The mechanism of first rain drops formation in deep convective clouds

A. Khain (1), T. V. Prabha (2), N. Benmoshe (1), G. Pandithurai (2), M. Ovchinnikov (3)

(1) The Hebrew University of Jerusalem, Israel
(2) The Institute of Tropical Meteorology, India
(3) The Pacific Northwest National Laboratory, USA

Acknowledgements

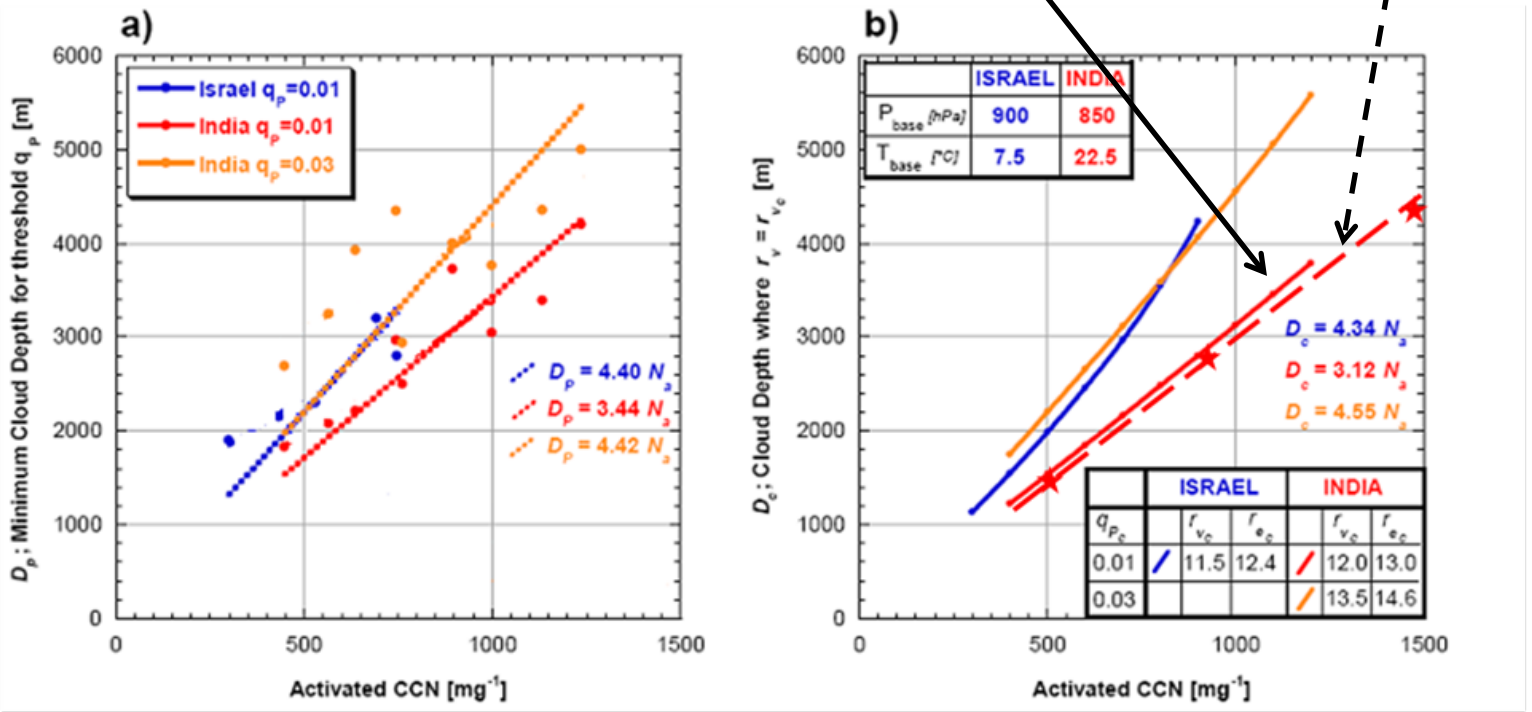
This research was supported by the U.S. Department of Energy's Atmospheric Science Program Atmospheric System Research, an Office of Science, Office of Biological and Environmental Research program, under Grant No. DE-SC0006788

The CAIPEEX project and IITM are fully funded by Ministry of Earth Sciences, the Government of India and the city of New Delhi.

(Khain et al 2013).

