Cloud electrification modelling
Preliminary results

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2/ Research project CREAT

The research project CREAT funded by EU & Ministry of Education of Czechia is a joint interdisciplinary project of Nuclear Physics Institute & Institute of Atmospheric Physics of the Czech Academy of Sciences, & Czech Technical University in Prague. The project CREAT (2016-2022) deals with Cosmic Rays and Radiation Events in the Atmosphere, and meteorologists are collaborating on it since recent studies suggested a likely connection between the cosmic rays and the genesis of lightning.

3/ Cloud Electrification Scheme

Convection, ice phase & strong updrafts are essential to cloud electrification, which starts by charge separation within the cloud particles. The charge separation can be inductive (dependent on the external electric field) or non-inductive.

The charge separation mechanism consisting in rebounding during the collisions of a hydrometeor with other particles is considered as the main contribution to the electrification:

During collisions the charge separates and the hydrometeor gets ionized (Fig. 1).

In our new model, we implemented the Gardiner/Ziegler (GZ) and the Takahashi (TA) schemes (Mansell et al., 2005) that enables to parametrize the non-inductive charge separation via collision among graupel, ice, snow and hail hydrometeors.

4/ Implementation

The cloud electrification scheme was implemented into the COSMO NWP model using 2-moment cloud microphysics.

The scheme contains:
- Equations describing positive and negative ion motion and the interactions of ions with hydrometeors.
- Charging and charge transfer among the hydrometeors.

The model was run at a time step of 6s to simulate the electrification during one hour (simulated time) and the horizontal resolution was 2 km.

An example of the model performance is illustrated in Fig. 2 using a prototype of a severe storm. Figure shows how the electric charge develops in time in a vertical cross-section through the centre of the storm in the direction of the storm motion. The electric field shows the development of the typical tripole (multipole) structure in a thundercloud.

It is supposed that basic structure should be: positively charged regions in the upper section and near the base of the cloud and a negatively charged region between. Figure shows that the model separates charges and that the results are dependent on the selected scheme and its parameters.

Since the new model has not explicitly treated the lightning yet, the charged regions remain without being discharged even when the conditions for discharge is fulfilled (after 0+25 min). The explicit treatment of lightning is the objective of our current research, which will soon be presented.

Fig. 2 Vertical profile [m] of electric charge [nC] and vertical velocity (contours) in a thundercloud at simulation time of (left) 0+25min and (right) 0+35min. The positively and negatively charged regions are depicted in red and blue, respectively. GZ scheme is tested for three threshold temperatures, at which the charge is thought to reverse; TA scheme is based on Takahashi’s experiments.

5/ Conclusions and Future Perspectives

Conclusions
A 3D model describing cloud electrification has successfully been developed and implemented into the COSMO model.

The model includes GZ and TA electrification schemes, the explicit parametrization of non-inductive cloud charge separation.

In case of idealized thundercloud, the model reproduces the structure of the charge with two positively charged layers separated by a negatively charged layer.

Future Perspectives
The model will be extended by including the explicit treatment of discharges and lightning, and will again be tested on idealized cloud.

The developed 3D model will then be tested on real data from the Czech Republic. Three case studies are going to be investigated.

The future research within the project CREAT aims at combining the developed model of electrification and lightning with that modelling the upper-atmospheric lightning.

References


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