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# WEATHER SERVICE BULLETIN

ARMY AIR FORCES HEADQUARTERS WEATHER WING
JAN. & FEB. 1944 ASHEVILLE. N.C. VOL. NO. 3

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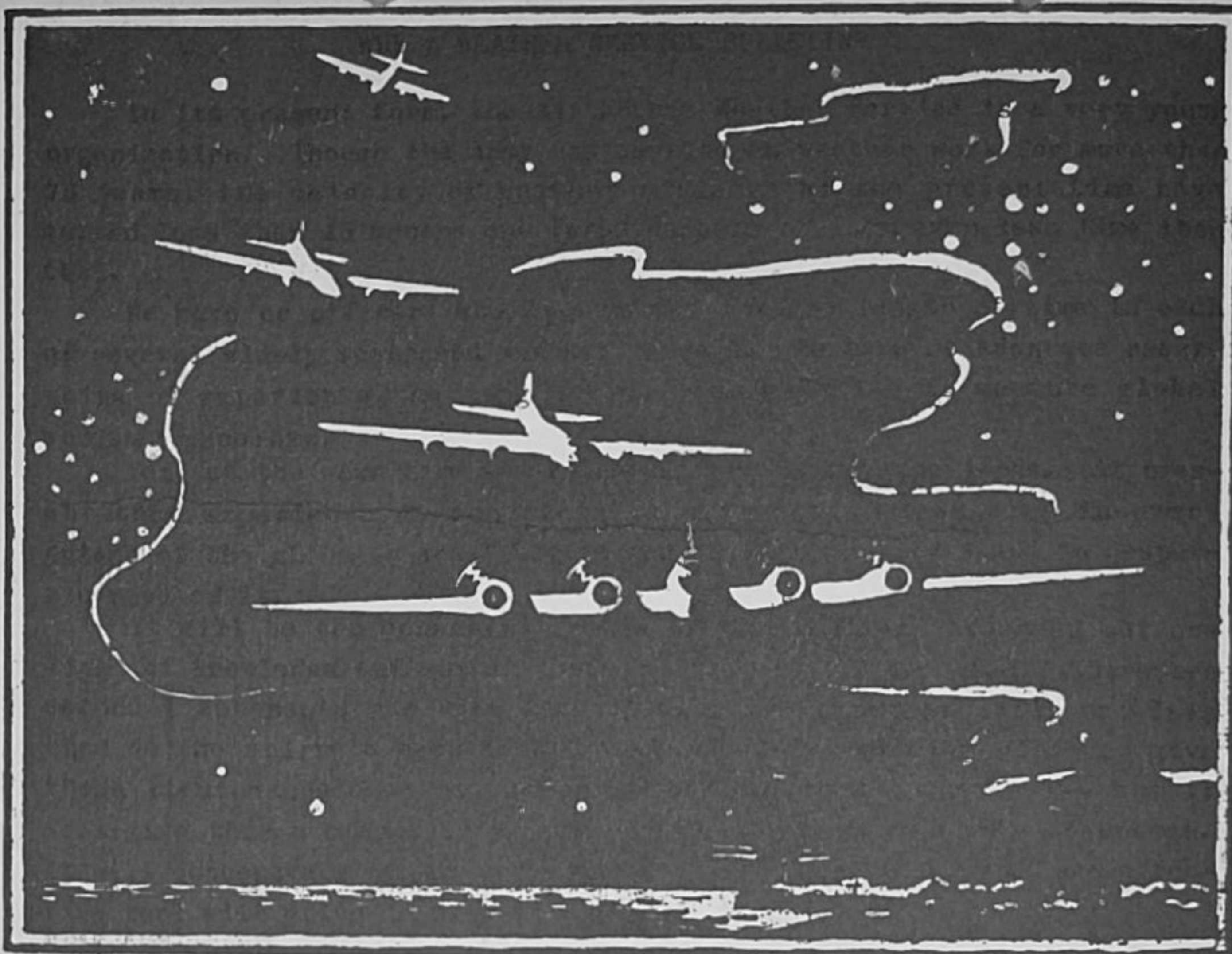

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# STRATUS
# ITS THERMAL STRUCTURE

BY *Major Wallace Howell*

Stratus clouds are usually classified as clouds of stable air, as they occur in air in which the lapse rate is originally less than pseudo-adiabatic (4).

If stratus clouds are sub-classified according to the circumstances of their occurrence, two important types are found. The first of these is a local, ephemeral cloud which usually occurs at night or in the early morning and which dissipates rapidly under the influence of diurnal heating. This cloud is generally found at a very low altitude, at times almost indistinguishable from ground fog. The second type occurs over comparatively large areas within an air mass, appears at a greater height, is much less affected by diurnal changes in temperature, and often remains unbroken throughout the day. Ceilings caused by this type of cloud may vary from a few hundred to as much as several thousand feet. However, the appearance of the cloud is always characterized by almost complete lack of any visible detail of form on its lower surface. (figure 1) Because of its occurrence in wide-spread layers and its persistence, this second form is of greater concern to aviators than is the more local and less persistent type.

In aerial observations of the second type of stratus carried on during the winter of 1941-1942 at Detroit and correlated with the radiosonde observations made at that station, the extent to which stability determined the appearance of the stratus cloud was investigated. Observations were limited to times when a stratus layer had formed within a single air mass, so that overrunning did not play a part in the maintenance of the cloud deck. The temperature change was diurnal in character rather than advective at the times of observation.

In the layer of air between cloud and ground, very light turbulence was found in the form of slight choppiness. The size of the eddies increased and their strength diminished as the base of the cloud was approached.

Even from close beneath the cloud its base was very difficult to see, so there was still no discernible detail of form. The first sign that the plane had actually entered the cloud was a rapid reduction in the forward visibility (figure 2), which diminished steadily until only the ground directly beneath the airplane could be seen, and that but dimly.

The theoretical conclusions reached by Middleton (3) concerning the behavior of radiation as a potential function within a cloud were verified for visible light by measurements made with a photometer after the plane had entered the cloud. The intensity of the light was found to be independent of the direction in which the photometer was pointed, but the intensity steadily increased in value as the sun illumined top of the cloud layer was approached. This increase continued until the first suggestion of blue sky was visible through the cloud overhead.

Vertical air motion was never altogether lacking within the stratus layer, but was always very slight and more marked within the cloud than below it. The motion seemed to be in the form of drafts with relatively sharp boundaries and with lateral dimensions of the same order of magnitude as the thickness of the cloud deck. These drafts reached their greatest intensity near the middle of the cloud deck and diminished in strength near the base and top.

In every case but one, the top of the stratus deck showed strong horizontal stratification, with undulations in it resembling snowdrifts on a snow-covered frozen lake (figure 3). The height of these undulations never exceeded 35 feet, and the wavelength was of the same order of magnitude as the size of the rising drafts within the cloud. The crests were gently rounded, but the troughs were more sharply curved, or even folded. In the one exceptional case, a higher overcast was present about 8,000 feet above the top of the stratus. The appearance of the top of the stratus cloud was then similar to the normal appearance of the base of the same cloud. No detail of outline was distinguishable in the cloud, and it was impossible to perceive the forward motion of the airplane over it. The brightness of the top of the lower stratus layer was nearly equal to that of the higher level, so that emergence from the lower cloud was not noticable until the horizon appeared; similarly, in descending, the only sign that the top of the lower cloud had been reached was the gradual dimming and disappearance of the horizon which paralleled the lowering of the forward visibility as the base of the cloud was entered.

On one occasion, a qualitative estimate of the manner of variation of the liquid water content of the cloud with altitude was possible. Light rime ice was observed forming on the leading edge of the wings of the airplane shortly after the clouds was entered. The rapidity of formation of the rime increased steadily until the top of the cloud was reached, at which time the rate of accumulation was in excess of an inch an hour at an airspeed of eighty miles per hour.

On two occasions the layer of stratus began to dissipate, presumably under the influence of diurnal heating, before completion of the flight. In both cases, the sequence of events was the same. The layer first became broken at the bottom in deep, irregular fissures. These fissures did not reach to the top of the cloud layer, however, but the remaining bodies of cloud near the base gradually assumed the shape of weakly cumuliform units moving successively up into the cloud layer which remained on top. The thinner portion of the cloud sheet appeared as darker areas when viewed from above. Succeding vertical development clouds were smaller until their formation ceased entirely. The umbrella of stratus remaining at the top of the original layer then broke into ragged elements which gradually melted away.

This dissipation process took place in an irregular fashion throughout the extent of the cloud sheet, so that breaks were already visible in some parts of the upper umbrella before breaks had begun to appear in the base of the cloud but a few miles away. This resulted in great variability of the ceiling for the period during which the dissipation took place.

Figure 1

On one occasion, the thickening of a stratus layer was observed from the air. A thin layer of stratus had already formed an an altitude of about 3,500 feet; cumuliform clouds which were almost devoid of vertical currents formed beneath this layer, moved up into, and merged with it. As the upper layer thickened from this addition of condensed vapor, the cumulus clouds grew larger and their sides became less distinctly cumuliform in character, until finally they closed in against each other and formed a continuous layer of cloud which, from the base, did not show any division into units.

The radiosonde observations made a short time previous to each of these flights showed in each case a conditionally unstable lapse rate between the ground and the base of the cloud (in some cases closely approximating a dry adiabat) and a lapse rate within the cloud layer which was neutral for saturated air. An inversion was always found above the top of the cloud except when a higher overcast was present above, in which case the cloud top was marked by an isothermal layer. In none of the cases studied was precipitation in any form falling from the cloud deck.

These observations justify certain conclusions about the thermal state of the cloud layer. Since on all but one occasion the sky above the stratus cloud was clear or with scattered clouds, there was a loss of heat by radiation from the top of the layer which was considerably in excess of the radiation received by it from the atmosphere at a higher level (2). Because of the steep lapse rate between the cloud and the ground, the base of the cloud must have been receiving more radiation from the ground and the air beneath it than it lost in that direction. Since the cloud behaves as a black body for heat radiation (2), the radiative flux of heat upward through it must be very small. Even assuming that heat radiation can, like light, be expressed within the cloud as a potential function, the heat flux along the gradient of this potential will be smaller than the flux above or below it.

Figure 2

The time of day at which the observations were made, i.e., late afternoon, and the slight temperature rises at the ground during the day indicated that the heated ground was warming the atmosphere, but that the rate of heating was very slow.

Since the lapse rate between cloud and ground was found to be very nearly but in most cases not quite as great as the dry adiabatic, the vertical currents in that layer must have been due to frictional turbulence rather than to thermal overturning. It is the transfer of momentum due to this turbulence, which retards the air flow below the gradient level, for which a mean altitude of 500 meters has been ascribed and which tends to deepen as the stability diminishes (1). Under the circumstances described, therefore, it is not improbable that frictional turbulence can account for the eddies found beneath the cloud layer. This view is further borne out by the weakening of the eddies beneath the cloud with increasing altitude.

When the lapse rate is less than the dry adiabatic, convection must result in a downward flux of heat (4), but since the only temperature changes at the ground were small and of a diurnal nature, the radiative heat loss from the ground may have approximately balanced the convective gain of heat at that surface. Therefore, it is suggested that the lapse rate may have been established and maintained largely by a balance between convective and radiative fluxes of heat.

In order for the total heat flux upward through the cloud layer to equal the radiative loss from its upper surface, most of this would have had to be accomplished by convection. The lapse rate, therefore, became steeper than the saturated adiabatic, initiating convective currents. The presence of convective currents was experimently verified.

In the chosen situations, large scale horizontal convergence was ruled out as a major factor in the weather situation. Therefore, convective rising currents within the cloud layer must have been compensated for by falling currents, and a sheet of convective cells produced (1). Yet no rifts appeared in the base of the cloud sheet except when it began to dissipate. It must be assumed, therefore, that the air followed a reversible moist adiabatic path, the moisture which condensed in the upward branch being reevaporated into the same air on the return branch of the path. As Schirn (6) has shown, this requires that the cloud contain more liquid water in its upper part than in its lower part by the amount condensed into saturated air rising through the depth of the cloud. This conclusion was experimentally verified in a qualitative fashion by the observation of the increased rate of

Figure 3

icing in the top of such a cloud.

Whether the reversible moist adiabat may be followed depends partly upon whether or not the condensed moisture will fall out of the air from which it was condensed. If we assume a cloud layer with a thickness of 1500 feet containing convective cells in which the maximum upward velocity is 50 feet per minute (a conservative value), a convective cycle would be completed in approximately three hours. If we take the average drop size as 50 microns, calculation of the speed of fall by Stokes' formula (5) yields a total fall of only 8.1 meters in 3 hours. It is obvious that even the slightest amount of small-scale turbulence within the convective cell would be sufficient to nullify the effects of such a slow rate of fall. No precipitation was observed from any of the stratus clouds observed.

If we assume the cloud layer to be a stratum of finite thickness which is undergoing cooling from the top and/or heating from the bottom, and we assume further that moving air within the stratum follows a reversible moist adiabat, thermal circulations will take place which will take the form of convective cells extending from base to top of the layer. The size of these cells will be a function of the thickness of the layer, their diameter approximating twice the thickness (1).

These cells would slightly deform the top of the layer: they would also deform its base were it not for the fact that the cloud is dissipated within the downward extension of the circulation. The deformation of the top, furthermore, would be in the form of softly rounded domes separated by sharp or even folded troughs. Thus, Helmholtz waves would not alone determine the conformation of the top of the cloud layer.

This seems to have been verified at least indirectly by the presence of drafts of as large dimensions as might be expected, considering the depth of the layer, and the fact that these drafts were strongest near the center of the layer. That the impulses reached the top of the layer with positive energy may be deduced from the conformation of that surface, which showed rounded bulges. The energy produced by the instability was only just sufficient to carry on the convective process, and was totally absorbed within the cloud layer. The evidence of instability is further supported by the manner of formation and dissipation observed.

