WMSI - A New Index For Forecasting Wet Microburst Severity

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Date Submitted: November 20, 2003

Abstract

A new index to assess the potential and severity of wet microbursts is currently under development. The index, designated as the Wet Microburst Severity Index (WMSI), accounts for the physical processes of convective storm development and downburst generation by incorporating such parameters as convective available potential energy (CAPE), to represent the process of updraft formation, and Theta-e Deficit (TeD), to represent downburst development. Since convective storm updrafts require buoyant energy, a very important parameter used in the analysis of convection is CAPE, which is easily computed from Geostationary Operational Environmental Satellite (GOES) sounding data. Since updraft strength is proportional to CAPE, large CAPE would result in strong updrafts that could lift the precipitation core within a convective storm to the mid-level dry air layer. CAPE also plays a major role in the formation of precipitation. The strong updrafts resulting from large CAPE will increase the size of precipitation particles, which, in turn, will then enhance the effect of precipitation loading. The amount of mid-level water vapor relative to the low-level water vapor in the atmosphere as indicated by a sounding profile is important in the determination of the strength of downdrafts that occur in convective storms. This condition is modeled by the Theta-e Deficit (TeD), represented by the algorithm TeD = theta-e_{max} - theta-e_{min}, where (theta-e_{max}) refers to the maximum value of theta-e at the surface and (theta-e_{min}) refers to the minimum value of theta-e in the mid-levels of the troposphere. TeD serves as an important indicator of the difference in water vapor concentration (plus thermal energy cpT) between the surface and mid-levels. Large TeD values imply the presence of relatively dry air at mid levels that will result in evaporative cooling and the generation of large negative buoyancy as the dry air is entrained into the convection cell. The WMSI algorithm is given as the following expression: WMSI = (CAPE)(theta-e_{max} - theta-e_{min})/1000.

WMSI has been implemented as a new GOES sounder-derived product in the suite of GOES microburst products during the 2003 convective season. This paper will outline the development of the WMSI algorithm and provide examples of the new WMSI product, in which index values at each sounding retrieval location are plotted on GOES imagery. Product validation will entail comparison of the non-dimensional GOES WMSI values to measured convective wind gusts at the surface for each wet microburst event. Validation data for the 2003 convective season will be presented. WMSI values were manually calculated for five events in the southeastern United States during the 2002 convective season and compared to measured surface wind gusts. WMSI correlated well to surface wind gusts and a value of approximately 30 was determined to be the threshold for the occurrence of severe winds (> 50 knots)

at the surface. In addition, a case study will be presented that demonstrates the performance of the WMSI during a convective event as well as to demonstrate the use of the WMSI product in forecast operations.

1. Introduction

Geostationary Operational Environmental Satellite (GOES) sounder-derived products have demonstrated utility in assessment of the potential for convective downbursts. These sounder-derived products in the suite of GOES microburst products include the Wind Index (WINDEX) for estimating the maximum wind gusts, a Dry Microburst Index (DMI) and maximum Theta-e Difference (TeD) for dry and wet microburst potential, respectively. However, during the 2001 and 2002 convective seasons, validation of the WINDEX product revealed a low bias, especially in the nighttime calculation (Pryor et al 2003). Due to the dependence of WINDEX on the square of the temperature lapse rate, the development of the nocturnal temperature inversion after sunset results in the decrease of WINDEX during the evening hours (Ellrod et al 2000). Also, Pryor et al. (2003) noted that in addition to the dependence of WINDEX on the lapse rate, large amounts of convective available potential energy (CAPE) available to "fuel" nocturnal convective systems may influence convective wind gust strength. CAPE is not explicitly accounted for in the WINDEX algorithm.

Accordingly, a new index to assess the potential and severity of wet microbursts is currently under development. The index, designated as the Wet Microburst Severity Index (WMSI), accounts for the physical processes of convective storm development and downburst generation by incorporating such parameters as CAPE (most unstable parcel) to represent the process of updraft formation, and Theta-e Deficit (TeD) to represent downburst development. Since convective storm updrafts require buoyant energy, a very important parameter used in the analysis of convection is CAPE, which is easily computed from GOES sounding data (Zehr et al. 1988). The amount of mid-level water vapor relative to the amount of water vapor in the low levels of the atmosphere as indicated by a sounding profile is important in the determination of the strength of downdrafts that occur in convective storms. This condition is modeled by the Theta-e Deficit (TeD), represented by the algorithm TeD = theta-e_{max} - theta-e_{min}, where (theta-e_{max}) refers to the maximum value of theta-e at the surface and (theta-e_{min}) refers to the minimum value of theta-e in the mid-levels of the troposphere (Atkins and Wakimoto 1991). It can be assumed that convection is a pseudoadiabatic process in which latent heat released during condensation (L_q) is proportional to the amount of water vapor contained by an air parcel (Hess 1959). It follows that the quantity theta-e is directly proportional to the amount of latent heat released as water vapor condenses during the convective process. Thus, TeD serves as an important indicator of the difference in water vapor concentration (plus thermal energy c_pT) between the surface and mid-levels. Large TeD values imply the presence of relatively dry air at mid levels that will result in evaporative cooling and the generation of large negative buoyancy as the dry air is entrained into the convection cell. The WMSI algorithm is given as the following expression: WMSI = (CAPE)(TeD)/1000.

WMSI will be implemented as a new GOES sounder-derived product in the suite of microburst products during the 2004 convective season. This paper will outline the development of the WMSI algorithm and provide examples of the new WMSI product, in which index values at each sounding retrieval location are plotted on GOES imagery. Product validation will entail comparison of the non-dimensional GOES WMSI values to measured convective wind gusts at the surface for each wet microburst event. Validation data for the 2003 convective season will be presented. WMSI values were manually calculated for five events in the southeastern United States during the 2002 convective season and compared to measured surface wind gusts. WMSI correlated well to surface wind gusts and a value of approximately 30 was determined to be the threshold for the occurrence of severe winds (> 50 knots) at the surface. In addition, a case study will be presented that demonstrates the performance of the WMSI during convective events as well as to demonstrate the use of the WMSI product in forecast operations.

2. Background and Algorithm Development

Previous research (Ellrod et al. 2000, Pryor et al. 2002) has noted that the current suite of microburst products including the WINDEX, DMI and Theta-e Deficit (TeD) are effective in assessing maximum possible convective wind gust magnitude (WINDEX) and the potential for wet and dry microbursts (TeD, DMI). However, the utility of these products in forecast operations are conditional upon the occurrence of convection. It has been found that deep convective storms that produce wet microbursts require the presence of large CAPE in the ambient atmosphere prior to convective initiation (Atkins and Wakimoto 1991). Ellrod (1990) also identified that large CAPE was a requirement in the development of downburst-producing convective storms. An early study of the utility of GOES sounder-derived parameters in the analysis of favorable pre-conditions for deep convection by Zehr et al. (1988) found that CAPE was easily computed from sounding data. Since convective storms derive most of their energy from CAPE, the analysis of CAPE is important in the determination of the probability of the development of deep convective storms that could generate wet microbursts. The present suite of GOES microburst products does not explicitly use CAPE in the calculation of microburst risk values (The DMI product only uses CAPE to filter regions that are too stable for microburst production). Thus, the new Wet Microburst Severity Index (WMSI) calculation utilizes the combination of TeD, already shown to be effective in the assessment of wet microburst potential, and CAPE.

The WMSI accounts for both positive and negative buoyancy in a convective storm, governed by the inviscid vertical momentum equation (Doswell 2001). It has been noted previously in this paper that the TeD product was effective in indicating the presence of a dry (low theta-e) layer in the middle troposphere that would be favorable for the production of large negative buoyancy due to evaporative cooling. In order for the process of evaporative cooling and downburst generation to evolve, it is necessary for the precipitation core to be elevated to or above the level of minimum theta-e, where dry air entrainment is likely to occur. Since updraft strength is proportional to CAPE (Weisman and Klemp 1986), large CAPE (positive buoyancy) would result in strong updrafts that could lift the precipitation core within a convective storm to minimum theta-e level. As discussed earlier, CAPE also displays a major role in the formation of precipitation. The strong updrafts resulting from large CAPE will also increase the size of precipitation particles that grow by the process of accretion. This process, in turn, increases precipitation content within the convective cell, which will then enhance the effect of precipitation loading (Doswell 2001; Wakimoto 2001). Once the process of precipitation loading has initiated a downdraft, entrainment of dry (low theta-e) air in the midlevels of a convective storm will enhance downdraft strength by the process of evaporative cooling. Figure 1 illustrates the role of CAPE and TeD in the process of updraft and downdraft formation, respectively. In addition to serving as an indicator of moisture stratification, the TeD is also an effective indicator of the presence of potential instability in a region of interest. In effect, the WMSI is a non-dimensional parameter, based on the thermodynamic structure of the ambient atmosphere that indicates both the potential for deep convective storm development as well as the relative strength of convective wind gusts. Similar to the TeD product, the threshold for severe wet microburst occurrence utilized by the WMSI is subject to local empirical tuning and adjusted regionally based on climatological "representativeness".

3. WMSI Product

The WMSI will be implemented in the suite of GOES microburst products in which index values at each sounding retrieval location will be plotted on GOES imagery. The WMSI product has the appearance as displayed in Figure 2, an example of the GOES sounder-derived WMSI values plotted over a GOES visible satellite image. WMSI imagery is currently available on the GOES WMSI web page: http://www.orbit.nesdis.noaa.gov/smcd/opdb/kpryor/mburst/wmsipage.html. In forecast operations, the WMSI can be applied to deduce the possibility of severe convection, especially if utilized in conjunction with other parameters. One such parameter is the bulk Richardson number (Weisman and Klemp 1986). The bulk Richardson number represents the relationship between storm type, wind shear, and CAPE. Use of the WMSI in combination with the bulk Richardson number can provide a forecaster with information pertaining to storm type (e.g. supercell, multicell) as well as the potential severity of wind gusts produced by the convective storm.

4. Validation

a. Methodology

Data from the GOES WMSI was collected during the 2003 convective season for 35 microburst events (24 daytime, 11 nighttime) from 29 July to 11 September and validated against conventional surface data. Measured wind gusts from SPC storm reports and surface weather observations, recorded during downburst events, were compared with adjacent WMSI values. In order to assess the predictive value of WMSI, GOES data used in validation were obtained for retrieval times one to three hours prior to the observed surface wind gust. WSR-88D base reflectivity imagery 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 (Fujita 1978; Przybylinski and Gery 1983), were effective indicators of the occurrence of downbursts. For 33 out of the 35 events, microbursts were associated with the bow echo signature.

