Progress in Cloud Electrification Model within COSMO NWP model

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$$\frac{\delta n_{\pm}}{\delta t} = -\nabla(n_{\pm}V \pm n_{\pm}\mu_{\pm}E - K_m \nabla n_{\pm}) + \boldsymbol{G} - \alpha n_+ n_- - S_{att} + S_{pd} + S_{evap}$$

$n_{\pm}V$	advection
$K_m \nabla n_{\pm}$	turbulent mixing
$n_{\pm}\mu_{\pm}E$	ion drift motion
$\boldsymbol{G}$	**ion generation rate by cosmic rays**
$\alpha n_+ n_-$	ion recombination rate
S_{att}	ion attachment to hydrometeors
S_{pd}	point discharge current
S_{evap}	release of any charge as ions from evaporated hydrometeors

Fig. 1 Ion equation in CEM-COSMO.

1/ Introduction

CEM, the Cloud Electrification Model, is a model which simulates electrical discharges explicitly and we implemented it into COSMO NWP model.
One of the source terms in the ion equation (Fig. 1), which is the main body of the CEM, is the ion generation rate by cosmic rays (G). G describes the change of the number concentration of positive and negative ions in time and height.
Generally, G is expressed analytically for fair weather conditions (**G def**). In our case, however, we compare Gdef with G (**G0**) based on ground measurements and calculations in CRAC: CRII model (Cosmic Ray Atmospheric Cascade: Cosmic ray induced ionization; Usoskin et al., 2010).
Fig. 2 depicts Gs that we consider in CEM.

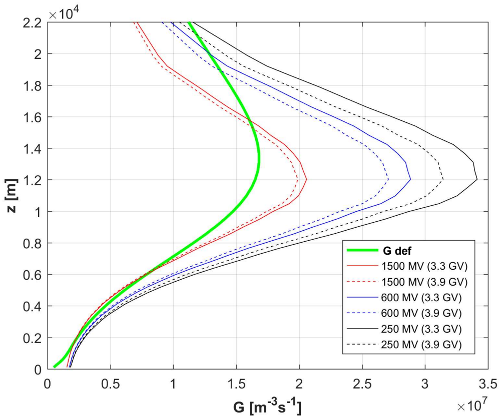

Fig. 2 Dependence of **G** [$m^{-3}s^{-1}$] on altitude [m]. **G def** depicts the analytical solution, while 1500, 600 and 250 MV the modulation potential, which corresponds to strong, mean, and weak solar activity, respectively; 3.3 GV (solid line) and 3.9 GV (dashed line) represent the value of cutoff rigidity. Except for Gdef, Gs are calculated in CRAC: CRII model based on observations.

Acknowledgements: We owe great thanks to Jakub Šlegl, who has made the calculations of G0 in the CRAC: CRII model.

2/ New approach to a source term G in the ion equation in CEM

In case of G as a function of height from CRAC: CRII model, equations below get overdetermined.

$\alpha = 1.6 \times 10^{-12}\ m^{-3}s^{-1}$
$e = 1.60217662 \times 10^{-19}$ C
$\epsilon = 8.8592 \times 10^{-12}\ F\ m^{-1}$

$$\frac{d}{dz}(n_p \mu_p E) = \boldsymbol{G} - \alpha n_p n_n$$

$$-\frac{d}{dz}(n_n \mu_n E) = \boldsymbol{G} - \alpha n_p n_n$$

$$\frac{d}{dz}E = \frac{e}{\epsilon}(n_p - n_n)$$

n_p, n_n number concentration of ± ions

μ_p, μ_n ion mobility: $\mu_p = 1.4x10^{-4} exp^{1.4x10^{-4}z}$, $\mu_n = 1.9x10^{-4} exp^{1.4x10^{-4}z}$

E vector electric field [V m^{-1}]

→ We release E and calculate it numerically (**G cal**).

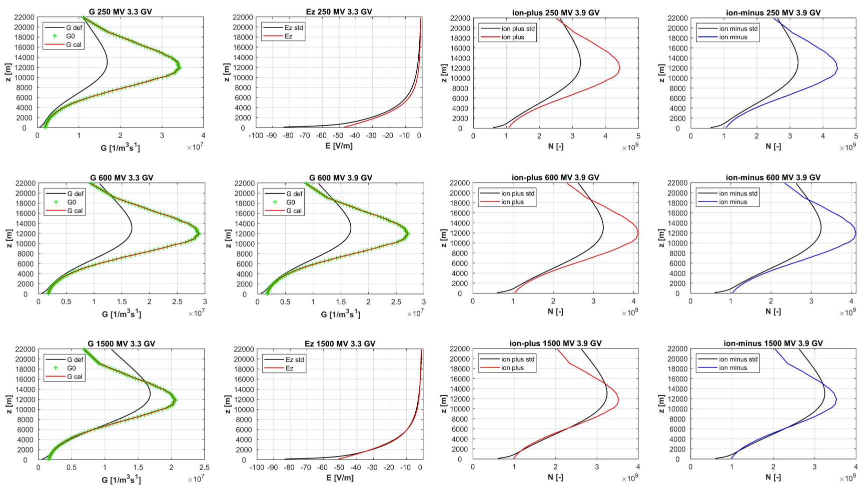

Fig. 3 Difference among **Gdef** and **G0**, **G cal** (1st column) and corresponding electric field E (2nd column), number concentration of positive ions (3rd column) and negative ions (4th column). From top to the bottom it corresponds to solar modulation potential of 250, 600, and 1500 MV, respectively. Diagrams are shown for a cut-off rigidity of 3.3 GV on two left panels except one and for a cut-off rigidity of 3.9 GV on the two right panels.

3/ Conclusions

- New approach to G in CEM seems reasonable
- Use of diverse G makes sense in CEM
- Discrepancy between G def and G cal close to the ground might be related to other processes (e.g., radon) that are not considered in CRAC: CRII model

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