A BEDEVILING EXPERIENCE

Joseph D. Kirkpatrick
National Weather Service Forecast Office
Louisville, Kentucky

It was a leisurely afternoon in the forecast office in Louisville, Kentucky. Skies were clear, winds were light, temperatures hovered near 70 and dewpoints registered in the 30s. It was the last day in April, 1988, another dry day that concluded another month that went into the records with significantly less than normal monthly precipitation.

At 4:30 that afternoon a call came into the forecast office from Sellersburg state police in southern Indiana. A somewhat shaken voice reported that a tornado had leveled a greenhouse in New Albany, Indiana, 5 miles northwest of Louisville. Five people were hospitalized as a result of injuries incurred by flying debris as the greenhouse was destroyed. The structure of the greenhouse consisted of cement block and wood with a transparent plastic cover.

Forecasters at the forecast office in Louisville were momentarily without an explanation and quite skeptical of the report on a day when skies were clear across northern Kentucky and southern Indiana. After further description of the event and a close examination of current weather conditions, the staff decided that a whirlwind, most likely a dust devil, had leveled the greenhouse.

THE PRE-DEVIL ENVIRONMENT

The single most important element for the formation of dust devils is thermal convection. This whirlwind is spawned by absolute instability in the lowest layers of the atmosphere caused by intense heating of the earth's surface. The lapse rate greatly exceeds the dry adiabatic, becoming extremely superadiabatic in a layer from the ground to about 0.5 meters. From 0.5 to 10 meters the lapse rate is strongly superadiabatic with the layer continuing moderately superadiabatic up to about 1 kilometer.

McClelland, Snow, and Conner of Purdue University, in a study of dust devils in 1986, found that when the lapse rate from 0.5 to 10 meters reached a value of approximately 0.25 degrees Celsius per meter the first devils developed. The first occurrences were around solar noon with the activity increasing during mid afternoon as the lapse rate increased to 0.38 degrees Celsius per meter. At that time, the maximum soil surface temperatures and convective heat flux were occurring. The last devils were observed during late afternoon with cessation occurring as the lapse rate decreased to less than 0.25 degrees Celsius per meter.

If the single most important element for the formation of dust devils is thermal convection, then the effects of wind, cloud cover, and topography must be examined. Cloud cover is directly related to the vertical stability of the lower atmosphere. Cloud cover negates the intense heating of the earth's surface needed for strong thermals, thereby acting as a depressing factor on the formation of dust devils.

Wind speed plays an equally important role on dust devil activity. As winds increase, an increase in the vertical mixing of the boundary layer is produced. Sinclair (1969) stated that this weakening of the super-adiabatic lapse rate has a dampening effect on dust devil vertical development by shearing off the tops close to the ground. Devil formation was ideal with boundary layer winds of 1 to 10 miles an hour.

Flat surfaces which are the best radiators of heat, such as blacktop and dry, dusty soil, are best for the formation of dust devils. Surfaces with less ability to absorb heat, such as grasslands, forests, marshes, etc., will produce significantly fewer and weaker thermals.

SOURCE OF VORTICITY

Vorticity, simply meaning the spin of a parcel of air, must be present within a dust devil. The turning motion must be present before the devil vortex develops. Past studies of dust devils have indicated several possible sources of vorticity in the vertical.

A theory by Maxworthy (1973) speculates on the source of vertical vorticity in the vortex. His theory states that the horizontal vorticity in the main boundary flow is translated into the vertical direction. As thermals develop, local low level convergence occurs and any existing ambient vertical vorticity is affected and a vortex is formed. For the vortex to continue and grow, this feed and changeover of horizontal to vertical vorticity must continue.

Carroll and Ryan (1970) speculated that the source for vertical vorticity was created by the strong updrafts from the earth's surface (convective heat transfer in the vertical) and the coinciding downdrafts. The downdrafts, diverging horizontally and asymmetrically, would cause short-lived areas of local horizontal shear thus providing a possible source for vertical vorticity.

