AISSTORM

ATMOSPHERIC IONISATION DURING SUBSTORMS

Model overview

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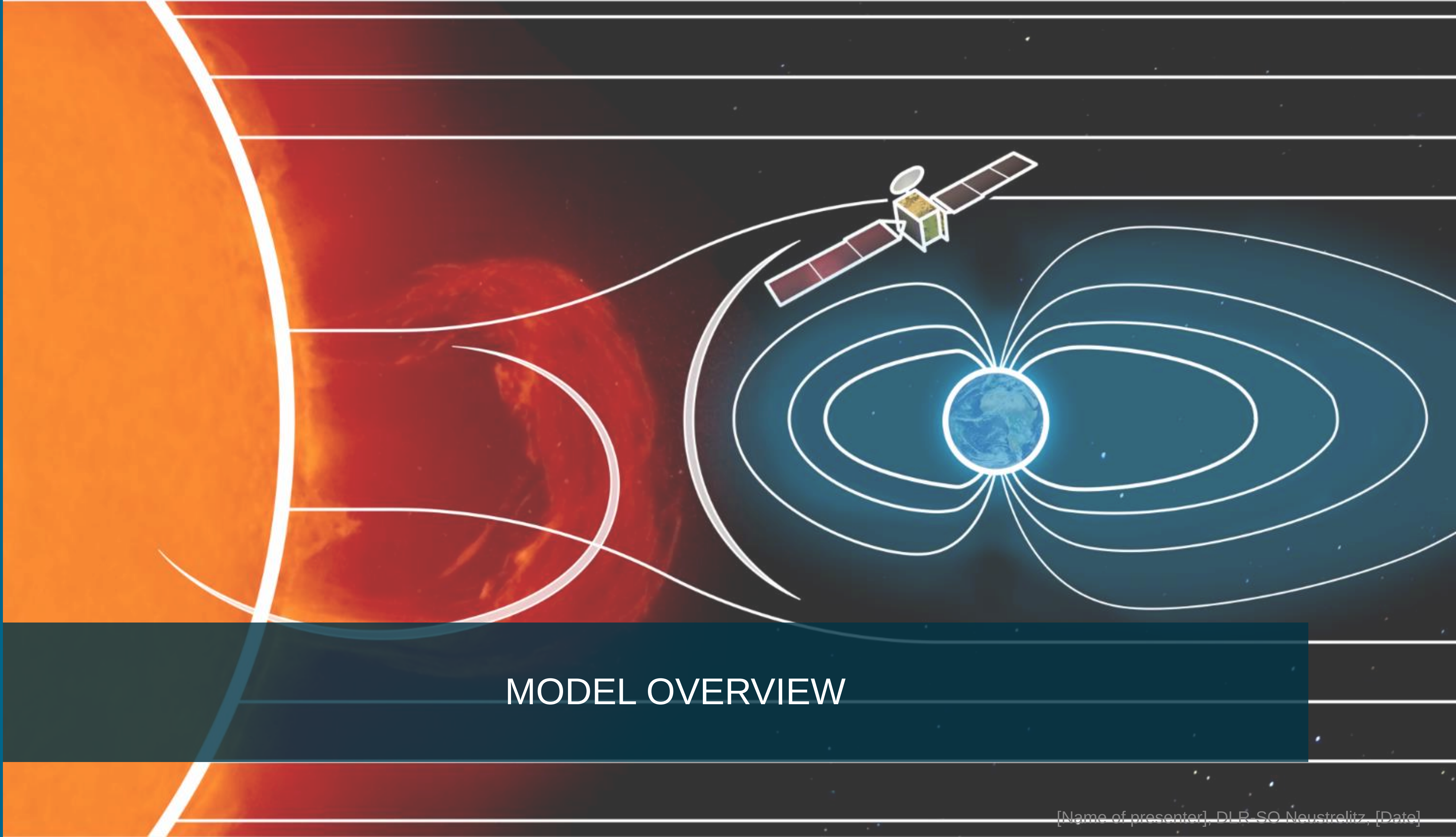
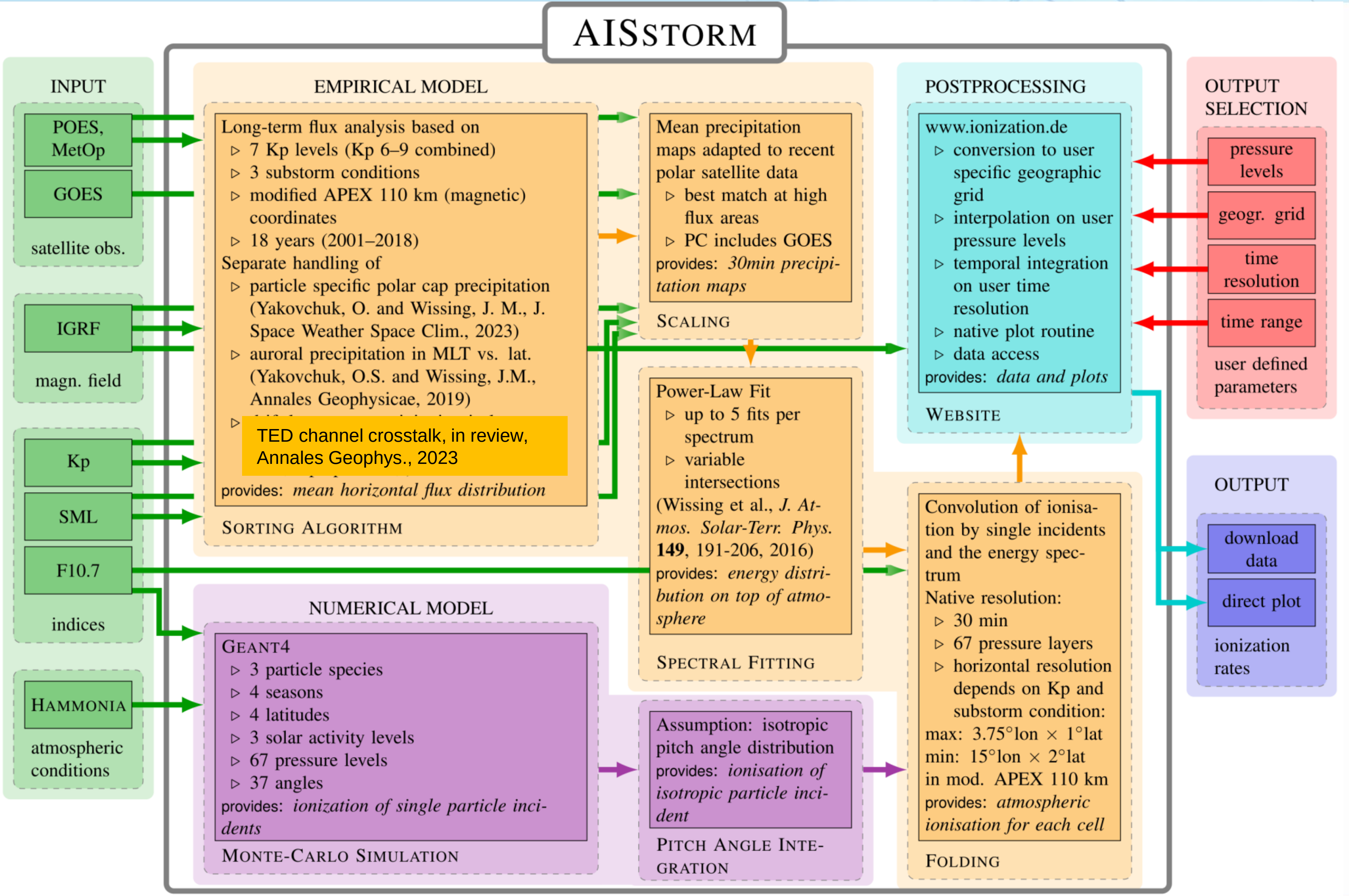


