

LMA Tutorial Workshop

Paul Krehbiel, William Rison, Ronald Thomas
New Mexico Tech
Socorro, NM

2015 GLM Cal/Val Forum
NSSTC/UAH
Huntsville, Alabama
9-11 September 2015

LMA Station (Briggsdale, CO)

Solar powered; cell data modem comm links



South Ontario LMA

- **Environment Canada, Toronto (David Sills; Helen Yang)**
- **14 station network; furthest north LMA (44 deg. Latitude)**
- **Will be used to help validate GLM observations**
- **Look at recent storms on 18 July 2015 over Lake Ontario**
- **CG lightning all bolt-from-the-blue negative discharges**

- **Data file: LYLOUT_150718_054000_0600.dat.gz**
- **Location: /DATA/toronto**

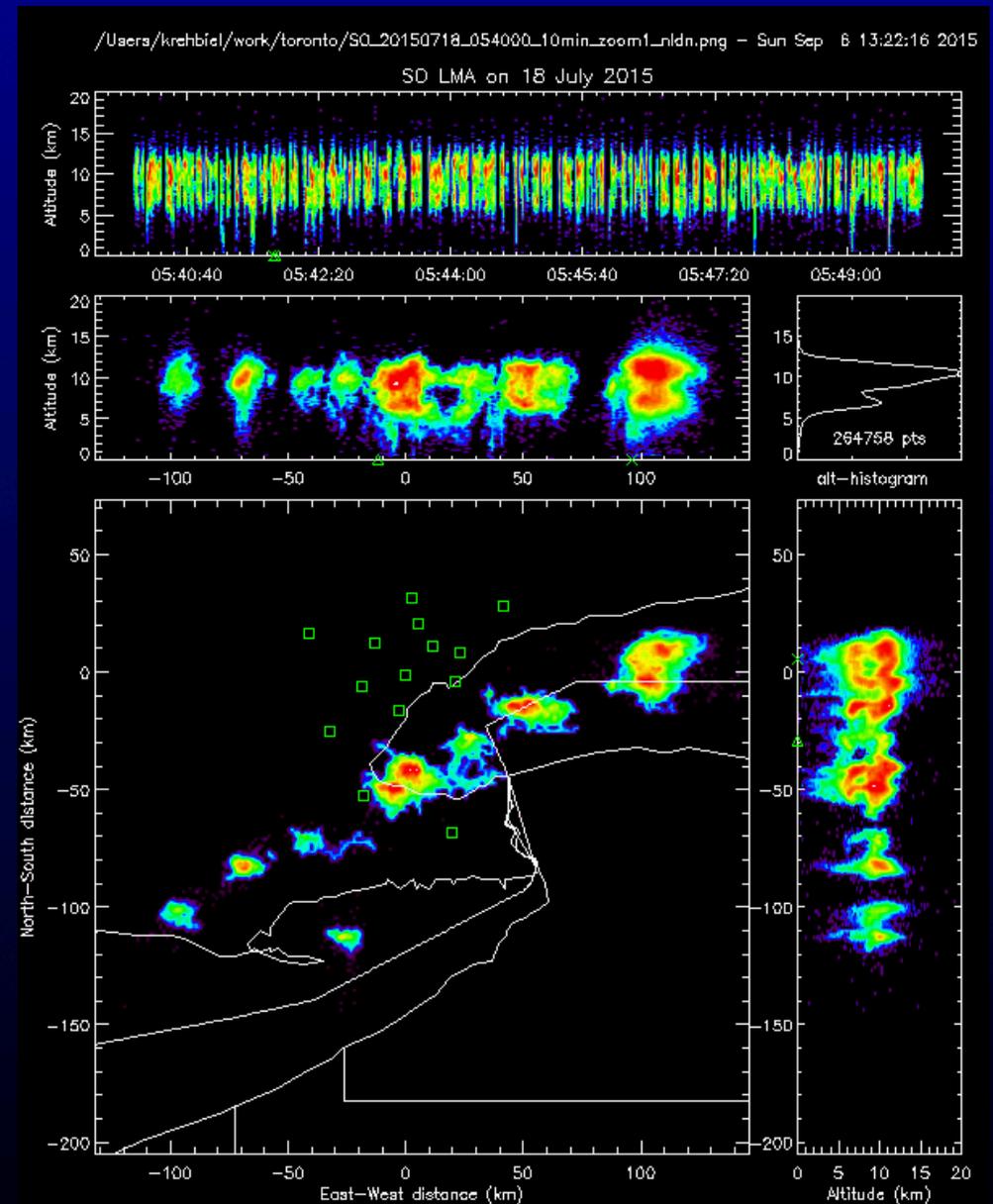
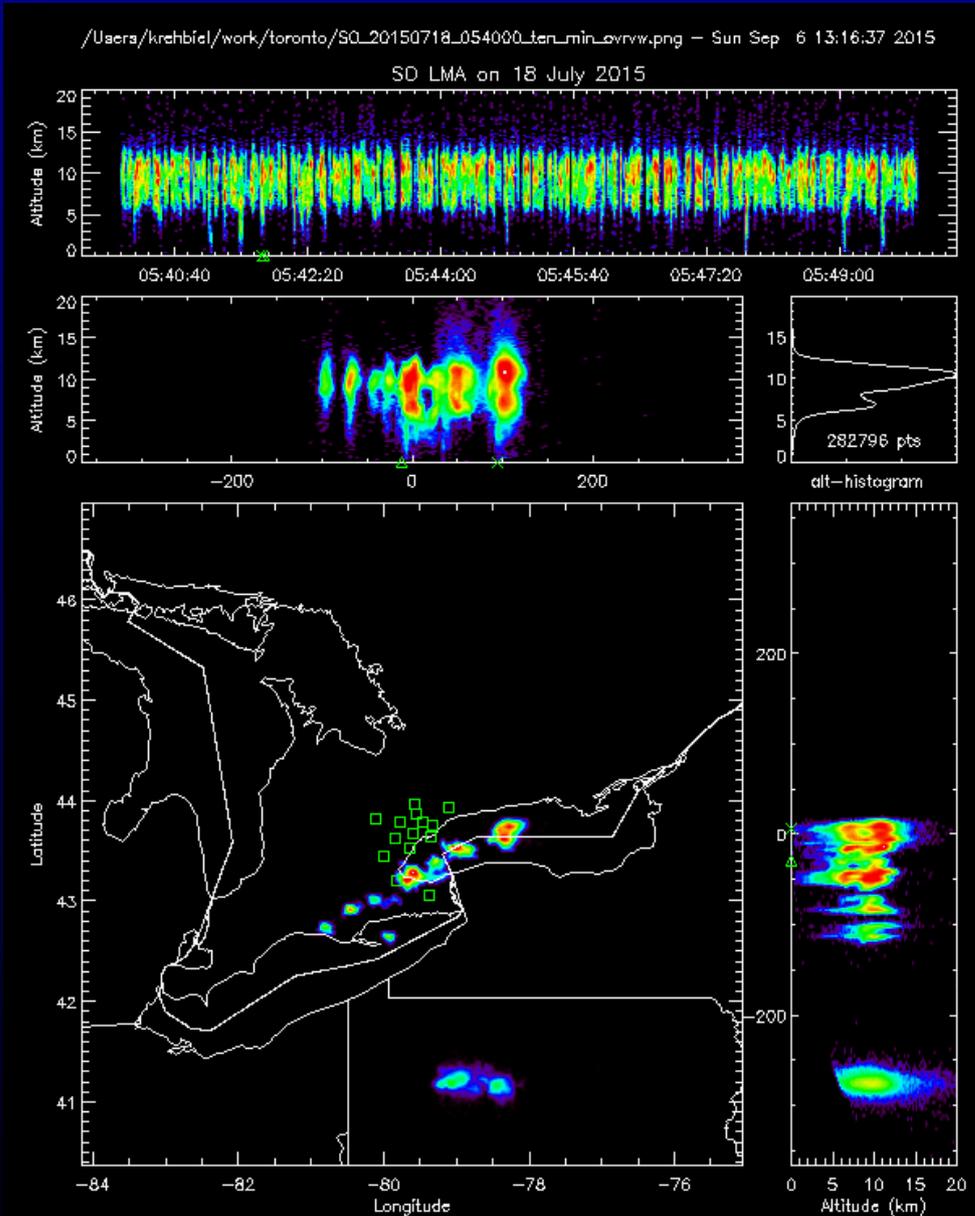
Bolt from the blue; 18 July 2015 05:41:46 UTC



Overview of lightning activity, 18 July 2015

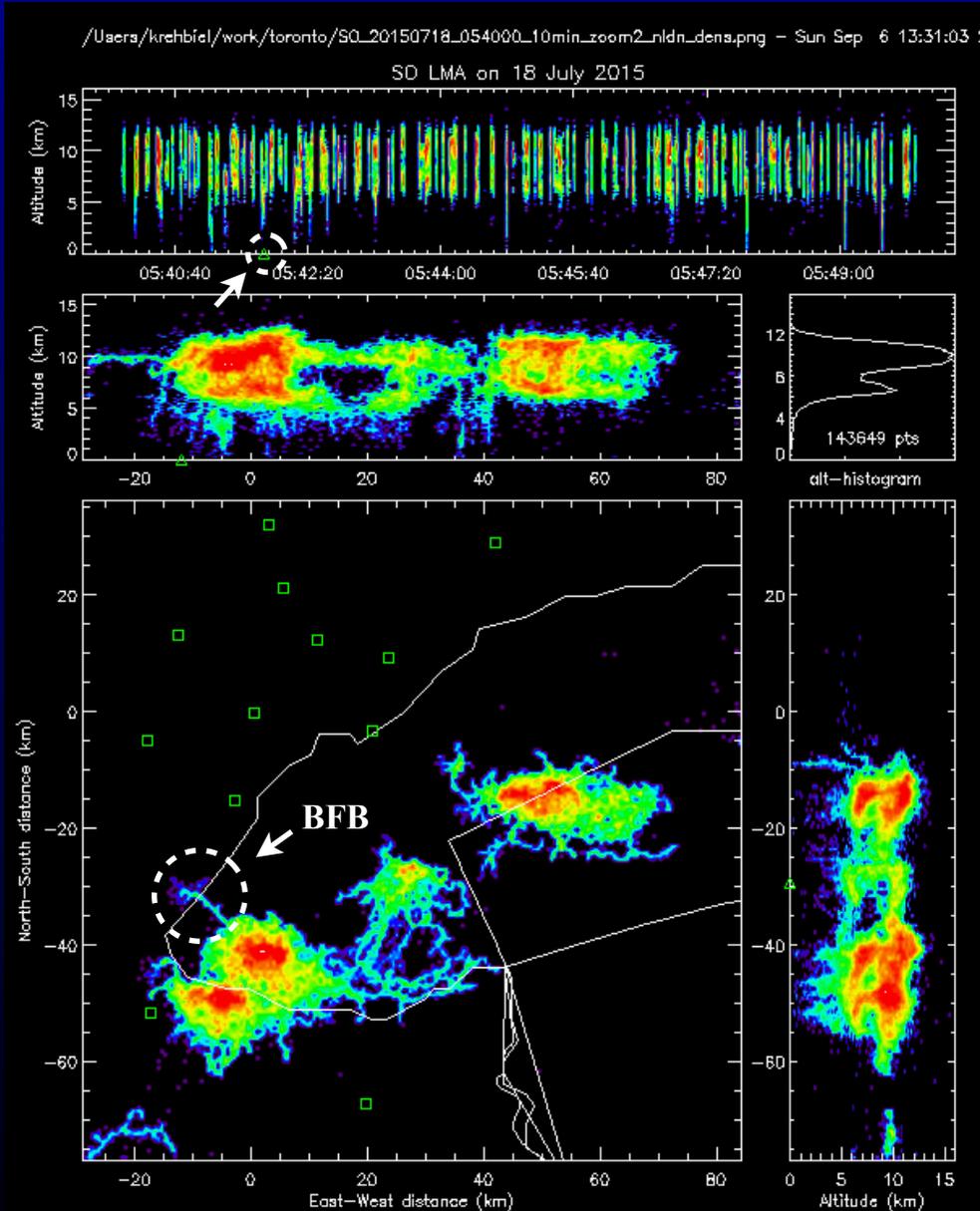
10-minute data file
580,000 VHF sources; density plots

Zoomed-in view

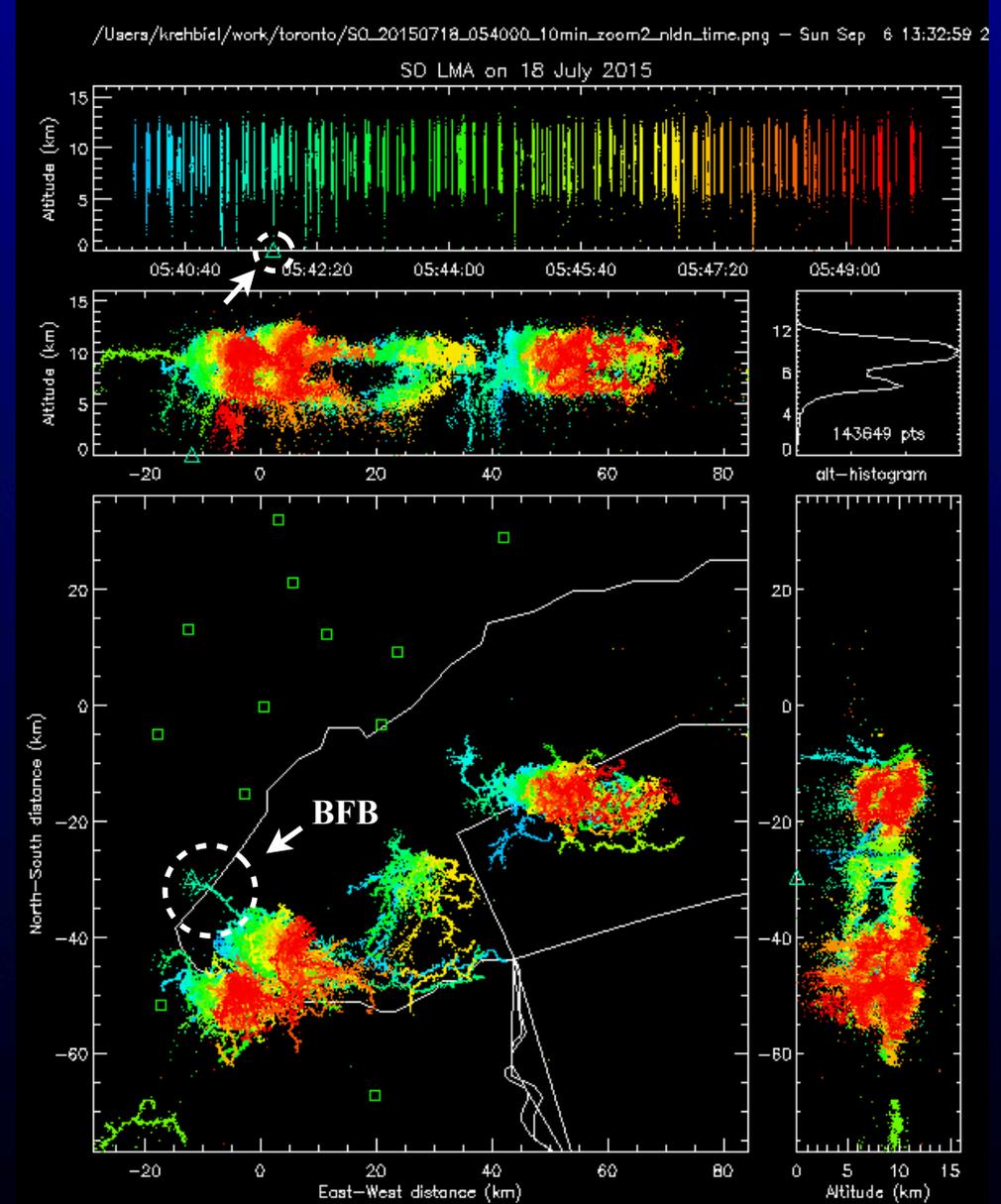


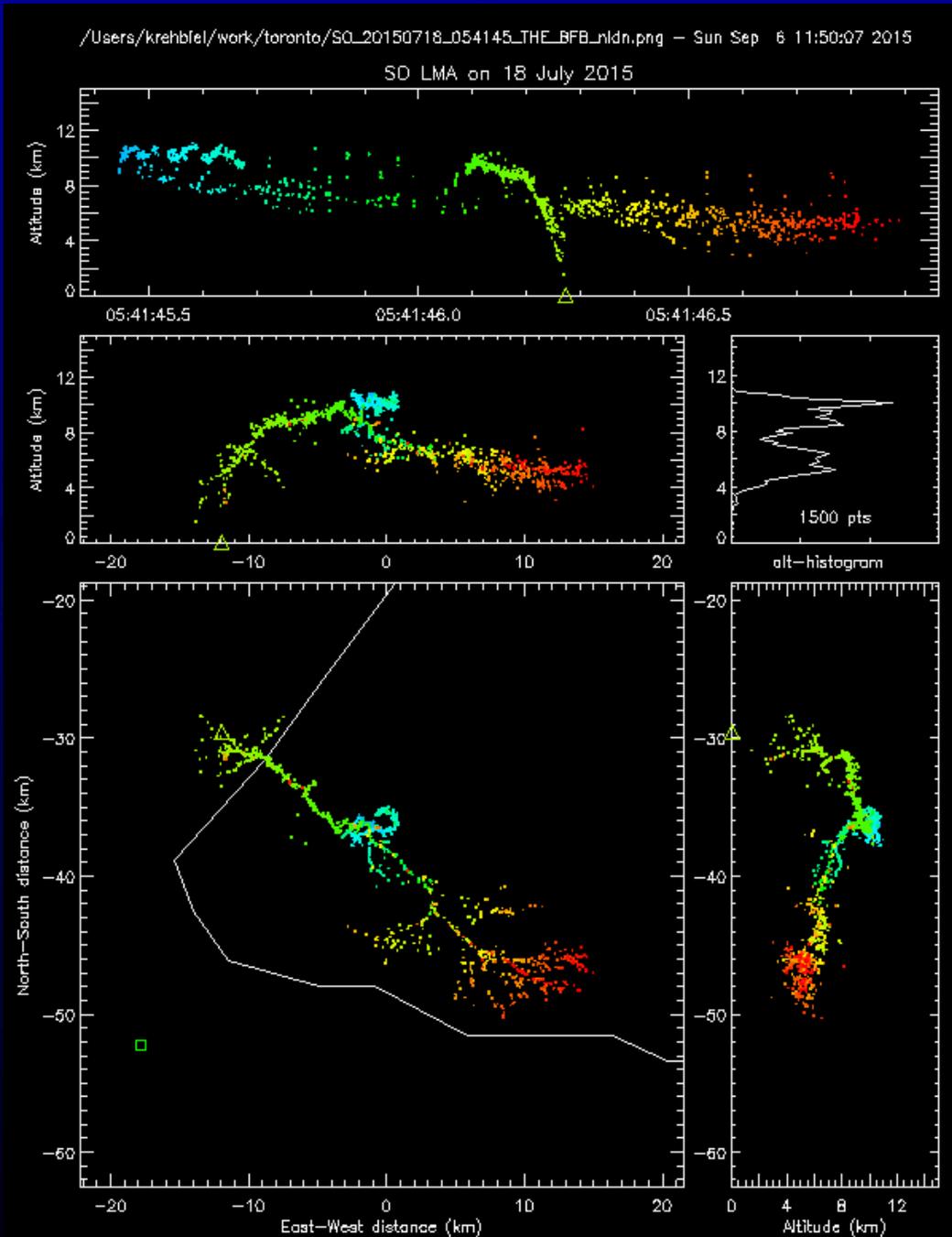
Overview of lightning activity, 18 July 2015

10-minute data file
580,000 total VHF sources; density plot



Individual sources; numerous bolt from the blue flashes (tentacles outside storm)



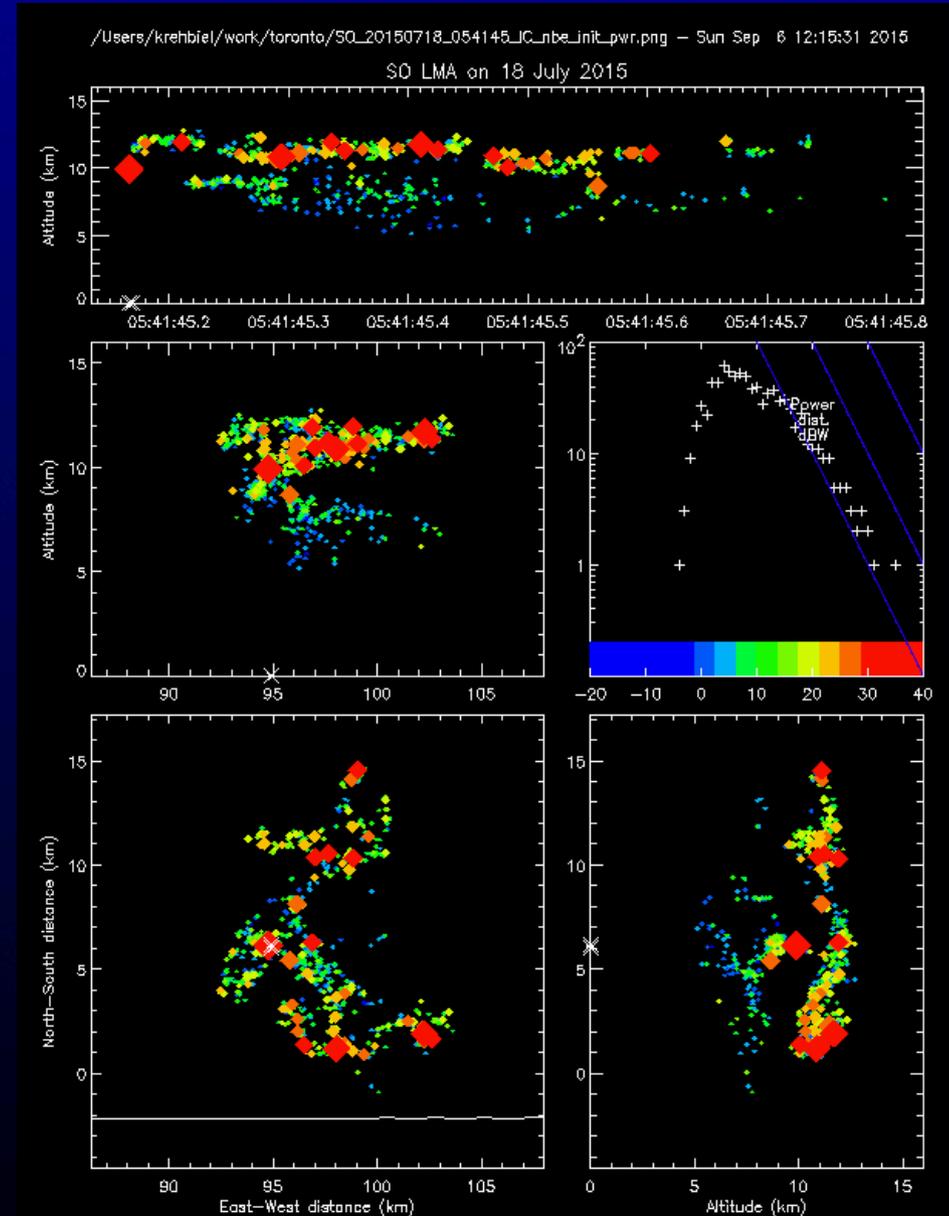
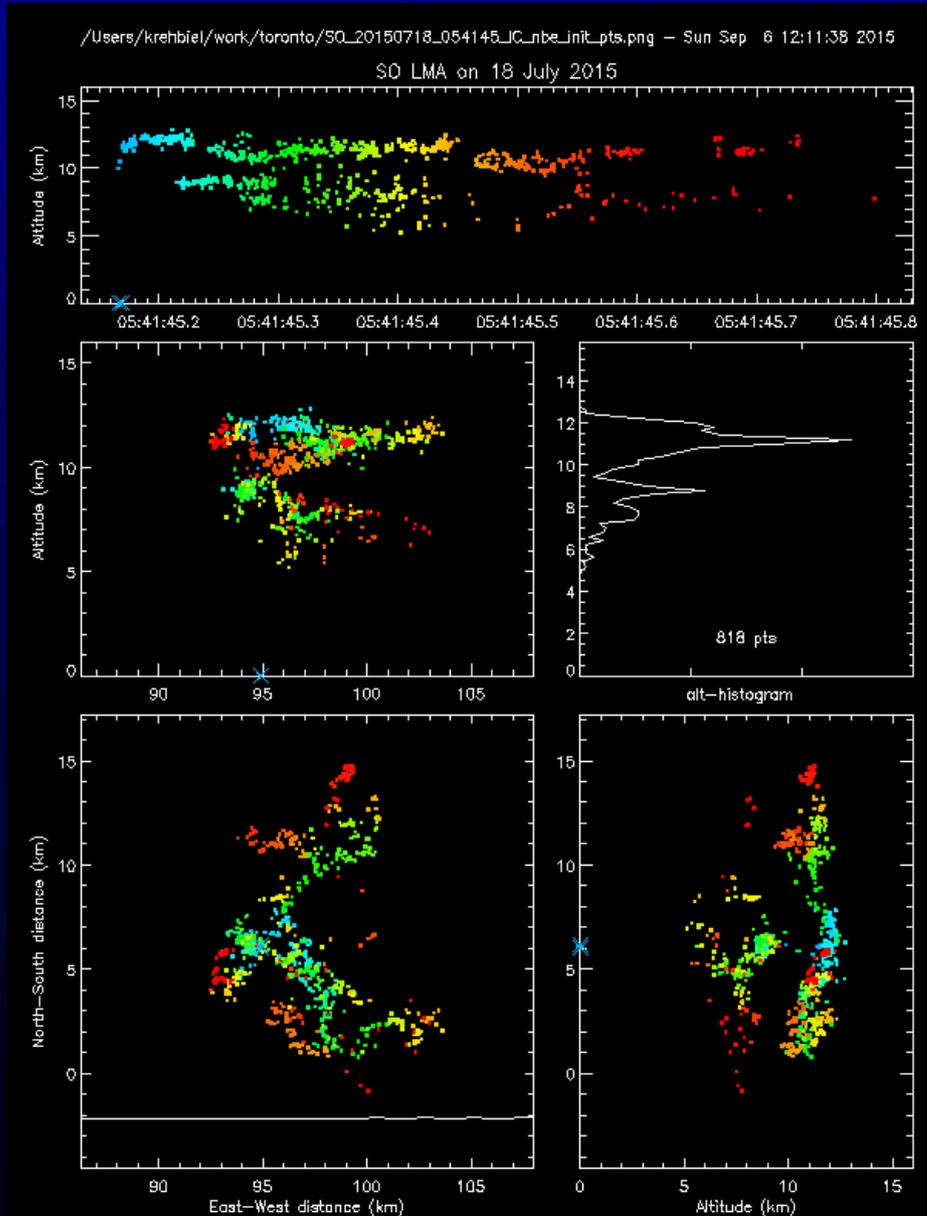


- Bolt from the blue (BFB) 05:41:46 UTC
- Hit ground ~10 km away from core
- Two ground contact locations (!)
- 41.0 kA negative CG stroke (triangles)
- Quiz: Roughly where was photo taken?

Intracloud flash (separate storm)

Normal polarity bilevel IC flash between mid-level (-) and upper (+) storm charges

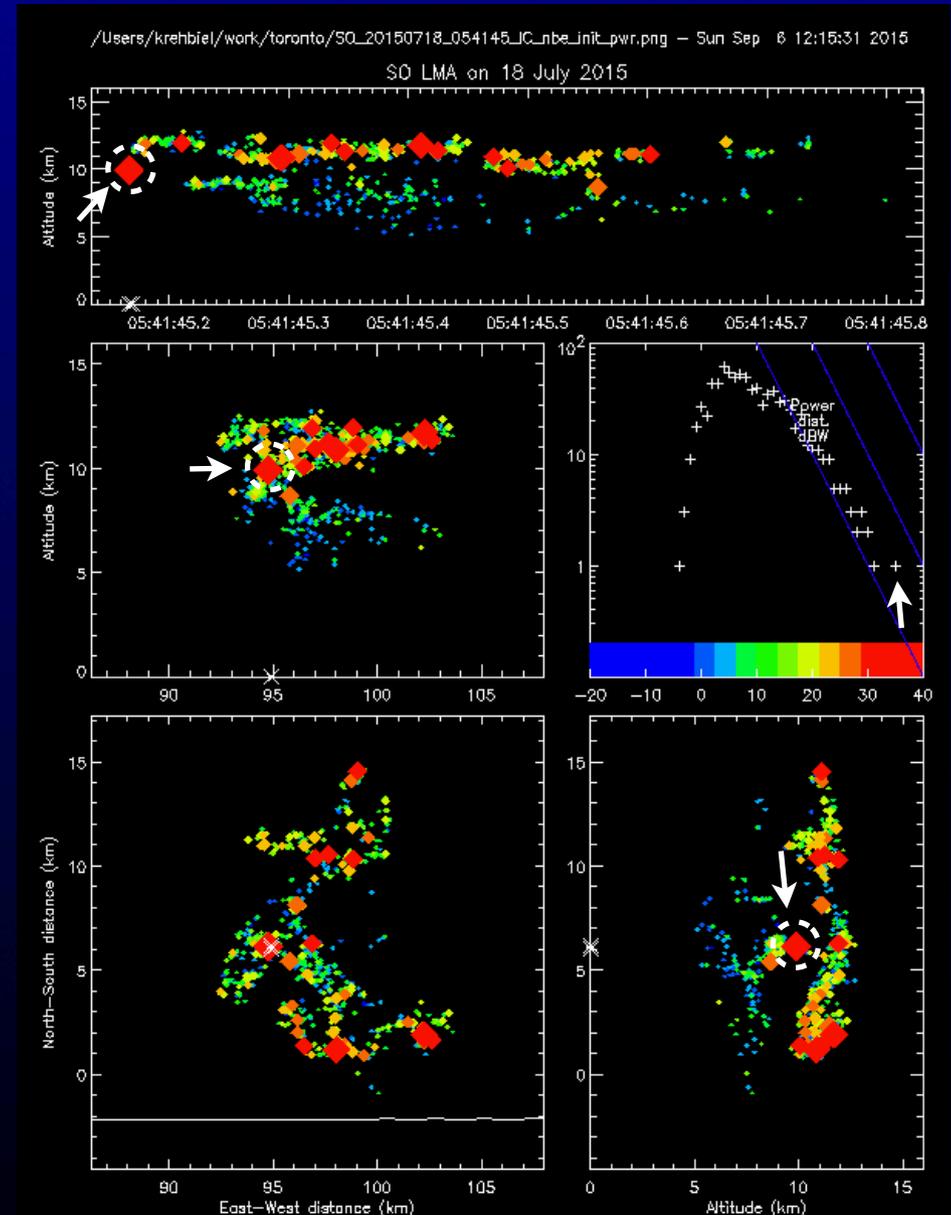
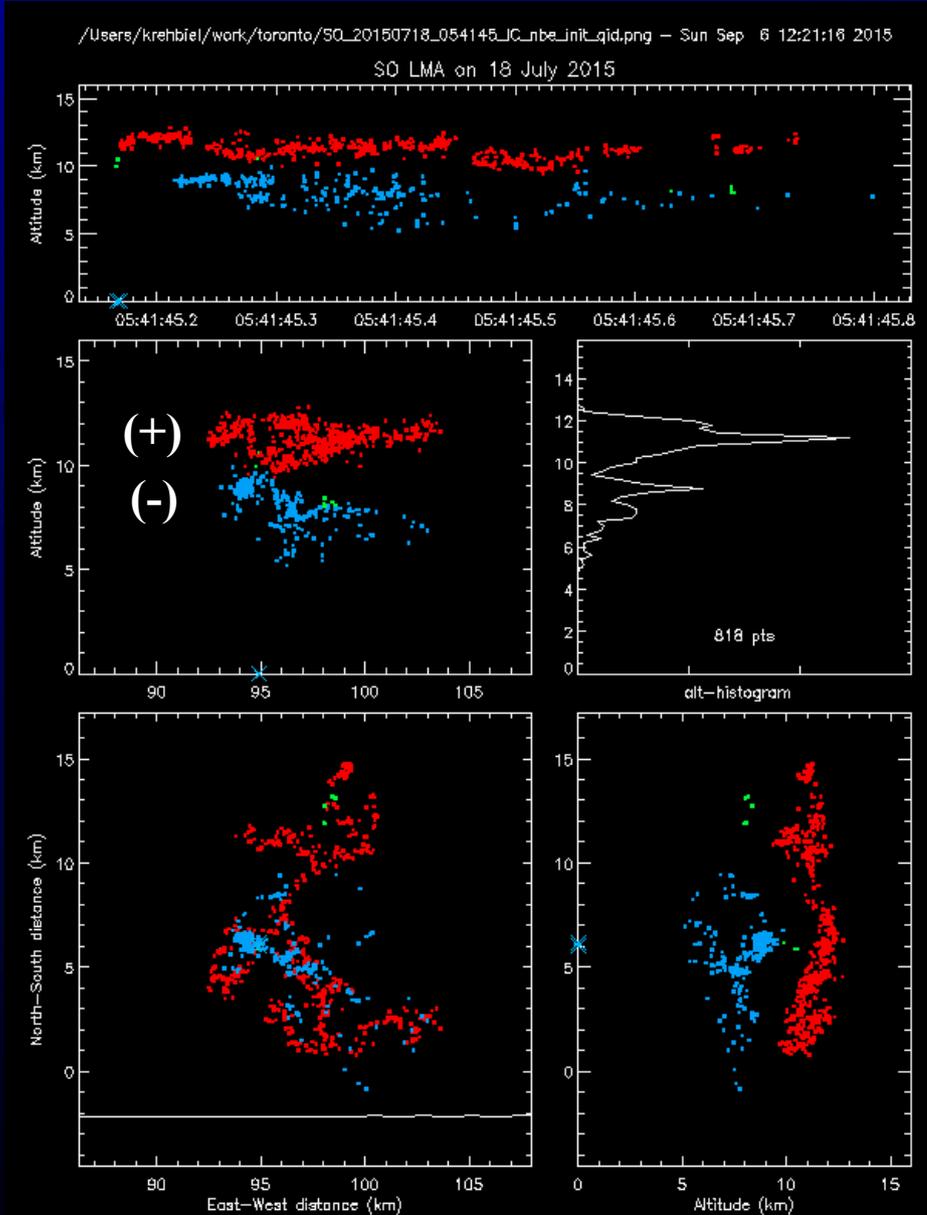
LMA-detected VHF source power (-) bkdn stronger than (+) bkdn



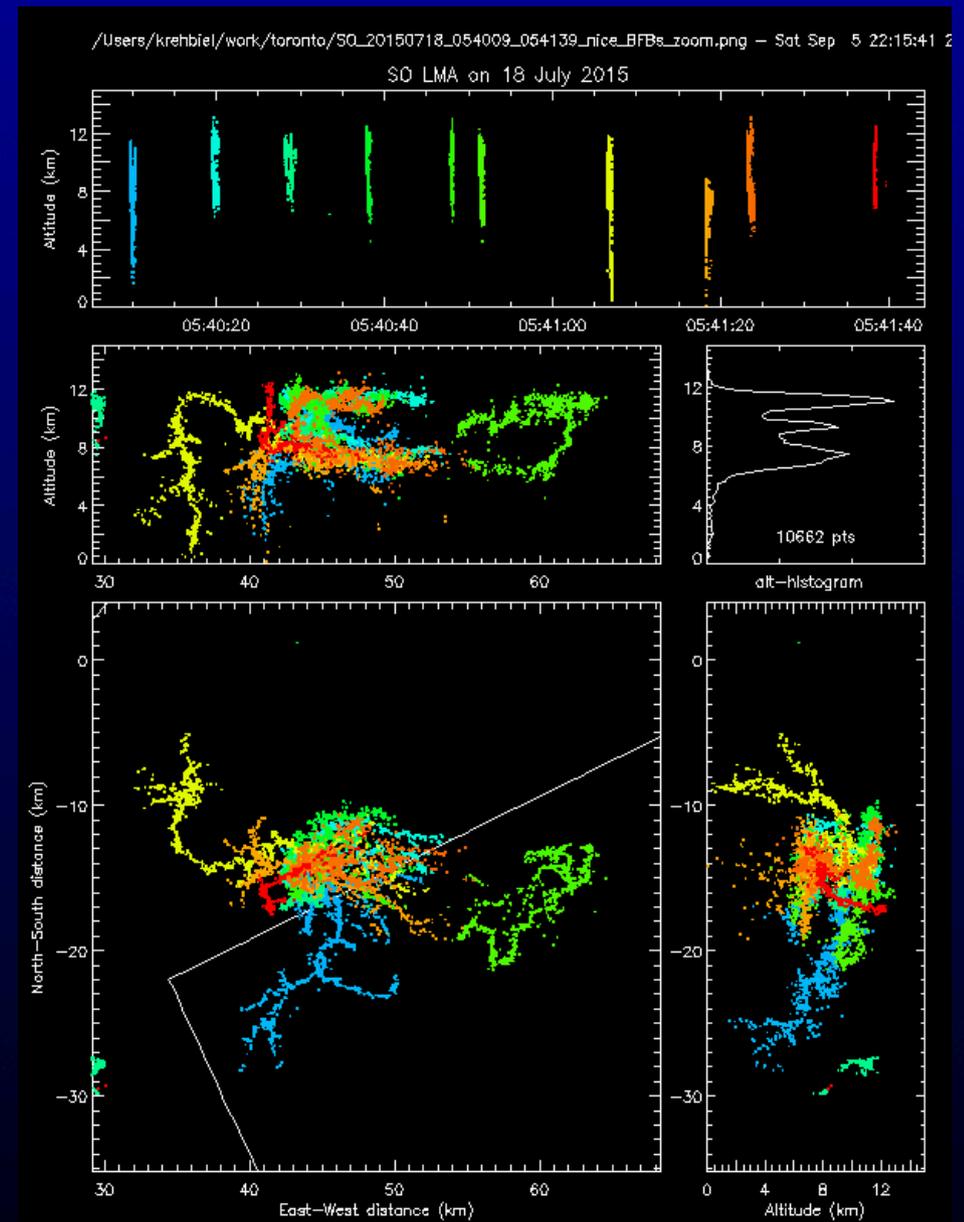
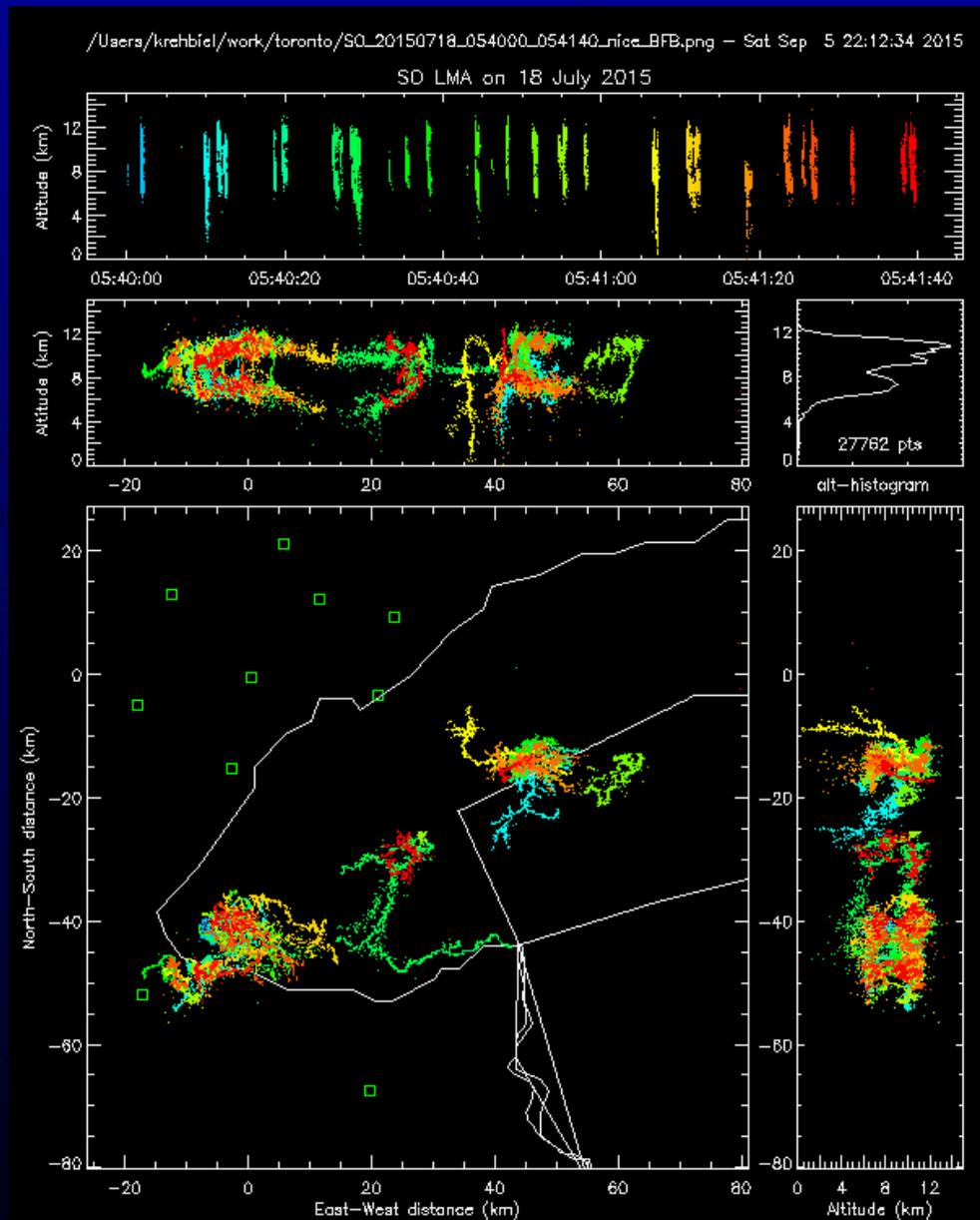
Charge identification results (qid)

Red: (-) breakdown (strong) into (+) charge
Blue: (+) bkdn (weak) into (-) storm charge

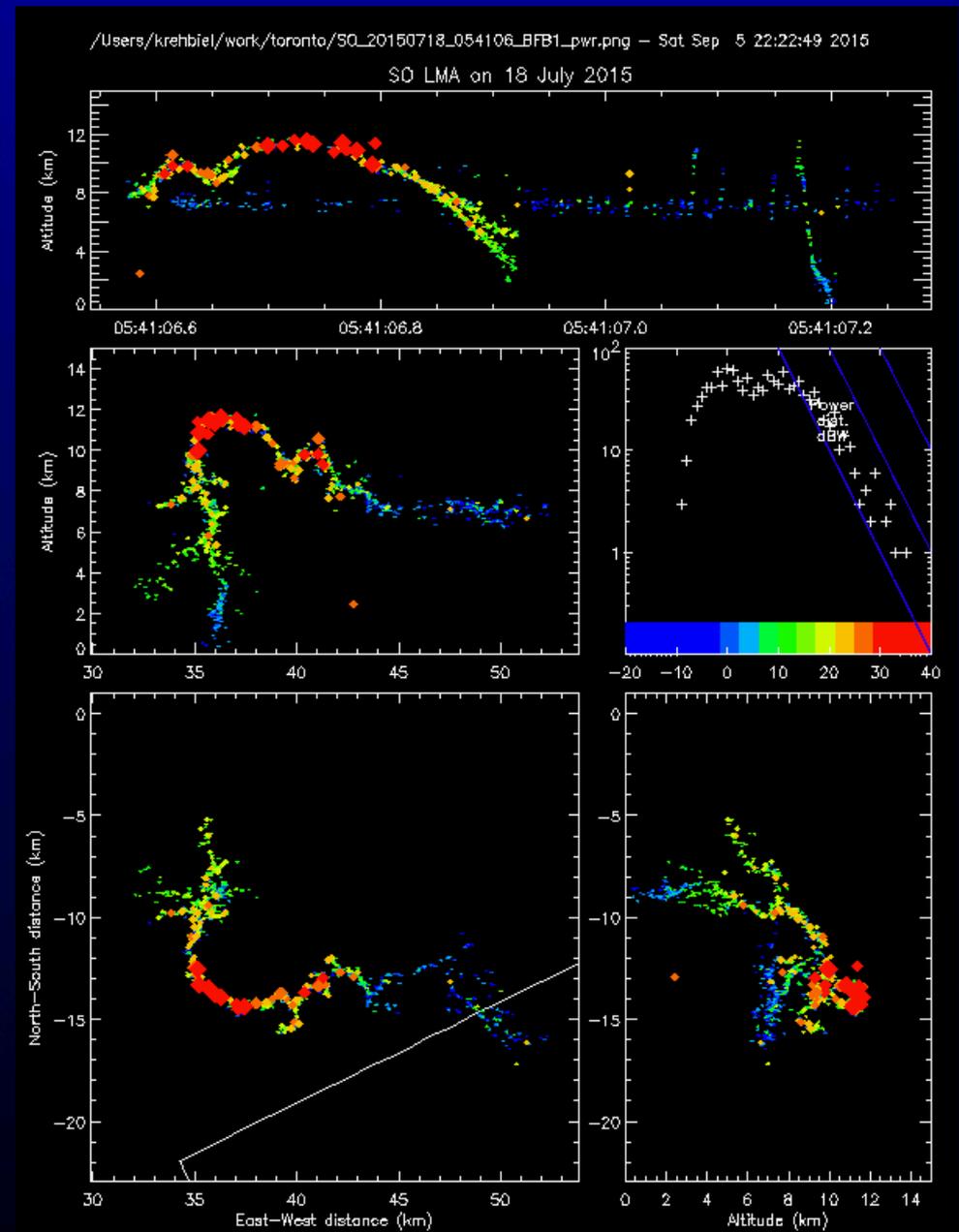
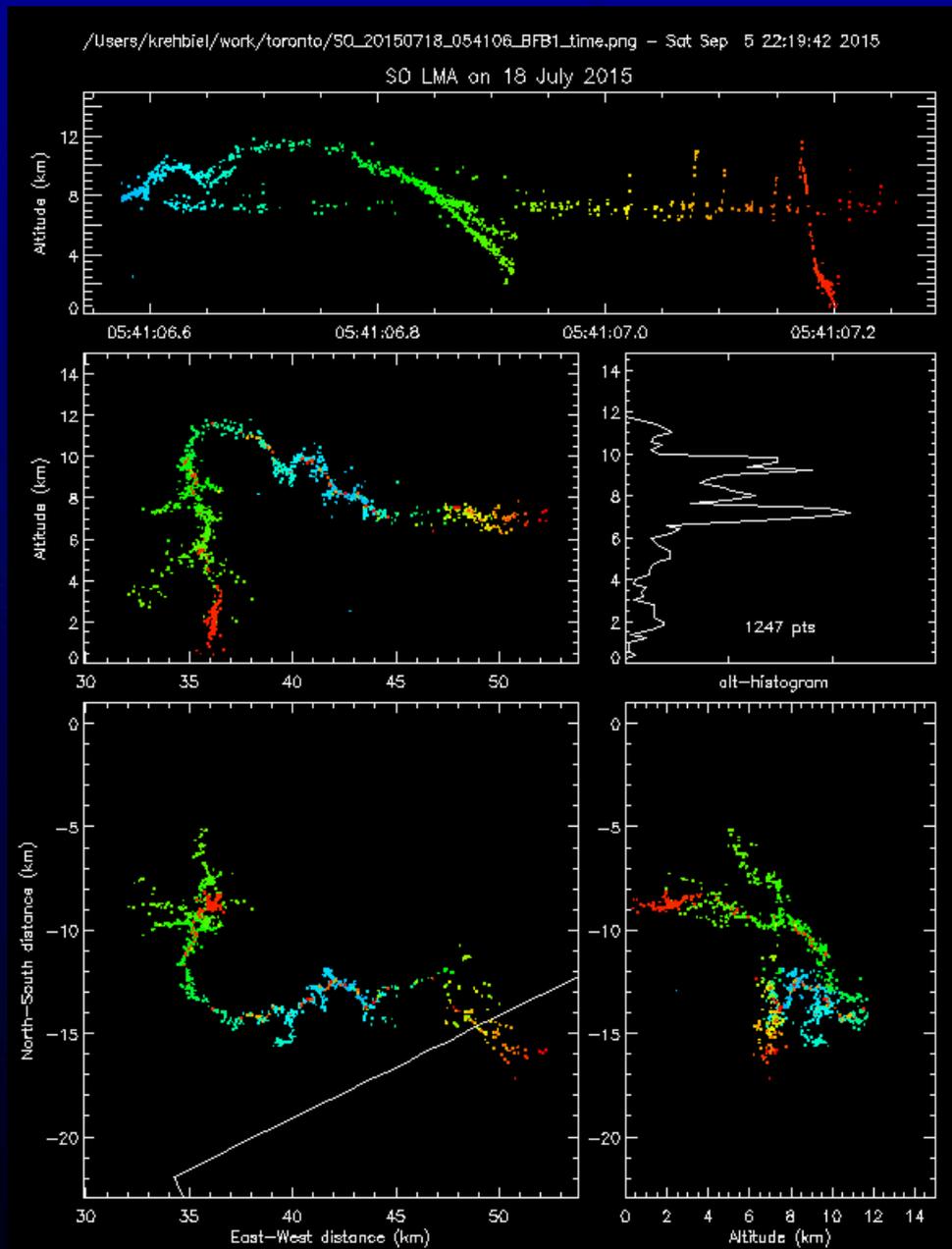
+44.4 dBW (28 kW) narrow bipolar event (NBE) initiated the flash



