Microburst Nowcasting Applications of GOES

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Topics of Discussion

- Convective Downbursts and Microbursts
- Description of the GOES Microburst Products
- Case Studies/Microburst Prediction Exercises

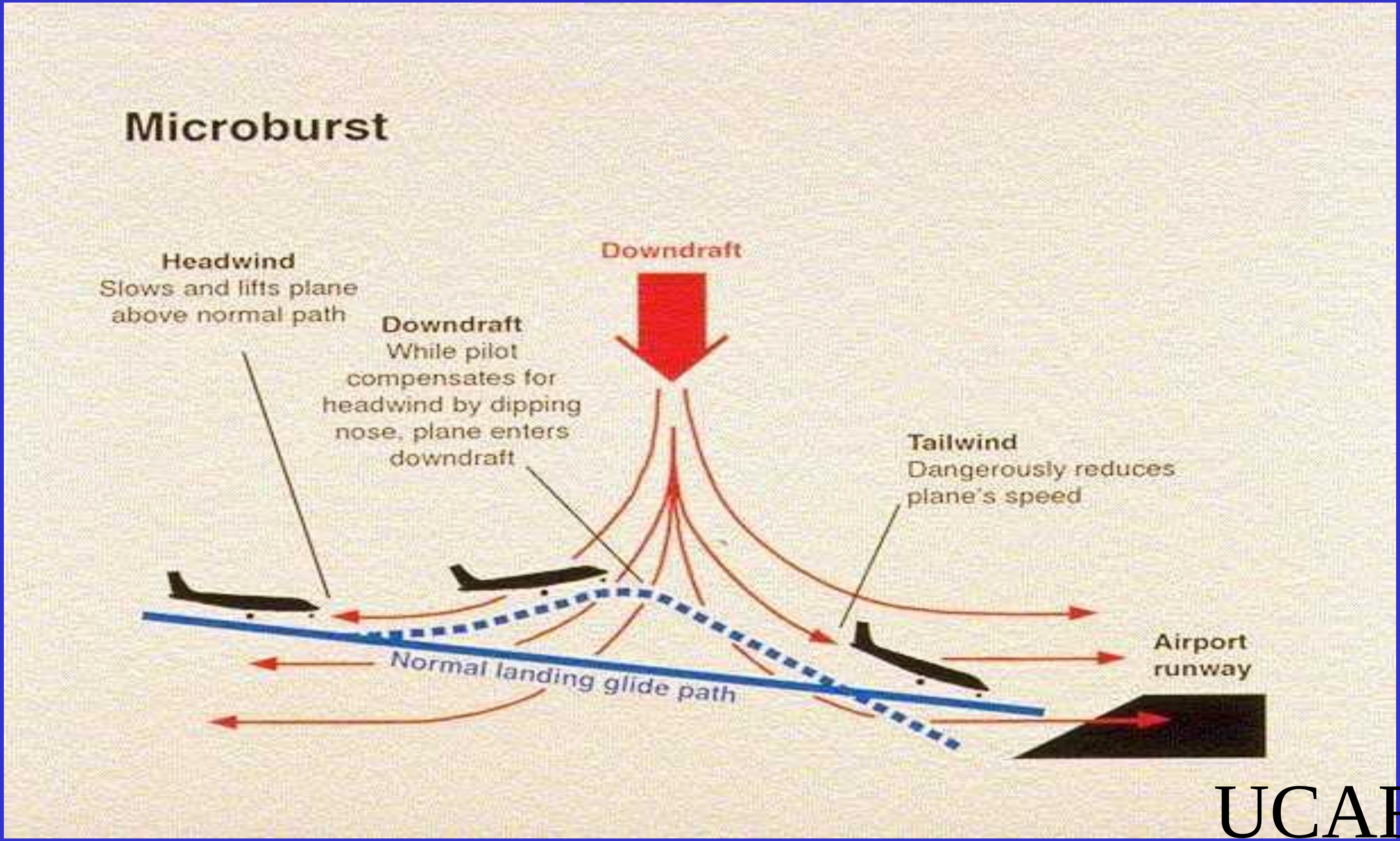
Downburst and Microburst

- Strong downdraft produced by a convective storm (or thunderstorm) that causes **damaging winds** on or near the ground. (Fujita and Wakimoto 1983)
- Due to the resulting **intense wind shear**, downbursts are a **hazard to aircraft** in flight, especially during takeoff and landing.

Downburst Types

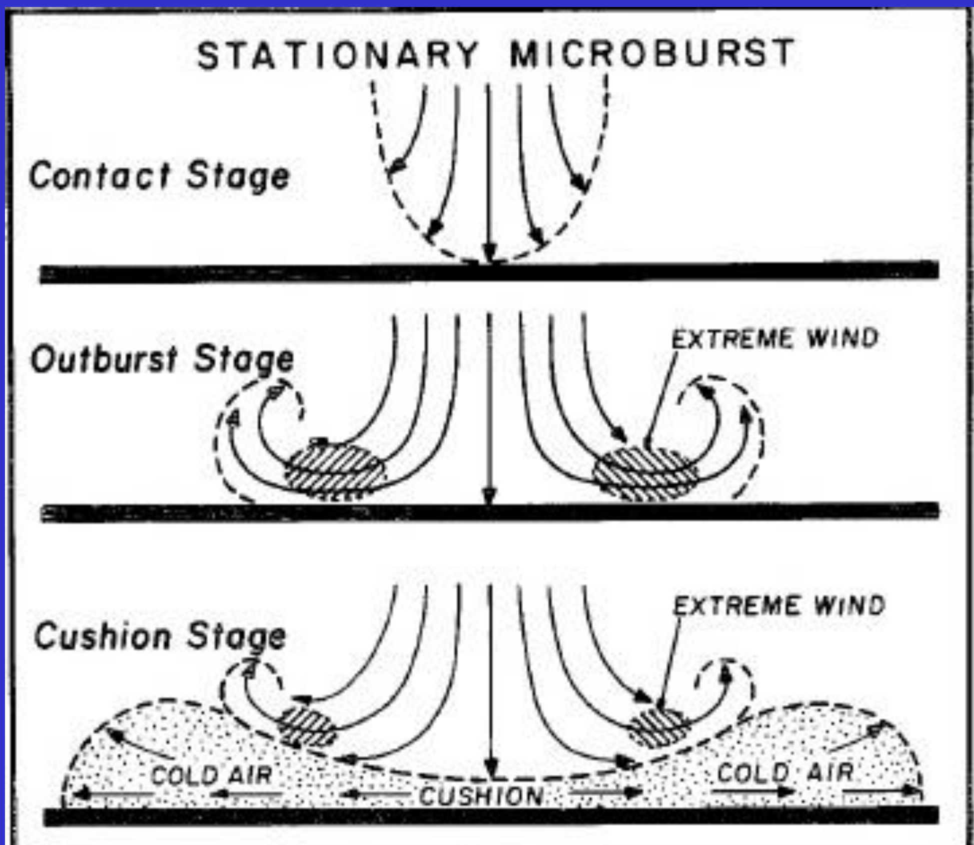
- Macroburst: Outflow size > 4 km, duration 5 to 20 minutes (Fujita 1981)
- Microburst: Outflow size < 4 km, duration 2 to 5 minutes (Fujita 1981)
- Microbursts (or clusters of microbursts) can evolve into larger downbursts.

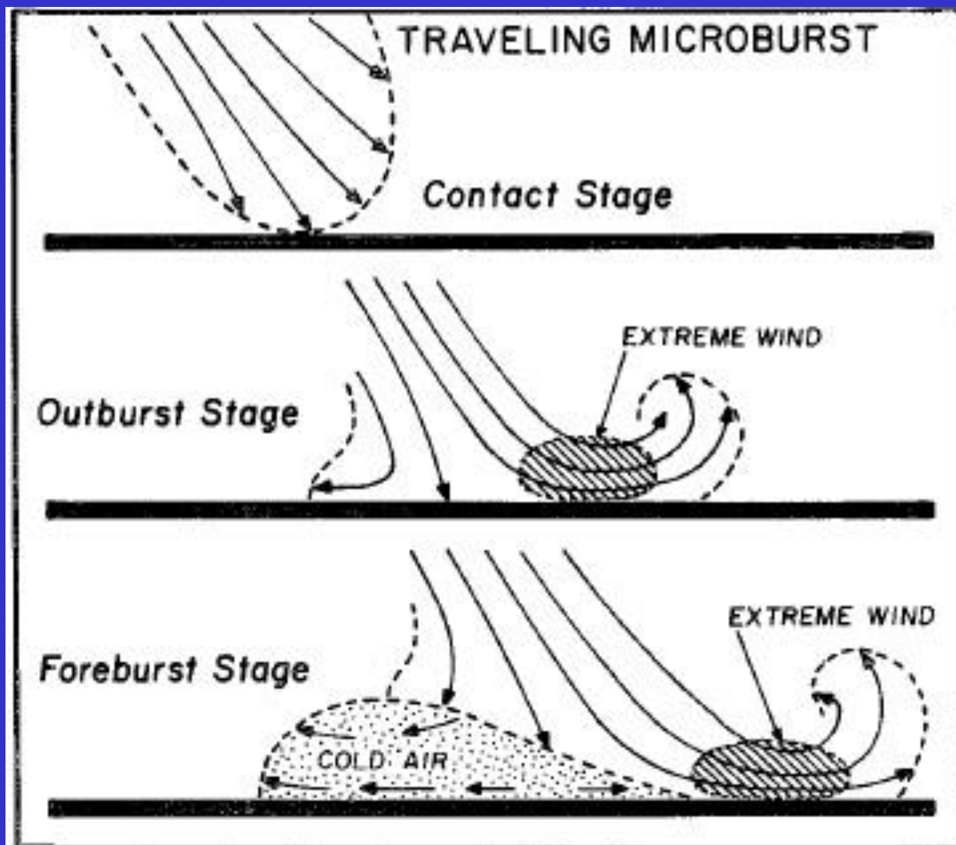
Microburst Aircraft Hazards



UCAR

Microburst Aircraft Hazards





From Fujita (1981)

Historic Downburst-Related Airline Disasters

- Eastern 66, New York (JFK), June 1975
- Continental 426, Denver, August 1975
- Pan American 759, New Orleans, July 1982
- Delta 191, Dallas-Ft. Worth (DFW), August 1985
- USAIR, Charlotte (CLT), July 1994
- American Airlines, Little Rock (LIT), June 1999

Introduction

- GOES sounder-derived parameters have been shown to be useful in assessing the potential for convective downbursts. Products include:
- **Wet Microburst Severity Index (WMSI)**
- **Dry Microburst Index (DMI)**
- **Microburst Windspeed Potential Index (MWPI)**
- **Wind Index (WINDEX)** for estimating **maximum convective wind gusts**

GOES Microburst Products

- Generated hourly at the NOAA Science Center in Camp Springs, MD
- Available on the GOES Microburst Products web page at the following URL: **http://www.orbit.nesdis.noaa.gov/smcd/opdb/aviation/mb.html**

GOES Microburst Products

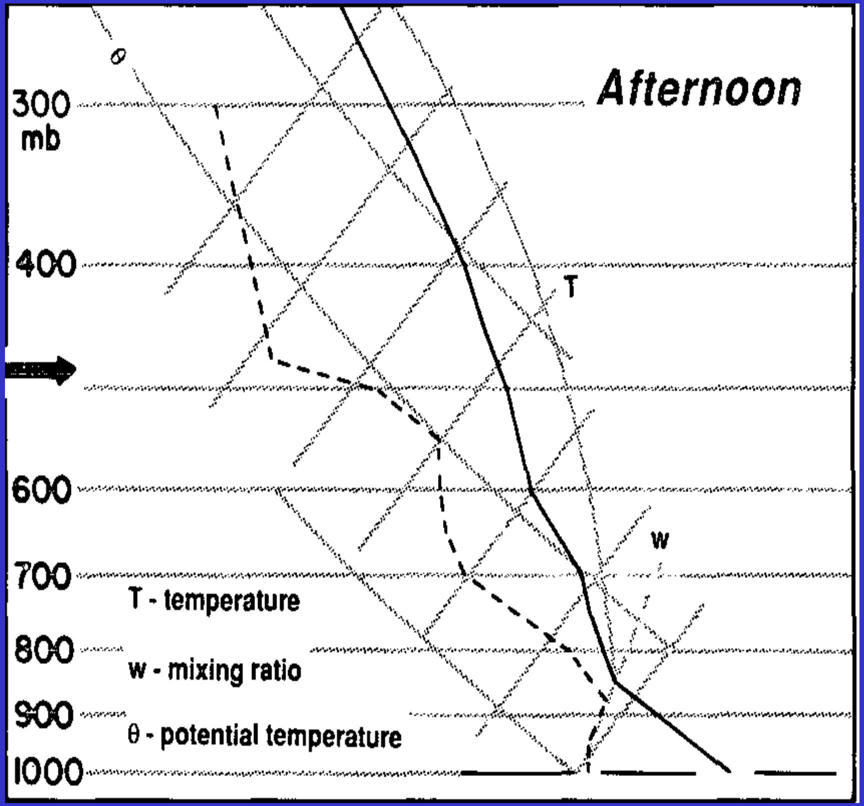
- Microburst program ingests the vertical temperature and moisture profiles derived from GOES sounder radiances, using a subset of single field of view.
- Microburst products are available approximately 50 minutes after sounder scan.
- Based on the **thermodynamic structure** of the ambient atmosphere.

GOES Microburst Products

Limitations:

- Risk values generated and plotted only in regions of clear skies or partial cloudiness.
- GOES microburst products evaluate wind gust potential from quasi-stationary, short-duration single-cell convective storms.
  - Must account for translational (forward) motion of storms in wind gust potential evaluation.

