March 19, 2019

Simulations of Cloud Electrification & Lightning Model implemented in COSMO

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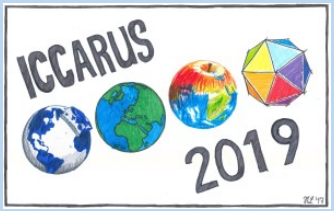

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European Structural and Investment Funds
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CRREAT

Motivation

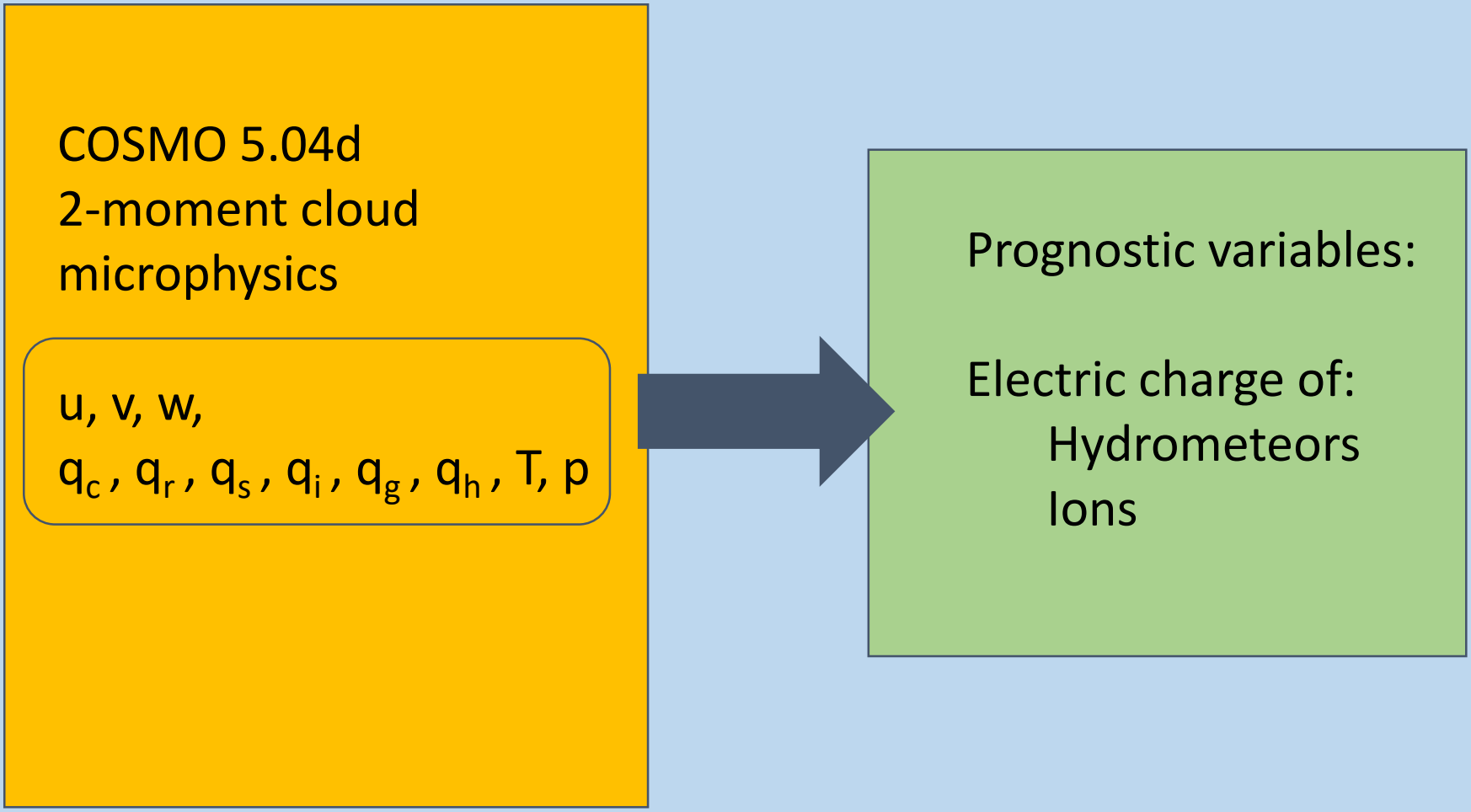
Research project CRREAT

- the relationhip between atmospheric phenomena and ionizing radiation
- variations of the secondary cosmic particles in the atmosphere

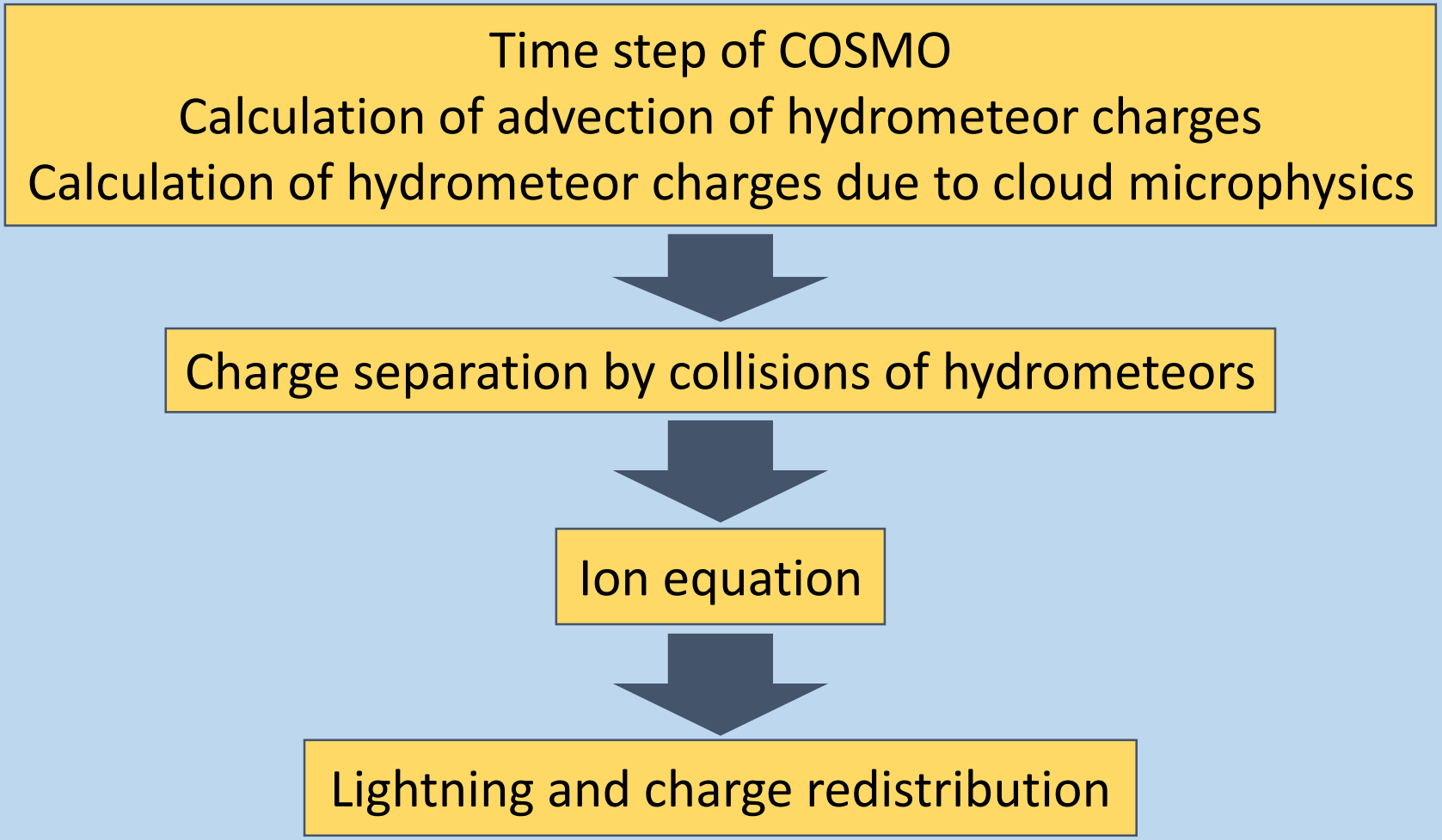
Explicitly simulate electrification of the atmosphere