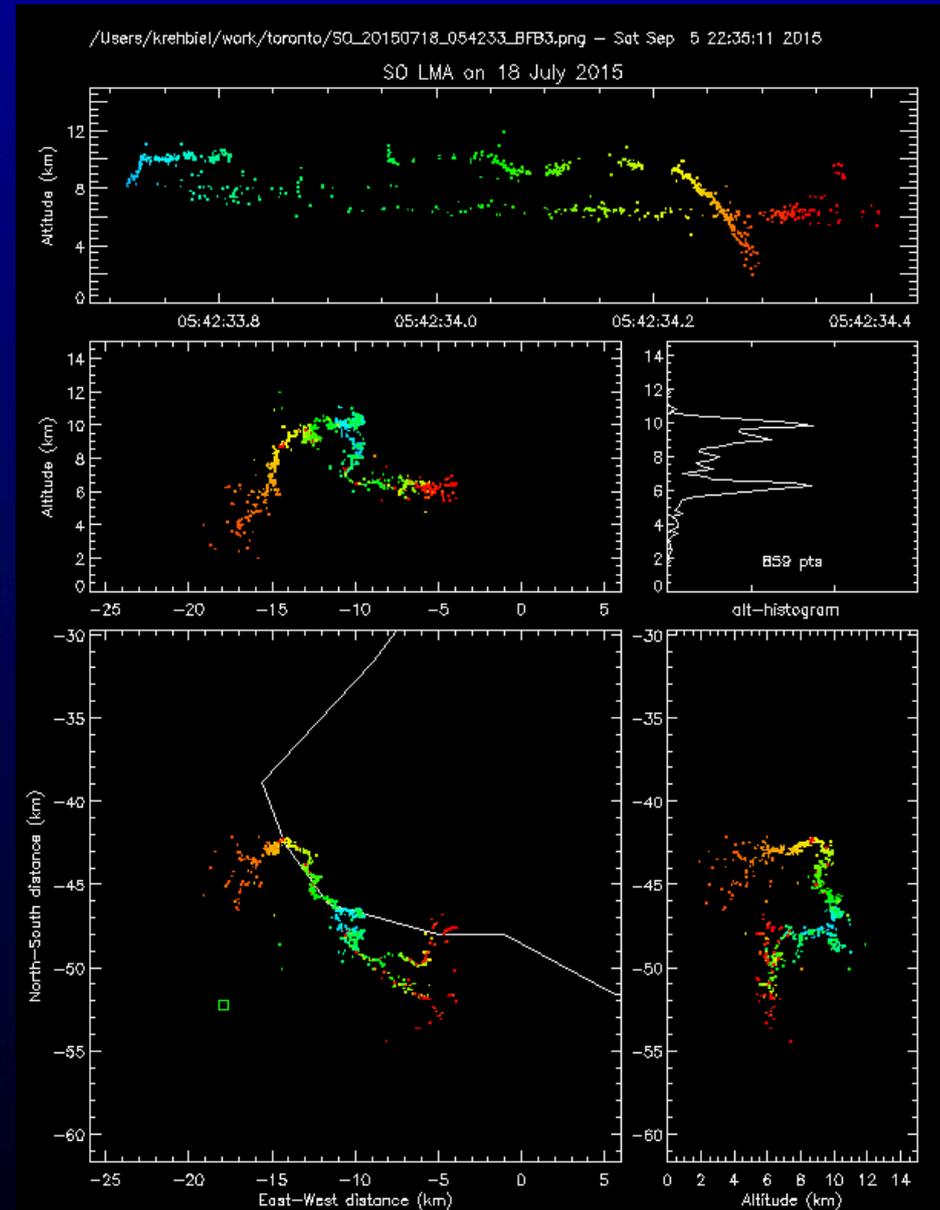
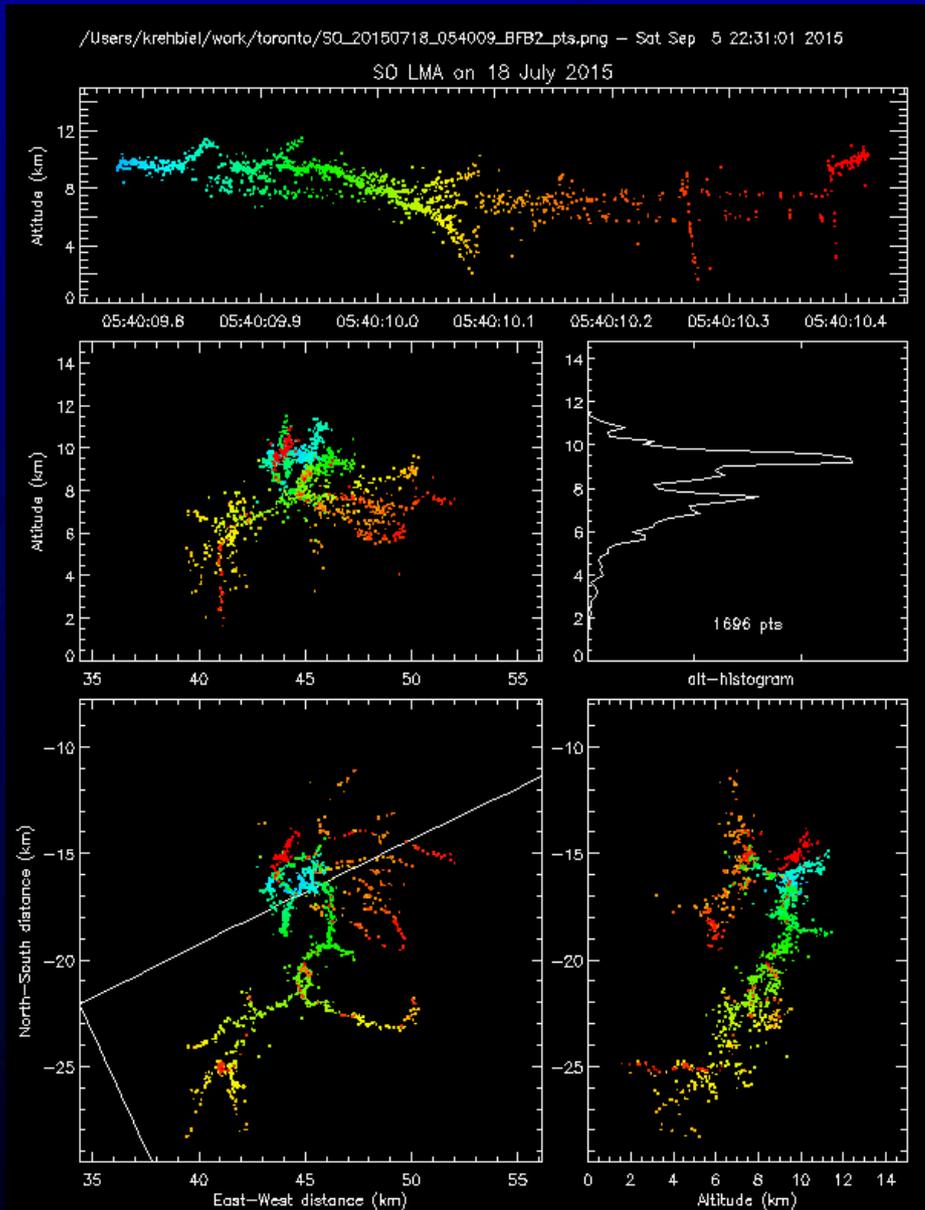
Additional flashes, Lake Ontario storms, 18 July 2015



Additional flashes, Lake Ontario storms, 18 July 2015



Additional flashes, Lake Ontario storms, 18 July 2015



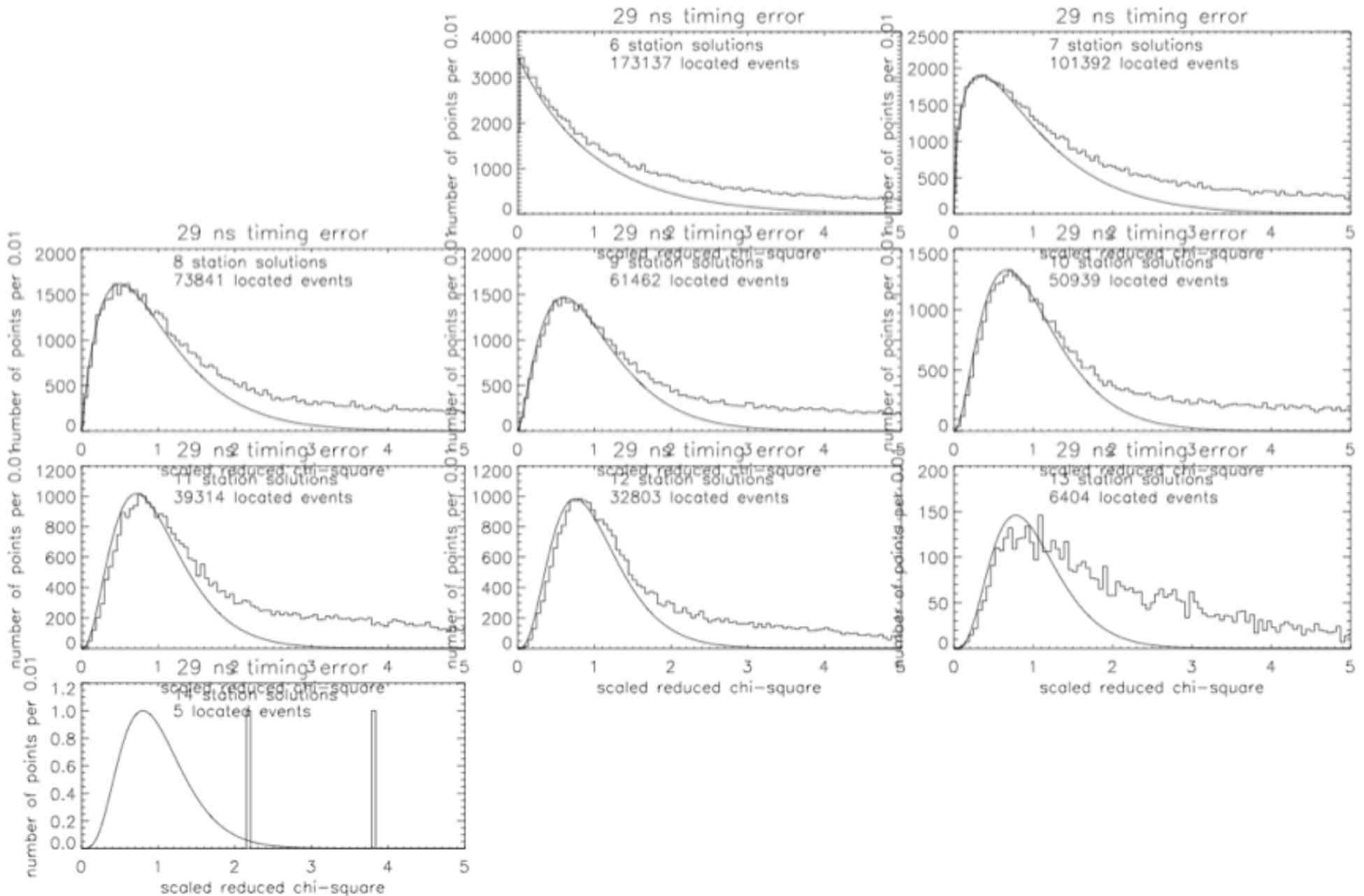
Southern Ontario Lightning Mapping Array, Station Health Data [Status Plots](#)

(Information updated hourly, at twenty past -- last updated: Sun Sep 6 04:21:01 2015 UTC)

station	name	status	sdate	stime	load	uptime	/	/boot	/dev/shm	/data	/data2	PID	PIDRD	PIDTL	PIDAT	PIDDEC	Phase	pdate	ptime	temp	gps	current	trigfile
ont_a	LVA	up	09/06/2015	04:16:01	0.32/0.14/0.14	15 days	95%	14%	1%	50%	36%	11308	11308	11310	11312	11314	-10	2015/09/06	04:16:03	39	8	TA150906	
ont_b	LKR	up	09/06/2015	04:16:02	0.40/0.20/0.19	20 days	95%	14%	1%	54%	1%	21684	21687	21689	21691	21693	-9	2015/09/06	04:16:03	39	7	TB150906	
ont_c	LDV	up	09/06/2015	04:16:01	0.26/0.20/0.16	18:04	95%	14%	1%	38%	1%	23252	23254	23261	23263	23265	182	2015/09/06	04:16:02	41	11	TC150906	
ont_d	LYC	up	09/06/2015	04:16:01	0.00/0.08/0.12	2 days	95%	14%	1%	54%	1%	11719	11721	11724	11726	11728	-10	2015/09/06	04:16:03	40	10	TD150906	
ont_e	LPA	up	09/06/2015	04:16:01	0.18/0.23/0.18	33 days	95%	14%	2%	54%	1%	14172	14174	14176	14178	14180	-11	2015/09/06	04:16:03	41	10	TE150906	
ont_f	LER	up	09/06/2015	04:16:02	0.15/0.13/0.14	7 days	95%	14%	1%	49%	1%	27146	27148	27150	27152	27154	-10	2015/09/06	04:16:04	34	11	TF150906	
ont_g	LCM	up	09/06/2015	04:17:01	0.08/0.19/0.22	25 days	95%	14%	1%	45%	26%	14212	14215	14217	14219	14221	-9	2015/09/06	04:17:03	37	10	TG150906	
ont_h	LBT	up	09/06/2015	04:16:01	0.36/0.21/0.17	14 min	95%	14%	1%	44%	1%	1982	1988	1992	1994	1996	-309	2015/09/06	04:16:02	36	10	TH150906	
ont_i	LNV	offline	09/06/2015	01:16:01	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
ont_j	LNY	up	09/06/2015	04:16:02	0.23/0.26/0.20	33 days	95%	14%	2%	48%	1%	11936	11939	11946	11948	11950	-9	2015/09/06	04:16:03	40	8	TJ150906	
ont_k	LCV	up	09/06/2015	03:46:01	0.31/0.32/0.26	2:44	95%	14%	1%	80%	1%	3654	3657	3659	3661	3663	-8	2015/09/06	03:57:31	36	10	TK150906	
ont_l	LMS	up	09/06/2015	03:46:02	0.21/0.15/0.14	7 days	95%	14%	1%	45%	1%	22141	22149	22152	22154	22156	-9	2015/09/06	03:54:00	39	9	TL150906	
ont_m	LHM	up	09/06/2015	04:16:02	0.17/0.29/0.25	2 days	95%	14%	1%	57%	1%	30863	30870	30872	30874	30876	-10	2015/09/06	04:16:03	39	11	TM150906	
ont_n	LPW	up	09/06/2015	04:16:01	0.19/0.18/0.15	2 days	95%	14%	1%	60%	1%	15381	15388	15390	15392	15394	-11	2015/09/06	04:16:03	40	9	TN150906	

trig ID	tdate	ttime	tver	tthresh	trigs/s	tsat	ttemp	files today	files today-1	files today-2	current datafile	Batt 1 Voltage	Batt 2 Voltage	Load Voltage	Bytes/Month	Decimation Status
A	9/06/15	04:15:59	v10	-85 dBm	1717	8	39	27	145	145	LA_ONT_LVA_150906_041000.dat	12.562	12.541	12.190	1082.87 MB	Decimation Active
B	9/06/15	04:15:59	v10	-91 dBm	1202	7	39	27	144	145	LB_ONT_LKR_150906_041000.dat	12.282	12.540	11.980	1805.42 MB	Decimation Active
C	9/06/15	04:15:59	v10	-67 dBm	1148	11	41	27	146	145	LC_ONT_LDV_150906_041000.dat	12.474	12.540	12.147	944.95 MB	Decimation Active
D	9/06/15	04:15:59	v10	-74 dBm	915	10	40	26	145	146	LD_ONT_LYC_150906_041000.dat	12.564	12.702	12.230	567.48 MB	Decimation Active
E	9/06/15	04:15:59	v10	-77 dBm	796	10	41	26	145	146	LE_ONT_LPA_150906_041000.dat	12.725	12.903	12.351	568.28 MB	Decimation Active
F	9/06/15	04:15:59	v10	-90 dBm	1667	11	34	26	146	145	LF_ONT_LER_150906_041000.dat	13.610	12.639	13.281	561.83 MB	Decimation Active
G	9/06/15	04:16:59	v10	-90 dBm	1063	10	37	26	146	145	LG_ONT_LCM_150906_041000.dat	12.494	12.718	12.156	1492.20 MB	Decimation Active
H	9/06/15	04:15:59	v10	-83 dBm	964	10	36	18	117	133	LH_ONT_LBT_150906_041000.dat	13.328	12.778	13.030	440.61 MB	Decimation Active
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
J	9/06/15	04:15:59	v10	-72 dBm	1313	8	40	26	146	145	LJ_ONT_LNY_150906_041000.dat	12.609	12.793	12.236	540.17 MB	Decimation Active
K	9/06/15	03:57:23	v10	-90 dBm	1336	10	36	27	157	154	LK_ONT_LCV_150906_035000.dat	12.591	12.717	12.186	212.89 MB	Decimation Active
L	9/06/15	03:53:47	v10	-81 dBm	1914	8	39	25	145	145	LL_ONT_LMS_150906_035000.dat	12.653	12.770	12.310	1308.34 MB	Decimation Active
M	9/06/15	04:15:59	v10	-87 dBm	887	11	39	27	145	145	LM_ONT_LHM_150906_041000.dat	12.819	13.085	12.519	264.89 MB	Decimation Active
N	9/06/15	04:15:59	v10	-88 dBm	966	9	40	26	146	145	LN_ONT_LFW_150906_041000.dat	12.607	12.701	12.242	394.33 MB	Decimation Active

Chi-square distributions, South Ontario LMA 14 stations, 30 ns rms timing uncertainty



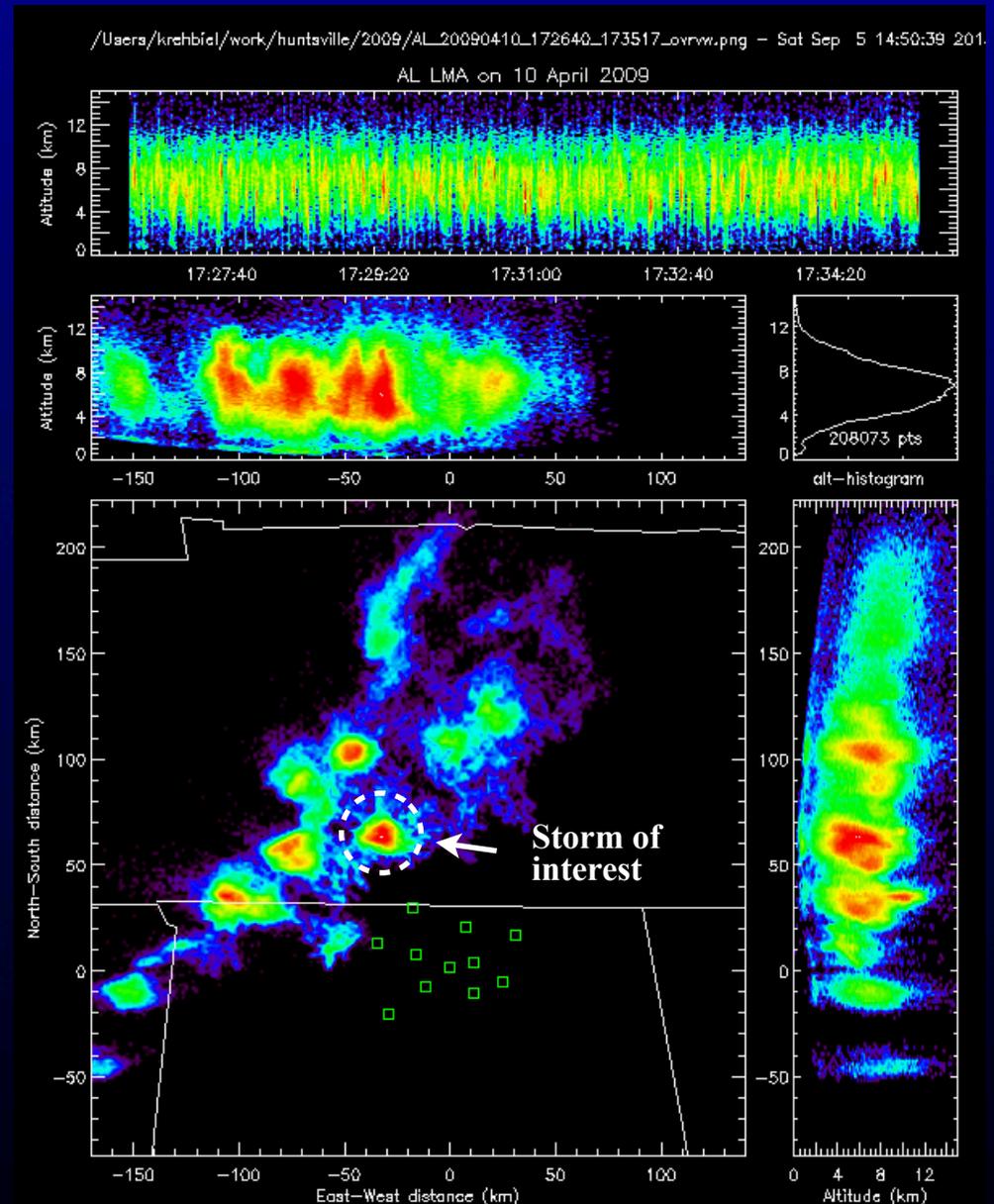
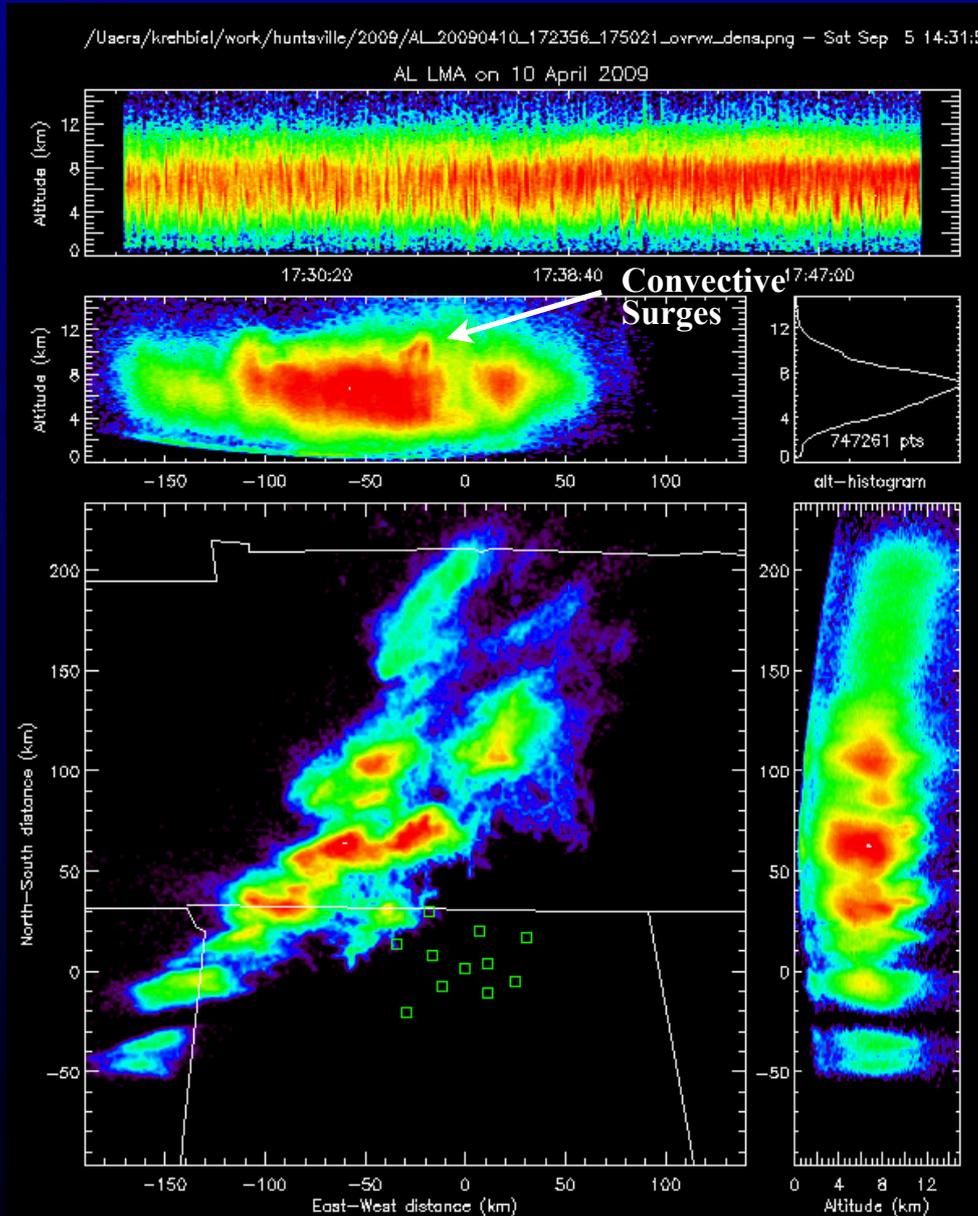
Supercell, North Alabama LMA, 10 April 2009

- Convective surge intensified the storm
 - Lightning ‘hole’ occurred at beginning of updraft/surge
 - Marked increase in lightning at time of hole (lightning ‘step’)
 - Storm produce inverted polarity intracloud discharges (ICs)
 - Classic anomalously electrified storm
-
- Data file: LYLOUT_090410_170000_3600.dat.gz
 - Time interval: 1725 to 1750 (25 min)

Overview of lightning activity, 10 April 2009

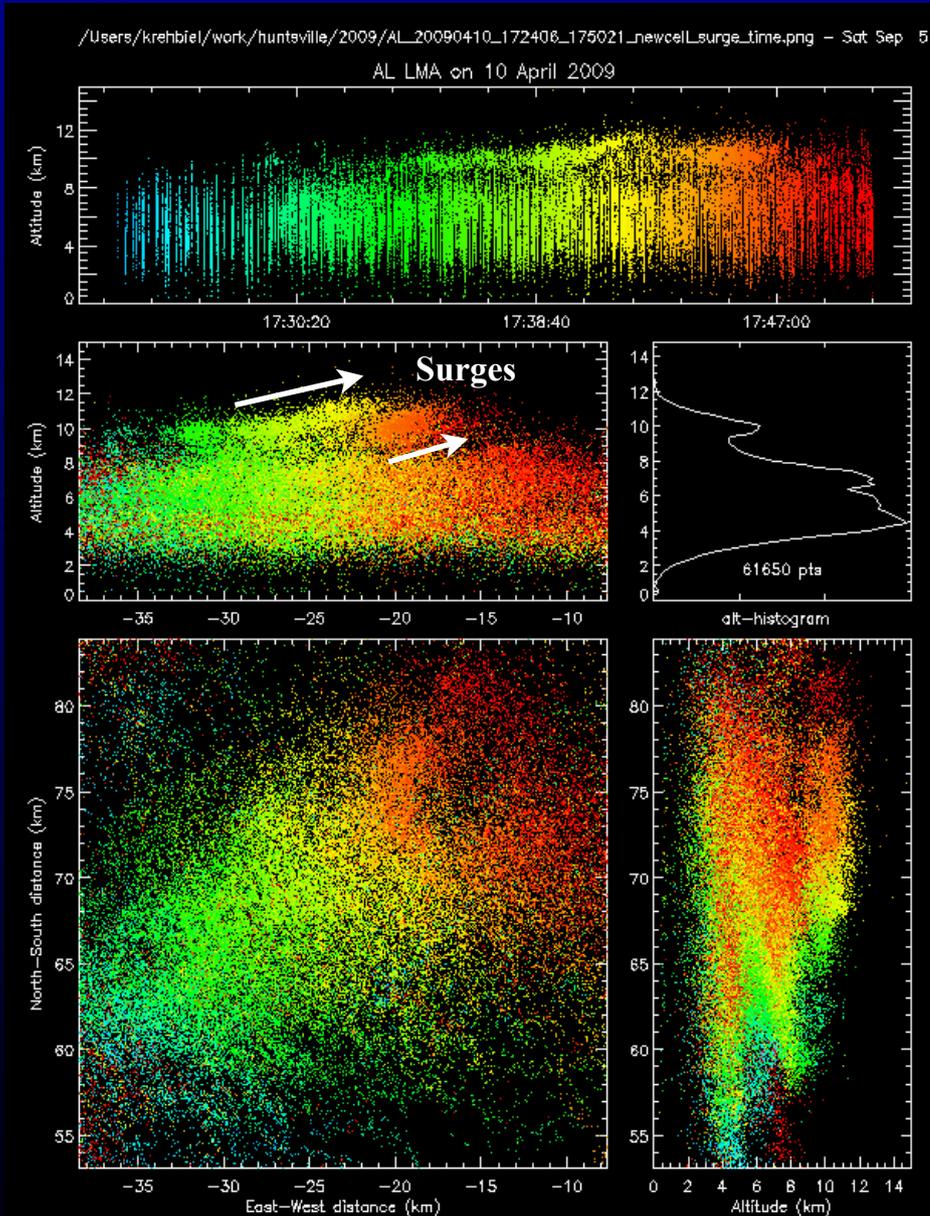
17:23:56 to 17:50:21 (~25 min)
750,000 sources; density plots

17:26:40 to 17:35:17 (~10 min)
(Less blurring due to storm motion)

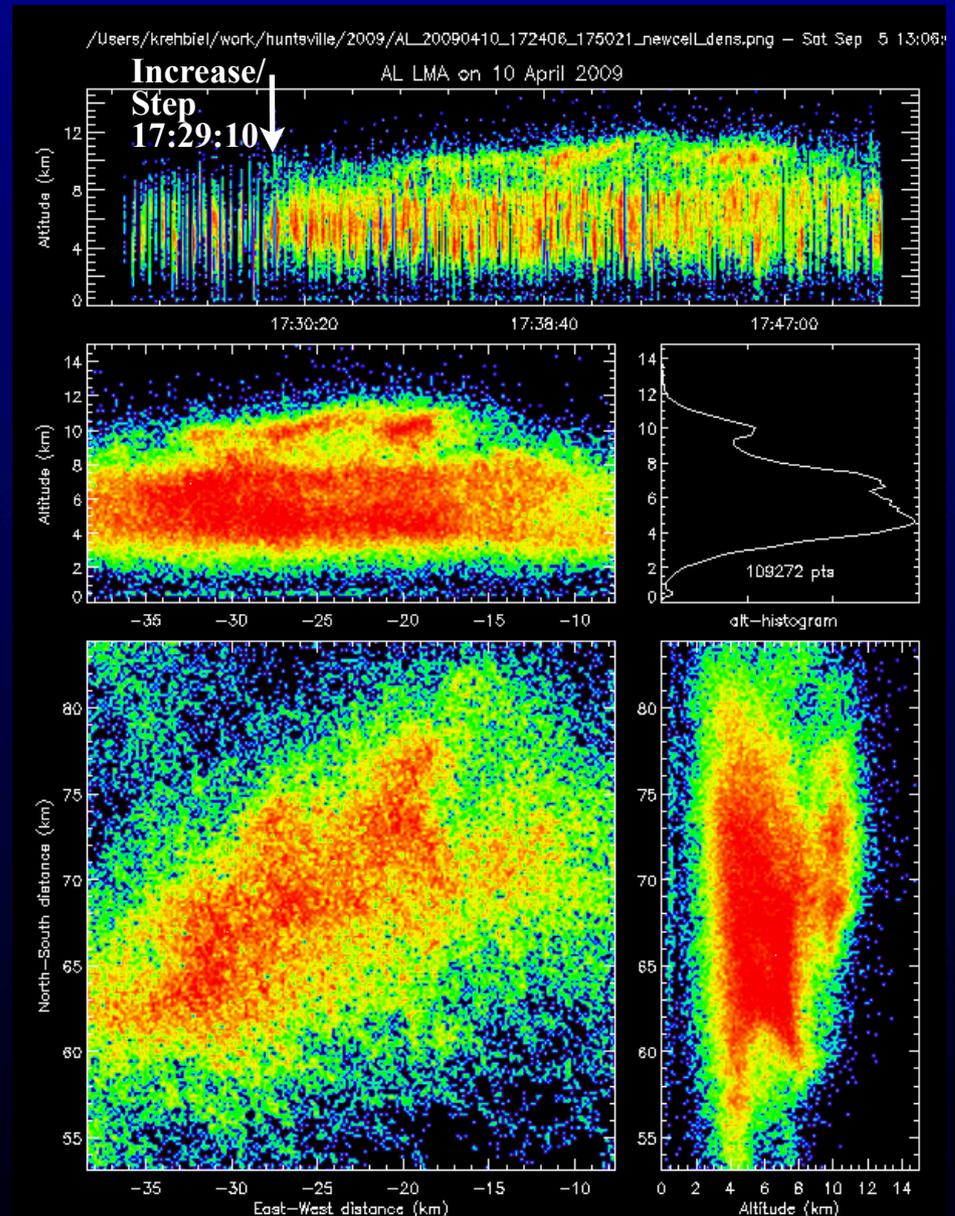


Intensification of close storm (10 min time interval)

Individual sources
Convective surges expanded

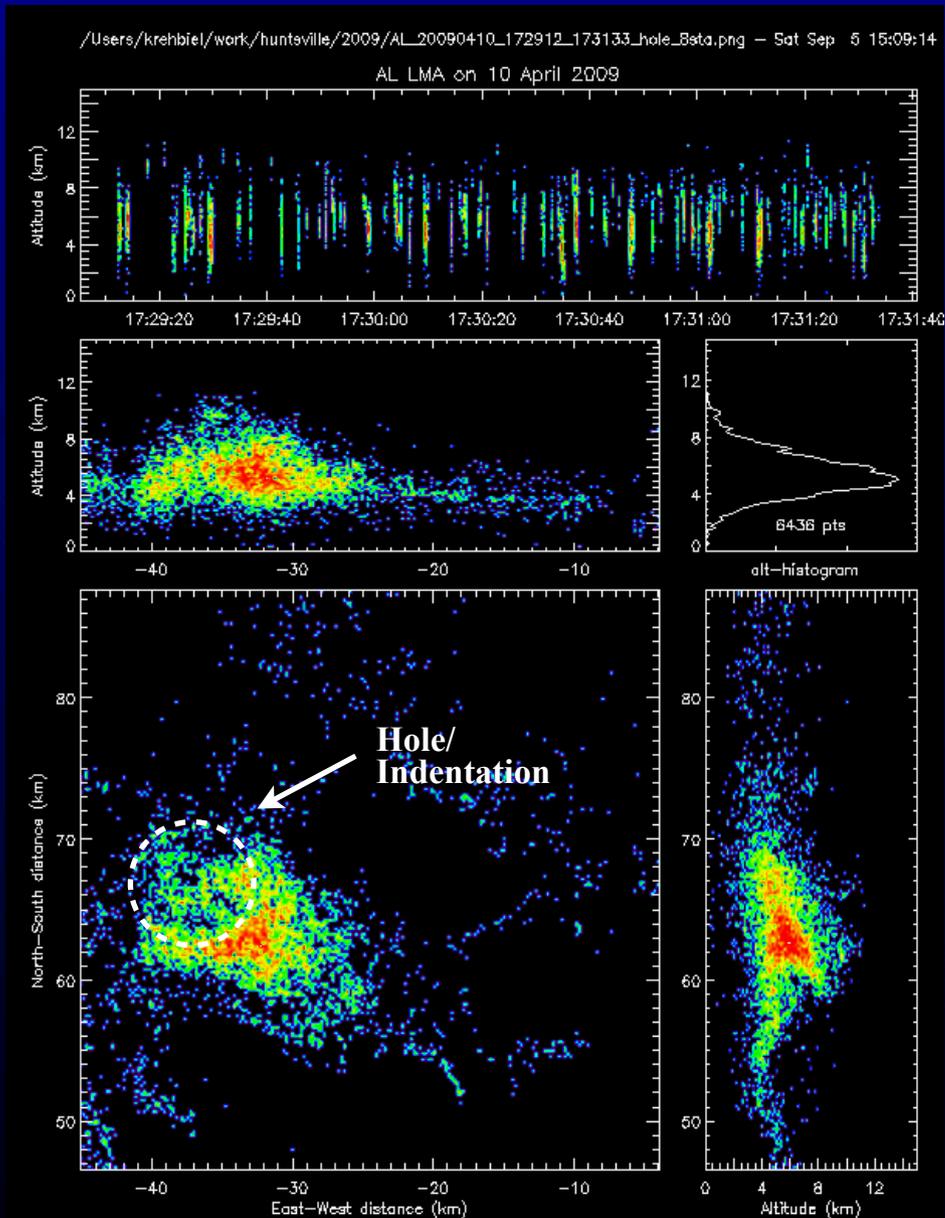


Source Density
Lightning 'step' assoc. w/ strong updraft

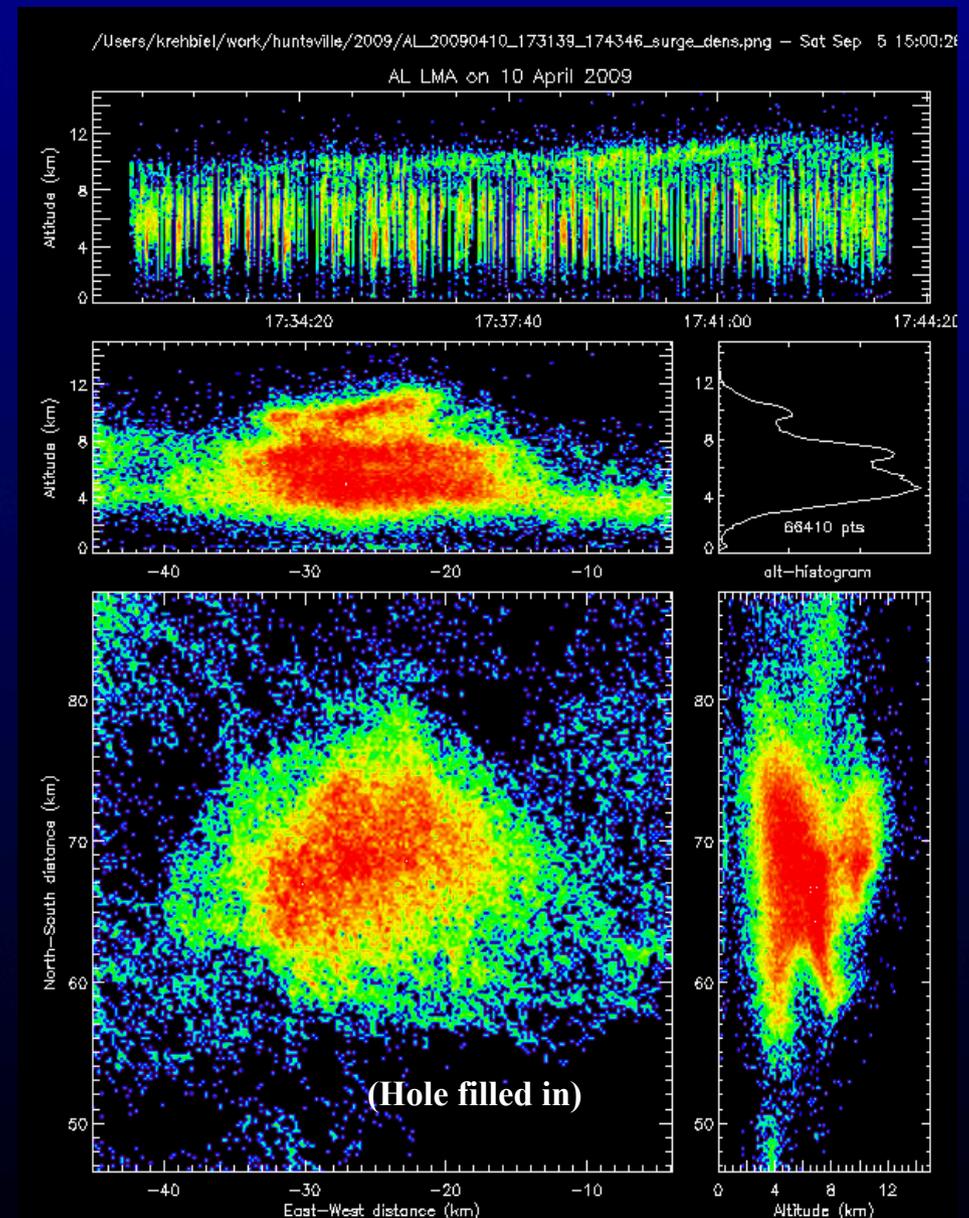


Lightning 'hole' at beginning of updraft

17:29:12 to 17:31:33
Hole coincident w/ step at ~17:29:10



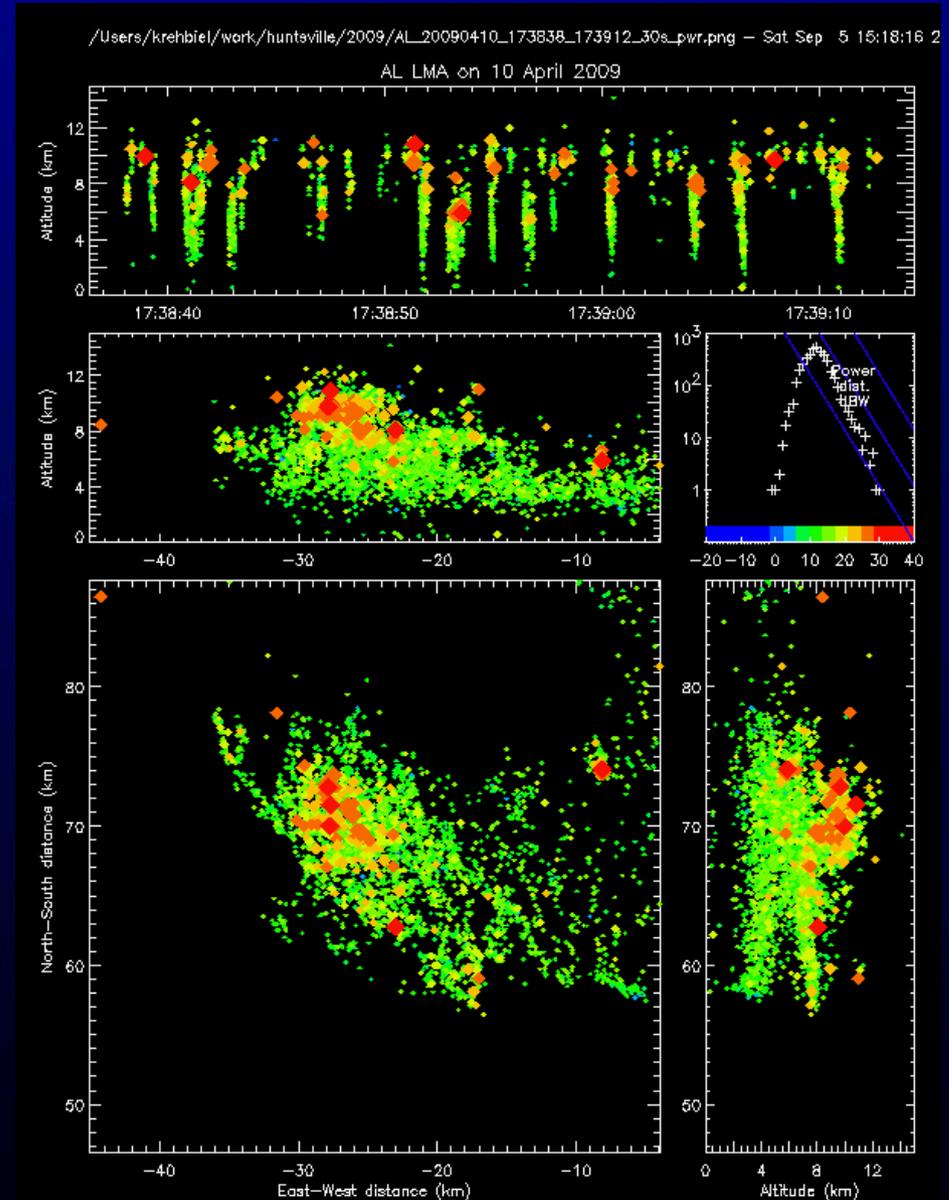
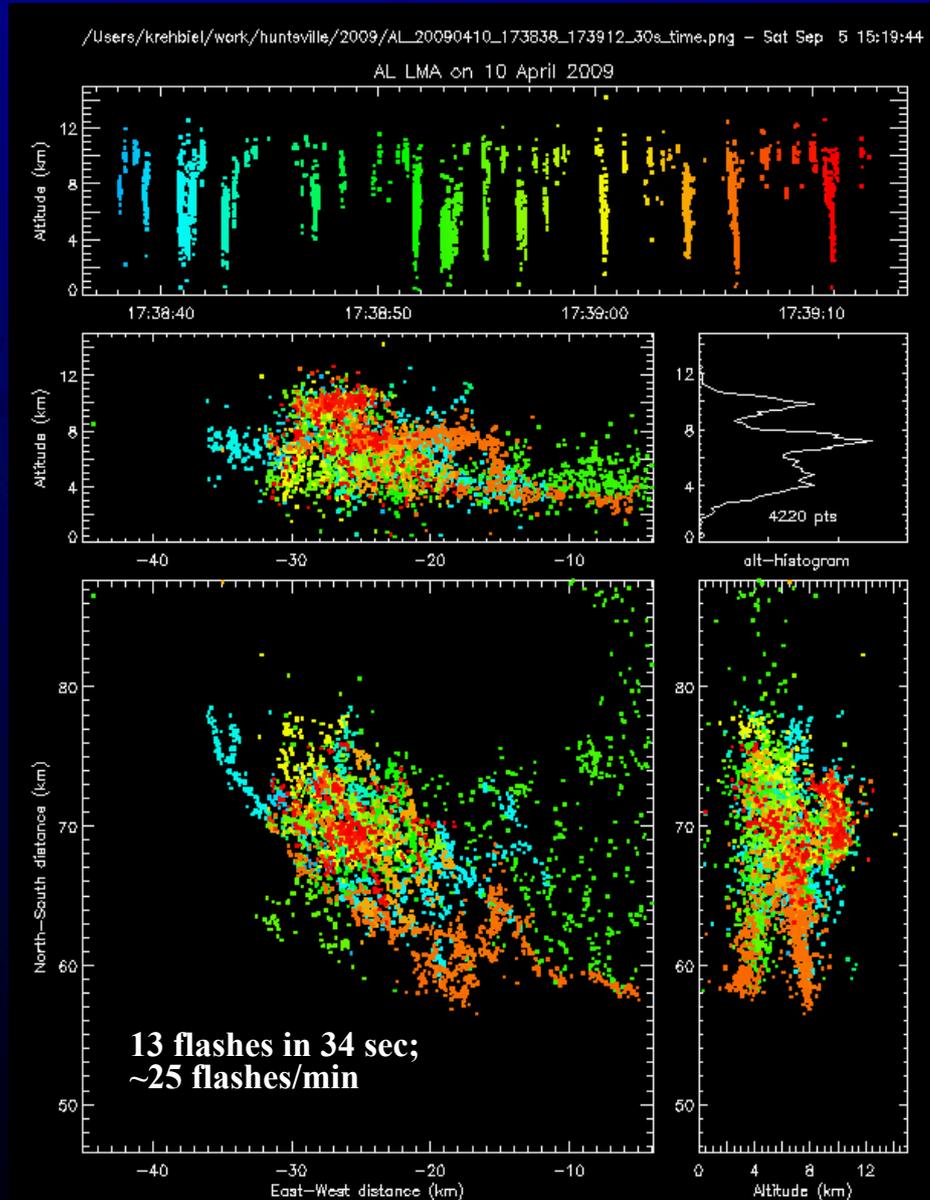
17:31:39 to 17:43:46; Activity 2 min into step;
surge distinctly above main part of storm



