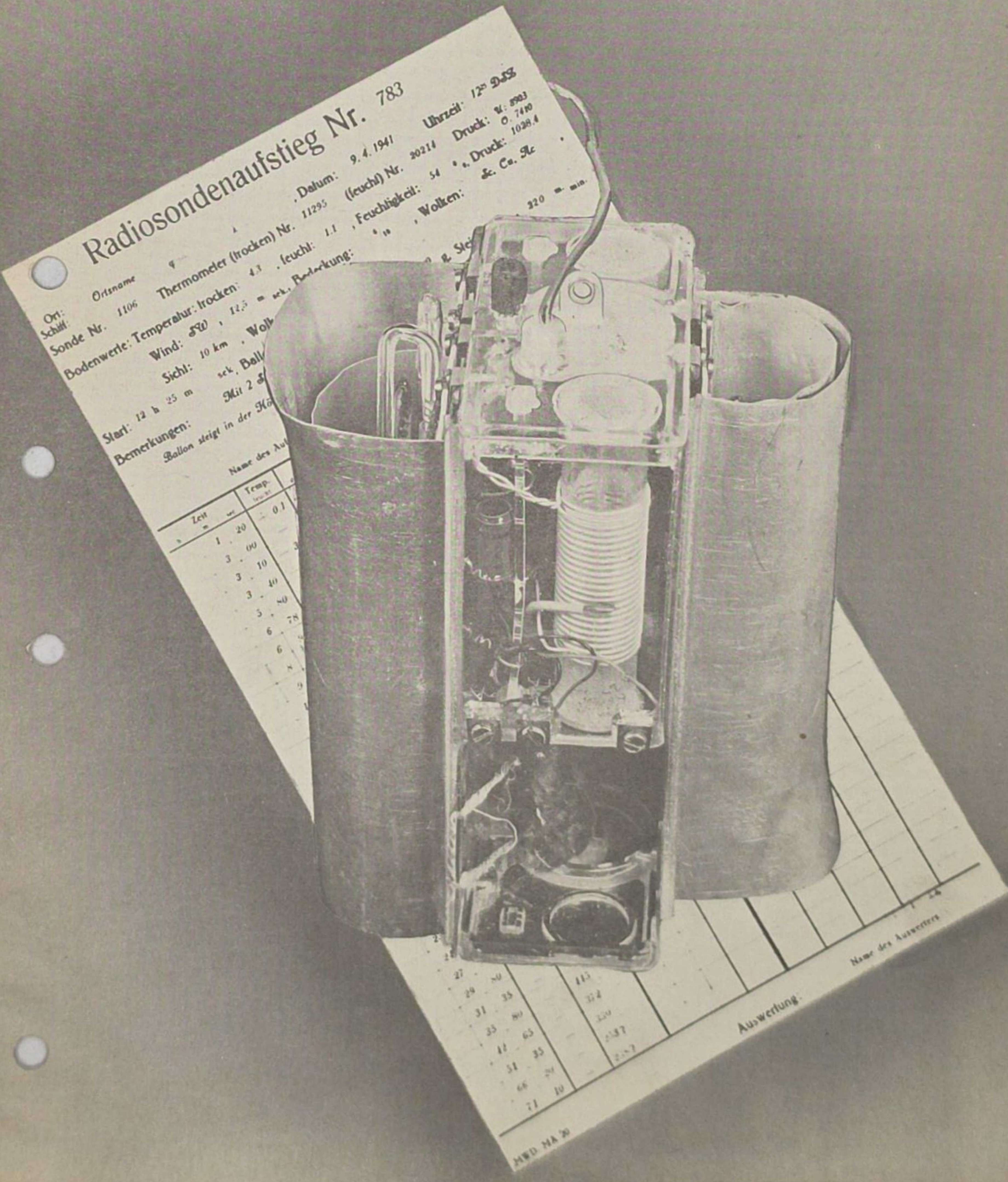
CT/OPN
TM SXN

RESTRICTED

# WEATHER SERVICE Bulletin

ARMY AIR FORCES HEADQUARTERS WEATHER WING
JANUARY 1945 ASHEVILLE, N.C. VOL. 3 NO. 1



## A CLASS FOR TEACHERS

*The Technical Consultant Teams assembled at Headquarters Weather Wing for two weeks of lectures, discussions, and study before their present (second) tour of the domestic Regions. Prominent meteorologists participated in this program: Dr. C-G. Rossby, Dr. H.C. Willett, Mr. L.L. Means, Lt. Colonel H.T. Harrison, CWO Andrew Weston, and others. One of its direct results was the formulation of decisions about several controversial topics, scientific or technical in nature.*

Changes in isobaric, isopycnic, and isallobaric patterns on maps of the upper troposphere and lower stratosphere are frequently followed by related shifts at 10,000 feet. But forecasts of these shifts, based on the study of advection at high levels by Wulf*, should be qualitative only. In addition, the 10,000 foot level seems to be the lowest to which pressure correlations with higher altitudes can be applied regularly. The procedure of forecasting surface changes *indirectly* from upper-air configurations, by preparing an intermediate prognostic map at 10,000 feet, is recommended. Three pertinent forecasting devices have been justified by field experience:

(1) The modified extrapolation of $\theta$ lines or isotherms at 13 km. qualitatively predicts changes through successive layers down to 10,000 feet. (2) The forecast position of 24-hour isallobaric centers is useful for predicting pressure changes of the same sign at those lower levels which are within the same advective current. (3) The general circulation intermittently floods middle latitudes with tropic and arctic air masses, the advance of which is led by characteristic cold and warm tropopauses.

Greenwich Mean Time, marked by the symbol "Z", will continue to be a required label on weather charts, diagrams, and forecast forms. Additional designations of time, such as LWT, would also serve a useful purpose.

Constant Vorticity Trajectory computation is a valuable technique for forecasting the winds aloft. But only in weather centrals, master stations, and other stations with large forecasting staffs is sufficient time presently available for its use.

Application of the Rossby trough formula to forecasting the movement of 10,000 foot troughs should be restricted to those weather stations where reliable and complete data is available on a hemispheric scale.

The base of a subsiding layer will normally be characterized on a pseudo adiabatic chart by an inversion which appears as a rounded curve, as distinguished from the abrupt discontinuity typical of a frontal zone. A subsidence inversion of temperature shows, with increasing height, a decrease of relative humidity and a backing or freshening of the wind.

Convection usually is responsible for those discontinuities through which the wind shear is slight and the relative humidity decreases. Typically, a very steep lapse rate exists between the surface and such an inversion, which leads to a concentration of moisture at the inversion base.

### PROPOSED PROGRAM FOR TECHNICAL CONSULTATIONS

| Subject | Hours |
|---|---|
| North American Air Masses (properties, definitions, designations) | 1 |
| Lapse-rate and Air Mass Analyses (Stuve and Rossby Diagrams) | 6 |
| Moisture Representation (forecasting significance on upper-air charts) | 1 |
| Lightning Hazards and Precipitation static | 1/2 |
| Icing (theoretical, operational, and forecasting aspects) | 2 |
| Turbulence | 3/4 |
| Prognostic Charts (use and preparation) | 1 |
| Current Weather Discussion | 2 |
| Stratus Forecasting, Local Problems, Convergence | Optional |

**Utilization of the Entire Course of Radiosonde Ascents*, University of Chicago Press.

# *Nazi Raobs*

*after "German Radiosonde Type RS-3,"*
*a report by Eatontown Signal Laboratory, SCGSA.*

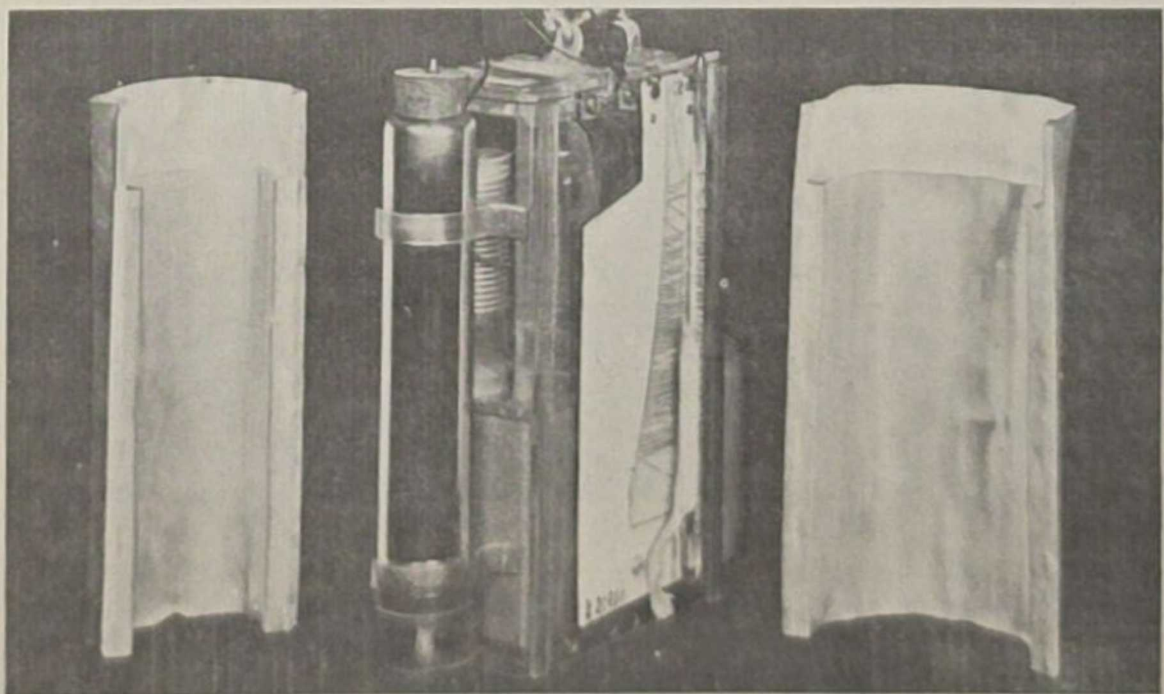
*The Army has been able to learn much about German aerological instruments through the analysis of field reports and captured equipment. Naturally, enemy radiosonde and radio-wind transmitters were the first to be obtained: the Signal Corps Laboratories received a Kriegsmarine transmitter found in the 1941 Grecian campaign, and instruments of the same type turned up later in North Africa. But the most illuminating find was a complete radiosonde station taken in Sardinia.*

The Radiosonde RS-3, in general use by the Nazi army and navy, is characterized by material and workmanship of the highest quality. The RS-3 is a minature transmitter, carried aloft by a free balloon, which reports pressure, temperature, and relative humidity data by varying the frequency of its signal. Its low power requirements (60% less than U.S. models), lightness of weight (20% less), and interchangeability of major parts are admirable characteristics. A device which facilitates launching of the flight assembly in high winds, and a chart which provides corrections for lag in temperature measurements, are also worthwhile features.

However, there is little in the design, construction, or operating principles of German radiosondes that would improve the instruments being made or developed in this country. The measuring elements are quite delicate: they require extreme care in manufacture, special handling in shipment, and restraint in field use. Temperature reports are very sluggish, and one should expect a smoothing-over of inversions encountered in flight. The accuracy of this element also relies upon the permanence of standard calibration points which are really transient, as frequent changes in construction indicate. And most important, the German use of frequency modulation throws great responsibility for accuracy of the final report on the operator's personal skill and attention. In consequence, RS-3 reports are probably no more reliable than ± 5 mb. in pressure, and no more than ± 1.5° C. in temperature. *This accuracy is markedly inferior to that of any U.S. model.*

The first captured radiosonde was numbered #9,423; but serial numbers up to #47,000 have been reported recently. Later models have shown changes in the pressure and temperature units, apparently adopted to eliminate some of the serious temperature and pressure lag. Moreover, the early instruments were designed for low-level soundings, and the recent changes must also have been influenced by a demand for high level data.

The German radiosonde houses two transmitters and one battery in a plastic case, with three meteorological instruments mounted outside under cover of aluminum radiation shields. One transmitter operates at a frequency of 8,000 kc, and the other at 10,700 kc. The pressure, temperature, and humidity instruments are quite similar to each other; essentially, each is a glass tube containing a liquid column. As the liquid rises or falls, the effective length of an inductance coil in each circuit is altered, thereby changing the transmitter frequency.



GERMAN RADIOSONDE RS-3, showing wet bulb thermometer and vacuum bottle for the pressure element. The radiation shields stand aside for display.

The three reports can be distinguished by noting certain individualities in the frequency shift peculiar to each element.

PRESSURE

The pressure element consists of two (and later, one) glass capillary tubes, in which a bubble of air is sealed by a half inch plug of mercury. Technicians call it a "differential manometer." As the free air pressure decreases, the air bubble expands and pushes the mercury higher. A series of contacts, aligned along the tubes, bring a new length of inductance coil into the transmitter circuit as each contact is closed by the mercury. In this manner, the frequency transmitted is altered by atmospheric pressure changes.

