Anvil glaciation in a CRYSTAL-FACE thunderstorm - Electrical and aerosol effects

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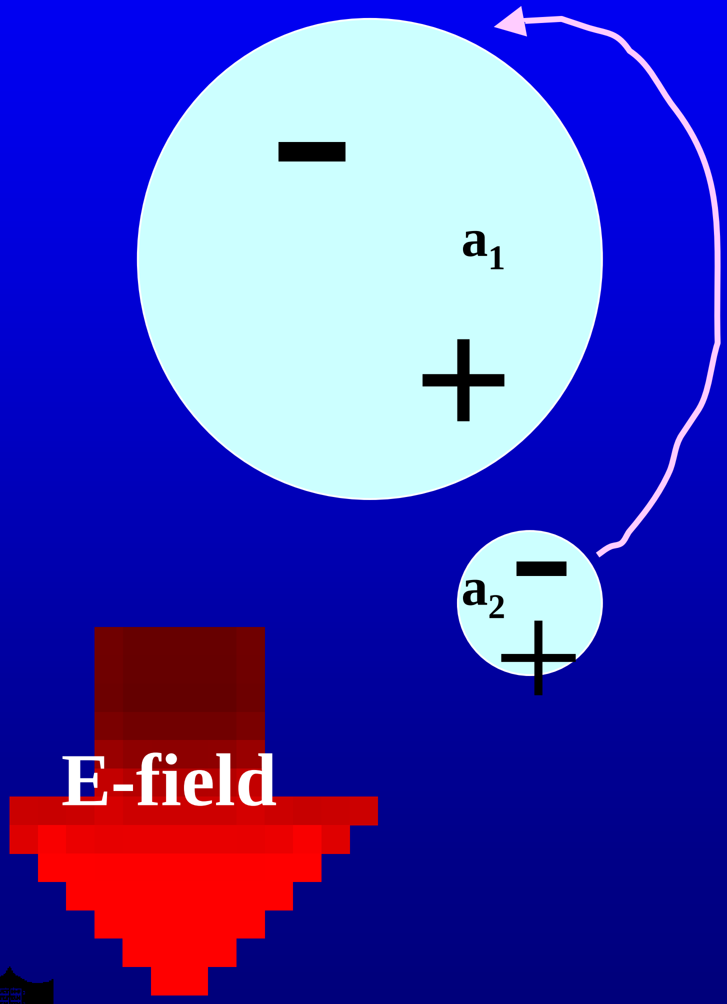
Outline

1. Overview
2. Description of Explicit Microphysics Model (EMM)
3. Comparison of control simulation with aircraft observations
4. Sensitivity tests
5. Conclusions

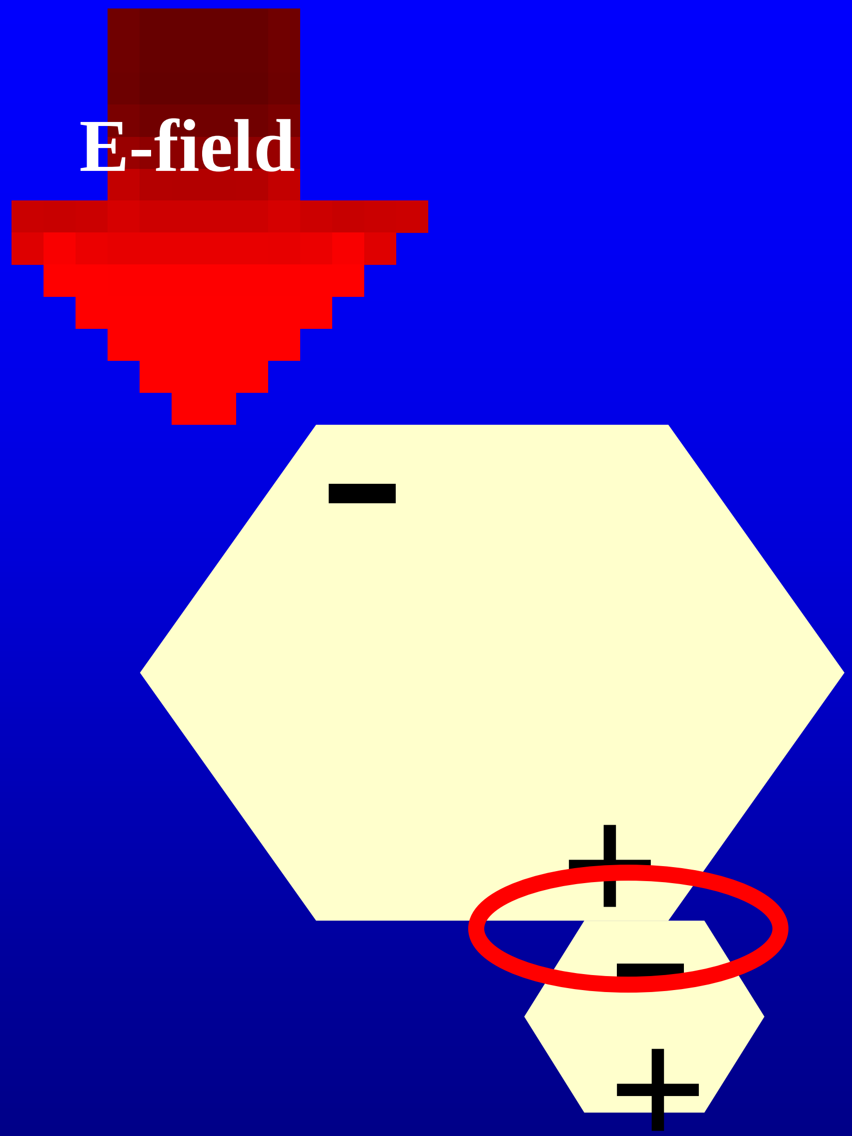
1. OVERVIEW



Polarisation charges induced in an E-field, especially when:-

$$a_2/a_1 << 1$$

Collision efficiency may be enhanced by up to 1 or 2 orders of magnitude in Cb E-fields



Electrostatic forces of adhesion produce increased bonding between colliding ice particles (Latham 1969).

Aggregation (or “sticking”) efficiency is enhanced by up to 100 %, or more, in Cb E-fields. Significan temperature dependence (Saunders and Wahab 1975).

But if $E < \sim 0.5$ kV/cm there is no effect.

