Indian Institute of Tropical Meteorology (IITM)

Welcomes you to Pune for International Commission on Clouds and Precipitation 2020

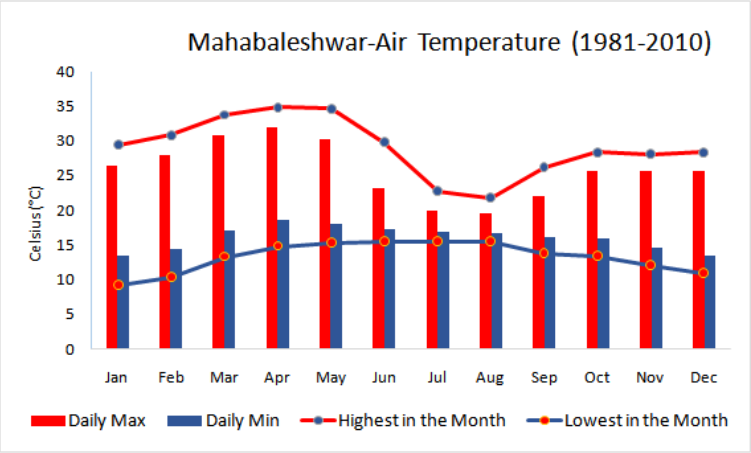
CAIPEEX

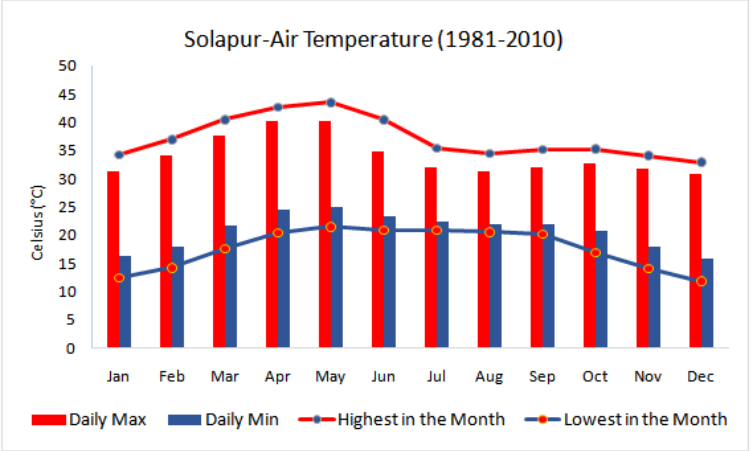
Cloud Aerosol Interaction and Precipitation Enhancement Experiment

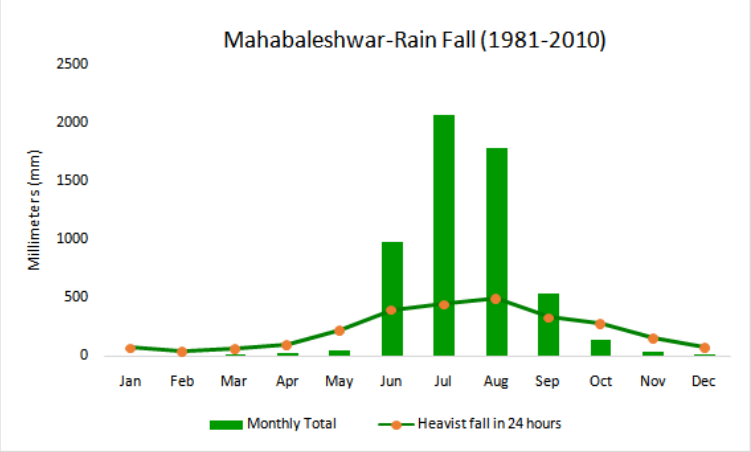
Thara Prabhakaran
CAIPEEX Team @ IITM
Indian Institute of Tropical Meteorology
Pune

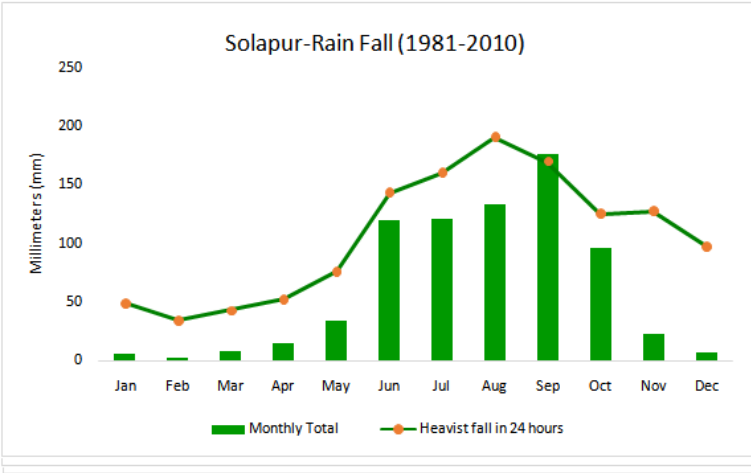

Dehradun
Posighat
New Delhi
Kathmandu
Jaiselmer
Jaipur
Lucknow
Gangtok
Guwahati
Kohima
Karachi
Ballia
Allahabad
Sylhet
Imphal
Udaipur
Patna
Varanasi
Agartala
Gaya
Dhakha
Bhopal
Ahmedabad
Jabalpur
Ranchi
Kolkata
Chittagong
Rajkot
Indore
Baroda
20°
Surat
Nagpur
Raipur
Bhubaneshwar
Mumbai
Pune
Vishakhapatnam
Hyderabad
Vijayawada
15°
Goa
Panaji
Mangalore
Bangalore
Chennai
Port Blair
Pondicherry
Coimbatore
10°
Kochi
Jaffna
Trincomalee
Thiruvananthapuram

Long term rainfall over WG and rain shadow region









Source: IMD

11 year seeding experiment India

11-YEAR WARM CLOUD SEEDING EXPERIMENT IN MAHARASHTRA STATE, INDIA

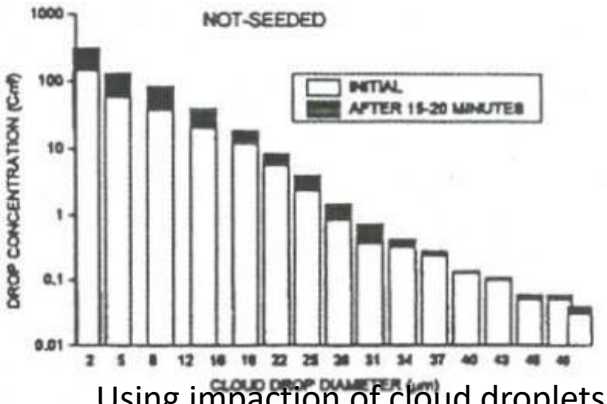
A.S.R. Murty, A.M. Selvam, P.C.S. Devara*, K. Krishna, R.N. Chatterjee, B.K. Mukherjee, L.T. Khemani, G.A. Momin, R.S. Reddy, S.K. Sharma, D.B. Jadhav, R. Vijayakumar, P.E. Raj, G.K. Manohar, S.S. Kandalgaonkar, S.K. Paul, A.G. Pillai, C.P. Kulkarni, S.S. Parasnis, A.L. Londhe, C.S. Bhosale, S.B. Morwal, P.D. Safai, J.M. Pathan, K. Indira, M.S. Naik, P.S.P. Rao, P. Sikka, K.K. Dani, M.K. Kulkarni, H.K. Trimbake, P.N. Sharma, R.K. Kapoor and M.I.R. Tinmaker

Physical Meteorology and Aerology Division, Indian Institute of Tropical Meteorology, Pune - 411 008, India

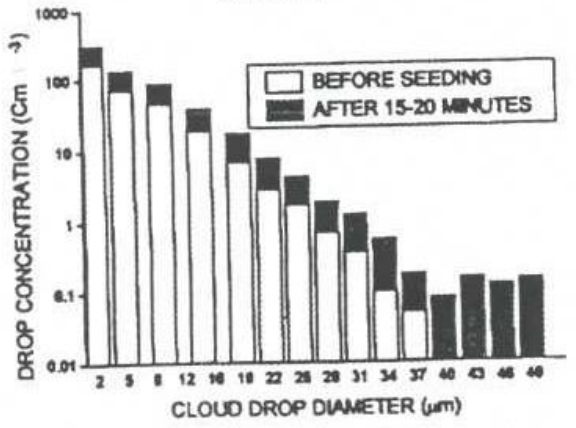
- 100 km inland from west coast
- June-Sept 1973-74, 1976, 1979-86

Area randomizationtwo (1600 km2 target areas (north and south) separated by a buffer area, the size of each area being 1600 km2

- Salt seeding (Stcu and Cu) to 200-300m above cloud base observations
- Salt seeding (0-30 kg in 3 km flight track)
- Results depended on cloud thickness, LWC
- Certain conditions produced increase in rainfall of 24 % at 4% level (1 km depth and LWC >0.5 gm-3)
- Hygroscopic particle seeding accelerated collision coalescence
- 24-h rainfall measured by 90 rain gauges

