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Evaluating Cloud Microphysics against Aircraft measurements over India : A *CRM* study using WRF-CHEM

Chandan Sarangi, S. N. Tripathi* and Shivam Tripathi

Department of Civil Engineering, Indian Institute of Technology, Kanpur, India

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Motivation

Weather Research and Forecasting model coupled with chemistry (WRF-Chem) is a regional model which is widely used to study aerosol-cloud-rainfall-climate feedbacks. In this study we are using unique in situ flight measurements obtained during *Cloud Aerosol Interaction and Precipitation Enhancement Experiment* (CAIPEEX) to evaluate the model's performance in reproducing vertical distribution of moist thermodynamics and cloud microphysics over Indo Gangetic Plains, located in Northern India.

Flight path and Model set-up

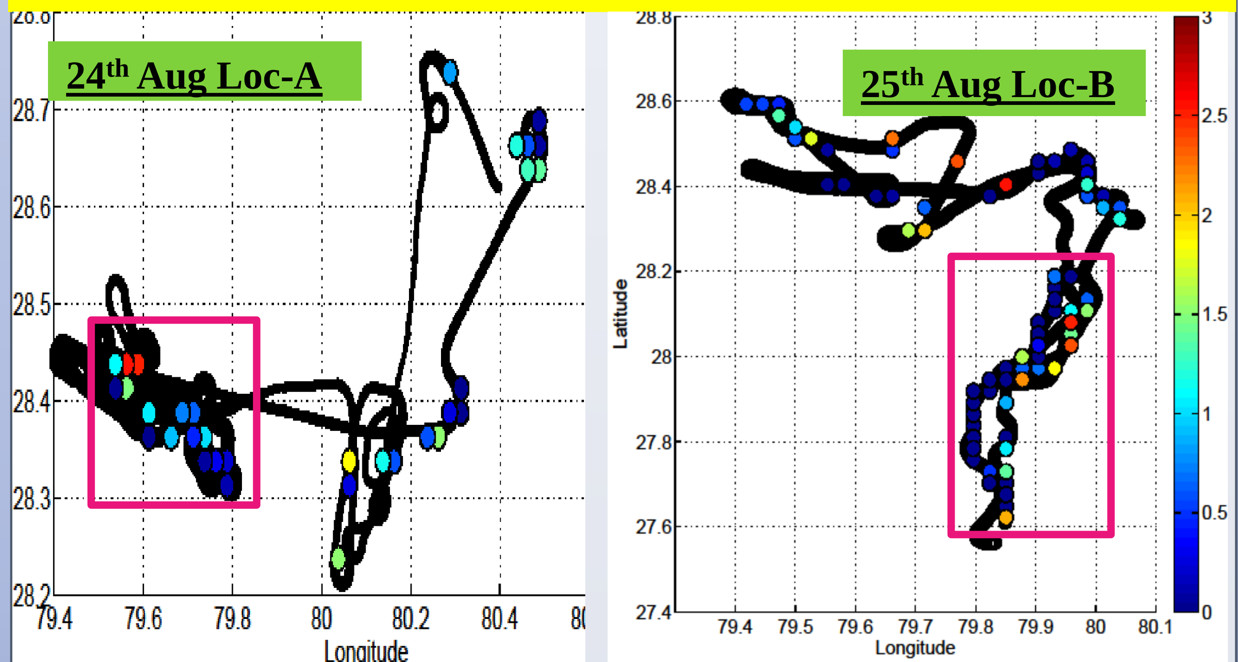


Figure 1 shows the flight path on 24th and 25th in black dots. The colored dots are total hydrometeor mass conc. (g/cubicmetre). Two regions (pink boxes) are studied where aircraft measurements are present upto 7 km altitude.

Methodology

1. Cloud resolving nested model is set up using WRF 3.5 for the 2 regions. (Model details in Table 1).
2. Performance of Morrison and Lin microphysics in WRF only simulations are evaluated to identify the better performing scheme.
3. WRF-chem simulated profiles of microphysical variables are evaluated against measured variables (see Table 2)

Figure 2 illustrates the nested domains of WRF and WRF-Chem simulations with innermost domain having 3 km resolution(CRM)

Table 1 : Model set-up details	
Radiation (LW and SW)	RRTMG scheme
Micro-physics	Morrison /Lin
Cumulus (Outer domains)	Grell-Fritsch (GF)
PBL	Mellor-Yamada-Janjic (MYJ)
Aerosol-Chemistry module	MOSAIC-CBMZ (4 bin)
Simulation time	72 hours (spin up –12 hrs)
Vertical layers	33
IC/BC (meteorology)	Reanalysis FNL
Anthropogenic emission	MACCcity global emissions
Biogenic emission	MEGAN (2009)
IC/BC (chemistry)	MOZART global model

