AVIATION SERIES NO. 14

# WEATHER REPORTS FROM PILOTS. . .

## How In-Flight Reports Help Others

U. S. WEATHER BUREAU

## Weather Reports From Pilots...

The Weather Bureau needs reports from pilots about the weather they see while in flight.

On first thought, the pilot may wonder "Isn't weather reporting the Weather Bureau's job?" "Why does the Weather Bureau want reports from me?"

The answer to the first question is definitely "Yes." Weather reporting IS one of the Weather Bureau's primary jobs. But let us explore the second question, why the Weather Bureau wants reports from pilots.

There are some 500 places in the United States where observations of the flying weather conditions are made hourly or more often when necessary. In one sense, this is a relatively dense network. Certainly, it permits weather men to chart the principal weather patterns and to pin-point some of the details of the weather picture. Yet, the network is not sufficiently dense to detect a great many weather phenomena that often exist between observing stations, and which may be vitally important to aircraft operations. Distances between weather stations may be as much as a hundred miles or more in some cases. Even when stations are much closer together, there are sometimes cases of very significant weather existing between them without anyone other than en route pilots being aware of the condition.

Regular weather observations of sky cover, ceiling, visibility and related conditions must of necessity be made from the surface. The observer can report only what he can see and measure. His field of vision, even in good weather, may in some areas be limited to perhaps 10 or 15 miles because of hills, mountains, or other obstructions, as well as ordinary atmospheric haze. When the clouds lower and visibility worsens, the ground observer's range of vision is lessened. (See Figures 1 and 2.) During instrument weather he may be able to see upward only a few hundred feet and his range of vision may be on the order of a mile or so. In such cases it is possible that a radically different weather condition existing nearby is unknown to the weather observer because it is out of his visual

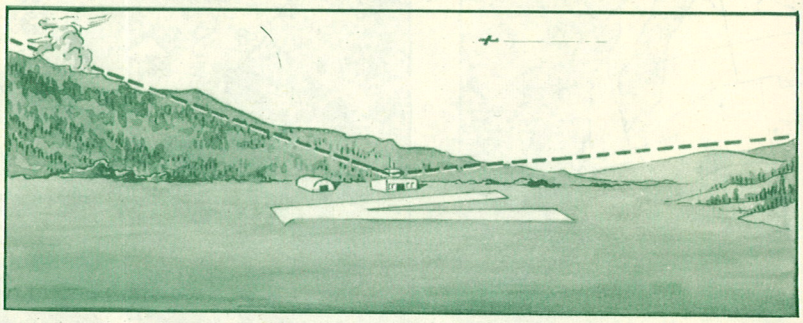


FIG. 1 - WHEN VISIBILITY IS GOOD OBSERVER CAN SEE AND REPORT SOME OF DISTANT WEATHER PHENOMENA.

range. At times like this the pilot can be of considerable help by reporting important weather phenomena.

Turning again to the observer on the ground, he can not state with certainty the height of the cloud tops because he has no way of measuring this. He can not state with certainty if there are other layers above the overcast, or if there is clear space between successive layers that might permit "between-layers" flight. The reason for this is that the observer has no instruments that will help him to determine directly how high the cloud tops are or if the clouds are in layers. For answers to these questions the meteorologist must deduce probable values from available upper air data -- a procedure that does not always

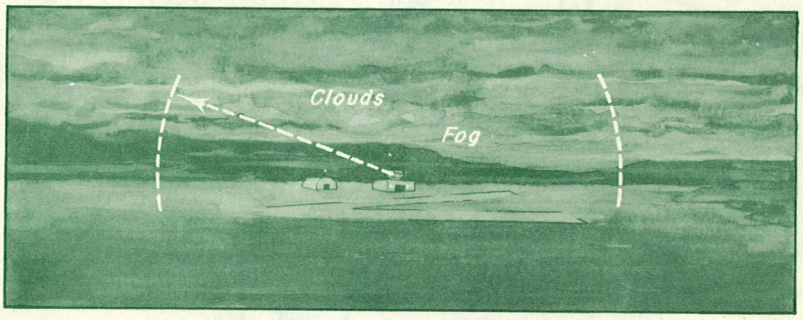
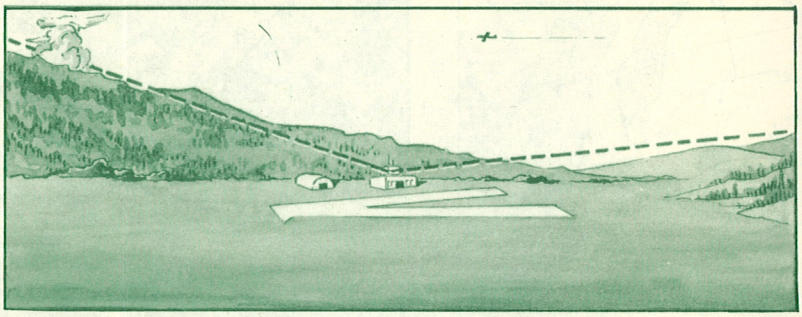



FIG. 2 - WHEN WEATHER DETERIORATES OBSERVER CAN SEE ONLY VERY SMALL PORTION OF SURROUNDING WEATHER CONDITIONS.



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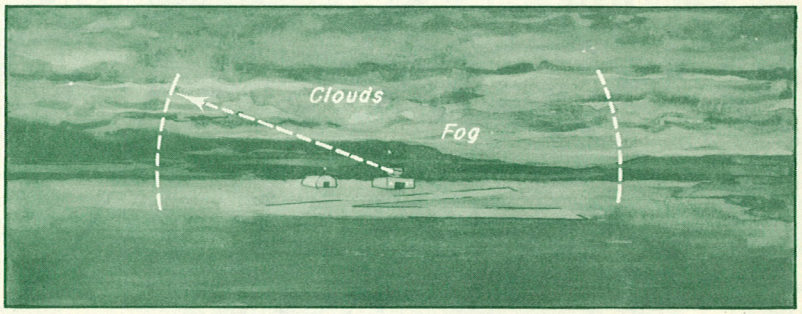


FIG. 2 - WHEN WEATHER DETERIORATES OBSERVER CAN SEE ONLY VERY SMALL PORTION OF SURROUNDING WEATHER CONDITIONS.

yield satisfactory results. Only the pilot observing the weather as he flies can satisfactorily answer these questions for the meteorologist to pass on to others.

Let us take icing as another example. The forecaster knows the general conditions needed to produce aircraft icing. From the upper air soundings that are available to him, and which show temperature and moisture conditions measured at selected places each 12 hours, he can deduce to a reasonable degree of certainty whether or not icing conditions may occur in a certain area, and he can indicate in a rather general way the probable degree of icing intensity. Yet, he can not be positive -- there are too many unknown factors. It is only the pilot flying in the area who can definitely state whether the anticipated icing is occurring, how fast it is accumulating, and at what altitude.

In the case of turbulence, the meteorologist can usually define the general areas and levels where turbulence will be experienced. He can indicate to some extent the approximate degree of turbulence. But, as in the case of icing, weather men have no direct, regular means of measuring these conditions, and they must rely heavily on reports from pilots.

A pilot report may be the first indication the meteorologist has that an anticipated serious icing or turbulence condition has actually begun to develop. On the other hand, a pilot report that an anticipated condition did not exist at the time of his flight in the area does not necessarily indicate that the anticipated condition will not develop. In other words, just as a ground observer's weather reports are perishable, so are pilot reports perishable. That is why it is important for successive reports to be available from a given area, both aloft and at the surface. A typical example is the oft-repeated case where one flight reported no icing in a certain sector and the next flight a few minutes later encountered considerable icing at the same altitude. The same applies to thunderstorms, turbulence. etc.

### *What Happens to the Pilot's Weather Report?*

When a pilot reports an important weather condition to the CAA or the Weather Bureau, a system goes into action to give this information the widest possible distribution. If the report is radioed to a CAA airway communications station (and this is the most direct way to get the "word" out to the largest number of pilots), the station rebroadcasts the report for the benefit of other pilots in the area who may be tuned in. Next, the report goes to the local Weather Bureau station and then via teletypewriter to surrounding weather stations, where it will be of value in forecasting and pilot briefing work, and to CAA airway communications stations.

Sometimes it is necessary for the pilot to wait until he has landed before advising the weather station of important weather conditions encountered. If he calls in person at a Weather Bureau station, he will find the meteorologist eager to learn about the weather encountered on the trip, for such first-hand information helps the meteorologist and pilot briefer to do a better job for aviation. Just as in the case of pilot weather reports that are radioed in to the CAA communications station, the reports made in person are given wide dissemination.

When the pilot's weather report is sent on the weather circuits it contains the basic weather information furnished by the pilot. However, limitations on communications time do not permit identifying the report by name of pilot or aircraft registration number. In the case of reports of turbulence and icing, the aircraft type is stated when known so others using the report will be able to better interpret it in terms of how it will affect their particular aircraft.

It sometimes happens that a pilot reports an important weather condition and later finds that his report was not given distribution. When this happens, it is nearly always because another pilot has very recently reported that particular weather condition, and to send the second report is therefore unnecessary.

Infrequently, other difficulties, such as crowded communications schedules, prevent a report from receiving distribution.

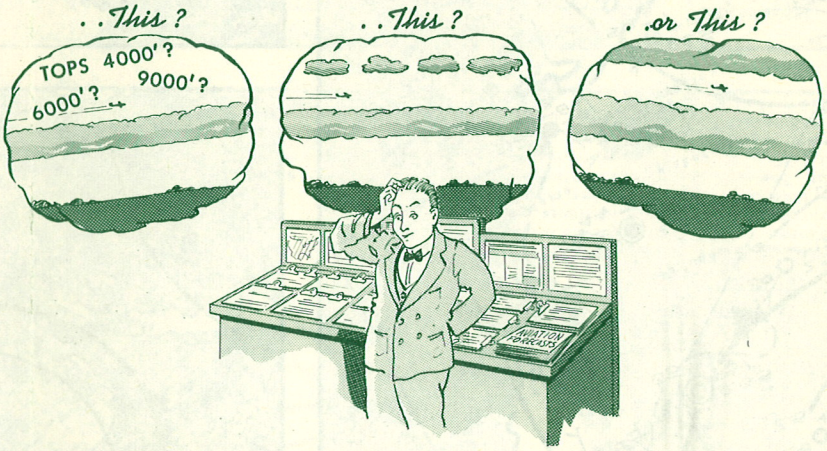


FIG. 3 - ONLY REPORTS FROM PILOTS CAN GIVE DEFINITE INFORMATION CONCERNING CLOUD TOPS AND LAYERS.

