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Interactive comment on "CELLS v1.0: updated and parallelized version of an electrical scheme to simulate multiple electrified clouds and flashes over large domains" *by* C. Barthe et al.

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Response to Anonymous Referee 1

We would like to thank this referee for her/his comment that helped to improve the manuscript.

This paper presents results of numerical simulations of two thunderstorm case studies, introducing a novel way to model lightning discharges as a function of time along the storm life cycle. The approach is innovative and prudent and is based on present understanding of the propagation of lightning channels and the removal of charge from

different regions inside the electrified thunderclouds. The model proceeds beyond a single-cloud simulation and offers new insights on the overall lightning activity of the entire storm. As such it presents significant progress in modeling the electrical behavior of storm systems and in principal offers a tool for detailed study of large scale convective systems, their dynamics, microphysics and electrical states.

Major comments

1. In section 3.1 the authors chose to use the parameterization of the non-inductive charge separation mechanism based on the laboratory work of Takahashi (1978). However, this formulation had been modified and updated to accommodate the results of laboratory experiments by other groups (e.g. Avila et al., (1998) and Saunders et al., 1998). The integrated formulation is reviewed by Saunders (2008). The authors need to explain their choice of the T78 parameterization, at least by referencing the sensitivity studies performed by Mansell et al. (2005) [E. R. Mansell, D. R. MacGorman, C. L. Ziegler, and J. M. Straka, 2005: Charge structure and lightning sensitivity in a simulated multicell thunderstorm, J. Geophys. Res., 110, D12101, doi:10.1029/2004JD005287].

In Meso-NH, several parameterizations of the non-inductive process are coded: Takahashi (1978), Saunders et al. (1991), Saunders and Peck (1998) and Gardiner et al. (1985). Up to now, all existing parameterizations relies on laboratory studies and there is no consensus about which one should be used in numerical experiments, while several modeling studies have tested their impact on the charge structure and lightning rate Helsdon et al. (2001); Mansell et al. (2005); Barthe et al. (2007).

In this study, the parameterization of Takahashi (1978) has been chosen to represent the non-inductive process for several reasons. First, this parameterization was already used for a previous numerical experiment of the STERAO storm (Barthe et al., 2007). Then we find more consistent to use the same parameterization for the EULINOX storm. It is important to note that the choice of Takahashi (1978) is not a value judgement about non-inductive parameterizations.

2. In section 3.1 the authors state that the magnitude of charge separated per rebounding collision is limited to specific values for the various types of collisions. There lacks a reference to experimental or empirical results for the values presented and it may seem arbitrary. Also it is not entirely clear if this value if prefixed for each collision or computed for individual collision between the various species. Please explain.

The charging limitation comes from a plot of Keith and Saunders (1990). It is reproduced in the textbook of MacGorman and Rust (1998) (Fig. 3.13, page 66). According to the particle type the non-inductive charging rate is proportional to the collision rate times the quantity of charge which is separated per colliding event. Here it is assumed that the charging rate of the pristine ice crystal with $D_{max} \sim 100\ \mu$m is the most limiting one that is 30(10) fC per collision with graupel(aggregate) particles. We take a larger value (100 fC) for the graupel-snow collisions because it corresponds roughly to an average of the saturation levels seen on the curves of Fig. 3.13 when the particle sizes reach $\sim$ 1 mm. This limitation is introduced in the computation of the bulk charging rates which result from an integration over the size spectrum of the ice particles.

As stated in Section 3.4, this is done for modelling study to limit the charge exchanged to reasonable values (Mansell, 2000; Mansell et al., 2005). A paragraph has been added in Section 2.1.2 to clarify this point:

"The analytical expressions of the charging rates relies heavily on the microphysical scheme:

$$\frac{\partial q_{xy}}{\partial t} = \int_0^{+\infty}\int_0^{+\infty} \frac{\pi}{4}\delta q(1-E_{xy})(D_x+D_y)^2|V_x-V_y|n_x(D_x)n_y(D_y)dD_xdD_y \qquad (1)$$

with D_x and D_y the diameter for species x and y, respectively. $|V_x - V_y|$ is the relative fall speed, n_x and n_y are the number concentrations of species x and y, respectively, and E_{xy} is the collection efficiency. The collection efficiency depends on the temperature

and follows Kajikawa and Heymsfield (1989) for ice-snow and snow-graupel collisions, and Mansell et al. (2005) for ice-graupel collisions.

As in Mansell et al. (2005), the charge exchanged per rebounding collision δq is limited to prevent unreasonable charging rate. Based on Keith and Saunders (1990), it is assumed that the charging rate of the pristine ice crystal with $D_{max} \sim 100\ \mu$m is the most limiting one, that is 30(10) fC per collision with graupel(aggregate) particles. We take a larger value (100 fC) for the graupel-snow collisions because it corresponds roughly to an average of the saturation levels when the particle sizes reach $\sim$ 1 mm (see Keith and Saunders (1990) or Fig. 3.13 in MacGorman and Rust (1998)). This limitation is introduced in the computation of the bulk charging rates which result from an integration over the size spectrum of the ice particles."

3. The present scheme includes charging by attachment of atmospheric ions (section 2.1.3), and introduces the term G for the generation of ions by cosmic rays. The value of G should be height dependent (G(z)) and should reflect the changes in ionization intensity along the solar cycle. It not clear if the same values of G were used for the two simulations - there are bound to be differences between the ionization profiles between case I (1996) and II (1998). Although this may be a few percent only, the authors need to address this issue.

Up to now all the studies were using a mean vertical profile assimilated to the climatology of the fair weather electric field. Due to the relatively short lifetime of the two case studies, we expect that using different profiles would not have changed the results too much. However, for a longer integration, the question of the sensitivity of $G(z)$ to the diurnal cycle should be taken into account if any parameterization does exist. In reality, it is the solar activity (emission of elementary particles and not only energetical photons by the sun) which is important in this case so it seems difficult to introduce this effect in a cloud electrification scheme.

A paragraph has been added at the end of Section 2.1.3:

"The ion generation source G is height dependent as in the previous studies, but it should reflect the changes in ionization intensity along the solar cycle. In the following two case studies, the same profile is used since the events occurred at the late afternoon (in local time) over a short period. However, it is probably more consistent to use time-variable height profiles if the convective systems have a longer lifetime."

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