Research model Cloud Electrification Model (CEM)

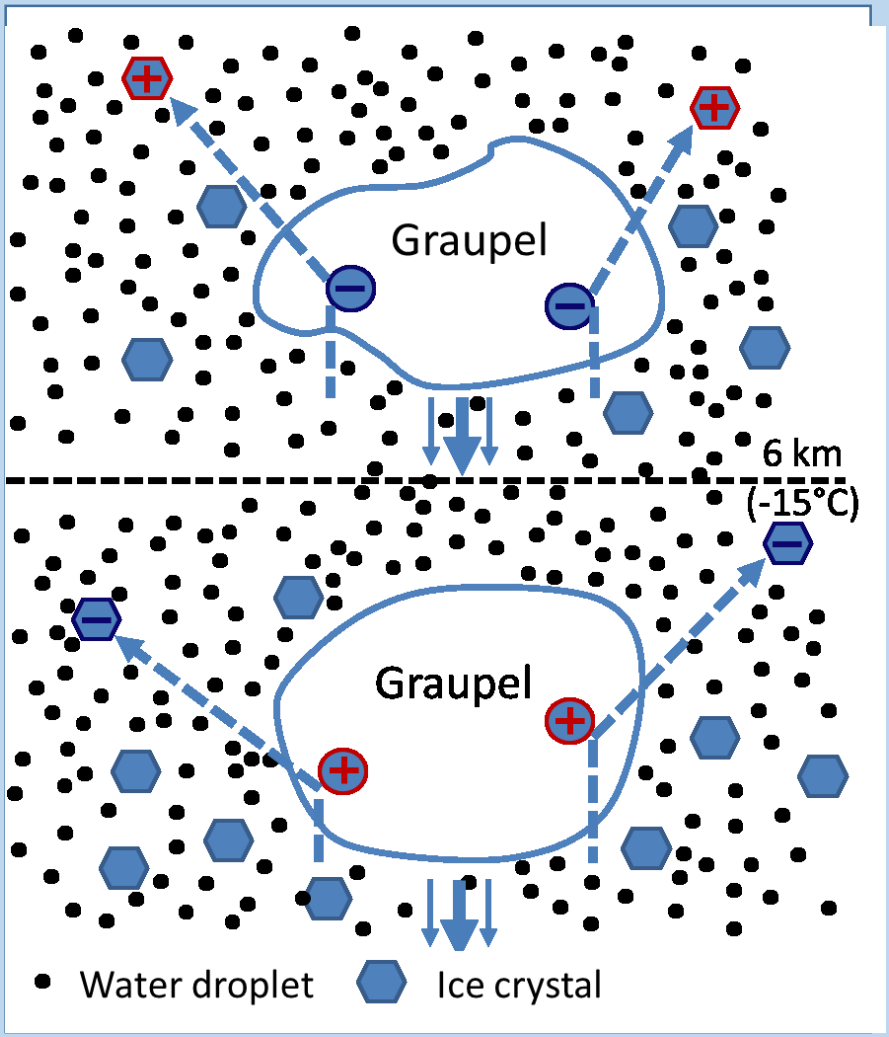
Cloud Electrification Model



Cloud Electrification Model



Charge separation by collision of hydrometeors



Source: Rakov & Uman, 2003

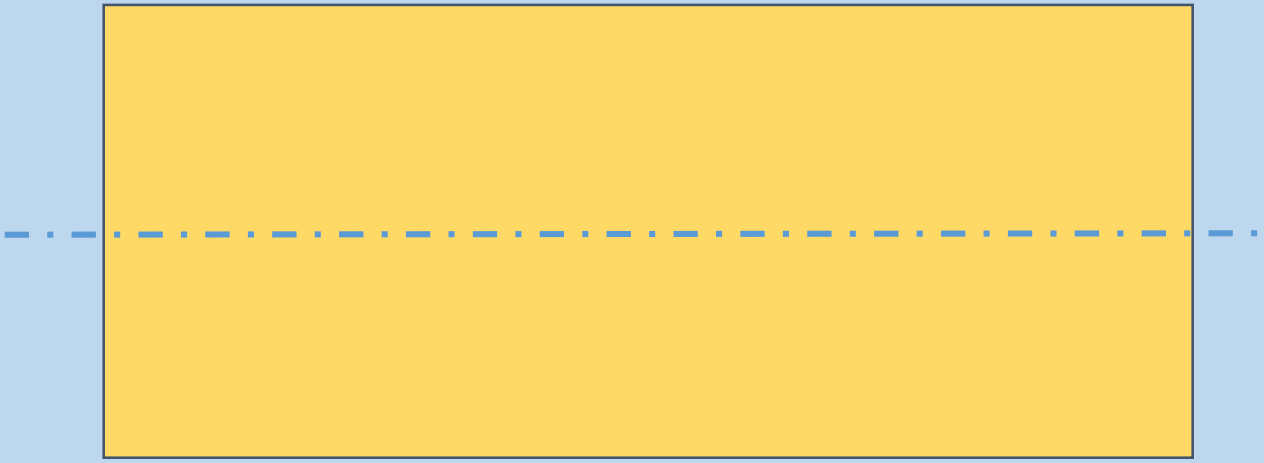
Ion equation

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

$n_{\pm}V$	advection
$K_m\nabla n_{\pm}$	turbulent mixing
$n_{\pm}\mu_{\pm}E$	ion drift motion
G	background 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

