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A MESO-LOW ASSOCIATED WITH A SEVERE STORM

BERNARD W. MAGOR

Severe Local Storms Forecast Center, U. S. Weather Bureau, Kansas City, Mo.
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ABSTRACT

A meso-Low was followed through a 14-hour period over a track about 600 miles in length. This Low was associated with severe storms along its route and subsequently became coincident with the vortex of a well-documented severe storm at Charleston, S. C. on January 18, 1955. The objective is to show that such Lows can sometimes be tracked with the present observational network and to point out some of the interesting meteorological features of this type of analysis, along with forecasting implications.

1. INTRODUCTION

Several investigators have pointed out that tornadoes and other severe thunderstorm phenomena are more closely related to small-scale meteorological features than to the larger scale of events usually depicted on the familiar synoptic charts. Means [13] detected the presence of micro-Lows or "tornado nests" which "frequently appeared an hour or two before the time at which tornadoes developed"; Kraft and Conner [10] describe "small lows" that occasionally "develop in the warm sector when conditions are favorable for major tornadoes"; Whiting [18] mentions the creation of "micro waves" along warm fronts in relation to severe weather. Each of these investigators identified severe convective phenomena with small-scale Lows. The term "meso" is now generally used to distinguish such small-scale events from the larger (macro) scale on the one hand and the very small (micro) scale on the other (c. f. Fujita [5] and Fujita, Newstein, and Tepper [6]). In line with these definitions the term "meso-Low" as used here defines a low pressure pattern of 30 to 50 miles in diameter—of a size that could move over a moderate portion of the country without identification if it happened not to pass over a reporting station.

Fujita [5] and Fujita, Newstein, and Tepper [6] have found mesoscale phenomena to be of such small scale and their life history usually so transitory that they can only infrequently be observed on routinely prepared synoptic charts. This observation will be readily attested to by many forecasters concerned with severe convective weather. Nevertheless, because of the importance of the mesoscale for local weather analysis and forecasting, forecasters should, in the absence of a mesonetwork, attempt to identify the mesosystems from whatever observations are available. Experience in forecasting the occurrence of tornadoes has shown that in some cases these small-scale Lows are strong enough to be discerned on the regular synoptic charts, and that they are occasionally long-lived enough to be followed for hundreds of miles.

This paper attempts to illustrate specifically the time-space continuity of a particular meso-Low of comparatively recent history that was sufficiently strong to be followed by careful analysis of available synoptic reports and special observations that reported altimeter settings. Although the evidence is usually more flimsy than for the case studied here, synoptic analysts and forecasters should be on the lookout for such cases as can be followed by this approach. The objective of this case study is to give some hints on what to look for and to offer evidence that a detailed pressure analysis over an area alerted for severe storms can sometimes indicate the presence of small-scale Lows, and that continuity of successive hourly analyses assists in ascertaining the direction and speed of movement of such Lows. If a forecaster can positively locate a meso-Low, his confidence in verification of a severe storm occurrence near the area of maximum convergence and vertical motion associated with the Low is increased.

2. METHOD OF INVESTIGATION

The case investigated represents a winter or early spring synoptic situation characteristic of severe convective storms. Convectively unstable air is overrun by a high-level short-wave trough which is typically moving eastward at moderate speed. A rapidly moving surface cyclone is also present; showers are brought about by the release of convective instability.

While the synoptic surface charts were used to some extent in locating the surface frontal positions and low center, the prime medium by which the meso-Low was detected and followed was the hourly surface chart of pressure readings composed of the last two digits (hundredths of an inch) of the altimeter settings sent over teletypewriter weather Circuit "A" by the various reporting stations. Altimeter settings are particularly suited for this type of analysis because many special observations ordinarily include them—thereby increasing the forecaster's chances of following the position of the small-scale Low *between* hourly record observations.

Also, because the altimeter setting differs from the sea level pressure essentially in its lack of a mean temperature correction at each reading, it may provide a more spontaneous indication of true pressure behavior in and around a meso-structure—particularly if the situation is occurring over an area of uniform terrain [2]. Specifically, the changes of altimeter setting in a small period of time over the area are more nearly correct than those of sea level pressure.

The altitude of terrain in this study is unlikely to introduce an error in the sea level pressure correction. It is conceivable, however, that the changes of sea level pressure readings from one hour to the next, inasmuch as they are obtained with a correction depending upon the temperature existing 12 hours beforehand, are smoothed excessively by the introduction of the correction at the very time the most absolute picture obtainable of the pressure distribution is needed to detect a mesosystem. Because reported elements are subject to error it would be to the forecaster's advantage to utilize those elements which tend toward a more absolute value. It is proposed here that the hourly plot of a station's altimeter settings more closely resembles that station's barograph trace.

Analysis of the synoptic chart for an isobaric interval of one millibar was necessary to detect the presence of the meso-Low studied here.

3. THE PARENT STORM

The parent storm with which this small-scale Low was subsequently associated developed during the evening of January 17, 1955. Maritime polar air spilled over the Continental Divide in southern New Mexico developing a squall line over central Texas where rapidly increasing dewpoints in the lower 4,000 feet earlier had signalled an ominous axis of moisture feeding into the trough. This cooler maritime polar air was associated with a short wave at 500 mb. moving eastward at 40 knots during the day (fig. 1). On the evening of the 17th potentially severe weather was anticipated for southern Texas as the line of thunderstorms formed east of the Rio Grande at the same time that movement of a cold Low in the vicinity of Monterrey, Mexico eastward into Texas became identified by a pressure fall maximum at Corpus Christi (fig. 2).

Within 2 hours of the observation time of this map, six separate severe turbulence reports were received from points along and ahead of the cold front as far east as Laredo, Tex. and northward to north central Texas. Hail was reported at San Angelo, Tex., and aloft over Lawton, Okla. Winds to 75 m. p. h. were recorded at Corpus Christi. The Low stayed just south of the shoreline that night and moved inland between Beaumont, Tex. and Lake Charles, La., at 0730 EST, January 18 (fig. 3).

