Det. 10, 24th Weather Squadron
Randolph AFB, Texas 78148

LYLE STRATUS STUDY
FOR
FORECASTING GULF STRATUS
AT
RANDOLPH AFB, TEXAS

BY

MAJOR RICHARD W. LYLE, USAFRES

JANUARY 1969

LYLE STRATUS STUDY

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LYLE STRATUS STUDY
FOR
FORECASTING GULF STRATUS AT RANDOLPH AFB, TEXAS

HISTORY OF STRATUS STUDY

Problem: Forecasting the occurrence and dissipation of stratus in the San Antonio area has been a problem since aircraft operations began. Many studies have been made since 1930 to determine an accurate method of forecasting the formation of stratus. Some of those that have worked on the problem have included J. J. George, Wayne Leach, Zahn and others not as well known. Most of the studies have been concerned with the formation of stratus rather than dissipation although some concluded that dissipation time varied with the cloud thickness. The parameters used by most of the studies in the past have included moisture and wind flow.

Action: Since the terrain rises from sea level along the Texas Gulf coast to about seven hundred to eight hundred feet in the San Antonio area, a nearly saturated air mass over the Gulf of Mexico would cool adiabatically to saturation if it were moved upslope into the San Antonio area. A further cooling due to nocturnal radiational heat loss acts to raise the relative humidity and bring an unsaturated air mass toward saturation. The downward sloping terrain toward the East and South makes the favored wind direction for stratus formation to be from 90° to 180° and other directions generally unfavorable since they would constitute downslope wind conditions and consequent adiabatic warming and drying. Most of the stratus studies have recognized the importance of the flow direction and have been largely based upon wind flow and moisture content. The study by Captain Wayne Leach of Kelly in 1954 and 1955 used the gradient wind taken from San Antonio 1500CST upper winds. The study was very productive until the Weather Bureau changed the wind observation times to 1200CST and 1800CST and finally discontinued the San Antonio winds in favor of a Victoria, Texas sounding in 1966. Various studies have used as a moisture parameter either relative humidity or temperature - dewpoint spread.

Definition of Gulf Stratus: Gulf Stratus is defined as a stratus cloud layer formed by a nocturnally cooled gulf air flow. The most important parameter is a measure of the East thru South or Gulf flow of Maritime Tropical Air upslope into the South Central Texas area. Stratus also occurs in the San Antonio area due to trapping of moist air below a frontal inversion and due to overrunning a frontal surface in which moist air is forced upward by the component of air flow normal to the frontal slope. The forecast of these frontally induced stratus conditions is largely a forecast of the frontal position and upper wind flow, while gulf stratus is largely a forecast of the low level flow below 5,000 feet.

The first objective work done by the author on stratus forecasting was conducted at Randolph AFB in 1961 because of an operational problem occurring when student training could not be begun during the mid and late morning hours because of the persistence of a stratus ceiling below 2500 feet. No reliable method of forecasting the time the stratus ceiling would lift above 2500 feet or become scattered was then known. The assumption was made that the stratus breakup time was a function of the cloud thickness through which the solar beam must pass to reach the earth's surface. Cloud thickness was determined by noting the difference in height between the minimum ceiling at Randolph and the cloud tops determined by the top of the moisture level on the San Antonio RAOB. Late breakup was occasionally noted and reasoned to be caused by a strong low level wind flow bringing additional moisture from the Gulf of Mexico.

Further work was conducted to determine the effect of the strength of the wind flow on breakup and was found to be more effective than cloud thickness. Because the low level flow could not be determined accurately enough, pressure gradient was chosen as representative of wind flow. The low level wind flow is often affected by terrain, obstructions, thunderstorms, and other local features and thereby often not representative of net flow over a large area. The variability of speed and direction of the local winds with time make determining mean flow very difficult. Winds taken at some altitude above the surface that minimizes local conditions are more reliable as forecast predictors than the surface flow conditions but are taken by a very sparse network and only every six hours. The upper air stations in use include Brownsville, Victoria, Del Rio, and Fort Worth, none of which are within 100 miles of San Antonio. Changes occurring between the observation times are not detected for as much as six hours. Upper winds are often not available at the times needed or are not representative by reason of location.

