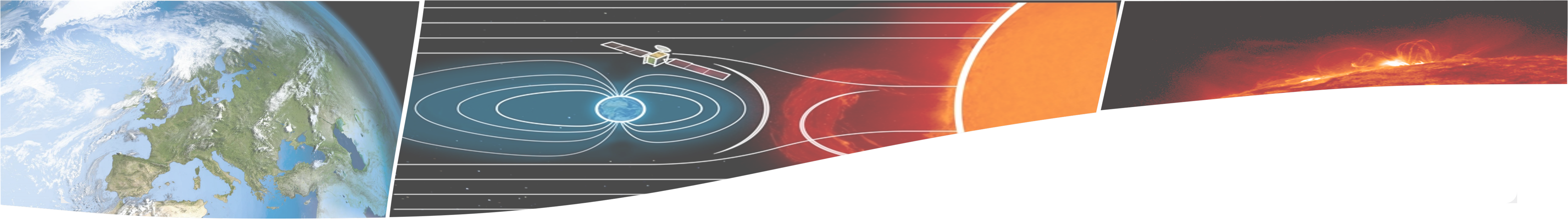

AISstorm 2.1
Modeling Particle induced atmospheric Ionization

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Abstract

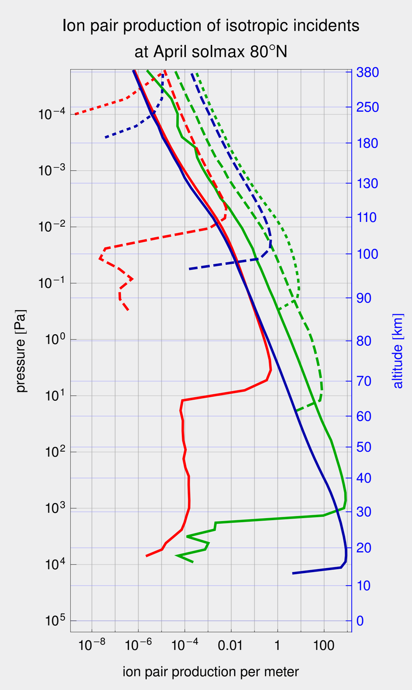
AISstorm (Atmospheric Ionization during Substorms Model) derives the global atmospheric ionization due to particle precipitation based on in-situ particle measurements. The model covers auroral precipitation as well as solar particle events on an altitude range of about 250km down to 16km for protons and down to 70km for electrons. The ionization of alpha particles is also included, but in a smaller height range. The overall structure is divided into an empirical model, which determines the 2D flux of the precipitating particles, and a numerical model, which determines the ionization profile of the individual particles. The combination of these two models results in a high-resolution 3D particle ionization rate pattern. AISstorm is the successor to the Atmospheric Ionization Module Osnabrück (AIMOS).

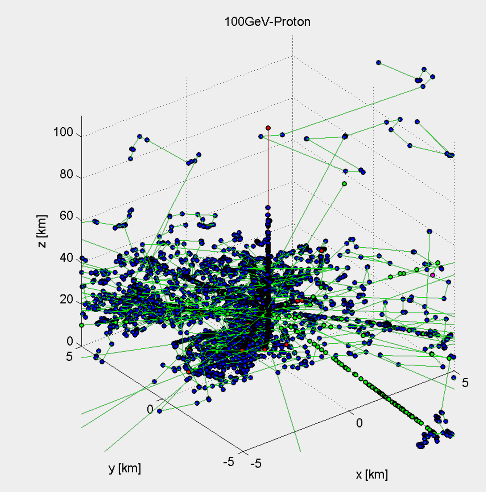
The main advantage of the updated ionization rates is a wider dynamic range during substorms and during the onset of geomagnetic storms, especially in the mesosphere - in agreement with observations.

The internal structure of the model has been completely revised in AISstorm. The main aspects are: a) an internal magnetic coordinate system, b) the inclusion of substorm properties, c) a higher temporal resolution, d) a higher spatial resolution, e) an energy-specific, separate treatment of auroral precipitation, polar cap precipitation and crosstalk-affected areas, f) a better MLT resolution.

