Comparing Energetic Electron Flux during Conjunctions of FIREBIRD and POES

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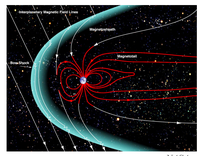
Introduction

THE MAGNETOSPHERE

The magnetosphere is a region of space that is formed by the interaction between the solar wind and Earth's magnetic field. The solar wind, which is composed of energized particles from the Sun, cause electrons within the Van Allen radiation belts to precipitate into the upper atmosphere, impacting its physical and chemical properties.



NASA

ELECTRON PRECIPITATION & THE RADIATION BELTS

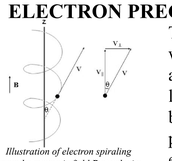


*Illustration of electron spiraling around a magnetic field **B** at velocity **V** with a pitch angle **θ**. Adapted from Singal [2016].*

The Earth's magnetic field can be approximated as a dipole. Charged particles within the magnetosphere travel perpendicular to the Earth's magnetic field lines at nearly the speed of light. As these particles spiral around the magnetic field lines, they are either trapped in the radiation belts and mirror back and forth between the poles, or they escape. Particles that leave the radiation belts either precipitate into the atmosphere or are lost to the magnetotail. The precipitation of electrons impacts orbiting satellites, changes the chemistry of the upper atmosphere, and is also the cause of the aurorae at the poles.

FIREBIRD & POES

The Focused Investigations of Relativistic Electron Burst Intensity, Range, and Dynamics (FIREBIRD) CubeSats [*Crew et al.*, 2016] and Polar-orbiting Operational Environmental Satellites (POES) [*Rodger et al.*, 2010] are both polar-orbiting spacecraft that measure energetic electron flux in the upper atmosphere. FIREBIRD orbits the Earth at an altitude of approximately 400 to 600 kilometers and observes electrons precipitating into the atmosphere from the Van Allen radiation belts. The POES satellites orbit at an altitude of 870 kilometers and are equipped with the Medium Energy Proton and Electron Detector (MEPED). There are currently five POES satellites in orbit (three operated by the US National Oceanic and Atmospheric Administration (NOAA) and two by the European Space Agency (ESA)). The FIREBIRD CubeSats were constructed by students at UNH and Montana State. FIREBIRD is unique because the instrument has a high energy resolution, measuring within five differential energy channels and one integral channel, whereas POES only measures in three integral channels.


UNH graduate student Alex Crew during the construction of the FIREBIRD CubeSats.

ESA


Artist's rendition of MetOp-2A in orbit around Earth.

WHY WE ARE COMPARING FIREBIRD & POES

The energy range of FIREBIRD corresponds to atmospheric altitudes of 60 to 80 kilometers affecting important constituents such as nitrogen oxides and ozone [*Randall et al.*, 2005]. The comparison between FIREBIRD and POES can provide a better understanding of how to quantify electron precipitation in global climate models.

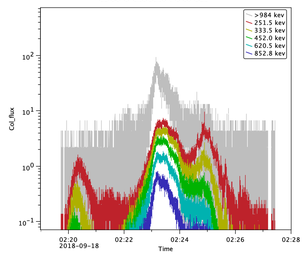
Methods

Conjunction times were found using the Satellite Situation Center (SSCWeb) with certain criteria in order to target areas of peak atmospheric ionization. These limitations include:

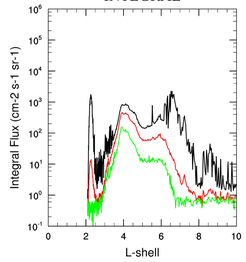
- **Geographic latitude between ±60 and ±80 degrees**
- **Any geographic longitude except between -90 and +40 degrees and between -50 to 0 degrees geographic latitude to avoid the Southern Atlantic Anomaly**
- **L-value values between 3 and 7 (the L-value is a parameter describing the distance of the magnetic field line at the magnetic equator in terms of Earth radii)**
- **Distance between satellites during conjunction is within 10 degrees latitude and 15 degrees longitude**

FIREBIRD data is converted from differential flux to integral flux in order to compare to POES data.

