Forecasting Convective Downburst Potential Using GOES Sounder Derived Products

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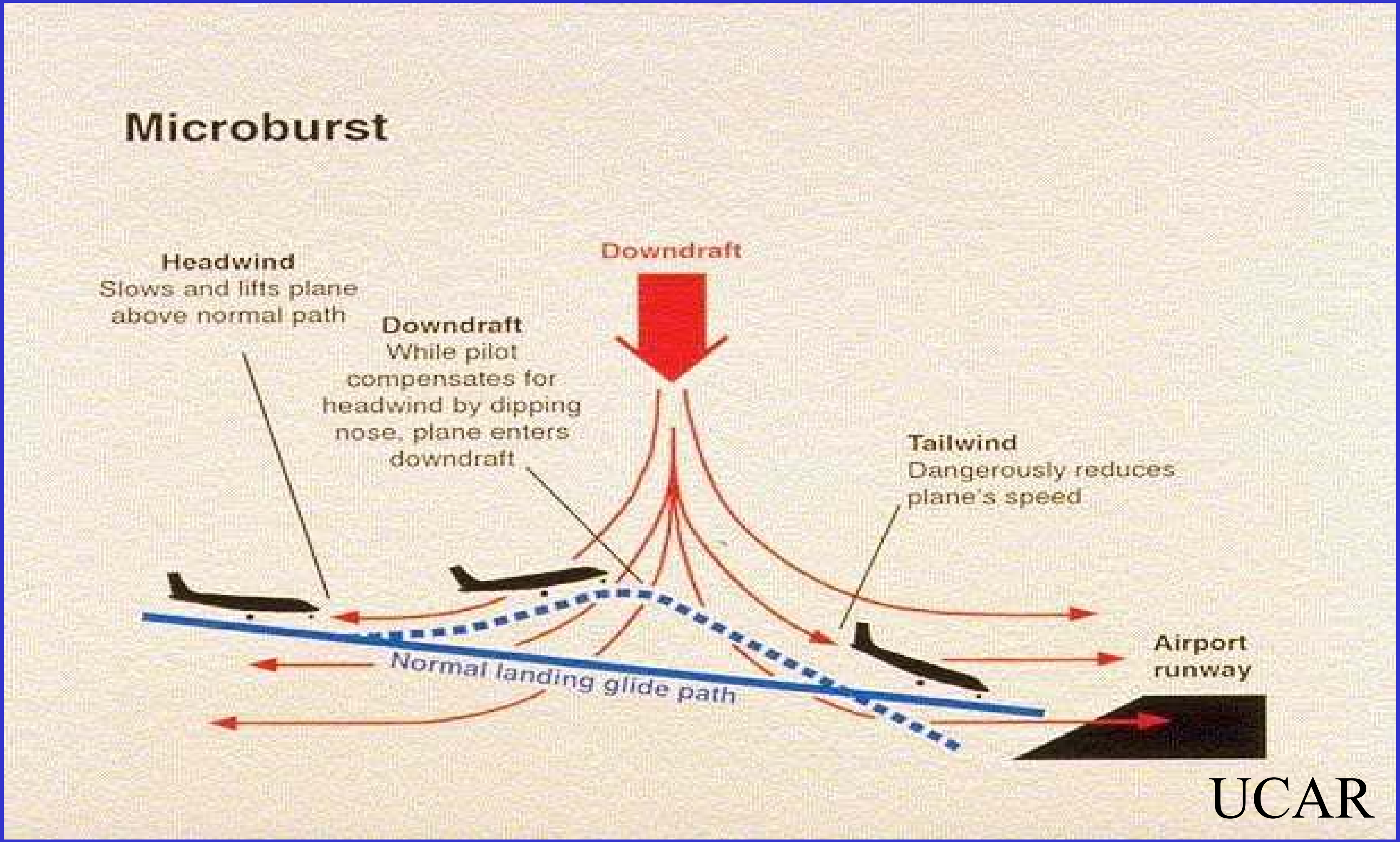
Topics of Discussion

- Convective Downbursts
- Description of the GOES Microburst Products
- Case Studies/Microburst Prediction Exercises
- Use of the GOES Microburst Products with Other Satellite Data

Introduction

- The **downburst** is defined as a strong downdraft produced by a **convective storm** (i.e., thunderstorm) that induces an **outward burst of damaging winds** on or near the earth's surface (Fujita and Wakimoto 1983) .
- Due to the **intense wind shear** they produce, downbursts are a **hazard to aircraft** in flight, especially during takeoff and landing phases.

Microburst Aircraft Hazards



Historic Microburst-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)**

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.

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.

Algorithm Development

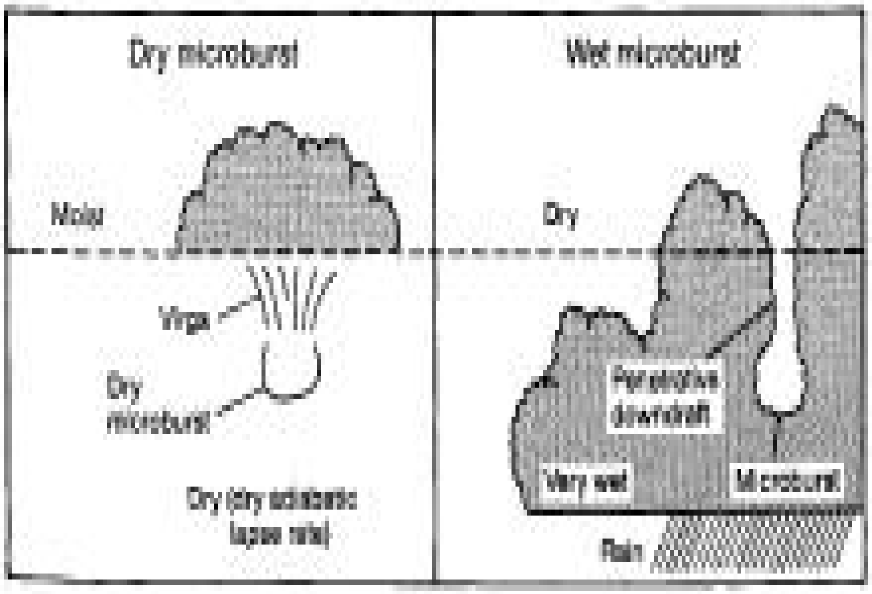


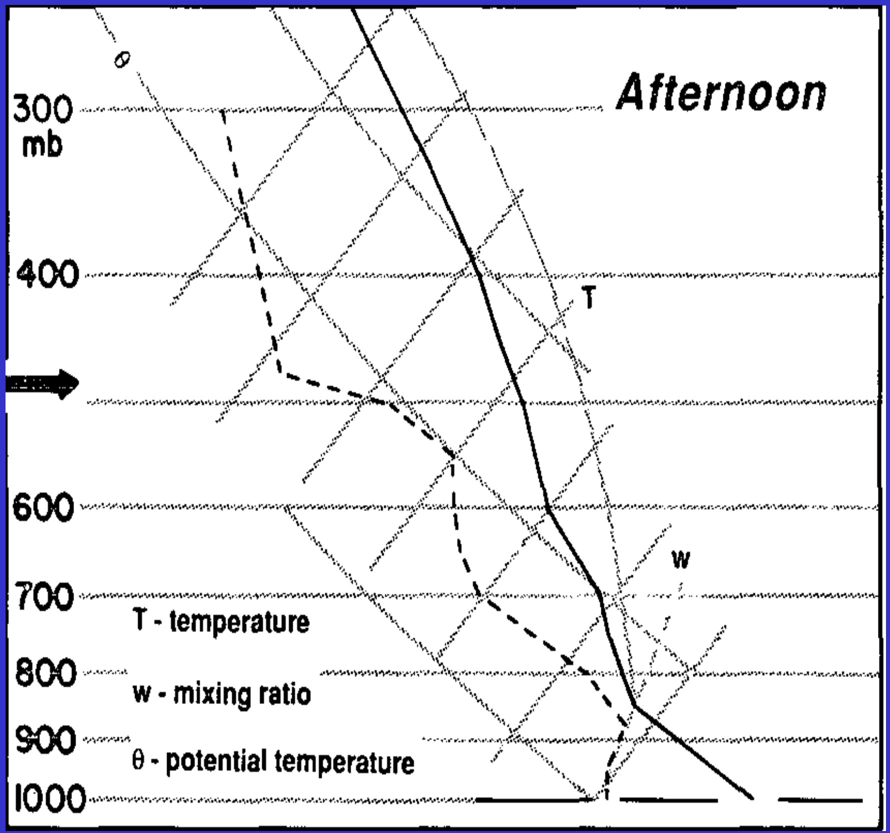
Fig. 2 Two extreme microburst environments: a) virga-type, and b) wet.

Table 1 Predictor and response variables utilized in the study

Variable	Description
Predictors based on a local sounding	
DPD7	Dew-point depression at 700 mb
DPD5	Dew-point depression at 500 mb
DPDS	Extrapolated dew-point depression in °C at surface
LAP75	Lapse rate of temperature between 700 and 500 mb
PRESS	Pressure at surface in mb
WDIR5	Wind direction in degrees at 500 mb
Predictor based on regional data	
TEMUP5	Temperature upwind at 500 mb
LDNHF5	Location of Denver in the 500-mb height field pattern (synoptic forcing: 0, 1, 2, 3)
SWTRH	Shortwave trough approaching, present, or past Denver (+ 1, 0, − 1)
Response	
BEDCNT	Bedard's count of number of microbursts observed on each day in JAWS
FUJCNT	Fujita's count of number of microbursts observed on each day in JAWS
RADCNT	Radar and chase team count of number of microbursts observed on each day in JAWS

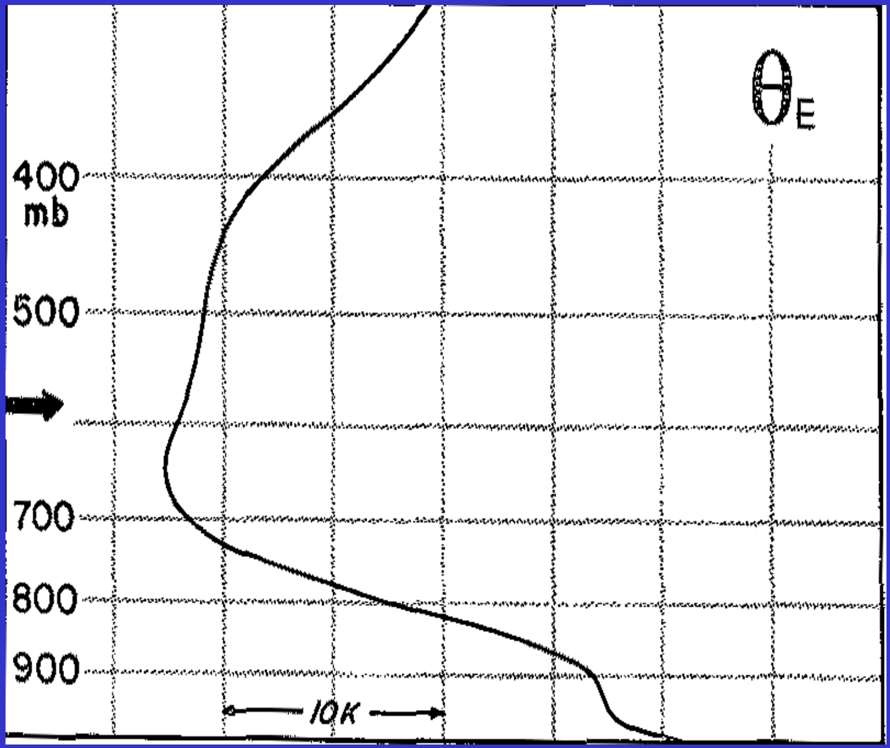
From Caracena and Flueck (1988)

Wet Microburst



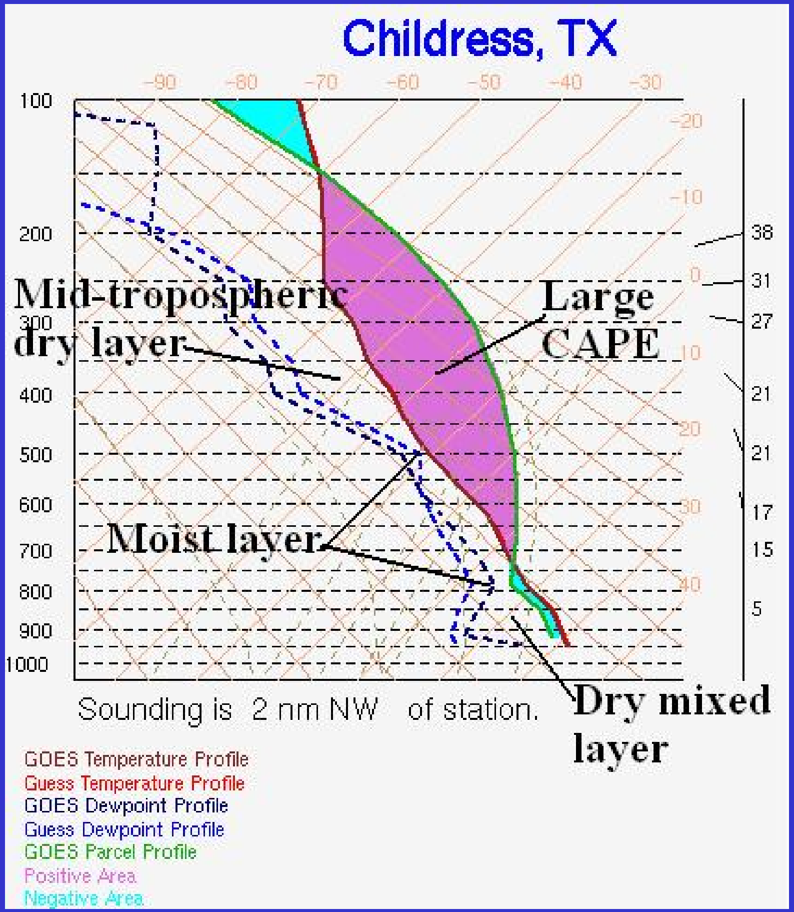
From Atkins and Wakimoto (1991)

