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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service

USE OF DETAILED RADAR INTENSITY DATA IN MESOSCALE SURFACE ANALYSIS

Robert E. Hamilton

Eastern Region
Garden City, N.Y.
March 1971

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UNITED STATES DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATOMOSPHERIC ADMINISTRATION
U.S. NATIONAL WEATHER SERVICE EASTERN REGION
Garden City, New York

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Robert E. Hamilton
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Scientific Services Division
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INTRODUCTION

The local weather watch, especially for hazardous weather, can be greatly improved by better utilization of radar information. Up until the past year or two only radar stations, particularly WSR-57 radar stations, had the necessary detailed radar information to prepare a mesoscale analysis utilizing radar data. With the implementation of Weather Bureau Radar Remote (WBRR-68) equipment, hard copy radar data is being made available to many other Weather Service Offices. The remote facsimile radar depiction also includes geographic information and weather reporting station circles which provides an excellent chart on which to plot surface data for a small area. The analyst can then utilize both the radar data and the synoptic data in a mesoscale analysis.

In many instances, it is only necessary to plot 4 or 5 stations surrounding and within the precipitation pattern. Station pressure or altimeter settings can be used if an isobaric analysis is desired. Winds can be plotted and may be the only parameter needed for locating a trough or areas of convergence, especially in the summer months when fronts are weak or non-existent. Surface dry bulb and dew point temperatures may also be utilized when trying to locate fronts more precisely; areas of freezing rain, sleet or snow; or areas of maximum surface moisture.

JULY 4 CASE STUDY

A case study of a storm on July 4 is used to illustrate the technique of combining radar and mesoscale pressure analysis. The area of analysis in this study is much greater than what is normally needed or recommended for local use and is presented only to illustrate the larger synoptic pattern. A very detailed radar data analysis is combined with the surface pressure field to reveal small-scale Low and High pressure centers and a significant squall line with Line Echo Wave Patterns (LEWP). These small-scale features are usually difficult to discern from the regular or small-scale analysis and in this case only through the use of detailed radar intensity data are the intricate pressure patterns recognizable. Service A data were used in the preparation of the mesoscale pressure analysis but for clarity all data and station location information except those indicated in the text were left off the figures.

SYNOPTIC SITUATION

The synoptic situation on the morning of July 4, 1969, revealed a macro-scale low pressure center in northern Iowa. At 1200Z a warm front extended eastward just north of Milwaukee, Wisconsin, to Muskegan, Michigan, then southeastward into the northwest corner of Ohio and on toward Wheeling, West Virginia. Thundershowers were occurring along the front through Wisconsin, Michigan, Illinois, and Indiana. (See Figure 1).

The surface front through Ohio was rather weak and not well defined with little difference in surface temperatures across the front. Surface dew-points were very high with mid-60's most common. The most unstable air, with a lifted index of -8, was centered over west central Illinois, but a low level jet was advecting this air east-northeastward toward Ohio.

The 700 mb. wind field, which is usually a good indicator of the direction and speed that most light to moderate intensity radar echoes move, was from the west to southwest in Michigan and Indiana, but veered to the northwest through eastern Ohio. As expected, echoes did move toward the east or northeast as they approached Ohio, then turned toward the southeast as they passed through eastern Ohio. The larger and stronger echoes with tops into the upper troposphere and lower stratosphere would be expected to deviate to the right of the 700 mb. wind in a more southerly direction. The higher level winds over Ohio were also from the northwest with the jet stream just east of Ohio from Sault St. Marie, Michigan, to near Buffalo, New York.

During the day, as the surface Low moved northeastward across Lake Michigan to southern Ontario, Canada, thunderstorms developed through Michigan and moved eastward into northern Ohio. Severe activity was reported in Michigan during the afternoon as echo tops reached 50,000 feet and above. Radar data for this study were obtained from intensity contoured overlays prepared hourly at the Pittsburgh, National Weather Service WSR-57 radar station. The intensity contours are traced from the PPI scope onto overlays each hour. The Sensitivity Time Control (STC) feature was used to reduce the differences in echo intensities resulting from range. The STC partially range normalizes all echoes between 10 and 125 n.m. of the radar. To delineate the moderate and strong intensity levels, withing 125 n.m., attenuation values of 21 and 36 decibels were inserted. Standard Weather Service radar calibration procedures and Rainfall Rate - Echo Intensity Graph statistics are provided in references 1 and 2. A summary of reflectivity and rainfall values for each intensity level is provided in the following table.

Radar Echo Intensity (within 125 n.m.)	Depiction	Theoretical Radar Rainfall Rate in/hr	Reflectivity (Z) mm^6/m^3
1. Very Weak - Weak	Stippled	0.01 to 0.09	$5x10^0$ - $9x10^2$
2. Moderate	Hatched	0.10 to 0.99	$9x10^2$ - $4x10^4$
3. Strong	Solid	1.00 to 5.00	$4x10^4$ - $5x10^5$

Quantitative intensity measurements are made only to a range of 125 n.m. of the Pittsburgh radar which includes the eastern half of Ohio northward to the center of Lake Erie, western Pennsylvania, northern West Virginia and the southwest corner of New York. All hatched or solid depicted echoes on figures 2,3,4,6,8 and 9, beyond 125 n.m. simply indicate cells of relatively stronger intensity than surrounding areas of lower intensity levels.

RADAR AND MESOSCALE ANALYSIS

By 2200Z, thunderstorm activity was occurring in Michigan, northeastern Ohio, northwestern Pennsylvania, and southwestern New York. A Meso-Low is depicted over the western end of Lake Erie on the 1 mb. interval small-scale analysis in Figure 2. The radar activity in southern Michigan was strong in intensity although the true intensity cannot be determined from the intensity contours due to a range greater than 125 n.m. from the Pittsburgh radar. At 2200Z a tornado was reported 29 n.m. south-southwest of Jackson, Michigan. The tornado was associated with the westernmost echo depicted.

After development of the Meso-Low, the activity increased in intensity as can be seen by the change in intensity levels from the 2145Z to 2245Z radar data. In Figure 3, the Meso-Low over western Lake Erie has become more elongated in an east west direction and the radar activity is becoming organized into a line oriented along and just north of the axis of the Low. A second tornado was reported 15 n.m. west southwest of Detroit, Michigan at 2223Z and 1 3/4 inch hail occurred in Detroit at 2230Z. The echo producing this severe weather is located over Detroit at 2245Z. Four stronger category echoes delineate a developing squall line embedded in a larger area of precipitation that extends from southern Michigan into Ontario, Canada, and northwestern Lake Erie.

