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# Empirical modelling of SSUSI-derived auroral ionization rates

## EGU general assembly 2022

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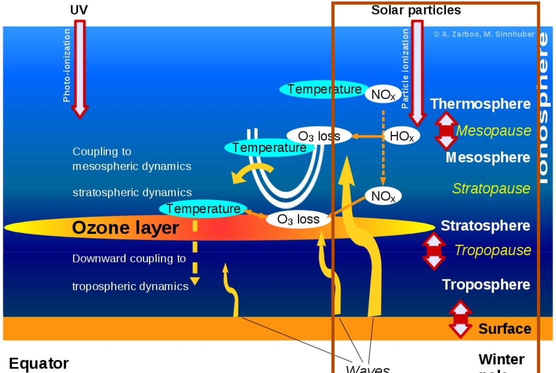
## Particle impact on the middle and upper atmosphere

- 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

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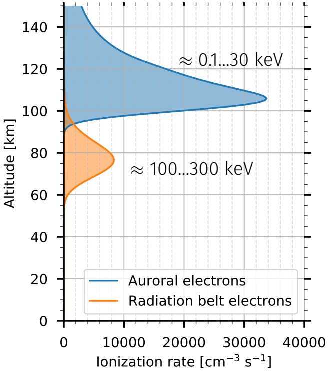


Auroral energy input: **Special Sensor Ultraviolet Spectrographic Imager**

- 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 (2–20 keV) and energy flux [mW $m^{-2}$]

## Scanning method

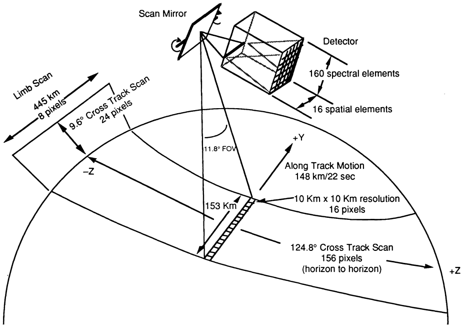
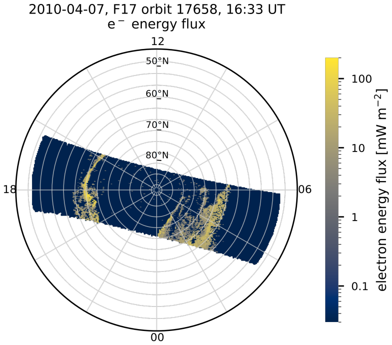



Figure: SSUSI scan pattern (Paxton et al., (1993))

## Electron energy flux



# Empirical model setup



- 3.6° geomagnetic latitude × 2-h magnetic local time (MLT) grid
- ionization rates (IR; Fang et al. (2010)), spectra according to validation (Bender et al., (2021))
- NRLMSISE-00 neutral atmosphere → scale height and density

→ IR profiles from 90 to 150 km

## Single grid box

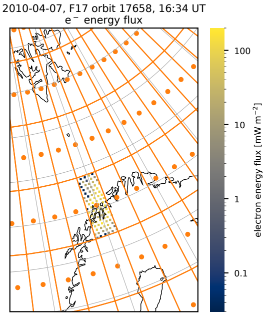
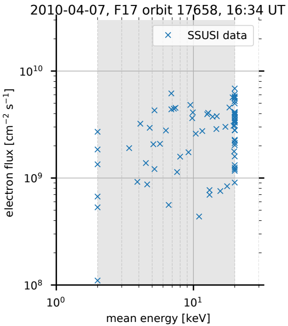