We compare the new ionization rates to AIMOS 1.6, AISstorm 2.0 and the HEPPA III multi-model study.

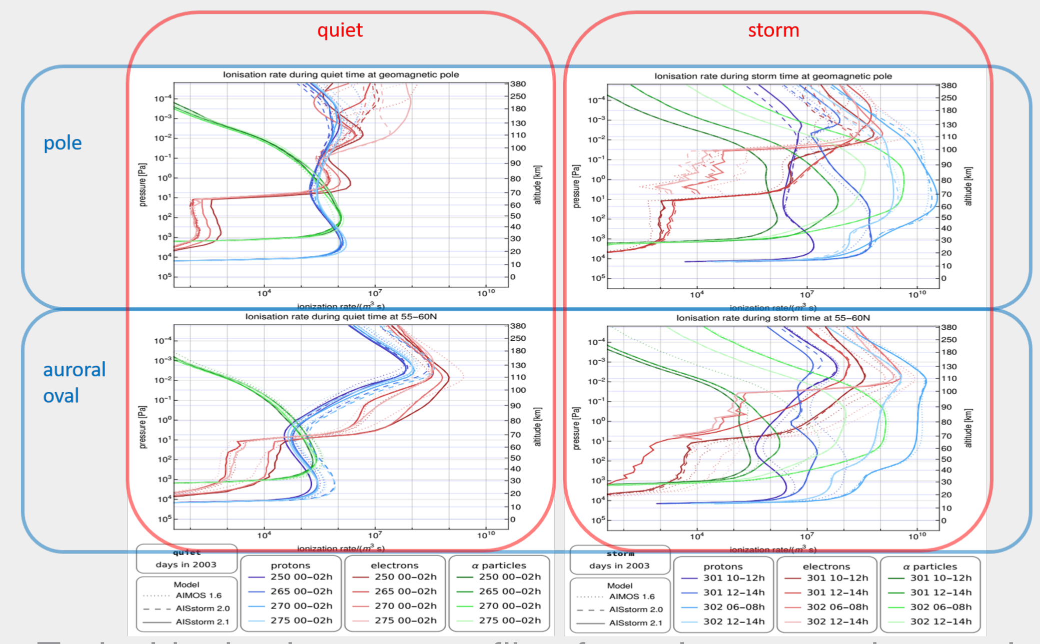
Atmospheric interaction





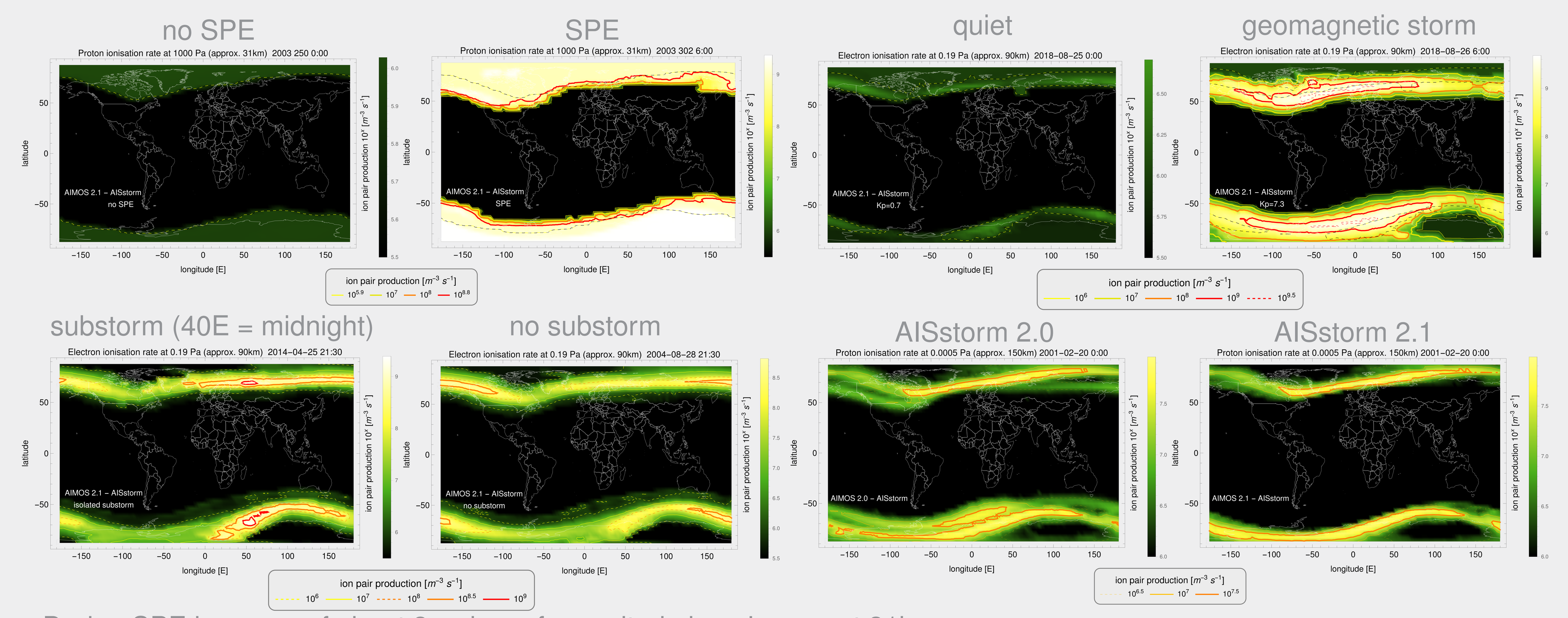
