Integration of the Total Lightning Jump Algorithm into Current Operational Warning Environment Conceptual Models

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Lightning Jump Background

Several studies have examined the positive relationship between total lighting flash rates and severe and hazardous weather production:

- Goodman et al. 1988, MacGorman et al. 1989, Williams et al. 1999

Recently algorithms have been developed to automatically detect these rapid increases in total lightning known as lightning jumps:

- Schultz et al. 2009, Gatlin and Goodman 2010, Schultz et al. 2011

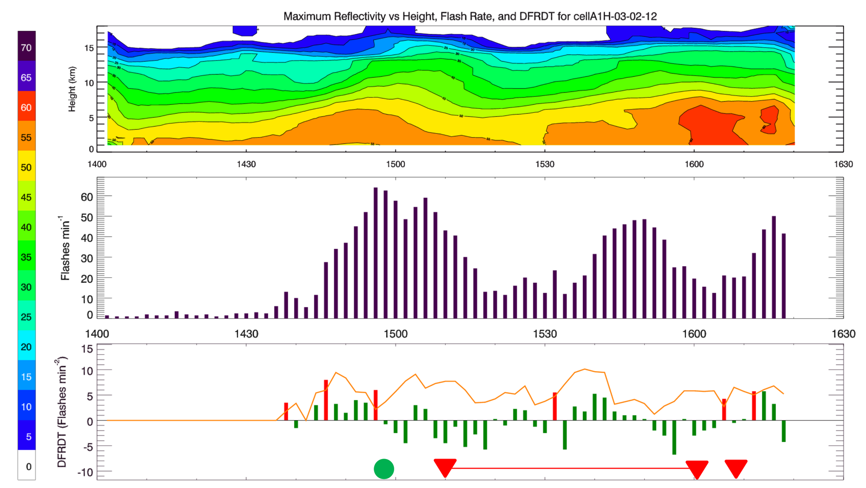
The current lightning jump algorithm is defined as:

$$2*stdev(DFRDT_{t}, DFRDT_{t4}, DFRDT_{t3}, DFRDT_{t2}, DFRDT_{t1})$$

- where $DFRDT_{t1} = (FR_{min3}+FRt_{min4})/2.0 - (FR_{min1}+FR_{min2})/2.0$

-where FR_{minx} = 1 minute flash rate within a storm.

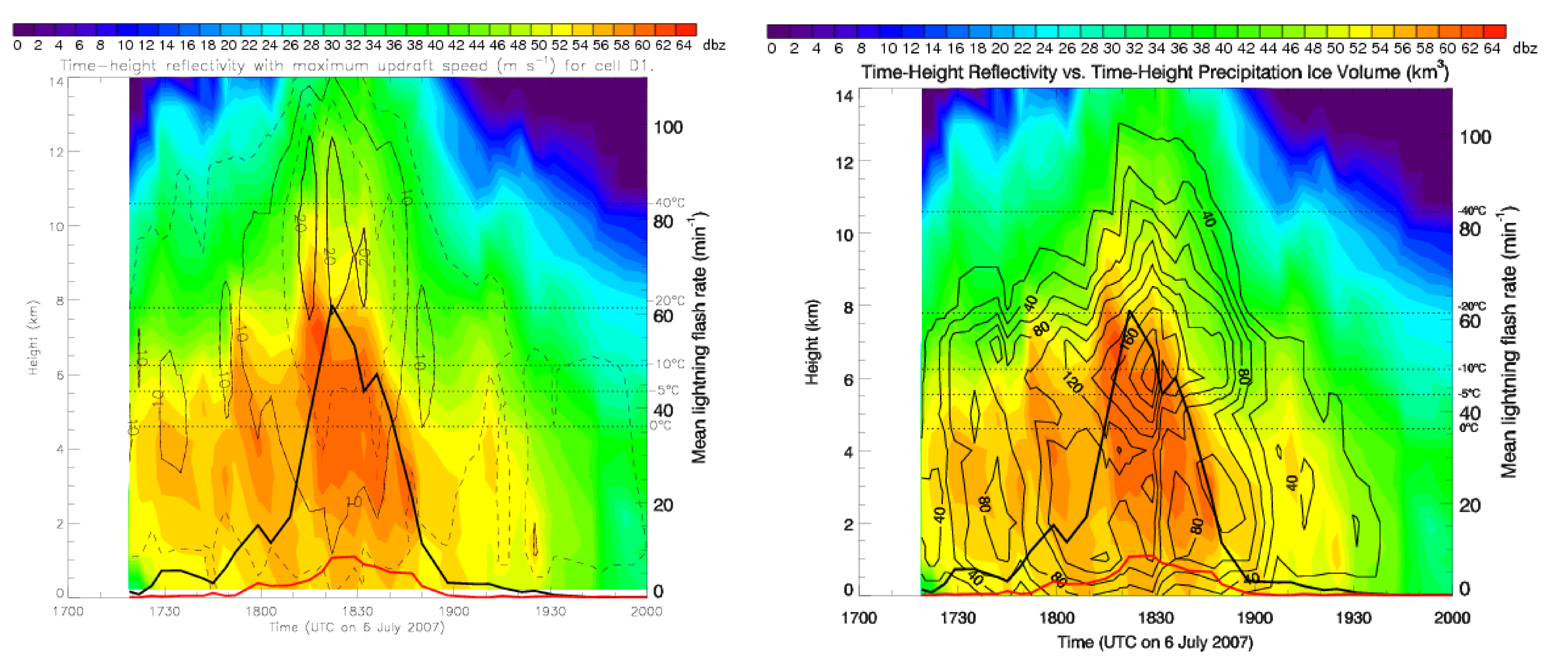
If the current DFRDT value exceeds this threshold a lightning jump has occurred