Correlation was computed for the 2003 convective season. GOES WMSI values and corresponding observed wind gusts for the convective season were further subdivided into daytime events, occurring between 1000 and 2000 local standard time (LST), and nighttime events, occurring between 2000 and 1000 (LST). Correlation was then computed separately for daytime and nighttime events. Correlation expresses the degree of a linear relationship between GOES WMSI values and actual measured wind gusts at a particular location for each downburst event. The degree of correlation can range between zero and one, where zero indicates no linear relationship between WMSI and surface convective wind gusts and one indicates a perfect linear 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 WMSI and surface wind gusts. The "null hypothesis" stated that no linear relationship exists between GOES WMSI values and surface convective wind gusts. The "research hypothesis" stated that some degree of correlation exists between the two variables. A "t" test was selected as the test statistic and was conducted for daytime and nighttime events. 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 calculated "t" value for each sample (i.e., daytime, nighttime) is greater than 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 WMSI to Measured Wind Gusts

	Daytime Events (N=24)	**Nighttime Events (N=11)**
Correlation (r)	0.67	0.65
t value	4.24	2.56
Critical Value	1.72	1.83

b. Analysis of Statistics

Validation determined that there exists a statistically significant correlation between GOES WMSI and observed surface wind gusts for both daytime and nighttime events. This result is displayed in Figure 3, which features scatterplots comparing GOES WMSI values to measured convective wind gust speeds, in knots, for both daytime and nighttime events during the 2003 convective season. Hypothesis testing revealed, for both daytime and nighttime events in the 2003 convective season, that correlation "t" values were greater than the corresponding critical values. The null hypothesis could be rejected in favor of the research hypothesis, indicating that there exists a strong positive linear relationship between GOES WMSI and surface wind gusts for both daytime and nighttime events. Thus, high WMSI values correspond to a high risk of severe wet microbursts. The relationship between WMSI values and the magnitude of convective wind gusts is shown in Table 2.

Table 2. Convective Wind Gust Magnitude Corresponding to WMSI Values	
WMSI	**Wind Gusts (kt)**
< 10	Convection/Microbursts Unlikely
10 - 49	< 35
50 - 79	35 - 49
> 80	> 50

The threshold of 35 knot surface wind gusts was selected due to its operational significance for aviation as well as its representation as the lower boundary for F0 intensity damage on the Fujita scale (Fujita 1971). The threshold of 50 knot surface wind gusts was selected due to its significance as severe thunderstorm warning criteria as established by the National Weather Service.

5. Case Study: Dallas-Fort Worth Microbursts

During the evening of 12 August 2003, a complex of convective storms developed over north-central Texas in the vicinity of the Dallas-Fort Worth metropolitan area. As the ambient air mass rapidly destabilized during the evening hours, convection intensified, resulting in the generation of several wet microbursts. The GOES Sounder-derived WMSI product indicated high WMSI values south and east of the Dallas-Fort Worth area, the direction from which the storm inflow originated. A peak convective wind gust of 72 knots was observed at Fort-Worth/Alliance (KAFW) Airport at 0116 UTC 13 August 2003. Other measured wind reports in the area are indicated in Table 2. Predicted wind gust speeds indicated in Table 2 are based on linear regression presented in section 4.

Table 3. Measured Wind Speed vs. GOES WMSI				
Time (UTC)	**Location**	**Measured(kt)**	**WMSI**	**Predicted Wind Gust Speed (kt)**
01:16	Fort Worth (KAFW)	72	111	50-64
02:04	Fort Worth (KFWD)	53	99	50-64
02:12	Fort Worth (KFTW)	40	67	35-49
02:22	Dallas (KRBD)	54	99	50-64

A broken line of deep convective cells developed over the Oklahoma-Texas border during the late afternoon of 12 August 2003. The air mass in which the convective activity was developing was marginally unstable as indicated in Figure 4a, by the 2245 UTC GOES WMSI values ranging from 17 to

28 over south-central Oklahoma. The GOES WMSI image at 2245 UTC also indicated very low values in the vicinity of Dallas-Fort Worth, signifying unfavorable conditions for deep convection. High WMSI values > 80 were apparent to the east of Dallas-Fort Worth associated with an area of low-level moisture. The presence of low clouds over northeastern Texas was an indicator of a more unstable air mass with significant low level moisture. During the next three hours, low-level easterly flow advected the moist and unstable air mass westward toward the Dallas-Fort Worth area while the complex of convective cells drifted southwestward into north-central Texas.

By 0059 UTC 13 August 2003, Figure 5a, Dallas-Fort Worth NEXRAD (KFWS) reflectivity imagery, revealed that an ouflow boundary, generated by a dissipating convective storm, was triggering a new convective cell just northeast of Fort Worth/Alliance (KAFW) Airport. At approximately the same time, Figure 4b, 0100 UTC WMSI imagery, indicated a dramatic increase in index values south and east of the Dallas-Fort Worth area, on the inflow side of the complex of convective storms. WMSI values had increased to well over 100 east and southeast of the deep convection, indicating a rapid destabilization of the air mass in the Dallas-Fort Worth area. Lower WMSI values (<50) in the immediate vicinity of the Dallas-Fort Worth area were most likely influenced by convective outflow and were not considered representative for this case. Approximately 15 minutes later, Figure 5b, 0113 UTC radar reflectivity imagery, indicated the storm cell developing north of KAFW had intensified significantly with a maximum reflectivity of over 60 dBZ. At 0116 UTC, a peak convective wind gust of 72 kt. was observed at Fort Worth/Alliance Airport. Seven minutes later, Figure 5c confirmed the occurrence of a microburst, as the storm cell had evolved into a bow echo shape (Przybylinski 1995).

Figure 4c, the WMSI image at 0145 UTC, displays that the area of low-level moisture (as indicated by the presence of low clouds) and high WMSI values (> 80) was in place south of the Dallas-Fort Worth area. The WMSI value of 99 displayed south of the Dallas-Forth Worth area indicated the presence of an unstable atmosphere with low-level moisture and dry air aloft and thus, indicated a high risk of severe wet microbursts. During the next 15 minutes, as displayed in Figure 5d, a cluster of convective cells, developing along an outflow boundary produced by earlier convection, merged to form a bow echo north of downtown Fort Worth. Thus, another microburst was in progress and at 0204 UTC, a wind gust of 53 kt. was recorded at the National Weather Service (NWS) Forecast Office (KFWD) in downtown Fort Worth. During this same time period, a convective cell developed east of the Dallas metropolitan area and rapidly intensified as it tracked southwest. By 0213 UTC, Figure 5e indicated that maximum reflectivity with the storm cell had increased to 60 dBZ. Ten minutes later, the cell had evolved into a distinct bow echo just north of Dallas/Redbird Airport (KRBD) as displayed by Figure 5f, the 0223 UTC radar reflectivity image. This signified that another microburst was in progress. Around this time, a peak convective wind gust of 54 knots was observed at KRBD.

Rapid destabilization of the atmosphere during the evening of 12 August 2003 was a major factor in the development and evolution of the severe convective storm outbreak in the Dallas-Fort Worth area. Figure 6, a comparison of GOES soundings for Dallas-Fort Worth between 2300 UTC 12 August and 0200 UTC 13 August, revealed a significant increase in (most unstable) CAPE, from 179 to 1490 J Kg^{-1}, as a result of the moistening of the low-levels of the troposphere. Although radar reflectivity imagery and surface observations indicated conditions associated with wet microbursts (e.g., high radar reflectivity, heavy rainfall), the 0200 UTC GOES sounding, just prior to the microburst activity, displays a profile with characteristics typical of both wet and dry microbursts (Ellrod 1989). In common with wet microbursts conditions, the profile indicated large CAPE as well as a mid-tropospheric dry air layer overlying a relatively deep moist layer. However, a deeper, dry subcloud region apparent in the sounding signified conditions more often associated with dry microbursts. Outflow boundary interaction was the dominant trigger in this severe convection outbreak. Outflow boundaries from prior convection served as a local surface lifting mechanism. Once upward motion was initiated by low-level convergence, large CAPE resulted in strong updrafts that lifted the precipitation core within the convective storms to the mid-level dry air layer. Large WMSI values implied the presence of large CAPE as well as relatively dry air at mid levels that would result in evaporative cooling and the generation of large negative buoyancy as dry air was entrained into the convection cells.

Statistical analysis revealed that the WMSI accurately portrayed this microburst event. Correlation between WMSI and measured surface wind gusts was calculated to be .92, where a correlation of 1 indicates a perfect linear relationship. In addition, hypothesis testing was conducted to determine the significance of a linear relationship between GOES WMSI and surface wind gusts. In the process of hypothesis testing, it was discovered that the linear relationship between GOES WMSI and surface wind gusts was statistically significant. Thus, this case demonstrates utility of the WMSI product in forecast operations. As evidenced by the study of this event, the WMSI product can be an effective forecasting tool in severe convective weather situations if used in conjunction with other data, such as radar imagery.

6. Future Plans

Further WMSI product validation, refinements to the display of the WMSI and operational implementation will be conducted during 2004. Virtual graphics will be overlain on the WMSI display to provide a product legend and description. It is also projected that by Spring 2004, the WMSI product will be accessible on the GOES Microburst Products website. The collection of more nighttime validation data during the 2004 convective season will be necessary to assess the performance of the WMSI during nocturnal microburst events, particularly with higher WMSI values. Further product validation should serve to ascertain thresholds of severity and emphasize the operational utility of the WMSI product.

7. Summary and Conclusions

The WMSI product is designed to account for convective storm development and downburst generation, incorporating the parameters CAPE and TeD, for the purpose of assessing the potential severity of wet microbursts. This preliminary study and the initial validation of the WMSI product during the 2003 convective season has highlighted its potential utility as an indicator of the magnitude of wet microbursts. Computed correlation statistics, hypothesis testing and an in-depth case study have revealed a strong positive linear relationship between the WMSI and measured surface wind gusts. Incorporation of the CAPE parameter into the index establishes the WMSI as an effective indicator of the strength of deep convection as well as microburst strength. The WMSI demonstrates versatility in forecast operations if used in conjunction with other data, such as radar and satellite imagery as well as other summary parameters.

8. 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.

Doswell, C.A., 2001: Severe convective storms- An overview. *Severe Convective Storms*, C.A. Doswell, Ed., Amer. Meteor. Soc., 1-26.

Ellrod, G. P., 1989: Environmental conditions associated with the Dallas microburst storm determined from satellite soundings. *Wea. Forecasting*, **4**, 469-484.

Ellrod, G. P., 1990: The assessment of microburst potential using GOES-VAS sounder data. Preprints, *16th Conf. On Severe Local Storms*, Kananaskis Park, AB, Canada, Amer. Meteor. Soc., 161-166.

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.

Hess, S.L., 1959: Introduction to Theoretical Meteorology. Krieger Publishing Company, Malabar, FL, 362 pp.

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)

Pryor, K.L., G.P. Ellrod, and A.A. Bailey, 2003: Recent Improvements to the GOES Wind Index.

National Weather Association Electronic Journal of Operational Meteorology, 2003-EJ1. (http://orbit-net.nesdis.noaa.gov/arad/fpdt/paper/windex.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.

Przybylinski, R.W., 1995: The bow echo. Observations, numerical simulations, and severe weather detection methods. *Wea. Forecasting*, **10**, 203-218.

Wakimoto, R.M., 2001: Convectively Driven High Wind Events. *Severe Convective Storms*, C.A. Doswell, Ed., Amer. Meteor. Soc., 255-298.

