Plasma Physics with Sounding Rockets in the Northern Lights

The Isinglass auroral sounding rocket mission: Poker Flat Alaska, Winter 2017

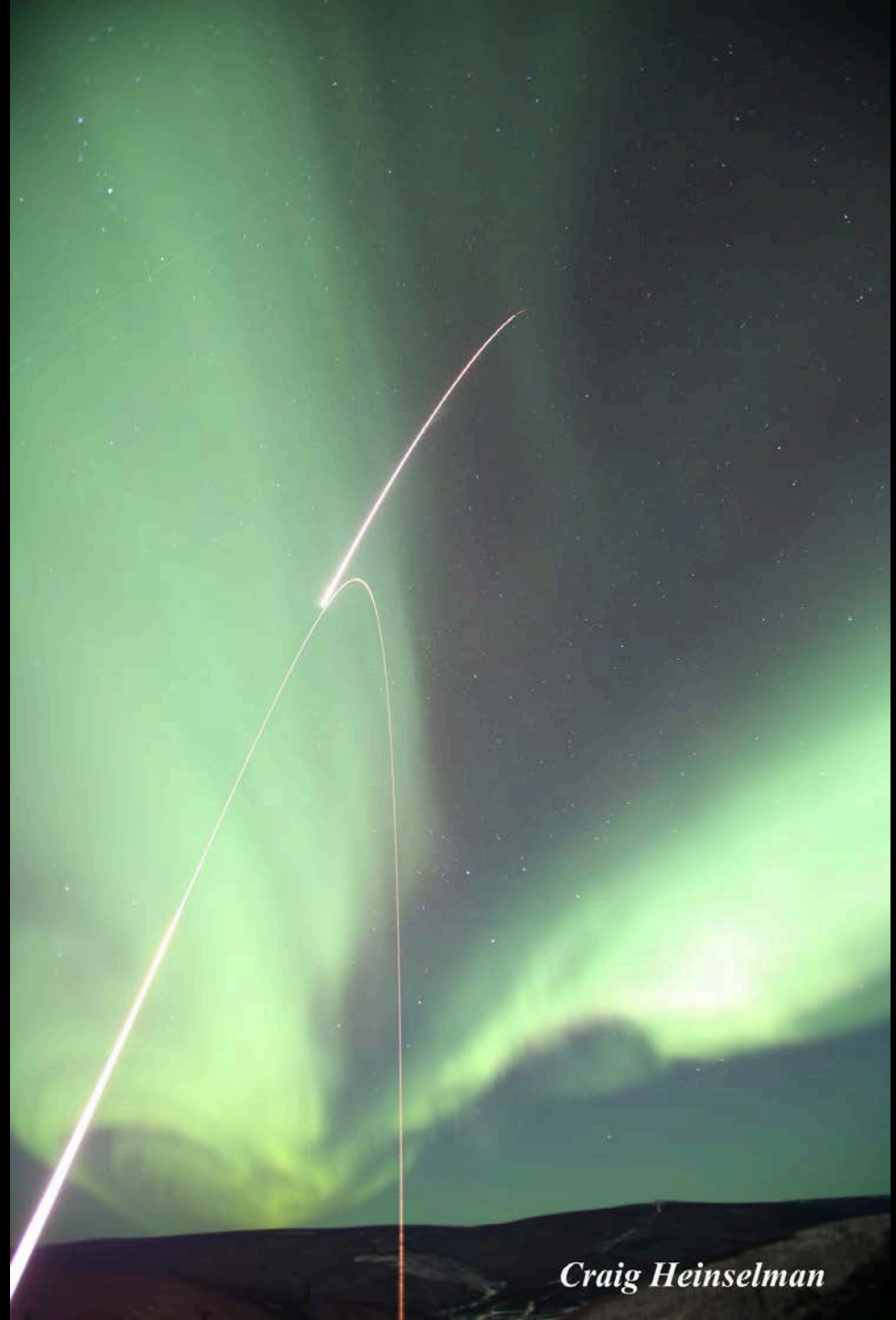
Kristina Lynch

Dartmouth Physics

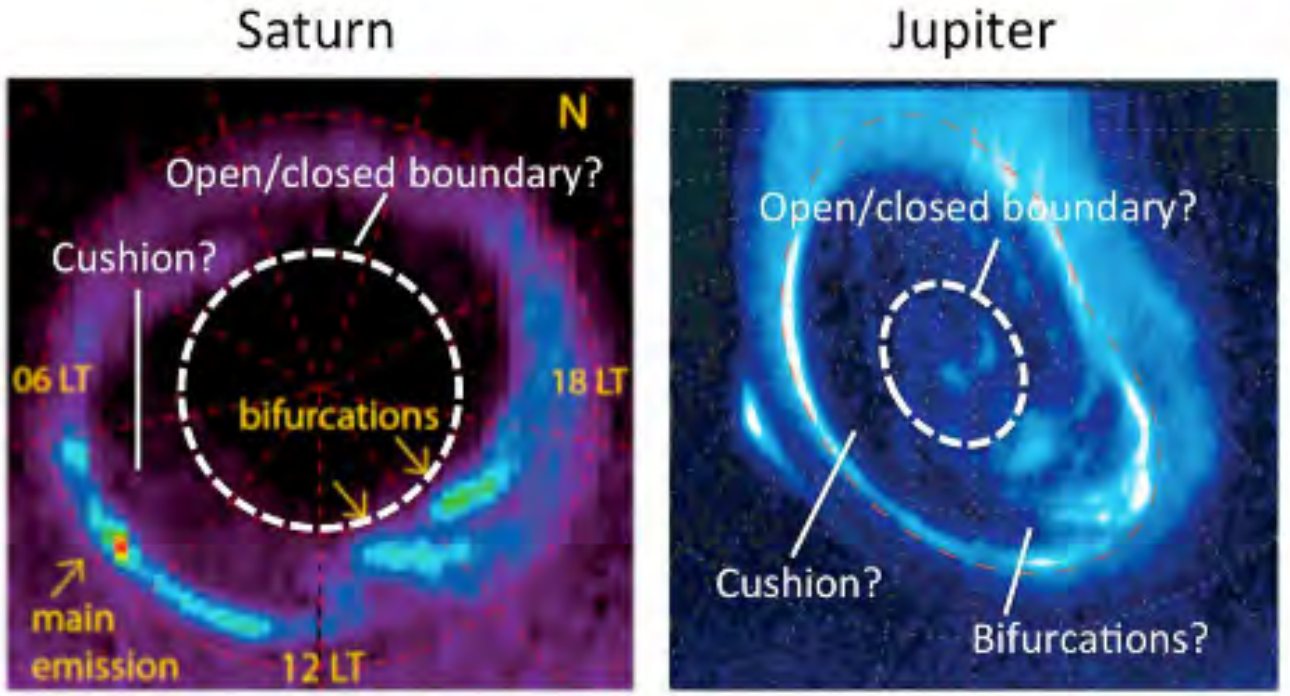
NEROC Meeting, Nov 2018, Haystack

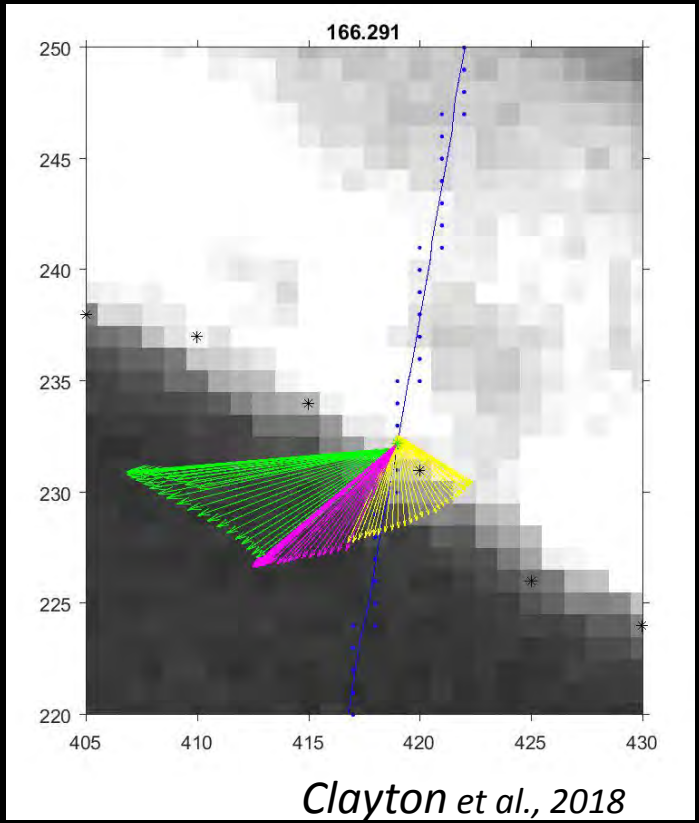

M Mella


J Ahrns

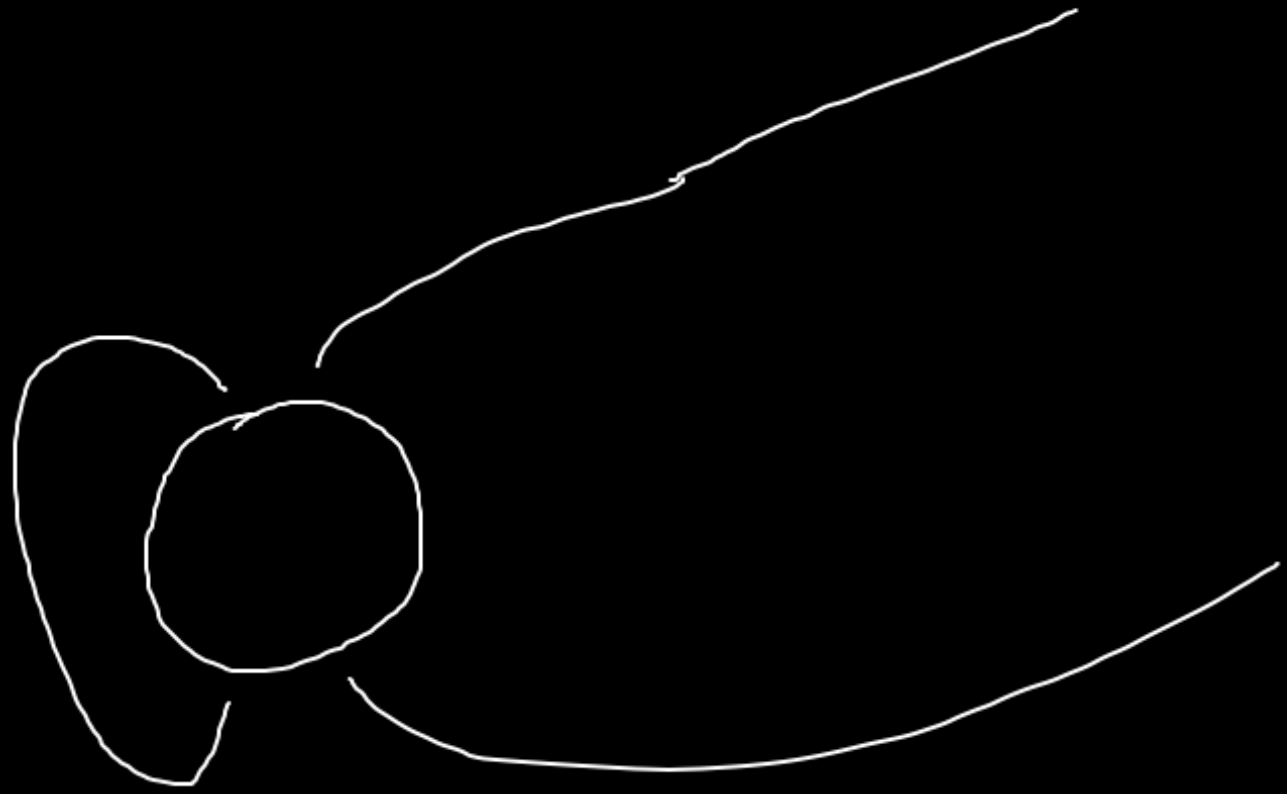

Craig Heinselman

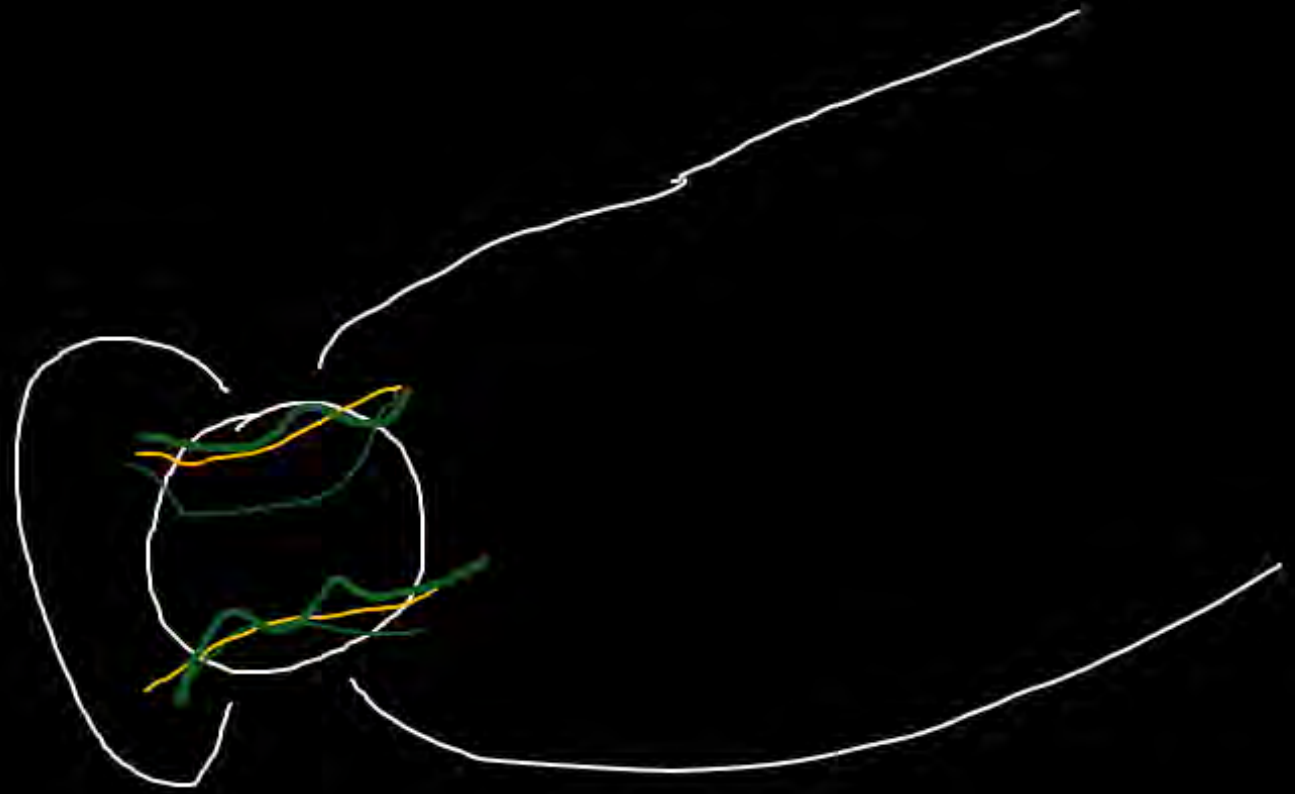
Merrick Peirce

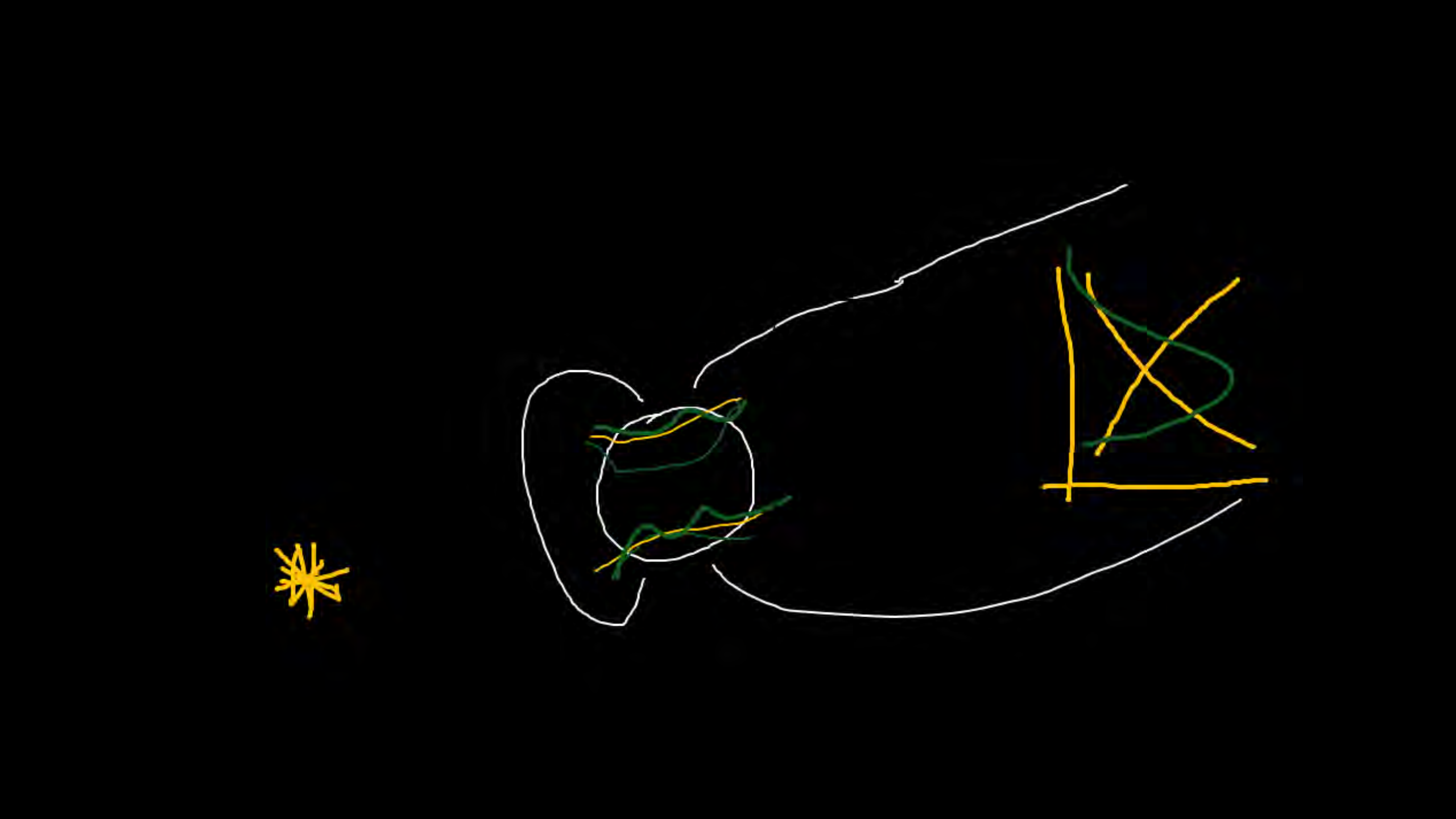

Saturn
N
Open/closed boundary?
Cushion?
06 LT
18 LT
bifurcations
main
emission
12 LT
Jupiter
Open/closed boundary?
Cushion?
Bifurcations?

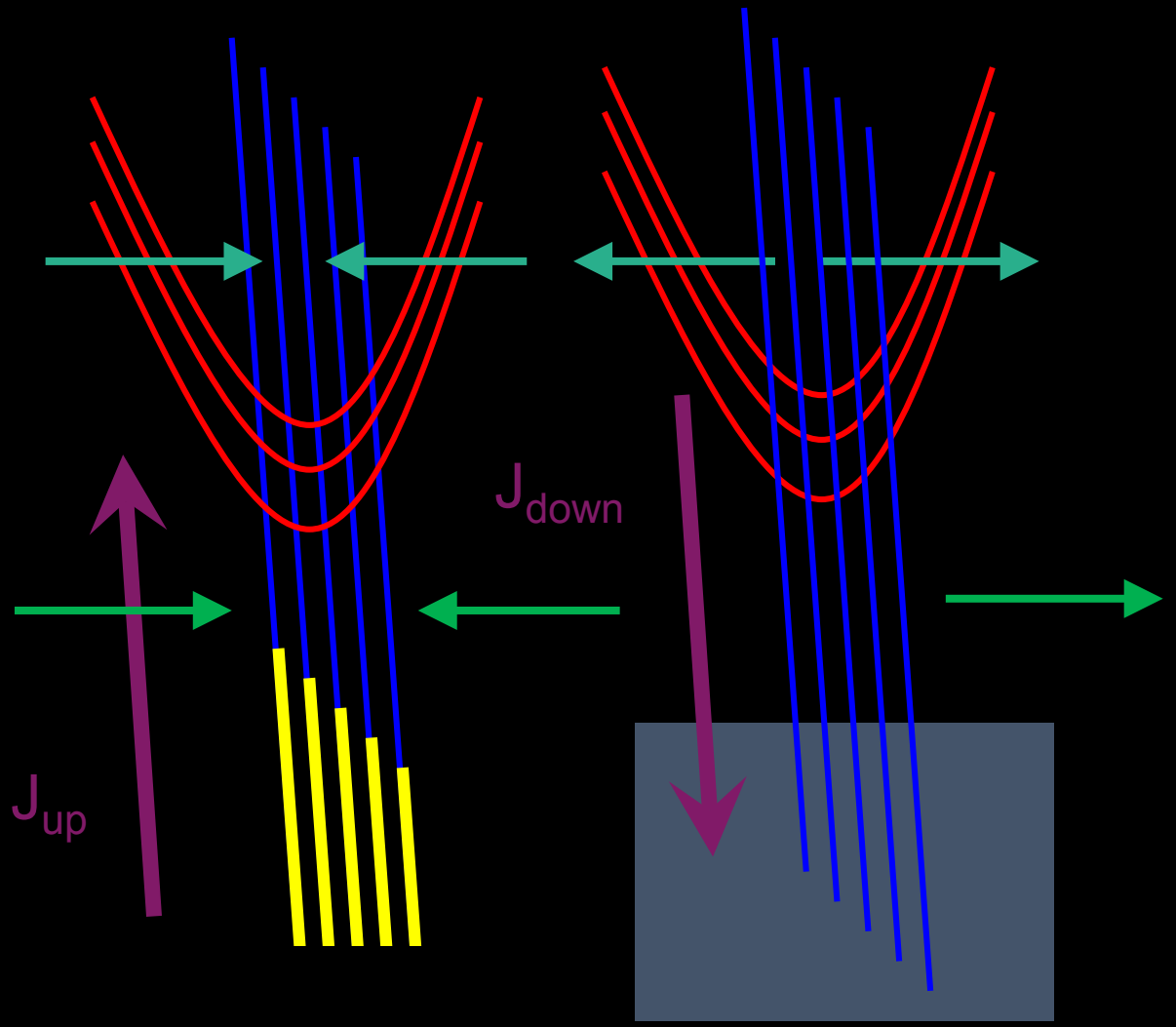


Clayton et al., 2018









$$J_{\parallel} = \Sigma_p(\nabla_{\perp} \cdot \mathbf{E}_{\perp}) + \nabla_{\perp}\Sigma_p \cdot \mathbf{E}_{\perp} - \nabla_{\perp}\Sigma_h \cdot (\hat{\mathbf{e}}_1 \times \mathbf{E}_{\perp})$$

Ionospheric current continuity rules

$$\int E_{Hi} \cdot dl = -\Phi_{arc} = \mathcal{E}_{char}$$

