

# *Variation of particle induced ionization due to different models and boundary conditions*

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Nadine Wieters<sup>b</sup>, Holger Winkler<sup>b</sup> and Miriam Sinnhuber<sup>b</sup>



October 7, 2009

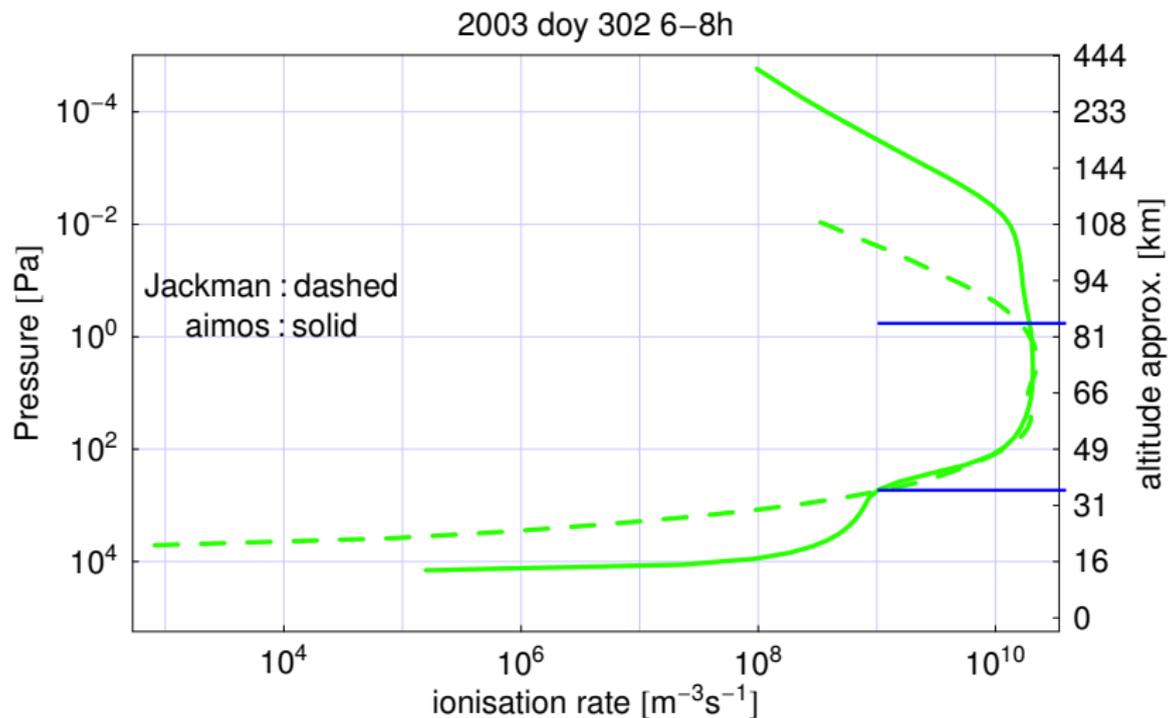
# *introduction*

## *particle induced ionization*

- ...is used as input for climate modeling
- ...is linked to NO<sub>x</sub> production and ozone
- ...should not depend (severely) on the model. General agreement is desirable... but realistic?