Wet Microburst

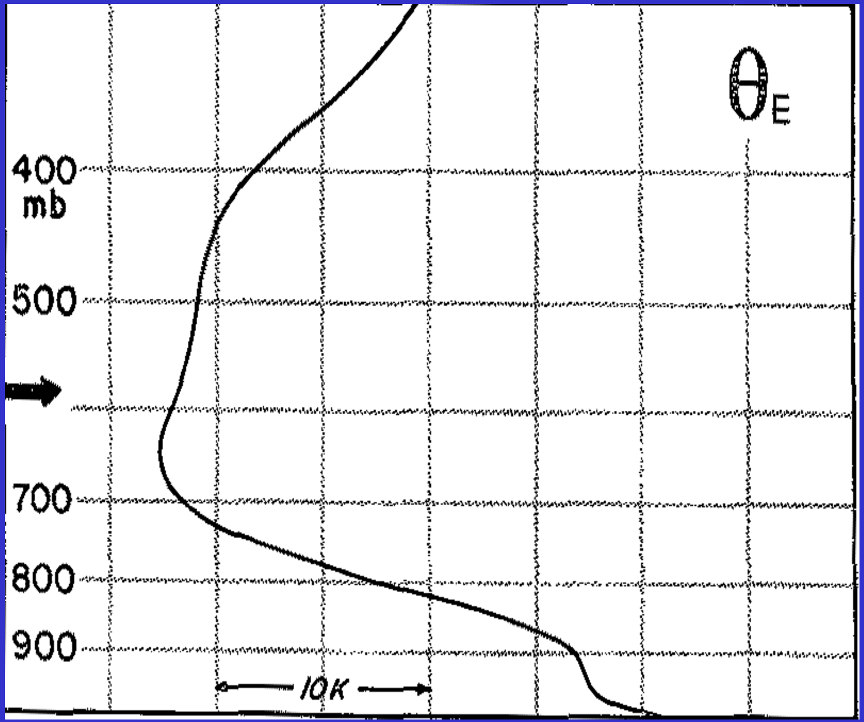


From Atkins and Wakimoto (1991)

Wet Microburst Severity Index (WMSI)

- Accounts for convective storm development and downburst generation by incorporating the parameters CAPE to represent the process of updraft formation and Theta-e Deficit (TeD) to represent downburst development.
- Governed by the inviscid vertical momentum equation (Doswell 2001).

Theta-e Deficit (TeD)



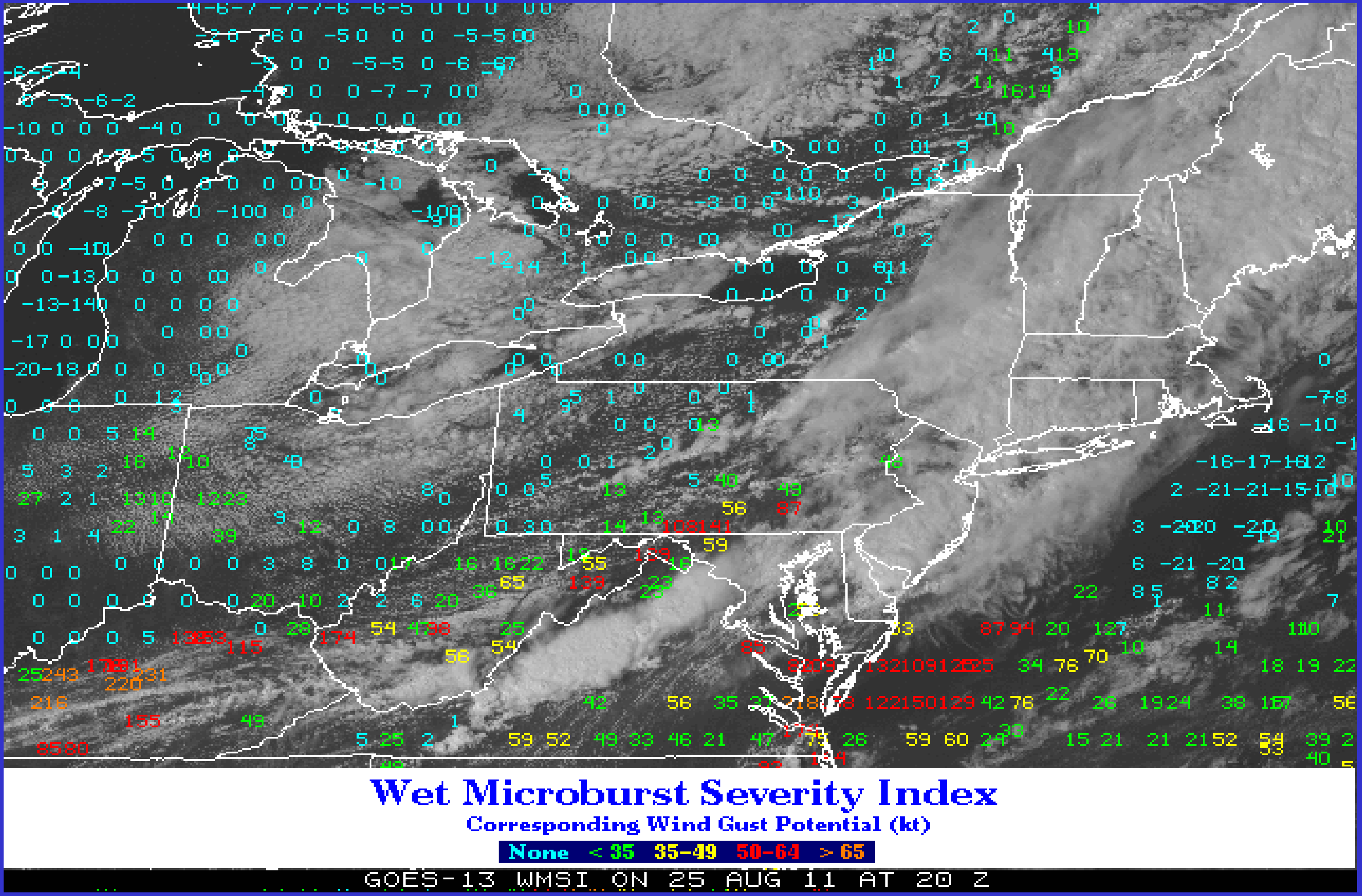
- Maximum vertical difference in equivalent potential temperature (θ_e) from the surface to the middle troposphere (Atkins and Wakimoto 1991).

Wet Microburst Severity Index (WMSI)

WMSI = (CAPE)(TeD)/1000

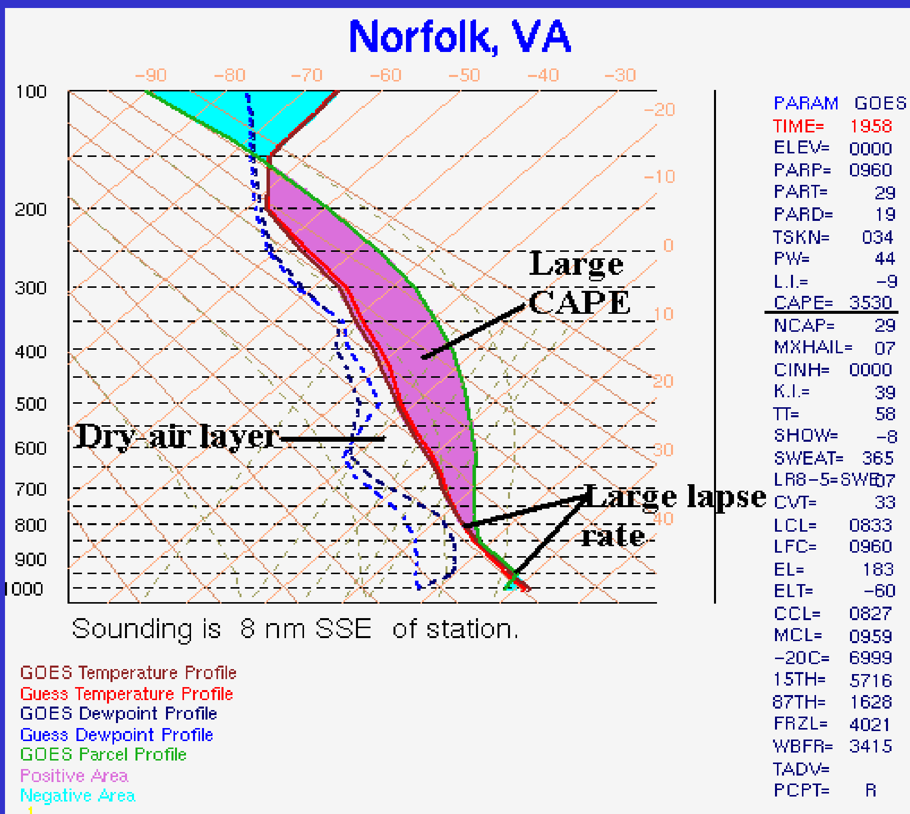
- Large CAPE (positive buoyancy) results in strong updrafts that lift the precipitation core within a convective storm to minimum theta-e level.
- TeD indicates the presence of a dry (low theta-e) layer in the middle troposphere that would be favorable for the production of large negative buoyancy due to evaporative cooling.

Wet Microburst Severity Index (WMSI)

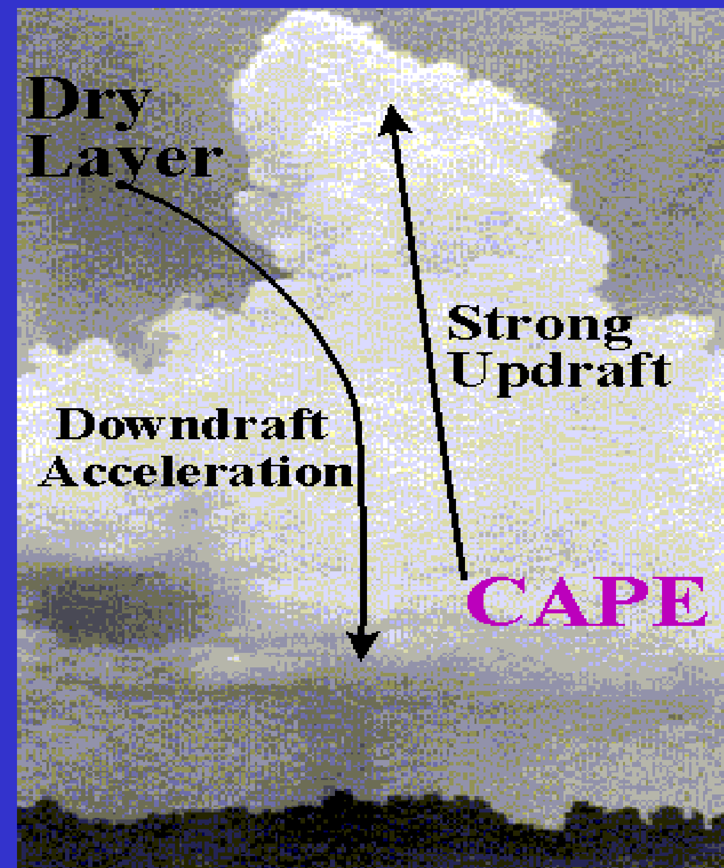


Wet Microburst Severity Index (WMSI)

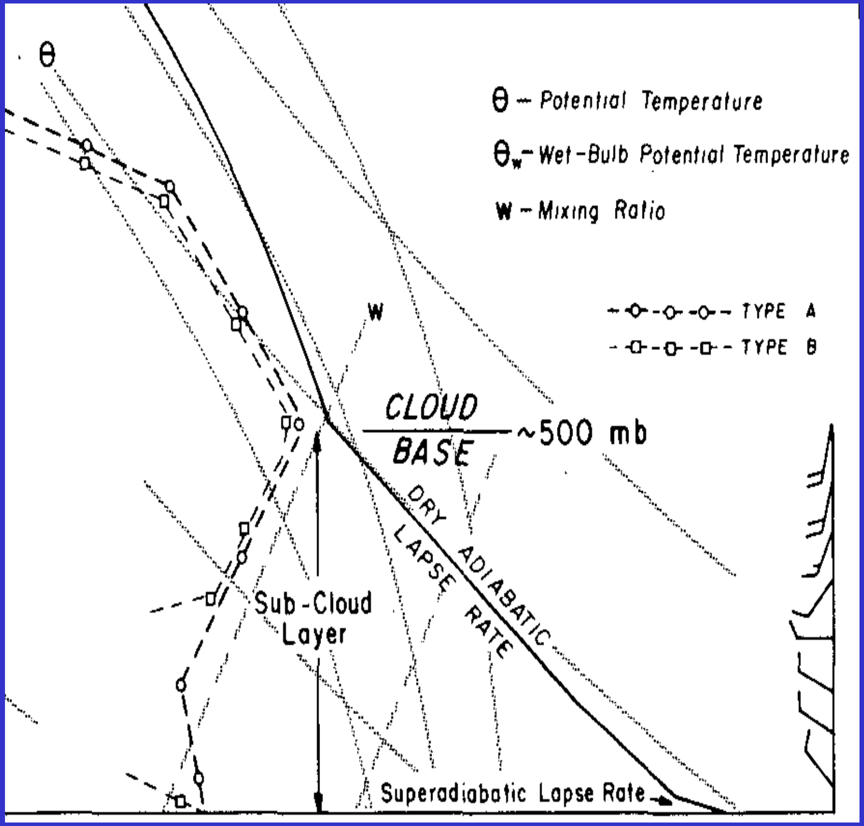
Prototype summer afternoon GOES sounding profile



Wet-microburst producing storm over Alabama



Dry Microburst



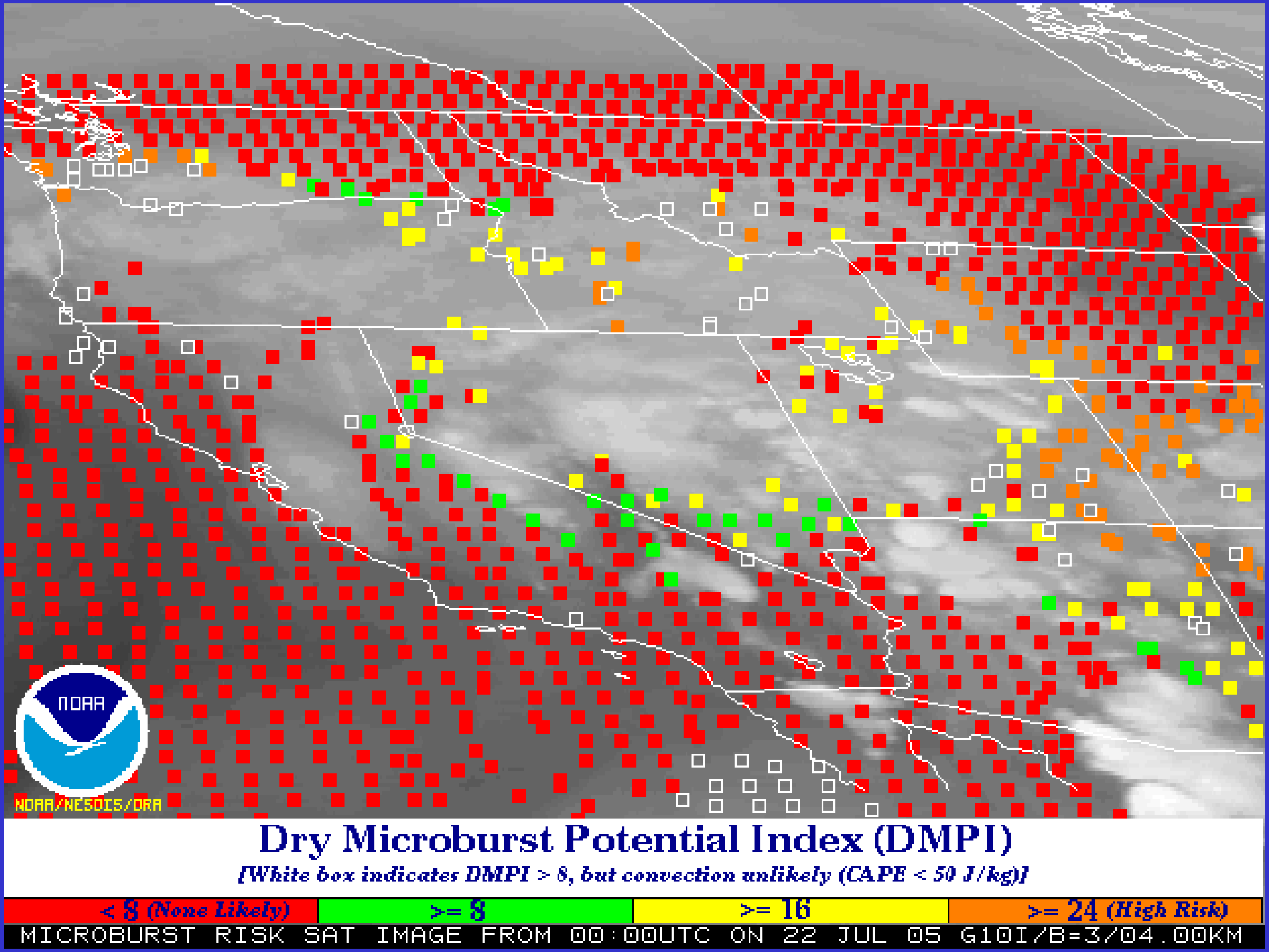
From Wakimoto (1985)

