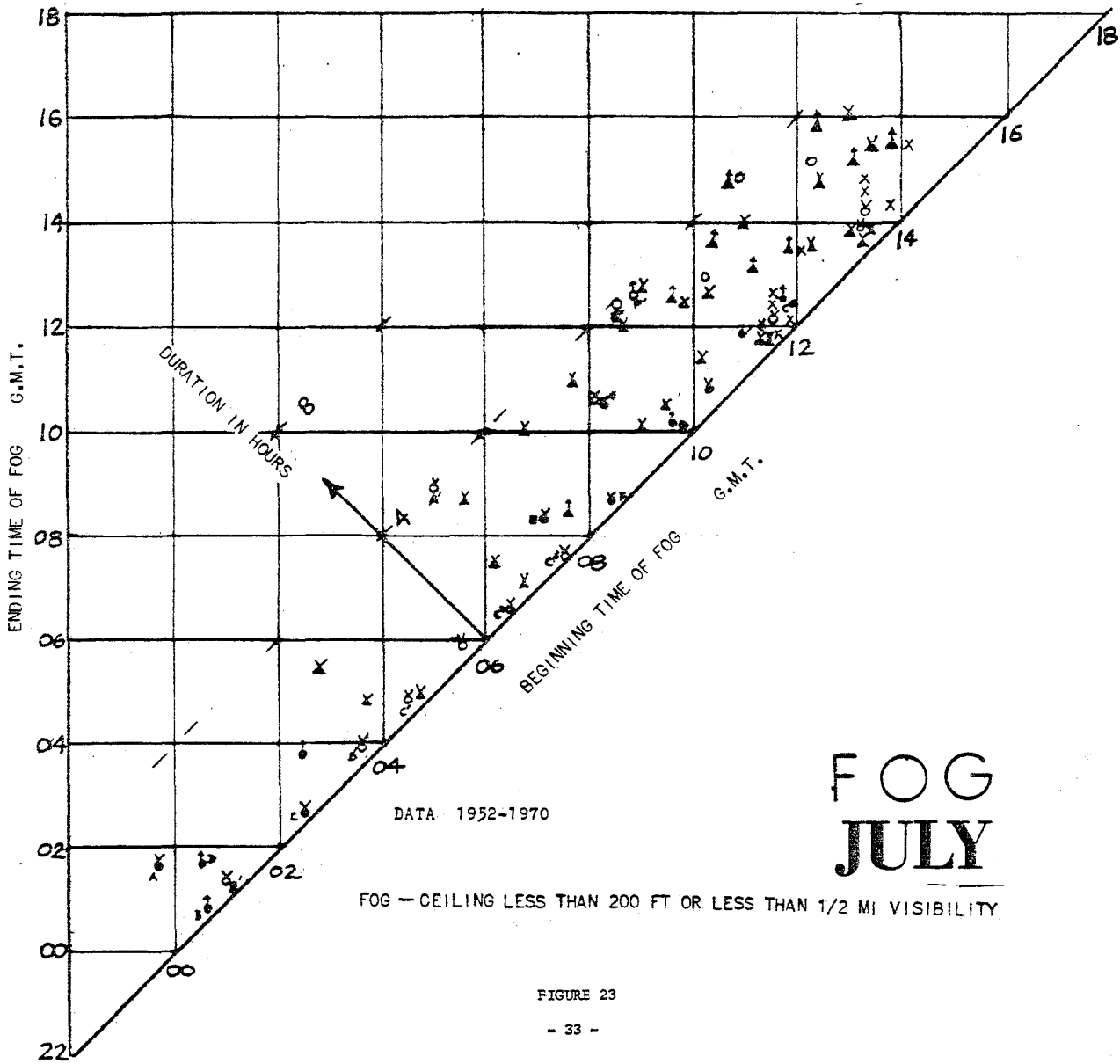


FIGURE 22



