Lightning Mapping Observations During DC3 in Northern Colorado

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Fall Annual Meeting
American Geophysical Union
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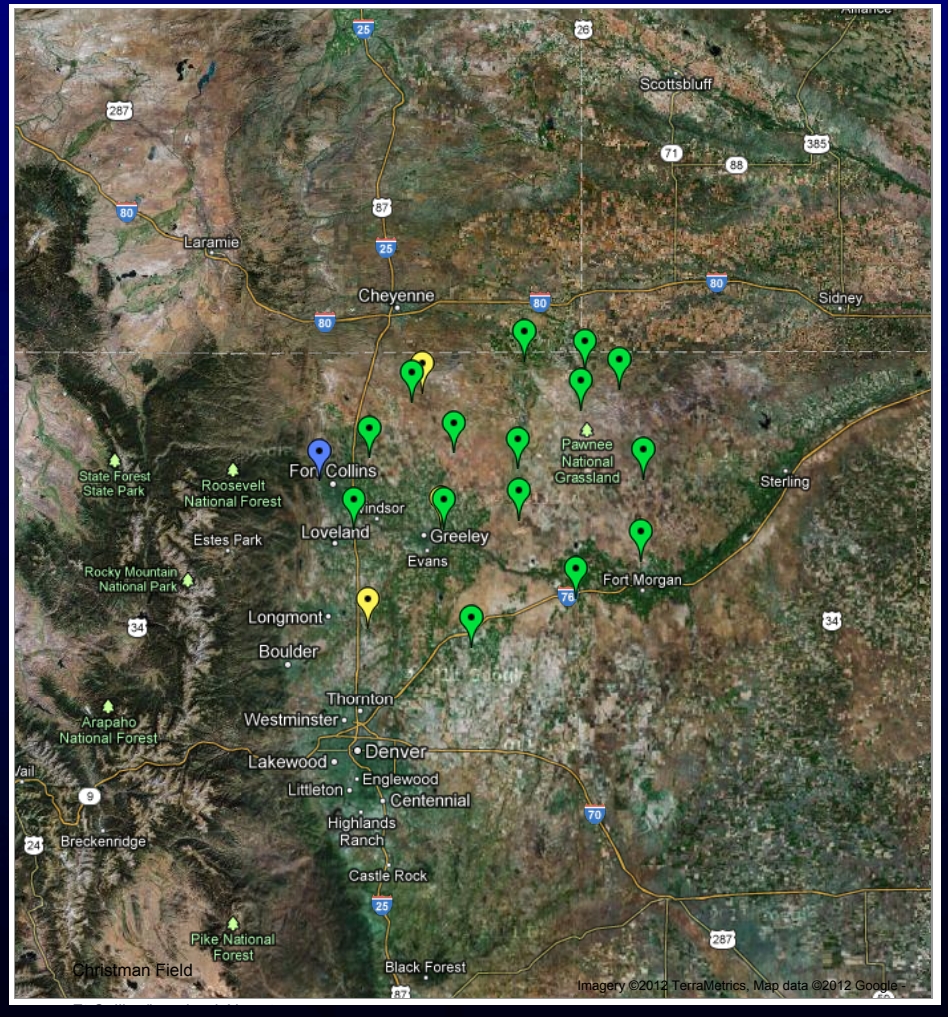
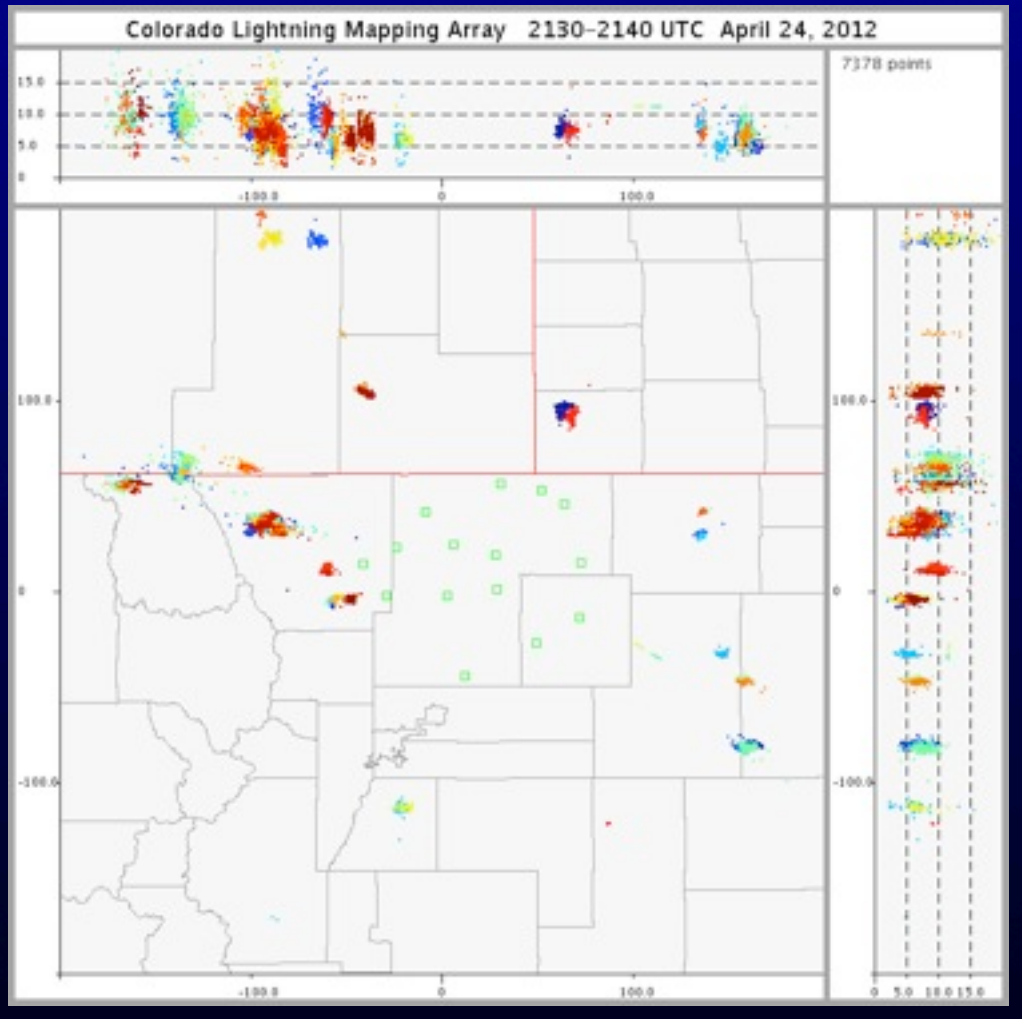
North Colorado LMA
15 stations, 100 km diameter area



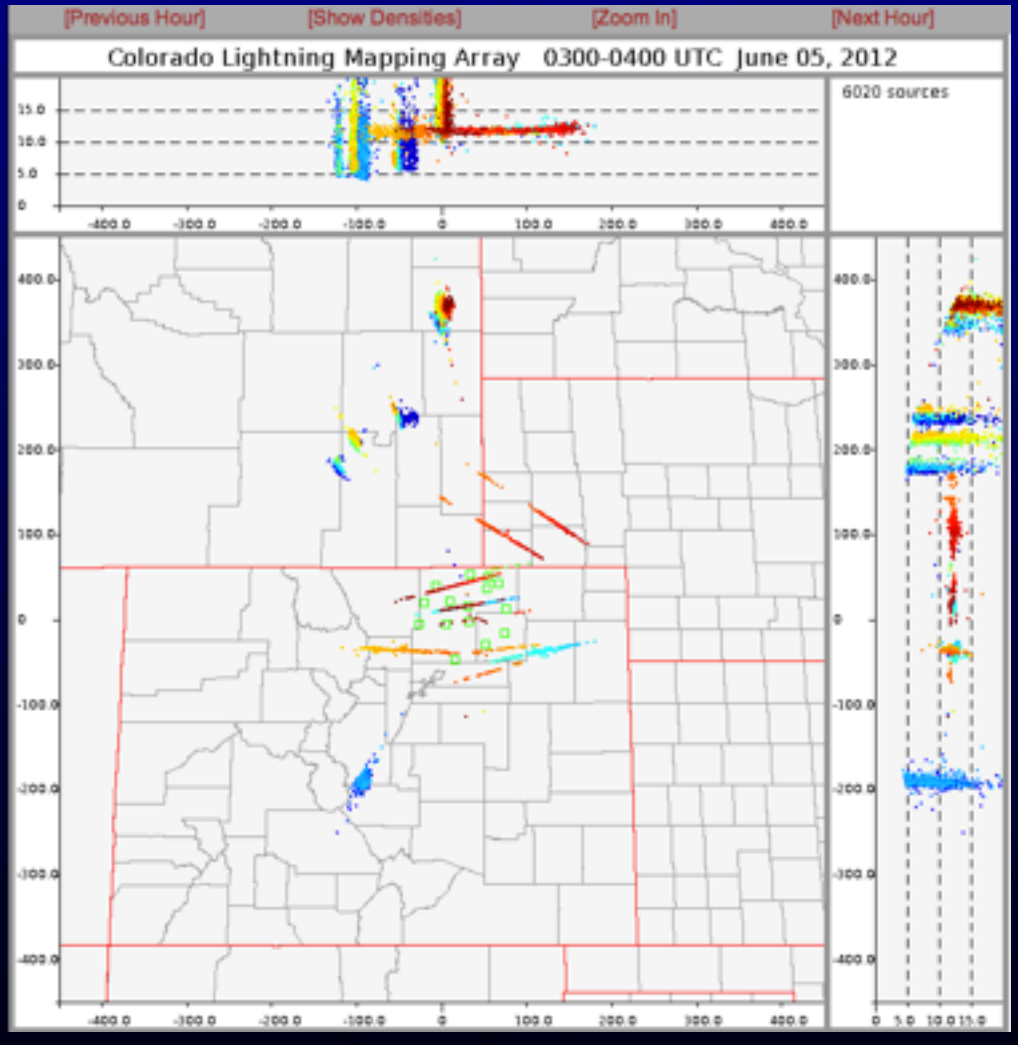


LMA Station (Briggsdale, CO)

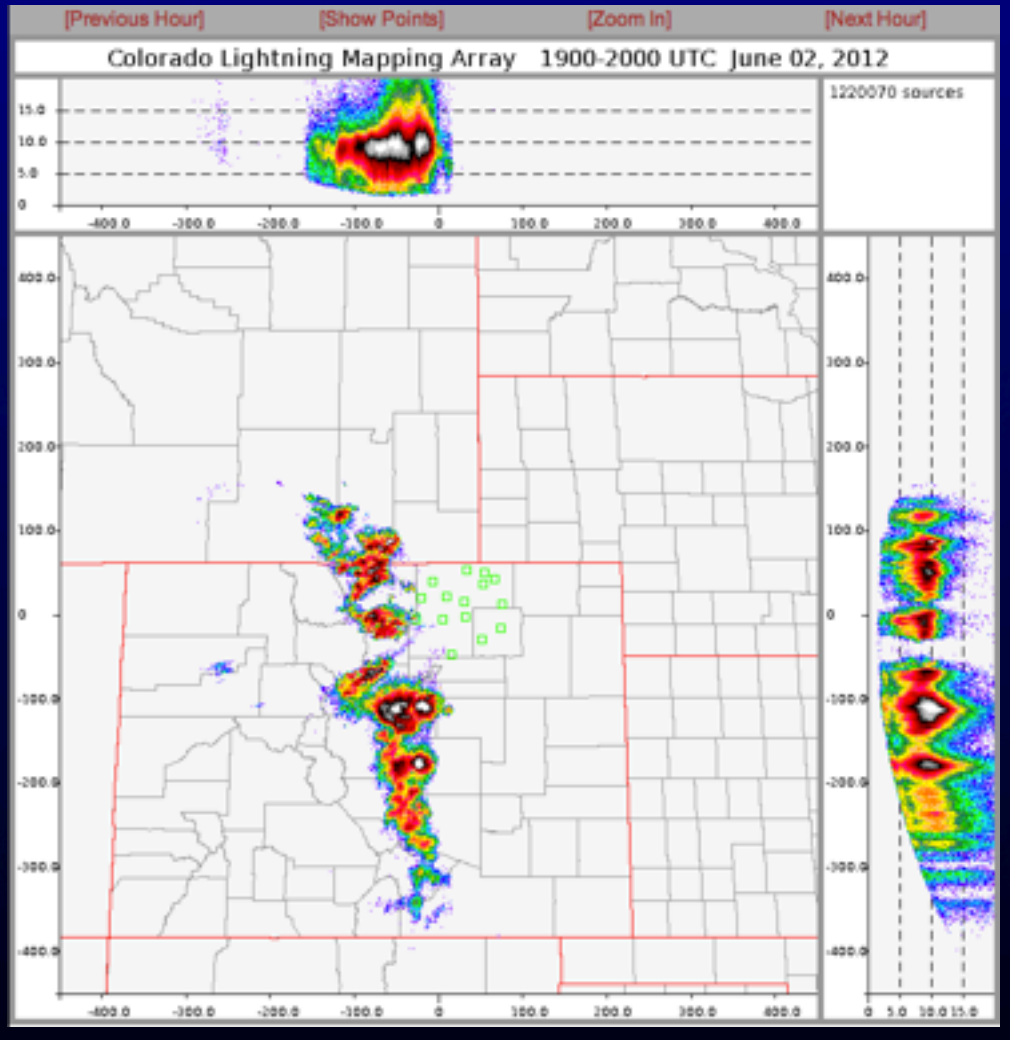
Solar powered; cell data modem comm links

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

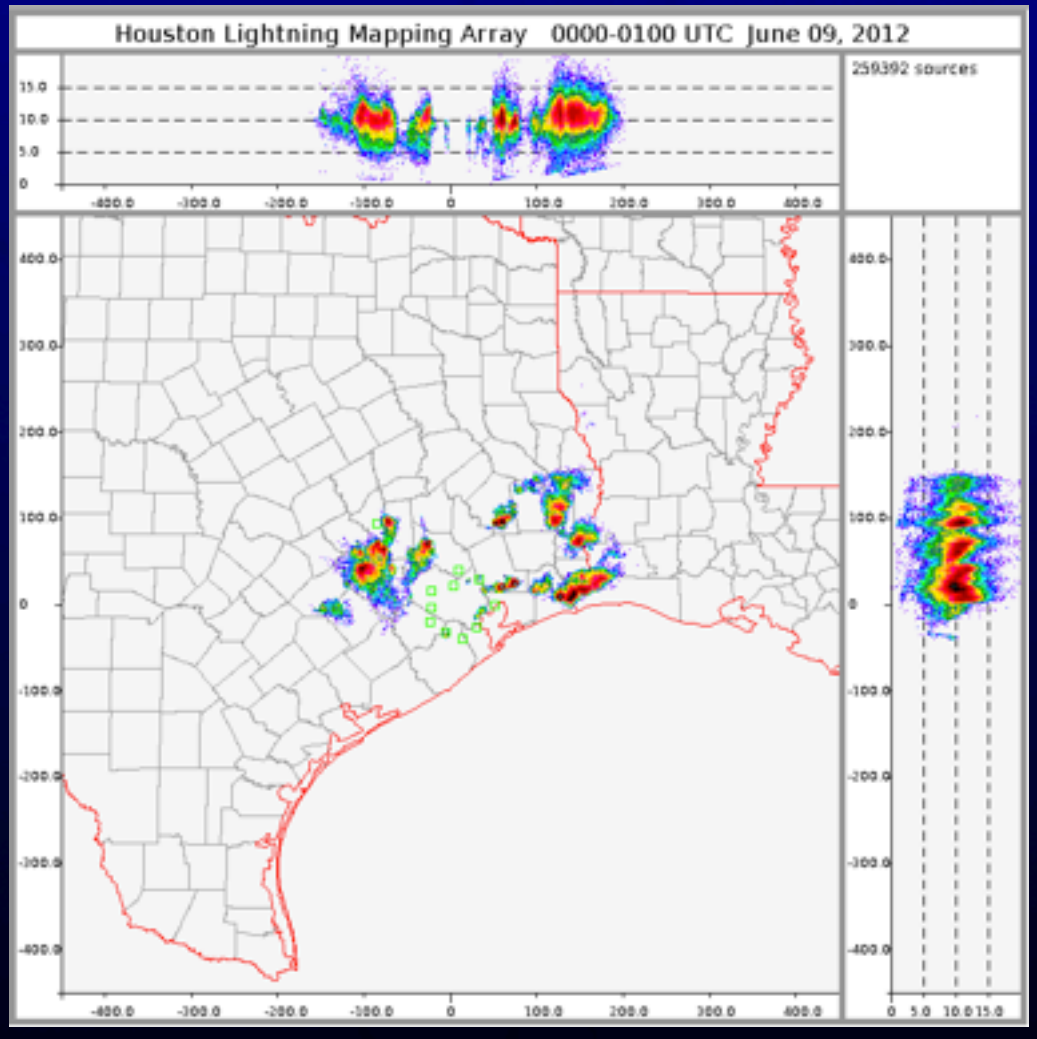
(information updated hourly, at twenty past -- last updated: Tue Nov 27 19:20:01 2012 UTC)

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/h	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%	83%	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%	84%	10632	10634	10636	10638	10640	-12	2012/11/27	19:16:03	27	11	TD121127	D	11/27/12	19:15:59	v10	-87 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%	83%	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%	85%	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%	84%	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%	84%	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%	84%	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

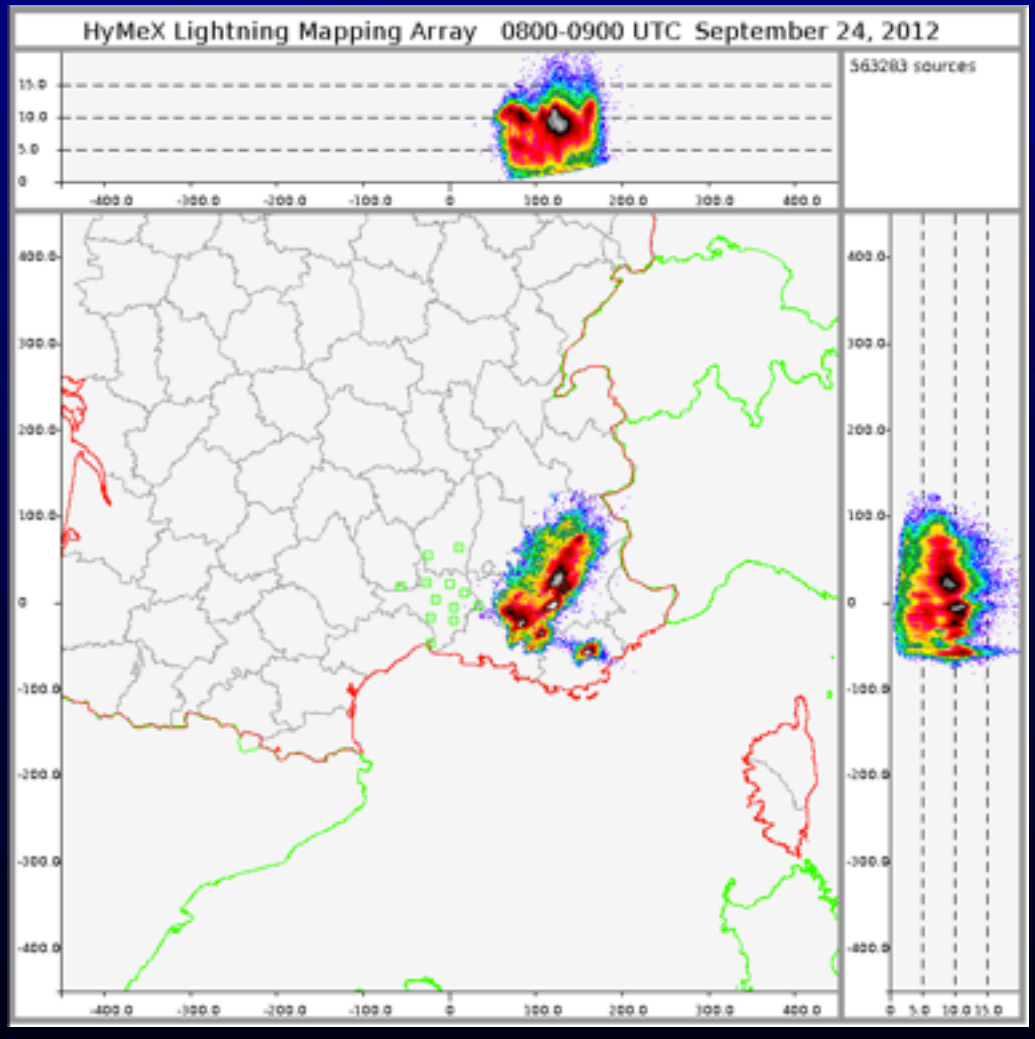
http://lightning.nmt.edu/nco_lma/status/

Other networks: Real-time web pages

Houston LMA (Texas A&M Univ.)



