Lightning Optical Signatures from LIS

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UAHuntsville
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

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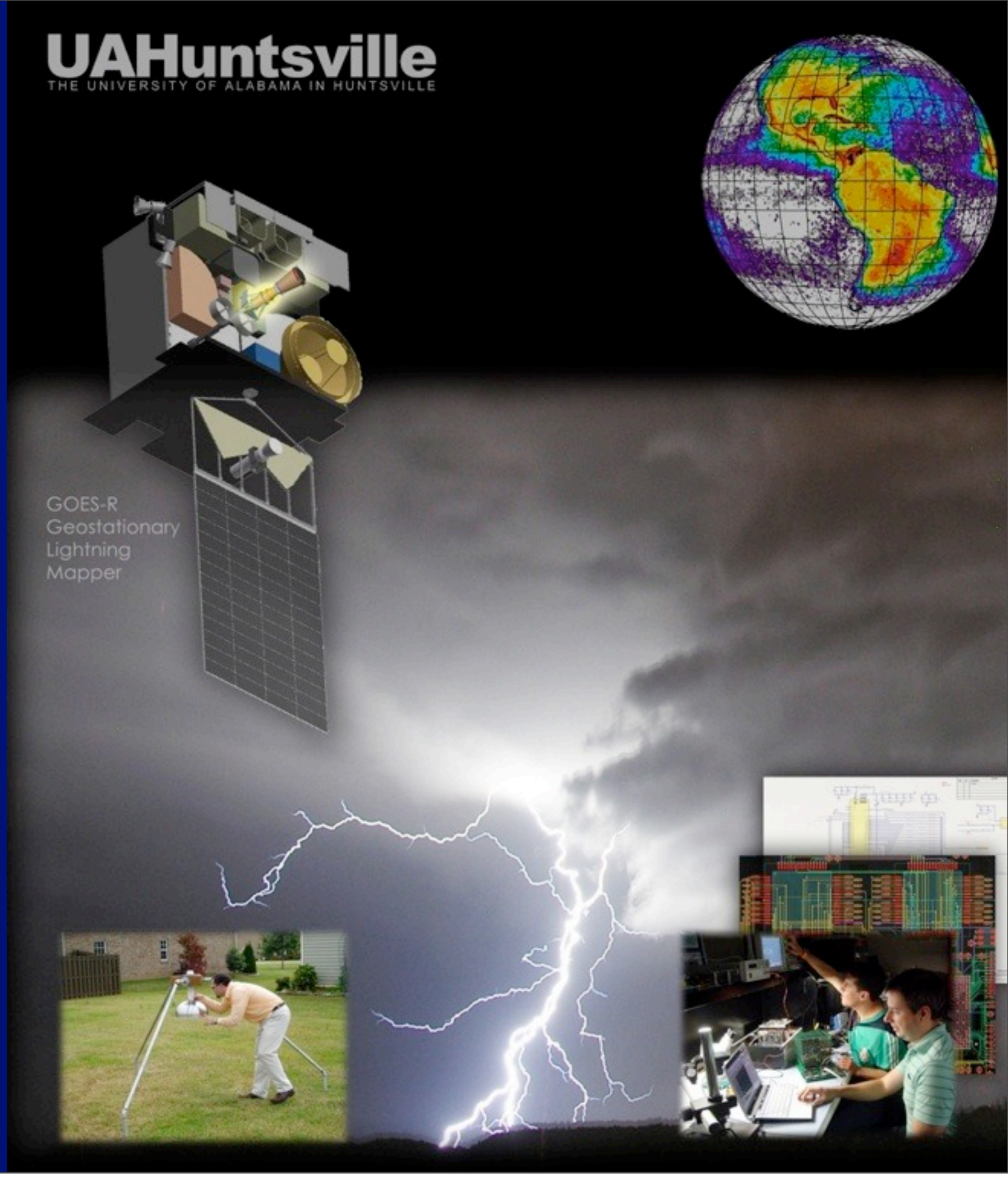
**Dan Cecil, Henry Everitt and Martin Heimbeck, Chris and Elise Schultz,
Brandon and Anne Marie Strickland, and Winfred Thomas Agricultural Research Station**

Fundamental question for *scientific* studies with LIS/GLM:

What part of the lightning process does LIS/GLM "see"?

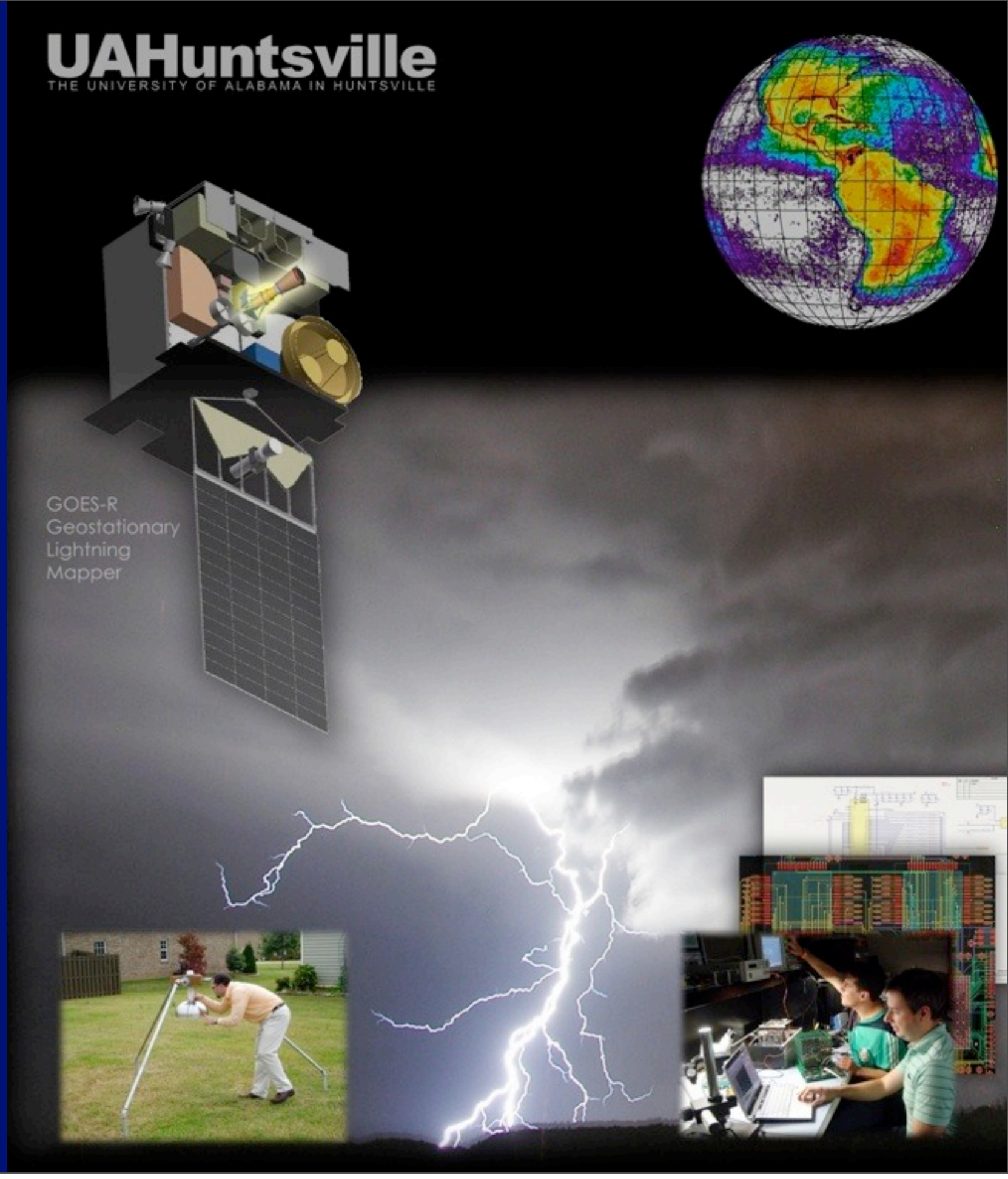


Fundamental question for *scientific* studies with LIS/GLM:

What part of the lightning process does LIS/GLM "see"?

Fundamental question for *validation* of LIS/GLM:

What ground measurements are best correlated with LIS/GLM groups?



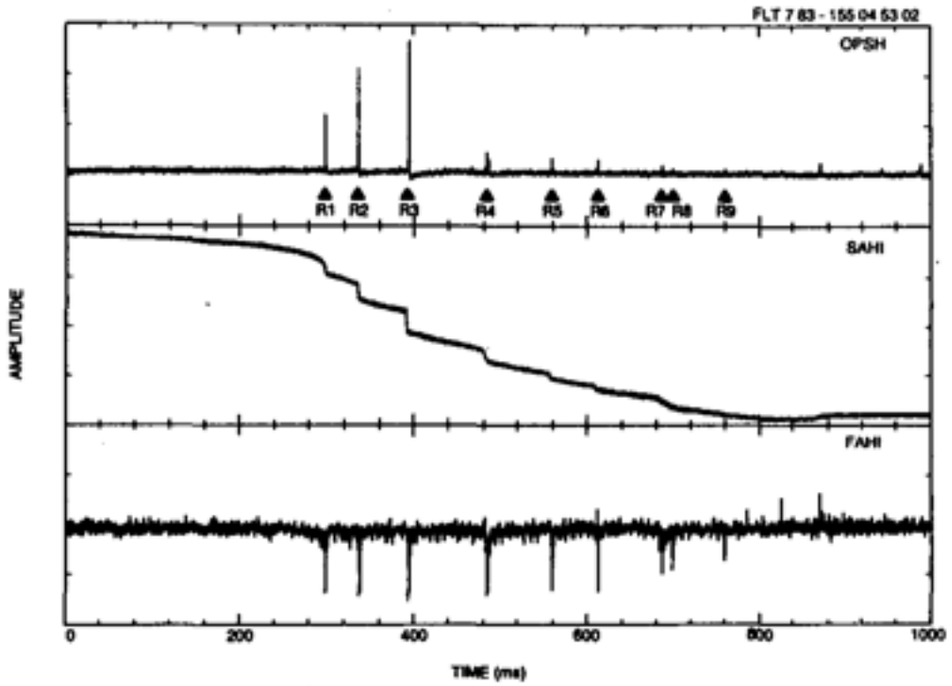


FIG. 8. Waveforms for a multiple stroke CG flash at 0453:02 UTC, visually confirmed at the mobile laboratory beneath the storm. The plots are of uncalibrated amplitudes for the optical pulse sensor (OPSH), the slow antenna (SAHI), and the quasi-fast antenna (FAHI).

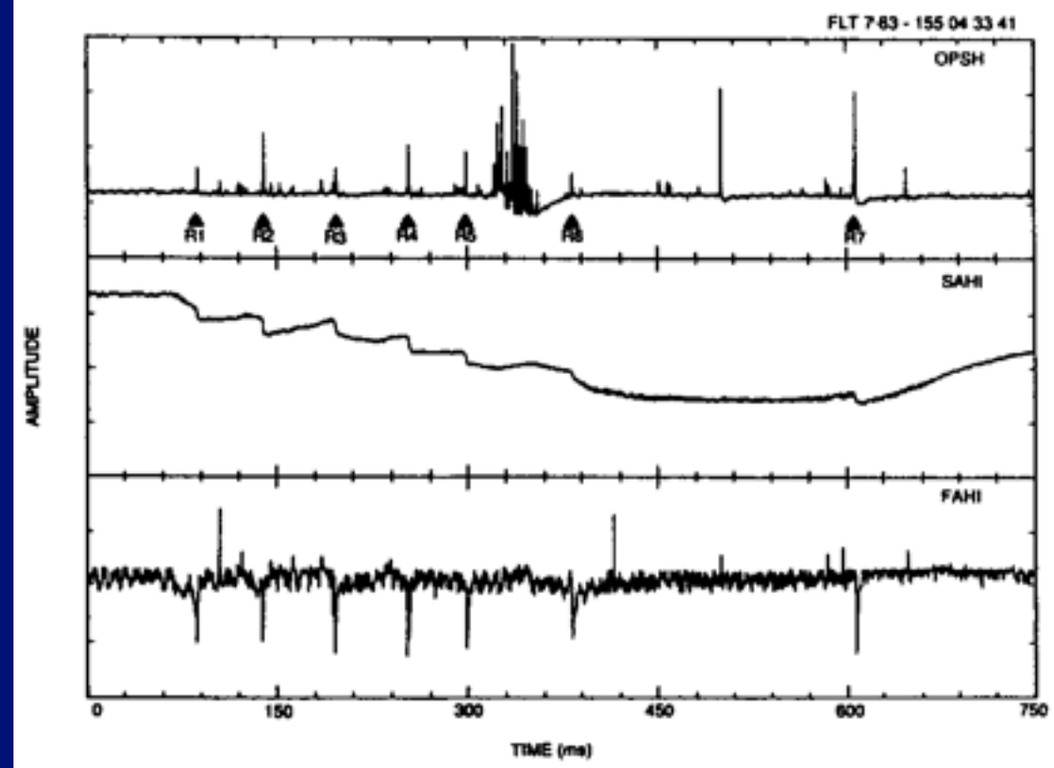


FIG. 10. Waveforms for a visually confirmed multiple stroke flash also at 0433:41 UTC. The plots are as indicated in Fig. 8.

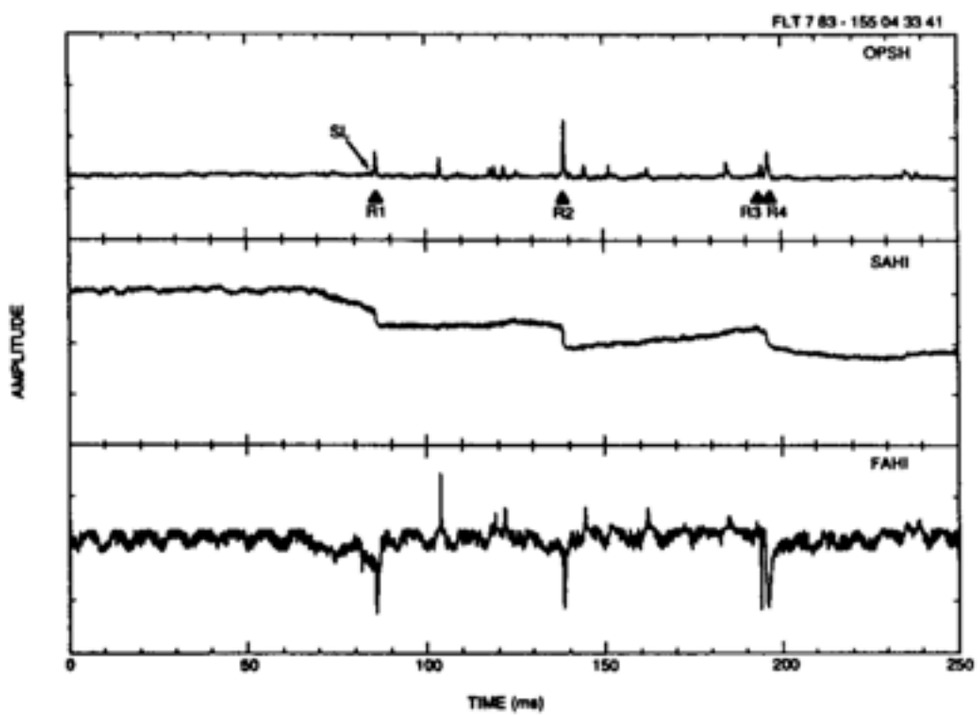


FIG. 9. Waveforms for a visually confirmed multiple stroke flash at 0433:41 UTC. The plots are as indicated in Fig. 8. SL denotes the stepped leader pulse.

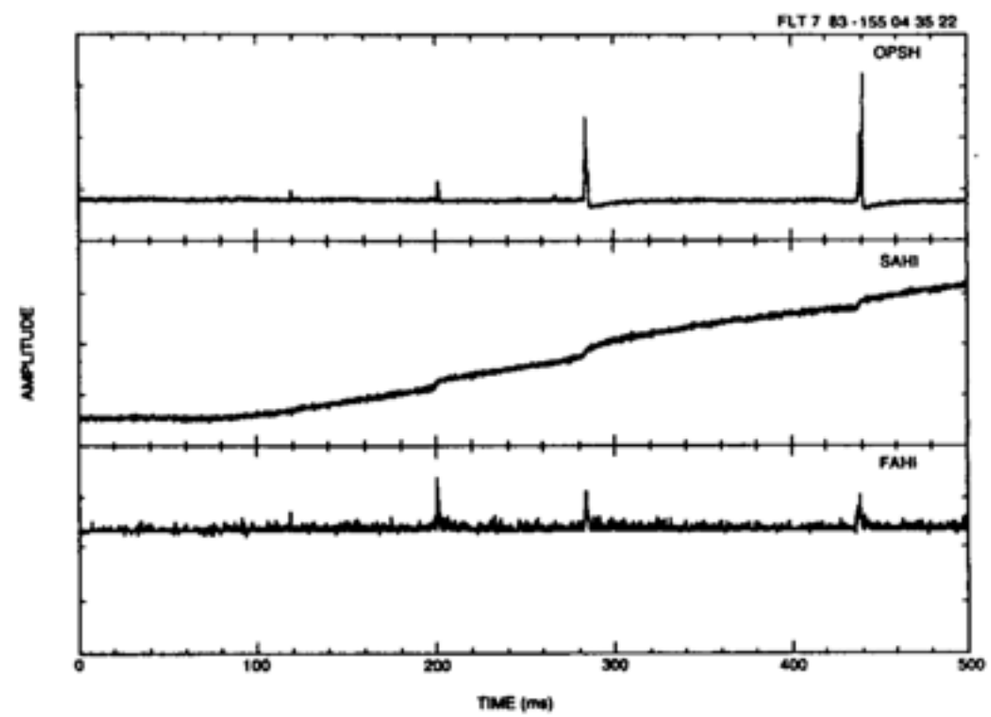
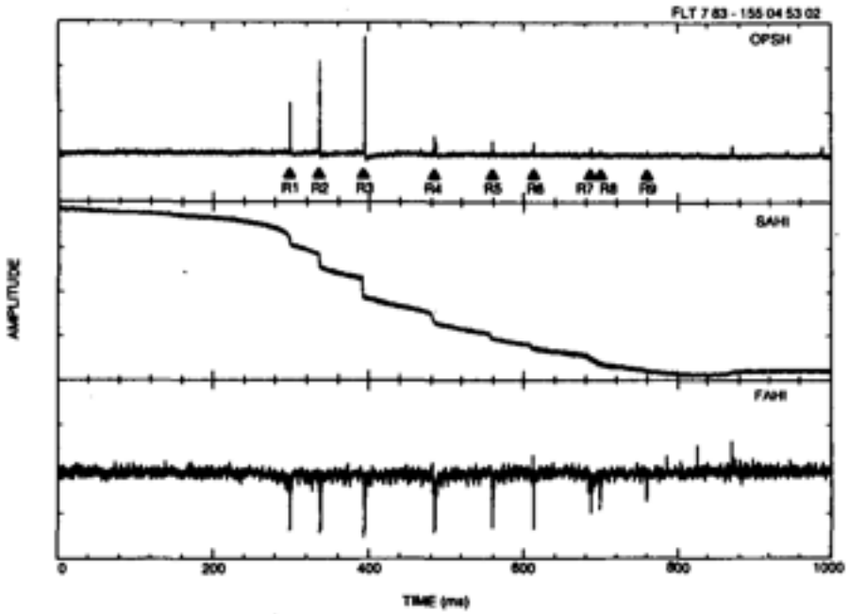


FIG. 11. Waveforms for an intracloud flash at 0453:02 UTC. The plots are as indicated in Fig. 8.

Goodman et al., 1988



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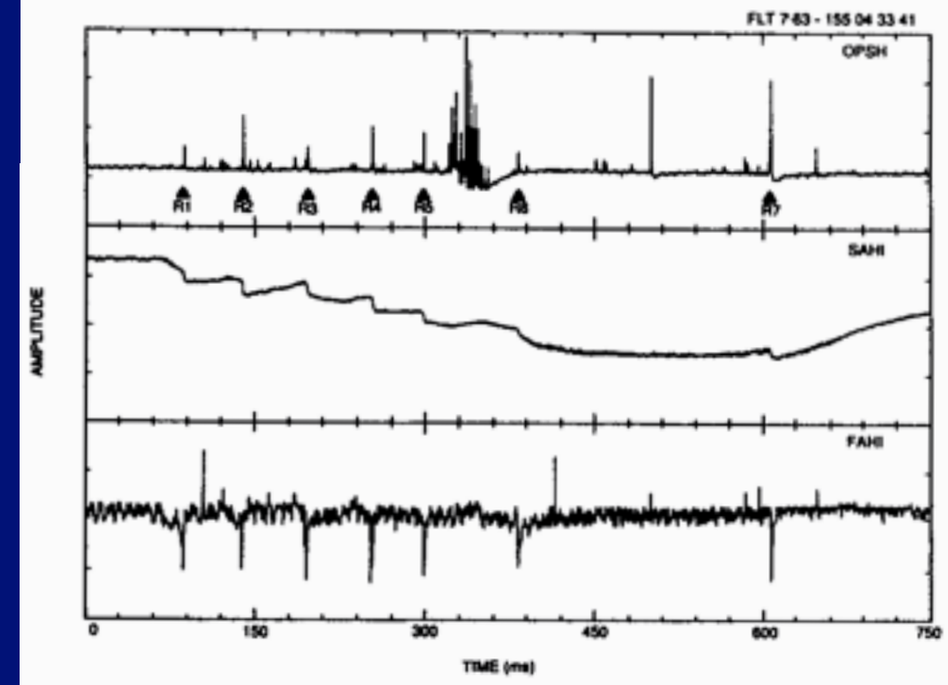

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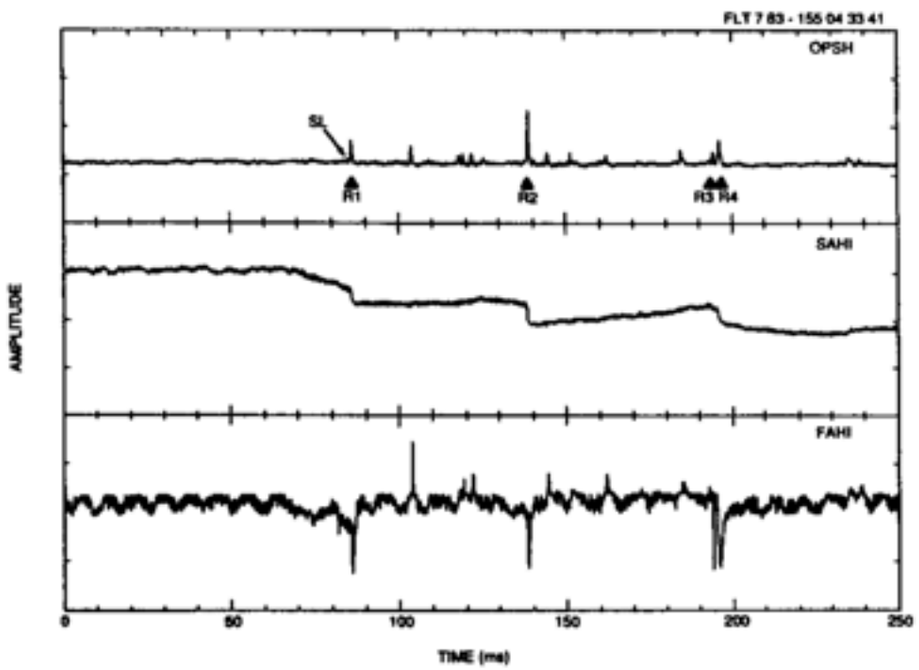

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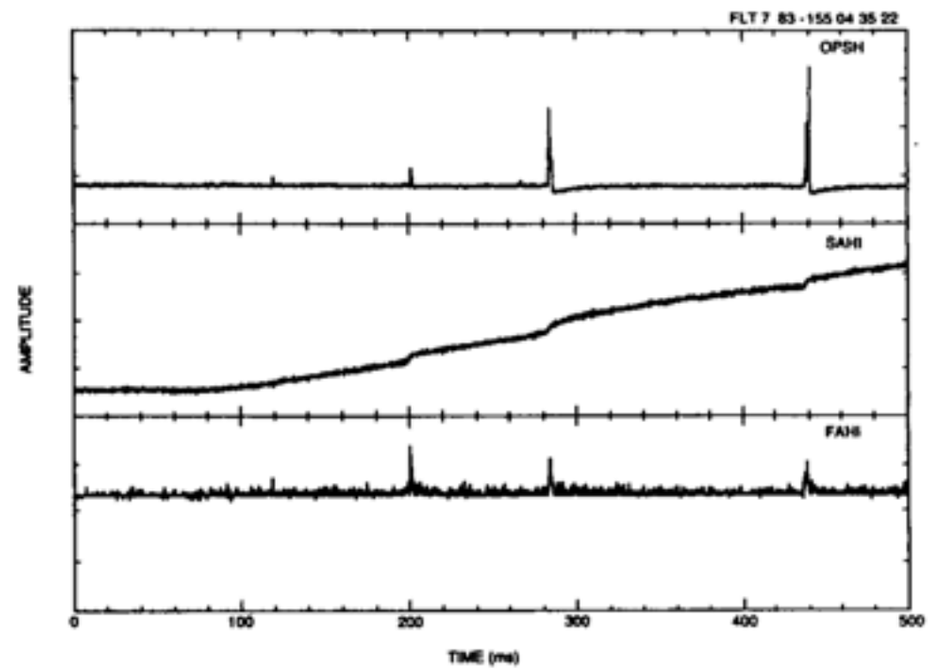
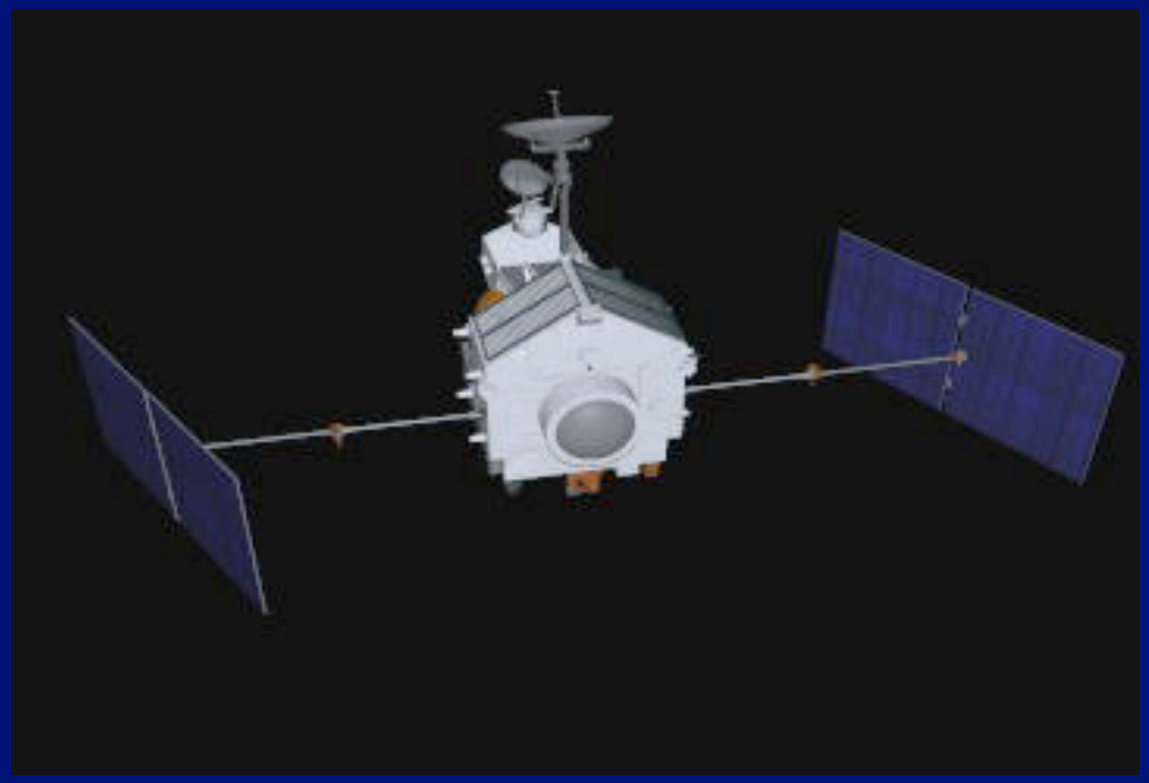