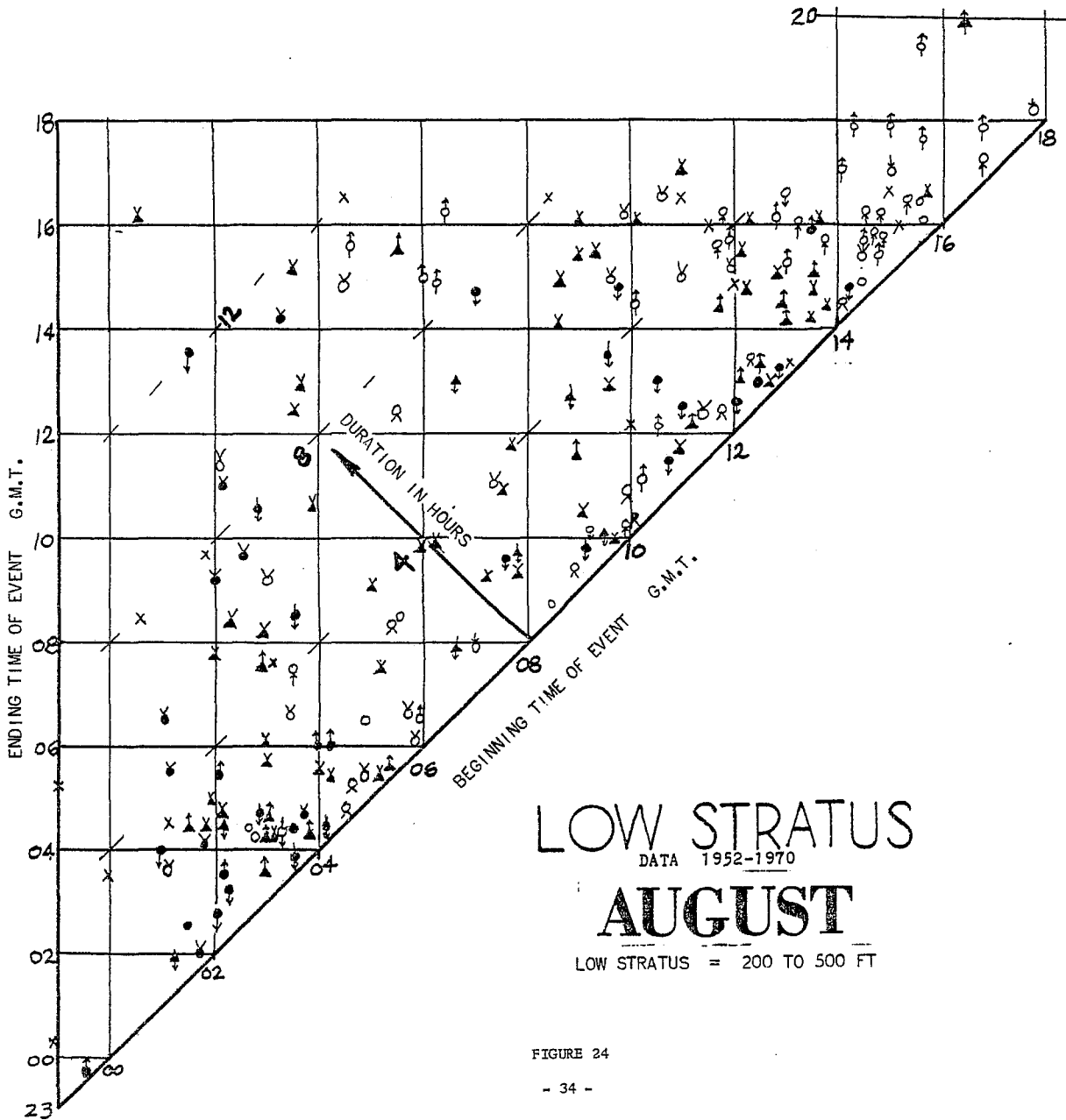
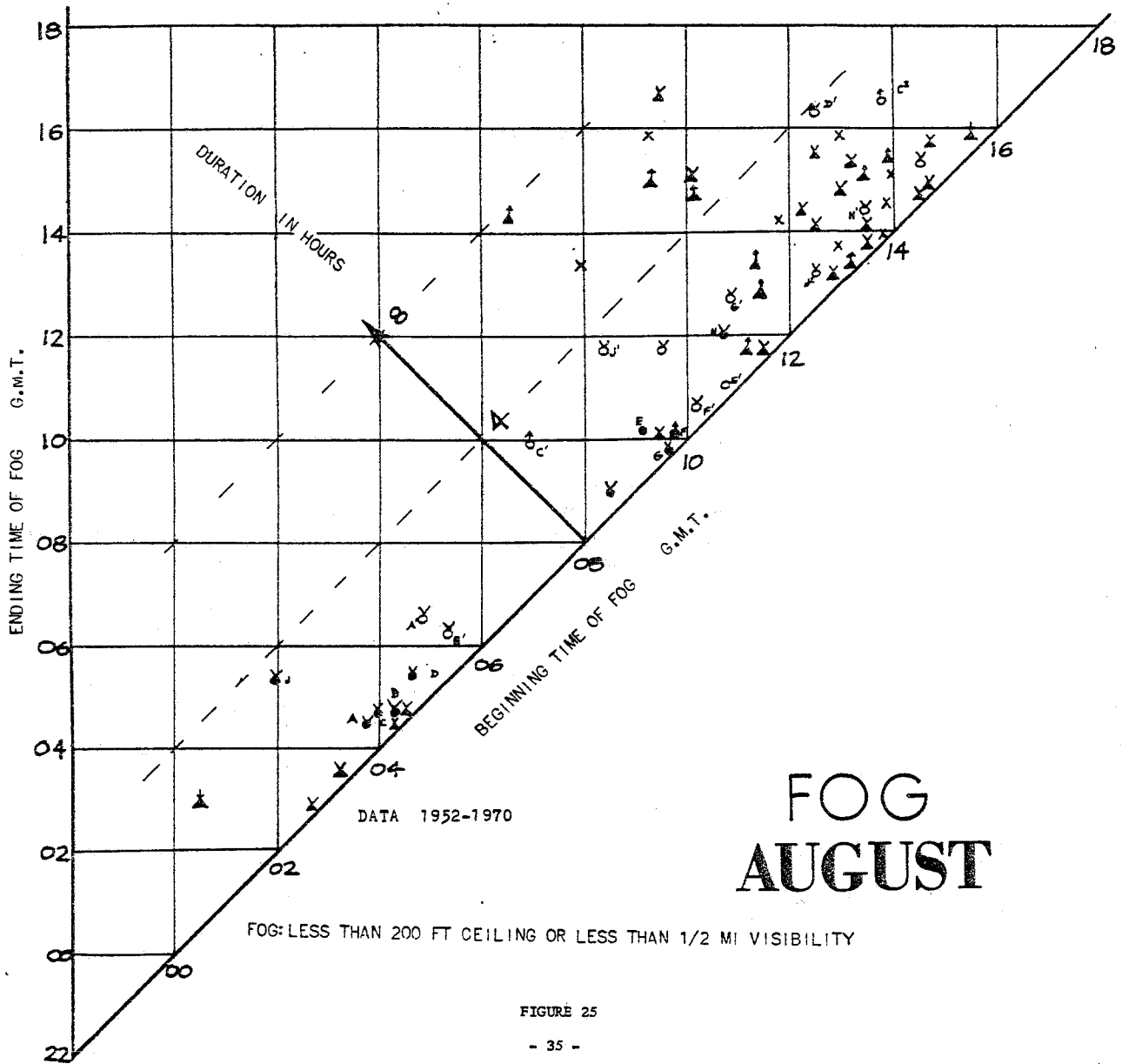


