THE APPLICATION OF BJERKNES LINES TO THE DEVELOPMENT OF SECONDARY LOWS.

By C. G. ANDRUS, Observer.

[Weather Bureau, Due West, S. C., Feb. 25, 1921.]

551.54

SYNOPSIS.

The application of the Bjerknes lines of wind convergence to the solution of the problems of trough development at the time of the National and International Balloon Races in September and October, 1920, afforded some useful conclusions concerning the principles of the Bjerknes hypothesis in secondary LOWS. This study has been made purposely only in terms of the surface elements and the winds aloft. Irregularities in these conditions, can be traced to imminent *development of a change in the cyclonic formation.* A description of these irregularities both at the surface and aloft has been made in order to record some forecasting hints, which, while neither infallible nor complete, offer some aid in detecting the sudden development of secondary LOWS in barometric troughs.

It has been mentioned[1] that the barometric trough requires cautious treatment by the aeronautical forecaster. The problem presented by these troughs does not concern merely the trough, for its effects on weather elements are well understood; the real problem is this: Will a secondary unit of low pressure develop in the trough, and if so, where and when will this occur? This was the major meteorological problem met in the preparation of advisory forecasts for the flyers in the National Balloon Race from Birmingham, Ala., September 25, 1920, and at that time the converging wind streams which have been discussed by Bjerknes were found extremely helpful. The results were so satisfactory that at the time of the International Race a month later *considerable reliance was placed on this method for a* solution of the problems of a somewhat similar pressure distribution. The conclusions reached by the study of these two troughs, and of many others previously examined, are based almost entirely on wind flow and temperature data, as it has seemed evident that the sea-level barometric values[2] are of doubtful meaning in defining the position or motion of the center of activity in these depressions. However, the Bjerknes system considers the cyclone which is moving and definite, so it has been necessary to adapt it to use on the indefinite depression.

So long as a squall line exhibits only the well-known properties of the line squall in more or less intense degree it may be treated as the normal squall line of Bjerknes. But should the squall line or the conditions along its extension manifest any tendency to resemble the properties of the steering line, this condition is likely to herald the birth of a separate cyclonic unit, and keen watch must be kept of this action. If the condition persists, it indicates a secondary LOW in process of formation; if it appears to be but temporary, it is nevertheless an excellent marker of the position on the squall line of possible future developments. In the steering line we have the elements of the inclined plane, its lower edge coinciding with the surface position of the steering line, its face containing the steering line's positions at successive levels aloft, and extending upward to the north of the line of travel of the depression. In the case of the steering line the inclined plane exerts no wedging force, but is propelled forward along the line of the storm's movement in a sideling fashion. Warm winds usually of southerly component, glide up the surface of the plane, which is composed of relatively cooler winds directed inward toward the storm center at an angle of considerable incidence to the isobars. The steering line, therefore, may be considered as a surface condition of passive character where wind streams leave the surface in a gradual ascent whose position is marked by cloud bases and usually announced by continuous rain or snow, and sometimes sleet.[3]

The squall line, on the other hand, is an inclined plane wedging forward in the same general direction as the LOW. This wedge, whose flat side in on the surface, consists of air relatively colder and heavier than the air it displaces, which is pried upward and forward. The line squall and the "clearing" shower are manifestations of the squall line passage. In the case of the squall line, the surface condition is one of increasing activity, this being first displayed there, and later and more to the rear, shown aloft. If topography is disregarded, the strongest winds of the surface circulation in a definite LOW are those at and immediately to the rear of the squall line, and those in the front half of the warm sector between the steering and the squall lines. Conversely the weakest or most variable winds at the surface occur just ahead of the steering line and over the forerunner of the squall line. This latter location is sometimes clearly marked by a widening of the isobars of the weather map and is occasionally the birthplace of tornadoes.

When a steering line exhibits characteristics of a squall line, the depression will weaken in intensity and lose definition. In this class are those steering lines whose east and north winds are too strong, have too strong a north component, or are irregularily deflected across the isobars.

