

Poynting and Kinetic-Energy Flux Derived from the FAST Satellite

Year 1

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Worcester Polytechnic Institute

- Worcester, MA
 - 35 miles west of Boston
 - 3100 miles east of Menlo Park
- ~3400 undergraduates, approx 1100 graduate students
- Project-based curriculum
- Four seven-week terms, 3 classes per term
- Major Qualifying Project (MQP)- 3 classes
 - team-based research or design experience in major field of study
- Important WPI Alum: Curt Carlson



Energy Input from Solar Wind

- Solar wind driven electromagnetic and kinetic energy input models for driving General Circulation Models
 - Describe global temperature and circulation of the upper atmosphere
 - Space weather!
- Funded by NSF Space Weather Program
- Four year project
- WPI/SRI collaboration

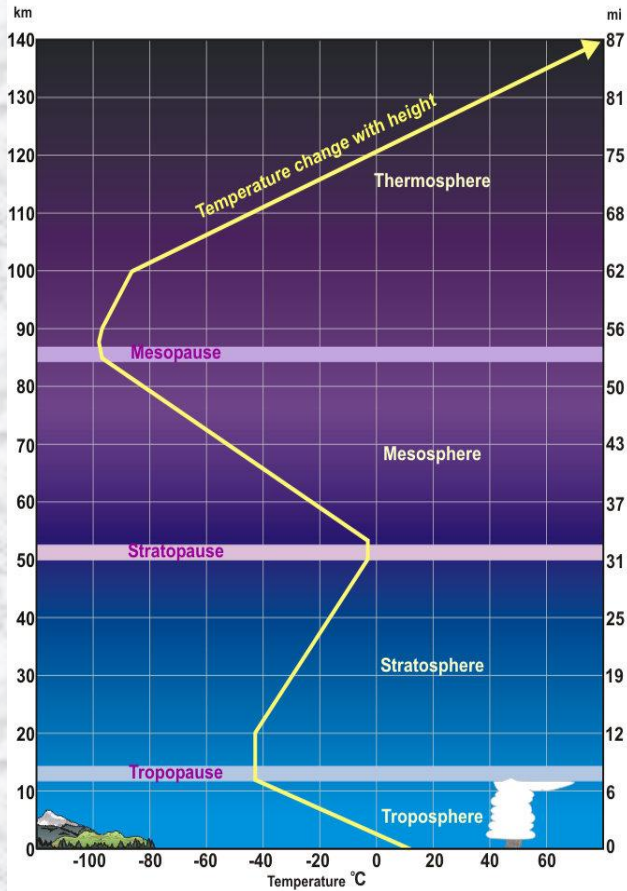


Goals for Year 1

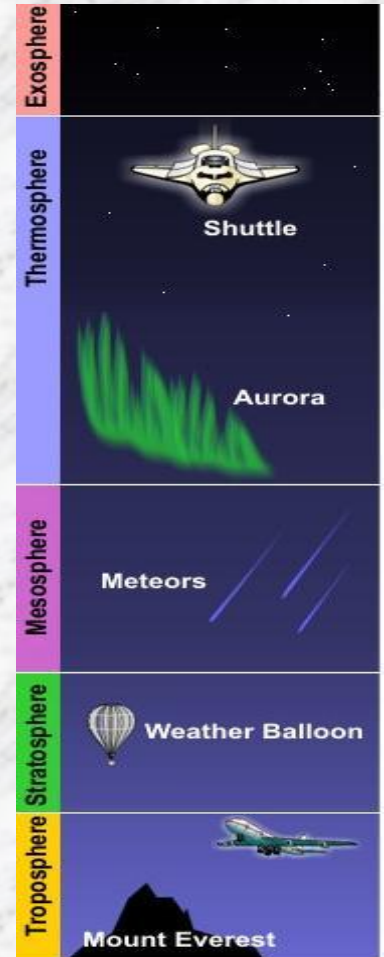
- Create/Document Methods and Routines for finding:
 - Poynting Flux
 - The amount of energy transported by an EM field
 - $P = E \times H$
 - Only interested in perturbations of magnetic field; must remove geomagnetic field from measurements
 - Kinetic Energy Flux
 - The energy flux of electrons and ions following the geomagnetic field lines
- Get the ball rolling for next 3 years of project...



Background- The Atmosphere



- 5 layers of various gases separated by “pauses”
- Lowest elevation is troposphere- ~75% of the mass of the atmosphere- lots of models



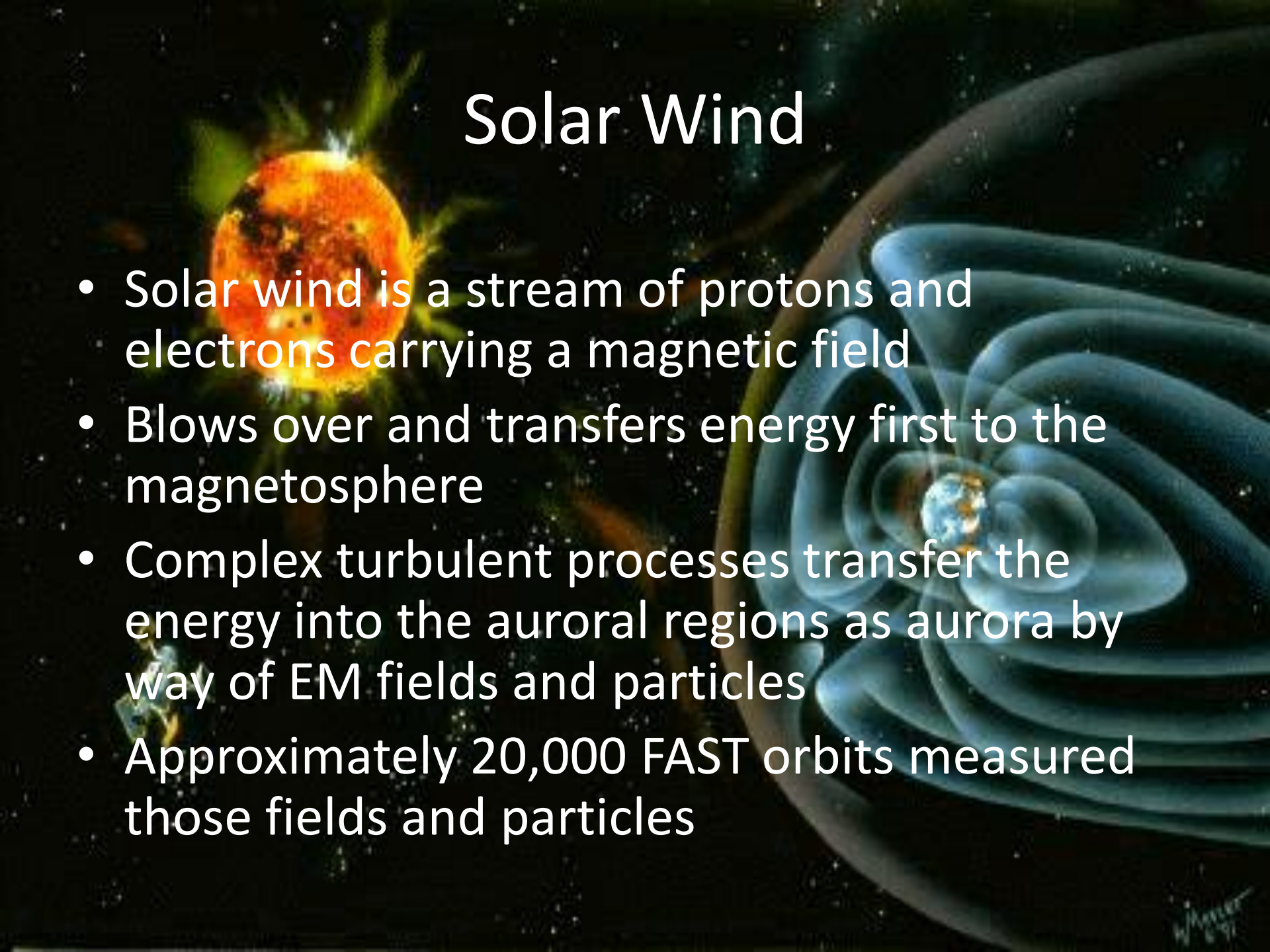
Background- The Aurora



- Caused by energetic particles that enter the magnetosphere- mostly electrons
- Travel along field lines, collide with atoms or molecules, which acquire some of the particle's energy
 - To release energy, releases a photon- light
- Solar wind is a stream of protons and electrons, contain the sun's magnetic field, transfers energy to the magnetosphere

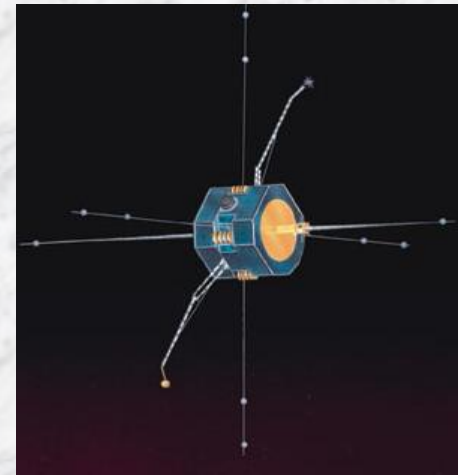
Solar Wind

- Solar wind is a stream of protons and electrons carrying a magnetic field
- Blows over and transfers energy first to the magnetosphere
- Complex turbulent processes transfer the energy into the auroral regions as aurora by way of EM fields and particles
- Approximately 20,000 FAST orbits measured those fields and particles



