Total Lightning as an Indicator of Mesocyclone Behavior

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26th Conference on Weather Analysis and Forecasting/22nd Conference on Numerical Weather Prediction

Introduction

- Apparent relationship between total lightning (in-cloud and cloud-to-ground) and severe weather suggests its operational utility.

- Goal of fusion of total lightning with proven tools, i.e. radar-lightning algorithms

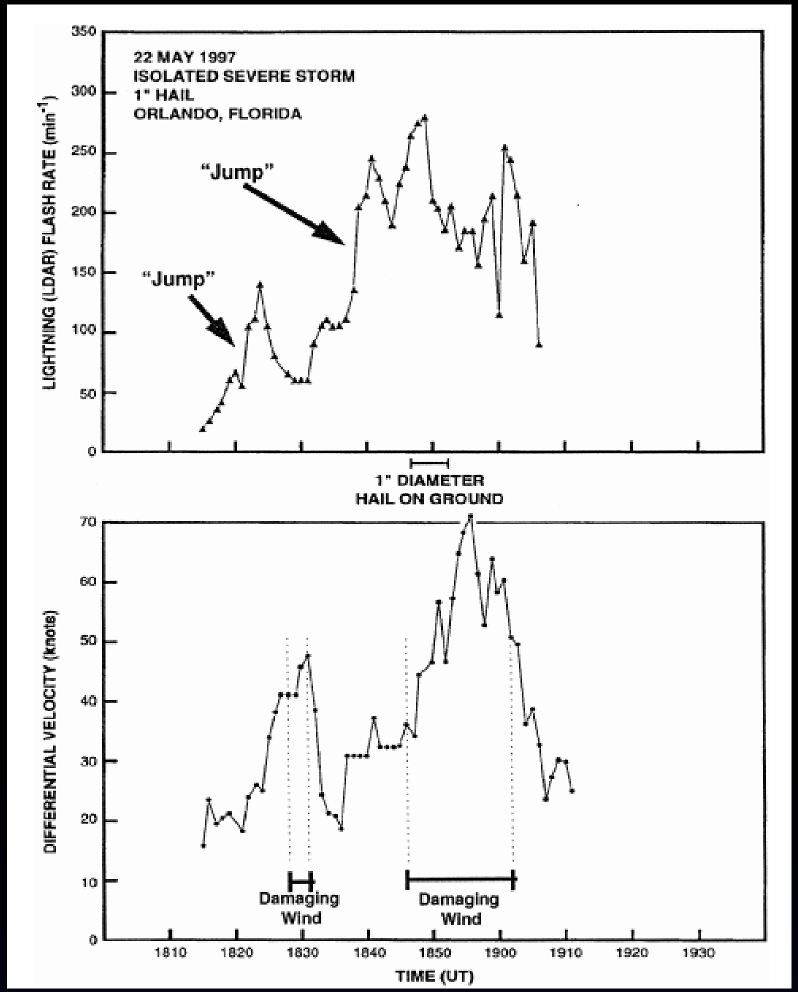
- Preliminary work here investigates circulation from Weather Surveillance Radar - 1988 Doppler (WSR-88D) coupled with total lighting data from Lightning Mapping Arrays

Background

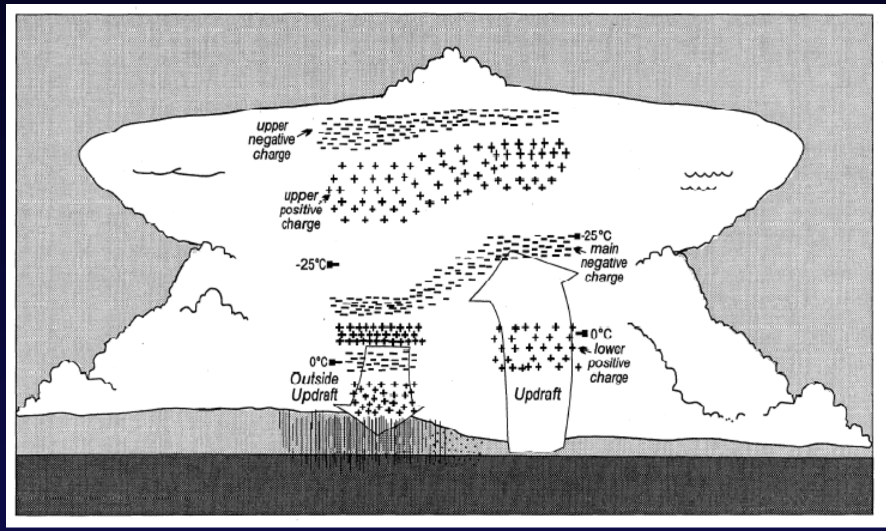
- Ongoing work relates severe events with rapid increases in lightning flash rate, known as lightning jumps (Schultz *et al.* 2009, 2011; Darden *et al.* 2010; White *et al*. 2012; Stano *et al.* 2014)

- Identification of a rotating updraft, or quasi-steady mesocyclone, often primary factor in determining a severe storm

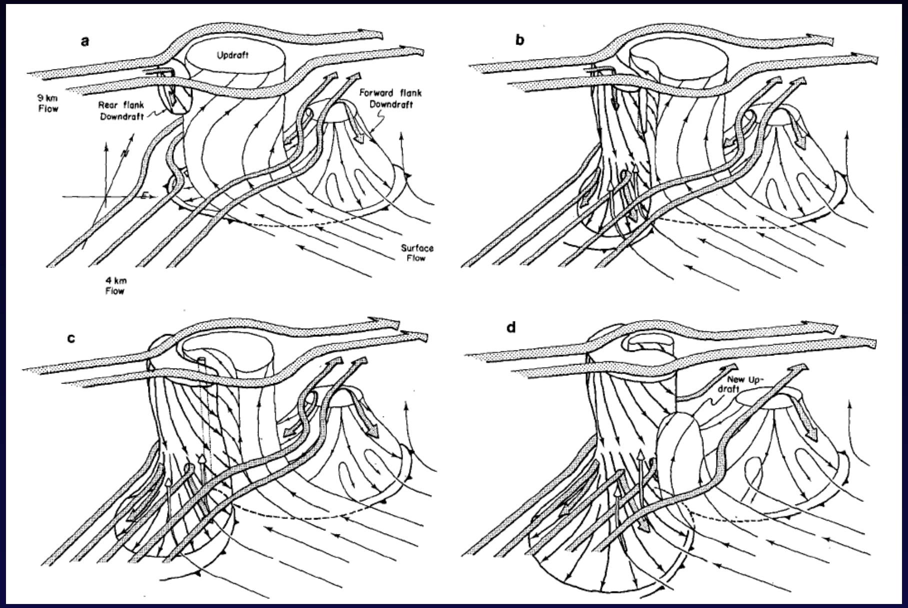
- Conceptual relationship between lightning, mesocyclone, and storm severity based upon the low-to-mid-level updraft of a convective storm, or specifically, a supercell



Williams *et al.* [1999], Fig. 7



Stolzenburg *et al.* [1998] , Fig. 3



Lemon and Doswell [1979], Fig. 9

Motivation

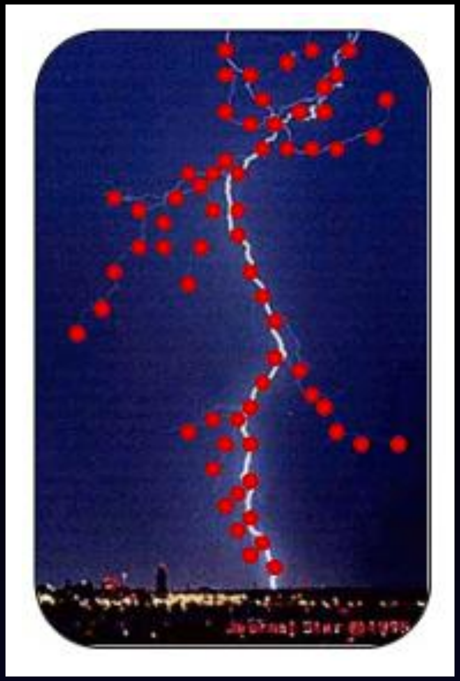
- Remaining challenges with forecasting severe weather (Brotzge and Erickson 2009, Brotzge and Donner 2013):
  - marginal severe convective events
  - first confirmed tornado warning of an event
  - tornadic versus non-tornadic supercells

