WMSI – Progress and Developments

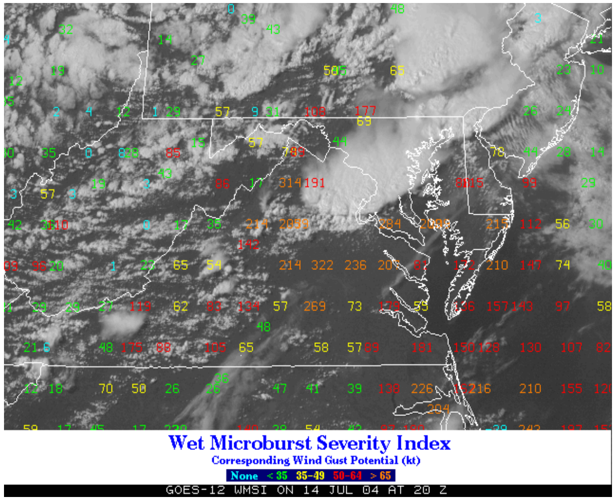
Kenneth L. Pryor and Gary P. Ellrod
Center for Satellite Applications and Research (NOAA/NESDIS), Camp Springs, MD

1. REVIEW OF THE GOES WMSI PRODUCT

The Geostationary Operational Environmental Satellite (GOES) **Wet Microburst Severity Index (WMSI)** is a summary parameter that approximates the physical processes of convective storm development and downburst generation by incorporating positive buoyant energy or **convective available potential energy (CAPE)** to represent the process of **updraft formation**, and **Theta-e Deficit (TeD)** to represent **downburst development** (Pryor and Ellrod 2004). 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 parameterized by the **Theta-e Deficit (TeD)**, represented by the algorithm **$\Delta\theta e = \theta e\text{max} - \theta e\text{min}$, where ($\theta e$max)** refers to the maximum value of θe at the surface and (θemin) refers to the minimum value of θe in the mid-levels of the troposphere (Atkins and Wakimoto 1991). Large CAPE (positive buoyancy) results in strong updrafts that lift the precipitation core within a convective storm to minimum theta-e level (Weisman and Klemp 1986). Entrainment of dry (low theta-e) air in the midlevels of a convective storm will enhance downdraft strength by the process of evaporative cooling. 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**. The **WMSI algorithm** is given by the following multiplicative parameter:

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

The WMSI was implemented during 2004 in the suite of GOES microburst products. In a similar manner to the other GOES microburst products, **index values at each sounding retrieval location are plotted on GOES imagery**. The WMSI product has the appearance as displayed below, an example of 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. A more detailed explanation of the GOES WMSI product is featured in the online paper: **www.orbit.nesdis.noaa.gov/smcd/opdb/kpryor/mburst/wmsipaper/wmsi.html**



An enhancement to the display of the WMSI product is featured in the image above. Note the new WMSI product label with product title and a legend to convert WMSI values to predicted convective wind gust magnitude. The relationship between WMSI values and the magnitude of convective wind gusts is shown in the table below (Pryor and Ellrod 2004).

WMSI	Predicted Wind Gusts (kt)
< 10	Convection/Microbursts Unlikely
10 - 49	< 35
50 - 79	35 - 49
80 – 200	50 – 64
>200	>65

The WMSI product is available on the GOES Microburst Products website:
http://www.orbit.nesdis.noaa.gov/smcd/opdb/aviation/mb.html