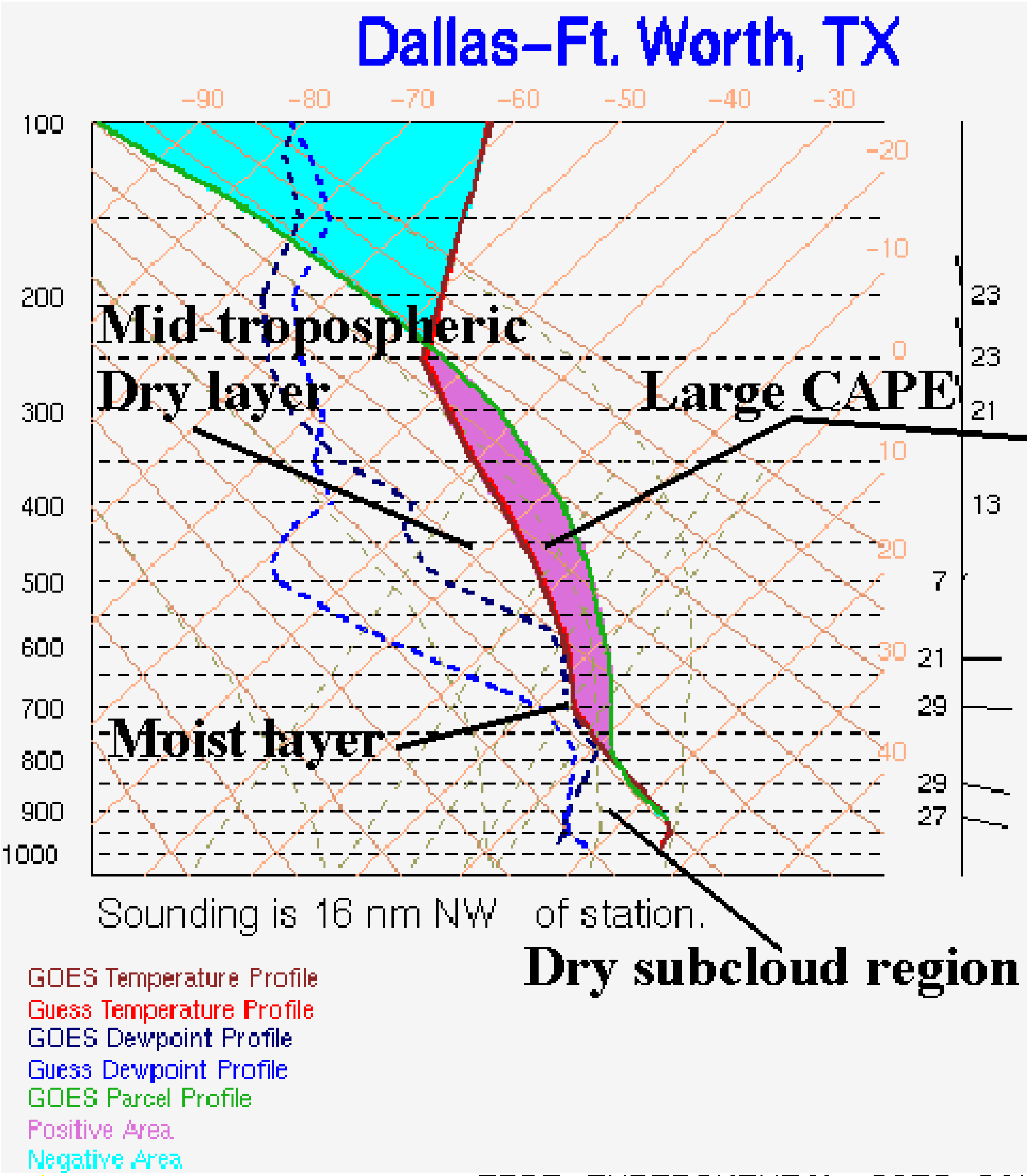
Weisman, M.L. and J.B. Klemp, 1986: Characteristics of Isolated Convective Storms. In Mesoscale Meteorology and Forecasting. P.S. Ray (Ed.), American Meteorological Society, Boston, 331-358.

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.

Acknowledgements

The authors thank Jaime Daniels (NESDIS/Forecast Products Development Team) and Raytheon contractors for providing GOES sounding retrievals displayed in this paper. Radar imagery (NIDS/NEXRAD) was provided by Peter Neilley, National Center for Atmospheric Research, Research Applications Program (NCAR/RAP).

Figure 1


Dallas-Ft. Worth, TX
-90
-80
-70
-60
-50
-40
-30
100
200
300
400
500
600
700
800
900
1000
-20
-10
0
10
20
30
40
23
23
21
13
7
21
29
29
27
Mid-tropospheric
Dry layer
Large CAPE!
Moist layer
Sounding is 16 nm NW of station.
Dry subcloud region
GOES Temperature Profile
Guess Temperature Profile
GOES Dewpoint Profile
Guess Dewpoint Profile
GOES Parcel Profile
Positive Area
Negative Area

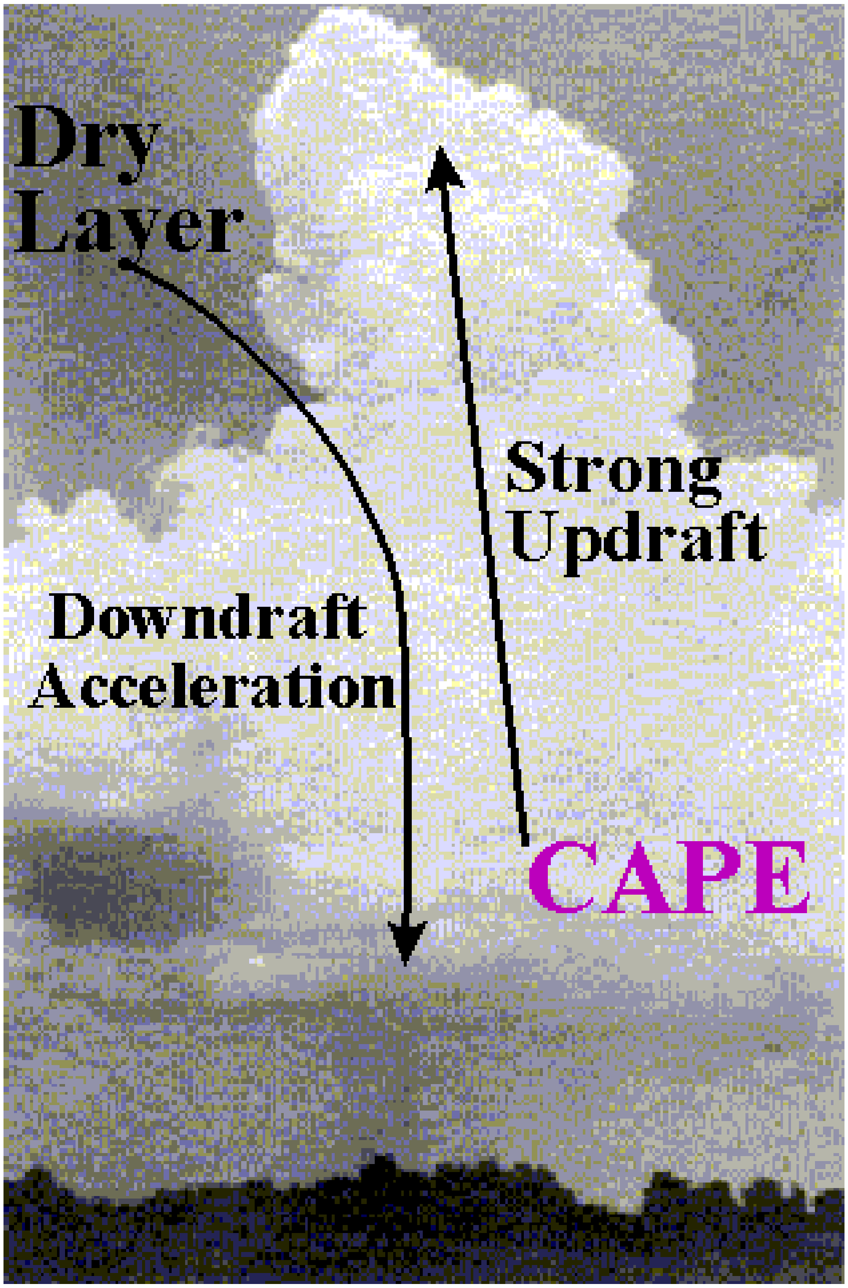


Figure 1. Comparison of a GOES derived sounding to a photograph of a single cell convective storm that produced a wet microburst (Atkins and Wakimoto 1991).