Height of the first rain formation as a **LINEAR** function of droplet concentration (Freud and Rosenfeld 2012).

Observations Adiabatic parcel model SBM cloud model

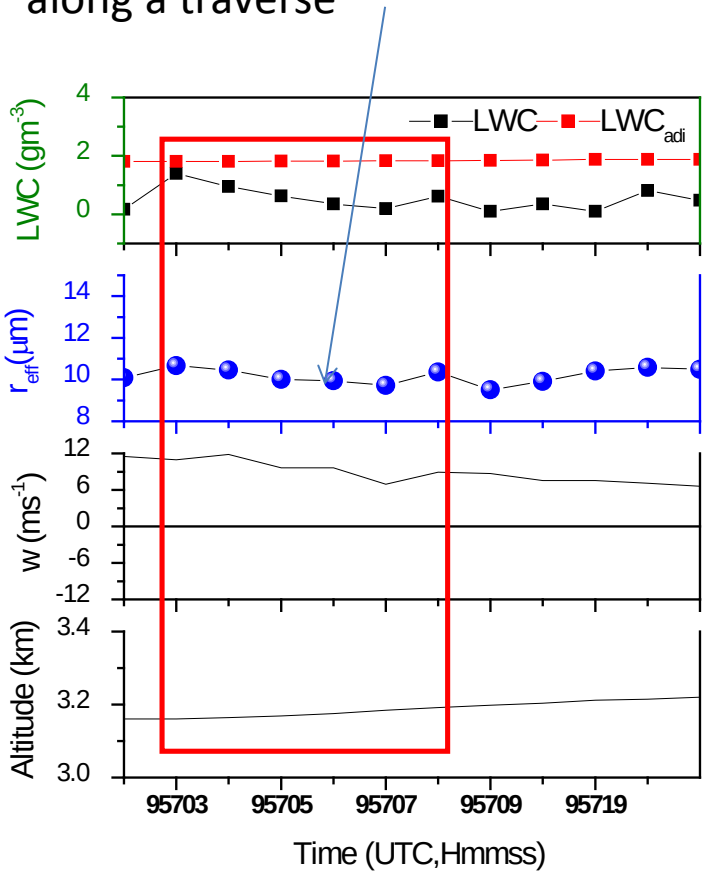


According to the theory, in adiabatic parcel $D_p \sim r_{v\_cr}^3 N$ with the proportionality coefficient slightly depending on the temperature (Pinsky et al., 2013).

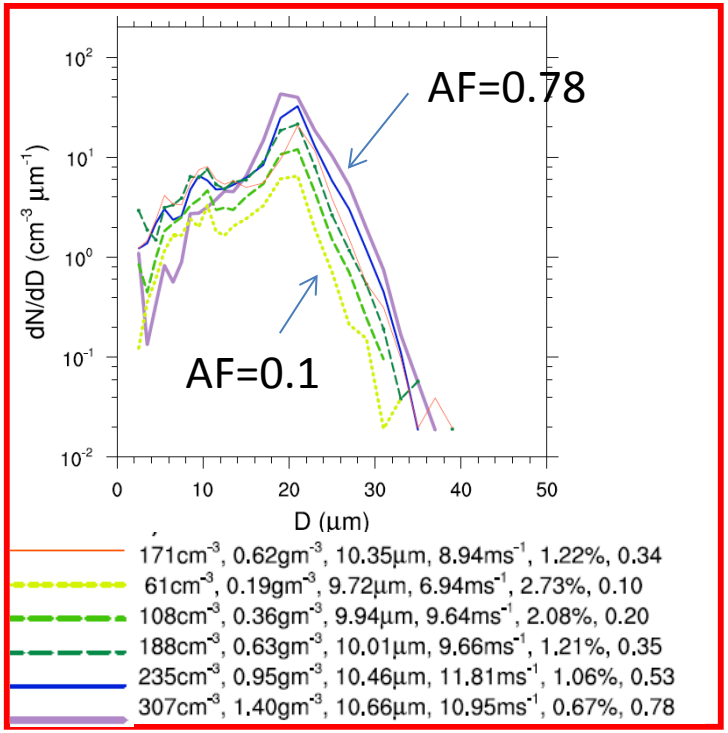
"Why a dynamically simple adiabatic parcel model is able to reproduce the height of the first rain drops formation in a dynamically complicated non-adiabatic convective cloud involved in mixing with environment?"

