P8.3 Electrical Behavior of Downburst-Producing Convective Storms over the High Plains

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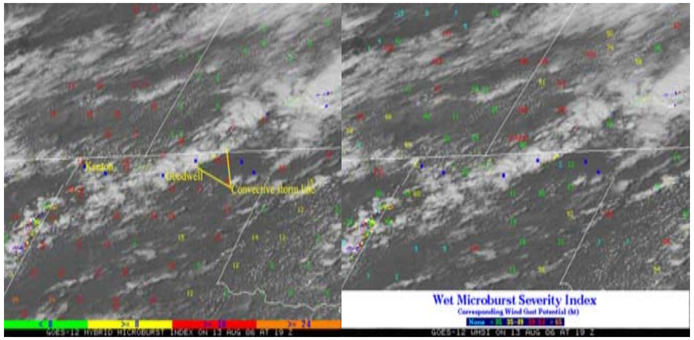
1. INTRODUCTION

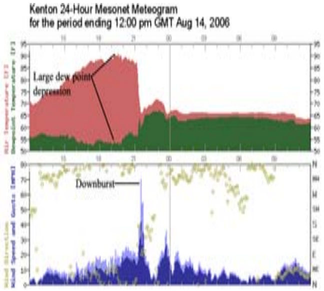
A great body of research literature pertaining to microburst generation (Fujita 1985; Wakimoto 1985) in convective storms has focused on thermodynamic factors of the pre-convective environment as well as storm morphology as observed by radar imagery. Derived products based on **Geostationary Operational Environmental Satellite (GOES) sounder data** have been found to be especially useful in the study of **thermodynamic environments**. However, addressed much less frequently is the relationship between **convective storm electrification**, lightning phenomenology and **downburst generation**. Previous research in lightning production by convective storms has identified that electrification, phenomenology (i.e. flash rate, density), and polarity are dependent upon the thermodynamic structure of the ambient atmosphere, especially vertical moisture stratification. Thus, **relevant parameters** to describe the thermodynamic setting would include **convective available potential energy (CAPE),** due to its influence on updraft strength, and **moisture characteristics of the boundary layer**, due to its relationship to precipitation physical processes. The basic concept of **charge generation** and separation in convective clouds maintains that the presence of **strong updrafts** and the resulting development of **precipitation** are instrumental in the formation of an **electric field** of sufficient intensity for **lightning** discharge. The **interaction between ice crystals and larger precipitation particles** will result in the acquisition of **opposite electric charge** between the lighter ice particles and the heavier precipitation particles, establishing a dipole and an **electric field intensity** necessary for electrical breakdown and subsequent **lightning** initiation (Saunders 1993). The descending precipitation within the storm is also vital for the development of convective downdrafts, accelerated as drier air from outside the convective storm cell is entrained. Thus, the physical process responsible for the **initiation of lighting** within a convective storm is also believed to be instrumental in the **initiation of convective downdrafts** that eventually produce **downbursts** at the surface.

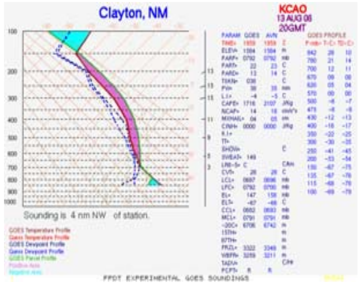


Pryor and Ellrod (2005) developed a **Geostationary Operational Environmental Satellite (GOES) sounder-derived wet microburst severity index (WMSI)** product to assess the potential magnitude of convective downbursts, incorporating **convective available potential energy (CAPE)** as well as the vertical **theta-e difference (TeD)** (Atkins and Wakimoto 1991) between the surface and mid-troposphere. In addition, Pryor (2006) developed a **GOES Hybrid Microburst Index (HMI)** product intended to supplement the use of the GOES WMSI product over the United States **Great Plains region**. The HMI product infers the presence of a **convective boundary layer (CBL)** (Stull 1988) by incorporating the sub-cloud temperature **lapse rate** as well as the **dew point depression difference** between the typical level of a convective cloud base and the sub-cloud layer. Lightning data imagery, generated by a program that ingests the data from the **National Lightning Detection Network (NLDN)** to be plotted and mapped by Man computer Interactive Data Access System (McIDAS), has been collected for several **severe convective storm events** that occurred in **Oklahoma** during the **summer of 2006**. It has been observed that **suppressed cloud-to-ground (CG) lightning** activity was associated with **downburst occurrence** in most cases. Common between the environments of these convective storms was the presence of a relatively **deep and dry CBL**, as indicated by **GOES HMI** imagery and surface observations. The reader is referred to MacGorman and Rust (1998) and Rakov and Uman (2003) for a discussion of **convective storm electrification** and **lightning phenomenology**. It has been suggested that **decreased CG flash rates** in convective storms may be a consequence of an **elevated charge dipole** resulting from especially **vigorous updrafts**. Periods of enhanced updraft intensity within a convective storm could be associated with an increased likelihood for downburst generation, and, hence, imply a relationship between **CG flash rates** and **downburst** occurrence.