The conclusions which may be drawn from these observations are that the type of stratus referred to is characterized by a lapse rate within the cloud layer closely coinciding with a pseudo-adiabat, while the lapse rate between the cloud and the ground will be stable with respect to unsaturated air. The only absolutely stable layer of air associated with the cloud, then, will be found lying next above it, induced by the radiative cooling of the top of the layer of cloud. The cloud will become thicker by continuance of this radiative heat loss, and will be dissipated, in the absence of other forces, by heat from the ground, warming the entire layer to such an extent that its relative humidity will fall below 100 per cent at the top of the layer. The quantity of liquid moisture will, in the absence of precipitation, be roughly proportional to the height above the cloud base.

These conclusions relate this type of stratus more closely to stratocumulus than does the usual classification of it as a cloud of stable air. In this case it is natural to ask what does differentiate between the stratocumulus clouds and the stratus clouds? One possible answer is that stratocumulus results when more energetic thermal circulations than those in the stratus clouds are set up. These penetrate the overlying stable air sufficiently to mix with or entrap drier air which then forms rifts in the stratocumulus cloud on the way down. Turbulence is generally more marked in a stratocumulus layer than in a stratus, and its top is usually much more broken up.

(1) BRUNT, D., "Physical & Dynamical Meteorology
(2) ELSASSER, W., "An Atmospheric Radiation Chart and Its Use"
(3) MIDDLETON, W., "Visibility in Meteorology"
(4) PETTERSSEN, S., "Weather Analysis & Forecasting"
(5) Phys.. Math. Papers, Vol. III
(6) SCHIRN, I., "Forecasting Ice Accretion in Clouds"

# *RELATIONS OF THE WEATHER SERVICE TO AIRCRAFT ACCIDENTS*

*A principal function of the domestic Army Weather Service is to afford a facility which will contribute to a reduction in the number of aircraft accidents. Accidents in which weather is a factor account for three times the fatalities statistically expected of aircraft accidents in general.*

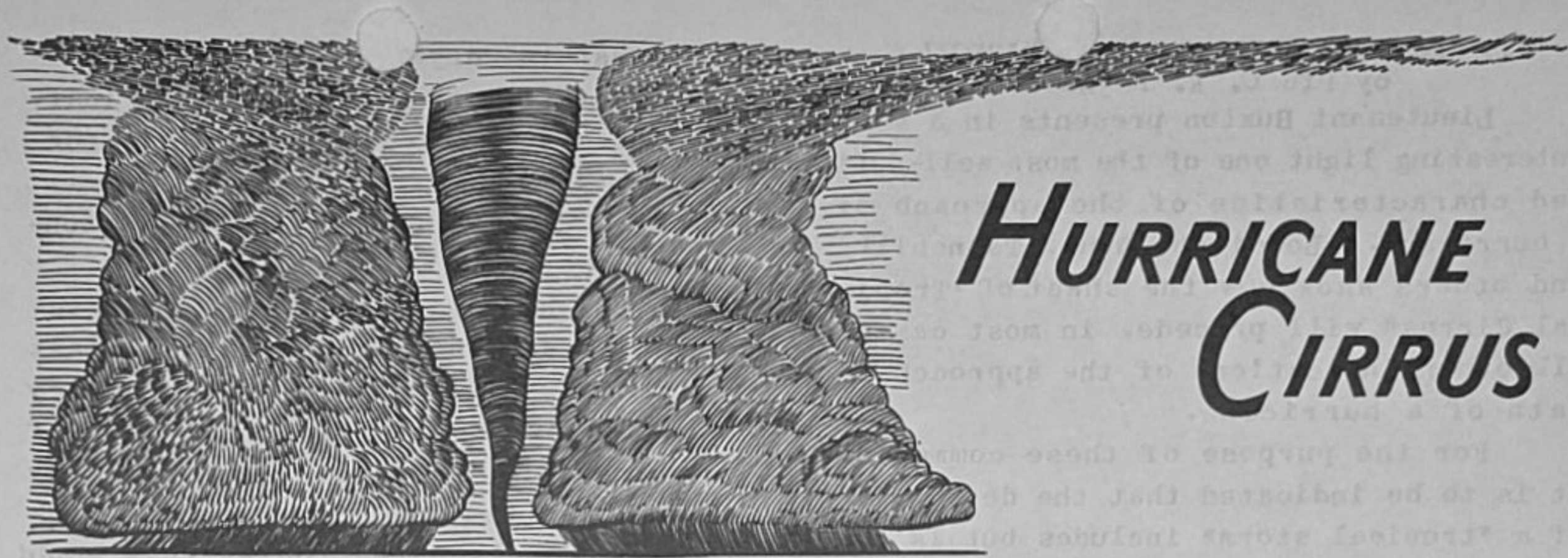
*A survey of 'weather' accidents in 1943 demonstrates that in half of the cases there was no apparent deficiency in weather services rendered: 'screwball' antics by the pilot such as disregard of the flight plan, unqualified instrument flying, and ignorance of emergency flight precedures (in icing conditions or thunderstorms for example) were at fault.*

*One tenth more of the total in which weather had a part resulted from accidents subsequent to takeoff from fields where weather service was not available. Army weather organizations must assume a part of the responsibility for the remainder, about equally divided between forecasting blunders and failure to use weather information properly by operational personnel.*

*The superficially acceptable record of only one fifth of weather accidents attributable to weather briefing errors is marred by disasters which continue to result through failure to call attention to weather hazards in firm, clear language during an otherwise technically correct description of the synoptic situation.*

*Claimed inability to have done better after a 'busted' forecast often is unjustified because predictions were based on a few phases of the information at hand. Forecasting cannot be made mechanical by use of a few handy tricks---careful weighing of all data will pay off in lives on that day when the unorthodox occurs.*

*The individual weather officer shoulders part of the responsibility for those accidents where weather service was available but was not used or was improperly used. The well-run station where forecasters are precise without being pedantic and conscientious but yet concise is sought out by pilots. Slow service or careless forecasts certainly tempt the pilot to skip the weather angle. On the back cover of this issue we initiate a series of post-mortems of aircraft accidents associated with the weather service. The object lesson of reply to an examining board with scrutiny of questionable forecasts following a crash costly in lives and equipment cures many a fault, yet that price is too high for instructional purposes.*



# HURRICANE CIRRUS

*I CIRROFORM STREAKS RADIATING FROM STORM CENTER*

by 1st Lieutenant E. B. Buxton

One of the first signs of a hurricane is a distinctive display of "Mares Tails" cirrus in streaks radiating from a point on the horizon which lies in the direction of the storm center. These wisps of cirrus are similar in appearance to the feathery plumes of $CH_1$ and $CH_5$ illustrated in the "U.S. Weather Bureau Cloud Atlas" (publication # 1249) and in "The Weather and Clouds of Manila" by C. E. Depperman, S.J. The streaks are frequently twisted and sometimes curve slightly as they extend across the sky from one point on the horizon.

The observation of this type of cirrus has for many years warned mariners of the location of hurricanes. Reference is made in Bowditch's famous navigation tables and manual to the importance of radiating cirrus as an indicator of storms. It can best be seen from middle latitudes and is visible 1000 miles or more from the center of the storm, but only at the time of genesis or during periods of deepening of the vortex. The disappearance of cirrus indicates that the cyclone has reached a stable state or is filling; no more air is being forced out of the top of the storm.

This cloud is most frequently observed at sunrise or sunset when local convective clouds are not so likely to obscure the view. The elements of the cirrus plume itself travel upward and outward from the storm center at high velocity, ending in a wispy tuft where the upthrusting ice particles of the cloud penetrate a level of counter-moving air. Usually not more than two plumes can be seen from place of observation. Since parallel bands of high and medium cloud also appear to converge toward the horizon, care must be taken in using convergence as a criterion of identification. Warm front cirrus bears considerable resemblance to the "Tropical disturbance but is more widespread and merges into a continuous cirro-stratus sheet. Moreover, it has an increasing tendency rather than the intermittent or decreasing tendency of the pulsating "Tropical Cirrus." Because the synoptic chart indicates where warm front cirrus is to be expected, any unexplained cirrus that fits the above description might well be attributed to a tropical cyclone in the process of formation.

This type of cirrus has been observed many times in New Zealand before the existence of a hurricane to the north has been confirmed by other reports. In similar fashion, the cirrus from hurricanes in the Gulf of Mexico can be seen in Chicago. Likewise from San Francisco displays of tropical cirrus have been seen radiating from a point on the southern horizon at the same time a hurricane has been reported off the west coast of Mexico.

Weather reporting codes should make provision for indicating the quadrant of the sky in which cirrus is observed. Then, even inexperienced observers can contribute valuable clues to the hurricane forecaster whether they correctly identify the form of cirrus or not. Some codes do provide a means of indicating the direction that cirrus cloud is moving, and from such reports the bearing of the storm from the observer can be determined.

## *II. IDENTIFICATION BY CLOUD DIRECTION*

by Pfc C. K. Reynolds

Lieutenant Buxton presents in a very interesting light one of the most well-defined characteristics of the approach of a hurricane. Bowditch, Dunn, Tannehill, and others show how the sheet of "Tropical Cirrus" will precede, in most cases, all other indications of the approach or path of a hurricane.

For the purpose of these comments, it is to be indicated that the definition of a "tropical storm" includes but is not sufficient for a "hurricane". A suitable description would show a tropical storm to be an area as much as five hundred miles across, exhibiting marked instability, thunderstorm activity, heavy rain, and gustiness. A hurricane, in addition, is associated with wind velocities of force twelve or greater distributed as in a true vortex and has a much more limited extent.

Unfortunately for the cirrus criterion of hurricane approach, false cirrus is very common. If the tropical storm is within five degrees of the Equator, the cirrus will extend westward from the main storm area. Between 5°N. and 20°N., the tropopause has lowered sufficiently that the cirrus extends eastward, for the cumulus development will extend up to the level of the Anti-Trades. We may then assume that in very low latitudes a westward movement of tropical cirrus is indicative of a storm to the east, while further north up to 20°N. an eastward movement of tropical cirrus portends an area of convective activity to the west.

We now have indicated that the movement of tropical cirrus from west to east or east to west, is not a satisfactory indication of the action or approach of a *hurricane*. I believe we may safely disregard any reference to cirrus moving from a northerly direction as this would probably be associated with extratropical circulations or with upper-level pressure cells.

Within the tropical and extratropical regions, cirrus regardless of type which is moving with a southerly component is often indicative of the location and path of a hurricane (see figure 2).

In the "dangerous" or northeast quadrant of a hurricane, we find maximum convergence between the south or southeasterly flow of warm air and the east or southeasterly current of slightly cooler air. If we assume equal temperatures in this convergence, the release of energy will be primarily dependent on convergence alone. It appears that we may expect the southerly current to be somewhat warmer than that from the east; therefore lifting of the southerly current will occur, indicated

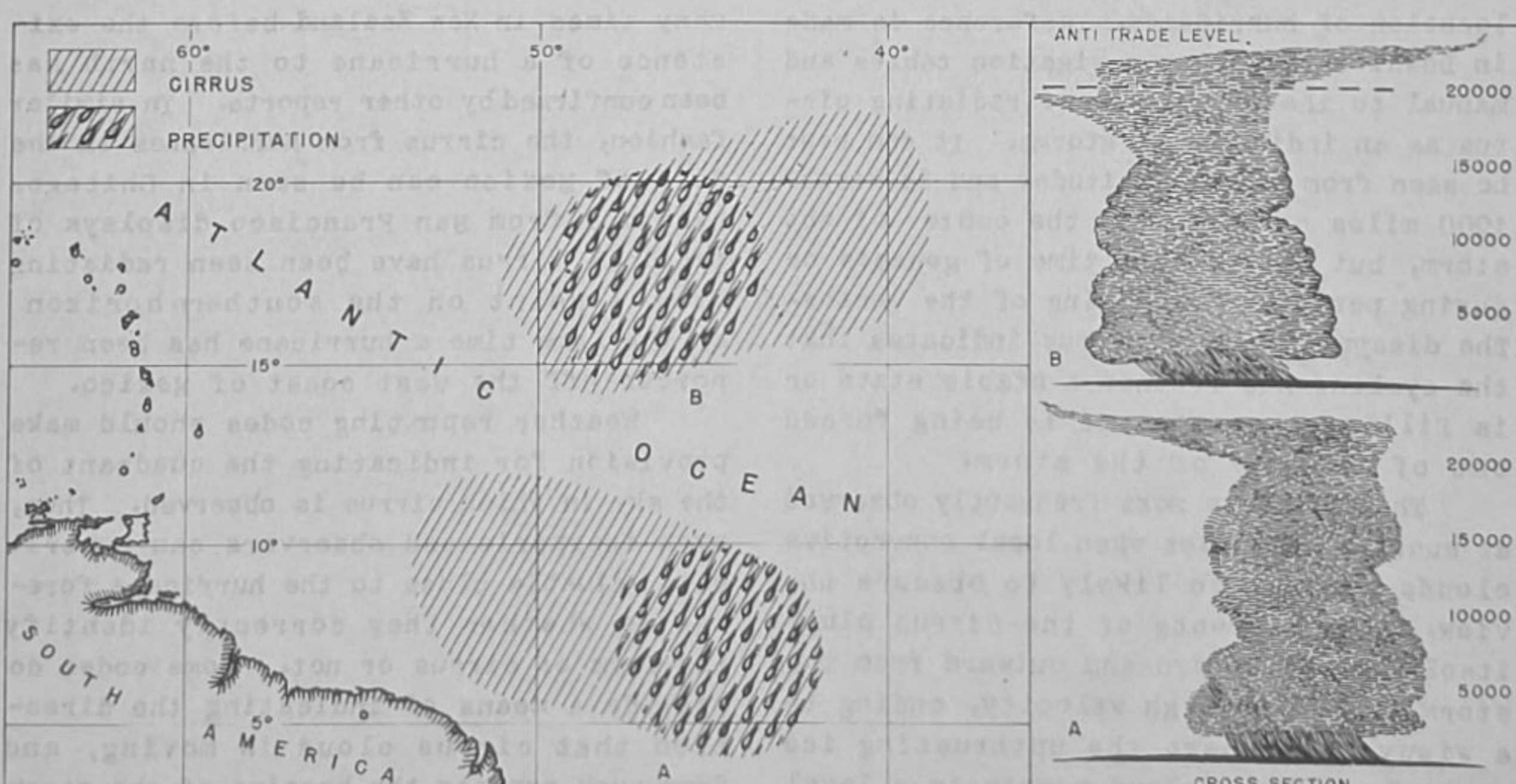



Figure I

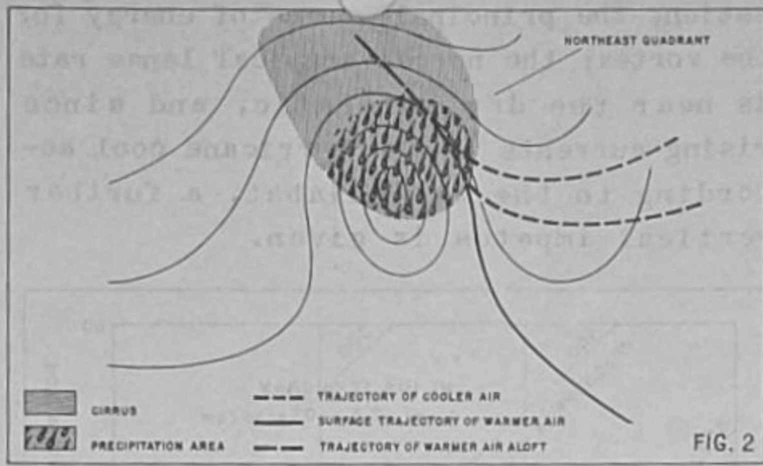


FIG. 2

by the advance of cirrus north and west of the hurricane center.