HUMIDITY

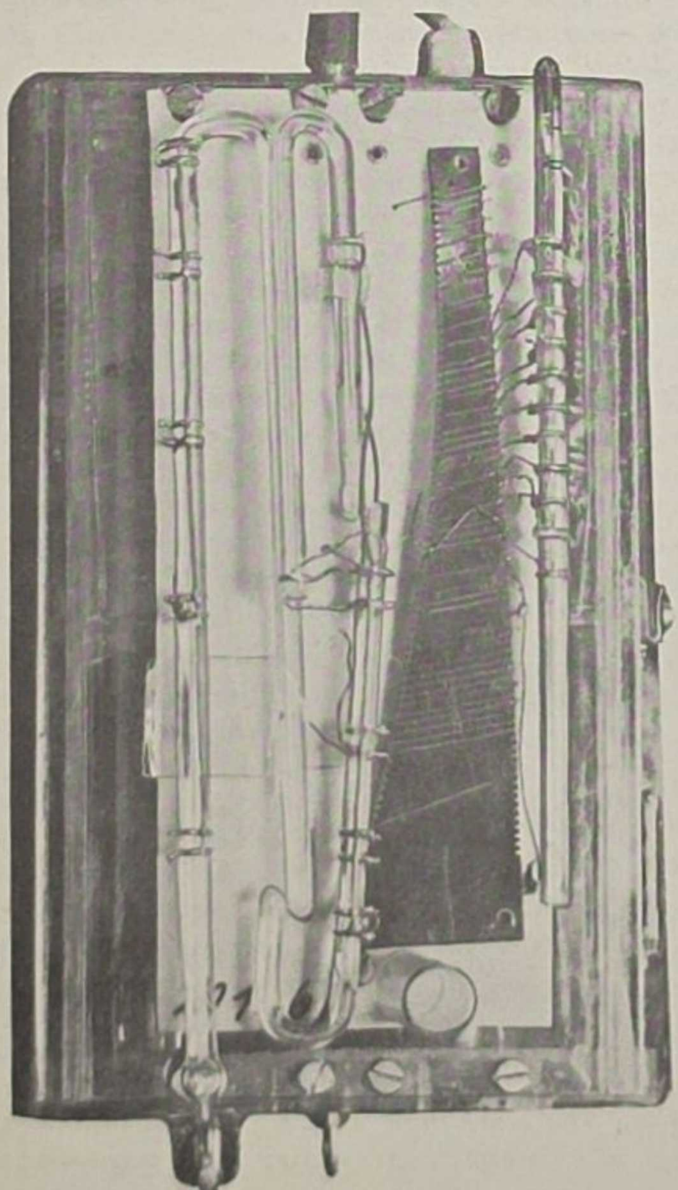
Mounted on a common base with the pressure element (and acting quite like it) is the humidity element, a wet-bulb thermometer in circuit with its own inductance coil and the aforementioned transmitter. As the thermometer liquid rises or falls, it opens or closes contacts which connect different lengths of coil to the transmitter. Again, this action causes a shift in frequency of the signal; but since the change occurs in a sequence of three special increments, wet-bulb data can be distinguished from pressure reports.

The wet-bulb wicking is kept moist by a container of liquid mounted nearby. Early models have 11 contacts on the inductance coil, but as many as 23 appear in later examples.

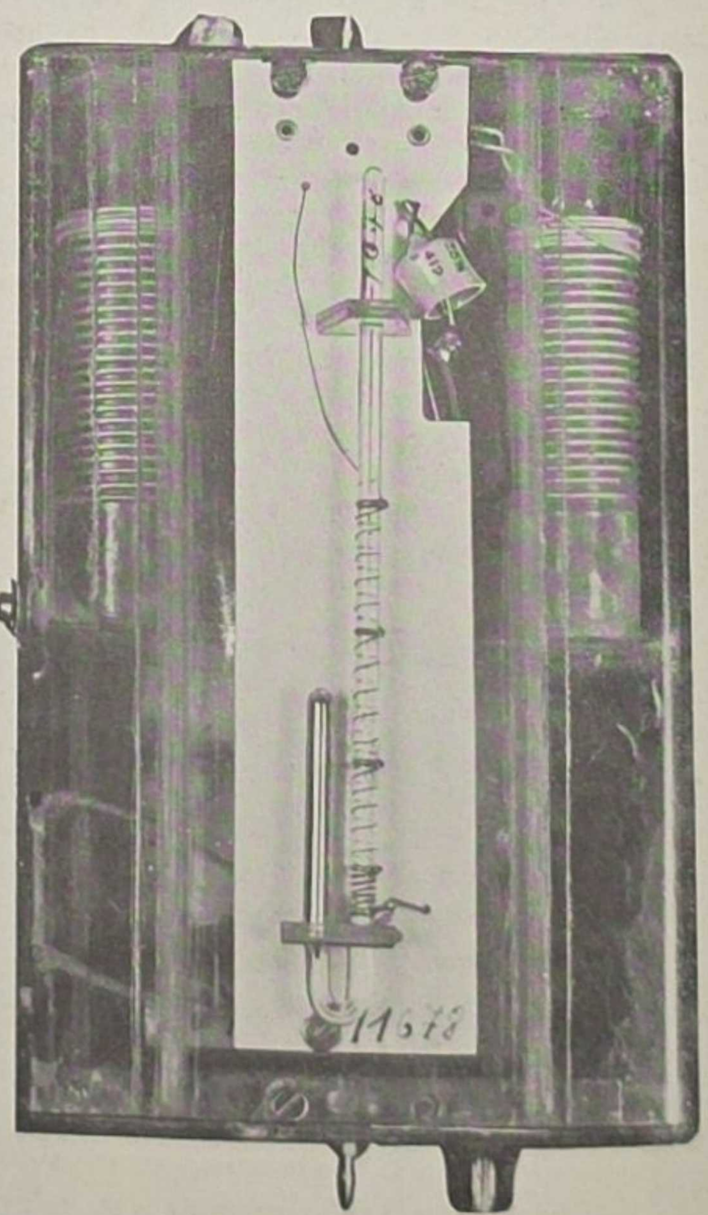
TEMPERATURE

Dry bulb reports alone are sent out by the second transmitter, operated at higher frequencies than its counterpart and recorded by a separate ground receiver.

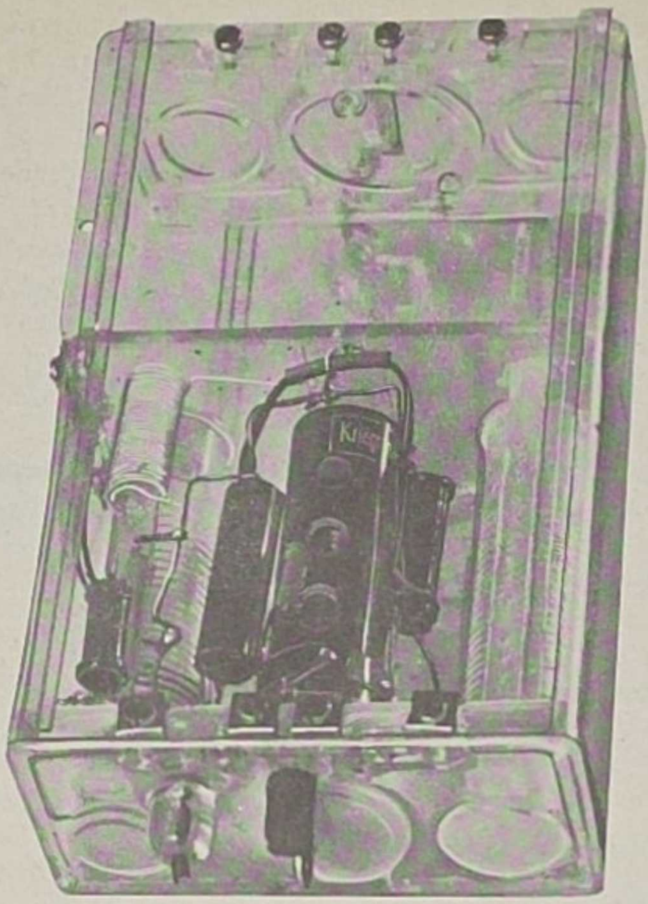
The temperature circuit is similar to those for pressure and humidity. The thermometer bore is lined with taps, each leading to graduated lengths of inductance



GERMAN RADIOSONDE RS-3, assembled, showing the pressure and humidity elements. Pressure is measured by two differential manometers, one for high and the other for low pressures. Humidity is evaluated by a wet bulb thermometer.



GERMAN RADIOSONDE RS-3, assembled, showing the temperature element. Five contacts along the bore of the thermometer are visible, each of which, when closed, connects a different length of inductance coil to the transmitter circuit.



GERMAN RADIO WIND TRANSMITTER, assembled, front and bottom view. This device is sent aloft with a free balloon; the high frequency signals it transmits are tracked with RDF equipment so that the winds aloft can be computed.

coil which are brought into (or dropped from) the temperature circuit by fluctuations of the mercury column. As a new contact is opened or closed, an abrupt shift in the transmitter frequency occurs. In this circuit, however, a temperature sensitive capacitor assists interpolation between contact points by making intermediate and continuous changes in the frequency.

OTHER CHARACTERISTICS

German radiosondes use a wet-cell power supply (U.S. models employ dry cells). The battery is shipped dry, but must be charged and filled with a salt solution before use. Its voltage output is the same as that of the battery in ML-141, but the U.S. batteries weigh considerably more. The familiar practice of using a zinc sheath as both electrode and case is not followed by the Germans, who contain their batteries in plastic. This technique, although it complicates manufacture somewhat, saves zinc and weight.

The German system of radiosonde reception relies heavily on the observer to perform complex duties with mechanical accuracy. There are two receivers and recorders in each set, one for each of the transmitters aloft. The operator keeps alert for shifts in frequency of the signals, and when one occurs he "tunes in" the new wavelength. The tuning knob is connected mechanically to a recording stylus, which accordingly cuts the record into a revolving wax drum.

The ground equipment uses two "L" type antennae 45 feet long, raised on 20-foot poles to form a horizontal "V". Nazi receivers, complete with recorder attached, measure 36 by 10 by 12 inches.

RADIO WINDS

The Germans have developed methods for determination of the winds aloft, by the use of Radio Direction Finding apparatus which follows balloon-carried radio transmitters. The wind transmitters seized in action are made from basic parts of the RS-3 Radiosonde, but operate on a much higher frequency (100 megacycles).

T/Sgt. George Hocker gave technical assistance in the preparation of this article for use in the 'Weather Service Bulletin.'

## *EXPENSIVE GIFTS*

*Many a SWO in South and Central America has been grievously embarrassed when natives have marched up to the weather station carrying a radiosonde transmitter. They have always pointed hungrily to the printed statements implying that the instrument should be returned, in obvious anticipation of a fat reward from the affluent Yanqui authorities. But no authorization for such a disbursement exists, and a mere 'thank you' has had to repay many a long trip.*

*The Signal Corps has agreed to delete the markings which request the return of radiosonde transmitters, and all future shipments of radiosondes will be without the offending Form #272. The return of recovered transmitters to the Signal Corps is now considered uneconomical, because new transmitters can be provided for less than the cost of transporting and recalibrating returned instruments.*

# Let experts do it

by Captain R.B. Kimball

Who knows best when marginal weather at a terminal will become worse, or better? Each forecasting staff is best qualified to forecast for its own base, of course, especially where local topographic effects are pronounced. Hence the value of spreading such specialized opinions, an idea which has become reality in the Eighth Region. A forecast of local weather is transmitted by every major air base at the end of its hourly weather report.

Consider an example of the vexatious forecasting problems which can be met with this information. The airfield at Narsarssuak (Greenland) has only a single runway, located at the head of a 50-mile fijord and hemmed in between formidable mountains. Every forecast for this terminal must also consider the weather to be found along the waterway, because this treacherous valley is the only feasible approach route. And once a pilot commits his plane to such an approach, he finds it very difficult to extract himself if the weather suddenly becomes sub-minimum.

But local, complex effects modify the general weather patterns at such a base as Narsarssuak. Even assuming an accurate forecast for both fijord and base, operational hazards impose high weather-minimums which are different for fijord and airport. Do you wonder that a forecaster, at say Goose Bay, hurries teletypeward to get the opinion of Narsarssuak weather specialists before he commits himself on a clearance to that base?

The local forecast is appended to each hourly sequence in two "operational groups," both coded in one form: AAXBB.* AA describes the current local weather, X the time in hours before a significant change is expected, and BB the weather after X hours. The first group therefore gives present weather and a nine-hour forecast. The second group, similarly, gives a forecast for the 9-18 hour period.

Present and forecast weather are both encoded as one of the following categories (lower numbers indicating worse weather), determined by the weather situation:

99---suitable for pursuit aircraft flying in formation.

88---suitable for bombardment aircraft flying formation.

77---suitable for single, bombardment aircraft flown by inexperienced pilots unfamiliar with the terminal.

55---suitable for individual cargo aircraft, flown by experienced pilots familiar with the terminal.

44---unsuitable for aircraft operations of any kind.

*(Repetition of the first and last code digits is used to counteract garbling).

Let's examine a typical situtation:

Fifty Flying Forts have stopped at Grenier Field, New Hampshire, enroute to the United Kingdom via Goose Bay. The forecaster at Grenier is "on the fence" as to whether or not Goose Bay will break open in time for the B-17's to land at their ETA, so he consults the latest Goose Bay operational groups (for 1030Z). The code received is 44588, which he interprets as:

"At present, weather conditions have closed Goose Bay to aircraft operations of any kind, but in five hours (at 1530Z) the weather will permit operation of bombardment aircraft in formation."

This message is just what the weather and operations men at Grenier want to hear: forecasters experienced in the vagaries of Goose Bay weather are confident of the necessary improvement. Preparations for dispatch of the B-17's are undertaken immediately.

Two years of experience in the North Atlantic area, that funnel through which tactical aircraft flow to the European battle-fronts, has proven two values of the "operational group" transmission: *safety* (when the local weather shuts down) and *time saved* (when the local weather breaks up). Certainly this is "Choosing the Weather for Action"---with refinements!