THE EVENT

On April 30, 1988, a dust devil destroyed a greenhouse 5 miles northwest of Louisville, Kentucky. (Fig. 1.) The damage to the greenhouse and its contents was estimated at $4000.00. The structure was built on a flat surface covered by blacktop. Directly across the highway was a plowed field surrounded by green vegetation. The damage observed (twisted metal, pieces of wood thrown 100 feet, plastic and other material wrapped around electrical wires above) indicated wind speeds on either side of the devil in the 50 to 70 mile an hour range.

The owner of the greenhouse, on his way to inspect the damage, noticed empty plant containers from the greenhouse a mile away. Strong vertical motions associated with large dust devils in the deserts of the west have been observed to reach above 5000 feet, but it is likely that a dust devil in the lower Ohio valley may have vertical motions reaching 100 to 200 feet.

WEATHER ANALYSIS

A cool and dry air mass lay over Kentucky on April 30, 1988. Surface high pressure was centered over Illinois (Fig. 2.) moving southeast. After an early morning low in the mid 40s, temperatures rose steadily under sunshine to around 70 by mid afternoon, despite weak cold advection. Dewpoints in the 30s indicated any cumulus development would likely result in less than 5/10 sky coverage with convective temperatures on upstream morning soundings around 70.

By late afternoon, a few cumulus did pop (See SDF obs - Table 1.) but the low level air was too dry to support a tenth or more. The presence of cumulus, despite the low dewpoints, was a sure sign of strong thermals with lots of lift. The 00Z Dayton sounding that evening (Fig 3) indicated a strong superadiabatic lapse rate in the lowest layers.

CONCLUSION

A whirlwind reaching destructive force in the lower Ohio valley is a rare event. The purpose of this paper was to better acquaint those of us in the eastern U.S. to this local warm core, low pressure weather phenomenon, and to provide the elements necessary for its formation.

Very dry soil conditions in much of the eastern U.S. combined with hot but unusually dry air during the spring and early summer of 1988 led to a dramatic increase in the number of whirlwinds reported to the forecast office in Louisville. The whirlwind that developed into an apparent dust devil in New Albany, Indiana, formed on a day when soil conditions were dry, topography in the area was ideal for strong thermals, low level moisture was scant, preventing cloud development, and thus allowing the lapse rate to become strongly superadiabatic in the lowest layers.

ACKNOWLEDGEMENTS

A special thanks to Ernest Goetsch, Lead Forecaster WSFO Louisville, for his input and encouragement.

REFERENCES

Carroll, J.J. and Ryan, J.A., 1970: Atmospheric vorticity and dust devil rotation. Journal of Geophysical Research, Vol. 75, 5179-5184.

Maxworthy, T., 1973: A vorticity source for large-scale dust devils and other comments on naturally occurring columnar vortices. Journal Atmospheric Sciences, Vol. 30, 1717-1722.

McClelland, T.M., Snow, J.T. and Conner, M.D., 1986: On using dust devils to test schemes for probing tornadoes by remote sensing techniques. Preprints, 15th Conference on Severe Local Storms (Baltimore, Md.), 1988 Amer. Meteor. Soc., S9.3 319-322.

Sinclair, P.C., 1969: General characteristics of dust devils. Journal of Applied Meteorology, Vol. 8, 32-45.

