THE SAINT LOUIS TORNADOES OF FEBRUARY 10, 1959

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INTRODUCTION

A tornado disaster hit the greater St. Louis area shortly after 2 a.m. on February 10, 1959. Most places in the area did not have a tornado, but experienced a thunderstorm with a high wind.

Tornado occurrence at night and in the winter is unusual in the United States. Statistics show that the most likely time for tornadoes is during an afternoon in spring, when the air is thermally unstable from surface heating while the upper air is still cold.

The purpose of this paper is to present a model of the development of those tornadoes which are not directly caused by surface heating.

CASUALTIES AND PROPERTY DAMAGE

The tornado death toll in midtown St. Louis was 21. Fortunately, the number of fatalities was small compared to the 79 and 306 deaths in the St. Louis tornadoes of September 29, 1927 and May 27, 1896, respectively. The small loss of life in the 1959 storm was due not only to its lesser intensity, but also to its occurrence at night, when most of the residents were in the comparative safety of their beds instead of on the streets, where they would have had a greater chance of being killed by flying debris. However, 12 people lost their lives in a brick house which collapsed as its heavy roof fell into the basement.

Tornado damage to property on the morning of February 10, 1959 was estimated at $12,000,000 in the St. Louis area. A television tower just south of Forest Park (Fig. 1), built to withstand winds of 125 mi./hr. broke off at about 1/3 of its height and crashed on some apartment houses. An eyewitness observed almost a calm 50 yards north of the tornado center in Brentwood (8 miles WSW of downtown St. Louis). This suggests a rotation of approximately 60 mi./hr. north of the center to cancel the 60 mi./hr. translation current (see below) and suggests the sum of 120 mi./hr., 50 yards south of the center. Winds even stronger than that must have occurred nearer the center. Maximum wind damage near the tops of most buildings supports the theory that windspeed increased rapidly with height. Damage was caused not only by the dynamic pressure of the wind, but also by the static pressure drop. Explosive-type damage from the outside pressure drop is most common on walls and roofs facing the north or northeast because there is not enough wind on this side to hold these surfaces in place (on the lee side in the predominantly southwest wind of a tornado). The north end of the oval roof of the Arena, also located just south of Forest Park, was exploded by unrelieved internal pressure. This type of damage could be minimized if north walls were vented to allow the air to rush out and keep the pressure difference across the surfaces from getting large enough to cause structural failure.

PERIODICITY IN TORNADO OCCURRENCES

It it interesting to note that the 3 major tornado situations in St. Louis were separated by the same time interval of 31 years and 4 months, which is approximately equal to 3 sunspot cycles (averaging about 11 years each). This equal timing between tornadoes may not be entirely a coincidence because the 3 storms occurred near years of sunspot maxima: 1958, 1928, and 1893. Figure 2 from a previous study (Brooks, 1958, pp. 7-8) shows the correlation coefficients between relative sunspot numbers and numbers of tornado days (1916-1950) in individual states. Near the times of sunspot maxima, tornado frequencies were higher than normal in the belt of states extending from Oklahoma to Pennsylvania. This is verified by tornado statistics for the St. Louis area, which lies in the middle of this tornado belt. For example, Bunker Hill and Wood River, Illinois, experienced severe tornadoes in March, 1948 and May, 1949, respectively (sunspot maximum in 1947), and St. Charles, Missouri and Bunker Hill both had tornadoes in March, 1938 (sunspot maximum in 1937). The tornado belt near the time of sunspot maximum was farther south than that at sunspot minimum (Iowa to Michigan with negative correlation coefficients). Apparently, the tornado belt was near the mean jet stream, which was presumably farther south at sunspot maximum. This was probably due to more outbreaks of polar air from Canada, indicated by cooler and wetter weather than normal in St. Louis at sunspot maximum.

LARGE-SCALE WEATHER PATTERN

Three years before February, 1959, a major tornado moved from south St. Louis County to Summerfield, Illinois before 1 a.m. on February 25, 1956. It was called the "Route 50 tornado" because its path was nearly along U. S. Highway 50, including By-Pass 50 around the south side of St. Louis (Stinson, 1957). The public might have dismissed this tornado as a freak because of its occurrence during a winter night. When there was a repeat performance on the winter night of February 10, 1959, it could hardly be labeled another freak. Instead, there is a need to recognize a common denominator to weather patterns favorable for the development of winter tornadoes.

