Quantifying Radiation Belt Electron Precipitation and Its Effect on Atmosphere and Ionosphere

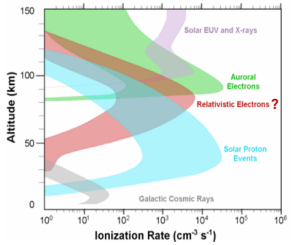
Chia-Lin Huang[1], Harlan E. Spence[1], Katharine Duderstadt[1], Sonya Smith[1], Charles Smith[1], Alex Boyd[2], Geoff Reeves[2], J Bernard Blake[3], J. F. Fennell[3], Seth Claudepierre[3], Drew Turner[3], Alex Crew[4], David M Klumpar[5], Mykhaylo Shumko[5], Arlo Johnson[5], John Sample[5], Wenbin Wang[6], Hanli Liu[6], and Earle Williams[7]

[1]*University of New Hampshire,* [2]*Los Alamos National Laboratory,* [3]*Aerospace Corporation,* [4]*Applied Physics Laboratory,* [5]*Montana State University,* [6]*National Center for Atmospheric Research,* [7]*Massachusetts Institute of Technology*

Motivation:

What is the influence of radiation belt electrons on the atmosphere and ionosphere?

- Do radiation belt electrons provide a missing source of HO_x and NO_x with implications for O_3 reduction in the upper and middle atmosphere? (*Randall et al.*, 2015)
- Can radiation belt electrons explain the Schumann resonance anomaly? (*Satori et al.*, 2016)



Goal:

To estimate the precipitation flux and energy spectrum of radiation belt electrons and quantify the contribution of electron precipitation to atmospheric chemistry and ionospheric conductance

Method:

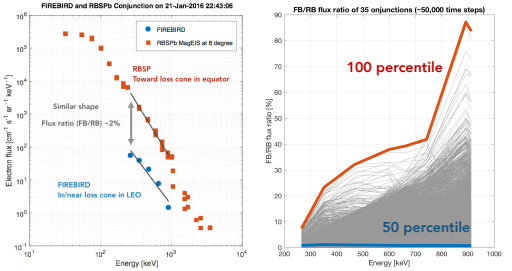
1. We combine measurements from Van Allen Probes near the equator and FIREBIRD CubeSat at low-Earth orbit during conjunctions, to estimate the precipitation flux and energy spectrum of radiation belt electrons in energies between 200 keV and 1 MeV during observed electron loss events within the radiation belt.
2. To quantify the contribution of radiation belt electrons to the atmosphere, we use a global climate simulation (WACCM) to calculate the production of HO_X and NO_X, and the reduction in O_3.
3. We calculate the ionospheric conductance caused by radiation belt electrons using a climate simulation with thermosphere and ionosphere extension (WACCM-X).

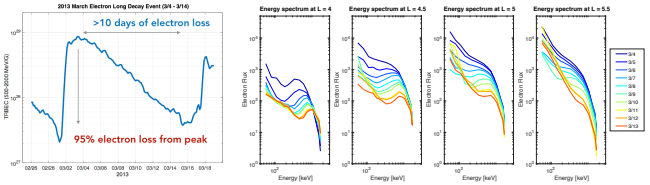
1. Quantify Radiation Belt Electron Precipitation

To quantify poorly known global radiation belt precipitation, we calculate electron flux ratio of the precipitated and trapped electrons at Van Allen Probes and FIREBIRD Conjunctions

- Precipitated electron data from FIREBIRD cubesat at low Earth orbit in/near loss cone)
- Trapped electron data from Van Allen Probes with continuous coverage in the radiation belt
- Calculate flux ratio between precipitated and trapped electrons
- Scaled Van Allen Probes data to provide more global, more continuous time series of precipitation
- Note: throughout the 35 conjunction events, the Dst minimum > -50 nT (moderate condition)