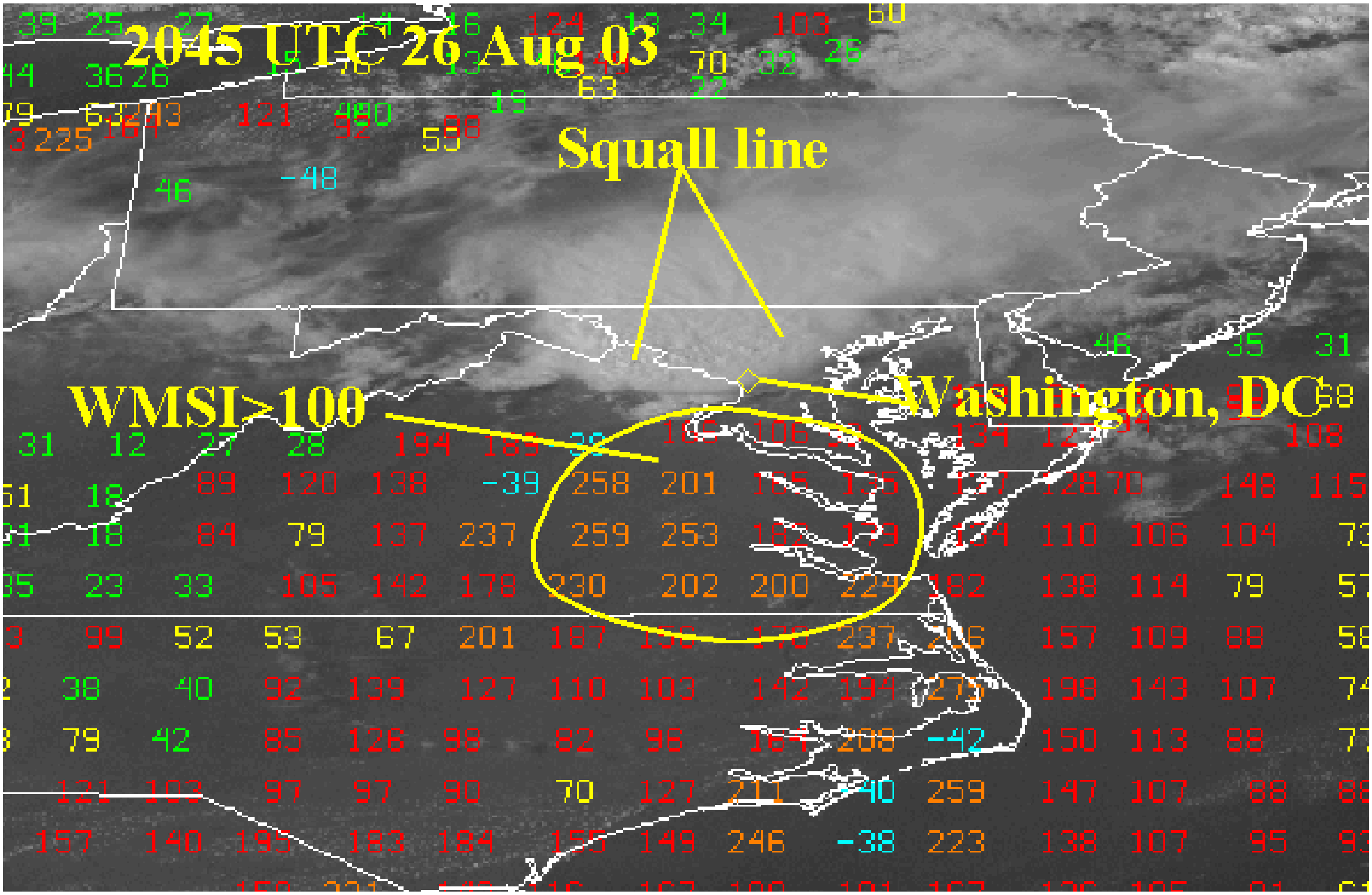
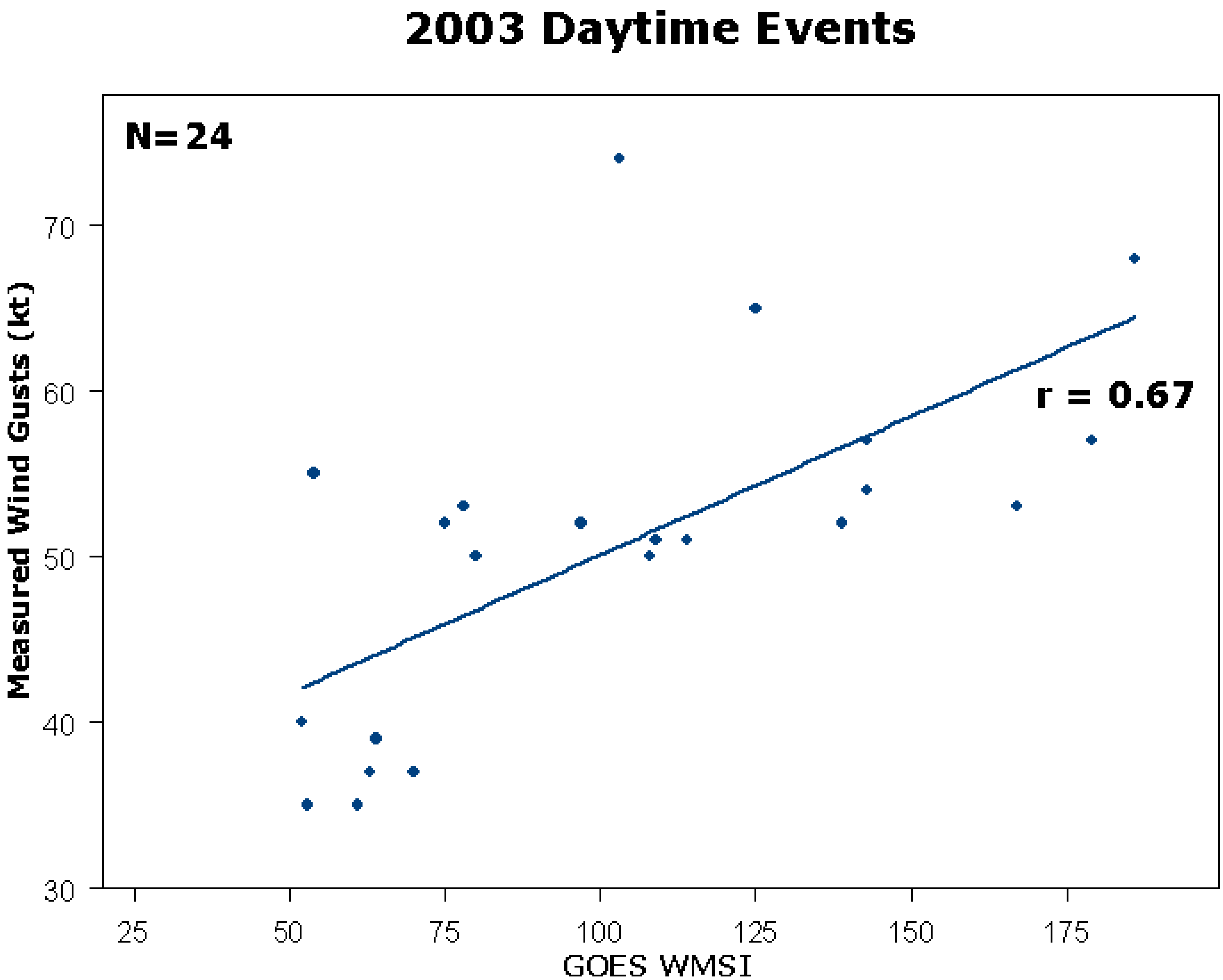


Figure 2. An example of a GOES WMSI image at 2045 UTC 26 August 2003.


2003 Daytime Events
N=24
r = 0.67
Measured Wind Gusts (kt)
GOES WMSI
70
60
50
40
30
25
50
75
100
125
150
175

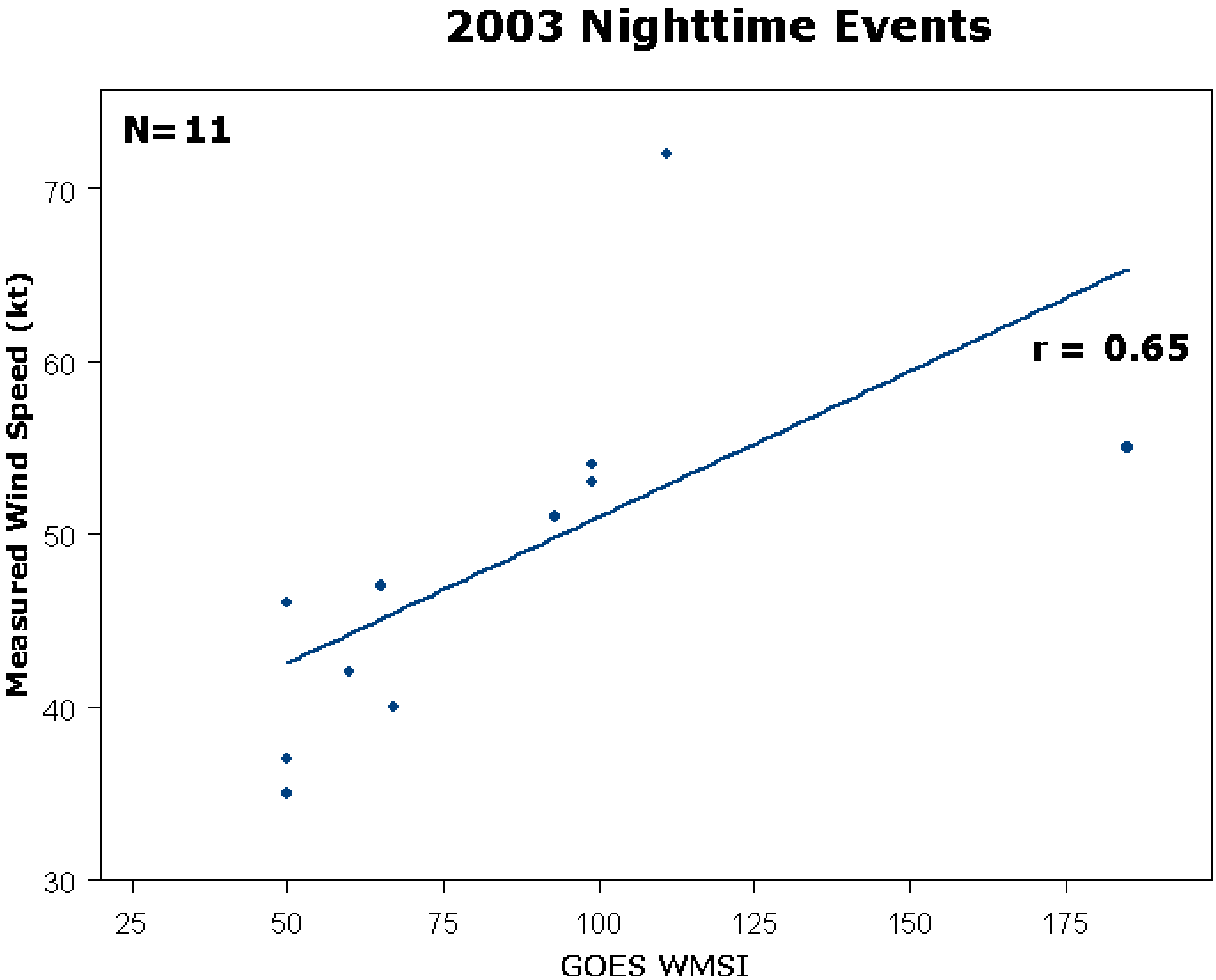
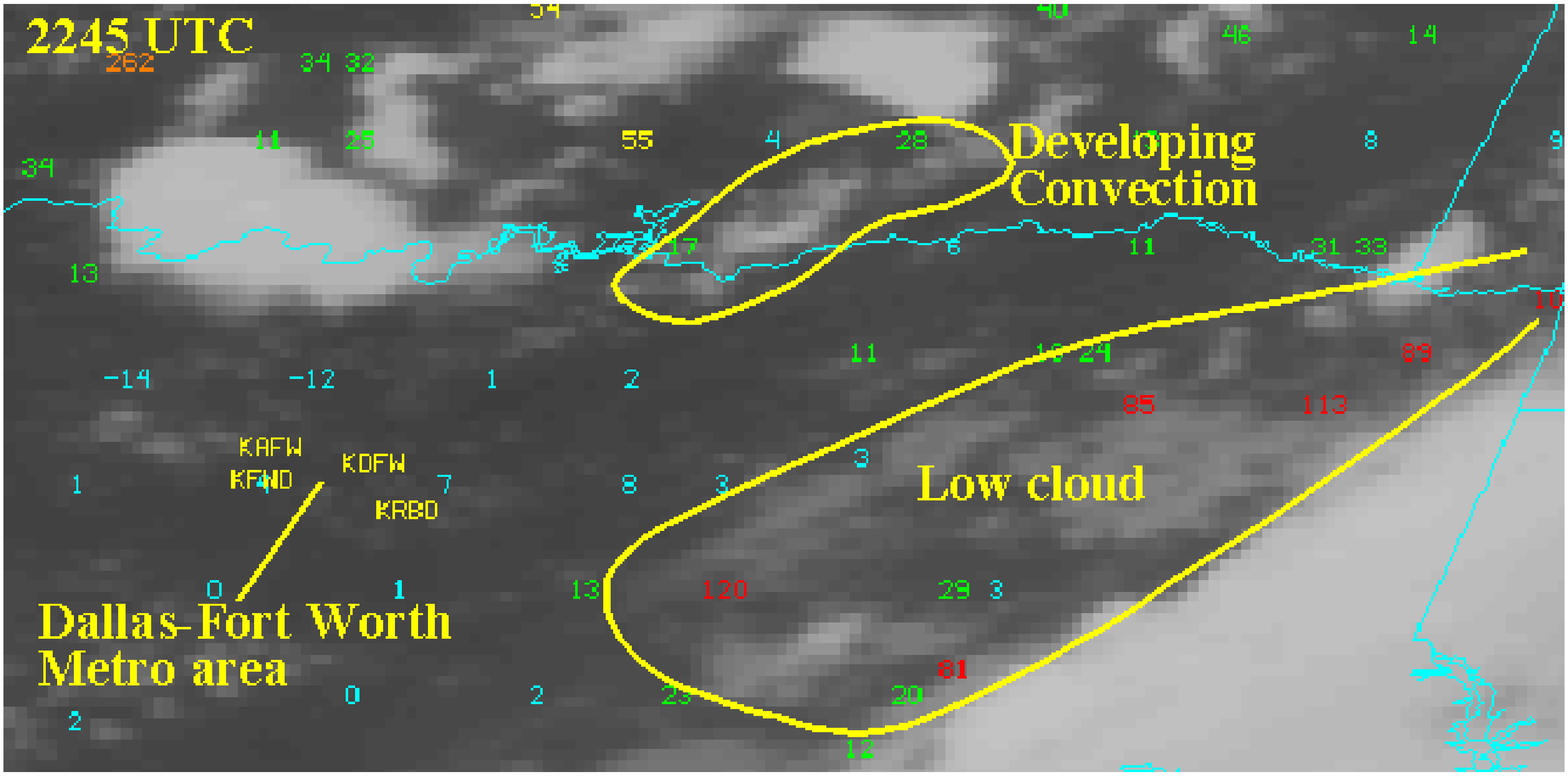


