Recent Improvements to the GOES Wind Index

Kenneth L. Pryor and Gary P. Ellrod
Office of Research and Applications (NOAA/NESDIS)
Camp Springs, MD

Andrew A. Bailey
Raytheon ITSS, Landover, MD

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Abstract

The downburst is defined as a strong downdraft produced by a convective storm (i.e., thunderstorm) that induces an outburst of damaging winds on or near the earth's surface. Due to the intense wind shear they produce, downbursts are a hazard to aircraft in flight, especially during takeoff and landing phases. Retrieved profiles of temperature and moisture obtained from the Geostationary Operational Environmental Satellite (GOES) sounders have been shown to be useful in assessing the potential for convective downbursts. A GOES sounder-derived parameter used for estimating the maximum convective wind gusts is the Wind Index (WINDEX). The Wind Index is plotted on regional GOES images (visible, infrared, or water vapor) and made available on the GOES Microburst Products web page (URL: http://orbit-net.nesids.noaa.gov/arad/fpdt/mb.html).

This paper will briefly review the development of the WINDEX product. Recent improvements to the WINDEX will be discussed. Updated validation data for the 2002 convective season will be presented as well as case studies demonstrating the performance of the WINDEX after the implementation of the improvements. Recent improvements in the GOES WINDEX product include a change in the calculation of nighttime WINDEX values to reduce the nighttime low bias. Improvements to the display of the WINDEX product include the plotting of color-coded numerical values instead of color-coded boxes as well as the plotting of Storm Prediction Center (SPC) severe weather reports. Mean error was < 2 kt for 43 daytime events during Summer 2002, a significant improvement over a mean error of 3 kt for the 2001 convective season. Also, there was a significant reduction in mean error for nighttime events, improving from > 6 kt for the 2001 convective season to 4 kt for Summer 2002. A case study will be presented that discusses the improved performance of the WINDEX during a nighttime convection event in the central Plains.

1. Introduction

Convective storms can pose serious threats to life and property. Of great concern are those storms that produce downbursts, defined as strong convective downdrafts that result in an outburst of damaging winds on or near the earth's surface (Fujita and Wakimoto 1983). A detailed discussion of the classification of downbursts as well as a discussion of the atmospheric conditions favorable for downbursts and the physical processes that contribute to downburst development are featured in Pryor et al. (2002). It should be noted that there are many downburst events that do not produce severe winds (> 50 kt) that are operationally significant for aviation. For example, a four-year data sample from the Cape Canaveral, Florida mesonet revealed that 90% of peak wind speeds for 282 microbursts were recorded between 25 and 44 kt (13-23 m s^{-1})(Ellrod et al. 2000, Sanger 1999).

Data from Geostationary Operational Environmental Satellite (GOES) sounders has proven to be useful in the assessment of the short-term potential for convective storms. GOES atmospheric sounders provide nearly instantaneous observations through a column in the atmosphere, with high spatial resolution and one uniformly calibrated sensor making all of the measurements. The Wind Index (WINDEX) is a sounder-derived parameter that indicates the speed of maximum potential wind gusts at the surface produced by convective storms (McCann 1994). The WINDEX algorithm ingests atmospheric sounding data (i.e., temperature and dew point) provided by satellite retrievals. Complete descriptions of the atmospheric sounding process are presented in Zehr et al. (1988) and Menzel et al. (1998).

2. A Review of the GOES Wind Index

The Wind Index (WINDEX) is defined as a parameter, developed by McCann (1994), that indicates the maximum possible convective wind gusts that could occur in thunderstorms. The WINDEX is represented by the following equation:

$$WI = 5[H_M R_Q (G^2 - 30 + Q_L - 2Q_M)]^{0.5} \quad (1)$$

where H_M is the height of the melting level in km above the ground; G is the temperature lapse rate in degrees C km^{-1} from the surface to the melting level; Q_L is the mixing ratio in the lowest 1 km above the surface; Q_M is the mixing ratio at the melting level; and $R_Q = Q_L/12$ but not > 1. For a complete discussion of the GOES microburst products, the reader is referred to Pryor et al. (2002).

The GOES WINDEX product is generated hourly at the National Oceanic and Atmospheric Administration (NOAA) Science Center in Camp Springs, MD and is available on the GOES Microburst Products web page at the following URL: http://orbit-net.nesdis.noaa.gov/arad/fpdt/mb.html. The program that generates the GOES WINDEX product ingests temperature and moisture data from the GOES derived soundings. It is important to understand that GOES WINDEX can only be calculated from sounding data obtained in clear sky conditions or in conditions of partial cloudiness. The presence of complete cloud cover in the field of view of the GOES sounder precludes the production of a complete retrieval of temperature and moisture profiles. The WINDEX program is dependent upon complete sounding retrievals to compute the temperature lapse rate as well as to compute low level mixing ratio. Ellrod et al. (2000) note that there are circumstances in which WINDEX values cannot be calculated from clear sky retrievals including the failure of the GOES sounder data ingest and the unavailability of the numerical model first guess or ancillary surface data.

The GOES WINDEX product consists of color-coded numerical values representing expected convective wind gusts displayed at sounding retrieval locations, superimposed on a visible (VIS) or Infrared (IR) image from the GOES Imager. Figure 1a is an example of a GOES WINDEX image. In this image of the northern Plains sector, a squall line extends from eastern North Dakota to northwestern Kansas, while new thunderstorm activity is developing over the western High Plains. High WINDEX values are indicated east of the squall line, but more noteworthy, extremely high WINDEX values in excess of 70 kt (indicated by numerical values of red color) are apparent east of the developing convection over western South Dakota. A comparison with a previous version of a WINDEX image (Figure 1b), displays significant improvements in the presentation. First, the plotting of numerical values, as opposed to colored boxes, increases the precision of the display as well as produces a less "cluttered" image. Also, WINDEX gradients are more apparent and areas of excessively high WINDEX values are highlighted more effectively. Thus, there are implications for the use of the improved GOES WINDEX in forecasting operations. The extrapolation of the movement of pre-existing convective systems or low-level convergence boundaries that could initiate deep convection (i.e., outflow boundaries, sea-breeze fronts) in to regions of high WINDEX can be useful in the determination of the possibility of damaging downbursts. Plotted numerical values have utility in producing a more precise forecast of maximum wind gusts at the surface.

3. Improvements to GOES WINDEX

Based on 2001 convective season validation data, a low bias for the GOES WINDEX in excess of 6 kt was revealed for downbursts that occur during nighttime hours. The nighttime low bias for the WINDEX was believed to be attributable to the diminished boundary layer lapse rate due to radiational cooling that typically begins around sunset (Ellrod et al 2000) and the subsequent development of a nocturnal temperature inversion. Due to the strong dependence of the WINDEX on the square of the temperature lapse rate, the development of an inversion results in the significant decrease of WINDEX values, particularly during the evening hours. Figure 2 demonstrates the development of a nighttime temperature inversion. Beginning in December 2001, WINDEX was calculated at night (after 2300 UTC) from the top of the boundary layer instead of the Earth's surface to reduce a nighttime low bias. The new nighttime calculation entails approximating the level of maximum Theta-e determined in the first guess profile (see Menzel et al. (1998)) as the top of the boundary layer. Atkins and Wakimoto (1991) identified that during periods of elevated downburst activity, as observed during the Microburst and Severe Thunderstorm (MIST) Project conducted in northern Alabama, the nocturnal and early morning thermodynamic environment was convectively stable over the lowest 75mb due to the radiation inversion. It was also found that a Theta-e maximum existed at the top of the radiation inversion. Replacing the surface with top of the boundary layer in the nighttime calculation of WINDEX was based on the assumption that the top of the nighttime temperature inversion coincides with the top of the boundary layer (Pryor et al. 2002). This change to the calculation of WINDEX for nighttime microburst events has resulted in a 30% reduction in the nighttime low bias (See Section 4). The remaining low bias (70%) could be attributable to such factors as translational speed of individual convective cells and convective systems as well as large amounts of convective available potential energy (CAPE) available to "fuel" nocturnal convective systems. These factors are not explicitly accounted for in the WINDEX algorithm. See section 5 for a detailed discussion of the development and evolution of a nocturnal downburst-producing mesoscale convective system (MCS) over the central Plains.

In May 2002, color-coded numerical values were plotted on WINDEX graphics instead of color- coded boxes. As discussed in the previous section, the plotting of color-coded numerical values on WINDEX images resulted in a less "cluttered" display as well as an increase in precision. New virtual graphics files were being used as well as a new magnification for the Florida (FL) microburst products. New FL image magnification, as displayed in Figure 3, extended coverage area into southern Alabama, southern Georgia and southern South Carolina. In addition, the plotting of Storm Prediction Center (SPC) storm reports on WINDEX images was implemented during May 2002. Storm reports plotted on WINDEX graphics included numerical values of observed wind gusts. As displayed in Figure 1a, wind reports are plotted in the color red and with a larger font size to be differentiated from WINDEX values. Wind reports are extracted from SPC Severe Thunderstorm Reports text messages (NWUS22) and then saved in a data file to be plotted on WINDEX graphics. Storm report plots have demonstrated utility in the product validation process. In conjuction with WINDEX values, storm reports associated with a particular convective system can be used in the extrapolation process to forecast (or nowcast) the likelihood and strength of downburst wind gusts.

4. Validation: 2001-2002 Convective Season

a. Methodology

Data from the GOES windex was collected for two convective seasons, 2001 and 2002, and validated against coventional surface data. In this study, the convective season was considered to comprise the months of June through September. Measured wind gusts from Storm Prediction Center (SPC) storm reports and surface weather observations, recorded during downburst events, were compared with adjacent WINDEX values. In order to assess the predictive value of WINDEX, GOES data used in validation were obtained for retrieval times one to three hours prior to the observed surface wind gust. Radar reflectivity imagery from Next-Generation radar (NEXRAD) was utilized for each downburst event to verify that observed wind gusts were produced by convective systems. Particular radar reflectivity signatures, such as the bow echo and the weak echo channel, were effective indicators of the occurrence of downbursts. Fujita (1978) noted that a bow echo was associated with a downburst and defined the term "bow echo" to refer to a bow or crescent shaped radar reflectivity echo with a tight reflectivity gradient on the convex (leading) edge, the evolution and horizontal structure of which is consistent with outflow-dominated systems. Przybylinski and Gery (1983) identified that the weak echo channel, usually located near the center of the bow, signifies where the highest downburst winds could be expected. Figure 4 is an example of a distinctive bow echo as described by Przybylinski and Gery (1983) that features the following radar echo characteristics:
(1) a concave shaped echo configuration,
(2) a weak echo channel, and
(3) a strong low-level reflectivity gradient along the leading edge of the concave shaped echo.

Validation statistics were then computed for both the 2001 and 2002 convective seasons. GOES

WINDEX values and corresponding observed wind gusts for each convective season were further subdivided into daytime events, ocurring between 1000 and 2000 local standard time (LST), and nighttime events, occurring between 2000 and 1000 (LST). Statistics were then computed separately for daytime and nighttime events for each convective season. Parameters computed included mean error, defined as the difference in mean values of GOES WINDEX from mean observed wind gusts, and correlation (r). In this study, mean error expressed the degree of accuracy of the GOES WINDEX in predicting the strength of convective wind gusts while correlation expressed the degree of a linear relationship between GOES WINDEX values and actual measured wind gusts at a particular location for each downburst event. The degree of correlation can range between 0 and 1, where 0 indicates no relationship between WINDEX and surface convective wind gusts and 1 indicates a perfect relationship. Hypothesis tests were then conducted for daytime and nighttime events in each convective season to determine the significance of a linear relationship between GOES WINDEX and surface wind gusts. A null hypothesis was constructed that stated that there is no linear relationship between between GOES WINDEX values and surface convective wind gusts. The research hypothesis stated that there is correlation between the two variables. A "t" test was selected as the test statisic and was conducted for daytime and nighttime events in each convective season. The "t" test selected was based on the following formula given by Gray (1983):

$t = r[N-2/1-r^2]^{0.5}$ (2)

where r is correlation and N is the number of downburst events. A significance level of 0.05 was chosen and critical values were selected using a "t" distribution table according to the number of events and significance level (Gray 1983). If the calcuated "t" value for each sample (i.e., daytime, nighttime) is > the critical value, the null hypothesis can be rejected in favor of the research hypothesis. Validation statistics as well as "t" test results are presented in Table 1.

