the trough eastward caused a drop of about 7° or 8° in temperature in the interior of California, while the Arizona temperature remained as high as ever.

Chart D shows the conditions the next day, July 12, and here we have more rain in the North Pacific States and British Columbia, most of which is attended by thunderstorms. The high-pressure area off the Pacific coast has apparently lost energy, and the secondary over southern Idaho has reappeared. There is also evidence of a storm developing over the Bering Sea which may complicate matters should it move southeastward.

On the 13th the conditions are shown on Chart E (fig. 2) and here is seen a development of the high-pressure area which was faintly indicated on Chart C. The low-pressure area over Bering Sea is less pronounced and the consolidation of the southern Idaho low-pressure area with the original low-pressure area over Arizona has taken place. The rain has diminished and most of it fell locally along the North Pacific coast.

The next day, July 14, is represented on Chart F, which is somewhat like Chart A; but with this difference, the barometer is lower in the north and rainfall, which was lacking on Chart A, is quite abundant along the North Pacific coast. Thunderstorms have occurred at Yakima, Spokane, and Kalispell. Temperatures in the interior of California have risen about 8° in consequence of the rearrangement of pressure.

The conditions on the 15th are shown on Chart G, and here is seen a secondary over Idaho, with relatively low pressure over the Canadian Northwest. The high-pressure area has moved east, and the high-pressure area over the ocean is about the same as it was for the last few days. So few reports from the ocean are available that this high-pressure area can not always be definitely located. The rains are light and sporadic. Thunderstorms occurred in the southern portion of California and also at Winnemucca and at Seattle.

The final chart, marked H, shows a general unsettled condition over the Pacific States. Rain has fallen quite generally in Nevada, northern Washington, and western Montana. The eastern high-pressure area is disintegrating, and the relatively low pressure of the day before over the Canadian Northwest has recovered somewhat. This low-pressure area two days later reached the upper Mississippi Valley, and still later passed down the St. Lawrence Valley. In doing so it caused showery conditions in the Lake region and in the North Atlantic States.

Nothing would be accomplished by showing more charts, for they are continually repeating themselves with slight variations all summer long. They give an excellent idea of the difficulties encountered in predicting rain during the summer months in the Pacific States. During the period from July 11 to 16, inclusive, rain fell in nearly all portions of the San Francisco forecast district, and it was evident that it would do so. However, to place this rain geographically for 12-hour intervals was an entirely different matter, and the only thing possible was to make an indefinite forecast for places where it was thought the rain was mostly likely to occur.

Reports from Mexico and a greater number of upper-air observations would undoubtedly be of help in obtaining more definite information regarding the mechanism of the offshoots from what I believe should be called the semipermanent Arizona low. The California part, which first attracted my attention, now seems to be an auxiliary that probably has something to do with directing the movement of the stream lines, or eddies, northward. By taking the northward course they receive additional heat as well as a greater supply of moisture than would be the case if they moved to the northeast or to the east.

DISCUSSION.

By E. H. BOWIE.

With regard to the quotation from Griffith Taylor in the opening of Mr. Beals's article, I would remark that my understanding of this matter is that it has been presented to us quite fully by the late Professor Ferrel in his discussion of the formation of cyclones; in the minds of some, however, convection does not account for the formation of cyclones but has to do with the origin of showers and thunderstorms as observed in the Tropics and other parts of the world.

Doubtless many meteorologists will take exception to the view that in overheated, arid areas there is built up a column, or dome, of warm, ascending, turbulent air as suggested by Taylor. The English idea, if I may so call it, is to the effect that air rises in threadlike streams, not *en masse*, and that between these threadlike streams there will be areas over which air is descending. Hence the sporadic character of thundershowers in regions of strong convection, such as the southeastern part of the United States.

Certainly if heat alone would produce cyclones there should be a considerable number over the far Southwest during the summer, but such is not the case as may be easily seen by reference to MONTHLY WEATHER REVIEW SUPPLEMENT No. 1, Types of Storms of the United States, by Bowie and Weightman. This report shows that for the months of June to September, inclusive, in 21 years but 30 cyclones moved out of the area under discussion, or a little more than 2 per year.

DISCUSSION.

By W. J. HUMPHREYS.