- Numerical model based on Geant4 calculates interactions, energy deposition and ionization rates.

Ionization profiles



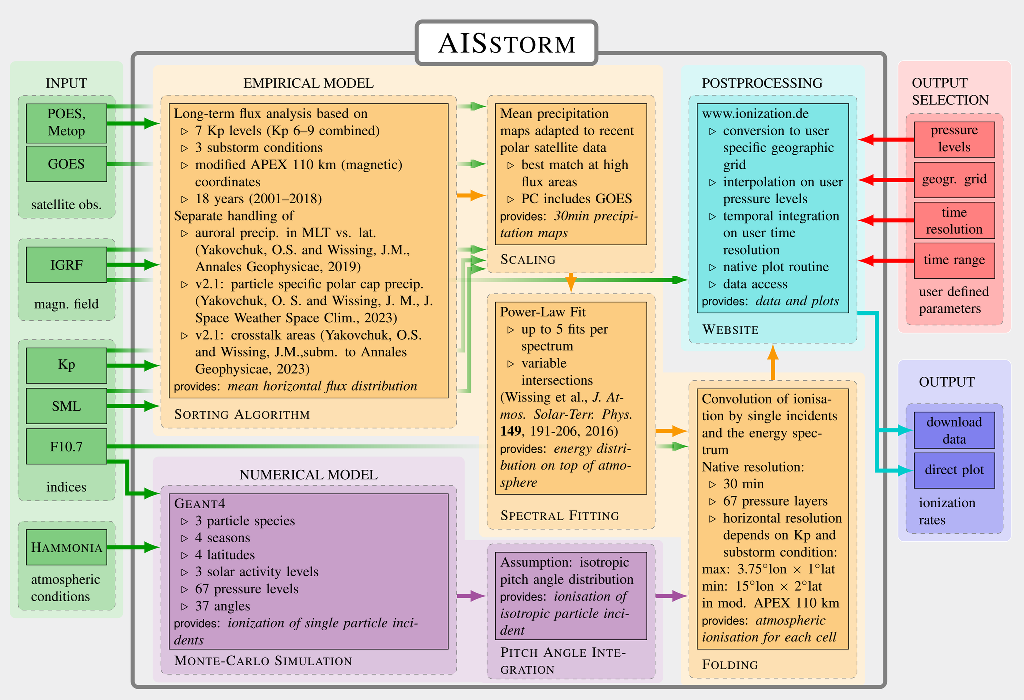
- Typical ionization rate profiles for polar cap and auroral oval during quiet and SPE conditions.