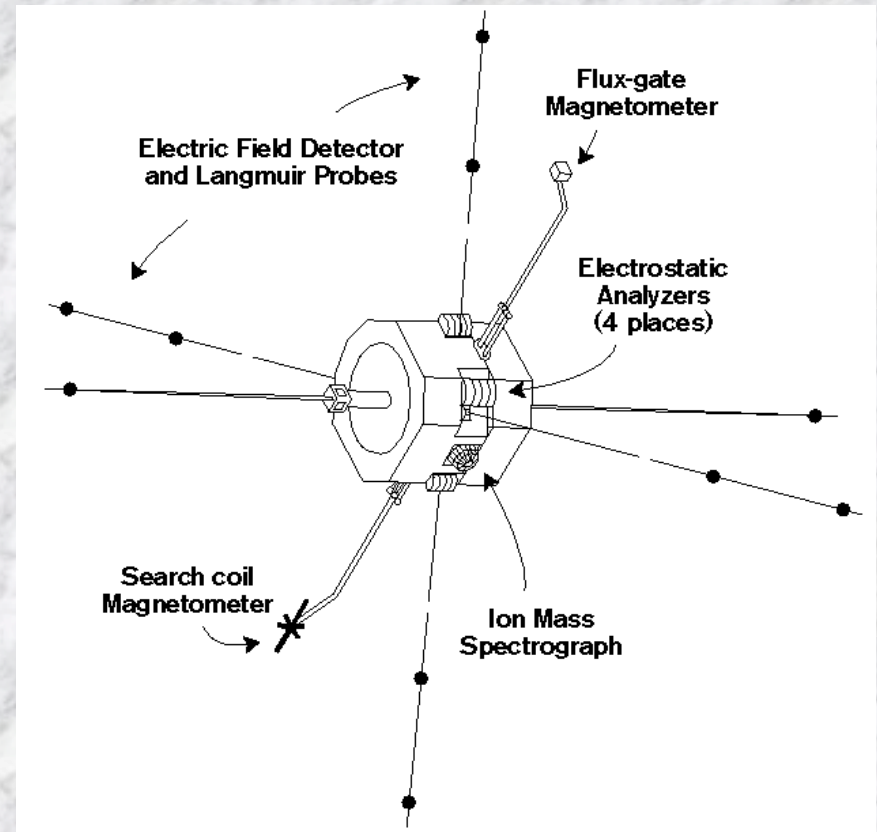
Background- The FAST Mission

- Fast Auroral SnapshoT Explorer, 8/21/96
- Designed by NASA to help scientists understand the causes and effects of the aurora
- Crosses Earth's Auroral zones four times/orbit
 - Collects high-resolution (km scale) data in these zones
- Measures
 - electric & magnetic fields
 - energetic ions and electrons
 - others (outside our scope)



FAST Data Gathering and Processing

- Electric field probes on booms
- Flux-gate Magnetometer
- Work around failed boom deployment
- Data comes in coordinate system relative to satellite
 - coordinate system conversions into GEO necessary



SRI Background

- Formerly known as Stanford Research Institute
- One of the world's largest contract research firms
- Diverse research base- topics include:
 - Engineering
 - Biosciences
 - Physical Sciences



SRI Background continued

- Clients include:
 - NSF
 - VISA
 - Charles Schwab
 - US Department of Defense
 - Toyota
 - Canadian Ministry of Industry, Science, and Technology
- Projects
 - Clairvoyance and ESP; Psychic warfare
 - USPS advanced letter sorting system
 - AMISR finished year-long run in 2008
 - Anti-Cancer Drug FOLOTYN
 - ARPANET



Reference Frames

- Geocentric Equatorial Inertial-GEI (Cartesian)
 - X points toward 1st star in Aries
 - Z through geographic North Pole
 - Y completes
- Geocentric Geographic-GEO (Cartesian)
 - X through Greenwich meridian
 - Z through geographic North Pole
 - Y completes
- Geodetic Geographic
 - Latitude and longitude
- FAST (Cartesian)
 - Y is the opposite of the trajectory
 - Z is the spin axis
 - X completes
- Data Coordinate System-DCS (Cartesian)
 - X is always equatorward
 - Y is always westward/ on the spin axis
 - Z is mostly parallel to B



Methods for Obtaining Data

- Download Summary Data in Common Data Format (CDF) from Berkeley website
 - Easiest method because data is partially processed
 - Import CDF files into MATLAB for flux processing
 - Potentially unreliable summary data
- Create in-house CDF files using Satellite Data Tool (SDT) and Interactive Data Language (IDL)
 - Ideal method
 - More difficult than anticipated



Calculations

- Poynting Flux
 - Search the FAST database for interesting events
 - Using MATLAB:
 - Align positional and field data through interpolation
 - Cross the Electric Field (E) with H
 - Project Poynting Flux onto IGRF Model
 - Convert all data to GEO
- Kinetic Energy Flux
 - Data is given by Berkeley summary files



Data and Results

- Given Data
- Correlating Data and Time Conversions
- Transformed Positional Data
- The International Geomagnetic Reference Field Model
- Poynting Vectors
- Kinetic Energy Flux

