WEATHER SERVICE

Bulletin

HEADQUARTERS AAF WEATHER SERVICE

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HEADQUARTERS
AAF WEATHER SERVICE
Asheville, North Carolina

18 September 1945

To All AAF Weather Personnel:

Now that the war is over, there is an understandable tendency to "let down", to relax our efforts. But the Japanese surrender has not lessened materially the responsibility of the AAF Weather Service to provide accurate and extensive weather information for the armed forces. During the days of redeployment just ahead, the demand for weather service is not likely to diminish, and in some areas it will increase. Weather personnel must continue to put forth their best efforts so that the safety of air transport operations will be maintained.

I do not underestimate the magnitude of this task. In domestic regions, where much of the increase will be felt, many stations are already operating with no more than half of their authorized strength. This shortage will be intensified by a gradual release of weather personnel from the service in accordance with War Department directives. While decisive action is being taken to relieve this condition, it will be some time before much improvement is noticeable. Until then, reduced staffs must continue to provide the best possible service.

It is my desire to commend each of you for your devotion to duty in the trying days which have passed. I am confident that you who have conducted yourselves so creditably throughout the war will continue to give the same conscientious attention to your new responsibilities in redeployment and adjustment to peace.

D. N. YATES
Colonel, Air Corps
Chief, AAF Weather Service

COELUM AD PROELIUM ELIGE

Reprinted from the
Technology Review

THE BUILDERS

by Dr. Vannevar Bush

The process by which the boundaries of knowledge are advanced, and the structure of organized science is built, is a complex process indeed. It corresponds fairly well with the exploitation of a difficult quarry for its building materials and the fitting of these into an edifice; but there are very significant differences. First, the material itself is exceedingly varied, hidden and overlaid with relatively worthless rubble, and the process of uncovering new facts and relationships has some of the attributes of prospecting and exploration rather than of mining or quarrying. Second, the whole effort is highly unorganized. There are no direct orders from architect or quarrymaster. Individuals and small bands proceed about their business unimpeded and uncontrolled, digging where they will, working over their material, and tucking it into place in the edifice.

Finally, the edifice itself has a remarkable property, for its form is predestined by the laws of logic and the nature of human reasoning. It is almost as though it had once existed, and its building blocks had then been scattered, hidden, and buried, each with its unique form retained so that it would fit only in its own peculiar position, and with the concomitant limitation that the blocks cannot be found or recognized until the building of the structure has progressed to the point where their position and form reveal themselves to the discerning eye of the talented worker in the quarry. Parts of the edifice are being used while construction proceeds, by reason of the applications of science, but other parts are merely admired for their beauty and symmetry, and their possible utility is not in question.

In these circumstances it is not at all strange that the workers sometimes proceed in erratic ways. There are those who are quite content, given a few tools, to dig away unearthing odd blocks, piling them up in the view of fellow workers, and apparently not caring whether they fit anywhere or not. Unfortunately there are also those who watch carefully until some industrious group digs out a particularly ornamental block; whereupon they fit it in place with much gusto, and bow to the crowd. Some groups do not dig at all, but spend all their time arguing as to the exact arrangement of a cornice or an abutment. Some spend all their days trying to pull down a block or two that a rival has put in place. Some, indeed, neither dig nor argue, but go along with the crowd, scratch here and there, and enjoy the scenery. Some sit by and give advice, and some just sit.

On the other hand there are those men of rare vision, who can grasp well in advance just the block that is needed for rapid advance on a section of the edifice to be possible, who can tell by some subtle sense where it will be found, and who have an uncanny skill in cleaning away dross and bringing it surely into the light. These are the master workmen. For each of them there can well be many of lesser stature who chip and delve, industriously, but with little grasp of what it is all about, and who nevertheless make the great steps possible.

There are those who can give the structure meaning, who can trace its evolution from early times, and describe the glories that are to be, in ways that inspire those who work and those who enjoy. They bring the inspiration that not all is mere building of monotonous walls, and that there is architecture even though the architect is not seen to guide and order.

There are those who labor to make the utility of the structure real, to cause it to give shelter to the multitude, that they may be better protected, and that they may derive health and well-being because of its presence.

And the edifice is not built by the quarrymen and the masons alone. There are those who bring them food during their labors, and cooling drink when the days are warm, who sing to them, and place flowers on the little walls that have grown with the years.

There are also the old men, whose days of vigorous building are done, whose eyes are too dim to see the details of the arch or the needed form of its keystone; but who have built a wall here and there, and lived long in the edifice; who have learned to love it and who have even grasped a suggestion of its ultimate meaning; and who sit in the shade and encourage the young men.

A-B-C's OF OBSERVING

by S/Sgt. David Nichols

At 1700Z the telephone rang at an AAF weather station located near the jungles of the Panama Isthmus. A weather observer picked up the phone and heard the voice of a Panamanian native.

"B - B - C - C - D: Jose."

The native pronounced the words very carefully and distinctly and then hung up. He had made his complete report.

At the time this message came in, similar reports were being telephoned to other nearby AAF weather stations. All the reporters were natives who could speak no English other than the letters "A", "B", "C", "D", and "E". To them, "A" meant *bonita;* to the American weather observers, it meant a clear sky. Similarly, "B" denoted *nubes*, a cloudy condition; "C" signified *oscuro*, an overcast sky; "D" indicated *agua*, rain; and "E" reported *peligro*, a thunderstorm. Every hour each native sent in his report, consisting of one five-letter group. The first letter indicated the sky condition at the observation point, and the remaining letters reported the condition of the sky in the four quadrants. The observer's name was his "station identification".

The rainy season in the Panama area lasts for about nine months. During this long stretch, great cumulonimbus masses wander erratically over the Isthmus, growing and dissipating in small-scale eddies. At the same time, the Intertropical Convergence Zone moves northward, crosses the Isthmus, and generates many more thunderstorms there.

These storm areas present a serious hazard to the fighter aircraft which guard the Canal on constant patrol duty. Weathermen of the Sixth Squadron at airports in Panama could not hope to observe and track them all, or even most of them. Then somebody remembered the Panamanian observers of the Aircraft Warning Service. Living on isolated hilltops in the interior of Panama, these natives had been hired to observe all aircraft flying over their jungle lookouts. Telephone lines had been strung through the wilderness so that the reports of the natives might be flashed to the Information Center of the Fighter Command. Now the idea was to make weather observers out of these boys. Spanish was the only language they knew, so the project was not to be an easy one.

S/Sgt Arthur R. Ortiz of the Sixth Weather Squadron had many friends in the Canal Zone, where he was the confidant of the *alcaldes* and a favorite of the *senoritas*. S/Sgt Ortiz was also a seasoned weather observer with a bilingual background. He could handle a surface observation in either English or Spanish. So what could be more natural than for Ortiz to visit these remote hills and instruct the Panamanians in a few basic principles of weather observing.

Ortiz started out by truck and before long he wished he had a power-driven winch instead to help him traverse the morass of the trails that kept disappearing beneath layers of mud. On one occasion it took him two days to reach a single station. Another time, just outside of a native village, after covering only 14 miles in seven hours, he bogged down completely. There was a small village ahead and a treacherous piece of territory containing a couple of rivers just beyond it. He managed to get the truck started and pulled up to the village. There he traded the truck for a horse and continued on his way, fording the rivers on hand-drawn ferries. S/Sgt Ortiz completed his journey all right, but there were many moments when he reflected how nice it would have been if they had left him sitting on his girl's patio.

The AAF weather service in Panama was well rewarded as a result of Ortiz's expedition. He formulated the simple five-letter group code which the natives grasped very easily. He made no attempts to teach them how to estimate cloud heights or wind speed and direction. Ortiz began his circuit with four stations reporting. As the value of the service was established, other points were added until he controlled a network of 11 stations serving a region of some 800 square miles. Today the visual observations made by the natives are handled according to schedule. Every hour they are telephoned to the nearest AAF weather station. The sequence is transmitted over the weather teletype circuit and ultimately relayed to other Sixth Weather Region stations that clear traffic through the area.

The stuff Ortiz taught his pupils was rudimentary, to be sure; but when considered along with the regular observations (and especially the Rareps), the data received from the Oritz "weather squadron" was an important contribution to the job of tracking down the most significant storms.

OBSERVERS' EXAM

Certain questions on the Weather Observer Proficiency Examination given in April 1945 were missed by a very large percentage of examinees. Although some of the incorrect answers may have been due to misinterpretation of the questions, it is believed that the majority of these errors was due to confusion that still prevails about some procedures. In order to reduce this confusion and to make observing practices more uniform, certain pertinent questions have been selected for discussion in this article.

The distribution of answers given to the selected questions is shown below, followed by an explanation of the correct answer to each question. All questions are from Part I of the examination. Correct answers are italicized.

DISTRIBUTION OF ANSWERS

Question	% of examinees			
	a	*b*	*c*	*d*
# 2	7%	7%	36%	*50%*
#46	6%	45%	*48%*	1%
#54	5%	40%	*43%*	12%
#61	50%	*12%*	10%	28%
#72	1%	27%	49%	*23%*
#73	14%	42%	*33%*	11%
#75	15%	9%	22%	*54%*
#98	58%	*39%*	2%	1%
#100	11%	35%	*48%*	6%

Question 2:

A pilot balloon observation was taken at Denver, Colorado. The balloon was released at 1415 MST, and the run lasted 30 minutes. The correct first group in the transmitted report would be:

a. DV15 b. DV17 c. DV21 *d. DV22*

This question deals with the time that should be assigned to a pibal observation. Paragraph 2-905, Circular N, states that the time of a pibal run continuing for more than 20 minutes will be reported as 20 minutes after the time of balloon release. The time will, therefore, be 1500 MST to the nearest hour, which converts to 2200 GMT. The group to be reported, therefore, is DV22.

Question 46:

Continuous moderate rain is restricting the vertical visibility to 1,000 feet and the horizontal visibility to ½ mile. Thirty minutes ago, prior to the beginning of the rain, the sky was completely covered by nimbostratus clouds at a measured height of 3,000 feet. The observer believes that the cloud type and base have not changed. The code for the current state of sky and direction of motion of the clouds ($C_LC_MC_HD_c$) is:

a. 3006 b. 0209 *c. 0000* d. 0706

The point of this question is that the sky is obscured by rain. Therefore, the state of the sky cannot be observed. Even though the observer believes that nimbostratus clouds are still present, he should not report them unless he can actually observe them. (See page 7 of Appendix II to 1941 edition of Circular N.)

Question 54:

When three layers of clouds are present and two of the layers are below 10,000 feet, it is necessary to report one of these layers in "remarks". If both layers below 10,000 feet are scattered, the layer to be reported in "remarks" is:

a. the highest layer.
b. the middle layer.
c. the lowest layer.
d. the less significant of the two upper layers.

It is recognized that Circular N is not definite about this question. (See subparagraphs 2-137 f and g, Circular N.) However, if both layers below 10,000 feet are scattered, the upper layer comes nearer to representing a ceiling. For that reason, the upper layer should be reported in the body of the report, and the lower layer in REMARKS. This point will be emphasized in the forthcoming revision to TM 1-235, 'Weather Station Handbook for the Observer".

Question 61:

At 1330 EWT, an overcast of stratocumulus clouds without breaks was observed, moving from the north. A pilot reported 6/10 altocumulus and altostratus, with base at 14,000 feet, at 1245 EWT. The code group ($C_LC_MC_HD_ch_+M_+$) for 1330 EWT should be:

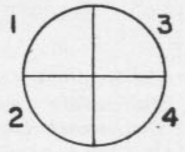
a. 5008 *b. 500843* c. 570841 d. 570943

Most examinees picked "5008", which makes no use of the pilot report. Appendix II to 1941 edition of Circular N states clearly on page 6 that h_+M_+ will be added to the $C_LC_MC_H$ group, *even when the upper clouds are obscured from observation at the surface*, if the pilot report is within one hour of the time of the surface observations. Many other examinees picked "570943", which uses the pilot report to determine the "state of the sky" with respect to middle cloud. But proper observations of "state of the sky" require a qualified observer on the ground, observing the sky at intervals over a period of time (page 21, Weather Bureau Circular S). A pilot is generally unable to judge the "state of the sky" because he is aloft in the air and is moving rapidly from place to place. To use pilot reports for the $C_LC_MC_H$ group would make the reports of this group non-uniform and lower their usefulness for plotting synoptic charts. The correct coding is, therefore, 500843. This coding will not seem inconsistent, if it is considered that: 1) the $C_LC_MC_HD_c$ group refers only to the state of the sky as it can be observed from the ground, and 2) the h_+M_+ group is a report of height and amount of clouds above 10,000 feet, which need not correspond to any particular element of $C_LC_MC_HD_c$.

Question 72:

The visual range in each quadrant is shown in the figure below. Select the prevailing visibility value you would report on the teletype:

a. 1 mile.
b. 2 miles.
c. 2½ miles.
d. 3 miles.



The answer to this question is clearly covered by subparagraphs 2-138 c, and 2-138 f, Circular N. The visibility should *not* be obtained by averaging the visual ranges observed in each direction.

Question 73:

Sparsely scattered water droplets, estimated 1/64 inch diameter, are falling continuously from overcast clouds, base 6,000 feet. Visibility is 7½ miles. The teletype report would be:

a. 60⊕ 8L-, remarks "L-VERY FINE".
b. 60⊕ 7L-, no remarks.
c. 60⊕ 7R-, remarks "PCPN FINE".
d. 60⊕ 8R-, no remarks.

Two points are involved in question #73: *Should the visibility be reported as 7 or as 8 miles?* and, *Should the precipitation be reported as rain or as drizzle?* The first point is covered in subparagraph 2-142 (a), Circular N. Although the drops are less than 1/50 of an inch in diameter, the precipitation should not be reported as drizzle because the drops are sparsely scattered and because the visibility is not low.

(See table 3 in subparagraph 2-145 (f), Circular N, under the subjects "rain" and "drizzle".)

Question 75:

There have been intermittent moderate rain showers for the last hour previous to the time of the observation, but at the observation no precipitation is occurring. Moderate squalls were observed 10 minutes before the observation. Under "weather" in the teletype report the observer will:

a. report no weather.
b. report moderate rain showers.
c. report moderate rain showers and moderate rain squalls.
d. report moderate rain squalls.

This question is covered by subparagraph 2-145 (k), Circular N. Squalls will be reported if they have occurred within 15 minutes prior to the observation.

Question 98:

If the cups of anemometer ML-80 are moving so slowly that a whole minute elapses without a buzz the speed will be indicated as:

a. calm. *b. 1mph.* c. 2 mph. d. 3 mph.

Most examinees answered "calm" to this question. The point is that the cups of the anemometer were *moving*. A calm should only be reported when the cups are not moving. (See subparagraph 2-161 (g), Circular N.) Therefore, whenever M_L-117 does not buzz within the period that it is observed, the observer should look at the anemometer cups before reporting "Calm".

Question 100:

An observer is determining the gustiness of wind by using the Indicator ML-117 and Anemometer ML-80. During a one minute period he counts 19 buzzes and the intervals between successive buzzes vary from 2 seconds to 5 seconds. The wind speed and gustiness should be reported as:

a. 19. b. 19-. *c. 19+.* d. 20-.

The answer to this question is 19+, since the indicated wind speed is varying from 12 mph to 30 mph (more than 10 mph) and the maximum velocity is greater than 24 mph. Circular N says [2-161 (i) and (j)]:

"(i) *Method of indicating character of*

1. *Fresh gusts* (-), when sudden, intermittent increases in velocity of 10 miles or more per hour reach 19 to 24 mph.

2. *Strong gusts* (+), when sudden, intermittent increases in velocity of 10 mph or more reach 25 mph or more.

(j) *Determining degree of gustiness:* It should be kept in mind when reporting gusts that the velocity of the wind at the peak of the gusts determines whether the gustiness will be reported as "fresh" or "strong". Further, gusts should never be reported, no matter what the velocity, unless the peak velocity is 10 miles per hour or more greater than the velocity between gusts. Unless the station is equipped with the pressure type of wind velocity indicator, it will be necessary for the observer to employ a great deal of care in estimating the degree of gustiness."

* * * *

Comments or questions about these solutions are invited (through channels).

ANALYSIS OF C.-P. SURFACES

by Major Robert Bundgaard

This article describes the operational procedure for the analysis of constant pressure surfaces which is practiced by the AAF weather centrals in Europe. The exact manner of work is set forth in terms of the specific requirements to be fulfilled in the actual practice of preparing the upper air analyses from constant-pressure-surface considerations. All the scales, charts, and tables necessary for the preparation of the analyses are included.

All analyses and prognoses are prepared upon charts of the same projection and scale in order to facilitate comparisons among them.

I. Preparation of the Observations:

The upper-air data are plotted on the charts according to the models on page 15 in black, red, and green ink. This use of color representation provides both for facility in plotting and for easy interpretation of the plot. The data appearing in black are present observations, which are available together and consequently are plotted together. The data plotted in green are observations taken 12 hours previous; these data are plotted at one time. The thermal thickness values and the observed wind shears, which are evaluated and tabulated separately from the heights and winds, are plotted in red. Only data in red are considered by one step in the analysis; whereas, only the data in black are necessary in another step of the analysis.

The abbreviated station model in Figure 5B is used where facilities for plotting and analysis are so limited that the complete procedure to be described in this article cannot be employed. The thermal model is used whenever it is required that the thermal analysis be made separately from the contour analysis.

The organization of upper-air observations into the plot of Figure 5 offers easy analytical interpretation. For example, a set of observations at the 700mb and 500mb surfaces is illustrated in Figure 5C, D. In the 500mb plot, the height of that surface is 18,170 feet, an increase of 400 feet during the past 12 hours. The total (1000-500mb) thickness has increased 450 feet, indicating that warmer air has replaced colder air during the last 12 hours. Inasmuch as the total thickness change is larger than the 500mb height change, it follows that the pressure at sea level has fallen during the past 12 hours. Since the 700-500mb thickness has increased 260 feet, the major contribution to the total thickness change is associated with a replacement of cold air by warm air in the 700-500mb layer, for by comparing +26 with +45 it will be seen that 60% of the 1000-500mb thickness change occurred in the 700-500mb layer. The 12-hour thickness change through the 700-300mb layer is 900 feet (Figure 5E). Comparison of +90 with +26 shows that 70% of the 700-300mb thickness change occurred in the 500-300mb layer. After comparing the 12-hour changes with the 24-hour changes in height and in thermal thickness, it can be calculated that the process of warm-air invasion is greater in the latter half of the 24-hour period. Further, by comparing +69 with +35 it can be seen that the warm-air invasion was uniform throughout the 1000-500mb layer during the previous 24-hour period. These considerations suggest that there is a warm front approaching the station and that the frontal zone has appeared in the 700-500mb layer.

