Tornado Outbreak of 31 May 1985

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1. INTRODUCTION

On the evening of May 31 1985 western Pennsylvania was hit by the deadliest tornado outbreak in the State's history. A strong cold front swept through the region, triggering a squall line containing embedded tornadic supercells. Post storm surveys revealed there were a total of 21 tornado touchdowns (Table 1 & Fig. 1) across the northwest and central part of the state. The most intense tornado, which passed through the town of Wheatland on the Ohio border, was rated an F5 on the original Fujita Scale[1]. Among several F4 tornadoes, one cut a path 105 km long through the Moshannon State Forest, producing a 1 km wide swath of downed trees which was still visible 20 years after the storm.

Casualties included 65 killed and 707 injured in Pennsylvania alone, with additional deaths and injuries reported across the neighboring States of Ohio and New York. 1009 homes were reported destroyed across Pennsylvania with a price tag at the time of $376,367,000.

On a wider scale, this outbreak of severe weather also affected portions of Ohio, New York and Southern Ontario (Fig. 2). Killer tornadoes were reported in both southeast Ontario and Ohio with hundreds of injuries from the storms.

Tornado Number	Tornado Name	Length (km)	Width (m)	Time (PM EDT)
1	Utica,OH	45	150	7:15-7:45
2	Cooperdale,OH	18	70	7:50-8:10
3	Mesopotamia,OH	25	425	5:05-5:20
4	Wheatland,PA-OH	75	425	6:30-7:35
5	Albion,PA-OH	23	375	4:59-5:17
6	Dorse,OH-PA	16	150	5:28-5:41
7	Meadville,PA	15	130	5:35-5:50
8	Linesville,PA	6	200	5:10-5:15
9	Middleton,OH	24	200	7:35-7:55
10	Big Beaver	63	250	8:10-9:05
11	Atlantic City,PA	63	350	5:40-6:30
12	Saegertown,PA	29	250	5:23-5:55
13	Centerville,PA	13	400	6:12-6:23
14	Corry,PA-OH	45	425	5:25-5:55
15	Tompson Run,PA	8	200	6:30-6:37
16	Emlenton,PA	8	30	7:56-8:03
17	Big Bend,PA	10	130	7:54-8:03
18	Tionesta,PA	48	800	6:30-7:10
19	Tidioute,PA	27	800	7:30-7:55
20	Kane,PA	46	950	8:00-8:40
21	Lamont,PA	33	300	6:50-7:35
22	Busti,NY	21	175	6:25-6:45
23	Penn Run,PA	10	25	9:52-10:03
24	Moshannon St Forest,PA	105	1000	7:35-9:00
25	Watsontown,PA	34	850	6:25-10:15
26	Hollenback Twp,PA	16	400	10:45-11:00

Table 1. List of tornadoes: 31 May 1985.

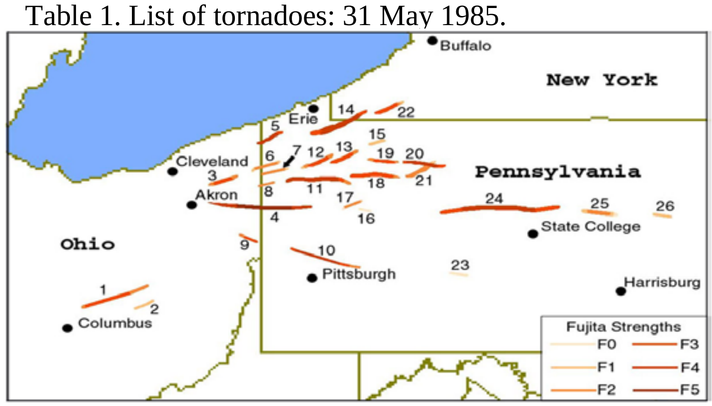

Figure 1. The tracks of the tornadoes, by F-scale, on 31 May 1985. Image courtesy of the Pennsylvania State Climatologist.

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[1] The enhanced Fujita or EF scale has replaced the older Fujita scale.