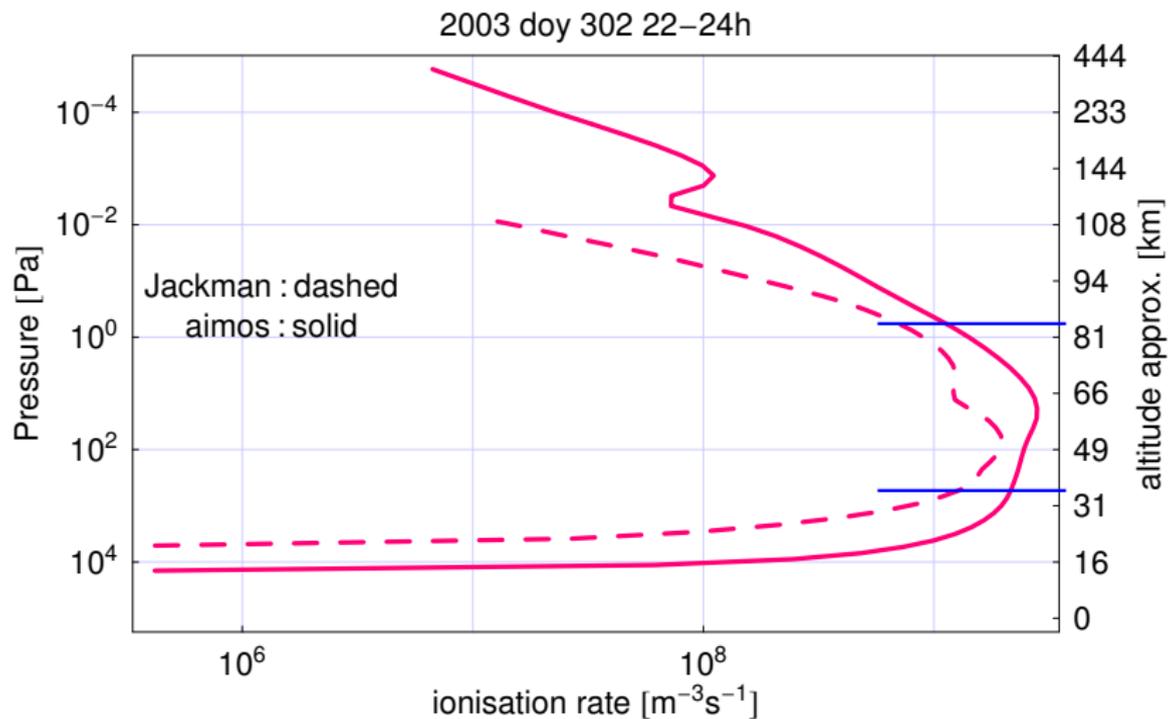
# motivation

good agreement (at altitudes covered by both models, 35-85 km)



# motivation

poor agreement



# *introduction*

## *general problem*

- Ionization models do not always “perfectly” agree.

Which conditions impair intercomparison of ionization models?

## *This talk will discuss:*

- reasons and
- implications on climate and atmosphere modeling.

## *possible reasons*

*potential suspects for variations between models are:*

- horizontal resolution (cap definition)
- particles considered (in particular electrons)
- different input data sets due to satellite selection (e.g. slightly different orbit, instrument performance)

Basic assumption: altitude/particle energy range is adequate.

## horizontal resolution (in particular cap definition)

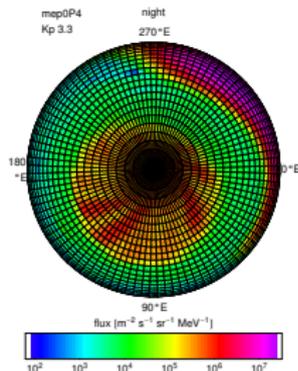
### polar cap

Common assumption: homogeneous precipitation in the polar cap  
 However the extension of the polar cap may differ:

- In **1D models** the polar cap often is defined as  $60^\circ$  polewards.

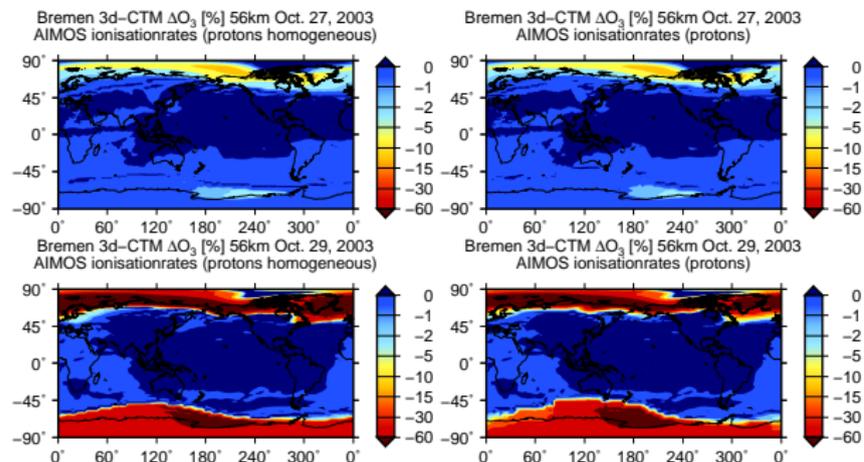
In **3D models** the cap definition might be based on direct measurements. (e.g.

- AIMOS empirically uses the high-energetic POES channels to determine the polar cap.) [Wissing and Kallenrode, 2009]



*polar cap definition: impact on ozone depletion modeling?*

- same flux: October event 2003, protons only
- same climate model: Bremen 3d-CTM, altitude range up to 65 km
- polar cap definition: 60° poleward vs. empirical



[Wissing et al., 2009b]

*detailed  
information:*

by N. Wieters  
and M.  
Sinnhuber in a  
few minutes

*No significant difference*

- Note: only solar protons are considered here (magnetospheric particles don't get down to 56 km)

## *missing particle species: impact on modeling?*

*Yes, electrons are significant!*

- Limited impact on altitudes below 65 km and within a solar event but definitely existent.
- Extended impact on altitudes above 65 km and within geomagnetically quiet time and of course in the auroral region.

