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Lightning Flash Length Estimation from Lightning Mapping Array Measurements

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Abstract

Lightning consists of bidirectional channels beginning at the initiation point and branching many times. One measure to compare two lightning flashes in the length of the channels. An effect of a storm on the atmospheric chemistry is chemical production in lightning channels. This effect should depend on the total channel lengths at different altitudes. Source locations from the Lightning Mapping Array (LMA) gives a picture of the channel development and branching. To get a channel length from the source locations, the sources need to be joined into the channels. There is not enough information to do this in a unique manner so any channels are an approximation. We have developed an algorithm to join the sources and are refining it. Not all the sources are detected and located so the length estimate will be an underestimate. The channel length from joining the sources seems to be sensitive to array sensitivity and noise. In an effort to estimate the channel length in a more robust manner we have a developed a method similar to flash extent density. It is based on the number of cells in a x-y projection of the lightning that are occupied by at least one detected source. A good length estimate is the number of cells times the length of a side of the cell. This estimate depends on cell size and a good cell size maximizes the estimate.

All flashes are from the Colorado LMA network set up for DC3

Joining LMA points into Branches

Joining points of a flash into branches is done in two different ways, with and without taking time into consideration. Negative leader breakdown into positive charge is usually in time order and works best when time order is maintained. When a channel is reused at a later time two branches retrace each other. Breakdown in negative charge is seen by the LMA as multiple recoil or re-ionizations. Branches joined without regard to time are much better in the negative charge region.

Length from Cell Count

$$L = N_c \, b_c$$

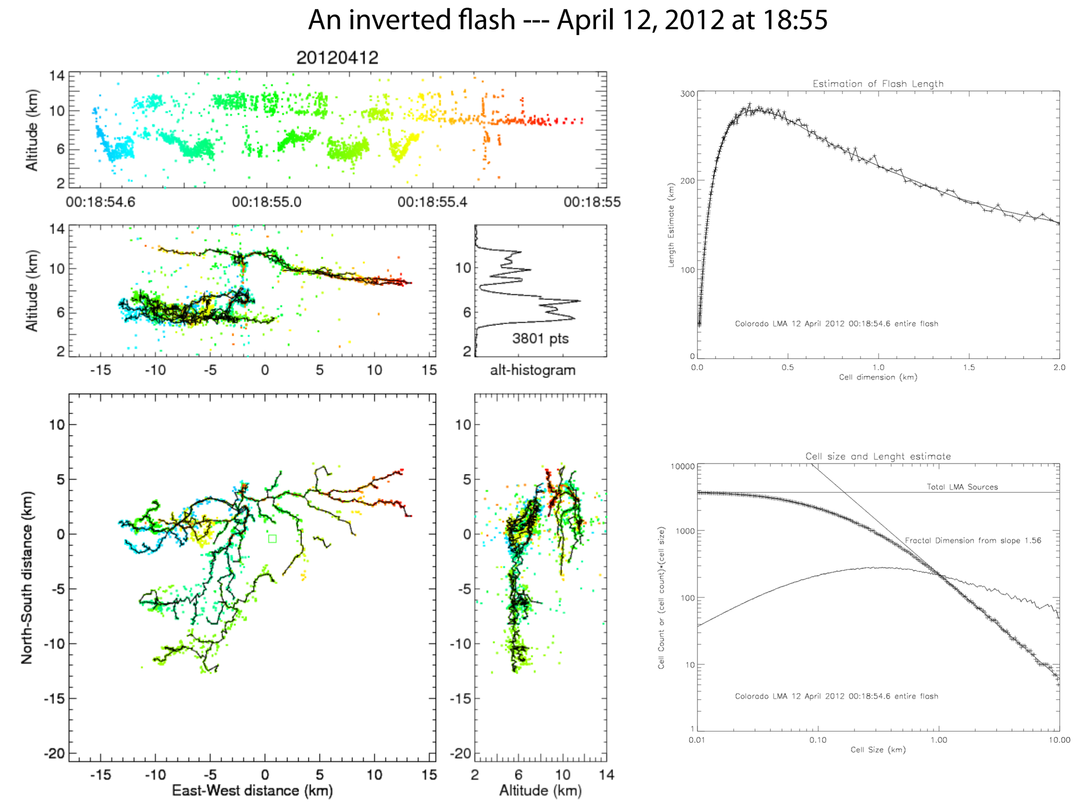
N_c is the cell count
b_c is the cell size