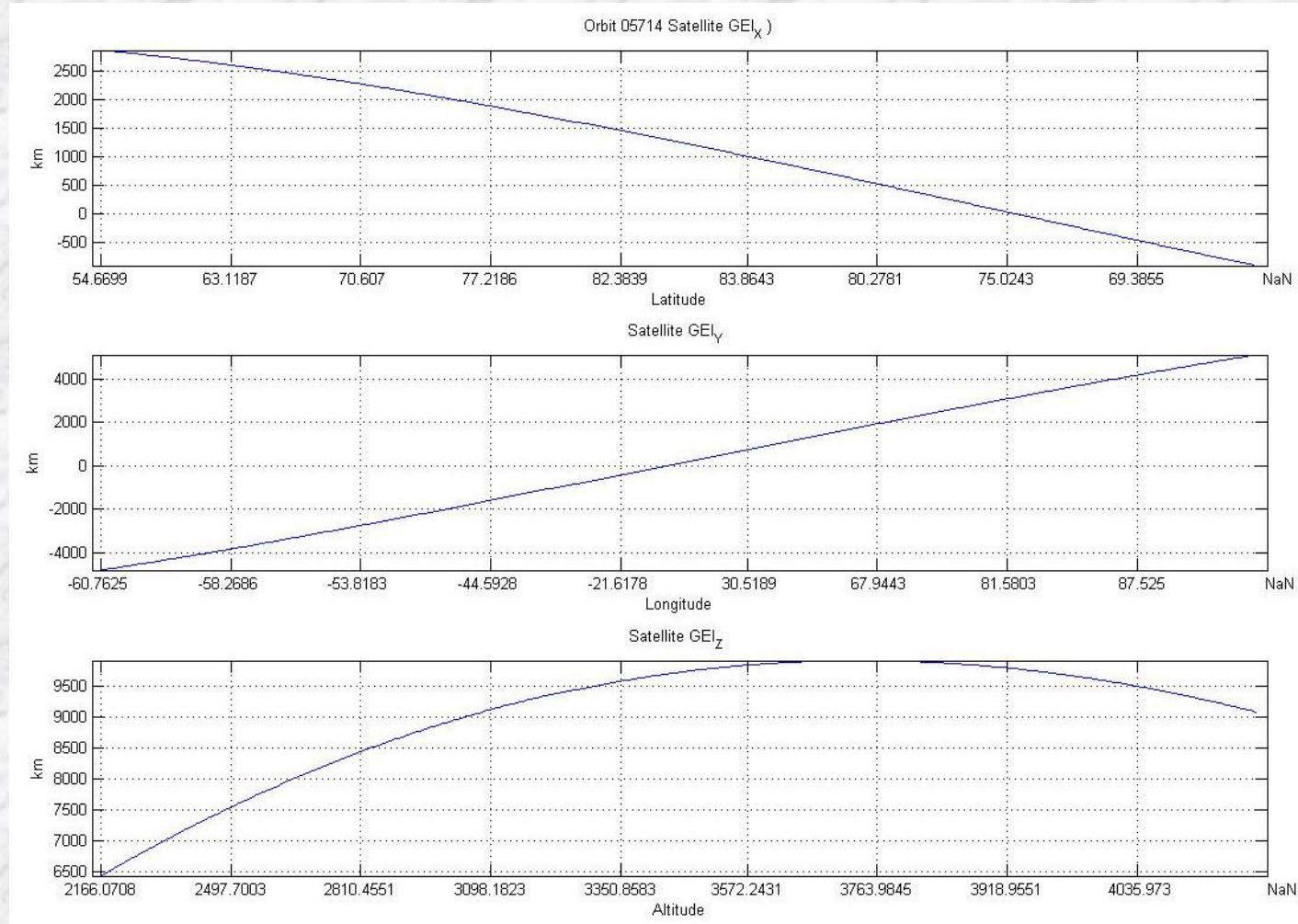


Data and Results

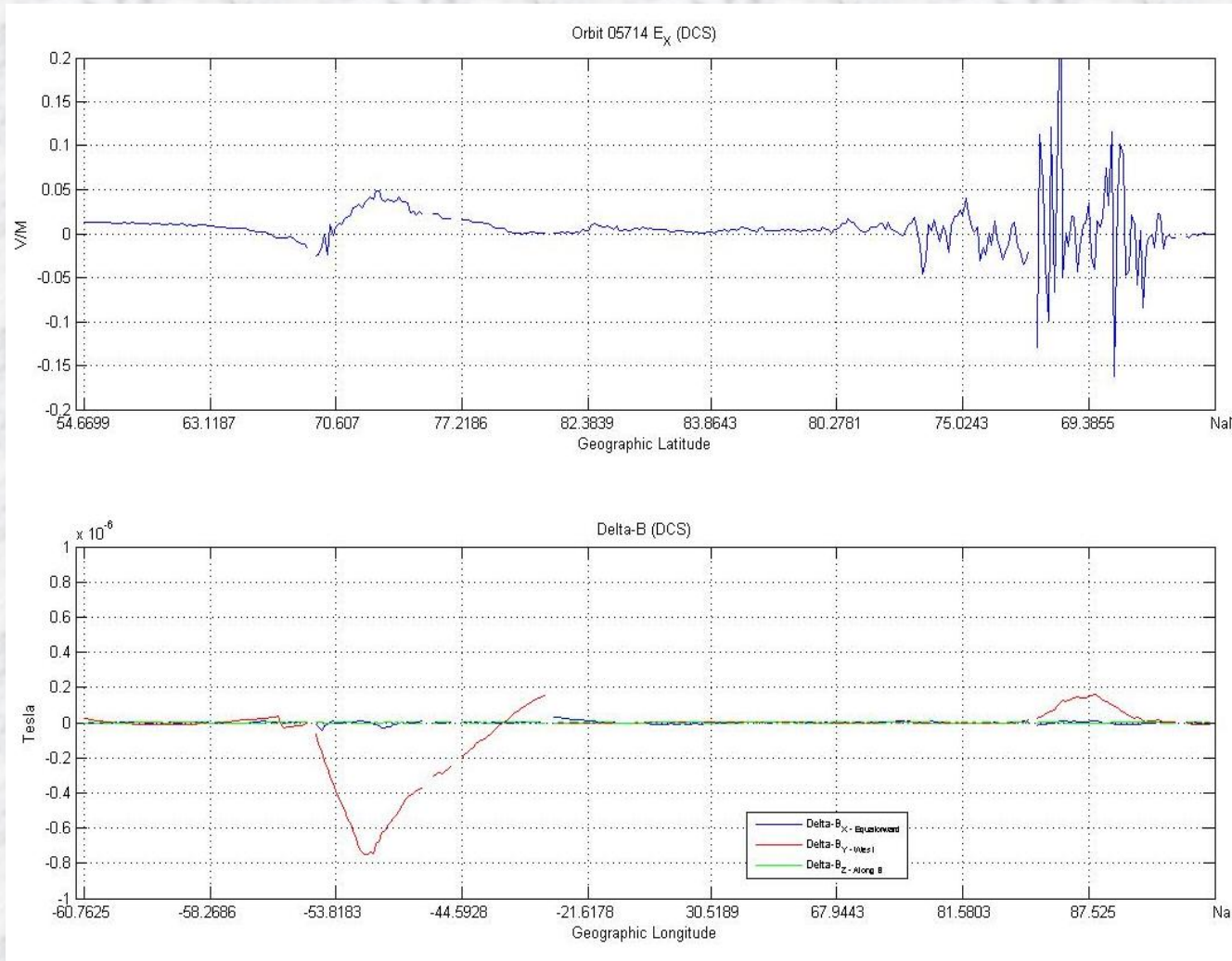
- 5 orbits: 1092, 2217, 5704, 5714, 5716
- DCS Plots
 - Electric Fields
 - Magnetic Fields
 - Poynting Vectors
- Kinetic Energy Flux
 - ion
 - electron



Given Data: Orbit 5714 Position in GEI



Given Data: Orbit 5714 Fields in DCS



Correlating Data and Time Conversions

good_f_matrix		interp_p_f_matrix		pos_matrix	
1	1	1	1	1	1
1	886180351.612547	1	886180351.612547	1	886179452.650000
2	886180351.612547	2	886180351.612547	2	886179472.650000
3	886180356.677359	3	886180356.677359	3	886179492.650000
4	886180361.742169	4	886180361.742169	4	886179512.650000
5	886180366.806975	5	886180366.806975	5	886179532.650000
6	886180371.871779	6	886180371.871779	6	886179552.650000
7	886180376.936581	7	886180376.936581	7	886179572.650000
8	886180382.001379	8	886180382.001379	8	886179592.650000
9	886180387.066175	9	886180387.066175	9	886179612.650000
10	886180392.130966	10	886180392.130966	10	886179632.650000
11	886180397.195748	11	886180397.195748	11	886179652.650000
12	886180402.260524	12	886180402.260524	12	886179672.650000
13	886180407.325301	13	886180407.325301	13	886179692.650000

