but local greenhouses were demolished and the stones beat through the broken lights, wreaking havoc among the plants and flowers within. Automobiles that were unfortunate enough to be caught in the storm as a rule received some mark signifying that fact. The large stones tore through their tops, one motorist reported twenty-one holes in his top. Wind shields were broken and wherever the hail hit the cars, the paint was knocked off and the body dented. Several people received minor injuries and bruises by being struck, but no reports were received of any serious injury.

TROPICAL STORM OF JUNE 22, 1921.

By B. BUNNEMEYER, Meteorologist.

[Weather Bureau, Houston, Tex., July 1, 1921.]

The storm was of comparatively short duration and of the milder type of hurricane. The sky was overcast throughout the day with nimbus or stratus and scud moving with the surface wind; upper clouds could not be observed.

The barometer fell until 5:40 p. m. and rose thereafter. The fall was slow with strong fluctuations until 9 a. m., then rapid, and the subsequent rise was about as fast as the preceding fall. The following barometer readings (reduced to sea-level) were taken:

	Inches.
9:40 a. m.	29.73
11 a. m.	29.87
1 p. m.	29.59
2 p. m.	29.53
3 p. m.	29.51
5:40 p. m.	29.37
6:30 p. m.	29.42

Rain fell from 2 a. m. to 9:15 a. m.; 10:50 a. m. to 1:30 p. m. and from 4:03 to 6:37 p. m., being excessively heavy between 6 and 9 a. m. when 2.77 inches fell.

Lightning and thunder were not noticed; residents about 5 miles south of Houston report faint flashes of lightning about 6:30 a. m.

The winds came in characteristic gusts throughout the day increasing in force until 5 p. m. and diminishing thereafter. The direction and force of the wind and other meteorological data are given in the table next below.

The storm moved inland over Matagorda Bay, the center passing in a northerly direction over Palacios, Wharton and Wallis, each of which reported a distinct calm, with wind coming from northwest and west after the calm.

TABLE 1.—*Wind and precipitation data for June 22, 1921.*

	A. M.												P. M.											
	1	2	3	4	5	6	7	8	9	10	11	Noon.	1	2	3	4	5	6	7	8	9	10	11	Midnight.
Wind direction	NE.	NE.	NE.	NE.	NE.	NE.	NE.	NE.	NE.	E.	SE.	E.	SE.	SE.	SE.	SE.	SE.	SE.	SE.	S.	S.	S.	SW.	SW.
Wind movement	11	11	13	13	16	17	23	23	21	23	28	32	44	38	44	47	49	41	37	36	28	19	16	16
Maximum velocities	......	......	......	......	......	......	29	28	34	26	42	41	49	52	54	58	60	58	42	48	34	......	......	......
and directions.	......	......	......	......	......	......	NE.	NE.	NE.	E.	NE.	E.	SE.	SE.	SE.	SE.	SE.	SE.	SE.	SE.	S.	......	......	......
Precipitation	......	T.	0.06	0.15	T.	0.02	1.04	0.27	1.46	0.03	0.01	0.04	0.01	T.	......	......	0.01	0.03	T.	......	......	......	......	......

METEOROLOGICAL ASPECTS OF THE NATIONAL BALLOON RACE, 1921.

551.5 : 629.132.1 (73)

C. G. ANDRUS, Observer.

[Weather Bureau, Due West, S. C., July 23, 1921.]

SYNOPSIS.

On May 21, 1921, the annual National Balloon Race started. Nine balloons were entered, and the start from Birmingham, Ala., was given the benefit of every sort of aerological advice. The several pilots were probably never before so well informed of the current and expected meteorological conditions. Acting as aide to Mr. Upson, in one of the balloons, the writer had an excellent opportunity to become intimately acquainted with the practical side of aerology in free ballooning. Air currents, true to forecasts, were light in speed throughout the race, and few opportunities for making important observations were afforded. By making utmost use of the winds of the lowest levels unaffected by surface friction, we gained advantage on the other balloons during the first night, and escaped a series of local storms of convectional origin, which forced most of the balloons to land early the 22d. The stagnation of air at all altitudes during the 22d prevented headway until after sunset, when we set out on a curved course which carried us through Kentucky, West Virginia, and to a landing place in southwest Virginia. Flying the second night was at moderate speed, low altitude above ground, and the landing was forced because no wind could be located that would increase our distance from Birmingham. While it is often the function of aerology to indicate where the highest or best directed winds prevail, in this race it was chiefly a matter of directing the escape from most unfavorable winds. Observations on the height and depth of the sea-level pressure gradient winds, their disruption by convection, and the average tendency of a free balloon to move toward decreasing pressure regions were noted. As all the other balloons were forced to land in central Tennessee by severe local thunderstorms, the victory was ours.