HyMeX 2012 (Toulouse University)



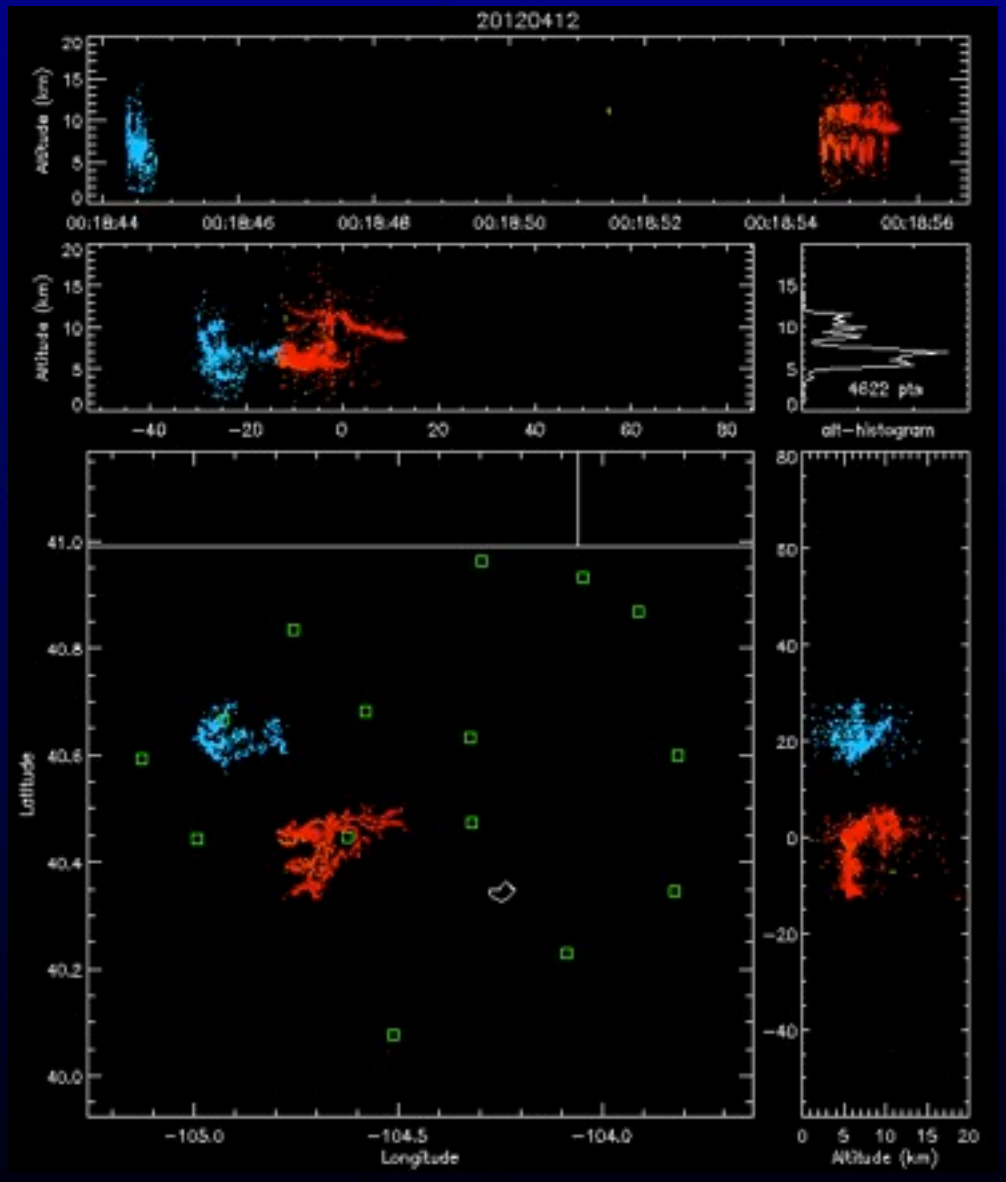
http://lightning.nmt.edu/hstnlma/

Results so far

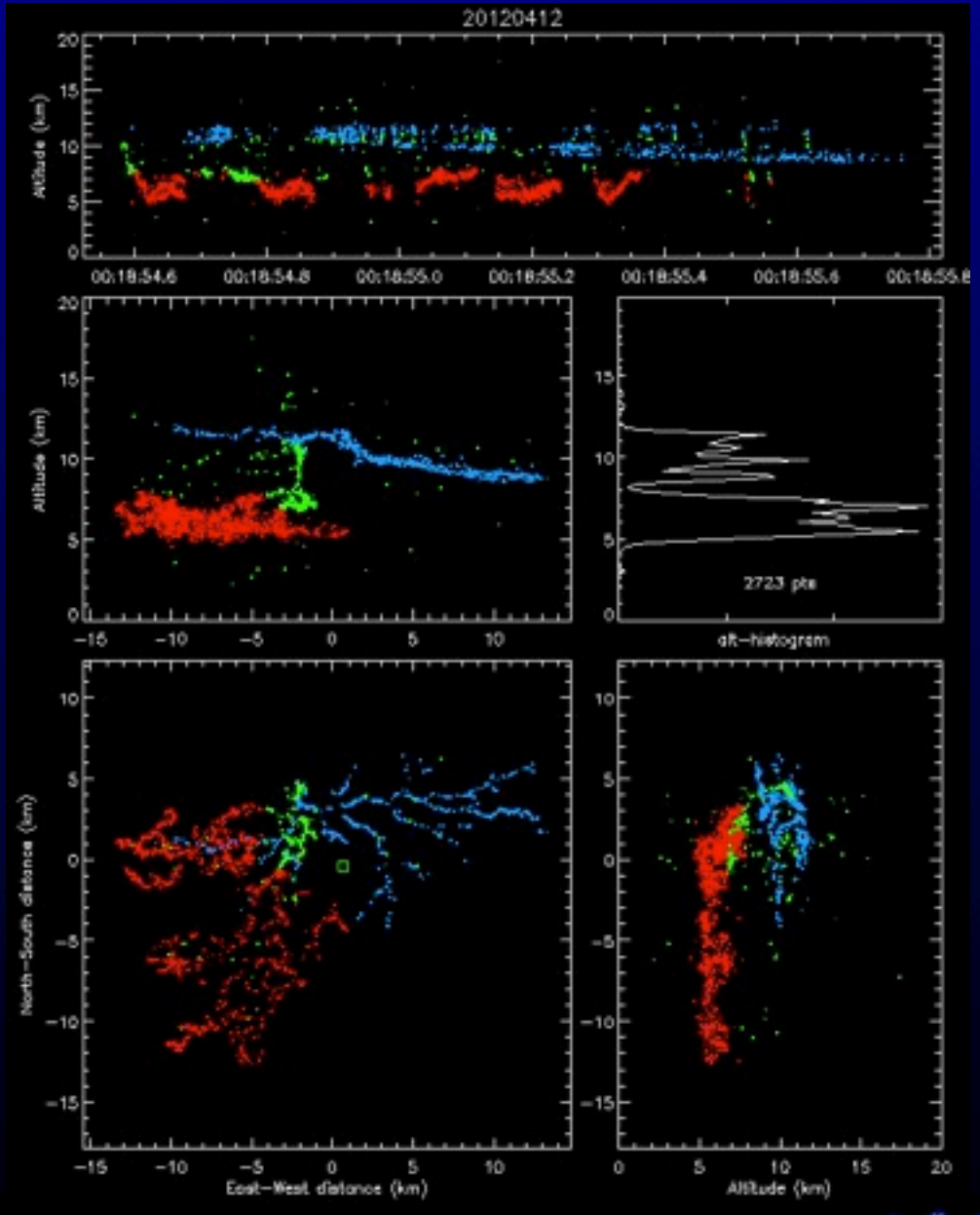
- Excellent data obtained in collaboration with CSU and the CHILL radar.
- Data Analysis: Work in progress
- This presentation: Show examples of kind of observations obtained during DC3
- A wide variety of storm electrical structures observed (normal and anomalous polarity)
- Anomalous storms common,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

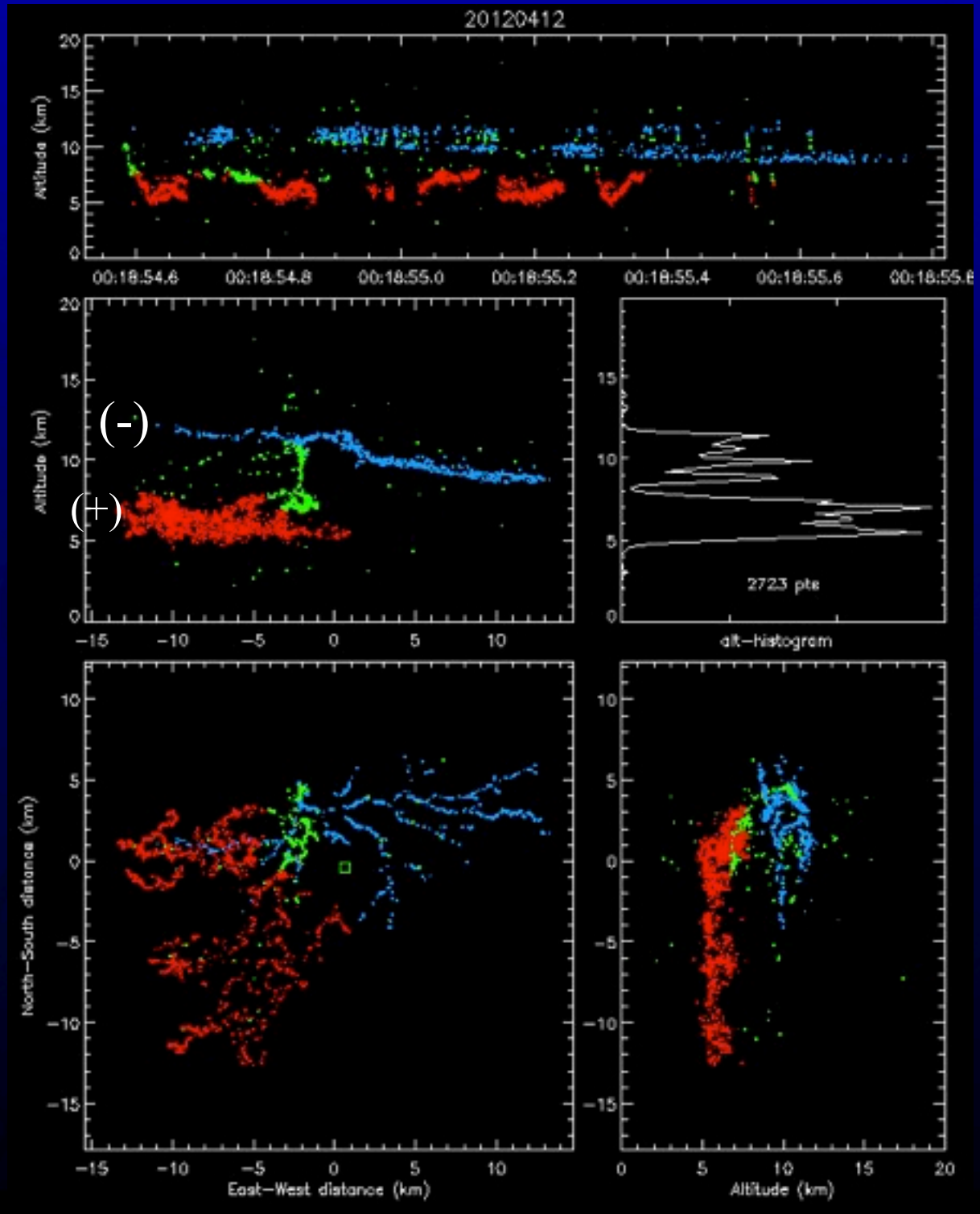
Early example of observations (April 11-12, 2012)
Inverted polarity IC discharge over CHILL radar, 6:18 pm MDT

Overview



Detailed Flash Structure





Flash Animation

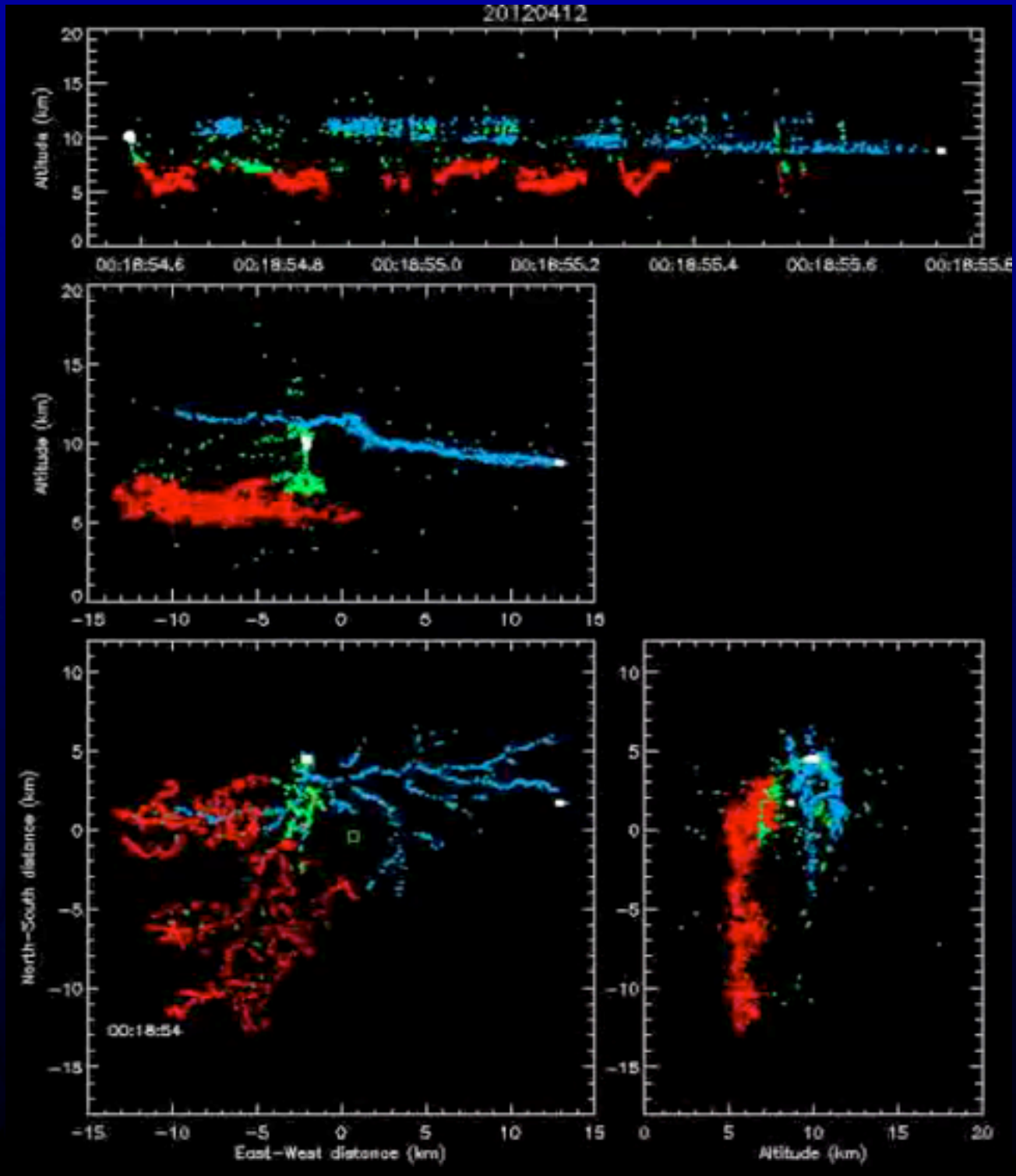
Between upper level (-) and mid-level (+) storm charges (anomalous or 'inverted' polarity)

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

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

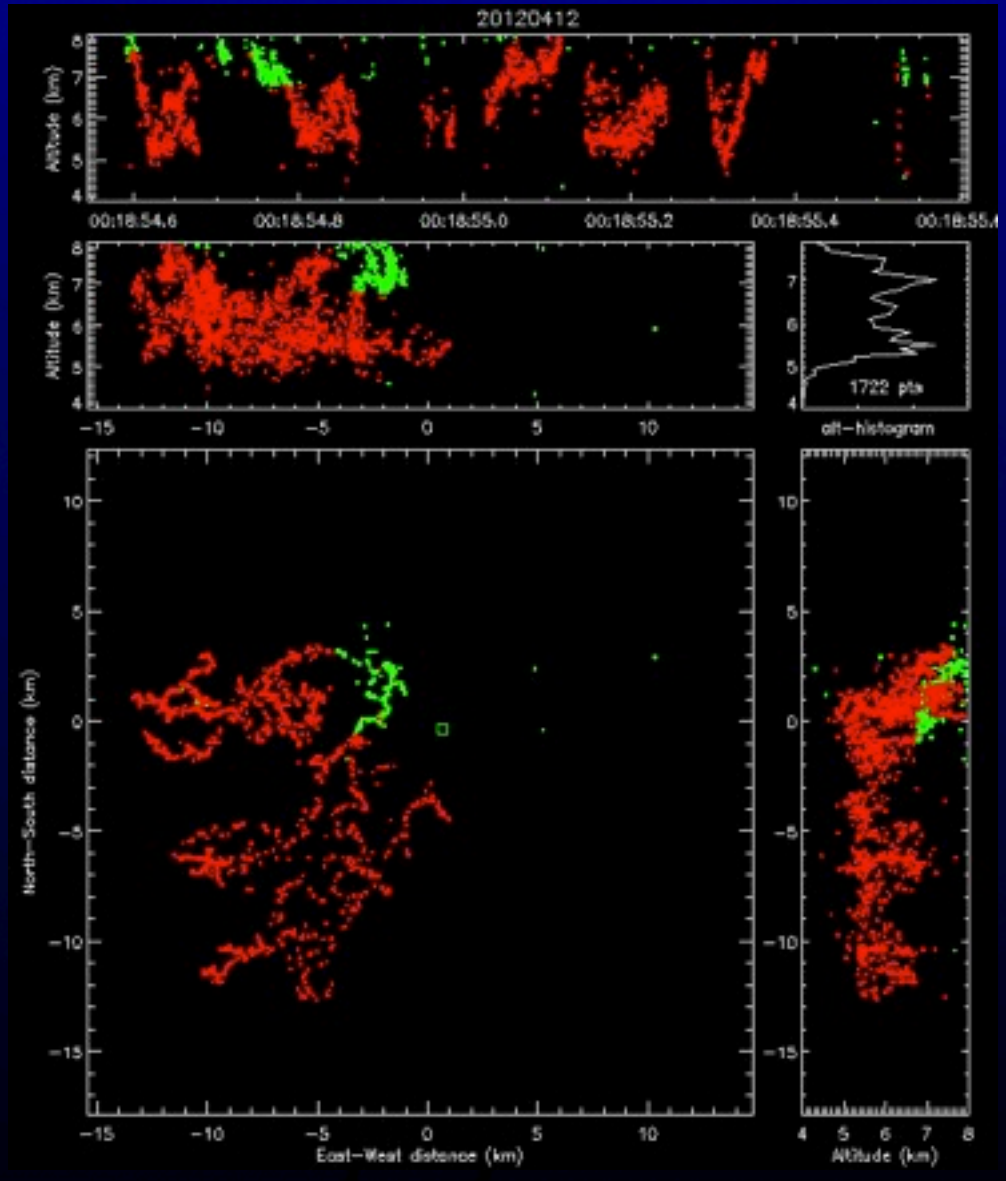
Positive leaders revealed by a combination of apparent (+) leader radiation and retrograde (-) ('recoil') events.