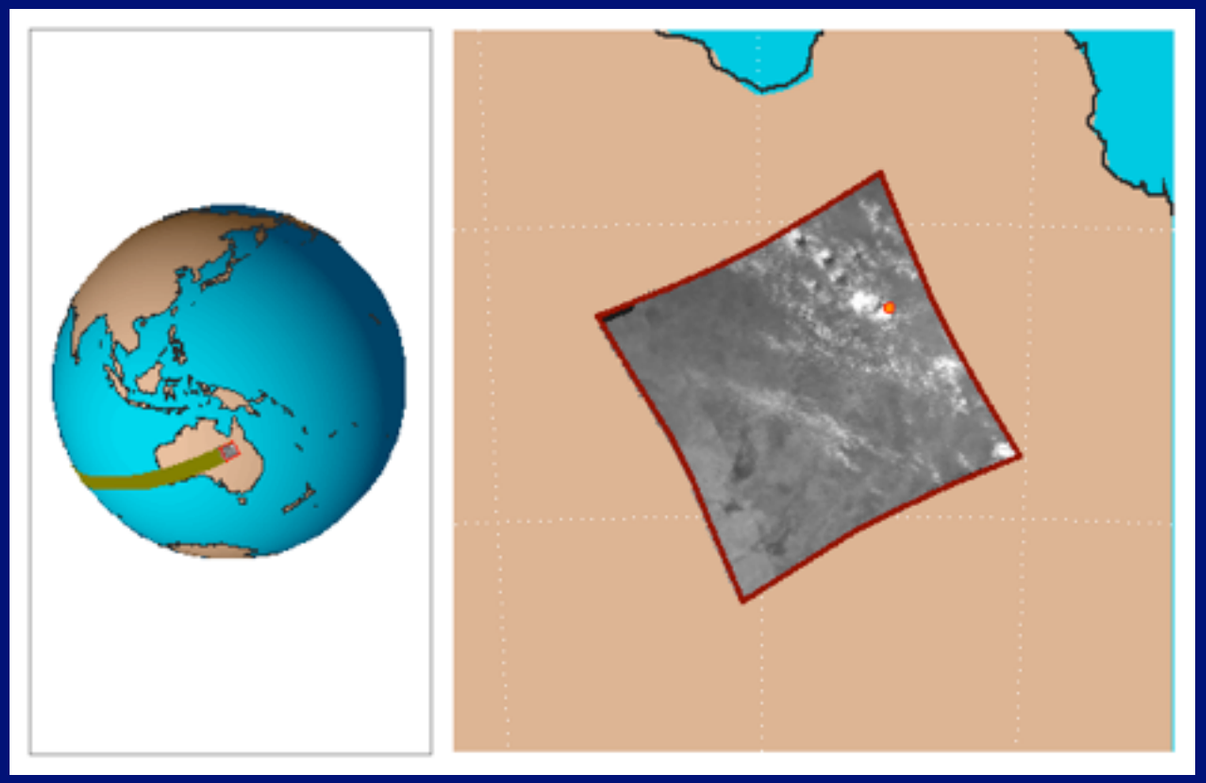
FIG. 11. Waveforms for an intracloud flash at 0453:02 UTC. The plots are as indicated in Fig. 8.

Goodman et al., 1988

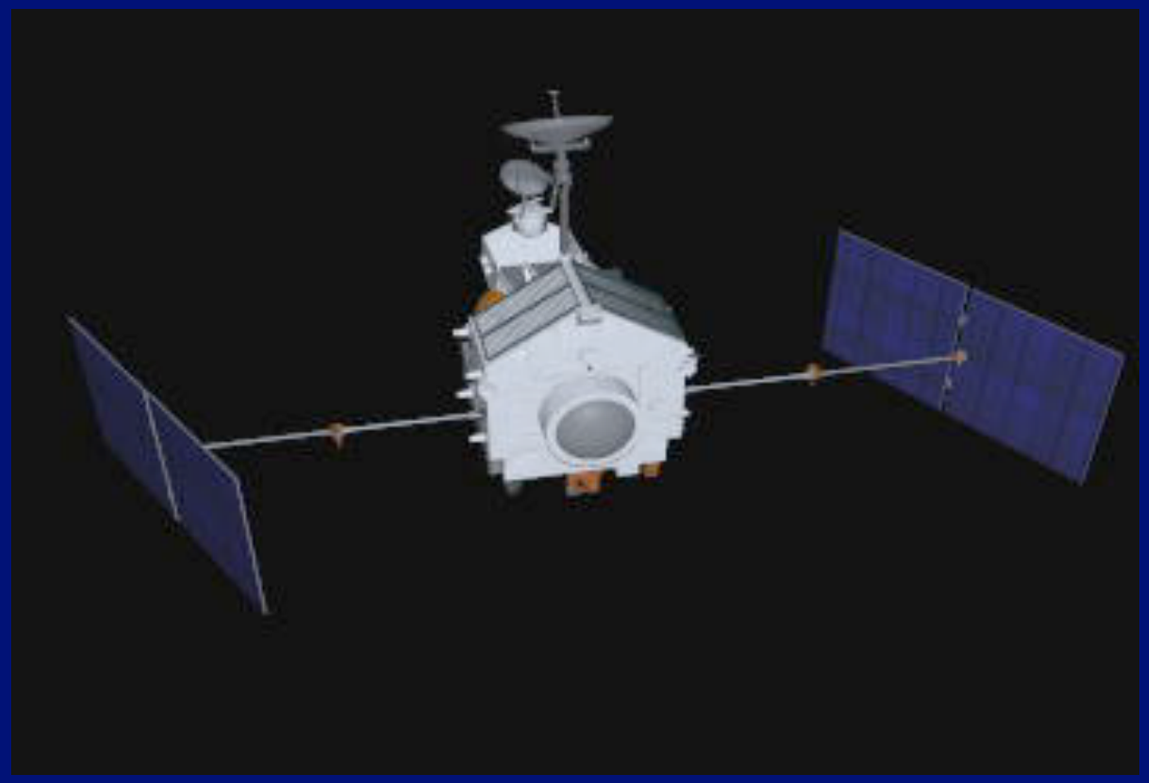
We already know efield and optical are highly correlated!

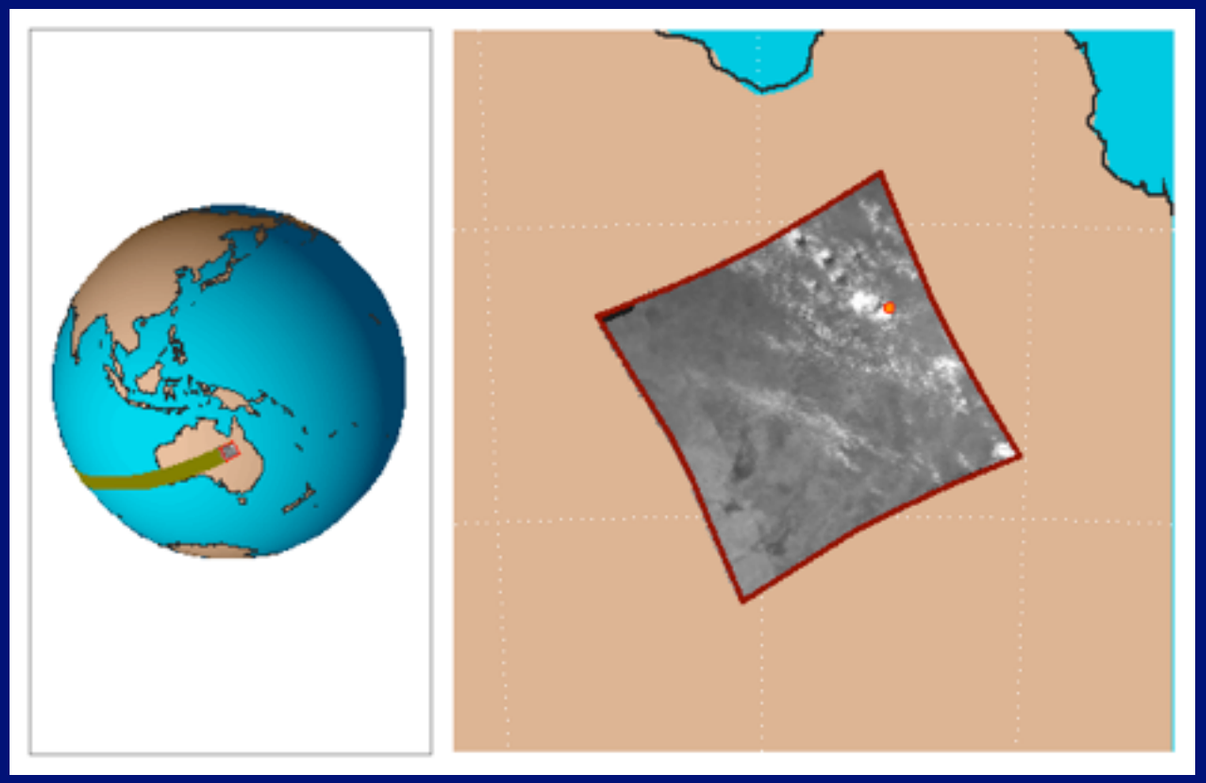
LIS (and by extension, GLM)
does not
detect *flashes...*





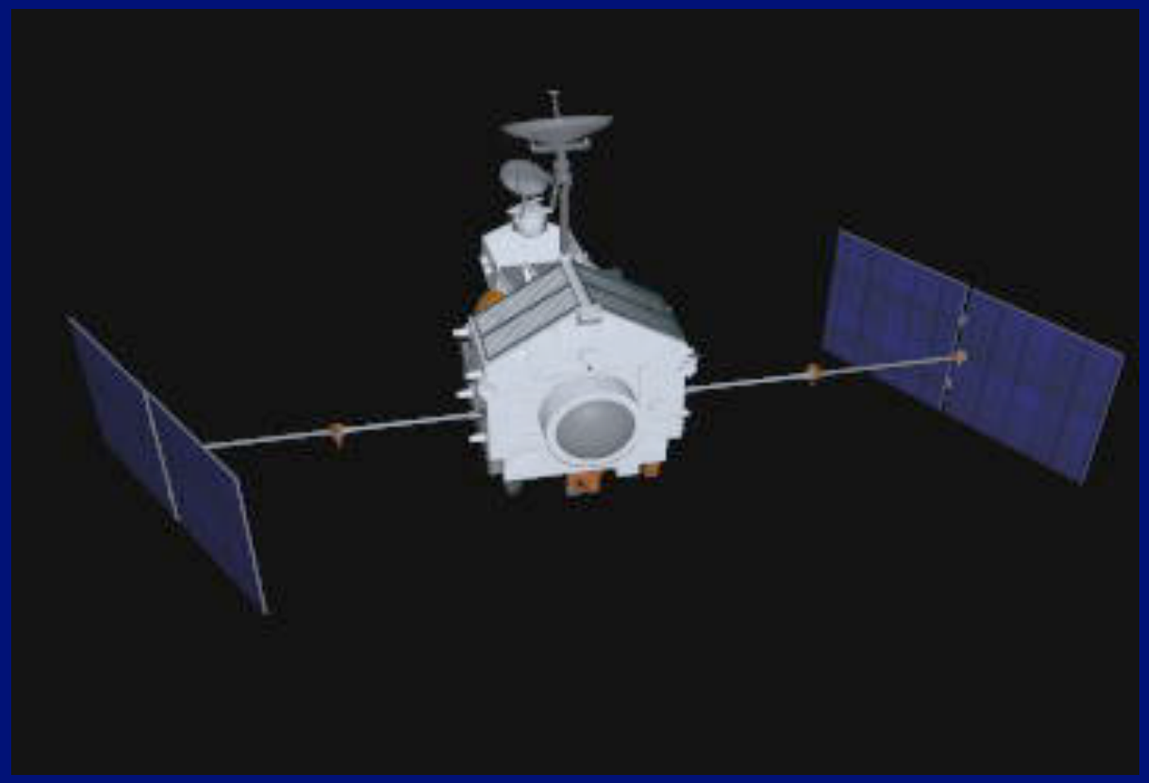
LIS is an **optical *event* detector**

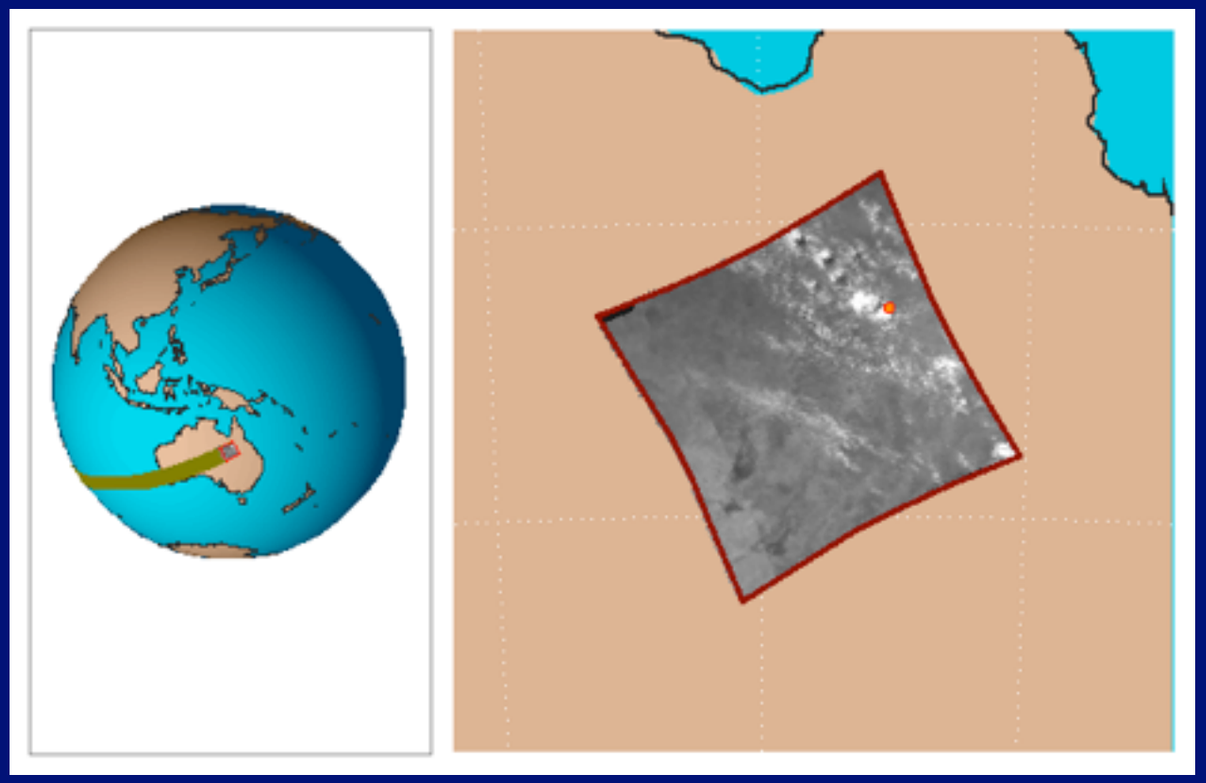




LIS is an **optical *event* detector**

These events can be classified into groups and flashes.



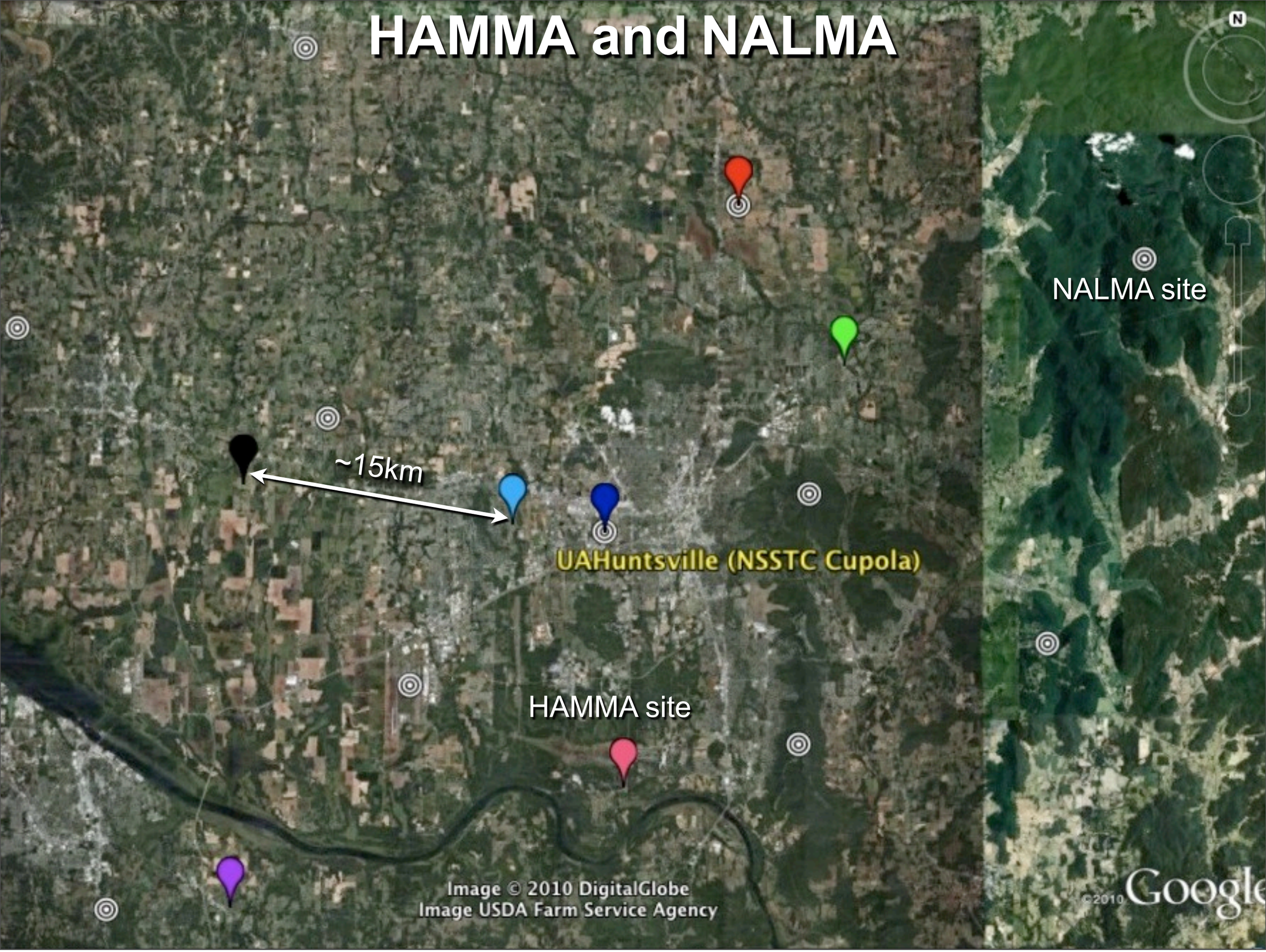


LIS is an **optical *event* detector**

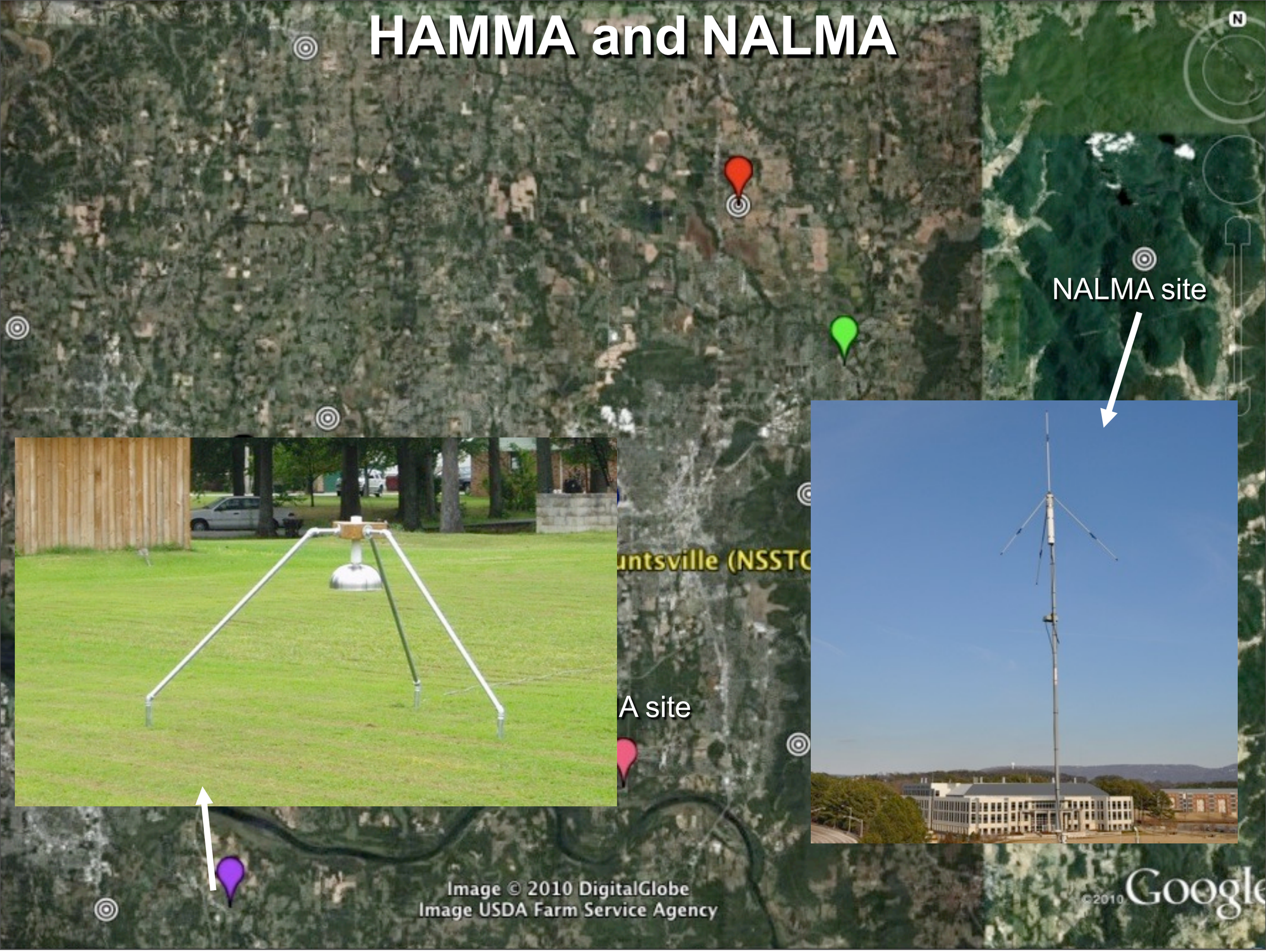
These events can be classified into groups and flashes.