$$\nabla \cdot J = 0 = \nabla_{\parallel} \cdot J_{\parallel} + \nabla_{\perp} \cdot J_{\perp}$$

At ionospheric footpoint,

$$\nabla_{\parallel} \cdot J_{\parallel} = J_{\parallel} = -\nabla_{\perp} \cdot J_{\perp} = \nabla_{\perp} \cdot (\Sigma \cdot E_{\perp})$$

so

$$J_{\parallel} = \Sigma_p(\nabla_{\perp} \cdot \mathbf{E}_{\perp}) + \nabla_{\perp}\Sigma_p \cdot \mathbf{E}_{\perp} - \nabla_{\perp}\Sigma_h \cdot (\hat{\mathbf{e}}_1 \times \mathbf{E}_{\perp})$$

Now, also

$$J_{\parallel} = \mathcal{E}_{flux}/\mathcal{E}_{char}$$

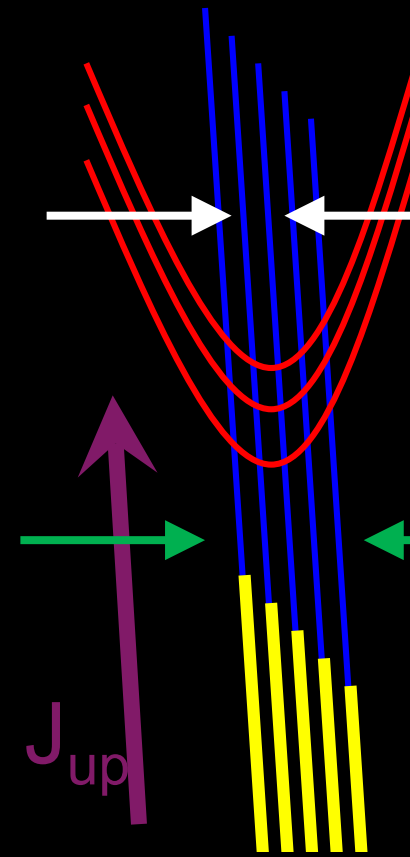
so

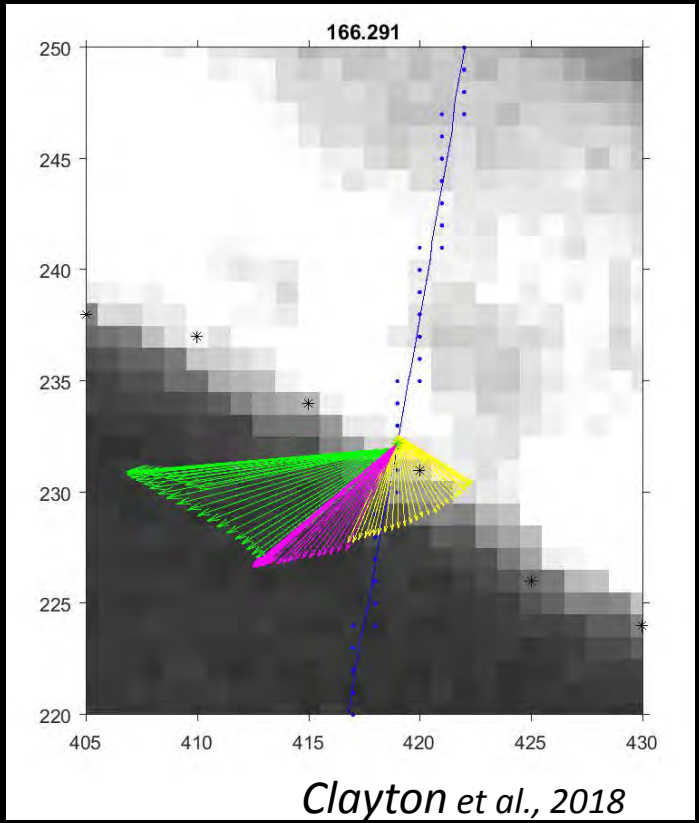
$$\mathcal{E}_{flux} = \mathcal{E}_{char} \cdot J_{\parallel}$$

and brightness gradient is

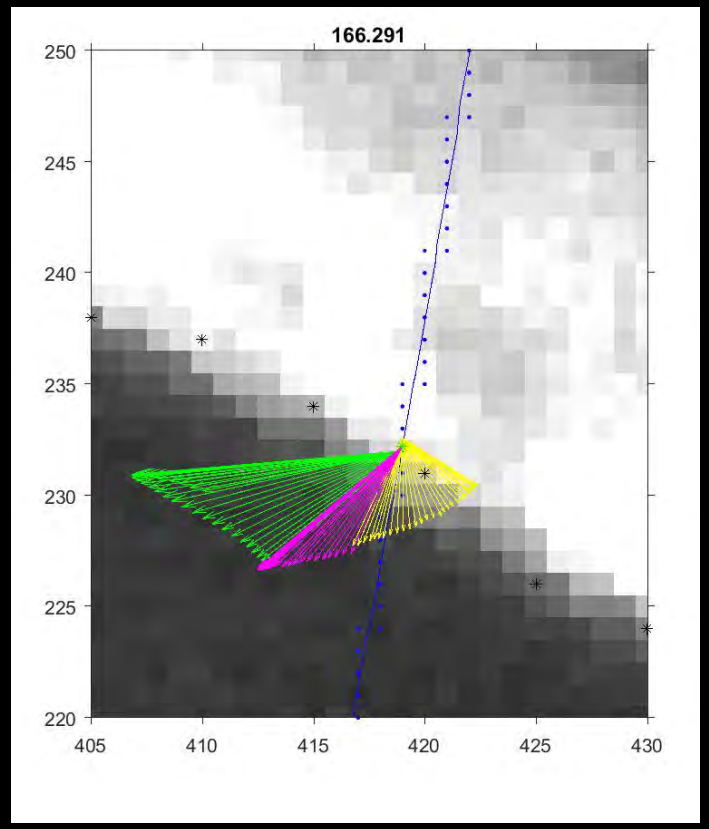
$$\nabla\mathcal{E}_{flux} = \mathcal{E}_{char} \cdot \nabla J_{\parallel} + \nabla\mathcal{E}_{char} \cdot J_{\parallel}$$

The last term gives back the high-altitude $\mathbf{E_{Hi}}$, and the other term involves conductivity gradients and ionospheric electric field divergences.