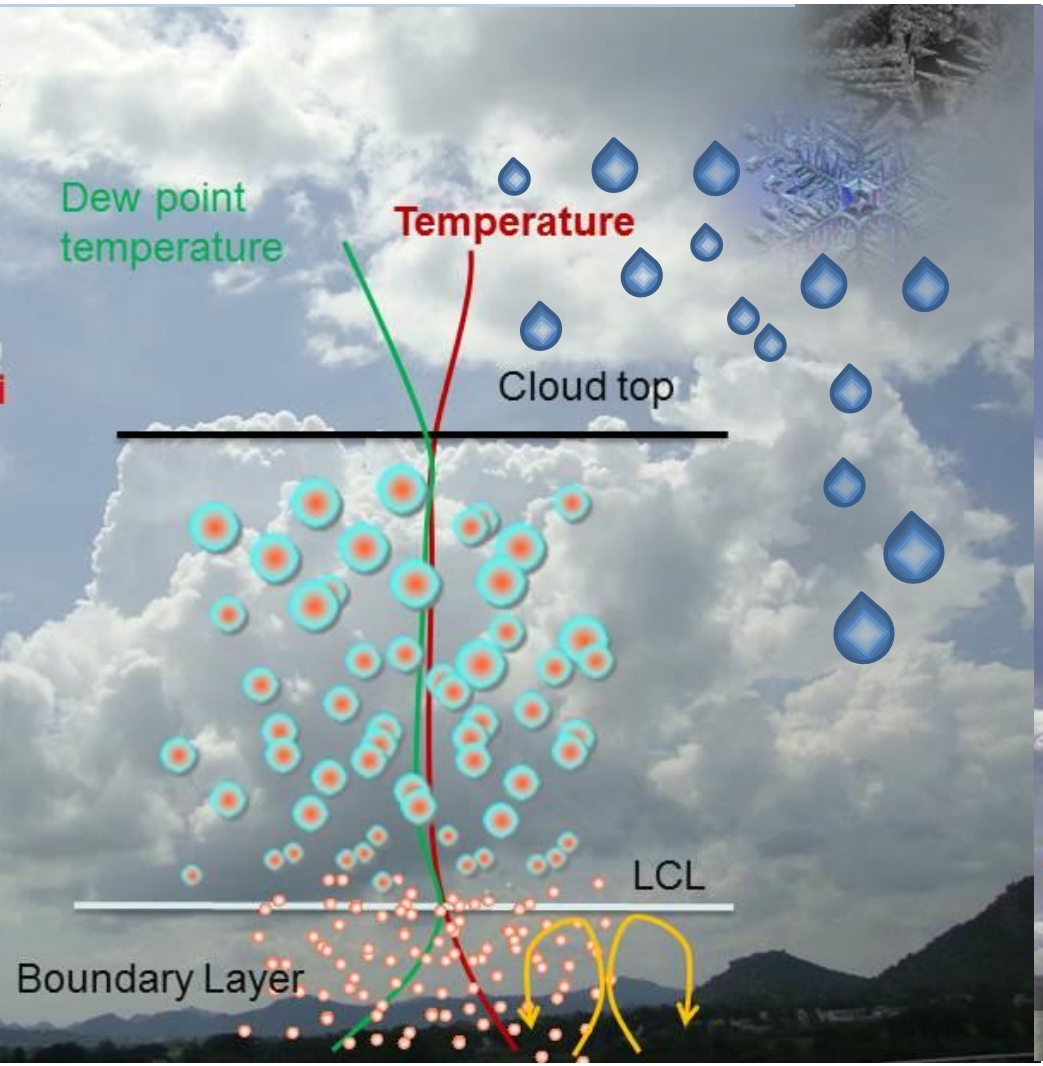


Using impaction of cloud droplets on the slides coated with MgO or soot

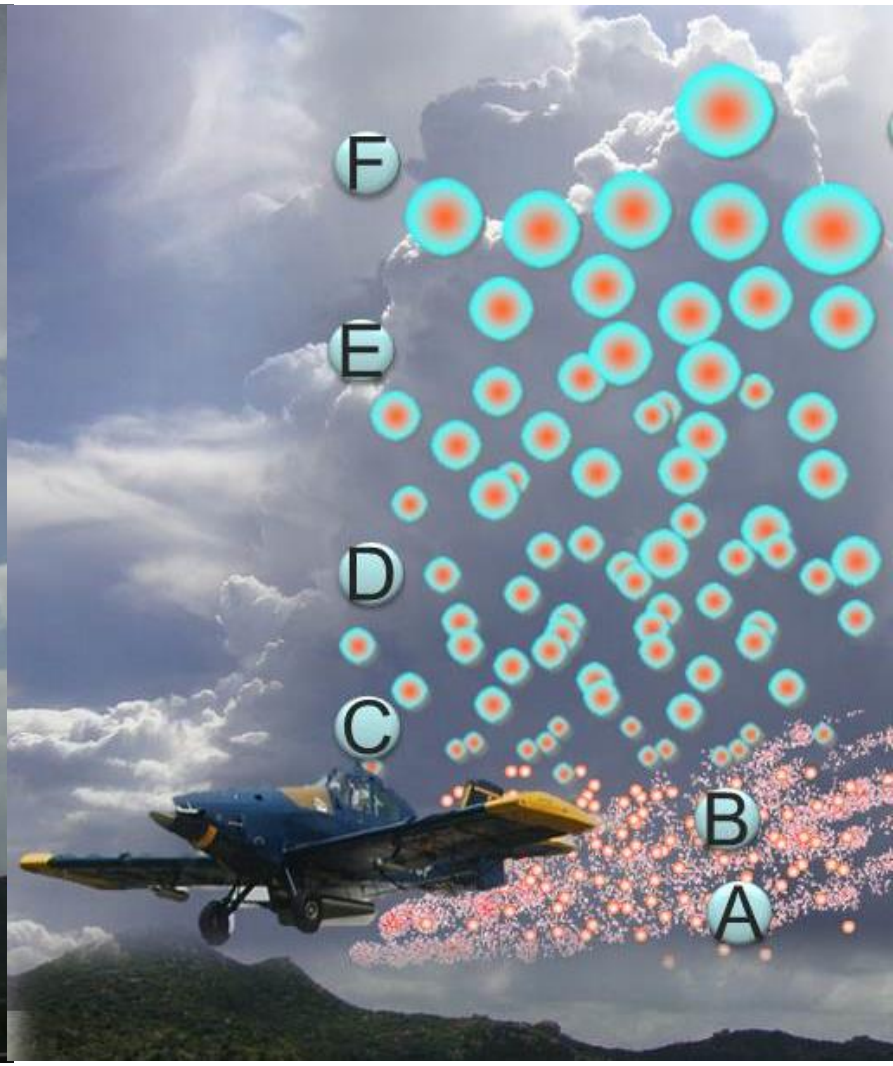


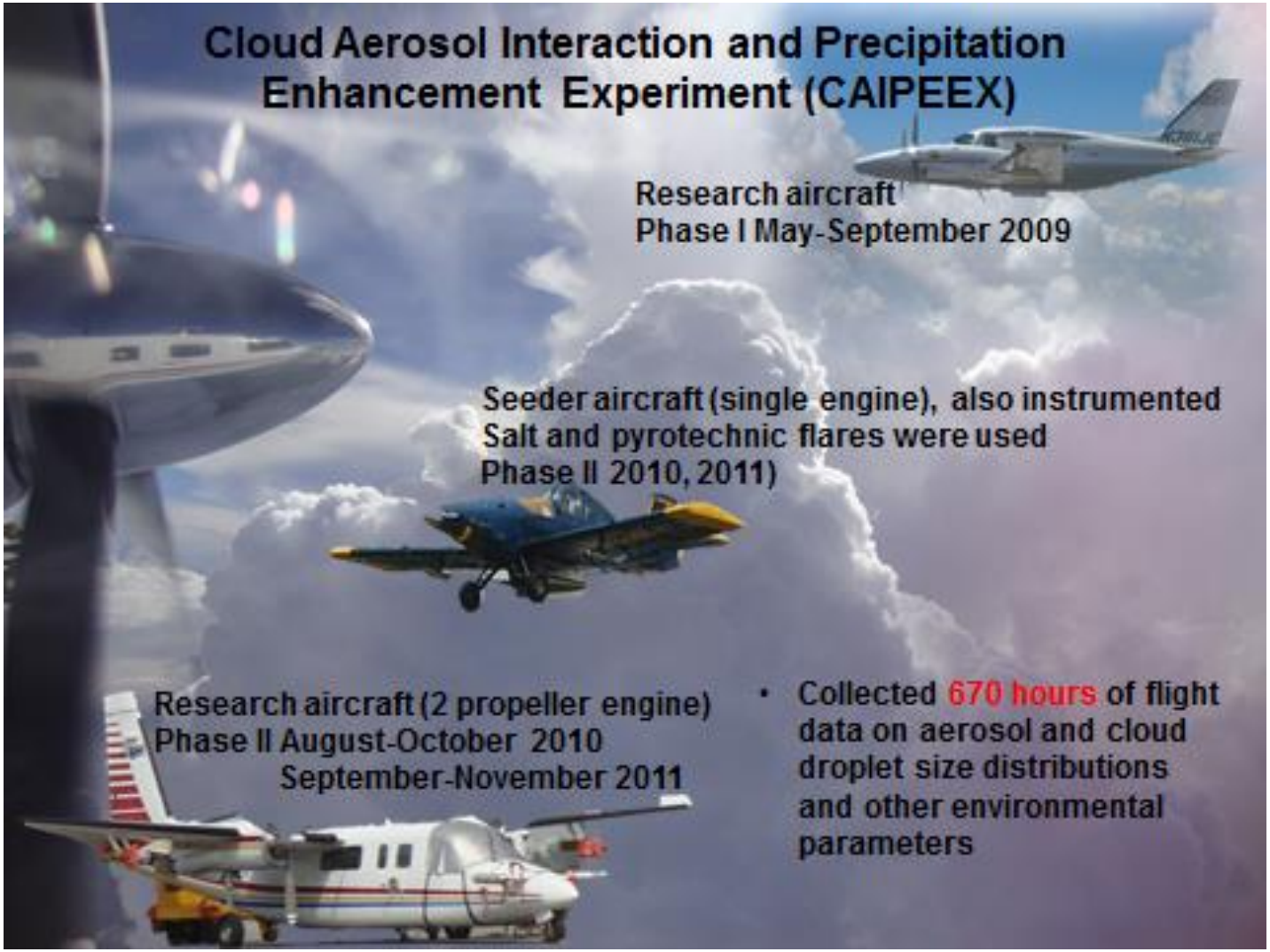
objectives

Aerosol-Cloud-Precipitation interaction



Hygroscopic cloud seeding





Major achievement:

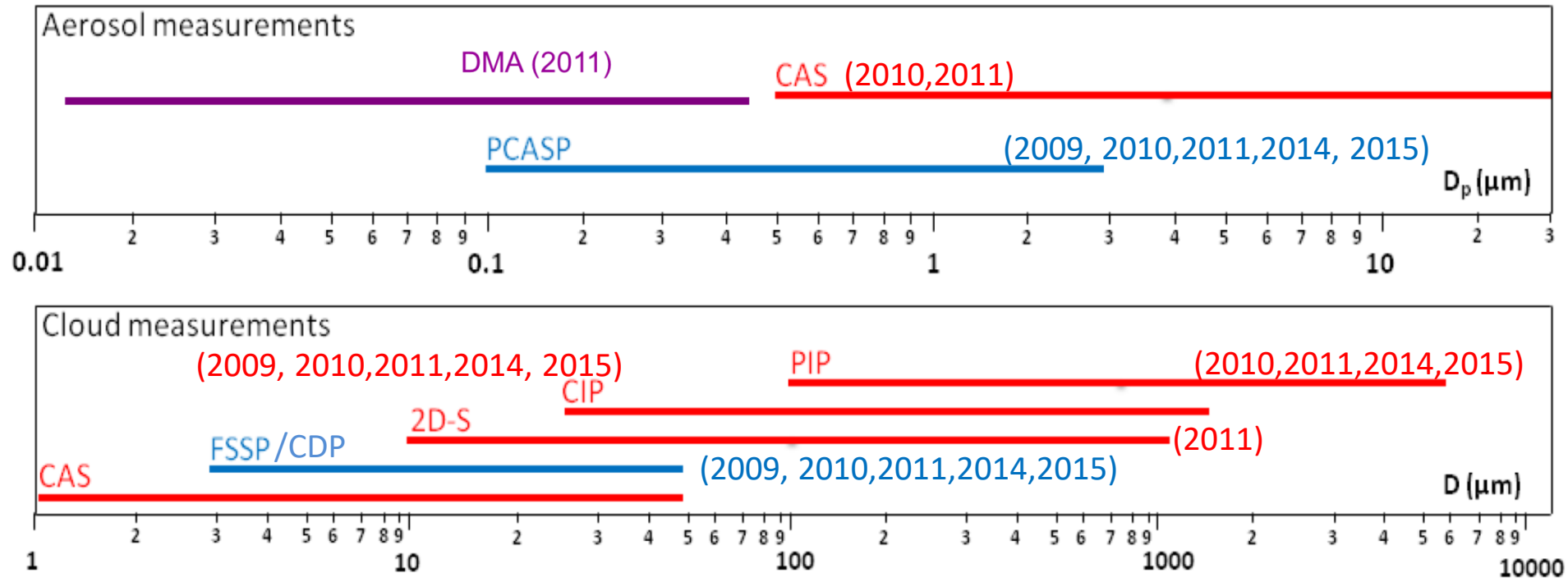
CAIPEEX has finished 820 hours of research flights and two integrated ground campaigns (2009-2015)

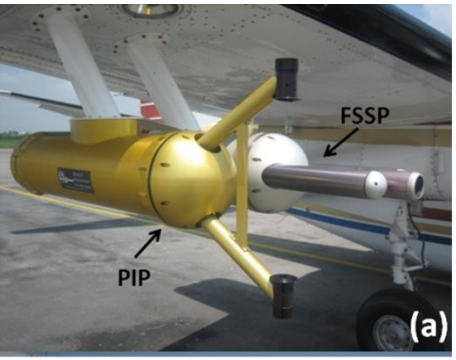
Phase III (2014-15)