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

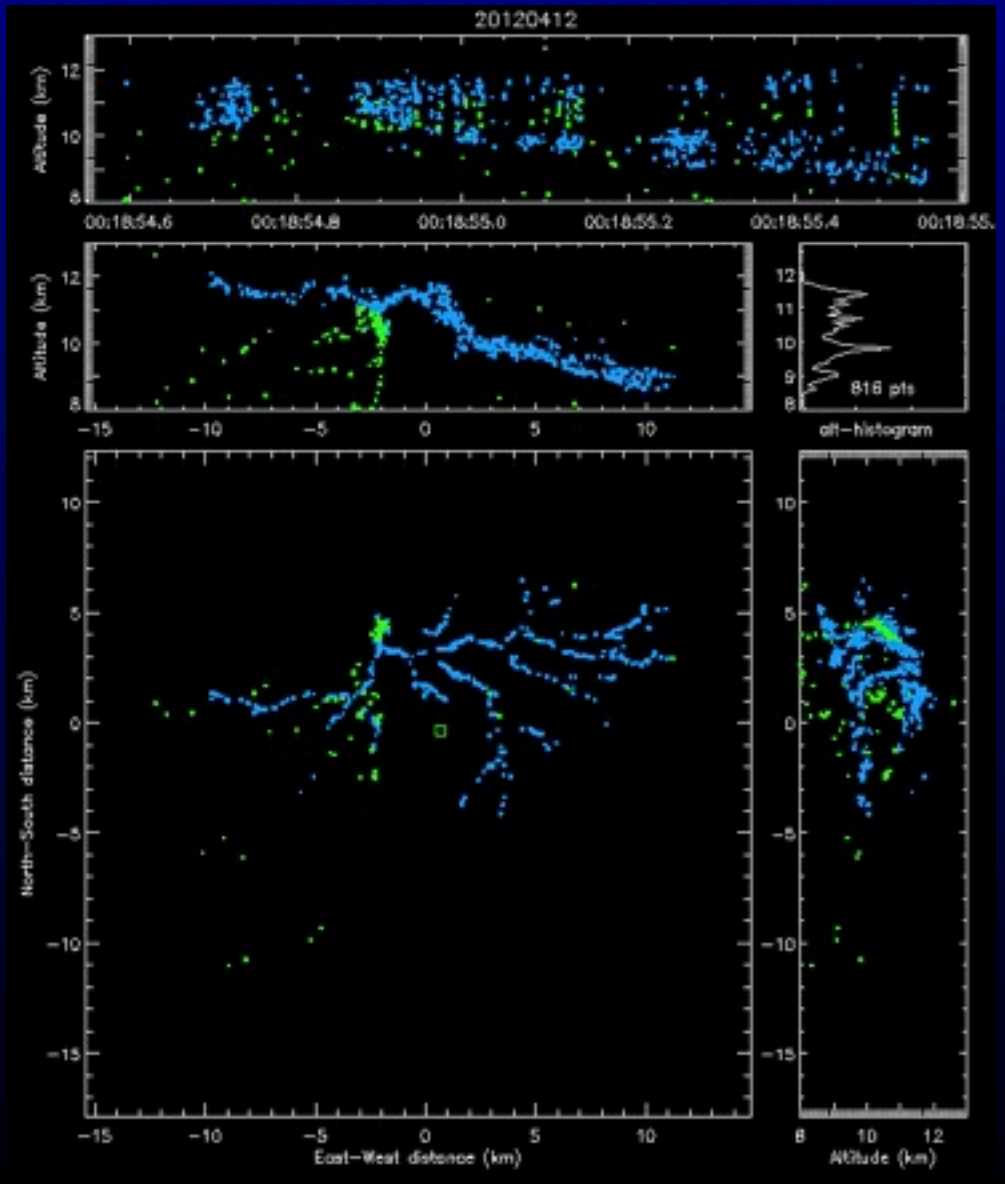

20120412
Altitude (km)
00:18:54.6
00:18:54.8
00:18:55.0
00:18:55.2
00:18:55.4
00:18:55.6
Altitude (km)
North-South distance (km)
00:18:54
East-West distance (km)
Altitude (km)

Separate out positive and negative breakdown channels

Negative leaders
one main branch at a time; spatially noisy



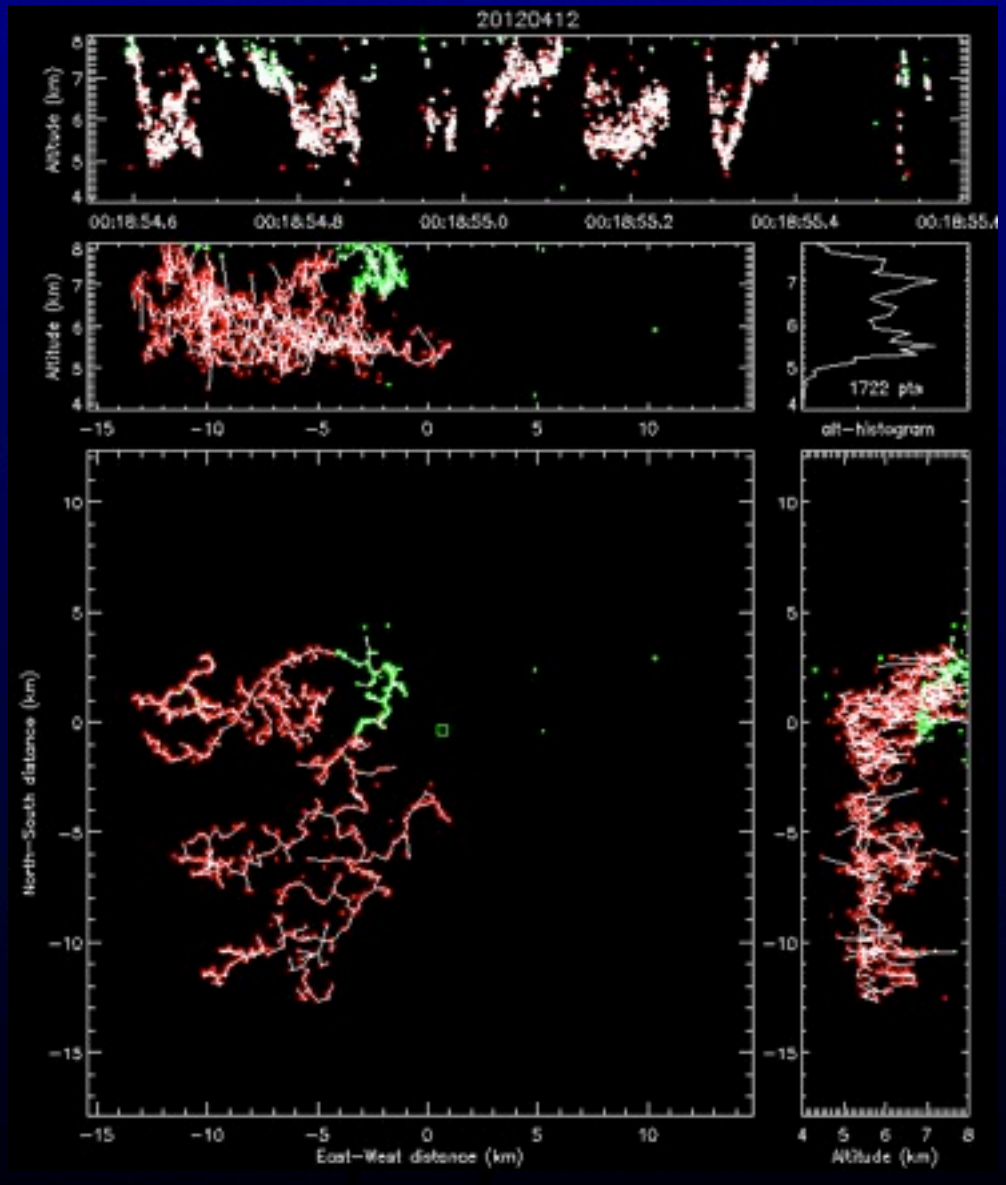
Positive leaders
well-defined filamentary structure, all in parallel



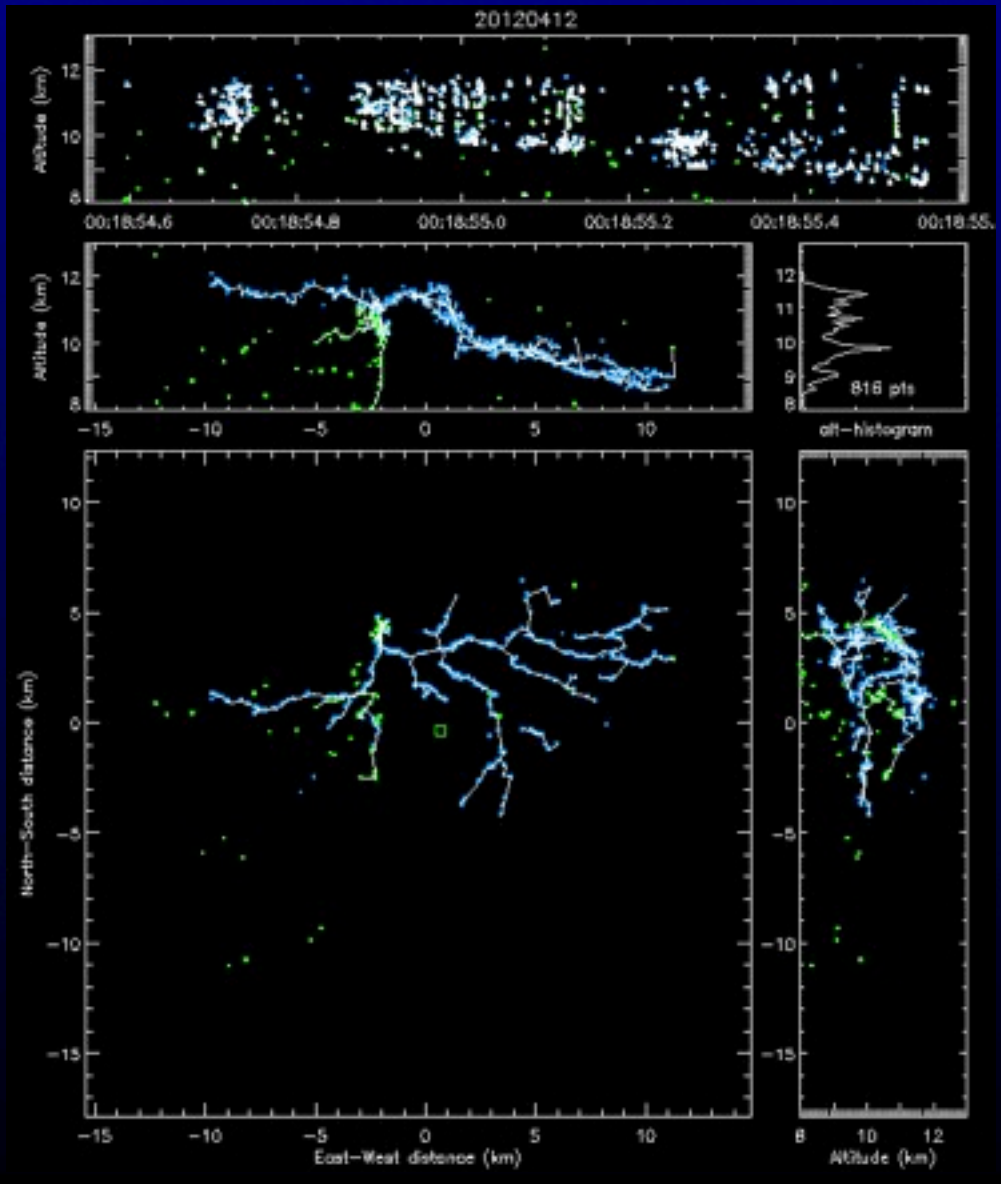
Separate out positive and negative breakdown channels

Add channel structure (Thomas branch/twig/leaf approach)

Negative leaders
(spatially noisy - side branches)



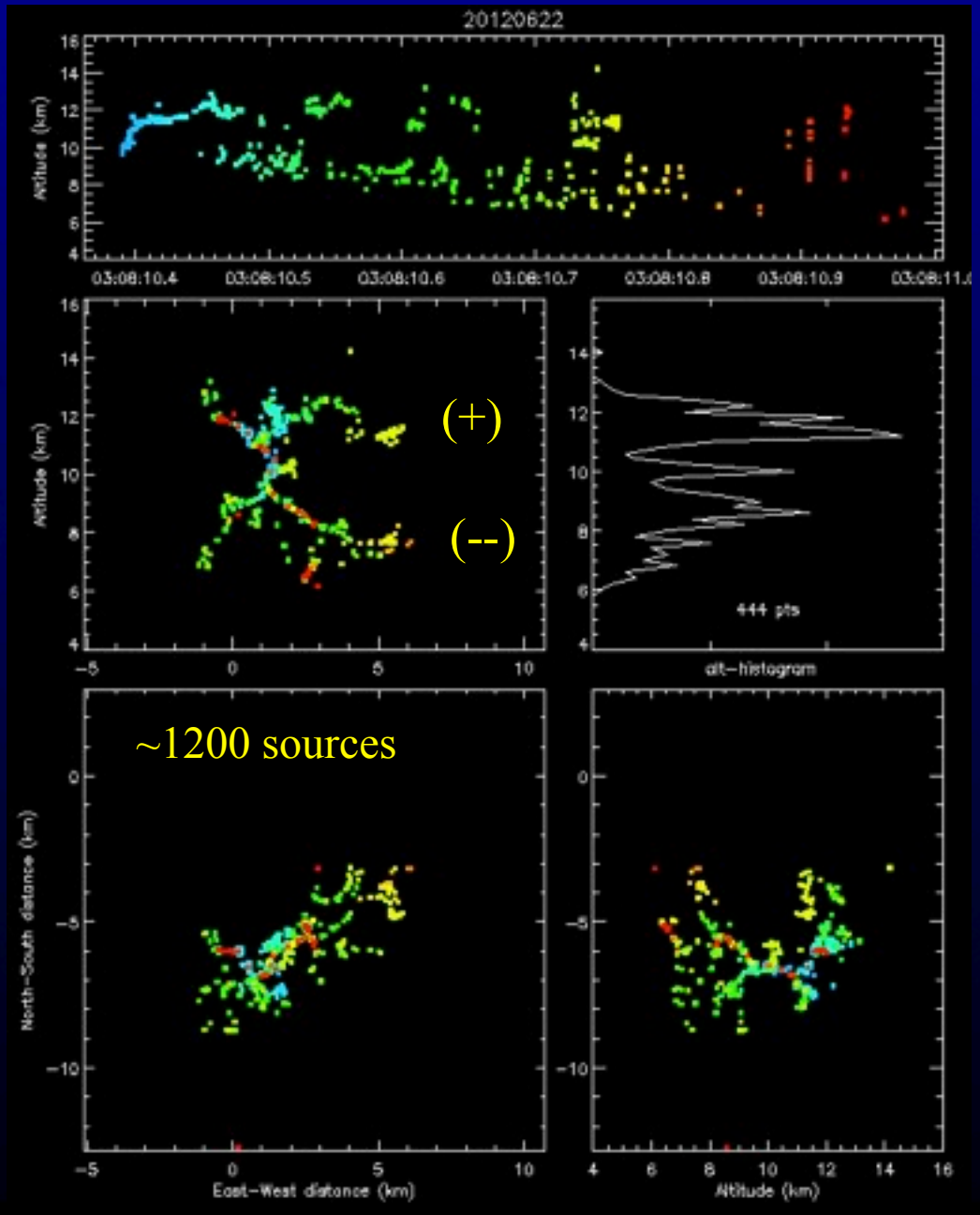
Positive leaders
(well-defined filamentary structure)



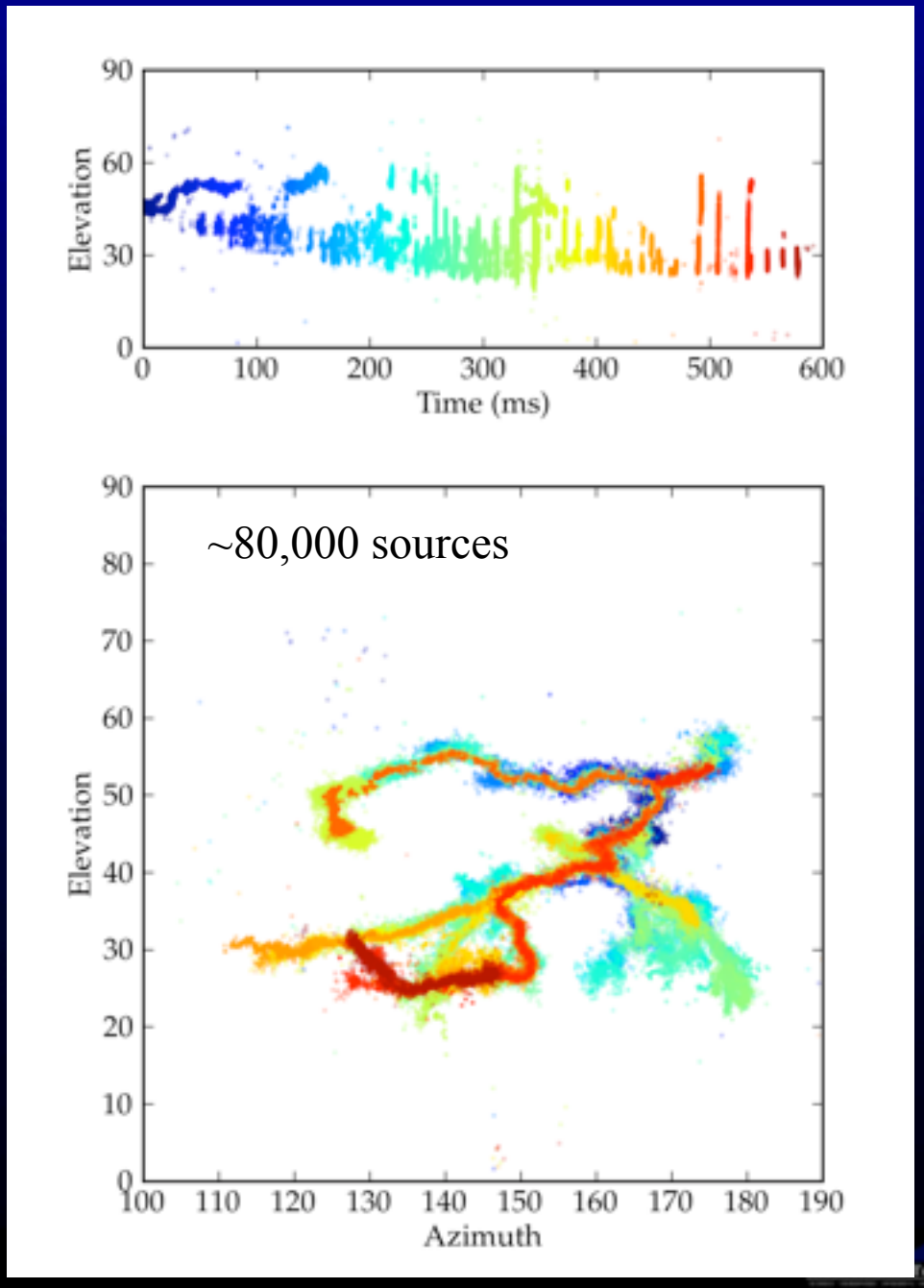
- Preview of microsecond resolution interferometric observations of of a bilevel IC flash; Langmuir Laboratory, 2012 (Akita, Stock, et al., Poster AE13A-0369, Monday p.m. session).