The four echoes are beyond 125 n.m.; however, their strong relative intensity at this range indicates unusually intense storms. Tops were 50,000 to 55,000 feet with the tropopause near 51,000, another indication of the severity of the storms. As the line moved southward, gusts to 92 knots 5 n.m. east of Toledo, Ohio at 2311Z and gusts to 52 knots 23 n.m. east southeast of Toledo at 2335Z were reported. A ship on Lake Erie reported gusts to 90 knots associated with the squall line.

By 2345Z, Figure 4, the severe squall line began to show a shape and movement that is usually associated with LEWP developments. Two wave crests on the line were identified, one located 40 n.m. north northwest of Youngstown, Ohio, the second 30 n.m. northwest of Youngstown. Possibly, a third wave crest is located 30 n.m. northwest of Cleveland. A review of the 35 mm time lapse film in which intermediate levels of intensity were checked, clearly depicted the line as solid and continuous.

The shape of the squall line is one of the first indications in this case that mesoscale features existed. The concave shape or bulge southeastward is related to a Meso-High moving rapidly to the south. Wave crests, however, moved east southeastward traveling along the line. The crest is associated with a Meso-Low which was verified by cyclonic circulation of echoes when viewed on the 35 mm time lapse film. The intense gradient caused by the mesoscale pressure patterns probably caused the reported wind of 90 knots on Lake Erie. It should also be noted that the western end of the squall line moved very little during the hour, but individual thunderstorms moved to the east southeast at 45 knots. The rapid movement of the line over north central Ohio combined with little movement in southern Michigan is another indication of a development of the bubble-High over Lake Erie. As the bubble increased in strength, the single Meso-Low that had been located over the western end of Lake Erie at 2245Z moved east south-eastward and probably split up into smaller centers located at the wave crests described in Figure 4. It should be pointed out that the subsynoptic analysis in Figure 4 is based mainly on radar data, especially echo intensity, shape and movement, since the squall line and mesoscale pressure patterns were either between surface reporting stations or over Lake Erie.

A tornado occurred 35 n.m. north northwest of Youngstown at 2342Z about the time of Figure 4. This was associated with the easternmost LEWP crest (Meso-Low). A second tornado was reported around 0000Z, 25 n.m. northwest of Youngstown. Wind damage was reported in the city of Cleveland around 0000Z and 0004Z.

A combined radar pattern and mesoscale pressure analysis is very important to forecasters and briefers since the NMC macro-scale analysis is not intended to depict the very small-scale pressure and precipitation patterns. By comparing the 0000Z NMC analysis, (Figure 5) with the 0000Z mesoscale analysis, Figure 4, the advisability of preparing a small-scale analysis utilizing radar data is readily apparent. By 0045Z, Figure 6, the section of the severe squall line associated with the meso-High -Low couplets had continued its rapid movement southeastward at 50 knots through Cleveland and caused widespread wind damage and heavy rains. The barograph at Cleveland indicated a sharp drop in pressure as the line approached and then an abrupt and very large rise in pressure which accompanied the strong winds. The LEWP crests moved east to east southeastward at 35 to 40 knots. Numerous reports of funnel clouds and wind damage occurred along the line between 0030Z and 0113Z. The well-defined LEWP to the northwest of Akron, Ohio is also shown in Figure 7 by the spectacular photograph taken of the Decca radar at Akron, Ohio, by Mr. G. Vaughn. The Decca 3-cm radar, with different characteristics than the WSR-57 10-cm radar, was depicting only the stronger echoes in the line. Note how sharp the crest is in the photograph.

At 0045Z, the western end of the squall line was still moving very slowly southward. This slow movement and continuous rainfall resulted in a moist boundary zone being established over northern Ohio. Strong low level convergence into the moist air resulted in numerous strong storms with tops to 50,000 feet. The maximum top reported along the squall line was 62,000 feet, 11,000 feet higher than the tropopause and was associated with the LEWP pictured in Figures 6 and 7.

During the next hour, the eastern end of the squall line continued its rapid movement southeastward at 55 knots while the western end moved very little (Figure 8, 0145Z radar overlay). The Meso-High became the dominant feature with no indication of Meso-Lows or LEWP's. It is interesting that when the squall line lost the wave configuration no other reports of tornadoes, funnel clouds or hail were received. However, several reports of strong winds were associated with the fast moving bubble-High. The leading edge of the bubble-High and wind gust line had moved 20 to 30 miles ahead of the squall line and was clearly the dominant surface pressure feature.

The 0245Z radar data and 0300Z surface analysis, figure 9, indicated the bubble High was continuing to increase in central pressure. Additional reports of strong winds and hail along the squall line were received but remained below severe limits. Activity began to increase in intensity in northwestern Ohio. The moist boundary zone became oriented northwest-southeast from near Toledo to Wheeling, West Virginia. This area of radar activity moved very little during the remainder of the night, with heavy storms moving through the area producing very heavy rainfall amounts of 10 to 11 inches in northeastern Ohio. Severe flooding resulted from the storm.

CONCLUSION

By utilizing detailed radar intensity information in the preparation of a subsynoptic analysis, mesoscale pressure features such as Meso-Highs and Lows, a squall line, LEWP's and cells of intense rainfall rates were identified and related to severe weather reports. The location and movement of these features are essential in the preparation of warnings and flash flood statements. At present, one of the best tools available for detecting these mesoscale features is the radar. The distance between surface reporting stations limits the forecaster's ability to define small-scale weather producing features without the use of radar.

Special radar features that may indicate mesoscale pressure patterns are: (1) organized lines with a bulge or concave shape (the echoes on the bulge will move faster than the end points and a pressure check tendency or pressure falling rapidly followed by pressure rising rapidly will occur at the station over which the concave line passes), (2) wave formation on an echo line, LEWP, and (3) echoes moving in a circular motion or rotating about some point. This last feature is easier to detect when viewing time lapse film or from a video replay system.

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(1) Weather Radar Manual (WBAN), U. S. Weather Bureau, Superintendent of Documents, U. S. Government Printing Office Washington, D. C. 20402; August 1967.

(2) Procedures for Standardization of WSR-57 Radar Performance and Echo Intensity Measurements, U. S. Weather Bureau Multiple Address Letter No. 58-62, November 27, 1962, 8 pp.

