WMSI - A New Index For Forecasting Wet Microburst Severity

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1. INTRODUCTION

Geostationary Operational Environmental Satellite (GOES) sounder-derived products have demonstrated utility in assessment of the potential for convective downbursts. 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)**, summarizes 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 (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 **$\Delta\theta e = \theta emax - \theta emin$, where ($\theta emax$)** refers to the maximum value of θe at the surface and ($\theta emin$) refers to the minimum value of θe in the mid-levels of the troposphere (Atkins and Wakimoto 1991). The WMSI is 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 GOES TeD product, the threshold for severe wet microburst occurrence utilized by the WMSI is subject to local empirical tuning and should be adjusted regionally based on climatological "representativeness".

2. THE GOES WMSI: BACKGROUND AND ALGORITHM

The **WMSI algorithm** is given as the following expression:

$$WMSI = (CAPE)(TeD)/1000 \qquad (1)$$

where the quantity **CAPE** represents **positive buoyancy** or convective available potential energy and the quantity **TeD** represents the **theta-e deficit**. Previous research has 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). The present suite of GOES microburst products does not explicitly use CAPE in the calculation of microburst risk values. 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.

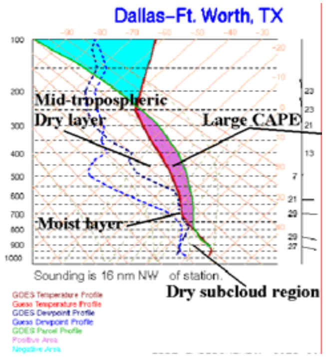
The WMSI accounts for both **positive and negative buoyancy** in a convective storm as governed by the inviscid vertical momentum equation (Doswell 2001).

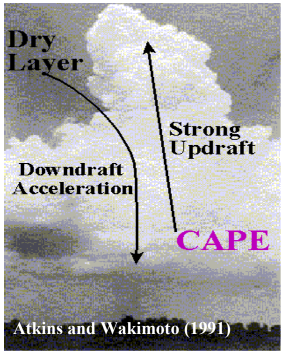
Role of CAPE in the WMSI algorithm:

- Since updraft strength is proportional to CAPE (Weisman and Klemp 1986), **large CAPE** (positive buoyancy) results in **strong updrafts** that could lift the precipitation core within a convective storm to minimum theta-e level.
- The **strong updrafts** resulting from large CAPE increase the size of precipitation particles that grow by the process of accretion, **enhancing the effect of precipitation loading** (Doswell 2001; Wakimoto 2001).

Role of TeD in the WMSI algorithm:

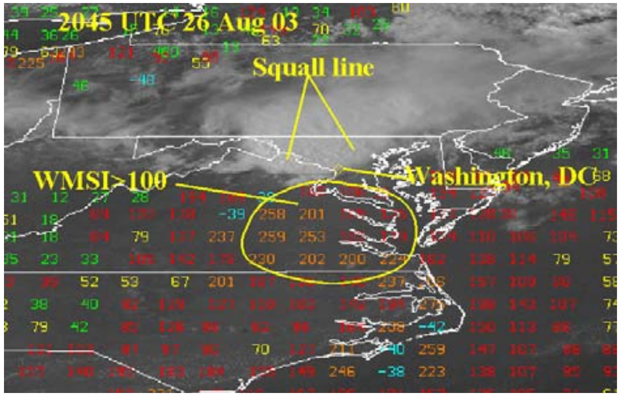
- Indicates the presence of a **dry (low theta-e) layer** in the **middle troposphere** that is favorable for the production of **large negative buoyancy** due to evaporative cooling.
- An effective indicator of the presence of **potential instability** in a region of interest.





3. THE GOES WMSI PRODUCT

The WMSI will be implemented, during 2004, 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 below, an example of the GOES sounder-derived WMSI values plotted over a GOES visible satellite image. **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.

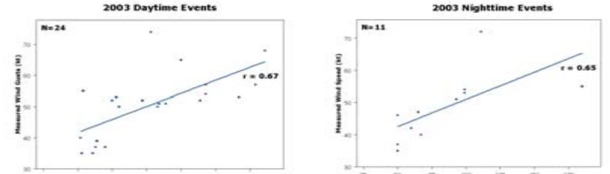


GOES Microburst Products website: http://orbit35i.nesdis.noaa.gov/arad/fpdt/mb.html

4. VALIDATION: 2003 CONVECTIVE SEASON

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. Correlation was computed for the 2003 convective season, for both daytime (between 1000 and 2000 LST) and nighttime (between 2000 and 1000 LST) events. Hypothesis tests were then conducted for daytime and nighttime events 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 while the "research hypothesis" stated that some degree of correlation exists between the two variables.

Comparison of GOES WMSI to Measured Wind Gusts



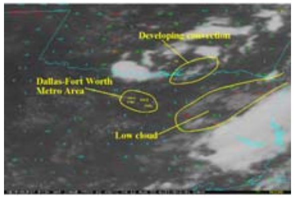
Validation determined that there exists a **statistically significant correlation between GOES WMSI and observed surface wind gusts for both daytime and nighttime events**. Hypothesis testing revealed, for both daytime and nighttime events in the 2003 convective season, that correlation "t" values were 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.

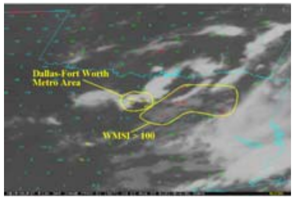
5. CASE STUDY: DALLAS-FORT WORTH MICROBURSTS

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 the table below.

Time(UTC)	Location	Measured Wind (kt)	WMSI	Predicted Wind (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 by the 2245 UTC GOES WMSI values (left) 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 potentially 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 0100 UTC 13 August (right), 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.





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 the process of hypothesis testing, it was discovered that the **linear relationship between GOES WMSI and surface wind gusts was statistically significant in this case**.

6. REFERENCES

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