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GOES WMSI – Progress and Developments

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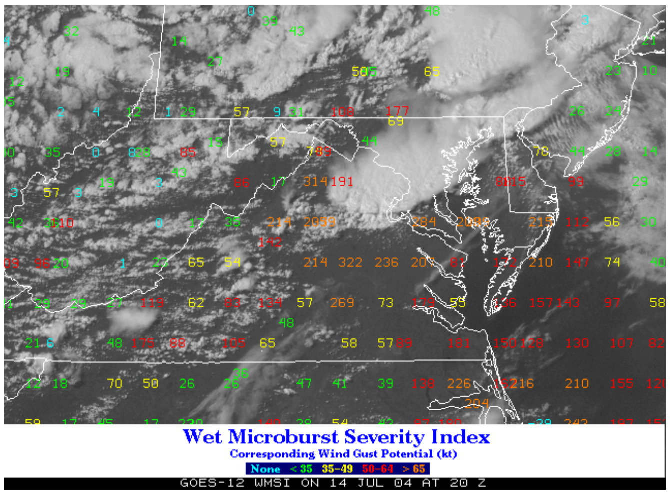
1. INTRODUCTION

A **multi-parameter index** has been developed to assess the **magnitude of convective** downbursts associated with heavy precipitation-producing, deep convective storm systems that occur over the central and eastern continental United States. The **Wet Microburst Severity Index (WMSI)** is composed of relevant parameters that represent the simultaneous physical processes of **convective updraft development** and **downburst generation**, incorporating **convective available potential energy (CAPE)** and the vertical **equivalent potential temperature (θ_e) difference** between the surface and the mid-troposphere (Pryor and Ellrod 2004). The WMSI algorithm is given as the following expression:

$$\text{WMSI} = (\text{CAPE})(\Delta\theta_e)/1000 \qquad (1)$$

$\Delta\theta_e = \theta_{emax} - \theta_{emin}$, where θ_{emax} refers to the maximum value of θ_e at the surface and θ_{emin} refers to the minimum value of θ_e in the midlevels of the troposphere (Atkins and Wakimoto 1991) . The Geostationary Operational Environmental Satellite (GOES) WMSI product, as displayed in the figure below, ingests atmospheric sounding data (i.e., temperature and dew point) provided by satellite retrievals. The **WMSI algorithm** is designed for use during the **warm season**, specifically from **1 June to 30 September**. Pryor and Ellrod (2004) found that there exists a **statistically significant correlation** between **GOES WMSI** and the magnitude of observed **surface wind gusts** for both daytime (r = 0.66) and nighttime (r = 0.64) events during the warm season.

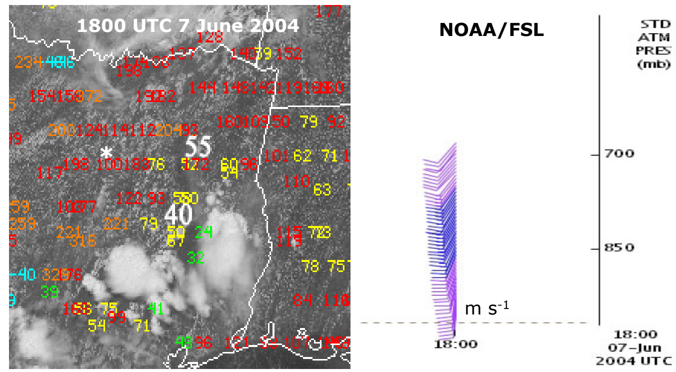


In addition to large CAPE and a significant $\Delta\theta_e$, previous research has identified other favorable conditions for **severe downbursts during the cold-season**. A **primary factor** in downburst magnitude associated with cold-season **forced convection** is the **downward transport of higher momentum**, possessed by winds in the mid-troposphere, into the planetary boundary layer. **Sasaki and Baxter (1986)**, in their analysis of convective storm morphology and dynamics, identified that **downward transfer of entrained momentum from the strong environmental flow aloft** was primarily responsible for the generation of **strong surface winds**. **Duke and Rogash (1992)** confirmed this finding by analyzing a severe, downburst-producing squall line that occurred in April 1991. Downward momentum transport is important when parcels, in an elevated dry (or low θ_e) layer, **conserve horizontal wind velocities** as they become negatively buoyant and descend into the boundary layer. A significant additional finding was that **wind directions** associated with the **surface convective wind gusts** would suggest **a contribution from downward momentum transfer**. Thus, the convective downburst process results in a **positive vertical momentum flux in the boundary (sub-cloud) layer**. Based on the review of previous literature, and an analysis of real-time surface observations, GOES WMSI product imagery and GOES sounding data for 14 cold-season downburst events, it has been found that **downward transport of higher momentum**, possessed by winds in the mid-troposphere, **into the boundary layer**, is a major factor in downburst magnitude. This finding is exemplified by two case studies that contrast warm and cold-season downburst events.

