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Middle atmosphere ionization from auroral particle precipitation as observed by the SSUSI satellite instruments

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UNIS The University Centre in Svalbard

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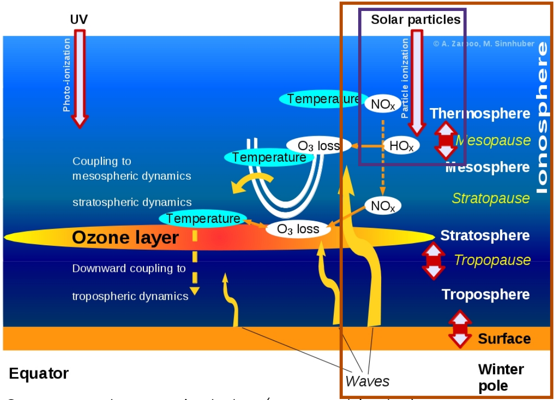
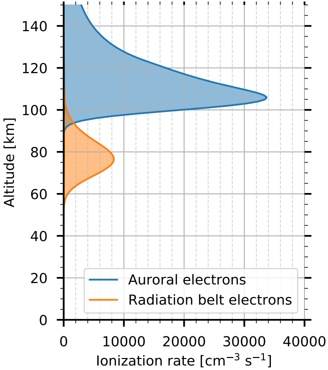
Particle impact on the middle and upper atmosphere

- Solar wind (space weather)
- Particle precipitation, e.g. e^-, p^+ → middle/upper atmosphere ionization
- Chemistry (HOx and NOx) and dynamics → ozone chemistry



© 2017 A. Zarboo, M. Sinnhuber (approx. altitudes)



Climate models — state of the art

Particle data (input)

- POES/GOES satellite detectors: e^-, p^+
- in-situ $\rightarrow$ confined to satellite orbits ($\approx$ 800 km)
- MEPED: 3 spectral channels for e^- ($>$ 30 keV) $\rightarrow$ (almost) **no** auroral input
- some problems (e.g. p^+ contamination in e^- channels)

Parametrizations (physics)

- AIMOS ionization rates, Wissing et al., (2009), AISStorm (next)
- AP, AE based parametrizations of POES/GOES MEPED data, Kamp et al., (2016)
- MIPAS (NO), Funke et al., (2016); Matthes et al., (2017)

Trace gas data (for model assessment)

- satellite data: ACE-FTS, MIPAS, Odin/SMR, SCIAMACHY, SOFIE, etc.
  global (dense) spatial sampling $\leftrightarrow$ sparse temporal sampling
- ground-based instruments: local sampling, high temporal resolution
- **Assessment:**
  model–measurement intercomparisons $\Rightarrow$ quality of models and input

SSUSI instruments

Auroral energy input: **Special Sensor Ultraviolet Spectrographic Imager**

Satellite instruments

- Defense Meteorological Satellite Program (DMSP)-Block 5D3 satellites (850 km)
- projected 20 year timespan
- 10/2003 first satellite → 4 currently operating (2020)

UV observations

- nadir auroral images, 5 UV channels, 10×10 km ground pixels, 1500 km swath
- ionosphere and thermosphere monitoring
- day and night low- to mid-latitude ionosphere and thermosphere

Data products

- characteristic **auroral** electron energy and flux (2–20 keV)
- F-region ionospheric electron densities

SSUSI data (example)

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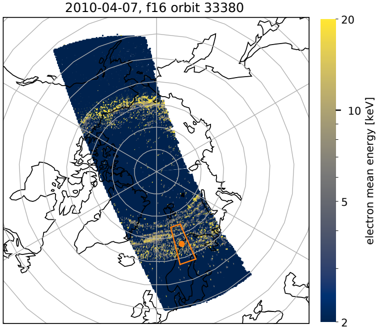
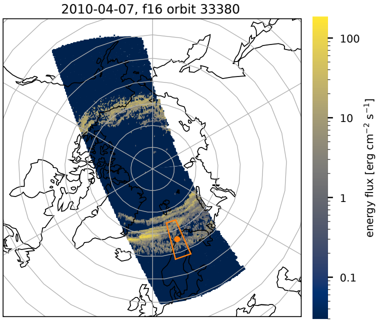
2010-04-07, f16 orbit 33380, ~17:30h UT

- auroral electron energy [keV] and energy flux [erg cm^{-2} s^{-1}]
- Tromsø EISCAT radar ($\pm 5°$ latitude $\times$ longitude)

Electron energy



Energy flux



SSUSI electron spectra

SSUSI sampled at Tromsø EISCAT radar ($\pm5°$ latitude $\times$ longitude)

