SATELLITE & MESOMETEOROLOGY RESEARCH PROJECT

Department of the Geophysical Sciences
The University of Chicago

F-SCALE CLASSIFICATION OF 1971 TORNADOES

by

T. Theodore Fujita

SMRP Research Paper
Number 100
April 1972

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F-SCALE CLASSIFICATION OF 1971 TORNADOES

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SMRP Research Paper No. 100

The research presented in this paper was sponsored by the National Aeronautics and Space Administration under grant NGR-14-001-008 and by the National Oceanic and Atmospheric Administration under grant E-198-68 (G).

F-SCALE CLASSIFICATION OF 1971 TORNADOES[1]

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Abstract

Based on F-scale assessments of tornado intensity as obtained by NOAA climatologists, the author made an initial attempt to produce a 1971 tornado map including both F-scale intensity and tornado paths. It was found that there were four parallel zones of tornado frequencies, oriented in a SSW-NNE direction but the appearance of these zones could be just accidental for this particular year. Despite the necessity of improved coordination between climatologists, especially when tornadoes cross state lines, the patterns of F-scale tornadoes appear to be very useful for better understanding of U. S. tornadoes.

1. INTRODUCTION

Since 1916 when the U.S. Weather Bureau started collecting tornado frequencies systematically, the cumulative numbers of tornadoes in each state or in the entire United States were regarded as a measure of tornado activities. Evidence shows that natural variation of tornadoes is extremely large, necessitating their sub-classification based on their physical parameters such as maximum wind speed, translational and rotational speeds, duration, path length and width, characteristics of funnel, distribution of pressure temperature and humidity, etc.

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[1] The research presented in this paper was sponsored by the National Aeronautics and Space Administration under grant NGR-14-001-008 and by the National Oceanic and Atmospheric Administration under grant E-198-68 (G).

Due to their abrupt formation coupled with a relatively short life, most tornadoes are not under surveillance throughout their entire life. Furthermore, those tornadoes occurring at night may not be seen at all, only confirmed by their characteristic damage patterns and/or the sound typical of tornadoes.

The largest tornado published in Storm Data for 1971 was 198-mile long and 0.6-mile wide while the smallest one confirmed yet as a tornado was 10-yard long and 7-yard wide. It is not logical to count each of these extreme tornadoes as "one" because the former was 5,000,000 times larger in damage areas. Likewise, their intensity was so different that the former killed 58 people while the latter resulted in minor structural damage.

There is no doubt that these extreme tornadoes must be differentiated for the improvement of statistics. To accomplish tornado assessment for this purpose, it is desirable to obtain the above-mentioned physical parameters of each tornado. The conclusion is quite unique however; the more tornado information requested, the less the number of tornadoes for which this information is given.

To overcome these difficulties, the F-scale damage categories along with the F-scale wind speed ranges were distributed to the NOAA climatologists for the 48 states. For details refer to Fujita's[2] original paper in which F 0 through F 5 damage specifications and pictures are presented. In response to the author's request, the NOAA climatologists informed the author of the F-scale assessment of "all confirmed tornadoes" for the year 1971. The author wishes to express his sincere gratitude for their effort in making the 1971 experiment successful.

Toward the end of 1971, Mr. Allen D. Pearson, Director of the National Severe Storms Forecast Center, Kansas City, Missouri, and the author discussed the possibilities of establishing scales of path length and width which are coarse enough to allow their estimation for all confirmed tornadoes. Thus the F P P scale[3] has been established, the descriptions of which were distributed to NOAA climatologists and potential tornado observers for their experimental use in 1972.

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[2] Fujita (1971): Proposed Characterization of tornadoes and hurricanes by Area and Intensity. SMRP Research Paper 91.

[3] Fujita, T. T. and A. D. Pearson (1972): F P P tornado scale and its applications. SMRP Research Paper 98.

2. DISTRIBUTION OF F-SCALE TORNADOES

After receiving the F-scale assessment of tornadoes from NOAA climatologists, the location and the path of each storm were plotted on 1:1,000,000 aeronautical maps. At the end of 1971, all tornadoes were compiled in one-degree squares covering the entire United States.