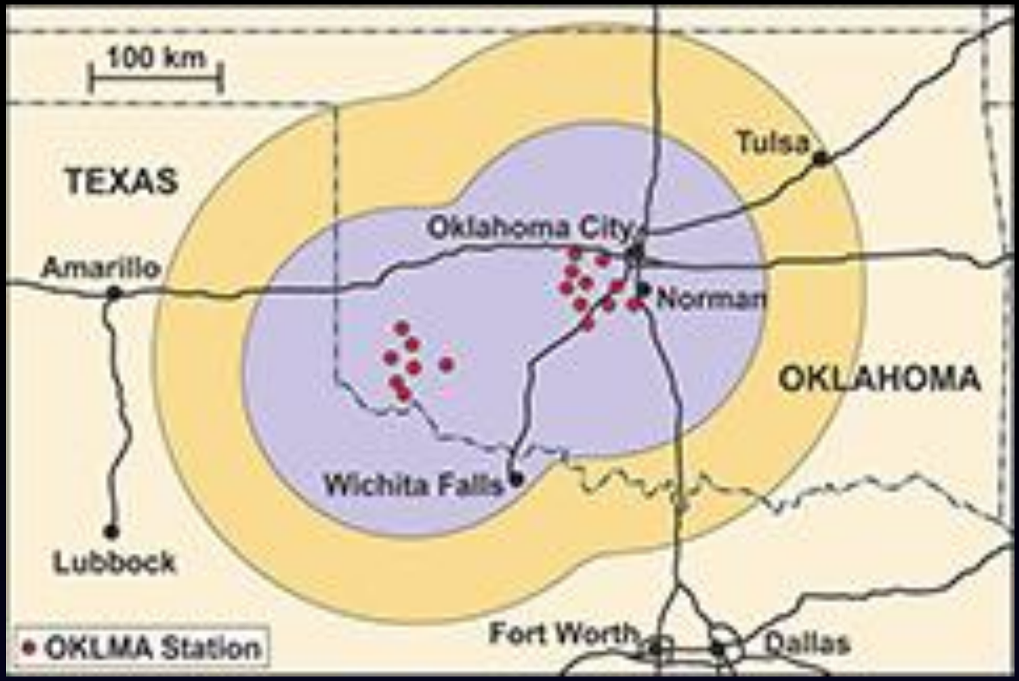
- If lightning can give earlier indication of updraft strength, when coupled with radar can it then:
  - improve situation awareness and increase lead time?
  - provide earlier differentiation between tornadic and non-tornadic supercells, or ability to “tip the scales”?

- Preliminary investigation of temporal relationship between enhancement of storm rotation and intensification of lightning activity, signaled by lightning jumps

Data

•Lightning Mapping Arrays: VHF sensors in a network for 2-D/3-D lightning depiction of total lightning





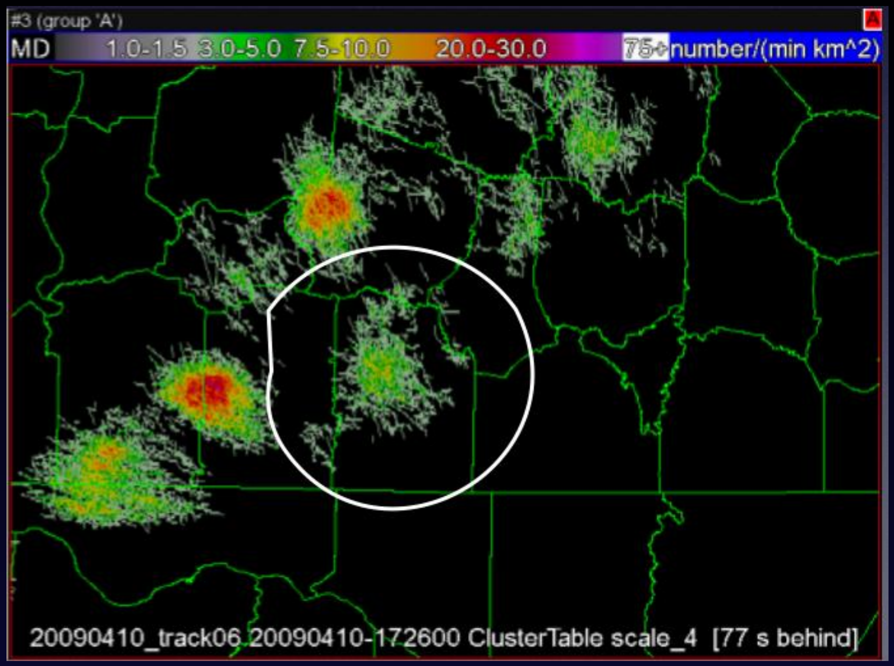
- Flash clustering and Schultz *et al.* two-sigma lightning jump algorithms

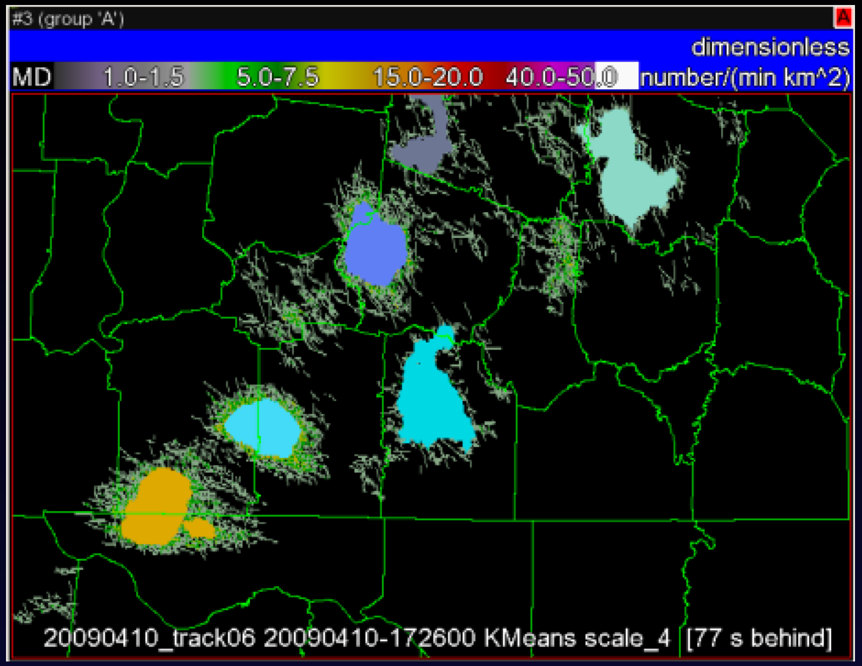
• Storm rotation and mesocyclone analysis:

- WSR-88D Level-III National Severe Storms Laboratory (NSSL) Mesocyclone Detection Algorithm (MDA) strength attributes
- Maximum azimuthal shear derived from WSR-88D data

Methods

- Warning Decision Support System - Integrated Information (WDSS-II) tool used to compute flash extent density to identify and track storms for flash association