Data on E-field enhancement of collection efficiency:-

– Uncharged droplet-droplet collisions:

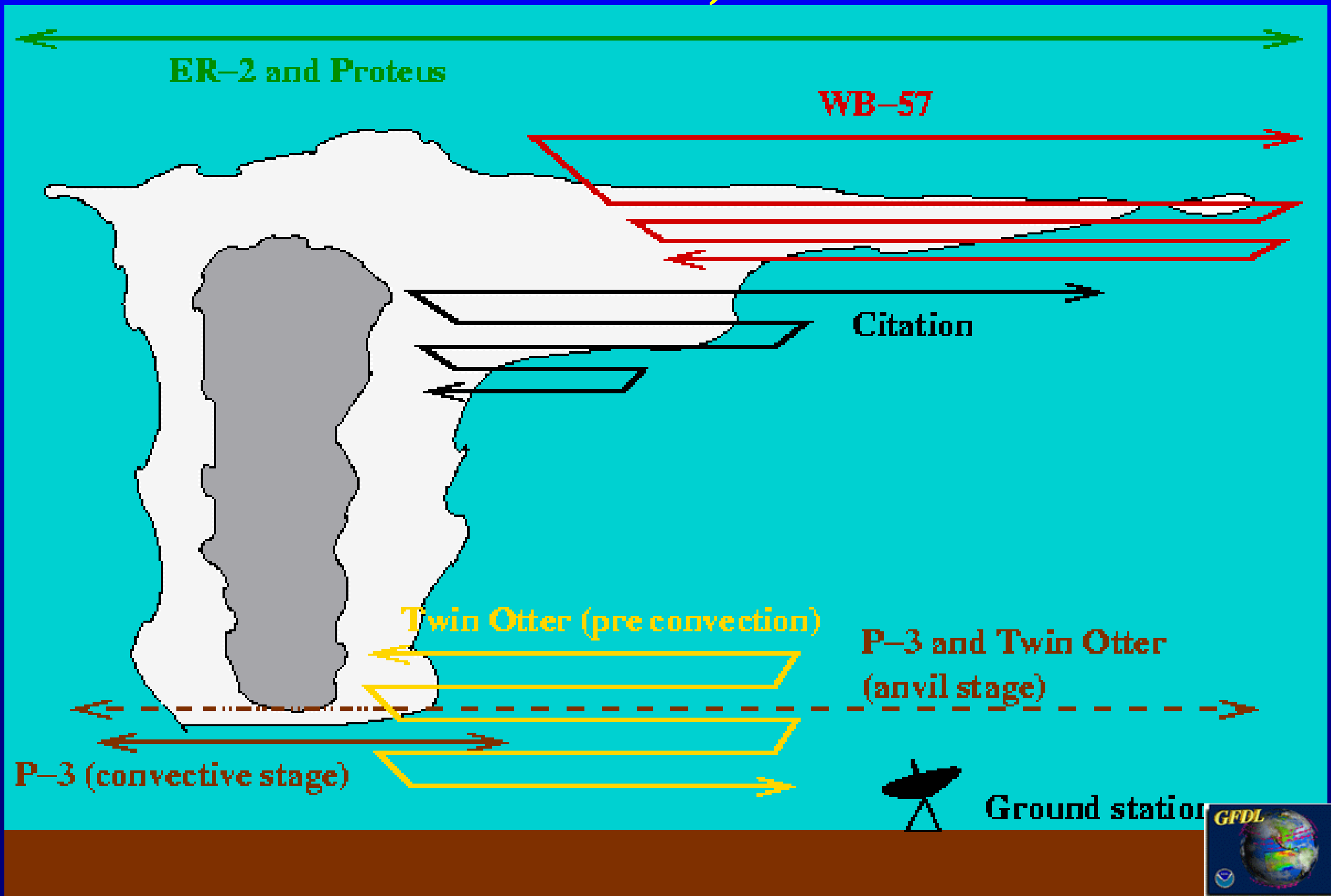
- Numerical data from Schlamp *et al.* 1976;

– Uncharged ice–droplet and ice-ice collisions:

- Experimental data from Latham (1969) and Saunders and Wahab (1975)

Colliding droplets always coalesce when $E > 0.25$ kV/cm (Jennings 1975)

Cirrus Regional Study of Tropical Anvils and Cirrus Layers - Florida Area Cirrus Experiment (CRYSTAL-FACE):



Aim of present study:

Elucidate possible effects on anvil glaciation from:-

- **electric fields modifying coagulation processes;**
- **environmental concentrations of ice nuclei (IN).**

2. DESCRIPTION OF EXPLICIT MICROPHYSICS MODEL

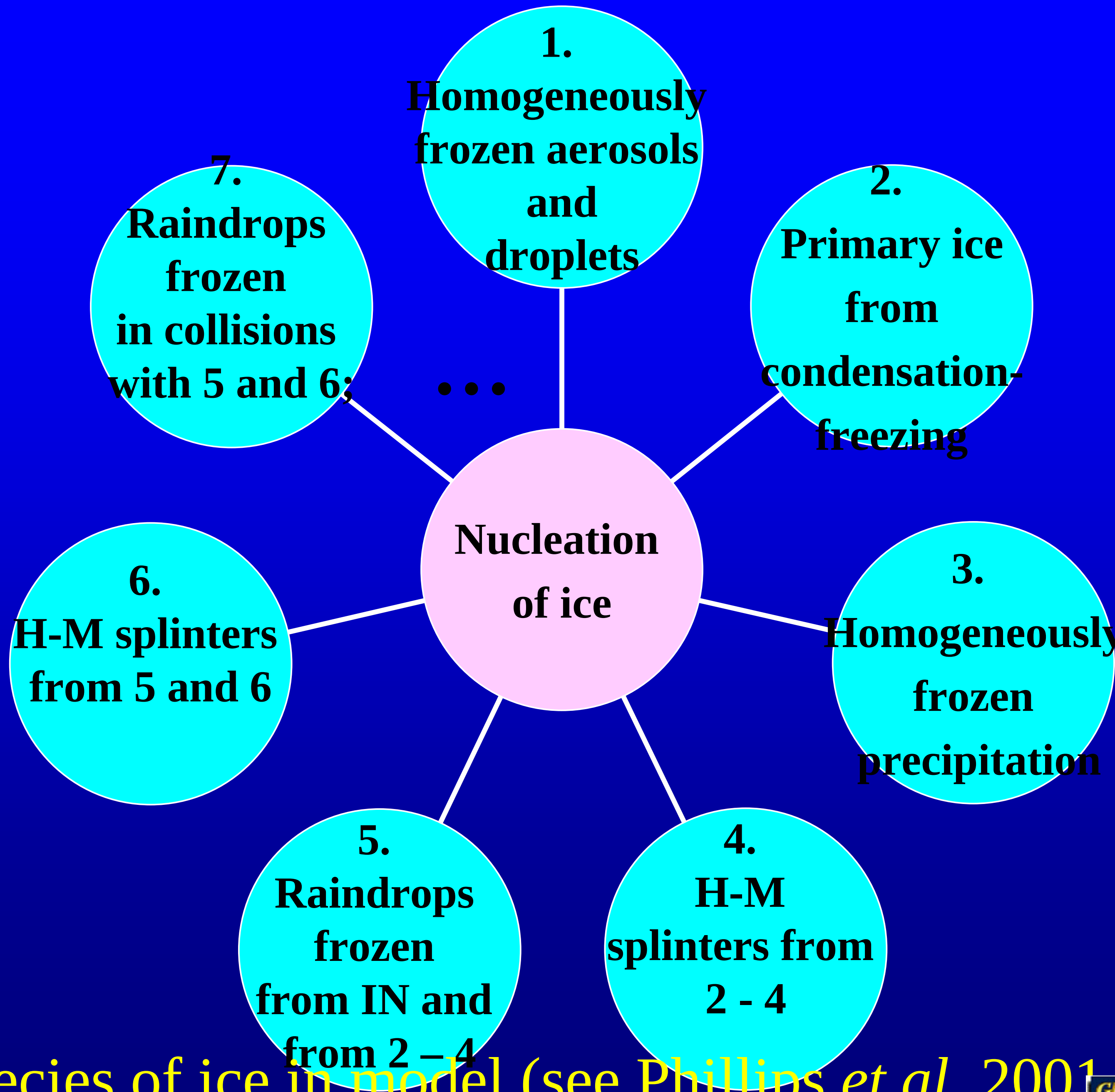
- **fully interactive components for vapour, cloud-water, rain, ice and CCN;**