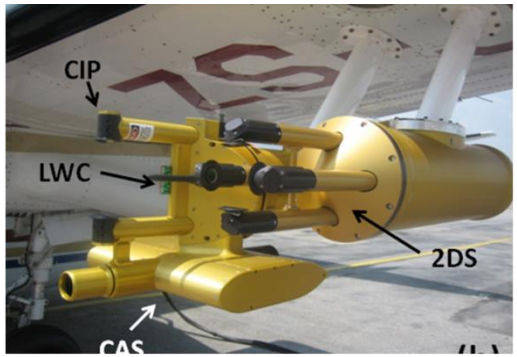
150 hours of research flights

Varanasi, Mahabaleswar, Arabian Sea, Kohlapur, Solapur

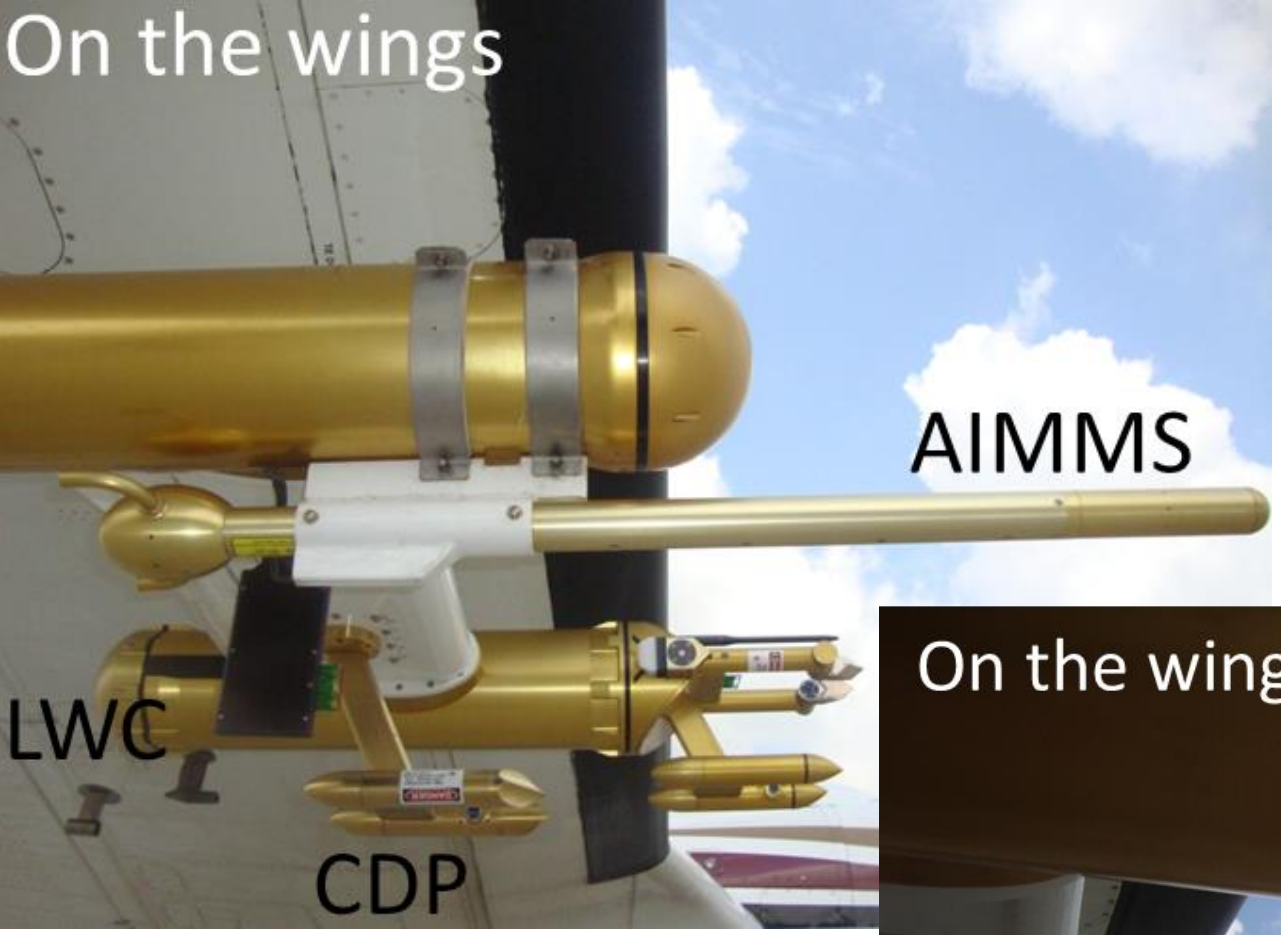
Aircraft instruments for aerosol and cloud microphysics





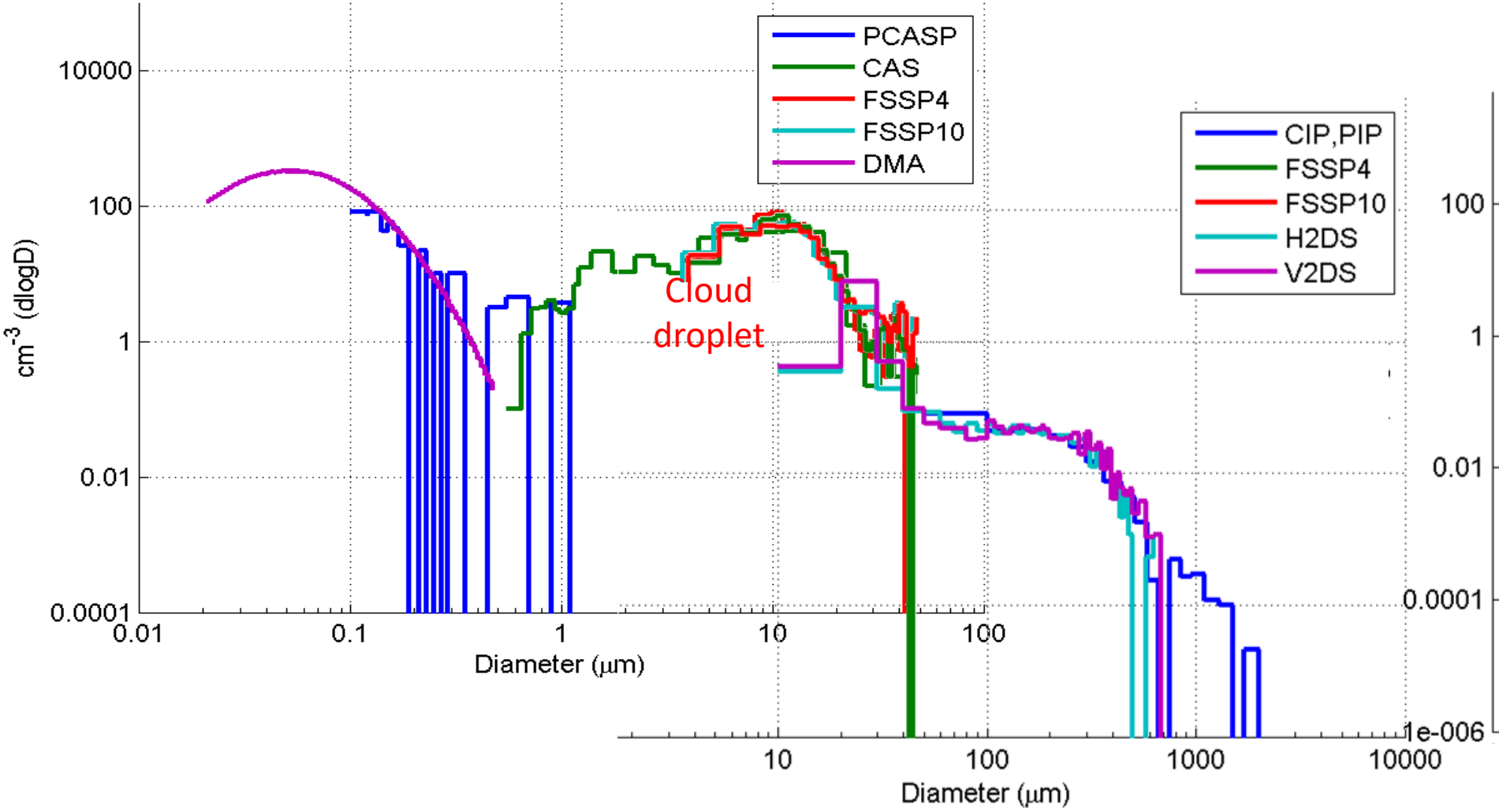


website: http://www.tropmet.res.in/~caipeex/


On the wings
AIMMS
LWC
CDP


On the wings
PCASP
PIP
Cloud Aerosol Interaction and
CAIPEEX
Precipitation Enhancement Experim
Phase III 2014

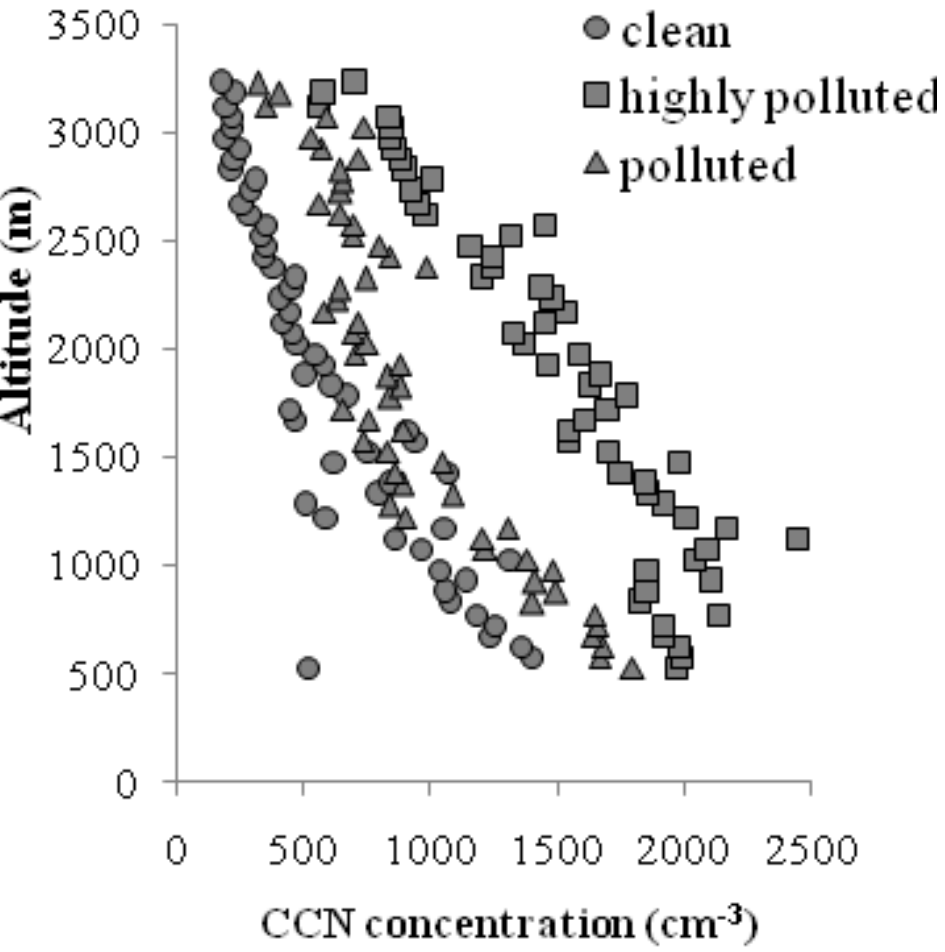
Particle/droplet size distribution from different probes



CAIPEEX Background CCN

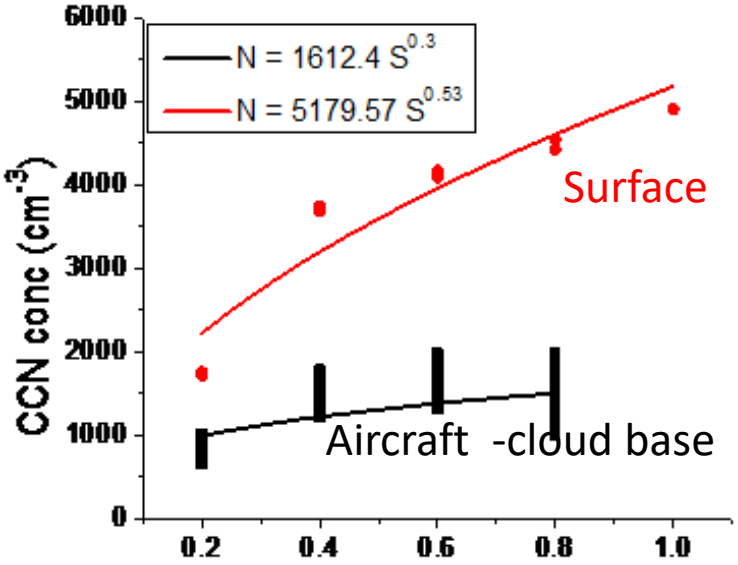
CCN airborne and ground based observations