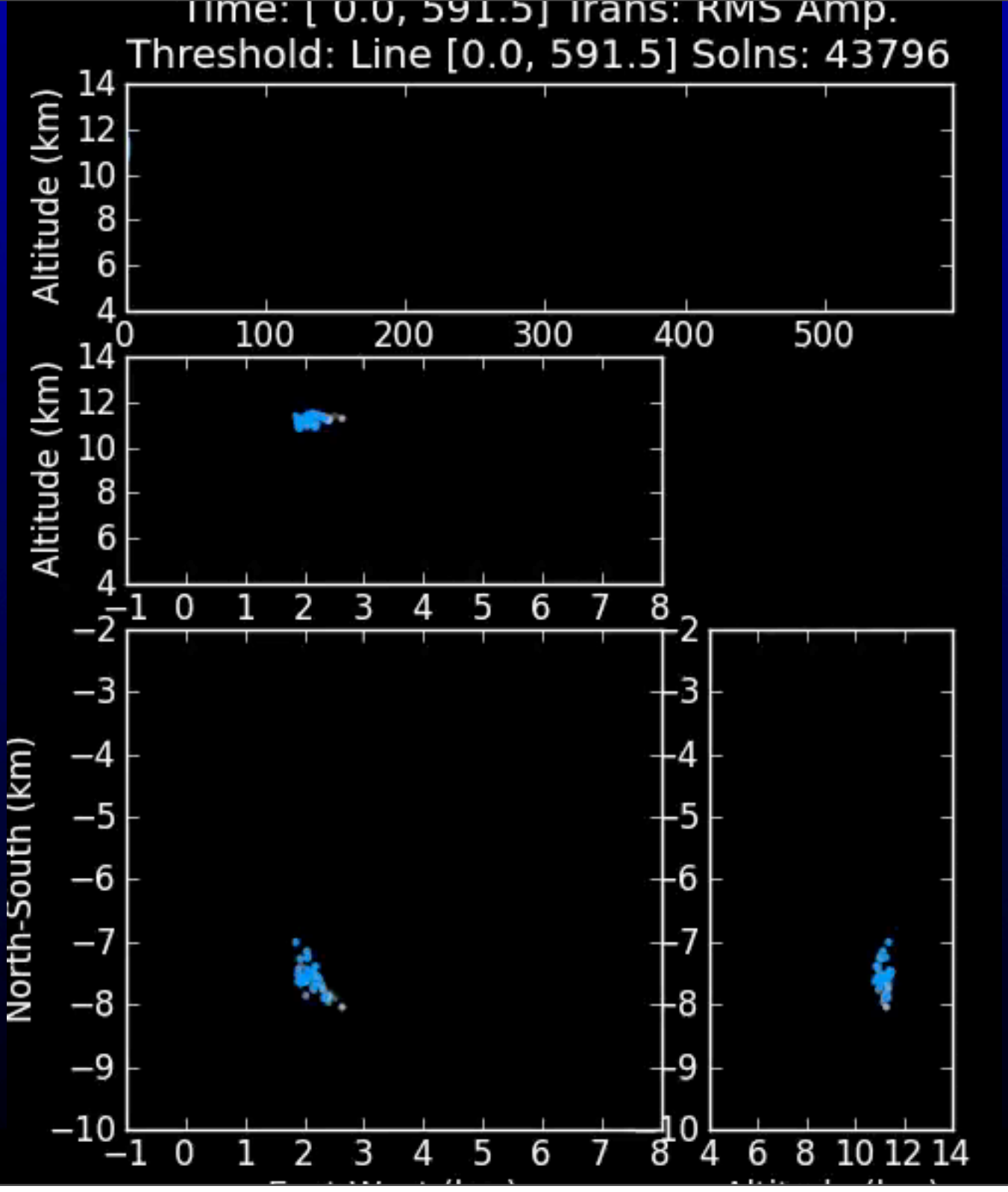
Continuously recorded broadband interferometer observations of bi-level IC flash

LMA observations (3D; 10 µs sampled)



Intf observations (2D Az, El; 1 µs continous)




Time: [0.0, 591.5] Trans: RMS Amp.
Threshold: Line [0.0, 591.5] Solns: 43796
Altitude (km)
Altitude (km)
North-South (km)

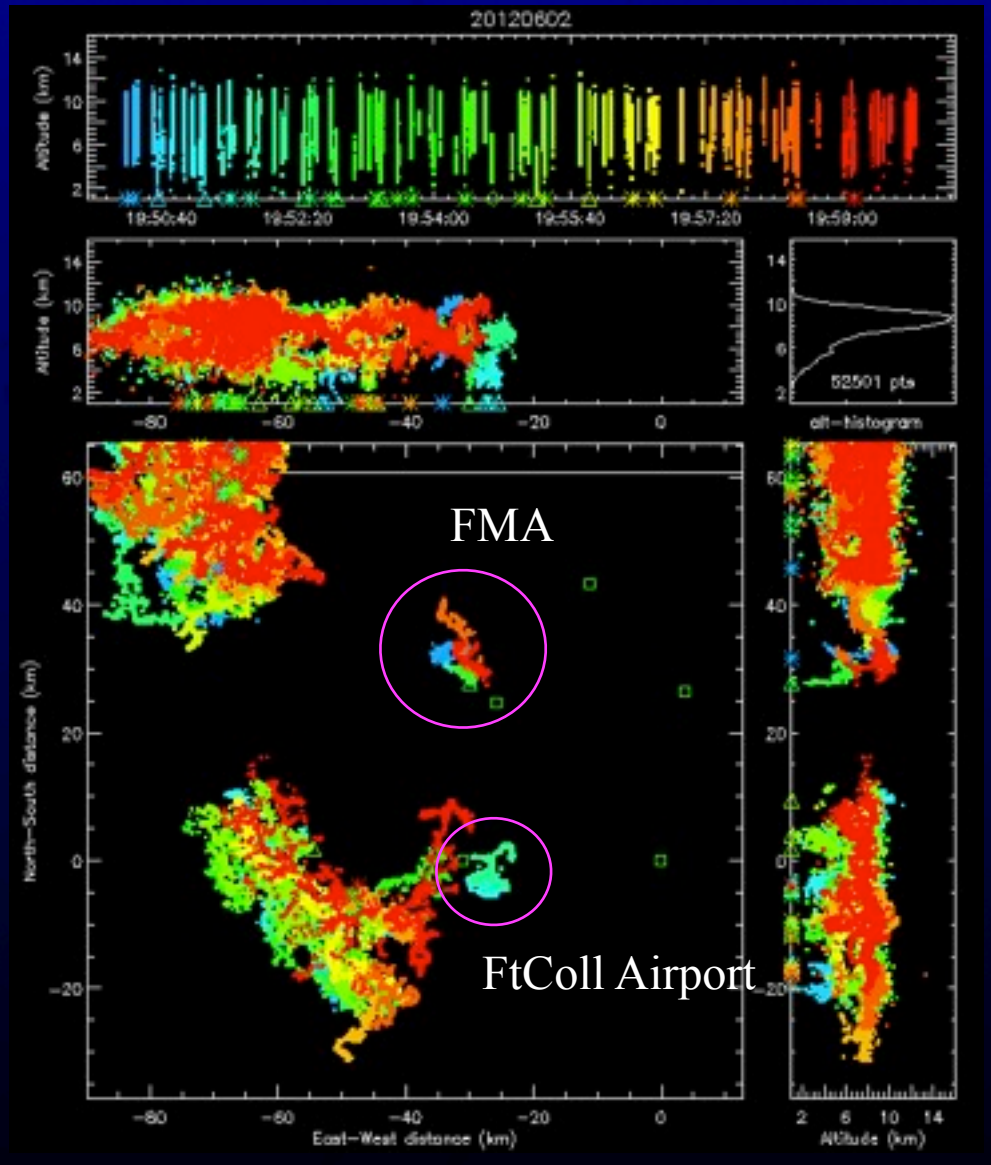
Electrical Charge Structure of DC3 Storms

- 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

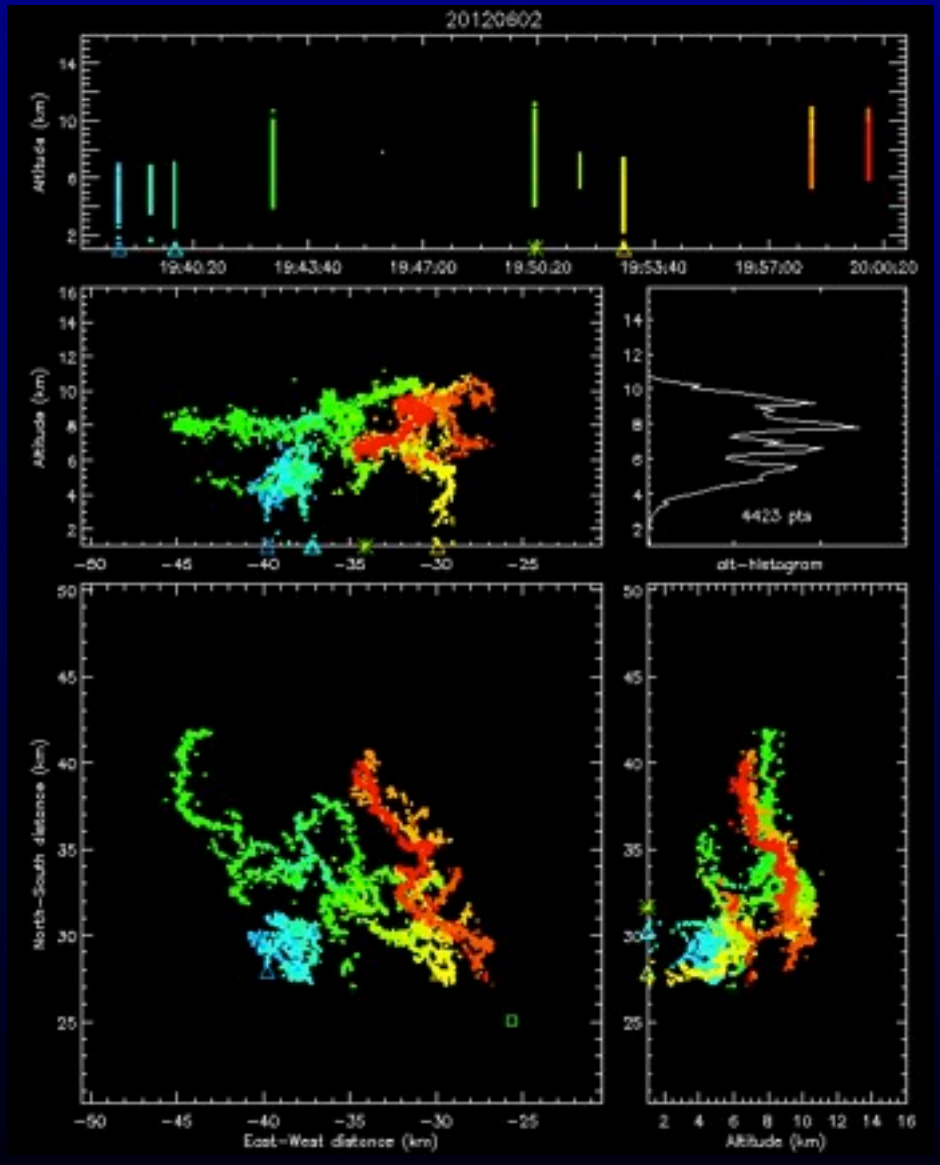
Example of normally electrified small storms, DC3, June 2, 2012