Detailed lightning activity

17:38:38 to 17:39:12 (34 sec); Descending ICs & upper-level attempted ICs (precursors)

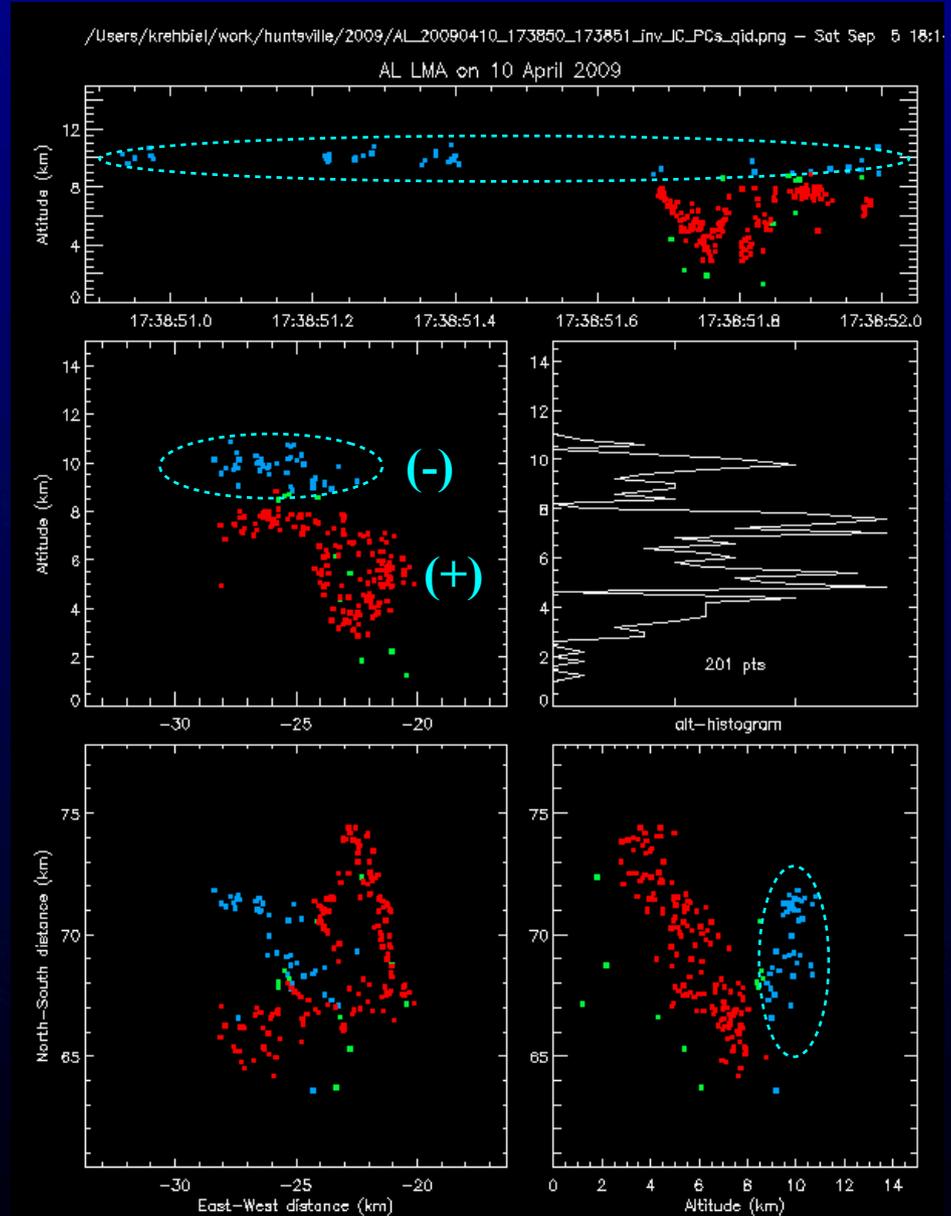
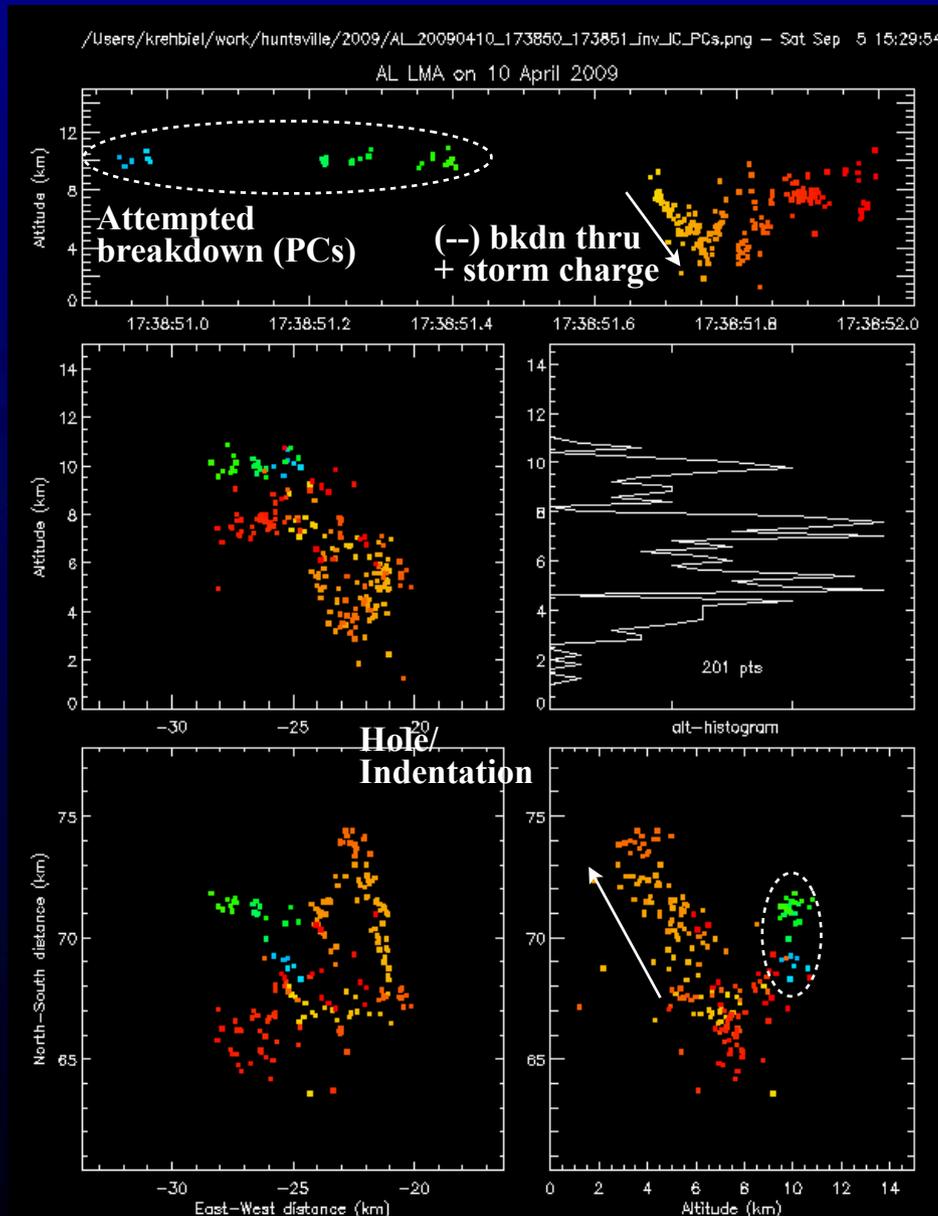
VHF source powers; strongest in upper part of storm (~40 dBW max, 10 kW)



Individual discharges and charge identification (qid)

1.0 sec of data, points colored by time;
showing downward IC and attempted ICs

Sources colored by inferred storm charge
blue = (--) red = (+)



Severe storm, Colorado LMA, 6 June 2015

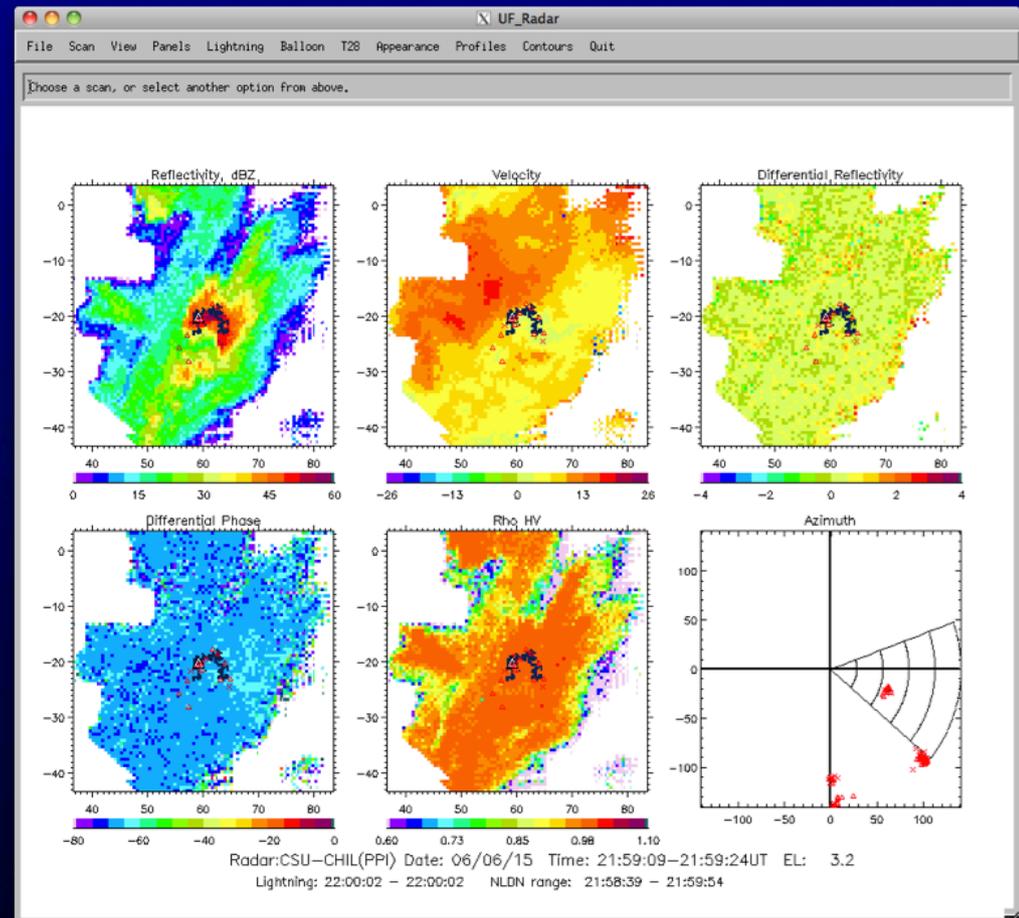
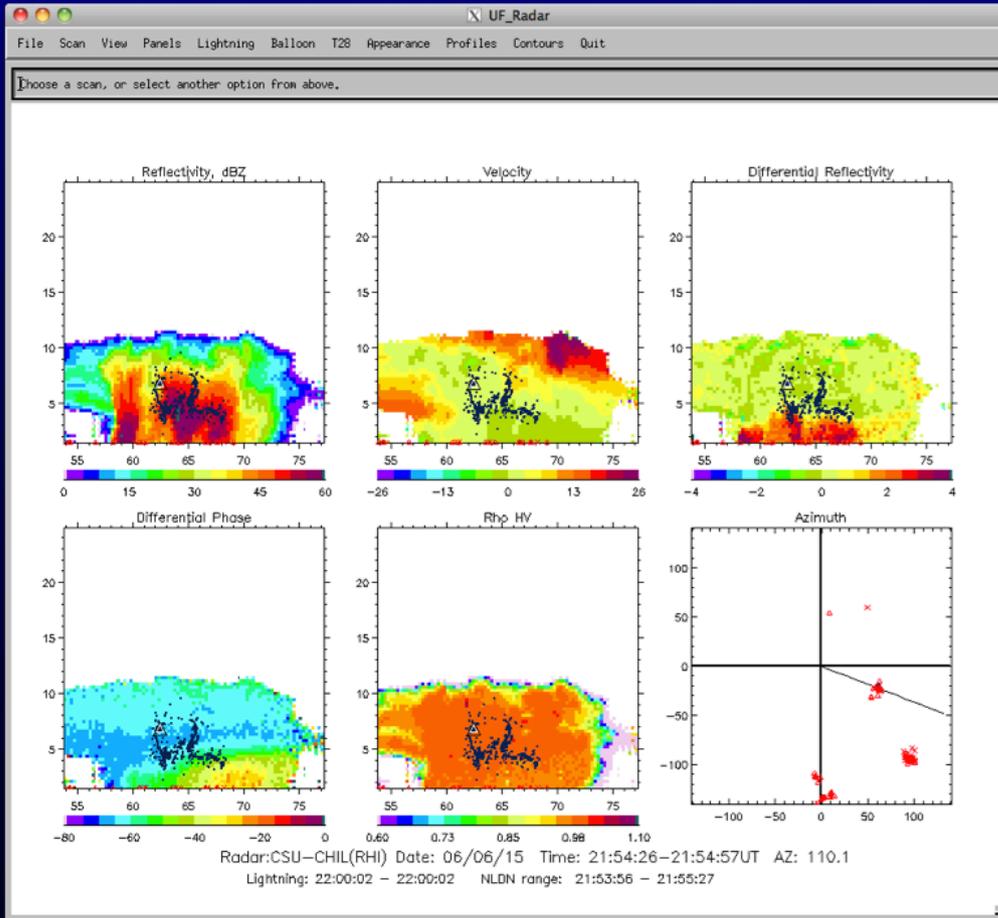
- Compact storm south of Fort Morgan, CO
- During GOES-14 Super Rapid Scan period
- Compare LMA data with CSU CHILL radar scans (Pat Kennedy)
- Quarter-size hail, funnel cloud spotted, tornado watch issued
- Intense lightning activity
- Downward, inverted polarity intracloud discharges (ICs)
- Broadband VHF Interferometer observations (Mark Stanley)

- Data file: LYLOUT_150606_220000_0600.dat.gz
- Time interval: Full 10 min

Two side-by-side downward IC flashes

Dual-polarization RHI comparisons
Between (-) at top of ppn core and (+) in core

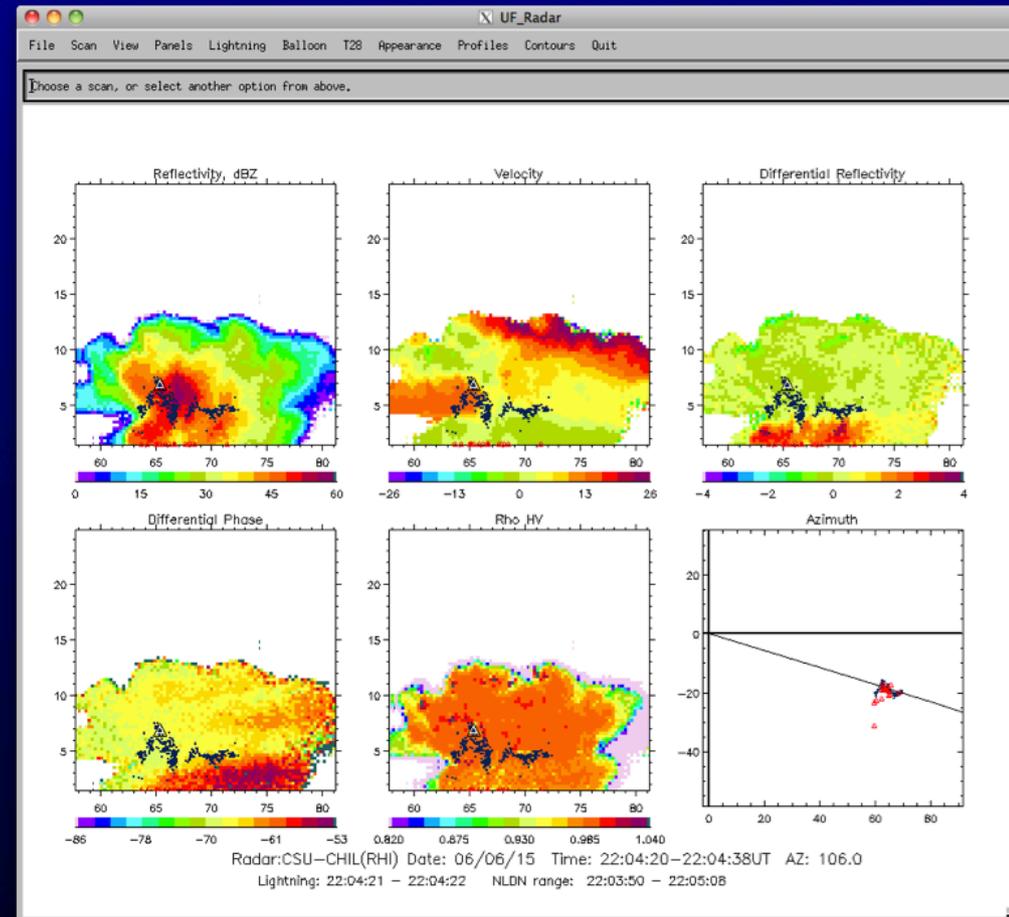
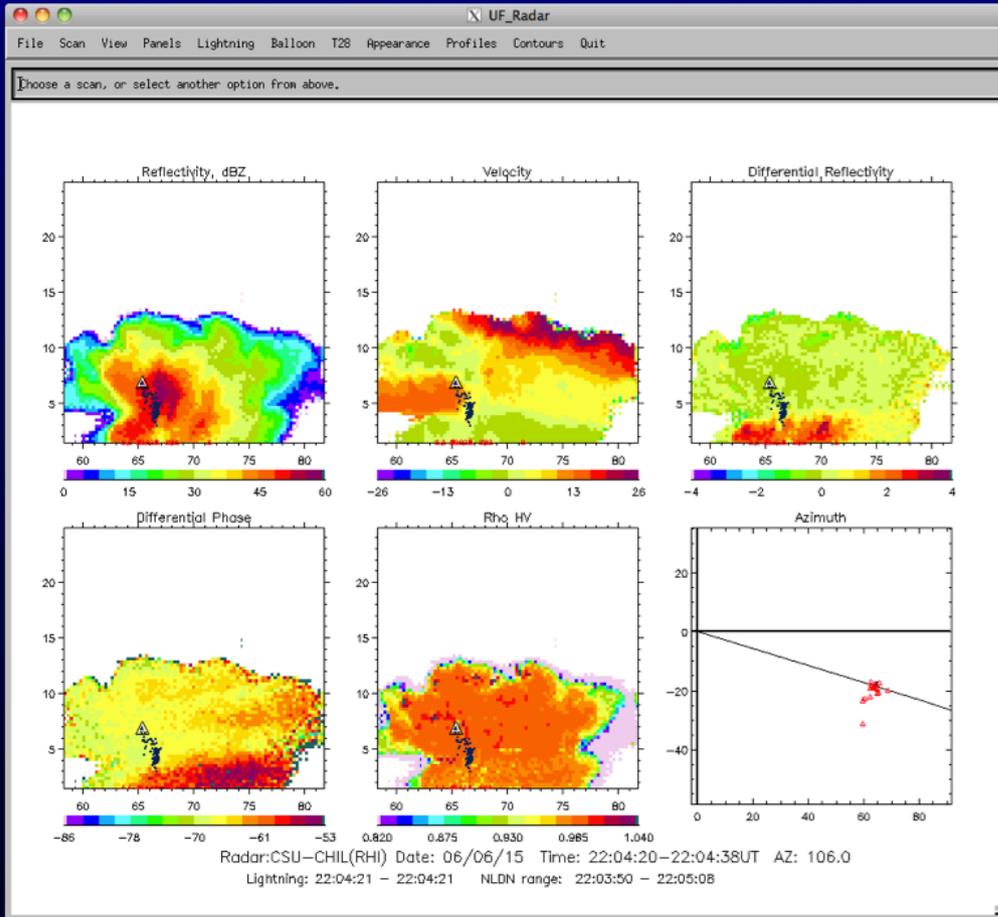
PPI comparison
Horizontal development through ppn core



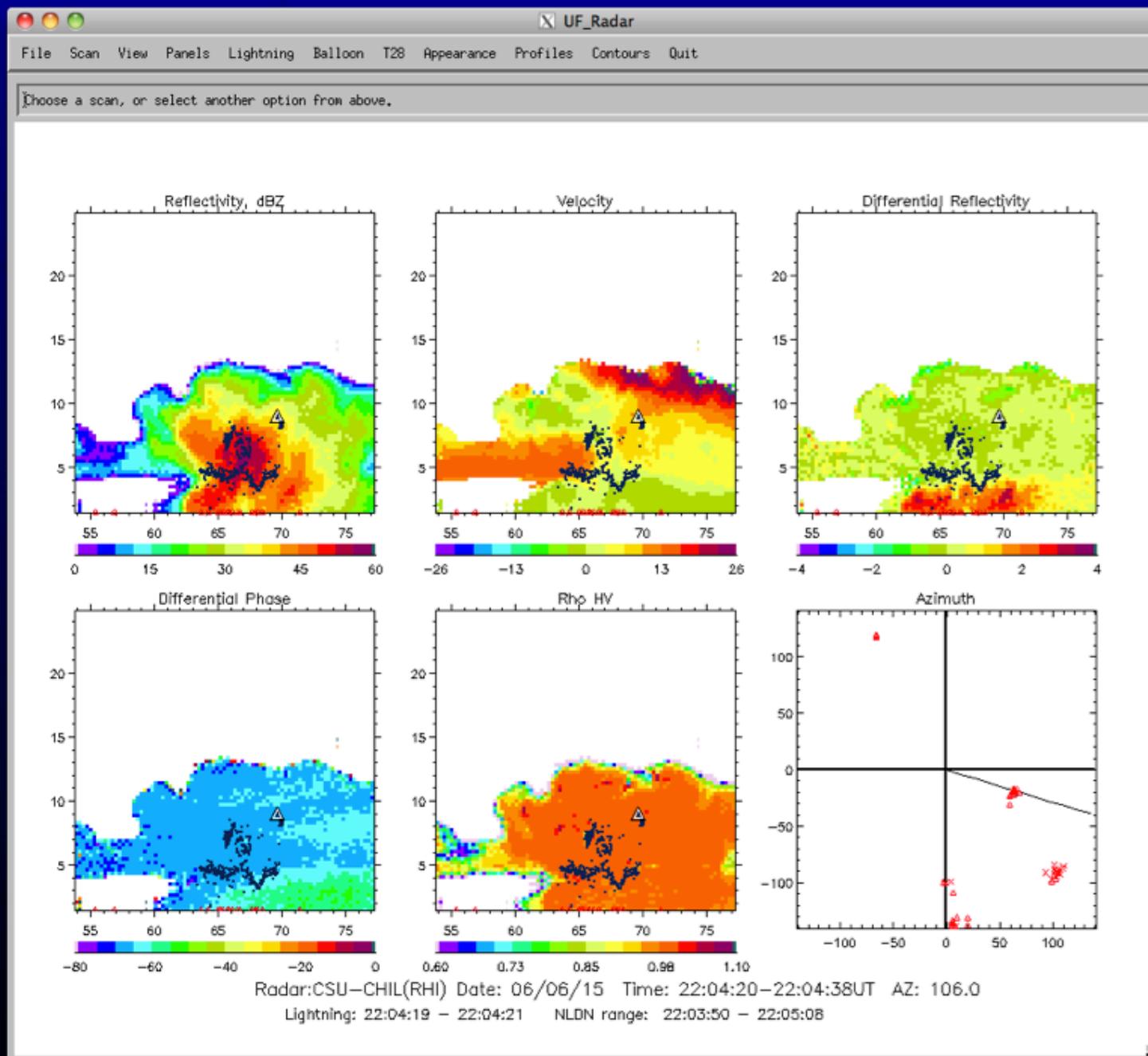
Downward discharge through precipitation shaft

Initial part of discharge, develops straight down through (+) charge in hail shaft

Remainder of flash; develops horizontally through (+) charge just above melting level



Downward vertical then horizontal discharge, with two upper-level, smaller discharges before and after



LMA Tutorial DARPA/KSC Workshop

Paul Krehbiel, William Rison, Ronald Thomas
New Mexico Tech
Socorro, NM

DARPA/Nimbus program
Kennedy Space Center, FL
October 6-7, 2014

Overlaying LMA data on radar observations

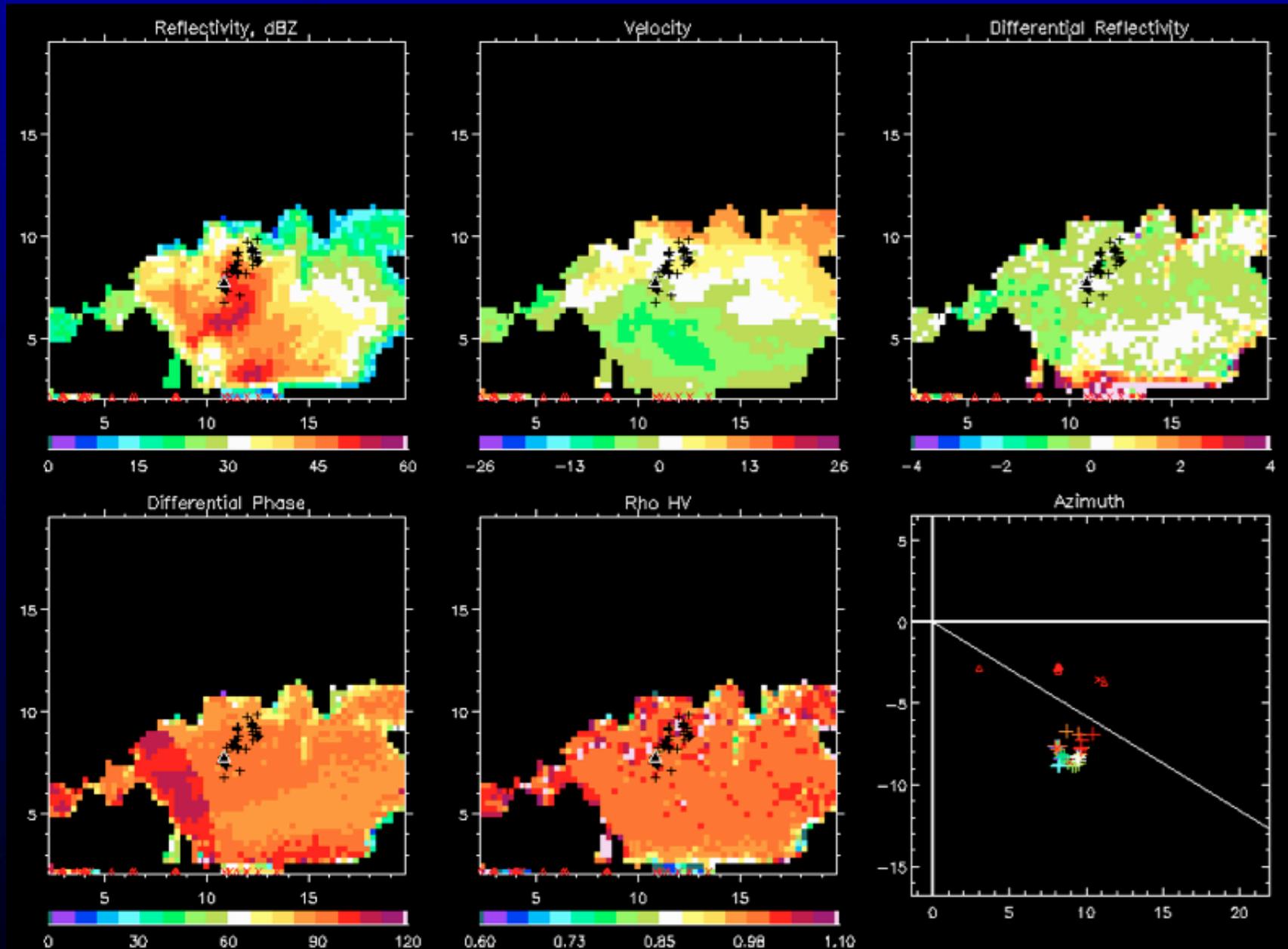
- Illustrate using observations of a storm on Aug 16, 2013 at Langmuir Laboratory with the LMA and the University of Oklahoma PX-1000 dual-polarization radar.
- Display using “UF_radar” IDL software developed in conjunction with xlma following 1999 Langmuir study and STEPS 2000 in NW Kansas and NE Colorado.
- UF_radar invoked either directly from the idl command line or from xlma under “other” > “radar”.
- Putting lightning data in storm context as shown by radar explains why the discharges behave as they do.

Sequence of 20 flashes in a small, localized storm overlaid on PX-1000 dual-polarization radar data

- Storm near Langmuir Laboratory produced 15 IC flashes, two bolt-from-the-blue (BFB) discharges, one --CG, one natural upward triggered CG flash, and one rocket-triggered flash, over a 17-minute period between 2100 and 2200 UTC on August 16, 2013.
- Radar supplied and operated by Michael Biggerstaff, Patrick Hyland and staff of University of Oklahoma.

Summary of results (Real-time processed data)

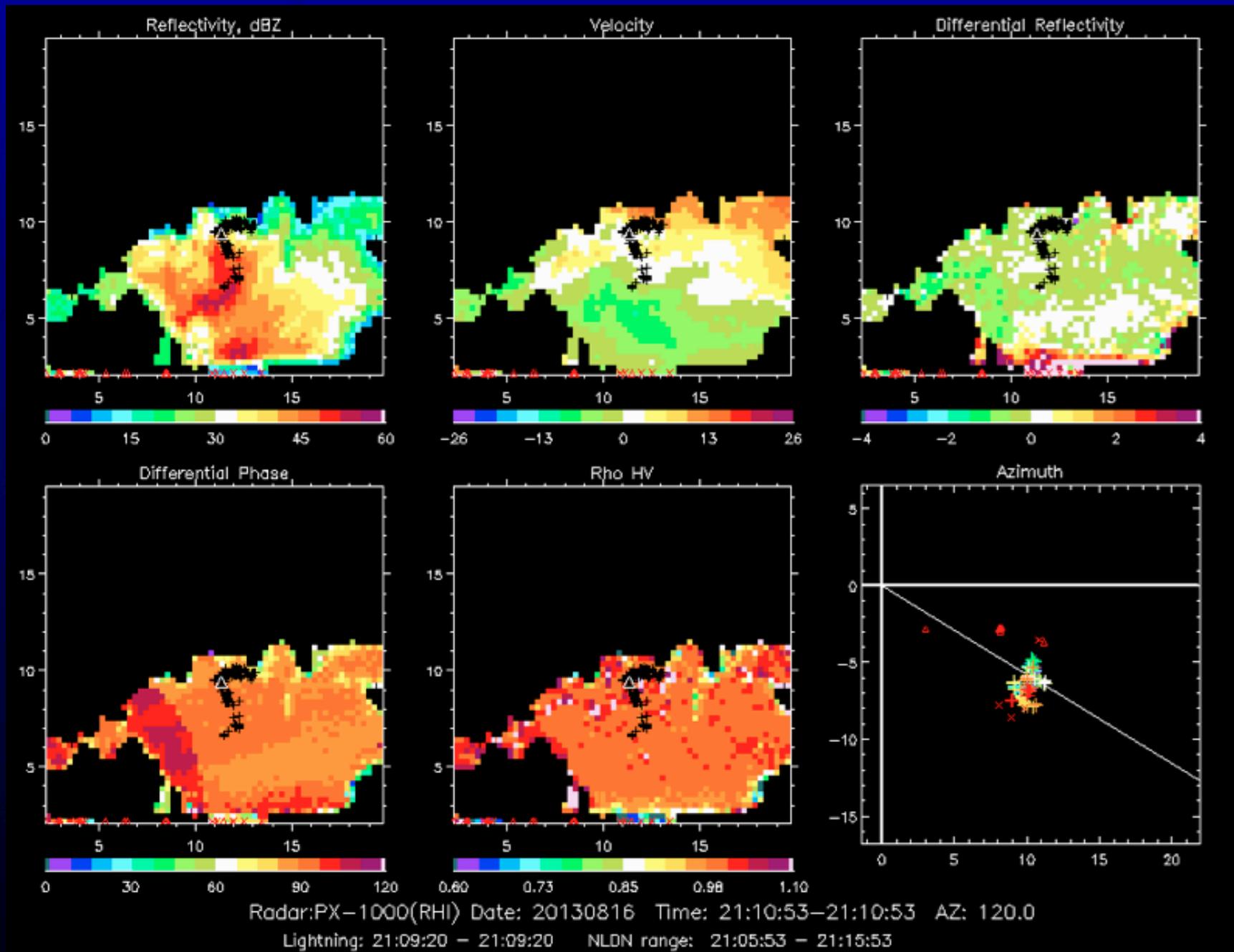
Initial Flash



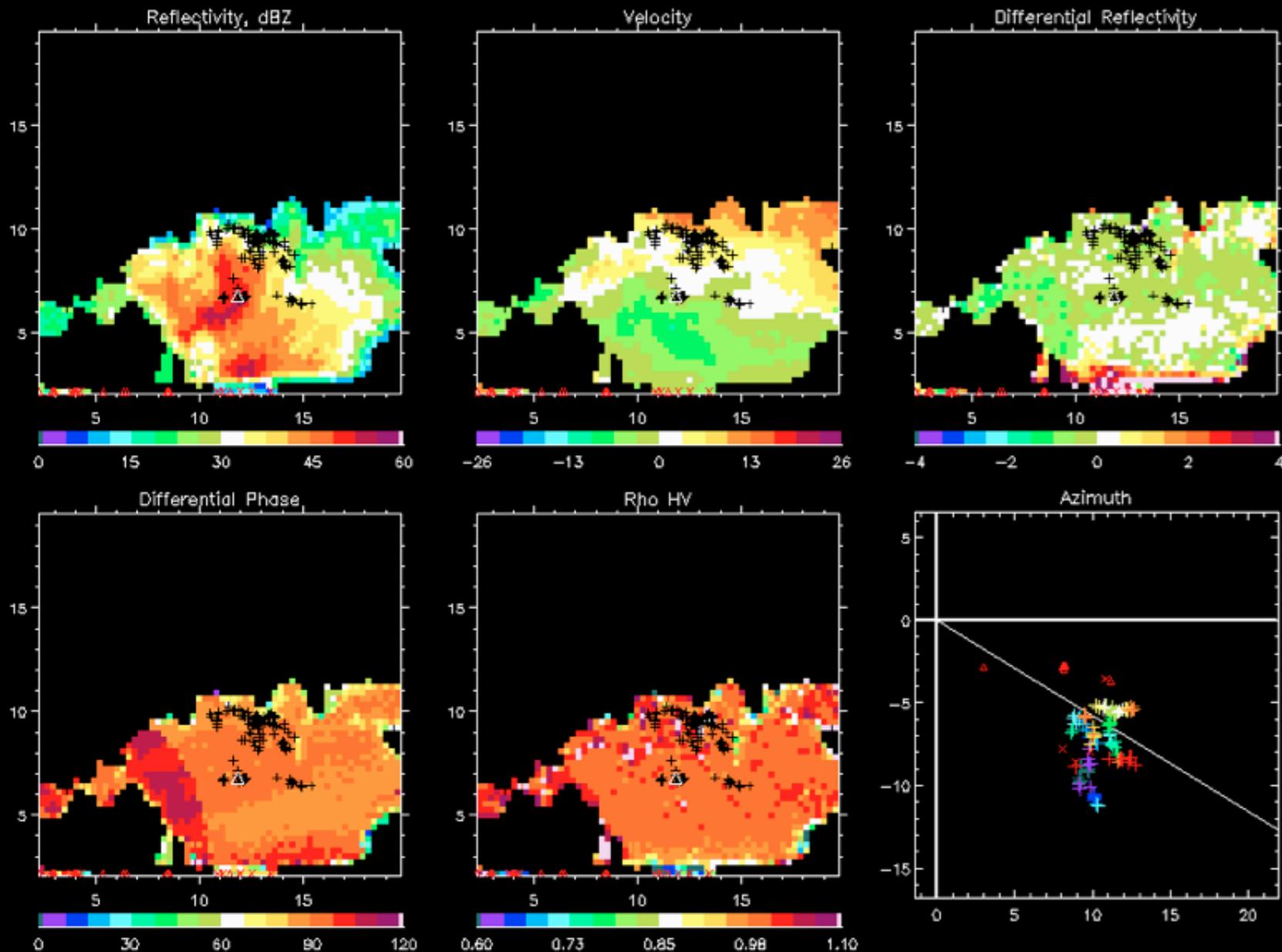
Radar:PX-1000(RHI) Date: 20130816 Time: 21:10:53-21:10:53 AZ: 120.0

Lightning: 21:08:15 - 21:08:16 NLDN range: 21:05:53 - 21:15:53

Flash 2, initiated at top of 40-45 dBZ echo, (-) charge in precip shaft



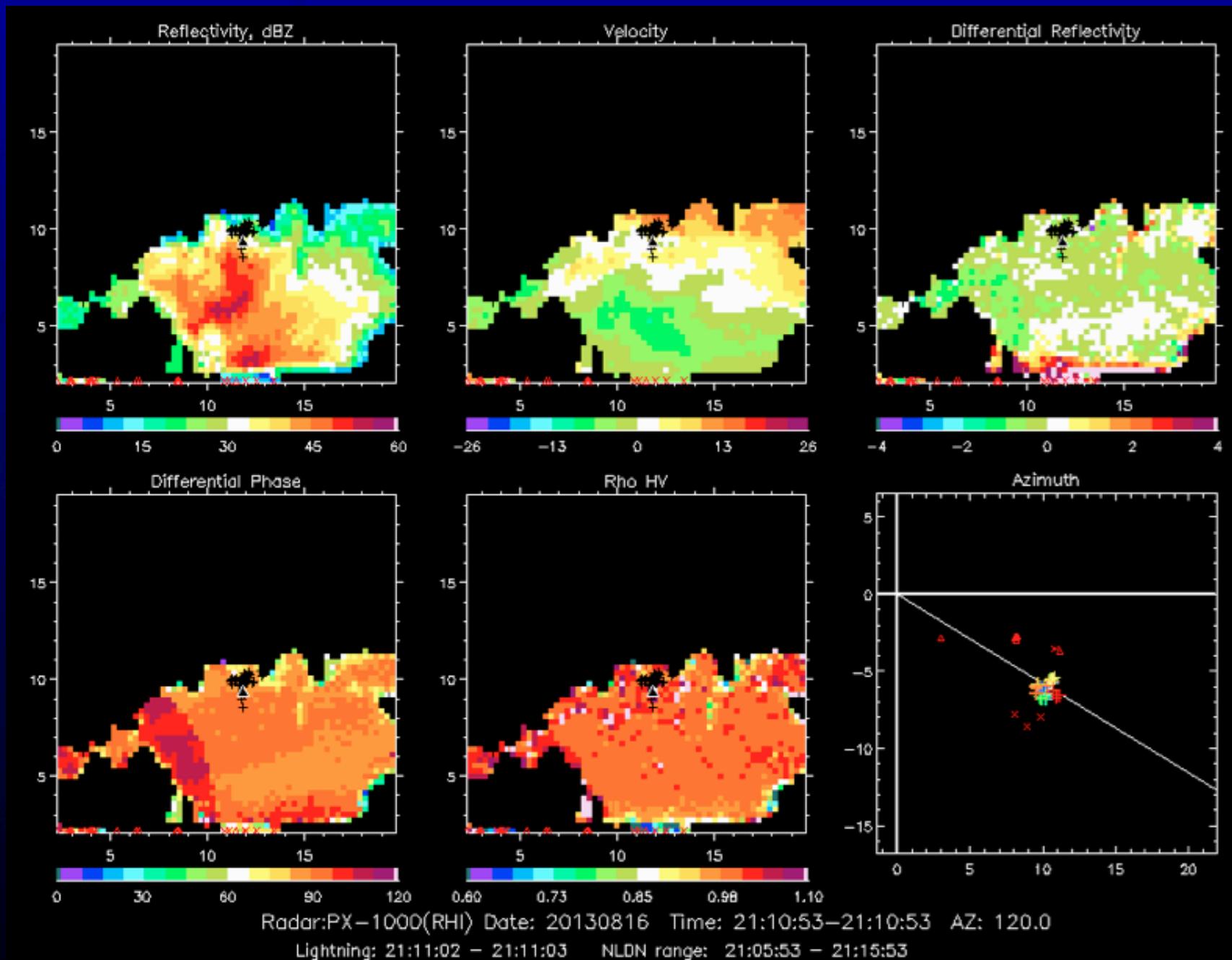
Flash 3, initiated at lower altitude in precipitation core



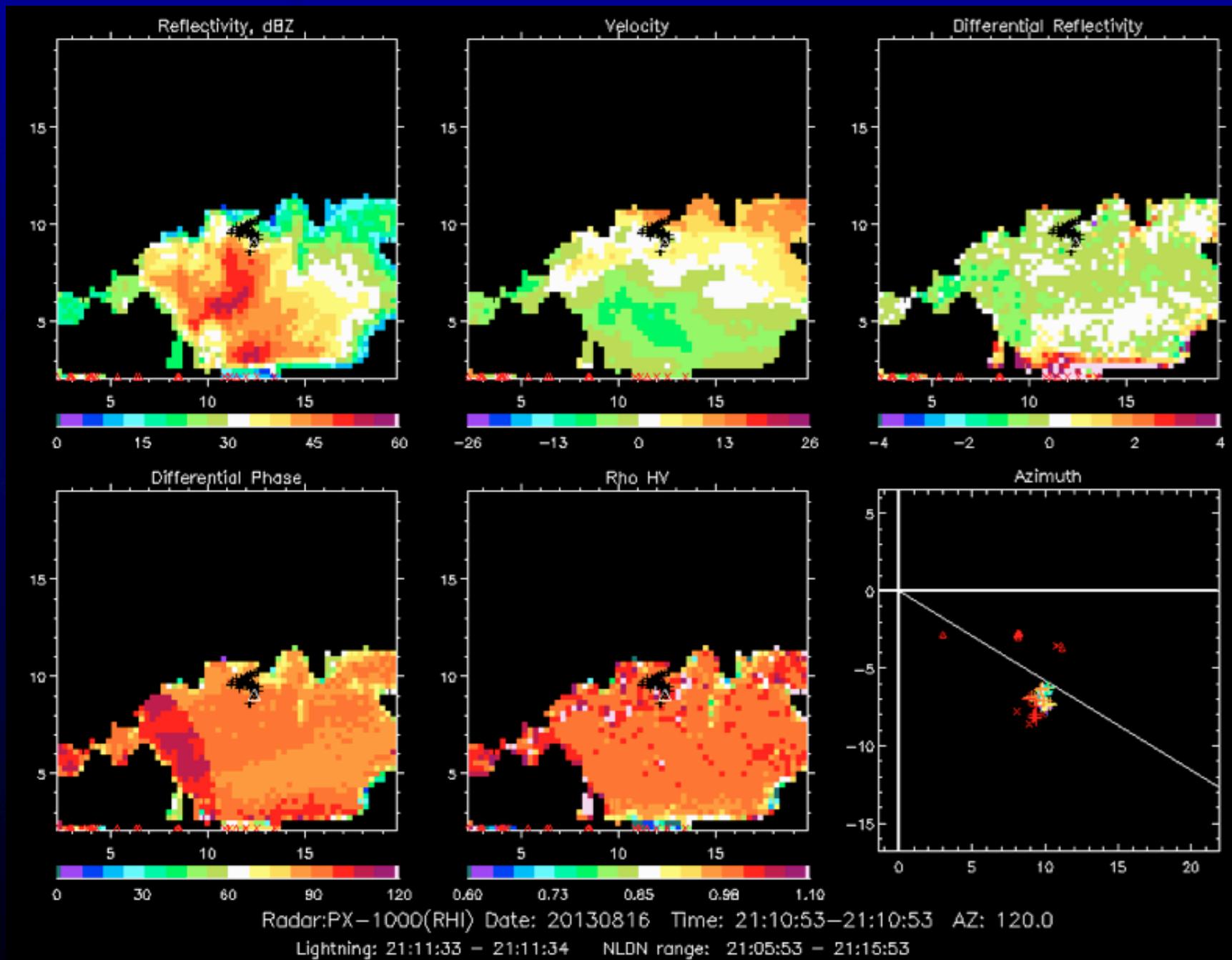
Radar:PX-1000(RHI) Date: 20130816 Time: 21:10:53-21:10:53 AZ: 120.0