Test example

Model domain: 141 x 61 x 50, dx=dy=560 m



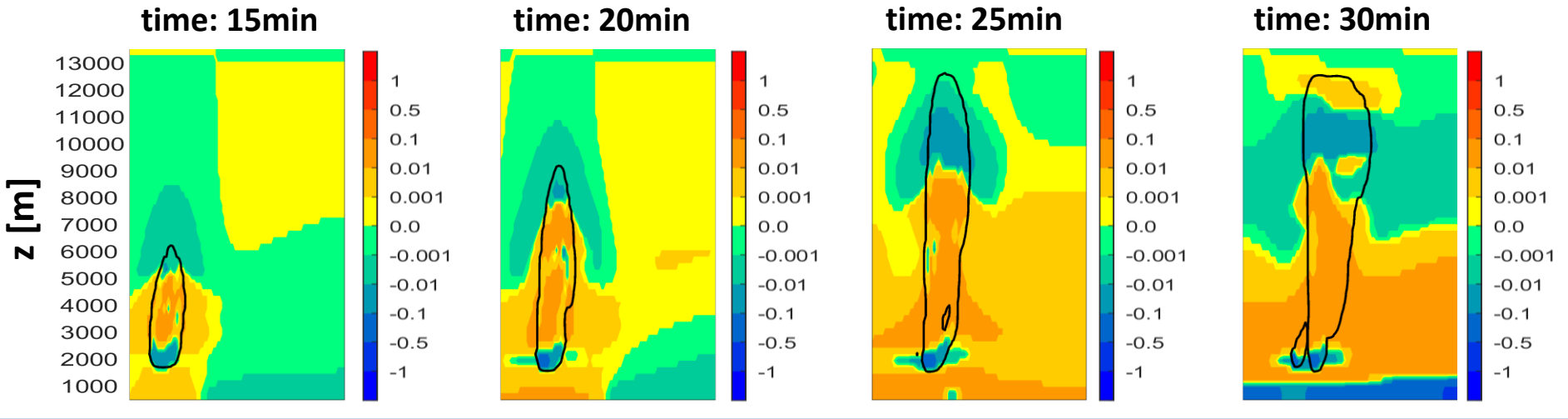
Initial conditions COSMO: WK82 (Weisman & Klemp, 1982)

warm air bubble (x=16, y=31, z=1400m, hor. radius=10km)

Initial electric fields: fair weather conditions

Integration 1h, dt = 6s, dt(ion eq.) = 1s

Development of electric field, cross-section, electric charge [nC]



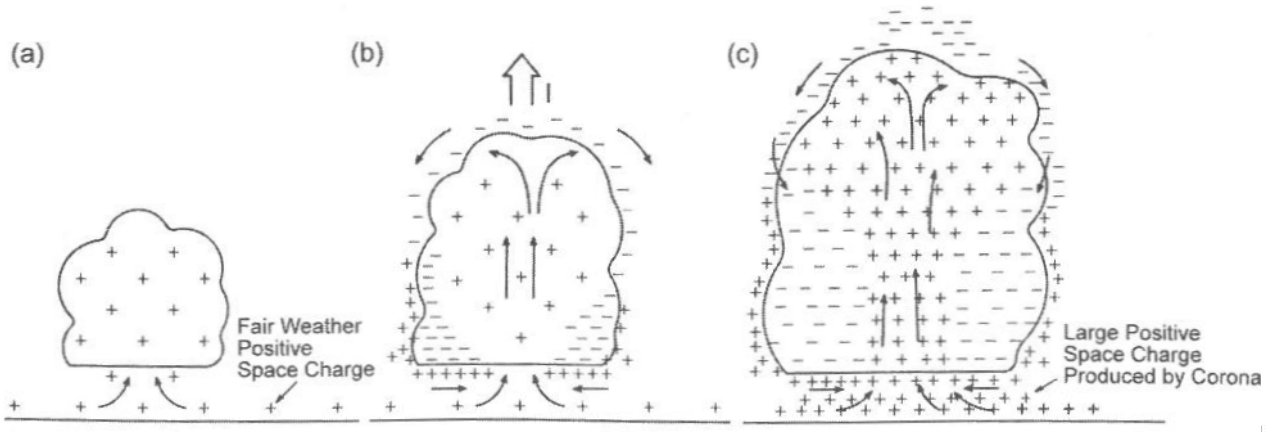
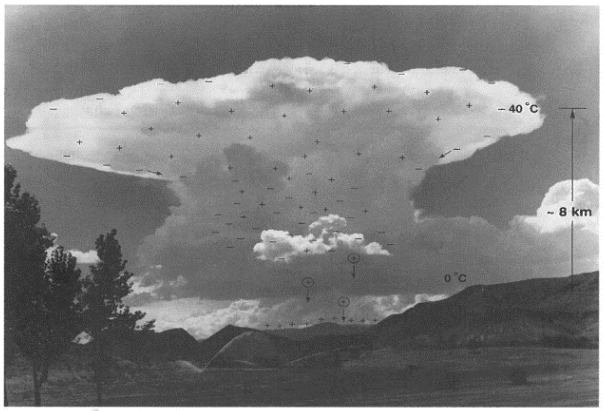
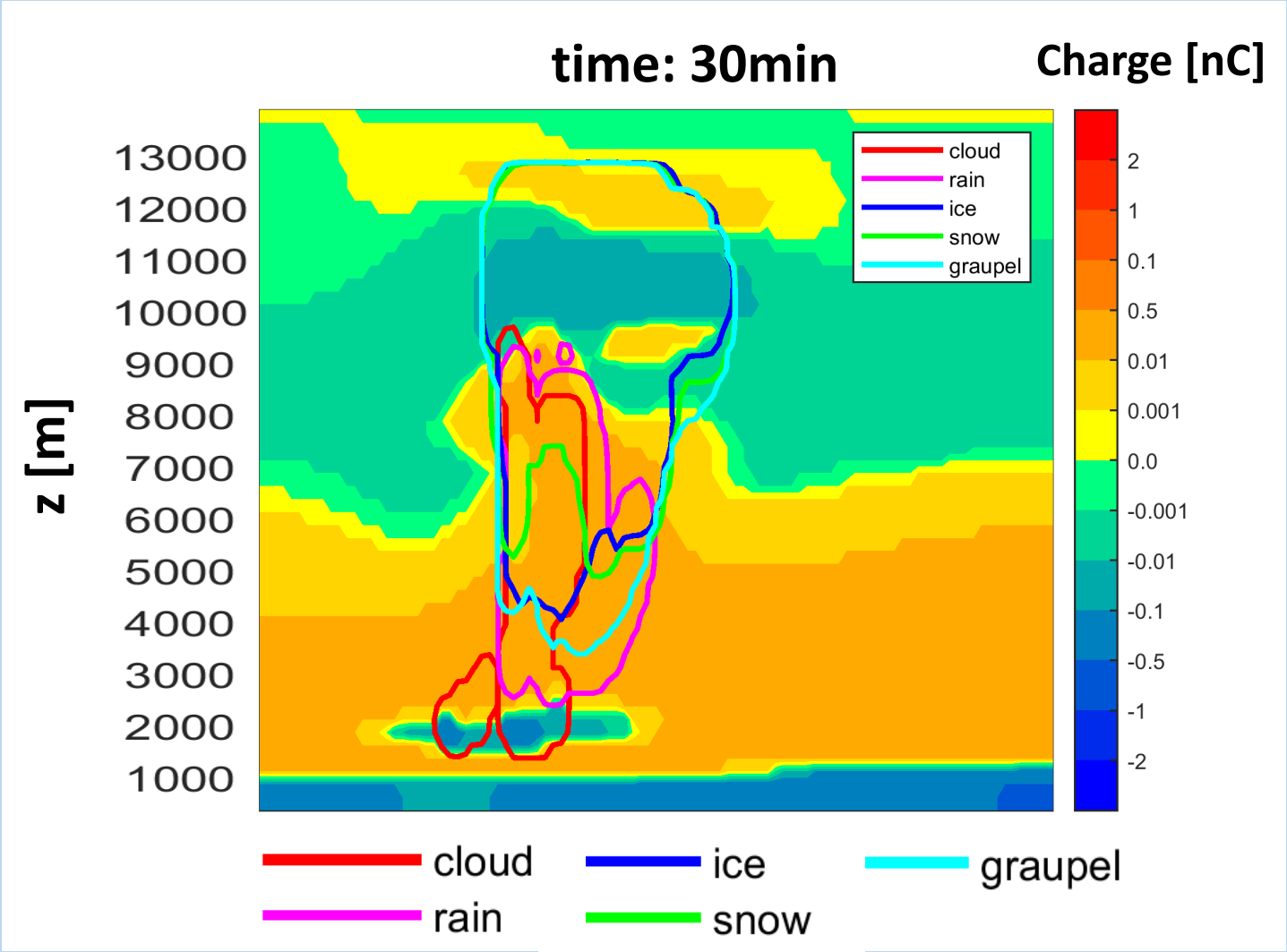