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

1950-2000 UTC overview



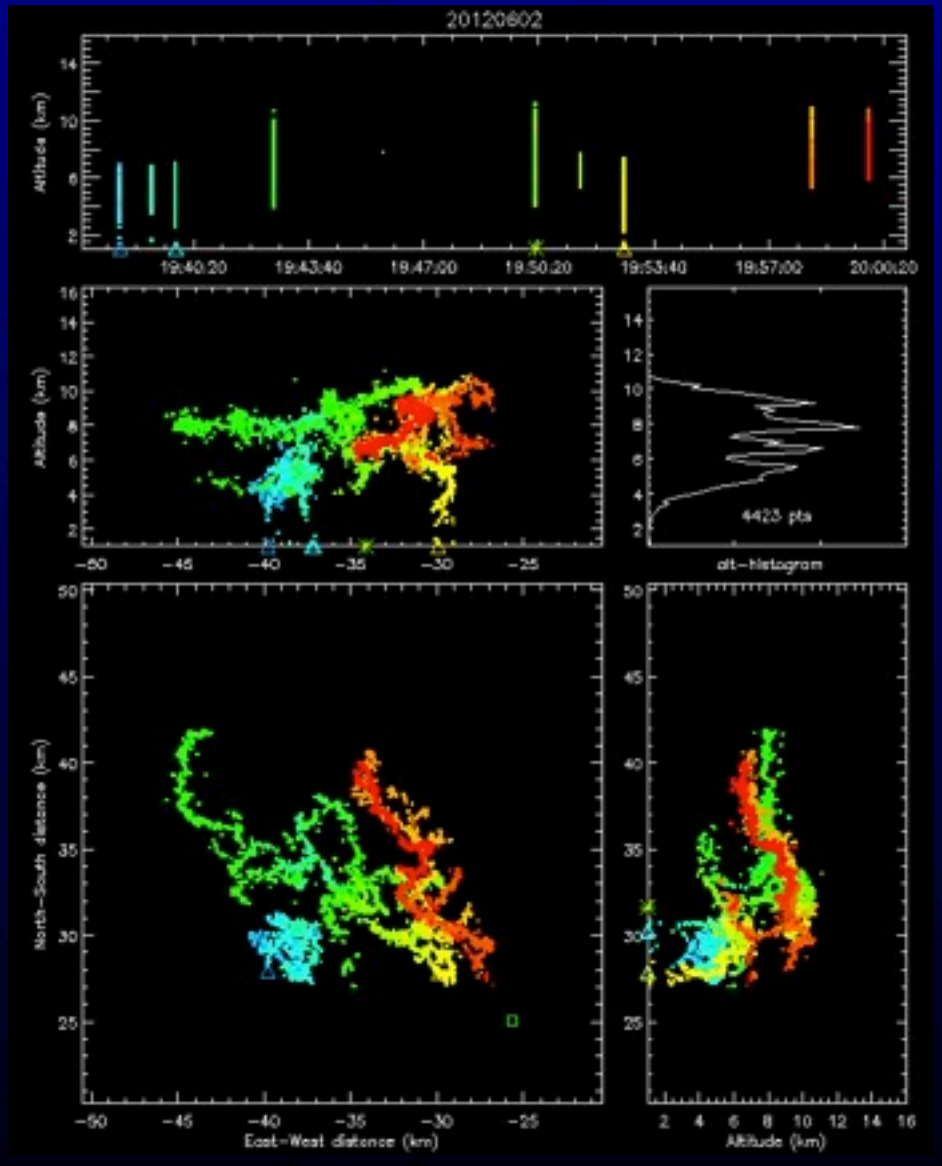
Initial lightning sequence, FMA storm



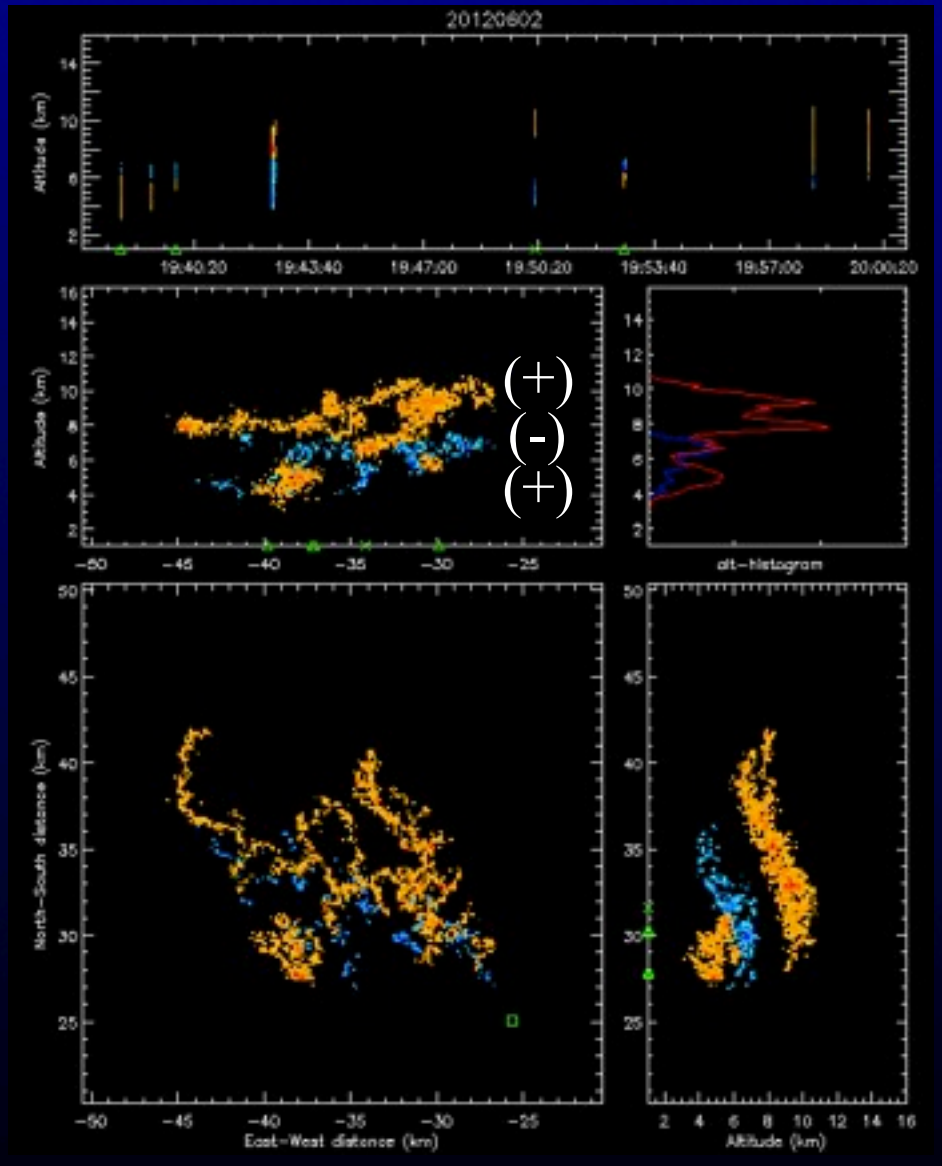
Electric charge structure, FMA storm

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

9 flashes during initial 20 minutes



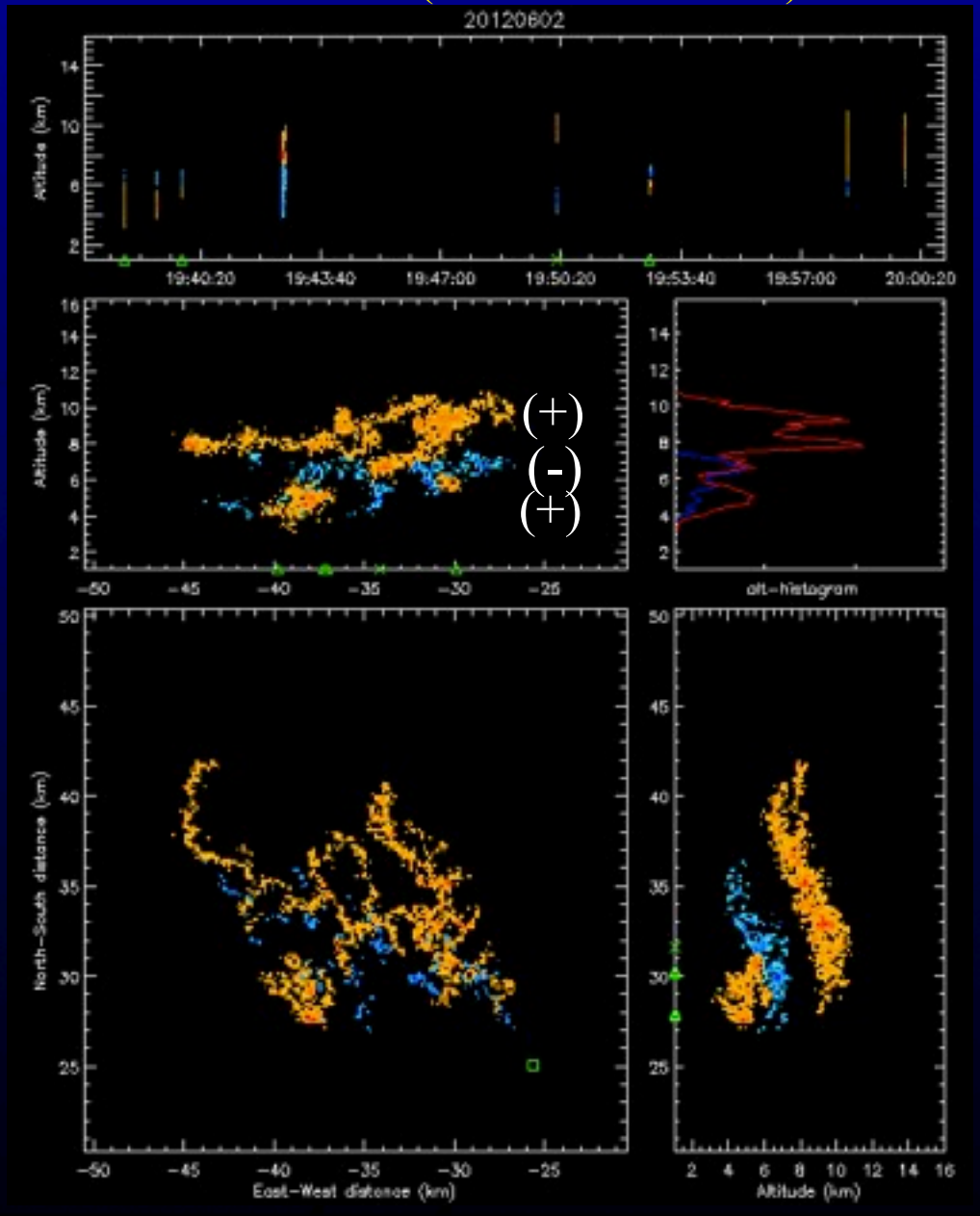
Lightning-inferred storm charge regions



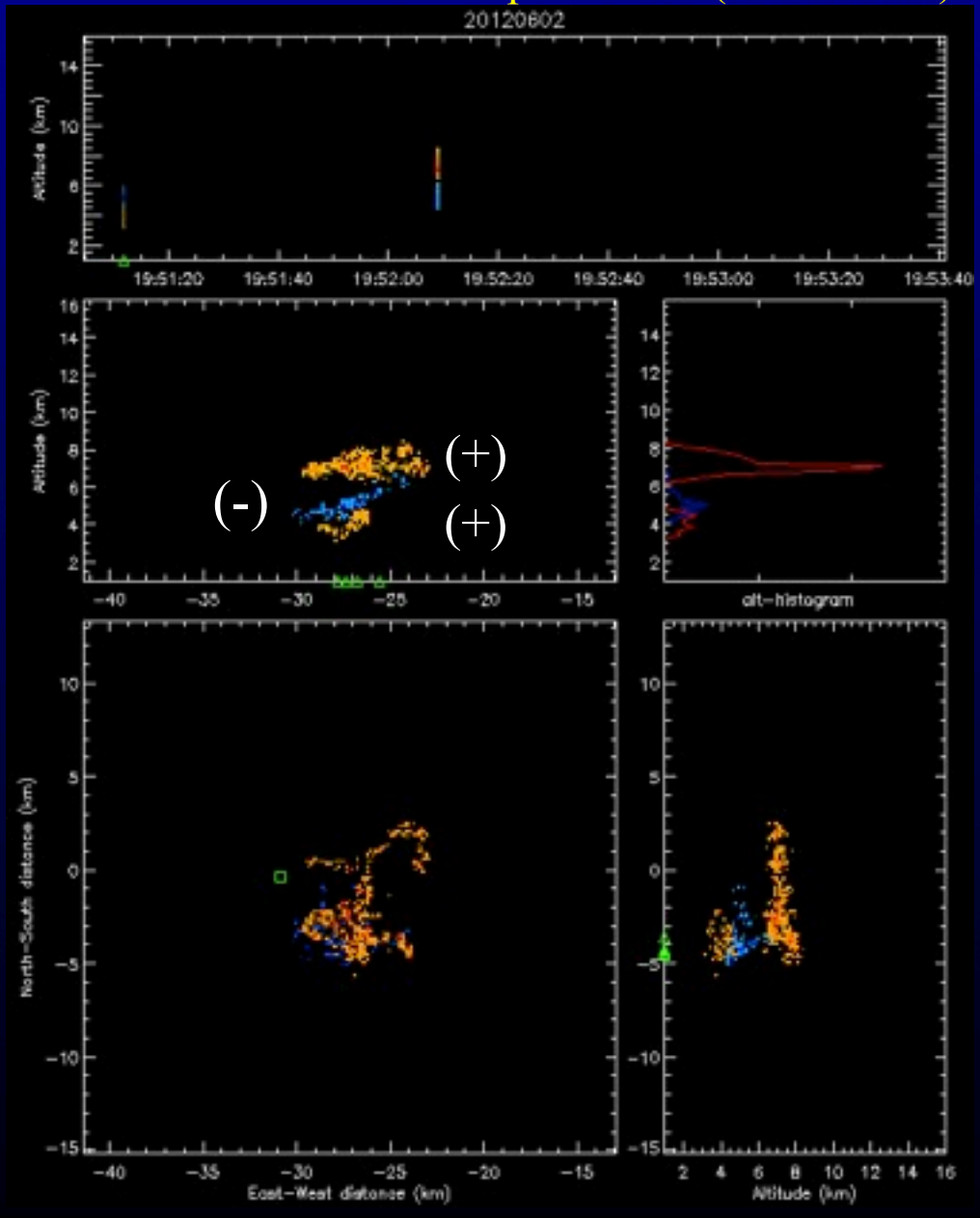
Comparative charge structure - Initial lightning sequences

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

FMA storm (9 flashes in 20 min)

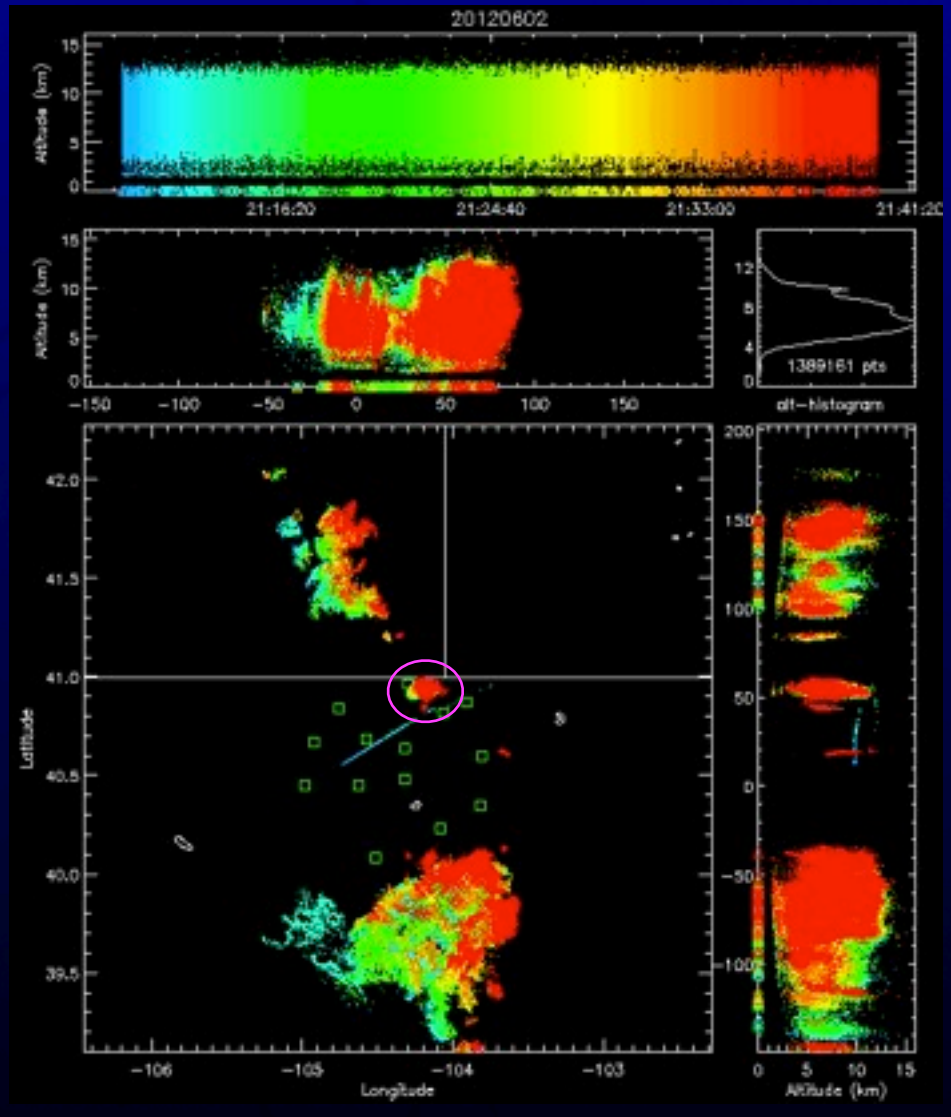


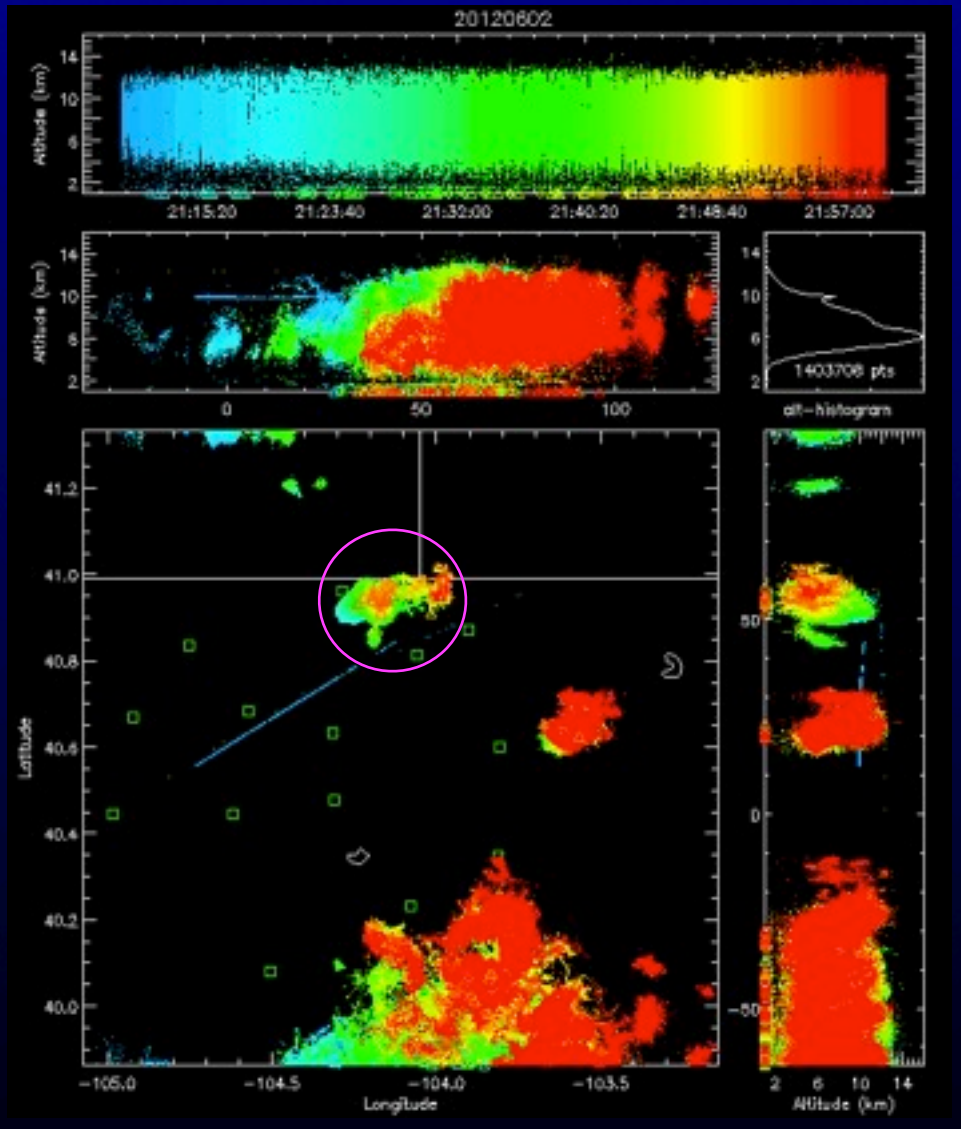
Ft. Collins/Loveland Airport storm (2 in 10 min)



Hereford storm, June 2, 2012

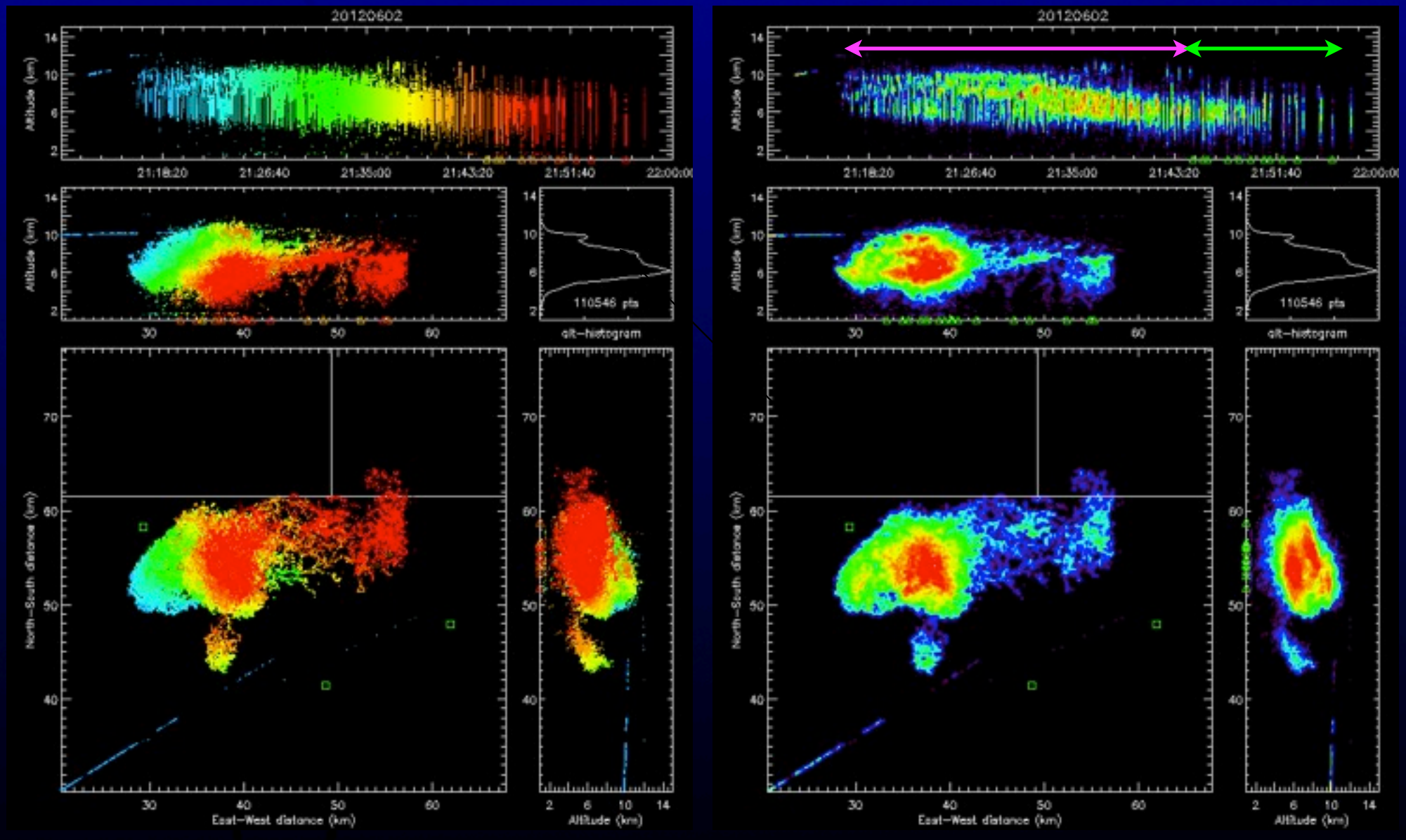
1.5 hours later, ~50 km northeast of the FMA and Ft. Collins storms, along the Wyoming border





