Quantifying Radiation Belt Electron Precipitation And Its Effect on Atmospheric Chemistry

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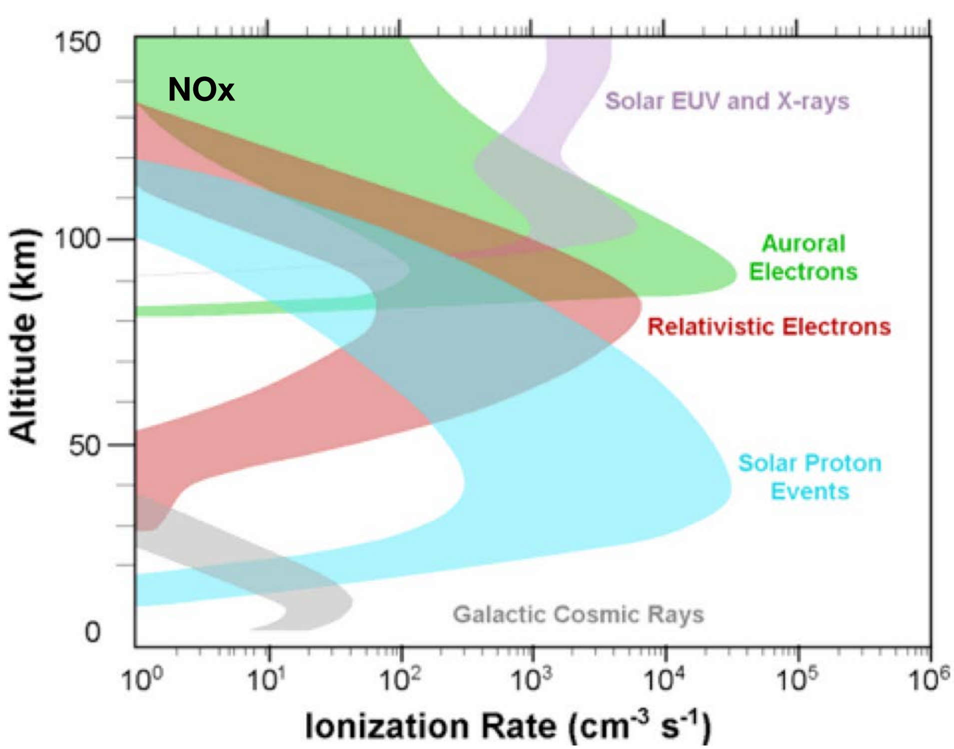
Energetic Particle Precipitation into the Atmosphere

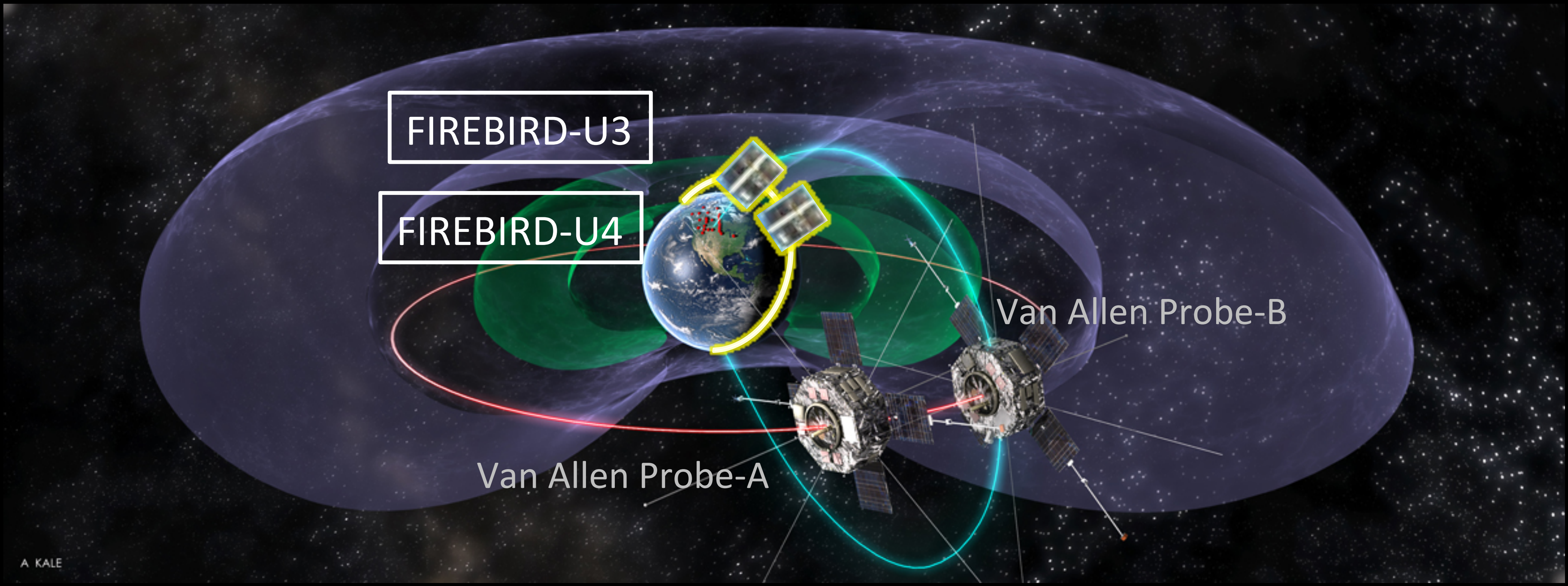


→ Not well-known

- "Missing source" of NOx in global climate models at 70 km (*Randall et al.*, 2015)
- Do radiation belt electrons provide this missing source?
- Goal: Estimate the precipitation flux and energy spectrum of radiation belt electrons and quantify the contribution of electron precipitation to atmospheric chemistry