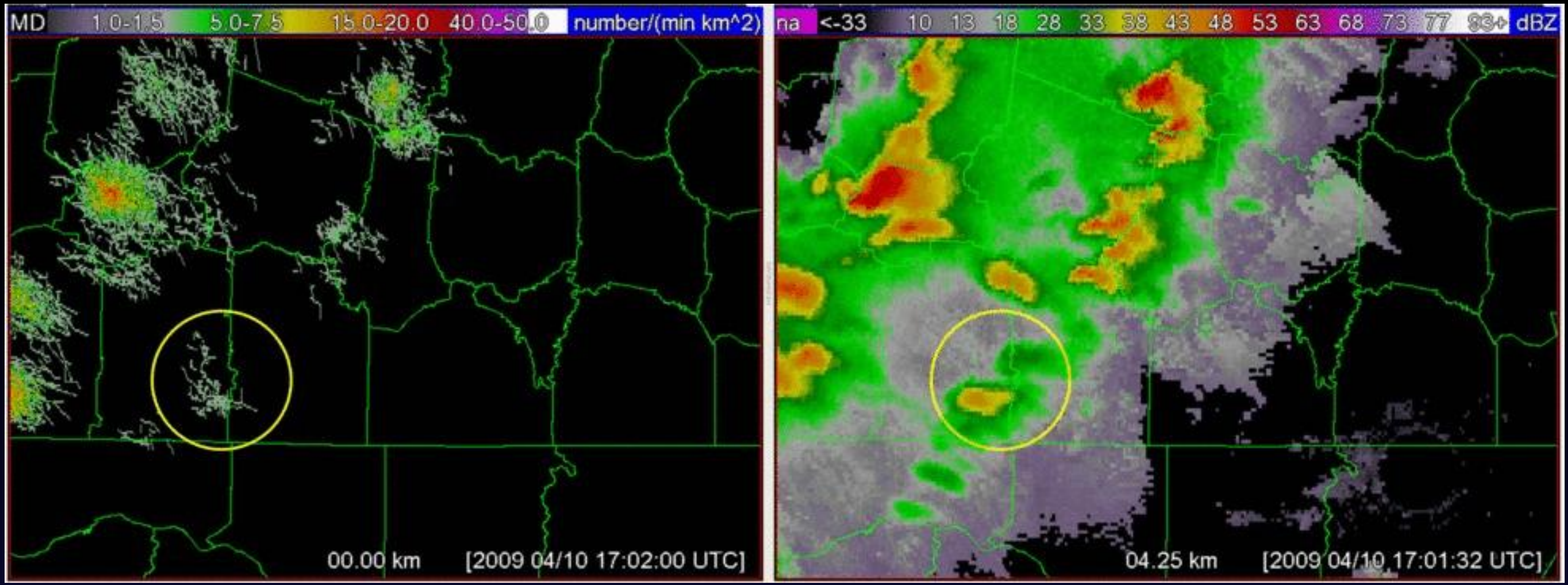
- Flash rate calculated from storm-associated flashes then analyzed for jumps

Case Overview

- North Alabama/Tennessee Valley Region:
    - **10 April 2009 - nontornadic supercell (S. TN)**
        - **Cellular convection ahead of convective line, some supercellular structure**
    - 25 April 2010 - long-track tornadic storm (N. AL)

- Southern Plains Region:
    - 20 May 2013 - tornadic storm (OK)

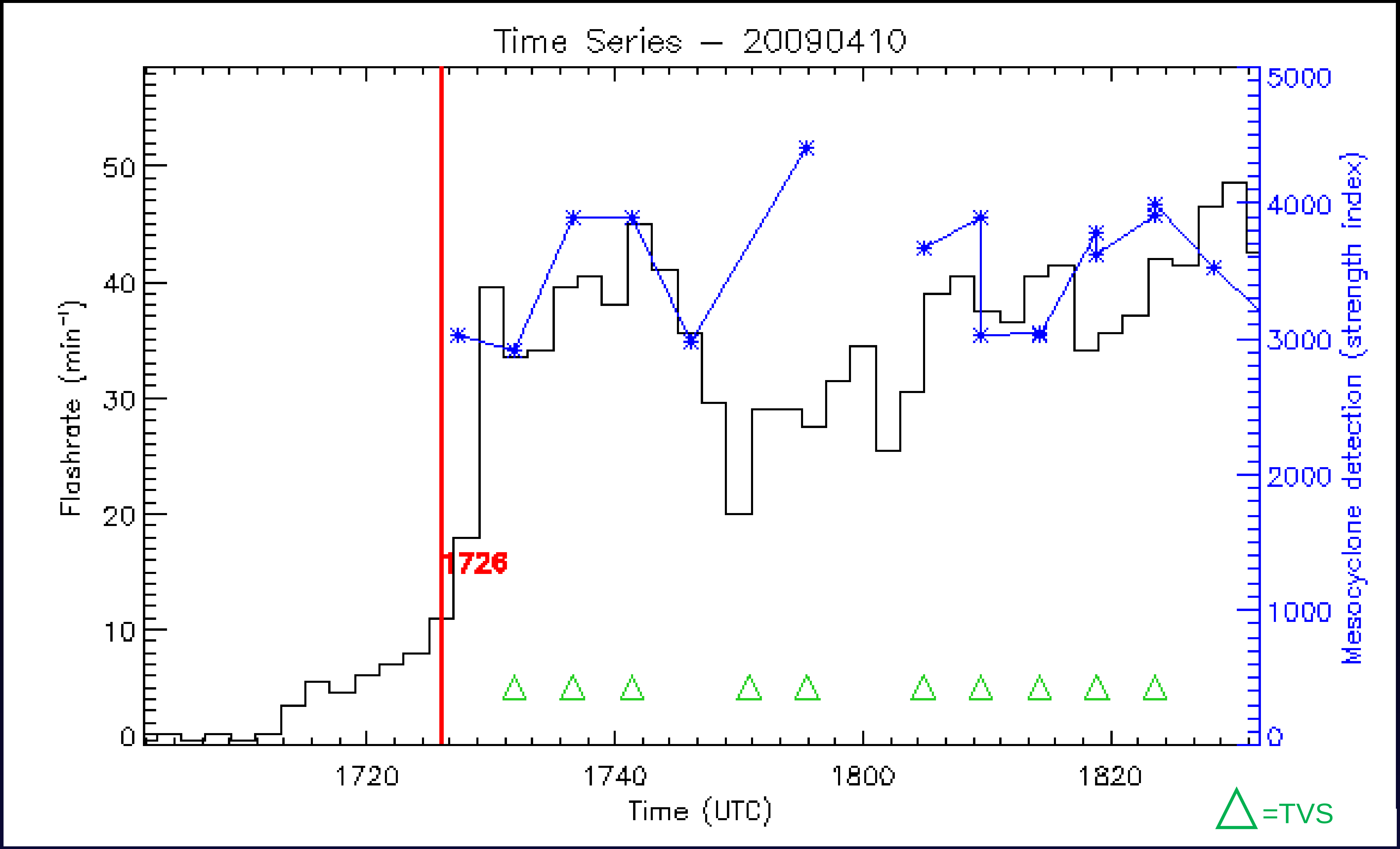
10 April 2009 - Tennessee Valley



Flash extent density

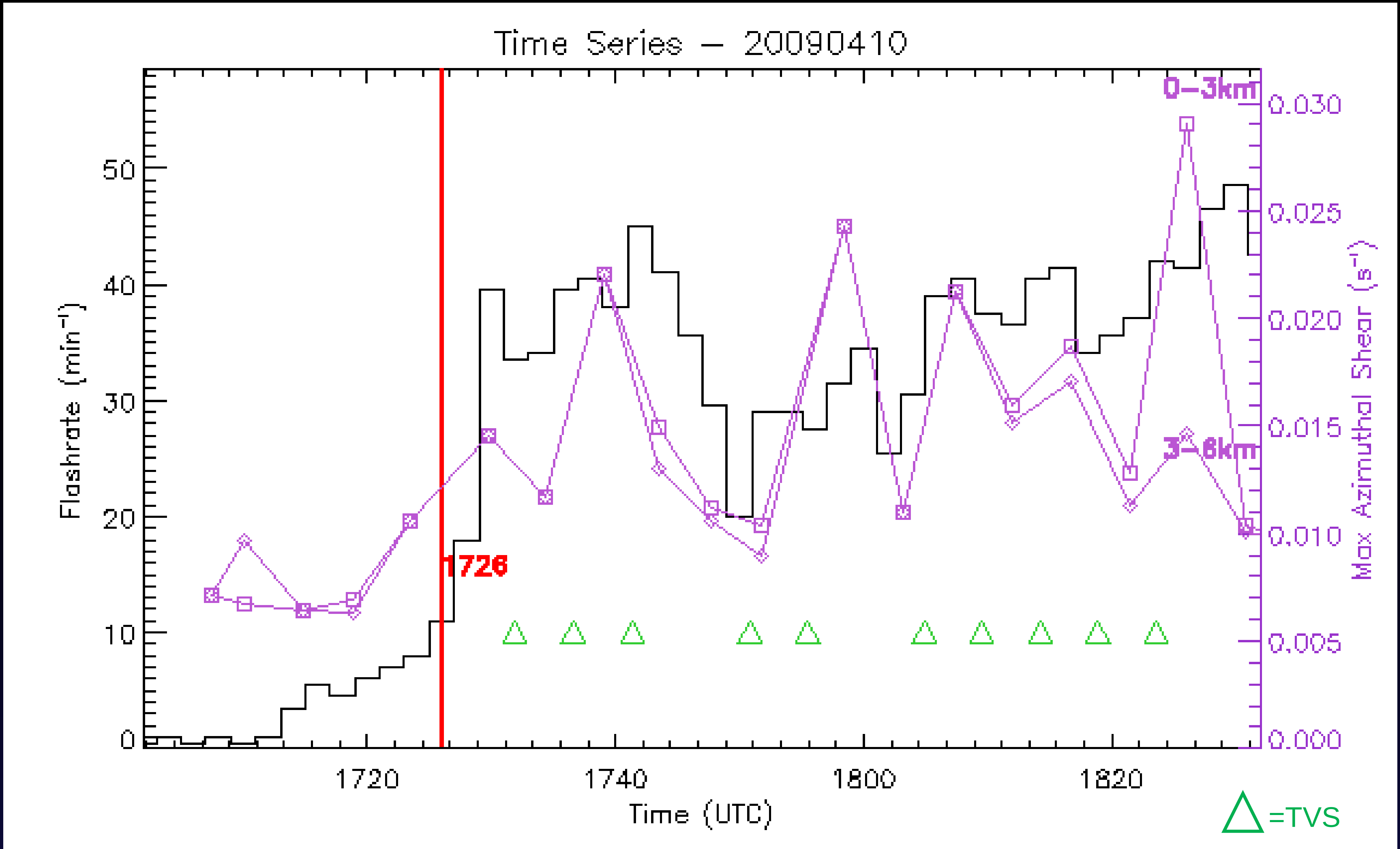
Radar reflectivity at the approximate -10°C height