FIGURE 24



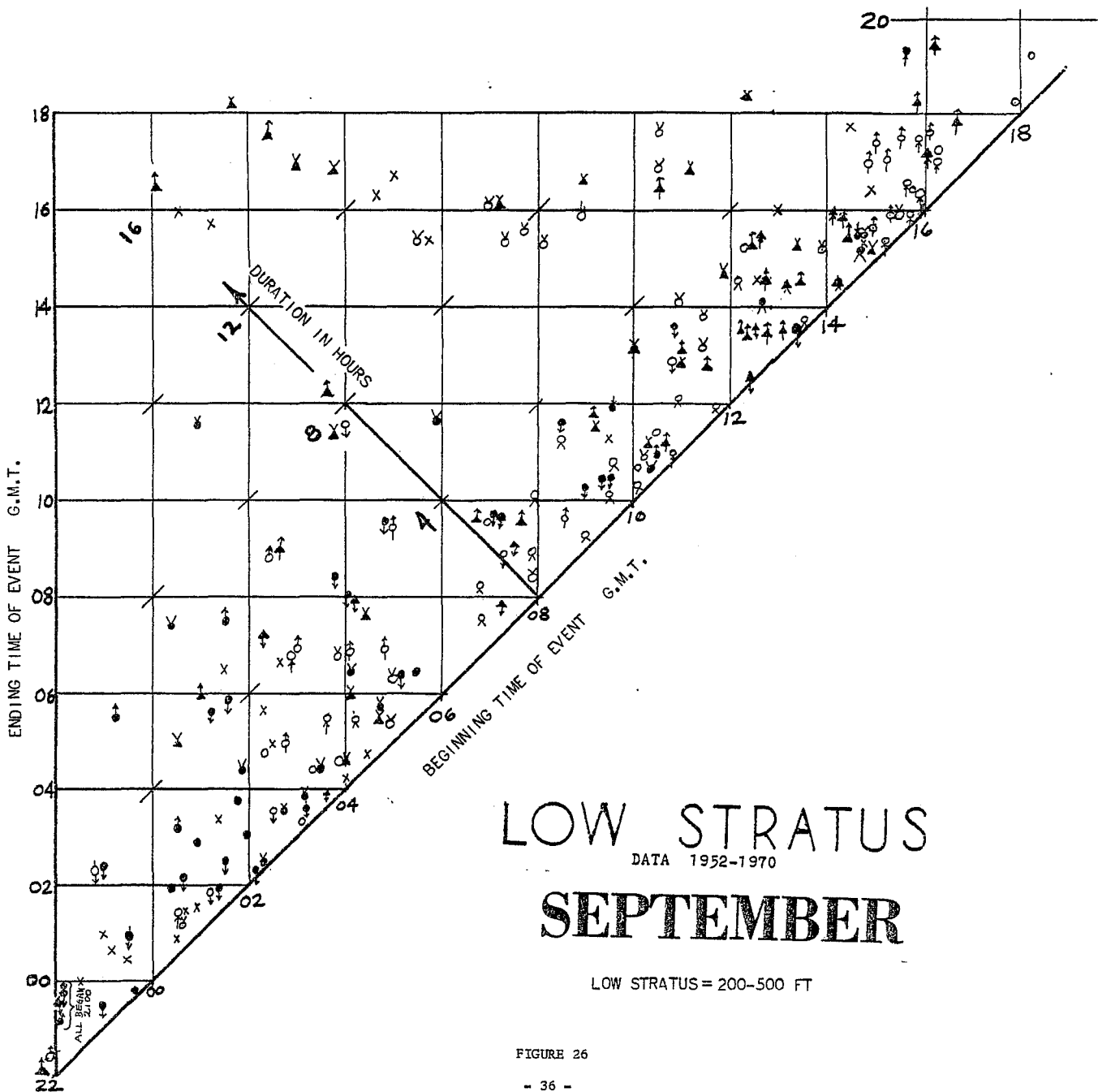


