4. Below 2 kilometers velocities are about equal for all directions, but above this level S. to W. winds are decidedly the stronger—4 to 5 m. p. s. on the average.

5. An investigation of the turning of winds with altitude gives results which are best presented in a table. The winds were not considered individually, but in groups by quadrants. Values are given in percentages.

Altitude, meters.	Quadrants.							
	NE.		SE.		SW.		NW.	
	CW.	CCW.	CW.	CCW.	CW.	CCW.	CW.	CCW.
1,000 to 2,000	32	57	67	26	45	45	44	44
2,000 to 4,000	27	66	44	52	66	21	52	44

The values in this table bring out very clearly the large percentage of counterclockwise turning of northeasterly winds, most decided in the higher levels, and the equally large percentage of clockwise turning of southeasterly winds, most decided in the lower levels. The results compare favorably with those found in the United States.

6. The percentage frequency of velocity increase or decrease has been treated in a manner similar to that above employed, and the results are shown in the following table:

Altitude, meters.	Quadrants.							
	NE.		SE.		SW.		NW.	
	+	−	+	−	+	−	+	−
1,000 to 2,000	50	24	48	36	58	37	44	17
2,000 to 4,000	58	30	51	38	76	16	96	0

7. Thirty-one of the observations were made when the land and sea breezes were well developed, and these were studied with a view to determining to what height this type of circulation extends, also to ascertain any other facts of interest. The results indicate that the land and sea breeze effect is still in evidence on the average at about 2,500 meters; above that level the general circulation prevails, the average values at 4 kilometers being almost identical both as to direction and velocity. At the surface the sea breeze is the stronger; from 100 to 300 meters there is little difference between the two; but from 500 to somewhat less than 2,500 meters the land breeze has a speed about 2 m. p. s. greater than has the sea breeze. This, however, may be in part a diurnal effect. Compare discussion under 3.

8. The paper concludes with a discussion of winds in the stratosphere, but the results are inconclusive, owing to the small number of observations, there being only two above 14 kilometers. These, however, indicate lighter winds between 15 and 20 kilometers than either below or above those levels.— *W. R. G.*

THE METEOROLOGICAL ASPECTS OF THE THIRTEENTH NATIONAL BALLOON RACE.

By VINCENT E. JAKL.

[Weather Bureau Aerological Station, Drexel, Nebr., June 28, 1922.]

To describe the meteorological conditions affecting the flight of the balloons participating in the National Elimination Balloon Race held at Milwaukee on May 31, 1922, and attempt to explain the meteorological control of the paths of the balloons at the various altitudes in which they flew, it is necessary to take a retrospective view of the weather conditions prevailing over the country for a period of a few days. In this way, after the method of forecasting, the predominating features of the weather map—specifically the areas of high and low pressure—are given characters from their history, supplemental or as an aid, to classifying them as belonging to some more or less definite type.

The race was somewhat unique in the annals of free ballooning in that a variety of courses was open to the contestants, in directions ranging from northeast through east to southwest, according to the altitudes chosen by the pilots in which to fly. Only two courses, however, merited any consideration as a means for winning the race. These courses were in almost opposite directions, one at high altitudes in a northeastward direction toward the Gulf of St. Lawrence, and the other at low altitudes in a general southwestward direction. The fact that the winner of the race, Major Westover, in choosing the path toward the northeast, covered a distance that did not lack much of being twice that of the balloon winning second place, and in such a comparatively short time (17 hours), justified the opinion, based on surface and aerological observations, that the upper northeastward course was by far the preferable one. However, it is evident both from Major Westover's report, and from the comparatively short distances covered by the other pilots who chose the northeastward course, and their slow rate of travel, that the desirable altitudes for a long fast flight in this course were neither easy to attain nor to hold.

In the present status of facilities for furnishing meteorological and aerological information to aeronauts by which they are left largely to their own resources as soon as they have left the ground, credit can not be entirely arrogated to itself by the Weather Bureau for accomplishments in the air aided or induced by Weather Bureau information and advice. (In this connection, see comments on radio service in this race by Mr. Upson). The result of the race was therefore a fine tribute to Major Westover's ballooning experience and acumen in taking advantage of existing weather conditions. The fact that the other pilots fell far short of equaling Major Westover's record does not in the least detract from their ability or courage; their failure by comparison was largely, perhaps entirely, fortuitous and circumstantial, as the following analysis of the weather conditions will undoubtedly prove.

A reference to the weather maps preceding the date of the race shows a persistency of high pressure over Ontario and the Lake region dating from May 21. This high pressure appears to have been periodically replenished by HIGHS drifting in along the northern United States border. A characteristic of Hudson Bay HIGHS, already noted by students of aerology, is the depth of winds on their southern side, conforming in direction to the surface isobars. The stagnation of HIGHS over the Lake region, typical of Lake influence in spring and early summer, appears to build up a structure having similar characteristics, i. e., deep winds from an easterly direc-

tion on the southern side of the HIGH. It was therefore not surprising to find deep east winds extending to over 4,000 meters altitude at Milwaukee on May 27. A strong HIGH with its crest over eastern Canada, extended southward to about the Ohio Valley.

The influence of depth to this HIGH on the 27th had the following significance to the outcome of the balloon race on May 31: If the stagnation of high pressure on the Lakes and Ontario persisted, the flight of the balloons would quite likely be in a course that would carry them successively west, northwest, and possibly north, at a moderate speed, with the prospect of landing not much beyond the Canadian frontier at Manitoba. If the HIGH receded to join the Atlantic HIGH, and a low area supervened—as subsequently happened—winds from a southerly to southwesterly direction to a great depth might be expected, excepting that the winds in the lower levels and at the surface would depend on other modifying influences that might develop.

The high pressure that enveloped the Lake region on June 1, and whose front edge was already encroaching on Milwaukee on the afternoon of May 31, was first identified on the weather map as an Alberta HIGH on May 27, being apparently a reinforcement of the HIGH approaching the north Pacific coast on May 25. The characterization of this HIGH may be summed up as follows: A moderate Alberta HIGH losing intensity with southeastward progress; a northwestern LOW that antedated it on the weather map dissipating in its advance; continuous precipitation in its front; and a renewed tendency for the development of a LOW in its front, this time from the south, on May 29.