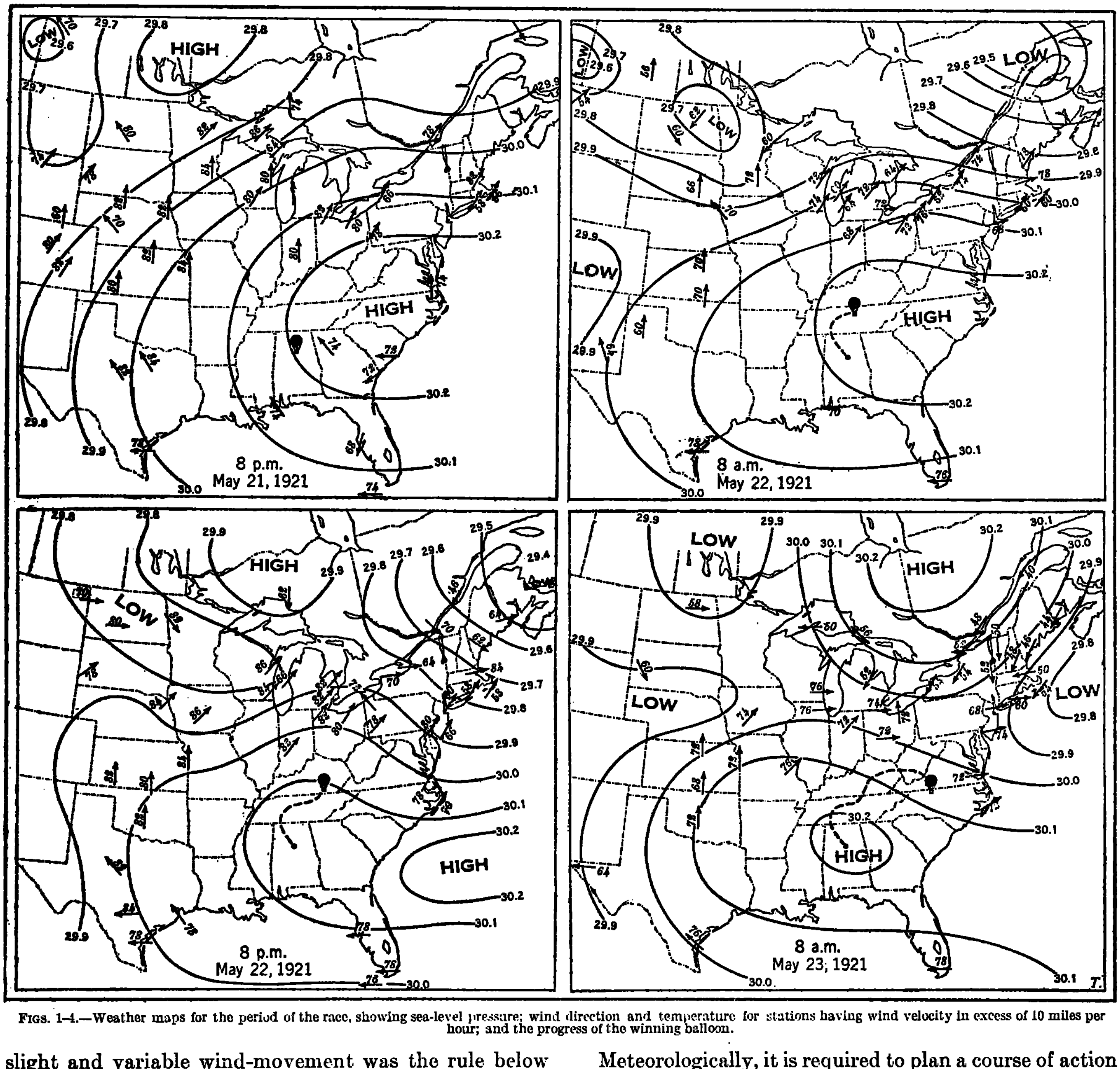
The importance of the meteorological factor in free-balloon races has been discussed in a previous paper,[1] in which the practical application and the correct interpretation of the aerological material now available was stressed. When Mr. R. H. Upson offered me the opportunity to go with him as his aide in the 1921 National Race, I saw there the chance to test the theory and to examine the practical needs of a free-balloon pilot by drawing directly from the original source. Successful forecasts and satisfactory weather "post-mortems" have not the direct contact with the many aerial problems that actual flying provides; in fact it seems almost necessary that aerological advisers get into direct contact with these problems by virtue of actual experience in them. In a racing balloon it is more desirable to win the race than to indulge in elaborate observations of weather and sky, except in so far as they offer an index to the changes in progress. To make a practical demonstration of the utility of a knowledge of meteorology rather than merely a set of observations which could be better made by means of kites and pilot balloons was the desire.