Table 1. Comparison of GOES WINDEX to Measured Wind Gusts

2002		
	Daytime Events (N=43)	**Nighttime Events (N=47)**
Mean Error	-1.58	-4.59
Correlation (r)	0.42	0.20
t value	2.96	1.40
Critical Value	1.68	1.68
2001		
	Daytime Events (N=92)	**Nighttime Events (N=55)**

Mean Error	2.91	-6.90
Correlation (r)	0.40	0.03
t value	4.14	0.22
Critical Value	1.67	1.68

b. Analysis of Statistics

As noted earlier, the most significant indicator of the improved accuracy of the GOES WINDEX was the reduction of the nighttime mean error, from -6.9 kt to -4.59 kt between the 2001 and 2002 convective seasons. Hypothesis testing revealed, for daytime events in both the 2001 and 2002 convective seasons, that "t" values were > the corresponding critical values. Thus, the null hypothesis could be rejected in favor of the research hypothesis, indicating that the linear relationship between GOES WINDEX and surface wind gusts was statistically significant. In contrast, for nighttime events during the 2001 convective season, the "t" value was < the critical value, favoring the null hypothesis that there is no statistically significant linear relationship between WINDEX and surface wind gusts. For nighttime events during the 2002 convective season, there was an increase in the "t" value, however, the "t" value was still < the critical value. This signified that the increase in correlation for nighttime downburst events was not statistically significant. The possibility exists that the slight positive correlation for nighttime events could be an artifact of the sampling process. Also, as discussed in section 3, other factors may be mitigating the relationship between GOES WINDEX and observed surface convective wind gusts at night including translational speed of convective systems and large amounts of convective available potential energy (CAPE) available for convective storm development. The poor nighttime correlation between GOES WINDEX and measured wind reports compared to the small mean error indicate that although the GOES WINDEX demonstrates improved accuracy for predicting maximum convective wind gusts, there is still a weak relationship between WINDEX values and actual wind gusts for nocturnal events. Thus, for nighttime downburst events, a decrease GOES WINDEX values does not necessarily correspond to a decrease in the strength of convective wind gusts. This again suggests that other factors mentioned previously that are not accounted for in the WINDEX algorithm influence convective wind gust strength. Pryor et al. (2002) discuss the role of translational motion of convective systems in the underestimation of WINDEX. As stated in Ellrod et al.(2000), the WINDEX algorithm is designed to estimate the maximum downdraft velocity due to negative buoyancy from a stationary storm.

Other trends noted between the 2001 and 2002 convective seasons were a shift from a 3 kt high bias for daytime events to 1.6 kt low bias and a reduction in the number of documented daytime microburst events. The bias shift was most likely the result of the documentation of a greater number of dry microbursts during the 2002 convective season. In a classic dry microburst situation, as illustrated by the GOES sounding in Figure 5, a significant mid-level moist layer is typically present in conjunction with very dry air in the low levels. Since the WINDEX algorithm is dependent on the difference in mixing ratio between the surface and the melting level, a slightly higher mixing ratio at the melting level than at the surface would exist, reducing the WINDEX. This finding underscores the necessity of investigating a modification to the WINDEX algorithm for the use in dry microburst environments. Accordingly, the overall reduction in the number of documented daytime microburst events for the 2002 season compared to the 2001 season reflected a much less active convective season over the southeastern United States during 2002.

5. Case Studies

a. Kansas/Oklahoma Downbursts

During the nighttime hours of August 26, 2002, a high wind producing mesoscale convective system (MCS) tracked southeastward at a speed of approximately 40 kt through western Kansas and western Oklahoma producing damaging winds in excess of 50 kt. Maximum winds were recorded as high as 81 kt (42 m s^{-1}) with a downburst at Dodge City, KS. The expansive cirrus shield associated with the MCS precluded the calculation of a WINDEX value in the vicinity of Dodge City during the 1 to 3 hour period prior to the observed downburst due to the fact that GOES sounding retrievals are only available in clear-sky regions. However, late afternoon WINDEX values in the Dodge City area were in excess of 60 kt. Since there was not a significant air mass change prior to the onset of the MCS, late afternoon WINDEX values could be considered representative for the time of downburst occurrence. Other measured wind reports in the area are indicated in the Table 2.

Table 2. Measured Wind Speed vs. GOES WINDEX

Time (UTC)	Location	Measured(kt)	WINDEX(kt)	Retrieval Time (UTC)
01:57	Garden City, KS	54	51	00:00
02:30	Holcomb, KS	52	51	00:00
04:15	Liberal, KS	53	44	02:00
04:23	Beaver, OK	50	47	02:00
04:25	Slapout, OK	60	50	02:00
04:45	Buffalo, OK	55	55	02:00

Based on numerous and widespread reports of damage rating F1 on the Fujita Scale (Fujita 1971) that occurred in a swath > 800 km in length, this system can be considered a derecho. A derecho is defined as a family of downburst clusters produced by an extratropical mesoscale convective system (MCS) (Johns and Hirt 1987). In this case, an MCS developed over southwestern Nebraska during the afternoon of August 26th. The air mass over western Kansas and Oklahoma, into which the MCS was propogating, was convectively unstable. Lifted index values were as low as –6 with CAPE over southwest Kansas and western Oklahoma > 3000 J Kg^{-1}. Also, there was significant low level moisture in place: surface dew points were > 60F over southern Kansas and Oklahoma. Figure 6a exhibits the 2345 UTC 26 August GOES WINDEX, overlying an enhanced infrared image, and displays an MCS over western Kansas with a well-developed enhanced-V signature. An enhanced-V, appearing as a V-shaped notch of cold temperatures in the cloud tops of a thunderstorm complex, is frequently associated with thunderstorms that produce intense convection and downbursts. In this image, WINDEX values were well in excess of 50 kt over southwestern Kansas and in excess of 60 kt over the Oklahoma panhandle. The 0115 UTC 27 August GOES WINDEX image, displayed in Figure 6b, indicates values > 50 kt over southwestern Kansas and western Oklahoma as the derecho continued to progress to the south, fed by a low-level warm and moist easterly flow. An enhanced-V signature was still apparent in Figure 6c, the 0245 UTC WINDEX image, as the MCS was approaching the Oklahoma border. The 0300 UTC GOES sounding for Woodward, Oklahoma, displayed in figure 6d, indicated a profile that was favorable for (wet) downbursts: a dry adiabatic sub-cloud layer extending from the surface to 850 mb level and a moist layer extending from the 850 mb level to the 500 mb level that is capped by a dry layer at the midlevels (Atkins and Wakimoto 1991). The sounding also indicated that a significant amount of buoyant energy (CAPE 2772 J Kg^{-1}) was available to "fuel" strong convection. The presence of a mid-level dry air layer is important in the process of entrainment of dry air into the convective storm cell, resulting in evaporational cooling, negative buoyancy and the development of strong downdrafts. Favorable conditions for downbursts resulted in the numerous reports of severe wind observed in southwestern Kansas and western Oklahoma between 0200 and 0500 UTC (Table 2).

Mean error for this event, defined as the difference between mean GOES WINDEX and mean measured wind reports, was determined to be -4 kt. This event demonstrated improved accuracy of the GOES WINDEX during nighttime convective events after implementation of the nighttime calculation method.

b. Dry Microburst: Alamogordo, New Mexico

A dry microburst is defined as a microburst that is accompanied by little or no rainfall between the onset and the end of high winds and is usually associated with virga from shallow, high based cumulonimbus clouds (Wakimoto 1985). During the evening of July 2, 2002, a strong, dry microburst was observed at Alamogordo in southern New Mexico. A downburst wind gust of 51 kt (26 m s^{-1}) was recorded at Alamogordo airport (KALM) with blowing dust and little or no precipitation observed at the surface. Alamogordo is located in the Tularosa Valley of southern New Mexico with the north to south oriented Sacramento Mountain range east of Alamogordo. Thunderstorms developed over the Rocky Mountains of central New Mexico during the afternoon of July 2, 2002 due to a combination of intense solar heating and orographic lift. The environment was favorable for dry microbursts in this region as displayed by the Figure 7a, 2300 UTC July 2, 2002 GOES sounding from Alamogordo. The sounding indicated a classic "hourglass" profile (Pryor et al. 2002) including a deep, dry-adiabatic layer extending upward to 500 mb and a significant mid-level moist layer. The convection temperature (33C) had been exceeded: the surface temperature at 2300 UTC July 2 was 100F (38C). With a surface dewpoint of 37F (3C), the sub-cloud layer was extremely dry, providing a highly favorable environment for sub-cloud evaporation of precipitation and the development of strong negative buoyancy. The atmosphere was slightly unstable with only modest amounts of buoyant energy (CAPE 587 J Kg^{-1}). The steep sub-cloud lapse rate had resulted in high WINDEX values at 2300 UTC in excess of 50 kt over south-central New Mexico at as displayed in Figure 7b.

At approximately 0000 UTC July 3, a radar image displayed in Figure 8a from the Holloman AFB NEXRAD (HDX) indicated that an outflow boundary, produced by earlier convection north of Alamogordo, triggered a high-reflectivity thunderstorm cell as the boundary interacted with the Sacramento Mountain range. The high-reflectivity cell propogated southward along the Sacramento Mountain range. By approximately 0100 UTC (Figure 8b), the cell began to dissipate, producing another outflow boundary which then triggered the development of a low-reflectivity cell in the vicinity of Alamogordo. As expected in association with dry microbursts, the reflectivity of the cell was only about 30 dBZ as displayed in Figure 8c, NEXRAD image at 0110 UTC. This low-reflectivity cell produced a peak convective wind gust of 51 kt at 0110 UTC at Alamogordo airport (KALM). An abrupt wind shift from a northeastery to a northerly direction and an abrupt increase in wind speed marked the onset of the dry microburst at KALM.

Strong downdraft generation in this case was exclusively the result of negative buoyancy due to the evaporation of precipitation as it descended below the cloud base. As is typical for dry microbursts, the maximum radar reflectivity of the cell that produced the microburst was approximately 30 dBZ. The atmosphere in which this dry microburst was generated was slightly unstable with relatively low CAPE. WINDEX values in this case were representative of the measured peak convective wind gusts that actually occurred. A wind gust of 51 kt was recorded Alamogordo where a WINDEX value of 49 kt had been indicated approximately two hours earlier.

6. Summary and Conclusions

Since 2001, several changes have been implemented to the display and calculation of the GOES WINDEX that have resulted in an improved display of GOES WINDEX products and an increased reliability of the WINDEX product in forecast operations, especially for nighttime convection events. The plotting of numerical WINDEX values have: (a) increased the precision of the display of WINDEX as well as resulted in a less "cluttered" image, (b) improved the display of WINDEX gradients, and (c) increased the utility of the image to monitor small-scale convection and boundaries that could result in the initiation of deep convection (i.e., outflow boundaries, sea-breeze fronts). Plotting of SPC storm reports has proven to be useful in the validation process in addition to demonstrating utility in the short-term forecasting of downburst winds by extrapolation. Most importantly, implementation of a nighttime calculation in the WINDEX program has resulted in a 30% decrease in the nighttime low bias of the WINDEX, increasing the representativeness of WINDEX values. Case studies were presented that highlighted improved accuracy of the WINDEX product during a nocturnal MCS event in the central Plains as well as during an afternoon dry microburst event. Implementation of the GOES WINDEX into the National Weather Service (NWS) Advanced Weather Interactive Processing System (AWIPS) Build 5.2.2.1 continues. The WINDEX, calculated from Raob data, is now available in the OB1 upgrade to Build 5.2.2.1 being implemented nationwide (National Weather Service 2003). Upon installation of the upgrade, the WINDEX will be listed among the skew-T parameter data in the bottom right corner of the skew-T display in AWIPS. In addition, improvements in the quality of satellite soundings derived from GOES-11/12 since activation will be monitored to assess the possibility of incorporating the soundings into WINDEX generation (Pryor et al. 2002).

7. References

Atkins, N.T., and R.M. Wakimoto, 1991: Wet microburst activity over the southeastern United States: Implications for forecasting. *Wea. Forecasting*, **6**, 470-482.