# Constant Level or Constant Pressure ?

*The international exchange of aerological data is most desirable, but such methodical differences in upper-air reports now exist across political boundaries that exchange of this information is often very difficult. Weather services in the Pacific areas and in America map the upper-air on levels of constant height; Anglo-Americans in the European Theater analyze a set of mandatory pressure surfaces; Soviet aerological maps are for another set of pressure surfaces. These discrepancies are dams to circulation within the world-wide network of weather observations.*

*Important figures in the meteorological world are seeking to level these barriers by establishing a standard procedure throughout the world. Certain considerations, practical as well as theoretical, have influenced them to propose constant-pressure analysis for general adoption. But grave questions will have to be settled before that objective can be consumated.*

Is the emergency of a war the "time for a change?" *Codes would have to be altered, climatic and synoptic literature changed, observers retrained, and experience of forecasters modified. The immediate concern of the Weather Service is to foresee the operational difficulties of changes in procedure, which would become pressing should the Joint and Combined Meteorological Committees adopt a standard method for world-wide use.*

Will a change to constant-pressure analysis be advantageous in itself, after all factors are weighed? *The answer is still in doubt, and it is this phase of the problem which is argued by two junior officers on the succeeding pages.*

## CONSTANT-LEVEL

by Lieutenant W.N. Stokes

no such word in this sense

Constant-level chartists have developed ways to satisfy every requirement of modern forecasting. Where greater accuracy and convenience are demonstrated for Constant-Pressure maps in certain aspects of analysis, it is important to question the practical nature of the difference. Minor refinements may be overshadowed by errors in current prognostic and instrumental techniques. And significant improvements may be counteracted by the loss of special advantages obtainable only within the Constant-Level procedures.

For example, Pibals and Radar winds are observed at fixed heights. The great mass of our actual wind data, therefore, is available precisely for mandatory heights. Prescribed pressure surfaces, on the other hand, can be far from the nearest level at which a wind is reported.

The geostrophic relationship does not hold in low latitudes, and therefore the theoretical advantages of CP methods do not apply in the tropics. Authorities in the meteorology of low latitudes favor an analysis of the streamline pattern drawn from winds reported at constant levels.

It is expected that the surface map would still be drawn if CP techniques were adopted. Comparison between this CL chart and CP maps aloft is an incongruous prospect. Differential analysis of the most vital atmospheric layer, that between the surface and the first upper-air chart, would be meaningless. How could the mean isotherms in that layer be determined? Probably an additional chart (at 1,000 mb.) would have to be analyzed each time; a disheartening outlook.

Turning now from the peculiar advantages of Constant-Level charts, consider the significance of certain arguments given in behalf of Constant-Pressure analysis.

The graphical subtraction of height lines on one CP chart from those on another does delineate the field of mean isotherms exactly. But weathermen are familiar with the device of subtracting every fourth millibar isobar at 10,000 feet from every sixth-millibar isobar at the surface, thereby obtaining a good approximation to mean isotherms. The CL "thermal wind" (a measure of the direction and spacing of mean isotherms) at 10,000 feet is over 90% of its precise counterpart.

When the effect of density on CL wind scales is derided by CP advocates, it is important to realize that there is a Bellamy slide rule* for determining the geostrophic and gradient winds at any height with great rapidity.

Some have declared that "pilots fly along an isobaric surface when they maintain a constant altimeter reading, and their weather briefings should therefore deal with CP surfaces." This is a most academic argument, because isobars slope only a few hundred feet in a thousand miles. What forecaster can define his predictions that closely? (Pilots rarely fly at a standard level anyway.)

An oft-repeated argument for CP states that Raob data is recorded directly at significant pressures while CL data must be computed by interpolation. The accuracy of this interpolation, within instrumental limits, depends on that of the pressure height curve drawn from hydrostatic considerations. But this same interpolation must be used in CP reports to obtain the heights of mandatory surfaces, isopleths of which determine the wind flow. And looking toward the future, one may anticipate that Radar will be used with Raobs to give the absolute height of upper-air data; perhaps even sooner than that date when a uniform procedure could be established.

One might assert that future refinements in equipment and forecasting techniques will endow the theoretical advantages of CP analysis with great practical significance. But instead, current research looks forward to the quantitative computation of convergence and divergence; a technique which is facilitated by reference to CL charts (Cartesian coordinates).

The arguments in behalf of Constant Level analysis influence one to believe that there is little to choose between the two methods, either for present or future usage. Then the question of whether or not to change does not involve any argument that a new method will *itself* introduce advantages. The decision is reduced to a relative evaluation of two factors: 1) The difficulties of a meteorological revolution during wartime demands on the Weather Service, weighed against 2) the advantages of a uniform reporting and forecasting procedure throughout the world.

**Horizontal Temperature and Pressure-Gradient Scale*

## CONSTANT-PRESSURE

by Lieutenant O.E. Dews

The problem of meteorology was stated by V. Bjerknes thus: "To investigate the five meteorological elements (pressure, mass, temperature, humidity, and motion) as functions of coordinates and time." Until it becomes possible to express the structure of the atmosphere by an equation, the synoptic investigation of the five meteorological elements must be carried on by means of graphic representations. In the United States the graphic representation of upper air data has been limited almost exclusively to surfaces of constant height: 5,000, 10,000, 20,000 feet and so on above sea level. This limitation is regrettable, for level surfaces are not the only ones possible, nor, it can be shown, the most desirable for general meteorological purposes. The alternative proposed is the Constant-Pressure surface. Aside from the obvious desirability of standardizing our practice with that of our allies, there are good theoretical and practical reasons for adopting the Constant Pressure surface for the representation of upper air data.

In comparing CP and CL charts, the need arises for a test principle. Petterssen proposes the following: "The most suitable method is the one which renders a complete analysis of the state of the atmosphere with a 'minimum of effort', which is the same as saying 'in a minimum of time'." On the basis of this principle, the primary advantage of the CP chart is the great simplicity with which it represents the basic meteorological elements.

First, *pressure:* CL and CP charts both provide good representations of the pressure distribution, the one by means of isobars and the other by means of pressure contour lines. The CP chart, however, has the advantage that it represents a surface which pilots are easily able to identify, for a plane which flies at one pressure altimeter reading is actually following a CP surface. Moreover, the contour lines on the CP chart indicate both the true height above sea level and the altimeter correction.

Second, *mass:* Mass per unit volume, or density, is represented directly on a CP chart by the isotherms, which are also lines of constant density; whereas an additional set of lines is required to represent density of a CL chart. The *mean* density of the layer between two isobaric surfaces is accurately represented by the mean isotherms constructed from the intersections of the two sets of pressure contour lines. The mean isotherms between two isobaric surfaces can therefore be used for the same purposes as (1) the mean isotherms between two constant levels, and (2) the CL weight lines, needed to supplement pressure data at higher levels. It is important to note that the mean isotherms constructed in this way are consistent with the isotherms determined from the wind shear through the layer, whereas the mean isotherms between two *level* surfaces differ from the wind shear isotherms by a term depending upon the vertical gradient of temperature.

Third, *temperature:* On both CL and CP charts, the temperature distribution is represented by isotherms. The isotherms on CP charts, however, also represent isolines of density, potential temperature, and saturation mixing ratio.

Fourth, *humidity:* Humidity is conveniently represented on CP charts by lines of constant mixing ratio or wet-bulb temperature. If the humidity is expressed in terms of mixing ratio, the interval between the mixing ratio and the saturation mixing ratio lines is an indication of the relative humidity. If the humidity is expressed as wet-bulb temperature, the humidity lines also indicate the wet-bulb potential temperature and the equivalent potential temperature, the most conservative air mass characteristics.

Fifth, *motion:* On CL charts the geostrophic wind depends upon the density as well as the latitude and pressure gradient, making it necessary to have a different wind scale for each level or to apply inconvenient corrections. For CP surfaces, however, the geostrophic wind is obtained independently of the density, with the result that the same wind scale can be used for all charts regardless of density variations.

Sixth, *co-ordinates:* It must be admitted that the CL chart has advantages which may justify its continued use for the evaluation of space differentials at individual levels. Of particular interest in this respect is the evaluation of horizontal convergence and divergence. It should be remembered that the slope of the isobaric surface is of the order of 1 to 10,000 and that the spatial errors introduced by regarding the isobaric surface as horizontal are therefore quite small. This is in fact the same assumption which is commonly made when the convergence-divergence term is developed from the principle of the continuity of mass, for the motion is assumed to be both horizontal and isobaric. When the divergence or convergence is summed through finite layers, it can be shown that the resulting expressions in the pressure-change integral are substantially simpler for Constant-Pressure than for Constant-Level surfaces.

In summary, it may be said (1) that the Constant-Pressure chart provides a complete graphic representation of the five meteorological elements by means of a surface, three sets of lines, and a wind scale, (2) that the CL chart performs the same functions by means of a surface, five or six sets of lines, and a wind scale for each level, and (3) that, for general meteorological purposes, rectangular space co-ordinates are as well adapted to Constant-Pressure surfaces as they are to level surfaces.

# BAROMETER CORRECTIONS

by Cpl. E.F. Peters & Pfc. H.J. Smith

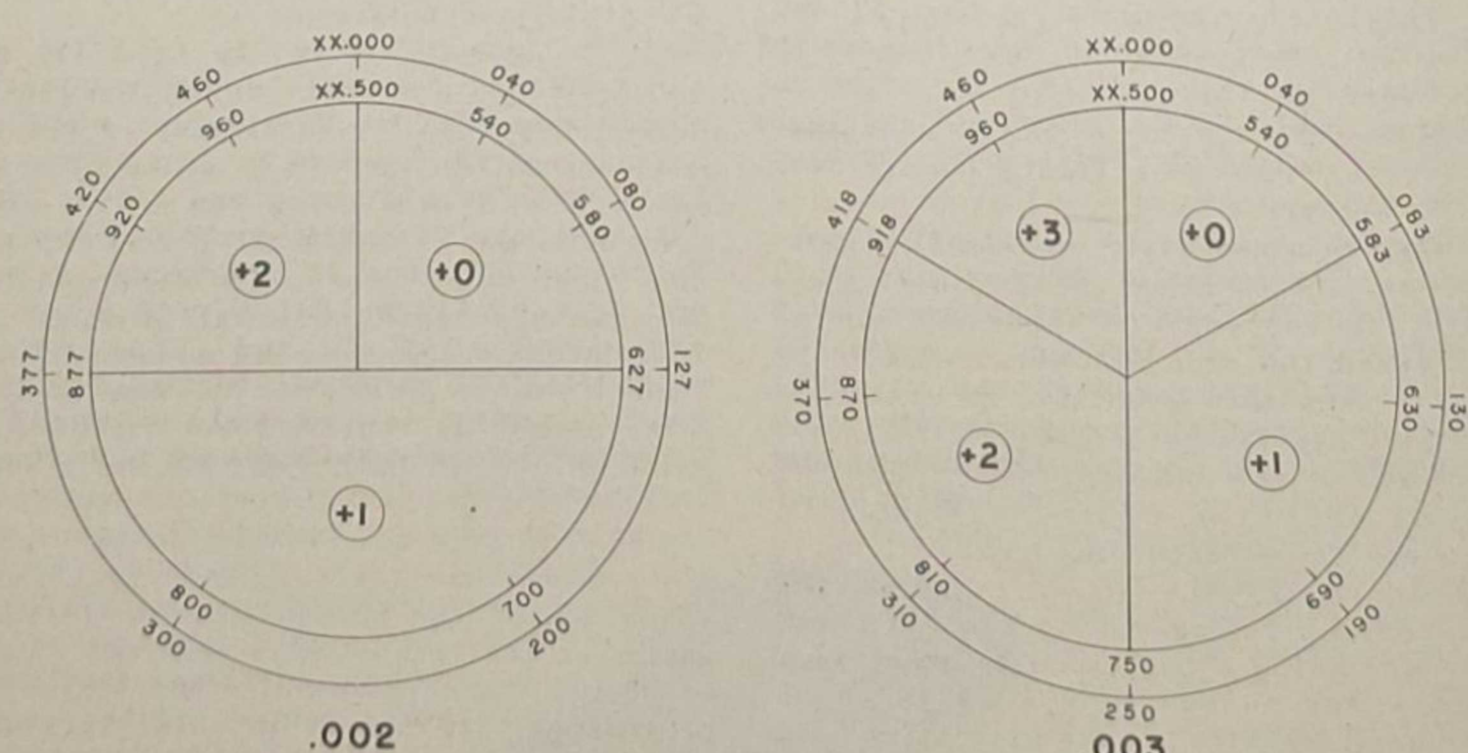
Barometric temperature corrections are made rapidly yet accurately at Stuttgart AAF, Arkansas, because diagrams were developed there to simplify the necessary interpolation. Mere inspection has replaced tedious arithmetic in the linear interpolations required by the Temperature Correction Table (Form 80).

Form 80 gives corrections only for half inch pressure intervals, at 29.5 and 30.0 inches of mercury for example, creating an interpolation problem with most barometer readings. However, there are only four possible differences between Form 80 corrections: .001, .002, .003, or .004 inches. Using this fact, the interpolation could be worked out graphically for each difference. But .004 appears very seldom, and the difference of .001 merely requires mental arithmetic, so only diagrams for differences of .002 and .003 inches were prepared.

Here is the method for using the diagrams: Form 80 is read as usual, but in those cases where the difference between the temperature corrections is .002 or .003, the appropriate diagram is consulted. The barometer reading appears in some sector of the circle, labelled there with a number to be added to that temperature correction given in Form 80 for the tabulated pressure just *lower* than actual. With that mental addition, the final temperature correction is obtained.