These tornadoes could not have been caused directly by solar heating. The required thermal instability must have resulted from a dynamic cause related to the overall field of motion. The surface weather maps for these two tornado situations were found to be so similar that they represented the same type of large-scale weather pattern. At the surface, polar continental air occupied the northern United States and tropical maritime air covered the southeastern states. Between these two contrasting air masses, a well-defined quasi-stationary front was oriented generally WSW-ENE through Missouri and Illinois. A small low pressure area was moving rapidly eastward along the front. At the same time, the front was approaching St. Louis from the north as a cold front, but the front became stationary in the St. Louis area about an hour before the low pressure area arrived there. The tornadoes occurred with thunderstorms near the low pressure center, as in the case of the tremendously destructive Tri-State (Missouri - Illinois-Indiana) tornado of March 18, 1925. Low-level convergence of maritime tropical air into the cyclonic circulation of the low pressure area released the potential instability of the air in small but violent updrafts as tornadoes. The great acceleration of the air was caused by the pressure gradient and could be represented by the approximate conservation of angular momentum in the inflow. A rapidly falling barometer near a strong stationary front suggests the approach of a fast-moving low pressure area. If tornadoes are expected with this low, the general location of the tornado tracks might be predicted about an hour ahead of time to be the location of the stationary front.

In the February, 1956 case, the low pressure area was traced on weather maps all the way from Colorado to the St. Louis area. It produced severe windstorms as it went straight eastward across Missouri. The cold front was moving slowly southward across St. Louis in the evening of February 24, 1956 before the low pressure center arrived. The front passed the St. Louis Airport (13 miles northwest of downtown St. Louis) at about 10 p.m. and reached downtown about 11 p.m. It then stalled in southern St. Louis County (10 miles southwest of downtown) after midnight, less than an hour before the tornado in the same place.

In the February, 1959 situation, the low pressure area came from Oklahoma and followed a course to the east northeast. The cold front reached northern Missouri on February 8, two days before the disaster. In St. Louis there was modified polar air at the surface, separated from maritime tropical air aloft and to the south by a poorly defined warm front. Light rain from this front moistened the polar air as the rain partially evaporated. A thin fog formed at 5 p.m., then thickened after sunset. The next day (February 9) was mild and rainy with a persistent low ceiling in St. Louis, which remained in the modified polar air between the two approaching fronts. Tornadoes broke out in and near Joplin in southwestern Missouri that morning. From 8 to 11 p.m. thunderstorms with heavy rain swept over St. Louis, followed by partially clearing skies. At midnight (February 9-10), a tornado was reported near Jefferson City, Missouri. The cold front passed the St. Louis Airport at the same time, causing the surface temperature to drop from 55°F to 47°F. In downtown St. Louis, however, the temperature remained 58°F until after 2 a. m., when the cold front and the low pressure area arrived together. This was a low temperature for a tornado occurrence. A previous case of a tornado with temperatures in the 50's occurred in the St. Louis area on March 18, 1952, when there were two polar air masses separated by an occluded front. In the 1959 case, tornadoes formed in the maritime tropical air above the shallow polar air at the ground, then penetrated the weak warm front to reach the ground. The same thing happened just before midnight on May

1, 1948 in South St. Louis, where tornadoes occurred north of a warm front.

INDIVIDUAL TORNADOES

On February 10, 1959 severe tornado damage occurred in Brentwood, Missouri and in midtown St. Louis. The path of damage between these points at first seemed to be explicable by one tornado. However, a more careful survey showed that the damage was not continuous in Forest Park, where parallel paths of tree damage were found ⅜ mile apart. The southern track formed the terminus of the Brentwood tornado, whereas the northern track marked the beginning of another tornado, the one which hit midtown St. Louis.

