WINTER FOG EXPERIMENT (WIFEX) 2015-2017

(IITM, Ministry of Earth Sciences, Govt. of India Initiative)

Sachin D Ghude

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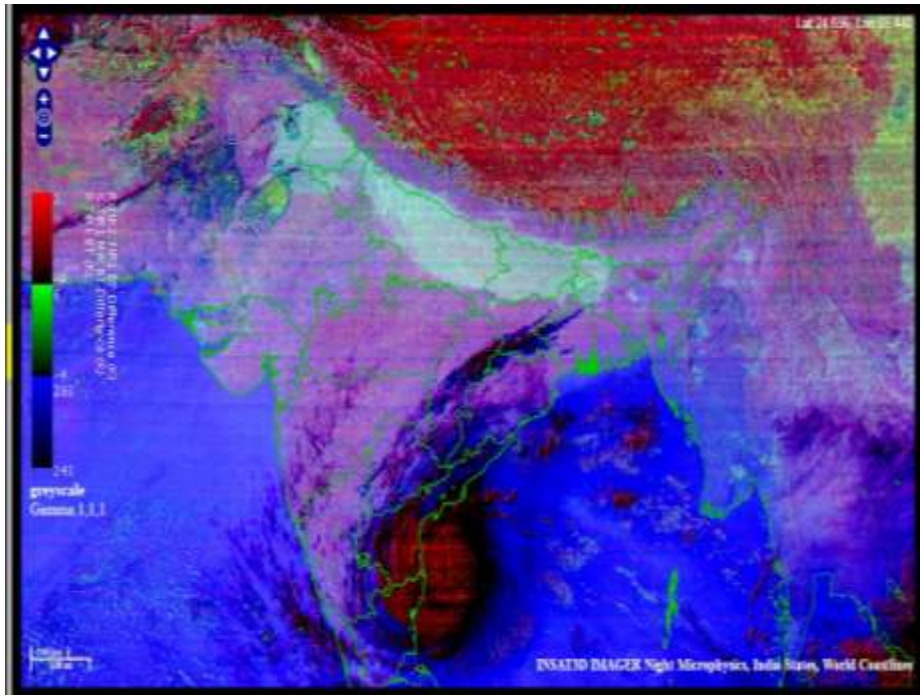
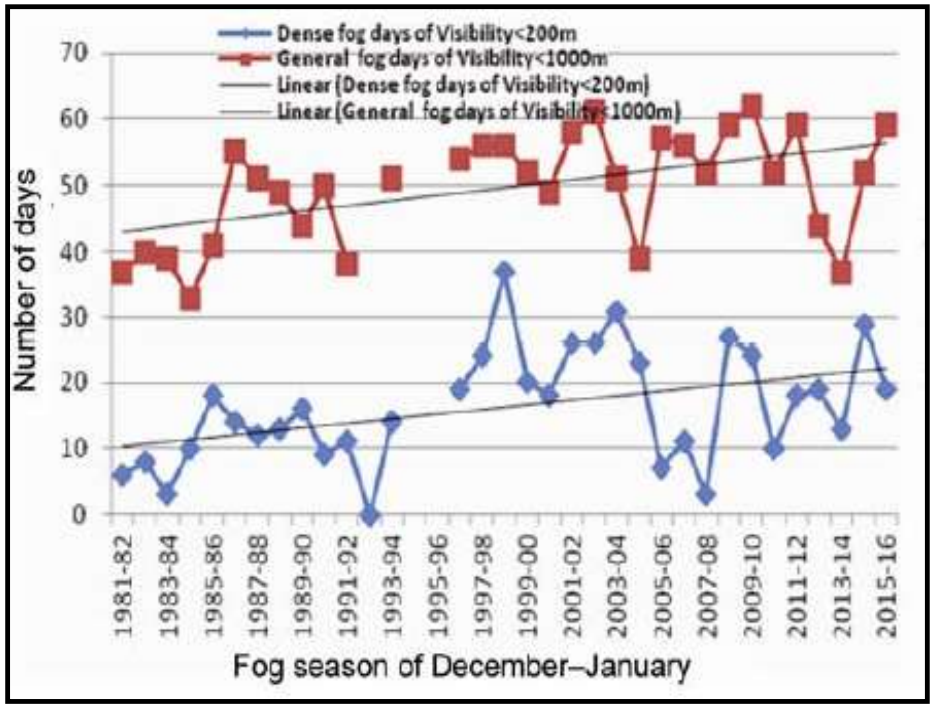
Objective: Understand the physical mechanism of fog formation and dispersal (fog life cycle), and develop a suitable fog forecasting system.