The foregoing evaluations are compared with the observed wind shears through the various layers. In the 500 mb plot, the strength and direction of the observed wind shear for the 700-500mb layer, in

**SURFACE CHART* (sea level): with isobars at intervals of four mb., starting at 1000mb.

850mb SURFACE CHART (850mb Chart): fronts, contours, mixing ratio lines, isotherms.

**700mb SURFACE CHART* (700mb Chart): fronts, mixing ratio lines, isotherms at 700mb; and thickness lines for 1000-700mb layer.

**500mb SURFACE CHART* (500mb Chart): fronts, contours, mixing ratio lines, isotherms; and thickness lines for 700-500mb layer.

**300mb SURFACE CHART* (300mb Chart): contours, isotherms at 300mb, and thickness lines for the 500-300mb layer.

150mb SURFACE CHART (150mb Chart): contours and isotherms.

**CHART OF POTENTIAL TEMPERATURE CHANGE THRU THE LAYER FROM 850mb to 700mb; FROM 700 to 500mb; FROM 500 to 300mb* (three charts, 850-700mb θ-change Chart, etc.).

CHART OF EQUIVALENT POTENTIAL TEMPERATURE AT THE 850mb SURFACE; THE 700mb SURFACE; THE 500mb SURFACE (three transparent overlays, the 850mb θ_e Chart, etc.).

**CHART OF EQUIVALENT POTENTIAL TEMPERATURE CHANGE THRU THE LAYER FROM 850 to 700mb; FROM 700 to 500mb* (two charts, the 850-700mb θ_e-change Chart, etc.)

700mb SURFACE HEIGHT-CHANGE CHART, 12hr PERIOD; 24hr PERIOD (two charts).

**CHART OF THICKNESS CHANGE THRU THE LAYER 1000-700mb; 700-500mb; 500-300mb FOR A 24-hr PERIOD* (three charts).

*24hr prognostics are drawn for these charts.

In a complete analysis, the above charts are prepared at 0400 and at 1600 GMT each day.

FORM 50

HEADQUARTERS UNITED STATES STRATEGIC AIR FORCE IN EUROPE
OFFICE OF DIRECTOR OF WEATHER SERVICES

UPPER AIR WIND DATA SHEET

FOR MAP: DATE________ TIME______Z OBSERVER________

MBS. FEET HECT.			GRADIENT WIND		850 5000 15		750 9000 27		700 10000 30		650 11000 33		SHEAR 750-650		SHEAR GRAD-700		550 17000 52		500 18000 55		450 19000 58		SHEAR 550-450		SHEAR GRAD-500		350 28000 85		300 30000 91		250 32000 97		SHEAR 350-250		SHEAR 700-300	
STA	LOC	TM	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV	DD	VV

The *Upper-Air Wind Data Sheet*, used for tabulation of winds in a form convenient for both the computation of the shears and the plotting of the winds and shears.

comparison with both the direction and strength of the observed wind shear of the 1000 to 500mb layer as well as the strength and direction of the actual wind, support the conclusion that the invasion of warm air below 500mb is largely confined to the 700-500mb layer. The temperature tendencies as well as the isothermal wind shears (defined later) support this contention. The rapid veering of the wind from 700mb to 500mb indicates that this layer is under the influence of a warm-frontal zone. If 12-hour tendencies in the direction and magnitude of the observed wind shear are evaluated, then the variation in the direction and intensity of warm-air invasion with time is ascertained. In the 500mb plot, the fact that during the previous 12 hours the wind has increased and veered less than both the observed wind shears is evidence that the intensity of the warm air invasion is greater at present than 12 hours previous.

Figure 5D is a plot at the 700mb surface with observations consistent with the plot at 500mb. The red 946 is a thickness value for the 1000-700mb layer (9,460 feet) found by assuming that a moist adiabatic lapse rate exists in the layer. There is a 100-foot difference between this moist adiabatic thickness and the observed thickness, 956.

The procedure for evaluating heights and moisture at the constant-pressure surfaces is omitted, because these data have been evaluated in the radiosonde transmissions received by most forecast sections in North America. The thicknesses are evaluated for all layers by finding the differences between the heights of the boundary surfaces. When the height of the 1000mb surface is not reported, it is necessary to obtain the thickness for the layer between the 1000mb surface and sea level from either (a) the station height and the station pressure and temperature, or, (b) from the sea-level pressure and the station temperature, using pressure-height tables or a pressure-height nomogram.

For the computation of the wind shears, a convenient device is employed. A large circular celluloid protractor is attached to a rectangular coordinate system as a base by an axis through the center of the protractor and the origin of the rectangular coordinates, so that the protractor may be rotated on the base. Three convenient scales of wind speed are defined on the rectangular coordinates. The wind velocities at the boundary surfaces of a layer are plotted on the celluloid protractor with a chinagraph pencil as two points: twice the protractor is rotated to bring a wind direction coincident with the positive direction of the Y-axis and a point is located along the Y-axis at the scale value for the wind speed. Then the protractor is rotated so that the line through the two plotted points is brought parallel to the Y-axis with the point representing the wind velocity at the upper level in the positive direction of the Y-axis. The direction of the shear is read from the protractor as the direction which is giver for the positive Y-axis. The magnitude of the shear is found by measuring the distance between the two plotted points.

II. *Preparation of the Analyses.*

The first step in the upper-air analysis is the location of the intersections of fronts with the 700mb surface. From the frontal positions observed in the hodographs, the soundings, and the surface chart and from the continuity in time and space of the frontal surfaces, the fronts are tentatively placed on the 700mb Chart in colored pencil.

Step two is the estimation of the thickness for the 1000-700mb layer (H' plus ΔH' in Figure 5A) for those regions where upper-air observations are sparse. The estimation is made from surface (sea level) weather observations: the temperature sequence, the wind speed, the amount of sky coverage, the type of cloud structure, the form and intensity of precipitation, the special weather phenomena (indicating the degree of stability), and the surface flow pattern (cyclonic or anticyclonic) are all observations of the atmosphere aloft.

The estimation of the 1000-700mb thickness from surface (sea-level) weather information is based upon the fact that the different aspects of the surface observations together express implicitly the

	WIND SPEED (mph)													
LATITUDE	10	20	25	30	35	40	45	50	60	70	80	100	150
15	400.5	200.2	160.2	133.5	114.4	100.1	89.0	80.1	66.7	57.2	50.1	40.0	26.7
20	289.1	144.6	115.6	96.4	82.6	72.3	64.2	57.8	48.2	41.3	36.1	28.9	19.3
25	224.6	112.3	89.9	74.9	64.2	56.2	49.9	44.9	37.4	32.1	28.1	22.5	15.0
30	183.4	91.7	73.4	61.1	52.4	45.8	40.8	36.7	30.6	26.2	22.9	18.3	12.2
35	155.3	77.7	62.1	51.8	44.4	38.8	34.5	31.1	25.9	22.2	19.4	15.5	10.4
40	135.5	67.8	54.2	45.2	38.7	33.9	30.1	28.1	22.6	19.4	16.9	13.5	9.0
45	121.1	60.5	48.4	40.4	34.6	30.3	26.9	24.2	20.2	17.3	15.1	12.1	8.1
50	110.6	55.3	44.3	36.9	31.6	27.7	24.6	22.1	18.4	15.8	13.8	11.1	7.4
55	103.1	51.6	41.2	34.4	29.5	25.8	22.9	20.6	17.2	14.7	12.9	10.3	6.9
60	98.0	49.0	39.2	32.7	28.0	24.5	21.8	19.6	16.3	14.0	12.2	9.8	6.5
65	94.9	47.4	37.9	31.6	27.1	23.7	21.1	19.0	15.8	13.6	11.9	9.5	6.3
70	93.8	46.9	37.5	31.3	26.8	23.4	20.8	18.8	15.6	13.4	11.7	9.4	6.2
75	94.9	47.5	38.0	31.6	27.1	23.7	21.1	19.0	15.8	13.6	11.9	9.5	6.3
80	99.4	49.7	39.7	33.1	28.4	24.8	22.1	19.9	16.6	14.2	12.4	9.9	6.6
85	110.9	55.5	44.4	37.0	31.7	27.7	24.6	22.2	18.5	15.9	13.9	11.1	7.4
90	148.0	74.0	59.2	49.4	42.3	37.0	32.9	29.6	24.7	21.2	18.5	14.8	9.9
	1.74	3.48	4.34	5.21	6.08	6.95	7.82	8.69	10.43	12.17	13.9	17.38	26.07
	WIND SPEED (^{o}Lat./12 hrs)												

Table I: A constant-pressure geostrophic wind scale for 200-foot contour intervals may be prepared by plotting these data on a piece of celluloid and constructing curves through the appropriate points. The scale will give a map spacing of 200-foot contour intervals in millimeters for WRC charts 4-1, 2, 3.

850mb Surface °C	700mb Surface °C	500mb Surface °C	300mb Surface °C
25	22	7	-17
20	17	3	-21
15	13	-1	-24
10	08	-5	-28
05	04	-10	-31
01	-01	-14	-35
-04	-05	-18	-38
-09	-10	-22	-42
-14	-14	-26	-45
-18	-19	-30	-49
-23	-23	-34	-52
-28	-28	-38	-56
	-32	-42	-60
	-37	-46	-63

Table II: Temperature values in °C at the different isobaric surfaces for which isotherms are constructed in order to represent a θ-change of five degrees between isotherms.

unknown sounding. In accordance with the barometric height formula, a unique thickness for the 1000-700mb layer is determined by the unknown sounding. The estimation of thickness is based upon an inference of this unknown sounding. The inference is the *effective lapse rate*, a constant lapse rate which, with the existing sea-level temperature and pressure, gives the true thickness. The estimate of the true thickness is made in two steps. A first approximation of the unknown sounding would be the moist adiabatic lapse rate. The first step, then, is to determine the thickness of the 1000-700mb layer by the moist adiabatic lapse rate from sea-level temperature and pressure. The second step is to add to the moist adiabatic thickness a "thickness correction" to account for the difference between the moist adiabatic lapse rate and the effective lapse rate.

850mb °C	700mb °C	500mb °C	300mb °C
Part A, Zero-degree Increase			
25	08	-18	-52
20	04	-22	-56
15	-01	-26	-60
10	-05	-30	-63
05	-10	-34	
01	-14	-38	
-04	-19	-42	
-09	-23	-46	
-14	-28		
-18	-32		
-23	-37		
Part B, Five-degree Increase			
25	13	-10	-42
20	08	-14	-45
15	04	-18	-49
10	-1	-22	-52
05	-5	-26	-56
01	-10	-30	-60
-4	-14	-34	-63
-9	-19	-38	
-14	-23	-42	
-18	-28	-46	
-23	-32		
-28	-37		
Part C, Ten-degree Increase			
25	17	-01	-31
20	13	-05	-35
15	08	-10	-38
10	04	-14	-42
05	-1	-18	-45
01	-5	-22	-49
-4	-10	-26	-52
-9	-14	-30	-56
-14	-19	-34	-60
-18	-23	-38	-63
-23	-28	-42	
	-32	-46	
	-37		
Part D, 15-degree Increase			
25	22	7	-21
20	17	3	-24
15	13	-1	-28
10	08	-5	-31
05	04	-10	-35
01	-1	-14	-38
-4	-5	-18	-42
-9	-10	-22	-45
-14	-14	-26	-49
-18	-19	-30	-52
-23	-23	-35	-56
	-28	-38	-60
	-32	-42	-63
	-37	-46	

Table III: Temperature relationships among the various surfaces for zero-degree, five-degree, ten-degree, and 15-degree increases in potential temperature through the layers.

The 1000-700mb layer thickness by the moist adiabatic lapse rate is obtained from Table VI, in which the coordinates are sea-level pressure and temperature and the entry is the desired thickness. The station temperature is reduced to sea-level temperature by adding a correction which for each station is a constant determined by the station height. For reference, the corrections are plotted on a chart or are tabulated.

The "moist adiabatic" thicknesses are plotted as shown in Figure 5D on the 700mb Chart for a selected distribution of stations throughout the areas in which there are surface observations but no upper-air observations. The moist adiabatic thicknesses are also found for the observed heights at the boundary of these areas, so that the true thickness correction is known adjacent to the areas where the thickness correction will have to be estimated.

The determination of the thickness corrections, a task of importance, is based upon the stability conditions expressed in the observed surface weather and analysis. Broadly speaking, large positive corrections are associated with slowly-moving anticyclonic flow of continental trajectory, clear skies, low temperatures, relatively high pressure, fog, etc.; whereas, large negative corrections are associated with rapidly-moving cyclonic flow, overcasts, vertical cloud structure, and instability weather (showery precipitation and thunderstorm activity). The stations for which thickness corrections are known serve as "fixes" for the extrapolation of corrections into the areas of no direct observations aloft. There, the correction is added to the moist adiabatic thickness to obtain an estimate of thickness, which is plotted in red (to distinguish it from observed thicknesses in black).

The thickness correction differentiates between conditional stability and absolute stability of the effective lapse rate through the 1000-700mb layer and expresses a measure of the amount of each.

The third step is the analysis of the 1000-700mb layer. The thickness lines are drawn lightly in blue at 200-foot intervals (860, 880, ...) so as to fit the observed thicknesses, the estimated thicknesses, and the observed wind shear vectors. Inasmuch as the family of thermal-thickness lines identifies the mean virtual temperature gradient, the spacing of the thickness lines can be obtained from considerations of wind variation through the layer as well as from the thickness of the layer. Since the shear of the geostrophic wind is a vector normal to the temperature gradient, the thermal shear not only gives the direction of the thickness lines but also provides a means for spacing them. Since the magnitude of the geostrophic wind shear through the layer stands in the identical relation to the gradient of the thermal thickness lines as the geostrophic wind stands in relation to the gradient of the contour lines, the geostrophic wind scale which is used for the spacing of the contours drawn at 200-foot intervals can be used without any variation whatever for the spacing of the thickness lines drawn at 200-foot intervals from the magnitude of the observed geostrophic wind shear.

It will be noted later that the direction of the observed wind shear identifies the direction of the thickness lines only if the contours at both boundary surfaces of the layer are straight lines, or if the curvature and speed of flow remains the same through the layer. The magnitude of the observed wind shear identifies the gradient of the thickness lines only if the contours of a boundary surface of the layer and the thickness lines are straight and in the same direction.

The fourth step is the conversion of the surface chart (sea-level) to a 1000mb Chart. The sea-level isobars are constructed at intervals of four millibars, beginning with the 1000mb isobar, and so they may be converted to contours at intervals of 100 feet. The 1000mb isobar becomes the zero-foot contour; the 1008mb isobar, the 200-foot contour; and so on. With temperatures of 50°F. or greater the height values assigned to the isobars for pressures outside the range of 984mb to 1016mb are somewhat too low for high pressures and too high for low pressures. However, the differences between the assigned values and the true values are slight, and these differences are accounted for in the use made of the 1000mb Chart.

The fifth step is the construction of the 700mb contours. The 700mb Chart, on which the thickness pattern of the 1000-700mb layer has been drawn lightly in blue pencil, is superimposed upon the Surface Chart on a tracing table. The contours are drawn in black pencil at 200-foot intervals, by reference to the winds and heights observed at the 700mb surface and by graphical addition of the thickness lines and 1000mb contours. The 700mb contours are adjusted so that they fit the observations and also are consistent with the analysis of the thickness pattern and the sea-level analysis.

With the construction of the 700mb

Layer	ΔT (C^o)
1000 - 850 mb	13°
850 - 700 mb	11°
1000 - 700 mb	6°
700 - 500 mb	6°
500 - 300 mb	4°

Table IV: Temperature differences between adjacent thickness lines.

Thickness (Feet)	0	1	2	Dry Adiabatic	Saturated Adiabatic
Part A, 700mb Surface					
8,600	-22	-26	-31	-34	-33
8,800	-16	-21	-23	-29	-27
9,000	-10	-16	-19	-23	-21
9,200	-4	-10	-13	-18	-14
9,400	1	-4	-8	-12	-7
9,600	7	1	-2	-7	-1
9,800	13	7	4	-1	6
10,000	19	13	9	4	12
10,200	24	18	14	10	19
10,400	31	24	20	16	26
10,600	36	30	26	21	32
Part B, 500mb Surface					
7,400	-44	-48	-51	-55	-55
7,600	-38	-42	-46	-49	-49
7,800	-32	-36	-39	-43	-42
8,000	-26	-29	-33	-37	-36
8,200	-19	-23	-27	-32	-29
8,400	-13	-18	-21	-26	-22
8,600	-7	-12	-16	-19	-15
8,800	-1	-6	-9	-14	-8
9,000	6	0	-3	-8	-1
9,200	12	6	3	-2	6
Part C, 300mb Surface					
10,200	-65	-71	-75	-80	-80
10,400	-61	-66	-72	-76	-76
10,600	-57	-62	-68	-72	-72
10,800	-53	-58	-64	-69	-68
11,000	-49	-54	-60	-65	-64
11,200	-45	-51	-56	-61	-61
11,400	-41	-47	-52	-57	-57
11,600	-37	-43	-49	-53	-53
11,800	-33	-38	-44	-50	-48
12,000	-28	-34	-41	-46	-44
12,200	-24	-31	-37	-42	-39
12,400	-21	-27	-33	-38	-34
12,600	-16	-23	-29	-34	-29
12,800	-12	-19	-23	-31	-24
13,000	-8	-16	-19	-27	-19

Table V: The temperature (°C) at a surface from the thickness (in feet) of the adjacent lower layer for various lapse rates (°C/1000ft).

contours, there is available additional information for the revision of the thickness analysis. If the 1000mb contours and the 700mb contours have the same curvature and if the speed of the wind is greater at 700mb than at 1000mb, the observed wind shears will point toward higher values of the thickness. If at the position of a wind observation the curvature of the contours changes markedly through the 1000-700mb layer, the direction of the actual (observed) wind shear through the layer will deviate from the true direction of the thickness lines for the layer. If the 1000mb contours are cyclonically curved and the 700mb contours are anticyclonically curved, the actual wind shears will point toward lower values of the thickness when the wind does not decrease significantly in speed with height. And if the 1000mb contours are anticyclonic and the 700mb contours are less anticyclonically curved or tend toward cyclonic curvature, the observed wind shear will point toward greater values of thickness for the layer. Thus the analyst considers the appropriate angle between the direction of the thickness lines and the direction of the observed wind shear. Moreover, if the curvature of flow through the 1000-700mb layer is cyclonic and the thickness lines are in the same direction as the contours, then the spacing of the thickness lines by the magnitude of the observed wind shear, using the geostrophic scale, will be greater than the true spacing of the thickness lines. If the contours are anticyclonic and remain through the layer in the same direction as the thickness lines, the observed wind shear will give a spacing of the thickness lines less than their true spacing. More generally, if the curvature of flow varies rapidly through the layer, the spacing of the thickness lines, which are not necessarily in the direction of the flow, by the magnitude of the actual wind shear used in the geostrophic scale will be different from the true spacing. The analyst thus accounts for the spacing of the thickness lines.