Wind Flow as Function of Pressure Gradient: By using surface pressure gradient as the wind flow parameter, the problem of timing of reports is solved since hourly reports are available from all the Weather Bureau and Flight Service Stations in the area. The fluctuations of pressure are also much less than those in wind observations and the pressure can be observed with a much higher degree of accuracy than the winds. The mean wind flow is assumed to be proportional to the surface pressure gradient over the area. Gradients selected for the stratus dissipation were Houston-Laredo sea level pressure added to the Houston-Brownsville SLP and plotted versus time after sunrise of stratus breakup. The sum of the two gradients resulted in 70% of the cases indicating breakup within plus or minus ninety minutes. Because of the success of the pressure gradient parameter for forecasting stratus breakup, the same system was thought possible for stratus formation.

Data was requested from Asheville and when the data years of 1951 thru 1955 were received, San Antonio surface observations for the time period were collected and tabulated according to stratus occurrence. Work on the basic graphs was completed in January 1966.

Many graphs were plotted using various parameters taken at various times from 1800CST to midnight. The temperature-dewpoint spread at various coastal stations was used as one parameter plotted against pressure gradient or combinations of pressure gradients. An optimum spacing for pressure gradient was found to be around two hundred and fifty miles. A spacing very much shorter permitted the fluctuations and local effects to mask the real pressure differences with the variations in time, at one station, often greater than the pressure difference between the stations.

A much larger spacing permitted important pressure features to be lost between the stations with mesoscale trough and ridges sometimes going undetected and thereby giving an erroneous picture of the Gulf air trajectory.

Selection of Graphs for Stratus Formation

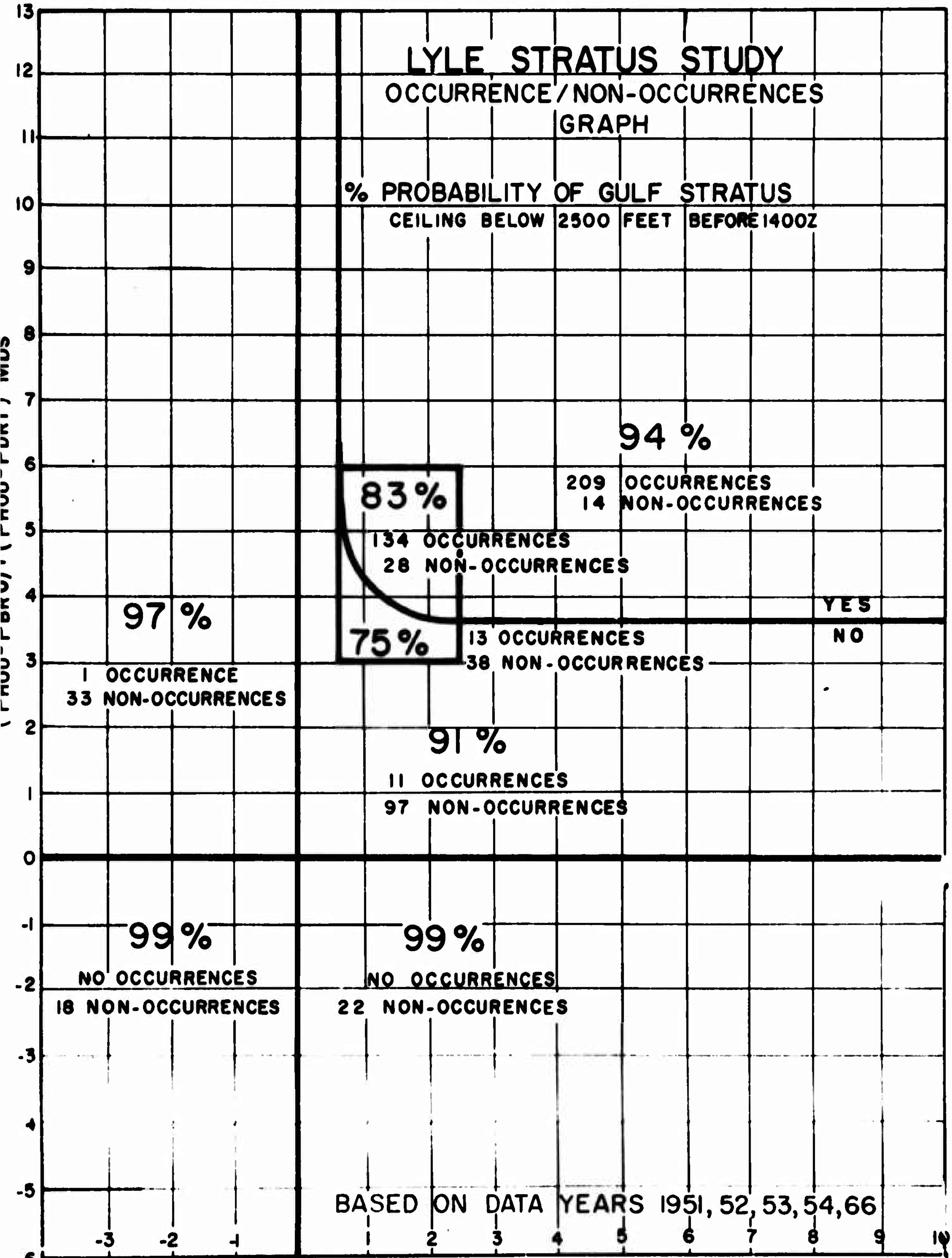
After the graphs were completed in January 1966 using San Antonio humidity and stratus data, work sheets were devised and the study was used as a forecast tool at Randolph AFB during the balance of the year. In January 1967, the graphs were recomputed using Randolph data for 1966. Only slight modifications were made in the basic curves.