The race was scheduled to start Saturday, May 21, under rules similar to those of the 1920 International Race. As in that race, surface conditions and aerological observations were made available by the Weather Bureau from its own stations and from some aerological stations of the Army and the Navy; special forecasts for the race were issued from Washington on the 19th, 20th,

[1] Andrus, C. G.: Meteorological aspects of the International Balloon Race of 1920. MO. WEATHER REV., Jan., 1921, 49: 8-10.

and 21st; and, in addition, Messrs. W. R. Gregg and R. E. Frushour of the Weather Bureau were assigned to Birmingham for the purpose of assisting all the contestants. The aerological stations provided important data in perhaps a new way—that of showing where the least wind existed rather than the greatest.

Nine balloons started in the early evening. Conditions had been forecast and described as decidedly "slow," as slight and variable wind-movement was the rule below the 35th parallel and at all elevations even to great altitudes. There appeared to be little chance of widespread storminess on the balloon tracks, no danger of riding out to sea, and in general conditions were neither ideal nor unfavorable; it promised to be an obstacle race. Opportunities for spectacular speed or extraordinary altitudes were not presented, but the real advantages, however indistinct, seemed to be minor variations tucked away below the 1,200-meter level. Isobaric charts, typically summer ones, held but one outstanding feature, the HIGH in the southeast and over the Atlantic; the widespread flatness of gradient and temperature differences persisted throughout the race, although a small LOW energized somewhat upon reaching the New England coast from the Lake Region late Sunday night and Monday morning.



FIGS. 1-4.—Weather maps for the period of the race, showing sea-level pressure; wind direction and temperature for stations having wind velocity in excess of 10 miles per hour; and the progress of the winning balloon.

Meteorologically, it is required to plan a course of action with consideration of these points: First, maneuvering to avoid foul weather and to remain in or get into fast and well-directed currents; second, geographic control, as in staying inland and away from the coast and dangerous topographic areas; third, ballast economy, involving the relative merits of rapid expenditure to gain great speed for a less time or careful throwing to keep in slower speeds for a greater time. In this race, the second and third considerations were disposed of before the start, for seaward currents did not exist, and neither improvement in speed nor bettering of direction could be obtained by sailing at great altitudes. The problems simmered down to that of avoiding foul weather and finding the best winds of the low altitudes. The likelihood of cyclonic rainstorms or general convection showers was considered small, but the chances of local disturbances were considered good enough to demand the utmost speed promptly upon leaving Birmingham and throughout the first night, in order that such showers would not overtake us until we had gained sufficient distance to compare favorably with other contestants should all the balloons be forced down. The desideratum was ultimately to find our way out of the slow winds to better ones.