Owing to the cloudy weather and rains attending the advance of this HIGH, not much direct information was available as to the depth, strength, and direction of winds within it after it had reached the range of aerological stations in the Middle West. It is, however, characteristic of many HIGHS approaching from the Northwest that have no pronounced LOW in their front, to be shallow in the sense of depth of winds conforming in direction to that indicated by the surface isobars. In other words, HIGHS of certain type of intensity originating in the Northwest may be defined as having predominately west to northwest winds in their structure, with comparatively shallow north to east winds in their eastern and southern quadrants.

The analysis of this HIGH by type and aerological reports favored the belief that the winds in its front shown on the surface weather map were shallow, that it was gradually encroaching on an extensive deep area of moderate winds from a southwesterly direction, that the rains in its front were due to a rolling up or convection of the air in its front into the winds aloft that had a component from the south or southeast; and as a conjecture, strengthened by the appearance of the isobars on May 29—that a more or less well-defined LOW would develop in its front by May 30 or 31.

The existence of a great drift from the southwest parallel to a trough of low or indifferent pressure extending from the Lakes to Texas, suspected from the result of an upper-air observation at Milwaukee on May 29, was confirmed by more extensive reports on May 30. It should be noted that by this time the Lake HIGH was merging into the Atlantic HIGH. The inference is optional, according to the theory one is inclined to favor, as to whether the SW. to NE. drift was incidental to the Atlantic HIGH and the process of its increment by the Lake HIGH, or that the SW. to NE. drift was an entity, and the HIGHS and their behavior only a visible evidence of the interaction between this drift and an oppositely directed one. (See writings of Bigelow on countercurrent theory and Bjerknes on Polar Front.)

The weather map on May 30 showed a better defined trough of low pressure extending from the Lakes southwestward and strong indications of a low pressure center forming southwest of the Lake region. It therefore appeared on the 30th that conditions would approach a crux on the 31st—that while the southwesterly winds at high altitudes aloft would continue on the 31st, stronger, deepening winds from a northerly direction would prevail in the lower altitudes near the ground. The indications were also for unsettled weather and probably rain for the night of the 30th and the 31st.

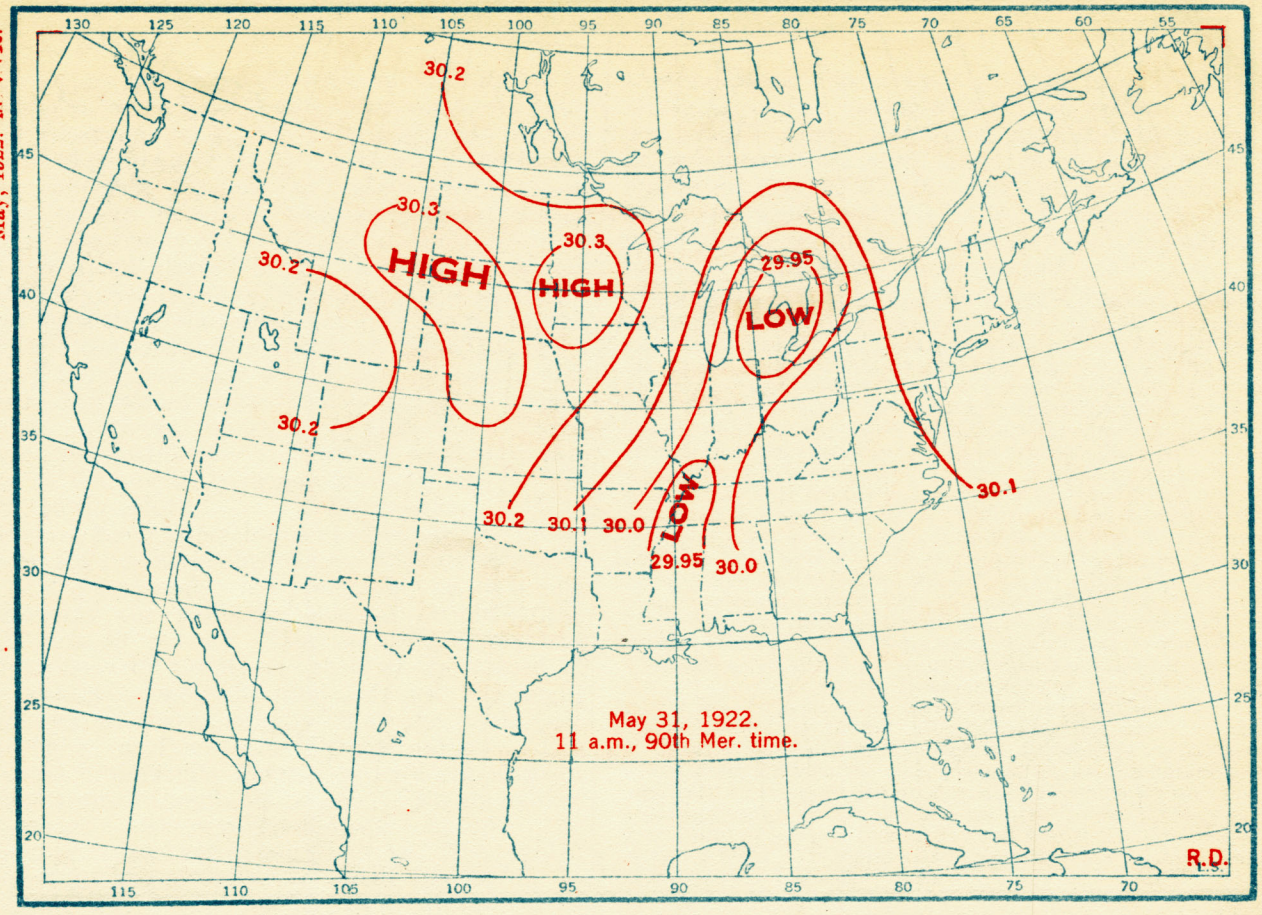
The regular morning and special 11 a. m. weather maps on the 31st showed long straight isobars in front of the northwestern HIGH, extending from Milwaukee southwestward to Texas, although the 11 a. m. reports showed a preceptible weakening of the gradients along that line. Apparently, a balloon taking off at Milwaukee and maintaining an altitude of between 2,000 and 3,000 feet would have its destination in southern Texas. Actually there was no possibility of accomplishing such a long flight in that direction, owing to a number of inhibiting factors in the weather element and the practice of free ballooning. As the HIGH was weakening and changing its configuration, there would be no strong far-flung, unidirectional winds in its front composition; moreover, its nature indicated extremely variable wind directions and velocities with altitude. Under these conditions, the endurance of the pilots and the expenditure of ballast necessary to maintain a favorable altitude precluded the possibility of a flight that would necessarily have to be of long duration. (Note comments in reports of Lieutenant Reed and Mr. Honeywell.)