This particular behavior of tornado dissipation and formation apparently duplicated the events of September 29, 1927, the date of the last major St. Louis tornado prior to 1959. Some 1927 maps show just one tornado path generally from southwest to northeast except for a pronounced jog to the left (from southeast to northwest) in Forest Park. Such a large deviation of a tornado path from a straight line is not likely to occur. A more reasonable interpretation of the damage is that it was caused by two tornadoes. Apparently, one tornado moved along a path just south of the 1959 Brentwood tornado, and a second 1927 tornado touched the ground in Forest Park and followed the same path as the 1959 midtown tornado, damaging many of the same buildings.

Forest Park with its open fields appears to be favorable for a tornado to dip down to the ground. However, two cases cannot be considered statistically significant. The Forest Park tornadoes must have developed from vortices aloft which formed west of Forest Park independent of the park's effect. Surface tornadoes seem to begin most frequently in river valleys, where the flat surfaces offer reduced wind friction and where the rivers moisten the air by evaporating water into it. This was well illustrated by the 1948 tornadoes near St. Louis.

A total of 5 distinct but intermittent tornado tracks were found in the St. Louis area for the February 10, 1959 storm. Of these, 2 appeared to have been generated first in the Meramec River Valley, 1 in Forest Park, 1 in the Mississippi Valley, and 1 in the Missouri Valley (Fig. 1). The Missouri Valley tornado dipped down in Florissant, about 10 miles north of the first 4 tornadoes, which moved along portions of parallel lines less than 2 miles apart. Two of these tornadoes first appeared 1 mile northwest and 1 mile southeast of Eureka, Missouri, near the Meramec River at 2:05 a.m. The first tornado traveled 20 miles to Forest Park in St. Louis in the next 20 minutes, or at an average translation speed of 60 mi./hr.; the second tornado hit only a few spots, at which the most damage was to a cotton mill in Valley Park, Missouri (Fig. 1). The other 2 tornadoes hit on both the south and north sides of Granite City, Illinois and the southeastern part of Edwardsville, Illinois.

The multiplicity of tornadoes suggests the presence of localized areas of horizontal convergence into several updrafts. Non-uniformity of convection was verified by irregular microbarograph traces. Tornadoes appeared successively slightly farther north, indicating that a tornado-generating mechanism aloft was moving more from the south than the surface tornadoes themselves. The counterclockwise turning of the wind with increasing height was consistent with the cold air advection associated with the cold front.

RELATION OF THE TORNADOES TO SMALL-SCALE WEATHER

The WSR-1 radar of the U. S. Weather Bureau at the St. Louis Airport was operating during the tornadoes of February 10, 1959. At 1:49 a.m., it was reported that the PPI scope showed a hook-shaped echo located over St. Albans, Missouri on the Missouri River (Fig. 1). Hooks have been observed by radar in connection with other tornadoes, such as the eastern Illinois tornado of April 9, 1953, the first well documented case of a hooked radar echo with a tornado (Huff, Hiser, and Bigler, 1954). The hook is not due to the tornado itself, but is an echo from a precipitating cloud in a larger cyclonic circulation, called the "tornado cyclone" (Brooks, 1949), smaller than the usual "low" on a weather map, but some 5 to 10 miles in radius. The March 19, 1948 tornadoes in St. Louis County were found to be inside a tornado cyclone.

By 2:03 a.m. on February 10, 1959 the hook-shaped echo on the radar scope seemed to have faded, apparently because it was hidden by intervening heavy rain. The hook was 6 miles south-southwest of this shower, which was west-southwest of the Airport radar. Most cases of hooked echoes appear southwest to south of the parent thundershower. If the radar were installed southwest instead of northwest of a large city, it should be able to follow a hooked echo to its north without losing it behind its associated heavy shower and thus it might offer greater protection to the city against a tornado. In this particular case, the hook was related to the northern tornado, which hit Florissant at 2:14 a.m., at least 11 minutes after the hooked echo was lost. No hook was noted in connection with the other four tornadoes.