Left – Time height plots of reflectivity (top), total flash rate (middle) and time rate of change of the total flash rate (bottom) for a tornadic supercell on March 2, 2012. Red bars indicate where lightning jumps occurred, and symbols below correspond to severe weather reports (green ball, hail; red triangles, tornadoes)

Other studies have examined the kinematic and microphysical relationship between updraft characteristics and lightning production.

- e.g., Tessendorf et al. 2005, Weins et al. 2005, Tessendorf et al. 2007, Deierling et al. 2008, Johnson 2009



Adapted from Johnson (2009). Updraft speed vs reflectivity vs total flash rate (left) and graupel volume vs reflectivity vs total flash rate

What has been lacking is the physical connection between lightning jump occurrence and thunderstorm characteristics. Therefore, key points that this analysis will begin to address are:

1)What physically is going on in the cloud when there is a jump in lightning?

- Updraft variations, Ice fluxes

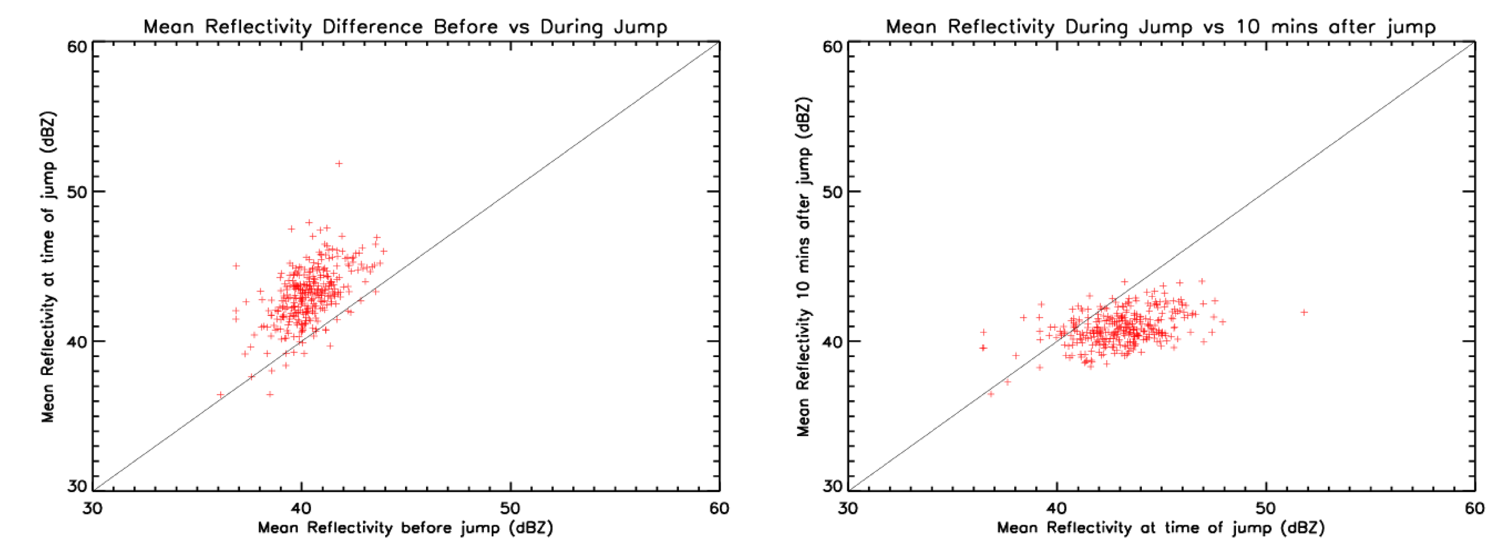
2)How do these processes fit in with severe storm conceptual models?