MODEL OVERVIEW

Model overview

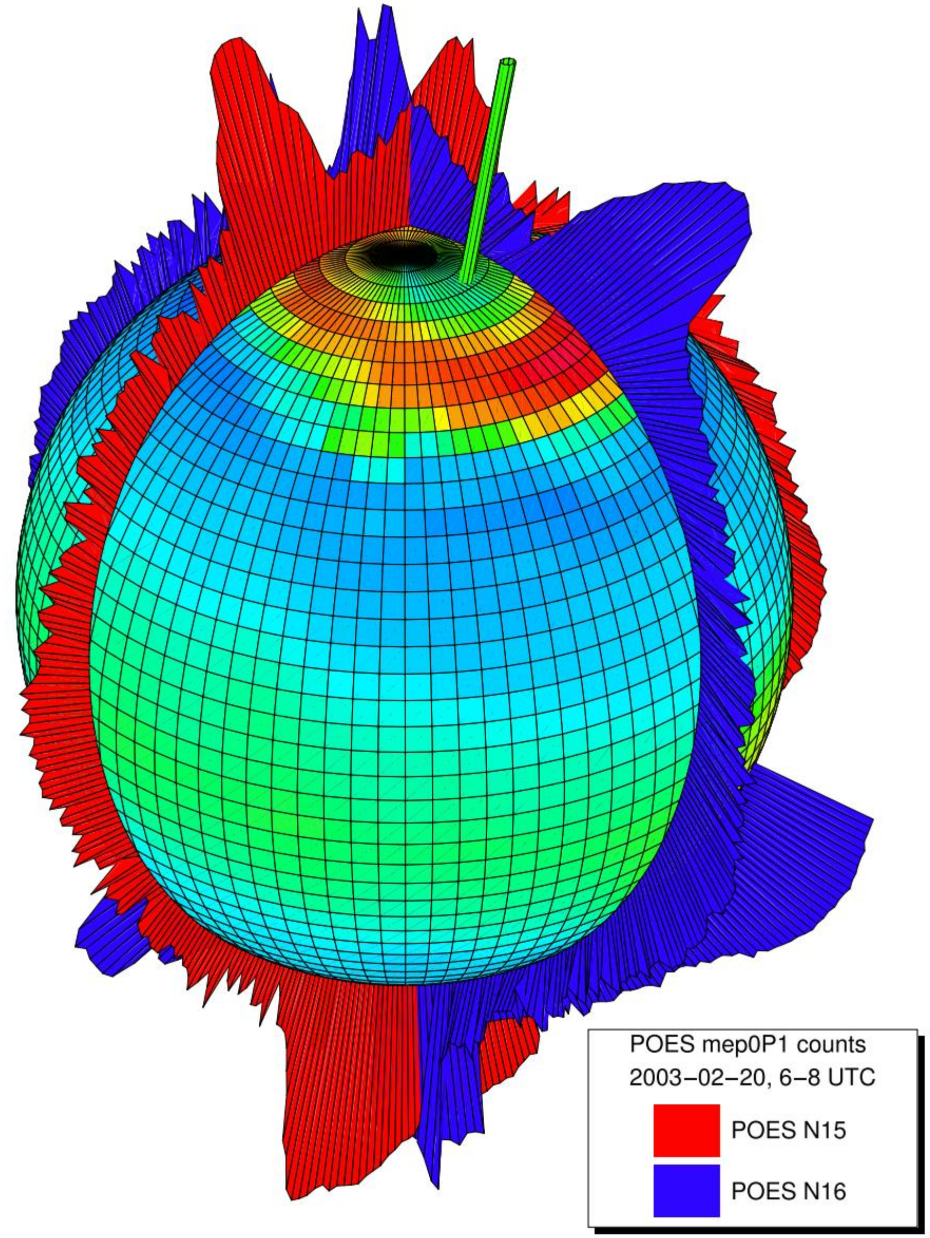
AISstorm

- Atmospheric Ionization during Substorms
- particle ionization model
- used in different studies e.g. in the SOLARIS-HEPPA working group



Derivation of the global (auroral) particle flux

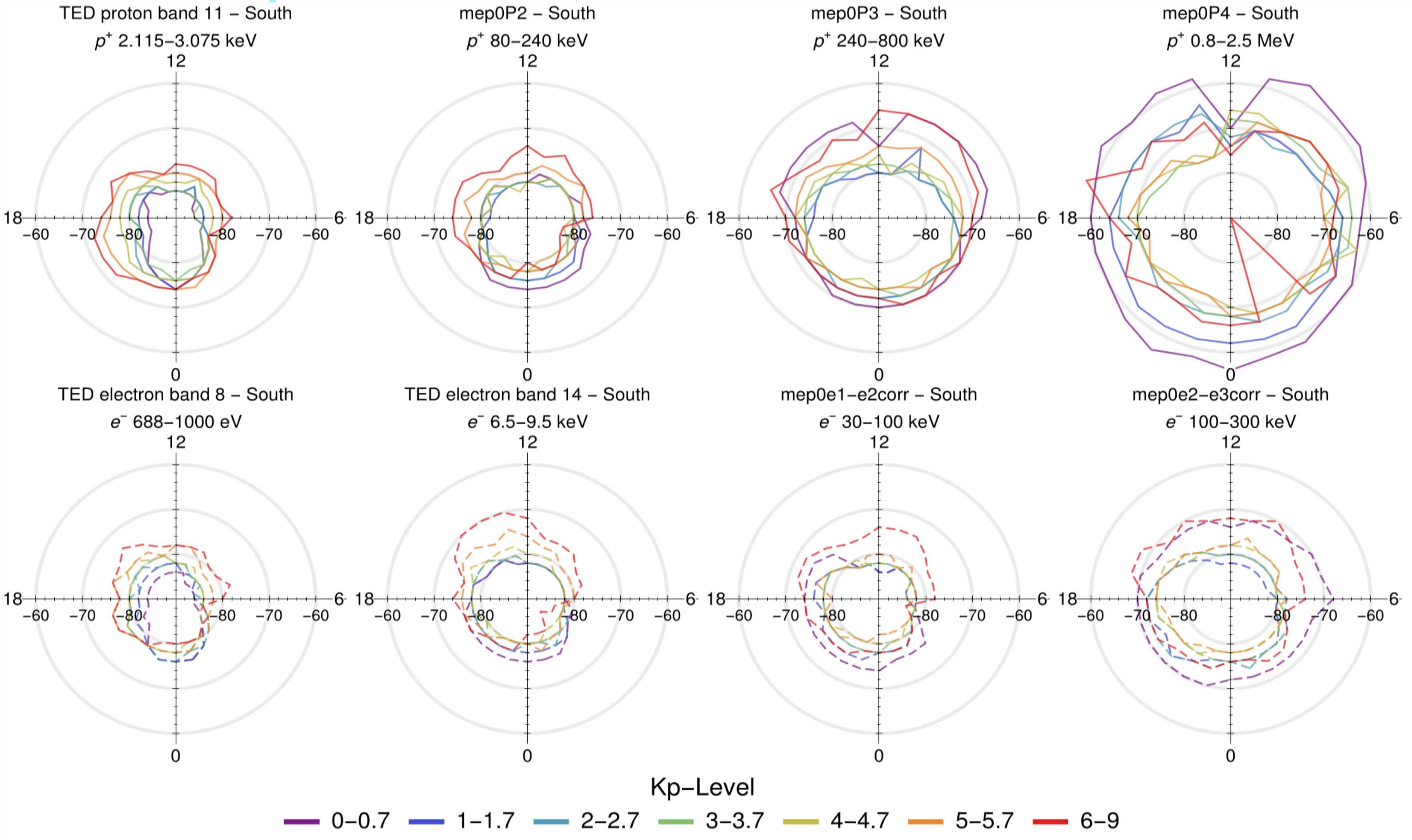
- Particle flux measured along track from POES and Metop satellites
- Needs to be interpolated for global coverage
- Mean precipitation maps are used depending on:
  - Kp
  - SML
- Scaled by recent measurements in the dominant precipitation regions
- Maps: Yakovchuk & Wissing, angeo 2019



Polar particle flux (polar rain, polar cusp, SPE)

Polar particle flux distribution and its spatial extent

- Determined by similarity of cumulated particle flux density distributions
- Leads to determination of particle precipitation regions with similar characteristics
- Allows a polar cap description that within which particle measurements are representative of the whole region (needed for GOES)
- Yakovchuk & Wissing, Space Clim. Space Weather 2023



