The possible role of small aerosols in the microphysics and lightning of deep maritime clouds

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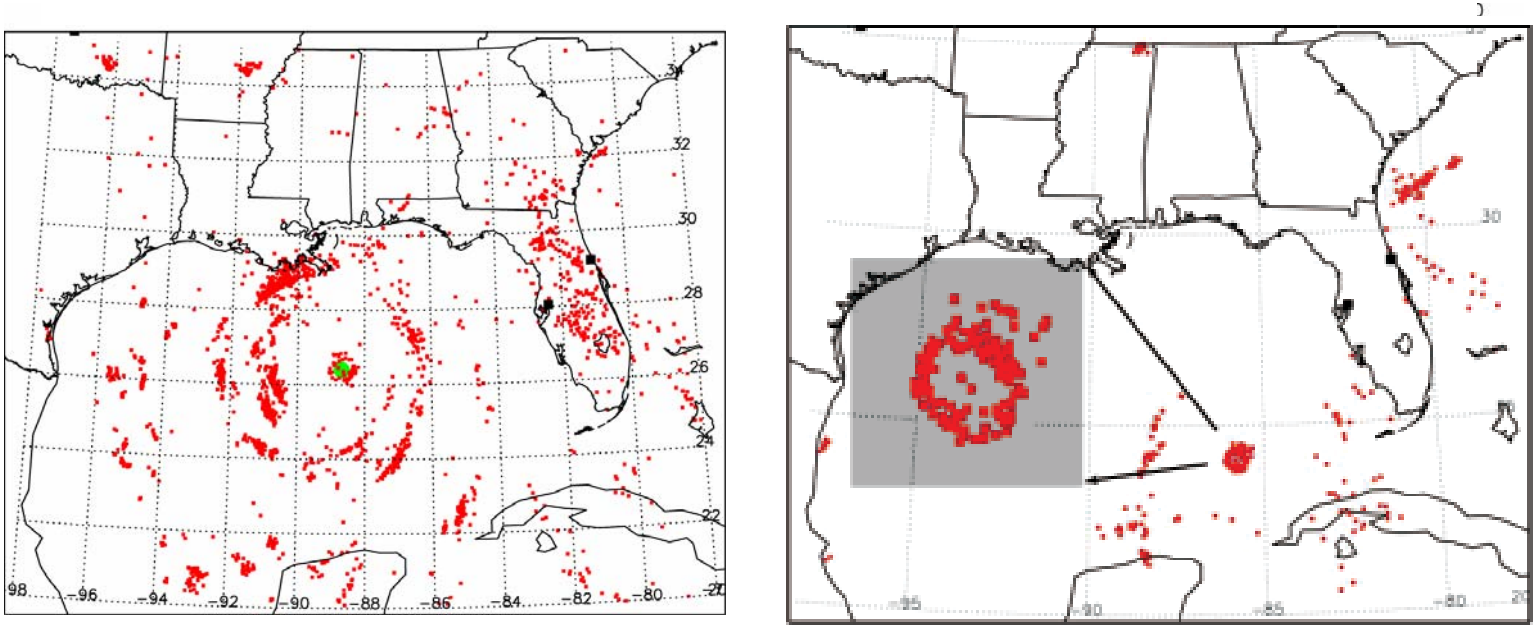
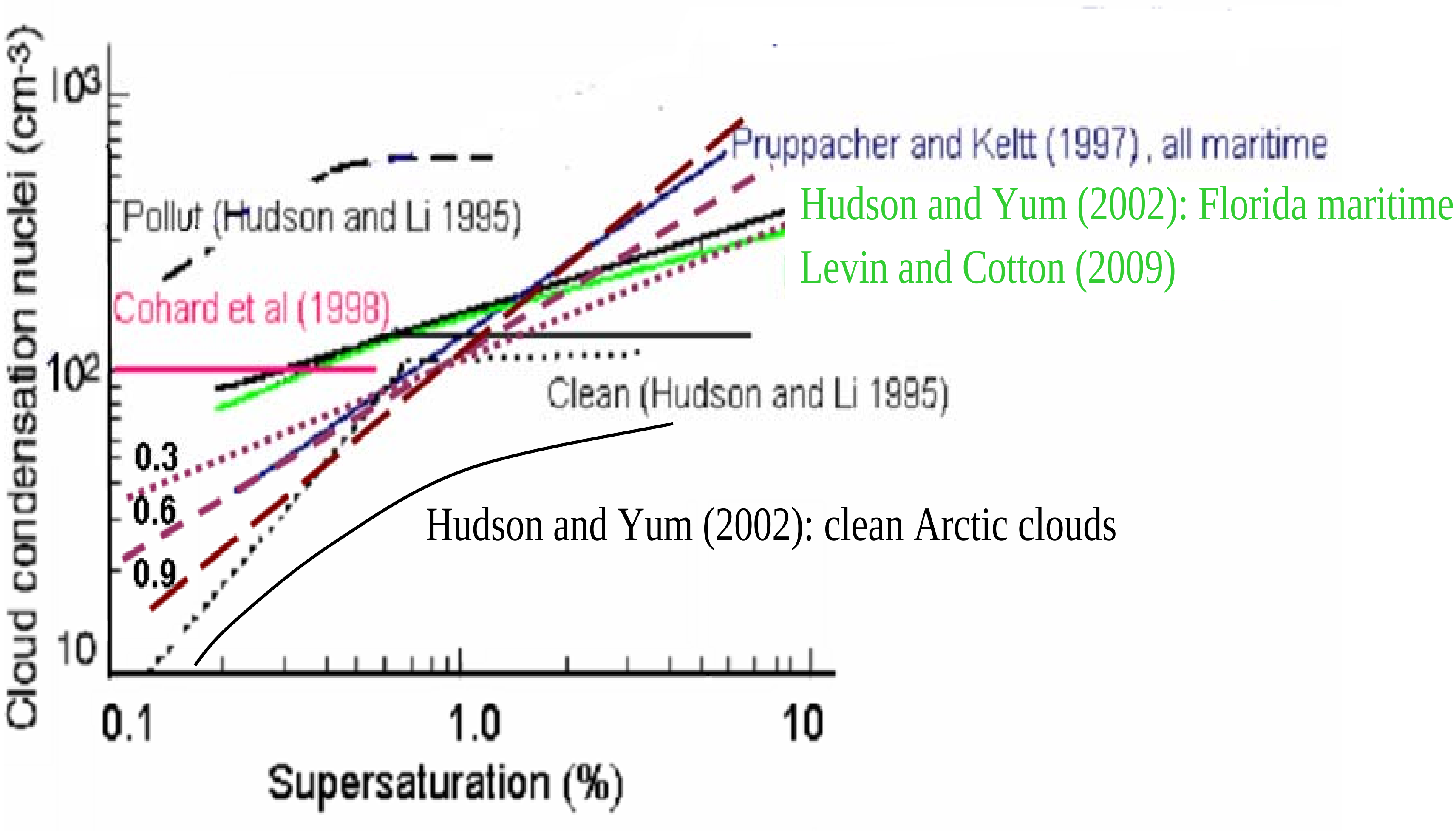