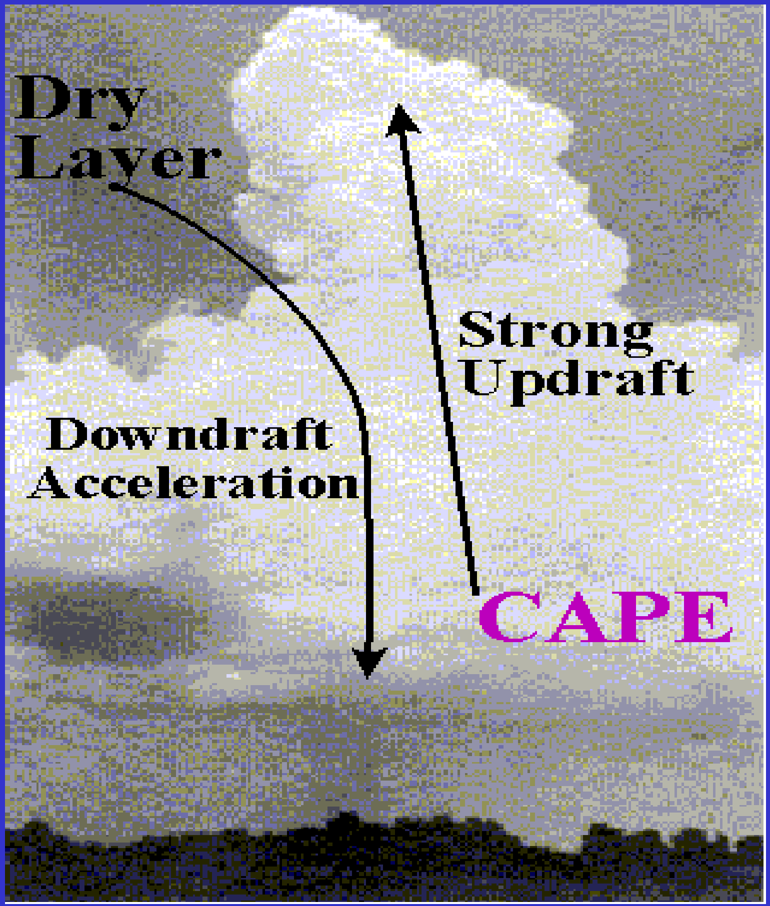
Theta-e Deficit (TeD)



- 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)



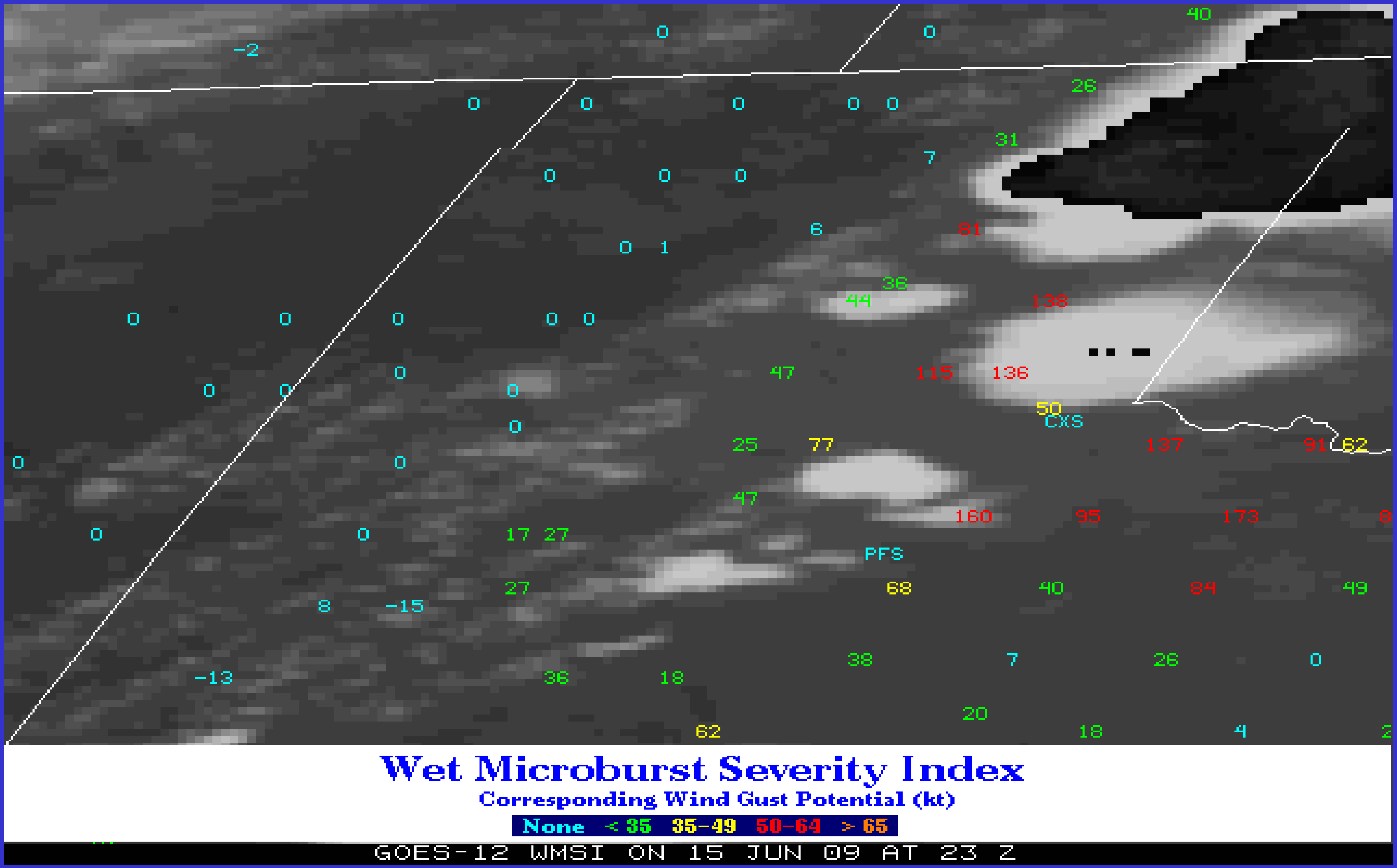


Wet Microburst Severity Index (WMSI)

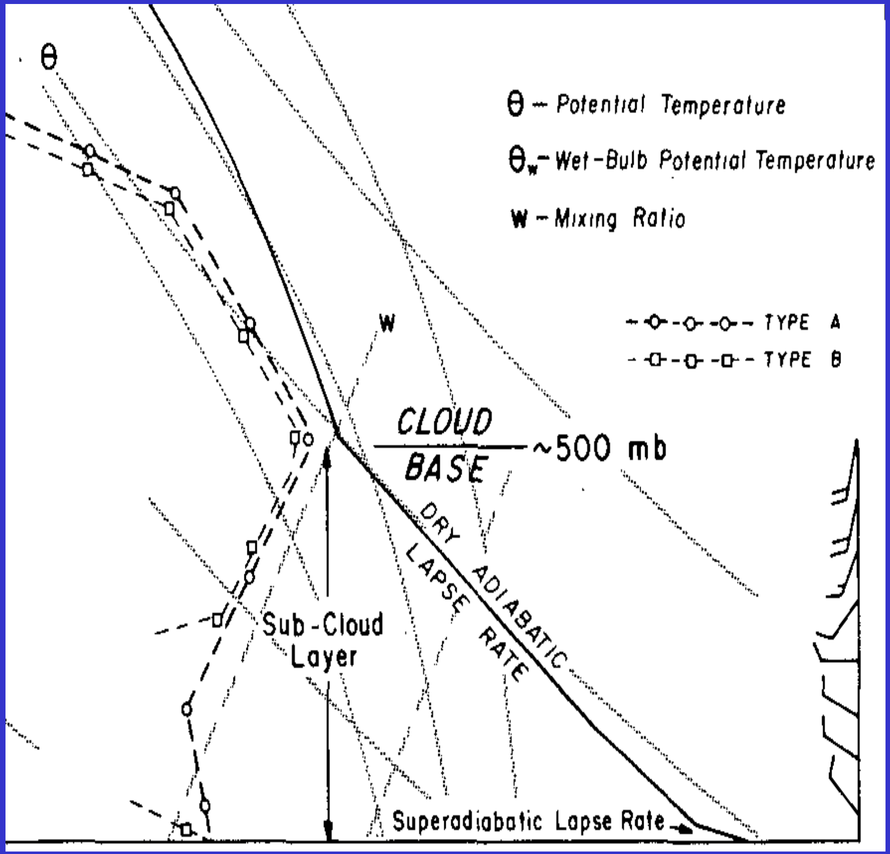
WMSI = (CAPE)(TeD)/1000

- Large convective available potential energy (CAPE) 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)



Dry Microburst



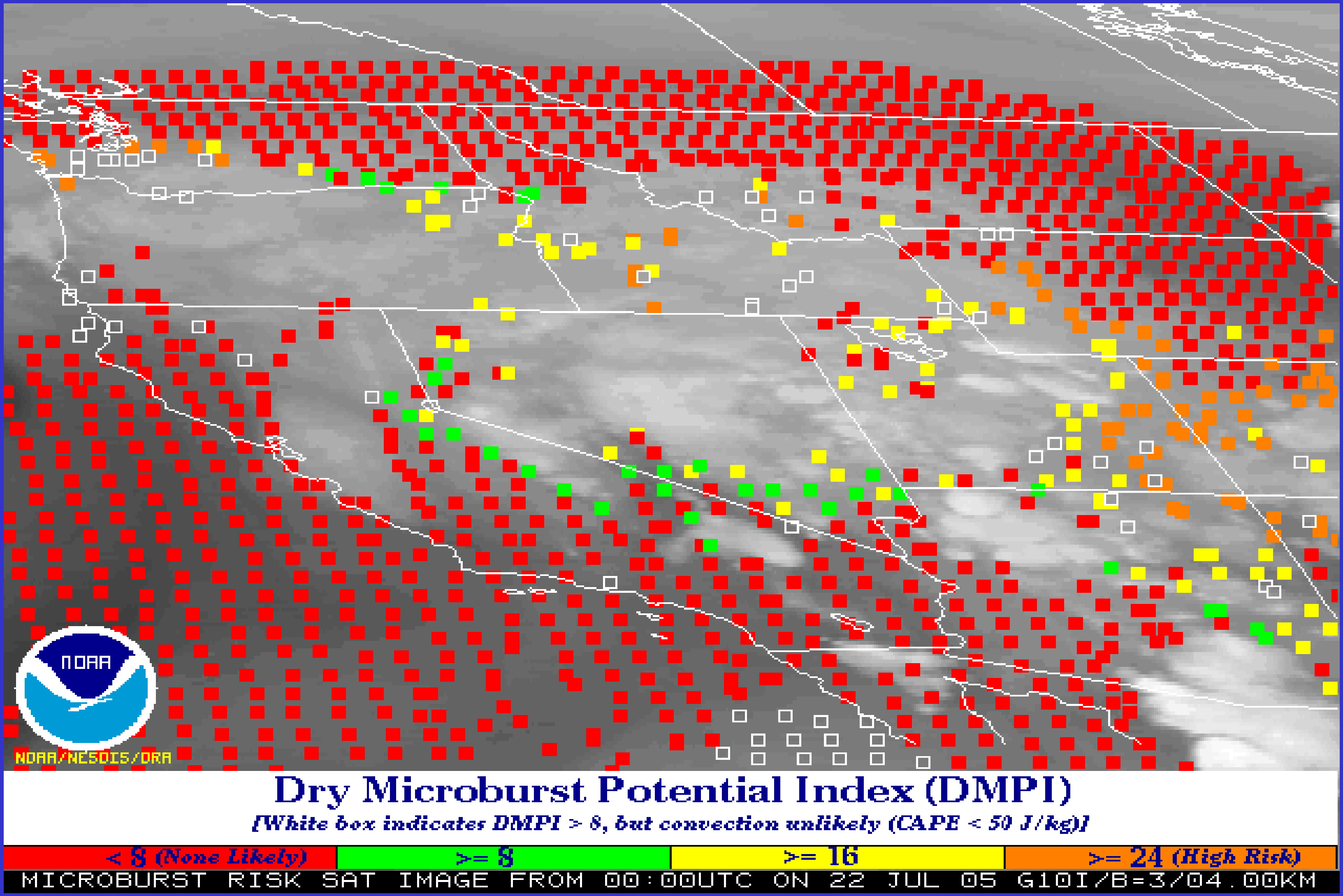
From Wakimoto (1985)

Dry Microburst Index (DMI)