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(6) Donaldson, R.J., Jr., "Methods for Identifying Severe Thunderstorms by Radar", Bulletin of the American Meteorological Society, Vol. 46, No. 4, April 1965, pp. 174-193.

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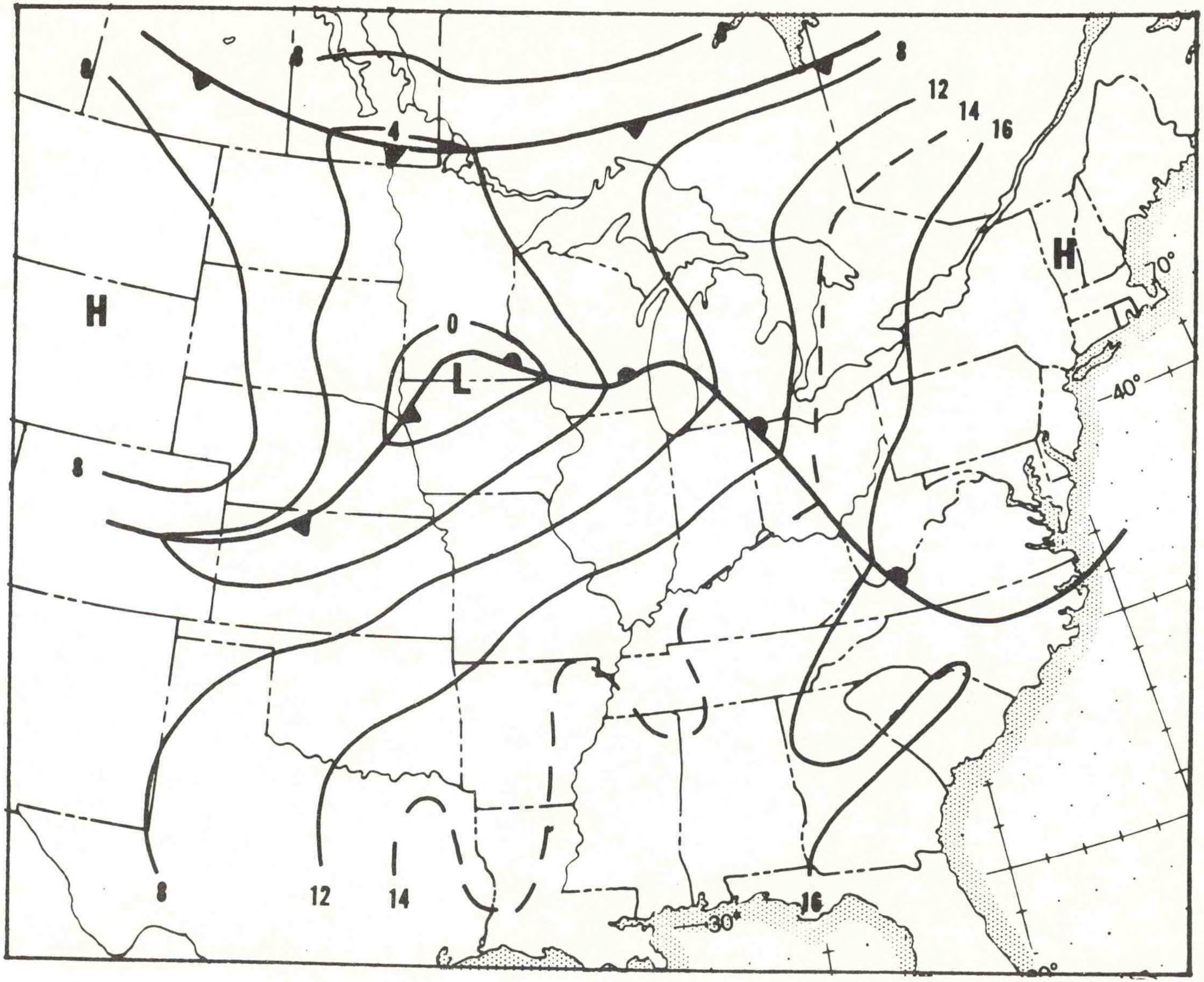

FIGURE 1. NMC surface analysis for 1200Z, July 4, 1969. Isobars are labelled in whole millibars with hundreds omitted.