- **coalescence and other collisional processes represented by explicitly solving the SCE (turbulent enhancement coefficients from Khain and Pinsky);**

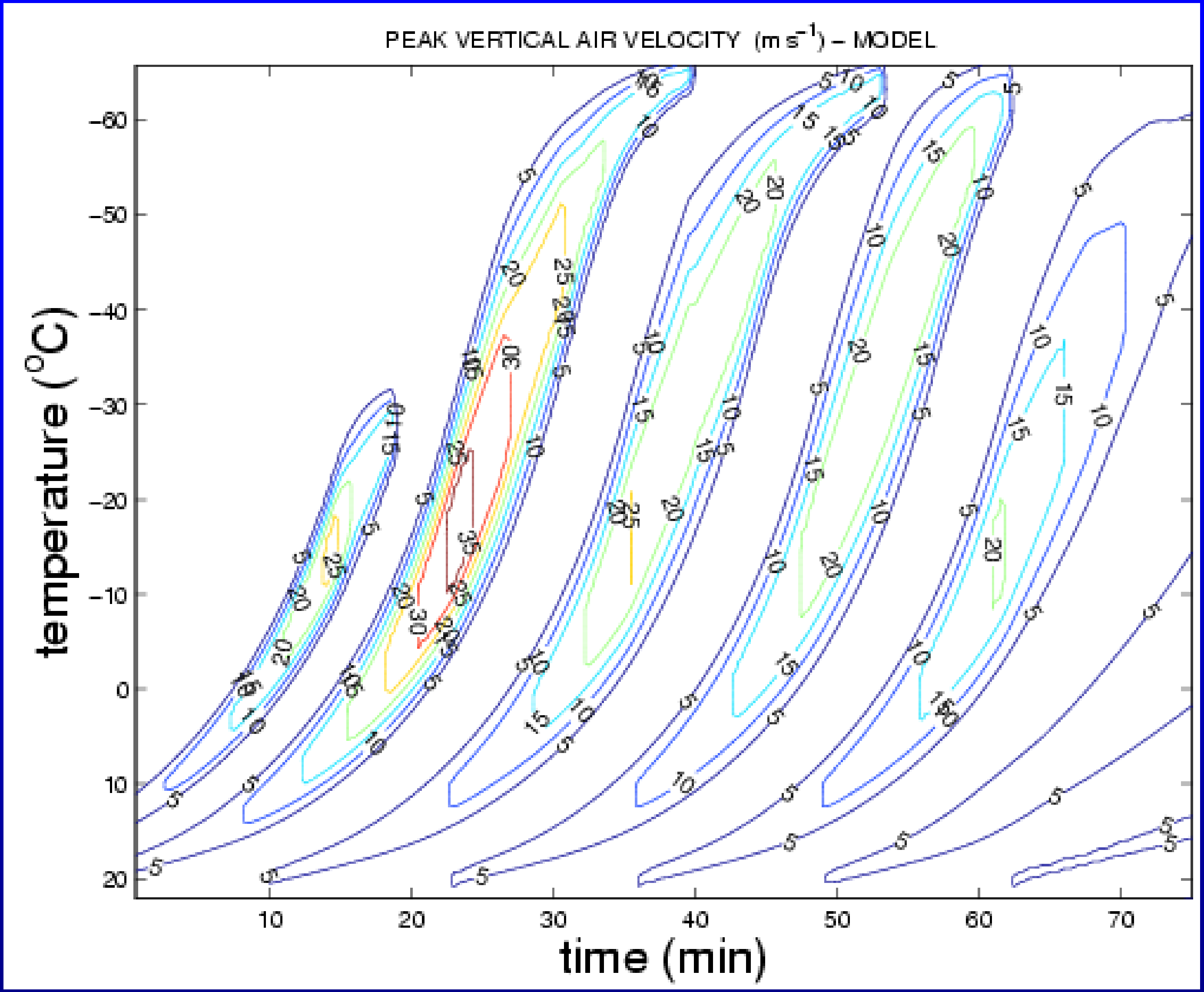
- **separate size distributions for several species of ice, drops and CCN explicitly predicted;**

- **ice shape and bulk density predicted with particle growth scheme – no categorisation assumptions**

(see Phillips *et al.* 2004, submitted to QJRMS)



Species of ice in model (see Phillips *et al*. 2001, 2002)



Prescribed evolution of vertical velocity profile in updraft

3. COMPARISON OF CONTROL SIMULATION WITH AIRCRAFT OBSERVATIONS

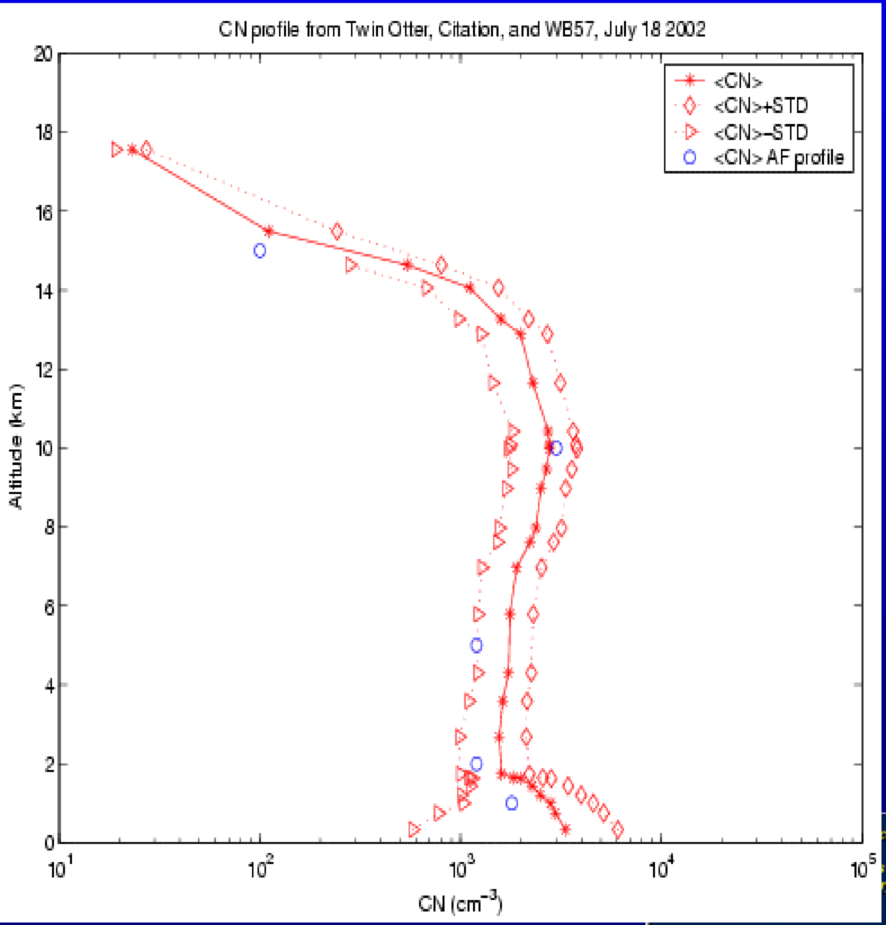
Case: 18th July 19:30 GMT, West side of Florida peninsula