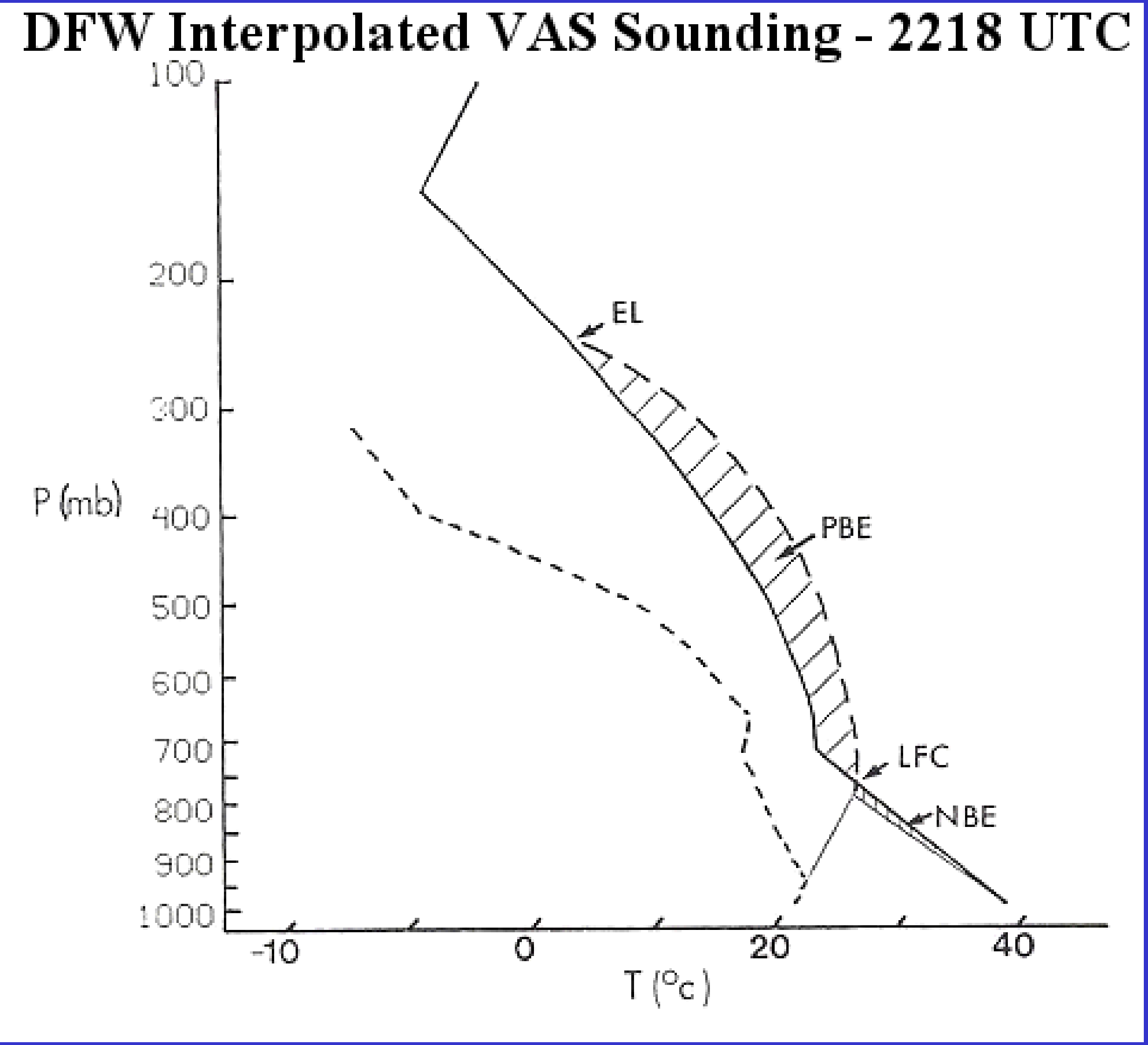
$DMI = \Gamma + (T - T_d)_{700} - (T - T_d)_{500}$

- 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

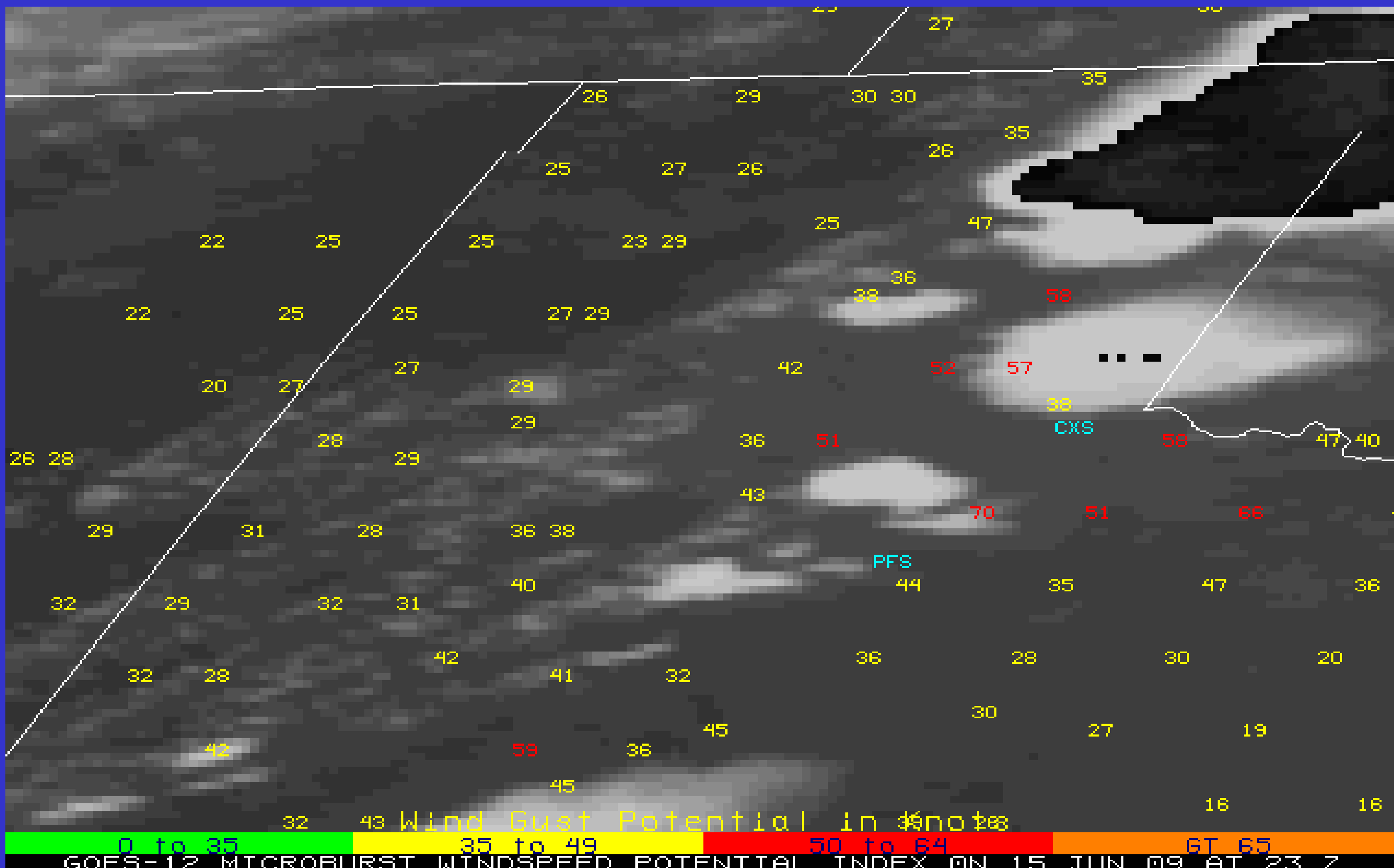


Microburst Windspeed Potential Index (MWPI)

$MWPI = CAPE/100 + \Gamma + (T - T_d)_{850} - (T - T_d)_{670}$ (Pryor2009a)

- 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**

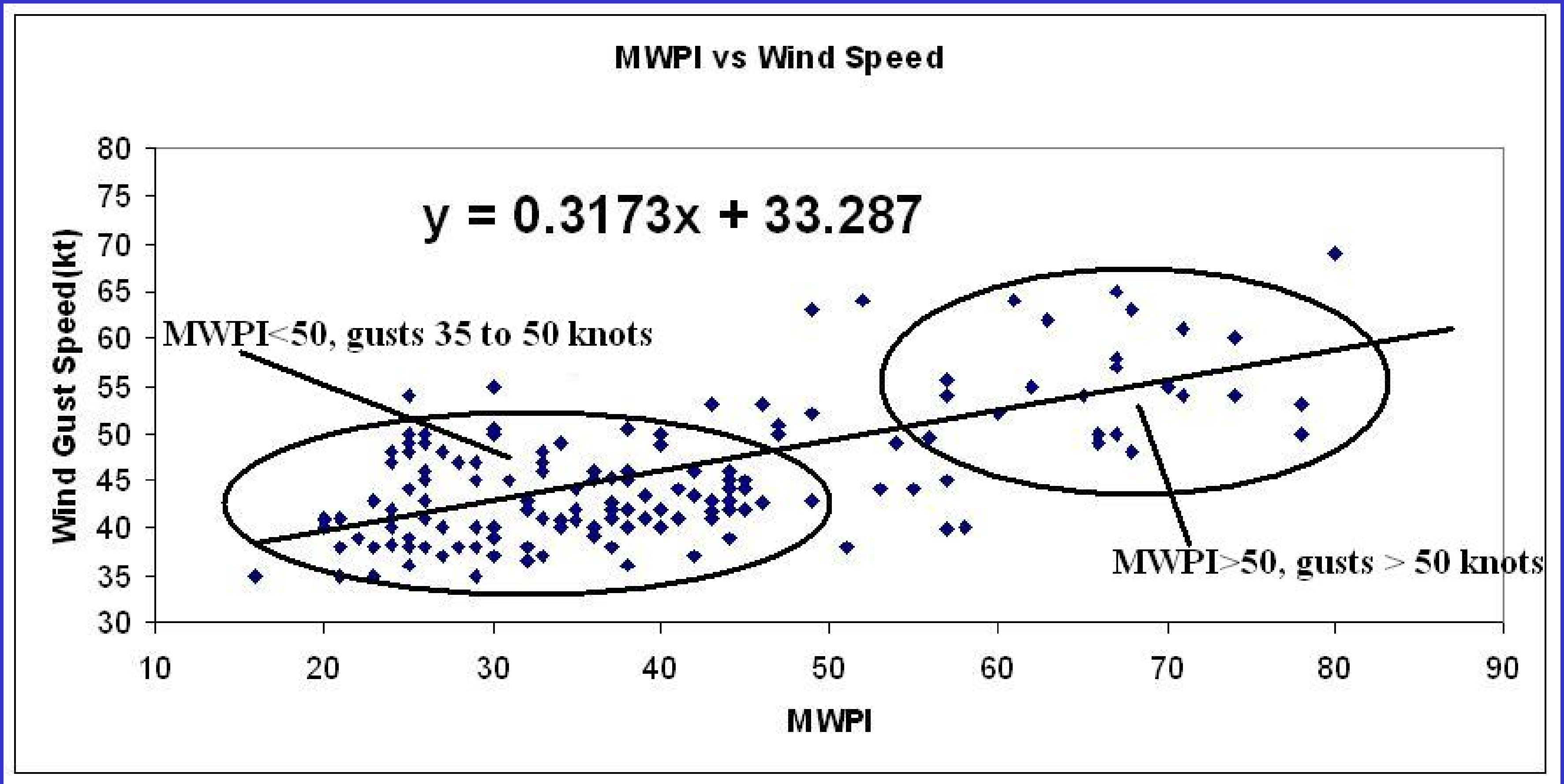
Microburst Windspeed Potential Index (MWPI)