Lightning: 21:10:23 - 21:10:24 NLDN range: 21:05:53 - 21:15:53

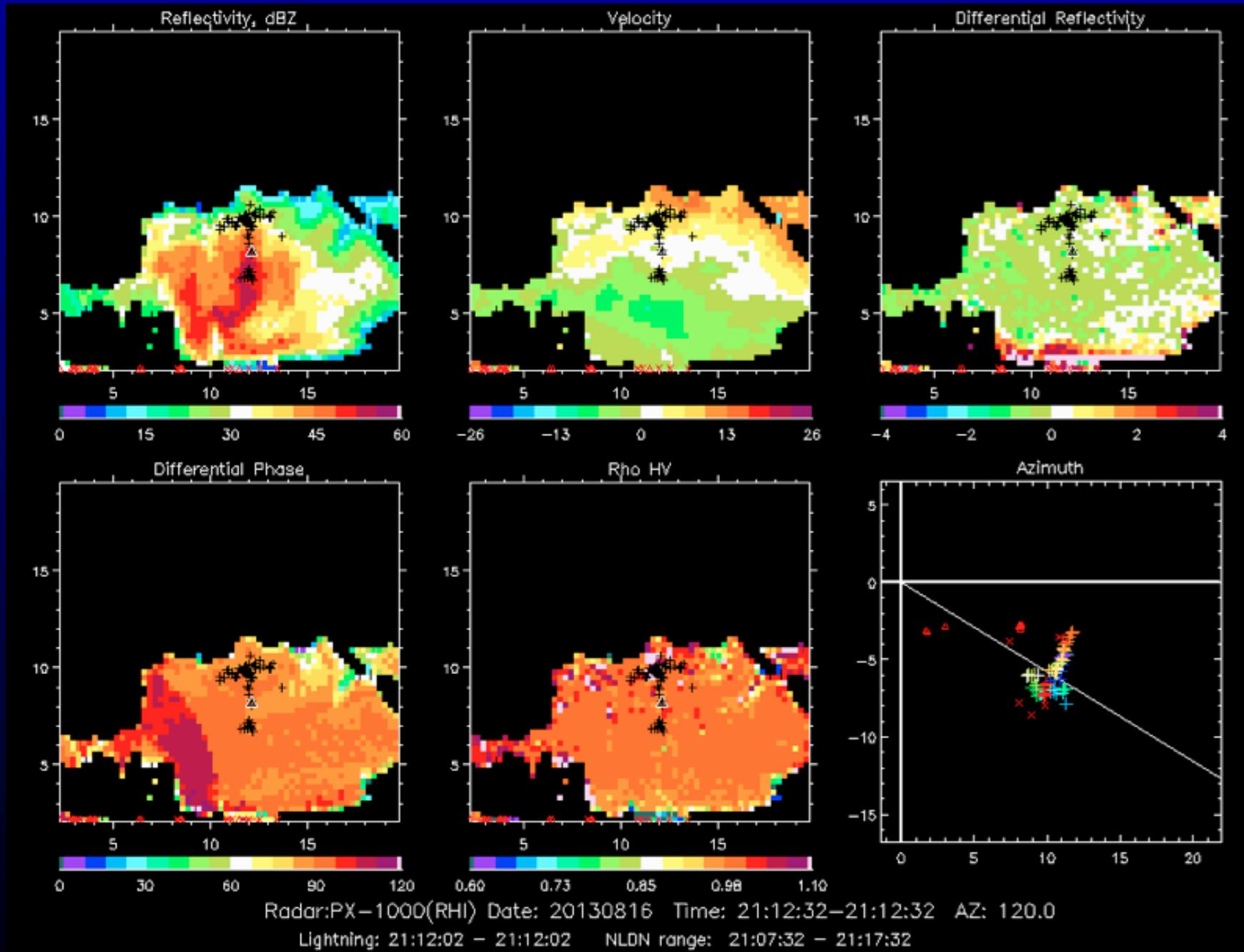
Flash 4, initiated back at high altitude, more horizontally extensive



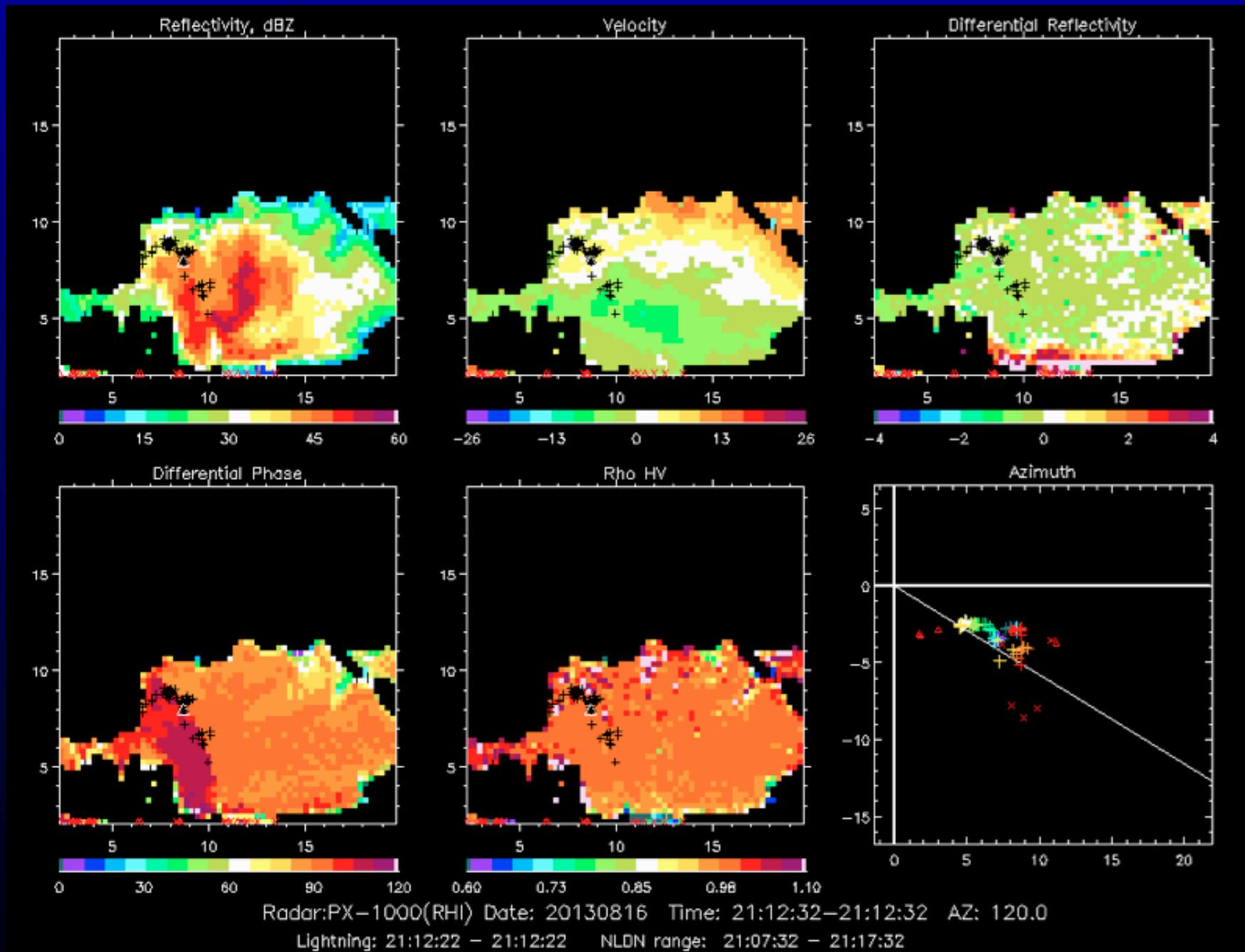
Flash 5, another IC in upper part of storm, at top of 45 dBZ echo



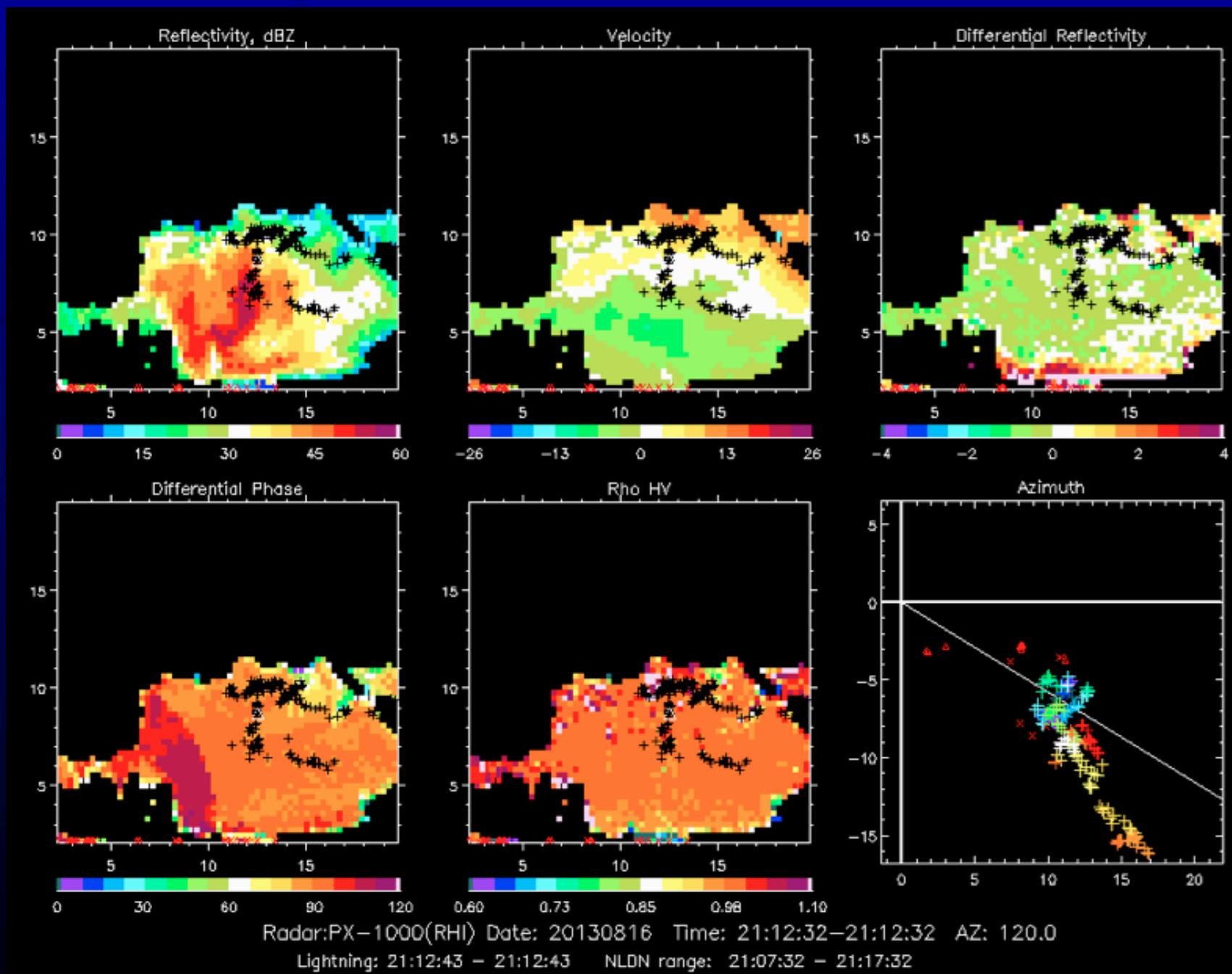
Flash 6, vertical channel between upper (+) above ppn and (--) in ppn core



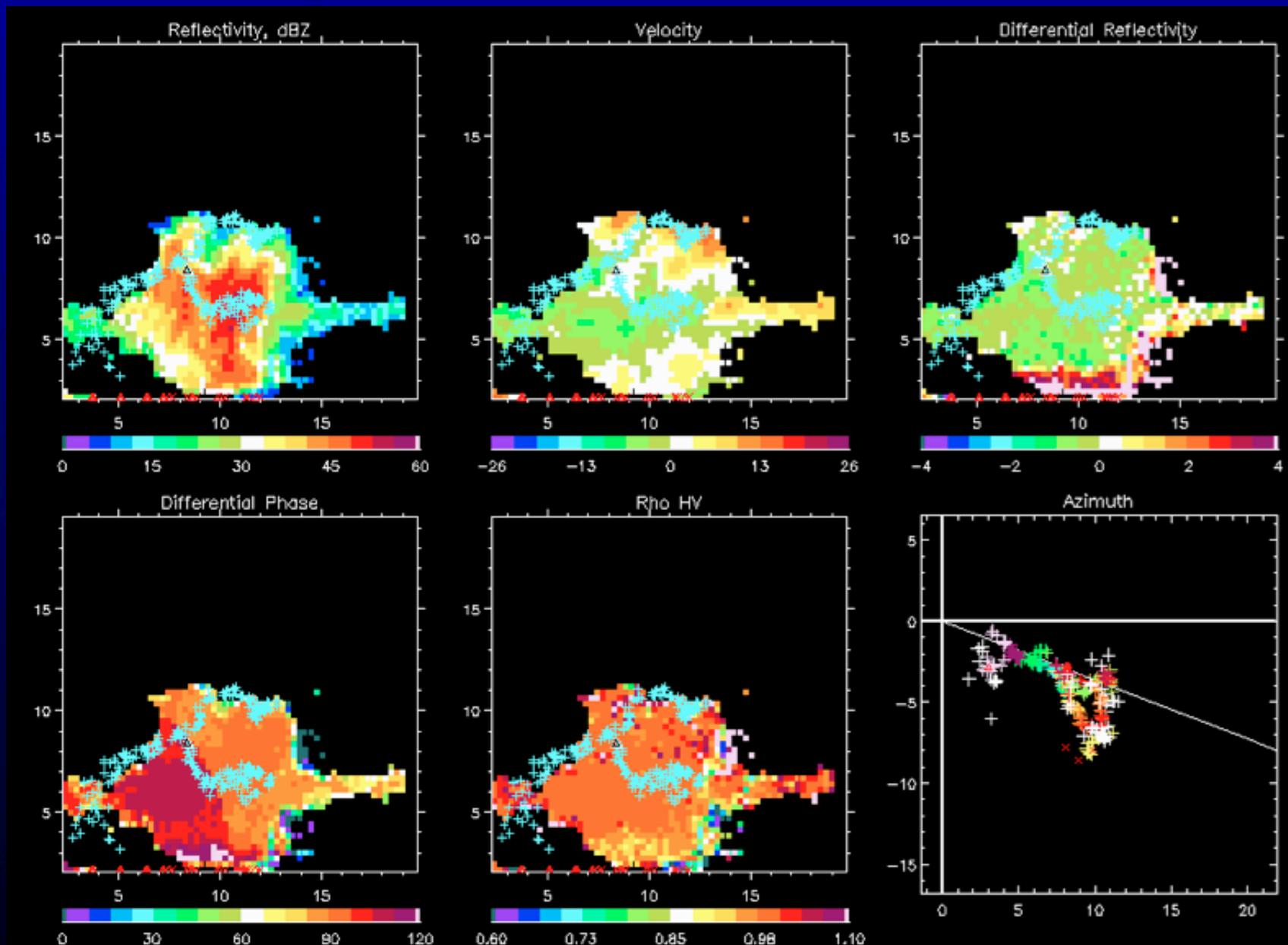
Flash 7, IC in new cell on west side of storm



Flash 8: Bilevel IC back in main ppn shaft and downwind side of storm



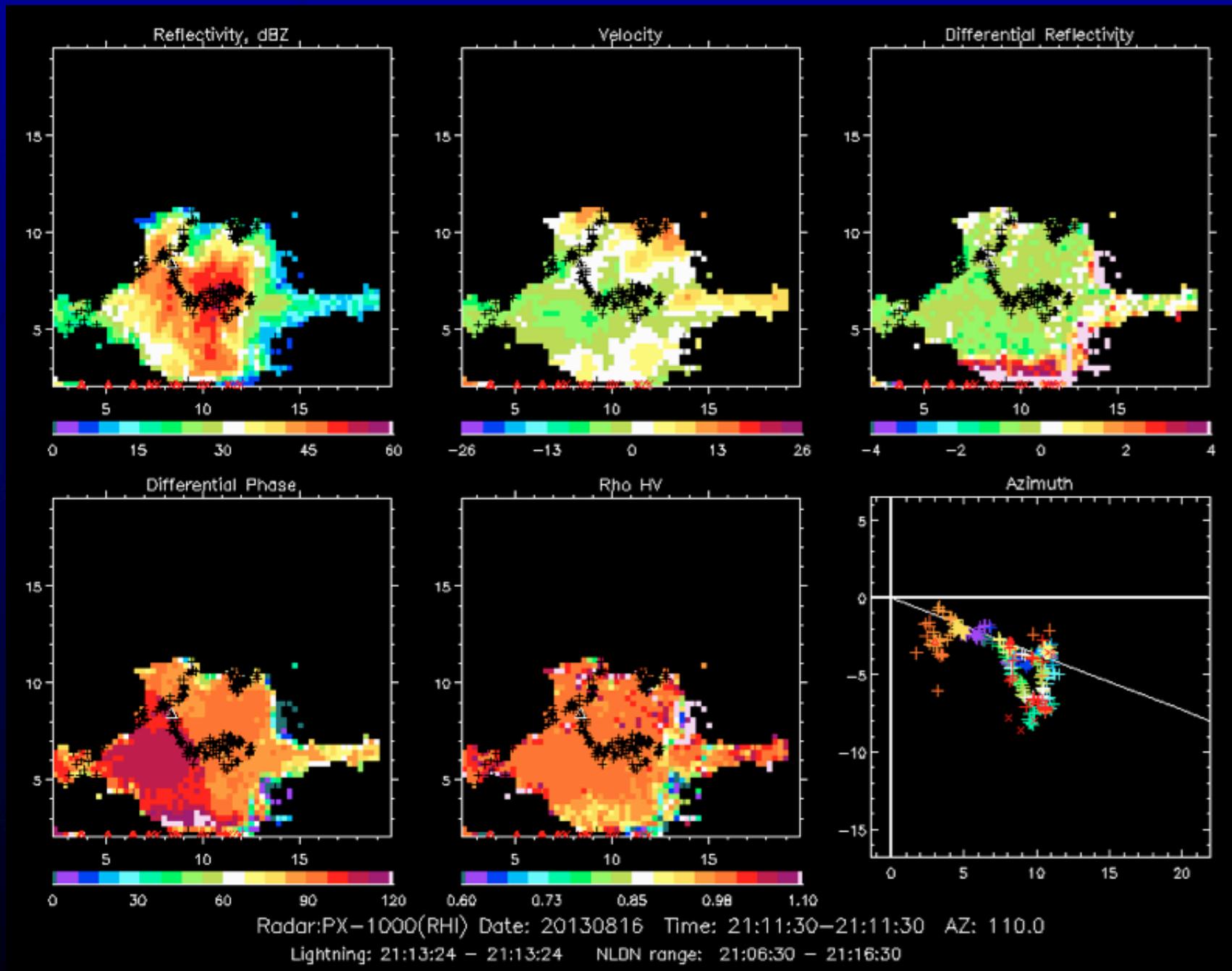
Flash 9: Bolt-from-the-blue CG (cyan) 5-6 km away from storm core



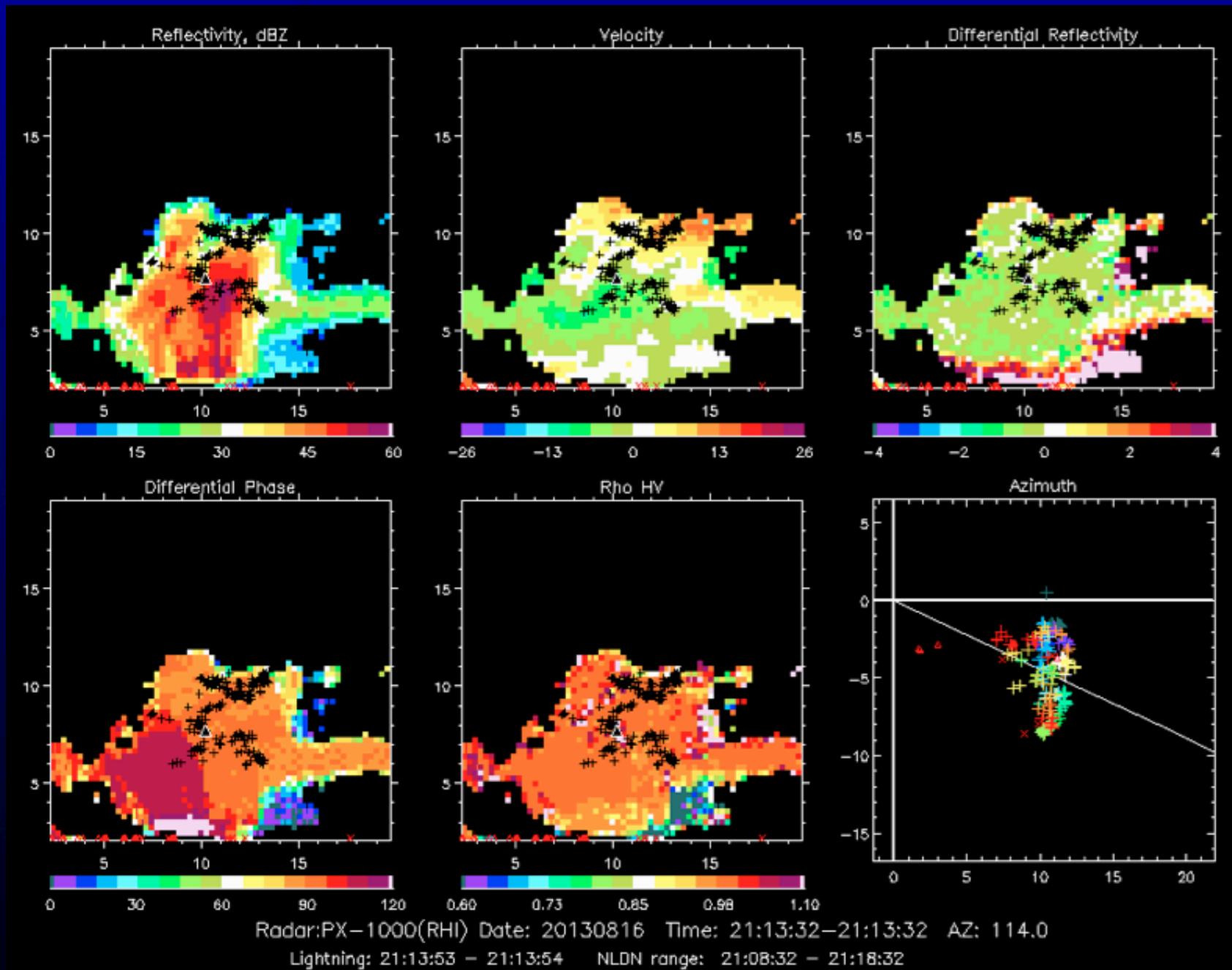
Radar:PX-1000(RHI) Date: 20130816 Time: 21:11:30-21:11:30 AZ: 110.0

Lightning: 21:13:24 - 21:13:24 NLDN range: 21:06:30 - 21:16:30

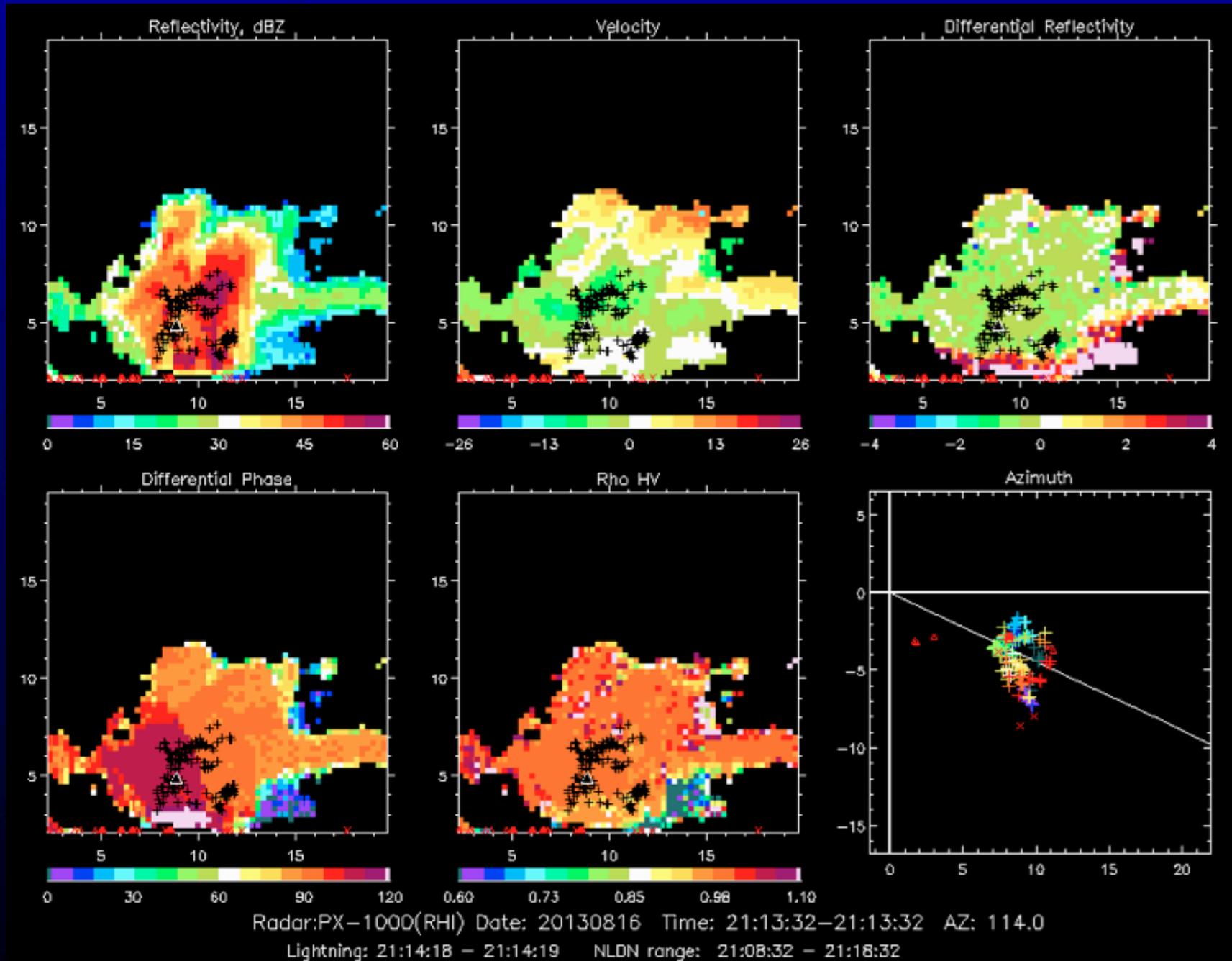
Flash 9: Bolt-from-the-blue CG (black) 5-6 km away from storm core



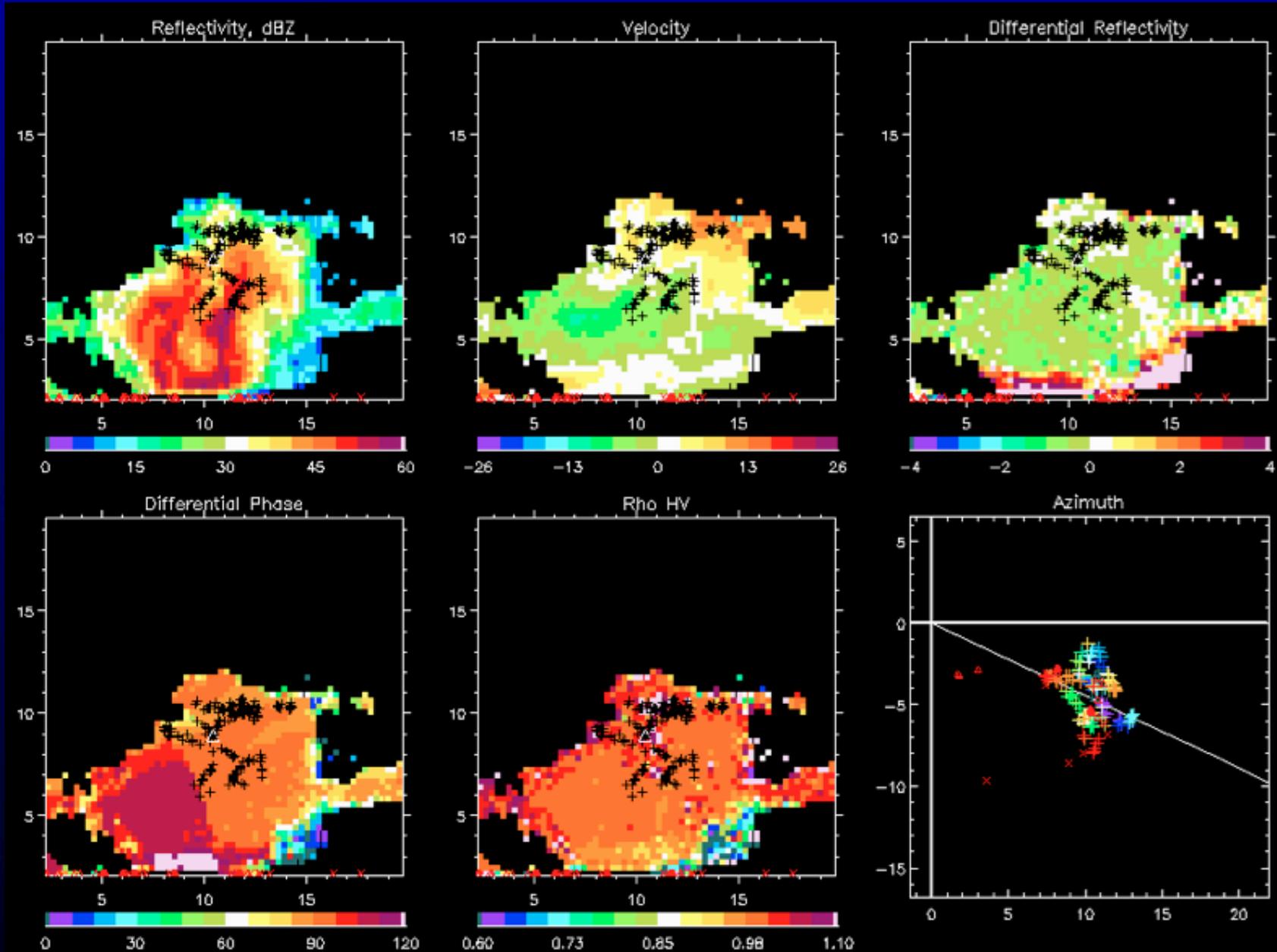
Flash 10: Active bilevel IC in main core



Flash 11: Normal --CG, four strokes to ground

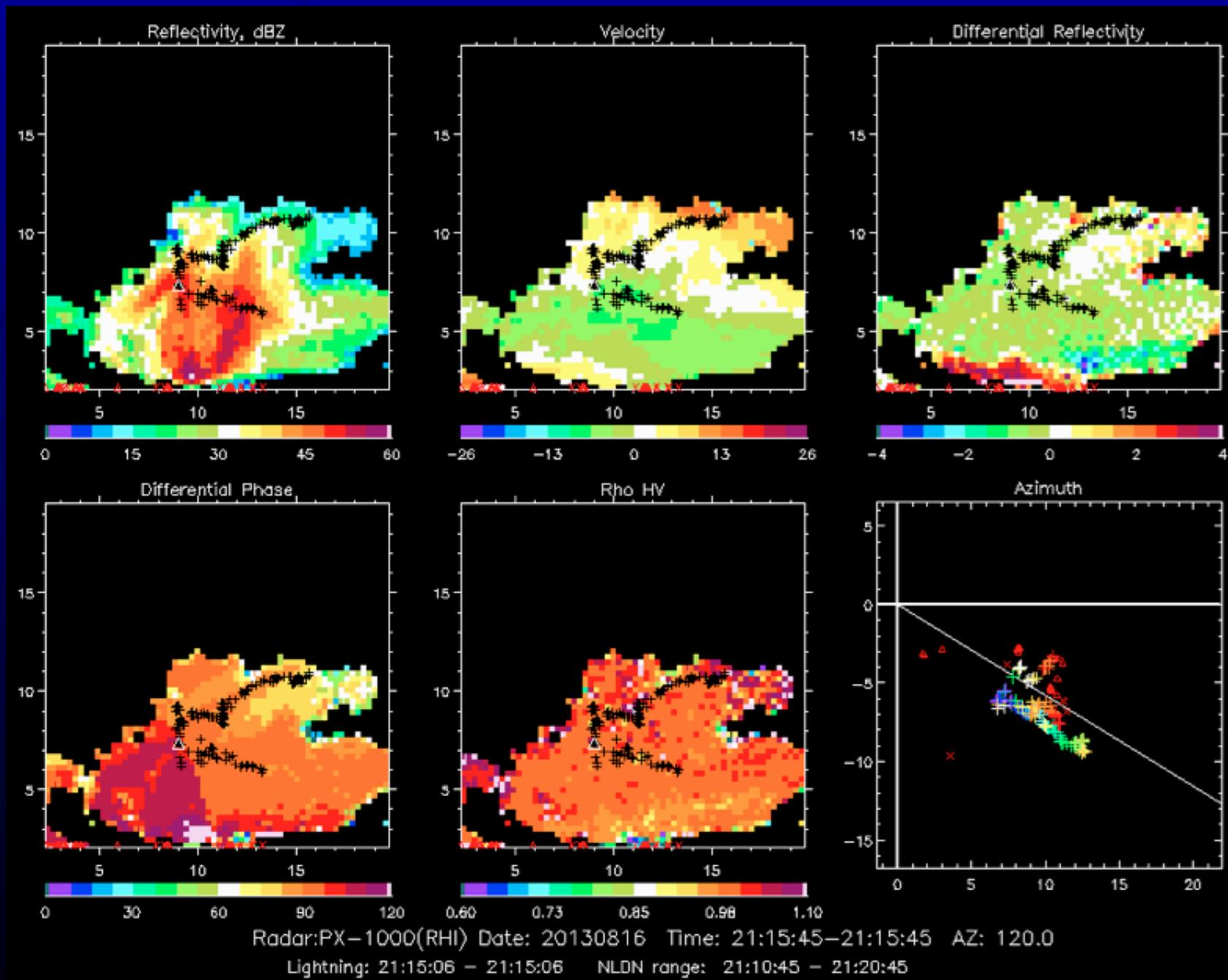


Flash 12: Complex bilevel IC

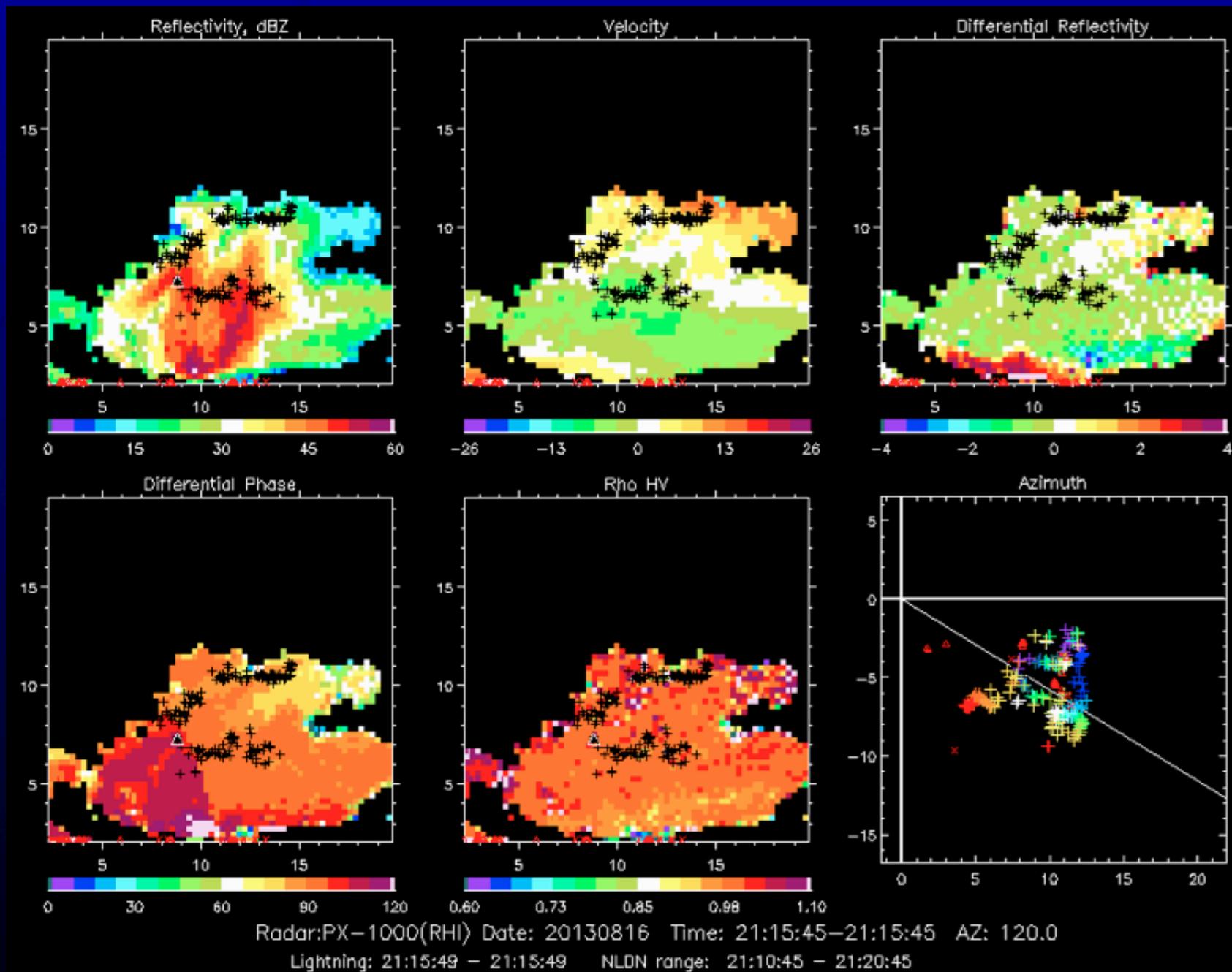


Radar:PX-1000(RHI) Date: 20130816 Time: 21:15:10-21:15:10 AZ: 114.0
Lightning: 21:14:48 - 21:14:48 NLDN range: 21:10:10 - 21:20:10

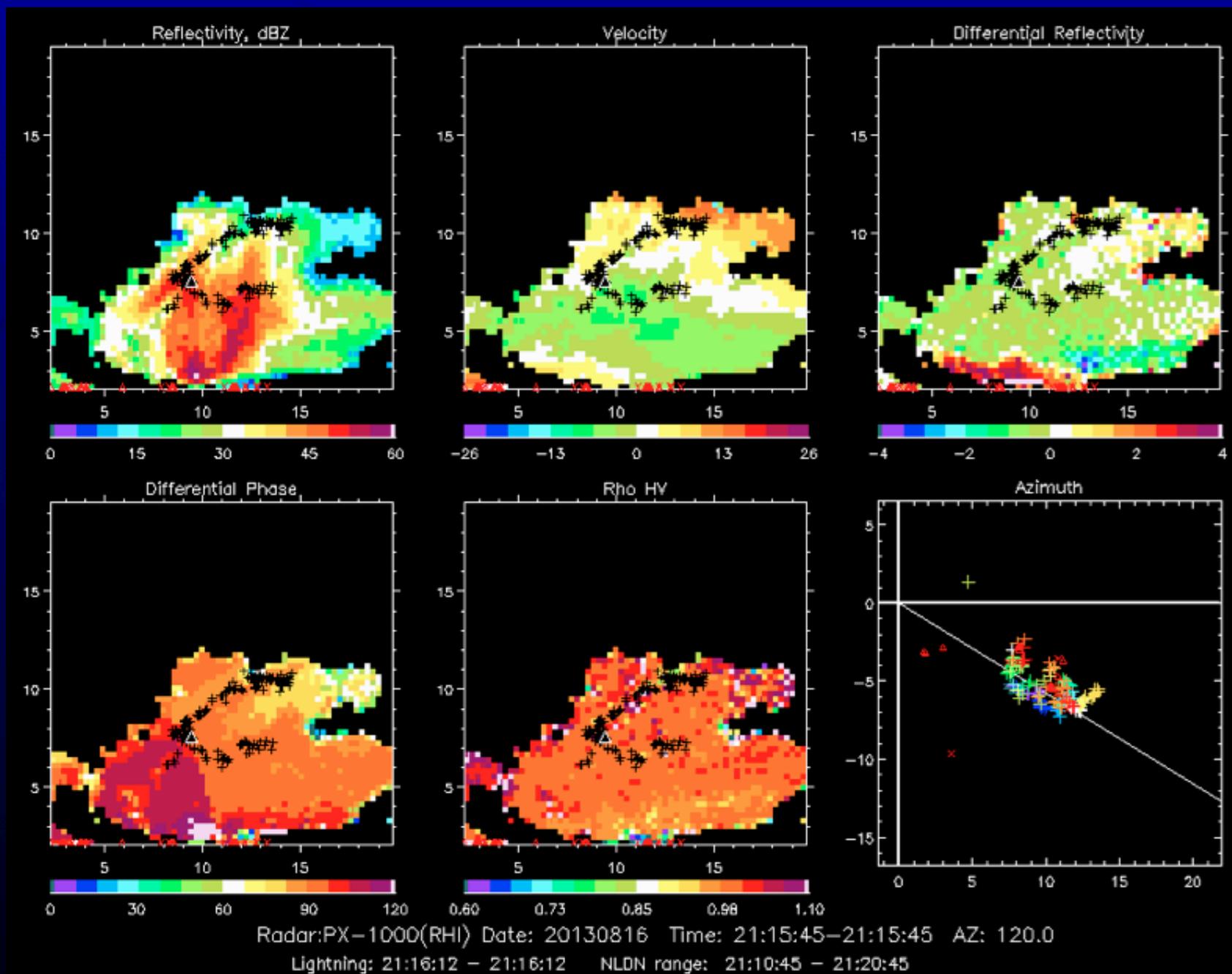
Flash 13: IC into positive charge above core and at higher altitude into anvil



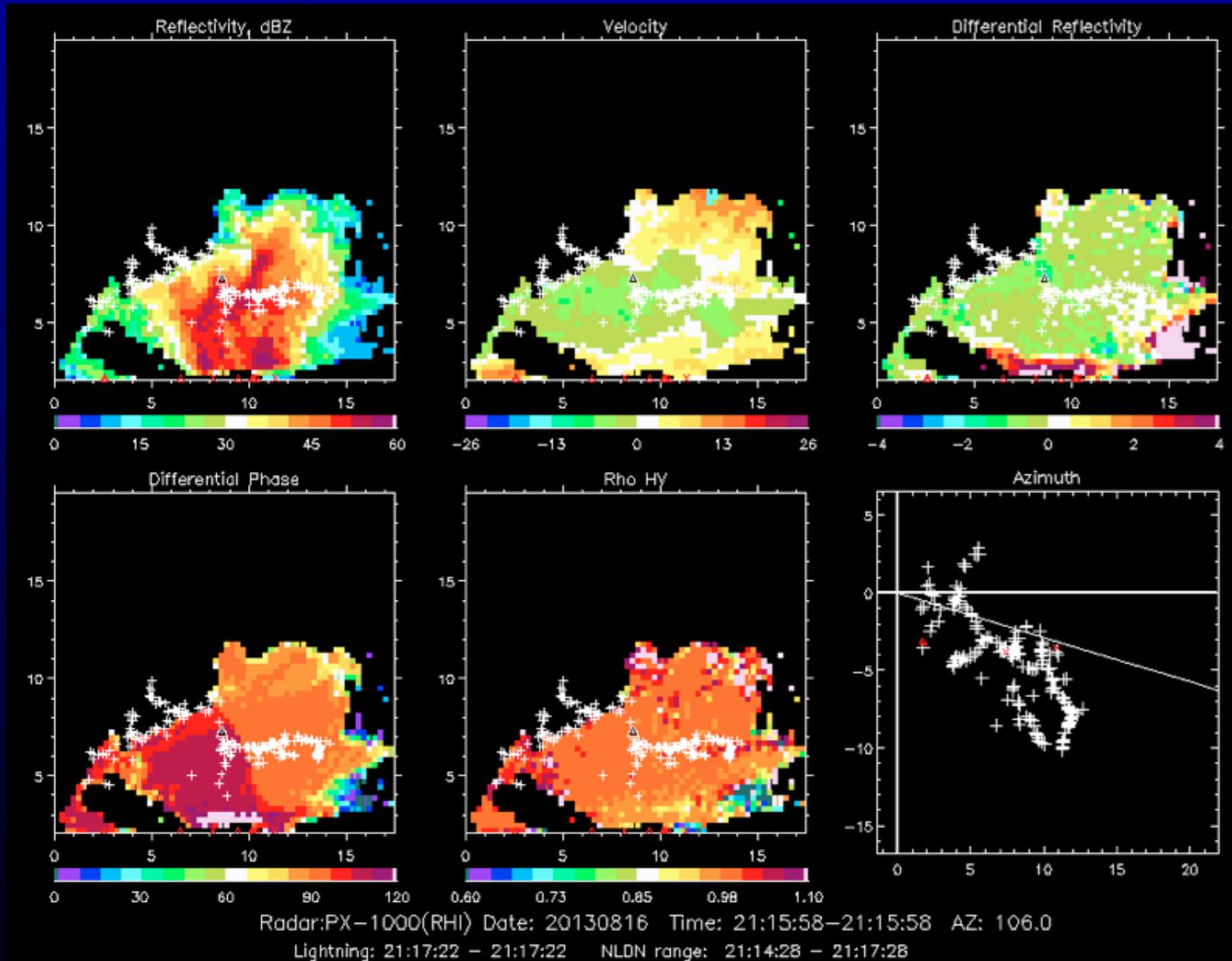
Flash 14: Bilevel IC in western cell, develops horizontally into eastern cell



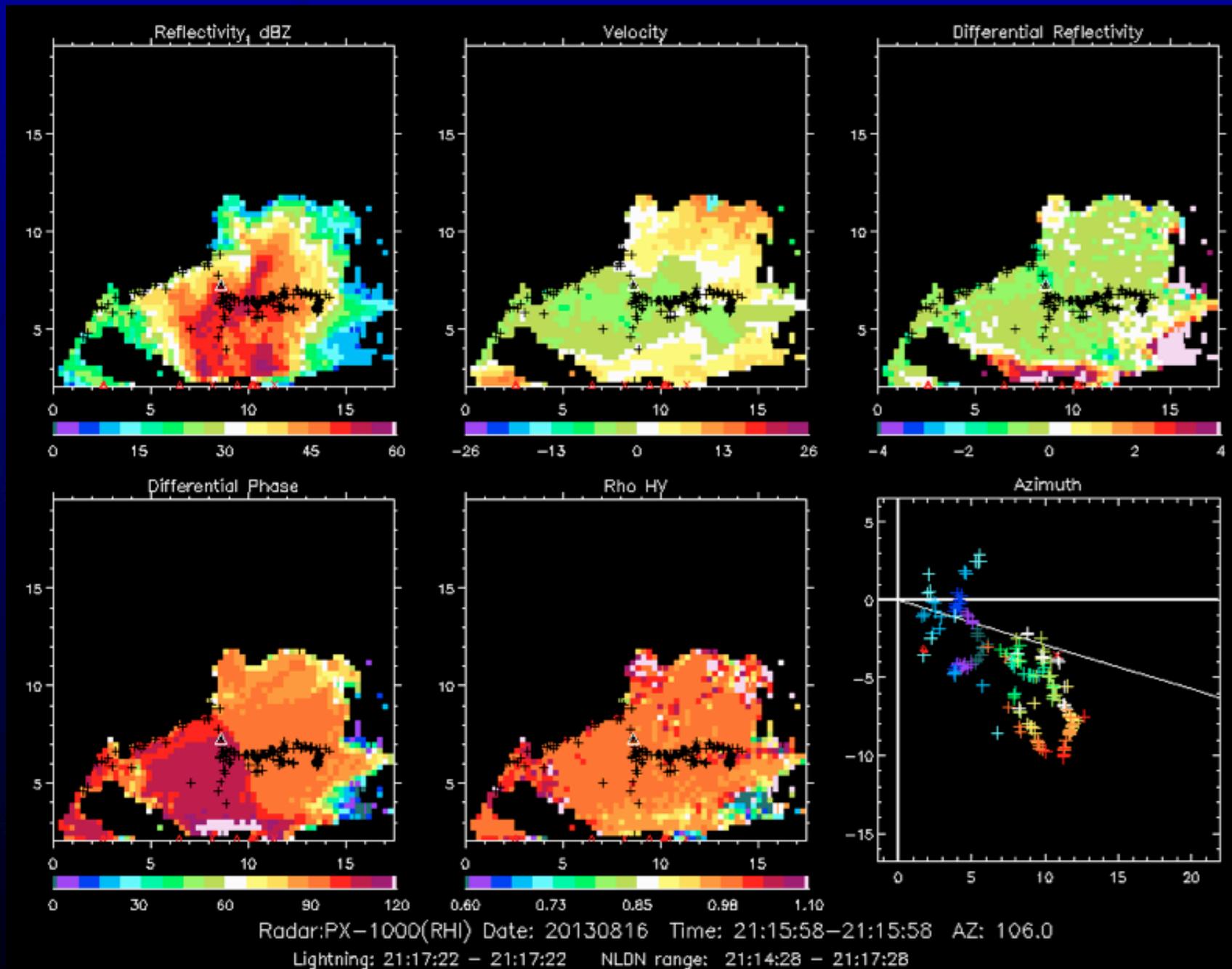
Flash 15: IC into upward sloping (+) charge into base of downwind anvil