2. CASE STUDIES

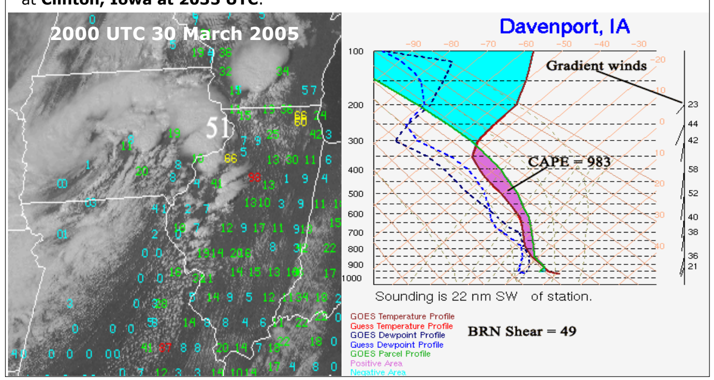
Warm Season Event: 7 June 2004 East Texas Downbursts

A **multi-cellular cluster** of deep convective storms developed over **east-central Texas**, near College Station, during the afternoon of **7 June 2004**. The air mass in which the convective activity was developing was statically unstable, due to intense solar heating of the surface, as displayed by the **1800 UTC GOES WMSI** image. High WMSI values, as well as the presence of widespread towering cumulus convection, were an indicator of the **strong instability** in the region into which the convective cluster was propagating. Also apparent was the presence of a **mid-tropospheric layer of dry (low θ_e) air** that could be entrained into the downdraft of a mature convective storm and result in subsequent **downdraft acceleration** and downburst development. The first observed downburst wind gust of **40 kt (21 m s-1)** occurred at **Palestine** at **1925 UTC**, where a well-defined bow echo was indicated in radar reflectivity imagery. The bow echo continued to track to the northeast during the next hour into a progressively more unstable air mass with **increasing WMSI values**. At **2011**, a stronger downburst wind gust of **55 kt (28 m s-1)** was observed at **Tyler**, where a considerably higher **WMSI value of 172** was indicated.



Cold Season Event: 30 March 2005 Severe Squall Line

During the afternoon of **30 March 2005**, a **squall line** developed over northern Missouri and southern Iowa ahead of negatively tilted upper-level short wave trough. The squall line intensified as it tracked east and northeastward into a **moderately unstable air mass**, producing **several strong downbursts** and wind damage over eastern Iowa, northern Illinois and southern Wisconsin. Associated with this **dynamically forced system** was a **pre-convective environment** that was characterized by **strong wind shear** in the low and middle levels of the troposphere, as inferred from the **Davenport, Iowa GOES sounding** profile. **2000 UTC WMSI** (figure below) indicated **significant potential instability** and positive buoyancy to result in **strong convective updrafts** over northern and western Illinois, as indicated by **WMSI value of 66** near Moline. Between **1900** and **2100 UTC**, significant **downburst winds** were observed at several reporting stations in the vicinity of the Iowa/Illinois border between Burlington and Dubuque. The **strongest downburst wind gust of 51 kt (26 m s-1)** associated with the squall line was recorded at **Clinton, Iowa at 2035 UTC**.



3. VALIDATION

Data from the **GOES WMSI** was collected during the **2003** convective season from **29 July to 11 September** and during the **2004** convective season from **2 June to 24 September** for a total of **135 downburst events** (89 daytime, 36 nighttime) and validated against conventional surface data. Data was also collected for the period from **24 November 2004 to 6 April 2005** to assess the performance of the WMSI product during the **cold season**. Validation was conducted in the manner described by **Pryor and Ellrod (2004)**. Validation, as presented in the table below, determined that there exists a **statistically significant correlation**, and thus a **strong positive linear relationship**, between **GOES WMSI** and observed **surface wind gusts** for both daytime and nighttime events during the **warm season**. Also shown in the table, a **strong relationship** between **surface and mid-tropospheric dry layer winds**, during the **cold season**, was found to be associated with downburst events. Based on hypothesis testing, this relationship was determined to be statistically significant. However, the correlation between WMSI values and surface wind gust magnitude was much weaker and determined to be statistically insignificant. Based on previous research and the case studies presented, the **strong correlation** between mid-tropospheric and surface winds suggested that **downward transport of momentum** from the midlevels of a convective storm environment to the surface played a **major role** in the **downburst magnitude** during this observation period.

The **absolute value** of the **WMSI** is **arbitrary during dynamically forced**, cold season events. The significance of the WMSI is in its relation to the likelihood that **instability is sufficient to result in updrafts** that will **lift** the **precipitation core** to the **mid-levels** of the convective storm, whereby **lateral entrainment** will occur and result in downdraft acceleration.

Observed surface wind speed vs. WMSI (2003/04 warm seasons, 2004/05 cold season) and dry-layer wind speed (2004/05 cold season).

2003/04	**Daytime (N=89)**	**Nighttime (N=36)**
Correlation	.66	.64
2004/05 (N=14)	**Wind Speed**	**WMSI**
Correlation	.82	-.32

4. REFERENCES

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