Variable Editor - Universal_Time

File Edit View Graphics Debug Desktop Window Help

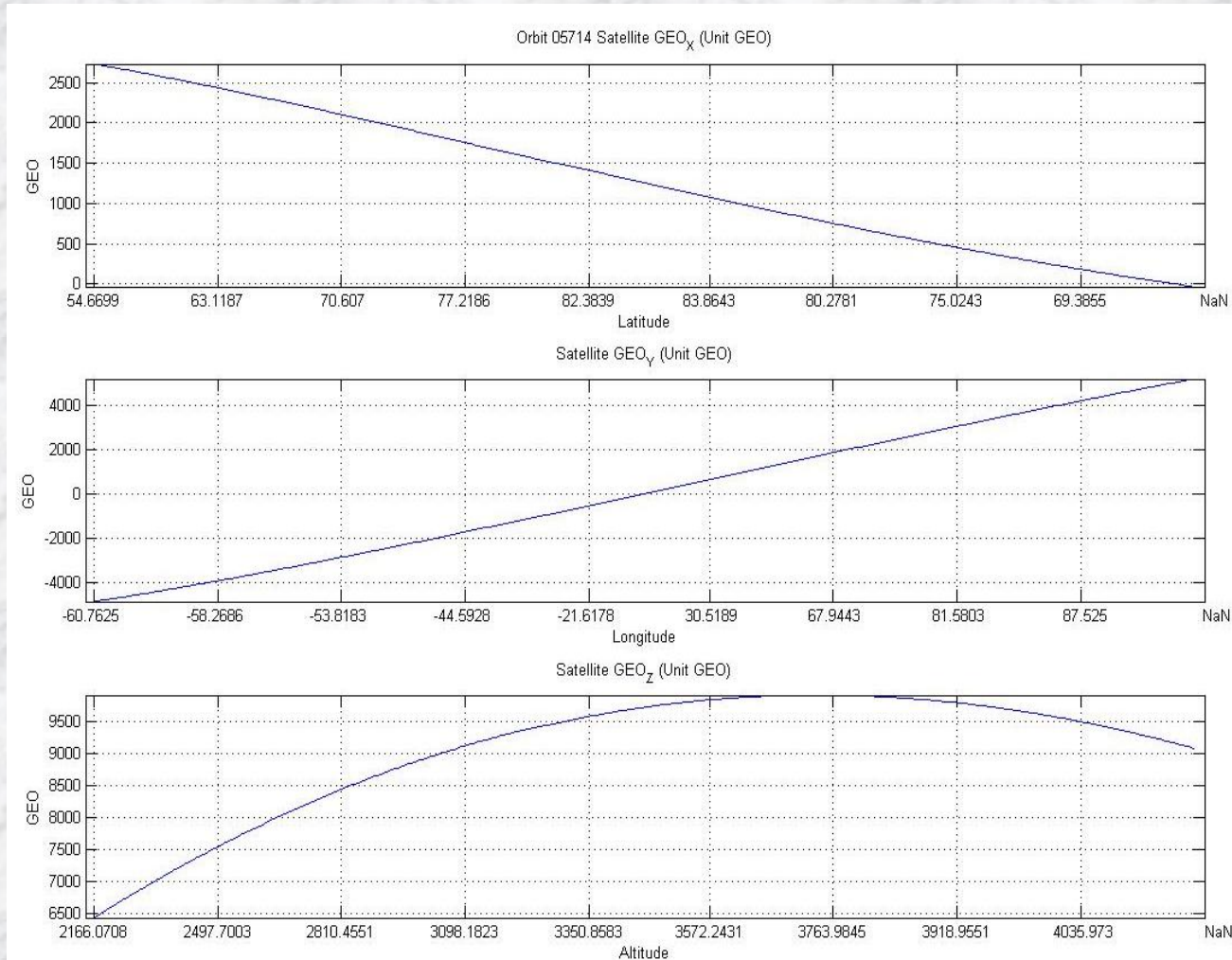
Stack: p_process Select data to plot

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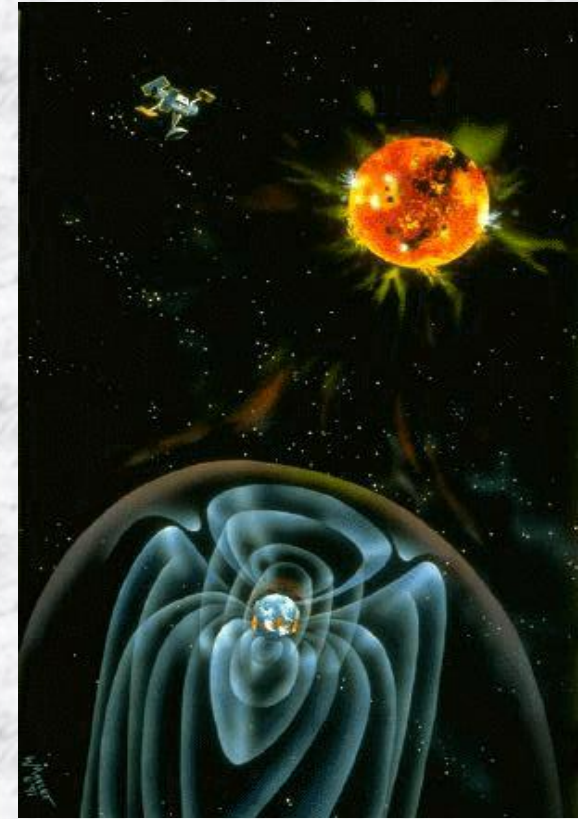
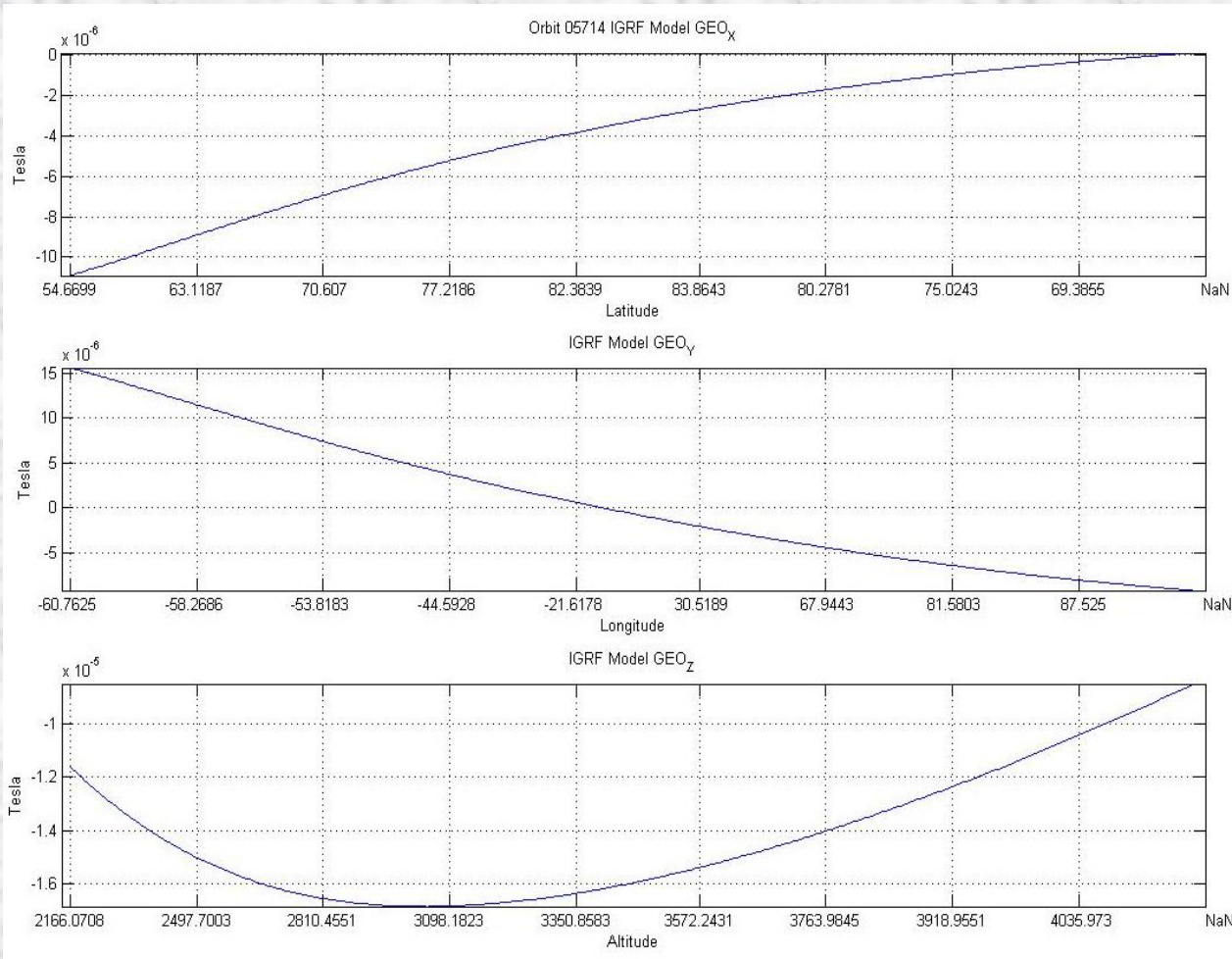
	1	2	3	4	5	6
1	1996	11	30	9	31	11.9674987...
2	1996	11	30	9	31	11.9674987...
3	1996	11	30	9	31	16.9949035...
4	1996	11	30	9	31	22.0223999...
5	1996	11	30	9	31	27.0497970...
6	1996	11	30	9	31	32.0773010...
7	1996	11	30	9	31	37.1047973...
8	1996	11	30	9	31	42.1323013...
9	1996	11	30	9	31	47.1597976...
10	1996	11	30	9	31	52.1874008...
11	1996	11	30	9	31	57.2151031...
12	1996	11	30	9	32	2.24269866...
13	1996	11	30	9	32	7.27040100...
14	1996	11	30	9	32	12.2981033...
15	1996	11	30	9	32	17.3257980...
16	1996	11	30	9	32	22.3535995...
17	1996	11	30	9	32	27.3814010...
18	1996	11	30	9	32	32.4092025...
19	1996	11	30	9	32	37.4369964...
20	1996	11	30	9	32	42.4648971...
21	1996	11	30	9	32	47.4927978...
22	1996	11	30	9	32	52.5206985...
23	1996	11	30	9	32	57.5486984...
24	1996	11	30	9	33	2.57669830...
25	1996	11	30	9	33	7.60469818...
26	1996	11	30	9	33	12.6326980...
27	1996	11	30	9	33	17.6606979...
28	1996	11	30	9	33	22.6887969...
29	1996	11	30	9	33	27.7167968...
30	1996	11	30	9	33	32.7449035...