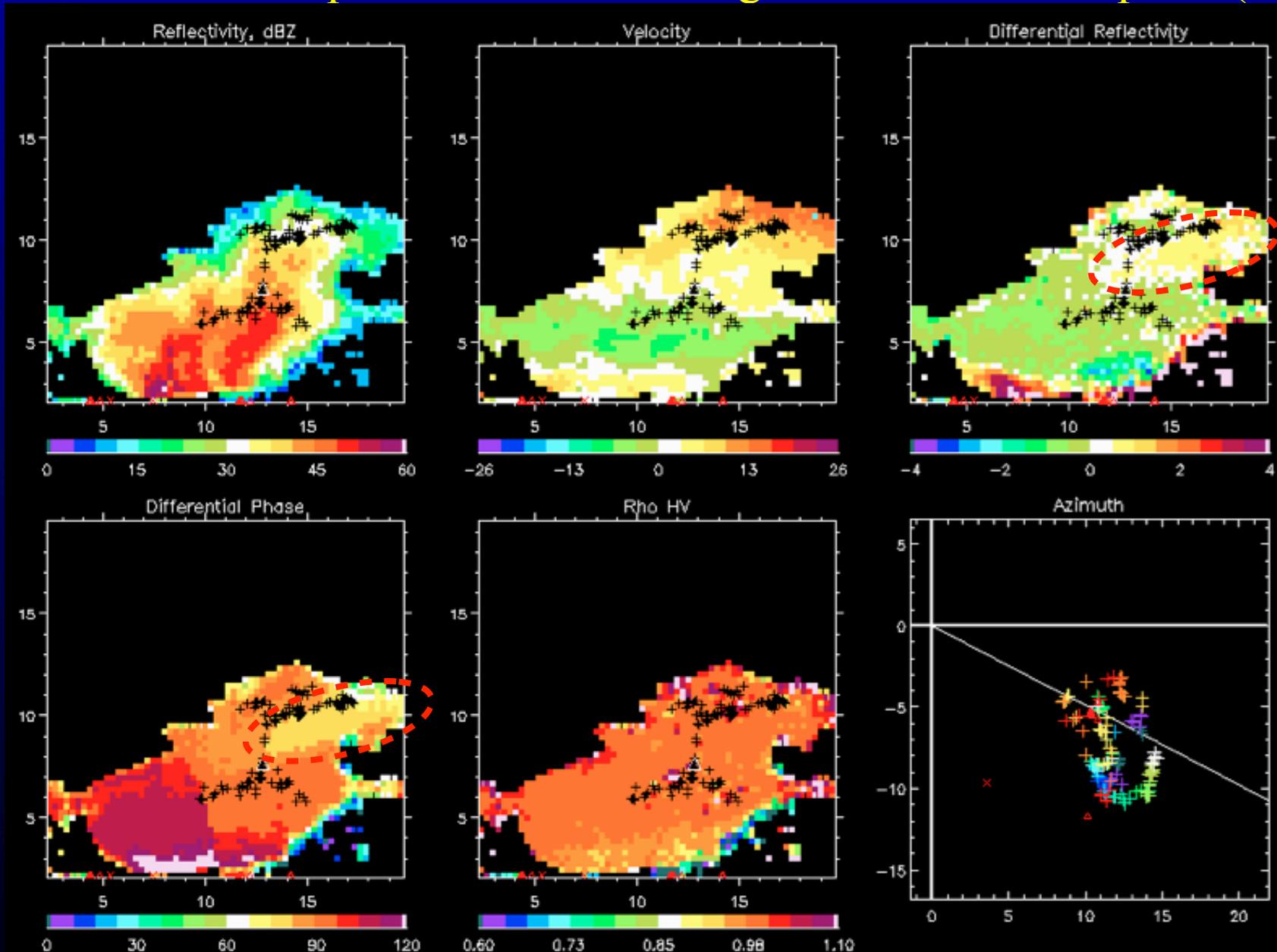
Flash 16: BFB2 (white) exiting storm to NW along upper part of shelf cloud



Flash 16: Source of negative charge for BFB2 (black)

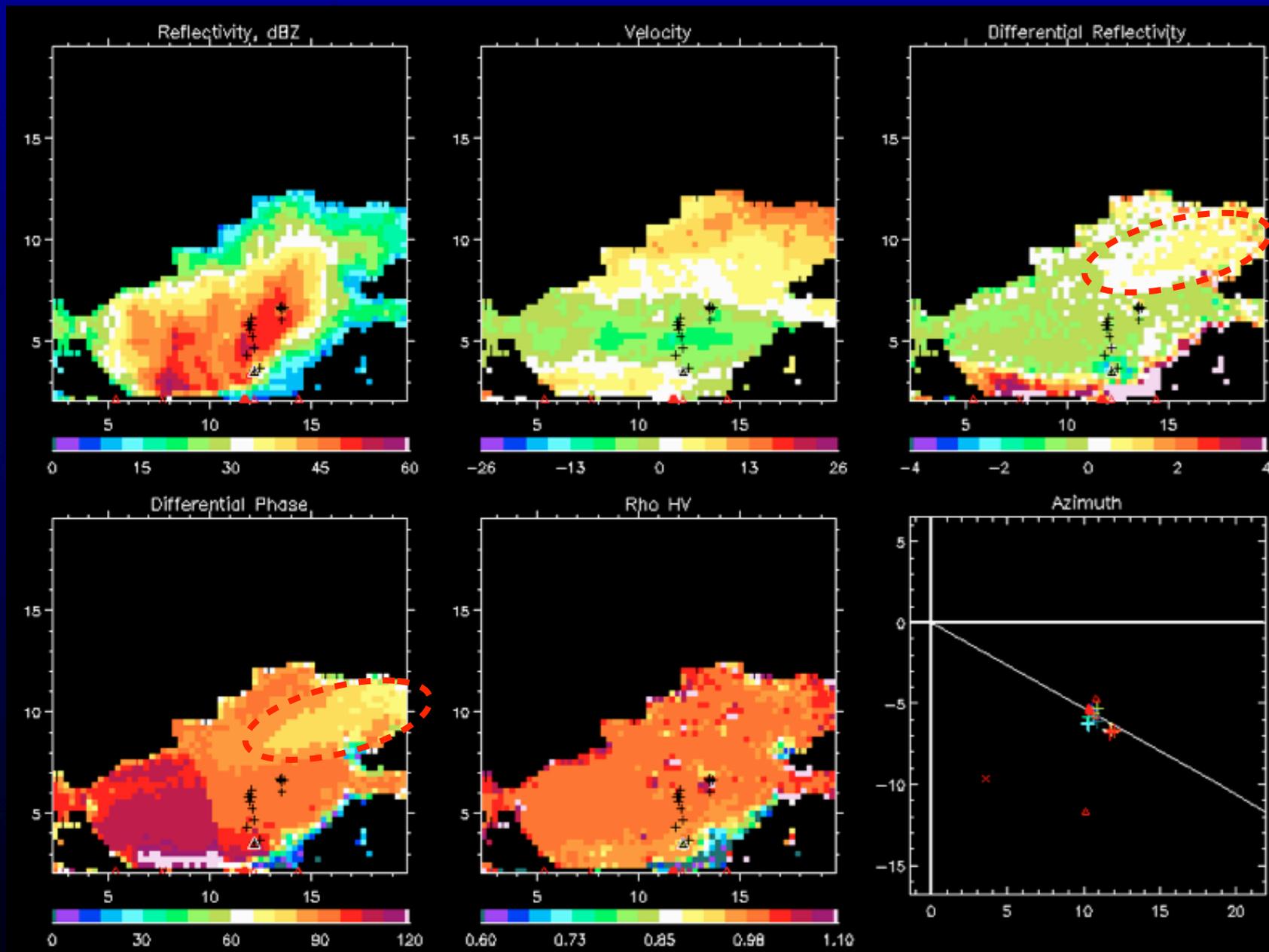


Flash 17: Bilevel IC tilted into downwind shear. Note electrical alignment signature in differential phase and Zdr starting at flash initiation point (red oval)



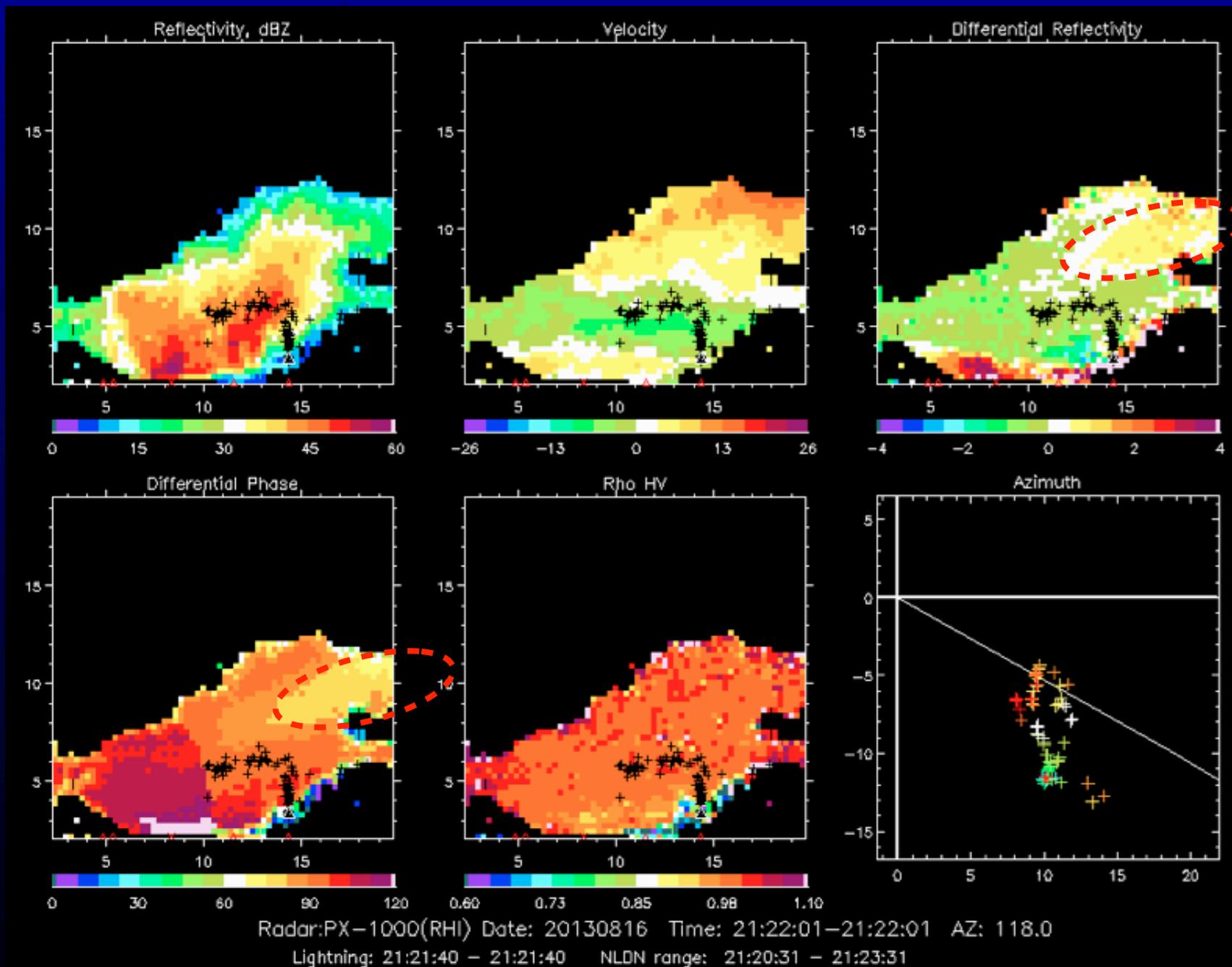
Radar:PX-1000(RHI) Date: 20130816 Time: 21:20:38-21:20:38 AZ: 116.0
Lightning: 21:18:33 - 21:18:33 NLDN range: 21:19:08 - 21:22:08

Flash 18: Naturally-triggered upward (+) discharge from mountain ridge 7 km north of rocket trigger site. 86.3 kA --CG in NLDN data!!

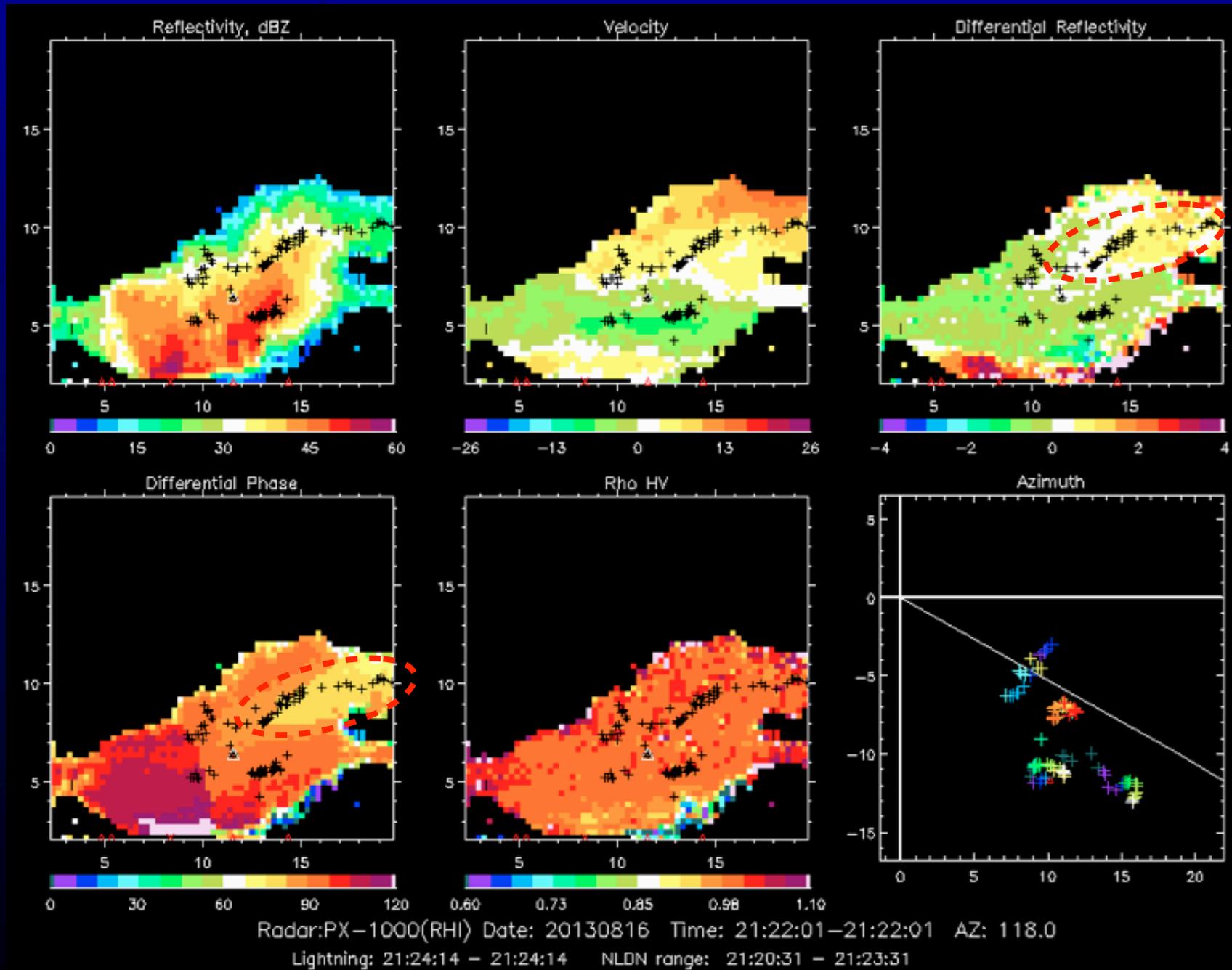


Radar:PX-1000(RHI) Date: 20130816 Time: 21:20:50-21:20:50 AZ: 118.0
 Lightning: 21:19:51 - 21:19:52 NLDN range: 21:19:20 - 21:22:20

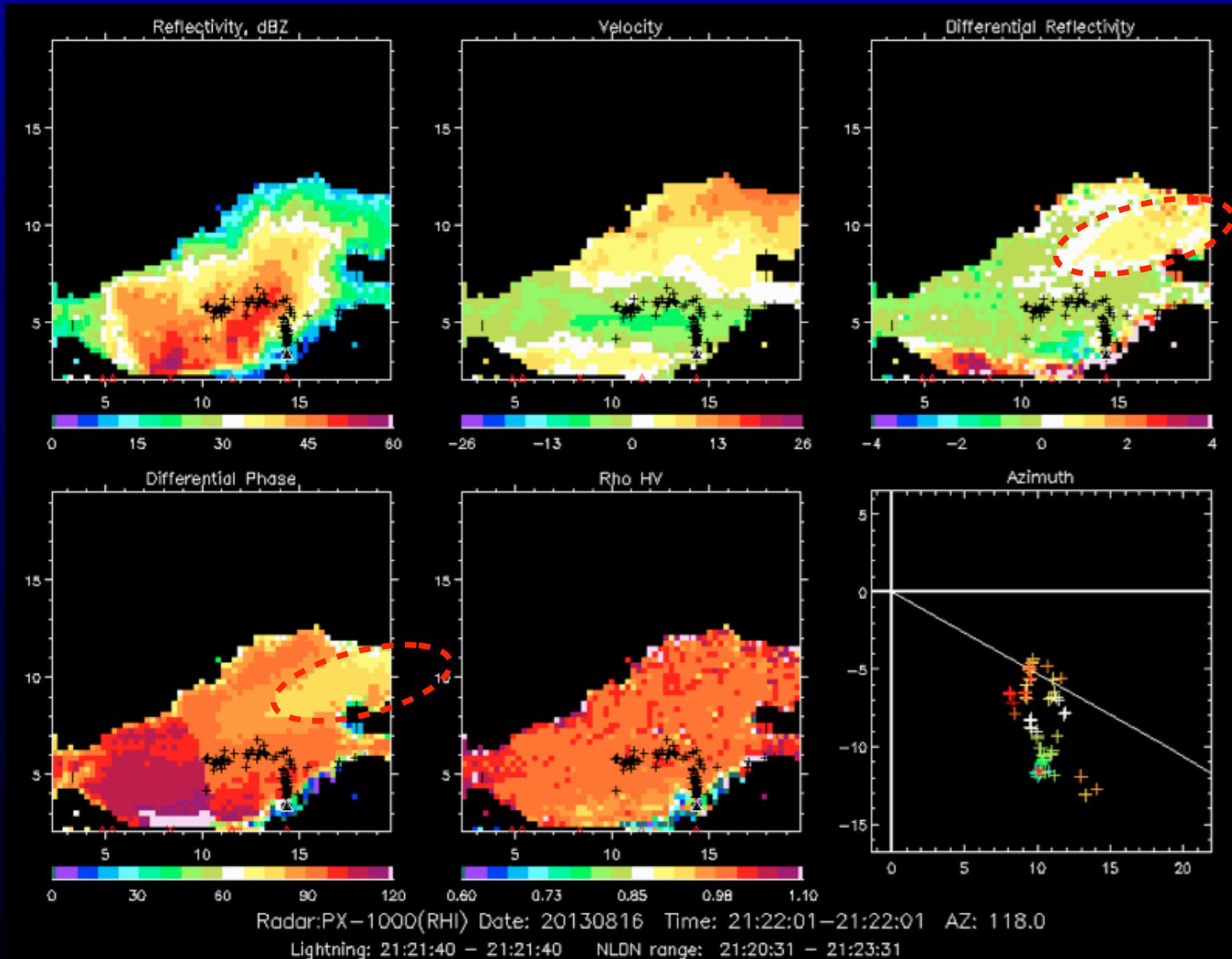
Flash 19: Rocket-triggered upward (+) discharge from South Baldy peak into subsiding negative storm charge as storm dies out.



Flash 20: IC flash between subsiding (--) and (+) charge regions as strongly sheared storm dies out (final discharge).



Flash 19: Rocket-triggered upward (+) discharge from South Baldy peak into subsiding negative storm charge as storm dies out.

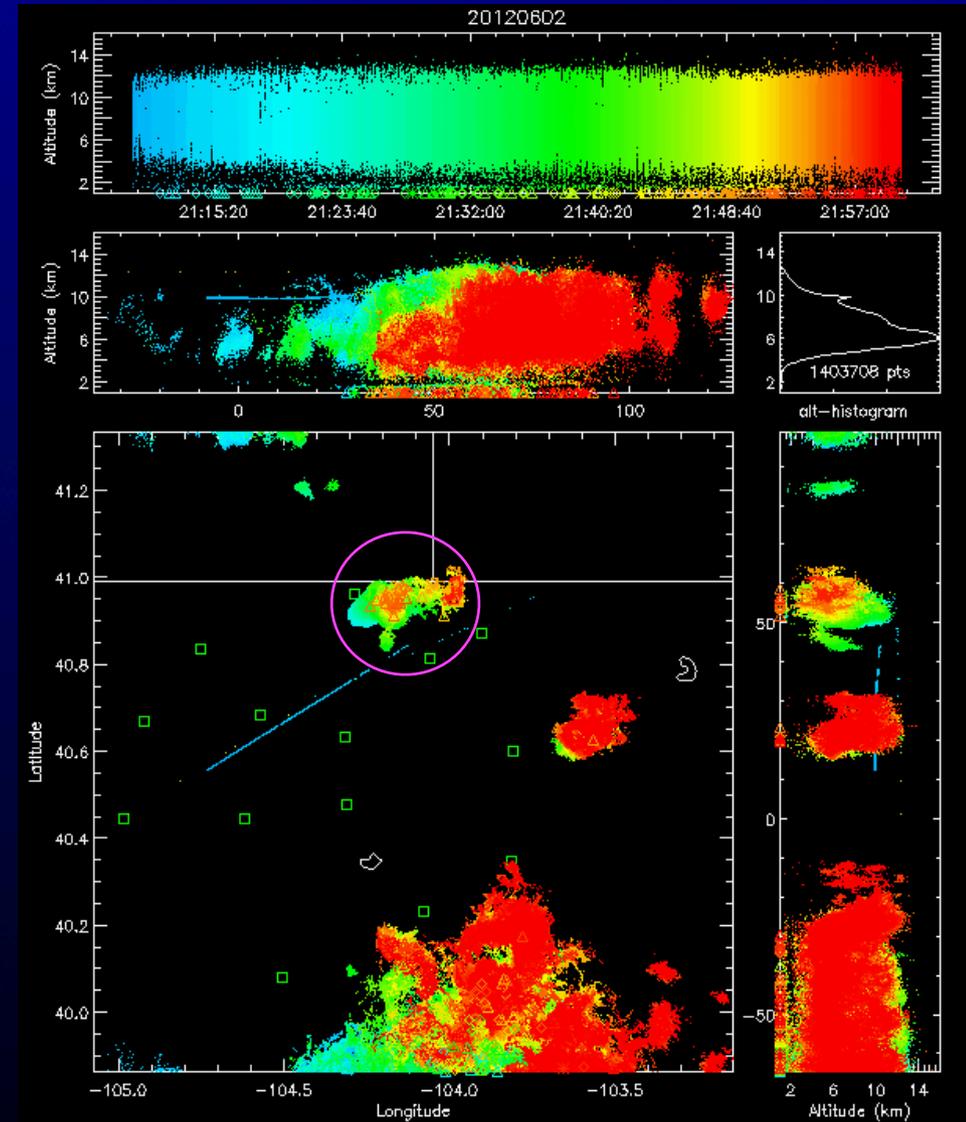
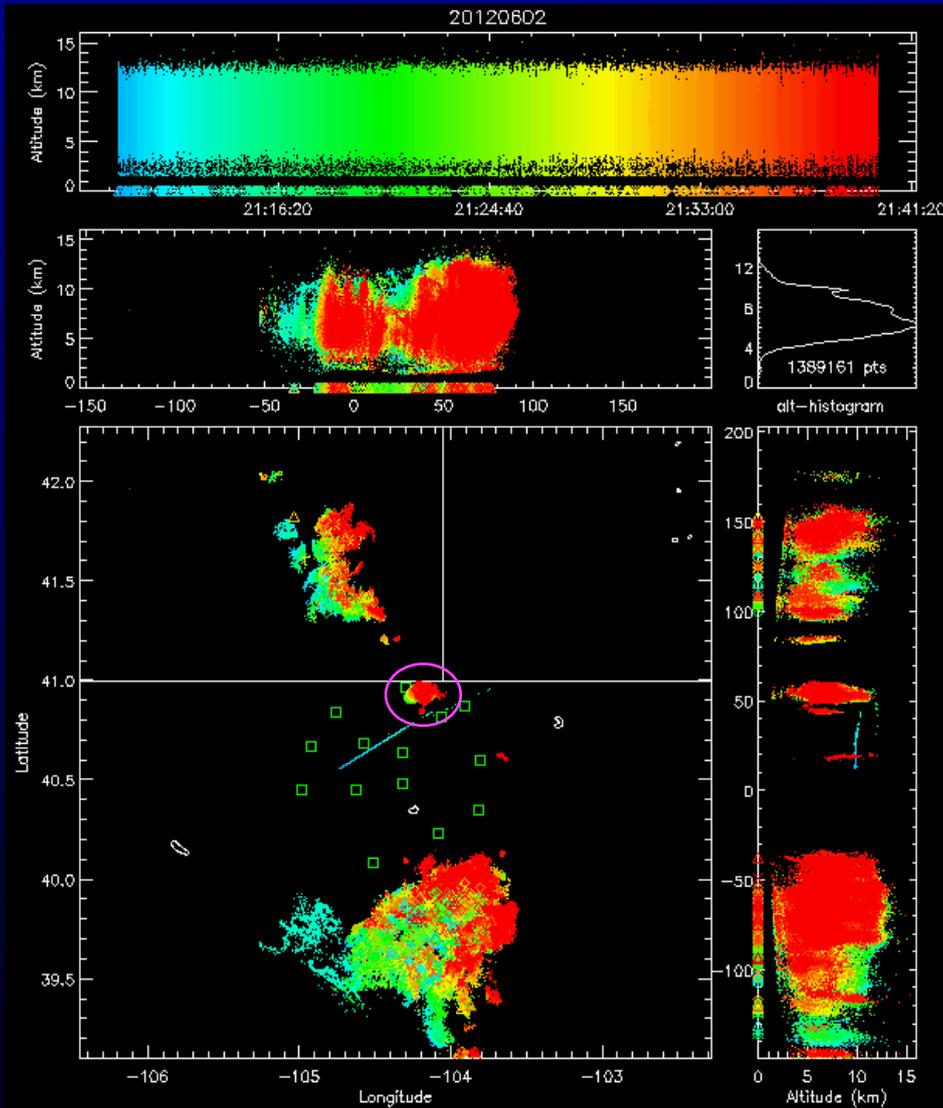


DC3 Atmospheric Chemistry Field Campaign, May-June 2012

- Excellent data obtained in collaboration with CSU and the CHILL radar.
- Data Analysis: Work in progress
- This presentation: Show examples of kind of observations obtained during DC3
- A wide variety of storm electrical structures observed (normal and anomalous polarity)
- Anomalous storms common, and best characterized as having a *deficit* of CGs [(-) or (+)]
- Detailed study of the observations should be very useful in understanding electrification processes
- (Adapted from presentation at 2012 Fall Annual AGU meeting.)

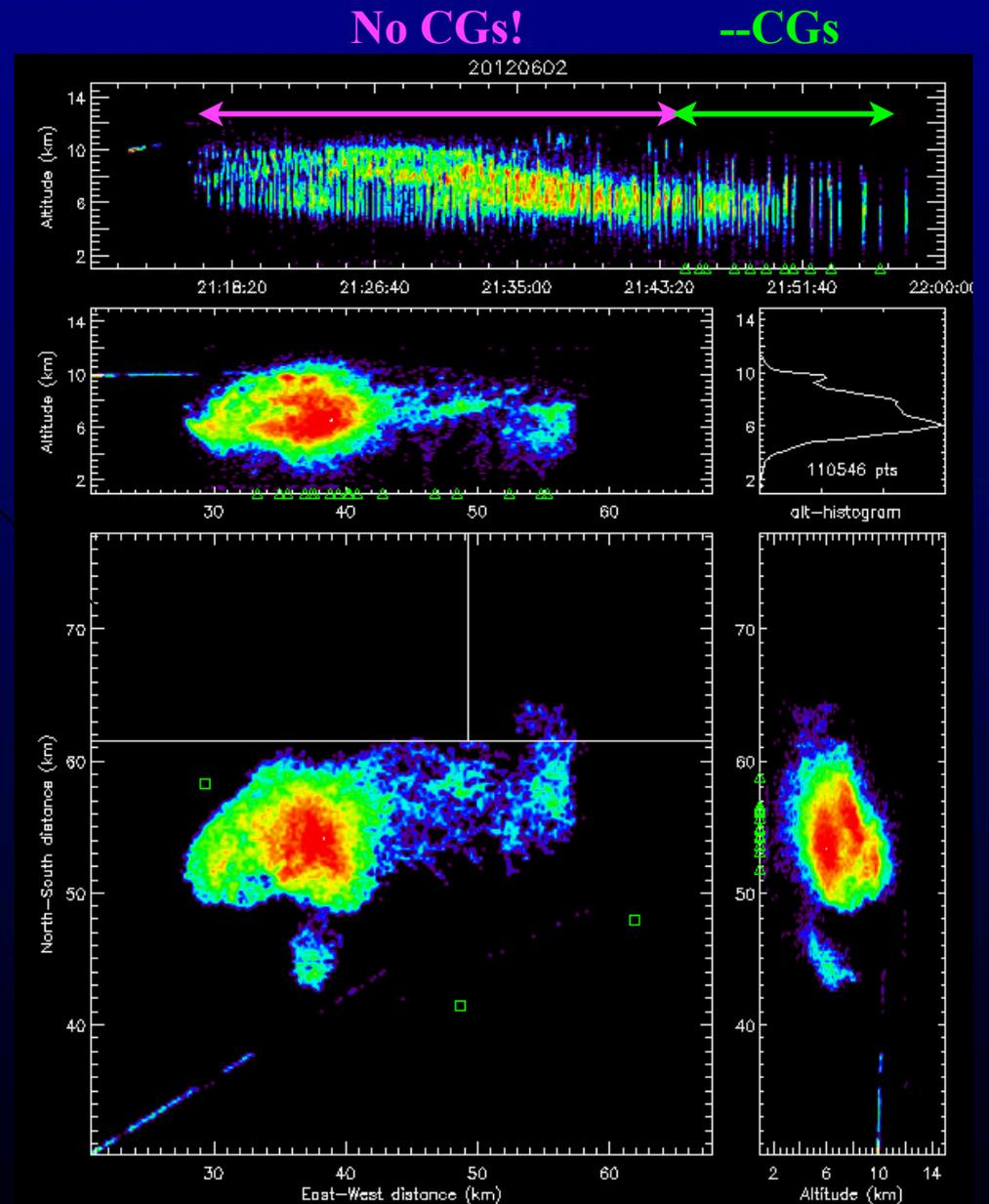
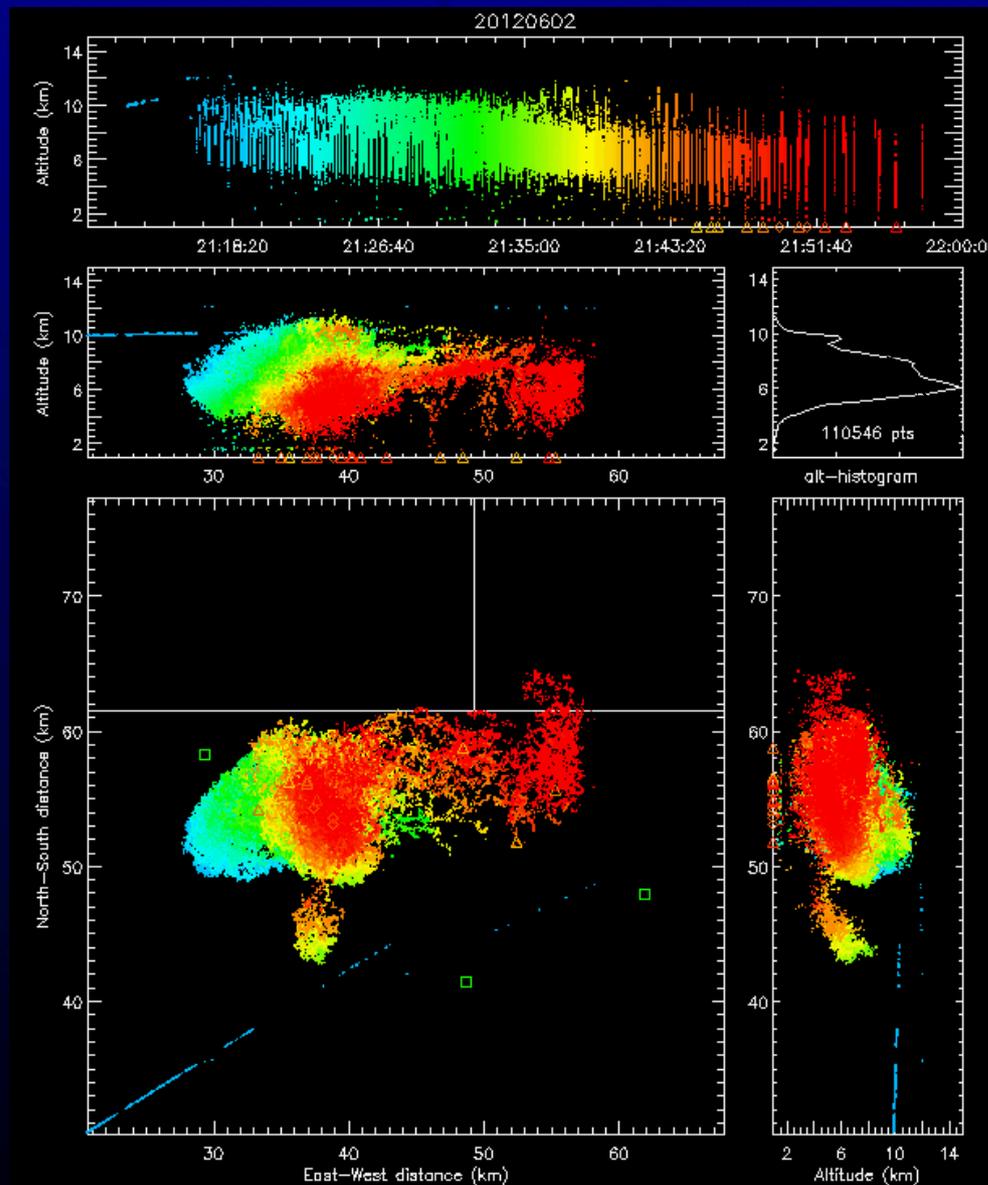
Hereford storm, June 2, 2012

1.5 hours later, ~50 km northeast of the FMA and Ft. Collins storms, along the Wyoming border



Hereford storm, June 2, 2012

45 minute duration: No CGs for first 34 minutes, then a steady stream of --CGs during decaying stages

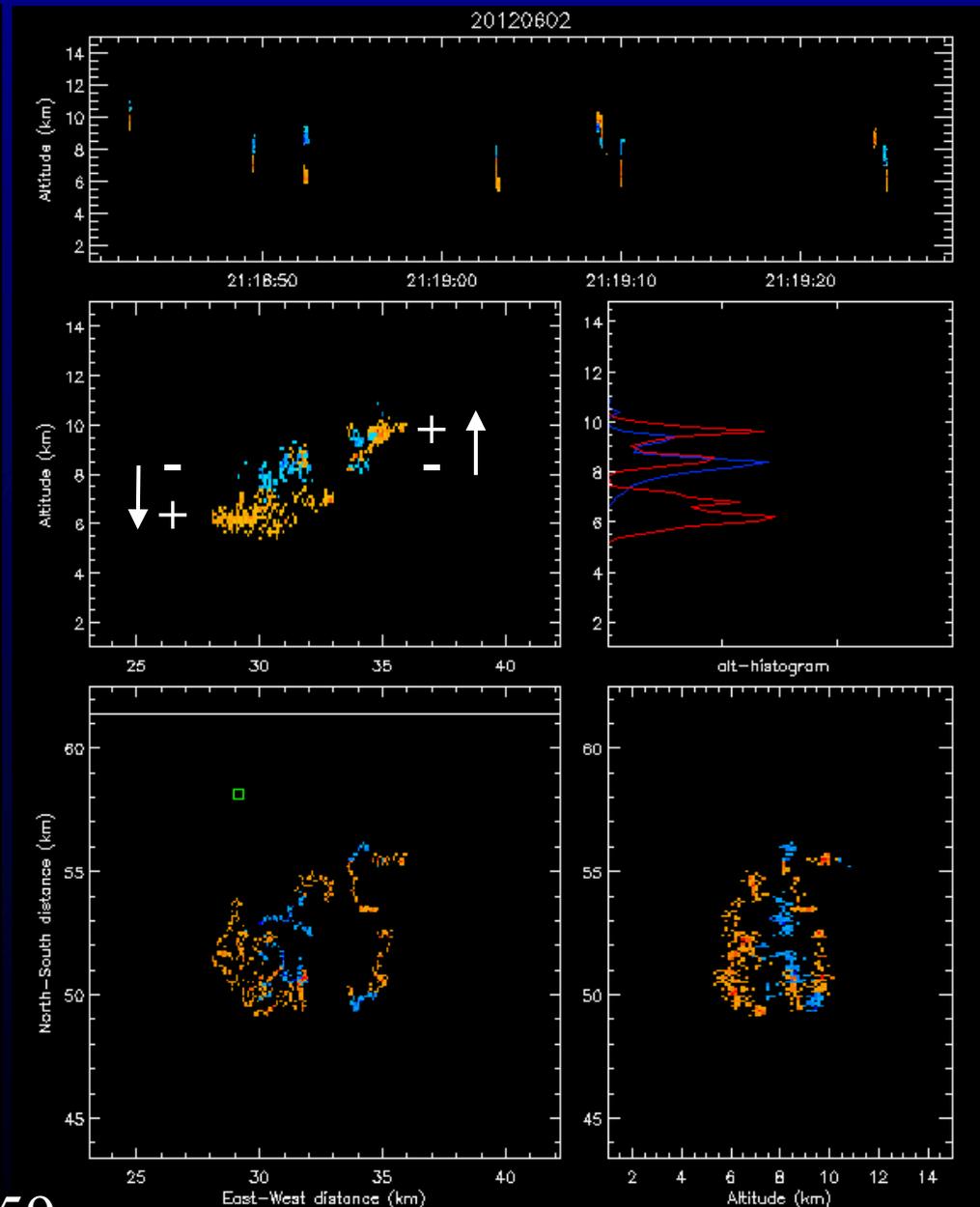
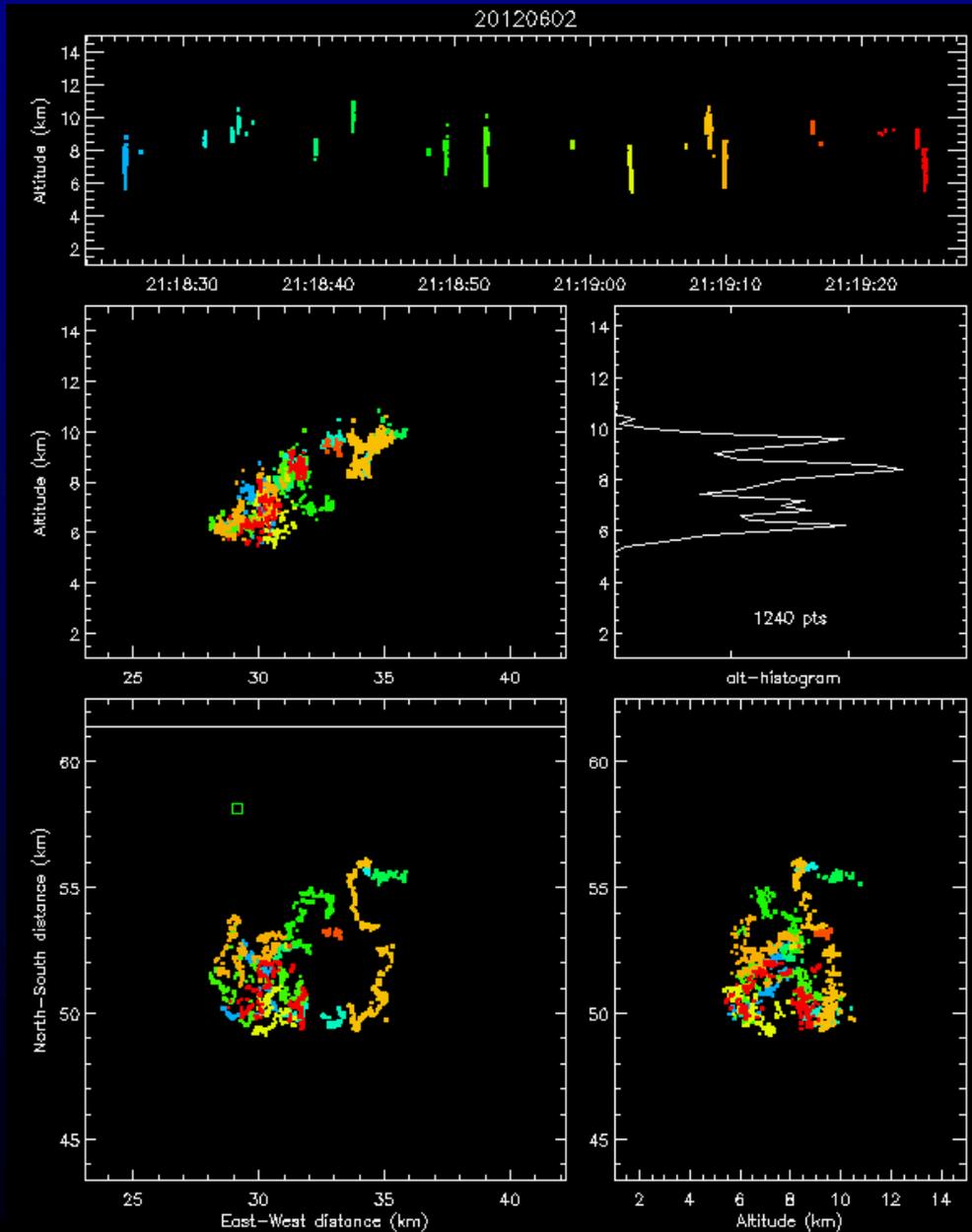


Initial lightning activity, Hereford storm

Elevated normal electrification, 'bottom heavy' (no --CGs)

Downward ICs at mid-levels (9-6 km);
upward ICs at upper level (9-11 km)

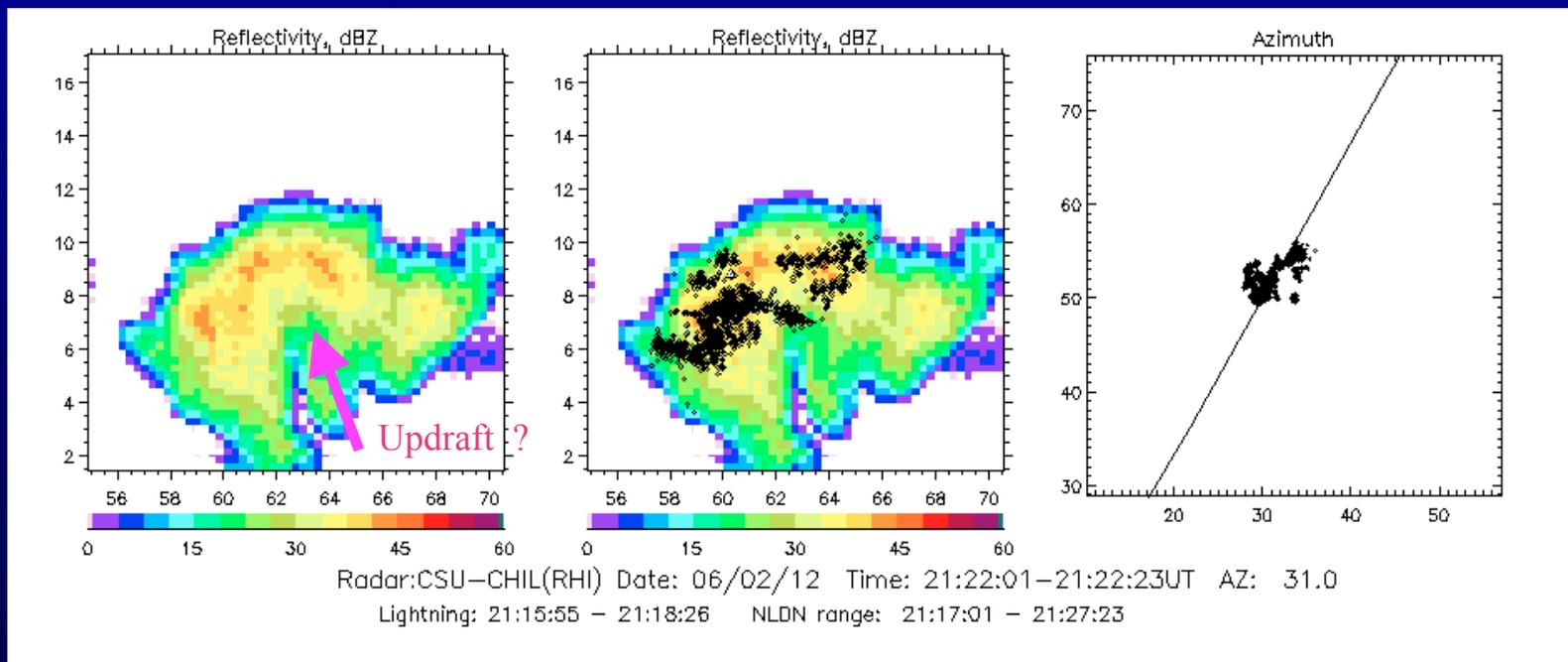
Double dipole charge structure about
elevated (-) charge at 9 km altitude



