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Initial observations from the Kinematic Texture and Lightning (KTaL) Experiment

Eric C. Bruning[1], V. C. Sullivan[1], V. Salinas[1], S. M. Berkseth[1], P. J. Ware[2], and S. A. Weiss[2]

[1] Amospheric Science Group, Texas Tech University, Lubbock, TX; [2] CIMMS/University of Oklahoma, Norman, OK

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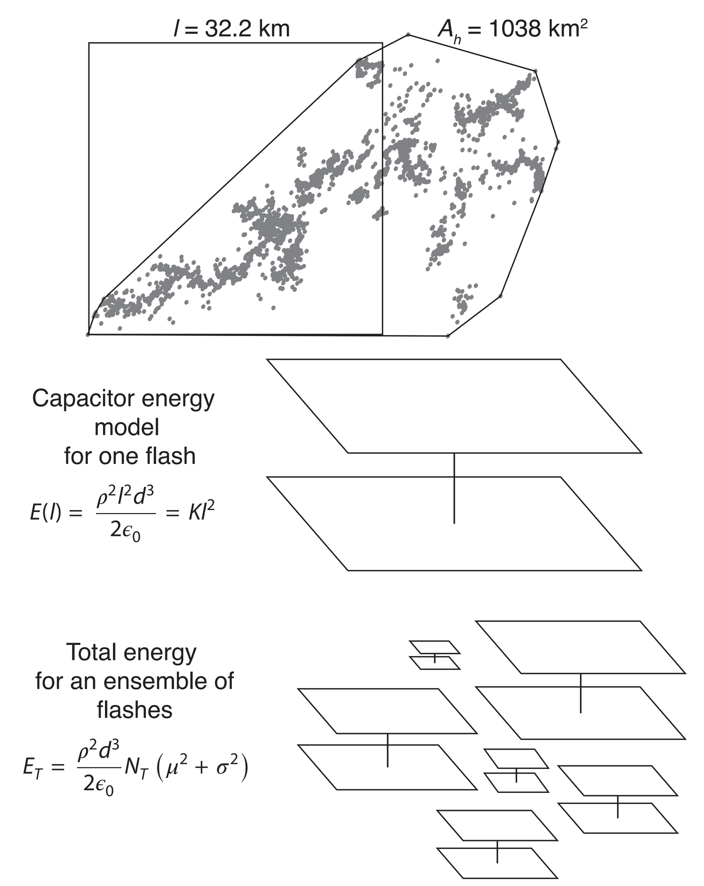
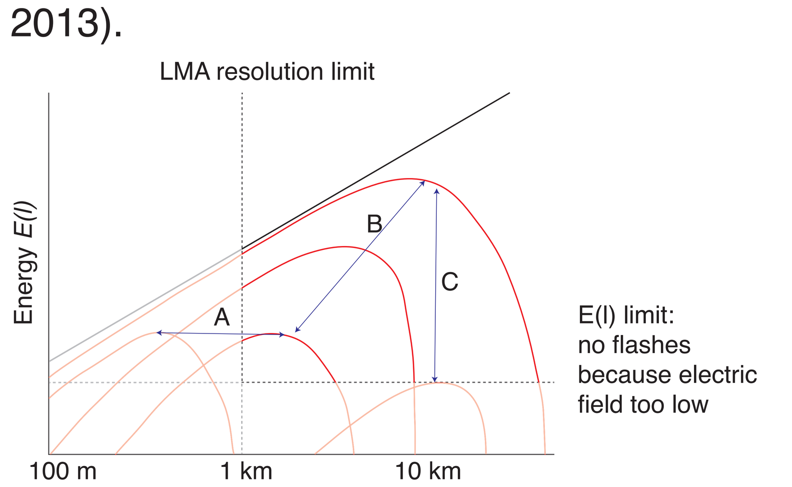
Motivation

Many more lightning flashes happen inside clouds than come to ground, and modern VHF Lightning Mapping Arrays (LMAs) readily detect these flashes in four dimensions. In addition to providing a count of flashes, these systems also map the complete extent of the flash in the cloud.



As shown above, total flash energy can be calculated from LMA data and depends on moments of the flash size distribution (Bruning and Thomas, 2015). Furthermore, the flash energy distribution varies with length scale much like a Kolmogorov spectrum, including a 5/3 scaling regime (Bruning and MacGorman, 2013).