Dry Microburst Index (DMI)

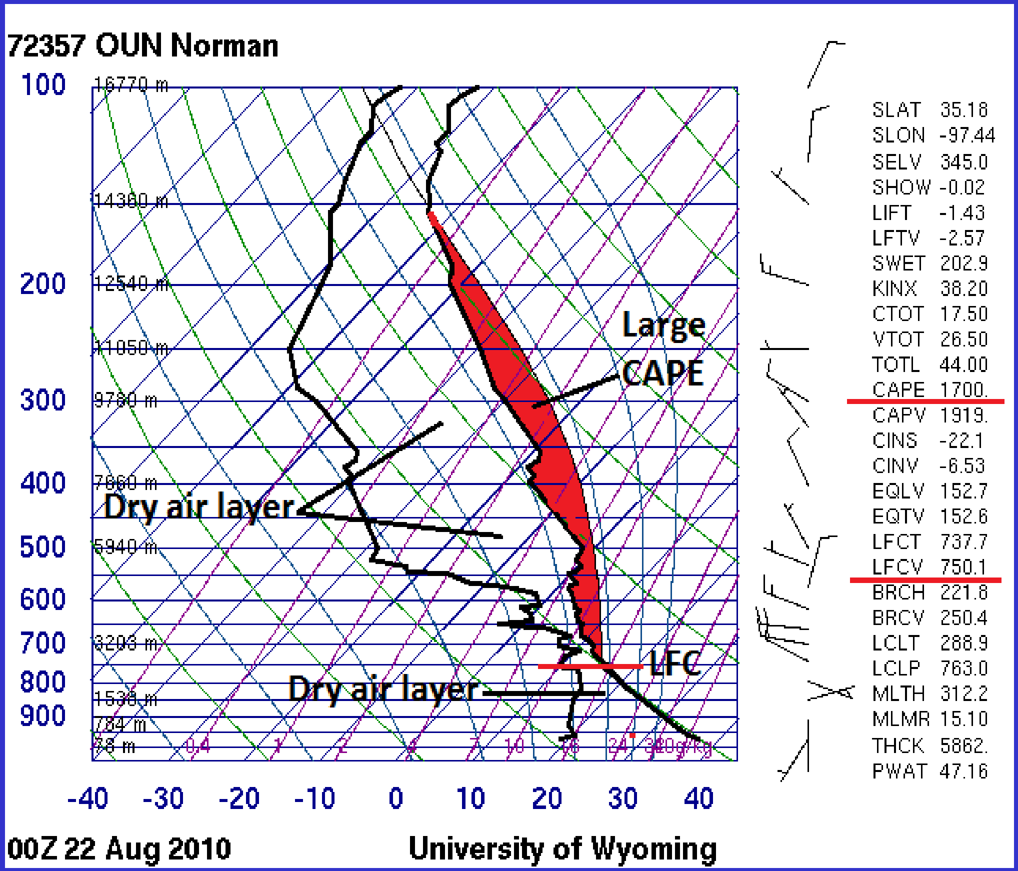
$DMI = \Gamma + (T - T_d)_{700} - (T - T_d)_{500}$

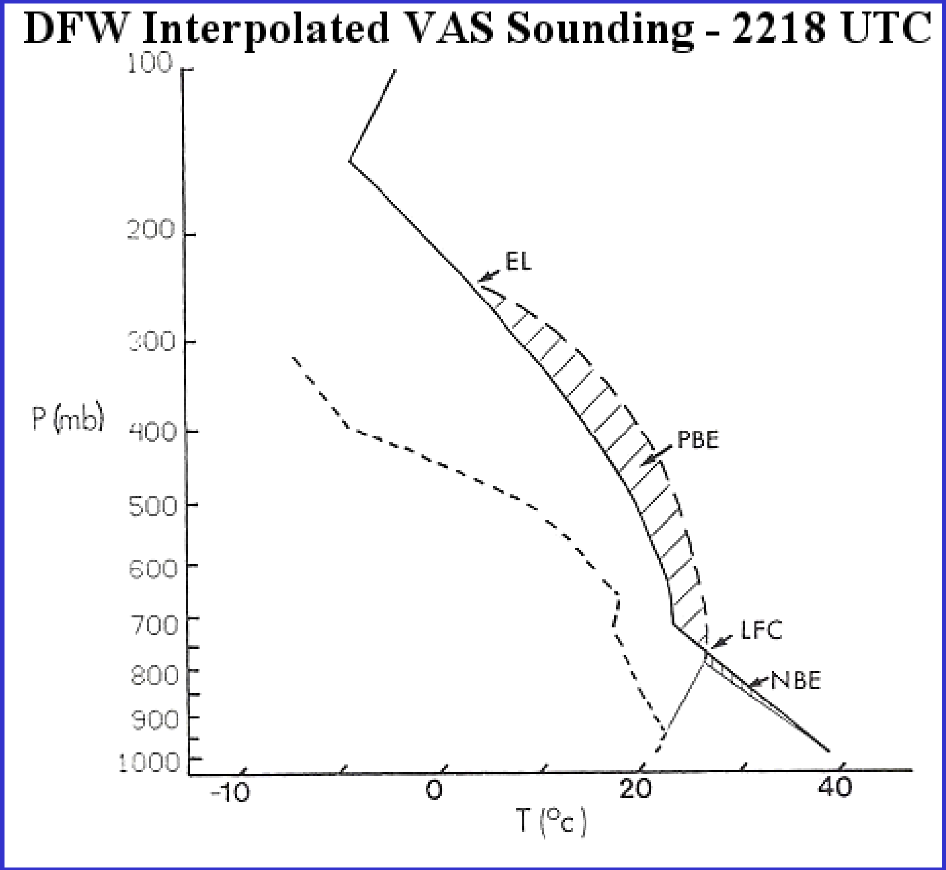
- Γ = temperature lapse rate (°C km^{-1}) from 700 to 500 mb
- T = temperature (°C)
- T_d = dew point temperature (°C)
- Dry microbursts may occur when the **DMI > 6** (Ellrod et al 2000)

Dry Microburst Index (DMI)



Hybrid Microburst





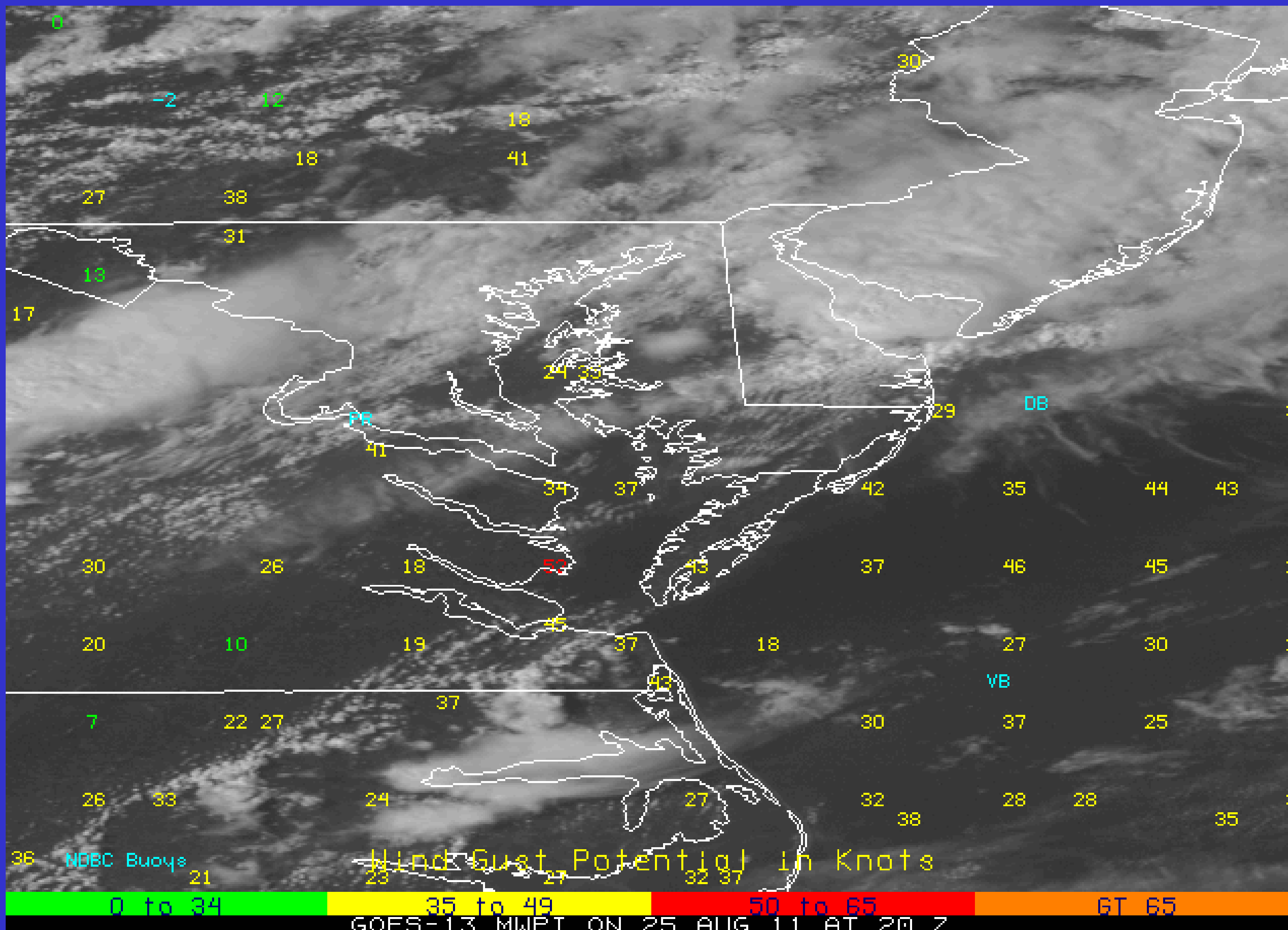
Hybrid Microburst

Microburst Windspeed Potential Index (MWPI)

$MWPI = CAPE/100 + \Gamma + (T - T_d)_{850} - (T - T_d)_{670}$ (Pryor 2010)

- Γ = temperature lapse rate (°C km^{-1}) from 850 to 670 mb
- T = temperature (°C)
- T_d = dew point temperature (°C)
- Severe microbursts may occur when the MWPI > **50**

Microburst Windspeed Potential Index (MWPI)



Wind Index (WINDEX)

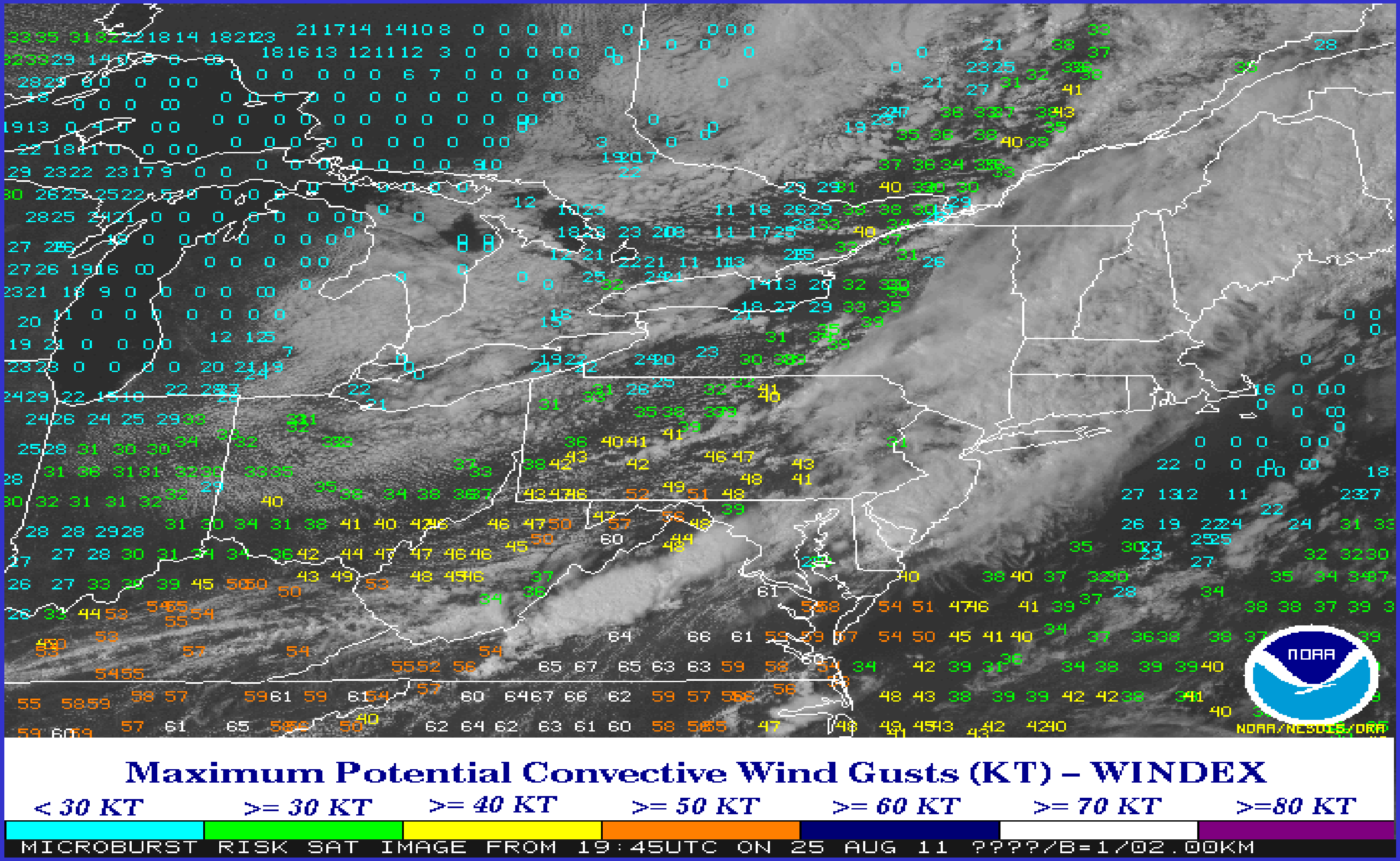
- Developed by McCann (1994)
- Indicates the maximum possible downburst wind gusts that could occur in stationary convective storms.
- Color-coded numerical values are displayed at sounding retrieval locations on visible or infrared imagery.