*advertisement*

More on this topic will be shown by Nadine Wieters and Miriam Sinnhuber in a couple of minutes.

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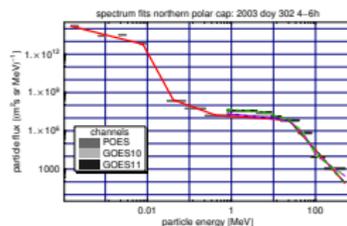
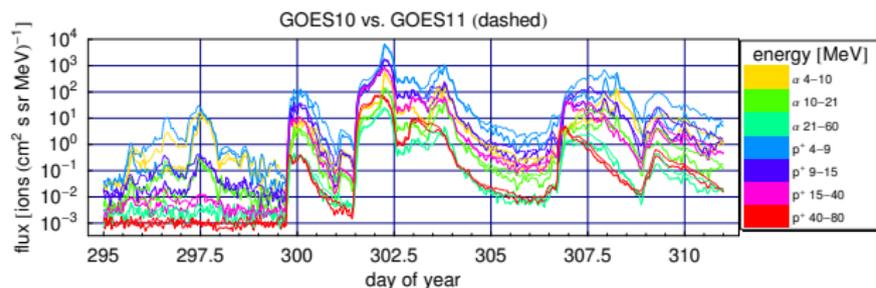
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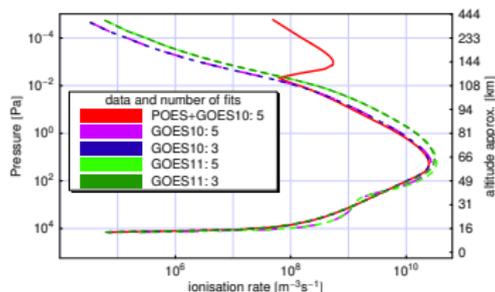
However none of the figures in the motivation contains electron ionization.

# satellite selection

## different input data set



- nominally same instruments
- different satellites (GOES-10/11)
- variation of input data (satellite in magnetosphere/magnetosheath)
- causes variation of ionization data up to an order of magnitude



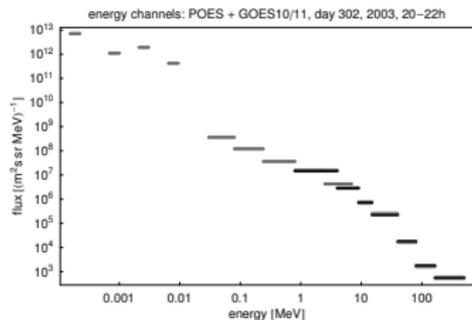
*Assuming these qualifications (same resolution, particle data, species) are fulfilled - variations persist!*

May boundary conditions be the culprit?

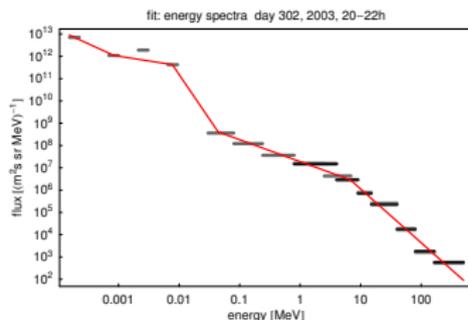
- fit function?
- energy range?

# insights into ionization operation methods

## satellite measurements

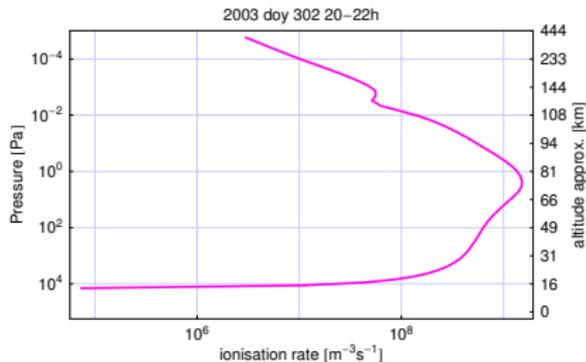
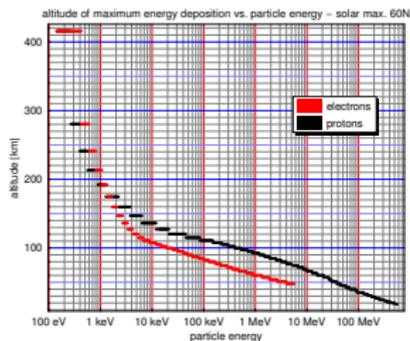


## fit function



## ionization model: ionization as function of particle energy

[Wissing and Kallenrode, 2009]



## *fit of the energy spectrum*

*fit function: the link between satellite measurements and ionization model*

- creation of a (necessarily) continuous particle spectra **always** includes assumptions on the shape of the spectra (fit function)

*Note:*

The fit function seems to be one of the pivotal (or even the main) driver/s of errors.