Aerological reports on the 31st showed the deep drift aloft from the southwest still prevailing over the clear area to the east and south of Milwaukee. The surface wind at Milwaukee was northeast to north, and weather cloudy and rainy to within an hour of the time the first balloon took off in the middle of the afternoon.

The upper air conditions on May 31 over Milwaukee, in the absence of direct aerological observation there, were construed to be as follows: A fresh wind from a northerly quarter, extending to about 2,500 to 4,000 feet, thence backing above the clouds through a shallow transitional layer of west wind to southwest at perhaps 6,000 feet, thence from a general southwesterly direction to an indefinite height. This is a typical arrangement of the winds above the clouded area in the rear of an elongated or crescent-shaped LOW extending SW.-NE. When the LOW is more constricted and the gradients in general steeper, there is a correspondingly increased strength in the oppositely directed winds aloft and below, with a still shallower transitional zone of wind from the west. Parenthetically, the analysis of such conditions shows the value of kite observations. In certain types of overcast weather the only available source of data of upper-air conditions is from the record of kite observations made under similar conditions, since it is often possible to penetrate the cloud layer with kites and extend the observation to considerable altitudes above.

The series of aerological reports from the morning of May 30 to 11 a. m. May 31 showed that, although the deep SW.-NE. drift aloft was quite weak, the winds increased in force with altitude and to a slightly perceptible extent with time. It therefore seemed evident

May, 1922. M. W. R.


30.2
30.3
HIGH
30.3
HIGH
30.2
29.95
LOW
30.2
30.2
30.1
30.0
LOW
29.95
30.0
30.1
May 31, 1922.
11 a.m., 90th Mer. time.
R.D.