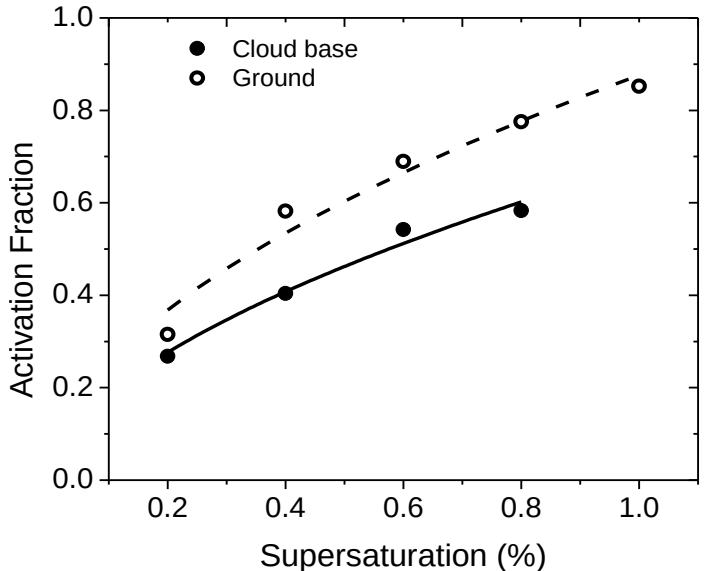
Vertical profile of CCN



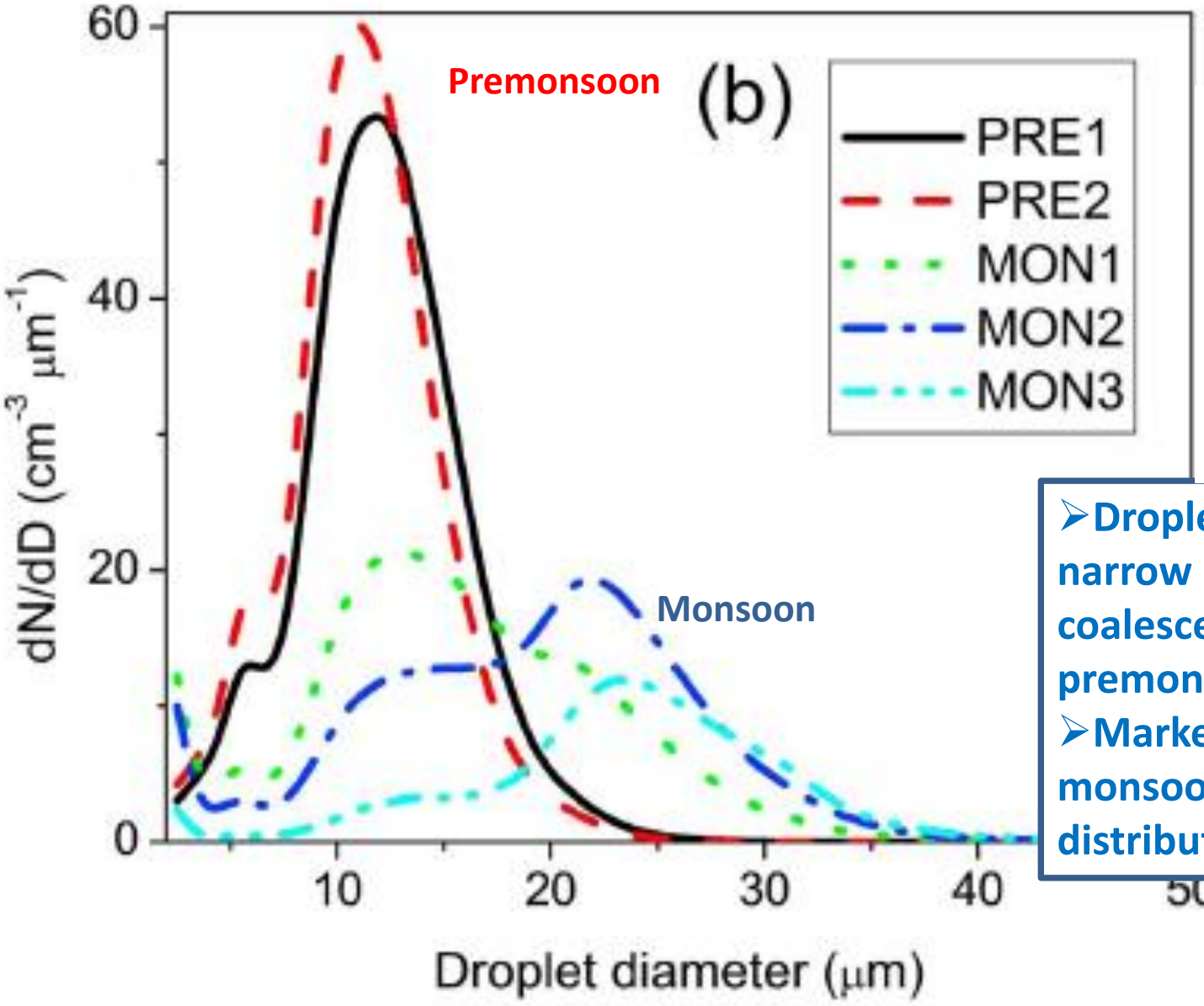
Varghese et al., (Atmospheric Environment, 2015)

CCN activation spectra





Droplet size distribution in the PREmonsoon and MONsoon clouds



High

High

Moderate

High

Low aerosol

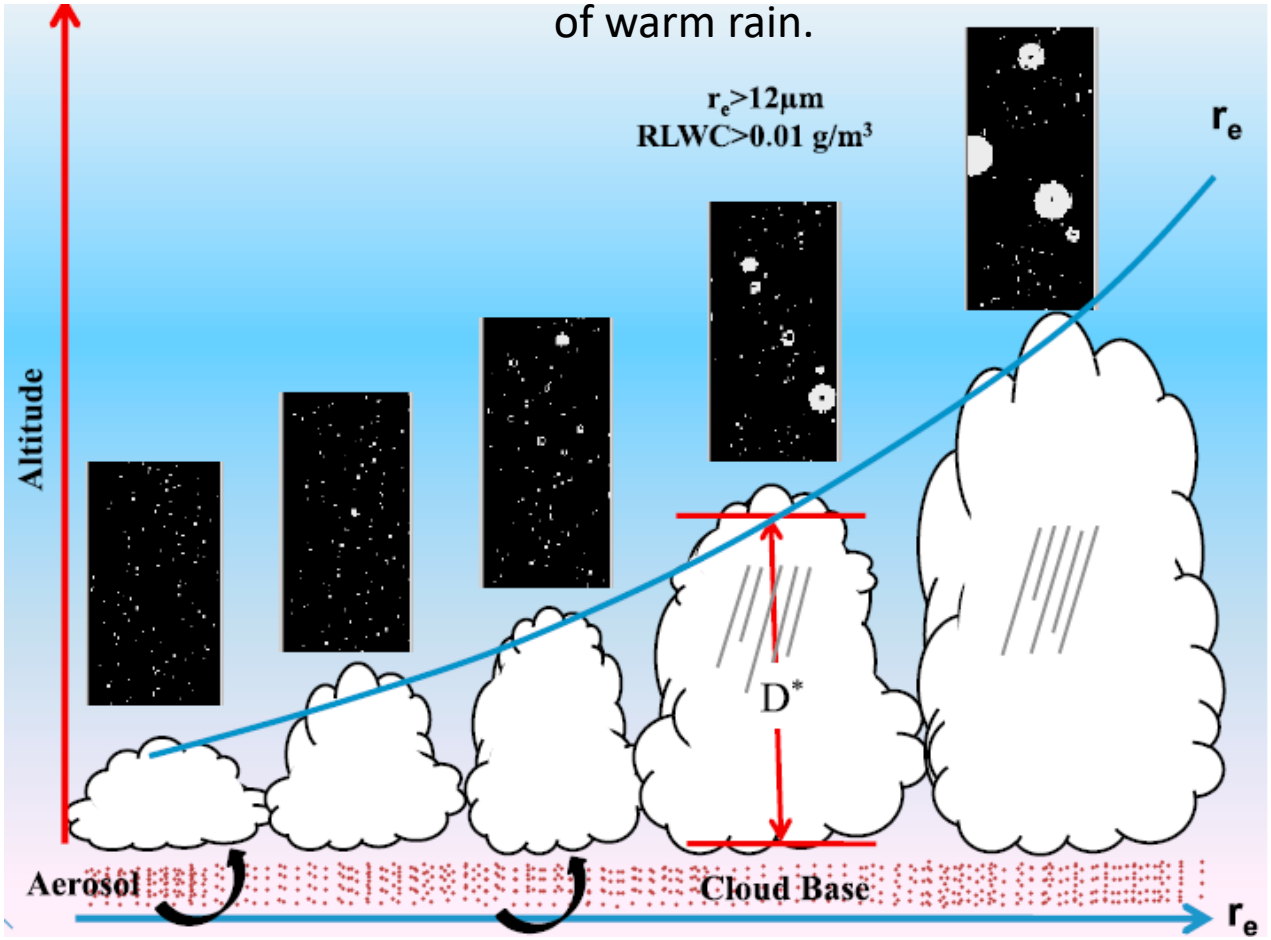
- Droplet spectrum is narrow and Collision-coalescence is absent in premonsoon clouds
- Marked differences in monsoon with bimodal distributions

Prabha et al., 2012), JGR

Aerosol control on depth of warm rain

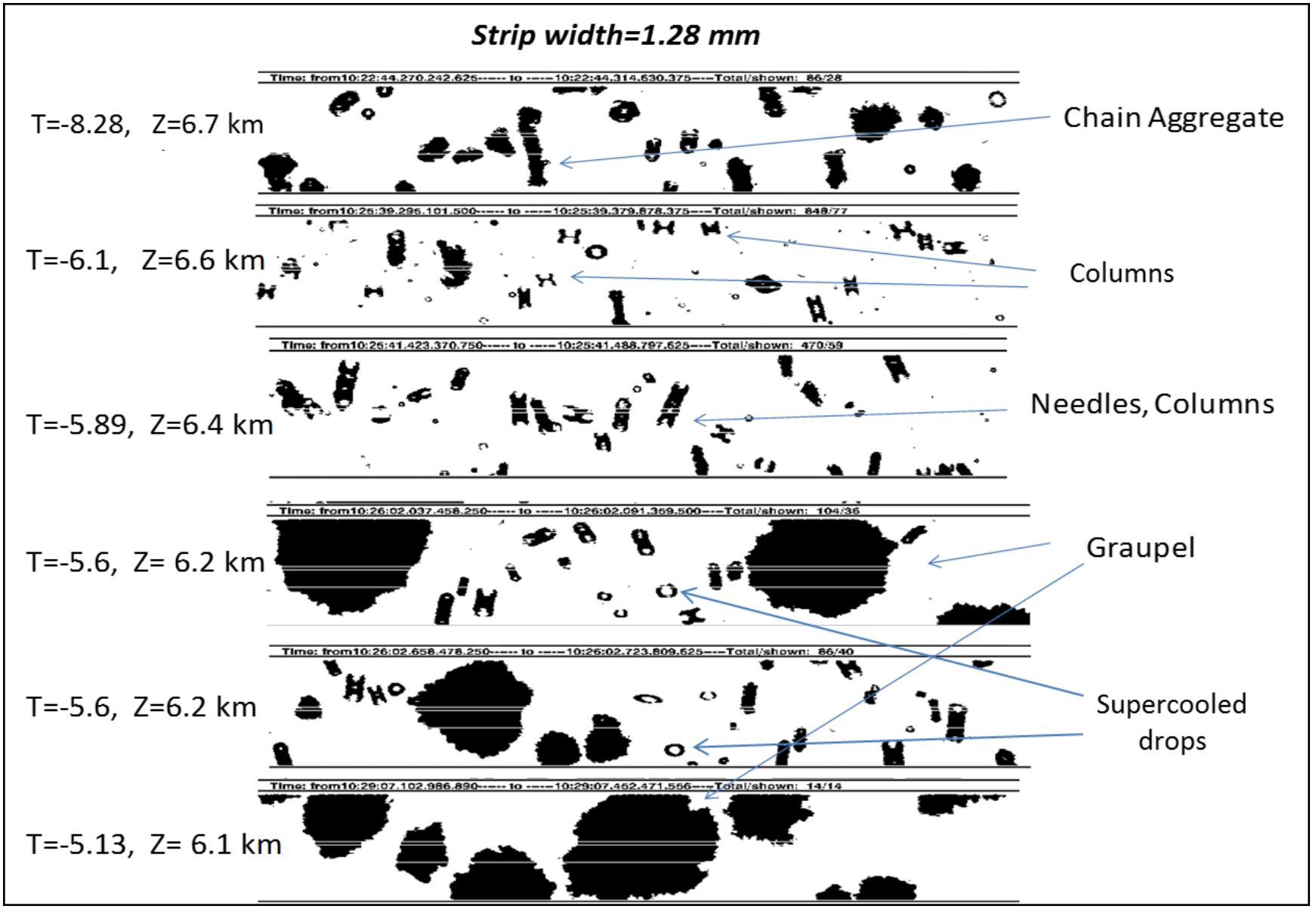
The hydrometeor images are from Cloud Image Probe; rain starts when effective radius of cloud > 12 micron and rain LWC> 0.01 g/m^3. D* is the distance from the cloud base.