10 April 2009 - Tennessee Valley



Lightning jump precedes MDA by a minute, TVS detection by several minutes. MDA strength and max low-to-mid shear correlate with lightning flash rate.

10 April 2009 - Tennessee Valley



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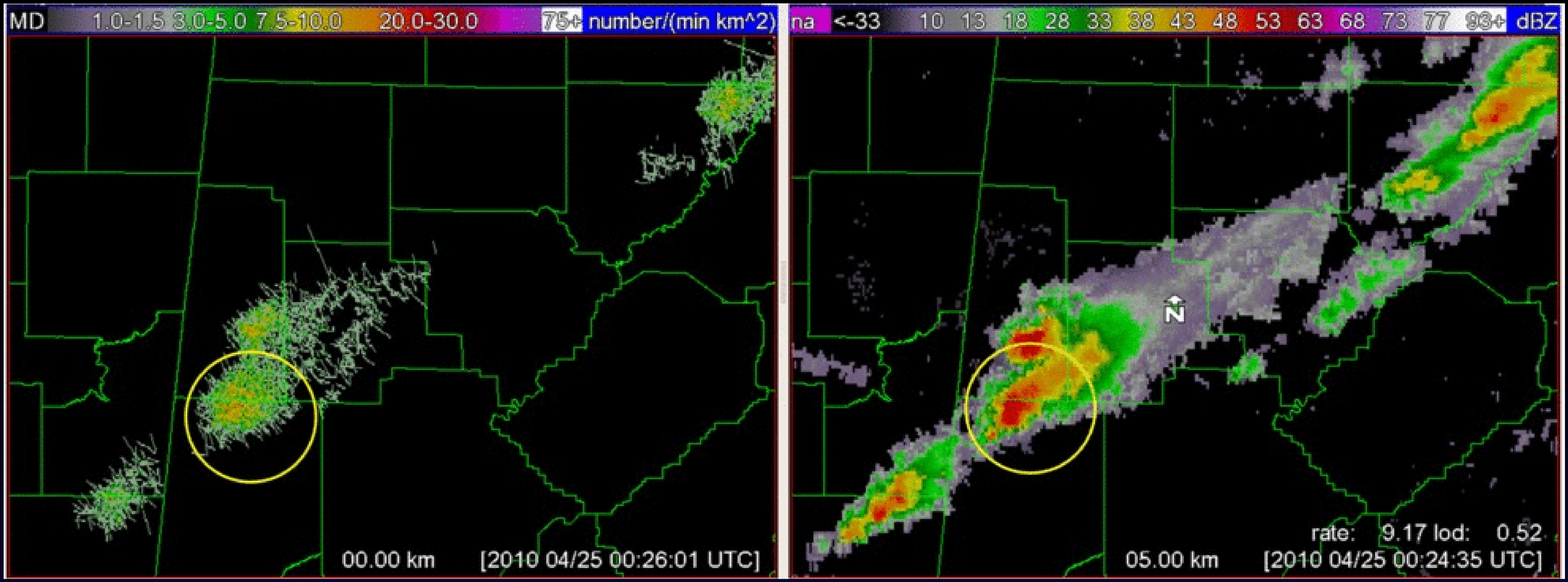
Case Overview

- North Alabama/Tennessee Valley Region:
  - 10 April 2009 - nontornadic storm (S. TN)
  - **25 April 2010 - long-track tornadic storm (N. AL)**
    - **Isolated supercellular structure**
    - **Two reports of EF1 tornadoes during first hour of storm life cycle**
    - **Long-track EF3 tornado roughly an hour later**
- Southern Plains Region:
  - 20 May 2013 - tornadic storm (OK)

25 April 2010 - Alabama

First tornadic period of storm



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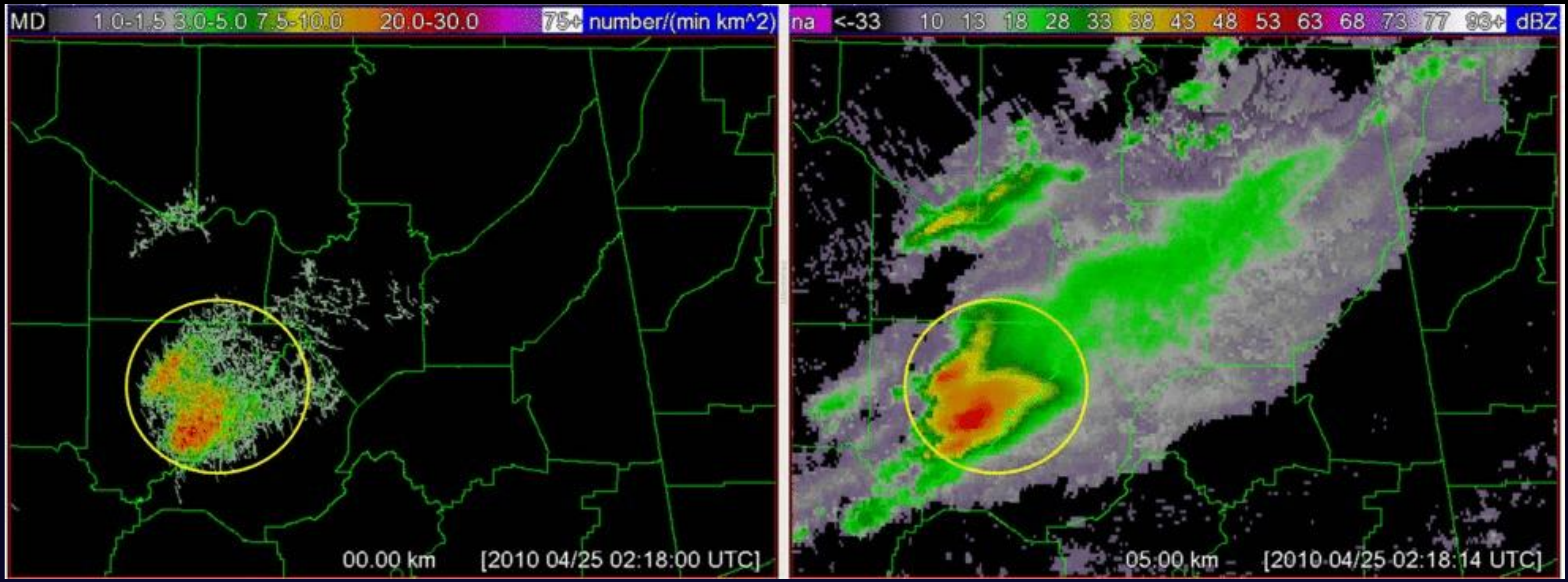
Second tornadic period of storm