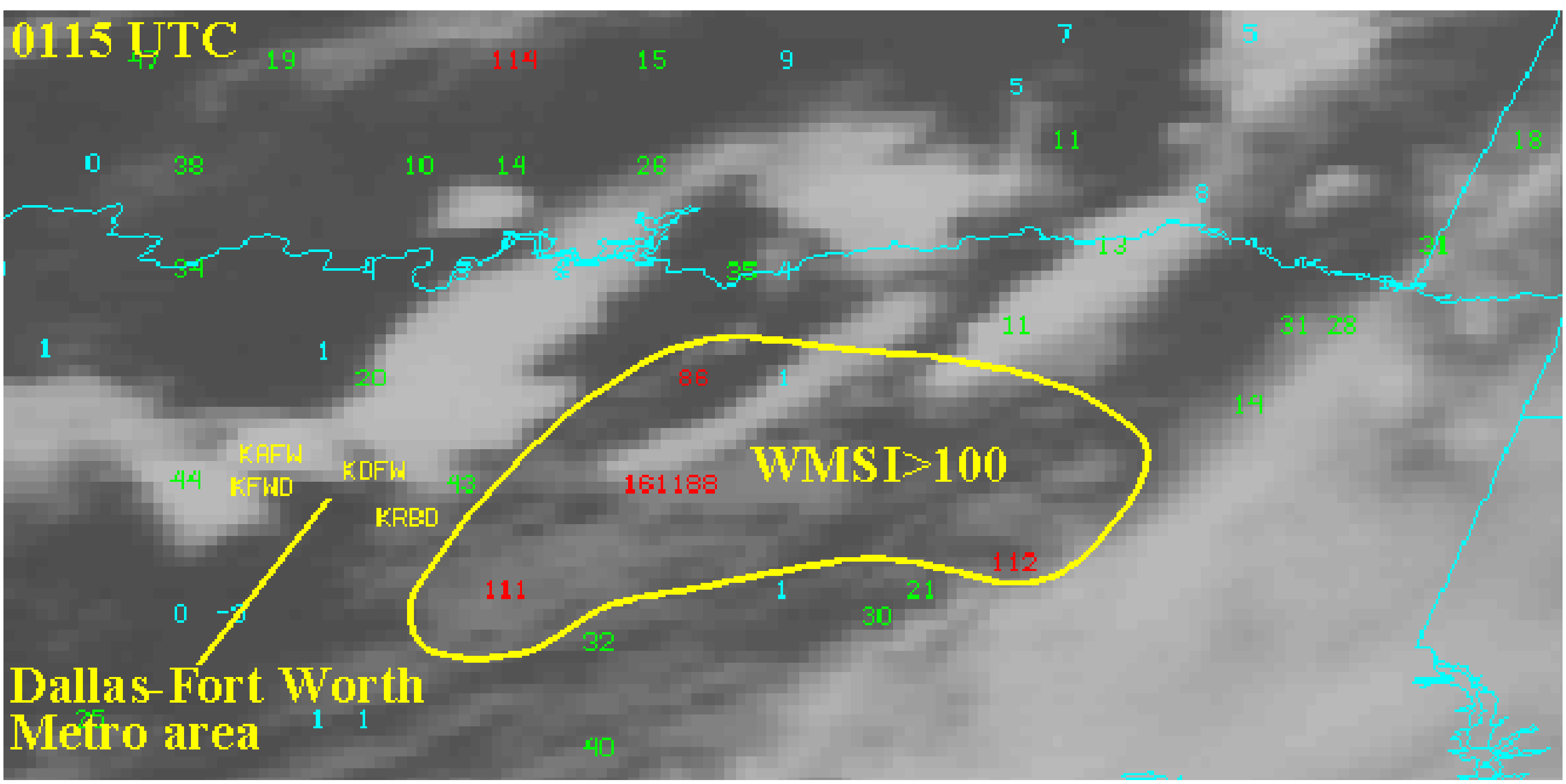
Figure 3. Scatterplots comparing GOES WMSI values to measured convective wind gust speeds, in knots, for both daytime and nighttime events during the 2003 convective season.

Figure 4



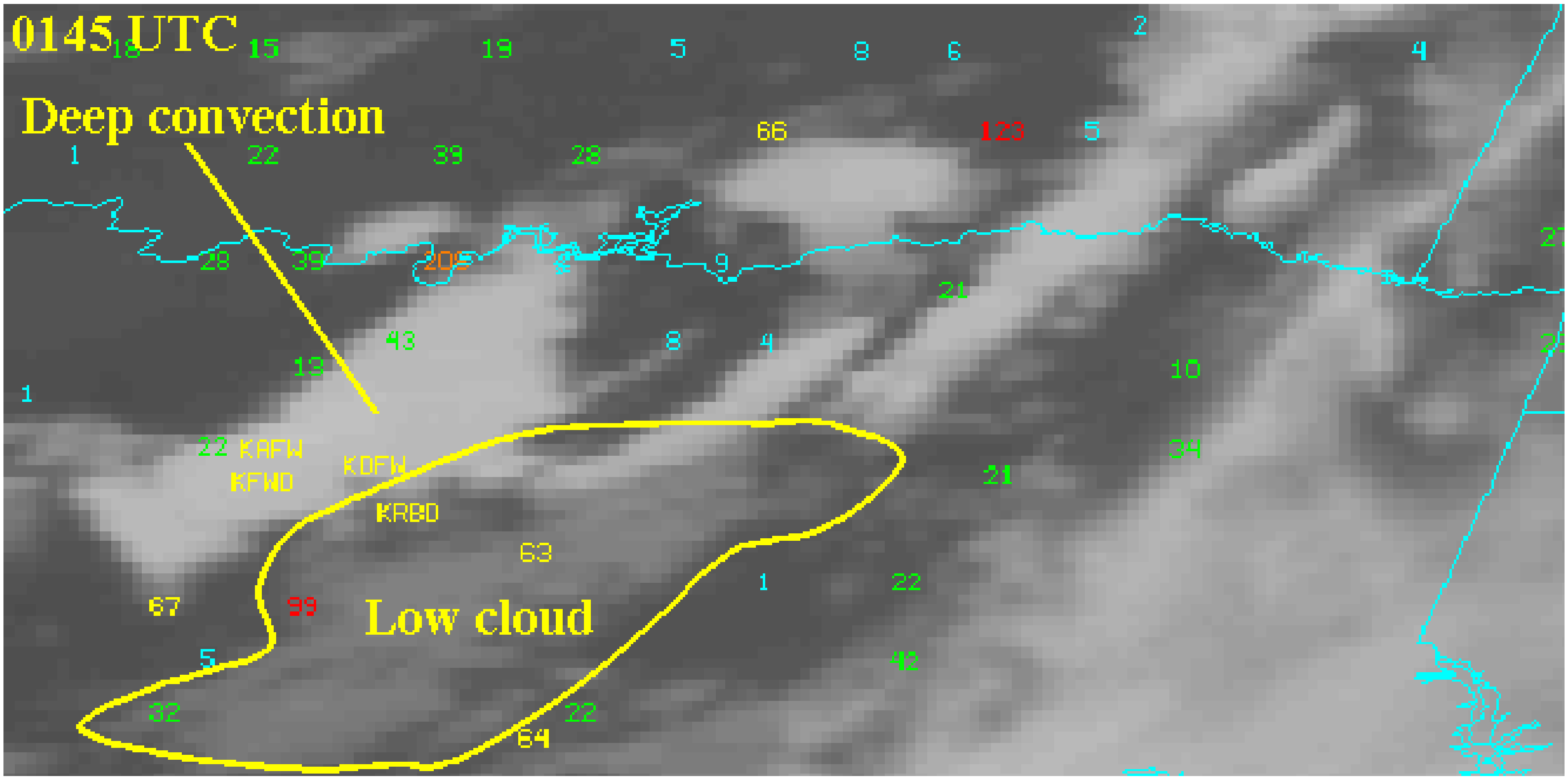
2245 UTC
Developing Convection
Low cloud
KAFW
KFWD
KDFW
KRBD
Dallas-Fort Worth Metro area