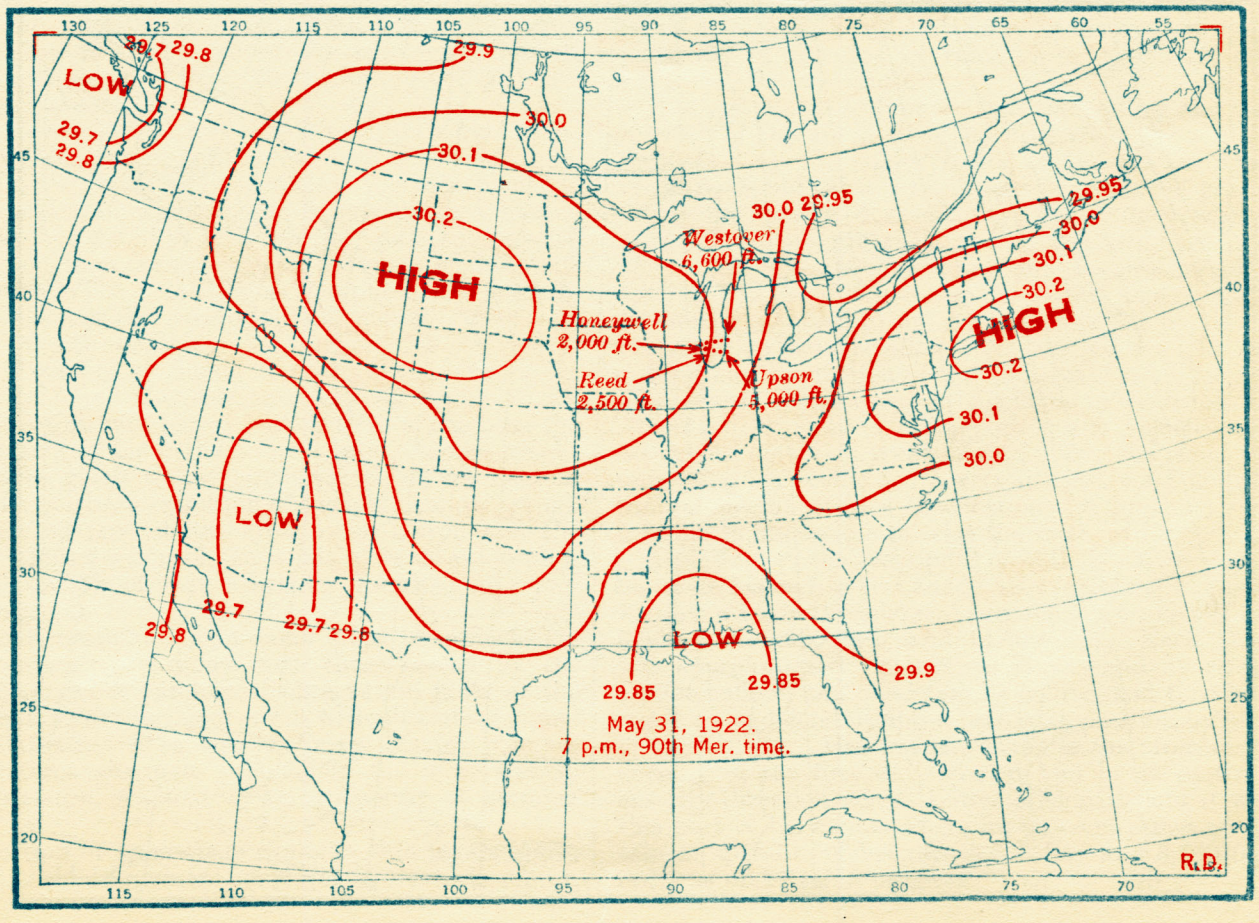
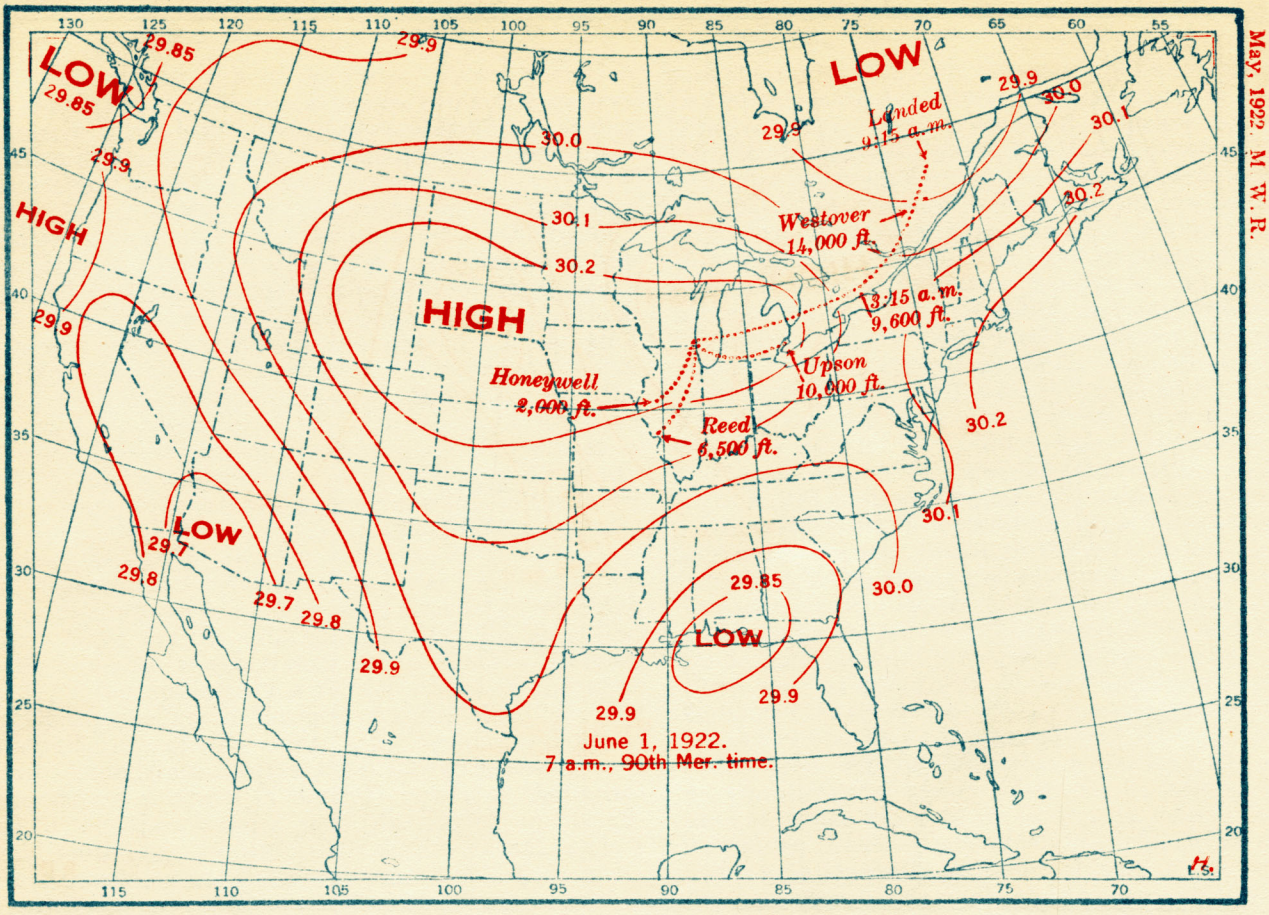
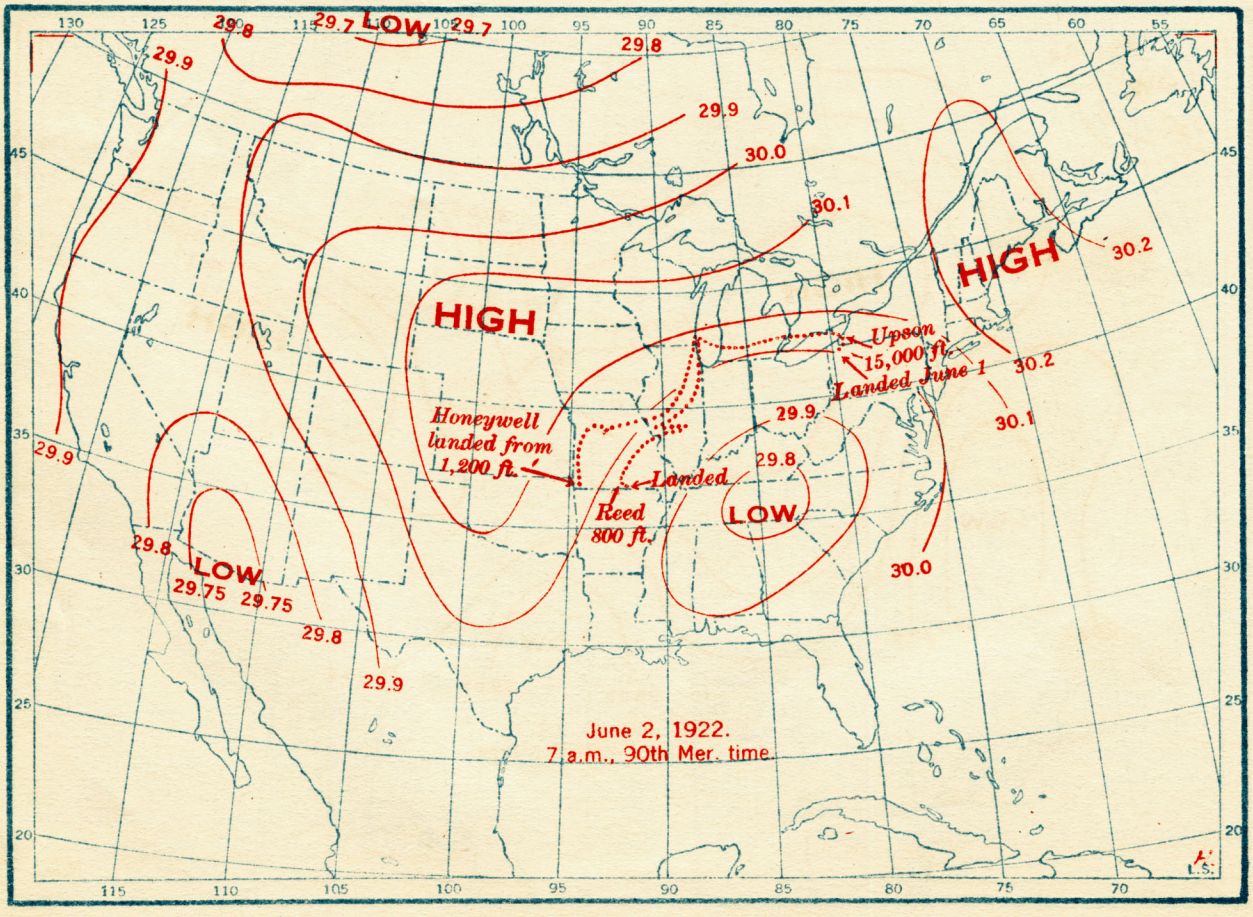

LOW
29.7
29.8
29.7
29.8
29.9
30.0
30.1
30.2
HIGH
30.0
29.95
Westover
6,600 ft.
Honeywell
2,000 ft.
Reed
2,500 ft.
Upson
5,000 ft.
29.95
30.0
30.1
30.2
HIGH
30.2
30.1
30.0
LOW
29.8
29.7
29.7
29.8
LOW
29.85
29.85
29.9
May 31, 1922.
7 p.m., 90th Mer. time.
R.D.