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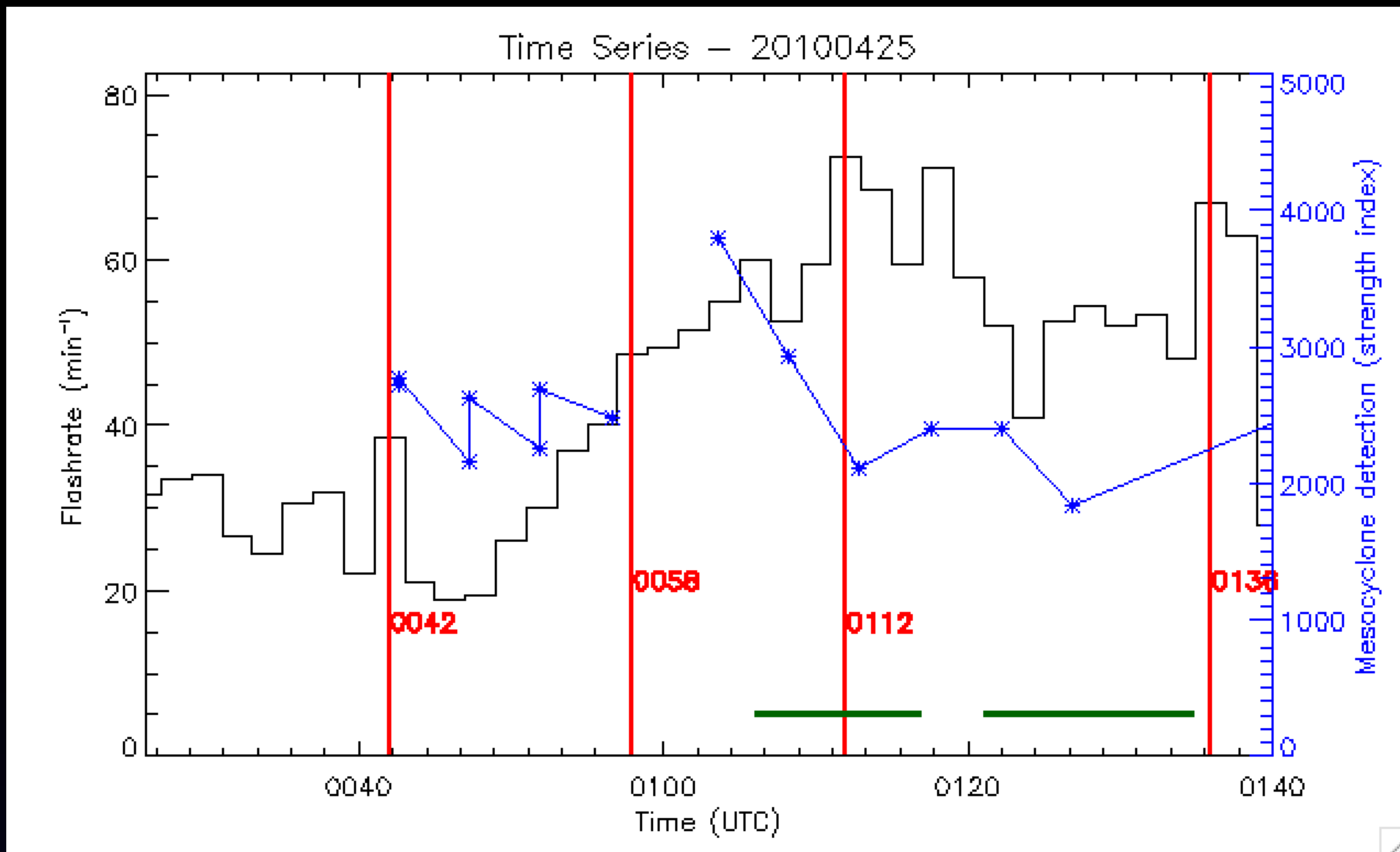
25 April 2010 - Alabama

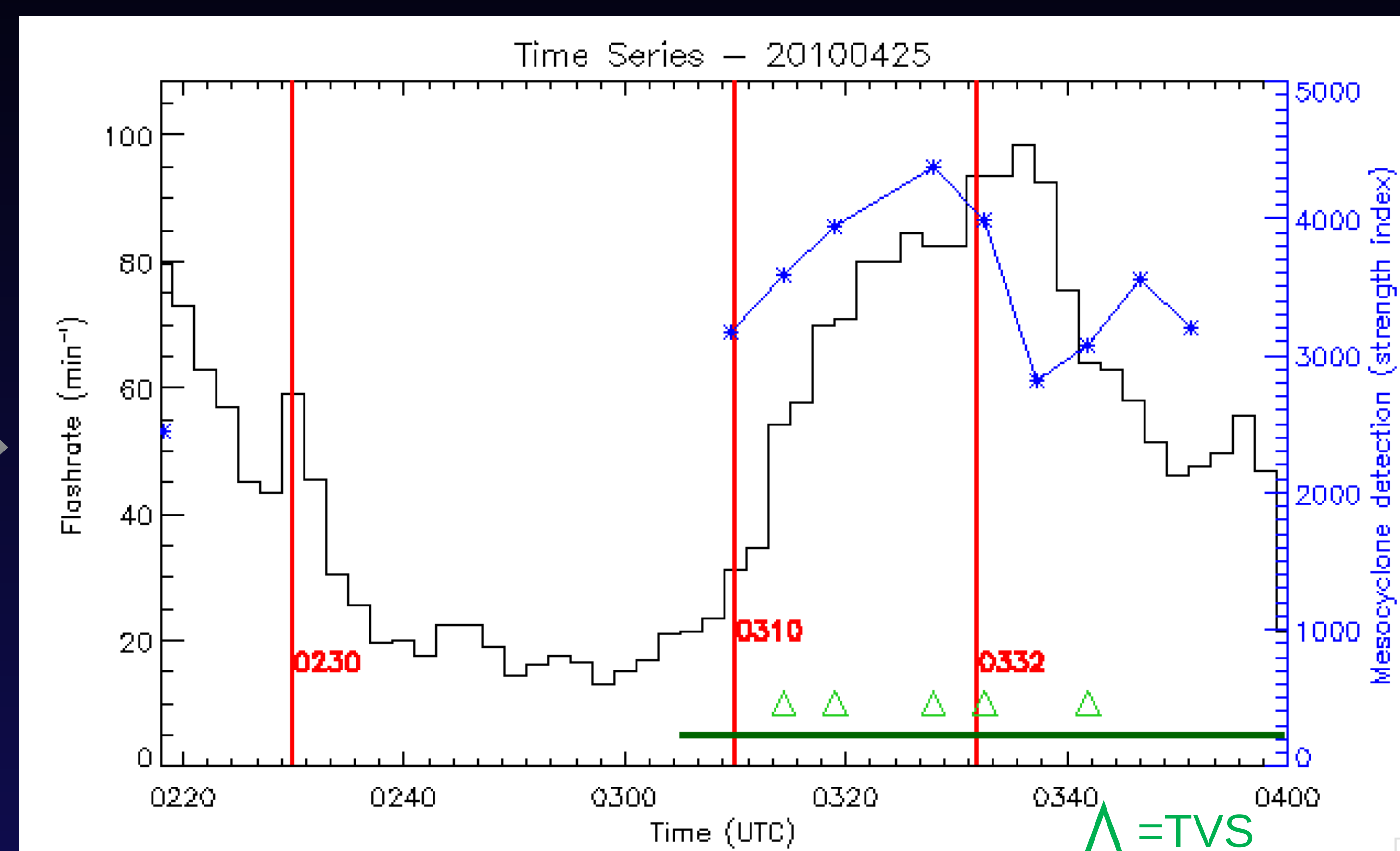


Earlier tornadic period, two reported EF1 tornadoes

Jumps precede the mesos, peaks in AzShr. Mid-level max AzShr mirrors lightning flashrate trends

Later tornadic period, long-track EF3 tornado.

