RESTRICTED

WEATHER SERVICE BULLETIN

ARMY AIR FORCES HEADQUARTERS WEATHER WING
AUGUST 1944 ASHEVILLE, N.C. VOL.2 NO.2

NEW OBJECTIVES

The month of June 1944 marks the end of a significant period in the establishment and growth of the AAF Weather Service. The problems of training personnel and expanding facilities are no longer paramount. Now our first duty is to examine weather operations critically: to discard methods now obsolete (because they were conceived to meet problems that have been solved) and to eliminate incompetence and inefficiency. This will insure that the Service is discharging its responsibility.

Continuous improvement of weather service by the addition of newly-developed techniques to forecasting methods is a fundamental part of this program. Yet such improvement is being jeopardized by reactionary opposition from some forecasters and observers who instinctively resent and oppose any changes of station schedules or operations to accommodate new developments. Such opposition may arise from an incomplete understanding of new concepts or from an ill-advised adherence to a rigid routine which allows no time for the preparation and use of charts employed in the new forecasting techniques. Even some recent graduates from meteorology schools, already trained in the use of these methods, are allowing their knowledge to fall into disuse because it is easier to conform to existing operational routines than to attempt to effect a change.

Reactionary opposition to new methods cannot be tolerated. Necessity for their use has been proven by the number of aircraft accident reports which demonstrate that forecasters have not made full use of all the information available to them. It is a primary objective of the new forecasting techniques to insure that each forecaster gives full consideration to all significant factors in making his forecast.

There can be no questioning the usefulness and worth of official technical recommendations; extreme care is exercised to insure that they are scientifically sound and have important practical value. The Station Weather Officer or forecaster should not presume, therefore, to pass on the validity of newly-recommended techniques.

Intensive, written reports and a program of technical consultations have been prepared to stimulate field use of the new methods. Mere instruction and explanation, however, cannot insure that these techniques will be used: RCO circulars and memoranda must make provision for their use. AAF Regulation 105-4 gives Regional Control Officers sufficient authority in the choice between optional and prescribed work to avoid overburdening station staffs when the new methods are put to use.

In the last analysis, responsibility for the adoption and use of new techniques must rest with the Regional Control Officers and the individual Station Weather Officers. Station schedules which are so rigidly defined that they leave no room for the inclusion of new techniques should be discontinued. If improvement in forecasting is to come about, a carefully balanced program of operations must be developed so that there is room for both the old and the new.

W. O. Senter

W. O. SENTER
Colonel,
Commanding

PROJECTILE NAVIGATION

Infantrymen in Italy, Normandy, Burma, and the Pacific Islands have learned in the most costly manner that a moving artillery barrage in support of an attack on fortified positions must be followed very closely. At Cassino the Nazis allowed their unmanned weapons to endure Allied shelling at H minus 1/2, but when firing ceased to permit infantry attack the Germans sprang uninjured to their posts. They and the Japanese prepare pillboxes so strong that even a direct hit by a heavy shell often only stuns the occupants for a few critical moments.

Yet variable factors like the effect of atmospheric conditions on projectiles in flight have made it necessary for Allied troops to lag behind their protecting curtain of fire. The dispersion of shells in fire from our heavy pieces has been too great to permit a satisfactorily small but interval between the lines of shellfire and attackers.

Faulty aiming of the first round of fire is the necessary result of lacking full data about *every* effect on the projectile's path, inside and outside of the barrel. This shortcoming is grave, and is correctible only when observers can spot the miss and correct the aim by sight. Certainly shells cannot be sprayed among advancing troops while empirical corrections are being made.

Obviously there is a serious limitation on the effective range of ground and antiaircraft artillery when poor visibility, cloudiness, terrain features, difficult communications, enemy air cover, and curvature of the earth interfere with vision. So it may be seen that the destruction of enemy pinpoint objectives can often be impractical, even when the targets lie well within the range of our heavy ground and antiaircraft artillery, *if all the variables affecting flight path are not known.*

At present, three meteorological factors---density of the atmosphere, temperature, and wind velocity---are the major "imponderables" in the desired prediction of shell trajectories. The problem's complexity, though, is belied by this simple statement which does not explain that a huge block of the atmosphere (perhaps 7 miles high and 21 miles long) can exert an influence on projectile flight that may vary greatly in a complex way every second.

The magnitude of these effects is dependent on the type of gun and its setting. For the 90 mm. antiaircraft weapon, reasonable atmospheric conditions might produce a density effect of 650 yards or a wind correction of 900 yards. The 155 mm. howitzer may commonly require compensation for density variations of 800 yards and as much as 1,300 yards for windage.

Field and Antiaircraft Artillery commanders have been furnished a list of Regional Control Officers by Headquarters AAF, with a statement that arrangements appropriate for an interchange of services may be made within a combat theater. Artillery units will provide RAWINS and surface observations, while weather stations have been directed to furnish forecasts of density and temperature for standard artillery zones (and wind forecasts when requested) to provide a 24 hour coverage.

Weather Division Report Number 735, "Weather Forecasting for Artillery Fire," should be used as the technical authority for weather personnel who may be called upon to furnish forecasts for artillery battalions.

FLIGHT VARIABLES

Advice from meteorological thinkers about the potential path of a projectile need only concern events taking place after ejection of the shell from the gun muzzle. Although there is an "interior" (to the barrel) variable of powder temperature, the artilleryman takes this into account at the gun by inserting a thermometer into a sample powder charge.

Air resistance and air translation modify the trajectory of a projectile from the parabola that theoretically would be described in a vacuum. Three factors sum up air resistance: density lapse rates in the atmosphere, characteristics of the projectile, and "residual effects."

Density: It is clear that air density at every level up to the maximum height reached will have an influence on the trajectory. If this maximum height is zoned for convenience into any arbitrary layers, each zone will have different density effect depending on (1) the speed of the projectile there, (2) the length of time spent in that zone, and (3) the mean angle of presentation that is maintained while in the specified layer.

ARTILLERY ZONES FOR TEMPERATURE AND DENSITY

Zone	Limits (feet)	Zone	Limits (feet)
1	0 600	6	6,000 9,000
2	600 1,500	7	9,000 12,000
3	1,500 3,000	8	12,000 15,000
4	3,000 4,500	9	15,000 18,000
5	4,500 6,000	10	18,000 24,000
		11	24,000 30,000

Standard artillery zones for winds aloft are the same as the above, except that Zone 2 is 0-1500 feet, overlapping Zone 1.

The density effect of a zone, in other words, plays a part in the whole deflection that is evaluated with these weighting factors. The density of a zone would be of greatest weight if the shell velocity was high, if entry was made at a slight angle by the missle, and if flight within the zone was prolonged.

It is interesting to note that ballistic density depends on the mass of the solids or liquids present in the air through which the projectile passes as well as on the air density computed from pressure and temperature conditions. Probably the question of glaze and rime icing deposits on the projectile in cloudy, freezing, low-velocity zones should be investigated.

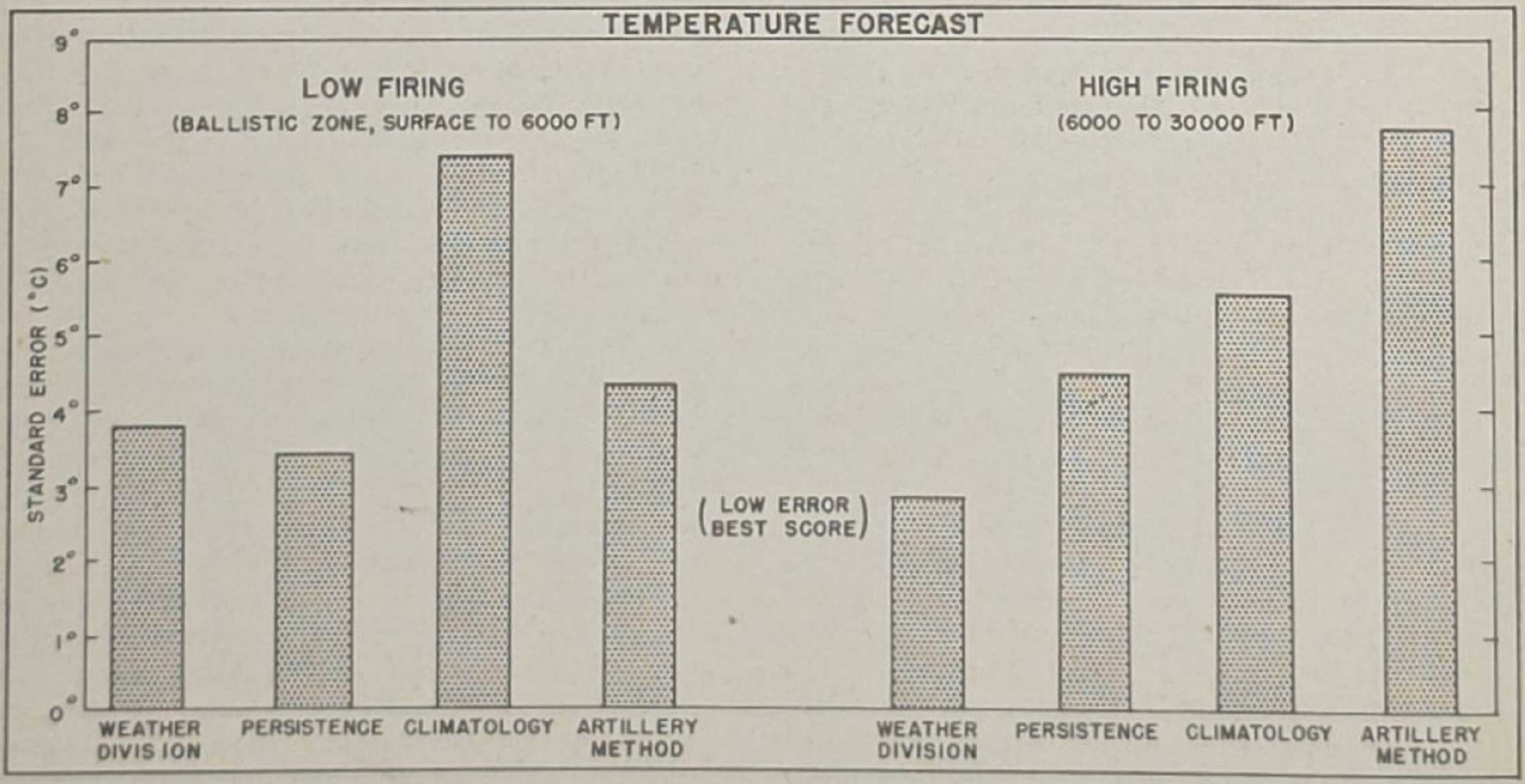
Projectile characteristics of size, weight, shape, angular velocity, and distribution of mass determine shell trajectories, but these factors can be lumped under a constant for a given projectile. The "Ballistic Coefficient" sums up these physical characteristics.

Residual effects have been found to depend mainly on the speed of the projectile relative to the speed of sound. The residual factor is small and bears a constant relation to the projectile speed when the latter is well below the speed of sound waves. However when the speed of sound is approached, the ratio of residual factor to projectile speed increases sharply to a maximum at a point where the projectile speed is slightly more than that of sound. The ratio decreases slowly thereafter, becoming constant again at high speeds.

These characteristics of the residual factor imply that the increased resistance at high speeds results from an interference with the shell's progress by *compressibility shock waves* or *burbles* which the shell itself propagates. High speed shells distrrb the atmosphere like a source of sound and propagate a shock wave that proceeds outward from the instantaneous position of the shell on an ever-widening sphere. Now if the shell moves faster than this shock wave (that is, faster than the speed of sound), the wave fronts that it must penetrate---belts of compressed air ---will exert a powerful retardation. Similar considerations must influence the design of aircraft with speeds near that of sound.

The speed of sound is proportional to the square root of the absolute air temperature. For this reason air temperature is important in evaluations of the residual factor, apart from its effect on density computations.

Now that we have considered the factors involved in atmospheric *resistance* to the passage of the projectile, the varia-



bles of "exterior ballistics" can be completed by a consideration of factors involving *translation* of the air. Of course the projectile velocity is being modified at every instant by the action of horizontal and vertical wind currents. In practice only horizontal velocities are considered, although qualitative compensations for terrain effects on upslope or downslope air motion have been attempted.

ARTILLERY METHODS

The Field and Antiaircraft Artillery correct gun settings for synoptic variations by using an assumed lapse rate of density and temperature. Actual surface observations of pressure and temperature ($\rho = k \frac{T}{P}$) are taken to permit the selection of that pair of climatologic, density lapse rate tables which is based on the actual surface density. One of these charts is appropriate for daytime use, the other for nocturnal firing. Five different series of such standard tables have been prepared for four quadrants of the United States and one oceanic area.

Temperatures aloft (for computations of the *residual effect*) are estimated by use of the lapse rate for a "standard artillery atmosphere" defined in firing tables.

The conventional method for determining the winds aloft is to have a single theodolite pibal run taken by the meteorological section of an artillery regiment. However, most antiaircraft batteries have radar sets which may be used for a far more accurate determination of winds aloft that furthermore is not dependent on conditions of good visibility and clear skies.

The Weather Division prepared forecasts of winds aloft, densities, and temperatures on the basis of modern meteorological theory from the regular 0400Z reports of upper-air data for the artillery trails recently held at Pine Camp, N. Y. This effort was designed to evaluate specialized weather services in relation to alternative procedures, including the conventional artillery methods mentioned above.

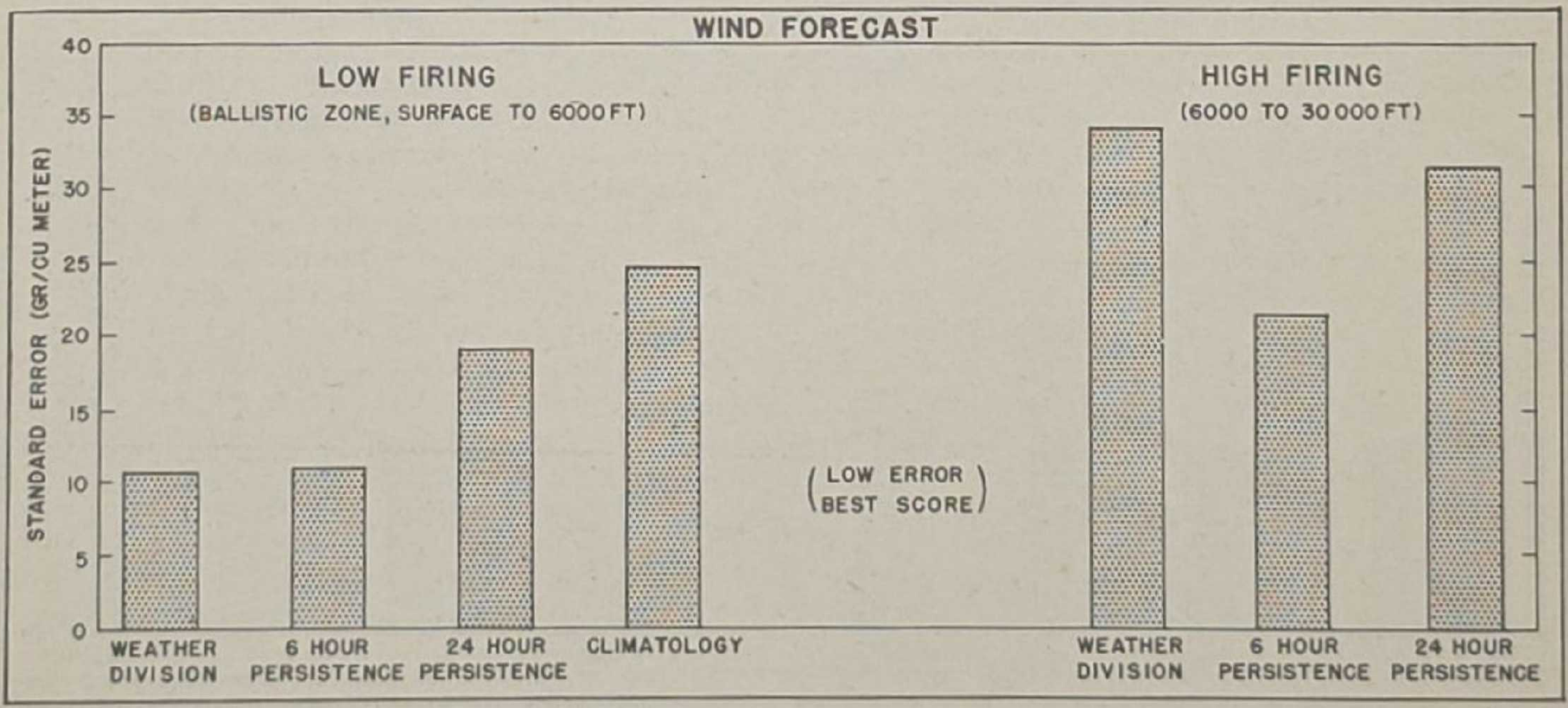
FORECASTING WINDS

Radar observations were made daily at firing time to provdde verification of the wind forecasts by the several methods in use. Obviously, forecasts of the winds aloft serve a useful purpose only when such RAWINS are not available.