Winter-time Fog In the Northern region of India





- What triggers fog formation?
- How do thermodynamic, microphysical, and chemical process interact with each other?
- What processes are responsible for extended-period fog and dissipation of the same?
- Can met models recreate the fog? is there room to improve fog prediction with better physics?

32 Instruments. Aim is to have simultaneous and collocated measurements of

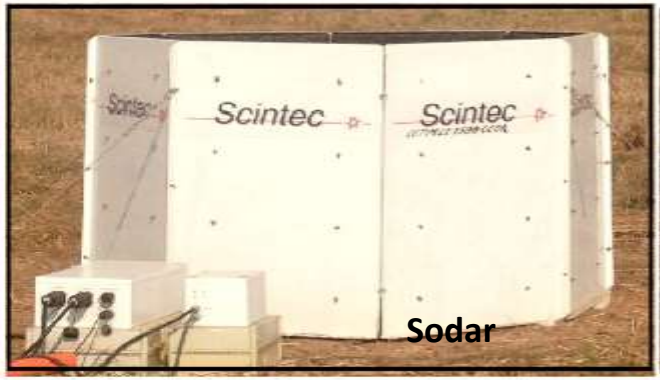
Category	Parameters	Instruments
Ground and surface properties	Temperature and water profile in the ground Ground heat flux	Soil moisture sensors
Surface layer meteorology	Temperature, humidity, pressure, wind speed, wind direction at1m, 2m, 5m, 10m, turbulence and precipitation	All in one whether station, 10m vertical mast, IMD-SAFAR AWS network, sonic anemometers
Radiation fluxes	Downwelling shortwave (SW) direct, diffuse, and global long wave (LW) irradiance	Sky Radiometer, Net radiometer, pyranometers
Atmospheric profiles	Temperature, humidity, pressure, wind speed, wind direction	Microwave radiometer, Tethersonde instruments, Radio-sonde (IMD)
Aerosols and fog optical properties	Visibility, fog and cloud base height, absorption coefficient, scattering coefficient, aerosol optical depth	RVR, fog detector, Photoacoustic Extinctiometer (PAX- aerosol absorption and scattering), Neflometer, sun-photometers, Aethalometer
Aerosols and fog microphysics	Aerosol particle size distribution, aerosol particle counter, Condensation Particle Counter/ Condensation droplet counter, CCN	SMPS, CPC/CDP, CCN counter, GRIMM
Aerosol/gas chemistry	Fog collector, Particle in Liquid Sampler (PILS), EC/OC analyser, VOCs, Aérosol filter collector, SO_2 gas analyzer , PM_1, $PM_{2.5}$, PM_{10}	Fog Collector, PILS, PTRMS EC/OC anayzer, SO_2 analyzer, PM analyzers