A pressure trace was recorded on an accelerated microbarograph only a block south of the severe midtown St. Louis tornado just west of the Mississippi River and 2 miles north of downtown St. Louis. The microbarograph was located at the Mallinckrodt Chemical Works in a closed room on an upper floor of the administration building. This structure was not damaged, but a building one block south lost the upper part of its brick wall on the south side. After a gradual pressure drop to a pressure minimum, there was a sudden pressure rise recorded at all the microbarograph stations in the St. Louis area. The pressure rose 0.12″ Hg (4 mb) in 2 minutes at the St. Louis Airport. At the Mallinckrodt Chemical Works the pressure rose only 0.05″ Hg (2 mb) after the first pressure minimum. Four minutes later the tornado struck. The microbarograph registered a sudden pressure drop of 0.08″ (3 mb) and a rise of 0.13″ (4 mb) immediately, then edged downward 0.02″ (1 mb) before leveling off. The net change in pressure from the first pressure minimum was +0.08″ (3 mb). A similar case of a tornado just behind a pressure minimum was observed 4 miles south of the St. Louis

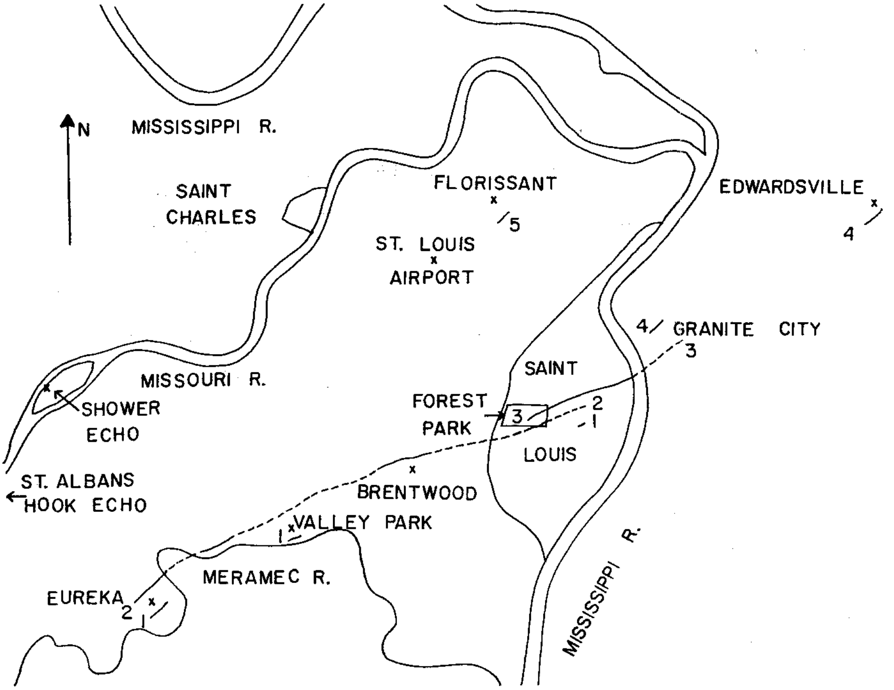

Fig. 1.—Paths of tornadoes, February 10, 1959.

Airport on March 31, 1952, when a minor tornado caused a small pressure dip 3 minutes after a larger pressure rise.

Model for Tornado Development

In severe weather situations, tornadoes have been found to be closely associated with other features, such as a front, a tornado cyclone, and a thunderstorm. Although these features have been described separately, there is a need for a model which will tie them together in a reasonable mutual relationship. An attempt to derive such a model led to the hypothetical one shown in Figure 3. A typical sequence of events leading up to this model might be as follows.

Suppose a NE-SW cold front is advancing southeastward across the Midwest. If the cold front is moving slowly, a surface wave cyclone may develop on it. Ahead of the new disturbance, the cold front becomes stationary as the winds in the cold air turn clockwise until they are blowing parallel to the front. The frontal convergence and lifting of the maritime tropical air, which is usually potentially unstable, creates an irregular line of thunderstorms along the stationary surface front. The major thunderstorm cells are marked by localized high pressure, from which rain-cooled air diverges. Most of these frontal thunderstorms