NSF FIREBIRD

High time resolution at critical energies in the loss cone at low Earth orbit



NASA Van Allen Probes (RBSP)

Continuous coverage in the radiation belt near equator

Efforts to Determine Electron Precipitation

	SAMPEX	POES	FIREBIRD	Van Allen Probes
Altitude	~600 km	870 km	400 - 600 km	700 km to ~6 Re
Inclination (degree)	82	98.7	82	10
Energies	~ MeVs	> 30 keV > 100 keV > 300 keV	265 keV 354 keV 481 keV 663 keV 913 keV > 1 MeV	10s keV to MeVs (MagEIS)
Challenges	High energies	Proton contamination & sensitivity limit	*Sparse*	Equatorial "near" loss cone

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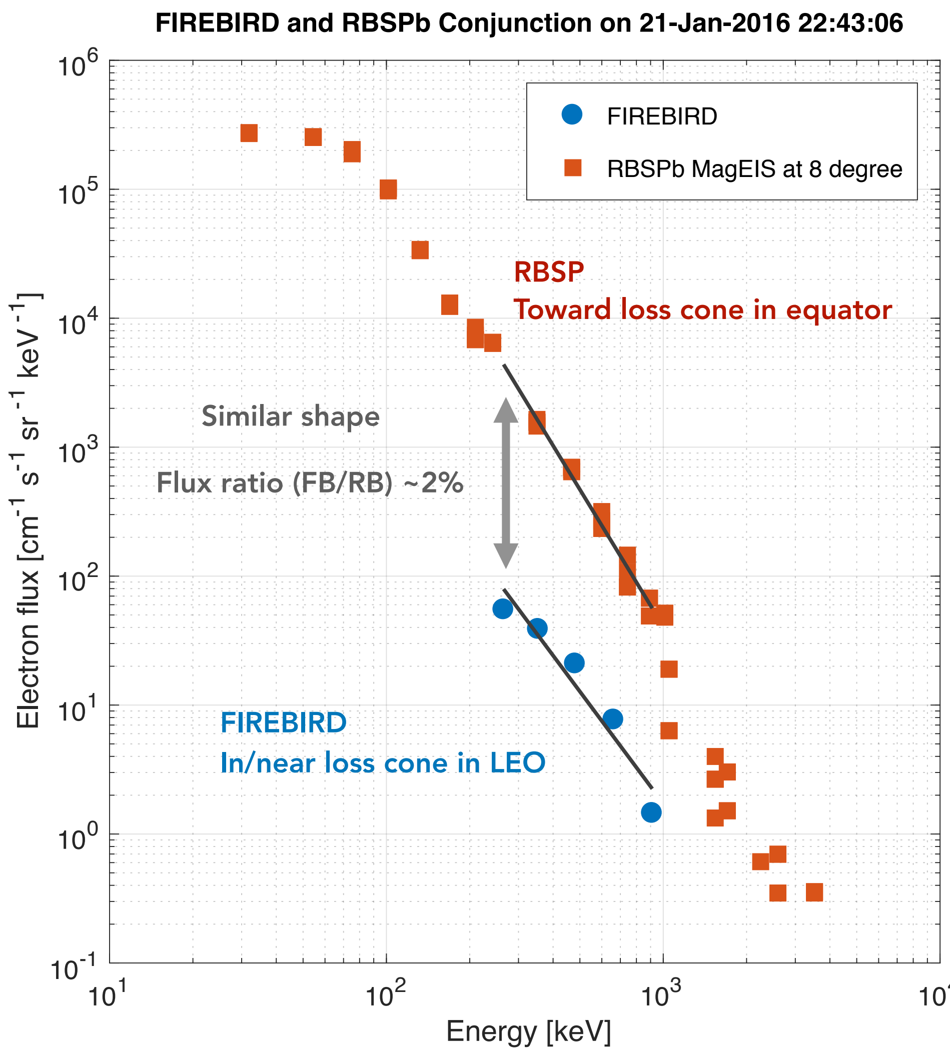
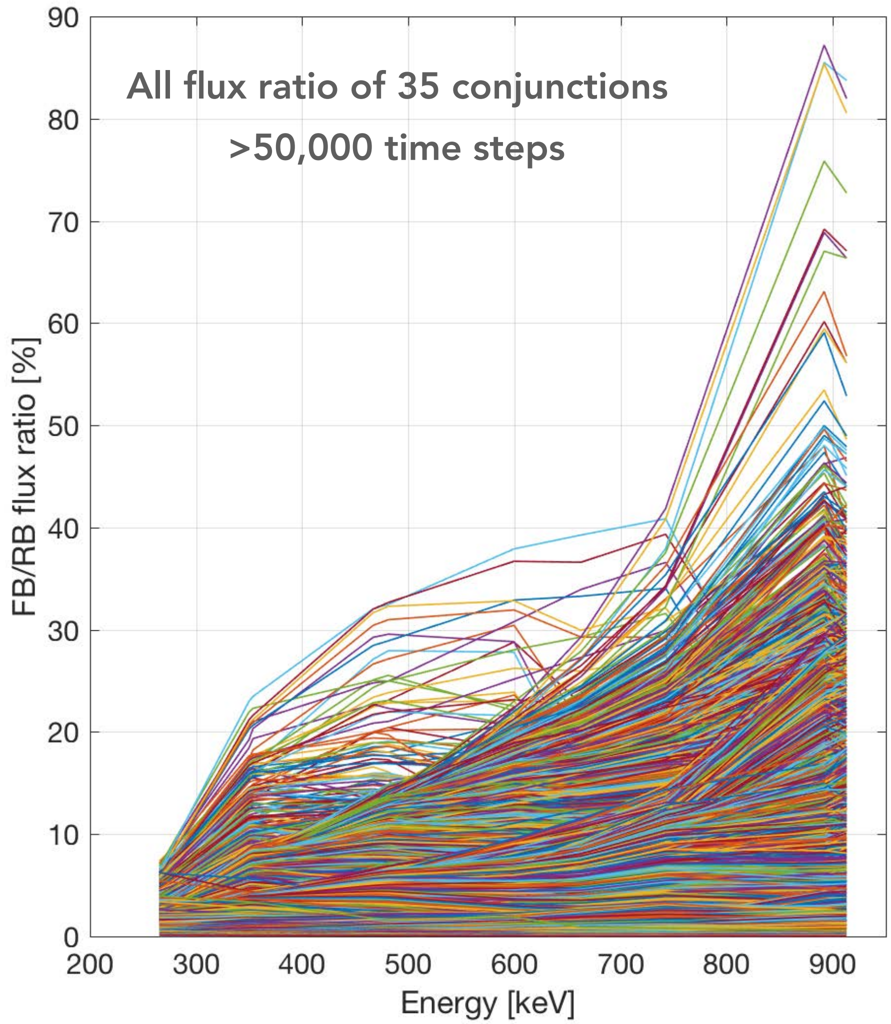
Compare FIREBIRD & Van Allen Probes at Conjunctions