Validation of LIS/GLM measurements should use instruments sensitive to the part of the lightning discharge which produces optical emission

HAMMA and NALMA



HAMMA and NALMA



HAMMA

Huntsville Alabama Marx Meter Array

NALMA

North Alabama Lightning Mapping Array

HAMMA

Huntsville Alabama Marx Meter Array

Wideband ~1Hz-500kHz
Sample Rate: 1MHz

NALMA

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Narrowband VHF ~80 MHz
Sample Rate: 20MHz

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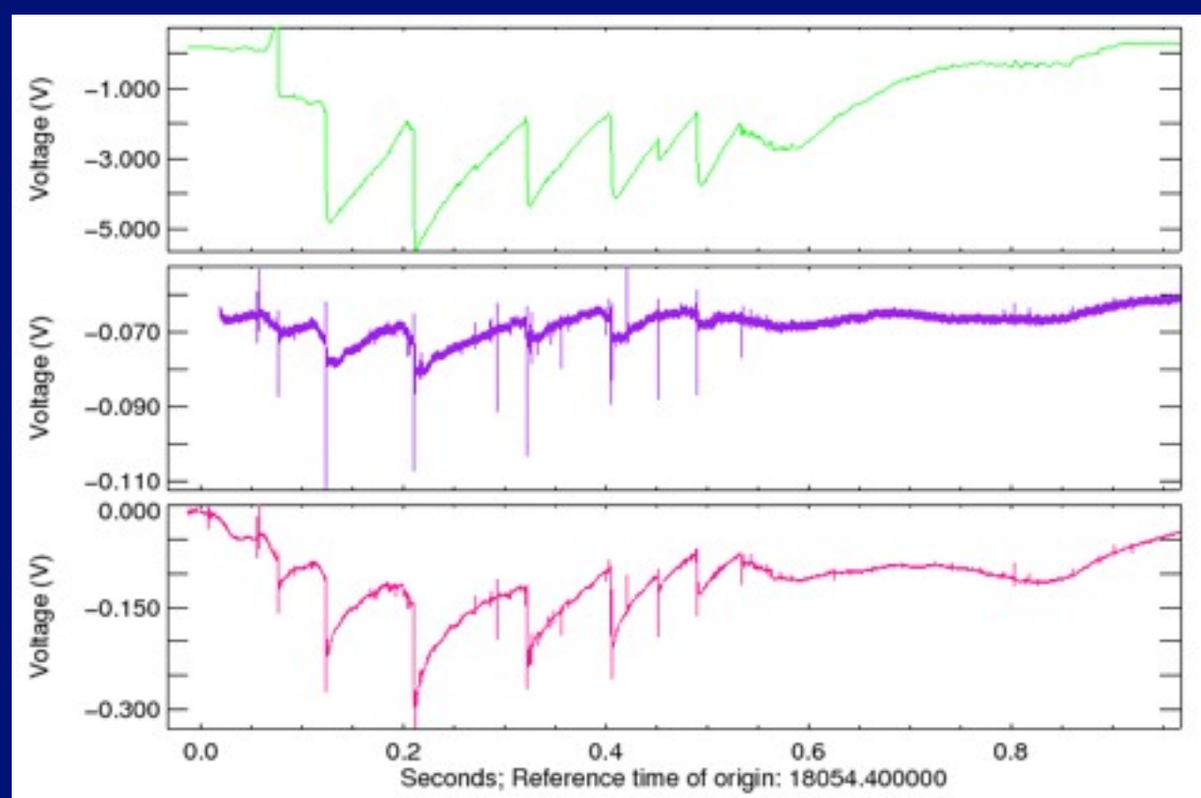
Can identify polarity/type of discharge

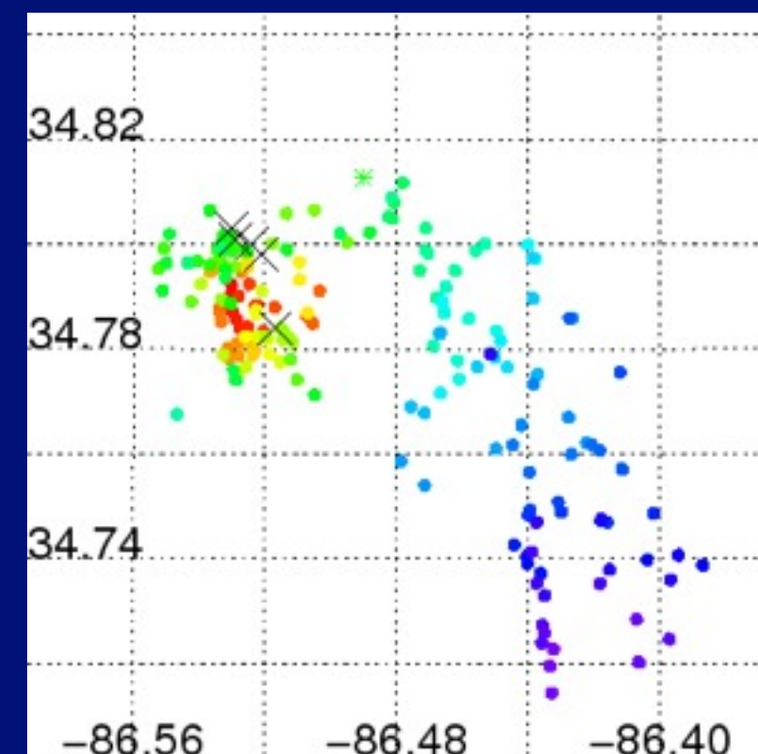


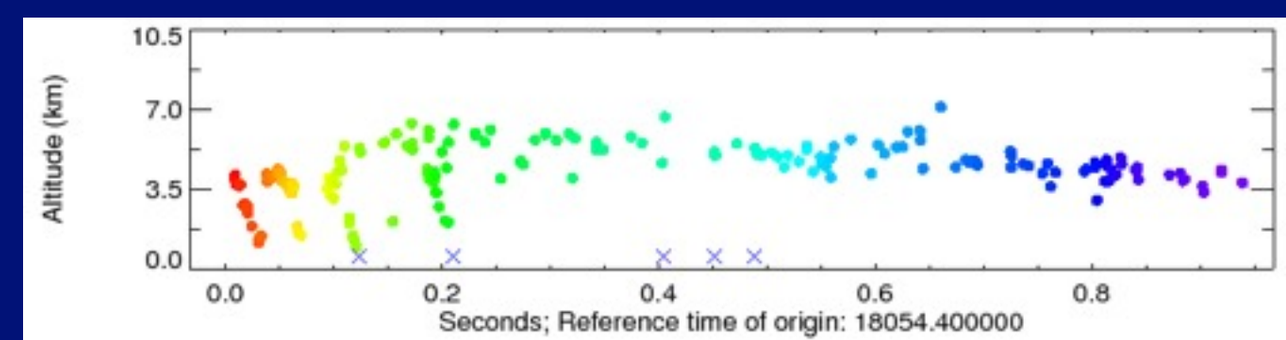
NALMA

North Alabama Lightning Mapping Array

Narrowband VHF ~80 MHz
Sample Rate: 20MHz

Provides accurate “maps” of lightning





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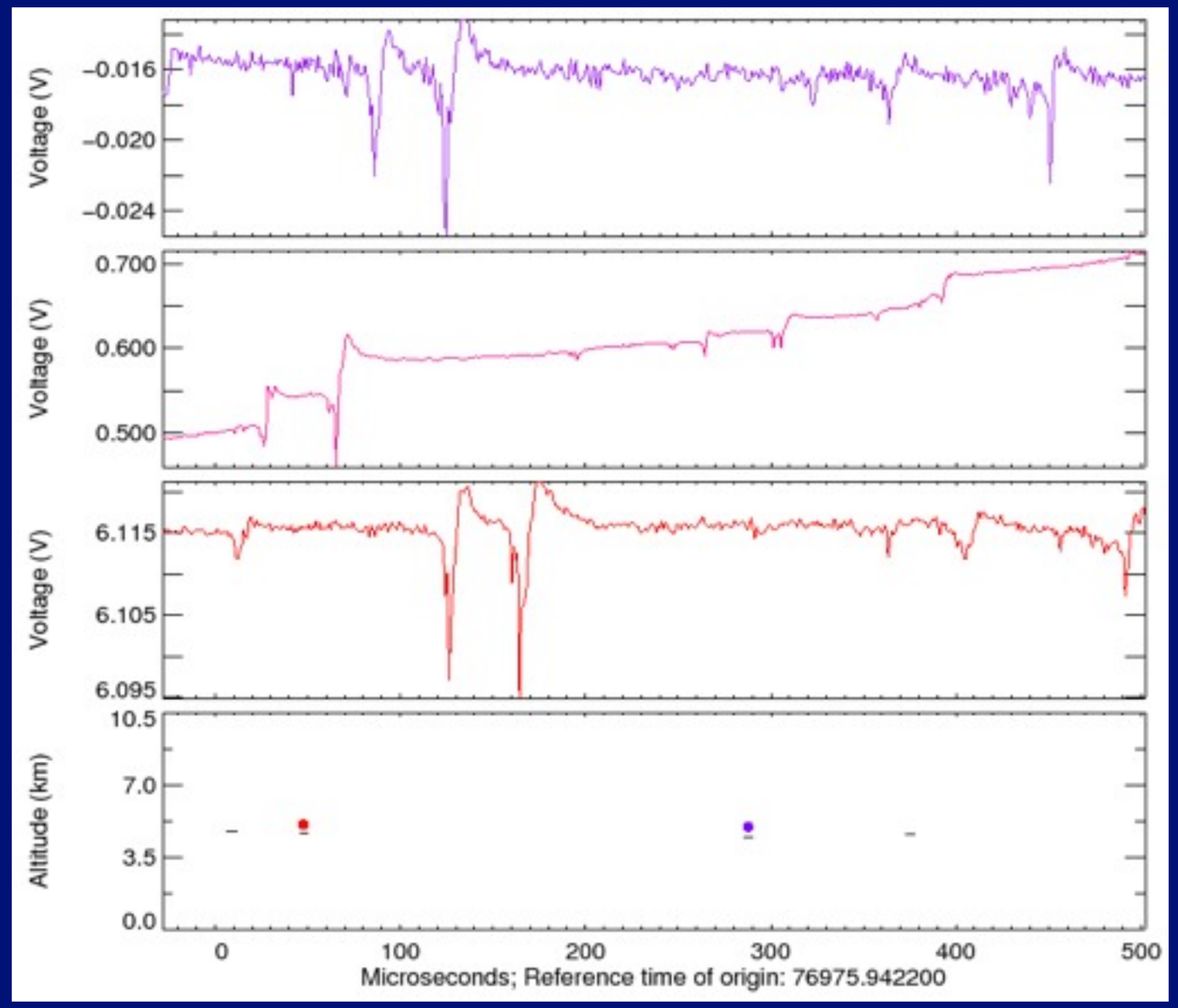
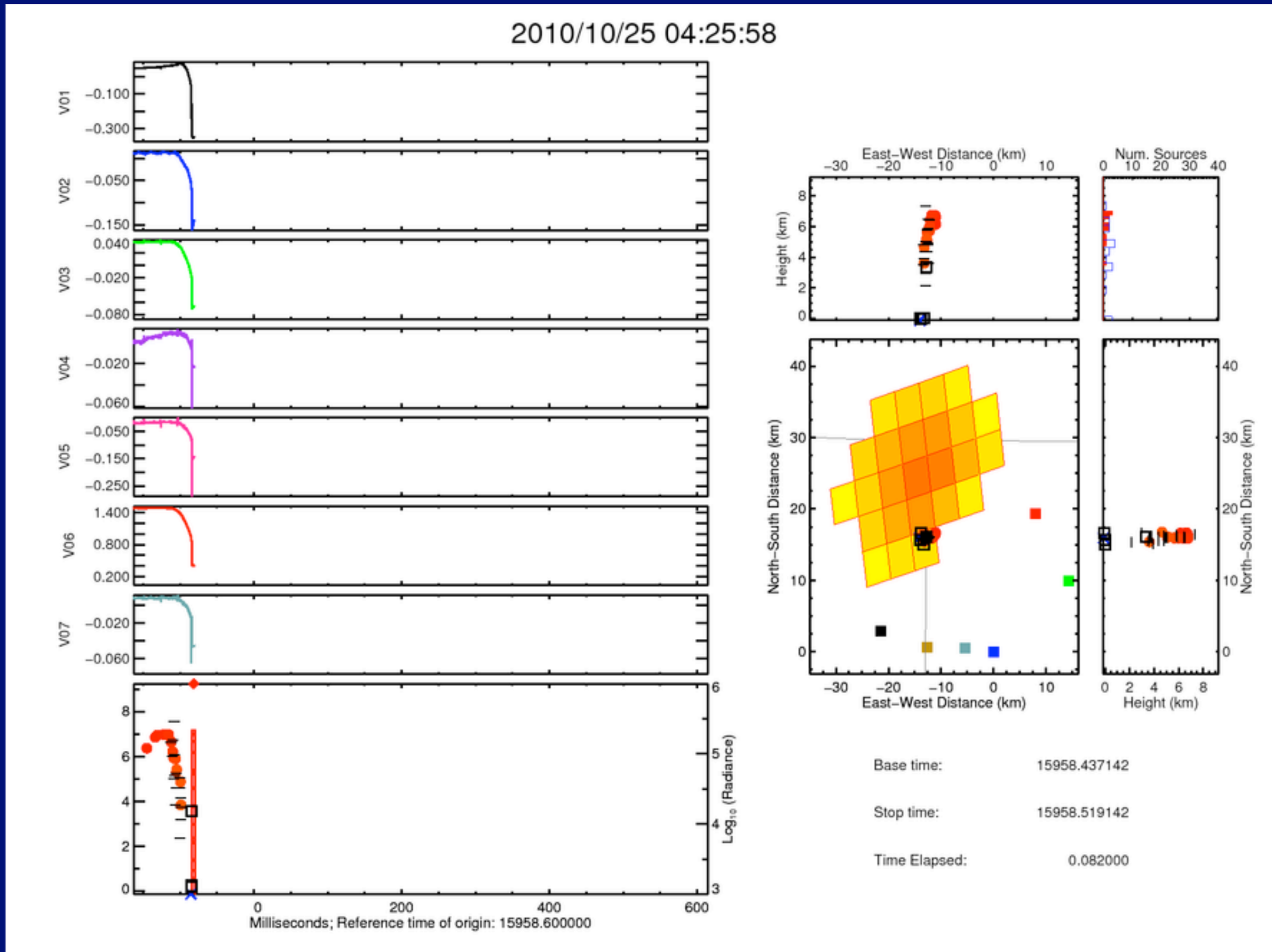
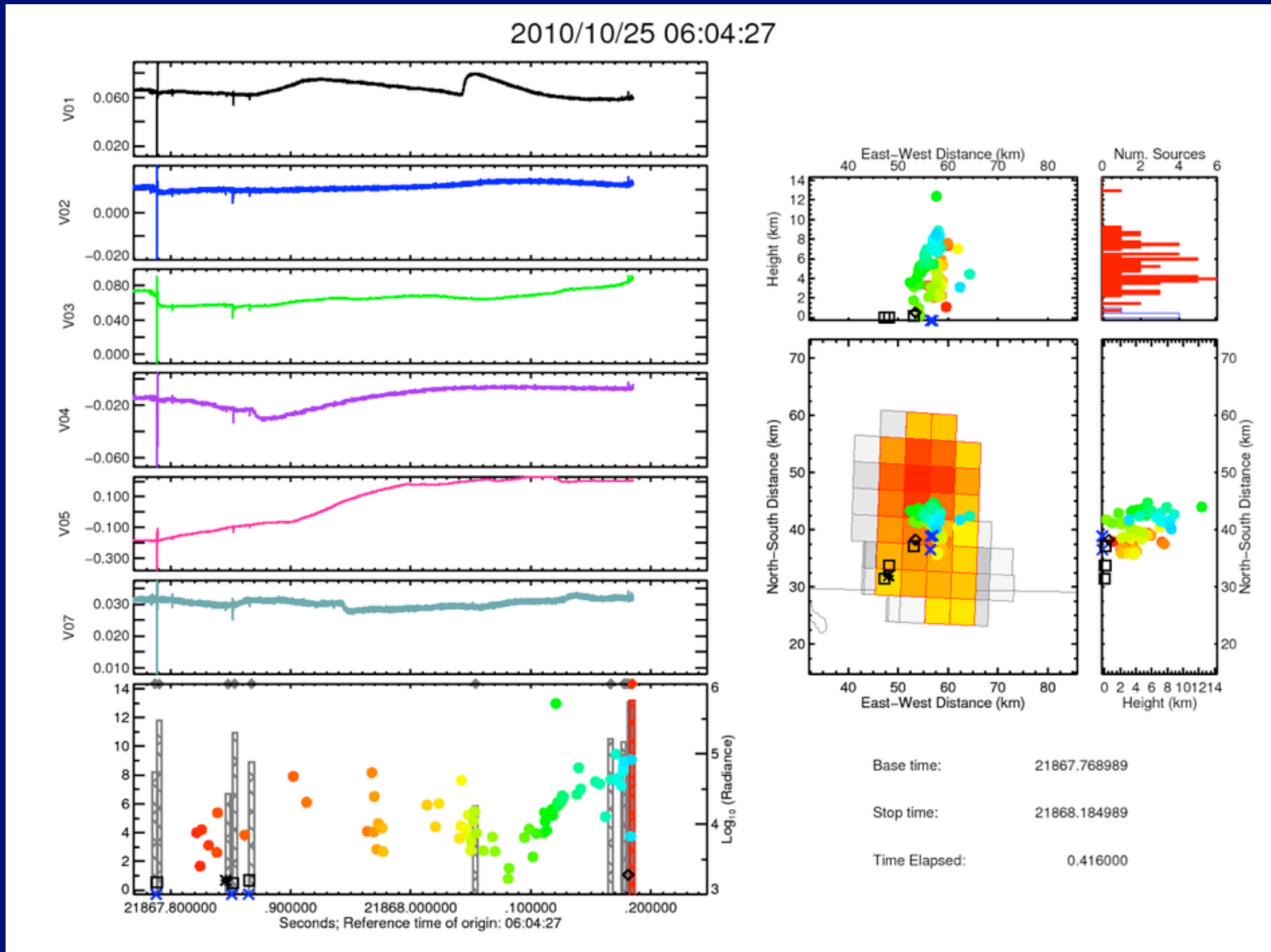
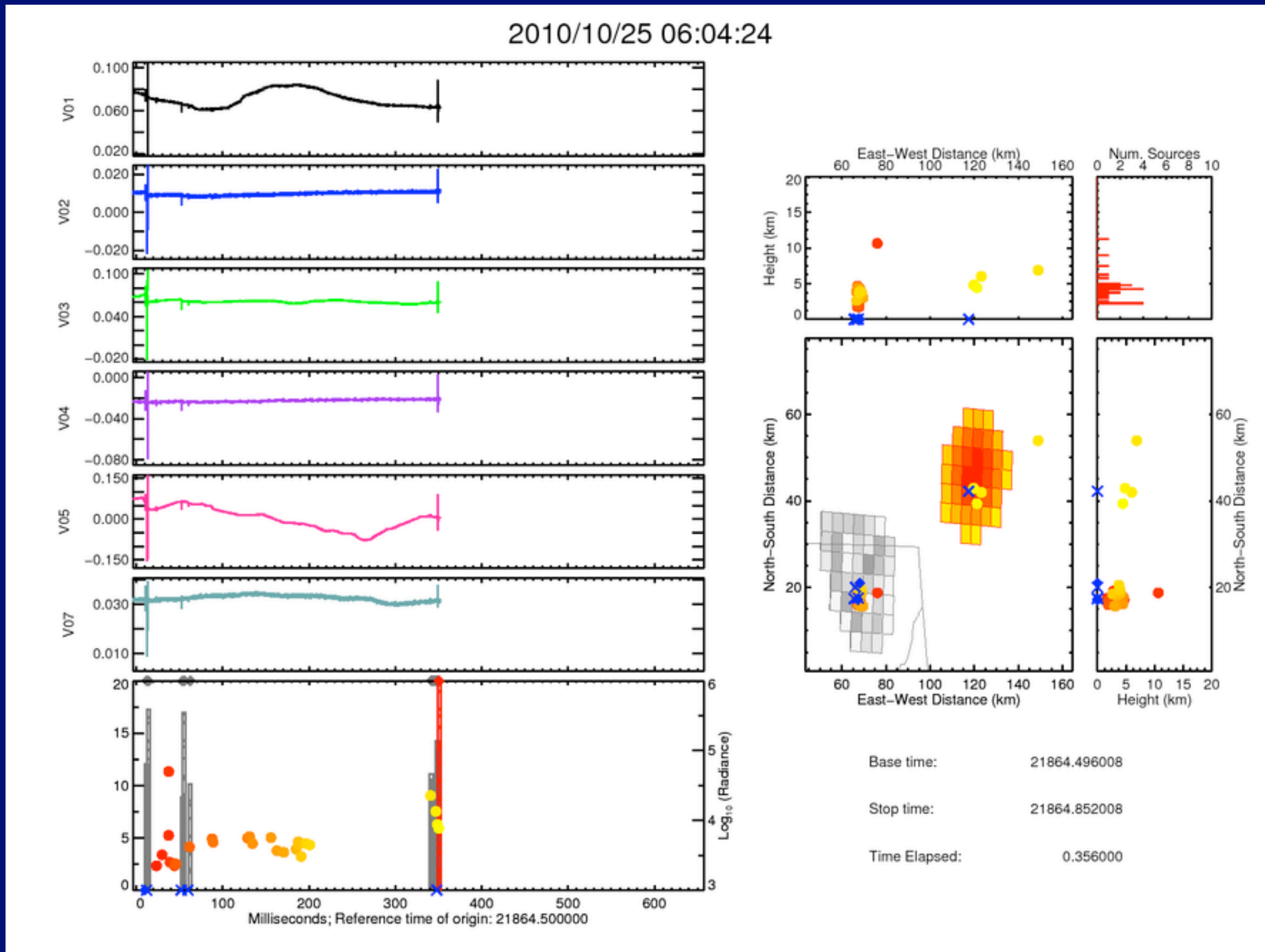


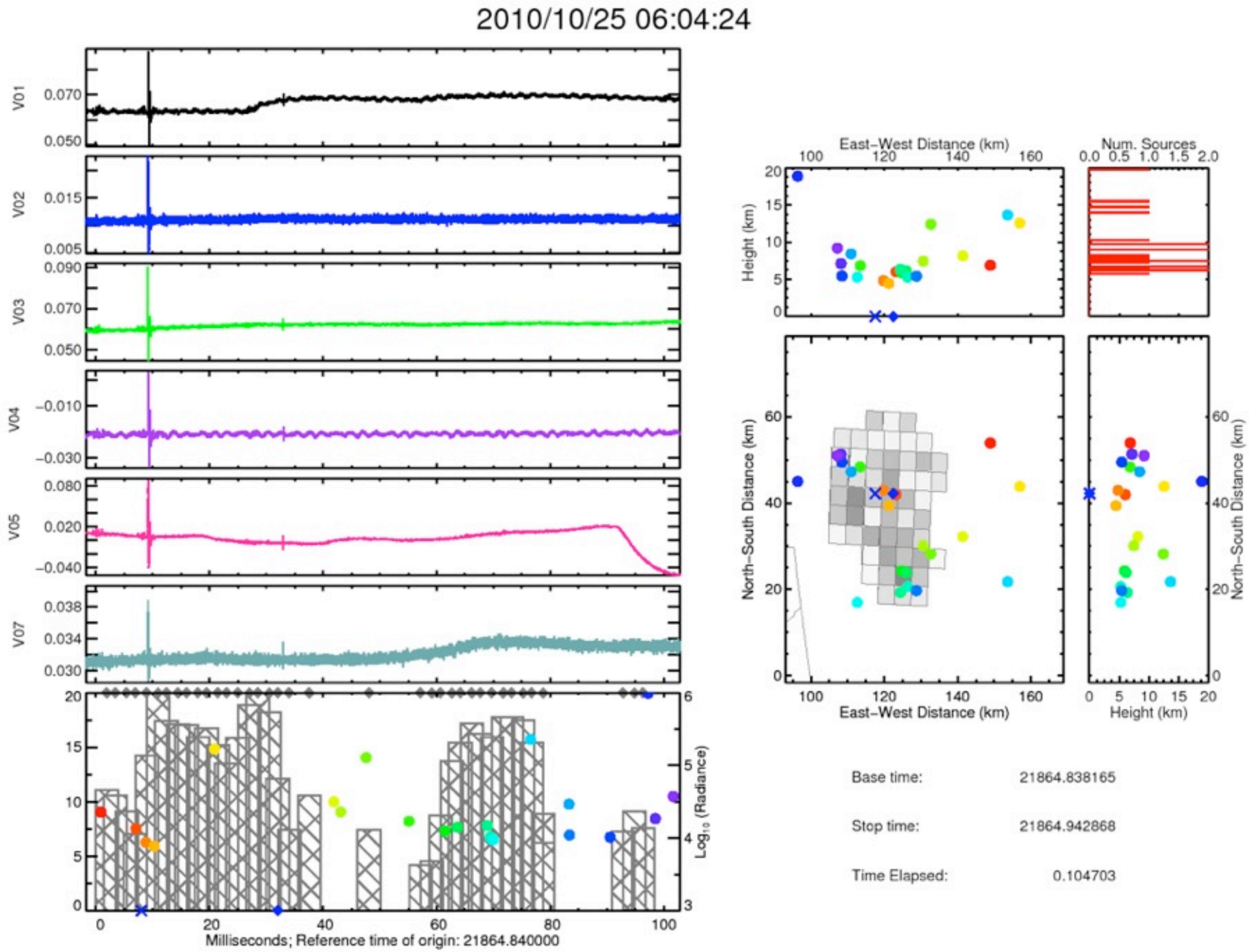
Both arrays can locate sources via time-of-arrival; HAMMA can also provide energetic information

Warning deep dive ahead....