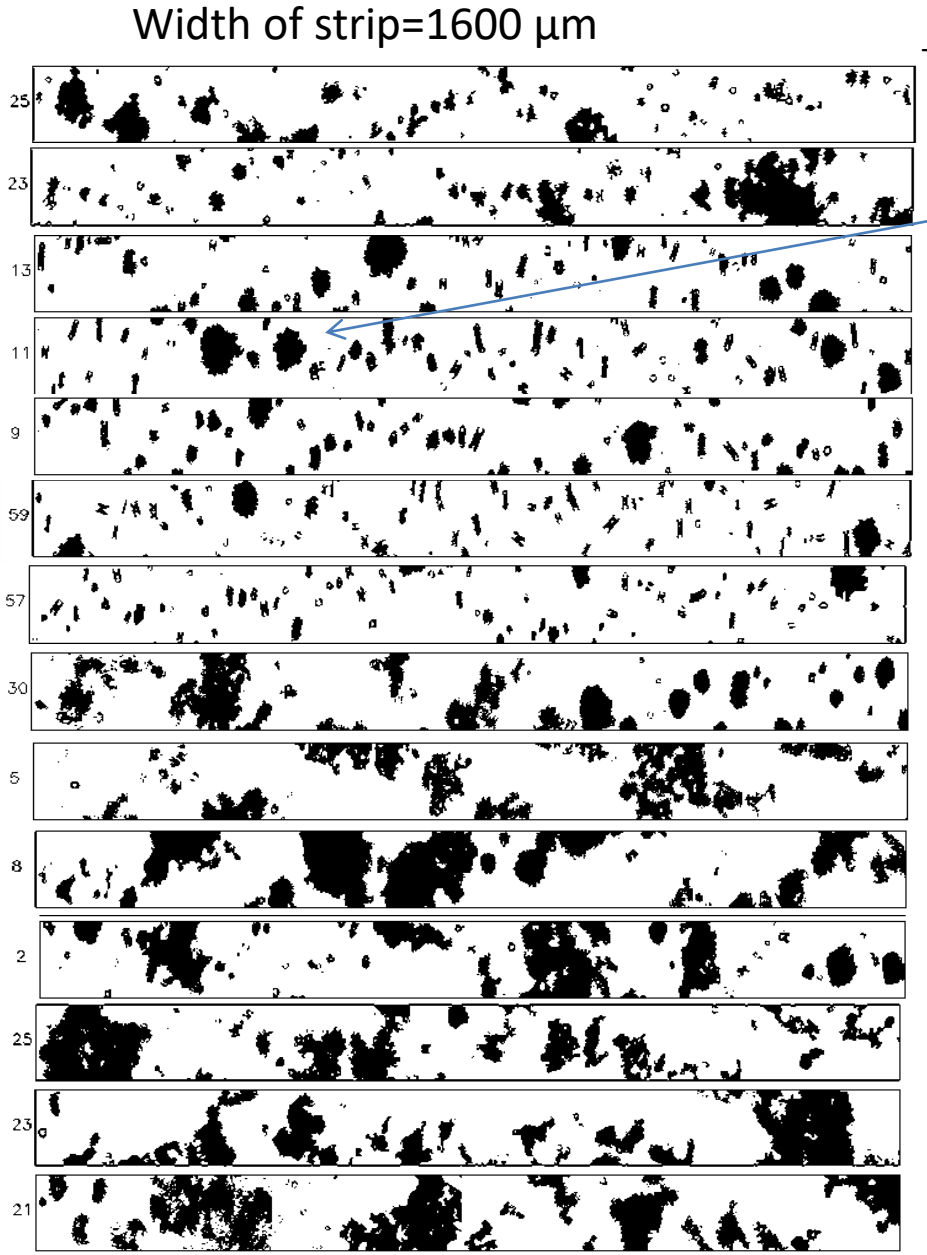
Schematic diagram of aerosol's influence on depth for onset of warm rain.



Konwar M., Maheskumar R. S., Kulkarni J. R.,. Freud E, Goswami B. N., Rosenfeld D., Aerosol control on *depth of warm rain in convective clouds* ***Journal of Geophysical Research, 117, 2012, D13204***

Clear evidence of large graupel and ice multiplication process





Time (UTC)	Temp (°C)
095025	-8.59
095023	-8.60
094713	-7.22
094711	-7.11
094709	-7.16
094659	-6.59
094657	-6.59
094430	-4.49
094305	-4.58
094208	-3.38
094202	-3.67
094125	-2.54
094123	-2.49
094121	-2.74

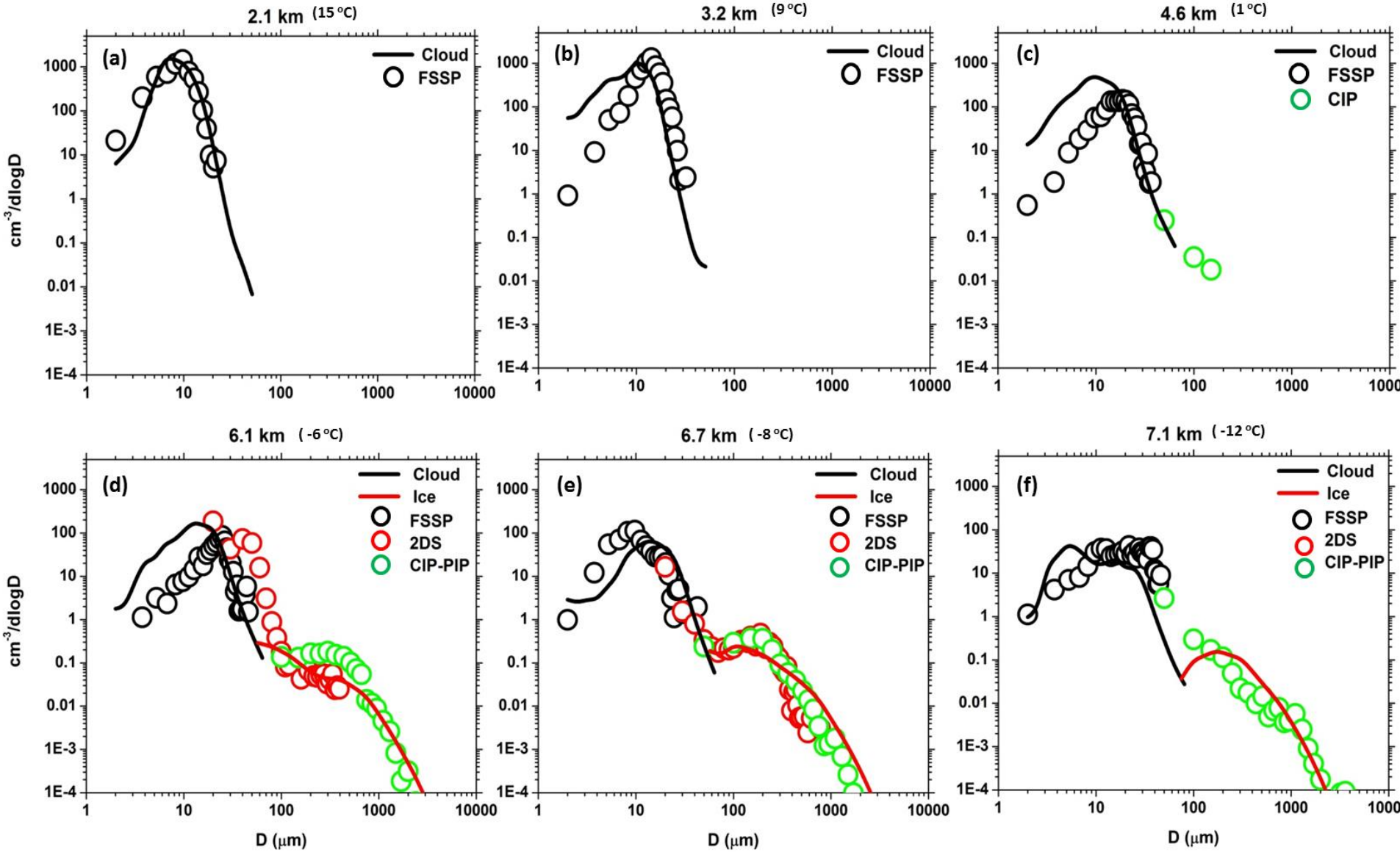
Needles and graupel

Active Hallet Mossop Zone

From Sachin Patade et al., 2015, Atmospheric research

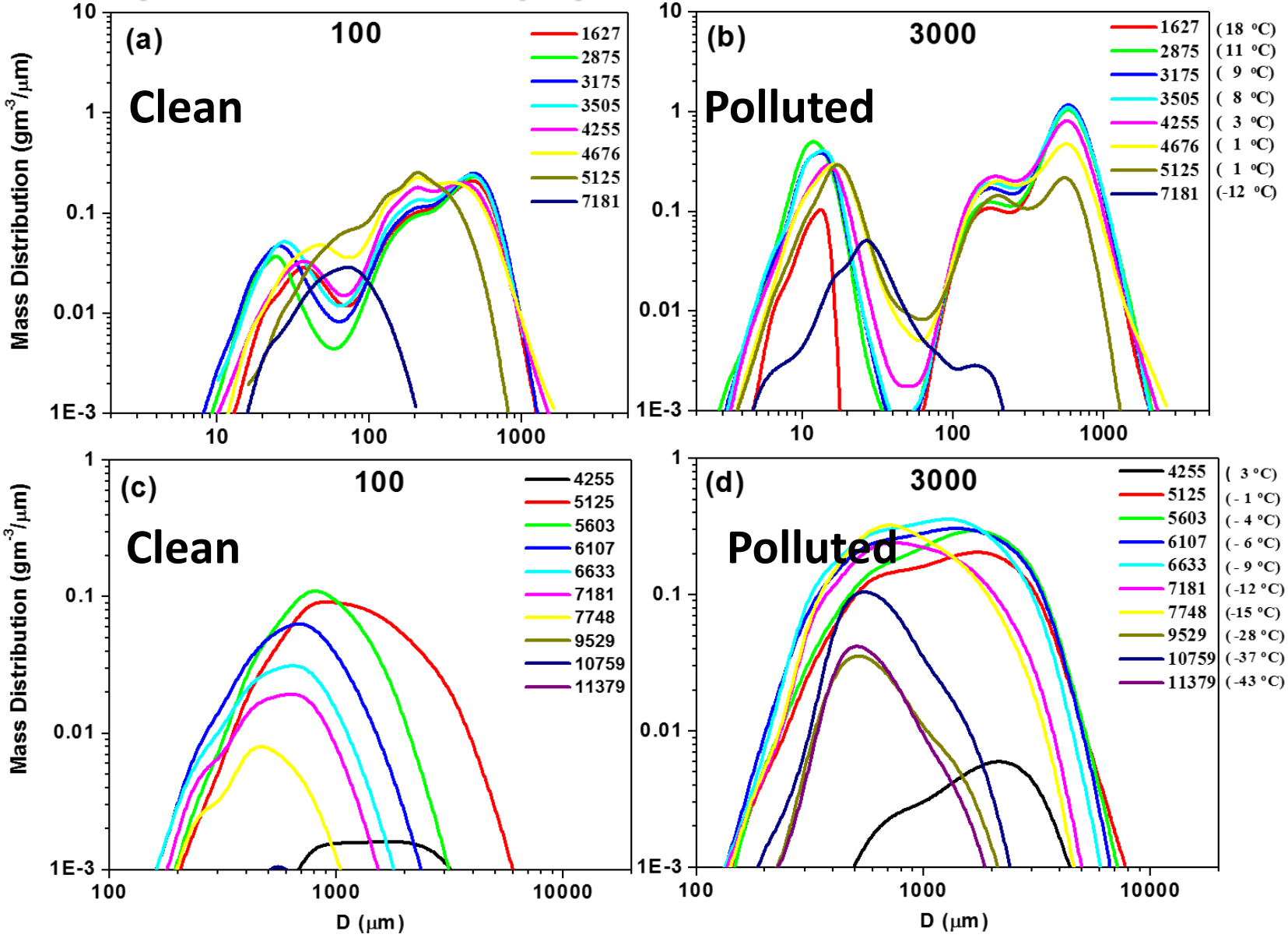
Seeding in numerical simulations and evaluations

Comparing particle size distribution from bin microphysics simulation and CAIPEEX observations at different altitudes



[Gayatri et al., under revision, JAS]

Comparison of liquid, graupel particle size distribution from clean and polluted bin microphysics simulation at different altitudes

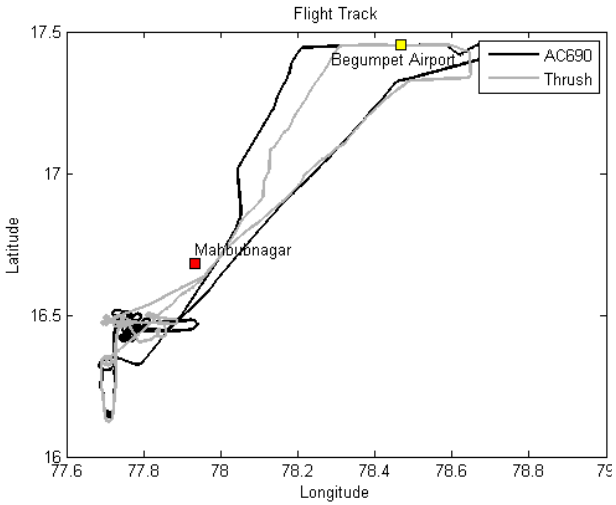


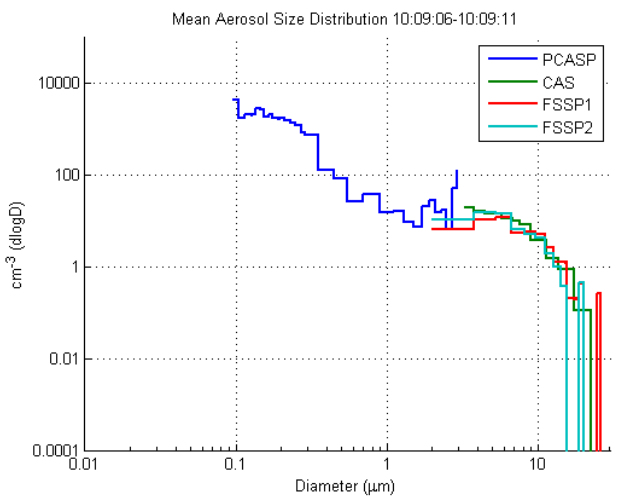
[Gayatri et al., under revision, JAS]