Birmingham was under anticyclonic control by the Bermuda southeast HIGH and wind-flow near the ground was inevitably slight. Pilot-balloon readings just before the race tell a story of weak winds, fickle currents, and energetic convection below the 2-kilometer level, and even less persistent directional drift between 2 and 10 kilometers south of latitude 35°. Further north somewhat improved speed was registered, but the balloonists could not reach this superior location. The 1-kilometer level is representative of the anticyclonic character of the wind drift, with the centers of outflowing streams respectively over eastern Virginia at 4 p. m., 21st; over North Carolina at 8 a. m., 22d; over South Carolina that afternoon, and in upper Alabama at 8 a. m., 23d. The entire problem for both forecaster and balloonist was bound up in the behavior of this HIGH. Temperature similarity and radiation equality over many degrees of latitude expressed themselves dynamically in the wiping out of wind flow at great altitudes.

The race thus became a search for the quickest way out of the HIGH. Reports indicated conspicuously that the currents of greatest strength and constancy within 500 miles of the start were toward the north and actuated by the near-ground pressure gradient. The optimum level was reckoned to be that altitude below which wind flow was less than gradient force owing to surface friction and topographic damping and above which wind flow was diminished progressively aloft as pressure gradients weakened in the free air; theory and observation agree that this level occurs at about 500 meters over the surface, and usually lower by night than by day. This promised to be a useful layer throughout the race, for it would be here that wind would develop as promptly and as favorably as at any other, whether the control were cyclonic or anticyclonic. In the event of encountering local storms, it was proposed to go to great lengths to keep out of the condensation area, since the ballast expense in this region of varying densities, vertical discontinuous currents, and precipitation may be as large as that required to navigate safely above the entire storm. These storms possess enough individuality to require a specific solution in navigating for each case, and the complete downfall of most of the other balloons in violent storms points to the sudden and fierce sort of local disturbance that is particularly menacing to balloonists.

Two balloons had already made their "get-aways" into the northwest when our balloon was borne across the field by the tugging of willing hands. The final weighing off, the last farewells, and the starter's greeting "Are you ready?" are thrilling affairs, but nothing can compare with the overwhelming sense of relief and joy at the first upward move. Ballast had been somewhat generously dealt at the start and we made a prompt swing upward to an altitude of 400 meters. Occupied by the cares of disorderly equipment and the wonderful novelty of this, my first free-balloon ride, the first hour slipped by rapidly. We had risen from the field at 7:57 p. m., and by 8:30 (ninetieth meridian time) had commenced the search for the optimum level. It was easily located by a series of soundings which indicated its presence between 450 and 500 meters altitude. The balloon had attained good equilibrium, the prospect was for smooth sailing, and Mr. Upson curled up and gained some three hours' sleep. Novel impressions were being made on all my senses, fair moonlight illuminated in faint but distinct fashion the various types of terrain we floated above, and varied sounds from field and woodland a half mile below were clearly audible. I distinguished plainly the croaking of frogs, the keener notes of the cricket and the barking of canine watchkeepers. Thin fog rested on the ground in places, probably hollow, while, above, a large sheet of alto-cumulus shaded the moon, and off to the west and north a row of castellated clouds rested on the horizon. A barn afire in the distance belched upward a cloud of smoke which rose at first quite vertically, then was flattened off by the currents above the ground. We now found our altitude increasing somewhat in our maintenance of the optimum level, partly because of greater height of the land above sea level. The sailing was luxuriously peaceful, and at 2 a. m. I took my turn at a three-hour nap.

It was during Mr. Upson's watch, during the last night hours, that the only occasion of sighting one of the other balloons occurred. This balloon was sighted above us, evidently in a slower current. It descended behind us, apparently searching for that current which we had run ahead in, but it descended too far, so that it was soon lost in the distance to the rear. When sunrise came and our balloon responded to the radiation, there was brought to a close a practically constant-altitude flight of about eight hours, at a level at which the actual wind closely approximated the gradient wind for sea-level pressure,[2] both in direction and speed. Other balloon runs have been undertaken intentionally for constant-altitude flying[3] but upon this particular occasion the constant altitude was maintained not by the use of valve and ballast to any extent after once attaining the proper level, but rather by the free motion of the balloon; and we may safely conclude that the path of the balloon closely resembled that of a particle of air starting with us at 8:30 p. m. The path is a smooth curve almost coincident with the isobar of 30.2 inches sea level at both 8 p. m., 21st, and 8 a. m., 22d, and indicates an average speed of about 8 m/s. The layer of optimum wind was 150 meters thick, between 600 and 750 meters sea-level altitude; above it the wind held the same direction but fell off, and below it the wind backed somewhat and fell off.