Ellrod, G.P., J.P. Nelson, M.R. Witiw, L. Bottos, and W.P. Roeder, 2000: Experimental GOES Sounder Products for the Assessment of Downburst Potential. *Wea. Forecasting*, **15**, 527-542.

Fujita, T.T., 1971: Proposed characterization of tornadoes and hurricanes by area and intensity. SMRP Research Paper 91, University of Chicago, 42 pp.

Fujita, T.T., 1978: Manual of downburst identification for project NIMROD. SMRP Research Paper 156, University of Chicago, 104 pp.

Fujita, T.T., and R.M. Wakimoto, 1983: Microbursts in JAWS depicted by Doppler radars, PAM and aerial photographs. Preprints, *21st Conf. on Radar Meteorology*, Edmonton, Amer. Meteor. Soc., 638-645.

Gray, S.H., 1983: No-Frills Statistics. Rowman and Littlefield, Inc., Savage, MD, 177 pp.

Johns, R.H. and W.D. Hirt, 1987: Derechos: Widespread Convectively Induced Windstorms. *Wea. Forecasting*, **2**, 32-49.

McCann, D.W., 1994: WINDEX-A new index for forecasting microburst potential. *Wea. Forecasting*, **9**, 532-541.

Menzel, W.P., F.C. Holt, T.J. Schmit, R.M. Aune, A.J. Schreiner, G.S. Wade, and D.G. Gray, 1998: Application of GOES-8/9 Soundings to Weather Forecasting and Nowcasting. *Bull. Amer. Meteor. Soc.*, **79**, 2059-2077.

National Weather Service, 2003: *AWIPS Release OB1 Release Notes*.

Pryor, K.L., G.P. Ellrod, and A.A. Bailey, 2002: Convective Downburst Potential Using GOES Sounder Derived Products. *National Weather Association Electronic Journal of Operational Meteorology* , 2002-EJ1. (http://orbit-net.nesdis.noaa.gov/arad/fpdt/cdp.htm)

Przybylinski, R.W., and W.J. Gery, 1983: The reliability of the bow echo as an important severe weather signature. Preprints, *13th Conf. on Severe Local Storms*, Tulsa, OK, Amer. Meteor. Soc., 270-273.

Sanger, N., 1999: CCAS microburst climatology, M.S. thesis, Dept. of Meteorology, Texas A&M University, College Station, TX.

Wakimoto, R.M., 1985: Forecasting dry microburst activity over the high plains. *Mon. Wea. Rev.*, **113**, 1131-1143.

Zehr, R.M., J.F.W. Purdom, J.F. Weaver, and R.N. Green, 1988: Use of VAS data to diagnose the mesoscale environment of convective storms. *Wea. Forecasting*, **3**, 33-49.

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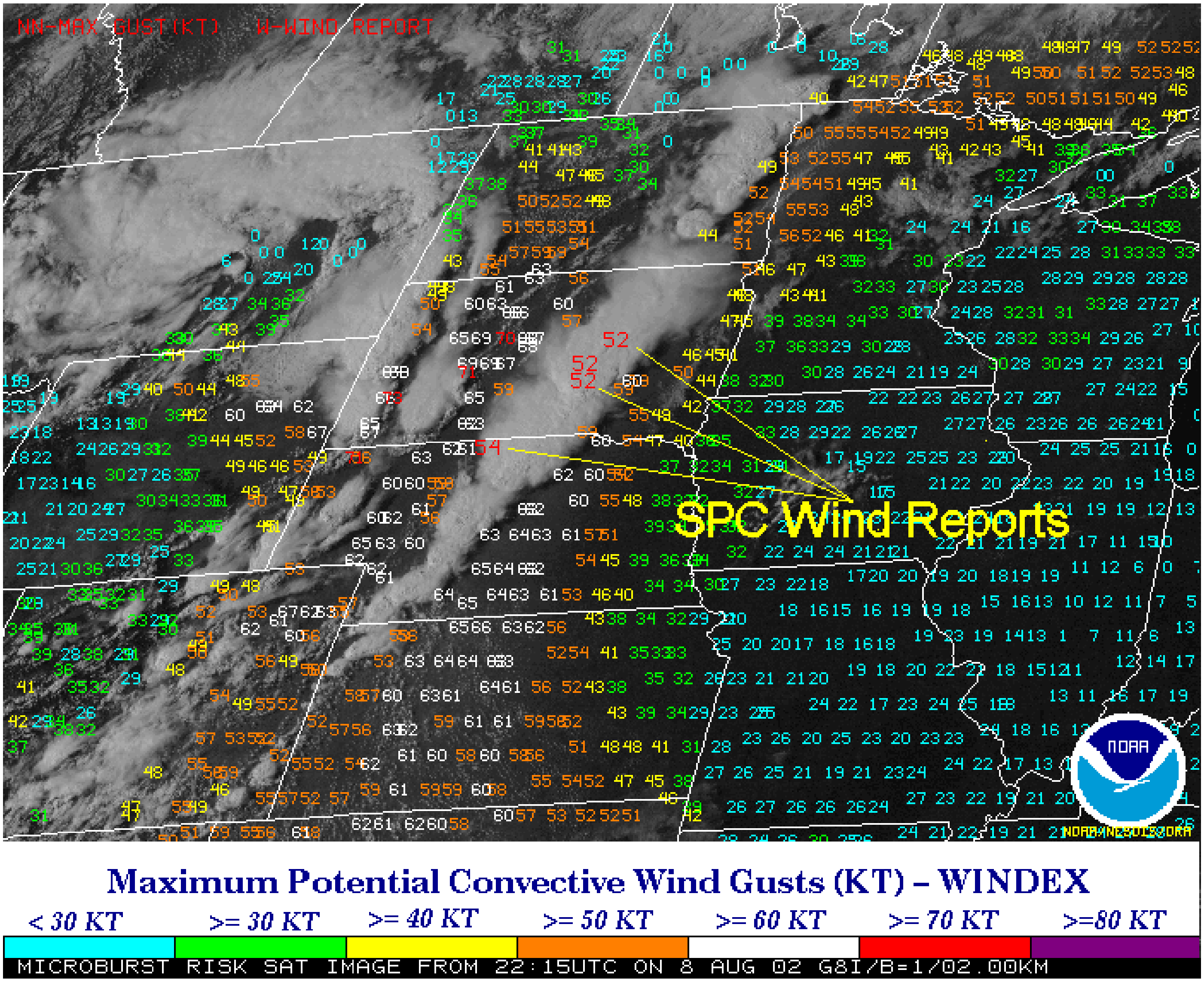
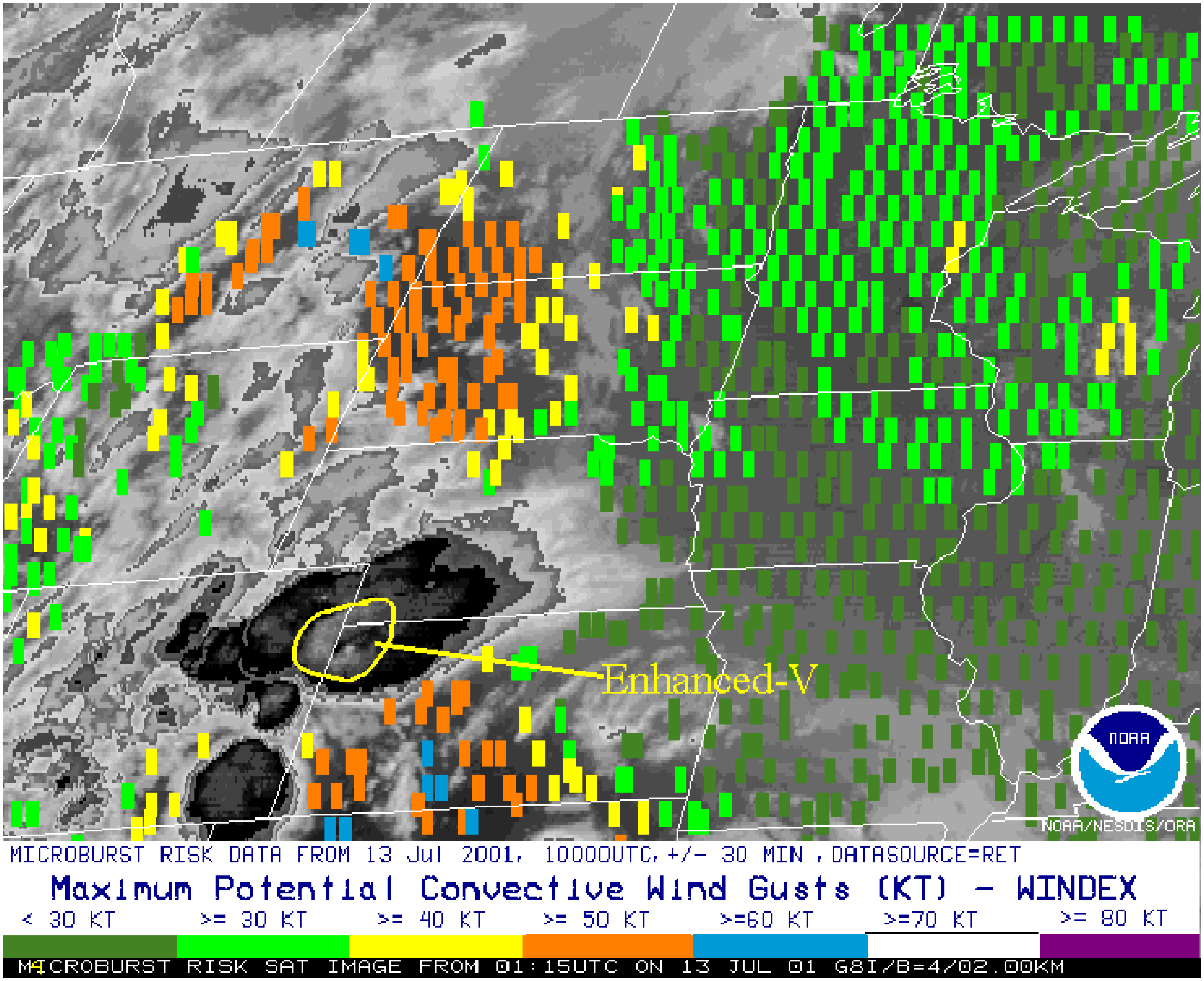
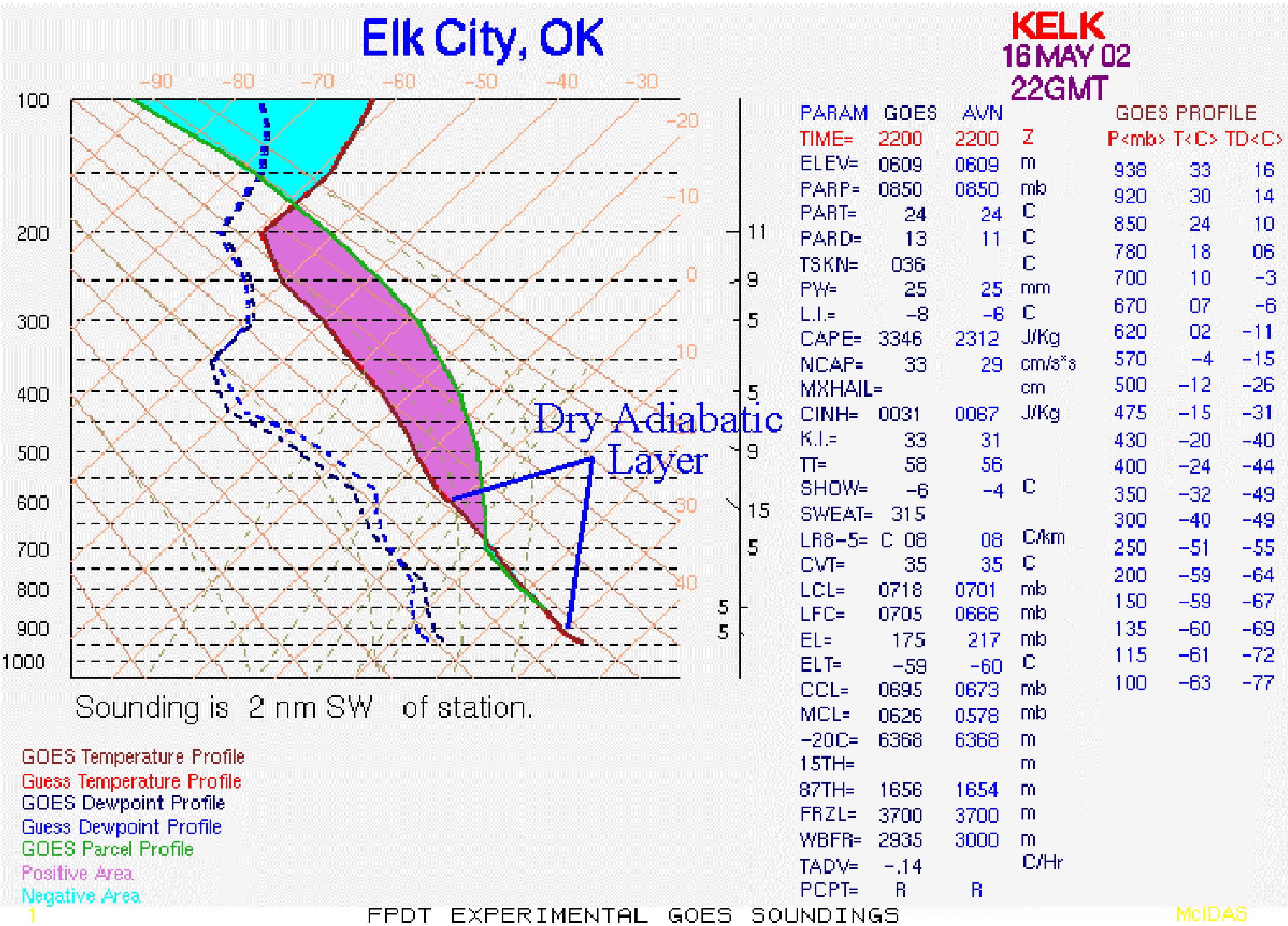