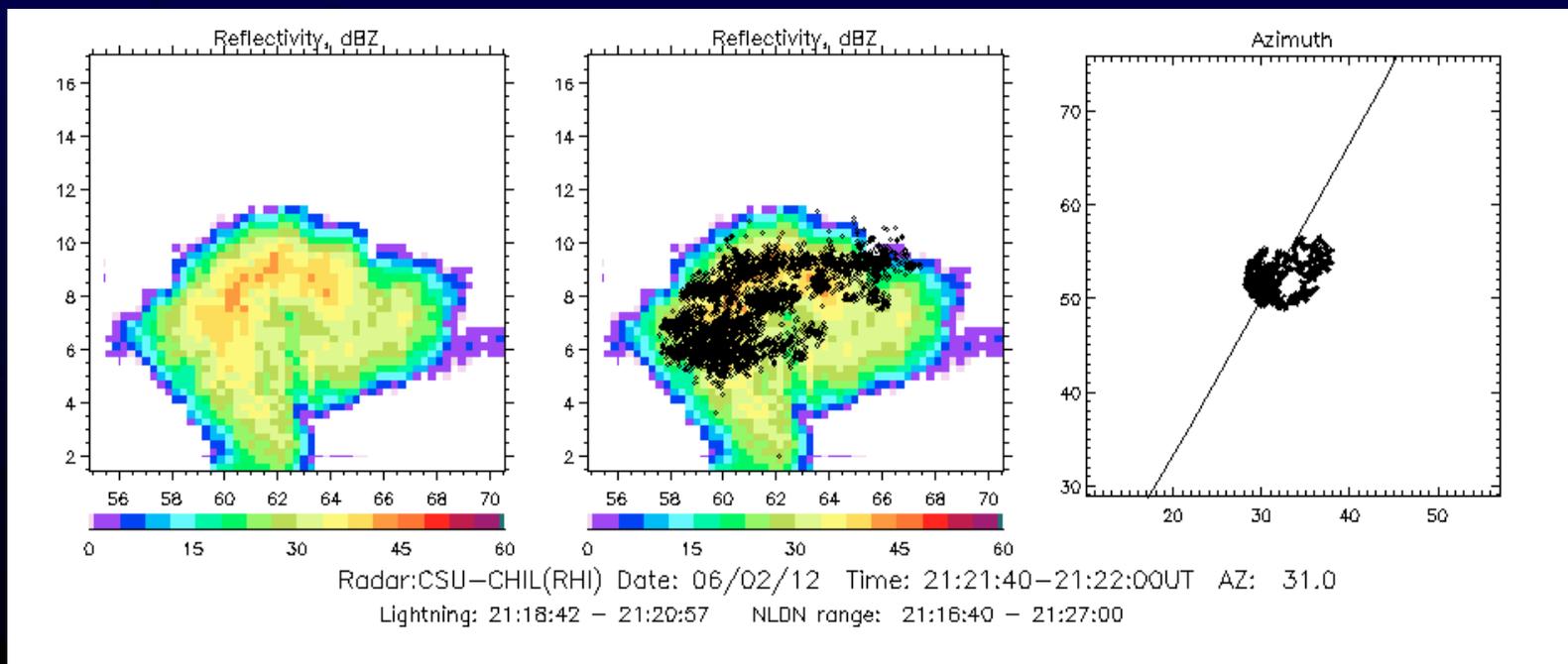
Comparison of lightning with CHILL vertical radar scans

Multiple dipolar charge regions correlated with overhanging reflectivity structure

2.5 min
of first
lightning

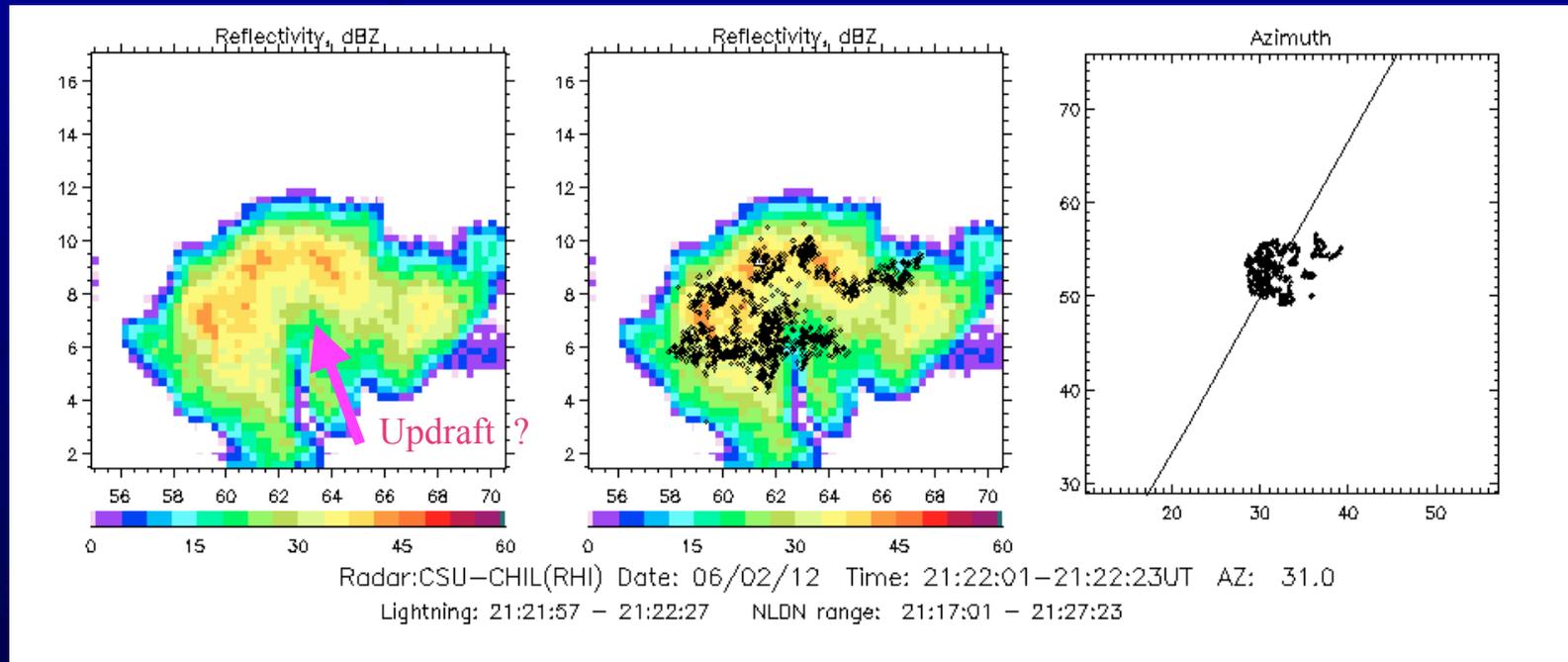


Next 2 min
of activity

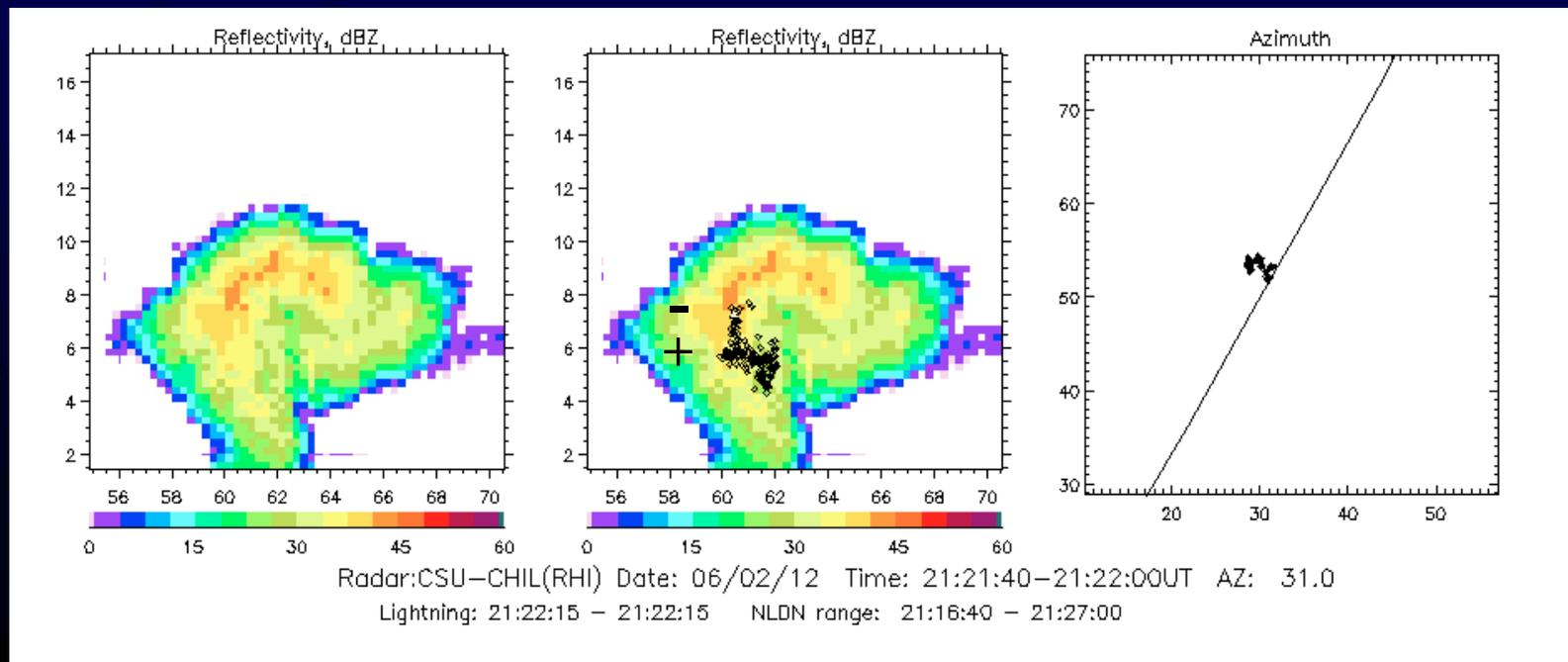


30 seconds of lightning activity, June 2 Hereford storm (6 minutes into storm; coincident with vertical radar scan)

30 seconds
of activity

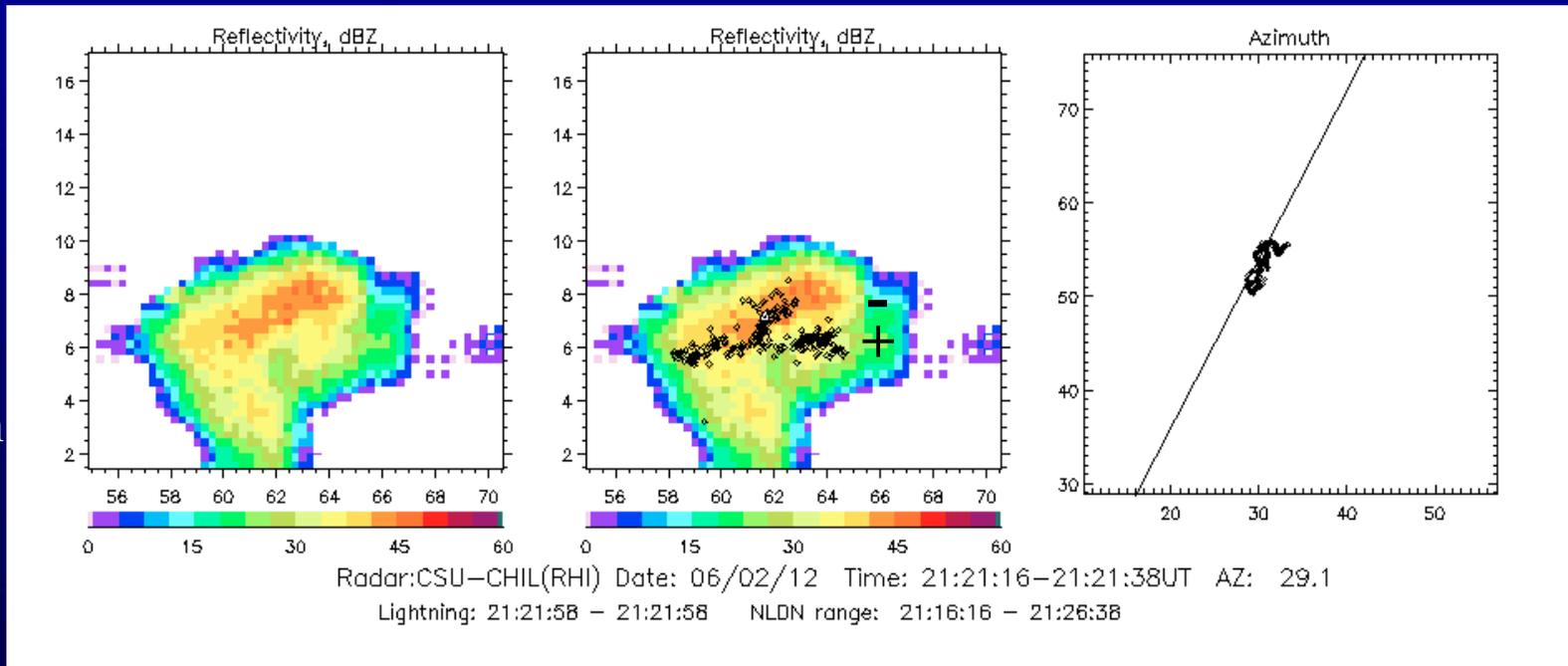


Individual
flash

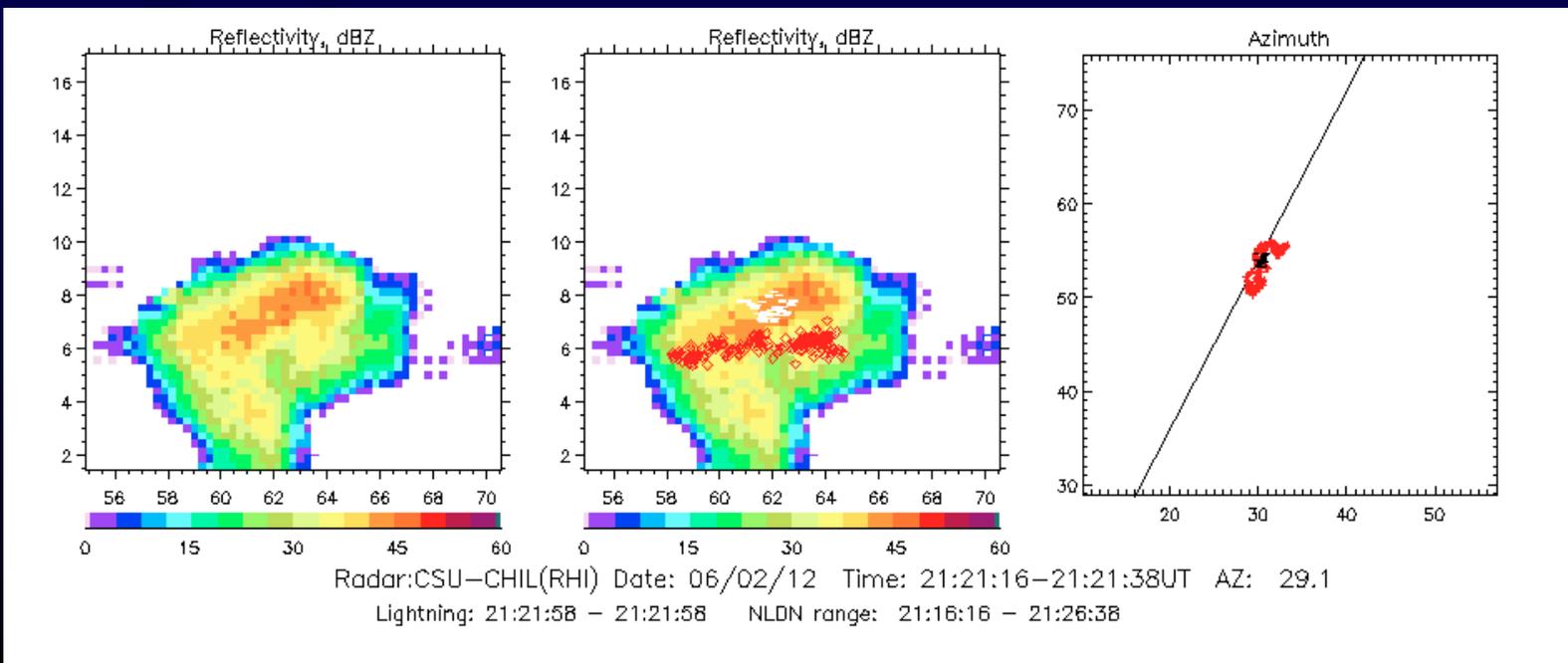


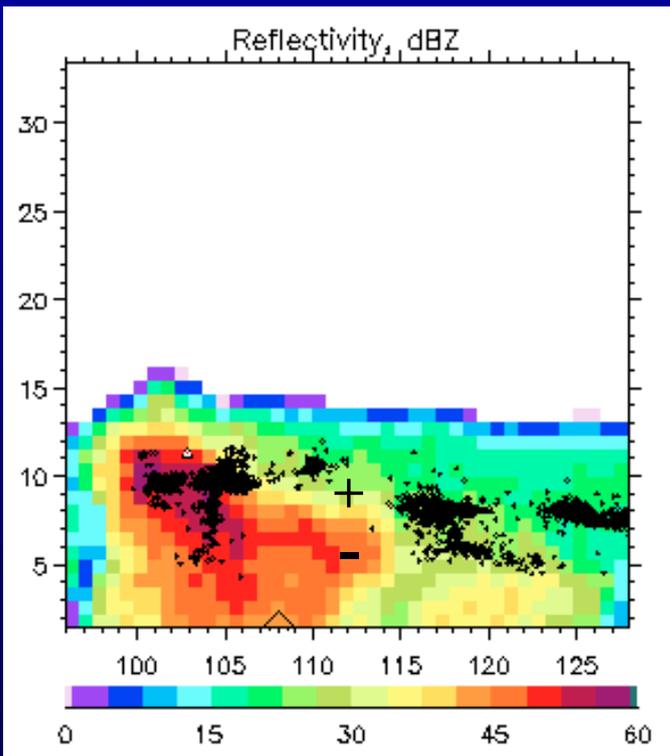
Bilevel IC flash, June 2 Hereford storm (6 minutes into storm; coincident with vertical radar scan)

Lower dipole
of normal
electrification

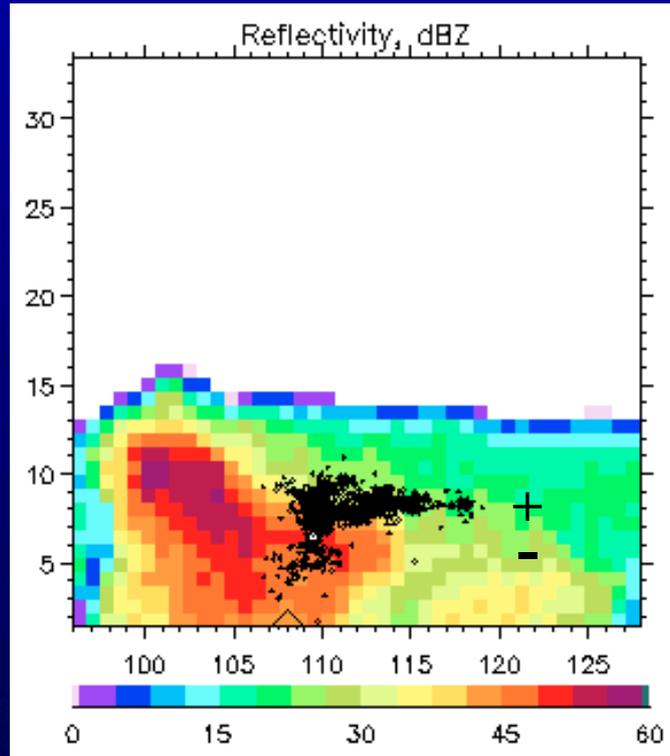


Charge
structure

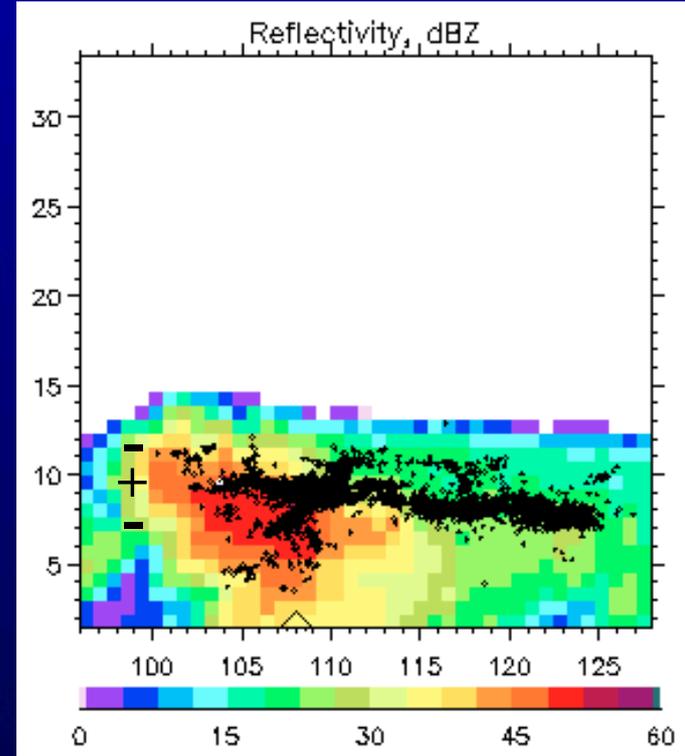




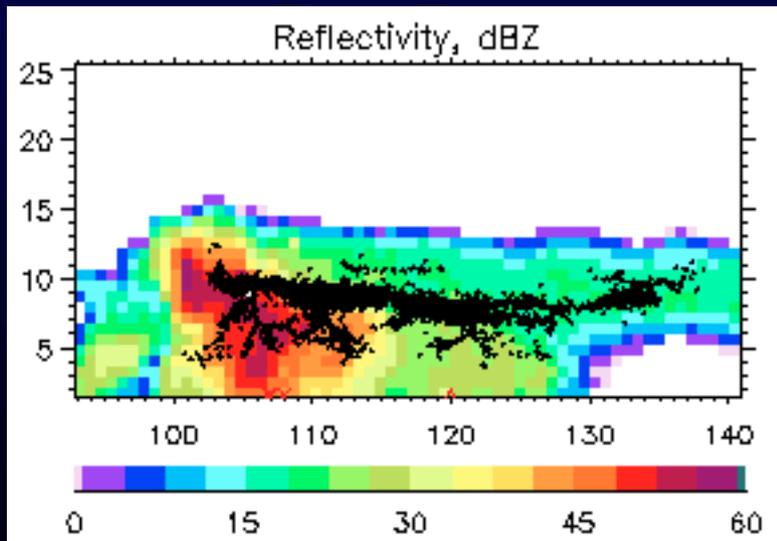
21:18:48 to 21:19:10
22 seconds of activity before +CG



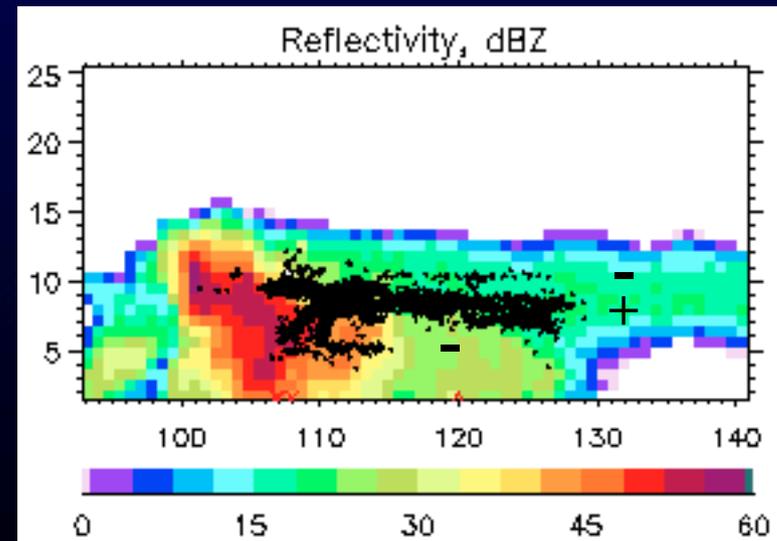
53.5 kA +CG at 21:19:12



21:19:16 to 21:19:42
26 seconds of activity after +CG



21:20:51 to 21:21:16
25 seconds of activity



21:21:24 to 21:22:13
49 seconds of activity

Bruning et al., 2012

Visualization of how non-inductive charging can give continuous variability in electrification, depending on how cloud liquid water is depleted in storm updraft.

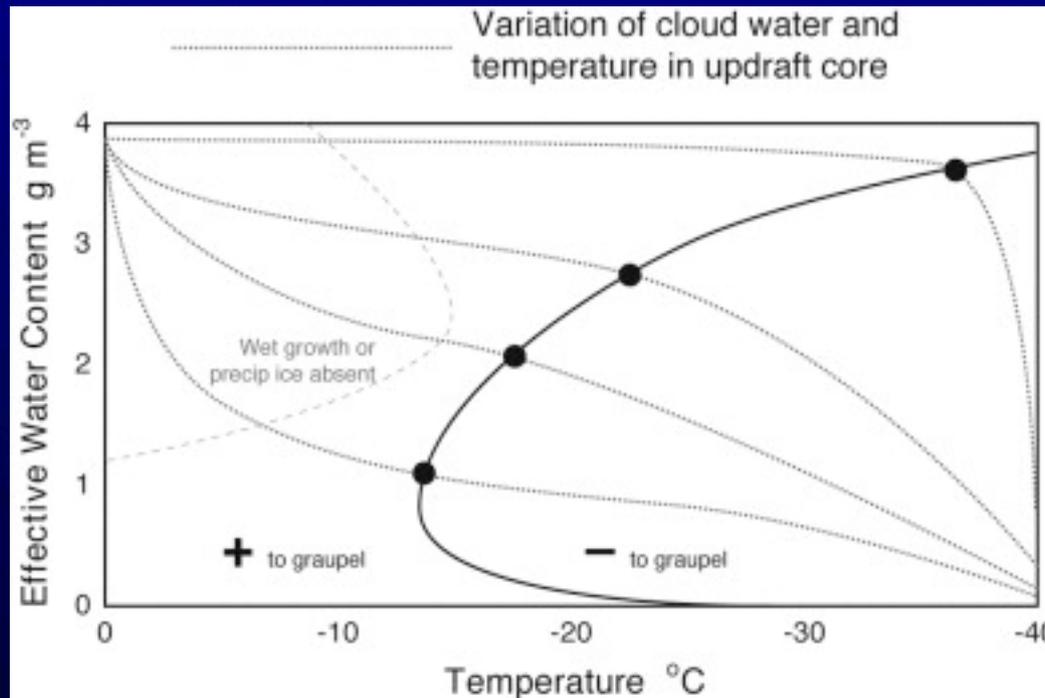


Fig. 3 Idealized variation of effective riming rate (a proxy for cloud water content) with temperature in storm's updraft trajectory as non-precipitating cloud water is depleted by precipitation growth processes (dotted line).

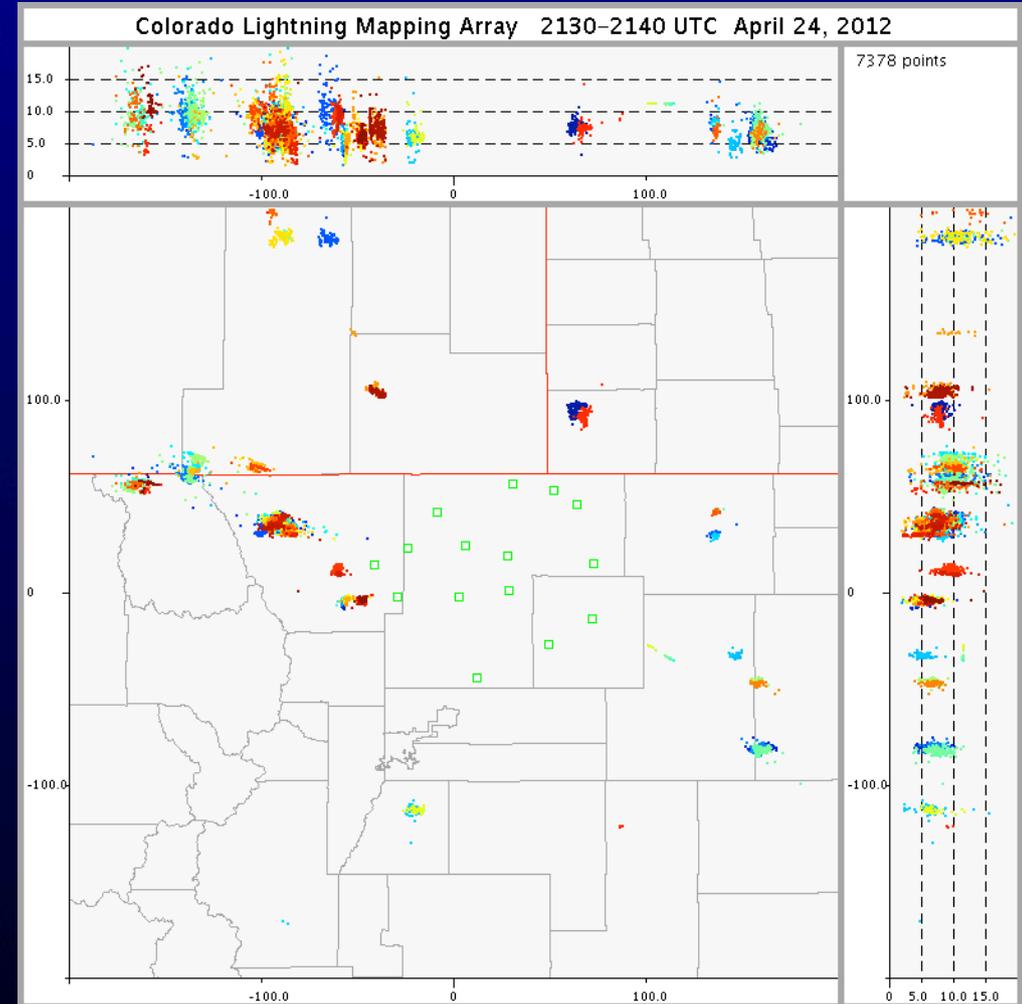
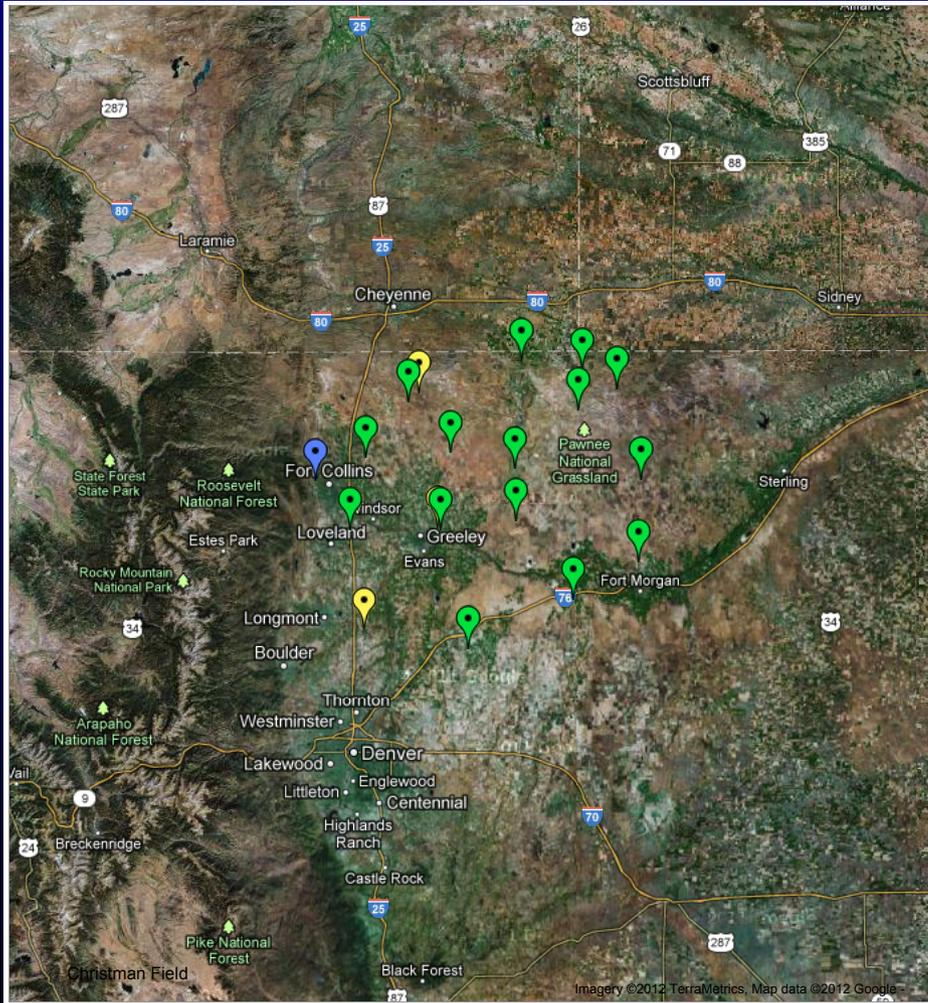
From: Continuous variability in thunderstorm primary electrification and an evaluation of inverted-polarity terminology

Eric C. Bruning , Stephanie A. Weiss , Kristin M. Calhoun

<http://dx.doi.org/10.1016/j.atmosres.2012.10.009>

North Colorado LMA

15 stations, 100 km diameter area



LMA Station (Briggsdale, CO)

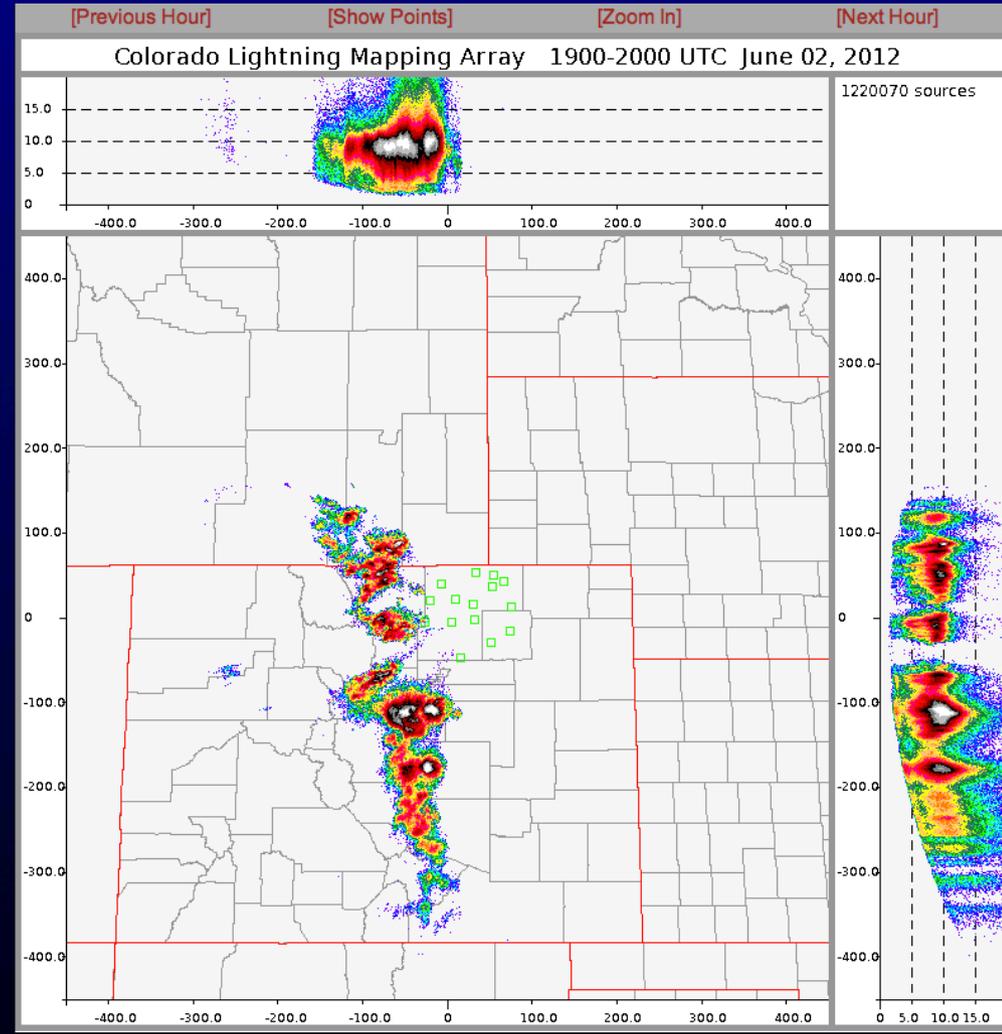
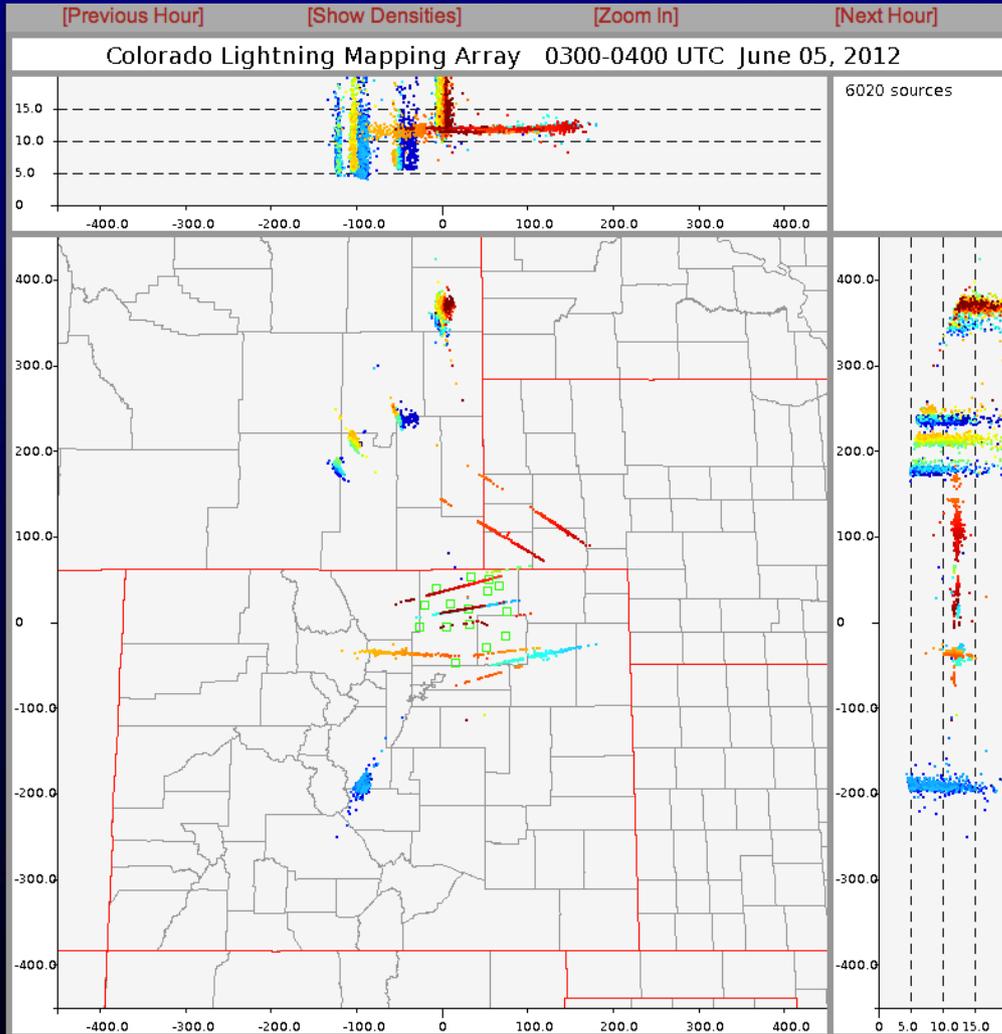
Solar powered; cell data modem comm links



Real time processing and web displays

Airplane tracks

June 2, 2012 1900-2000 UTC



<http://lightning.nmt.edu/colma/>

Real-time Status Page: Colorado LMA Stations (15 each)

Northern Colorado Lightning Mapping Array, Station Health Data

(information updated hourly, at twenty past -- last updated: Tue Nov 27 19:20:01 2012 UTC)

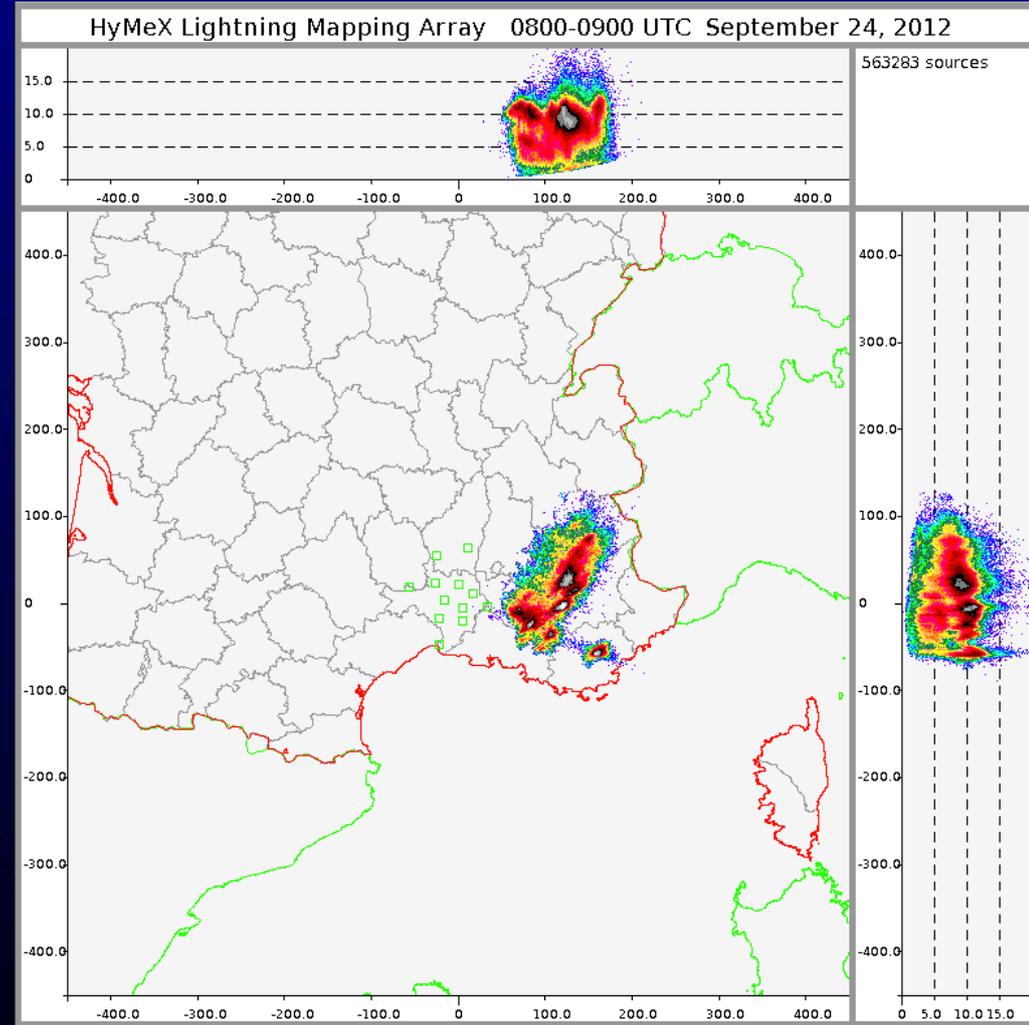
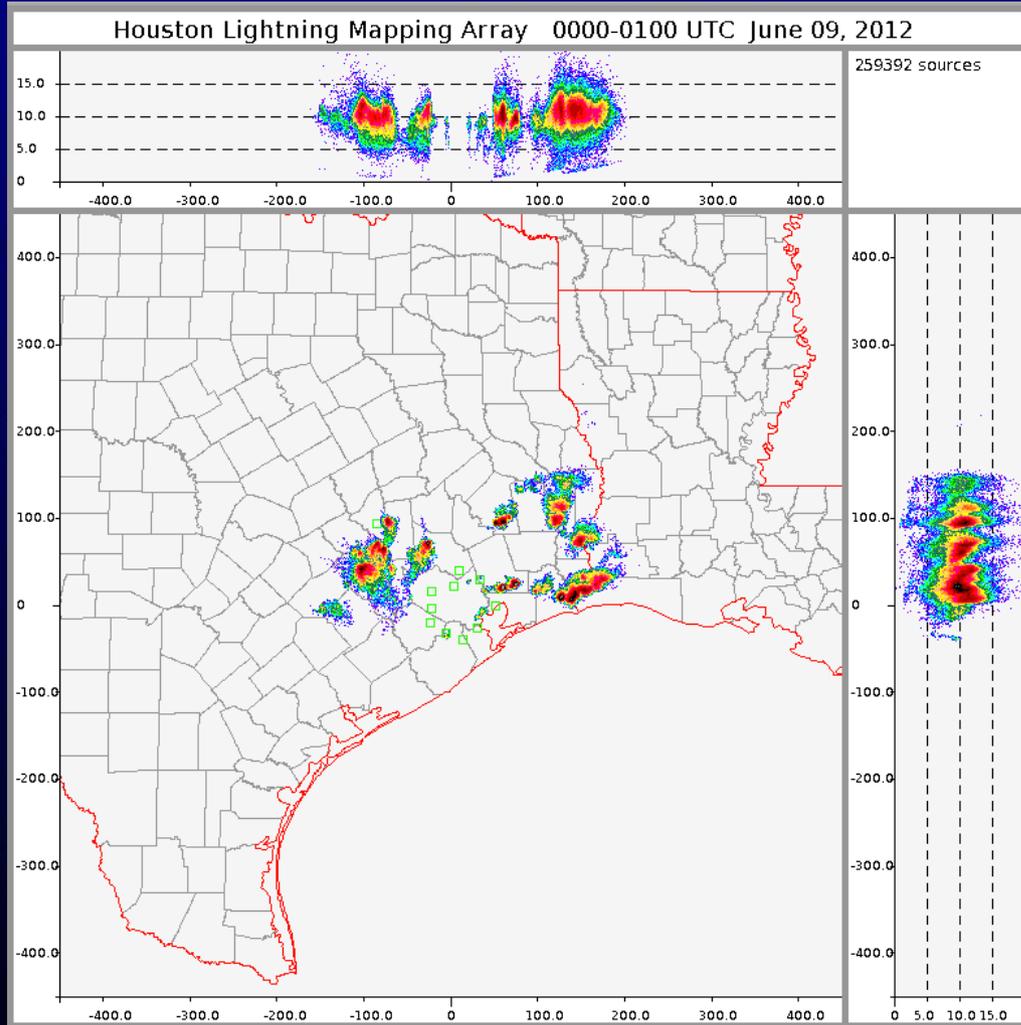
station	name	status	sdate	stime	load	uptime	/	boot	/dev/shm	/data	PID	PIDRD	PIDTL	PIDAT	PIDDEC	Phase	pdate	ptime	temp	gps	current trigfile	trig ID	tdate	ttime	tver	tthresh	ttrigs/s	tsat	ttemp	files today	files today- 1	files today- 2		
dc3_b	Rodenburg	up	11/27/2012	19:16:02	2.02/2.01/2.04	74 days	83%	10%	4%	93%	4060	4062	4064	4066	4068	-11	2012/11/27	19:16:02	25	11	TB121127	B	11/27/12	19:15:59	v10	-88 dBm	617	11	25	116	144	144		
dc3_c	Briggsdale	up	11/27/2012	19:16:02	2.02/2.04/2.05	74 days	82%	10%	3%	66%	27141	27143	27145	27147	27149	-21	2012/11/27	19:16:03	25	11	TC121127	C	11/27/12	19:15:59	v10	-88 dBm	1817	11	25	117	144	144		
dc3_d	Lone Tree	up	11/27/2012	19:16:01	2.08/2.04/2.05	74 days	82%	10%	4%	94%	10632	10634	10636	10638	10640	-12	2012/11/27	19:16:03	27	11	TD121127	D	11/27/12	19:15:59	v10	-67 dBm	1838	11	27	116	144	144		
dc3_e	Greeley Airport	up	11/27/2012	19:16:01	2.13/2.03/2.01	5:03	82%	10%	1%	93%	1830	1832	1834	1836	1838	-10	2012/11/27	19:16:02	19	8	TE121127	E	11/27/12	19:15:59	v10	-86 dBm	11916	8	19	115	144	144		
dc3_f	Raymer	up	11/27/2012	19:16:01	2.03/2.02/2.05	51 days	82%	10%	3%	76%	12220	12222	12224	12226	12228	-11	2012/11/27	19:16:02	30	11	TF121127.gz	---	---	---	---	---	---	---	---	---	116	144	144	
dc3_g	Ft Collins Airport	up	11/27/2012	19:16:01	2.08/2.04/2.05	4:57	82%	10%	1%	66%	1829	1832	1834	1836	1838	-10	2012/11/27	19:16:02	20	11	TG121127	G	11/27/12	19:15:59	v10	-84 dBm	955	11	20	70	144	144		
dc3_h	Hereford	up	11/27/2012	19:16:01	2.16/2.06/2.06	4:47	82%	10%	1%	63%	1909	1912	1914	1916	1918	-8	2012/11/27	19:16:01	24	9	TH121127	H	11/27/12	19:15:59	v10	-82 dBm	1010	9	24	28	128	116		
dc3_i	Wiggins	up	11/27/2012	19:16:01	2.01/2.03/2.05	5:22	82%	10%	1%	85%	2230	2232	2234	2236	2238	-11	2012/11/27	19:16:01	23	11	TI121127	I	11/27/12	19:15:59	v10	-80 dBm	820	11	23	115	144	144		
dc3_j	Homestead	up	11/27/2012	19:16:02	2.04/2.03/2.05	73 days	86%	10%	4%	95%	5113	5115	5117	5119	5121	-12	2012/11/27	19:16:03	30	11	TJ121127	J	11/27/12	19:15:59	v10	-88 dBm	3595	11	30	113	144	144		
dc3_k	Purcell	offline	11/24/2012	17:16:01	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
dc3_l	FMA	up	11/27/2012	19:16:01	2.00/2.02/2.05	2:50	82%	10%	1%	55%	1826	1828	1830	1832	1834	-20	2012/11/27	19:16:02	28	11	TL121127	L	11/27/12	19:15:59	v10	-80 dBm	948	11	28	21	108	144		
dc3_m	Ft Morgan Airport	up	11/27/2012	19:16:01	2.18/2.16/2.10	54 days	82%	10%	4%	94%	1918	1920	1922	1924	1926	-19	2012/11/27	19:16:02	27	11	TM121127	M	11/27/12	19:15:59	v10	-75 dBm	12500	11	27	116	144	144		
dc3_n	CPER	up	11/27/2012	19:16:01	2.03/2.04/2.05	13 days	82%	10%	1%	65%	1855	1857	1859	1861	1863	-8	2012/11/27	19:16:01	32	9	TN121127	N	11/27/12	19:15:47	v10	-88 dBm	1202	9	32	116	144	144		
dc3_p	Weld CHS	up	11/27/2012	19:16:01	2.00/2.01/2.05	5:02	82%	10%	1%	94%	1832	1834	1836	1838	1840	-14	2012/11/27	19:16:02	24	11	TP121127	P	11/27/12	19:15:59	v10	-78 dBm	2818	11	24	91	144	145		
dc3_r	Butte Edge	up	11/27/2012	19:16:01	1.87/1.97/1.94	73 days	85%	10%	5%	94%	17611	17613	17615	17617	17619	-3	2012/11/27	19:16:02	29	11	TR121127	R	11/27/12	19:15:59	v10	-82 dBm	3328	11	29	73	144	141		

http://lightning.nmt.edu/nco_lma/status/

Other networks: Real-time web pages

Houston LMA (Texas A&M Univ.)