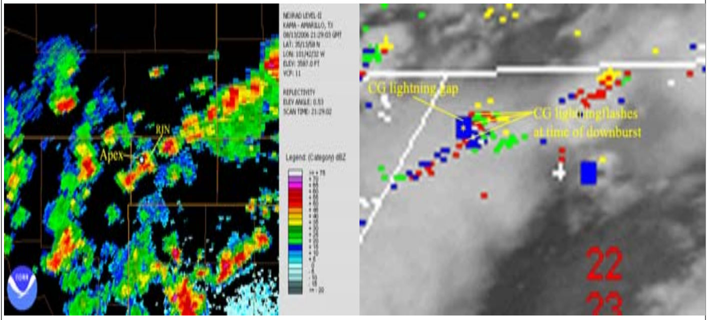
2. CASE STUDY: 13 August 2006 Downbursts

During the **afternoon of 13 August 2006**, clusters of **convective storms** developed along a diffuse frontal boundary that extended from Kansas southwestward through the **Oklahoma Panhandle**. Two particularly **intense downbursts** occurred in association with **multi-cellular storms** that evolved over **Cimarron and Texas Counties** in the western panhandle. The early afternoon (1900 UTC) **GOES HMI** product indicated the presence of a **very unstable convective boundary layer** over the **Oklahoma Panhandle**. The meteogram from **Kenton** mesonet station displayed the evolution of the **convective mixed layer** through the afternoon. Inspection of a **GOES sounding** profile from Clayton, New Mexico, near Kenton, revealed an **"inverted-v"** profile with significant **CAPE** and an **elevated mixed layer depth** typical of the warm-season environment over the High Plains.





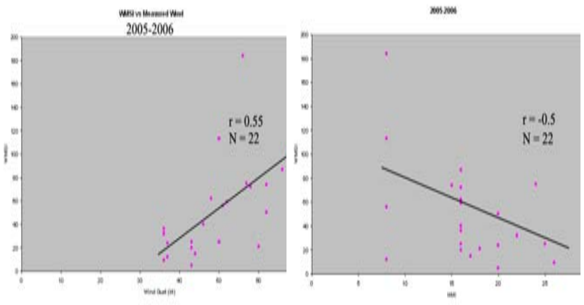
A **multi-cellular convective storm** propagated northeastward over western Cimarron County between **2100 and 2200 UTC**. A **severe downburst** observed over **Kenton** occurred as an embedded cell evolved into a **bow echo**. Radar reflectivity imagery displayed a well-defined **bow echo** over Kenton at the time of **downburst occurrence**. Also noteworthy is the **close correspondence** between the location of **maximum echo tops** and the location of the **bow echo apex** associated with the downburst. This observation suggests that the **presence of strong updrafts** was a possible contributor to the **development of an elevated electric charge dipole** within the downburst-producing convective storms.



Cloud-to-ground (CG) lightning strikes that occurred during the **period 2100 and 2200** UTC are shown in association with the convective storms. Apparent in a magnified microburst product image at **2100 UTC** is **suppressed CG lightning activity** in the vicinity of observation of **peak downburst winds** at Kenton. Analysis of **echo tops** as well as **elevation scans** in VCP 11 from Amarillo, Texas NEXRAD revealed that at the time of downburst occurrence at Kenton, **storm echo tops** approached or exceeded **15240 meters (50000 feet),** well above the level of the **-20C isotherm at 6706 meters (22000 feet),** as indicated by the GOES sounding profile at Clayton. In addition, **30 dBZ echo top** heights significantly **exceeded the height of the -20C isotherm**, suggesting that the observed **CG lightning gaps** were most likely the result of an **elevated charge dipole**. It is apparent that **peak downburst winds**, observed at the surface, are believed to be associated with an **elevated electric charge dipole** resulting from the intense **storm updraft**, thus providing a tentative explanation of the relationship between **CG lightning discharge** and **downburst observation** at the surface. Most importantly, the analysis presents a readily identifiable signature: **microscale regions** of **suppressed CG lightning** activity associated with **downburst occurrence**.

3. VALIDATION

Data from the **GOES HMI and WMSI** products was collected over **Oklahoma** from **1 June to 31 August 2006** and validated against **conventional surface data**. Downburst wind gusts, as recorded by **Oklahoma Mesonet** (Brock et al. 1995) observation stations, were measured at a height of 10 meters (33 feet) above ground level. Hypothesis testing revealed a **statistically significant correlation** between **WMSI** values and measured downburst **wind gusts**. Also interesting is the **statistically significant negative correlation** between **WMSI** and **HMI** values. This **inverse proportionality** between WMSI and HMI values for convective wind gusts of comparable magnitude likely reflects a **continuum of favorable environments** for downbursts, ranging from **wet** to an intermediate or **hybrid** regime, characterized by a combination of lower WMSI values and elevated HMI values.



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