- To quantify poorly known global radiation belt precipitation
- 35 quality conjunctions from 14 FIREBIRD campaigns
- Calculate flux ratio between precipitated and trapped electrons
- Scaled Van Allen Probes data to provide more global, more continuous time series of precipitation



Flux Ratio as Function of Energy - All

$$Flux\ ratio = \frac{Electron\ flux\ in\ loss\ cone}{Electron\ flux\ at\ equator\ near\ loss\ cone}\ \%$$

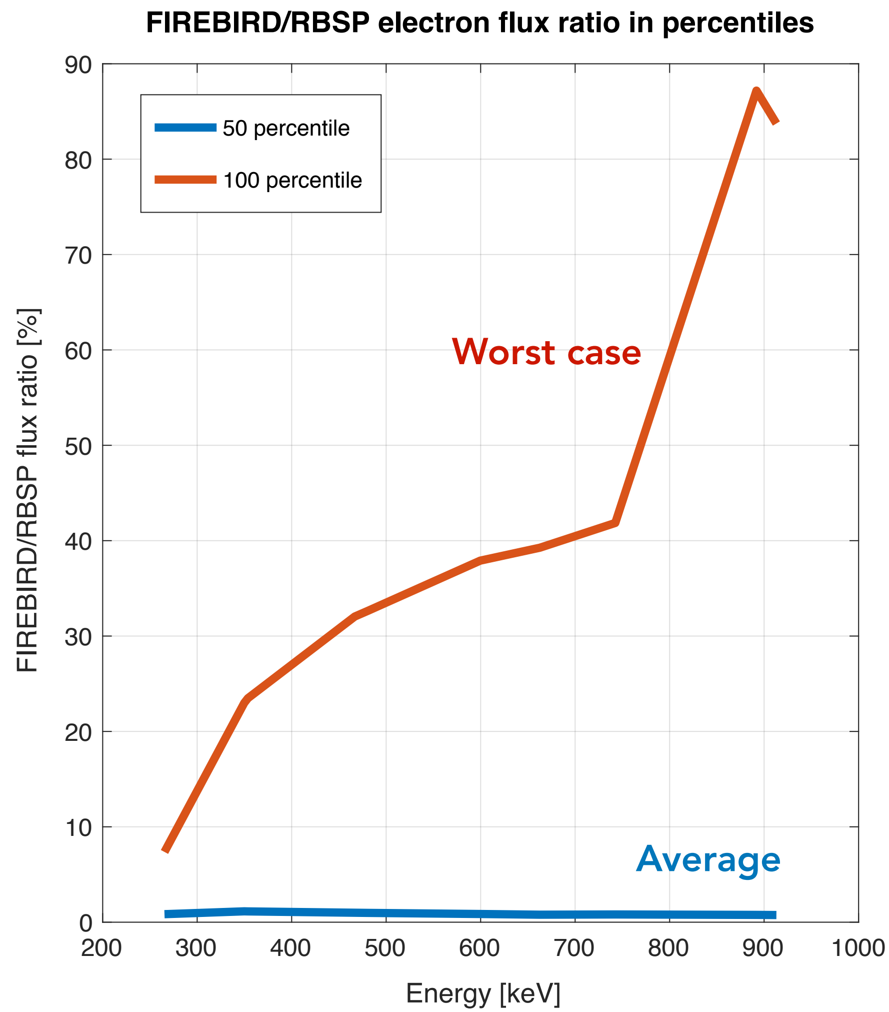


Strong diffusion

Weak diffusion
or
missed the precipitation

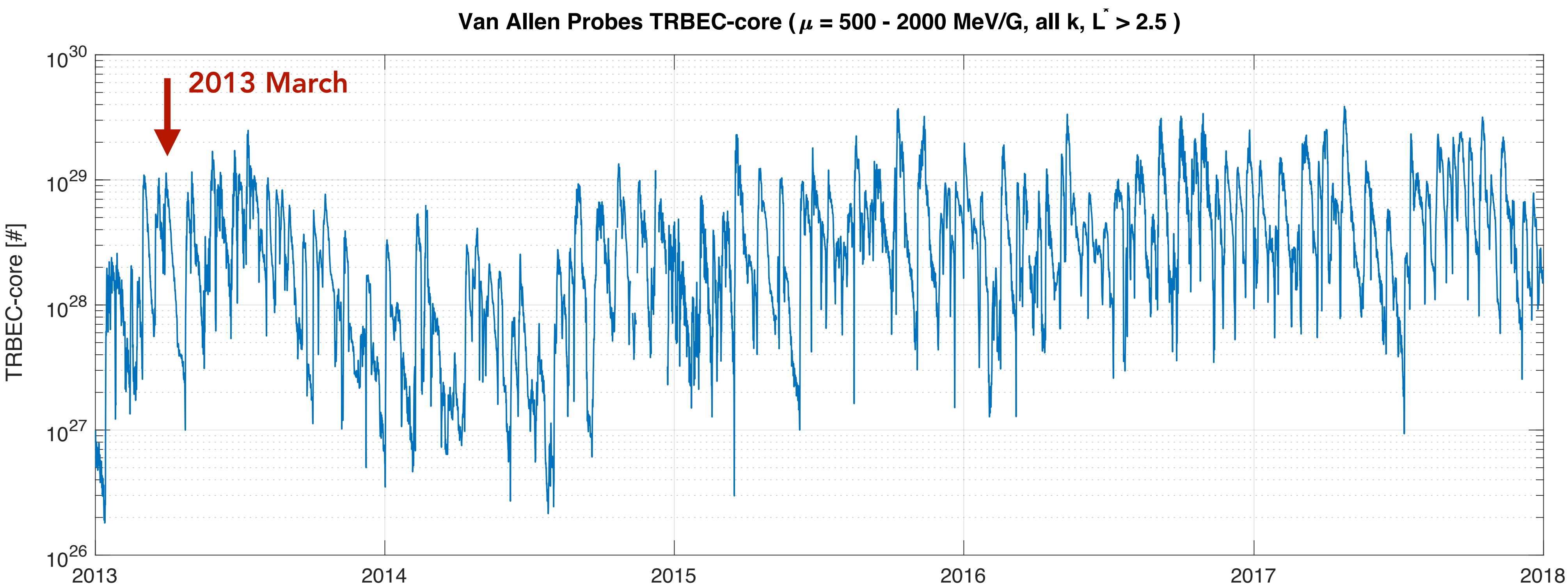
Flux Ratio as Function of Energy - in percentile

- Electron flux ratios in 50 and 100 percentile
- Average precipitation rate is ~1% across energies
- Strongest precipitation rate is ~90% at 900 keV
- Use 100 percentile flux ratio to simulate atmospheric impact
- Note: Throughout the 35 conjunction events, the Dst minimum > -50 nT (moderate condition)