After the 700mb contours have been provisionally constructed, the analysis of the 1000-700mb thickness lines is revised, observing the above rules. Then the 700mb contours are readjusted to conform with the revised thermal pattern.

In fitting the 700mb contours to the observed winds, allowance is made for the curvature of the flow at the surface. Only if the contours are nearly straight is their spacing found by considering the observed wind as a geostrophic wind. If the contours are appreciably curved and/or if the contour system is moving rapidly, their spacing is found by considering the observed wind as a gradient wind.

One variation of the foregoing procedure of analysis which is practiced when facilities and personnel are limited is to omit the analysis of the 1000-700mb thickness pattern. Surface observations are used to estimate the 700mb height directly, and the 1000mb Chart is not prepared.

At this point, the 700mb Chart has been analyzed tentatively for the contours and total thickness lines. The analysis for isotherms and mixing ratio lines is delayed until later so that the method of graphical addition and subtraction involving the 700mb contours will not be confused by the presence of additional lines.

The sixth step is the preparation of the contour analysis on the 500mb Chart. The 500mb Chart is superimposed upon the 700mb Chart on a tracing table. The fronts at the 500mb surface are provisionally indicated. The thermal-thickness lines for the layer from 700mb to 500mb are constructed by employing the procedures given in the third step. These thickness lines are added graphically to the 700mb contours to obtain the 500mb contours, which are also required to fit the height and wind observations at the 500mb surface. The thickness lines and contour lines must be mutually adjusted in order that both families of lines together fit all observations as well as possible. Next, the 500mb Chart is superimposed upon the 1000mb Chart on the tracing table. A transparent overlay, in which has been engraved the outline of the weather chart, is placed upon the 500mb Chart and the 1000mb Chart. With chinagraph pencil the thickness pattern for the 1000-500mb layer is obtained by constructing lines for the successive intersections in the grid formed by the 1000mb contours and the 500mb contours, proceeding toward higher values on both charts. The total thickness lines must fit the actual 1000-500mb thicknesses and observed wind shears, which are plotted on the 500mb Chart. The 1000-500mb thickness pattern must also satisfy continuity with the previous 1000-500mb thermal pattern. Thus, another check is made to determine the consistency of the several analyses with the observations.

If there is no necessity for using the 1000-500mb thermal pattern in the forecasting procedure, this analysis is not prepared. Instead, the analyst may construct the total thickness lines mentally in order to test the consistency of the analysis.

The 500mb Chart now has been analyzed for the contour lines (in heavy black pencil), the thickness lines of the adjacent layer (in faint blue pencil), and thickness lines of the total layer. The completion of the 500mb surface analysis is withheld until later.

The seventh step is the analysis of the 300mb surface. Fronts usually are not located in the 300mb surface. After the thermal pattern of the adjacent 500-300mb layer has been prepared, the 300mb Chart is superimposed upon the 500mb Chart on the tracing table to prepare the 300mb contours by graphical addition. Next, the 700-300mb thermal pattern is obtained on a transparent overlay by graphical subtraction of the 300mb contours and the 700mb contours, allowing for the observed 700-300mb thicknesses and wind shears.

The analysis for the circulation of the atmosphere now has been completed. By commencing at sea level, with use being made of all information contained in the surface observations, the individual analyses of higher surfaces have been obtained by building one atmospheric layer on top of another. This method, which is often called differential analysis, not only requires that all the analyses be mutually consistent but also provides a means for extrapolating the upper-air analyses into those regions where there is a paucity of observations. The importance for developing the analyses upward is realized when the information contained in the observations at the lower levels is compared with that in the observations made aloft. The method of differential analysis not only invests the pressure pattern at sea level into the upper-air analyses by graphical methods, but also exploits the surface observations upon the state of the atmosphere aloft. The configuration of the thermal pattern in the lower layers of the atmosphere (where observations are most frequent) may be extrapolated to the higher layers by acknowledging in the 500-300mb and 700-300mb thickness patterns the interpreted trends with height of the thermal pattern.

Step eight is the preparation of height tendency charts and thickness tendency charts.

The height-change (with time) charts are prepared in one of two ways. A family of lines representing the 12-hour height change, at intervals of 200 feet, is obtained by graphical subtraction of the contours of two 700mb charts prepared for observations 12 hours apart. Similarly, a 24-hour height change chart is made. A second method for making the height tendency charts involves the tabulation of 700mb heights at intervals of five degrees of latitude and longitude. From the sequence of tabulated heights, which have been entered into a data table, the 12-hour tendencies, as well as the 24-hour tendencies can be obtained and then plotted upon a chart, for which tendency analysis can be made.

The thickness tendency charts are prepared in the same way. If change charts for the thermal-thickness of a layer are prepared, their graphical addition to the height-change chart for the lower surface of the layer gives the height-change chart for the upper surface. In this way the height-change charts can be related to the

°F	1000	°F	1000
-20	803	10	858
-19	805	11	859
-18	806	12	861
-17	808	13	863
-16	810	14	865
-15	812	15	867
-14	814	16	869
-13	816	17	870
-12	817	18	873
-11	819	19	875
-10	821	20	878
-09	823	21	880
-08	825	22	882
-07	826	23	884
-06	828	24	886
-05	830	25	888
-04	832	26	890
-03	834	27	892
-02	836	28	894
-01	838	29	897
00	839	30	899
01	841	31	901
02	843	32	904
03	845	33	906
04	847	34	908
05	848	35	910
06	850	36	913
07	852	37	915
08	854	38	917
09	856	39	919
°F	1000	°F	1000

8, -- 0 Ft. | 9, -- 0 Ft.

MILLIBARS

DEGREES FAHRENHEIT	960	970	980	990	1000	1010	1020	1030	1040	
40	27	25	24	22	21	19	17	15	13	40
41	29	28	26	24	23	21	19	18	16	41
42	31	30	28	26	25	23	21	20	18	42
43	34	33	31	29	27	25	23	22	20	43
44	36	35	33	31	29	27	26	24	22	44
45	38	37	35	33	31	29	28	26	24	45
46	40	39	37	35	33	31	30	28	26	46
47	42	41	39	37	35	33	32	30	28	47
48	44	43	41	39	37	35	34	32	30	48
49	46	45	43	41	39	38	36	34	32	49
50	48	47	45	43	41	40	38	36	34	50
51	50	49	47	45	43	42	40	39	37	51
52	52	51	49	47	45	44	42	41	39	52
53	53	52	50	49	47	46	44	43	41	53
54	55	54	52	51	49	48	46	45	43	54
55	57	56	54	53	51	50	48	47	45	55
56	60	58	57	55	53	52	50	49	47	56
57	62	60	59	57	55	54	52	51	49	57
58	64	62	61	60	58	56	54	53	51	58
59	66	64	63	62	60	58	57	56	54	59
60	68	66	65	64	62	60	59	58	57	60
61	70	68	67	66	64	63	62	60	59	61
62	72	70	70	69	67	65	64	63	61	62
63	75	73	72	71	69	67	66	65	63	63
64	77	75	74	73	71	69	68	67	65	64
65	79	77	76	75	73	72	70	69	67	65
66	81	79	78	77	75	74	73	71	70	66
57	83	81	80	79	77	76	75	73	72	67
68	85	83	82	81	79	78	77	75	74	68
	960	970	980	990	1000	1010	1020	1030	1040	

MILLIBARS

9, -- 0 Ft. | 10, -- 0 Ft.

MILLIBARS

	960	970	980	990	1000	1010	1020	1030	1040	DEGREES FAHRENHEIT
69	86	85	84	83	81	80	79	77	76	69
70	88	87	86	85	83	82	81	80	79	70
71	90	89	88	87	85	84	83	83	81	71
72	93	91	90	89	88	87	86	85	84	72
73	95	94	93	91	90	89	88	87	86	73
74	97	96	95	93	92	91	90	89	88	74
75	99	98	97	95	94	93	92	91	90	75
76	01	00	99	97	96	95	94	93	92	76
77	03	02	01	00	98	97	96	95	94	77
78	05	04	03	02	00	99	98	97	96	78
79	07	06	05	04	02	01	00	99	98	79
80	09	08	07	06	04	03	02	01	99	80
81	11	10	09	07	06	05	04	03	01	81
82	13	12	11	09	08	07	06	05	03	82
83	15	14	13	11	10	09	08	07	05	83
84	17	16	15	13	12	11	10	09	07	84
85	19	18	17	15	14	13	12	11	09	85
86	21	20	19	17	16	15	14	13	11	86
87	23	22	21	19	18	17	16	15	13	87
88	25	24	23	22	20	19	18	17	15	88
89	28	27	25	24	23	22	20	19	17	89
90	30	29	28	26	25	24	22	21	19	90
91	32	31	30	28	27	26	24	23	21	91
92	34	33	32	30	29	28	26	25	23	92
93	37	36	34	32	31	30	28	27	25	93
94	39	38	37	35	33	32	31	29	27	94
95	41	40	39	37	35	34	33	31	29	95
96	43	42	41	39	37	36	35	33	31	96
	960	970	980	990	1000	1010	1020	1030	1040	

MILLIBARS

Table VI: The 1000-700mb thickness derived from a moist-adiabatic lapse rate and sea-level data.

RULE: For temperatures between -20° and +40°, add (subtract)"1"---which is ten feet---to the thickness value at 1000mb for every five millibars of pressure less (greater) than 1000mb.

thermal-thickness change charts.

The 850mb Chart is analyzed, without the use of differential analysis.

The 150mb Chart is analyzed, to account for the movements of polar air and tropical air in the stratosphere. The replacement of warm light air by cold dense air in the stratosphere imposes itself in hydrostatic fashion upon the lower atmosphere. The differential analysis is not used, since the presence of the tropopause in the layer between 300mb and 150mb complicates the analysis of thermal structure.

The ninth step is the construction of isotherms on the 850mb, 700mb, 500mb, 300mb, and 150mb Charts. The isotherms of an isobaric surface are lines of equal potential temperature (θ) and are the intersections of certain isentropic surfaces with the constant-pressure surface.

Everywhere on a given isobaric surface the thermal gradient is also the θ gradient. However, a constant isothermal gradient does not represent the same θ gradient at different pressure levels. It is necessary to determine the values of temperature at the different surfaces for which the isotherms should be drawn in order to represent the same interval between θ lines at all the different levels.

Table II lists the values for temperature at the different surfaces for which isotherms are drawn to represent a θ spacing of five degrees at each surface. These particular values of temperature were selected because they provide an isotherm on each contour chart within one degree of the zero degree isotherm, and because the intersections of a certain isentropic surface with isobaric surfaces are a set of the isotherms which are drawn (for example, the 25°C isotherm at 850mb, the +8°C isotherm at 700mb, the -18°C isotherm at 500mb, and -52°C isotherm at 300mb are the intersections of the 310° isentropic surface).

The isothermal wind shear is computed for all wind data through the layer from 50 millibars below the isobaric surface to 50 millibars above the surface. Using an appropriate geostrophic wind scale the isotherms are properly oriented and spaced according to the wind shear. The isothermal wind shears, the surface temperatures, the flow pattern, and the frontal surfaces provide additional information for the construction of the isotherms. The configuration of the isotherms is related to the thermal patterns of the adjacent layer: the thermal thickness lines are isotherms, at even intervals, of the mean virtual temperature through the layer. The isothermal analysis at a particular surface is, therefore, referred to the thermal thickness analysis of the adjacent layer in order to extend the isothermal analysis into areas where observations are sparse.

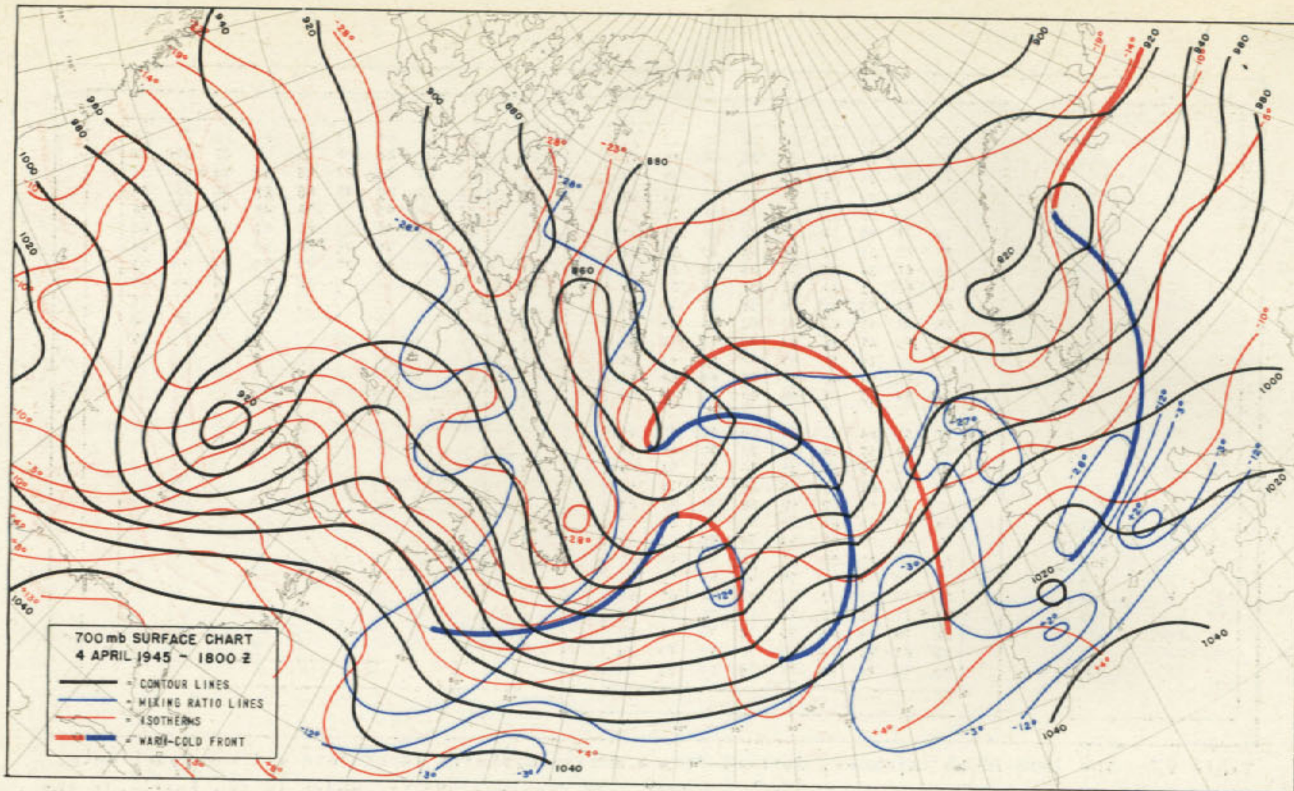


Figure 1: a 700mb surface chart, with the 1000-700mb thickness analysis omitted for clarity. Observe the intensity of the temperature and moisture patterns in the warm sector west of the British Isles; compare these patterns with the tongue of tropical air shown in Figure 4A. Compare the 20° dew-point spread in the English Channel area, with the marked convective stability forecast for that area in Figure 4C. Note the intensity of the isothermal gradient behind the strong cold front in the western Atlantic.