4. THE MESO-LOW

For purposes of tracking, hourly maps of altimeter settings were plotted commencing with the 0930 EST observations on the 18th. This first chart (fig. 4) suggests that a secondary low pressure pattern (the meso-Low) was ahead of the major Low—about 120 miles east-southeast, just over New Orleans.

This Low was followed with little difficulty by using the hourly tendencies of pressure with particular heed to the changes in pressure determined from altimeter settings reported on special observations taken along the area traversed by the storm. A close scrutiny of figure 5 makes evident that the greatest rate of change of pressure moved over southern Georgia in an east-northeasterly direction. This Low apparently was steered by the cold upper trough which was moving eastward at about 40 knots. Figure 6 illustrates the barograph traces simulated by plotting the available hourly and the gratuitous special observations made of the altimeter setting at stations affected by the path of the small Low.

Figure 6 enables us to put a greater degree of confidence in the analysis of figure 5. Note how a small trough of 30 to 45 minutes time duration existed over Tallahassee, Fla. at 1630 EST, and Albany, Ga., at 1715 EST, while to the north-northwest the pressure at Columbus, Ga. (which had fallen in conjunction with the trough over Tallahassee) was rising at the same time that Albany was falling. The more shallow trace at Valdosta, Ga., plus its record of surface wind, veering from an easterly wind at 1630 EST

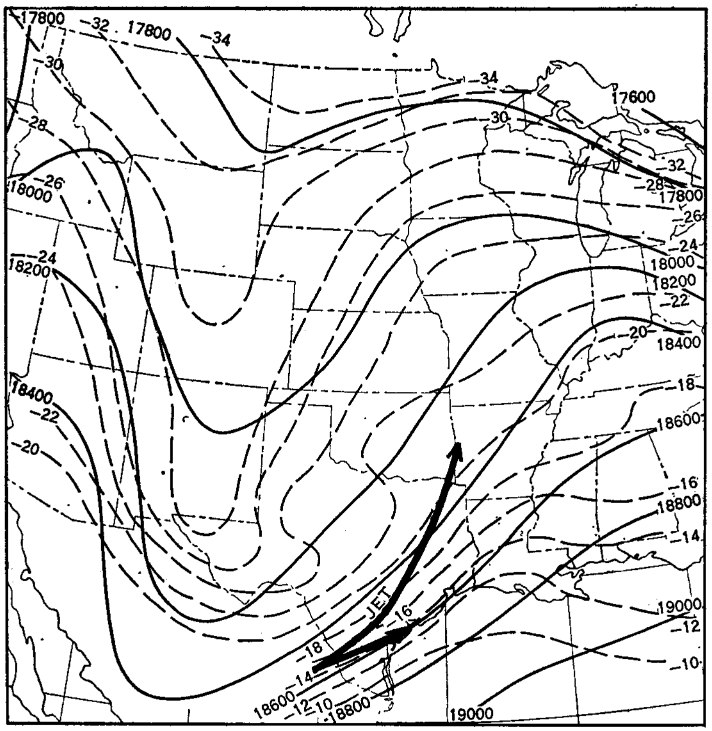

Figure 1.—500-mb. contours (solid lines) and isotherms (dashed lines) 2200 EST, January 17, 1955.

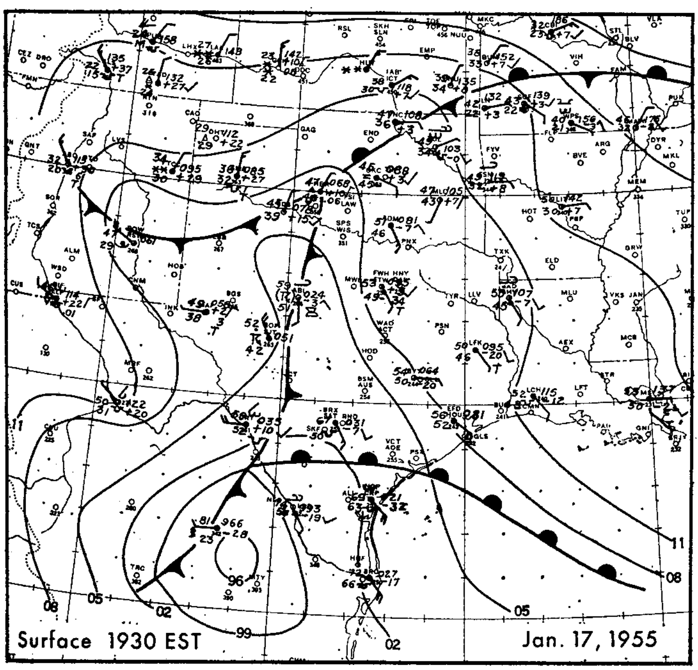

Figure 2.—Surface weather map, 1930 EST, January 17, 1955.

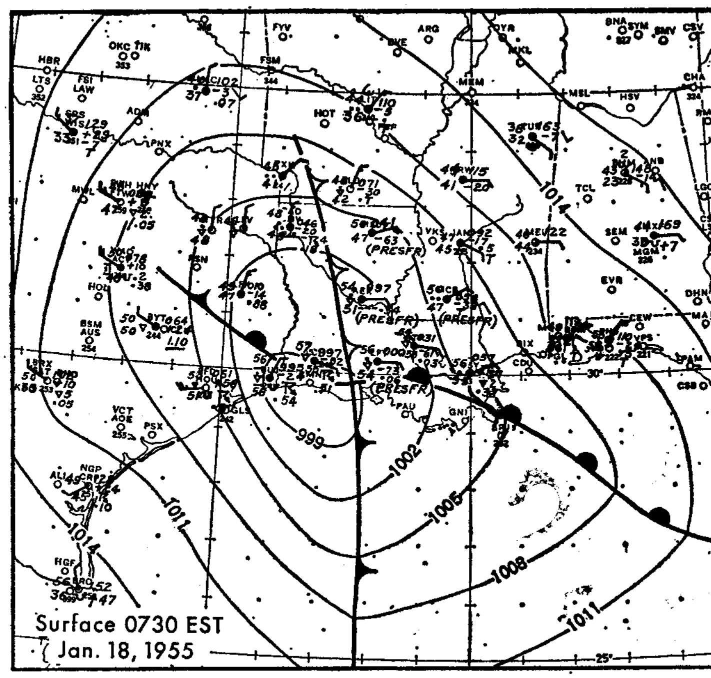

Figure 3.—Surface weather map, 0730 EST, January 18, 1955.