Wind Index (WINDEX)

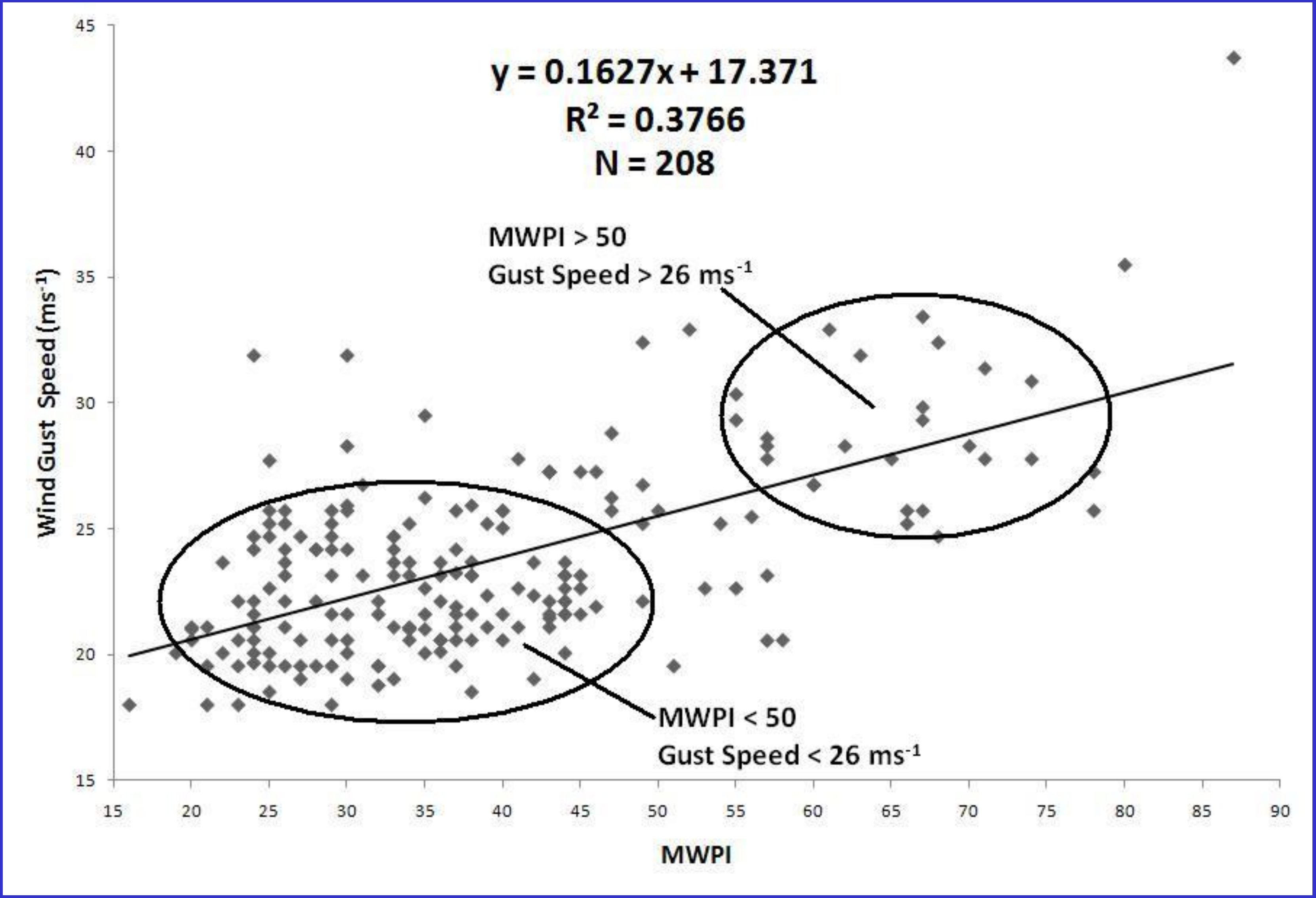
$WI = 5[H_M R_Q(\Gamma^2 - 30 + Q_L - 2Q_M)]^{0.5}$

- WI = Maximum surface wind gusts (kt)
- H_M = Melting level height (km)
- Γ = Surface to melting level temperature lapse rate (°C km^{-1})
- Q_L = Lowest 1 km Mixing ratio (g kg^{-1})
- Q_M = Melting level mixing ratio (g kg^{-1})
- $R_Q = Q_L/12$

Wind Index (WINDEX)



Statistical Relationships

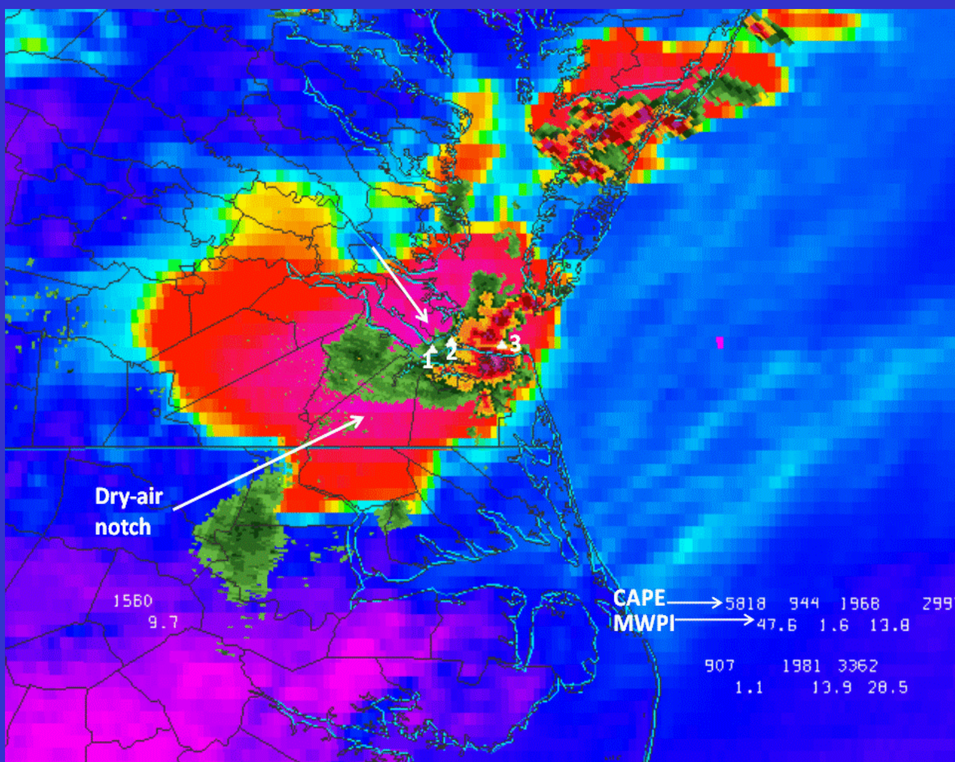


GOES-East Imager Product

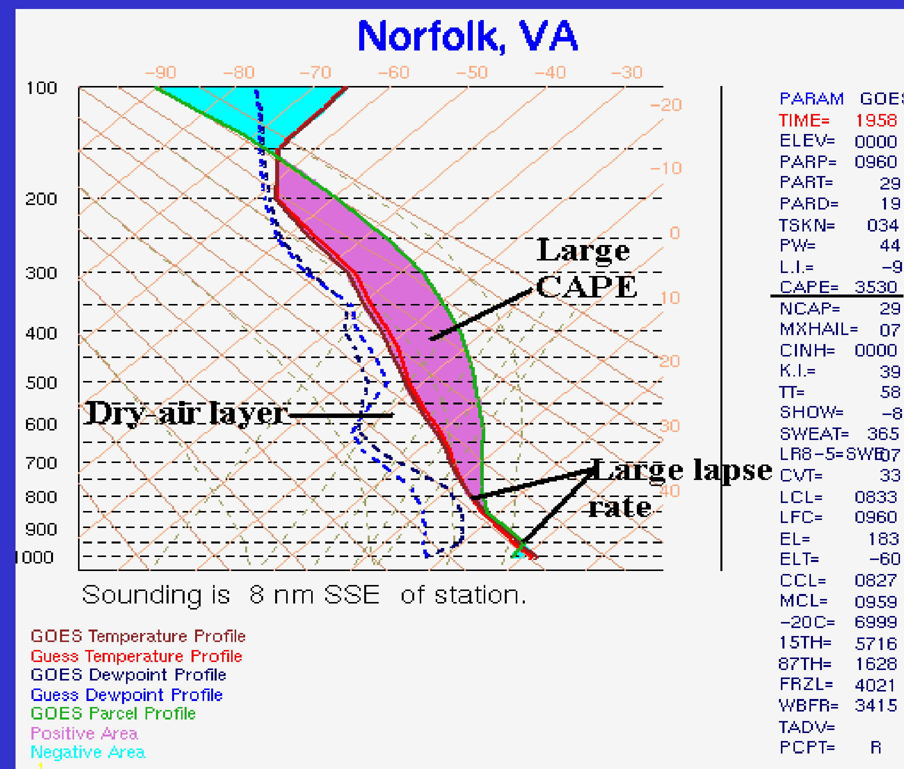
- Bispectral GOES imager product (Pryor 2010):
- The BTD between GOES infrared band 3 (water vapor, 6.5μm) and band 4 (thermal infrared, 11μm) can highlight regions where severe outflow wind generation (i.e. downbursts, microbursts) is likely due to the channeling of dry mid-tropospheric air into the precipitation core of a deep, moist convective storm.
- Readily apparent in BTD imagery is a "dry-air notch" that signifies the channeling of dry air into the rear flank of a convective storm.

GOES-East Imager Product

Enhanced band 3 – 4 BTD image showing well-defined dry air notches.



GOES sounding profile with well-defined mid-tropospheric dry air layer above 700 mb.



http://www.star.nesdis.noaa.gov/smcd/opdb/kpryor/mburst/mbimg.html

Overshooting Top Detection

- The OT detection algorithm (Bedka et al. 2010) is a pattern recognition-based technique that employs **brightness temperature (BT)** data from the GOES thermal infrared channel.
- Output OT detection algorithm parameters that include **cloud top minimum BT** and a **BT difference** between the overshooting top and surrounding convective anvil cloud have been compared to MWPI values and measured downburst wind gusts. Close correspondence between the location of overshooting tops, proximate MWPI values, and the location of observed downburst winds is evident in this case study.

Microburst Prediction Exercises

10 August 2009 Oklahoma Downbursts

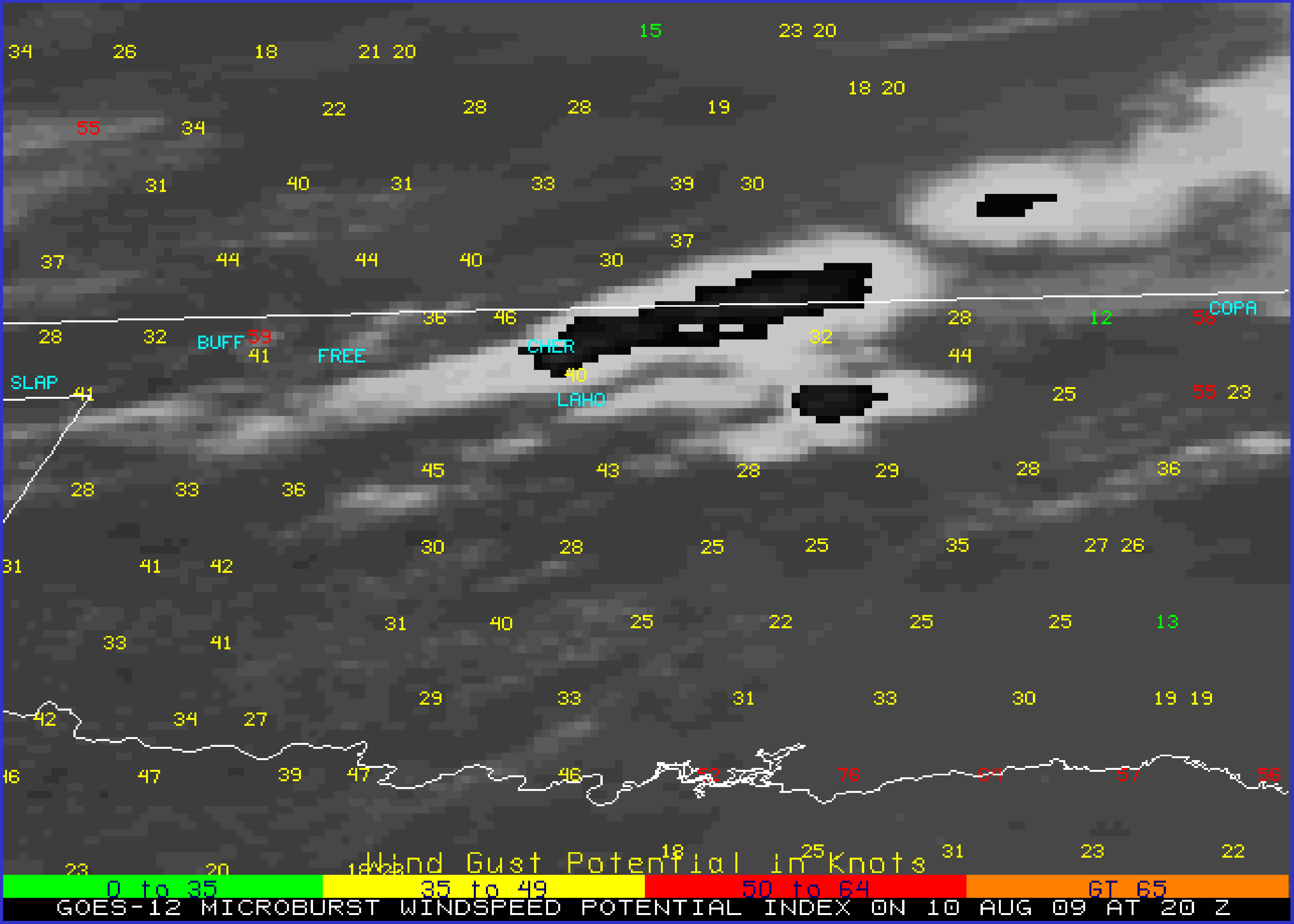
- Strong convective storms developed along a cold front that extended from eastern Kansas to the Oklahoma Panhandle and produced several downbursts over northwestern and north-central Oklahoma during the late afternoon and evening.
- 33 ms^{-1} (64 kt) wind gust was recorded at Freedom mesonet station at 2345 UTC.