The Weather Division forecasts of wind direction and speed, based on movements of pressure systems and thermal wind considerations, were prepared daily from the 0400Z data for firing at 1200Z and 1800Z the same day. Climatological forecasts of winds aloft in this case represented the average conditions for the same period in 1943. The latter source gave sufficient data for comparison to 9,000 feet only.

The Weather Division forecasts were no better than 6-hour persistence up to 9,000 feet. Above this level, these forecasts became progressively inferior to 6-hour persistence. This disappointing showing is attributable to the fact that the forecasts were made without the aid of wind observations at Pine Camp and, on frequent occasions of prevalent cloudiness, without aid of observed upper winds over a wide area.

Later, when gradient winds determined from isobaric maps *on which the forecasting was based* were compared with radar winds observed at map time, it was found that errors in isobaric configuration alone accounted for from 45 to 85 percent of the



error in the forecast winds. Certainly therefore, the evidence seems to indicate that a winds aloft observation at firing time is by far a better practice than an attempt at forecasting.

TEMPERATURE AND DENSITY FORECASTS

The average error for the Weather Division temperature forecasts was 3° either way, without much variation among the different zones. (There was a tendency for this forecast to be best around 10,000 feet). "Weather Forecasting For Artillery Fire" describes the forecasting technique employed.

The conventional artillery method, using surface data observed at firing time, was the most accurate up to 3,000 feet, but above this height results were poorer: the average temperature error up to 30,000 feet was 7°C. Above 9,000 feet the artillery method was by far the poorest of the estimates.

These Pine Camp tests, then, demonstrated that meteorological forecasts of temperature and density below 3,000 feet are likely to be inferior to an extrapolation of surface data taken at firing time. This fact is attributed to local influences such as the presence of water bodies nearby (especially true for Pine Camp which is only a few miles from Lake Ontario).

Above 3,000 feet however, local influences are of little importance and forecasts based on the general flow pattern (advective temperatuee and pressure changes) and air mass distributions are superior. These considerations suggest that the best method would be an extrapolation of surface temperatures and densities to about 3,000 feet by the use of a reasonable lapse rate, combined with forecasts made from weather charts above that level.

This coordination seems to require frequent transmission to the weather station of surface observations taken by the using artillery unit. Additional temperature observations made by observation planes attached to the artillery unit would also be of value.

BALLISTIC VERIFICATION

The Pine Camp program records included 23 pairs of radiosonde observations in which both members of each pair were taken within an average time of 4 hours. The second member of each pair was considered to describe the atmosphere encountered by the projectile when the firing took place, the gun having been laid either by (a) the direct observational message computed from the earlier radiosonde, (b) the Weather Division forecast prepared from weather data about 8 hours old, or (c) the conventional artillery message based on surface observations made at the time of the earlier radiosonde observation.

The verification was then carried out in two ways; first by comparing the earlier radiosonde, forecast, and "artillery" temperatures and densities with those of the second radiosonde observations; secondly by recourse to firing tables for computation of the error resulting from use of the three methods---

BALLISTIC ERROR OF VARIOUS CORRECTIONS

	Density		Temperature	
	Range	*Altitude*	*Range*	*Altitude*
Earlier radiosonde..	1.20	1.29	3.1	3.1
Forecast.....	1.13	1.41	5.9	5.8
Artillery....	1.73	1.75	14.7	14.9

Shell-Burst Error (yds.) from above error in:

	Density	Temperature
Earlier radiosonde......	37	4
Forecast.........	36	7
Artillery........	52	10

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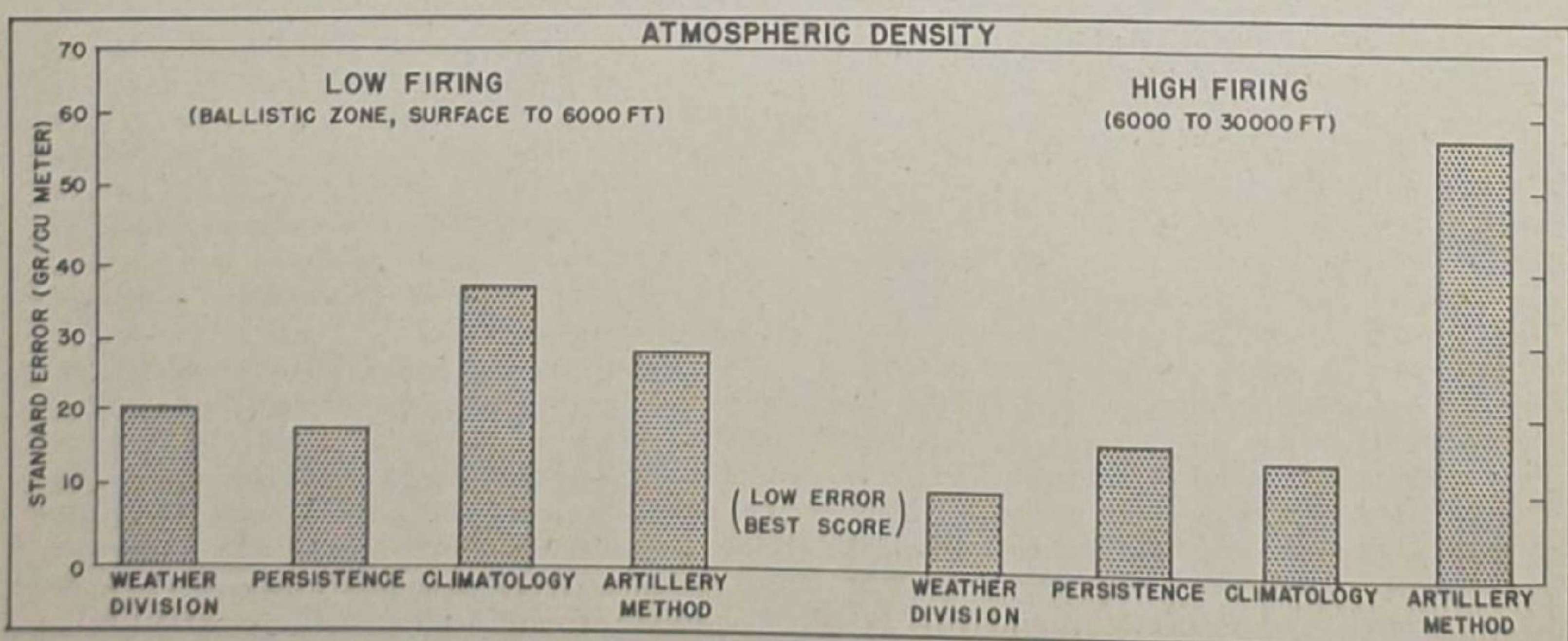

BUZZ BOYS EXPLOIT CLOUDS

by MAJ OLIVER K. JONES *STAFF WEATHER OFFICER VIII FIGHTER COMMAND*

The relative aerial strength of the Allies and the Nazis in the European Theater is so heavily in our favor that operations are designed to entice the Luftwaffe pursuit force into action with our fighters whenever possible. For example, fighters sent out on a light-bombing mission may hide from visual observation in clouds along the target approach in the hope that they will be mistaken for heavy bombers---and thereby excite some Nazi fighter opposition.

Furthermore, such a subdivision of this article as "Use of Weather on Defense" refers only to a momentary situation over Europe where single fighters become detached from their Group formation and are bounced by several enemy planes. This theme of power runs through the tactical use of weather by Allied fighter aircraft.

OFFENSF TACTICS

Most Continental fighter missions are devoted to providing support for heavy bombers, either as close escort or as an "area support." The melody of strength in these excursions is the bomber's role, to appear in crescendo over the target: fighters provide a forceful accompaniment that never encroaches on the melody---enemy interceptors do not succeed in luring the protective counterpoint away, even by the promise of easy scorss.

Not much fighter use of weather is feasible, then, on relatively clear days when the danger of interception is great. The convenience of "atmospheric topography" must be sacrificed in such cases to discourage or thwart enemy attacks by having strong fighter cover close to the bombers.

Now and then a bold Jerry will try to sneak up on the combined formation through condensation trails formed by the four-engined giants. Only if our fighter cover is strong and close enough can the enemy be spotted in time and forced to break away. Surprise bounces on our fighters providing this top cover near the contrail level are prevented by having a flight or two out of each group sitting above to surprise the Hun who thought *he* was going to do the surprising.

Except for occasional sorties like this, enemy plans call for a *concentration* of interceptors to attack the formation at some convenient point en route so as to saturate the Allied defensive power. In the event that our attacking force is flying over an overcast, the well-known difficulties of fighters in instrument conditions obstruct a formation strike in force by the Luftwaffe. In such an unfavorable situation, Nazi air marshals usually place the whole responsibility on flak, saving their dwindling fighter strength for a better day.

When an undercast prevails, the bombers need not be sscorted as closely as on clear days. The fighters range some distance to each side of the bombers with about half of the force going down to a lower level near the cloud tops to catch any Jerry that pokes up through.

Enemy fighters climbing up through an overcast are perfectly outlined. Furthermore, their formation is at most in flights of four, permitting our fighters to be spread over a wide area to make their bounce just as the Hun leaves the clouds *without sacrificing local superiority in numbers*. The only recourse for a Jerry so attacked is to duck back into that layer which protects but neutralizes him. Pure *Fighter Missions*.

There are three types of missions in which fighters alone are used: *dive bombing*, *level-bombing*, and *strafing*.

An ideal weather situation for level bombing is set up by the presence of an old occlusion across the route. Then a residual, layer cloud at middle levels with good visibility between the layers can be expected (with little low cloud beneath to interfere with bomb sighting). Our fighter bombers are enabled to approach the target without being visually identified as fighters: in the ideal situation, the Germans anticipate heavy bombers and send up fighters into the evenly-matched encounter that the Allies seek.

In any case, the fighter-bombers descend through the layer cloud (but only if the base is no lower than 10,000 feet in ordinary circumstancss), line up on the target, drop their bombs, and then get ready to take on any opposition the enemy may have sent up. When there are no Jerry fighters around to provide interest, the fighters hit for the deck and come out strafing.

Essentially the same type of weather is desired on a strafing show, except that low cloud is preferred to middle cloud. When the cloud base is from 1,000 to 3,000 feet above the ground, a local element of surprise can be attained by the strafers when they swoop down out of the cloud onto a target of opportunity. Furthermore, evasive action from ground fire becomes easy when there is a cloud within easy reach after a strafing pass. Only one pass over a given target is made by a strafing group because ground defences can be an awful nuisance once they have determined the proper lead for a strafing aircraft. The strafer then flies on to the next target while utilizing cloud available for cover to catch the ground defensss unprepared again.

Navigation to the target in instrument conditions is easier for strafing missions, because dead reckoning is accurate enough to hit the *areas* where targets of opportunity are sought. On level-bombing missions, however, breaks in the undercast are useful to permit approach by pilotage to the pinpoint that has been chosen.

For a dive bombing show, fighter pilots would rather not see any cloud at all. A deck of stratus en route that breaks completely or nearly so at the target is satisfactory, and perhaps scattered cloud will afford some defense from light ground AA fire. Otherwise, clouds over the target are a hazard to the dive bomber.

Flight in thin cirrus has been found to be a very successful tactic for the predatory fighter. Enemy fighters are easily seen below, but vision from lower levels is confused by refraction and diffusion in the milky cirrus deck. The same idea is employed by small formations of fighters that cruise along in the base of any layer cloud looking for a bounce on an unwary Hun stooging about below.

DEFENSIVE TACTICS

Engagements of sizable groups of opposing fighters usually result in the separation of individual aircraft or elements. Then a pilot may find himself isolated from his companions with two to three Jerries queued up on his tail and firing everything at him but their Very pistols. If there is a saving cloud handy, the unfortunate one breaks for the cover with full speed.

If the cloud is extensive, slight changes in course suffice to eliminate chances of the Hun firing blindly but still scoring hits. When the cloud is patchy (fair weather cumulus), the "pursued pursuit" pilot makes a violent change of direction when Jerry is close behind. However, if the enemy is at some distance that is safe for the moment, the recourse taken in patchy clouds is to make only a moderate change of direction in the cloud and to work up the best speed possible along the most direct route to home.

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FORECAST CONSISTENCY

Apparently, 8-12 hour forecasts of temperature and density by the methods of Weather Division Report #735 from general data are as good as the use of an on the spot radiosonde run only four hours old.

It is necessary that the separate forecasts of density-temperature field and wind field should be compatible according to the Thermal Wind relationship. Prediction of a set of winds that would produce cold air advection in a particular layer (backing with height) while forecasting a warming of that same layer in the density-temperature forecast would be inconsistent unless the effects of subsidence are expected to offset those of advection. This check is valid because changes occurring in the temperature-density field result principally from horizontal advection and less from vertical motions.

The hydrostatic relation between the mean virtual temperature of a layer, its geometric depth, and the pressure limits should be satisfied in every case. Starr's Diagram is convenient for this use.

The military importance of cooperation by the Weather Service to solve artillery problems is very great; fully as significant as the familiar duties in behalf of aircraft operations. In the words of General Arnold,

"All possible cooperation should be extended to the artillery units which call upon the Weather Service for assistance."

APOBs *WITHOUT AEROGRAPHS*

by CAPT. A.F. GUSTAFSON

Numerous requests for airplane meteorographs, known also as aerographs, have reached Headquarters Weather Wing. The reason given is always the same, the weather officer in question would like to make APOB soundings to be used in forecasting local stratus and/or thunderstorms. It is usually pointed out that the nearest radiosonde observation is either for the wrong time of the day or is too far away to be of much use. Unfortunately, most of these requests had to be turned down for the simple reason that no aerographs were available for such use, and would probably not be for sometime to come. No doubt the weather officer concerned thought that without an aerograph there was no possibility of his making APOB soundings.