Two concentric circles in each diagram cover a range of two half inches of pressure. "XX.00" and "XX.50" can mean the whole and half-inch barometer reading which "encloses" any given synoptic pressure.

A numerical example follows:
Assume an observed reading of 29.754 inches, at a temperature of 85.5 degrees. Form 80 shows that the correction for 29.5 inches is .152 and for 30.0 it is .154 inches. Accordingly, the diagram dealing with the differences of .002 must be used. Reference to it shows that an observed reading of 29.754 falls in that portion of the circle requiring an addition of .001. Hence, the total correction is .152 plus .001, or .153 inches. Adding this value to the observed pressure of 29.754 inches, the corrected pressure of 29.907 inches is obtained.




INTERPOLATION CHART FOR BAROMETER TEMPERATURE CORRECTION

# AH, RELIEF!

Models of topography are now being prepared by the Weather Wing for distribution to all AAF forecasting stations in the United States, in response to many requests from the field. Use of these models, in briefing and in studying the effects of terrain on weather, is expected to decrease materially the number of aircraft weather accidents involving terrain.

Each station will receive two relief replicas, one of its local area and the other of the entire United States. Both will probably be ready for distribution by May 1945.

The models of the United States are 32 by 48 inches in size, which allows representation on a horizontal scale of 1:4,000,000 (64 miles to the inch). The vertical relief of the lowlands is exaggerated by a factor of three in relation to the mountains, so that small but important details of relief are not masked. Changes in the *actual* elevation above sea level are shown by colored shading. Every weather reporting station is identified and its call letter given; airways are drawn to scale and colored conventionally; important airfields, cities, and topographic features are marked and named; and political boundaries are entered. These replicas are being made from an original model prepared by Dr. Erwin Raisz, School of Geographical Exploration, Harvard University.

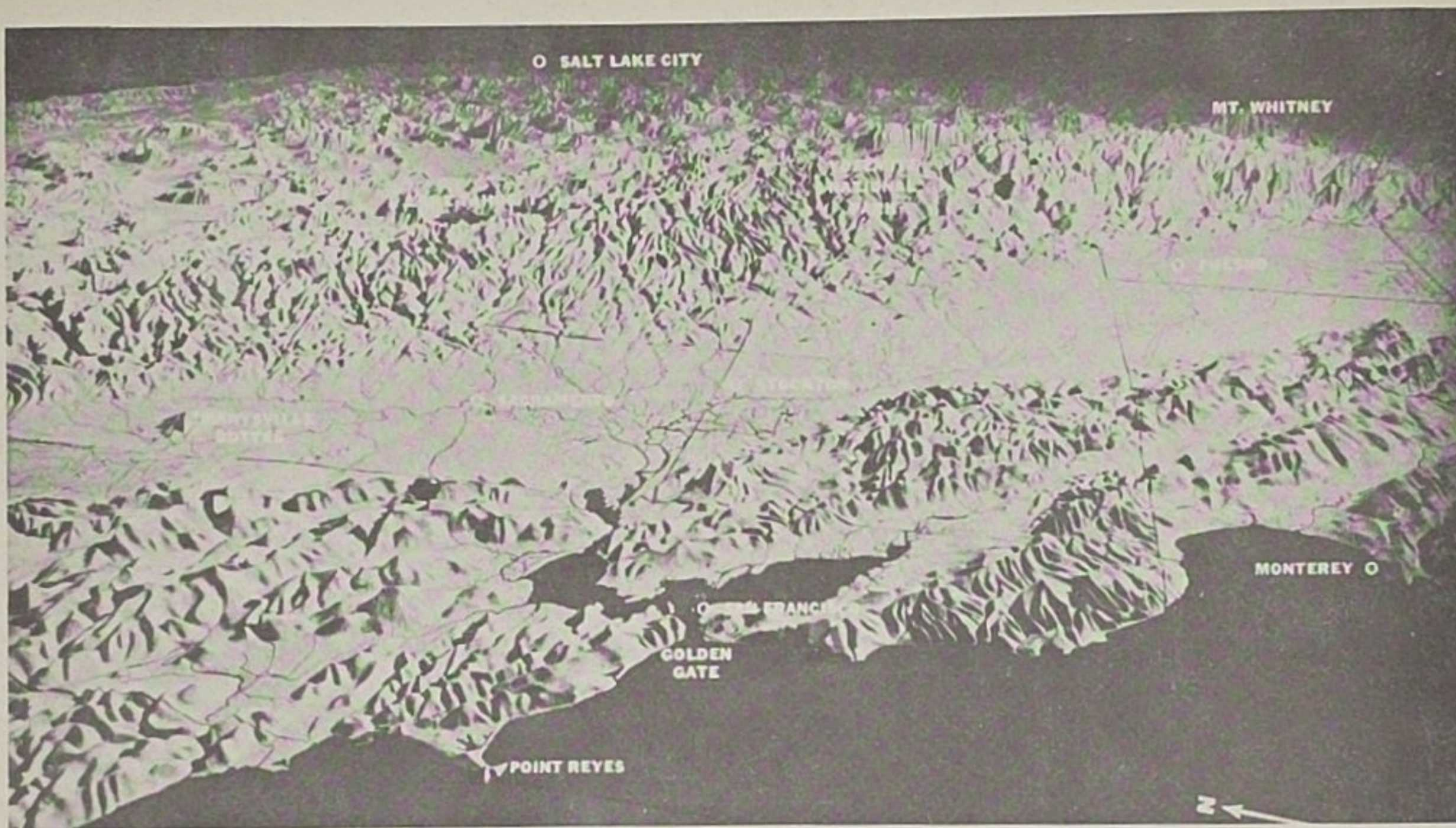
The sectional models will be issued in unit blocks, each bounded by one degree of latitude and one degree of longitude. Stations will be furnished the combination of blocks needed. The horizontal scale is 1:250,000 (four miles to the inch). Vertical relief of the lowlands on these models is exaggerated by a factor of two in relation to the mountains.

These latter replicas, naturally, contain more detail than the United States models. The name, index number, call letter, and elevation of every weather reporting station are given. Airfields and airways are shown in the manner of the Sectional Aeronautical Charts. These replicas are being made from a 65 by 45 foot model of the United States at the Babson Institute of Business Administration.

Two forecasters at the Wing Weather Station study a sectional relief model to determine how the local weather will be influenced by the southwesterly circulation indicated on the synoptic chart over Asheville's mountains.

Replicas of local topography will be distributed to all AAF forecasting stations, for use in predicting the weather and in explaining it to pilots.

Regional Control Officers have advised the Weather Wing whether individual stations in their regions require a small model of the entire United States in addition, and, in each case, they have indicated the appropriate extent of the local area replica.




Relief models of local topography are being prepared for every domestic AAF forecasting station from this extensive model housed at the Babson Institute of Business Administration. The unit blocks which will make up the local area replicas can be seen plainly.

## HEADQUARTERS NOTES

*HISTORICAL MEMO*

*Historical officers of those weather squadrons assigned to the AAF Weather Wing are advised that supplements to squadron histories for the last quarter of 1944 should be prepared in time to reach this headquarters not later than 31 January 1945.*

*WATER IN THE CEILING LIGHT*

*Condensation in ceiling light projectors is often an annoying phenomenon. Why not place a packet of silica-gel drying agent inside the projector; a new one every few days?*

*No such dessicating agent can be ordered at present, but the packet found in every radiosonde transmitter envelope is excellent for this purpose.*

*RAOB THRIFT*

*The glass vials which contain the radiosonde's electric hygrometer element are being put to good use in several regions. Radiosonde units turn them over to Medical Corpsmen, who fill the tubes with serums and medicines for kits to be taken as emergency equipment on long flights.*

# Forecasters' Exam

Results of the Forecasters' Proficiency Examination (2,3,4 October 1944) are being examined and interpreted at Headquarters Weather Wing. This analysis seeks to determine how widely and how well the techniques of modern forecasting are understood by field forecasters *in general.* The performance of each region will define the subject matter of a training program now being initiated by this headquarters, a program which will be effective because it meets specific deficiencies.

A "passing grade" has not been set: the Weather Wing is rarely interested in the particular grade of any individual. Rather, the general training level is being investigated. If an individual's achievement were considered separately, it is entirely possible that his efforts might have been hindered by extraneous influences like a cold, a headache, or worry. But when very many forecasters show marked deficiencies in certain subjects, determined on the basis of 3,200 examination grades, a reliable basis for training plans is revealed.

The achievements of those weathermen who are on probationary forecasting status will be used for deciding whether they will be disrated or reinstated, but *only as one factor.* Emphatically, each case is an individual problem, on which all the known facts will affect the deliberation. Those who took the examination in an attempt to be rated as a forecaster will also find that their grade is only one consideration.

Each forecaster probably is curious about the relative standing of his grade, inter- and intra-regionally. This information can be gained from the charts on the following page. Examination grades are given on the vertical axis, while the percentage of forecasters who received better grades than the reader is given on the horizontal. Three curves have been plotted for each of the foreign regions, one for each part. In the domestic regions, however, the curve representing the domestic average grade also gives the scores of the 1st, 3rd, 4th, 23rd, and 24th regions satisfactorily.

The inter-regional comparison of results on Part III should be confined to those units which took the same test. The domestic regions analyzed a U. S. map, the 8th and 16th handled separate arctic situations, and the tropical regions also had their own analysis. It would be a great coincidence indeed if these four Part III's were equally difficult. Parts I and II, however, were identical on each examination.

| Weather Region | Complete Average | Average (Part I & II) |
|---|---|---|
| 2 | 76 | 80 |
| 1 | 75 | 79 |
| 3 | 75 | 78 |
| 4 | 75 | 78 |
| 8 | 75 | 78 |
| 23 | 75 | 78 |
| 24 | 74 | 78 |
| 25 | 74 | 76 |
| 9 | 73 | 75 |
| 16 | 69 | 74 |
| 6 | 69 | 69 |
| 22 | 67 | 69 |

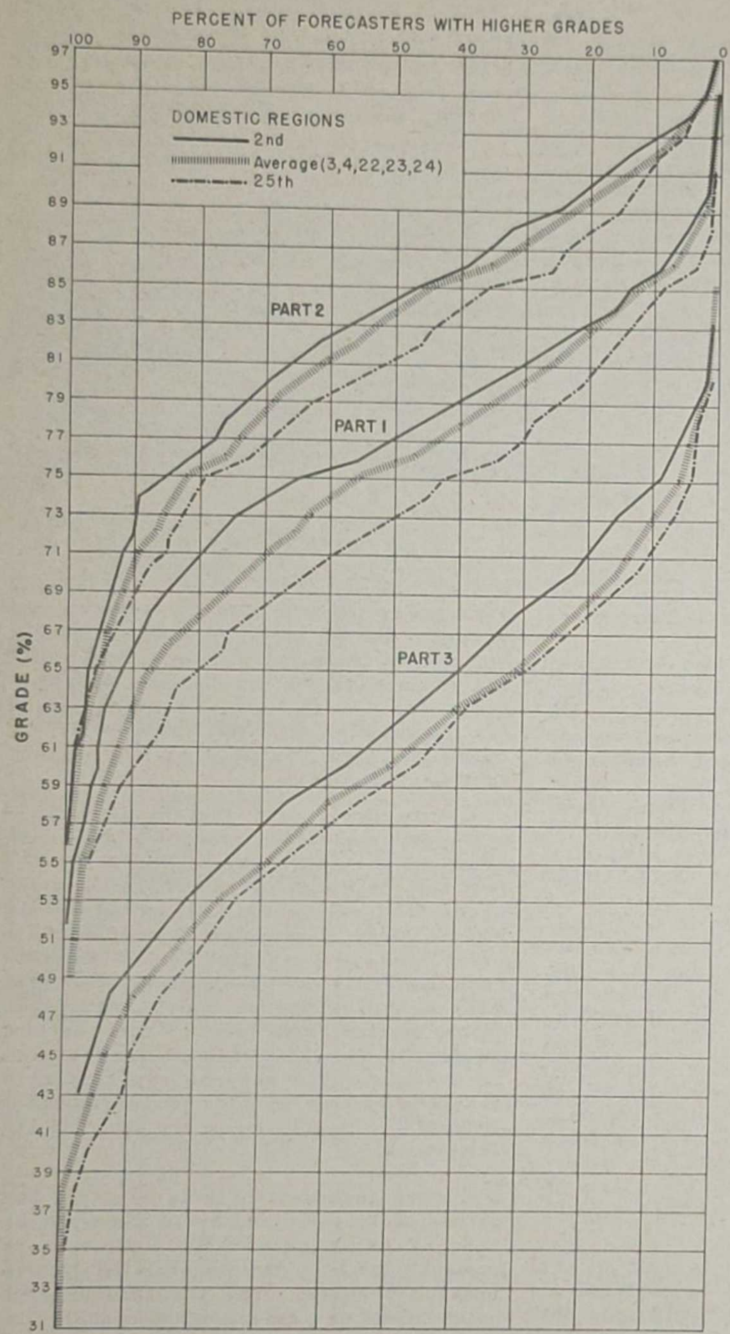
The spread of averages from low to high is only nine percent; hardly a significant difference, one might say. Yet the graphs which follow show an important discrepancy in the scores by regions. For example, 65% of the 2nd Weather Squadron achieved at least 75% on Part I, while only 43% of the 25th Weather Squadron were that successful. Furthermore, the average curve for the domestic regions is superior to the curve for that region with the highest ranking, the Eighth.