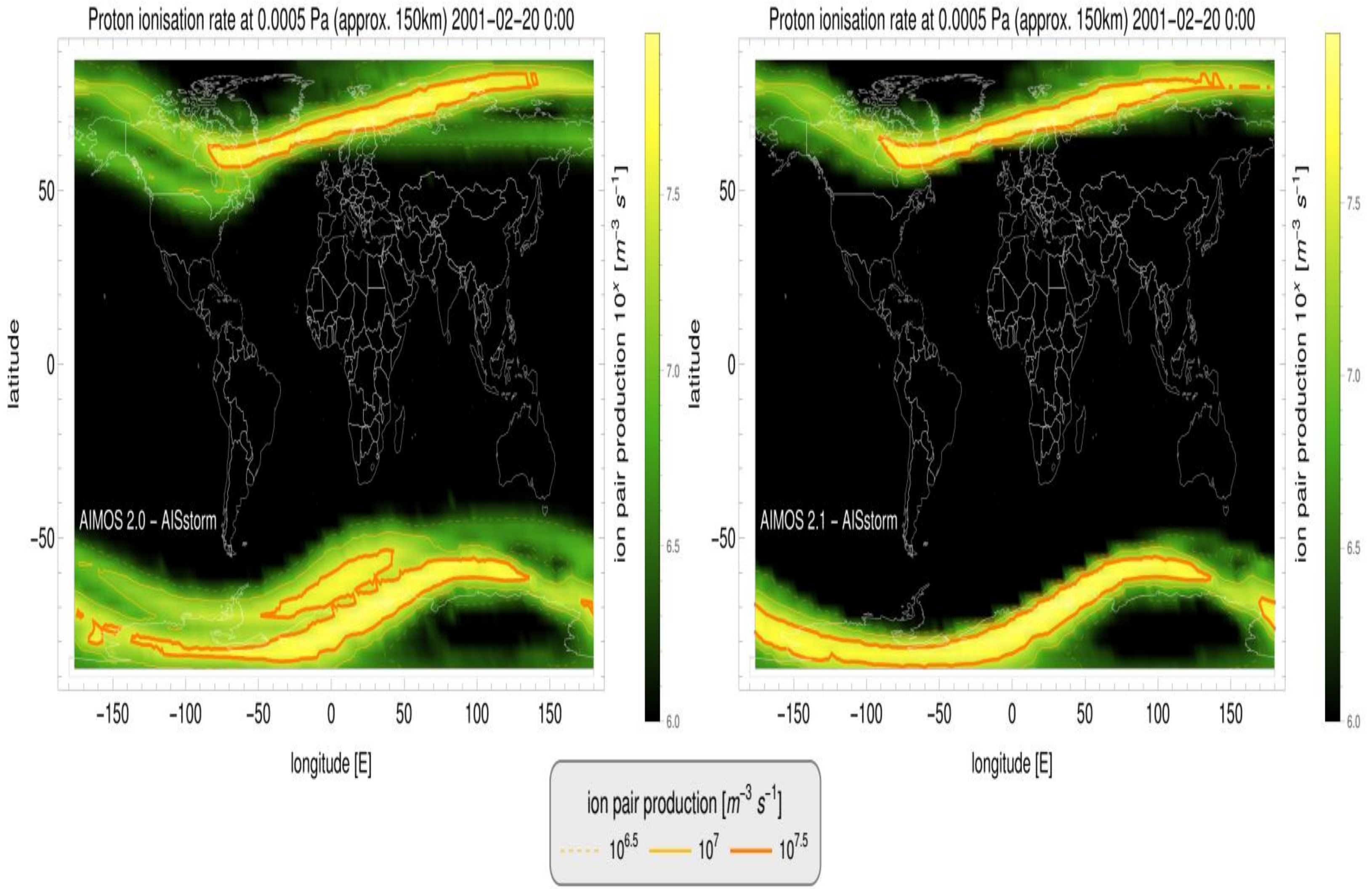
Particle channels need to be corrected

Meped electron channel detect protons:

- Proton flux threshold to set MEPED electrons to an error value

Subauroral Crosstalk in POES/Metop TED proton channels

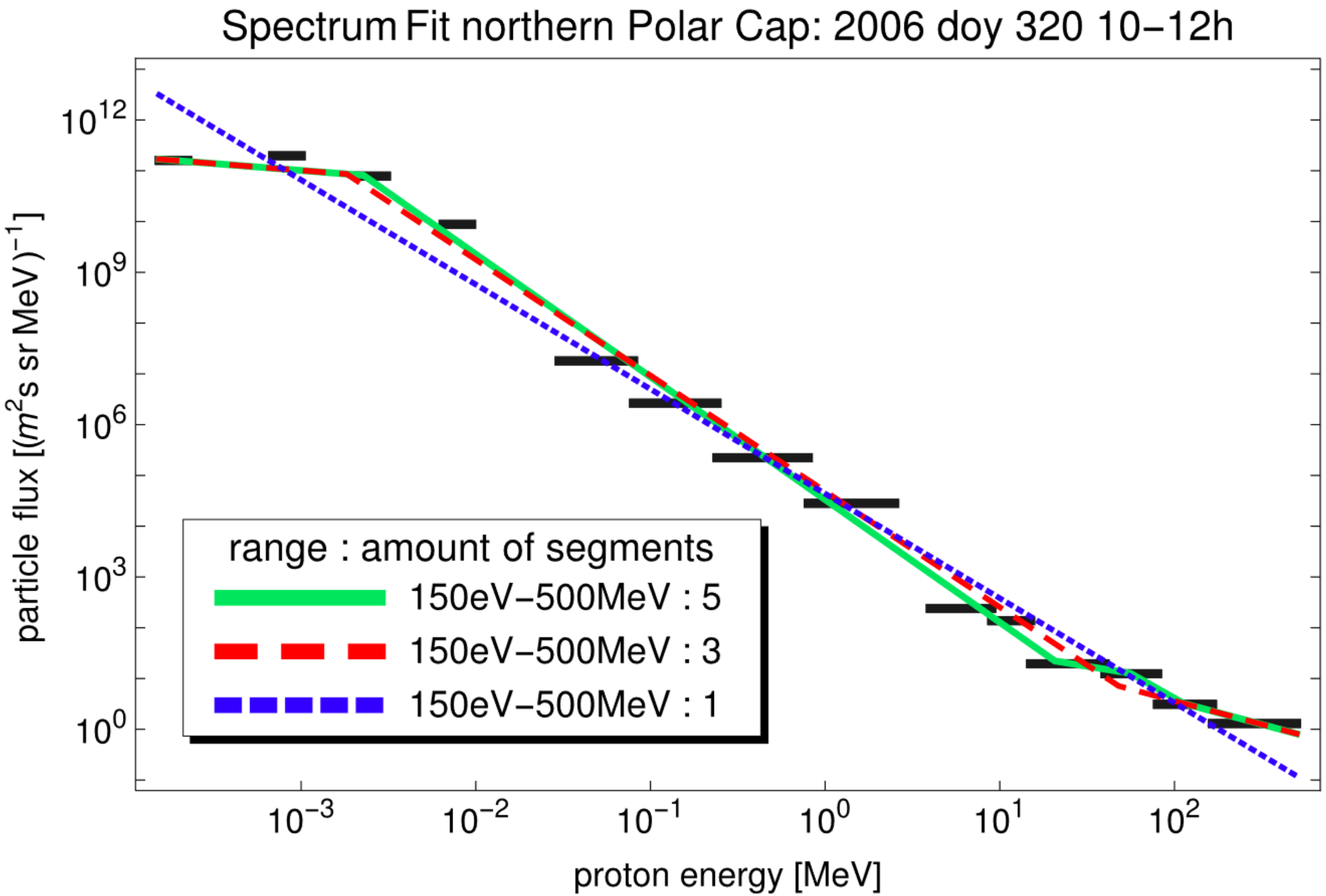
- The POES/Metop TED protons data is contaminated by high energy radiation belt electrons
- A preliminary cut of latitude is suggested in order to reduce the subauroral contamination (see right image)
- Wissing & Yakovchuk, angeo in review