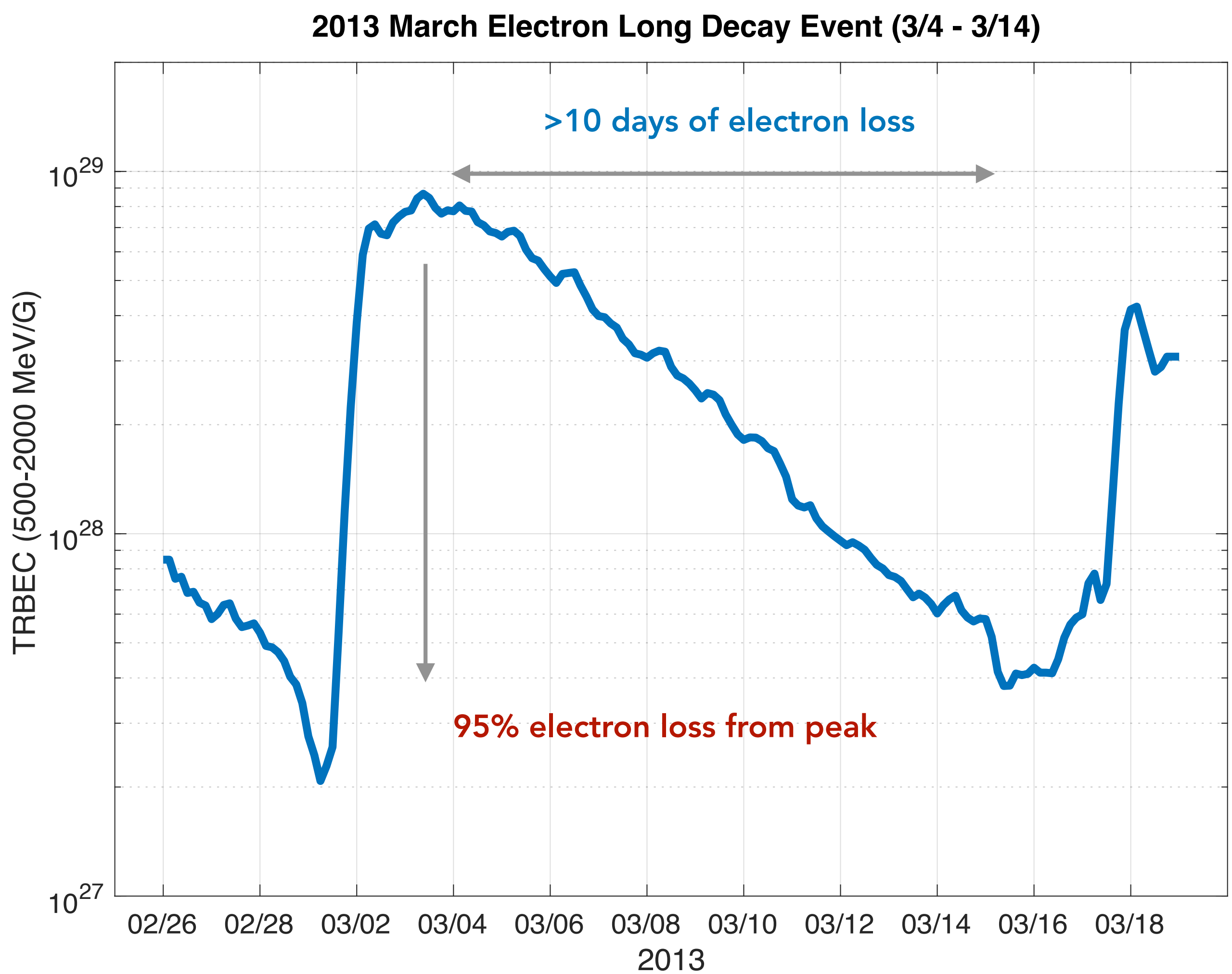
Select Electron Loss Event Using

Total Radiation Belt Electron Content



Electron Long-Quiet Decay Event

2013 March 4-14

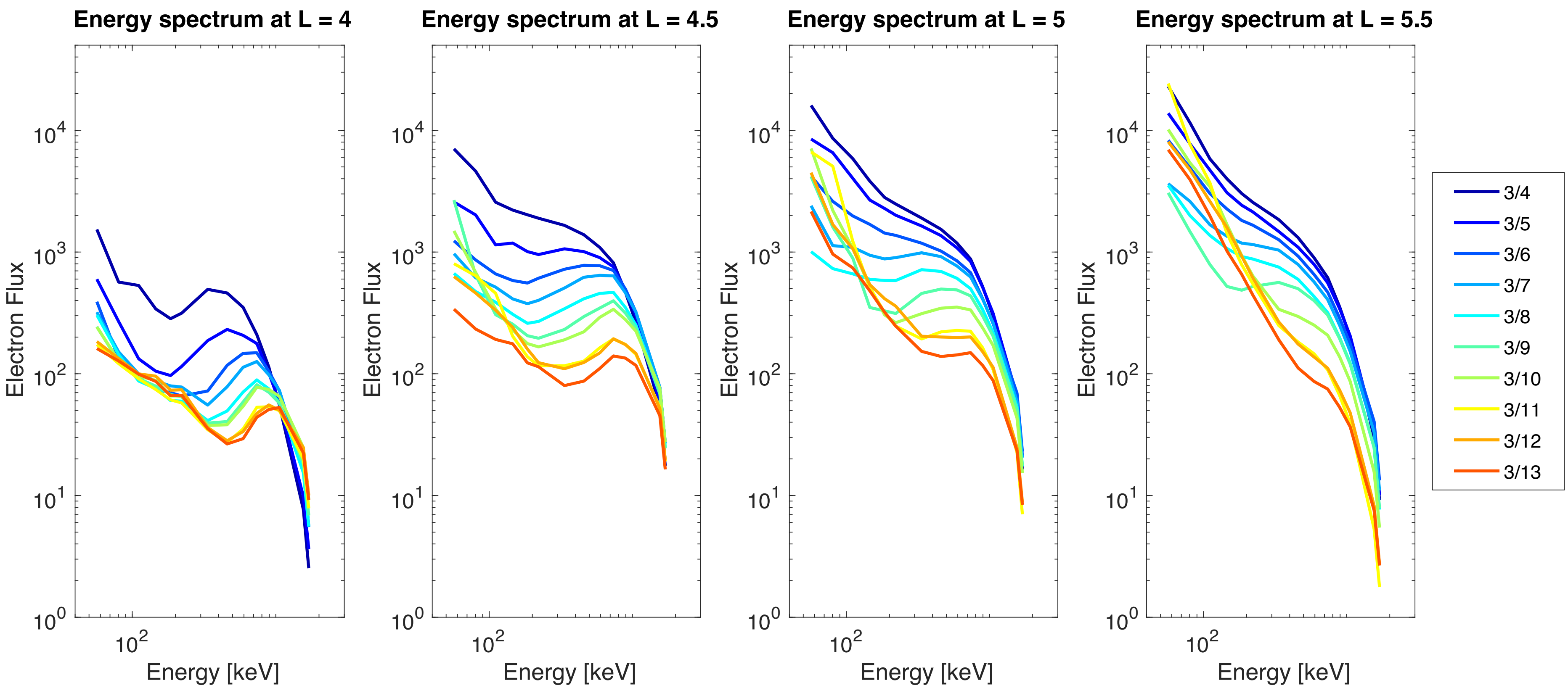


Little or no magnetopause shadowing loss

Electron Long-Quiet Decay Event

