Paper No. 1

THUNDERSTORM/ENVIRONMENT INTERACTIONS THAT AFFECT SUBSEQUENT CONVECTION

R. A. Maddox and L. R. Hoxit, *NOAA, Environmental Research Laboratories, Boulder, Colorado*

ABSTRACT

Mesoscale kinematics and thermodynamics of severe thunderstorm-baroclinic zone interactions, and the development and evolution of mesoscale pressure systems associated with strong convective storms, are being studied in an ongoing research project.

INTRODUCTION

Four intensive case study days were selected - 24 April and 6 May 1975; 4 April and 27 May, 1977. All available conventional data sets have been analyzed for these days. In addition to extensive subjective analyses, computer generated objective analyses have been performed on selected data fields.

The kinematics of severe thunderstorm baroclinic zone interactions are being considered in the 24 April and 6 May cases. On both days intense tornadic development occurred as severe thunderstorm cells approached strong baroclinic zones to the east of surface moisture and thermal ridges. A review of other intense, but relatively isolated, tornado events indicates that this scenario is not unusual. Detailed time series, both of surface and sounding data, seem to indicate that horizontal and vertical wind shears within the planetary boundary layer play important roles in the concentration of mesoscale vorticity in the storm region.

The 27 May case is being used to study the temporal evolution of PBL wind fields near such a thermal boundary. At midmorning a thunderstorm outflow boundary was situated just south of the NSSL mesonet in Oklahoma and instrumented tower time series data are being utilized.

The 4 and 24 April cases have provided an opportunity to study the development and evolution of two distinctly different types of mesoscale low pressure systems. In the 4 April case at least two meso-β scale lows are detectable and the thunderstorms associated with these pressure systems produced significant severe weather. Upper-air data are being analyzed and important interactions between the storms and the larger scale flow fields have been detected. On 24 April a meso-α scale cyclonic circulation persisted and intensified during the afternoon helping to trigger storm development within a somewhat hostile larger scale environment. In the one case a mesosystem developed in conjunction with, or in response to, intense thunderstorms, while in the other case a pre-existing meso-pressure system acted to initiate storm development.

The following sections present some preliminary results of this study.

MESOSCALE VORTICITY FIELDS AND SATELLITE IMAGERY

Adler and Fenn (1977) and Peslen (1977) have related satellite data (IR cloud-top temperatures and derived wind fields) to the severity of the 6 May storms. In the present study objectively computed kinematic parameters (divergence, relative vorticity, etc.) for the surface wind fields were considered relative to GOES imagery. It was noted that most fields maximized in regions where severe storms subsequently occurred.

Barnes (1978) suggested that a tornado cyclone's ability to produce vortices in the friction layer depended upon ambient vorticity exceeding a threshold of $10^{-3}\ S^{-1}$ on scales of about 25 km. Although features on such small scales are not detectable in routine surface data, it is hypothesized that analyses of meso-β scale ambient vorticity fields might indicate the likelihood of the required vorticity threshold being reached at smaller scales. To investigate this hypothesis a vorticity time parameter was defined:

$$VTP = \frac{10^{-3} - (\xi+f)}{\{-(\xi+f)\ \nabla\cdot V - V\cdot\nabla(\xi+f)\}}\ S$$

Smaller values of VTP (negative values are not allowed) may indicate that mesoscale ambient conditions are more favorable for occurrence of intense tornadic storms. Objective analyses were accomplished utilizing an analysis scheme developed by Barnes (1973). This method employs an exponential weight function and produces a gridded and smoothed field in only one iteration. The filter response for the examples shown retained >90% of the amplitude of waves longer than 200 km. Analyses are also being considered for stronger filter responses.

A mesoanalysis of surface conditions at 2200 GMT 24 April 1975 is shown in Fig. 1. The VTP is contoured in regions of $5X10^4$S and less and 2230 GMT thunderstorm areas, from GOES imagery, are cross-hatched. The thunderstorm in NE Oklahoma was the only storm coincident with favorable mesoscale kinematic fields and it generated destructive tornadoes at 0000 and 0040 GMT. Contoured VTP fields are shown for 2000 GMT 6 May 1975 in Fig. 2 and two favorable (low value) VTP regions are superposed on a 2000 GMT GOES image in Fig. 3. One favorable area existed behind the surface front in a region where very dry air was being pulled