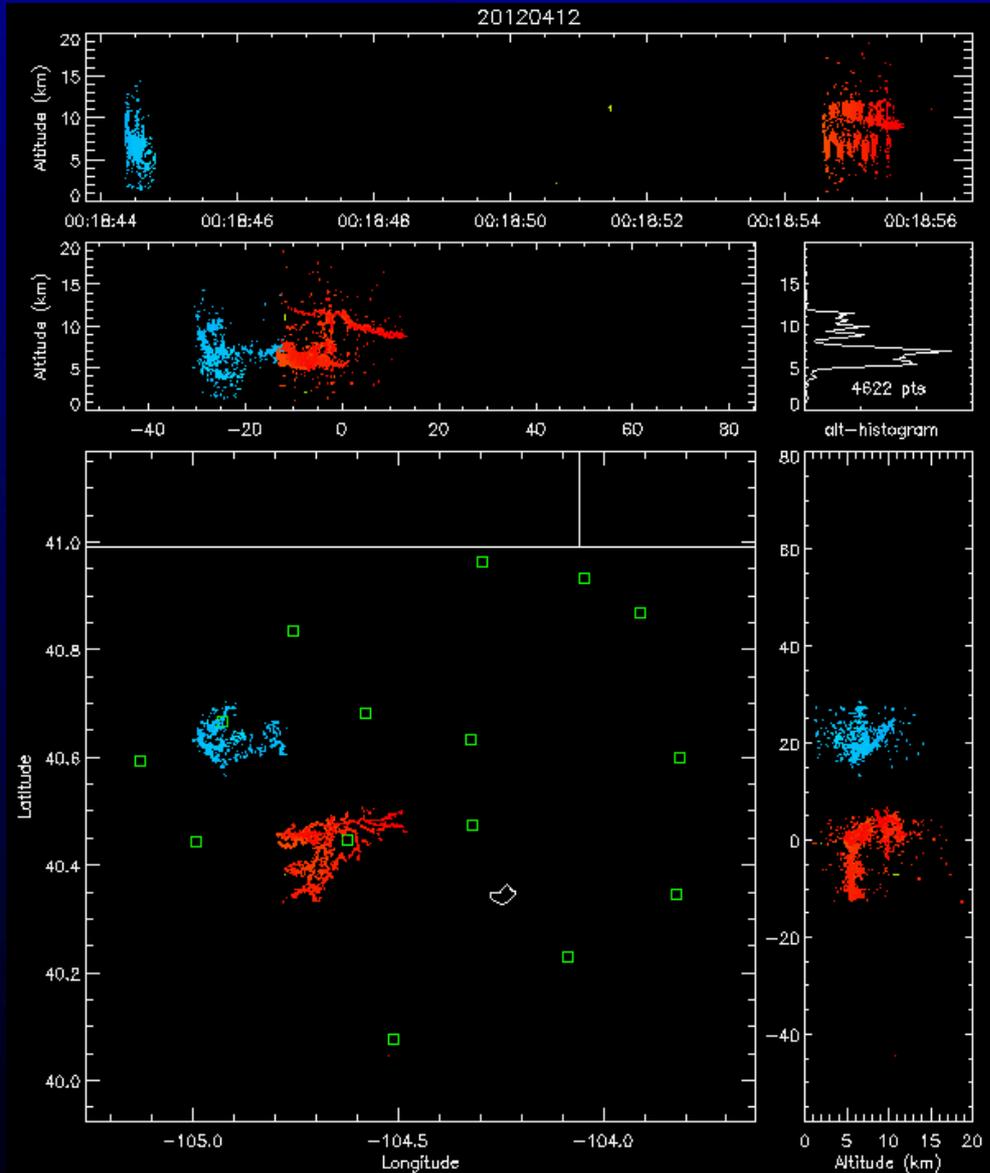
HyMeX 2012 (Toulouse University)



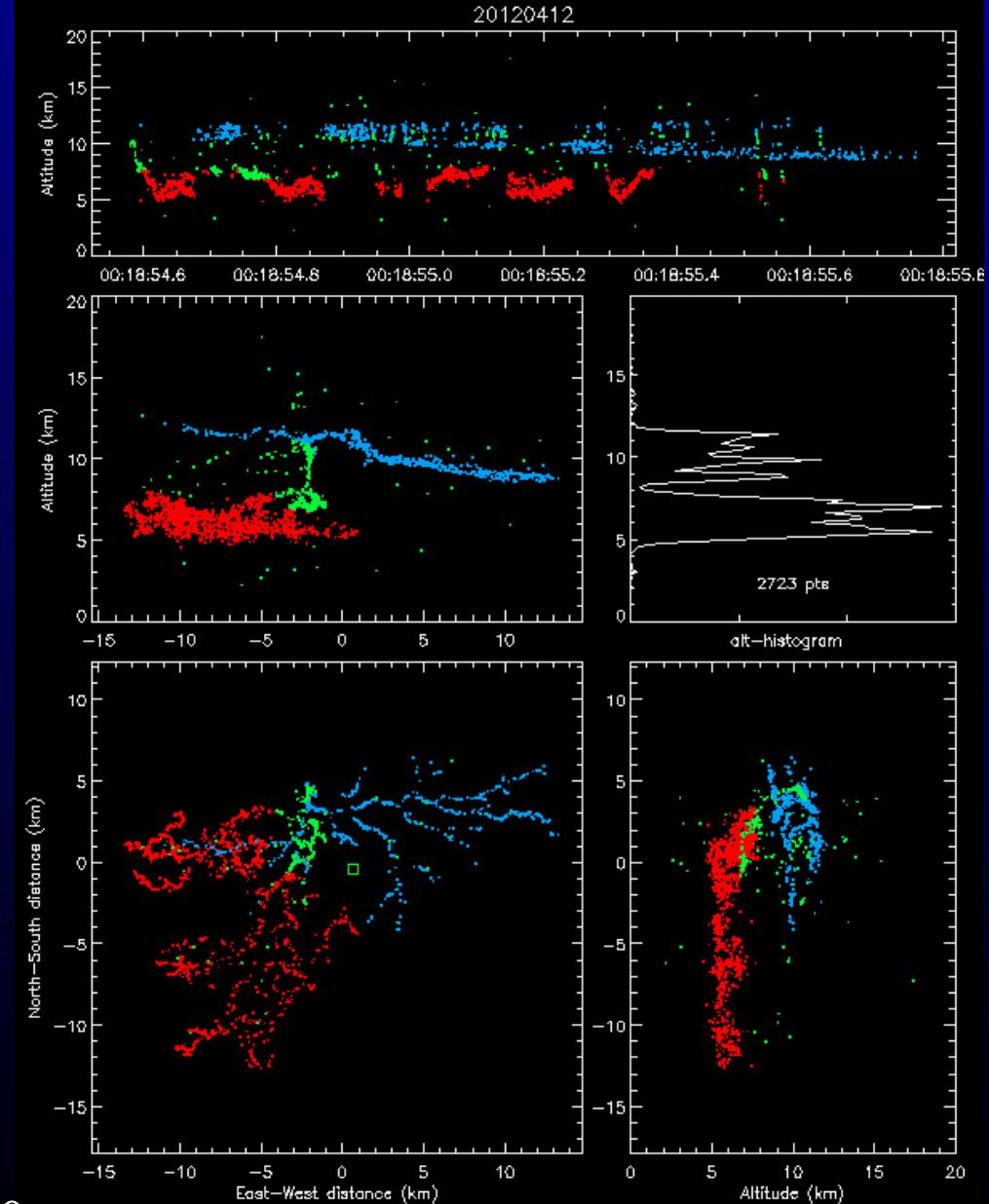
<http://lightning.nmt.edu/hstnlma/>

Early example of observations (April 11-12, 2012) Inverted polarity IC discharge over CHILL radar, 6:18 pm MDT

Overview



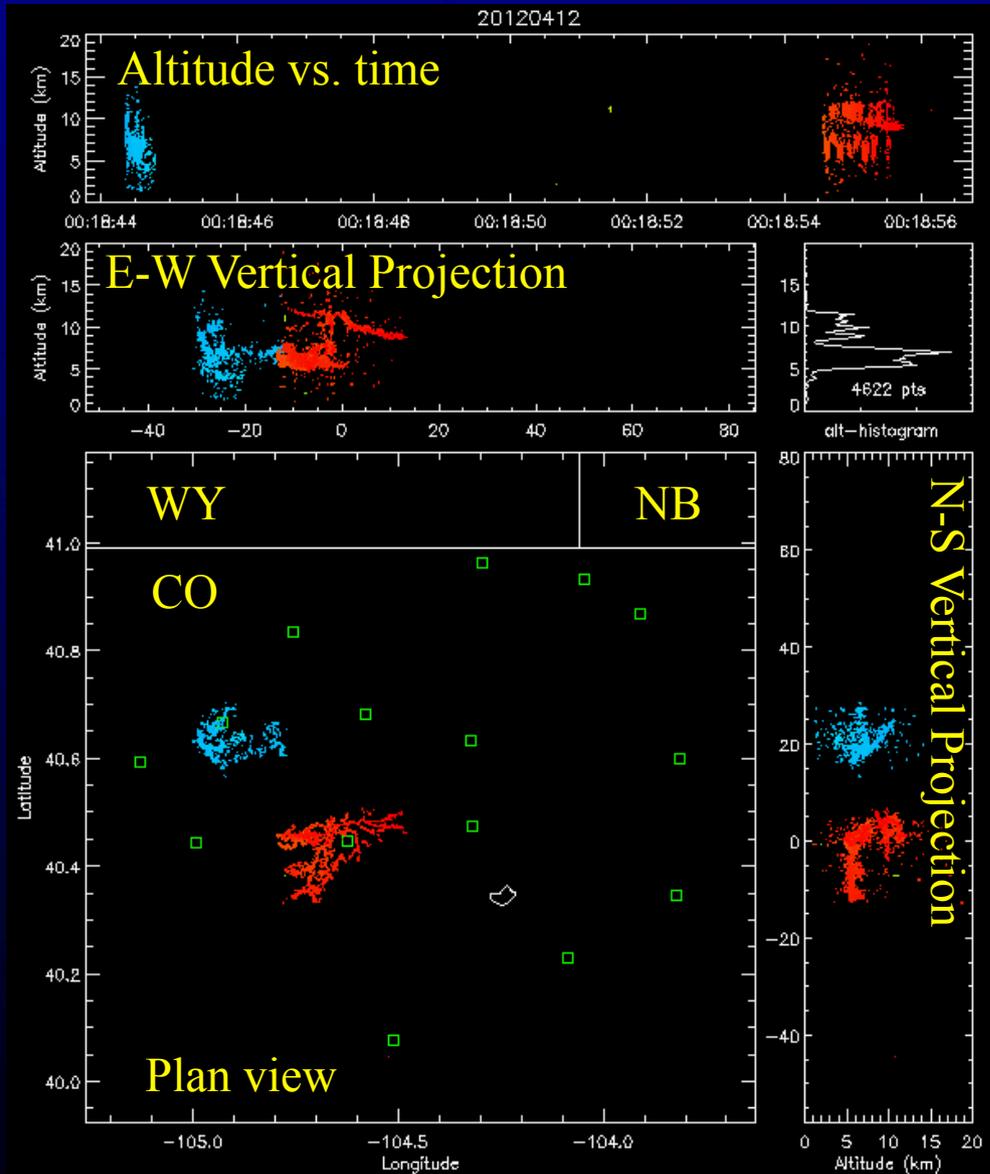
Detailed Flash Structure



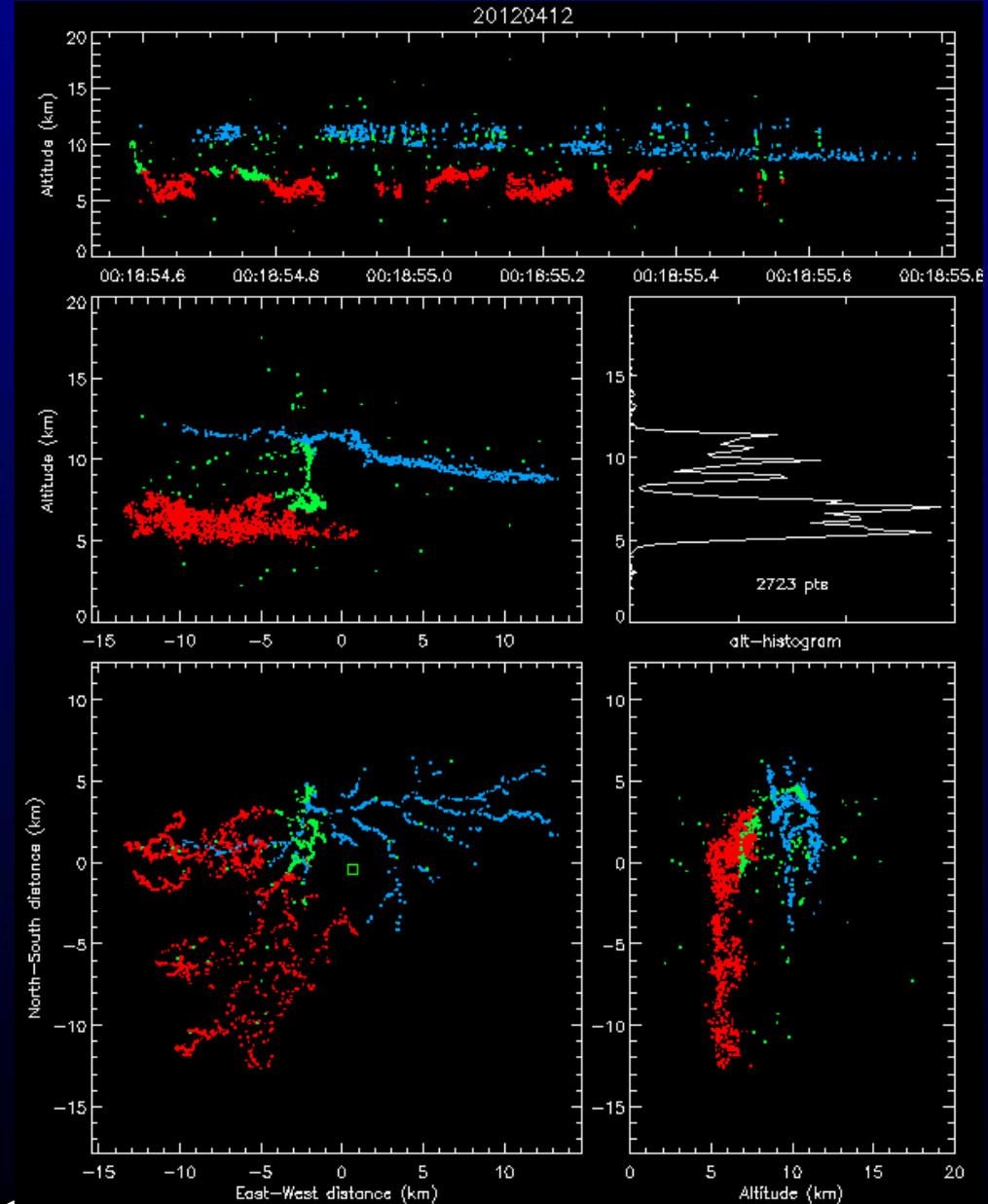
Example observation of an individual lightning discharge

Bilevel intracloud flash over North Colorado LMA; April 11, 2012

Overview



Detailed Flash Structure



Flash Animation

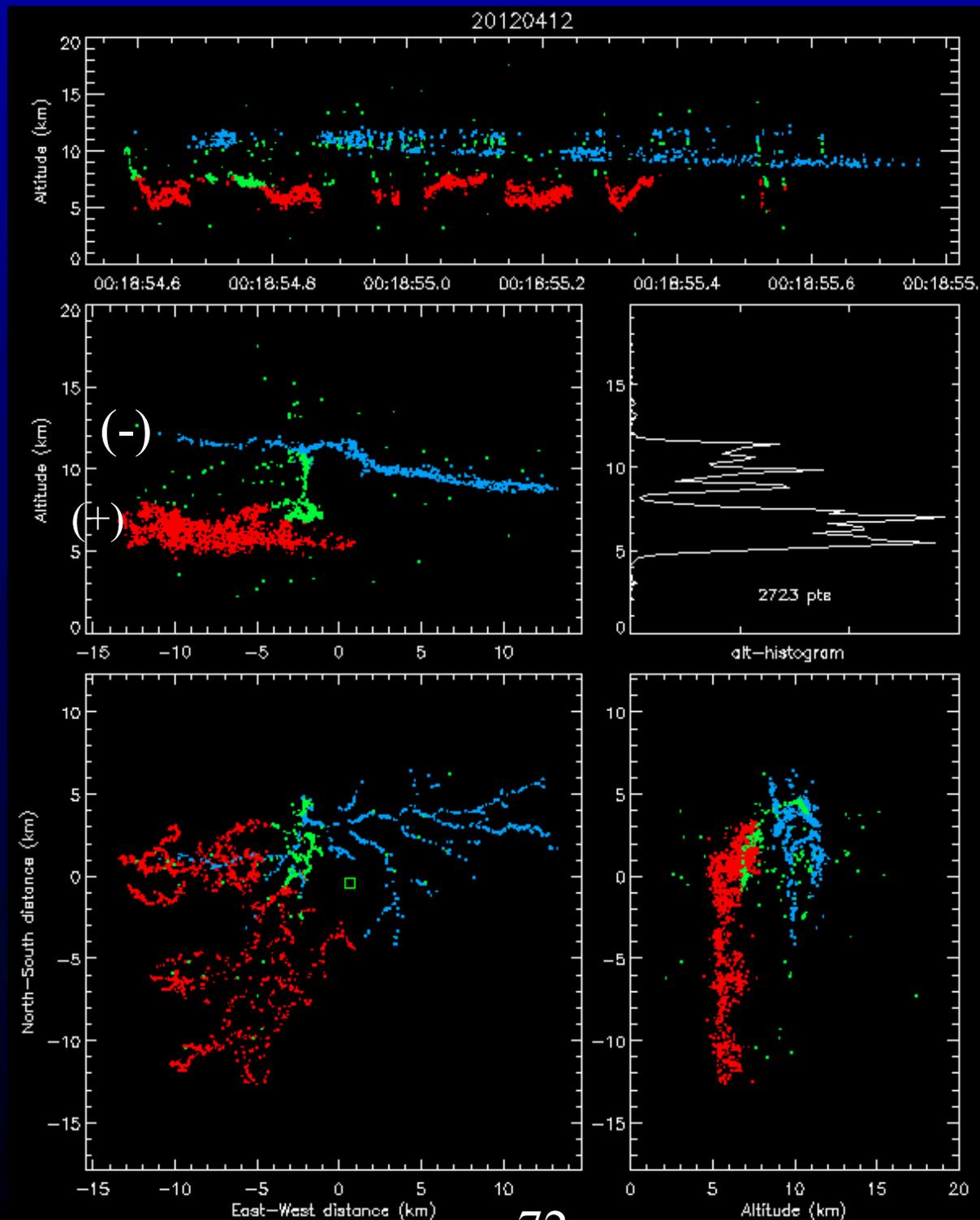
Between upper level (-) and mid-level (+) storm charges (anomalous or 'inverted' polarity)

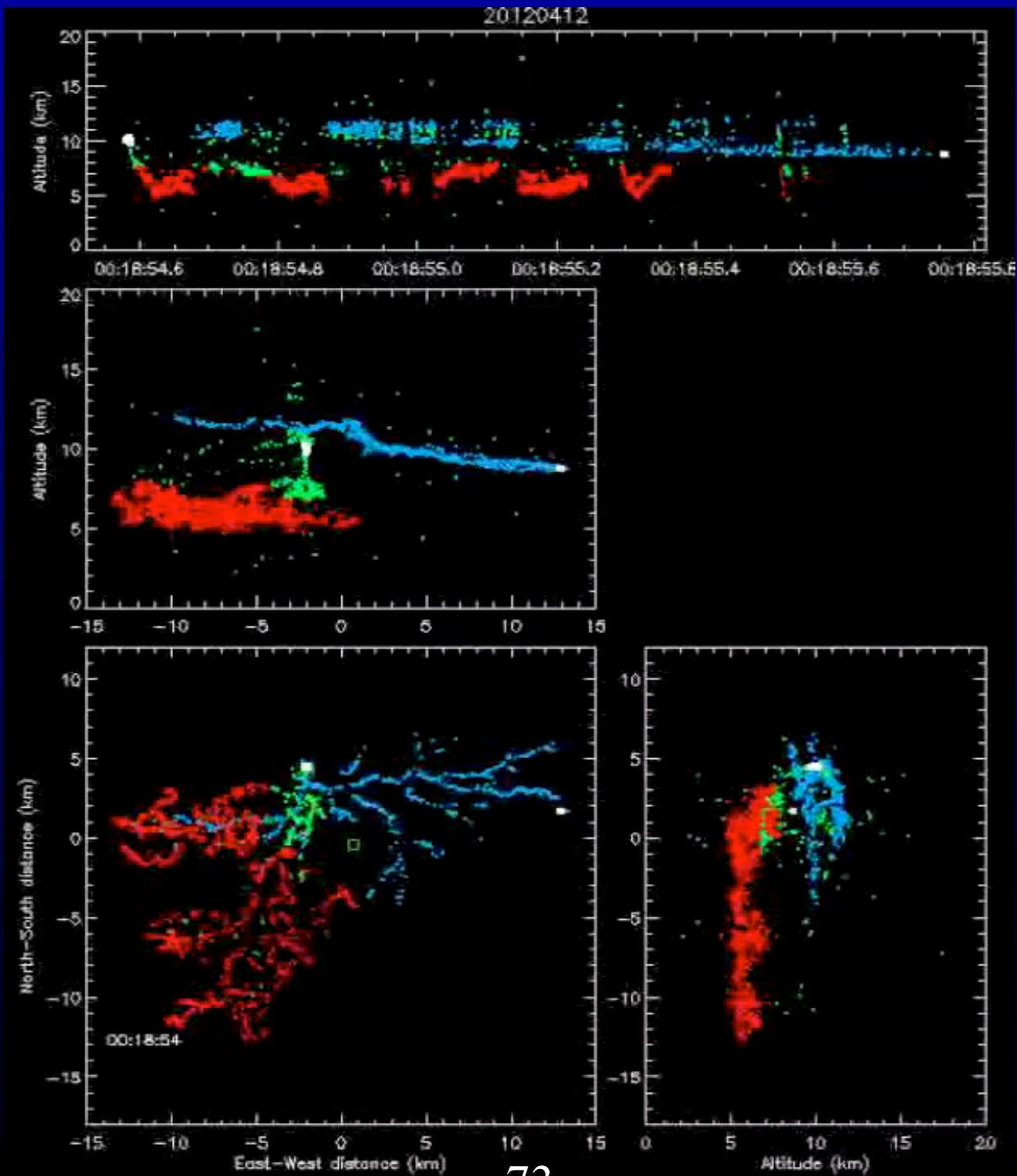
Red sources: (-) break-down into (+) charge

Blue sources: (+) break-down into (-) charge

Positive leaders revealed by a combination of apparent (+) leader radiation and retrograde (-) ('recoil') events.

Note difference in (+) and (-) channel structures.

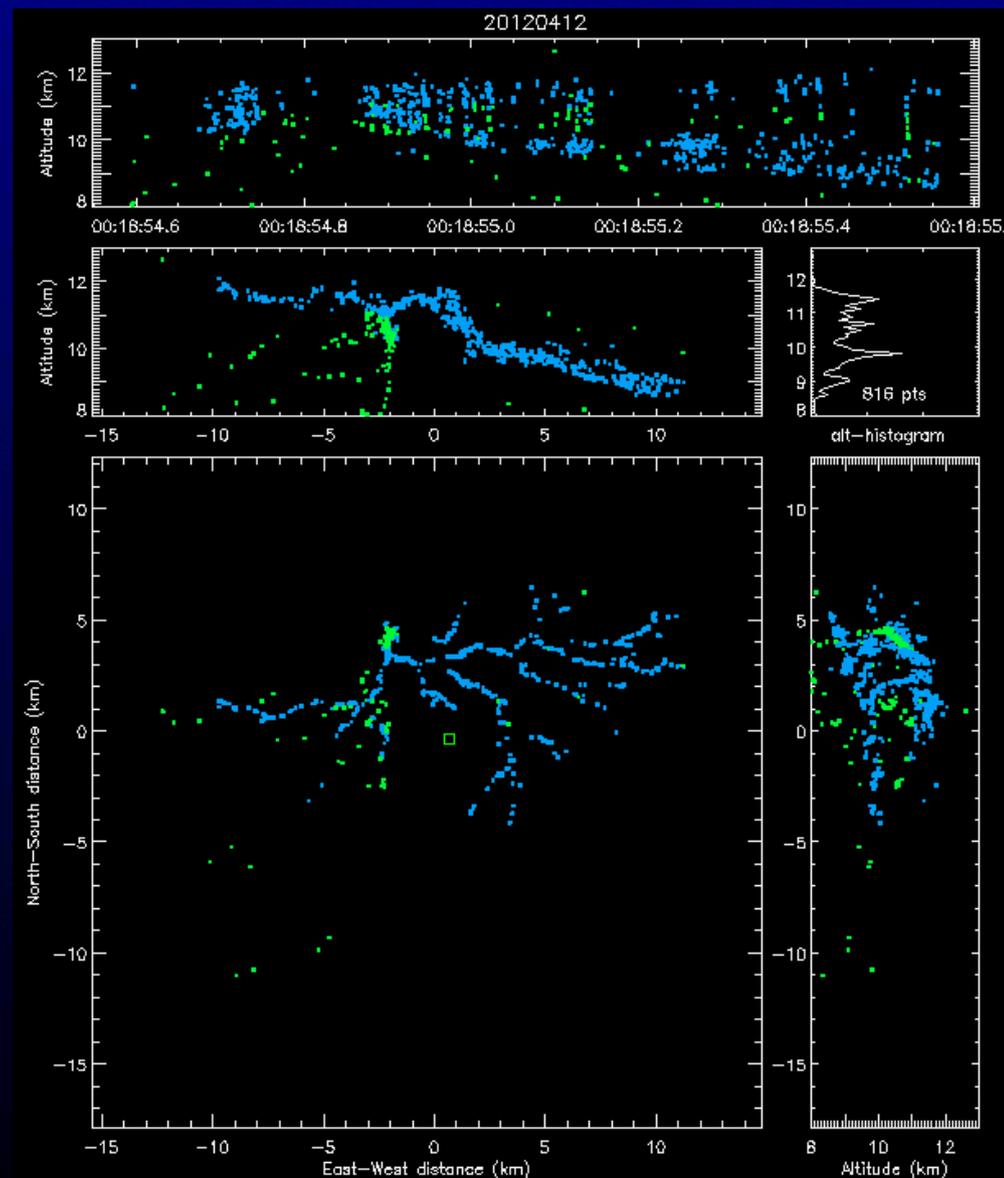
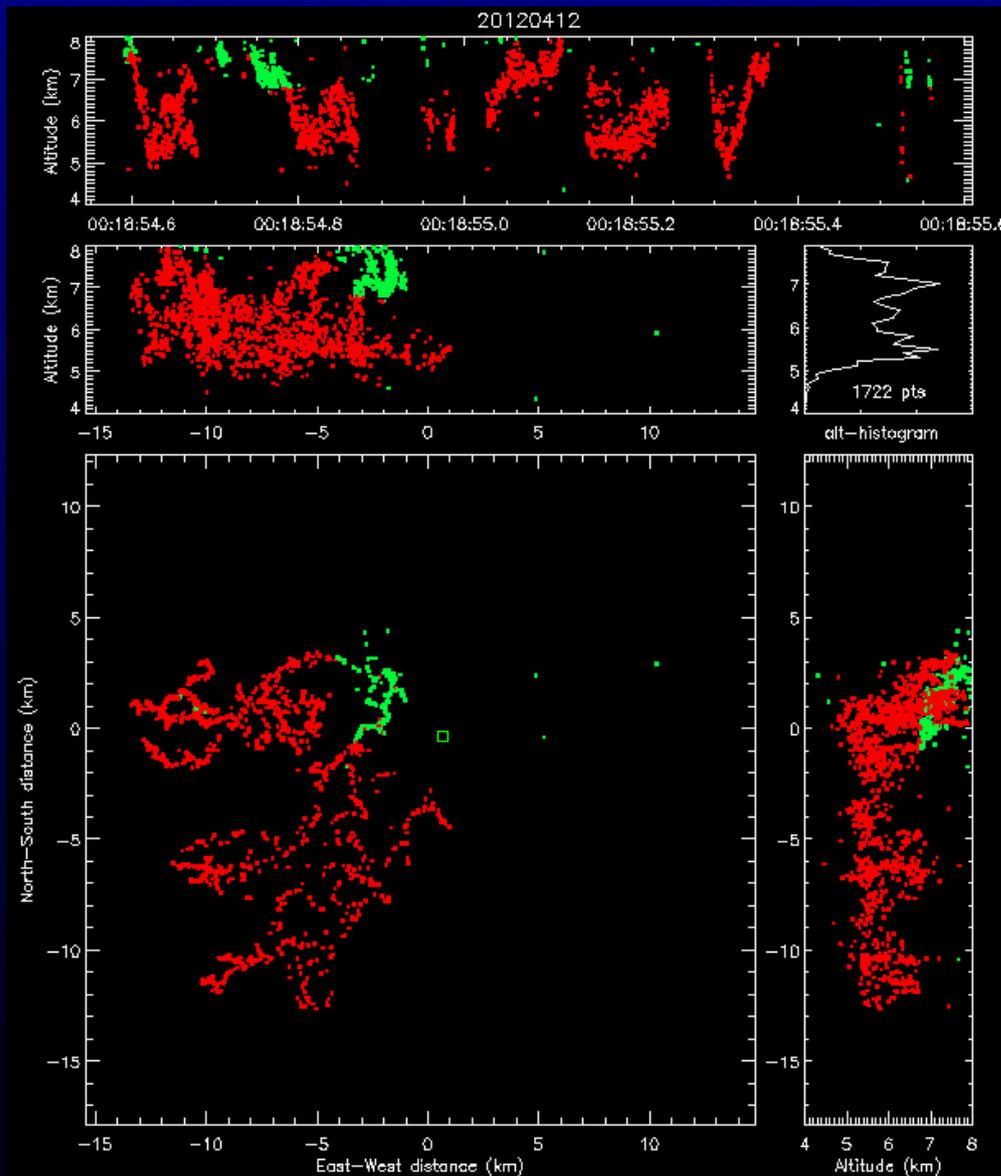




Separate out positive and negative breakdown channels

Negative leaders
one main branch at a time; spatially noisy

Positive leaders
well-defined filamentary structure, all in parallel



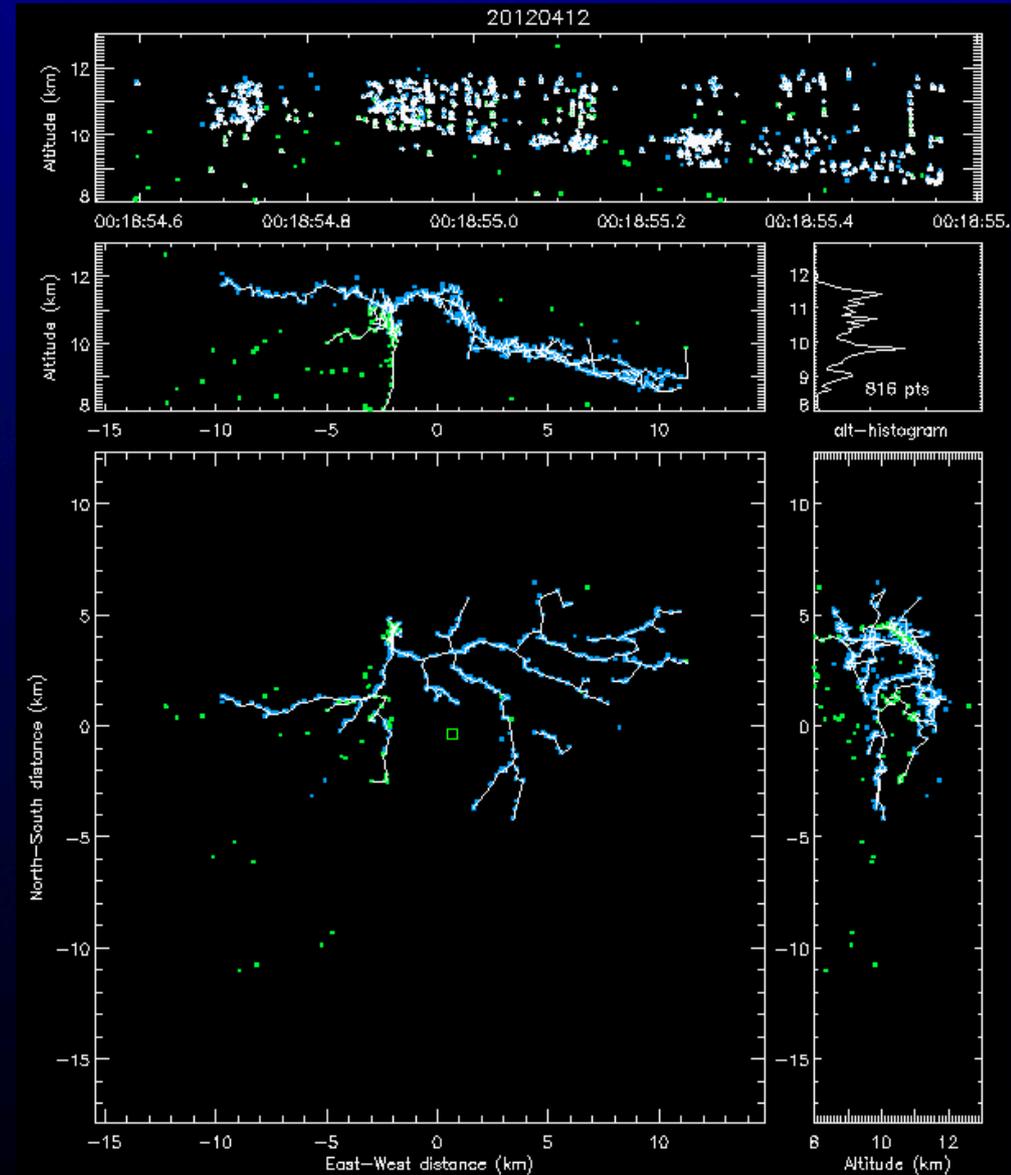
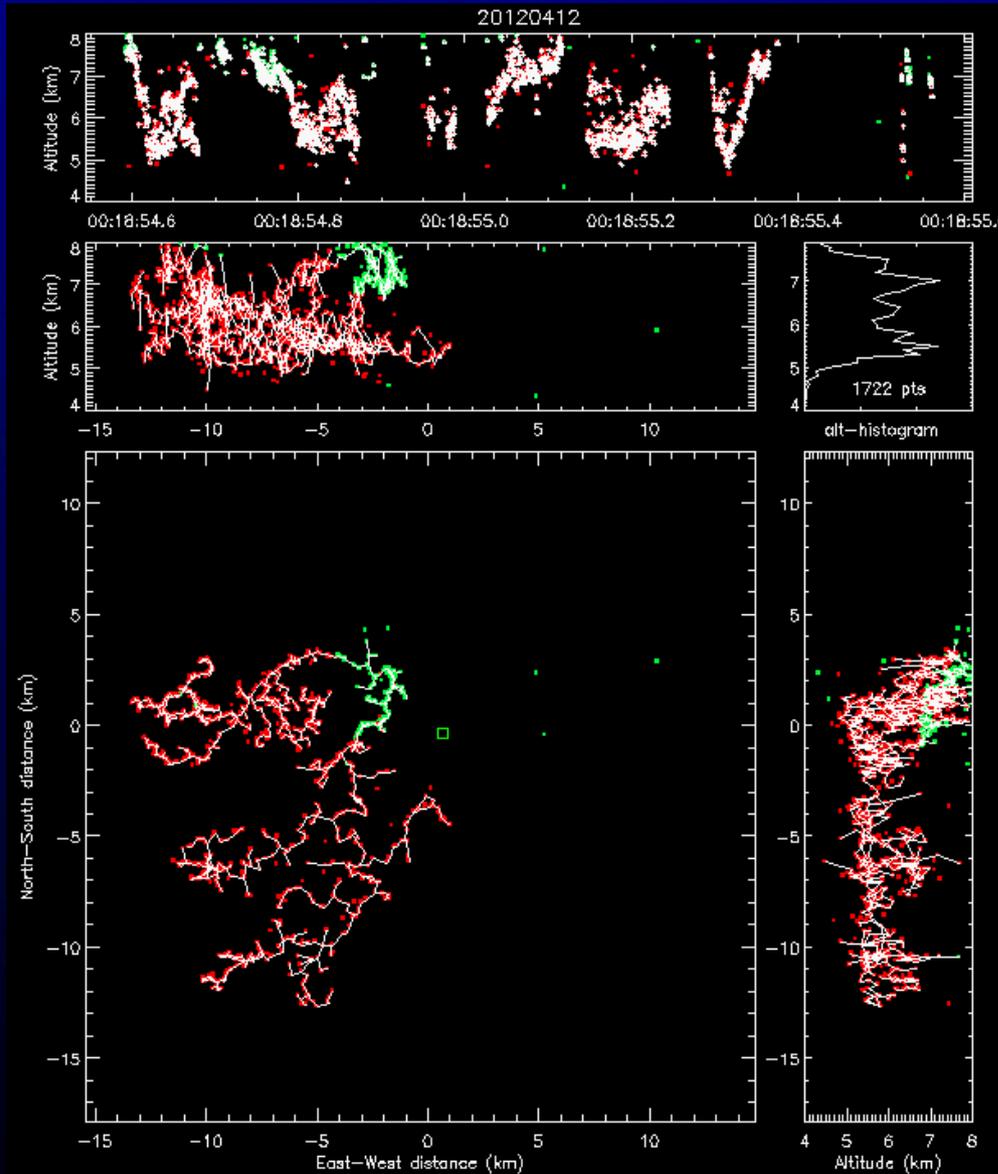
Separate out positive and negative breakdown channels

Add channel structure

Negative leaders
(spatially noisy - side branches)

(Thomas branch/twig/leaf approach)

Positive leaders
(well-defined filamentary structure)



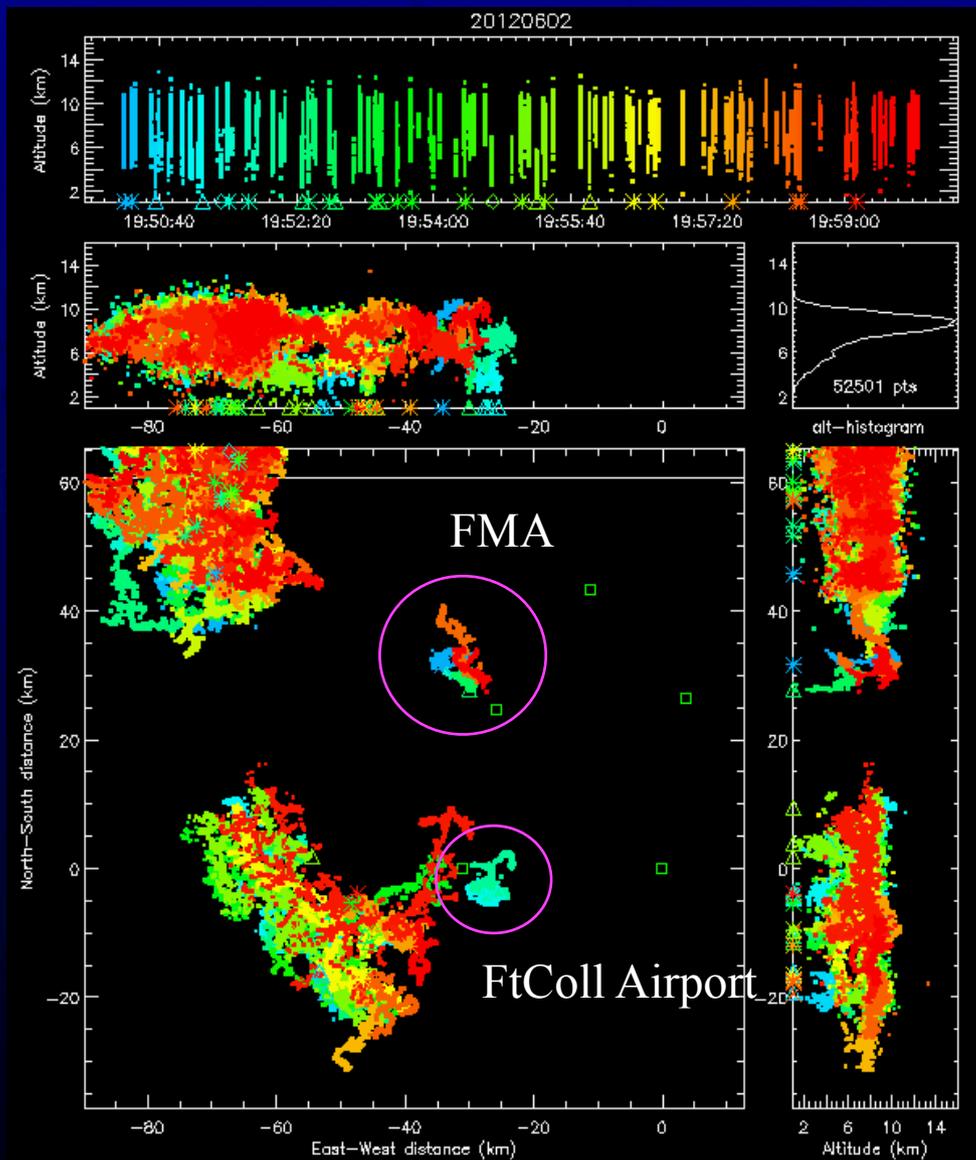
Electrical Charge Structure of DC3 Storms

- Aimed at elucidating the electrification processes
- Just getting started on this aspect of the studies.
- Focus for now on initial lightning sequences.
- Also on comparing lightning mapping observations with dual-polarization CHILL radar data