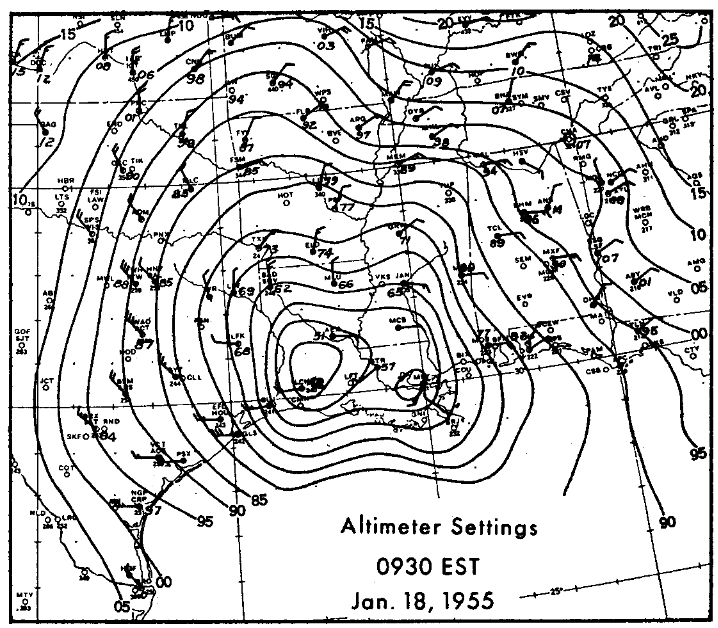

Figure 4.—Surface map based on altimeter settings, 0930 EST, January 18, 1955. Isobars at intervals of .05 inch. Note the meso-Low that has formed about the point of occlusion of the tropical and maritime polar fronts just west of New Orleans.

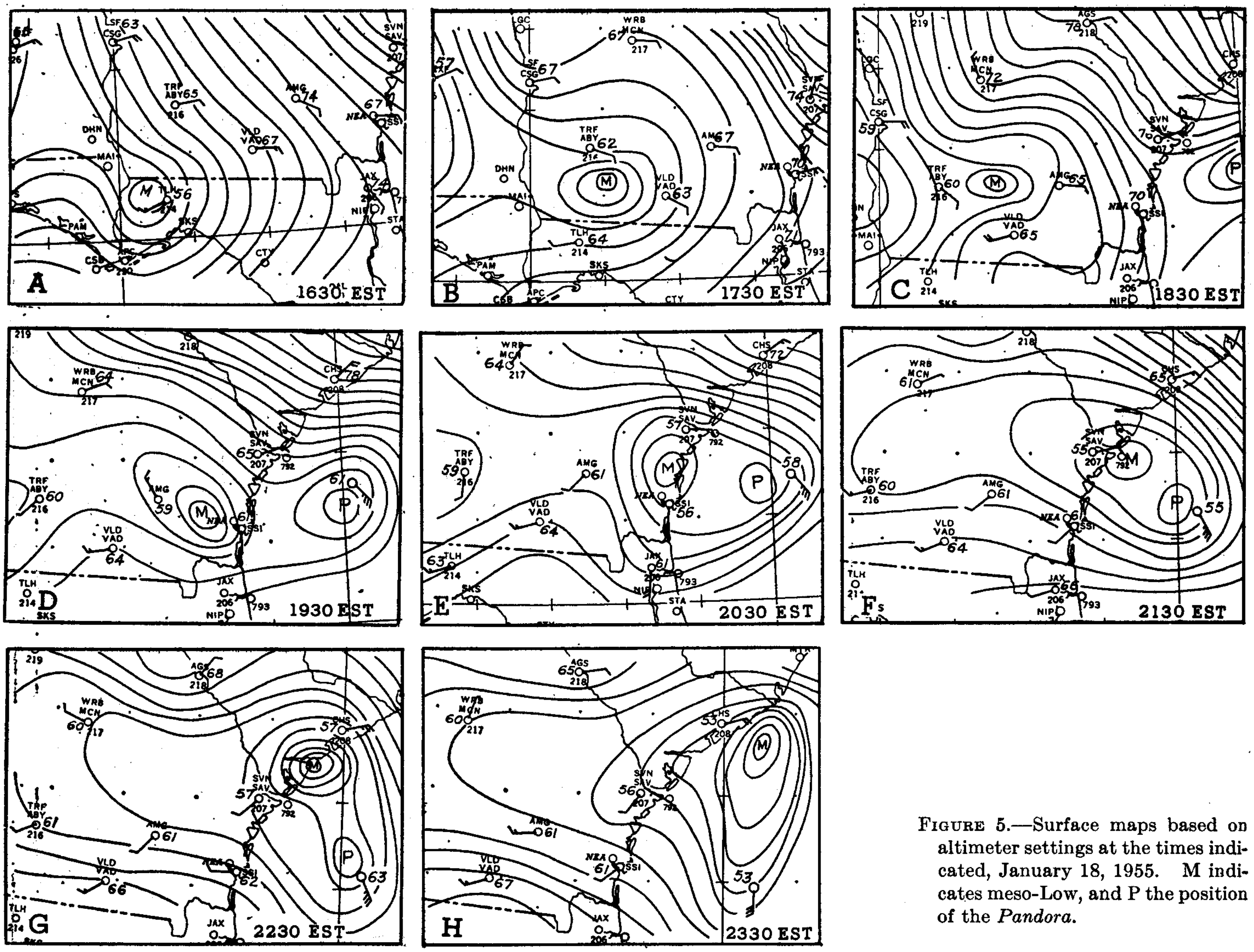

FIGURE 5.—Surface maps based on altimeter settings at the times indicated, January 18, 1955. M indicates meso-Low, and P the position of the *Pandora*.

through southerly to a westerly at 1830 EST, implies that the core of lowest pressure passed north. The fact that the pressure at Alma, Ga., fell at 1930 EST *after* the leveling off at Tallahassee and Albany, and the fact that the wind at Alma shifted from easterly to northwesterly would imply that a Low passed just south of Alma—logical continuity would permit this to be associated with the same trough which, we concluded above, passed between Tallahassee and Albany 2½ hours earlier.