Actually, however, APOBS *can* be made using only the pressure altimeter and the free air thermometer which are standard on most aircraft. Except for the fact that no relative humidities are obtained, this type of sounding is comparable in every respect to a sounding made with an aerograph. The absence of relative humidity data is less serious than might first appear when one considers that the observer can record the base and tops of clouds. Furthermore, as will be shown later in this article, the procedure of obtaining relative humidity from an aircraft by the use of a hair hygrometer is not too satisfactory anyway.

In making an APOB sounding with the aid of the pressure altimeter and the free air thermometer, pressure is obtained by converting pressure altitude to pressure in millibars by using a standard atmosphere table. For a discussion of the theory underlying this conversion, reference can be made to Section IV of Weather Division Report No. 708, "Determination of Absolute Height and Wind for Aircraft Operations," copies of which have been distributed to all AAF forecast stations. Appendix II of this publication contains a Table of the U.S. Standard Atmosphere.

In order to obtain accurate pressure measurements it is necessary to take into account instrumental and installational errors which are inherent in the altimeter. A complete discussion of altimeter errors can be found in Section VII, paragraphs 3 and 4, of Tech Orders 05-30-1. Several sources of instrumental error exist, but the correction for scale error is usually the only one made.

Altimeter scale corrections have been determined for all altimeters and can be found on the altimeter scale correction card mounted somewhere near the altimeter. The date of the last calibration should be noted. If it is more than six months old, the altimeter should be recalibrated. The Instrument Section of any depot or sub-depot should be able to do this calibration.

The following procedure is recommended for obtaining installational corrections:

a. Station an observer in the control tower to make simultaneous readings of the control tower altimeter with readings taken in the aircraft. Set the control tower altimeter at 29.92 inches. (A negative altitude will be obtained if the ambient pressure is greater than 29.92 inches).

b. Set the aircraft altimeter at 29.92 inches. Fly the airplane toward the control tower at the exact level of the mounting of the control tower altimeter (as nearly as possible). Tap the altimeter a few times to be sure that the pointer is not sticking.

c. Record the indicated altitudes of both the aircraft and tower altimeters at the instant the control tower is passed.

d. Repeat this process at 20 mph intervals of indicated airspeed throughout the range of airspeeds to be flown in making the APOB sounding.

e. Add the proper scale corrections algebraically to the indicated altitudes obtained in (c.).

f. Subtract the aircraft indicated altitude (corrected for scale error) from the control tower indicated altitude (corrected for scale error, if any). Tabulate the differences for each corresponding indicated airspeed. These are the installational corrections in feet.

g. To convert these corrections from feet to millibars, multiply them:

By	If control tower altimeter (set at 29.92 inches plus correction) indicated between
.037	-800 and 100 ft.
.036	100 and 1000 ft.
.035	1000 and 1900 ft.
.034	1900 and 2900 ft.
.033	2900 and 3900 ft.
.032	3900 and 5000 ft.
.031	5000 and 6100 ft.
.030	6100 and 7200 ft.
.029	7200 and 8300 ft.
.028	8300 and 9400 ft.

and *change* the sign!

h. Plot the resulting values obtained in f. against their corresponding indicated airspeeds and draw a smooth curve connecting the points so obtained. This is the desired installational correction curve to be used in applying installational corrections to the pressure obtained, using the pressure altimeter.

For example, suppose the altimeter in the control tower (set at 29.92 inches and corrected for scale error) indicates 1530 feet. Flying past the control tower at an indicated airspeed of 180 mph, the aircraft's altimeter (set at 29.92 inches and corrected for scale error) indicates 1470 feet. The installational correction would then be plus 60 feet or -.035 times 60, which is -2.1 millibars. On the graph, -2.1 millibars is plotted opposite 180 mph.

Having insured that the scale correction card is up to date, and having obtained the installational correction curve, the APOB sounding is made as follows:

a. Record the station pressure, temperature, and relative humidity.

b. Set the altimeter in the airplane at 29.92 inches.

c. Take off and climb slowly to the first level (note the indicated altitude at the base or top of any clouds and identify the cloud type).

d. Level off and fly at constant airspeed and constant altitude for about one minute, tapping the altimeter with the finger tips to avoid any "sticking" of the pointer.

e. Record the indicated airspeed (read to the nearest single mile per hour), the indicated altitude (read to the nearest five feet), and the indicated temperature (read to the nearest 1°C).

f. Climb slowly to the next level and repeat the process.

g. Continue in this manner until the sounding is completed.

Do not make a sounding during descent except as an experiment. Altimeter scale corrections are determined at various check point pressures as the pressure is decreased. If, after completing the calibration, the pressure is again increased, it will be noted that the same check point pressures do not yield the same indicated altitude. This effect, known as hysteresis, may result in serious error is an APOB is made during descent.

It is always advisable to fly at as low an indicated airspeed as possible when making an observation. The reasons for this will not be discussed here except to say that at low airspeeds slight errors that may result in the temperature corrections made for dynamic heating are minimized.

Clouds and precipitation should be avoided whenever possible. The presence of water droplets results in erroneous temperature measurements because an unknown amount of the dynamic heating effect will be consumed in evaporating water---invalidating any temperature correction.

Furthermore, a wet bulb effect of unknown magnitude may be experienced when rain is entered at a level where the humidity is less than 100%. Obviously, then, the measured air temperature will be too low. If clouds and precipitation cannot be avoided their presence should be carefully noted to assist the interpretation of data.

It will be noted that no definite intervals for leveling off were given. This was purposely done since the magnitude of these intervals will depend on the local situation. If the sounding is to be used for forecasting the formation or dissipation of stratus, for example, these intervals should be made quite small until the top of the inversion is reached, after which they may be increased. In other words, the forecaster should use his own judgment as to the intervals at which observations should be made.

When the sounding has been completed, the data sheet will contain a series of indicated airspeeds, altitudes, and temperatures. It now remains to make the necessary corrections and conversions. The following procedure is recommended:

a. Correct the indicated altitude for scale error.

b. Convert this corrected altitude in feet to pressure in millibars, using the standard atmosphere tables contained in Appendix II of Weather Division Report No. 708.

c. To the pressure thus obtained, add algebraically the installational correction corresponding to the indicated airspeed. *This is the* desired true pressure. (note: Do *not* apply the installational correction in feet to the indicated altitude and then convert to millibars as this will result in a significant error at higher altitudes).

d. Using the E-6B Computer, compute the true airspeed as usual. Use the calibrated airspeed instead of the indicated airspeed if the former is available.

e. From the indicated free air temperature,

Subtract	If the True Airspeed is between
1°C	79 and 137
2	137 and 177
3	177 and 209
4	209 and 237
5	237 and 262
6	262 and 285
7	285 and 306

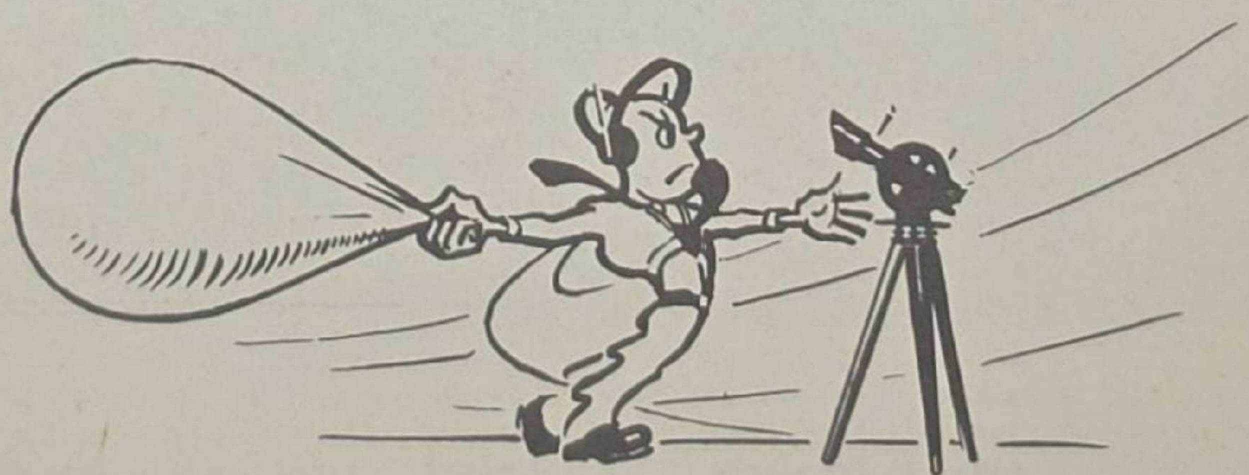
to obtain the true free air temperature.

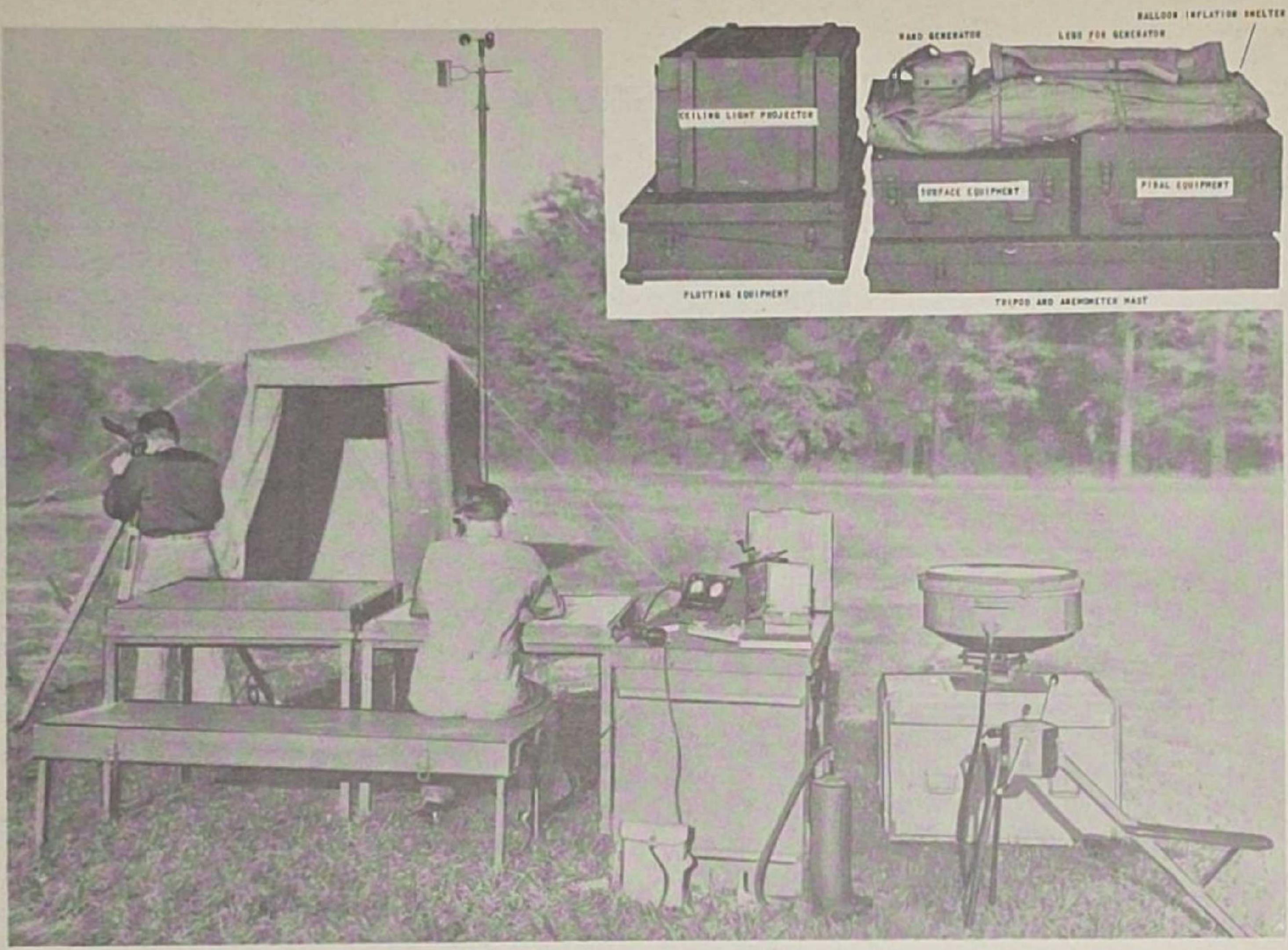
As an example, suppose that at a given level the indicated airspeed was 166 mph, the indicated altitude (altimeter set at 29.92 inches and corrected for scale error) was 8910 feet and the indicated free air temperature was -4°C. Referring to page 67 of Weather Division Report No. 708, it is seen that 8910 feet corresponds to approximately 726.7 millibars (by interpolation). Now, if the installational correction for 166 mph were -3.4 millibars, the true pressure would be 726.7 - 3.4, which equals 723.3, or to the nearest whole millibar, 723 millibars. Using the E-6B computer, the true airspeed is found to be 188 mph. Referring to the table it is seen that this corresponds to a subtractive correction of 3°C. From -4°C, 3°C is subtracted to obtain a true free air temperature of -7°C. On the adiabatic chart, -7°C is plotted against 723 millibars.

All this may seem very complicated. "Give us an aerograph," someone might say, "so that we can avoid all this trouble." But wait a minute: if accuracy is desired, the aerograph must also be calibrated for scale and installational corrections. As a matter of fact, this is usually done by first calibrating the altimeter and then using it as a standard. In making a sounding with the aerograph it is still necessary to level off and fly with constant airspeed at given intervals of altitude, because the same lag characteristics present in the altimeter and the free air thermometer are present in the aerograph. The temperature must still be corrected for dynamic heating. The presence of clouds and precipitation have the same adverse effects on the measurements of temperature and, in addition, make the determination of relative humidity inaccurate.