### *What the Pilot Should Report*

There are no hard and fast rules on how pilots should report in-flight weather. Pilot reporting of in-flight weather as done within the United States can be quite informal -- there is no specific item or number of items to be reported, and no required order of reporting them. Also, the pilot need not concern himself about the exact form of the report, or the terminology, for the weather observer will put the pilot's report in the form needed for teletypewriter transmission. Brief statements like "I spotted a large thunderstorm 30 miles east of Jackson at 1830C," "Clouds on Red 18 east of Elkins are on the hills -- can't get through VFR," "Tops between North Platte and Omaha are about 7,000 feet, clear above," or "I'm picking up light rime ice at 8,000 feet, temperature is 22°F," are very useful. Of course, if the pilot can add other details, such as cloud types, outside air temperature,

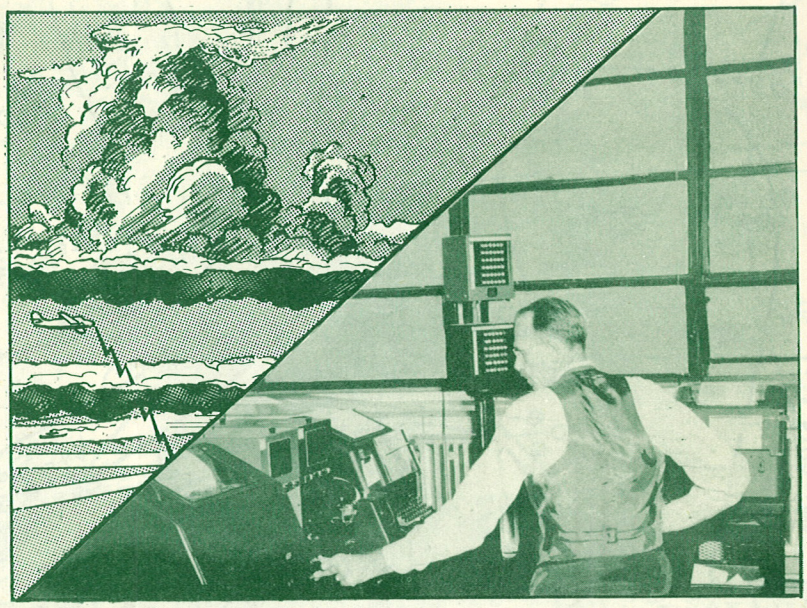

Photo Courtesy Civil Aeronautics Administration

FIG. 4 - FAST, MODERN COMMUNICATIONS SEND THIS PILOT'S REPORT OF APPROACHING THUNDERSTORMS TO SURROUNDING WEATHER STATIONS IN A MATTER OF MINUTES.

or wind conditions, this too would be helpful to the meteorologist.

Pilots initiating reports of in-flight conditions should be sure to state WHEN and WHERE the reported conditions were encountered. Without this information reports are of very limited value.

A simple, basic rule that will help the pilot to decide whether or not to report on the weather he encounters is to ask himself "If I report this weather condition, will it help the next fellow flying this way?"

On some days you will be the "next fellow."

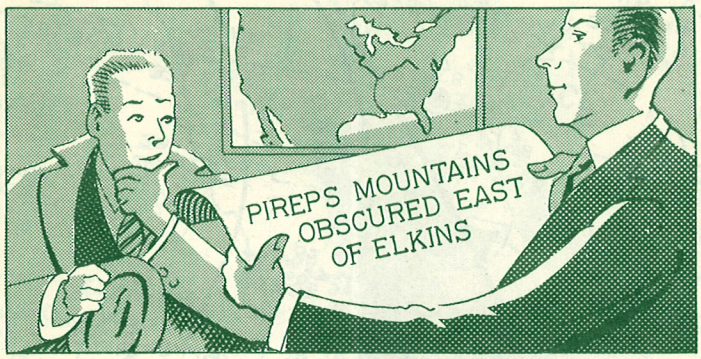


FIG. 5 - PILOT'S WEATHER REPORT OF LOW CLOUDS ON RED 18 AIRWAY IS USED TO BRIEF ANOTHER PILOT.

## PILOT'S REMINDER LIST

1. When did I observe the conditions I am about to report?

2. Where did I observe them?

3. What would be significant to other pilots -- Thunderstorms? Turbulence? Icing? Low ceilings or visibilities? Expected bad weather did not materialize? Other useful information? (If turbulence or icing, be sure to state what altitude encountered.)

AVIATION SERIES NO. 15

# AERONAUTICAL CLIMATOLOGY. . .

# *Low Ceilings and Visibilities*

U. S. WEATHER BUREAU

## Low Ceilings and Visibilities. . .

Of all the weather conditions adversely affecting aircraft operations, low ceilings and low visibilities are by far the most common, and are the cause of most of the flight delays and cancellations due to weather. Low ceiling and visibility conditions can cause the strictly VFR pilot to be grounded for extended periods.

To learn more about the characteristic flying weather of the United States, one can use the charts shown in this article. Figures 1, 2, 3, and 5 show the average percentage of time low ceiling and visibility conditions prevail over the United States during each of the seasons. Specifically, they show the percentage of time, by seasons, that the ceiling was recorded as being below 1000 feet and the visibility less than three miles. For convenience of use, succeeding references in this article to "low ceiling and visibility" should be understood to mean: CEILING BELOW 1000 FEET AND VISIBILITY LESS THAN THREE MILES. These limits are used because they are broadly representative of the lower limits of the range of weather conditions suited for operation under visual flight rules (VFR). They do not take into consideration other unfavorable weather features, such as high winds or thunderstorms, that may have existed at the same time.

It should be remembered that the percentages shown on these charts are average values, based on at least several years of record. They are not necessarily indicators of the ceiling and visibility conditions that may occur in the future at any one time and place. Also, because data are not available from all airports, the charts cannot show all of the variations in frequency of low ceiling and visibility, such as are caused by unusual local effects.

Figure 1 shows the average percentage of time in the summer season that the ceiling is below 1000 feet and the visibility less than three miles. From this chart it is evident that the areas affected are confined almost entirely to the Atlantic Coast, the northern section of the Appalachians, and parts of the Pacific Coast region. Turning to Figure 2, which shows the average conditions for the fall season, it is evident that the area affected appreciably by low clouds and visibility conditions is much larger than that of the summer