The squall line is usually much better defined and of much greater extent, so that a departure from its normal form can be more promptly detected. When a squall line shows any characteristics of a steering line, the propagation of a secondary unit of cyclonic circulation may be expected at the location of the irregularity, if it persists more than 12 hours. These irregularities are manifested as, (1) the entering of an east or the falling off of the proper west component directly at the rear of the squall line; (2) the development of precipitation of a steady rather than shower type to the front of the squall line, an indication of the upriding southerly currents rather than the underrunning northwesterly or of the *occurrence of both of these actions; (3) the failure* of the line of falling temperature to proceed forward along a solid front but instead, making an enveloping attack on the warm area; (4) the lagging of the lower end of the squall line, resulting in the orientation of this end toward the southwest and west in greater degree, hence giving greater opportunity for irregularities (1) and (3) to become operative. The steering line of a developing unit of cyclonic circulation may be expected to occur along the location of these four irregularities, all four of which are sometimes present.

Conditions aloft are more indeterminable in the present scattered condition of the available observations. Sometimes only two points are available over an immense area, and two points will not determine a plane. But we may judge where a squall line's plane should cut successively higher layers of the atmosphere and determine

---

[1] Andrus, C. G.: Meteorological aspects of the International Balloon Race, 1920. This REVIEW, pp. 8-10.

[2] *Meisinger, C. LeRoy: Preliminary steps in the making of free-air pressure and wind* charts. MO. WEATHER REV., May, 1920, 48: 251-263.

[3] Meisinger, C. LeRoy: The precipitation of sleet and the formation of glaze in the *eastern United States, Jan. 20 to 25, 1920, with remarks on forecasting.* MO. WEATHER REV., Feb., 1920, 48: 73-80.

Unauthenticated | Downloaded 10/24/21 11:23 AM UTC

whether the actual wind approximates the estimated wind for that position, laying great stress on the actual wind's direction. Hence we may consider as irregularities aloft, (1) in the rear of a squall line, any SE., E., or light NE. wind above the 1,500-meter altitude (there the wind should be westerly and equal to or stronger than the 500-meter altitude wind), (2) to the north of the steering line, the lack of a marked veering of the higher altitude winds with reference to those at lower levels, (3) too strict an adherence of the wind motion at an elevation of about 600 meters above ground to the gradient values deduced from isobars for the sea level along the region in the vicinity of the steering and squall lines. The 600-meter wind along the squall line should be extraordinarily deflected outward across the isobars, and the 600-meter wind along the steering line should be somewhat deflected inward across the isobars.

The formation and propagation of a secondary in the lower end of the trough of low pressure in the central States during the International Balloon Race was foretold by irregularities in the wind streams. The first appeared over central Texas on the evening of October 23d, when rain was reported well in front of the squall line in Texas. The upper winds at 2,500 and 3,500 meters altitude (fig. 4) in the rear of the squall line over Oklahoma showed a pronounced easterly and southerly component, indicative of the overrunning of the cold current by one from the south. Absence of marked west winds at altitudes up to 4 kilometers over the Southwest and Middle West was an indication of the slow movement of the cyclonic unit after its formation. The following day at 8 a. m., a definite subcenter of low pressure had become established in eastern Texas and the steady rain area had extended over eastern Texas, western Louisiana, Arkansas, and Missouri; a line of convergent wind streams, which we may consider a steering line, extended northeastward from northeast Texas; another convergence line, the squall line of the new circulation center, extended from northeast Texas southeastward to the Gulf coast. The secondary LOW was now a definite one, yet the large size of its warm area without marked increase of temperature on its front, and the position of the HIGH to the northeast meant that the countercurrents were not dynamically powerful enough to feed an intense storm, hence the development of the depression was but moderate. The wind at the altitude of 3 kilometers and 4 kilometers had apparently increased in westerly component throughout the Middle West, since the only two available observations, at Madison, Wis., and Kelly Field, Tex., found WSW. winds of 17m/s. and 10 m/s., respectively, at the 4 kilometer level that morning. From this is was concluded that the forward movement of the storm would be slower than normal at first, but later increasing somewhat as it reached higher latitudes.