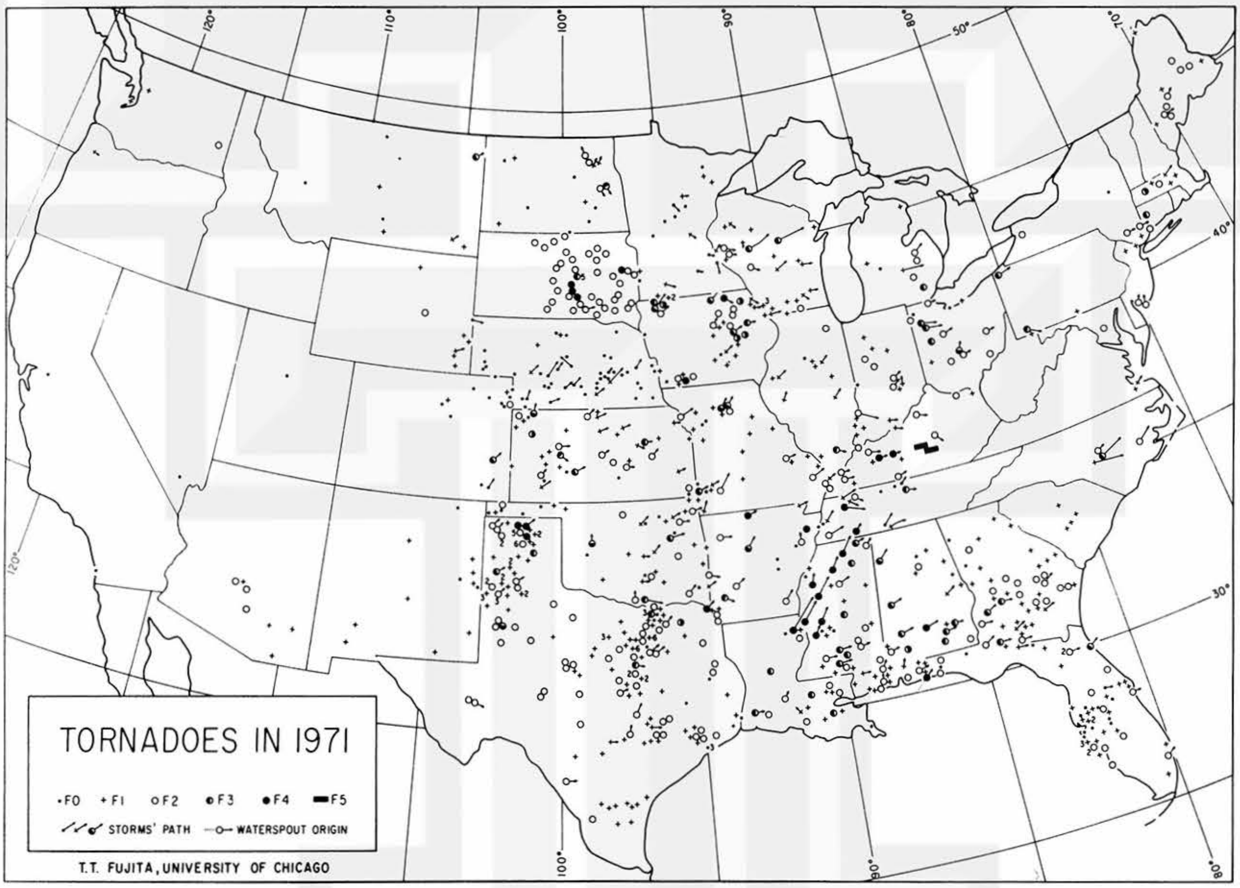

Fig. 1. Distribution of tornadoes in 1971 characterized by the F-scale intensity and the direction of travel. A waterspout-originated tornado at Pensacola, Fla. was rated as F 4, and a F 4 tornado with a 198 mile length was divided into 4 tornadoes based on aerial survey.

The tornado touchdown points identified by F-scale damage estimates by NOAA climatologists as well as the storms' paths are presented in Fig. 1. There were two F 5 tornadoes while the total occurrences were 872. When the distribution is examined on the map, it is seen that there were four major zones of tornado concentrations extending in a SSW-NNE direction. The first zone extends from west-central Texas to northeastern North Dakota; the second, from central Texas to northwestern Wisconsin; the third, from Louisiana to Ohio; and the fourth, from Georgia to Maine. A concentration of frequency over central Florida might represent the fifth zone. The average spacing of these zones is 370 miles which may or may not have meteorological significance. Nonetheless, these zones appeared to be very distinct.

3. STATE-BY-STATE STATISTICS

State-by-state statistics of annual tornado frequencies in F 0 through F 5 categories are tabulated in Tables 1 and 2. It should be noted that there were no F 3 or stronger tornadoes in the western states nor F 4 or stronger tornadoes in the eastern states during the year 1971.

In the entire United States there were 152 F 0 tornadoes consisting of 18% of all storms. The F 1 category was the largest in frequency, 367 or 42%, suggesting that 60% of all tornadoes were assessed as F 0 and F 1, characterized by 40 to 112 mph wind speed. These weak storms, yet classified as tornadoes by definition, are probably confirmed by light to moderate damage spotted beneath passing funnel clouds or by the typical sound of nearby tornadoes. If there were no visible damage, the storm is likely to be classified as funnel aloft. Light damage to chimneys and TV antennae, twig breakage off trees, and pushed over trees will result in an F 0 classification.

F 2 storms comprised 29% of the total or 256 in number while F 3 comprised 8%, indicating that F 3 or stronger storms -- the 23 (3%) F 4 and the 2 (0.2%) F 5 -- were the most dangerous storms in 1971. If we intend to improve the prediction of F 3 or stronger storms, it will be necessary to investigate the formation of only about 25% of the total tornadoes rather than worrying about all confirmed storms.

4. ANNUAL AND DIURNAL VARIATIONS

Annual variation of 1971 tornadoes was characterized by a significant frequency maximum in June when 192 storms occurred. There were other maxima in February and December when 84 and 54 tornadoes were reported, respectively.

Table 1. Frequencies of F-scale Tornadoes in Eastern and East Central States.

EASTERN STATES

STATES	F 0	F 1	F 2	F 3	F 4	F 5	Total
Maine	0	4	7	0	0	0	11
Vermont	0	0	0	0	0	0	0
New Hampshire	0	0	0	0	0	0	0
Massachusetts	0	4	1	1	0	0	6
Rhode Island	0	0	0	0	0	0	0
Connecticut	0	0	1	1	0	0	2
New York	1	1	3	0	0	0	5
New Jersey	0	2	1	0	0	0	3
Pennsylvania	0	1	0	2	0	0	3
Delaware	0	0	0	0	0	0	0
Maryland	0	0	2	0	0	0	2
West Virginia	0	1	0	0	0	0	1
Virginia	0	2	0	0	0	0	2
North Carolina	0	1	2	1	0	0	4
South Carolina	0	4	0	0	0	0	4
Georgia	2	26	15	3	0	0	46
Total Number	3	46	32	8	0	0	89
in per cent	3	52	36	9	0	0	100%

EAST CENTRAL STATES

STATES	F 0	F 1	F 2	F 3	F 4	F 5	Total
Minnesota	10	8	0	0	0	0	18
Wisconsin	0	24	4	2	0	0	30
Michigan	1	3	3	1	0	0	8
Ohio	2	2	7	4	0	0	15
Indiana	1	9	5	0	0	0	15
Illinois	2	12	1	1	0	0	16
Iowa	3	11	8	9	2	0	33
Missouri	3	20	6	3	0	0	32
Arkansas	3	3	5	2	2	0	15
Kentucky	0	4	8	0	2	2	16
Tennessee	6	4	3	1	2	0	16
Total Number	31	100	51	23	8	2	215
in per cent	14	46	24	11	4	1	100%

Table 2. Frequencies of F-scale Tornadoes in West Central, Gulf, and Western States.