Clayton et al., 2018



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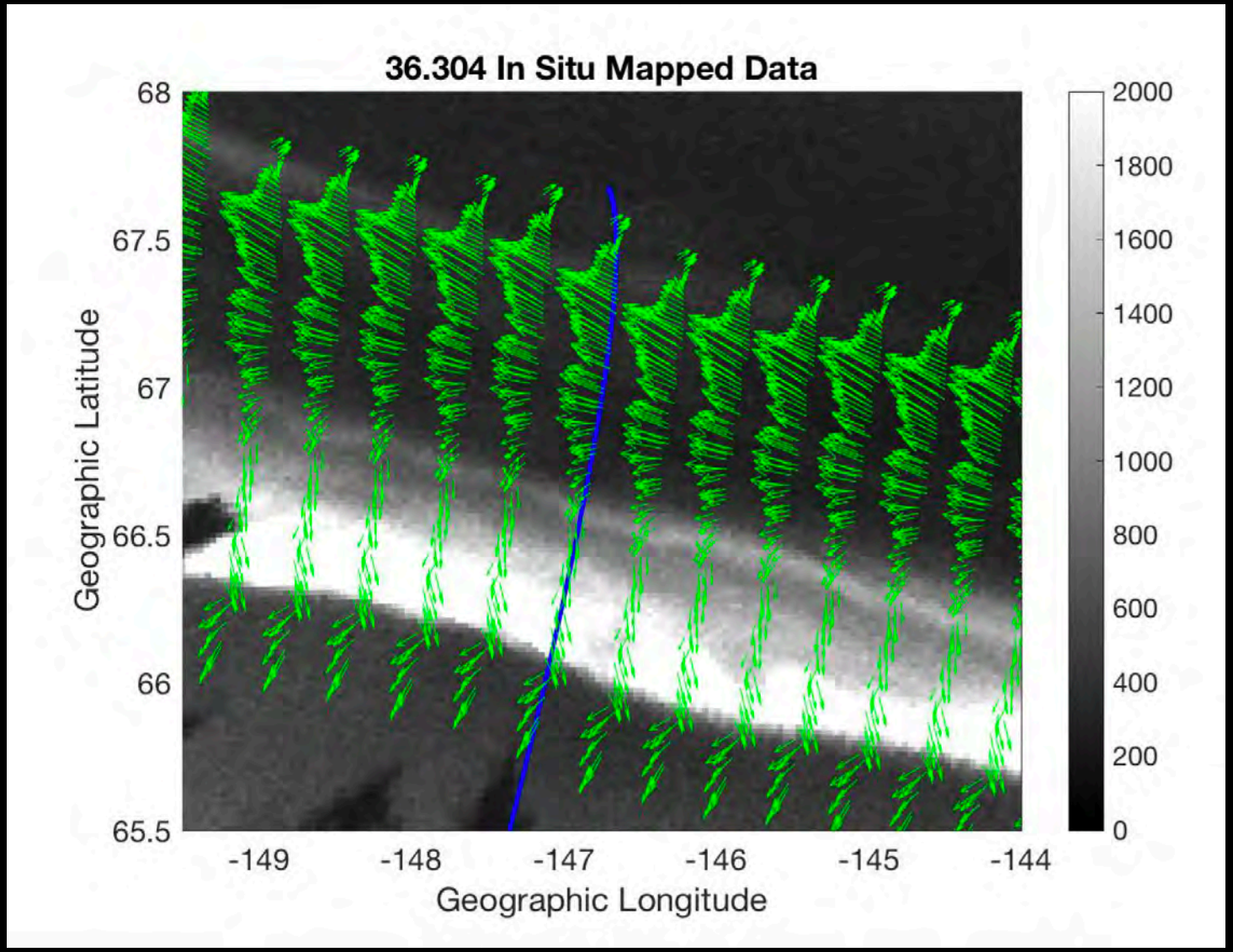
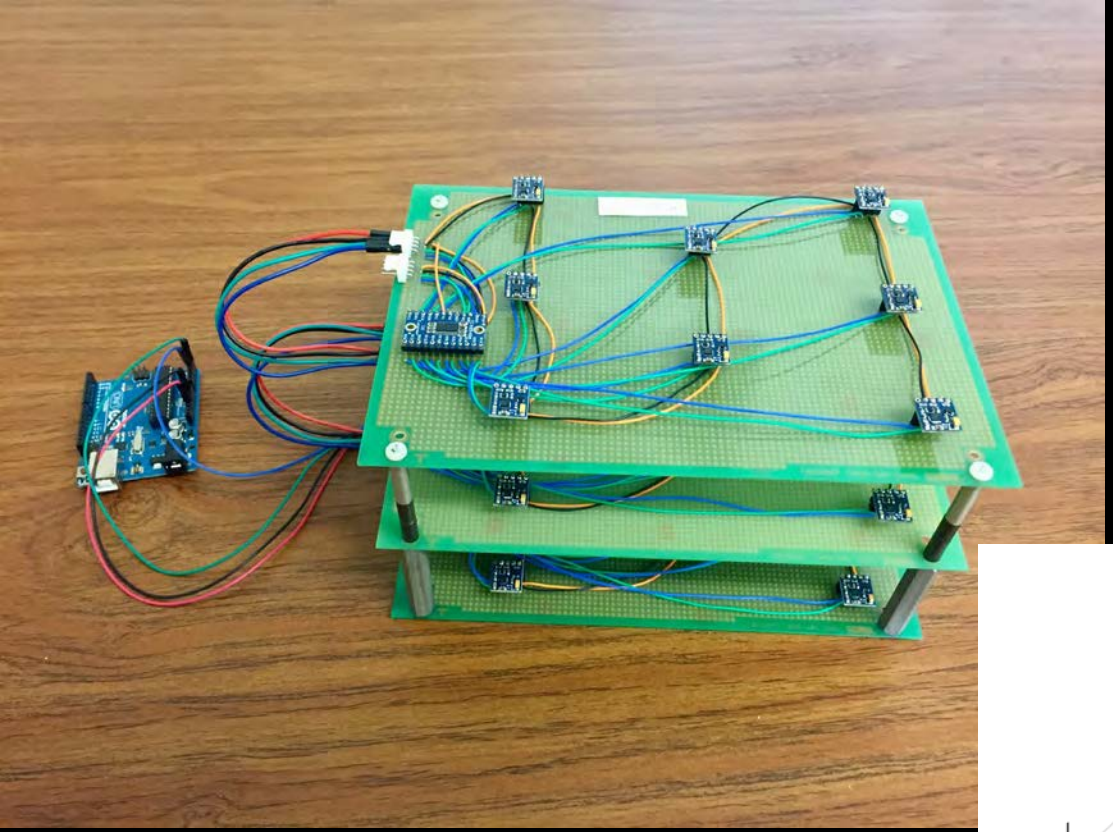
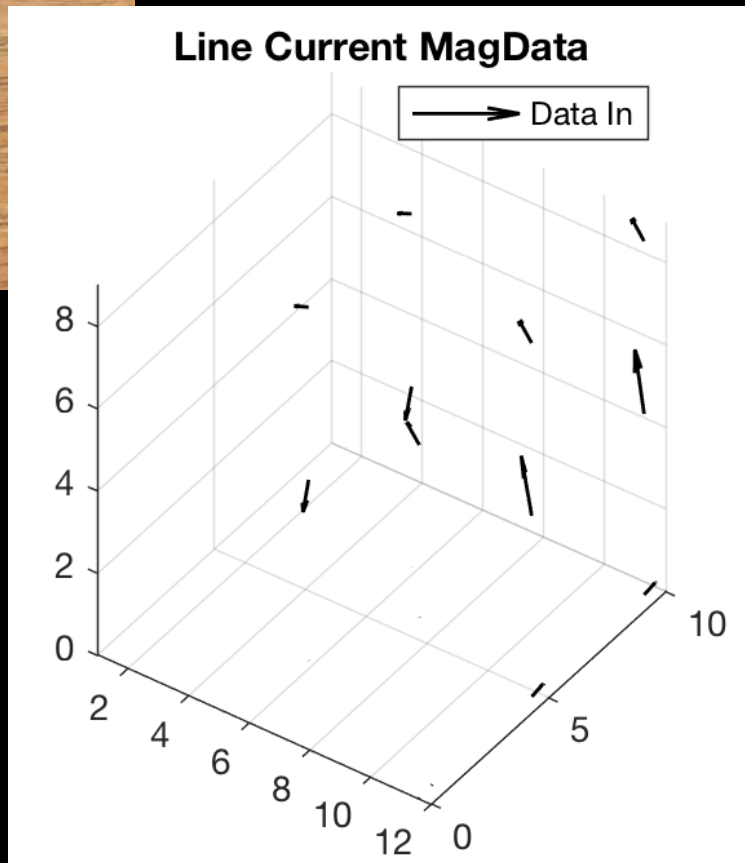
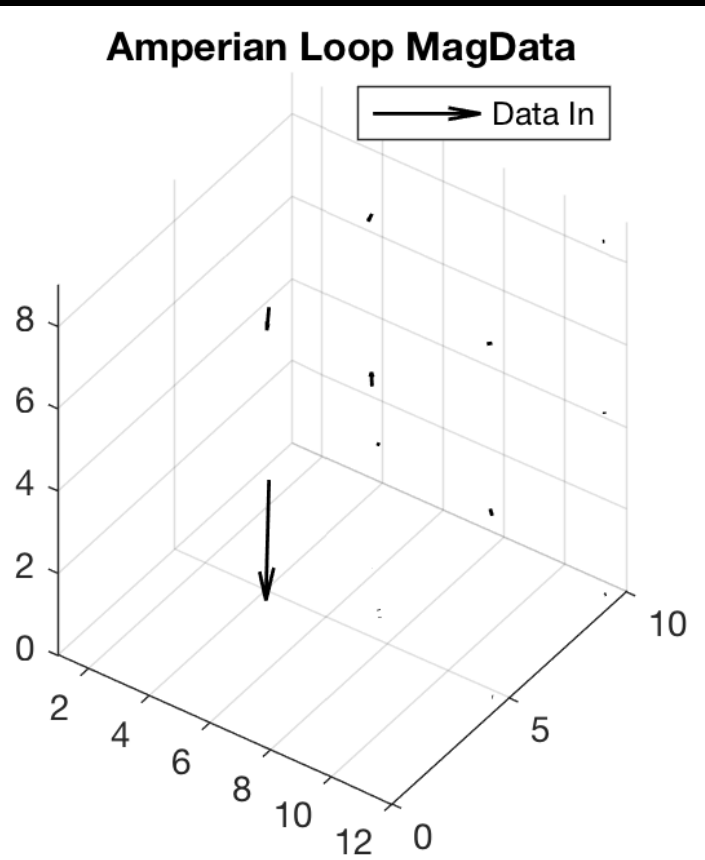
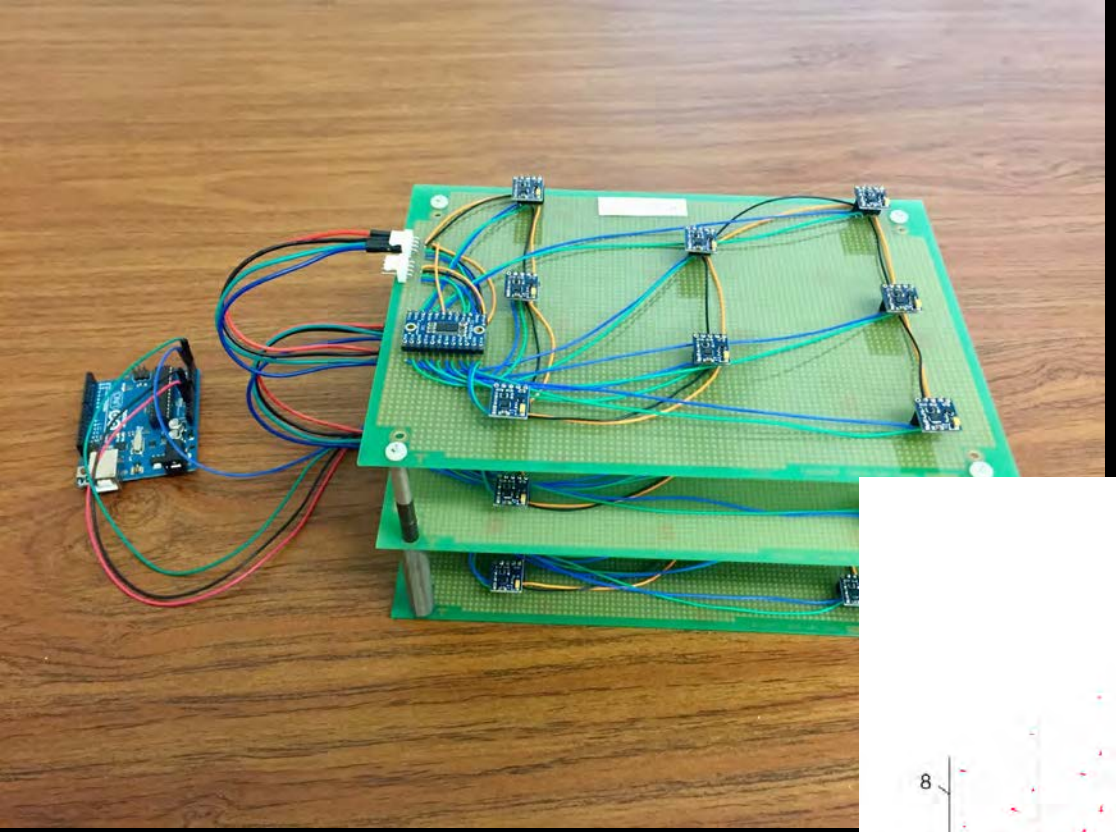