Figure 7 compares the apparent path of this Low with the severe weather of record on this particular day, and with the successive positions of the jet maximum at 500 mb. Most of this severe weather occurred within 100 miles of the locus of the Low. The afternoon's severe weather reported and associated with this meso-Low had been predominantly that of severe turbulence (with experienced pilots reporting turbulence in the southern Georgia area as "the worst ever encountered") [18].

Mr. H. L. Jacobson, then Meteorologist-In-Charge, U. S. Weather Bureau Office, Kansas City, Mo., was motoring westward along U. S. Highway 90 in southern Mississippi the morning of the 18th, directly in the path of this meso-Low. His brief account of the storm follows:

> At about 0900 C, we were passing through Mobile, Ala. As we later went into Pascagoula, Miss., we encountered first class downpours; and upon reaching Gulfport about 1000 C we found the storm had just passed through—it was still raining, with intensity variable. Everything there was flooded; electric power was out; trees were down, shutting off lanes in the highway. Diameters of some trees were estimated to be 10 to 12 inches. The same conditions existed in Biloxi, but by that time the storm was letting up; the sun broke through there around noon. As we proceeded into Louisiana, we took note that trees were down all the way from Gulfport, Miss. to New Orleans. One large tree had been downed in the park at New Orleans.

Referring again to the track of the meso-Low in figure 7, we can make a more assured assumption that the Low that was east of New Orleans at 1030 EST would have been over Mr. Jacobson's route between 1130 and 1230 EST (1030 and 1130 CST according to his log).

The meso-Low moved to sea south of Savannah, Ga.

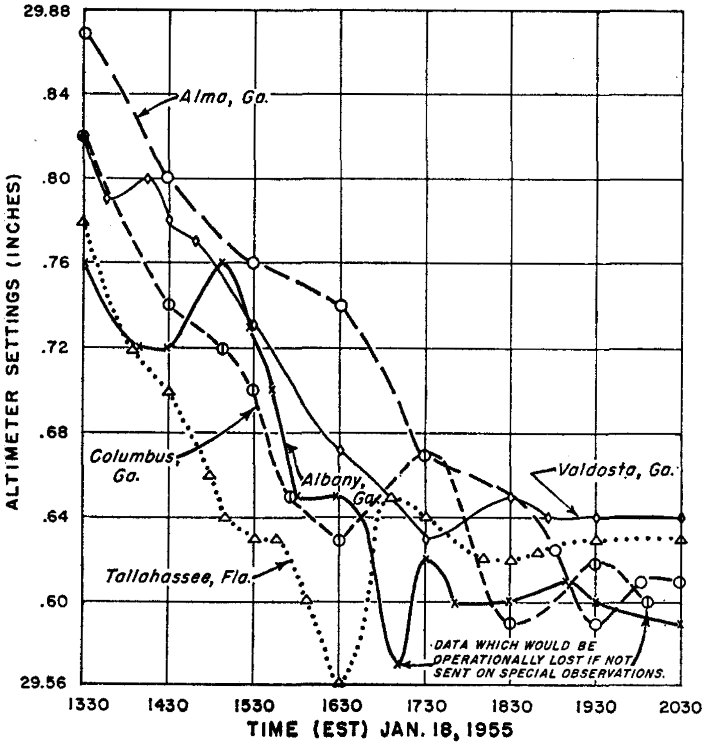

FIGURE 6.—Simulated barograph traces obtained from altimeter settings reported in "record" and "special" observations.

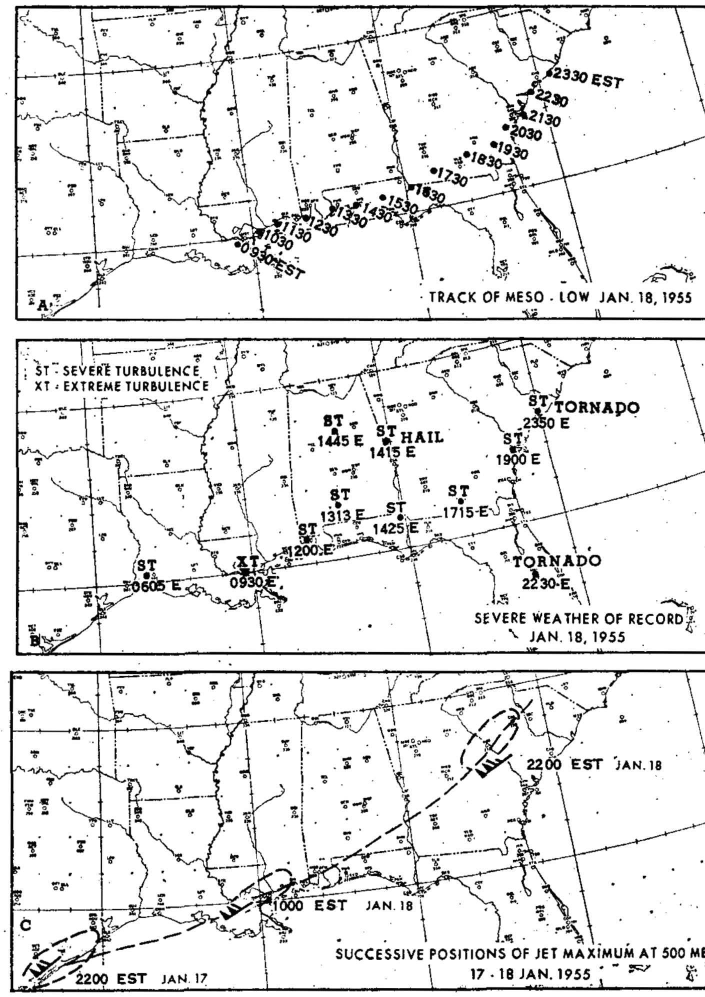

FIGURE 7.—(a) Hourly positions of center of meso-Low, January 18, 1955. (b) Severe weather reports, January 18, 1955. (c) Successive positions of jet maximum at 500 mb., January 17–18, 1955.