Sensitivity of profiles to microphysical schemes

- WRF can simulate the prevalent thermodynamic conditions reasonably well with both the microphysical schemes performing similar.
- Mean RMSE of Temp is 0.82 (0.87) degree C and of RH is 17 (21) % respectively for Morr (Lin).
- Morrison scheme is performing better in simulating total hydrometeor mass concentration compared to LIN scheme on 24th Aug. But both the schemes are unable to capture cloud layer between 3km and 5km on 25th Aug.
- Hence Morrison scheme is used in WRF-Chem

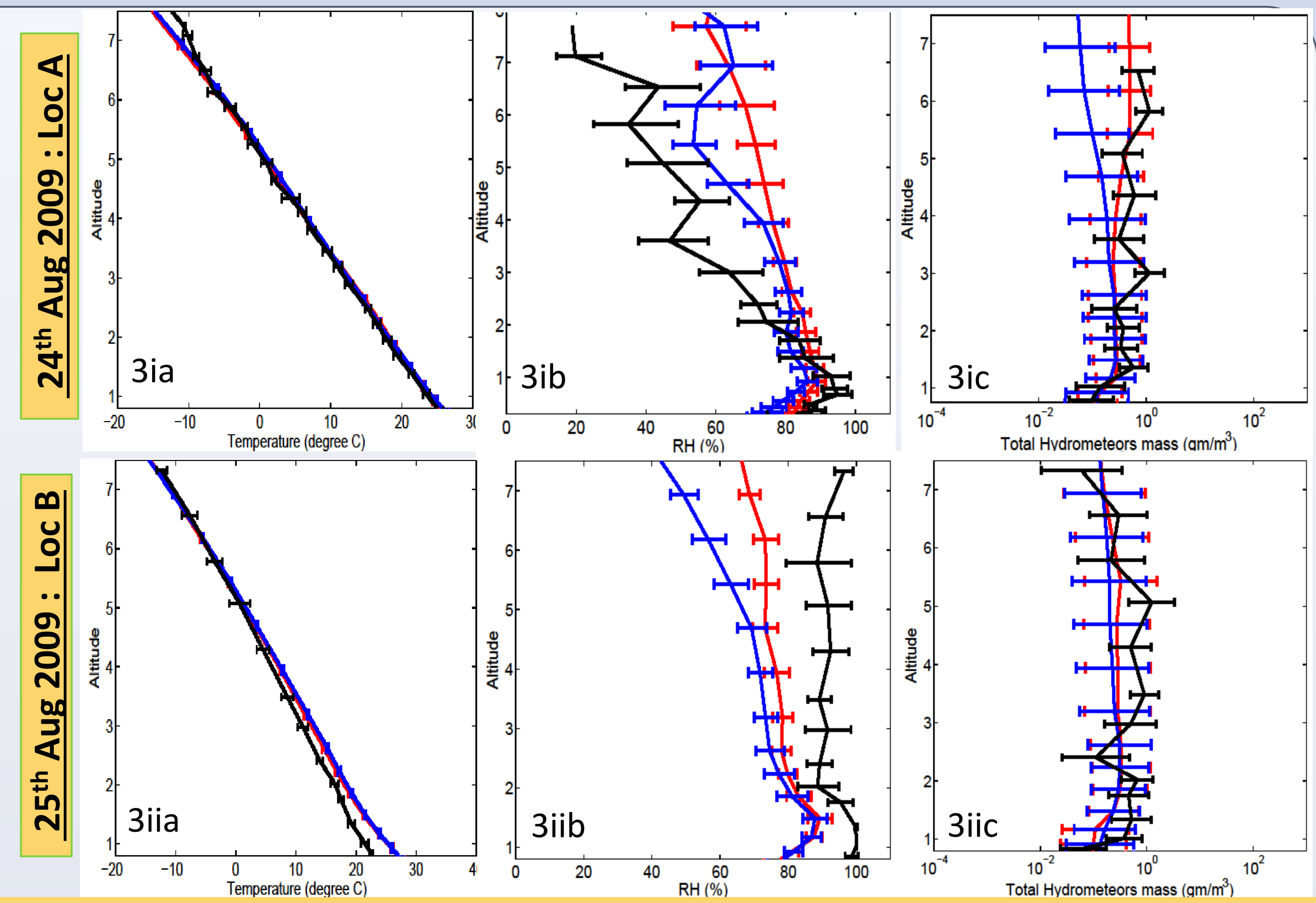
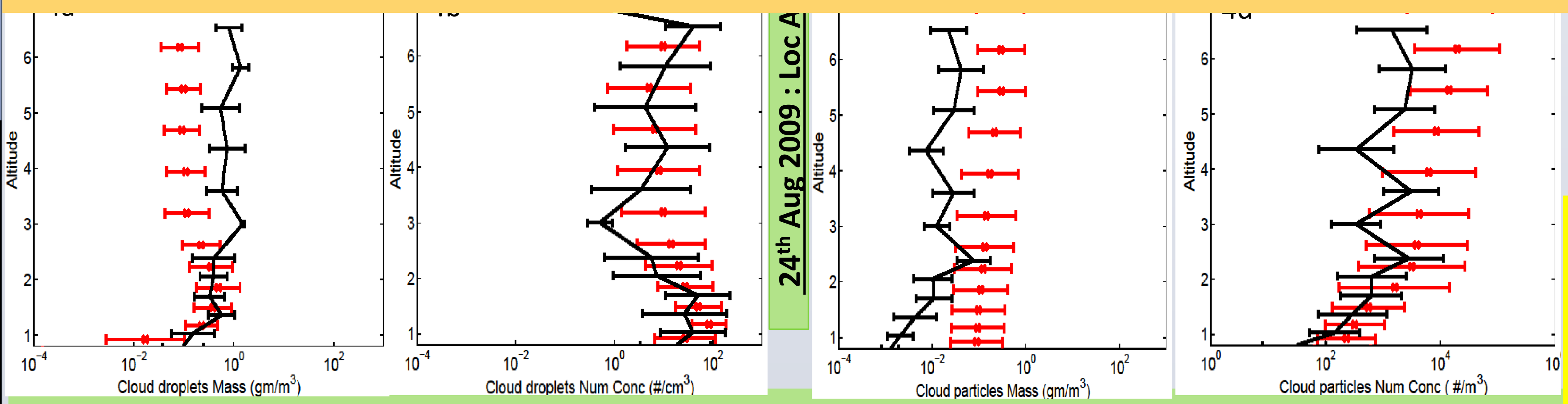
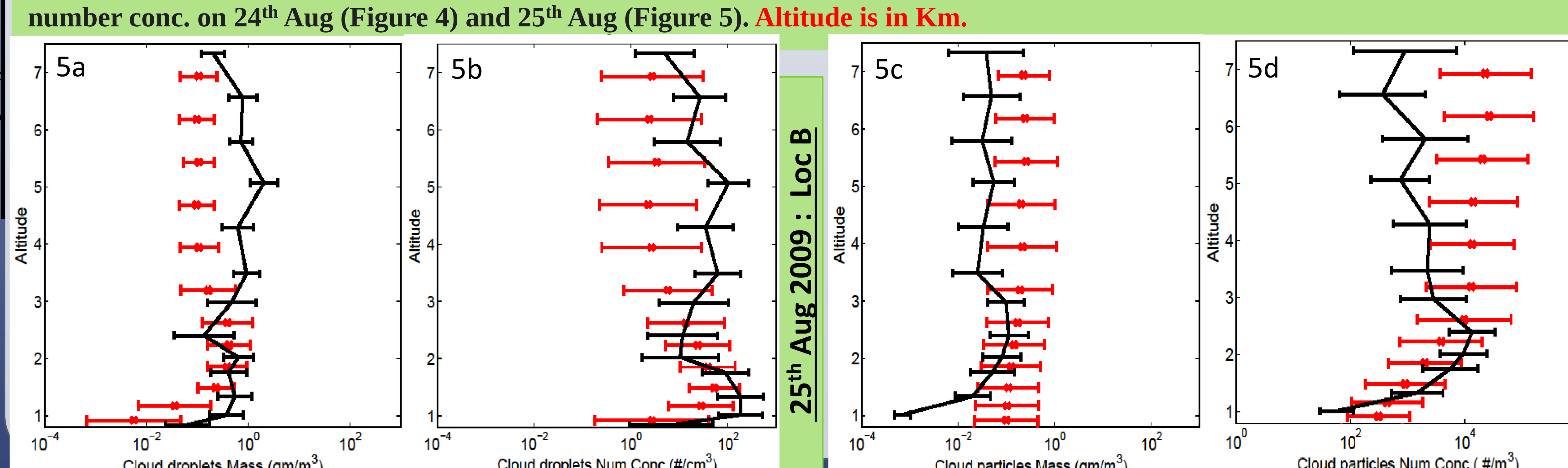


