CENTRAL REGION TECHNICAL ATTACHMENT 96-03

REAL-TIME MONITORING AND RECONSTRUCTION OF A SEVERE THUNDERSTORM ENVIRONMENT USING UNIQUE DATA SETS

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1. Introduction

A hallmark of National Weather Service (NWS) modernization is the acquisition and use of new data sets in the operational realm. These data can also be invaluable in post analysis of major events. The Weather Service Forecast Office (WSFO) Chicago has been fortunate to have access to two rather unique data sets that have shed considerable light on both meso and synoptic scales of the atmosphere. These data sets are ACARS and SODAR. Both are briefly described below, then an application is shown.

2. Discussion

Many commercial jet aircraft are now equipped with a communications system known as ACARS (ARINC[1] Communications Addressing and Reporting System) that transmits information from the aircraft to ground receiving stations and airlines. The information includes airline system (gate assignment, etc.), aircraft performance, and weather data. The latter include temperature and wind speed/direction reported at 300-2,000 foot intervals during ascent and descent, and at six minute intervals during level flight.

ACARS has been used as information for initial analyses of NCEP models. Even though it is an important data source for the Rapid Update Cycle and research, ACARS is relatively unknown to most meteorologists in its "raw" form. A few airlines have made this information available locally to a nearby NWS office. United Airlines has provided the NWS Chicago office with this data for the last three years, and it has become an important source of data in many forecast and research situations.

A recent airline decision to allow ACARS weather data to become more widely available (to the operational community) has allowed NWS Chicago forecasters access to current ACARS data in the northern hemisphere through Forecast Systems Laboratory (FSL). This is an experimental arrangement that may be expanded to the extent the computer and network capabilities allow. Access is through the World Wide Web.

The abundant ACARS data from the O'Hare vicinity has allowed forecasters to more accurately predict the precipitation type of winter storms, high and low temperatures, lake effect snow and strong winds. We recently found the data to have very important applications in an environment favorable for thunderstorm development, allowing real-time assessment of vertical wind shear and stability.

The Illinois Dept. of Nuclear Safety acquires real-time boundary layer wind data (plus many other surface parameters) using SODAR (SOund Detection And Ranging) at the Zion Nuclear Power

[1]Aeronautical Radio Incorporated

plant near Zion, Illinois. The site is on the Lake Michigan shoreline just south of the Wisconsin/Illinois state line. This state agency uses this data for emergency planning and monitoring purposes.

SODAR is in effect a three beam acoustical Doppler radar. Rather than probing with electromagnetic waves, sound waves are employed. Three "beams", similar to that used in the profiler network are used to calculate Doppler shift for wind measurements. Vertical range of the return is generally limited to 500 meters or less but resolution is about 20-30 meters. Data is frequently displayed as a time series (similar to profilers) using 15 minute average winds. Thus a very detailed profile in both time and space of the lowest elevation is the boundary layer is possible from this equipment.

The two data sites, O'Hare International (ACARS) and the Zion SODAR, are very complimentary in that they are physically about 25 nmi apart and the SODAR data ends at 400-500 meters (1300-1500 ft) AGL while ACARS begins about 1400 ft AGL. This makes for a "complete" profile and allows cross checking for consistency.

3. Case Study: April 19, 1996

A High Risk area of severe thunderstorms was issued for virtually all of Illinois for the afternoon of April 19, 1996. Moisture was returning rapidly northward through the state while a very strong and favorable wind field was evolving. Most tornadoes and large hail occurred south of Chicago as the deep moisture field remained across central Illinois. Despite marginal moisture in the lowest layers a very strong shear profile favorable for tornadoes extended into northeast Illinois and supported a number of supercells, one of which produced 3½ inch hail in Livingston County (240 deg/50 nmi from ORD).

Profiler data has allowed forecasters to view the evolution of the wind field during severe events. With the use of ACARS data available at WSFO Chicago we can monitor changes in both the wind and temperature profiles simultaneously. In real-time this is valuable information, for example to monitor the status of any capping inversion, while in post event analysis one can reconstruct a sequence of events with some certainty.

Figure 1 shows the ambient atmospheric conditions at ORD for about 1247 UTC 19 April. This is ascent or descent data from commercial aircraft using ORD. A mid level stable zone is evident as well as a rather uninspiring wind field.