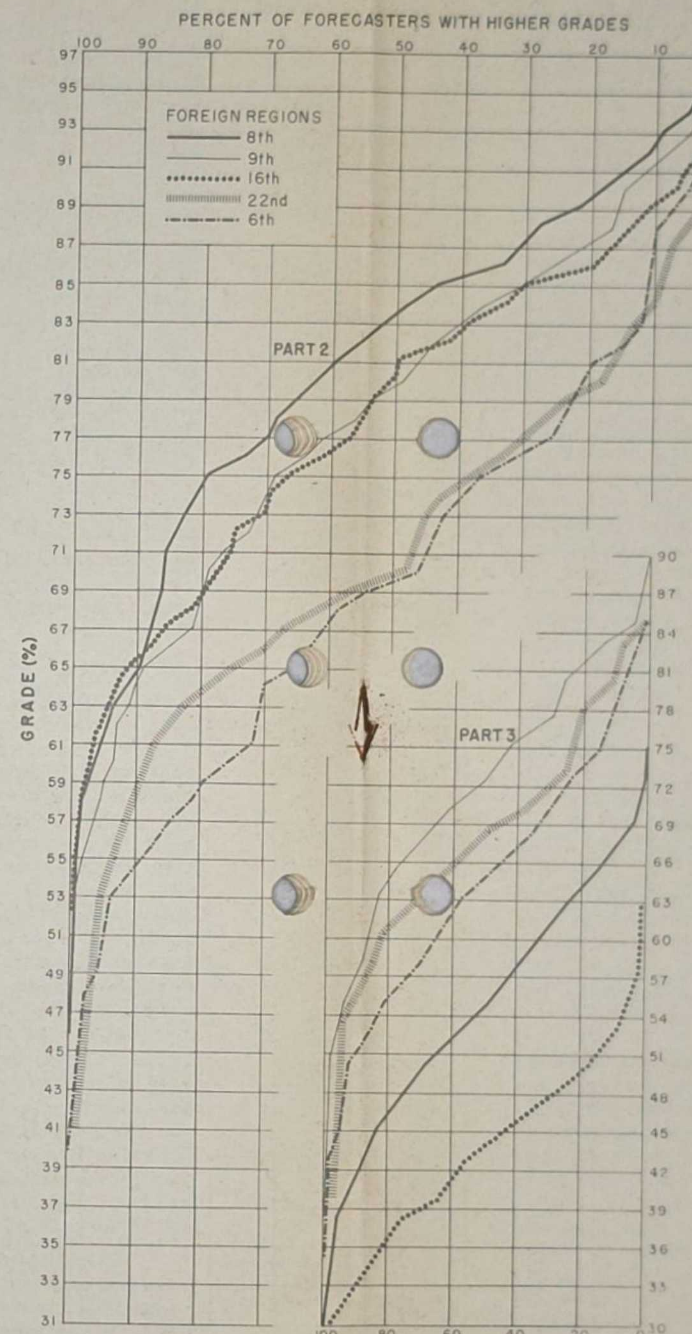
Of course, many factors produced a superior examination grade for a certain group of regions, some of which are not obvious. It was expected that recent graduates from meteorological schools would receive higher grades, and most of the last cadet class are assigned to the domestic regions. Only the domestic regions were visited by Technical Consultant Teams before October 1944. Many of the questions on Part I and II refer to forecasting techniques which are not applicable to everyday weather outside of the Temperate Zone. And probably there are other subtle influences.

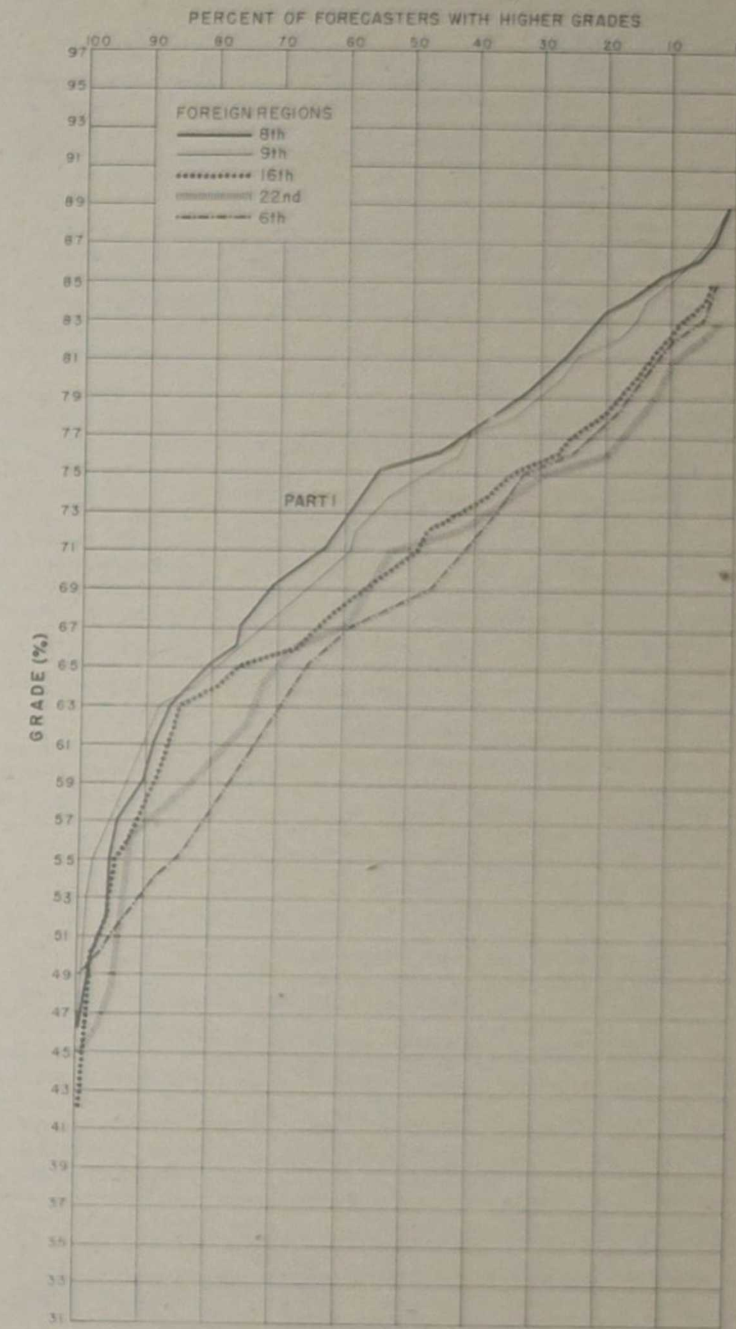
Such information is intriguing, but it does not bear directly on the composition of training plans. This end was accomplished by a further division of examination results. The tabulation given below shows one aspect of this analysis: which is the averages of all scores for each Test Part.

*Continued on page 14*

# DISTRIBUTION OF TEST GRADES



*Continued from page 11*

## PART I

| *Section* | *Average* | *Content* |
|---|---|---|
| 1 | 79.2 | Radiation, Vertical Temperature Distribution, Pressure, Tropopause. |
| 2 | 72.1 | Stability, Adiabatic Displacement, Conservativeness. |
| 3 | 84.5 | Condensation, Thunderstorms. |
| 4 | 73.4 | Wind |
| 5 | 82.5 | Frontal Structure, Icing, Tropical, Zonal Index. |
| 6 | 68.1 | Dynamic Meteorology |
| 7 | 66.0 | Climatology |

## PART II

| *Section* | *Average* | *Content* |
|---|---|---|
| 1 | 82.2 | Auxiliary Charts (General), Energy Diagrams, Constant-Level Charts, Cross-Sections, Isentropic Charts. |
| 2 | 76.9 | Auxiliary Charts (Advanced) |
| 3 | 77.7 | Pressure, Kinematics of Pressure Systems, Air Mass Analysis, Frontal Structure and Analysis; General Correlated Information |
| 4 | 85.8 | Meteorological Codes |

## PART III

| *Section* | *Average* | *Content* |
|---|---|---|
| 1 | 58.8 | Forecasting Questions Temperate North America (1st, 2d, 3d, 4th, 23d 24th, and 25th Regions). |
| | 64.1 | Carribbean Sea and Northern South America (6th, 9th, and 22nd Regions). |
| | 50.5 | Eastern Canada, Greenland and North Atlantic (8th Region). |
| | 42.0 | Northwest Canada, Alaska and North Pacific (16th Region). |
| 2 | 56.3 | Lapse Rate Analysis (Domestic Regions). |
| | 71.2 | Tropical Meteorology (6th, 9th, and 22nd Regions). |
| | 58.9 | Lapse Rate Analysis (8th Region). |
| | 38.3 | Lapse Rate Analysis (16th Region). |

Official interpretation of the examination(from tables similar to this one) has selected Climatology, Lapse-rate Analysis, Dynamic Meteorology, and Upper Air Charts for particular attention in the Wing's training program.

The typical reaction to every examination may be anticipated: certain questions will be declared ambiguous after scrutiny by 6,000 eyes, even when the finest care has been exercised; and memories will fasten upon and magnify those few invalidities which may have existed. But consider the relative weight of such inperfections in a test which has 250 separate answers. If there were as many as 15 "poor" questions, and if an unlucky forecaster missed them all, he would have been penalized only 6% in that extreme case.

More than three thousand weathermen took the examination of 2-4 October: all forecasting personnel assigned to the AAF Weather Wing; a few applicants for forecaster ratings; and some personnel of other headquarters and commands, such as the Weather Division (Headquarters AAF), the 1st, 2nd, 3rd, and 4th Air Forces, the Troop Carrier Command, the Eastern Central and Western Flying Training Command, the First Weather Reconnaissance Squadron, and the Air Transport Command.

A second Forecasting Proficiency Examination is scheduled tentatively, to be given during the early summer of 1945. This test will be held for the purpose of determining the effectiveness of the present training program.

# Air Mass Classification

*by H. C. Willett*
*Department of Meteorology*
*Massachusetts Institute of Technology*

*Several suggestions toward the improvement of air mass classification, as well as a discussion of the designations already in AAF use, were given by Dr. Willett to the "orientation meetings" of Technical Consultant Teams at this headquarters. Of primary interest is the plan to add a code letter to the trio of familiar symbols (cPk, for example), one which describes the stability above the limit to convection as either "u" or "s". The omission of these dynamic designators is advised whenever the air mass does not show definite characteristics. Then, it is believed that there is no need to distinguish in origin between high-latitude air masses as either "Polar" or "Arctic," or between low-latitude masses as either "Tropical" or "Equatorial."*

The thermal stratification which characterizes an air mass is determined essentially by *two* sets of influences. In the surface frictional layer, and as far up as convection from the ground can extend, the lapse rate is determined largely by direct thermal influence of the ground surface, described by the conventional symbols "k" and "w". But at upper levels, the dynamic effects of subsidence or lifting of air mass strata largely determine the thermal stratification. Yet many air mass classifications overlook this effect.

LOWER-LEVEL CHANGES

The influence of the earth's surface can be one of pronounced heating when the air mass is significantly colder than the underlying surface, or one of pronounced cooling when the air mass is significantly warmer than the surface, or an indifferent effect when air and ground are at about the same temperature. The designation k (cold) is applied to the air mass which is significantly colder than the underlying surface, so that it is being rendered *unstable* from the ground. The designation w (warm) is applied to that air mass which is significantly warmer than the underlying surface, so that it is being rendered *stable* from the ground. The neutral type of air mass is left without any surface stability designation. The w and k characteristics may be acquired by any air mass, either in the source region or after leaving it, wherever the thermal conditions are favorable. In practice, the designation is applied whenever an air mass shows the stability characteristics at low levels which the "w" or "k" influence tends to produce.

The depth to which the surface thermal influence extends in an air mass depends upon its w or k character. Because of the stability which is produced by surface cooling, and the consequent restriction on vertical turbulent and convective transport of heat, the w characteristic is restricted to the lowest 2 km. of an air mass, and usually is most pronounced in the first kilometer above the ground. In the absence of wind, this influence is shown by a sharp ground inversion, and condensation forms (if present) are in the nature of ground fog. In the presence of a moderate or fresh wind, on the other hand, this influence manifests itself in a cold, surface-frictional layer that is topped by a significant temperature inversion. Any air mass condensation forms are in the nature of stratus or stratocumulus clouds at the top of the turbulence layer.

The k characteristic, by its convective nature, extends to a greater depth in an air mass than does the w characteristic. If the air mass is stable aloft by reason of subsidence or other dynamic influences, then the top of the surface convective layer is usually found between 1 1/2 km and 2 1/2 km, is bounded at the top by a moderate temperature inversion. In this case, the air mass condensation forms which usually occur are in the nature of stratocumulus or (in winter) low, cumulonimbus clouds and light showers (snow flurries) of the small droplet variety. In drier air masses, only scattered cumulus appear.

With moderate instability aloft, there is practically no limit within the air mass to the height to which surface convection may extend. Consequently, the k characteristic may extend throughout the air mass, but the amount by which the surface heating can change the prevailing temperature at any point is small. Under this condition, the characteristic air mass condensation forms are of the unlimited convective variety: towering cumulonimbus clouds, and heavy showers or thunderstorms when the moisture content permits.

Evidently, the depth to which the high moisture content of the maritime air masses extends is determined by the same turbulent and convective transport of water vapor upward by which the vertical extent of the surface thermal influence is determined. Hence the maritime air masses of the w type have the shallowest moist layer, those of the k type and stable aloft are moist to a greater depth, while those of the k type and unstable aloft may show the maritime characteristic of high moisture content at all levels.

