BIRKELAND CENTRE FOR SPACE SCIENCE

Empirical modelling of SSUSI-derived auroral ionization rates

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Stefan Bender[1,2], Patrick J. Espy[1,2], Larry J. Paxton[3]

[1] Department of Physics, Norwegian University of Science and Technology, Trondheim, Norway
[2] Birkeland Centre for Space Science, Norway
[3] Applied Physics Laboratory, Johns Hopkins University, Laurel, MD, USA

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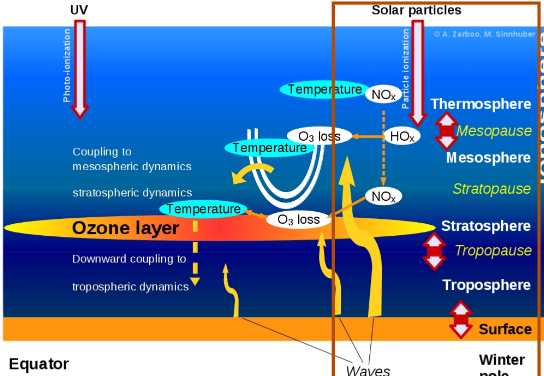
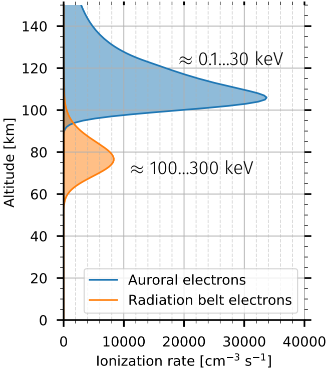
Particle impact on the middle and upper atmosphere

- Particle precipitation, e.g. e^-, p^+ $\rightarrow$ middle/upper atmosphere ionization
- Chemistry (HOx and NOx) and dynamics (NOx descent winter/spring) $\rightarrow$ ozone chemistry
- (whole-atmosphere) climate models still struggle to get it right
- Aurora will be the focus of upcoming HEPPA studies





SSUSI observations

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

- Defense Meteorological Satellite Program (DMSP)-Block 5D3 satellites (850 km)
- nadir auroral images, 5 UV channels, 10×10 km ground pixels, 3000 km swath
- auroral electron energy [keV] and energy flux [mW m^{-2}]

Scanning method

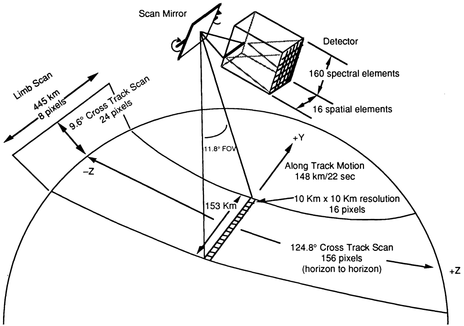
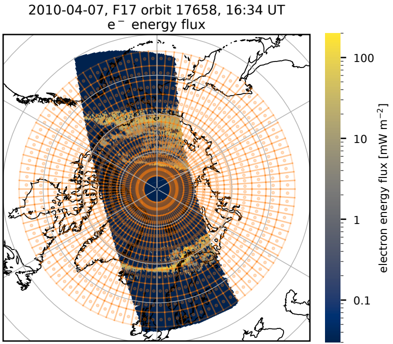


Figure: SSUSI scan pattern (Paxton et al., (1993))