The description of the development of cyclonic storms in the region of southwestern Arizona is both interesting and useful.

It may be remarked with reference to the trough of low pressure which appears to be largely induced by the high temperature of the Arizona and California valleys, that such trough, as indeed all troughs, is unstable and likely to break up into isolated lows or secondaries. This is especially true when the trough is well developed or flanked by a high to the west and another to the east with oppositely directed winds on its two sides.[1]

If there is no precipitation, such a low (secondary) probably will soon be dissipated. With precipitation it may persist for some time and over long distances.

DISCUSSION.

By A. J. HENRY.

Before entering upon a discussion of Mr. Beals's paper it would be helpful to state briefly the several aspects of the paper upon which there is general accord.

Although the author does not specifically state the number of cyclones of the type described he has considered, I think we can accept the count given in Supervising Forecaster Bowie's statement, viz, about 2 per year (in summer).

[1] While this situation may and does arise in the cold season it would fail in the warm months, since high-pressure areas at that time of year seldom, if ever, extend as far south as the lower margin of the Great Basin in Nevada.—EDITOR.

The topographic control of the weather of the Great Valley of California.—Any discussion of the weather of California without a full understanding of the topographic effect upon the weather would be useless and this is our excuse for describing what probably most readers are familiar with. The dominating topographic features of the State are the two mountain ranges, the Sierra Nevada on the east and the Coast Range on the west; between these two mountain systems lies the Great Valley of California broadly open from the Tehachapi on the south to Shasta on the north, a distance of about 400 miles. While the valley may be divided into three parts according to the drainage, yet for our purpose it may be considered as a single geographic unit which, except for the Tehachapi, may be extended southeastward to, and merging into, the valley of the lower Colorado River. Between the Tehachapi and the Colorado is the almost rainless waste known as the Mohave and Colorado Deserts. In the northern half of this waste the surface relief is broken by volcanic hills and low ranges of mountains between which deep salt-covered valleys lie. The Great Valley is, of course, a highly populated region devoted to agriculture, whereas the region southeast of the Tehachapi is, in places, a typical desert waste.

The Weather Bureau has maintained for years a station at Yuma, Ariz., in the lower Colorado River Valley. In drawing isobars and isotherms on the daily weather maps it is customary in summer to connect the lower Colorado Valley and the Great Valley of California by a system of continuous lines. These lines at times follow the contours of the valley and at other times, as may be seen from the figures submitted by Mr. Beals, they extend in a north-south direction over the southern part of the Great Basin. In the summer months, owing to the proximity of the Pacific on the west, both the temperature and pressure gradients between the hot dry interior and the cool, moist coast are very much exaggerated and are artificial in a sense rather than actual by reason of the contrast in the temperature before mentioned. Thus it happens that the barometric gradients of the weather map for California in the months June to September represent a more or less distorted pressure distribution due to the great temperature contrast within the short distance which separates the coast line from the hot interior. It can be easily shown that with initially low pressure in the Great Valley a very slight fall in pressure, such as is associated with cyclonic systems approaching the coast of Washington or Oregon will result in lower pressure in the valley than in adjacent regions both to the west and the east. It is therefore difficult at times to distinguish between real and fictitious LOWS (cyclonic systems). The wind circulation because of the sparseness of the stations is of very little aid in determining whether cyclonic circulation is present or absent.

The thought which most impresses the writer is that only a beginning in this problem has been made. The study of the development of secondaries south of the primary cyclone is one of the major problems which confronts forecasters of the Bureau.

At this point I wish to invite attention to some of the results of sounding-balloon observations made at Santa Catalina Island, off the California coast, by the Weather Bureau in 1913, summarized in this REVIEW for July, 1914, page 410.

Some of the soundings were made on consecutive days and at practically the same hour of the day. The changes in temperature in steps of 1 kilometer have been extracted from that summary and are presented in the table below. For comparison with these data I have copied the daily weather maps for the dates on which consecutive soundings are available (not reproduced).

