Efforts relating to LMA flash size and flash energy

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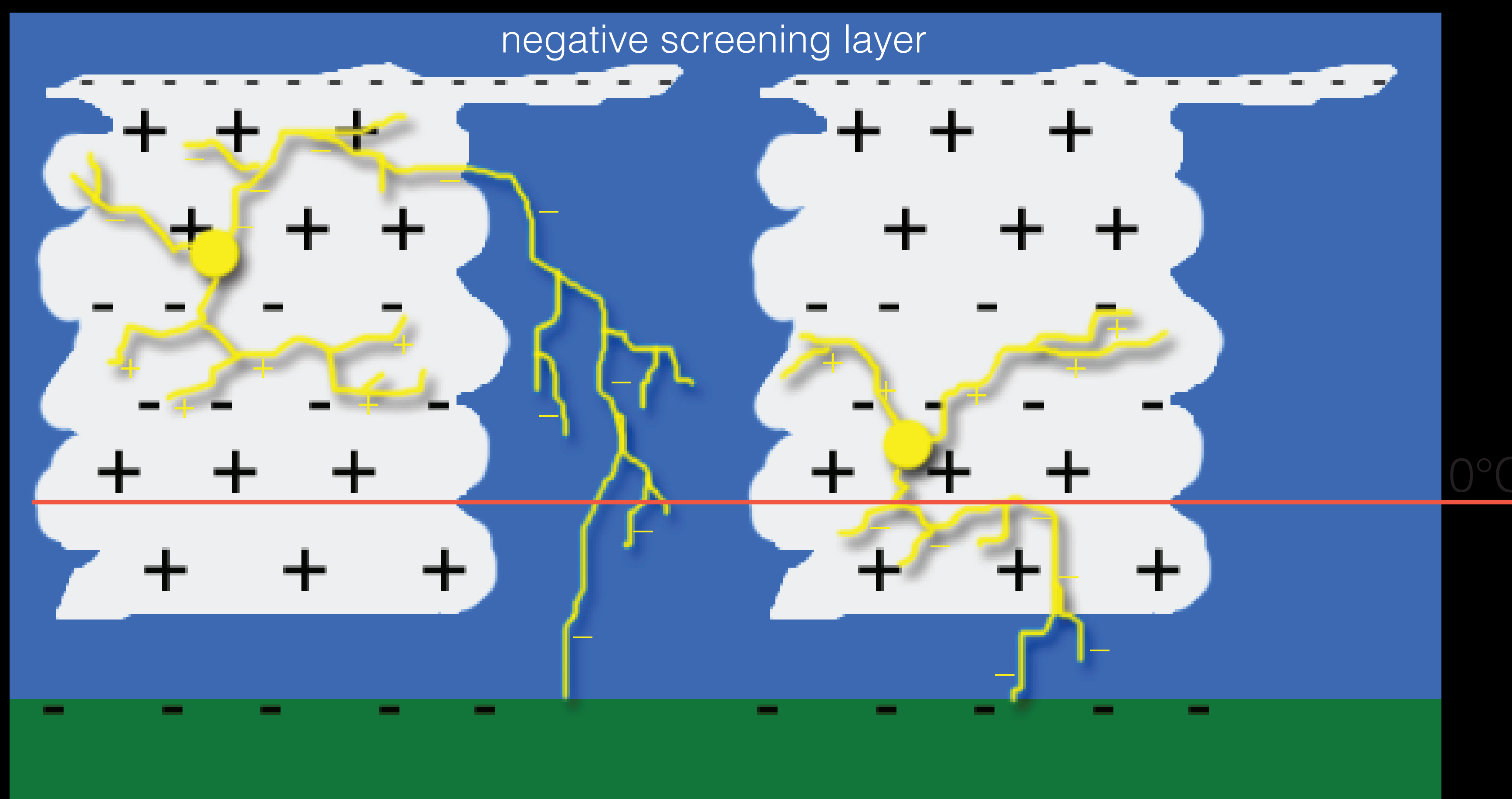
Photo: Pat Skinner

Variation in net charge structures reflect storm structure and organization

Multicellular storms: 1D (up / down)



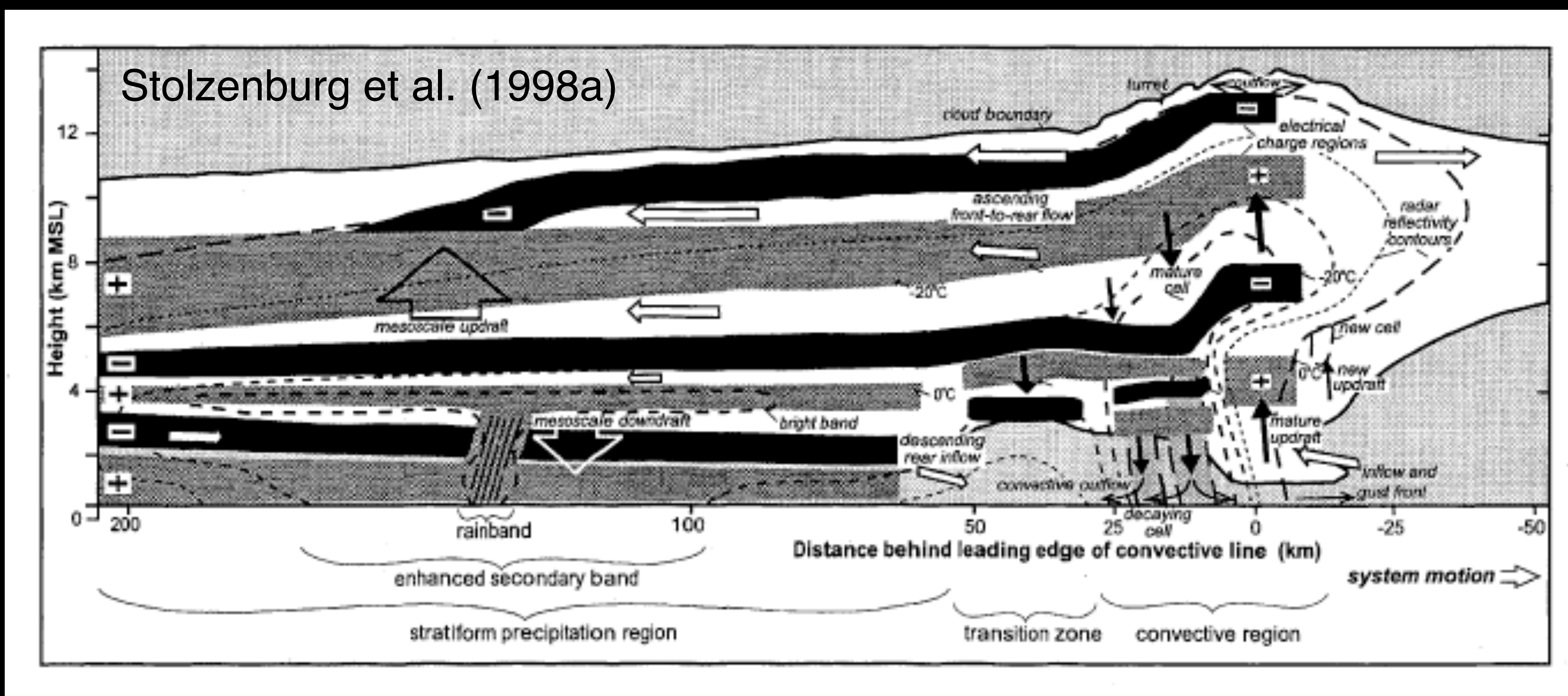
+ cloud flash (+IC) or
bolt-from-blue –CG

–IC or –CG

Variation in net charge structures reflect storm structure and organization

Multicellular storms: 1D (up / down)

Squall line / MCSs: 2D (up / down, front / rear)

