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
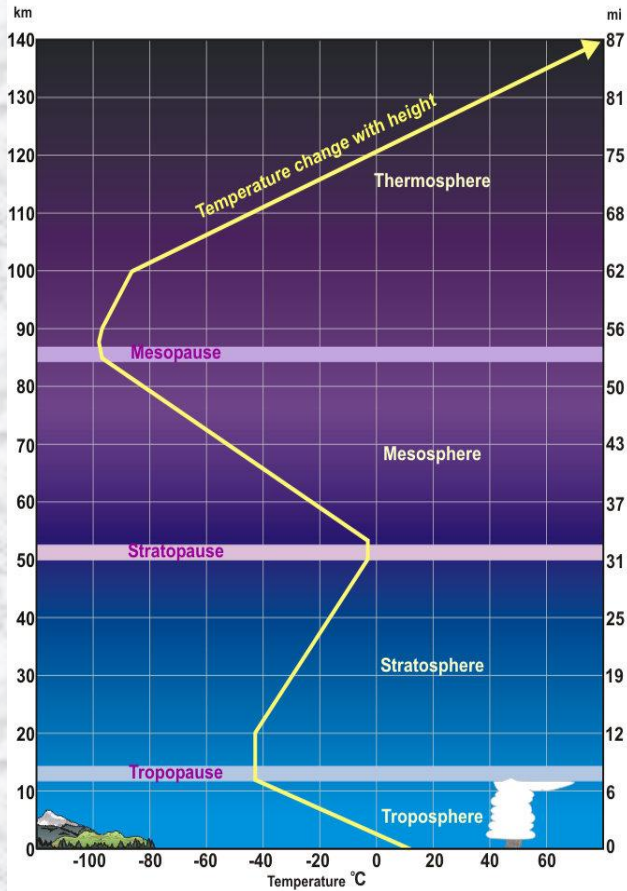
- 5 layers of various gases separated by "pauses"

- Lowest elevation is troposphere- ~75% of the mass of the atmosphere- lots of models