Transformed Positional Data: Orbit 5714 in GEO



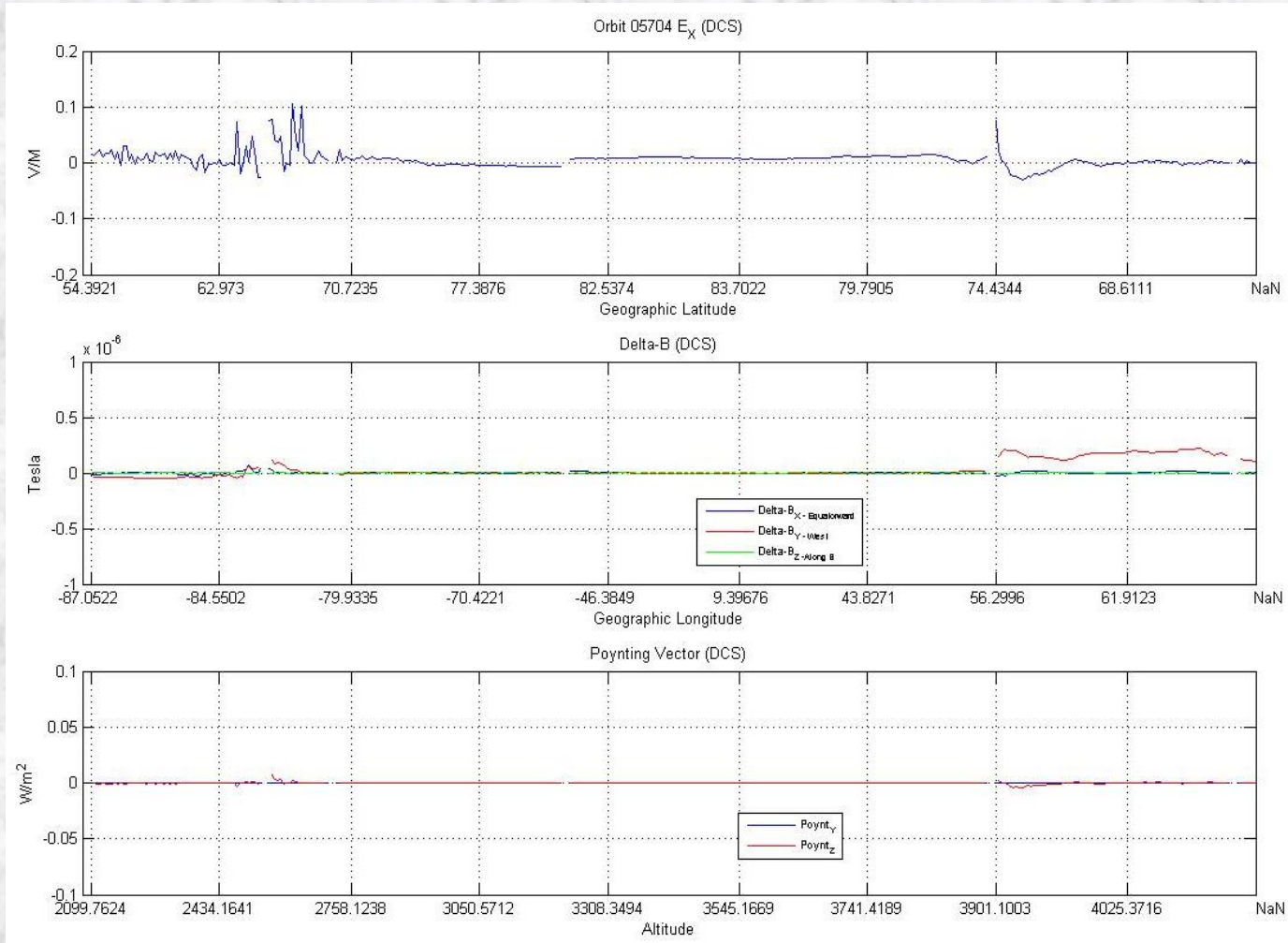
The IGRF Model



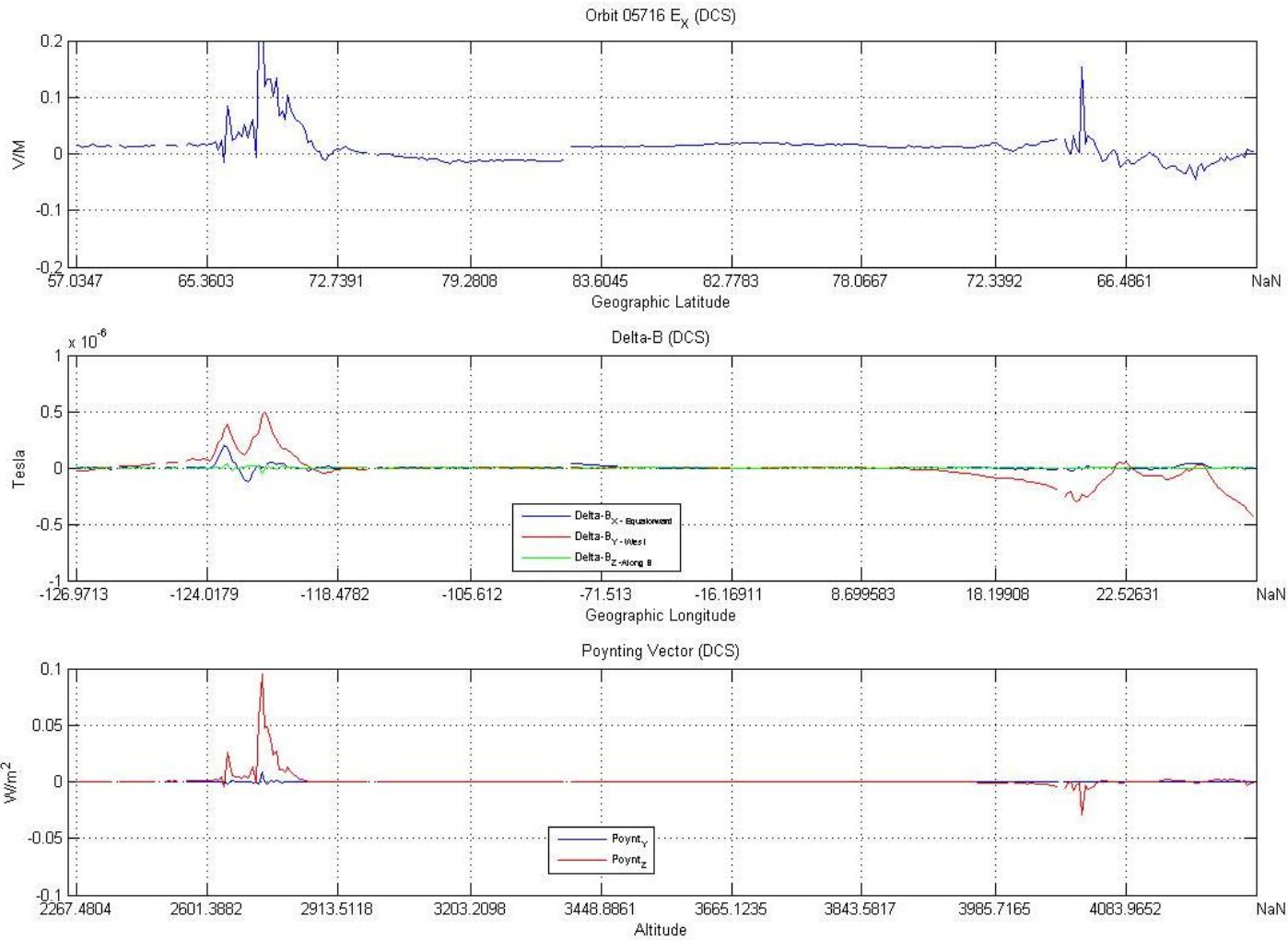
MATLAB code to find this model provided by NASA Langley Research Center