Figure 3 compares WRF simulated mean profiles of (a)Temp, (b)RH profiles and (c) Total hydrometeor mass conc using Morrison double moment scheme (Red) and LIN single moment scheme (Blue) with *CAIPEEX* measurements (Black). Model values are spatially averaged over (i)Loc-A on 24th Aug and over (ii)Loc-B on 25th Aug at each vertical level. The measured variables are vertically averaged between each model levels and shown at the centre of each model layer. The horizontal lines shows std deviation of spatial average. Altitude is in Km.

Microphysical Profiles : WRF-Chem



Comparison of vertical profiles from *CAIPEEX* (Black line) flight measurements with WRF Chem (Red dots) simulated (a)mean cloud droplet mass conc., (b)mean cloud droplet number conc., (c)mean cloud particle mass conc. and (d)mean cloud particle number conc. on 24th Aug (Figure 4) and 25th Aug (Figure 5). Altitude is in Km.



	Microphysical variables	Flight Instrument used for measuring these properties	Model variables
A	Cloud droplet	Cloud Droplet Probe (CDP) (3 microns-50 microns)	Cloud water
B	Cloud particles	Cloud imaging probe (CIP) (25microns – 1500 micron)	Rain + ice +Snow + Graupel
C	Total Hydro Meteor	A + B	A + B

Table 2

Percentage of matching occurences (PMocc)

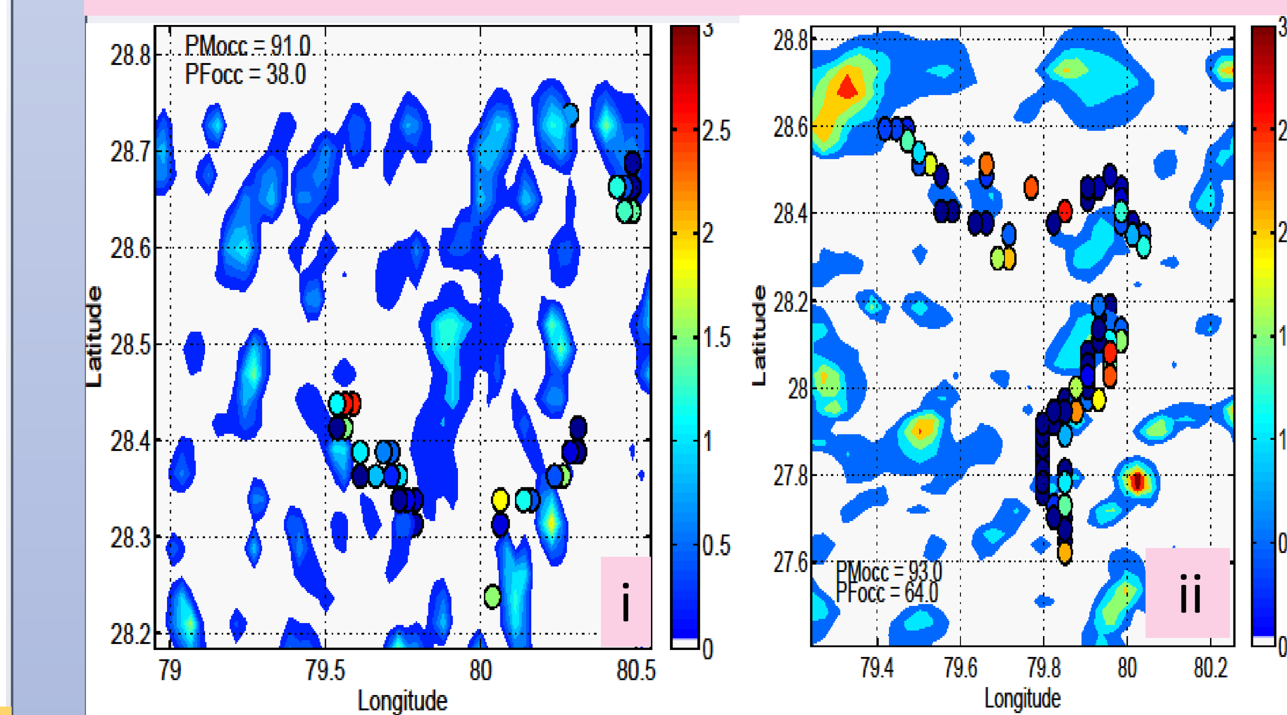


Figure 6 compares the simulated (filled contours) and measured (filled dots) columnar mean total hydrometeor mass conc at (i) Loc A (24th) and (ii) Loc B (25th). Measurements are segregated into columns of 3km x 3km x 8km (altitude) and averaged. Similarly columnar average of model values from nearest 4 grid point's up till 8 km altitude represents the corresponding model values. Pmocc indicates the percentage of positive occurrences, when both model and measurement shows occurrence of cloud in a grid column. PFocc indicates the percentage of false occurrences where model sees cloud which is absent in measurement (within flight path).

Conclusion

- WRF-Chem is able to simulate cloud at ~9/10 locations corresponding to CAIPEEX flight measurements
- From cloud base till 2.5 km, magnitudes and vertical gradients of modeled cloud droplet mass and number conc. are well within the spread of measured range in both cases.
- The number concentration of cloud particles is well simulated below 2.5 km but model is over predicting the mass concentration most probably due to lack of measurement of particles with diameters greater than 1.5mm by CIP.
- Over 2.5 km model is under predicting cloud droplet number and mass concentration while over predicting cloud particle's number and mass concentration.

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