Figure 2. Eye-wall lightning density in hurricane Katrina when it progressed from Cat 4 to 5 (17:30-18:30 UTC, 28 Aug 2005) (left) and in hurricane Rita (right panel) during its intensification from Cat 3 to 5 (14–15 UTC, 21 Sep 2005) (right) (after Shao et al., EOS, 86, 42, 18 Oct. 2005)

We ask:

"Why does lightning take place in deep maritime convective clouds in the Intertropical Convergence zone and in hurricane eyewalls at all?"

Dependences of concentration of activated CCN on supersaturation over the sea



$$N_{ccn} = N_o S^k$$

In simulations we used: $N_o = 100 cm^{-3}$

$$k = 0.3,\ 0.6\ and\ 0.9$$

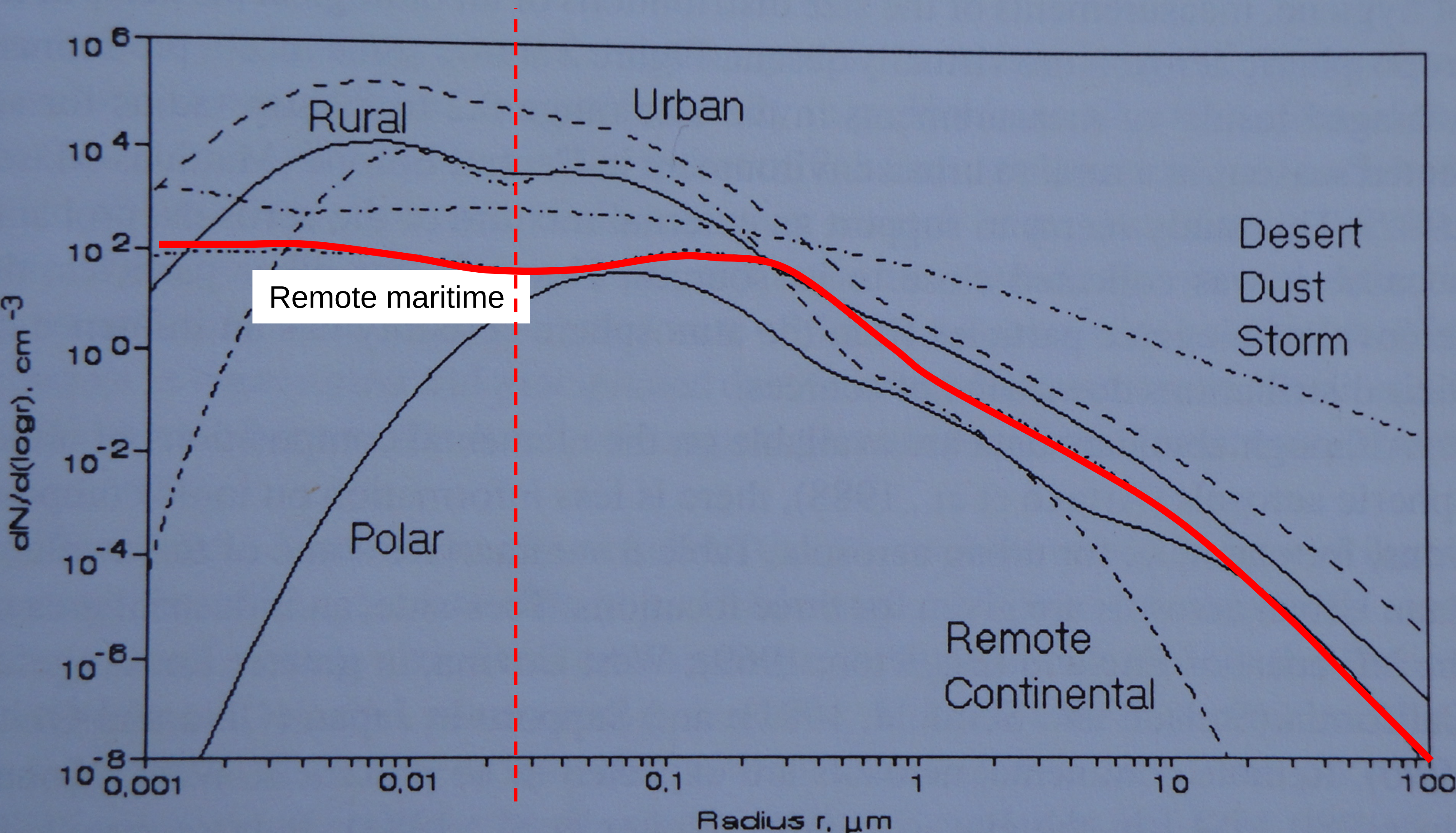


Figure 1 Model number size distributions of selected atmospheric aerosols according to Table 2.

