Introduction to Huntsville Alabama Marx Meter Array

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Special thanks to:
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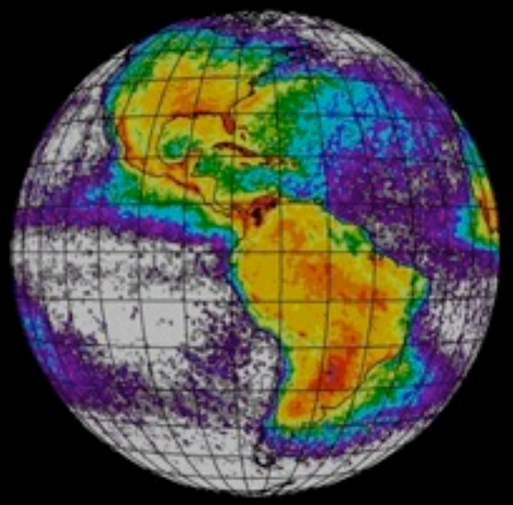
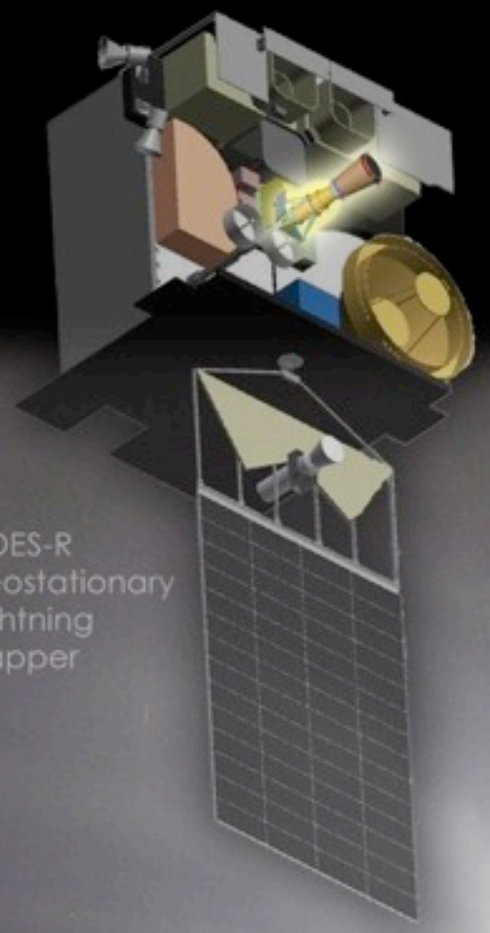
Christy Bitzer, Dan Cecil, Henry Everitt and Martin Heimbeck,
Brandon and Anne Marie Strickland, Winfred Thomas
Agricultural Research Station, Chris and Elise Schultz

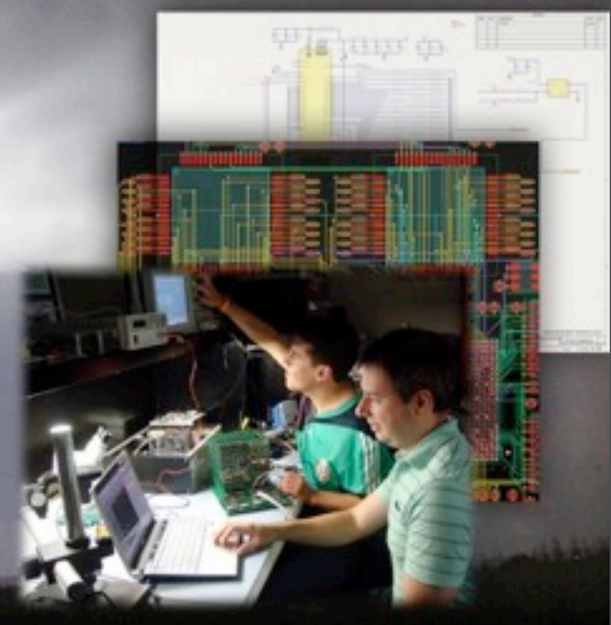
UAHuntsville

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE





GOES-R
Geostationary
Lightning
Mapper



Fundamental question for validation:

What is the best way from the ground to characterize what GLM “sees?”

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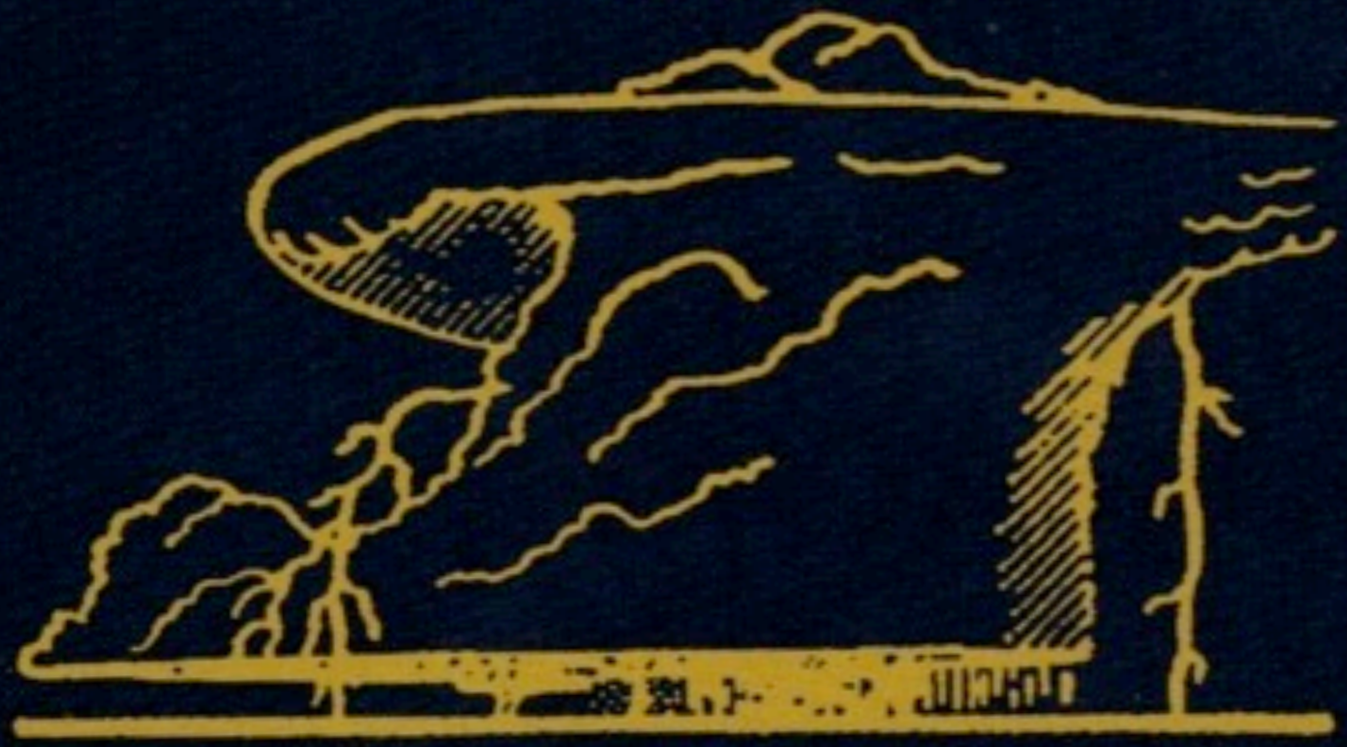
Fundamental question for operation:

What attribute of lightning is most useful?

THE ELECTRICAL NATURE of STORMS



DONALD R. MacGORMAN
W. DAVID RUST

"The equivalent charge center analysis (from analyzing electric field changes) is the only technique that estimates directly the net charge involved in lightning processes"

Why do we need this?

- Underlying assumption: the energetics of a lightning process is tied to the “net charge involved”
- So, although lightning can be measured in various ways, in order to measure the *energetics*, we need to measure the electric field change due to a stroke/flash
- Others have measured electric fields
  - e.g., arrays of instruments that focus only on the electrostatic component of radiated electric field (e.g. KSC, NMT)
  - single station fast antennas

Krehbiel, 1979

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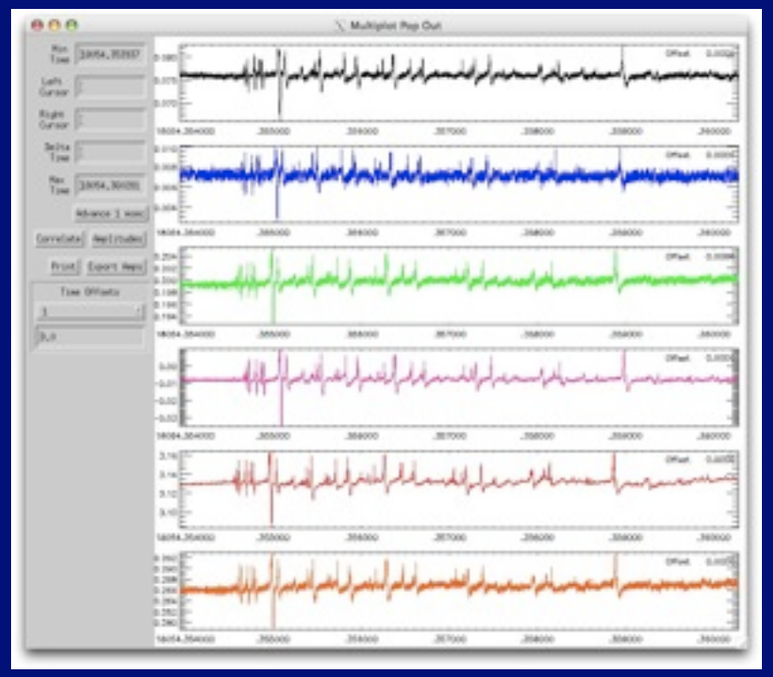
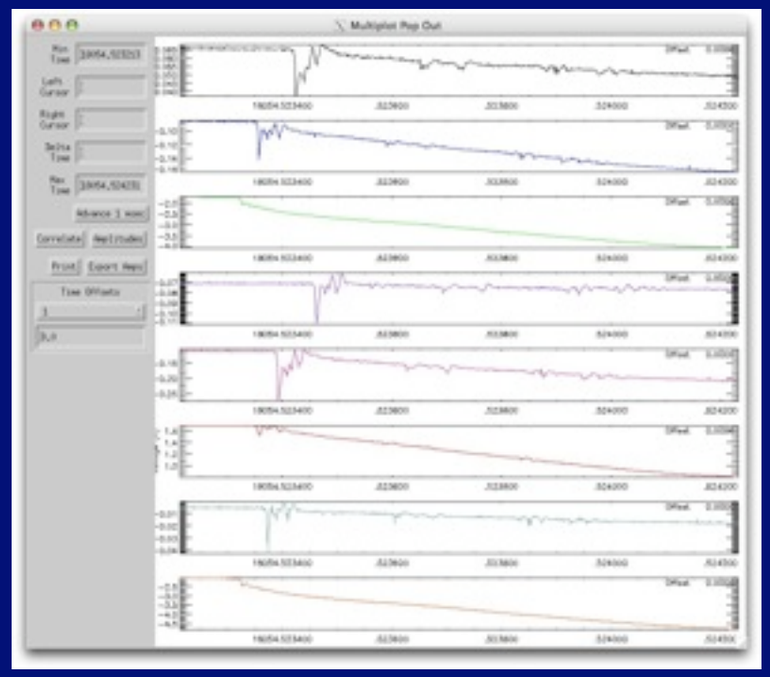
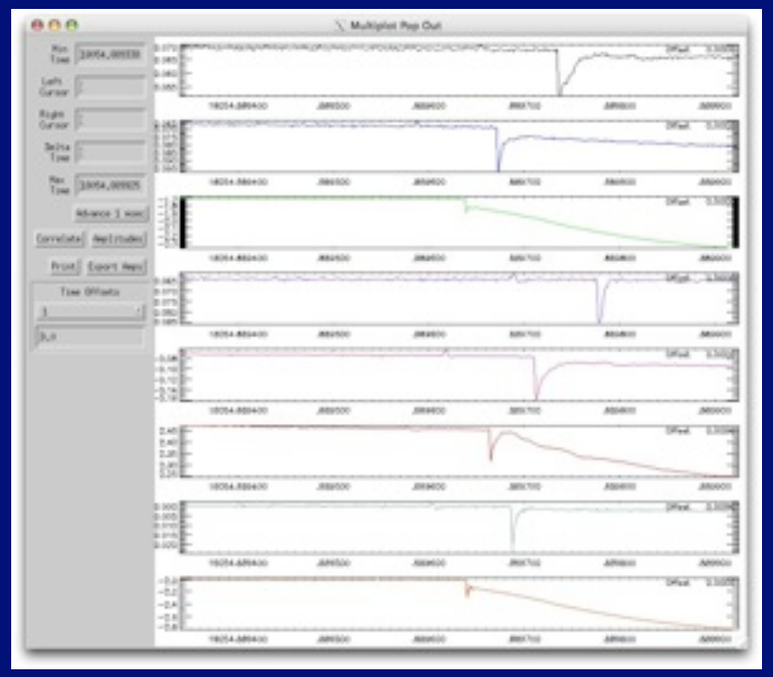
What if we design an array that can measure all components of the radiated electric field?

Krehbiel, 1979

Efield signatures are quite distinct...







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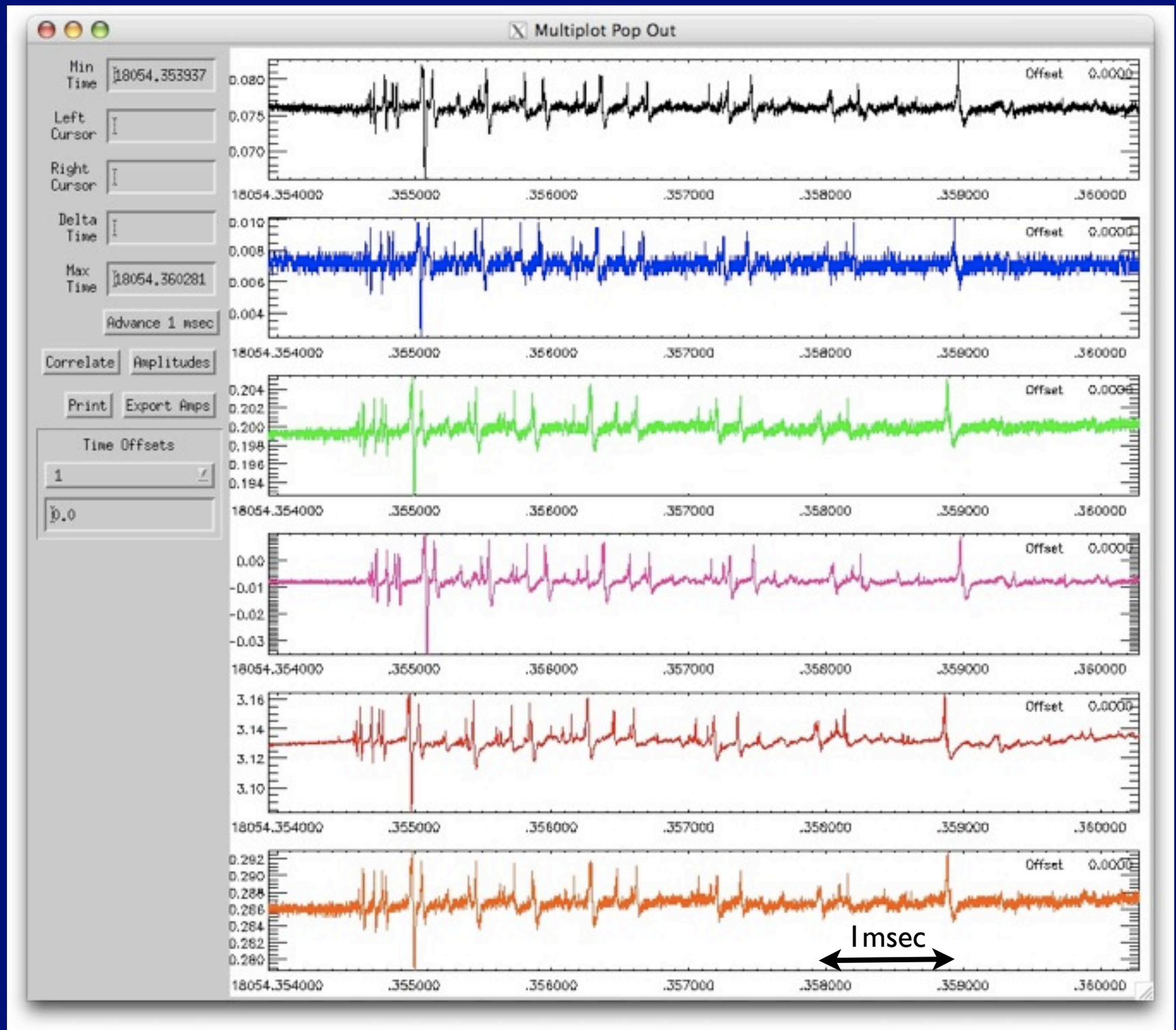
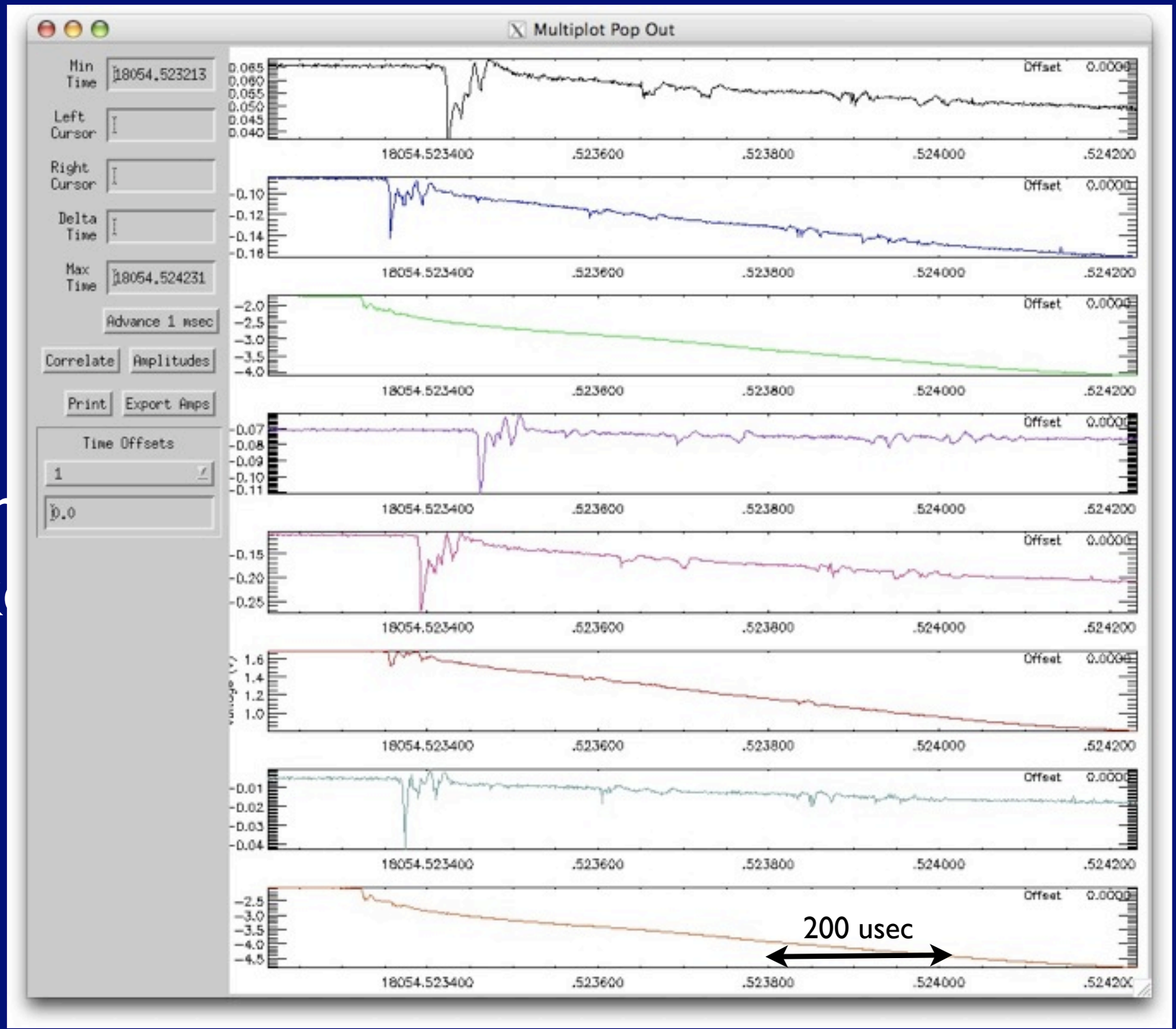


preliminary breakdown

Efield signatures are quite distinct...

prelim
breakd



"early"
return stroke

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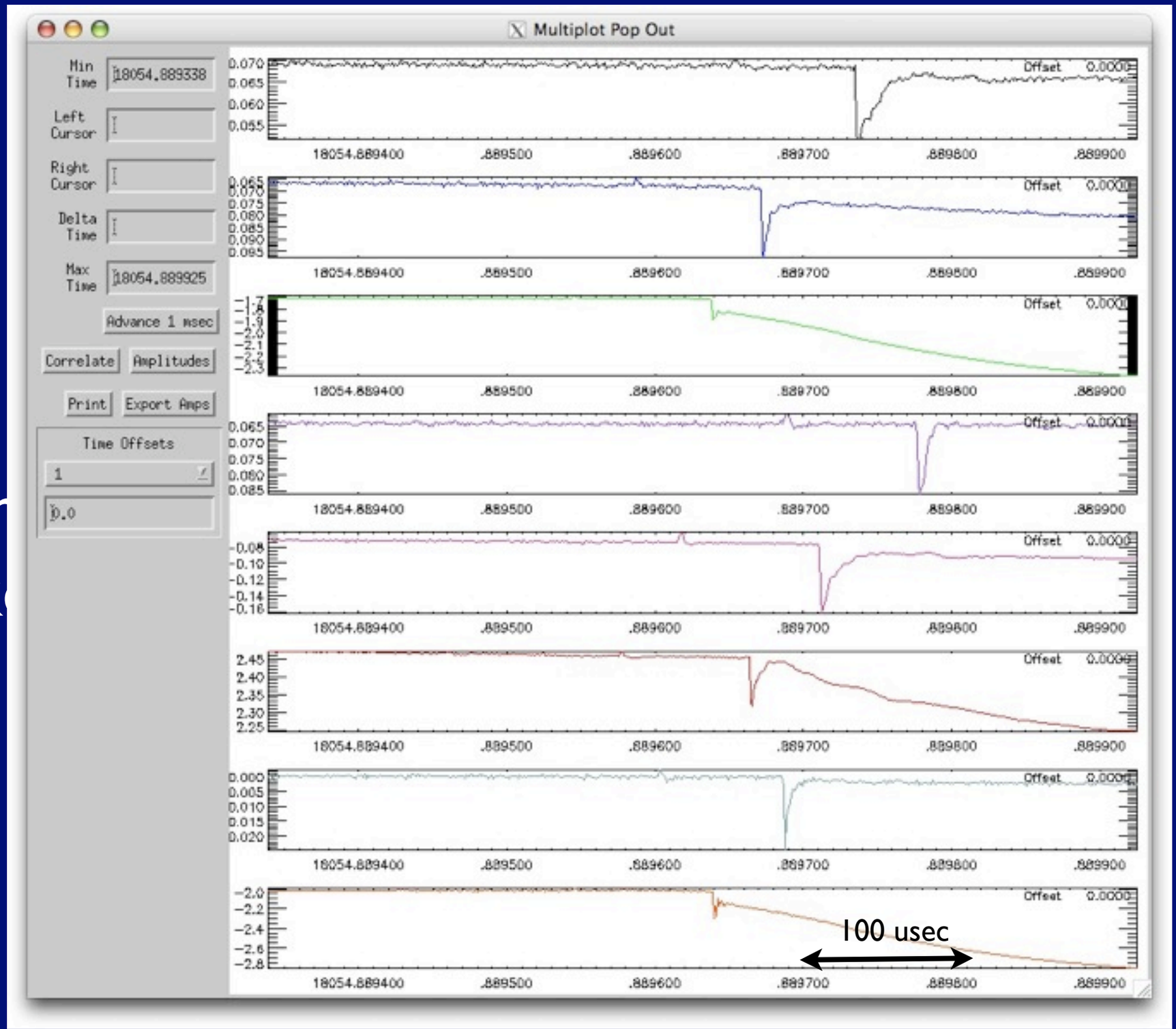
prelim
breakd