Fractal length estimate L is:

$$L = b_s \left(\frac{\sqrt{A_h}}{b_s} \right)^D$$

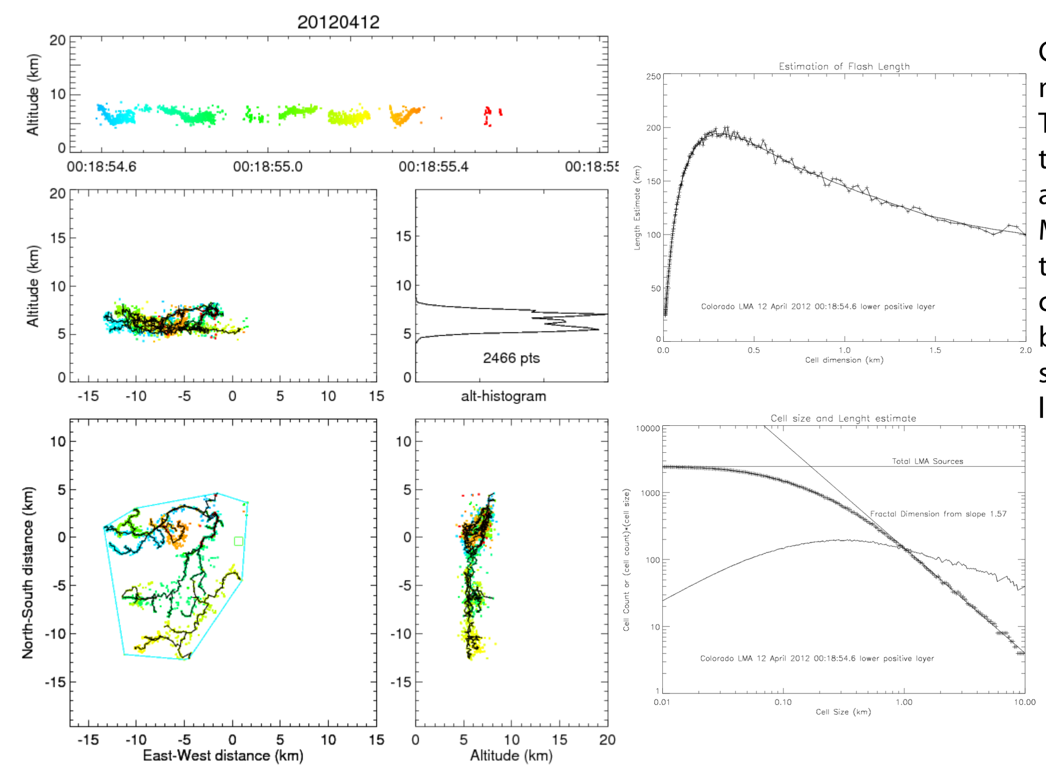
D is the fractal dimension
b_s is the stepping length
A_h is the flash area - convex hull

An inverted flash --- April 12, 2012 at 18:55



Length estimates for the entire flash 3 different ways, joining points, counting cells, and the fractal dimension. Joining the points into the main branches, twigs, and leaves gives 324 km of branches and 665 km total. Cell counting gives 281 km. Estimating the length from the measured fractal dimension 1.56 and hull area 322 km², and an assumed step length of 100 m gives 328 km. To the right upper and lower parts of the flash are considered separately. Summing the separate length estimates gives 324, 307, and 309 km (joining, cell count, and fractal)

