1. INTRODUCTION

A great body of research literature pertaining to microburst generation (Fujita 1985; Wakimoto 1983) in convective storms has focused on thermodynamic features of the pre-convective environment as well as storm morphology as observed by radar imaging. Derived parameters on the dynamics of the high-resolution 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 rates, 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 lightning within a convective storm is also believed to be instrumental in the initiation of convective downracks 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. Lighting data imagery, generated by a program that ingests the data from the National Lightning Detection Network (NLDN) to be plotted and mapped by Map 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 occurrences of these convective storms were the presence of a relatively deep and dry CBL, as indicated by GOES HMI imagery and surface observations. The reader is referred to the article by Atkins and Wakimoto (1991) 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.

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 over-echo top occurrence, 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, 3D-BZ 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 occurrence at the surface. Most importantly, the analysis presents a readily identifiable signature: microscale regions of suppressed CG lightning activity associated with 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 multiple-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 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, associated with observed downburst occurrence at Kenton, revealed 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 progression of the 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 storm.

3. VALIDATION

Data from the GOES HMI and WMSI products was collected over Oklahoma from 1 June to 31 August 2006 and validated against observation stations. Downburst winds, 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.

4. REFERENCES


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