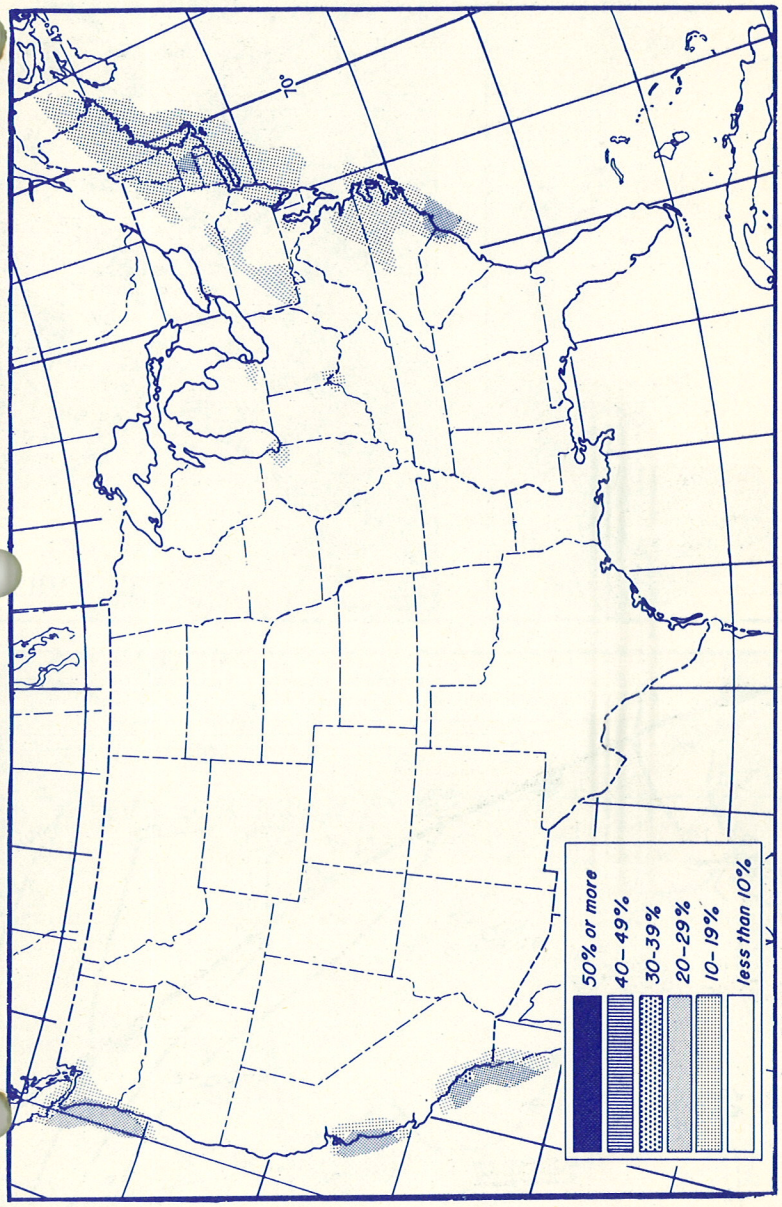


FIG. 1 - AVERAGE PERCENTAGE OF TIME IN SUMMER WHEN CEILING IS BELOW 1000 FEET AND VISIBILITY BELOW THREE MILES

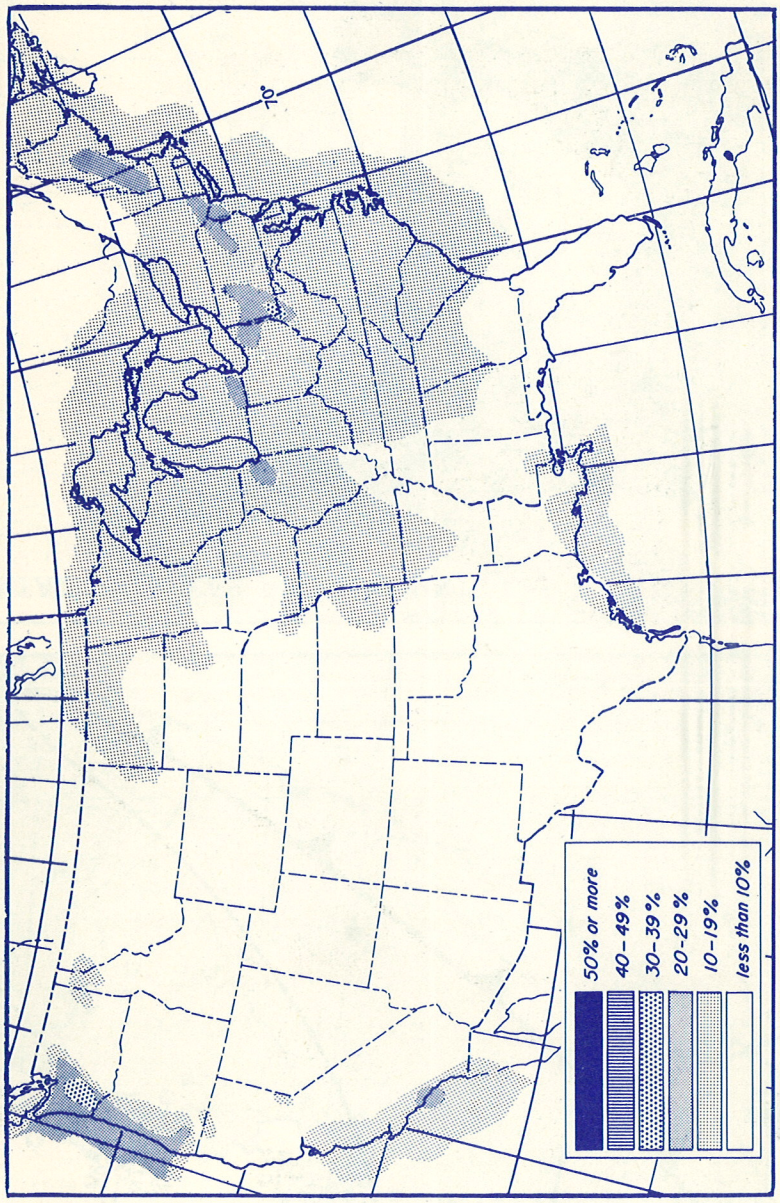


FIG. 2 - AVERAGE PERCENTAGE OF TIME IN FALL WHEN CEILING IS BELOW 1000 FEET AND VISIBILITY BELOW THREE MILES

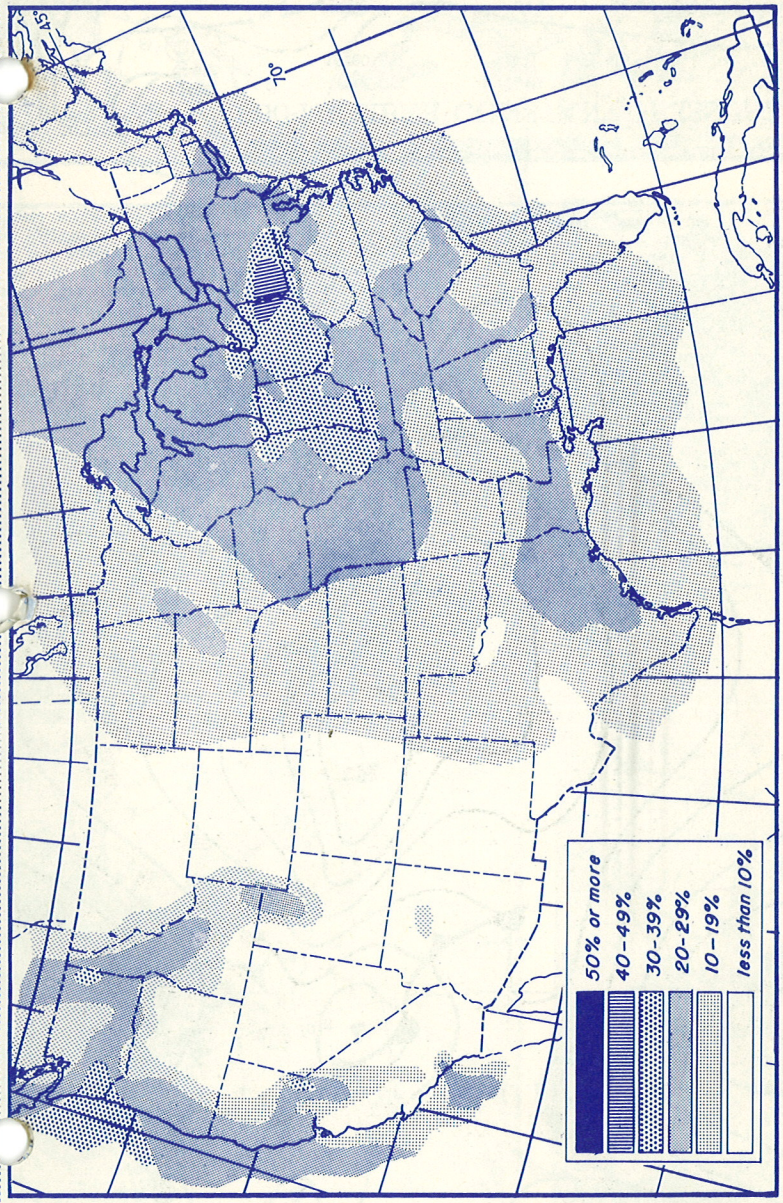


FIG. 3 - AVERAGE PERCENTAGE OF TIME IN WINTER WHEN CEILING IS BELOW 1000 FEET AND VISIBILITY BELOW THREE MILES

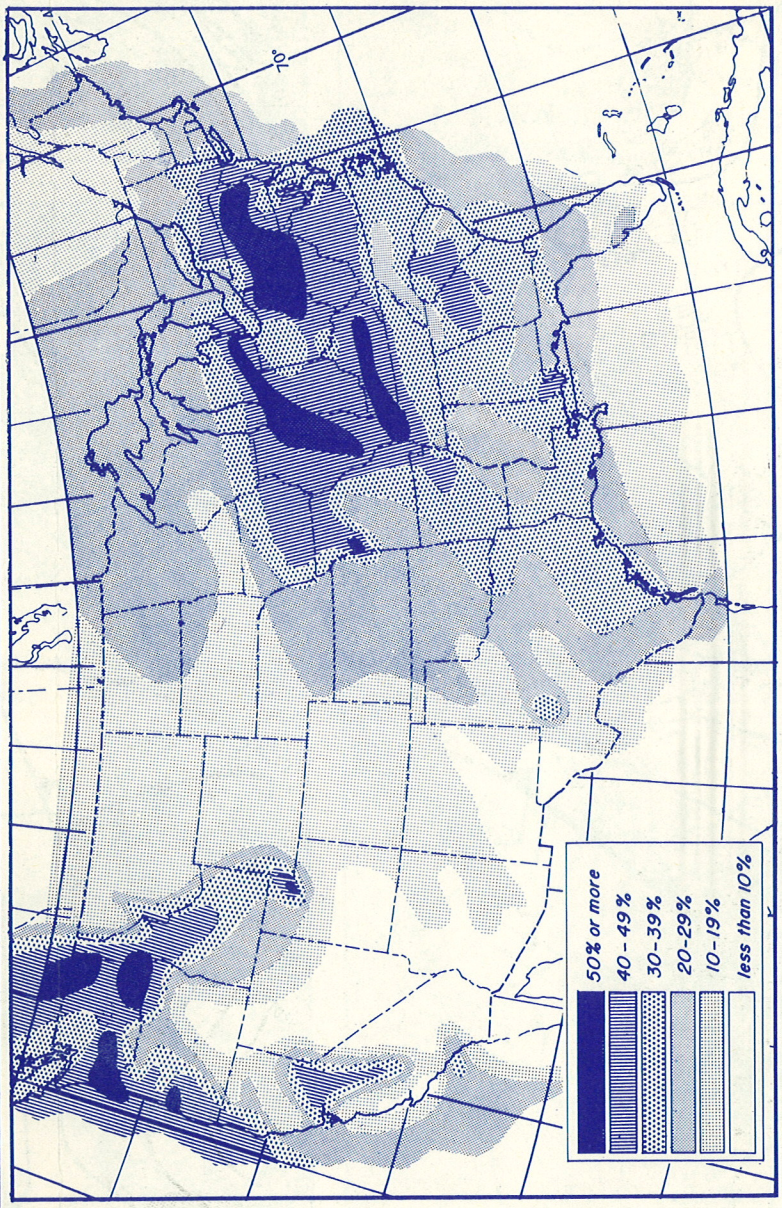


FIG. 4 - MAXIMUM PERCENTAGE OF TIME IN ANY WINTER MONTH WHEN CEILING IS BELOW 1000 FEET AND VISIBILITY BELOW THREE MILES

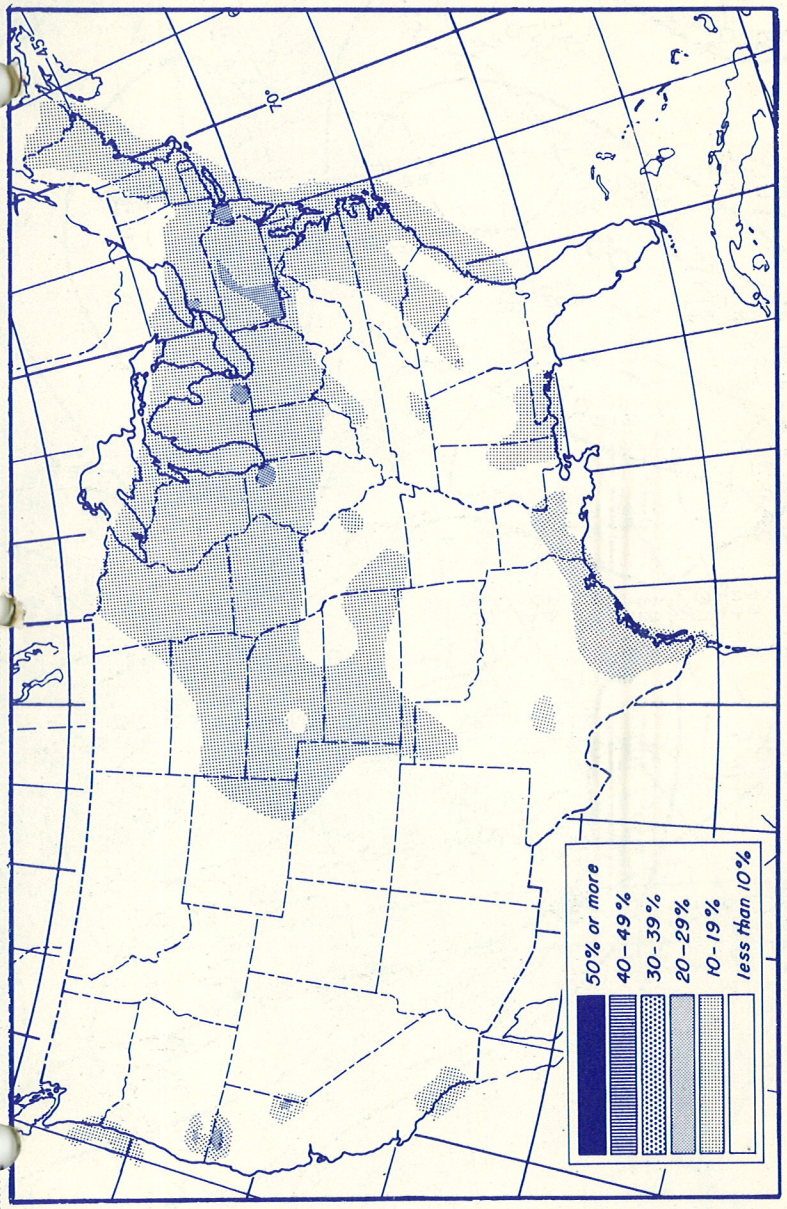


FIG. 5 - AVERAGE PERCENTAGE OF TIME IN SPRING WHEN CEILING IS BELOW 1000 FEET AND VISIBILITY BELOW THREE MILES

months and covers much of the eastern half of the country with the exception of the southeast. The area of low ceiling and visibility on the Pacific Coast is also larger than in summer, and it will be noted that during this season some small areas of higher percentage of occurrence of low ceiling and visibility show up on parts of the Pacific Coast and in the northeastern part of the United States. During the winter season, the occurrence of low ceiling and visibility reaches its maximum in most sections in terms of frequency of occurrence as well as area affected, as shown in Figure 3.

The extreme conditions for a winter month are shown in Figure 4. This chart was constructed by using the records of the highest percentage of occurrence of low ceilings and visibilities recorded for any winter month. This chart helps to emphasize that the low ceiling and visibility averages for a single winter month may differ appreciably from the average of a number of winter seasons.

Figure 5 shows the average occurrences of low ceilings and visibilities for the spring season and indicates that for nearly all sections the characteristic weather shows a rapidly improving trend over that found in winter.

One might well ask: "What value do such weather averages have in flight planning?" First, weather averages of low ceiling and visibility give an indication of the frequency with which we may expect to encounter such conditions when the period of the flight is longer than that for which it is possible to make reasonably accurate forecasts. To that extent