TABLE 1.—*Twenty-four hour changes in free-air temperature (°C.) from sounding-balloon flights at Santa Catalina Island, Calif.*

Dates.	Kilometers.								
	3	4	5	6	7	8	9	10	11
July 29-30	+9.2	+8.8	+10.0	+9.9	+10.6	+12.7	+13.6	+13.2	+12.0
July 30-31	−5.7	−5.2	−5.3	−7.8	−10.8	−12.7	−11.8	−12.0	−10.1
July 31-Aug. 1	−1.9	−2.2	−0.1	+1.8	+3.1	+5.1	+4.6	+5.6	+4.2
Aug. 1-2	+1.4	+2.7	+1.0	+2.7	+3.1	+1.0	+1.5	−0.5	−2.4
Aug. 2-3	+2.3	+1.0	+0.1	−1.4	−2.6	−2.0	−2.6	+0.3	+2.9

Dates.	Kilometers.							
	12	13	14	15	16	17	18	19
July 29-30	+13.1	+8.5	+7.0	+10.0	+9.9	+8.9	+5.3	+6.0
July 30-31	−8.1	−7.8	−5.4	−6.2	−7.4	−8.8	−5.0	−5.7
July 31-Aug. 1	+2.9	+4.6	+6.9	+4.9	+3.7	+2.6	0.0	−1.2
Aug. 1-2	−5.0	−2.9	−4.3	(?)	(?)	(?)	....	....
Aug. 2-3	+4.8	+5.1	−5.1	(?)	(?)	(?)	....	....

The remarkable fact shown in Table 1 is the magnitude of the rise in temperature on the 30th as compared with the 29th in all levels up to 19 kilometers. The rise began at the surface and seemed to be at a maximum in the levels between 8 and 12 kilometers. The winds on the 29th in the layers next to the surface were from the NW. The balloon was lost in the clouds at 1,012 meters elevation; its general movement was toward the north. The flight on the following day started in a surface wind from the NE., but soon the winds shifted to SE. and S., being south at 1 kilometer S. 86° W. at 1,184 meters, then backing to S. 42° E. at 1,338 meters, it held for a short time in about that direction and was S. 18° E. at 4,362 meters when the balloon was lost in the clouds. This balloon traveled toward the NNW. 140 kilometers from its starting point and yielded a fine temperature and pressure record. Winds from the SSE. on Santa Catalina Island must have traversed 60 to 70 miles of water surface before reaching the island. If projected still greater distance from the island they must have passed over land in southern California.

On the 31st, the temperature fell rather sharply in practically all levels. The wind on this date was S. 57° E. at 1,000 meters, S. 24° E. at 2,000 meters, and finally at 8,384 meters, where the balloon was lost in the clouds, the wind direction was S. 4° E., from which direction it should have come from a water surface. It is to be noted that with the shifting of the wind into a nearly true southerly direction the temperature fall increased, the greatest fall being recorded at 8 kilometers.

There does not seem to be any obvious relation between the direction of the free-air currents and the temperature changes; on the 29th, 30th, and 31st the former were from the south in the main yet the temperature changes on each date were decidedly different the one from the other. Many more flights will be necessary before tentative conclusions can be reached.

The data of kite flights have shown rather conclusively that the temperature in the free air up to 4 kilometers, and perhaps higher, follows that of the surface with respect to the sense of the change from normal and also in a broader sense which may be stated as follows: Free-air temperatures, up to at least 4 kilometers, correspond to surface temperatures, the more so the less is the free air mixed by the local circulation of cyclones and anticyclones.

From these considerations the air over desert areas should be considered as warmer, level for level, than air over surrounding areas with a vegetative cover. It would seem that the free air over deserts receives a greater increment of heat in the daytime than it loses by radiation at night and that the excess, small though it may be, is cumulative, so that after a time we should expect that free-air currents from the lower Colorado Valley and the Gulf of California would be warm as compared with currents from the Pacific. The former by reason of the lower specific gravity of the air in them can not flow to the westward. The most likely course of the air is therefore in the direction impelled by the pressure gradient. The latter generally indicates a movement toward the north. The sounding balloons liberated on the six successive days, July 29 to August 3, traveled in a northerly direction and the lowest temperature recorded during the flights was experienced on August 3—the last day of the six in which the free-air currents moved as above stated. When flights were resumed on August 5 the free-air winds were from the SSW. and the minimum temperatures were distinctly higher than during the first-named period, although in some of the flights the balloon did not reach so great a height as in the first period. A better comparison, however, would be to use a definite level reached by all of the balloons furnishing useful records up to, say, 14 kilometers. Such a comparison shows that the temperature in southerly winds was on the average 2.7° lower than in westerly winds. The interpretation of this fact is left in some uncertainty, since the southerly winds of the group July 29 to August 3 had more or less easterly components, which might mean that originally they were of continental origin.