Progressing through Figures 2 and 3 (1625 UTC and 1804 UTC) a capping inversion persists just below 600mb while the lowest layers warm. A more favorable low level veering signature in the wind field gradually appears. Figure 4 is an approximate hodograph (using SHARP) from Figure 3. Storm motion (arrow) is that observed a few hours later in the convection that developed. Benchmark helicity values remain well below 100.

During the following 6 hours, Figures 5-7 (every other hour) lapse rates below the capping inversion steepen under the influence of surface heating. By 0030 UTC, Figure 7, precipitation is occurring at ORD and is reflected in the cooling below 800mb. The cap has eroded near 600mb. A more impressive feature is the strongly sheared environment now present. It is certainly indicative of the tornadic situation occurring further south. Benchmark helicity values have zoomed to nearly 700 m^2/s^2 in the 0-3km layer (Figure 8). Storm relative inflow approaches 60 kts.

The corresponding SODAR data from the Zion Nuclear plant is seen in Figure 9. Length of the arrows reflect speed while direction is a conventional interpretation (i.e., up arrow is a south wind, etc.). An increasing easterly flow is evident after 1200 LST (1700 UTC) with the veering signature reflected even in these lowest layers. A line of thunderstorms causing wind damage passed the site around 2215 LST (0315 UTC) 20 April.

An example of a supercell that developed in this environment is seen in Figure 10. This 4-panel display shows the strong reflectivity gradient and BWER associated with this cell. The associated VAD wind profile from the KLOT WSR-88D is shown in Figure 11. Several reports of funnels and weak F0 tornadoes were received from this storm. Most notable, however, was the 3½ inch hail observed about the time of the image.

4. Summary

The intent of this discussion was to illustrate the utility of ACARS and SODAR data to monitor and reconstruct (and by that better understand) a severe local storm environment. These data vividly illustrated the rapid changes that can occur at a locality during a severe thunderstorm episode.

At this time both data sources are unique to an operational forecaster. SODAR may be a singular data set to northeast Illinois. ACARS wind and temperature profiles, on the other hand, are dependent upon ascent/descent data that are often more abundant at major airports (particularly hubs). Most of this data has an initial altitude of 2000 ft MSL that skips the true boundary layer. However, recent inclusion of nocturnal data from UPS (overnight delivery service) flights include winds/temperatures from the surface at 300-600 ft intervals. Thus a real-time nocturnal "sounding" can be obtained from locations where these aircraft operate. This information can supplement that generated by the meso-eta and RUC models or the WSR-88D radar.

An important point is that real-time data such as SODAR and ACARS, along with model output sets can address operationally significant problems such as ongoing changes in the atmosphere between 12-hourly RAOBs and at locations far distant from these fixed sites. The data can also serve as a critical supplement to model generated soundings. The case study is only one of many instances where short term forecasts for the Chicago area were measurably affected and improved using such resources.

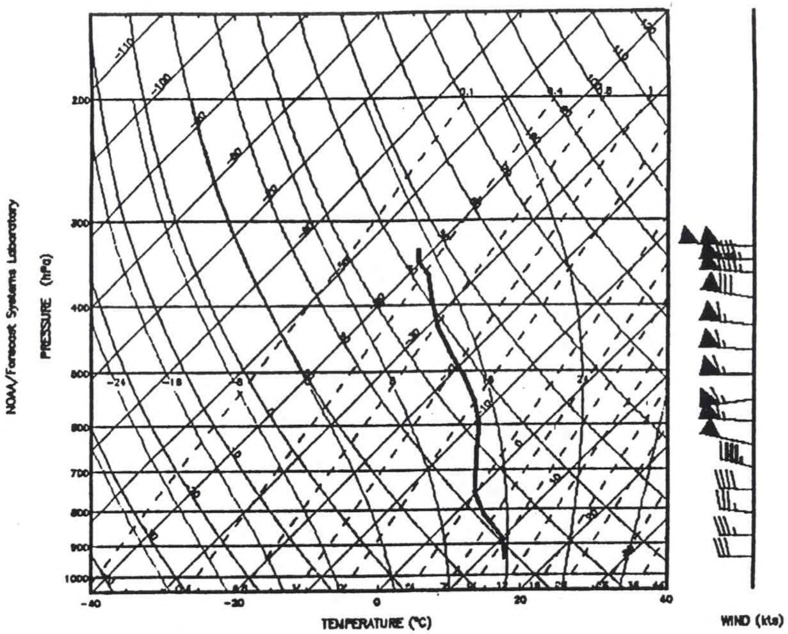


Figure 1. Aircraft sounding from ORD toward GRR on April 19, 1996 starting at 1247 UTC, lasting 30 minutes and covering 269 km.