The distribution of flash sizes may shift depending on the average flash size (A) or the total number of flashes (C) or its width. Observed variability (including in volcanoes; Behnke and Bruning, 2015) typically shows both (B).

Size and rate typically both increase as storm begins, and are anticorrelated during for the rest of the storm's life. Ware (2015) showed that flash size gradient ascends along storm relative shear and sedimentation trajectories, and that the smallest flashes and largest rates are near the tops of updrafts.

Purpose

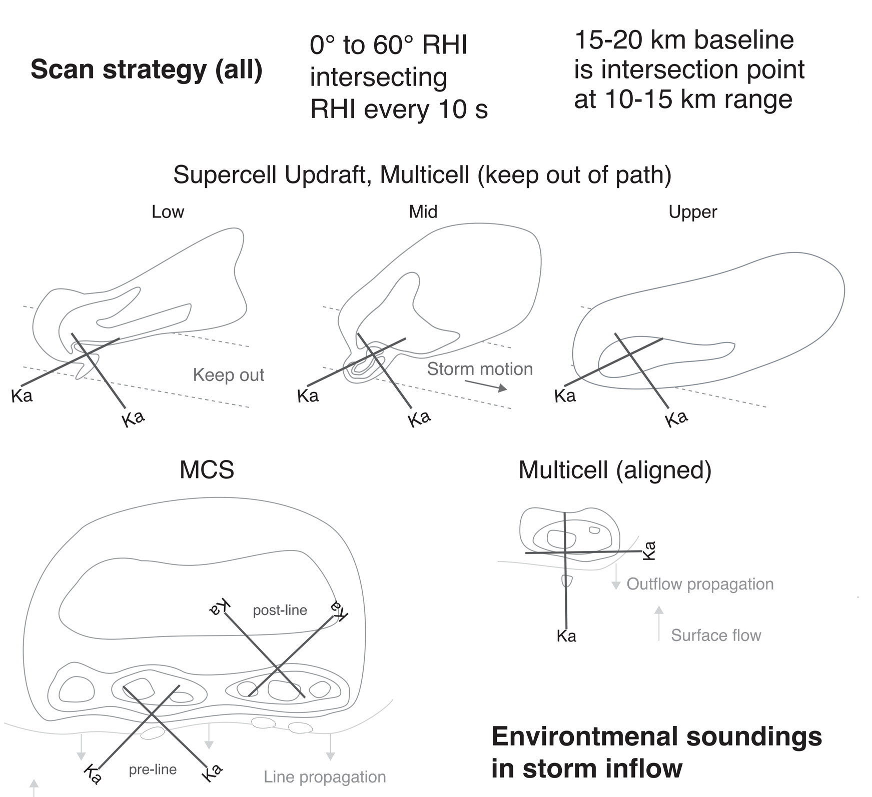
Together these factors lead us to hypothesize that turbulence associated with eddy-scale convective overturning (Williams, 1985; Weinheimer, 1987) is largely responsible for organizing charge into small pockets which are discharged by lightning (Coleman et al., 2003; Maggio et al. 2005). The purpose of the 2014-2016 Kinematic Texture and Lightning Experiment is to quantitatively compare turbulence inferred from weather radar data to conicident lighting flash size variability.