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

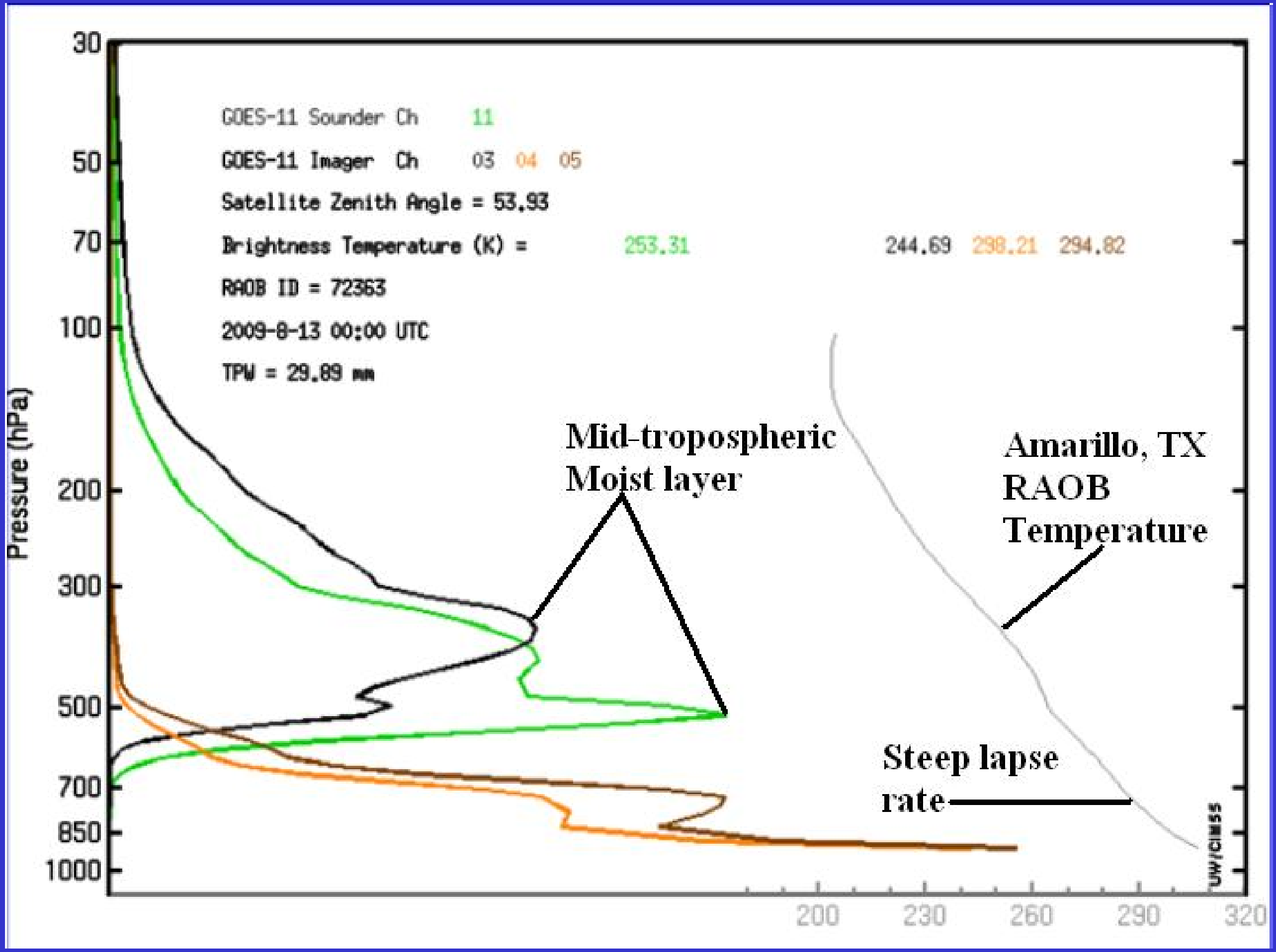
Statistical Relationships



GOES-West Imager Product

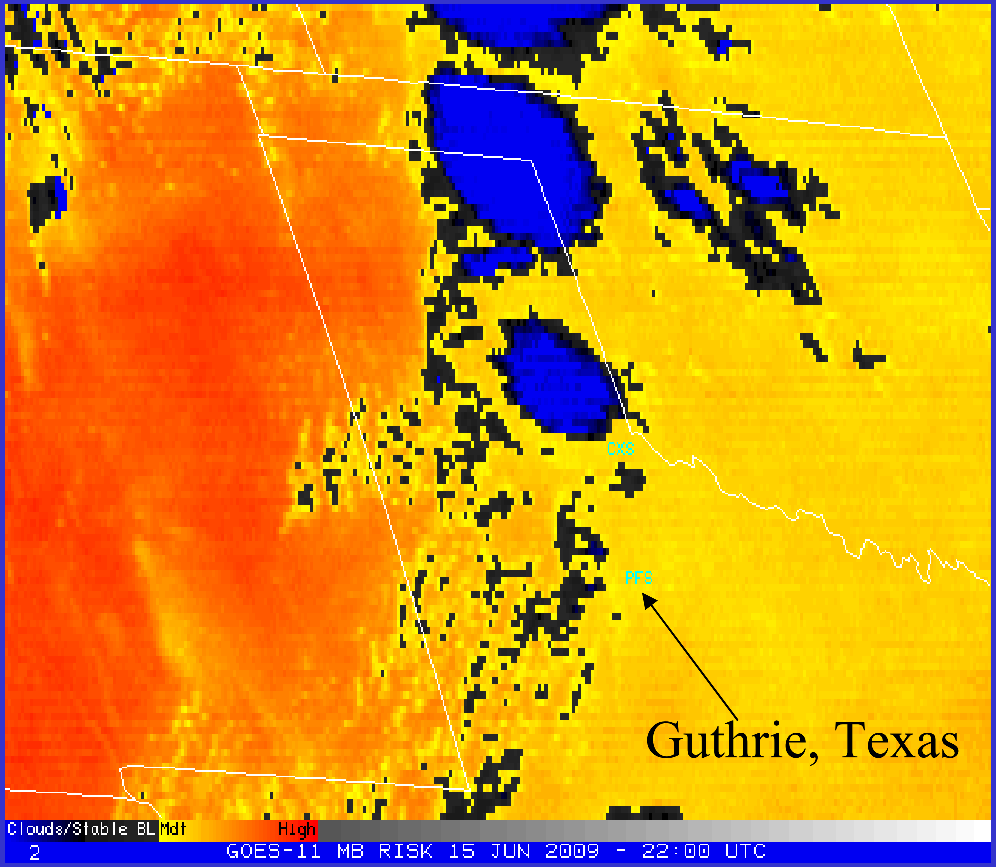
- Multispectral GOES imager product (Pryor 2009a):
  - Improved spatial and temporal resolution (4 km, 30 minutes) over sounder products (10km, 60 minutes).
  - Split-window channel (band 5, 12μm) allows for the inference of boundary layer moisture content.
  - Strong negative correlation between 6.7μm brightness temperature (T_b) and layer-averaged relative humidity (RH) between the 200 and 500-mb levels.
- Output brightness temperature difference (BTD) is proportional to microburst potential:
- $BTD = \{T_5 - T_3\} - \{T_4 - T_5\}$
- Best suited for assessment of dry microburst potential