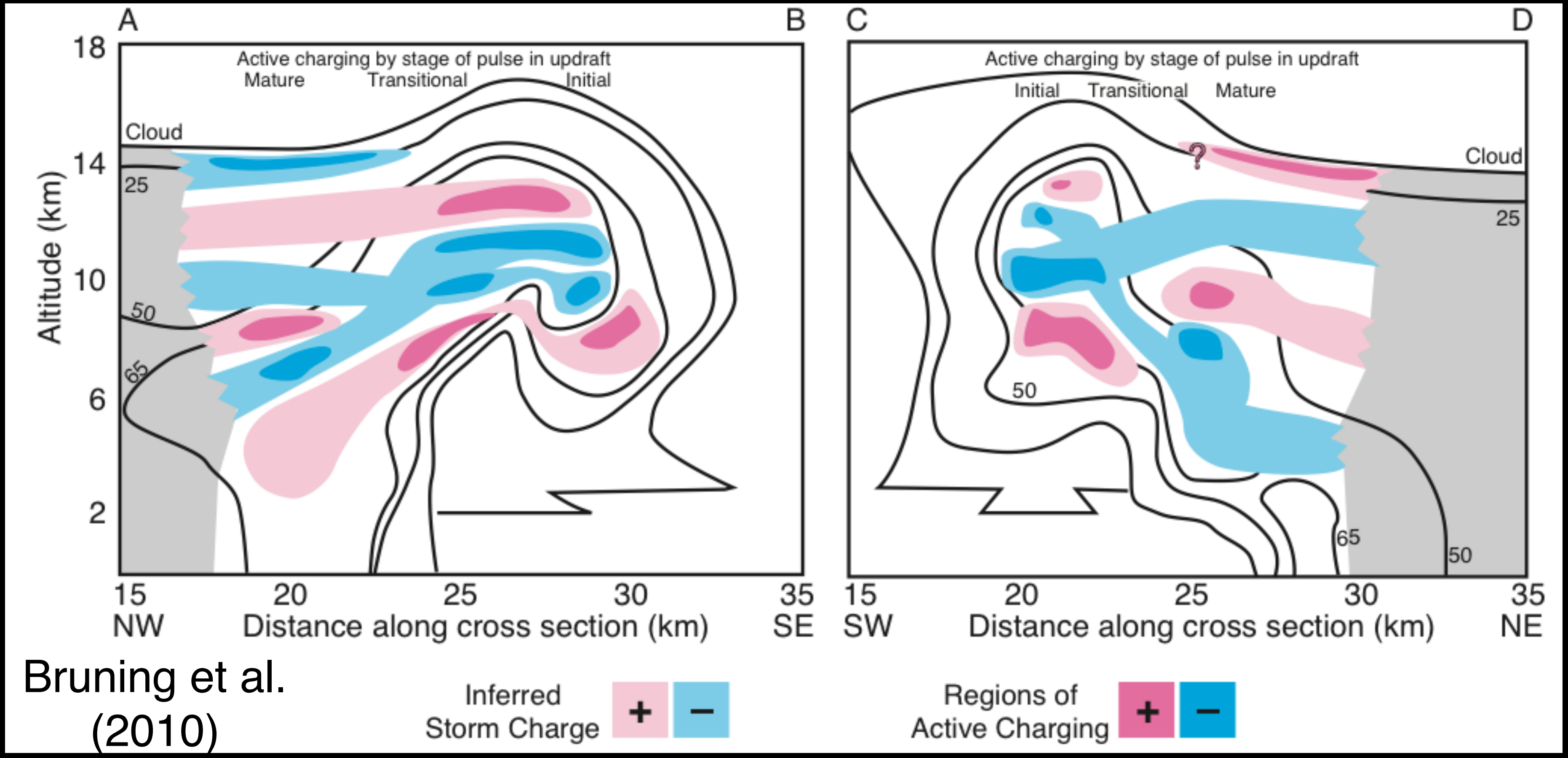


Variation in net charge structures reflect storm structure and organization

Multicellular storms: 1D (up / down)

Squall line / MCSs: 2D (up / down, front / rear)

Supercell: 3D (up/down, left/right, front/rear)



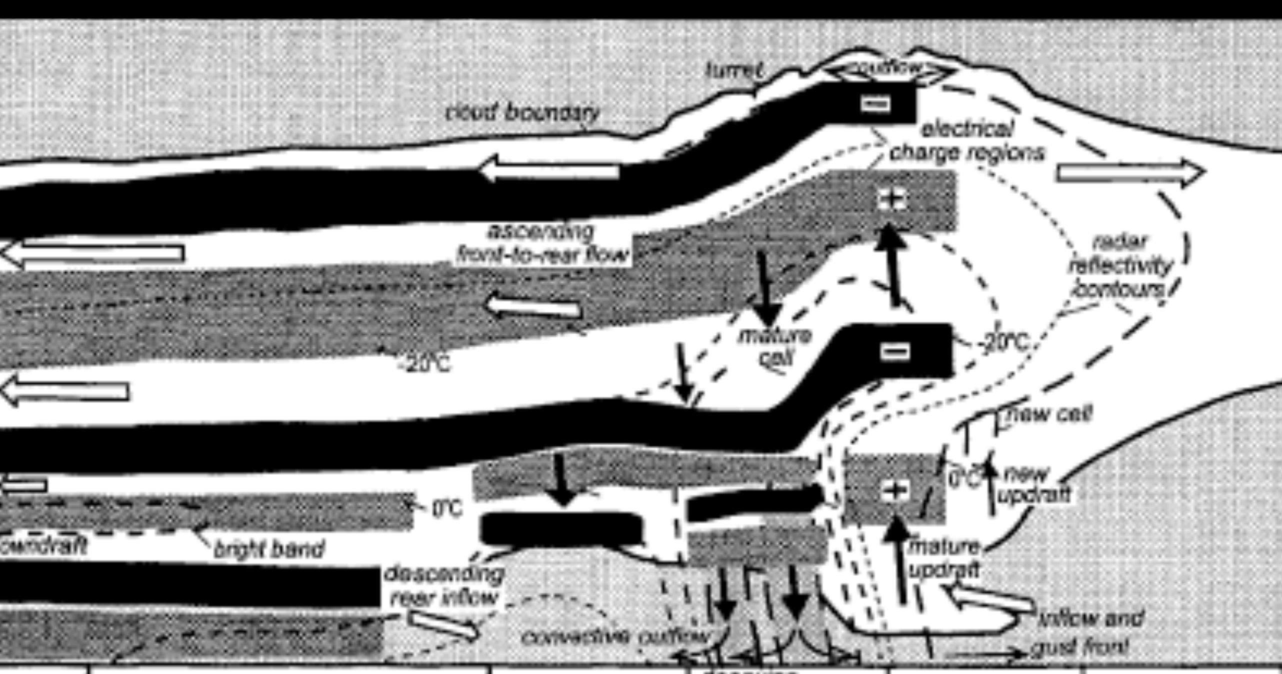
Bruning et al. (2010)

How are net charge regions formed and organized, beyond sedimentation of hydrometeors and storm-average flow?

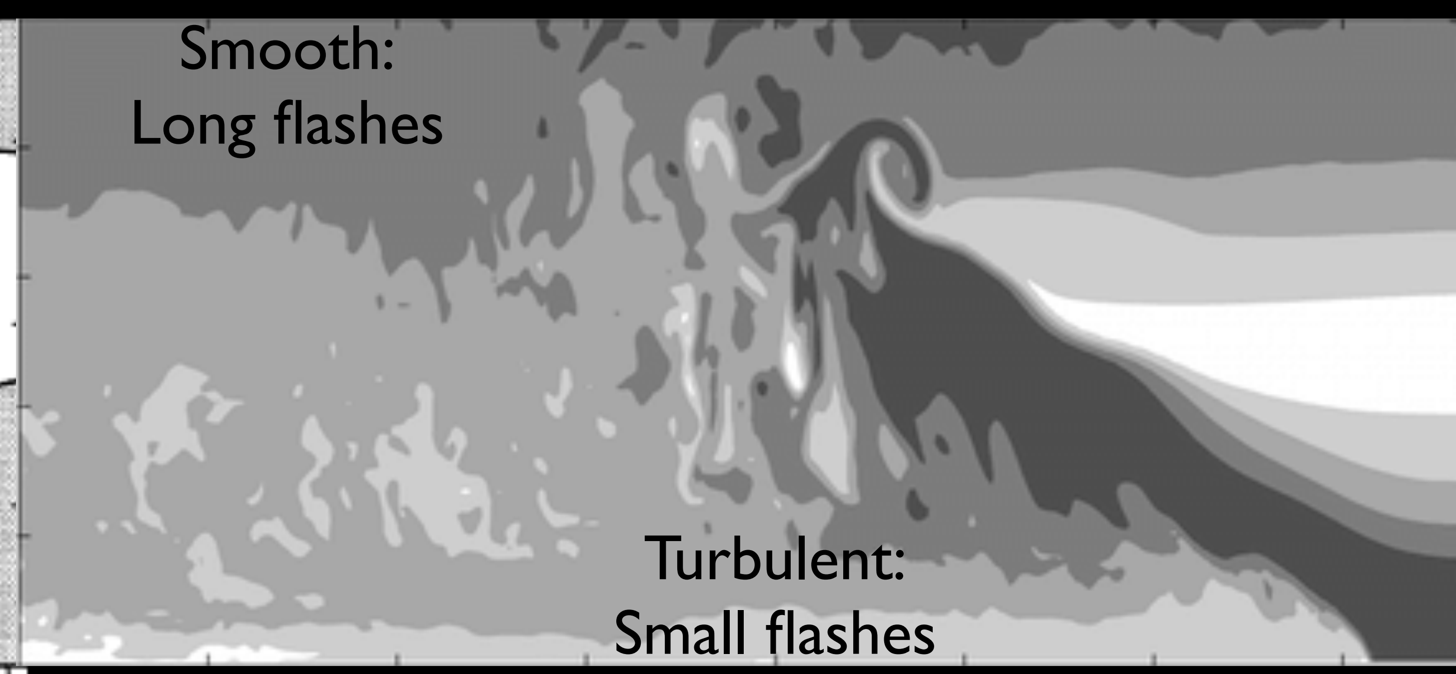
Convective motions are a key source of electrical energy (Williams 1985; Weinheimer 1987).