To make the most of the first night it was important that we have faith that an optimum layer existed, that we prove its presence and maintain our position within it. Aerology gave us confidence in the existence of the layer, and constant attention and speed soundings produced the desired results. At least one other balloon had twice been through the layer but had failed to stay there, and it was within easy reach of all. We now know it was the biggest opportunity of the race, though not apparently a striking one at the time. But we did try to use it to the fullest. Then and there the race was won.

[2] The sea-level gradient here referred to is the gradient as it appears on a map of station pressure reduced to sea level. The wind between 500 and 1,000 meters above the surface usually corresponds closely to this gradient. It should be remembered that this is true only where the elevation of the surface above sea level is not great.—EDITOR.

[3] Meisinger, C. LeRoy: Constant-elevation free-balloon flights from Fort Omaha. MO. WEATHER REV., Aug., 1919, 47: 535–538.

Night flying, when normally smooth, is delightful in its steadiness and equilibrium. But sunrise magically changes this, and the identically ripe conditions for smooth sailing at night are likewise and proportionally favorable for disturbed and convection-harassed sailing by day. At 8 a. m., Sunday this convection had so cut up the horizontal wind flow that we could find little more than half the speed we had held all night. The vertical currents had distributed the 150-meter optimum layer of the night over a layer perhaps more than 3,000 meters thick, all of whose parts possessed only the average of the entire layer. Free balloons tend to continue or augment vertical motion imparted to them, on account of momentum, a continuation of the contraction or expansion of the gas, and the usual persistence of the vertical components of the air surrounding the balloon; thus the effect of convection is telling on the supply of ballast. There is also much difference in a day's convection. That of the early morning is vigorous, but it is of smaller magnitude than that of the later hours. In the early morning it is merely a series of jets and spurts of warmed air; these grow in extent, strength, height, and speed until by mid-afternoon they become the great pillars for cumulus and cumulo-nimbus clouds.

Shortly after daybreak, a bank of "threatening and rainy clouds to the northwest" (to quote our log) indicated inclination toward local storms, and we then decided to stay as low as economically possible in respect to ballast. The bank moved slowly southward and we moved northeastward, so that we gradually drew away from it. It is altogether likely that this storm was the one which enveloped the other balloons, behind and to the west of us, and caused their descent, on account of violent convectional winds. Investigation of the currents aloft showed neither steady currents of strength nor favorable direction at high altitudes, and by midday we were meandering slowly eastward; by 3 p. m. below us rose the foothills of the wooded mountains of eastern Tennessee. This was a trying period. We dodged around cumuli, were borne up and down, but always without a break in the stagnation of wind. The best promise that I could make Mr. Upson was that nightfall should restore to us the gradient winds of the previous night, and that if the few cirri which had spread upward out of the northwestern sky were trustworthy the wind might be even stronger than on the previous evening.

And just before 4 p. m., far off to the east, smoke was discovered drifting slowly toward a northerly point. And then springing up from nowhere two small rows of strato-cumuli rolled along the hilltops also in a northerly direction and far below us. It was disconcerting that this favorable breeze should spring up so far beneath us, for we were shortly to undergo the usual contraction of gas due to sunset, with the accompanying loss of buoyancy and altitude, and we faced the question of expending gas at the time, and a corresponding weight of ballast later to overcome the natural contraction of the balloon, or waiting for the nocturnal contraction and wasting that lower breeze. Another trying period was endured, while we waited, hopefully extravagant of that wind far below in order to save ballast for the night. Temporarily shaded by horizon-clouds, we made two descents to near ground, only to rise again when the sun once more shone upon the envelope; thus we oscillated between 600 and 2,400 meters altitude from 4 to 6 p. m. The best current, 6 meters per second from south-southeast, was found about 150 meters above ground; this diminished and veered steadily up to about 1,100 meters where it was 3 meters per second from west-northwest; above that level direction was constant and a slight increase in speed prevailed. By 8 p. m. contraction of the gas bag had been practically completed, and we again made plans to stay within the sea-level gradient winds the second night.