The Cloud Aerosol and Precipitation Enhancement EXperiment (CAIPEEX-2010)

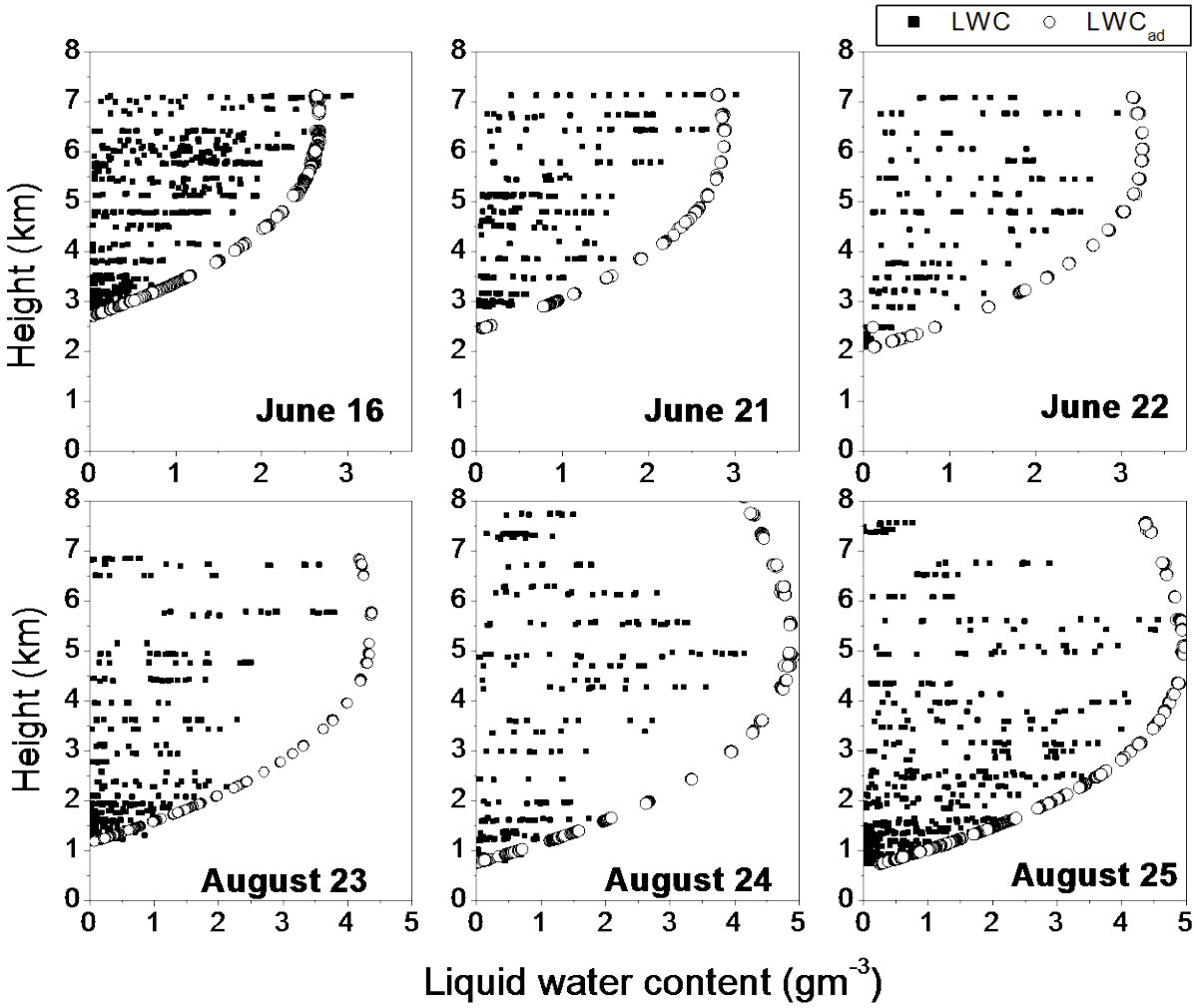
1) Effective radius is nearly constant along a traverse