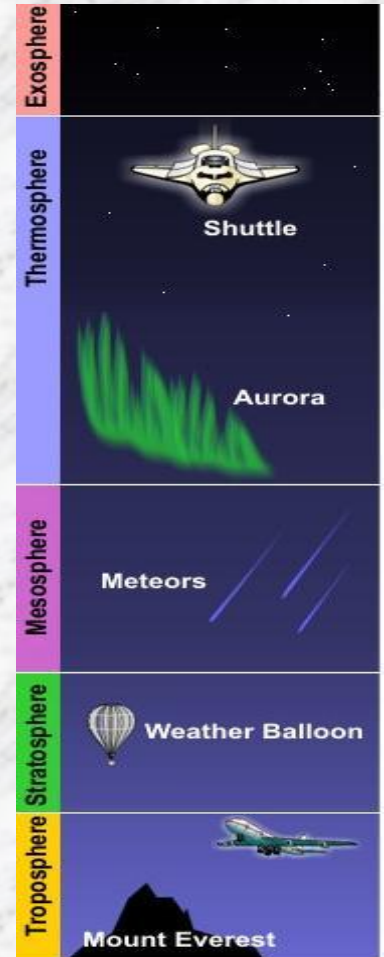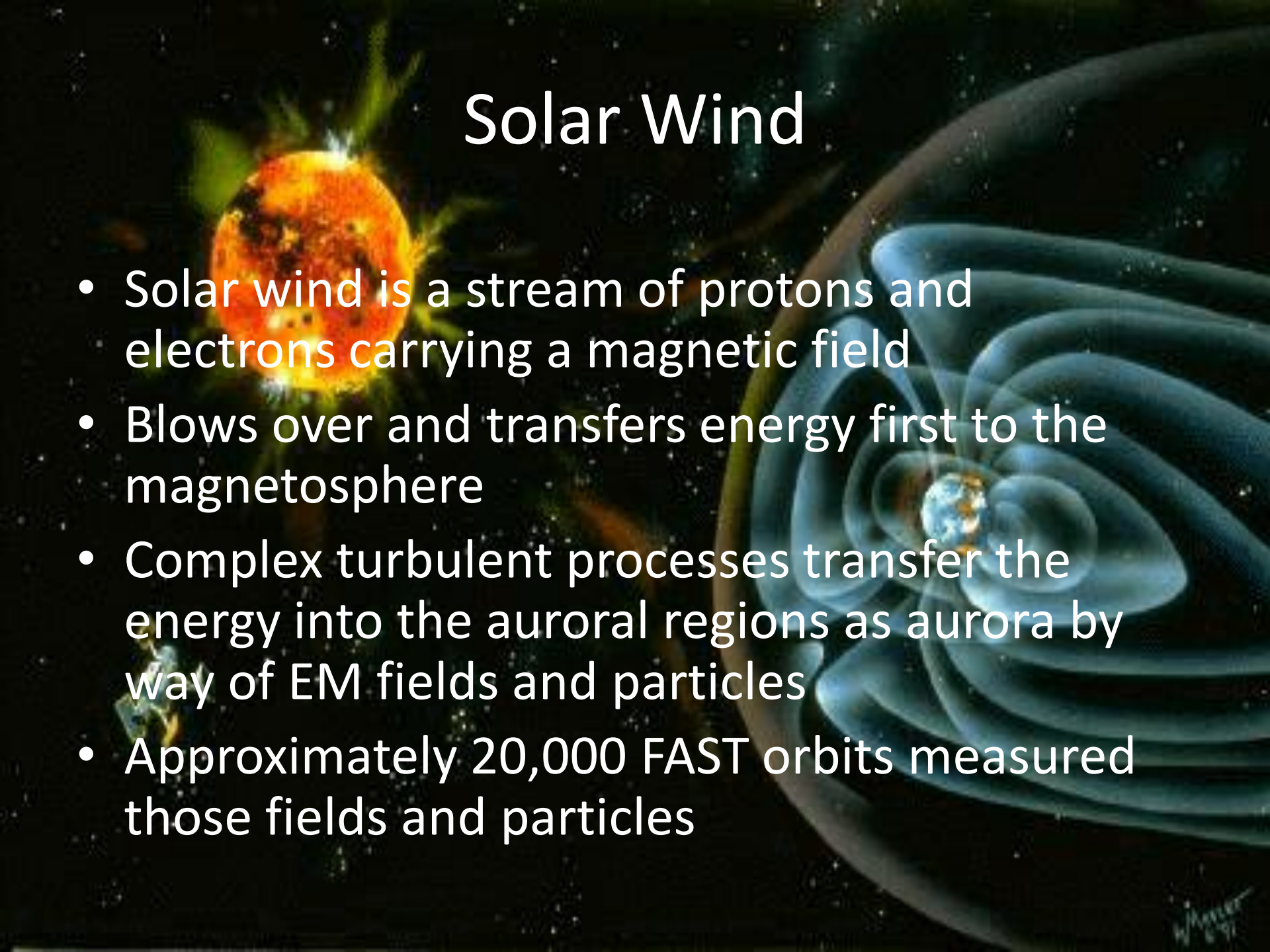
Background- The Aurora

- 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)
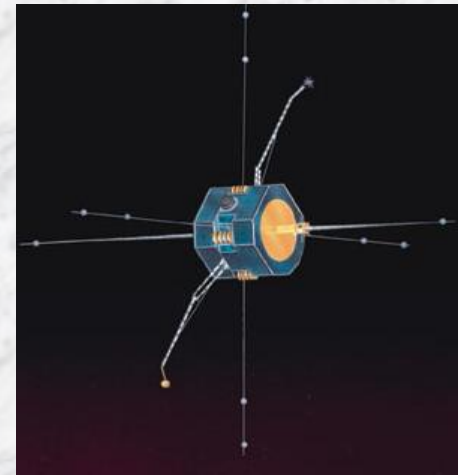
FAST Data Gathering and Processing