NN-MAX GUST(KT)   W-WIND REPORT
SPC Wind Reports
Maximum Potential Convective Wind Gusts (KT) – WINDEX
< 30 KT
>= 30 KT
>= 40 KT
>= 50 KT
>= 60 KT
>= 70 KT
>=80 KT
MICROBURST RISK SAT IMAGE FROM 22:15UTC ON 8 AUG 02 G8I/B=1/02.00KM

a



b

Figure 1. Examples of GOES WINDEX images: a) New version from 2215 UTC 8 August 2002; b) Old version from 0115 UTC 13 July 2001. Note enhanced-V signature, indicative of severe convection, over northwestern Kansas and high WINDEX values in excess of 60 knots over southern Kansas.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KELK
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100
200
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400
500
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900
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-20
-10
0
10
30
40
11
9
5
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9
15
5
5
5
Dry Adiabatic Layer
Sounding is 2 nm SW of station.
GOES Temperature Profile
Guess Temperature Profile
GOES Dewpoint Profile
Guess Dewpoint Profile
GOES Parcel Profile
Positive Area
Negative Area
PARAM GOES AVN
TIME= 2200 2200 Z
ELEV= 0609 0609 m
PARP= 0850 0850 mb
PART= 24 24 C
PARD= 13 11 C
TSKN= 036 C
PW= 25 25 mm
L.I.= -8 -6 C
CAPE= 3346 2312 J/Kg
NCAP= 33 29 cm/s*s
MXHAIL= cm
CINH= 0031 0067 J/Kg
K.I.= 33 31
TT= 58 56
SHOW= -6 -4 C
SWEAT= 315
LR8-5= C 08 08 C/km
CVT= 35 35 C
LCL= 0718 0701 mb
LFC= 0705 0666 mb
EL= 175 217 mb
ELT= -59 -60 C
CCL= 0695 0673 mb
MCL= 0626 0578 mb
-20C= 6368 6368 m
15TH= m
87TH= 1656 1654 m
FRZL= 3700 3700 m
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TADV= -.14 C/Hr
PCPT= R R
GOES PROFILE
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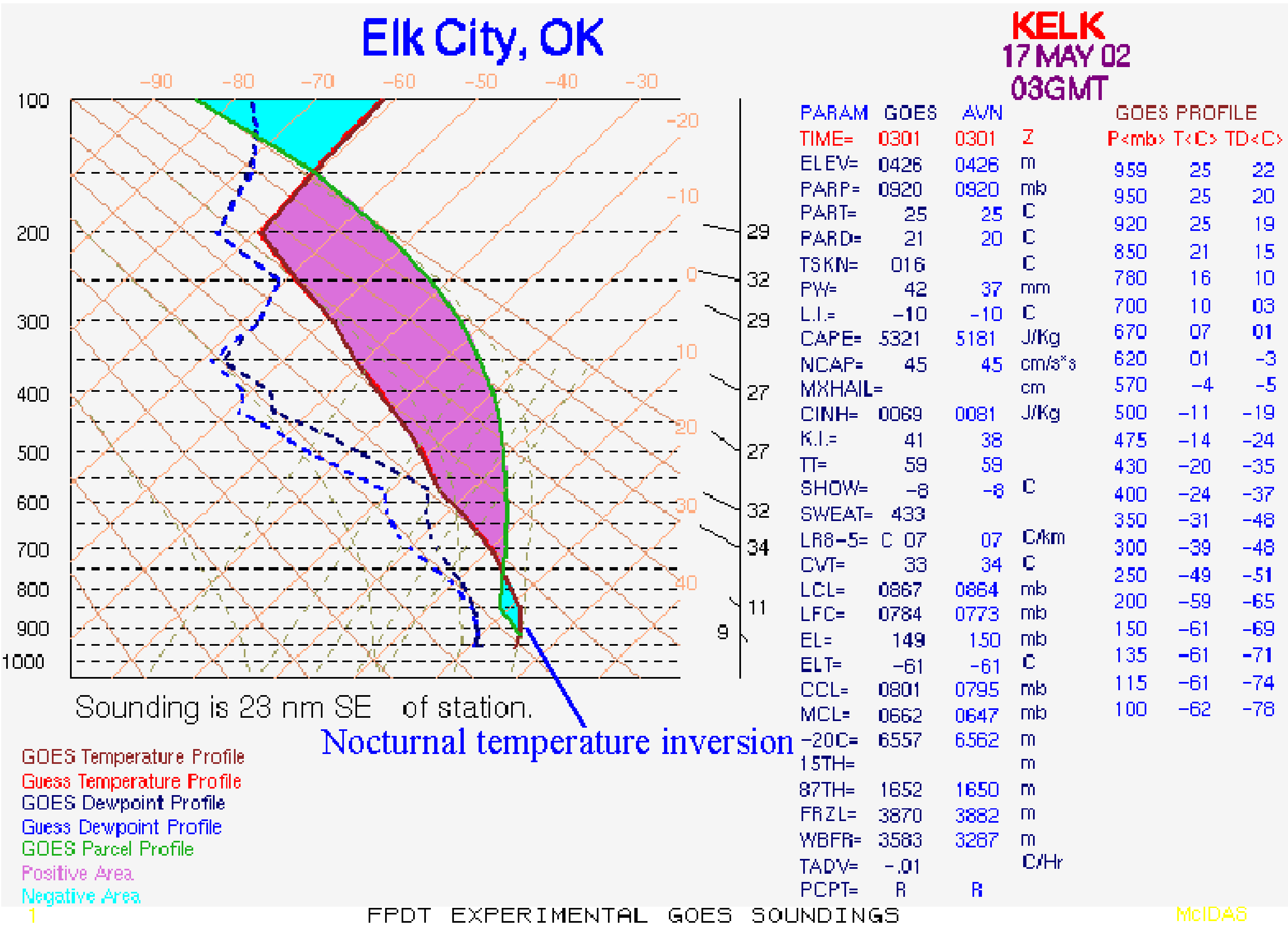
850 24 10
780 18 06
700 10 -3
670 07 -6
620 02 -11
570 -4 -15
500 -12 -26
475 -15 -31
430 -20 -40
400 -24 -44
350 -32 -49
300 -40 -49
250 -51 -55
200 -59 -64
150 -59 -67
135 -60 -69
115 -61 -72
100 -63 -77
1
FPDT EXPERIMENTAL GOES SOUNDINGS
McIDAS

a



b

Figure 2. GOES soundings at Elk City, Oklahoma demonstrating the development of a nocturnal temperature inversion: a) 2200 UTC 16 May 2002; b) 0300 UTC 17 May 2002. Contrast deep dry adiabatic layer in sounding a) with isothermal layer developing below 850mb in sounding b).

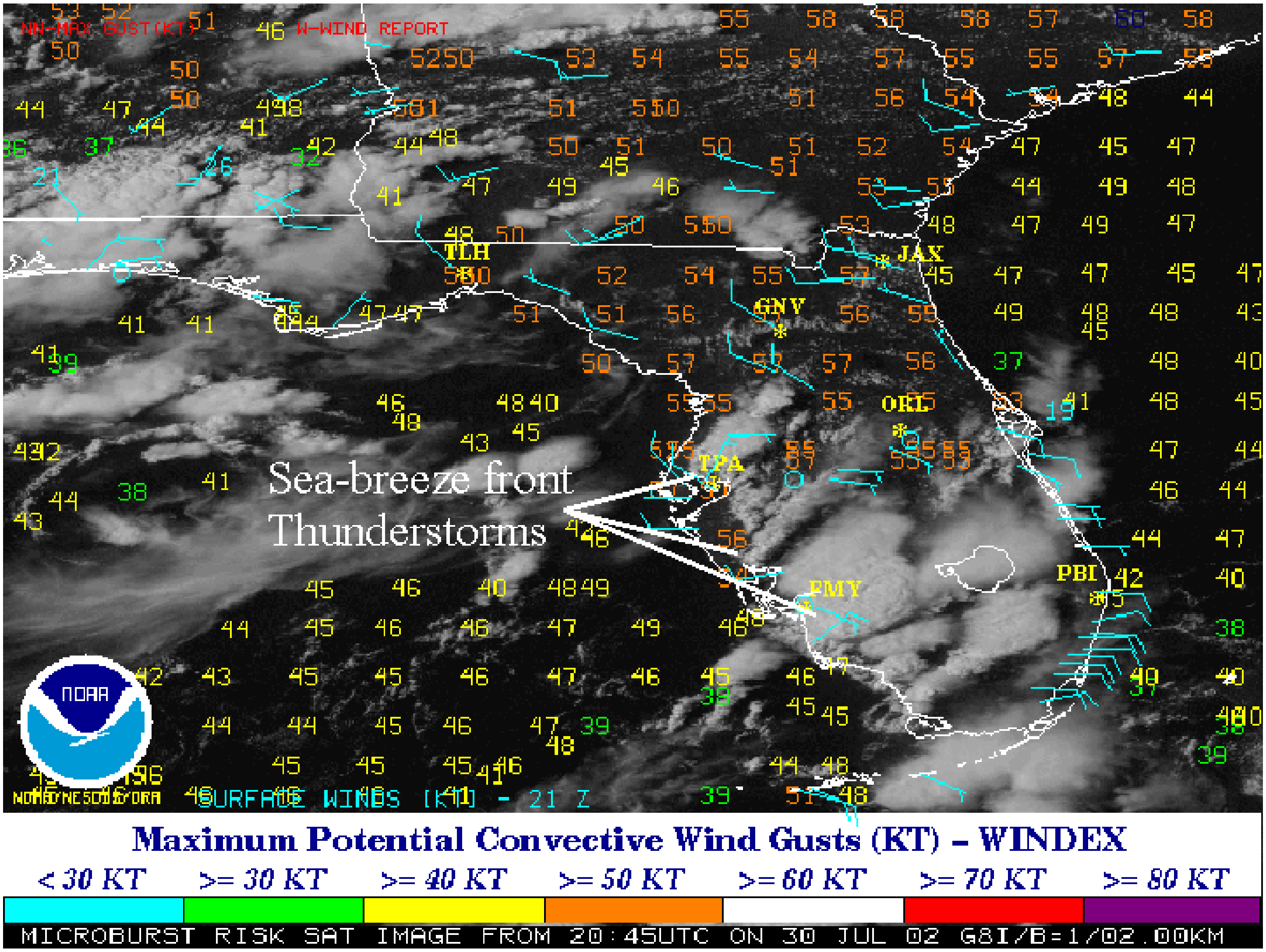


Figure 3. GOES WINDEX Florida sector image at 2045 UTC 30 July 2002, displaying intense convection developing along the west coast sea-breeze front. Note WINDEX values in excess of 50 knots over west-central Florida in the vicinity of developing thunderstorm activity.