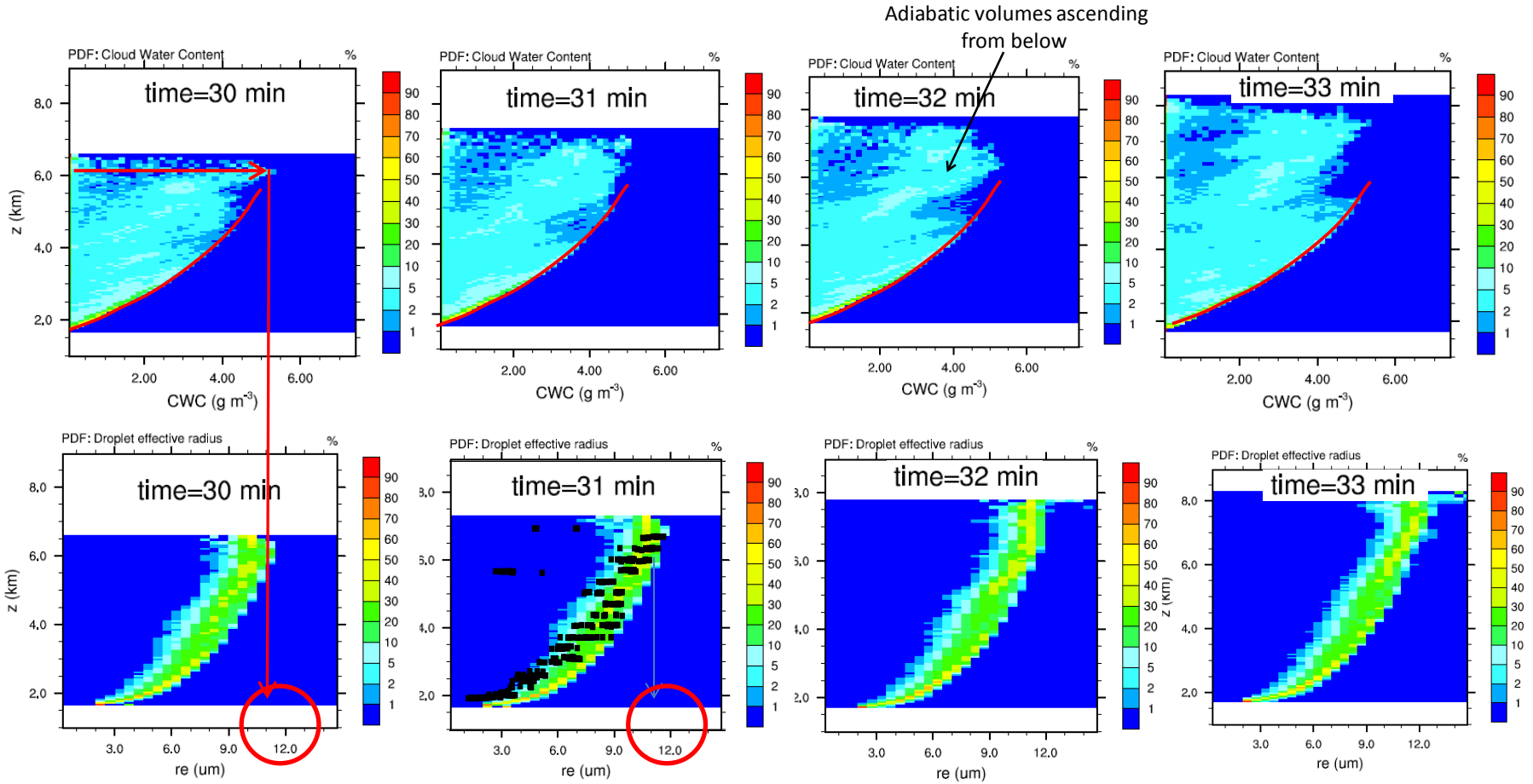
2) High adiabatic fraction corresponds to the widest DSD



CAIPEEX 2009: LWC values measured at different heights in developing cumulus clouds observed : a) in premonsoon clouds developing in extremely polluted and dry atmosphere (June 16); b) transition period (June 21-) and
c) monsoon clouds developing in moist and less polluted air (June -22, August 23, 24, 25).