I have been in the northeast quadrant of four hurricanes and several distinct circulations not of hurricane intensity, and I think the cloud plates chosen by Lt. Buxton for reference are typical of the early stages of approach. However, the most experienced observer might suggest the use of cloud plates 47, 48, and 50 to show the increase in amount and intensity of the cirriform clouds as the hurricane approaches.

Unfortunately, these plates are all photographed in middle latitudes and are not associated with hurricane activity. This fact indicates perhaps the most serious condition imposed on nephanalysis in relation to hurricane forecasting.

Nonetheless, we may safely draw the conslusion that the circulation attendant upon a hurricane will give a directional component to the cirrus which is not present in non-circulating storm areas.

### *III A CRITIQUE OF CIRRUS WARNINGS*

by Rev. C. E. Depperman, S. J.
(from "Outlines of Phillippine Frontology")

What about the use of radiating cirrus to tell both the direction in which a typhoon is located and also its direction of motion? Fr. Vines of Havana, Cuba, was very enthusiastic about this criterion in the case of hurricanes of the West Indies. Fr. Algue was more reserved about its application in the Philippines, but still considered that used with care it could be of great help at times.

The writer confesses that, at least with regard to typhoons which have come under his personal observation during the past few years, he has had very little success with the criterion. A little figuring will show that, for a typhoon 500 km. away, the radiating cirrus must

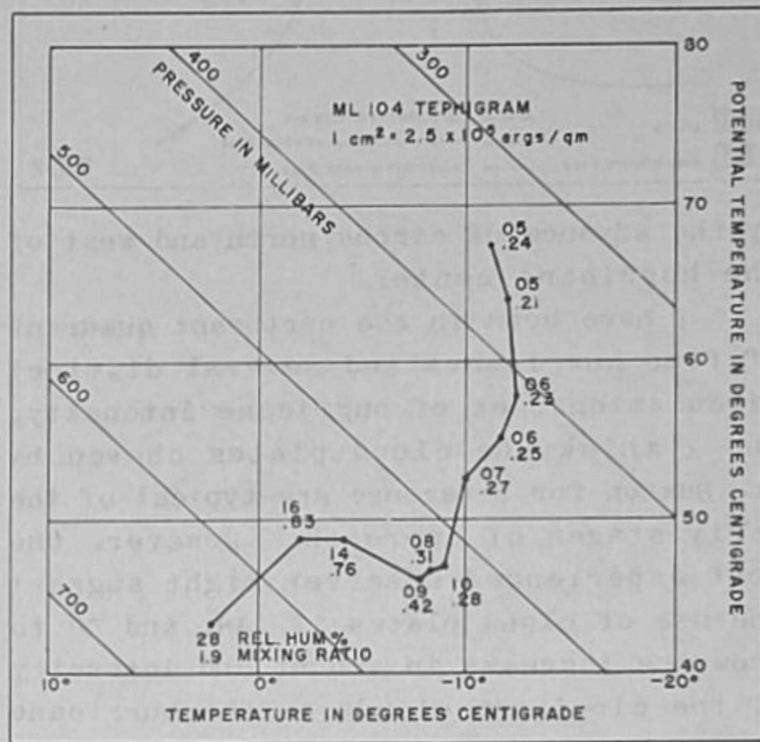
show a convergence of a comparatively few degrees from horizon to horizon, quite difficult to discern, unless very sharply defined, from the parallel cirrus which is also often present. In quite a few cases where the writer thought he had convergent cirrus, careful observation showed that there were generally *two* sets of *parallel* cirrus of different altitudes meeting near the horizon. The significance of these two sets of cirrus has not yet been found.

In many cases, especially with smaller typhoons, nothing could be done with cirrus for the simple reason that no cirrus was on hand. It seems quite sure that the influence of *small* typhoons does not reach so high, although the contrary must definitely be postulated for large ones. Fr. Gherzi of Zi-Ka-wei Observatory (Shanghai), has written the writer of the case of an airplane pilot near Shanghai looking towards the top of a distant typhoon, which certainly did not have cirrus above it and whose clouds were no higher than the height of altocumulus. It would seem, therefore, that the radiating cirrus criterion should be used with great reserve.

### *IV. SOME FAMILIAR DYNAMIC CONSIDERATIONS*

The observed distribution of airflow in a hurricane is that of a true vortex, defined by conservation of angular momentum in the flow about the center of the disturbance. This condition requires that the pressure gradient increase in the second power as distance from the center decreases linearly.

As $r$ becomes small, then, the velocity becomes very great. Extremely heavy precipitation, accompanying tremendous clouds of vertical development, releases great quantities of latent heat of condensation, the principal source of energy for the vortex: the normal tropical lapse rate is near the dry adiabatic, and since rising currents in the hurricane cool according to the wet adiabat, a further vertical impetus is given.




*Apob taken in eye of hurricane on 18 Sept. 1943 between 1440 and 2040 at 27°30'N. 94°10' W (Gulf of Mexico). Navigator calculated 10000 ft. wind near center at 64 mph."Eye surrounded by huge cumulonimbi, which reached at least to 40000 ft. while storm center was cloudless above and below the plane."*

When $r$ is of the order of 3-15 miles, though, the steep pressure gradient abruptly ceases and a calm is typical. The sounding shown above, taken in the "eye" of the hurricane, shows a stability and a dryness expected of subsiding air. The popular explanation is that pressure decreases toward the storm center until air aloft is drawn downward, wiping out clouds and rain in the "eye".

*Weathermen of all ranks and duties are urged to give literary form to unusual experiences and achievements in any of the many and varied Weather Service activities. The 'Weather Service Bulletin' is meant to disseminate any information that will ease or improve the performance of any weather duties. Contributions ranging from 'How to Fix a Radiosonde with a Hairpin' to 'A Mathematical Analysis of Atmospheric Motions' all have their place.*

# Arctic Rescue

# BY AIR MISSION

BY *Capt.* Elmer Stettler

*FOREWORD*

The Hudson's Bay Company supply ship "Nascopie" on its 1942 voyage in the far north, carried supplies and personnel to equip a weather station at Fort Ross, as well as provisions for the maintenance of the Company's trading post there. However, heavy pack ice in September prevented the ship from penetrating southward through Prince Regent Inlet to reach Fort Ross. The supplies for the weather station and the post were landed at Arctic Bay instead.

A year later, the Nascopie was again forced to turn back to avoid being frozen in for the winter after three weeks in the pack ice almost within view of Fort Ross. It then became apparent that it would be necessary to evacuate the factor, his wife and the clerk by air, since they did not have enough resources to survive the winter,

An appeal was made by the Canadian government to Lt. Colonel J. P. Fraim, commanding officer of the USAAF in Central Canada, who organized and directed the rescue expedition.

*CAPTAIN STETTLER'S REPORT*

The part that weather played in the solution of this problem was a vital one. Plans for completion of the rescue mission were conditioned more by the rarity of weather suitable for flying and the rapidly diminishing duration of daylight than by the limited food supply of the persons to be rescued.

Reports given by the post factor demonstrated that no direct sunlight strikes Fort Ross between 17 November and 5 February. Because the duration of twilight increases as the sun's rays strike the earth at an ever smaller angle (days get shorter), the use of sun and stars for navigational purposes would be restricted.

Since the first preliminary flight did not take place until 27 October, haste was essential.

A summary of weather and climate for the field of our proposed operations, obtained from various sources, described frontal activity as the most significant meteorological condition throughout the early winter season. Later in the winter, weather is of a semi-permanent character associated with the large North American anti-cyclone.

November, October, and December in that order are the snowiest months of the year. Further, the period of the rescue preparations was coincident with the most frequent occurrence of blowing snow, sometimes called ground drift, which often limits surface visibility to less than three miles.

An examination of existing meteorological facilities, including Canadian Department of Transport as well as U. S. Army installations within the operational area, indicated at once that the major problem facing the staff forecaster would be to secure sufficient synoptic weather reports in the area north of $65^{\circ}$N. to lend confidence to the weather analyses.

Several outlying Hudson's Bay Company posts were recruited as weather observing stations. Previous sources of data were organized for purposes of the rescue to give frequent and precise reports. The entire network was then tied through the communications center to the Weather Division in Washington where special forecasts were made and forwarded to Southampton Island, the base of rescue operations.

After preliminary flights between Churchill and Southampton Island, "dry runs" with skiis on the ice near the latter base, and an orientation flight over Fort Ross, Captain John Stanwell-Fletcher parachuted to the ice near Fort Ross to mark out a landing strip for the final evacuation. Three days later a successful landing was made on a frozen lake about ten miles from the post.

The importance of open water surfaces for forecasting local stratus cloudiness was not to be underestimated—low ceilings and dangerous icing conditions were typical of wide areas in the vicinity of Hudson Bay when winds were blowing from the direction of such a large surface of open water.

From Great Falls, Montana, came regular map analyses via radio and teletype. These turned out to be of major significance in the preparation of operational forecasts. Weak frontal systems, associated with little or no weather and a shallow trough, often gain in strength as they move across the sub-Arctic. More weather and more clearly-defined surface indications are seen to develop. Surface observations taken as far south as Churchill do not indicate anything except variable high and intermediate cloudiness as these troughs pass. The type, extent, intensity and movement of occluded systems entering the continent constitute essential information to the forecaster of conditions in the far north.

There is no doubt that the attention paid to weather was necessary and justified. All things considered, actual flights were made on the best flying days. In one instance the forecast for the day's operations underestimated the intensity of cloudiness, but even then the flight was completed satisfactorily.

*FORECASTING AND OPERATIONAL DISCOVERIES*

The "Beaver", magazine of the Hudson's Bay Company, had the following to say about the rescue: "In bare outline it sounds simple, but actually it was far from that. Fort Ross is nearly four hundred miles above the Arctic Circle, just opposite the northernmost tip of the continent, and the expedition will undoubtedly go down as an outstanding event in the long story of arctic adventure. Certainly the men who brought it to such a successful conclusion deserve the highest praise."

Yet more was accomplished than simply the rescue of three marooned people. From the most complete weather-reporting network ever assembled in the American Arctic came information about the weather along the northern border of the continent which has never before been available. Specific forecasting aids have been contributed to future operations.

Above all, the mission demonstrated the practicability of aircraft operation in the Arctic during the worst season of the year. In fact, Lt. Colonel Fraim was so impressed with the performance that he was all for establishing and maintaining weather stations by air even farther north than Fort Ross: on Axel Heiberg Island or at the North Pole itself.

# *ICING* ON AIRCRAFT: III

by DAVID L. ARENBERG

### *AERODYNAMIC EFFECTS OF ICING*

It is well recognized that the hazard produced by icing is not due to the weight of ice but to the following factors:

1. *Increased drag.*
2. *Decreased lift because of change in airfoil shape.*
3. *Increased stalling speed.*
4. *Decreased propeller efficiency.*

Any difference in the smoothness of a wing surface, especially at the leading edge, disturbs the flow in the boundary layer and greatly increases the drag. In a series of wind-tunnel tests it was shown that one-half inch of ice deposited at the 5 percent position on a 100 inch airfoil reduced the lift about 50 percent and increased the stalling speed by an equal amount. Applied to BT-9 this means that the stalling speed would increase 20 mph, and on a P-39 it would jump 50 mph. Frequently the pilot is not aware of this condition and has no indication that a critical change is occurring until he comes in to land. A small deposit of ice may be formed on the leading edge that is of no importance in normal flight; but as speed is reduced for landing and the angle of attack changes, an increase in stalling speed also will take place. The safe rule is to maintain flying speed whenever there is any ice on the plane.

The aerodynamic effects of icing are cumulative. Increased drag makes it harder to maintain airspeed at the same time that the stalling speed becomes greater. The loss of propeller efficiency simultaneously reduces the amount of engine power available for maintaining the necessary speed and the fact that the ice does increase the weight of the craft is no help. Planes with high wing loading or critical control characteristics are quickly rendered unflyable or will be forced to lose altitude by even a small accumulation of ice. Because different types of airplane react differently, it is important that a pilot know the characteristics of his airplane before attempting to fly in an icing condition.