about 2130 EST. However a continued plotting of the altimeter settings for continuity showed the pressure at Charleston continued to fall and at 2300 EST that station recorded a gust to 70 knots followed by a gradually rising barometer. From this it seemed likely that the meso-Low had swung northward briefly after going to sea. A study was begun on this situation when reports arrived from Charleston depicting damage done to aircraft and power lines, along with eyewitness descriptions which strengthened suspicions that a small tornado had occurred there. Such reports as, "Thunder, the characteristic roar of tornadic winds," trees broken and uprooted with considerable evidence of cyclonic shearing action, an automobile proceeding in low gear being blown against a building, and, more conclusively, a report from the Tower at Charleston Airport, that speeds and directions of "the wind observed . . . from 2245 E to 2300 E were from the east-northeast 50–55 knots with occasional gust to 60 knots, with a peak gust to 70 knots. *A shift to a southwesterly direction was noted for above five minutes then returned to east-northeast. The highest velocities were noted during this shift.*" This is quoted from the report of Mr. C. E. Davis. This statement is deemed particularly significant in view of the fact that the gradient flow pattern over Charleston would have been northeasterly preceding and following the passage of the small Low.

The micro-barograph trace at the airport showed that during this period described by Mr. Davis the pressure rose from 29.50 to 29.60 inches between 2243 and 2251 EST; then in the next 2 minutes fell back to 29.50 inches, falling more gradually the following 8 minutes to its lowest value of 29.44 inches. During this 18-minute period the 5-minute wind shift and strongest gusts were reported. A night watchman at the airport reported that there was thunder and lightning shortly before the high winds struck. He also noted a roaring sound to the wind. From this evidence it might be conjectured that a thunderstorm downdraft had concentrated its subsidence over the area resulting in the brief pressure surge, followed by increased lateral convergence within the meso-Low increasing the cyclonic vorticity over the station. Mr. Davis also stated that "at the passing the clouds were extremely dark, but no funnel was observed." At a distance of 4,600 feet in an east-northeasterly direction from the location of damage to aircraft at the airport the storm blew down a number of telephone poles and at a distance of 6 miles farther in the same direction, wind-