The w or k characteristic of an air mass is easily reversed. This usually happens when a northward or southward moving air mass reverses its direction of motion and returns to its tropical or polar source region. It is likely to occur quite sharply when an air mass crosses a coast line from continent to ocean or from ocean to continent. Continental air masses frequently reverse this characteristic between night and day, because of the large diurnal fluctuation of the ground surface temperature. Such a diurnal reversal of the surface thermal influence does not occur over the thermally conservative ocean surface. But in general, the diurnal variation of this influence which may occur over insolationally-heated land areas is not recognized in the air mass designation. The k, w, or neutral designation is retained according to the overall, day-to-day influence to which the air mass is subjected, irrespective of the minor diurnal variation which is superimposed on the general modification.

UPPER-LEVEL CHANGES

Especially in air masses of the k type at the ground, the difference between dynamic stability and instability aloft may make all the difference between a condition of stratocumulus or scattered cumulus clouds on the one hand, and a condition of heavy convective showers on the other; between maritime air masses which are moist only in the lowest 2 km, and maritime air masses which are moist at all levels. The tendency in the past has been to overlook this upper level stratification of air masses, to try to explain stability characteristics entirely on the basis of the surface k or w influence. But the increasing availability of aerological observations from upper levels has proved conclusively that air masses from the same region at the same season and with the same trajectory may differ greatly in their upper level stratification.

The designation *s* therefore is proposed for air masses within which the dynamic influences maintain significant stability aloft, and *u* for air masses in which these influences produce instability aloft. The numerous air masses which appear reasonably neutral in this respect should remain without special designation. Thus the maritime polar air masses for example, in order of decreasing stratification or of increasing vertical homogeneity of lapse rate and moisture content might be designated as mPw*s*, mPw, mPw*u*, mP*s*, mP, mP*u*, mPk*s*, mPk, and mPk*u*. The same classification holds for each of the other three air masses; cP, mT, and cT, except that the latter occur so rarely that some of the forms are not observed.

The stability of an air mass above the level of the surface thermal influence, the *s* or *u* characteristic that is, depends upon the presence of horizontal divergence or convergence within the air mass. This effect causes vertical compression (or stretching) of the mass, and resultant decrease (or increase) of the lapse rate. The conditions in the free atmosphere which are principally responsible for horizontal divergence or convergence appear to be the following:

*(1) Marked cyclonic (convergent) versus anticyclonic (divergent) circulation.*

The reduction of the gradient wind by surface friction in the frictional layer at the ground, and less effectively by the internal friction aloft, permits a steady inflow towards cyclonic centers, and outflow from anticyclonic centers. The same effects occur in troughs of low pressure, hence in frontal zones, and in ridges of high pressure. The *s* or *u* characteristics are most favored when the anticyclonic or cyclonic circulation is strong, and when it extends to high levels. The shallow thermal circulation which reverses itself two or three kilometers above the surface does not indicate in itself much about the upper level stability of the air mass in which it occurs.

*(2) Marked cyclogenesis (or frontogenesis) versus anticyclogenesis (or frontolysis).* The deepening of a low pressure center or trough causes horizontal convergence, because it adds a component to the wind which is directed toward the

center of pressure fall. Thus the deepening of a Low, or of a High, should have instability effects on an air mass, giving it the *u* characteristic. Similarly, the intensification of a High, or the filling of a Low, should have a stabilizing effect on the upper stratification of any air mass which is present, giving it the *s* characteristic. In general, frontogenesis is marked by an isallobaric low, or *u* characteristics of the participating air masses, and frontolysis by an isallobaric high, or *s* characteristics of the prevailing air masses.

Exactly the same tendency towards horizontal convergence or horizontal divergence is experienced by an air mass which is transported by the gradient wind into a field of greater cyclonic or greater anticyclonic curvature of the isobars, (as by that air mass which is subjected to cyclogenesis or anticyclogenesis of the field of pressure). Consequently, an air mass that is flowing from an anticyclonic to a cyclonic circulation should show a tendency to *u* characteristics, while an air mass that is flowing from a cyclonic to an anticyclonic circulation should show a tendency to *s* characteristics. Thus with a stationary or slowly-moving pressure system, unstable air masses are expected between each Low and the following High, and stable air masses between each High and the following Low.

*(3) Strong poleward versus strong equatorward flow of air masses.* In any uniform meridional air current, the geostrophic wind velocity which is required by any pressure gradient varies inversely as the sine of the latitude. Consequently, there is a lag in the adjustment of the geostrophic or gradient wind to the existing pressure gradient at any point, such that in a current moving poleward the wind velocity tends always to be slightly supergradient. Some horizontal convergence occurs, therefore. In a current moving equatorward the wind velocity tends to be slightly less than gradient, so that some horizontal divergence occurs. Furthermore, the warmth of the poleward moving tropical current relative to the surrounding atmosphere favors ascending movement, while the coldness of the equatorward moving polar current favors subsidence and horizontal spreading. Consequently there is a tendency for polar air masses to reach lower latitudes with *s* characteristics, and for tropical air masses to reach higher latitudes with *u* characteristics.

It is to be noted that the *s* or *u* characteristic of an air mass cannot be definitely associated with the air mass source region and the subsequent trajectory of the mass like the other characteristics. In most cases if the air mass source region, the trajectory, and the season of the year are known, then the correct designation of the other characteristics of the air mass is readily deduced; but the *s* or *u* characteristic varies from one occasion to the next, according to the local variation of the circulation pattern in which the air mass moves. However, source regions or other areas which normally are occupied by frontal zones and cyclonic cells, or by anticyclonic cells of the general circulation, can be designated as normally imparting *u* or *s* characteristics, respectively, to the air masses which originate in them or migrate through them.

SOURCE REGIONS

The primary air mass source regions are either in high latitudes or in low, and on this basis the designators P (polar) and T (tropical) are chosen. An attempt to fashion greater detail, for example to consider whether high latitude air masses are either *Arctic* or *Polar*, yields no further information. It has been found that such a differentiation must be based on the thermal stratification and vertical homogeneity of the mass, a matter which is treated more objectively by the *s* and *u*, k and w designators already considered.

It is true, of course, that some have made the Arctic-Polar, Tropical-Equatorial distinctions on the basis of surface or upper-air temperature, but such criterion is not reliable. Examples of Arctic air can be found which are either colder or warmer than Polar air at the surface, depending on the strength of the radiation inversion in the Polar air mass. Furthermore, the 10,000 foot temperature in an air mass with even middle-latitude characteristics can be reduced by dynamic, nonadvective effects below the corresponding temperature in an "Arctic" air mass.

When a polar air mass moves into the tropics, or a tropical air mass into a polar region, it rapidly loses its original characteristics, and acquires the properties and the designation of the new source region. This is essentially the process of the general circulation. The final transformation of the polar into tropical air masses at low latitudes is observed repeatedly, but the corresponding transformation of tropical air masses in polar latitudes is seldom observed directly, for the tropical air masses are usually forced aloft above the polar air masses in the higher latitudes.

## LAND AND SEA EFFECTS

From the condition of homogeneity which is required of an air mass source region, it is evident that the source regions must be uniformly continental or maritime. Both the thermal and the hydrometric influence of a source region on its air mass properties depend primarily upon its continental or maritime characteristics. Thus the four primary source regions, where the air masses acquire their basic homogeneous characteristics, are cP, mP, cT, and mT. The c or m designation indicates whether the air mass leaves the source region with the relatively dry continental characteristics such that condensation forms are scarce and not easily produced, or whether it leaves with moist maritime characteristics such that condensation forms are to be expected.

It does not necessarily follow, however, that a maritime air mass is moist at upper levels as well as in the surface layers. If the thermal stratification of the air mass in a maritime source region is markedly stable, then the moistening effect of the water surface is restricted to the lowest frictional turbulence layer. If the stratification is unstable, the moistening effect is carried upward as far as convection from the surface can extend.

The transformation of a continental into a maritime air mass usually takes place rapidly when the air mass moves from a continental area over the ocean, for evaporation into dry air takes place uniformly at a rate which depends upon the difference between the saturation vapor pressure for the temperature of the water surface and the prevailing vapor pressure in the air. The transformation of a maritime into a continental air mass, however, seldom takes place with the same promptness, for there is nothing which necessarily effects the immediate removal of moisture on a large scale from a maritime air mass which moves inland. Such a removal of moisture may be effected gradually by extreme continental cooling of the maritime air mass at high latitudes in winter, or more rapidly by the forced ascent of the inland moving maritime air mass over mountain barriers. But in the absence of one or the other of these active dehydrating influences, the maritime air mass retains its maritime designation even to the interior of a continent, whereas the continental air mass usually acquires maritime characteristics at least in the surface turbulence layer (and is given a maritime designation), while it is still not far offshore.

## *HEIGHT LINES FOR ML 124*

*Some domestic weather stations have found it worthwhile to prepare a transparent overlay for ML 124, the Pseudo-Adiabatic Diagram. The overlay is marked with pressure-height curves derived for several surface temperatures from the lapse-rate in the standard atmosphere. Such a device facilitates comparison of the synoptic sounding with the standard atmosphere, and gives approximate information about the true height of each significant point.*

*Orientation of the overlay is often accomplished by marking the 0° isotherm thereon, and lining it up with the corresponding abcissa on ML 124 when each raob is to be plotted.*

# WEIGHT CHARTS

by Lts. RICHARD BRAUN & AVRON DOUGLIS

In recent years, it has become increasingly common in the drawing of surface prognostic charts to supplement the evidence of surface maps by reference to charts of various upper levels in the atmosphere. Even casual reference to upper charts frequently provides useful indications of what is to occur. Thus, if warm or neutral advection is indicated at all levels below 13km over a particular area, and pressure falls are forecast at 13 km, it is probably safe ordinarily to conclude that surface pressures over the area will fall. Visual inspection alone, however, will not suffice to indicate the amount of the fall. Moreover, if expected reductions in the density below 13km are offset by expected pressure rises at 13 km, it may be difficult to decide whether a fall in the surface pressure will occur at all. Evidently, therefore, a method is required which will balance quantitatively the expected changes in various layers.

A simple method of doing this, which has been successful on 24 hour forecasts during summer and fall, is achieved through the use of "weight charts". This device was originally suggested by Dr. O. R. Wulf of the Department of Meteorology, University of Chicago.

The weight of a column of air of unit cross section between two levels is measured by the pressure difference between the levels. The weight, and hence the mean density, of a moving column are not ordinarily conservative with time. Hence, weight isolines cannot be prognosticated to move with the gradient wind. However, the movement of these lines can be extrapolated with considerable success, and this fact provides the basis of the weight method of forecasting surface pressures.

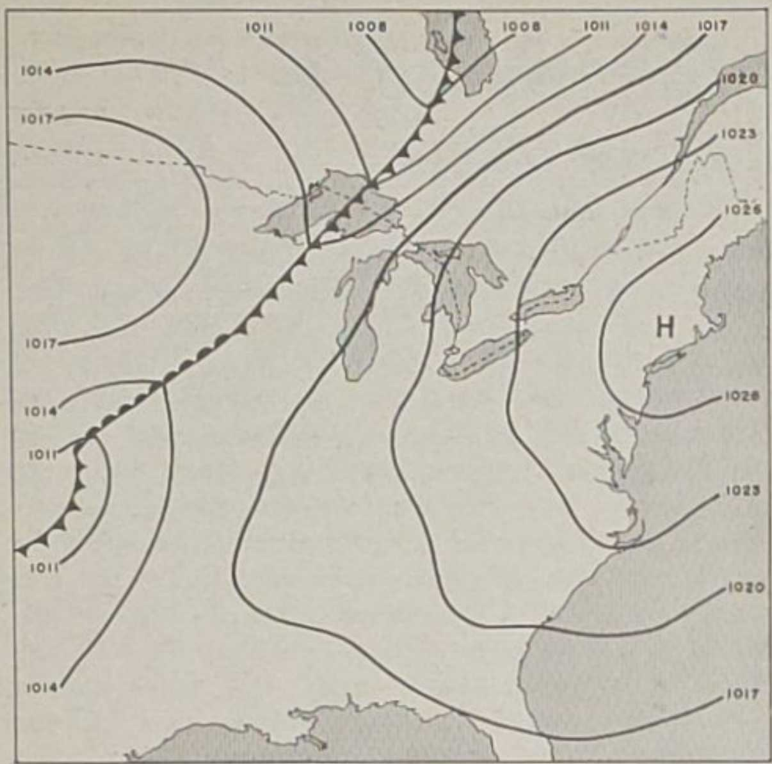
For purposes of forecasting, the atmosphere is divided into three layers between sea-level and 13 km. The first layer is between sea-level and 3.05 km (10,000 ft), the second layer between 3.05 km and 10 km, and the third layer between 10 km and 13 km. For each layer on a separate map, weights (i.e., pressure differences between top and bottom of the layer) are plotted. Isopleths of weight for every 2 mb are then drawn on each map, and the isobars for an intermediate level of the layer are superimposed. Thus, the 5,000 ft. isobars are drawn on the weight map for the layer between sea-level and 3.05 km; the 20,000 ft isobars on the map for the 3-10 km layer; and the 10 or 13 km isobars on the map for the 10-13 km layer.

This procedure is carried out by drawing isopleths of weight, instead of isotherms, on the 5,000 ft, 20,000 ft, and 10 or 13 km charts. 24 hour forecasts of weights for each layer are made at given stations. In making these forecasts, the isopleths of weight are usually assumed to move in the direction indicated by the corresponding isobars or actual (reported) winds. The speed of movement of the isopleths is assumed to be the same as the speed in the preceding period, unless the isobaric gradient has changed, in which case the prognosticated speed is changed in proportion. After these forecasts are made for each of the three layers separately, it is necessary to obtain independently a forecast of the 13 km pressure at each station. Finally, an estimate of the sea-level pressure at each station is obtained as the sum of the prognosticated layer weights and the prognosticated 13 km pressure.