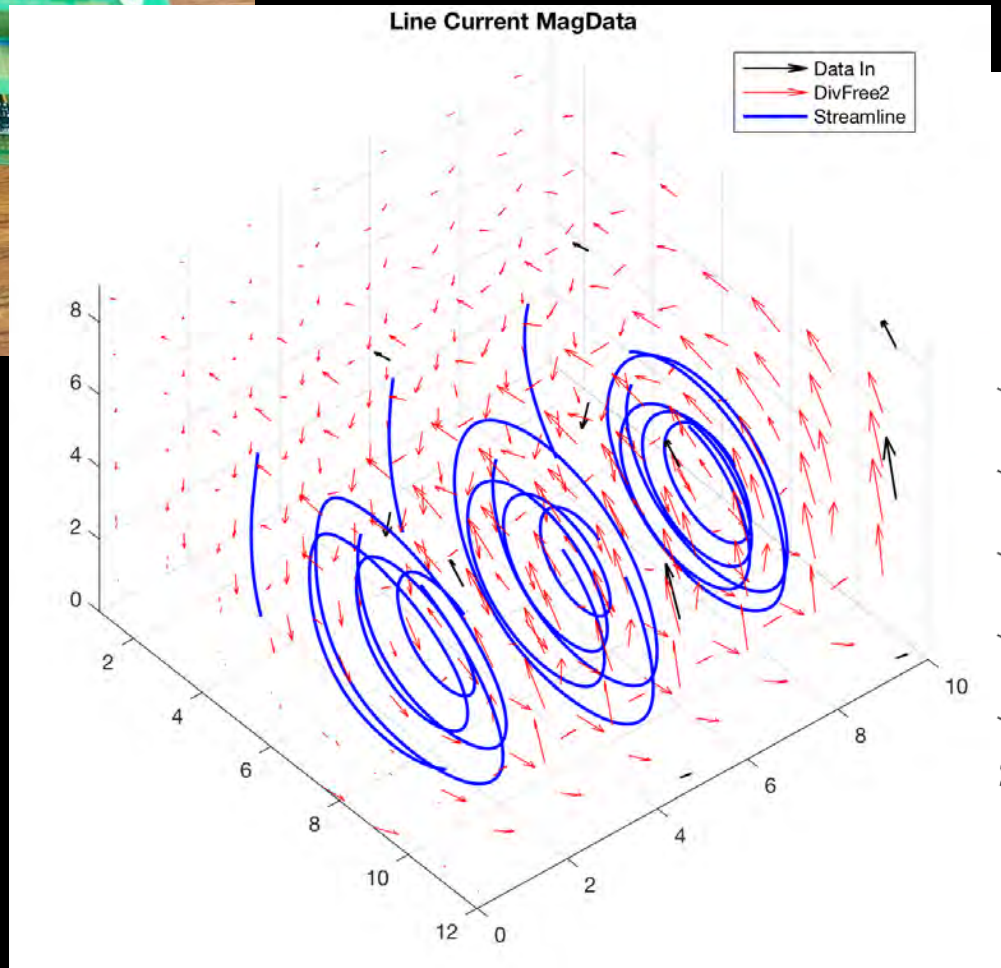


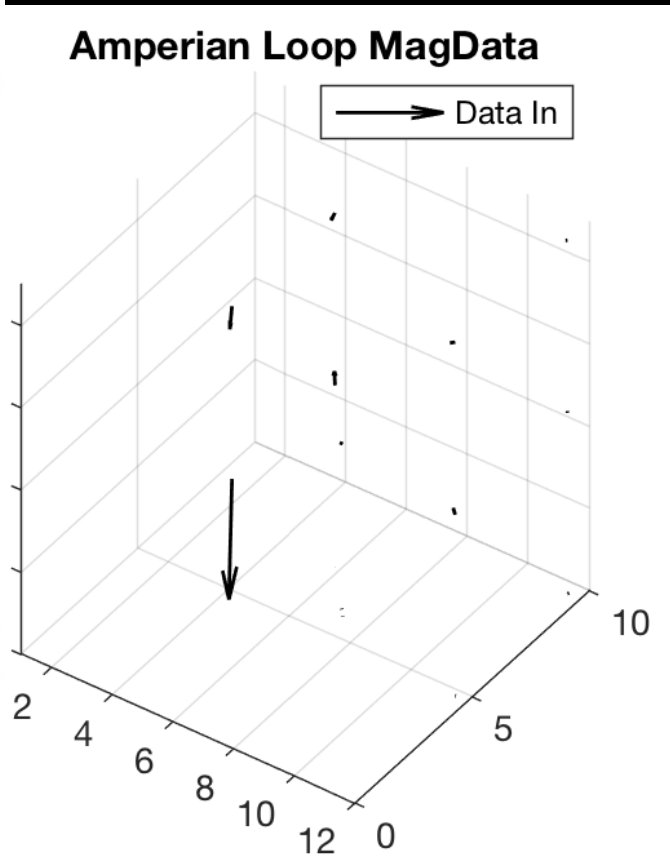

Line Current MagData
Data In
8
6
4
2
0
2
4
6
8
10
12
0
5
10


Amperian Loop MagData
Data In
8
6
4
2
0
2
4
6
8
10
12
0
5
10

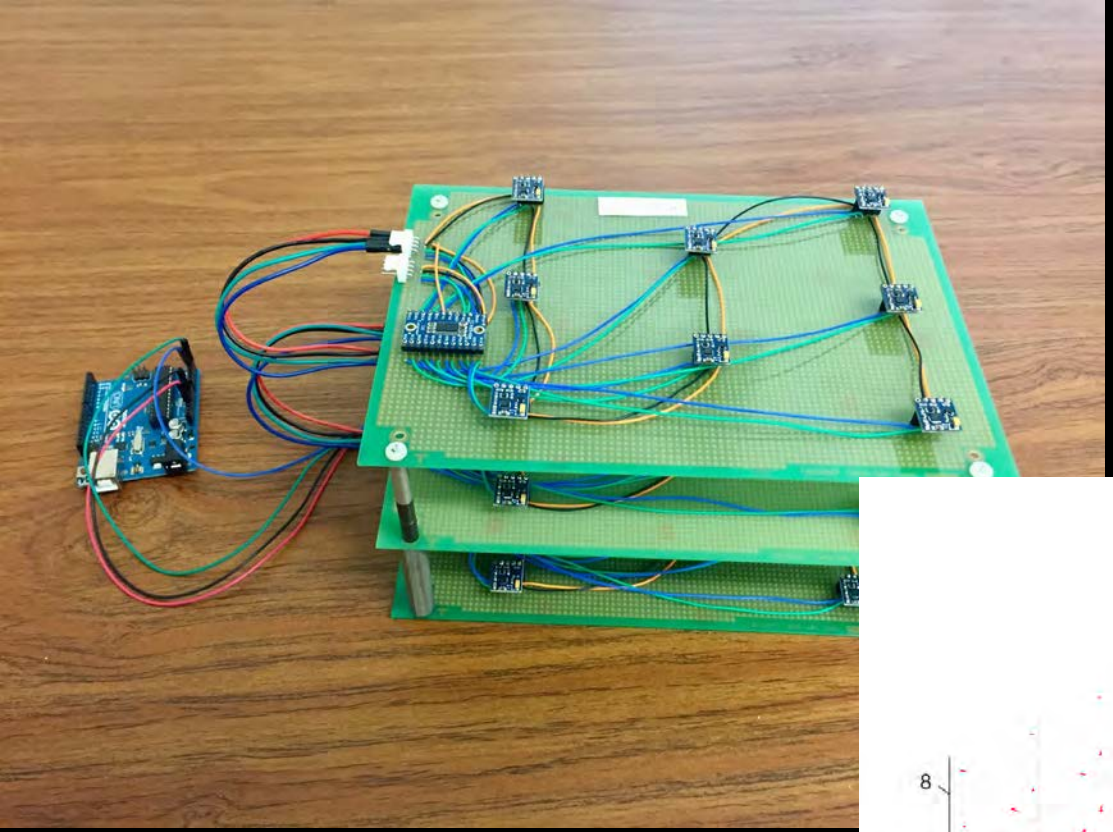
Tremml, 2018

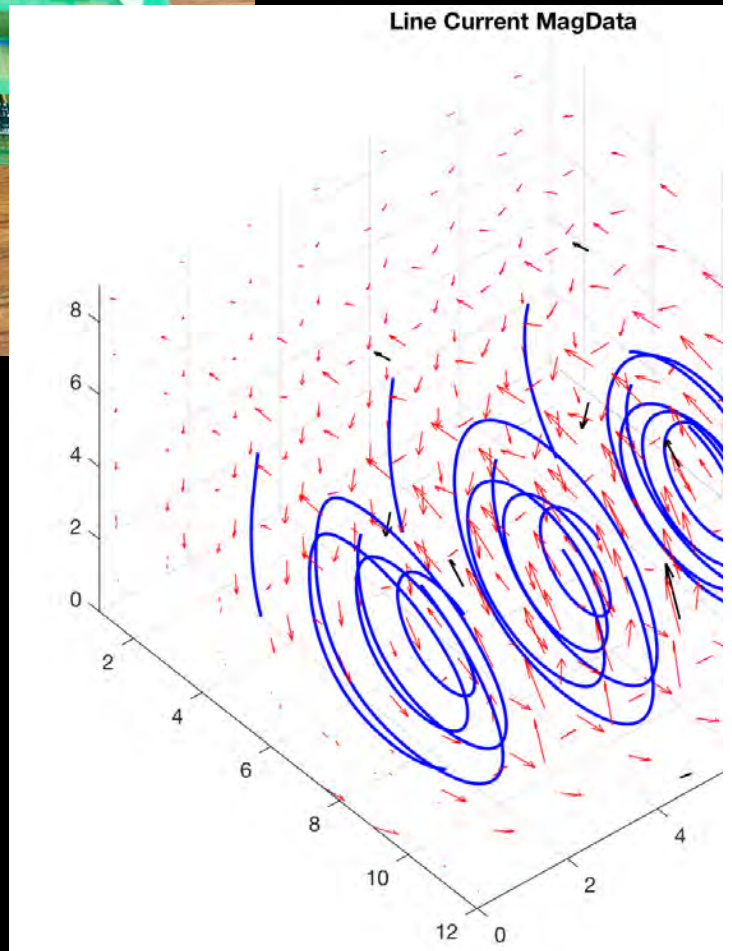


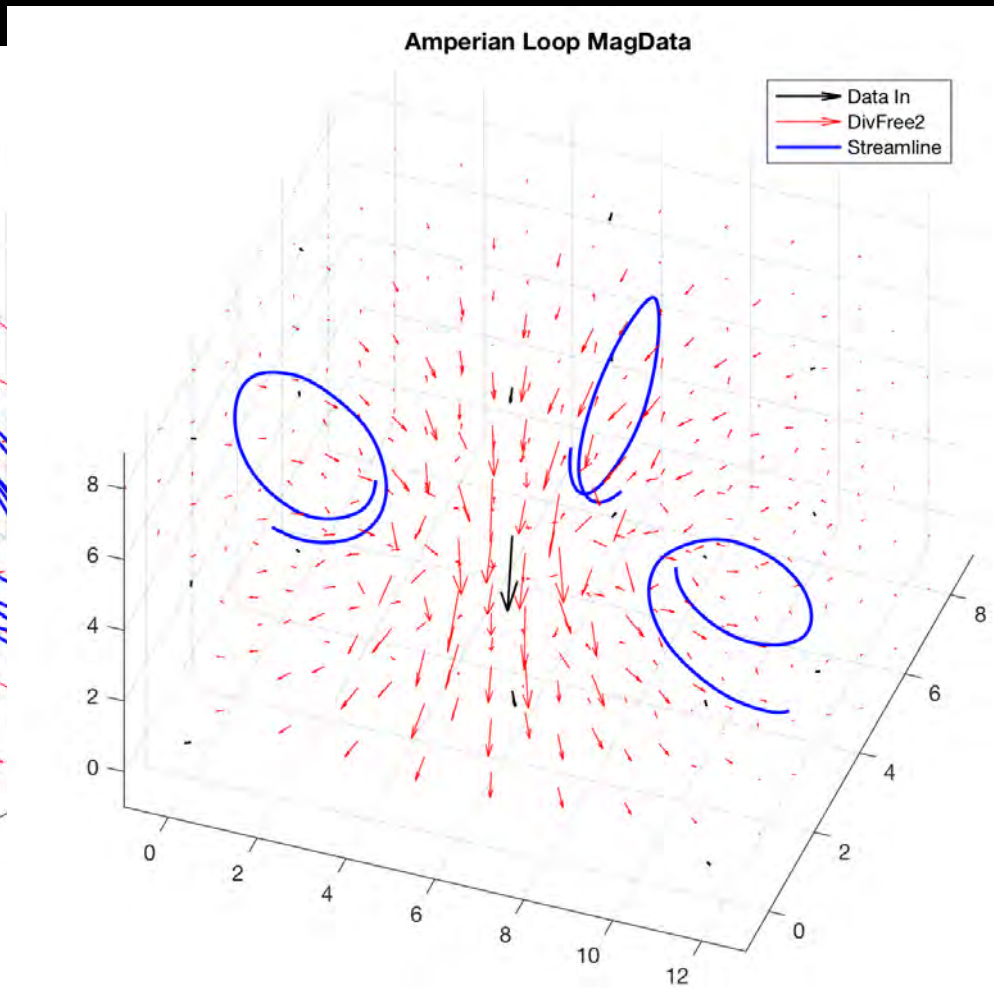

Line Current MagData
Data In
DivFree2
Streamline
0
2
4
6
8
0
2
4
6
8
10
12
0
2
4
6
8
10


Amperian Loop MagData
Data In
2
4
6
8
10
12
0
5
10

Tremml, 2018

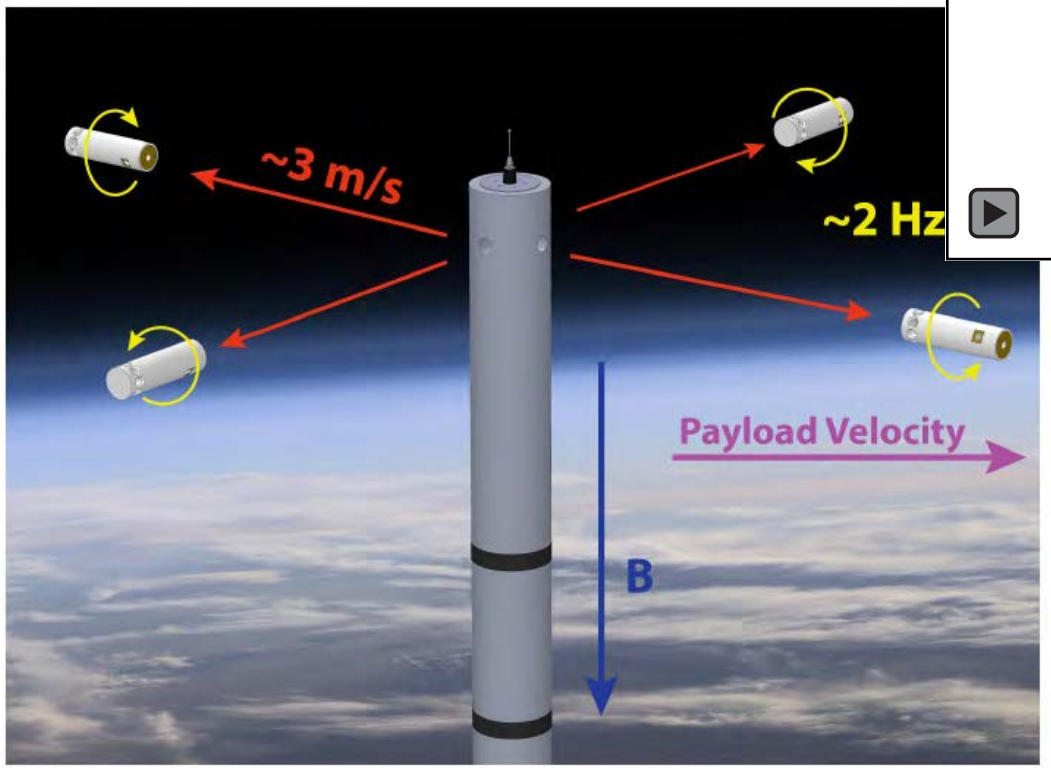



Line Current MagData
8
6
4
2
0
2
4
6
8
10
12
0
2
4


Amperian Loop MagData
Data In
DivFree2
Streamline
8
6
4
2
0
0
2
4
6
8
10
12
0
2
4
6
8