Spatial ionization pattern

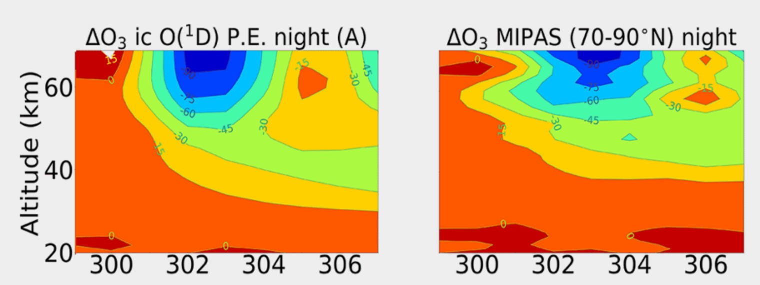


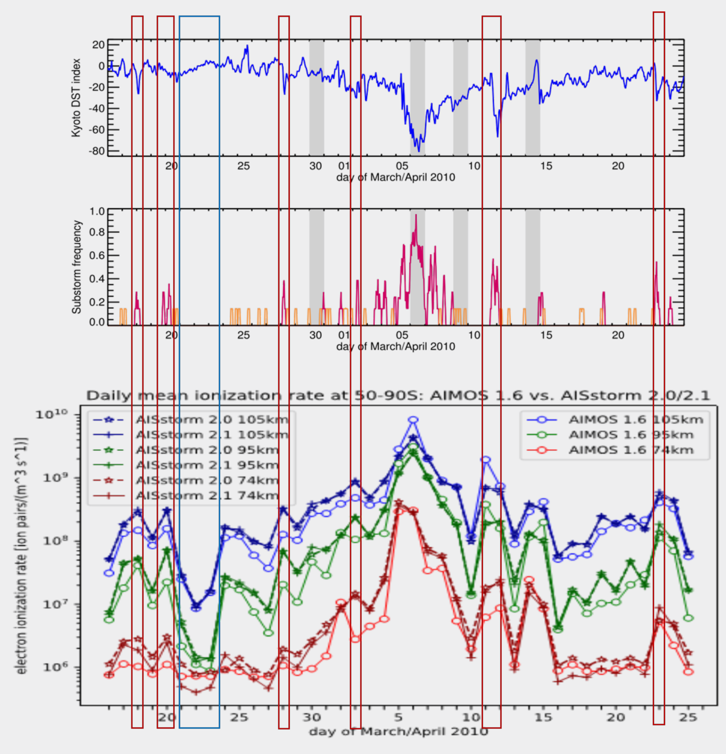
- During SPE increase of about 3 orders of magnitude in polar cap at 31km.
- Geomagnetic storm boosts ionization rates in the auroral oval by almost 3 orders of magnitude at 90km.
- During substorms the ionization at local midnight is enhanced.
- keV proton channels produce a subauroral ionization peak at about 150km. This may be a crosstalk effect!