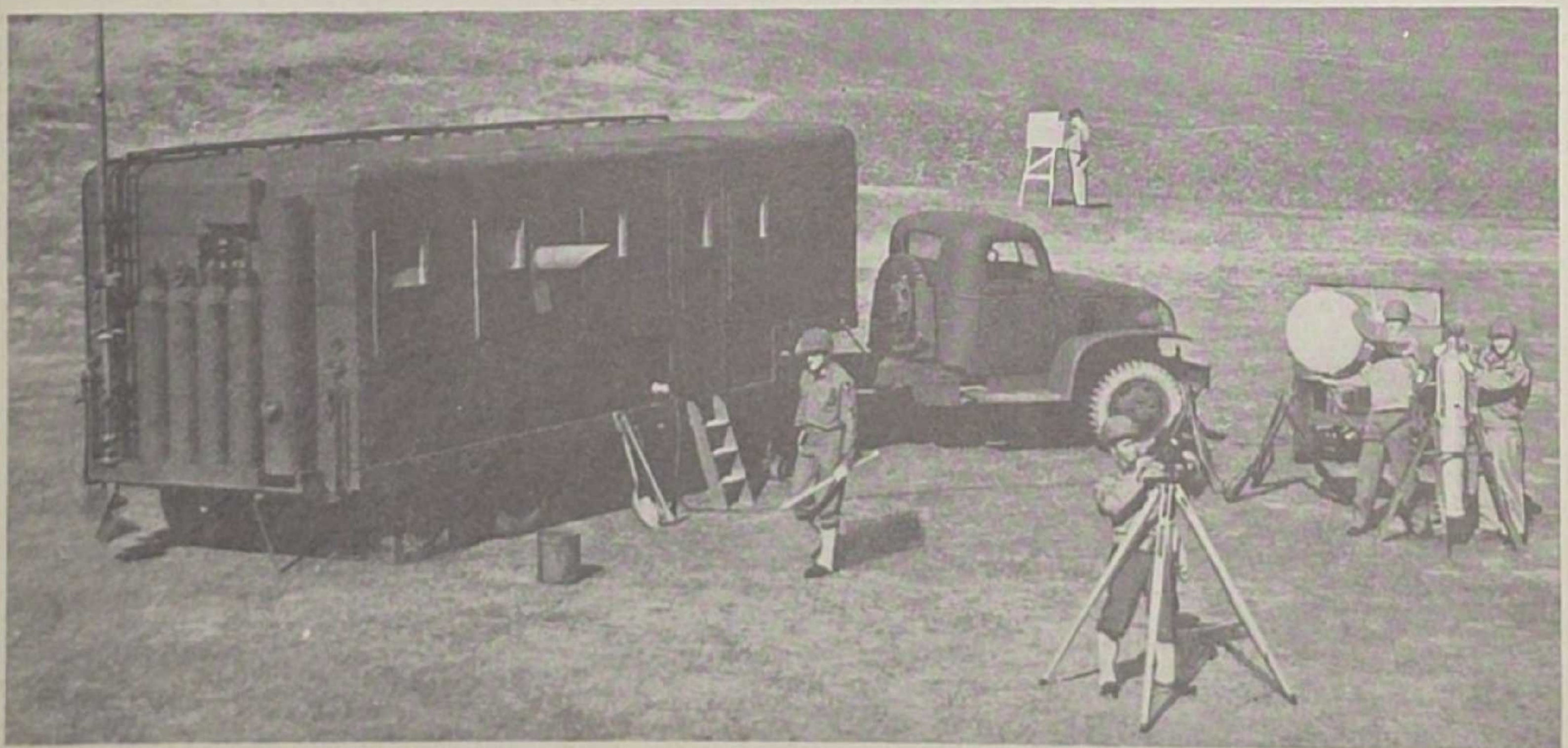
As mentioned before, the advantage of obtaining relative humidity values which an aerograph has over the other type of APOB sounding is not as great as it might seem. In the first place the hair hygrometer does not give consistently accurate measurements even under ideal conditions. Quite large errors are likely to occur due to the high lag coefficient of the hairs, especially at low temperatures. Furthermore it is necessary to correct the relative humidity for the dynamic effects of airspeed and this correction is not simple.

Finally, it is not difficult to see why radiosonde observations, which do not have to take into account the dynamic effects of an aircraft in flight, have a great advantage over airplane soundings. Some day, perhaps, radiosondes may be available to every forecasting station which has need for local atmospheric soundings.





The *PORTABLE METEOROLOGICAL STATION* provides all of the necessary instruments and equipment for surface observations end charting the winds aloft by pibal ascents. The packing cases open into convenient furniture for the preparation of maps and charts. The entire set weighs only 1200 pounds and occupees less than 60 cubic feet. The inset (upper right) shows the station in packaged form, appropriate for transportation in a medium bomber, a one ton cargo trailer, or by manpower if necessary.

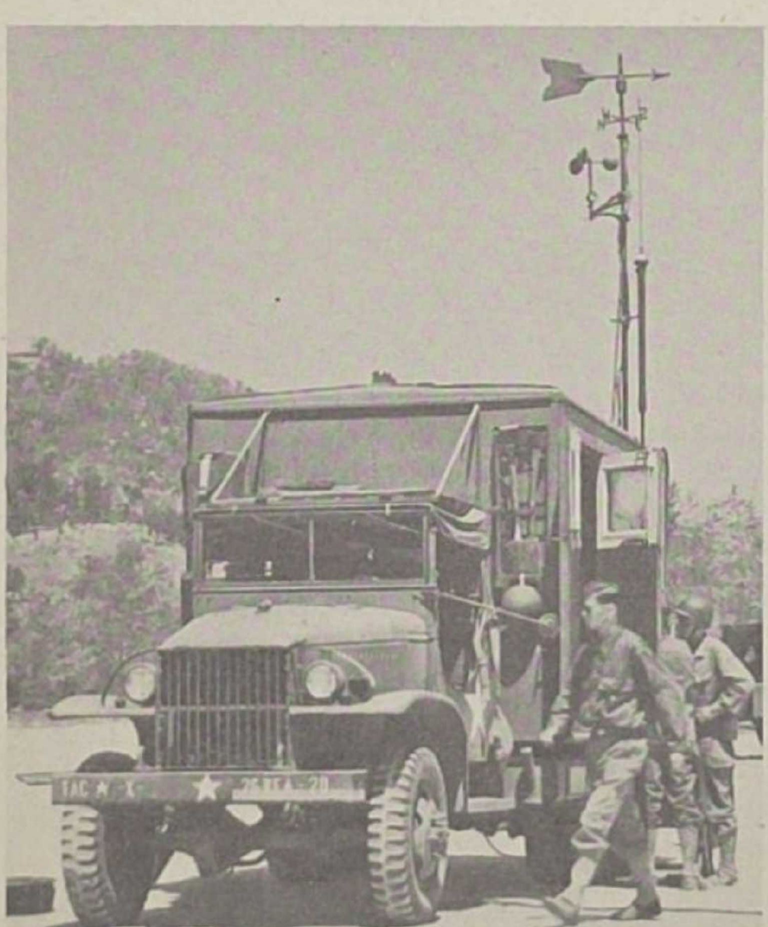


This mobile weather unit was the first development in complete service on wheels by the Weather Service. Although this equipment is still in combat use, it has the shortcomings of bulkiness and a detachable trailer. Fifth Army Headquarters on the Italian Front utilizes the services of such a Class "A" station as is housed in this outfit.

MOBILE METEOROLOGISTS

The campaign in Africa taught military authorities just how fluid modern war can be: there the line of battle rolled up and a continent no less than six times. Tactical air forces, husbanding the limited range over enemy territory of their fighter planes, followed each latest advance by laying down hundreds of hastily-made, feverishly-used, then-forgotten airstrips around the northern perimeter of Africa.

AAF weathermen drew an object lesson when the armies of both Wavell and Rommel outstripped their supplies and left fixed bases behind: permanent weather stations obviously would not be efficient in operations of such rapid movement. The fixed stations could not be set up fast enough for one thing; then too, there was little point in having an enduring network of reporting stations scattered helter-skelter in the wake of advancing armies. So a *mobile* meteorological unit, long under consideration, was made a first-priority measure for the equipment of our ground and air forces.



SCM 1 T4 in this picture is the improved mobile station built into a K 53 van. This model is preferred to the T3 because it is far more compact and it operates as a unit.

Both military and civilian agencies had experimented with portable observing stations before our entry into the war, but the AAF maintained that the full services of both observing and forecasting based on complete equipment and data would be a minimum requirement.

The first development in complete mobile weather service was the familiar SCM-2-T3. This trailer carried a full complement of instruments and equipment, sufficient to perform Type 'A' station functions. However, its bulkiness meant a losing competition with priceless aircraft for deck-loading space on shipments to foreign theatres. Furthermore, line crews in combat zones soon discovered how handy it was to detach the motive unit from the weatherman's trailer and use it for other purposes. Then when a general movement was ordered, weathermen often found that their 'mobile' unit had that 'get-a-horse' permanence.

An improved station model was built into a K-53 van. There is less floor space in this type, but the station carries every stick of the essential equipment and can provide the same service as the trailer station. Units of both types are now in use in this country and in the European Theater of Operations.

In the rugged mountains of Sicily and Italy, however, the army came upon roads that were too narrow to permit the passage of such heavy equipment. In tough situations the army often turns to the jeep, and in this case that workhorse was outfitted with the most essential weather instruments to accompany forecasters and observers into those areas where trucks or trailers could not go. There the equipment was unloaded and assembled in a tent or an abandoned building. In Italy, for example, some stations were built in caves. '*Soozie*' the jeep which landed with the initial invasion forces on Sicily and performed her duty so successfully that she was selected to accompany the invasion forces at Salerno, is probably the most famous: her story is already well known to weathermen. (*Air Force* Magazine, March 1944).

There were other places, however, which were inaccessible even to the jeep: places like Makin, Eniwetok, Hollandia, and the Burmese jungles. Our forces were there too; they needed weather service just as much as the armies fighting in Italy. For such places the army developed a *portable* weather station and put it into field operation just eight months ago.

The Portable Meteorological Station, AN/TMQ-(XO-1), consists of five wooden chests and two canvas cases which contain all of the necessary instruments and equipment for surface observations, pilot balloon observations, and preparation of the necessary maps and charts for forecasting. Current models, though, do not include any radiosonde equipment. A hand generator is included in one of the units to supply electric power for the ceiling light projector. The set also has a hydrogen generator, ML-303/TM(XO-1) using charges of calcium hydride. Balloons and hydride charges are packed in separate cartons and are furnished in amounts determined by the length of service anticipated for the package station.

The wooden chests are so constructed that when they are emptied and lose their function as packing cases, they can be assembled to serve as plotting tables, benches, and other necessary office furniture. By having these components serve a double function, valuable packing space or the time previously needed to beg, borrow, or make office furniture is saved.

When the package station includes one-month's supply of balloons and chemicals, it occupies only 60 cubic feet of space and weighs about 1200 pounds, transportable in a one-ton cargo trailer or in a 3/4-ton truck. The largest unit weighs 180 pounds and can be handled easily by two men. If transportation by air is necessary, tests have shown that the entire station can be carried in the fuselage of a B-24, a B-17, or an AT-11. Although doors on the B-25, the B-26, and the AT-23 are too small to allow either of the two largest wooden chests to be carried inside the fuselage, they can be carried easily in the bomb bays. The station has been assembled and put into operation in less than 75 minutes, but the average time required is about two hours.

At the present time no communications equipment is supplied except the field telephone used in pibal runs. Tests are now underway at AAFTAC, Orlando, Florida to determine which of the several communications sets is most efficient for use with this type of portable station.

Weather equipment usually receives an involved evaluation before it is ever released for field use (*Equipment-O-Genesis* in the Weather Service Bulletin for June 1944), but the Portable Meteorological Station has been used in Pacific combat action concurrently with 'field tests' at AAFTAC. Nonetheless, reports have been enthusiastic enough to indicate that the portability of the package station does not interfere with meteorological accuracy. Certainly the Portable Station is a most practicable method for bringing weather service to isolated outposts.

THE COURSE THAT REFRESHES

The Forecaster's Refresher Course, being given at Chanute Field for AAF meteorologists who have long since completed their formal weather training, has just ended its first session. In view of the Weather Service's brief history as an important military function, the first graduates represent a considerable total of seniority and rank: Lt. Col. Warling, new R.C.O. of the Fourth, and Majors Beatty, Hayes, Howell, Jameson, Kolb, Magar, Moore, and Wilcox for notable examples.

"Limited Data Analysis"--what most of us know as "Single Station" with several stations---was a notable item on the curriculum. Navigation, Oceanography, Tropical Meteorology, Long Range and Flood Forecasting, investigation of uses by other arms and services (Artillery, Chemical Warfare), the applications of RADAR and RDF to meteorological purposes, climatological aids, and the Trajectory Method of fog forecasting all received attention for at least a week apiece.

The major portion of the training, of course, was directed at fundamental problems of forecasting. The latest principles of upper-air analysis were treated at length from each of the auxiliary diagrams approved for use.

AAF WX : 1937 194?

by LT. CUSHMAN REYNOLDS
WING HISTORICAL OFFICER

At Headquarters Weather Wing a narrative history of the Weather Service is in preparation. The history begins with the transfer of the Weather Service from the Signal Corps to the Air Corps in the summer of 1937. Where it ends is yet to be determined. It is being compiled by the Historical Officer from the archives of the Weather Wing and from the detailed histories of individual squadrons. Gathering material involves laborious contemplation of general orders, special orders, memorandums, directives, reports and correspondence down through the sixth, seventh and eighth endorsements. The story revealed by the archives is being filled in and augmented by conversations and correspondence with the men most competent to report on both the administrative and operational history of the Service. Compiling the overall history is obviously a Headquarters function--and a full-time job for the Historical Officer.

But the overall history cannot be complete unless each squadron contributes its own story, directly and simply told. That is why letters come out from the Weather Wing urging the squadrons to bring their histories up to date and send copies to the Wing Historical Offcer, (and copies to the Assistant Chief of Air Staff Intelligence (Historical Division). Because the Wing Historical Officer must in a degree cover the Weather Service as a round-the-world enterprise, the Wing has requested copies of the histories of those squadrons which are under theater commanders as well as those of squadrons directly assigned to the Wing.

Squadron histories will not be rewritten at Wing Headquarters. They will stand by themselves as histories. They will also provide valuable source material for the Wing Historian who must relate the history of the headquarters to what has happened in Georgia and California and to what has happened in Italy, in Brazil, in China, in Normandy, in the Pacific Islands.

As a matter of fact many of the squadrons already have submitted histories and are submitting quarterly supplements as requested. The histories received vary considerably in method and quality. The greatest flaw in many of them is the almost total lack of material on actual operations. Presumably the slowness of the histories in arriving and their lack of operational detail are due to a general misunderstanding of their functions and importance. This misunderstanding can be easily cleared up.

WHY A HISTORY ANYWAY?

The overall history of the Weather Service and the detailed histories of the individual squadrons are being prepared for these reasons:

1) The most prosaic and the most immediately cogent reason is that such histories are required by AR 345-105 and by AAF Regulation 20-8. In fact AR 345-105 goes so far as to outline a form in which they may be submitted. (However, this form has its limitations.)

2) There are a good many thousand of us weathermen. By and large, we have lived by ourselves, worked by ourselves. Our responsibilities as forecasters and observers have been our own. Even our discipline has been peculiarly our own. Accordingly we have become an extraordinarily close-knit group of men, though we have lived in small and scattered detachments. We are going to remember the Weather Service for a long time to come, whether we hit the beach on the coast of Europe or on a Pacific atoll or whether we sweat the war at an advanced twin-engine school in Mississippi. After the war, a great deal of the weather story which is now classified will be released. A comprehensive, readable narrative of our own Service will serve to sharpen that memory for the rest of our lives. The history is being written for us who are the Weather Service. It will be our story; the record of our growth, our mistakes, and our achievements.

3) The historical regulations do not exist, however, simply to provide us with an intramural pat on the back. There is a more basic reason. Should human fallibility make it necessary for the United States once again to procure and train the men to maintain a world-wide military Weather Service, we will turn to the record of this war for counsel. The first question will be "What did we do last time?" The history of the Weather Service can be a vital source book for future planning. It is

this function of the history more than any other which dictates the material that must be included.

That is why all squadrons, but especially those in combat theaters and along ferry routes, should include in their histories an account of actual operations. Did a detachment from your squadron go ashore at H-hour, or at H plus 40? If so, tell how the operation was accomplished and how it was planned. It is to make sure that the whole story will be told that AR 345-105 has been supplemented by more comprehensive instructions.

There is nothing wrong with AR 345-105 except that it does not ask for enough. It is a kind of questionnaire. The Historical Officer who complies with it unimaginatively will end up with a skeleton history, a gravestone biography of his unit. AR 345-105 is, of course, a peace-time regulation. War-time historians cannot produce histories by filling out questionnaires. The stories they have to tell are too intricate and too fluid. Historians must *write* histories.