10 August 2009 Oklahoma Downbursts

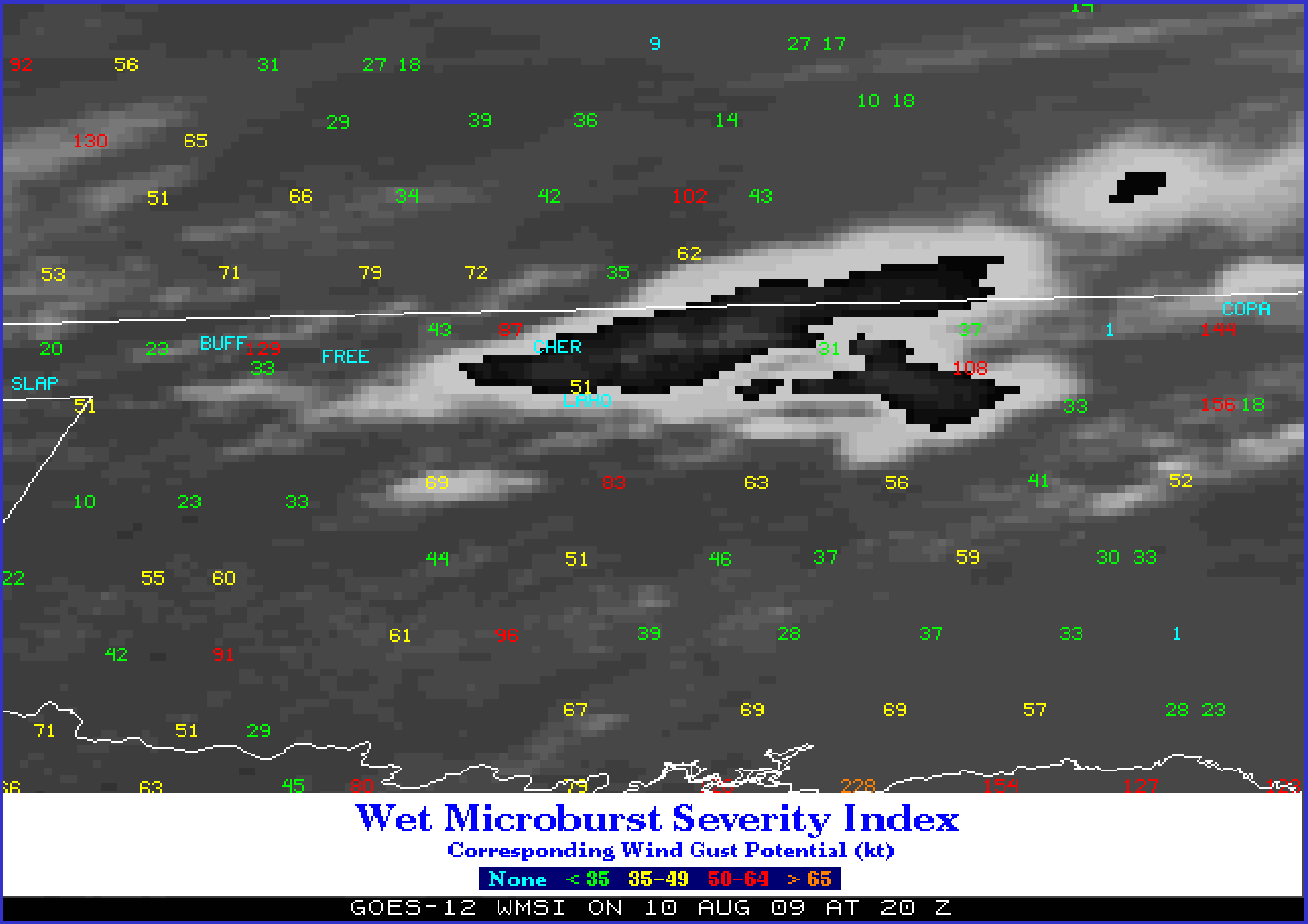
Time	Gust Speed ms^{-1} (kt)	Location	MWPI	OT Time	OT Dist (km)	OT Min (°K)	OT Mag (°K)
2115	20.6 (40)	Copan	31	2115	9	206.5	-9.2
2125	22.1 (43)	Lahoma	44	2115	9	210.1	-7
2230	21.1 (41)	Slapout	33	2215	12	211.6	-8.7
2305	23.1 (45)	Buffalo	39	2302	13	203.5	-8
2345	32.9 (64)	Freedom	52	2332	13	196.8	-11.2

Oklahoma Mesonet Stations

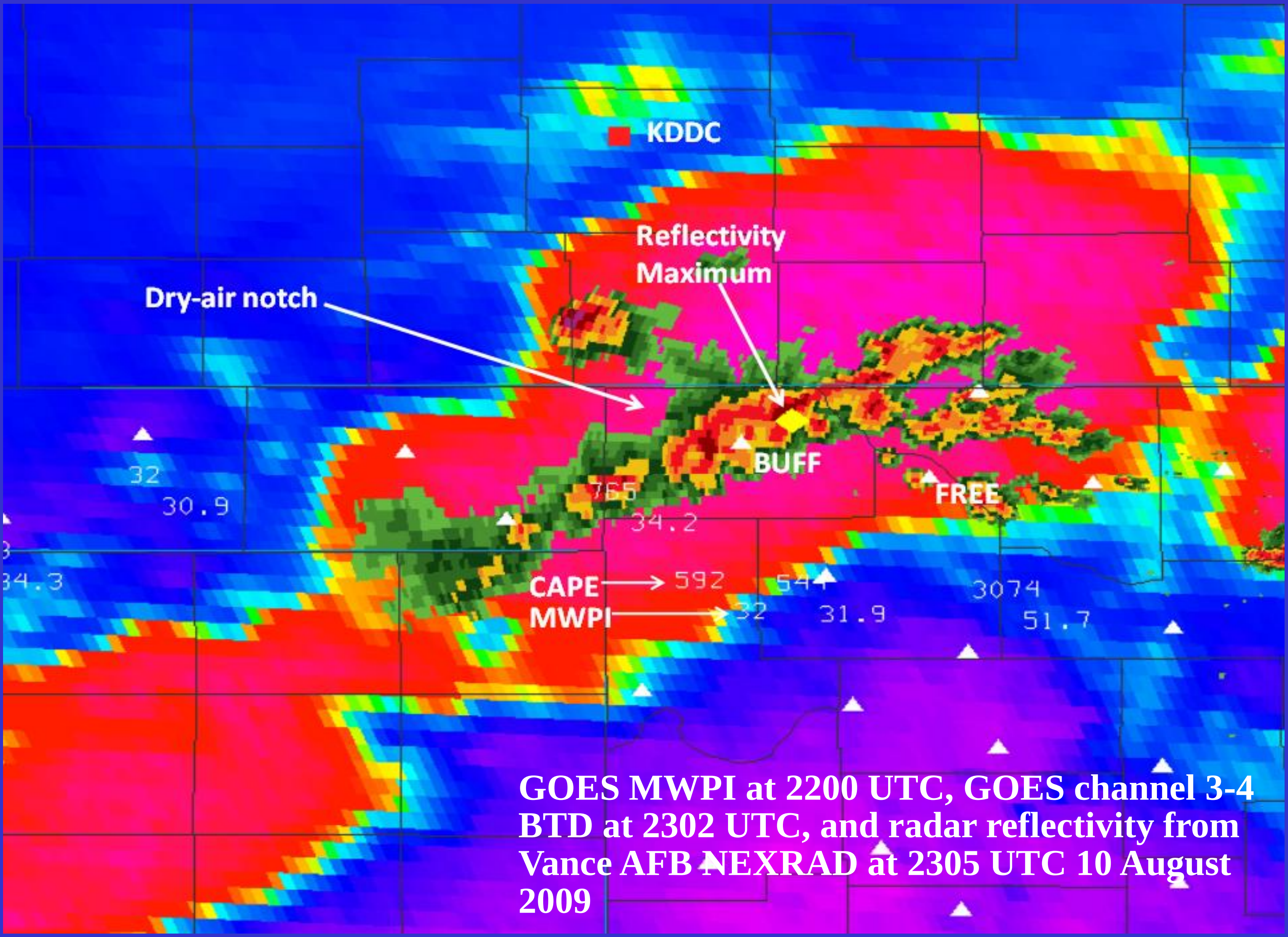
GOES MWPI 10 August 2009



GOES WMSI 10 August 2009

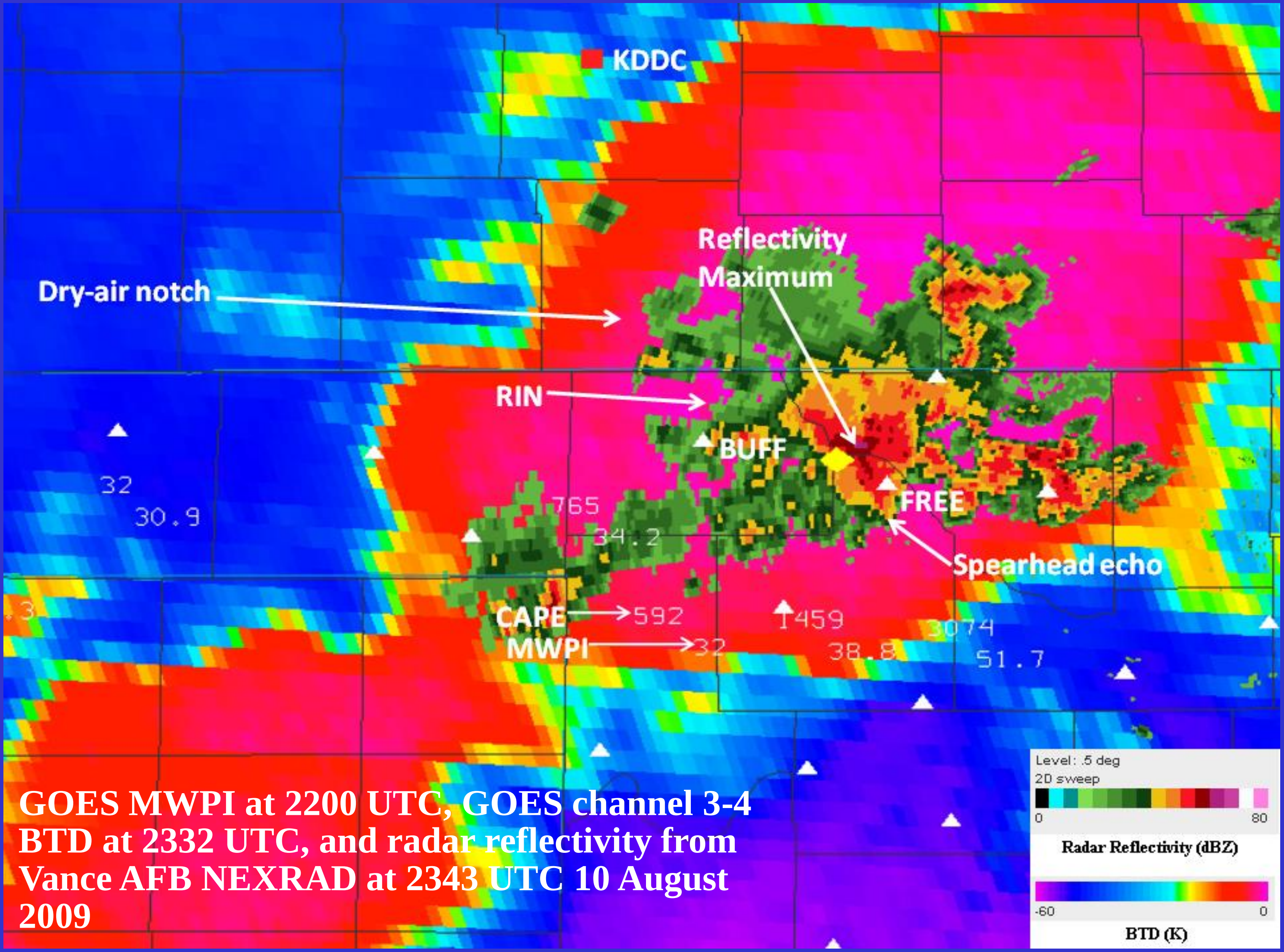


GOES-NEXRAD Composite



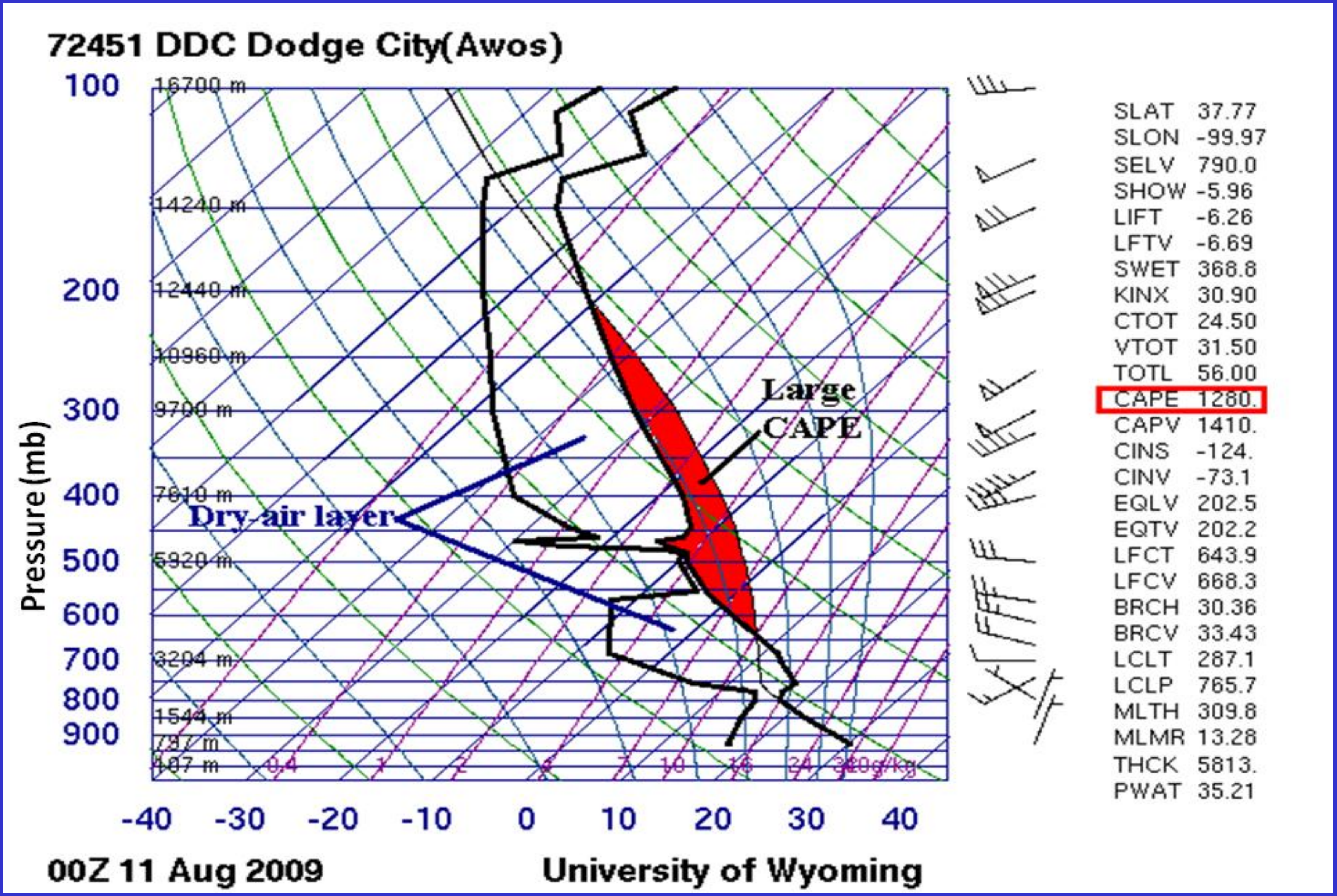
GOES MWPI at 2200 UTC, GOES channel 3-4 BTD at 2302 UTC, and radar reflectivity from Vance AFB NEXRAD at 2305 UTC 10 August 2009