2010/10/25 04:25:58
V01
V02
V03
V04
V05
V06
V07
Log10 (Radiance)
Milliseconds; Reference time of origin: 15958.600000
East–West Distance (km)
Num. Sources
Height (km)
North–South Distance (km)
Base time: 15958.437142
Stop time: 15958.519142
Time Elapsed: 0.082000


2010/10/25 06:04:27
V01
V02
V03
V04
V05
V07
Seconds; Reference time of origin: 06:04:27
Log10 (Radiance)
East–West Distance (km)
Num. Sources
Height (km)
North–South Distance (km)
Base time: 21867.768989
Stop time: 21868.184989
Time Elapsed: 0.416000


2010/10/25 06:04:24
V01
V02
V03
V04
V05
V07
Milliseconds; Reference time of origin: 21864.500000
Log10 (Radiance)
East–West Distance (km)
Num. Sources
Height (km)
North–South Distance (km)
Base time: 21864.496008
Stop time: 21864.852008
Time Elapsed: 0.356000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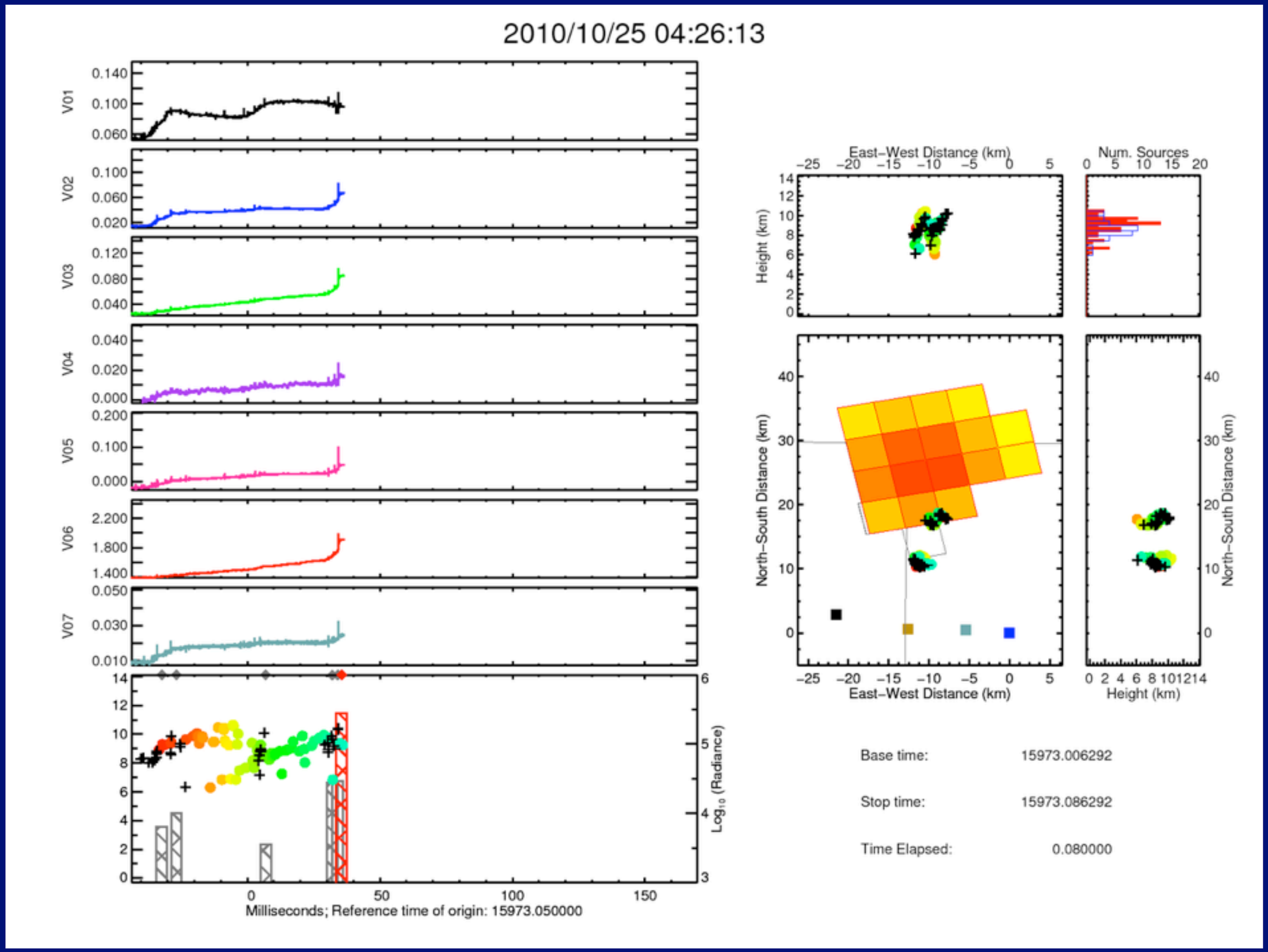
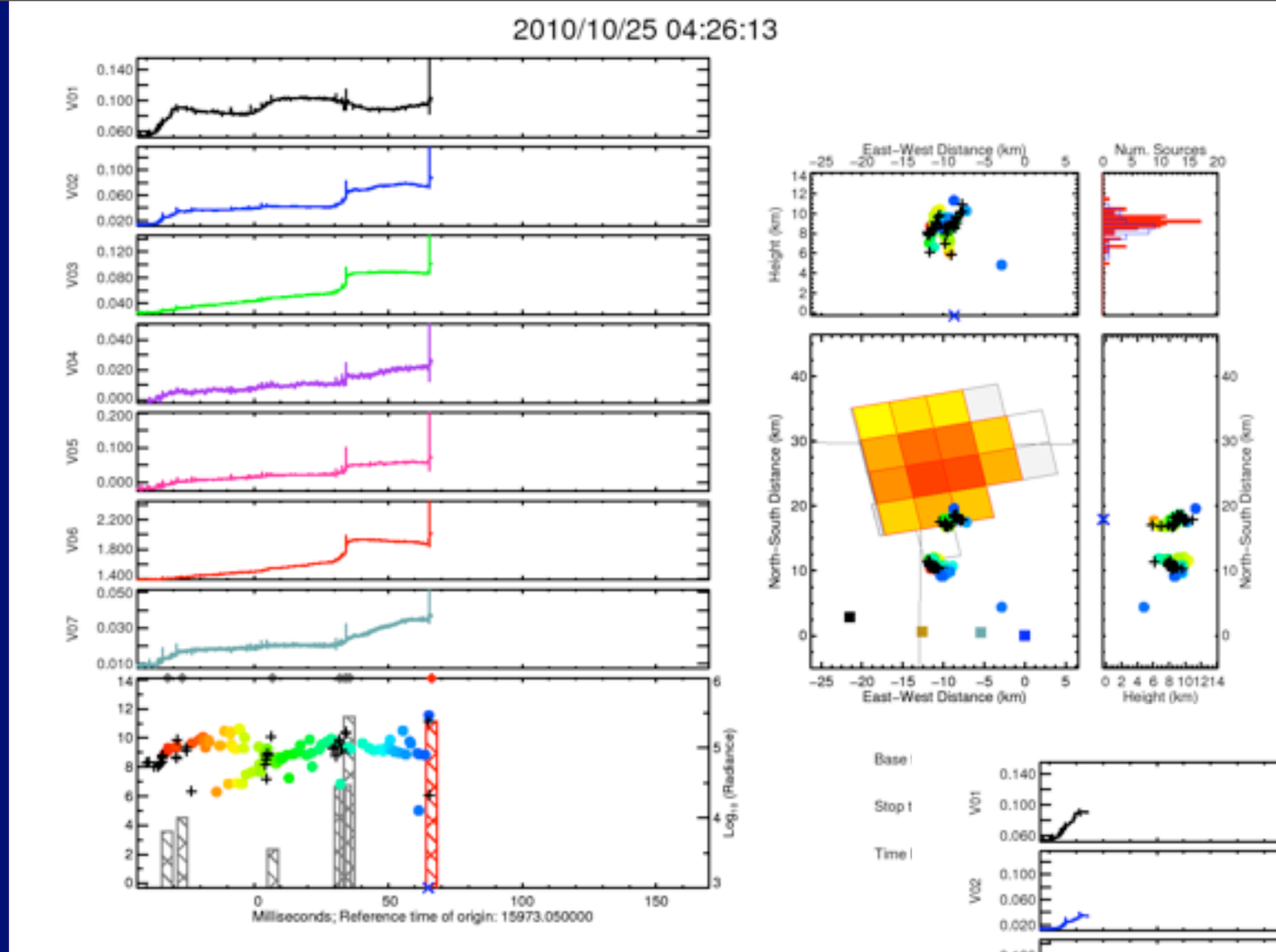
V01
V02
V03
V04
V05
V07
Milliseconds; Reference time of origin: 21864.840000
Log10 (Radiance)
East–West Distance (km)
Num. Sources
Height (km)
North–South Distance (km)
Base time: 21864.838165
Stop time: 21864.942868
Time Elapsed: 0.104703


2010/10/25 04:26:13
V01
V02
V03
V04
V05
V06
V07
Milliseconds; Reference time of origin: 15973.050000
Log10 (Radiance)
East–West Distance (km)
Num. Sources
Height (km)
North–South Distance (km)
Base time: 15973.006292
Stop time: 15973.086292
Time Elapsed: 0.080000

Although each flash has ~same number of LMA sources, the “north” flash is much brighter...



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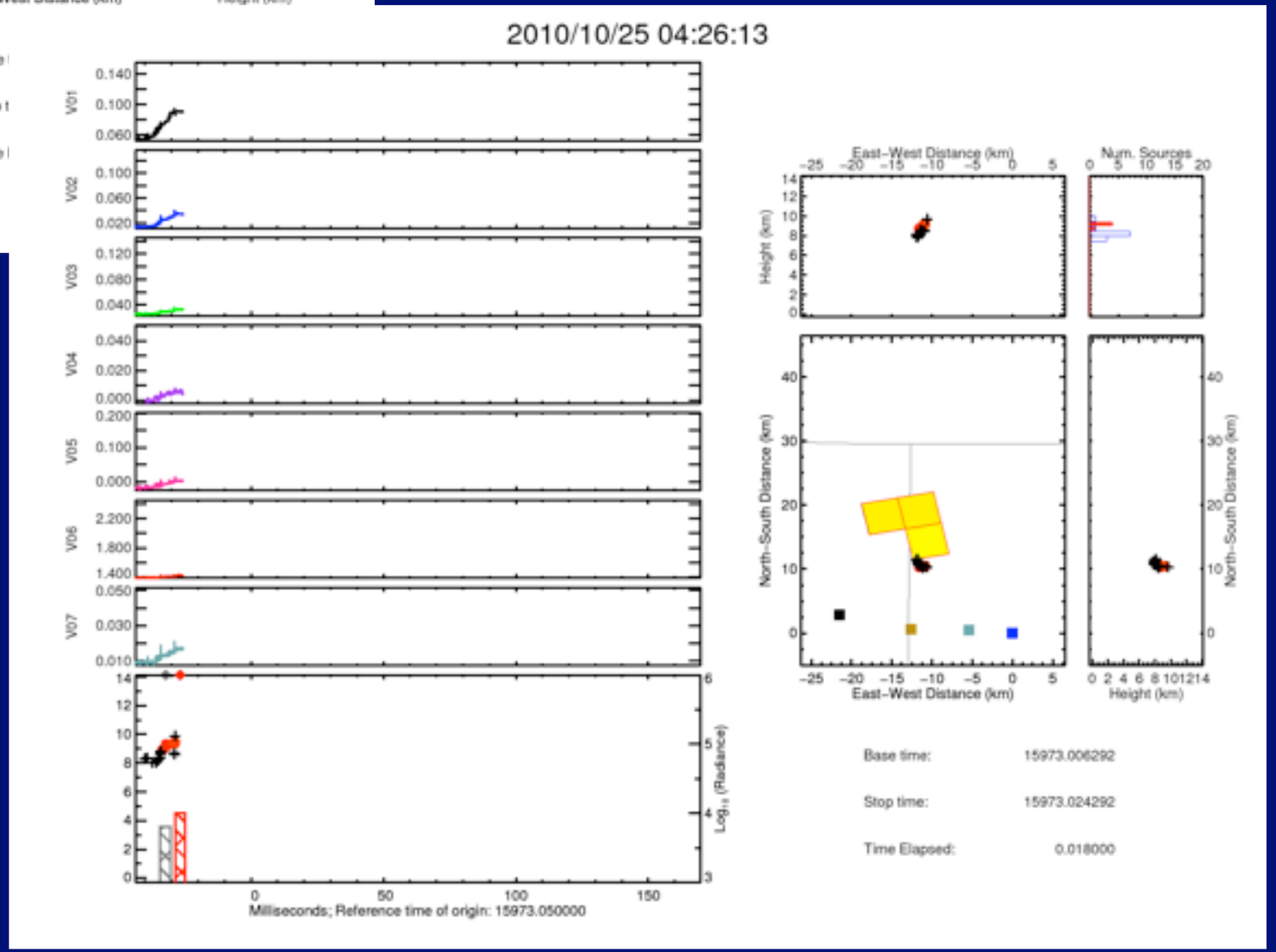
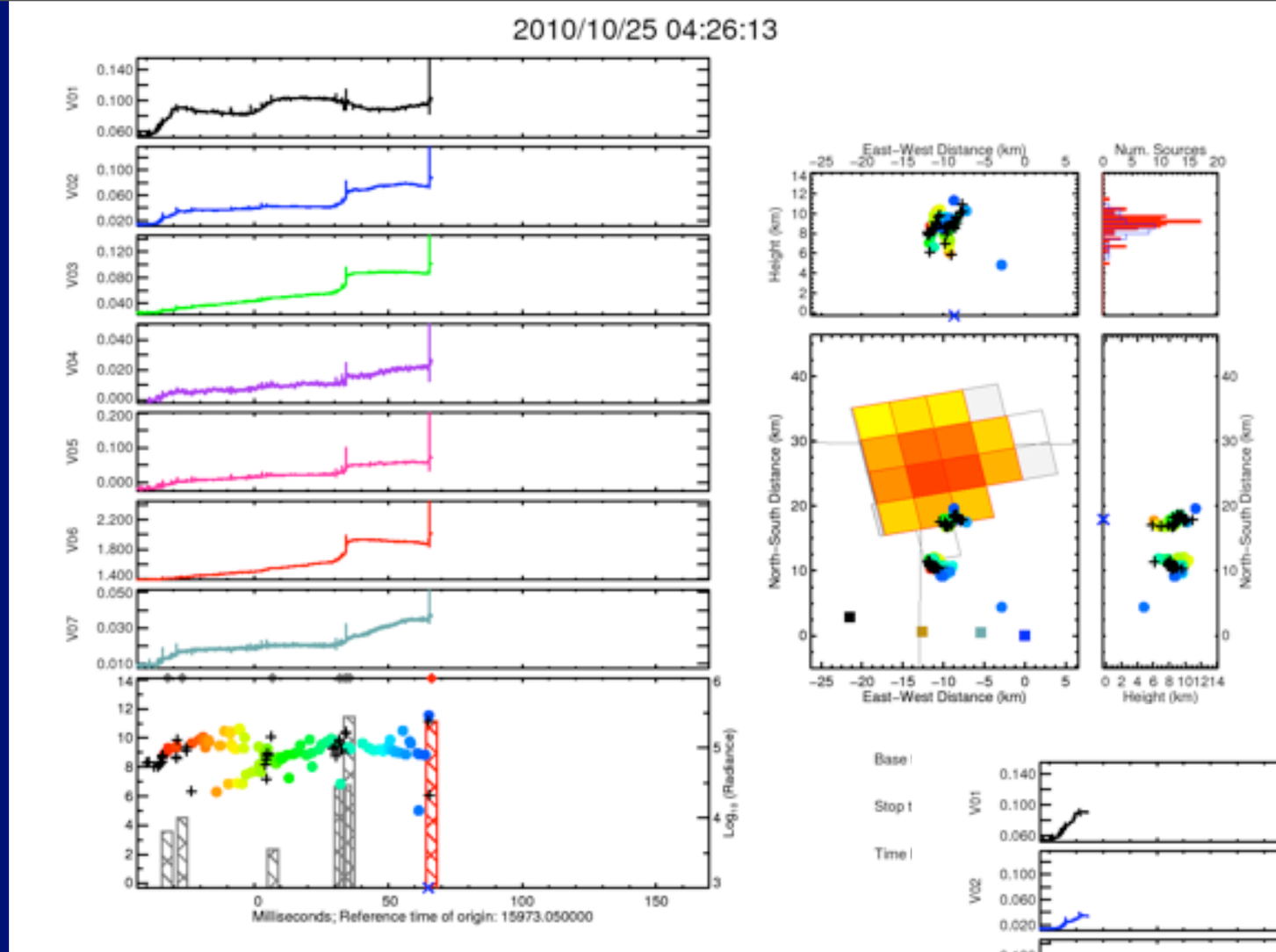
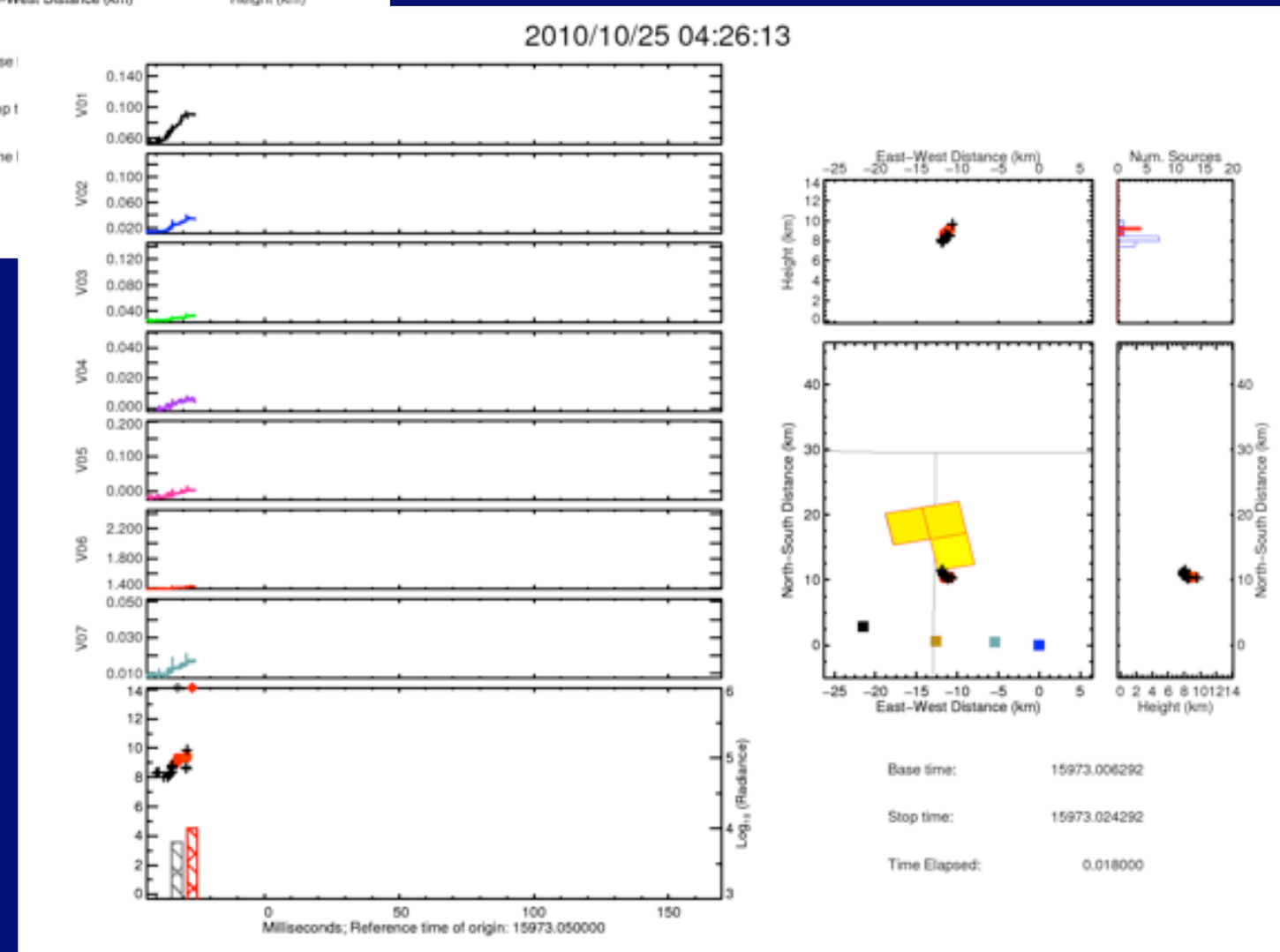
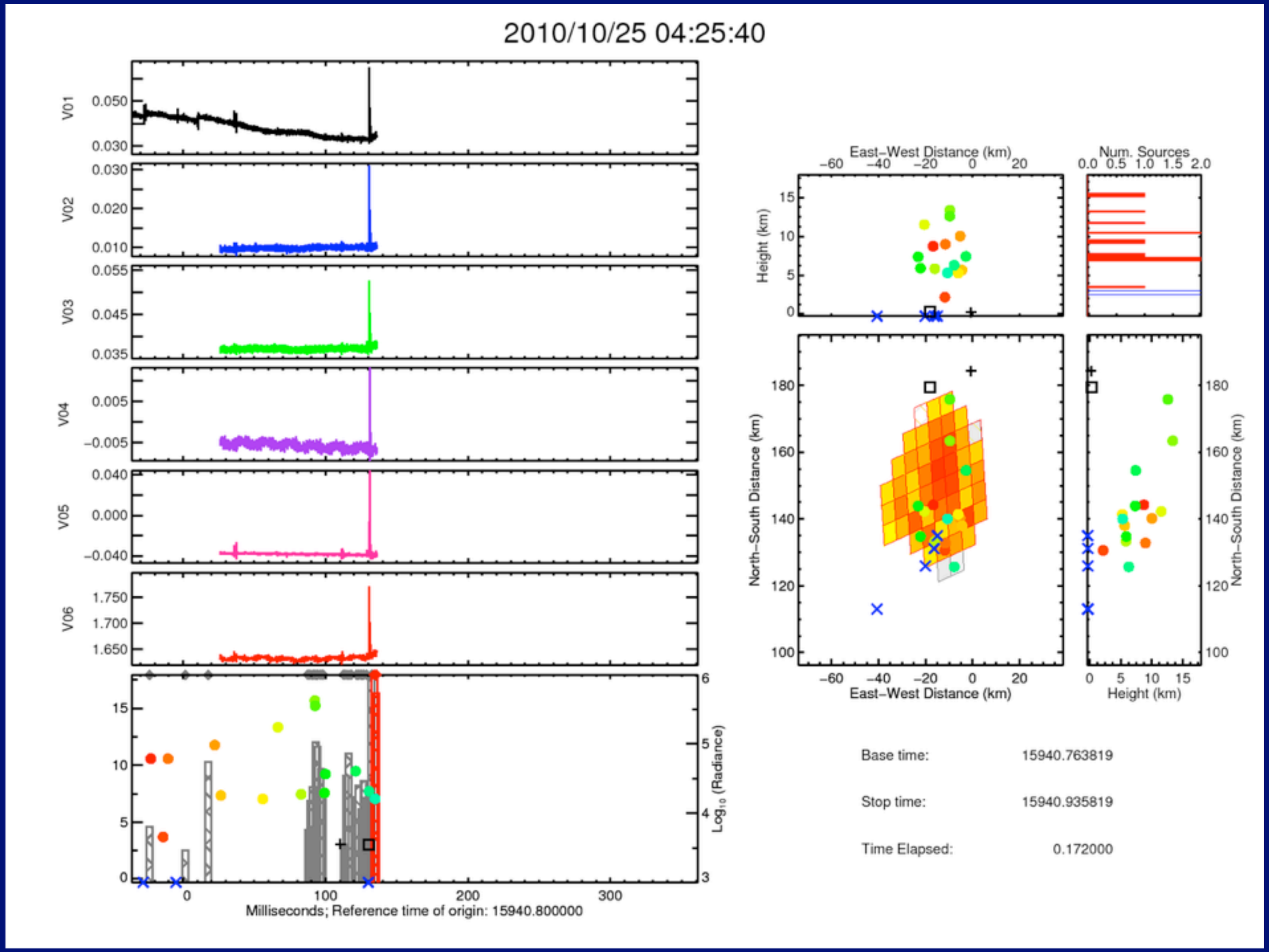


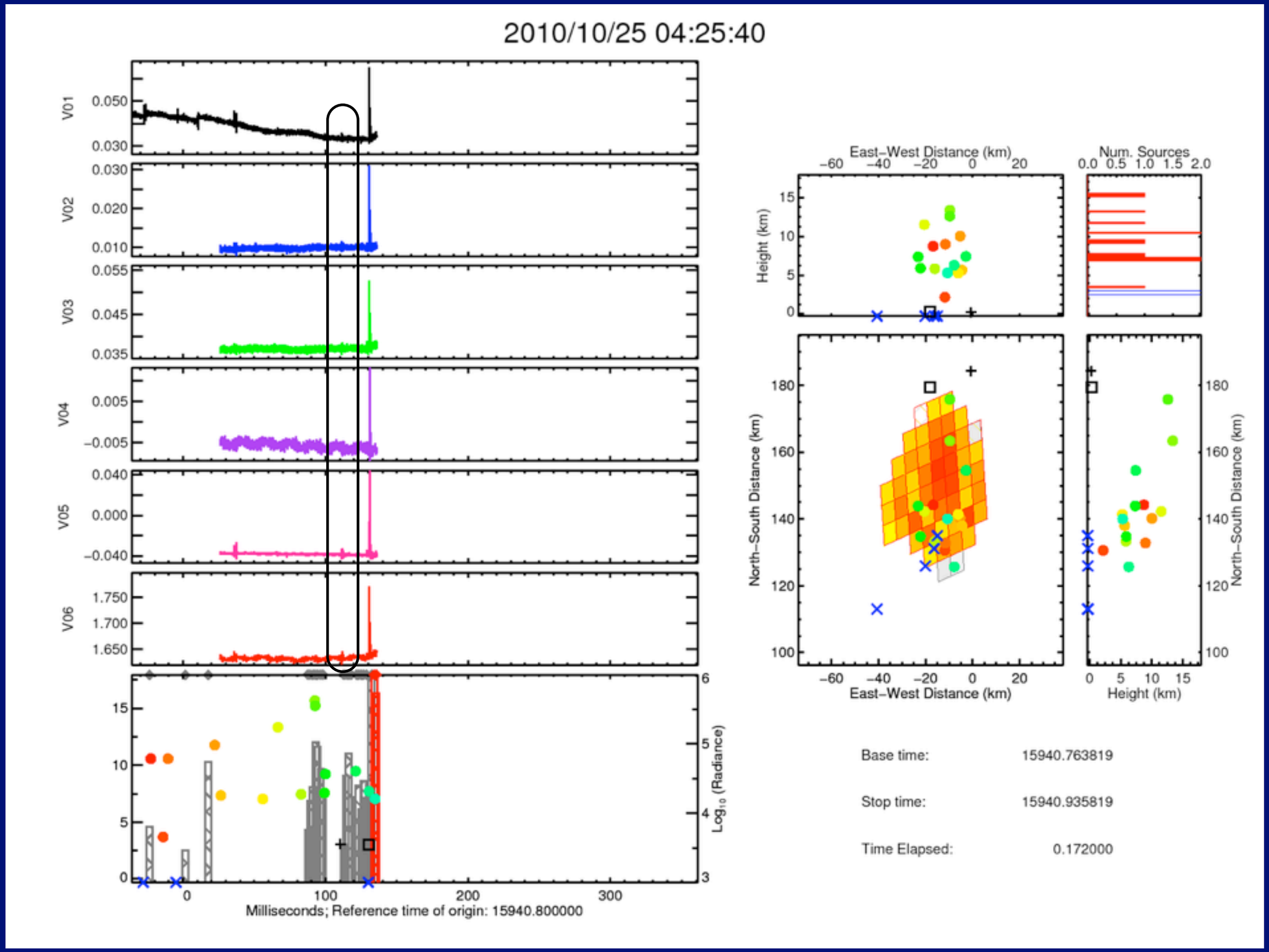


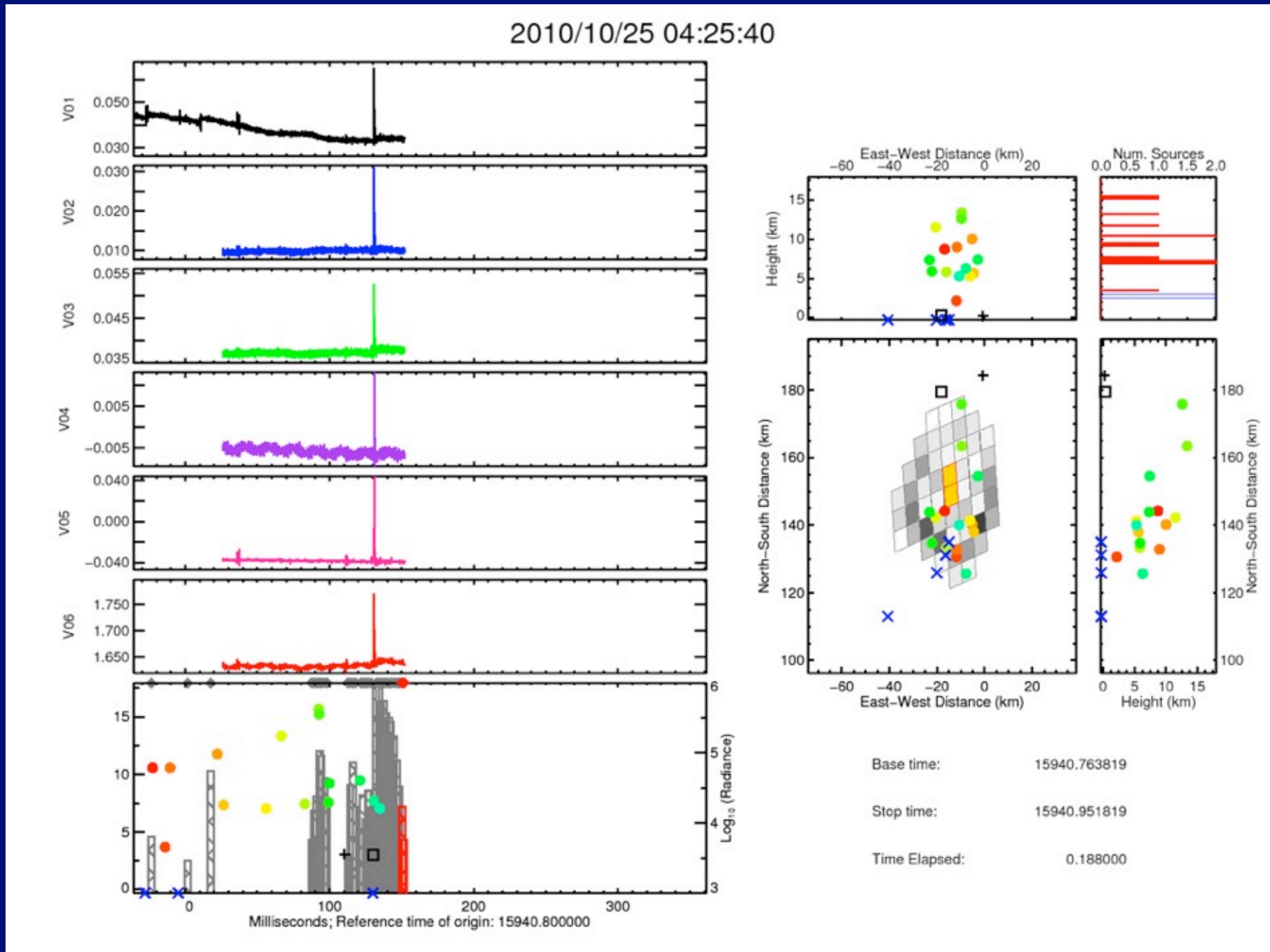
Although each flash has ~same number of LMA sources, the "north" flash is much brighter...