WEST CENTRAL STATES

STATES	F 0	F 1	F 2	F 3	F 4	F 5	Total
Montana	3	4	0	1	0	0	8
Wyoming	0	6	1	0	0	0	7
North Dakota	5	6	3	1	0	0	15
South Dakota	0	0	38	5	4	0	47
Nebraska	44	5	0	0	0	0	49
Kansas	5	20	10	4	0	0	39
Oklahoma	11	17	8	3	0	0	39
Colorado	10	2	1	1	0	0	14
New Mexico	3	9	0	0	0	0	12
Total Number	81	69	61	15	4	0	230
in per cent	25	30	26	7	2	0	100%

GULF STATES

STATES	F 0	F 1	F 2	F 3	F 4	F 5	Total
Florida	15	24	16	1	1	0	57
Alabama	2	8	4	7	1	0	22
Mississippi	3	17	11	6	4	0	41
Louisiana	2	7	6	4	1	0	20
Texas	11	89	71	8	4	0	183
Total Number	33	145	108	26	11	0	323
in per cent	10	45	34	8	3	0	100%

WESTERN STATES

STATES	F 0	F 1	F 2	F 3	F 4	F 5	Total
Washington	0	2	1	0	0	0	3
Oregon	0	1	0	0	0	0	1
Idaho	0	0	0	0	0	0	0
Utah	1	0	0	0	0	0	1
Nevada	1	0	0	0	0	0	0
Arizona	0	4	3	0	0	0	7
California	2	0	0	0	0	0	2
Total Number	4	7	4	0	0	0	15
in per cent	27	46	27	0	0	0	100%

TOTAL UNITED STATES

	F O	F 1	F 2	F 3	F 4	F 5	Total
Total Number	152	367	256	72	23	2	872
in per cent	18	42	29	8	3	0.2	100%

Frequencies of F-scale tornadoes during the 12 months in 1971 is presented and contoured in Fig. 2. The unit of the numbers in the figure is frequencies per month per F scale. Of interest is the in-phase variations of F 0, F 1, and F 2 tornadoes, meaning that both F 0 and F 2 tornadoes were spawned in proportion to F 1 tornado frequencies.

Occurrences of F 3, F 4, and F 5 tornadoes were not in-phase with weaker tornadoes. Two F 5 tornadoes occurred on April 27 in Kentucky while most of the 7 F 4 tornadoes in February were contributed by the Mississippi tornado outbreak of February 21. It may, thus, be concluded that the conditions of spawning F 3 or stronger tornadoes need to be investigated for effectiveness of tornado forecasting.

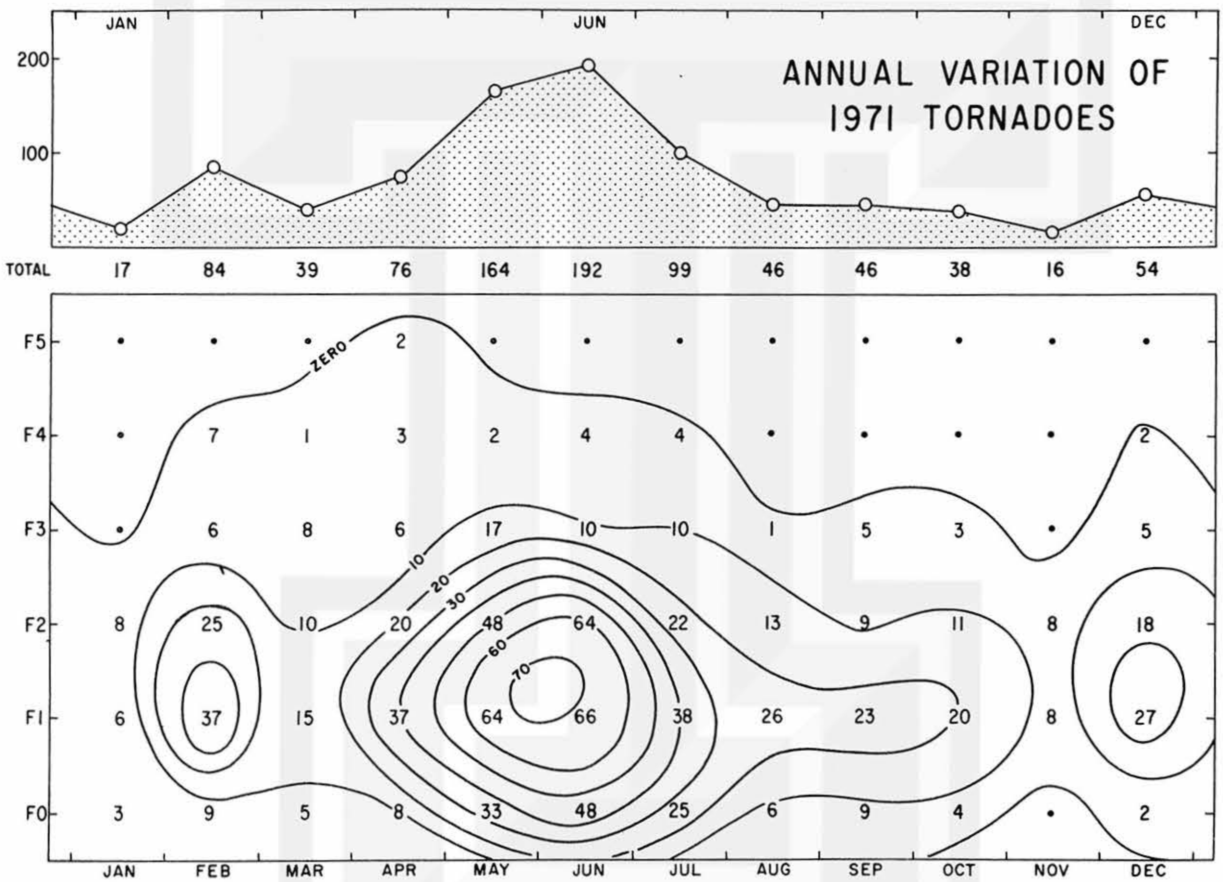

Fig. 2. Annual variation of 1972 tornadoes.