they can be helpful to the pilot who wishes to determine the best time of year to make an extended business or vacation trip. Another example would be that of the flight service operator seeking to open a new operation. He might use these averages to estimate the extent to which weather would affect flight operations, or to select the area which offers the best advantage from the standpoint of flying weather conditions. Thus, weather averages can also be used as one of the measures of probable aircraft utility.

AVIATION SERIES NO. 16

# AERONAUTICAL CLIMATOLOGY. . .

# *Thunderstorms*

U. S. WEATHER BUREAU

## Thunderstorms. . .

Thunderstorms occur in practically all parts of the United States. Because thunderstorms contain heavy turbulence and usually are accompanied by strong gusty surface winds, rain, and occasionally hail, they are of particular interest to airplane pilots.

Previous articles of this series have presented information on the structure and characteristics of thunderstorms, and how the individual thunderstorm cell goes through a definite life cycle (Aviation Series 7 and 8). The purpose of this article is to show how the frequency of thunderstorms varies with location and the seasons. The charts in Figures 1 through 4 show the average number of days thunderstorms occur during each of the seasons.

Figure 1 shows the average number of days with thunderstorms during the winter season. For the months of December, January, and February, thunderstorms are quite infrequent except for a small area in the lower Mississippi Valley. As a general rule, the pilot can consider that thunderstorms are rarely a problem to aircraft operations during these months except along the central Gulf Coast.

As the spring season arrives, the frequency of thunderstorms increases quite rapidly. At first, the increase in thunderstorm frequency is most apparent for the area along the Gulf Coast, but as the season progresses the thunderstorm frequencies increase northward into the Great Plains, the lower Great Lakes region, and the Central Atlantic Coast states. Figure 2 shows this over-all area has an average of ten or more thunderstorm days during the spring, and the highest average number of thunderstorm days is near the Texas-Oklahoma-Arkansas border, where at least 20 out of the 90 days have thunderstorms.