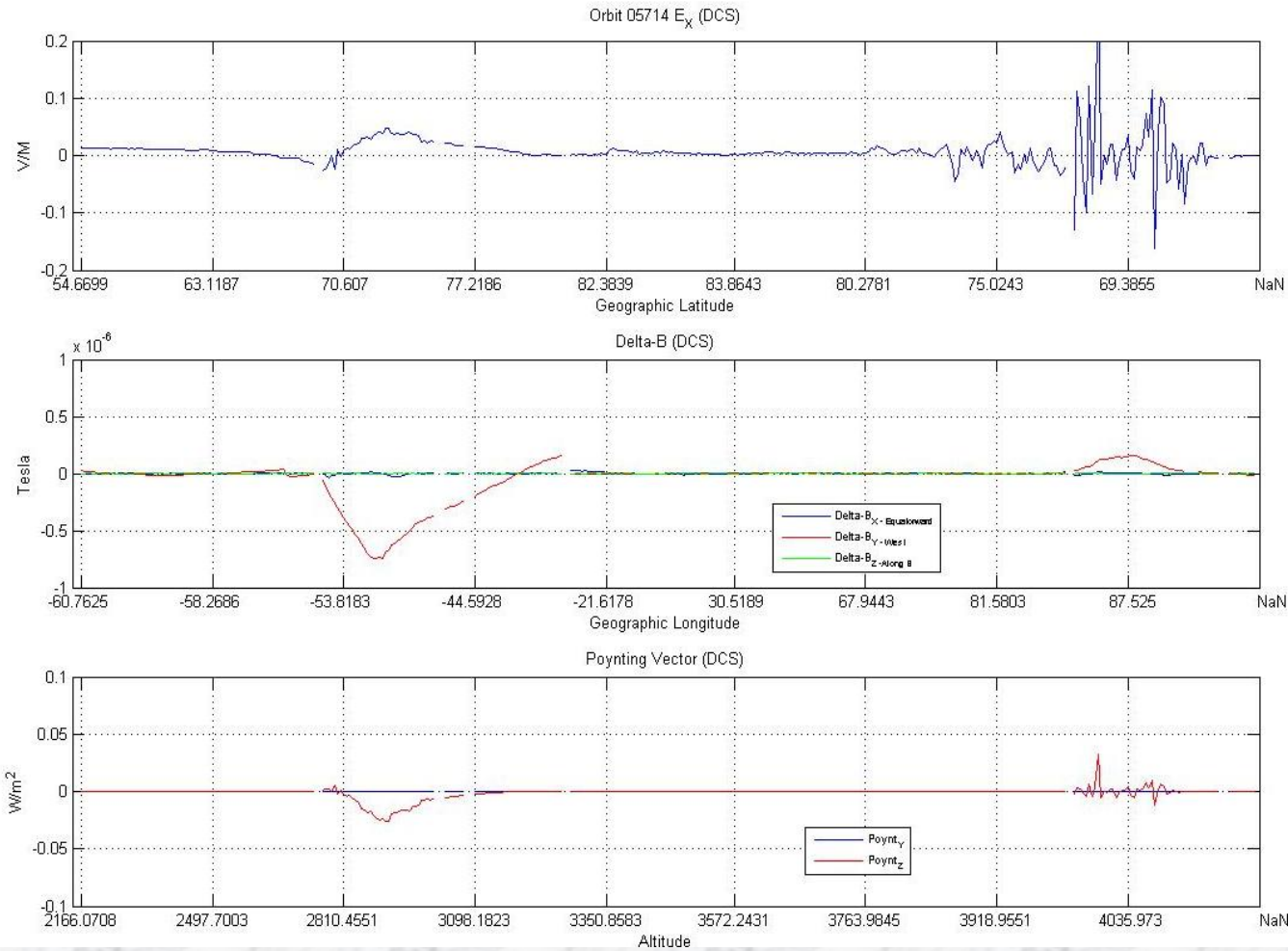
Poynting Vector: Orbit 5704



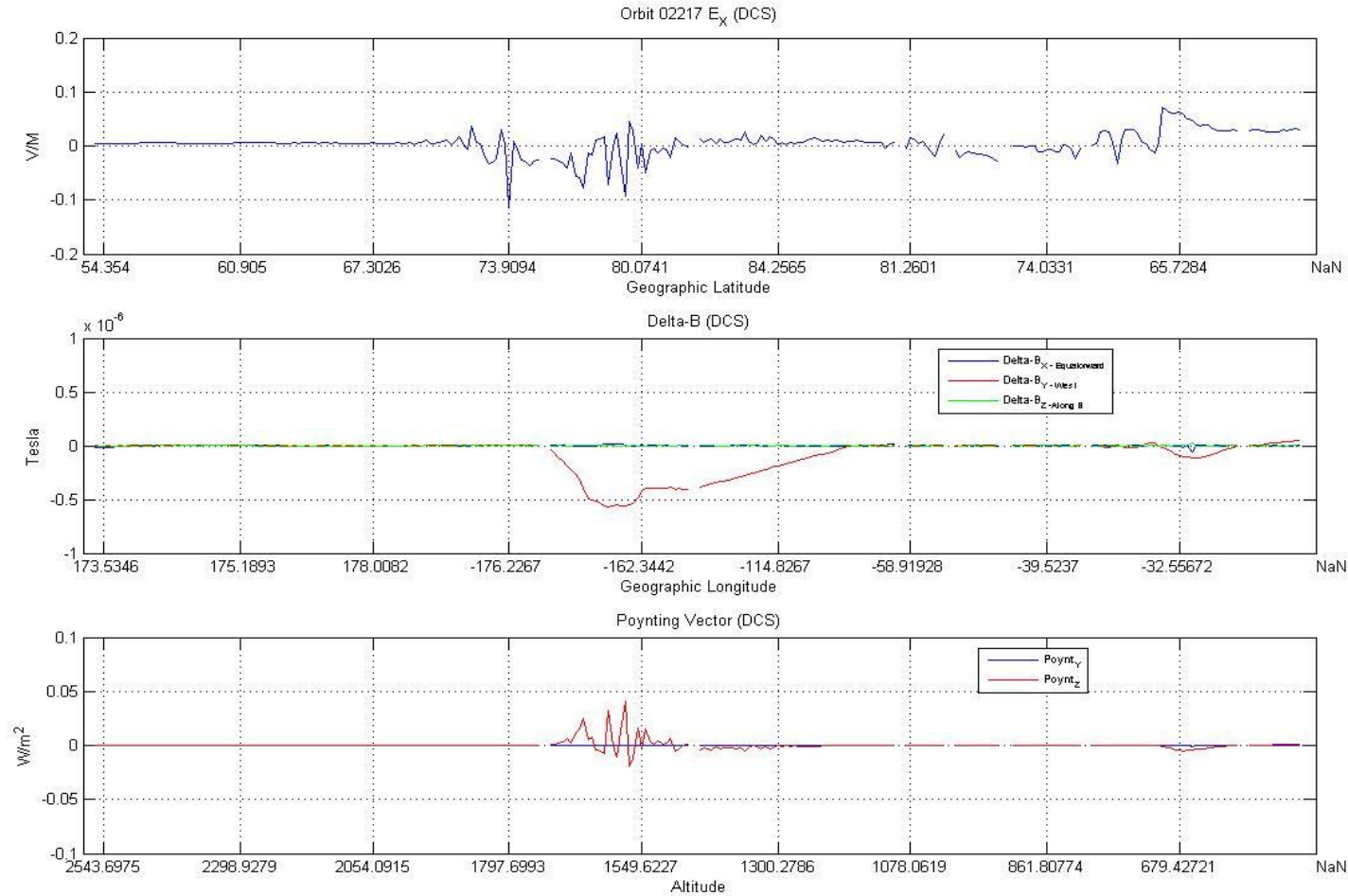
Poynting Vector: Orbit 5716



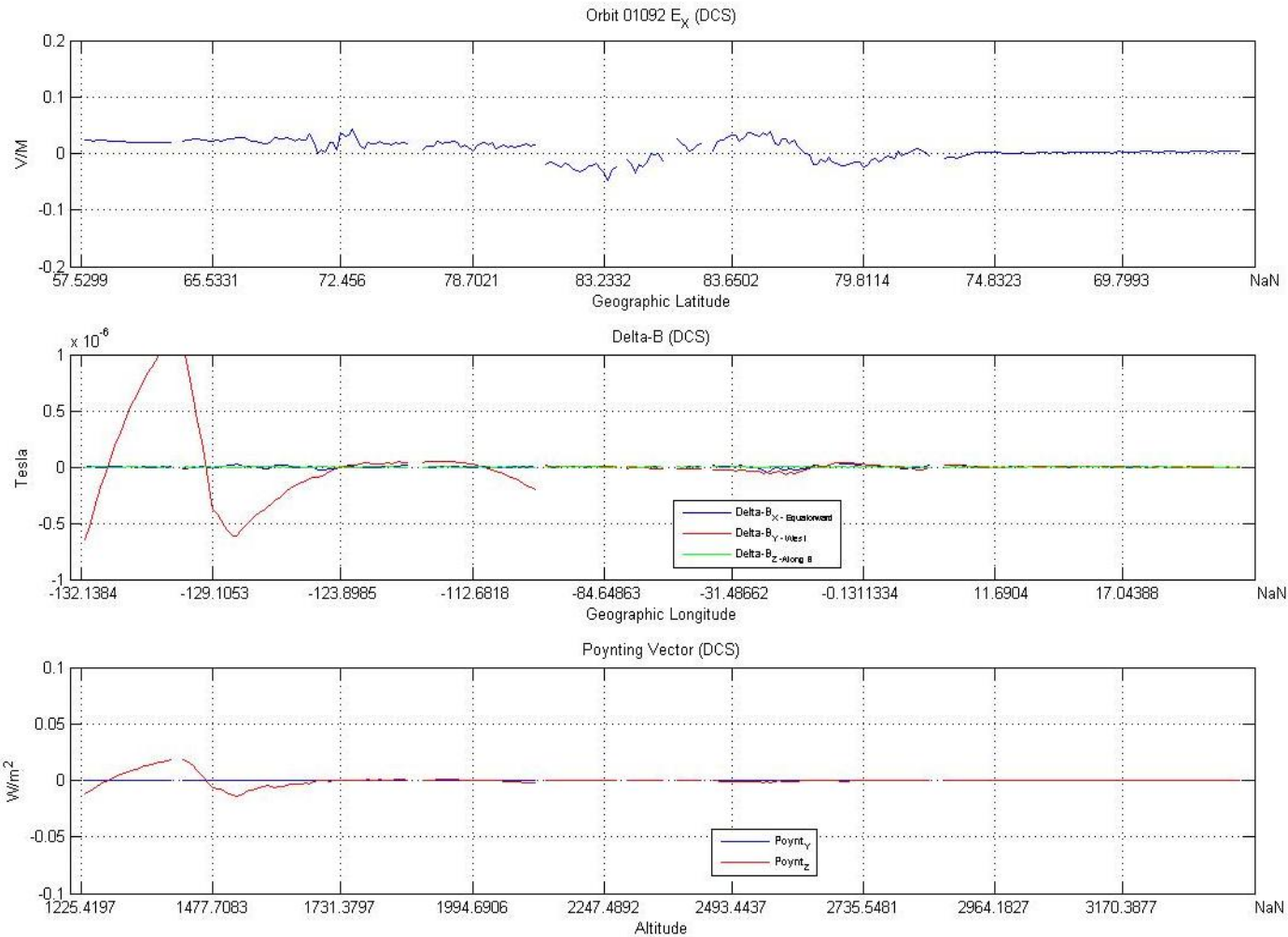
Poynting Vector: Orbit 5714



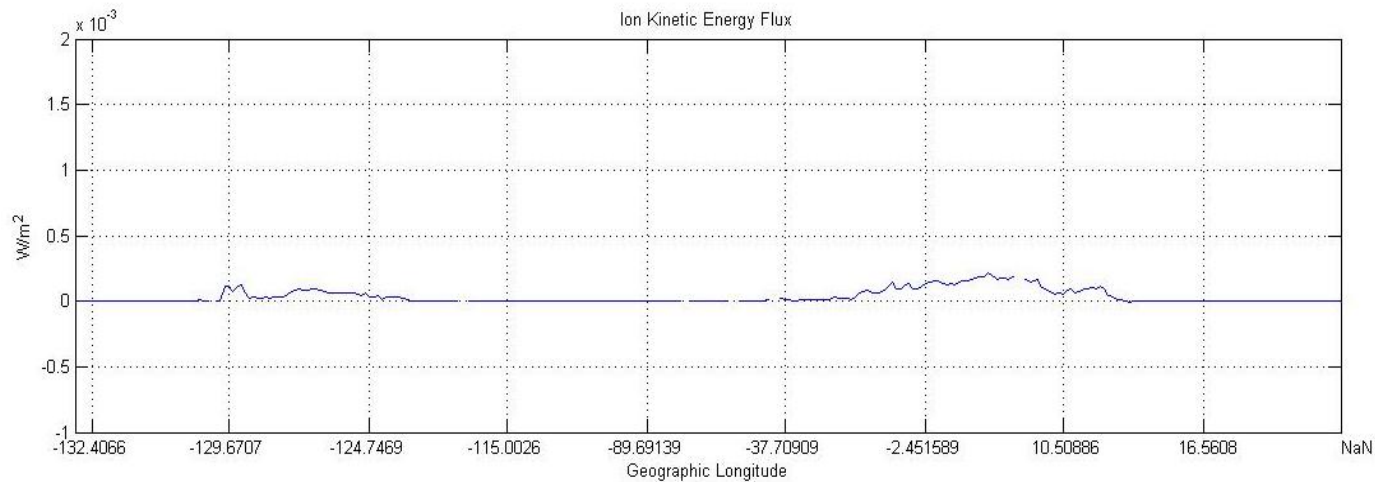
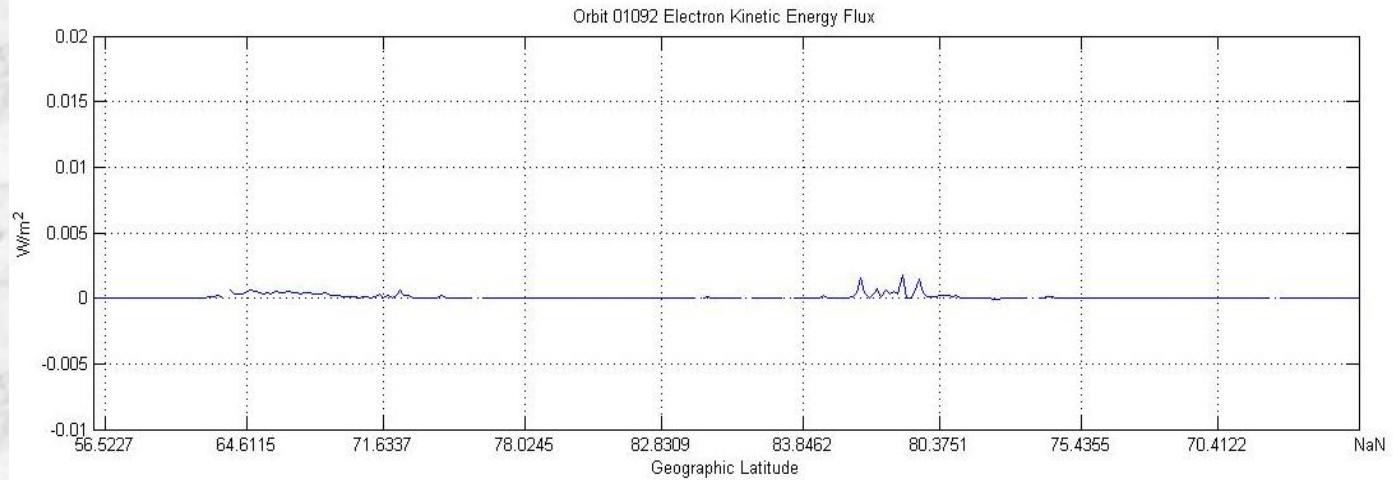
Poynting Vector: Orbit 2217