Diurnal variation of all tornadoes in 1971 showed a significant peak at 5 PM local standard time. A breakdown of diurnal variation in each F-scale category in

Fig. 3 shows that the peak frequency of F 1 storms occurred at 4 PM while F 2, F 3, and F 4 storms equally show peaks at 5 PM. Two F 5 storms occurred at 8 and 10 PM where occurrence hour denotes that the tornado occurrence took place within one hour following the specific hour.

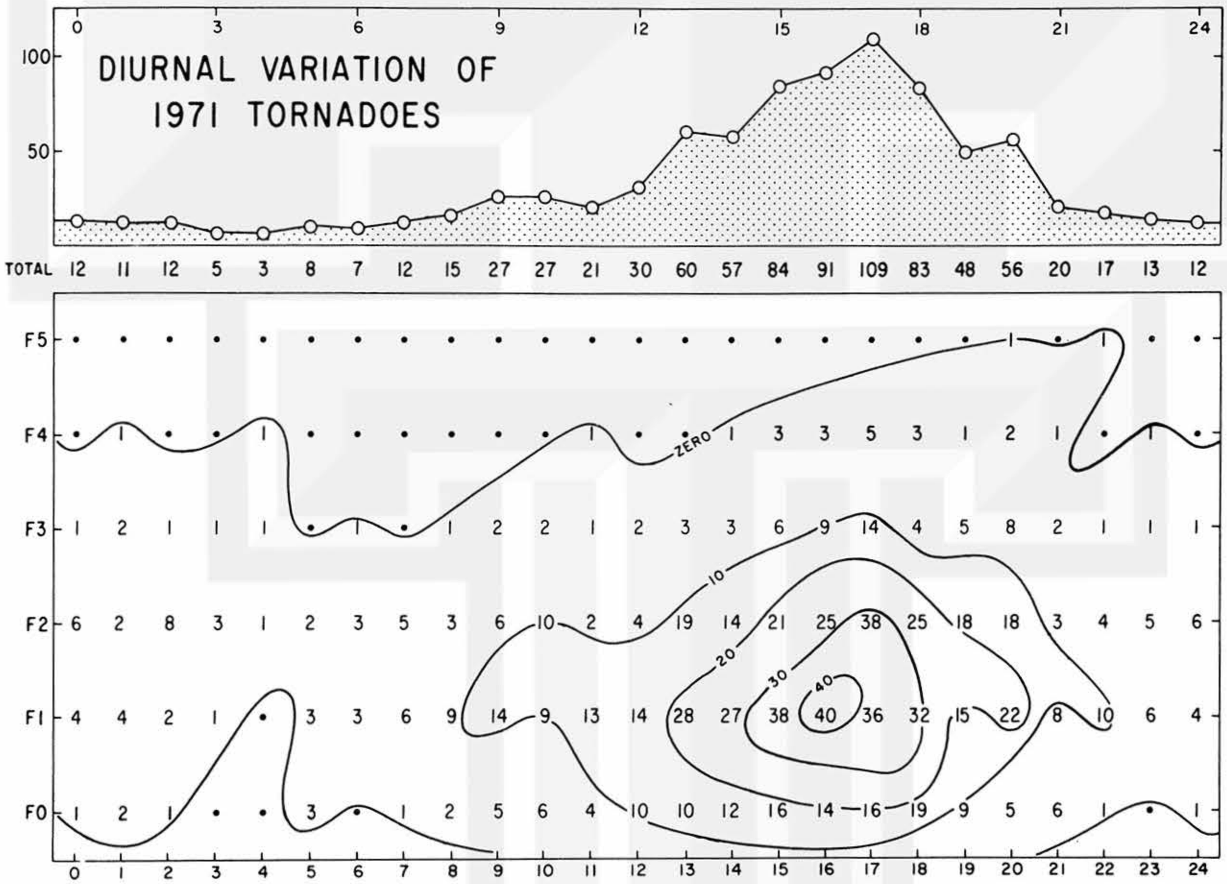

Fig. 3. Diurnal variation of 1971 tornadoes.

5. SPECIFIC TORNADOES UNDER STUDY

Three tornado outbreaks in 1971 are under investigation by the author and his collaborators. Both aerial photogrammetric damage surveys and synoptic studies of meteorological conditions are being performed for later publication. However, a few highlights of these storm characteristics are presented hereunder.

A. Mississippi tornadoes of February 21.

Outbreak of F 4 tornadoes took place within a narrow alley extending from northeastern Louisiana, Mississippi to southwestern Kentucky. 121 were killed while 1566 were injured. All of these tornadoes spawned along a prefrontal squall line shown in the 1400 CST map including echoes from LCH, JAN, and LIT radars (see Fig. 4). The heights of reported echo tops are entered in 1000 ft unit. There were warm-frontal echoes to the north of the warm front extending eastward from the low center. These echoes did not produce tornadoes.