GOES-NEXRAD Composite



GOES MWPI at 2200 UTC, GOES channel 3-4 BTD at 2332 UTC, and radar reflectivity from Vance AFB NEXRAD at 2343 UTC 10 August 2009

RAOB Sounding

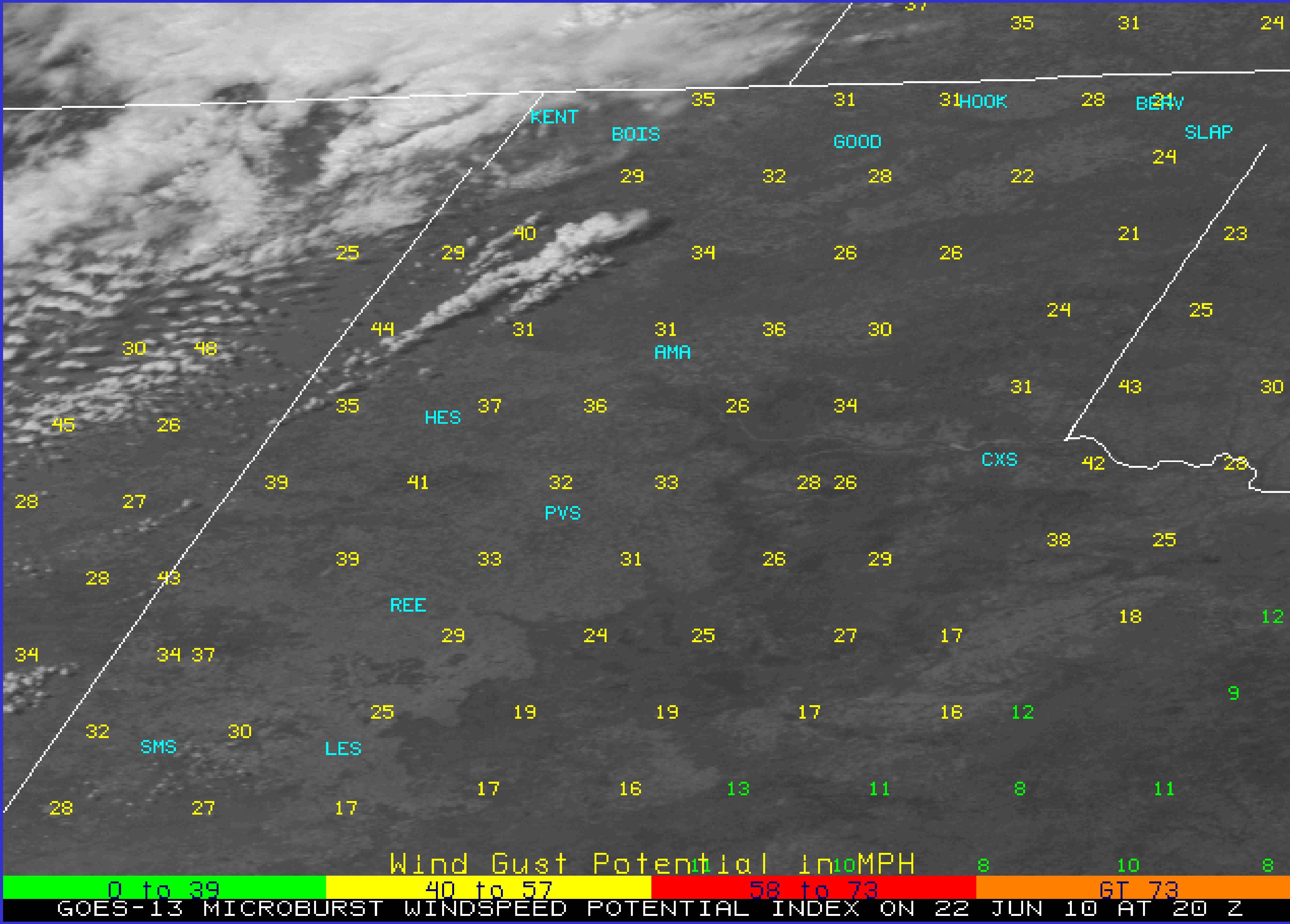


June 2010 West Texas Downbursts

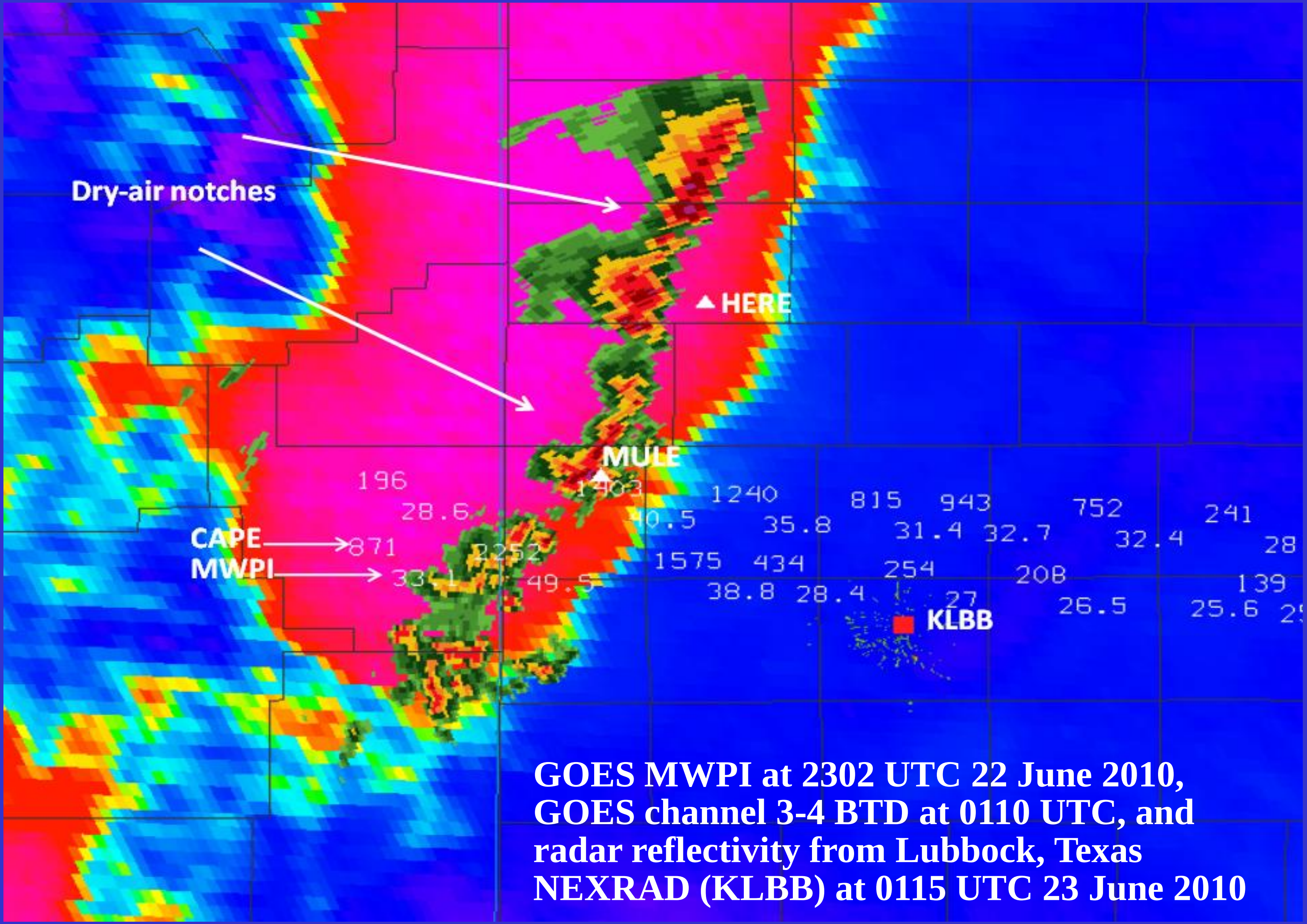
- During the afternoon of 22 June 2010, an upper-level disturbance interacted with a dryline near the Texas-New Mexico border and triggered strong convective storms that tracked eastward into the western Texas Panhandle region. Convective storms produced scattered strong downbursts over western Texas during the evening hours.