Comparison of the data of Table 1 with the weather maps for corresponding dates leads to some interesting suggestions. The distortion of the isobars in the summer months, before mentioned, makes it difficult to determine the probable direction of the free-air winds from surface isobars, but when the pressure distribution over the entire Rocky Mountain and Plateau region is considered there is better agreement between the pressure gradients and the direction of the free-air winds.

Thus on July 28–29 the west-southwest winds above Santa Catalina Island were evidently due to a cyclonic disturbance that was moving eastward over southern Alberta. This disturbance deepened somewhat and moved east-northeast in the next 24 hours, so that by the morning of the 29th the whole of the northern Rocky Mountain region and the upper Missouri Valley were under its influence. On this date an anticyclone began to pass from the ocean to the land over the States of Washington and Oregon.

On the next day, July 30, this anticyclone had advanced inland as far as northwestern Wyoming and the barometer level at its center had risen to 30.20 inches. Coincidently with this movement the temperature in the free air, as shown in Table 1, rose decidedly; pressure in the free air also rose, but fell slightly at the surface and as a result the isobar inclosing the center of low pressure over Arizona is now projected northward to include the Great Valley of California. In other words, from surface indications one would say that the Arizona and California lows have intensified and merged. But if we take the free-air observations under consideration as an index to what occurred over California and Arizona, it is at once seen that the surface indications are no sure guide to what has actually happened in the free air.

On the next day, July 31, the free-air temperature fell about as much as it had risen the day before. The anticyclone by this time had advanced to western Nebraska; its center now stretched to southeastern Idaho as an oval with central pressure of 30.30 inches, a rather unusual anticyclone for the month of July.

With the entry of this anticyclone over the continent the free-air winds which previously had been southwest now became southerly and as the anticyclone advanced to the eastward the winds became SSE.

It is rather significant that the lowest temperature reached in the whole series of sounding-balloon ascensions was on August 3 at a height of 17,428 meters, and that on the previous day an almost equally low temperature was reached at an elevation of 21,302 meters, thus perhaps indicating a slight lowering of the current of cold equatorial air.

The important thought of the paper, as I see it, is the necessity of a further study of the influence of summer North Pacific anticyclones upon the weather of the Rocky Mountain and Plateau region. It is already known that the movement eastward of these anticyclones gives the clue to shower forecasts for western and central Colorado, New Mexico, Arizona, and southern Utah.[2]

[2] Weather Forecasting in the United States, p. 115.

THE PRESSURE DISTRIBUTION AT VARIOUS LEVELS DURING THE PASSAGE OF A CYCLONE ACROSS THE PLATEAU REGION OF THE UNITED STATES.

By C. LEROY MEISINGER.

[Weather Bureau, Washington, D. C., August 15, 1922.]

INTRODUCTION.

Barometric reductions in the Plateau.—It is important to ascertain what effects, if any, a mountain range, or lofty plateau, exerts on the meteorological elements of a passing storm. The Plateau region of western United States projects into the atmosphere to an average height of approximately a kilometer and a half above the level of the sea over an area of more than 5,000,000 square kilometers. Situated, as it is, in a position of the greatest strategical importance, from the viewpoint of the forecaster, it is essential that he understand very clearly the relations between the surface weather conditions and the pressure distribution.

The problem is a complex of hypsometric effects, and meteorologists are thoroughly cognizant of the fact that reduction to sea level in the Plateau introduces much that is unreal in the horizontal barometric gradients. Owing to the hypothetical nature of the process, the allowance for fallacious effects is a difficult, if not impossible, task, and it is necessary, therefore, to be content with the knowledge of the presence and mode of origin of these false features.

The differences, however, between the probable distribution of pressure at sea level were the continent removed and the actual distribution at the average level of the Plateau where the weather occurs *do* admit of investigation. These differences arise not through faulty