a



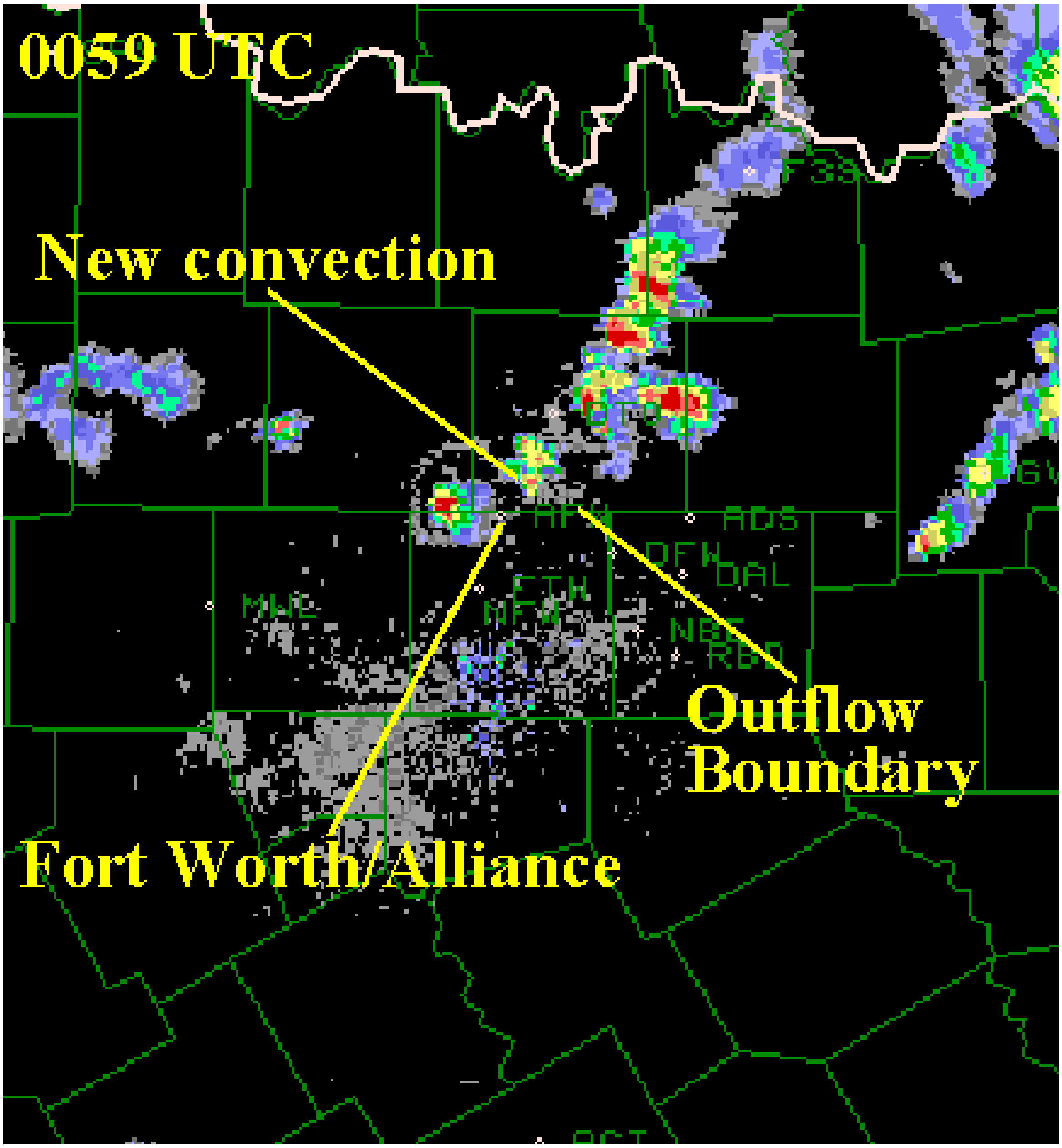
0115 UTC
WMSI>100
KAFW
KFWD
KDFW
KRBD
Dallas-Fort Worth Metro area

b

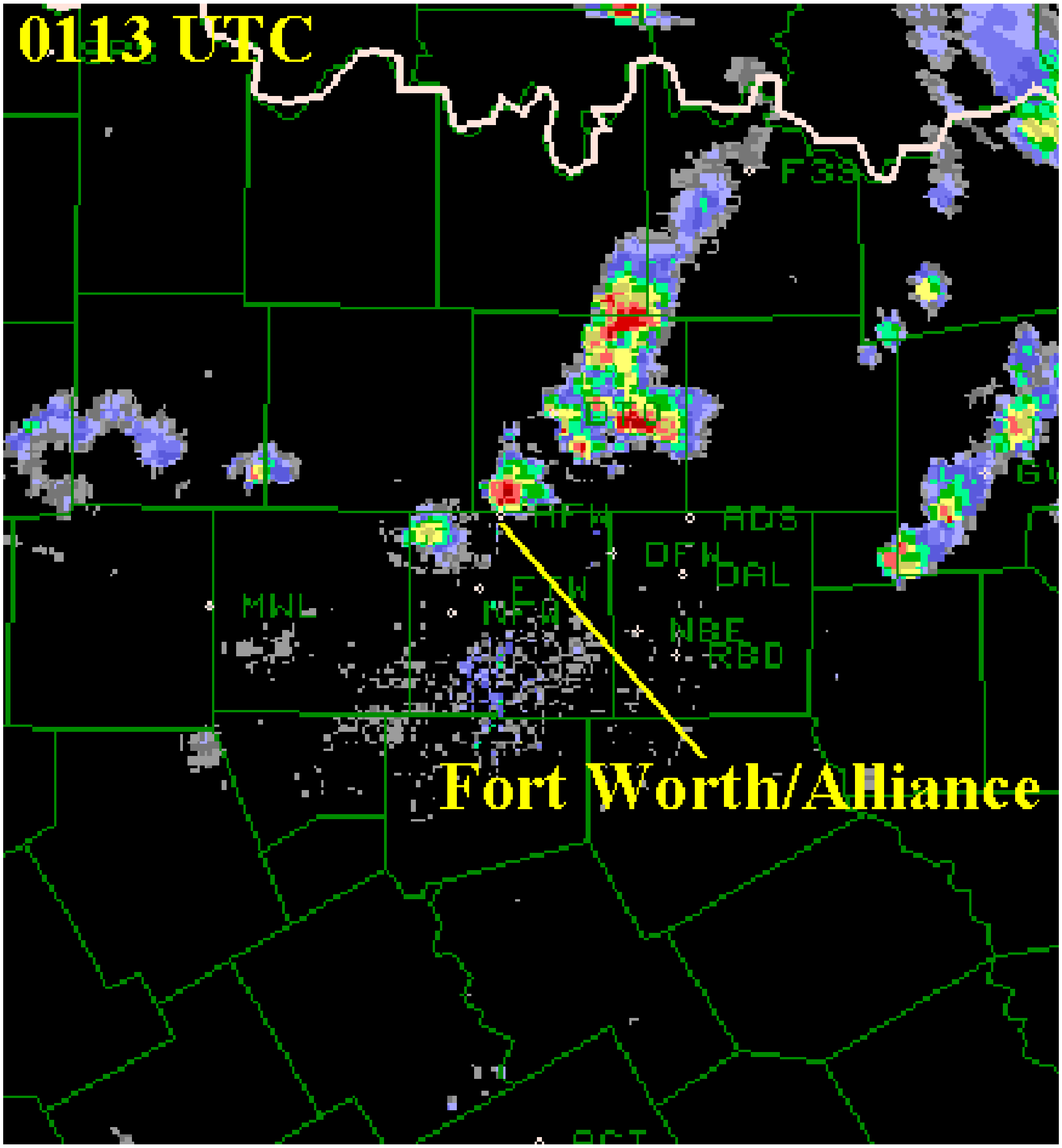


c

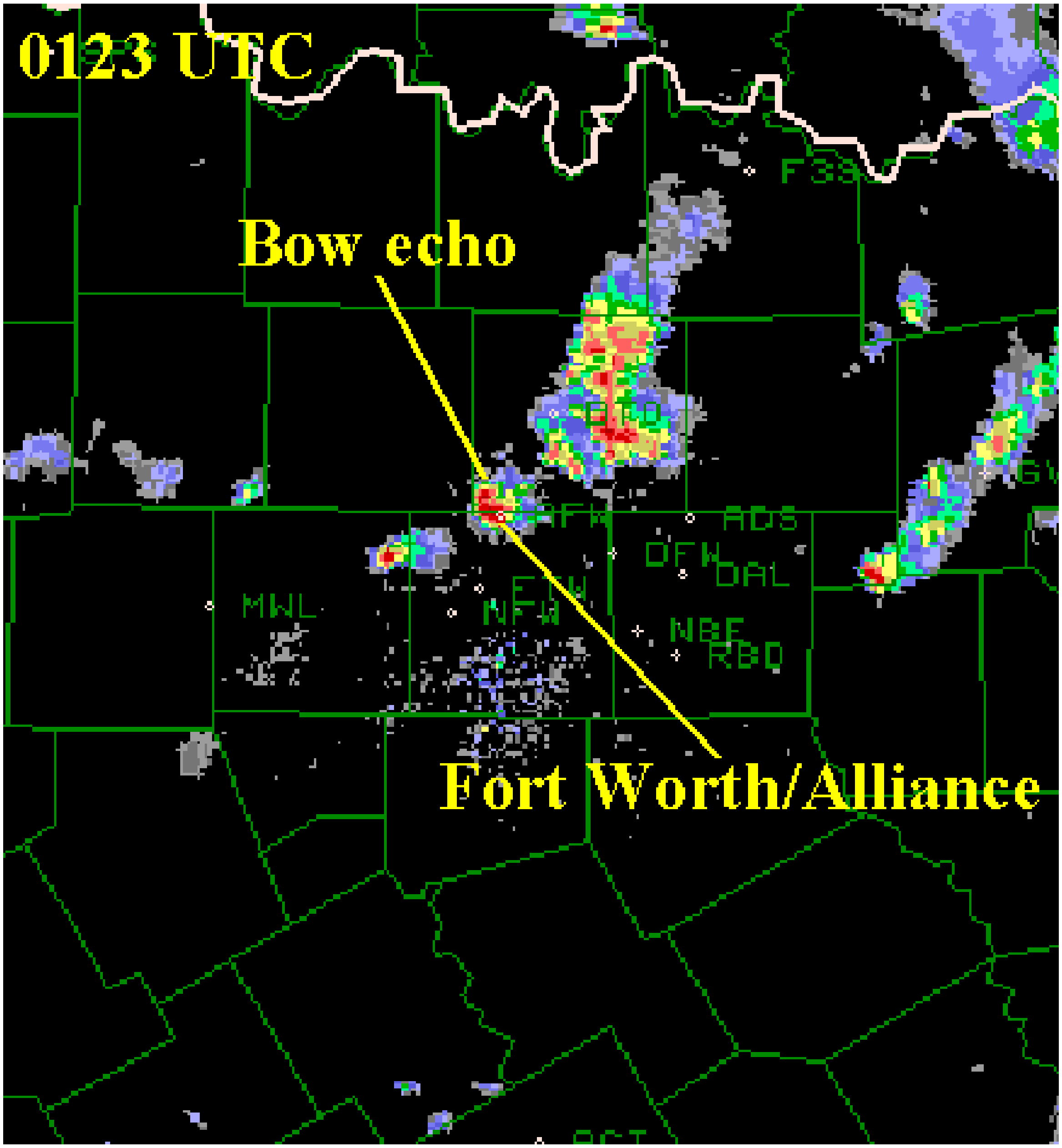
Figure 4. GOES WMSI plotted on infrared imagery at a) 2245 UTC 12 August 2003; b) 0115 UTC 13 August 2003; c) 0145 UTC 13 August 2003.