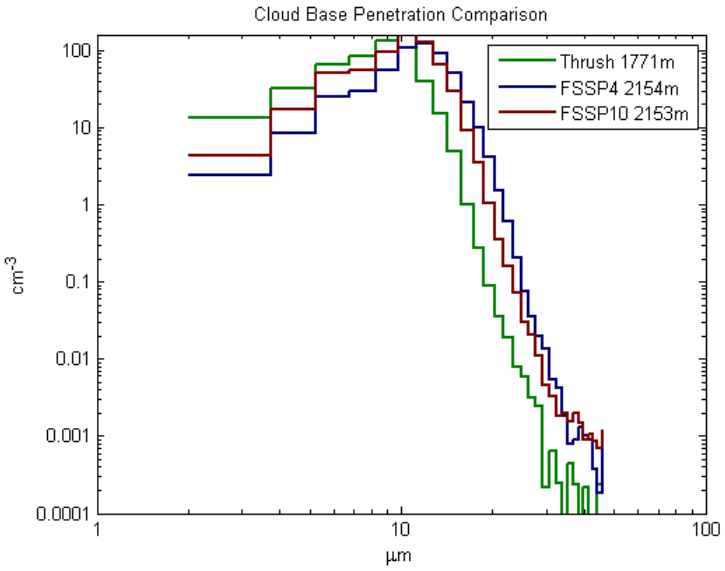
Salt seeding example from CAIPEEX

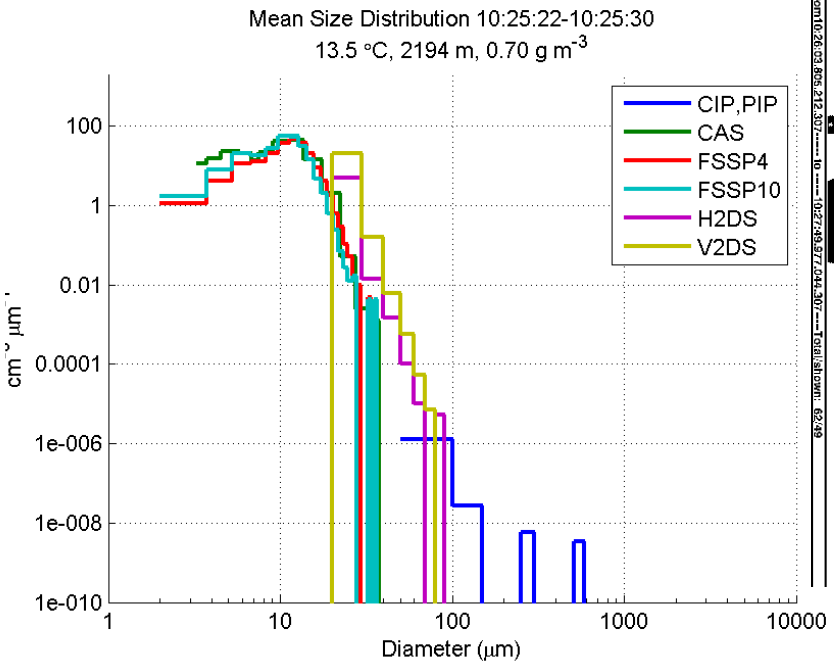
Cloud base ~4800 ft

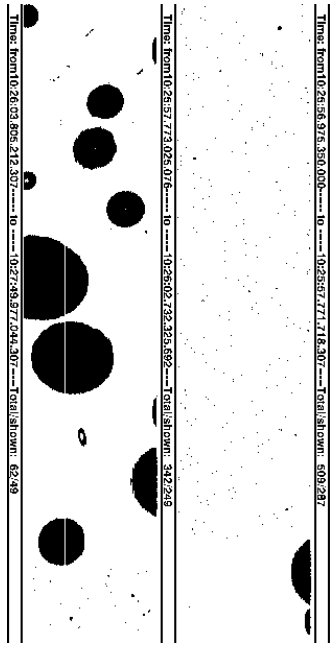
Dissipating base of seeded target (10:47)





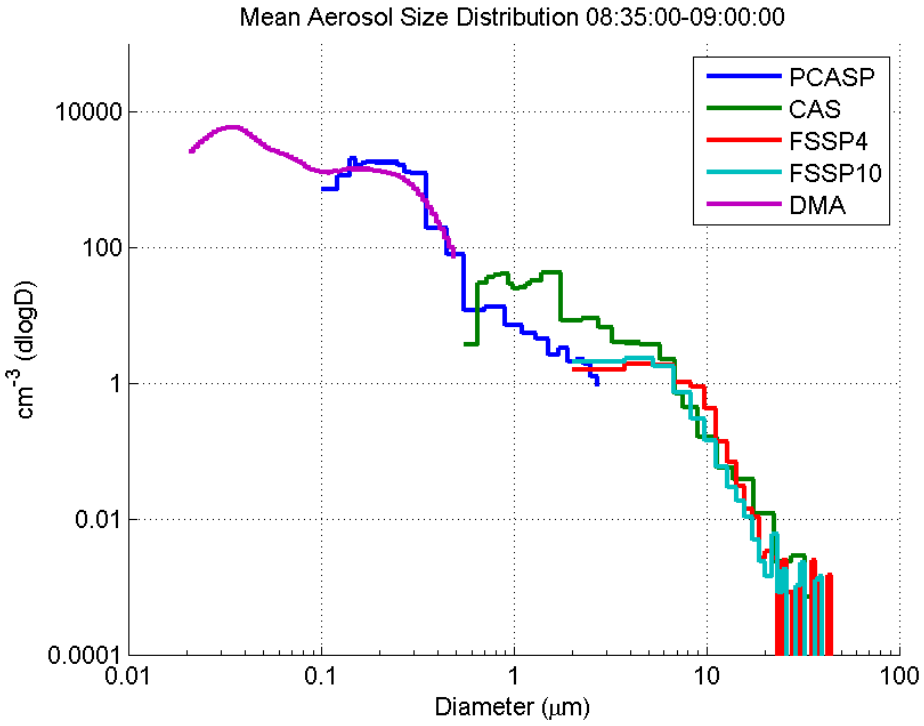


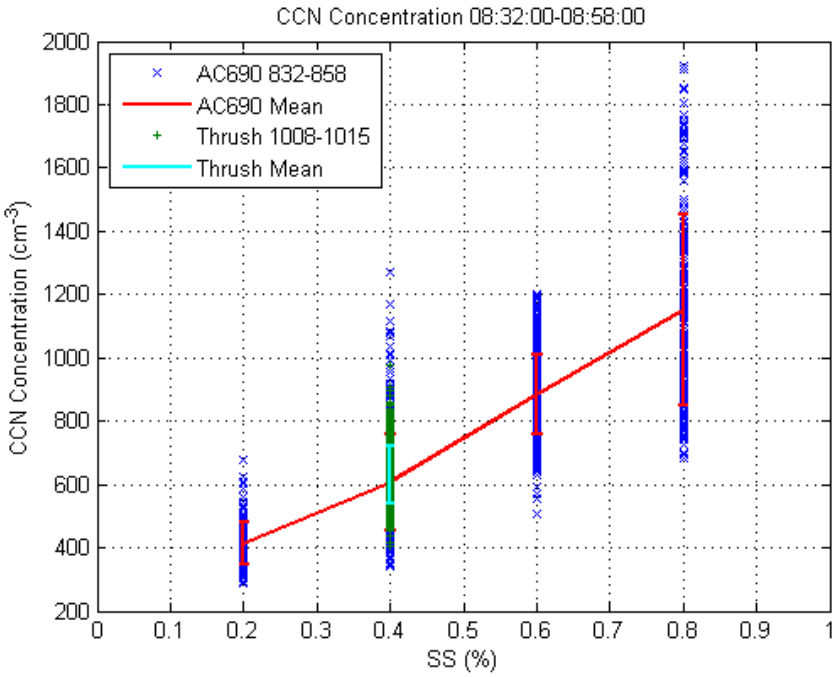




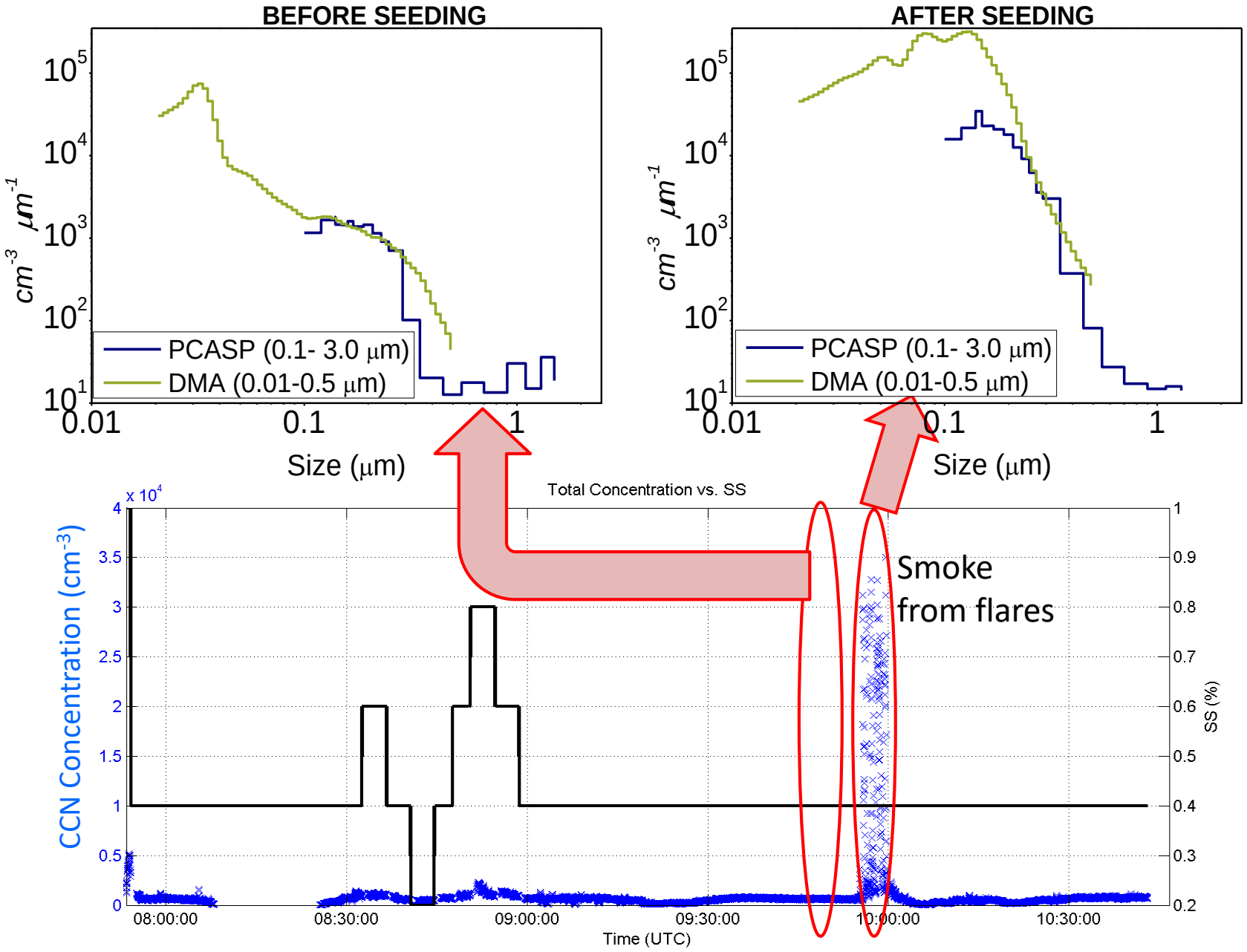
Salt seeding at base was ineffective !!