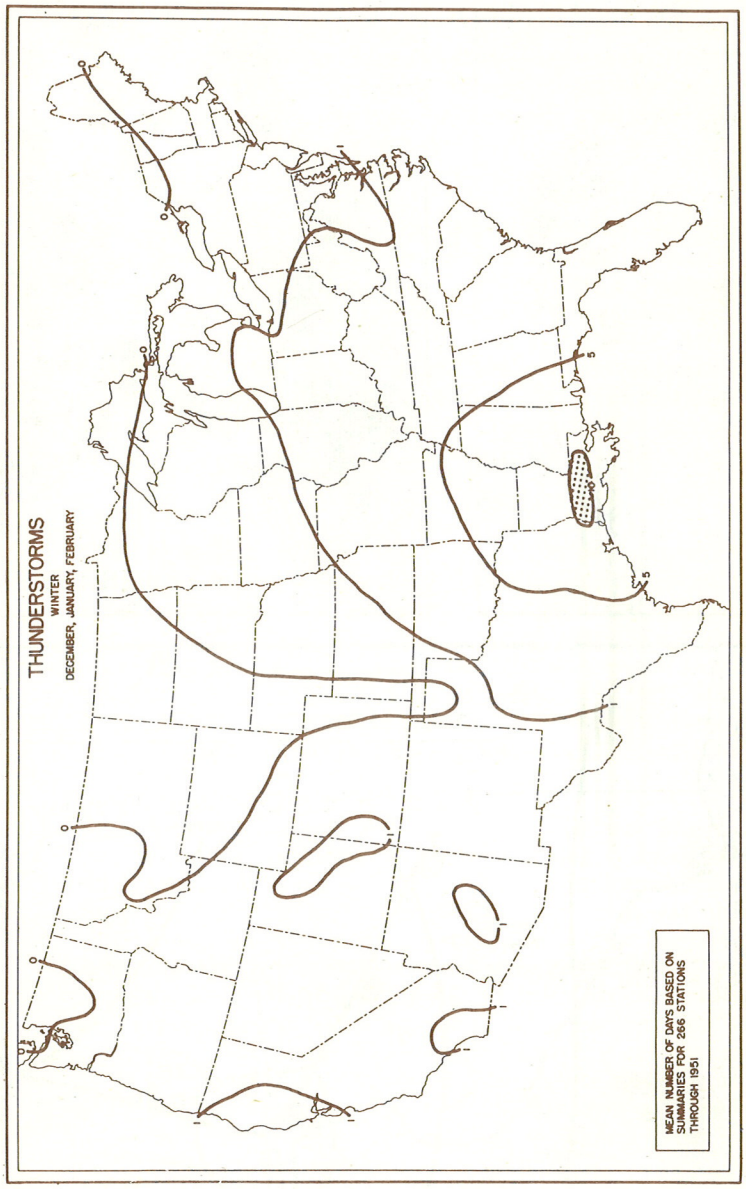


FIG. 1 - AVERAGE NUMBER OF DAYS WITH THUNDERSTORMS DURING WINTER SEASON

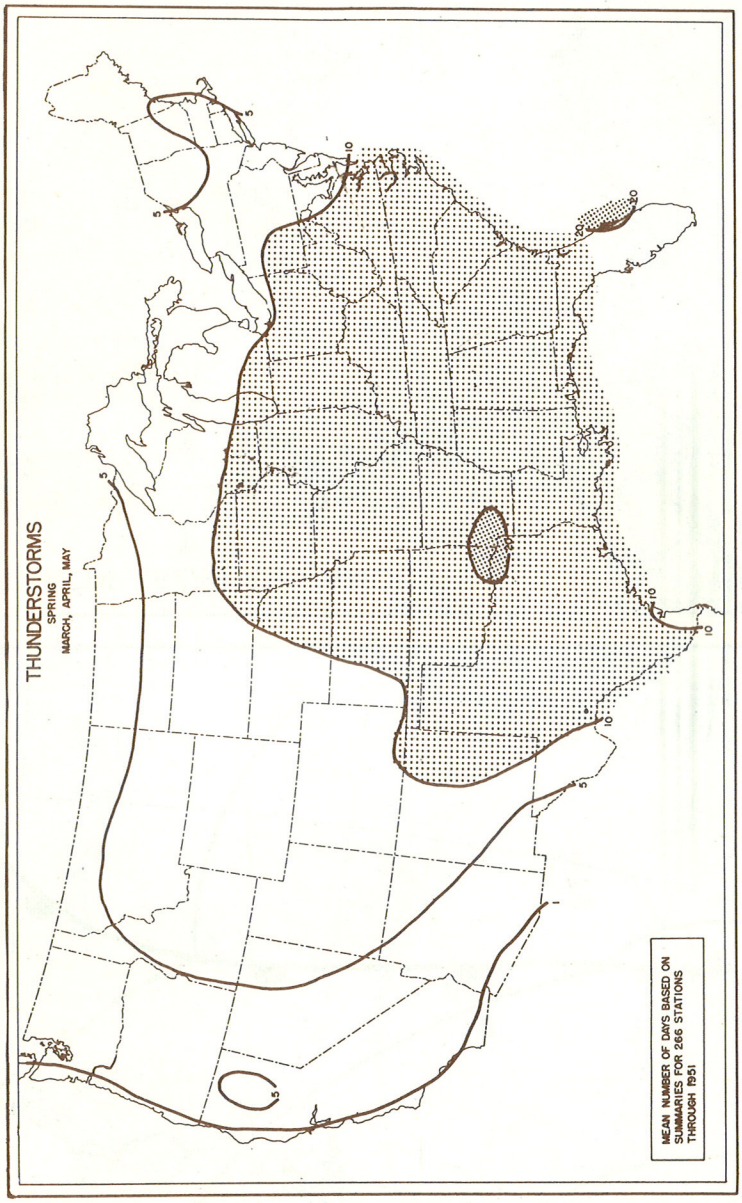


FIG. 2 - AVERAGE NUMBER OF DAYS WITH THUNDERSTORMS DURING SPRING SEASON

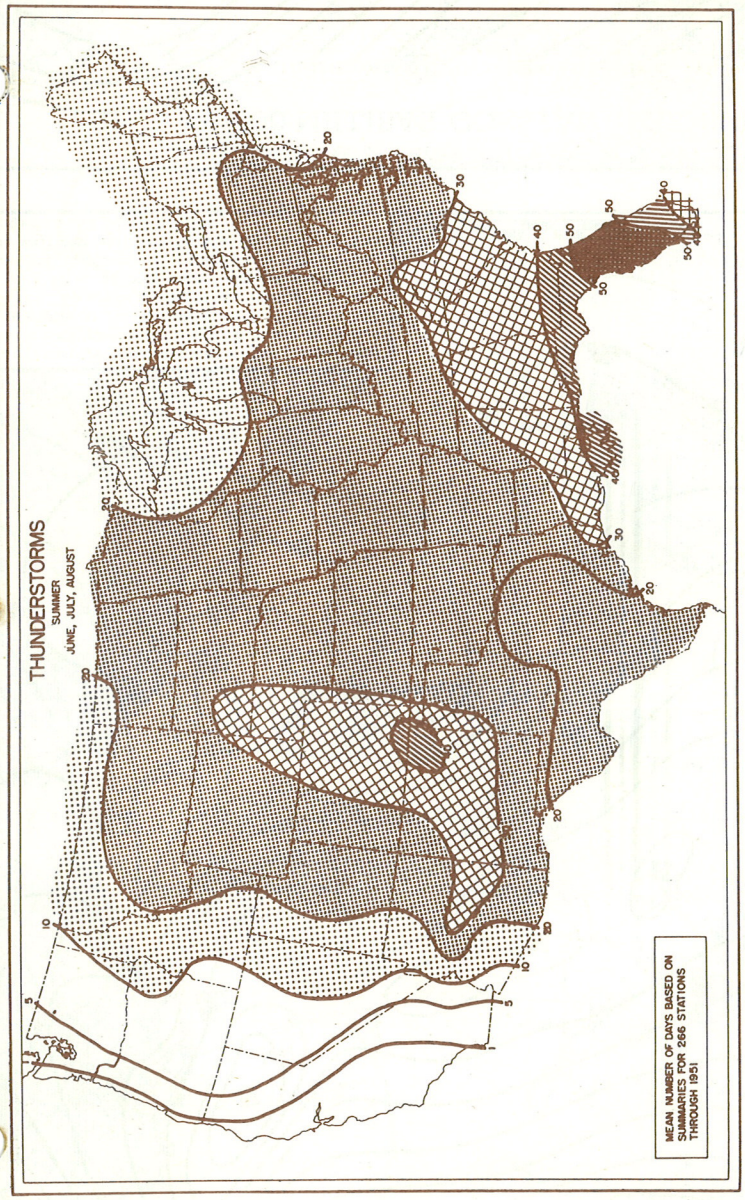


FIG. 3 - AVERAGE NUMBER OF DAYS WITH THUNDERSTORMS DURING SUMMER SEASON

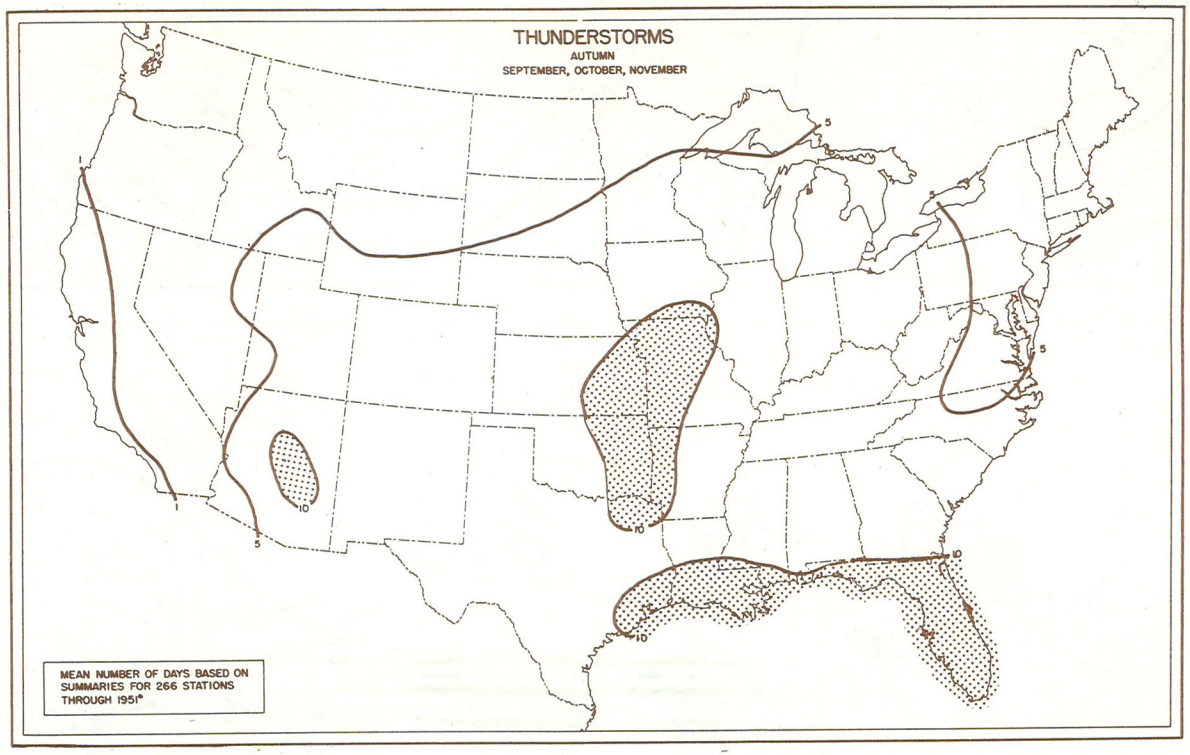


FIG. 4 - AVERAGE NUMBER OF DAYS WITH THUNDERSTORMS DURING FALL SEASON

Referring to Figure 3, we see that the average number of days with thunderstorms during summer shows an appreciable increase over the average for spring. During the summer season an area of high frequency of thunderstorms (30 or more days with thunderstorms) extends from central Arizona into New Mexico and then northward over the central Rocky Mountain area and its eastern slopes. In the southeastern states there is another area of high frequency of thunderstorm occurrence, beginning in the lower portion of the Appalachian Chain and increasing in frequency toward the south. The maximum is reached in central Florida, where more than half of the days in the summer season have thunderstorms.

In the fall, the average number of thunderstorm days decreases rapidly, and is considerably less than in summer, as shown in Figure 4.

Figure 5 shows the average number of thunderstorm days per year for the United States. As would be expected from examination of the charts of seasonal frequency of thunderstorm days, this chart also shows that the greatest number of days per year with thunderstorms is along the Gulf Coast, and the least number along the Pacific Coast.

We have noted the change in the number of thunderstorm days with the seasons and location. It is also interesting to note that while we customarily think of thunderstorms as warm summer afternoon phenomena, thunderstorms do occur at other times of the day. Over the coastal waters of Florida and other Gulf Coast states, many thunderstorms occur at night. In the Great Plains nighttime thunderstorms, sometimes called "nocturnal thunderstorms," occur with considerable frequency during the spring and summer. In other cases, thunderstorms are closely associated with cold or warm fronts and therefore occur at night as well as during the day.