0059 UTC
New convection
Outflow
Boundary
Fort Worth/Alliance
AFW
ADS
DFW
DAL
FTW
NFW
MWL
NBE
RBD
GVT
F39
ACT

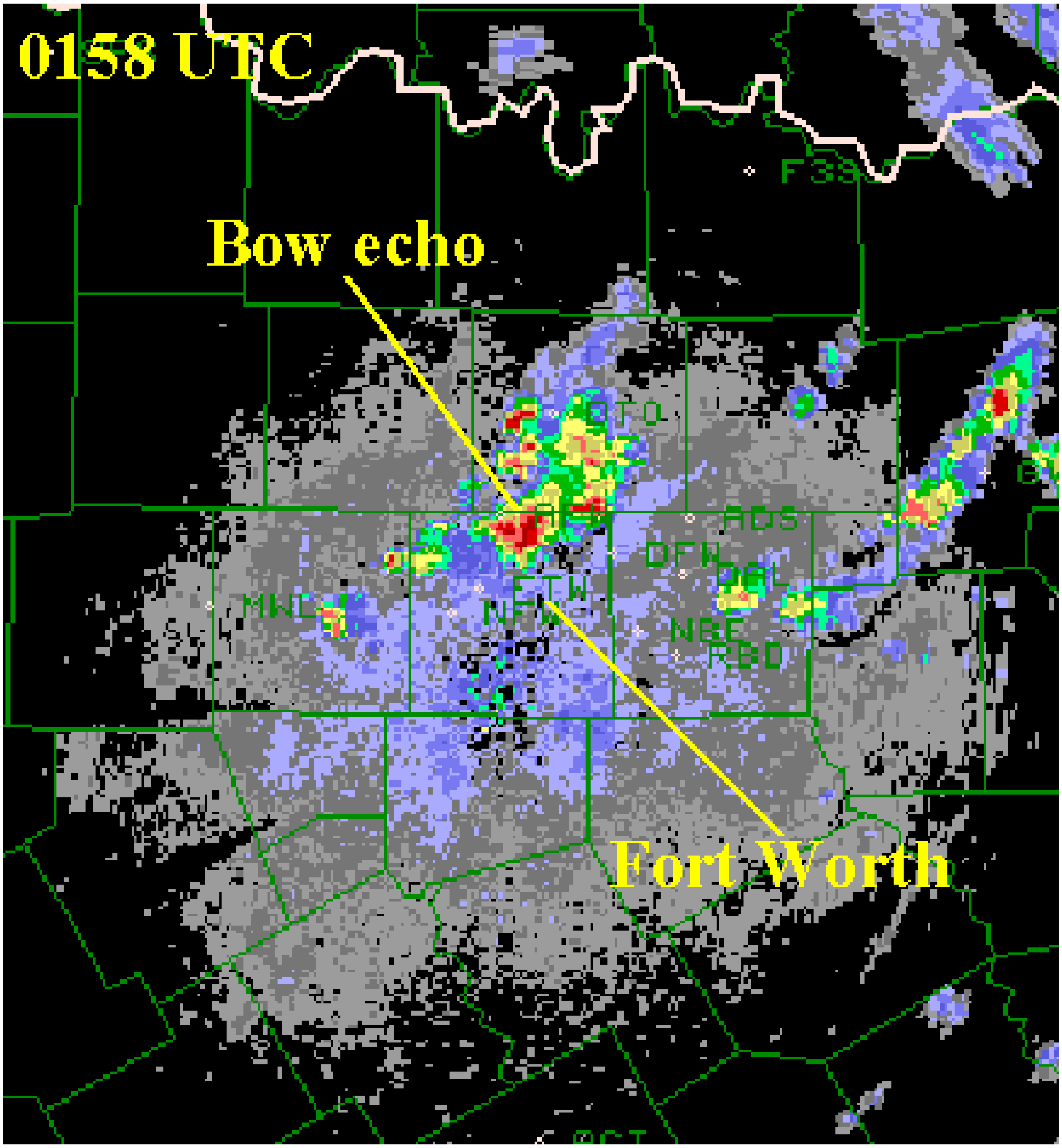
a


0113 UTC
Fort Worth/Alliance
AFW
ADS
DFW
DAL
MWL
FTW
NFW
NBE
RBD
F39

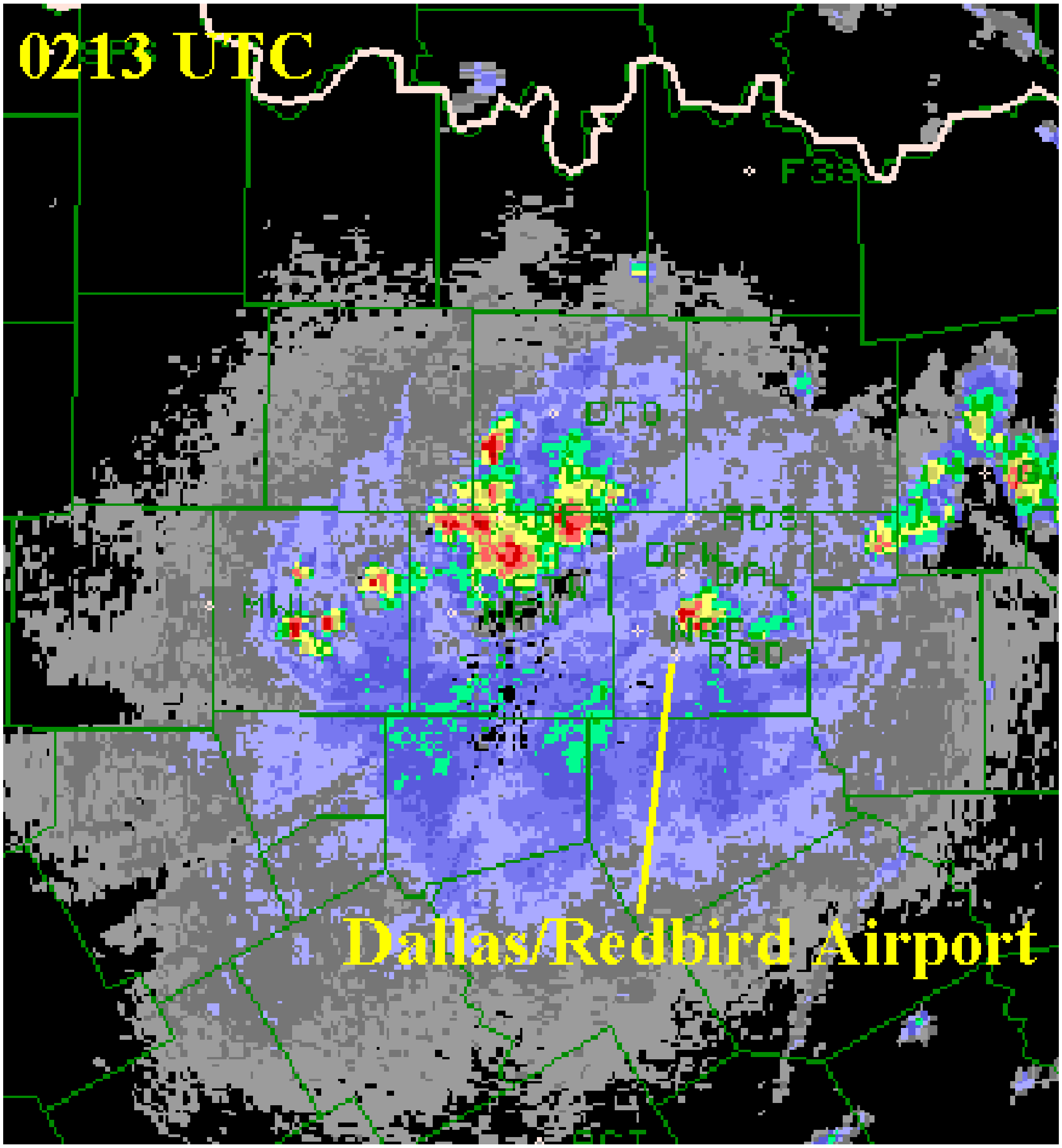
b


0123 UTC
Bow echo
Fort Worth/Alliance
F39
FTW
ADS
DFW
DAL
MWL
NFW
NBE
RBD
GVT

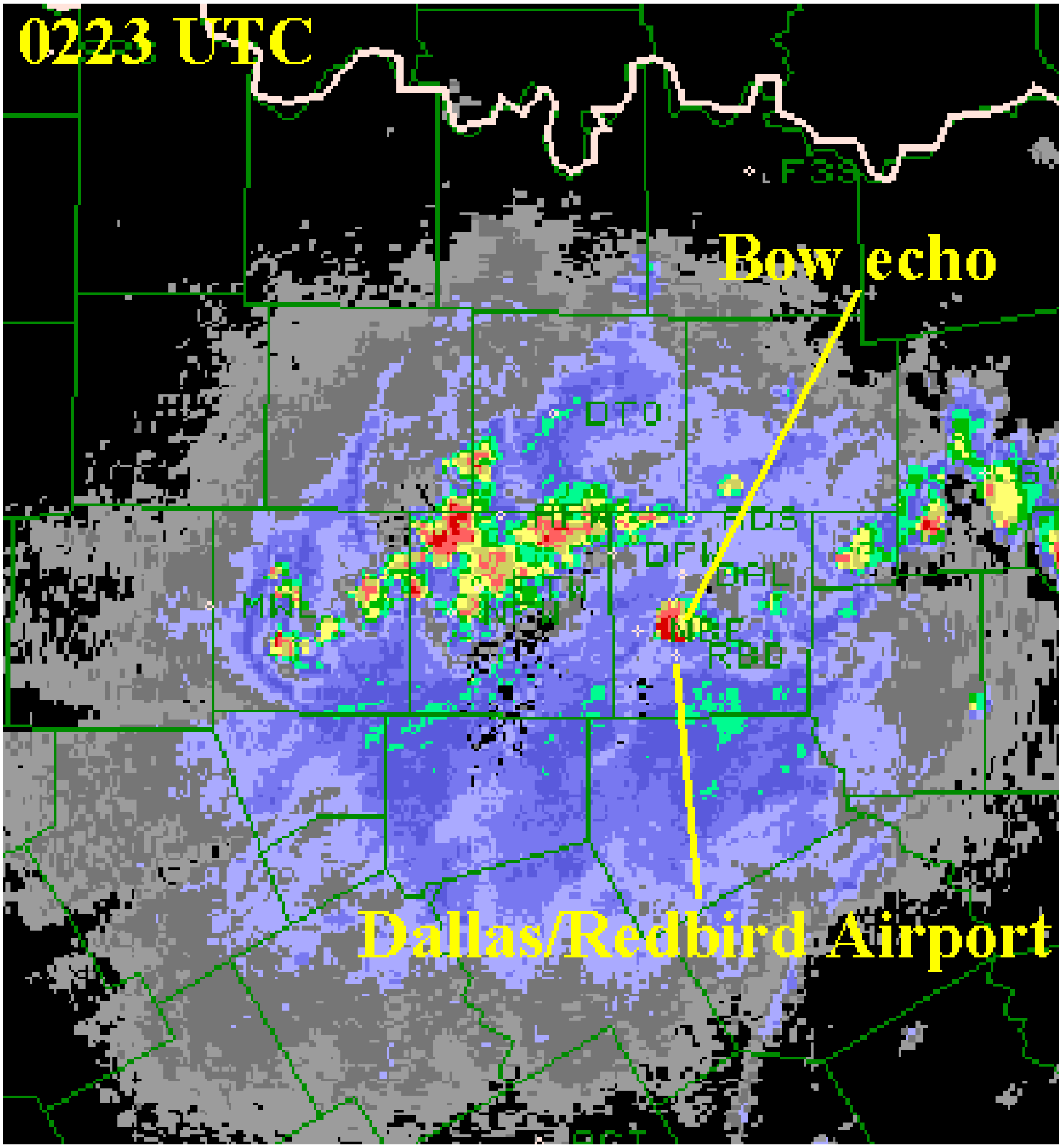
c


0158 UTC
Bow echo
Fort Worth
ADS
DFW
MWL
NFW
FTW
NBE
RBD
DAL
GYI
DTO
F39

d



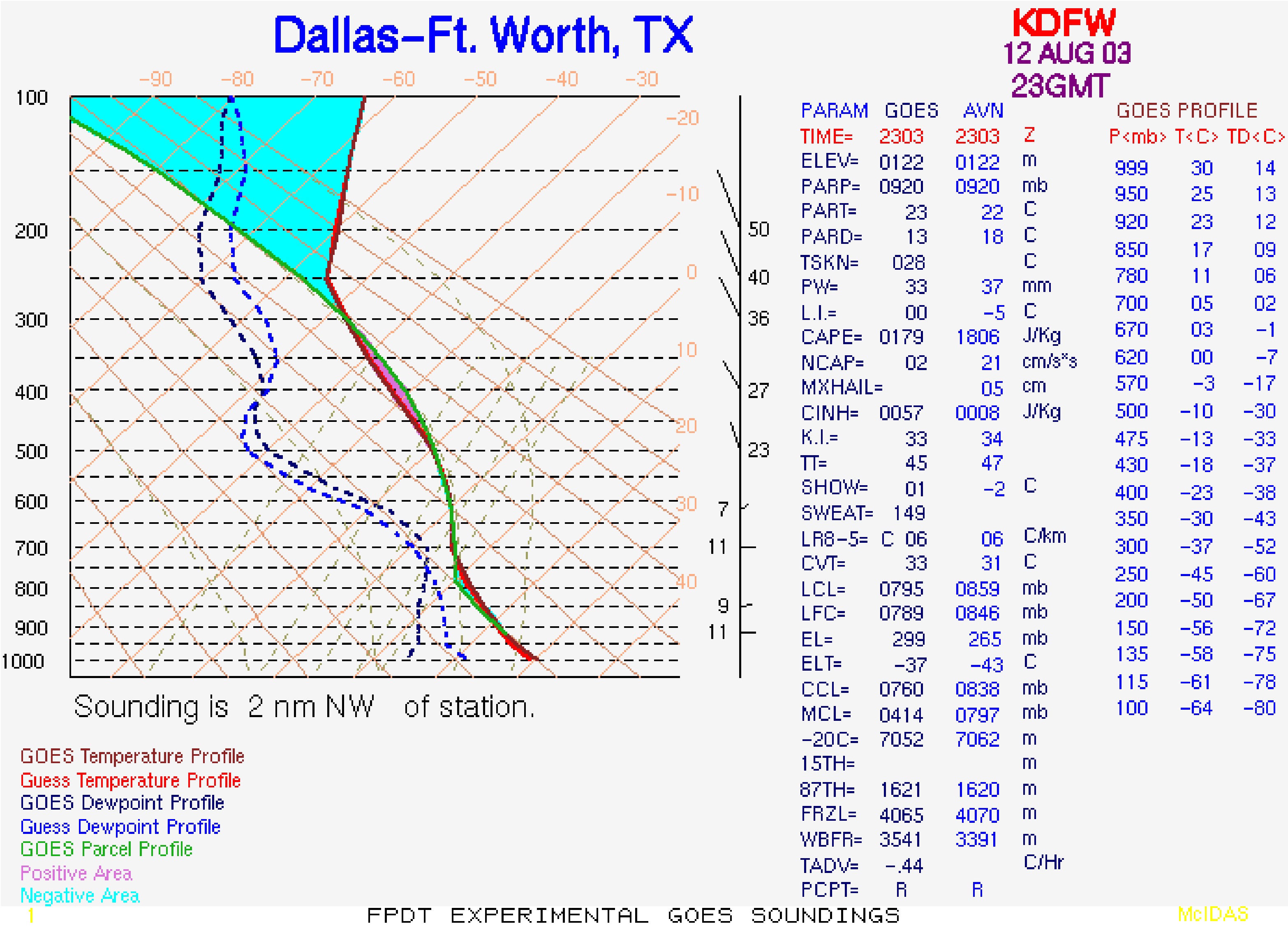
e



f

Figure 5. NEXRAD reflectivity imagery from Dallas/Fort Worth, TX (FWS) for 13 August 2003: a) 0059 UTC; b) 0113 UTC; c) 0123 UTC; d) 0158 UTC; e) 0213 UTC; f) 0223 UTC.

Figure 6


Dallas-Ft. Worth, TX
KDFW
12 AUG 03
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
50
40
36
27
23
7
11
9
11
Sounding is 2 nm NW 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= 2303 2303 Z
ELEV= 0122 0122 m