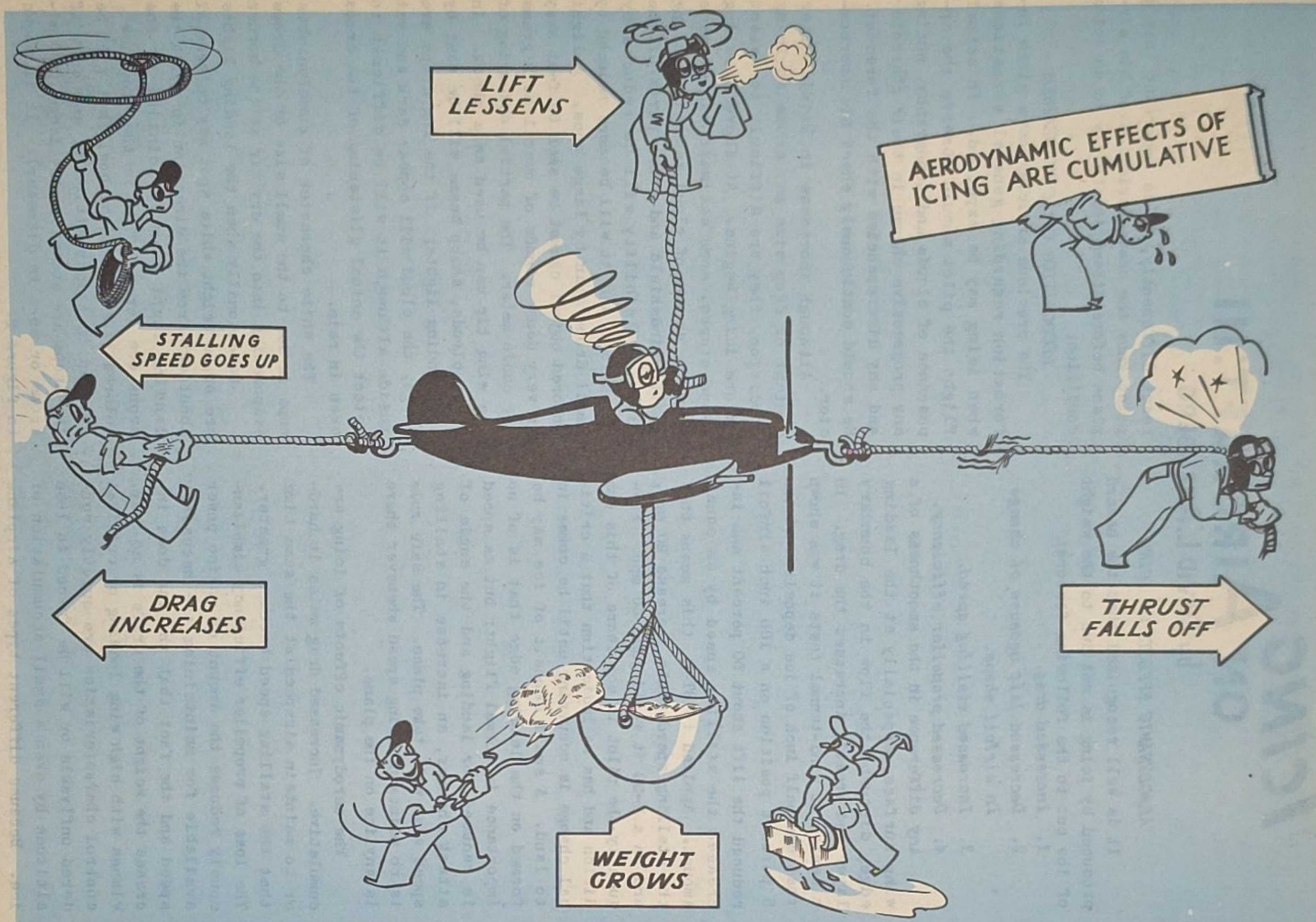
### *RECOGNITION OF ICING WEATHER*

The previous articles have given information regarding general situations when icing may be expected. In actual flight the pilot should observe the appearance of clouds and topography, noting any progressive change in their character and any discrepancies with the forecast. He should continuously check his thermometer.

Although increases in liquid water content or drop size may cause an icing condition, they are difficult to detect before icing begins. At above freezing temperatures, some estimate can be made from the amount of cloud water collecting on the windshield and other parts of the plane. Visibility will be reduced by thick fogs, but it will be more reduced by small drops than by large ones. A light colored object cannot be seen 60 feet away in very dense clouds of over 1 to 2 grams per cubic meter. The partial obscuring of the wing tip can be used as a check. In dense clouds, sharp beams will be cast by the landing lights; if the fog drops are large, the cloud will appear dark and wet inside although it will be difficult to detect the actual glistening of the drops even in rain.

The white character of cumulonimbus tops is due to the small size of the drops evaporating into the dry air at the border.

Occasionally when the landing lights are on, a bright white spot may be seen at about 42° from the direction in which the landing light beam is pointing if the drops are large. This is the "fog bow", colored like a true rainbow, that will be located in this position if and only if the drops are exceptionally large (100 microns or more in diameter). It is shown in figure 2.


LIFT LESSENS
AERODYNAMIC EFFECTS OF ICING ARE CUMULATIVE
STALLING SPEED GOES UP
DRAG INCREASES
THRUST FALLS OFF
WEIGHT GROWS

If the cloud .. composed entirely of ice needles, a whitish spot may be seen at about the same point, corresponding to an antisolar halo; but these are usually too faint to be seen.

Even a somewhat inaccurate icing-rate indicator, however, would be more reliable than trying to make a guess on the basis of such indirect measurements of drop size.

Increasing turbulence in the air is an important indication of changing stability and convection. As was shown in a previous article, the rate and density of icing usually increases with altitude in turbulent clouds but diminishes with altitude in clouds without turbulence. In warm fronts, turbulence gives warning of approach to thunderstorm areas hidden to the observer in the plane when flying on instruments.

Reports from other pilots of icing, turbulence , and precipitation will help when they are available. Flights beneath a warm front are generally safe at high altitudes above land and over oceans.

*EFFECT OF PRECIPITATION FORMS*

*Sleet* may be encountered. It is no hazard in itself but is a warning of super-cooled rain at a slightly higher altitude which should be avoided by *not* climbing. It also indicates freezing rain at the same level in the direction of the warm air mass.

*Freezing rain* can cause heavy icing over a small locality, but the area involved is usually so small and the intensity so low that it would not be serious. The presence of freezing rain indicates an inversion with higher temperature above. Climbing into the warmer air above will allow the deposit to melt off. Icing will recur at a still higher altitude and should be avoided.

*Heavy Snow* sweeps out water drops from the cloud and reduces the icing hazard. At temperatures near freezing the snow may be wet and sticky. It will then pack against the wings and windshield and may clog air passages around the oil radiators and inside the engine cowl, producing excessive head temperatures. Mechanical devices have been designed to reduce these annoyances to a minimum.

*Hail* o..urs in connection with thunderstorm activity and severe icing. Because hailstones occasionally reach a diameter of five inches, they can cause structural damage to a plane traveling at 200 mph. Even small hailstones will dent wings, break out landing lights, and chip the windshield. Damage can be minimized by slowing down to minimum safe airspeed. Flying beneath the projecting shelf of a forward edge of a thunderhead as well as flying in the icing region above should be avoided.

*Small hail* is composed of small round conical particles of ice-covered snow. Small hail falls out of petty shower clouds and usually indicates local showery areas of severe icing and turbulence. Such areas are usually easily avoided by flying around the clouds or by changing altitude.

*Snow pellets* (graupel) are rime covered snowflakes. They indicate a region of icing in the lower layers of the clouds from which they fall. Usually they are seen only at the beginning or end of a storm and generally accompany showery weather. When observed from an airplane in flight striking against the windshield, they indicate a change in icing intensity.

*Effect of High Speed*

High speed will affect the chances of icing. At very high speed, impact and friction of the air are enough to raise the skin temperature of the airplane above the temperature of the surrounding air. This is important only at speeds above 300 mph. The energy in a drop of water striking a plane at 400 mph is enough to heat it 4°C.. Increasing the speed has the effect of raising the altitude of the freezing level, and even when freezing is occurring, the drag of the airstream may remove a large proportion of the water before it can solidify. The effective 0°C. isotherm will be lifted about 2,500 feet at 400 mph. Forecasts should be made with this in mind.

The pilot, however, should remember that his thermometer reads the wing temperature, not the true air temperature, and he has no further margin of safety. As soon as ice begins to form at high speed, unless the pilot can immediately descend and find warmer air, he should slow down to a safe margin above stalling speed to minimize the deposit rate and density of the ice.

Most protective measures should be applied before icing begins or as soon as possible thereafter. Glaze may be difficult to detect, particularly if it is light and clear (as when caused by supercooled rain below the cloud) because it will conform to the shape of the airfoil. Even when ice is not visible on the smaller parts of the plane, pilots should recognize the following danger signals:

1. *Logy, unresponsive controls.*
2. *Sudden, foreign vibrations.*
3. *Inability of the plane to climb.*
4. *Loss of altitude.*
5. *Loss of airspeed.*

### *AVOIDANCE OF ICING*

*It is always wiser to avoid ice than it is to combat it,* except when military necessity dictates that icing conditions must be flown through. The following is a summary of methods for avoiding icing:

1. Study the weather map ahead of time. Know the altitude of the freezing level so you will know whether you can safely find above-freezing temperatures by descending. Note the levels of cloud layers, the motions of cloud systems, and the direction in which the best weather lies.

2. Avoid cumulus, cumulonimbus, and stratocumulus clouds at freezing temperatures by flying above them, around them, or below them.

3. If you encounter icing while on instruments in smooth air, descend if you know that you can reach above-freezing temperatures safely. If freezing temperatures extend all the way to the ground, if you are over mountains, or if there is danger of enemy interception beneath the clouds, ascend to reach a temperature of less than $-15^{\circ}C.$.

4. If you encounter ice in turbulent clouds, (even if the turbulence seems slight) descend if this can be done safely. Even if you do not avoid ice entirely it will become lighter. If you cannot descend, climb only with the object of getting on top of the clouds. Make the climb as rapid as possible to shorten the time of exposure to icing.

5. Avoid clouds over mountain regions or fly over them as high as possible when icing levels cannot be avoided entirely.

6. Turn around, if your mission permits it.

7. A report of moderate or heavy precipitation at a station ahead on your course indicates that icing will not be severe there.

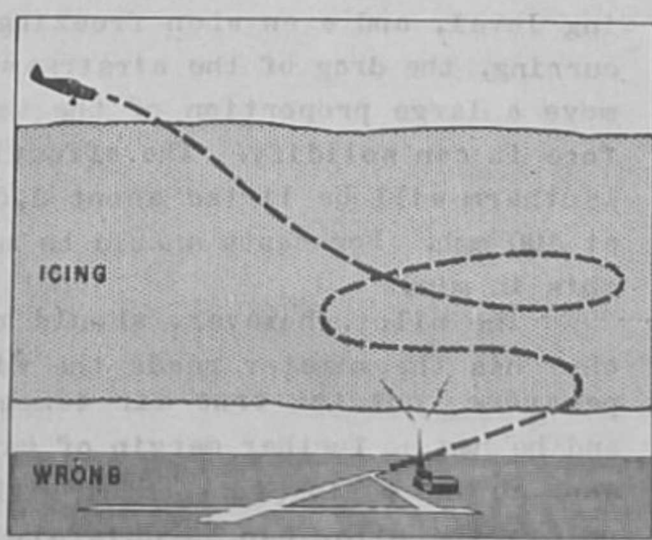
8. In freezing rain, climb only to above-freezing temperatures, not higher.

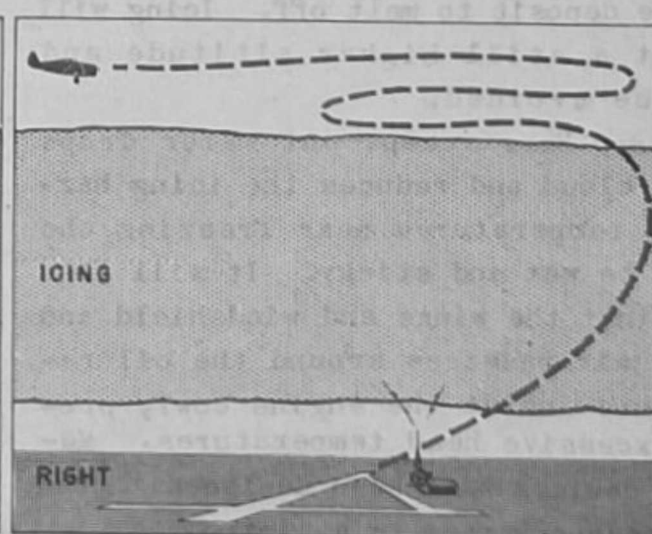
9. In sleet do not climb. There is freezing rain above.

10. Do not fly on unconcernedly while your plane ices up. Icing is most easily avoided when it is first encountered. Decide what to do, then *do it*. Don't just wait for a change for the better.

### *MINIMIZING ICING*

When, because of emergency or for reasons of military necessity, it is impossible to avoid an icing region, steps should be taken to minimize the amount of ice forming on the airplane and thus preserve as much as possible of its efficiency for future demands. There are three



things that can be done in practically every case:

*Take the shortest route* through the icing condition. By heading directly through the icing region, even if it means a departure from the shortest map route to the destination, maximum efficiency of the airplane is maintained; time and fuel are thus saved in the long run, and the safety factor is greater.

When crossing mountain regions where local areas of cloud exist, it is better to fly away from the range and cloud system to gain sufficient altitude to clear them rather than to take the shortest route.

In descending for landing or ascending through an icing layer, slow rates of climb or descent should be avoided.

The same rule applies when crossing a front that cannot be avoided. Either from advance information or observations from the plane, direction of the front is determined and then a course at right angles is selected and maintained until the plane is in the clear. In a cold front where thunderstorms are present, a path between the major storm areas should be sought.

*Reduce airspeed* to a safe margin above the stalling speed, remembering that the stalling speed will be increased by the ice accretion. A one-half reduction of airspeed will nearly halve the amount of ice picked up *per mile*; and the ice will be less dense and easier to remove. A reduction to 50 percent above stalling speed is recommended to diminish in turbulent air mechanical stresses on the plane. This procedure may also reduce the rate of the deposit and density of ice to the point where the de-icing equipment can function more effectively. Its advisability will depend on the type of plane. Lowering the landing gear will increase the drag if it is necessary to maintain engine manifold pressure to prevent overcooling.