Flux Ratio between precipitated and trapped electrons





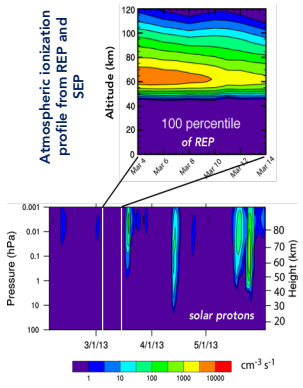
Selecting Radiation Belt Electron Loss Event

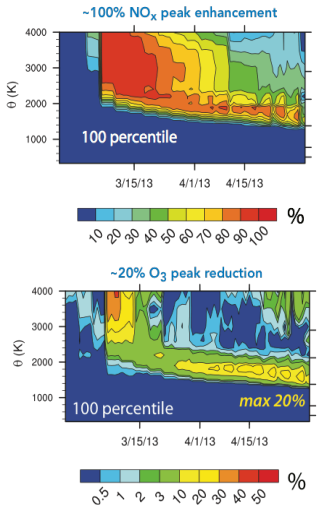
Total radiation belt electron content: (TRBEC) - a simple and global index to represent RB electrons by integrating the phase space density data from RBSP-ECT MagEIS data

2013 March 3- 14 event: long-quiet decay without or little magnetopause shadowing loss

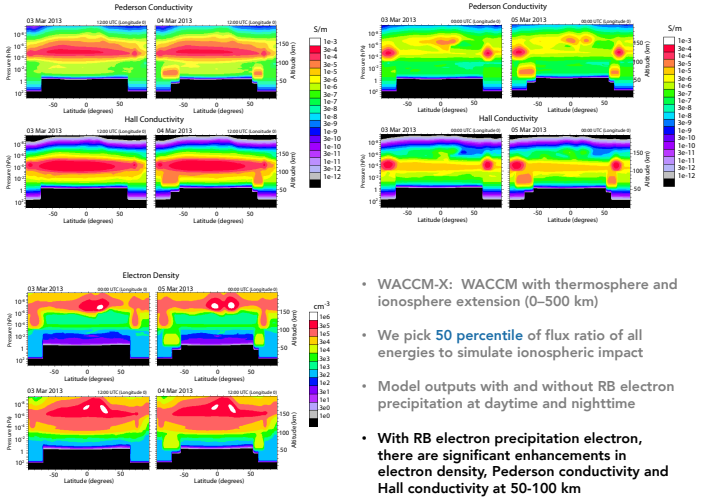
2. Atmospheric Impact from RB Electron Precipitation

- WACCM: a comprehensive numerical model, spanning the range of altitude from the Earth's surface to the thermosphere
- WACCM model version SD-WACCM4/CESM 1.2: all runs include solar protons and low-energy auroral electrons
- *We pick **100 percentile** of flux ratio of all energies to simulate atmospheric impact*
- Calculate ion pair production using Fang et al. (2010) parameterization: comparable to solar protons near 70 km
- **Compared to simulations without radiation belt electron input, the northern hemisphere polar vortex-averaged NO_X enhancement (~100%) and O_3 reduction (~20%)**





3. Ionospheric Impact from RB Electron Precipitation



- WACCM-X: WACCM with thermosphere and ionosphere extension (0–500 km)
- We pick 50 percentile of flux ratio of all energies to simulate ionospheric impact
- Model outputs with and without RB electron precipitation at daytime and nighttime
- **With RB electron precipitation electron, there are significant enhancements in electron density, Pederson conductivity and Hall conductivity at 50-100 km**

Summary

- **We estimated radiation belt electron precipitation flux and energy spectrum using FIREBIRD and Van Allen Probes data**
- **We quantified the contribution of electron precipitation to atmospheric chemistry: 20% reduction of O_3 in stratosphere from moderate RB electron precipitation**
- **A preliminary WACCM-X simulation shows significant enhancement in electron density and conductivities with RB electron precipitation**

University of New Hampshire

Contact: Chia-Lin.Huang@unh.edu