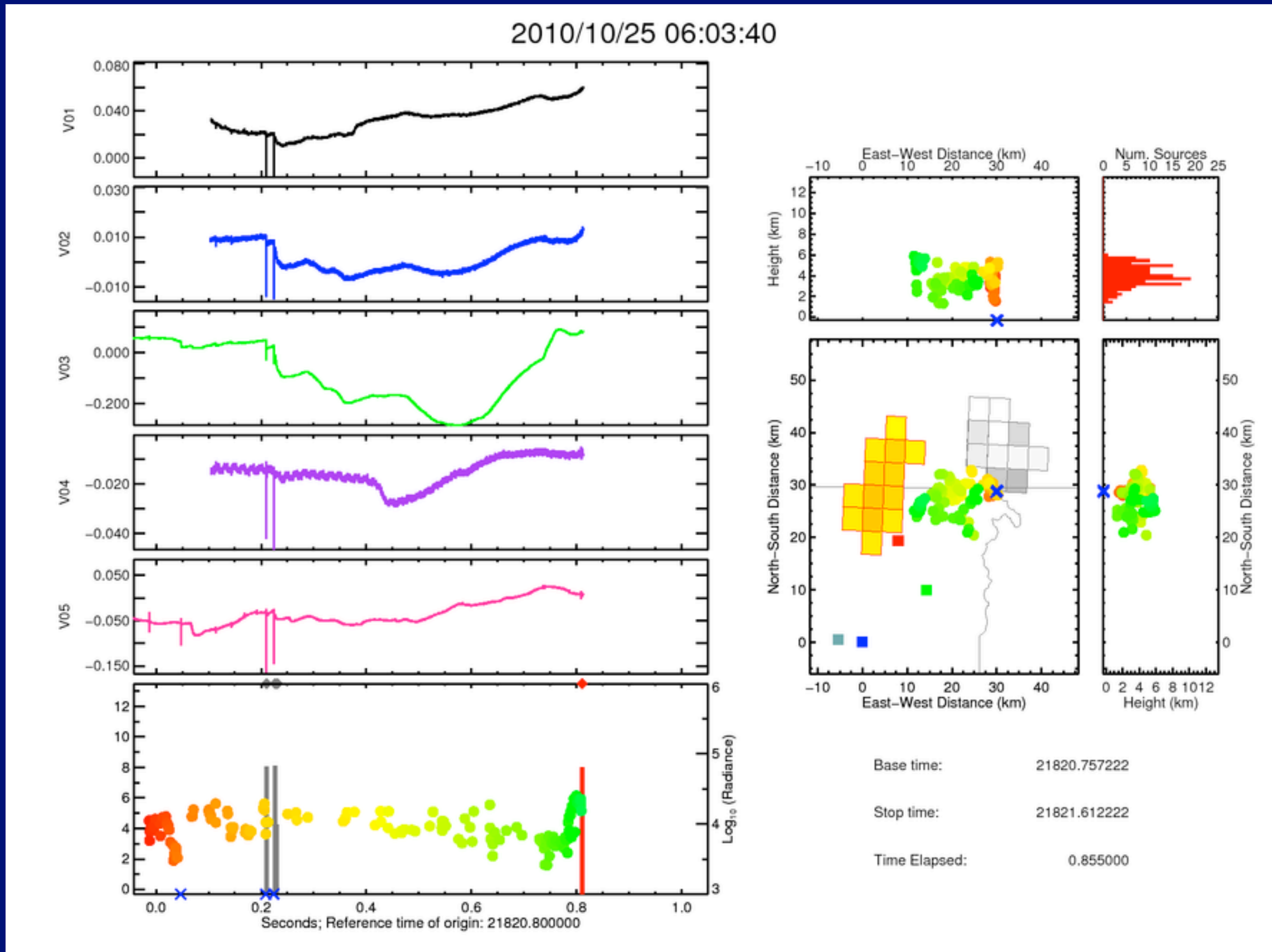
than the "south" flash => much more ***energetic****!*

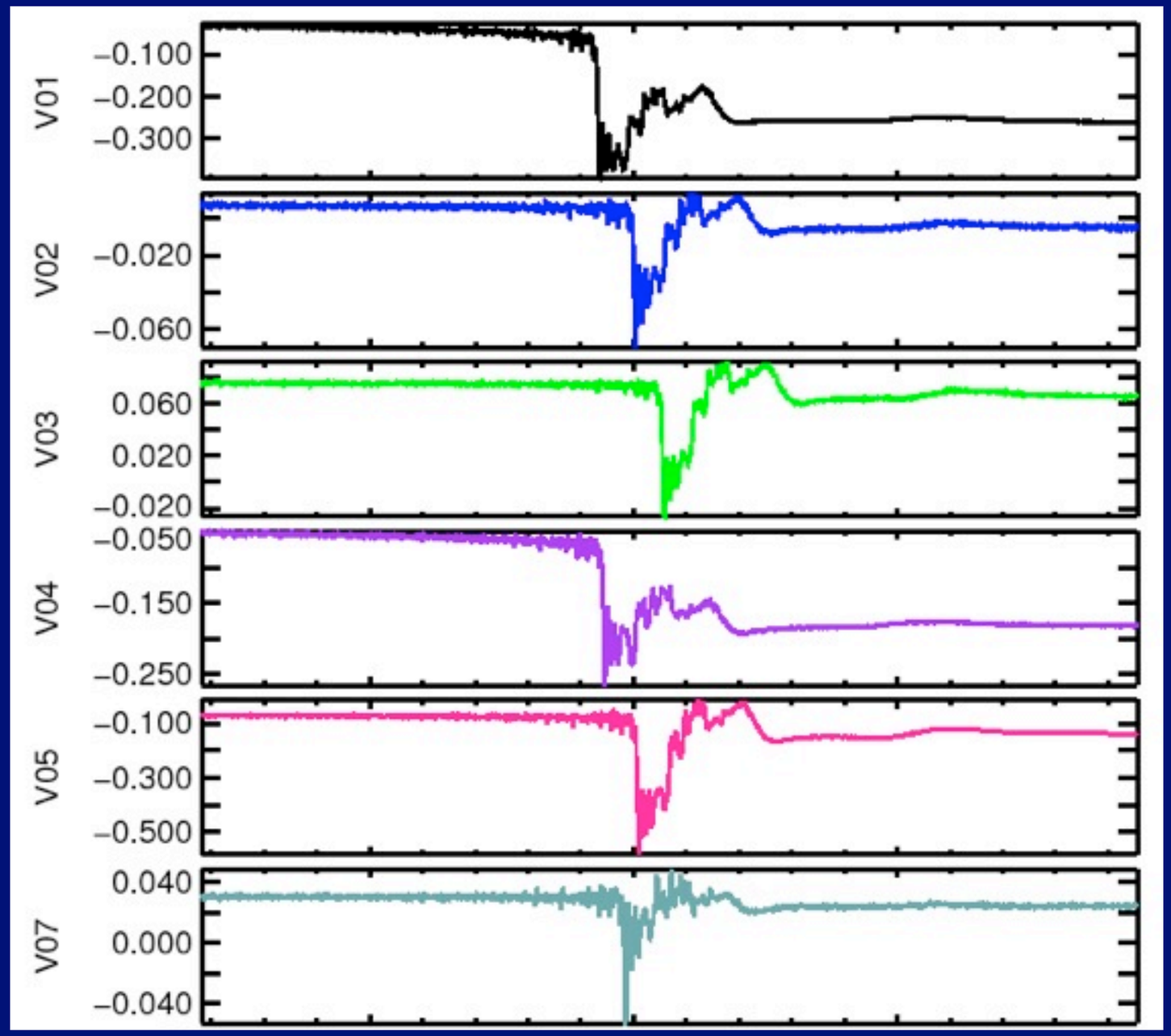


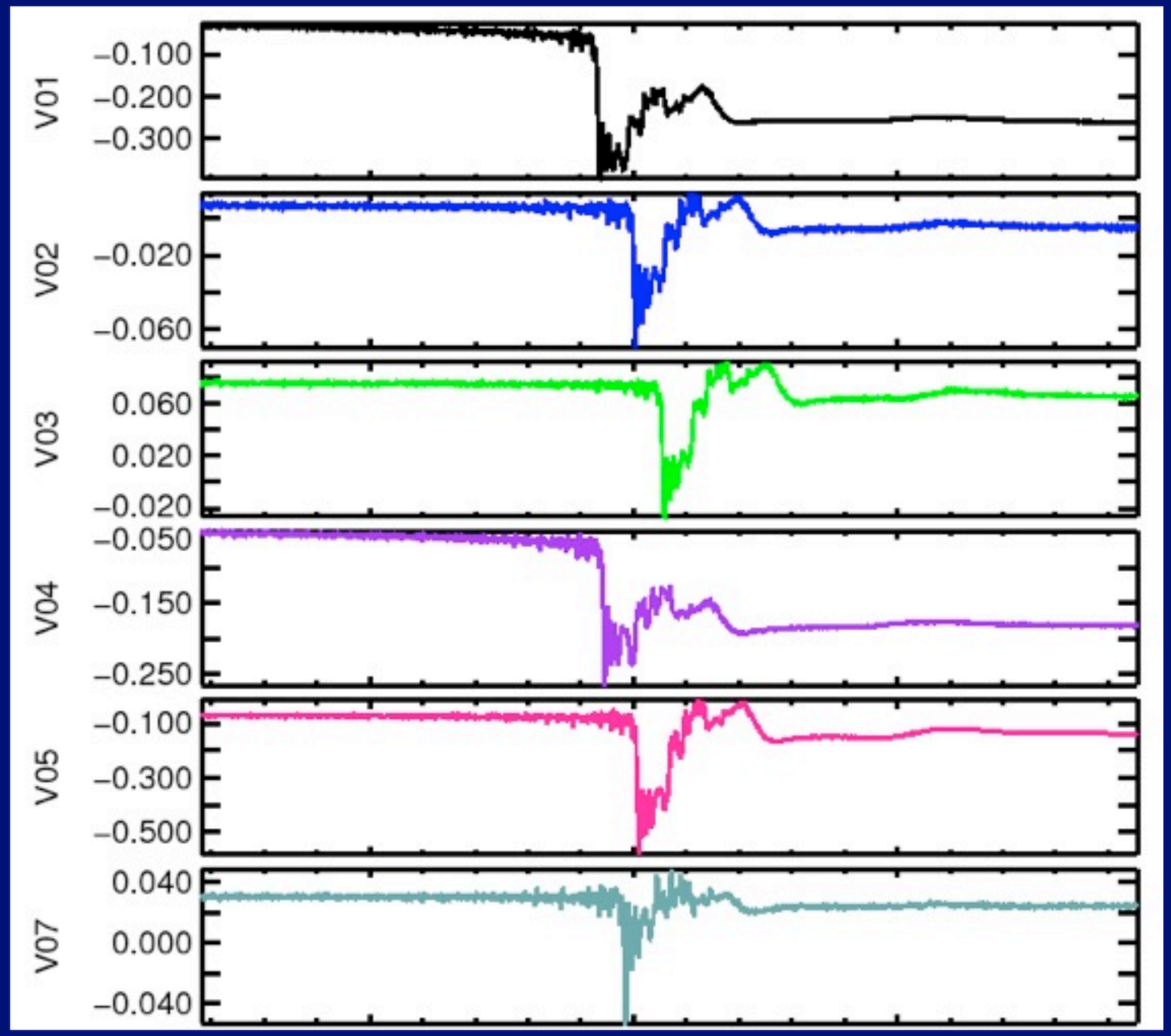

2010/10/25 04:25:40
V01
V02
V03
V04
V05
V06
Milliseconds; Reference time of origin: 15940.800000
Log10 (Radiance)
East–West Distance (km)
Num. Sources
Height (km)
North–South Distance (km)
Base time: 15940.763819
Stop time: 15940.935819
Time Elapsed: 0.172000


2010/10/25 04:25:40
V01
V02
V03
V04
V05
V06
Milliseconds; Reference time of origin: 15940.800000
Log10 (Radiance)
East–West Distance (km)
Num. Sources
Height (km)
North–South Distance (km)
Base time: 15940.763819
Stop time: 15940.935819
Time Elapsed: 0.172000

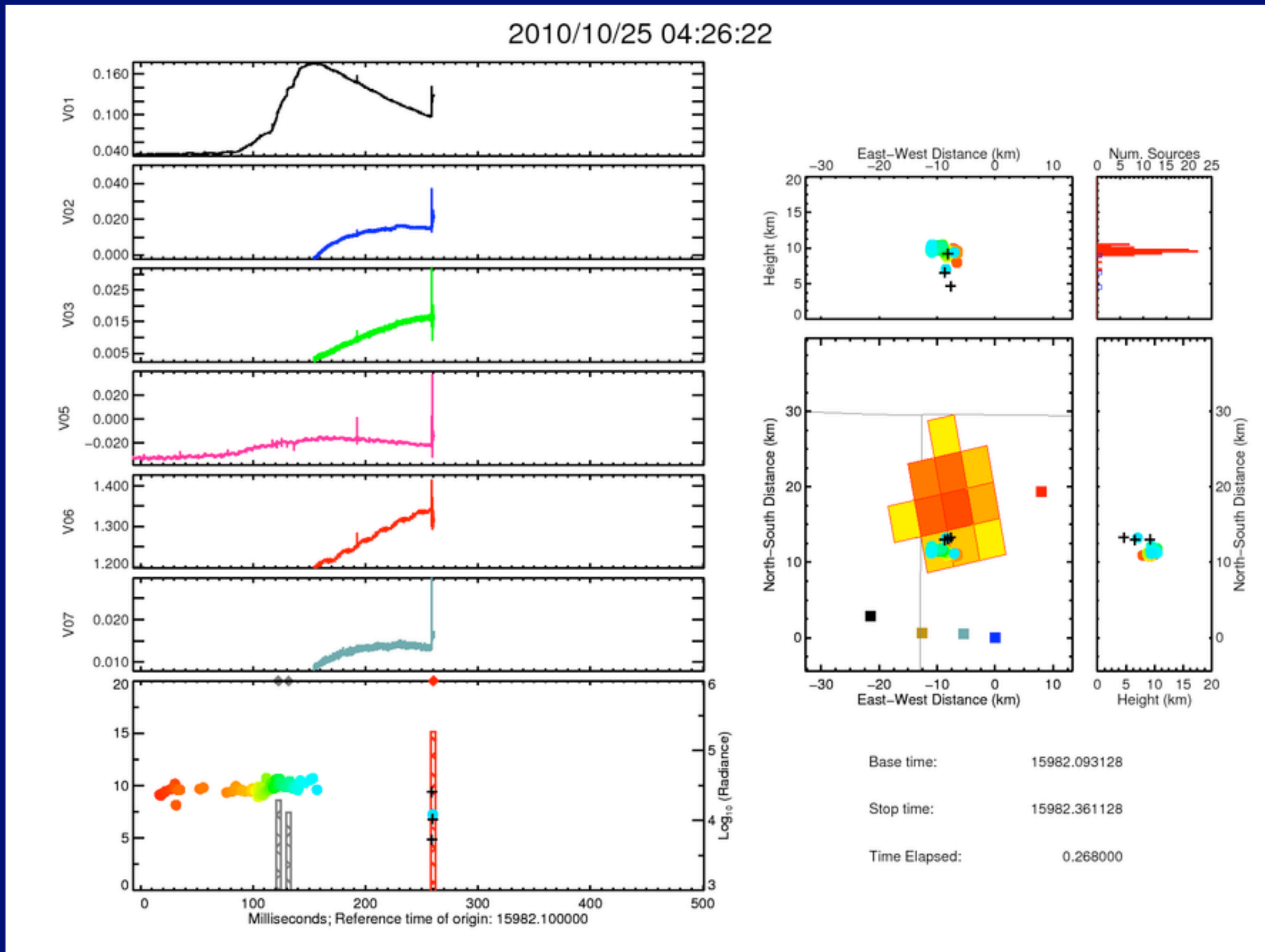

2010/10/25 04:25:40
V01
V02
V03
V04
V05
V06
Log10 (Radiance)
Milliseconds; Reference time of origin: 15940.800000
East–West Distance (km)
Num. Sources
Height (km)
North–South Distance (km)
Base time: 15940.763819
Stop time: 15940.951819
Time Elapsed: 0.188000


2010/10/25 06:03:40
V01
V02
V03
V04
V05
Log10 (Radiance)
Seconds; Reference time of origin: 21820.800000
East–West Distance (km)
Num. Sources
Height (km)
North–South Distance (km)
Base time: 21820.757222
Stop time: 21821.612222
Time Elapsed: 0.855000


V01
−0.100
−0.200
−0.300
V02
−0.020
−0.060
V03
0.060
0.020
−0.020
V04
−0.050
−0.150
−0.250
V05
−0.100
−0.300
−0.500
V07
0.040
0.000
−0.040



Efield suggests this stroke is highly branched!


2010/10/25 04:26:22
V01
V02
V03
V05
V06
V07
Milliseconds; Reference time of origin: 15982.100000
Log10 (Radiance)
East–West Distance (km)
Num. Sources
Height (km)
North–South Distance (km)
Base time: 15982.093128
Stop time: 15982.361128
Time Elapsed: 0.268000

Since LIS/GLM does not detect “flashes,” we must find a way to validate what LIS/GLM does detect.

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Clearly, electric field measurements are better correlated to these optical events...

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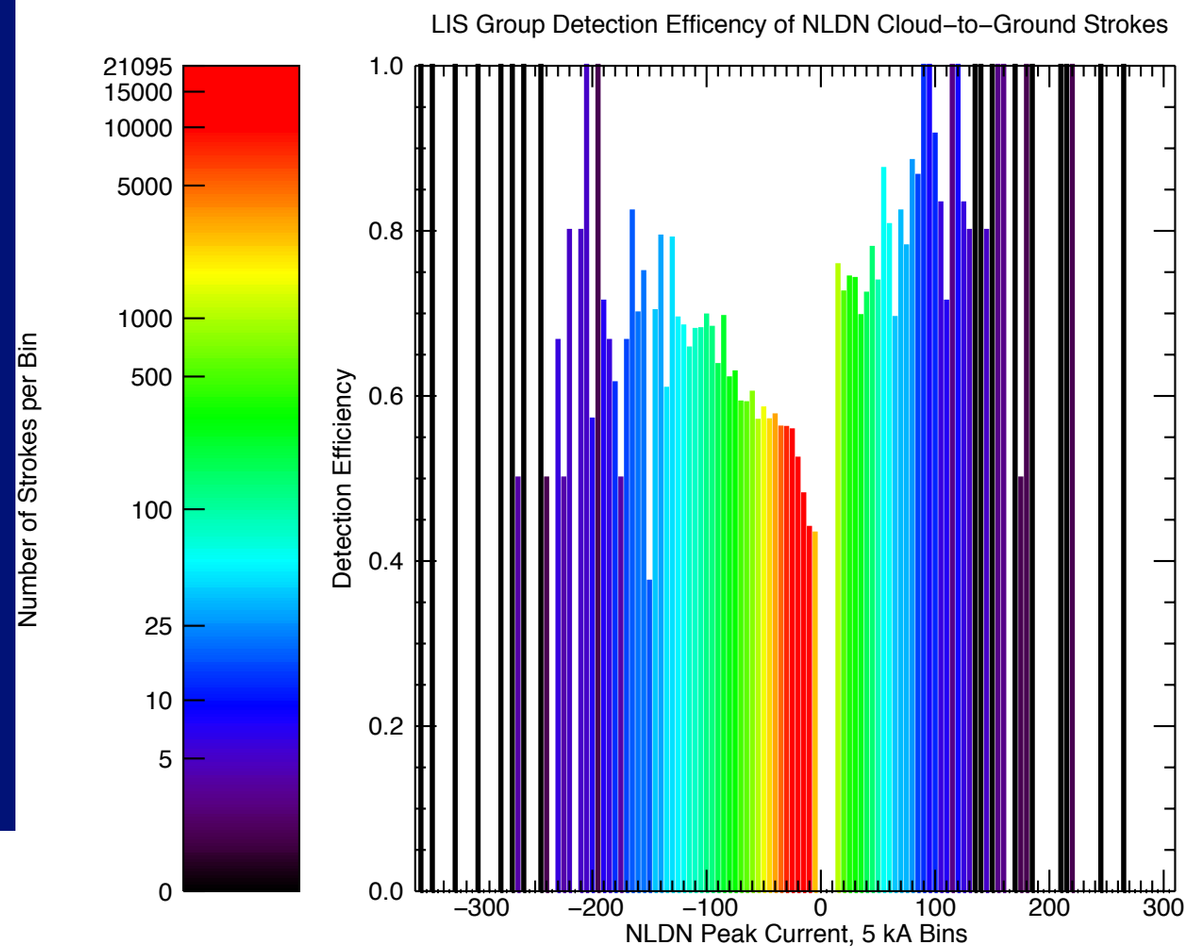
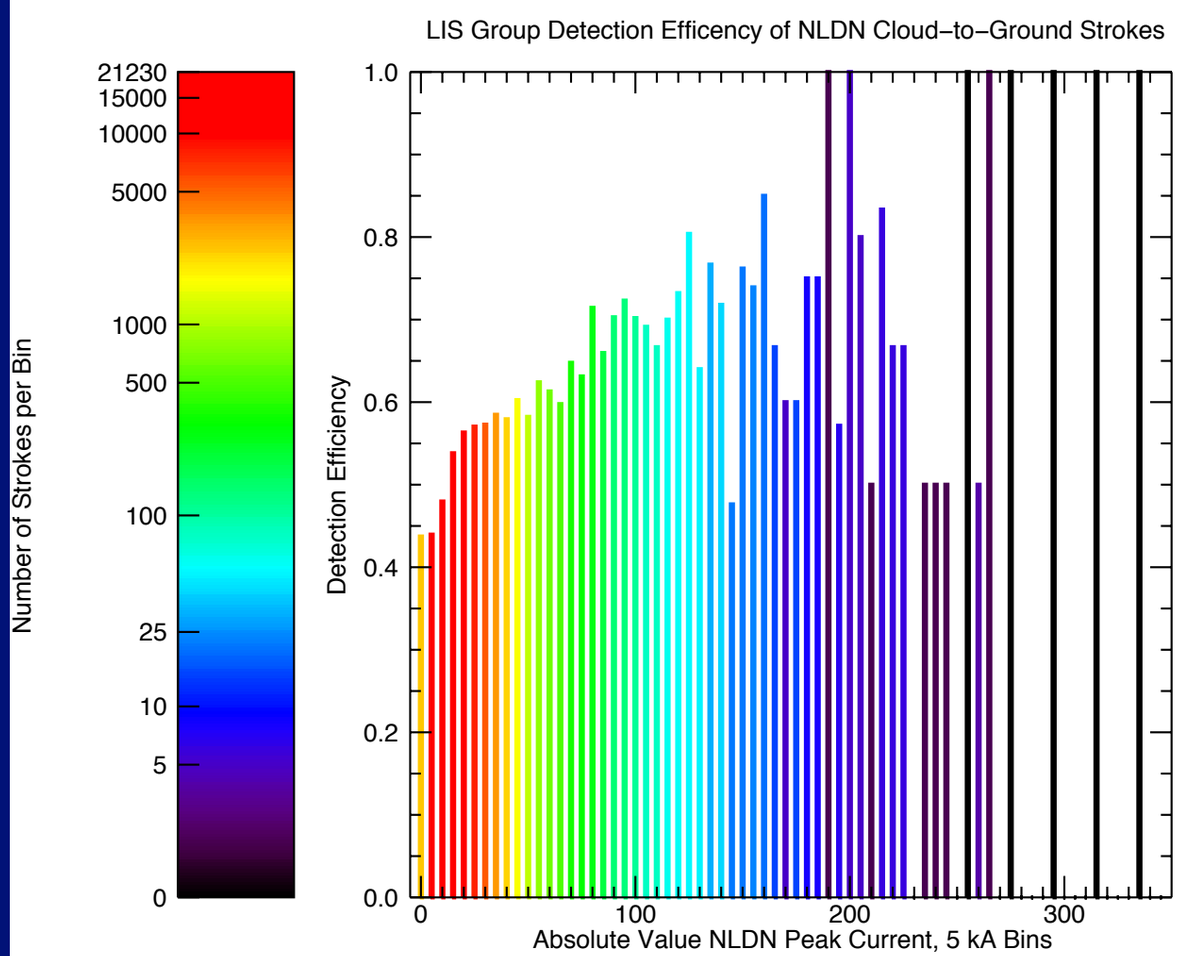
Clearly, electric field measurements are better correlated to these optical events...

and even suggest what features LIS can successfully detect!