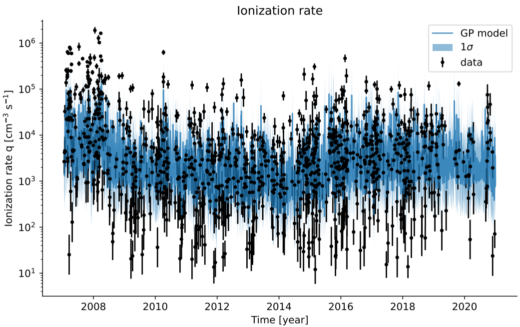
Electron energy flux



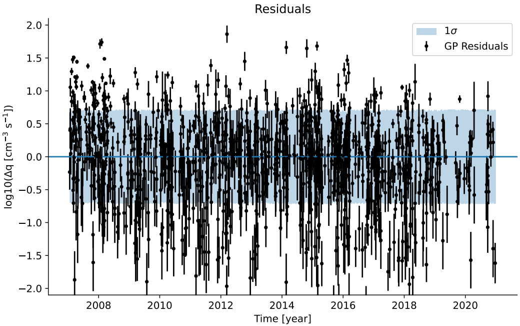
Ionization rate empirical model

- 3.6° × 3.6° latitude × longitude grid, 5 km altitude grid, 2-h magnetic local time (MLT)
- ionization rates (IR; Fang et al. (2010)), spectra according to validation (Bender et al., (2021))
- NRLMSISE-00 neutral atmosphere (scale height and density)
- model: $\log q \sim \log v_{\text{plasma}} + \log F_{10.7} + K_p + \text{const.}$
- Data selection (empirical): q > 1 cm^{-3} s^{-1}; log-scale: log q > 3 relative error
- Example: latitude 70.2° N, longitude 19.8° E, altitude 100 km, 19:00 MLT

Data and model fit in example bin



Residuals

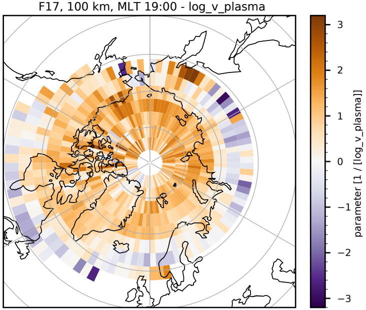


Ionization rate empirical model parameters

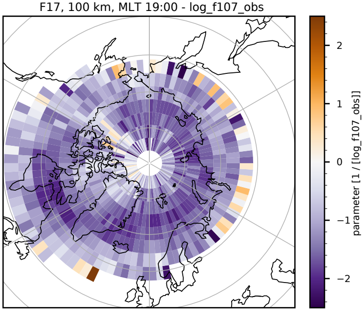
North Hemisphere

Parameter distributions for altitude 100 km, 19:00 MLT

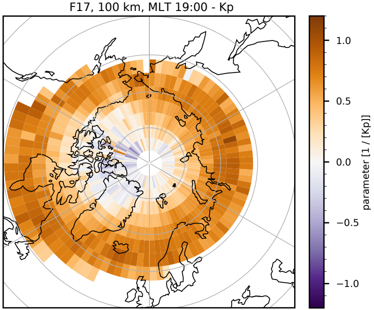
v_{plasma}



$F_{10.7}$



Kp



Summary and Outlook

Summary

- SSUSI on DMSP F17 e^- energy and flux data $\rightarrow$ gridded ionization rate profiles
- time series of IR per MLT, altitude, latitude, and longitude
- fit log(IR) to proxies: v_{plasma}, $F_{10.7}$, and K_p + constant
- works well for general behaviour (within 2σ, single grid box)
- example maps at selected MLT (19:00) and altitude (100 km)

Outlook

- Find "optimal" proxies (best fit + data availability)
- Principal Component analysis to reduce search space
- Data set and empirical model for whole-atmosphere climate modelling

References

Bender, S., P. J. Espy, and L. J. Paxton. **Validation of SSUSI-derived auroral electron densities: Comparisons to EISCAT data**.
Ann. Geophys. 39(5): pp.899–910 2021. doi: 10.5194/angeo-39-899-2021

Fang, X., C. E. Randall, D. Lummerzheim, W. Wang, G. Lu, S. C. Solomon, and R. A. Frahm. **Parameterization of monoenergetic electron impact ionization**.
Geophys. Res. Lett. 37(22): p.L22106 2010. doi: 10.1029/2010gl045406

Paxton, L. J. et al. SSUSI - horizon-to-horizon and limb-viewing spectrographic imager for remote sensing of environmental parameters. In Huffman, R. E. (ed) *Ultraviolet technology IV*, SPIE doi: 10.1117/12.140846

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