To summarize, it may be stated that of the available observations the most effective in predicting the formation of secondaries are the wind convergence lines, at the surface and aloft, the temperature contrasts, the barometric gradient, and the deflection of the actual wind along the isobars. The 600-meter altitude has been found to represent the approximate position of the gradient wind above ground, although this altitude is sometimes taken as low as 300 meters. Prevention of the failures of forecasts due to suddently forming Texas or Gulf LOWS may be increased by the application of the principles just considered. Other principles of wind-shifts and free-air motions have been found, but have been observed too seldom to warrant their consideration until further material is obtained.

ORIGIN OF SOME SECONDARY CYCLONES ON THE MIDDLE ATLANTIC COAST.

551.515 (75)

By CHARLES F. BROOKS, Meteorologist.

[Weather Bureau, Washington, D. C., Mar. 1, 1921.]

SYNOPSIS.

When a strong cyclone centered in the Middle West extends its influence to the Atlantic coast a small secondary low-pressure area is often formed just inland from the coast. The southerly wind readily establishes itself at the surface along the low, flat coast, and therefore brings about a rapid fall in pressure not only by blowing away the dense, cold air, but also by bringing much warmer air soon from over the Gulf Stream. Perhaps a hundred miles inland, on the other hand, the relative roughness of the land tends to retain the cold surface air for some time, while the southerly wind rides over it. Once the pressure along the coast has become lower than that inland, a secondary cyclone develops and survives for the short time till the relatively small volume of cold air becomes mixed with the warm and blown away.

With the approach of a large cyclone from the Middle West, the cold air of the preceding anticyclone is more rapidly swept away by the southerly wind along the flat coast than over the maturely dissected Piedmont backed by such an effective retaining wall as the Blue Ridge. Furthermore, the arrival of warm air from over the Gulf Stream occurs much sooner on the coast than 100 miles inland at the same latitude. For example, a SSE. wind would have to travel 200 miles from the Gulf Stream to reach Norfolk, Va., and 300 miles to reach Lynchburg. With the substitution of the more tenuous, warm air for the denser cold air taking place from sea-level to an appreciable height, the atmospheric pressure on the coast falls rapidly. Inland, however, the substitution of more tenuous for denser air is in progress only above the retained, surface layer of cold air, which may extend, near the mountains, up to 500 or more meters above sea level. Thus, even were there no change in relative pressure at, say, 1,000 meters above sea level, a closed area or trough of low-pressure would form over the coast, or rather just inland, because the lowest pressure would occur just west of the place of greatest fall, the pressure gradient originally having been from east to west. In accordance with the new distribution of pressure the cold air hugging the Piedmont starts to move southwestward and southward. This movement brings colder air in greater volume, which tends to raise the pressure over the Piedmont at the same time that the warmer and warmer air arriving over the coast is lowering the pressure there. Thus, the secondary low-pressure area becomes strengthened, and its cyclonic circulation becomes complete—all within the lowest kilometer or two of the atmosphere. Through holes in the lower clouds, the heavy St.Cu. and A.St. at about 1.5 or 2 kilometers may be seen moving rapidly from the SW. over the whole area, in conformity with the more or less regular distribution of pressure about the primary cyclone hundreds of miles to the northwest. The cold air over the Piedmont provides a steep mountain slope up which the warm air from the Gulf Stream rises, expanding and discharging much of its great load of moisture.

Before long, the east winds in the northeast quadrant of the secondary have pushed in from the ocean to the Blue Ridge. The supply of cold air is becoming adulter-

Unauthenticated | Downloaded 10/24/21 11:23 AM UTC