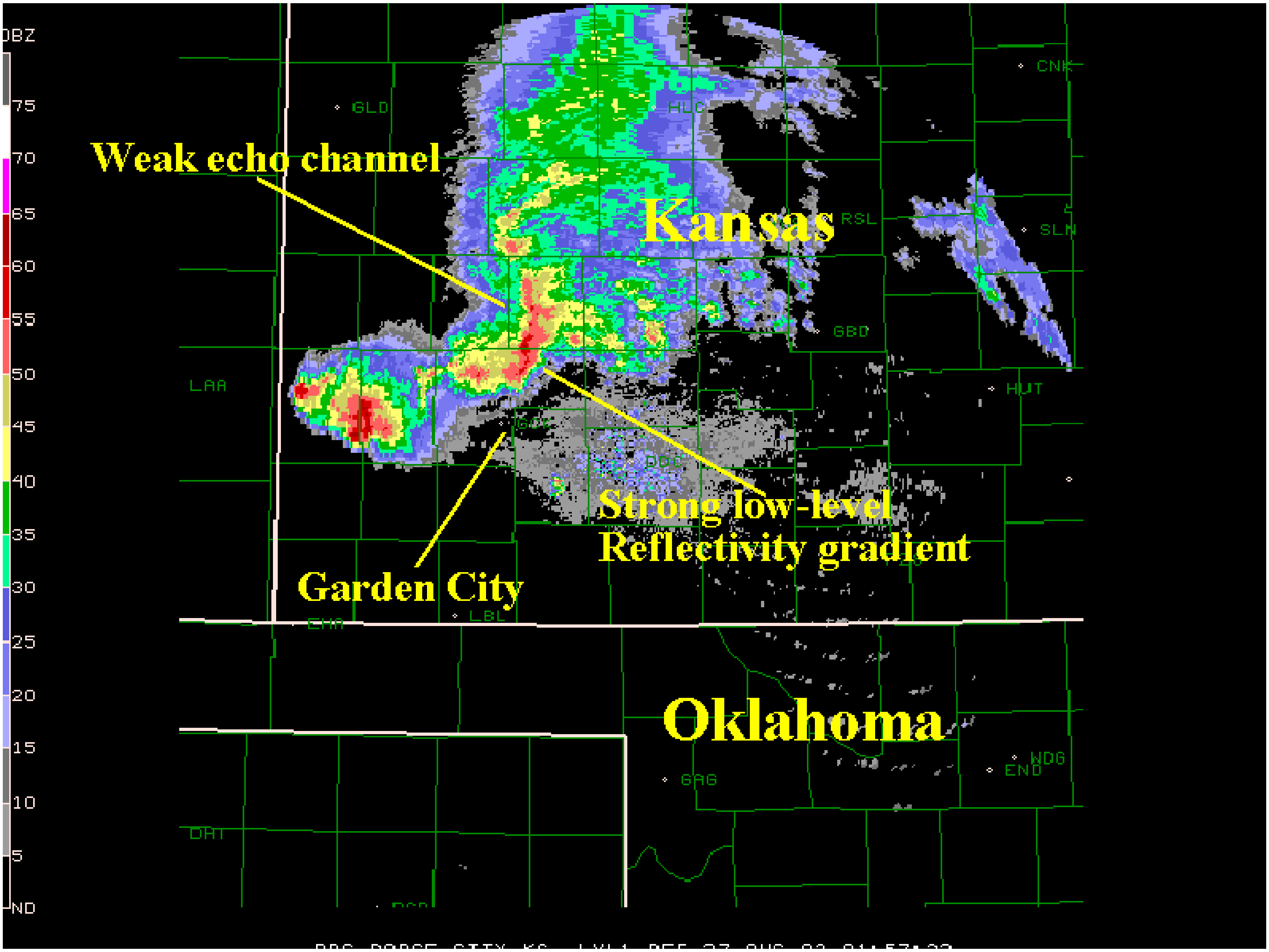


Figure 4. NEXRAD reflectivity imagery from Dodge City, KS (DDC) for 0157 UTC 27 August 2002 displaying a distinctive bow echo north of Garden City, KS. This bow echo was associated with a high wind producing mesoscale convective system (MCS) that tracked through western Kansas and western Oklahoma. A detailed case study of this event is presented in Section 5.

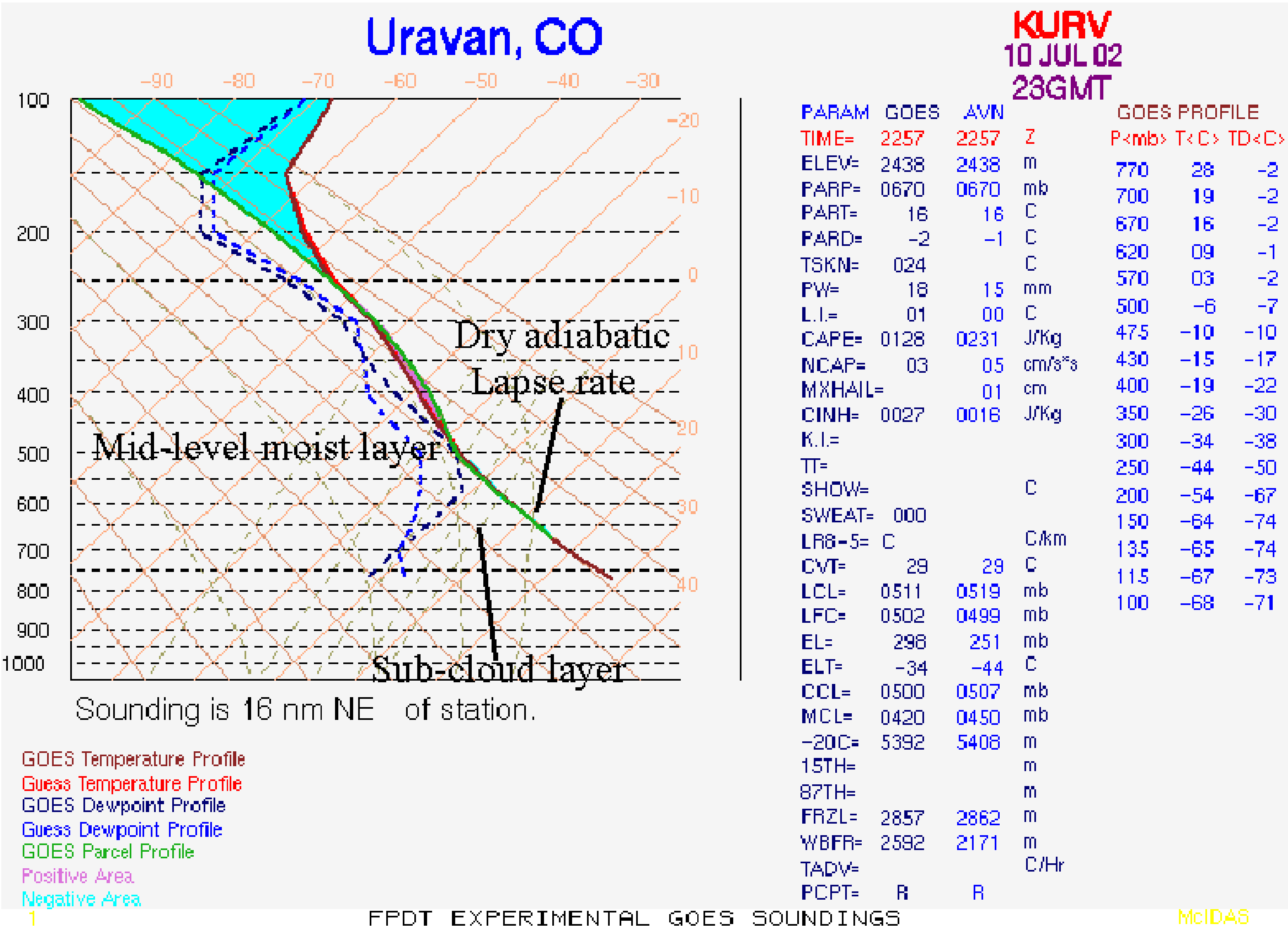
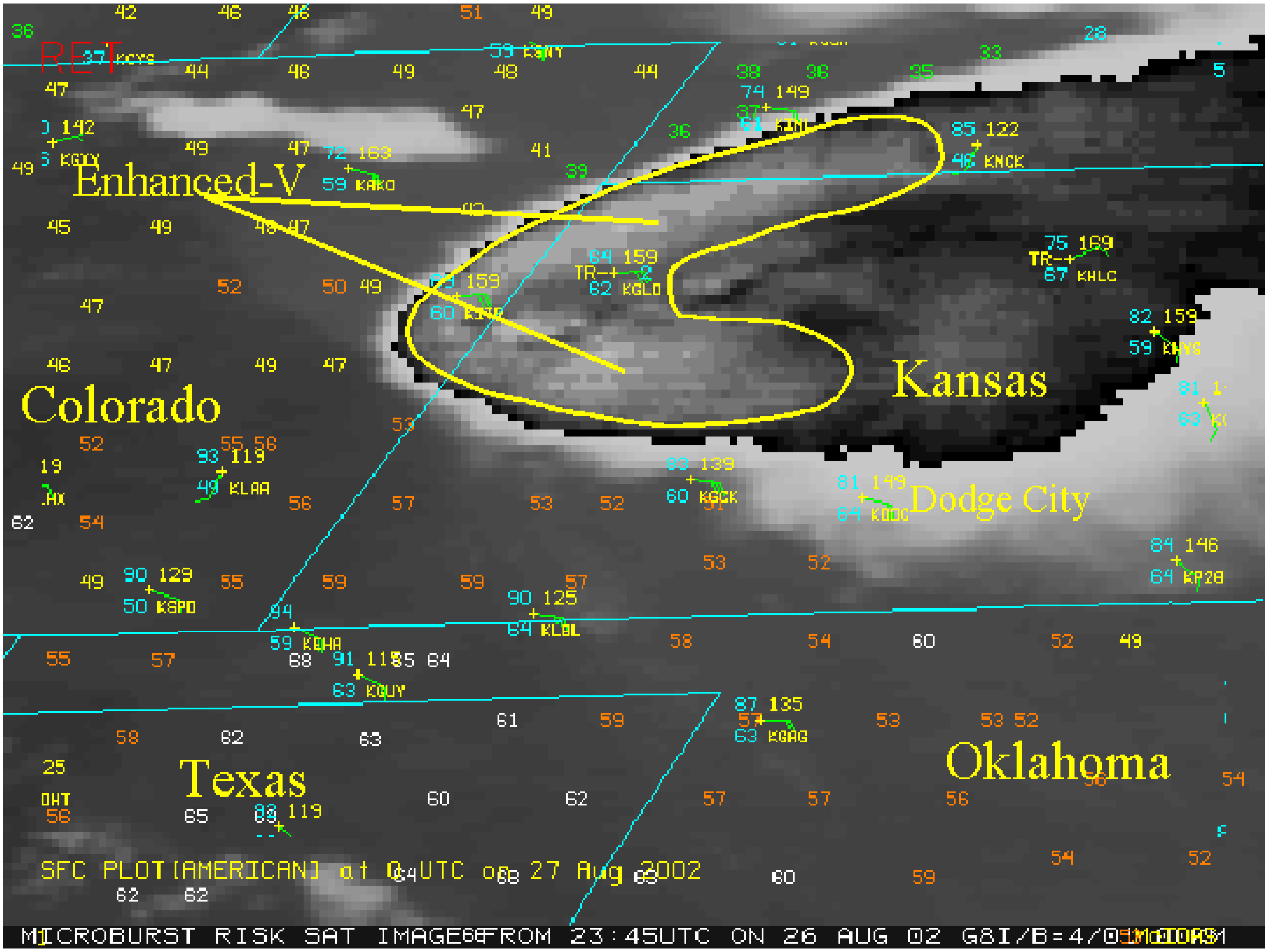
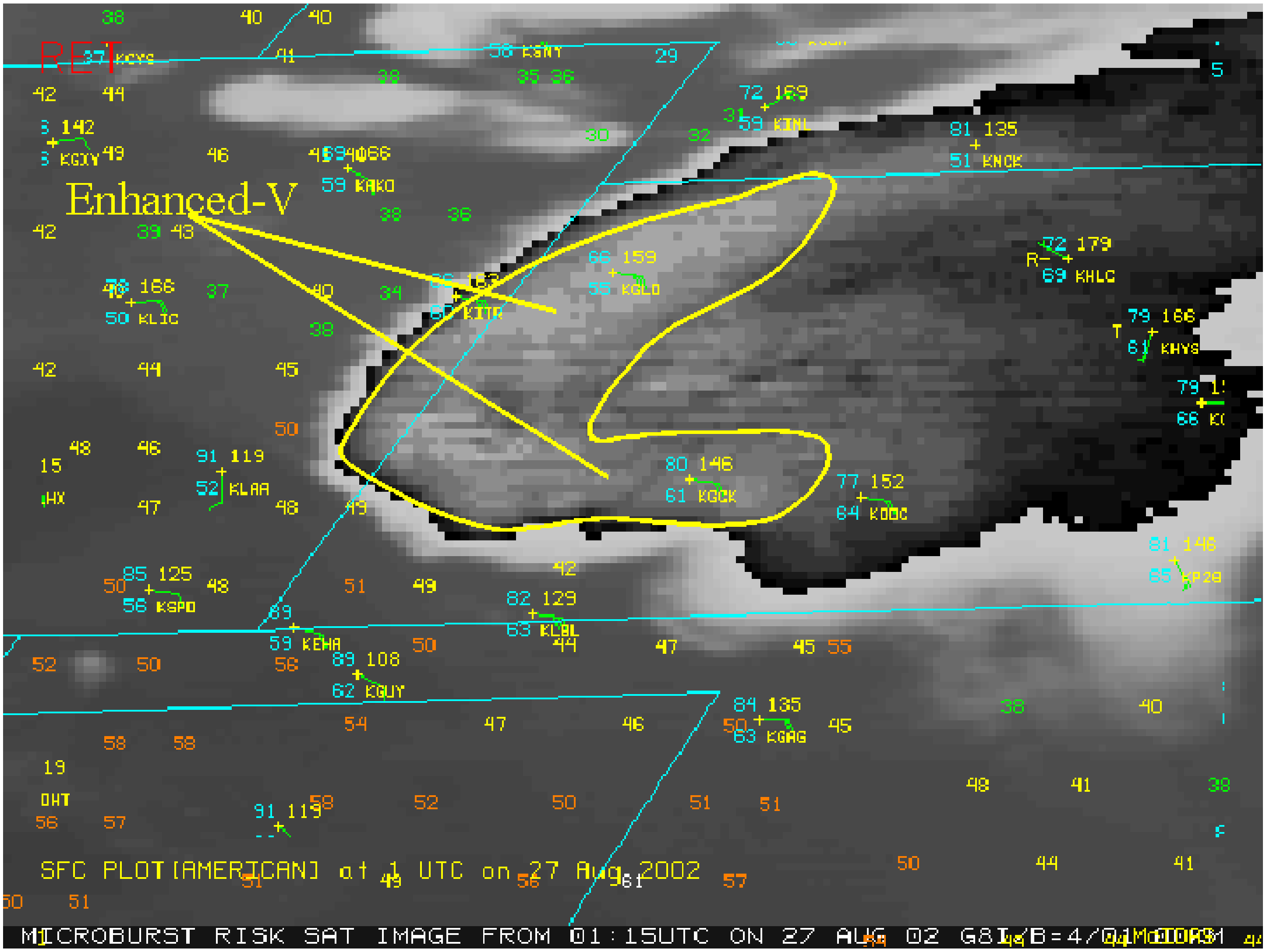