Satellite : cloud-top at 14 – 15 km MSL

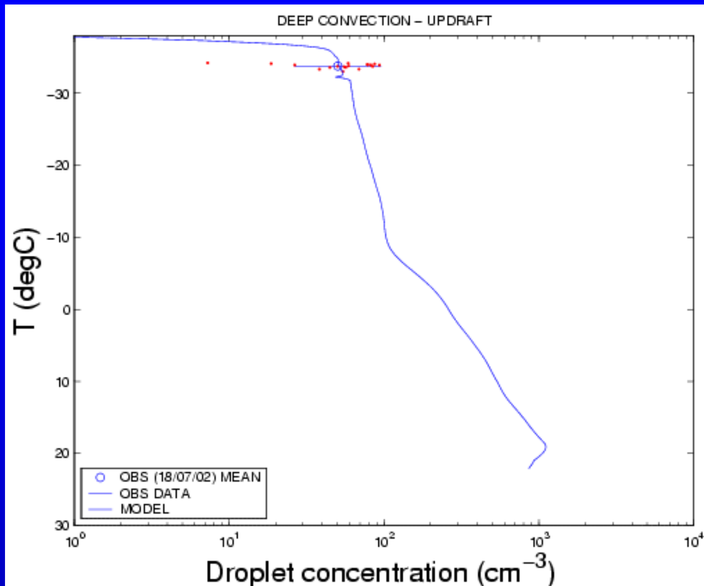
WB-57: CN size distribution observed.

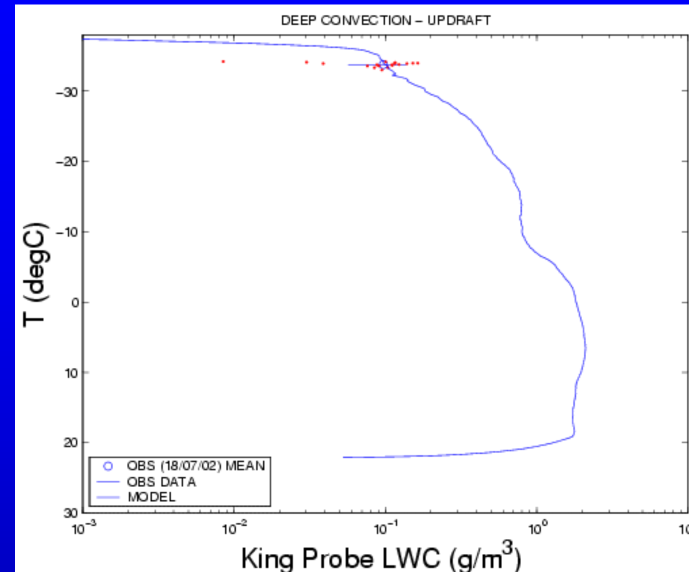
Citation: w_{max} = 24 m/s; Total CN observed

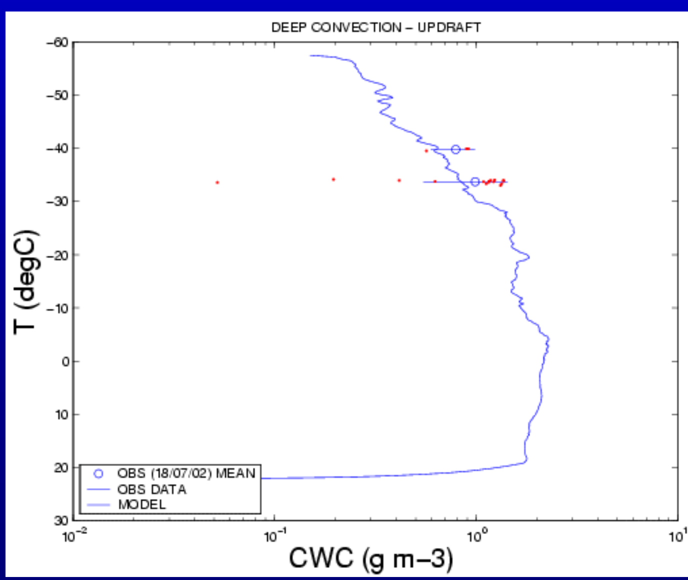
Twin Otter: At cloud base, peak updraft speed of Cu is 1 – 2 m/s; CN size distribution observed.