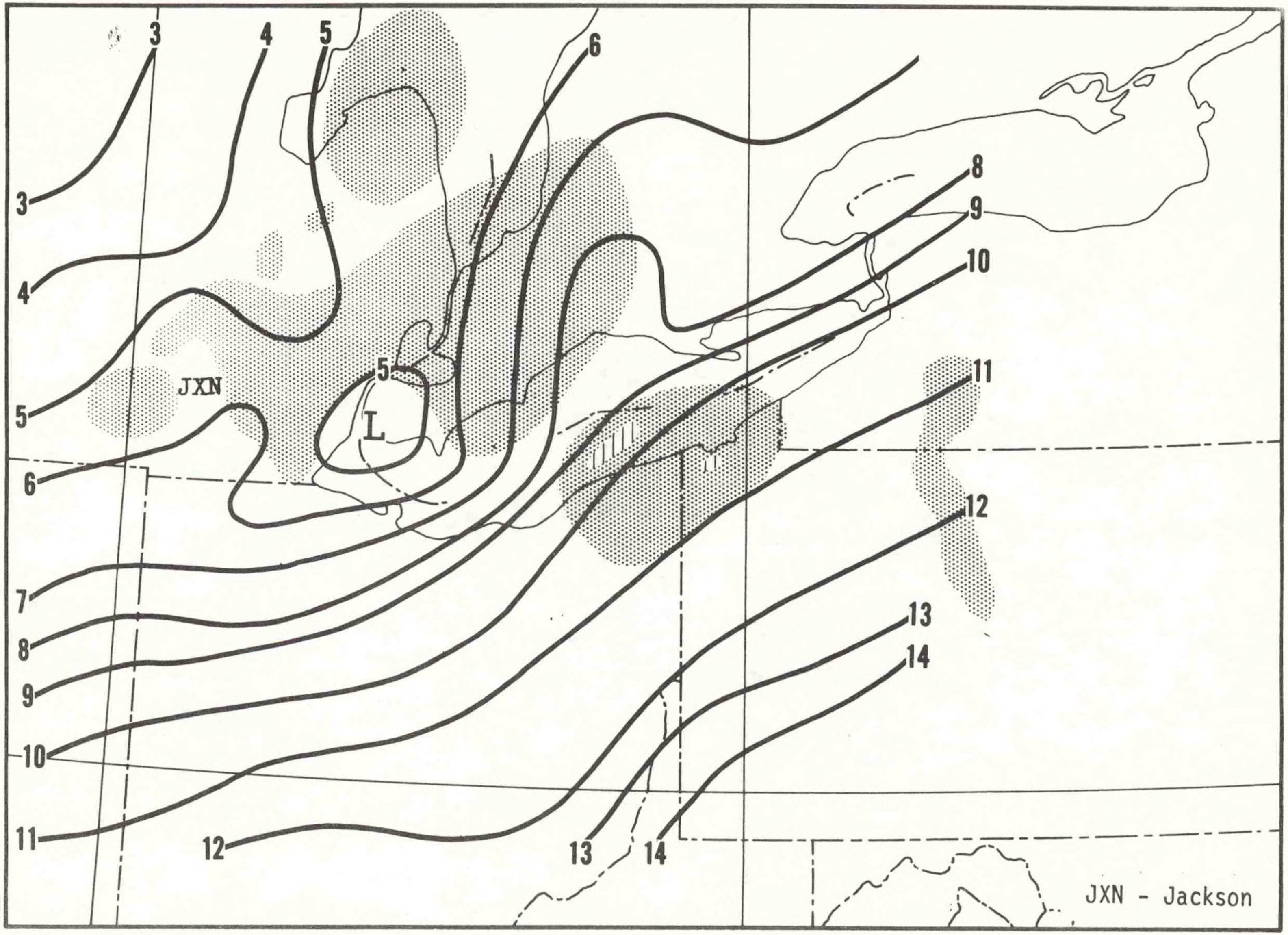

FIGURE 2. Mesoscale analysis - surface isobars (solid lines, labelled in whole millibars with hundred omitted) for 2200Z, July 4, 1969. Shading is Pittsburgh, Pa., WSR-57 (10 cm. wave length) radar data for 2145Z. Intensity of radar return is indicated as follows: Stippled - very weak and weak, Hatched - moderate, Solid - strong. See text for further information.

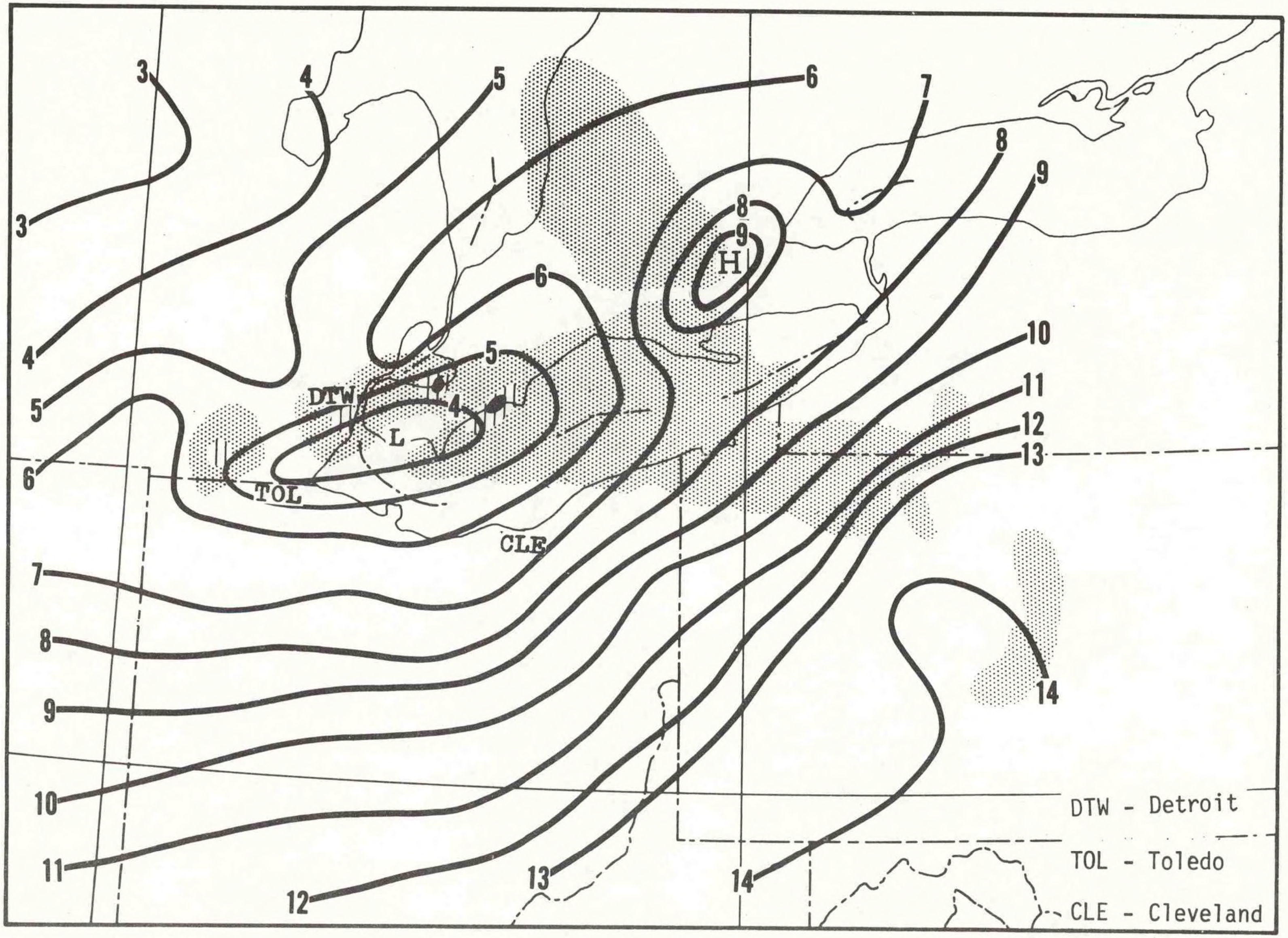

FIGURE 3. Mesoscale analysis - surface isobars (solid lines, labelled in whole millibars with hundreds omitted) for 2300Z, July 4, 1969. Shading is Pittsburgh, Pa., WSR-57 (10 cm. wave length) radar data for 2245Z. Intensity of radar returns is indicated as follows: Stippled - very weak and weak, Hatched - moderate, Solid - strong.