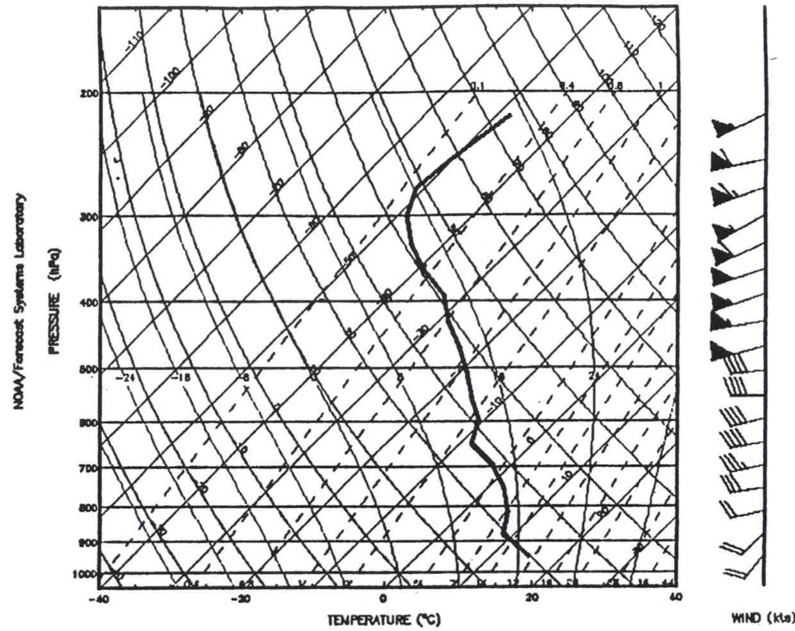


Figure 2. Aircraft sounding from ORD toward MLI on April 19, 1996 starting at 1625 UTC, lasting 37 minutes and covering 497 km.

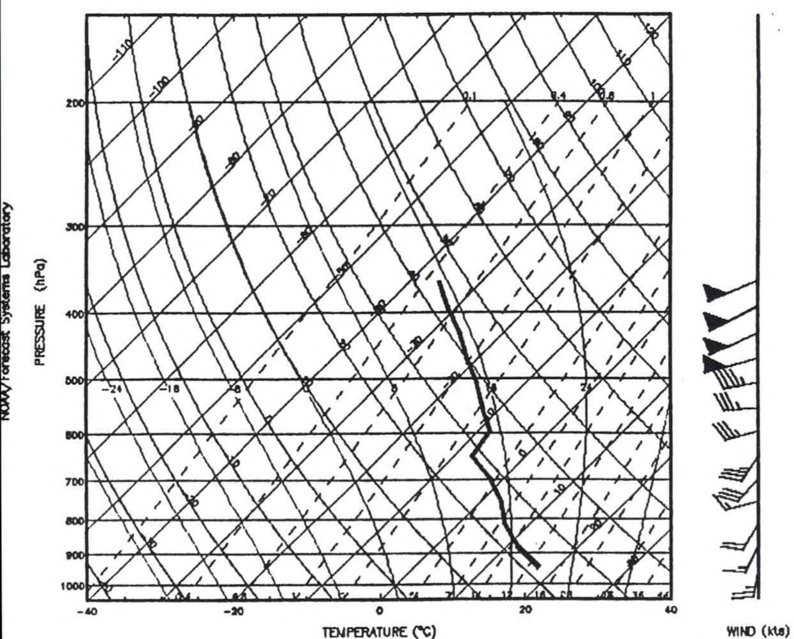


Figure 3. Aircraft sounding from MSN toward CID on April 19, 1996 starting at 1804 UTC, lasting 124 minutes and covering 104 km.