2013 March 4-14

Use MagEIS electron flux and scaled with flux ratio to simulate RBE impact on atmosphere



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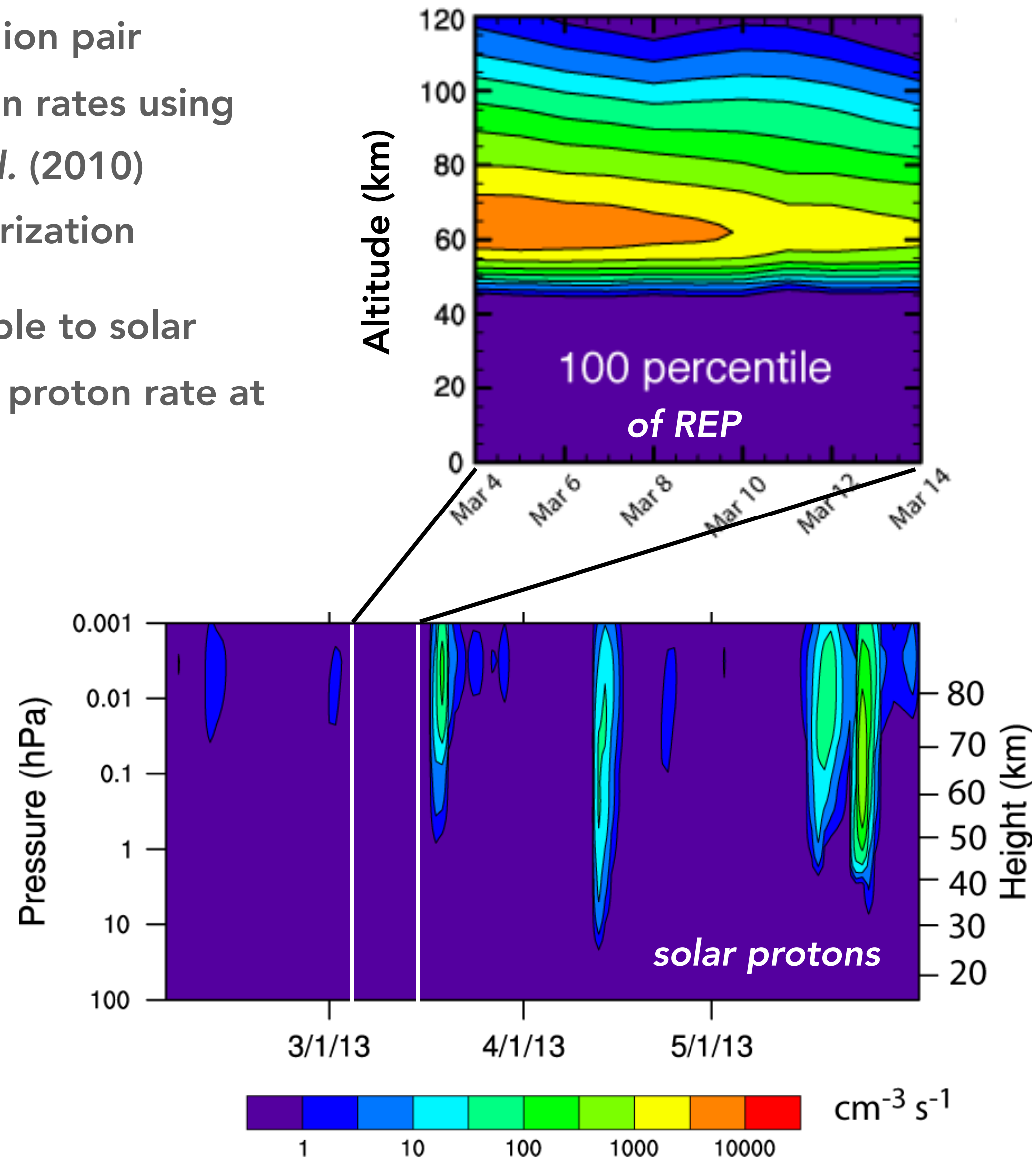
Atmospheric Ionization Rate of Electron Precipitation