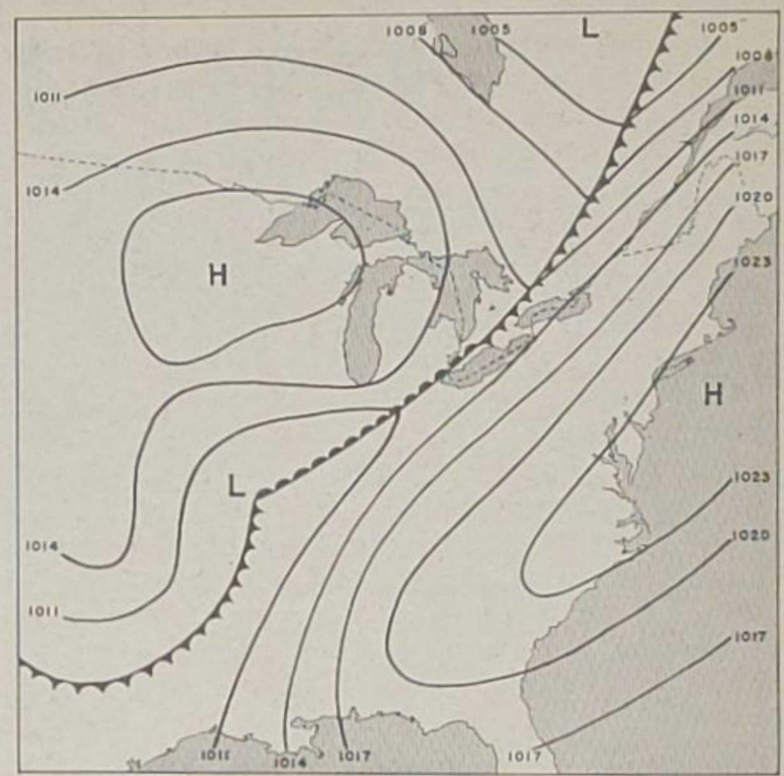
The procedure described so far, the one which has been tested at this station, has been entirely mechanical without reference being made to the synoptic maps, except to obtain the mean flow patterns. At times, much better forecasts might have been made had certain known synoptic factors been taken into account. However, the purpose was to test the basic method with as much objectivity as possible and to introduce subjective elements into the procedure only after this appraisal had been made.

Weight forecasts for 15 to 20 points in the Eastern United States are regularly made at the University of Chicago Weather Station to supplement the other available data used in the preparation of 24 hour prognostic charts from 0630 Z data.

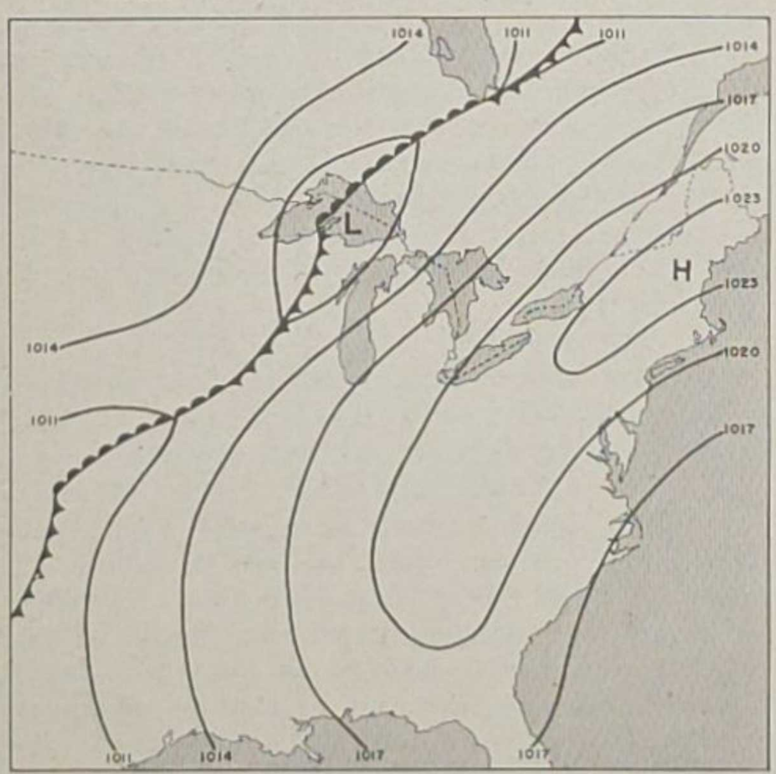
In order to illustrate their utility in drawing surface prognostic charts, a day was picked on which it was felt that a 24 hour prognostic of the 13 km chart could be drawn with considerable confidence. On this day, 19 September 1944, two 24 hour surface prognostics from the 0630 Z map were drawn. The first was made by customary means without the use of weight forecasts; the second, according to the weight forecasts only. The results are shown in the accompanying figures.



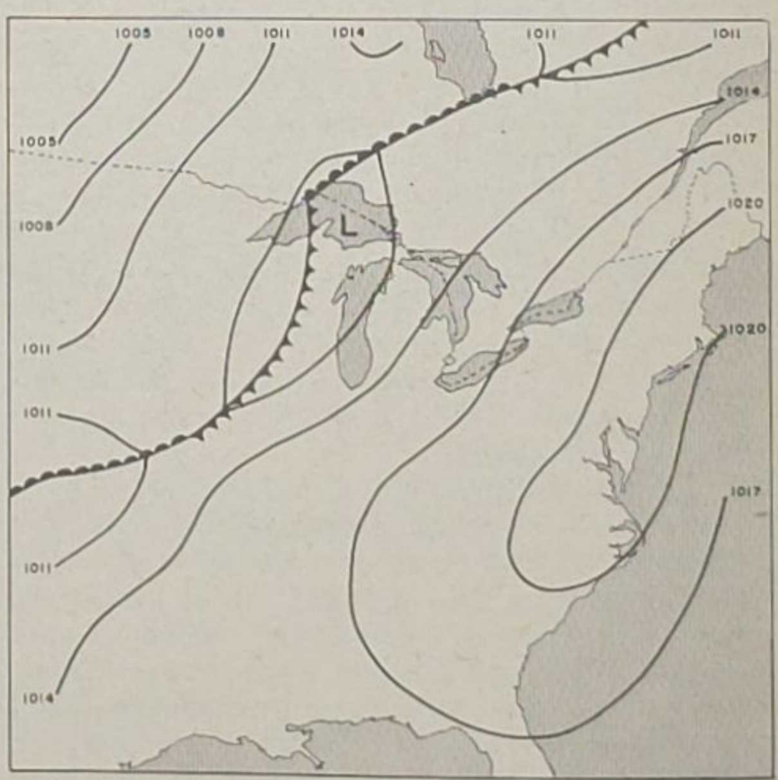

ACTUAL MAP: 19 September 1944, 0630Z




24 HR PROGNOSTIC MAP: made without weight forecasts




25 HR PROGNOSTIC MAP: using weight forecasts




VERIFICATION MAP: 20 September 1944, 0630Z

It is both interesting and important to note that by the use of the weight fore casts the pressure trough and accompanying fronts would remain to the west of Chicago, and not move to the Detroit region as was prognosticated without the weight forecasts. The sea level pressure as forecast by the weight method, although a little too high in the East and at Chicago, nevertheless clearly indicated the fact that the high would maintain itself over the eastern half of the United States; and secondly, that the pressures would not build up in the Minneapolis region. The latter of these facts was not evident from the indications in that region on the 19 September, 0630 Z, map. Although the average deviation of the forecast sea level pressures from the verification was 2.2 mb, it is important to note that they presented a pattern that was consistent within itself, and very close to the pattern of the verification map.

A second illustration of the potentialities of weight forecasting occured a week later. It is remarkable then that cyclogenesis was anticipated correctly in the Minneapolis area by weight analysts, while the contemporaneous routine prognostic map did not evidence the deepening. The main decrease in surface pressure was due to the advection of light air below 10,000 feet.

A further illustration of the utility of weight analysis in coordinating the interpretation of all the upper air charts is furnished by the events of the succeeding two days over Oklahoma City. Sea level pressure was 1015 mb at midnight, falling to 1009 mb 24 hours later. As at Minneapolis the day before, this decrease in pressure was due entirely to the advection of less dense air between the surface and 13km. In this instance there was a decrease in density in each of the layers rather than in the lowest layer alone. This advection was forecast correctly, and the weight chart prognostic indicated the Low over Oklahoma City. The weight charts then indicated eastward movement to the vicinity of Jackson for this center in the next 24 hours, contrary to other indications that the Low should move more to the north. The actual translation was eastward: quite close to the weight chart prediction.

A simple and effective method for summarizing the results of mechanical pressure forecasting is found in the use of three quantities:

(1) *The mean of the absolute value of the forecast error:* deviation of the forecast value from the verified value).

(2) *The error ratio:* the ratio between the mean absolute error and the mean absolute change over the forecast period.

(3) *The proportion of forecasts which were made in the correct direction.*

These three quantities were applied to the data for 7 September to 15 December. The lowest mean absolute error is found for the column 10-13km, in which the least mean absolute change is ordinarily observed. The greatest error is found for the column 0-3km. A tendency is apparent from the data in Table 2 for errors in the weight forecast for one layer to be compensated in part by the errors in forecasts for the other layers. In the month of November, for example, the mean absolute error of sea level pressure forecasts is actually less than the mean absolute error of weight forecasts for the entire column!

Table 2: Mean Deviations in Four Months

| Height (km) | Abs Change | Abs[1] Error | No. Fcsts | Error[2] Ratio | %Correct[3] Direction |
|---|---|---|---|---|---|
| 13 | 1.9 | 1.7 | 619 | 89 | 79 |
| 10-13 | 1.9 | 1.4 | 656 | 74 | 85 |
| 3-10 | 2.5 | 1.8 | 687 | 72 | 79 |
| 0-3 | 3.8 | 2.4 | 609 | 63 | 80 |
| Surface | 4.9 | 3.1 | 542 | 63 | 77 |
| 0-13 | 4.9 | 3.0 | 575 | 61 | 80 |

A steady increase was noted in the mean absolute error, from 1.9mb for the summer to 3.4mb for the first half of December. This increase, however, is primarily the result of an increase in the mean absolute 24 hour weight changes, for the error ratios do not exhibit a corresponding rise over the period.

It has already been emphasized in this report that the method of weight forecasting has been made as mechanical as possible

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| OFFICERS | Avg Dev of Forecast From Verified Values of all Layers (147 Values) | Avg Dev of Initial From Verified Values of all Layers (147 Values) | Avg Dev of Forecast From Verified Values of Layer (0-13km) Where Range is 0-5 mb. (33 Cases) | Avg Dev of Initial From Verified Values of Layer (0-13km) Where Range is 0-5 mb. (33 Cases) | Avg Dev of Forecast From Verified Values of Layer (0-13km) Where Range is 5-10 mb. (12 Cases) | Avg Dev of Initial From Verified Values of Layer (0-13km) Where Range is 5-10 mb. (12 Cases) | Avg Dev of Forecast From Verified Values of Layer (0-13km) Where Range is 10-15 mb. (4 Cases) | Avg Dev of Initial From Verified Values of Layer (0-13km) Where Range is 10-15 mb. (4 Cases) | Correlation of Forecast with verified weight Chgs. for layer from 0-13km. |
| A | 1.7mb | | 1.8mb | | 4.4mb | | 5.5mb | | +.814 |
| B | 1.2mb | | 1.3mb | | 2.5mb | | 2.5mb | | +.912 |
| C | 1.7mb | | 2.0mb | | 3.3mb | | 5.6mb | | +.805 |
| D | 1.7mb | 2.4mb | 1.8mb | 2.2mb | 3.7mb | 7.1mb | 4.0mb | 1.3mb | +.811 |
| E | 1.8mb | | 1.9mb | | 4.6mb | | 6.5mb | | +.721 |
| F | 1.7mb | | 2.3mb | | 4.0mb | | 5.5mb | | +.744 |
| G | 1.6mb | | 1.6mb | | 3.0mb | | 5.6mb | | +.831 |

TABLE 4: Results of a test to determine the value of previous experience in forecasting weights. Officers A, C, D, and G had made 4 forecasts beforehand; E and F were inexperienced; and B had had four months of experience with the method.

so that it may be appraised with as much objectivity as possible. Despite this, there is admittedly some element of personal judgment involved, and it was considered desirable to ascertain how important this element might be. Accordingly, a test was devised, the results of which are given in Table 4. A comparison of the officer B, who was experienced in the making of weight forecasts, with E and F who were not, clearly indicates the advantage of some experience. However, the results of all six inexperienced officers were good. It is true, as indicated by column 8, that experience would be an advantage in the few cases of large actual changes; but for the majority of cases, a forecaster with little experience could do almost as well.

There were 343 forecasts for the 0-13 km layer made during this test, but only 36 were in the opposite direction from the actual change. And it is especially interesting to note that the number of stations at which "wrong direction" forecasts were made is quite small. On October 10, for example, when there were 16 forecasts made in the wrong direction, only three stations were involved. Of six such forecasts on 11 October, five were for Omaha. The methods which have been adopted to forecast weights seem to give fairly uniform results, even in the hands of personnel inexperienced in this technique.