Illustration of the convection mechanism of cloud electrification. Adapted from MacGorman and Rust (1998).

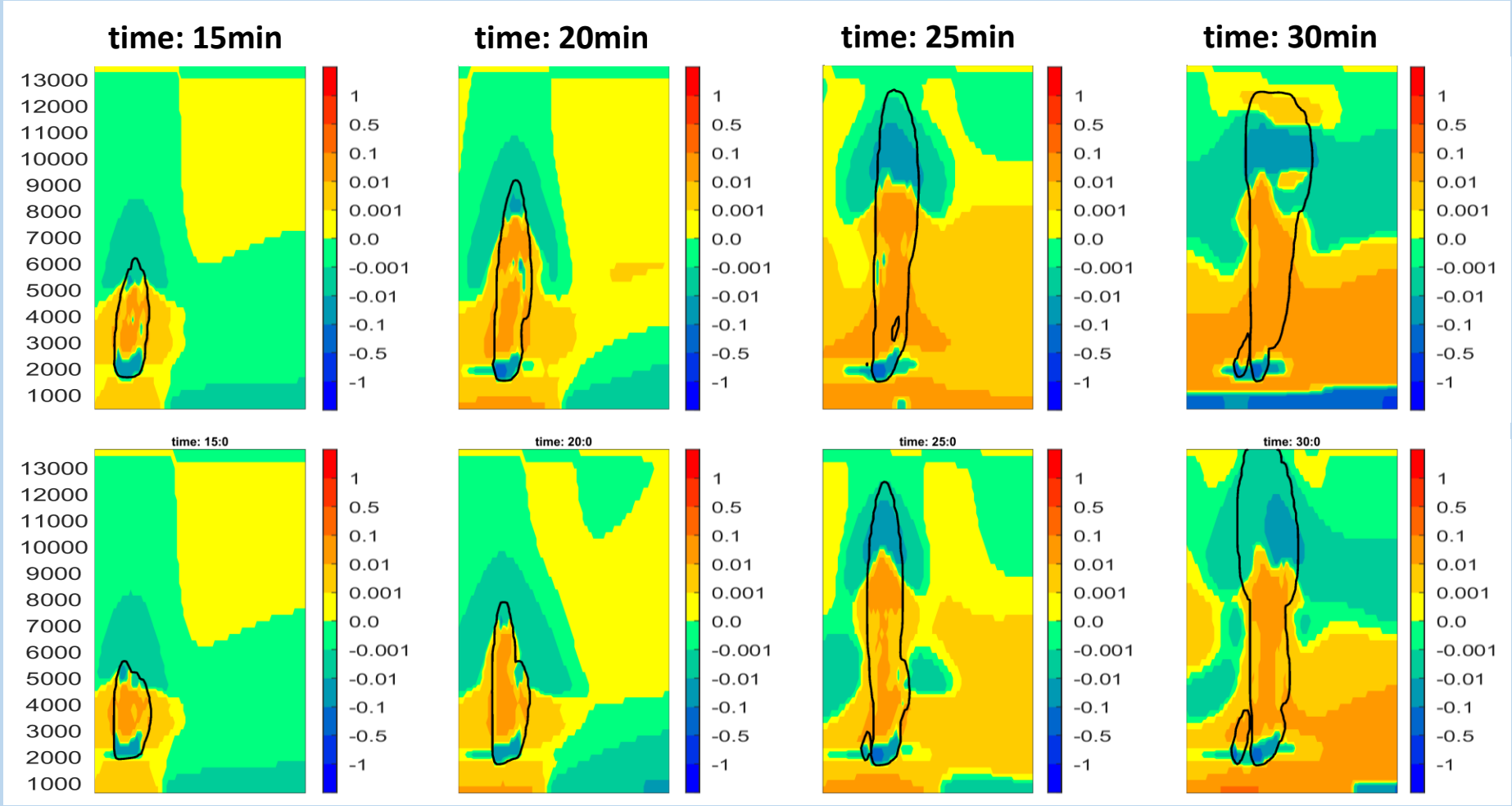


An isolated thundercloud in central New Mexico and a rudimentary picture of how electric charge is thought to be distributed inside and around the thundercloud, as inferred from the remote and in-situ observations. Adapted from Krehbiel (1986).