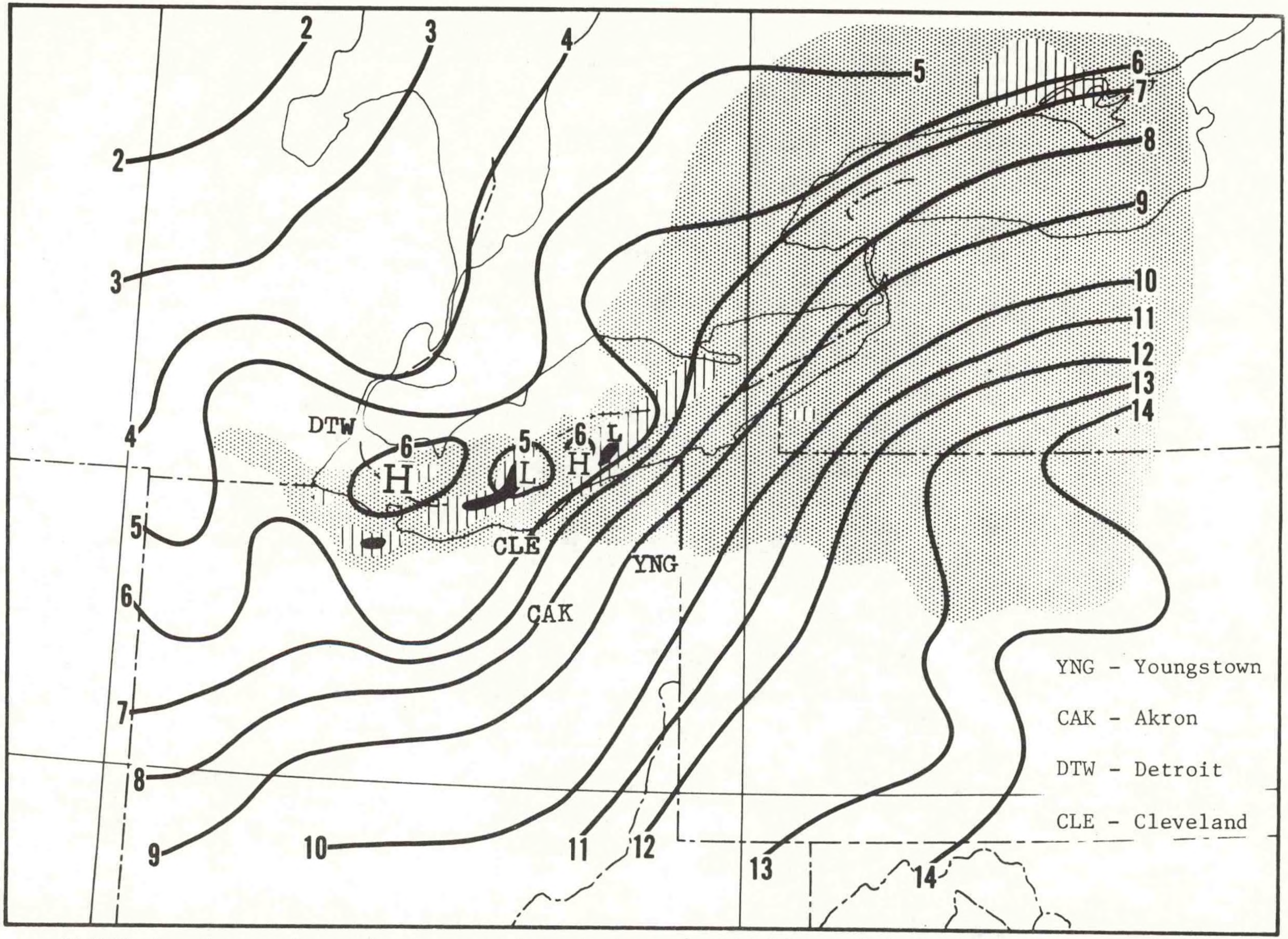

FIGURE 4. Mesoscale analysis - surface isobars (solid lines, labelled in whole millibars with hundreds omitted) for 0000Z, July 5, 1969. Shading is Pittsburgh, Pa., WSR-57 (10 cm. wave length) radar data for 2345Z. Intensity of radar return is indicated as follows: Stippled - very weak and weak, Hatched - moderate, Solid - strong.