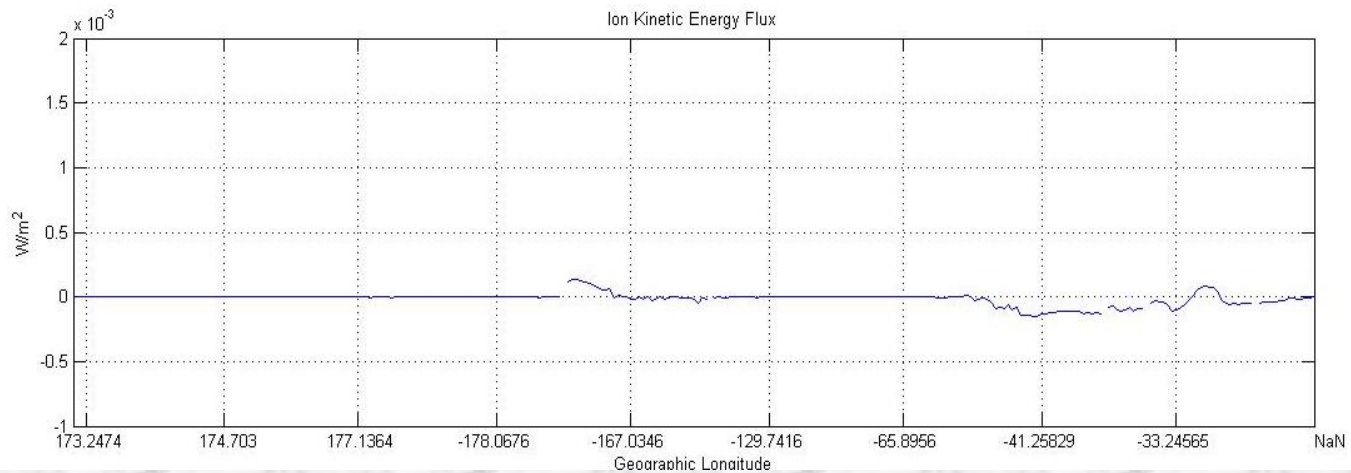
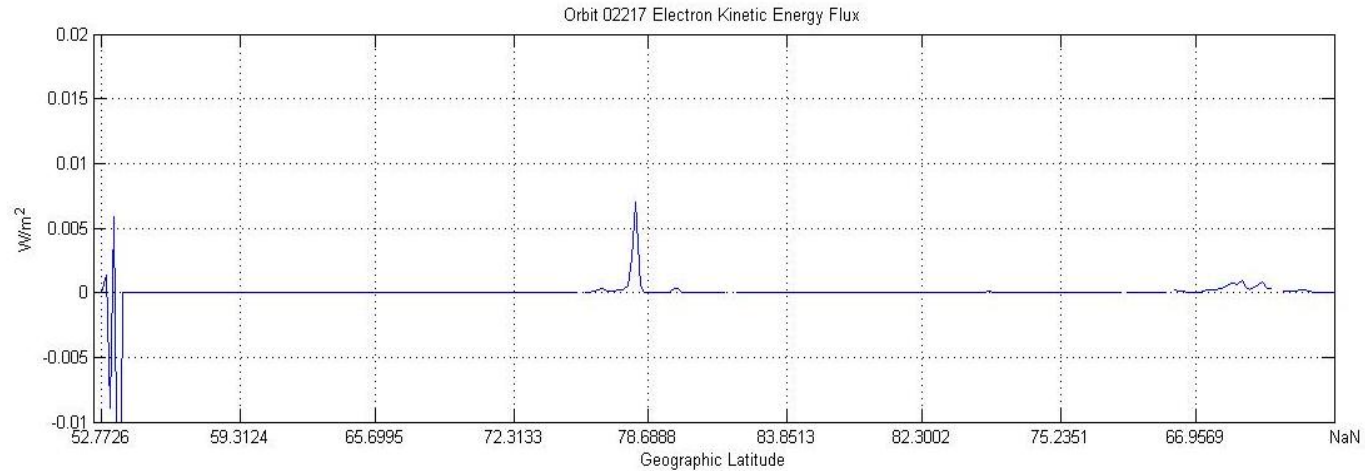
Poynting Vector: Orbit 1092



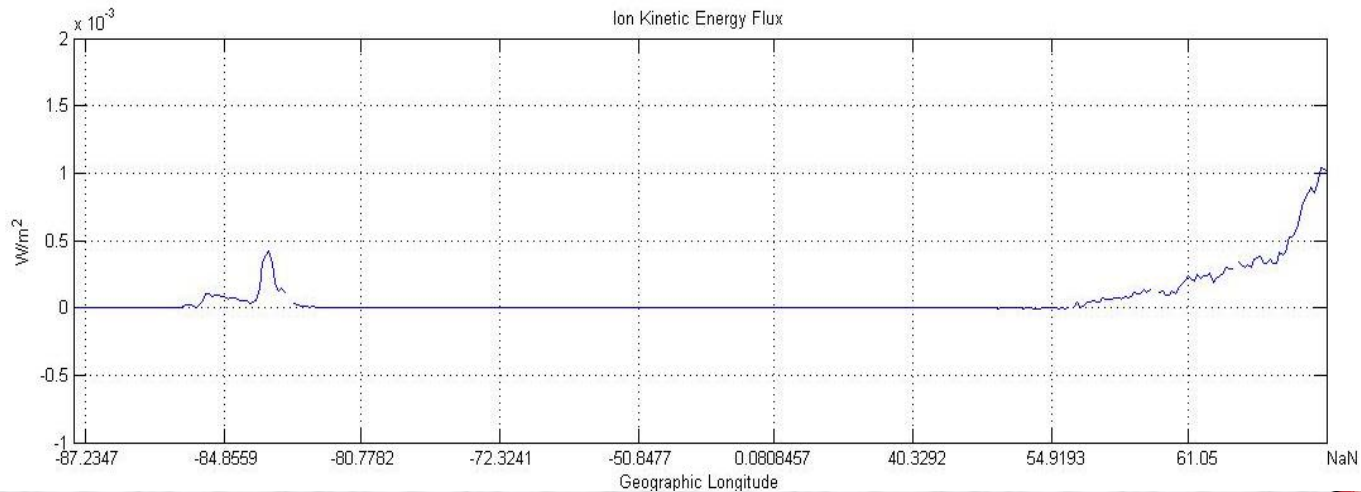
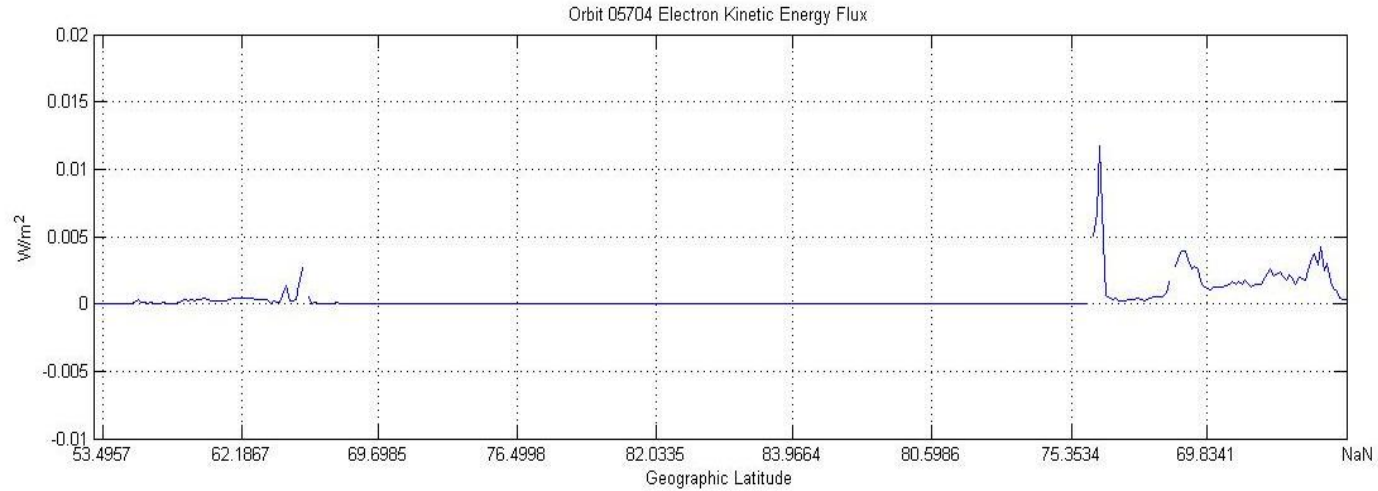
Kinetic Energy Flux: Orbit 1092