- 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
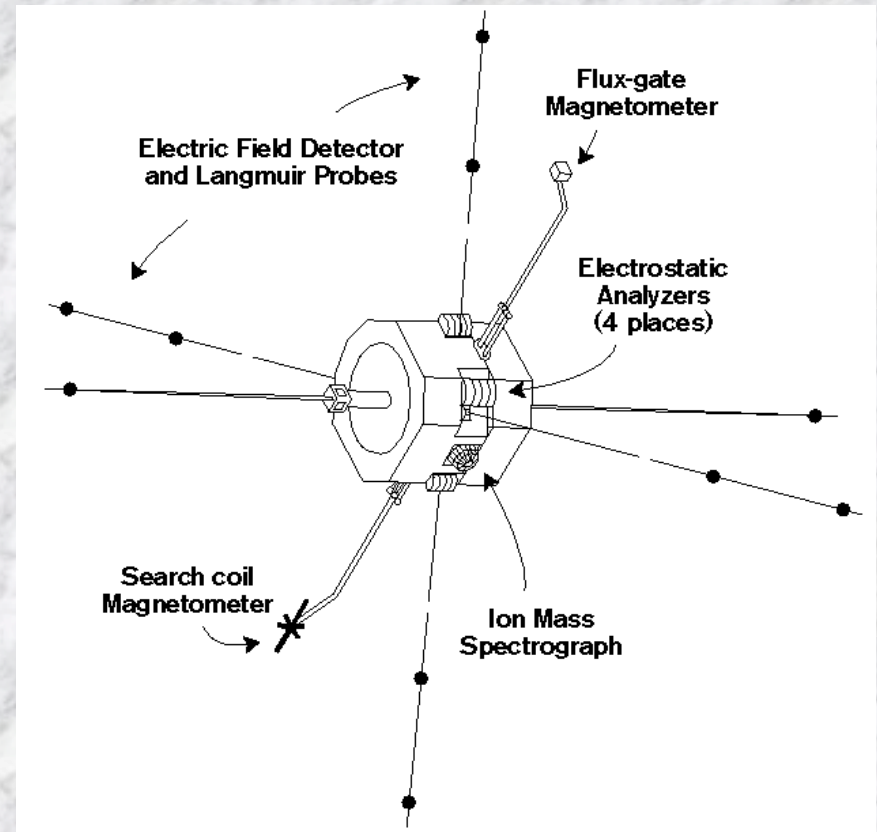
SRI Background

- 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
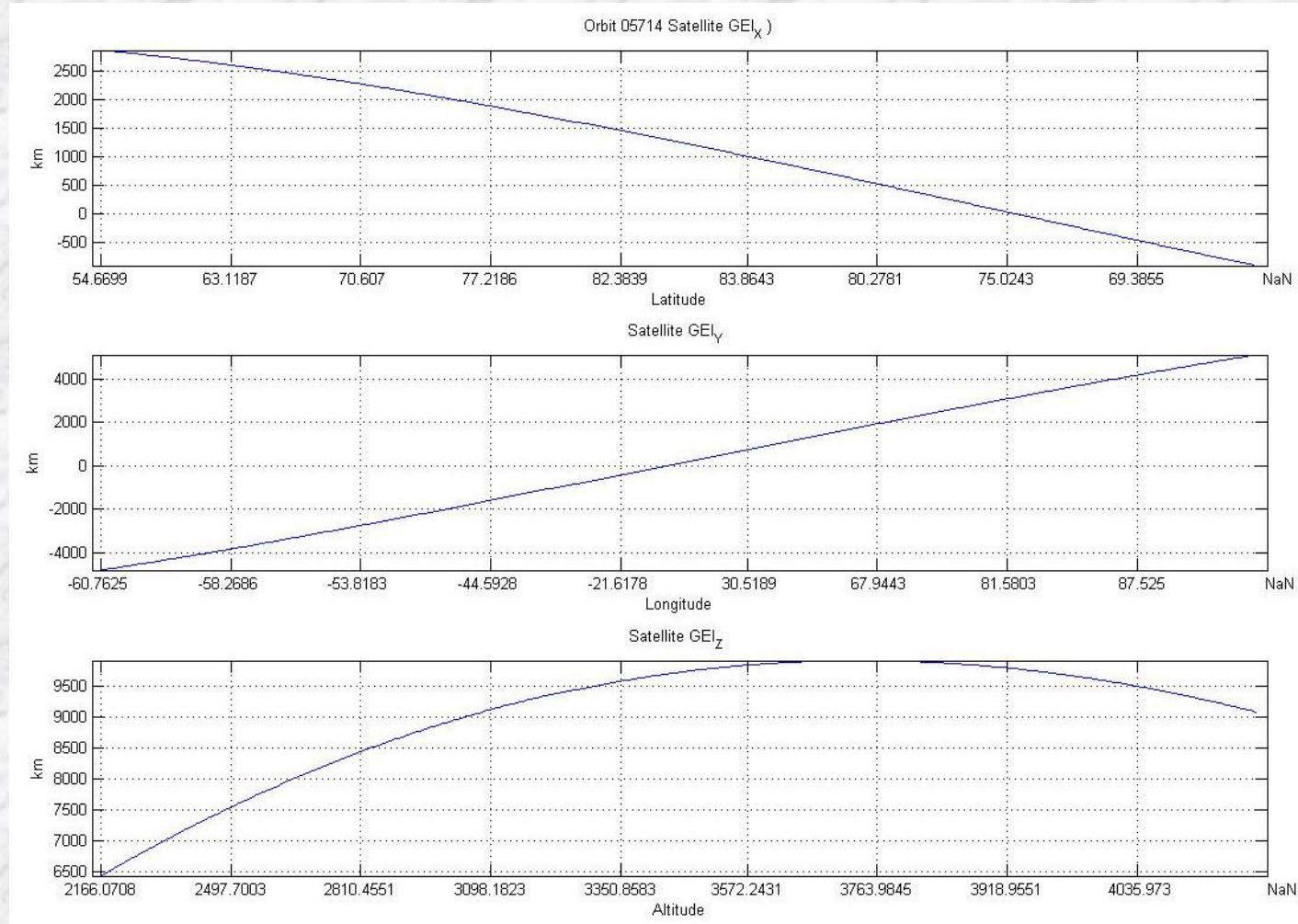
Given Data: Orbit 5714 Fields in DCS