Surface from the "deep dive"....





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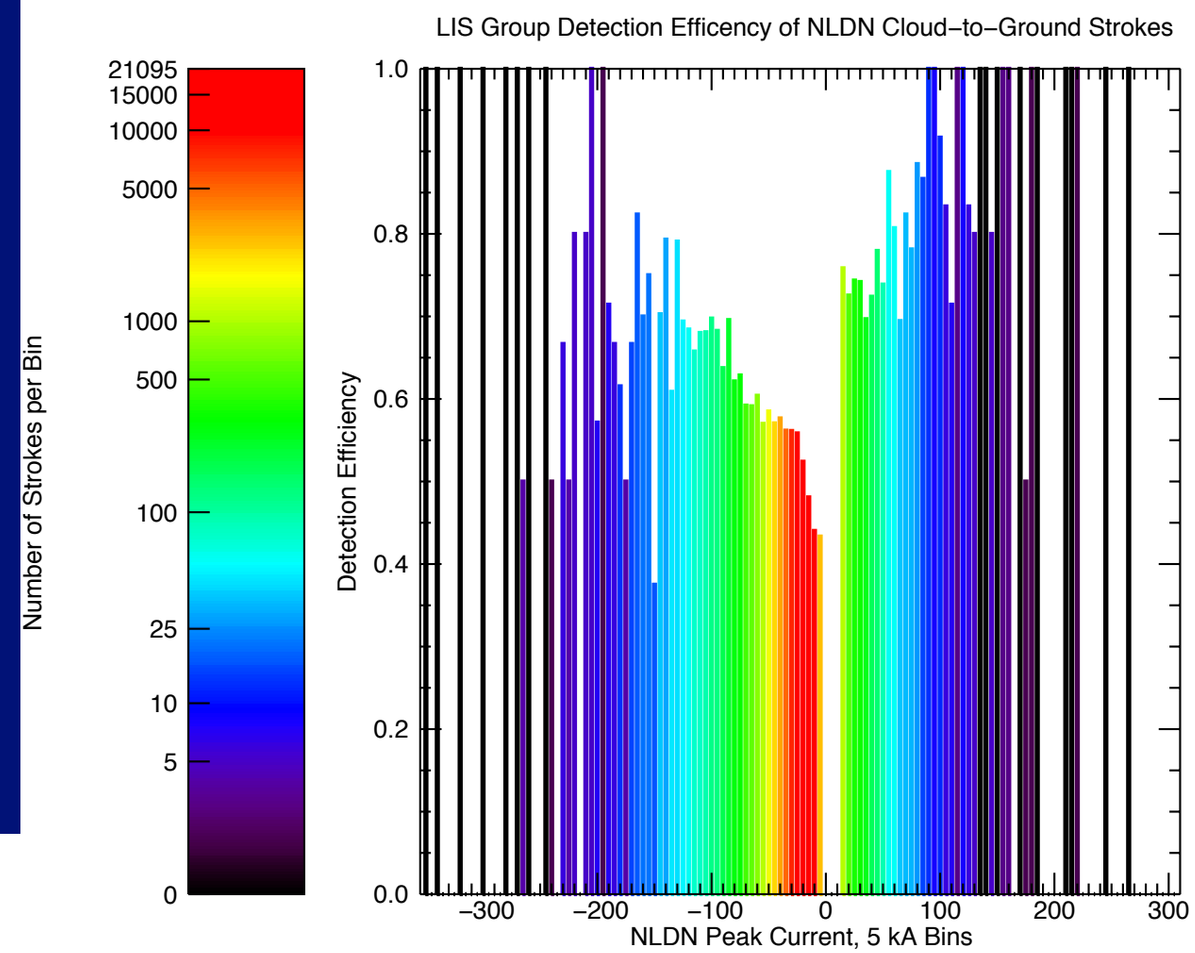
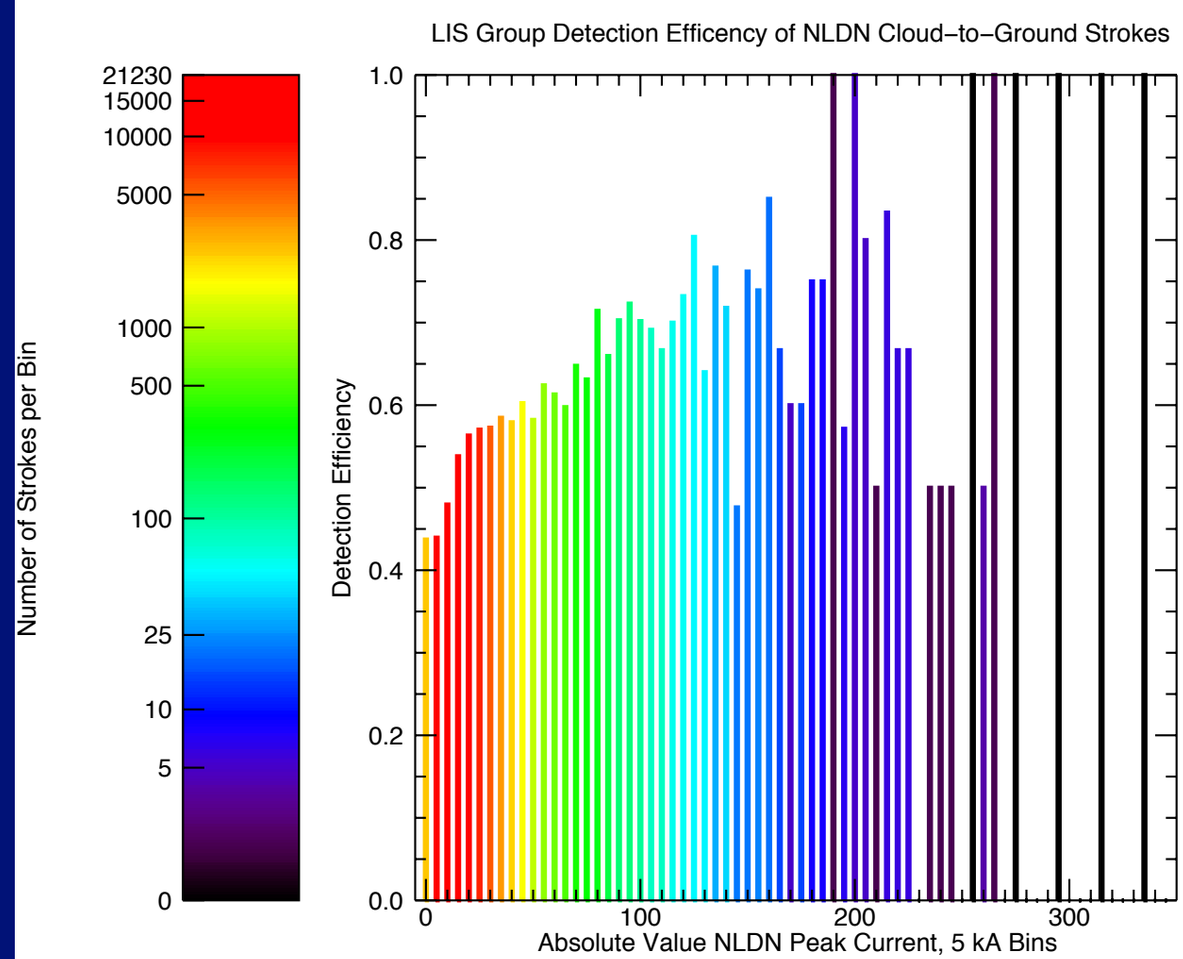
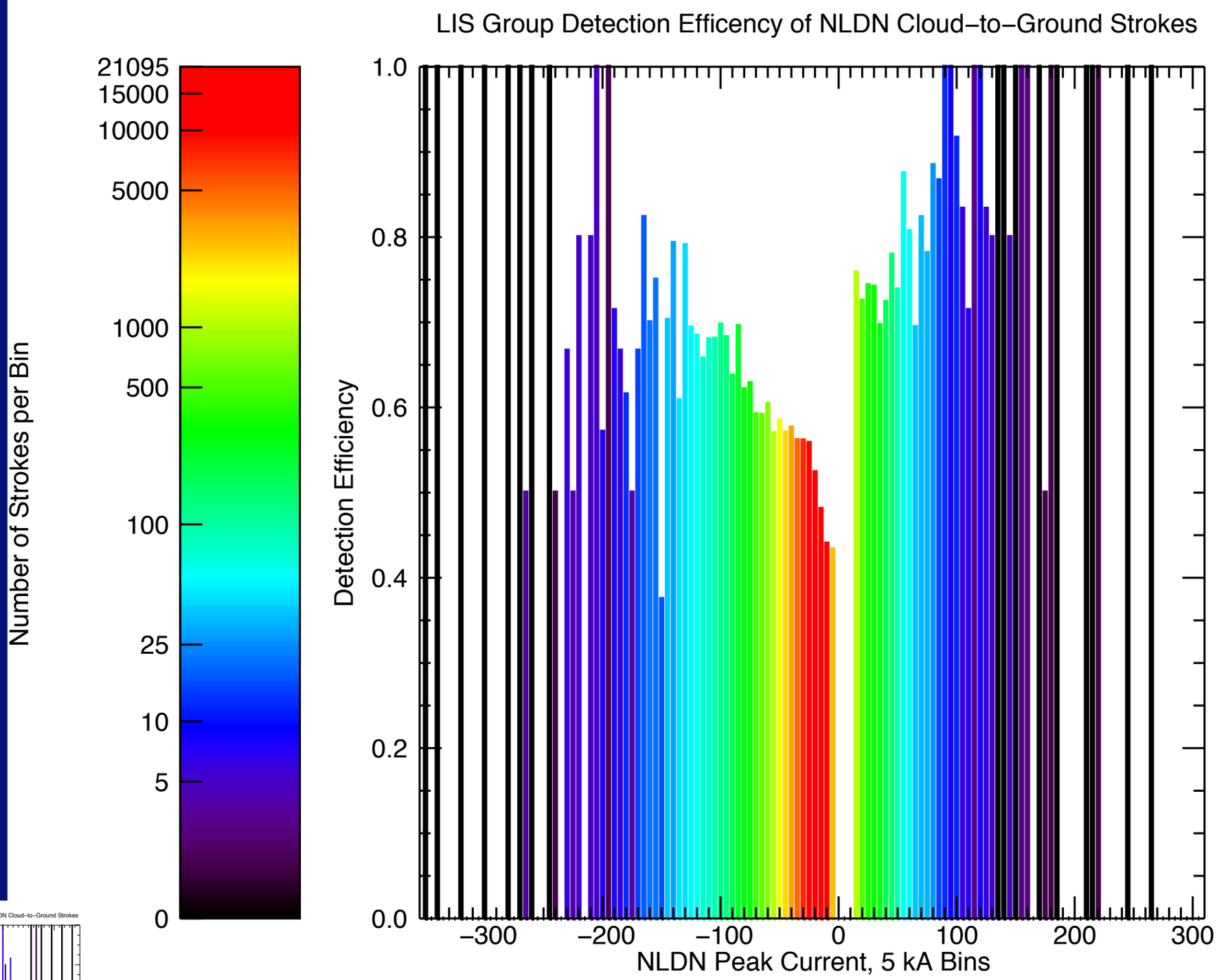
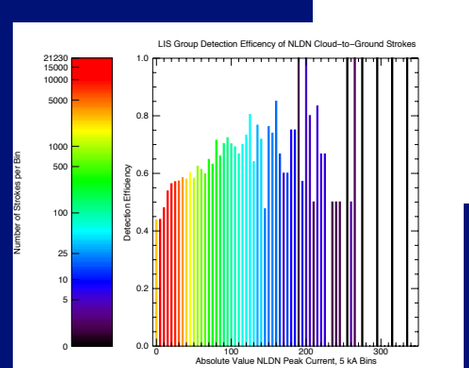
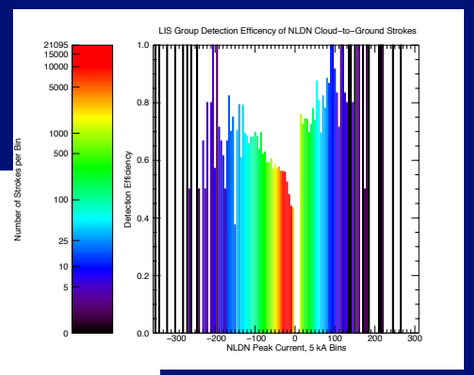


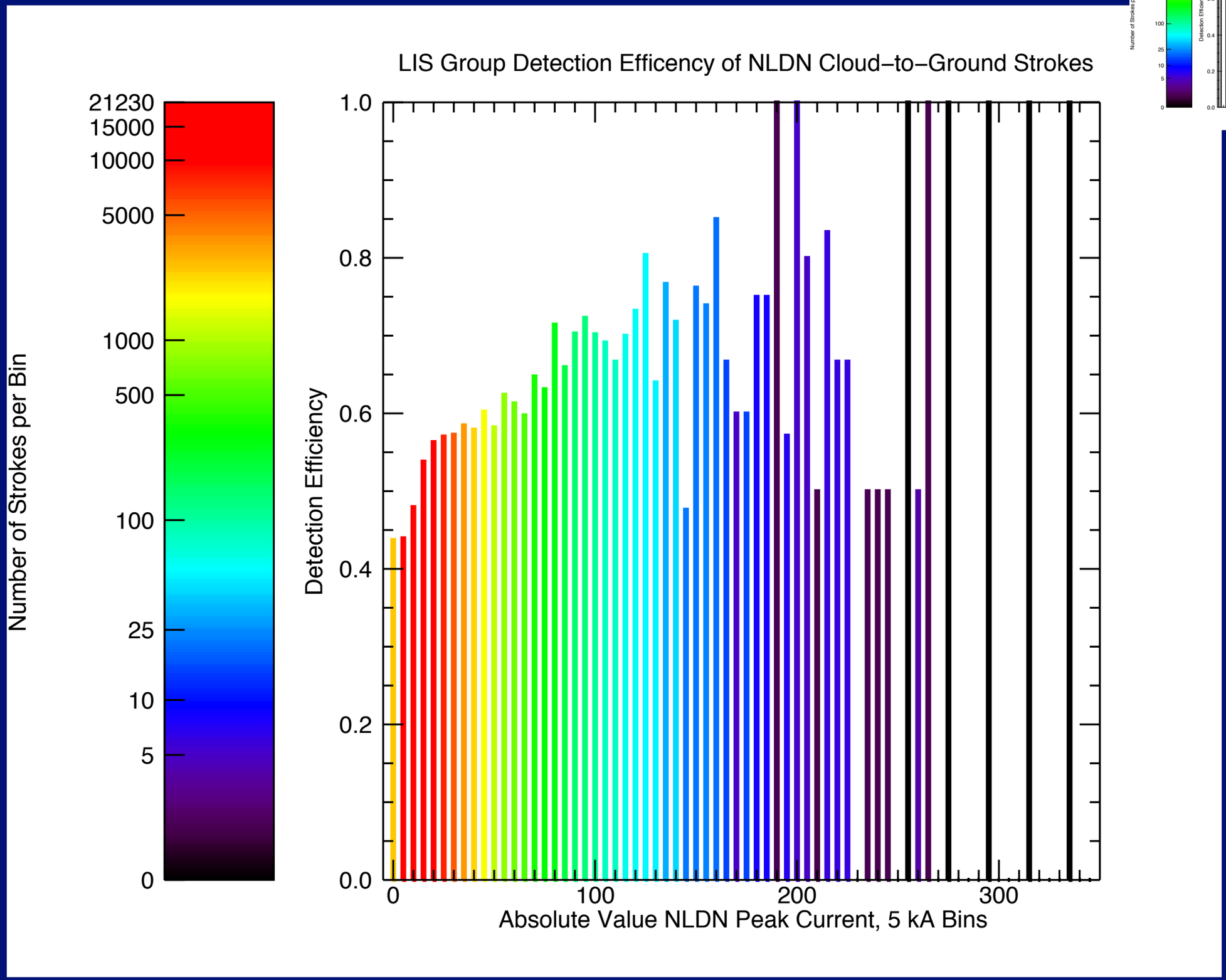


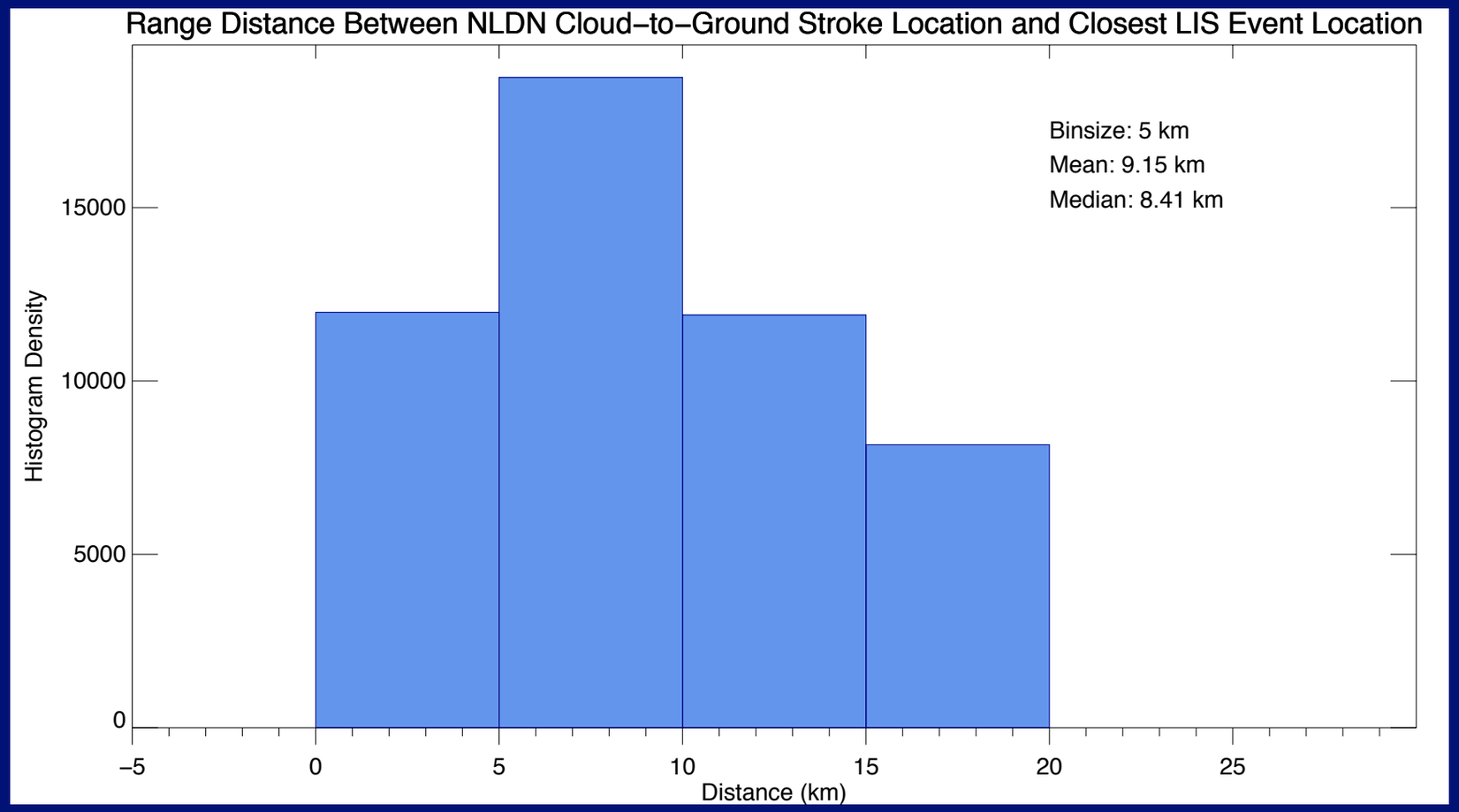
How often does LIS detect a return stroke... on a large scale?


LIS Group Detection Efficency of NLDN Cloud–to–Ground Strokes
Number of Strokes per Bin
21095
15000
10000
5000
1000
500
100
25
10
5
0
Detection Efficiency
1.0
0.8
0.6
0.4
0.2
0.0
–300
–200
–100
0
100
200
300
NLDN Peak Current, 5 kA Bins

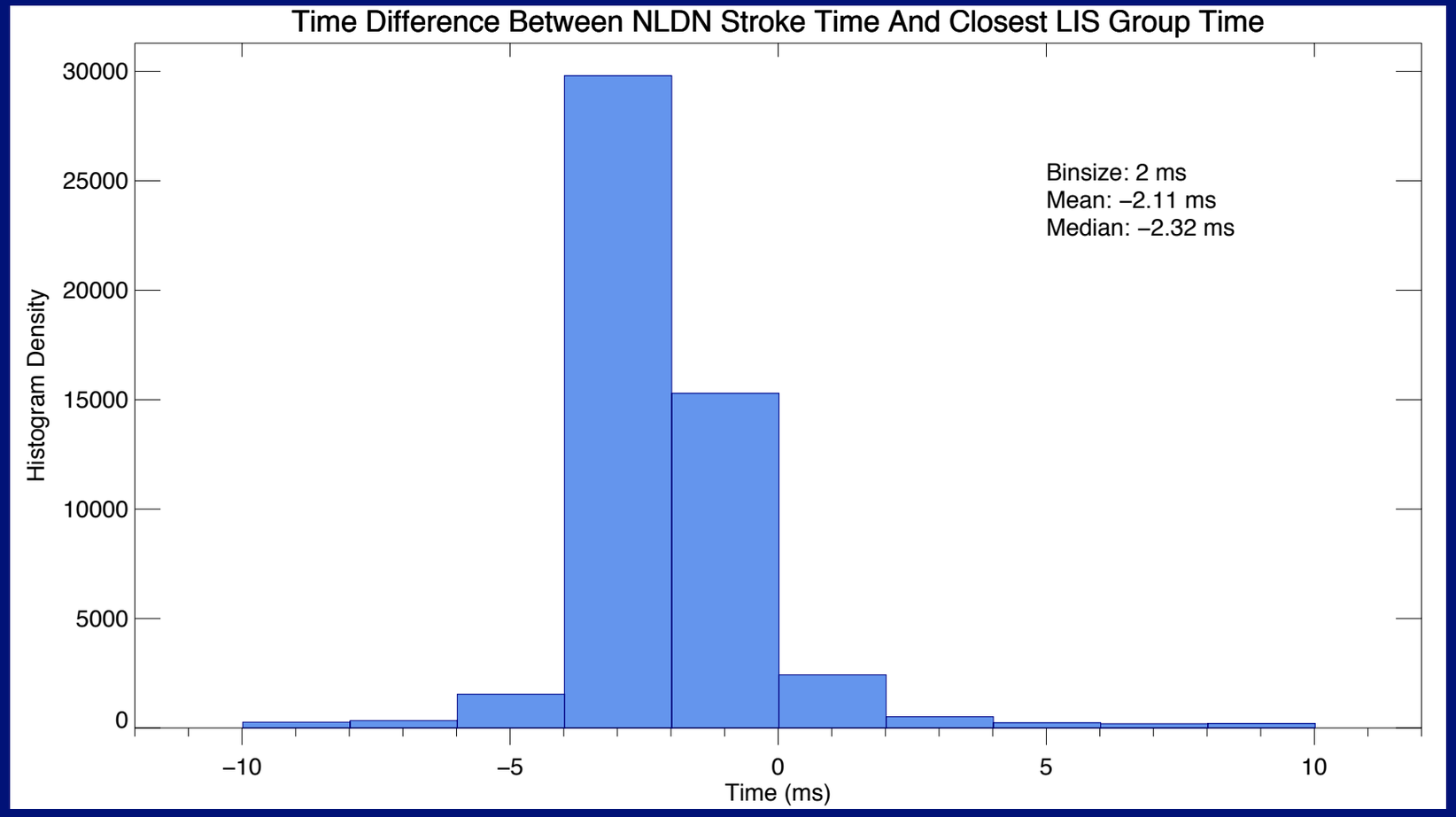

LIS Group Detection Efficency of NLDN Cloud–to–Ground Strokes
Absolute Value NLDN Peak Current, 5 kA Bins