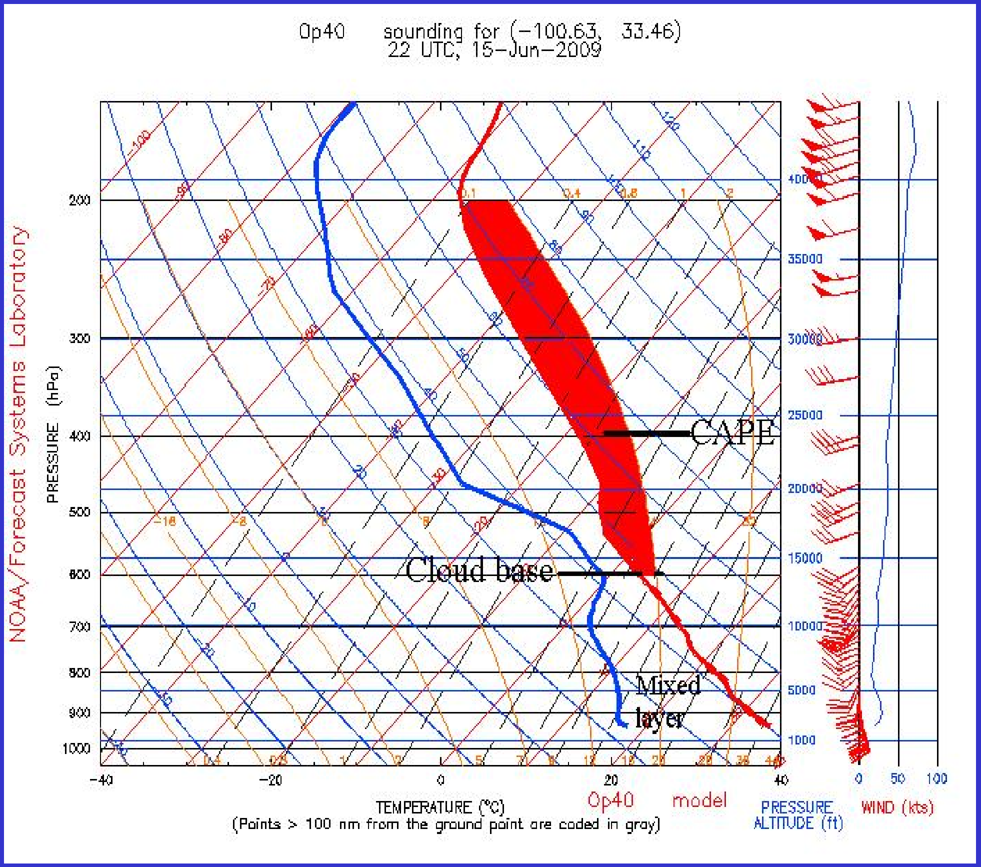
GOES-West Imager Product



GOES-11 transmittance weighting functions and Amarillo RAOB

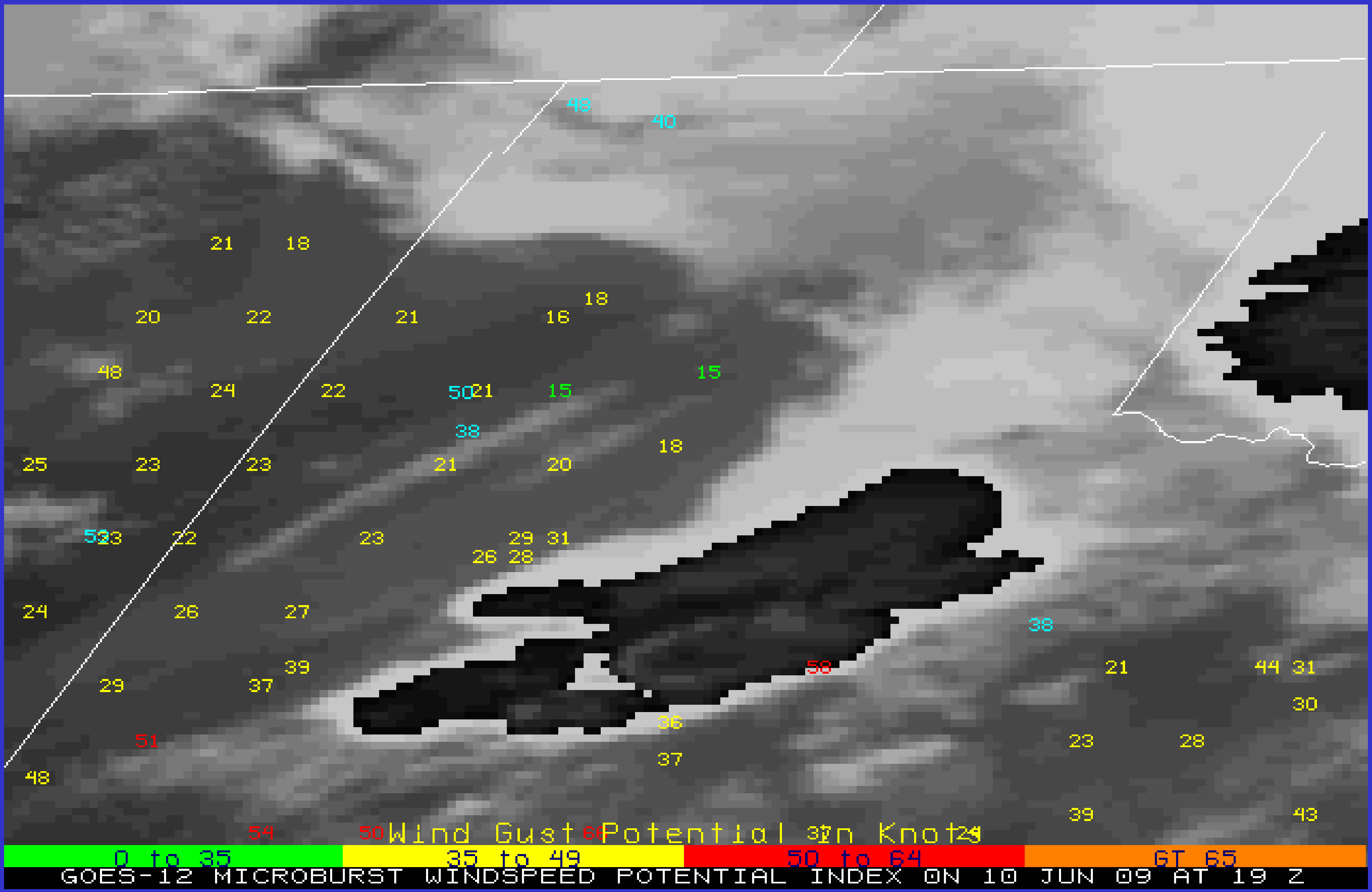
GOES-West Imager Product





Case Studies

Case 1: High Plains Downbursts



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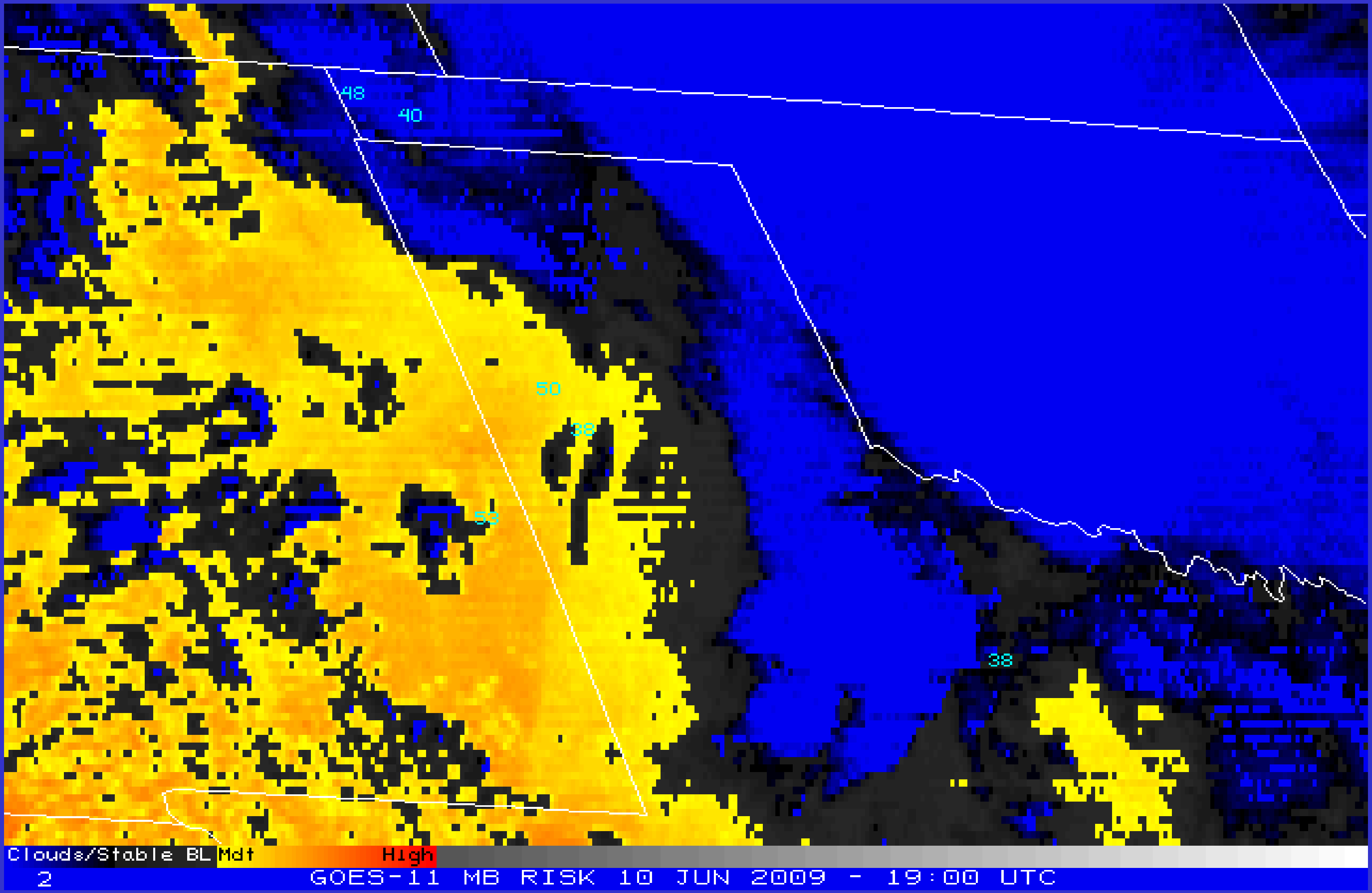

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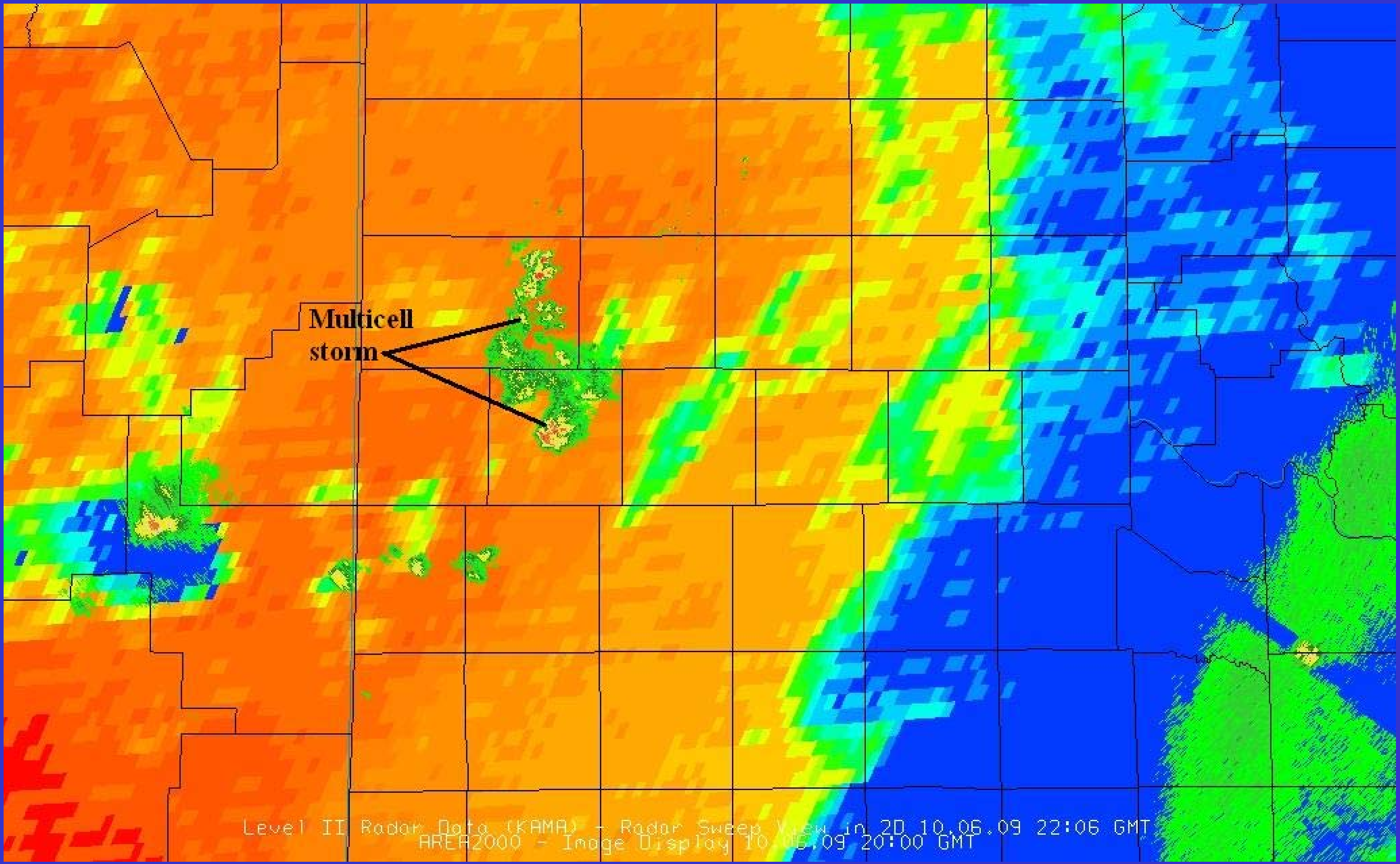
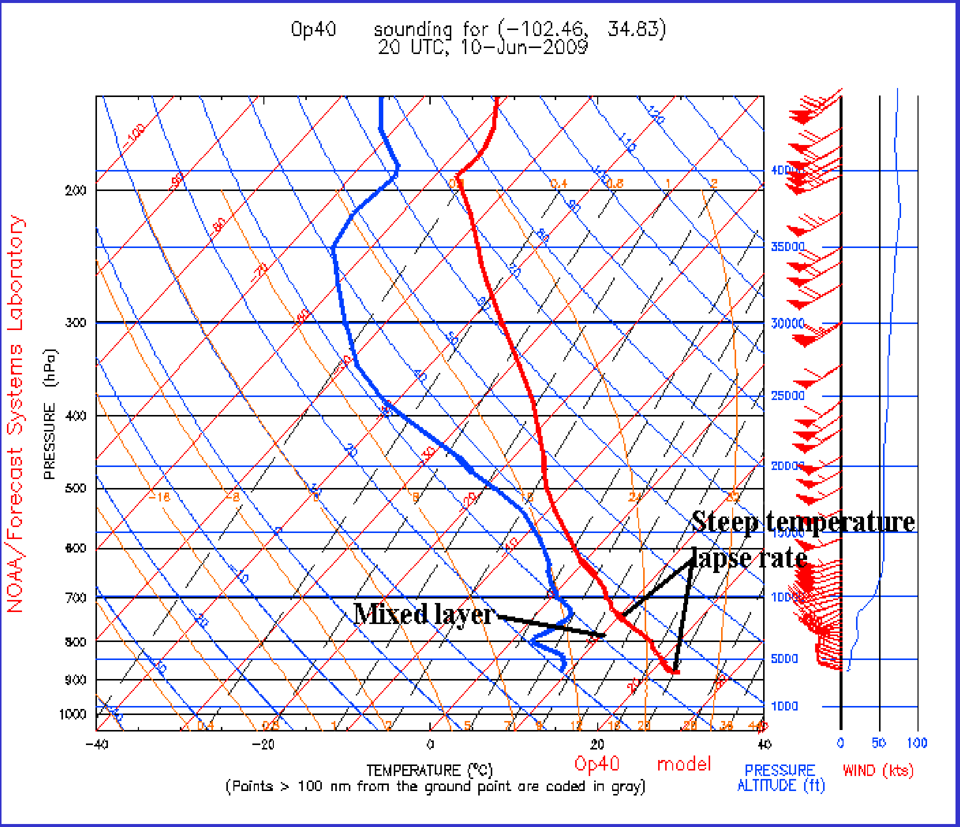
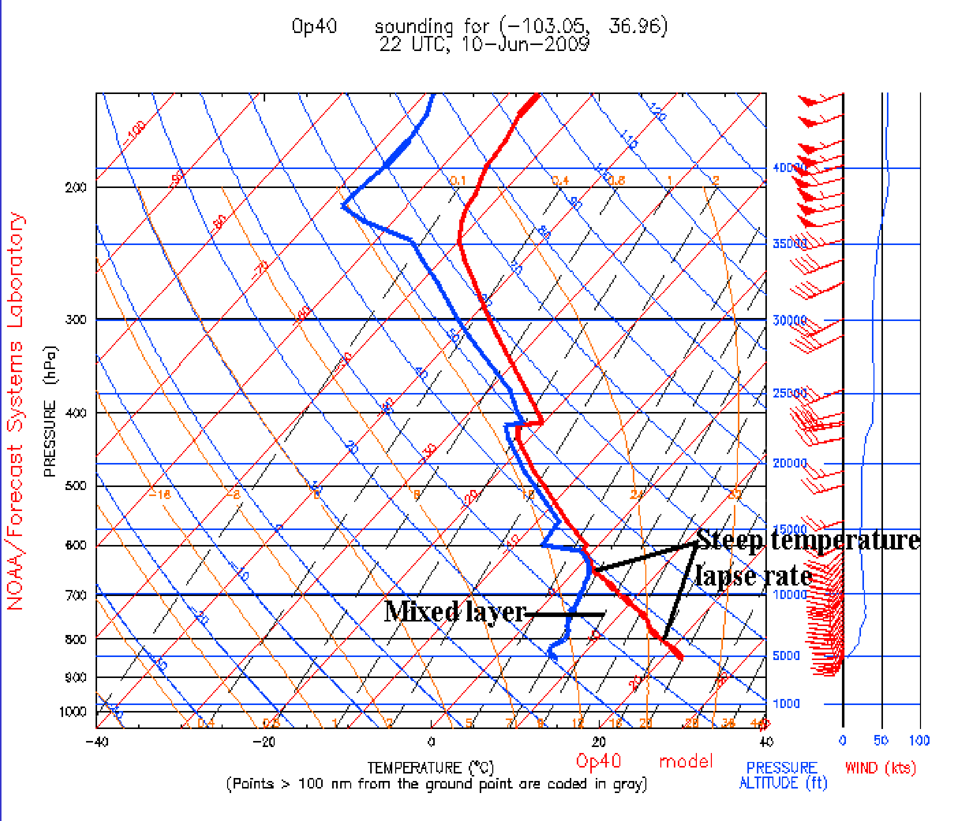


McIDAS-V visualization

Case 1: High Plains Downbursts



Hereford, Texas



Kenton, Oklahoma

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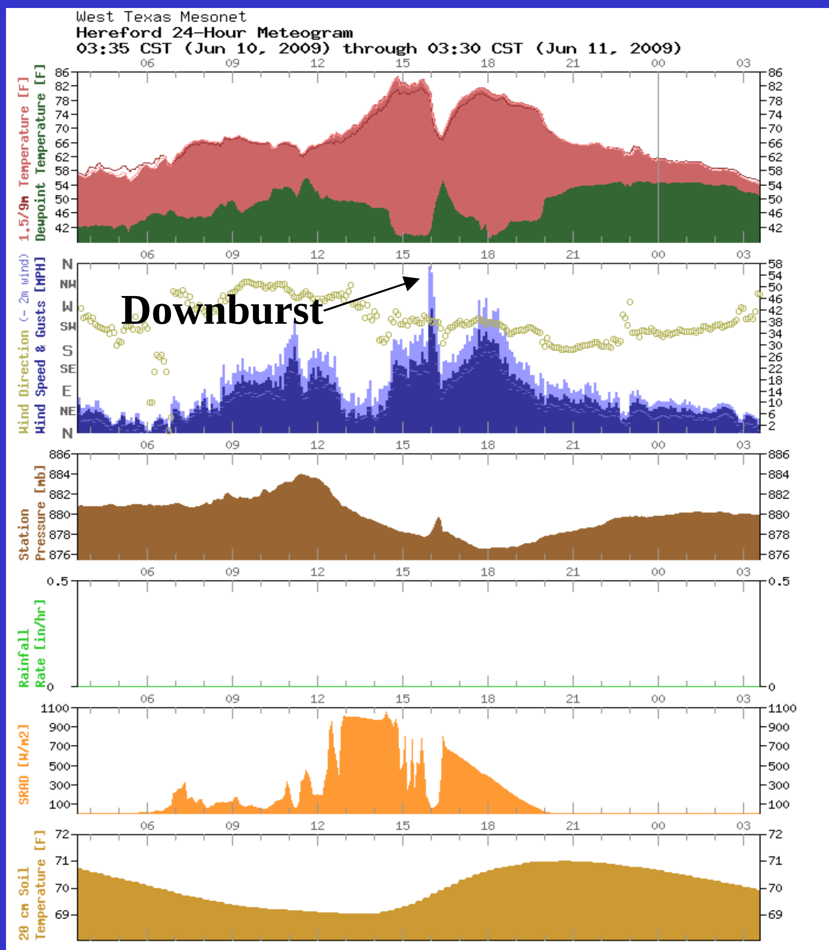