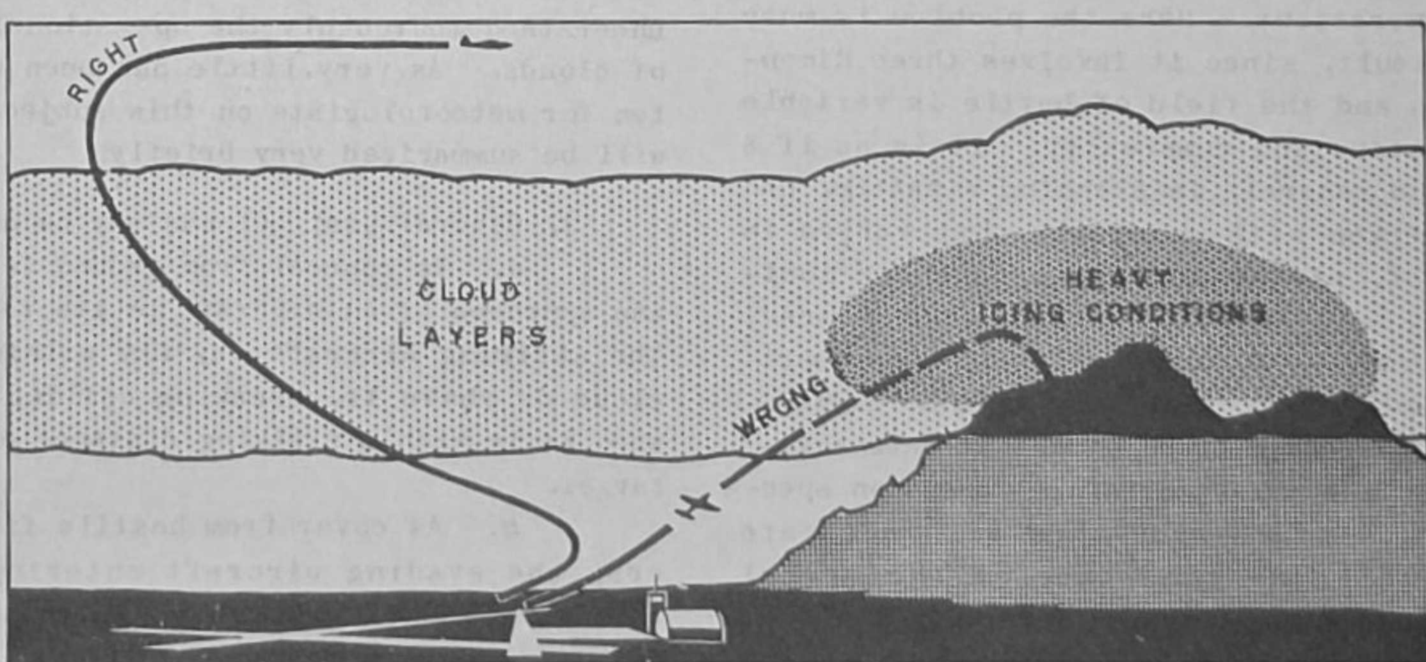
*Change altitude:* downward if it is *certain* that above-freezing temperatures can be reached at a safe altitude or if the air is turbulent; upward if it is certain that the airplane can top the clouds or if the air is smooth.

In stable clouds, it usually will be sufficient to ascend to a higher level where temperatures of -15°C are found, even if still within the cloud. Normally the temperature drops 1.6°C per thousand feet but occasionally isothermal layers of inversions will nullify this rule and make a longer climb necessary.

Descent will bring the airplane to warmer air that can melt the ice if near the freezing point. Ascent into the clear air above may allow the ice to evaporate slowly. Evaporation is most effective with rime or light ice.

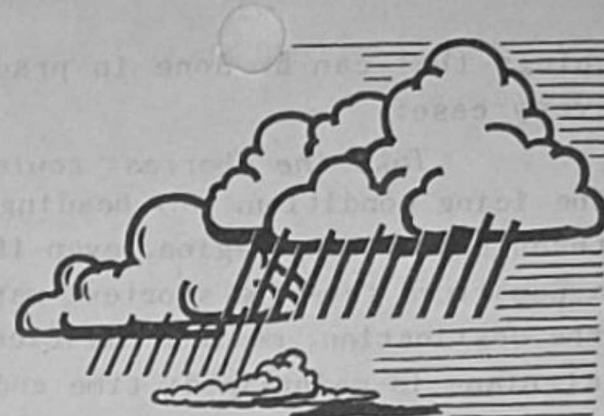
Ascending in unstable air is inadvisable unless there is assurance that the top of the cloud can be quickly reached. This should be attempted, if at all, before the plane ices up so badly that operating ceiling and power are lowered.

It may be possible to maintain flight at the same altitude when the air speed is reduced.



# METEOROLOGY
## IN RELATION TO AIR OPERATIONS

by *Clarence Palmer*



I. GENERAL PRINCIPLES

If the Weather Officer is to play a part in this war worthy of the importance and dignity of his science, he must understand, if only to a limited extent, the manner in which air operations against the enemy are planned and carried out. His theoretical equipment may be excellent and his forecasts accurate within their scope, but if he cannot understand the point of view of commanders controlling operations and of the pilots and navigators that carry them out, or if he does not know what aircraft engaged on a mission are supposed to do, then his forecasts will not fully serve military purposes and much of his effort in the field will be wasted.

It is well known that a good commander of ground forces should have an intimate knowledge of the terrain over which his supply lines are to run and his fighting troops are to operate. As classical literature shows, the great captains of the past were also, in a sense, competent geographers. But it is not yet fully understood, even in military circles, that air generalship similarly depends upon a good knowledge of the weather in the area of operations. Here the problem is more difficult, since it involves three dimensions and the field of battle is variable in extent and complexity. It is as if a ground general, in planning a battle, had to reckon with mountains that varied in height, plains that changed their position, and rivers that altered course, dried up, or flooded, all with disconcerting speed. It is improbable that commanding officers will be competent meteorologists; they must therefore depend on specialists to provide them with accurate knowledge of the state of the aerial battlefield. Moreover, the parallel extends further. In the same manner as the individual infantry soldier must learn to take advantage of irregularities of the ground, of forests, streams, and roads, so the air soldier must know enough meteorology to use wind, cloud, and precipitation to carry out his missions and to save his life. Therefore, the weather officer must not only provide individual pilots and navigators with complete information on the present and future states of the weather but also convince them that meteorological knowledge adds to their efficiency and may, on occasion, bring them out of danger.

II. OPERATIONAL USE OF THE WEATHER

Most meteorologists realize the importance of their science to commercial aviation; that information on flying hazards such as violent turbulence and ice formations and on favorable weather conditions, such as the levels at which tail winds will be found, is essential to the safe and profitable peace-time air operations. This kind of information is just as important to the military airman, but in addition he requires a very good knowledge of cloud types and of the manner in which the different forms may aid or hinder his work--in other words, he must understand thoroughly the operational use of clouds. As very little has been written for meteorologists on this subject, it will be summarized very briefly:

1. General Use: Clouds may be used-

*a.* To conceal from ground forces the approach of an aircraft to its target. The striking aircraft may fly within the cloud or above it, breaking ceiling only when it is within striking distance of the target.

*b.* As cover from hostile fighters; the evading aircraft entering the cloud and then changing course or height or both before emergence.

c. As an ambush; fighters maneuvering within, above, or below the cloud until opposing aircraft are within striking distance.

2. Particular use:

*a. Cirrus:* Scattered cirrus is of little use in operations except that its occurence sometimes warns a pilot of the possibility of his entering a trail-forming region at the cirrus level. These trails facilitate anti-aircraft attacks from the ground defenses.

*b. Cirrostratus:* It is usually too thin to be an effective cover from observation by opposing aircraft. It forms an excellent background against which a plane can be seen, and may indicate a region where condensation trails will form. Snow staic may be heavy in it. If low enough and thick enough, it may occasionally serve for concealment from ground defenses.

*c. Altostratus:* This, particularly in the form of upglide cloud is the most valuable type. For most purposes thin altostratus is better than thick. Its value lies in its horizontal extent *(in the warm front)*, its thickness vertically, the good visibility within the cloud *(occasionally as much as 1,000 yards)*, and the absence of turbulence. This makes it suitable for formation flying. Flying in formation is of the utmost importance in many air operations. It was discovered during the last war that an aircraft in a formation *(e.g. the familiar V formation)* protects and is protected by its fellows through a concentration of fire power. With heavily armed bombers such as the B-29 or B-17, the weight of fire that can be brought to bear by a formation is very formidable; so much so, indeed, that such aircraft are sometimes sent out without fighter escort, especially when only weak or moderate fighter opposition is expected. Formation flying is also important in pattern bombing. It is obvious that formation flying in a cloud is difficult or impossible when turbulence is strong or visibility is poor within the cloud owing to the very short distance between the individual aircraft and the risk of collision. The continuity of the clouds also is significant. If it is to se. e the purposes outlined above the elements of the cloud must have reasonable horizontal and vertical extent. On all these counts upglide altostratus tops the list of cloud forms.

*d. Nimbostratus:* It affords excellent concealment but is often too turbulent for formation flying; almost always the visibility is too poor *(0-20 yards)* for maneuvers by formations. To single aircraft, it is often very useful.

*e. Altocumulus:* Lacks continuity, but a more serious objection is the small vertical extent of the cloud elements. In the South Pacific, however, the Japanese have used extensive altocumulus decks in offensive operations. In an attack on Henderson Field toward the end of January, 1943, decoy fighters were flown under the altocumulus in an endeavor to draw American fighters up through the deck to be pounced upon by an upper layer of Zeros in ambush above cloud. Such tactics are not usually successful as radar can give the fighting squadrons warning of the existence of the upper layer of enemy fighters.

*f. Stratocumulus:* After altostratus this is a most valuable cloud form, expecially when it extends as an almost continuous sheet *(such as in winter anticyclonic conditions over the continents)*. It makes excellent cover when sufficiently thick but the visibility is not as good *(10-50 yards)* as that in altostratus. The meteorologist when he knows that a stratocumulus sheet is to be used in an operation should be on the watch for penetration of the layer by convective cloud and give warning of its delevopment. A formation of aircraft flying in stratocumulus may come to grief if it runs into a turbulent cumulus head imbedded in the layer.

*g. Stratus and Fog:* These are useless in operations except that they blind enemy ground observation, and in most cases are to be regarded as hazards.

*h. Cumulus and cumulonimbus:* Very dangerous for formation flying owing to poor visibility *(0-10 yards)* and strong turbulence. Moreover, even 5/10 cumulus lacks the necessary continuity. In spite of this, much use of cumulus has been made in the tropical South Paci[illegible], chiefly by reconnaissance planes. In this region, airmen have found that turbulence is not too severe under the cloud base and the light showers often found under cumulus of moderate vertical development is an excellent screen; the same applies to the heavier showers under cumulonimbus. Occasionally an aircraft being pursued by enemy fighters can maneuver to place a large cumulus between itself and the enemy-- it can then change course and height and, perhaps, escape.

Advances in radar development tend to minimize the effectiveness of cloud concealment from the ground defenses. However, it is always an advantage to those defenses to see the target aircraft, particularly during low-level and dive bombing attacks.

## III. TYPES OF AIR OPERATIONS

We may now classify the ways in which aircraft are used in military operations and indicate briefly why meteorology is usually important during planning and performance. Aircraft serve four major purposes that are already well known in connection with fighting; communication and supply *(ferry flights)*, attack *(strike flights)*, reconnaissance, and defense *(fighter and interception flights)*.

*Classification:*

1. Ferry

*a.* Air Transport and communication.

*b.* Fighter ferries.

2. Strike

*a*. Dive bombing

*b*. Horizontal low level bombing.

c. Horizontal high level bombing.

*d.* Ground strafing and army cooperation.

*e.* Troop carrying *(gliders and paratroops).*

3. Reconnaissance:

*a.* Low l[illegible]l reconnaissance. *(usually over the sea)*

*b.* Photographic reconnaissance and high level weather reconnaissance.

4. Interception

*1. Ferry:* Ferry flights are point to point flights over land or ocean and are similar to those carried out by peacetime aircraft. The meteorological requirements of such flights are sufficiently well known to meterologists; information on surface and upper winds, weather, cloud bases, tops, and amounts, visibility, fog, icing, turbulence hazards, and terminal conditions is required as for commercial flights. In parts of the tropics where westerly winds are found at a moderate height above the surface trade winds, advice on the most favorable flying level is often very useful.

There is a type of ferry flight almost peculiar to military operation in the South Pacific. In the type of combat zone found in the Western Pacific where the scattered air bases are separated by large stretches of oceans, it is unwise to concentrate too many fighters on advanced aerodromes where they may be exposed to night bombing. When a heavy attack is anticipated in the forward area, fighters from reserves in the rear can be ferried in to reinforce the defenses. Navigation over long stretches of ocean is difficult or impossible for fighter pilots, so a reconnaissance plane or a bomber is set the task of leading the formations of fighters across the sea to the advanced base. The fighters usually have little reserve fuel for such a flight and in addition must keep together and in sight of the lead bomber. Weather conditions then assume considerable importance. The weather officer should warn officers planning such ferries of the existance of zones of even moderate turbulence, fronts, and convective cloud, and above all he should be able to estimate the amount of blind flying that will be necessary to complete the mission. Serious losses have occurred owing to the lack or neglect of such warning.

*2. Strike:* [illegible] strike missions have this in common--the maximum effect is obtained when the target is clearly visible to the striking force. The target or targets, therefore, assume major significance to the forecast. In addition to the usual point-to-point forecast such as would be issued for a ferry flight, the weather officer should provide his commanding officer with a forecast over the whole operations area or over alternative routes so that in planning the operation, the latter can vary the routes of the bombers to avoid unsuitable weather or to take advantage of safe cover or favorable winds. Other things being equal, the forecast will determine whether the attack on the target will be high-level, low-level, or dive bombing; and this should be kept in mind when composing the forecast. Dive bombers are sometimes used at the extreme limit of their range, so that any bad weather enroute will have a disasterous effect. Under these circumstances, the success of a whole operation depends on the forecast. Since troop carrier planes release their loads, either gliders or paratroops, at a low altitude, their operating personnel are particularly interested in conditions near the ground. They often prefer to operate beneath a low ceiling.