Hypothesize that turbulent eddy-scale motions are the source of the electrical potential differences that lead to flash initiation and control the flash size distribution

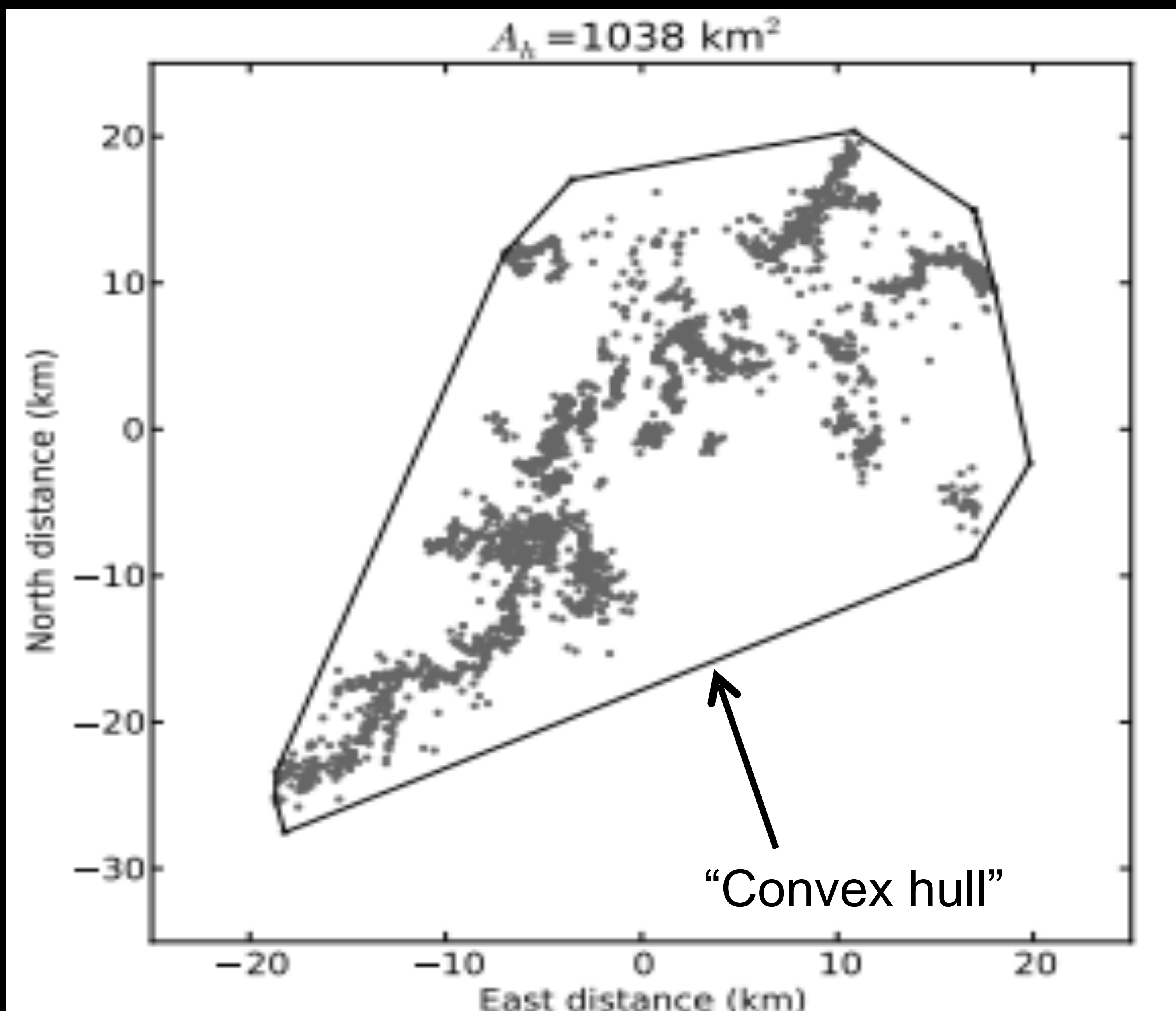
Charge structure for a generalized mesoscale convective system (Stolzenburg et al. 1998a)



Turbulent folding in an eddy-resolving simulation of the same type of storm. (Bryan et al. 2003)



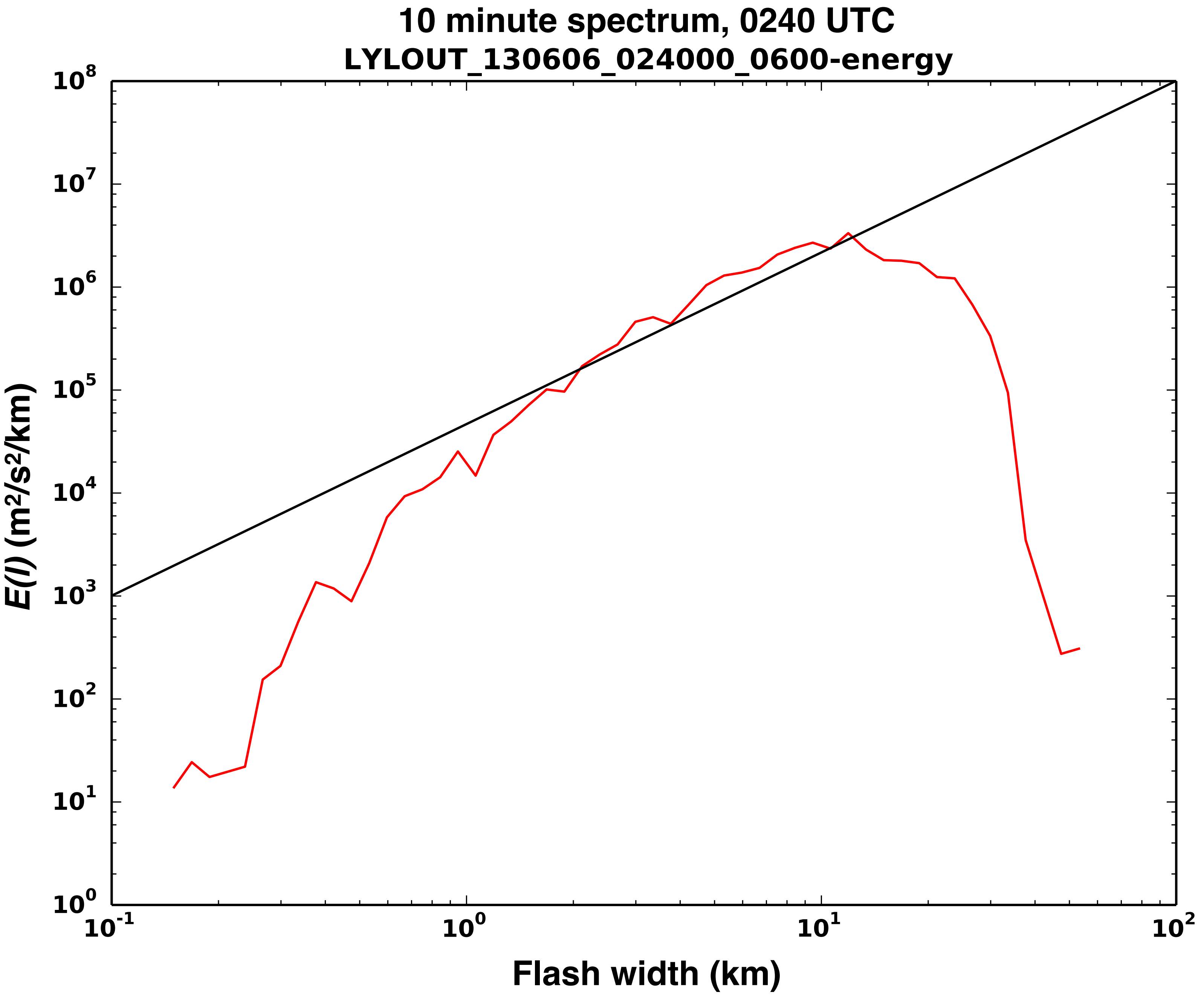
Flash size



- In this talk, flash size refers to the square root of the area of the convex hull of the plan projection of the VHF sources comprising the flash.

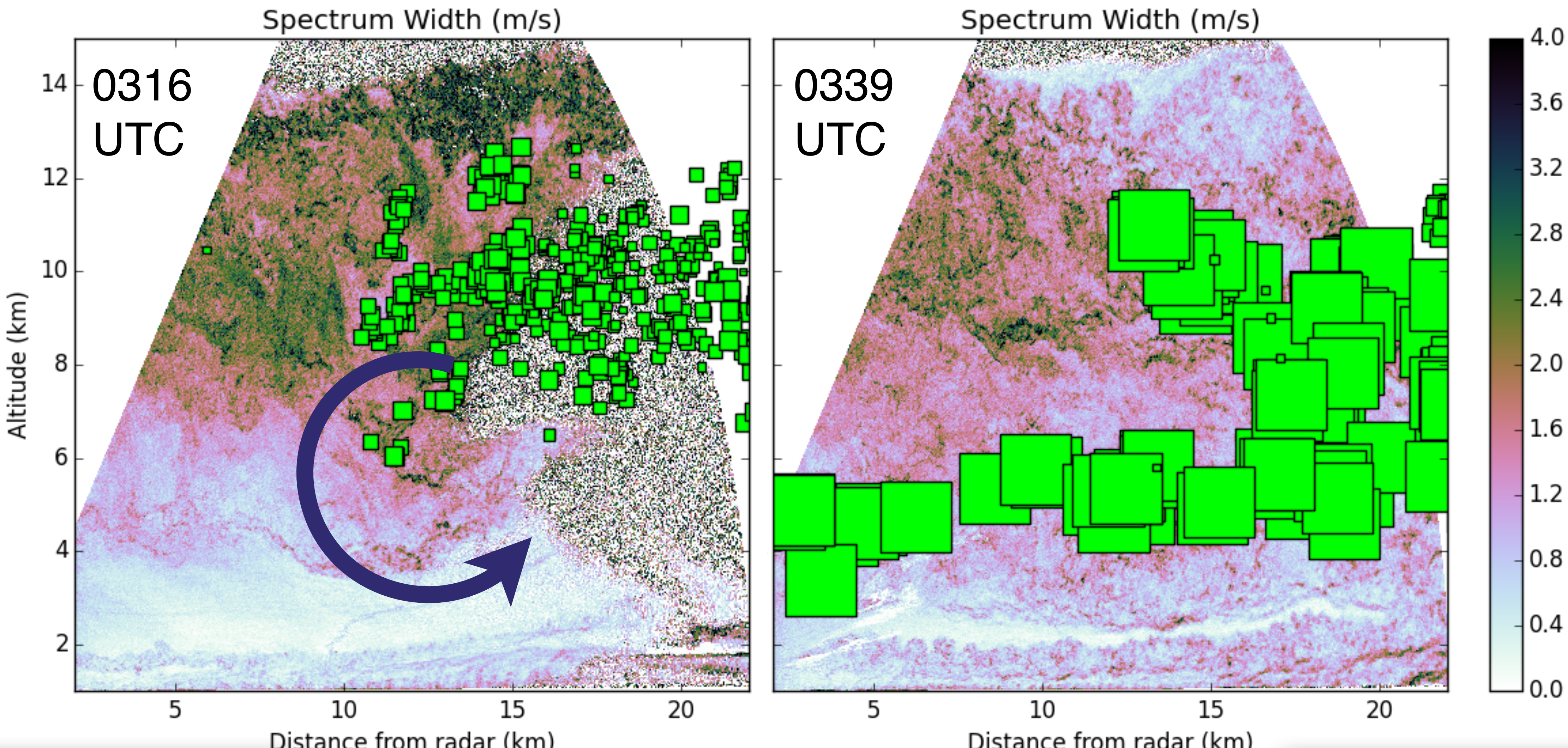
The flash size distribution and a simple model of flash energy