Hydrometeors & electric charge

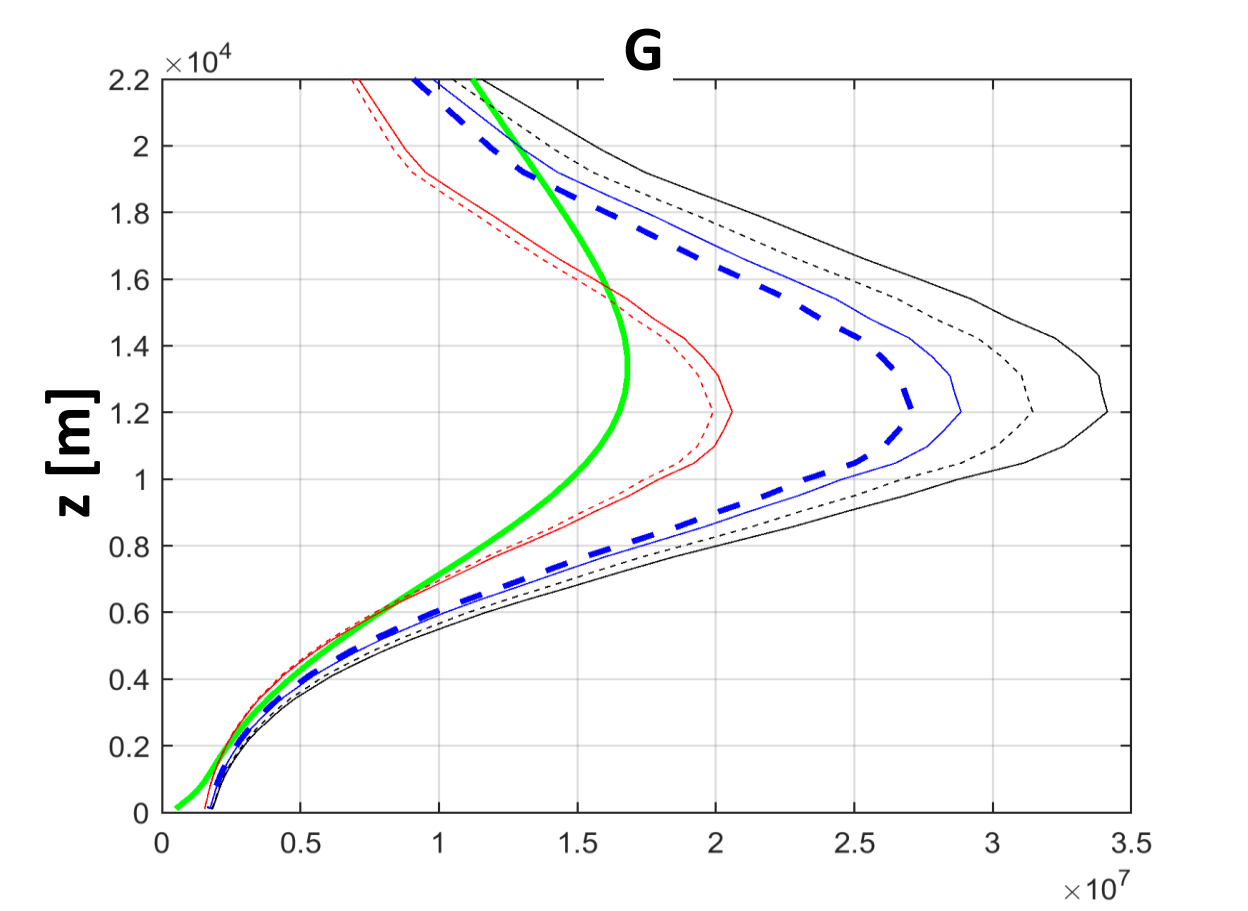


Development of electric field, cross-section, electric charge [nC]