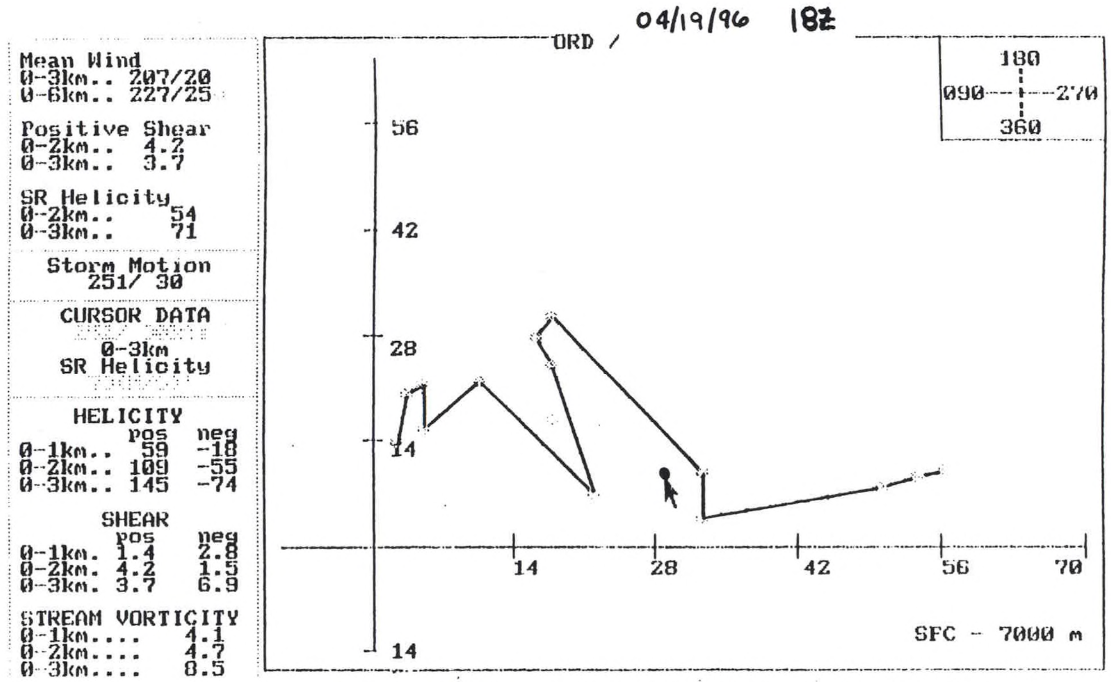


Figure 4. SHARP Hodograph presentation of the velocity field utilizing the same aircraft sounding data for Figure 3, approximately 1800 UTC 19 April 1996.

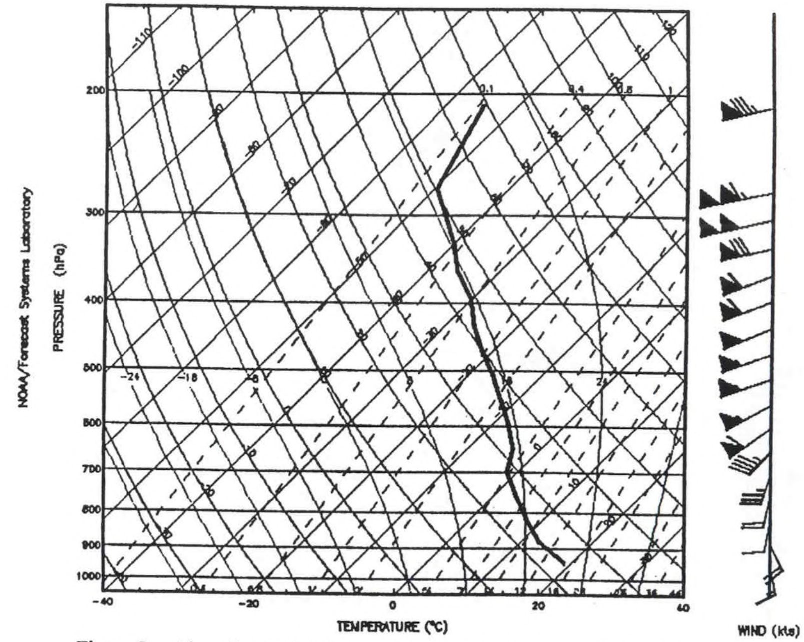


Figure 5. Aircraft sounding from SBN toward OMA on April 19, 1996 starting at 2040 UTC, lasting 23 minutes and covering 223 km.