Stability became well pronounced before midnight; evidence of it could be observed on the ground where fog in great white lakes filled every valley and glistened like snow in the moonlight. Occasionally a wreath of fog would be whisked off the upper surface and be carried along by the wind to dissolve soon in wind-blown threads, and it was evident that the surface wind failed to penetrate into these hollows where air-drainage alone could produce the thick fogs observed. This smoothing of ground contours by the wind is well marked, and surprising in its force, for upon approaching the first mountain that towered above us an impulse to expend ballast was apparently correct but we soon found ourselves to have ascended far above the mountain, and we then learned that we could trust the wind flow across the hills to carry us over their tops and down their leeward sides. It was my impression that the speed was increased on the windward sides and decreased on the leeward but the perspective effect of nearing and withdrawing ground may have been partly responsible for this effect. We skimmed the hills all night.

During this night we described an arc of a circle about 200 miles in radius drawn around a center east and north of Birmingham and eventually such a procedure would result in our arrival at a point whence we would commence to backtrack toward our starting point Sunrise came when we were crossing the main ridges of the Appalachians, 1,200 meters in altitude; our speed was now the highest of the voyage, over 11 meters per second from northwest, but our distance from Birmingham was being bettered but slightly. Finally, we crossed the last range of hills, the Blue Ridge, with lower levels of land visible beyond, but to our dismay we found our direction now veering still farther, so that we moved on the circumference of a circle centered upon Birmingham, temporarily anyway, with every prospect of incurving at any moment. A field was selected close within the "shadow of the hills," in the belief that the wind would be shut out there by the hills and an easy landing would be possible, but our plans were suddenly disrupted by a large cumulus which had built up around us and tossed us up like a bubble to 1,600 meters altitude. Our descent from here to the ground at about 500 meters was so gentle we hardly knew when we reached the surface.

Naturally we had not landed without deliberating on the feasibility of trying the wind at great altitudes, but from observations of the cirrus clouds and by an excursion to 2,600 meters, we were convinced that the wind veered even more unfavorably the further aloft we might go, and we could not consider yielding any of the precious miles from Birmingham. Our deliberations over the gain or loss of a single mile seem rather comic now, for we might have landed 20 hours earlier and still taken the first place, but such is balloon racing's creed: never lose a mile nor fail to gain one.

Our landing was an unusual one in some respects. It was gentle and easy, was effected with the valve only, and was made with full equipment and even ballast aboard, for it was forced not because of the usual circumstances of ballast exhaustion and foul weather or open sea, but by the malevolent direction of the wind which we could then neither escape nor improve. The barometric situation appeared to be that of a deepened LOW (perhaps the rehabilitated northwest LOW) passing out to sea, with high pressure following eastward behind it, and such a situation promised no improvement in the wind direction for several hours, so that a struggle for time seemed impractical. The actual weather map does not quite agree with the hypothetical one, but the wind reports show that we could have gained nothing by remaining aloft and might have lost some distance. We had been aloft over 34 hours and were the only team to go through the second night.

The balloon voyage itself provides two important observations. One is the height of the ceiling of the wind produced by sea-level isobars. Each night we flew near this ceiling, and we may conclude that when stagnation occurs aloft the wind will tend to increase with altitude up to this ceiling where friction is at a minimum and thence upward will decrease as pressure gradients diminish. It is gratifying to note that the sea-level gradient wind, agrees closely with the actual wind observed at the expected altitude above ground (about 500 to 700 meters), both in direction and speed. Another observation is the tendency, which I have found exhibited in other balloon flights, for a balloon to land at a point where pressure is slightly lower than at the start of the balloon (with correction for altitude). On our voyage, the average rate at which we crossed isobars of decreasing pressure was 0.005 inch per hour.