Note: The Graphs will not be valid if:

1. Randolph is forecast to be under frontal or squall line influence.
2. Over-running is occurring or forecast.
3. Stratus or rain is already occurring.

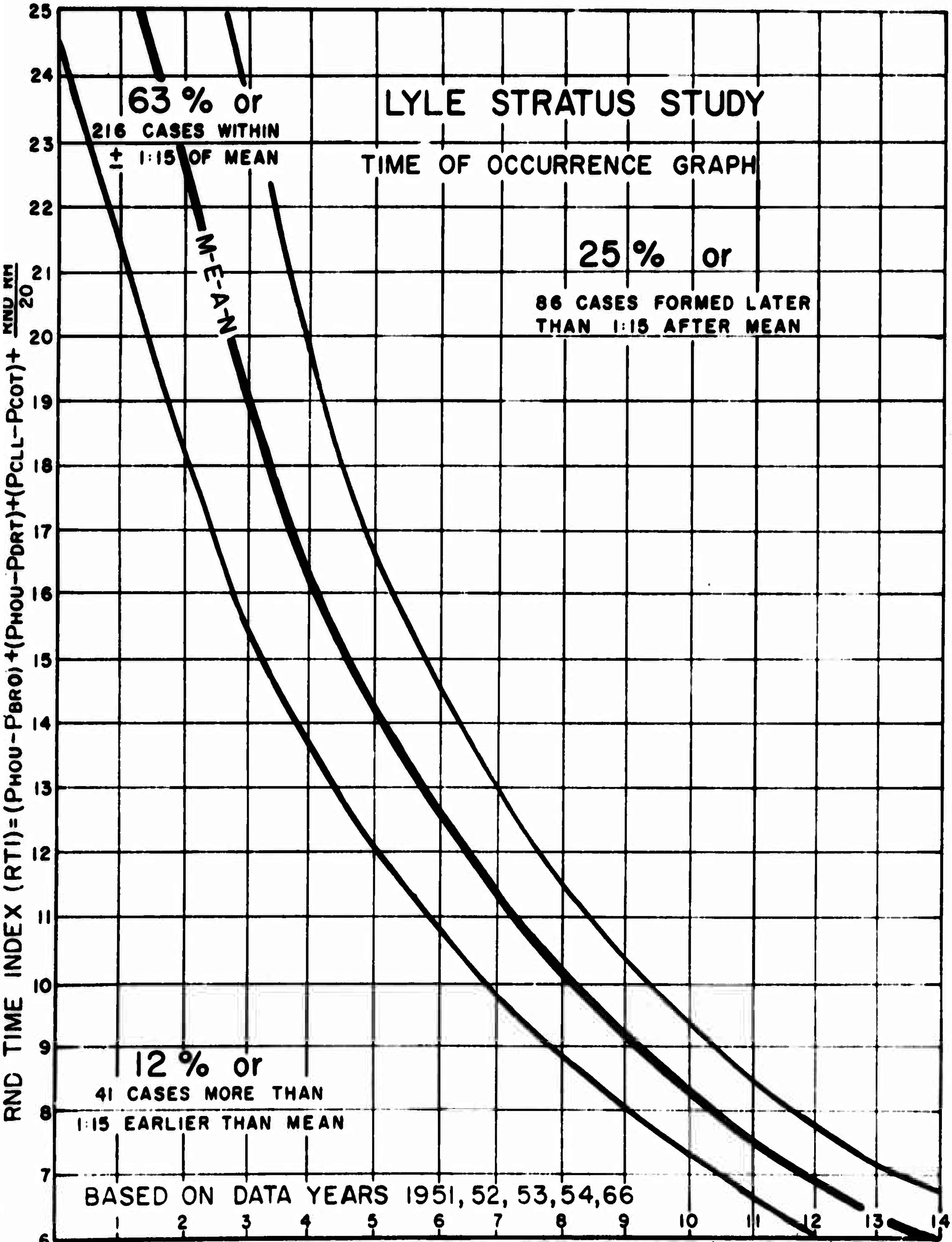
The Occurrence/Nonoccurrence Graph (FIG 1): The graphs plotted generally indicated a better relationship with respect to the gradient parameters than the moisture parameters. The basic gradient versus gradient graph was then drawn and found to be more accurate than any other combination of parameters used at that time. The gradients chosen were (Houston Sea Level Pressure - Brownsville SLP) added to (Houston SLP - Del Rio SLP) plotted versus (College Station SLP - Cotulla SLP). Accuracy of around 89% can be expected from this basic chart using only the 1800CST data. The formation of Gulf Stratus is relatively independent of moisture with stratus occurring even with low initial humidities if a strong enough gradient is present.

From a yes on the occurrence/nonoccurrence graph proceed to the time of occurrence graph.