Figure: Selected grid box

## "Spectrum"




## Ionization rates

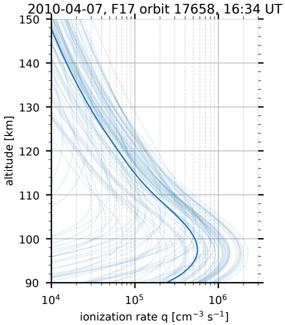


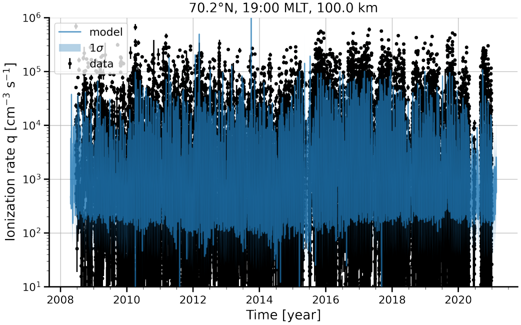

Figure: Fang et al. (2010) ionization rates in

# Ionization rate empirical model

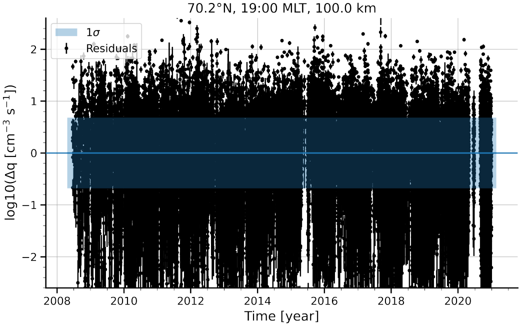


- 3.6° geomagnetic latitude × grid, 5 km altitude grid, 2-h magnetic local time (MLT)
- ionization rates ($q$; Fang et al. (2010)), spectra according to validation (Bender et al., (2021))
- NRLMSISE-00 neutral atmosphere (scale height and density)
- model: $\log q \sim \mathrm{K_p} + \mathrm{PC} + \mathrm{A_p} + \log \overline{F_{10.7}} + \log v_{\text{plasma}} + \text{const.}$
- Example: geomagnetic latitude 70.2° N, altitude 100 km, 19:00 MLT

## Data and model fit in example bin




## Residuals



# Ionization rate empirical model parameters

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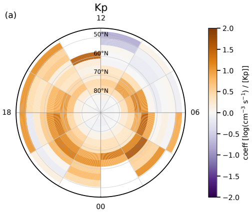
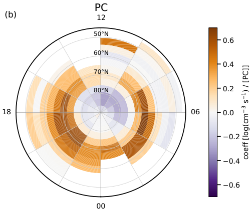
## Parameter distributions for altitude 100 km, Northern Hemisphere

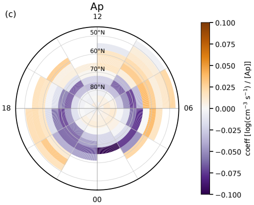
### Kp



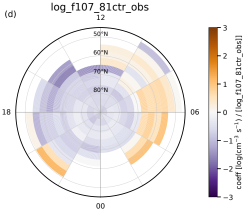

### PC



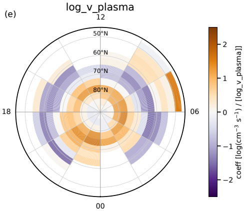

### Ap



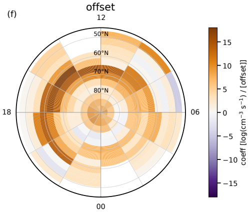

### F_10.7




### v_plasma




### constant



# Initial comparison (possible Heppa-IV input)

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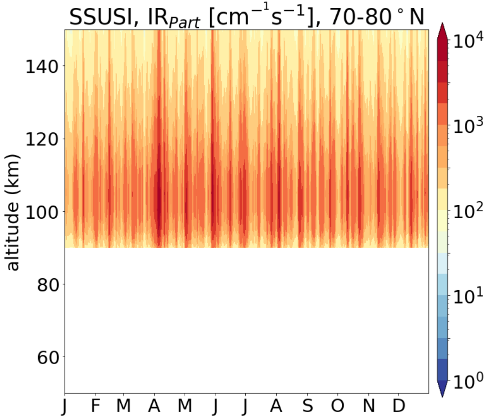
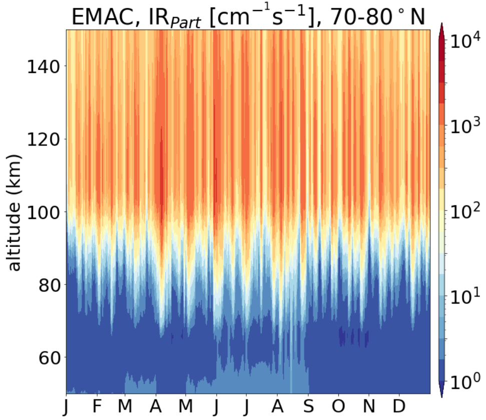
Daily mean zonal mean ionization rate, 2010

## SSUSI




## EMAC/AISStorm




EMAC/AISStorm courtesy of M. Sinnhuber, J. M. Wissing, O. S. Yakovchuk

## Summary

- SSUSI ionization rate profile time series from DMSP F17 and F18 (validated)
- moderate spatio-temporal resolution in MLT and geomagnetic latitude
- fit log(IR) to empirical best-fit proxies: Kp, PC, Ap, $F_{10.7}$, $v_{\text{plasma}}$, and constant
- initial comparison:
  comparable to other parametrizations based on NOAA/POES particle measurements

## Outlook

- More extensive comparisons
- Data set and empirical model for whole-atmosphere climate modelling
- Auroral NOx production for whole-atmosphere climate model simulations
- Principal Component analysis to reduce search space

# References



Bender, S., P. J. Espy, and L. J. Paxton. **Validation of SSUSI-derived auroral electron densities: Comparisons to EISCAT data**.
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