R. Jaenicke 1993

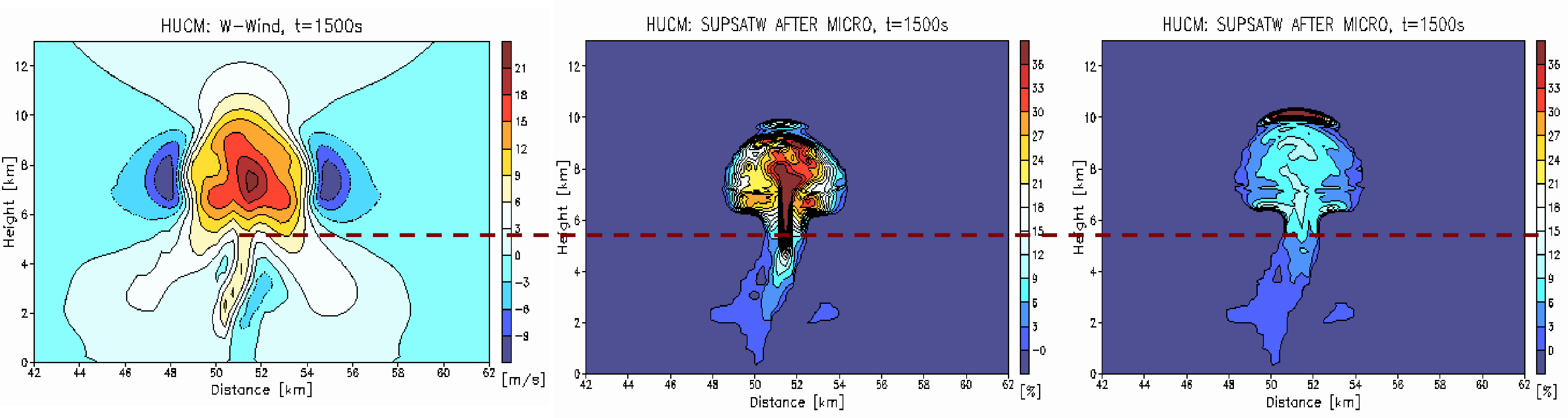
$$S_{eq} = \frac{W}{N_d \bar{r}}$$

In continental clouds Smax~2%-3%

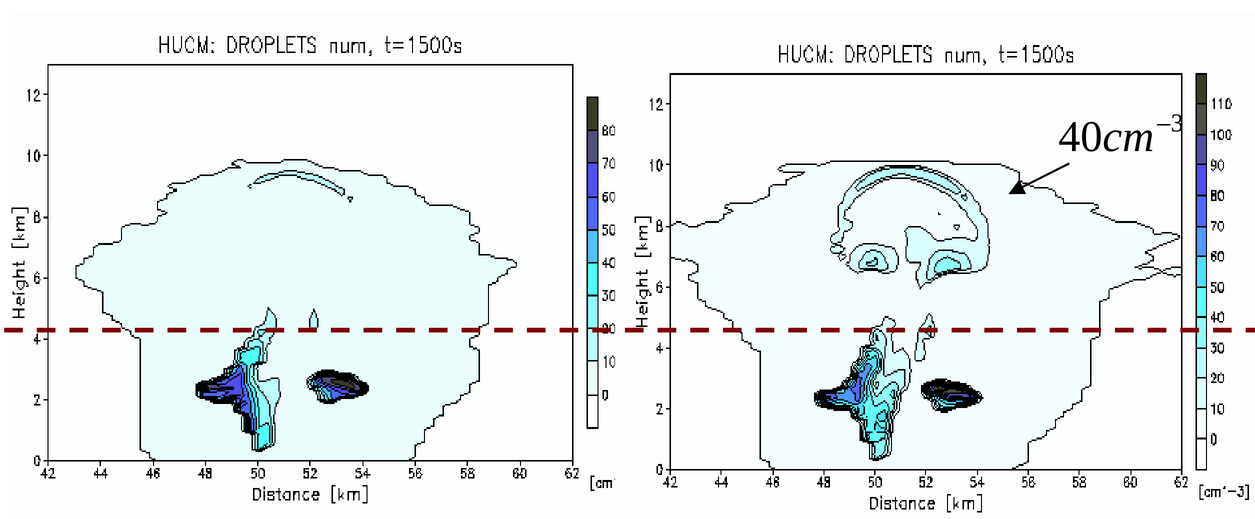
W

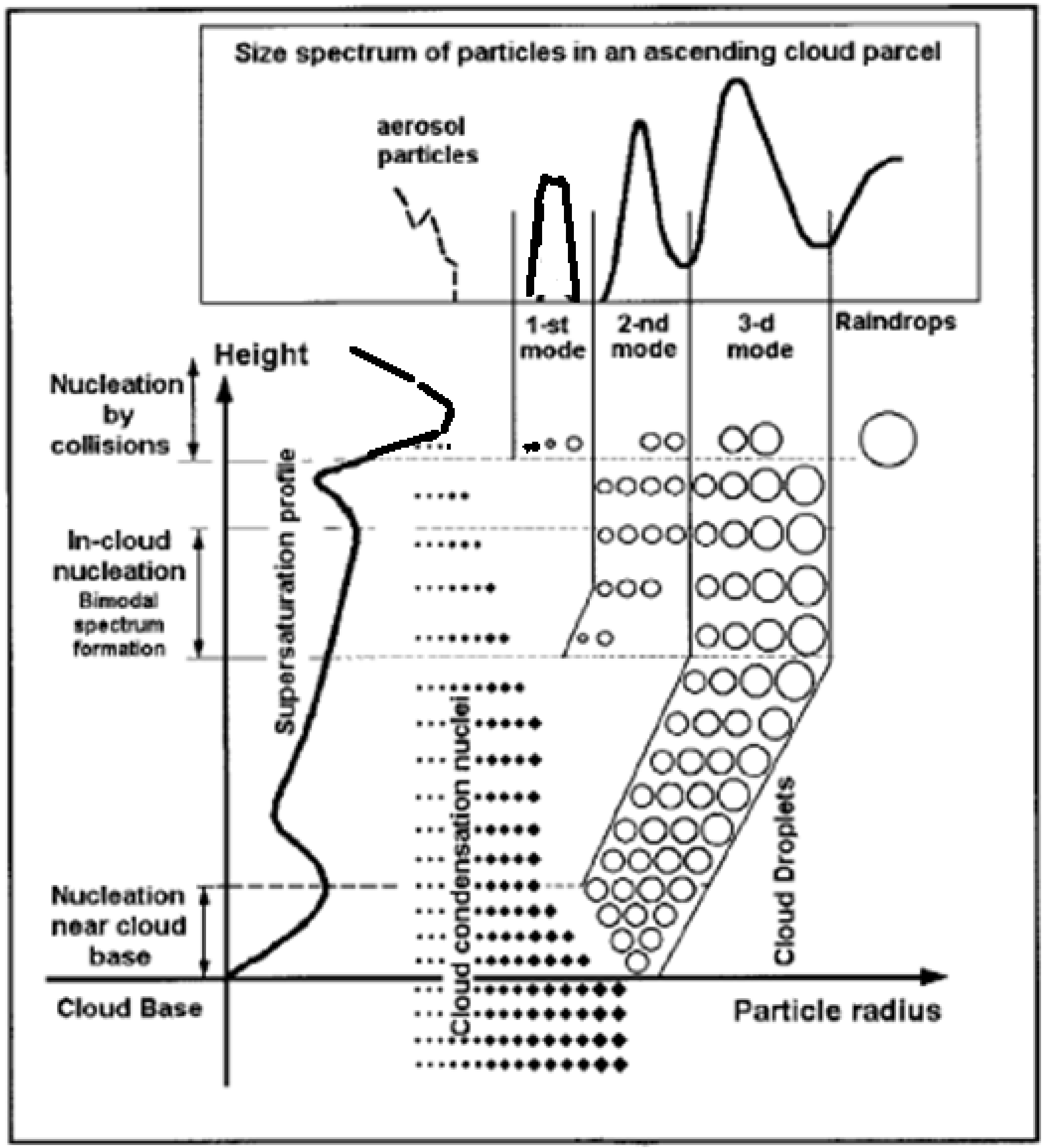
K=0.3, Smax=36%

K=0.9, Smax=12%



Dramatic decrease in droplet concentration




Size spectrum of particles in an ascending cloud parcel
aerosol particles
1-st mode
2-nd mode
3-d mode
Raindrops
Height
Nucleation by collisions
In-cloud nucleation
Bimodal spectrum formation
Supersaturation profile
Cloud condensation nuclei
Cloud Droplets
Nucleation near cloud base
Cloud Base
Particle radius