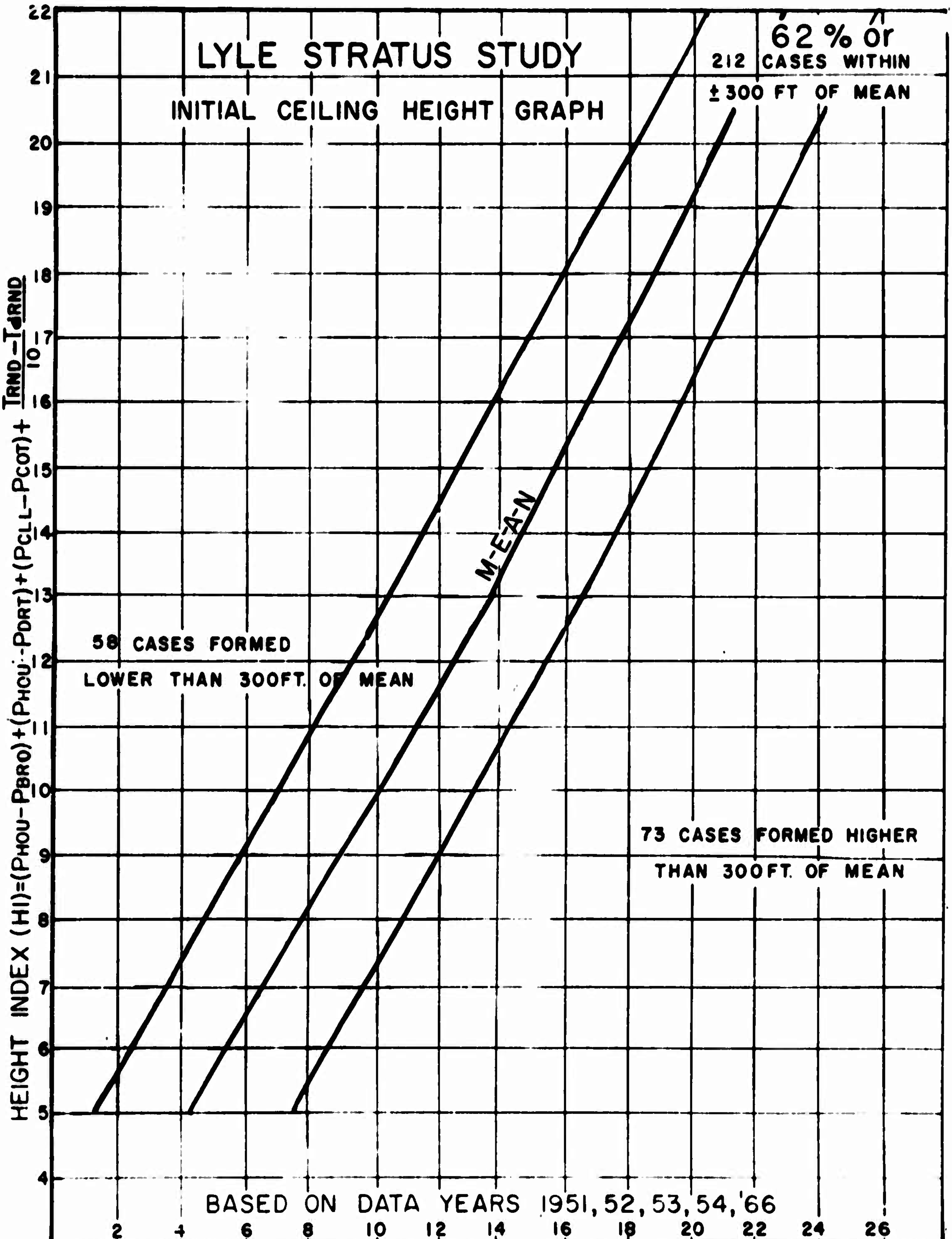
0000Z DATA ($P_{CLL}+P_{COT}$) MBS FIG.1

Time of Occurrence Graph (FIG 2): The time of occurrence of Gulf Stratus was thought to be related to the humidity and pressure gradient. A factor of 10% of the relative humidity was originally chosen to bring the humidity term into the same order or magnitude as the gradient term. A graph was later drawn using 5% of the humidity with better verification than the 10% factor. Seventy percent of the cases verified within one hour and fifteen minutes and seventy-seven percent within one and one-half hours of the prediction using the 5% factor. Graphs were eventually drawn using relative humidity factors of 0%, 5%, 10% and 20%. The 5% graph was significantly better than the others when the best curve was drawn through the plotted data. For those who are disturbed by the mixed units of the time index, consider the gradient terms to be multiplied by a constant term of $1mb^{-1}$, and the index therefore to be a unitless quantity.