Figure 5. 2300 UTC 10 July 2002 GOES sounding from Uravan, Colorado. The sounding indicates a classic "hourglass" profile (Pryor et al. 2002) including a deep, dry-adiabatic layer extending upward to 500 mb and a significant mid-level moist layer. The presence of a significant mid-level moist layer in conjunction with very dry low levels results in a slightly higher mixing ratio at the melting level than at the surface, thus, reducing the WINDEX.

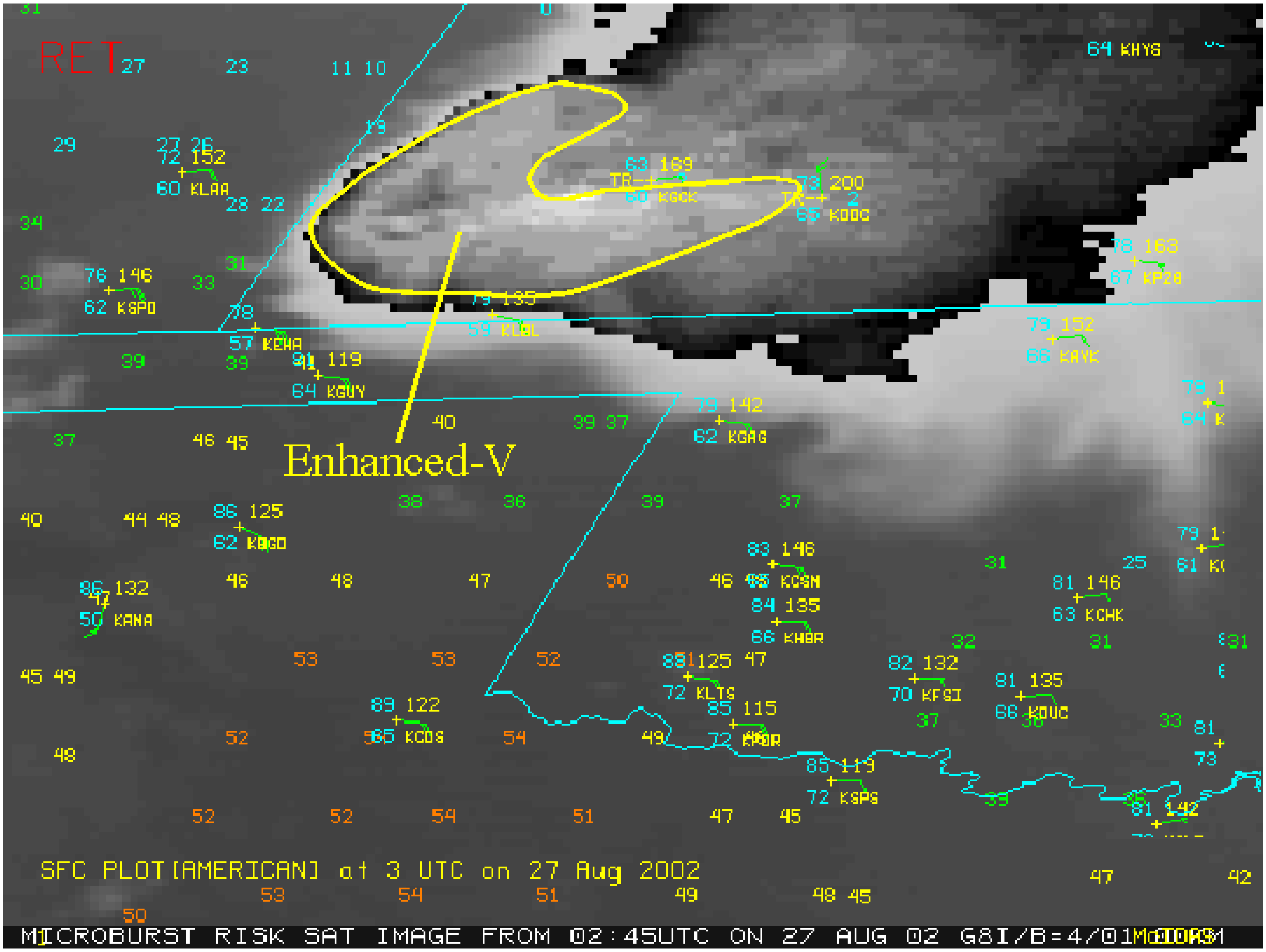

Enhanced-V
Colorado
Kansas
Dodge City
Texas
Oklahoma
SFC PLOT [AMERICAN] at 0 UTC on 27 Aug 2002
MICROBURST RISK SAT IMAGE FROM 23:45UTC ON 26 AUG 02

a

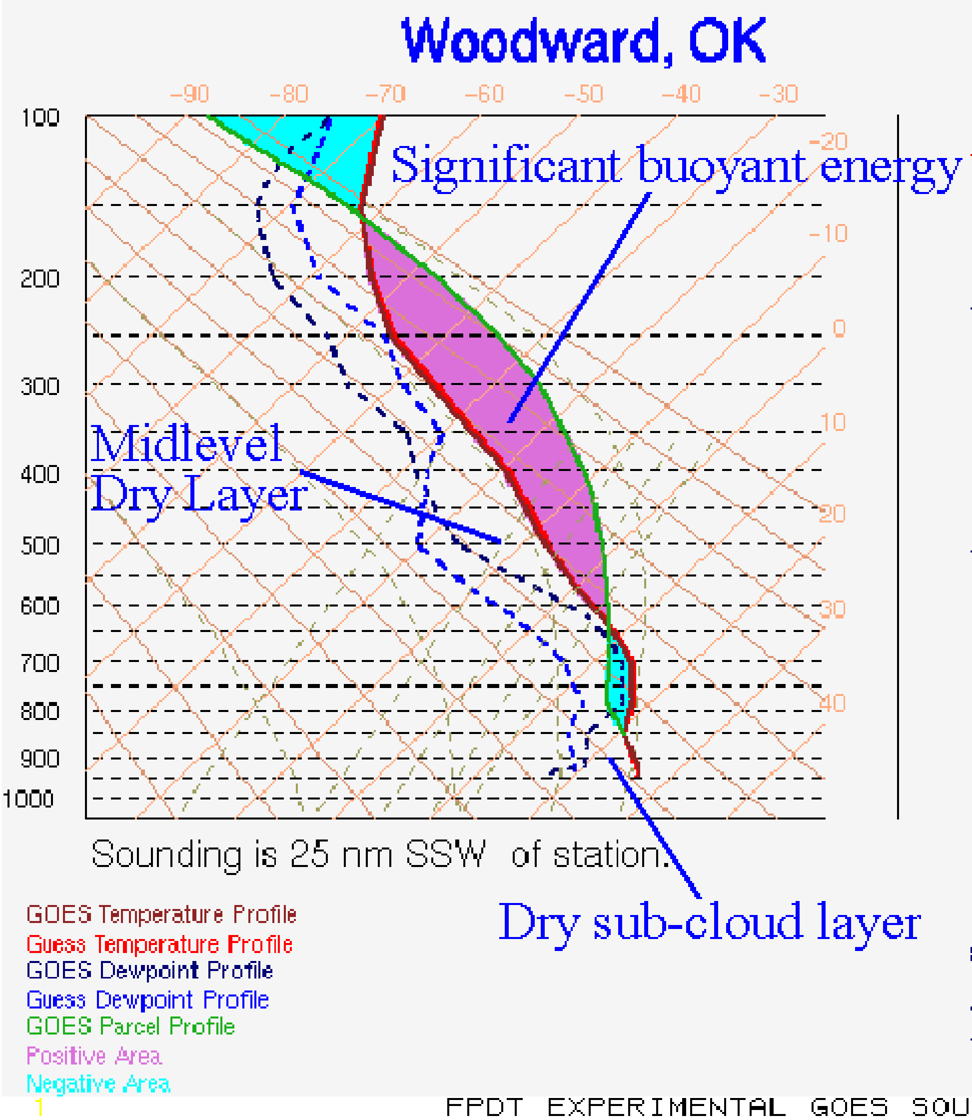
Figure 6


Enhanced-V
SFC PLOT [AMERICAN] at 1 UTC on 27 Aug 2002
MICROBURST RISK SAT IMAGE FROM 01:15UTC ON 27 AUG 02

b


RET
Enhanced-V
SFC PLOT [AMERICAN] at 3 UTC on 27 Aug 2002
MICROBURST RISK SAT IMAGE FROM 02:45UTC ON 27 AUG 02 G8I/B=4/01