Fit of the particle spectrum

Power law fits

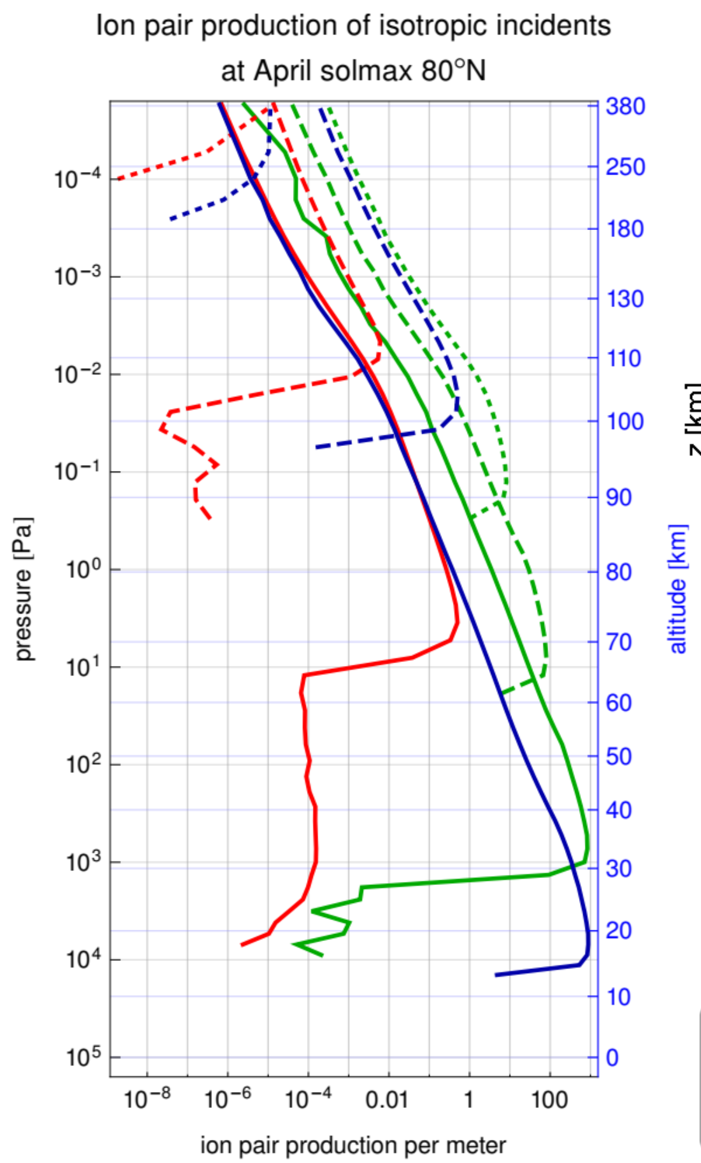
- due to Fermi II acceleration
- Segmented, up to 5 fits
- Determined iteratively using the barycentric energy of every channel
- Every bin is handeled separately
- ~750 000 spectra per day