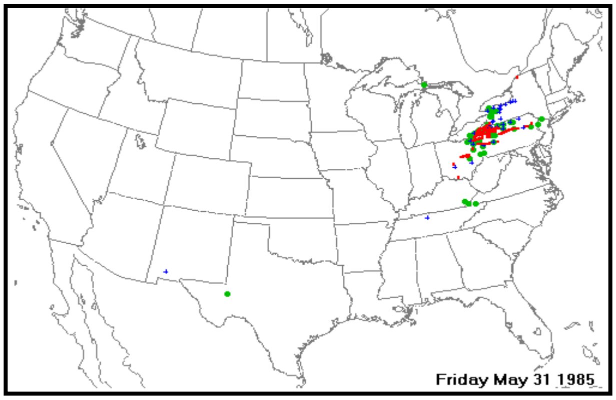

Figure 2. Severe weather reports from 31 May 1985. Red = tornado. Blue = wind reports. Green = hail. Figure is courtesy of the Storm Prediction Center.

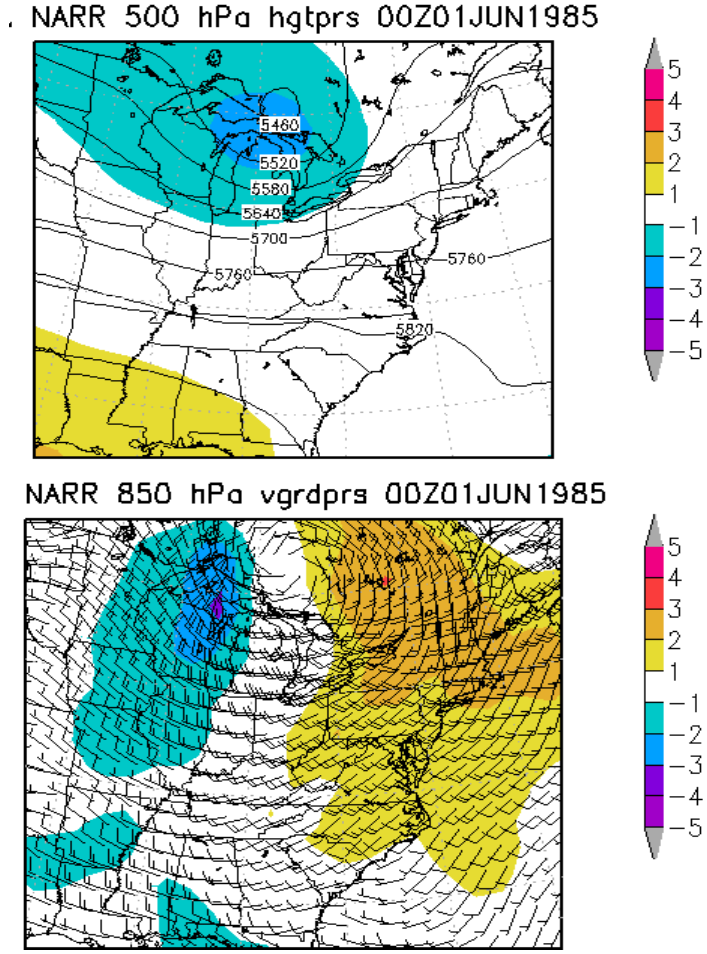

Figure 3. NARR re-analysis data valid at 0000 UTC 01 June 1985 showing a) 500 hPa heights (m) and 500 hPa height standardized anomalies. b) 850 hPa v component wind vectors and anomalies.

METHOD and DATA

Images of atmospheric parameters were obtained from the North American Regional Re-Analysis (NARR) data and the Weather Research and Forecasting (WRF) Model. The anomalies and values of the 500 hPa heights, 850 hPa wind speeds, precipitable water and mean surface level pressure are shown in Figures 3 and 5. These fields appear to be useful predictors in many tornadic events. CAPE and low level shear values are the most useful derived fields in predicting tornado outbreaks. These values are displayed in Figures 6-8. Tornado statistics were obtained from the Pennsylvania State Climatologist. Additional severe weather plots were obtained from the Storm Prediction Center (SPC).

2. RESULTS

i. Overview of the large scale pattern

Analysis data for this case shows many of the synoptic scale signatures typical of Pennsylvania tornado outbreaks, including a progressive, anomalous upper low and associated deep surface low tracking through the Great Lakes, a jet exit region over Pennsylvania and an anomalous, moist low level jet over the region.

Figure 3a shows negative 500 hPa height anomalies during the height of the event of between 2 and 3 standard deviations across the Great Lakes. South of this feature, deep layer shear values in excess of 40kts (Fig. 4) provided a favorable environment for supercells. Significant upper level divergence can be inferred by the diffluent height contours in the jet exit region over Pennsylvania at this time.