Hereford storm, June 2, 2012

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

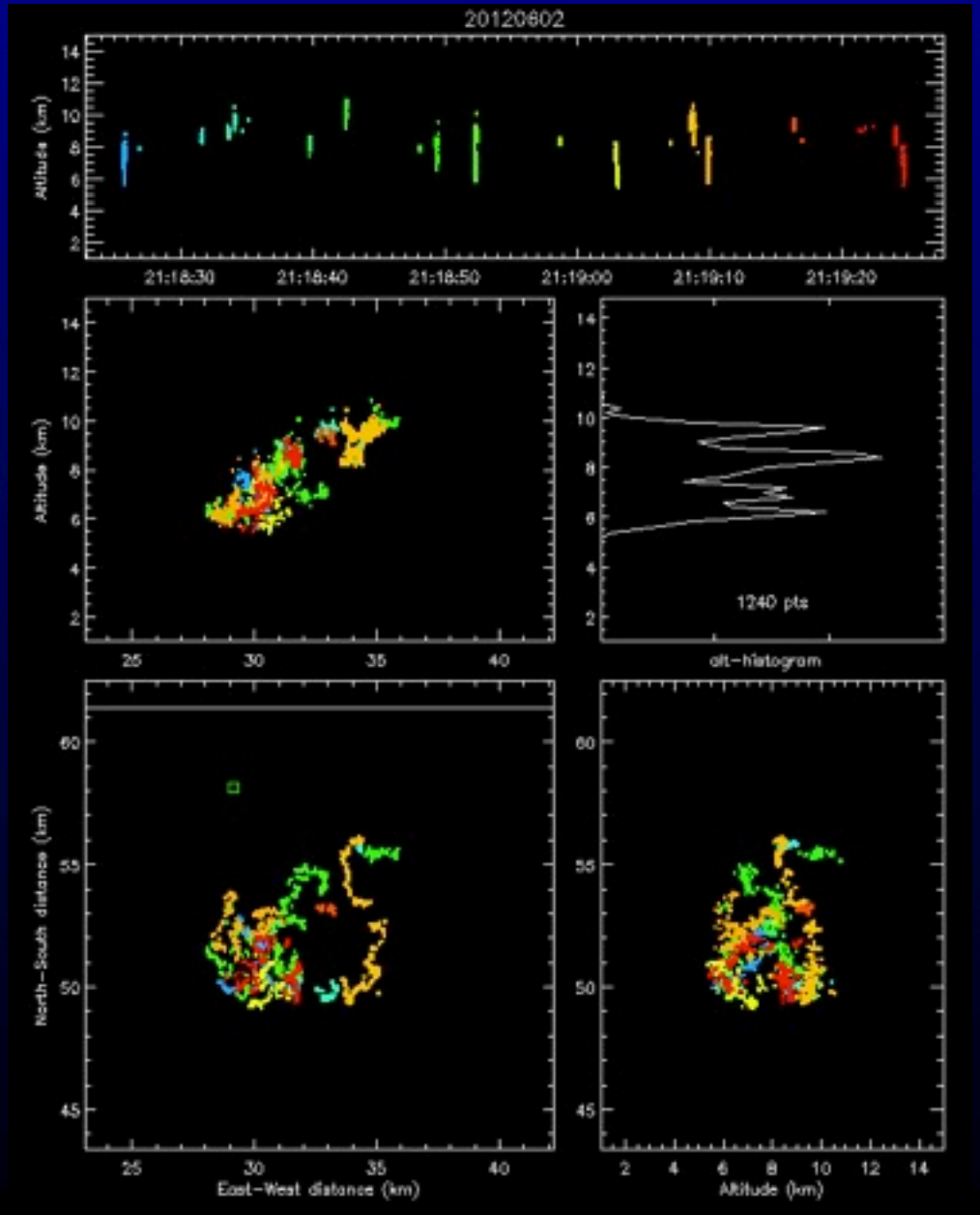


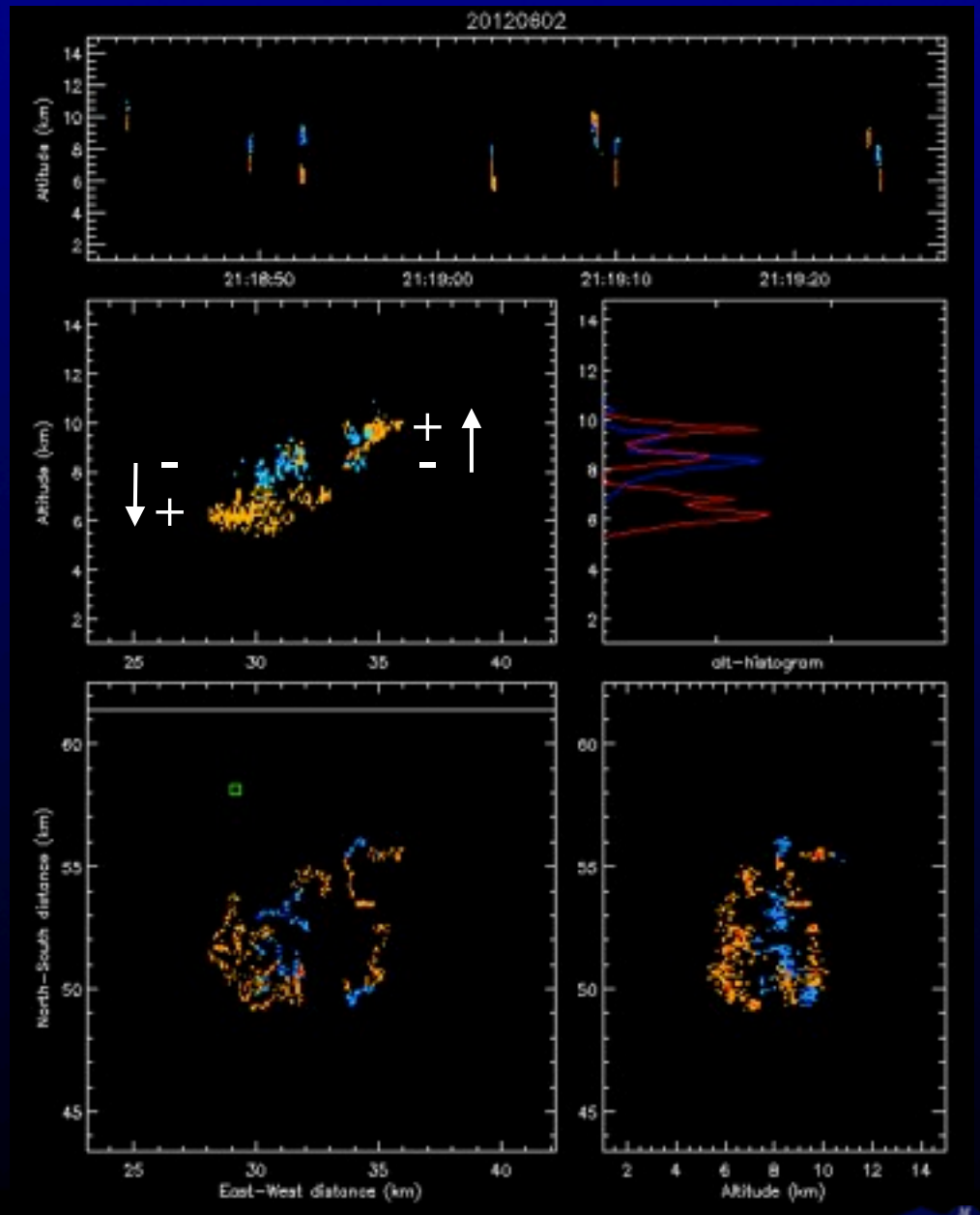
Initial lightning activity, Hereford storm

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

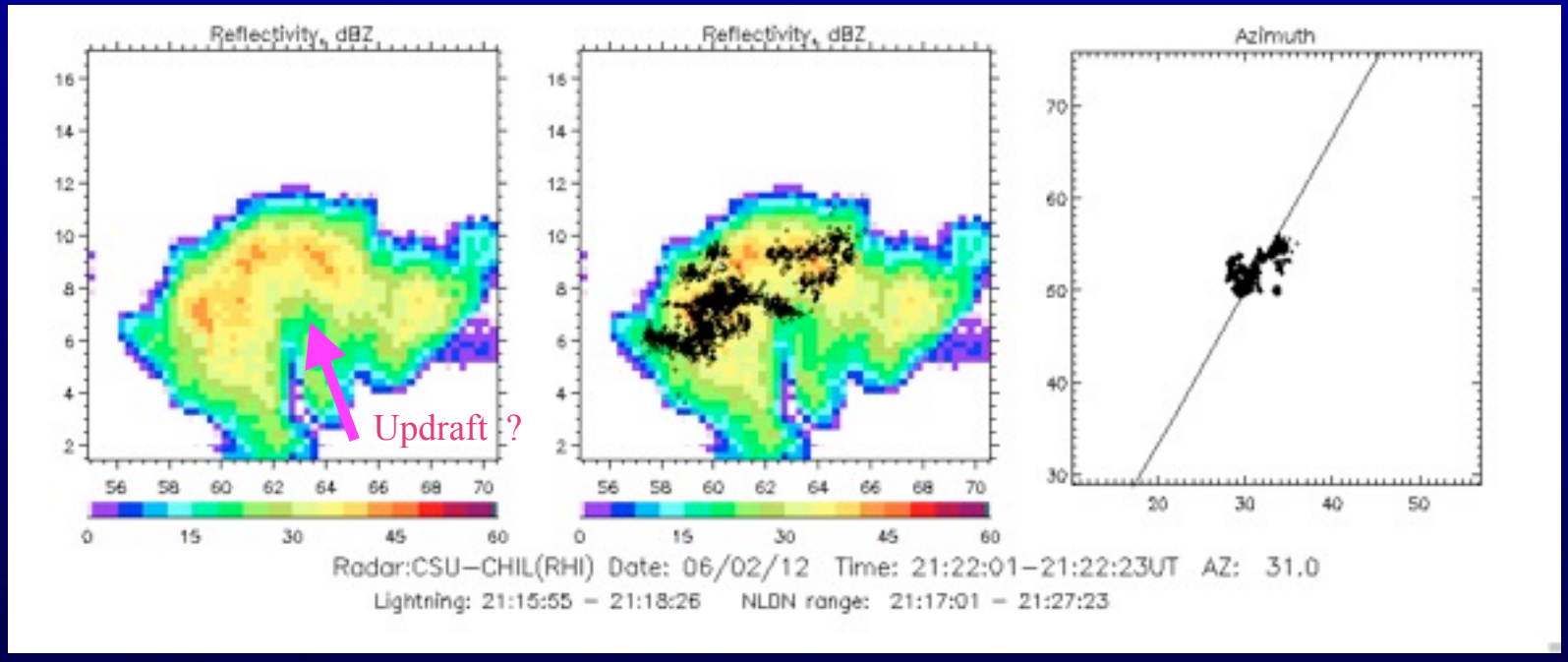




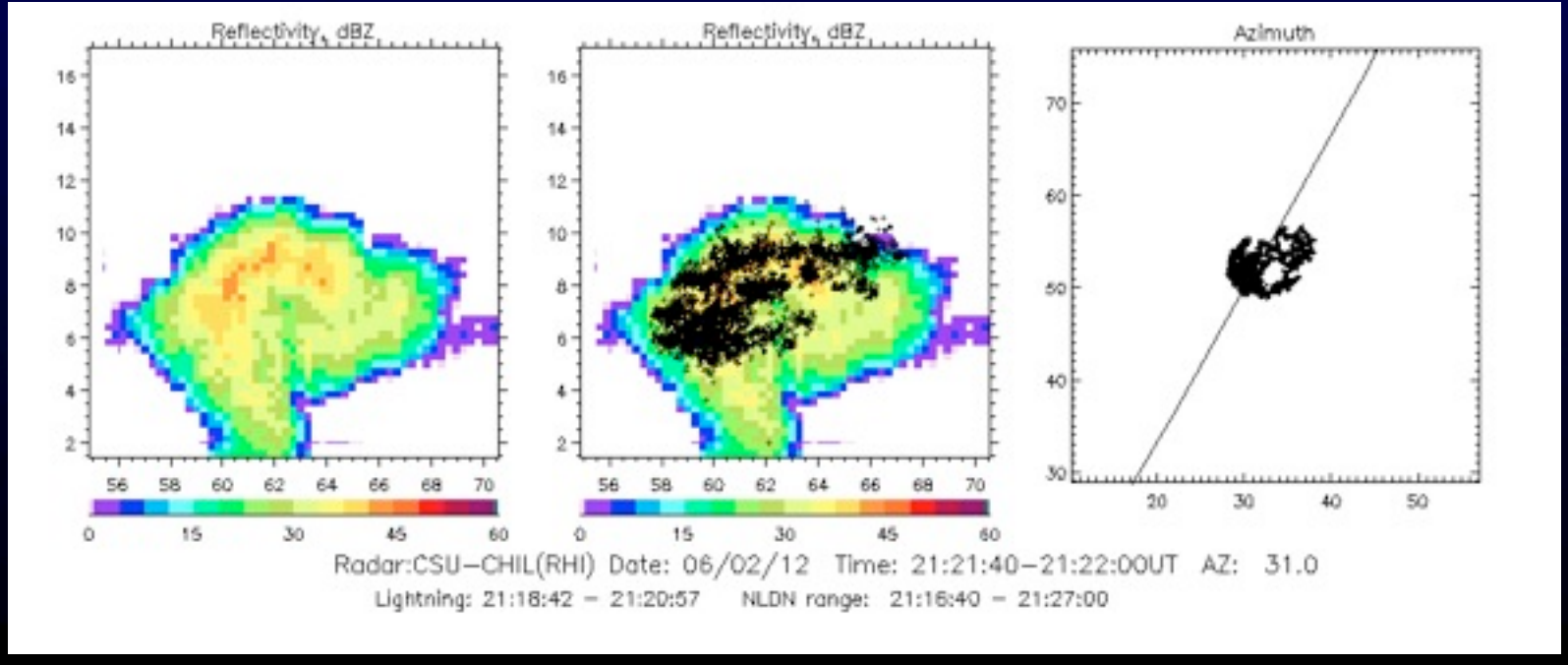
Comparison of lightning with CHILL vertical radar scans

Multiple dipolar charge regions correlated with overhanging reflectivity structure

2.5 min of first lightning

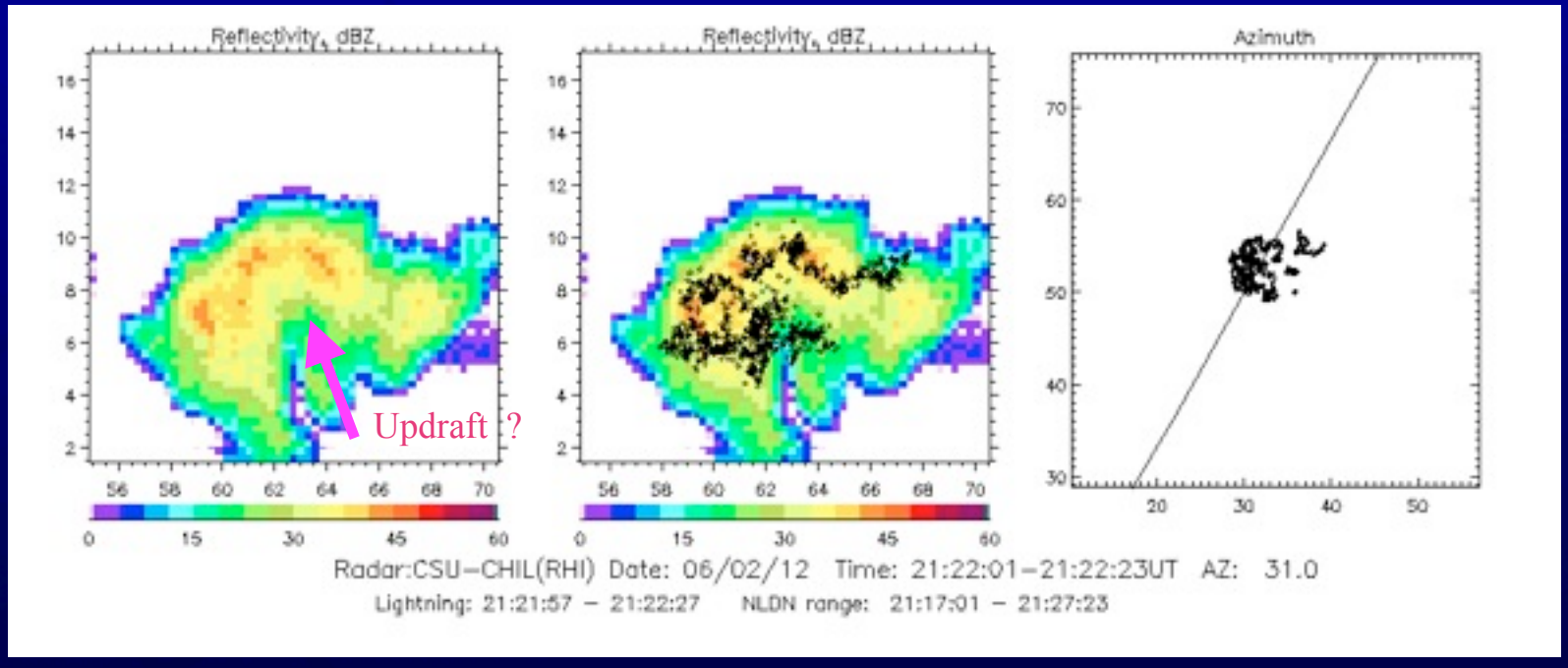


Next 2 min of activity

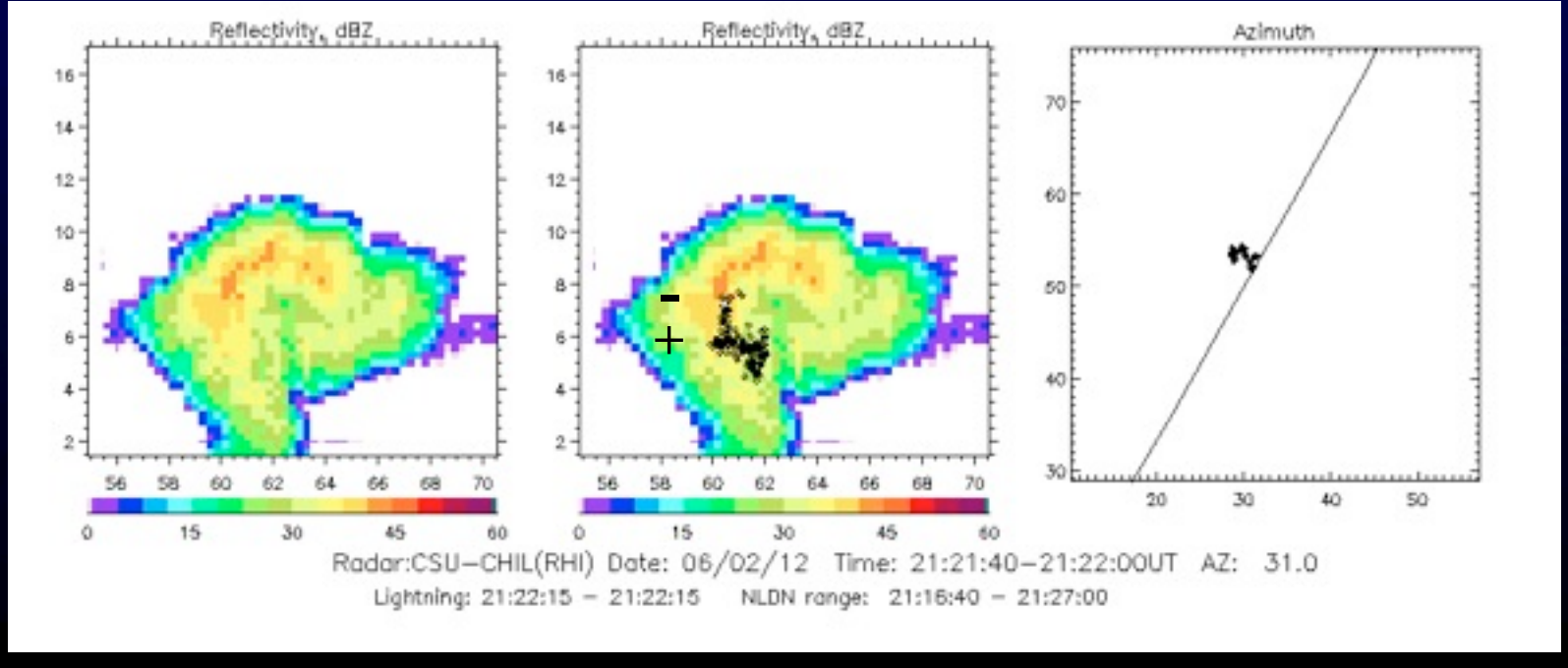


30 seconds of lightning activity, June 2 Hereford storm
(6 minutes into storm; coincident with vertical radar scan)