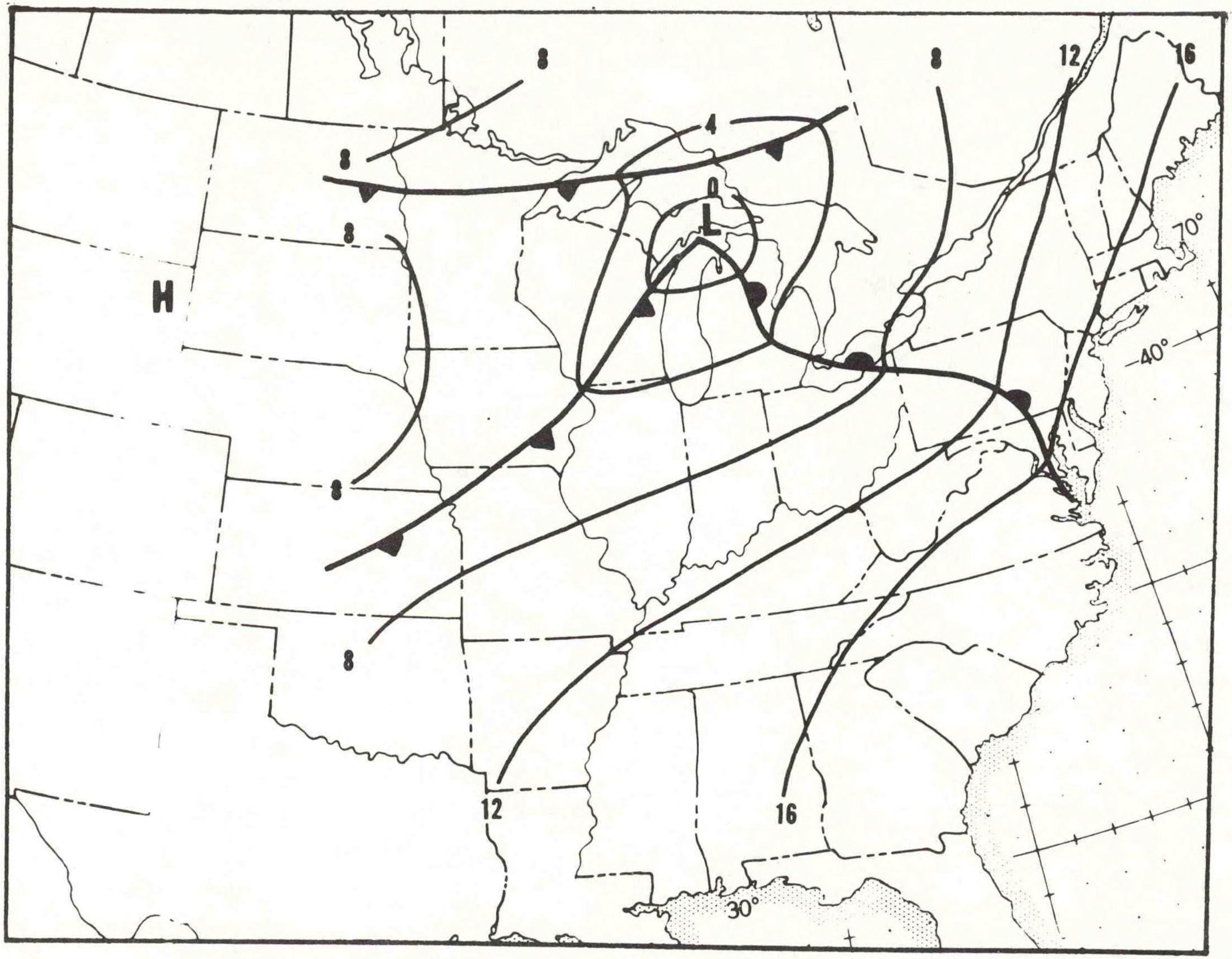

FIGURE 5. NMC surface analysis for 0000Z, July 5, 1969. Isobars are labelled in whole millibars with hundreds omitted.

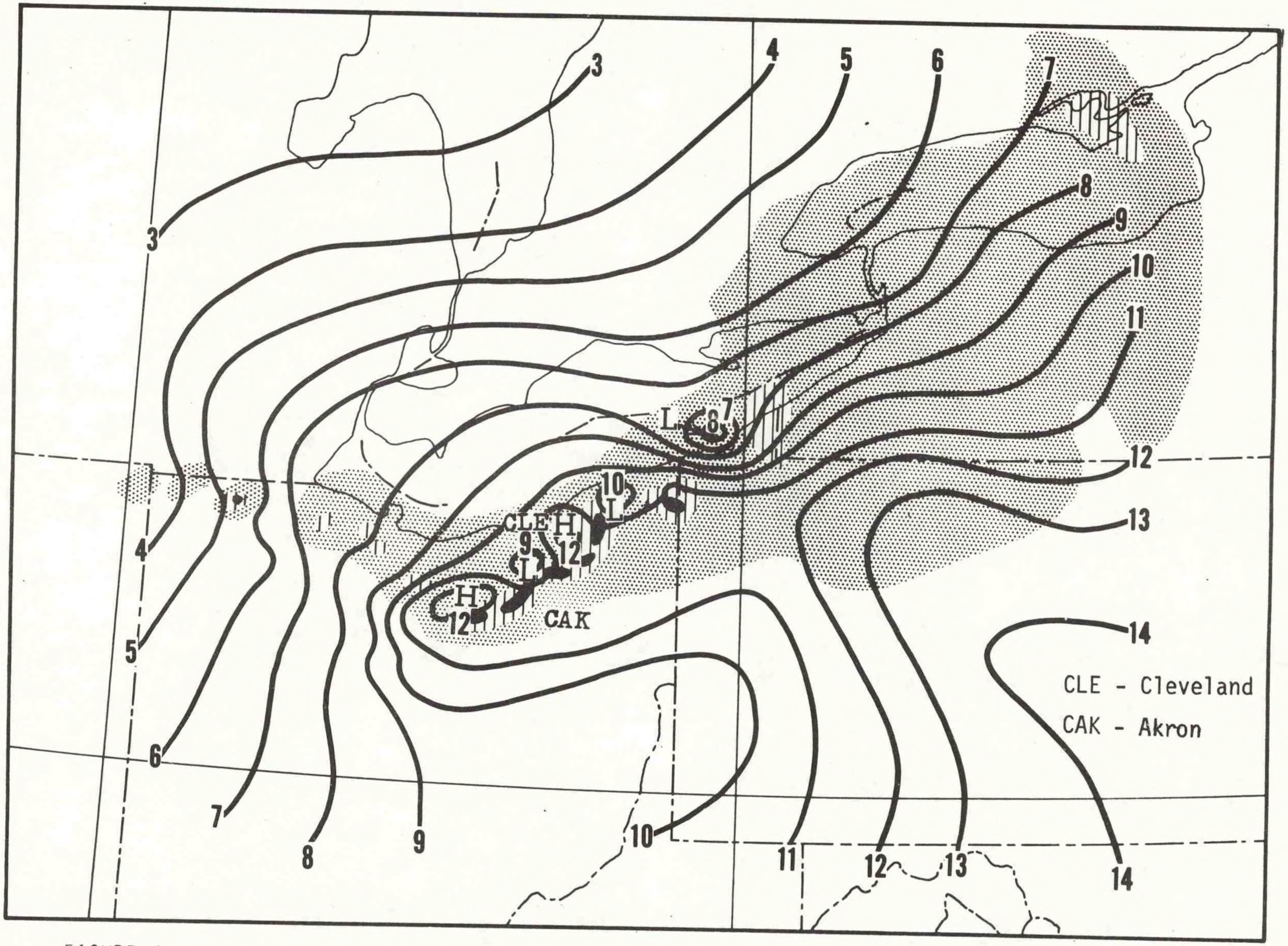

FIGURE 6. Mesoscale analysis - surface isobars (solid lines, labelled in whole millibars with hundreds omitted) for 0100Z, July 5, 1969. Shading is Pittsburgh, Pa., WSR-57 (10 cm. wave length) radar data for 0045Z. Intensity of radar return is indicated as follows: Stippled - very weak and weak, Hatched - moderate, Solid - strong.