Background Aerosol PSD and CCN spectra during seeding material (flare) characterization

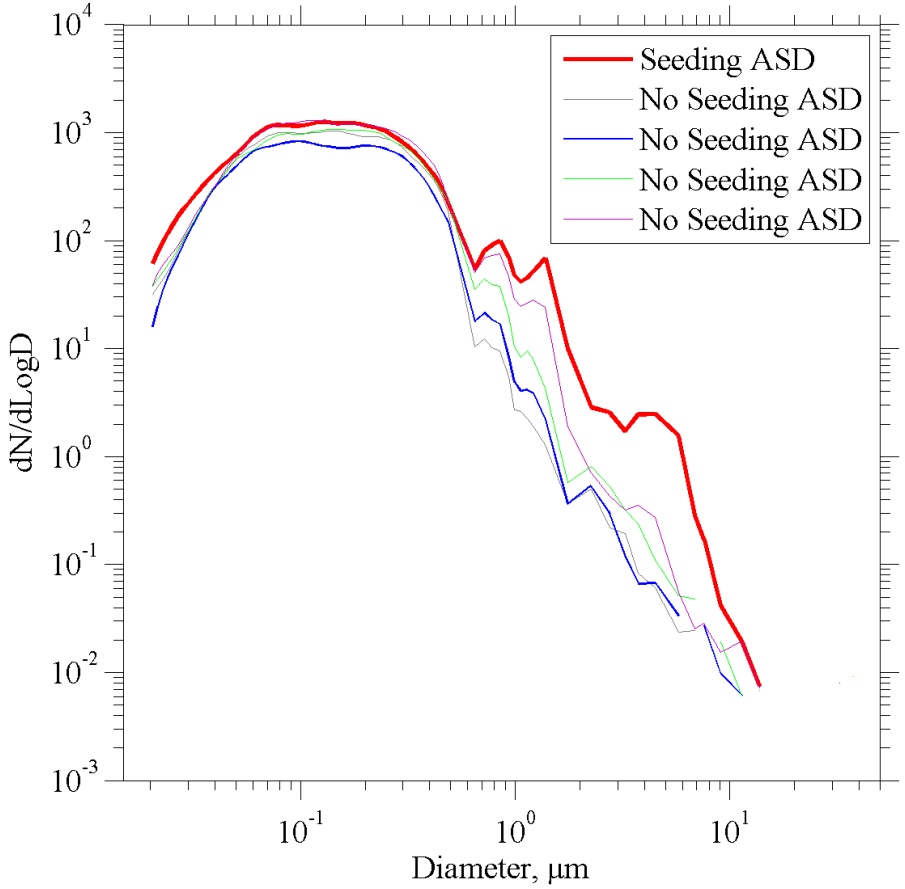


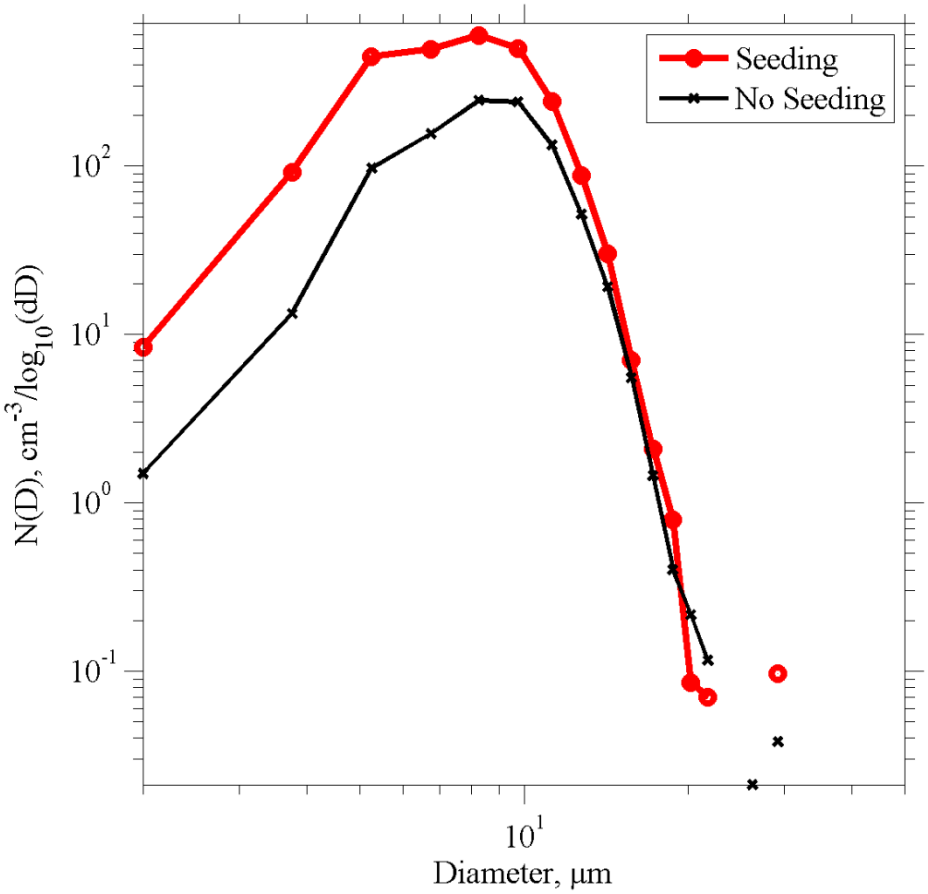


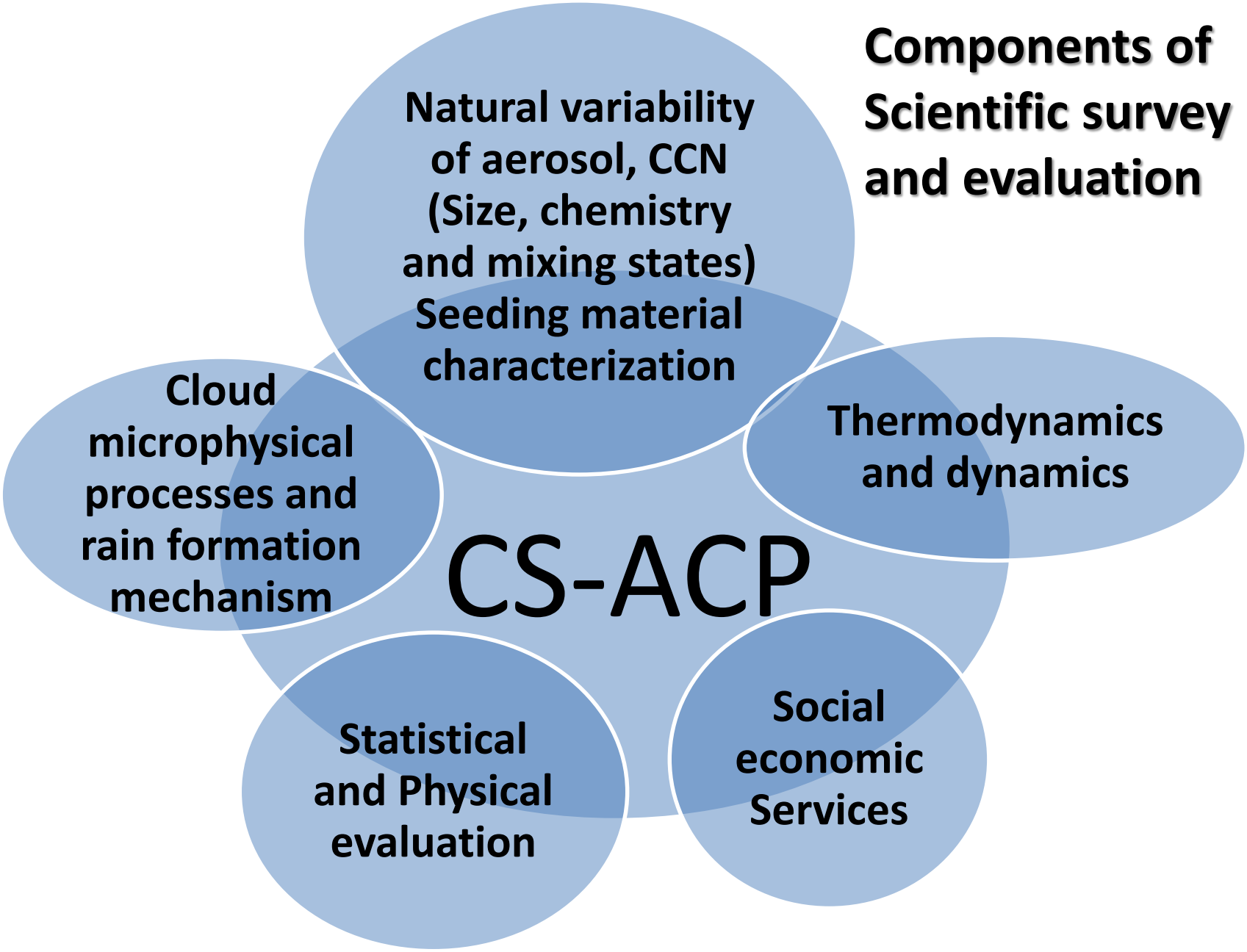
Seeding material characterization



Joint PSD with DMA and PCASP seeding and no-seeding times and associated cloud droplet spectra from FSSP





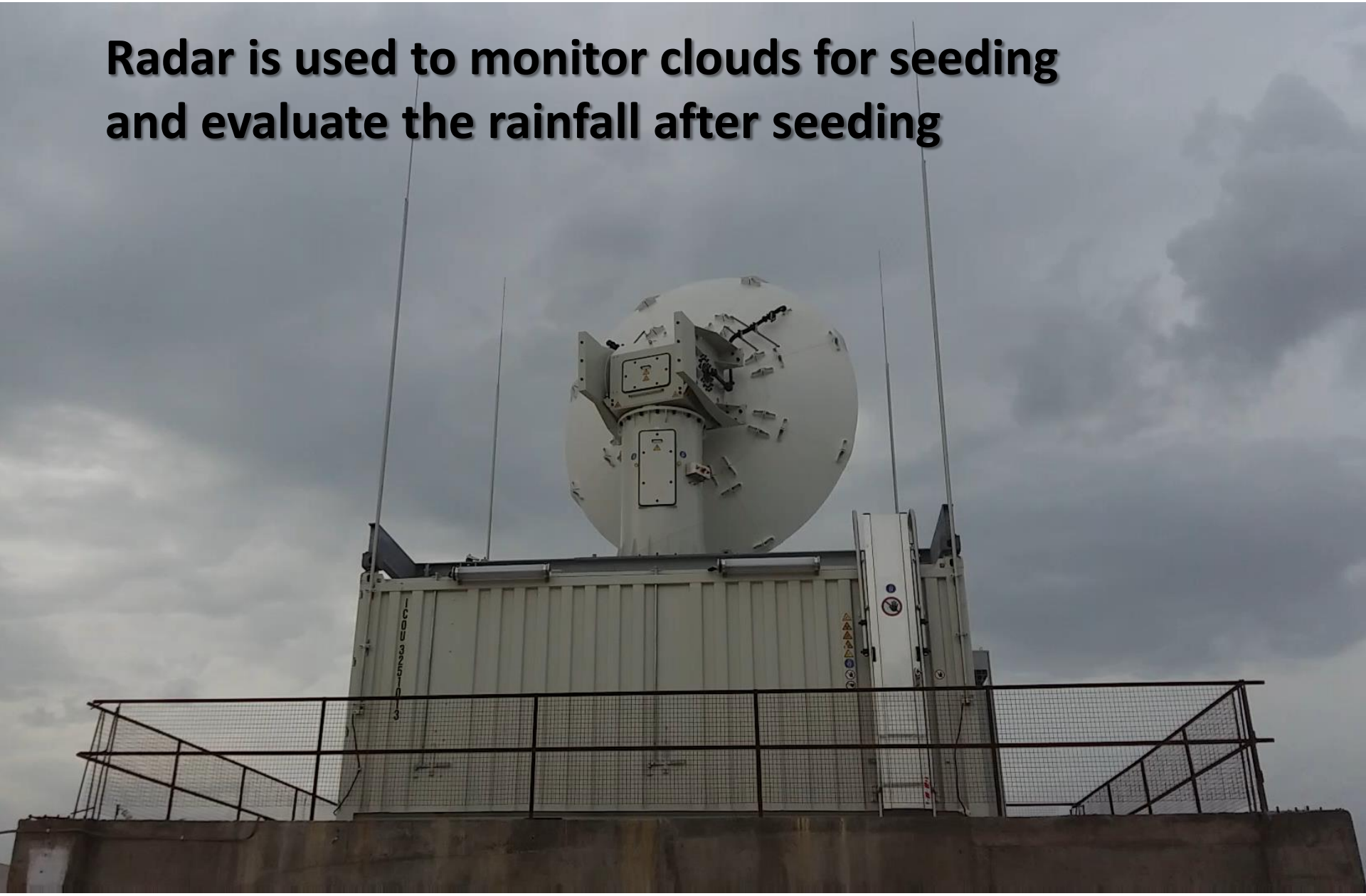

Components of Scientific survey and evaluation
Natural variability of aerosol, CCN (Size, chemistry and mixing states) Seeding material characterization
Cloud microphysical processes and rain formation mechanism
Thermodynamics and dynamics
CS-ACP
Statistical and Physical evaluation
Social economic Services