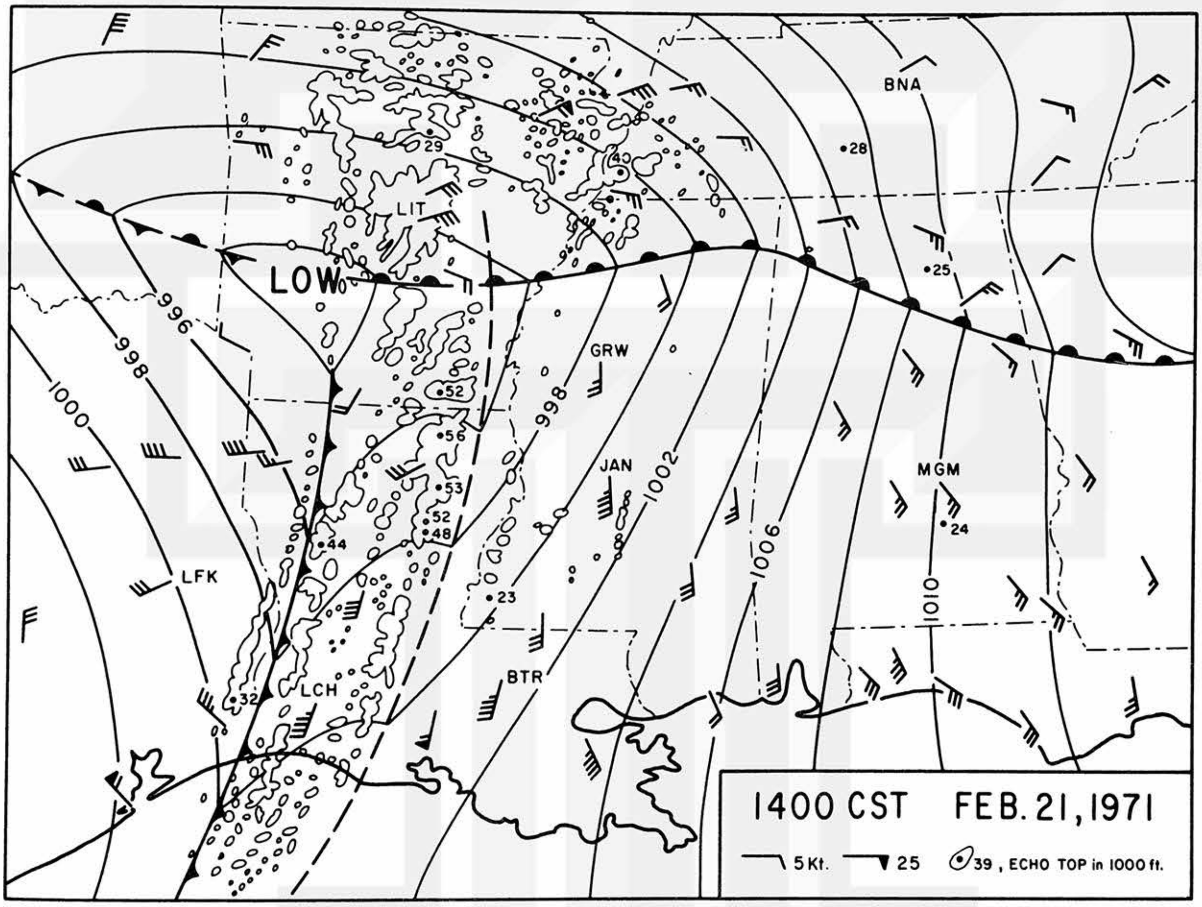

Fig. 4. Surface flow and radar echoes at 1400 CST, shortly before the outbreak of Mississippi tornadoes.

A scatter diagram of reported echo tops during the 24-hr period beginning 04 CST, February 21 reveals that the maximum tops of warm frontal echoes decreased with time with a small maximum at 12 CST. On the other hand, the maximum tops of pre-frontal echoes increased very rapidly after 11 CST reaching a peak at 14 CST. Thereafter, the maximum top decreased very gradually. As shown in Fig. 5, all tornadoes occurred within 8 hours following the peak echo top at 14 CST.

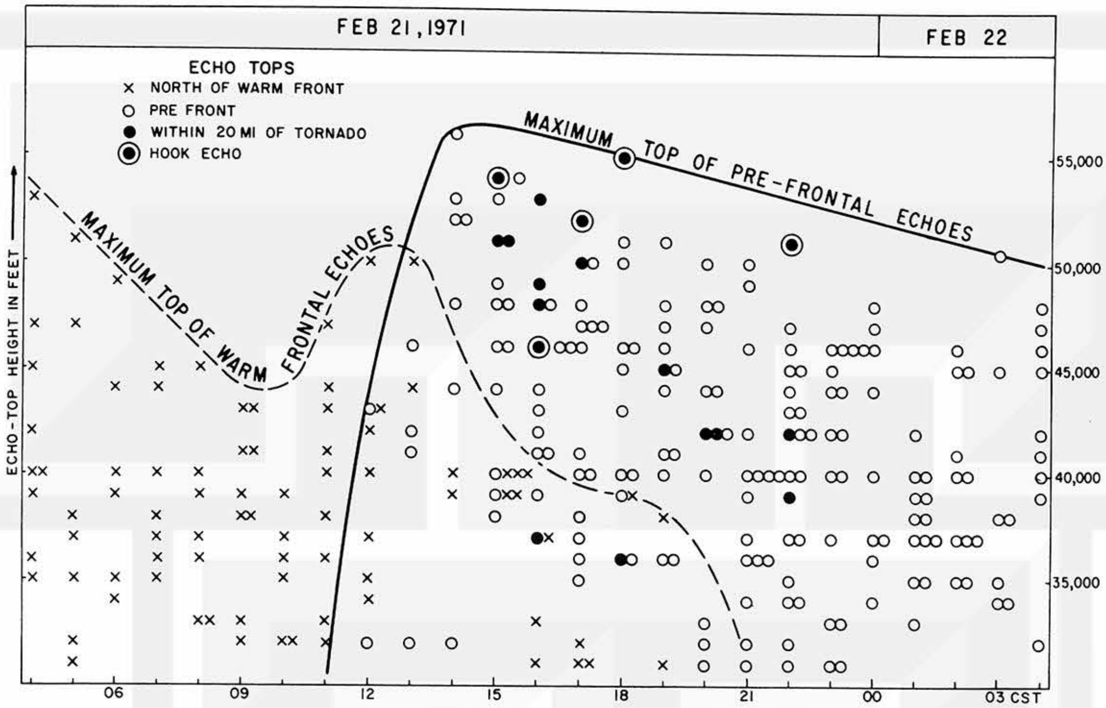

Fig. 5. Variations of echo top heights during a 24-hour period. Echoes within 20 miles from tornado locations are painted black.

28 hook-echo reports were given in Radar Weather Observations from Jackson, Mississippi, although the number of the hook echoes traveled within the radar range have not been confirmed at the present time. Some scope pictures taken with proper gain and elevation angle showed up to 6 hook echoes at one time, suggesting that hook-echo circulation played an important role in spawning families of F 4 tornadoes.