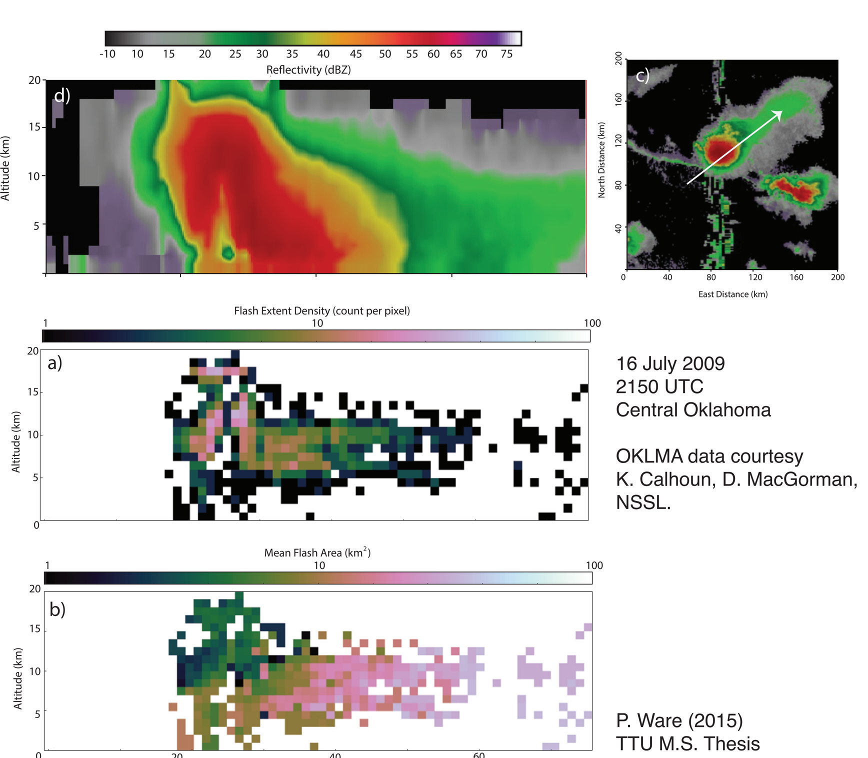
Methods

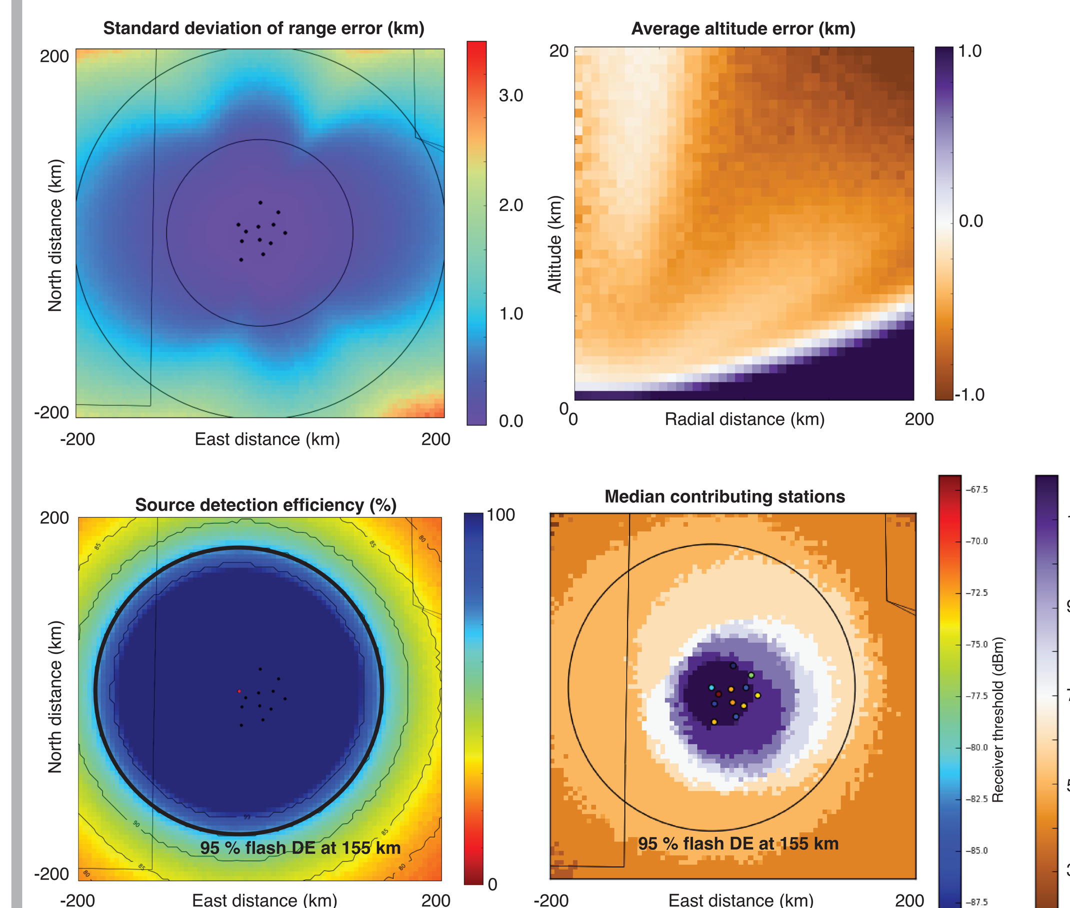
Use lightning flash area and flash volume to characterize energy dissipated by each flash. Ongoing work by Salinas (2015 AGU Fall Meeting) is retrieving charge densities constrained by the breakeven electric field initiation threshold.