FIGURE 26

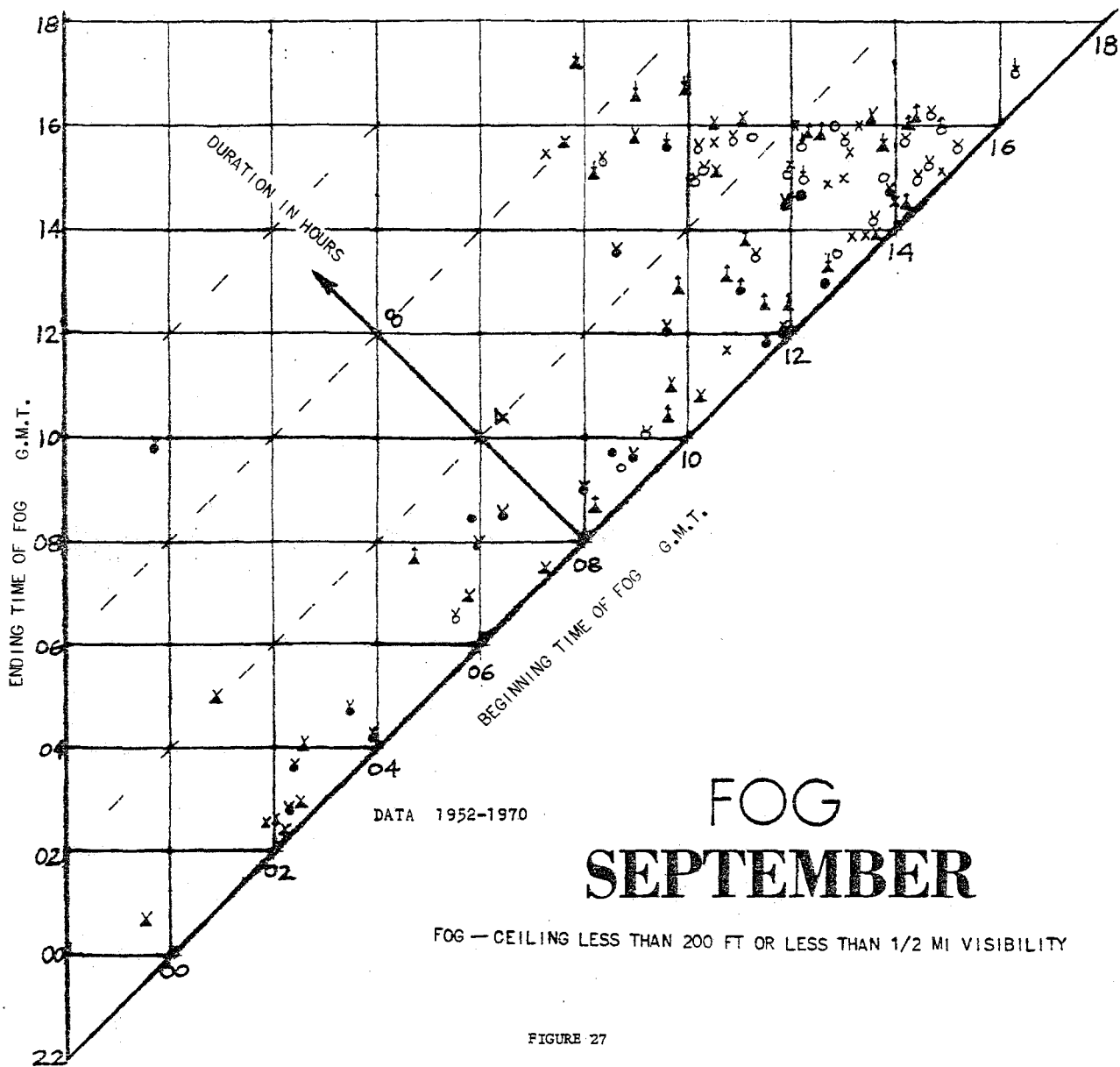


FIGURE 27