As shown in ITOS 1 visible picture exposed at 1428 CST and NOAA 1 infrared picture scanned between 1414 and 1419 CST, there was a spectacular pre-frontal squall line (see Figs. 6 and 7, respectively). The visible frontal cloudiness extended to the Gulf Coast of Mexico, but the cold cloud tops seen in IR picture terminated near the Gulf Coast, suggesting the heated surface stimulated the squall-line convection. The northward extension of the squall line way beyond the warm front is apparent also in IR picture. For the detection of individual echo tops it is necessary to improve both spatial and temperature resolutions.

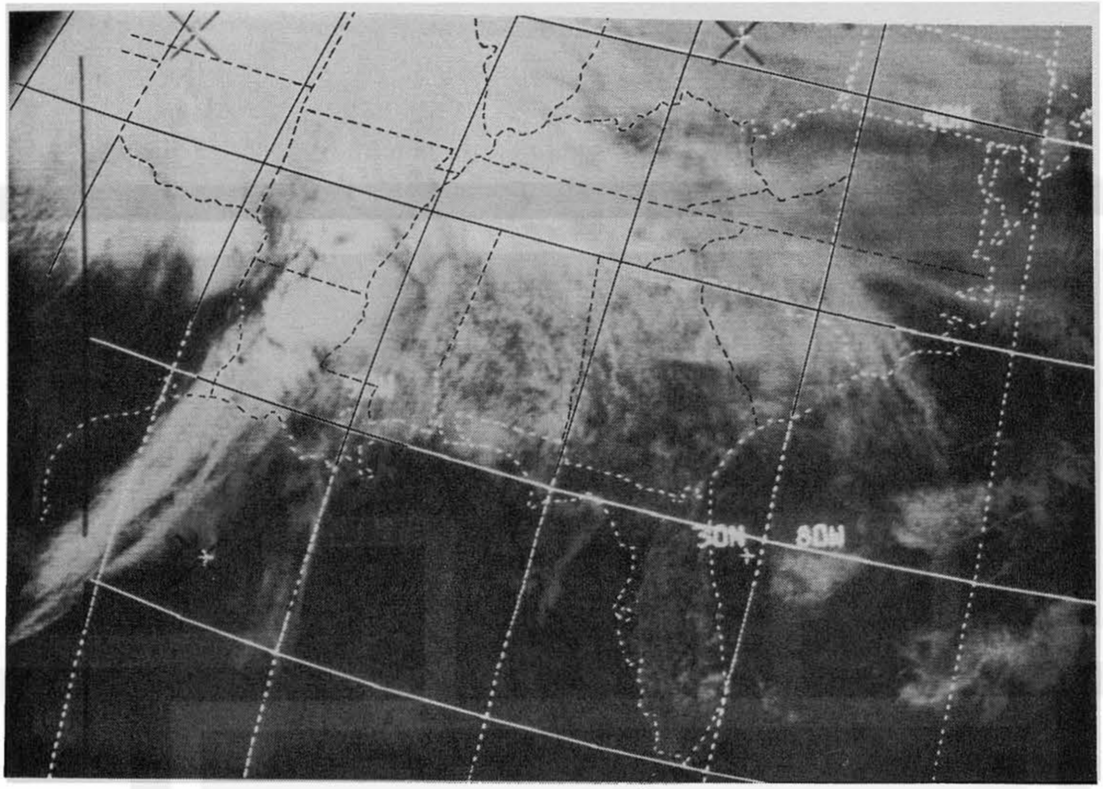

Fig. 6. ITOS 1 visible picture exposed at 1428 CST, Feb. 21, 1971.

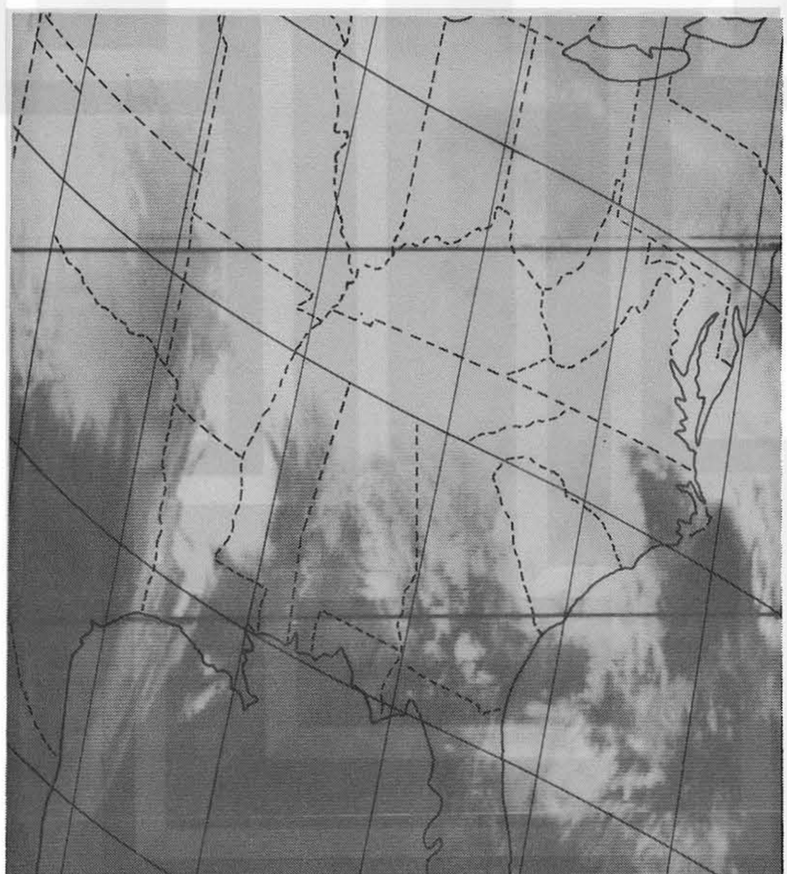

Fig. 7. NOAA 1 IR picture scanned between 1414 and 1419 CST, Feb. 21, 1971.

B. Kentucky tornadoes of April 27.

The author and Mr. J. J. Tecson of SMRP flew down to Kentucky in a Cessna piloted by Mr. L. A. Schaal, NOAA Climatologist for Indiana. Detailed aerial photographs of two F 4 and two F 5 tornado damaged areas were taken from 500 to 1000 ft above the terrain.