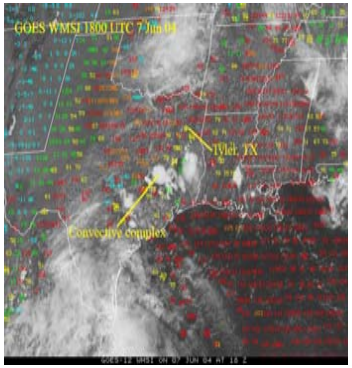
2. CASE STUDIES

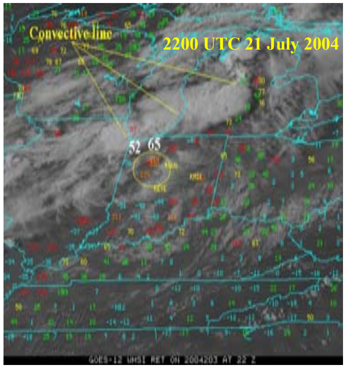
7 June 2004 East Texas Downbursts

During the afternoon of 7 June 2004, a cluster of convective storms developed over eastern Texas in the vicinity of College Station and then tracked northeastward. The GOES Sounder-derived WMSI product indicated high WMSI values over east-central Texas. A peak convective wind gust of 55 knots was observed at Tyler at 2011 UTC. Other measured wind reports in the area are indicated in the table below. Predicted wind gust speeds are based on linear regression as presented in Pryor and Ellrod (2004).

Time(UTC)	Location	Measured Wind (kt)	WMSI	Predicted Wind (kt)
19:25	Palestine	40	55	35 - 49
20:11	Tyler	55	172	50 – 64

The air mass in which the convective activity was developing was potentially unstable as displayed by 1800 UTC GOES WMSI image below. High WMSI values, as well as the presence of widespread cumulus convection, was 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 theta-e) air that could be entrained into the downdraft of a mature convective storm and result in subsequent downdraft acceleration and downburst development.





21-22 July 2004 Severe Squall Line

During the afternoon of 21 July 2004, a squall line formed over northeastern Illinois, triggered by an outflow boundary from previous convective storm activity. The squall line moved southeastward across Indiana and Ohio during the evening hours. The convective system was characterized by a solid line of intense cells with several embedded bowing line segments, similar to the type I radar signature as described by Przybylinski (1995). The squall line produced several severe wind gusts over northern Indiana during the late afternoon before weakening as it moved into Ohio during the evening hours. Measured wind reports across the region are indicated in the Table below. Predicted wind gust speeds are based on linear regression as presented in Pryor and Ellrod (2004).

Time(UTC)	Location	Measured Wind (kt)	WMSI	Predicted Wind (kt)
2214	Gary, IN	52	107	50-64
2250	Michigan City, IN	65	214	> or = 65
0221	Muncie, IN	39	63	35-49
0438	Marion, OH	39	56	35-49
0458	Columbus, OH	37	65	35-49

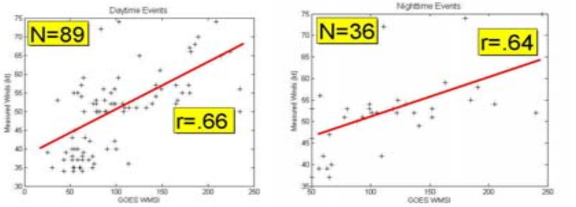
At 2200 UTC 21 July 2004, the GOES WMSI image above revealed values in excess of 200 (circled in yellow) over northwestern Indiana, indicating the presence of a significantly unstable air mass ahead of the squall line that was extending from central Michigan to northeastern Illinois and was propagating southeastward. Large WMSI implied potential for the development of strong updrafts and heavy precipitation and the subsequent development of intense convective downdrafts and downbursts. Overshooting tops, identifying intense convection and strong updrafts, were apparent in the convective line.

These two cases demonstrate the utility of the WMSI product in forecasting downburst potential with a variety of convective storm types. The close correspondence between WMSI values and observed convective wind gusts demonstrated that the WMSI accurately portrayed downburst potential and severity with both events.

3. VALIDATION: 2003-2004 CONVECTIVE SEASONS

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 microburst events (89 daytime, 36 nighttime)** 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 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 and 2004 convective seasons, 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.

4. FUTURE PLANS

- Product validation through the 2005 convective season.
- Case studies investigating the utility of WMSI during cold season events.
- Virtual Institute for Satellite Integration Training (VISIT) training sessions
- Operational implementation into the National Weather Service AWIPS system.

5. REFERENCES

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Corresponding author address: Mr. Kenneth Pryor, Satellite Meteorology and Climatology Division, Operational Products Development Branch, NOAA/NESDIS/STAR, Room 711, 5200 Auth Rd., Camp Springs, MD 20746-4304

E-mail: Ken.Pryor@noaa.gov