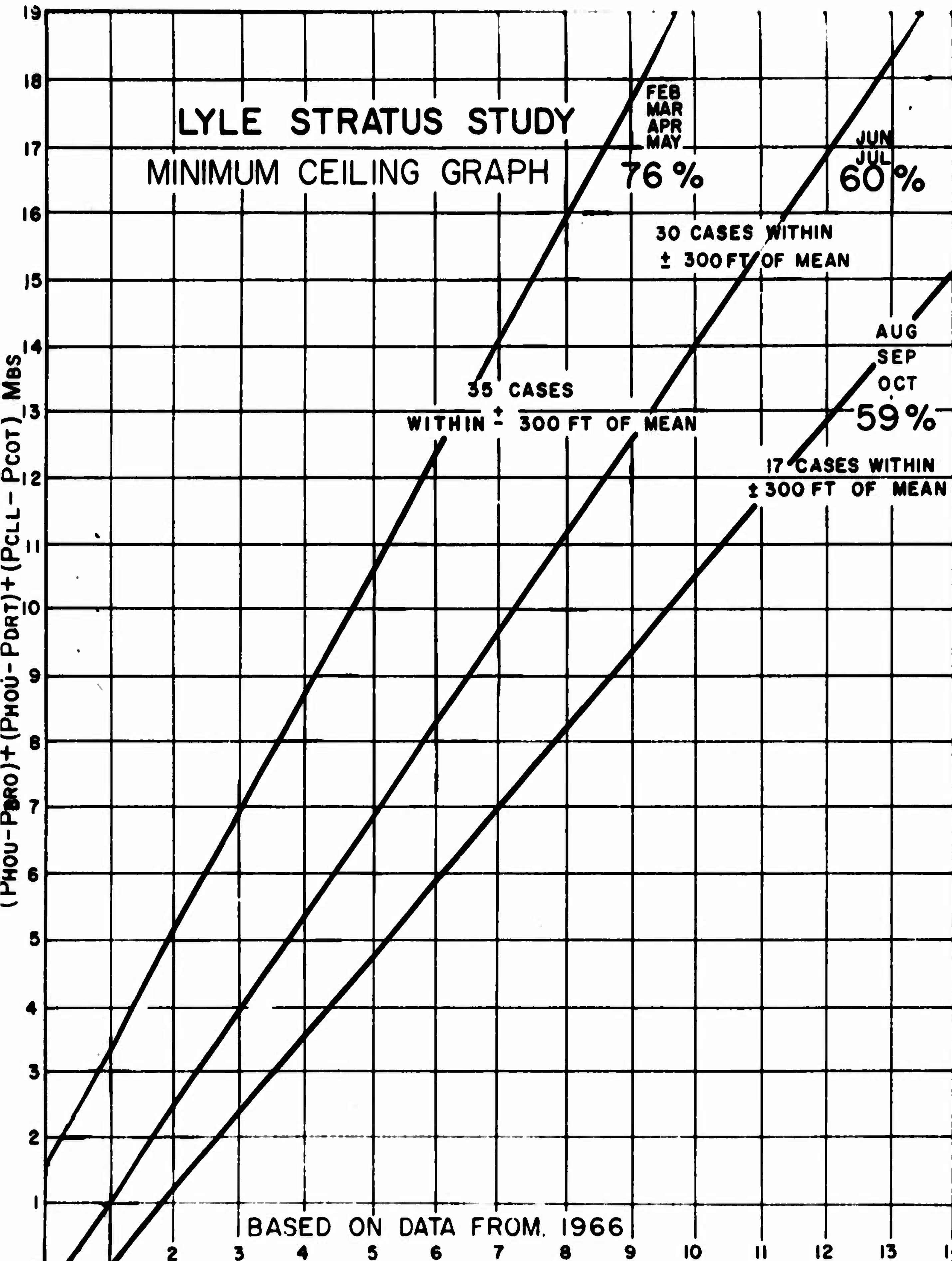
0000Z DATA TIME CIG FORMS AFTER SUNSET (Hrs. & Min.) FIG. 2

Initial Ceiling Height Graph (FIG 3): The height of the ceiling at the time of occurrence was thought to vary inversely with the humidity factor. The reasoning, although not a completely valid assumption, was that a fairly constant mixing ratio existed in the tropical low level flow and that the height of the saturated layer would therefore be inversely proportional to the surface humidity and mechanical turbulent mixing. Since temperature-dewpoint spread would be an integrated measure of humidity and mixing, it was used in conjunction with the gradient factor. Ten percent of the temperature-dewpoint spread was taken to bring the moisture factor into the same order of magnitude as the gradient factor. For the 1966 data, factors of 5% and 20% for the temperature-dewpoint spread were also calculated but were not as accurate as the previously used 10% of temperature-dewpoint spread added to the sum of the pressure gradients. Sixty two percent of the cases fell into the ± 300 feet curve as compared to the 63% for the San Antonio Weather Bureau data. One must again consider the index as a unitless quantity.