*3. Reconnaissance:* In some respects low-level reconnaissance crews have the hardest task in aerial warfare. The aircraft fly singly without the protection given by formation; they are often slow and, in some cases, are only lightly armed. The crews must spend many weary hours watching sea and air. Reconnaissance planes are not supposed to "mix it" with enemy fighters. Their task is to search. Thus they require forecasts that give them an accurate picture of the cloud cover over the patrol area. They must cover the area, but are usually allowed a certain latitude to vary their tracks so as to take advantage of any cloud cover they expect from the forecast. This, indeed, is their chief interest in the forecast, for they must complete their mission whatever the weather may be and they must return to some base however bad the forecasted terminal conditions. The weather officer can be of co[illegible]siderable assistance by indicating the most suitable base for return.

Photographic reconnaissance is usually carried out by specially adapted fighters flying at high levels. The object is to photograph target areas, aerodromes, etc., in enemy territory at frequent intervals so that hostile activities may be analyzed and the results of strikes assessed. Good weather over the objectives is therefore essential. Accurate forecasting will often prevent useless flight. The forecasting of haze assumes great importance in this work.

*4. Interception:* The success of fighter defense depends not only upon the courage and skill of the pilots, but also to a very large degree on the efficiency of ground control. Without ground control the only way to defend a base which could be attacked by over-sea flights by hostile planes would be to keep a continuous fighter patrol circling in the neighborhood of the base, a very wasteful and, in most cases, an ineffective defense. But in the Battle of Britain, the German bombers and fighters were beaten off and destroyed as much by the highly developed ground control as by the fighter pilots. In this ground control meteorology plays a significant part. As an example, let us take the defense of the south of England.

There are large numbers of fighter aerodromes in the south of England divided among several "groups". Each Group Headquarters controls by teletype and radio telephone a number of aerodromes and the fighters assigned to them, and at the same time it receives information on enemy movements from nearby radar units and ground observation posts. When an enemy attack is imminent, the hostile formations are picked up by radar a considerable distance off the coast and the bearings, distances, heights and numbers of the aircraft are transmitted by the radar observers to Group Headquarters. There, a great mass of information is quickly sifted and the situation is summarized in the form of model aircraft which are moved across a huge table map of the area by specially trained WAAF personnel.

*Continued to page 30*

# WINGS *For* WEATHER MEN

*by* 1st. Lt. Edward Brennan

A blind painter, a deaf music critic, and a wine taster with a cold all have something in common with a grounded weather forecaster. None of them have first-hand dope about what they are working with. Nobody audibly disagrees with the principle that weather forecasters should become familiar with weather aloft through frequent ascents, yet surprisingly little is done to make such flights possible.

Thanks to splendid training facilities, our young weather officers arrive in the field with an excellent theoretical background. However, a mathematically precise view of weather is not enough. The forecaster must also have the pilot's viewpoint. Aerial flights shatter once and for all the idea that a front looks just like the illustration in the textbook. The fact that every weather situation is an individual problem will be forcibly brought home to the "green" forecaster. He soon finds out that a mathematical formula is not enough to satisfy a pilot.

Nor is the novice forecaster the only one who can benefit by regular flights. Even after ten thousand hours of flying, pilots still meet new and unfamiliar weather conditions in the air. Similarly, no forecaster, however experienced, can afford to become too engrossed in his maps and charts. He should be up in the sky enough of the time to keep the "feel" of weather fresh in his consciousness and should cover all the principal routes for which he forecasts repeatedly under varying weather conditions. Just as the airline dispatcher is required to keep himself "checked out" over the routes in his area, just as the pilot must "check out" with the various types of ship he is required to fly, so the forecaster should keep himself "checked out" in various flying conditions.

The weather service is in a peculiar position. The strides made in military meteorology within the past few years are so tremendous that even professionals have been pressed to keep up with the pace; many people with no direct connection with it have fallen behind. Since some users of weather forecasts have only the vaguest idea of the service that is at their finger tips and because the scientific basis for modern meteorology is not fully appreciated, the detachment of forecasters from aerial operations becomes significant.

The result is that weather officers on the spot must sell themselves and their product to pilots and higher commanders with whom they are connected. To do this they must first of all acquire an insight into the mind of a pilot. It is unfortunate that not all forecasters can be pilots. But we can do the next best tning; adopt at least some portion of the pilot's mode of thinking by making it an axiom for each forecaster, enlisted or commissioned, to make as many aerial flights as possible under the circumstances.

A missionary tries to save a man's soul despite a certain natural reluctance on the part of the convert. We are fighting the same kind of reluctance on the part of those whose lives and property we are trying to safeguard. The successful missionary is the one who adapts his methods of persuasion to the habits and manner of living of the benighted heathen. If we are to sell the weather service to its principal users, the pilots, we must descend from the aloof pedestal of mathematics and learn to see eye to eye with the pilot. Familiarization flights are the best means at our disposal.

—·—·—·—·—·—

Shortly after Lt. Brennan submitted this article, the Western Technical Training Command instituted a program which provides familiarization flights for forecasters at weather stations under its jurisdiction. Specific flights for the purpose of this training will not be made, but missions scheduled under directives already in effect will be utilized after coordination with the post operations officer.

The Training Command order authorizes two types of flights, each over all routes and terminals for which the meteorologist regularly forecasts, provided they are within 500 miles of the base. First, the terrain in the specified zones will be examined from the air under CAVU conditions. Secondly, the same routes will be flown under relatively poor weather conditions for examination of meteorological effects produced by the topography and to illustrate the limitations imposed on flight by weather hazards.

A syllabus for familiarization flight training as offered by the Training Command suggests for each flight:

a. Prepare written forecasts 48 and 24 hours in advance and at time of departure.

b. Draw prognostic cross-section for flight route shortly before takeoff.

c. Plot course on aeronautical charts and from these identify terrain characteristics and landmarks on line of flight.

d. Recommend flight altitude and forecast winds and temperature at this altitude.

e. Compute true ground speed, true heading, and ETA at destination and intermediate points, using indicated air speed given by pilot together with the forecast winds and temperature at flight level.

f. In flight, sketch on a cross section the actual weather encountered for comparison with the forecast cross-section.

g. At each point of landing, visit the weather station and discuss with the forecaster on duty the weather through which the flying has just been done and expected weather on the remainder of the flight. Be alert for any new or better ideas in weather station operation while visiting other stations.

h. Upon completion of the flight, write a statement on the accuracy of the forecast. For any portions of the flight that this forecast is in error, state why the bad forecast was made together with suggestions for preventing the same mistake in the future.

i. Throughout the flight keep oriented and observe approaches to airports, local conditions tending to restrict visibility, and any other factors which might complicate the problems of the pilot.

j. Turn all material in to the weather officer upon return from the flight for his recommendations and files.

*A. M. S. BULLETIN TO FEATURE 'THE AAF WEATHER SERVICE AT WAR'*

*A forthcoming issue of the 'Bulletin of the American Meteorological Society' will feature the Army Air Forces Weather Service. Articles will deal insofar as possible with weather as it applies to war. Contributions from AAF personnel who are also members of the Society are particularly desired, although contributions from non-members are also welcome.*

*The American Meteorological Society holds an important position in the professional world of meteorology, and the forthcoming Air Forces number of its Bulletin offers a splendid opportunity for officers who intend to make a career of meteorology to have their work published.*

*Papers intended for publication in this Air Forces issue should be so marked and forwarded without delay through the Regional Control Officer to the Public Relations Office, Headquarters Weather Wing, Asheville, North Carolina.*

# Headquarters Notes

## IMPROVED TEMPERATURE AND HUMIDITY ELEMENTS INTRODUCED FOR RADIOSONDE

The confident utilization of all information potentially available from radiosonde flights would be a development of the greatest moment in forecasting. At present, the familiar phenomena of "motorboating" and "lag" in the hair hygrometer of ML-141, the Diamond-Hinman radiosonde now in use, invalidate much important data. In particular, the forecasting of condensation trails (requiring information on the water content at levels where the temperature is less than -25°C.) necessitates improvement in these respects.

A new Diamond-Hinman radiosonde (AN/AMQ-1) equipped with an electric hygrometer and a ceramic temperature element, and having a 3-volt filament requirement is now in production and will shortly be distributed. Actual field tests demonstrate that the electric hygrometer follows accurately the rapid changes in relative humidity down to -40°C.. The ceramic temperature element has an indefinite shelf life, it is not fragile (there are no points of weakness such as joints between metal and glass), and there is no acid to corrode other parts of the instrument when the element is broken---all of which are major shortcomings in the vial of sulfuric acid now used as a temperature element.

The hygrometer element functions by varying the resistance of an electrical circuit as the moisture content of the surrounding atmosphere changes; it is essentially a resistor composed of a hygroscopic film coating the surface of an insulating strip between two metallic electrodes.

In practice a sheet of plastic coated with lithium chloride solution finely dispersed over the surface of the element and held in place by a film-forming resin is used. Lithium chloride is deliquescent in relative humidities of 15% or above at ordinary temperatures (higher lower limit at lower temperatures): below this figure crystallization occurs, raising the resistance too rapidly.

Like other hygroscopic salts, lithium chloride solutions have definite vapor pressures which vary with the concentration of the solution. The solution will give up or absorb moisture until its vapor pressure reaches equilibrium with the vapor pressure of the atmosphere to which it is exposed. The resistance of course varies with the concentration of the electrolyte, resulting in the usable relation of water vapor pressure of the atmosphere as a function of the element's resistance.

Immediately after manufacture the hygrometer is calibrated and sealed in a partially dehydrated glass vial, from which it is not removed until the time of preflight test when the element is removed from the vial and clamped into the oscillator circuit. Strips tested after seven months of shelflife under these conditions show no appreciable loss of calibration.

The ceramic temperature element, essentially merely a stick of a special carbon, is also a resistor, but one in which the conductivity is a function of the temperature. The virtues of long shelf life and sturdiness enables distribution of the new radiosonde device to be made with one-fifth as many spare temperature elements as was previously necessary.

The Radiosonde AN/AMQ-1 will be sealed in a moisture-proof wrapping, which should not be broken for inspection until the pre-flight test is made. This method of packaging is designed to eliminate deterioration of the instrument due to weather, shipping, and storage conditions and to relieve the field of a detailed inspection on receipt except to examine the seal.

The radiosonde AN/AMT-1 is an instrument now in the first stages of development composed of two parts: 1. Radiosonde Modulator ML-310/AMT-1 which includes the meteorological elements only: baroswitch, ceramic temperature element, and electric hygrometer. 2. Radiosonde Transmitter T-49/AMT-1 having a 3-volt filament requirement and used with Battery BA-67, or one Battery BB-51 and three Batteries BB-52.

## COLLECTION AND PUBLICATION OF LOCAL EFFECTS ON FORECASTING

Local forecasting studies, now being collected by Headquarters Weather Wing from all parts of the world where AAF weather stations are operating, will be published eventually in looseleaf form by the Weather Information Branch. The WIB is compiling and editing the material which has already been submitted by several hundred stations.

The history of this project is a long one, beginning in 1938 with the publication of a widely-acclaimed investigation of the forecasting of fog and low stratus at Atlanta, Georgia, by J. J. George, chief meteorologist of Eastern Airlines, who subsequently completed many similar studies at terminals along EAL routes.

In 1942 George was commissioned in the AAF for weather duty and assigned to the newly organized Joint Army- Navy Weather Central. One of his first assignments was a trip over the Northeast Route to Greenland, on which he prepared a local forecasting report. The Director of Weather foresaw such utility in this effort that he ordered the Army Weather Central to prepare a series of similar analyses covering major AAF operating bases over the world. Although this directive was not carried out by the Central before the dissolution of that organization, it remains as the basic document authorizing the studies at present being collected by the WIB.

After a decision that terminal weather inquiries could best be performed by station weather officers working "on location", an outline of the material to be covered was prepared and discussed at the conference of Regional Control Officers, held in Asheville on 21-25 June 1943, with the decision that "the Weather Wing will prepare a letter to the regional control officers to initiate and standardize local weather studies at all AAF stations."

It may be noted that prior to this action, the RCO of the Third Weather Region has issued a memorandum requiring each weather station in his region to make an investigation of local forecasting, but no approved outline had been specified to assure a uniformity among the resulting reports. Nevertheless, these became part of the project.

"The purpose of these studies," the Weather Wing letter stated, "is to improve the forecasting service by making available locally the results of such research, and to facilitate the compilation of weather studies for use by the General Staff, the Air Staff, the commanding generals of theatres of operations, and other Army units requiring the use of such information."

A Hawaiian Island station submitted a spectacular presentation, using a panoramic camera revolved in a circle to obtain a complete picture of the terrain around their station. The view showed the lowlands nearby, mountains in the distance, and the sea in another direction. The azimuth was divided into degrees and the elevation of the distant mountain peaks indicated. At least a score of the reporting stations sent in mosaic aerial photographs of the neighboring country - side.

Contributing weather officers will be given credit in the final publication, which will be done in looseleaf form so that the various regions can select the studies of individual interest. Classification as low as restricted is projected for the majority of the studies, facilitating a widespread distribution and ready use.

### OUTLINE FOR LOCAL FORECASTING REPORTS

**1. Geographic and Topographic Considerations**

a. Location of station with respect to land and water masses. (A small scale map is considered desirable).

b. General Topography and smoke pollution sources within a 100 mile radius of the station.

(1) Polar diagram of area for radius of 100 miles, divided into 16 points with three rings at 25, 50, and 100 miles, summarizing up and down slope effects and smoke sources. (Example attached). A rather large scale map of the local area showing topography and local smoke sources is also desirable.

c. Where available, both aerial and ground photographs should be included showing exposure of instruments and general local topography.

d. Peculiarities of a circulation due to ocean or large water mass in vicinity of the station.

e. Peculiarities of topography affecting weather in the vicinity of the of the station.

(1) Marked up and down-slope effects
(2) Air drainage
(3) Valley winds
(4) Type of ground coverage in immediate vicinity of station. (i.e. open fields, marshland, or wooded country.) This in regard to areas conducive to formation of radiation fog.