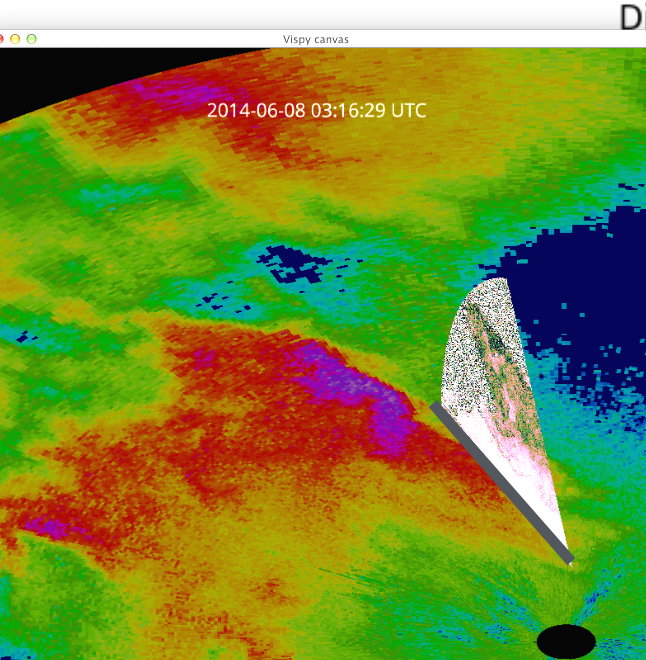
- Flashes sizes are distributed in a predictable way. Scaled energetically, the distribution looks like a thunderstorm's turbulent kinetic energy spectrum. (Bruning and MacGorman, 2013)
  - Peak at ~10 km scale
  - 5/3 power-law in the inertial range at < 5 km
- Suggests that eddy-scale flow is organizing charge



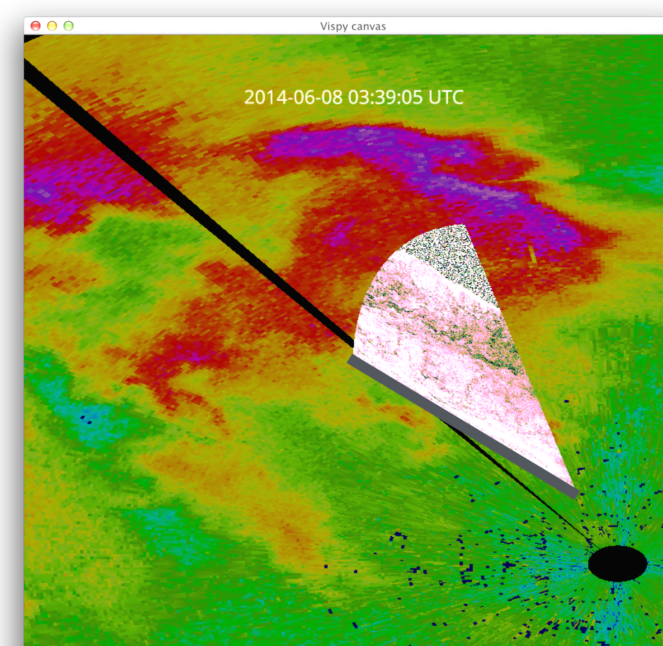
$$l = \sqrt{A_h} \qquad E(l) = \frac{\rho^2 l^2 d^3}{2\epsilon_0} = K l^2$$

Fewer, larger flashes in less-turbulent regions





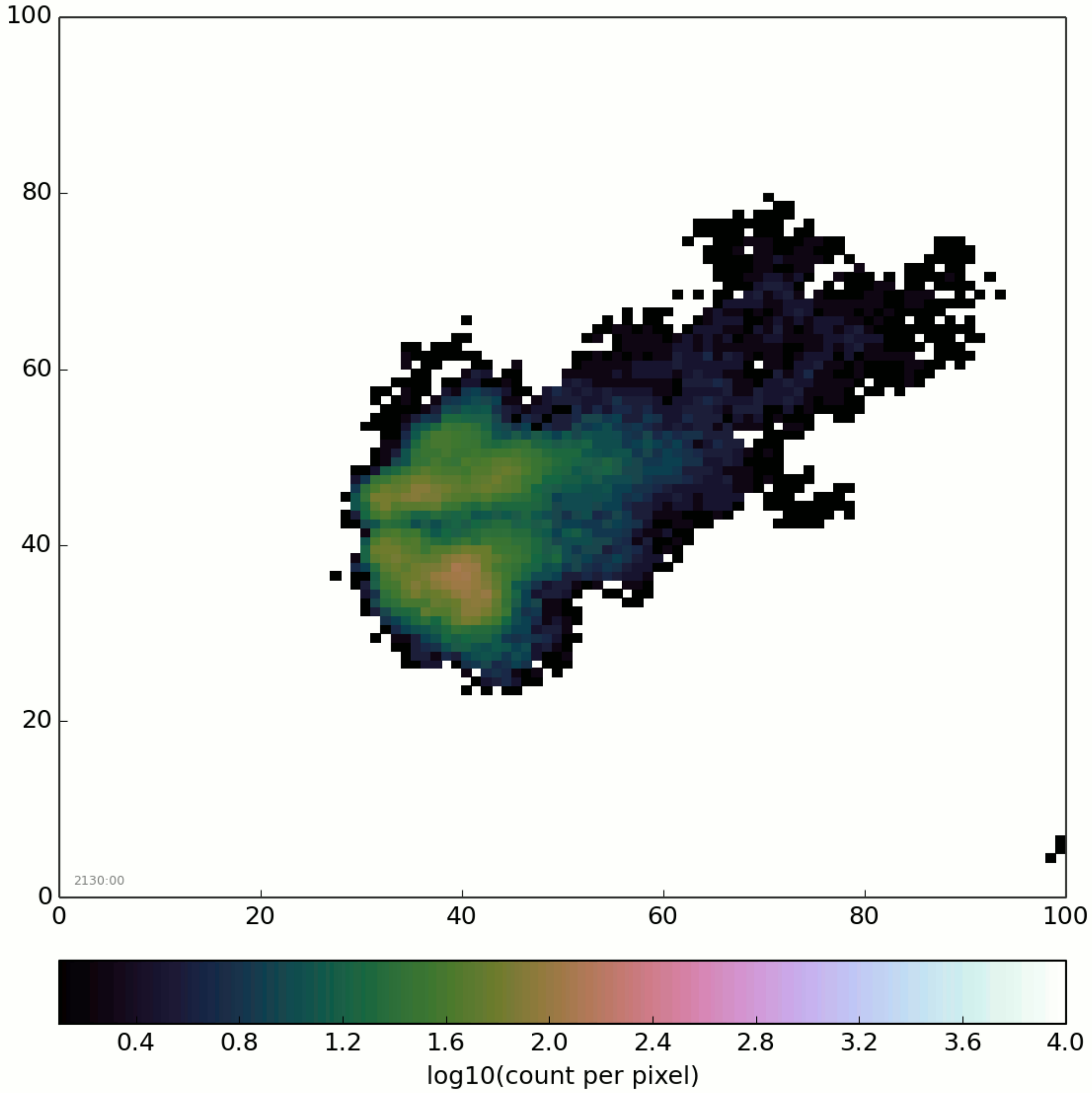
- All LMA sources from flashes within 10° of RHI
- Size of symbol = area of flash to which source belongs