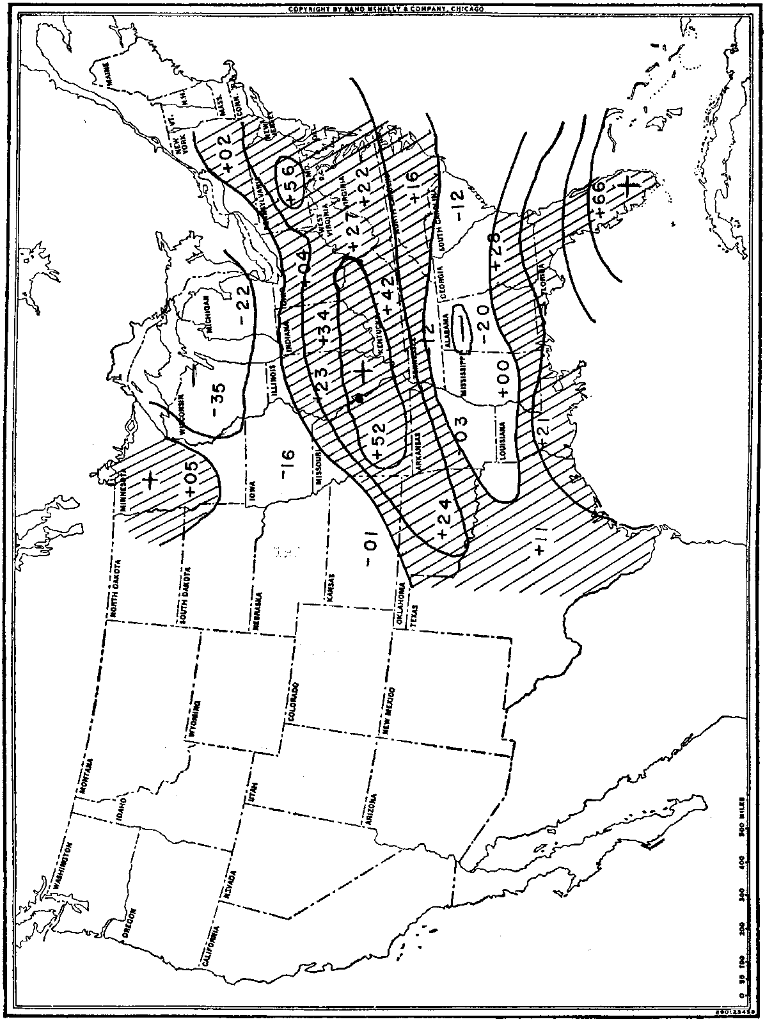

Fig. 2.—Correlation coefficients between relative sunspot numbers and number of tornado days in each state (both numbers annual for 1916-1950, incl.).

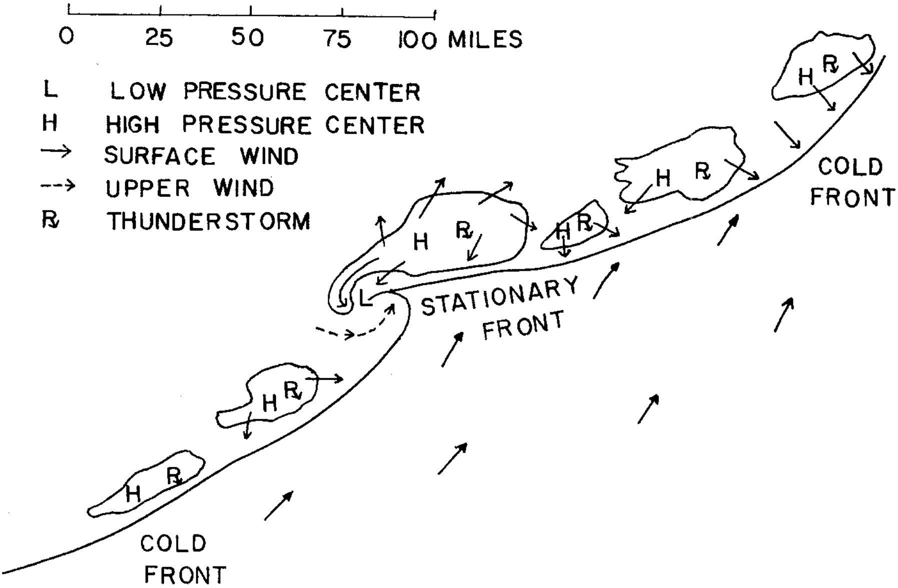

Fig. 3.—Model for tornado development.

are not accompanied by tornadoes because the warm-sector winds generally blow without cyclonic turning.