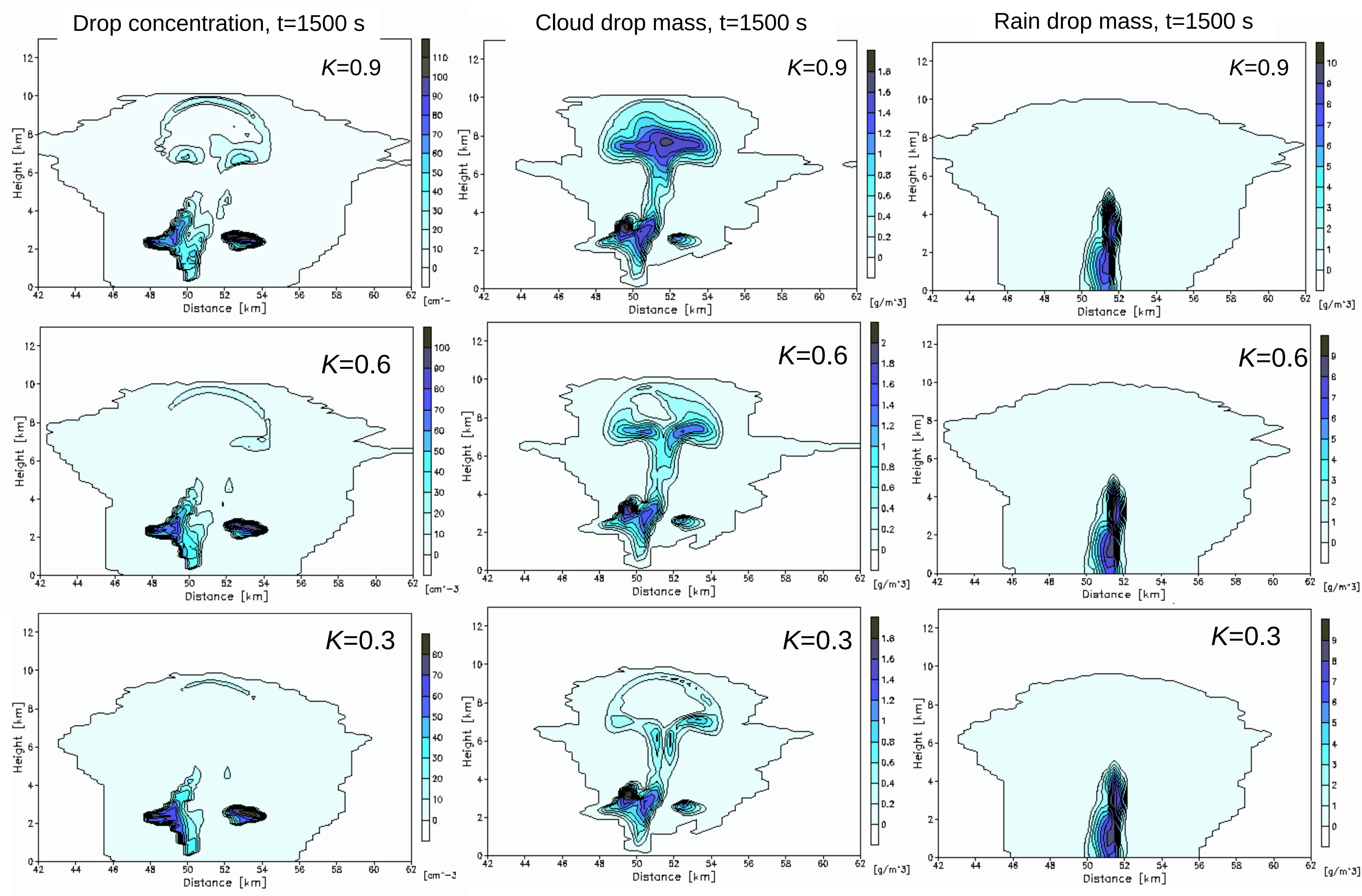


Figure 4. Fields of the droplet concentration Nd (left), the cloud water content (CWC) (middle), and rain water content (RWC) (right) for $N_o = 100\ cm^{-3}$ at different slope parameters: k=0.9 (upper panels), k=0.6 (middle panels) and k=0.3 (low panels).