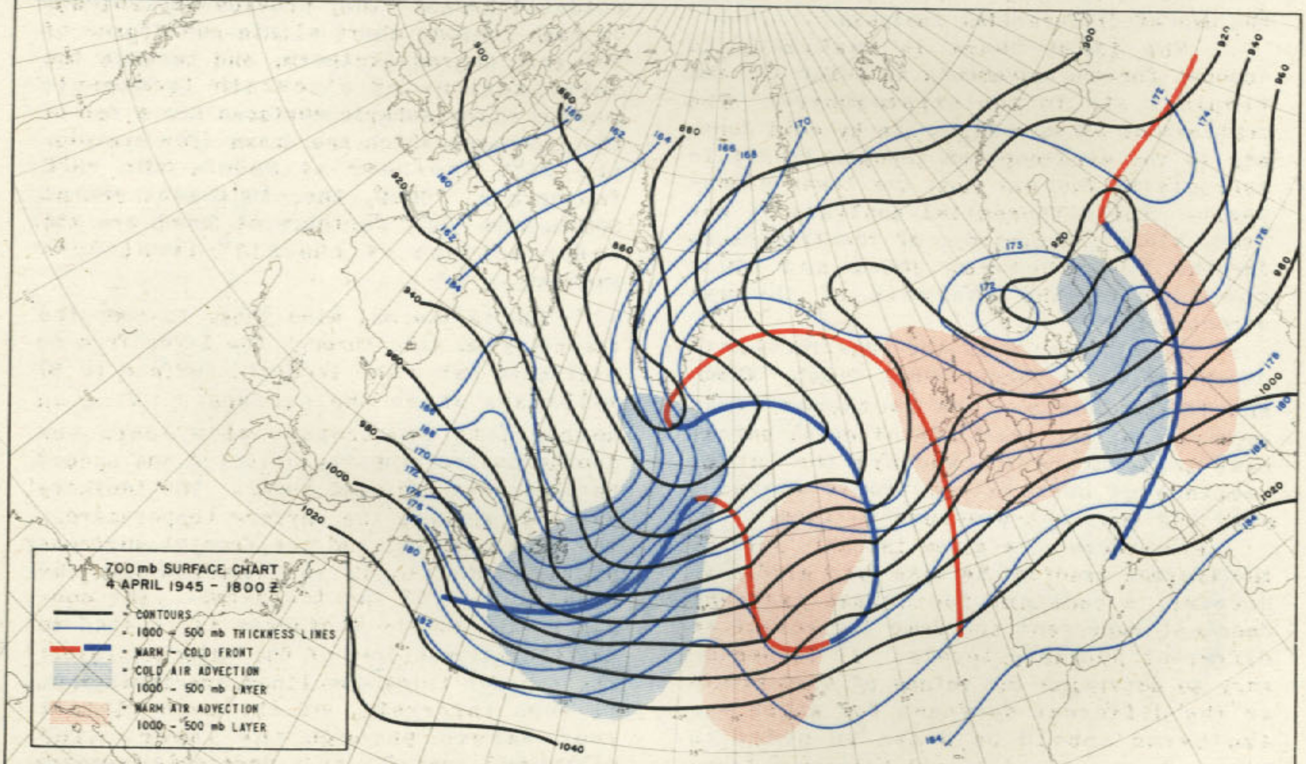


Figure 2: the transparent overlay with the 1000-500mb thickness analysis here is superimposed on the 700mb surface analysis of Figure 1. In one method of forecasting, the thickness lines are considered as material lines embedded in the geostrophic flow (preferably at the mid-level of the layer) and are displaced to obtain a 12-hour prognostic thickness chart, which, when graphically added to the 12-hour prognostic surface chart, yields the 12-hour prognostic 500mb surface chart.

The thermal-thickness lines should be labeled with the corresponding mean temperatures for the layer by using columns one and two in Table V (A, B, and C). Since the thermal thickness lines are drawn at intervals of 200 feet, the particular magnitude of the mean temperature gradient corresponding to the gradient of the thermal thickness lines can be determined. In Table IV there are tabulated the temperature differences between successive thermal thickness lines drawn at 200-foot intervals. Furthermore, the isotherms can be drawn to fit the thermal pattern by referring to Table V (A, B, & C), which presents the temperature at the surfaces from the thickness of the adjacent layer for various lapse rates through that layer.

Step ten is the preparation of three auxiliary charts: a θ-change Chart from 850mb to 700mb, from 700mb to 500mb, and from 500mb to 300mb.

The stability and the moisture content of the atmosphere are important considerations in forecasting precipitation and cloudiness (type, amount, structure, and level). In addition, a knowledge of the stability is used to impoove the subsequent upper-air analysis, on the basis that the thermal thickness of a layer varies with its stability.

The θ-change charts present a horizontal organization of stability data, which is prepared as a continuous pattern through the inference of analysis. This analysis of stability is in a convenient form for comparison with other weather charts. On the other hand, stability analysis from reference to soundings alone is restricted to the points of radiosonde observation.

Each θ-change pattern is prepared on a transparent

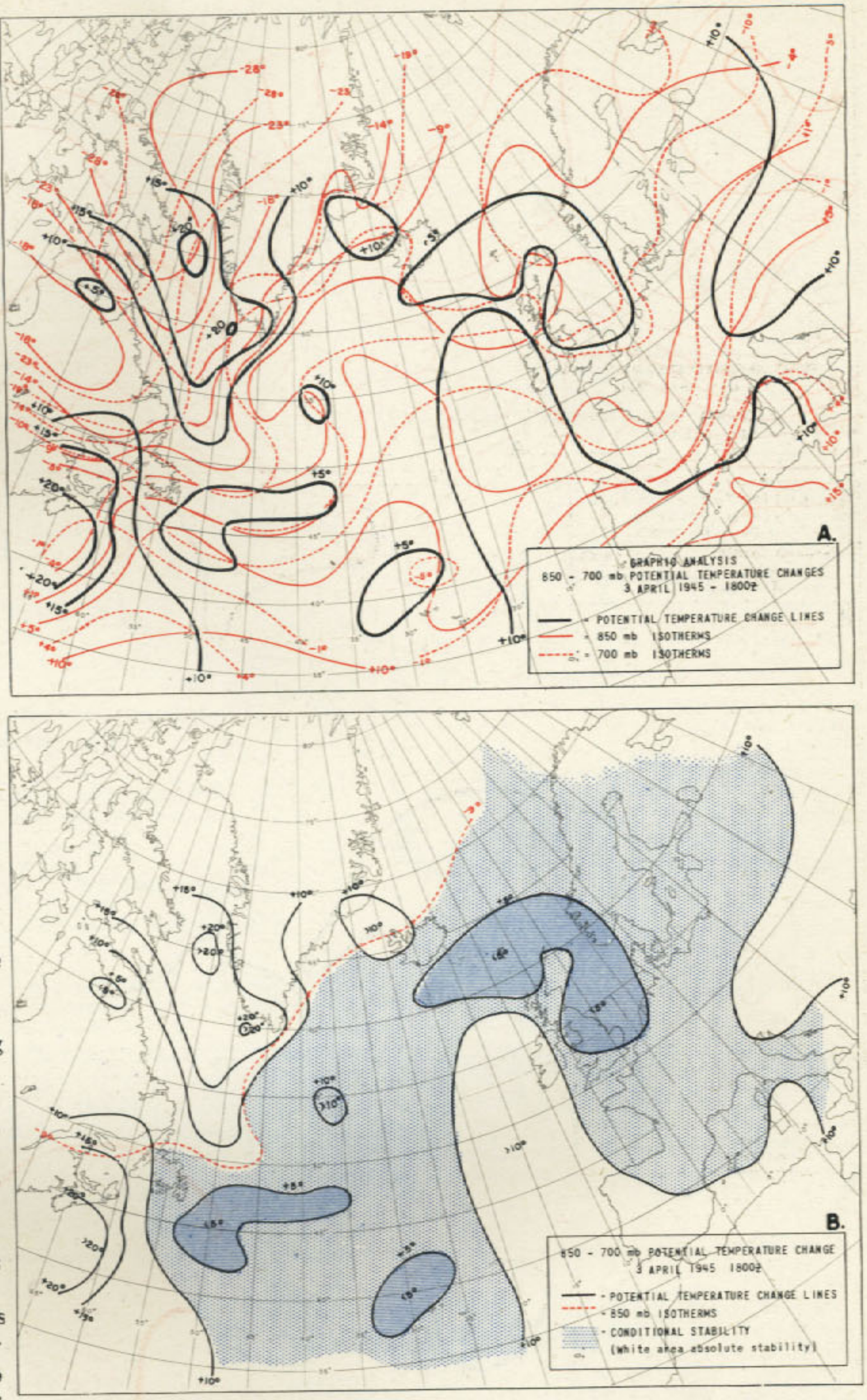


Figure 3: "A" is the Graphic Analysis for θ-Change from 850mb to 700mb. The continuous and the dashed red lines are isotherms from the 850mb and the 700mb surfaces, respectively. The continuous black lines, of θ-change, are constructed on a transparent overlay by graphical subtraction in about five minutes. These lines never cross one of the two families of isotherms without also crossing the other. Their positions between intersections are interpolated from the relative position of the two families of lines. In "B" the full black lines constructed in "A" have been reproduced to show how they appear on the transparent overlay. The white areas represent areas of absolute stability, whereas the shaded blue areas represent areas of conditional stability. In the North Sea there is shown an area of strong conditional instability. The non-frontal trough in Figure 6 over the North Sea area is evident in the surface observations, which show Sferics activity and instability weather.

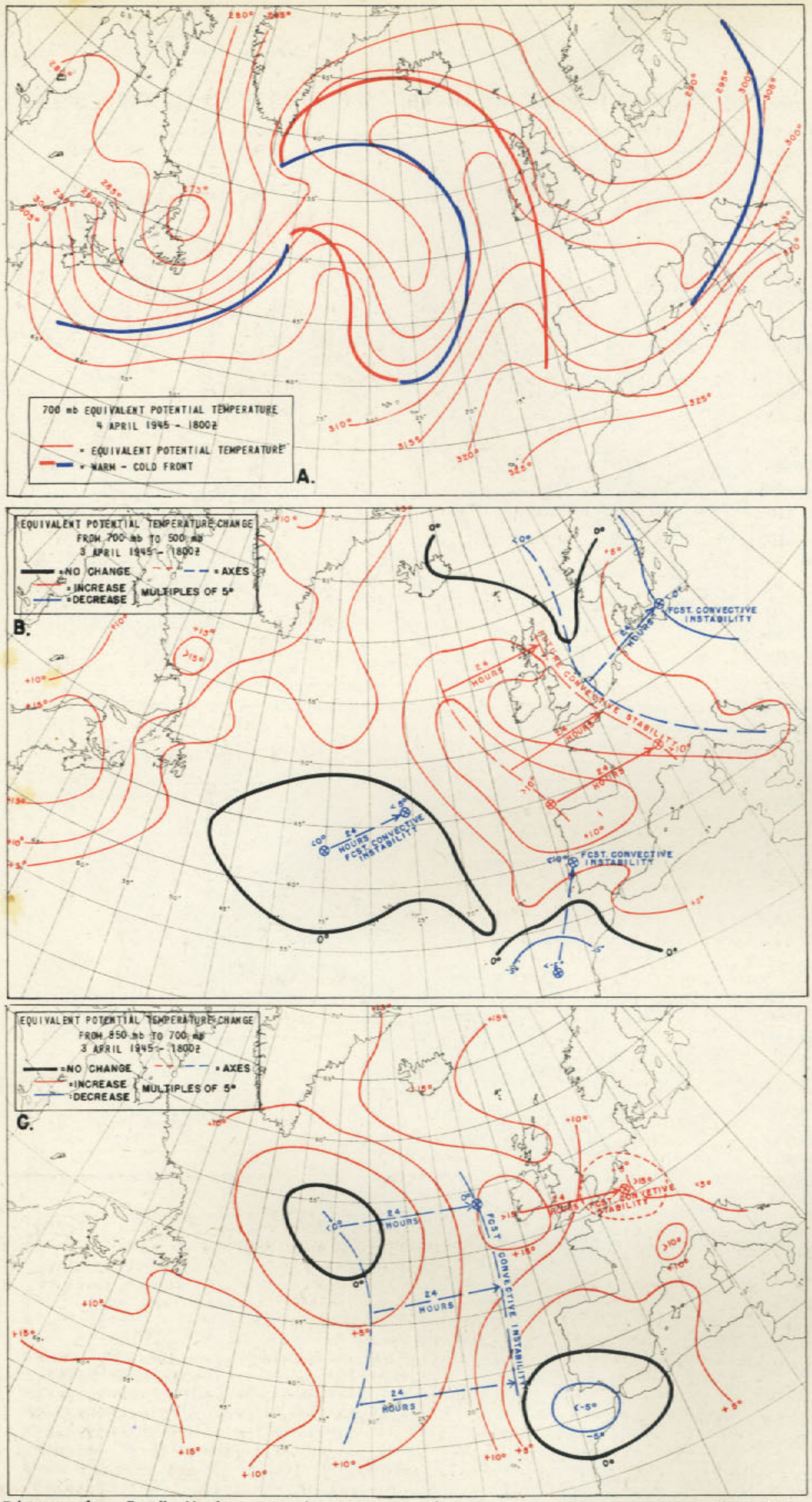
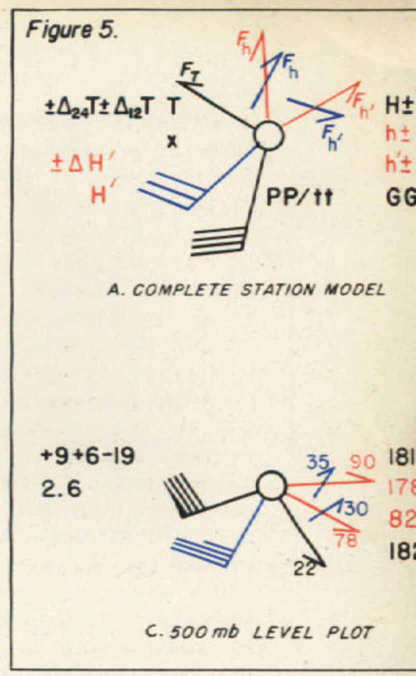


Figure 4: In "A" observe the tongue of tropical air at 14°W. Note the extreme continental nature of the air mass behind the cold front which lies southeast of Newfoundland. Observe the strong air mass difference across the cold front in northern Italy. The front in France (Figure 6B) is moving southeastward into an area over Marseilles where there is a strong θ_e gradient, or a rapid transition from dry continental air to moist tropical air in the mid-Mediterranean. Therefore, precipitation and cloudiness is expected in Corsica, due to the lifting of this moist air mass by a cold frontal surface. "B" and "C" are θ_e-change charts from 850mb to 700mb and from 700mb to 500mb, respectively.



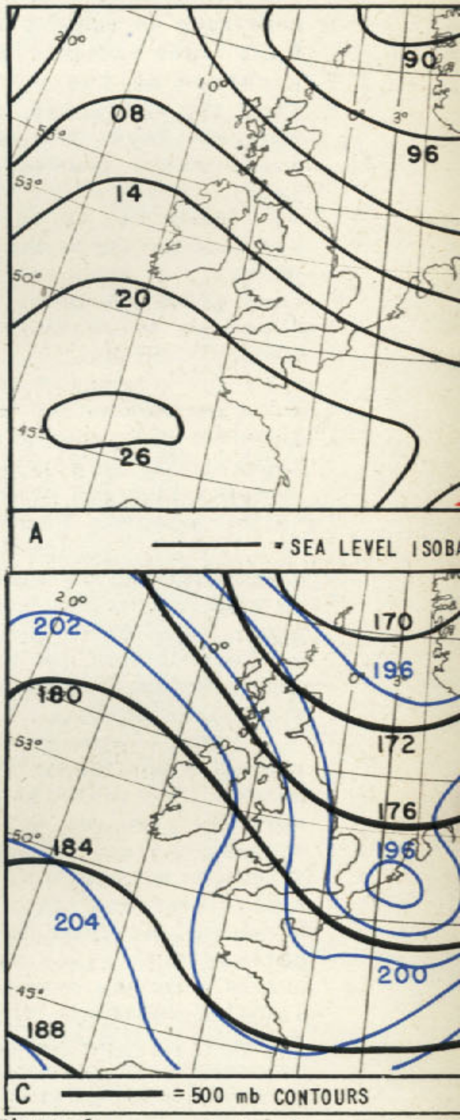
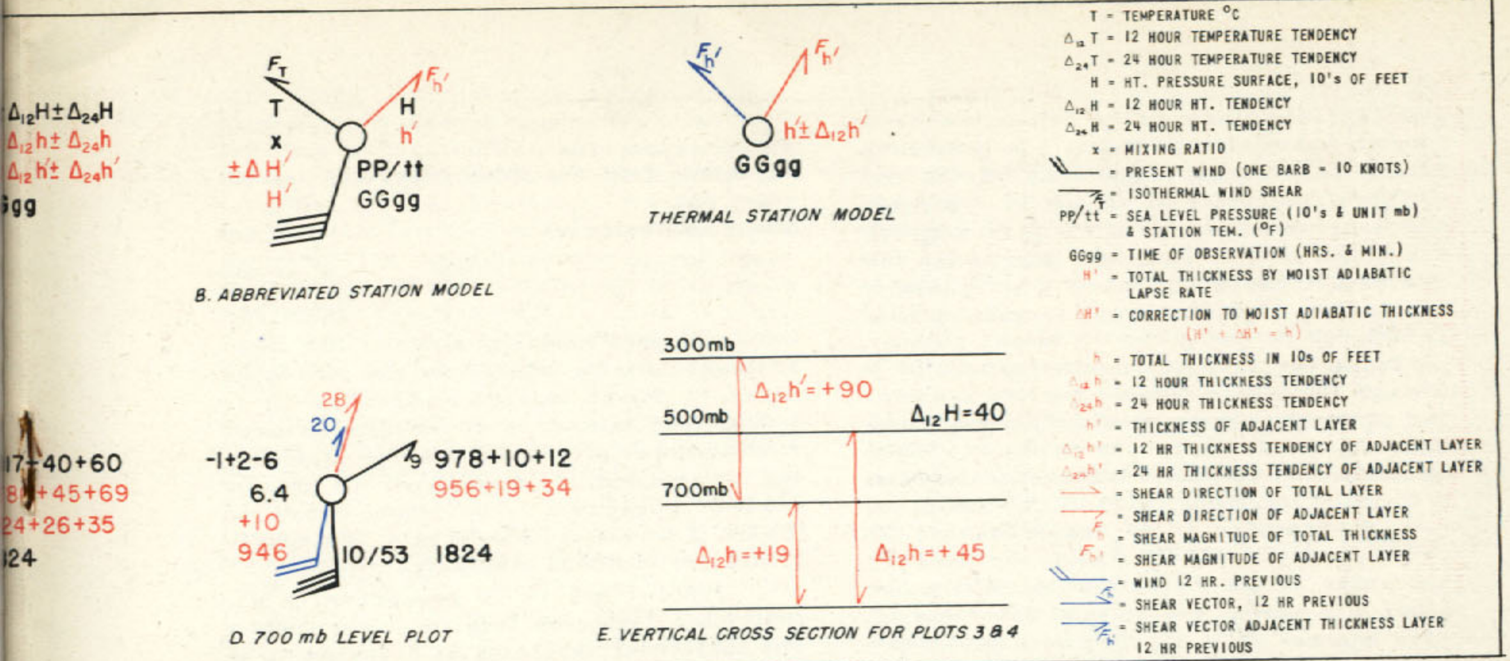