Chart II.—Weather Maps during National Balloon Race.





that the balloons would have to rise about 2 miles or more in order to make good headway, at which altitude, judging by meager reports from the region east of Milwaukee, a wind of about 30 m. p. h. from about southwest might be expected. Surface and aerological reports from the Canadian Provinces to the northeast would have been invaluable.

As the barometer started to rise at Milwaukee a few hours before the race began, a deepening of the northerly winds was indicated, the significance of which to the race was that the longer the taking-off of the balloons was delayed the higher they would have to ascend and the farther they would drift toward the south before reaching the southwest winds aloft that would carry them toward the northeast. Information relative to this deepening of the northerly winds was included in the final report to the pilots.

Notwithstanding this development of conditions in the lower levels, the northeastward course was advised, as it still seemed unquestionably the preferable one for a long flight, providing the balloons took off at about the scheduled time (3 p. m.). The taking-off time was nevertheless close to a critical epoch in the march of changing weather conditions that affected the flight of the balloons, as the experience of all the pilots that attempted the northeastward course attests. Undoubtedly the opportunity for taking the northeastward course, that seemed inevitable of choice for about two days, passed soon after the last balloon took off. (See remark in this connection in report of Mr. Honeywell.)

The report of Major Westover shows that, after he was well under way toward the east from Milwaukee, he drifted at an average speed of about 55 miles per hour along the curved path to his destination in Quebec, Canada. After allowing for the decidedly increased velocity at which he traveled in the last lap of his journey, he still appears to have traveled in a decidedly stronger wind than that shown by aerological reports from stations east to Ithaca, N. Y., during the 30 hours preceding the race.

Since the aerological reports showed the winds to be of slightly variable strength and direction with altitude, and from observation to observation, it seems plausible that thin strata of winds might be encountered by the balloonists that would be of perceptibly different velocity and direction than that shown by the plots of the pilot-balloon runs. The velocities as computed are actually average velocities for successive 360 meter (1,180 feet) intervals of altitude, while Major Westover states that in the early part of his flight the depth of the air stratum in which he found the strongest wind favorable to his desired direction was barely sufficient to encompass the vertical extent of his balloon and basket. Some weight must also be given to the circumstance of the detachment of the northern extension of the low pressure trough into a marked LOW central over Lake Huron and the probable intensification of the winds aloft in accordance with the principle of such a system discussed in a previous paragraph.

The winds encountered in small steps in altitude are evidently often at variance with those shown by the smoothed curves of aerological observation plots or the orderly backing or veering of winds with altitude assumed from examination of a weather map. Quite possibly such variations are more peculiar to the more weakly defined pressure gradient systems typical of summer maps.

A succession of anomalous winds in thin layers above the cloud sheet is revealed in Major Westover's report, the first being shown by a peculiar back tracking over Milwaukee, after having first drifted a short distance to the south. Above this apparently shallow south wind he rose into a west wind, thence into a south wind again, and eventually, at about 6,600 feet, into a strong west-southwest wind, in which favorable position he remained until about nightfall. His search for this altitude is herewith narrated in his own words:

> The weather reports and maps for the day of the race, as well as the final report at 2 p. m., indicated that my preliminary judgment in this matter would be affirmed and that it would not only be possible to hurdle the low area, but that we could actually get winds in the desired direction when above the clouds. The final confirmation of this fact came about one hour before the race started, when a break in the clouds, which we happened to observe, showed a thin veil-like cloud drifting in the northeastern direction, whereas the clouds themselves were moving in a southerly direction. I made up my mind at that time I would find the particular stratum of air indicated by that veil-like cloud and would immediately attempt to cross Lake Michigan.
>
> When we finally took off our balloon traveled rapidly in a southerly direction. We were soon lost in the clouds over the southern part of Milwaukee. The higher we went the more confused we became both as to direction and speed, but we finally emerged from the clouds and found ourselves traveling toward the north at an appreciable rate of speed. We kept up this course until we had again crossed Milwaukee, when we seemed to fall into a current of air moving in an eastern direction. * * * Presently, however, due to the increased altitude gained from expansion, we found ourselves again in a current of air moving toward the north. After following this course for about 15 minutes, during which time we sighted, apparently, the balloon of Mr. Upson emerging from the clouds behind us, we determined to search especially for the northeastern current of air which we were confident existed, because we felt that the northerly course we were pursuing would take us toward Hudson Bay and would give us a rather short range for flight. Of course at this time there was nothing visible beneath us except clouds.

Making some allowance for error in estimated direction on account of the blanket of clouds beneath him, there is little doubt that Major Westover encountered a number of cross winds from north and south before he finally reached the sought-for wind to the east-northeast. In these apparently vagrant winds probably lies the explanation of the line of rains along the front of the advancing Alberta HIGH.

It is reasonable to suppose that the chilling and underrunning of the air in the deep drift from the south and southwest by the colder strata of the advancing high pressure should cause a rapid rearrangement of gradients above the line of discontinuity, particularly when the general gradients are weak, as they ordinarily are in summer. The repeated overthrow and restoration of balance is capable of explaining the stream line of air from the south, hemmed in by currents from the north. The precipitation would follow from the consequent direct cooling and convection of the air stream from the south. The records of kite observations made in the front of this Alberta HIGH show a falling off in the velocity of the north and northeast winds in and above the cloud layer, indicating a possible south or southeast wind above the limited height of the observations, into which it was manifestly impossible to raise the kites.

According to the remainder of Maj. Westover's report, he made his course to Canada after reaching his first favorable wind in three laps at successive altitudes of about 6,600 feet, 9,600 feet, and 14,000 feet. Each altitude was approximately determined beforehand by releasing a pilot balloon and observing its course, and then following it up and establishing a favorable position by control of the balloon. His first lap, made in the afternoon and evening of the first day, carried him in an east-northeasterly direction across Lower Michigan, and it was in this part of his course where he was compelled to maintain an altitude of between 6,600 feet and 6,700 feet in order to make rapid progress.