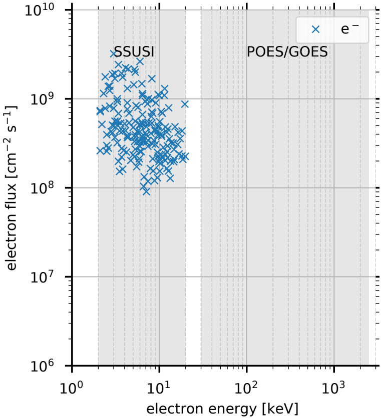


Figure: Electron spectra around Tromsø EISCAT radar

Ionization and recombination rate parametrizations

- NRLMSISE-00 atmosphere, fixed flux (1 erg cm^{-2} s^{-1})
- ionization rates Fang et al., (2008) (also tested Roble et al., (1987); Fang et al., (2010))
- recombination rates Vickrey et al., (1982); Gledhill, (1986)

Ionization rates

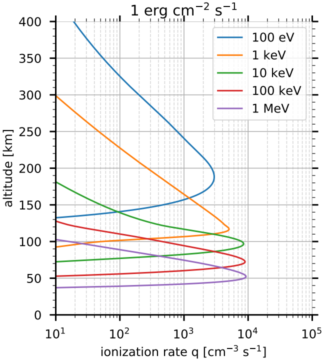


Figure: Fang et al., (2008) ionization rates for different energies

Recombination rates

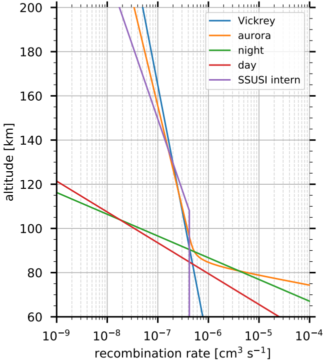


Figure: Recombination rate profiles for different parametrizations

Example comparison to EISCAT and AIMOS

- AIMOS Wissing et al., (2009)
- **Svalbard** EISCAT radar ± 5 min, SSUSI $\pm 5°$ latitude $\times$ longitude

Ionization rates

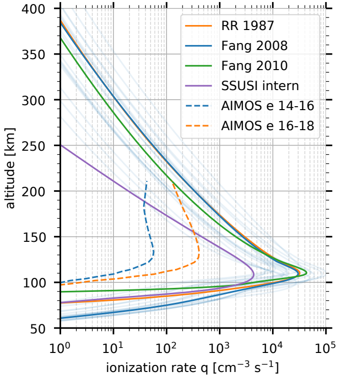


Figure: Ionization rate profiles for SSUSI energies and fluxes

Electron densities

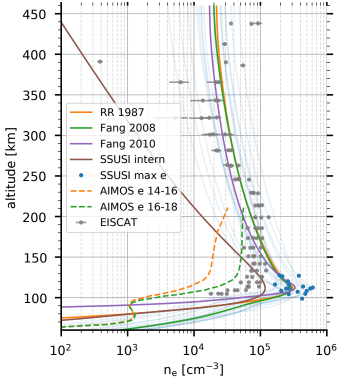
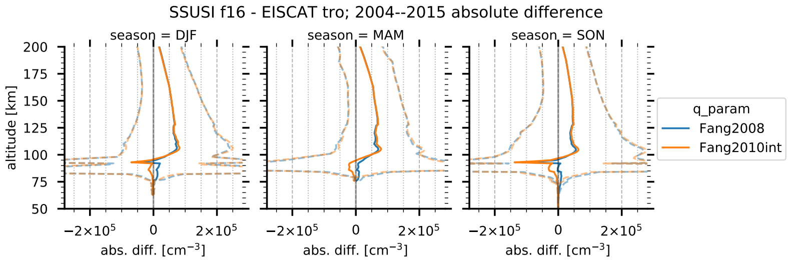
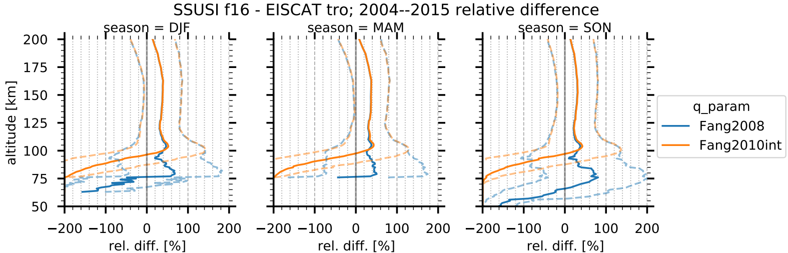


Figure: SSUSI and EISCAT electron densities

Statistics SSUSI f16 vs EISCAT Tromsø UHF

Seasonal averages, SSUSI 2×2 °, EISCAT ±5 min, MLT > 15h, SZA > 90°, radar elveation > 75°





Summary and Outlook

Summary

- SSUSI e^- energies (2–20 keV) and fluxes
- Various ionization and recombination parametrizations
- Initial comparison to AIMOS ionization rates (2h resolution)
- Initial comparison to EISCAT e^- densities
- Initial statistical comparison to Tromsø UHF and VHF radars

Conclusion

- 20–60% difference in lower thermosphere (90–150 km)
- **not** significant (difference $< 1\sigma$)

Outlook

- Re-evaluate parametrization(s)
- Comparison to NO data (photochemical model)
- Complement higher energy data (POES/GOES)
- Data for climate modelling and trace gas retrievals