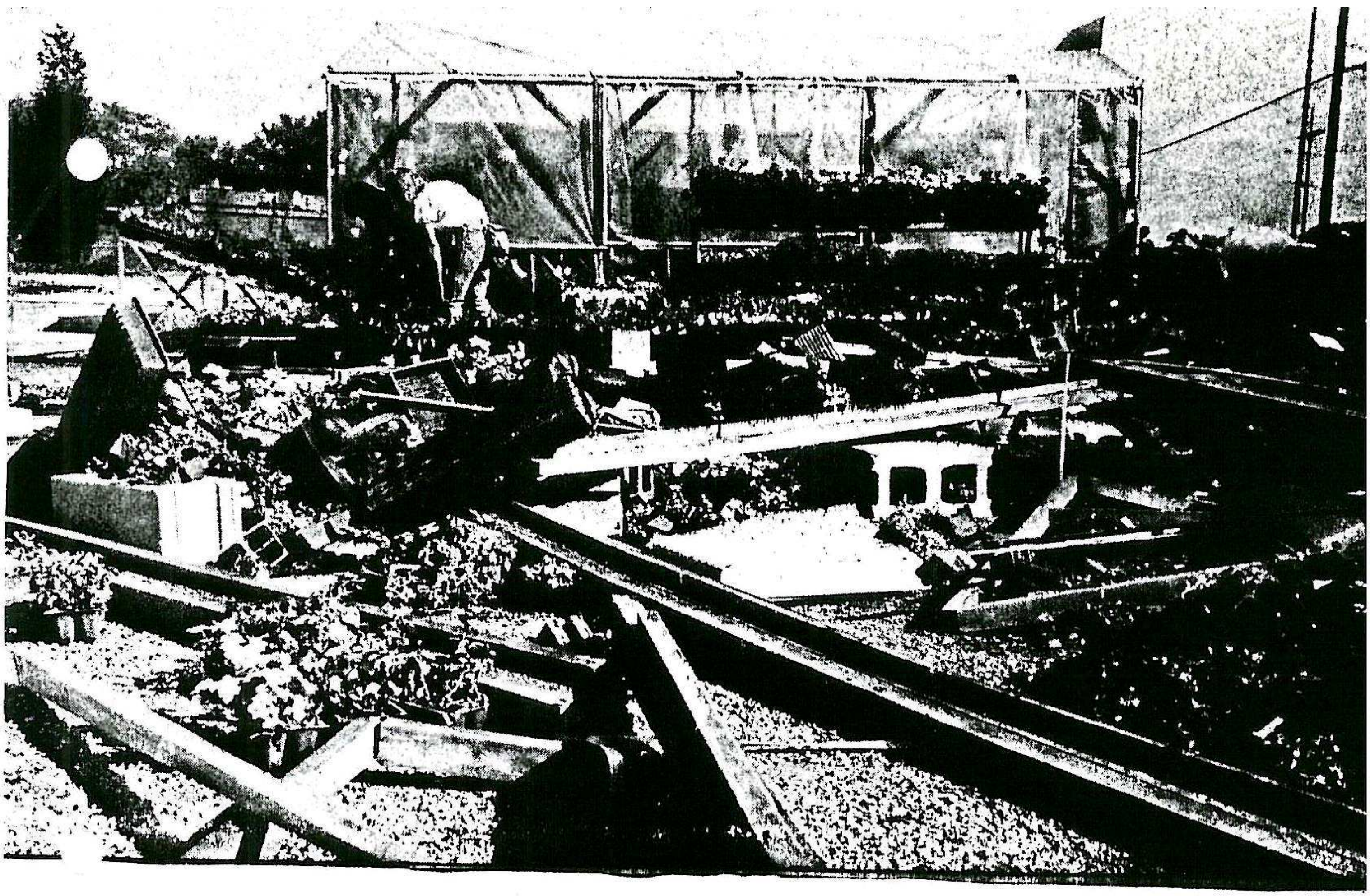

Fig. 1. Shoppers rummage through the debris left after a dust devil destroyed one of two greenhouses at a business in New Albany, Indiana.