# *fit functions*

## *typical fit functions*

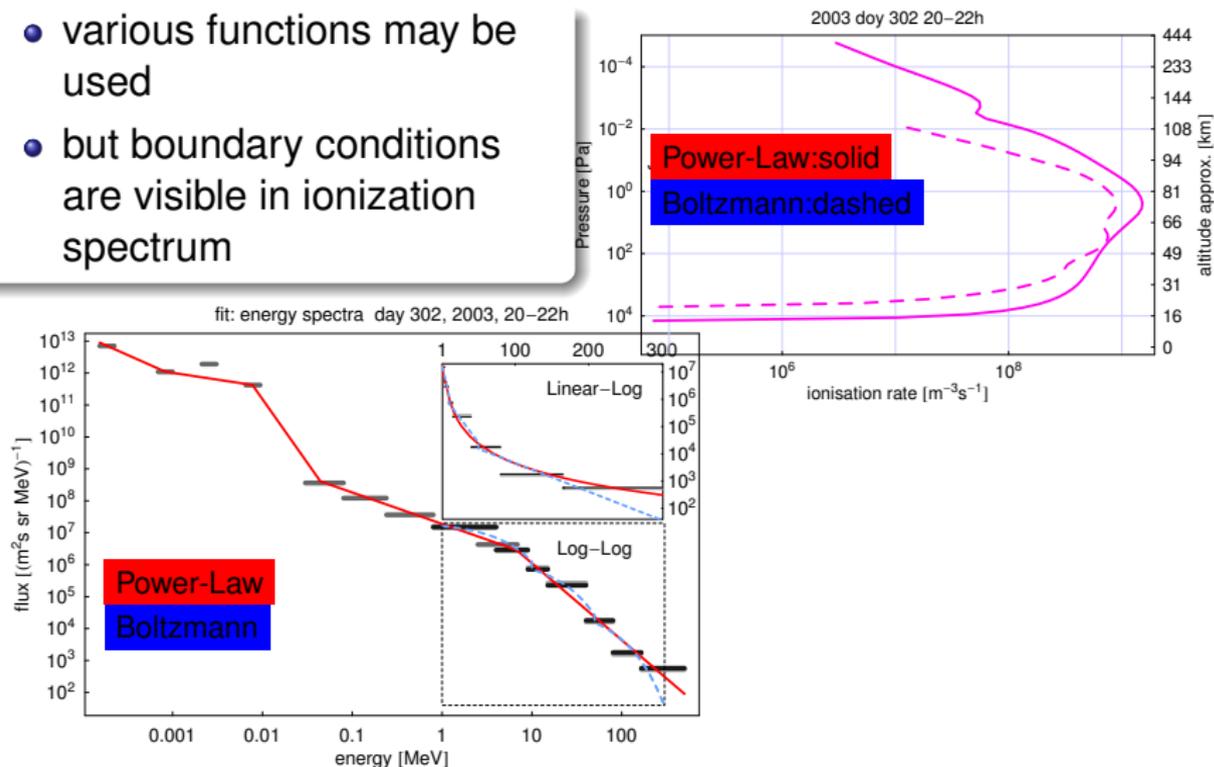
- Power-Laws
  - shock acceleration
  - $N(E) = K_C E^{-\gamma}$
  - straight line in log-log graph
- Boltzmann distribution
  - thermal spectra
  - $N(E) = K_B \exp(-E/(kT))$
  - straight line in linear-log graph

## *additional variables*

- energy range of the spectra
- number of fits/intersections
- variable or fixed position of intersections