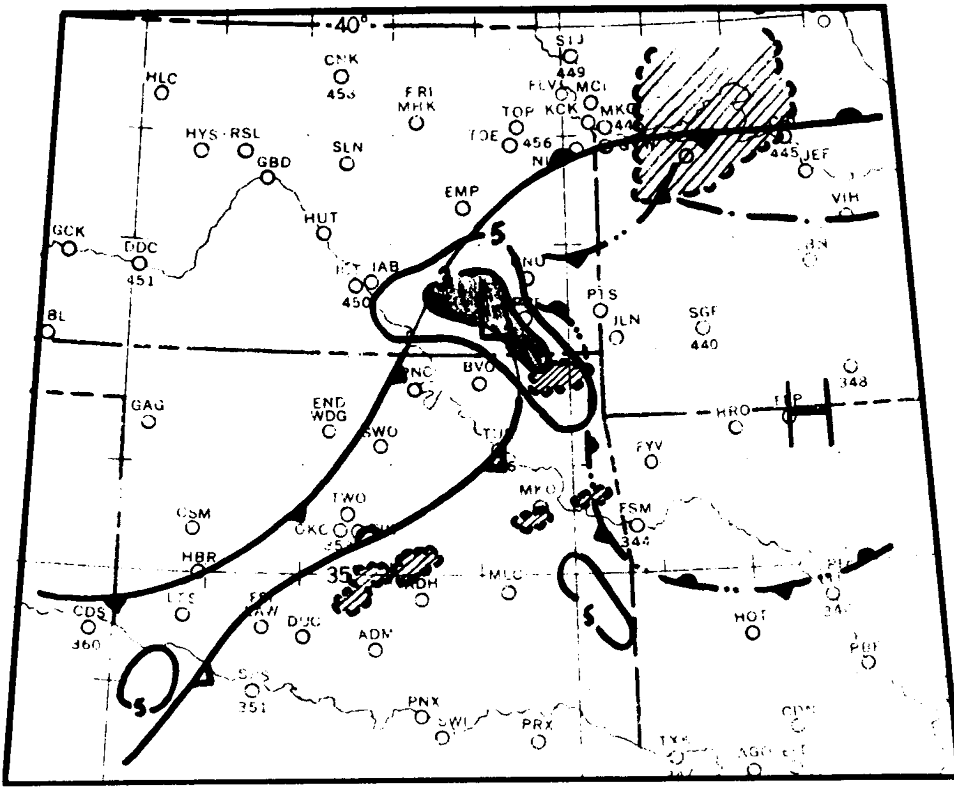

Fig. 1. Mesoanalysis of surface features at 2200 GMT 24 April 1975. VTP values are contoured and thunderstorm areas, from 2230 GOES imagery, are cross-hatched.

into a low pressure circulation. No thunderstorms existed in this dry zone; however, destructibe tornadoes occurred during the next 90 minutes in both favorable regions shown on Fig. 3.

Although only two cases have been examined, the results are encouraging and indicate that fields derived from conventional observations might be used in conjunction with satellite data to specify regions where the threat of intense tornadic events is maximizing. The short term forecast and warning applications could be valuable once such a technique is tested in many situations. An interactive data processing and analysis system, such as AOIPS, would be of great use in developing and displaying these types of data blends.

BOUNDARY LAYER WIND FIELDS NEAR THERMAL BOUNDARIES

Individual soundings and NSSL tower data, along with observational and theoretical boundary layer studies (e.g. Hoxit, 1974,

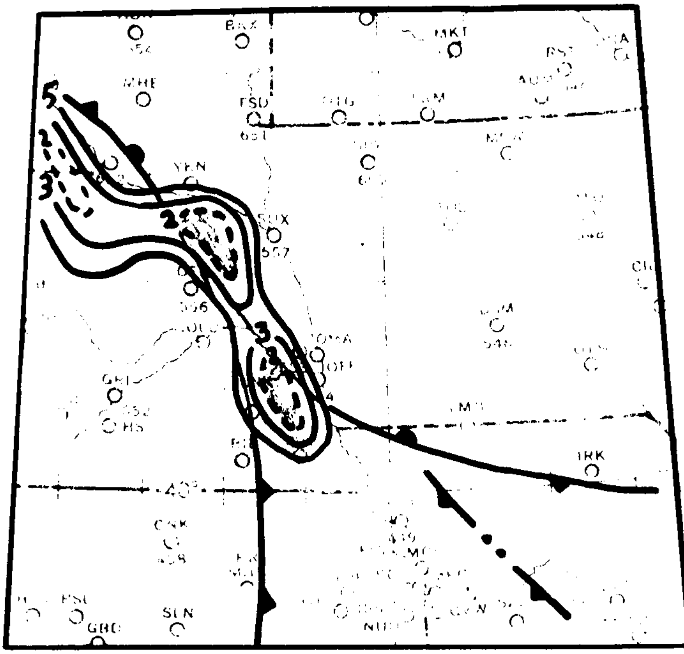

Fig. 2. Mesoanalysis of surface features at 2000 GMT 6 May 1975. VTP values of $\leq 5X10^4$ S are contoured.