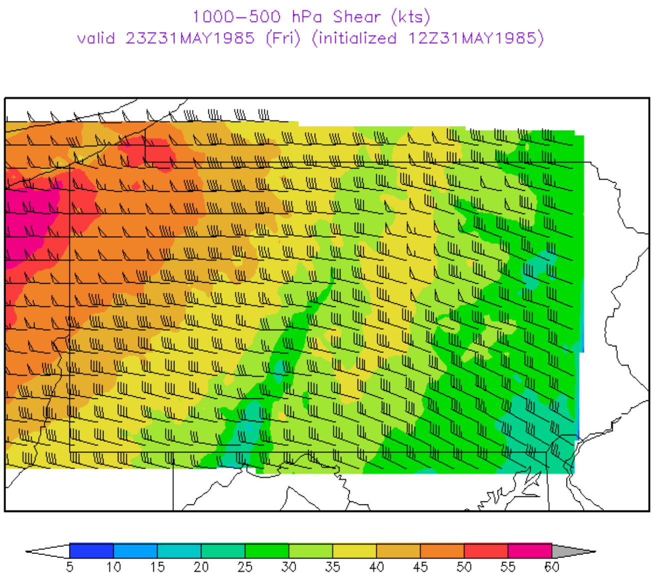

Figure 4. Ensemble mean 1000-500 hPa shear (kts) valid at 2300 UTC 31 May 1985

An unseasonably deep surface low accompanied this upper level shortwave. Negative mean surface level pressure anomalies on the order of -4 SD were centered over the Great Lakes (Fig. 5b), where a 984 mb center (not shown) was analyzed at 1800 UTC 31 May 1985.

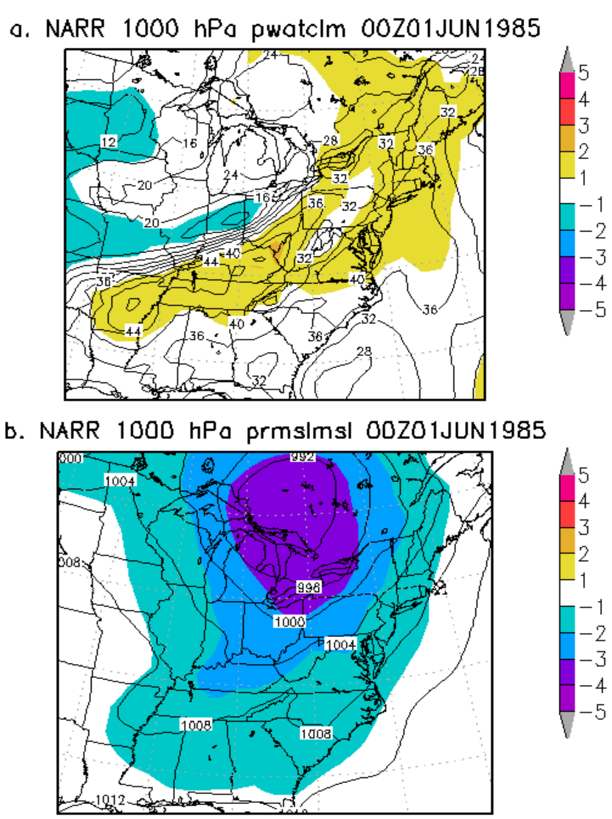

Figure 5. NARR re-analysis data valid at 0000 UTC 01 June 1985 showing a) 1000 hPa Precipitable Water (mm) and 1000 hPa Precipitable Water standardized anomalies. b) 1000 hPa heights (m) and 1000 hPa height standardized anomalies. .

A 50 knot low level jet (not shown) accompanying this system was instrumental in creating large low level shear profiles (Fig. 6) favorable for tornadoes. Strong horizontal vorticity resulting from such wind shear is capable of being tilted into the vertical and brought to the ground by the downdraft within the rear flank of a supercell. This source of low level vertical vorticity is a primary ingredient for tornadogenesis.

850-1000mb shear values in this case were around 35 kts, or around +4 SD above normal (Fig. 6). 850 hPa southerly winds (positive v component) during this event were close to +2 SD (Fig. 3b). This low level jet also aided convection by drawing moisture (instability) northward into Pennsylvania.