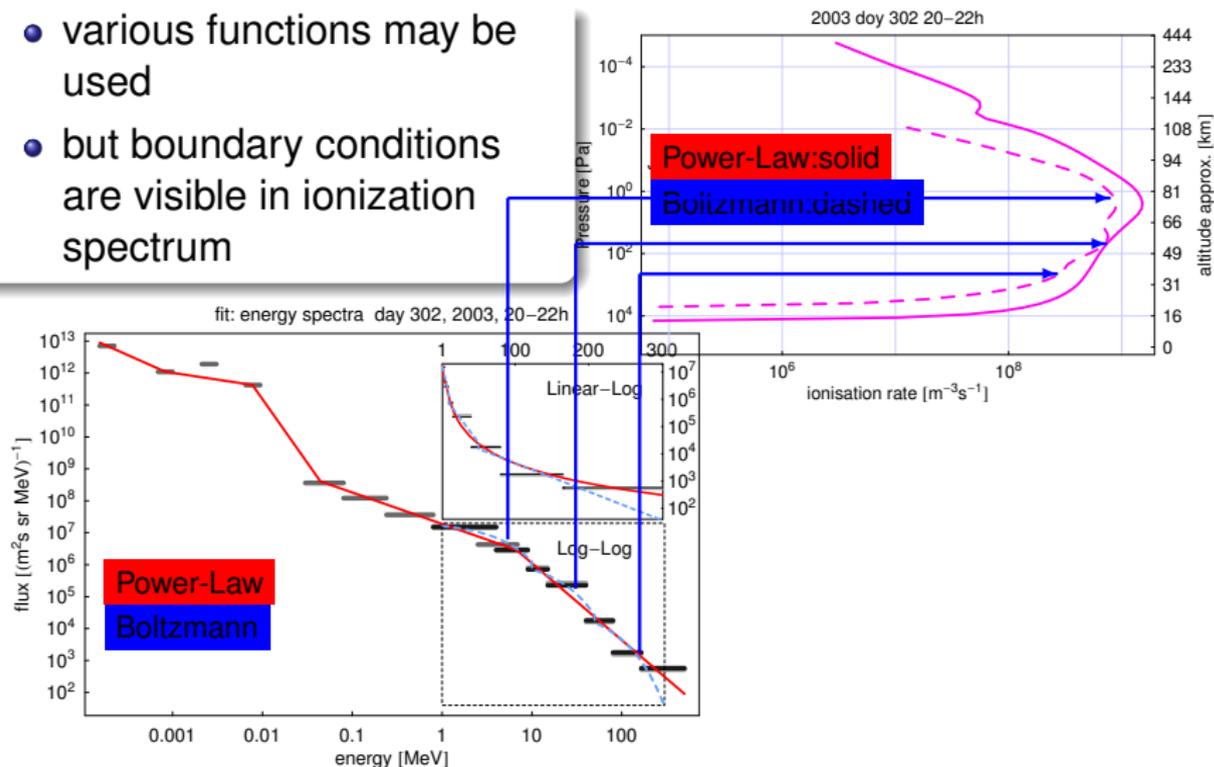
# assumptions on fit function show up in ionization

- various functions may be used
- but boundary conditions are visible in ionization spectrum