Figure 6: an analysis of several isob
have been prepared in scale so that th
the actual patterns of Fig 6. 7A is
3°E longitude. 7B is an east-west ver
angles to 7A thru the dashed line "A
cold front, lift over the warm front,
surface. 7C, relating a portion of 6

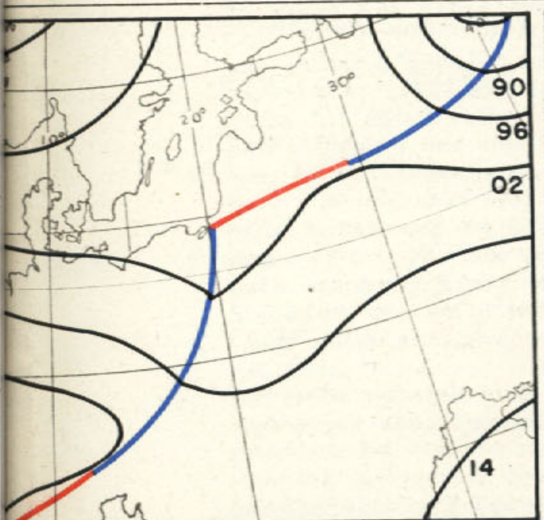


B. ABBREVIATED STATION MODEL

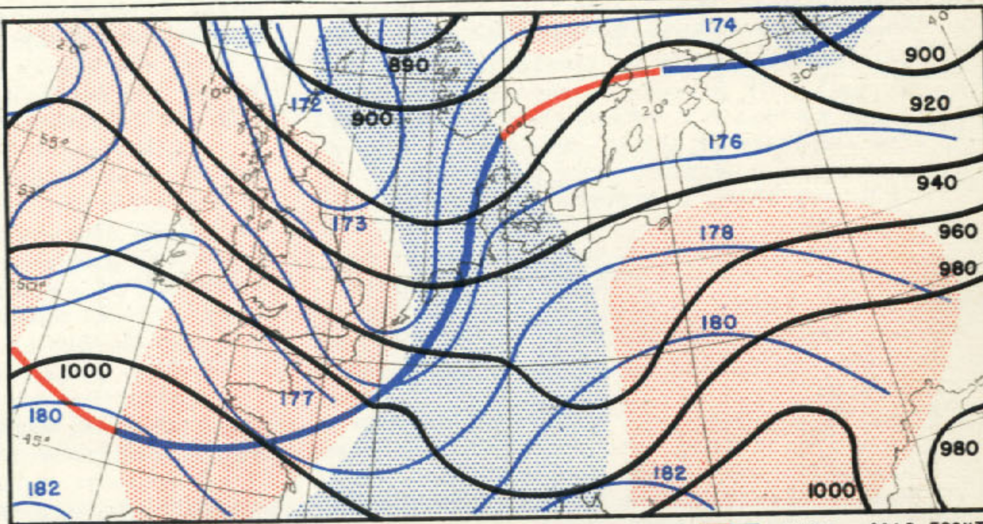
THERMAL STATION MODEL

D. 700 mb LEVEL PLOT

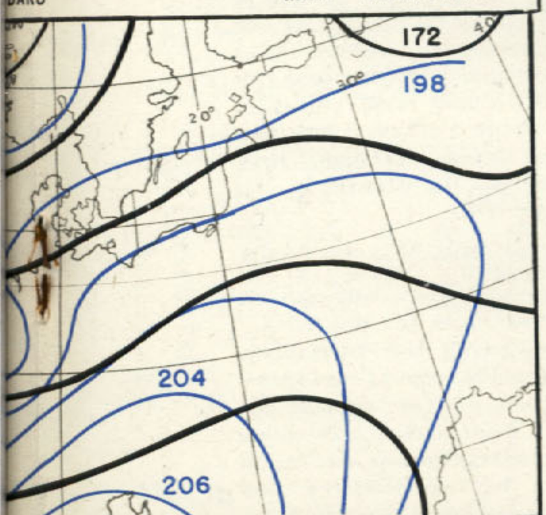
E. VERTICAL CROSS SECTION FOR PLOTS 3 & 4



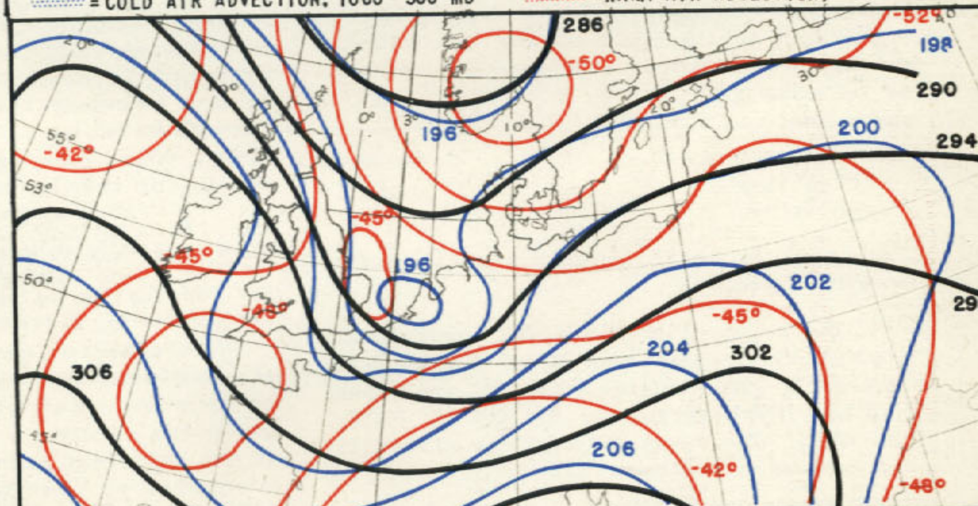
BARS = WARM - COLD FRONT



B = 700 mb CONTOURS = 1000-500 mb THICKNESS LINES = WARM - COLD FRONT
= COLD AIR ADVECTION, 1000 - 500 mb = WARM AIR ADVECTION, 1000-500 mb



= 700 - 300 mb THICKNESS LINES



D = 300 mb CONTOURS = 700-300 mb THICKNESS LINES = 300 mb ISOTHERMS

obaric surfaces. Figs 7, 8, and 9 on page 18 the directions and magnitudes there represent s a north-south vertical cross section along ertical section at 53°N lat, passing at right "AB", which illustrates subsidence over the , and the consequent displacement of the 500mb 6C to 7A and 7B, describes the relationship between the 500mb isotherms and contours after the initial deformation due to the subsidence has occurred. The warm front in 7B and 8A is dashed because it lies north of the cross section. Figure 8 presents the secondary stages in the development of the upper trough. In 8A the thicknesses between the 700mb and 300mb surfaces are shown, to describe the intensification of the trough at successively higher surfaces. 8A is a vertical section thru the dotted line in 8B, showing

(continued on page 18

overlay superimposed on contour charts for two successive surfaces. By graphical subtraction of the isotherms of the two surfaces, isopleths of change in θ through the layer at intervals of five degrees are drawn with chinagraph pencil on the overlay. Table III part B presents a tabulation of the particular temperature relationships among the different contour surfaces for five-degree increments of θ through the layers between any two successive surfaces. Lines obtained by graphical subtraction of the isotherms whose values are adjacent in these tables are labeled with the θ increment value of the table.

In practice it is not necessary to refer to Table III in order to identify the value of the θ-increment. Since the lines of θ-change are at even intervals of five degrees (0^o, 5^o, 10^o, . . .), their values can be ascertained from the analysis when the θ-change associated with the intersection of two particular isotherms is known. This process is repeated for each layer to obtain a set of charts indicating the stability of all the atmospheric layers under observation. The upper chart in Figure 3 shows a graphical analysis for θ-change.

The change in θ through a layer is a measure of the stability of the atmosphere in the layer. The θ-change pattern represents both the distribution and the intensity of the stability through the layer.

The patterns of θ-change on the overlays are divided into areas of absolute stability and of conditional stability within each layer by selected isotherms from the lower surface in the layer. This division of areas is accomplished for the 850-700mb θ-change pattern by tracing on it the 850mb isotherms for -9^oC and $+20^oC$. The areas of absolute stability are defined as follows:
where the

850mb temperature is		θ-change is
-9^o or less	and	5^o or more,
$+20^o$ " "	"	10^o " "

The layer is conditionally stable in the remaining areas*.

The areas of absolute and conditional stability in the 700-500mb layer are defined by the θ-change lines of the layer and the 700mb isotherms for -10^oC, -1^oC, and $+8^oC$. The areas of absolute stability are defined as follows:

850mb temperature is		θ-change is
-10^o or less	and	5^o or more,
-1^o " "	"	10^o " " ,
$+8^o$ " "	"	15^o " " .

On the θ-change pattern for the 500-300mb layer, the -18^oC, -10^oC, and -5^oC isotherms from the 500mb Chart are traced. where the

500mb temperature is		θ-change
-18^o or less	and	5^o or more
-10^o " "	"	10^o " "
$+5^o$ " "	"	15^o " "

the layer is absolutely stable. The layer is conditionally stable in the remaining areas.* There has been obtained in an economical manner a three-dimensional comprehension of the stmospheric stability for unsaturated air throughout the area of weather analysis. The lower chart in Figure 3 presents an analysis for conditional and absolute stability.

(*Sometimes it is necessary to use additional isotherms from the lower surface and additional isopleths of θ-increment in order to define completely the areas of conditional stability.)

In the charts of θ-change through the layers the degree of stability is derived from the temperature and θ-change values.

Estimates of clouds and precipitation are obtained from considerations of the moisture content of the atmosphere. Step ten is the construction of the mixing ratio lines (in green) on the 850-, 700-, and 500mb Charts. Mixing ratio lines are also lines of equal dew-point, and are relabeled with the appropriate dew-point value from Table VII.

Comparison of the isotherms with the lines of equal mixing ratio on a contour chart indicates the amount of cooling (the "dew-point spread") along the constant pressure surface needed for saturation. The magnitude of the dew-point spread indicates the amount of lifting in 400's of feet required for the air parcel at an isobaric surface to reach its condensation pressure level, provided that no mixing occurs between the parcel and the air through which it is being lifted. For the 1000-, 850-, 700-, and 500mb surfaces, this convenient rule is correct to within:

Dewpoint (°C)	-50	-40	-30	-20	-10	0	10	20	30
Correction %	-2.4	-1.6	-0.6	+0.6	+1.6	+3.0	+4.5	+6.4	+8.8

See "Evaluation of the Lifting Condensation Level," *Weather Service Bulletin* for Nov. 1945.

Information concerning the formation of cloudiness and precipitation is extracted from an examination of the amount of dew-point spread in a particular air mass at the different constant-pressure surfaces. Forecasts of changes in temperature and moisture at the surfaces in the air mass are made to ascertain whether saturation will be likely. The vertical extent and slope of frontal surfaces affecting the air mass under consideration are considered to discover whether the condensation level can be reached from a constant-pressure surface due to mechanical lifting by the invading frontal surface. Further, the dew-point spread is evaluated in terms of the stability considerations already made to determine whether saturation lift can be achieved by other means.

Since mixing ratio lines can be identified as dew-point lines, the analysis of mixing ratio is related to the isotherm analysis by considering the dew-point spread. The interpretation of the effect upon dew-point spread by fields of convergence and divergence, flow patterns, frontal positions, and air mass distributions is applied to the analysis of the mixing ratio lines by adjusting the distance between the isotherms and mixing ratio lines. In this manner it is possible to interpolate the mixing ratio lines into regions for which no moisture observations are available.

Now the analysis of the 850mb, 700mb, 500mb, and 300mb Charts is complete. Figure 1 illustrates a complete analysis at the 700mb surface.

Step eleven is the preparation of the analyses (on transparent overlays) for equivalent potential temperature at 850mb, at 700mb, and at 500mb; and for the equivalent potential temperature *change* through the 850-700mb layer and through the 700-500mb layer.

Equivalent potential temperature (θ_e) remains constant during the approximate adiabatic process for saturated air. Since it is also constant for the adiabatic process of unsaturated air it is a conservative expression for a sample of moist air. Therefore, the θ_e is used to identify an air mass and so allow the air mass to be observed in its displacement through space and time. At a given surface, θ_e is uniquely determined by the temperature and mixing ratio.

The family of isotherms and the family of mixing ratio lines intersect each other on a constant-pressure surface. If the values of temperature and mixing ratio for which the isotherms and the mixing ratio lines will be drawn are determined so that the intersections define θ_e for multiples of five degrees, then the family of lines obtained by graphical addition of the isotherms and mixing ratio lines.

Table VII: Dewpoint (°C) for various values of mixing ratio at different surfaces.

Mixing Ratio	850mb Surface	700mb Surface	500mb Surface
0.2	-	-	-42
0.3	-	-	-38
0.5	-27	-28	-32
0.7	-23	-25	-29
1.0	-19	-20	-25
1.5	-14	-16	-21
2.0	-11	-12	-17
3.0	-05	-07	-12
4.0	-02	-03	- 9
5.0	1	0	-
6.0	4	2	-
7.0	6	4	-
8.0	8	6	-
9.0	-	-	-
10.0	11	-	-
12.0	14	-	-

Table VIII: Values of equivalent potential temperature for various values of dewpoint °C (horizontal) and temperature °C (vertical) at the 500mb, the 700mb, and the 850mb surfaces.

Actual Temperature (°C.) 500	700	850													850	700	Actual Temperature (°C) 500
500			-	-	-	-	-	-	-9	-12	-17	-21	-25	-32			500
	700		-	-	+6	+4	+2	0	-3	-7	-12	-16	-20	-28		700	
		850	+14	+11	+8	+6	+4	+1	-2	-5	-11	-14	-19	-27	850		
+7	-	-	384	377	369	366	363	359	356	353	350	348	347	345	-	-	+7
+3	-	-	378	372	364	361	358	354	351	348	345	343	342	340	-	-	+3
-1	-	-	372	366	358	355	352	349	346	343	340	338	337	335	-	-	-1
-5	+22	-	367	360	353	350	347	344	340	338	335	333	332	330	-	+22	-5
-10	+17	-	361	355	348	345	342	339	335	333	330	328	326	325	-	+17	-10
-14	+13	-	355	349	342	340	336	333	330	327	324	323	321	320	-	+13	-14
-18	+8	+25	350	343	337	334	331	328	325	322	319	318	316	315	+25	+8	-18
-22	+4	+20	344	338	332	329	326	323	320	317	314	313	312	310	+20	+4	-22
-26	-1	+15	338	332	326	324	321	318	315	312	309	308	306	305	+15	-1	-26
-30	-5	+10	332	327	321	318	315	313	310	307	304	302	301	300	+10	-5	-30
-34	-10	+5	327	321	316	313	310	307	305	302	299	297	296	294	+5	-10	-34
-38	-14	+1	321	316	310	308	305	302	300	297	294	292	291	289	+1	-14	-38
-42	-19	-4	315	310	305	302	299	297	294	291	289	287	286	284	-4	-19	-42
-46	-23	-9	310	304	300	297	294	292	289	286	284	282	281	279	-9	-23	-46
-	-28	-14	304	299	294	292	289	287	284	281	278	277	276	274	-14	-28	-
-	-32	-18	298	293	289	286	284	281	279	276	273	272	270	269	-18	-32	-
-	-37	-23	292	288	284	281	278	276	274	271	268	267	265	264	-23	-37	-
-	-	-28	287	282	278	276	273	271	268	266	263	262	260	259	-28	-	-
		850	+14	+11	+8	+6	+4	+1	-2	-5	-11	-14	-19	-27	850		
	700		-	-	+6	+4	+2	0	-3	-7	-12	-16	-20	-28		700	
500			-	-	-	-	-	-	-9	-12	-17	-21	-25	-32			500
Press. Level in Mb.			Actual Dew Point Temp °C												Press. Level in Mb.		
			12.0	10.0	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.5	1.0	0.5			
			Actual Mixing Ratio (g/kg)														

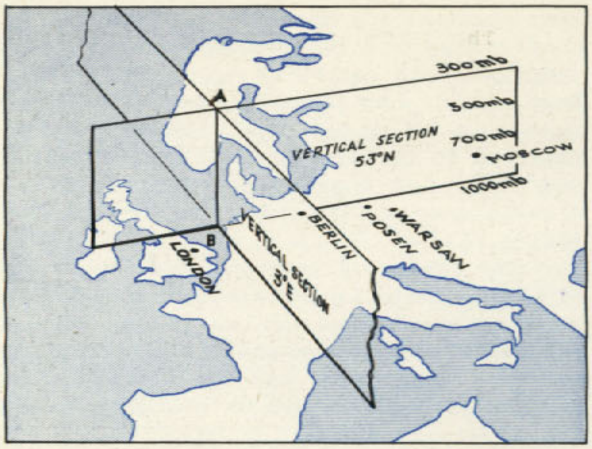
PART B

T_{500}(°C)	7	3	-1	-5	-10	-14	-18	T_{500}(°C)
T_{700}(°C)	-	-	-	22	17	13	08	T_{700}(°C)
θ_e(°A)								θ_e(°A)
365	7.0	8.0	10.0	12.0				365
360	5.0	7.0	-	10.0	12.0			360
355	4.0	5.0	7.0	-	10.0	12.0		355
350	2.0	4.0	5.0	7.0	-	10.0	12.0	350
345	0.5	2.0	4.0	6.0	8.0	-	-	345
340		0.5	2.0	4.0	6.0	8.0	-	340
335			0.5	2.0	4.0	6.0	7.0	335
330				0.5	2.0	4.0	6.0	330
325					0.5	2.0	4.0	325

PART A

T_{500}(°C)	-18	-22	-26	-30	-34	-38	-42	-46					T_{500}(°C)
T_{700}(°C)	08	04	-01	-05	-10	-14	-19	-23	-28	-32	-37		T_{700}(°C)
T_{850}(°C)	25	20	15	10	05	01	-04	-09	-14	-18	-23	-28	T_{850}(°C)
θ_e(°A)													θ_e(°A)
338	8.0	10.0	12.0										338
332	6.0	8.0	10.0	12.0									332
325	4.0	6.0	8.0	10.0	12.0								325
320	2.0	4.0	6.0	8.0	10.0	12.0							320
315	0.5	2.0	4.0	6.0	8.0	10.0	12.0						315
310		0.5	2.0	4.0	6.0	8.0	10.0	12.0					310
305			0.5	2.0	4.0	6.0	8.0	10.0	12.0				305
300				0.5	2.0	4.0	6.0	8.0	10.0	12.0			300
294					0.5	2.0	4.0	6.0	8.0	10.0	12.0		294
289						0.5	2.0	4.0	6.0	8.0	10.0	12.0	289
284							0.5	2.0	4.0	6.0	8.0	10.0	284
278								0.5	2.0	4.0	6.0	8.0	278
273									0.5	2.0	4.0	6.0	273
268										0.5	2.0	4.0	268
θ_e													θ_e

Table IX: Equivalent potential temperature values for the isopleths drawn by graphical addition of the isotherms and mixing ratio lines at each of the 850mb, the 700mb, and the 500mb surfaces.