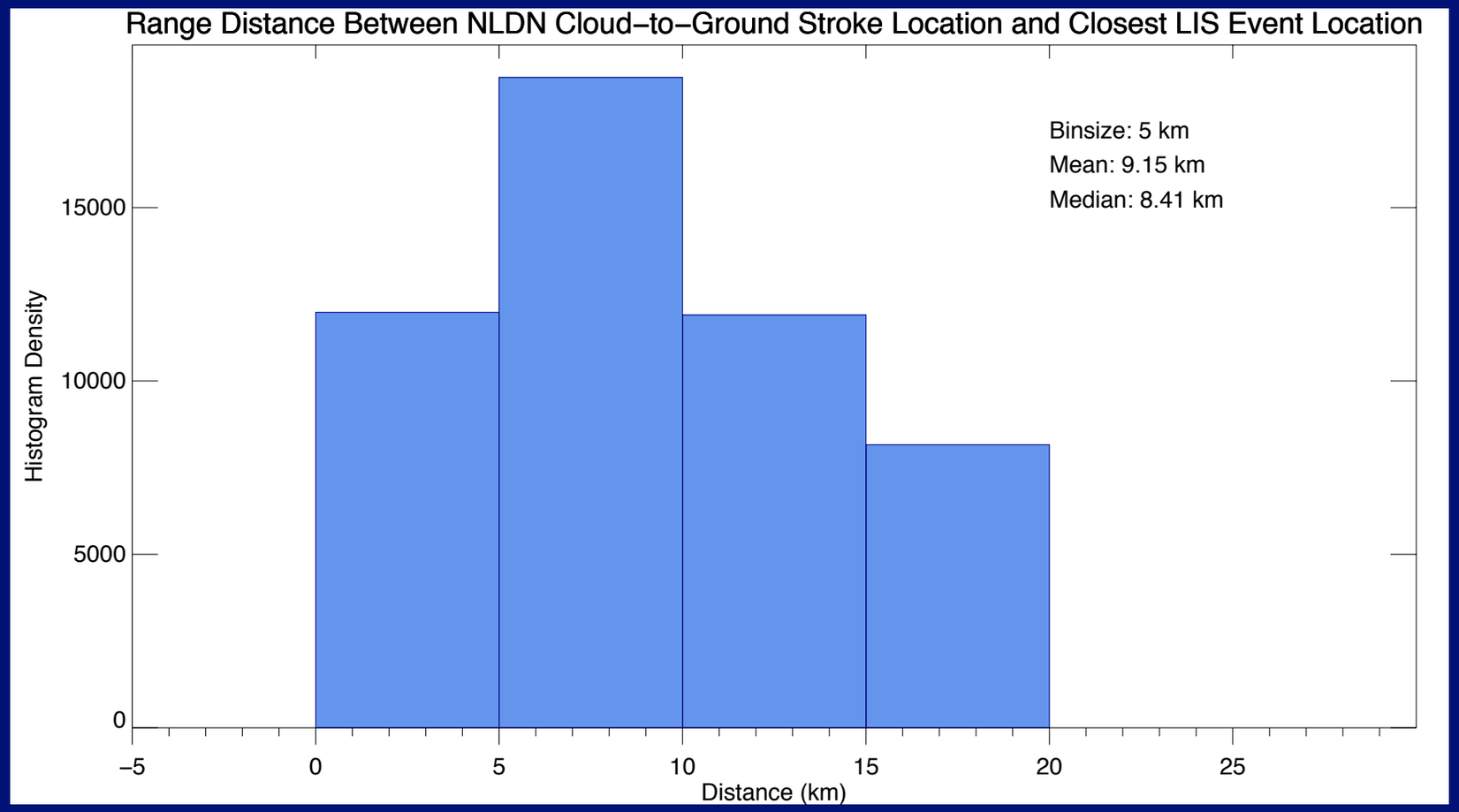

LIS Group Detection Efficency of NLDN Cloud−to−Ground Strokes
Number of Strokes per Bin
Detection Efficiency
NLDN Peak Current, 5 kA Bins


LIS Group Detection Efficency of NLDN Cloud−to−Ground Strokes
Number of Strokes per Bin
21230
15000
10000
5000
1000
500
100
25
10
5
0
Detection Efficiency
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
Absolute Value NLDN Peak Current, 5 kA Bins

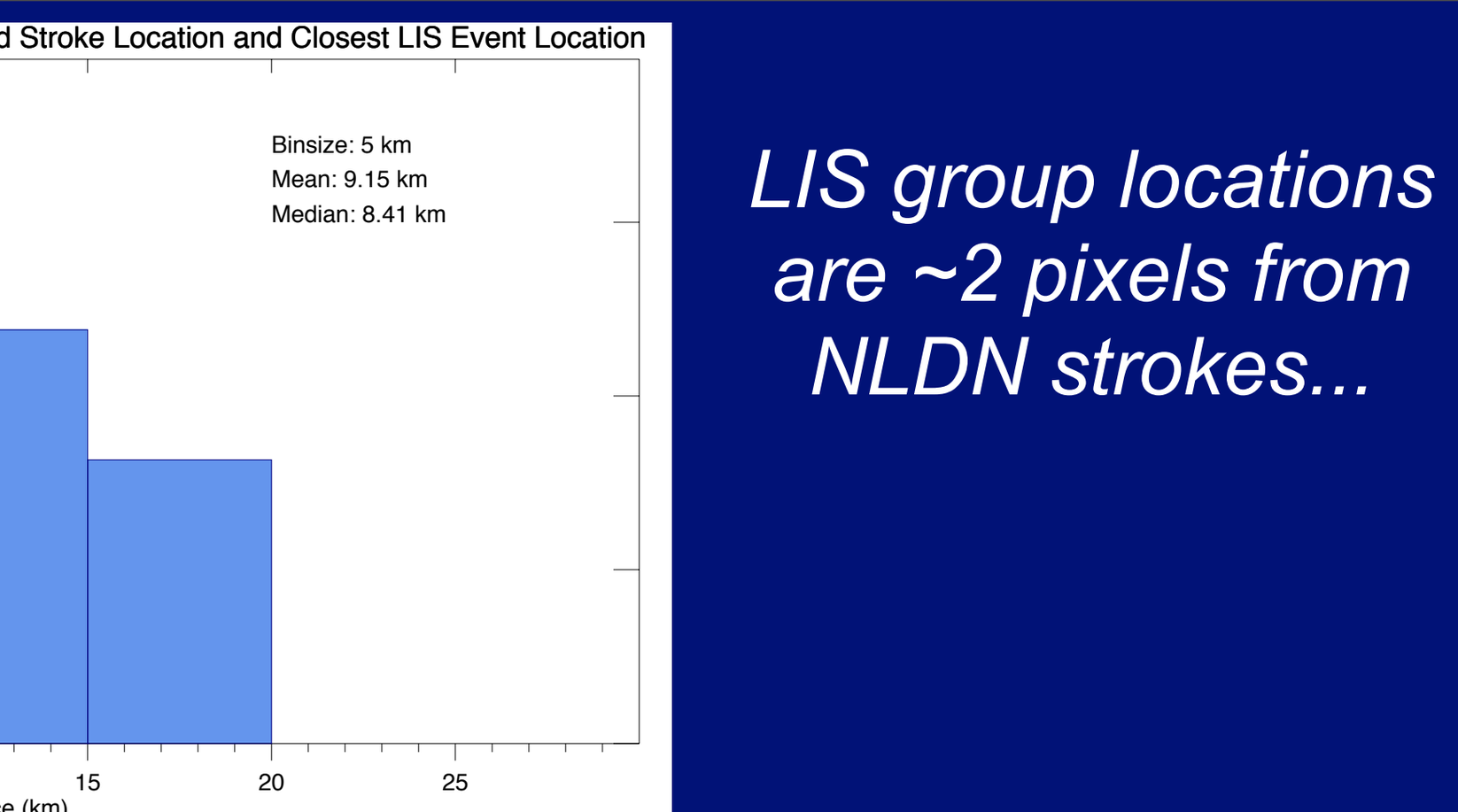


LIS group locations are ~2 pixels from NLDN strokes...



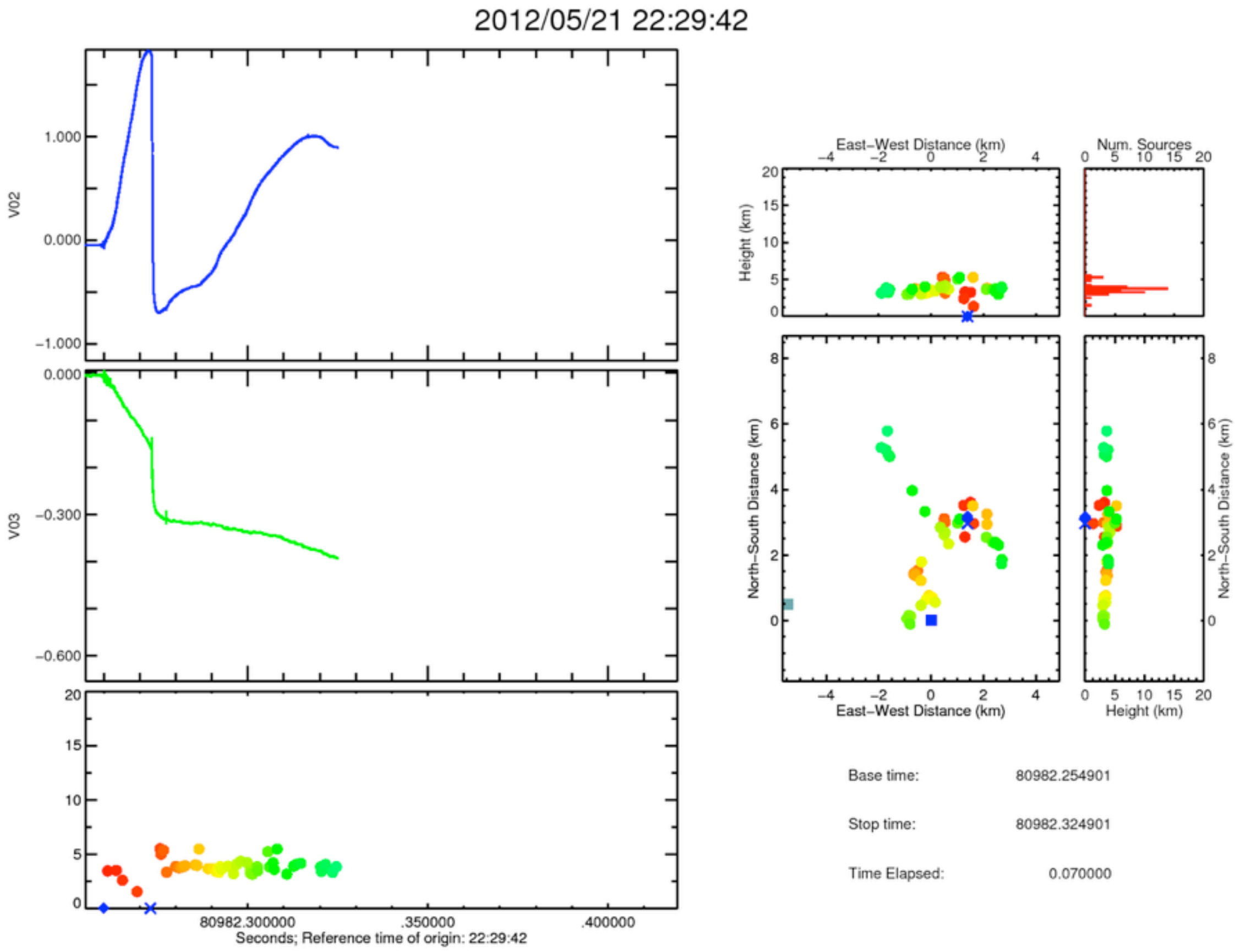


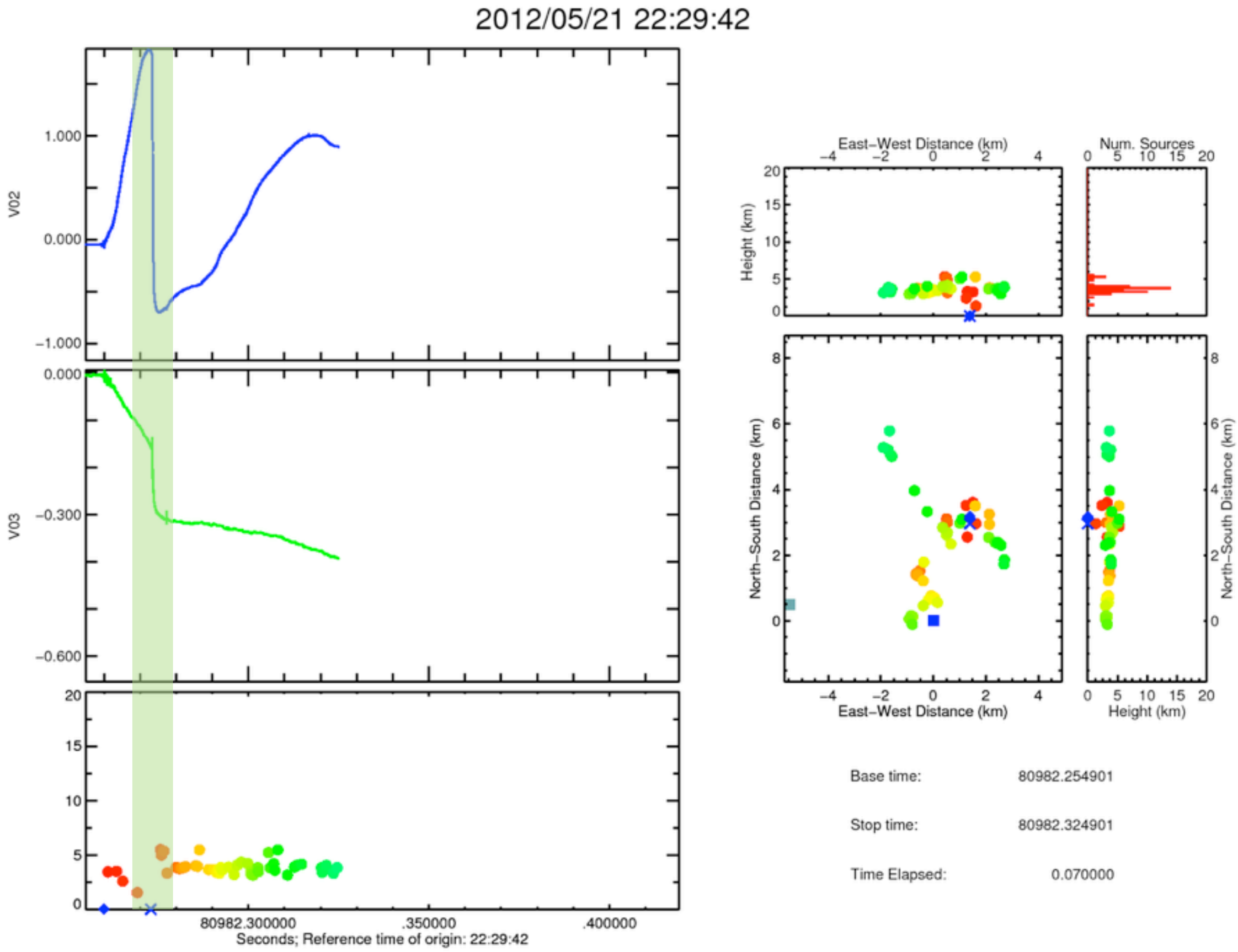
LIS group locations are ~2 pixels from NLDN strokes...

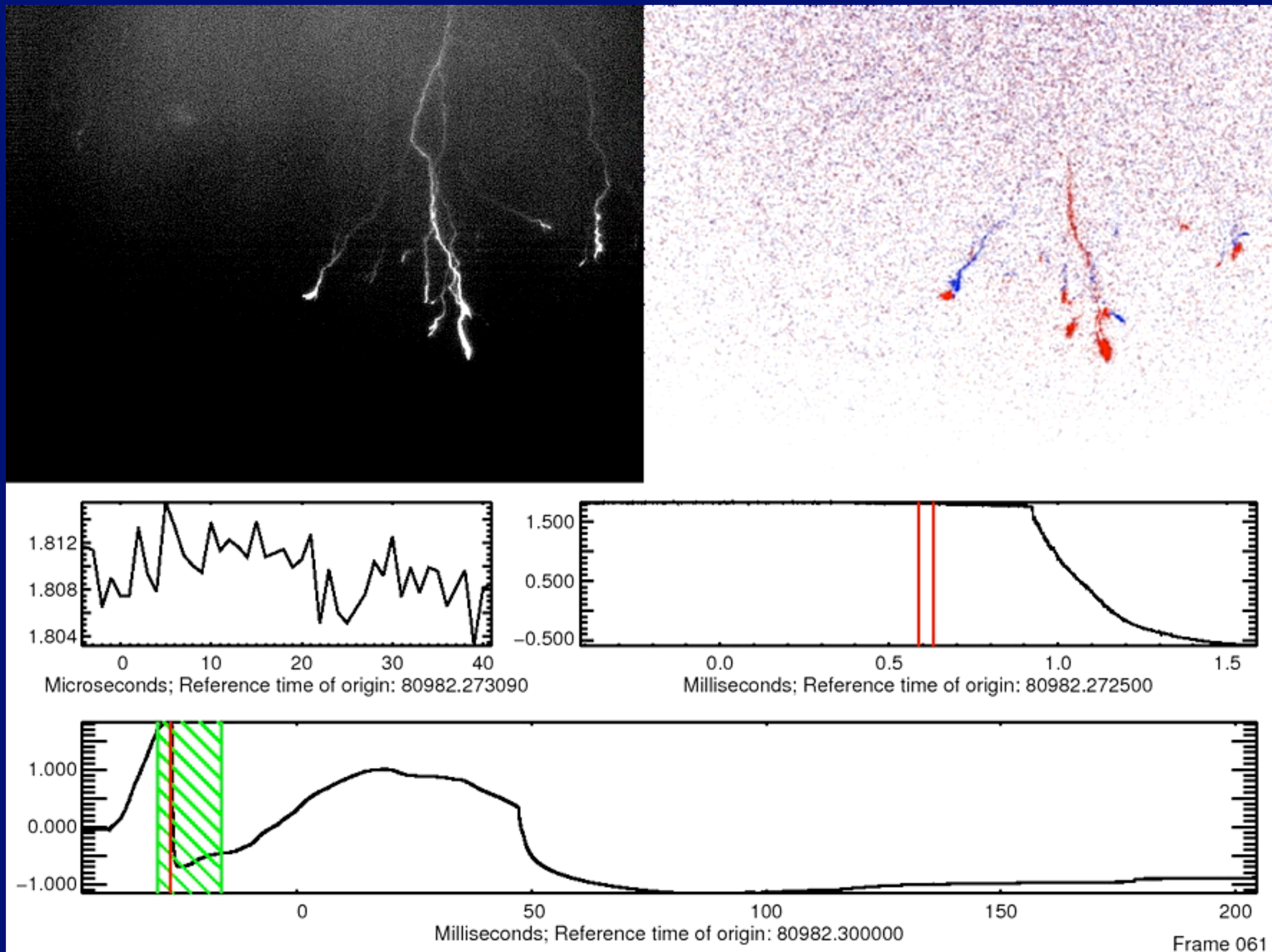


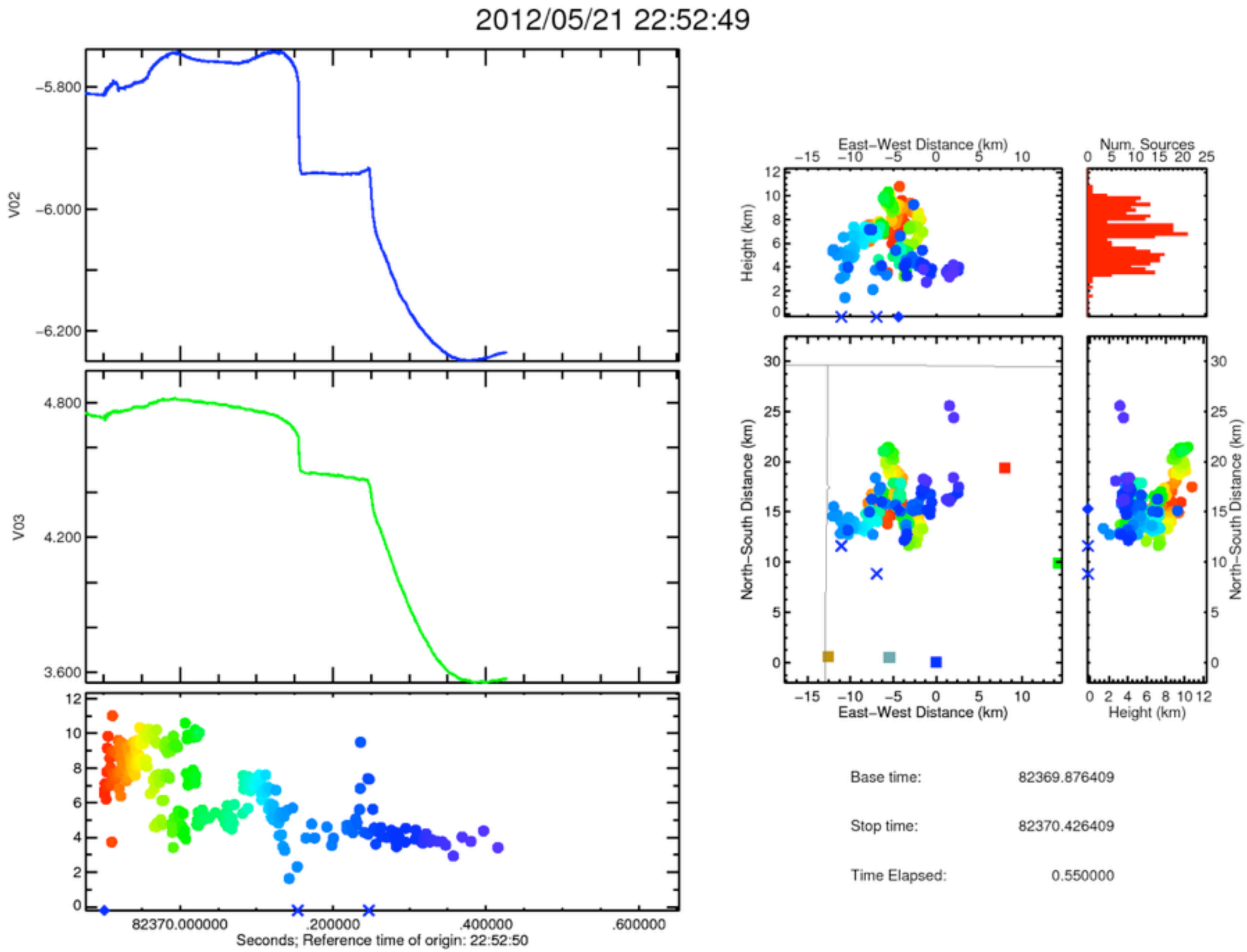
and occur within two frames of the NLDN stroke!

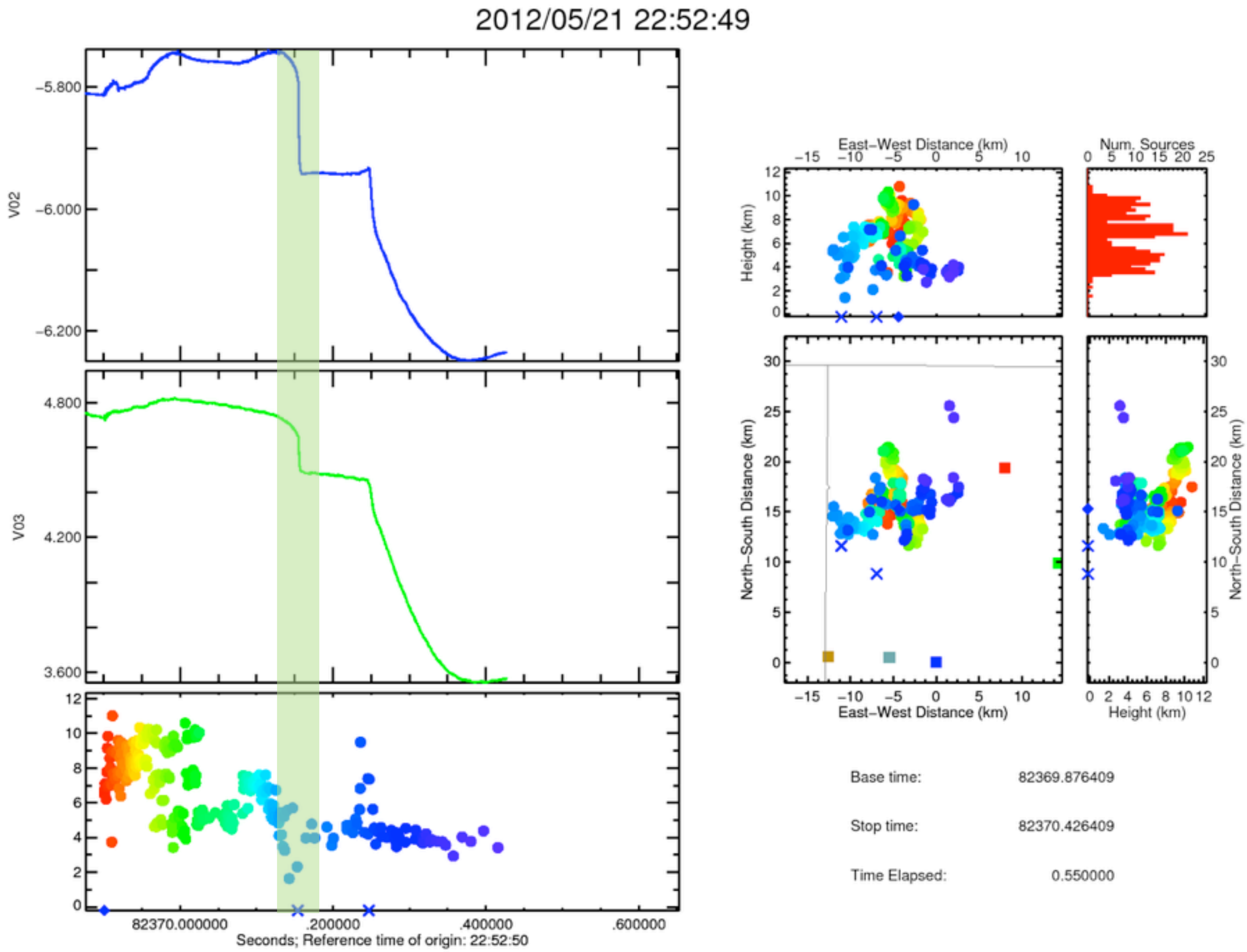
Is there anything else we can do at the ground?