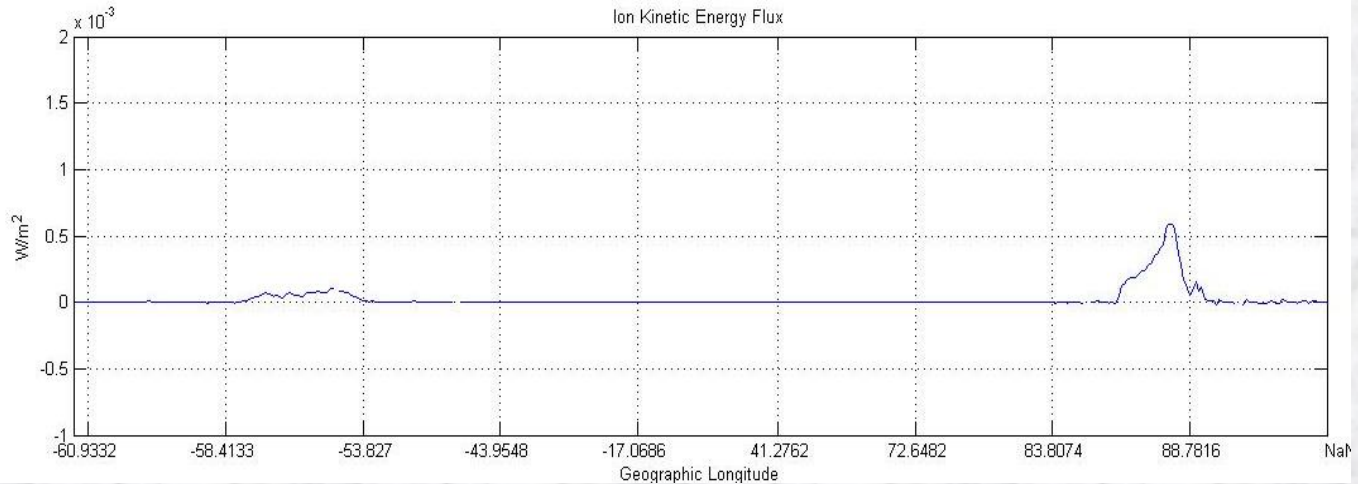
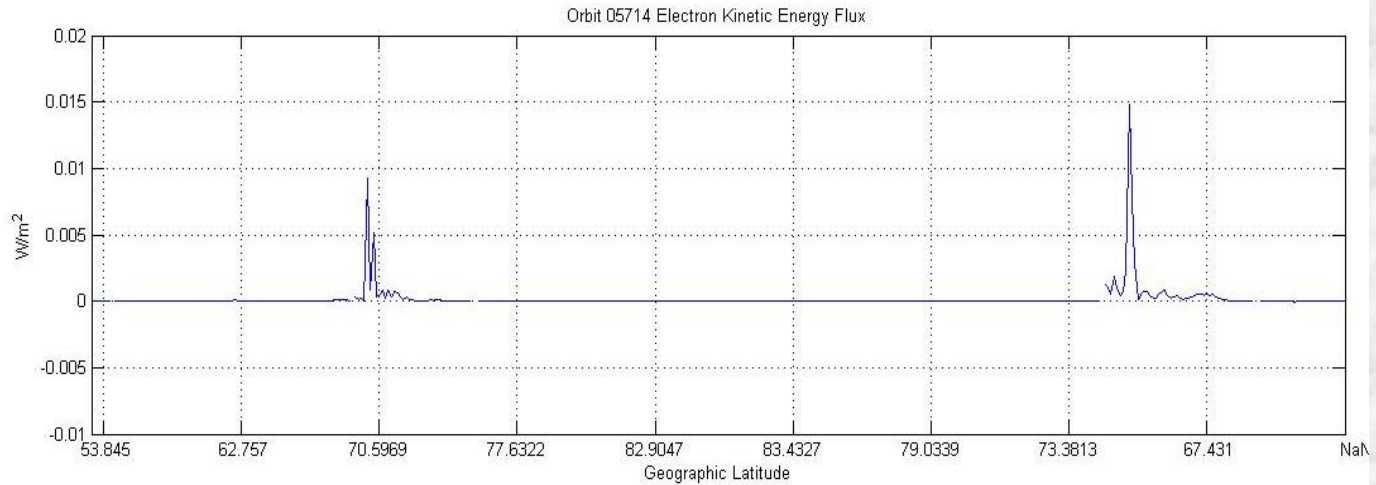
Kinetic Energy Flux: Orbit 2217



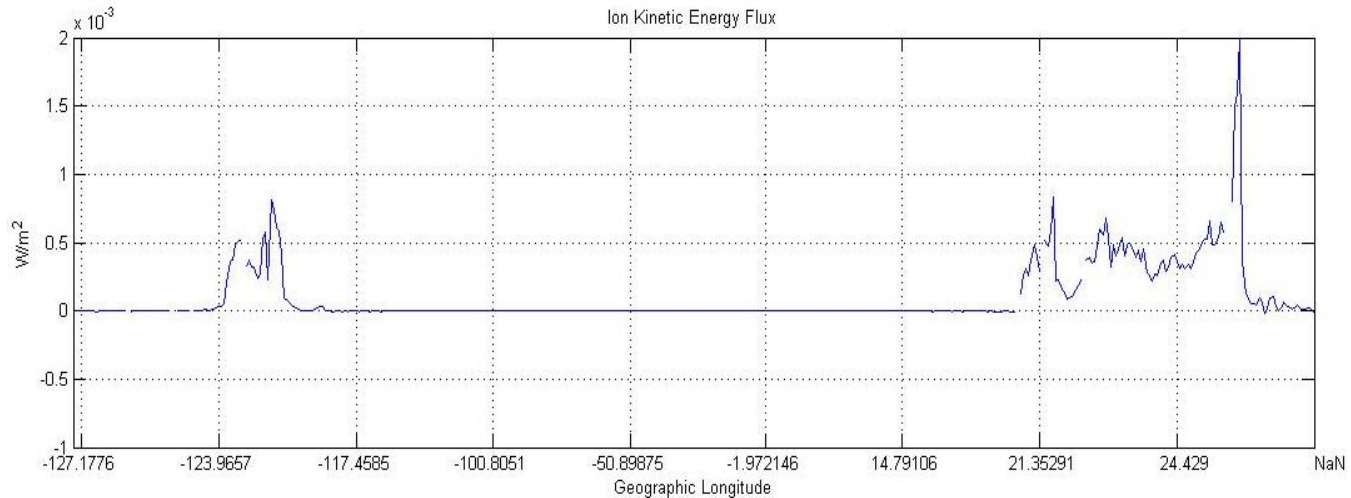
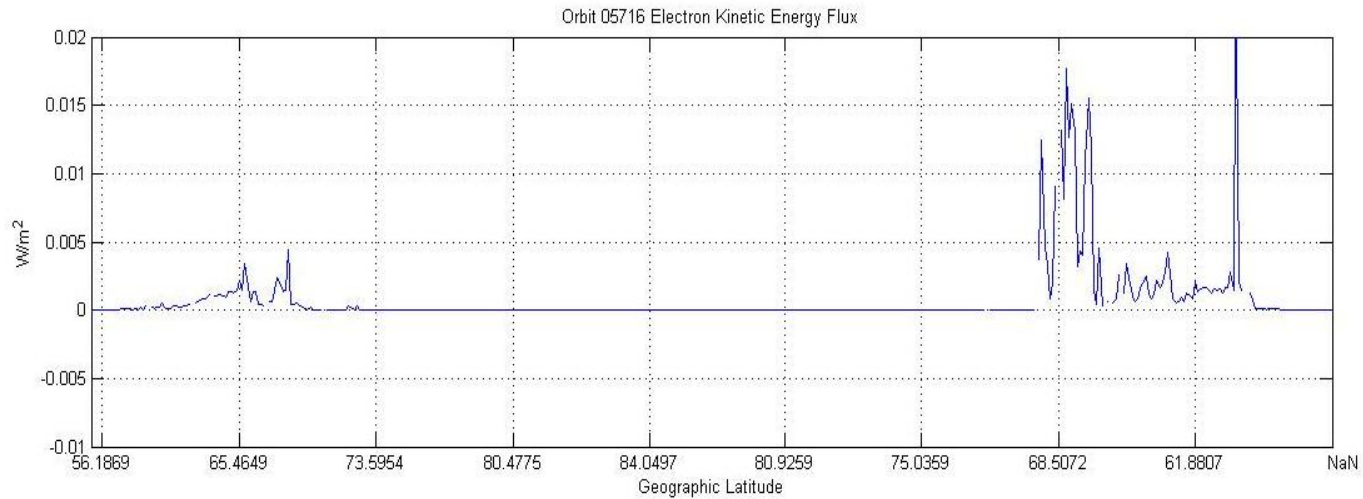
Kinetic Energy Flux: Orbit 5704



Kinetic Energy Flux: Orbit 5714



Kinetic Energy Flux: Orbit 5716



Future Work

- Next year, more WPI senior undergrads will use our methods to calculate Poynting and Kinetic Energy Flux for approx. 20,000 orbits, and create statistical models
- The 3rd year, more students will use those models to create analytical models
- In the 4th year, SRI scientists will complete the project



Questions?

Poynting and Kinetic-Energy Flux Derived from the FAST Satellite

Nicole Cahill & Sebastian Musielak