Characterize turbulent kinematics using mobile weather radar data. Berkseth et al. (poster this session) provides more details.

Observation strategy







Instruments

West Texas Lightning Mapping Array

Number of stations:	12 (2 mobile)
Receive Frequency:	60-66 MHz
Mapping Technique:	GPS Time of Arrival
Timing precision:	25 ns
Trigger rate (max):	12,500 per second
Typ. points per flash:	10-1000
Location precision:	O(10) meters (over network)
Range (3D/2D):	100 km / 250 km
Temporal coverage:	Continuous

Monte-carlo simulation of WTLMA error characteristics

This model characterizes location precision and detection efficiency. Sources are emitted with a realistic power spectrum, and propagated to each receiver. Station locations introduce azimuthal asymmetry to errors. Use of observed receiver thresholds (environmental noise floor) introduces additional asymmetries that vary from day to day.

BOLT: Ballooning and Observation Laboratory for Thunderstorms

Vehicle:	Freightliner Sprinter 2500, high roof Factory aux battery; variable high idle
Cabin:	2+2 seating, roof-mounted A/C
Sounding system:	Vaisala DigiCORA MW41 RS92-SGP sondes, 400 MHz 2 helium tanks and launch tube
Communications:	VHF radio, cellular data modem 4.5 m pneumatic mast, roof-mounted

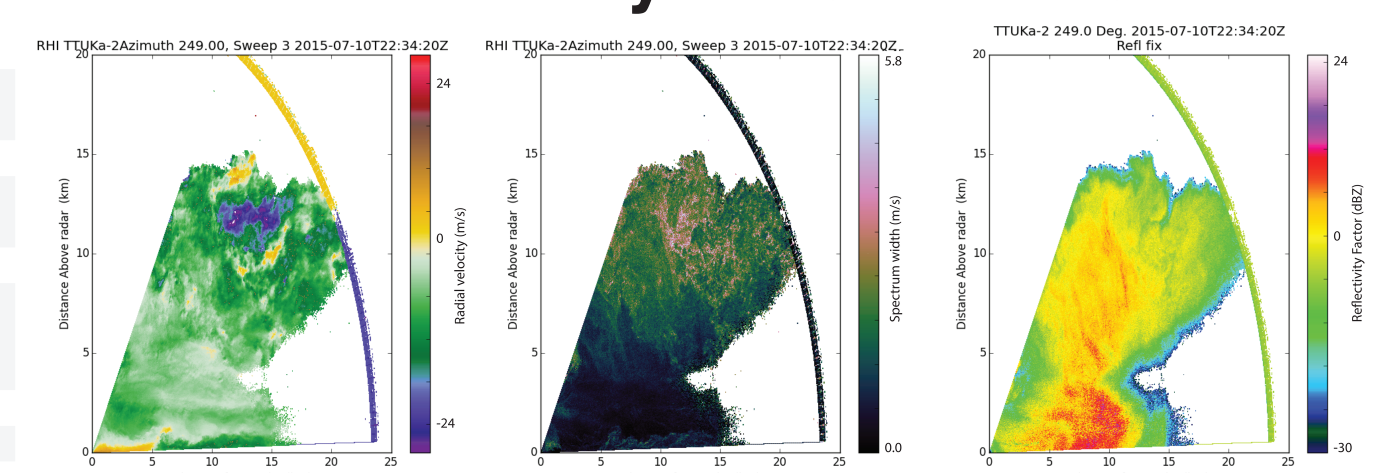
TTU Ka-band mobile Doppler radars

Transmit Frequency:	34.86 GHz (wavelength: 8.6 mm)
Transmit Power:	200 W peak, 100 W average
Transmitter Type:	**TWTA, up to 50% duty cycle**
Antenna Type:	Cassegrain feed, epoxy reflector
Antenna Beamwidth:	**0.33 degrees**
Polarization:	Linear, horizontal
Waveguide:	WR-28, pressurized
PRF:	Variable, up to 20 KHz
Gate Spacing:	**9 m (pulse compression)**
Receiver MDS:	-118 dBm
IF Frequency:	60 MHz
Pedestal System:	Orbit AL-4016
DSP:	Sigmet RVP-9
Vehicle:	Chevy C5500 Crewcab; 15' flatbed
Stabilization:	Computer assisted hydraulic leveling
Moments:	Reflectivity, radial velocity, spectrum width