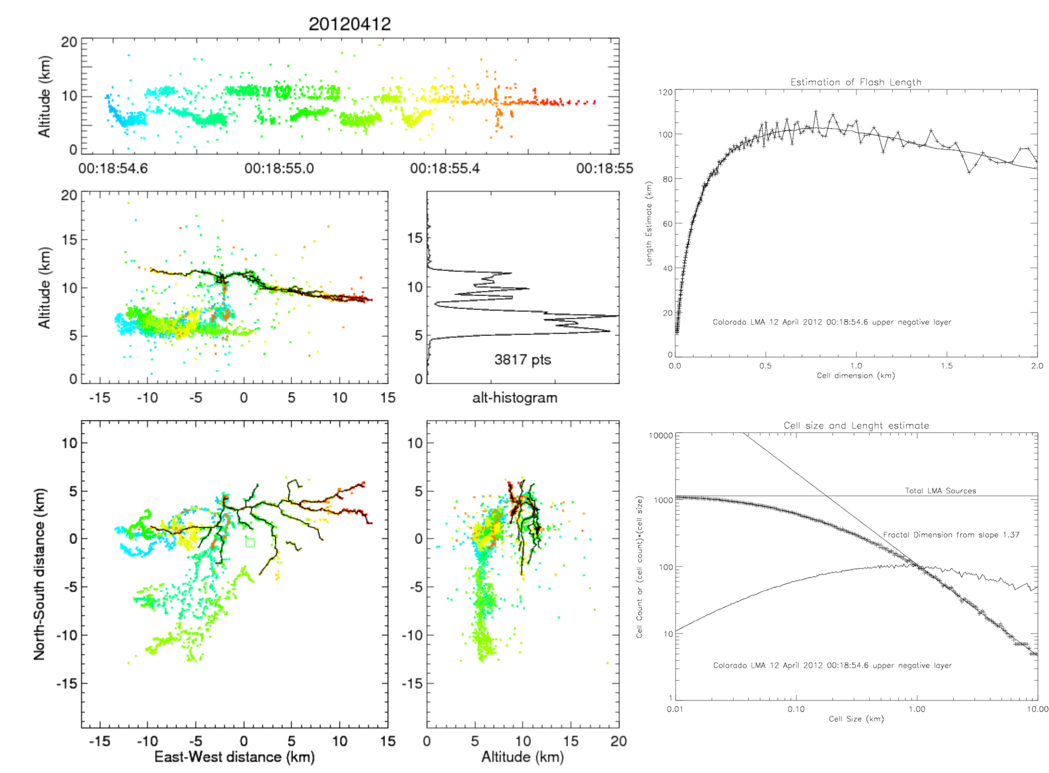
Lower part of the flash in positive charge --- April 12, 2012 at 18:55



Cell Count. The length estimate is cell count X cell size. The estimate is plotted versus the cell size. The length peaks at a cell size of about 300 m. Much smaller cells just count the LMA sources. Much bigger cells contain more than one branch. The peak of the smooth curve is taken as the length estimate.

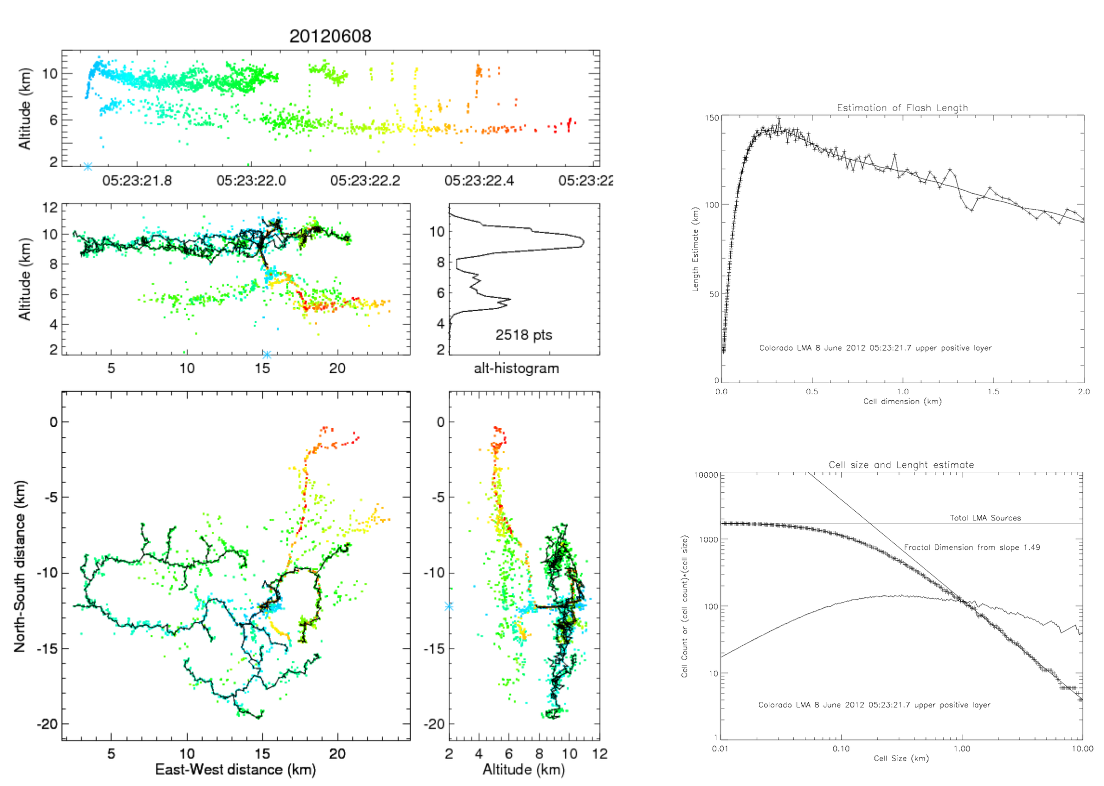
The lower part of this flash is in positive charge. The appearance and nature of the branching is different from that in the negative charge region, so it seems it may be useful to treat the regions separately. The estimates for this are cell count 194 km, branches 226 km total branches, twigs, and leaves 497 km, fractal estimate 212 km.