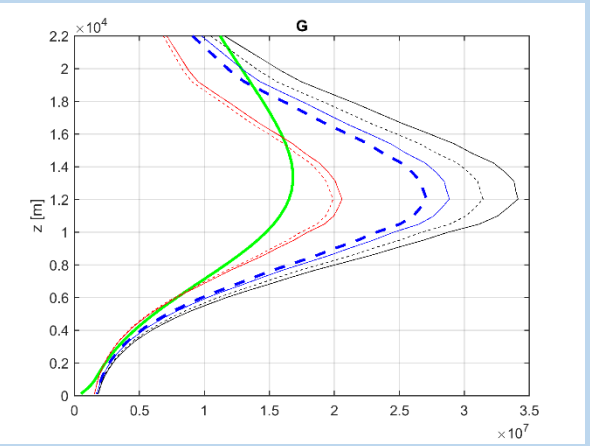


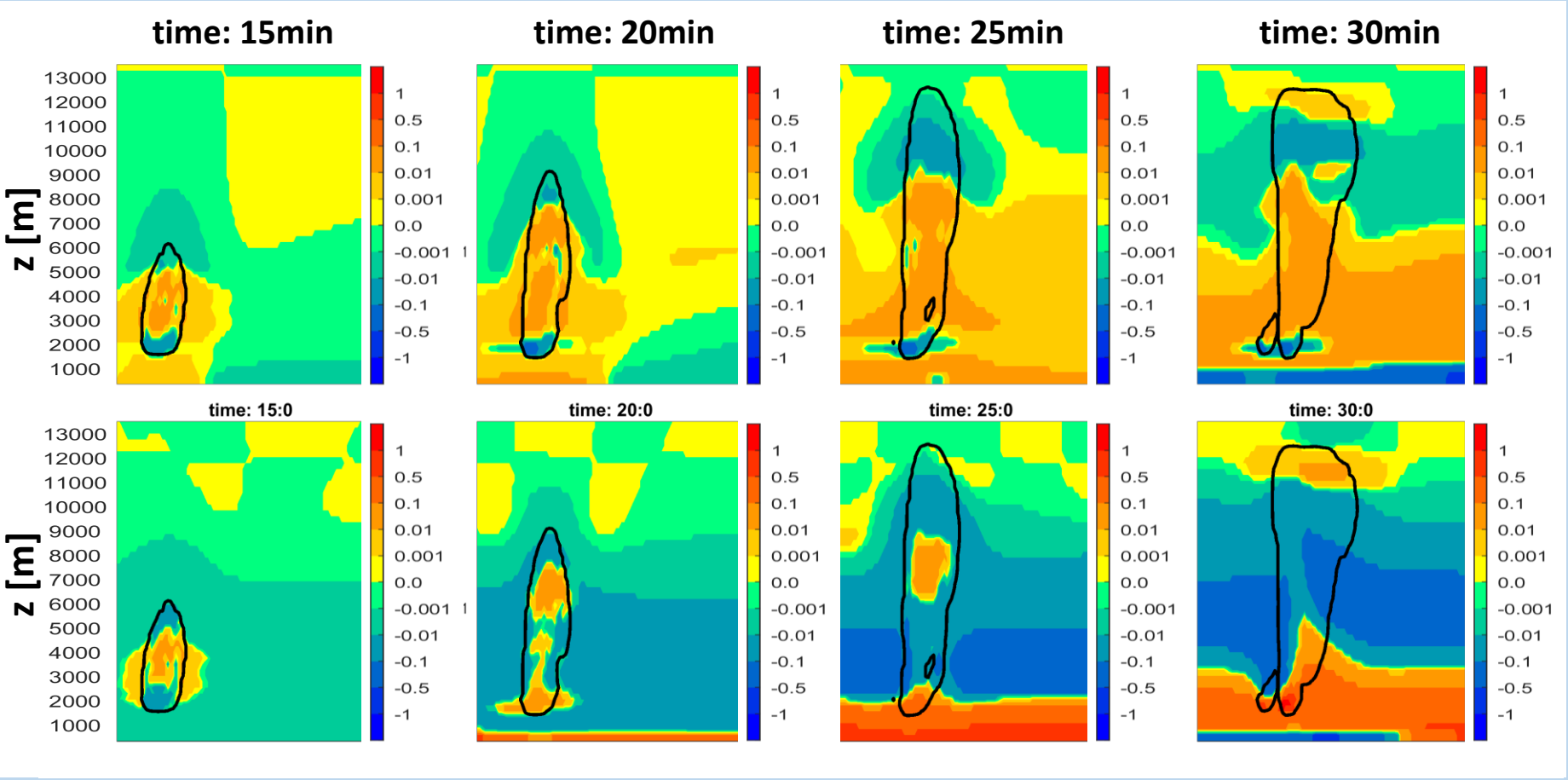
G function, the ion generation rate

Model: Cosmic Ray Atmospheric Cascade: Cosmic Rays Induced Ionization