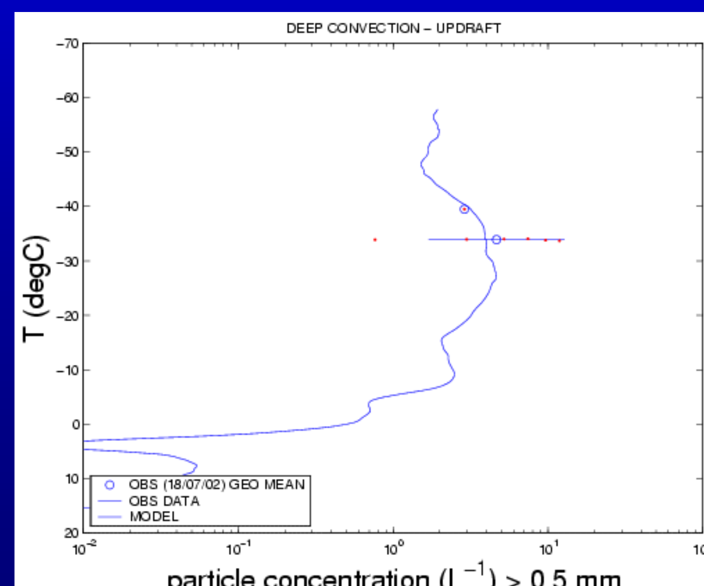


CRYSTAL-FACE observations vs EMM









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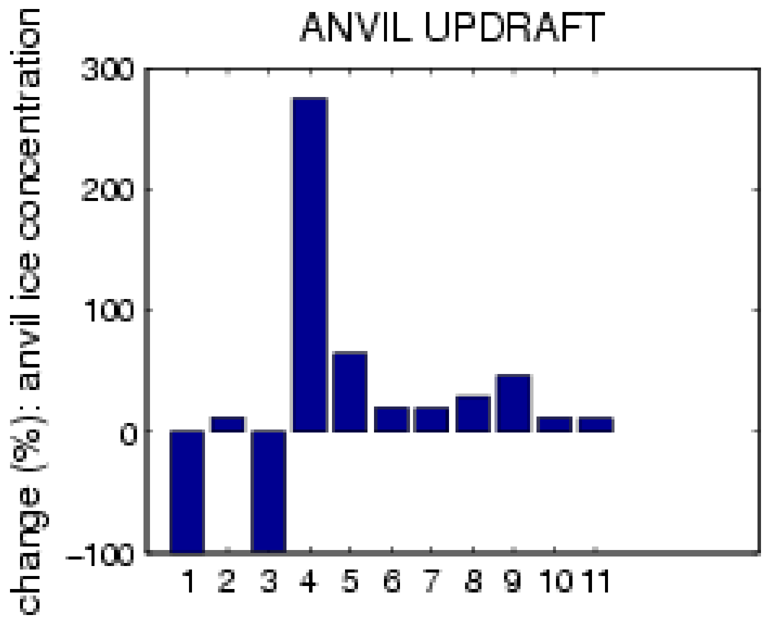
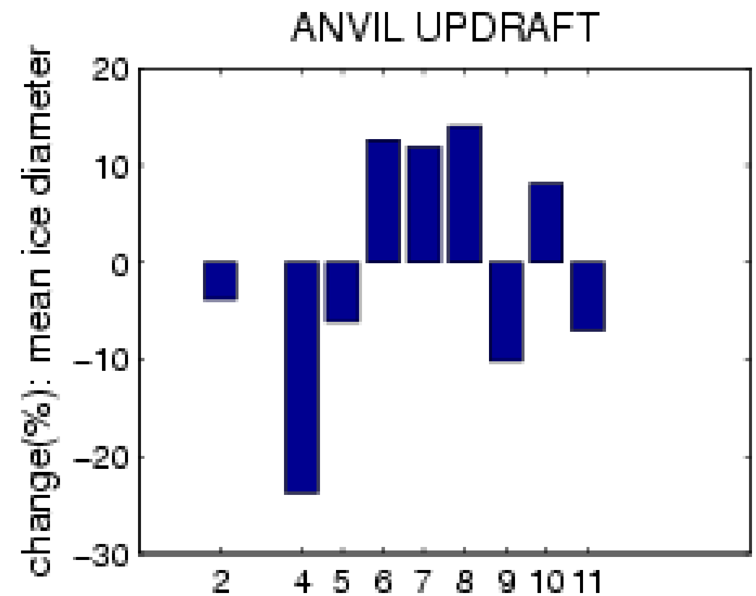
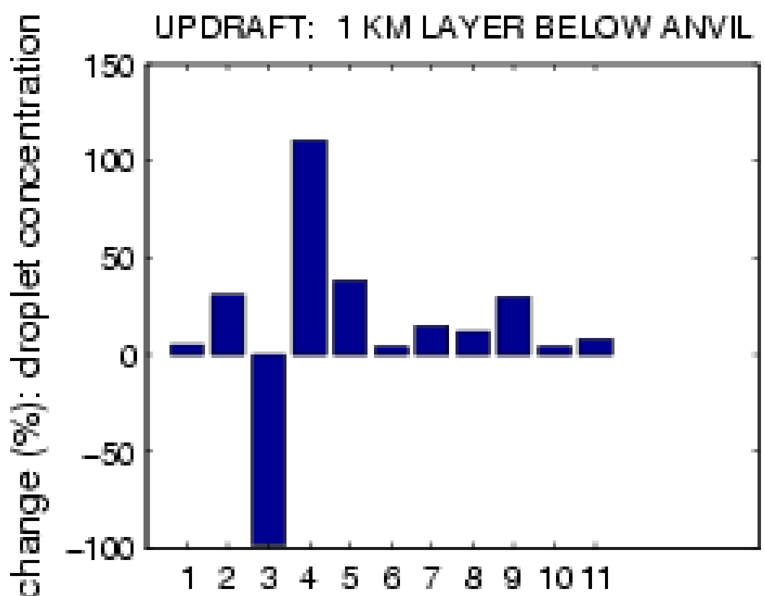
4. SENSITIVITY TESTS







Exclusion of:– (1) all homogeneous freezing; (2) all heterogeneous freezing; (3) in–cloud droplet nucleation; (4) coalescence; (5) turbulent enhancement of coalescence; (6) homogeneous aerosol freezing; (7) aggregation; (8) primary ice nucleation; (9) raindrop–freezing; (10) raindrop break–up; and (11) HM process.

Prescribed electric field:-

elow 5 degC level: 0.5 kV/cm;

to -36 degC level : E_{max};

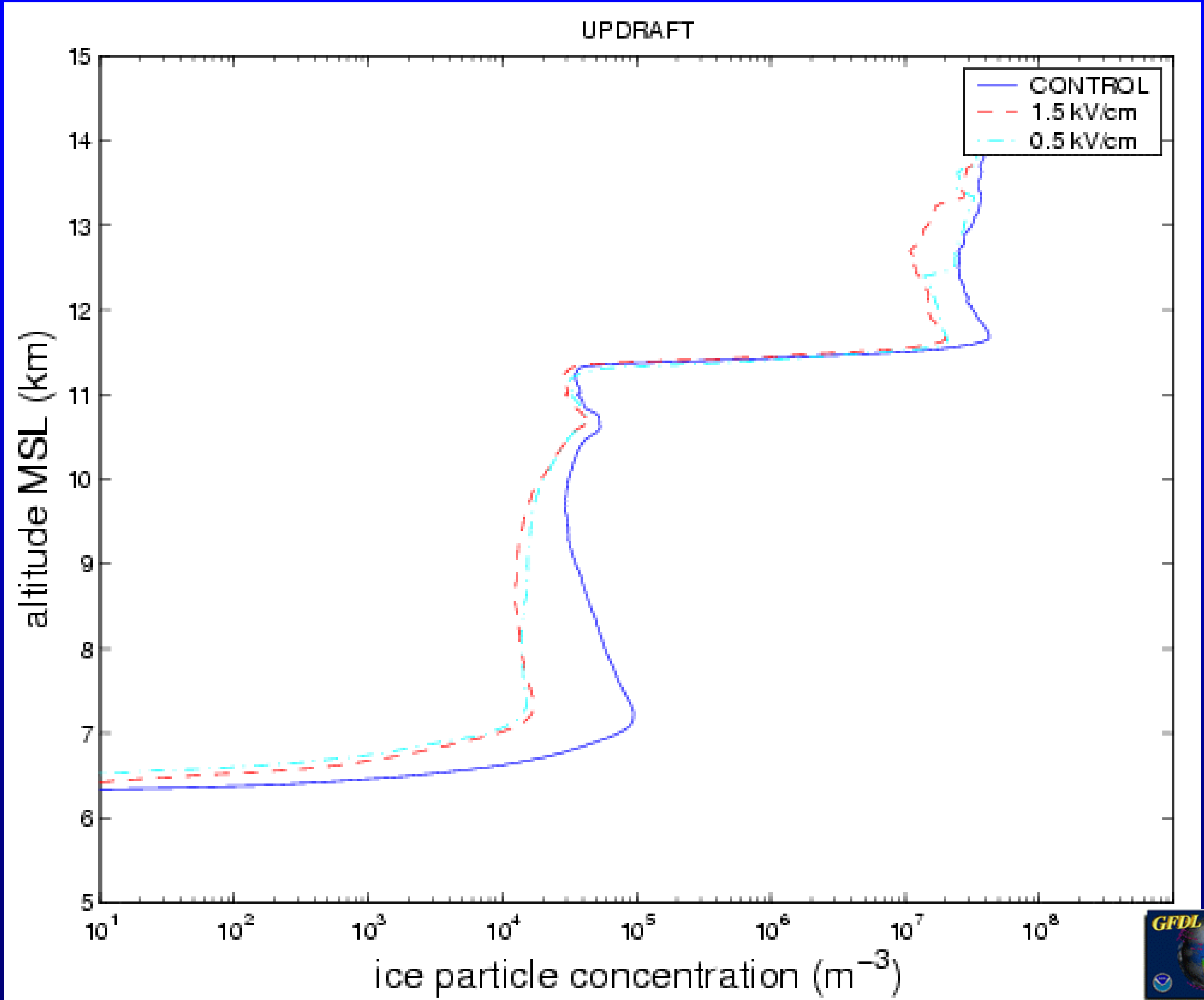
bove -36 degC level: reduce towards 0.5kV/cm.