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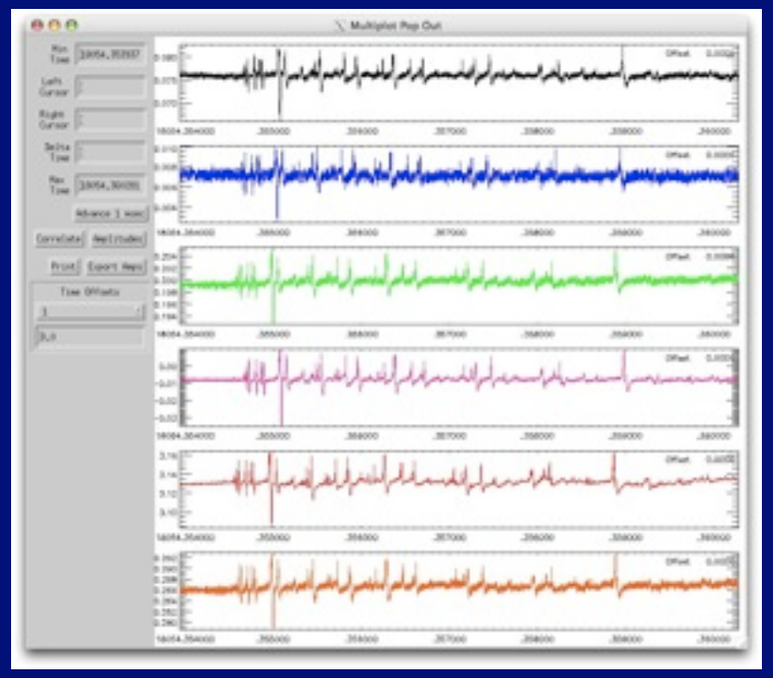

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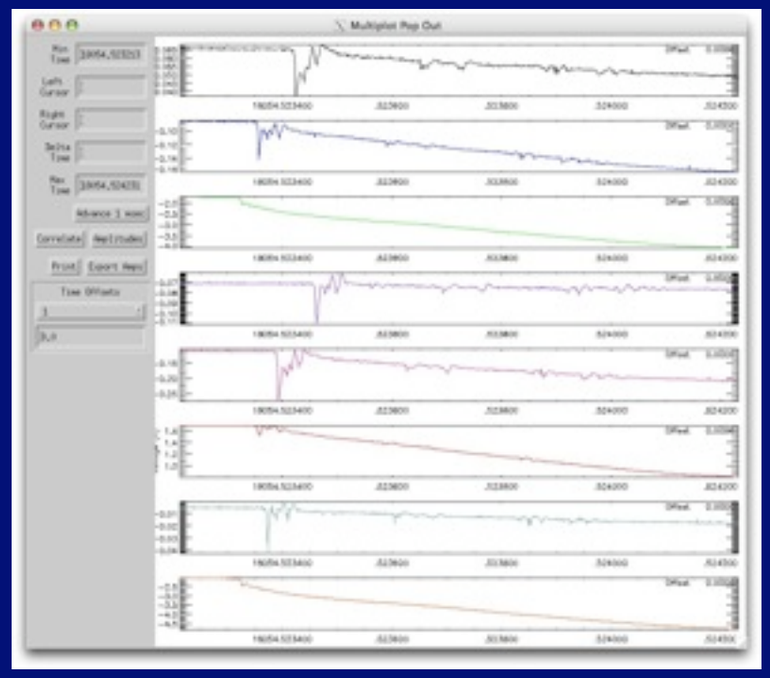
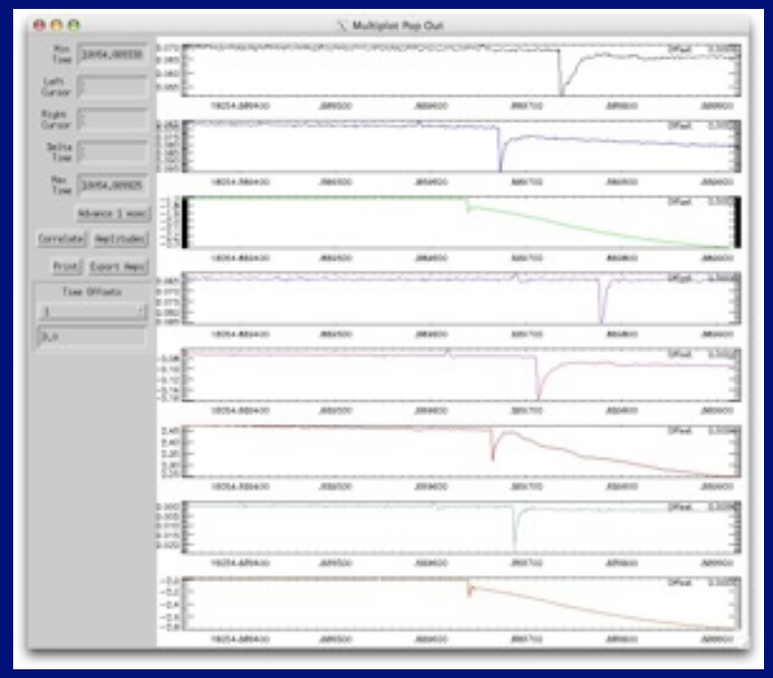


“early” return stroke



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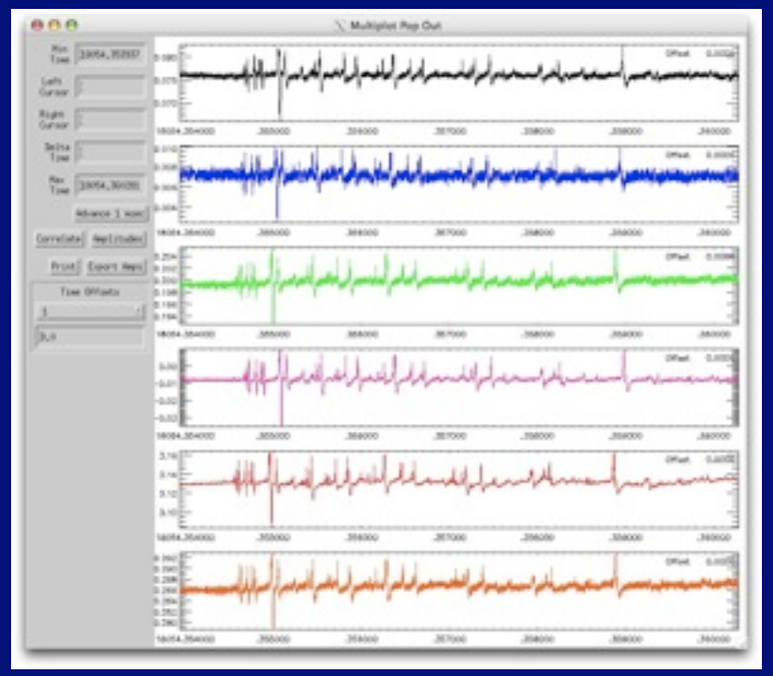

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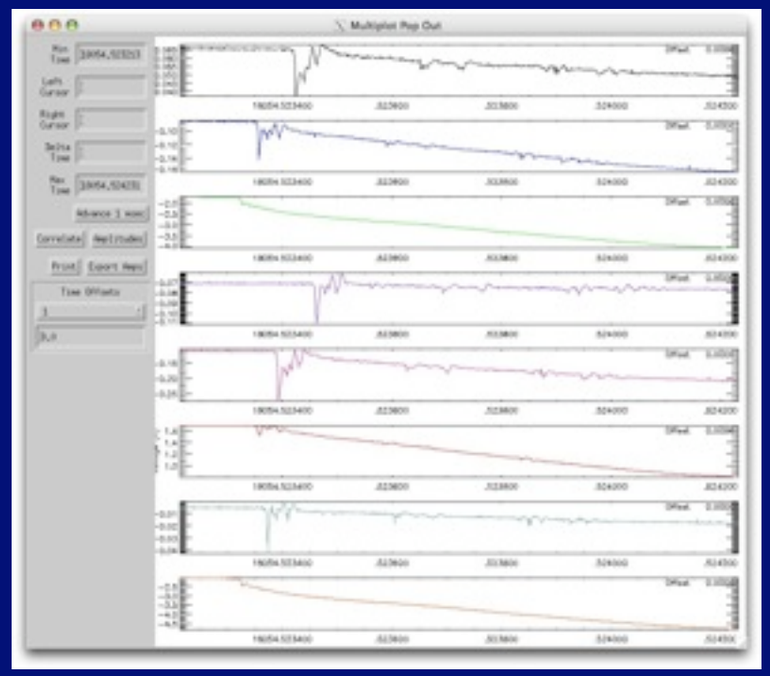

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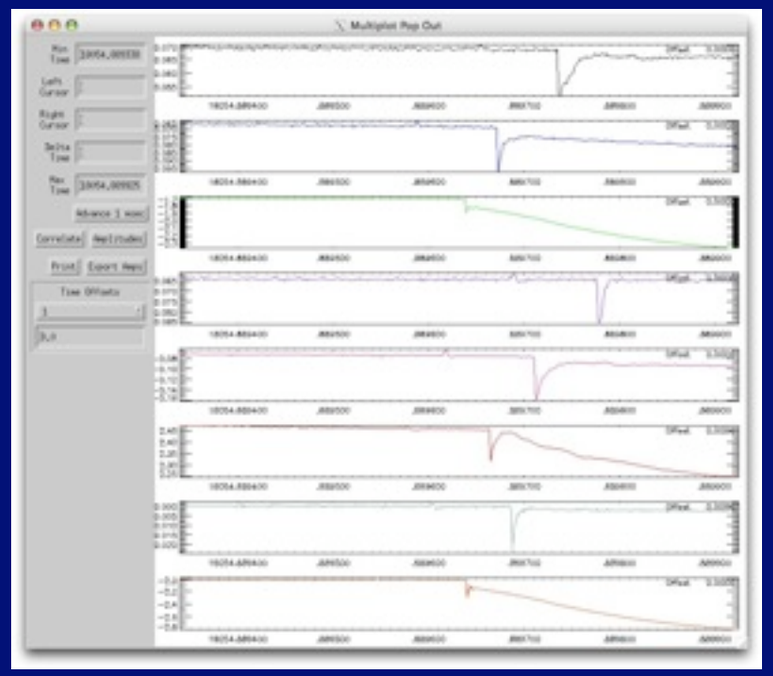

“later” return stroke

$$E_z(r,t) \propto$$

$$-\int_0^{H(t)} \left[\frac{r^2}{c^2 R^3(z')}\right] \frac{\partial I\left(z', t-\frac{R(z')}{c}\right)}{\partial t} \mathrm{d}z' \ldots$$

$$+\int_0^{H(t)} \left[\frac{2z'^2 - r^2}{cR^4(z')}\right] I\left(z', t-\frac{R(z')}{c}\right) \mathrm{d}z' \ldots$$

$$\int_0^{H(t)} \left[\frac{2z'^2 - r^2}{R^5(z')}\right] \int I\left(z', \tau-\frac{R(z')}{c}\right) \mathrm{d}\tau \mathrm{d}z' \ldots$$

$$\left[\frac{r^2}{c^2 R^3(H(t))}\right] I\left(H(t), \frac{H(t)}{v_f}\right) \frac{\mathrm{d}H(t)}{\mathrm{d}t}$$

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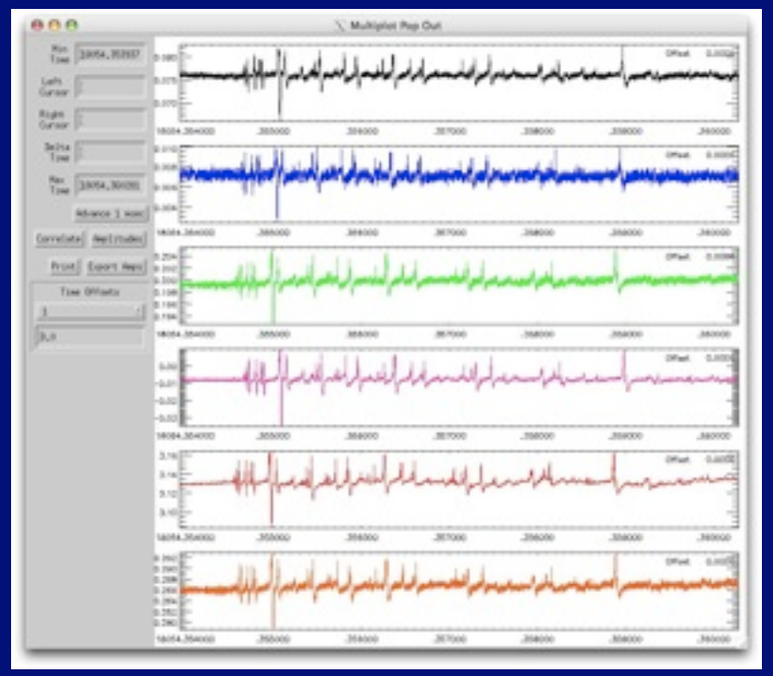

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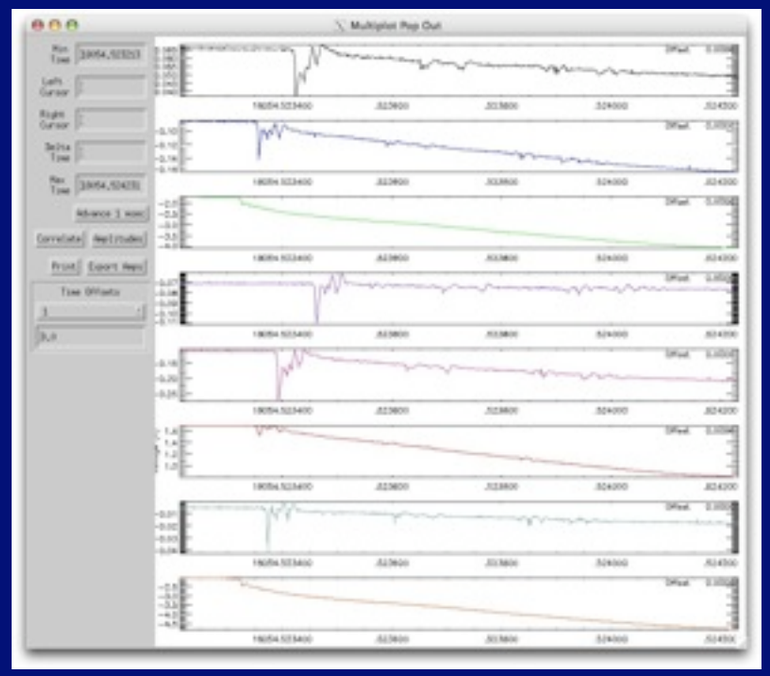

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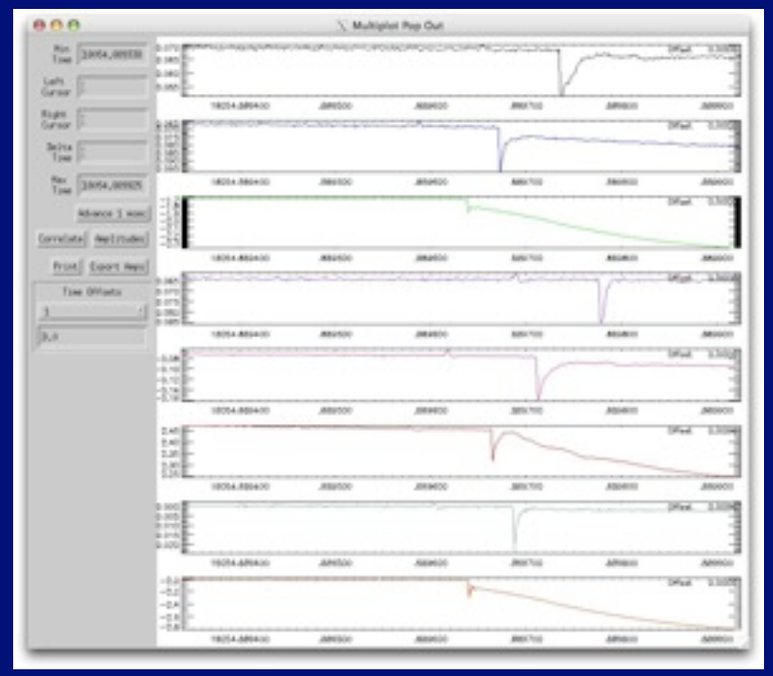

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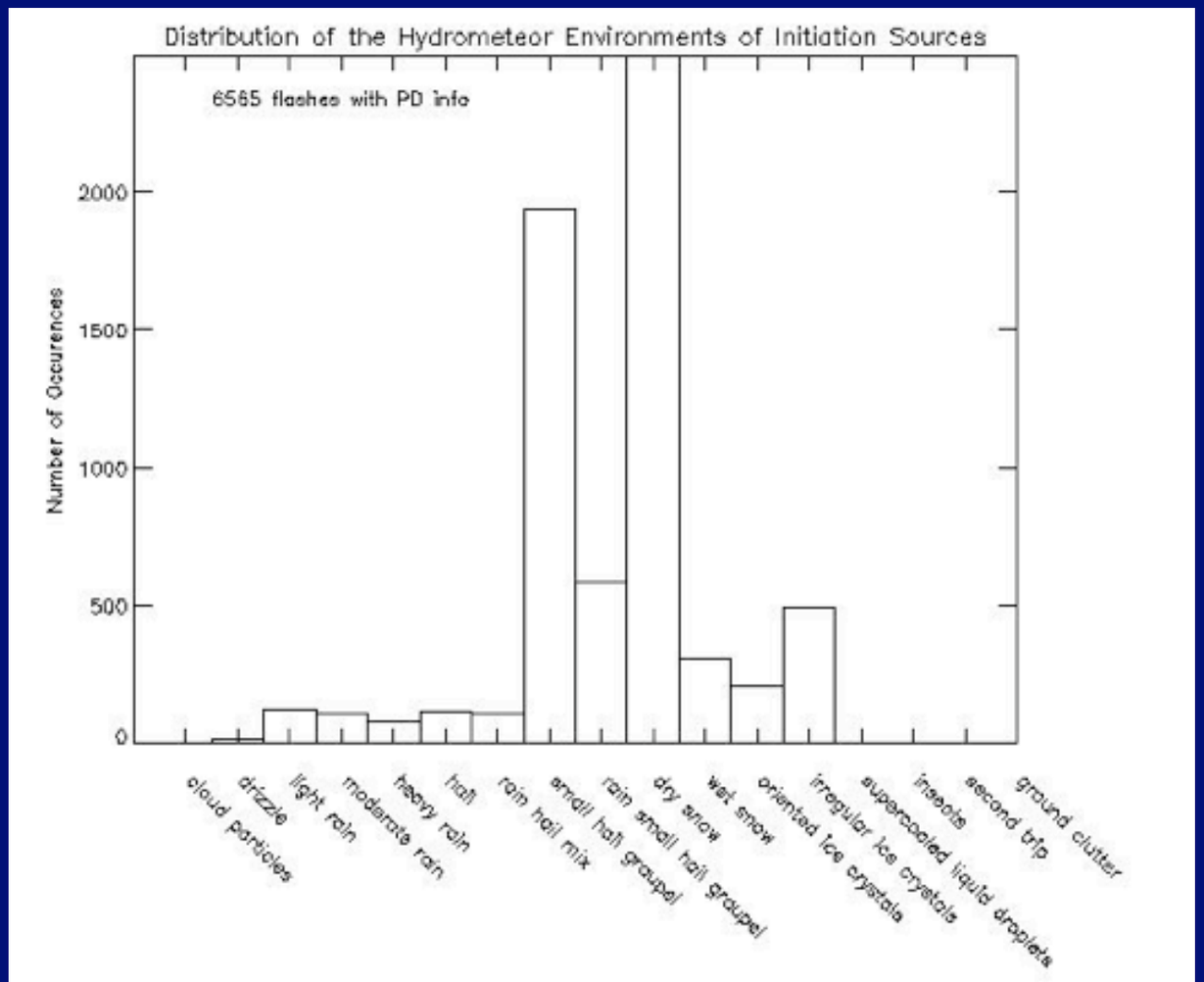
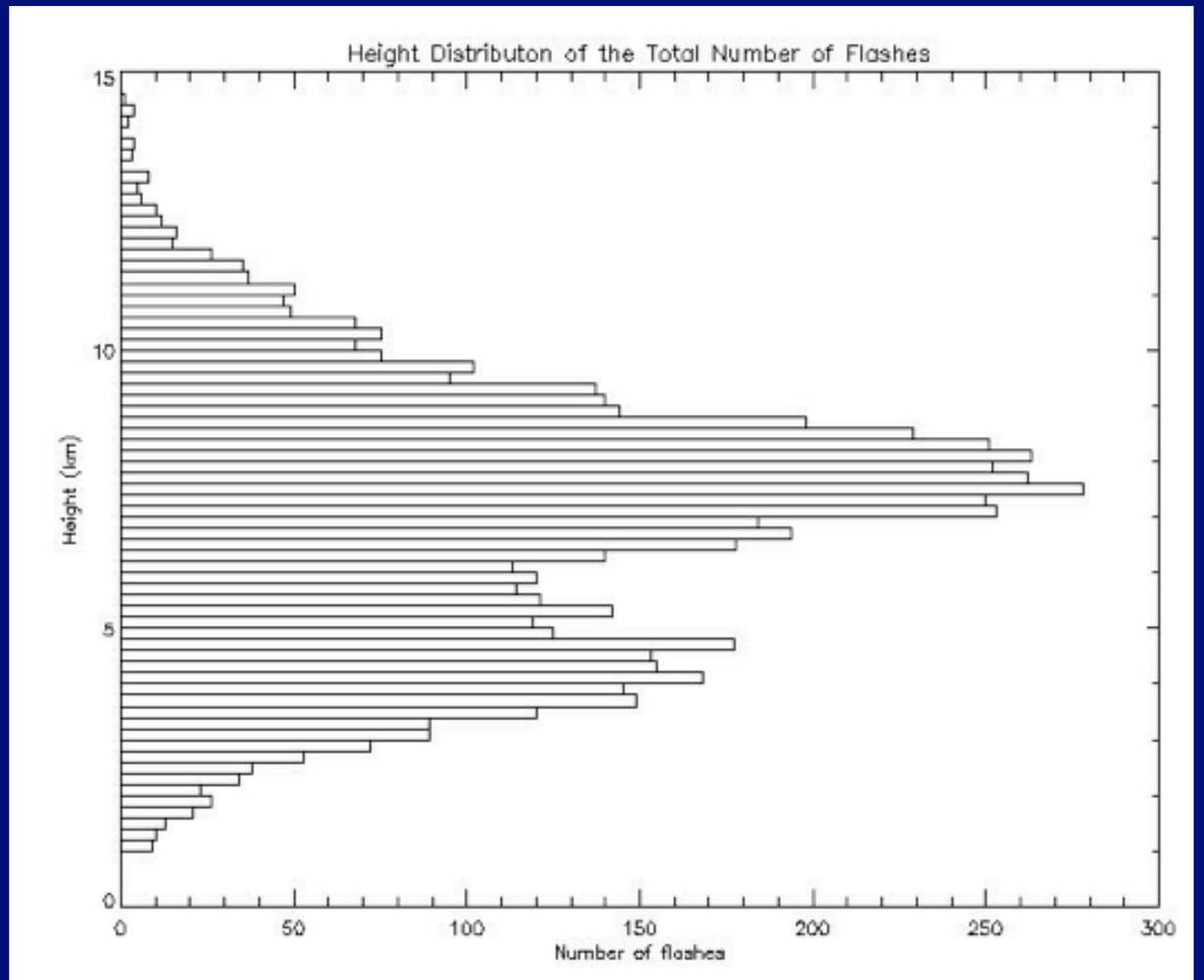
$$\int_0^{H(t)} \left[\frac{2z'^2 - r^2}{R^5(z')}\right] \int I\left(z', \tau-\frac{R(z')}{c}\right) \mathrm{d}\tau \mathrm{d}z' \ldots \quad \text{electrostatic}$$

$$\left[\frac{r^2}{c^2 R^3(H(t))}\right] I\left(H(t), \frac{H(t)}{v_f}\right) \frac{\mathrm{d}H(t)}{\mathrm{d}t}$$

“Low hanging fruit”

- Lightning initiation
  - still one of the great unanswered questions - how does lightning get started?