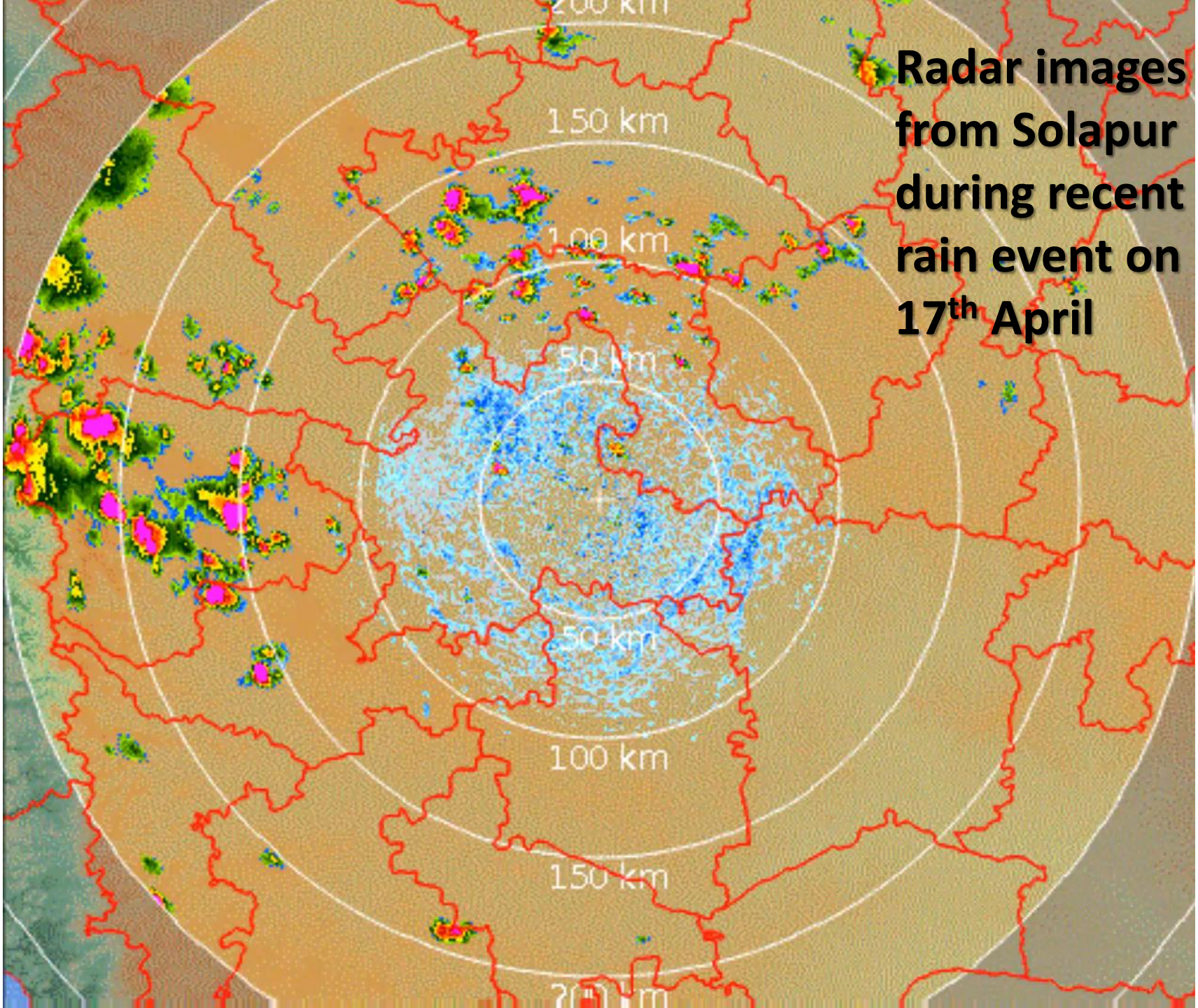
Cloud seeding science Experiment 2018-19

CAIPEEX Phase IV

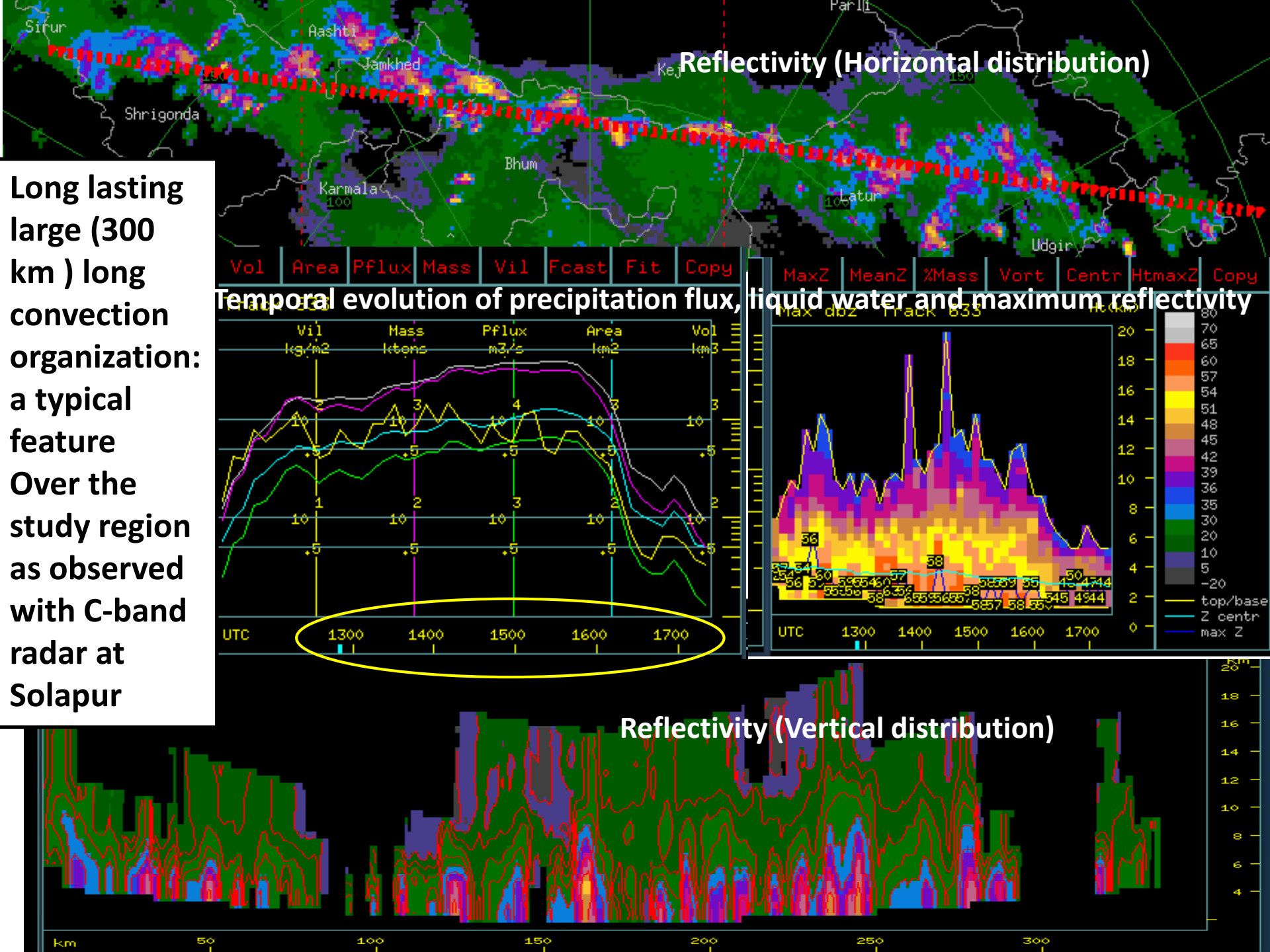
C-band polarimeteric radar, Raingauge network
Ground station with radiaometer, wind profiler, MRR, disdrometer
SMPS, CCNC, Aerosol and gas Chemistry, Aethalometer,
Videodistrometer. 50 m meteorological flux tower , radiosonde

Radar is used to monitor clouds for seeding and evaluate the rainfall after seeding





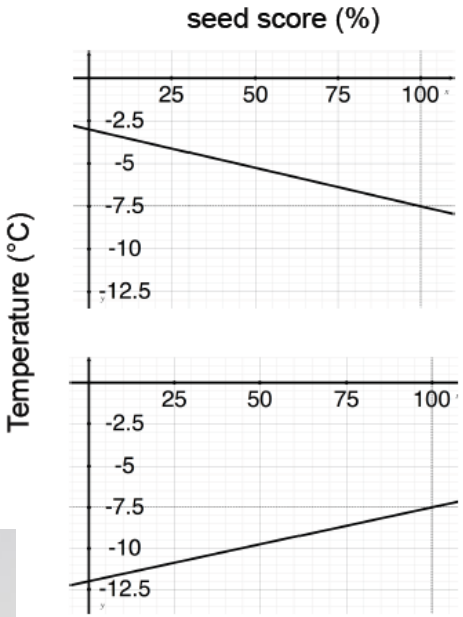
Radar images from Solapur during recent rain event on 17th April



Long lasting large (300 km) long convection organization: a typical feature Over the study region as observed with C-band radar at Solapur

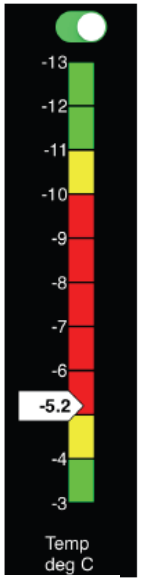
Targeting clouds effectively

- Aircraft targeting same size cloud
- Same thermodynamic conditions
- Reduce human bias in selection

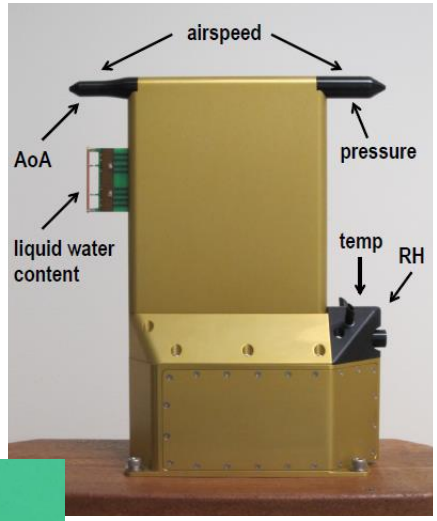


Range -3 to -7.5°C
Temp seed score =
(-temp – 3)/0.045

Range -7.5 to -12°C
Temp seed score =
(-temp + 12)/0.045



Cloud water inertial probe
-Cloud liquid water content
-Temperature
-Pressure
-Relative humidity
-Air speed
-Vertical velocity



Aerosol Counting, Composition, Extinction, and Sizing System (ACCESS)

Pilot decision making tool for the targeting the cloud (on ipad)

Increases collision and coalescence of drops to rain drop

Rainfall within 10 min

Radiosonde

Dew point

Temperature

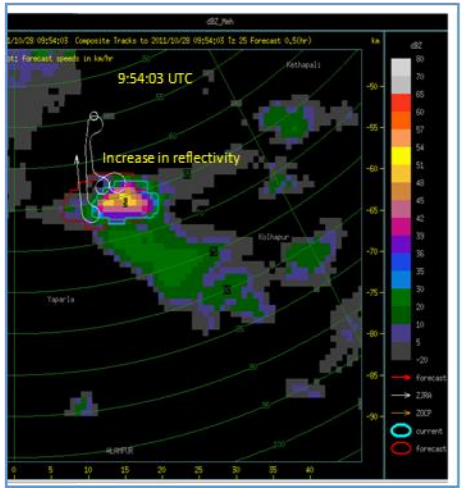
Seeder aircraft with flares

1-5 micrometer hygroscopic particles released in cloud updrafts at the cloud base

Telemetry

C-band radar

TITAN



Rain gauge network

Ground campaign