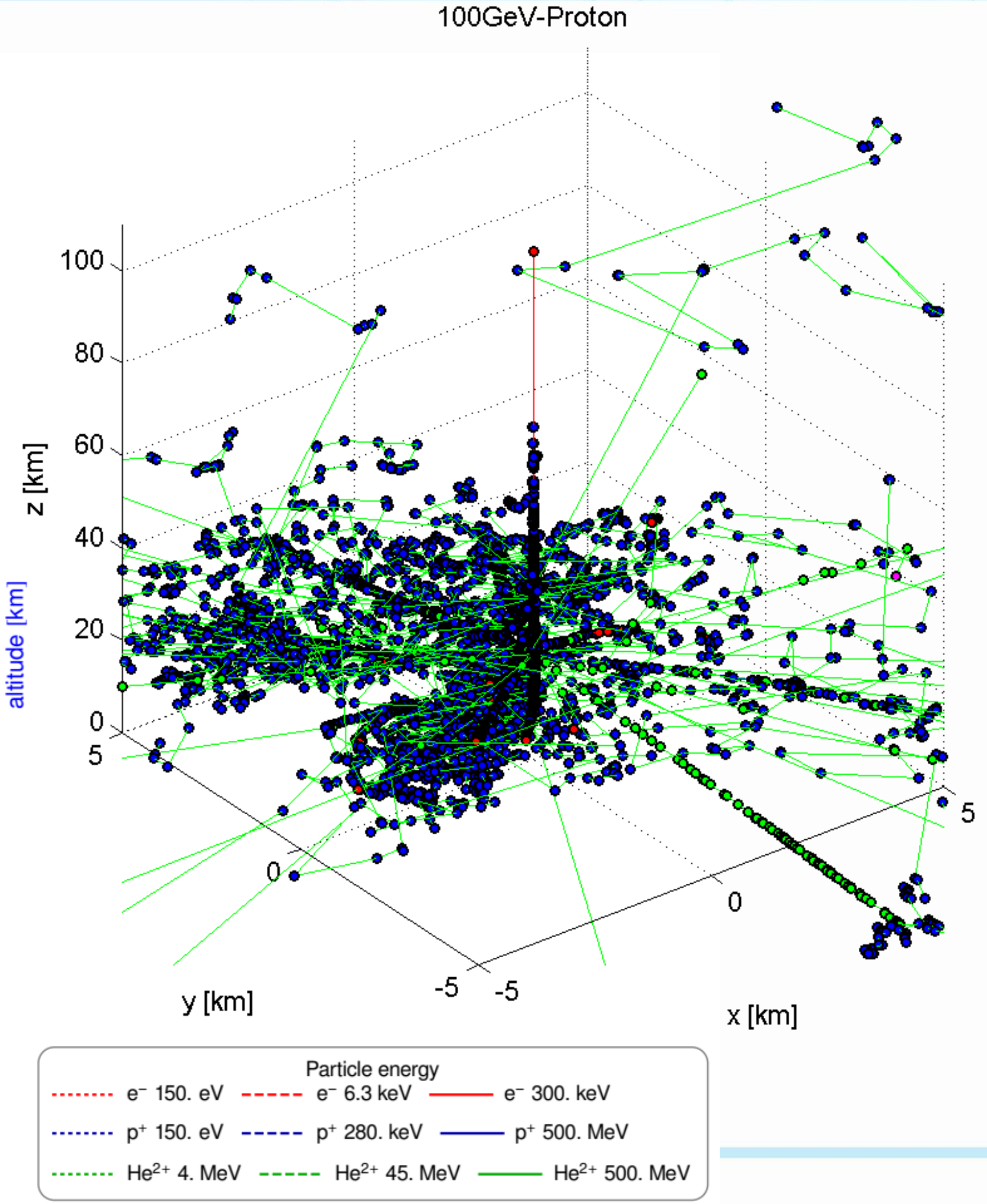


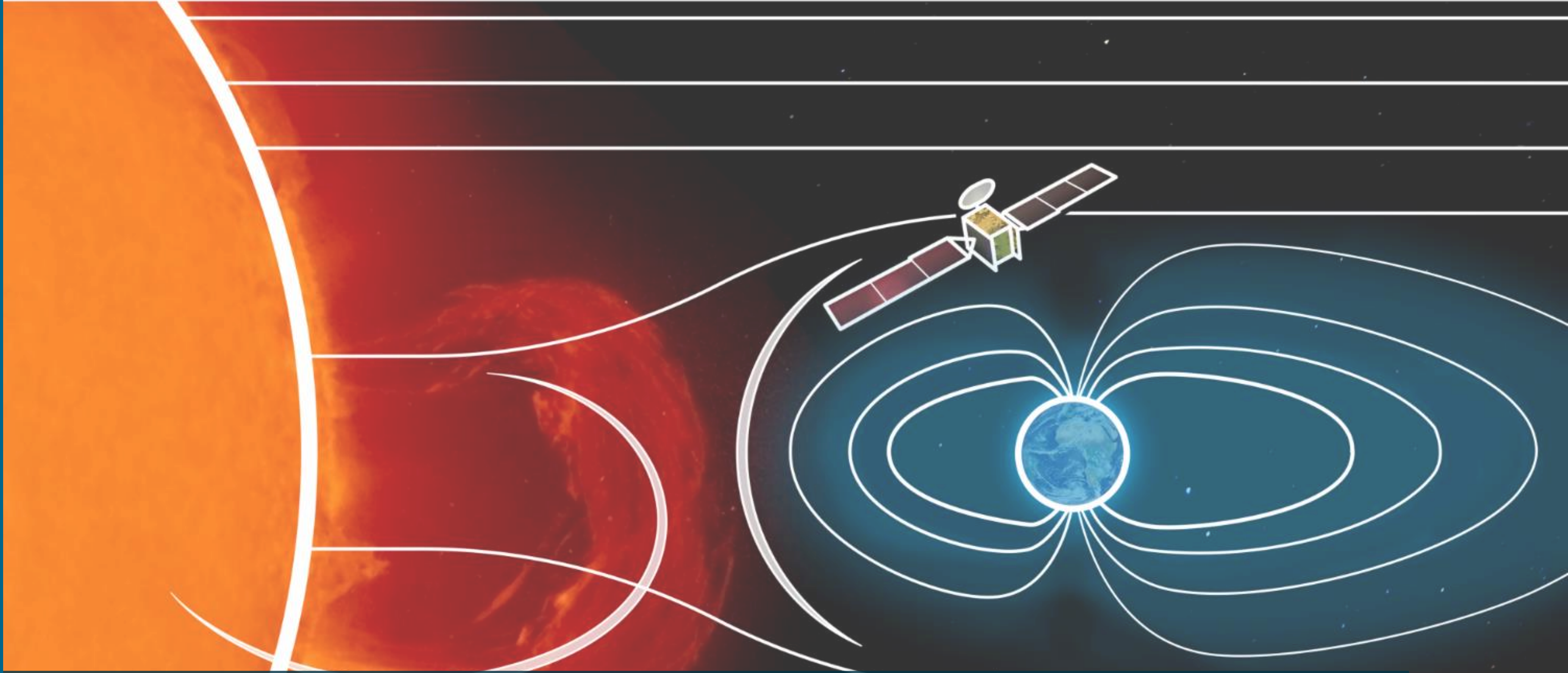
Particle interaction with the atmosphere

Numerical model based on Geant4 (toolkit from CERN)

- Calculates interactions, production of secondaries and energy deposition
  - for incident particle ensembles at given energy and angle
  - for a given detector:
    - E.g. for typical atmospheric conditions at different latitudes, seasons and F10.7 activity
- Gives: energy deposition profile for a single particle
- Folding of particle spectra and energy deposition profile gives: ionization rate profiles