Moisture data from this case show positive PWAT anomalies of around +1 SD observed along the length of the low level jet (Fig. 5a), from the Tennessee Valley northward through the eastern Great Lakes. Resulting CAPE values, based on an ensemble mean forecast of the WRF model, were between 2500-3000 J/kg during the early evening hours (Fig. 7). These values were between

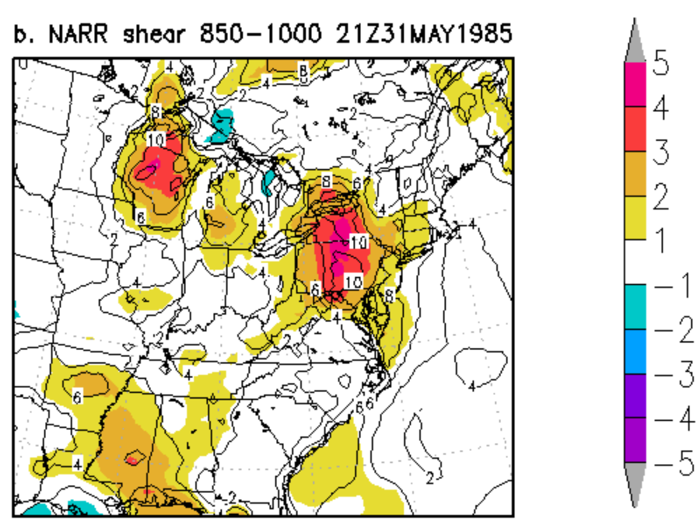

Figure 6. NARR Re-analysis data valid at 2100 UTC 31 May 1985 showing 850-1000mb shear anomalies.

+3SD and +4SD above normal for late May (Fig. 8) and indicate an atmosphere capable of producing the vigorous updrafts required to stretch exiting low level vertical vorticity into a tornado.

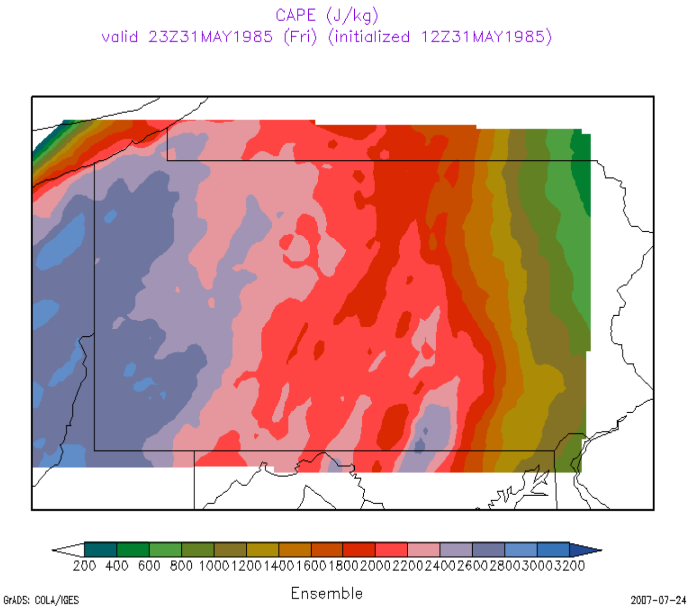

Figure 7. Ensemble mean CAPE (J/kg) valid at 2300 UTC 31 May 1985

ii. Simulations

The atmospheric conditions across northwest Pennsylvania on the evening of May 31 1985 were marked by strong vertical wind shear, especially below 1 km, and high thermodynamic instability. This volatile environment resulted in a vigorous squall line, with embedded long-lived tornadic supercells, tracking southeast through the region ahead of an advancing cold front.

The Weather Research and Forecasting (WRF) Model, employing the Arakawa-Schubert convective parameterization scheme, was used to produce derived radar images of this squall line (Figures 9-11). The Arakawa-Schubert parameterization was used because it most realistically depicted the intense convection, despite being too slow with the evolution of the squall line.

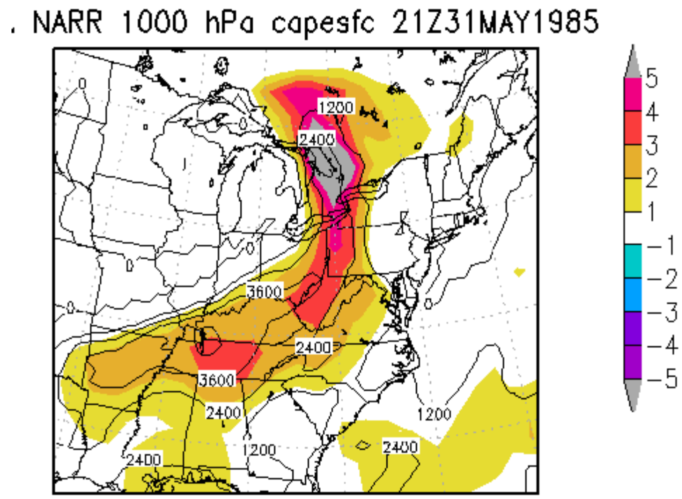

Figure 8. NARR Re-analysis data valid at 2100 UTC 31 May 1985 showing surface CAPE.