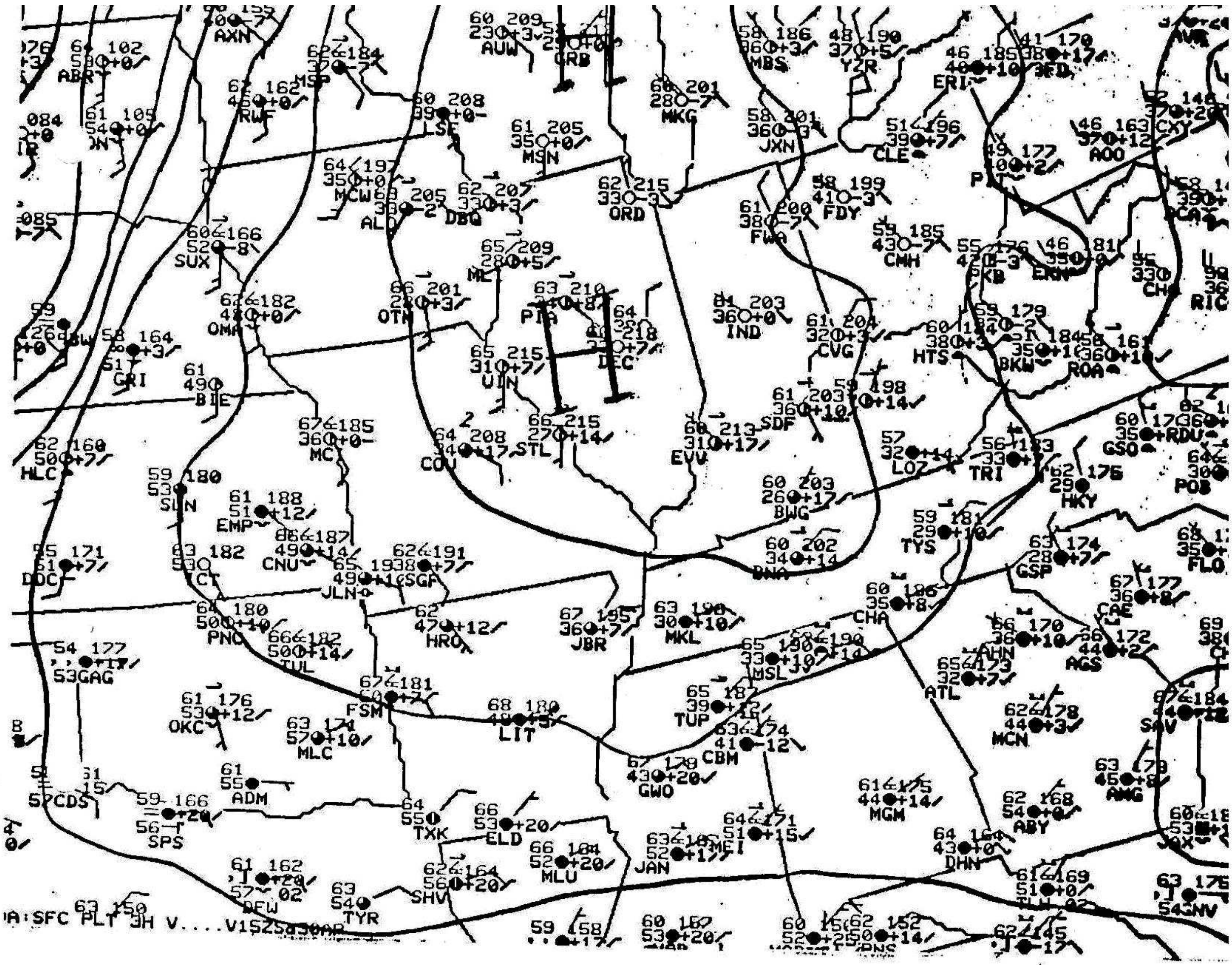

Fig. 2. 15Z surface pressure analysis (every 2 mb.)

SDF SA 2050 CLR 12 175/70/38/0707/005/FEW CU/ 717 1100
SDFSAOSDF
TTAA00 KSDF 301951
SDF SA 1950 CLR 12 182/71/38/0409/007/FEW CU
SDFSAOSDF
TTAA00 KSDF 301851
SDF SA 1850 CLR 12 189/70/37/0305/009/FEW CI
SDFSAOSDF
TTAA00 KSDF 301750
SDF SA 1750 250 -SCT 12 192/68/36/0606/010/ 810 1001 46946
SDFSAOSDF
TTAA00 KSDF 301653
SDF SA 1650 250 SCT 12 199/66/37/0608/012
SDFSAOSDF
TTAA00 KSDF 301549
SDF SA 1549 250 SCT 12 206/65/35/0705/014
SDFSAOSDF
TTAA00 KSDF 301453
SDF SA 1450 250 SCT 12 203/61/36/1706/013/ 210 1008

Table 1. Hourly observations for Louisville.
Dust devil occurred between the 1950 and 2050 obs.