Tremml, 2018

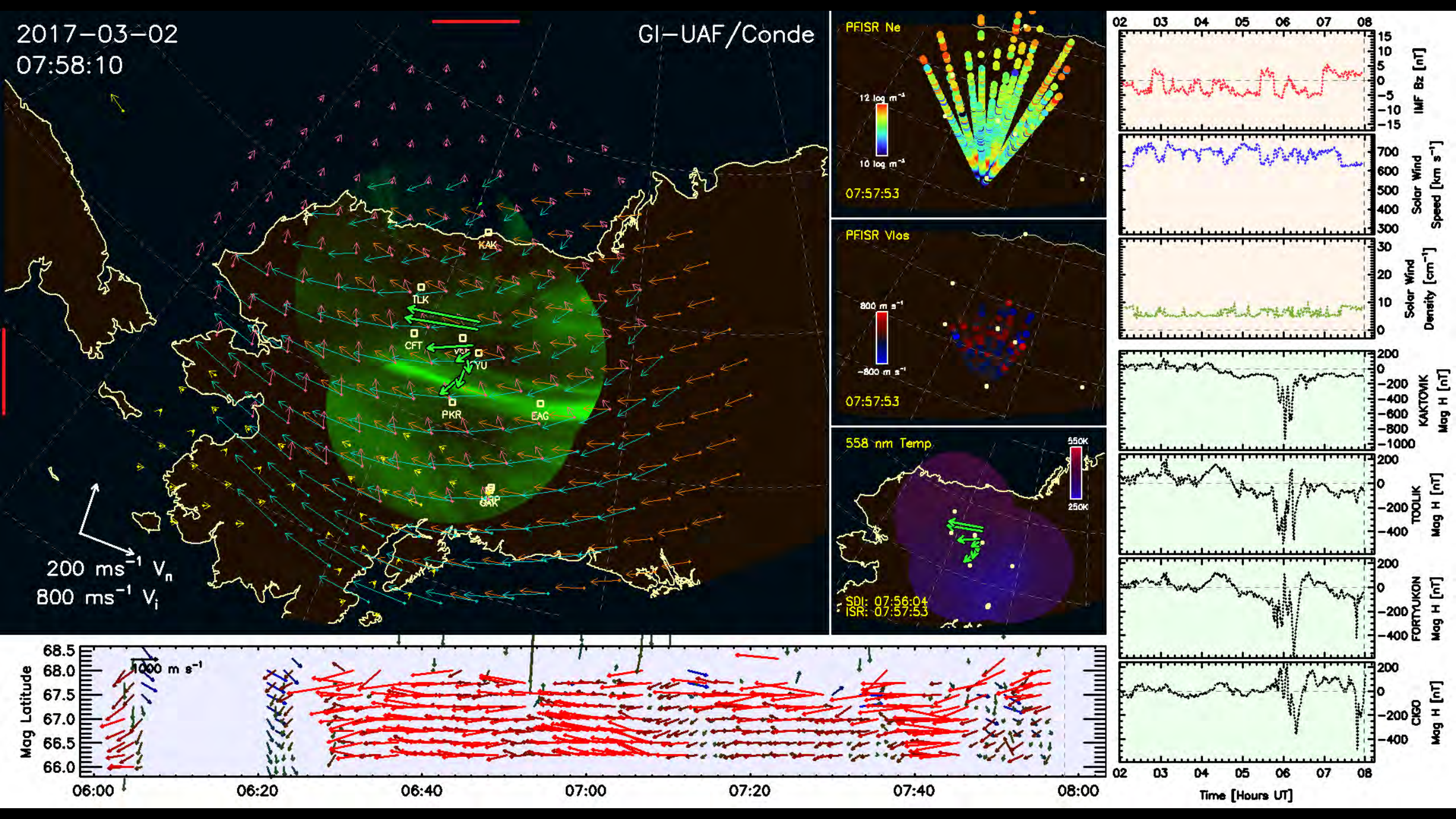
Isinglass array

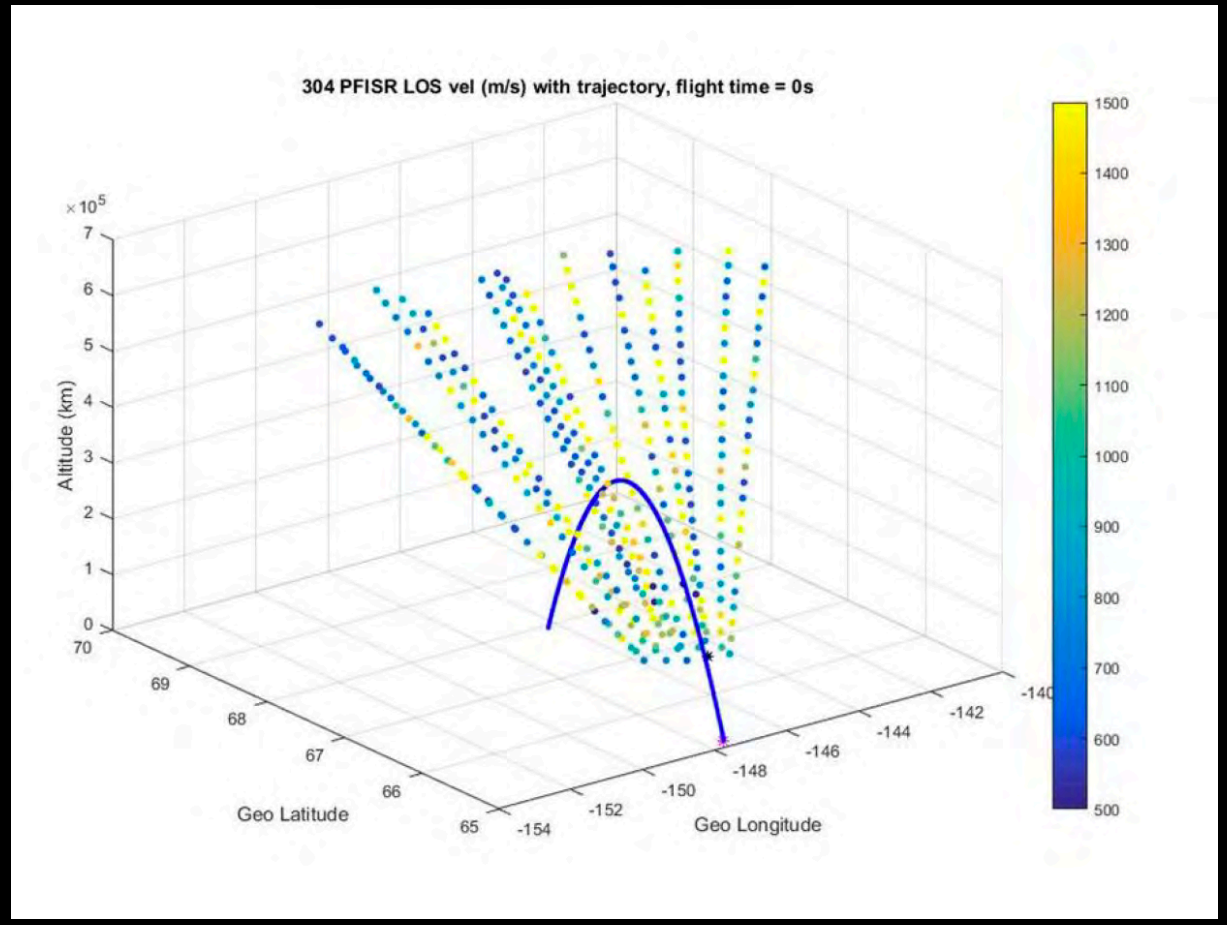


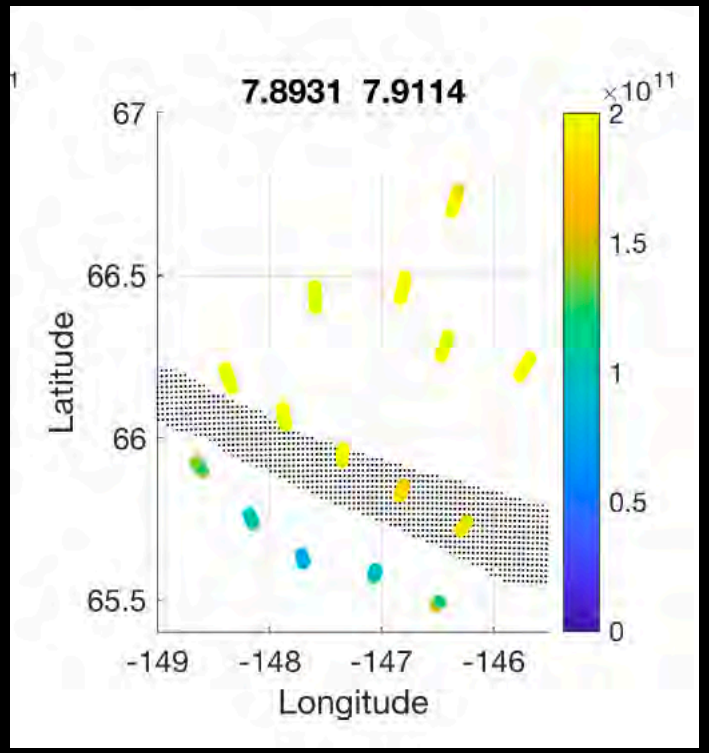
Isinglass payload model,
T Max Roberts,
Dartmouth /JPL

Lots of parts

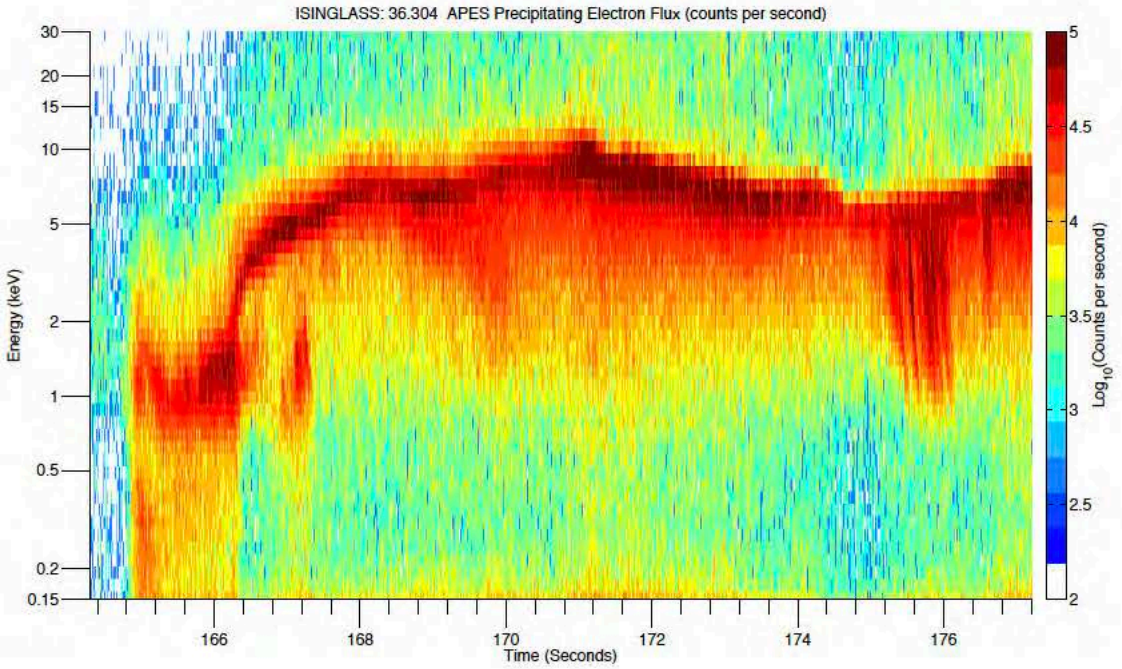
Correcting 40 pips post-cedar!

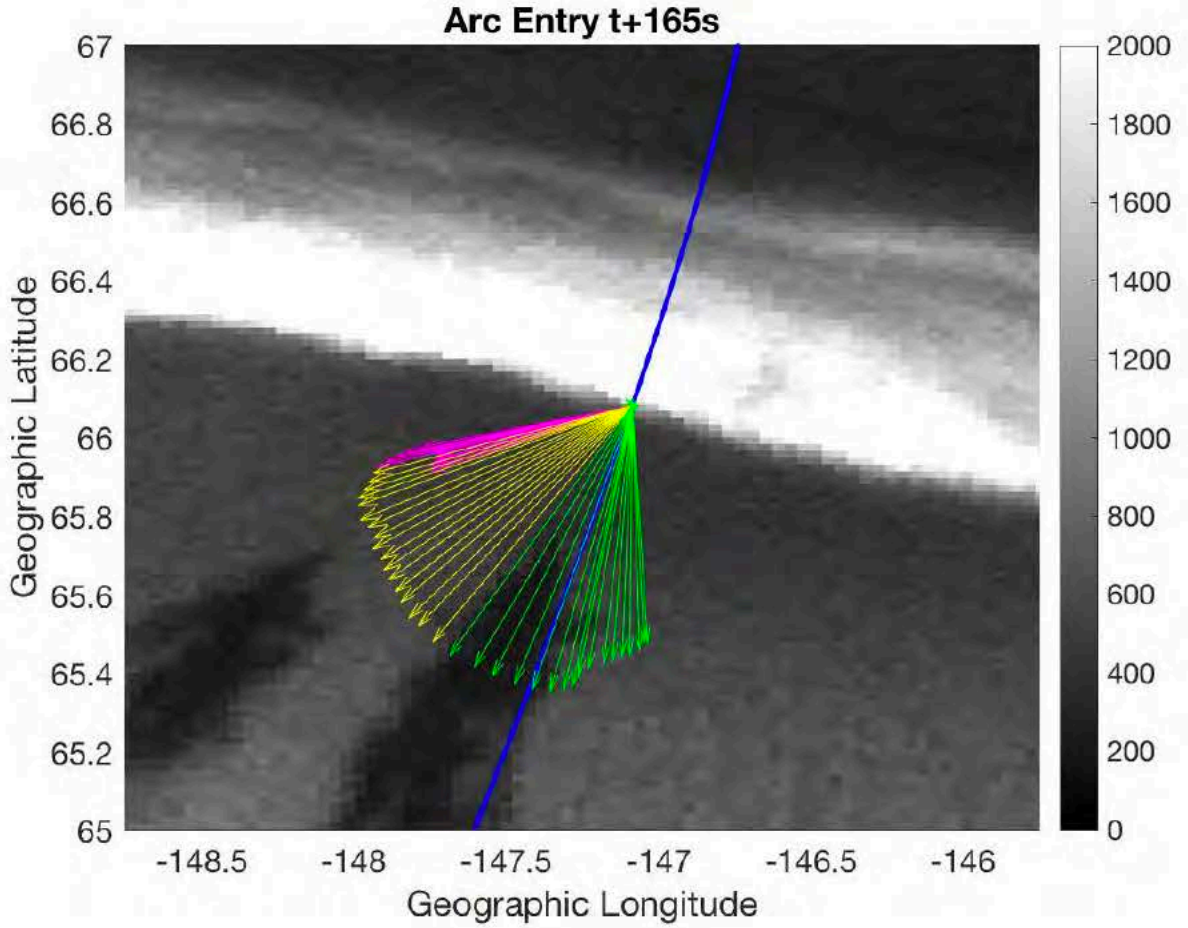

2017-03-02
07:58:10
GI-UAF/Conde
KAK
TLK
CFT
YKC
YU
PKR
EAG
GAK
200 ms^{-1} V$_n$
800 ms^{-1} V$_i$
PFISR Ne
12 log m^{-3}
10 log m^{-3}
07:57:53
PFISR Vlos
800 m s^{-1}
-800 m s^{-1}
07:57:53
558 nm Temp
550K
250K
SDI: 07:56:04
ISR: 07:57:53
IMF Bz [nT]
Solar Wind Speed [km s^{-1}]
Solar Wind Density [cm^{-3}]
KAKTOVIK Mag H [nT]
TOOLIK Mag H [nT]
FORTYUKON Mag H [nT]
CIGO Mag H [nT]
Time [Hours UT]
Mag Latitude
1000 m s^{-1}