Upper part of flash in negative charge --- April 12, 2012 at 18:55

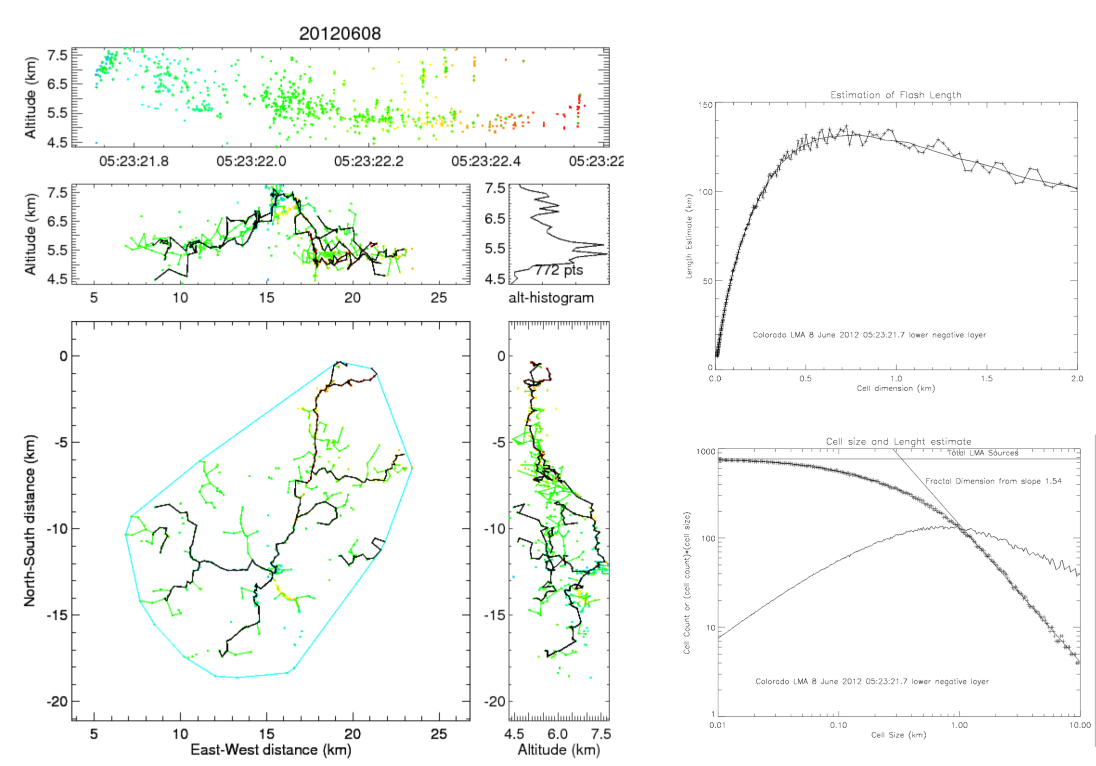


The peak of the cell count is at a larger cell size for the negative charge region, 724 m for this example.