Correlating Data and Time Conversions
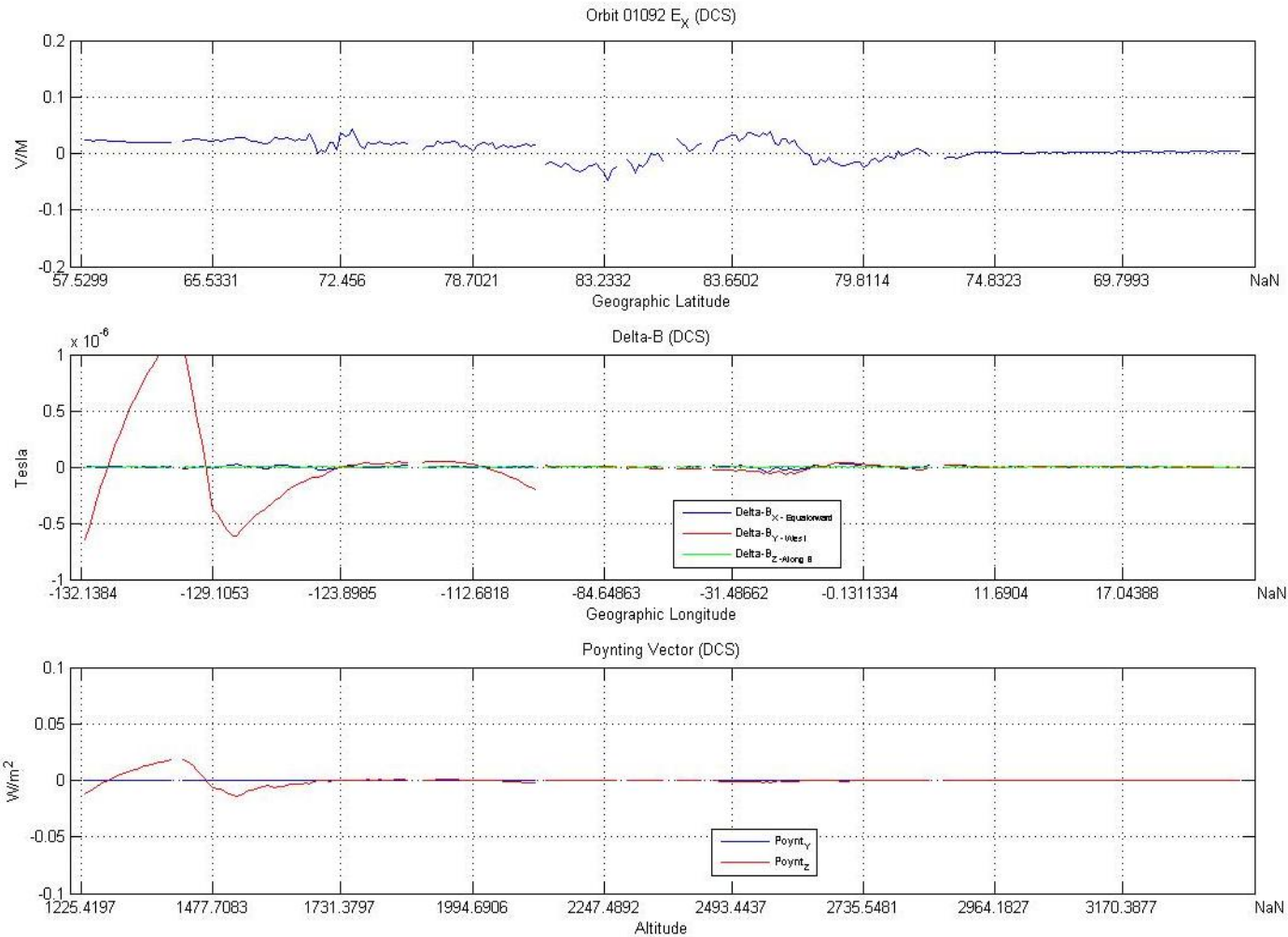
Transformed Positional Data: Orbit 5714 in GEO
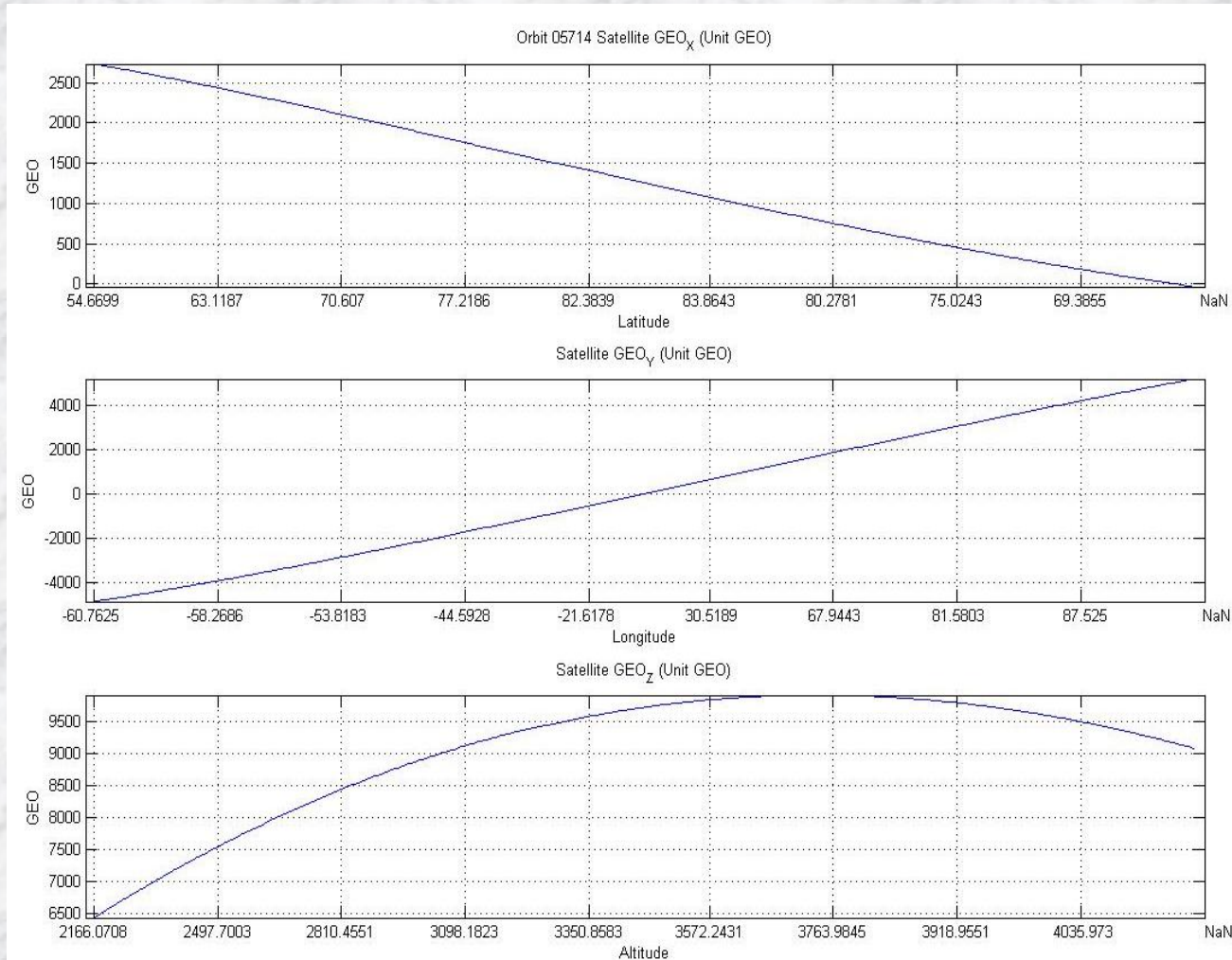
The IGRF Model
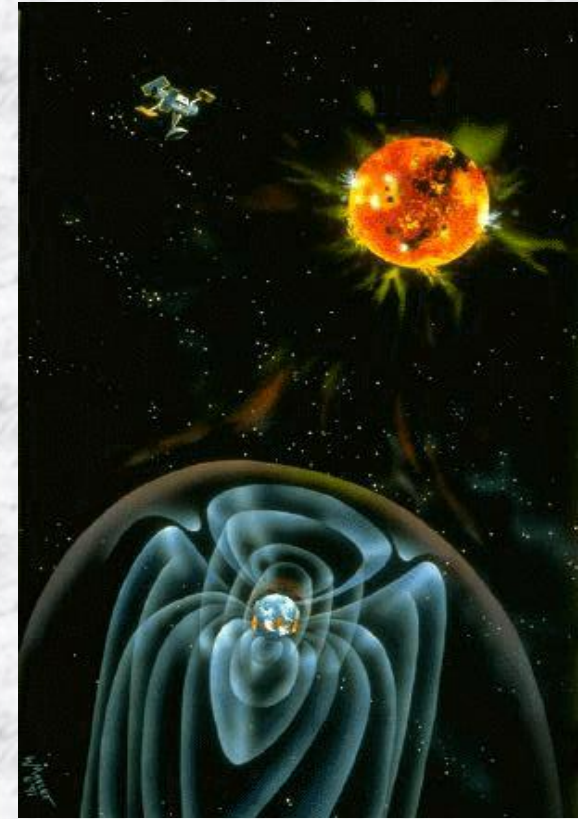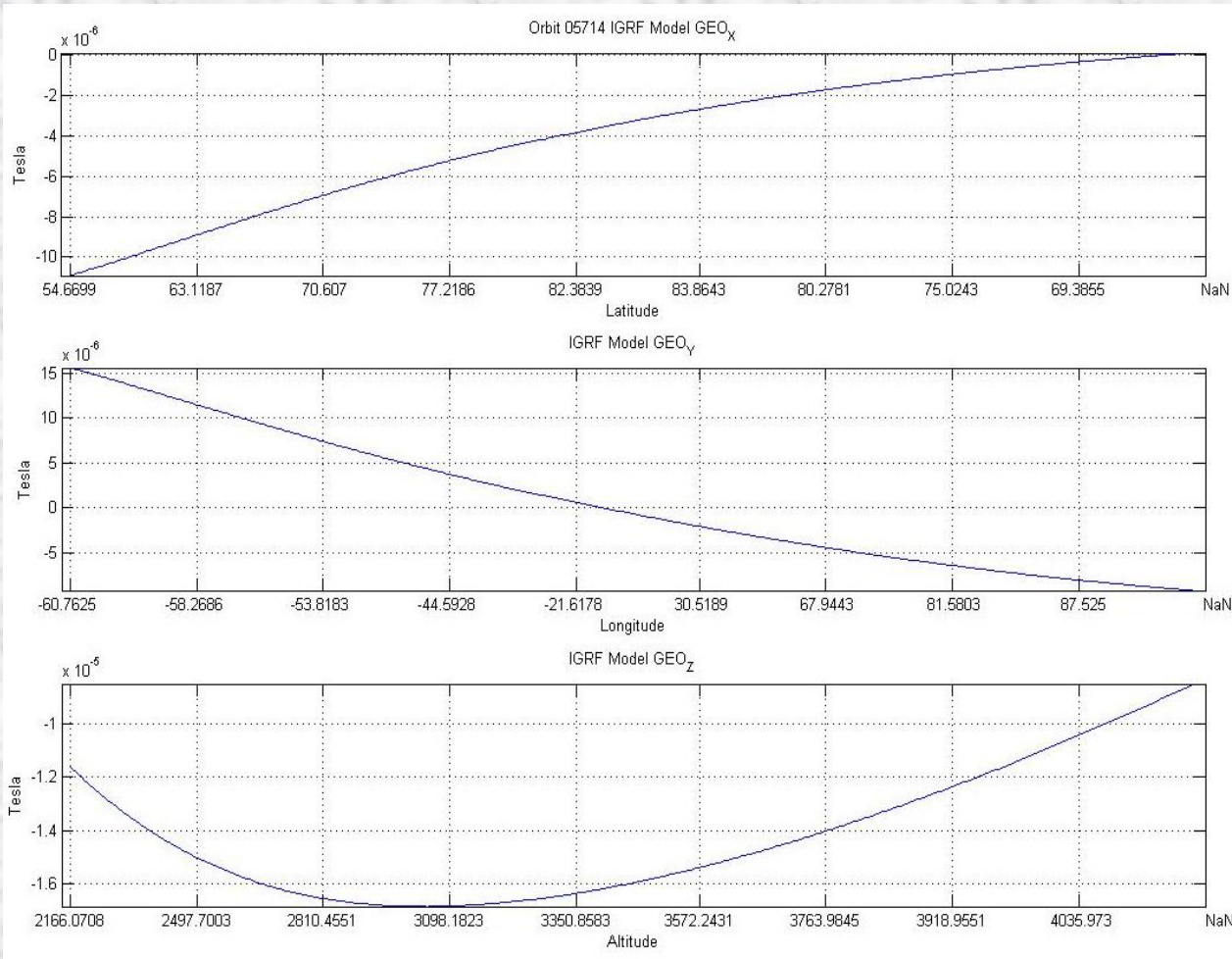