Marshall and Rust (1991) observed E_{max} ~ 1 kV/cm in continental Cb

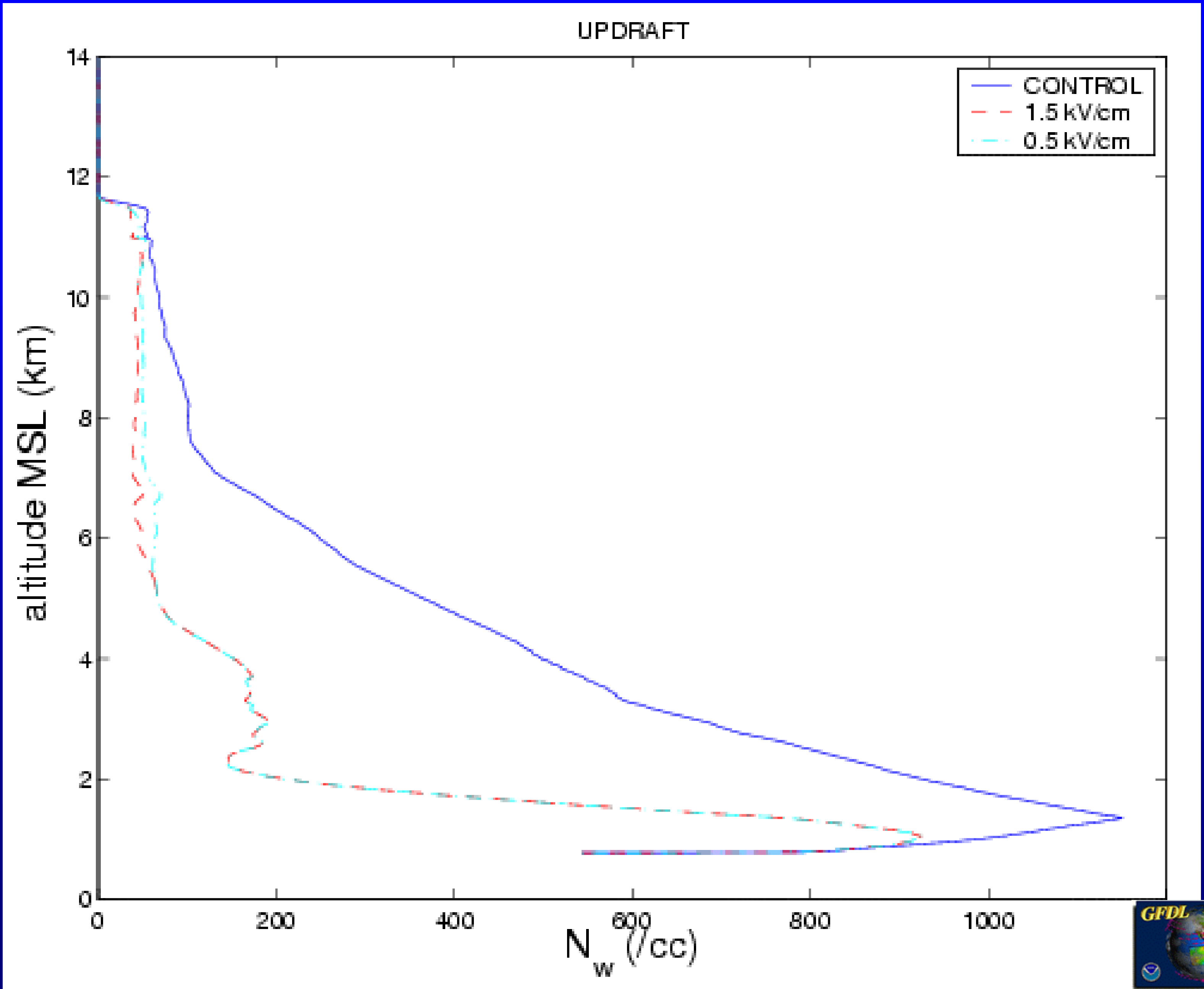
Simulations:-

– Control: no E-field
– Perturbation simulation: E_{max} ~ 0.5 to 1.5 kV/cm