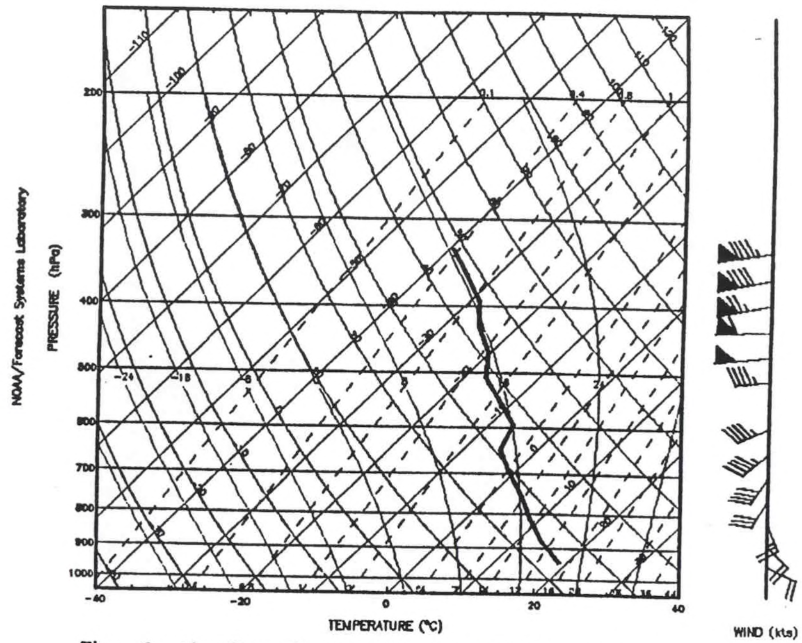
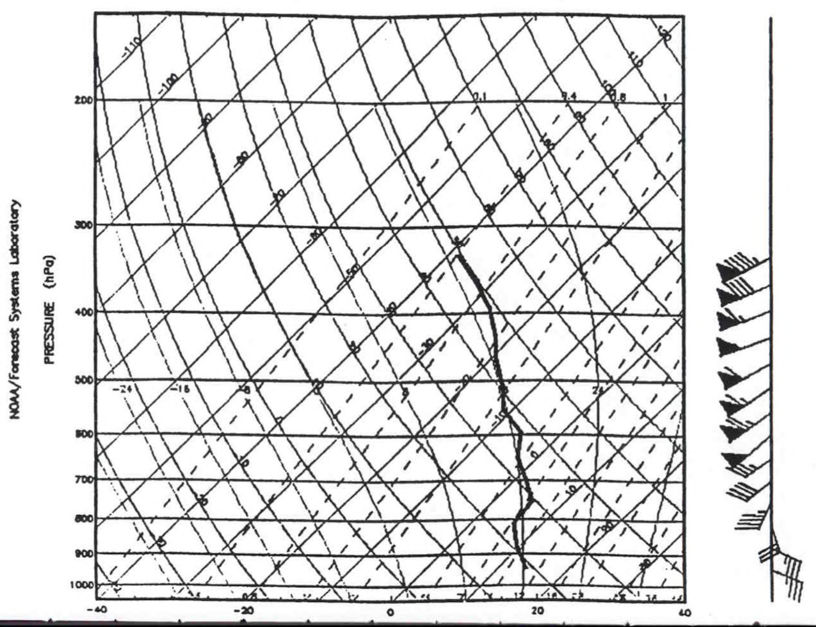
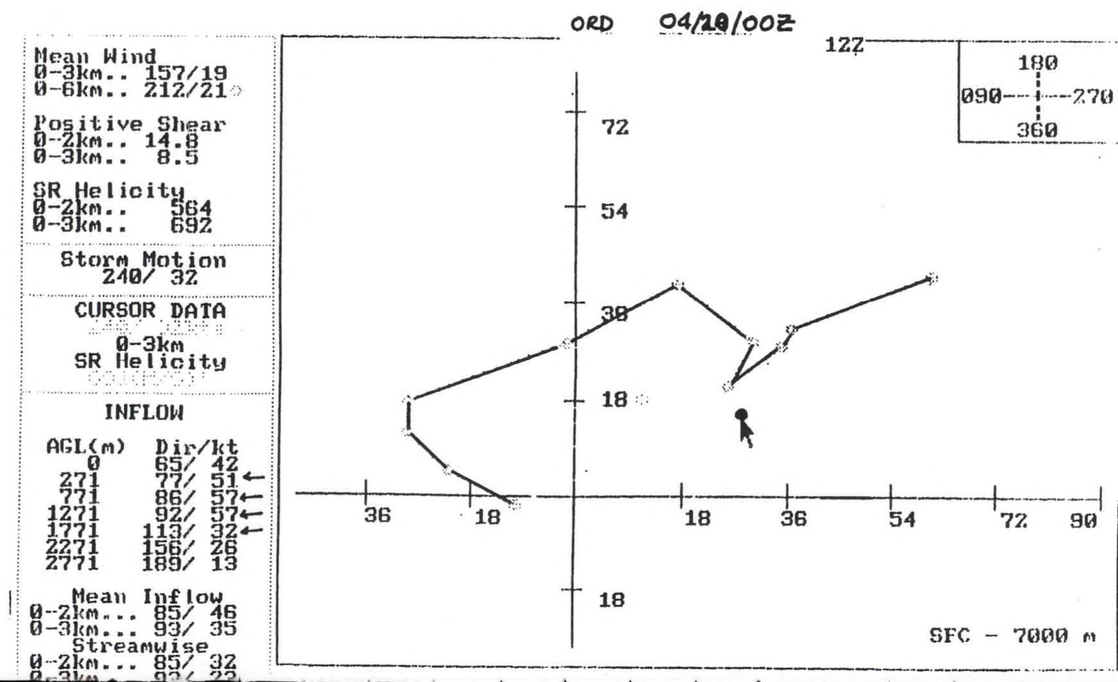