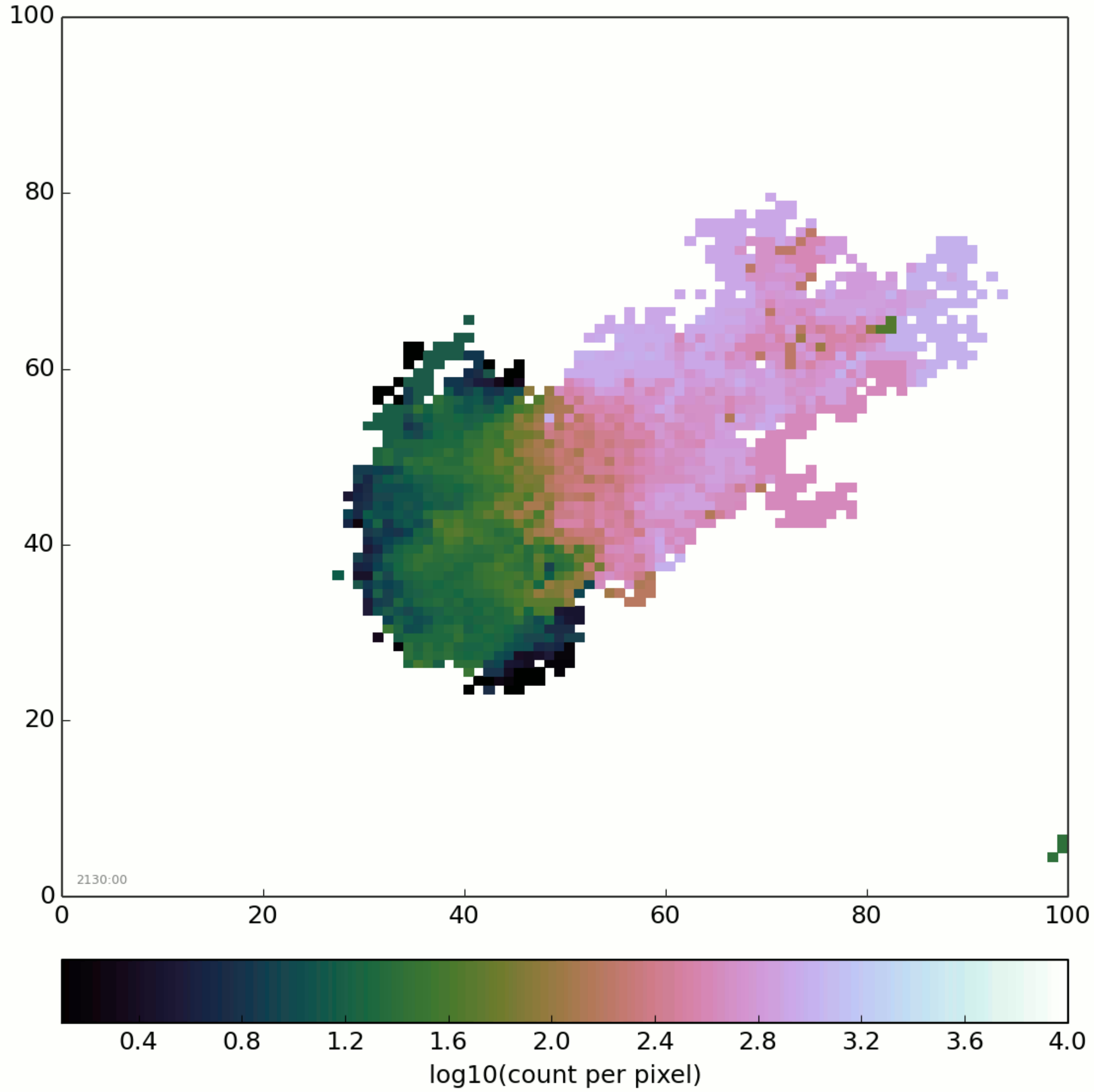
Spatial grids of flash size

07/16/2009 Supercell, OKLMA

Flash Extent Density (Count)



Average Flash Area (Total Area / Count)