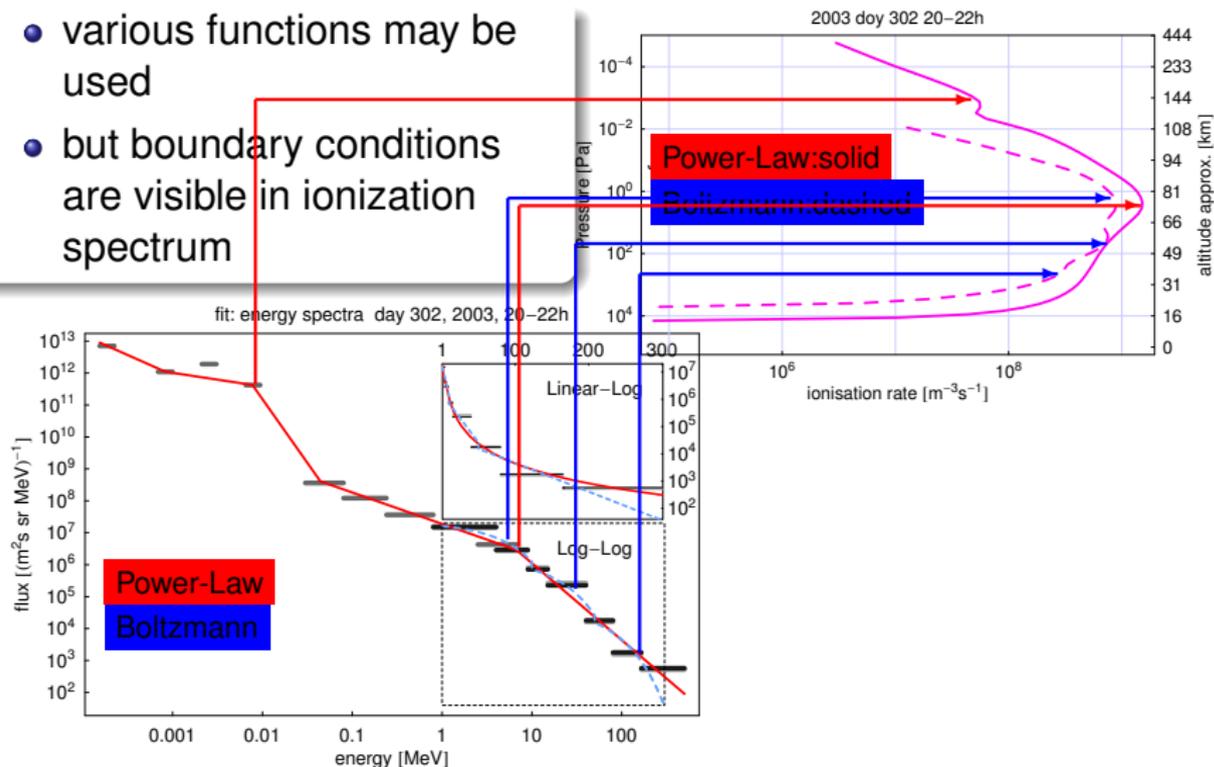
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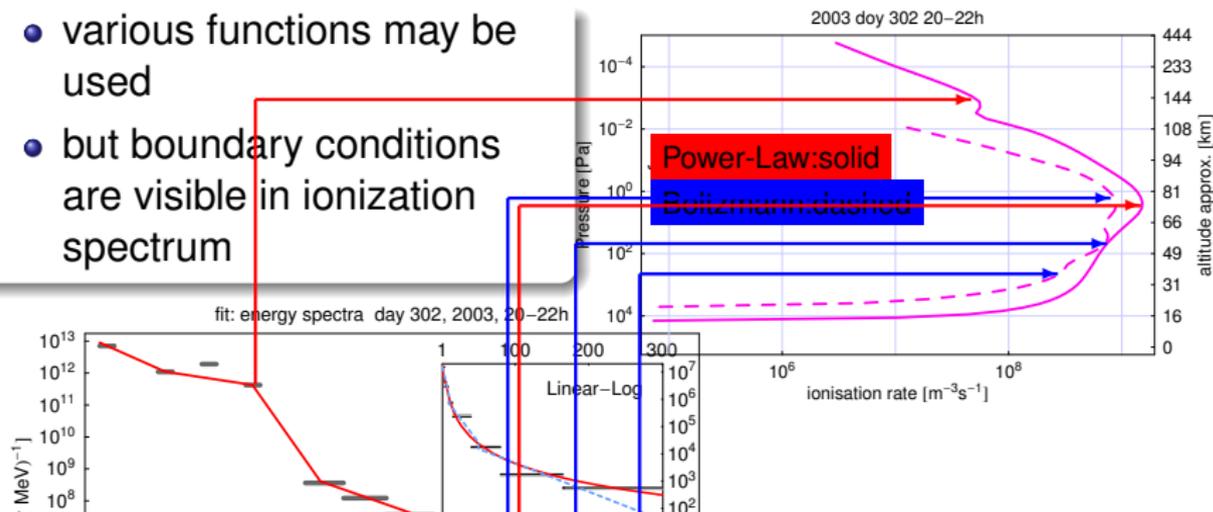
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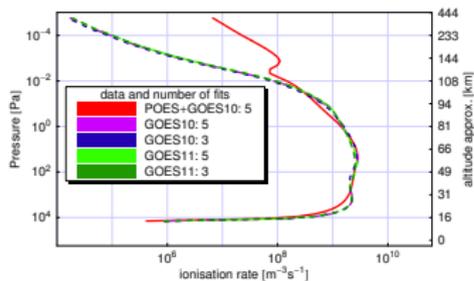
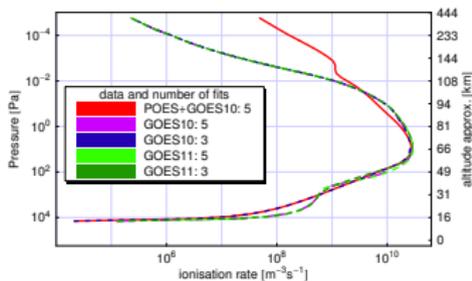
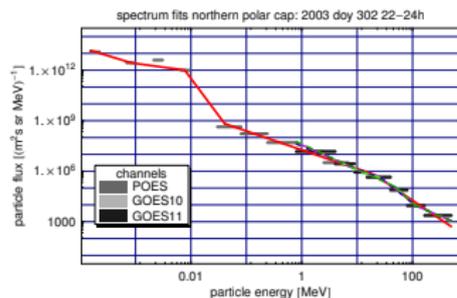
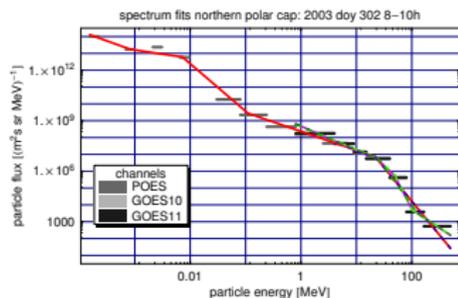
### impact of fit function

- Every fit function shows its characteristics in the ionization profile.
- In case of fixed intersections the ionization profile even may show constant characteristics.