Figure 6. Aircraft sounding from SBN toward SBN on April 19, 1996 starting at 2244 UTC, lasting 14 minutes and covering 138 km.





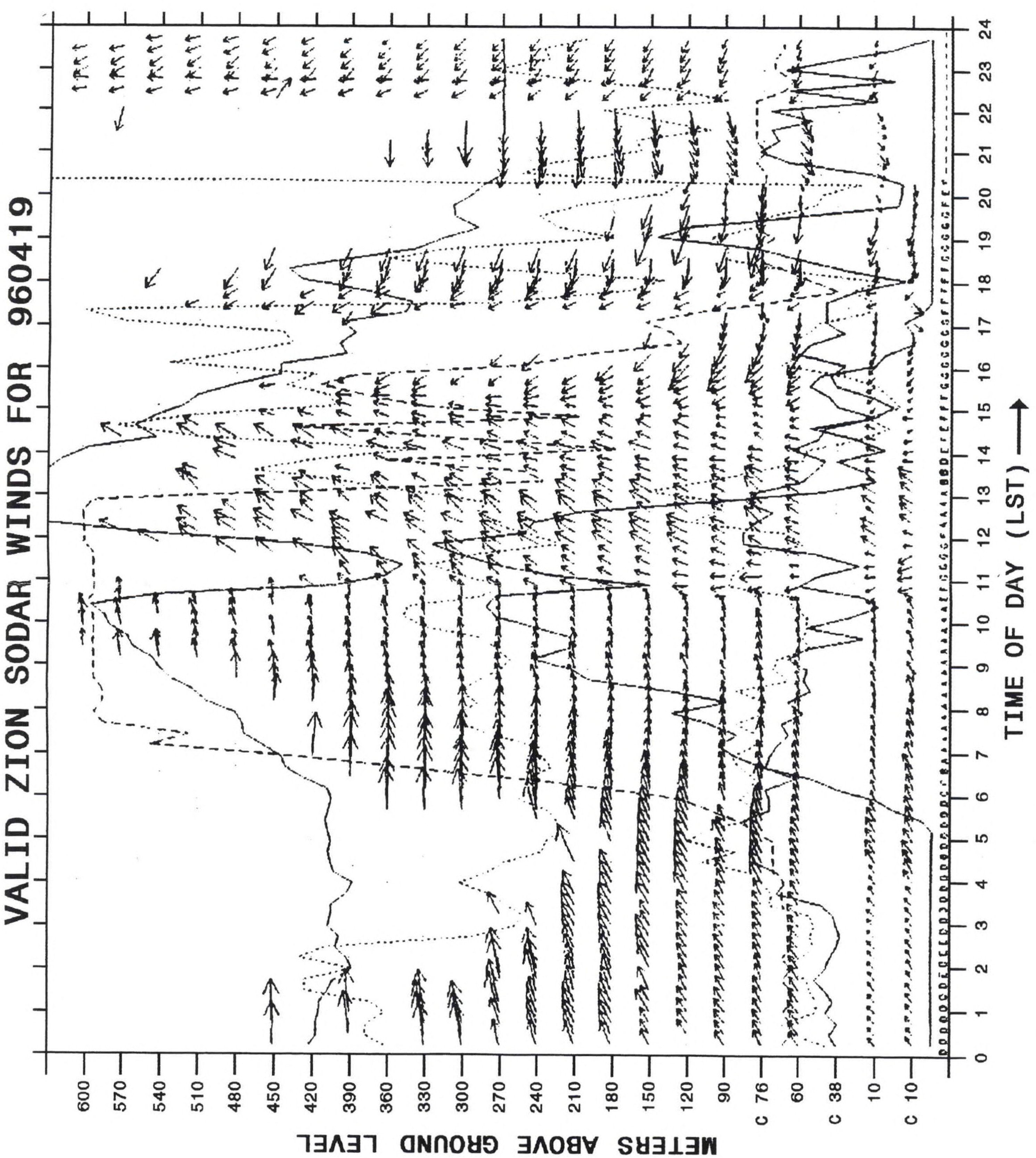


Figure 9. SODAR time series plot from the Zion Nuclear Power plant on April 19, 1996. Refer to the text for additional details.