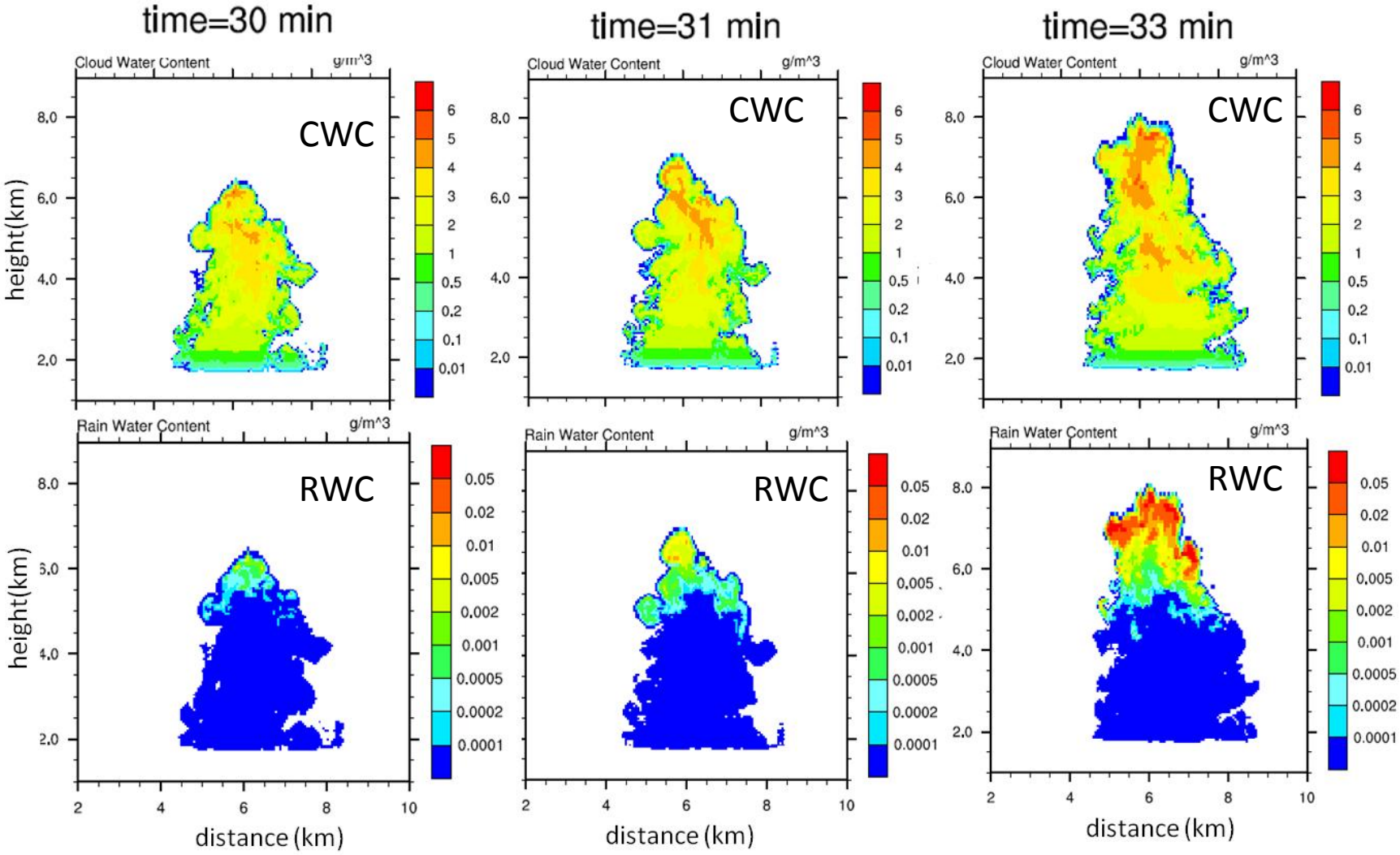


Upper row: PDF of cloud water content at different time instances (3D SAM/SBM) .