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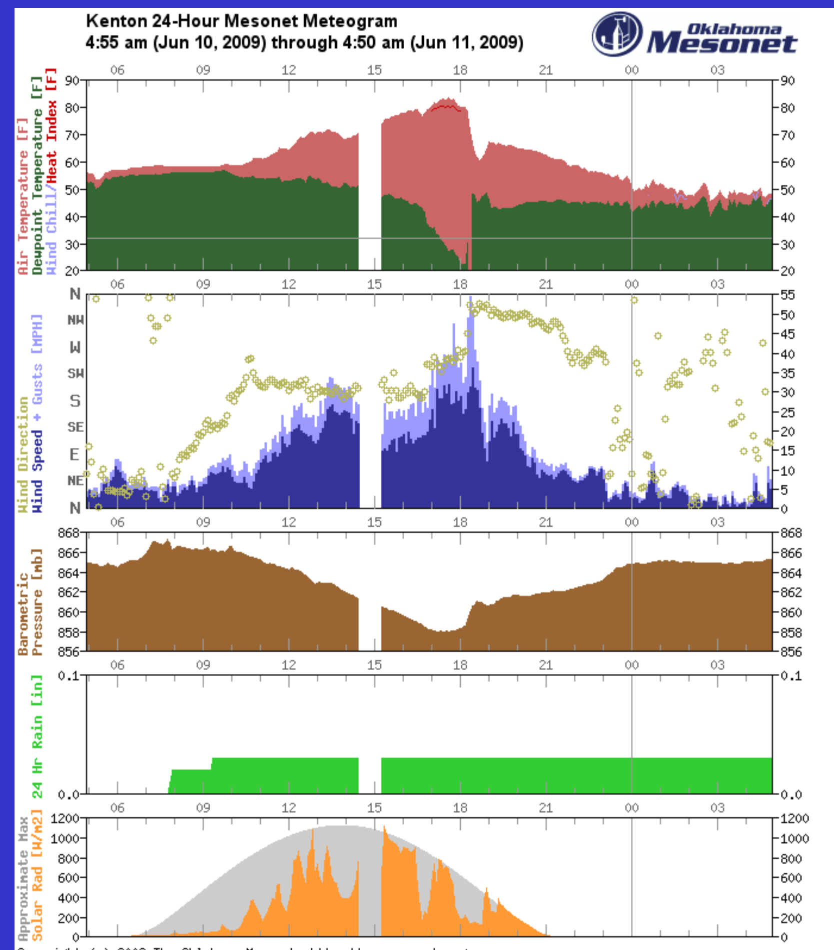
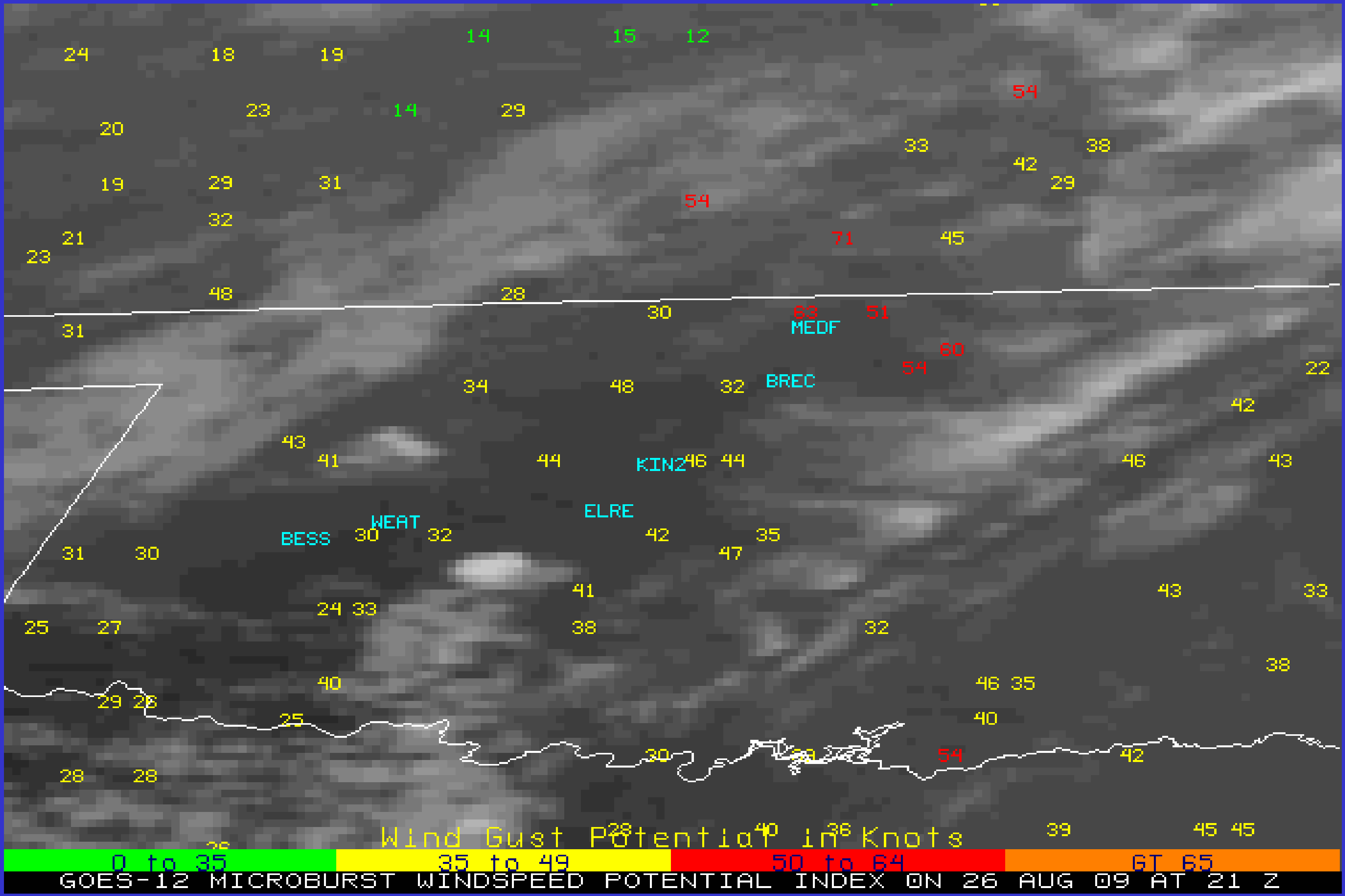


Kenton, Oklahoma

Case 2: Oklahoma Downbursts



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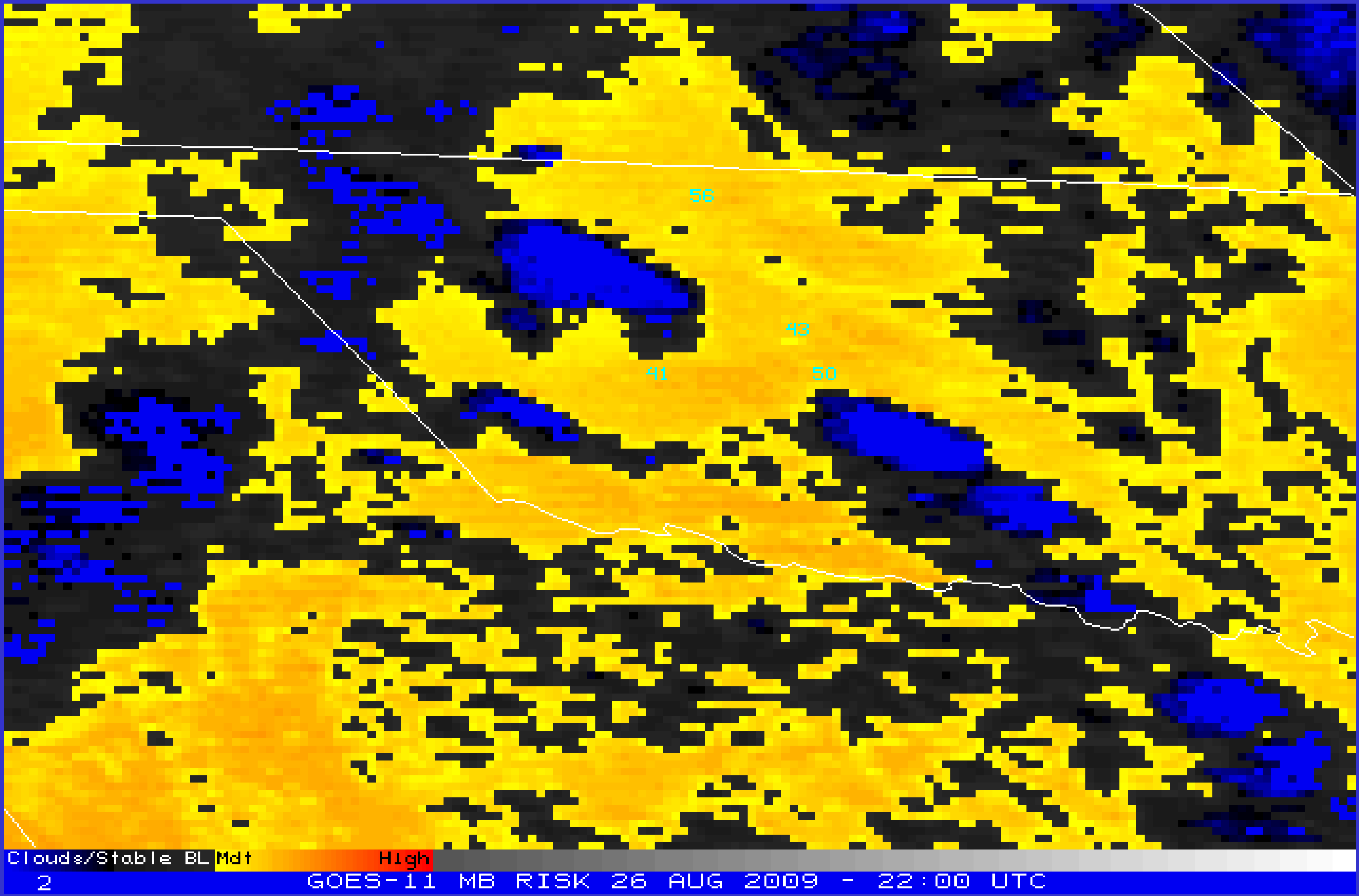

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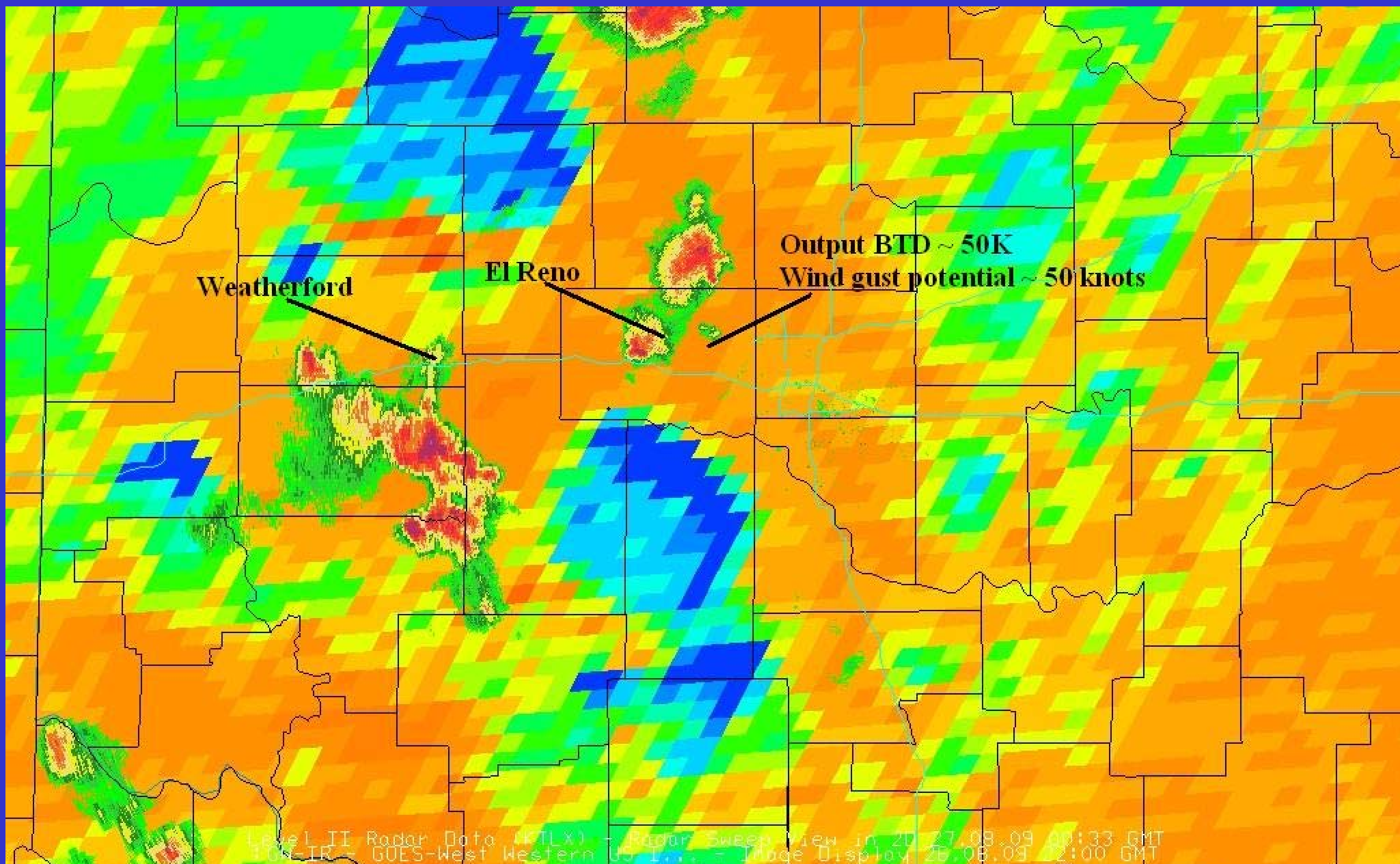