c



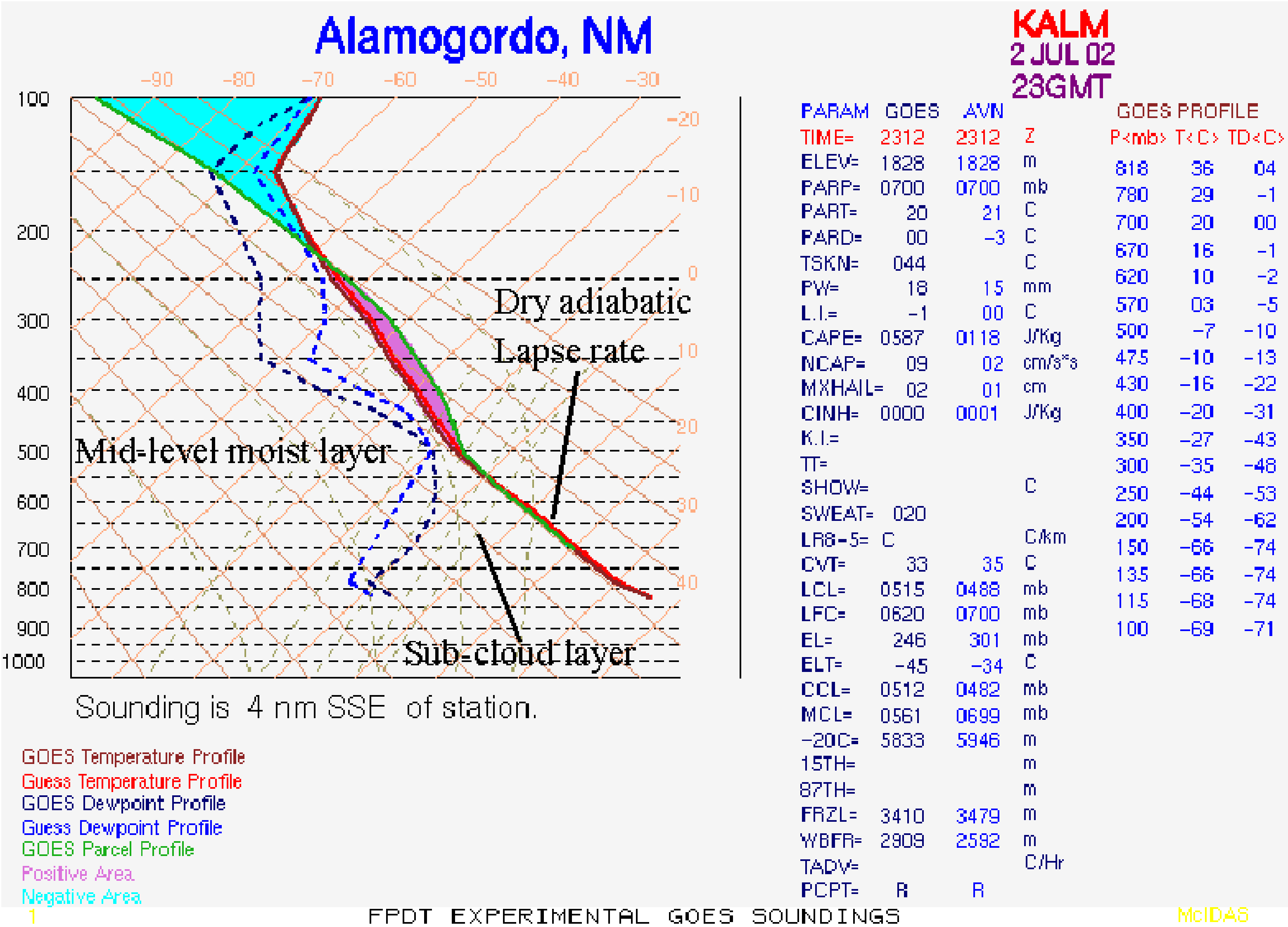
PARAM	GOES	AVN	
TIME=	0300	0300	Z
ELEV=	0609	0609	m
PARP=	0850	0850	mb
PART=	21	21	C
PARD=	18	18	C
TSKN=	023		C
PW=	53	41	mm
L.I.=	-6	-5	C
CAPE=	2772	2290	J/Kg
NCAP=	29	28	cm/s*s
MXHAIL=			cm
CINH=	0138	0166	J/Kg
K.I.=	44	36	
TT=	53	50	
SHOW=	-6	-3	C
SWEAT=	275		
LR8-5= C	06	06	C/km
CVT=	37	38	C
LCL=	0816	0813	mb
LFC=	0677	0660	mb
EL=	187	212	mb
ELT=	-56	-51	C
CCL=	0725	0712	mb
MCL=	0527	0505	mb
-20C=	7060	7114	m
15TH=			m
87TH=	1665	1661	m
FRZL=	4296	4333	m
WBFR=	4093	3701	m
TADV=			C/Hr
PCPT=	R	R	

GOES PROFILE

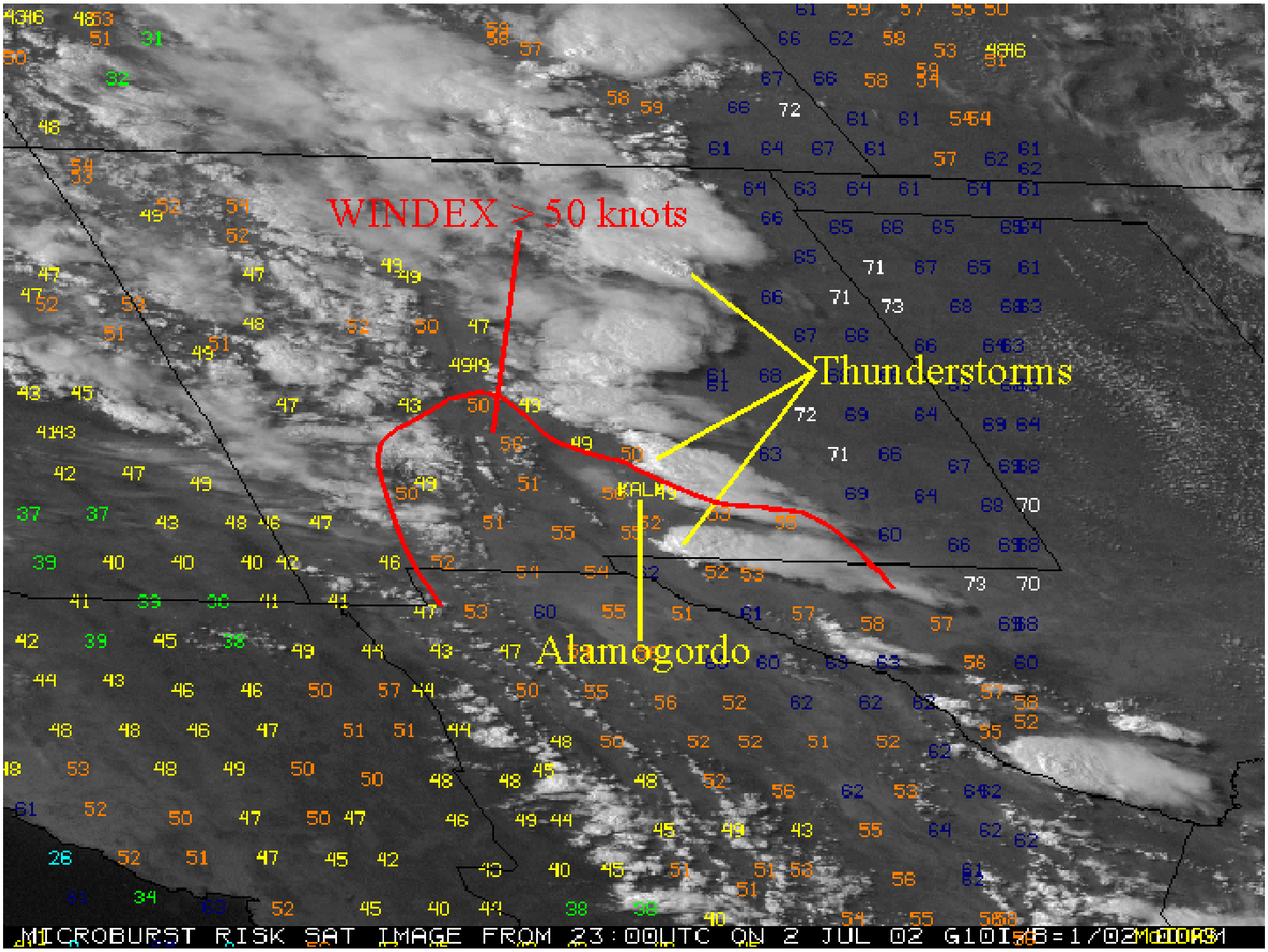
P<mb>	T<C>	TD<C>
943	26	17
920	25	20
850	20	17
780	18	17
700	13	13
670	11	10
620	06	04
570	00	-3
500	-8	-17
475	-11	-19
430	-16	-25
400	-20	-29
350	-27	-34
300	-36	-45
250	-46	-52
200	-54	-64
150	-63	-74
135	-65	-75
115	-67	-76
100	-70	-75

d

Figure 6. GOES WINDEX plotted on enhanced infrared imagery at a) 2345 UTC 26 August 2002; b) 0115 UTC 27 August 2002; c) 0245 UTC 27 August 2002; d) 0300 UTC 27 August 2002 GOES sounding for Woodward, Oklahoma. Note persistant enhanced-V signature in a) through c).


Alamogordo, NM
KALM
2 JUL 02
23GMT
-90 -80 -70 -60 -50 -40 -30
100
200
300
400
500
600
700
800
900
1000
-20
-10
0
10
20
30
40
Dry adiabatic
Lapse rate
Mid-level moist layer
Sub-cloud layer
Sounding is 4 nm SSE of station.
GOES Temperature Profile
Guess Temperature Profile
GOES Dewpoint Profile
Guess Dewpoint Profile
GOES Parcel Profile
Positive Area
Negative Area
PARAM GOES AVN
TIME= 2312 2312 Z
ELEV= 1828 1828 m
PARP= 0700 0700 mb
PART= 20 21 C
PARD= 00 -3 C
TSKN= 044 C
PW= 18 15 mm
L.I.= -1 00 C
CAPE= 0587 0118 J/Kg
NCAP= 09 02 cm/s*s
MXHAIL= 02 01 cm
CINH= 0000 0001 J/Kg
K.I.=
TT=
SHOW= C
SWEAT= 020
LR8-5= C C/km
CVT= 33 35 C
LCL= 0515 0488 mb
LFC= 0620 0700 mb
EL= 246 301 mb
ELT= -45 -34 C
CCL= 0512 0482 mb
MCL= 0561 0699 mb
-20C= 5833 5946 m
15TH= m
87TH= m
FRZL= 3410 3479 m
WBFR= 2909 2592 m
TADV= C/Hr
PCPT= R R
GOES PROFILE
P<mb> T<C> TD<C>
818 36 04
780 29 -1
700 20 00
670 16 -1
620 10 -2
570 03 -5
500 -7 -10
475 -10 -13
430 -16 -22
400 -20 -31
350 -27 -43
300 -35 -48
250 -44 -53
200 -54 -62
150 -66 -74
135 -66 -74
115 -68 -74
100 -69 -71
1
FPDT EXPERIMENTAL GOES SOUNDINGS
McIDAS