(continued from page 15)

showing the successive displacements of the 700-300mb thermal thickness line due to advection. In its initial position after subsidence has just occurred, it is drawn as a continuous red line. The full line, the dashed line, and the dot-dashed line are successive displacements of the thickness line by the *relative* wind. Fig. 9 compares in a vertical manner the contours and isotherms at the 1000mb, 700mb, 500mb, and 300mb surfaces. The contours and isotherms in Fig. 9 are tracings from Fig. 6 at the vicinity of 50°N from the 10°W to 40°E. In the blue shaded area both convergence and advection of cold air is taking place, whereas advection of warm air and divergence is occurring in the red areas. These shaded areas do *not* define the regions of greatest intensity for cold- and warm-air replacement.

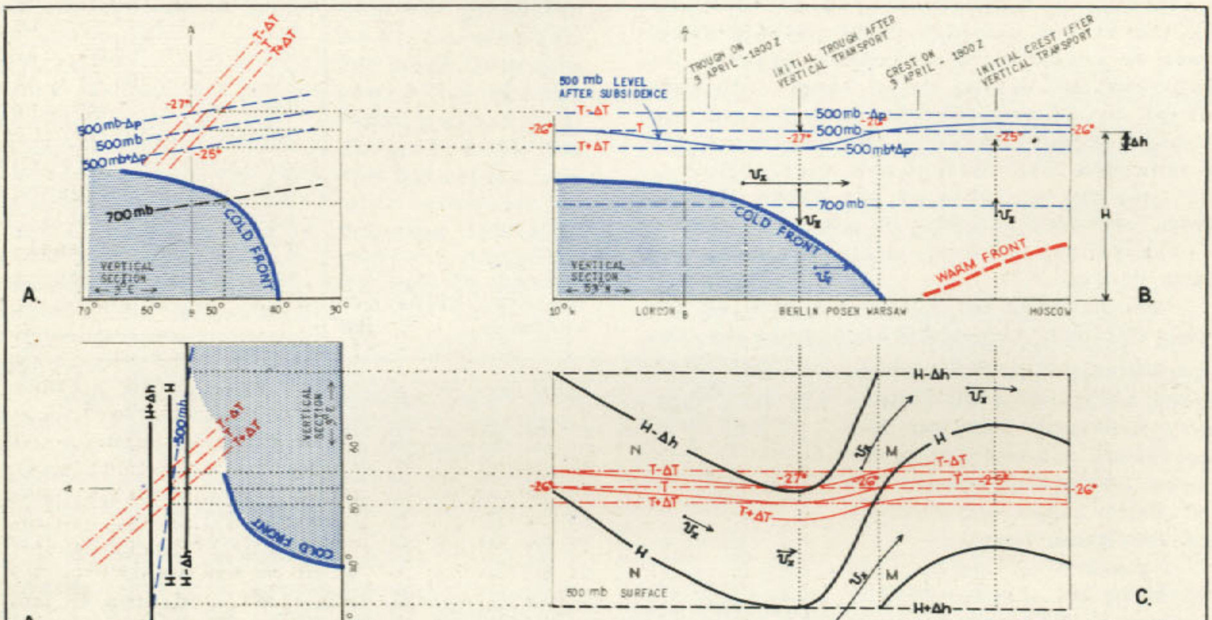


Figure 7

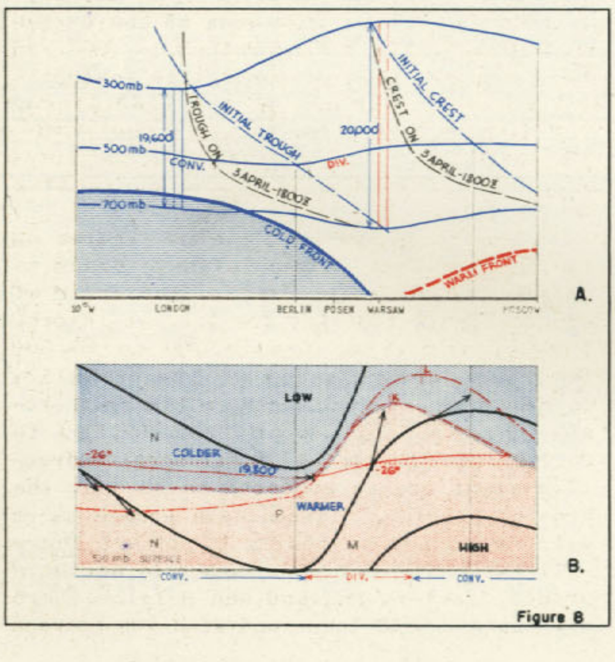


Figure 8

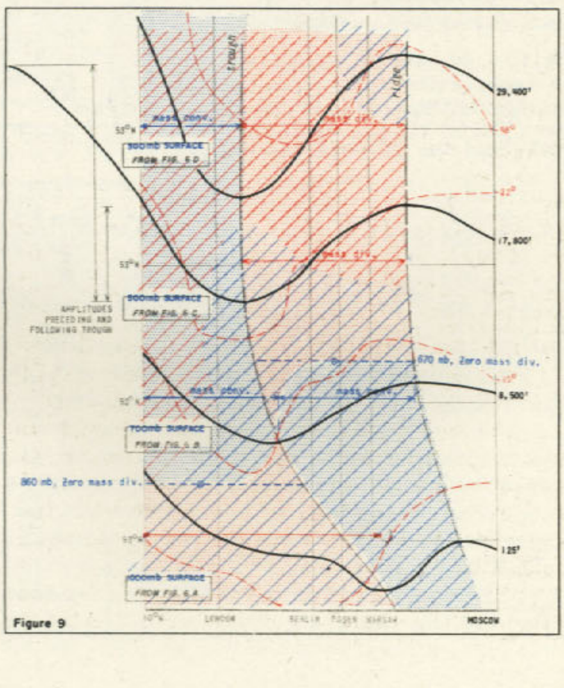


Figure 9

isopleths of mixing ratio will define a continuous pattern of θ_e at intervals of even five degrees.

The main lines of actual mixing ratio are drawn for values of 0.5, 2.0, 4.0, 6.0, 8.0, 10.0, and 12.0, and the isotherms are drawn for values of temperature specified in Table II. The family of lines constructed by graphical addition of the mixing ratio lines and isotherms on the same surface are isopleths of θ_e at five degree intervals (300°, 305°, 310° . . .).

This relationship holds throughout the 850mb surface. At the 700mb surface, for mixing ratios greater than 8.0 grams per kilogram and temperatures greater than $+8^\circ C$ there is a slight variation. However, the instances with moisture and temperature greater than these values are beyond the range of values normally encountered at the 700mb surface. Likewise, the relationship is essentially maintained at the 500mb surface, because the variations, which are slight, occur for values of moisture and temperature which are greater than those values generally encountered in practice.

Tables VIII and IX could be used to label θ_e lines, but since the intervals are always of five degrees, it is sufficient to remember one relationship at each surface (θe,t, x).

The analysis of θ_e from isotherms and mixing ratio lines in this manner compares favorably with the practice of analyzing a surface for θ_e by interpolation between values of θ_e plotted at raob stations. The isotherms have been prepared by reference to wind data, thickness lines, and frontal positions in addition to the observations of temperature; and the mixing ratio lines have been prepared by reference to the isotherm analysis and the flow pattern in addition to the observations of moisture.

The distribution of an air mass in its vertical as well as horizontal extent can be obtained by comparing the θ_e charts at the different levels. Subsidence of a stable layer is denoted by a decrease of the field of θ_e for successively lower surfaces, whereas ascent of an air mass generally is denoted by a decrease of θ_e at successively higher surfaces. The intensity of non-adiabatic processes can be obtained by noting the changes in θ_e.

The analysis for θ_e-change through the layers is prepared so as to examine the displacement of air masses. The patterns of θ_e-change through a layer are obtained by graphical subtraction of the θ_e lines on the boundary surfaces.

In the regions where θ_e decreases with height, there is convective instability. The intensity of the convective instability is expressed by the amount of θ_e decrease. Positive values of θ_e change indicate convective stability. These change patterns of θ_e for each layer are tracked with time. They are compared from one layer to another for a given time, noting the orientation of the patterns with height as well as their intensity.

The θ_e-change charts together, showing a continuous analysis of convective stability throughout the region of weather analysis, are evaluated by comparing them with the surface analysis, noting frontal locations, cloud formations, precipitation, and other indications of stability or instability. These charts are referred to the θ-change charts, which show the patterns of absolute and conditional stability for the same layer. They are compared with the thickness charts for the same layers. They are also compared with the patterns of moisture at the pressure surfaces. This inter-relation of stability analysis with the other features of analysis enhances the understanding of present weather and allows for a comprehension of future weather.

The use of the two types of stability analyses together with prognostic surface and upper-air charts assists the forecasting of cloud; the level, the structure, and the amount. The patterns of conditional instability and convective instability are extrapolated together with the systems on the surface, retaining the identity of the relationship of surface systems with the instability patterns aloft. Figures 4B and 4C present the analysis of θ_e-change through two adjacent layers. This analysis defines two areas: the area of convective stability which is described by the red lines and the area of convective instability which is defined by the blue lines. The black line, which is labeled 0° θ_e-change, divides the layer into the areas of convective stability and convective instability.

The θ_e-change patterns in Figures 4B and 4C have been extrapolated in order to obtain a 24-hour forecast of the areas of convective instability for the two layers. Through the layer from 5,000 to 10,000 feet the strongest convective stability is expected to be in southern France whereas, through the layer from 10,000 to 20,000 feet the region of strongest convective stability is expected to be over the area of Belgium. In southern France there will be no low or medium cloud but there will be 2 - 3/10 high cloud. In northern France, eastern England and Belgium there will be 4 - 6/10 low cloud with top between

8,000 and 10,000 feet. There will be no middle or high cloud in the area.

In Figure 4C the center of convective instability in the mid-Atlantic has been forecast to reach 53°N, 15°W in 24 hours. This pattern of convective instability is associated with the frontal system in the mid-Atlantic which is moving eastward toward the British Isles (Figure 1). The forecast convective instability pattern expresses the degree of intensity of the frontal system.

III. *An Example in the Evaluation of the Analysis.*

The manner in which an isobaric surface analysis and a thermal thickness analysis are exploited in order to comprehend synoptic developments will be shown by the evaluation of a particular weather situation. The important feature of this example is the development in the upper-air circulation of a marked trough which is not discernable at the surface.

In Figure 6C, a 19,600-foot thermal thickness low is observed in the 700-300mb layer over Belgium and the North Sea, but not in the lower layers. The presence of a colder air mass through the higher layer is expressed in the development of a contour trough which intensifies considerably at successively higher surfaces (Figures 6C and 6D). This contour trough is not observed at the lower surface (Figure 6B). The contribution by each atmospheric layer to the thermal development of the trough is shown by the thickness analysis of each layer.

When the layers of the atmosphere are examined separately for their thermal characteristics, an understanding of the inter-relationship of the flow patterns at the various levels is achieved. Insofar as evaluation of analysis is concerned, the statement in italics is the most important result of the differential analysis; for its clear, succinct, and quantitative description of the relation between the circulation and the temperature variation facilitates many well-known dynamical and kinematical interpretations. Some of these interpretations are given below for the particular situation under consideration.

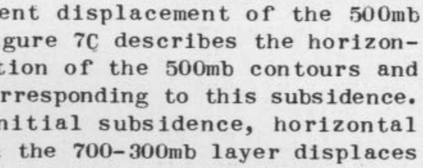
Heavy intermittent showers, convective clouds with considerable vertical extent, thunderstorms, and other unstable weather are occurring in the north Channel area (Figure 6A). This line of convective activity in the slight trough from the North Sea southward to the Channel area, often misinterpreted as a secondary cold front, is explained by the upper-air analysis. The trough aloft has expressed itself in intense, non-frontal weather at the surface.

A physical interpretation of the non-frontal weather and the manner of development of the upper air trough at the 500 and 300mb surfaces are obtained from a consideration of Figures 7-9.

If the air mass aloft moves faster than the surface frontal system, subsidence occurs over the cold front. This physical displacement of air downward initiates a series of dynamical and kinematical processes which result in the development of a high-level trough and resultant convective weather. In Figure 7B the strong zonal flow at the upper levels, as observed in Figure 6C and 6D, is moving eastward more rapidly then the frontal surface. There results a downward movement of the air mass.

When subsidence occurs over the cold front, the 500mb surface is displaced downward. For a vertical, 200-foot displacement of the 500mb surface, there occurs a horizontal deformation in the contours of 380 miles.[1] If the slope of the isentropic surfaces is seven times steepe. than the slope of the constant-pressure surfaces,[2] the subsidence effects a horizontal deformation of the contours which is seven times greater than that of the isotherms[2]. Figure 7B shows subsidence over the cold front and the consequent displacement of the 500mb surface. Figure 7C describes the horizontal deformation of the 500mb contours and isotherms corresponding to this subsidence. After the initial subsidence, horizontal flow through the 700-300mb layer displaces the thickness lines, and the thermal trough commences to overtake the contour trough. With the advection of colder air into the trough, deepening will continue. Figure 8 describes the manner in which the trough in Figure 6C and 6D intensifies in successively higher levels with the advection of colder air through the layer. The amplitude of the thickness lines becomes greater. The thermal trough and crest overtake the trough and crest of the contours. The contours, isotherms, and thermal thickness lines approach an in-phase relationship. When they become in phase, the deepening effect of advection on the trough ceases.

Considering the distance from the equator to the pole:



[2] $\tan\theta = \left|\frac{\partial T}{\partial Y}\right| \Big/ \left|\frac{\partial T}{\partial Z}\right| = \frac{40}{10^7} \Big/ \frac{6}{10^7} = 6.7 \times 10^{-4}$

[1,2] slope of isobar $= 2\Omega_z v/g = 1 \times 10^{-4}$

In addition to initiating the advective flow, the initial subsidence also provides for a kinematical deepening with height of the trough by convergence and a deepening of the ridge by divergence.

The super-geostrophic wind at the crest due to the cyclostrophic effect predominates over the sub-geostrophic wind at the crest due to the latitudinal effect. Similarly, at the trough the cyclostrophic effect predominates over the latitudinal effect and the gradient wind is generally sub-geostrophic. Then for the area following the crest and preceding the trough divergence is occurring. The only manner in which a depletion of air mass through an isobaric layer can be effected is by a decrease of density caused by a "warming" of the air. Since divergence describes a "depletion" of the air mass, the divergence following the crest and preceding the trough effects an increase in the thermal thickness of the layer. The divergence aloft produces two contrasting effects: a falling height tendency field at the lower surface and a rising thermal-thickness tendency field in the layer. Similarly, the convergence following the trough and preceding the second ridge produces two contrasting effects, a tendency field of rising heights at a lower surface and a tendency field of falling thermal thickness in the layer above.

An asymetrical development of the upper-air wave is observed (note amplitudes in Figure 9), due initially to the difference between the downward rate of subsidence, v_z, over the cold front (in the vicinity of Berlin, Figure 7B) and the rate of upward lift over the warm front (in the vicinity of 30^oE). The initial lift at 30^oE is negligible at 53^oN and is relatively small farther north over the warm front in the vicinity of 60^oN. In Figure 7B the downward displacement of the 500mb surface over the cold front is shown to be twice as great as its upward displacement over the warm front. By this difference in initial subsidence and lift, the contours of the 500mb surface are skewed, as shown in Figure 7C. The skewness of the contour wave effects an intense gradient in the vicinity of MM, which is greater than the super-geostrophic wind at the crest, the sub-geostrophic wind at the trough, or the geostrophic wind at the inflection point NN.

Further, the isotherms at MM (Figure 7C) are oriented across the gradient flow of the contours, whereas the isotherms at NN are oriented somewhat along the contour flow. The successive displacements of the isotherms result in an asymmetrical isothermal pattern. The thermal ridge, denoted K and L in Figure 8B, is rapidly overtaking the contour crest. In this region the isotherms soon become in phase with the contours, and intensification of the contour ridge due to advection ceases. In the region of NN the isotherms are being displaced more slowly and remain out of phase with the contour lines for a much longer period of time. In Figure 8B the deepening due to advection will continue at the left for a considerably longer time than the deepening at the right. Consequently, the crest preceding the trough ceases to intensify, whereas the trough continues to deepen.

As the deepening of the trough commences, its axis is displaced westward, as shown in Figure 7A. With the westward, displacement of the trough, the contour gradient at MM decreases. The curvature of flow at MM likewise decreases, and the cyclostrophic effect is lessened. Not only does the effect of advection in the area MM cease, but also the effect of divergence diminishes.

On the other hand, in area NN the effects of advection and convergence increase as the curvature of flow becomes greater with the westward displacement of the trough.

In the area between Berlin and Warsaw, divergence above 700mb is partially compensated by convergence below that surface. Moreover, as shown in Figure 7A, the orientation of the isotherms at the 1000mb surface is such that advection below 700mb compensates for the advection above that surface. Hence, the ridge preceeding the trough has a small amplitude because of the limited development. And the asymmetrical development of the upper air wave occurs because of the difference between the initial subsidence and lift over the frontal surfaces, which influences convergence and advection.