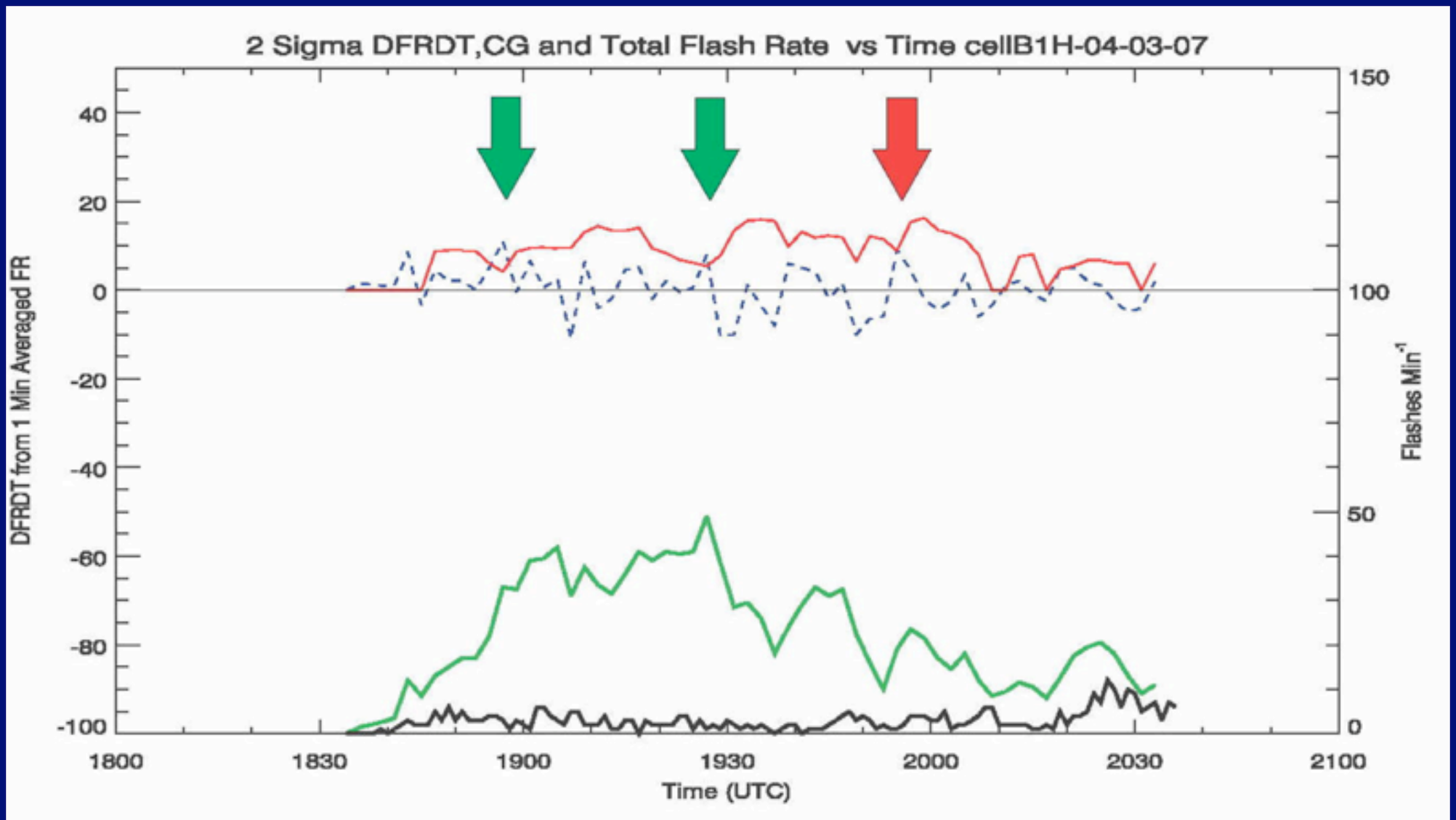




Bitzer et. al., 2007

“Low hanging fruit”

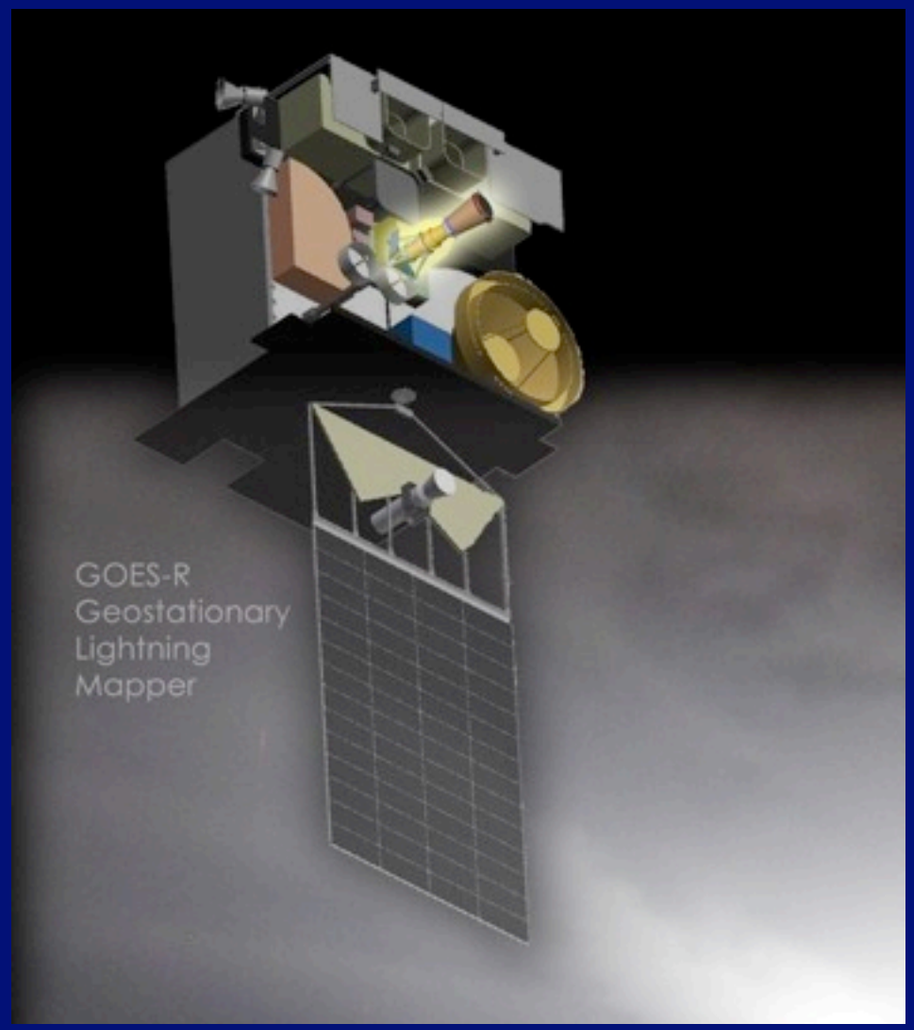
- Forecasting severe weather
  - LMA is currently used as a proxy for lightning. But, what part of the lightning process does LMA measure? Is it a lightning stroke?
  - What is best statistic for “how much” lightning? Number of flashes? Number of strokes? Amount of charge neutralized by a flash?



Shultz et. al., 2009

“Low hanging fruit”

- Ground truth for space-based measurements
  - LMA is great at detecting lightning, but can LMA yield any energetic information?
  - Could use NLDN, but it’s notoriously bad at measuring ICs



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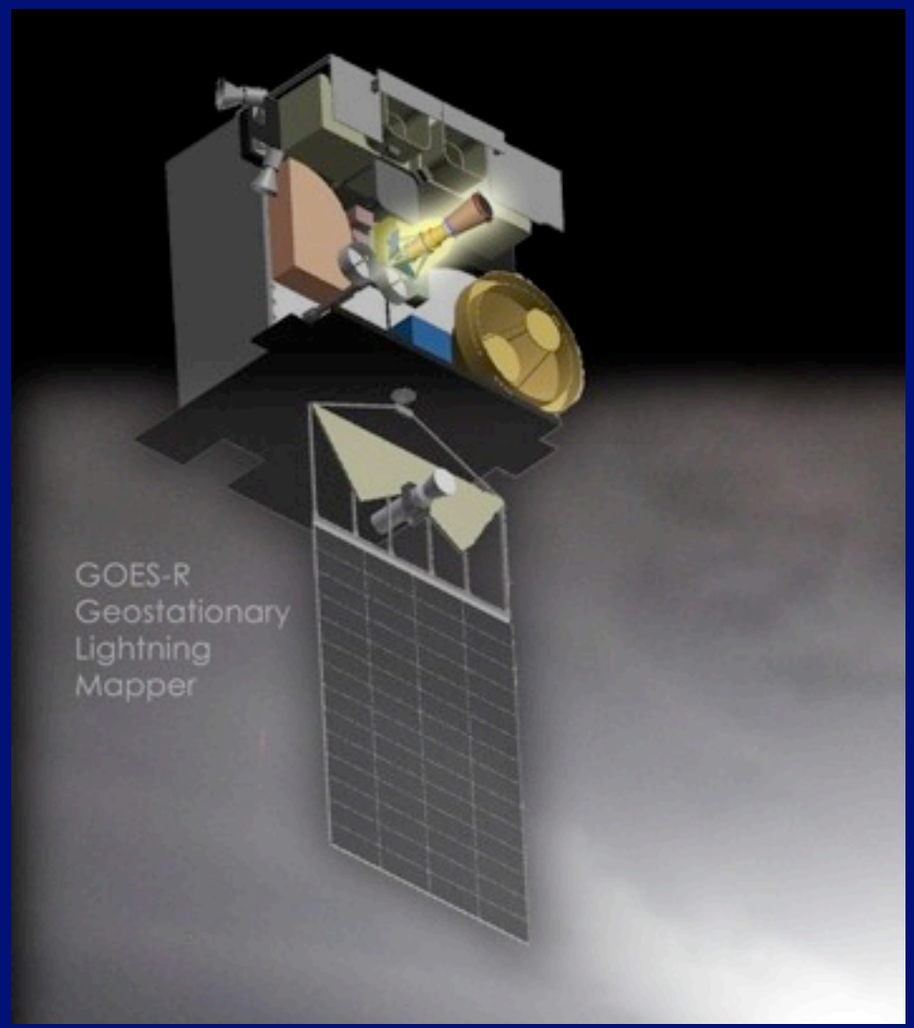
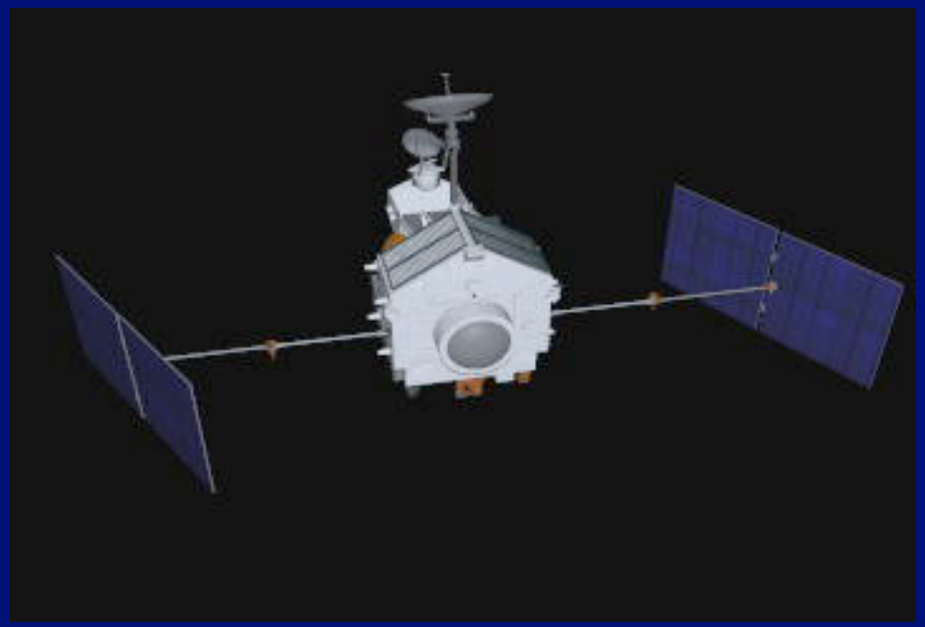
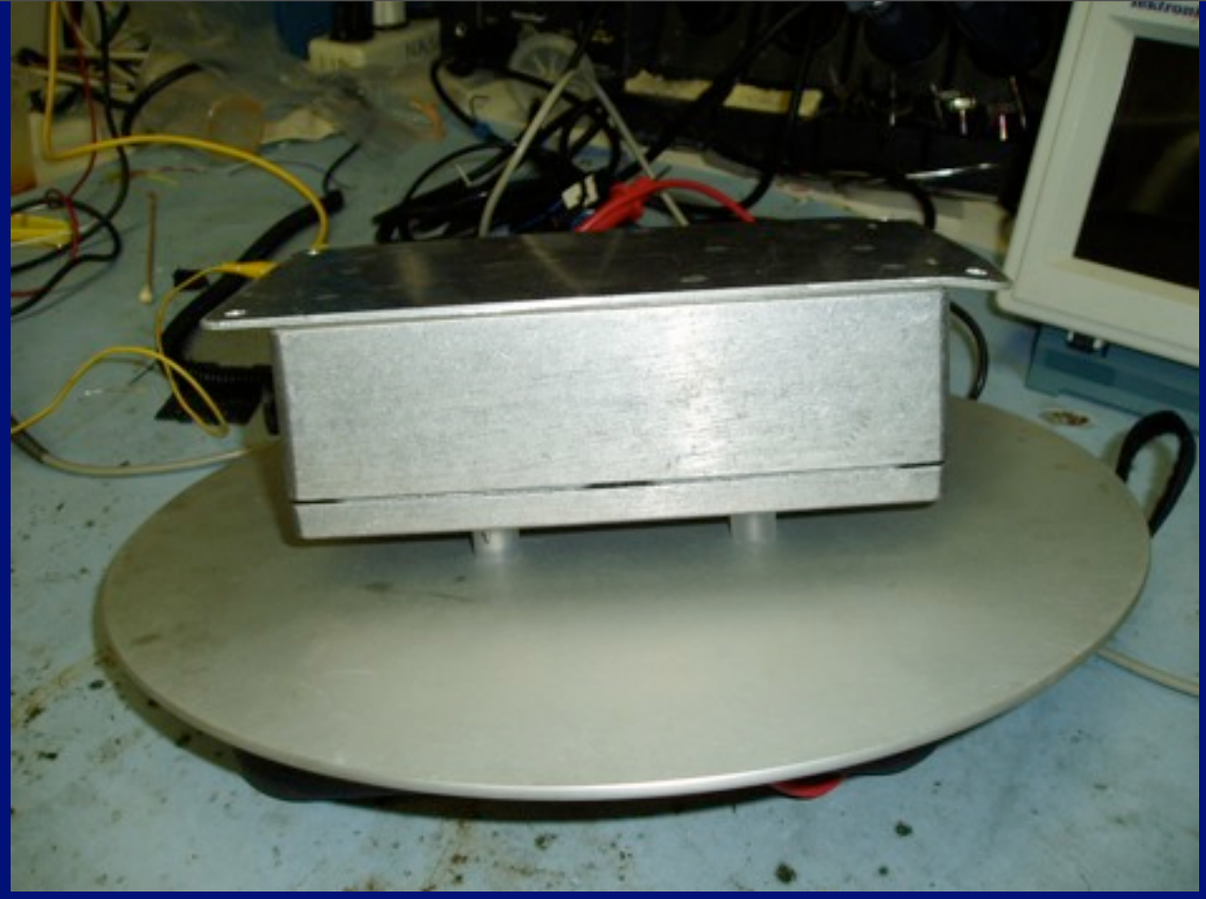


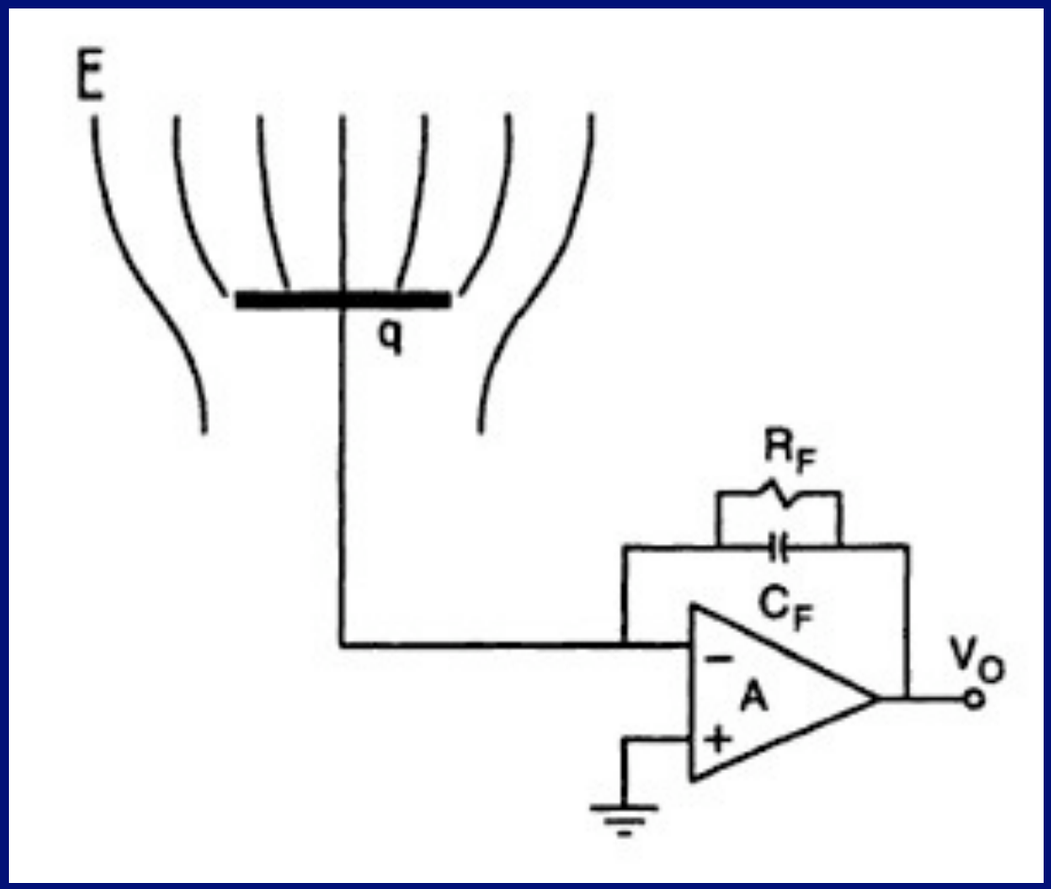


Marx meters

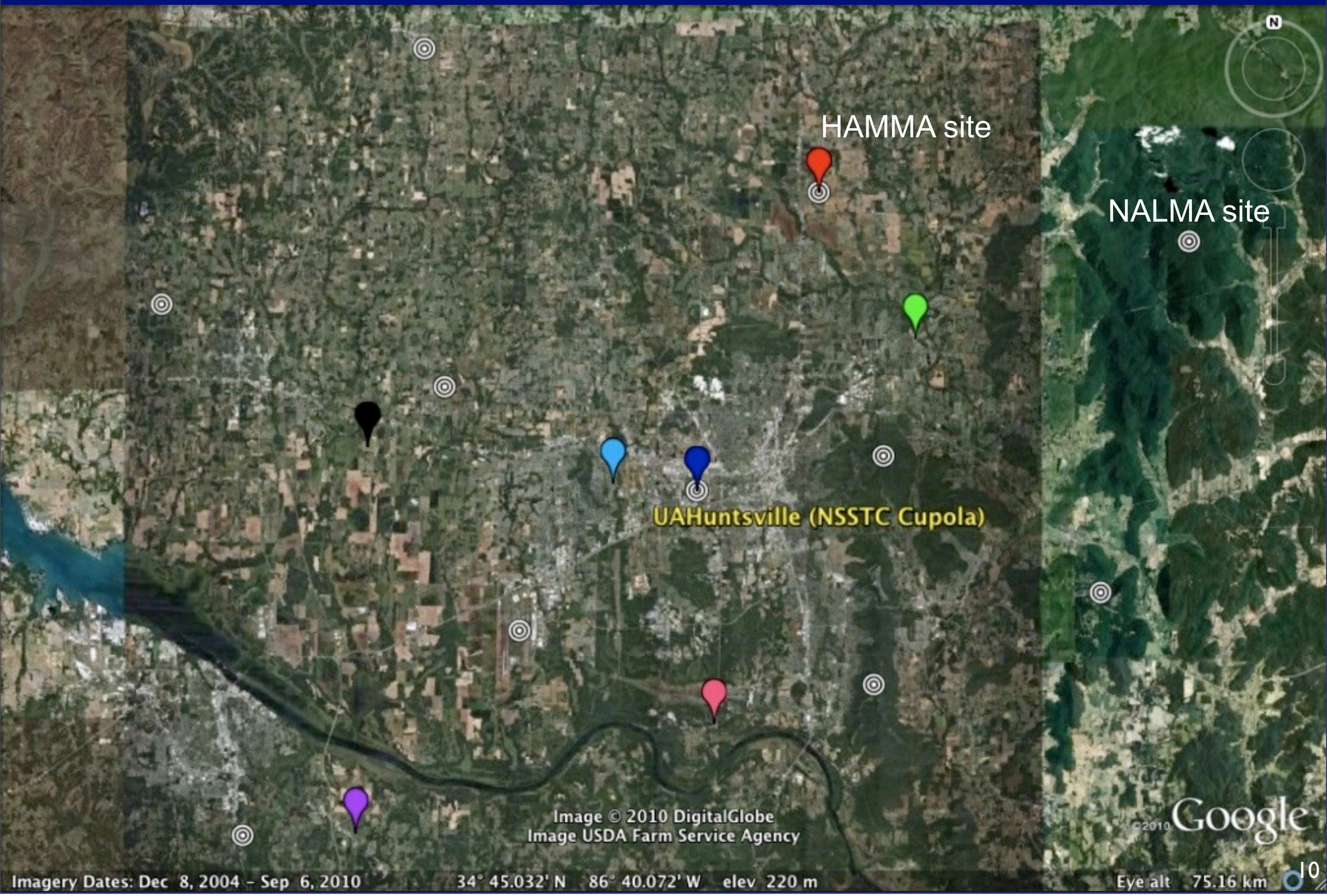
- The basis for our array is a ~~field change meter~~ Marx meter
- Each instrument has two systems – an analog front end and a recording system
  - essentially a charge amplifier connected to a sensing plate

Time Constant	100 msec
Sample Rate	1MHz





Huntsville Alabama Marx Meter Array (HAMMA)



Friday, December 3, 2010

Huntsville Alabama Marx Meter Array (HAMMA)

UAHuntsville (NSSTC Cupola

Image © 2010 DigitalGlobe
Image USDA Farm Service Agency

Google

Imagery Dates: Dec 8, 2004 - Sep 6, 2010 34° 45.032' N 86° 40.072' W elev 220 m Eye alt 75.16 km