The best weight forecasting for the entire column has been done for Nashville, with a mean absolute error of 1.9mb. This is hardly surprising, since Nashville is not near the periphery of the data, and orographic effects should be relatively unimportant there. It was also to be expected that some of the poorest results would be obtained at Sault Ste. Marie and Minneapolis, since the flow over these stations is frequently from a region of sparse radiosonde data. This explanation might also account in part for the large error ratios for Jackson and Atlanta. It fails, however, to explain the mean absolute error of 3.0mb obtained at Oklahoma City. Forecasting at this station, Jackson, and Atlanta was often confused by the fact that the isopleths of mean densities frequently will move in a direction opposite to that indicated by the existing wind flow. This effect is the result of vertical motions and horizontal convergence.

It is evident from the data presented above that weight forecasts can be useful in the preparation of surface prognostic charts. It is seen from the same data, however, that moderate to large errors in forecast pressures do occasionally occur. Some of these errors will be seen at once if the prognosticated sea-level pressure is inconsistent with almost unmistakable indications of the surface synoptic chart. More often, however, it will be difficult to decide whether to draw for the weight forecasts or not, or, if some of the prognosticated pressures are seemingly inconsistent with others, which of them to neglect. It is, therefore, of interest to consider the various known sources of error inherent in weight forecasting technique.

*(1) Data Inadequacy.* Forecasting for Sault Ste. Marie, Chicago, Albany, etc., is always difficult under conditions of northerly flow because of the sparseness of radiosonde data in Canada. For similar reasons, forecasts for stations near the Gulf Coast are uncertain with southerly winds, and Atlantic coast pressures provide a problem with easterly currents.

*(2) Reduction of pressure to sea-level.* For a station situated above sea-level, the "weight" of a column of air from 0-3 km is fictitious, because the sea-level pressure is used in the computation. Between the mountain ranges, this limitation of the method is not ordinarily of significance. Over mountainous country, however, it is not believed that the weight of the lowest layer could be forecast successfully, partly because of sea-level reduction, and partly because of the dynamic adjustments associated with flow over uneven terrain. Further work might serve to elucidate this matter, as it has not received systematic attention at this station.

*(3) 13 km pressure forecast.* The application of any weight forecasting procedure must involve an independent pressure forecast at some level in the atmosphere. In the work at the University of Chicago Station, this level has been 13 km, except for a period of one week in which 10 km forecasts were made. It is apparent, therefore, that successful prognostication by the weight technique of sea-level pressures depends as much upon good 13 km pressure forecasts as upon good weight forecasts in the three layers from 13 km to sea-level. The problem of forecasting the 13 km pressure, however, is distinct from that of forecasting the weights of layers, and it will not be discussed in this paper. The results of the 13 km forecasting, however, as presented in Table 2, are noteworthy. For all stations over the period 7 September to 15 December 1944 the average absolute error

of 13 km pressure forecasts was 1.7 mb compared with the average absolute error of 3.0 mb in the weight of the layer 0-13 km. The actual average absolute change in the 13 km pressure over the given period of time was 1.9 mb. It is obvious therefore that although the 13km forecast may be poor, relative to the actual change at 13 km, it may yet be of relatively small importance as a source of error in the prognosticated surface pressure. A tendency has been observed, furthermore, for mutual compensation to occur to some extent between errors in the pressure forecast for 13 km and those in the weight forecast for the column 0-13 km.

*(4) Vertical Wind Shear in Column.* It has already been explained that weight forecasts for a layer are obtained by the extrapolation of weight isolines in accordance with the indications of the wind flow at an intermediate level of the layer. Moderate changes in wind direction and speed from bottom to top of the column do not appear to have been important sources of error in the method. Large changes in association with moderately close spacing of weight isolines would, however, invalidate the use as a mean flow pattern of the isobars of an intermediate level. A possible alternative to the latter device, which would be free of this objection, is furnished by the "transport function" of Professor V.P. Starr, Department of Meteorology, University of Chicago. Work will soon begin on the transport function to see if its use results in measurable improvement of forecasting.

*(5) Flow-pattern Changes.* Even if a mean flow should be used in prognosticating weights, which eliminates the error ascribable under existing means to vertical wind shear, there would still be an error in prognosis because of the change in flow pattern over the forecast period. Ordinarily, a 24 hour interval is sufficiently short that the weight isolines can be moved in accordance with indications of the flow prevailing at the beginning of the period, Occasionally, changes in the pattern are so pronounced, however, that considerable error results from that procedure. Instances have been observed where the direction of flow over the area considered was approximately west-east at the beginning of the period, and changed to northwest-southeast by the end. Isopleths of weight, in accordance with the procedure described above, had been extrapolated towards the east-southeast, the direction approximately of the mean flow during the period, and the results obtained were disappointing. Up to the present, no means has been found to deal with this problem satisfactorily. Until an adequate method is discovered, it will be up to the analyst to anticipate sudden pattern changes by independent means and then to modify the weight forecasts according to his own discretion.

*(6) Changes in the Pressure at the Top or Bottom of a Moving Column.* One of the most common factors associated with the failure of the weight (and, hence, the mean density) of a moving column to be conservative is a change in the pressure at the top of the column. Other things remaining the same, a fall in the pressure at the top of a moving column should be associated with a fall in the mean density of the column, and vice versa. Occasionally, it has been plausible to ascribe weight forecasting errors predominantly to this cause. There is, however, no quantitative measure of the change in weight of a column which should be associated with a prognosticated change in the pressure at the top of the column. The analyst is guided only by the qualitative knowledge that they should probably change in the same direction.

(7) *Horizontal convergence and Divergence.* The weight of a moving column, which is proportional to its mean density, will increase with horizontal convergence and decrease with horizontal divergence (unless the latter effects are overbalanced by vertical divergence or convergence, respectively). Since weight forecasting is not concerned with individual moving columns as such, but is based on the extrapolation of isopleths of weight, it is apparent, however, that the mere existence of convergence, divergence, or of any other disturbing factor is not sufficient to result in forecast error. For an error to occur, it is necessary that the intensity of operation of the disturbing factor should be changing. Thus, with increasing horizontal convergence, it can usually be anticipated that forecast weights will be too low; with increasing horizontal divergence, too high.

*(8) Vertical Motions.* The transport of mass through the top or bottom of a moving column may affect the mean density of the column, hence its weight. As explained in the preceding paragraph, no such process, however, can be a source of forecasting error, unless it is changing in intensity. A detailed study of vertical movement and horizontal divergence, in which attention will be paid to the impli-

cations held for weight forecasting. is to be begun shortly.

*(9) Water Vapor Condensation and Evaporation.* Because of the release of latent heat at condensation and the absorption of latent heat at evaporation of water, the weight of a moving column, especially between sea-level and 10,000 feet, can be expected to depend on some water vapor processes which occur in it. It is to be emphasized, however, as with the other factors mentioned above, that only the changes which occur in the intensity of these processes will result in forecasting error.

*(10) Radiation.* The emission of radiant energy during the night and its absorption during the day, to the extent that these processes change in intensity from day to day, probably are disturbing factors in weight forecasting. It is believed, however, that changes in the operation of other factors are of more significance than this for forecasts over a 24 hour interval.

*(11) Diurnal Changes.* Little of the diurnal effect is known exactly. 12hr forecasts in the summer were abandoned because of the extreme difficulty in estimating the diurnal pressure changes that occur at 13 km. An effect which probably influences even 24 hour forecasts is the normal change in pressure pattern and wind flow which is known to occur diurnally. Little is understood of this matter, however, and it is probably of considerably less importance to the making of weight forecasts than others of the factors discussed.

*(12) Failure of Surface and Upper-Air Charts to be Synoptic.* There is a two and one-half hour difference between the times of the observations on the surface map and on the upper-air maps. Ordinarily, this probably makes little difference to the results. Where the three-hour tendencies on the surface synoptic chart are more than a millibar, however, it would be worthwhile to correct the reported surface pressures by the amount of the tendencies. This procedure has not been followed as yet in this station, but its adoption is anticipated.

It should be evident from the foregoing discussion that the practical use of pressures which are forecast by the weight method must be preceded by the careful consideration of those factors at work which might lead to error. Blind acceptance of the results of the mechanical procedure will frequently not lead to the construction of satisfactory prognostic charts. If weight forecasts are used with discrimination, however, they can be of decided aid in the construction of such charts. The procedure which has been found most satisfactory at the University of Chicago Station is (1) to determine by use of all the ordinary means the movements of frontal and pressure systems, (2) to determine, also by ordinary means, the changes during the forecast period in the intensity of systems, (3) to sketch hurriedly the isobaric pattern which would result from these determinations, and, only after complete use has thus been made of all the ordinary techniques used in forecasting, (4) to mark at each station the pressure as prognosticated by the weight method. Occasionally, there will be close agreement between the pressure forecast obtained from weights and that obtained from the provisional isobars already drawn. Frequently, however, there is a discrepancy between the two forecasts. When this occurs, it is necessary to reconsider the basis of each. Thus, for example, suppose the weight forecast is higher than the isobar forecast for a station which will be on the eastern side of a cold high which probably is beginning to subside. In this instance, it would be wise to discard the weight forecast and to draw for the other, since it is known that under the given circumstances weight forecasts are subject to an upward bias. On the other hand, under circumstances, say, of persistent, strong, and deep southerly flow, with the advection of less-dense air in the troposphere and of more-dense air in the stratosphere above it, weight forecasts would ordinarily be superior.

The variety of synoptic situations which can occur is so great that the sample of them which is presented in a season of a single year is probably not very representative. Partly for this reason, and partly because of the heterogeneous character of the aggregate of stations included in the study, it is believed that the further accumulation of data may result in the modification of some of the conclusions stated in this paper. In addition, it is hoped that future research undertaken in the directions already mentioned in this paper will succeed in the further elucidation of some of the obstacles which still exist to the application of a truly objective method for predicting pressure patterns.

Lts. Harold Wagner, Jerome Rygg, Melvin Beemer, and William Fralick; Capt. R.T. Nelson (SWO); and the University of Chicago staff gave assistance and advice in this research project.

CONTENTS



(R) means Restricted

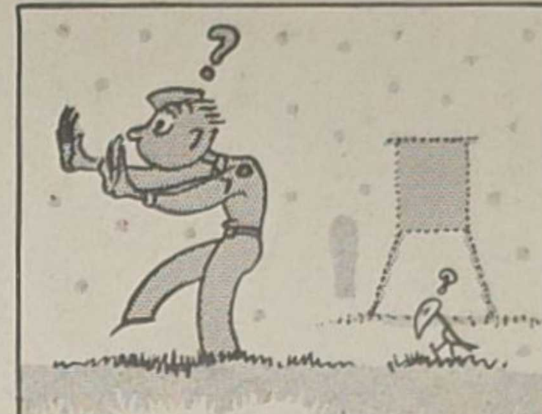
# REASONS FOR NO PILOT BALLOON OBSERVATION

SNOWING

**PISO**


RAINING

**PIRA**

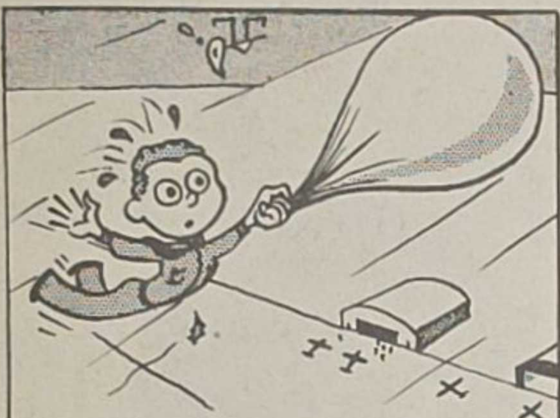


FOGGY

**PIFO**

LOW CLOUDS

**PICO**



HIGH OR GUSTY SURFACE WIND

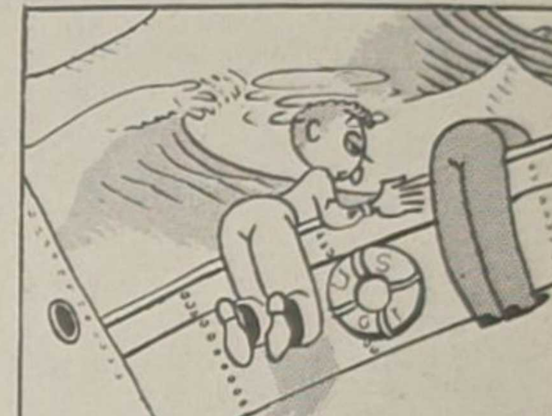
**PIWI**

THICK DUST

**PIDU**

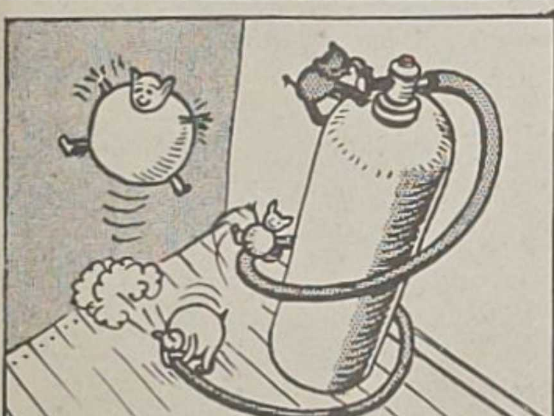
SMOKY

**PIKO**



UNFAVORABLE SEA CONDITIONS

**PISE**



NO GAS

**PIHE**


NO BALLOONS

**PIBA**

INSTRUMENT TROUBLE

**PIIO**

NOT FILED

**PIFI**

AFTER SGT GLENN STONEX 8TH WX