3)What would this information provide an end user (i.e., the forecaster)?

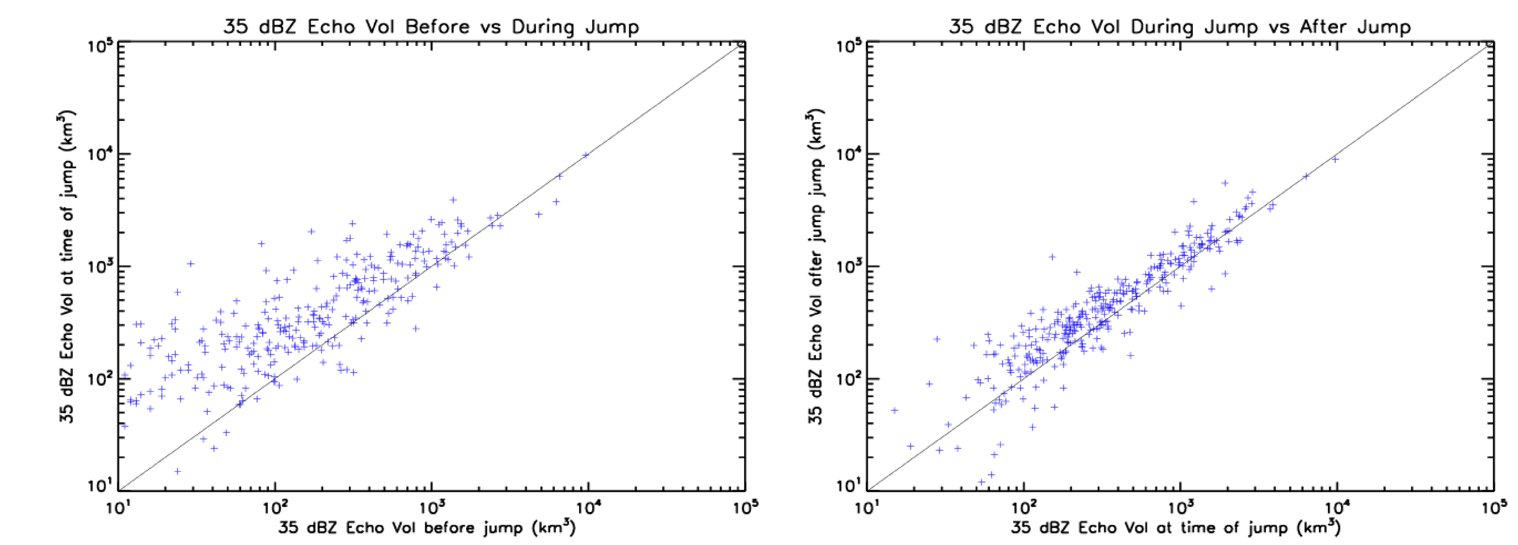
- Relate LJA to radar observations, like changes in reflectivity, MESH, VIL, etc. based multi-Doppler derived physical relationships

4) How do we best transition this algorithm into the warning decision process.

Reflectivity and Precipitation Echo Volume Trends Compared and the Lightning Jump