Flux Tower

Ramdas Layer

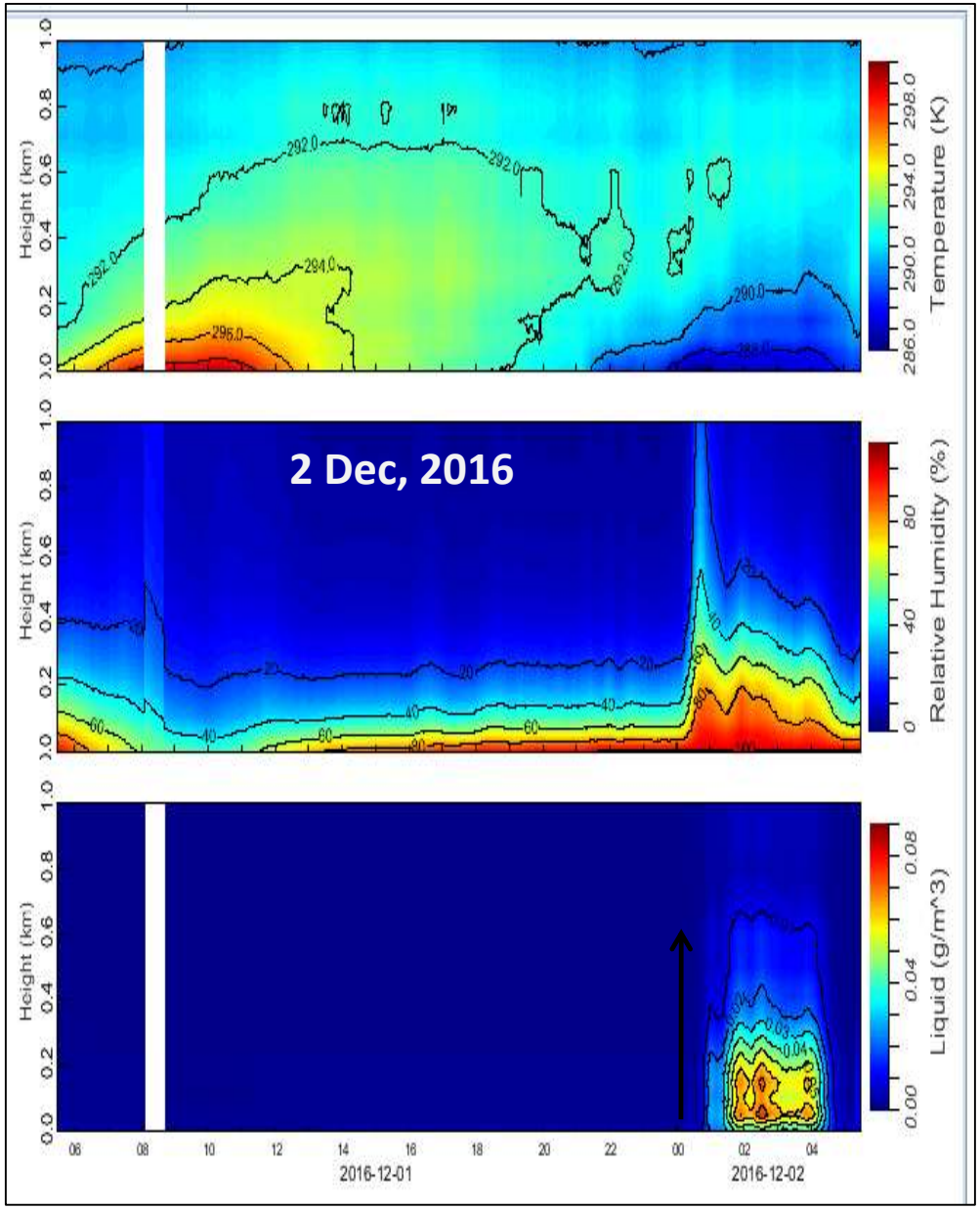
CDP

Fog sampler, PM2.5 collector



Sodar

Variability in Fog Layer Vertical Structure and associated thermodynamic features during dense fog day