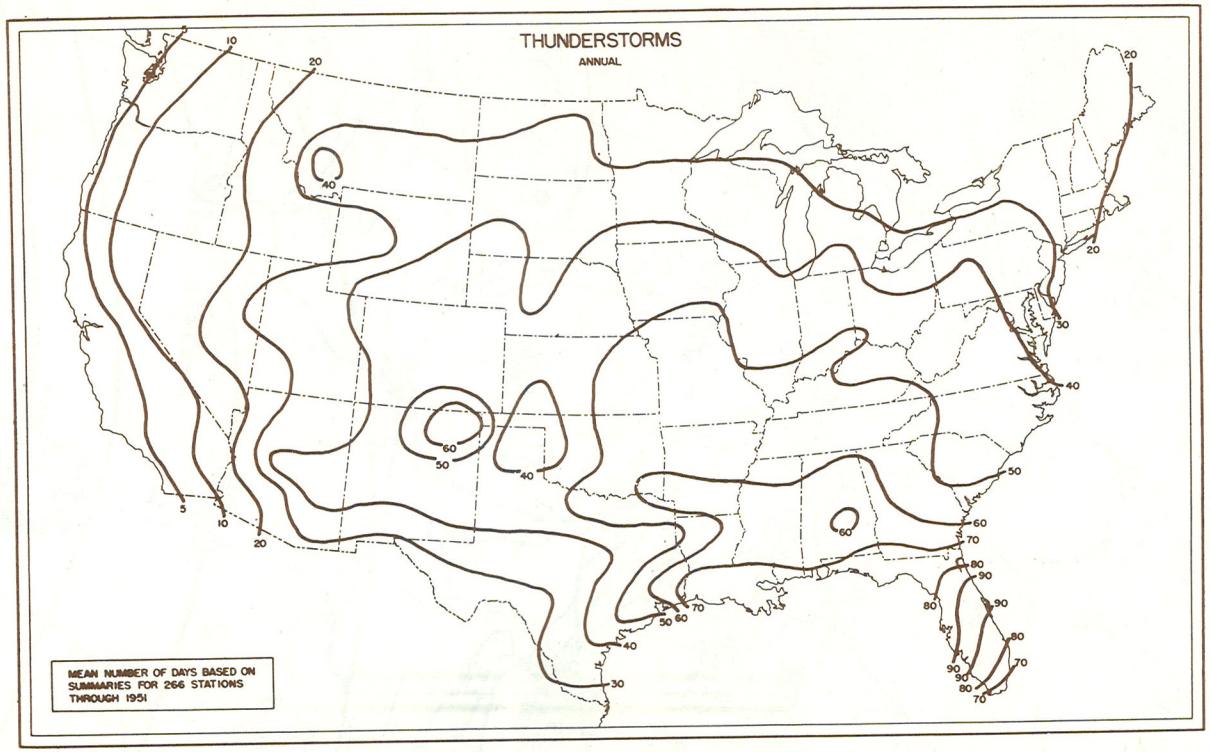


FIG. 5 - AVERAGE NUMBER OF DAYS PER YEAR WITH THUNDERSTORMS

AVIATION SERIES NO. 17

# SEVERE WEATHER FORECASTS....

## Their Importance to the Pilot

U. S. WEATHER BUREAU

Many of the thunderstorms that occur in the United States are quite localized in their extent. Brief periods of thunder and lightning, a fresh breeze, perhaps the raising of a little dust, then a short downpour of rain -- these conditions characterize the average thunderstorm as seen by a person on the ground.

All thunderstorms are potentially hazardous to airmen. Some are violent storms. Then they are accompanied not only by thunder, lightning, and rain but hailstones, capable of doing extensive damage, may fall. Strong, gusty surface winds may herald the approach of the storm. Sometimes a number of storms align themselves to form a broad approaching band of severe weather. On infrequent occasions these severe thunderstorms bring with them the dreaded tornado.

FIG. 1 - A SEVERE THUNDERSTORM AS SEEN IN FLIGHT.

## *Storm Damage*

We all know that hail can cause considerable damage, and that thunderstorm winds sometimes are strong enough to wreck small buildings or do other damage. For the airman, the severe thunderstorm presents an unusual problem. An aircraft on the ground and unsheltered may suffer major damage from hail that riddles fabric surfaces, or dents the metal skin be-

yond repair. Surface winds may tear aircraft from their moorings and overturn them, or fling them into other parked aircraft.

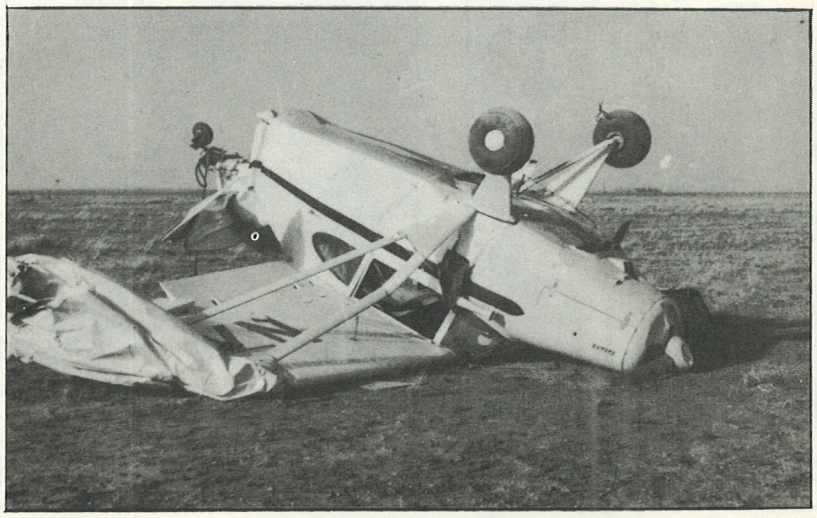

FIG. 2 - THE RESULTS OF A SEVERE THUNDERSTORM.

For the airman in flight, hail can smash the windshield or do other structural damage. The turbulence found in a severe thunderstorm can be exceedingly violent and cause an aircraft to be uncontrollable. If a tornado is present it may be hidden from the pilot's view by rain or clouds. In the case of the tornado, few objects in its direct path escape its fury.

## *The Forecasts*

Because these severe local storms occur with sufficient frequency to be of considerable concern to the general public, to airmen, and the countless others whose activities are vitally affected by the weather, the U. S. Weather Bureau several years ago began a program to warn of the development and movement of severe local storms.

For the pilot, these forecasts are of great importance. They indicate to him the areas which he should view with caution and which if entered, should be flown so as to maintain careful watch on weather developments.

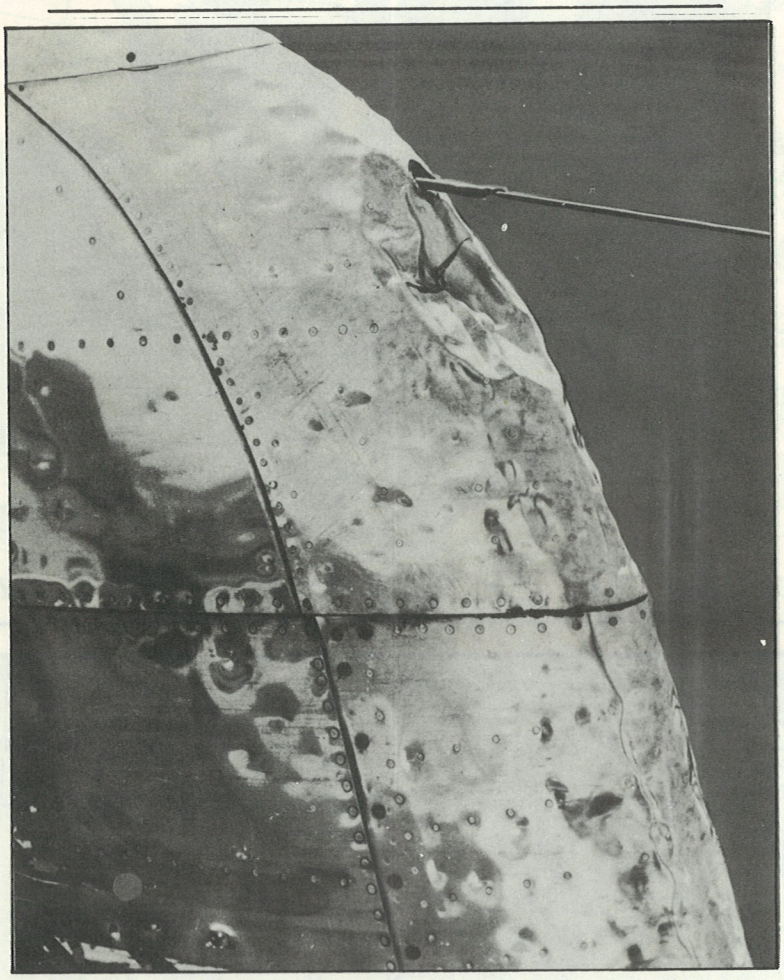

FIG. 3 - RESULT OF AN ENCOUNTER WITH HAIL. THIS SHOWS VERTICAL STABILIZER OF A DC-6 AIRPLANE. NOTE COMPLETE BREAK IN SKIN JUST BELOW ANTENNA.

At the special Severe Local Storm Forecasting Center (SELS) in Kansas City skilled meteorologists, specially trained to recognize potential severe local storm conditions and in forecasting their development and movement, maintain a constant vigil. When an

incipient severe local storm condition is detected, special conference calls and discussions are carried out by direct telephone with the other forecast centers concerned. Then these offices go on an "alert" basis. Subsequent reports from weather stations, conditions detected by radar, and in-flight reports from pilots are carefully scrutinized for clues to further developments.

Once it is clear that conditions are becoming favorable for the formation of severe local storms, special messages describing the weather condition, its loca-

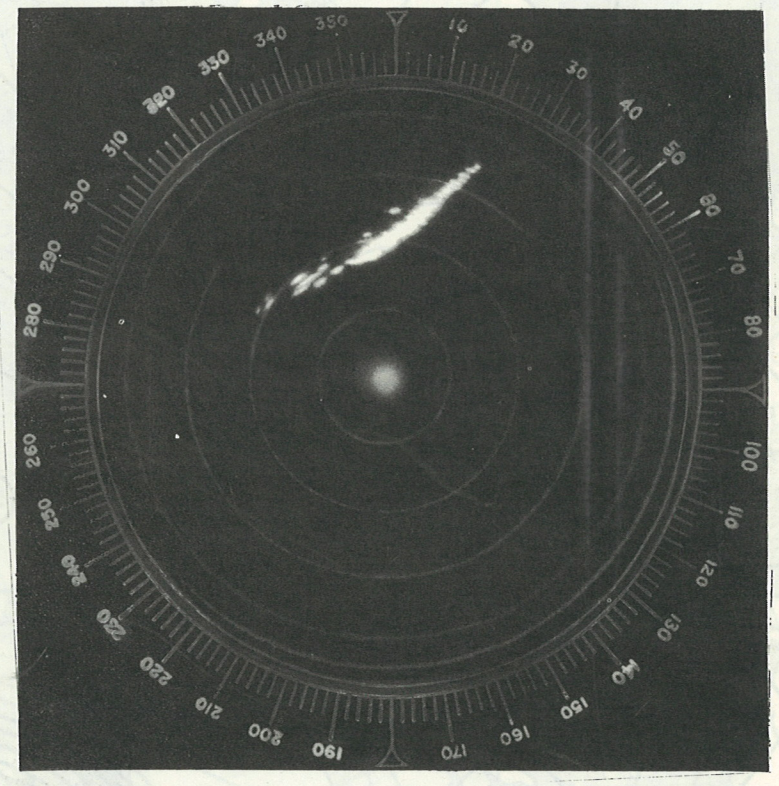


FIG. 4 - A DEVELOPING SEVERE STORM CONDITION AS SEEN WITH RADAR. RADAR STATION IS AT CENTER OF PICTURE AND STORM AREA IS SHOWN CENTERED 40 MILES TO NORTH OF THE STATION. DISTANCE BETWEEN CIRCLES IS 25 MILES.