2. Climatic Considerations, (Give the following information under each of the four seasons: Winter, Spring, Summer, and Fall).

a. Climatic regime - general frontal and air mass frequencies and types, prevailing winds, predominant air mass, etc.

b. Marked climatic peculiarities such as fog, haze, dust, snow, high winds, thunderstorms, low ceilings, low visibility, etc. Prep table of normal frequency by months, if sufficient information is available. (Example Attached) Much of this information can be obtained from local Weather Bureau Station and Cooperative Weather Bureau Stations.

c. Effects of air circulation due to water masses and topography on climate and weather in the vicinity of the station.

d. Description of typical weather conditions preceding, attending, and following the passage of cold fronts, warm fronts, and occlusions.

e. Typical weather conditions under anti-cyclone conditions.

f. Attach examples of weather maps to illustrate the above items where applicable.

3. Any other weather peculiarities of the locality or weather forecasting information which may be of value, and examples of outstanding adverse weather types (synoptic or diagrammatical presentation to accompany text).

## CODES AND CIPHERS---WHAT'S THE DIFFERENCE?

Don't say, "So what?"---weather men on foreign duty are cryptographers by the force of circumstance and there is always the chance that domestic security regulations may be retightened. With 378 codes and ciphers on the books, a little foresight seems advisable.

*Code* is planned substitution of a symbol or a small group of symbols for a word, a phrase, a sentence, or even a *larger* group of symbols: encoded material is always shorter than the original, with emphasis on the convenience of brevity. A *cipher* is systematized transposition *or* substitution of notations, stressing secrecy; enciphered material is at least as long as the original. To be technical,

The high priests of this occult science wear Signal Corps insignia and intone a ritual of attractive(?) feminine terms like Mona and Poly Alphabet. For the men with wings, however, its considered sufficient and simpler to work with plain number symbols.

the size of the unit treated is fundamental in differentiating between codes and ciphers---large unit, code; small unit, cipher. Of course there are enciphered codes, many of use to Weather.

Let's run over an example or two to demonstrate these bits of wisdom. In our most common *code*, the International Synoptic, the symbol "61" is substituted in a specified position for the phrase "intermittent light rain". To keep the enemy from knowing that we are getting wet, we *encipher* these figures by substituting two other figures for them; our substitution in this case is controlled by random numbers obtained from a cipher book and a process we call false subtraction.

Examples of secret codes are ALACO and ALAMETCO. Security is obtained by elaborate systems of frequently changing the letters substituted for the phrases describing weather. FERRIMET tops them all when it comes to a choice of tagging it code or cipher. Twelve good cryptos and true would never reach a verdict on that, but we call it an automatic enciphering code.

# REPORTS FROM THE REGIONS

## 18th WEATHER REGION

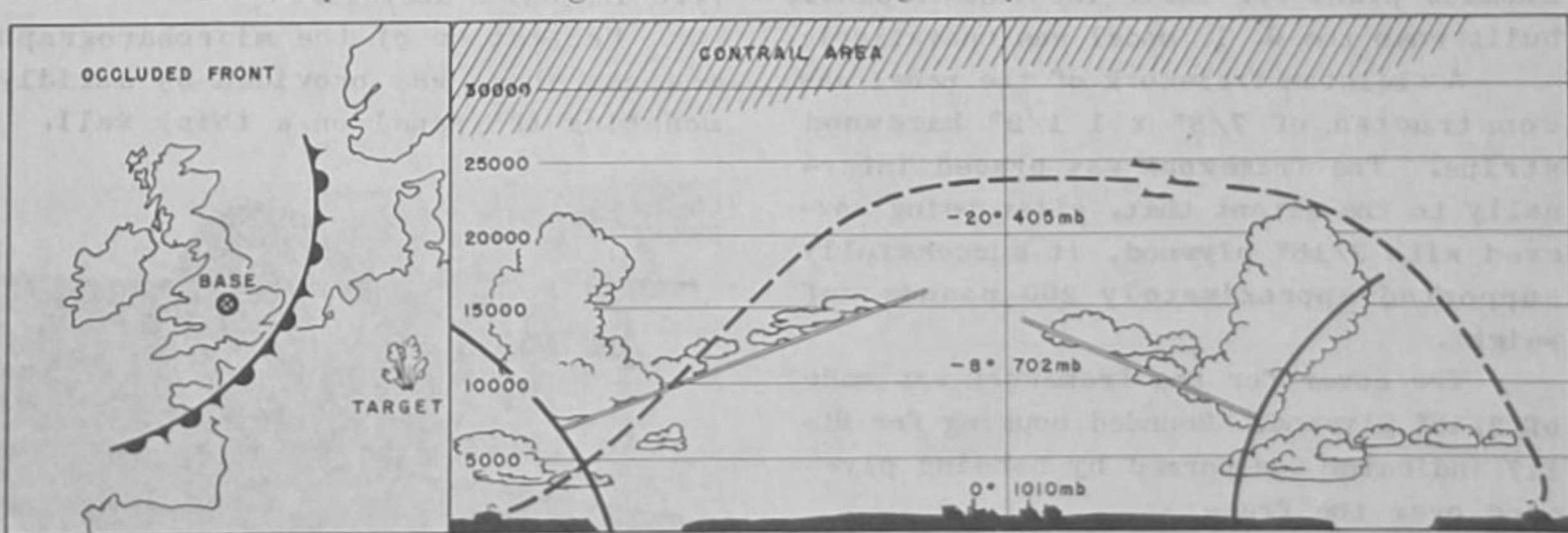
A brief, graphic demonstration of the many details that enter into weather briefing of bomber aircrews is found necessary to make a clear impression in competition with the great weight of other information directed at flying personnel in pre-operational discussions. An 18th Weather Region station reports such a method now being used:

As shown in the diagram, a map of the British Isles and the target areas is drawn or traced on the left-hand side of a strip of teleprinter paper approximately two feet long; the latest synoptic situation, along with a prognostic analysis, is superimposed on the map.

To the right is portrayed a plane perpendicular to the earth's surface, where cloud types and heights, freezing level, visibilities, and frontal locations are shown as in the conventional cross-section. The sequence of flight in a round-trip with varying routes for the trip out and back is given in one continuous line on the teleprinter paper, approximating the actual impression of the weather that the aircrews will obtain. A single front intersecting the line of flight can logically be shown in two places on this cross-section where contact will be made with it.

As the weather officer delivers the verbal briefing, this pictorial representation of the weather can be drawn through the ephidiascope, stimulating both the hearing and the vision of the aircrews.

Vertical extent of the flight path is obtained from the navigator in charge and entered on the cross-section. Visual representation of airplane altitudes at each point enroute has been found to impress upon the pilot his relation to various cloud types and icing conditions at every moment and thereby to prepare him for emergency procedure.




Weather observers in the British Isles have sometimes found it difficult to accustom themselves to British methods and equipment. A case in point is the method for computing upper winds from pilot balloon ascents. The British use a specially made slide rule, speedy and accurate in the aands of an expert, but which appears to the novice to be closely related to Einstein's theory of the fourth dimension in its complexity. Nevertheless, since American plotting boards are not available in this theater, observers have learned to use the rule with fairly general success.

The observers at one air base in Britain longed for the simplicity of the plotting board to which they had been accustomed in "the old country". Since it was impossible to obtain a plotting board through supply channels, they decided to build one themselves. The final result of much discussion and a little work was preparation of upper-wind plotting equipment that is quite satisfactory.

Swindle an old bed sheet from the quartermaster and tack it smoothly to the clean surface of a large, approximately square table. In the above instance the top of a British-type supply cabinet was used. Apply three coats of airplane dope by brush, allowing each one to soak through the sheet and to dry. Special care should be taken that the table is clean and smooth and that each coat is sanded with the finest grade of abrasive paper available. The sanding is necessary to remove air bubbles.

Upon this surface, the standard pattern as TM 1-235 illustrates, is inscribed with India ink. It is best to draw the original lines lightly in pencil, which may later be erased. Then apply several more (at least three) coats of dope. The final product will be an excellent, hard surface which is very durable and resists the ordinary cracking and pin-pricks to which the standard issue model is so susceptible. A small nail driven into the center of the board will finish the job.

The metal rule, ML-63, can be made by the local engineering shop. The wind-speed scale is best made from 1/16 inch Plexiglas which is sanded on one side until it is almost opaque, drawing the scale in India ink on the rough surface. A coat or two of liquid dope will make the scale transparent, serving also to keep the ink from wear.

Now that we have figured out the plotting board, rule, and speed scale for you, work out your own tables of vertical and horizontal components. Or better still, see if there is a book of them lying about the RCO's office, as in our case.

The final item that made the outfit complete was the addition of a field telephone supplied and installed by a very cooperative Signal Officer. Since the standard head and chest sets were not available throat microphones and headsets were utilized with excellent results.

## TENTH WEATHER REGION

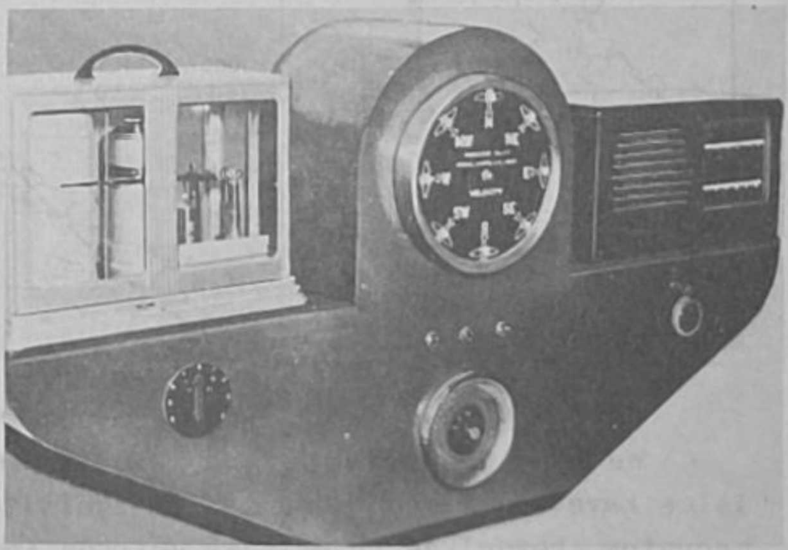
A station in the Tenth Weather Region submits plans for their instrument panel, built when the G. I. model was unavailable.

A skeleton framework of the panel was constructed of 7/8" x 1 1/2" hardwood strips. The framework was braced internally to the extent that, after being covered with 3/16" plywood, it successfully supported approximately 200 pounds of weight.

The cover for the framework was made of 3/16" plywood. Rounded housing for ML-117 indicator was formed by bending plywood over the frame.

The original design called for the additional installation of a GMT and a local time clock, but inasmuch as these items were not available in the locality, a barograph correction indicator and a stopwatch mount, both made of Plexiglas, were installed instead.

Protection of the microbarograph against shock was provided by solidly mounting the panel on a thick wall.



## FIRST WEATHER REGION

There exists a high correlation beween the accuracy of forecasts at Hammer Field, Fresno, California, and the price of raisin pie in your favorite restraurant! Mathematicians may laugh this off as mere prestidigitation with numbers, yet a physical explanation can be given'.

The raisin growers of Madera, Fresno, Kings, and Tulare counties in California responded this summer to Department of Agriculture exhortations with a record crop of 365,000 tons at an average value of $150 per ton. While the raisins were drying in the fields, worries of the farmer had just begun, because this was a product that rain would ruin.

Colonel Guy Kirksey, C.O. at Hammer Field, notified the station weather officer at Hammer that the Army had organized 10,000 G.I.'s to stack raisins in case of a rain forecast for the vicinity. The forecasting staff was then faced with the alternatives of irate superiors or bankrupt farmers to even a slight misjudgment of precipitation.

One day the chairman of the Fresno Farm Council telephoned the Hammer Field Station in a panic: a weather forecasting agency in San Francisco had advised that a hard rain was certain and that the several regiments of soldiers should be mobilized for defence of the raisin crop.

The synoptic situation showed an influx of Maritime Tropical air east of the Sierra Nevada Mountains, causing heavy showers and thunderstorms on the eastern slopes. Lt. George Long and M/Sgt. Arthur Arbanas assured the farm council head that no more than a trace of precipitation would occur; actually the amount that fell was only enough to show a few spots in the dust.

On two other occasions the AAF weather station justifiably scoffed at forecasts of imminent rain, earning a toast (in raisin wine we presume) from grower, soldier-stackers, and lovers of raisins. As the farm council chairman said in a letter of thanks to Col. Kirksey, at least $100000 had been saved.

## ABSTRACT

### PROLONGING LIFE OF DRY BATTERIES

*Signal Corps Technical Information Letter*
*December 1943*

Many dry batteries are arranged so that contact with the negative terminal is made by a brass or copper spring pressing against a portion of the zinc case of one of the cells which make up the battery. Since current flows through this contact while the battery circuit is closed, there is opportunity for electrolytic action to occur at the contact surface. Such electrolytic action is greatly increased by the presence of water. The wet contact acts exactly like an electrolytic cell, with two damaging results:

1. Electrolytic action causes the zinc to oxidize, forming zinc oxide. This is indicated by a white coating on the zinc surface, powdery when dry, and wet and sticky when damp. The layer of zinc oxide acts as an insulator, reducing the current which can be drawn from the battery. This means less light from flashlights, less volume from radio and telephone receivers, less range from transmitters.

2. If the battery is continued in operation while the layer of zinc oxide is damp, holes will be eaten in the zinc and the battery ruined.

When the battery output falls off, as evidenced by the effects noted in paragraph 1 above, the battery is often condemned and thrown away, although it may actually have more hours of serviceable life remaining. These service hours can be retained by cleaning the contact as follows:

1. Scrape the zinc surface with a knife to remove the layer of white material, being careful not to gouge into and remove scraps of the metal itself.

2. Polish the scraped surface with

fine sandpaper until it is bright.

3. Wipe dry the batteries, the contact springs, and the inside of the battery compartment.

Batteries should be examined daily, paying particular attention to the contacts, cleaning them as necessary. This precaution will increase the service obtained, and will in many cases prevent unexpected failure of equipment.

## TORNADOES

*Technical Note #11-43, BuAer, Navy Dept.*

Further investigation is needed before much will be known of the cause or mode of formation of tornadoes. Apparently they are caused when friction retards the surface layer of a rapidly advancing cold front, causing cold air to over-run potentially warmer air at the surface. The combination of rapid convection and large vorticity contrast produces the tornado funnel. Condensation due to adiabatic expansion in the center of the vortex causes the cloud which outlines it. Tornadoes are usually accompanied by severe thunderstorms.