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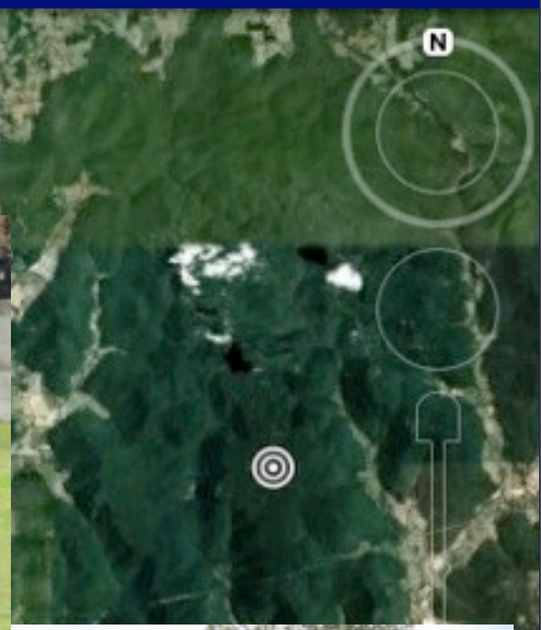

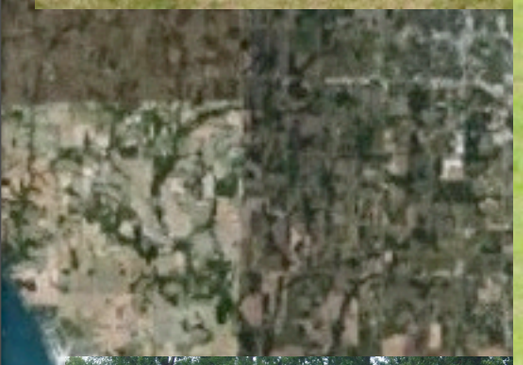

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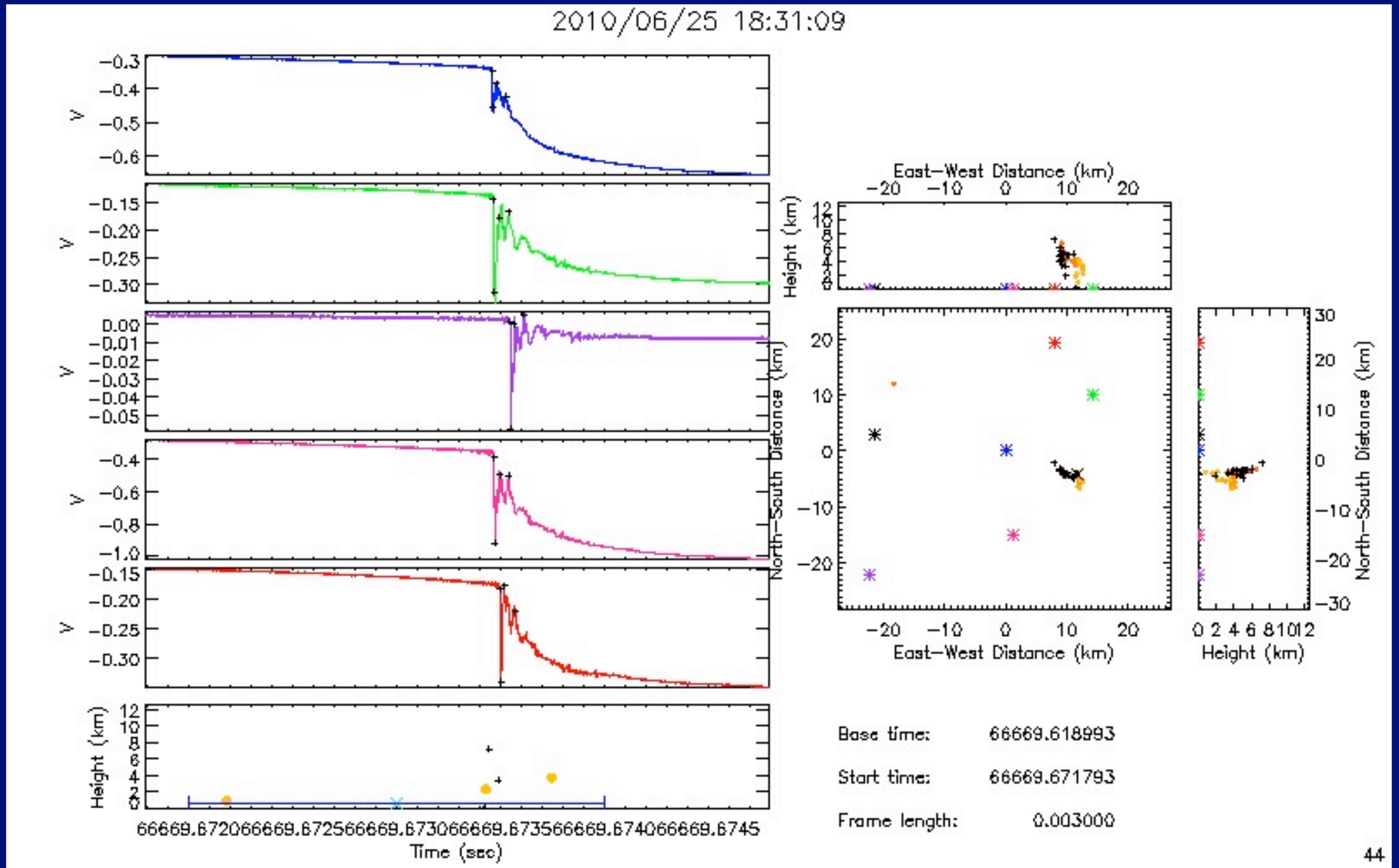
So, what does the data look like?



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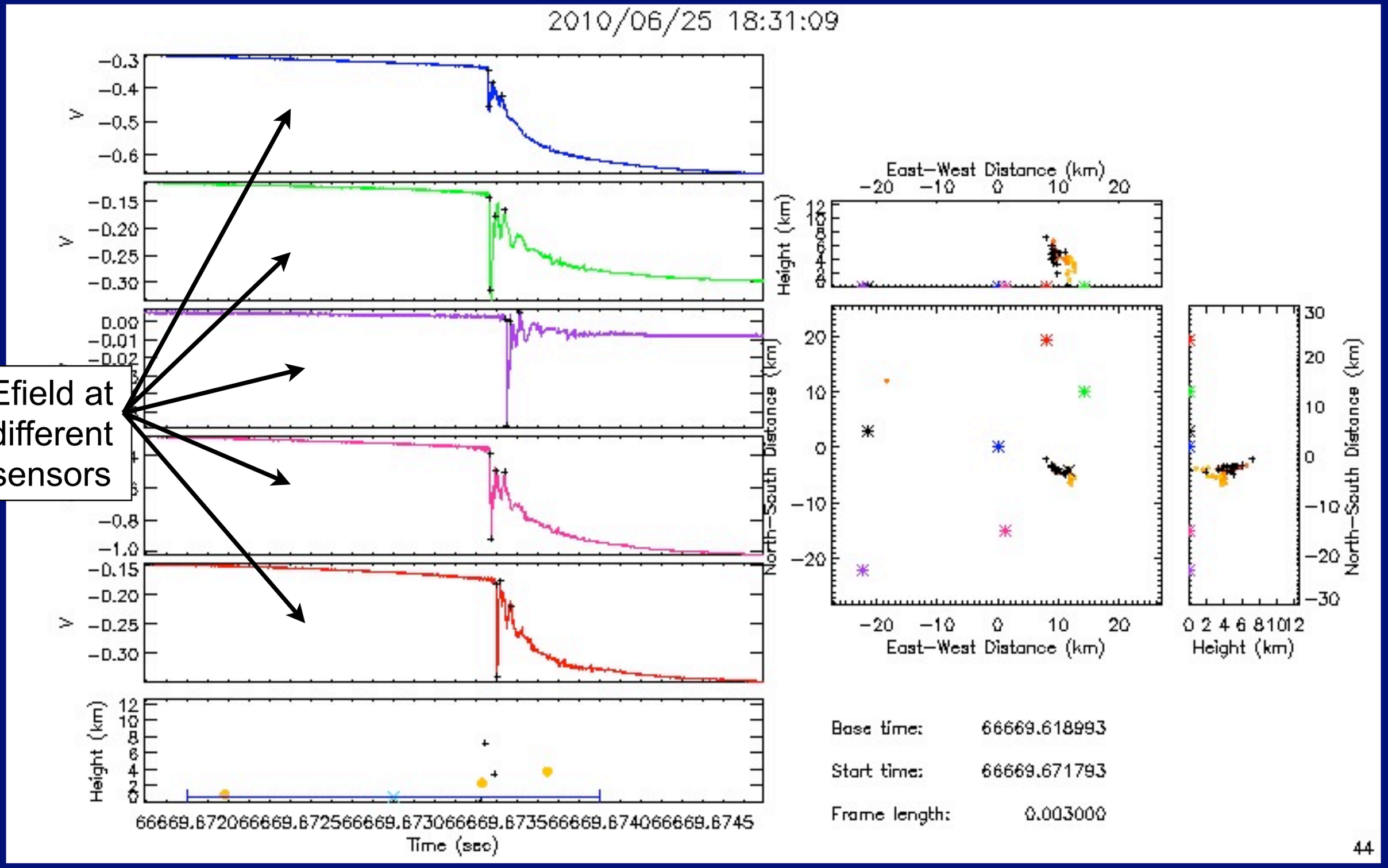

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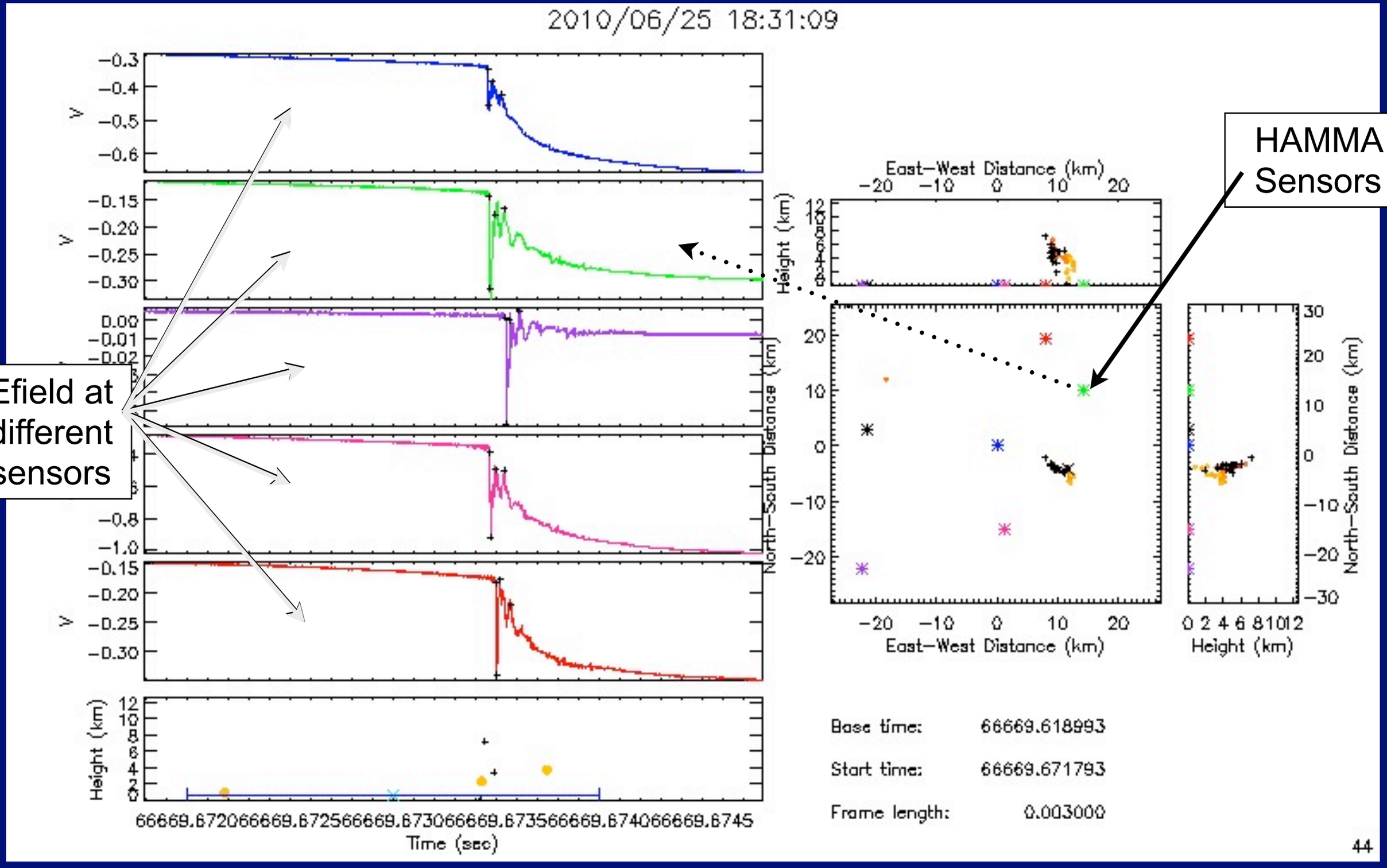

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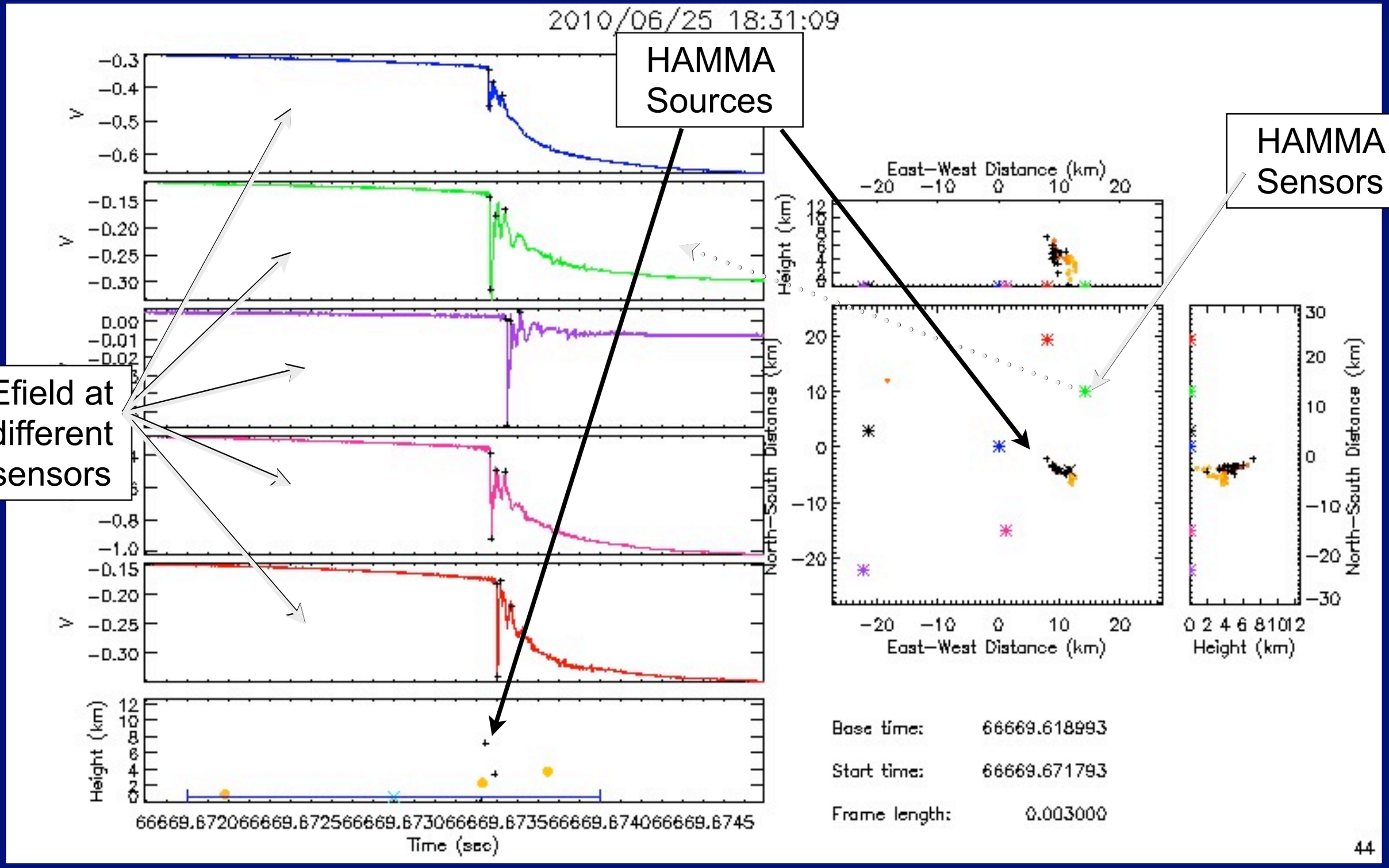

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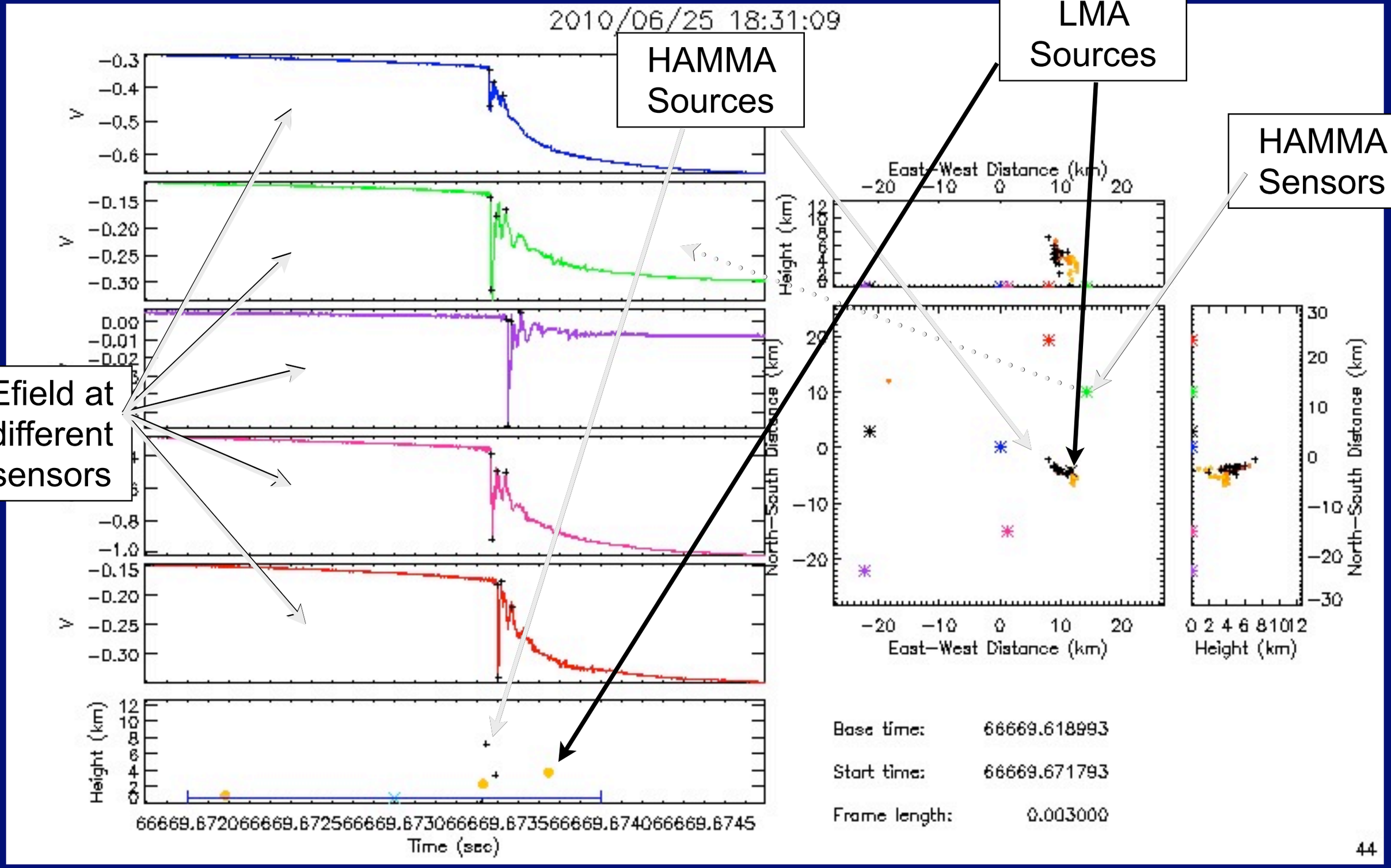

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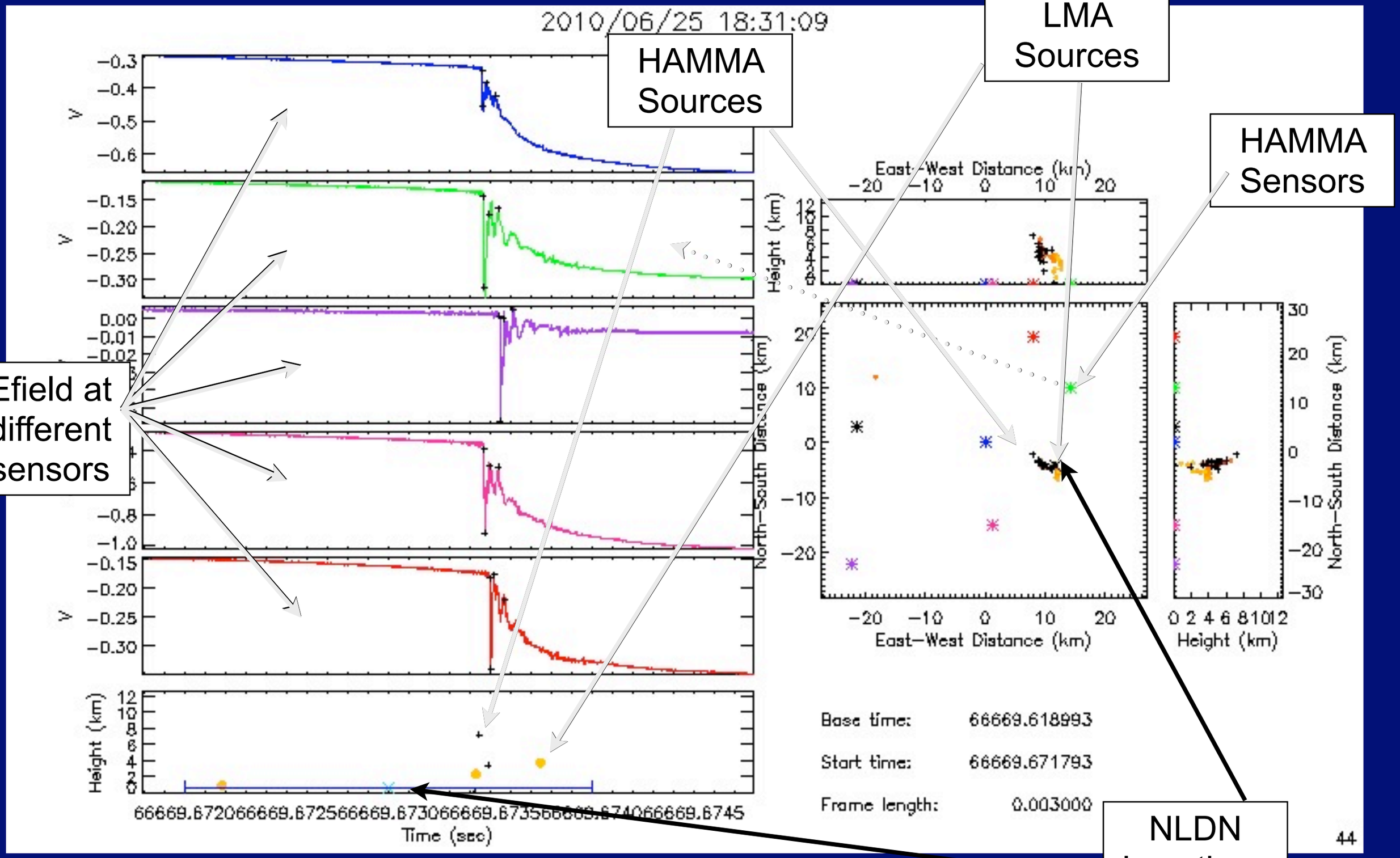