Jump, meso, simultaneous after tornado but flash rate and azshr increase prior



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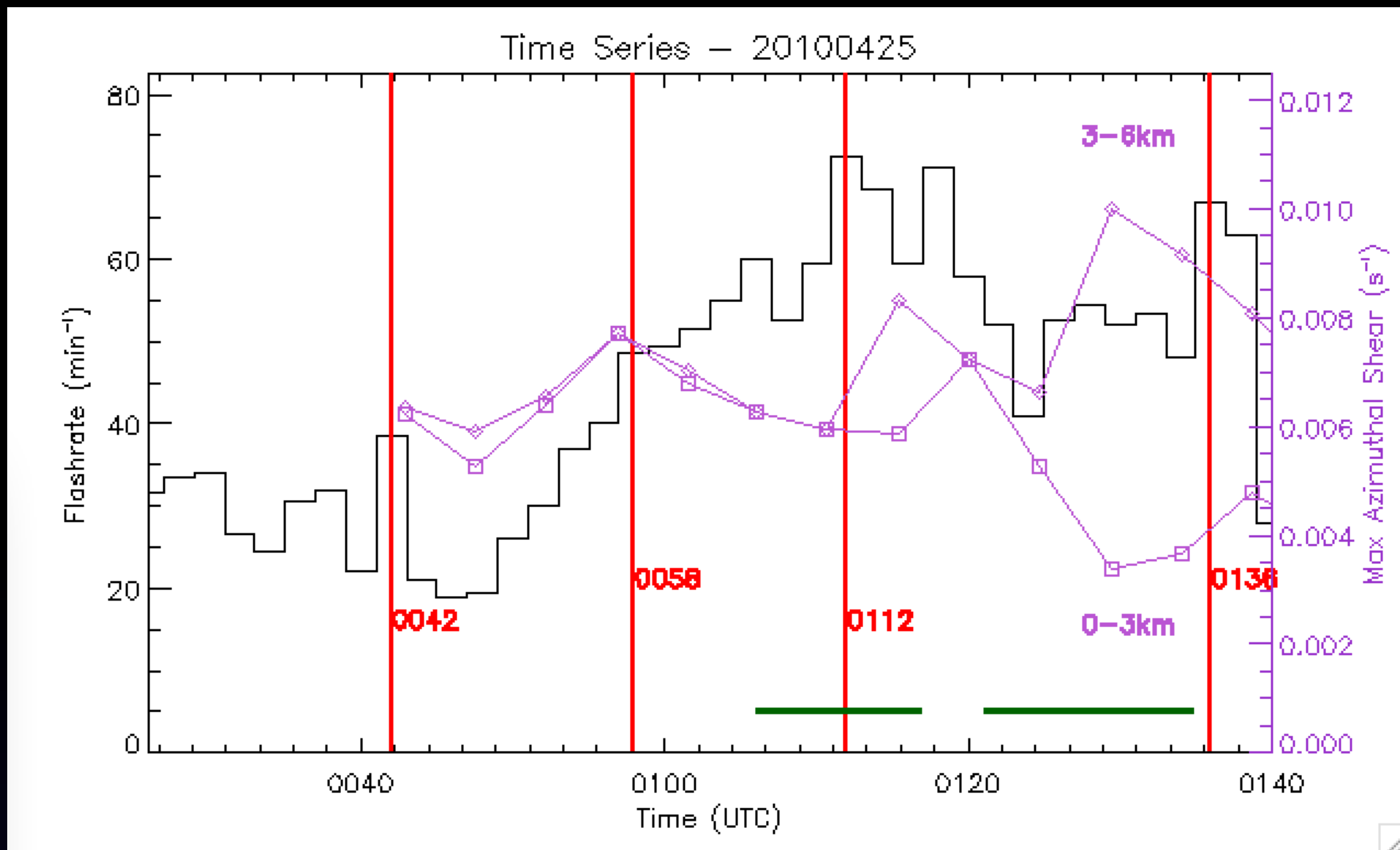