West Texas Station

GOES MWPI 22 June 2010

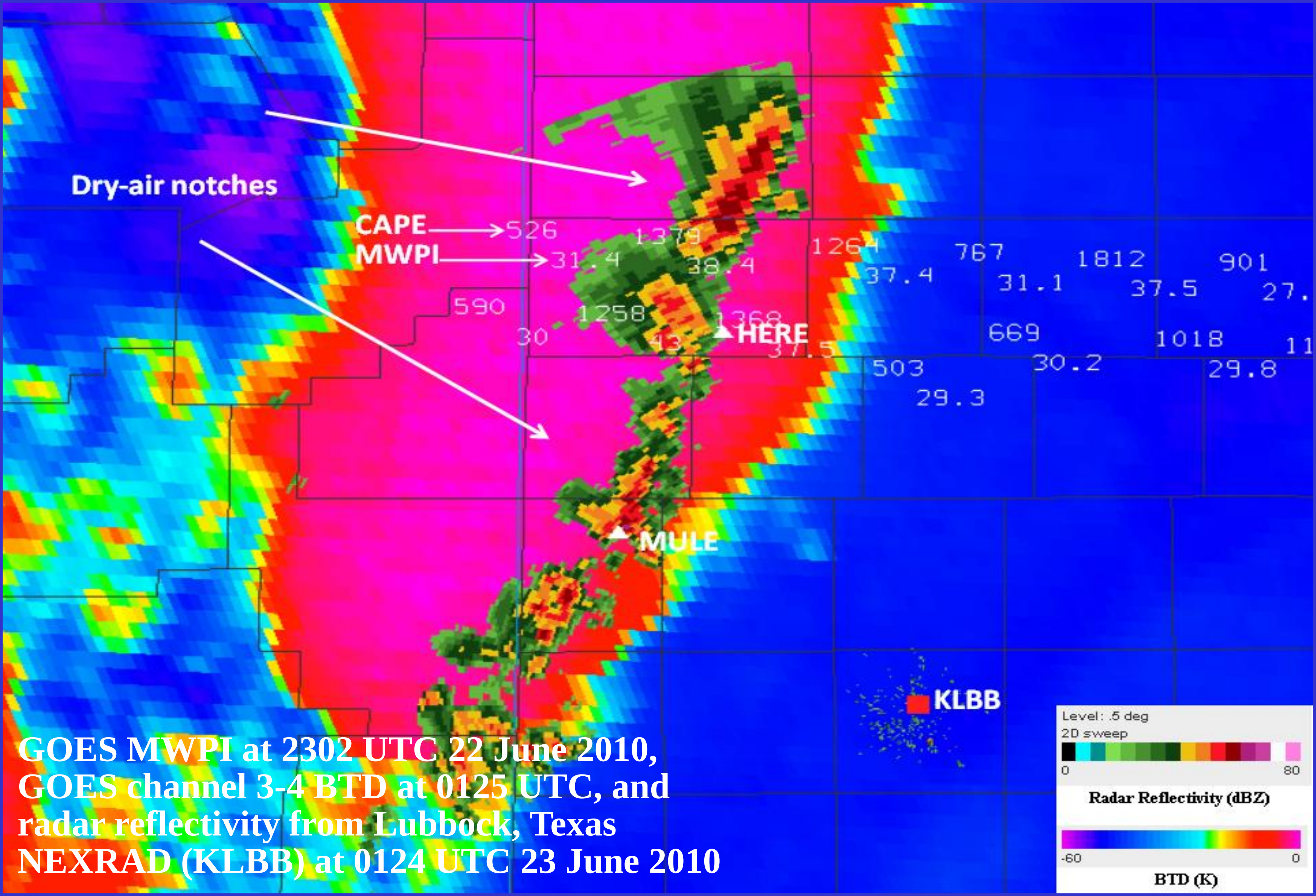


GOES-NEXRAD Composite



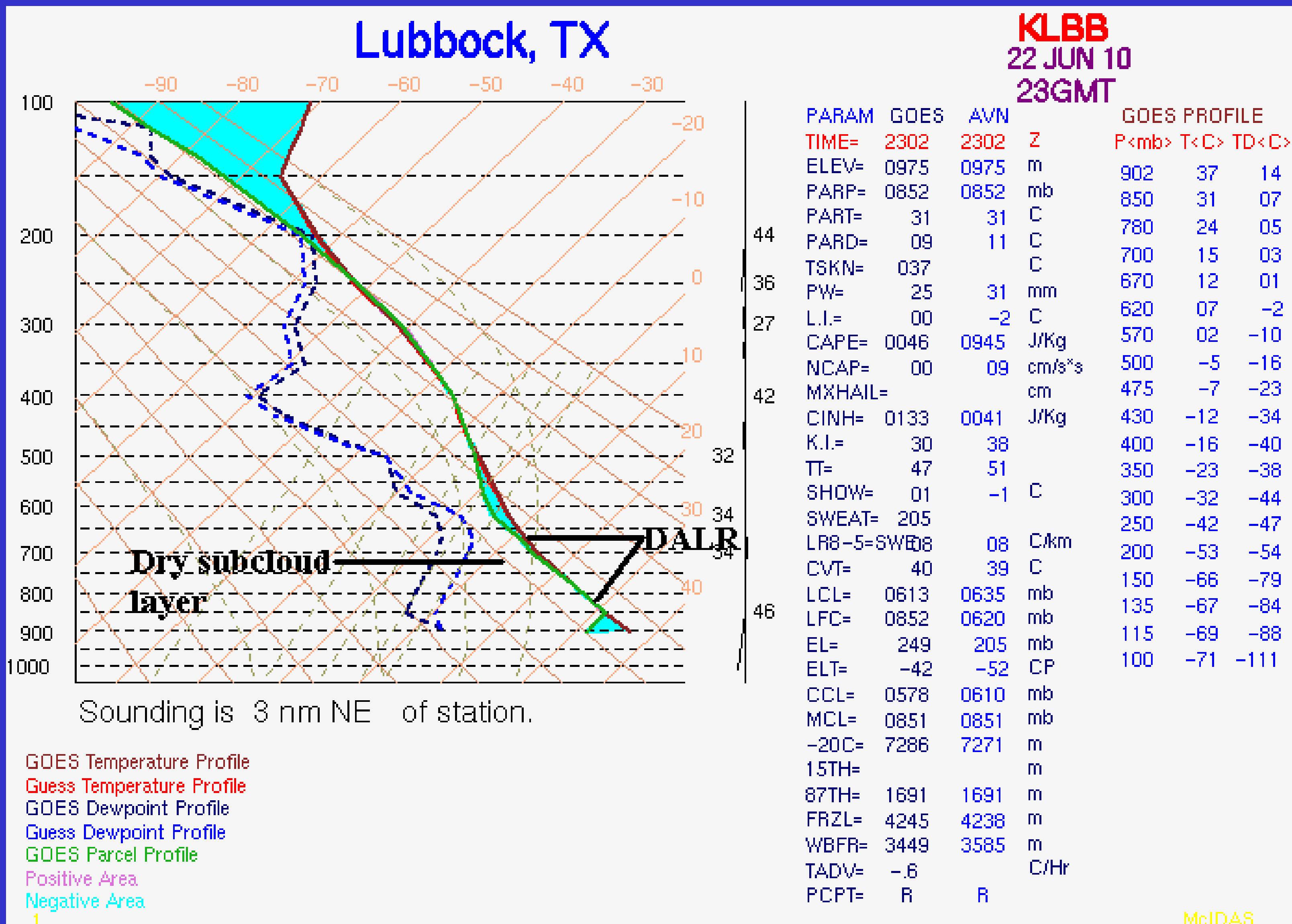
GOES MWPI at 2302 UTC 22 June 2010, GOES channel 3-4 BTD at 0110 UTC, and radar reflectivity from Lubbock, Texas NEXRAD (KLBB) at 0115 UTC 23 June 2010

GOES-NEXRAD Composite



GOES MWPI at 2302 UTC 22 June 2010, GOES channel 3-4 BTD at 0125 UTC, and radar reflectivity from Lubbock, Texas NEXRAD (KLBB) at 0124 UTC 23 June 2010

GOES Sounding



May 2011 Hampton Roads Downbursts

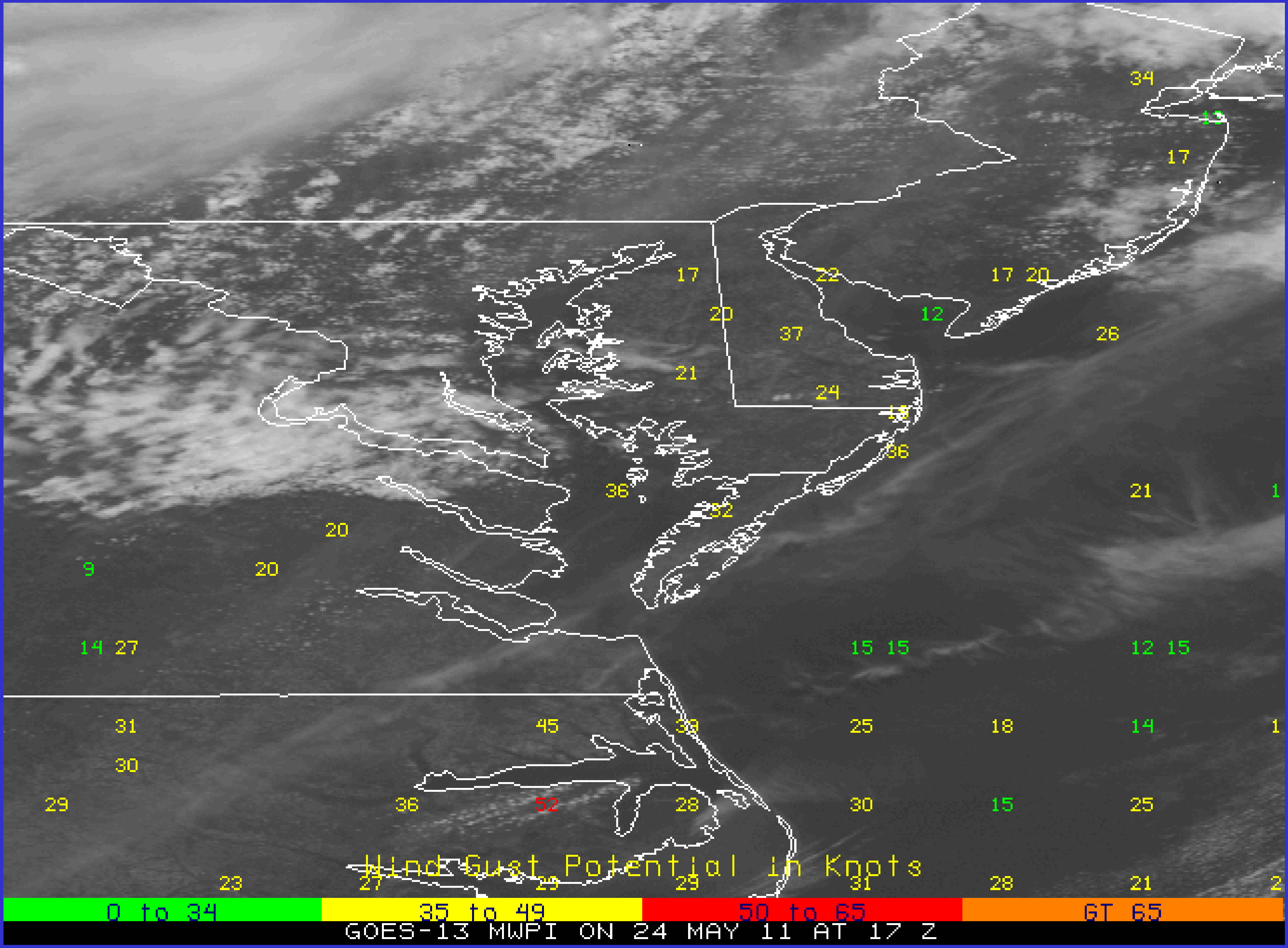
- During the afternoon of 24 May 2011, a multicellular convective storm developed over the southern piedmont of Virginia and tracked rapidly eastward toward the Atlantic coast.
- Between 2000 and 2100 UTC, as the convective storm passed over the Hampton Roads, one of the busiest waterways in the continental U.S., numerous severe wind gusts were recorded by coastal observing stations.

May 2011 Hampton Roads Downbursts

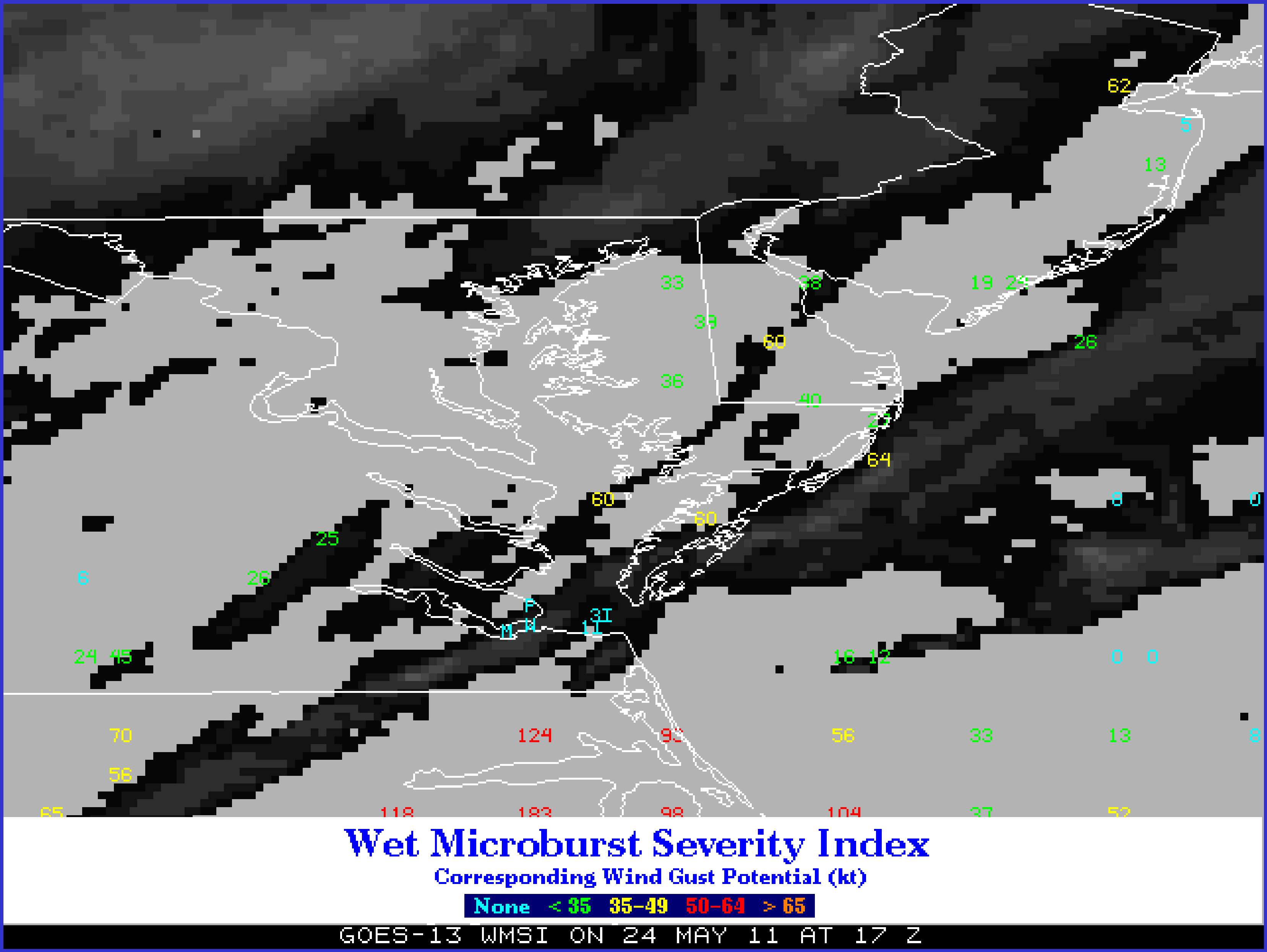
Time	Gust Speed ms^{-1} (kt)	Location
2015	27.3 (53)	Poquoson (WF)
2017	29.3 (57)	Monitor-Merrimack Memorial Bridge Tunnel (WF)
2018	32.4 (63)	Willoughby Degaussing Station (PORTS)
2020	30.4 (59)	Hampton Flats (WF)
2036	34.5 (67)	1st Island (PORTS)
2040	31.9 (62)	3rd Island (WF)