# energy range

extended energy range (e.g. down to 150 eV)

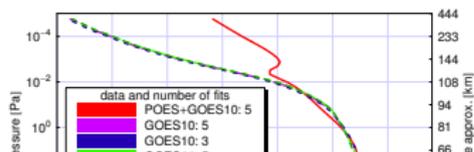
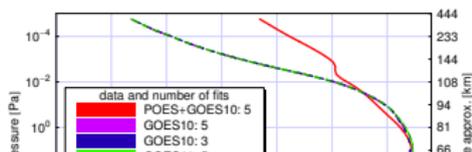
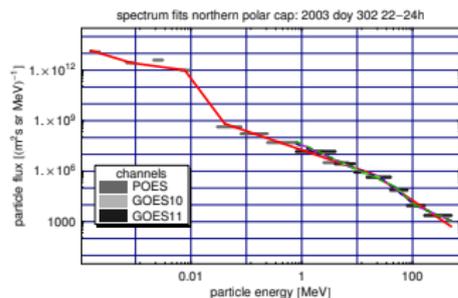
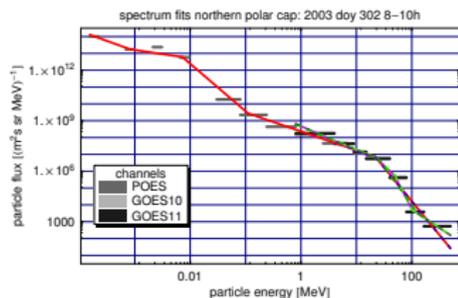
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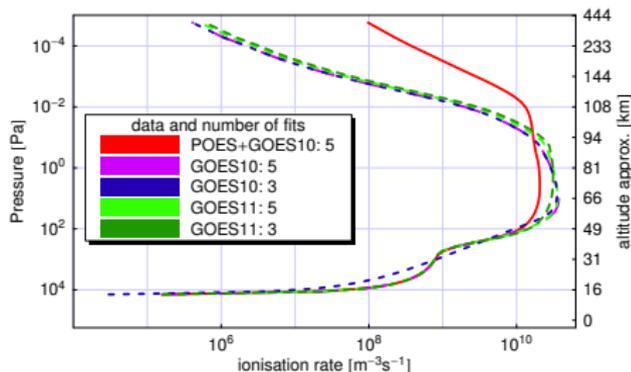
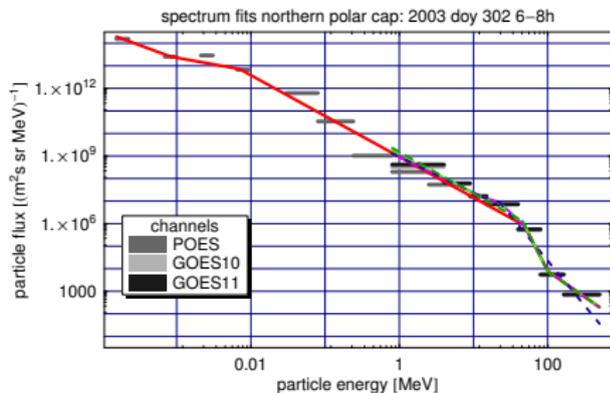


*But an extended energy range may affect other altitudes!*

ionisation rate [ $\text{m}^{-3}\text{s}^{-1}$ ]