DIFFERENTIAL

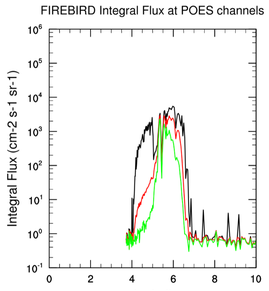


INTEGRAL

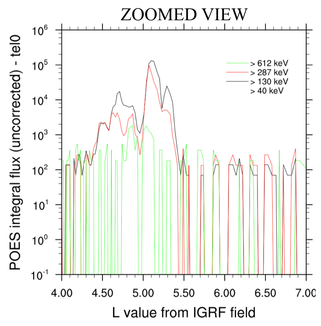


Results

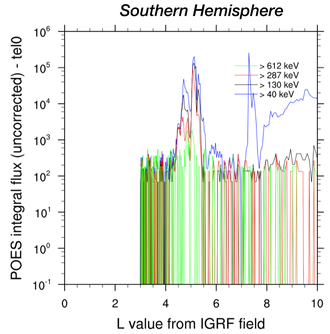
September 22, 2018
19:45:00 - 19:49:00



FIREBIRD 3 & METOP-1B



Latitude: -65.10
Longitude: 47.89
Southern Hemisphere



September 28, 2018
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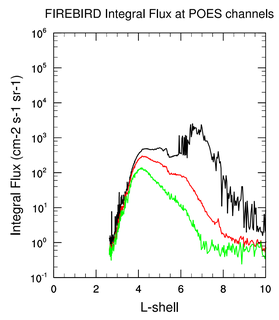
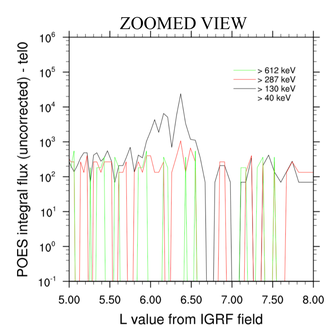
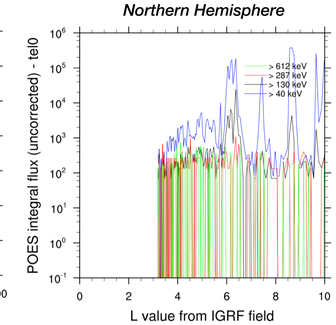


FIREBIRD 4 & NOAA-18



Latitude: 64.81
Longitude: 174.53
Northern Hemisphere



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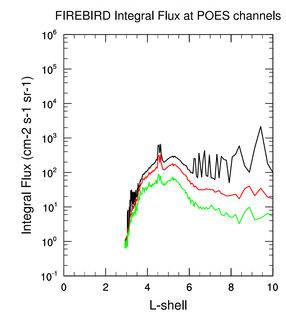
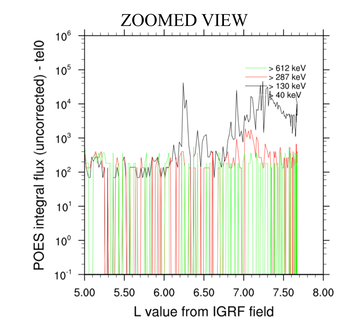
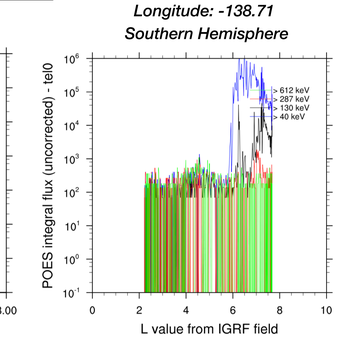


FIREBIRD 3 & METOP-2A



Latitude: -68.35
Longitude: -138.71
Southern Hemisphere



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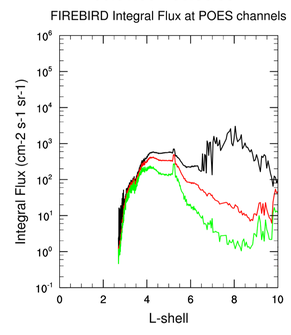
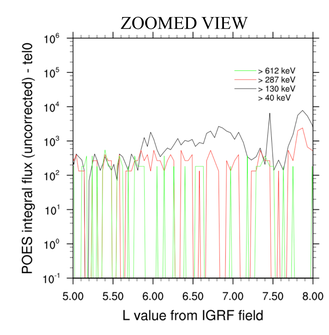
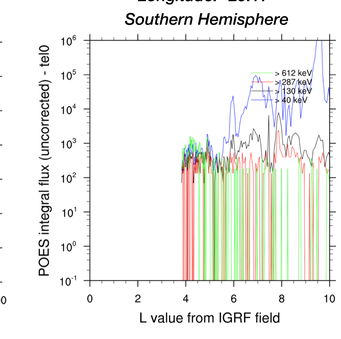


FIREBIRD 4 & NOAA-18



Latitude: -70.67
Longitude: -29.17
Southern Hemisphere



Conclusions

This comparison of energetic electron flux between FIREBIRD and POES shows that:

- **POES over-predicts in all energy levels during peak times compared to FIREBIRD; however, the magnitude is not uniform**
- **Overall structure between FIREBIRD and POES are similar**
- **POES noise floor is high, making it difficult to see enhancements in higher energy levels**

Next Steps

The over-prediction of electron flux from POES compared to FIREBIRD is not a surprise, given significant proton contamination of the higher energy electron channels in the POES MEPED instruments and an instrument geometry (narrow field of view) that results in a high noise floor [*Rodger et al.*, 2010; *Peck et al.*, 2015; *Nesse Tyssøy et al.*, 2016]. The comparisons with FIREBIRD provide a method of quantifying this over-prediction. Recent methods for correcting POES electron observations for both proton contamination and instrument geometry have been proposed by *Peck et al.* [2015] and *Nesse Tyssøy et al.* [2016]. The next step of this work will be to correct the POES data using these recommended methods in order to assess improvements in comparison with FIREBIRD.

References

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The FIREBIRD Team

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