Cases to Date

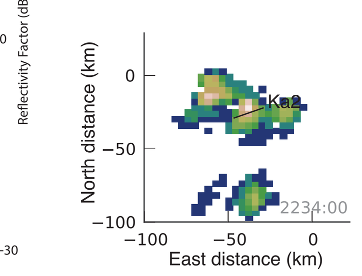
Date	Storm Mode	Deployment Location:	Radiosonde Launch (UTC)	Ka-1 Scans (UTC)	Ka-2 Scans (UTC)	Possible Dual Doppler Scans (UTC)	Ka1 lat	Ka1 lon	Ka2 lat	Ka2 lon
05/25/14	Multicell	Slaton	NA	0219-0350	0205-0346	0219-0346	33.46258	-101.67542	33.39560	-101.60680
		Lubbock					33.48718	-101.89252	33.47616	-102.06165
05/26/14	Squall line	Littlefield	NA	0353-0548	0348-0550	0353-0548	33.76336	-102.17293	33.87933	-102.15456
		Shallowater							33.73708	-102.02688
06/07/14	MCS	Spade	NA		0144-0255				33.98316	-102.15428
06/08/14	Supercell	Roaring Springs	NA		0110-0352				33.89167	-100.79614
		New Deal							33.73732	-101.84326
06/09/14	MCS	Abernathy	NA		0642-0732				33.94875	-101.85426
06/29/15	Squall line	Littlefield	2147	2146-0031	2127-0029	2146-0029	33.78537	-102.34583	33.90716	-102.39993
		Anton					33.73731	-101.96632	33.83704	-102.20798
		New Deal					33.73734	-101.85448	33.73697	-101.71645
07/04/15	MCS	Olton	0447	0443-0633	0447-0632	0447-0632	34.18830	-102.16474	34.18824	-101.99068
07/06/15	Multicell	Shallowater	2121	2104-0157	2135-0204	2135-0157	33.73492	-102.02699	33.81676	-102.02745
07/07/15	MCS stratiform	Post	0601	0539-0648	0450-0652	0539-0648	33.28581	-101.39397	33.21759	-101.43405
		Reese Center					33.66461	-102.00955	33.53104	-102.00910
07/10/15	Multicell	S Littlefield	0116	0122-0504	0123-0506	0123-0504	33.87331	-102.32767	33.75645	-102.32774
07/10/15	Multicell	Ropesville	2300	2226-2253	2217-2253	2226-2253	33.30546	-102.13410	33.40950	-102.09339
07/11/15	Multicell	O'Donnell	NA	0058-0254	0116-0255	0116-0254	32.97823	-101.84190	33.96381	-102.01155
		Near Tahoka					33.16708	-101.90841	33.16667	-102.05418