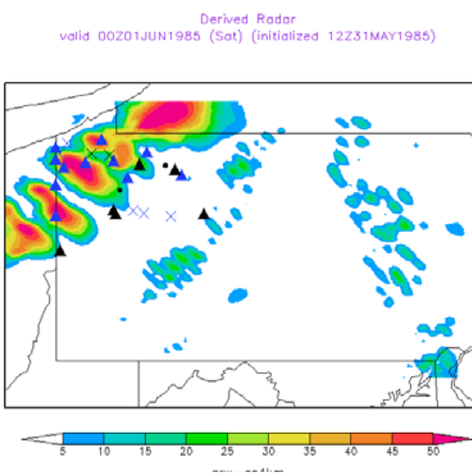

Figure 9. Derived radar valid at 0000 UTC 01 June 1985. Triangles - tornado, X = hail, Circle = wind

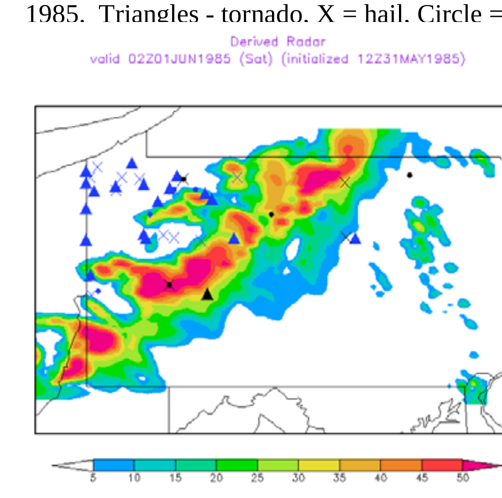

Figure 10. Same as Figure 9 except valid 0200 UTC 01 June 1985. Triangles = tornado, X = hail, Circle = wind

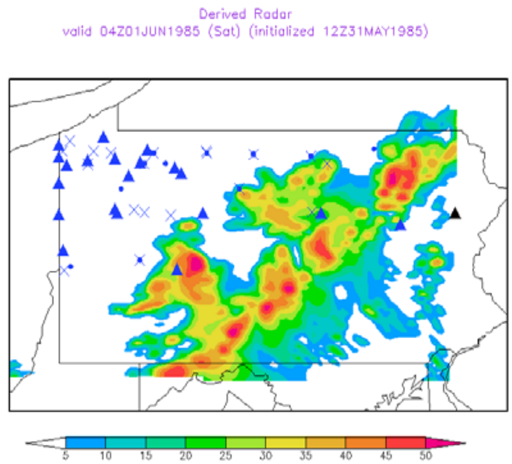

Figure 11. Same as Figure 9 except valid 0400 UTC 01 June 1985. Triangles = tornado, X = hail, Circle = wind

3. CONCLUSIONS

A violent tornado outbreak occurred on the evening of 31 May 1985 across Northwest Pennsylvania, as well as neighboring Ohio, New York and Southeast Ontario. The number and intensity of tornadoes produced (Fig. 1) remain unprecedented for this part of the country. The greatest concentration of severe weather reports (Fig. 2) were found in the area of anomalously high CAPE and wind shear (Fig. 4,6,7 and 8).

This case bore similar synoptic scale atmospheric signatures to other documented tornado outbreaks in Pennsylvania, including an unseasonably deep upper level trough and surface cyclone over the Great Lakes, a jet exit region positioned over Pennsylvania and a strong, moist low level jet maximum.

With regard to derived fields, this case also bore analogous signatures to previous tornado outbreaks, including anomalous CAPE, deep layer shear and especially low level shear. High CAPE values indicate an atmosphere capable of producing strong updrafts capable of stretching the available low level vertical vorticity into a tornado. Strong wind shear produces elevated horizontal vorticity, which in turn can be tilted and brought to ground level within the Rear Flank Downdraft (RFD) of a supercell.

4. ACKNOWLEDGEMENTS

5. REFERENCES