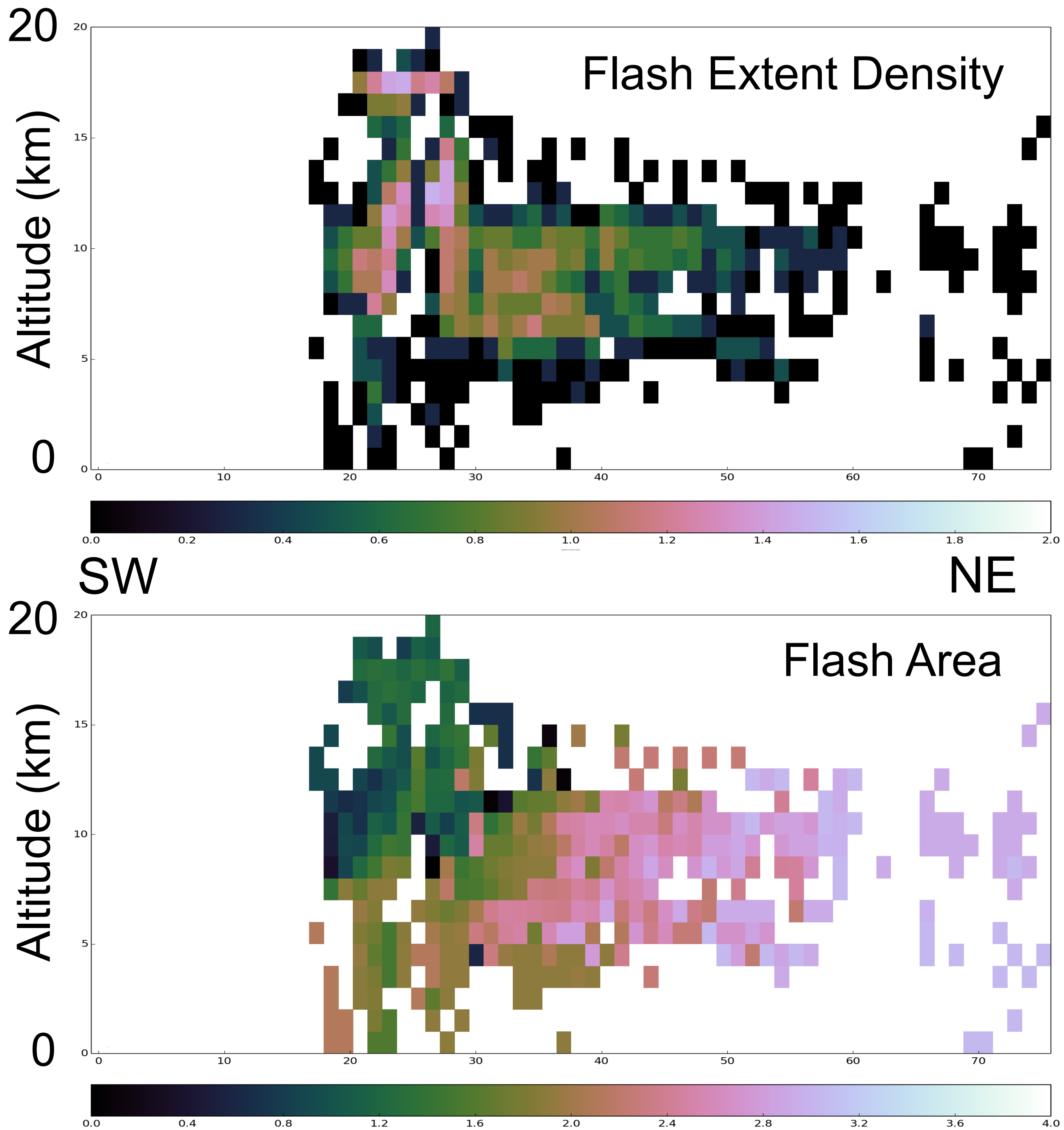
All flash color scales are $\log_{10}$

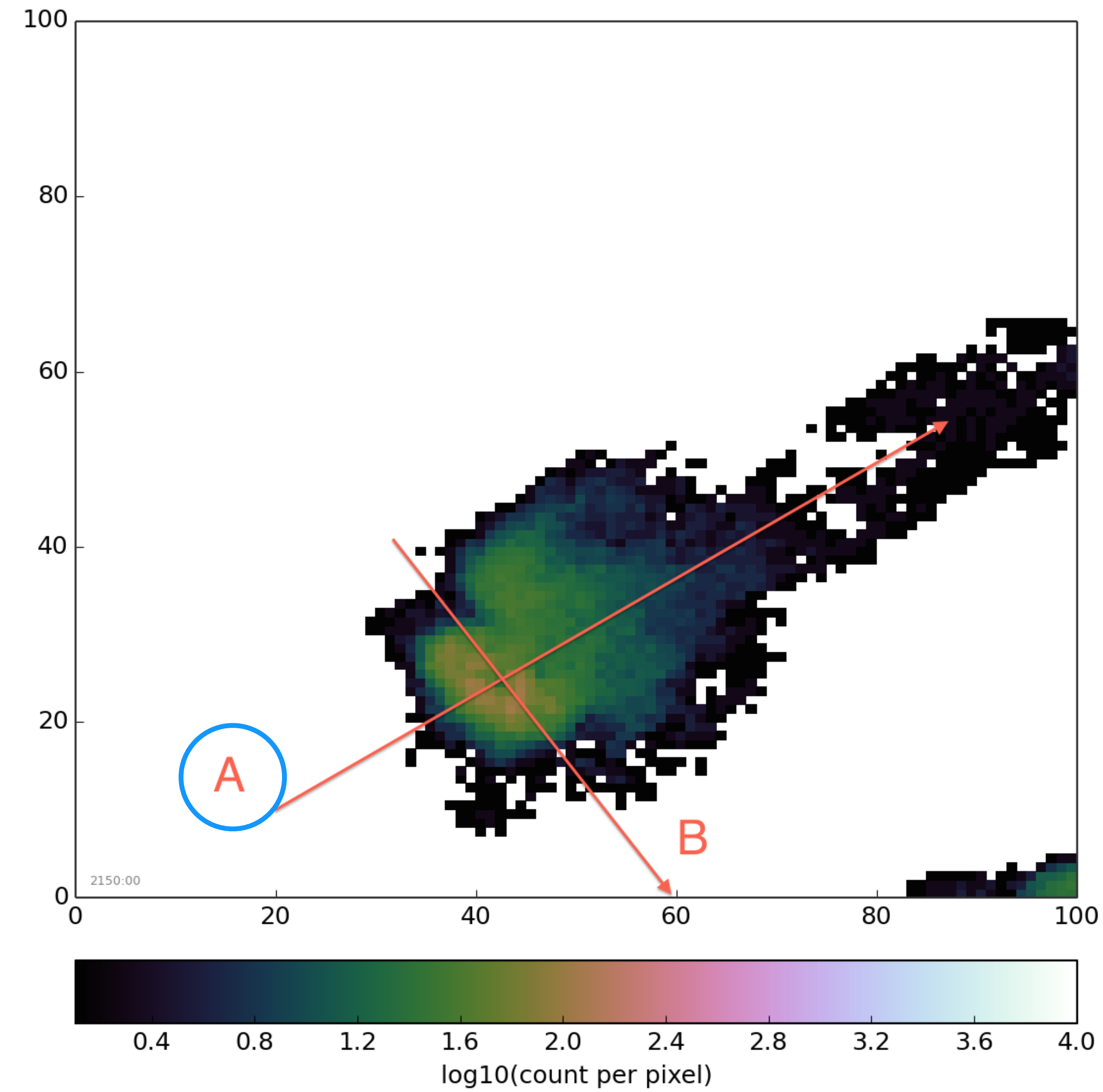
Analysis: P. Ware

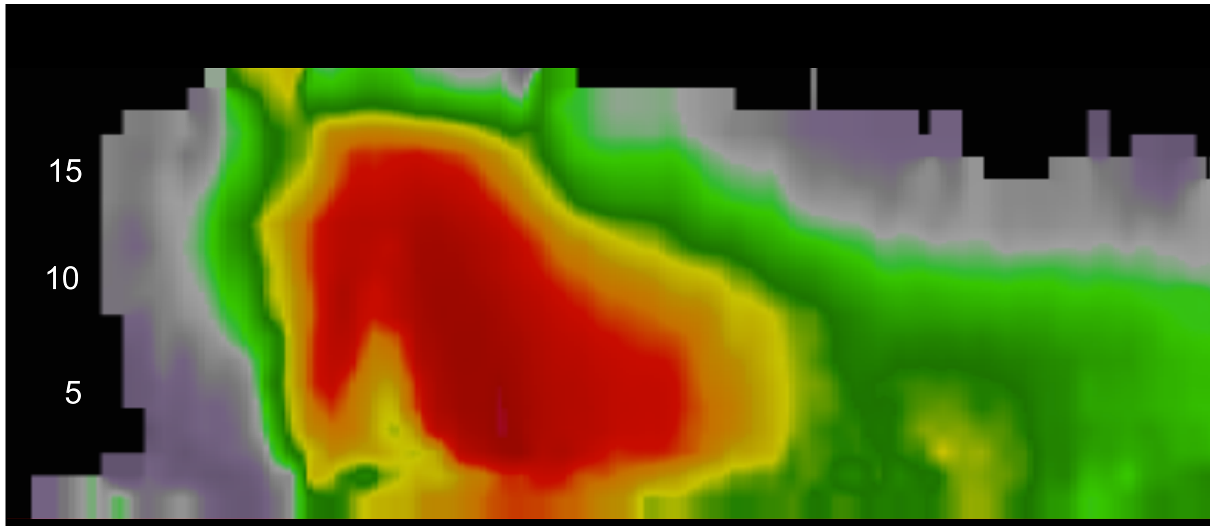
Vertical distribution of flash size

07/16/2009 Supercell

Cross-Section A





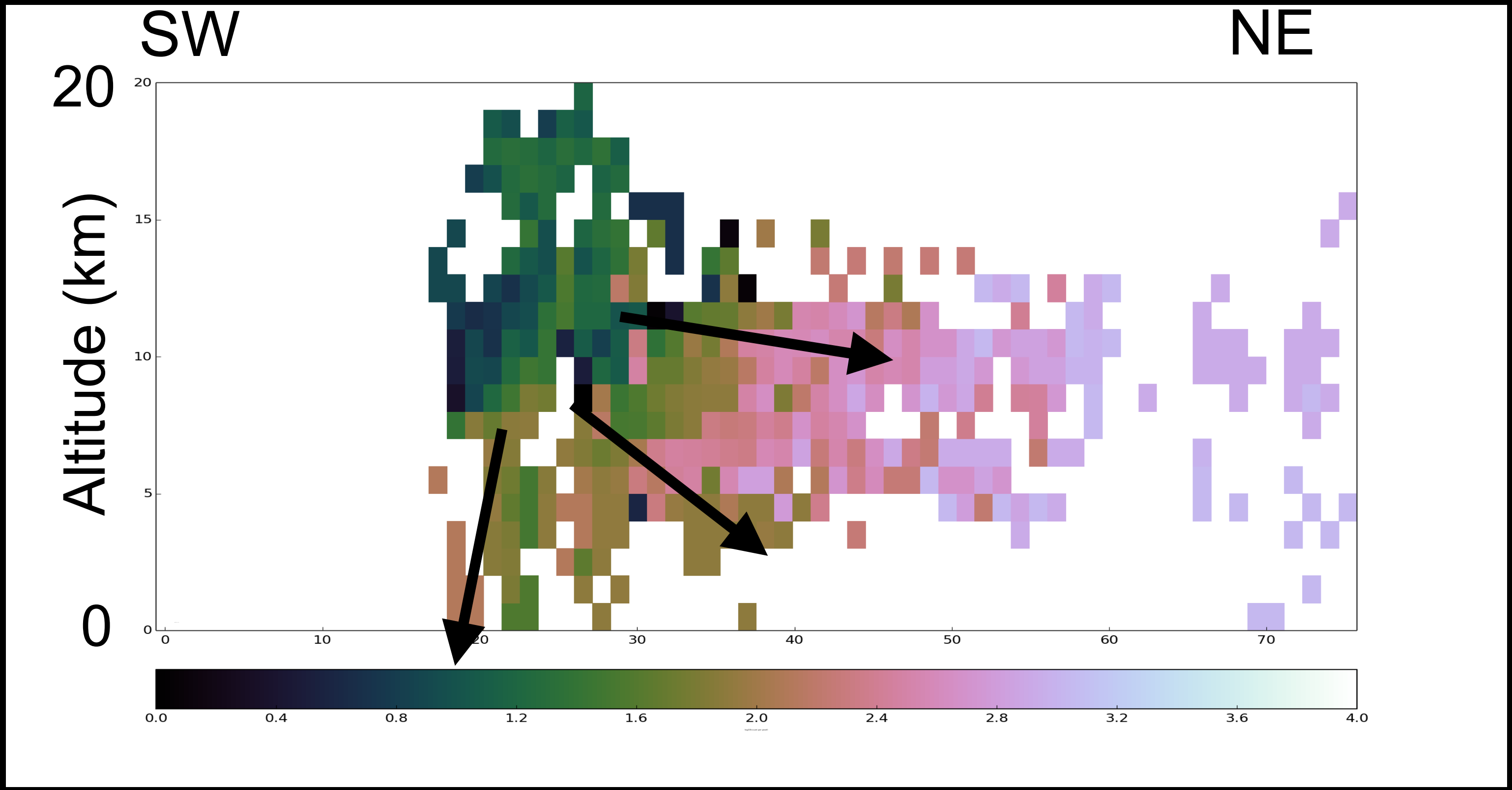


Radar Reflectivity

Analysis: P. Ware

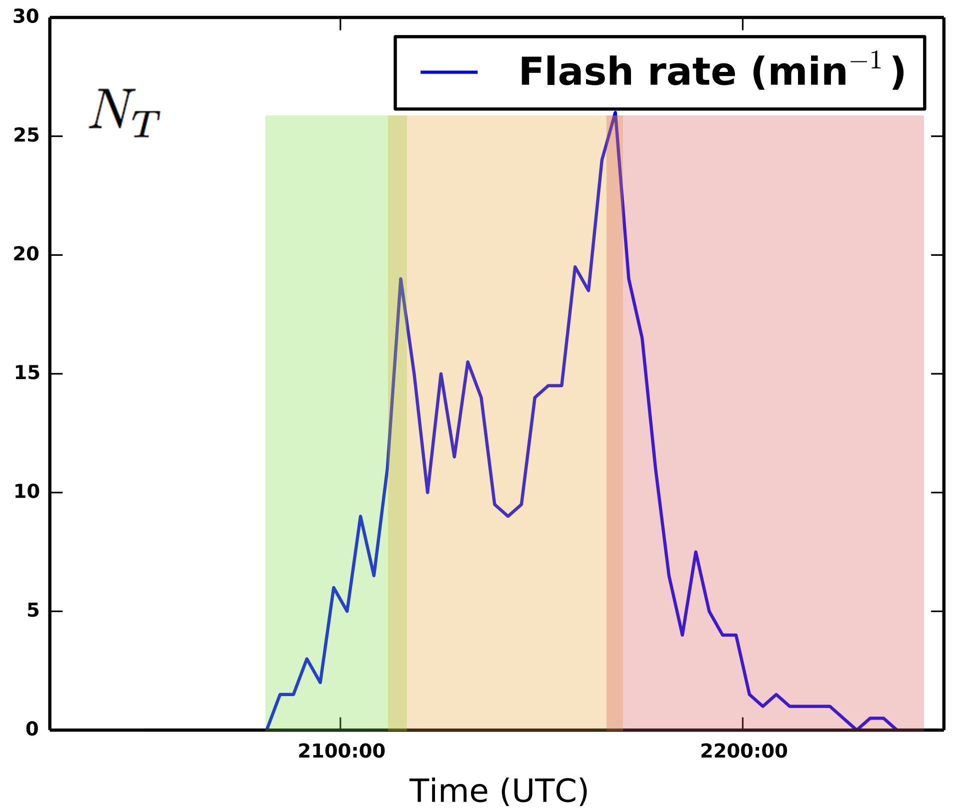
Summary of spatial distribution of flash sizes