tion, and its expected future development and movement are quickly sent out over the weather teletypewriter circuits. The messages go to other Weather Bureau stations, to Civil Defense headquarters, to CAA Airway Communications Stations, and to aircraft operations offices having their own extensions on the weather circuit. At the CAA stations the messages are available for broadcast to airmen in flight and to render special in-flight assistance if that should become necessary. Here is an example of such a message:

SCATTERED SEVERE THUNDERSTORMS ARE EXPECTED BETWEEN 1400C AND MIDNIGHT. THEY WILL BEGIN ALONG AN INSTABILITY LINE THAT AT 1400C WILL EXTEND FROM OMAHA, NEBRASKA, TO 30 MILES WEST OF TOPEKA, KANSAS, TO NEAR PONCA CITY, OKLAHOMA, AND THEN MOVE EASTWARD AT 25 KNOTS AND DEVELOP SOUTHEASTWARD. THE AREA OF MOST INTENSE THUNDERSTORMS WILL BE ALONG AND 50 MILES EITHER SIDE OF A LINE FROM 30 MILES WEST OF TOPEKA, KANSAS, TO OTTUMWA, IOWA, WITH SCATTERED TORNADOES EXPECTED IN THIS AREA BETWEEN 1400C AND 2200C.

The importance of such a message for the pilot is obvious.

Severe local storm forecasts are issued when the forecaster believes the weather conditions associated with the thunderstorms will meet one of the following criteria:

1. Surface wind gusts of 75 miles per hour or more
2. Sustained surface winds of 50 miles per hour or more
3. Hail 3/4 inch in diameter or larger, at the surface or aloft
4. Extreme turbulence aloft

In the SEVERE WEATHER FORECASTS, an indication is given of the area expected to be affected by the severe thunderstorms. For this purpose the descriptive terms "few," "widely scattered," "scattered," and "numerous," are used. Specifically, and as

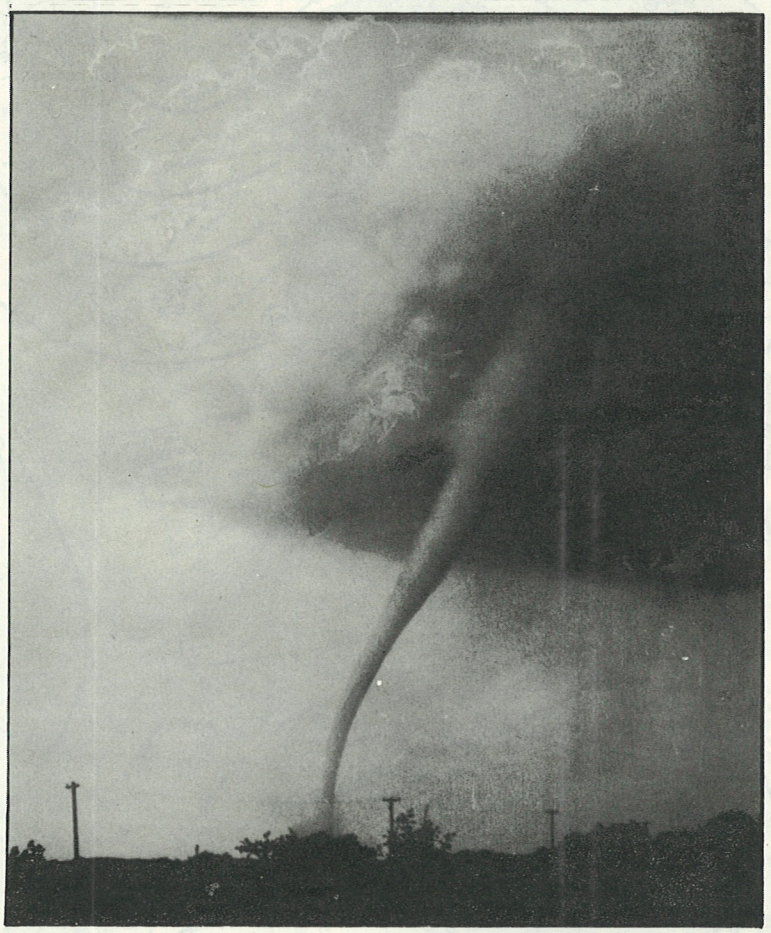

FIG. 5 - INSIDE THE FUNNEL OF A TORNADO, WINDS MAY EXCEED 500 MPH. SHARPLY REDUCED AIR PRESSURE IN FUNNEL CAUSES BUILDING IN PATH LITERALLY TO EXPLODE.

applied to the entire area for which severe thunderstorms are forecast, the meaning of these terms are:

FEW SCATTERED THUNDERSTORMS --
Less than 15% of the area affected

WIDELY SCATTERED THUNDERSTORMS --
From 15 to 30% of area affected

SCATTERED SEVERE THUNDERSTORMS --
From 31 to 45% of area affected

NUMEROUS SEVERE THUNDERSTORMS --
More than 45% of the area affected

## *The Tornado*

Fortunately for the airmen, the tornado is a highly localized storm. Because it is closely associated with its parent thunderstorm, the pilot knows that the probability of running a close encounter with a tornado while in flight is greatly minimized if he flies sufficiently clear of the severe thunderstorms to be able to fully observe their behavior.

As yet, meteorologists do not know with certainty the height to which tornadoes may reach. An extreme case, reported by a pilot, is that of a funnel extending upward to about 30,000 feet. Other indications are that they may ordinarily extend to perhaps half that height. The visible indications of a tornado usually develop in a matter of seconds. Too, it is not unusual to have "families" of tornadoes occurring simultaneously or in quick succession, each lasting but a few minutes, but all associated with the same thunderstorm situation. Some may develop only pendants that reach part way to the ground.

The Severe Weather Forecasts cannot say with certainty the exact spot where tornadoes will occur, or state positively that a given severe thunderstorm situation will have tornadoes. However, the Weather Bureau's Severe Weather Forecasts serve to alert the airman to the likelihood that severe turbulence, hail, and damaging winds are to be expected in certain areas so he can plan his flight to avoid these hazardous conditions.

AVIATION SERIES NO. 18

# ALTIMETERS . . . How Their Readings are Affected by Temperature and Other Factors

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U. S. WEATHER BUREAU

## ALTIMETERS. . .

Altimeters have been used in airplanes since the very early days of aviation. From a relatively simple device whose accuracy sometimes left much to be desired, the barometric-type aircraft altimeter has been developed into a precision instrument that is vital to aircraft operations.

The principal use of the barometric altimeter is to give an indicated height above some reference point, usually sea level.

One may wonder "Why discuss altimeters in a series of articles on aviation weather?" The reason is that the heights shown by the barometric altimeter are determined from the air pressure, but the air pressure changes as a result of certain weather phenomena. Knowledge of ways in which altimeter readings are affected by weather conditions will help the airman to interpret intelligently what the altimeter tells him. To better understand what

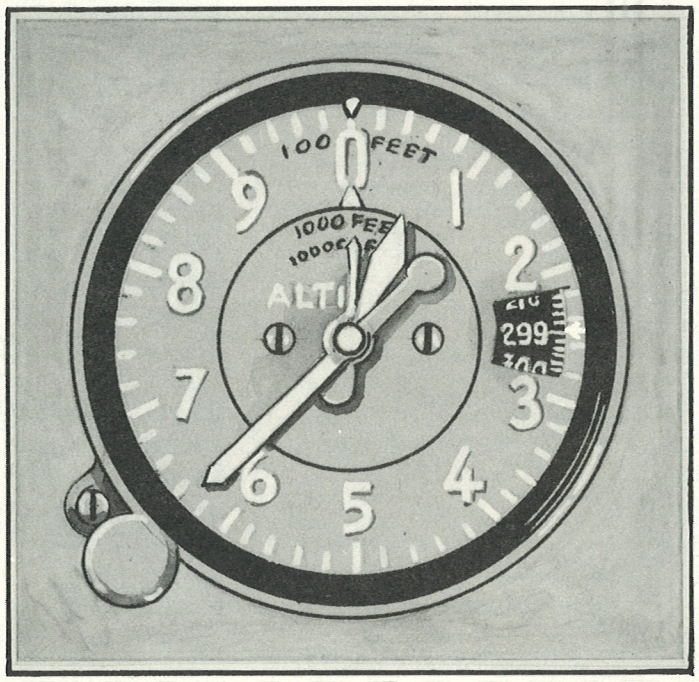


FIG. 1 - A TYPICAL ALTIMETER FOR AIRCRAFT.

the barometric altimeter can do, and its limitations, let us review briefly how it works.

Figure 1 shows the basic instrument, familiar to all pilots. Inside the instrument is a pressure-sensitive metal capsule from which the air has been removed and the opening sealed. This sealed metal capsule is made so it expands when the air pressure decreases and contracts when the pressure increases. This small movement is transmitted and multiplied through a linkage and gear train system which actuates the indicators on the dial.

AT ANY PARTICULAR POINT ON THE GROUND OR ALOFT, THE AIR PRESSURE DEPENDS PRINCIPALLY ON THE WEIGHT OF THE AIR ABOVE IT. IT IS THIS PRESSURE AT THE INSTRUMENT, AND THE ALTIMETER SETTING, THAT DETERMINES THE INDICATED ALTITUDE.