His second lap, made during the night of May 31–June 1, carried him farther east-northeast to somewhere north of Lake Ontario. Although he rose about 3,000 feet from the first to the second laps, he again found it necessary to confine himself to a shallow stratum ranging from 9,400 to 9,800 feet. Within these limits of altitude he maintained his position throughout the night. At daybreak on June 1 he rose to about 14,000 feet, where he established himself in a strong current blowing toward the northeast, which apparently greatly accelerated his movement toward the end. In this last lap he reports the same stratification of the air as regards velocity and direction that he observed in the two previous laps, for to quote his words:

> Here again (at 14,000 feet) the thickness of the particular current of air which gave us speed as well as direction was rather limited, and we found considerable difficulty in keeping ourselves within that stratum. Owing to the expansion caused by the sun we found it necessary to valve frequently.

An approximate outline of Major Westover's course is shown in Charts I and II. As nearly as can be estimated from his report, he traveled at the rate of about 50 miles per hour in the first two steps in altitude that carried him east-northeast from Milwaukee to north of Lake Ontario; thence at the rate of about 60 miles per hour at 14,000 feet altitude in a due northeasterly direction to Lake St. John, Quebec.

Of the 13 pilots who took part in the race, only four—Major Westover, Lieutenant Neeley, Mr. Upson, and Mr. Von Hoffman—attempted the northeast course aloft. Excepting Mr. Donaldson, who landed 5 miles from the starting point on account of a defective balloon, the remaining pilots chose the lower course toward the southwest.

No report is at hand from either Lieutenant Neeley or Mr. Von Hoffman, but that of Mr. Upson, who in 27 hours' flying landed at Painesville, Ohio, is probably fairly descriptive of the experiences and difficulties encountered by all three.

The following excerpts from Mr. Upson's report appear to have the most significance on the outcome of his flight:

> A brief study of the weather conditions, shown by data published before the start, led us to reject the idea of following surface currents toward the south and southwest, in favor of a bold attempt to get into currents taking us east, which we believed existed above the clouds. The result of the race proves that this was the right course, although we ourselves were not to take full advantage of it. As the wind was rather gusty at the ground, and as we wanted to get above the clouds anyway, we arranged with the ground crew so that we would be approximately six bags light when we took the air, carrying about 41 bags. The result was that we shot up fast, and without further ballast expenditure for the moment found ourselves above the clouds in the bright sunlight within 20 minutes of the time we left the field. We went almost at once to 6,000 feet altitude, but soon dropped back again to an average of about 5,000 feet, where the air seemed a little more stable.
>
> The contraction (the first night), due to the disappearance of the sun with its brilliant reflection on the clouds below us, was the greatest I have ever experienced. It was after 10 o'clock before the contraction process was fully taken care of, and it cost us altogether 22 bags, or over half of our ballast supply. * * * To get the most out of it we should have kept the balloon somewhat higher during the night, but intentionally compromised to some extent on account of our limited supply of ballast, for we wanted to make sure of being able to get through a second night. * * * For a while equilibrium was fairly good in the neighborhood of 12,000 feet, but the altitude at which we were stable steadily increased after 10 o'clock (a. m., June 1). As it turned out afterwards, the favorable wind was pushed up at about the same rate, but we did not realize it at the time. Finally, we reached about 15,000 feet altitude, but even here it soon got unstable and we started on a strong drop precipitated by more clouds forming above. * * * At the end of about an hour and a half we realized by checking our relative position in various ways that we had hardly moved at all during that time. In other words, we were practically becalmed, although we had no means over the water of realizing it immediately.
>
> The second night, which we had so carefully saved up for, was now before us, but was a liability instead of an asset. Hence we made a quick decision to land before losing any more ground, which already amounted to between 30 and 40 miles. We landed at 7 p. m. (June 1) in practically a calm about 6 miles south of Painesville, Ohio, with one bag of ballast left and practically no dispensable equipment.

Comparing the positions of Major Westover's and Mr. Upson's balloons with the series of weather maps from 11 a. m., May 31, to 7 p. m., June 1, it is apparent that the center of the Lake LOW was continually displaced to the northeast of the positions of the balloons, and that while Major Westover did not actually "hurdle" the LOW which was increasing in depth, he apparently gained on the LOW, and succeeded in keeping well within its influence. His position relative to the low-pressure center advanced from a point to the southwest at the beginning of his flight to a point about south-southeast of the center when he decided to land, indicating that he progressed northeastward faster than the LOW.

Undoubtedly the winds above the LOW were increasing in force, while in the rear of the LOW, attending the rising pressure and deepening northerly component to the winds, the favorable winds toward the northeast were dying out at progressively higher altitudes. At 3 p. m. on June 1 an aerological observation at Lansing showed a northeast wind to about 5,000 feet, backing to west at 10,000 feet. The west wind persisted in direction and increased in strength from 10 m. p. h. at 10,000 feet to 34 m. p. h. at 20,000 feet. There is therefore justification in the statement of Mr. Upson that "the altitude at which we were stable steadily increased after 10 a. m. June 1 * * * As it turned out afterwards, the favorable wind was pushed up at about the same rate * * * Finally we reached about 15,000 feet altitude, but even here it got unstable and we started on a strong drop."

Figures 1 to 5 show the pressure distribution at successive 90th meridian observation times from 11 a. m., May 31, to 7 a. m., June 2, and approximate geographic positions and altitudes of the four balloons, piloted by Westover, Upson, Reed, and Honeywell. The lines connecting the successive positions of the balloons show, for the most part, only the general directions in which they traveled, inasmuch as detailed reports of their positions, except in the report of Lieutenant Reed, were not furnished.

It is evident from the reports of Major Westover and Mr. Upson that neither rose much above 6,600 feet altitude during the afternoon of the first day. Presumably this applies also to Lieutenant Neeley and Mr. Von Hoffman.

In the technique of free-ballooning it is a handicap when preparing for a long flight to sacrifice much ballast at the start unless the pilot is assured of a swift course without frequent changes in altitude. Considerations of this nature may have deterred the pilots who chose the northeastward course from rising directly to greater altitudes. This handicap is alluded to in the following paragraph from Major Westover's report:

> The stiff ground breeze at the start of the race made it quite difficult to take off from the ground, and we had to sacrifice 16 of the 33 bags of ballast which we had in our basket for the preliminary take-off in order finally to be assured of the lift that would clear us of adjacent balloons and the grandstand of the ball park from which the start took place. I mention this fact because it had a rather vital bearing upon the speedy termination of my flight.