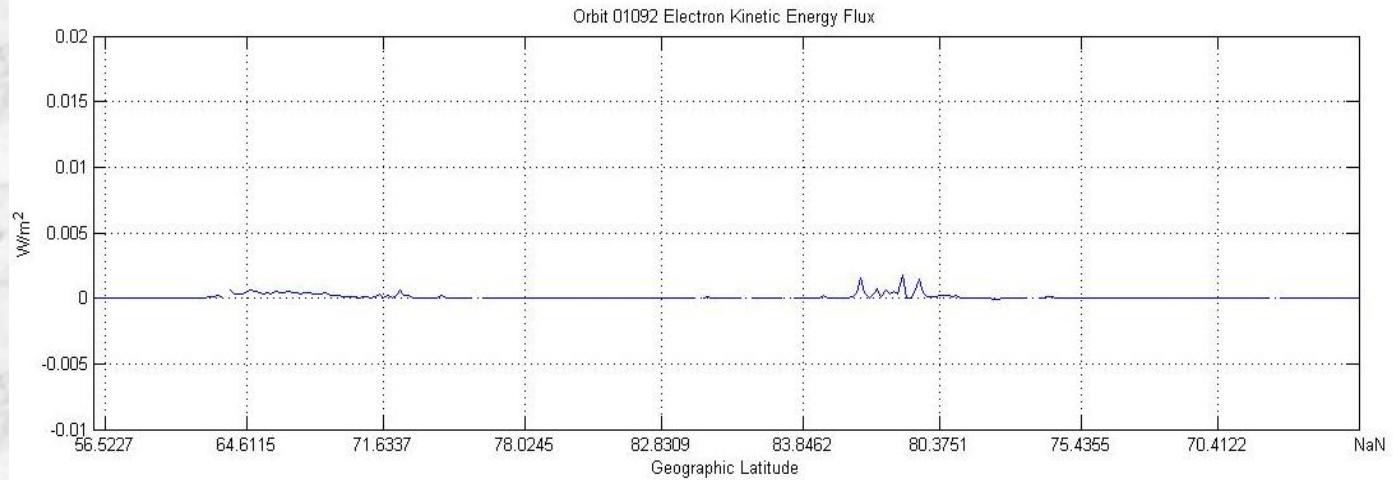# Poynting Vector: Orbit 5704
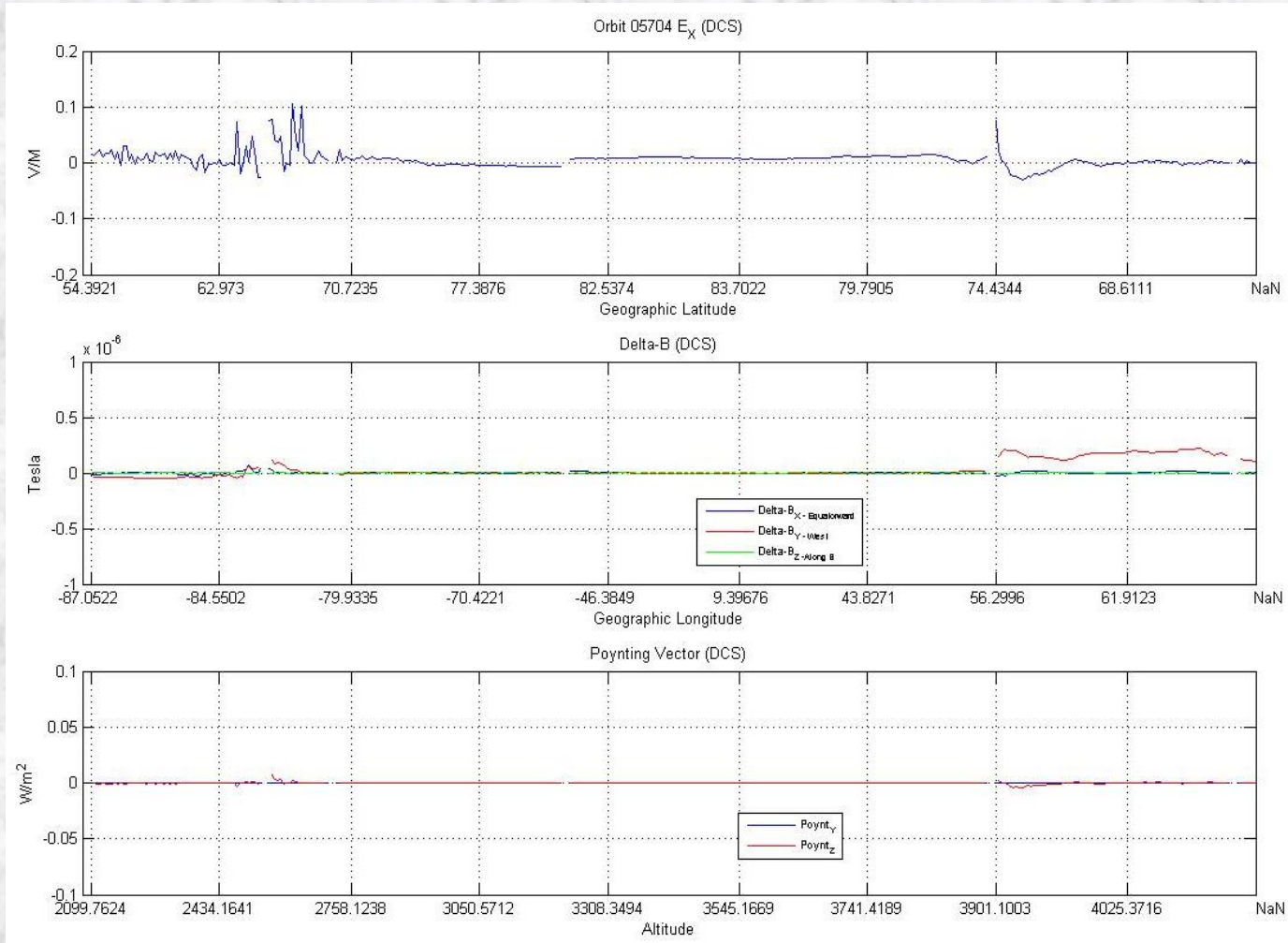
Poynting Vector: Orbit 5716
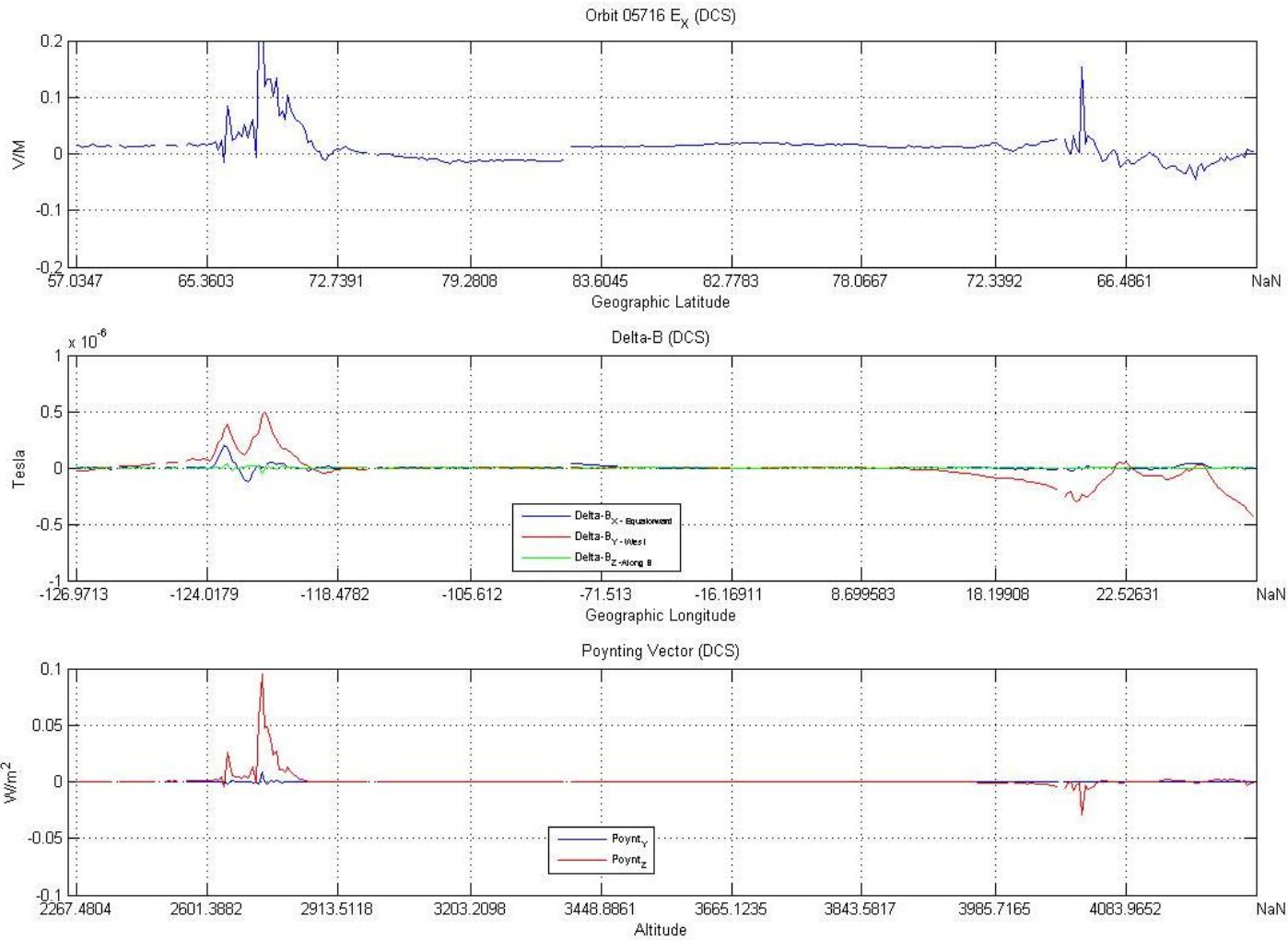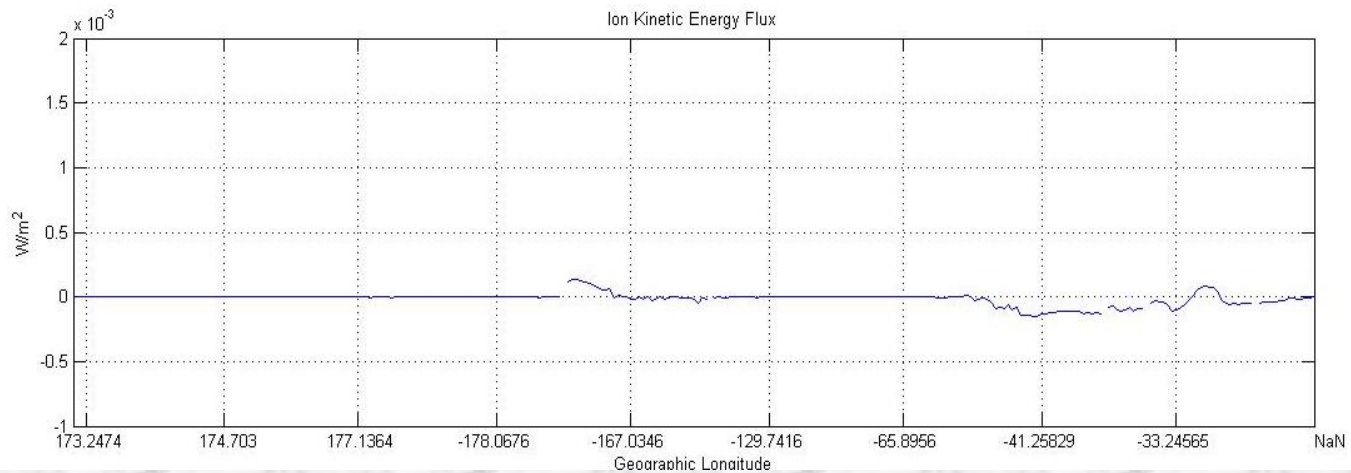