A different situation applies to the thunderstorms close to or within the wave cyclone. On the south side of the low, the warm air curves cyclonically, aided by vertical stretching as it descends off the cold front southwest of the low center. The horizontal convergence of the surface air is supplemented by surface friction and by an isallobaric wind component toward the region of negative pressure tendencies, particularly if the wave cyclone is deepening. By the approximate conservation of angular momentum, the winds of the warm air mass increase rapidly toward centers of localized convergence. These centers are located on the southwest sides of thunderstorm cells because the warm surface air, cutting across the isobars, runs into the thunderstorm cells as they move more from WSW to ENE, parallel to the isobars above the friction layer. In other words, as the warm surface air motion with respect to the thunderstorms is from the south, the south sides of the thunderstorms experience the horizontal convergence. The strong updrafts of the the warm moist air there feed the thunderstorm cells and create localized low pressure areas, or tornado cyclones there. It is within these tornado cyclones that the individual tornadoes develop and trail along behind the thunderstorm centers by as much as 15 to 20 minutes sometimes. These tornadoes extend their action to the ground when they pass over topographical regions favorable for tornado intensification, such as river valleys. The St. Louis tornadoes in February of both 1956 and 1959 appear to fit into this model of tornado formation.

Tornadoes in the southwest portions of thunderstorms have been noted when the thunderstorms travel in other directions, provided that the warm moist air is being brought into the thunderstorms from the southwest faster than the storms are moving. Tornadoes have also been observed in the southwest portions of non-frontal thunderstorms, located in pressure troughs with cyclonic flow.

Not all tornadoes occur in the southwest portions of their associated thunderstorms. In the case of a rapidly moving squall line, the microcold front from the thunderstorms converges with the maritime tropical air to the east. As soon as the warm air is lifted, its potential instability is released and a tornado may occur at the ground within 10 minutes after the forward edge of the squall line passes. In this case, where the tornadoes precede the thunderstorm, the lifting mechanism is moving much faster than the warm surface air, which is therefore unable to overtake from the southwest the squall-line thunderstorms. The wake low behind the thunderstorm is characterized by a downdraft with clearing sky and by cooled surface air, conditions unfavorable for tornadoes.

SUMMARY

Shortly after 2 a.m., February 10, 1959, tornadoes struck the St. Louis area, killing 21 people, and causing about $12,000,000 property damage due to winds over 125 mi./hr. and sudden pressure drops. The major St. Louis tornadoes of May 27, 1896, September 29, 1927, and February 10, 1959 occurred at intervals of 31 years and 4 months, about 3 sunspot cycles apart, near maximum-sunspot years.

The large-scale weather pattern of February 10, 1959 was similar to that of February 25, 1956, when a major tornado struck south Saint Louis County. These nocturnal winter tornadoes were not produced by surface heating, but by strong dynamical action in low pressure areas moving rapidly eastward along stationary fronts. The 1959 tornadoes struck in spite of the fact that there was a modified polar air mass with a temperature of only 58°F. at the surface.

Five February 10, 1959 tornadoes apparently developed or touched down in the Meramec, Mississippi, and Missouri River valleys and in Forest Park. Four of these tornadoes appeared to be generated within the same tornado cyclone and occurred successively on parallel paths, each farther north than its predecessor. A microbarogram record one block south of the midtown St. Louis tornado showed a pressure minimum 4 minutes before the tornado pressure dip.

Another tornado cyclone, associated with the Missouri River tornado, was indicated on the U. S. Weather Bureau radar at the St. Louis Airport by a hook-shaped echo 6 miles SSW of a shower.

A model of tornado development, proposed to explain the February,

1956 and February, 1959 tornadoes in St. Louis, consists of tornadoes within tornado cyclones in the southwest portions of thunderstorm cells located near the center of a wave cyclone on a stationary front. The tornadoes develop in cyclonically curving maritime tropical air, whose potential instability is released by frictional and isallobaric convergence and lifting as the warm air overtakes the frontal thunderstorms on their southwest sides.

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