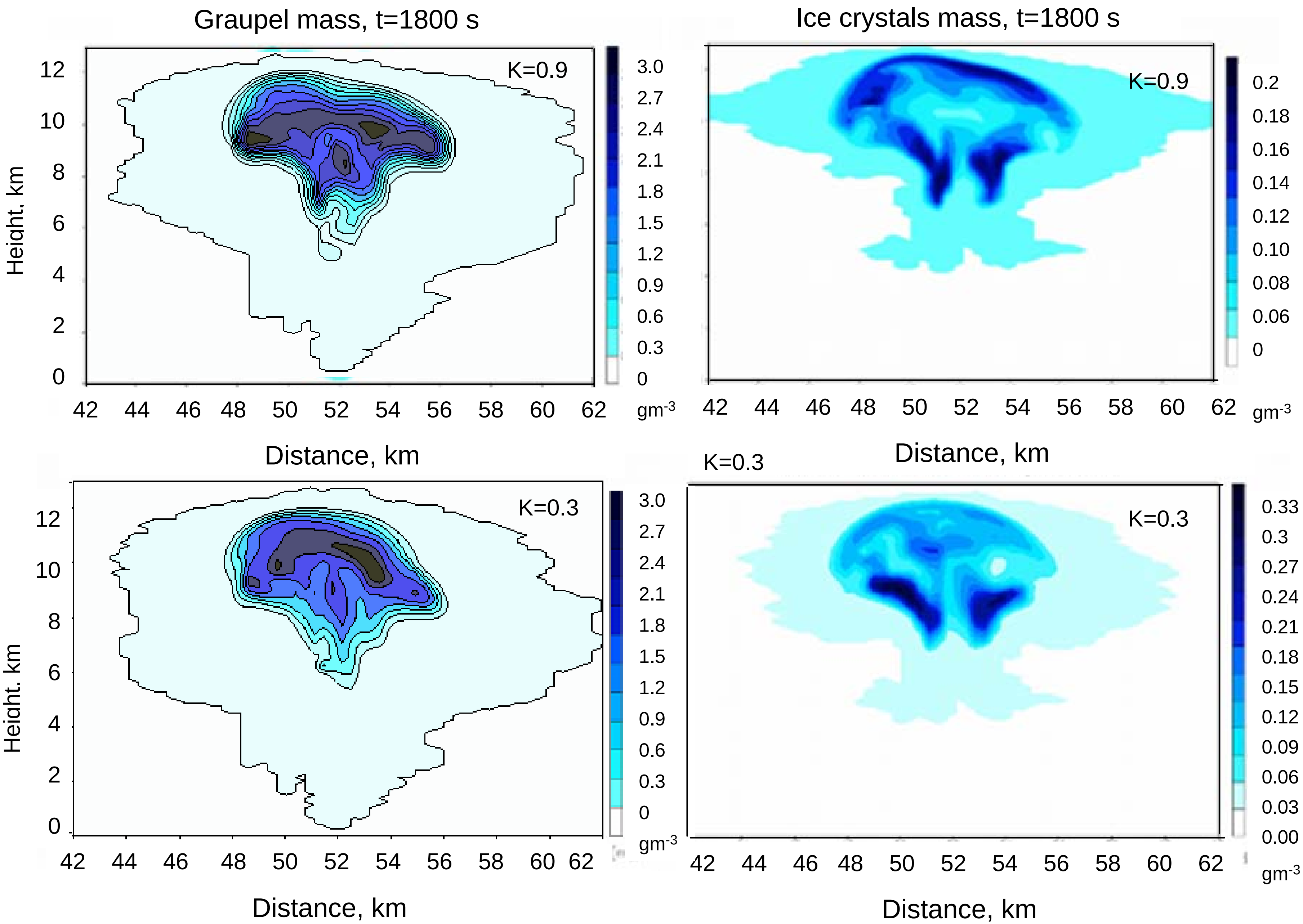


Figure 7. Fields of graupel (left) and ice contents (right) in the simulation with k=0.9 (upper row) and k=0.3 (low) at t=1800 s.