10 July 2015 - Multicellular storm



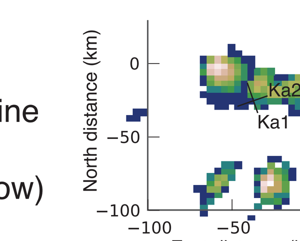
Through core of cell

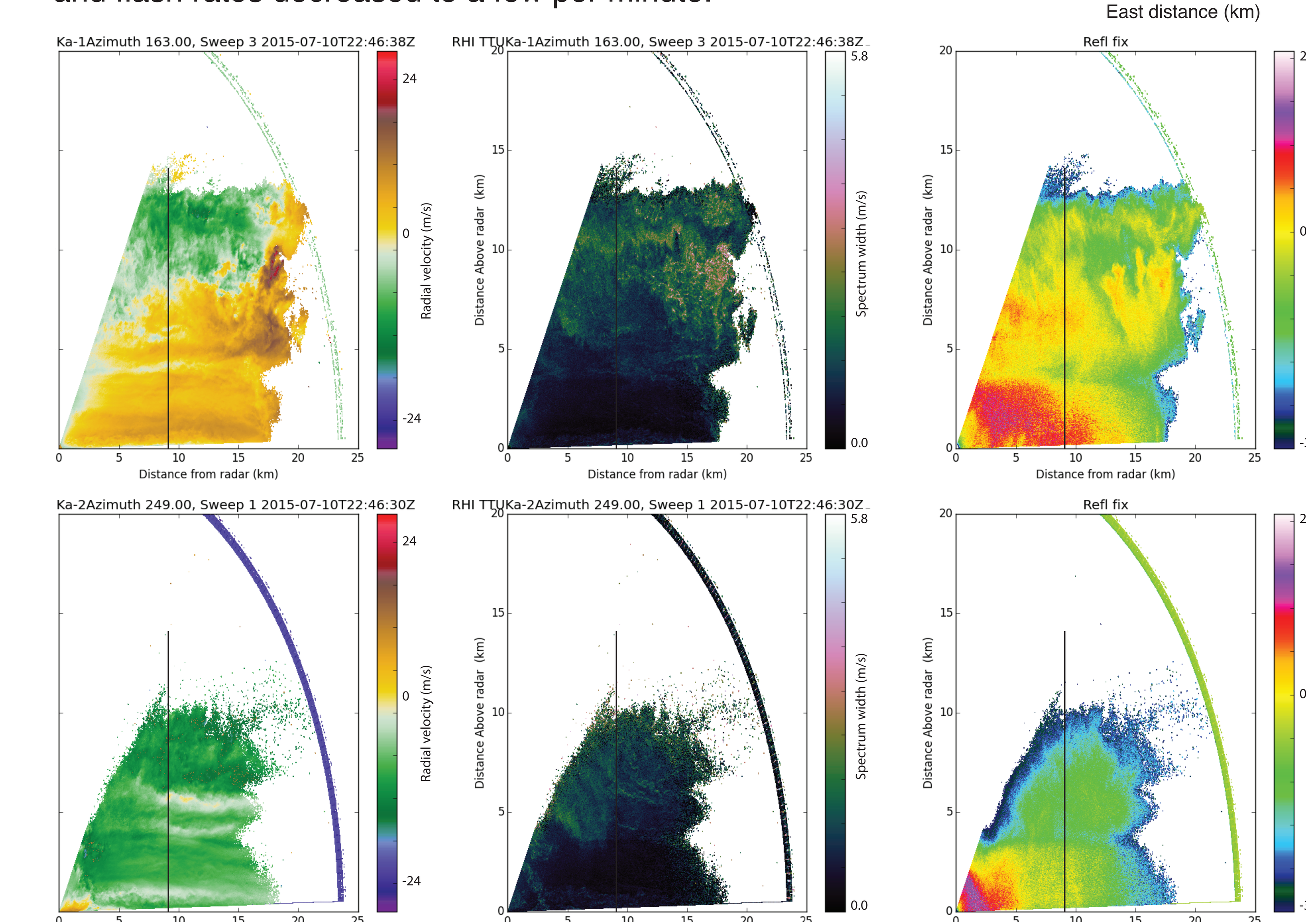
Convective overturning and large spectrum width and variable resolved velocities. Flash rates of 25 min⁻¹.