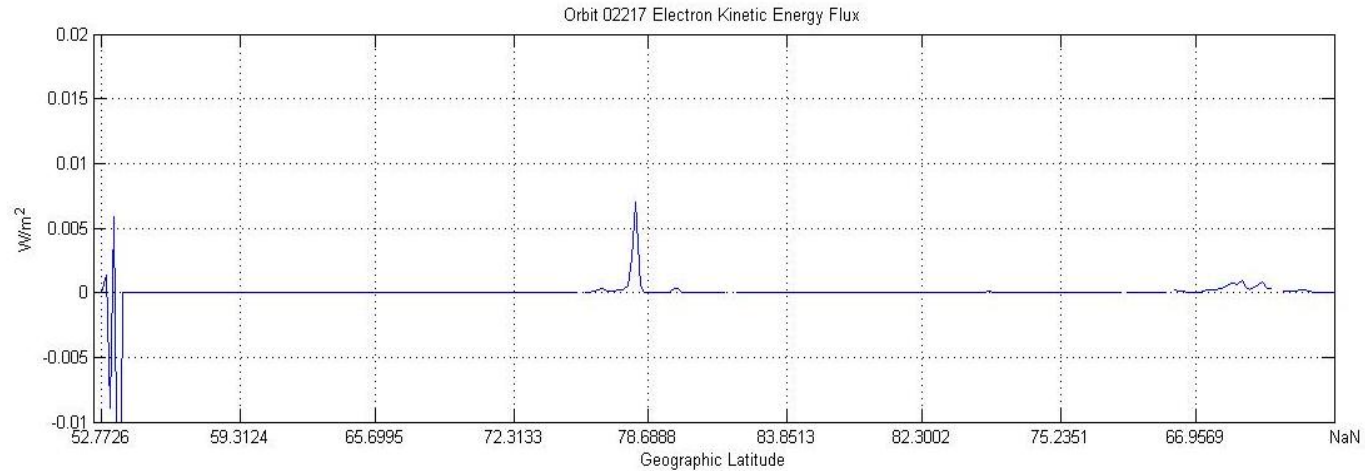
Poynting Vector: Orbit 5714
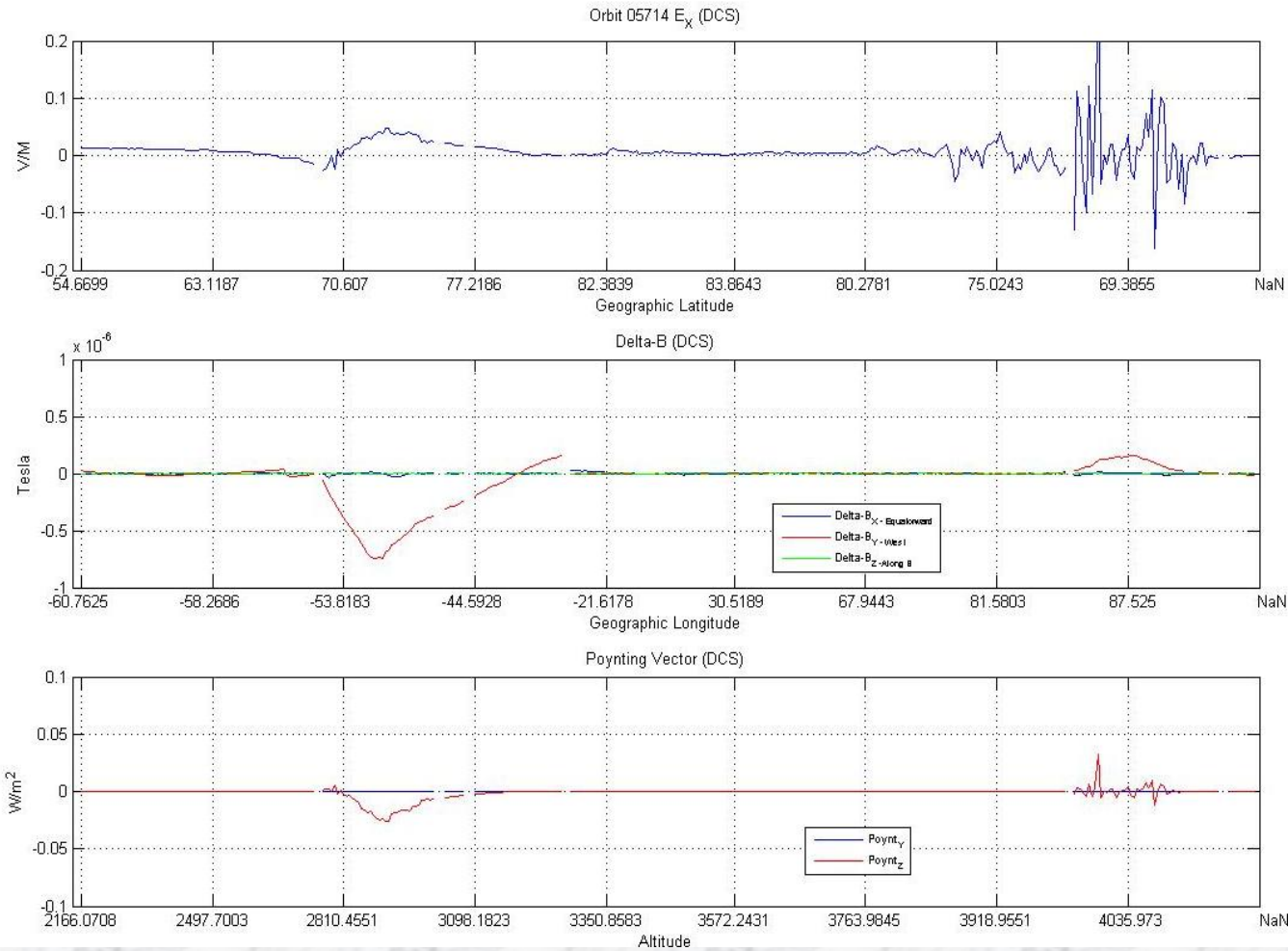
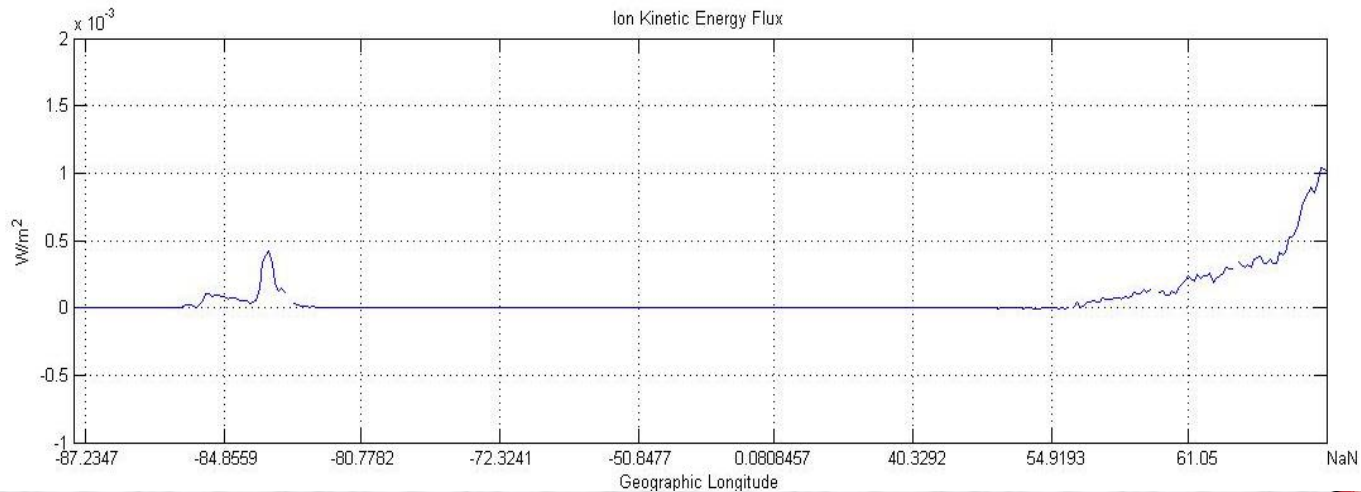# Poynting Vector: Orbit 2217
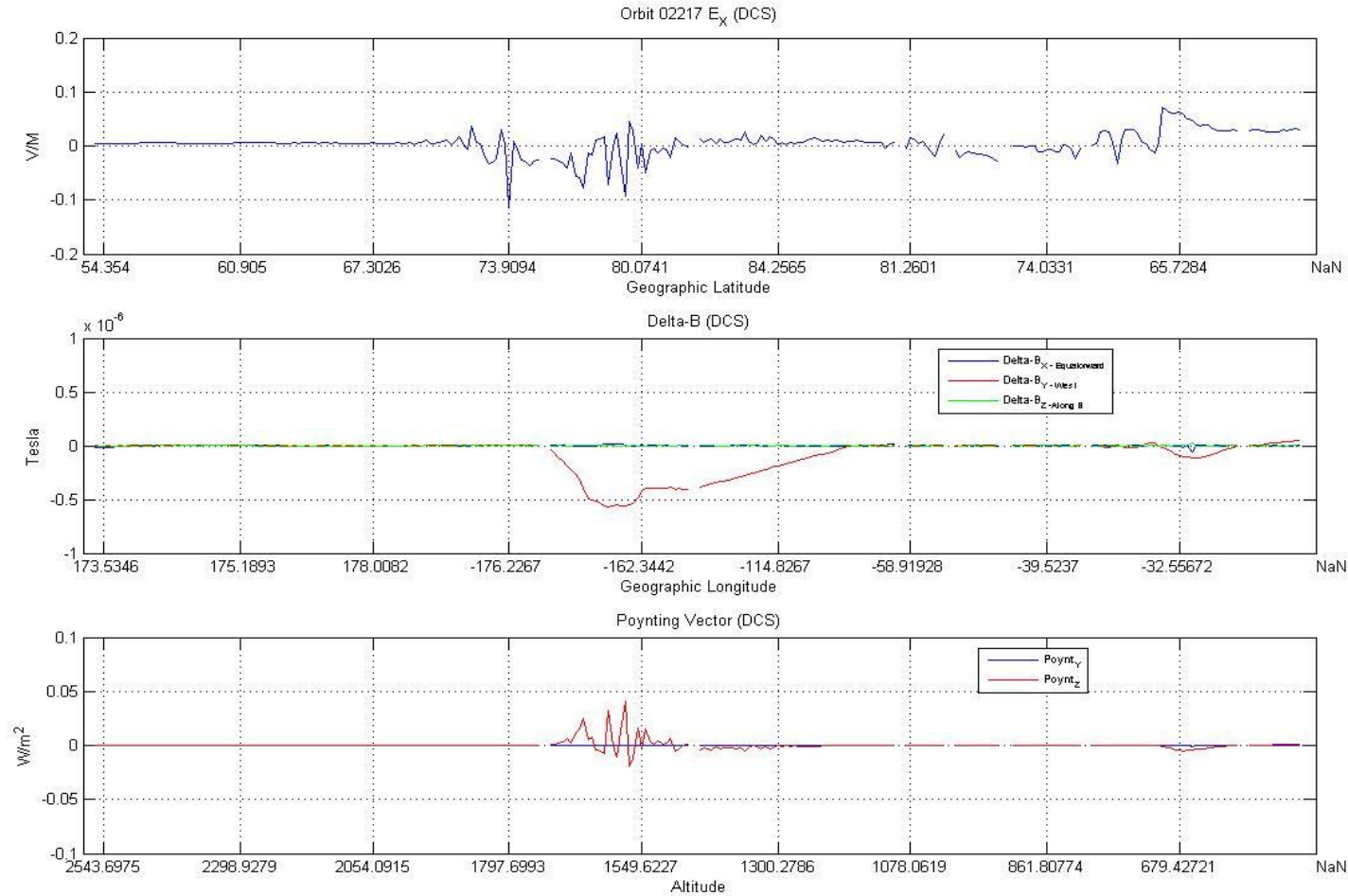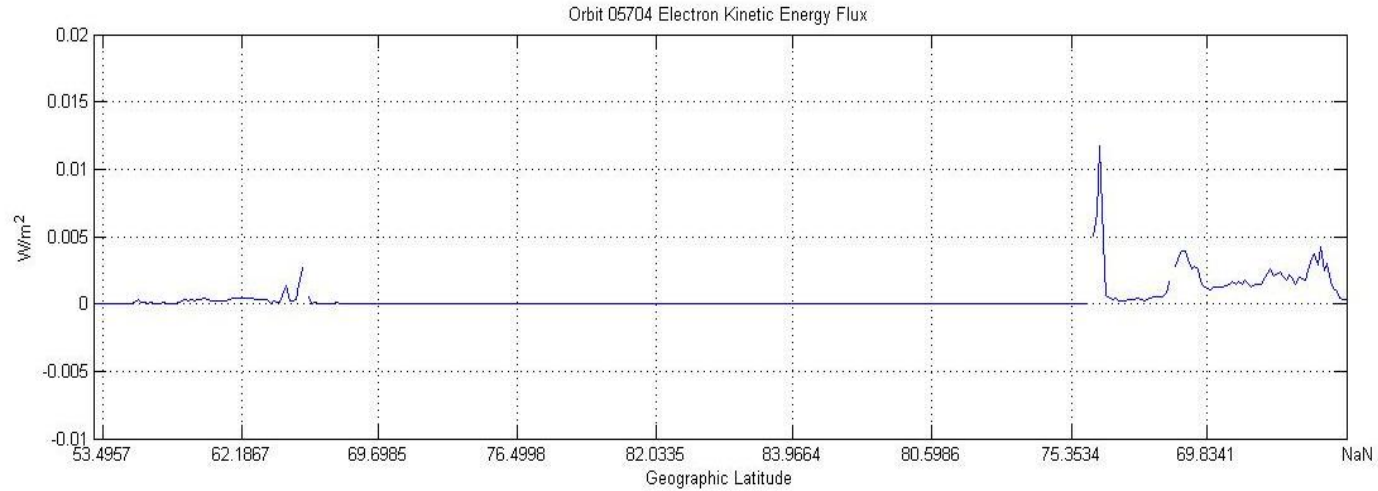