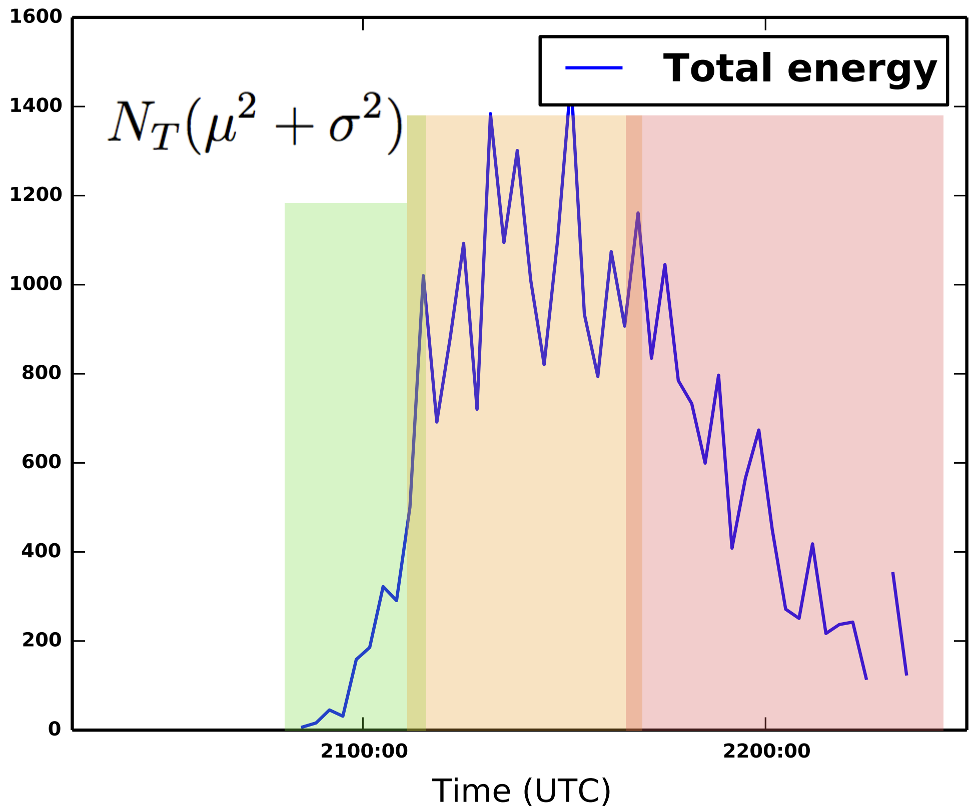
- Top of updraft is smallest sizes.
- Average flash size increases in sedimentation- or advection-dominated regions with less turbulence
    - At lower altitudes near the updraft
    - Toward forward anvil
    - Toward stratiform region
    - Gradient in flash size is directed along the storm-relative 0-8 km bulk shear vector
- Vertical wind shear and sedimentation trajectories link meteorology to spatial distribution of flash size:

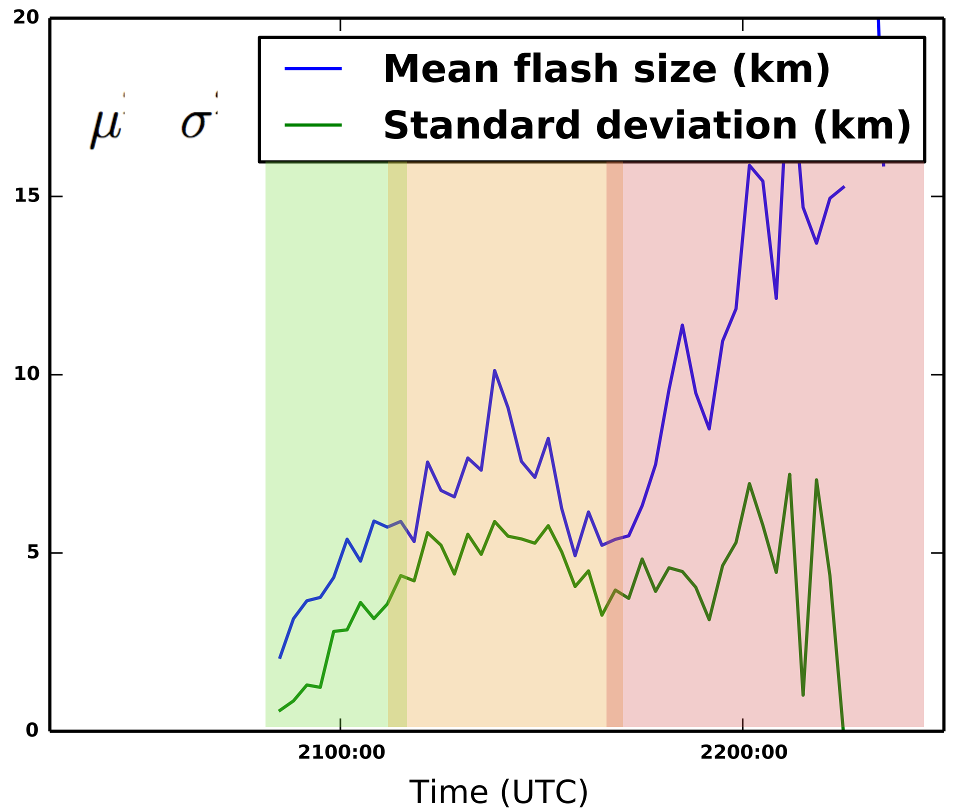


Analysis: P. Ware

22 June 2012 - DC3 IOP 21a - isolated cell in Colorado
Meteorological lifecycle and flash trends
from moments of the flash size distribution







Establishment

- Flash rates and total energy increase
- Small flashes
- Dominated by active convection

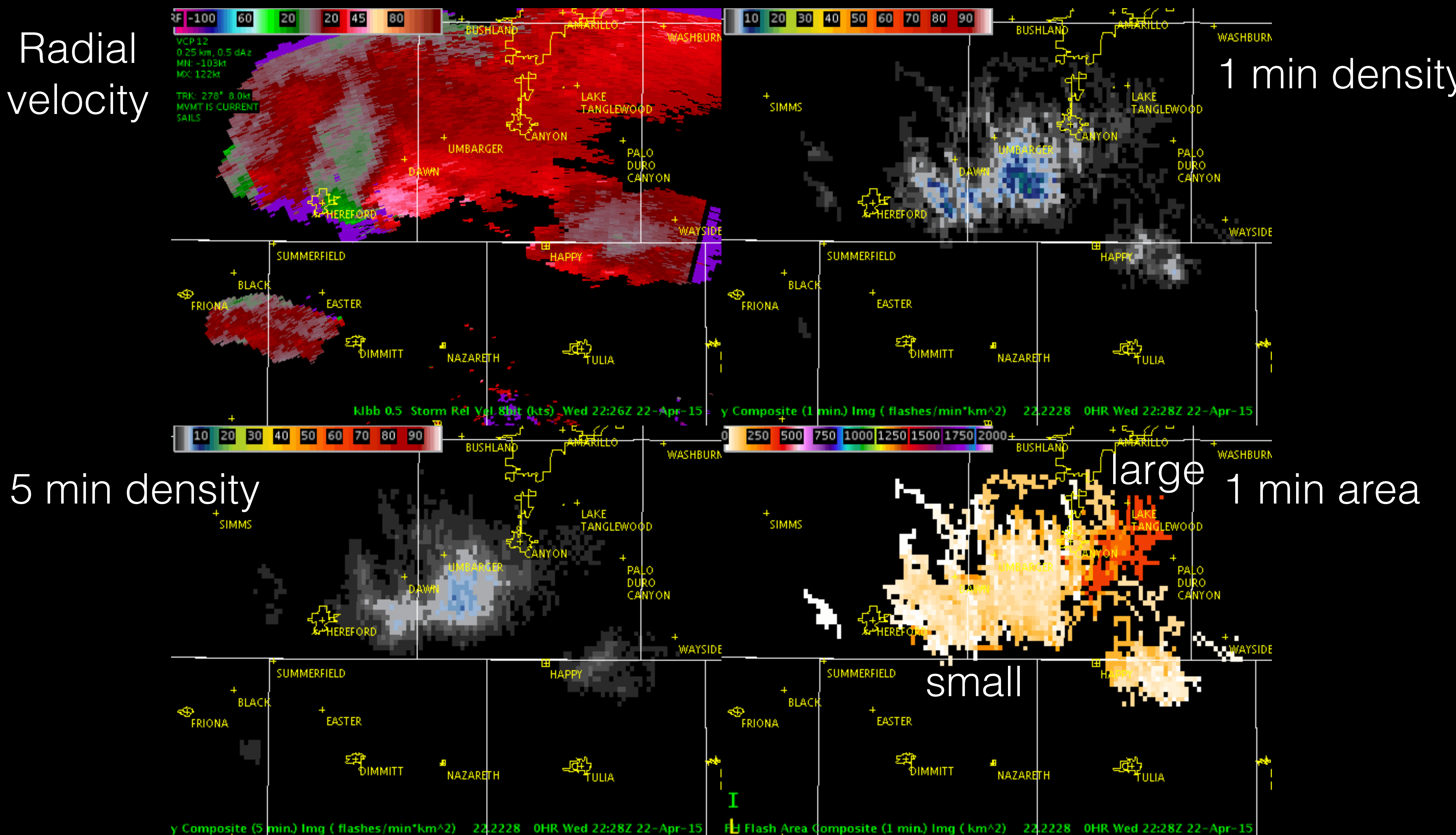
Modulation

- Average flash size fluctuates between 5-10 km wide
- No discernible energy trend as anticorrelated size and rate balance