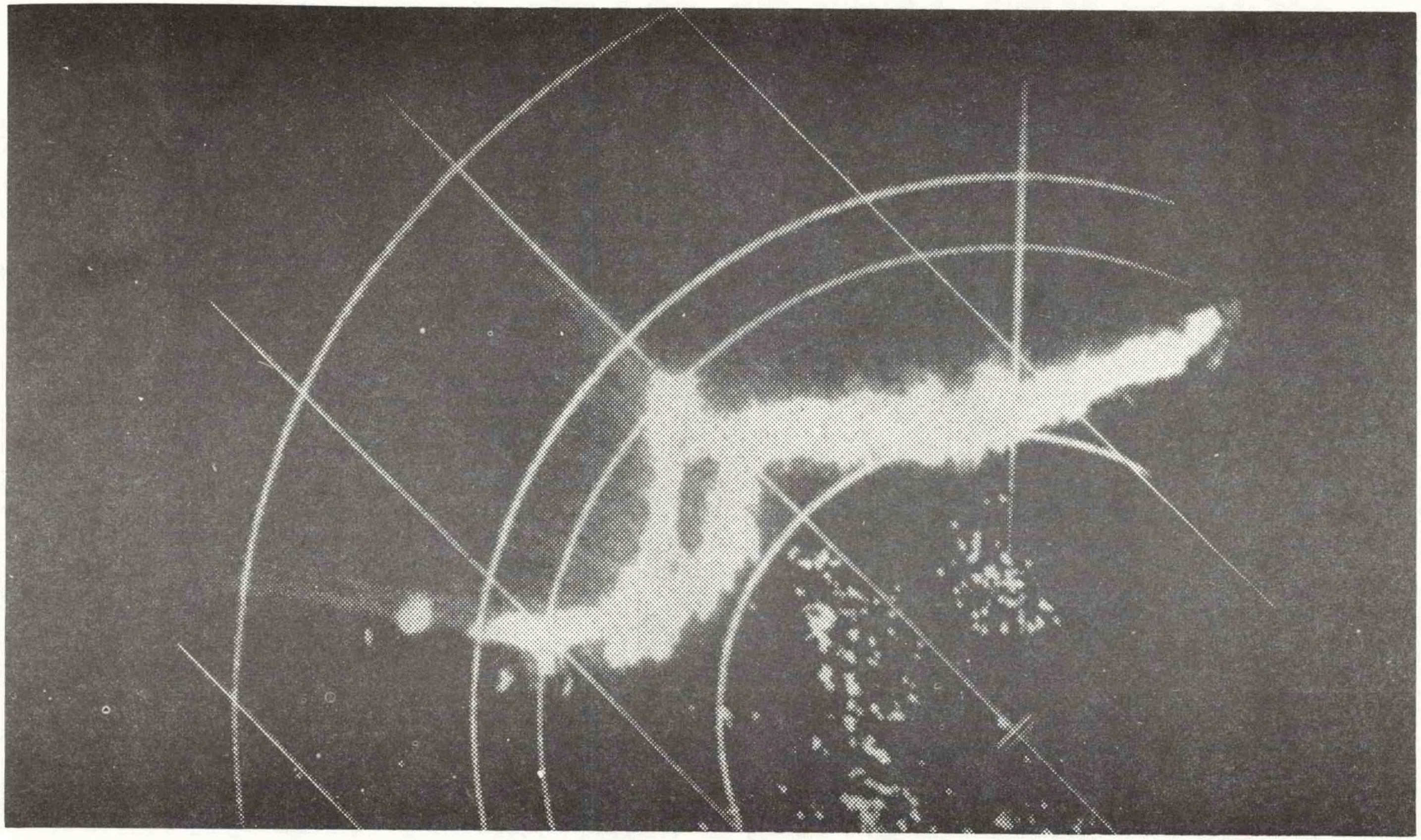

FIGURE 7. Radar PPI display observed at 0030Z, July 5, 1969, by the Decca radar (3 cm. wave length) at Akron, Ohio. Note the proncunced line echo wave pattern located 35 n.m. northwest of Akron.