Accordingly the Historical Division of the Assistant Chief of Air Staff, Intelligence, has issued a number of historical circulars instructing historical officers in the compiling of comprehensive, carefully researched narratives. The most important circular yet issued is Number 2, a copy of which is in the files of every Regional Control Office. Circular Number 2 is devoted to research methods. The manner of presentation is left largely to the individual Historical Officer, but he must produce a narrative that is supported by careful documentation.

The narrative history of a Weather Squadron should include a great deal more than the activation date, general orders, and other routine matters. Included should be an account of the technical weather problems in the region, the tactical problems if any, the supply problems, the administrative problems, and the human problems. This information will be surprisingly hard to come by at Headquarters unless the squadrons send it in. For instance, one of the great stories of the war, one with unlimited implications for the future, is the story of how trans-ocean flight has changed from hazardous adventure to something that might be called a routine, albeit a difficult one. The Weather Service has played a vital role in this development. The squadrons concerned should report their part in considerable detail.

WATCH YOUR SHOTS

AR 345-105, directs that photographs be included in unit histories. And photographs can be an indispensable part of any historical record - photographs of people, of stations, of equipment, of terrain. But photographs should illustrate something that would not otherwise be appreciated. The picture of a lean, sunburned observer holding an inflated white balloon against a dark sky will not do---not even if it is a salon print. It simply does not tell anything about the Weather Service that adds to anybody's understanding. Neither do most photographs of station interiors. Every Historical Officer should be sure that photographs included in his history illustrate something peculiar to his region or record an interesting human incident or an unusual event.

Few squadron historians are experienced at putting one little word after the other. And few are trained in the historian's art of sifting evidence. Accordingly, they are overwhelmed by the prospect of writing a history as intricate as that of the average weather squadron. However, the histories must be written.

Here is a bit of counsel which may prove helpful to an inexperienced writer: Sectionalize your history so that it can be written in small doses. Get your facts organized before you write anything. Then write simple, straight-forward sentences. The material is rich. If it is properly organized it will almost write itself.

Clouds IN AEROLOGY: I

by PROFESSOR G.F.BROOKS

This paper was first presented by Dr. Brooks to an A.M.S. meeting in 1938; since then however, it has been revised and expanded (Bulletin of the American Meteorological Society, *Nov. 1941*). *References such as (Fig. 2) are to Weather Bureau Circular 'S'*, Codes for Cloud Forms.

Clouds are indicators of humidity, temperature lapse rate, wind direction and speed (including shear and turbulence) in the free air. As such they are valuable aids in airmass analysis and forecasting.

HUMIDITY WITHIN CLOUDS

The mere presence of a cloud does not necessarily mean that a relative humidity of 100% exists within it. However, this assumption is justified for practical purposes in the case of all young, liquid droplet clouds at temperatures above freezing.

Smoke stratus may have a humidity as low as 70%, so well does the oily film reduce evaporation from the droplets. *Fumulus*, the hazy preliminaries of a forming cloud or the faint smootch left where one has just evaporated (fig. 2 lower left quadrant), is under 100% but usually not far. For example, the white *fumulus* haze beginning at 100 feet below a cumulus base which helps glider pilots identify a young cloud would be no lower than 98%.

A liquid-droplet cloud with dense portions and sharp outlines may be taken to indicate a relative humidity slightly in excess of 100%. This is not only because the cloud droplets tend to evaporate faster than a flat water surface which is the basis for humidity tables (the droplets are exposed to air in all directions), but also because condensation must lag slightly behind the rapid cooling in the strong convection responsible for such clouds. *Mammatus* clouds may also indicate supersaturation (at least the sharply-outlined and presumably liquid ones of low and middle levels) for unless there is such supersaturation or much condensed water present, the cloud would evaporate within the descending currents due to compressional heating.

A cloud of liquid droplets and ice crystals mixed will have a relative humidity below 100% with respect to the water droplets, which will therefore be evaporating; and above 100% with respect to ice crystals, which will therefore be growing. This is because liquid water evapo rates faster than ice at the same temperature. The specific humidity of the mixed cloud will be less than that of any cloud of liquid droplets at the same temperature. A cloud of ice crystals will be at 100% with respect to the ice but far from saturated with respect to water. At -30°C, for example, the relative humidity at saturation for ice will be but 75% with respect to a water surface. So, when snow falls through a cloud of liquid droplets this cloud rapidly disappears unless it is being actively formed. The equivalent of all the condensed water that has disappeared will have been frozen or sublimed on to the ice crystals and much of the previously uncondensed vapor will have sublimed as well.

The air in heavy showers of rain or snow is probably not usually saturated, for the rain or snow pushes air downward into altitudes where the pressure is greater, with consequent compressional rise in temperature in spite of the cooling of the air by conduction and evaporation from the precipitation. This descent of air thus continually tends to increase the moisture capacity of the space through which the rain or snow is falling, and probably keeps the relative humidity at times well below 100%. The common aerological indications of humidities under 100% in Ns may not be due to instrumental error. One of the characteristics of Ns, the "cloud" of falling rain or snow, is that it appears to be lighted from within---the light coming through more readily by virtue of the relative absence of small cloud particles.

A cloud of dust or smoke will probably have a humidity appreciably below 100%, though such clouds, when they have risen high, may become capped with a denser mass containing liquid droplets of water. Among the numerous published descriptions of cloud tops on smoke, particularly over fires, the outstanding account is that of the cloud over the 1923 Tokyo fire.

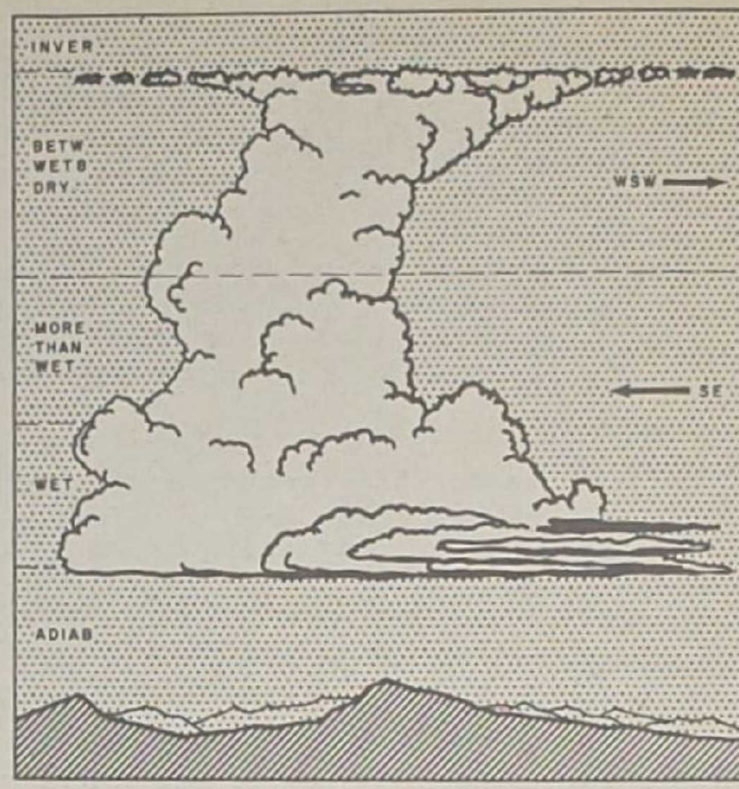
The humidity at clear levels may be surmised in some cases. For instance, when Cu clouds are forming it is easy to interpolate relative humidity values between the surface and the cloud base. Moreover, Deppermann has shown that Cu bases are convex or concave downward when the lapse-rates of relative humidity are respectively less or greater than that in adiabatically ascending air.

When *pileus* are forming the humidity at their level must be high, especially so if a rising Cumulus dome reaches it or if the size of such a *pileus* is greater than usual. If the humidity is nearly 100%, a very small vertical disturbance may form lenticular clouds. The absence of such lenticulars, on the other hand, is evidence of rather low humidities at 1, 2, or even 3 km.

The height at which Altocumulus bases form above a wind boundary will give some indication of the humidity of the under current.

If a cloud has been observed to evaporate at a certain level, the presumption is justified, for a few hours at least, that the air there has a high relative humidity.

The very presence of a sheet cloud may be indicative of a turbulent layer, for the high humidity shown by the clouds may be due to mixture on the interface between two winds of differing temperature yet high relative humidity.



Cloud View (Schematic) from Lanconia, N.H. seen at 1800 L.S.T. on 27 May 1938.

This example shows how differences in lapse rate may be surmised from variations in the shape of a Cumulus cloud. Four distinct divisions in vertical development may be noted: (1) At the lowest level, a broad puffiness shows a lapse rate that is no greater than the wet adiabatic. (2) Immediately above this, however, the cloud has begun a vigorous growth upward and a rate exceeding the wet adiabatic lapse may be expected. (3) Above the wind boundary the cloud, now in a narrow column, seems to indicate an even steeper lapse rate. (4) A very sharp inversion is then met, made evident by flattening of the Cu top into Ac fragments.

CLOUD SHAPE AND LAPSE RATES

The vertical characteristics of a cloud (thickness, form, and rate of growth) are controlled largely by the steepness of lapse rates of the surrounding air---steep rates favor the formation of *cumulo-* and *cirro-* forms and stable lapse rates favoring the *strato-* forms. In general the taller the cloud in proportion to its width, the greater is the lapse rate. A flat, smooth cloud (Fig. 30) has a lapse rate of less than the wet adiabatic.

The flatter the cloud top, the smaller must be the lapse rate above the cloud. In fact, the flattened tops of clouds are usually appreciably cooler than the air immediately above them. The lower temperature may be due to the inertia of convection having carried the top too high, and in part to evaporation and radiation. The low temperatures of the outer surfaces of Cumulus has been explained more recently by the frictional involvement and forced ascent of cooler air surrounding the warmer convective column.

A detached lumpy cloud with a flat base and rounded top has a dry adiabatic lapse rate below, a wet adiabatic rate inside, and a rate in excess of the wet adiabatic outside extending nearly to the maximum height that the cloud will reach.

A tall, sharply-defined, cumuliform cloud tells by the variation in its diameter at different heights the relative steepness of the lapse rate (except of course when there is a considerable wind shear). The narrower such a cloud is relative to its height, the greater is the lapse rate in the surrounding air. If the lapse rate is steep through a considerable depth of cloud and if there is a layer of stability within reach, the top of the cloud will go beyond its level of equilibrium (humps in Fig. 64)---but only to fall back, spreading out into a *mammatus* sheet.

Cumuliform clouds that are more or less attached by a basal cloud sheet are not usually indicative of the presence of adiabatic lapse rates below them. Their formation and growth have been rendered possible only by the previous formation of a *sheet* of cloud in air having a lapse rate somewhat greater than the wet adiabatic without the necessity of convective currents from the ground up to the cloud layer. Such a basal cloud sheet is likely to have a partly *mammatus* character where downward thrusts of the convective circulation within the cumuliform masses have put dents in the lower surface. If these descending eddies are dry enough, they may blow round holes in the basal sheet---even to the extent of leaving the basal cloud in patches.

Warm-front *mammatus* usually indicates an inversion at or near its level. If this cloud is surmounted by cumuliform outgrowths, the lapse rate above must be greater than the wet adiabatic; if it does not have these rounded tops, the lapse rate must be less than the wet adiabatic.

CLOUDS PRODUCE INSTABILITY

Within clouds of falling rain or snow lapse rates tend toward isothermalcy because the lower parts of the cloud are cooled by evaporation and some conduction. Immediately below such clouds, however, the lapse rates tend toward the adiabatic because of the cooling above. So, when cirrus clouds are drifting in, one may safely assume falling temperatures aloft and a steepening of the lapse rate at the snow's lower limit.

Then it follows that the forward moving, overflow cloud of a thunderstorm is an important factor in propagating strong convection ahead of the storm. The falling crystals of ice from this cirrus cool the air. although they may become entirely evaporated at a level far above the reach of diurnal cumulus clouds. However, as the cyclonic center or the belt where thunderstorms are forming approaches, the evaporating Cumulonimbus tops arrive denser and their snow falls lower.

Then one day near noon some Cumulus tops reach the cool ayer, mount suddenly, and become detached from the rest of the cloud to which they belonged. The liquid portions disappear quickly, leaving a columnar smirch for a few minutes longer. During the early afternoon, the stronger cumulus-topped columns of heated air that rise from the surface begin to arrive in considerable volume at the base of the cool layer. The inevitable result is the production of local thunderstorms, which in turn send their snowing, air-cooling tops to leeward.

The level of the 0° C. isothermal surface may be marked by the ragged, melting lower ends of cirrus streamers or by a ragged cloud which gives a lurid red or orange glow at sunset or sunrise. The height at which Cirrus streamers disappear will actually be a few hundred meters below the level of freezing because the melting of snow is not instantaneous. The lower end of cirrus fall-stripes is most frequently found at the 2°C. level---normally 300 m. below the freezing level.

CLOUD FORMS IN WIND STREAMS

Progressive motion of a cloud, turbulence on its periphery, and deviations of tall clouds from the vertical indicate actual and relative winds aloft. Clouds are composed of individual particles without mutual attraction, and as such are free to move with the wind current in which they are embedded. The direction and speed of the winds aloft at any height at which clouds can be seen is then indicated.

When a cloud goes from one air current to another, turbulent curls or frayings all pointing in the same line (Fig. 1) indicate the direction of the stream just entered relative to the current the cloud has just left.

Turbulent motions in clouds must be interpreted according to the distance from the observer. For example, actual movement may be discerned in a Fc cloud, while great turbulence in a Ci cloud may hardky be visible as motion. Shapes of details (Fig. 44) and the length of time that any definite point or line lasts defines the amount of turbulence in very distant clouds

When cumuliform clouds lean (Figs. 1, 4, 5, 6 lower, 8 upper right, 10, 37, 38, 65, 66) or Cirrus trails depart from the vertical (Figs. 41, 45, 46, 52), it is obvious that the wind at one height in the cloud is not the same as that at another height. In a rapidly growing cloud, the amount of deviation from the vertical is the resultant of the vertical velocity of cloud particles and the rate of change of wind velocity with height. Thus a cloud passing from one wind current to another will lean at a 45 degree angle when the resultant velocity of the two winds is equivalent to the vertical velocity of the cloud particles. In other words, clouds make visible the streamlines of the air currents in which they are carried.

Making the assumptions of a continuous wind shear and a constant ascent rate, the "lean of a cloud will be curved: convex upward for a convective cloud and convex downward with a descending cloud (the characteristic curl of Cirrus, Fig. 45). Conversely, when young clouds of uniform rate of growth are straight, a uniformity of velocity at all levels pierced by the clouds may be inferred. According to the geostrophic relation, the decrease of density with height combined with this condition of constant velocity defines a situation where the horizontal pressure gradient must decrease with height in the line of sight.

When a uniformly-growing Cu bends backward in its higher portions (Fig. 4, 2nd cloud from right) there is a strongly decreasing pressure gradient with increase of height. When a Ci becomes more vertical or points its lower end downstream, the pressure gradient at the top must be very much less than at the bottom.

Let us examine now the effect of our artificial assumption of a constant ascent or descent rate. Actually the Cu or the Ci usually rises more slowly near the top because the cloud's upper limit is often determined by a stable layer. Ci particles similarly fall more slowly as they reach lower, warmer layers because they have become smaller through evaporation. These facts magnify the apparent increase of velocity with height. Then when wind velocity appears to *decrease* with height, the observer can be sure that questions of ascent rate do not confuse appearances and pressure gradients are actually less at higher elevations.