OOOOZ DATA CEILING HEIGHT-(HUNDREDS OF FEET) FIG. 3

Minimum Ceiling Graph (FIG 4): The final chart in the series is the minimum ceiling graph. Wind speeds in the lower two thousand feet of atmosphere have long been used to determine the stratus cloud base. I have used pressure gradient as a measure of the net wind speed due to its availability and representativeness. New curves were drawn for the Randolph AFB data from 1966 which agree with the frequently lower ceilings at Randolph as compared with San Antonio and Kelly AFB. Insufficient cases were available for the curves to be seasonally divided as accurately as desired.



MINIMUM CEILING (HUNDREDS OF FEET) FIG. 4

Verification of 1968 Data: Independent data from 1968 were recorded on the worksheet shown on page 17 and were used to verify the forecast study. Throughout 1968 the stratus study was used as a daily forecast tool at Randolph AFB and was verified for all the forecast parameters. Results indicated slightly better verification than the original graphs called for on Occurrence/Nonoccurrence, Height of Ceiling at Formation, and Minimum Ceiling Height, and poorer than expected on the Time of Occurrence.

Stratus occurrence is defined as a stratus ceiling below 2500 feet initially occurring after sunset but before 1400Z the following morning. Results of the first year of independent data (1968) are shown in FIG 5.

FORECAST

		YES	NO	TOTAL
O	YES	125	8	133
B				
S				
E				
R	NO	17	87	104
V				
E				
D	TOTAL	142	95	237

Percent correct forecasts	89.5
Percent correct occurrence forecasts	88.0
Percent correct non-occurrence forecasts	91.6
Percent correct occurrences forecast correctly	94.0
Percent correct non-occurrences forecast correctly	83.7

Heidke Skill Score	.78
Appleman Skill Score	.76

TOTAL CASES 125

Forecast Time of Onset	Forecast Ceiling at Time of Onset	Forecast Minimum Ceiling
Within 2 hrs of Forecast Time	Within 300' of Forecast Ht	Within 300' of Forecast Ht
85%	74%	74%
Within 1 1/2 hrs of Forecast Time	Within 400' of Forecast Ht	Within 400' of Forecast Ht
58%	82%	83%
Within 1 hr of Forecast Time	Within 500' of Forecast Ht	Within 500' of Forecast Ht
44%	85%	90%
Within 30 Min of Forecast Time		
35%		

FIG 5

Guidelines for Using the Graphs: The graphs should not be used when the mechanism of cloud formation is other than a nocturnally cooled maritime air flow or when the necessary parameters are non-representative. Some of the cases of non-verification have been due to erroneous sea level pressures or rapidly changing pressure patterns. Stratus formation on the first day of return flow from the Gulf after a cold frontal passage is usually the hardest to forecast and will often be later in formation than the "time of occurrence" graph normally indicates. About an eighteen hour overwater trajectory is necessary for sufficient moisture to be picked up to form stratus. Expect fog in Fall and Winter when dewpoints are high and surface or low level winds are Southwesterly and less than eight knots. This is a legitimate Gulf stratus with the very weak gradient flow modified by thermal and terrain features.

LYLE STRATUS STUDY WORK SHEET | MONTH:

DATE 0000Z	CLL PRESS	COT PRESS	HOU PRESS	DRT PRESS	BRO PRESS	RND RH %	RND TT-TdTd
DOES STUDY APPLY YES NO (CK BELOW)	1 CLL-COT		2 HOU-DRT		3 HOU-BRO	4 RH/20	5 TT-TdTd/10
Fnt-Tstms-Rain-Sqln Ovrng-St Presnet	1	2+3	TIME INDEX (1+2+3+4)=		HGT INDEX (1+2+3+5)=		MIN HGT INDEX (1+2+3)=
FORECAST	YES	NO	TIME:	Z	INITIAL CIG:		LOWEST CIG:
VERIFICATION	YES	NO	TIME:	Z	INITIAL CIG:		LOWEST CIG:
DATE 0000Z	CLL PRESS	COT PRESS	HOU PRESS	DRT PRESS	BRO PRESS	RND RH %	RND TT-TdTd
DOES STUDY APPLY YES NO (CK BELOW)	1 CLL-COT		2 HOU-DRT		3 HOU-BRO	4 RH/20	5 TT-TdTd/10
Fnt-Tstms-Rain-Sqln Ovrng-St Present	1	2+3	TIME INDEX (1+2+3+4)=		HGT INDEX (1+2+3+5)=		MIN HGT INDEX (1+2+3)=
FORECAST	YES	NO	TIME:	Z	INITIAL CIG:		LOWEST CIG:
VERIFICATION	YES	NO	TIME:	Z	INITIAL CIG:		LOWEST CIG:
DATE 0000Z	CLL PRESS	COT PRESS	HOU PRESS	DRT PRESS	BRO PRESS	RND RH %	RND TT-TdTd
DOES STUDY APPLY YES NO (CK BELOW)	1 CLL-COT		2 HOU-DRT		3 HOU-BRO	4 RH/20	5 TT-TdTd/10
Fnt-Tstms-Rain-Sqln Ovrng-St Present	1	2+3	TIME INDEX (1+2+3+4)=		HGT INDEX (1+2+3+5)=		MIN HGT INDEX (1+2+3)=
FORECAST	YES	NO	TIME:	Z	INITIAL CIG:		LOWEST CIG:
VERIFICATION	YES	NO	TIME:	Z	INITIAL CIG:		LOWEST CIG:
DATE 0000Z	CLL PRESS	COT PRESS	HOU PRESS	DRT PRESS	BRO PRESS	RND RH %	RND TT-TdTd
DOES STUDY APPLY YES NO (CK BELOW)	1 CLL-COT		2 HOU-DRT		3 HOU-BRO	4 RH/20	5 TT-TdTd/10
Fnt-Tstms-Rain-Sqln Ovrng-St Present	1	2+3	TIME INDEX (1+2+3+4)=		HGT INDEX (1+2+3+5)=		MIN HGT INDEX (1+2+3)=
FORECAST	YES	NO	TIME:	Z	INITIAL CIG:		LOWEST CIG:
VERIFICATION	YES	NO	TIME:	Z	INITIAL CIG:		LOWEST CIG:

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) Det 10, 24th Weather Squadron Randolph AFB, TX 78148	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP N/A

3. REPORT TITLE

LYLE STRATUS STUDY FOR FORECASTING GULF STRATUS AT RANDOLPH AFB, TEXAS

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

Final

5. AUTHOR(S) (First name, middle initial, last name)

Major Richard W. Lyle, USAFRES

6. REPORT DATE January 1969	7a. TOTAL NO. OF PAGES 17	7b. NO. OF REFS 0

8a. CONTRACT OR GRANT NO. N/A	9a. ORIGINATOR'S REPORT NUMBER(S) N/A
b. PROJECT NO. N/A	
c. N/A	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) N/A
d. N/A	

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES N/A	12. SPONSORING MILITARY ACTIVITY Hq 7th Weather Wing Scott AFB, IL 62225

13. ABSTRACT

Gulf stratus in Texas is defined as a stratus cloud layer formed by a nocturnally cooled gulf air flow. Warm moist air from the Texas Gulf coastal area is cooled to saturation by nocturnal radiation and by adiabatic cooling as it moves upslope from the coast to the five to nine hundred foot elevation of central Texas. Forecasting methods have concentrated primarily on the forecasting of low level moisture and wind flow. Pressure gradient is used rather than wind flow for this study because pressures were thought to be more representative and timely than wind parameters. The 00Z pressure data gave 89% accuracy for occurrence and nonoccurrence of a stratus ceiling at Randolph AFB. Formation of stratus ceilings occurred within one hour and fifteen minutes in 63% of the cases and formed within 300 ft of forecast height in 62% of the cases. Minimum ceilings within 300 ft of forecast occurred in about 65% of the cases.

DD FORM 1 NOV 65 1473

UNCLASSIFIED
Security Classification

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Meteorology						
Randolph AFB, TX						
Local Forecast Studies						
Gulf Stratus						
Stratus						

UNCLASSIFIED
Security Classification