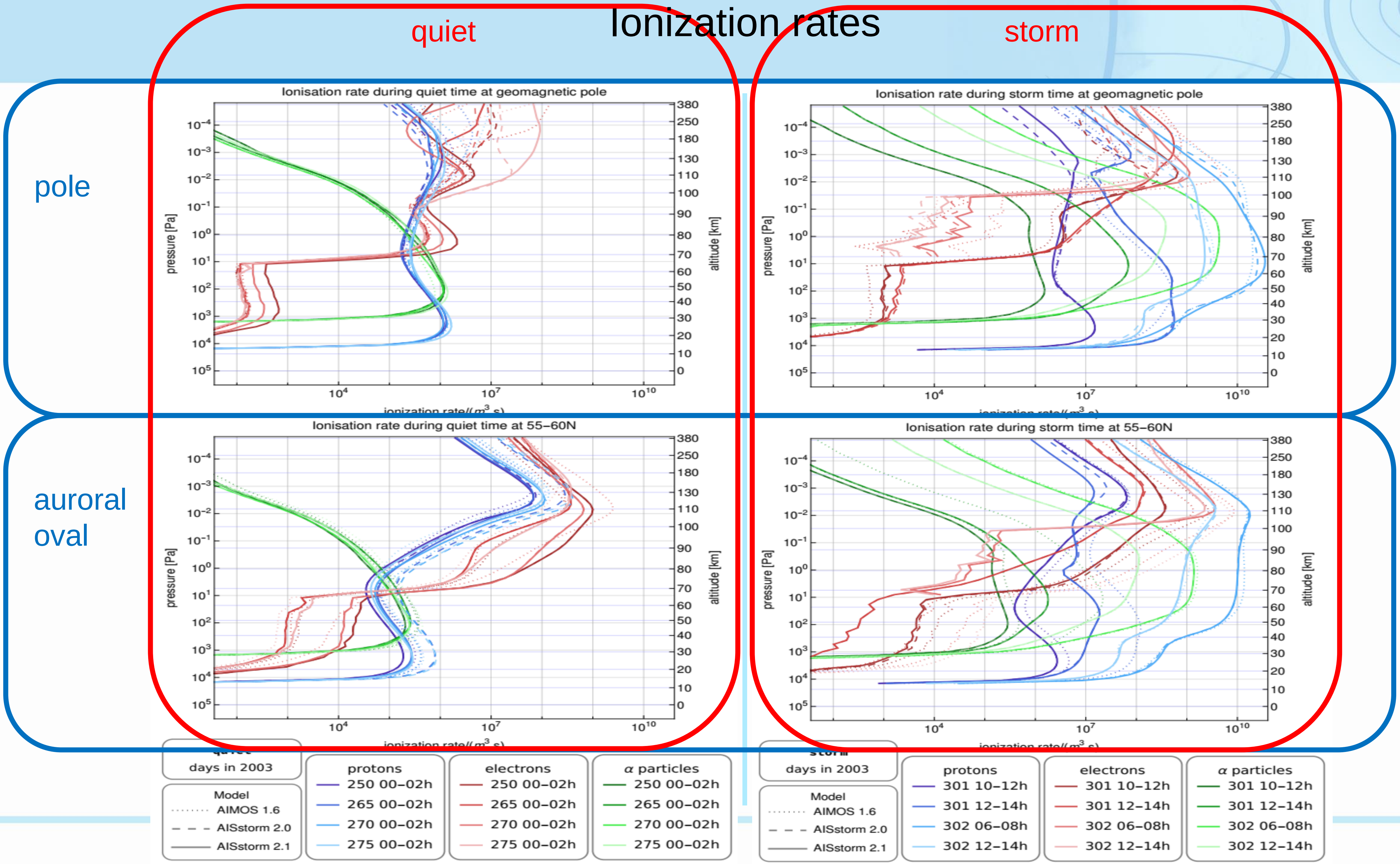




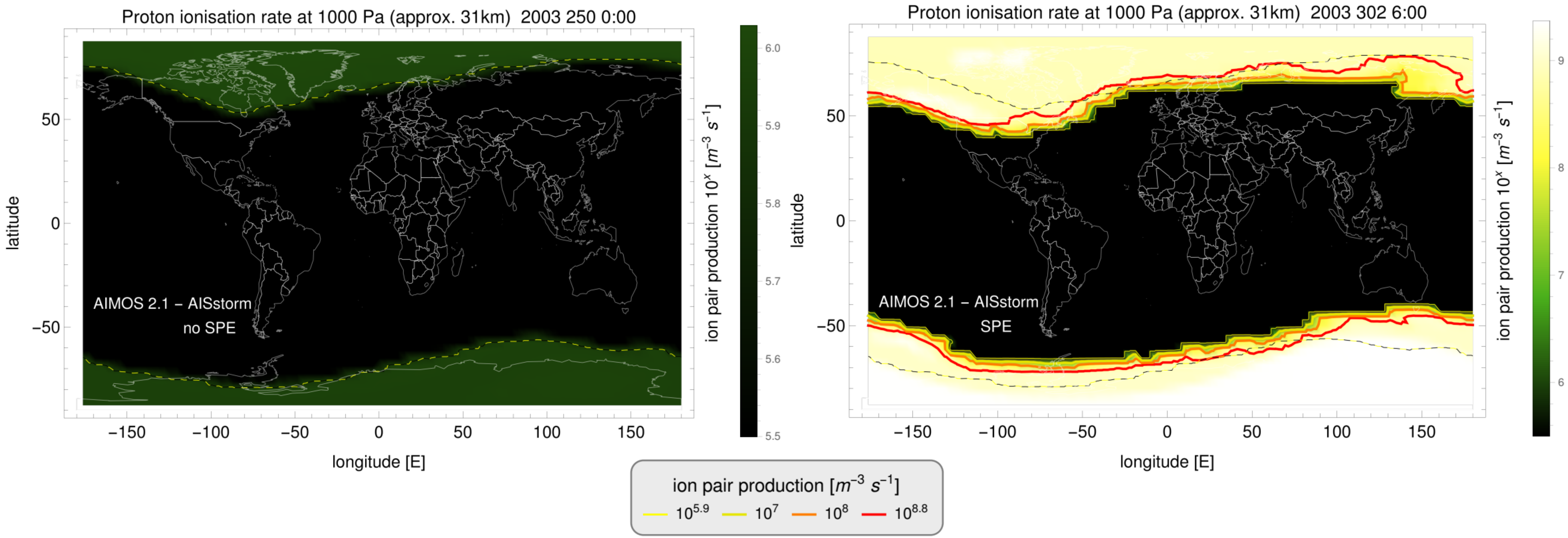


MODEL RESULTS

Ionization rates



Ionization rates during quiet time and a solar proton event



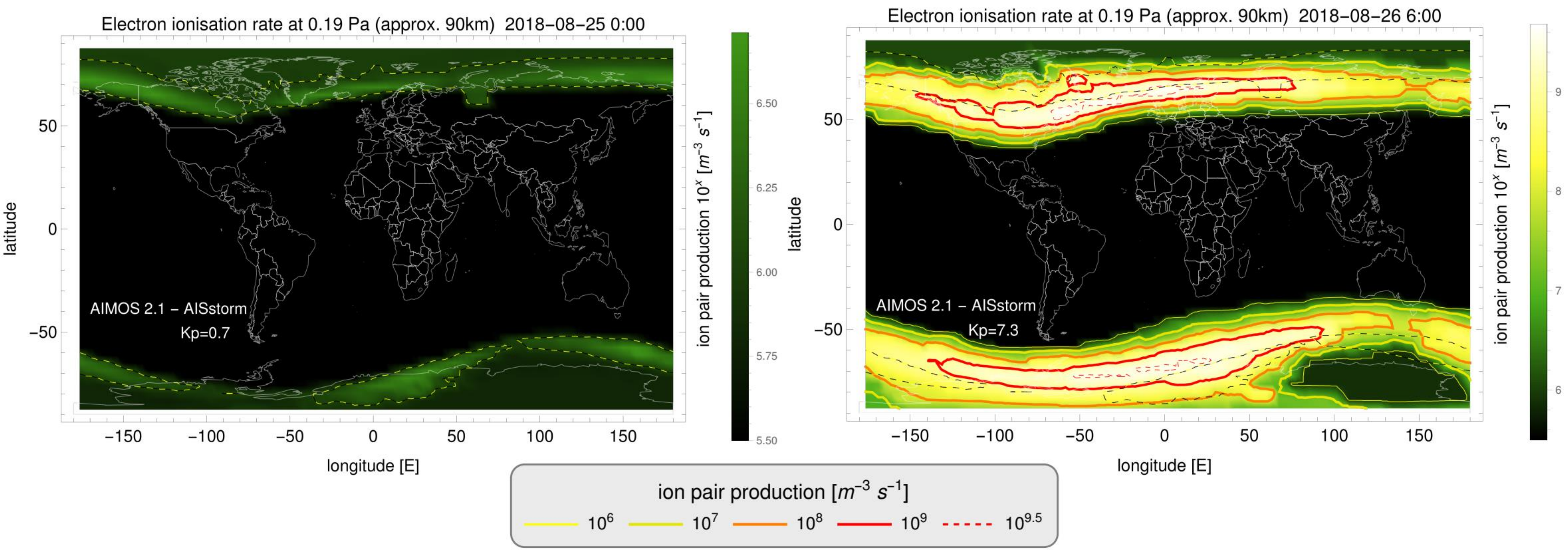
Quiet time:

Polar cap ion pair production: ~10^6 m^{-3} s^{-1} at 31km

SPE:

Polar cap ion pair production: >10^9 m^{-3} s^{-1} at 31km

Geomagnetic Storm



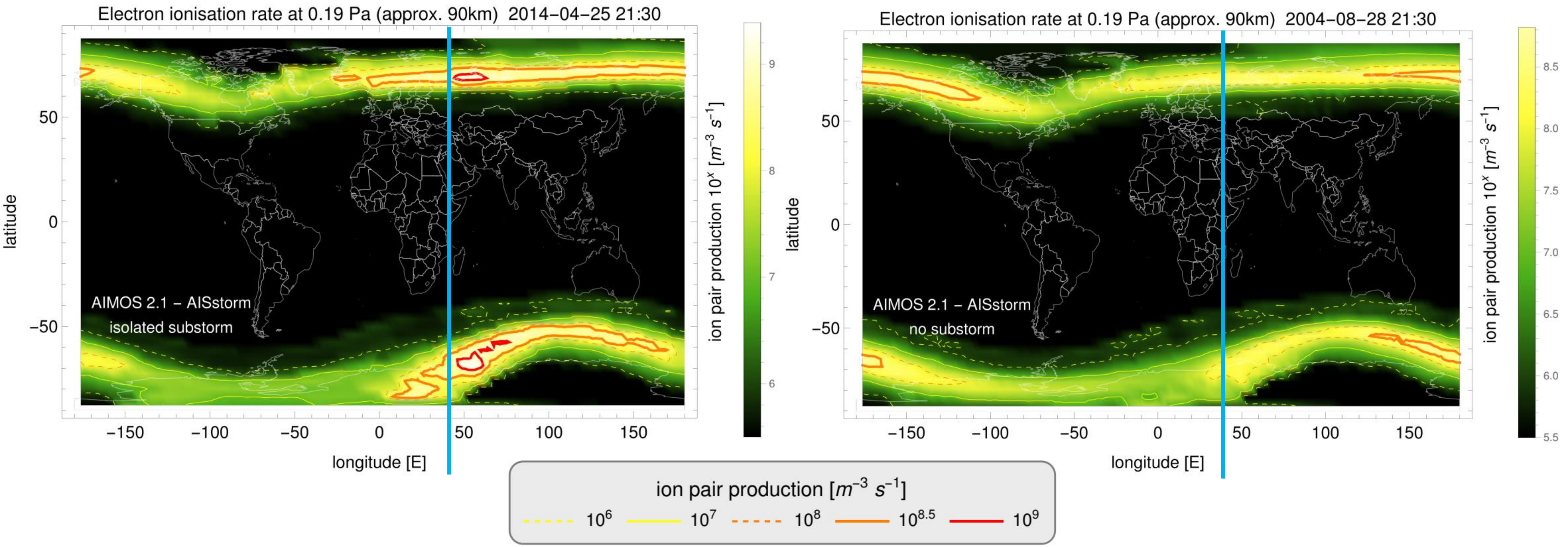
Quiet time:

Auroral ion pair production: ~$10^{6.5}$ m^{-3} s^{-1} at 90km

Geomagnetic storm:

Auroral ion pair production: >10^9 m^{-3} s^{-1} at 90km

Substorms

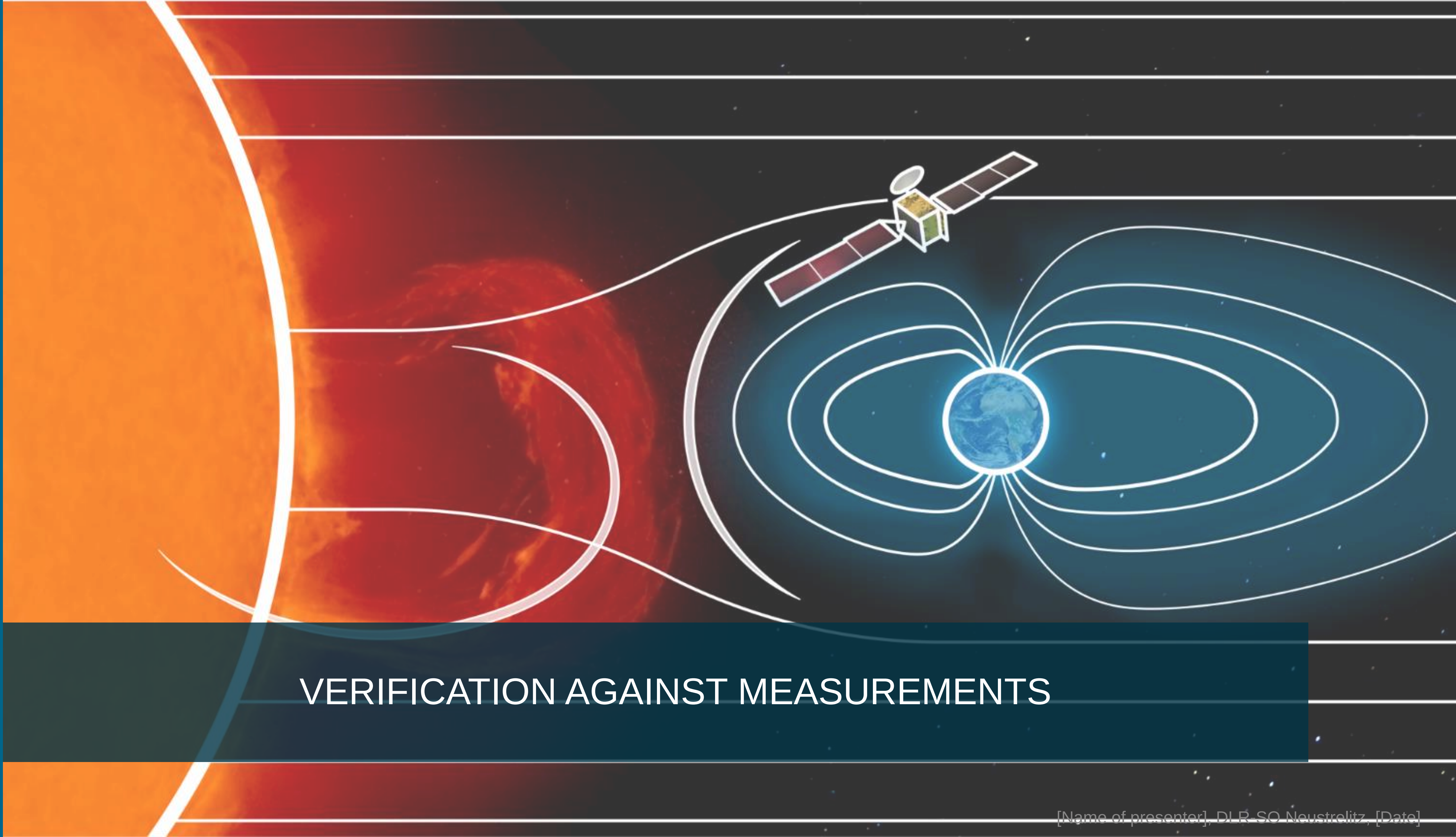


Isolated substorm:

- Additional intense ionization rates at local midnight (~40°E)

No-substorm:

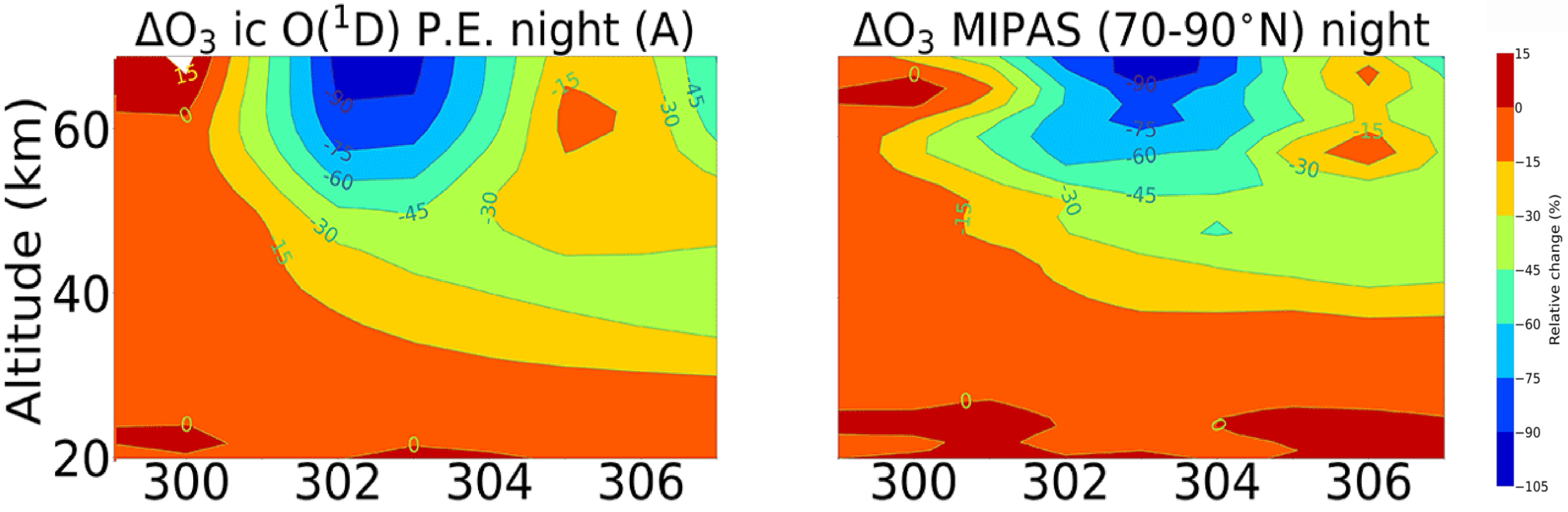
- Local midnight ionization decreased



VERIFICATION AGAINST MEASUREMENTS

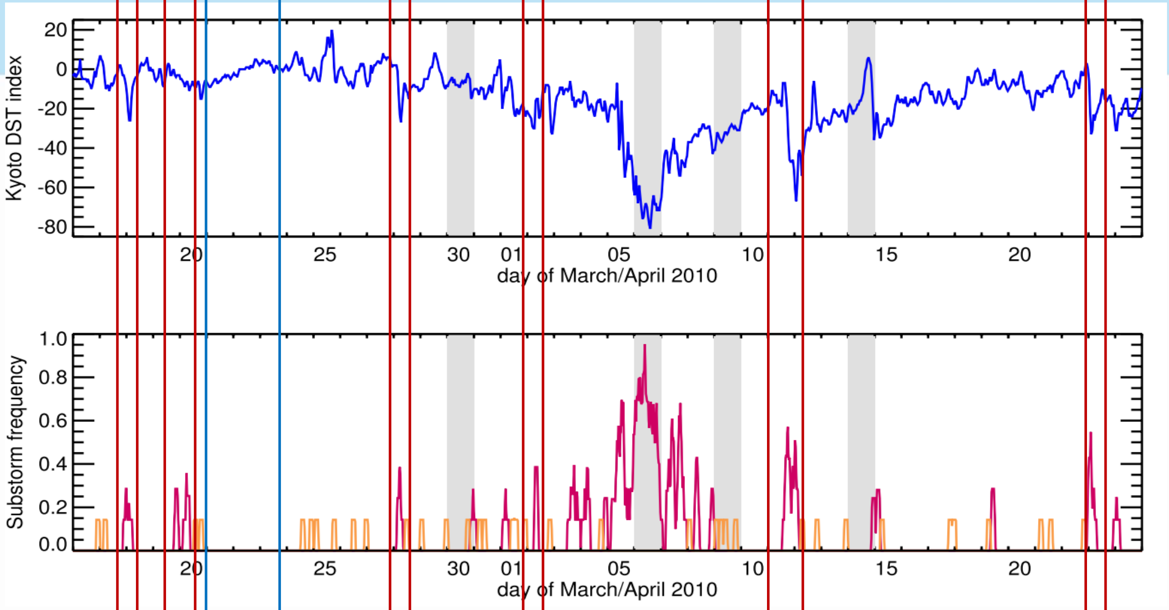
Verification of model chain AISstorm -> ExoTIC (KIT) by MIPAS/Envisat measurements