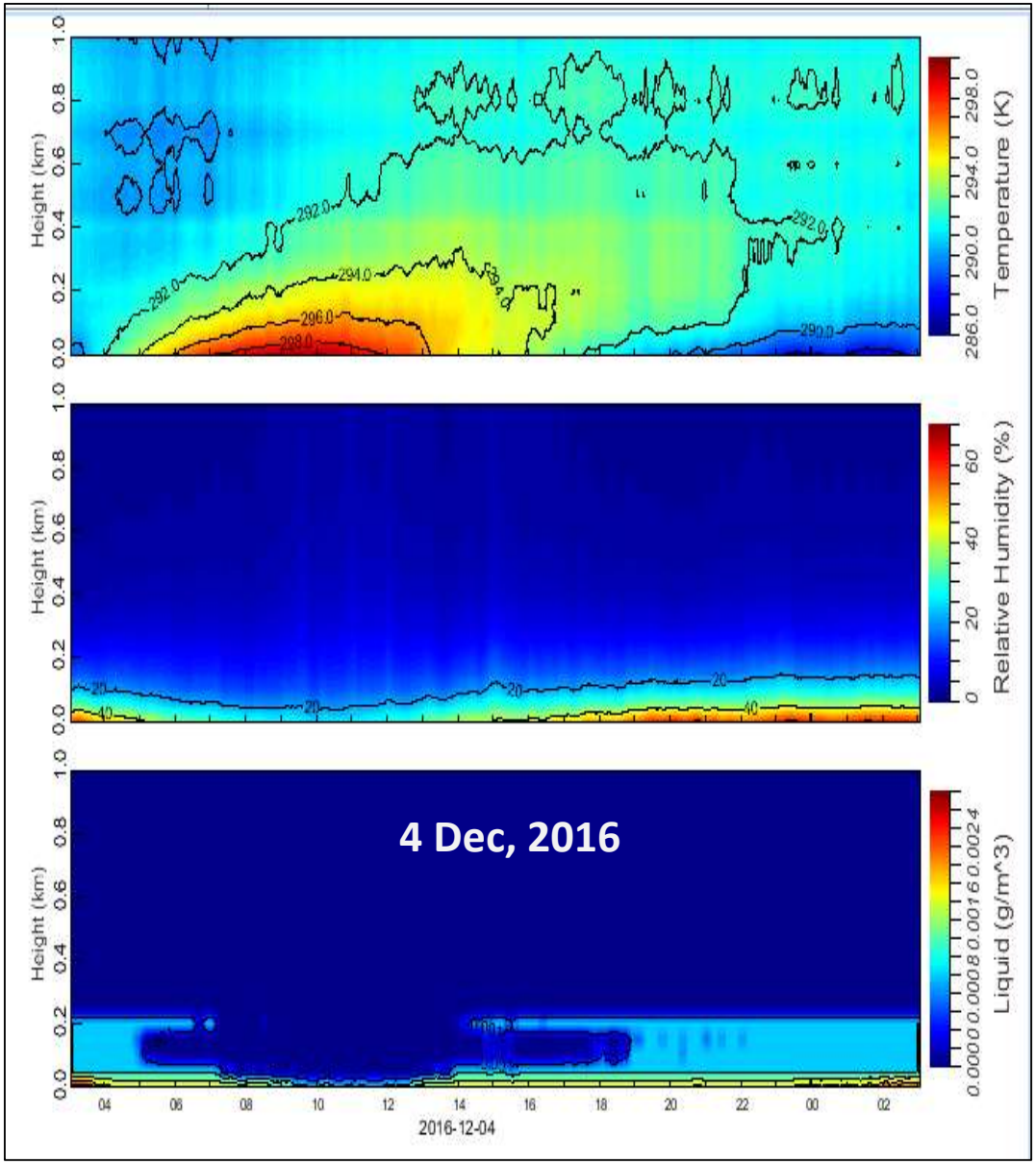
Clear low level inversion in midnight

Humidification and development of deep moist layer

Triggered fog early morning

Vertical dept of fog is about 400 meter

Variability in Fog Layer Vertical Structure and associated thermodynamic features during hazy day