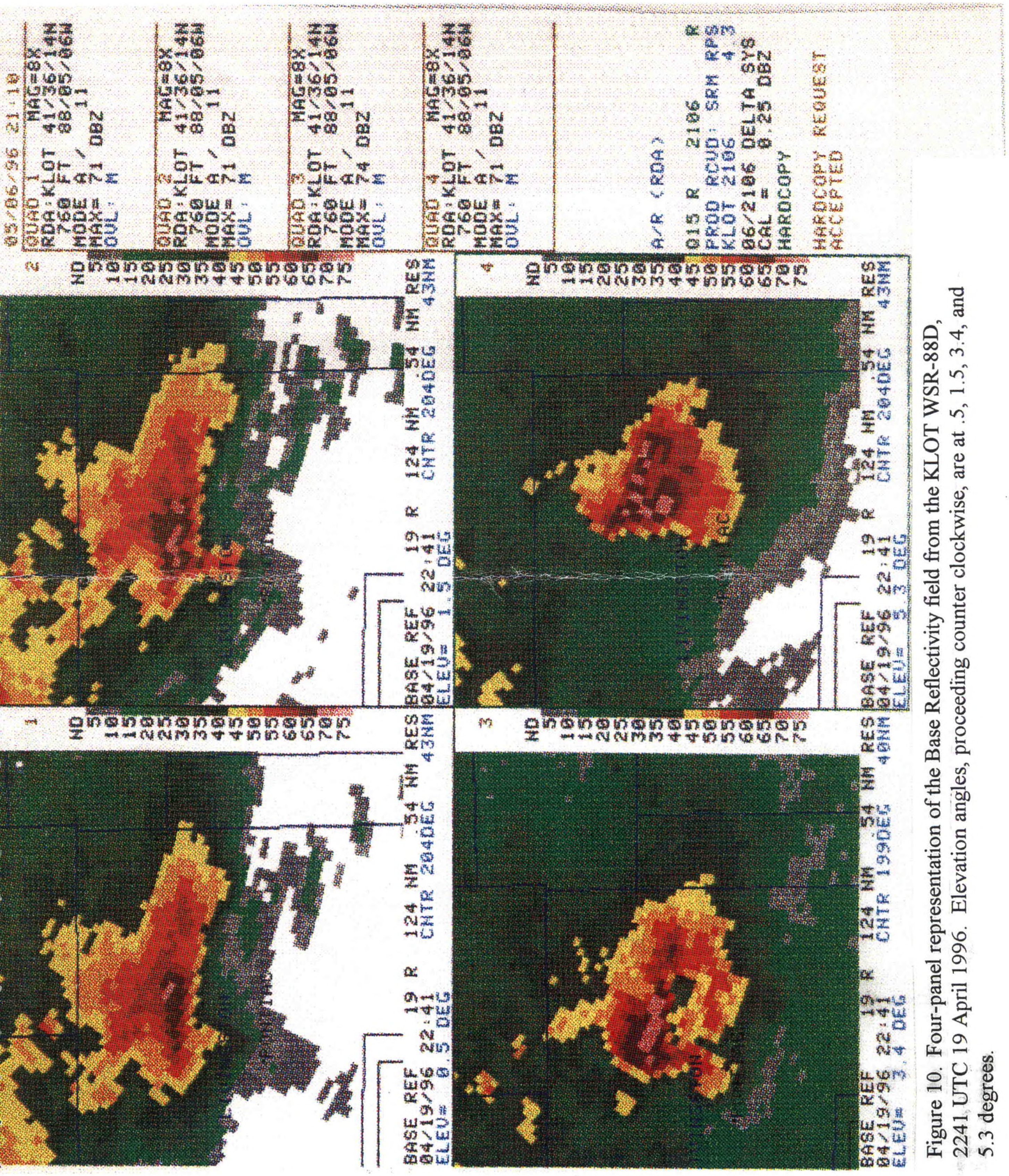


Figure 10. Four-panel representation of the Base Reflectivity field from the KLOT WSR-88D, 2241 UTC 19 April 1996. Elevation angles, proceeding counter clockwise, are at .5, 1.5, 3.4, and 5.3 degrees.