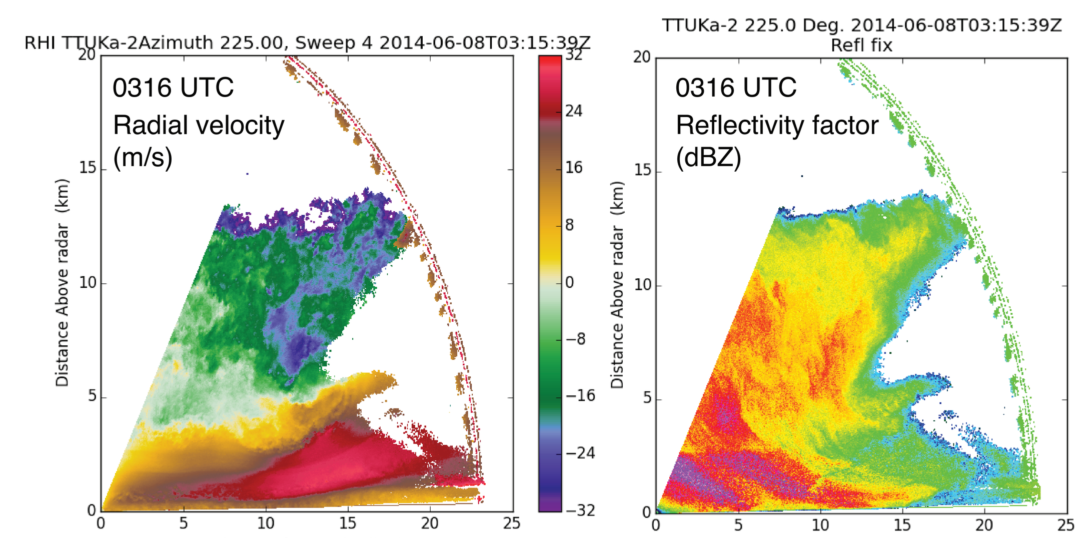
Dual-Doppler at RHI intersection

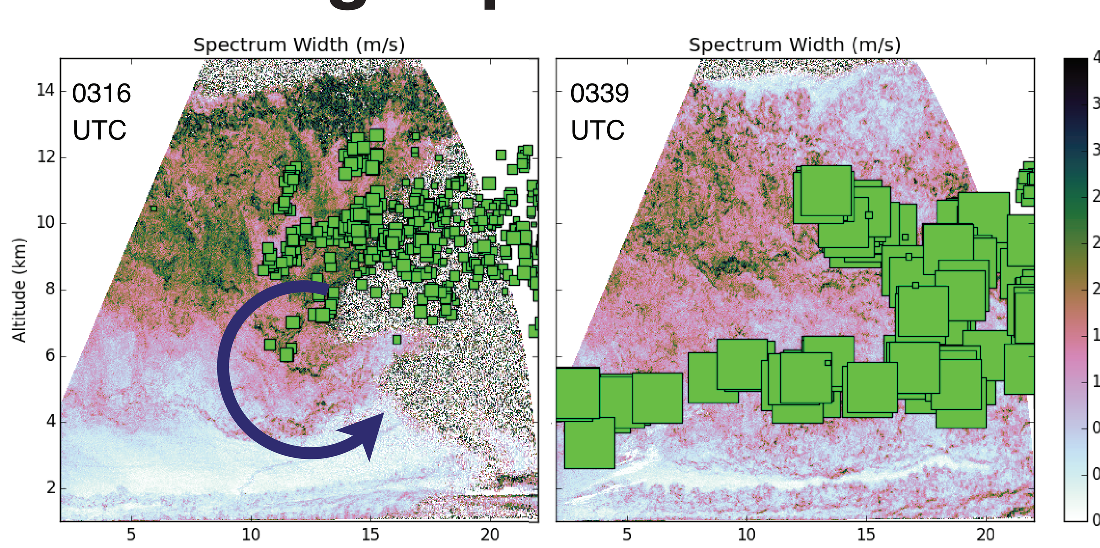
Simultaneous scans intersected at 9 km range (vertical black line to 15 km altitude). Compared to 13 min earlier, velocities were less variable as the storm moved away from Ka1 (below, top row) and flash rates decreased to a few per minute.





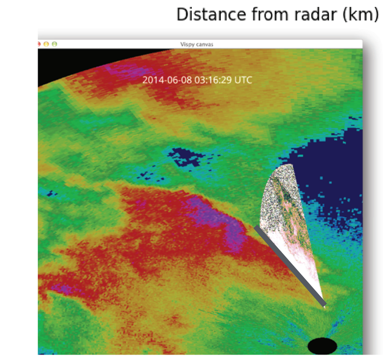
7-8 June 2014: Left-moving supercell





Fewer, larger flashes as spectrum width decreases

Along the forward flank: velocity couplet and S-shaped band of elevated spectrum width associated with horizontal vorticity $\sim 0.02\ s^{-1}$



LMA sources from flashes within 10° of RHI

Size of symbol is area of flash to which source belongs