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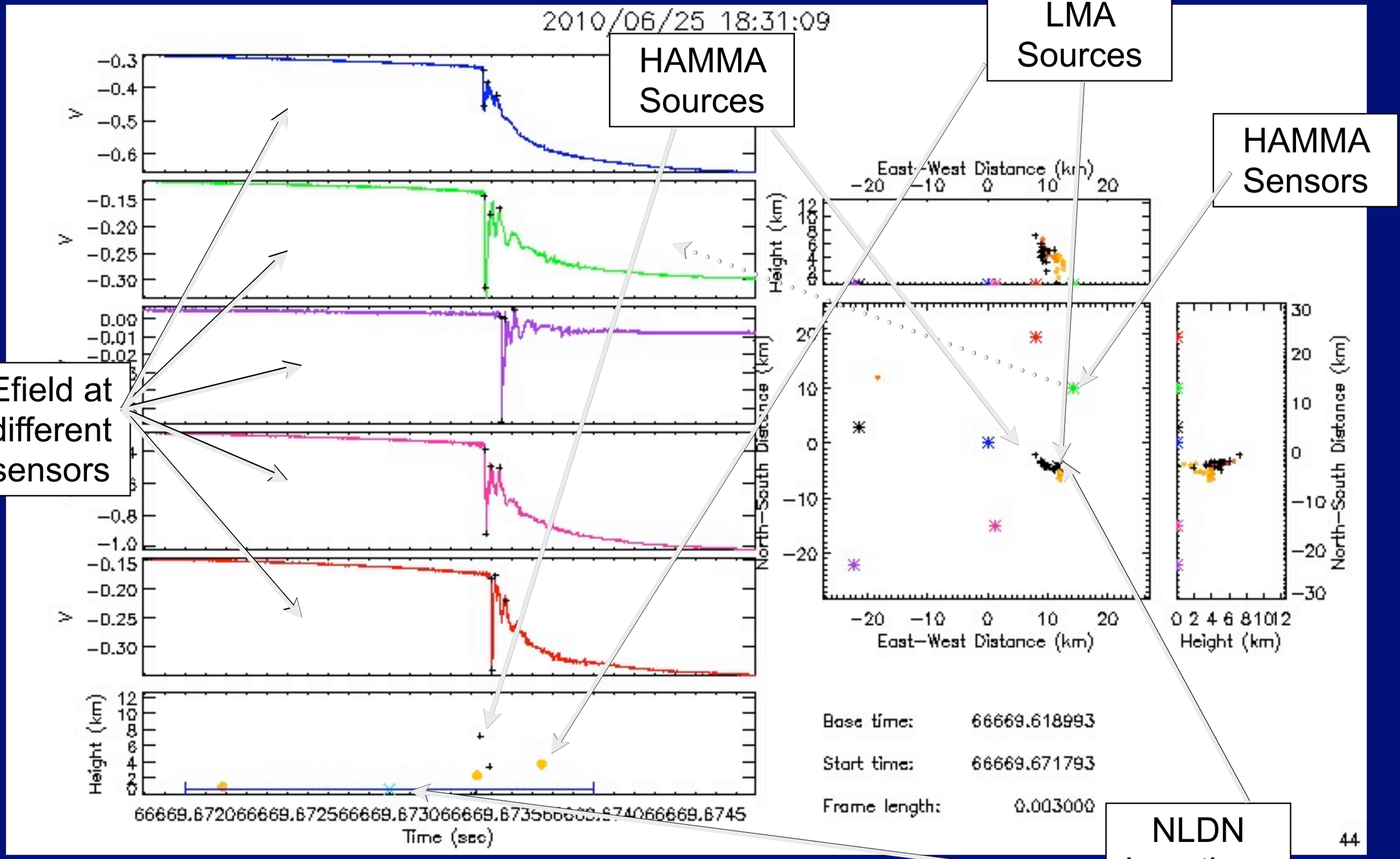
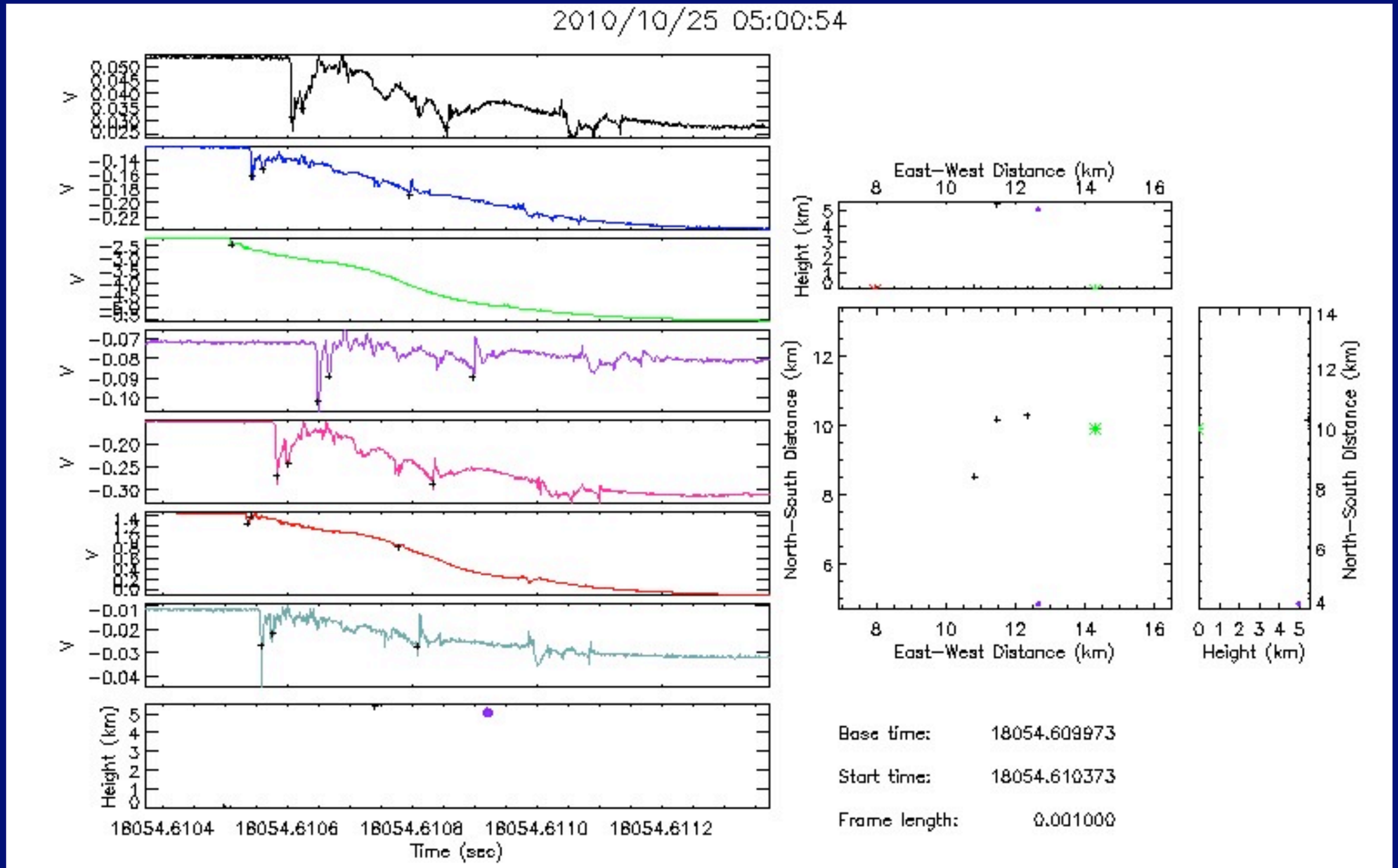
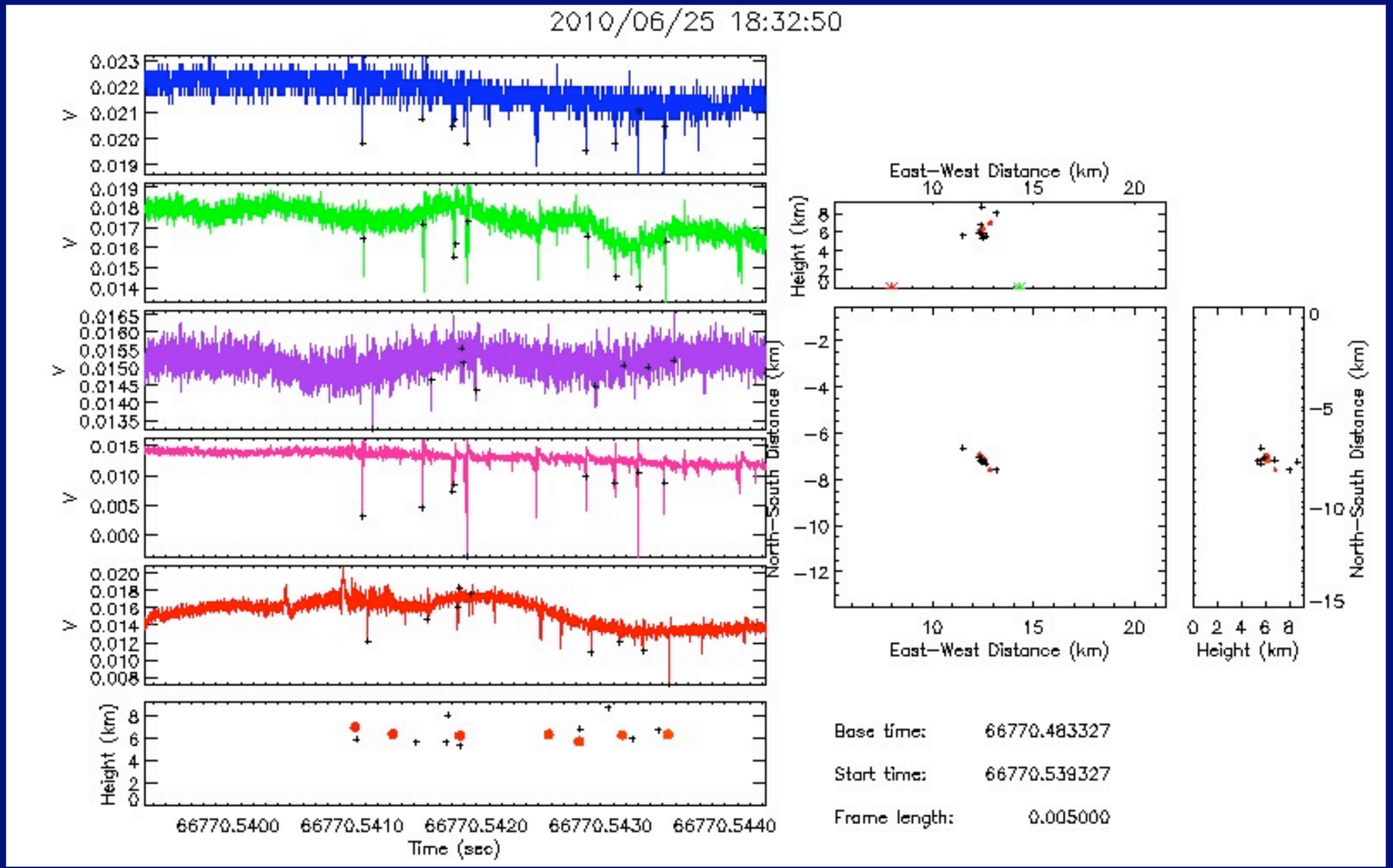


We can do spacetime locations...



We can look at initiation...



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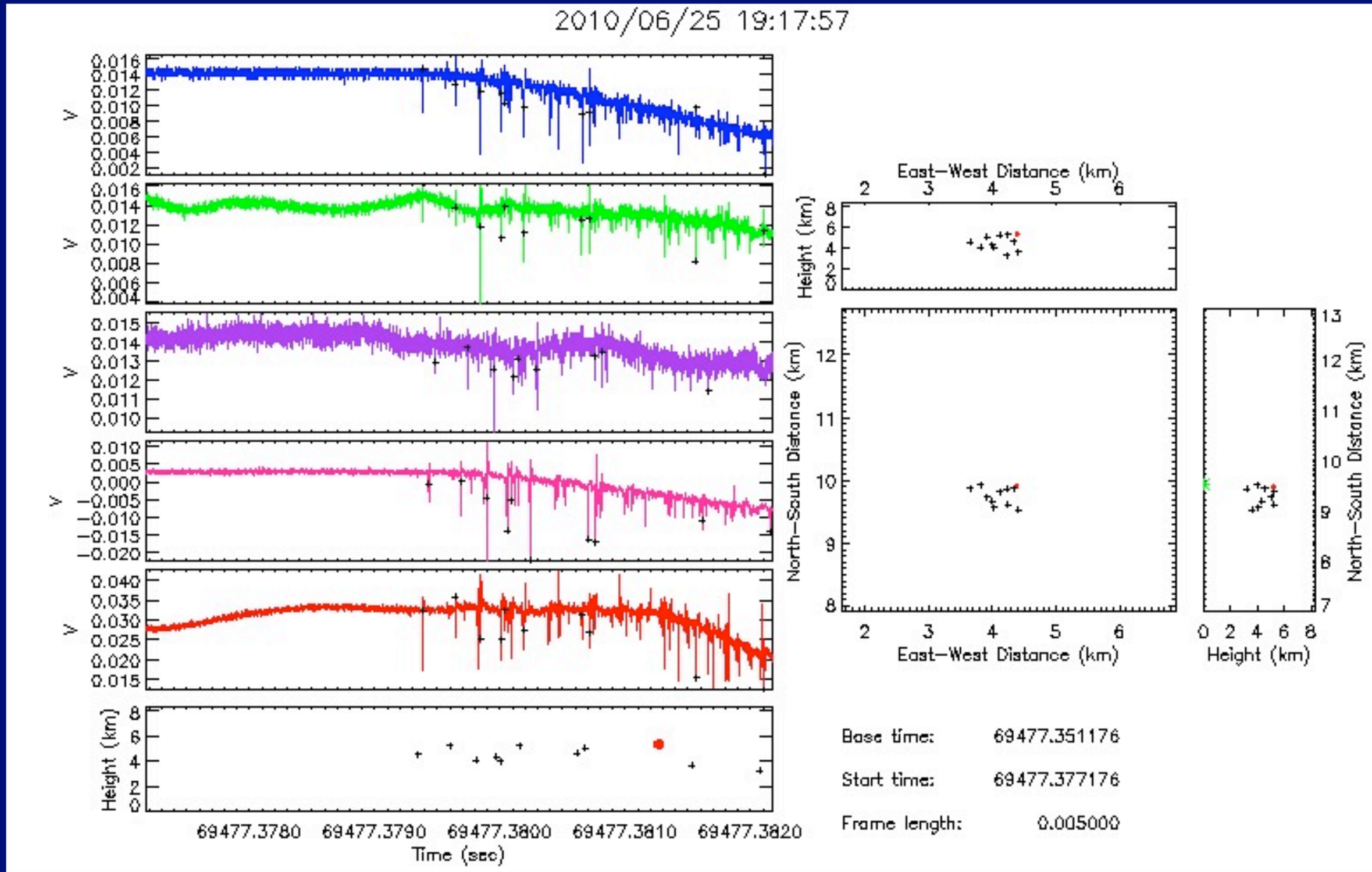
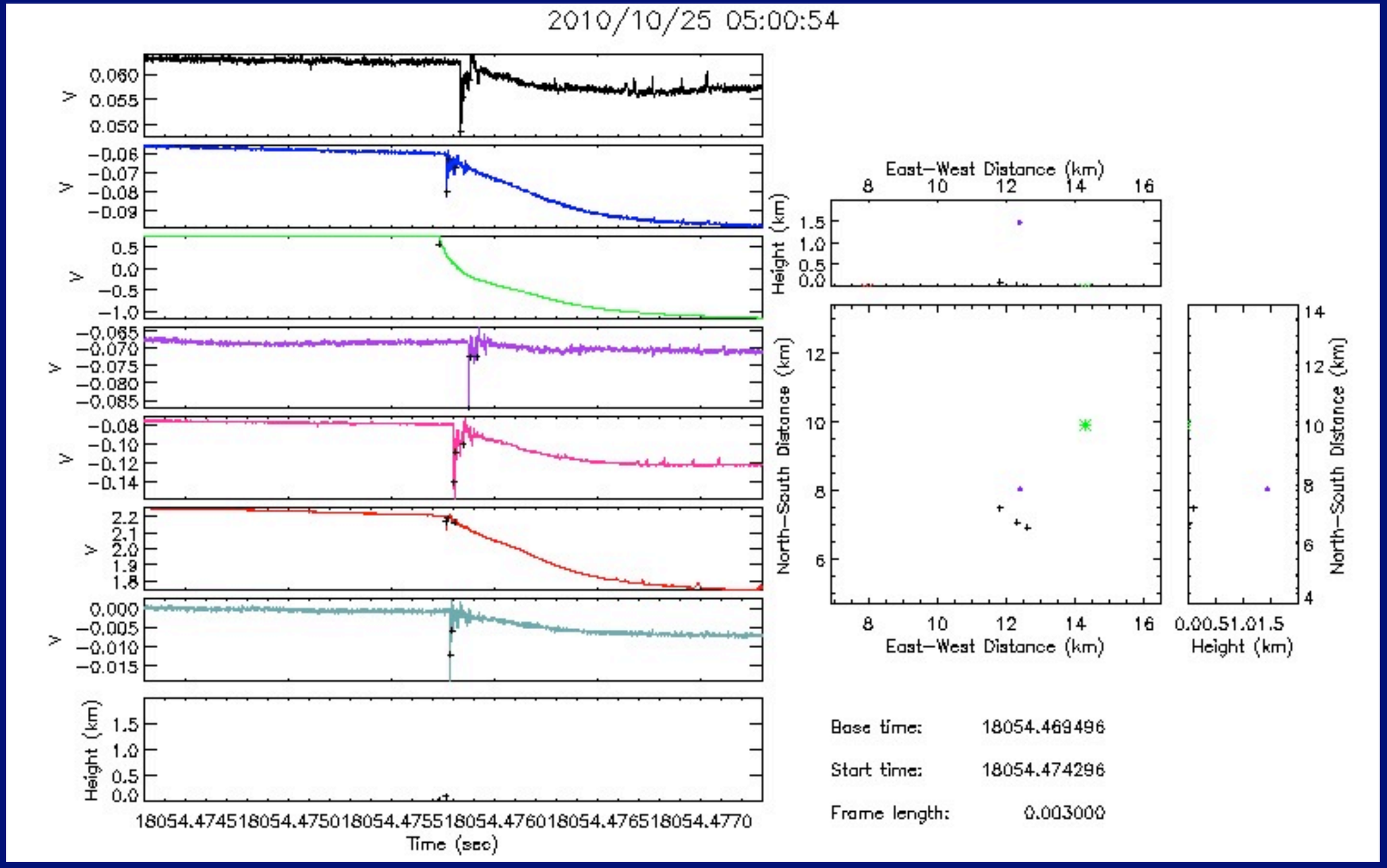


We can compare with NLDN...



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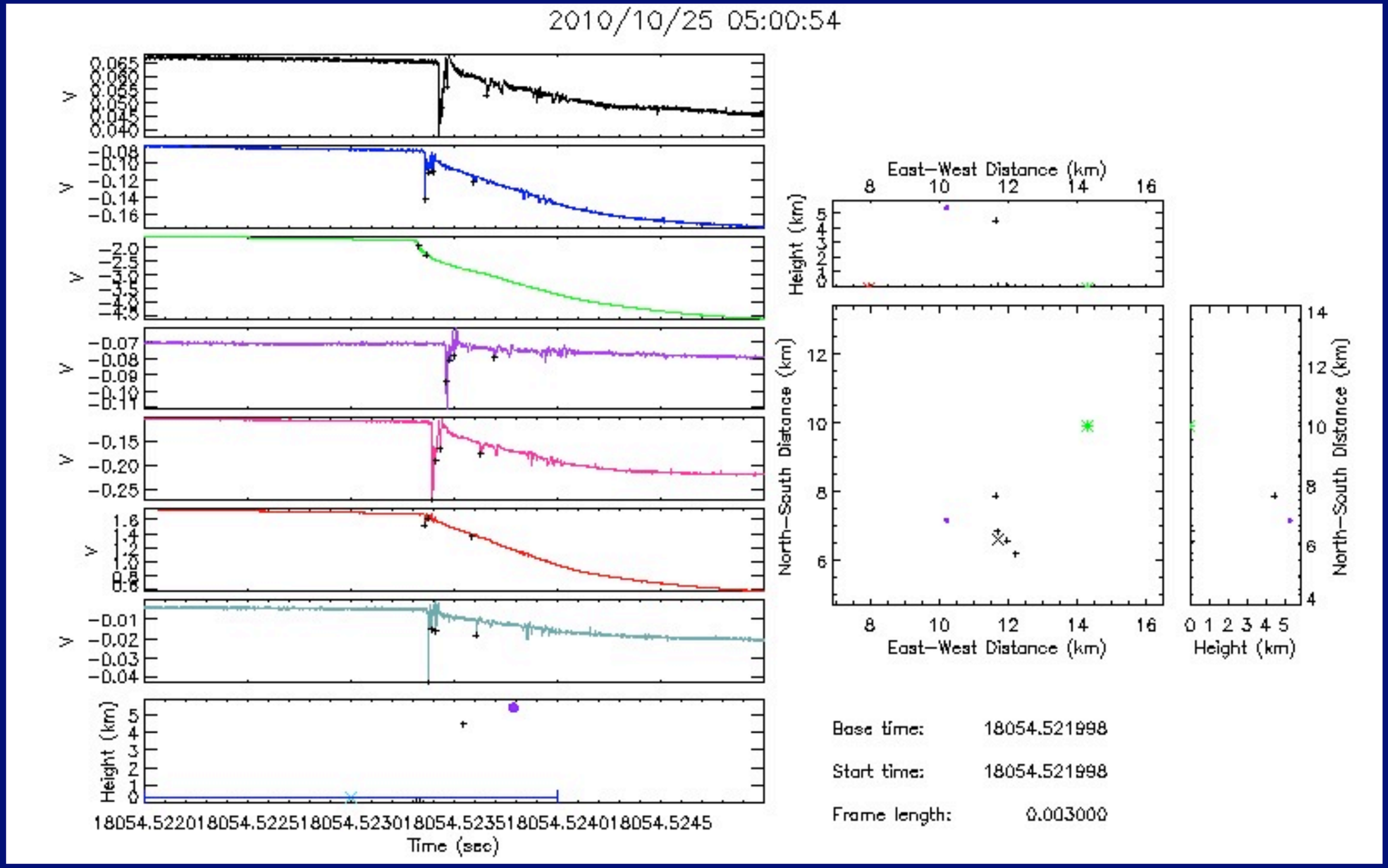

We can compare with NLDN...

- Without assuming the strike point is at the ground...

NLDN vs Hamma	delta x	delta y	delta d
Mean	0.217	0.292	0.306
Spread	0.159	0.556	0.529

NLDN stroke detection efficiency = 0.72

We can get charge retrievals...