The decision of the pilots who took the southwestward course was undoubtedly in part for the reasons just stated and partly from considerations of probably stormy

weather conditions that would attend the northeastward movement of the Lake LOW. Skepticism of the probable weather conditions along the route would naturally lead to speculations as to the probable danger and the difficulty of reckoning position in and among the clouds in a swift course during the night.

That this caution had some justification is shown by the following references to the weather conditions experienced by Major Westover on his northeastward course: "I may add that we entered the area of clouds after we had gone about 20 miles beyond Muskegon, and that we drifted over clouds throughout the remainder of our trip," and "A quick decision was made to descend (after reaching Lake St. John), and at 11,000 feet we entered the storm area of the clouds. * * * At about 8,000 feet we ran into the rain area and were carried in a noticeably different direction from that first encountered when we entered the clouds." A decision influenced by foregoing reasons is expressed as follows by Lieutenant Reed: "High aloft at perhaps 10,000 to 15,000 feet there was a southwest gale, but it gave little assurance to the pilots of no interference by thunderstorms over Lake Huron, so that the majority preferred the lower and safer routes." Another phase to the situation, relating to the time of departure of the balloons, is brought out by Mr. Honeywell in giving his reasons for deciding on the course to the southwest: "Some time prior to taking the air I felt certain that we would not catch the NE. LOW which was fast getting away from us. * * * Major Westover was nearly three hours ahead of my time, I being last (13th) decided I was too late and fought for the next most likely distance, SW."

With all these factors to consider, the pilots were in more or less of a quandary, and the final decision as to course to pursue and speed and height of ascent naturally rested with their own judgments. From purely a meteorologist's point of view, the conviction persists, and this conviction is strengthened by a review of the weather conditions, supplemented by aerological reports from a few Canadian stations received a few weeks after the race, that a steady rise from the take-off to about 2 miles altitude would have assured a swift course toward the northeast to a distance equaling or exceeding Major Westover's record. It would probably have been necessary or expedient later to rise higher, particularly in view of keeping above the cloud layers that were deepening as the LOW developed strength toward the northeast.

An aerological observation near Toronto on the morning of June 1 shows that the deepening winds from the north had already extended that far east to an altitude of about 6,500 feet, above which the winds backed to west. At about 11,000 feet there was still a 30-mile an hour wind from the west, notwithstanding that this position relative to the weather map was by that time in a sort of col or saddle with respect to the adjacent high and low areas.

The reports of Lieutenant Reed and Mr. Honeywell show that they followed a more or less staggered course, as with changing altitude they found winds of variable directions. In the search for favorable winds and from the effects of diurnal expansion and contraction they flew at various altitudes ranging from a few hundred feet above the ground to about 6,000 feet. Lieutenant Reed records that at times midday expansion carried him to 10,000 feet. The back tracking of Lieutenant Reed's balloon on June 1 (figure 4) illustrates one of the peculiarities of the vertical arrangement of winds in the front of a HIGH. A similar situation on the same day is described as follows in the report of Mr. Honeywell:

> The sun expanding our gas carried us up to 4,000 feet (the morning of June 1), where we caught a very desirable current toward the southwest, passing over the Mississippi River south of Hannibal, maintaining a beautiful equilibrium for hours. About noon clouds began thickening beneath us, always growing thicker and denser until they finally touched the bottom of our basket at times; later, as they became higher and heavier, we were dragged through the tops of them, exceeding their speed by at least 10 miles per hour. * * * At 3 p. m. this fast stratum of air gave out and I allowed the balloon to rise, seeking another stratum above the now broken cloud banks below, through which we saw the Missouri River at Glasgow, Mo., altitude 5,000 to 6,000 feet, and course northwest. I knew then we had neared the western side of the HIGH, and immediately dropped down to between 1,200 and 1,400 feet, where we caught the surface southwest ind again, but our progress was slow.

As a matter of fact, when Mr. Honeywell found his northwest course at 5,000 to 6,000 feet he was still in the front of the HIGH, slightly east of its southern extremity. This complexity of the winds along the front edge of moderate HIGHS is entirely in accordance with records of aerological observations. Ordinarily on the eastern and southeastern edges of such HIGHS the winds will back with altitude, as, for example, from north or northwest to west; while in a position from southeast to south of the center of the HIGH, winds veering as much as 200° or more with altitude may be expected, as, for example, from about northeast through south to southwest or west. Confirmation of such a condition in the track of the balloons is given in the aerological observations taken at Scott Field, Ill. (near St. Louis), and Broken Arrow, Okla., on June 1 and 2. On June 1 the observation at Scott Field showed light north-northeast wind from the ground to 3,000 feet, thence veering and diminishing in velocity to south-southwest at about 11,000 feet. On June 2 the observations at both Scott Field and Broken Arrow showed light to moderate winds backing from north and northwest near the ground to about west at 6,000 feet, thence generally light to moderate west to southwest winds to over 15,000 feet.

By the time Lieutenant Reed and Mr. Honeywell made their landings (about 7 a. m., June 2), the high-pressure area had flattened out considerably and showed diminishing gradients in its front. It was obviously no longer possible or practicable for these two pilots to make any further headway from Milwaukee. Lieutenant Reed landed near Eminence, Mo., 440 miles from Milwaukee, and Mr. Honeywell near Joplin, Mo., 550 miles from Milwaukee, in about 42 and 39 hours, respectively.