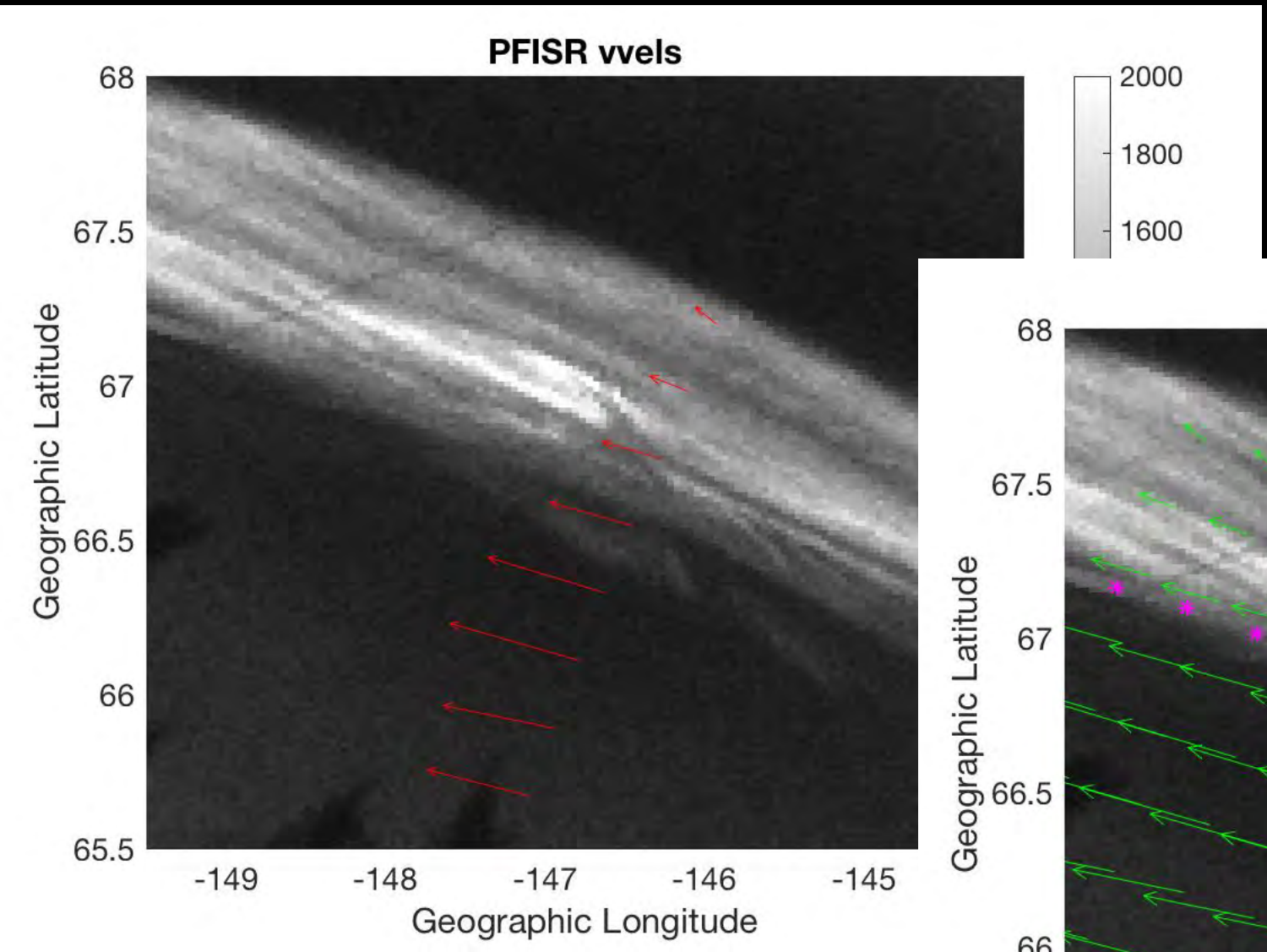


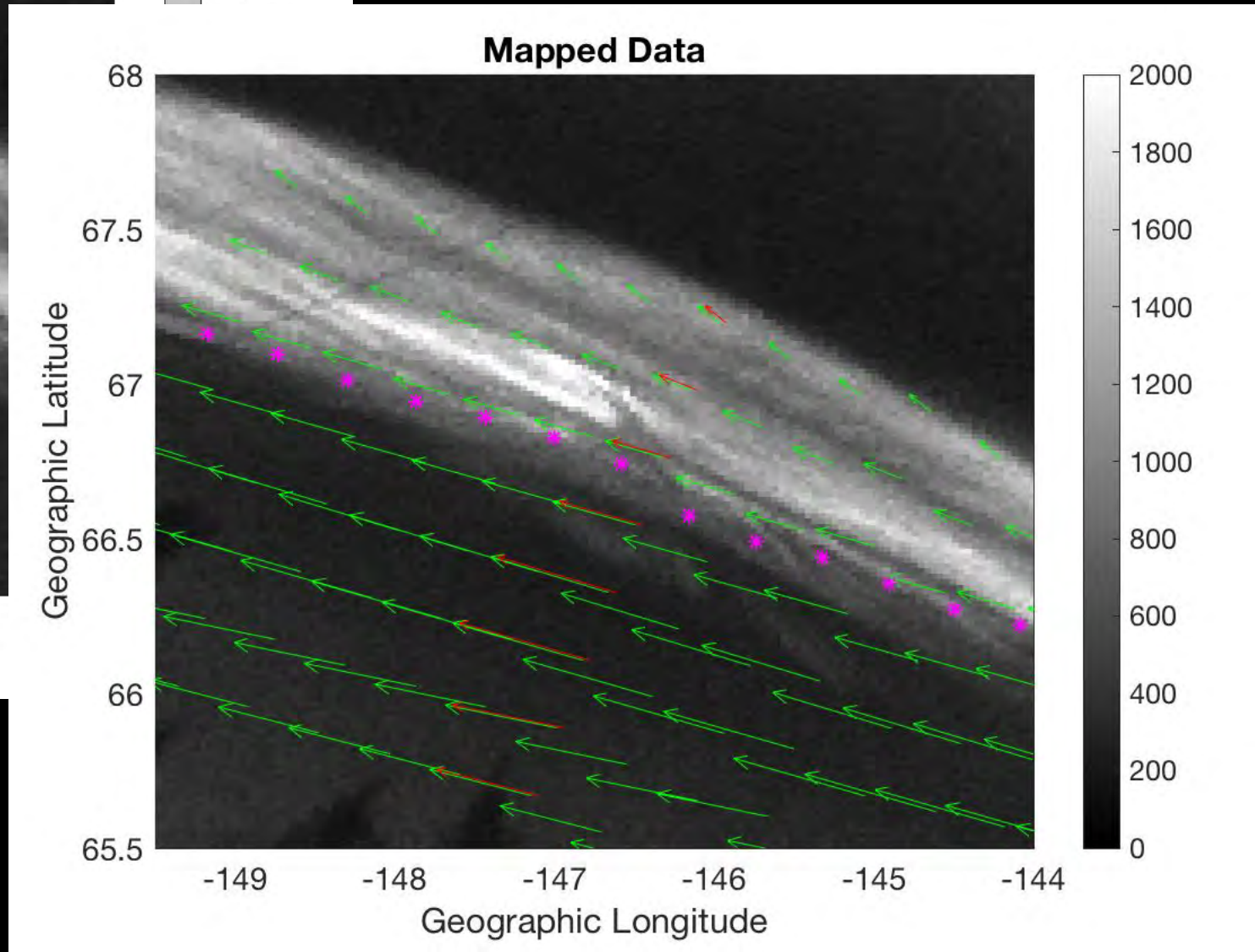


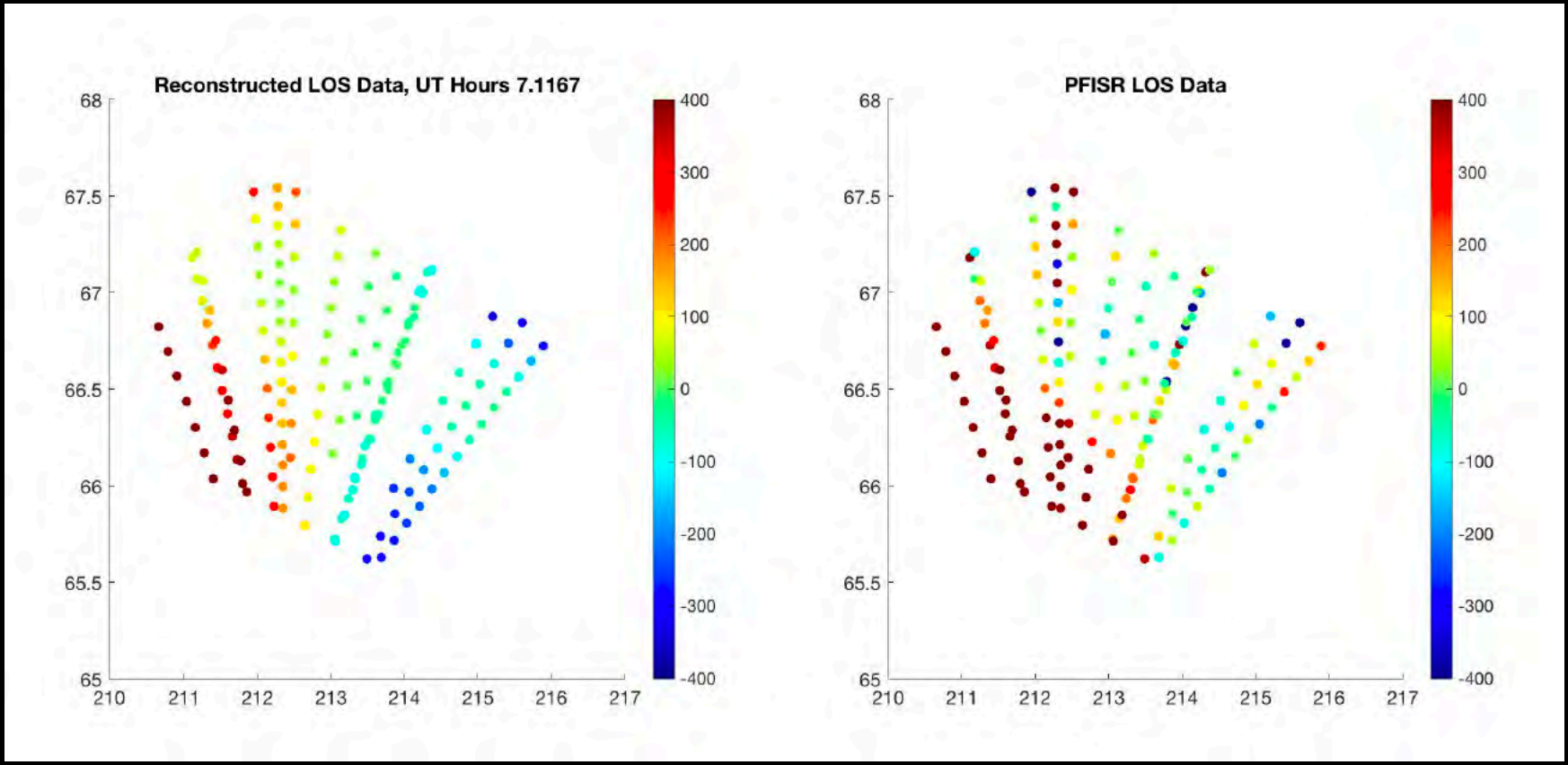
Isinglass data analysis,
Rob Clayton, Dartmouth

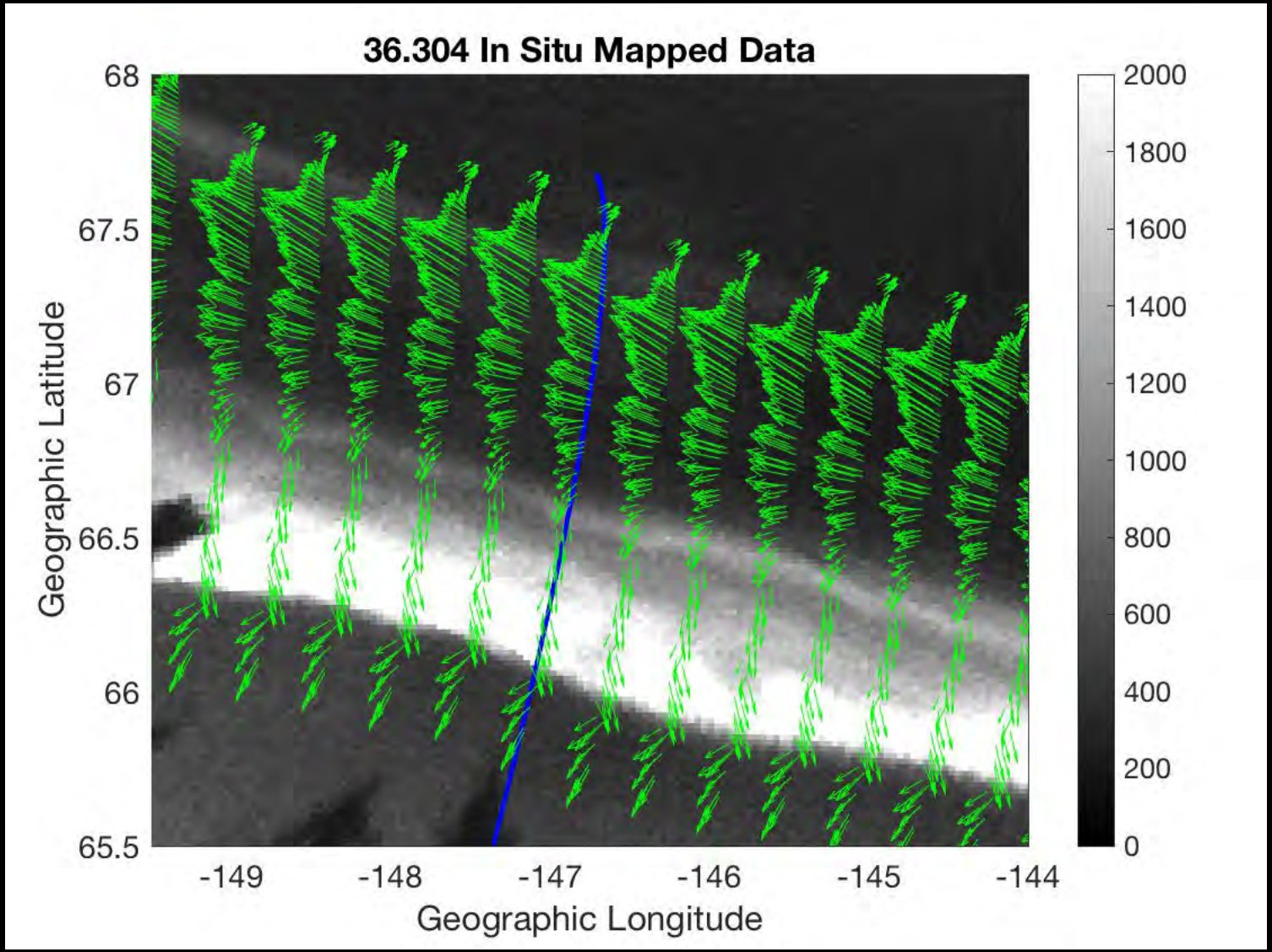

ISINGLASS: 36.304 APES Precipitating Electron Flux (counts per second)
Energy (keV)
30
20
15
10
5
2
1
0.5
0.2
0.15
166
168
170
172
174
176
Time (Seconds)
5
4.5
4
3.5
3
2.5
2
Log10(Counts per second)