This joint effort in aerial photography of damage swaths across relatively rough terrain in Kentucky resulted in a golden opportunity for investigating the effects of orography upon tornado circulation and intensity. Preliminary report by Fujita, Tecson, and Schaal[4] revealed that tornado vortex intensified as it moved down into canyons and valleys. The F 5 tornado near Russell Springs moved across deep canyons without weakening at all (see Fig. 8). This might have something to do with

Fig. 8. Pattern of uprooted trees left by an F 5 tornado which traveled across a region of deep canyons and valleys in Kentucky on April 27.

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[4] Fujita, T. T., J. J. Tecson, and L. A. Schaal (1971): Preliminary Results of Tornado Watch Experiment 1971. Preprint of 7th Conference on Severe Local Storms, Kansas City, pp. 255-261.

the nocturnal occurrence of the tornado.

C. Missouri tornadoes of May 5.

A large number of tornadoes, funnel clouds and hailstorms occurred on May 5 (see Fig. 9) when a cold front swept across the Midwest.

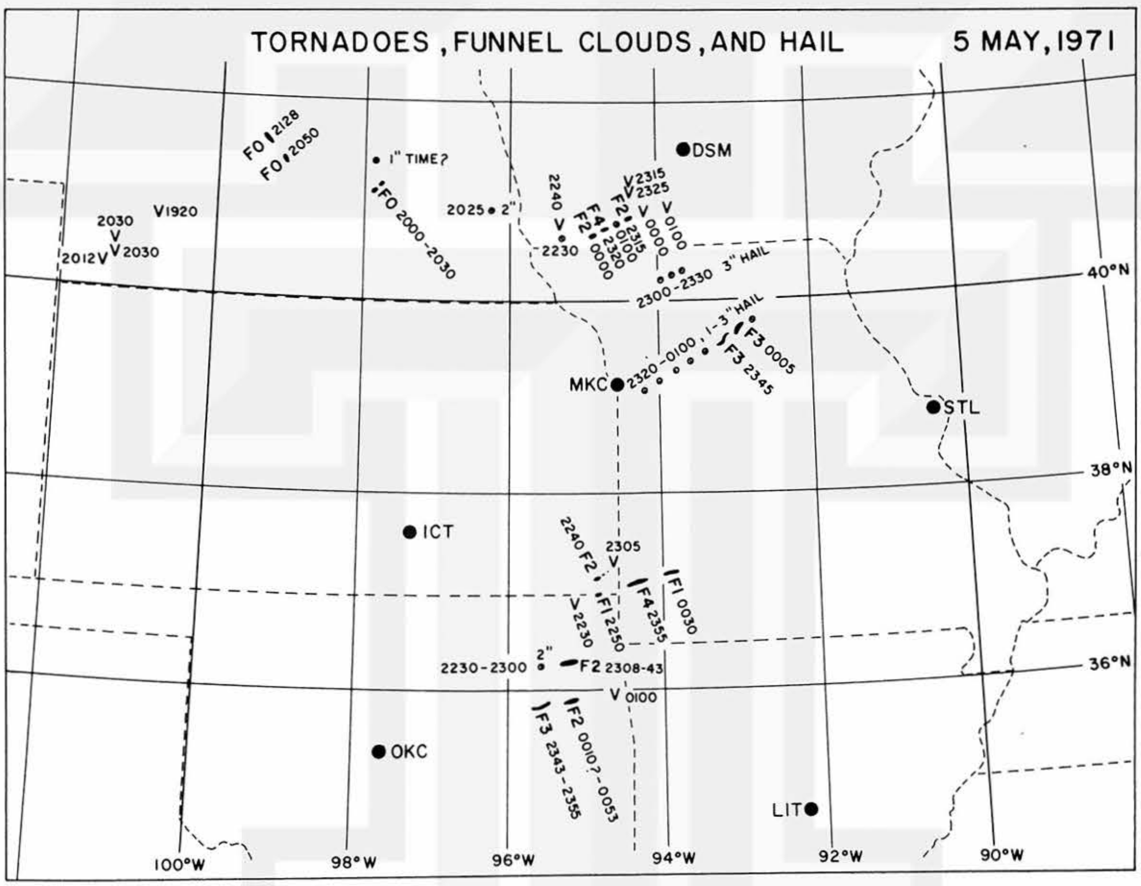

Fig. 9. A map showing the distribution of May 5 tornadoes. Both hail and funnel clouds are also included.

The author made an aerial survey of the Rothville and Joplin tornadoes, both in Missouri. 67 Santa Fe freight cars were derailed (see Fig. 10) just south of Rothville, Missouri where suction swaths were found (see Fig. 11). It is thus assumed that the Rothville storm was a tornado with multiple suction vortices.