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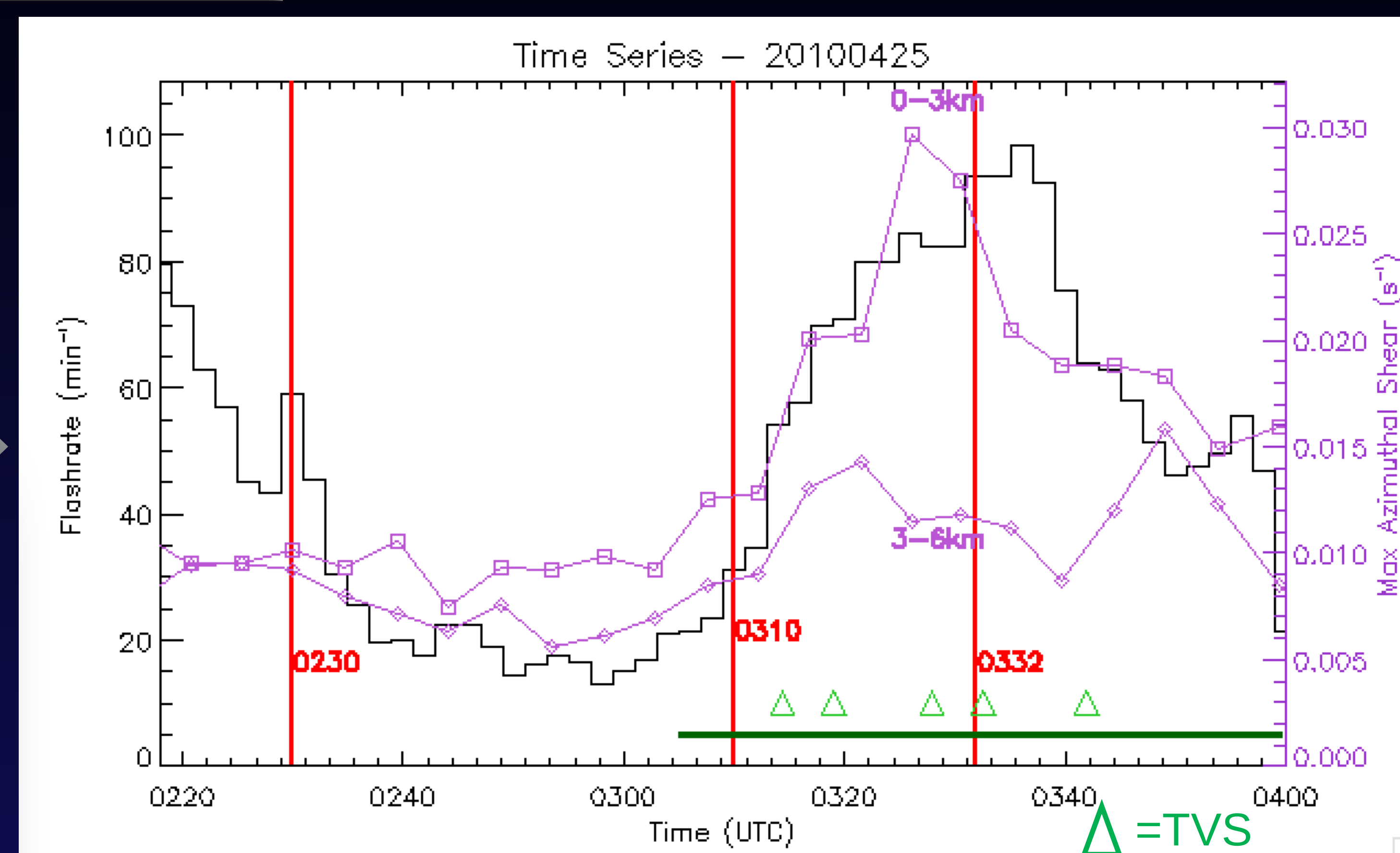
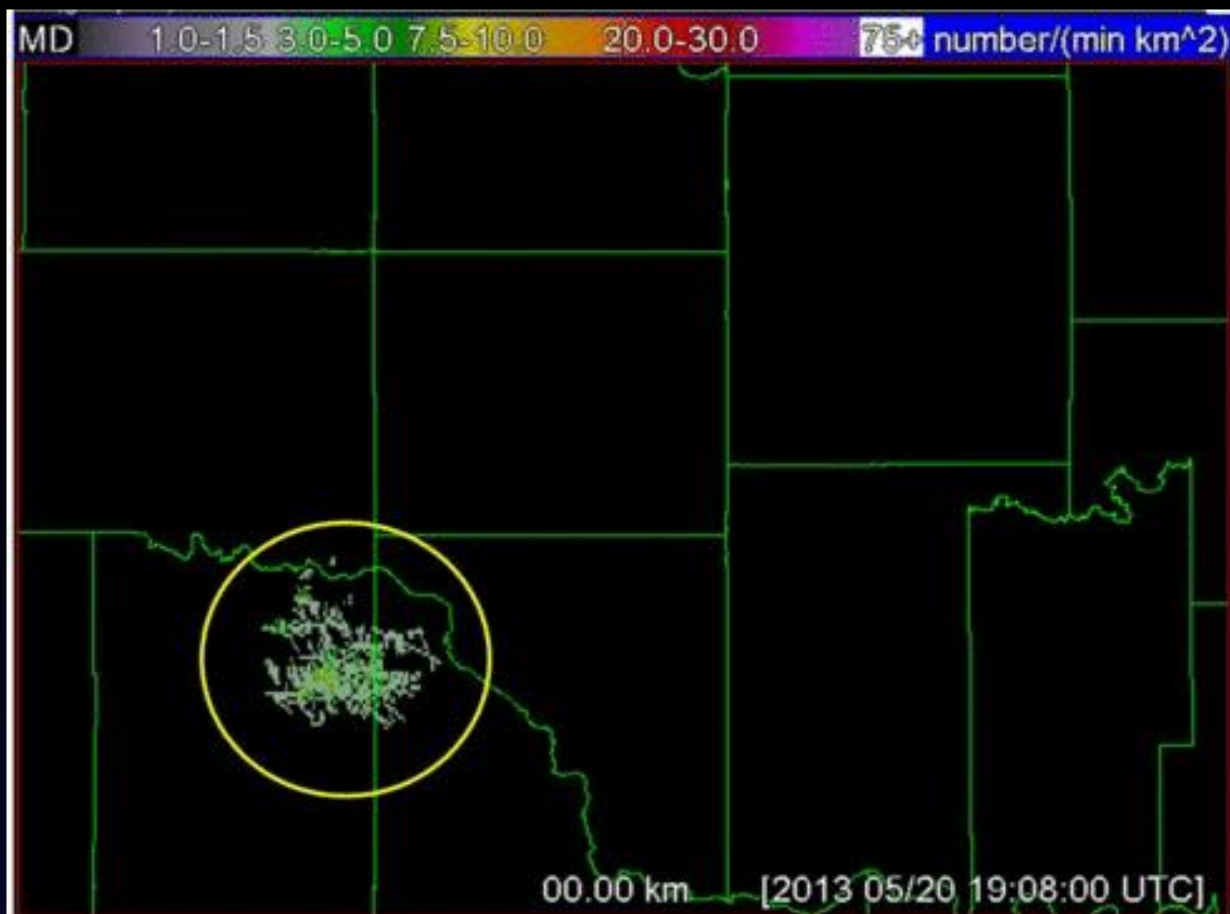
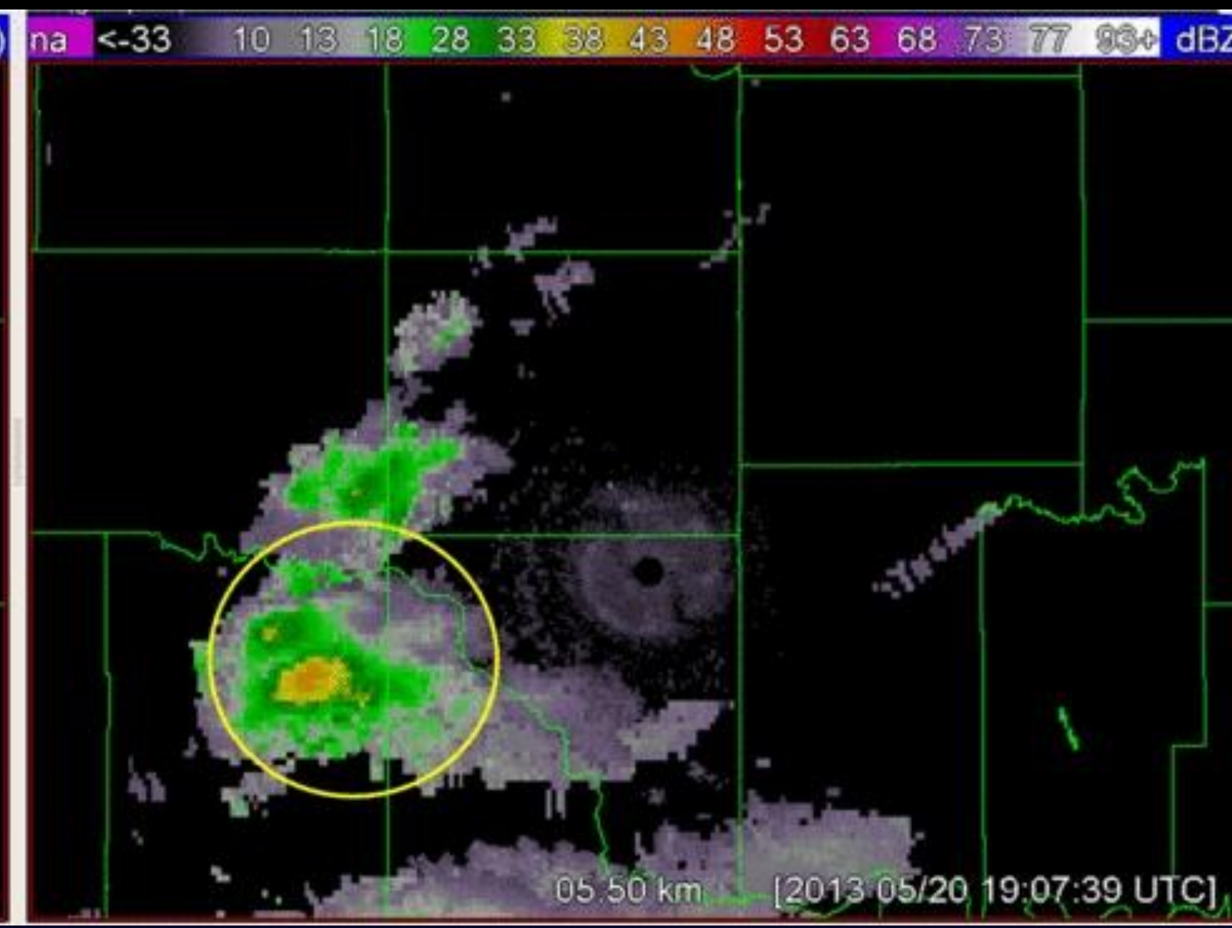


Case Overview

- North Alabama/Tennessee Valley Region:
  - 10 April 2009 - nontornadic storm (S. TN)
  - 25 April 2010 - long-track tornadic storm (N. AL)
- Southern Plains Region:
  - **20 May 2013 - classic supercell structure, tornadic storm (OK)**
    - **Classic supercell structure**
    - **Strong EF5 tornado developed early in storm life cycle**