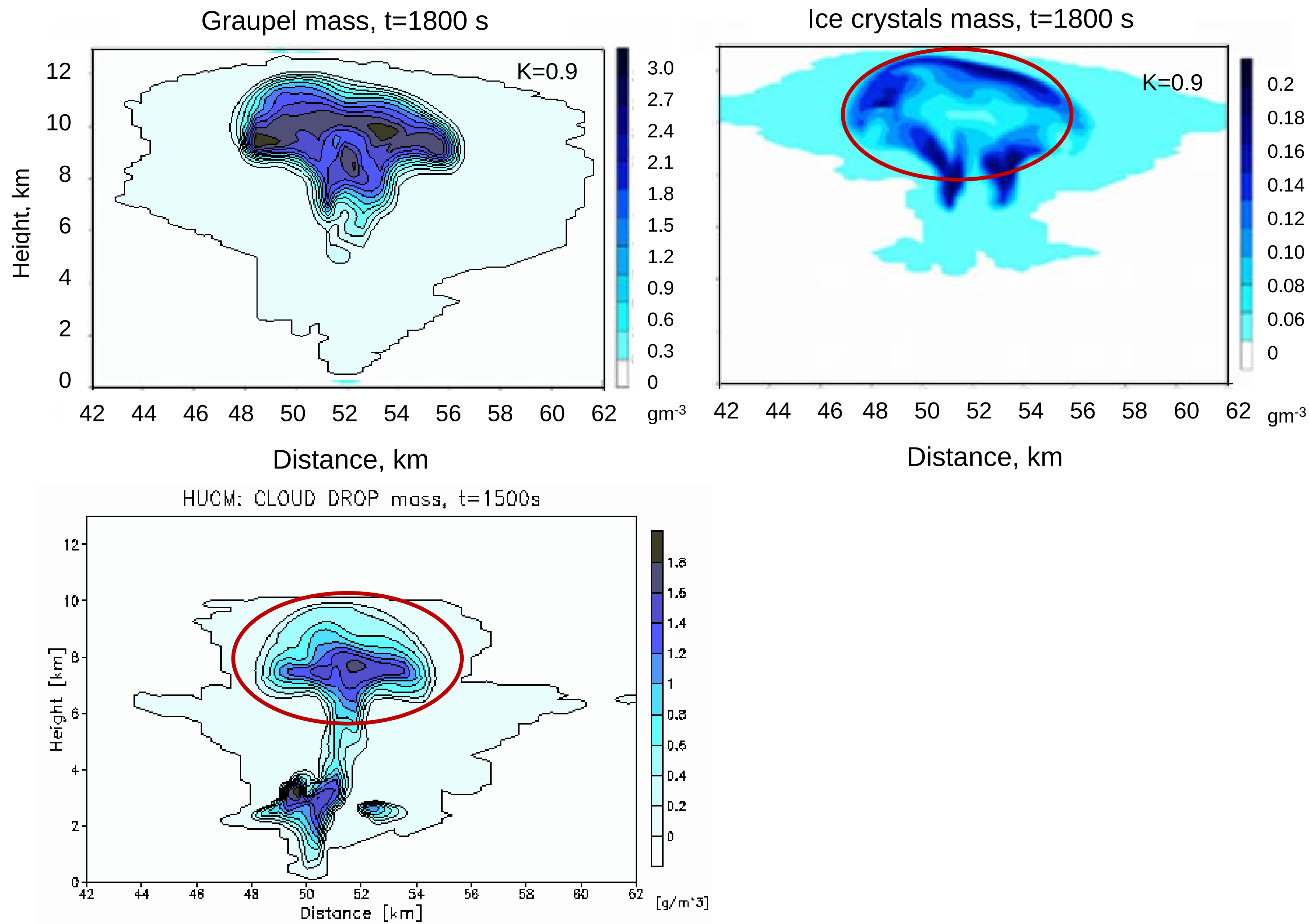


Figure 7. Fields of graupel (left) and ice contents (right) in the simulation with k=0.9 (upper row) and k=0.3 (low) at t=1800 s.

Discussion and conclusions

1) This study demonstrates the importance of atmospheric aerosols with diameters below ~0.01-0.02 μm in the creation of microphysical structure of deep convective clouds over the ocean.

2) Low CCN concentration (at supersaturation of 1%) determines rapid formation of warm rain and decrease in concentration of droplets nucleated at cloud base. Under such conditions supersaturation in cloud updrafts of maritime convective clouds increases during ascent.

3) In-cloud nucleation and formation of small cloud droplets several km above the cloud base explain formation of supercooled water at high levels, formation of graupel and ice crystals in cloud anvils.

4) The process of in-cloud nucleation allows one to explain formation of lighting in extremely maritime clouds in eyewall of hurricanes, high optical depth of anvils of deep tropical clouds in the ITCZ.

5) The existence of giant CCN and other factors accelerating warm rain formation cannot prevent formation of new droplets aloft. Moreover, the faster is washout due to warm rain, the higher can be supersaturation in clouds aloft and the greater the production of supercooled droplets at upper levels.

Thanks!