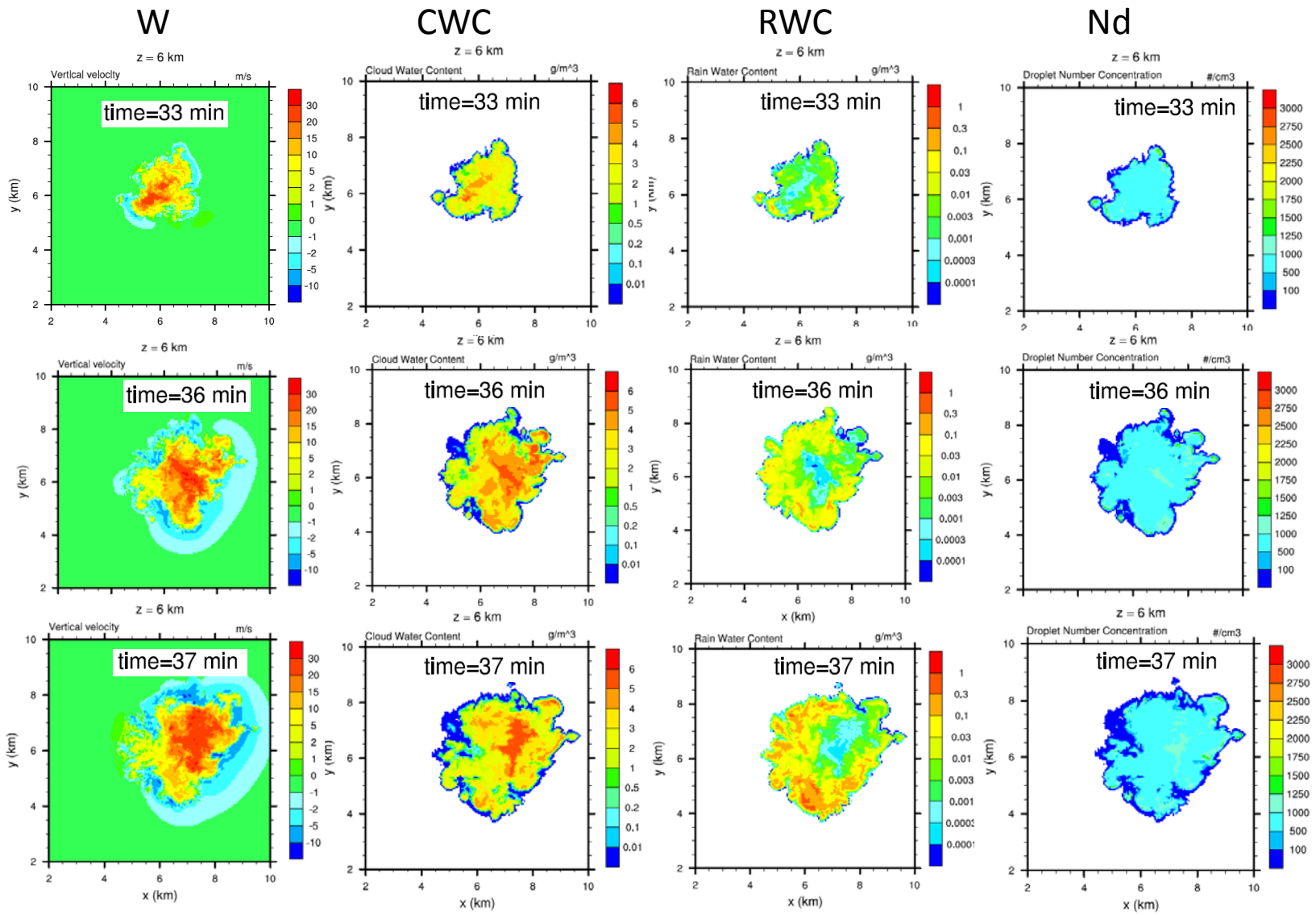
Bottom row: Vertical profiles of probability distribution function of effective radius at the time period of first raindrop formation. Height is measured from the surface.

Observations of effective radius during a transition (pre-monsoon to monsoon) period with high aerosol concentrations is shown with black symbols.



a) First raindrops form in zones of maximum LWC, i.e. in undiluted zones

b) In a few minutes rain is shifted to cloud edges and collect droplets. As a result, correlation between RWC and CWC becomes negative



a) In a few minutes after formation of first rain drops, raindrops sediment along the cloud edges in downdrafts.

b) In these zones CWC and drop concentration are minimum

Conclusions:

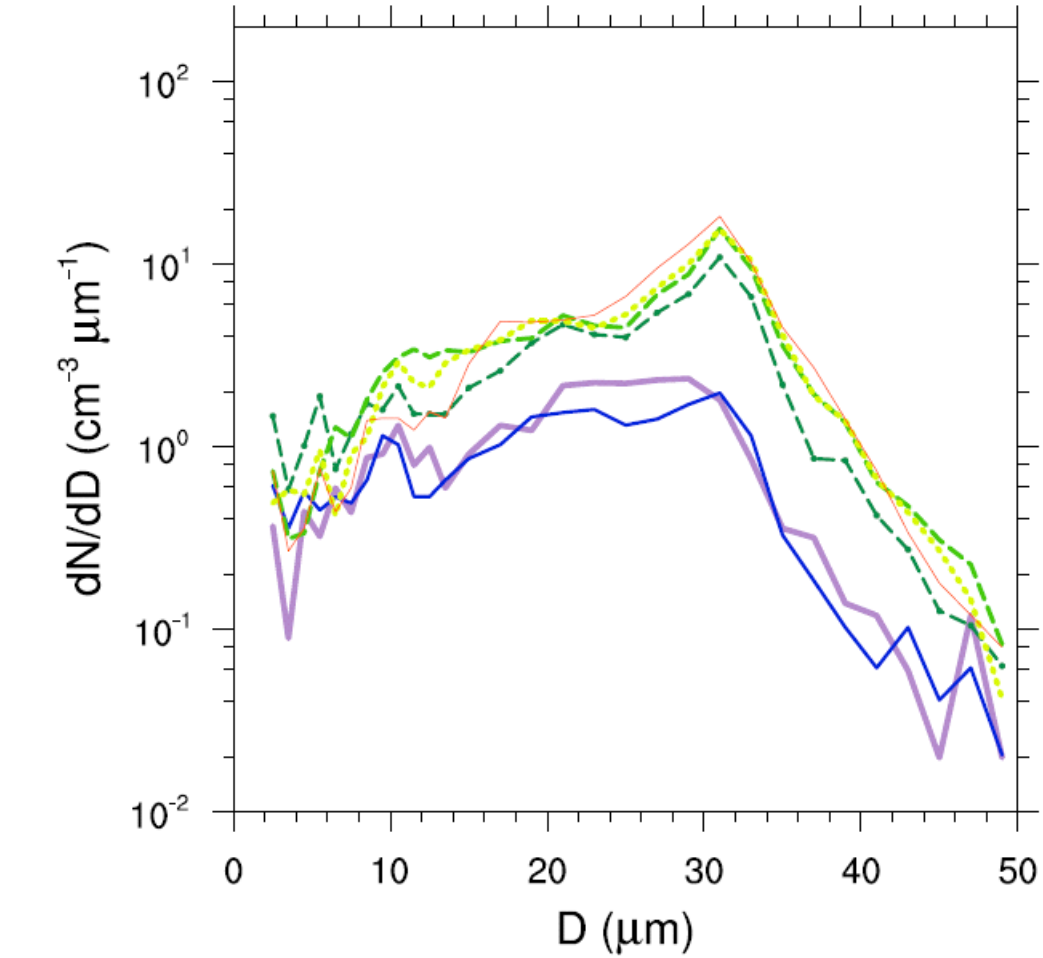
1. **Droplet size distributions in the non-diluted and slightly diluted cores are wider and contain more large droplets than in diluted volumes (non-trivial).**

2. **Process of raindrop formation is determined by the basic microphysical processes within ascending adiabatic volumes.**

   This allows one to predict the height of the formation of first rain drops considering the processes of nucleation, diffusion growth and collisions in adiabatic volumes.

3. **The results obtained in the study explain observational results reported by Freud and Rosenfeld (2012) according to which the height of first raindrop formation depends linearly on the droplet number concentration at cloud base.**

Thank you!



93506UTC, 5447m, 191cm^{-3}, 2.32gm^{-3}, 15.06µm, -2.76ms^{-1}, -0.23%, 0.72

93505UTC, 5451m, 175cm^{-3}, 2.05gm^{-3}, 15.07µm, 0.95ms^{-1}, 0.09%, 0.64

93504UTC, 5454m, 171cm^{-3}, 1.96gm^{-3}, 15.09µm, 0.72ms^{-1}, 0.07%, 0.61

93503UTC, 5455m, 128cm^{-3}, 1.37gm^{-3}, 14.78µm, 2.36ms^{-1}, 0.33%, 0.43

93502UTC, 5457m, 37cm^{-3}, 0.31gm^{-3}, 14.04µm, 5.69ms^{-1}, 3.11%, 0.10

93501UTC, 5458m, 45cm^{-3}, 0.38gm^{-3}, 13.86µm, 4.98ms^{-1}, 2.18%, 0.12