Electric field:-



Electric field:-



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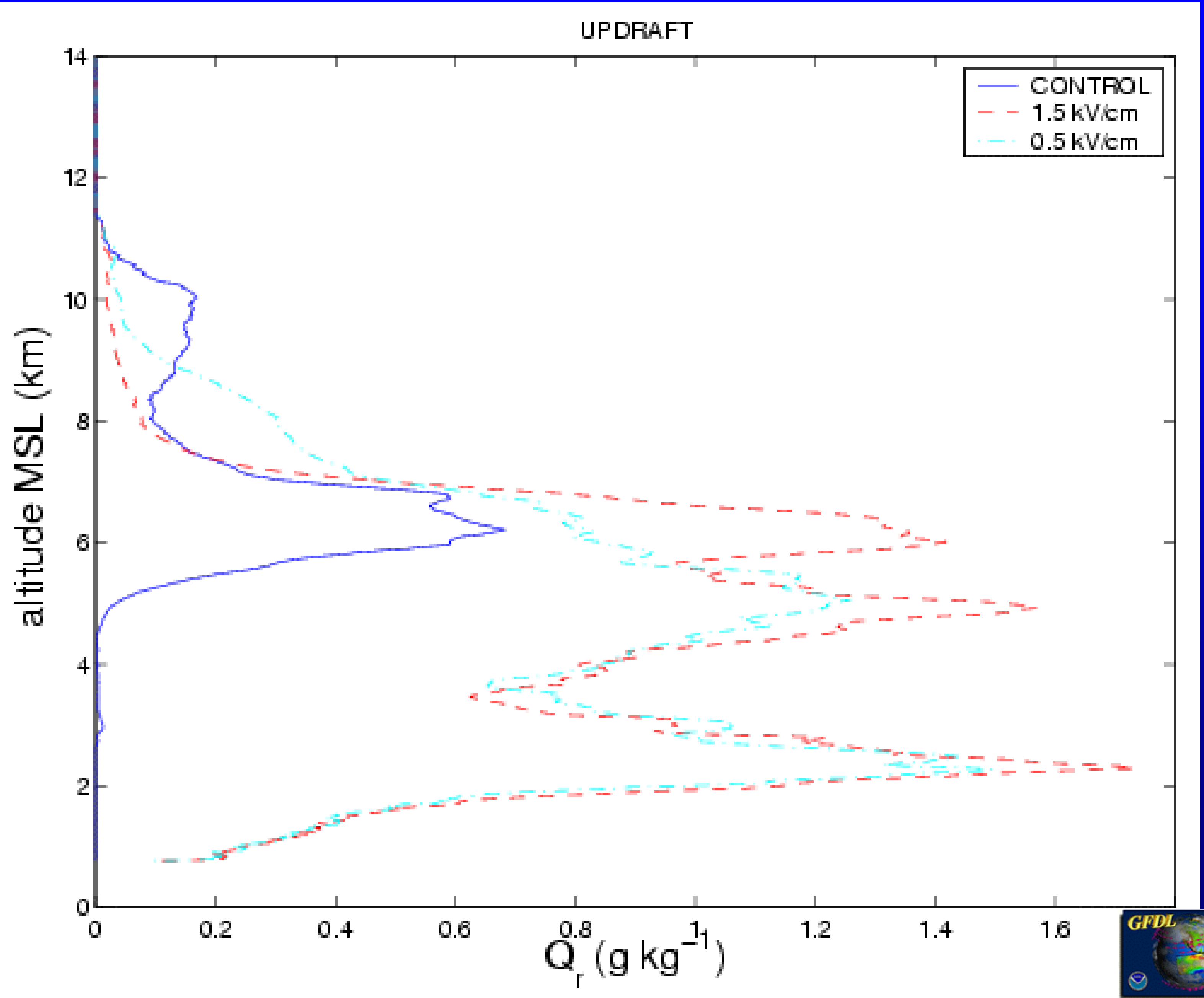
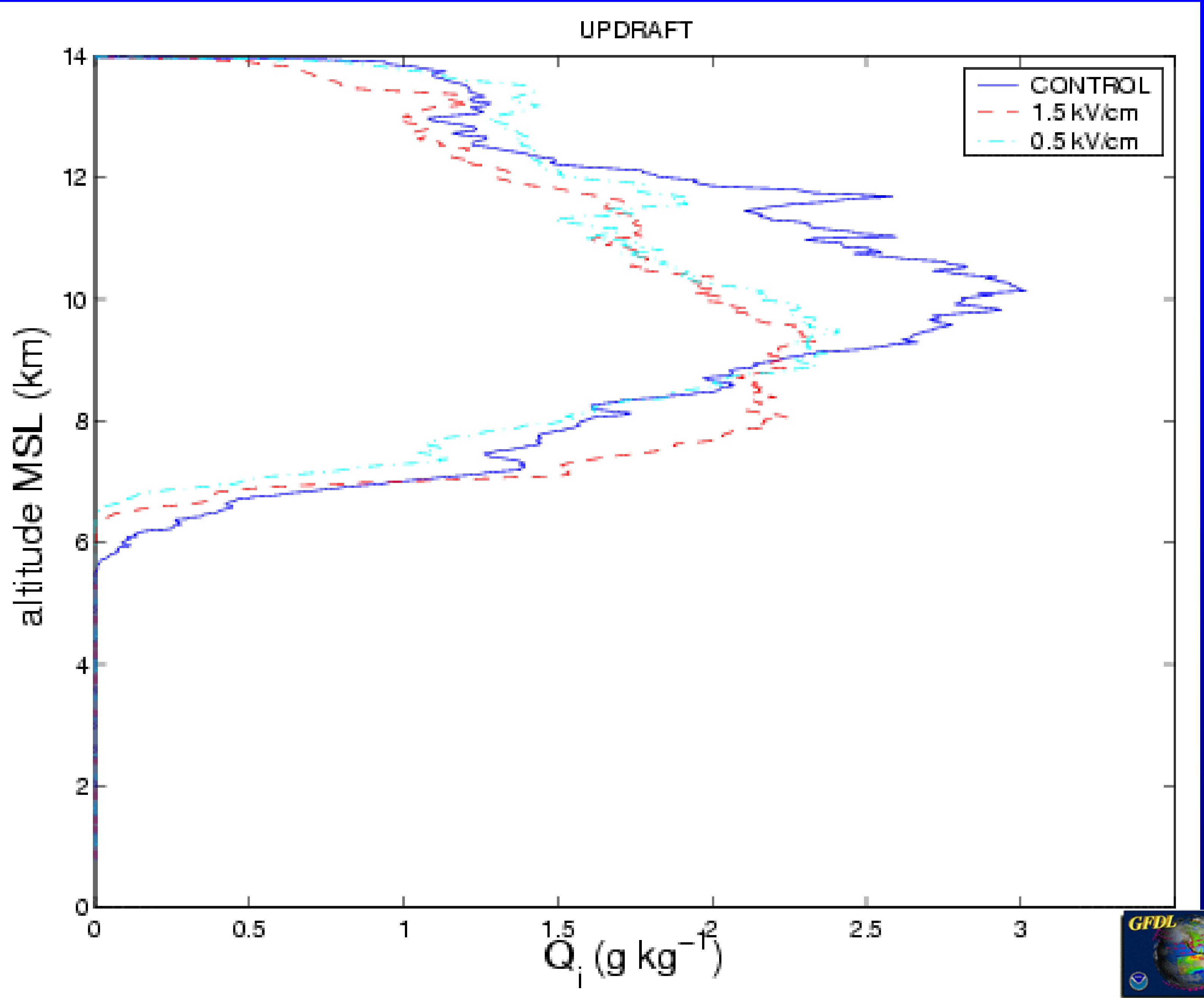
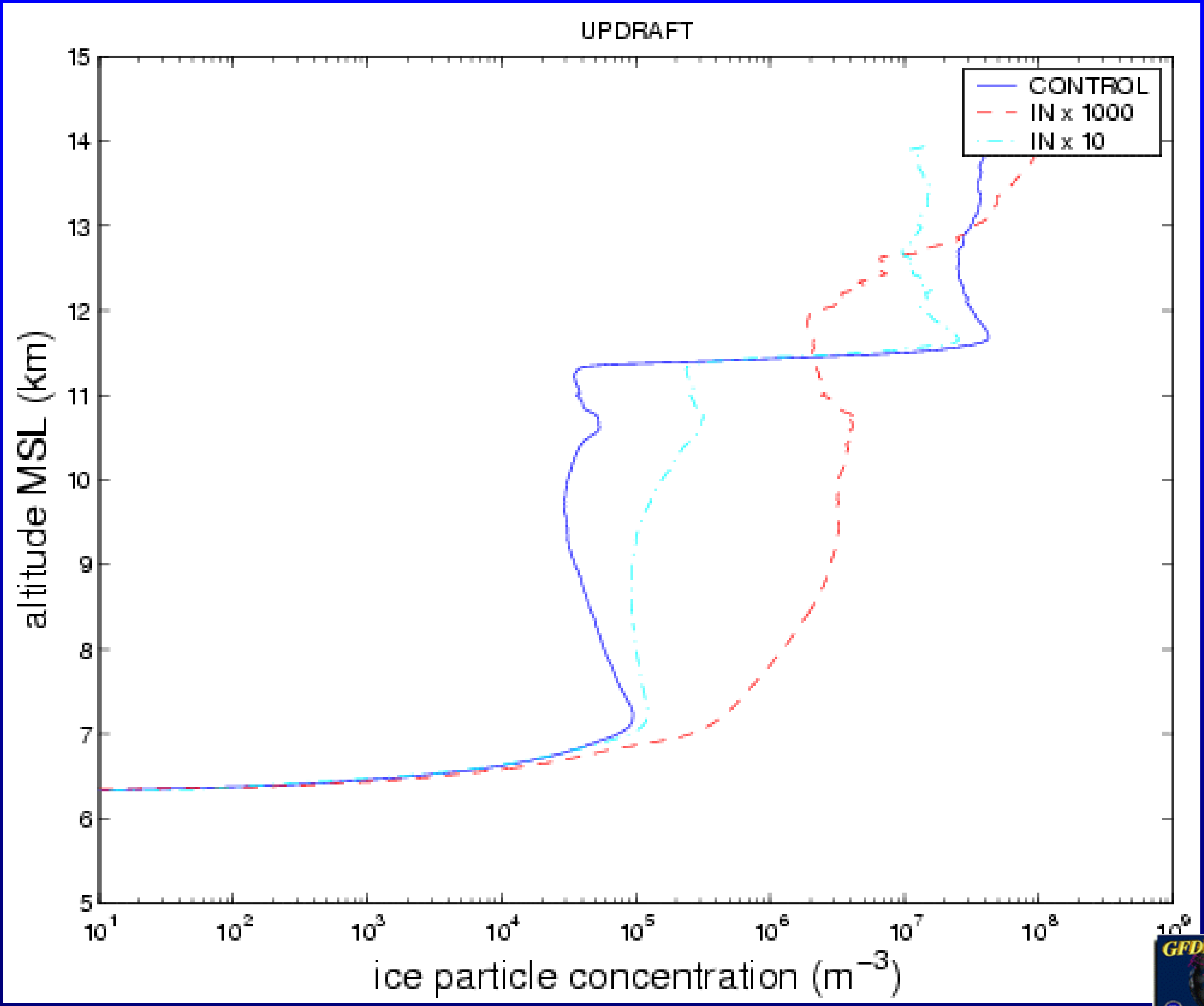