30 seconds of activity

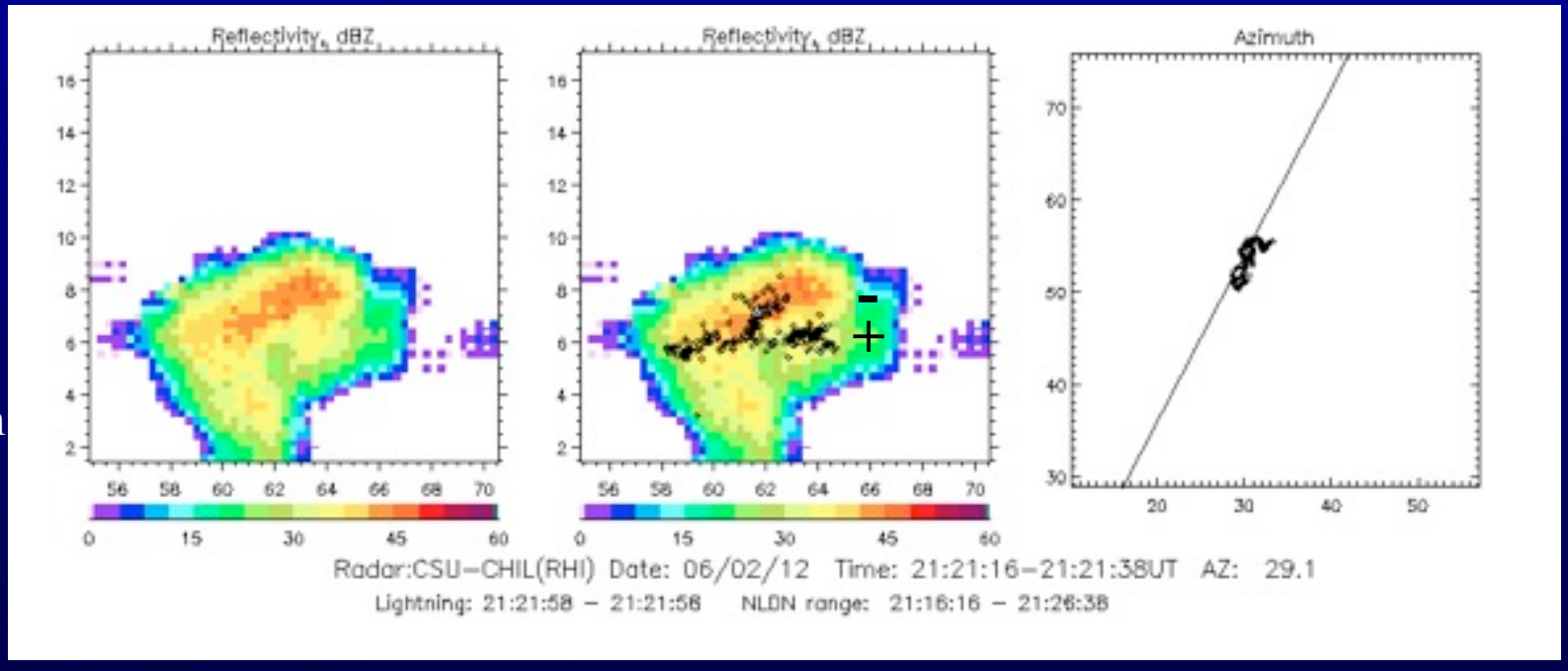


Individual flash

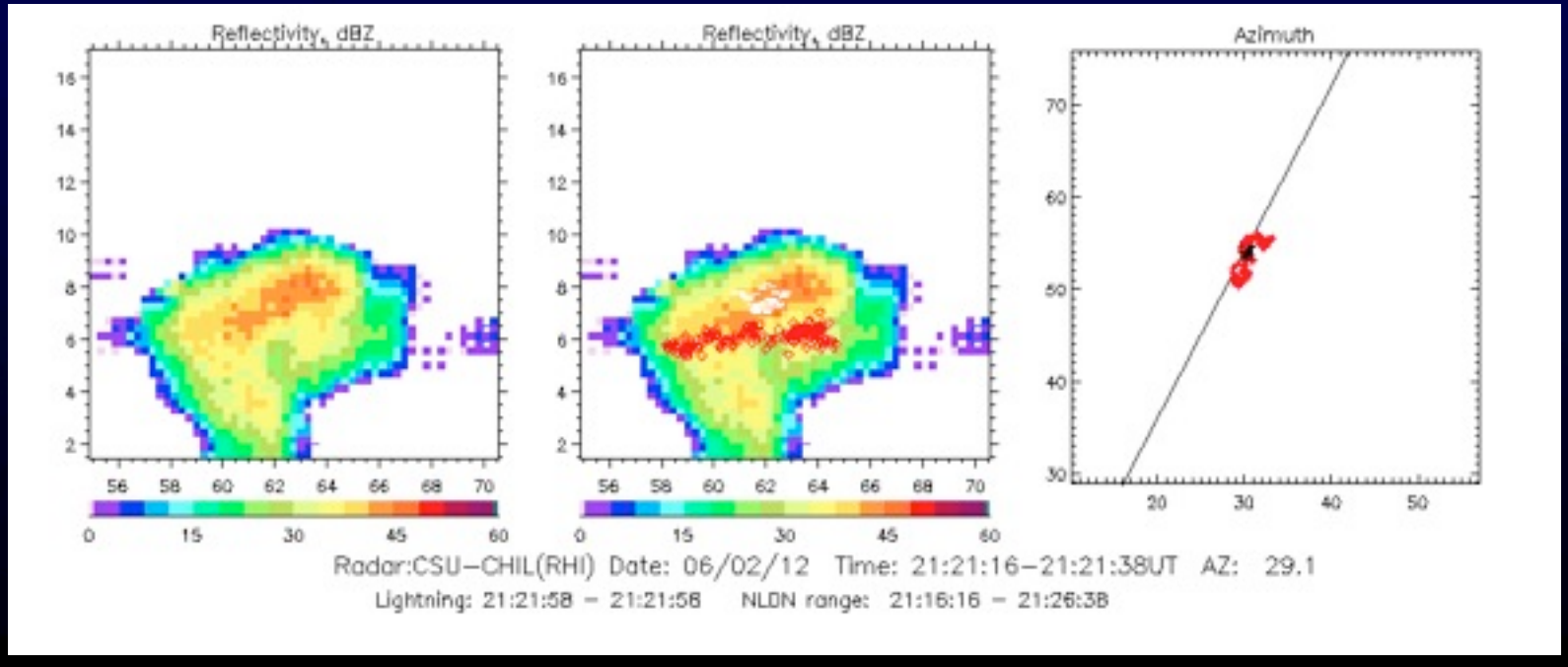


Bilevel IC flash, June 2 Hereford storm
(6 minutes into storm; coincident with vertical radar scan)

Lower dipole of normal electrification

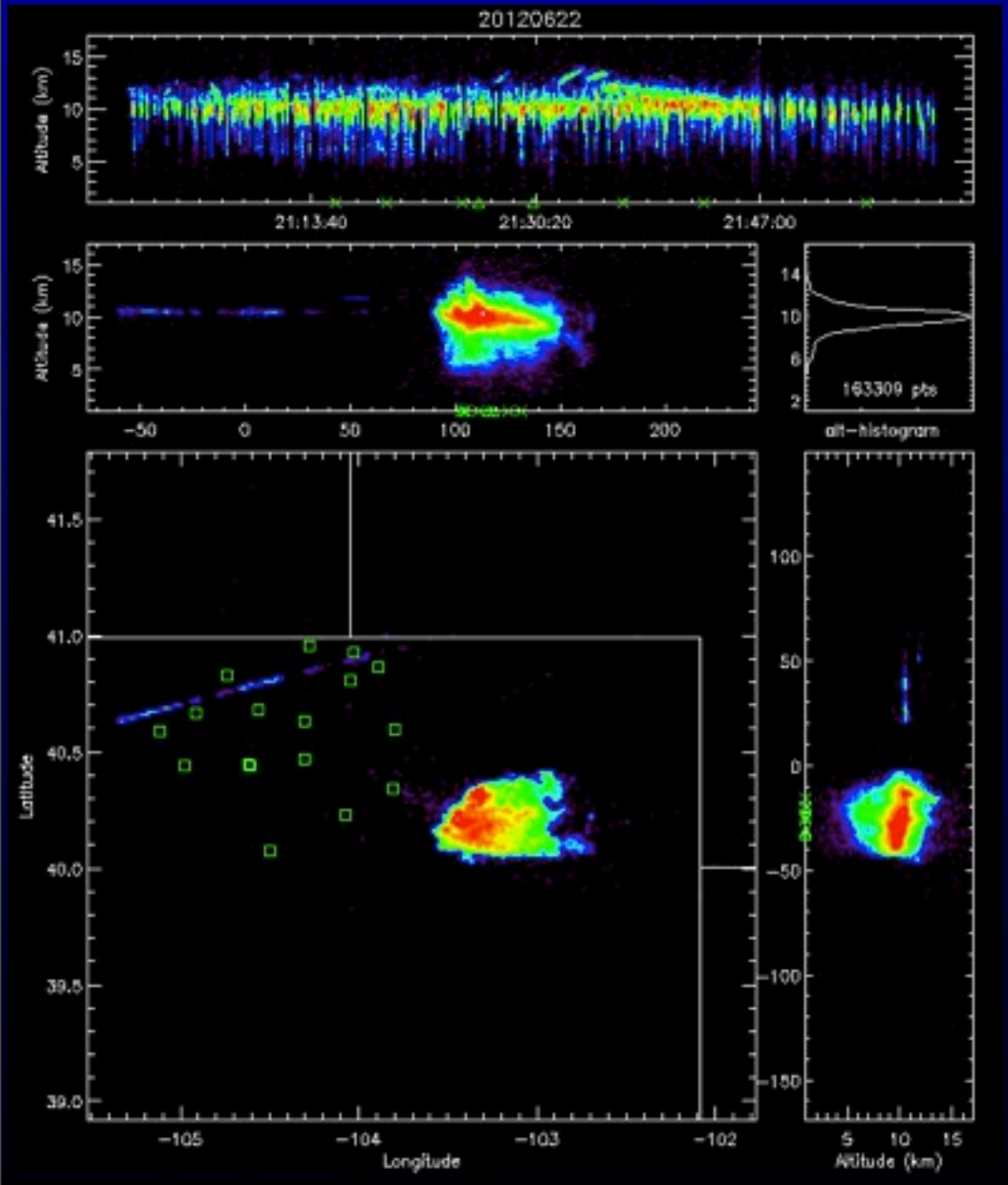


Charge structure

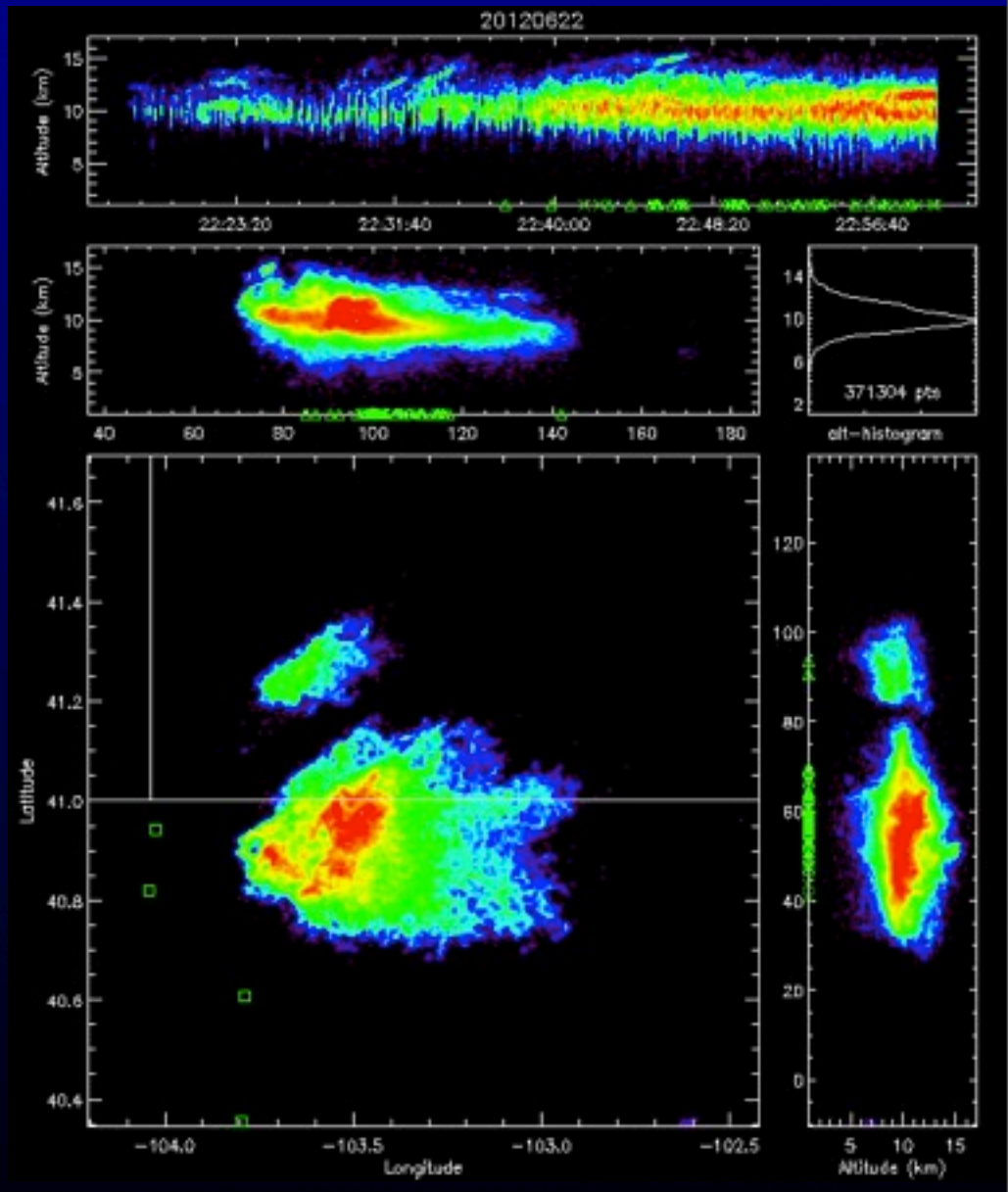


June 22 2012 storms (targeted by G-V and DC8)