The experiences in this race emphasize the need of furnishing advice by radio to the pilots while on their course. Consequently, the arrangements and experiments made by Mr. Upson for receiving radio bulletins of weather conditions are very interesting. He relates:

> With my experience in the International Race of last fall fresh in my mind, when I became becalmed for nine hours in the Irish Sea, I determined that the real remedy was to get up-to-date and complete reports in the air. The answer of course was radio.
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> I took my problem to the Westinghouse Co. and the Radio Corporation of America, who very kindly offered to help in the experiment by furnishing the proper apparatus and broadcasting service in connection with the American National Balloon Race taking place from Milwaukee on May 31. The country which we proposed to traverse was divided into zones for which I eventually got support from four different broadcasting stations as follows: Westinghouse, Chicago; Westinghouse, Pittsburg; General Electric, Schenectady; Free Press, Detroit.
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> Besides the usual weather report we made arrangements to get the special aviation bulletin issued twice daily by the Chicago station of the U. S. Weather Bureau. This was to be telegraphed to the different broadcasting stations as soon as released by the Weather Bureau. The

final operation was broadcasting by radiophone at various times and wave lengths, all prearranged. * * * For our radiophone receiver we carried a standard Westinghouse "RC" set with special light-weight batteries. * * *. We were now about a mile above Lake Michigan (evening, May 31) and could dimly see the outlines of the approaching Michigan shore. * * *. I first picked up a soprano solo—very pretty but hardly what we needed to win a balloon race. I was just putting down the receiver when the words of the announcer came clear and distinct—something about the balloon race. I gave one receiver to Andrus and we both listened in. "Four balloons in the National Race from Milwaukee are reported nearing Chicago." * * * After passing the shore line I checked our location and route, while Andrus tuned in for our weather report now about due. He quoted the words aloud as they came. (Here follows a complete synopsis of the weather map and wind forecast for the Lake region based on the 7 p. m. map of May 31).

The first weather information that we hoped to pick up was the regular daily report sent out by the Detroit News at 10.30 a. m. (June 1). Just previous to that time I conscientiously listened to several jazz pieces played on the phonograph, then, finally, came the announcement: "We will now conclude our program this morning with the reading of the daily weather report." Here I passed the receiver to Andrus, who tried to get a better adjustment, but lost connection and was not able to pick it up again. Later, at the scheduled time for our special report we also tuned up, but were unable to catch a thing. We later found the trouble to have been with the Western Union, who failed to deliver our message for about three hours after it was sent to Chicago, but we did not know then but that it was our own fault and gave up the message as lost. * * * . We had organized a successful system of getting weather reports in the air and had demonstrated to our entire satisfaction that it was not only a great help in operating a balloon but also a step forward toward greater safety.

We had been more than 15 hours over water, but felt perfectly safe throughout the whole time simply because we were still in touch with the world by radio. Our failure to get one of the messages brought home to us its importance more strongly than anything else could have done.

But the best thing I leave for the end. Major Westover, the winner of the race, also carried radio, which I procured for him before the race and which he used on the same schedule. Hence, the big idea in its first trial was not only proved sound but was a real winner as well.

From a brief résumé of the broader aspects of the meteorological conditions from May 29 to June 2, the impression is given that the dominating factors, insofar as they affected the Lake region and adjacent territory, were a succession of great drifts, first an extensive one from the southwest, and then in succession one of lesser magnitude from the west. The drift from the southwest apparently had its inception as early as May 26 or 27, in the form of a weak current from the South Atlantic, drifting inland toward the northwest, that progressively deepened, strengthened, and veered until it had attained the proportions of the extensive SW.–NE. drift observed on May 30 and 31. This drift temporarily blocked the passage of HIGHS along the northern frontier to the Lakes from the west, but gave way in its lower levels before the advance of the eastern segment of the Alberta HIGH on the afternoon of May 31.

The protrusion of the eastern segment of the Alberta HIGH into the Lake region, and the attendant formation of a definite low center over the Lakes may be construed as due to the overlapping at this point of a current from the west that was originally of Polar or northern origin, eventuating the final cycle in the development of the LOW that had its genesis in the southern portion of the deep SW.–NE. drift. Attention is brought to the striking resemblance of this construction to the life cycle of a LOW as depicted by Bjerknes and Solberg (page 80, V. Bjerknes, Dynamics of the Circular Vortex, Christiania, 1921); likewise to the other points of similarity between the assembled mental picture described in these concluding paragraphs, and the general theory of the Polar Front advanced by these Norwegian investigators.

The assumed Polar current, just referred to, had apparently backed in direction from an originally NW. to SE. tongue of cooler air, and was now (June 1–2) evidenced by aerological observations as a drift aloft from the west, that bent toward the northeast where it merged with the SW.–NE. drift over the Atlantic States. This drift from the west, or remnant of the assumed Polar current, was dying out, with which fact may be connoted the flattening out of the HIGH over the Central States, and the eventual becalming of all the pilots who were still in the air by the evening of June 1, 1922.

BUMPY FLYING CONDITIONS ALONG THE ATLANTIC COAST.[1]

By A. W. PARKES.

The writer was a radio observer on naval seaplanes and flew the Atlantic coast from Cape Cod to New Orleans and over many of the West Indian islands.

As a general rule, under similar geographical conditions, the hotter the climate the greater the bumpiness in the air. The worst places experienced were the Hudson River at a low altitude (200 feet or lower), the Florida Keys, and the bay at Guantanamo, Cuba.

The probable explanation of the bumps in the Hudson is that the west wind passing over the Palisades tends to form an eddy on a horizontal axis, going down over the Hudson, flowing westward near the water, and rising near the sides of the Palisades as is roughly shown in the accompanying diagram.

A seaplane going up the river often experiences a drop of 15 to 50 feet very abruptly, and sometimes only one wing goes down or just the nose or just the tail. Under these conditions with a large plane both pilots have all they can do to manage the controls.

The case over the Florida Keys is quite different, though the effect is the same or worse. On nearly every day there seem to be strong convectional currents rising over these small islands, which are heated to a much greater heat by day than the water, thus causing that less dense air to rise and, consequently, the colder to descend to fill its place. "Bumps" are the consequences.

I have heard pilots say "I'll bet I could tell when we were over Guantanamo Bay if I were blindfolded or if it were pitch dark, it's so bumpy in that vicinity." Guantanamo Bay lies on the southern part of Cuba, and there are mountains about two-thirds of the way around it. During the months of February and March, while the writer was there, the weather rotated daily like clockwork—a very calm morning, followed by a breeze at 2 p. m., becoming strong at about 4 to 5 p. m. every evening, with almost no exception, during those two months. But even though there was little surface wind in the morning, this excessive bumpiness occurred throughout the day, although it was worse in the afternoon. This necessitated as much flying as possible to be done in the early morning. The reason for the bumpiness seems to be a combination of the two reasons given previously, i. e., the heated land and the deflections due to the mountains. A thing of interest is the fact that when flying directly over the funnel of a battleship the effect can be felt for at least 200 feet up.

It may also be interesting to note that we could feel the concussion on our plane from a broadside of a battleship when we were 4,000 feet above the ship.

[1] Submitted in reply to the request in the MO. WEATHER REV., Aug., 1919, p. 532, for notes on flying and the weather.