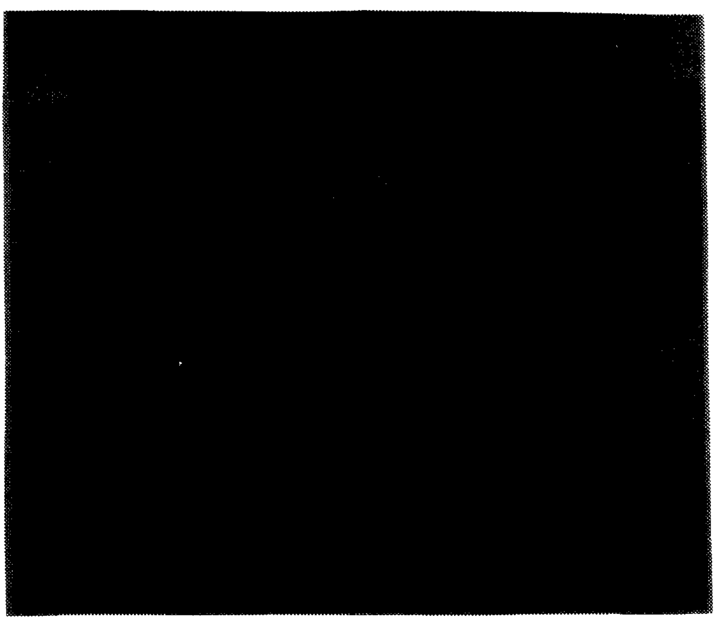

Fig. 3. Regions of VTP $\leq 2X10^4$ S within the moist air mass superposed on the 2000 GMT 6 May 1975 GOES visible image.

and Cattle, 1971), have been utilized to develop a physical model of sub-cloud wind profiles near thermal boundaries. Figure 4 shows a schematic representation of wind profiles in the lowest kilometer for three different air masses within a meso-α pattern often associated with severe thunderstorms. At point A, within a warm, dry and well mixed airmass, the wind veers slightly with height and the speed increases slowly. In the hot, moist and conditionally unstable airmass (point B) warm thermal advection and surface friction produce a wind profile which veers and increases in speed with height. At point C, in a cool, moist thunderstorm outflow region, the cold low-level thermal advection acts to decrease the veering. Winds at this point have maximum speeds near the surface and veer little with height until a transition occurs into the warmer airmass above. Within this cool, moist airmass the cross-isobaric flow is greater than in the other two airmasses.

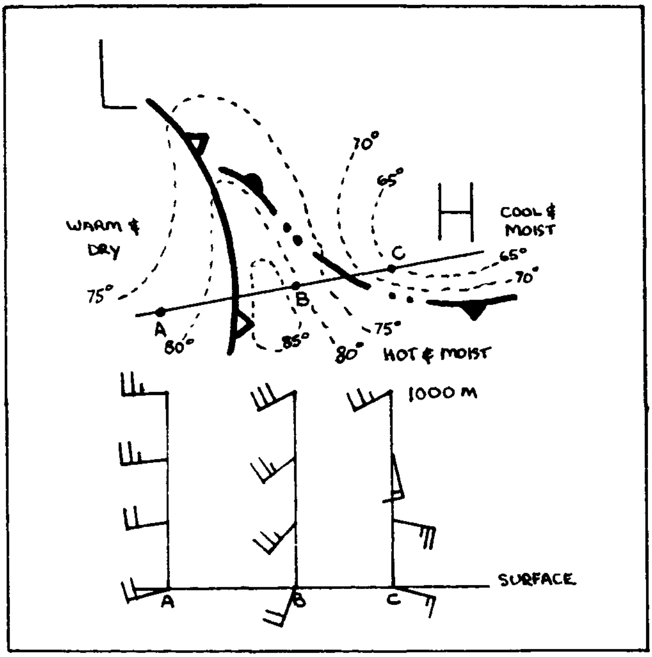

Fig. 4. Schematic representation of boundary layer wind profiles within a typical severe thunderstorm producing surface pattern. Surface features and isotherms (^{o}F) are indicated.

The Fig. 4 cross-section of wind profiles indicates that the vertical wind profiles are modified in a manner which acts to maximize convergence and cyclonic vorticity within a narrow zone along the thermal boundary between B and C. Such systematic perturbations in planetary boundary layer wind profiles may, in part, explain why storms often reach maximum intensity and become tornadic as they approach thermal boundaries. Satellite imagery and satellite derived low level wind fields might, on some occasions, be utilized to locate wind shear zones associated with thermal boundaries.

ACKNOWLEDGMENTS

This research is being partially supported by NASA Grant RC-7705.

REFERENCES

Adler, R.F., and D. D. Fenn, 1977: Satellite-based thunderstorm intensity parameters. Preprints Tenth Conf. on Severe Local Storms, AMS, Omaha, Neb., 8-15.

Barnes, S. L., 1978: Oklahoma thunderstorms on 29-30 April 1970. Part II: Radar-observed merger of twin hook echoes. Mon. Wea. Rev., 106, 685-696.

__________, 1973: Mesoscale objective map analysis using weighted time-series observations. NOAA Tech. Memo. ERL NSSL-62, 60 pp.

Cattle, H., 1971: The terrestrial low latitude boundary layer. Ph.D. dissertation, Imperial College of Science and Technology, 201 pp.

Hoxit, L.R., 1974: Planetary boundary layer winds in baroclinic conditions. J. Atmos. Sci., 31, 1003-1020.

Peslen, C. A., 1977: A satellite interpretation of the dynamics of a severe local storms area using 5 minute interval SMS data. Preprints Tenth Conf. on Severe Local Storms, AMS, Omaha, Neb., 1-7.