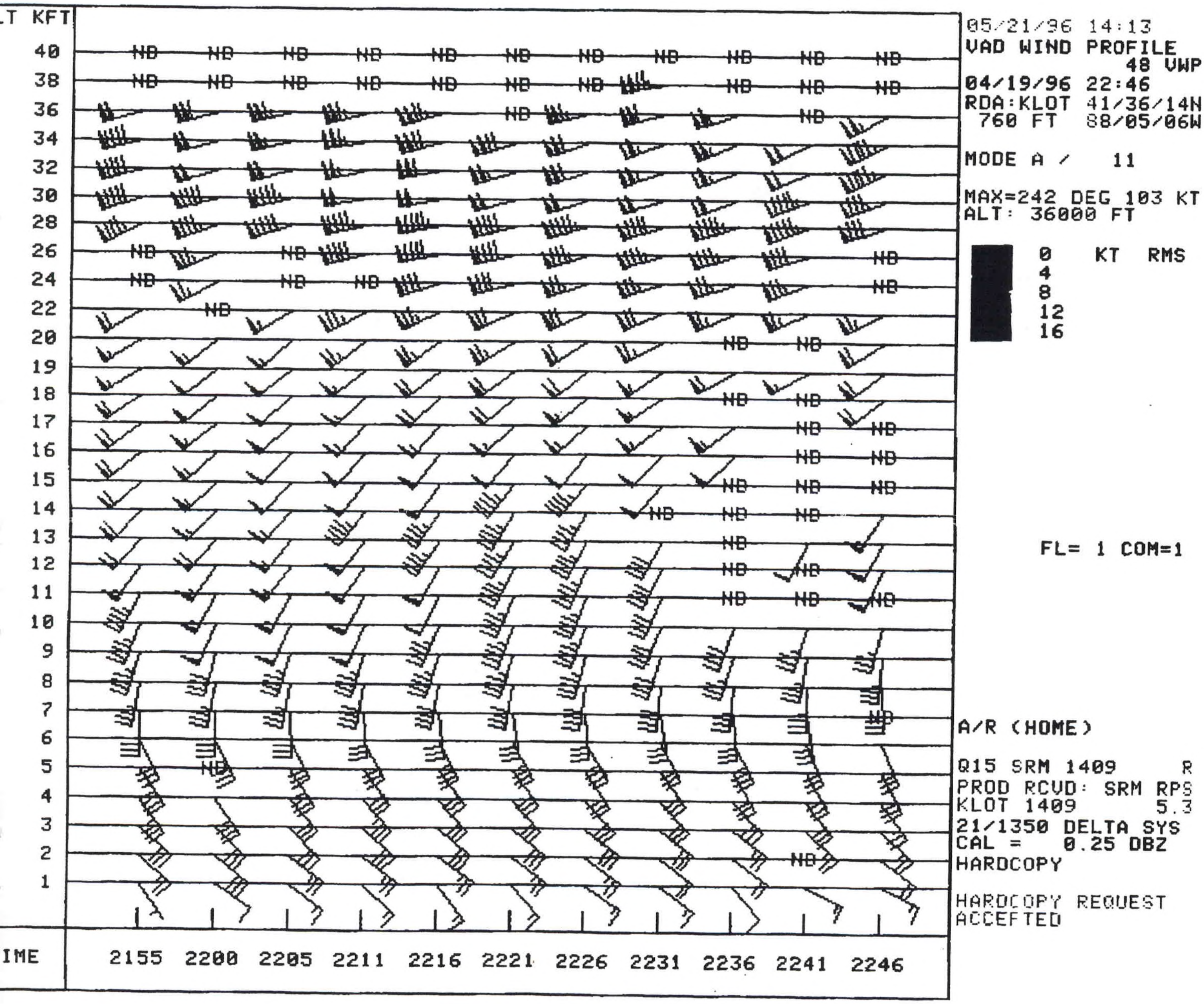


Figure 11. VAD wind profile from KLOT WSR-88D, April 19, 1996. Times are given in UTC format.