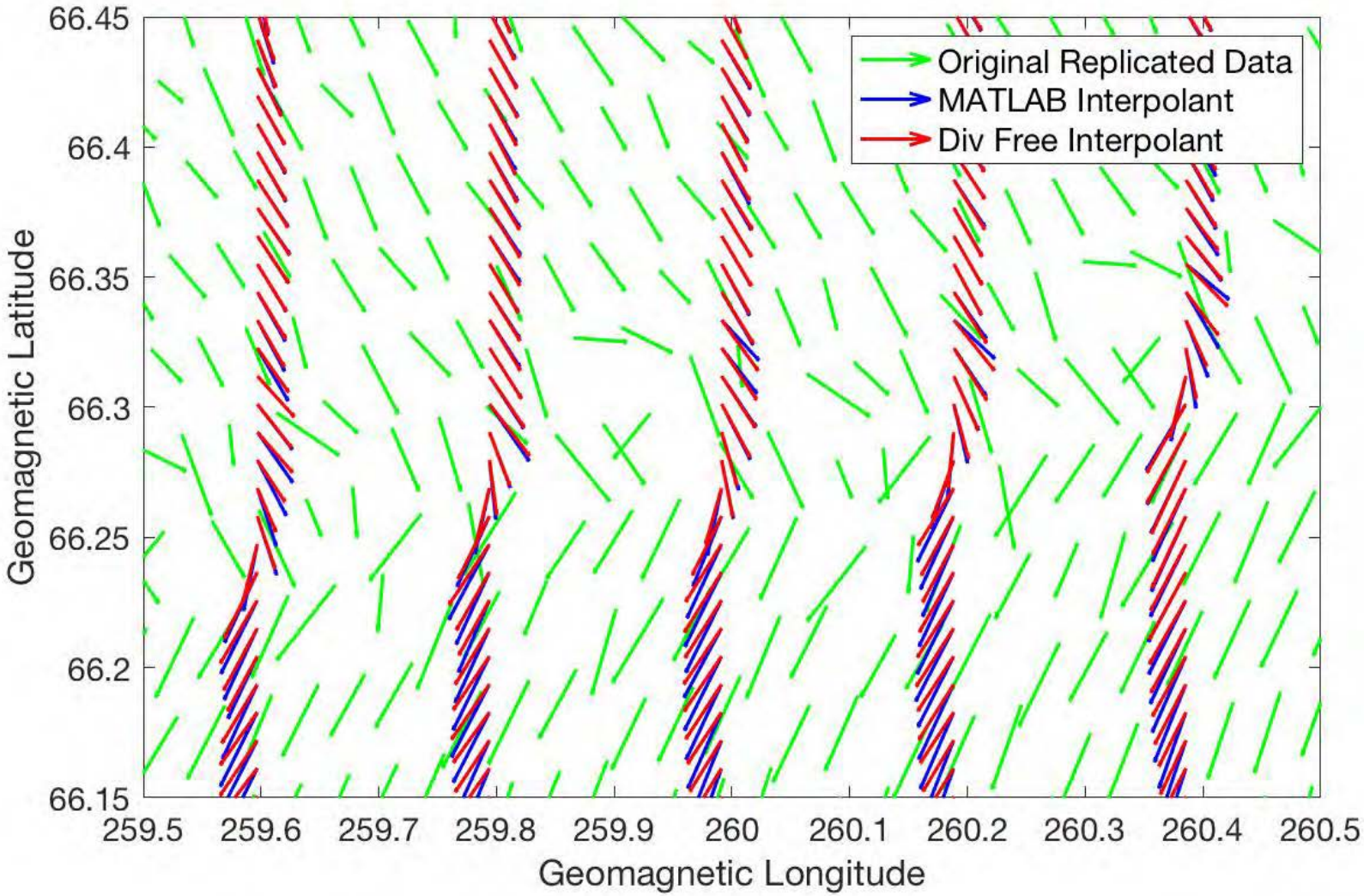

Arc Entry t+165s
Geographic Latitude
67
66.8
66.6
66.4
66.2
66
65.8
65.6
65.4
65.2
65
-148.5
-148
-147.5
-147
-146.5
-146
Geographic Longitude
2000
1800
1600
1400
1200
1000
800
600
400
200
0

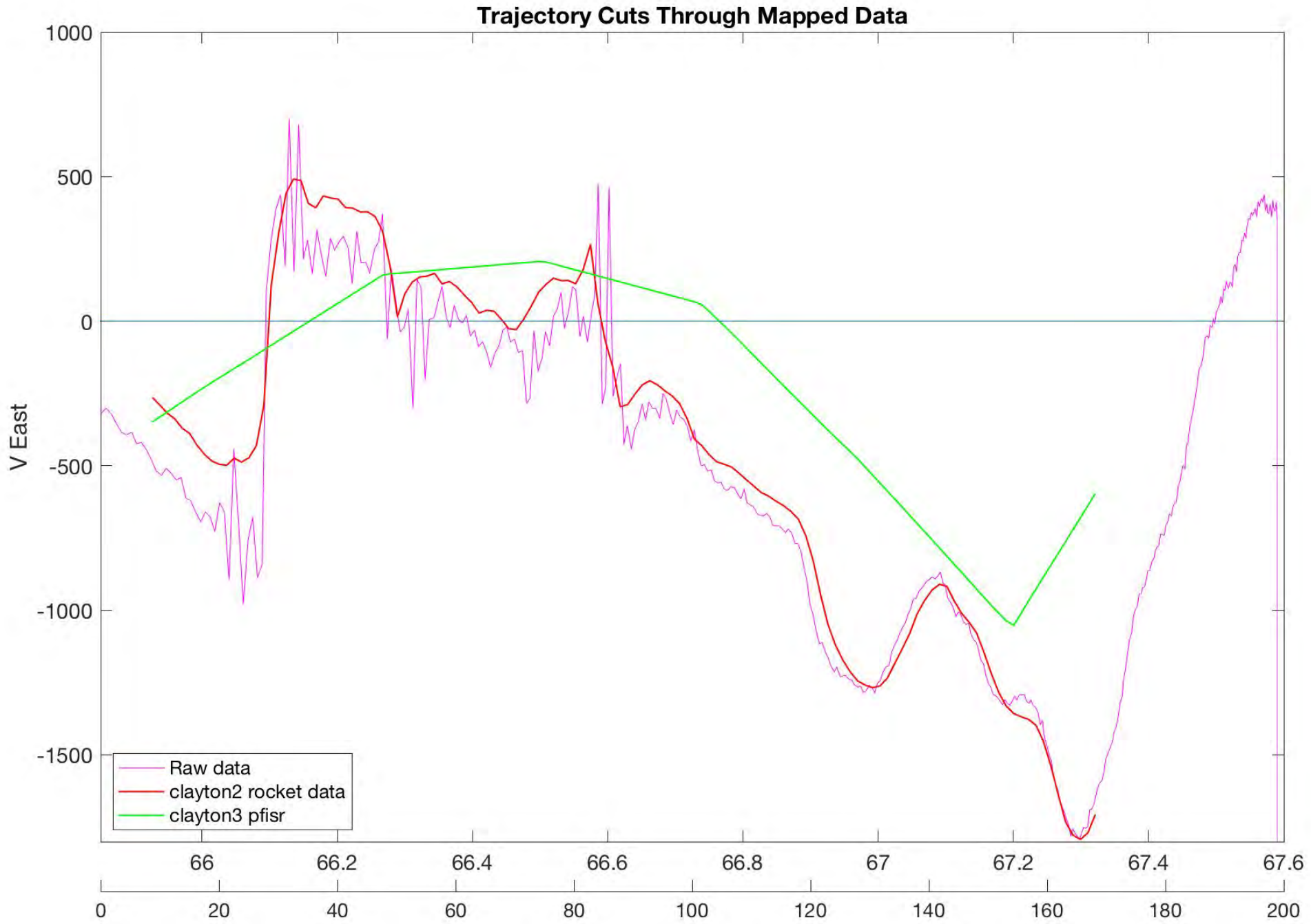

PFISR vvels
68
67.5
67
66.5
66
65.5
Geographic Latitude
-149
-148
-147
-146
-145
Geographic Longitude
2000
1800
1600

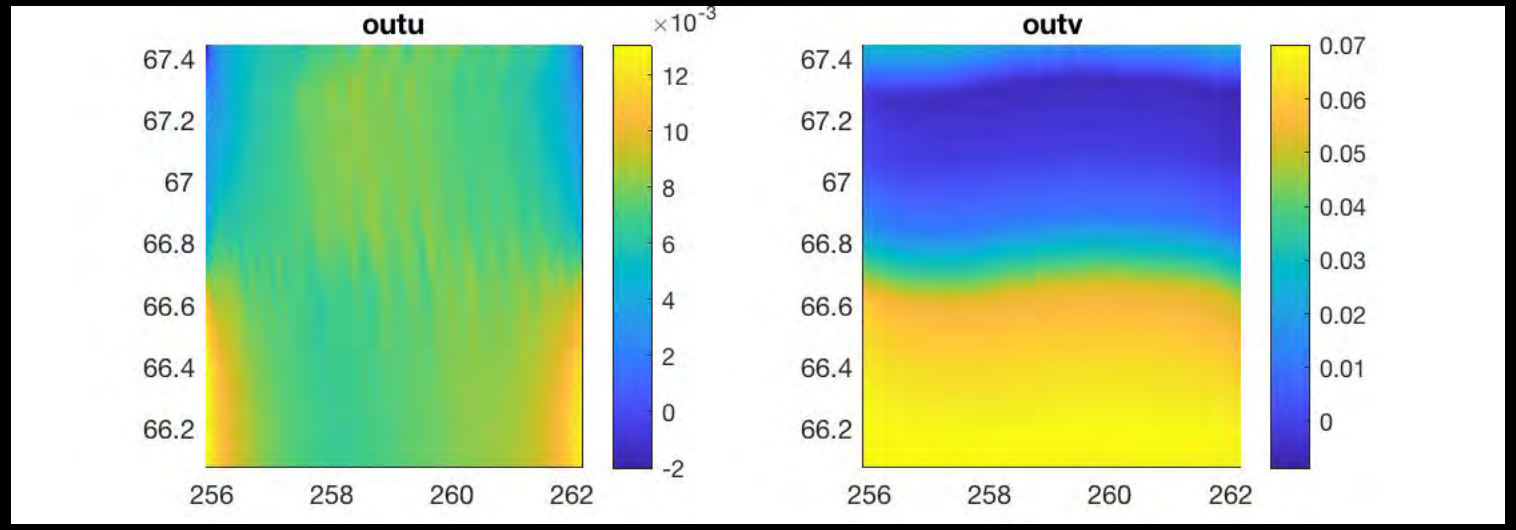

Mapped Data
68
67.5
67
66.5
66
65.5
Geographic Latitude
-149
-148
-147
-146
-145
-144
Geographic Longitude
2000
1800
1600
1400
1200
1000
800
600
400
200
0


Reconstructed LOS Data, UT Hours 7.1167
PFISR LOS Data
68
67.5
67
66.5
66
65.5
65
210
211
212
213
214
215
216
217
400
300
200
100
0
-100
-200
-300
-400

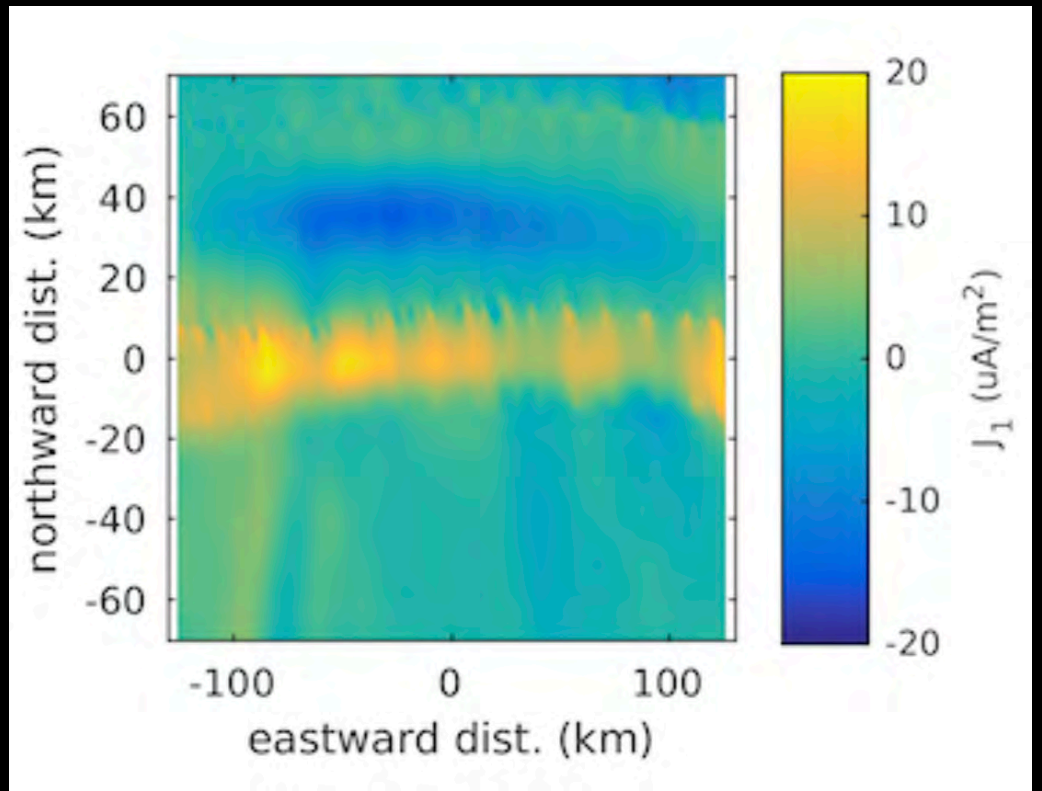

36.304 In Situ Mapped Data
68
67.5
67
66.5
66
65.5
Geographic Latitude
-149
-148
-147
-146
-145
-144
Geographic Longitude
2000
1800
1600
1400
1200
1000
800
600
400
200
0