Two types of tornado may be recognized. The first is directly associated with a cold front, occurs in groups of four to a dozen, and is characterized by a long, sinuous funnel and a cloud ceiling of 2,000 to 3,000 feet. The second type is associated with the rain-induced pseudo-cold-front of an intense thunderstorm, occurs singly or in pairs, and is characterized by a thick funnel and a ceiling of less than 1,000 feet.

The average tornado moves in a straight path eastward or northeastward at 20 to 40mph. It sometimes leaves the ground momentarily, striking again farther ahead. The usual path is 20 to 40 miles long and 1,000 feet wide. The wind in the center of the vortex is estimated to reach 200 to 500 mph, with a vertical rate of 100 to 300 mph.

The zone of maximum tornadic activity migrates from the Gulf states in early spring to the Canadian Border in midsummer, and returns south in the autumn. Tornadoes are most frequent between 1500 and 1800LST, and least frequent between 0700 and 0800LST. The diurnal period nearly disappears in winter.

In daytime, a tornado may be easily avoided by an airplane (in contact flight--ed). At night (or on instruments --ed) lightning should give a clue, and cold fronts should be entered with caution and at right angles.

Precautions, when a tornado is seen approaching, include flying away all possible aircraft and removing all objects, such as oil barrels, which might be thrown about by the wind.

*Continued from page 21*

The Commanding Officer of the Group, sitting in a kind of pulpit overlooking the map, can then trace the progress of the hostile aircraft and direct his own fighter forces to intercept them. Orders are given to the fighters in the air through a complicated radio telephone system. The weather officer plays his part by supplying information on the upper winds at the levels where the fighters are flying. These are used by navigating officers working out courses for the fighters. The aim of the commanding officer is to intercept the hostile aircraft at a pre-determined point and bring them to battle. Here again meteorological information is used. Other things being equal, an experienced commander will try to intercept the enemy at a point in the aerial battlefield at which the meteorological conditions are to his advantage and to the disadvantage of the enemy. For example, if he has strong fighter forces he will endeavor to attack the enemy at a point where escape into clouds is difficult or impossible. Perhaps he may ambush opposing fighters from a sheet of altostratus.

Weather Officers will, in the future, play a more and more important role in air operations since it is only a matter of time before controls similiar to the fighter control are extended to other air activities.

# REVIEW

## "A Simplification of the Formulas for Displacement of Pressure Systems"

Horace Byers

Bull. Am. Met. Soc., Vol. 24 No. 1, Jan. 1943

The Petterssen formulas giving numerical means for kinematic analysis of significant points in pressure fields: troughs, ridges, fronts, and high or low centers are of fundamental importance partly because of the mere mental nature of the necessary calculations. However, application of the calculus to hydrodynamics in the derivation obscures for many the conditions imposed on the analysis.

To counter this difficulty, Byers introduces an *arithmetic* demonstration of formulas akin to those of Petterssen, which nonetheless introduce certain refinements. The use of simple concepts tends to clarify the ramifications of such fundamentals as deepening, trough velocities, and the relation between the trough and front displacement methods.

The clarity of Byers' demonstration is exemplified by his discussion of isobar speeds:

"Station pressure tendencies always represent some form of movement or deformation of isobars. The pressure change in one hour at a station is the number of unit isobars crossing the station in one hour. The number of any series of evenly-spaced things passing a point in one hour is the speed of these things in miles per hour multiplied by the number of these things per mile. Considering isobars, we have then, for the pressure change (tendency) in one hour:

$$T_1 = U \cdot N$$

where U is the speed of the isobars and N is the number of unit isobars per mile. The barograph gives us $T_1$ and we can obtain N from the isobars drawn on a weather map. Thus, we can use the one-hour tendency at a station and the pressure map in the vicinity of the station to find the speed of the isobars, viz:

$$U = \frac{T_1}{N}$$

Actually, in the synoptic weather reports, the tendencies are given in terms of three hours. If the speed is considered in terms of miles per three hours, then the three hour tendency may be used directly in the expression above so that:

$$U_3 = \frac{T}{N}$$

where T is the reported tendency. This is the general equation for the speed of isobars in terms of miles per three hours."

Kinematical analysis of the other significant pressure phenomena is approached in a similar, lucid manner. An understanding of the relationship between the individual and the local change of a property in a system of moving fluid particles, demanded by Petterssen, is by-passed by Byers.

In language no more profound than that of simple algebra, the reader is led cogently to an appreciation of the basis for such conclusions in relation to the trough formula as, "The speed of a symmetrical trough is the arithmetic average of the speed along the normal to the trough line of the isobars in advance of and behind the trough line." If the isobars behind the trough line move more rapidly than the isobars in front of the trough, filling is indicated.

THE BYERS KINEMATIC FORMULAS

A. For a symmetrical system of isobars:

$$U = \frac{U_B + U_A}{2} = \frac{1}{2}\left(\frac{T_B}{N_B} + \frac{T_A}{N_A}\right)$$

B. For an asymmetrical system:

$$U = \frac{aU_B + bU_A}{a+b} = \frac{1}{a+b}\left(\frac{aT_B}{N_B} + \frac{bT_A}{N_A}\right)$$

where a and b are respectively the distances intercepted by the trough line and the exterior isobar of the trough ahead of and behind the trough line. Case

A is a special form of Case B in which a=b=L as in figure (2).

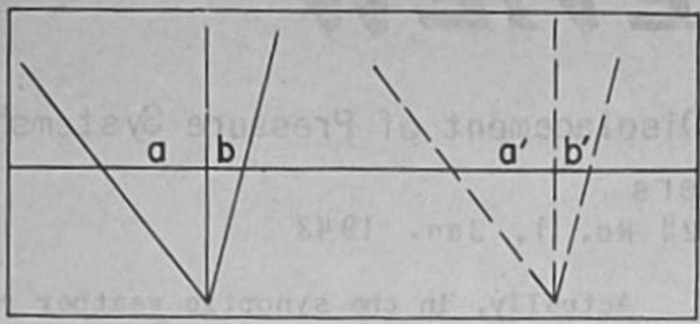



Figure 1: Displacement of an asymmetrical trough (filling indicated in this case)

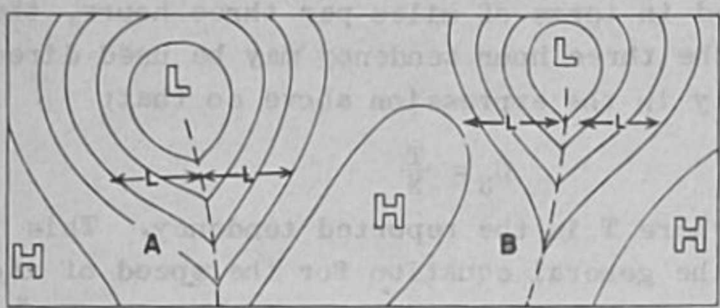



Figure 2: a. Method of computation using the Petterssen Formula.
b. Method of computation using the Byers Formula.

The improvements over the Petterssen formula which Byers claims for his appear valuable. In the application of the former, (figure 1) it is necessary to measure continuously through the axis perpendicular to the trough line. In Byers' formula the velocities can be obtained by measurements at rather widely separated points along the axis.

It is cautioned that the unit L be selected along a direction in which a representative value of the pressure gradient can be obtained. Of course this is more likely to be observed in applying the Byers formula, where more latitude is given in the placing of the unit.

A large unit length is desirable to suppress inaccuracies in the reported tendencies, but the length must be limited by surrounding regions having a substantially different gradient. The unit length L should also have its middle point of the rear portion far enough back so that it is not in a region through which the trough line has passed in the tendency interval. "Check" tendencies behind a trough should therefore be avoided.

The derivation by Petterssen of the velocity formula for fronts as well as troughs, wedges, and centers makes use of the slope of the tendency profile. In the case of a front, the profile is more or less discontinuous at the front, characterized by falling pressure ahead of the front and a sudden rise behind, so that in the scale of synoptic charts, continuous isallobars cannot be drawn.

A slight change in the Petterssen trough formula is introduced in order to take this into account. In the formula for a trough introduced by Byers, no modification is necessary in order to make it applicable to fronts. Furthermore, by separate consideration of the isobar velocities ahead of and behind the trough line (facilitated by the two parts of Byers' formula), information regarding the extent of deepening or filling is secured at the same time.

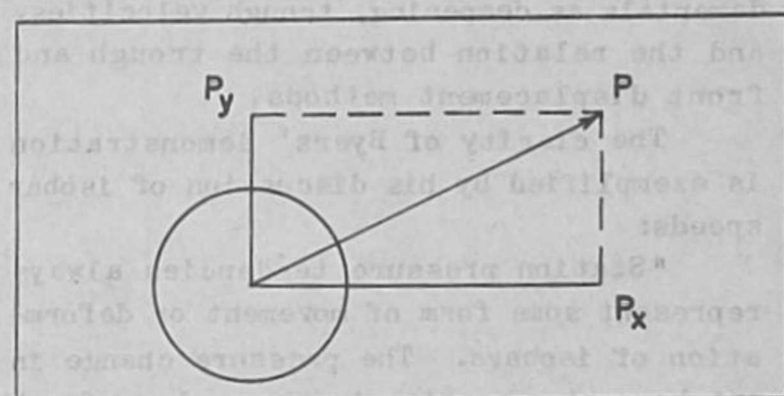



Figure 3: Components of motion of a center.

Byers' formula applies to centers of high and low pressure as well. Although definition of motion in the normal direction is enough for troughs and ridges, centers can exhibit motion in any direction and computations must be made in two components as shown in figure 3, each one calculated in the same manner as U. These components are resolved into the line OP which represents the actual movement of the center.

# "WEATHER AT LEAST A CONTRIBUTING FACTOR..."

A flight of 13 AT-7's performing a navigation training flight from San Marcos, Texas, to Garden City, Kansas, took off at 1957 9 September 1943 under the direction of Flight Leader Lt. Leslie Summerfield. The forecaster on duty provided them with a preview of the weather conditions on their route with the following statement: "High scattered to clear spots on whole route; visibility unrestricted; turbulence smooth to light." Yet two of these planes crashed and were completely demolished, killing two pilots, two navigators, and six cadets.

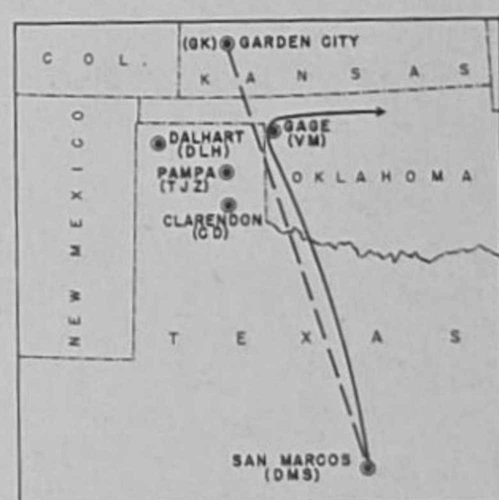
Lt. Summerfield's account of the weather the formation actually met follows:

"Weather CAVU until 20 miles north of Gage. Distant lightning to the west passing Abilene. About 30 miles south of Gage I noticed lightning to the north, northwest, and west in the distance, becoming severe and constant as I approached Gage. About 40 miles north of Gage the storm appeared to be at its severest. Approached the storm looking for a way to circumnavigate or go beneath it. The lightning was frequent and vivid and it was severe cloud to cloud and cloud to ground. Turbulence became very severe and I noticed severe line squalls as the lightning flashed. The ceiling became lower and I lowered my altitude to 5500 feet. About 40 miles north of Gage the storm was so severe I altered my course to Enid, Oklahoma."

"Ascertained the storm was moving very rapidly. In my opinion there was a line of storms and not scattered storms."

Significant teletype sequences are listed:

DLH 091857 SPL E40 T SVR LTNG NW
DLH 091916 SPL E40 T BD+
DLH 091950 SPL TSTM MVD TO E
091957 take-off time
TJZ 092030 SPL CLD TO GND LTNG NW
TJZ 092035 SPL T CENTRD NW APTLY APCHG STN
VM 092130 SPL LTNG HRZN W
TJZ 092230 T RW-
VM 092230 SVR LTNG SW




Reply of the forecaster involved, given in a post-accident report was:

"Since there was no indication of frontal activity on the 1830Z map, I decided that those storms were local and would tend to dissipate near midnight and would notmove eastward into the flight route."

If *at least the possibility* of thunderstorms are evident to the forecaster, warning given to a pilot will prompt him in an emergency to react to the *first* indications of danger; in this case, Summerfield might have turned off course when first faced with severe lightning.

When a mission has been given a clearance and the teletype provides information that the forecast is dangerously in error after takeoff, responsibility for persistent attempts to reach the flight by radio must be assumed by the forecaster responsible.

Check all possibilities of special phenomena against the climatological averages for the season as modified by the complete synoptic situation, including positive identification of the air masses, the upper air circulation and moisture content, and the type of terrain features that may be expected to modify the special phenomena.

## WEATHER SERVICE INSIGNE APPROVED

The design shown on the front cover of this issue has been approved as a distinctive badge for the Weather Service by the Secretary of War. If critical materials are released, the Quartermaster General will procure a plastic button with this device for all weather personnel; commissioned, warrant, and enlisted, to be worn on the shoulder loop of the service coat.

"Coelum ad Proelium Elige" or "Choose the Weather for Action" heralds meteorology as a vital consideration in modern strategy and tactics. The great military figures of history entered campaigns with the future weather an unknown consideration---a factor which could destroy the hopes of either side. Victor Hugo cites the defeat at Waterloo, where Napoleonic strategy must have overcome Wellington before the arrival of decisive Prussian aid, had not a sudden rain rendered artillery immobile. Today the Weather Service, providing long range forecasts for strategical planning and short range predictions for tactical considerations, "sits in" at conferences of the highest generals.

The first participation by a U.S. Army weather service in combat took place in France during World War I; commemorated by the fleur-de-lis. Performance of meteorological duties both day and night is indicated by the blue and black background. Anemometer cups, an important source of data for weather forecasting, identify the service.