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PRELIMINARY ANALYSIS OF SOUNDINGS FROM VORTEX-95

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1. INTRODUCTION

As a part of the 1995 field phase of the Verification of the Rotation in Tornadoes EXperiment (VORTEX-95) (Rasmussen et al. 1995), a large number of upper air soundings were collected. These included regular and special soundings from the standard National Weather Service (NWS) rawinsonde network and soundings from both fixed and mobile platforms using the Cross-chain LORAN Atmospheric Sounding System (F-CLASS and M-CLASS, respectively). Fifty or more soundings were collected in or near the VORTEX domain on operational days, with the F-CLASS sites at Lubbock (LBB), Woodward (WWR), Altus (LTS), and Ardmore (ADM) launching balloons with nominal times of 1200, 1800, 2100, and 0000 UTC and the NWS sites at Topeka (TOP), Dodge City (DDC), Amarillo (AMA), Midland (MAF), Norman (OUN), and Fort Worth (FWD) launching 1800 and 2100 UTC soundings when requested, in addition to their normal 1200 UTC and 0000 UTC soundings (Fig. 1). Beyond that, M-CLASS soundings were taken by up to 5 vehicles on certain days. Some of these vehicles had missions to collect soundings in the updrafts of thunderstorms, while others sampled the environment at locations not covered by the fixed sites. Taken together, these soundings provide a picture of the evolution of the environment associated with severe thunderstorms than is available on a typical day, when a special observational project is not taking place. In this paper, we examine the soundings taken on two VORTEX operational days, 19 April and 2 June 1995. These days have been chosen for presentation because of the particular interesting problems that the

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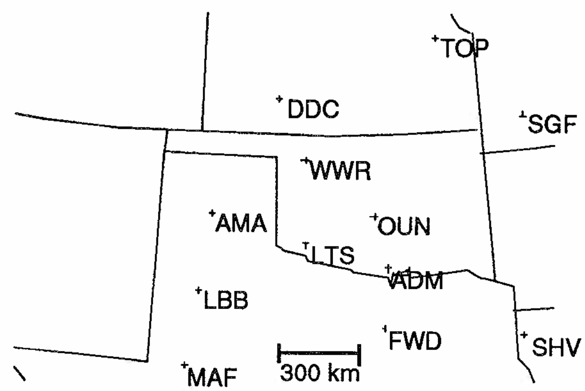

Fig. 1: Map of NWS and F-CLASS sounding sites for VORTEX-95.

soundings illustrate, both from the perspective of our scientific understanding of tornadic storms, and for the difficulties that the events provide for operational forecasters.

2. 2 JUNE 1995

On 2 June 1995, strong to violent tornadoes occurred near the small towns of Friona and Dimmitt, Texas, northwest of Lubbock (Watson et al. 1996), as part of a large supercell outbreak in the Texas Panhandle and northeastern New Mexico. VORTEX field and aircraft teams collected data on both of these storms. The environment of the southern Texas Panhandle was characterized by strong gradients, particularly in the moisture field. Soundings launched at approximately 2100 UTC (about the time that the supercells initiated near the Texas-New Mexico state line west of Lubbock) from four locations illustrate this variability well (Fig. 2). The two soundings nearest the convection, those taken by NSSL4 (Fig. 2a) and LBB (Fig. 2c) are