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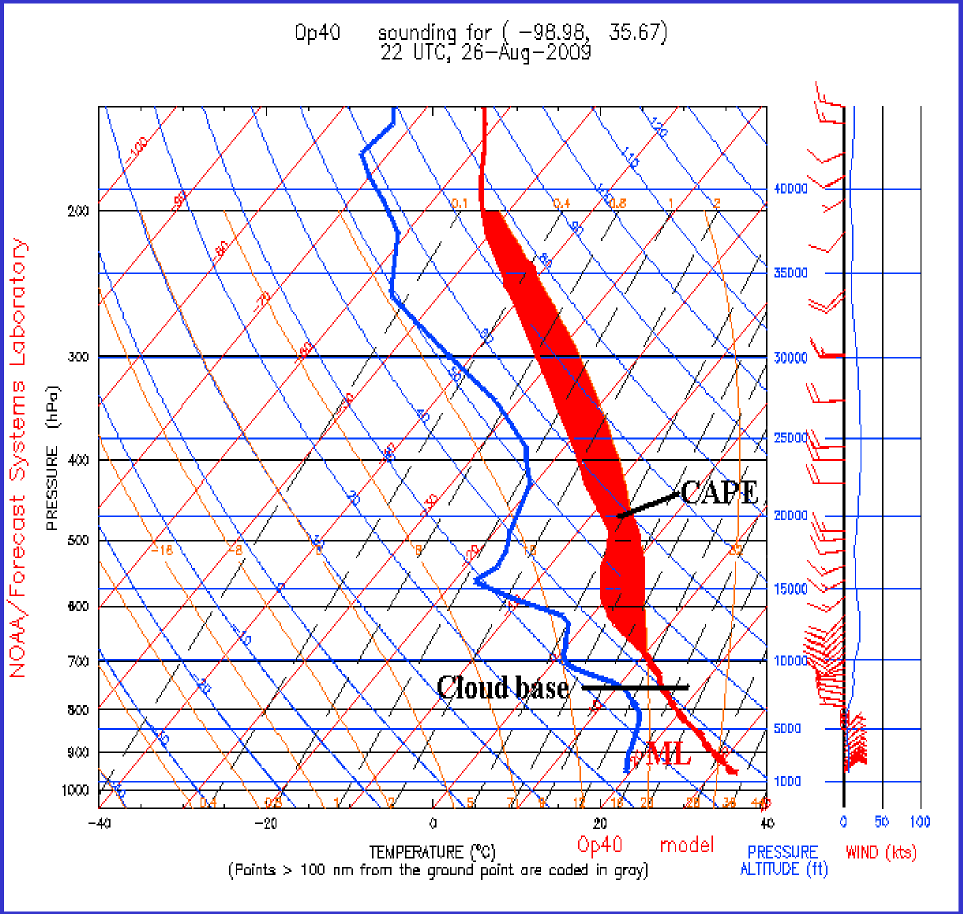
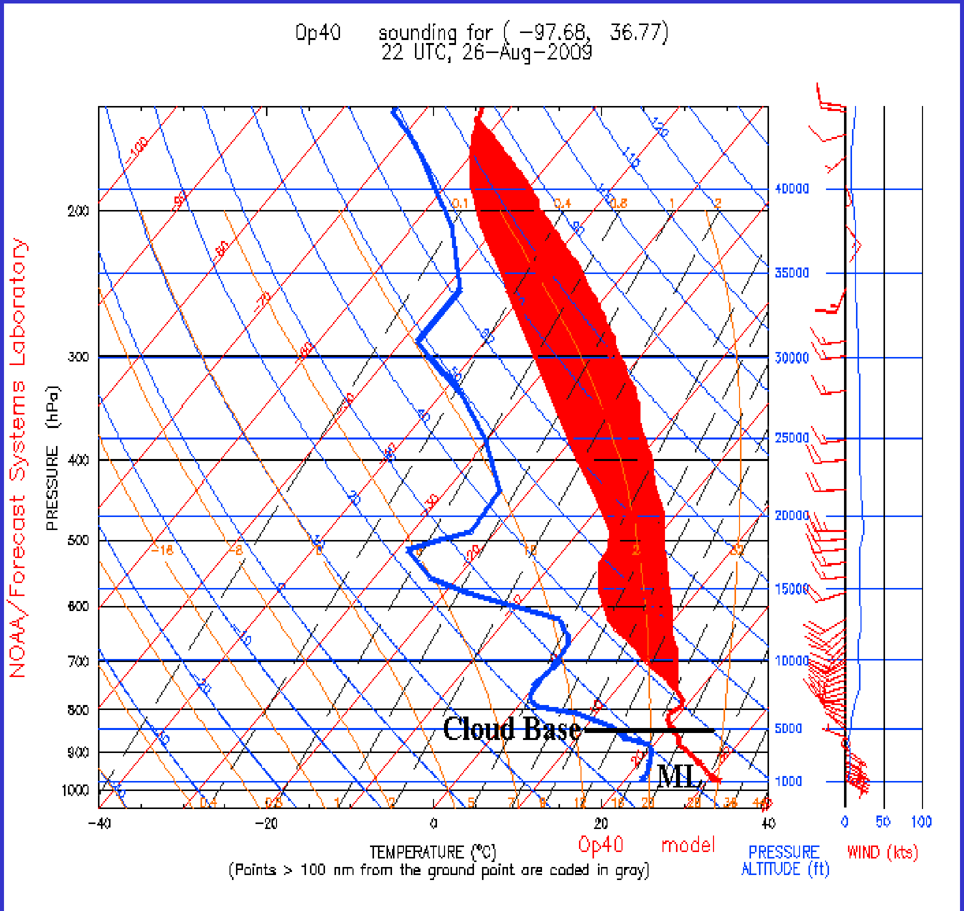


Weatherford, Oklahoma



Medford, Oklahoma

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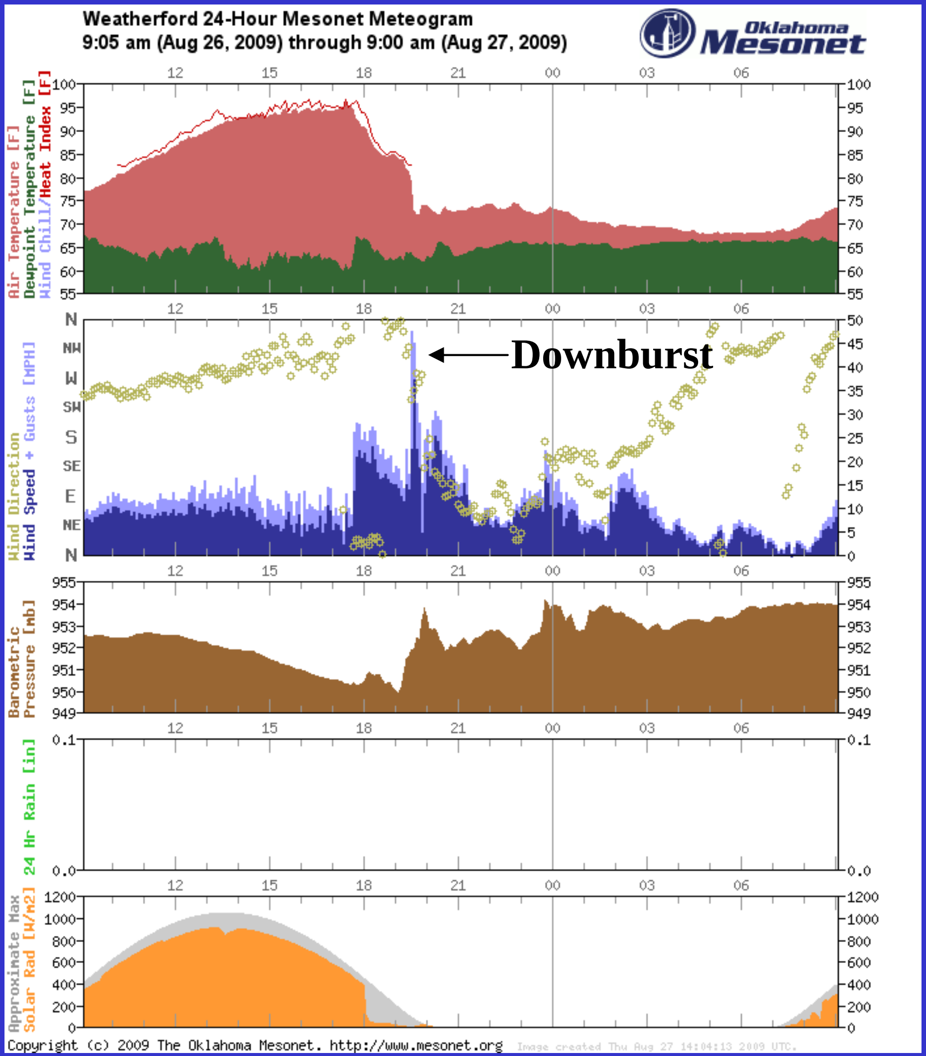
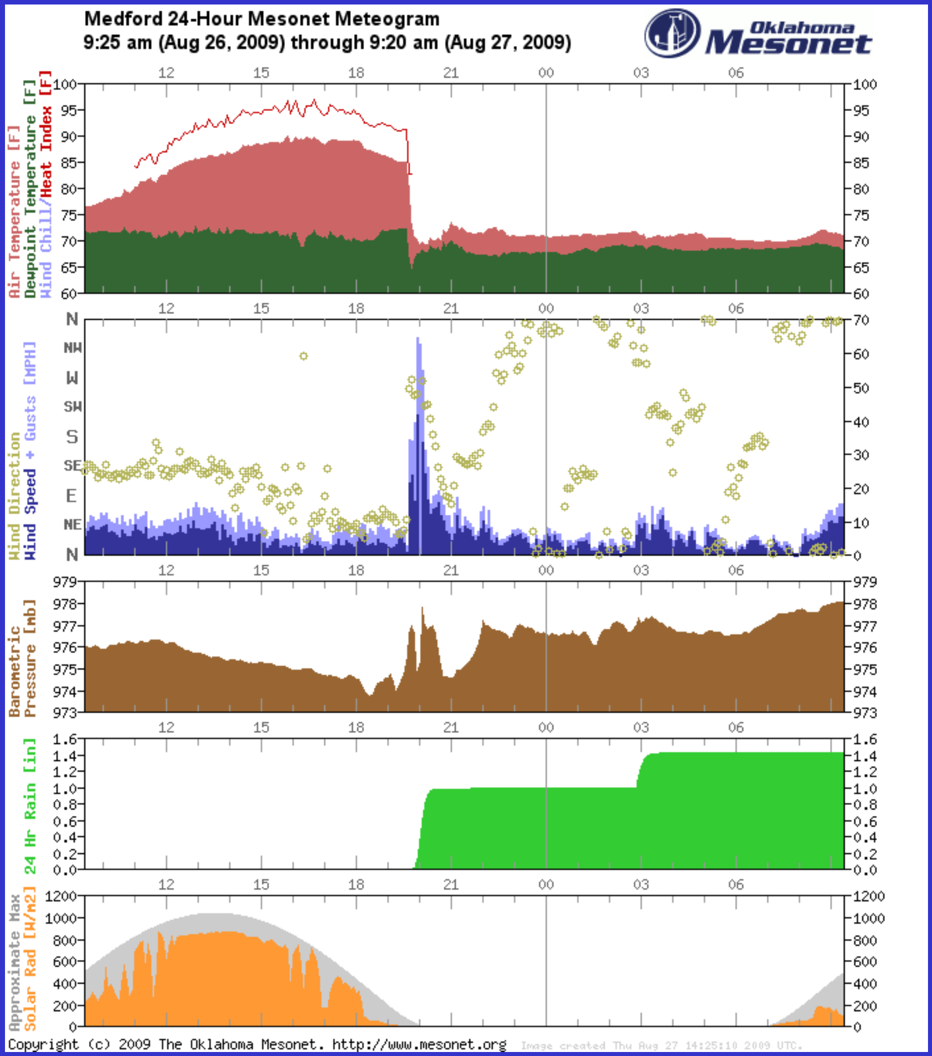
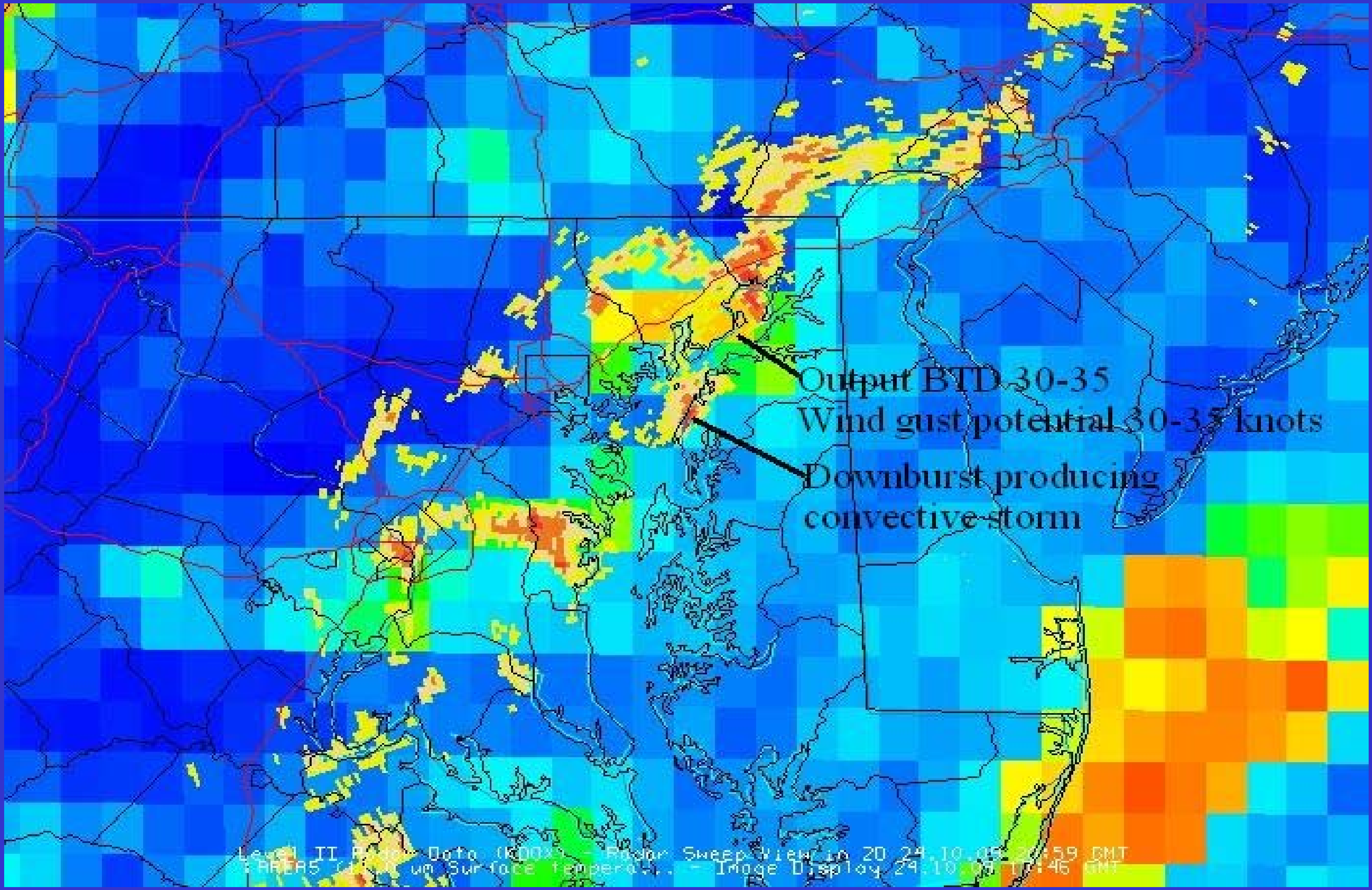