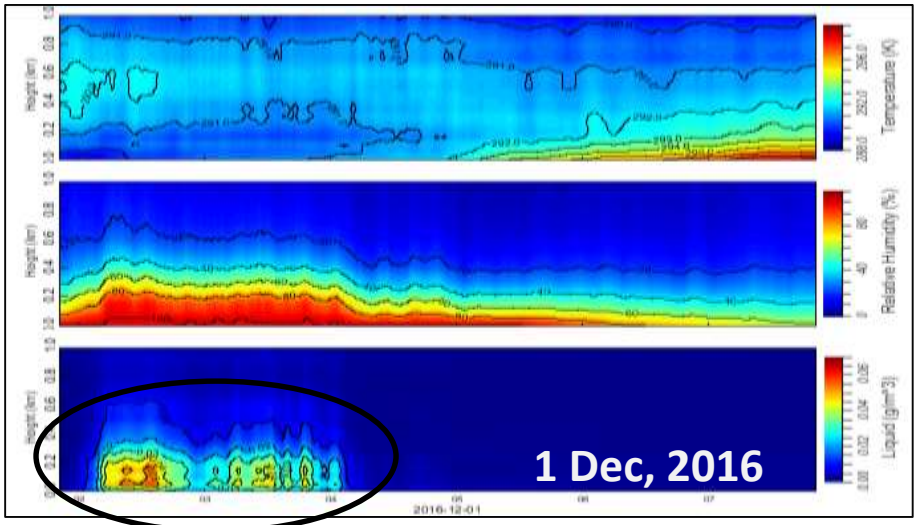


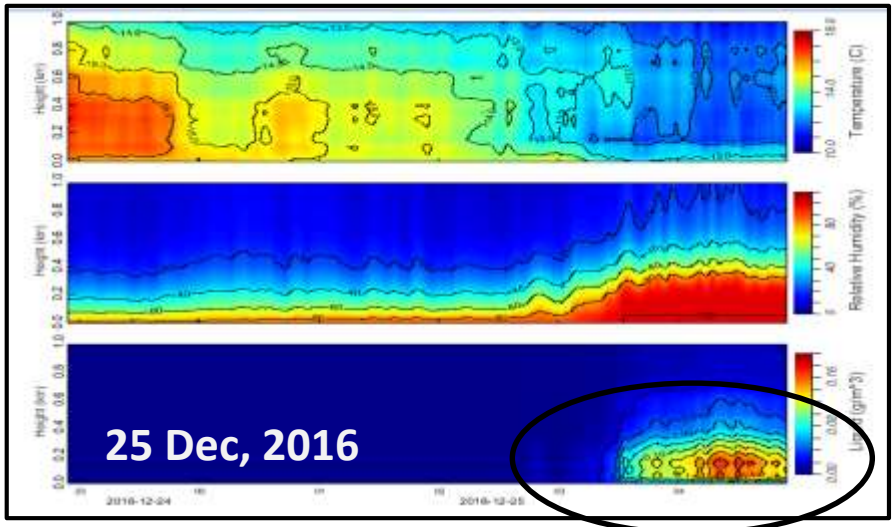
Clear low level inversion in midnight

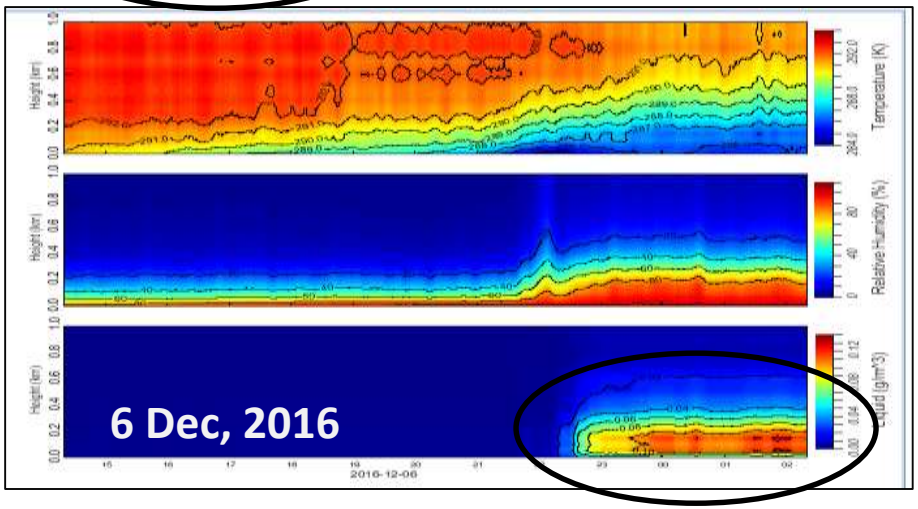
Shallow and sub-saturated moist layer

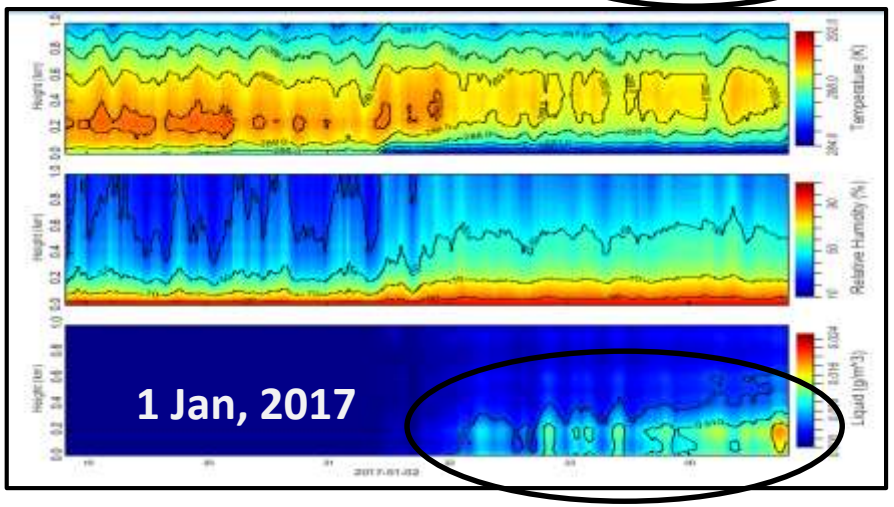
Formed haze

Variability in Fog Layer Vertical Structure and associated thermodynamic features on different fog days