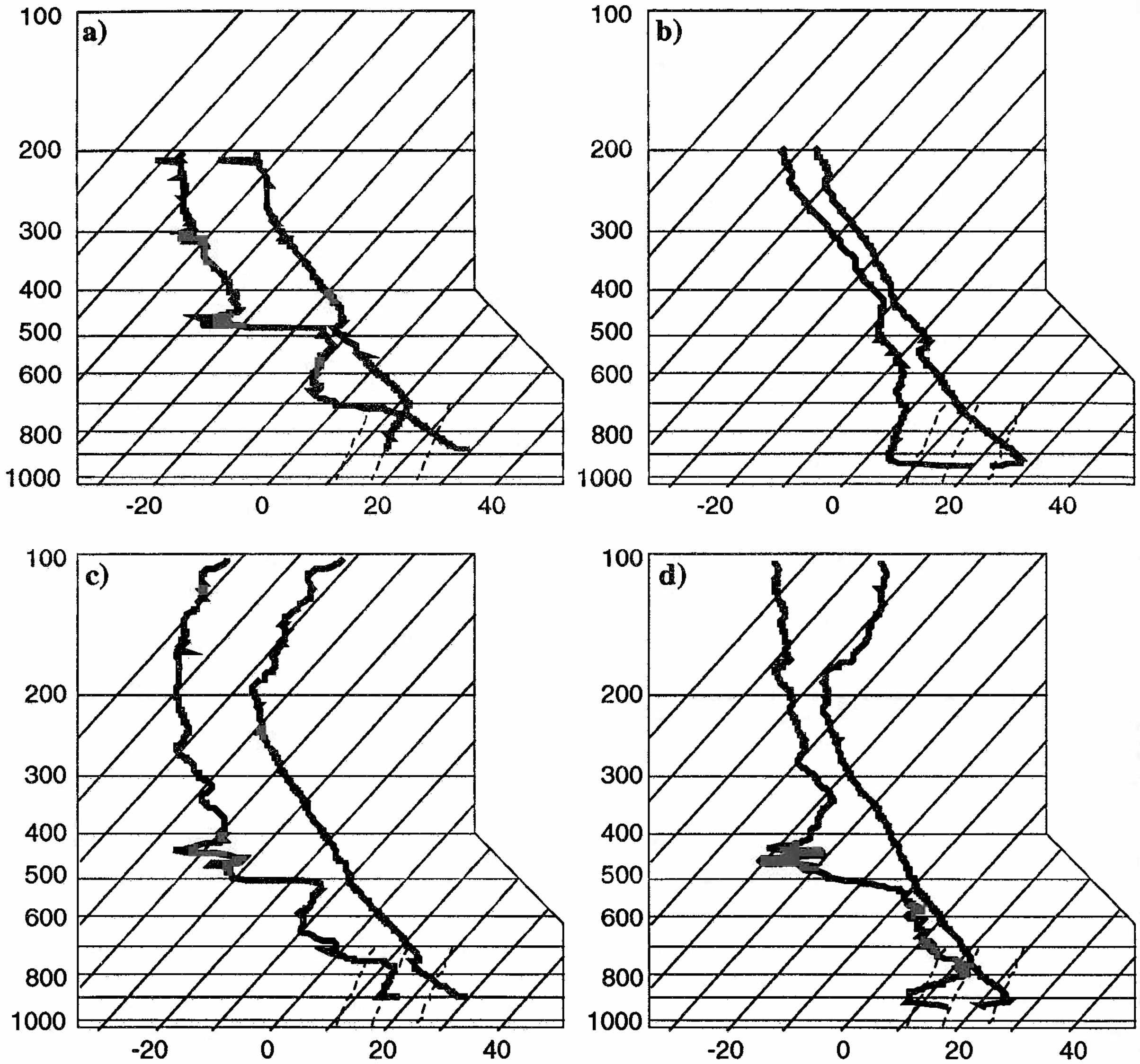

Fig. 2: Skew-t plots of soundings launched near 2100 UTC 2 June 1995. a) M-CLASS from vehicle NSSL4 approximately 160 km NW of LBB (launched at 2058 UTC). b) F-CLASS from LTS (2107 UTC). c) F-CLASS from LBB (2014 UTC). d) M-CLASS from vehicle NSSL3 approximately 110 km W of LTS (2018 UTC). Short dashed lines are mixing ratio lines of 8, 12 and 20 g kg-1, from left to right, respectively. Data plotted are raw 10-second observations.

similar in the low-levels, with a well-mixed layer of 12 g kg^{-1} boundary layer air approximately 100 mb deep. The eastern soundings, however, show a dry layer just off the surface. This is particularly true of the LTS sounding, where the moisture is apparently on the order of 20 mb deep (Fig. 2b). The NSSL3 sounding shows a shallower dry layer than LTS, but is moister than any of the other soundings from 800-500 mb. This elevated moisture is sufficient to make the column-integrated precipitable water approximately equal in all of the soundings except that from LTS. It is clear, however, that the potential for boundary layer-based convection is different for the three "wet" soundings. This serves as a note of caution for the application of column-integrated precipitable water values, from remote-sensing platforms, for the purpose of determining the convective potential of the atmosphere. Note also that all of these soundings are taken within a quadrilateral of four NWS sounding sites, at off-synoptic times, so that the information on the gradients presented here would be unavailable to the operational forecast community. Because of the very shallow moisture at LTS and NSSL3, even the use of surface observations would not help in identifying the gradients.