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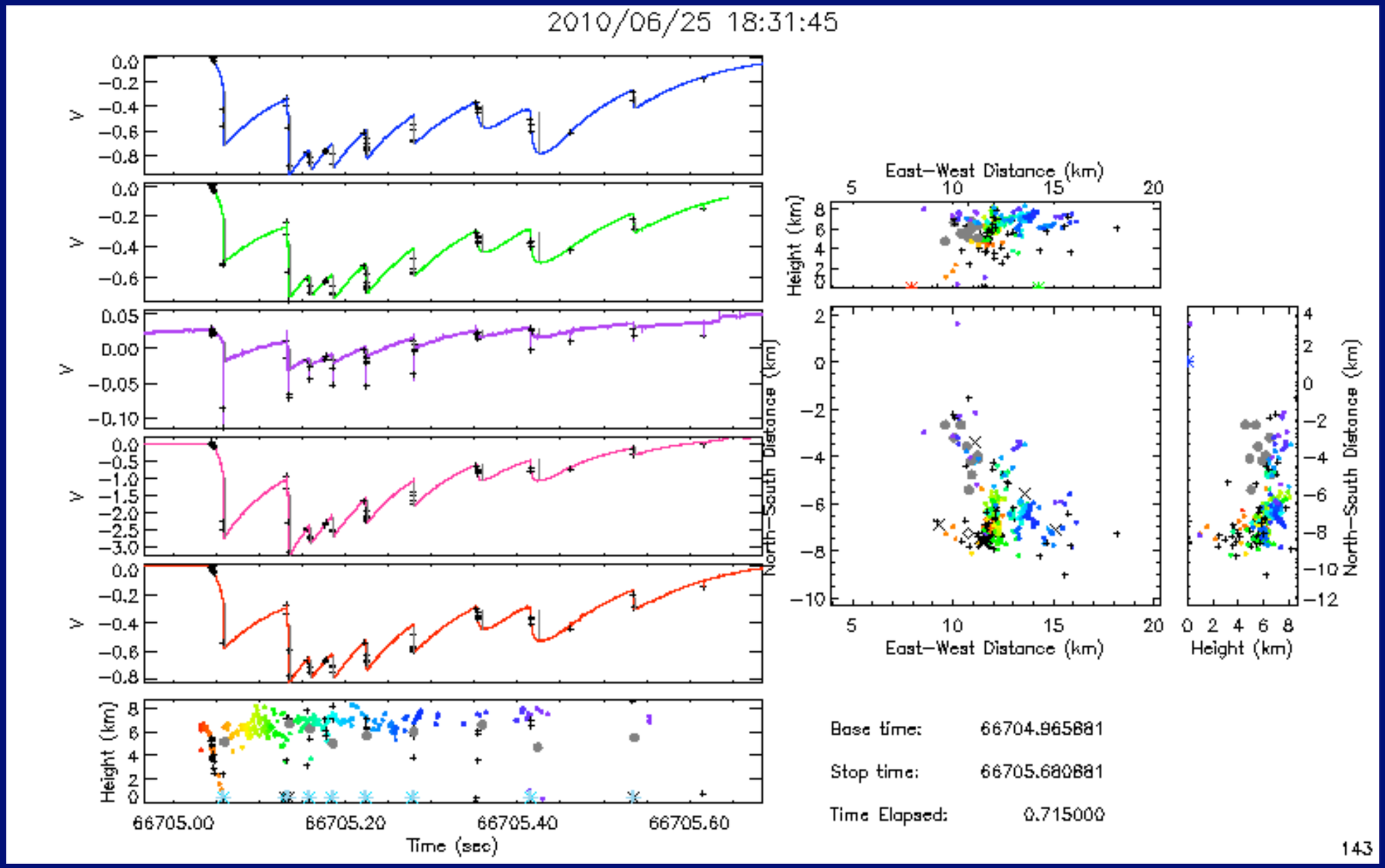
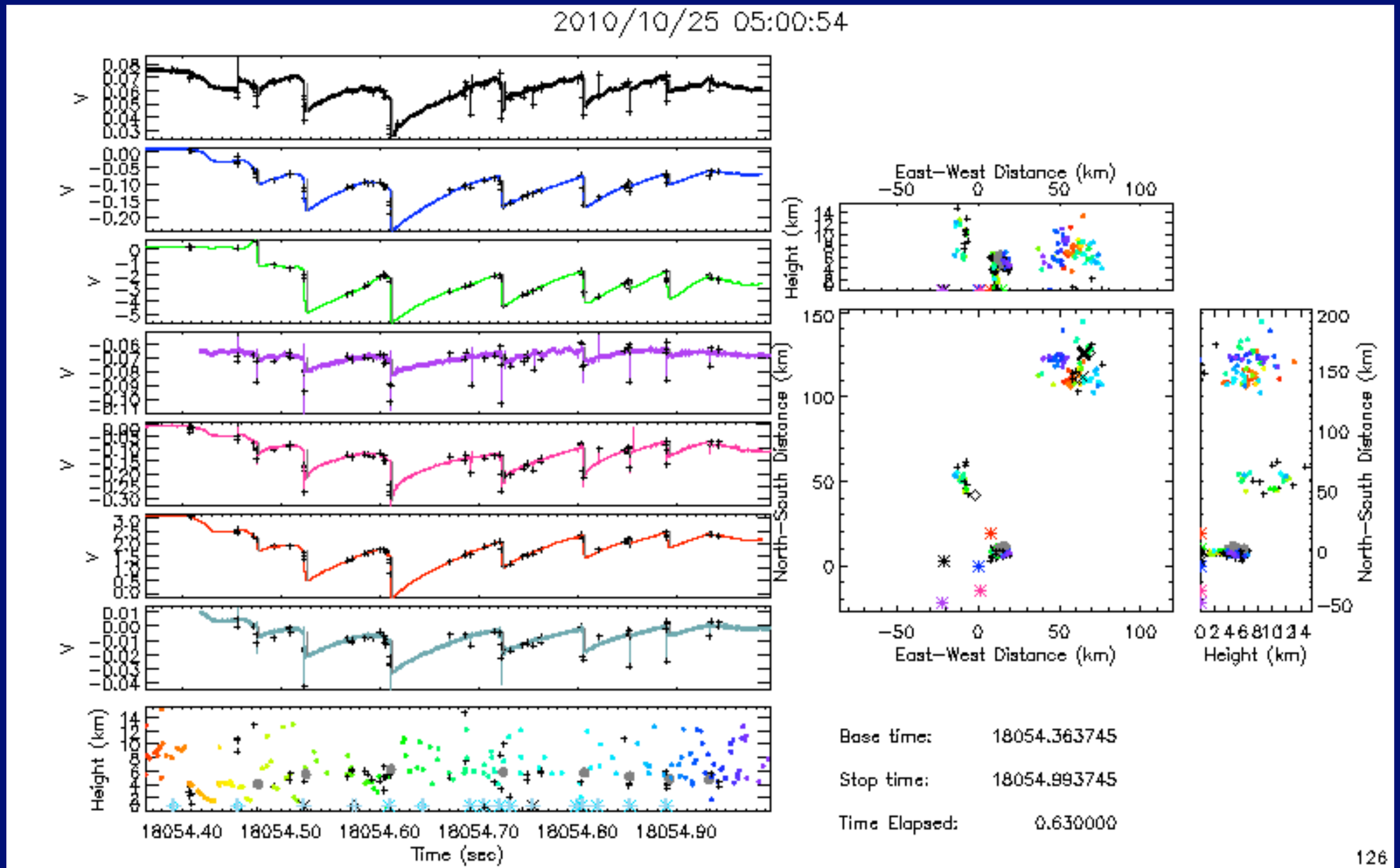
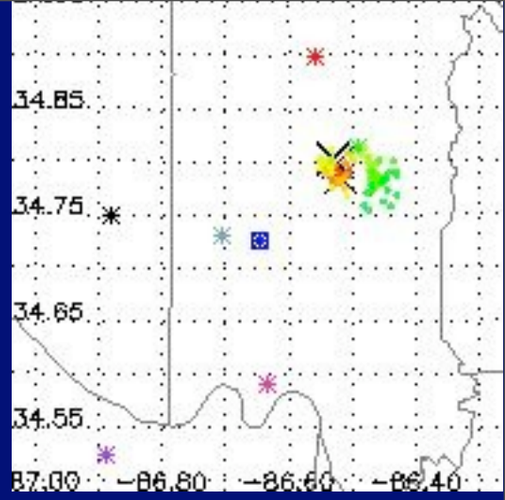


Case 1

Case 1


2010/10/25 05:00:54
V
Height (km)
Time (sec)
18054.40
18054.50
18054.60
18054.70
18054.80
18054.90
East–West Distance (km)
North–South Distance (km)
Base time: 18054.363745
Stop time: 18054.993745
Time Elapsed: 0.630000
126

Case 1, part 2



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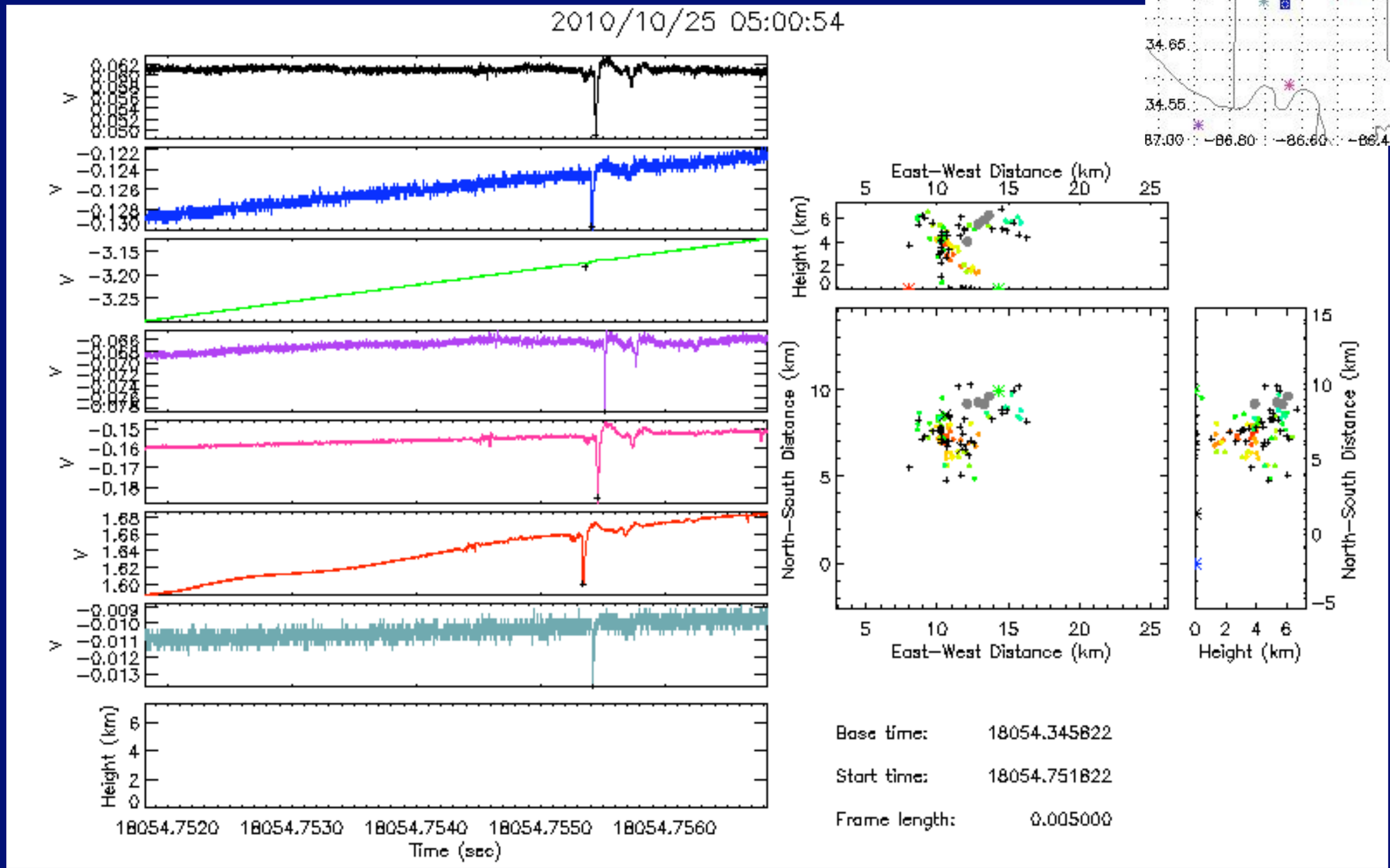
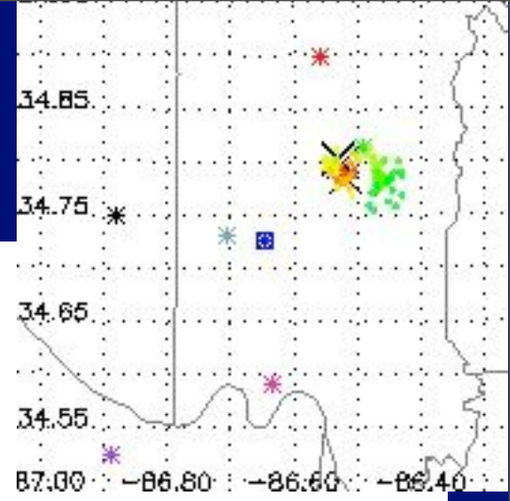
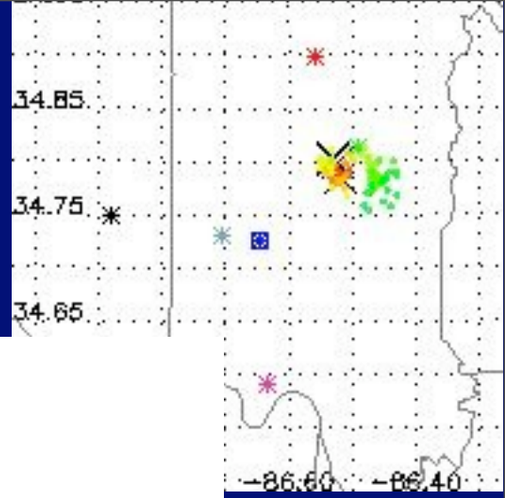
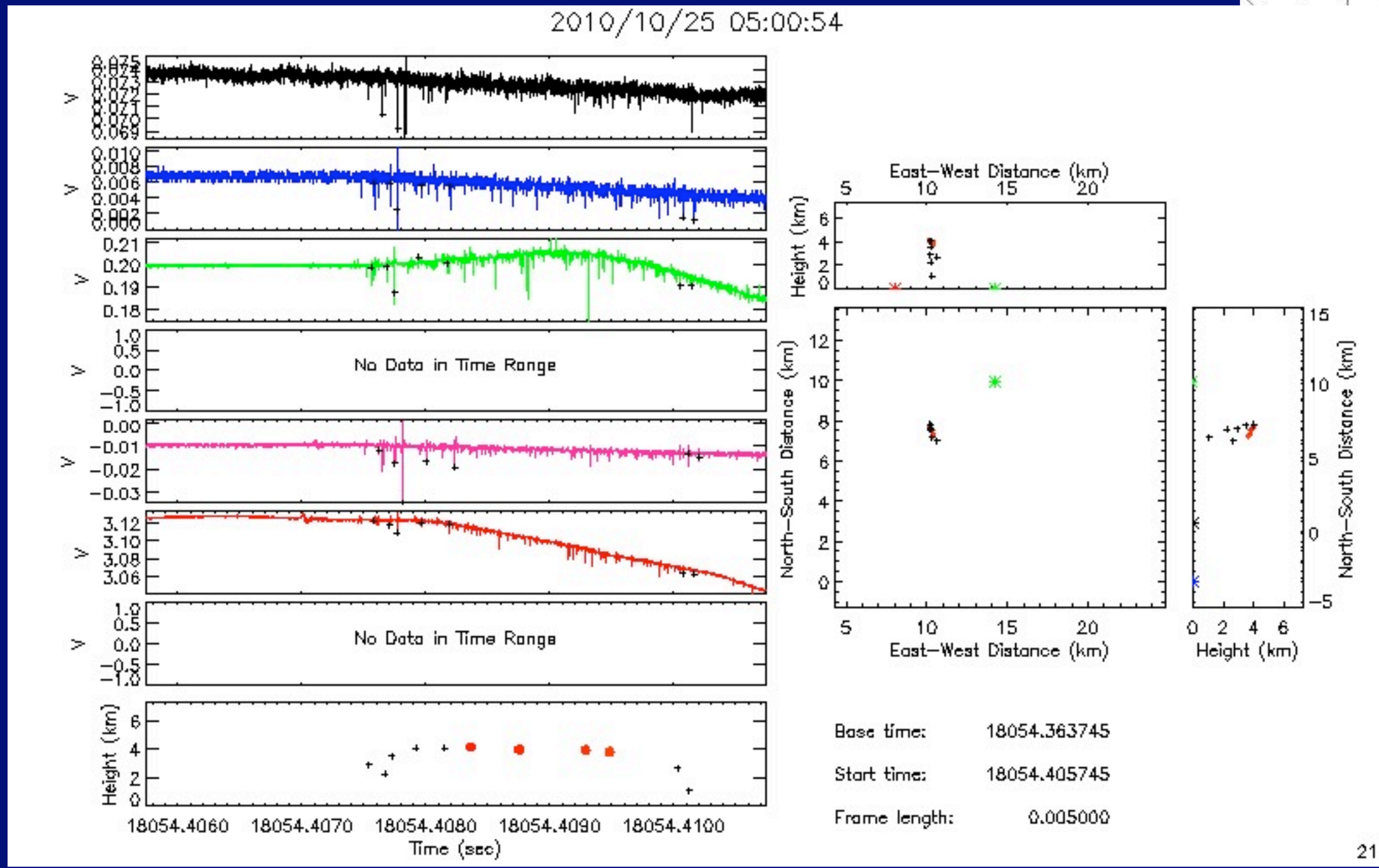
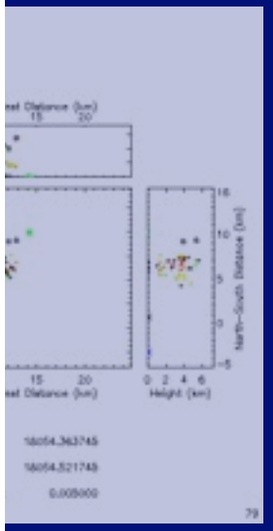

2010/10/25 05:00:54
V
−0.122
−0.124
−0.126
−0.128
−0.130
−3.15
−3.20
−3.25
−0.15
−0.16
−0.17
−0.18
1.68
1.66
1.64
1.62
1.60
−0.009
−0.010
−0.011
−0.012
−0.013
Height (km)
0
2
4
6
18054.7520
18054.7530
18054.7540
18054.7550
18054.7560
Time (sec)
East−West Distance (km)
5
10
15
20
25
Height (km)
North−South Distance (km)
0
5
10
15
−5
0
2
4
6
Base time: 18054.345822
Start time: 18054.751822
Frame length: 0.005000


34.85
34.75
34.65
34.55
87.00
−86.80
−86.60
−86.40

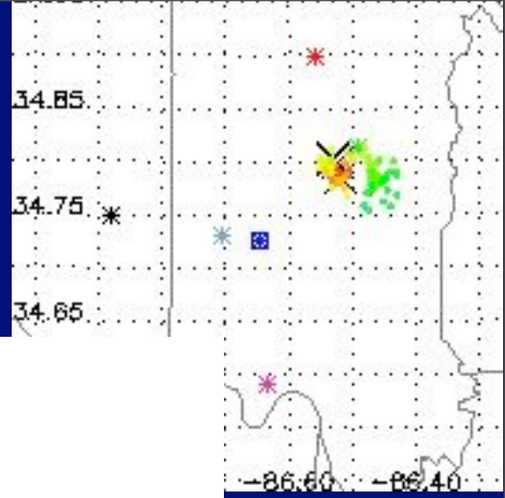
Case 1, part 3

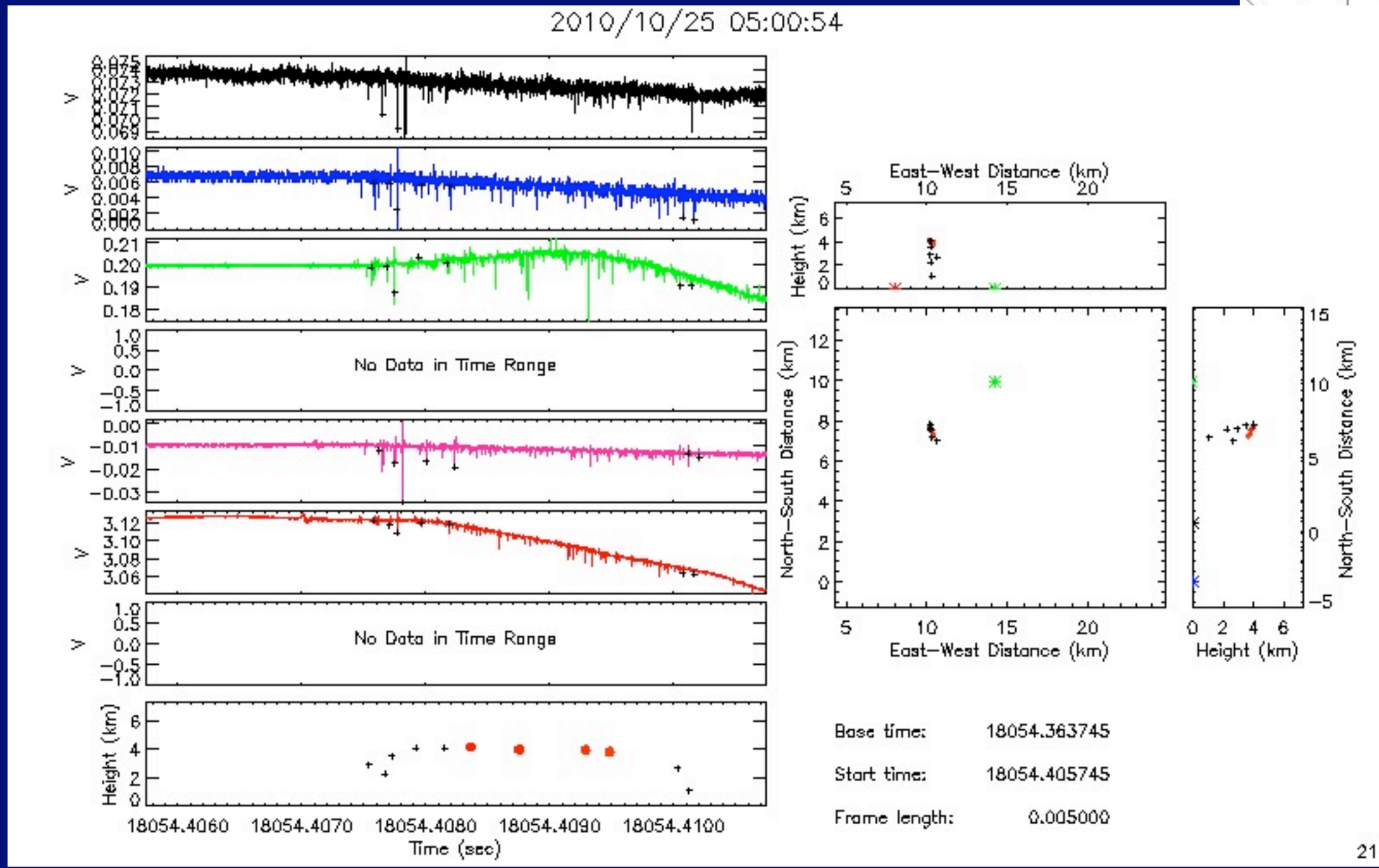

34.85
34.75
34.65
−86.60
−86.40

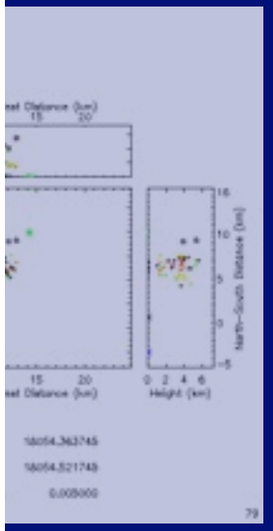

2010/10/25 05:00:54
No Data in Time Range
No Data in Time Range
Height (km)
Time (sec)
18054.4060
18054.4070
18054.4080
18054.4090
18054.4100
East−West Distance (km)
North−South Distance (km)
Base time: 18054.363745
Start time: 18054.405745
Frame length: 0.005000
21