- Calculate ion pair production rates using *Fang et al.* (2010) parameterization
- Comparable to solar energetic proton rate at 70km



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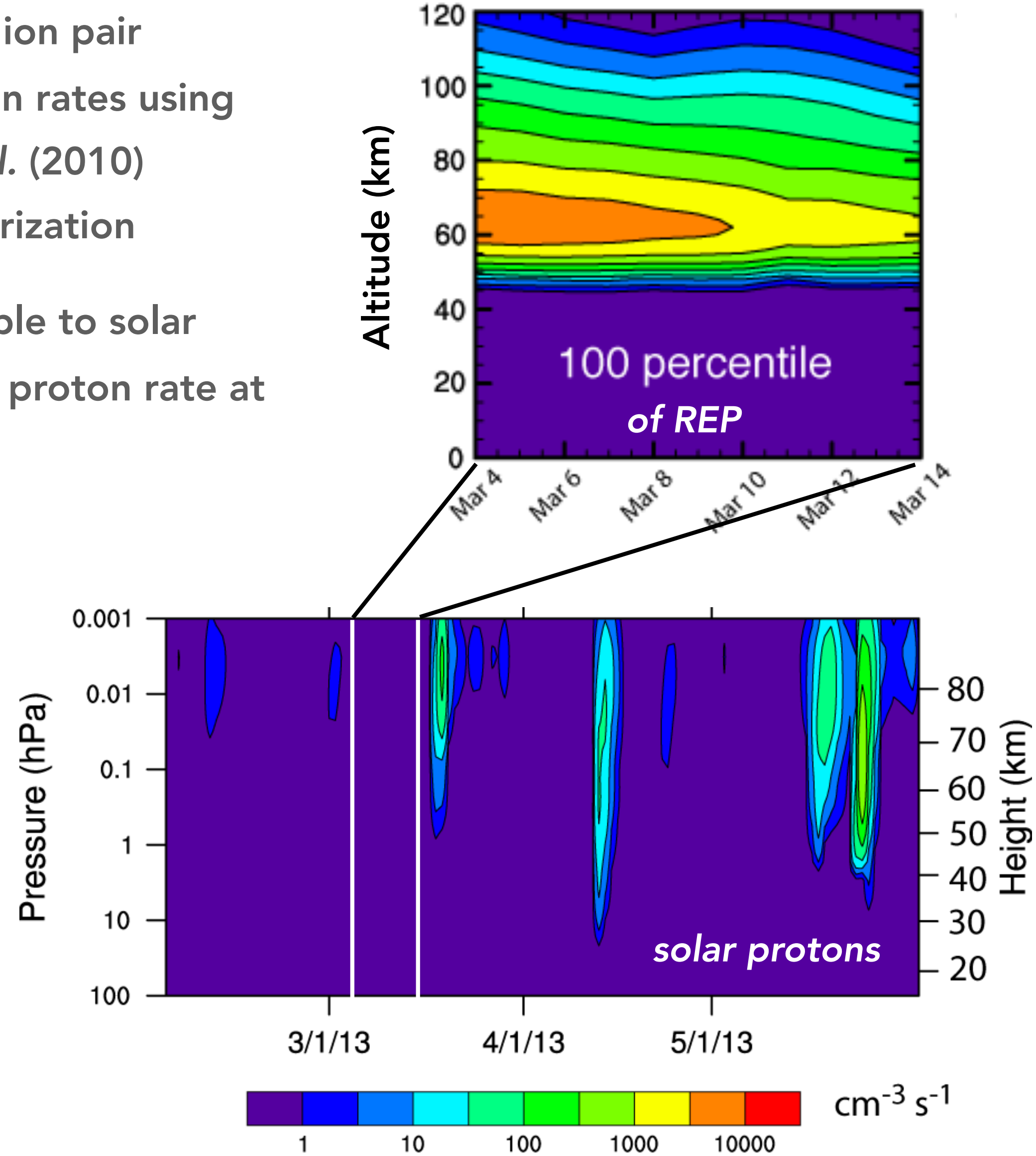
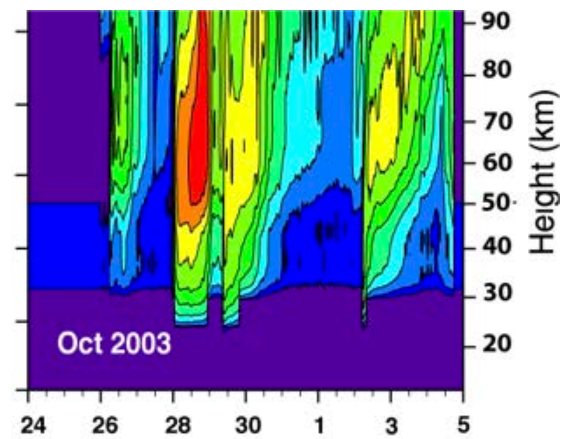
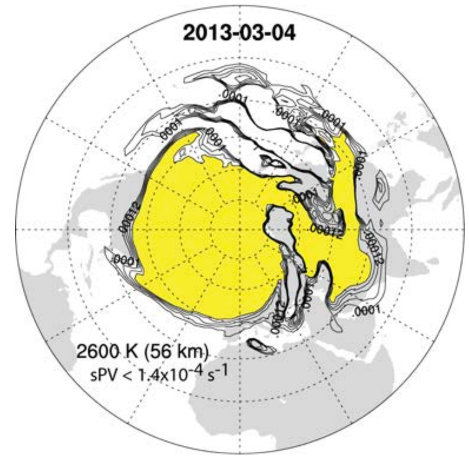