It is appropriate to add that the position of meteorological observer in a racing balloon is exacting and constantly fraught with perplexities over weather and wind, yet the exhilaration and serenity of quiet air travel is so delightful and the unfolding of meteorological processes is so interesting that the net result is a keen joy in the game. Upon landing, one is overwhelmed with three fierce desires: to learn where the other balloons landed, to see a weather map and hold a "post-mortem" on your own flight, and to sleep.

While good luck, complete and reliable equipment, and plenty of courageous endurance are always necessary ingredients in a recipe for winning balloon races, it will be one of the most satisfying results of the race if it's outcome has proved that in addition to these ingredients, meteorology, providing reliable data of current conditions and future prospects, correct assumptions as a basis for operating tactics, and capable interpretations of weather processes as they unfold, has taken a higher place on the list of the necessities of the balloonist.

A study of the stormy conditions reported by the other balloonists indicates that the disturbances into which they were drawn were confined to a small area, and were of the class of local convectional showers, which may exhibit over a small area all the violence of the fiercest storms. No showers were reported in the southeast on Sunday, except in Florida and in the vicinity of Nashville, Tenn., where the balloons were forced to descend. It may be possible that the surface relief was in some measure responsible for the formation of thunderstorms in the more level land around the river valleys than in the hilly regions of the eastern part of the State, although it was our experience even there that cumuli seemed to assume huge proportions. Unfortunately there was no strong alternate wind at high altitude to which escape might have been had, but there seems to have been a slow current in those upper regions which, if attainable in ample time, should have carried the balloons to a safe distance from the storm even if toward Birmingham, and from this place the voyage might have been resumed and continued into the second night. The logs of the other balloons show unmistakeably that a hard fight was made to outride the storm; and we may again conclude that well-defined local disturbances and thunderstorms must be respected by all travelers in the air.

EFFECT OF CHANGE IN THE POSITION OF THE THERMOMETER SHELTER AT ESCONDIDO, CALIFORNIA, UPON THE MINIMUM TEMPERATURE.

551.524: 551.568 (794) By HENRY F. ALCIATORE, Meteorologist.

[Weather Bureau, San Diego, Calif., Apr. 17, 1921.]

SYNOPSIS.

An analysis of minimum temperature readings taken at Escondido, Calif., both before and after the instrument was moved to higher ground showed that an increase of elevation of 20 feet raised the minimum temperatures considerably in respect to mild mornings during November and February, and on all mornings during December and January. Also that the effect was more pronounced for temperatures ranging from 33° to 38° than for the limits between 30° and 33°.

In October, 1919, the instrument shelter of the special meteorological station at Escondido, Calif., was moved from the old site at the end of the Hubbard lemon orchard to another point in the same orchard about 408 feet north and 72 feet west of the old site, and 20 feet higher, at the suggestion of the chamber of commerce with a view to obtaining temperature records representative of a larger portion of the citrus belt centered about Escondido.

Now, did the change affect the minimum temperatures recorded after October, 1919? If "yes," to what extent and in what way? Is the science of climatology likely to be benefited by such a practice? Tentative answers to these questions will be found in what follows.

The data used were the daily minimum temperatures at Escondido, and El Cajon, for three seasons before the change and the two seasons next following. The elevations of the stations named are, 742 and 482 feet, respectively, above sea level, and separated from each other by a distance of about 15 miles in an air line.

As a basis of comparisons we chose the El Cajon temperature record. All the minima recorded at that place (below 40°) were tabulated in groups differing from each other by 1°, and the corresponding, simultaneous minima of the other station were entered oppositely thereto. The mean variations from the base-station temperatures were computed for each degree of temperature (39, 38, 37, etc.), and tabulated by months as indicated in Table 2. (The Bonita and San Diego records were used as checks on the work.) The values in Table 2 were then plotted in the manner shown in the graphs (not reproduced).

A glance at the Escondido graph shows that the coldness or mildness of the mornings at the base station is a function of the variations of the Escondido minima; also, that while some were plus and some minus before the shelter was moved, all the variations after the change were of one order, i. e., plus. On the other hand, the curves in the Bonita and San Diego graphs, do not show any marked positive or negative departures from the base-station minima, as might have been anticipated inasmuch as the shelter at Escondido was the only one of the four whose position was altered.