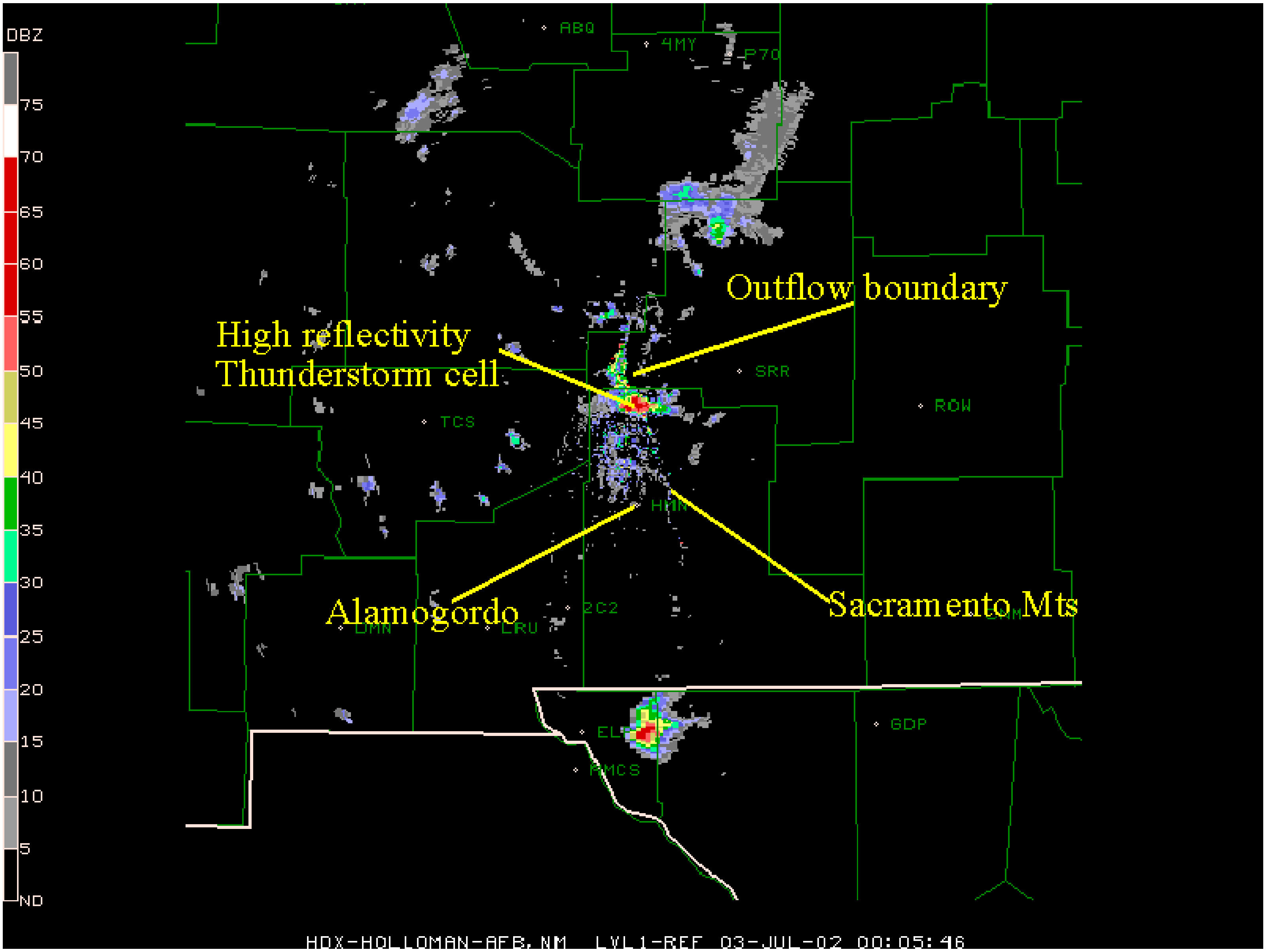
a



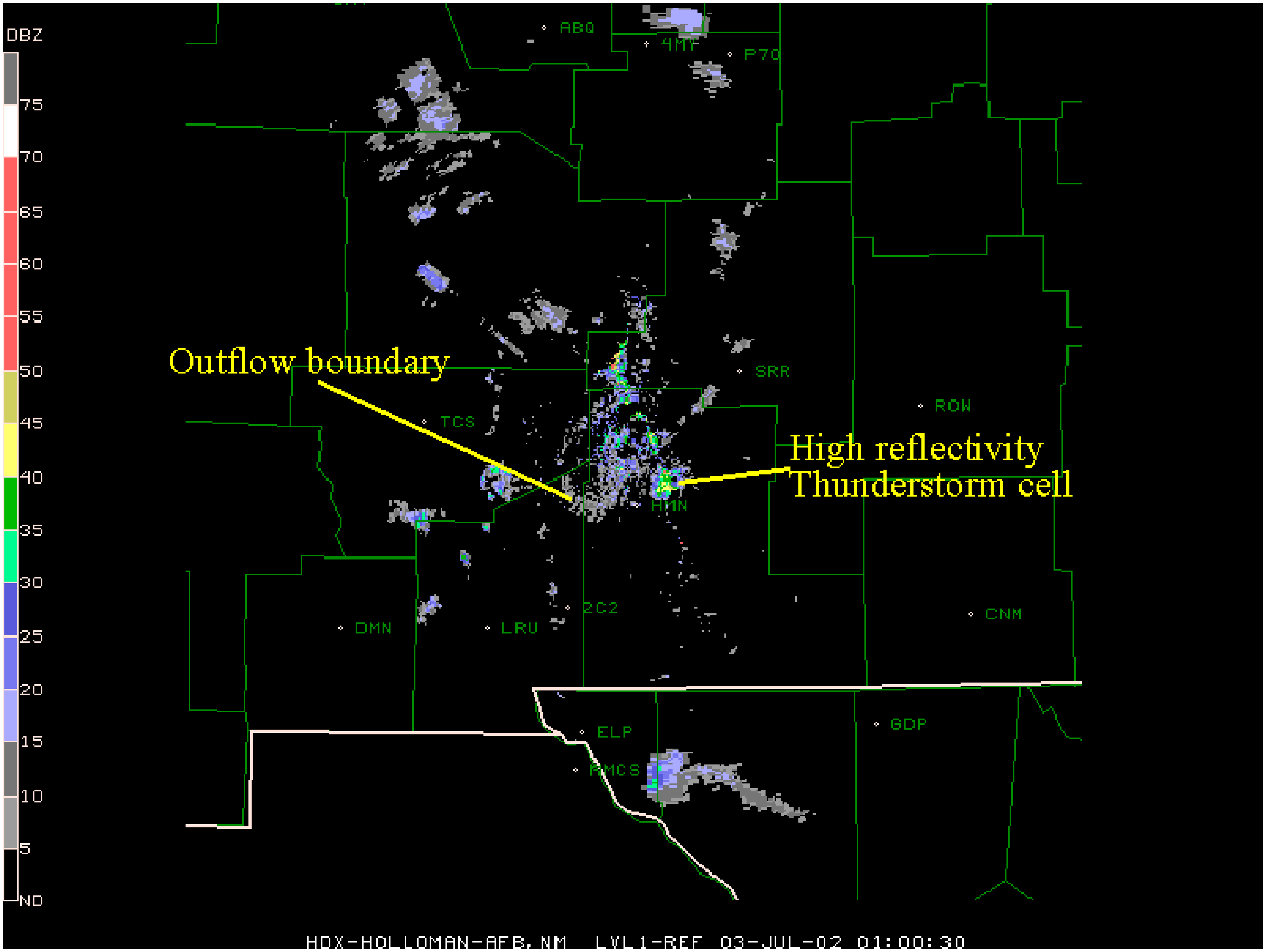
b

Figure 7. a) 2300 UTC 2 July 2002 GOES sounding for Alamogordo, New Mexico, displaying an "hourglass" profile; b) GOES WINDEX plotted on visible imagery at 2300 UTC 2 July 2002. Note WINDEX values in excess of 50 knots in the vicinity of Alamogordo with convection developing over the mountains to the east.

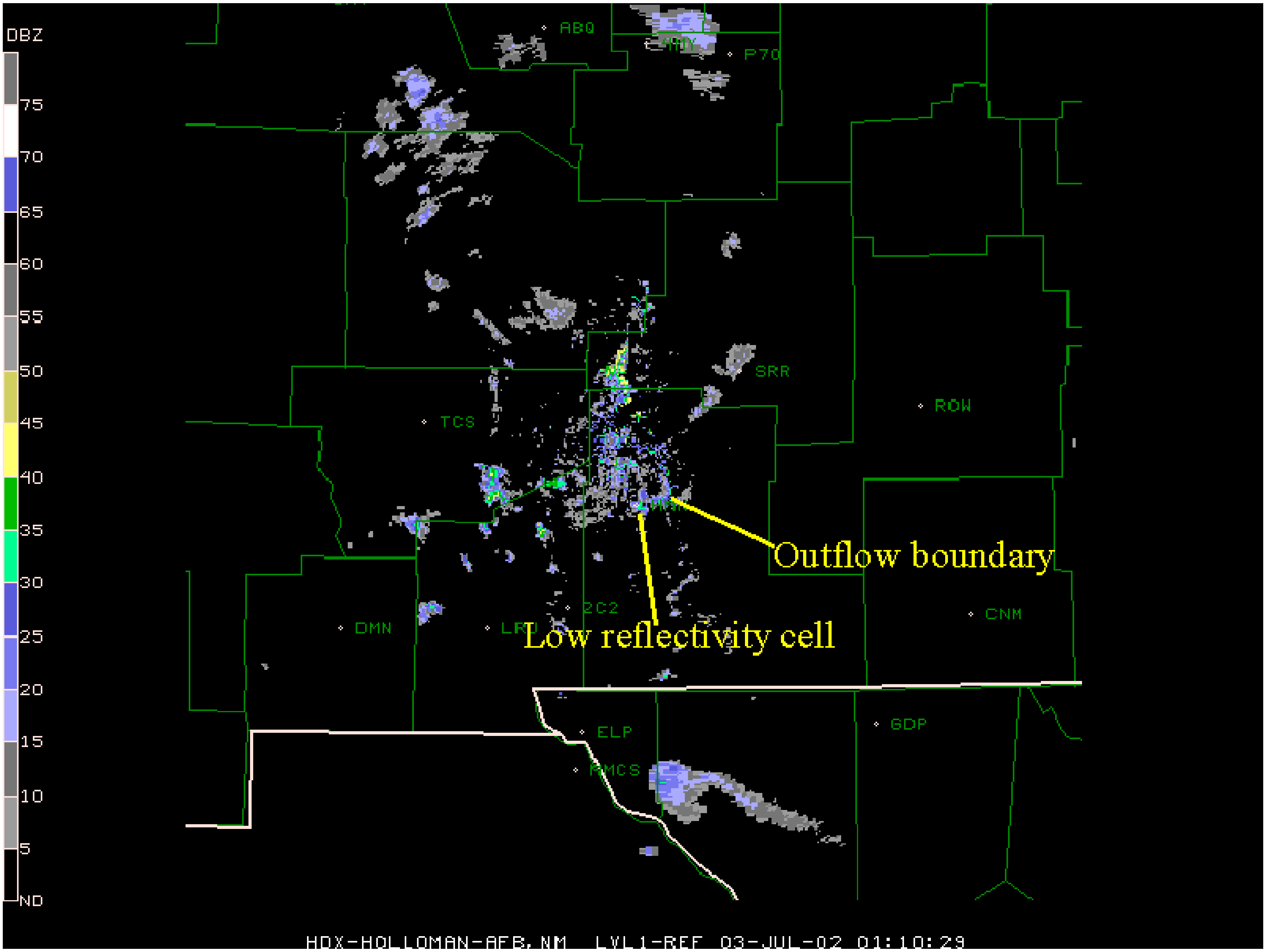
Figure 8


DBZ
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
ND
ABQ
4MY
P70
SRR
ROW
TCS
HMN
2C2
DMN
LRU
ELP
MMCS
GDP
Outflow boundary
High reflectivity
Thunderstorm cell
Alamogordo
Sacramento Mts
HDX-HOLLOMAN-AFB, NM LVL1-REF 03-JUL-02 00:05:46

a


DBZ
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
ND
ABQ
4MY
P70
Outflow boundary
SRR
ROW
TCS
High reflectivity
Thunderstorm cell
HMN
2C2
CNM
DMN
LRU
ELP
GDP
MMCS
HDX-HOLLOMAN-AFB, NM LVL1-REF 03-JUL-02 01:00:30

b



c

Figure 8. NEXRAD reflectivity imagery from Holloman Air Force Base (HDX) for 3 July 2002: a) 0005 UTC; b) 0100 UTC; c) 0110 UTC.