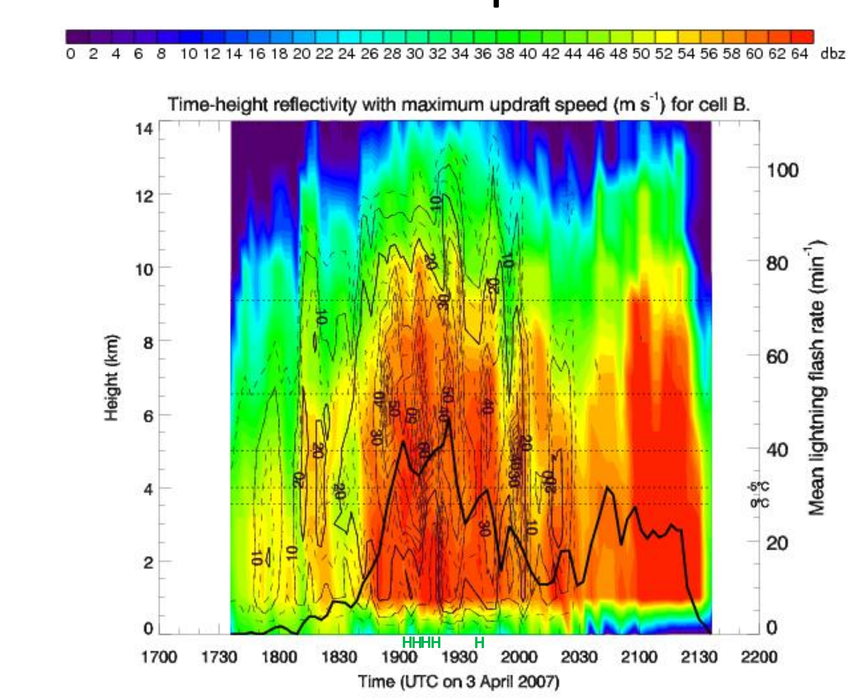


Mean reflectivity profile change comparison for the first lightning jump in 329 storms from Schultz et al. (2011). Results indicate that during the 10 minute period prior to jump occurrence, the mean reflectivity profile increases by an average of 2.72 dB (+/- 1.60 dB) and during the period 10 minutes after the jump the profile change is -2.19 dB (+/- 1.80 dB).

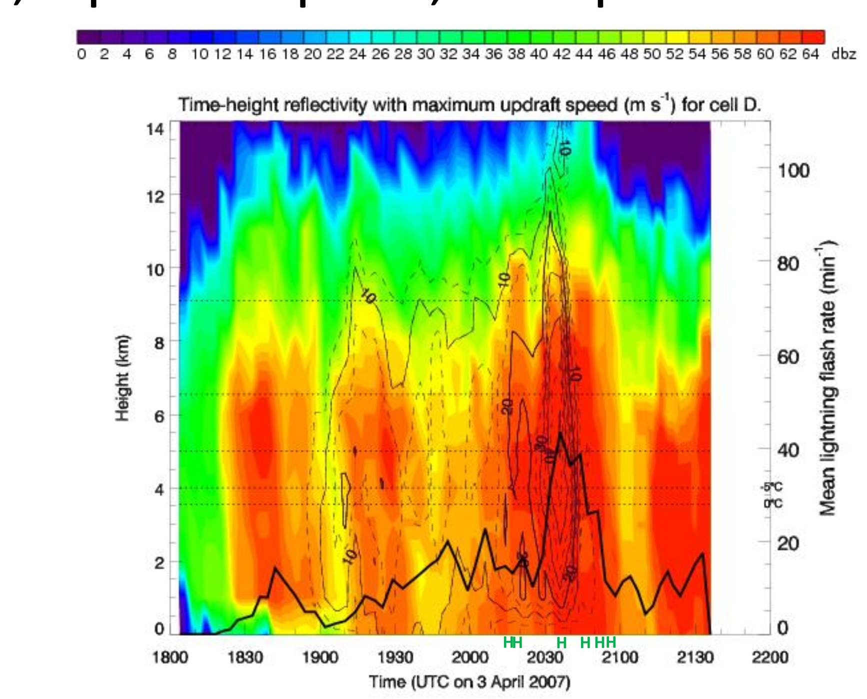


Changes in mixed precipitation echo volume for the first lightning jump in 329 storms from Schultz et al. (2011). Results indicate that during the 10 minute period prior to jump occurrence, the average change in precipitation echo volume increases by an average of 225 km³ (+/- 413 km³) in the 10 minutes after the lightning jump, the echo volume continues to increase slightly at 122 km³(+/-356 km³).