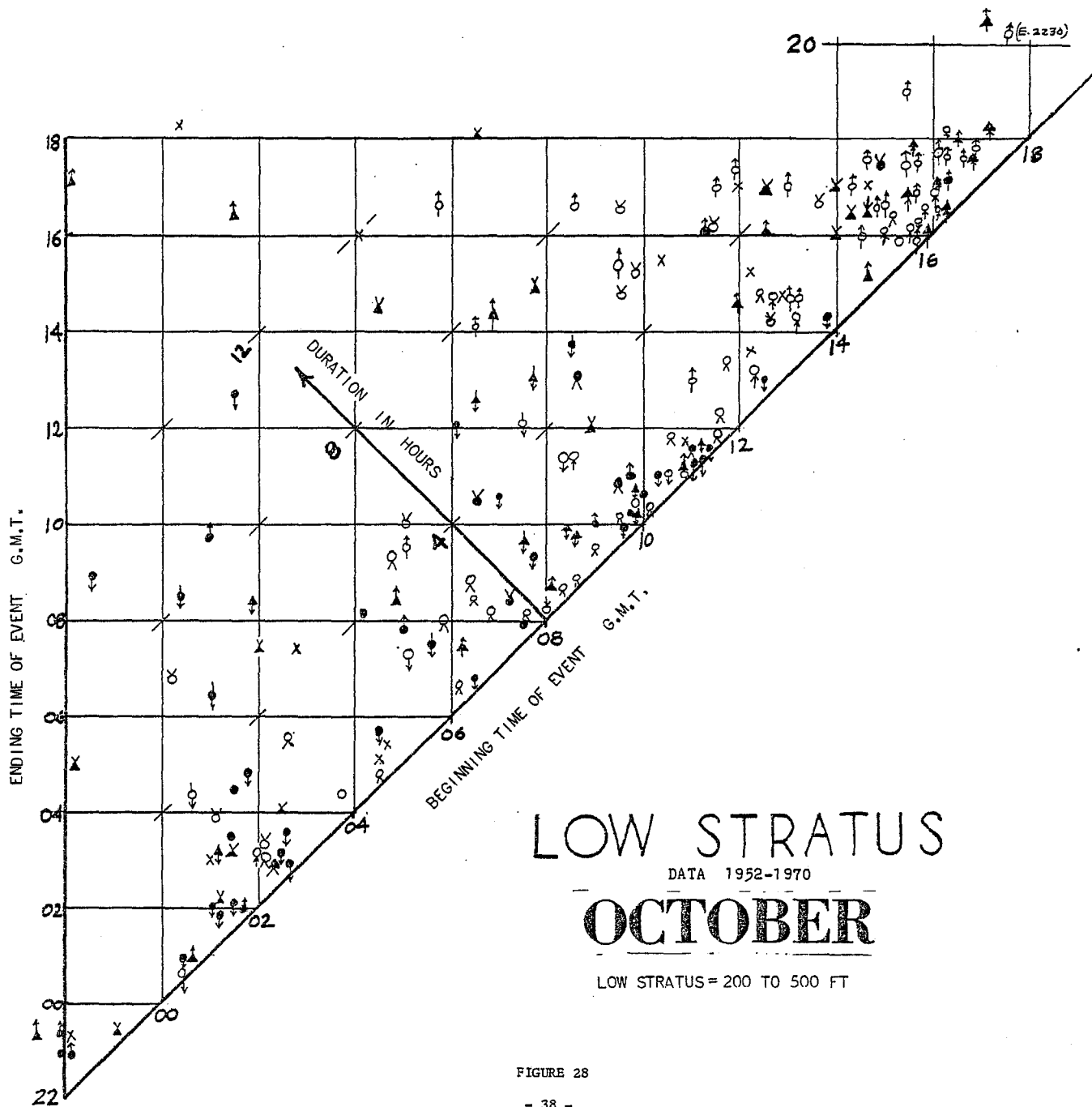
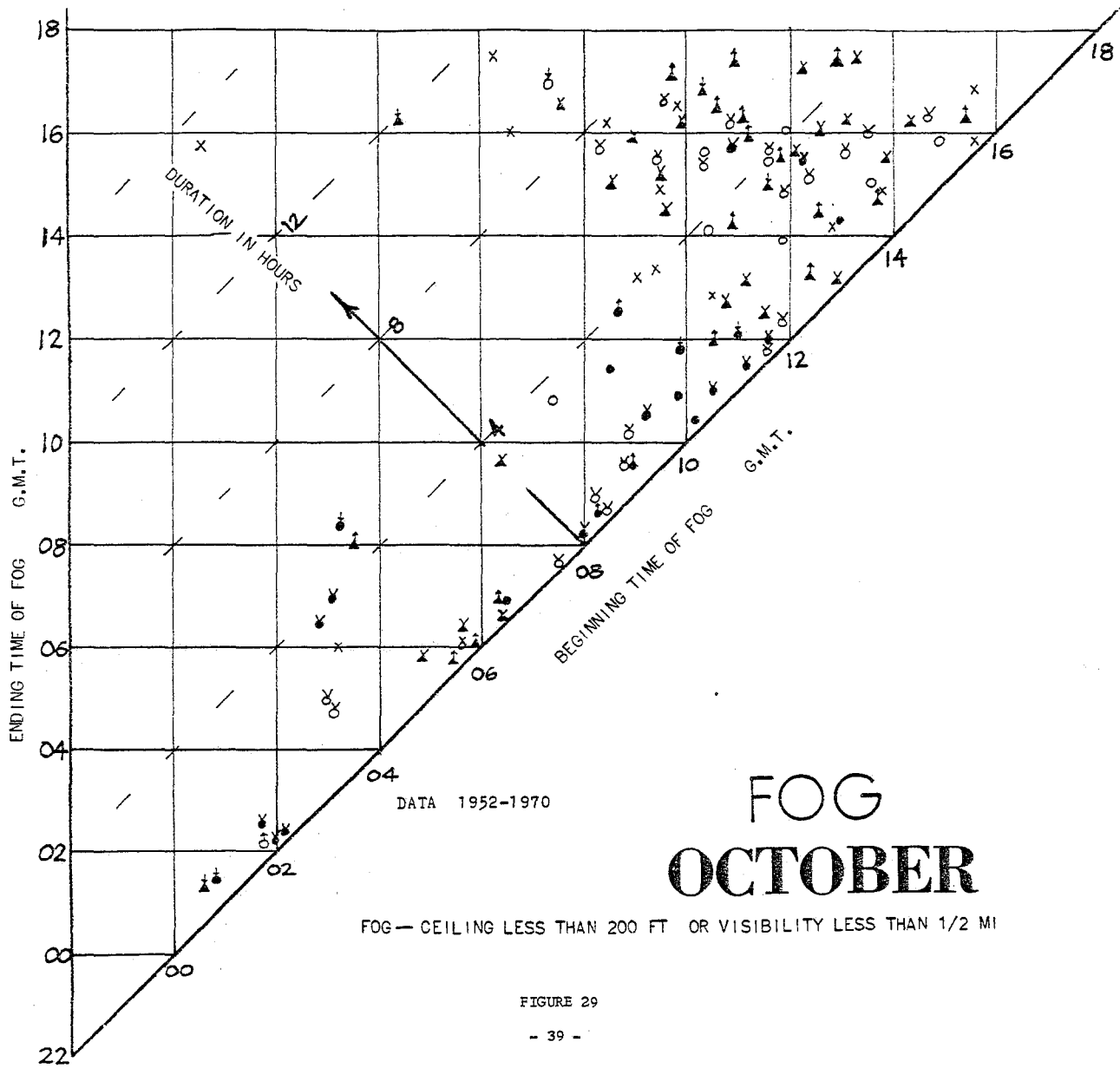