All barometric altimeters are calibrated with reference to an established standard relating pressure to altitude. This standard is known as the U. S. Standard Atmosphere. It assumes the sea level pressure to be 29.92 inches of mercury, and the sea level temperature 59° F. Also, it is based on a uniform rate of decrease of temperature with height of approximately 3 1/2° F per thousand feet from sea level to the stratosphere. This relationship is shown in Figure 2.

When in flight, the barometric altimeter reads correctly only when the instrument is adjusted to the prevailing local altimeter setting and the air column between the airplane and the ground satisfies the conditions set for the U. S. Standard Atmosphere. Consequently, the instrument indicates true heights.

### *How Pressure Changes Affect the Altimeter*

Any surface weather map shows wide differences in the pressure over the country. Keeping in mind that the altimeter responds only to pressure changes, we can see from Figure 3 that these pressure changes have an important effect on the altimeter. In this illustration, we have an aircraft flying from Tampa, Florida, to

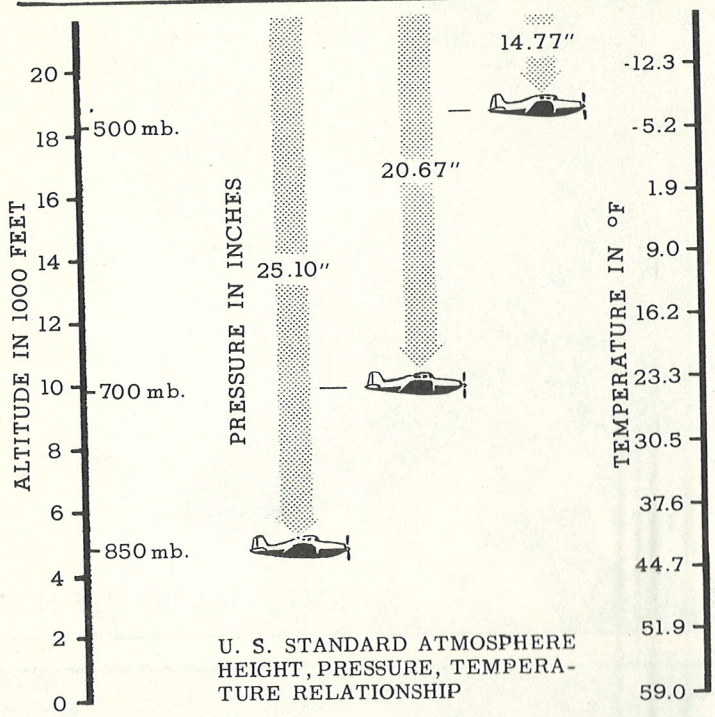


FIG. 2 - SOME FEATURES OF THE U. S. STANDARD ATMOSPHERE. NOTE UNIFORM CHANGE OF TEMPERATURE WITH HEIGHT AS SHOWN ON RIGHT MARGIN. AT 18,000 FEET, AIR PRESSURE IS APPROXIMATELY HALF THE SEA LEVEL PRESSURE.

Mobile, Alabama with the altimeter remaining set to 29.92 inches, (the altimeter setting at Tampa at departure). In this case, the altimeter setting decreases as the flight progresses. Although the pilot flies at an indicated altitude of 500 feet all the way, his true altitude of 500 feet at Tampa decreases to only about 200 feet on reaching the Mobile area. In some weather situations, the pressure changes over a similar distance may be even greater than in this example.

Obviously, if the altimeter is to show as accurately as possible the heights above sea level, there must be some way to compensate for these pressure changes. This compensation is accomplished through the "altimeter

setting'' system. The pilot can obtain the current value for the altimeter setting from ground stations by radio. The usual practice is to obtain the altimeter setting on passing successive CAA Communications Stations, and to re-set the instrument accordingly. In Figure 1, the altimeter is set to 29.90.

### *How Temperature Changes Affect the Altimeter Reading*

We have said that the air pressure at any particular point depends on the weight of the air directly above it. We know that warm air is lighter (less dense) than cold air, but the altimeter does not consider these temperature changes. It senses only that the pressure on it has decreased, and changes its indicated altitude accordingly.

In flight, a correctly set altimeter will read too high when the mean temperature of the air column below it is colder than the U. S. Standard Atmosphere.

Similarly, the altimeter will read too low when the mean temperature of the air column below it is warmer than the specified standard.

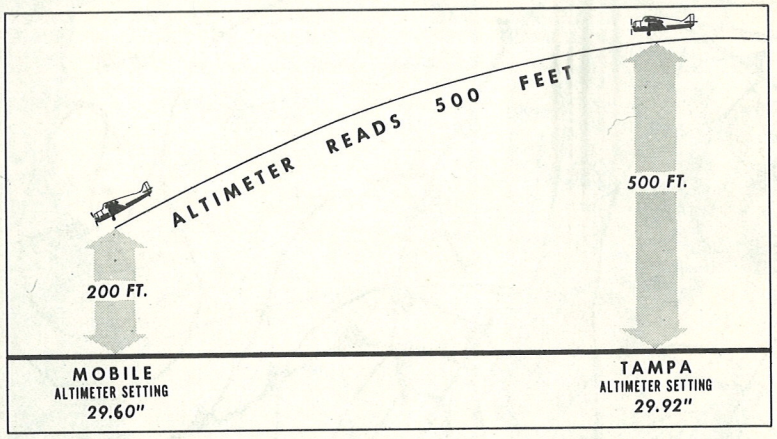


FIG. 3 - THE TRUE HEIGHT OF THE AIRPLANE CHANGES WHEN THE SURFACE PRESSURE CHANGES IF THE PILOT FLIES AT A CONSTANT INDICATED ALTITUDE AND DOES NOT RE-SET HIS ALTIMETER.

For purposes of landing and maintaining vertical distance from other aircraft flying assigned altitudes, we do not correct for the effect of temperature on the altitude reading. In the case of landing, the altitude error introduced by non-standard temperatures diminishes to practically zero during the descent and landing. For vertical separation of aircraft flying at assigned altitudes, all aircraft in a given area will be using the same altimeter setting and any errors introduced by non-standard temperatures will affect all the aircraft alike.

However, when the pilot must determine, if on a certain flight, how much clearance he will have between his assigned pressure altitude and a mountain ridge, he must take temperature into account. To do this he computes a correction to his indicated altitude. A practical rule is to reduce the indicated altitude by 1% for each 5° F that the actual temperature at flight level is below the Standard temperature for the indicated altitude. Similarly, he increases indicated altitude by 1% for each 5° F that the actual temperature is above the Standard. (These corrections can be most easily applied by referring to the correction scales provided for this purpose on most air navigation computers.)

The temperature correction does not account completely for errors in the indicated height which result from non-standard temperature conditions. The reason is that in using the outside air temperature at flight level to compute the correction, one assumes that all the air from the surface upward to the flight level is colder or warmer than the Standard Atmosphere by the same amount when, in fact, that is rarely the case.

The magnitude of the difference between actual altitude of the airplane and the indicated altitude caused by non-standard temperatures can be appreciable. For example, if the air is 40° F colder than the Standard condition, an altimeter reading 10,000 feet will indicate about 800 feet too high.

***Effects of Other Weather Conditions on Altimeter Indications***

Within and in the immediate vicinity of thunderstorms

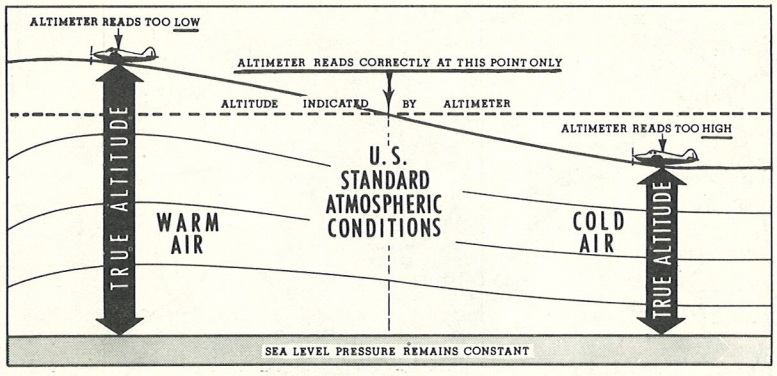


FIG. 4 - THE ALTIMETER READING IS TOO HIGH WHEN THE AIR IS COLDER, AND TOO LOW WHEN THE AIR IS WARMER THAN THE U. S. STANDARD ATMOSPHERE.

localized and brief pressure changes occur which affect the altimeter reading and can not be allowed for with the altimeter setting system. These conditions can cause indicated altitudes to be in error by at least several hundred feet.

Mountain waves, a condition in which air spills rapidly over the crest of a mountain ridge and down the slope, only to be forced upward again to complete one or more wave-like motions, cause localized but very important changes in air pressure. There are reliable reports of altimeters on aircraft flying in standing waves reading more than 1,000 feet too high. (See Aviation Series Article No. 5.) Even when standing waves do not form, strong winds blowing over mountain ridges or peaks can induce local reductions in pressure which will cause the altimeter to read too high. Pressure in neighboring valleys will also be caused to fall by this phenomenon.

### *Other Effects*

Besides the differences that result from non-standard atmospheric conditions and certain phenomena, there are basic instrumental and installation errors that cannot be completely eliminated. For example, the altimeter must be vented to a "static" pressure which approaches the true outside air pressure at flight level. This static pressure is seldom obtained exactly because of the ef-

fects resulting from the airplane's movement through the air. In the case of airplanes of sonic or near-sonic speeds, the errors in altimeter reading often are of such magnitude that special corrections are necessary.

## GOOD PRACTICE RULES

1. Set altimeter to latest reported value just before takeoff. (If the instrument is calibrated properly, the indicated altitude while on the ground should be within 50 feet of the field elevation.)

2. Remember that when in flight the altimeter shows heights based on standard atmospheric conditions, not actual height above sea level.

3. When considering terrain clearance, correct indicated altitude for non-standard temperatures.

4. When flying in mountainous areas, allow greater than normal terrain clearance if standing wave conditions are suspected, or thunderstorms or strong winds aloft exist.