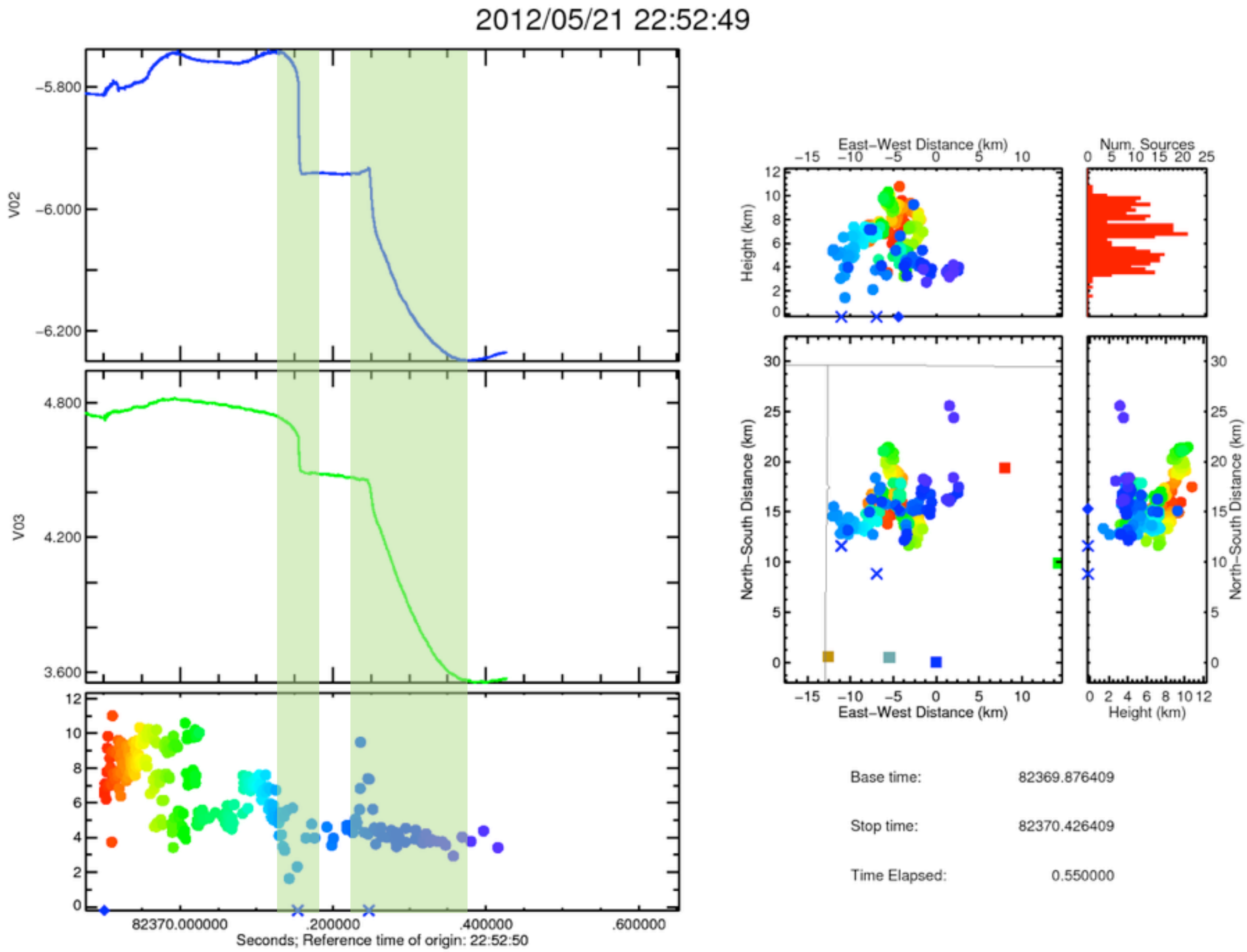

2012/05/21 22:29:42
V02
1.000
0.000
−1.000
V03
0.000
−0.300
−0.600
20
15
10
5
0
80982.300000
.350000
.400000
Seconds; Reference time of origin: 22:29:42
East−West Distance (km)
Num. Sources
Height (km)
North−South Distance (km)
East−West Distance (km)
Height (km)
Base time: 80982.254901
Stop time: 80982.324901
Time Elapsed: 0.070000

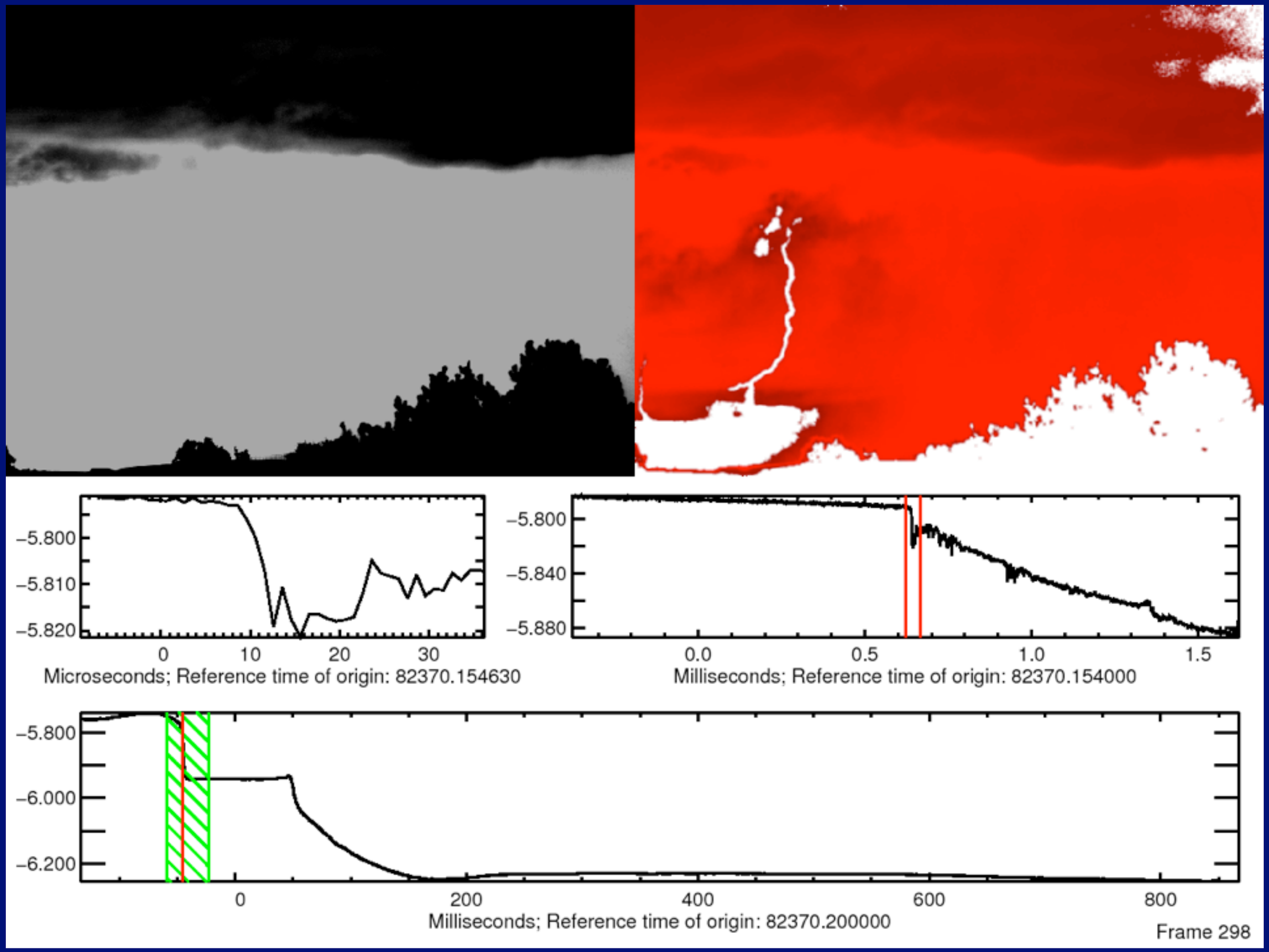

2012/05/21 22:29:42
V02
1.000
0.000
−1.000
V03
0.000
−0.300
−0.600
20
15
10
5
0
80982.300000
.350000
.400000
Seconds; Reference time of origin: 22:29:42
East−West Distance (km)
Num. Sources
Height (km)
North−South Distance (km)
East−West Distance (km)
Height (km)
Base time: 80982.254901
Stop time: 80982.324901
Time Elapsed: 0.070000

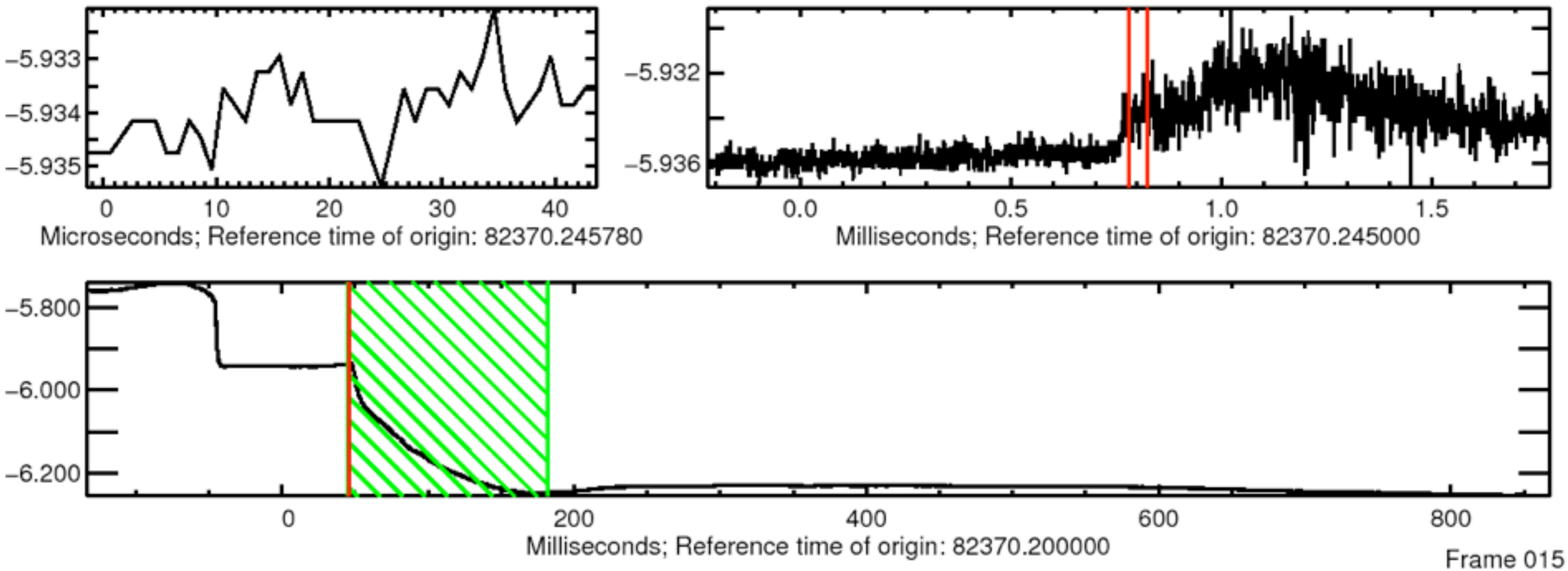

1.812
1.808
1.804
0
10
20
30
40
Microseconds; Reference time of origin: 80982.273090
1.500
0.500
−0.500
0.0
0.5
1.0
1.5
Milliseconds; Reference time of origin: 80982.272500
1.000
0.000
−1.000
0
50
100
150
200
Milliseconds; Reference time of origin: 80982.300000
Frame 061


2012/05/21 22:52:49
V02
V03
Seconds; Reference time of origin: 22:52:50
East–West Distance (km)
Num. Sources
Height (km)
North–South Distance (km)
Base time: 82369.876409
Stop time: 82370.426409
Time Elapsed: 0.550000

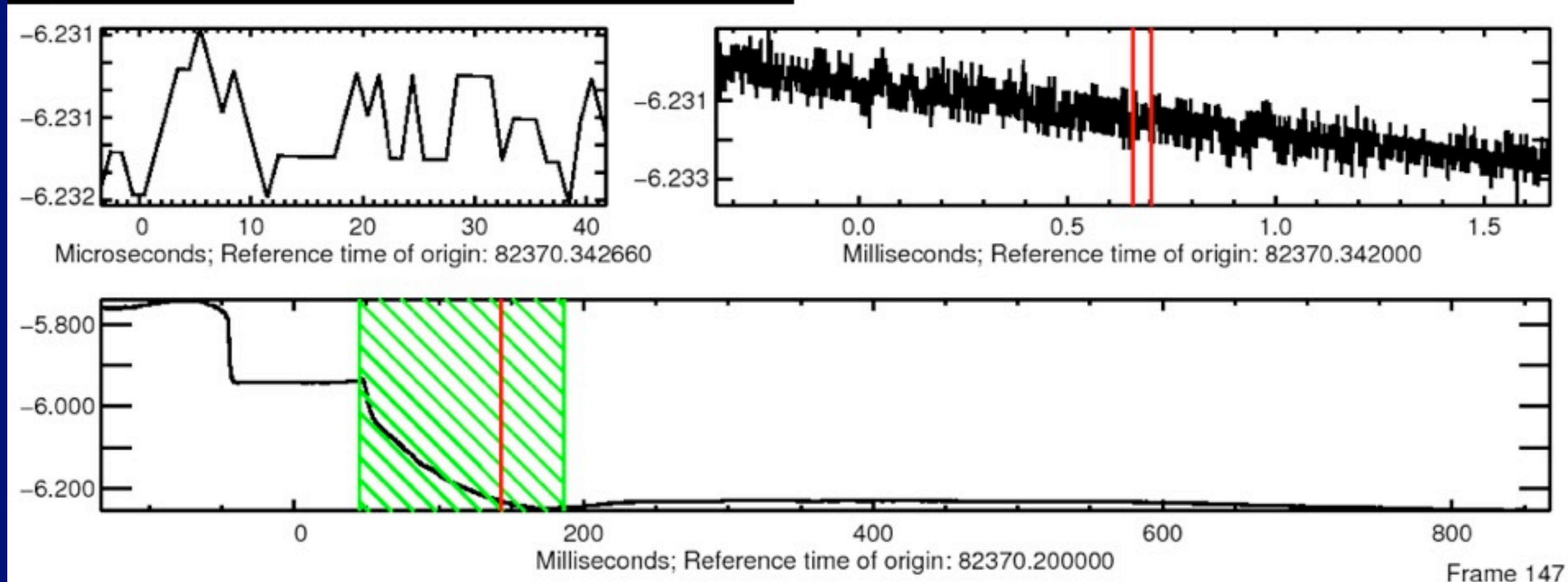

2012/05/21 22:52:49
V02
V03
Seconds; Reference time of origin: 22:52:50
East–West Distance (km)
Num. Sources
Height (km)
North–South Distance (km)
Base time: 82369.876409
Stop time: 82370.426409
Time Elapsed: 0.550000

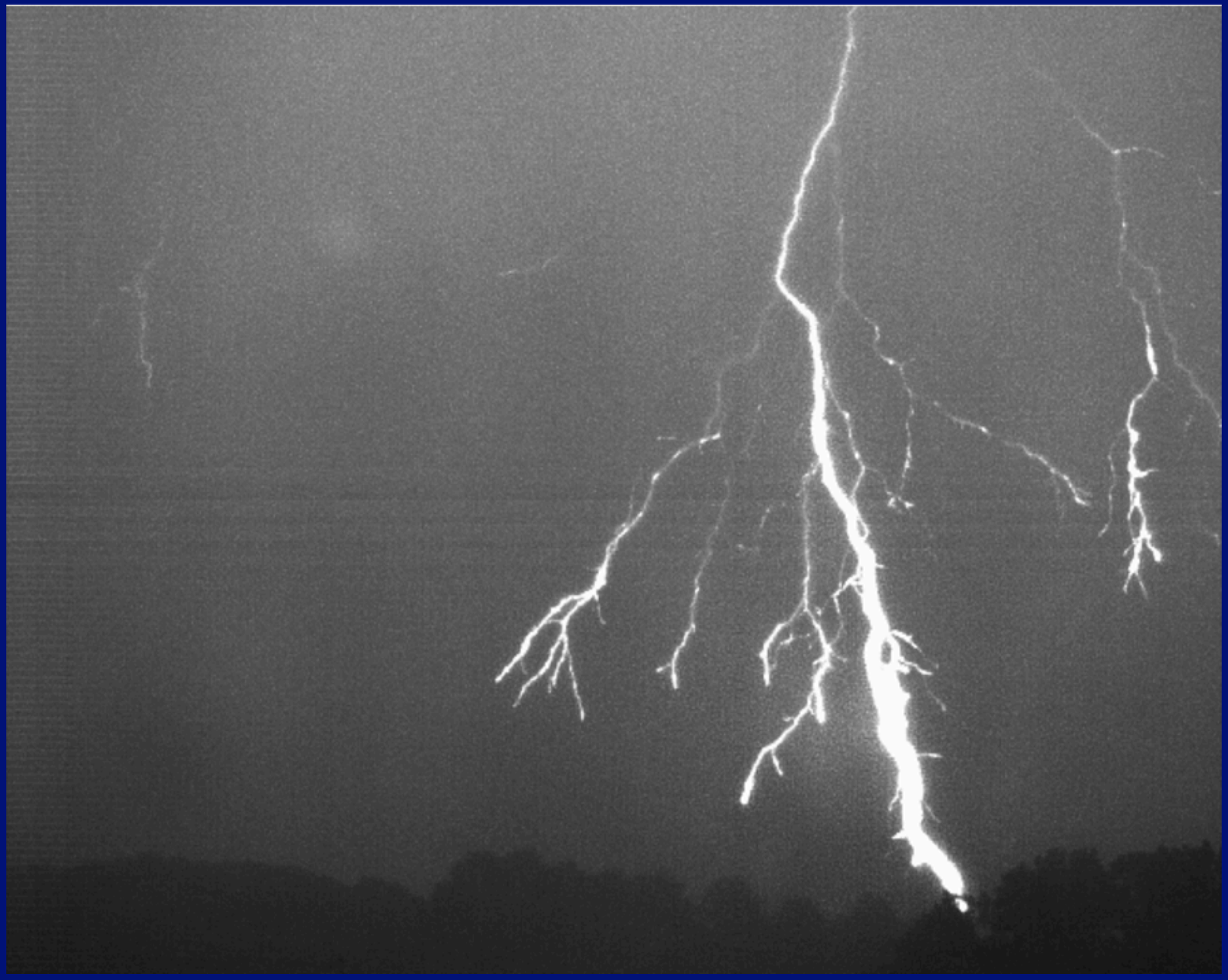

2012/05/21 22:52:49
V02
V03
Seconds; Reference time of origin: 22:52:50
East–West Distance (km)
Num. Sources
Height (km)
North–South Distance (km)
Base time: 82369.876409
Stop time: 82370.426409
Time Elapsed: 0.550000


−5.800
−5.810
−5.820
0
10
20
30
Microseconds; Reference time of origin: 82370.154630
−5.800
−5.840
−5.880
0.0
0.5
1.0
1.5
Milliseconds; Reference time of origin: 82370.154000
−5.800
−6.000
−6.200
0
200
400
600
800
Milliseconds; Reference time of origin: 82370.200000
Frame 298

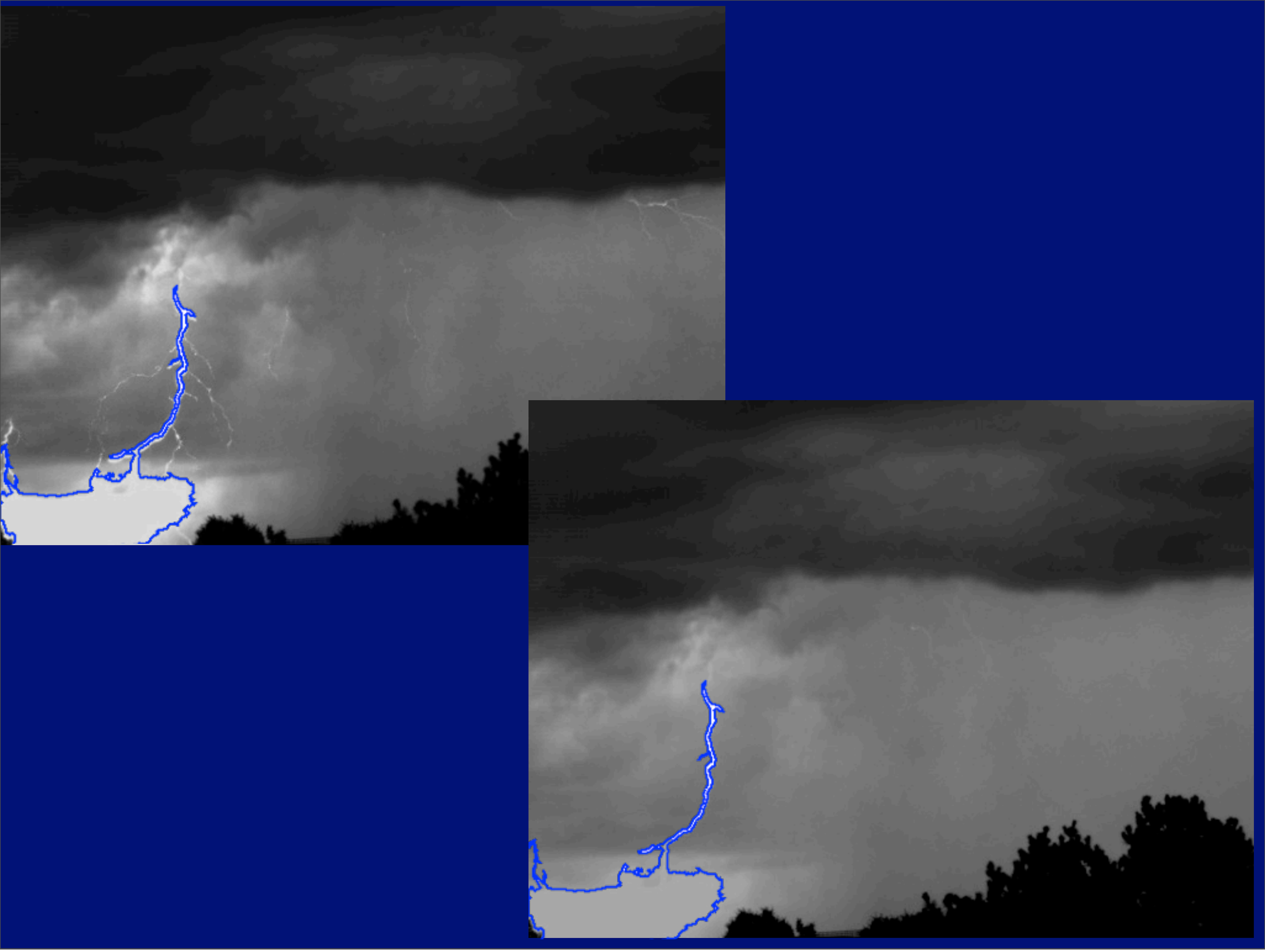

−5.933
−5.934
−5.935
0
10
20
30
40
Microseconds; Reference time of origin: 82370.245780
−5.932
−5.936
0.0
0.5
1.0
1.5
Milliseconds; Reference time of origin: 82370.245000
−5.800
−6.000
−6.200
0
200
400
600
800
Milliseconds; Reference time of origin: 82370.200000
Frame 015

Still going...


−6.231
−6.231
−6.232
0
10
20
30
40
Microseconds; Reference time of origin: 82370.342660
−6.231
−6.233
0.0
0.5
1.0
1.5
Milliseconds; Reference time of origin: 82370.342000
−5.800
−6.000
−6.200
0
200
400
600
800
Milliseconds; Reference time of origin: 82370.200000
Frame 147



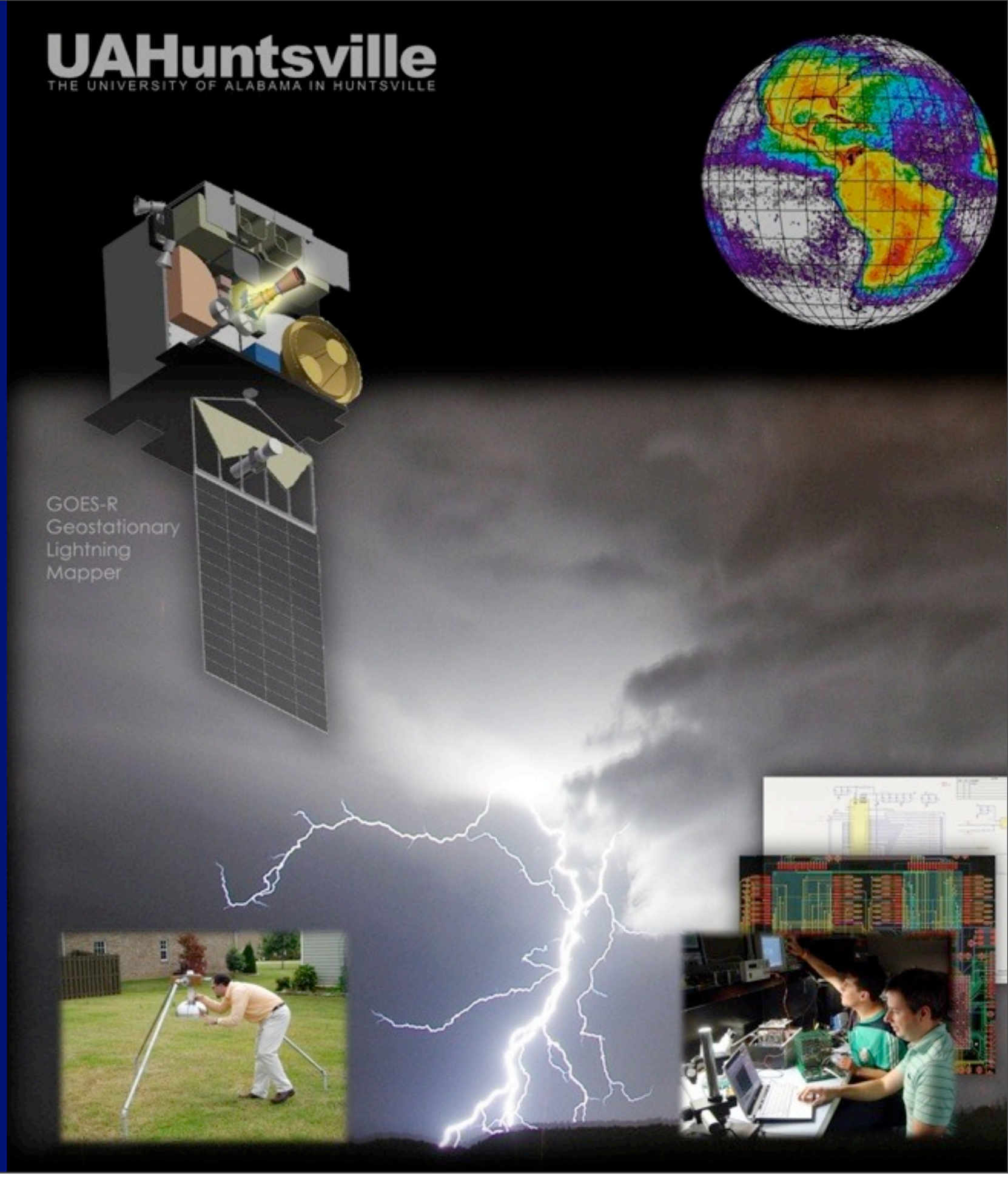
Wednesday, September 19, 2012



Wednesday, September 19, 2012

Fundamental question for *scientific* studies with LIS/GLM:

What part of the lightning process does LIS/GLM "see"?

Fundamental question for *validation* of LIS/GLM:

What ground measurements are best correlated with LIS/GLM groups?