An even more dramatic example of the gradients observed on 2 June can be seen in soundings taken

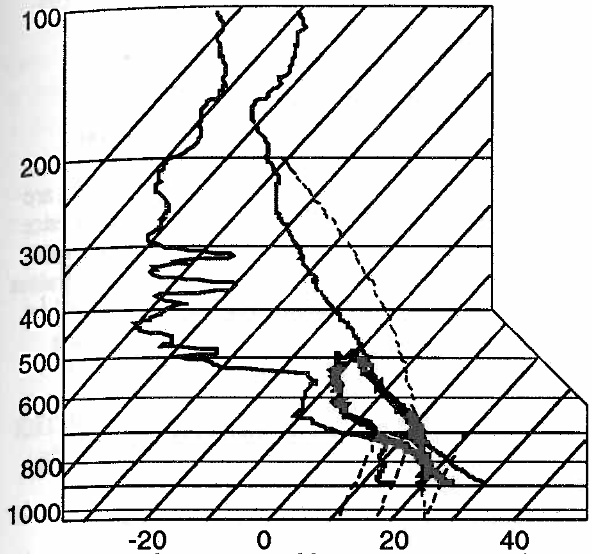

Fig. 3: Soundings from Lubbock (light line) and a location about 60 km north of Lubbock (heavy line) launched near 2300 UTC 2 June 1995. Curved line is 24°C pseudoadiabat and short dashed lines are constant mixing ratios of 8, 12, and 20 g kg-1, from left to right.

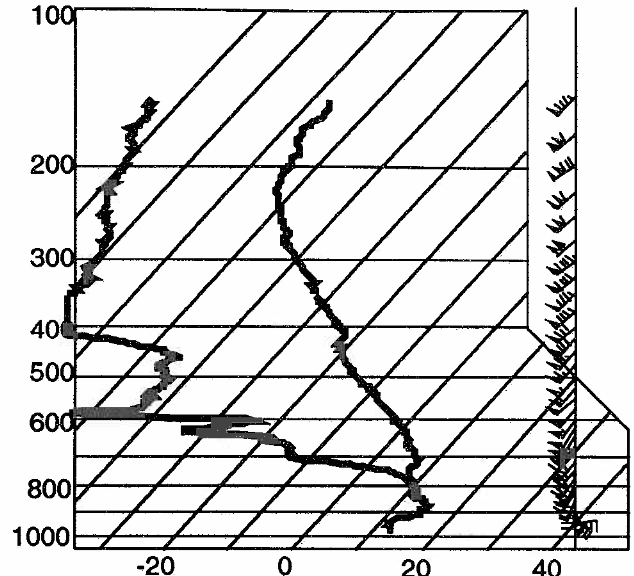

Fig. 4: F-CLASS sounding from ADM, launched at 2315 UTC 19 April 1995.