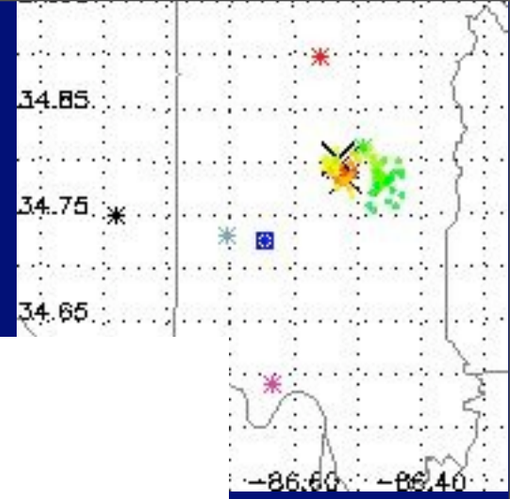
Case 1, part 3

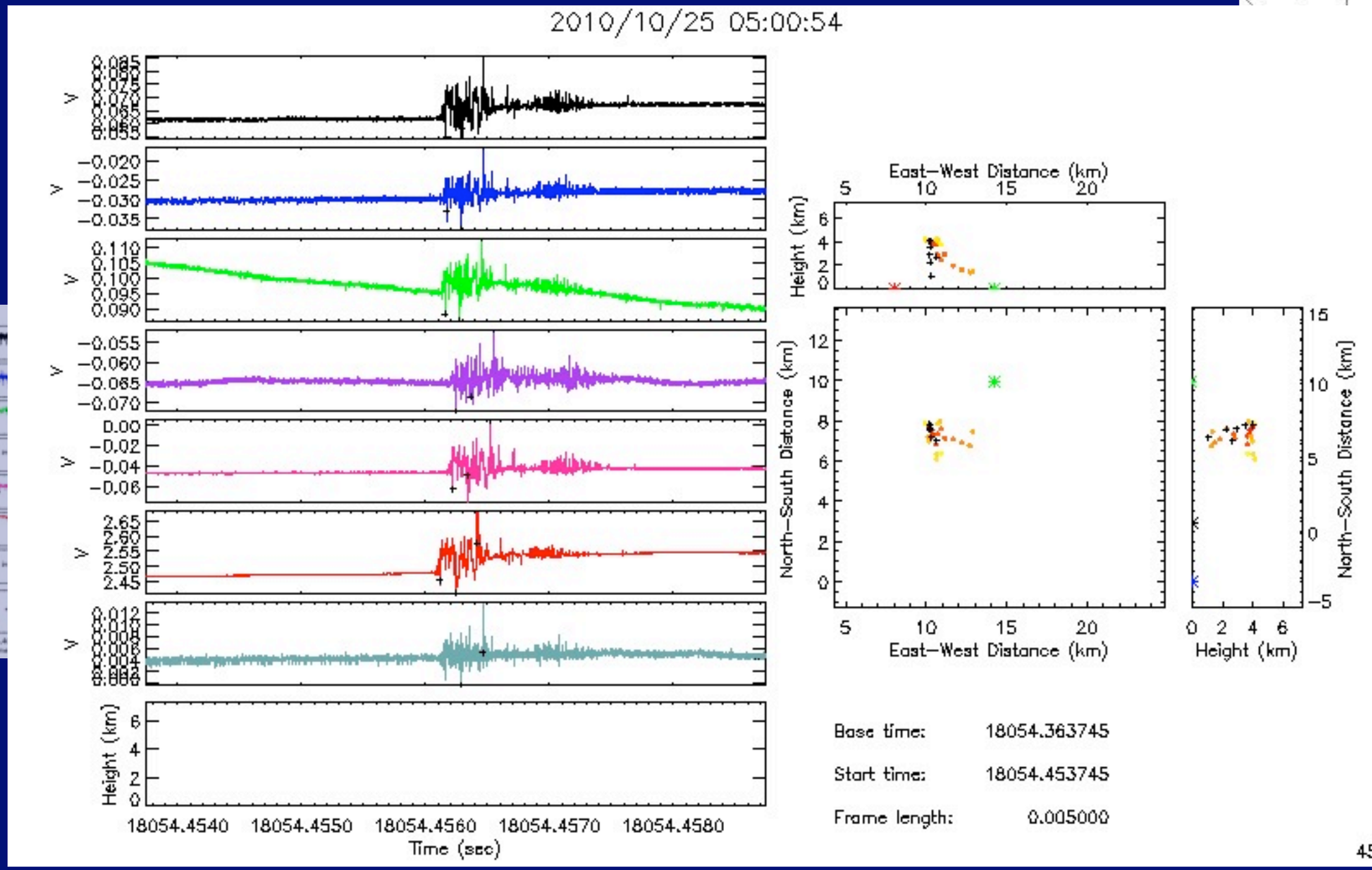

34.85
34.75
34.65
−86.60
−86.40


2010/10/25 05:00:54
No Data in Time Range
No Data in Time Range
Height (km)
Time (sec)
18054.4060
18054.4070
18054.4080
18054.4090
18054.4100
East−West Distance (km)
North−South Distance (km)
Base time: 18054.363745
Start time: 18054.405745
Frame length: 0.005000
21

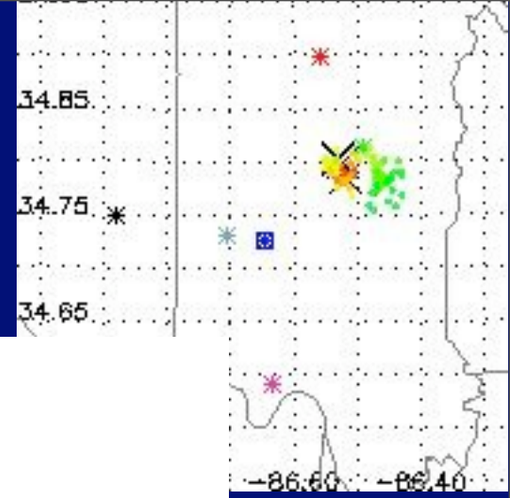


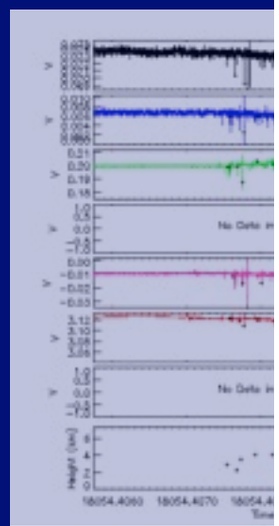
Case 1, part 3

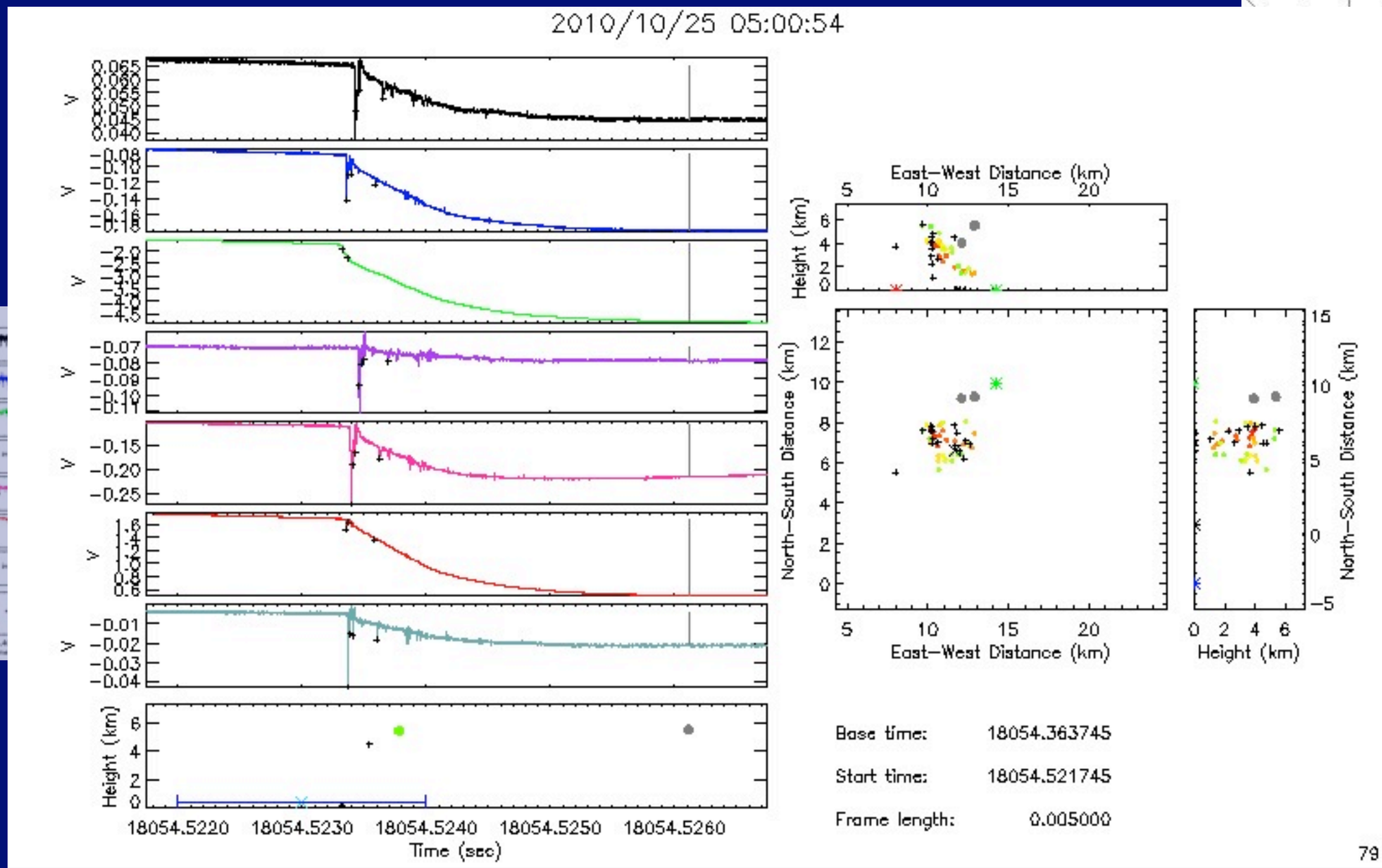

34.85
34.75
34.65
−86.60
−86.40


2010/10/25 05:00:54
V
Height (km)
Time (sec)
East−West Distance (km)
North−South Distance (km)
Base time: 18054.363745
Start time: 18054.453745
Frame length: 0.005000
45

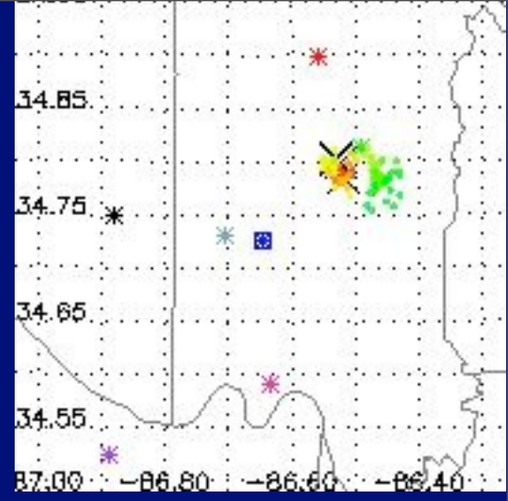
Case 1, part 3

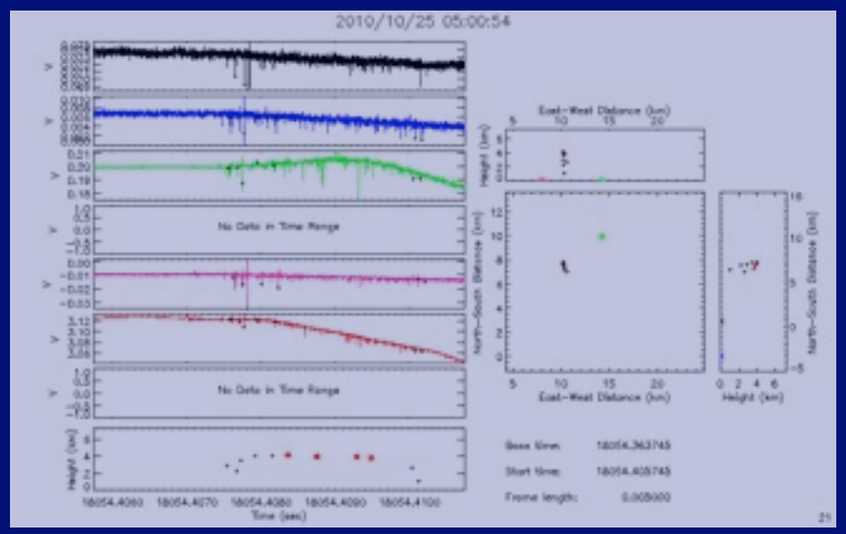

34.85
34.75
34.65
−86.60
−86.40

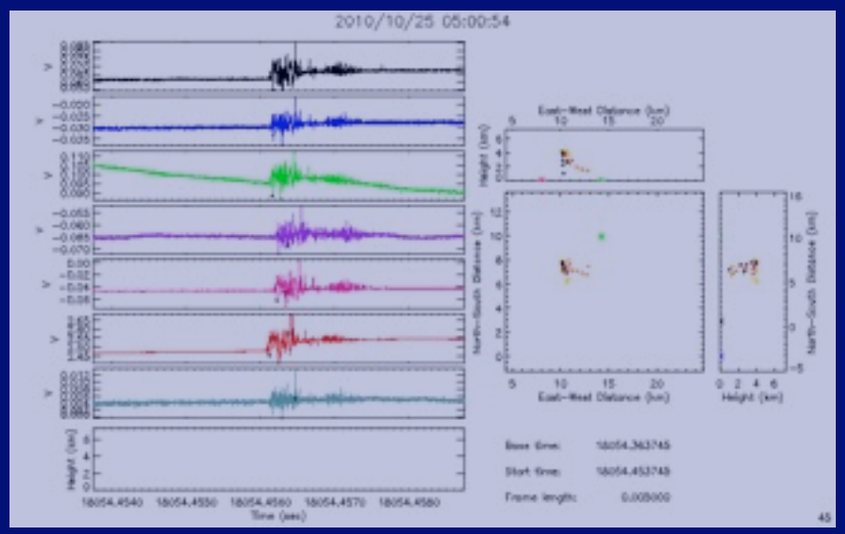


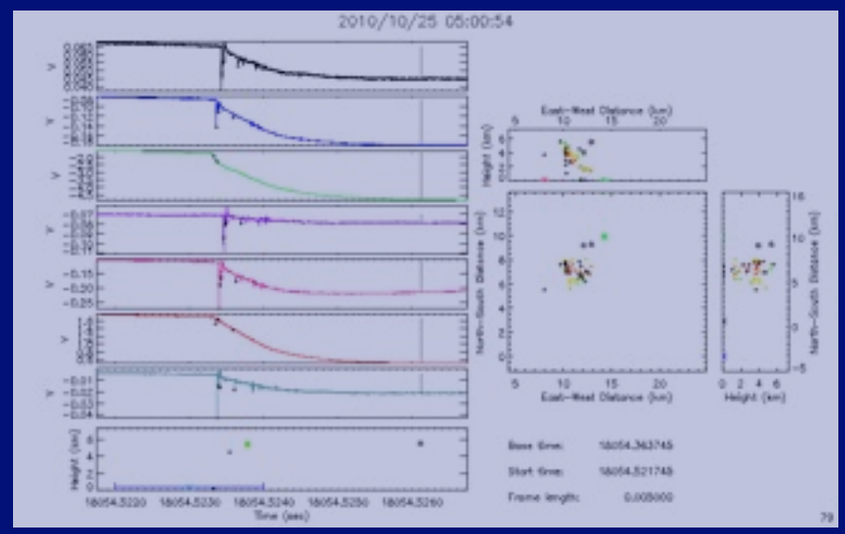

2010/10/25 05:00:54
V
Height (km)
Time (sec)
18054.5220
18054.5230
18054.5240
18054.5250
18054.5260
East−West Distance (km)
North−South Distance (km)
Base time: 18054.363745
Start time: 18054.521745
Frame length: 0.005000
79

Case 1, part 3

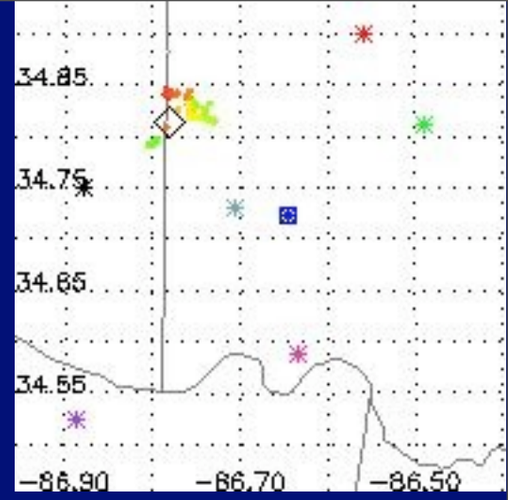

34.85
34.75
34.65
34.55
-87.00
-86.80
-86.60
-86.40


2010/10/25 05:00:54
No Data in Time Range
No Data in Time Range
East-West Distance (km)
North-South Distance (km)
Height (km)
Time (sec)
21

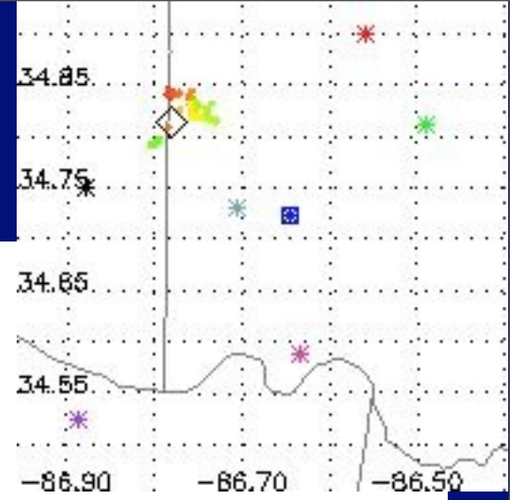

2010/10/25 05:00:54
East-West Distance (km)
North-South Distance (km)
Height (km)
Time (sec)
45

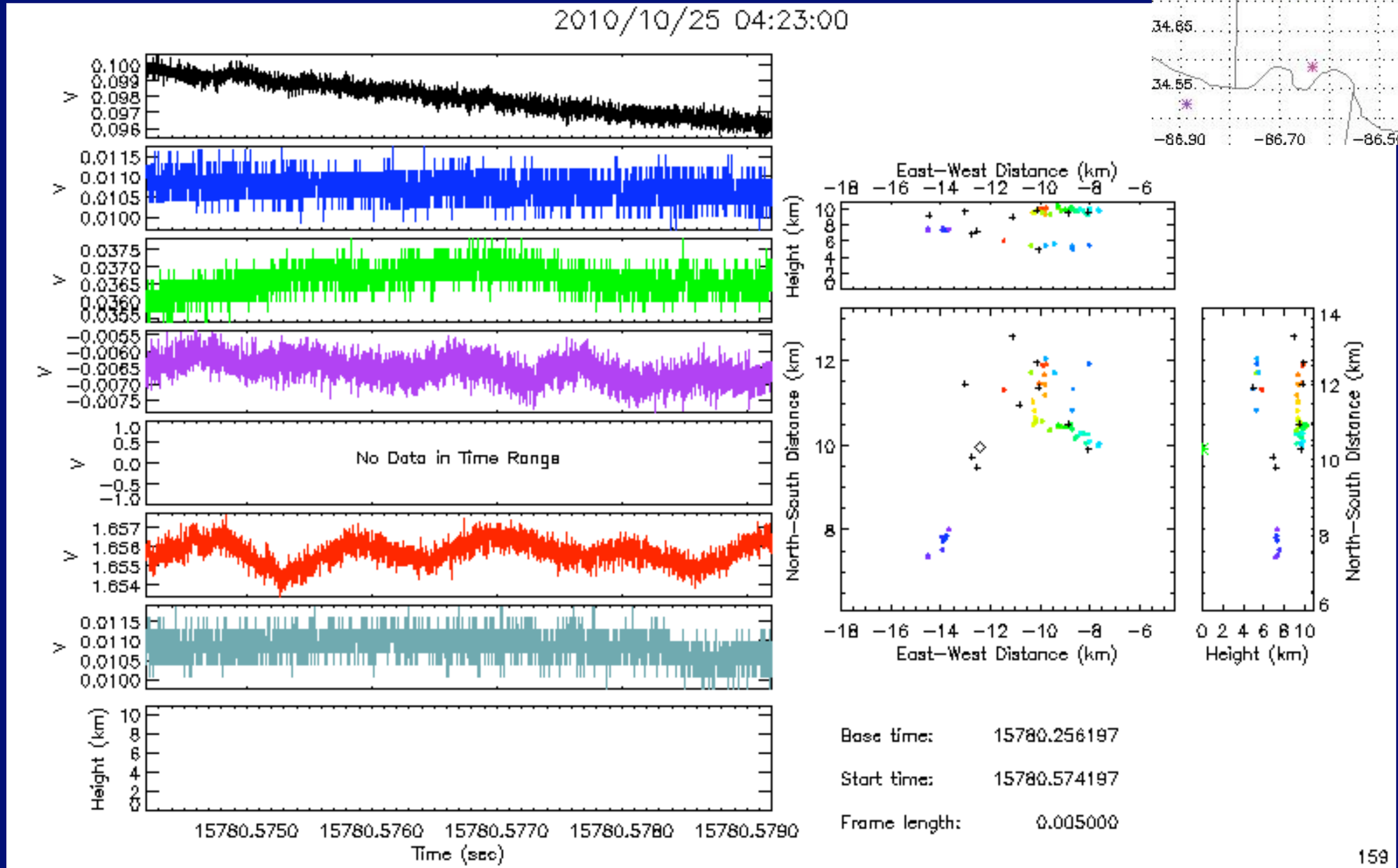

2010/10/25 05:00:54
East-West Distance (km)
North-South Distance (km)
Height (km)
Time (sec)
79