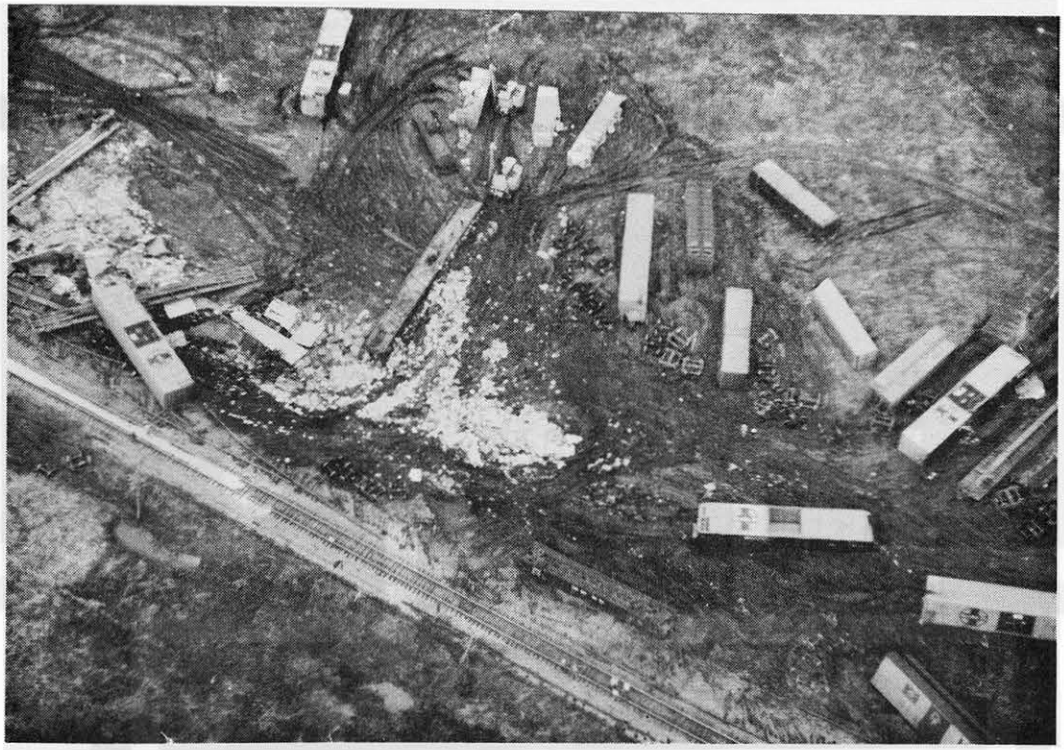

Fig. 10. A close-up areal view of Santa Fe freight cars. Since the derailment blocked the trunk line connecting Chicago with Kansas City, repair crew started working during the night.

Fig. 11. Suction swaths found near Rothville when an F 3 tornado moved toward the north-northeast.

Aerial survey revealed that the Joplin tornado formed about 3 miles WSW of the city, moving directly over the downtown area leaving scattered F 1 damage. After leaving Joplin, the tornado gained its intensity into F 4, uprooting large number of trees in rural areas until it disappeared to the south of Carthage. The path length determined from the air was 15 miles. As shown in Fig. 12, the Joplin tornadoes left no evidence of suction swath, instead the pattern of uprooted trees appeared to be caused by a single suction center which traveled across relatively flat terrain.

A preliminary result of mesosynoptic and radar-satellite combined analyses was presented by the author in the Satellite Applications meeting at Kansas City on September 14, 1971.

Fig. 12. Direction of uprooted trees in a forest east of Joplin, Mo., showing the passage of a fast-moving single-suction tornado.

6. CONCLUSIONS

While appreciating the cooperation of the NOAA climatologists in the F-scale classification of U. S. tornadoes, the author has been convinced that the assessment of all tornadoes based on simple parameters is of vital importance in learning the effects of tornadoes on the immediate environment. The results and the experience of the 1971 tornado watch experiment have developed into a new classification scheme devised jointly by the author and Mr. Pearson of NSSFC. The F P P scale is to be used for the classification of all tornadoes in 1972 and beyond so that large ones can be distinguished from small ones, and strong ones from weak ones.

It is expected that all tornadoes, F 3 or stronger and P 3 or longer will be investigated during 1972 in an attempt to improve the prediction of damaging tornadoes.

Acknowledgement:-

The author wishes to express his sincere gratitude to the NOAA Climatologist for each state who kindly assessed F-scale intensity of all tornadoes in the United States during 1971. Without their effort it would not have been possible to obtain the intensity distribution of U. S. tornadoes with an accuracy much higher than originally anticipated for the first experimental year.

MESOMETEOROLOGY PROJECT - - - RESEARCH PAPERS

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45. Death Valley Temperature Analysis Utilizing Nimbus I Infrared Data and Ground-Based Measurements - Ronald M. Reap and Tetsuya Fujita

46. On the "Thunderstorm-High Controversy" - Rodger A. Brown

47. Application of Precise Fujita Method on Nimbus I Photo Gridding - Lt. Cmd. Ruben Nasta

48. A Proposed Method of Estimating Cloud-top Temperature, Cloud Cover, and Emissivity and Whiteness of Clouds from Short- and Long-wave Radiation Data Obtained by TIROS Scanning Radiometers - T. Fujita and H. Grandoso

49. Aerial Survey of the Palm Sunday Tornadoes of April 11, 1965 - Tetsuya Fujita

50. Early Stage of Tornado Development as Revealed by Satellite Photographs - Tetsuya Fujita

51. Features and Motions of Radar Echoes on Palm Sunday, 1965 - D. L. Bradbury and T. Fujita

52. Stability and Differential Advection Associated with Tornado Development - Tetsuya Fujita and Dorothy L. Bradbury

53. Estimated Wind Speeds of the Palm Sunday Tornadoes - Tetsuya Fujita

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57. Some Effects of Lake Michigan upon Squall Lines and Summertime Convection - Walter A. Lyons

58. Angular Dependence of Reflection from Stratiform Clouds as Measured by TIROS IV Scanning Radiometers - A. Rabbe

59. Use of Wet-beam Doppler Winds in the Determination of the Vertical Velocity of Raindrops inside Hurricane Rainbands - T. Fujita, P. Black and A. Loesch

60. A Model of Typhoons Accompanied by Inner and Outer Rainbands - Tetsuya Fujita, Tatsuo Izawa,, Kazuo Watanabe and Ichiro Imai

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62. Split of a Thunderstorm into Anticyclonic and Cyclonic Storms and their Motion as Determined from Numerical Model Experiments - Tetsuya Fujita and Hector Grandoso

63. Preliminary Investigation of Peripheral Subsidence Associated with Hurricane Outflow - Ronald M. Reap

64. The Time Change of Cloud Features in Hurricane Anna, 1961, from the Easterly Wave Stage to Hurricane Dissipation - James E. Arnold

65. Easterly Wave Activity over Africa and in the Atlantic with a Note on the Intertropical Convergence Zone during Early July 1961 - James E. Arnold

66. Mesoscale Motions in Oceanic Stratus as Revealed by Satellite Data - Walter A. Lyons and Tetsuya Fujita

67. Mesoscale Aspects of Orographic Influences on Flow and Precipitation Patterns - Tetsuya Fujita

68. A Mesometeorological Study of a Subtropical Mesocyclone -Hidetoshi Arakawa, Kazuo Watanabe, Kiyoshi Tsuchiya and Tetsuya Fujita

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