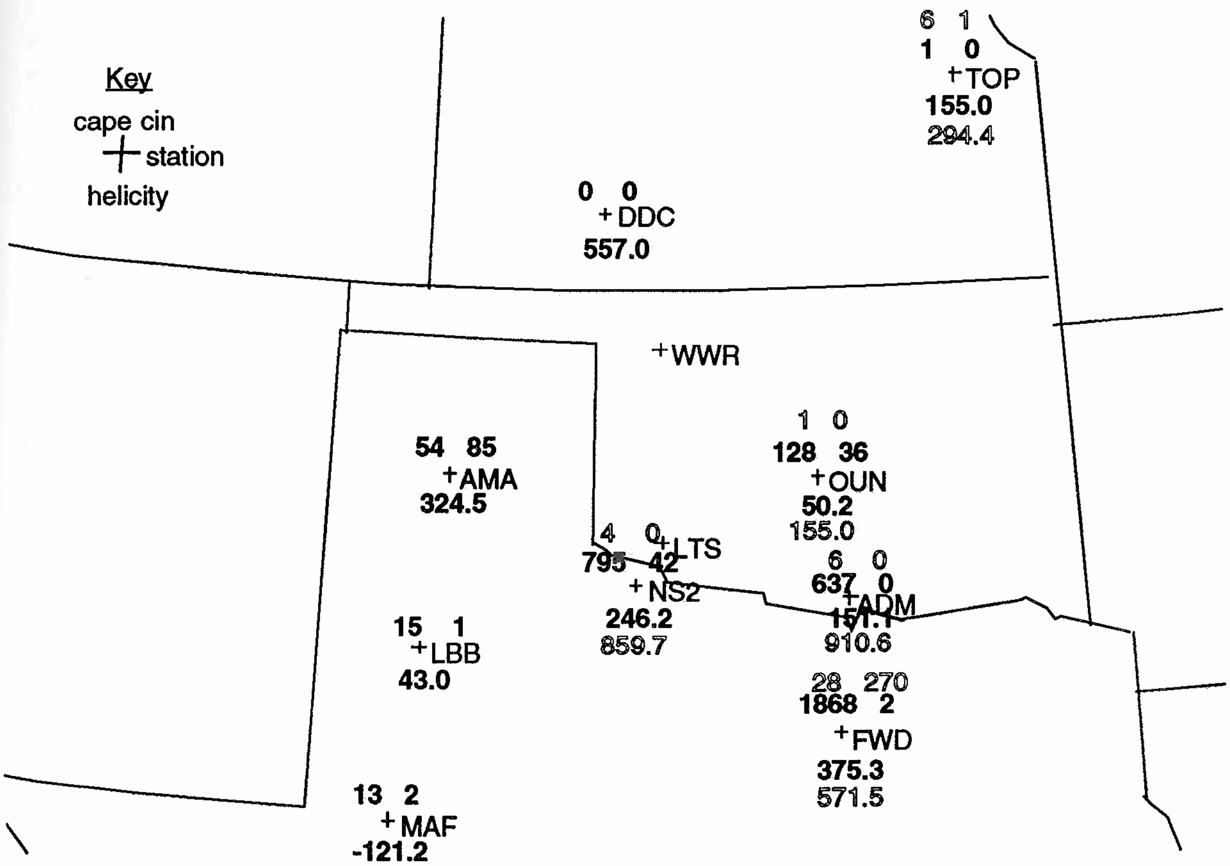

Fig. 5: Parameters for soundings with nominal time of 0000 UTC 20 April 1995. Station model at upper left. Outlined values are for entire sounding. Bold values are for parcel lifted from top of inversion layer.

during the violent tornadoes (Fig. 3). Over the distance of approximately 100 km, the well-mixed boundary-layer increases from approximately 10 g kg^{-1} at LBB to 16 g kg^{-1} at the NCAR sounding. This results in an increase of the computed CAPE value from about 1100 J kg^{-1} to 3500 J kg^{-1} (using the upper part of the sounding from LBB for the environment) and a lowering of the level of free convection from 690 mb to 800 mb. Again, since these are special soundings, operational forecasters would be unaware of these significant gradients in thermodynamics. Both of these soundings would be considerered "proximity" soundings, by any definition. This calls into question the nature of what is meant by proximity and the meaning of any previous studies using proximity criteria to identify environmental conditions. The existence of strong storm-produced gradients in the vicinity of convective storms has been modelled and the implications for our understanding of severe convection discussed in Brooks et al. (1994).

3. 19 APRIL 1995

Storms formed over a wide area of north Texas on 19 April 1995. Tornadoes were reported in the early afternoon south and east of Dallas, in the late afternoon northwest of Abilene, Texas, and, near dark, north of Wichita Falls, Texas near the Red River in Texas and Oklahoma and in Fort Worth. In part because of the widespread convection occurring near the boundaries of the VORTEX domain very early and late in the operations period, as well as the rapid storm motion, VORTEX did not collect data on any of the storms on this day. The environmental soundings are of interest, however. A typical sounding from southern Oklahoma and northern Texas is characterized by a deep surface inversion (Fig. 4). In the surface layer, winds veer rapidly with height, producing large values (nearly 1000 J kg^{-1}) of 0-3 km Storm-Relative Environmental Helicity (SREH), given the observed storm motion. Boundary layer parcels, however, show near zero values of Convective Available Potential Energy (CAPE).

We have also calculated values of SREH and CAPE for parcels immediately above the inversion layer for comparison (Fig. 5). Parcels from above the inversion layer have significantly higher values of CAPE (up to more than 1800 J kg^{-1} at FWD), while having much lower SREH (O~150 J kg^{-1}). This raises questions about the nature of the environment that the thunderstorms near the Red River "saw" that evening. In order to get a significant value of CAPE, the relevant parcel had a much lower SREH than the entire depth of the sounding indicated. In addition, deep surface inversion layers do not fit current conceptual models of supercell tornadogenesis. Thus, there are several interesting questions for future research raised by the 19 April soundings.

4. DISCUSSION

VORTEX-95 collected a large number of soundings about the environmental conditions on a number of days on which tornadoes occurred. We have examined two of those days to identify features that are of scientific and operational importance. The existence of extremely strong gradients in thermodynamic has been known at least anecdotally for some time. It raises serious questions about the meaning of "proximity" as applied to storm environments, as well as providing difficulties for the operational assessment of storm environments that should, conceptually, help in severe weather forecasting and warning. Second, the VORTEX soundings have captured environmental conditions that do not fit the current conceptual models for tornadogenesis. Again, these raise important questions for the operational assessment of storm threat.

5. ACKNOWLEDGMENTS

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