Compare to 2003 "Halloween" Solar Proton Event

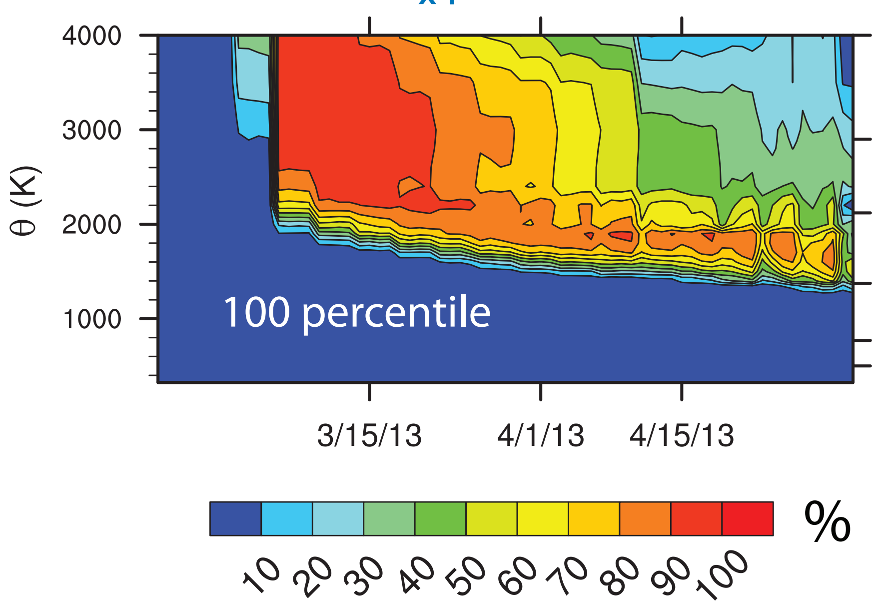


Atmospheric Impact from RB Electron Precipitation

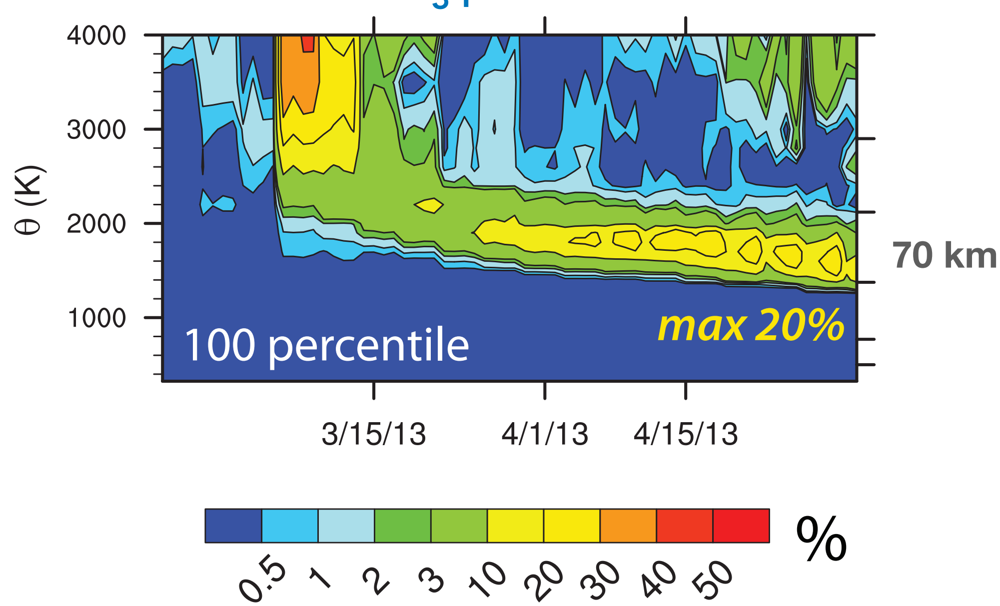
- Whole Atmosphere Community Climate Model (WACCM)
- Northern hemisphere polar vortex-averaged **NO_x enhancement (~100%)** and **O_3 reduction (~20%)** compared to simulations without radiation belt electron input



~100% NO_x peak enhancement



~20% O_3 peak reduction



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Summary

- We estimated radiation belt electron precipitation using FIREBIRD and Van Allen Probes
- We quantified the contribution of electron precipitation to atmospheric chemistry
- We found a substantial change in atmosphere with moderate electron precipitation inputs

Future Work

- Use more extreme electron precipitation to simulate its atmospheric influence and compare results with satellite observation
- Calculate the ionospheric conductance caused by radiation belt electrons using TIE-GCM and WACCM-X
- Compare precipitation measurements from other satellites, radar, and riometer