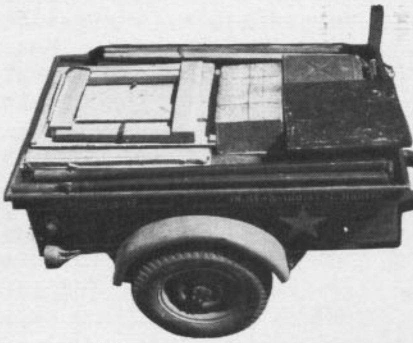
IV. *Flexibility of Isobaric Analysis.*

The manner of work presented in parts I and II for preparing a *complete* upper air analysis from constant-pressure surface considerations includes all the present AAF techniques. Because of the particular conditions and purposes of work at the AAF Centrals in Europe, this procedure is followed rather exactly there. Inasmuch as the provisions for isobaric analysis are certainly different elsewhere, the procedure described may not be necessarily applicable in its full extent.

An attribute of this method of analysis is its flexibility. Even though one or more parts of the analysis may be omitted completely or partially, the others can be performed. Isobaric analysis is quite adaptable to the individual needs and requirements of different weather sections. The exhaustiveness of the complete analysis procedure does not imply that the method is impractical, but rather that it accounts for many possibilities of upper-air analysis.

Metro Musings

JEEP WEATHER STATION



A "jeep and trailer" mobile weather station, small enough to fit into a transport plane, is now seeing service in the Burma fighting areas. Designed to answer the problems of mobility and completeness of service in forward areas, the jeep station is the idea of Captain Herman L. Hums and Sgt Joel Miller, both of the 10th Weather Region.

Several factors eliminated the use of the van-type K-53 mobile station: it would be highly impractical for the terrain in which the unit was to operate; it would be too large to transport by air, the only available route to the front; and, once there, it would be extremely difficult to move on very short notice, and the enemy was expected to make such moves necessary.

Although a "package weather station" would have provided all the necessary equipment for the trailer, none was available at the time, and ordinary items had to be gathered and modified to outfit the mobile station. Even so, the equipment can be unloaded and put into operation by two men within 30 minutes; disassembly and packing takes them about 25 minutes.

Some ingenuity was necessary to fit the equipment into the trailer. An instrument shelter was built large enough to accomodate a cased ML-47 theodolite during moves. Support for the shelter is furnished by tripod ML-178, which can be quickly assembled. An inflation tent for pibals serves as housing for the entire station. The support for wind equipment SCM-20 was cut down to fit into the trailer. A field desk, supported by the box containing the wind equipment, is used as storage space for the thermograph and some of the expendable supplies. Two officer mess kits provide additional storage space during moves and also serve as props for the desk during operations. An empty kit holds 72 calcium hydride charges. An old metal container was made into an eight-inch rain gauge, with a funnel of sheet metal and an inner measuring tube of pipe. Economic arrangement of equipment provides enough space inside the tent to accomodate two cots for sleeping.

HELP WANTED

Weathermen who are separated from the Army may receive some guidance and assistance toward civilian employment in meteorology from the A.M.S. Those interested should write: The American Meteorological Society, 5727 University Avenue, Chicago 37, Illinois.

NIGHT WEATHER ACCIDENTS

Clearances for flight during the hours of night deserve special consideration from weathermen. Nocturnal flying in the United States is rather infrequent, but at night the total accident rate is high, the influence of weather in causing accidents is extraordinary, and the occurrence of forecasting errors is far above the average for daytime flights.

A detailed study has been made of aircraft accidents at night in the United States for the first three months of 1945. Although only 13% of the flying accomplished in the United States by the AAF was done at night, 45% of the accidents which involved weather as a contributing factor occurred after nightfall. The night rate of weather accidents per 100,000 hours flown was 5.5, while the day rate was 1.0. But this is the punch line: forecast error contributed to nocturnal accidents *eight times more frequently.*

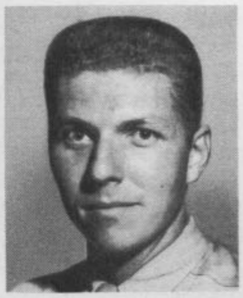
Weather accidents at night were, in general, exceptionally serious. For weather accidents, the ratio of the night rate to the day rate in fatalities was 5.3, and in wrecked aircraft it was 7.2.

AIR SUPPORT WEATHER: I

by Corporal Irving Ripps

In early April of 1943 during the Tunisian campaign, the American 34th Division was getting ready for a big push. The plan was to drive the Germans past Fondouk and on to the Kairouan Plains. Somebody thought of an idea in connection with air support. Why not send a forward party of weathermen to an observation post on the front lines to get the exact weather conditions over the target area? The reports would be sent back to the Allied fighter base at Thelepte, an advance strip where most of the air support fighter missions would originate. Major David M. Ludlum (then a lieutenant), StaWO at Thelepte and later SWO for General Clark, offered to test the plan. When the offensive was ready to be launched, he and two observers took off for Fondouk. This was the first air support weather party to operate in this war.

In February 1945, S/Sgt Phillip L. Voland was getting ready to leave France for home. During the last two years he had been through seven campaigns with Mobile Unit #2 in North Africa, Sicily, Italy, and France and was being sent back now on rotation. But before he left, a call came in from the 12th Weather Region RCO in Italy. They wanted Voland to write the history of the mobile unit. He did, finally getting home on April 20. Right now he's the historian for the Weather Service's Redeployment and Training Unit at Goldsboro.



S/Sgt Phillip Voland

When you talk to Voland about his campaign experiences, invite him to sit down first. He's got much to talk about, and he's 6:4 tall, so if you don't sit down while you're conversing, you'll develop a very sore neck. (This medium-high interviewer did.) If you don't think of it when you start the interview, it will come to you after a while.

"I guess I got this tall from playing basketball ever since I was this high," Voland naively remarks, holding his palm about three feet above the floor.

Voland continued to play basketball at Beloit College in Wisconsin, squeezing in enough credits in his spare time to graduate with a B.A. degree in economics in 1941. Possessed of a hard-headed viewpoint on coming world events, Voland didn't see much sense in getting started on a career; so he enlisted in the Army before the ink had quite dried on his sheepskin. After basic he had a 10-week course in weather observing at Chanute Field, followed by 10 months of station practice at Harlingen, Texas. He said goodbye to his friends and relatives on 5 August 1942 and sailed the following day for England with the original cadre of the 18th Weather Squadron.

A month after D-day in North Africa, on 5 December 1942, Voland was at Oran. He was supposed to go to work there but instead he and the other new weathermen were handed air transport hitch-hike orders to proceed to a newly established fighter base on the Tunisian border, outside a small town called Youks les Bains. (A Youks census taker hardly ever counts beyond 100.) The weather station in Oran was already operating with a full complement, and there was no room for additional men.

"There wasn't a pinpoint of light on the field when we landed," relates Voland. "It was too close to the German lines, I guess. We waited in the plane about half an hour for somebody to come along. There was no sense in going out into that blackness---it was too easy to get lost and we were scared to flash a light. Well, nobody came. The result was, we slept in the plane all night, and boy, don't let anybody ever tell you North Africa isn't cold at night, especially in December."

It took them several hours to locate the weather station the following morning. The field was new, and nobody knew who anybody was or where they were. Besides, everything was either underground or cleverly concealed. A mechanic told them to try the little camouflaged wigwam at the other end of the field. It turned out to be the weather station. The station wasn't fully equipped and had to depend on the nearby French station at Tebessa for most of its data. Two of the observers, Van Dyne and Kurlansky, prided themselves on their knowledge of French until they began taking down the French reports over the phone. The boys soon admitted that perhaps it would be best if they brushed up a little on the subject first. A French meteorologist was borrowed from Tebessa, and the weather station, such as it was, began operations.

The third day Voland was on the field, General Doolittle stopped off on an inspection tour. That was the day Jerry really poured it on. A new American AA outfit had just set up that afternoon and hadn't coordinated yet with the British unit at the foot of the field, which usually gave the signal for anti-aircraft fire. When Jerry came over, our boys went right ahead and tried out their new guns. This gave them away. From about 500 feet, the Germans dropped 20 bombs. Each one counted. It all happened so fast, the P-38s never had a chance to get off the ground. Nine planes were blasted, ammo dumps were blown up, and a couple of AA guns were knocked out. As soon as the raid started, the Doolittle crew made for their B-25 guns. They must have just about lined up their sights when a bomb hit the plane square in the belly, killing every man. In the four months Voland was stationed at Youks, the field was raided about twice a day---usually around chow time---but this raid was by far the worst.

As it happened, Youks was at the end of the supply line and the chow and cigarette situation left much to be desired. The Americans were on British rations and the boys didn't go for porridge. The weathermen got together and decided to do with one man less on shift and make him a cook. Voland volunteered for the job.

"I always enjoyed cooking," he says, "and this gave me a chance to do my stuff with some eggs and chickens I'd manage to get in the village in exchange for cigarettes. I did most of the cooking for the outfit until we got into Caserta in Italy several months later. Here we hired two Italian cooks who travelled with us all through southern France after the invasion. In my spare time, I also took care of supplies. Once I got hold of a couple of cartons of Camels. I can't tell you how I did it but that was the only time in Africa we smoked popular American cigarettes."

From Youks, Voland went to Thelepte, mentioned earlier as the base from which the first air support weathermen operated. Voland was not in on the initial operation at Fondouk. S/Sgts Mark E. Cogswell and Maurice E. Thomas accompanied Major Ludlum. They were supposed to set up on top of a hill called Jebel Trozza which overlooked the Fondouk valley and the Kairouan plains. Instead, they walked up the wrong hill and practically into the hands of a German patrol before they realized their error. Luckily, they got down before the Germans saw them.

The weathermen finally established contact on Jebel Trozza with a forward artillery observation post directing the fire of all 155s in the valley. They took obs every hour of conditions over and beyond the battlefield and phoned them in to the divisional air support party of the 2nd Tactical Air Communications Squadron. They used converted Alaco code. This air support party, which handled air-ground liaison for the 34th Division, relayed the weather reports to Thelepte. Voland mourns the fact that he didn't go along on this job.

"Those boys had mezzanine seats to a real, full-scale operation," he says. "All the action took place right under their noses and they didn't miss a trick. Something very tragic happened. A P-40 was shot down by our own infantry with small arms fire. I guess those guys thought it was a Messerschmitt."

By April 6, the decisive part of the battle was over. From then on the idea of using air support weathermen became an integral part of future military operations in the Mediterranean theatre. When the Tunisian campaign ended in May 1943, the Thelepte station was converted into Mobile Unit #2 to operate with the 12th Tactical Air Command. The unit became the monitor station for a mobile weather net covering an area of about 300 miles. Personnel consisted of 10 observers, three forecasters, and three weather radiomen. Four of the observers were specifically designated as air support men, and in future campaigns through Sicily, Italy, and France each man was to be stationed with front-line 3rd T.A.C. Squadron command posts from where he would report back hourly weather to the monitor station which, in turn, would disperse the information to fighter units and ground force intelligence. The four observers picked for the job were Voland, Cogswell, and S/Sgts Kenneth F. Brechler and Philip L. Craig. The forecasters were Major Ludlum, WOJG Lewis N. Niles, and M/Sgt Robert W. Bailey. The unit was completely furnished with standard equipment, including a K-55 van with fluorescent lights, an SCR-299 radio truck, a PE-95 generator, and a jeep.

"We also picked up a German jeep, a

German field stove, and an Italian truck," Voland adds. "This stuff had been abandoned on the road by the retreating Jerries. The jeep and truck came in handy for the extra equipment we had. The stove was just what we needed later on when we had trouble with mess facilities in combat zones."

In July Mobile Unit #2 moved on to Bizerte, staging area for the Sicilian invasion. Here the men were given practice in amphibious landings, grenade throwing, rifle and small arms firing, tent pitching, pack rolling, guard duty, and various kinds of defense against snipers, flak, airborne attack, and air raids. Sicily was to be their first major test and nerves were a little stretched. The next stop was Cap Bon for some pre-invasion practice assignments and here the boys' morale was given a big lift. The ground was deluged with destroyed German aircraft as a result of the Nazis' desperate evacuation attempt at the close of the North African phase. The Jerries had tried flying out some of their high-ranking officers, and all they had to do it with was a bunch of JU-52 transports. The 52s were like sitting ducks, having a top speed of only 150 mph. Voland says our P-40s had a great time knocking off those babies. One American pilot said that while he was taking part in the engagement, he kept thinking about the time he won a prize for shooting up clay pigeons at a carnival back in his home town.

Because of a delay in shipping orders, the unit didn't land at Palermo until August 6, when the battle for Sicily was about half finished. Headquarters was established at Termini Immerse. Outside of a short run-in with one of General Patton's MP's on account of improper attire (no leggings, no helmets, suntans instead of O.D.'s---despite 100-degree temperatures at the time), the unit lost no time in going into action. With Major Ludlum at the wheel of the jeep carrying passengers Voland, Brechler, and Craig, the party started up the torn coastal road to the small mountain town of Cerami, which overlooked Troina. Troina was in German hands. Brechler was to join the air support party assigned to the 1st division of the 5th Army and Craig was to take up duties with the 45th. Voland was to contact the 2nd Armored Division, but when it was learned that the 2nd at the time was located farther away from the front than the mobile weather station, Voland's assignment was cancelled. So after Brechler and Craig were delivered to their respective outfits, Major Ludlum and Voland pointed their battered jeep back to the mobile station in Termini Immerse.

"On the road in front of us," Voland recalls, "a Sicilian peasant was driving an old wagon filled with vegetables. We started to pass him when the poor guy ran over a land mine. Thank God, we were still far enough behind not to get hurt."

The weather was good at the time and Craig and Brechler hardly ever reported anything other than "few cumulus, unlimited ceiling, and unlimited visibility." One day a flight of American dive bombers let go with some 500-pounders. This opened the way for a concerted drive by both American divisions. The town was taken and the Nazis were rolled back into Messina.

The battle for Sicily ended in August and Mobile Unit #2 was ordered to report to Milazzo near Messina, staging area for the invasion of Italy. Voland was again instructed to join the 2nd Armored Division. When he arrived at Partinico where the division was located, he found no air support party. He learned from an intelligence officer that the division was not going to Italy; that, in fact, it was not going anywhere for awhile. A little bit vexed at the idea of having to report another "dry run," Voland returned to Milazzo.

"If I had stuck around with the 2nd Armored Division," Voland says, "I would have landed on the Normandy beachhead in June 1944."

Mobile Unit #2 now faced its toughest assignment. Italy's surrender on 8 September 1943 was wonderful news, but it hardly eased the tension felt by the air support weathermen for the coming invasion. On Sept 12, D plus 3, personnel and equipment were on a British LST headed for Salerno. Their first attempt to land was repulsed by Jerry 88mm fire. On the second try, they moved farther up the shore along British-held North Beach and sneaked in during a lull. They had advanced about a half-mile inland when a shell exploded about 15 yards away, hurling a large hunk of shrapnel through the top of the van. And then all of a sudden the area around them took on the atmosphere of a monstrous July Fourth celebration. The Nazis were zeroing in, and Mobile Unit #2 was the target. They started a lateral run along the beach with the hope of reaching a British artillery unit about a mile away. The jeep got bogged down in a break in the wire netting that covered the edge of the beach. The driver abandoned the jeep and jumped onto the radio truck. Another piece of shrapnel flew past Thomas, the driver of the van, missing him by inches. Thomas had the gas accelerator down to the floor now and the van bolted forward like a shot.

It took them little more than a minute to reach the British sector, but Voland swears it seemed more like an hour.

With the coming of nightfall, the boys looked forward to a little relief from the German shelling, but Jerry had different ideas.

"We were supposed to contact the 64th Fighter Wing," Voland relates, "about a mile and half from the front lines. We figured we could make it under cover of night. When we started out, things were comparatively quiet. We were moving along very nicely when suddenly we heard two muffled explosions and felt the van jolt. We thought we were hit, but it turned out to be two blowouts. The beach was full of shrapnel and we couldn't avoid it. We were just beginning to change tires when the circus started. The shells began to fall again, and as though this wasn't enough, a bunch of Mark VI Tiger tanks broke through, on their way to splitting the beach in half. German tanks don't take prisoners, you know, so we were doing a little sweating. We could see the tanks from the flares that the British were sending over, and they looked like moving mountains, spitting fire. It scared the pants off us. We figured they were about half a mile away. Well, the only thing to do was to go back, blowout or no blowout. Then the Tommies opened up with their Bofors anti-tank guns. We were in the middle, and really holding the bag. We kept looking at each other, hoping somebody would have an idea. But we were all frozen dumb, except for one guy who made the bright remark that this was the kind of weather work we had volunteered for, what could we expect. Somebody else cracked to shut up, he couldn't hear his teeth chatter. There were a couple of more dumb remarks and maybe it was a good thing, because it kept us talking. Every time somebody said something, he was told to shut up. It was funny, in a way, listening to that crazy talk. But I don't think the boys really knew what they were saying at the time; they spoke almost machanically. Well, I don't know how long we were pinned down in that spot, but the British held them. They sent up a terrific artillery barrage and that finally stopped the Tiger tanks. When we got back, we were ready to kiss the whole British army."

The Germans kept up their fire intermittently during the night. In the morning the unit took advantage of a break in the shelling and, except for a flat tire on the radio truck, reached the 64th Fighter Wing without a mishap. They went to work immediately, and in between obs camouflaged equipment and dug foxholes. Operation was set up with two observers and one forecaster on each eight-hour shift. A schedule was arranged to radio target weather to mobile stations in Sicily and Tunisia for bomber use. Pibals were taken and no one could ever understand why the Nazis didn't shoot down the balloons. They never figured on making a complete run. The first time a balloon was released, it was watched with a great deal of anticipation. At any moment, they expected to see a little puff of smoke where the balloon was. If for no other reason, the boys figured Jerry would at least make a sport of shooting them down. But nothing of the kind ever happened. On clear days, 32-minute runs were averaged.

Once the unit was pounced on by a technical inspector for not using the ceiling light to obtain measured ceilings. When it was pointed out that the use of the ceiling light would give the Nazis a perfect target for their night shelling, the inspector quickly dropped the subject and demanded to know why there wasn't a sufficient supply of ferrosilicon on hand for hydrogen-making. The answer to this was that the chemical took up too much space during moves, space that was being used for more basic items, such as food, guns, and ammunition. Sufficient amounts of hydrogen could always be obtained from nearby artillery units. Nobody ever learned what went into the tech inspector's report, but nothing further was ever heard about it.