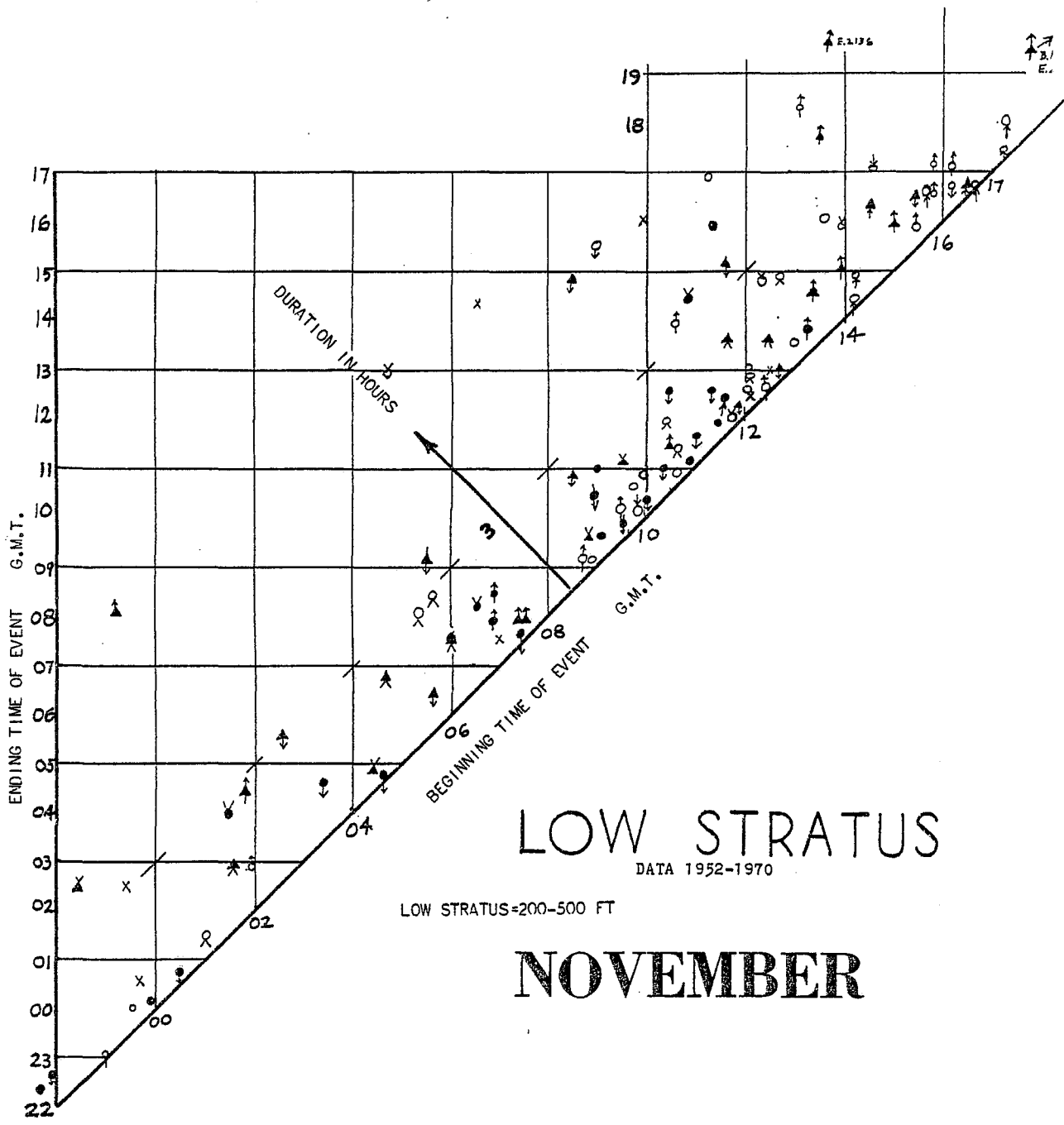