Poynting Vector: Orbit 1092
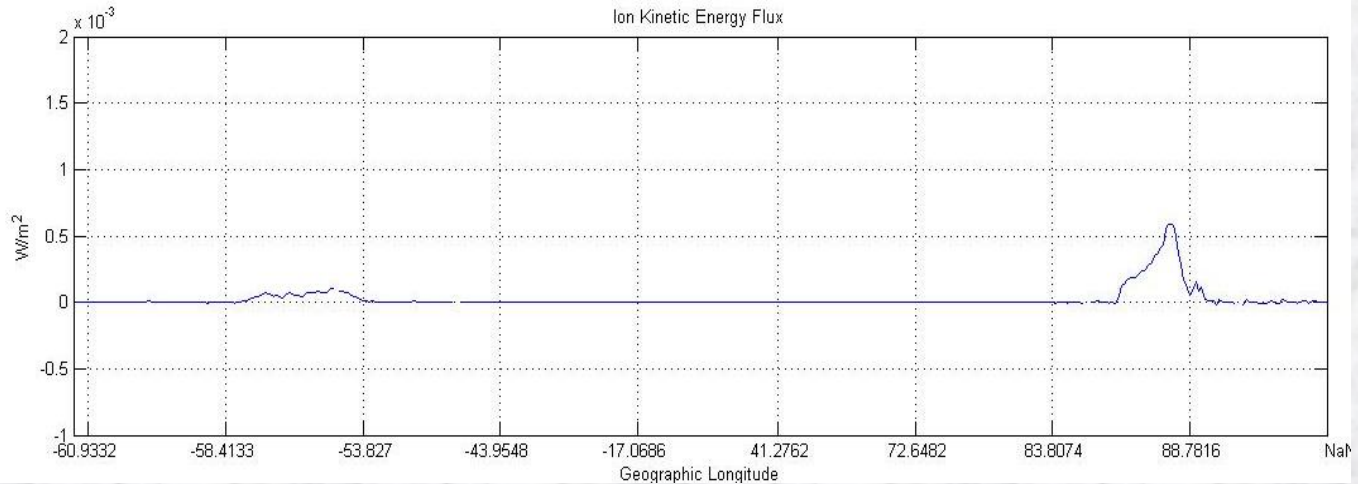
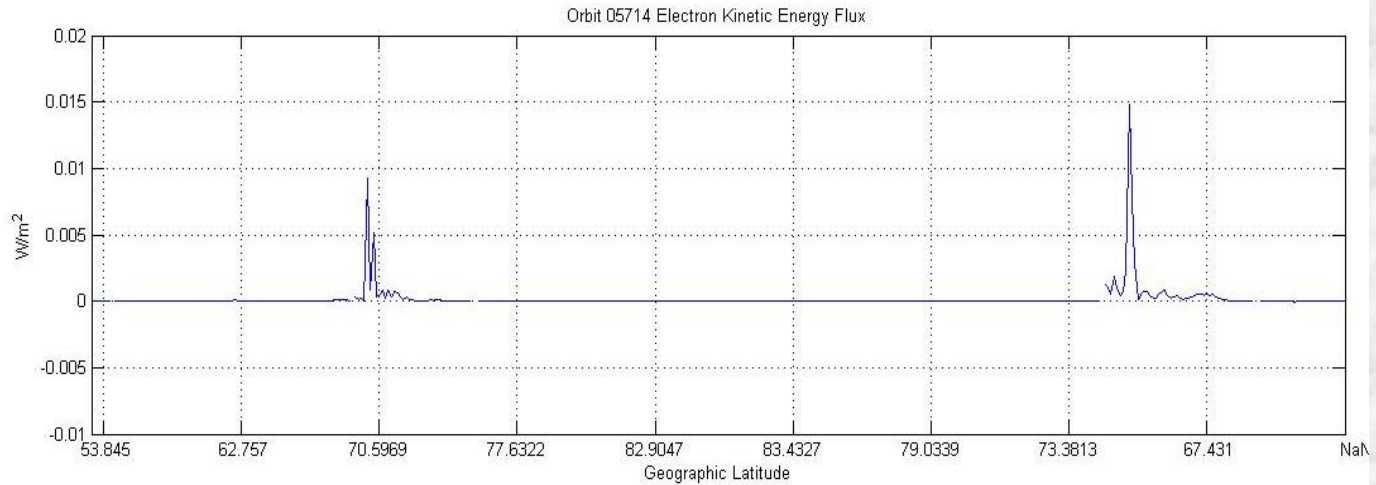# Kinetic Energy Flux: Orbit 1092
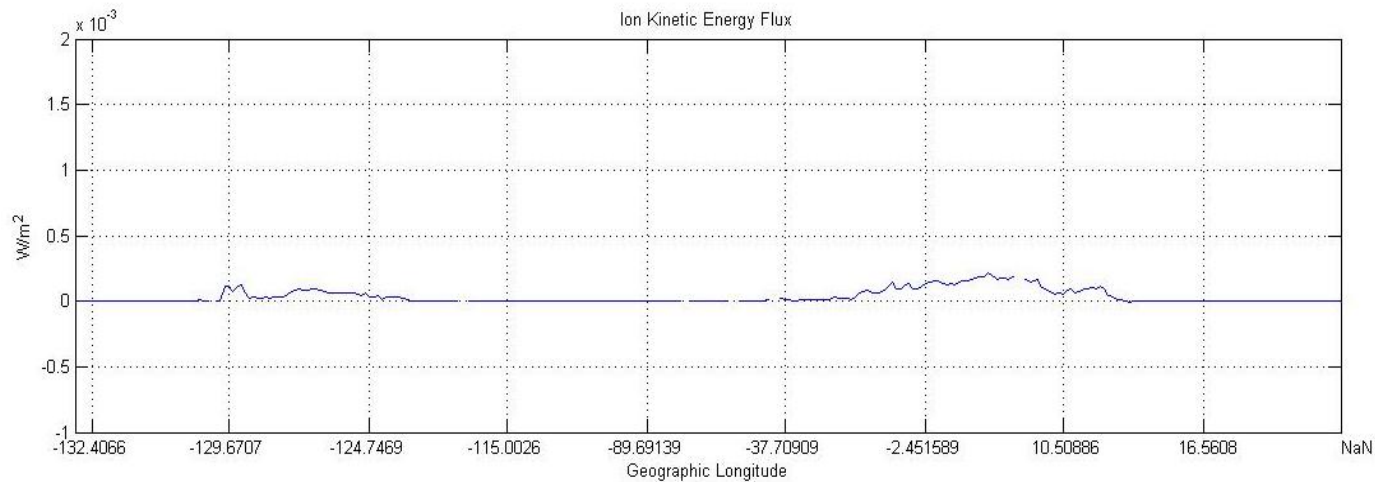