RESEARCH AT ASHEVILLE

By Captain Paul Worthman
Wing Station Weather Officer

How close are personnel of the Weather Wing to the daily routine of forecasting and the problems of weather station operation?

A good answer would be that this headquarters *is* a weather station in one of its phases. A complement of weathermen assigned to regular type "B" duties provides a 24-hour forecasting service in the Wing Station as a background for many important special activities. For example, forecasting procedures which are contemplated for general station use are given laboratory examination under close supervision of the Technical Advisor: the daily staff meeting is briefed on the synoptic situation; various routines and mechanical aids to assist in effective briefing are given careful evaluation.

All headquarters meteorologists, no matter what their duty assignment in the Weather Wing's complex structure, analyze the daily synoptic surface map. The latest sequences, upper air data, and an official surface map analysis as displayed in the Wing Station are put to good use by this wealth of forecasting talent.

When concern is felt about the value of a novel forecasting method under press of actual weather station operation, the project is investigated at the Wing Station. Ideas that are now being weighed in this manner include:

a. The most advantageous methods of conveying meteorological data to pilots, involving map, chart, and sequence displays as well as novel ideas for functional furniture. The *Weather Service Bulletin* front cover for March shows an example of this experimental equipment.

b. Briefing methods now in use to determine the most choice devices for specific audiences and situations. Special attention is given to methods of exhibiting data at briefing sessions.

c. Construction of a "briefing" map which utilizes hourly sequences to show instantaneous weather conditions within 800 miles of the station.

d. Construction of large-scale cross-sectional charts under *Plexiglas* showing features of special interst to pilots. Study of the feasibility of maintaining current cross-sections corrected every two hours.

e. Upper-air isallobaric patterns are being correlated for forecasting value with surface *summer* maps.

f. Construction of a 24-hour prognostic 10,000-foot map; determination of the value of such maps to the field forecaster under standard field conditions.

g. Analysis of reports received from upper-air sounding stations to establish the average number that is received, the average height limit, the percentage of stations each day for which the second transmission is not received, and the average number of radiosonde reports at each of the 10, 13, and 16 Km. levels.

h. Investigation of equivalent potential temperature properties at the 10,000 foot level in an effort to determine the value of this variable in thunderstorm forecasting.

i. The 465 mb. (20,000 foot) map of altimeter correction is regularly analyzed to evaluate a reported relationship to isolated, nocturnal thunderstorms.

C-54 WEATHER OBS

FLYING THE NORTH ATLANTIC

By Lt. R. B. Doremus and Lt. H. W. Mueller

British civilians are impressed by the stupendous stockpiles of war equipment that have been piled up in their sturdy little island as invasion supplies. One Englishwoman employed by the Barrage Balloon Command, for example, discovered a new significance for her job:

'If they took the balloons down, England would sink!'

The Air Transport Command was hard at work in the late summer of 1943 to overbalance the Islands' buoyancy, but more and more under the looming shadow of the North Atlantic Winter. The consensus was that winter flying along the Northwest Route would be precarious if not impossible, but little exact information about weather hazards was at hand to assist the planning boards to give answers to these queries:

Could long-range cargo aircraft be operated in winter over existing routes? Would such operation be justified by the useful cargo that could be safely carried and the time involved? What flight techniques, special equipment, and new instruments would be desirable? How could weather reports from land stations and post-trip discussions be supplemented to provide the necessary detailed information about winter's intense and dangerous cyclones?

The operation of three long-range, transport aircraft on tranoceanic observation duty as 'weather ships' began at the close of 1943 to investigate these problems. An aerograph, a psychrometer, and an absolute altimeter supplemented the planes' customary weather instruments. American Airlines, TWA, and the ATC's North Atlantic Wing each assigned a C-54 to collect meteorological and operational data on cargo-carrying runs. The 8th Weather Squadron provided six weather officers to pair off with each plane.

The idea of North Atlantic weather reconnaissance was not new. The 30th Weather Reconnaissance Squadron had pioneered such work on the Route's shorter legs, but the Squadron's shorter-range planes were considered more suitable for operation in the tropical South Atlantic during the winter.

The three transport *weather ships* flew a total of 584 hours of weather exploration and passed through 46 fronts in the first three months of 1944. The length of a continuous flight leg was sometimes as much as 17 hours and several landings had to be accomplished in 55-mile winds and under 400 foot ceilings after bucking trip winds of 110 mph. There were occasional delays and re-routings of cargo aircraft because of weather, but it was shown that experienced pilots with suitable planes could overcome the North Atlantic's winter fury.

The *weather ships* were much more than guinea pigs proving that the route was flyable; they were also reporters and agents of research. The observers kept careful statistics on the amount of cloud cover to to be expected at various levels, the frequency of turbulence, the severity and duration of icing, and the percentage of time during which navigational observation of surface and sky is possible. This experience showed how useful an aerograph could be for analyzing the changes in air mass encountered in horizontal flight in addition to its known function of taking APOBS.

Hourly in-flight reports by radio, complete with 10,000 foot pressures and accurate wind information, gave tangible and immediate aid to terminal forecasters. A forecaster's judgment and undivided attention lent reliability to the radioed statements of frontal locations and activity, the height of cloud tops, and the prevalence of icing---such facts as these were of direct air in routing other cargo planes, in dispatching ferry flights of tactical aircraft, and in forecasting weather.

Aerial Observations

Hours of darkness are many when winter rules the North Atlantic, requiring an intent and prolonged peering through a plane window before cloud data can be recorded. The absence of stars is conclusive evidence of an overcast, but the presence of clouds surrounding the plane must be detected by watching for the glow of a wing tip light among the water droplets. Snow will give a similar effect and can only be identified by use of the landing lights or the Aldis lamp (manual signalling lantern). The height of cloud tops below a plane at night can be gauged by the speed with which shadowy areas appear to pass below the plane.

Weather ship observers using the pressure altimeter and the absolute altimeter in combination, can compute drifts by the Bellamy method, otherwise known as the 'D System of Weather Navigation'. First the pressure altimeter is used by the pilot to fly the ship along an isobaric surface. Then variations in the absolute altitude over a fixed length of time give the slope of the isobar which is being flown. Finally, the theoretical relation which gives the component of the wind perpendicular to an isobar in terms of its slope can be used to compute drift.

The method is complicated by the fact that absolute altimeters are difficult to read closely, that pressure altimeters must be tapped before each reading to overcome frictional lag, and that the altitude of a plane in flight generally varies slightly from moment to moment. Obtaining representative, simultaneous readings obviously is difficult.

Psychrometer readings are an old story with only a little twist of novelty, but nonetheless time-consuming. Thermometers are withdrawn from mounts, one bulb wetted with distilled water, and replaced to await equilibrium before the reading is taken.

The observer then glances at the aerograph to note any significant changes that may have occurred in the traces---hoping that this is not the moment when it will be necessary to change the trace sheet, blot the lines with a dampened blotter to keep them from smearing (since they take several hours to dry normally), and refill the pens one drop at a time with a small metal dropper. He then turns to ask the navigator for the position of the aircraft at the time of observation, but may find that the navigator is industriously working out a celestial fix and cannot yet give a position. The observer's alternative is to encode his report (which has as many as 15 five-digit groups), putting in the position at the last moment. He enciphers it and makes a fair copy for the radio operator. By that time it is necessary to start another observation, for obs must be taken frequently even though they are broadcast only once an hour; the cloud coverage has probably changed, and the cycle begins again.

The observer's life is not one of steady routine, however. He eats meals whenever the plane lands---two breakfasts, perhaps, and lunch at midnight. He may be weathered along the route for hours and find time heavy on his hands or he may circle the North Atlantic for 40 hours without sleep.

Perhaps it is just as well that North Atlantic weather observers have their hands full picking up and transmitting weather information without a chance to think about the safety of their plane; one spent an idle few minutes watching the refueling of his C-54 after a transocean hop---he saw 250 gallons poured into the tank and then, curious about the reserve with which the landfall had been made, measured just 250 gallons in the tank!

NORTH ATLANTIC FORECASTS

By Lts. Albert Badanes and Holt Ashley

Real forecasting experience comes with the checking of predictions against the weather that actually develops. It is serious then that forecasts made from land stations for trans-oceanic routes suffer from a partial lack of positive verifications.

To meet this need, six weather officers flew a total of 200,000 miles over the ocean between North America and the United Kingdom in C-54 *weather ships*, investigating the relation of actual to forecast weather patterns. The summary of their observations which follows introduces a quantitative analysis of North Atlantic flying weather that is one of the few reliable evaluations of this region's climate aloft for the January-March period.

In general, weather was observed to be less formidable than forecast, although nothing in this report should be construed as an attempt to minimize weather hazards over the North Atlantic. The hazard is there, but none of the *weather ship* flights had to be rerouted because of trip weather alone. Several reasons accounted for this record: the crews were skilled and experienced, the position and intensity of storms were forecast accurately, and the C-54 is a very flyable craft.

Forecasting the weather to be met on a trans-Atlantic hop is certainly important, but transoceanic flights in modern, four engine, non-combatant aircraft are more immediately dependent for survival on accurate forecasts of the winds at flight level. One plane which had set out for the United Kingdom was forced down at an alternate airport without fuel after 16 hours of flight---short of its goal because of an inaccurate wind forecast.

CLEARANCE THROUGH FRONTS

Weather ship flights investigated the possibility of traversing fronts in a clear layer *between* low-cloud and middle-cloud decks. The tables below show that 85% of the weaker fronts encountered could be penetrated or topped in the clear at a mean height near 10,000 feet. The appropriate choice of altitude for 'sandwiched flight' varies with the type of front as shown:

COLD FRONTS

	Total Encountered	Stronger	Weaker
Total	40	18(45%)	22(55%)
Number with clear layers between cloud decks.	21(52%)	8	13
Average tops of lower clouds in ft.		11,100	8570
Average base of higher clouds in ft.		14,500	12,200
Zone A (5^{o}-35^{o}W. Long.)	17	8	9
Zone B (35^{o}-60^{o}W. Long.)	23	10	13

OCCLUDED FRONTS

	Total Encountered	Stronger	Weaker
Total	37	23(62%)	14(38%)
Number with clear layers between cloud decks.	19(51%)	7	12
Average tops of lower clouds in ft.		9580	9000
Average base of higher clouds in ft.		12,250	11,800

WARM FRONTS

	Total Encountered	Stronger	Weaker
Total	11	6	5
Number with clear layers between cloud decks	5		

Best flight level for weaker warm fronts 9,000 ft.	Best flight level for strong warm fronts 12,000 ft.

Classification of the fronts encountered as 'stronger' or 'weaker' was based on the following criteria:

1. The size, classification, continuity and activity of cloud structures.
2. Stability and magnitude of the temperature discontinuity between airmasses.
3. Indications from the surface map: pressure gradients, wind shift, temperature difference, and so on.
4. Upper-air data: Position of related low aloft, vorticity over the surface front, etc.

A separate consideration was made of fronts which were found east and those found west of 35^{o} West Longitude. The study revealed that occluded and cold fronts are generally more intense in the eastern section, for there the fronts were found to have cloud systems reaching higher levels and covering greater areas. Also, swelling cumulus observed during polar outbreaks attains greater heights east of 35^{o} W.

One explanation may be that fronts move under the semi-permanent, cold-core Icelandic Low as they pass this line and deepen in association with the cyclonic vorticity aloft. Then too, the sea-surface isotherm pattern for this period (January to March 1944) shows the Gulf Stream's warm current extending northward in the eastern section while the cold Labrador Current is shown to influence the western part. (The flying routes are north of the region south of Newfoundland that is influenced by the Gulf Stream.)

FORECASTING THE LEVEL

The above tables and similar, more detailed studies demonstrate that aircraft may often fly in the clear through any front except a strong occlusion. The best method of flying most systems seems to be one of seeking a flight level in the clear between cloud levels; that is, within a forecast zone three or four thousand feet thick. It is difficult to forecast the exact level of this clear path.

a. 86% of all weaker occluded fronts encountered on these flights could be topped or traversed completely in the clear by flying somewhere between 9,000 and 12,000 feet.

b. 17 out of 22, or 77% of all weaker cold fronts could be topped or traversed between 8,500 and 12,000 feet.

c. 11 out of 18, or 61% of all stronger cold fronts could be topped or traversed between 11,000 and 14,500 feet.

d. All weaker warm fronts could be topped or traversed at 9,000 feet, and only two strong warm fronts were found that could not be topped at 15,000 feet.

e. However, only 4 out of 23, or 17%

of the stronger occlusions could be traversed in the clear within the 8,000 to 11,000 foot zone. Of the rest, 11 extended unbroken to 15,000 feet and above.

It appears that these levels could be recommended almost all of the time for flight through weaker fronts. Cloudiness would be at a minimum and icing would be light in the few cases when this blanket rule should be inapplicable. In the case of stronger fronts, particularly strong occlusions, other factors would enter: degree of severity of the front, type of aircraft, necessity of the flight, experience of the crew, navigating conditions. All these factors must be weighed and considered before recommending a flight level.

Although it is obviously easier to recommend a flight zone (layer) of 3000-4000 feet rather than a particular altitude, it is nevertheless often necessary to decide upon an altitude for the recommended flight level. Following are single optimum flight levels:

	Between layers in the clear	Feet
Weaker occlusions:	50% " "	10,000
Stronger "	19% " "	12,000
Weaker Cold fronts:	64% " "	10,000
Stronger " "	50% " "	13,000
Weaker warm "	100% " "	9,000
Stronger " "	3 of 6 " "	12,000

4 of 6 could be topped at 15,000 ft.

NON-FRONTAL CUMULUS

A related study made on non-frontal cumulus formed by the instability of cold arctic outbreaks advancing over the relatively warm ocean during January, February, and March showed that the maximum height of cloud tops between Greenland and the United Kingdom was 18,000 feet; only two cases were reported higher than 16,000 feet in the absence of fronts. Maximum height noted between Greenland and North America was 14,000 feet; only one case was reported at a higher figure than 12,000 feet. Observation of these clouds suggests a study of the correlation existing between the free air temperature of the cold outbreak and the height of the cumulus. An attempt at such a study will be made at a later date.

THUNDERSTORMS

Three cases of thunderstorms were reported by the observers. A line of thunderheads was seen in connection with warm frontal overrunning just west of Scotland on 25 January. An isolated storm was sighted on 16 February. A flight eastward from Newfoundland passed through a cold frontal thunderstorm on 5 March, encountering moderate clear ice and moderate to severe turbulence. These three cases were the only thunderstorms reported during the period.

ICING ON AIRCRAFT

The *weather ships* recorded 112 instances of icing despite a careful choice of route and flight altitudes to avoid clouds. Light rime which did not interfere with performance or require removal with de-icing boots was experienced in 77 of the icing cases. The remaining 35 examples, however, meant the deposit of light and moderate glaze and moderate rime, affecting performance of the aircraft (air speed reductions) necessitating the use of mechanical de-icing equipment.

Heavy glaze was deposited twice, both times within occluded systems: one in the warm air being lifted above the warm front and the other in freezing rain below the occluded warm air. In the first case, the cloud deck was successfully topped by a climb from 7,000 to 12,000 feet; in the second case the plane was let down to a level of above-freezing temperatures below the ceiling. On one occasion the radio altimeter stopped working, supposedly because the antenna was iced. Flight in warm air restored the radio altimeter to satisfactory operation.

Most of the moderate icing was experienced in connection with occlusions, warm front activity, and southerly air currents. Although a few cases of moderate rime and clear ice were found in non-frontal cumulus, this source did not produce nearly as high an icing rate or so many cases as had been anticipated in forecasts.