Impact of G on simulations





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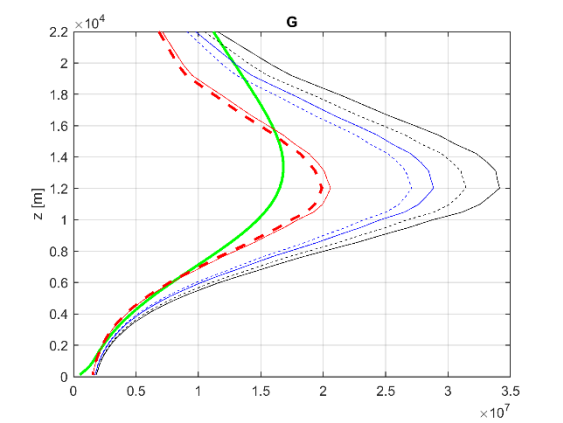
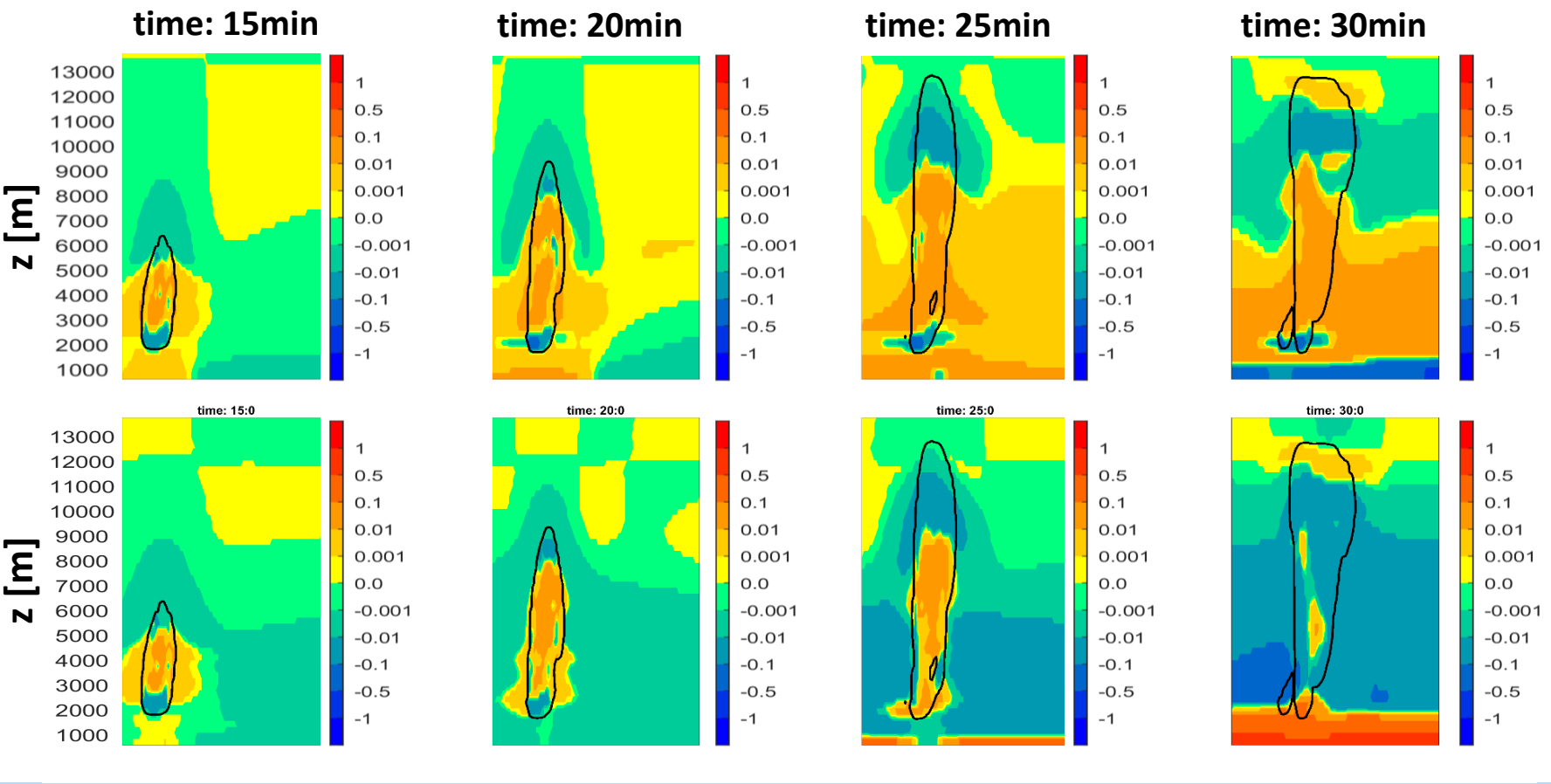
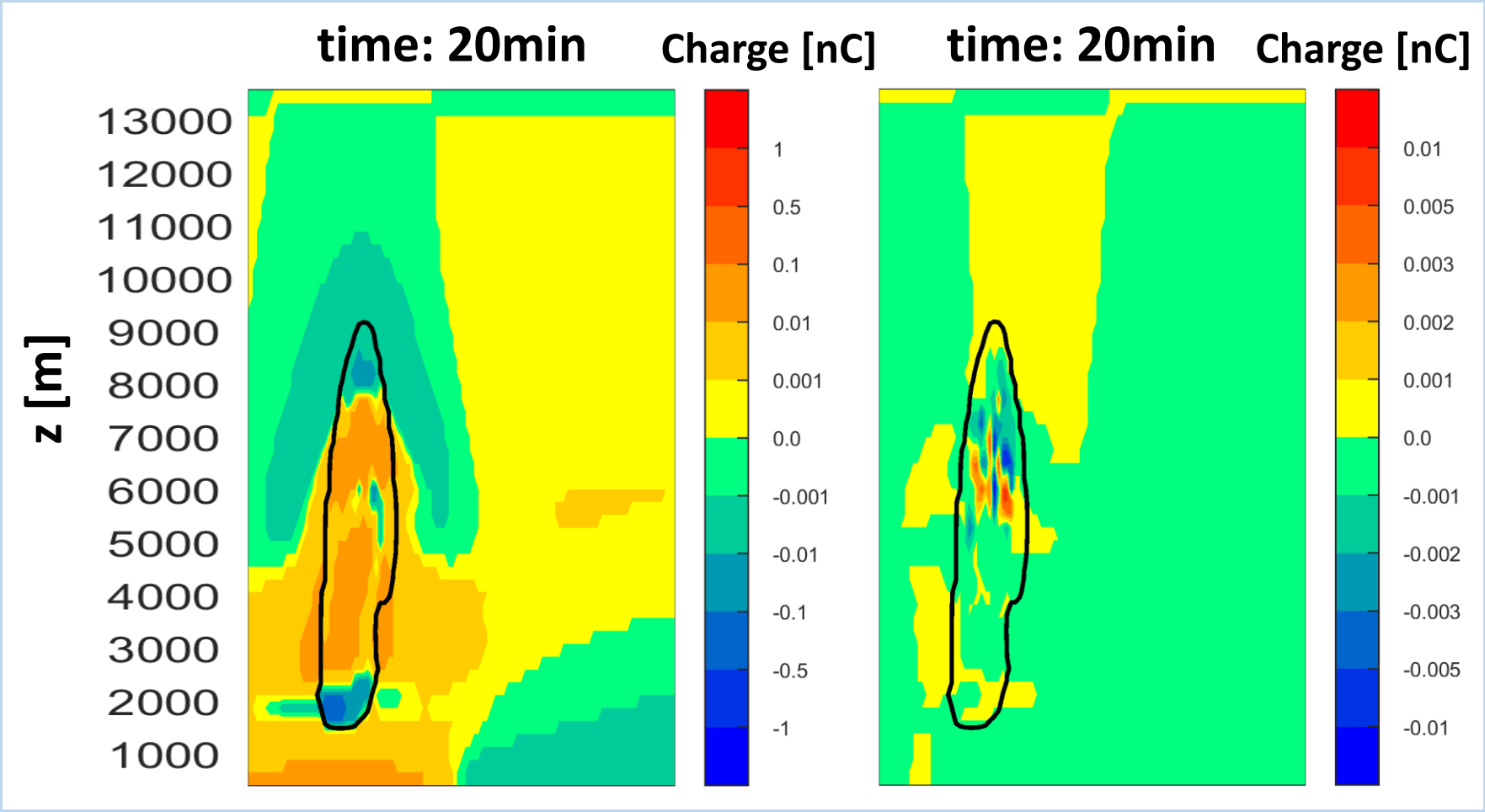