20 May 2013 - Oklahoma





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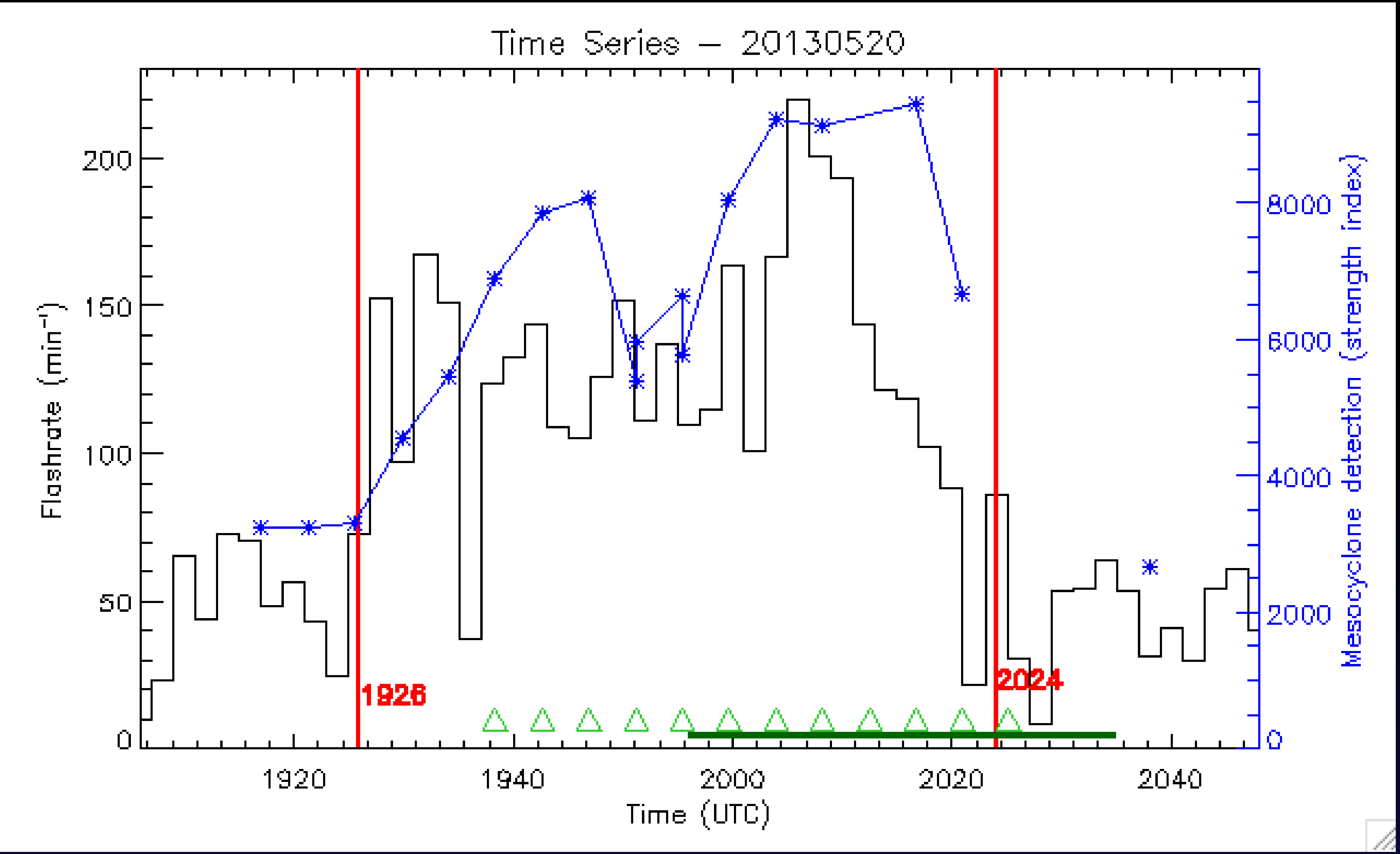
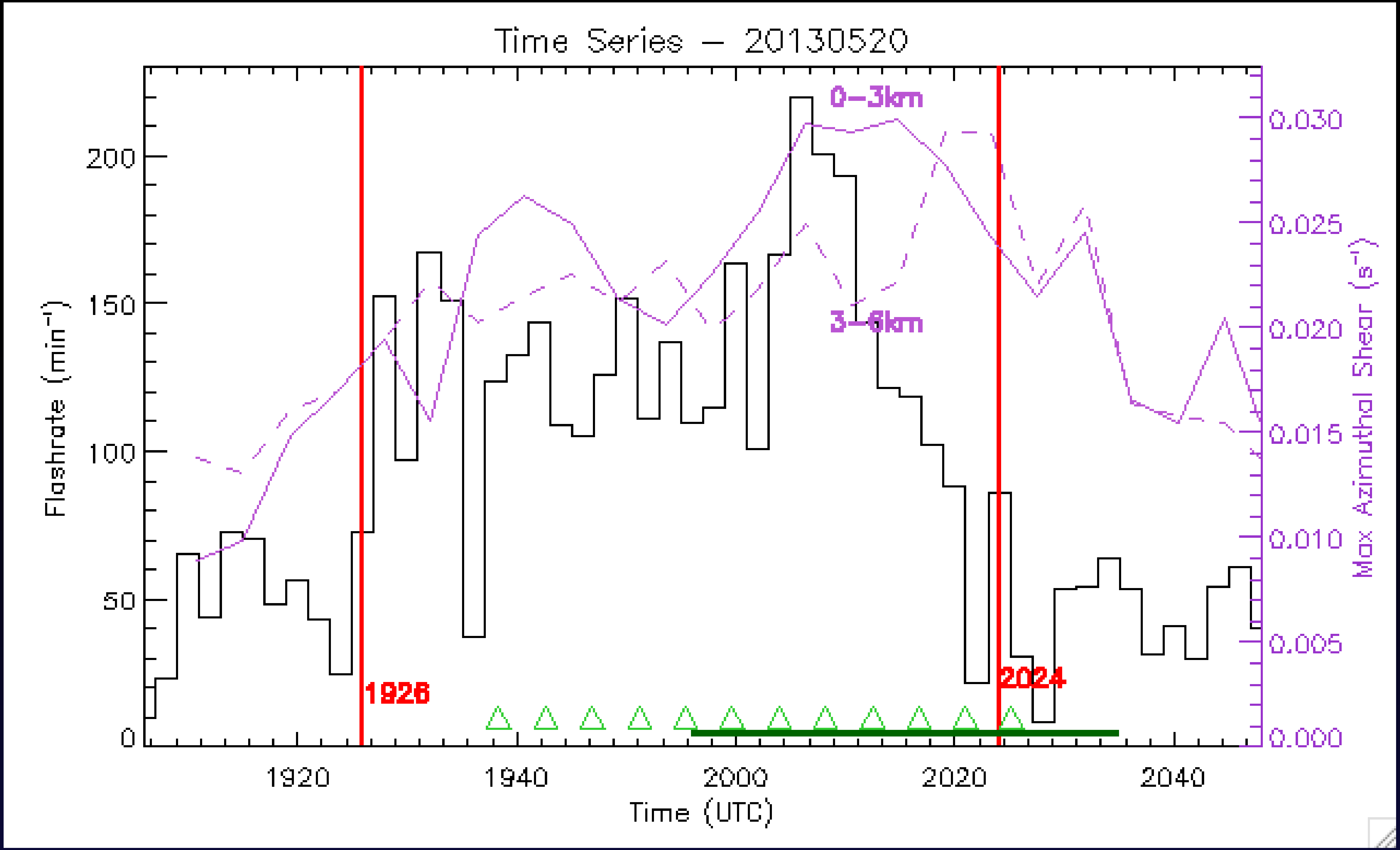


Mesocyclone detected several minutes prior to first lightning jump, put prior to first peak in azimuthal shear. Jump preceeded TVS detections by <10 minutes, actual tornado by 30 minutes.

20 May 2013 - Oklahoma



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Summary of Preliminary Results

- Increased lightning activity (i.e., a jump) coincides with or precedes the increase in radar-derived circulation
- More agreement between flash rate and low-level azimuthal shear vs. mid-level azimuthal shear, yet trends between three parameters are consistent
- Tornadoes not always preceded by lightning jump or mesocyclone – other dynamic factors involved in severe weather production than result from the updraft alone

Ongoing and Future Work

- Additional cases in a variety of climatologic regions and seasons
  - LMA data from Colorado, Washington D.C.
- Further assessment of nontornadic storms
- Analyze other characteristics/components of total lightning for further trends. Does the charge structure or ratio of IC/CG lightning provide further insight?
- Do trends in azimuthal shear at other levels of the storm offer additional insight compared with lightning activity?
- Add analysis dual-polarization radar signatures that indicate storm relative helicity (e.g., Z_{DR} arc and separation of Z_{DR} and K_{DP})

References and Acknowledgements

Brotzge and Ericksen [2009]
Brotzge and Donner [2013]
Schultz *et al.* [2009, 2011]
Stumpf *et al.* [1998]
http://wdssii.org/

Citations from figure sources: [Stolzenburg et al. 1998, Lemon and Doswell 1979, Williams et al. 1999, http://weather.msfc.nassa.gov/sport/lma, http://www.nssl.noaa.gov/projects/lma.php]

NOAA/NASA GOES-R GLM Risk Reduction Research (R3)
Thanks to Geoffrey Stano for providing OKLMA data

Questions?