In-flight observations by experienced weather reconnaissance officers making in-flight observations drew cross-sectional diagrams of conditions on 113 legs of the trans-Atlantic routes. A compilation of the data for levels between 5,000 and 15,000 feet shows that unsuitable flying weather generally decreases with greater altitude of the flight route:

Level (ft)	5,000	8,000	10,000	12,000	15,000
Time in cloud	60%	33%	24%	17%	12%
Time when celestial navigation possible	24%	46%	60%	70%	83%
Time in icing	42%	27%	19%	13%	4%
Time in precipitation	36%	22%	14%	11%	3%

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MICROANALYSIS

by CAPT. REID BRYSON & LT. PHILLIP W. ALLEN

Weather forecasting for military air operations in the tropics is complicated by the fact that local and diurnal effects have the same weight as synoptic changes. Furthermore, spot forecasts for landing strips or targets on small, isolated islands are regularly required. Aircraft must often operate at their extremes of range without the fuel to compensate for the time and space inaccuracies of the familiar large-scale analysis. Therefore, special techniques, under the descriptive title of *Microanalysis,* have been developed to delineate the structure of tropical weather in detail.

WEATHER DISTRIBUTION CHART

(figure 1), is useful when accurate and detailed information is needed for a small area. Reports from individual stations in the tropics are seldom representative of conditions over the sea nearby, indicating use for this chart as a supplement to the synoptic map. Aircraft, naval, and representative land reports may be used, but the most serviceable information for the Weather Distribution Chart has been derived from postflight interrogation of patrol aircraft crews (over and above that which appears on the aircraft weather reporting form).

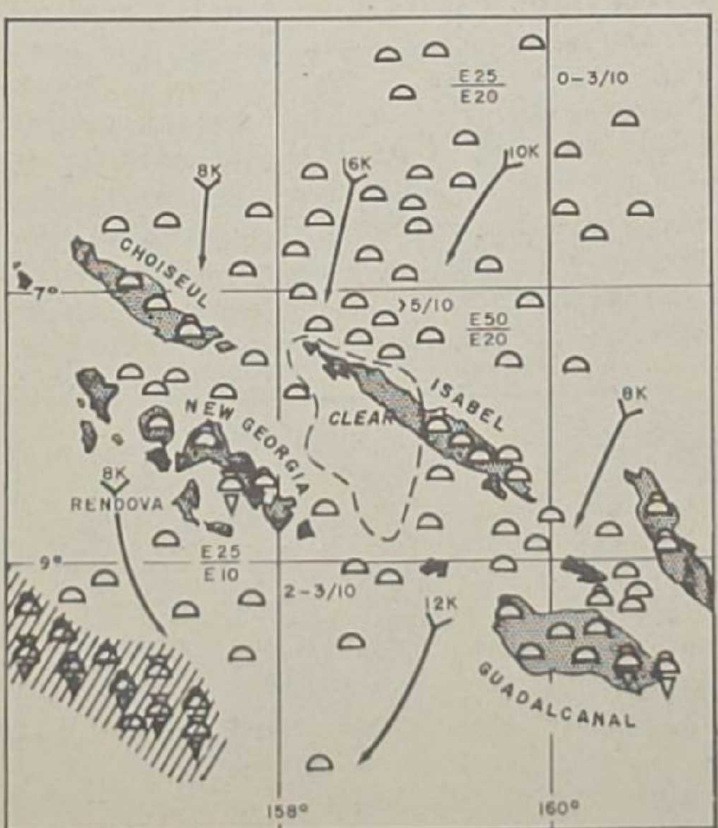


Figure 1

The diagram discussed is drawn on a large-scale map (about one degree of latitude per inch) so that an individual cumulonimbus may be entered in its exact position. Smaller clouds are entered as scattered symbols, proportional in number and size to the sky cover and cloud size. Cloud tops and bottoms are entered as a ratio in the given order.

The weather distribution chart has the advantage of being a plain, yet detailed, statement of current weather. A few simple ideas which may be used as a nucleus for building a specialized forecasting technique are set forth here:

a. A streamline chart prepared on the same scale as the distribution diagram from many wind reports (isobars do not represent streamlines in low latitudes) is effective for demonstrations of divergence and convergence. Intense convective activity is associated with the disappearance of streamlines while regions of clear weather may often coincide with appearing streamlines in the lower atmosphere.

b. Positions of clouds or cloud systems may be forecast successfully for short periods (6 to 8 hours) by extrapolating their past motions, *with due consideration* for their diurnal trends. Rapidly building clouds move more slowly than the general air stream; and of course winds tend to blow through orographic clouds---at least until rain begins to fall.

c. The movement and intensity of large convective systems formed on the line of convergence between two major wind streams is a function of the vector difference length and the velocity component normal to the convergence line.

d. Stability analysis and topographic condiserations inform about the development of a cloud system. (See "Clouds in Aerology" on page 15)

A prognostic weather distribution chart has far more meaning to a pilot than the same forecast in writing. Furthermore, it can be more detailed than any verbal forecast of reasonable length.

A modification of this diagram has proven useful in the Panama Canal area where aircraft and surface observations of shower clouds are plotted on a large map covered by transparent plastic. Successive positions of the showers, their state of development, and their movement are quite accurately forecast for limited periods by this means. Rain occurrence at a given landing strip has been predicted to within a few minutes as much as six hours in advance.

Flight cross-Section is a sketch of the vertical distribution of clouds and weather along the track of an aircraft drawn while in flight. In the microanalytic use of this diagram, the principle of careful and detailed entry of information is stressed.

STATION CIRCLE REPORTS: Where the weather at a particular point is greatly affected by the surrounding sea and land masses---and therefore forecasts from even the Weather Distribution Chart are not detailed enough---the *station circle* has been used to record the location of weather with respect to these features. It outlines the circle of vision from the station, showing prominent topographic reference points and including the prominent features of weather within sight.

Since the direction of cloud motion is of major importance is using this form for forecasting purposes, extreme care must be taken to obtain the correct vector. It should be possible to trace the path of each prominent cloud or shower across the sky from the time of appearance on the periphery until its disappearance from view. Such minute plotting requires observation at fifteen minute intervals, or at least every half-hour. For a series of six such observations see figure 2.

TIME SECTIONS are graphs of various elements with time as abscissa, and height or the element as ordinate: synoptic trends and the diurnal influence become evident with this treatment.

1. Time graphs of temperature and dewpoint are of little value in the tropics where synoptic variations are minor compared to diurnal effects.

2. Pressure trends must be shown by time graphs of points at 24 hour intervals to avoid the masking effect of diurnal changes.

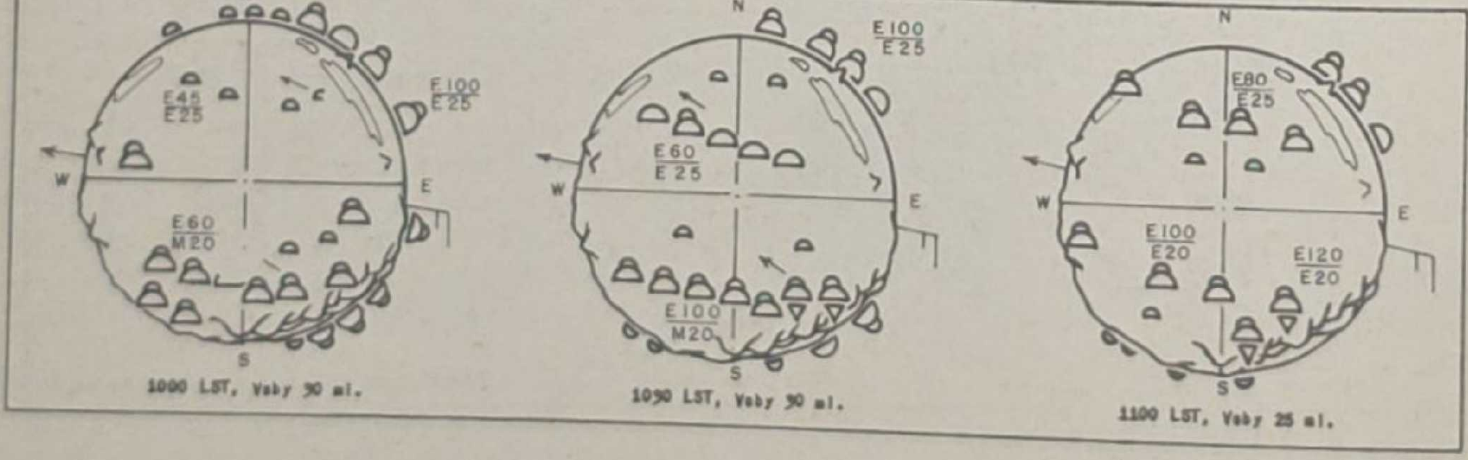
3. Height of the moist layer, a key to the depth of convection liable to take place, is a significant quantity. The height may be arbitrarily taken at the point where the relative humidity drops below 30% say, or where the specific humidity drops sharply.

4. The altimeter correction is the difference between the true height of a pressure value and the standard atmosphere height for that value. Isopleths of this quantity have many valuable properties which have been described by Bellamy in Weather Division Report Number 708, "Determination of Absolute Height and Wind...", a copy of which is available in all weather stations. For example, centers of high positive values of altimeter correction on a height-time chart are also centers of high pressure relative to their surroundings. Also, the gradient of this quantity along the line of flight determines the component of the cross wind.

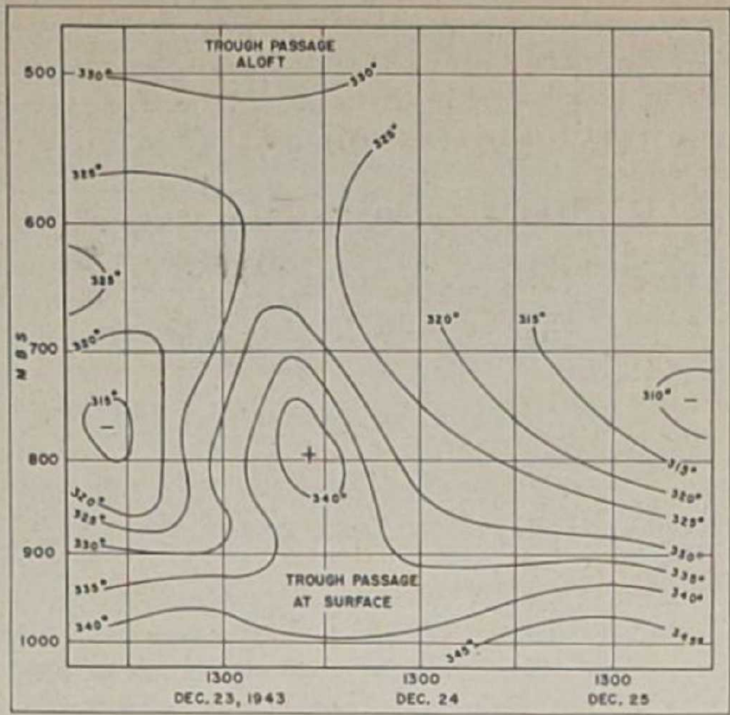
5. A time section of the winds is almost a necessity in tropical regions where it is of great importance to record variations in the base of the westerlies.

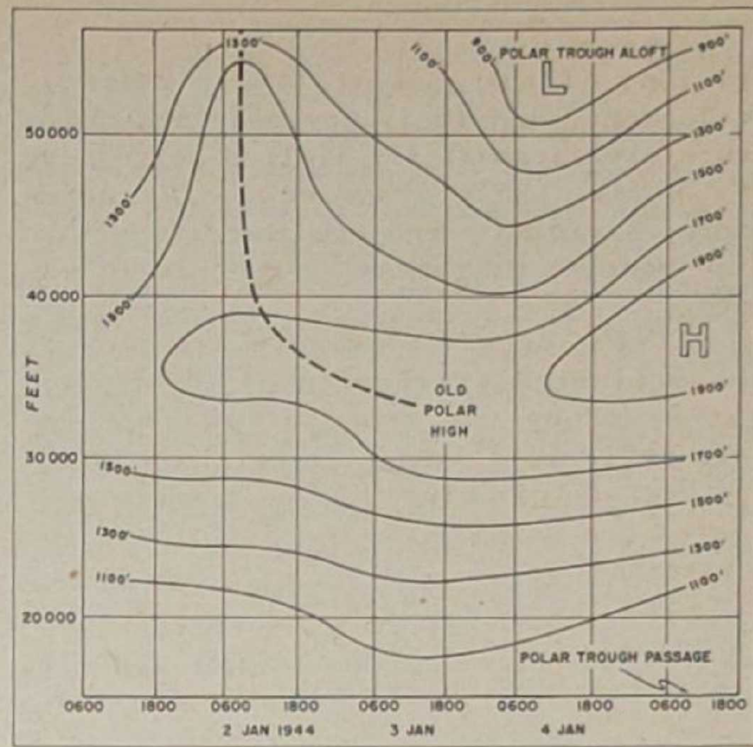
6. Isopleths of equivalent potential temperature (with consideration of the height of the moist layer) are the best means for following variations in the moisture content of the lower troposphere.

Application of the time section to forecasting requires particular evaluation of the geographic location of the station and the season. For example, general steering in the Antilles during summer is from the east, indicating a combination of changes due to advection and local effects. However, the weather at a station may be tempered by its leeward or windward position without showing the expected changes. In winter, forecasting in the Antilles is



1000 LST, Vsby 30 mi. 1030 LST, Vsby 30 mi. 1100 LST, Vsby 25 mi.





This *Time Section* shows the distribution of equivalent potential temperature above a single station. In the interval shown, strong mixing before a polar trough passage is indicated.

***Altimeter Correction* is the quantity plotted on this Time Section from single station data. Notice that these polar highs and lows have distinctive patterns in the higher troposphere only.**

hampered by indeterminacy of the steering; easterly steering gives way quickly and often to westerly.

Aircraft In-Flight Reports: Much weather data from aircraft is coded and transmitted by radio. Unfortunately, no code is quite satisfactory for the microanalytic approach, and such reports should never be used as a substitute for post-flight interrogation.

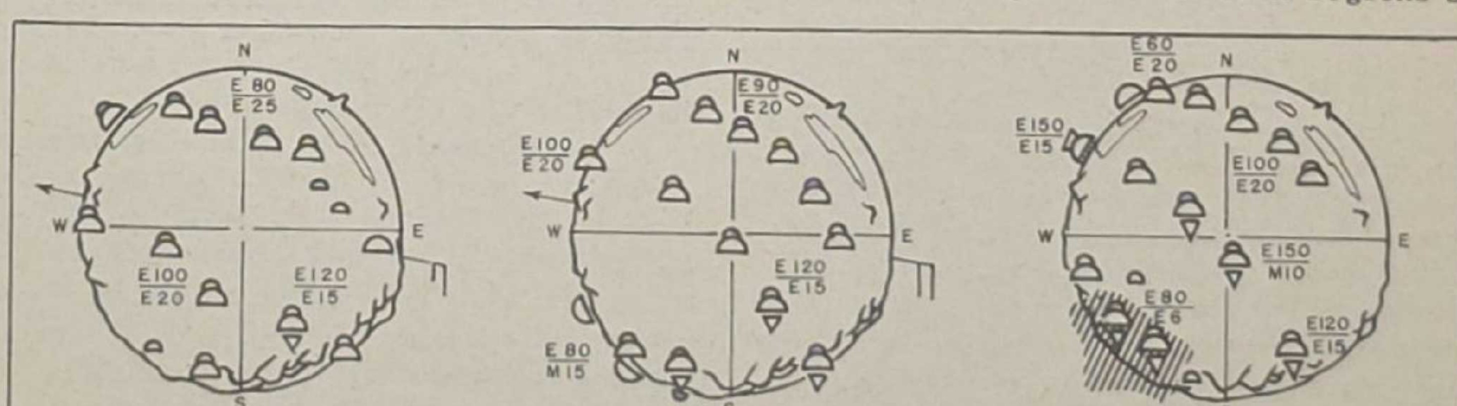
WEATHER DETAILS: In oceanic areas, moisture content of the air is high and convective instability common. Any mountain which approaches the height of the lifting condensation level then, will become a continuous point of formation of cumulus congestus or cumulonimbus if there is sufficient wind for the initial impulse. Clouds formed in this manner will obviously have lower bases than those formed by surface heating over the land.