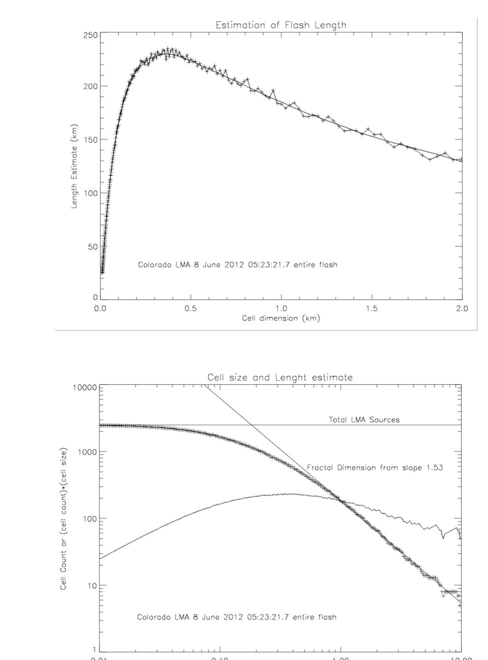
The upper part of this flash is negative charge. The branching looks different from that in the positive charge (to the left). This difference is reflected in the cell size (724 m versus 288 m) and the fractal dimension (1.37 versus 1.57). It is interesting that the estimated branch lengths in the positive and negative charge regions (98 km versus 226 km) are not balanced. In almost every aspect negative and positive breakdown differ.



This is a normal polarity intracloud flash, with more torturous branches in the this upper positive region. In the positive charge region the flash length estimates are 170, 142, and 139 km for branch, cell counting, and fractal estimates.



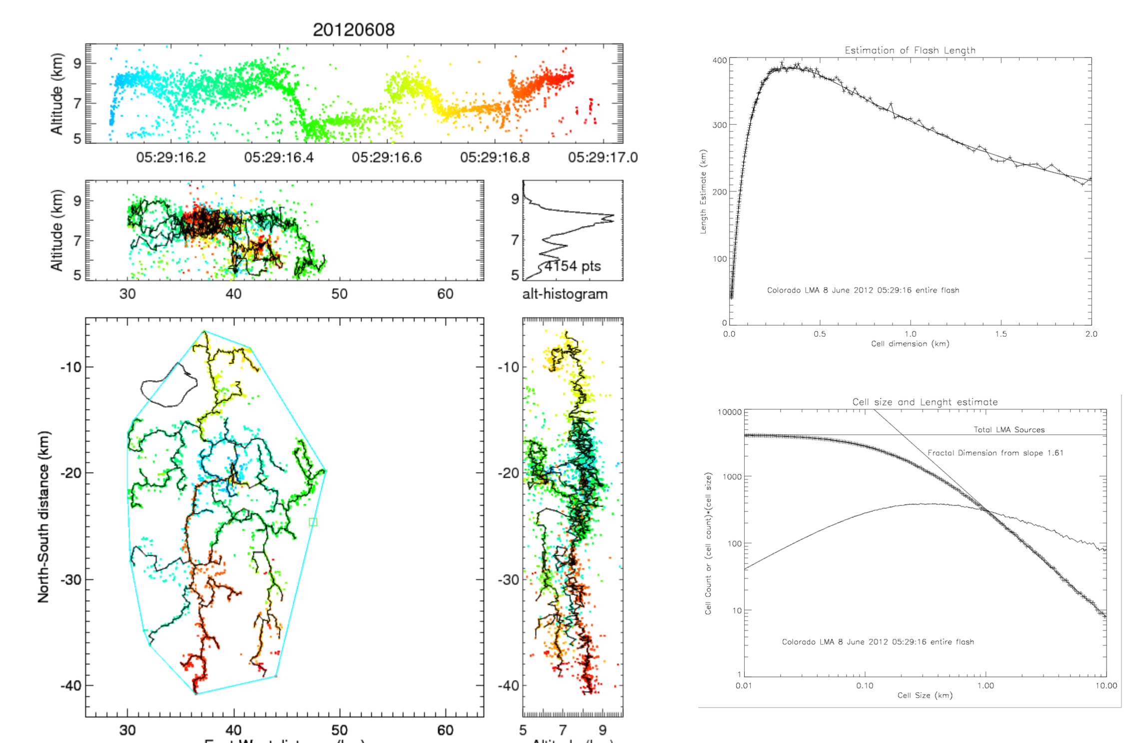
Lower negative charge region. The flash length estimates are 82, 132, and 197 km for branch, cell counting, and fractal estimates.