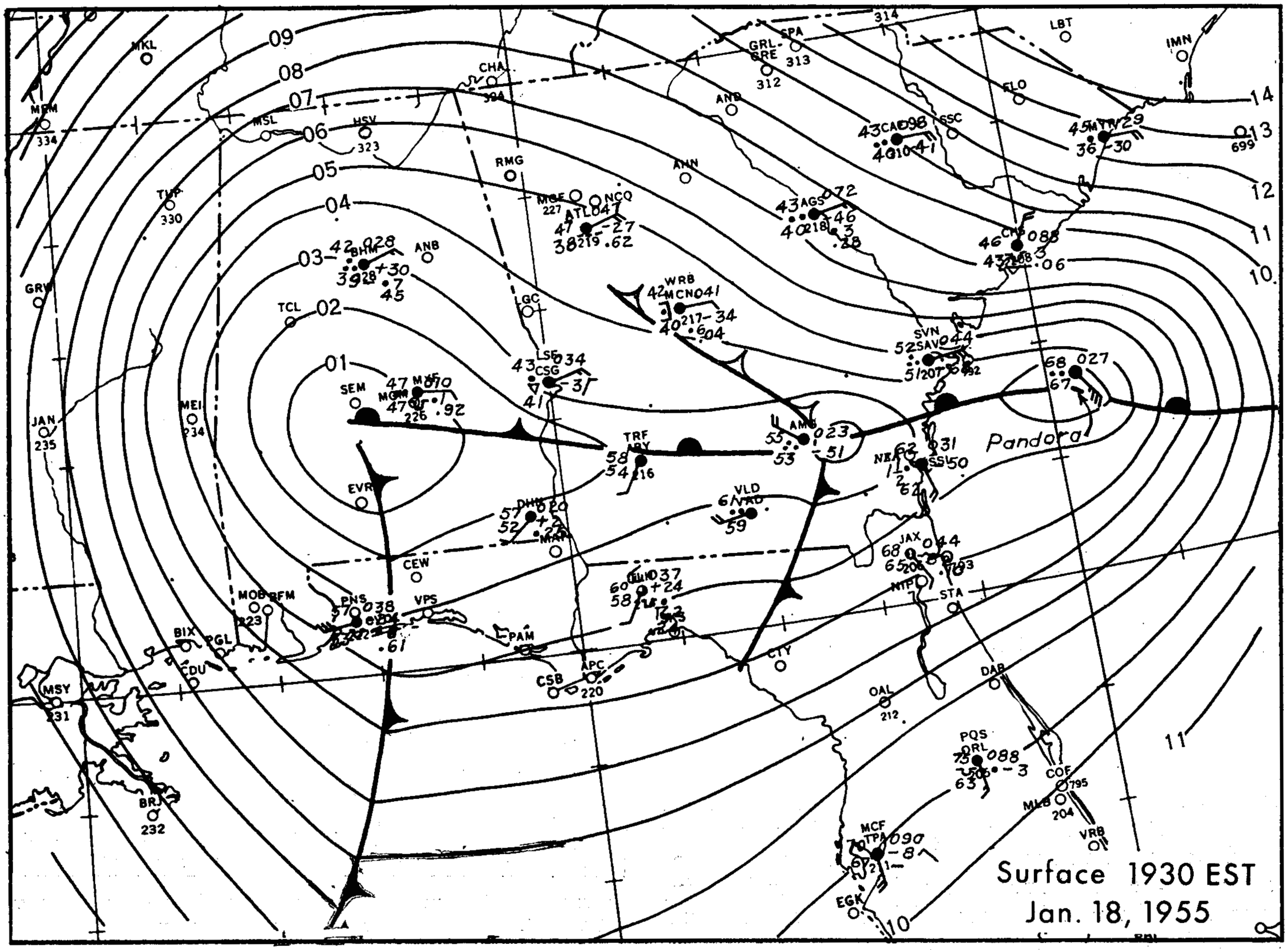

FIGURE 8.—Surface weather map, 1930 EST, January 18, 1955.

blown debris caused a power failure. Mr. S. K. Parrish of the U. S. Weather Bureau said that if it was only the low pressure system that moved across the area, then it was the tightest Low he had ever seen.

5. ACTIVITY AT SEA

Reports had also reached the mainland that the Coast Guard Cutter *Pandora* had reported herself in heavy seas while enroute out of Charleston for Miami. Consequently, her commanding officer was contacted for any information he could offer specifically as to whether or not the storm came up suddenly or if it was fairly well sustained; also as to whether or not the heavy seas were of major storm proportions and characteristics [17] or if they were more local and chaotic with little or no indicative swell, as could be the case if a convective storm suddenly appeared. The Commanding Officer, Lieutenant Commander L. Mason, U. S. C. G., furnished a copy of his log. This log showed that he began to encounter a storm about 1900 EST January 18 about 90 miles due south of Charleston. He wrote "The storm came up rather suddenly." His log affirmed that the suddenness of the storm was virtually coincident with the seaward movement of the meso-Low. There was no evidence of tornadic activity, but the storm continued to intensify over those waters until 1700 EST on the 19th.

Figure 8 shows the *Pandora's* position at approximately 31°40′ N., 79°48′ W., and hourly weather reports interpolated to the half hour to approximate the synoptic conditions coincident with the 1930 EST chart. Significant is the presence of a low pressure system immediately offshore from the Georgia-South Carolina coast line with a strong frontal contrast between the maritime tropical air of the open water and the continental polar air over land.

It is of particular interest to note that the *Pandora's* pressure has already been corrected for a reading .04 inches too low. This correction was easily obtained with

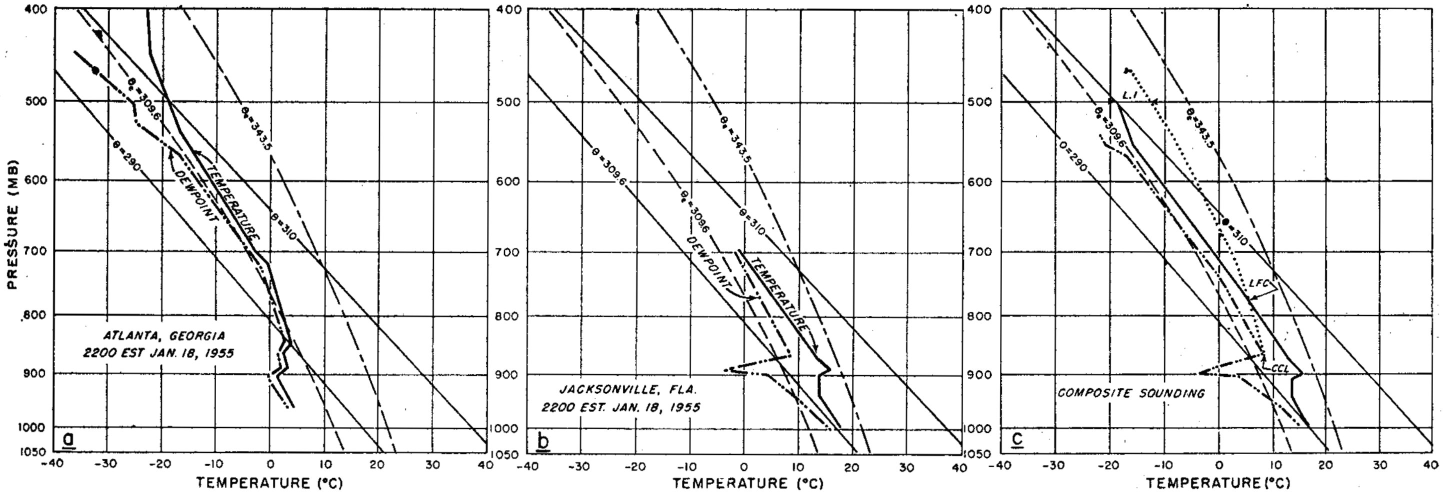

FIGURE 9.—Temperature and dewpoint soundings, 2200 EST, January 18, 1955. (a) Atlanta, Ga. (b) Jacksonville, Fla. (c) Composite of Jacksonville and Atlanta soundings that might result from low-level convergence of the two airmasses.

respect to Charleston, S. C. as the *Pandora* was recording pressure readings as she proceeded underway out of Charleston harbor at noon. This is mentioned here to forestall the objection against too much reliance upon a ship report that appears to be reading too low—the pressure given here is believed to be valid.