Weatherford, Oklahoma



Medford, Oklahoma

Case 3: Chesapeake Bay Downbursts



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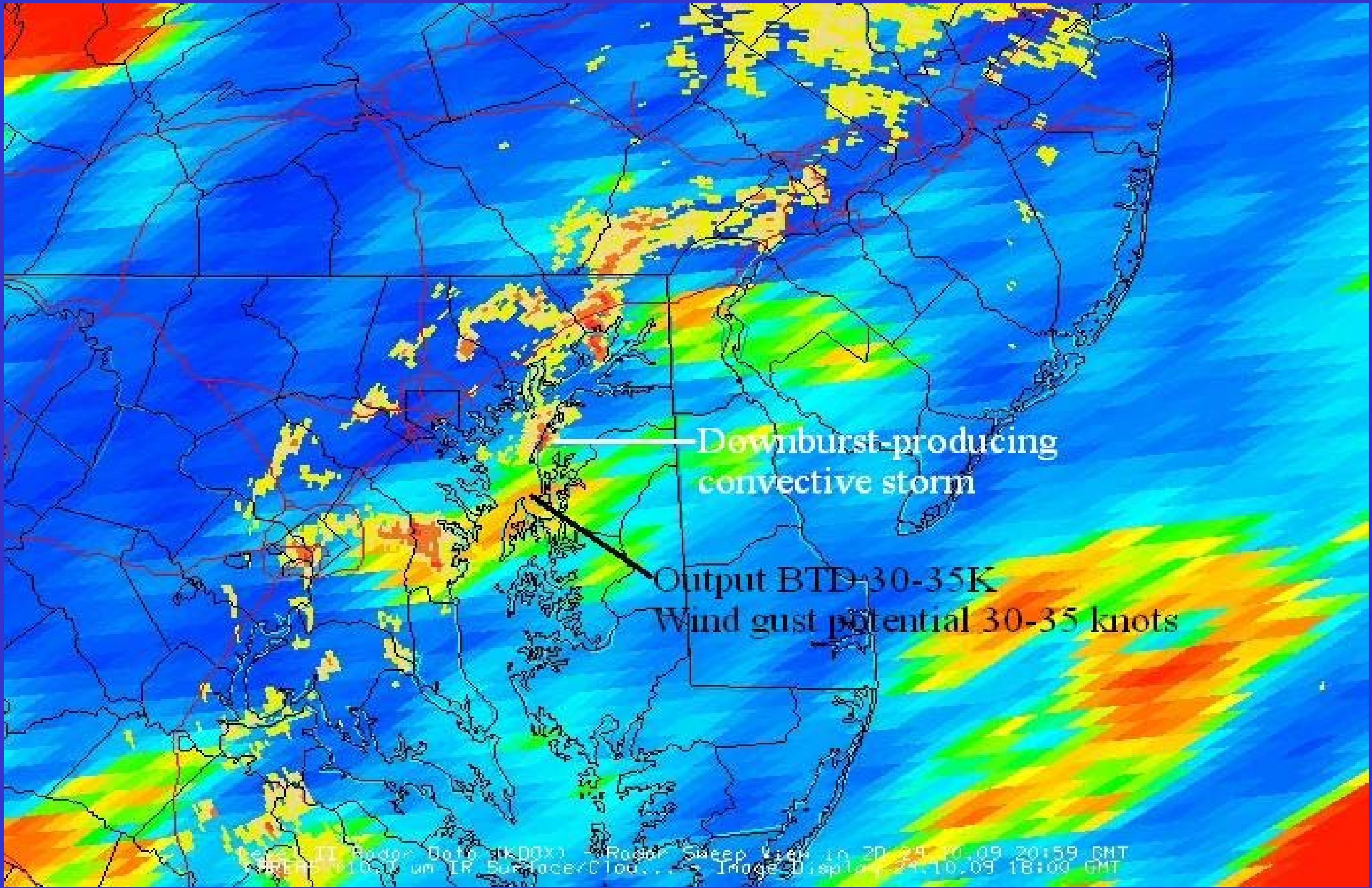

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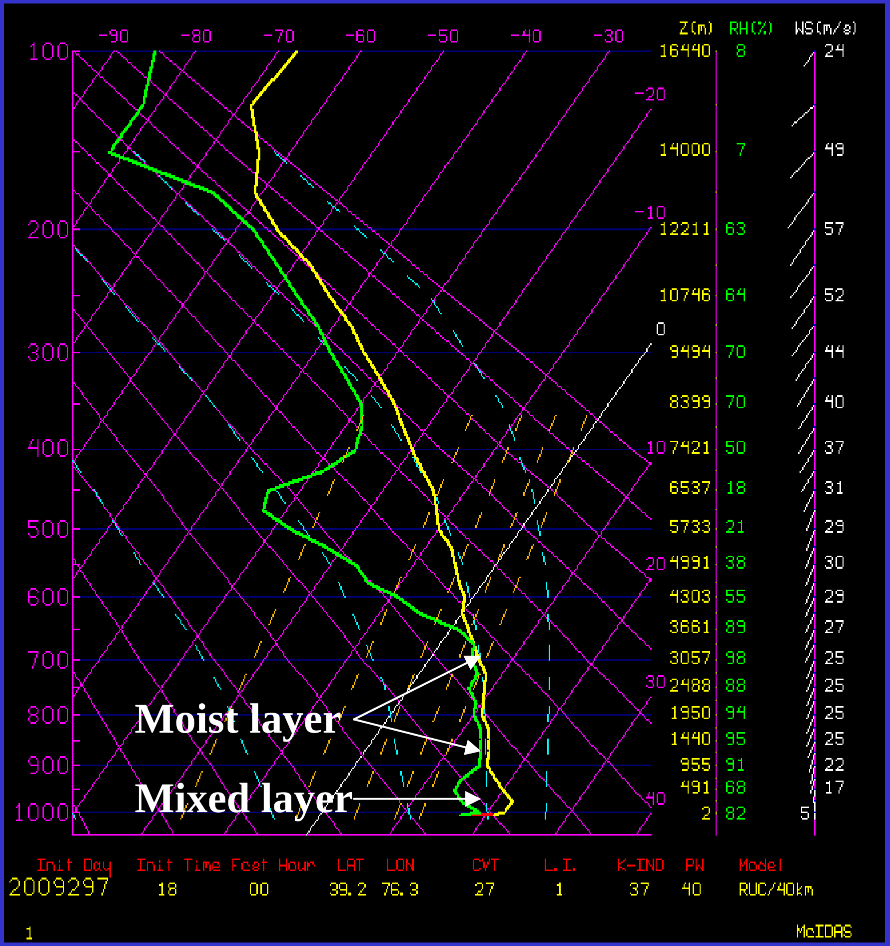

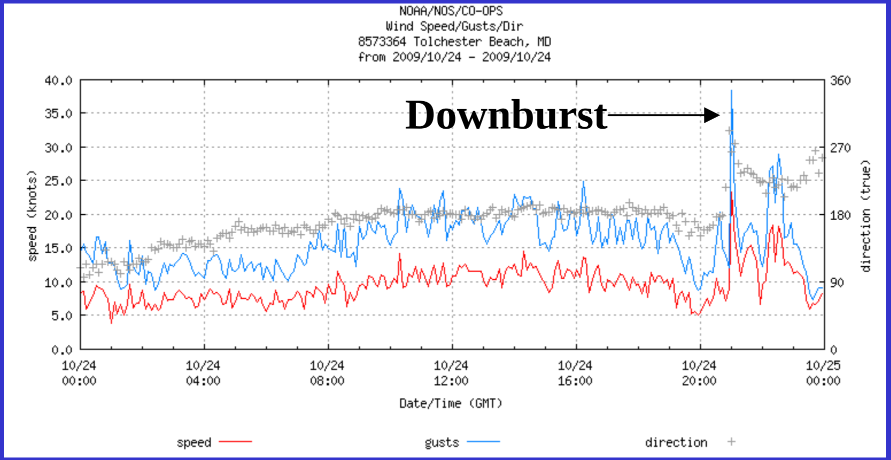

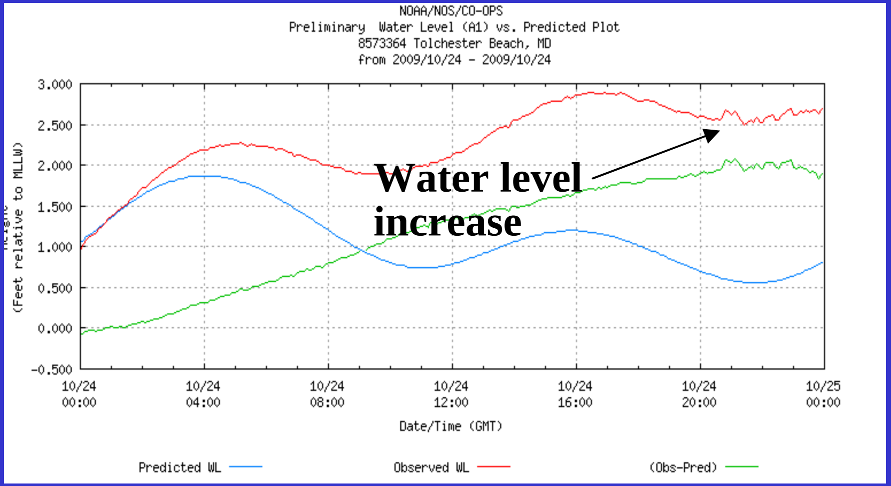

Tolchester Beach, Maryland

Future Research Direction

- Refinement and validation of GOES sounder and imager microburst products:
  - Focus over eastern U.S. using NOS observation data
- Investigate and develop nowcasting technique employing GOES imager product and radar reflectivity imagery.
- ArXiv.org:
  - http://arxiv.org/find/physics/1/au:+Pryor_K/0/1/0/all/0/1

Conclusions

- GOES sounder MWPI and GOES-W imager products have demonstrated capability in the assessment of wind gust potential over the Great Plains and Atlantic Coast regions.
- Case studies and statistical analysis for convective storm events have demonstrated effectiveness of the microburst products:
  - Significant correlation between risk values and microburst wind gust magnitude.
- The GOES sounder and imager products are especially useful in the inference of the presence of intermediate or “hybrid” microburst environments, especially over the Great Plains region.

References

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Questions?

Thank You!