PARP= 0920 0920 mb
PART= 23 22 C
PARD= 13 18 C
TSKN= 028 C
PW= 33 37 mm
L.I.= 00 -5 C
CAPE= 0179 1806 J/Kg
NCAP= 02 21 cm/s*s
MXHAIL= 05 cm
CINH= 0057 0008 J/Kg
K.I.= 33 34
TT= 45 47
SHOW= 01 -2 C
SWEAT= 149
LR8-5= C 06 06 C/km
CVT= 33 31 C
LCL= 0795 0859 mb
LFC= 0789 0846 mb
EL= 299 265 mb
ELT= -37 -43 C
CCL= 0760 0838 mb
MCL= 0414 0797 mb
-20C= 7052 7062 m
15TH= m
87TH= 1621 1620 m
FRZL= 4065 4070 m
WBFR= 3541 3391 m
TADV= -.44 C/Hr
PCPT= R R
GOES PROFILE
P<mb> T<C> TD<C>
999 30 14
950 25 13
920 23 12
850 17 09
780 11 06
700 05 02
670 03 -1
620 00 -7
570 -3 -17
500 -10 -30
475 -13 -33
430 -18 -37
400 -23 -38
350 -30 -43
300 -37 -52
250 -45 -60
200 -50 -67
150 -56 -72
135 -58 -75
115 -61 -78
100 -64 -80
1
FPDT EXPERIMENTAL GOES SOUNDINGS
McIDAS

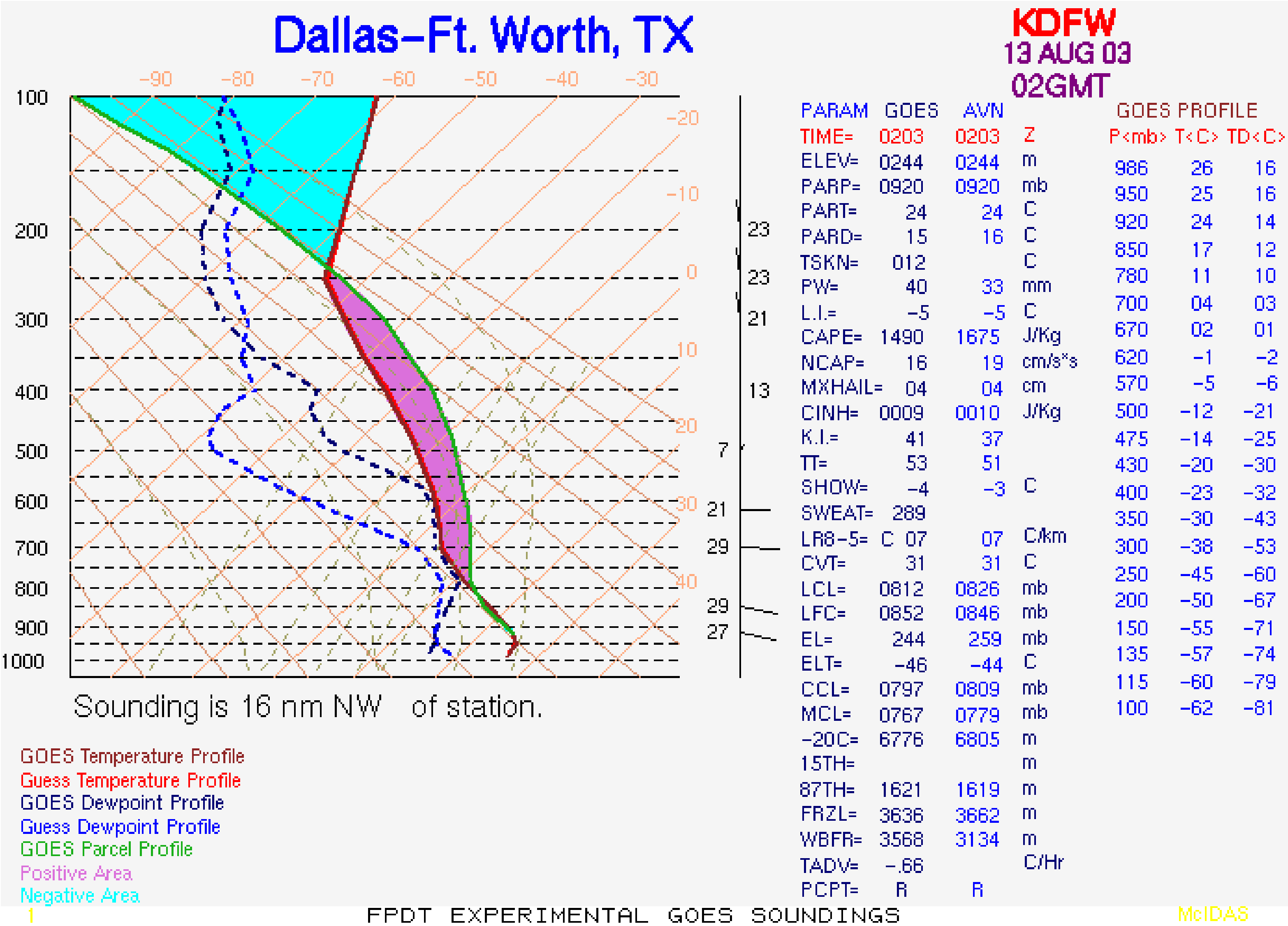


Figure 6. Comparison of GOES soundings for Dallas-Fort Worth between 2300 UTC 12 August and 0200 UTC 13 August 2003.