Decay

- Sizes increase
- Rates decrease
- Energy decreases less quickly. Consumes energy stored earlier

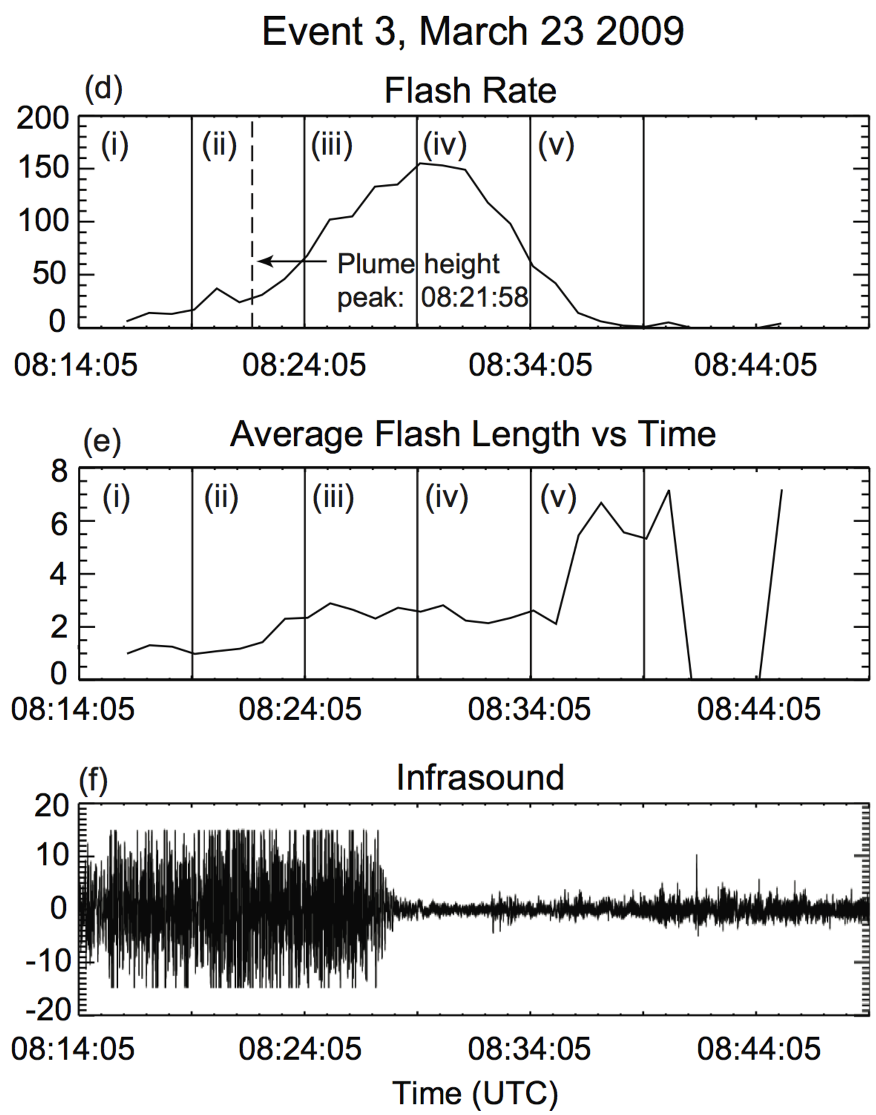
Real-time flash area products in AWIPS-II at NWS Lubbock — prototype with NSSL/OU (Calhoun, Kingfield)

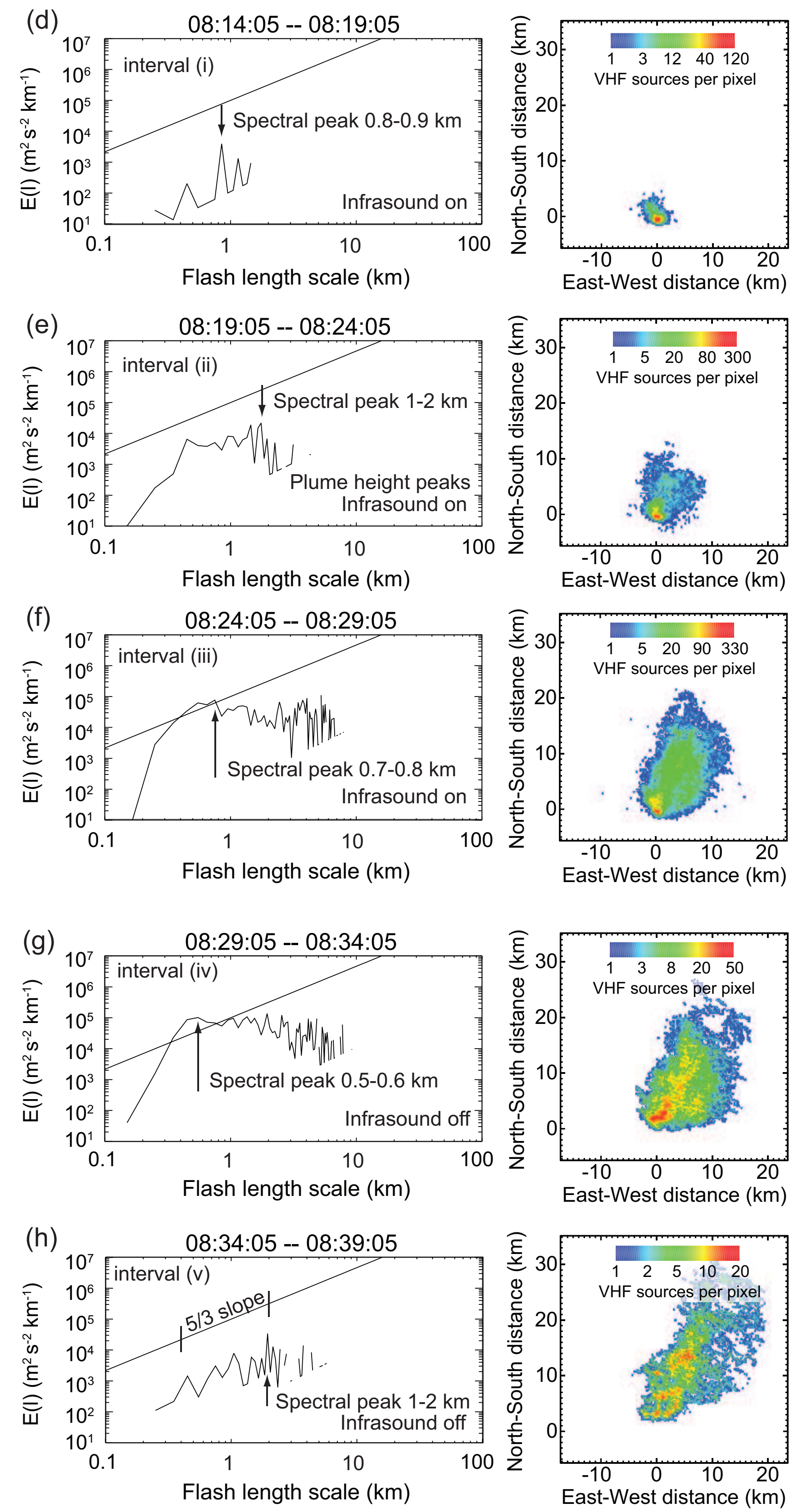


Cell-lifecycle and turbulence thinking works in volcanoes

(Behnke & Bruning 2015, GRL: 10.1002/2015GL064199)

- Infrasound indicates active eruption (gas-thrust phase) along with buoyant convection.
- Initial turbulent convection and small flashes transitioned to less-turbulent flow and large sizes at anvil level.
- Anticorrelation of size, rate was obvious due to impulsive nature of event.
- Shift to peak of energy distribution due to superposition of two forcing modes (gas-thrust, buoyant) for turbulent convection





- Statistics of flash size in LMA data (suggested by energetics) have meteorological applications. Size data can be presented in grid and time series form and calculated simply from the flash metadata.

- A longer time series and/or large ensemble of flashes seems to help with clustering uncertainty — while the details of the lightning physics are highly interesting, it’s the trends that matter for meteorological applications.

- GLM and MTG LI have obvious group and flash metadata analogues to LMA flash size and energy: footprint and radiance.

- GLM and MTG LI will be the first long time series observations of optical pulses over large areas. Might we find similar signals that complement (add value to) flash counts? LMA data suggest that’s the case.