Another reason for cloud formation on mountains is found in the application of diurnal heating at a lower pressure on a mountainside than the pressures at which the heating is applied nearby. A sounding which would damp out a certain amount of heating at a low level might produce mulus clouds if that insolation were introduced at higher levels.

With winds at cloud level of 15-20 knots, clouds tend to detach from peaks and move away in the wind stream. If sufficient energy has been imparted by the initial impulse, showers will continue to fall from the clouds.

Clouds moving from a warm land surface over a cooler ocean are often observed to dissolve at the shore, indicating convection over the land and subsidence at sea (streamlines disappearing over the land and appearing on the sea).

In dry, continental areas where both lifting and convective condensation levels are high, topography has much less effect. The cumulus bases are often above 10,000 ft. and most precipitation evaporates before reaching the ground. In such regions blow-



1130 LST. Vsby 25 mi. 1200 LST, Vsby 25 mi. 1230LST, Vsby 1 mi to S & W, 25 mi to N & E ing sand is a definite hazard, especially in its effect on the moving parts of aircraft. Only local study of the wind velocity and stability necessary across the particular surface to raise the small particles will produce forecasting results. Dust devils (rotation in either direction) are common but do not constitute a flying hazard.

Thunderstorms in such areas, called *haboobs* in the Sahara, may develop pseudo-cold fronts colored back or brown from dust or mud. If the amount of precipitation is sufficient to cool the air under the cumulonimbus strongly, and enough turbulence is present to make the air very dusty (yet not enough rain to wash the dust out), then a *haboob* may result. The cooled air containing the dust advances as a local cold front, often exhibiting a bulging nose. With the passage of the *haboob*, the wind shifts and the temperature drops abruptly, later rising to its original value.

Nocturnal radiation regularly forms a layer of cool air over land areas: this layer is at most a few hundred meters deep, but it acts very much like a cold high. As the cold air moves off shore in the late evening with the land breeze, it may form a miniature "cold front" with much convergence along its forward boundary.

As clouds build up at the line of convergence, they may extend into the undisturbed flow above the land breeze and drift off. Thus light showers which originate along such a discontinuity often drift over San Juan, P.R., after having been caught by the ENE Trades aloft. In the Gulf of Carpentaria, the morning sea breeze may have strong squalls along its forward edge, proceeding on shore very much like a true cold front.

The effect of local features on tropical weather is so profound that successful *Miscroanalysis* is largely dependent on special studies of the region. Certair elements have been found more important than others; suggested for primary determination are:

1. Direction and depth of land and sea breeze.
2. Stability conditions under which hills produce various sizes and types of clouds.
3. Lines of drift of showers and time of detachment from the formation point.
4. Local zones of convergence due to hills, sea breezes, etc. Forecasting accuracy depends upon the accuracy of observations with a true picture of the wind field a necessity. Aircraft observations offer the best means of obtaining the necessary wind and cloud data.

Fundamental to the microanalytic approach is specialization to fit the particular problem of the area. In the Panama region, for example, this problem is the defence of the Canal Zone where an emergency called by training or combat may demand that interceptor aircraft strike at maximum range. Effective use of fuel supply often determines the success of such a mission, requiring that terminals and objectives be so weather-free that delays or changes of plans at the last minute are unnecessary---in fact they may be impossible. Successful and detailed short-term forecasts have been achieved through *Microanalysis* for this and other notable military problems.

continued from page 22

The figures are percentages of the total flight time. There was no appreciable deviation from the three-month average in any one month.

LIMITATIONS OF THE STUDY

This entire discussion deals solely with the zone between 5,000 and 15,000 ft. because of the visual limits of aerial observations taken at an average altitude of 10,000 feet. The data included in this report was obtained on flyable days, and conclusions drawn are of conditions and routes which were selected as 'flyable.

There were only a few instances when deviations from the normal flight path were made to investigate special phenomena, so it may be said that the weather samples represent true random c hoices. The study is based on a fairly small number of flights, however. 40 round trips (120 legs that is) may not provide a large enough basis for general conclusions.

Furthermore, the data was taken in three months of *one year*. During the last half of the February in question, the normal westerly flow was interrupted by an extensive high located in the Faroe Island Greenland area associated with a negative zonal index and a minimum of cloudiness or weather. The persistence of such a high pressure cell is not likely to be an annual event.

THE TECHNICAL CONSULTANT TEAMS, seven in number, began their program of in station indoctrination on 5 July throughout the domestic regions -- somewhat later than indicated last month.

Each team of four officers operates under the supervision and guidance of the Regional Control Officer of the region to which the team is assigned. The R.C.O. or his representative will accompany the team to each station visited in order to supervise the program and to render necessary decisions on matters concerning regional policy which may be brought up during the seminars.

The purpose and organization of the Technical Consultant Teams were presented in 'Keeping the Pace' by Major C. L. Rawson in the Weather Service Bulletin for June 1944.

The agenda for Technical Consultations follows:

FIRST DAY

0830-0845:
Introduction by RCO
0845-0945:
Uses of mechanical aids
- a. Pressure-height computations
- b. Geostrophic-gradient wind computations
- c. Air particle trajectory computations

1000-1230:
Construction and analysis of 5,000, 10,000 and 20,000 ft. constant level maps.
- a. Station model
- b. Isobars, mean isotherms and isallobars
- c. Consistency checks of data
- d. Micro troughs
- e. Applications to forecasting
  - (1) Advection processes
  - (2) Convergence-divergence
  - (3) Steering effects
  - (4) Persistency patterns
  - (5) Warm and cold HIGHS and LOWS
  - (6) Upper wint-temperature forecasts

1230-1330:
Lunch
1330-1530:
Construction and analysis of 10 km., 13 km., and 16 km. maps
- a. Station model
- b. Consistency checks of data
- c. Limitations of data

1545-1700:
Construction and analysis of surface maps.
- a. Definition of front
- b. Air mass identification
- c. Use of PIREPS and spot weather reports.
- d. Consistency checks of data
- e. Isobaric analysis
- f. Analysis of non-frontal troughs
- g. Micro waves and incipient waves
- h. Consistency with upper air analysis
- i. Analysis of blank areas
- j. Moisture discontinuities
- k. Requirements for neatness and simplicity

SECOND DAY

0830-0930:
Construction and analysis of surface maps. (continued)
- k. Uses of canned analyses
- l. Uses of analogues
- m. Application of climatology to analysis
- n. Telephone conferences and continuity (RCO)

0930-1015:
Construction and uses of time cross-sections.
1030-1130:
Analysis of thermodynamic diagrams.
1130-1230:
Problems of mountain forecasting.
1230-1330:
Lunch
1330-1445:
Problems of thunderstorm forecasting.
1500-1600:
Problems of stratus forecasting.
1600-1700:
Local forecasting problems.

THIRD DAY

0830-1230:
Construction of prognostic 24-hour maps for surface and 10,000 ft. levels.
- a. Extrapolation
- b. Advection
- c. Steering
- d. Trajectories of particles
- e. Isallobaric relationships
- f. Analogues
- g. Climatology
- h. Empirical relationships

1230-1330:
Lunch
1330-1700
Analysis and prognosis of current situation.
- a. Surface, 5,000, 10,000, 20,000 ft., 10 km., 13 km., and 16 km. maps
- b. Stuve diagrams and Rossby diagrams analyzed in detail for selected stations.
- c. Prognostic 10,000 ft. map
- d. Prognostic surface map
- e. 24-hour and 48-hour forecast for local area

FOURTH DAY

0830-0930:
Post-mortem on previous day's forecast
0930-1130:
Content, order and wording of written forecasts
1100-1200)
:
1300-1400)
Construction and use of visual aids in weather briefing
1400-1630:
Seminar discussion of correct techniques of various types of weather briefing with special emphasis on briefing needs of stations represented.
1630-1730:
Briefing demonstration -- either synthetic or actual -- if actual briefing can be given it will be fitted in with schedule of using personnel.

YOUR FUTURE IN WEATHER

With the graduation of the 5 June class of cadets, the Weather Service will have 1,500 officers over authorized strength---and there is no alternative but to divert 1,500 of our commissioned personnel to other services. So it may be seen that this headquarters and its field authorities are profoundly concerned with matters of personnel evaluation in order to retain the weathermen deemed to be of most value to the Service.

The problem is complicated mainly because we cannot safely evaluate our men with an adding machine or a punch card system. The quantitative criteria of Short Range Verification and efficiency reports are significant of course, but other considerations must be of equal weight. Effort made toward developing technical proficiency and absorbing the refinements produced by research; efficiency in duties as a soldier; and a history of cooperation with base personnel and in base activities---all these factors will be given grave consideration in this classification.

The observer examination will not be used as a method of disrating in the forseeable future. If observers fail completely, naturally it will be a signal to make a more detailed examination of the failures, but the examination will be only one of the items used in evaluating personnel.

Particular attention is directed toward the men returned from overseas duty. The same principles of immediate value to the Service are to apply in their case within the statements outlined above. Transfer from a combat to a domestic theater does not lessen in any degree the responsibilities of an AAF weatherman.

If you believe in the Weather Service, you should be working to improve it: if you don't, you ought to get out---and I mean that seriously. There are extraordinary professional opportunities for enterprising men within our organization that are not to be wasted on the uncooperative or the unfit.

At the present time, leading civilian and military meteorologists are devoting important time and effort to the establishment of postwar positions for military weathermen through the agency of the American Meteorological Society. The A. M. S. is presently directing its publicity program toward industry; getting public utilities, construction companies, and fuel concerns for example to realize how individual meteorologists can be of use to them. The field is unlimited, and I can safely say that the men who justify the confidence of the Weather Service will not have anything to worry about as far as future opportunities are concerned.

Army weathermen are getting training that cannot be evaluated in terms of achievements in rank. Many had no vocation or job before they came into the service, but are now in a strong position with respect to the postwar world. Careful and sincere performance of duty will react in many ways to secure this alluring future.

(from a speech by Lt. Colonel T. R. Gillenwaters, Operations Chief, Headquarters Weather Wing, to Station Weather Officers of the 23rd Region.)

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WEATHER SERVICE UNITS

	Total		
REGIONAL CONTROL & SQUADRON HQ	18	THE REGIONAL CONTROL AND SQUADRON HEADQUARTERS HAVE A COMPLEMENT SUFFICIENT TO INSURE THE MAINTENANCE AND SUPERVISION OF TECHNICAL CONTROL WITHIN THE REGION AND TO GOVERN THE SQUADRON ACCORDING TO DIRECTIVES FROM HIGHER HEADQUARTERS.	COL. FC(A); MAJ. FC (×2); CAPT. FC; CAPT. (B); CAPT. (C); WO (D); WO (E); ★M/SGT. FC; 1 SGT (F); T/SGT. (G); ★T/SGT SC; S/SGT (H) (×2); S/SGT (I); SGT (G); ★SGT CK; ★CPL OB
A STATION	19	EQUIPPED AND STAFFED TO FURNISH COMPLETE 24-HOUR FORECASTING AND OBSERVING SERVICE AT THE PRINCIPAL A.R TERMINALS AND BASES. FUNCTIONS AS REPLACEMENT AND CONDITIONING POOL FOR REGION.	MAJ FC; CAPT FC; 1ST LT FC (×2); WO FC; ★M/SGT FC; ★T/SGT FC; S/SGT OB TD; ★S/SGT OB; ★SGT CK; ★SGT OB (×3); ★CPL OB (×6)
B STATION	10	EQUIPPED AND STAFFED TO FURNISH COMPLETE WEATHER FORECASTING SERVICE ONLY.	CAPT FC; 1ST LT FC; 2ND LT FC; ★M/SGT FC; ★T/SGT FC; S/SGT OB TD; ★SGT CK; ★SGT OB; ★CPL OB (×2)
C STATION	12	EQUIPPED AND STAFFED TO FURNISH *LIMITED* WEATHER FORECASTING AND COMPLETE WEATHER OBSERVING SERVICE.	1ST LT FC; 2ND LT FC; ★T/SGT SC; S/SGT OB TD; ★SGT OB (×2); ★CPL CK; CPL OB (×5)
D STATION	4	EQUIPPED AND STAFFED TO FURNISH COMPLETE WEATHER OBSERVING SERVICE ONLY.	★S/SGT OB; ★SGT OB (×3)
O SECTION	3	AUTHORIZED WHERE VOLUME OF ENCIPHERED WEATHER REPORTS TRANSMITTED AND RECEIVED REQUIRES ADDITIONAL QUALIFIED PERSONNEL.	★SGT OB; ★CPL OB (×2)
S SECTION	2	MAINTENANCE UNIT TRAINED AND EQUIPPED TO INSTALL AND MAINTAIN WEATHER EQUIPMENT.	S/SGT. ET; SGT. ET
R SECTION	3	A RADIOSONDE UNIT, EQUIPPED AND STAFFED TO OPERATE RADIOSONDE EQUIPMENT.	T/SGT RS; S/SGT RS (×2)
T SECTION	4	SUPPLY UNIT TO COORDINATE WEATHER STATION EQUIPMENT AND SUPPLIES. ONE SECTION AUTHORIZED EACH FOREIGN REGION.	S/SGT. I; SGT. I (×3)

LEGEND

- OFFICERS
- WARRANT OFFICERS
- ENLISTED MEN
- ★ may be filled by WAC Technicians.

FC WEATHER FORECASTER (8219) (787).
OB WEATHER OBSERVER (784).
CK ADMINISTRATIVE AND TECHNICAL CLERK (501). MUST BE QUALIFIED AS OBSERVER.
RS RADIOSONDE OPERATOR (942) MUST BE QUALIFIED AS OBSERVER.
SC WEATHER SECTION CHIEF (787).

OB/TP WEATHER OBSERVER - TELETYPEWRITER TECHNICIAN (790).
ET WEATHER EQUIPMENT TECHNICIAN (782).

(A) FLYING OFFICER
(B) COMMUNICATIONS
(C) ENGINEERING AND SURVEY; MUST BE QUALIFIED AS WEATHER EQUIPMENT TECHNICIAN (8205).

(D) AVIATION: WEATHER (9912).
(E) CLERICAL: GENERAL (9901).
(F) FIRST SERGEANT (581).
(G) ARMY AIRPLANE AND ENGINE MECHANIC (747).
(H) ADMINISTRATIVE NCO (502).
(I) TECHNICAL SUPPLY NCO, AAF (826).

To permit greater flexibility for the performance of assigned functions, it is authorixed to combine, as needed, any type station with any type section or sections. Addition of any one section to a station will increase the personnel of that station by the number in the added section.