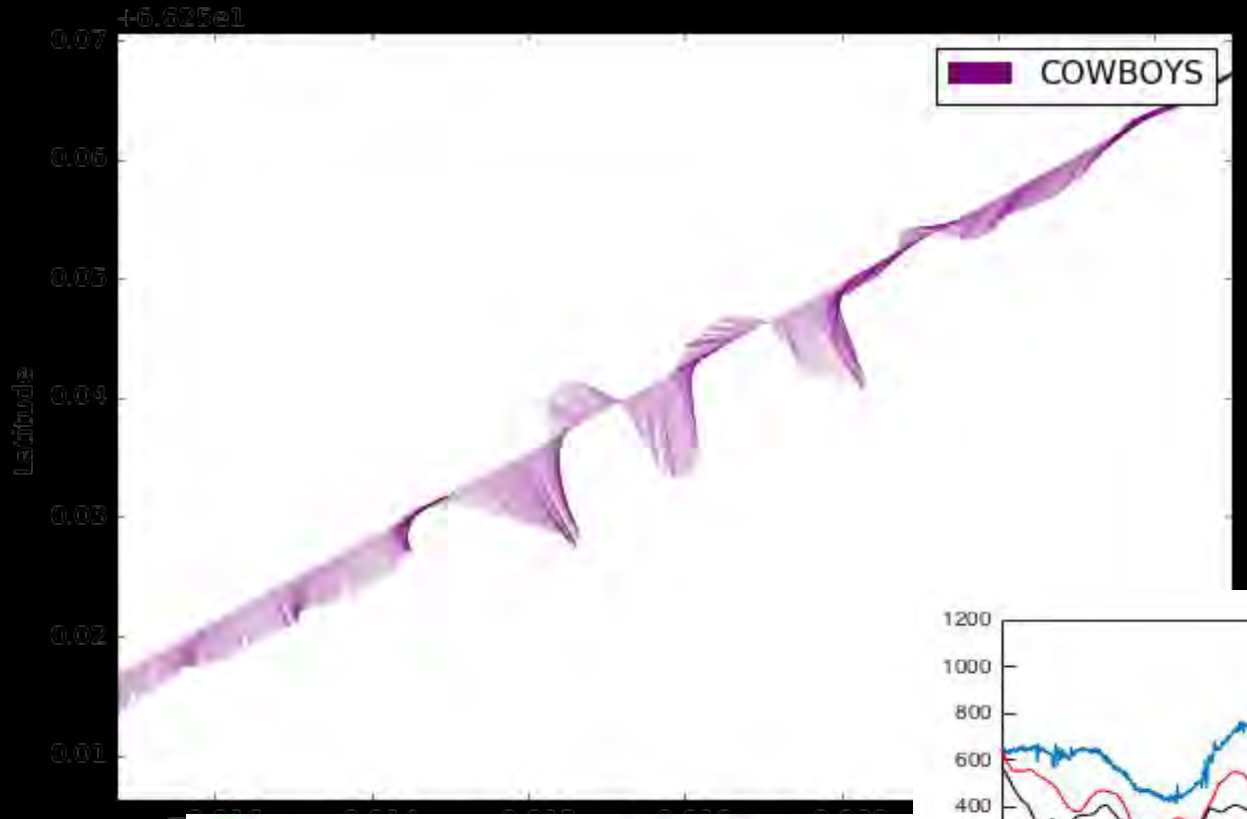

Original Replicated Data
MATLAB Interpolant
Div Free Interpolant
Geomagnetic Latitude
66.45
66.4
66.35
66.3
66.25
66.2
66.15
259.5
259.6
259.7
259.8
259.9
260
260.1
260.2
260.3
260.4
260.5
Geomagnetic Longitude

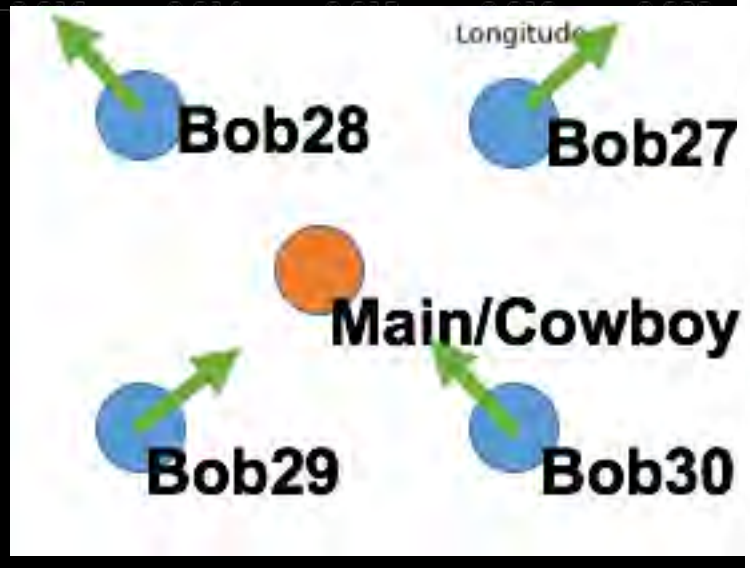

Trajectory Cuts Through Mapped Data
V East
1000
500
0
-500
-1000
-1500
Raw data
clayton2 rocket data
clayton3 pfisr
66
66.2
66.4
66.6
66.8
67
67.2
67.4
67.6
0
20
40
60
80
100
120
140
160
180
200

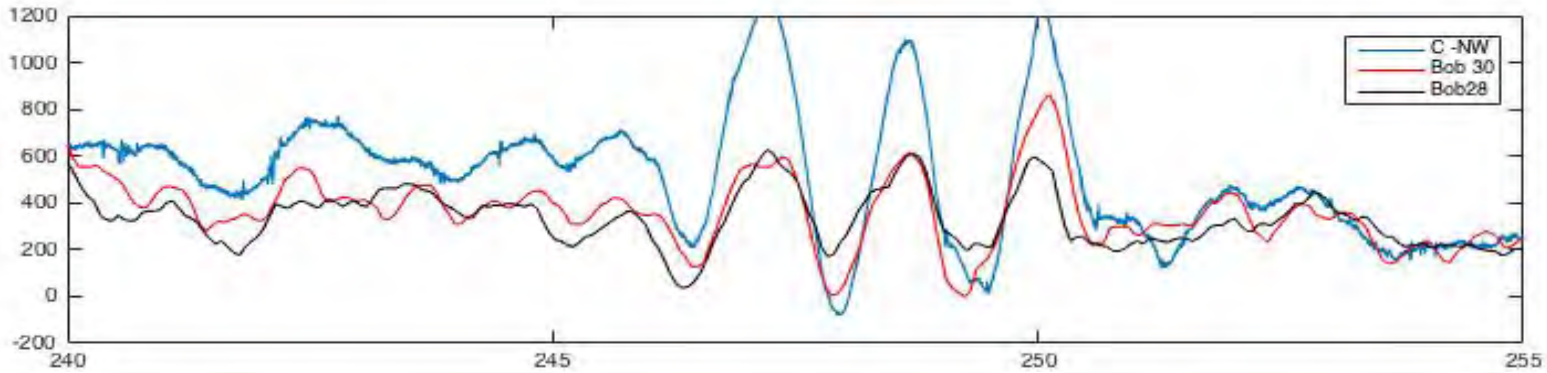


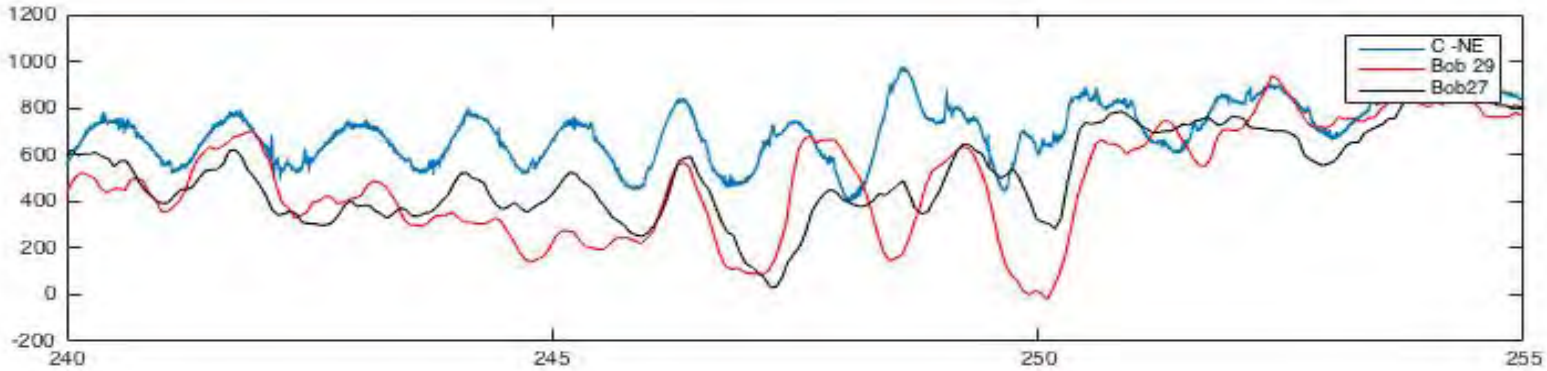
Gemini model run,
Matt Zettergren



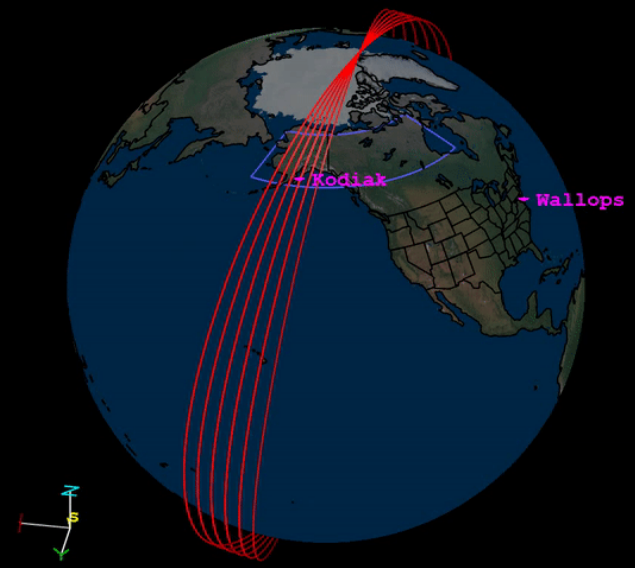

+6.625e1
COWBOYS
Latitude
0.07
0.06
0.05
0.04
0.03
0.02
0.01


Longitude
Bob28
Bob27
Main/Cowboy
Bob29
Bob30

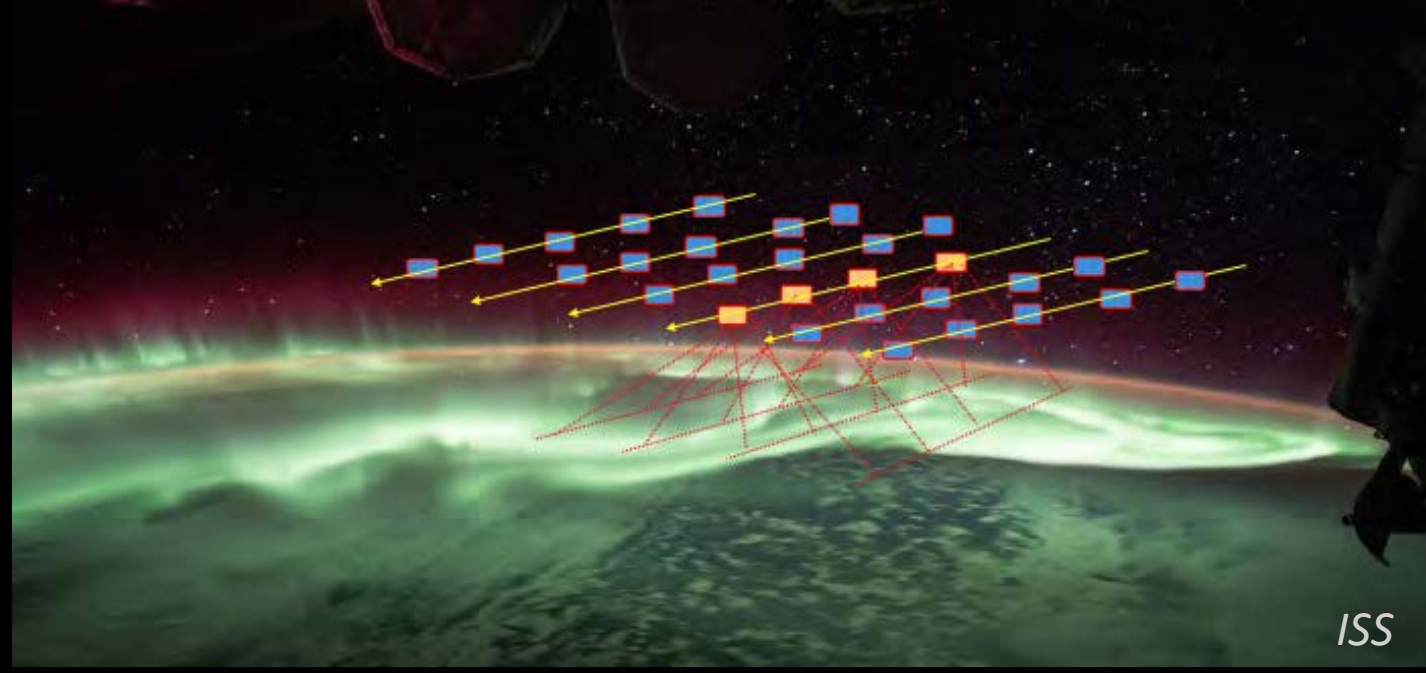

C -NW
Bob 30
Bob28
1200
1000
800
600
400
200
0
-200
240
245
250
255


C -NE
Bob 29
Bob27
1200
1000
800
600
400
200
0
-200
240
245
250
255

Mission Concept



Phase Four



ISS

AURORAL RECONSTRUCTION CUBESWARM

- What is the role of the ionosphere in the creation of auroral arcs?
  - What causes the aurora? How do the magnetosphere and ionosphere work together to control the dynamics and structure of auroral arcs across scales?
  - How do ionospheric flows, current structures, and conductivities work together to regulate/create auroral arcs?
  - What magnetospheric generator theories are consistent with the observed 2d current, flow, and conductivity patterns in the ionosphere?

Some thoughts about auroral plasma physics

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- Basic plasma equations a surprisingly common thread

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