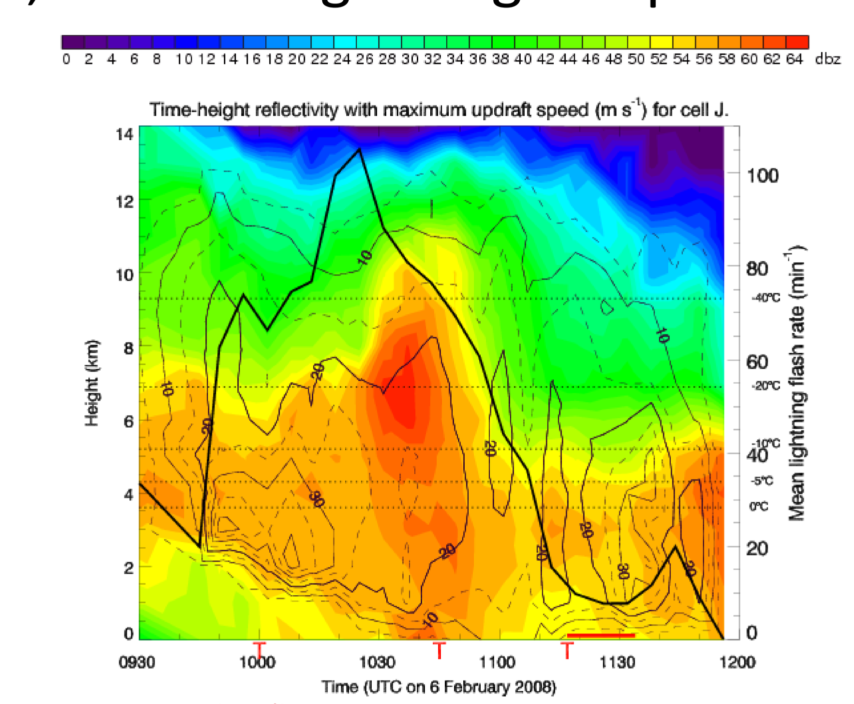
Relationship between Flash Rates, Updraft Speed, Precipitation Ice Volume, and the Lightning Jump



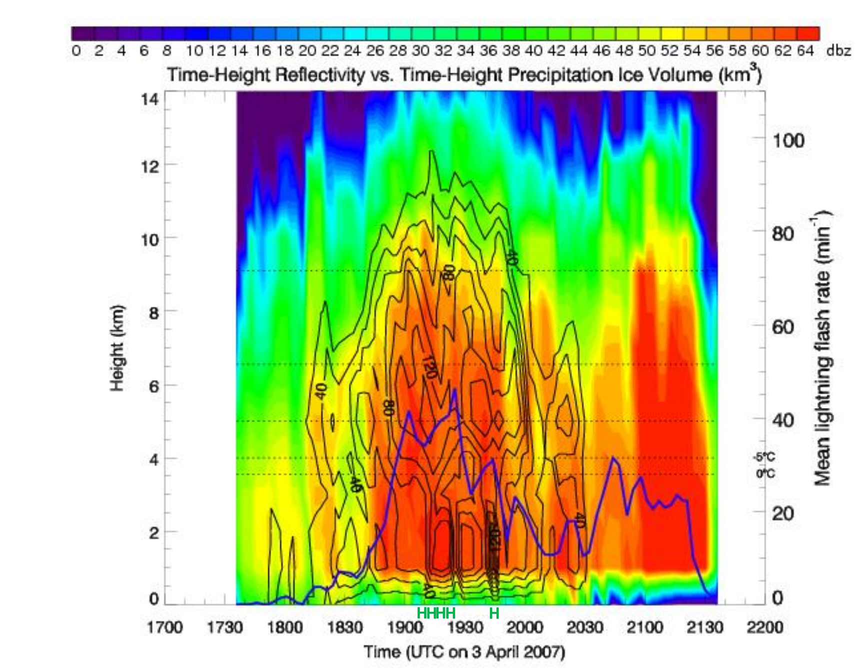
Updraft Speed (m s⁻¹) vs total flash rate vs reflectivity in a severe supercell from April 3, 2007. Lightning jumps occur at 1857, 1927 and 1955 UTC.