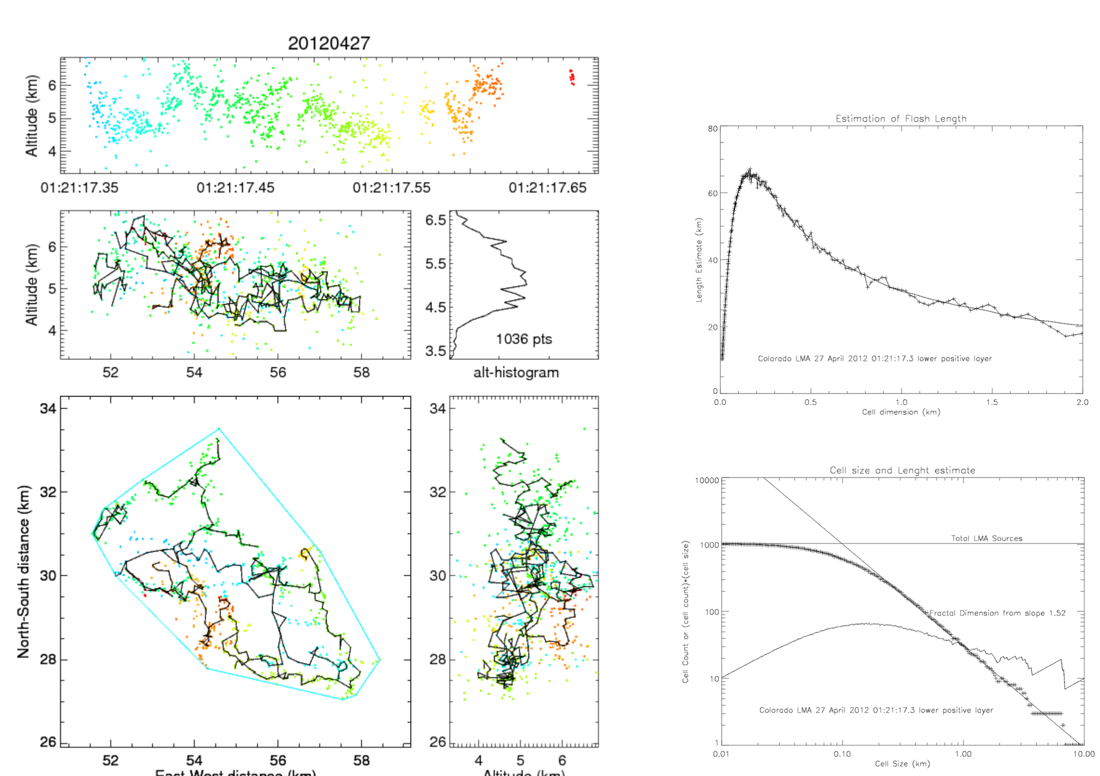
For the entire flash the flash length estimates are 252, 230, and 228 km for branch, cell counting, and fractal estimates.