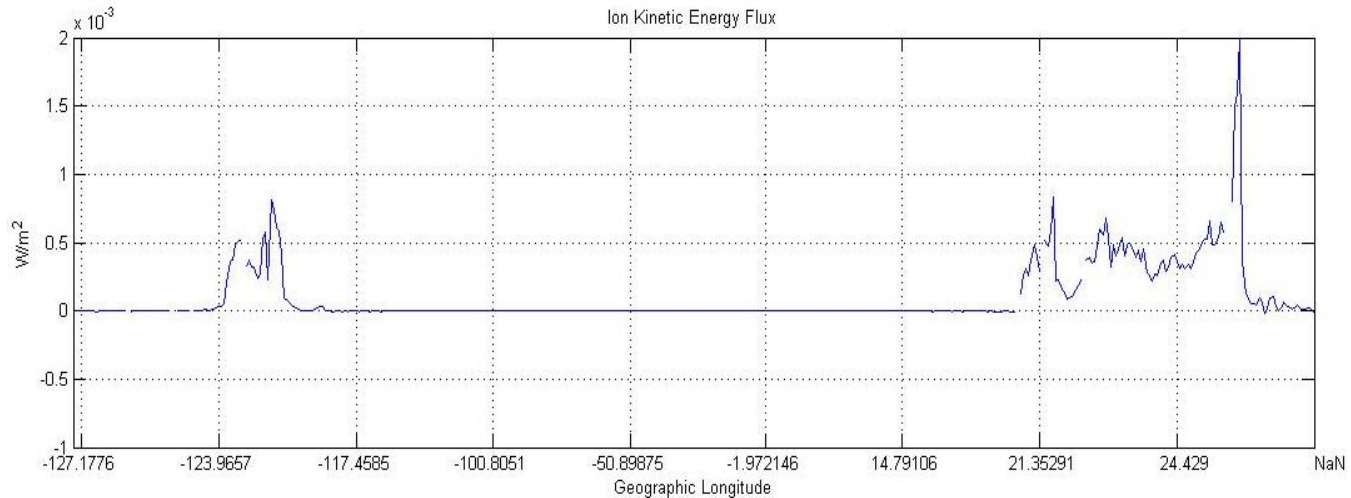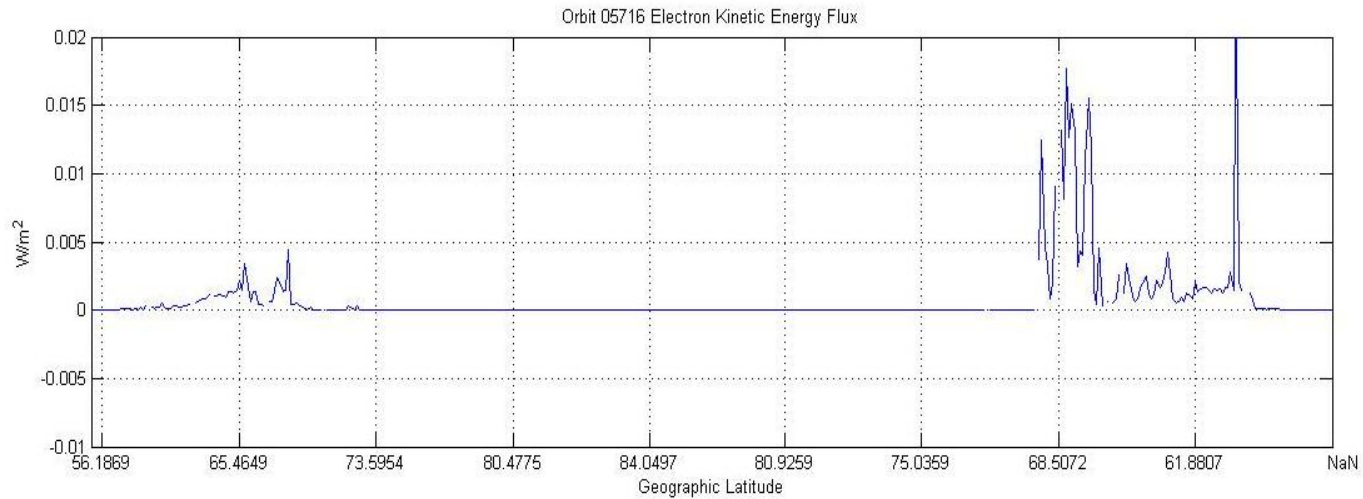
Kinetic Energy Flux: Orbit 2217

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?

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Nicole Cahill & Sebastian Musielak