Further, the fact that the *Pandora* began penetration southward into a warmer and more moist airmass between 1500 and 1700 EST about 40 to 60 miles south of Charleston, with the wind veering from east-northeast to east-southeast and increasing from force 4 to force 6 on the Beaufort Scale, implied she had crossed into a maritime tropical airmass with a surface wind structure which gave evidence of undergoing cyclonic intensification as early as 1830 EST. This would be 2 hours before the meso-Low moved to sea. Study of figures 5d through 5h reveals that with the knowledge obtained from the ship's report there can be small doubt that there were actually two Lows—the meso-Low which approached the sea from Georgia, and the small Low over the *Pandora's* position 65 miles at sea. One of the most interesting features of this study is the presence of this latter Low at sea, for a close inspection of figures 5f and 5g suggests that the low-level convergence of the meso-Low was further intensified by the fresh inflow of maritime tropical air at the gradient levels from the Low which had been operating over *Pandora's* route.

6. FORECAST IMPLICATIONS

THERMODYNAMIC AND DYNAMIC

Figure 7 indicates rather conclusively that most of the severe weather reported on the 18th was in the vicinity of or north of the successive positions of the meso-Low. The isolated tornado reported near Orlando, Fla. at 2230 EST possibly occurred on the same activity line accompanying our meso-Low to the north, but because of its isolated position, it has no apparent relationship with this Low and consequently is of no concern in this study. However, the question of predictability of the possible tornado at Charleston demands an attempted explanation since it apparently was in connection with the meso-Low.

As stated earlier, the predominant severe weather associated with this meso-Low was that of severe turbulence—with some of it beyond the prior experiences of capable pilots. An analysis of the Jacksonville, Fla. raob data for 1000 EST indicated that several degrees of cooling were necessary at 700 and 500 mb. to produce convective instability of sufficient magnitude for severe storms to occur. An analysis was made of upper-air data for 2200 EST over southern Georgia to obtain insight into the thermodynamic changes that accompanied the severe activity in that corner of the State. Because Charleston's raob was not released until after the severe storm occurrence it was not used in this study, for which the primary need is to obtain a picture of the precedent sounding.

If one accepts the theory that a cold downdraft into a warmer regime is necessary before one can expect a substantial surface gust associated with a thunderstorm [4, 16], then figure 9 indicates that surface temperatures in the lower 50's (such as existed north of the front between Alma and Savannah, Ga. at 1930 EST) would have precluded much surface gust activity in the northern quadrant of the meso-Low unless the Low itself was able to bring a temporary invasion of tropical air from the south (e. g., Jacksonville). For example, a wet-bulb temperature of 0° C. at 750 mb. as depicted at Atlanta would yield a surface temperature of about 12° C., or about 8C.° warmer than the surroundings, if a parcel were to descend from that level moist adiabatically to the surface. Considering, on the other hand, the 0° C. wet-bulb at

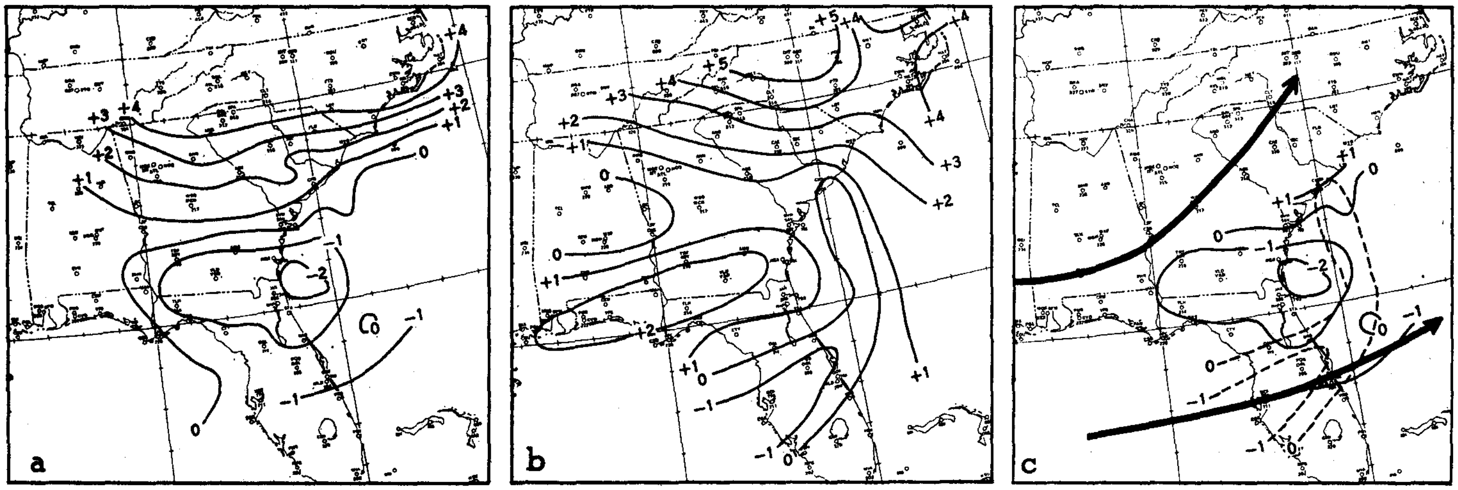

FIGURE 10.—Differences in potential pseudo-wet-bulb temperature between upper level and lower level: (a) 700 mb.–850 mb.; (b) 500 mb.–700 mb.; (c) negative isolines, indicating instability, extracted from (a) (solid) and (b) (dashed); arrows indicate 500-mb. jets.

Jacksonville, the same reasoning would find a descended parcel 3 or 4C.° cooler than its surroundings.

Most of the severe weather of record was turbulence; the lack of reports of damaging winds might be attributed to the above-mentioned downdraft relationship. It is of course quite possible that strong surface gusts did occur but were not reported by the public (perhaps occurring erratically only within the environs of convergence associated with the meso-Low). If the lowest 200-mb. layer of Jacksonville's sounding could be visualized to have been advected by the streamflow to Atlanta and to have ascended due to convergence, then it would have been possible for a parcel to attain a level of free convection at about 770 mb. with a lifted index [7] of -5 at the 500-mb. level. Then also, if a 0° C. wet-bulb at Atlanta had been reduced to the surface along the moist adiabat, the parcel would have been 5C.° cooler than air at the surface; gusts reaching the surface could be anticipated under these circumstances.