Case 1.5



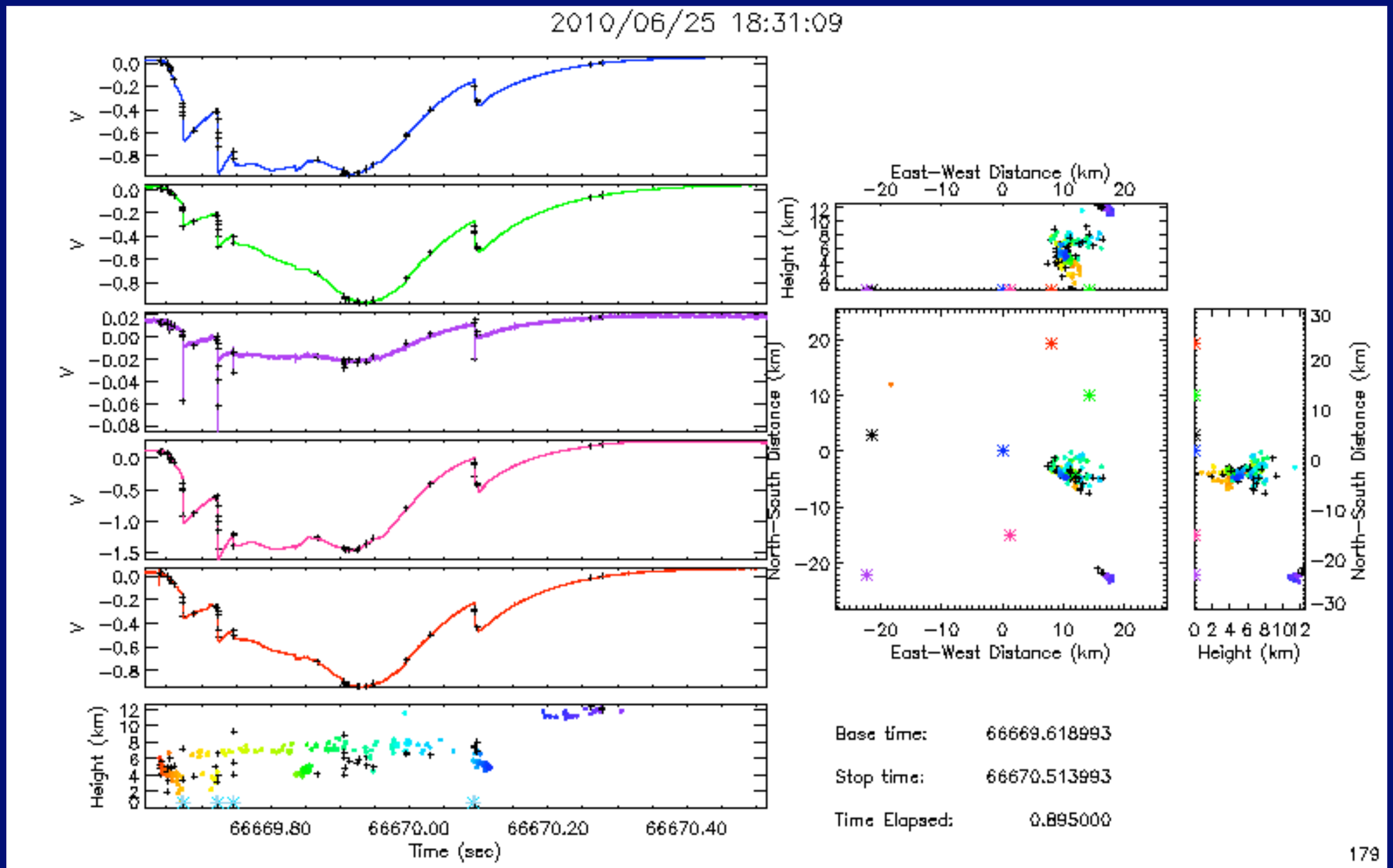
Case 1.5


34.85
34.75
34.65
34.55
−86.90
−86.70
−86.50


2010/10/25 04:23:00
V
0.100
0.099
0.098
0.097
0.096
0.0115
0.0110
0.0105
0.0100
0.0375
0.0370
0.0365
0.0360
0.0355
−0.0055
−0.0060
−0.0065
−0.0070
−0.0075
1.0
0.5
0.0
−0.5
−1.0
No Data in Time Range
1.657
1.656
1.655
1.654
Height (km)
10
8
6
4
2
15780.5750
15780.5760
15780.5770
15780.5780
15780.5790
Time (sec)
East−West Distance (km)
−18 −16 −14 −12 −10 −8 −6
North−South Distance (km)
12
10
8
0 2 4 6 8 10
Height (km)
14
6
Base time: 15780.256197
Start time: 15780.574197
Frame length: 0.005000
159

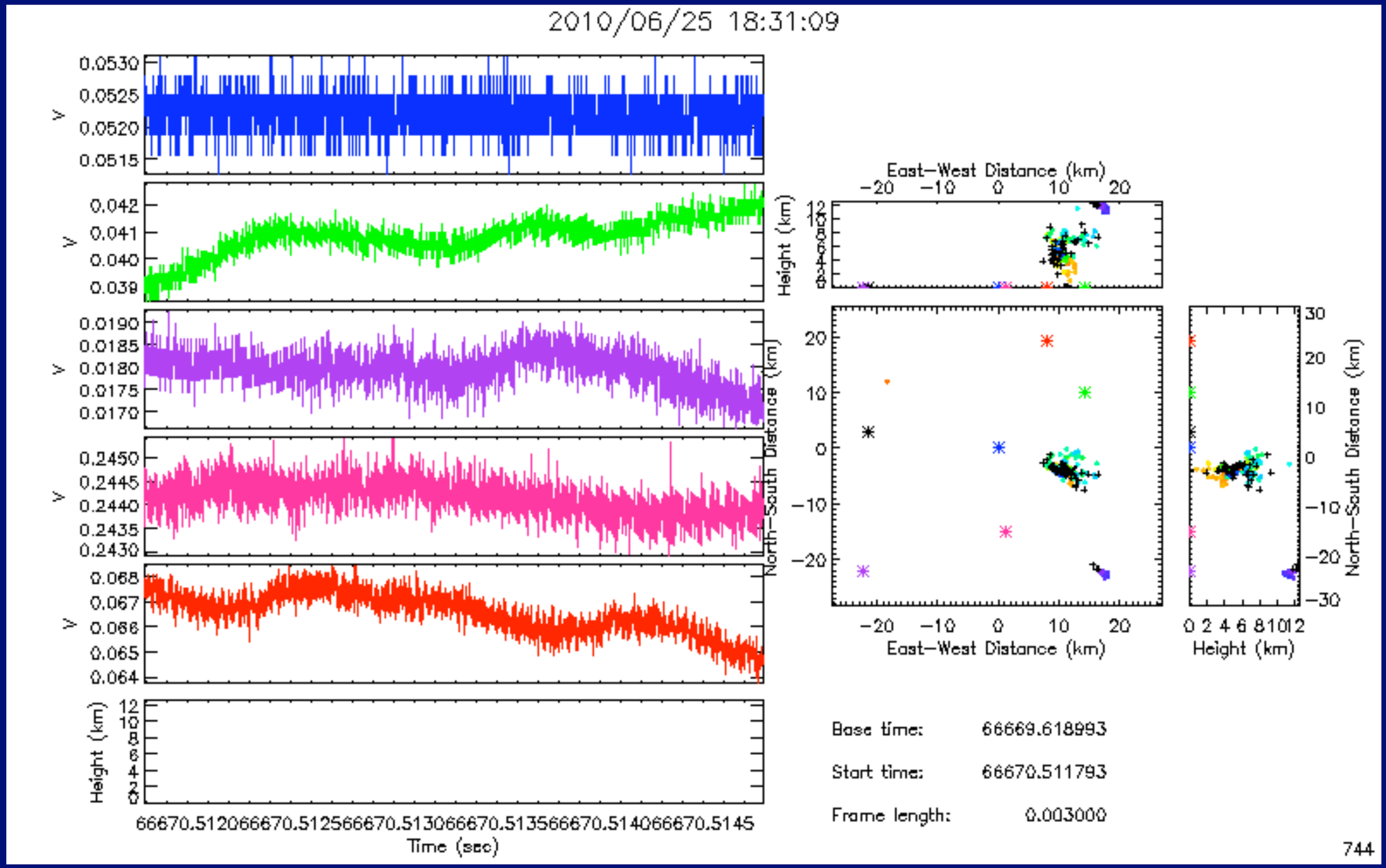
Case 2

Case 2

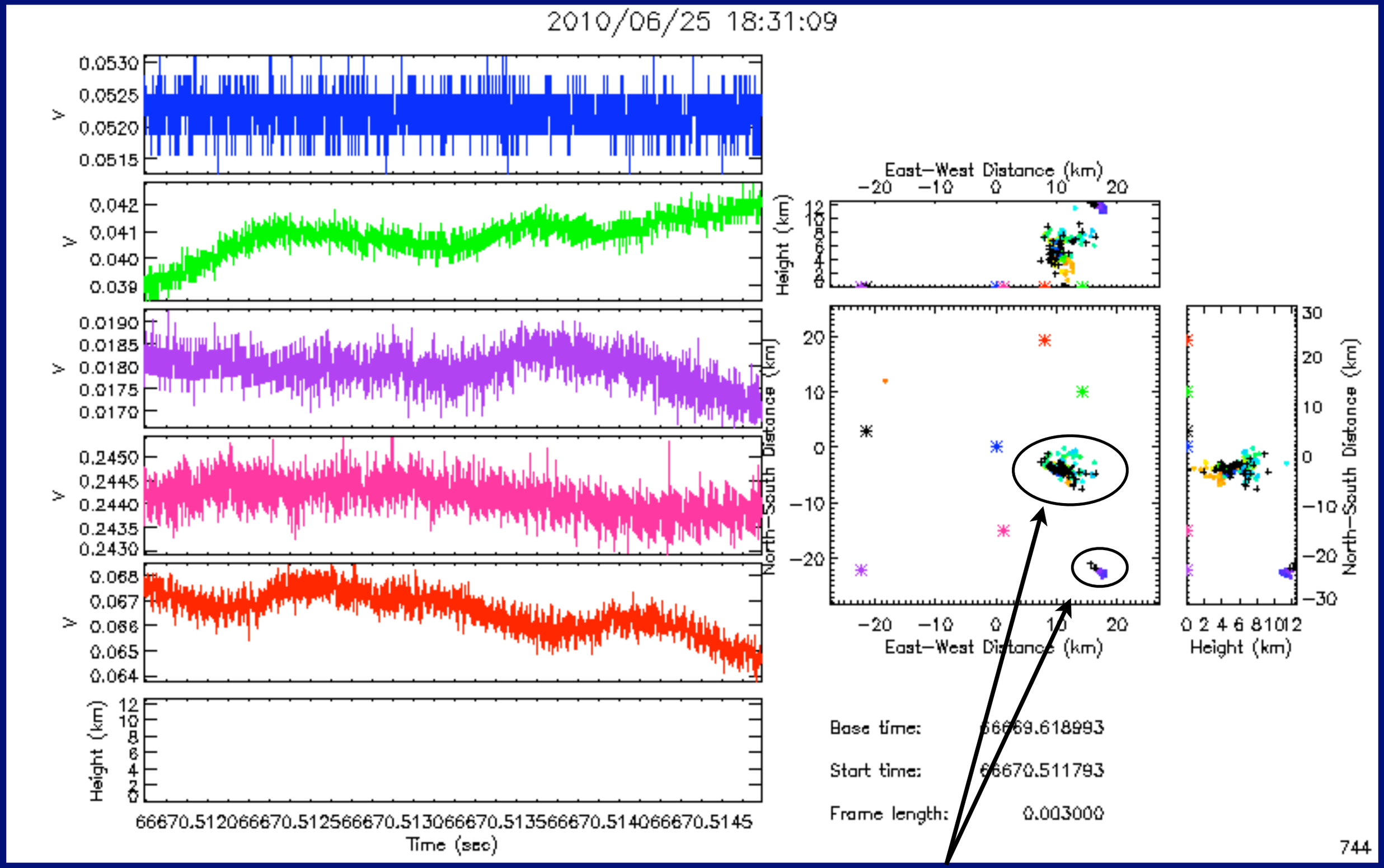

2010/06/25 18:31:09
V
Height (km)
East–West Distance (km)
North–South Distance (km)
Time (sec)
66669.80
66670.00
66670.20
66670.40
Base time: 66669.618993
Stop time: 66670.513993
Time Elapsed: 0.895000
179

Case 2, part 2

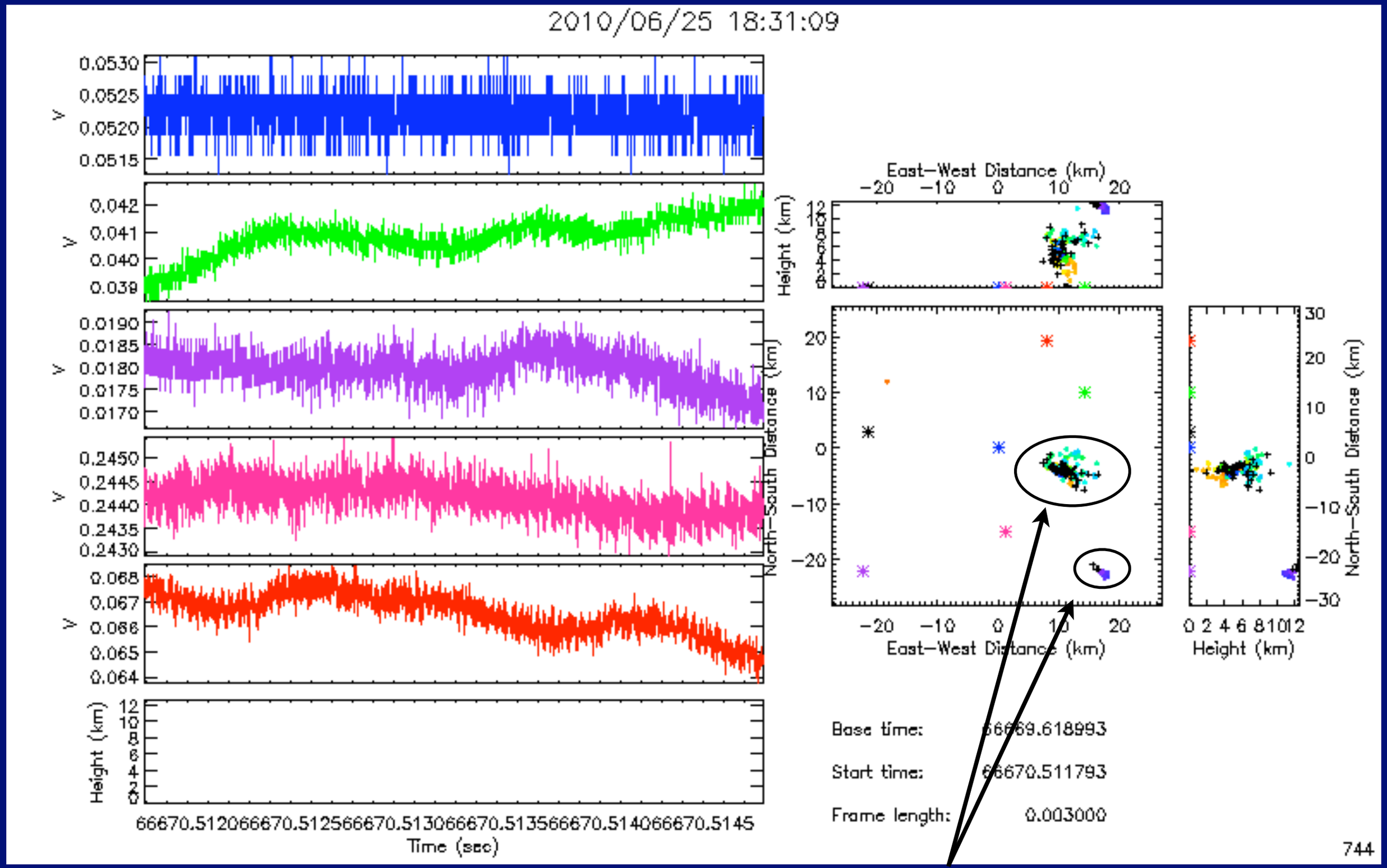
Case 2, part 2


2010/06/25 18:31:09
V
0.0530
0.0525
0.0520
0.0515
0.042
0.041
0.040
0.039
0.0190
0.0185
0.0180
0.0175
0.0170
0.2450
0.2445
0.2440
0.2435
0.2430
0.068
0.067
0.066
0.065
0.064
Height (km)
12
10
8
6
4
2
0
66670.512066670.512566670.513066670.513566670.514066670.5145
Time (sec)
East–West Distance (km)
−20 −10 0 10 20
North–South Distance (km)
20
10
0
−10
−20
0 2 4 6 8 10 12
Height (km)
30
Base time: 66669.618993
Start time: 66670.511793
Frame length: 0.003000
744

Case 2, part 2


2010/06/25 18:31:09
0.0530
0.0525
0.0520
0.0515
V
0.042
0.041
0.040
0.039
0.0190
0.0185
0.0180
0.0175
0.0170
0.2450
0.2445
0.2440
0.2435
0.2430
0.068
0.067
0.066
0.065
0.064
Height (km)
66670.512066670.512566670.513066670.513566670.514066670.5145
Time (sec)
East–West Distance (km)
North–South Distance (km)
Base time: 66669.618993
Start time: 66670.511793
Frame length: 0.003000
744

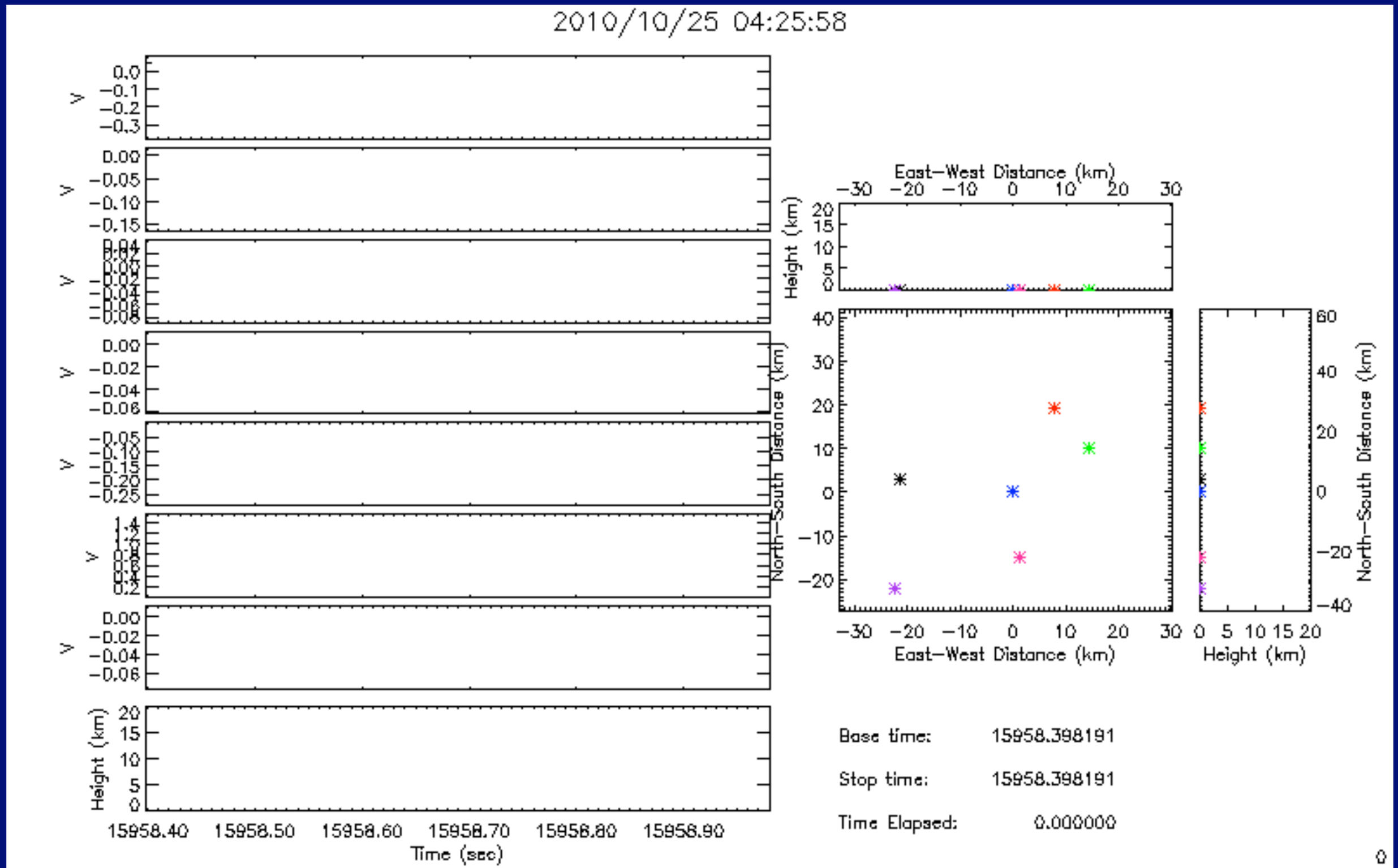
Case 2, part 2



Are these equivalent?

Case 3 (part 2?)

Case 3 (part 2?)


2010/10/25 04:25:58
V
Height (km)
Time (sec)
East–West Distance (km)
North–South Distance (km)
Base time: 15958.398191
Stop time: 15958.398191
Time Elapsed: 0.000000

Wrapping up...

- HAMMA is starting to yield results that can characterize an entire flash
- Each part of the flash has a distinct signature in the electric field record, allowing us to improve current lightning detection techniques
  - Inside the array, we see the same strike point as NLDN
  - Generally speaking, we see similar locations as LMA for in-cloud processes
- Typical location *measurement* errors* are ~350m in x,y and ~1-1.5km in z
- Typical charge values are in the expected range
  - ~3 coulombs/stroke

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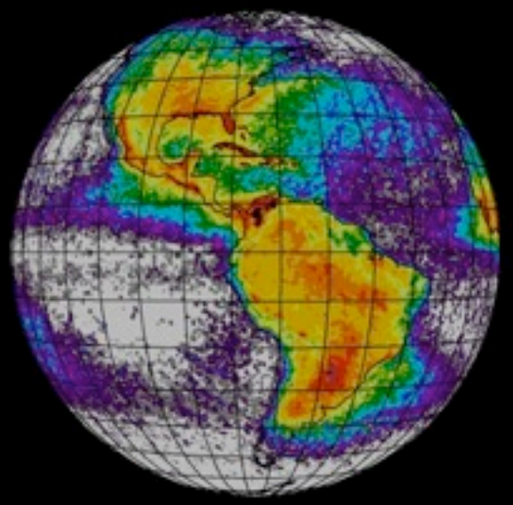
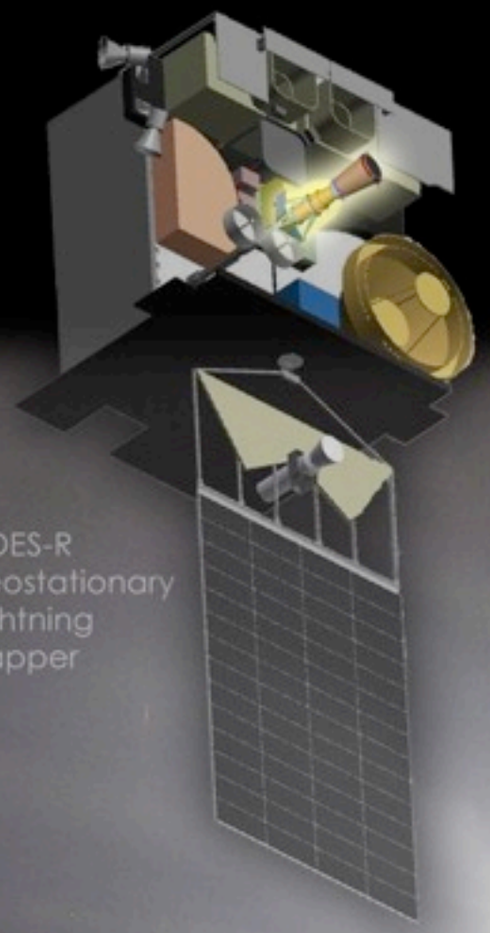
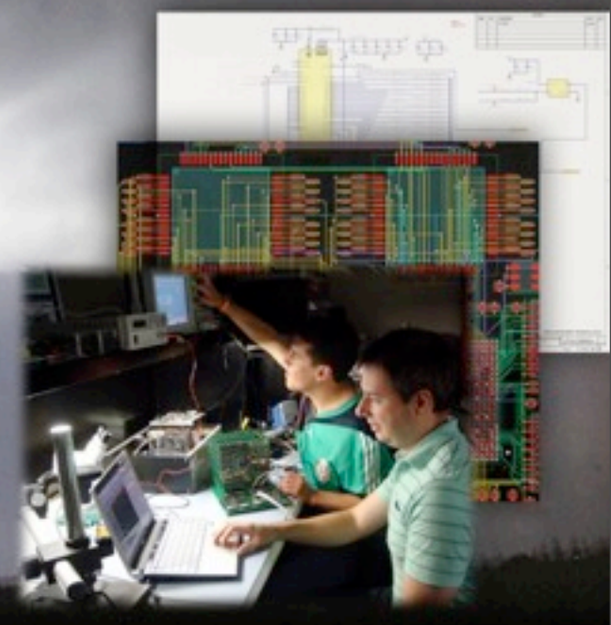




GOES-R
Geostationary
Lightning
Mapper



Fundamental question for validation:

What is the best way from the ground to characterize what GLM “sees?”

Fundamental question for validation:

What is the best way from the ground to characterize what GLM “sees?”

Fundamental question for operation:

What attribute of lightning is most useful?