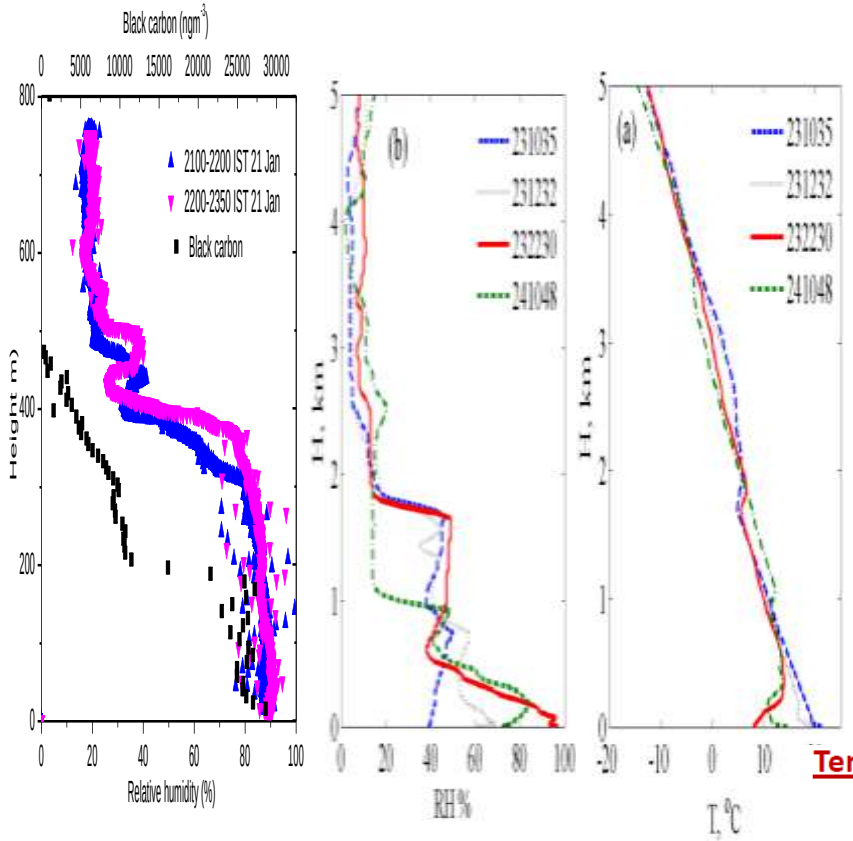






Significant variation indicate fog layer itself is dynamic
Eroded from the layer above 30% humidity.
In spite of being dynamic the most layer sty deep and extensive

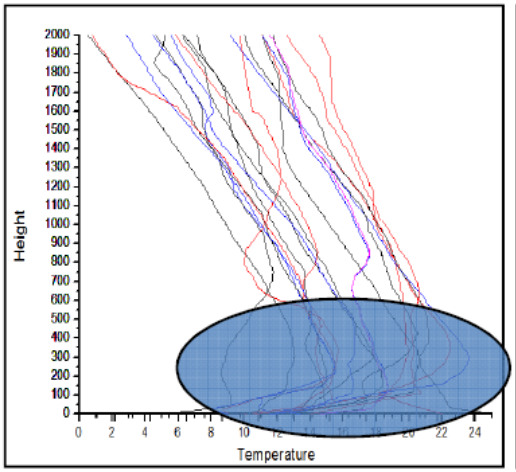
Tethered balloon and GPS-sonde profiles on 23-24 January 2016

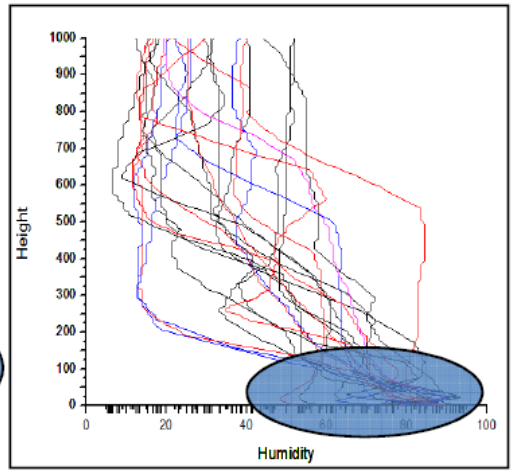


Temperature and humidity profiles during fog and dense-fog events at Delhi during WIFEX-2016-17