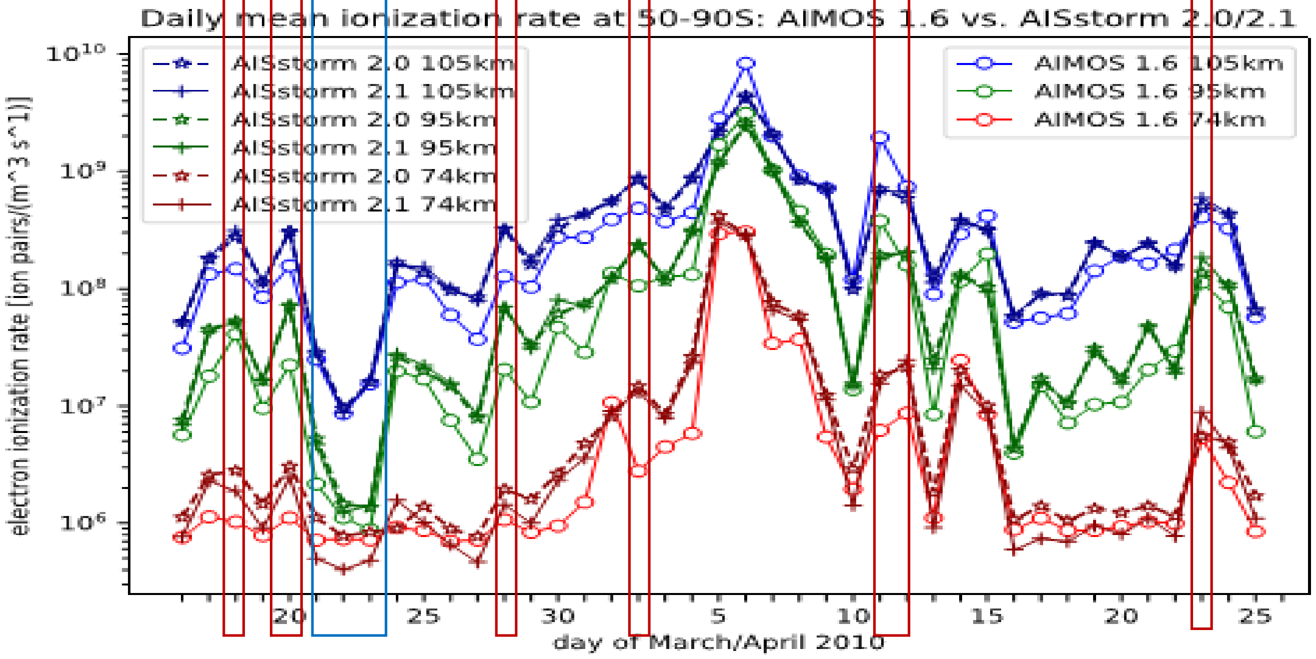
Ozone change during major event



- Collaboration with KIT in order to test their exoplanetary climate model with real forcing data from AISstorm
- Very convincing agreement with MIPAS/Envisat measurements of the Ozone change during a big event (upper panel)
- https://doi.org/10.5194/acp-23-12985-2023

Comparison to MIPAS/Envisat in HEPPA 3





JGR Space Physics

RESEARCH ARTICLE
10.1029/2021JA029466

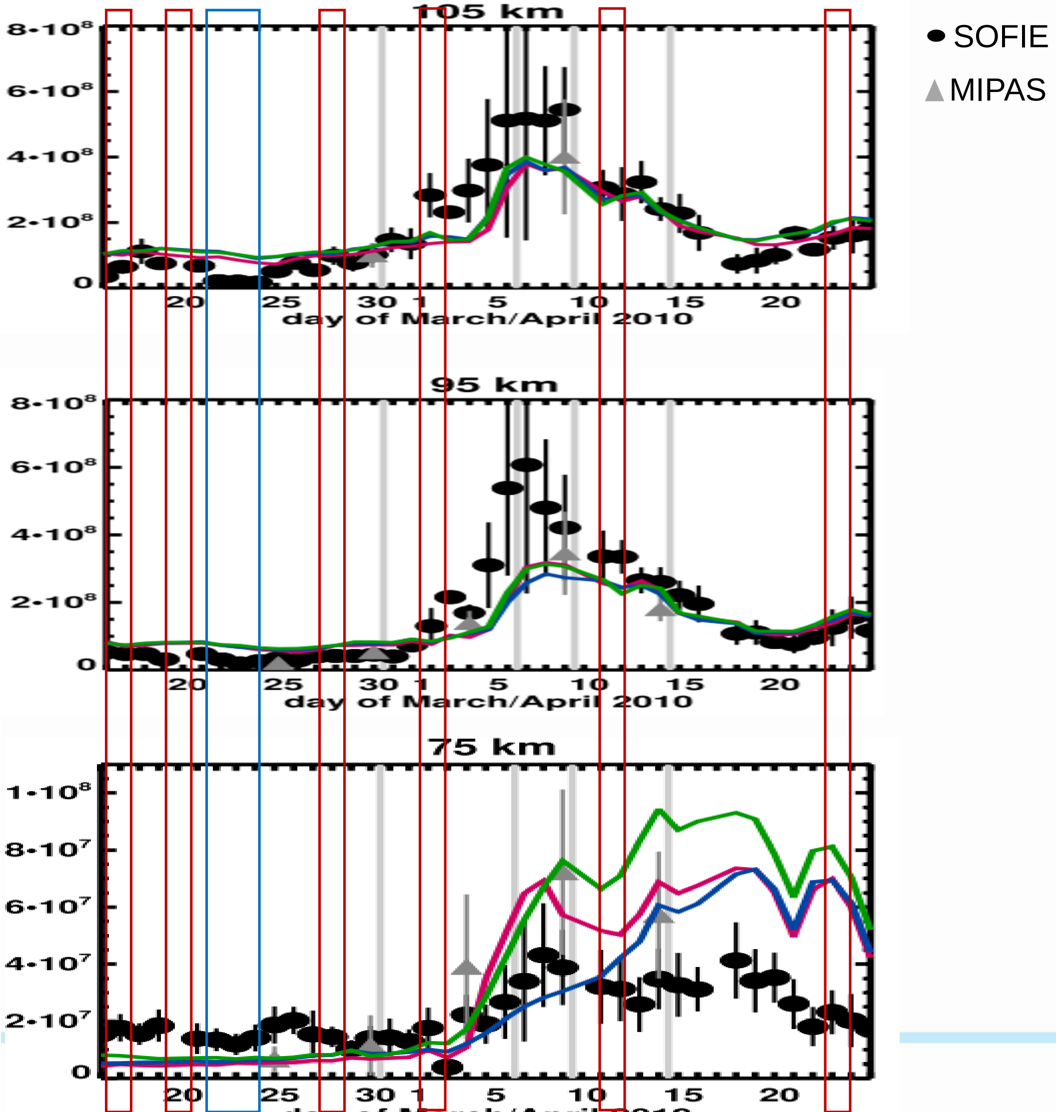
This article is a companion to Nesse Tyssøy et al (2021), https://doi.org/10.1029/2021JA029128.

Heppa III Intercomparison Experiment on Electron Precipitation Impacts: 2. Model-Measurement Intercomparison of Nitric Oxide (NO) During a Geomagnetic Storm in April 2010

M. Sinnhuber[1], H. Nesse Tyssøy[2], T. Asikainen[3], S. Bender[4,2], B. Funke[5], K. Hendrickx[6], J. M. Pettit[7], T. Reddmann[1], E. Rozanov[8,9], H. Schmidt[10], C. Smith-Johnsen[2], T. Sukhodolov[8,9,11], M. E. Szeląg[12], M. van de Kamp[12], P. T. Verronen[3,12], J. M. Wissing[13], and O. S. Yakovchuk[9,13,14]

Key Points:

- Differences between multi-model mean results at high latitudes are consistent with differences in the



Summary

AISstorm:

- **Derives atmospheric ionization due to particle precipitation**
- Able to reproduce impact from solar proton events, geomagnetic storms and substorms
- Verification of SPEs very convincing
- AISstorm shows increased dynamical fluctuations in phase with substorm activity than AIMOS and this seems to be in agreement to observations.

Use Cases

Ionization rates are used as:

- **Forcing for different chemistry climate models**
- Intercomparison studies with other IR models
- Evaluation of detector, IR, GCM against measurements
- Intercomparison with EISCAT, MIPAS/Envisat, SCIAMACHY/Envisat, SOFIE/Aim
- Verification of radiation belt impact
- Forcing of high latitude tidal waves
- Extreme case scenarios
- Ozone, NOx, HOx simulations
- UV impact
- Deriving origin of radar signals (SAURA radar)
- Validation or falsification of particle detectors (MEPED electrons, TED protons)

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