First storm, 2100-2200 UTC

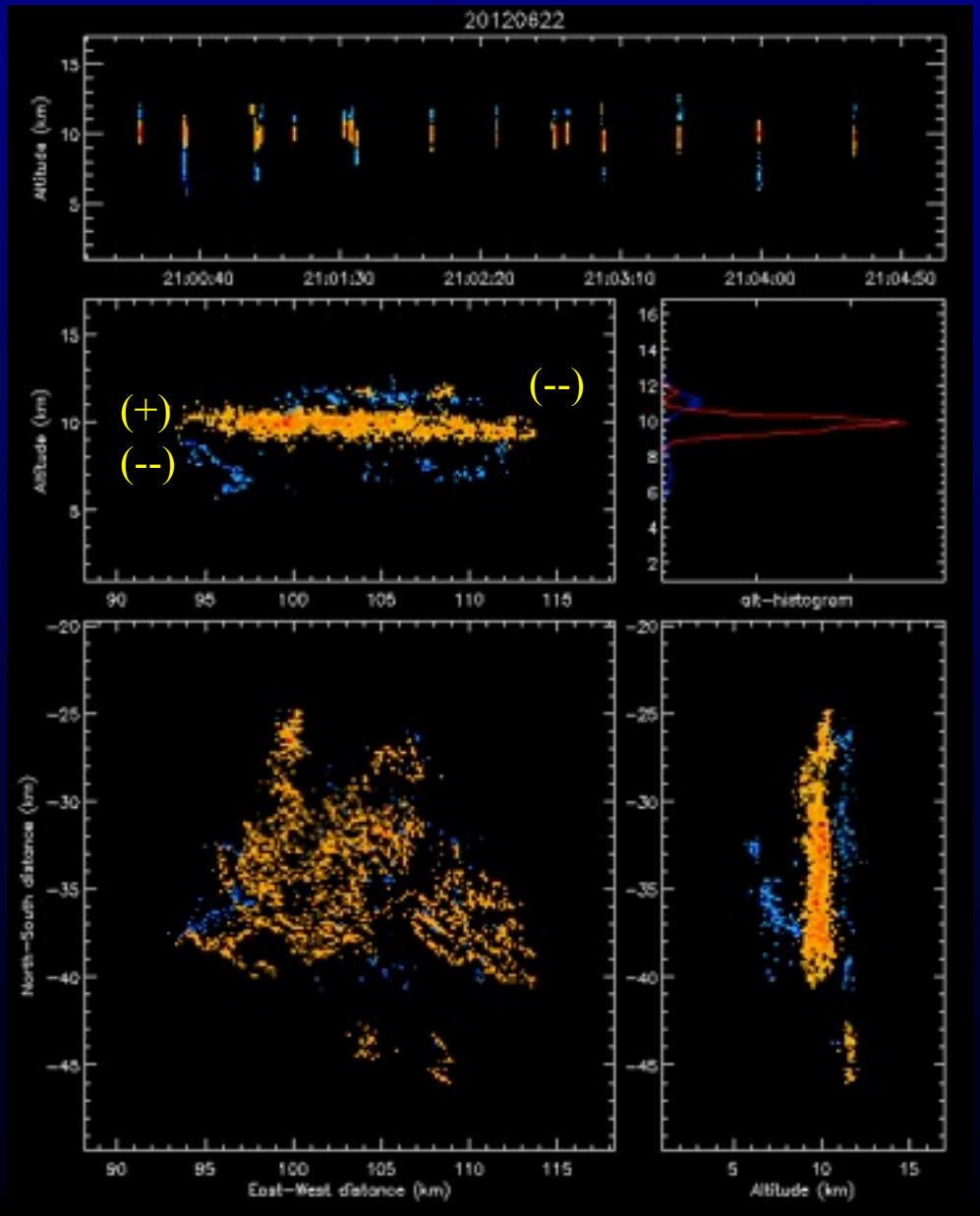


Second storm, 2215-2300 UTC

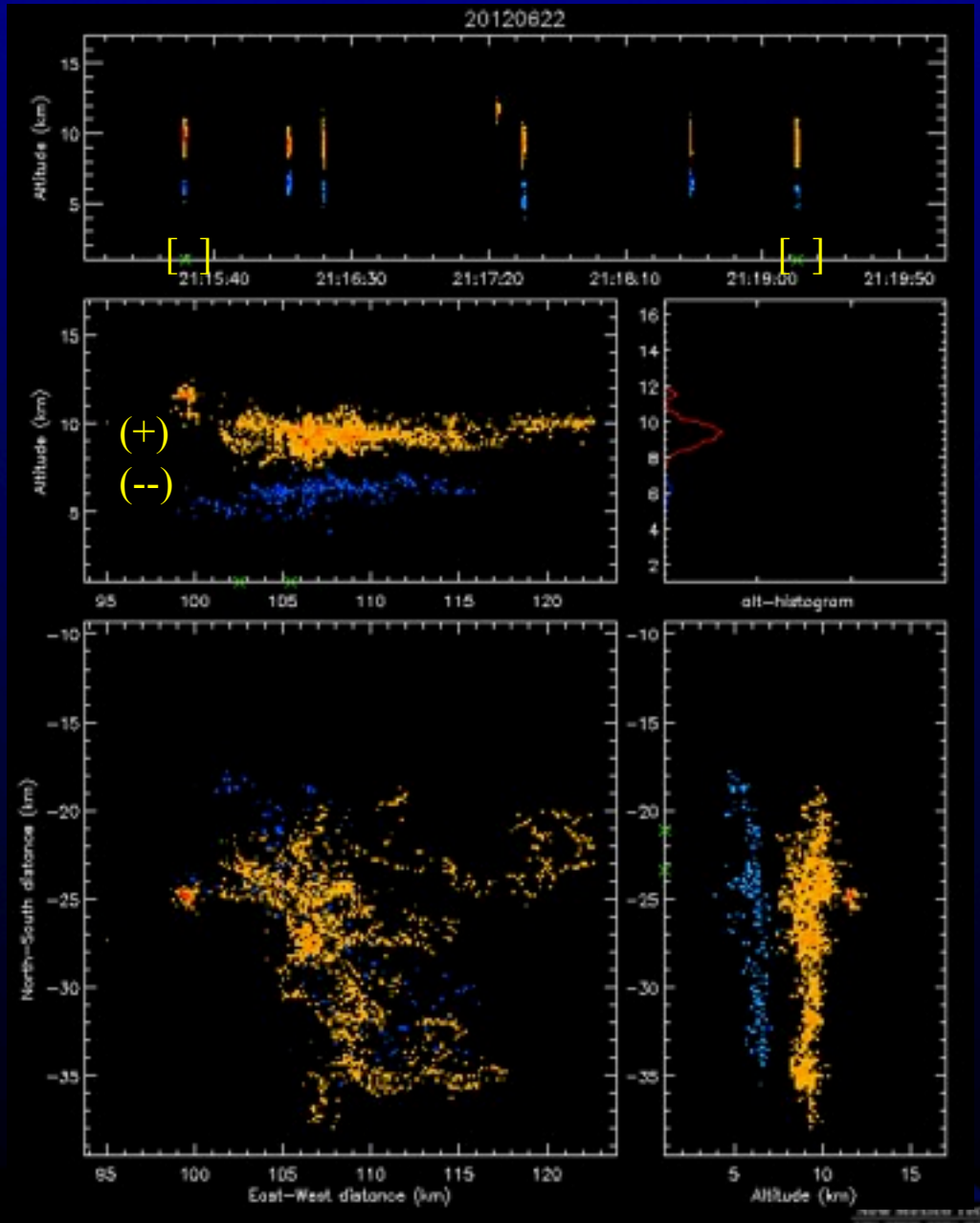


June 22 2012 First Storm: Charge Density Results

2100-2105 UTC (Initial activity)
ICs into upper (+) charge from above and below

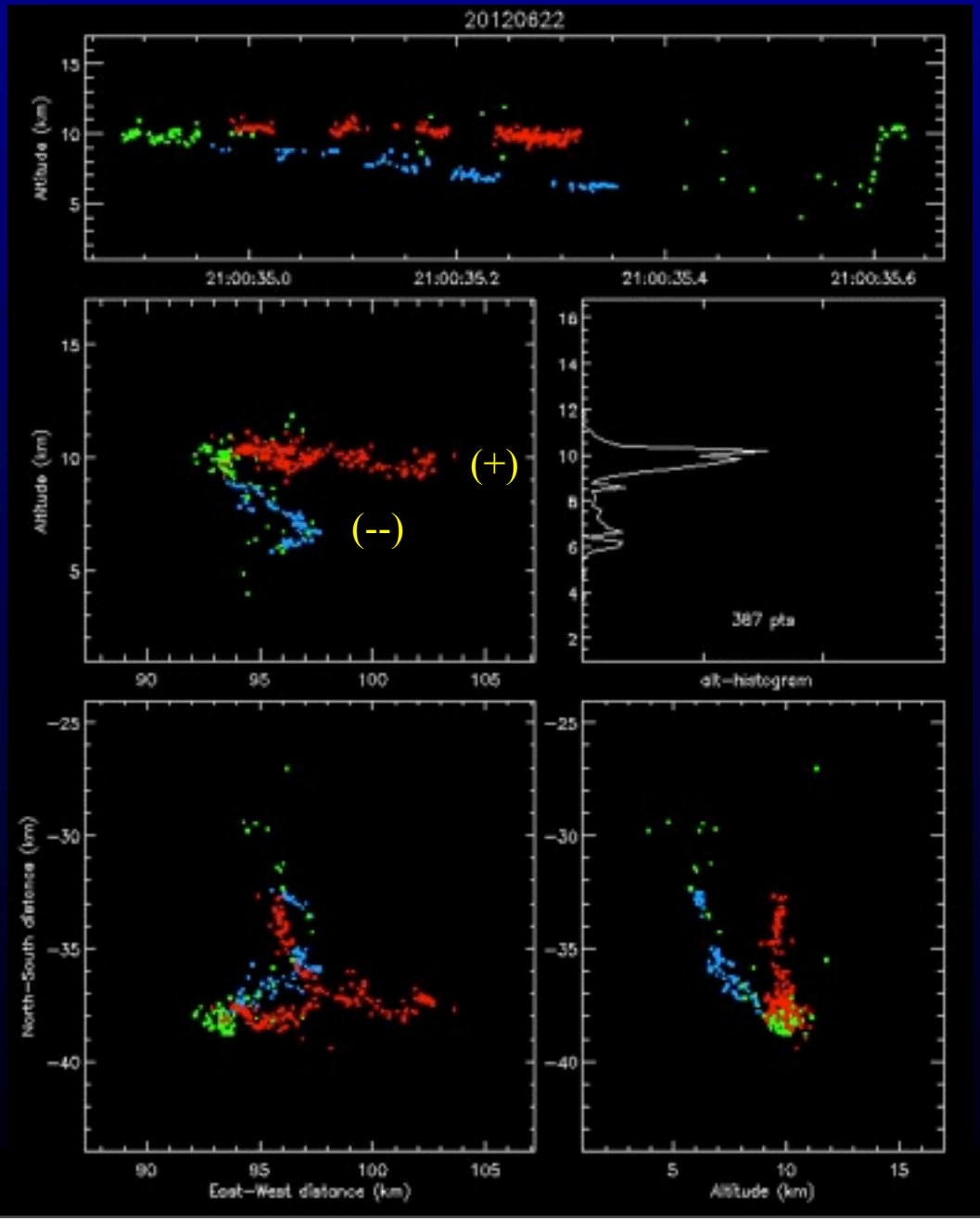


2115-2120 UTC (later)
(normal ICs and +CGs!)

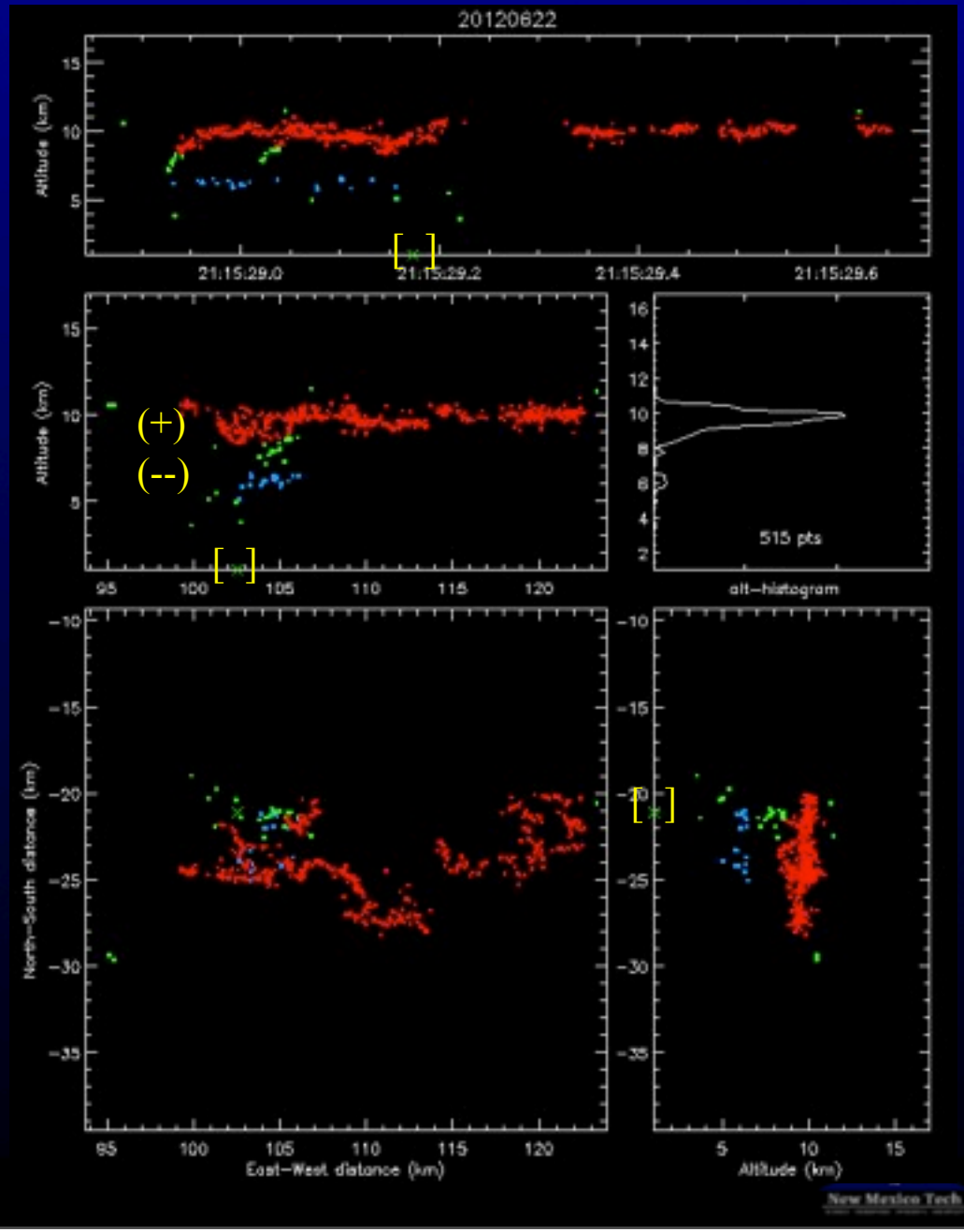


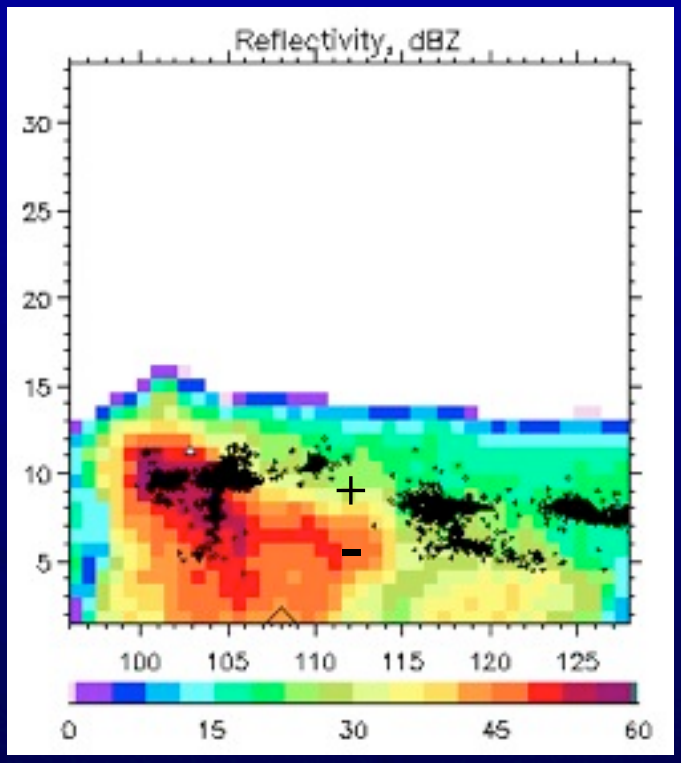
June 22 2012 First Storm: Early and later flash examples

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

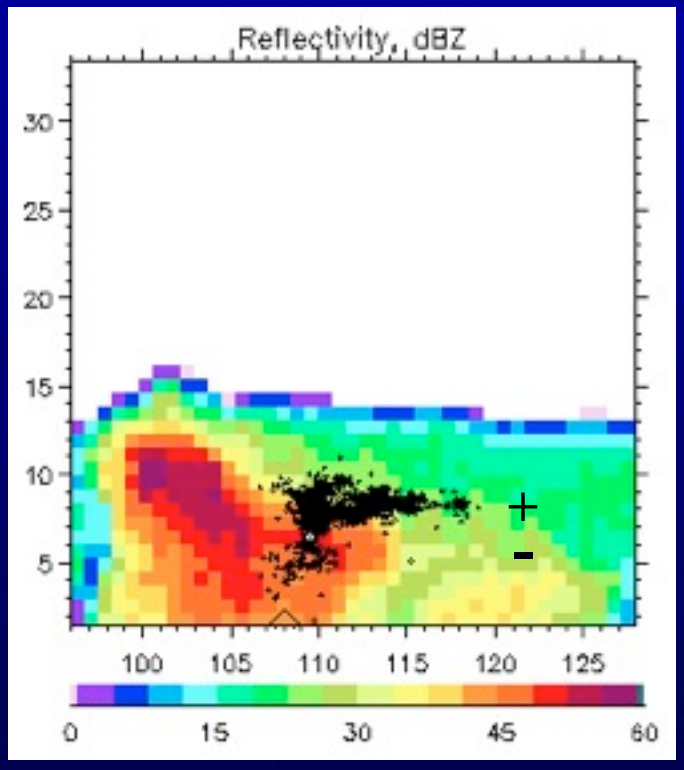


21:15:29 UTC
Upward IC (normal polarity) & 39 kA +CG!!

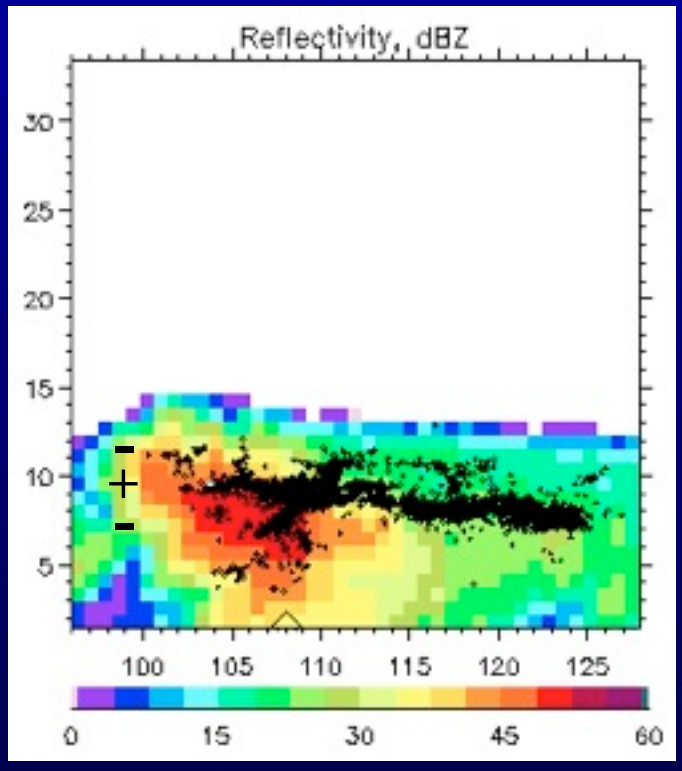




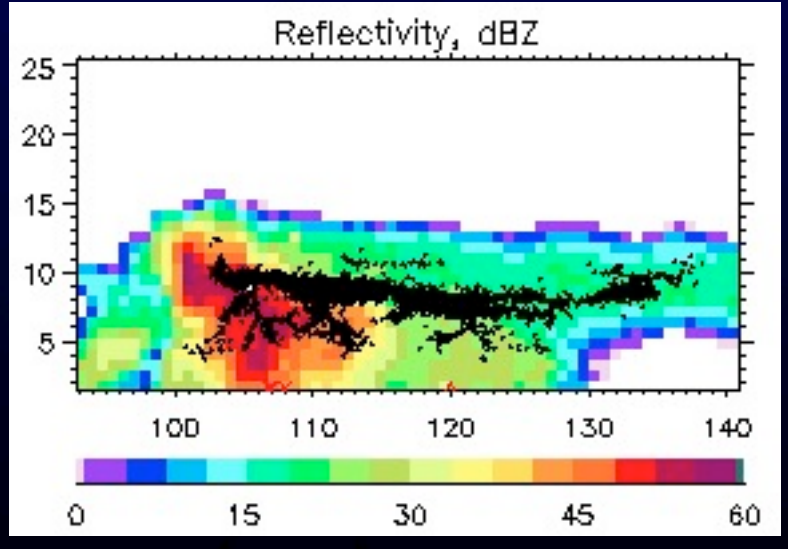
21:18:48 to 21:19:10
22 seconds of activity before +CG



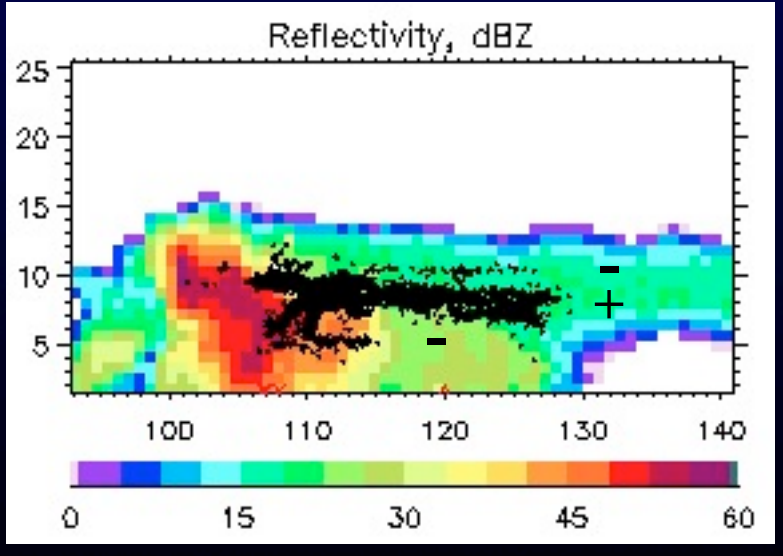
53.5 kA +CG at 21:19:12



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

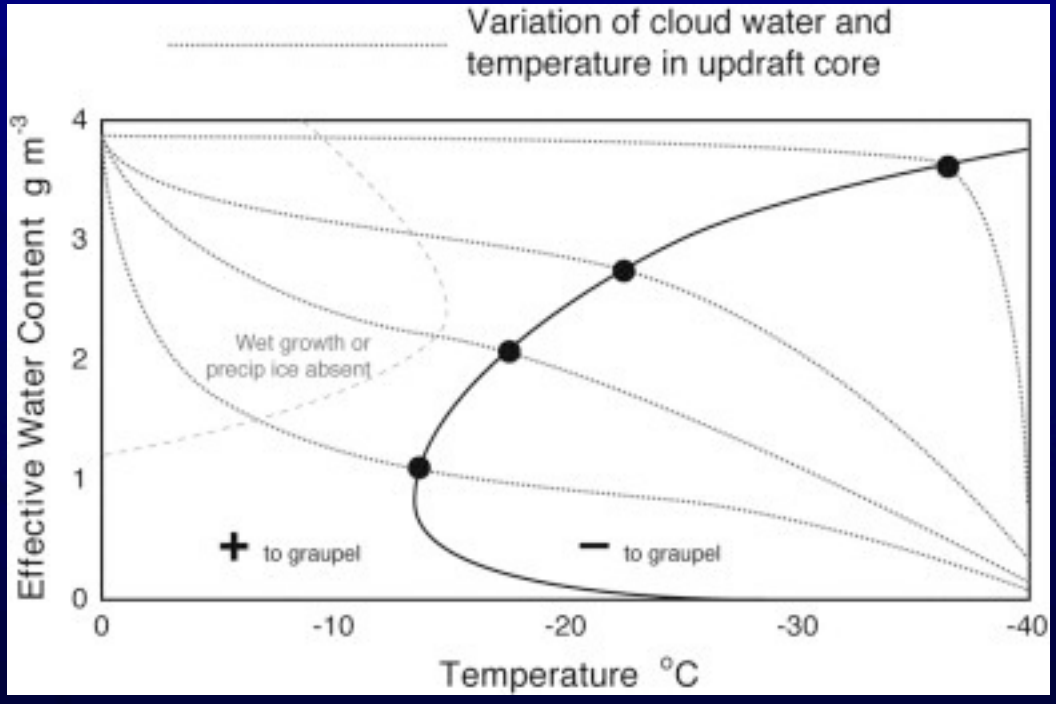


Fig. 3 Idealized variation of effective riming rate (a proxy for cloud water content) with temperature in storm's updraft trajectory as non-precipitating cloud water is depleted by precipitation growth processes (dotted line).

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

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