FIGURE 28





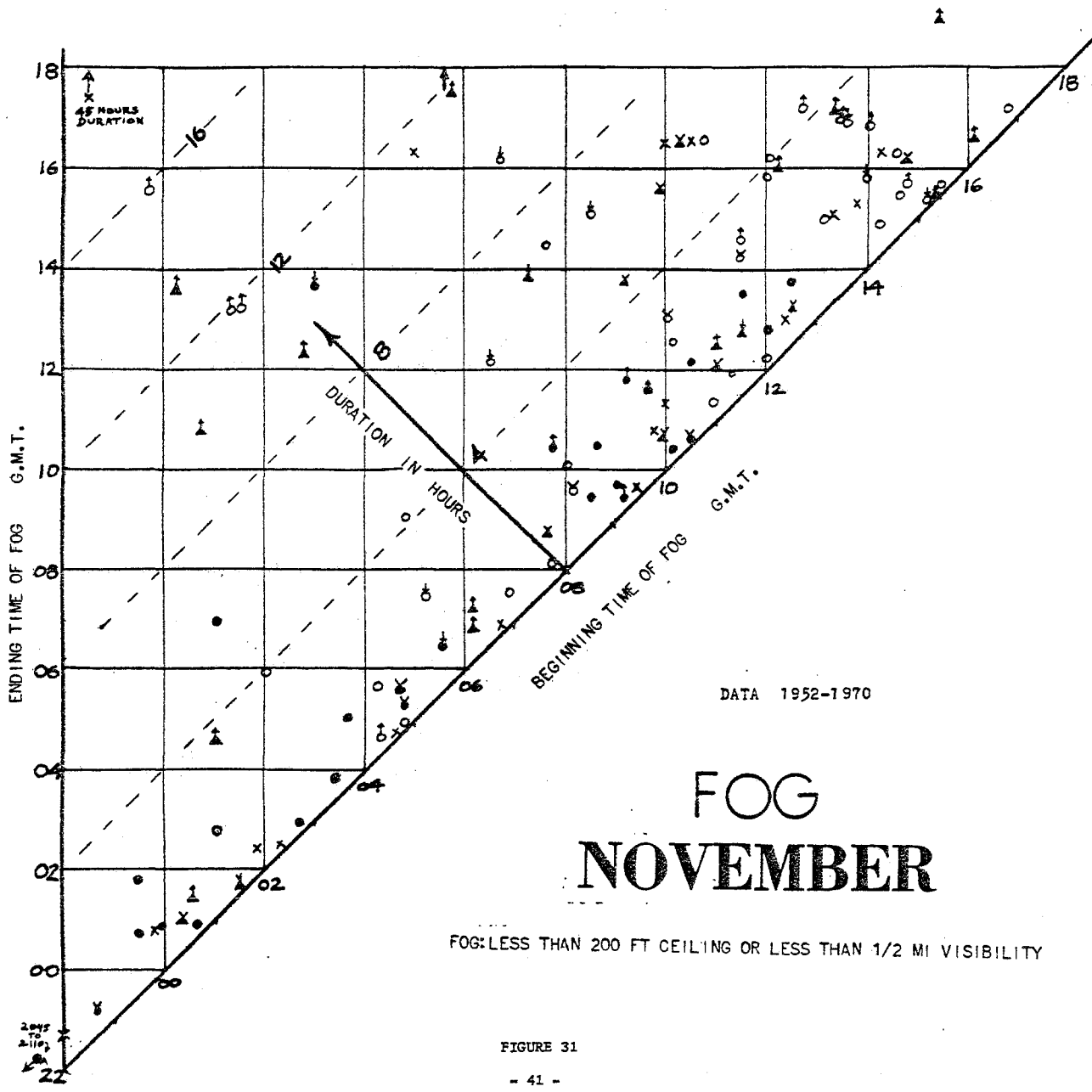
LOW STRATUS

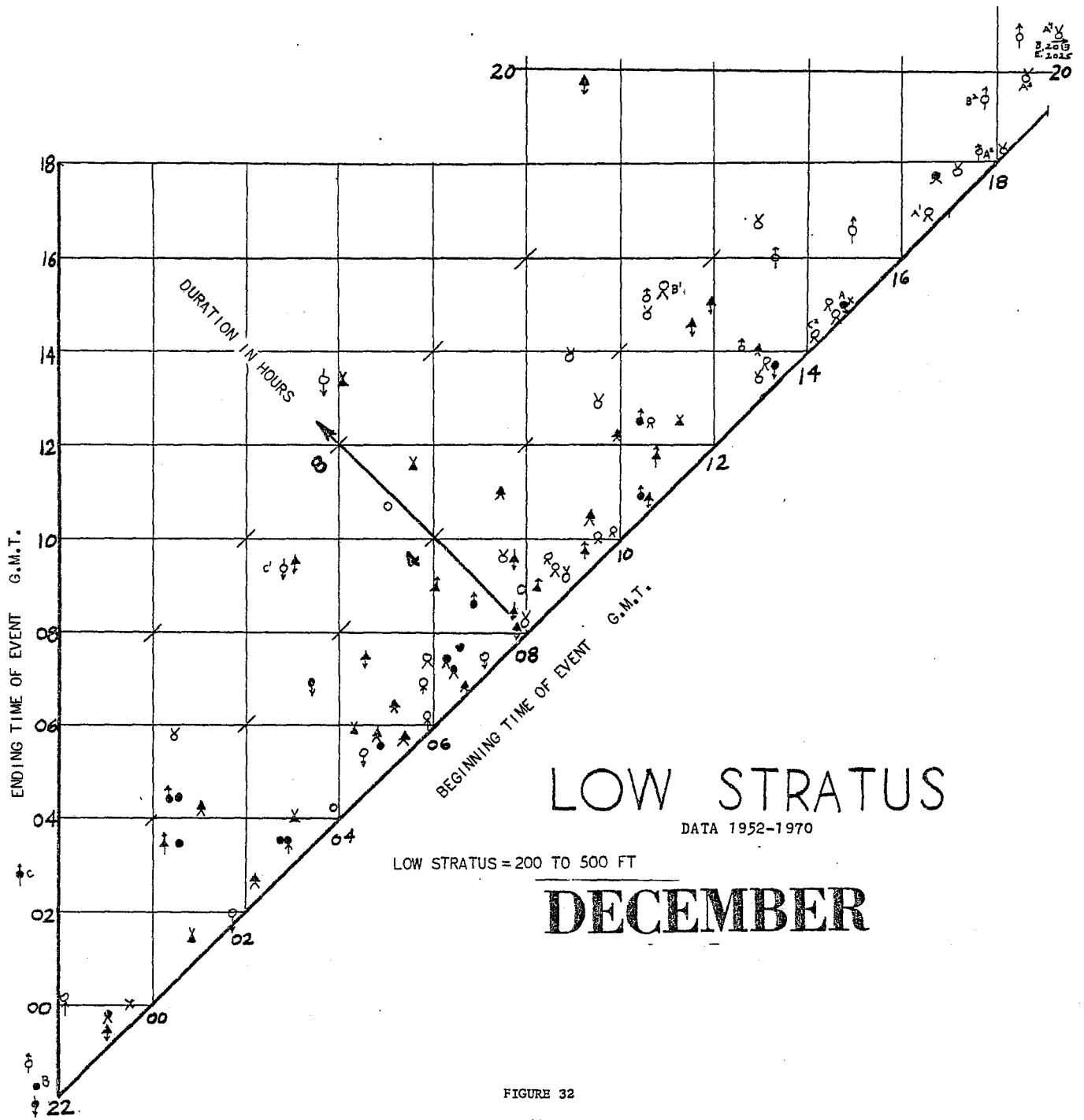
DATA 1952-1970

LOW STRATUS=200-500 FT

NOVEMBER

FIGURE 30





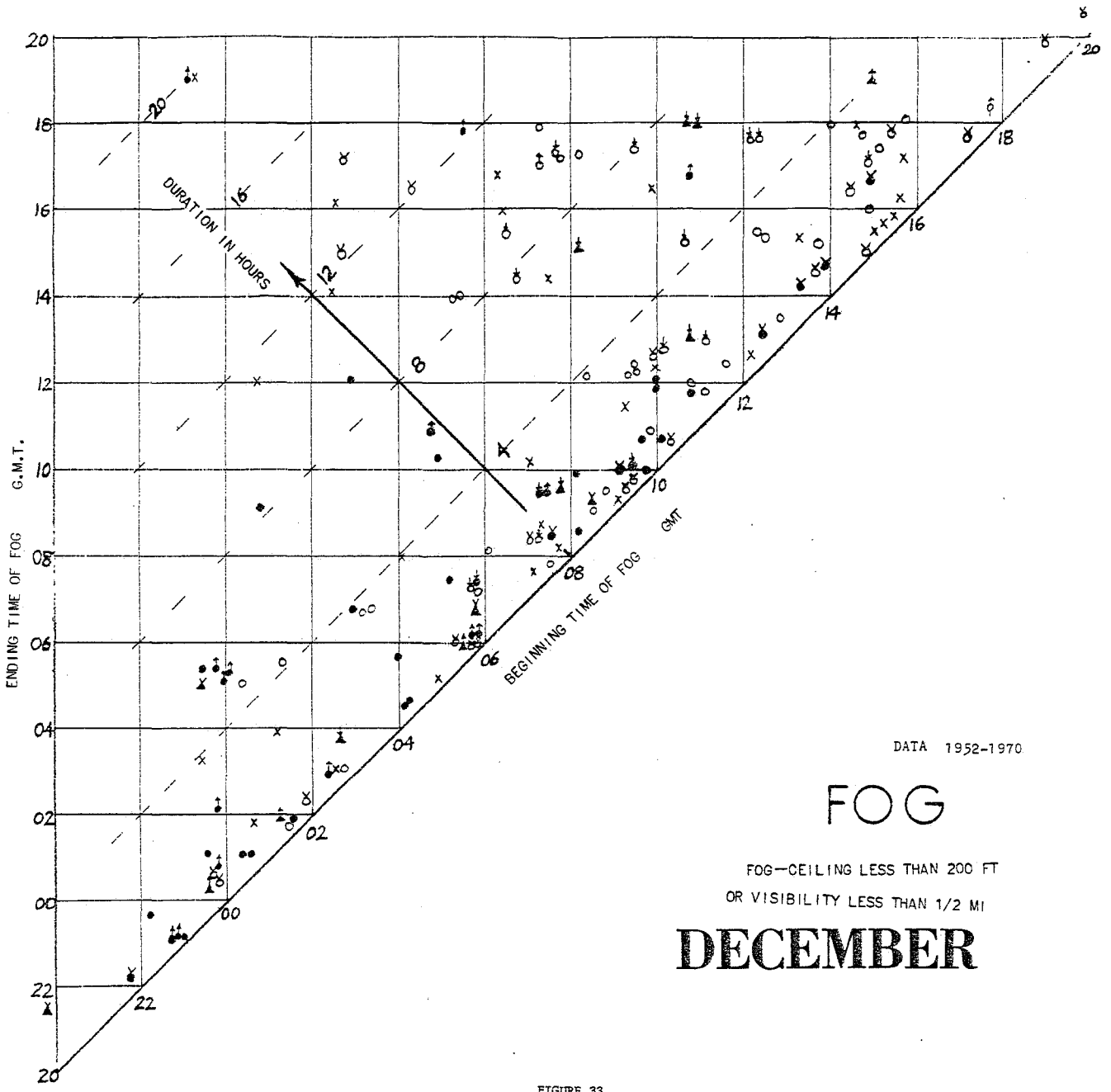


FIGURE 33

Western Region Technical Memoranda: (Continued)

- No. 45/2 Precipitation Probabilities in the Western Region Associated with Spring 500-mb Map Types. Richard P. Augulis, January 1970. (PB-189434)
- No. 45/3 Precipitation Probabilities in the Western Region Associated with Summer 500-mb Map Types. Richard P. Augulis, January 1970. (PB-189414)
- No. 45/4 Precipitation Probabilities in the Western Region Associated with Fall 500-mb Map Types. Richard P. Augulis, January 1970. (PB-189435)
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