PORTS Station

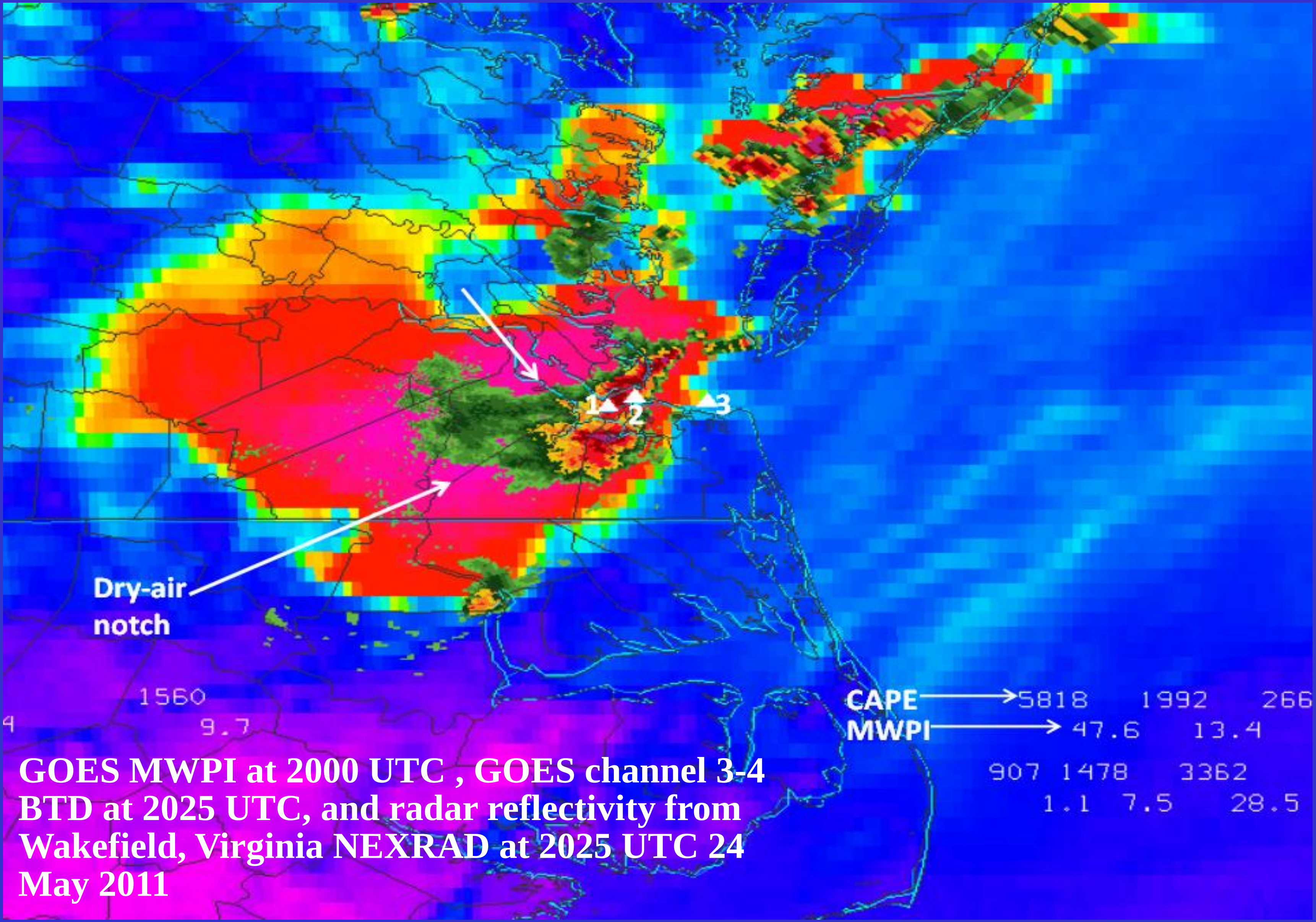
GOES MWPI 24 May 2011



GOES WMSI 24 May 2011

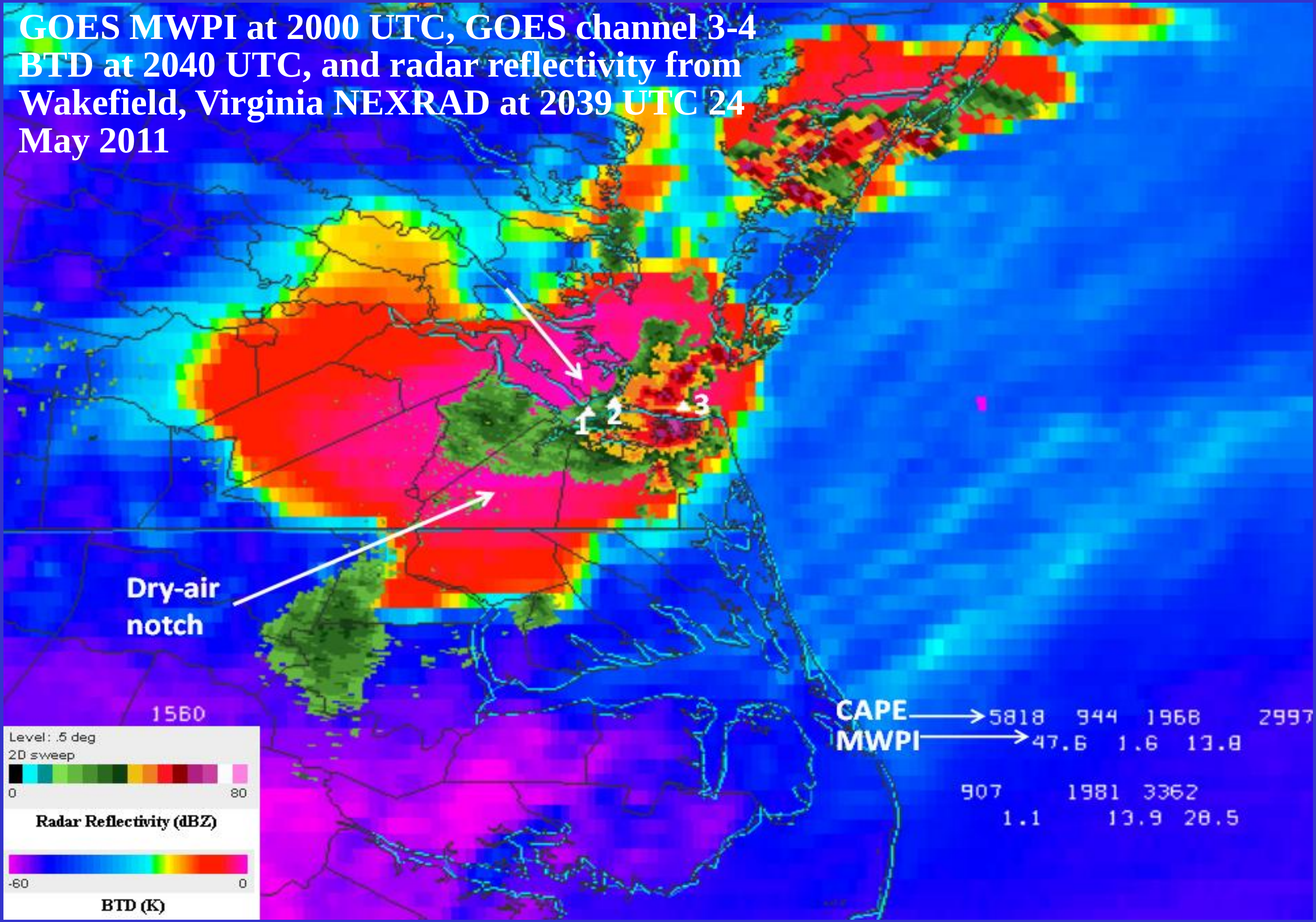


GOES-NEXRAD Composite

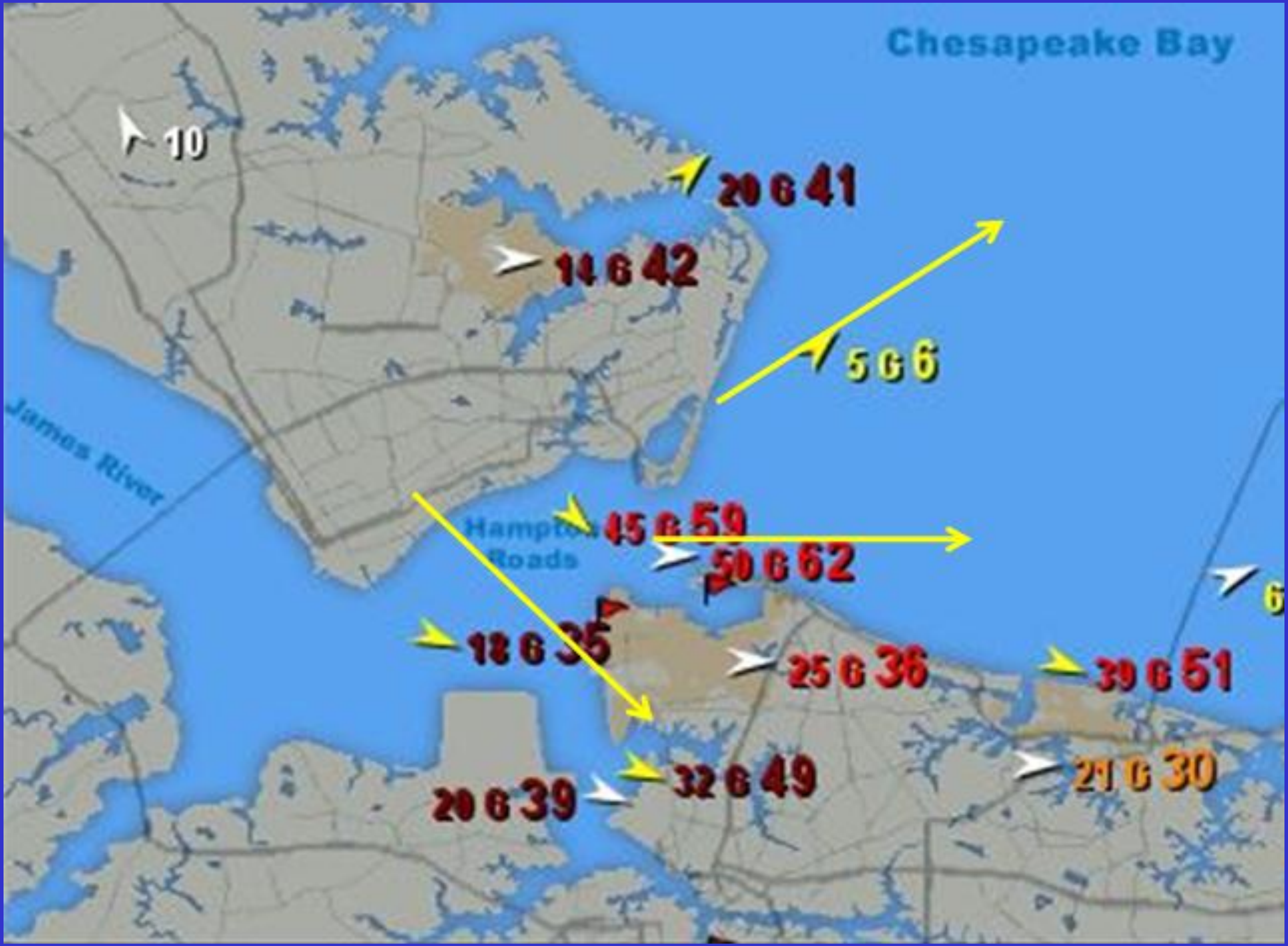


GOES MWPI at 2000 UTC , GOES channel 3-4 BTD at 2025 UTC, and radar reflectivity from Wakefield, Virginia NEXRAD at 2025 UTC 24 May 2011

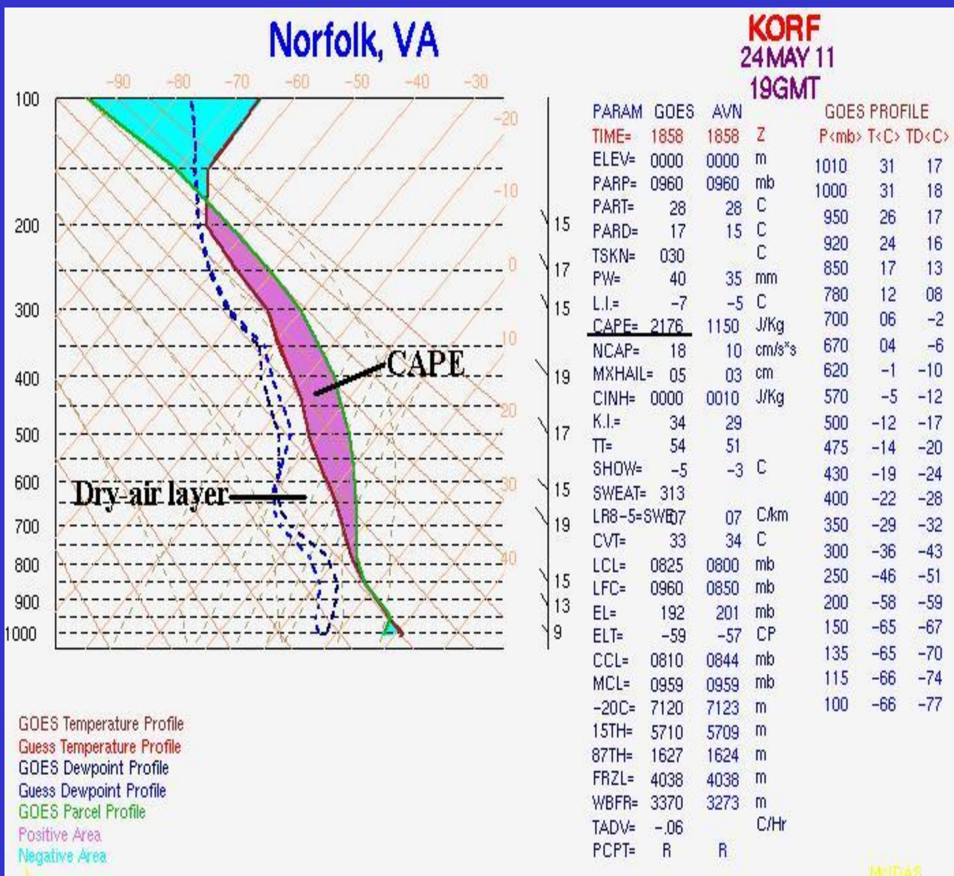
GOES-NEXRAD Composite

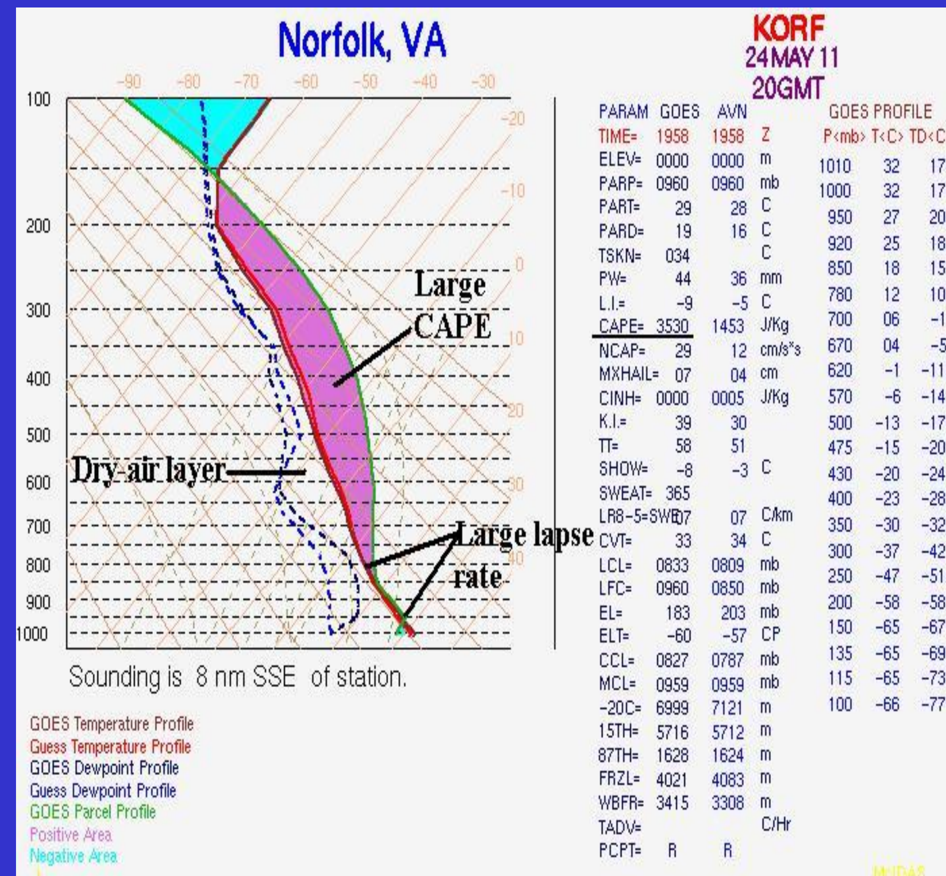


Wind Observations



GOES Soundings





Summary of Microburst Generation Processes

- **DMI**: subcloud evaporative and sublimational cooling (Caracena and Flueck 1988)
- **WMSI**: precipitation loading and evaporative cooling from the entrainment of dry ambient air into the precipitation core (Wakimoto 2001)
- **MWPI**: combination of above processes

Questions?

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