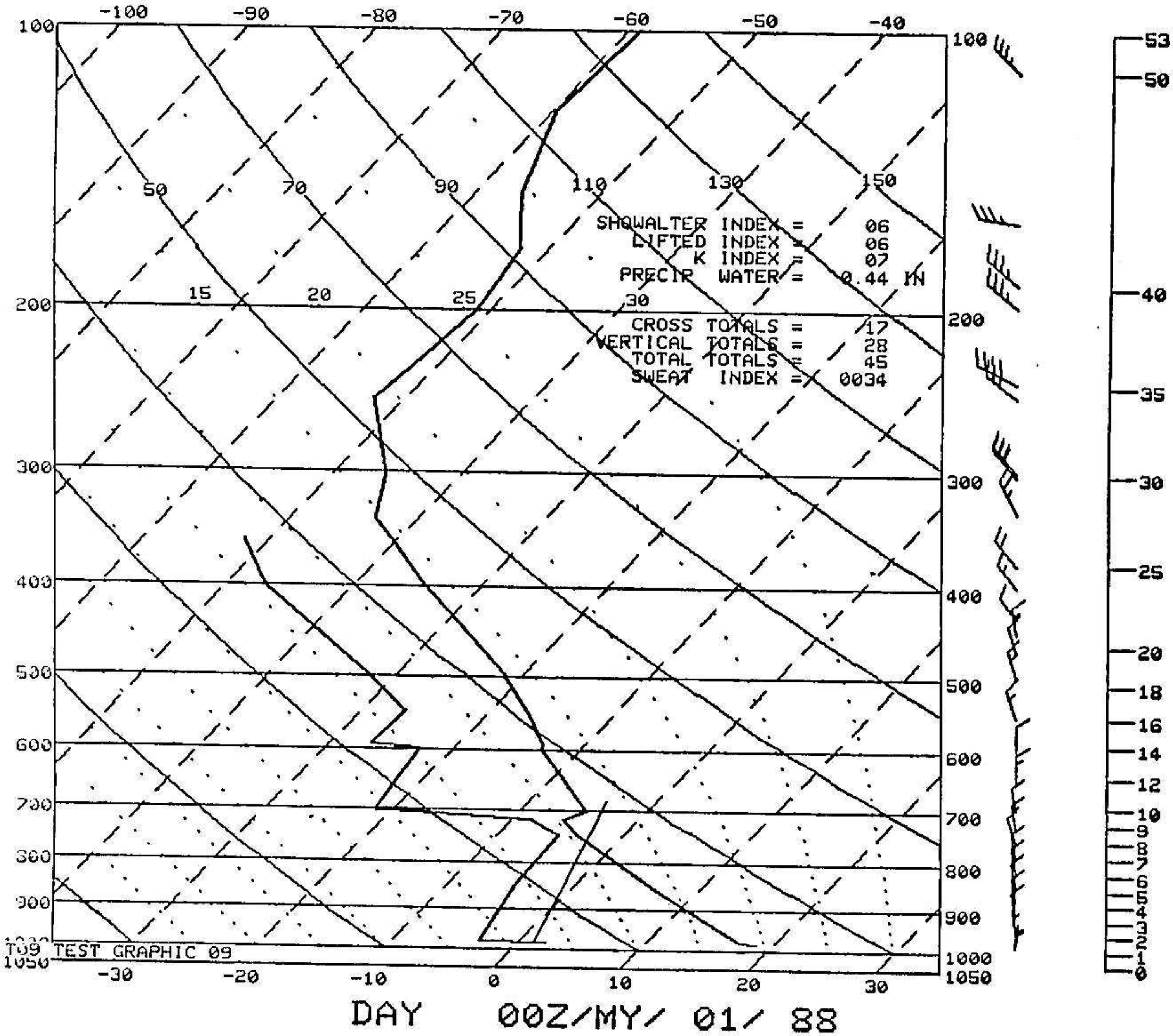

Fig. 3. 00Z May 1, 1988 Dayton, Oh. sounding