Although the Germans had no visible target in the mobile unit because of excellent camouflaging, they threw shells constantly during the 10 days the unit spent on the beach. So many of them were duds that some of the infantrymen in the area began living in tents, abandoning their ditches. Every time a dead shell hit the dirt somebody would have a good word to say about the wonderful job the underground was doing in the German munition factories. The weathermen had a funny experience with a dud. One morning they were sitting around outside Major Ludlum's tent chewing the fat. The major had picked up a German tent in Tunisia which he prized very highly and come hell or high water, he wouldn't sleep in a ditch for any Nazi. He even slept in pajamas, the rest of the crew just removing their shoes when turning in. On this morning, the major had just got up and stepped outside his tent in his pajamas. (Voland thinks they were cream-colored.) Somebody suddenly saw a shell heading their way and the boys buried their heads in the dirt. The major started to run for a ditch and fell into a pile of manure. That's where the shell landed, too. The shell didn't explode, but Major Ludlum did.

Somehow the men got adjusted to working under fire. Once when Voland was spotting a map, pieces of shrapnel went whizzing through the trailer, missing his head by a foot and smashing a bottle of ink over the map. Voland dug out a piece of the shrapnel imbedded in the opposite wall, wrapped it up for a souvenir, and started to spot a fresh map. Another time Thomas had just gone off shift and went outside to take a bath in a barrel of water. He was standing in the barrel wearing nothing but a helmet when a shell swished through a tree, shearing off a heavy branch. The branch knocked the helmet off his head and sent Thomas to the ground with the barrel on top of him. He lay in the mud unconscious for about 20 minutes, and when he came to, got up with a severe cold. The thing that had the boys bothered was the rumor going around that Allied casualties were so heavy up front that all available men not directly in the line would be called up at almost any time. But nothing ever came of it.

One morning a couple of British sappers walked over to the weather area and started poking around on the ground. When they got through, four live mines lay exposed. The weather boys sweated for weeks thinking about it.

Nights were spent guarding the trailer and listening to the falling shells. The Tiger tanks tried breaking through on four consecutive nights and although each time seemed to make a little more headway, they'd end up in retreat. Night bombing was a regular occurrence and for awhile little could be done about neutralizing Jerry raids. The British had laid out a strip on the beach for their Spitfires, but concentrated attacks by Focke-Wolfes and Messerschmitts had rendered it useless, and any attempts to repair it were impeded by further Nazi harassments. On the evening of September 14, the weathermen were asked for a 24-hour forecast of flying conditions over German strongpoints. The forecast was given and on the following morning, the showdown took place. From early morning till dusk, Nazi hill entrenchments above North Beach were pounded incessantly by a cavalcade of P-38s, P-40s, A-20s, A-36s, B-25s, and B-17s, all coming in from distant bases. British artillery laid down a continuous barrage, and offshore were heard the distant reports of Allied cruisers pumping projectiles into the hills. Fast on the heels of this terrific onslaught of power came the swift approach of the British 7th Armored Division, the famous "Desert Rats" who had routed the Nazis at El Alemein. The Germans cracked, the beachhead was made secure, and the infantry took up the offensive once again.

"Craig, in the meantime," Voland recounts, "had got in a jam on South Beach. He landed there on D plus one with the air support party attached to the 45th Division. It seems as though they went in too fast and were cut off by some Mark VIs on their way to block the American landings. The boys still had time to go back, but the road was narrow and flanked by ditches on both sides. They couldn't get their radio truck turned around. Time was growing short, so they did the only thing possible under the circumstances. They set off the demolition charge inside the truck and fled back in their jeep to the main American force. It was impossible to have the truck replaced during the entire beachhead period, so the boys didn't have a thing to do but duck shells and squat on their fannies."

Surprisingly enough, the men were pretty well fed at Salerno. A new 5-in-1 ration was just being issued and was found to be far superior to the C-rations. However, during the entire beachhead period, there were no eggs to be obtained. All the chickens were shell-shocked.

Up to this point Mobile Unit #2 had been so close to the front lines that air support observers were not needed with divisional parties. Now that the front had moved on, the men prepared to join advancing infantry outfits. Brechler, Cogswell, and Sgt Hunt, a new man, left to join air support parties with the 36th Division, 3rd Division, and 6th Corps, respectively. Voland was assigned to the 4th Ranger Battalion fighting near the town of Maiori on the cape north of Salerno. Although Maiori was only a short distance away, it took Voland almost a week to reach it. The Nazis had control of a hill overlooking a long bridge leading into the Maiori coastal road, and everything short of armored vehicles was being stopped by heavy machine gun fire. Somehow Voland managed to get through, only to learn that the 4th Rangers had moved on to Castellammare di Stabia and that the air support party had returned to divisional headquarters.

(The experiences of Voland et al. of Mobile Unit #2 in the MTO will be continued in the next issue of the BULLETIN.)

C.-P. Geostrophic Winds

by Lieutenant Edmund Dews

The geostrophic wind nomogram printed on charts of the WRC 4 series can be used directly for obtaining wind speeds on constant-pressure charts, by entering the contour spacing along the scale for isobar spacing and multiplying the resulting speed by 2-1/3. The geostrophic wind equation for constant-pressure surfaces can be written in a form convenient for mental computations.

The constant-level geostrophic wind nomogram printed on weather charts of the WRC-4 series may be used with a single correction factor for calculating geostrophic wind speeds at all constant-pressure surfaces. The correction factor is the ratio V_p/V_1, where V_1 is the geostrophic wind speed at the 500-meter level (for which the nomogram is designed) and V_p is the geostrophic wind speed on any constant pressure surface.

In practice, it is convenient to measure the contour spacing in the same way as the isobar spacing, and to use the contour spacing so measured directly with the scale for the isobar spacing in the nomogram. If V_1 is defined as the fictitious wind speed read from the nomogram when the 200-foot contour spacing is entered along the scale for the isobar spacing, the correction factor may be written in terms of the constant-pressure and constant level geostrophic wind equations, thus:

$$\frac{V_p}{V_1} = \frac{(g\partial z)\ /\ (\partial n\ 2\Omega\ \sin\phi)}{(\partial p/\rho)/\ (\partial n\ 2\Omega\ \sin\phi)} = \frac{\rho g \partial z}{\partial p} = 2.32 = 2\ 1/3$$

approximately. In this expression, ∂z is taken equal to 200 feet, ρ is the standard air-density at 500 meters, g is the acceleration of gravity, and ∂p is 3 millibars.

The geostrophic wind speed for any constant-pressure chart plotted on a base chart of the WRC-4 series may now be determined in the following way:

(1) Treating the contour lines drawn for 200-foot intervals as if they were isobars drawn for 3-millibar intervals, read the (fictitious) value of the wind speed according to the constant-level geostrophic wind nomogram printed on the base chart.

(2) Multiply the value so obtained by the factor (2 1/3). The result is the constant-pressure geostrophic wind speed in miles per hour.

SHORTHAND WINDS

In many cases it is inconvenient to apply a geostrophic wind scale to the solution of the geostrophic equation. It is useful, therefore, for the forecaster to be acquainted with the following simplified forms of the geostrophic equation for constant-pressure charts.

Expressing the normal distance (L) between contours in degrees of latitude, the constant-pressure geostrophic wind equation may be written $V_p = \frac{82.7}{L \sin\phi}$, where V_p is in miles per hour.

The following table gives to 3% accuracy the form of the equation when $\sin\phi$ is absorbed into the constant.

Latitude	Equation (V_p in mph)
30°	$V_p = 165/L$
40°	$V_p = 130/L$
50°	$V_p = 110/L$
60°	$V_p = 95/L$
70°	$V_p = 90/L$

In this form the constants are easily memorized, and the value of L, expressed in degrees of latitude normal distance between contours drawn for 200-foot intervals, can be determined directly from any base chart, no matter what its scale. Usually it is sufficient for the forecaster to memorize the constants for three latitudes, selected so that the intermediate latitude corresponds approximately to the latitude of his station.

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CONTRIBUTORS

VANNEVAR BUSH has become famed as the coordinator of the nation's war effort in science, from his position as Director, Office of Scientific Research and Development. Dr. Bush's office cooperated in the varied and widespread activities which finally produced the atomic bomb. Between 1932 and 1938, he was vice-president of M.I.T. and dean of its School of Engineering. He has served as chairman of the National Advisory Committee for Aeronautics, of the National Defense Research Committee, and as director of the American Institute of Electrical Engineering. The differential analyzer, a machine for solving differential equations, is one of his many contributions to science.

DAVID NICHOLS, staff sergeant and observer in the 6th Weather Region, is now in the RCO, Albrook Field, Panama. He holds a degree in business administration from an eastern university.

Major ROBERT BUNDGAARD was awarded the Bronze Star Medal in December 1944, after 16 months of service in the ETO as chief of the upper-air section at the USSTAF Weather Central. He spent his collegiate years at Denver University and, later, at Columbia, specializing in math and physics. A native of Colorado, Major Bundgaard was a high school teacher and a violinist in the Denver Symphony Orchestra in his pre-army days. He graduated with the November 1942 cadet class at UCLA, and is now in the Evaluation & Development division of Headquarters Weather Service.

JOE DOPE
"IN THE ART OF WARFARE," SAYS BARON VON SHLAGKAMPF, "..ARMIES AND THEIR LEADERS ARE FOREVER PREY TO THE DIRE RESULTS OF IMPONDERABLES. THE FATE OF NATIONS OFTEN HINGES UPON SOME INFINITESIMAL CIRCUMSTANCE"
OR
AS PFC. PHILANDER P. FINK, LATRINE ORDERLY, PUTS IT, QUOTE ... UNQUOTE
TAKE, FOR EXAMPLE, THE MATTER OF REQUISITIONING PUBLICATIONS...
..WHICH, BY THE WAY, ARE NEVER AROUND WHEN Y'NEED 'EM ...BECAUSE GUYS HOG 'EM....
SHADDAP!
BANG
BANG
BANG
...AHEM! AS I WAS SAYING.... TAKE JOE DOPE F'RINSTANCE
ONE DAY HE CAME UPON FM 21-6 AND LEARNED THAT TM 11-2403 JUST CAME OUT FOR THE RADIOSONDE RECEPTOR
HE WROTE EVERYWHERE.. TO EVERYONE... BUT IN VAIN!
THEN A BRIGHT IDEA HIT HIM....
NO!! NO!! NO!!
NO!
next day.....
YES, MR. PRESIDENT..I GOT ONE, TOO..NO, MR. PRESIDENT, I DO NOT KNOW WHO PFC. JOE DOPE IS..NO SIR, I DO NOT PERSONALLY DISTRIBUTE TM 11-2403
GEN. MARSHALL
BAH!
HSST.. SAKI- GET THAT PIECE OF PAPER..JUST THLOWN FLOM GEN. MOSSHAL'S WINDOW!
AND PAPAH CAPTURED FLOM HON'BLE GENNILAL MOSSHAL INLICATE PFC. DLOPE MAY SOON LECEIVE VITAL INFLOMATION ON LADIOSONDE..WHICH HE MUST NEVAH USE! UNNASTAN', NAKI?
FIX FUZES IN EARS, PLEEZ
HIGH EXPLOSI
BANZAI BOMB SQUAD
FUZES
NEXT DAY
GASP...SERGEANT SHORTPANTS... ONE LAST REQUEST... HOW CAN I REKAZISHUN PUBLICATIONS?
JOE DOPE
VERY SIMPLE, JOE... ALL Y'GOTTA DO IS FOLLOW INSTRUCTIONS IN AAF REGULATION 5-9, IN WEATHER SERVICE MEMORANDUM 5-9, OR OF YOUR THEATRE COMMANDER. DON'T WASTE TIME WRITING OUTA CHANNELS!

THE RELATIONSHIP BETWEEN THE GRADIENT WIND SHEAR AND THE GEOSTROPHIC WIND SHEAR

The relationship between the observed* wind shear and the direction of the thickness lines and magnitude of their gradient for the layer is expressed by the following equation, which is due to Captain George E. Forsythe:

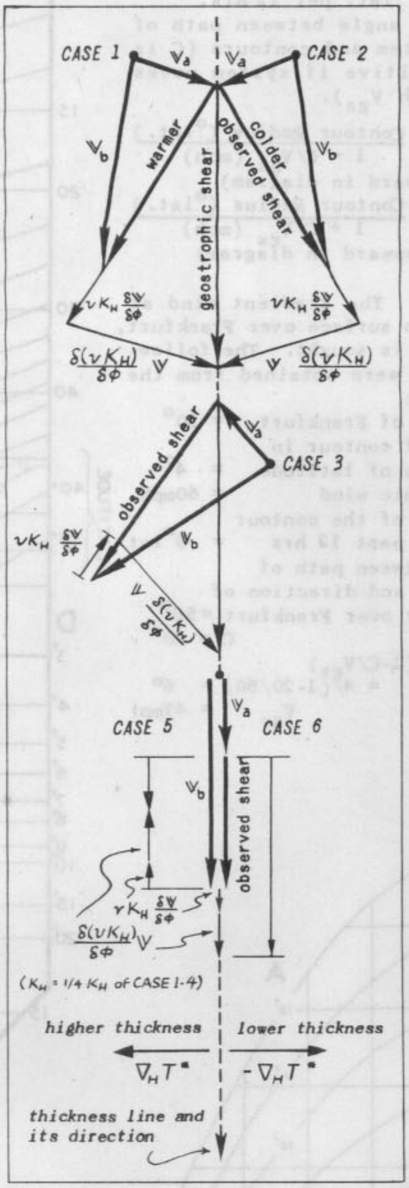
$$(2\Omega_z + \nu K_H)\frac{\delta \mathbb{V}}{\delta\phi} + \frac{\delta(\nu K_H)}{\delta\phi}\mathbb{V} = -\frac{1}{T^*}\nabla_H T_p^* \times \mathbb{K}$$

in which

$\mathbb{V}$, ν	variable wind velocity and wind speed through the layer.
$\mathbb{V}_{at}$	observed wind velocity at lower boundary of layer.
$\mathbb{V}_b$	observed wind velocity at upper boundary of layer.
K_h	variable horizontal curvature of flow in the layer.
δ	geometric differential symbol.
ϕ	geopotential; dynamic height in dynamical decimeters.
Ω_z	the absolute value of the angular velocity of the earth multiplied by the latitude.
$\nabla_H T$	horizontal isobaric ascendent of virtual temperature, T^*
$\mathbb{K}$	unit vector directed toward the local zenith.
$\times$	indicated vector product.
$2\Omega_z \frac{\delta \mathbb{V}}{\delta\phi}$	observed* wind shear through the layer.
$-\frac{1}{T}\nabla_H T \times \mathbb{K}$	direction of the thickness lines and magnitude of their gradient at the point of observation.
$(\nu K_H)\frac{\delta \mathbb{V}}{\delta\phi}$	a correction applied in the direction of the observed wind shear-to the observed* wind shear to obtain the direction of the thickness lines and magnitude of their gradient (the geostrophic wind shear).
$\frac{\delta(\nu K_H)\mathbb{V}}{\delta\phi}$	a correction applied in the direction of the observed* wind at the lower boundary surface of the layer to the observed wind shear to obtain the direction of the thickness and magnitude of their gradient lines.

It is difficult to express empirical rules from equation (1) because both the wind velocity and curvature of flow vary independently through the layer. Six cases are presented schematically in the figure below.

*Here, the gradient wind has been referred to as the observed wind and the gradient wind shear as the observed wind shear.



CASE 1: *If there is*
1. warm air advection,
2. constant (or increasing with height) cyclonic curvature, and
3. increasing wind speed with height;

then a. the observed wind shear points toward higher thickness values, and
b. the distance between thickness lines may be greater or less than that prescribed by observed wind shear.

CASE 2: *If there is*
1. cold air advection,
2. constant (or increasing with height) cyclonic curvature, and
3. increasing wind speed with height;

then a. the observed wind shear points toward lower thickness values, and
b. (see b, Case 1).

CASE 3: *If there is*
1. cold air advection,
2. constant (or increasing with height) *anti*cyclonic curvature, and
3. increasing wind speed with height;

then a. the observed wind shear points toward lower thicknesses, and
b. (see b, Case 1).

CASE 4: *If there is*
1. warm air advection,
2. constant (or increasing with height) *anti*cyclonic curvature, and
3. increasing wind speed with height;

then a. the observed wind shear points toward higher thicknesses, and
b. (see b, Case 1).

CASE 5, 6: *If there is*
1. No warm or cold air advection, and
2. the wind speed increases with height,

then a. the distance between thickness lines will be less than that prescribed by the observed wind shear for constant (or increasing with height) cyclonic curvature (Case 5) and greater for constant (or increasing with height) *anti*cyclonic curvature (Case 6), and
b. the observed wind shear points along the thickness line.

Correction: *In the article "Analysis of C.-P. Surface," the empirical rules given on page 9, column 1, lines 3-41 apply only when warm-air advection is in progress. Sentence one is valid only if, in addition, "same curvature" means cyclonic or increasingly-cyclonic curvature thru the layer.---R.C.B.*

EVALUATION OF GRADIENT WINDS

Procedure:

(1) A = movement of system in deg. lat. per 12 hrs.

(2) B = angle between path of system and contours (C is positive if system moves with V_{gs}).

(3a) $D = \dfrac{\text{Contour Radius } (^{\circ}\text{lat.})}{1 - C/V_{gs} \text{ (mph)}}$

(go upward in diagram)

(3b) $D = \dfrac{\text{Contour Radius } (^{\circ}\text{lat.})}{1 + C/V_{gs} \text{ (mph)}}$

(go downward in diagram)

Example: The gradient wind at the 500mb surface over Frankfurt, Germany, is sought. The following data were obtained from the analysis:

Latitude of Frankfurt	= 50°
Radius of contour in degrees of latitude	= 4°
Geostrophic wind	= 60mph
Movement of the contour low in past 12 hrs	= 6° lat
Angle between path of center and direction of contour over Frankfurt	= 50°
	C = 20°

$D = r_i / (1 - C/V_{gs}) = 4/(1-20/60) = 6^{\circ}$

V_{gr} = 47mph