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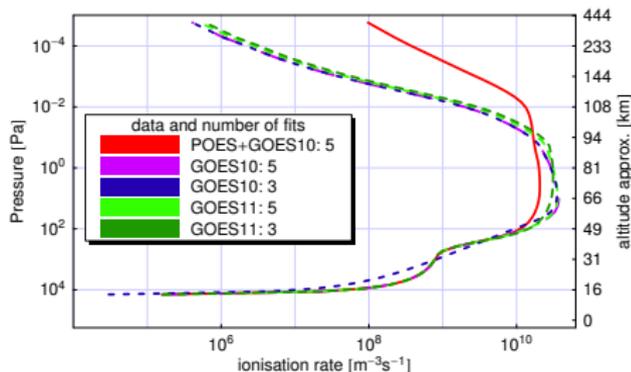
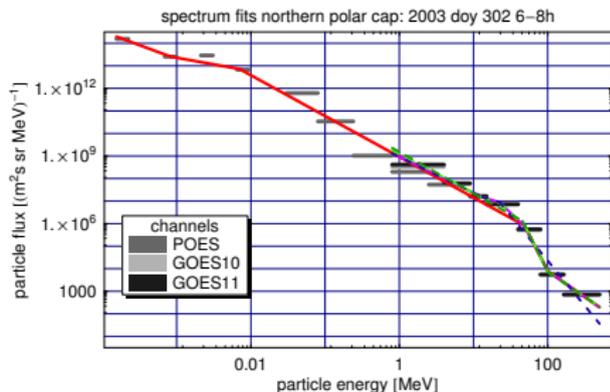
Extended energy range implies variations at lower altitude due to other fit parameters



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### *general problem*

Variations due to energy range and fit function affect **all** ionization models based on particle measurements.



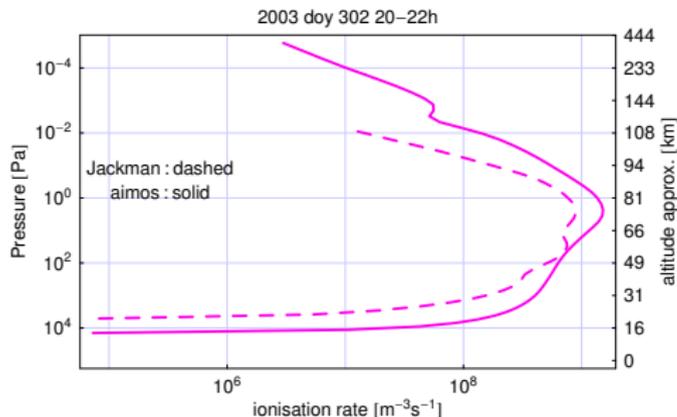
## *direct effects of the ionization model*

Assuming that boundary condition effects are under control, do the ionization models agree now?

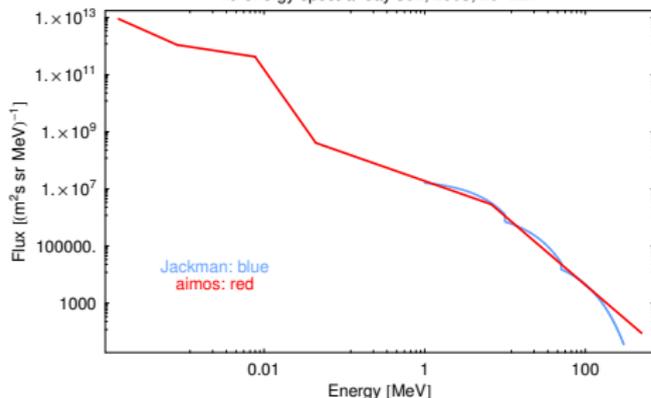
# direct effects of the ionization model

## energy

- same input from precipitating particles
- factor 2 in atmospheric deposition/ionization



fit: energy spectra day 302, 2003, 20-22h



## origin not identified

Both models will be re-checked regarding to:

- identical assumptions
- energy conservation
- agreement with measurements

## summary

### input values

- no 3D resolution needed for proton ionization below 65 km (60° cap)
- electron impact should be considered (listen to next talks ;-)
- similar instruments on different satellites may cause a factor 10 in ionization

### fit function

- **every** kind of/assumption on the fit function severely affects ionization profile
- different energy range may also affect the ionization rate as minimal variation in the spectrum fit easily creates significant variation in the ionization profile
- **impact of fit function and energy range is as important as the ionization model itself**

### open question

- How to improve the model chain?
- Which part of of the model chain has to be adjusted:
  - ionization modules or
  - production rates/interaction cross sections ( $\text{NO}_x$ ,  $\text{HO}_x$ )?

## Thanks to...

- Charles Jackman for providing spectra and ionization rates for the comparison.
- the DFG for their financial support.
- the audience.

## references



Wissing, J.M., and M.-B. Kallenrode, Atmospheric Ionization Module OSnabrück (AIMOS) 1: A 3D model to determine atmospheric ionization by energetic charged particles from different populations, *J. Geophys. Res.*, **114**, A06104, doi:10.1029/2008JA013884, 2009



Wissing, J.M., M.-B. Kallenrode, M. Sinnhuber, H. Winkler, N. Wieters, AIMOS 2, *J. Geophys. Res. in press*, 2009