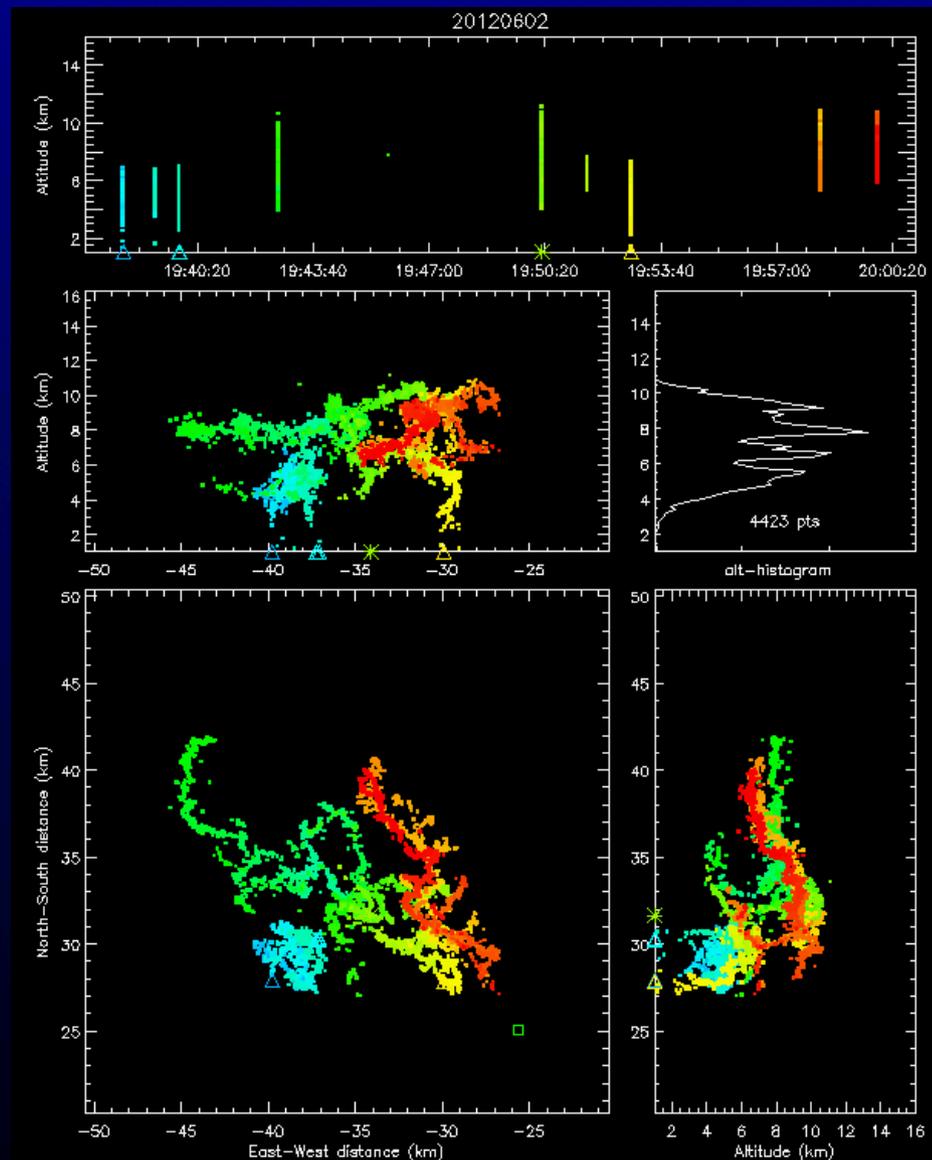
Example of normally electrified small storms, DC3, June 2, 2012

Readily produced --CG flashes (both storms began with --CGs)

1950-2000 UTC overview



Initial lightning sequence, FMA storm

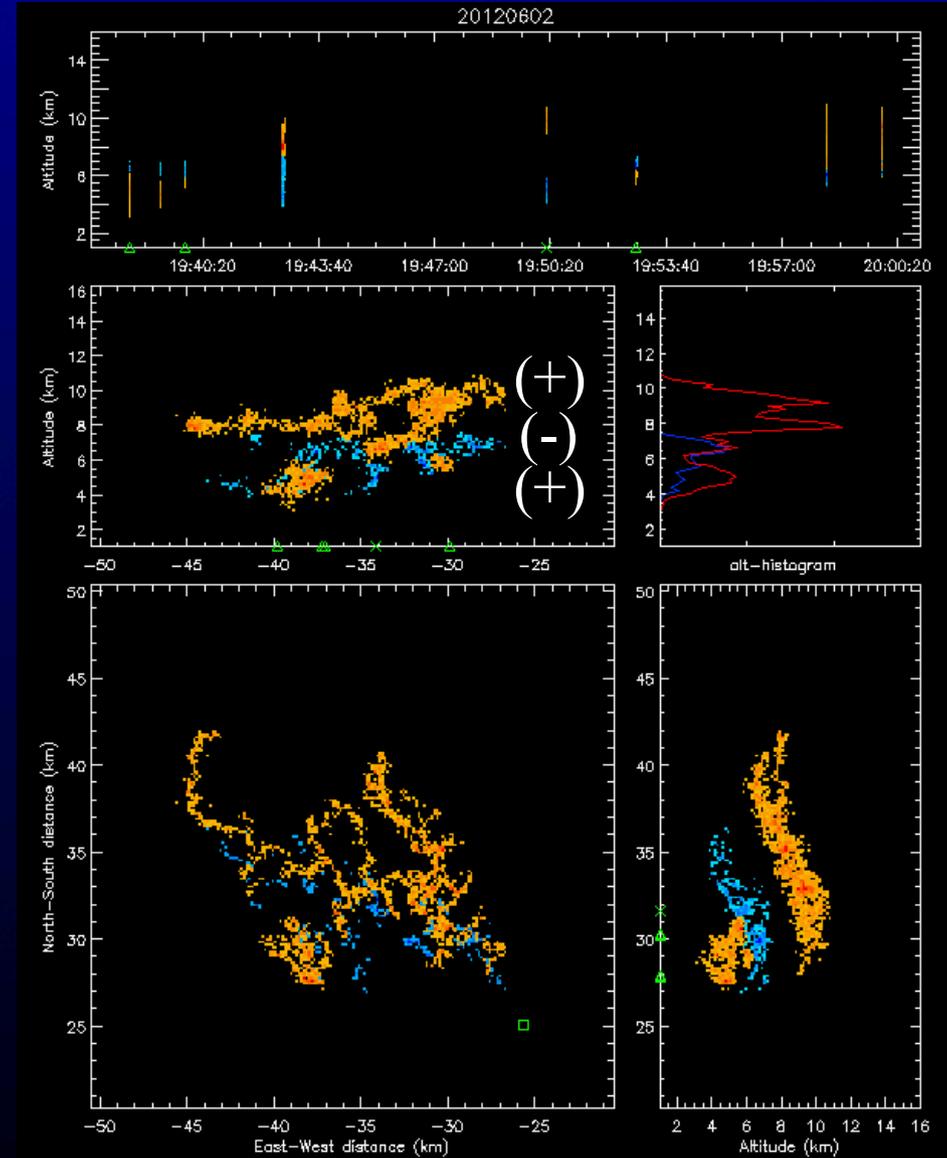
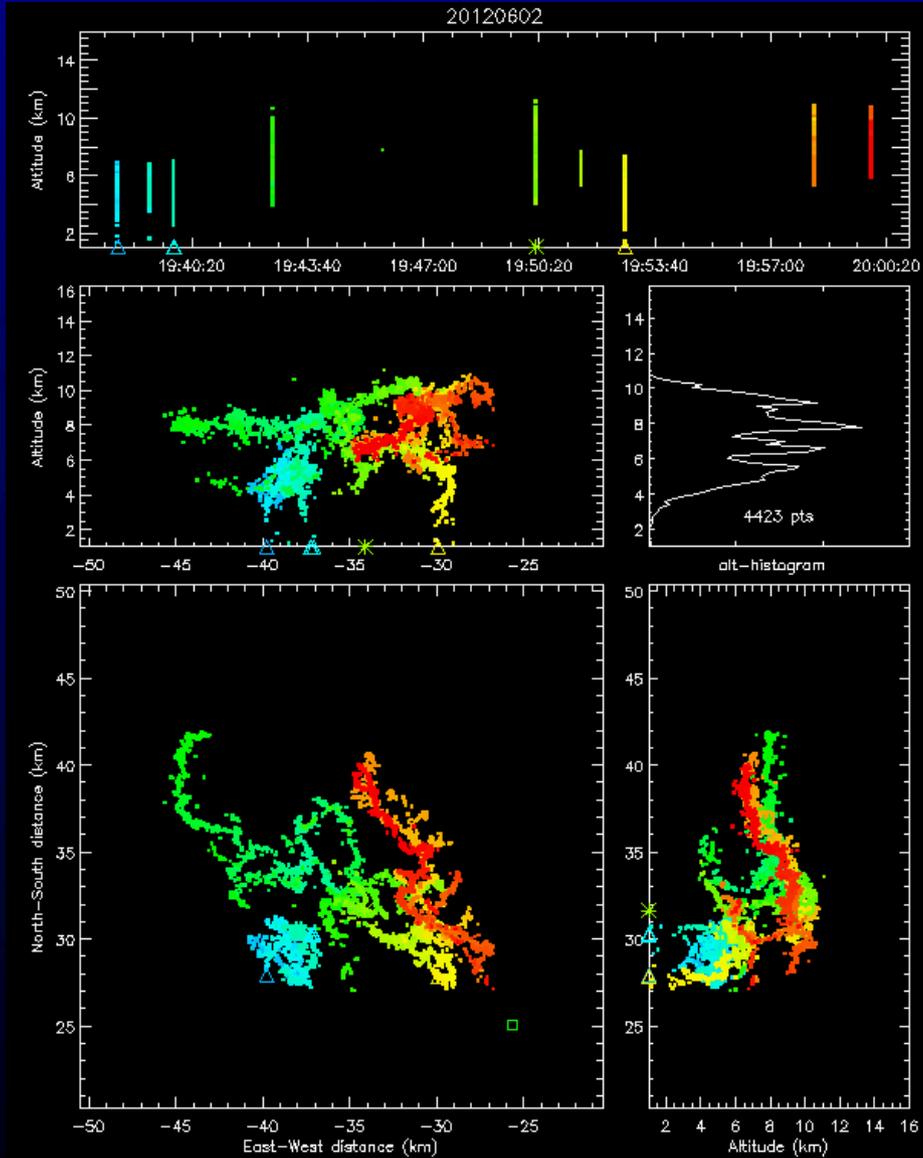


Electric charge structure, FMA storm

Normal polarity tripole, with lower positive charge and (-)CGs

9 flashes during initial 20 minutes

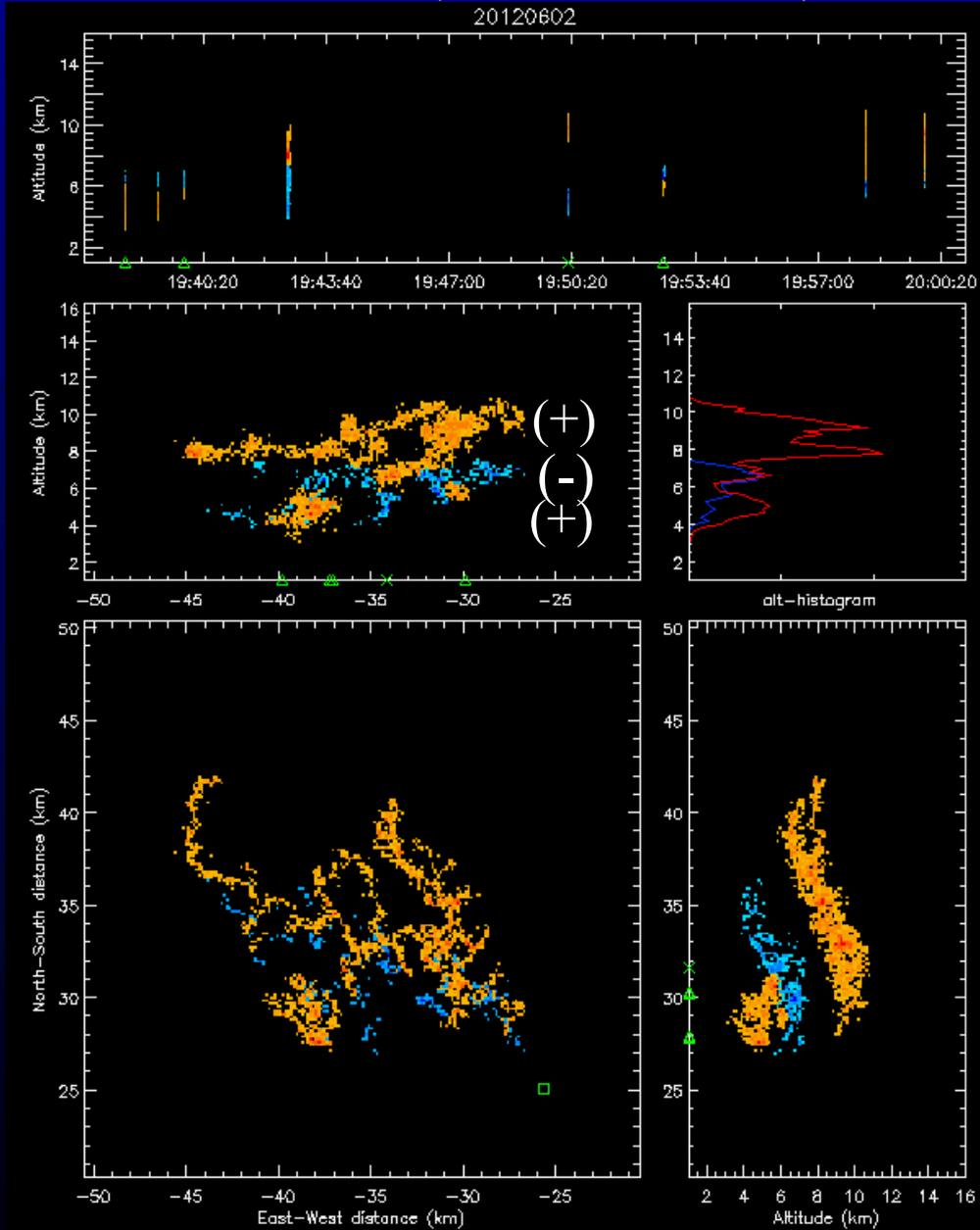
Lightning-inferred storm charge regions



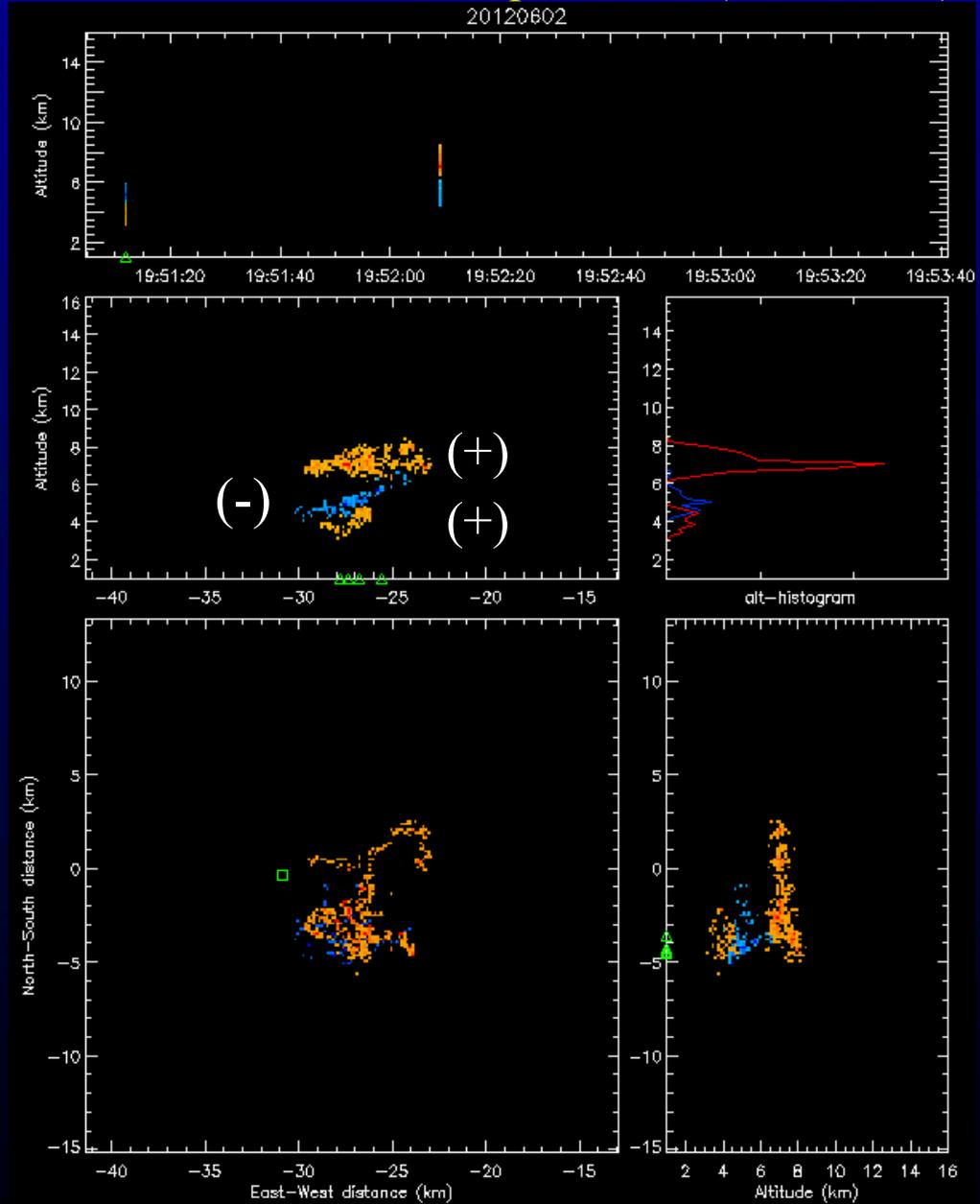
Comparative charge structure - Initial lightning sequences

Negative charge a bit lower in southern storm (~5 vs. ~6 km MSL)

FMA storm (9 flashes in 20 min)



Ft. Collins/Loveland Airport storm (2 in 10 min)

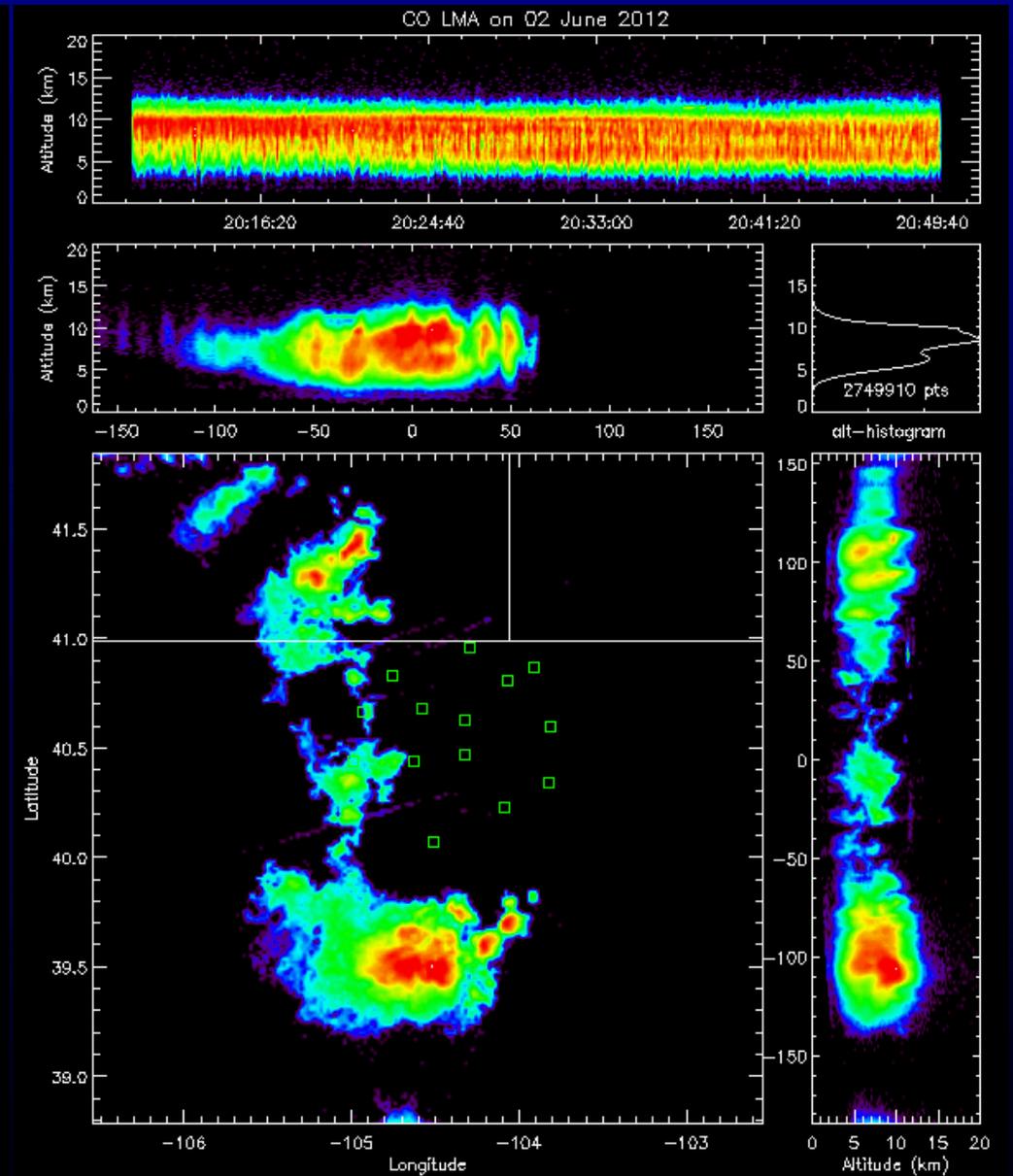
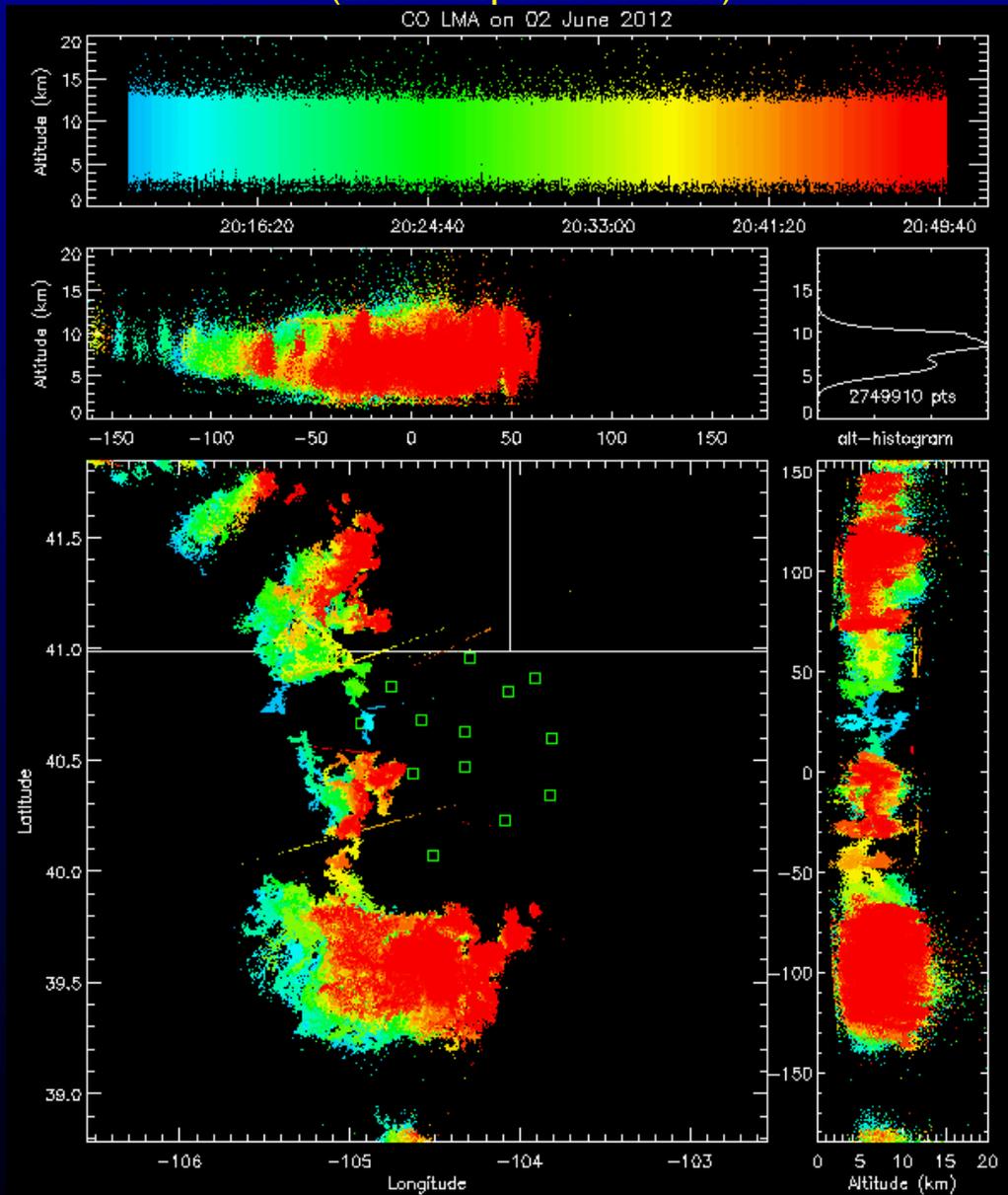


Anomalous Electrified Storms, June 2, 2012

Three storms, one hour of data (2000-2100 UTC)

Individual sources, colored by time
(note airplane tracks)

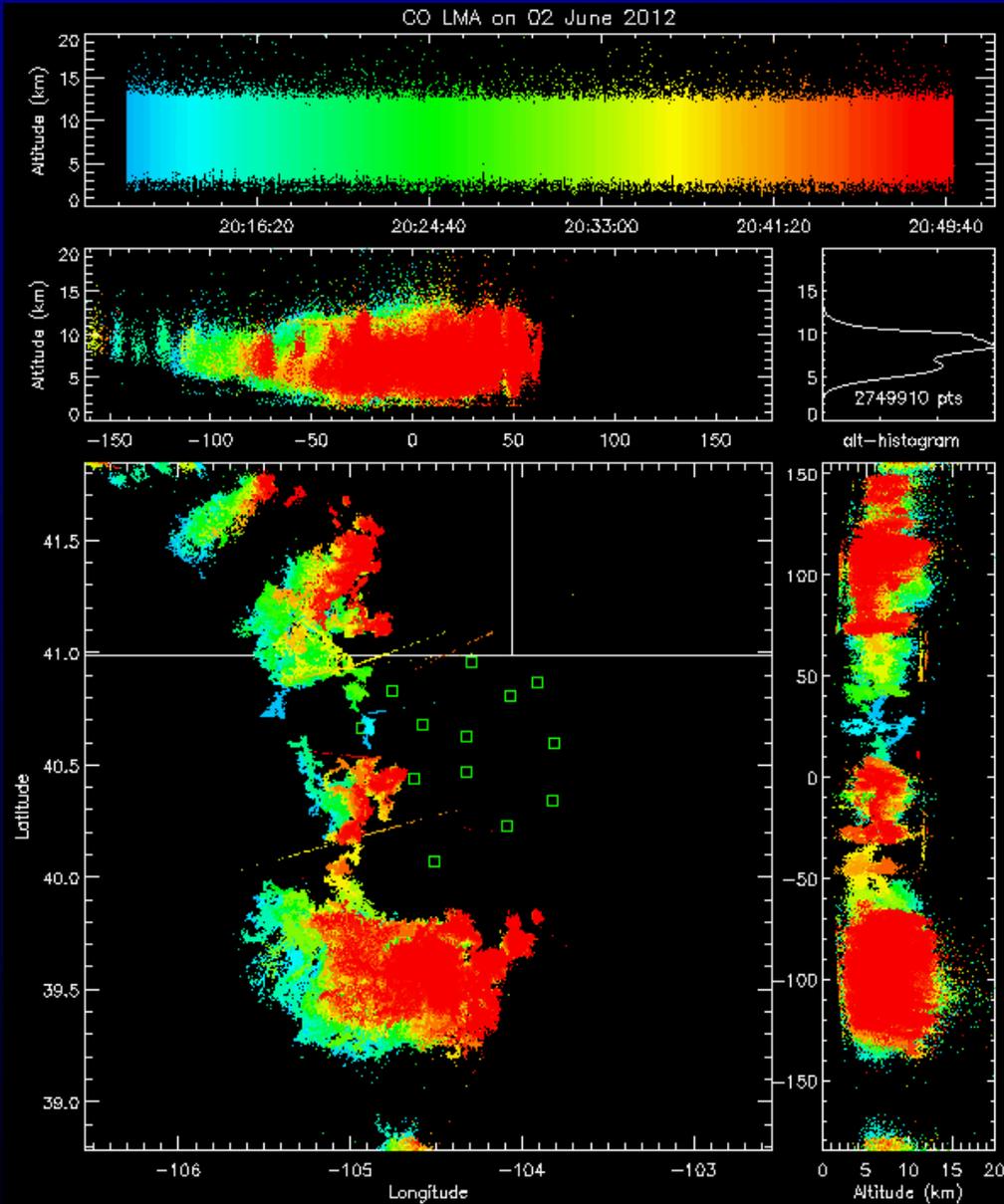
Density of sources (logarithmic color scale)



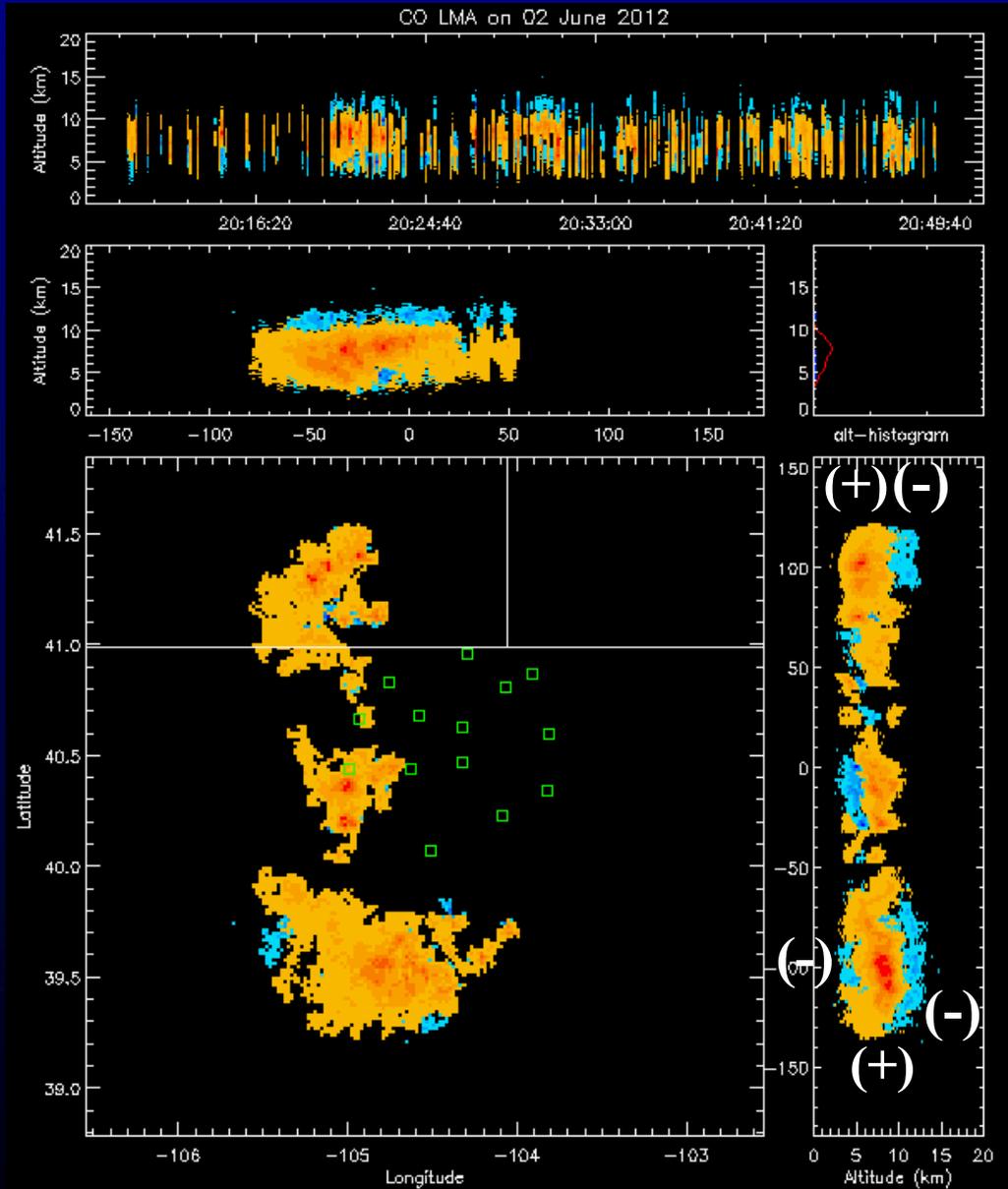
Anomalous Electrified Storms, June 2, 2012

Inverted dipolar/tripolar charge structures

Individual sources, colored by time



Lightning-inferred *charge* density



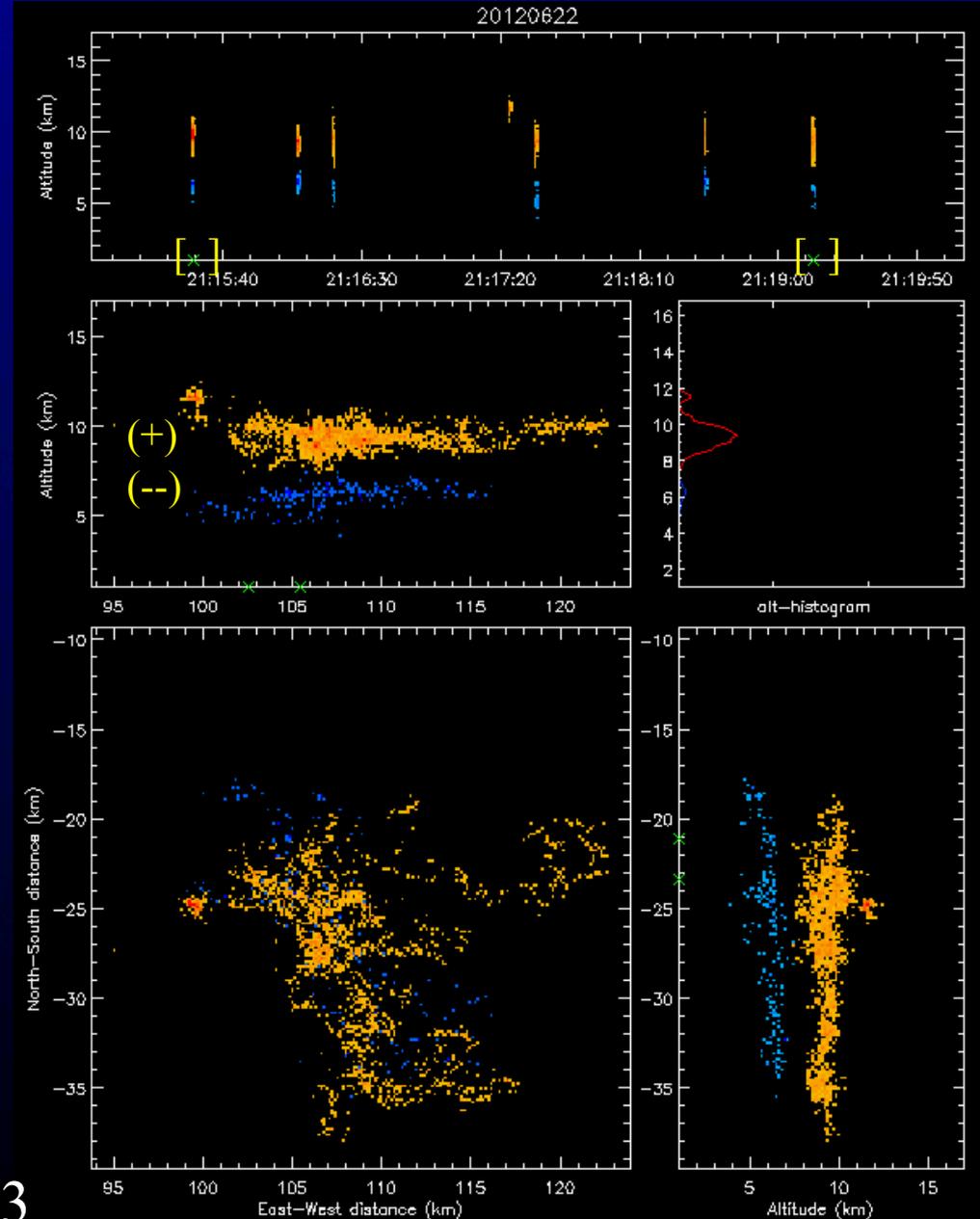
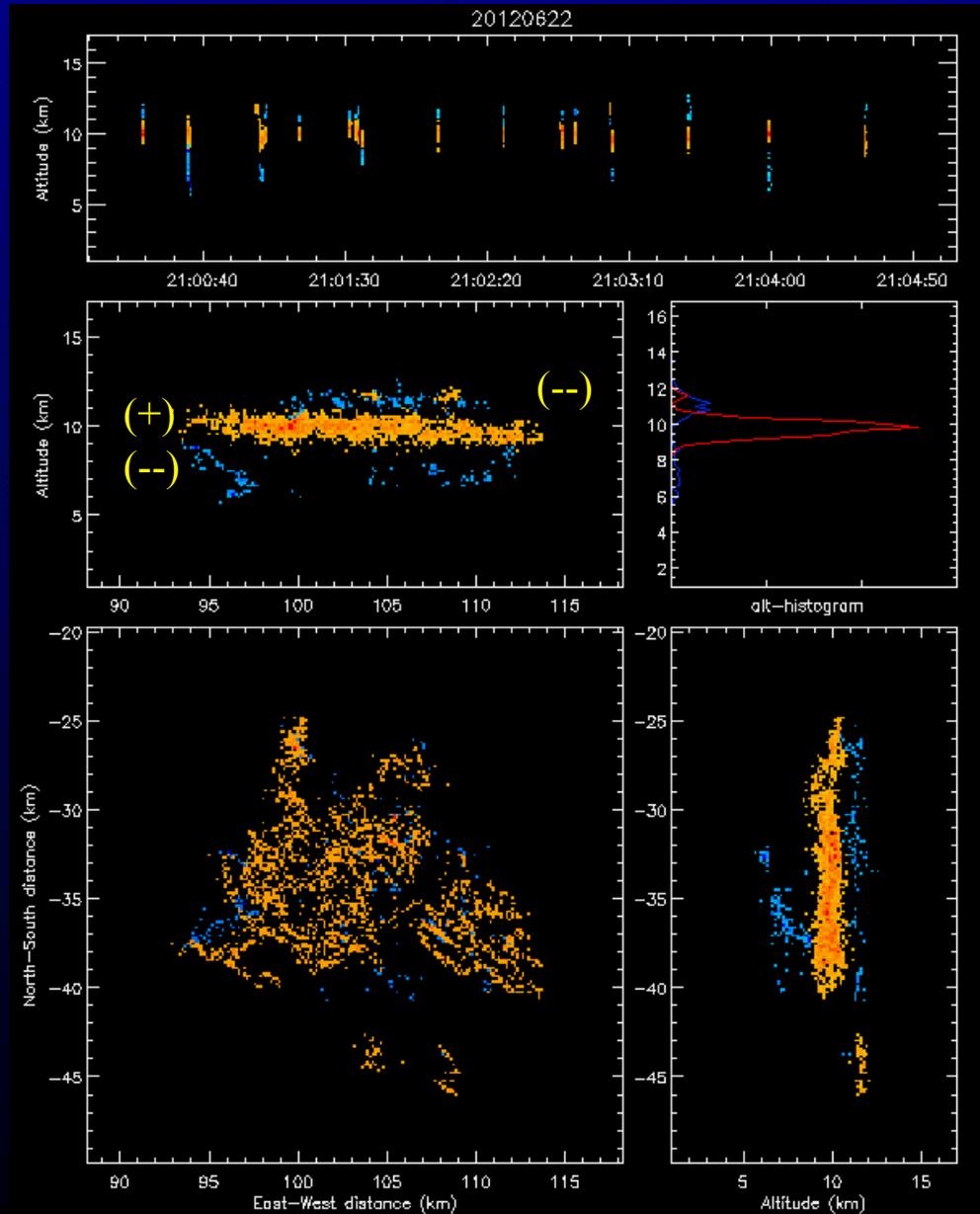
June 22 2012 First Storm: Charge Density Results

2100-2105 UTC (Initial activity)

ICs into upper (+) charge from above and below

2115-2120 UTC (later)

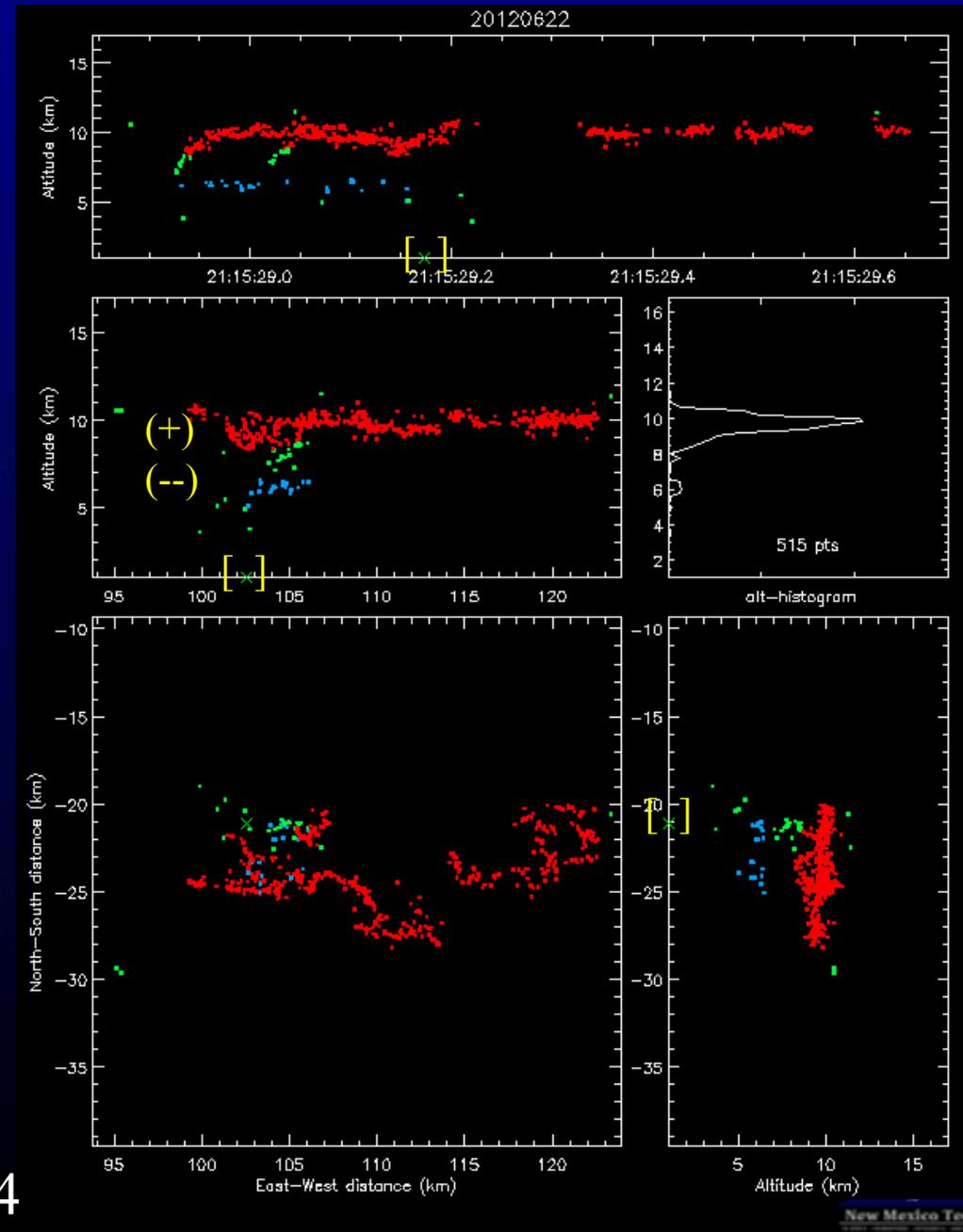
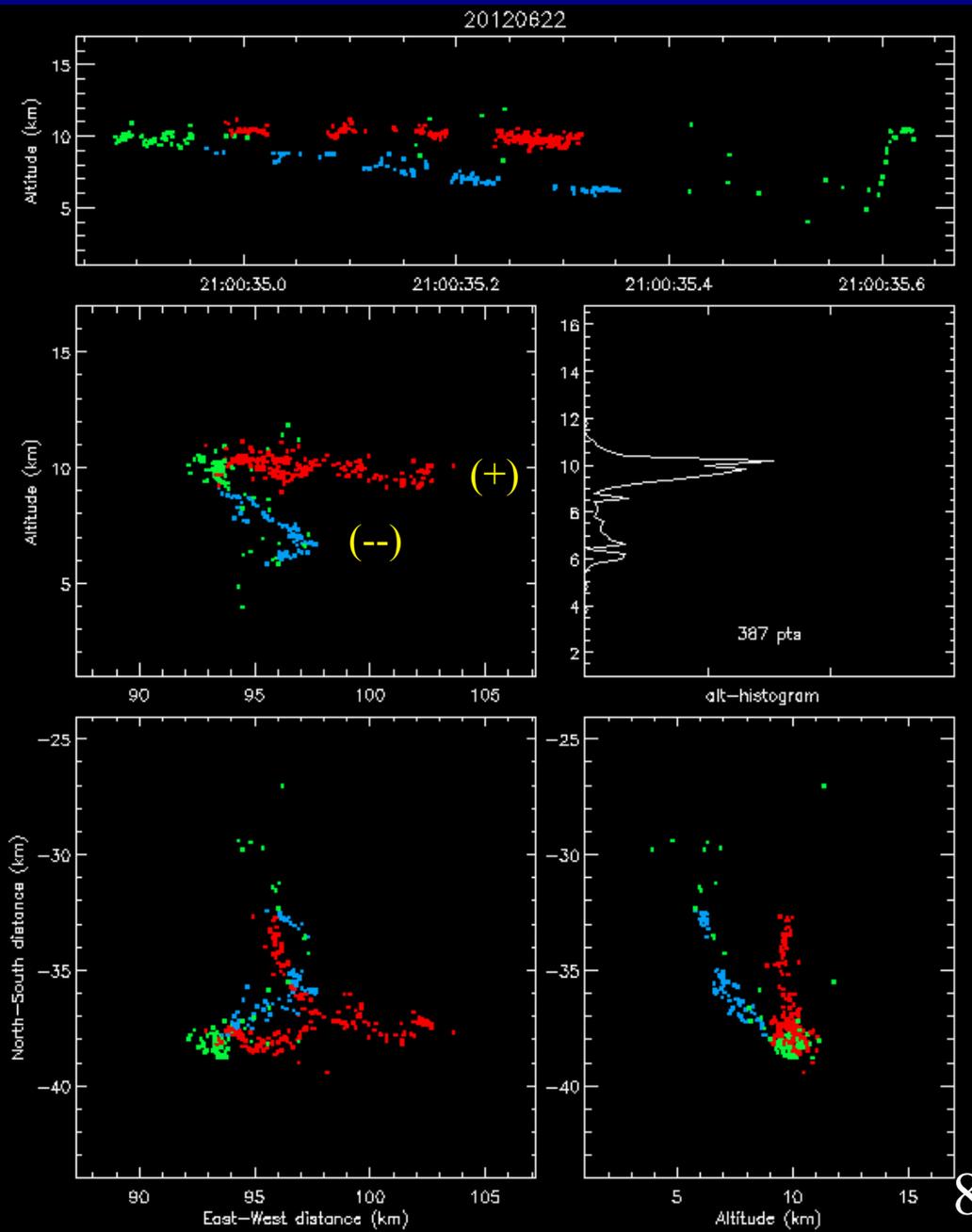
(normal ICs and +CGs!)



June 22 2012 First Storm: Early and later flash examples

21:00:34 UTC
Downward IC (normal polarity)

21:15:29 UTC
Upward IC (normal polarity) & 39 kA +CG!!



Summary

Lightning mapping observations made during DC3 have provided valuable datasets not only in support of the atmospheric chemistry objectives, but also pertaining to the question of how storms become electrified. The observations have been obtained in Colorado, Oklahoma, Alabama, and West Texas. A lot is to be gained from detailed analyses of the observations.

End