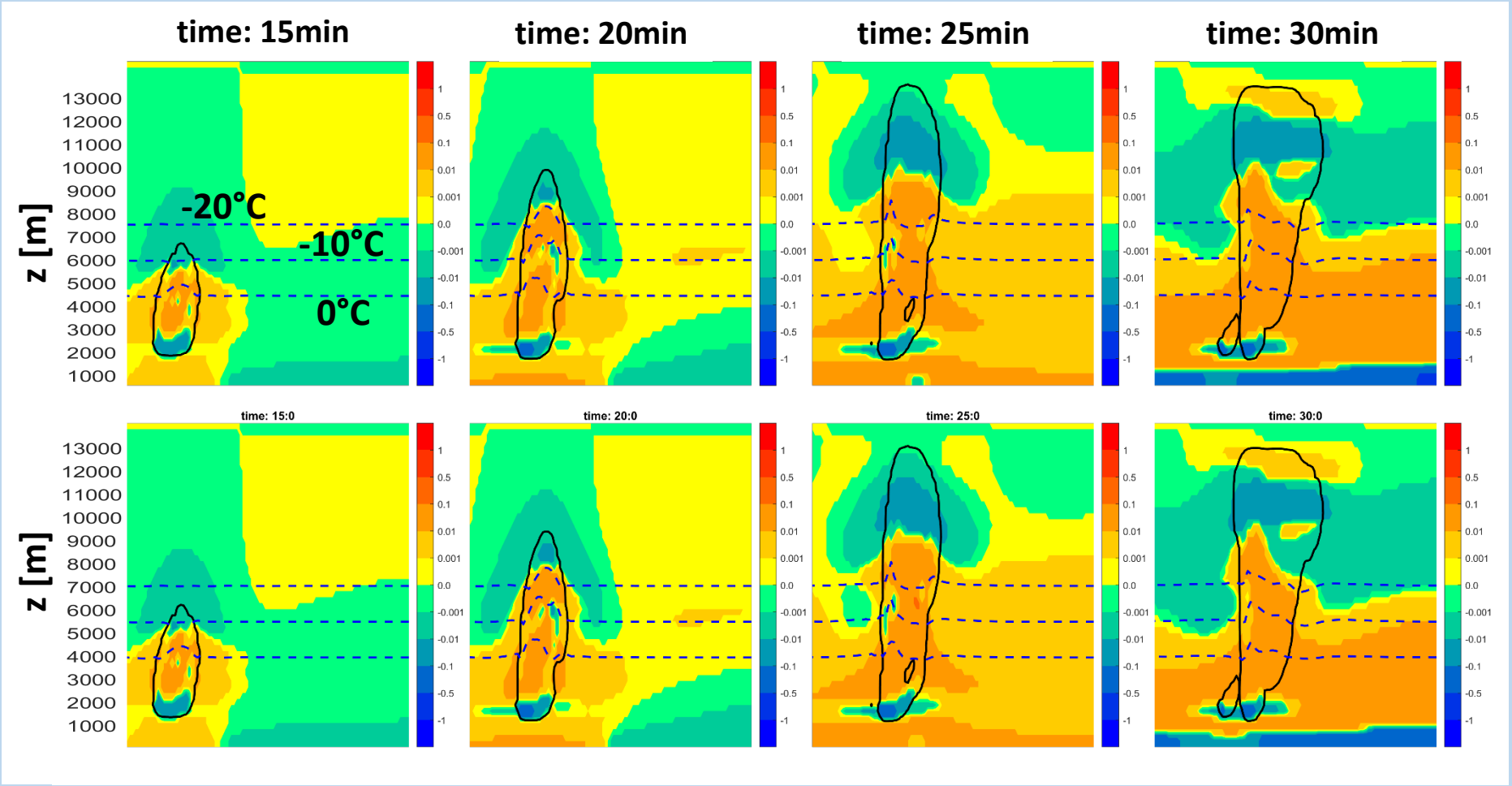
Impact of collisions (COL)

Difference of simulations without COL minus with COL



Impact of different COL schemes

Takahashi vs. Gardiner-Ziegler schemes



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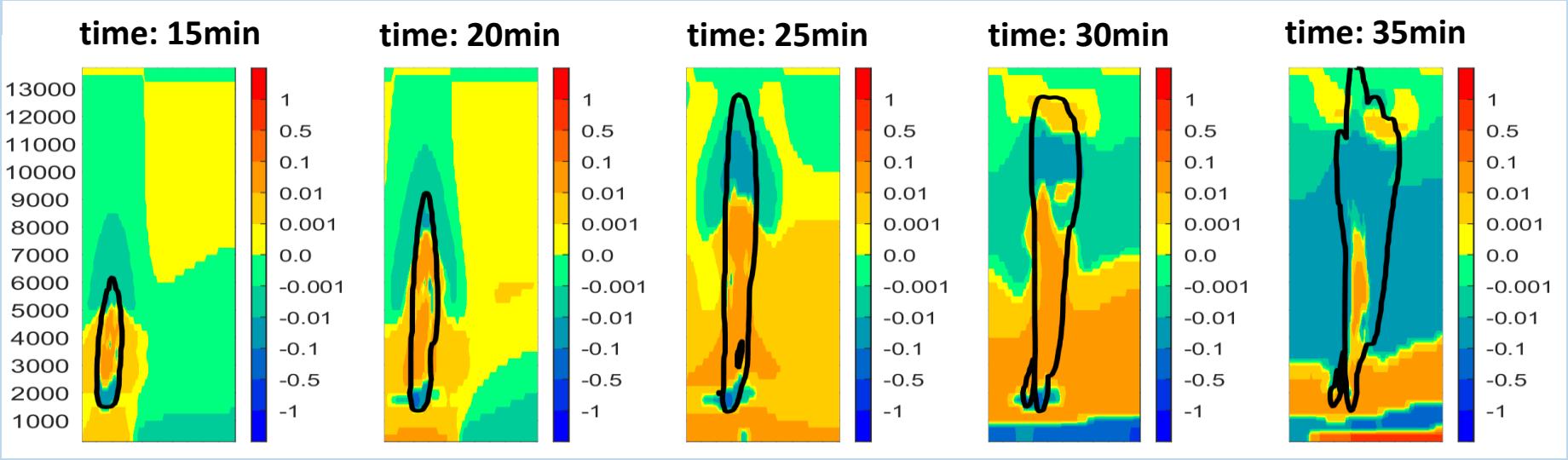
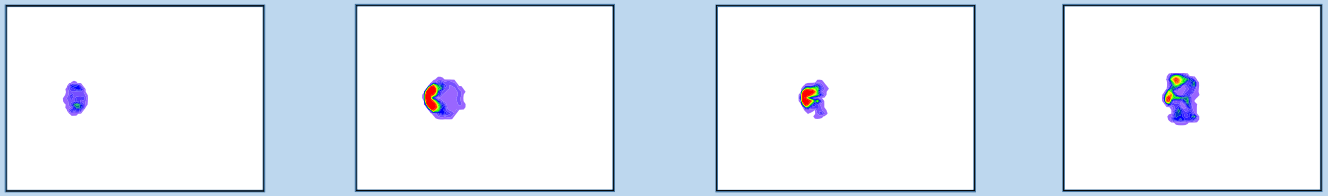
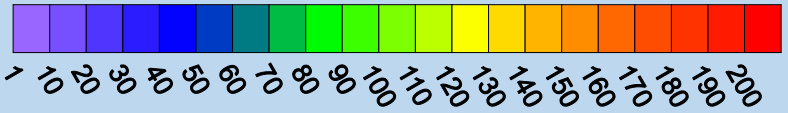


LPI



Lightning Potential Index



Conclusions & remarks

1. CEM is based on COSMO 2-moment cloud microphysics
2. CEM cannot be exactly verified
3. Structure of forecasted electric field roughly correspond to „expected“ structure in a convective storm
4. G is important, G is source of uncertainty
5. LPI vs. CEM

Problems with pos. def. advection scheme (Bott’s scheme)

Ion equation apparently requires smaller time step than COSMO including special corrections to ensure numerical stability