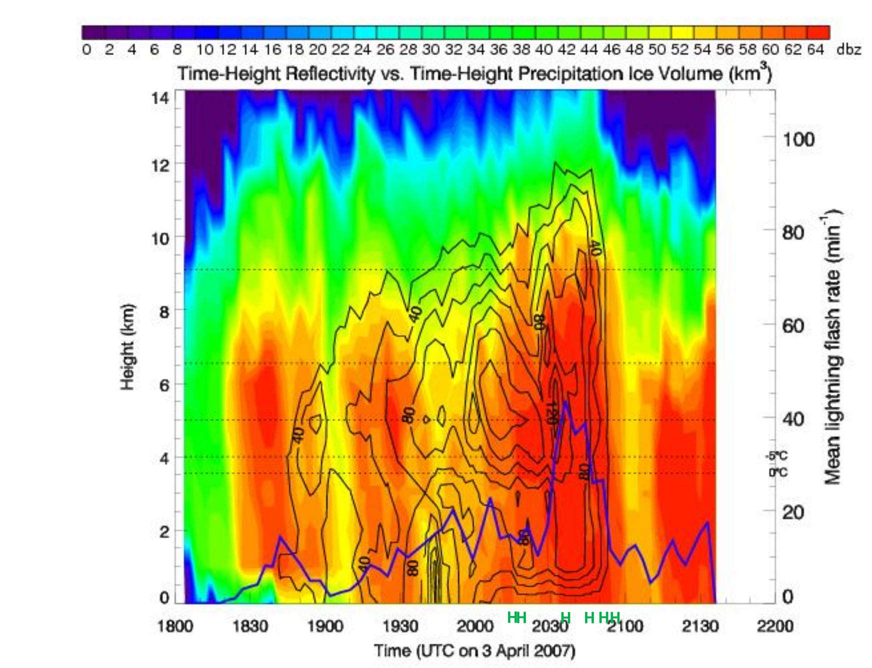
Updraft Speed (m s⁻¹) vs total flash rate vs reflectivity in a severe multicell from April 3, 2007. Lightning jumps occur at 1931, 1953, 2005 and 2033 UTC.



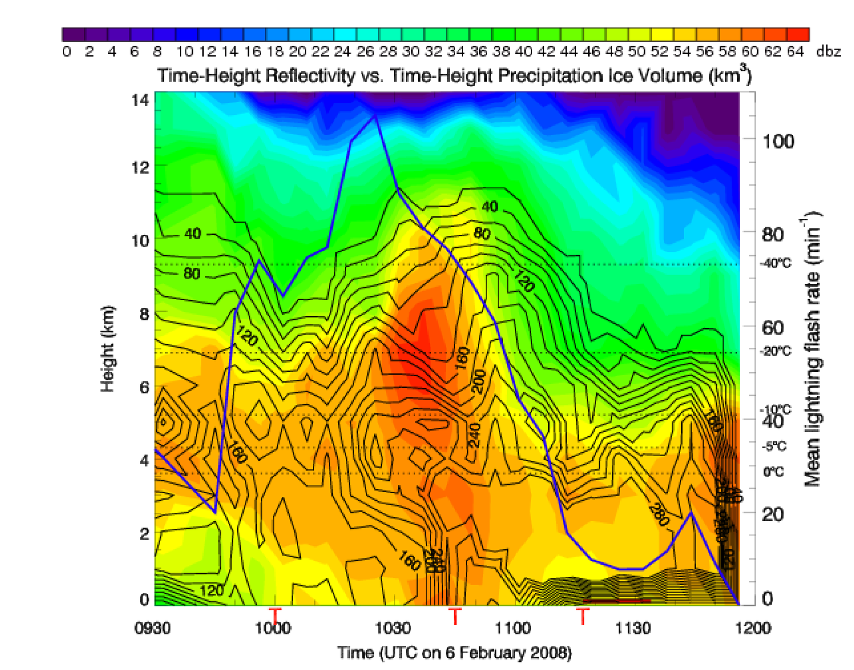
Updraft Speed (m s⁻¹) vs total flash rate vs reflectivity in a tornadic supercell from Feb 6, 2008. The initial lightning jump occurs at 0949 UTC.



Precipitation Ice Volume (km³) vs total flash rate vs reflectivity in a severe supercell from April 3, 2007. Lightning jumps occur at 1857, 1927 and 1955 UTC.



Precipitation Ice Volume (km³) vs total flash rate vs reflectivity in an April 3, 2007 severe multicell. Lightning jumps occur at 1931, 1953, 2005 and 2033 UTC.



Precipitation Ice Volume (km³) vs total flash rate vs reflectivity in a tornadic supercell from Feb 6, 2008. The initial lightning jump occurs at 0949 UTC.

Summary and Future Work

- The known relationship between lightning updraft strength/volume and precipitation ice mass production can be extended to the concept of the lightning jump.
- Examination of the first lightning jump times from 329 storms in Schultz et al. (2011) shows an increase in the mean reflectivity profile and mixed phase echo volume during the 10 minutes prior to the lightning jump.
- Limited dual-Doppler results show that the largest lightning jumps are well correlated in time with increases in updraft strength/volume and precipitation ice mass production; however, the smaller magnitude lightning jumps appear to have more subtle relationships to updraft and ice mass characteristics.
- Future work will extend to a number of cases, including a variety of convective morphologies to further tie the concept of the lightning jump into severe storm conceptual models used in operational meteorology.