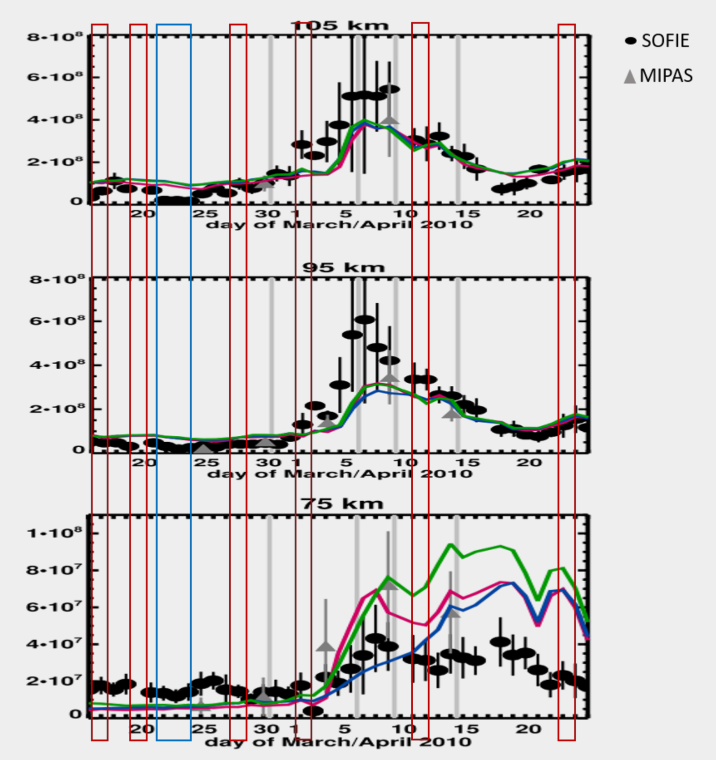
Model overview



Verification and benefit



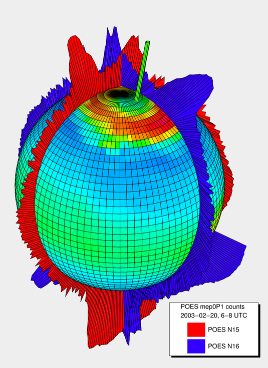


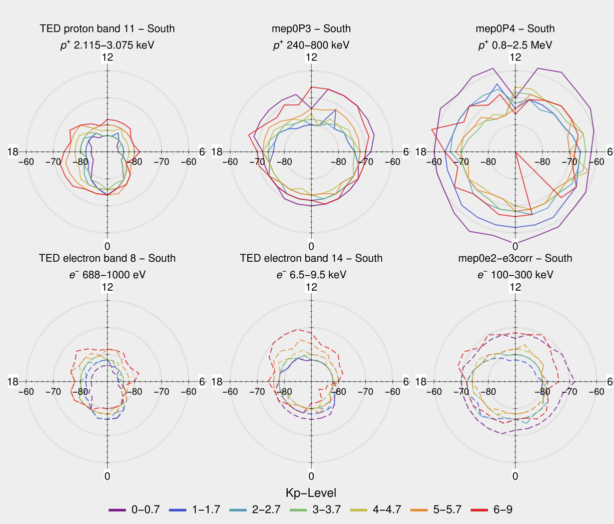


- (Verification, top) AISstorm ionization rates of the Octoberevent 2003 in the exoplanetary climate model ExoTIC lead to very convincing Ozone agreement with MIPAS/Envisat measurements [4].
- (Benefit, right panels) AISstorm input leads to increased dynamical NO fluctuations in phase with substorm activity (red boxes: substorm, blue: no substorm). This seems to be in agreement to observations from SOFIE and MIPAS especially at 75km [5].

Global coverage

- Mean precipitation maps from [2] are used depending on Kp and SML.
- Scaled by recent measurements from POES and Metop in the dominant precipitation regions.





- Polar particle flux areas from [3] determined by similarity of flux distributions allow e.g. spatial mapping of GOES. Images from [1] and [3].

References:

[1] Wissing & Kallenrode 2009: "Atmospheric Ionization Module Osnabrück (AIMOS)", JGR: Space Physics, Vol. 114, A6

[2] Wissing & Yakovchuk 2019: "MLT asymmetries in precipitating electron and proton populations with and without substorm activity", Vol. 37, issue 6 ANGEO, 37, 1063–1077

[3] Yakovchuk & Wissing 2023: "Polar particle flux distribution and its spatial extent", J. Space Weather Space Clim. Vol. 13

[4] Borthakur et al. 2023, "Impact of chlorine ion chemistry on ozone loss in the middle atmosphere during very large solar proton events", ACP, 23, 12985-13013

[5] Sinnhuber et al. 2021, "HEPPA III"JGR: Space Physics, Vol. 127, Issue 1

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