Electric field:-



IN concentrations:-



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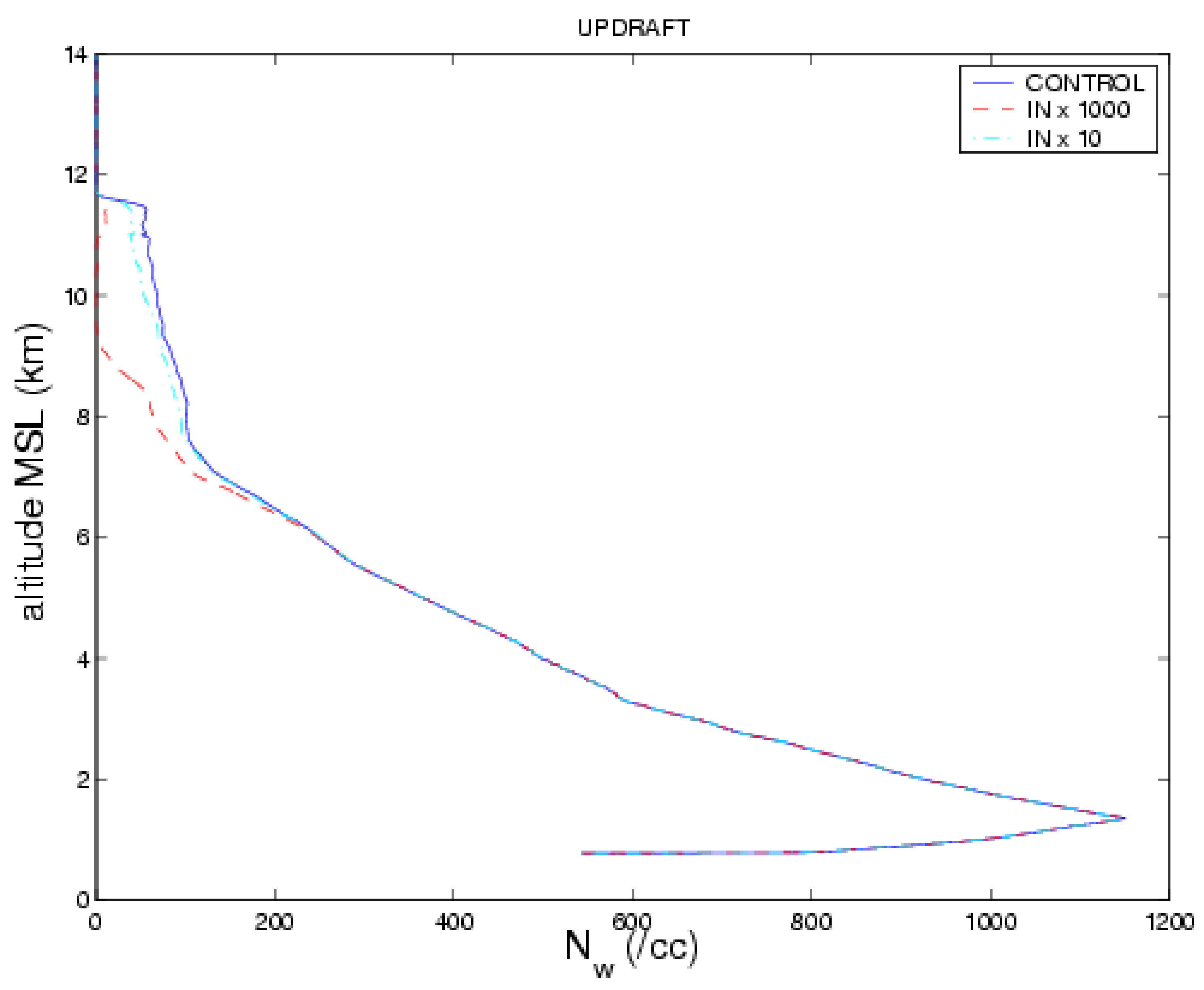

5. CONCLUSIONS

Prescribed E-field alters the collision efficiency for coalescence, causing:-

- rain and ice precipitation enhanced, allowing fewer droplets/aerosols to reach the anvil base;
- **anvil ice concentrations reduced by about 50%;**
- a less active H-M process.

Good idea to measure electric fields in Cb at the same time as observing their microphysical properties *in situ*.

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- Even in the IN x 10 case, homogeneous freezing of cloud-droplets still accounts for most (99%) of the anvil ice crystals.

- The anvil ice concentration is reduced by about two thirds, due to extra losses of droplets, in the IN x 10 case.

- **Saharan dust episode (IN x 1000 case) causes all the cloud-water to disappear – apparently by evaporation - in the updraft aloft.**

- Homogeneous freezing of aerosols then dominates the anvil glaciation in this Saharan dust episode. This contrasts with homogeneous freezing of cloud-droplets dominating the control. Consequently, the effective anvil base is raised by 1- 2 km.