With the meso-Low providing a discernable converging and lifting mechanism and with a source of moisture (i. e., increasing convective instability) over the waters south of Charleston, it is entirely possible that the first thunderstorm downdraft could have become imbedded in the deepening Low and could have swept a small area with a damaging wind.

Figure 10 is an attempt to illustrate the three-dimensional distribution of convective instability present prior to the possible tornado occurrence. The chart was initially analyzed as a Theta Prime Chart [9]; i. e., charts of isotherms of potential pseudo-wet-bulb temperature Θ_{sw} for 850, 700, and 500 mb. were drawn (not shown). Next, the convective instability of the stratum between 700 and 850 mb. was determined by subtracting Θ_{sw} of the lower layer from that of the upper, so that the potential instability of an unstable stratum is indicated as a negative value (fig. 10a). Similarly, the potential instability of the 500–700-mb. stratum was determined (fig. 10b). Finally, the vertical distribution of potential instability was pictured by superposing the zero and negative values in the upper stratum on those of the lower stratum (fig. 10c).

The presence of low-level convergence has already been mentioned; divergence above the 500-mb. level was likely present as the two jet axes at that level suggest difluent flow over northern Florida and southeastern Georgia (fig. 10c). Hence, thermodynamically, the air over Charleston immediately prior to the possible tornado occurrence could realize the ample convective instability.

SYNOPTIC

The meso-Low, although of exceedingly small scale, appears to have been originally the point of occlusion of a warm-type occlusion. The cold front aloft was the apparent steering mechanism for movement of the small Low; and the fact that the Low deepened as it moved out over the waters east of Charleston and south of Cape Hatteras while the original Low filled, puts the meso-Low in the classification that George [8] called a "center jump."

Lloyd's [11] proposed tornado model, wherein a tornado could be theorized to form at the apex of intersection of an upper front of maritime polar characteristics with a warm front between the polar and the tropical air is best met by a warm-type occlusion model.

7. CONCLUSION

The objective of this paper was to illustrate that a meso-Low closely associated with severe weather can sometimes be detected and subsequently followed in time and space by a small-scale pressure analysis based on routinely available reports. Use of altimeter settings as a medium for obtaining the small-scale analysis was recommended because of the accuracy of the rate of pressure change obtained by this method, and, most important, because of the increased chance of obtaining a significant pressure change on a special observation when and if the setting is reported.

It is believed that the meso-Low and associated severe weather phenomena were adequately correlated in this study to be of particular significance. It suggests future study to prove or disprove that small-scale analysis of the surface pressure field can, because of its immediate response to convergent and divergent mechanisms within the atmosphere, enable the forecaster to "keep his finger on the pulse" of the most intense storms within a severe storm situation. This would be of most value to the forecaster in the field who is responsible for initiating the first warnings to his public; however, it will be of equal value to the research forecaster, enabling him to "close in" on a more concise model of the severe storm and tornado situation.

The circumstances whereby continuity of pressure perturbations could be followed in this study were somewhat fortuitous to be sure, yet not unique. In several other instances the writer has been able to anticipate or suspect tornado activity by the sudden appearance of small-scale *concentrations* of pressure fall as differentiated from the general falls on the larger (macro) scale in an area of severe weather potential—one indicating the advent of the tornado activity that began predawn in east central Indiana on March 11, 1955. Two cases occurring in 1956 and studied in this manner were highly enlightening. In one case, a study of the southern Missouri and Ohio Valley tornadoes of February 24–25, 1956, the presence of a meso-Low was detected approaching Vichy, Mo., at 2330 EST and moving over Belleville, Ill., in the time and space coincident with several tornadoes near Belleville between 0100 and 0130 EST. In the second case, the afternoon and evening of May 12, 1956, a meso-Low showed up between Lansing and Flint, Mich. at 1930 EST at about the time tornado activity was reported in that area. The relatively narrow band of concentrated pressure falls moving southeastward along the western portion of Lake Erie that evening was favorably associated with the tornado and severe thunderstorm activity reported in the Detroit area at 1845 EST, later at Cleveland, Ohio, and yet later north of Akron, Ohio, and northwest of Pittsburgh, Pa. It appears that this particular meso-Low moved southeastward from the Flint area toward Pittsburgh at a rate of 42 knots.

It should be noted here that many times the meso-Low is *suspect* rather than positively identified when hourly isallobaric minima focus attention upon a small area (perhaps 30 to 50 miles square) where the falls are considerably greater than in the surroundings. It is especially important when such a concentration is continuous and moving in time and space. As suggested earlier, altimeter settings are useful for detecting these pressure falls especially because of the fact that time-continuity can be more accurately positioned with the intermediate special reports than with hourly reports alone.

It is the author's opinion that the meso-Low by its very nature of concentration of local winds (spontaneously assisting in the creation of a low-level jet) can often become the "tornado low" of which Brooks [3] writes and which findings of Tepper and Eggert [15] support—particularly when it is discovered within an area that has been recognized as having a favorable dynamic and thermodynamic environment for severe storm formation [14]. It can also be recognized as an indication of the presence of a dynamic lifting mechanism, particularly when it is being tracked into an area which is becoming laden in the lower levels with warm, moist air moving downstream on a "low-level jet" [1, 12]. The case studied in this paper was essentially of the latter type.

Since the original writing of this paper additional cases have been identified where severe thunderstorm and tornadic activity have been associated with meso-Lows. The only hope to identify these Lows operationally is by impressing upon observational personnel the value to be gained through the addition of such remarks on regular and special observations transmitted on circuit "A" as PRSFR, PRSRR. Since most altimeter settings are taken now with an aneroid barometer it is considered by this writer that the effort expended in adding the altimeter setting to a special observation has merit.

Until all hourly and special weather transmissions include hourly tendency characteristics of pressure and temperature either verbally or coded, mesoanalysis for severe weather will be operationally limited, but still useful on the research level.

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