Summary of length estimates

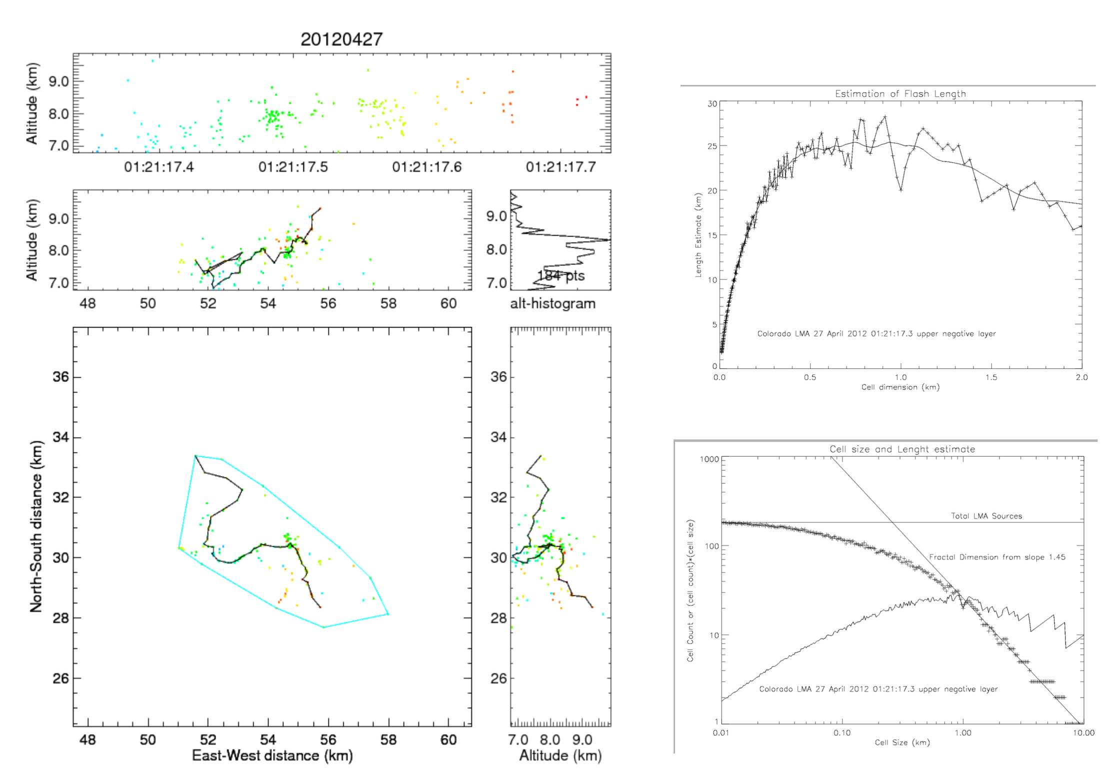
date	time	section	charge	Convex Hull Area	points	Cell Counting cell size	Fractal Dimension D	Length of Branches, twigs, leaves	Length of Branch (km)	Cell Counting Length (km)	fractal Length (km)
Jun 8, 2012	5:23:21.700										
		top	pos	166	1737	282	1.49	460	170	142	139
		bottom	neg	190	772	794	1.54	167	82	132	197
		all		245	2509	380	1.53	627	252	230	228
Apr 12, 2012	0:18:54.600										
		top	neg	172	1312	724	1.41	168	98	113	97
		bottom	pos	173	2489	288	1.57	497	226	194	212
		all		322	3801	309	1.56	665	324	281	328
Apr 27, 2012	1:21:17.300										
		top	neg	20.3	184	933	1.45	48.2	13.5	25.4	25
		bottom	pos	25.0	1053	158	1.52	231	83	66	38
		all		29.2	1237	151	1.55	279	96	74	48
Jun 8, 2012	5:29:18.200										
		all		468	4179	309	1.61	691	332	386	575
Jun 8, 2012	5:24:20										
		all 8 flashes		1801	11993	280	1.45	20058	801	801	646



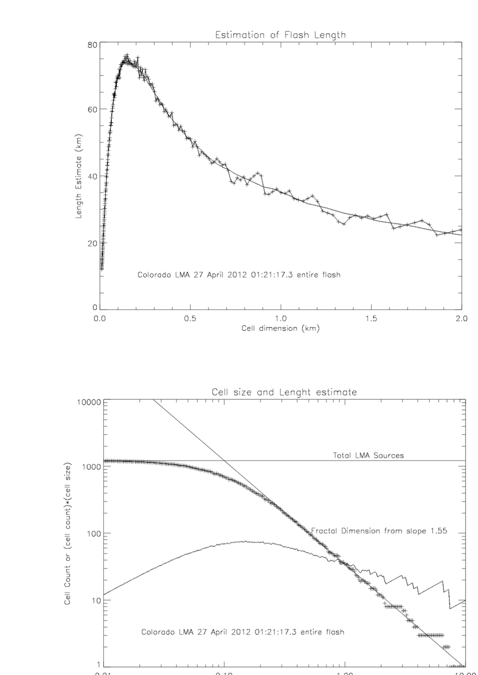
In this flash the charge layers are close together and were not separated. Considering the entire flash, the length estimates are 332, 386, and 575 km for branch, cell counting, and fractal estimates.



An Inverted flash. In this lower positive region, the flash length estimates are 83, 66, and 38 km for branch, cell counting, and fractal estimates.



In the upper negative region, the flash length estimates are 13.5, 25.4, and 25 km for branch, cell counting, and fractal estimates.



For the entire flash the flash length estimates are 96, 74, and 48 km for branch, cell counting, and fractal estimates.

Most of the length estimates have been made on single flashes, However at times it can be hard to divide sever storms into flashes as the rate is very high. In this test I took 10 seconds of data and preformed all the same length analysis. The total length estimates are 801, 801, and 646 km for branch, cell counting, and fractal estimates. These agree as well as they do on a flash by flash basses.

The flashes do not seem overlap in a short period of time. This makes sense as they deposit the opposite charge in the channels to effectively neutralize them.