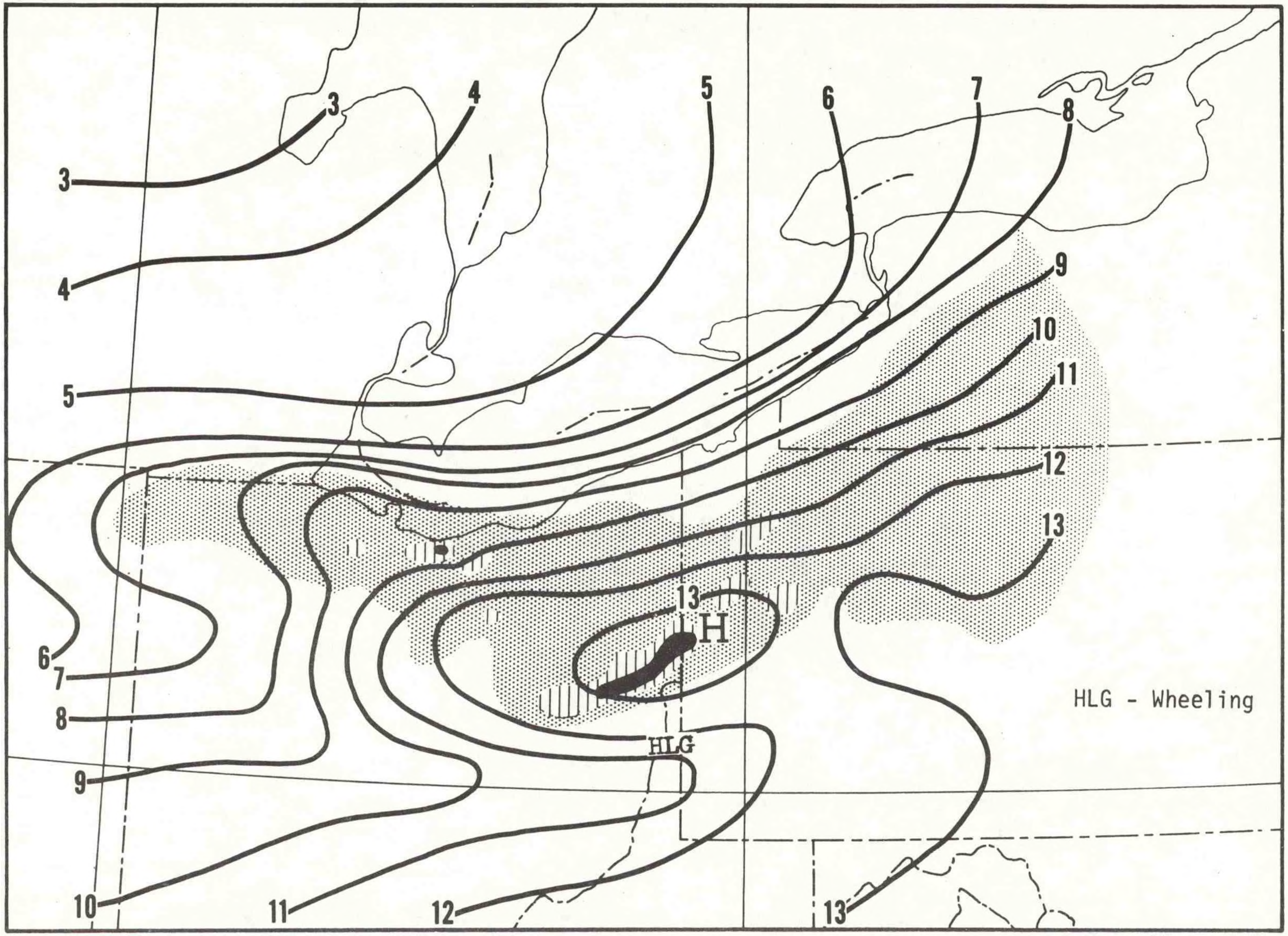

FIGURE 8. Mesoscale analysis - surface isobars (solid lines, labelled in whole millibars with hundreds omitted) for 0200Z, July 5, 1969. Shading is Pittsburgh, Pa., WSR-57 (10 cm. wave length) radar data for 0145Z. Intensity of radar return is indicated as follows: Stippled - very weak and weak, Hatched - moderate, Solid - strong.

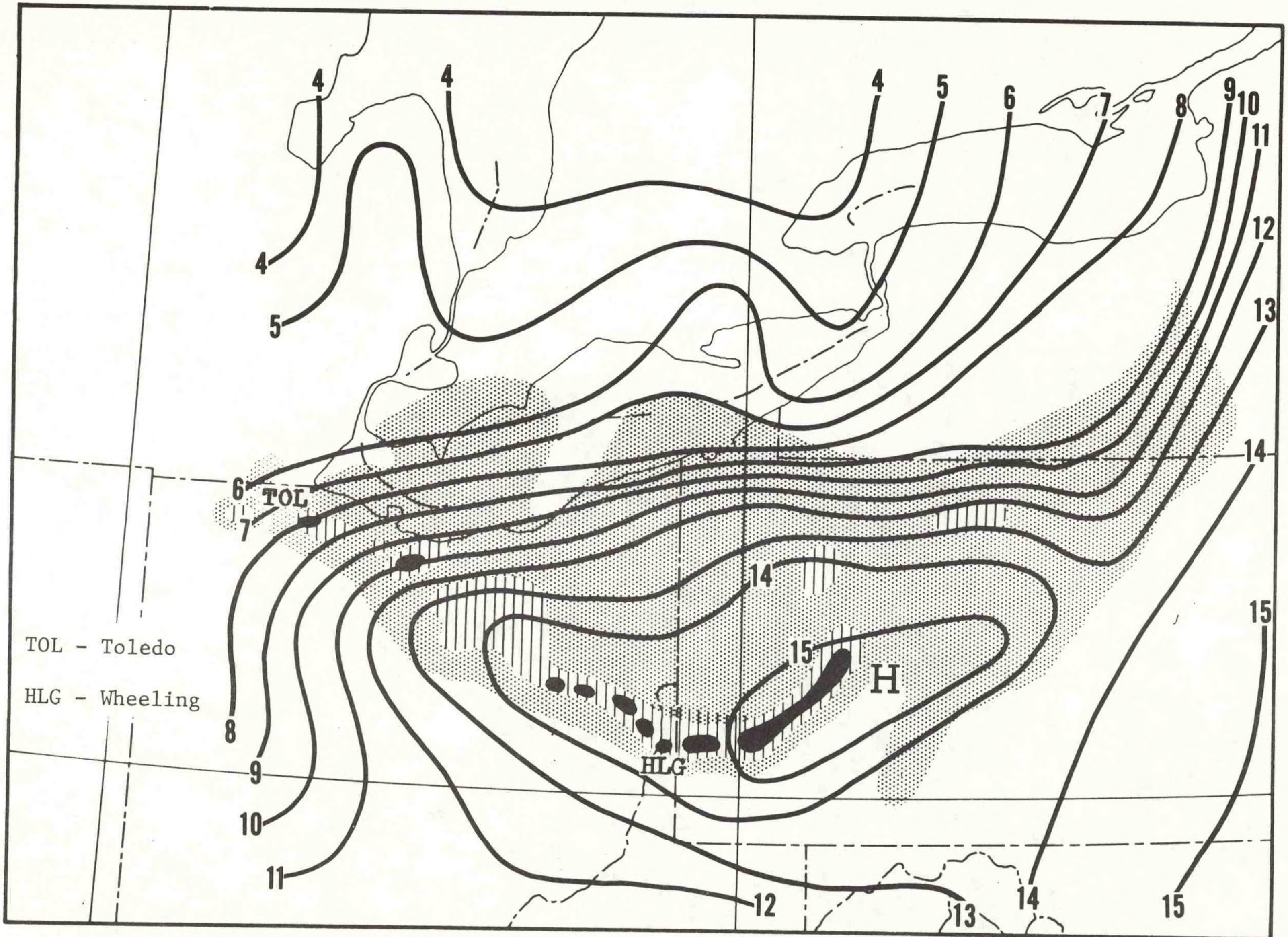

FIGURE 9. Mesoscale analysis - surface isobars (solid lines, labelled in whole millibars with hundreds omitted) for 0300Z, July 5, 1969. Shading is Pittsburgh, Pa., WSR-57 (10 cm. wave length) radar data for 0245Z. Intensity of radar return is indicated as follows: Stippled - very weak and weak, Hatched - moderate, Solid - strong.

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No. 33 A Climatology of Weather that Affects Prescribed Burning Operations at Columbia, S.C. S. E. Wasserman and J. D. Kanupp, December 1968

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No. 37 Objective Mesoscale Temperature Forecasts. Joseph P. Sobel, September 1970. (COM-71-0074)

No. 38 Use of Primitive Equation Model Output to Forecast Winter Precipitation in the Northeast Coastal Sections of the United States. S. E. Wasserman and Harvey Rosenblum. December 1970. (COM-71-00138)

No. 39 A Preliminary Climatology of Air Quality in Ohio. Marvin E. Miller. January 1971 (COM 71-00204)

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