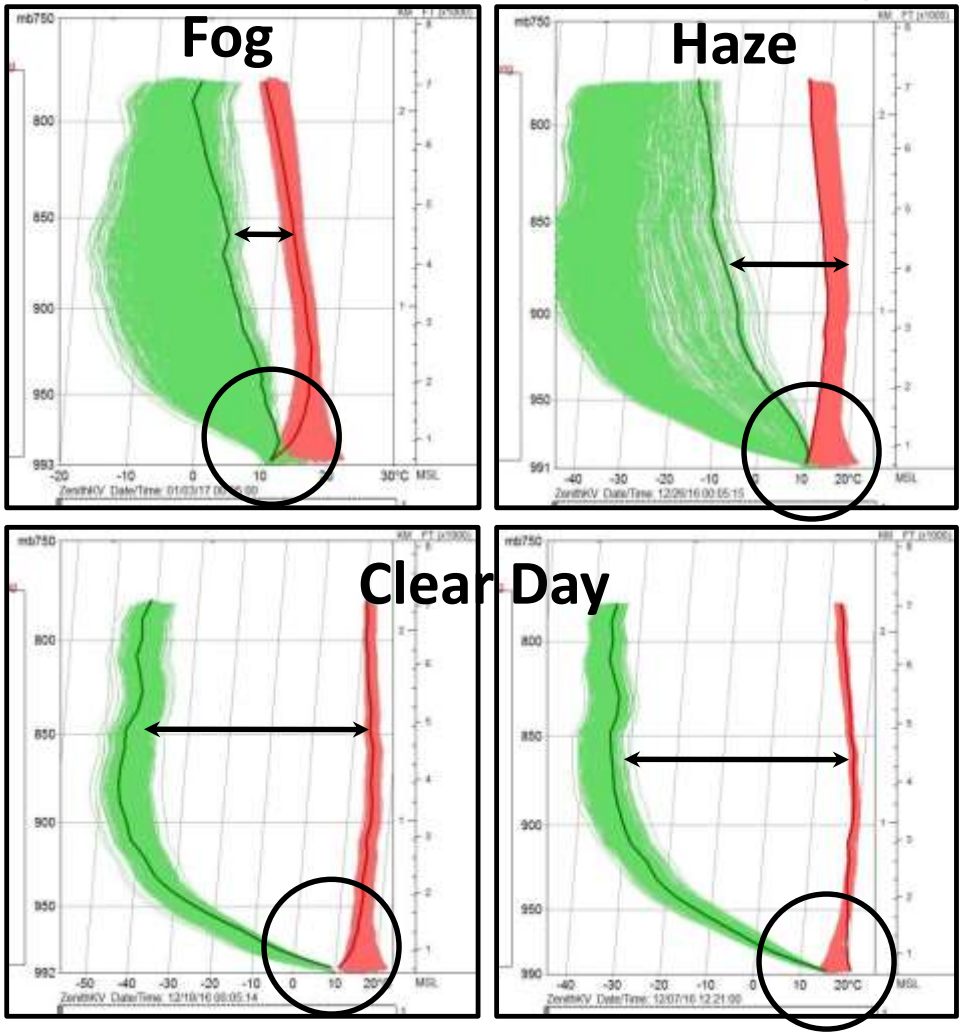
Deep moist layer and typical inversion below 500-700m

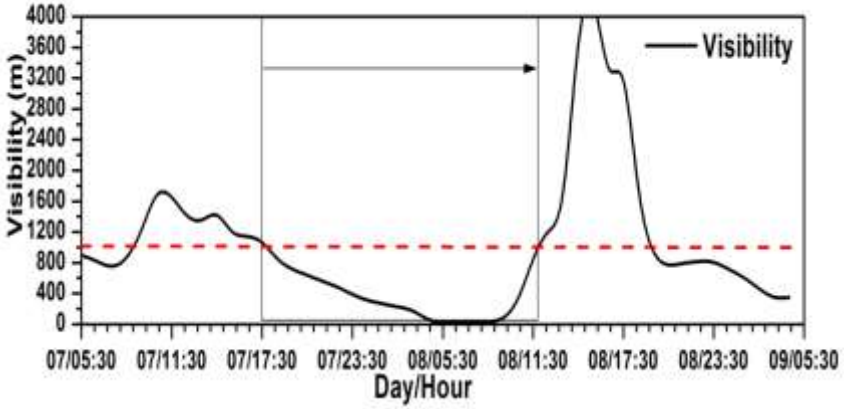
Formation of deep moist layer up to 100-200 m

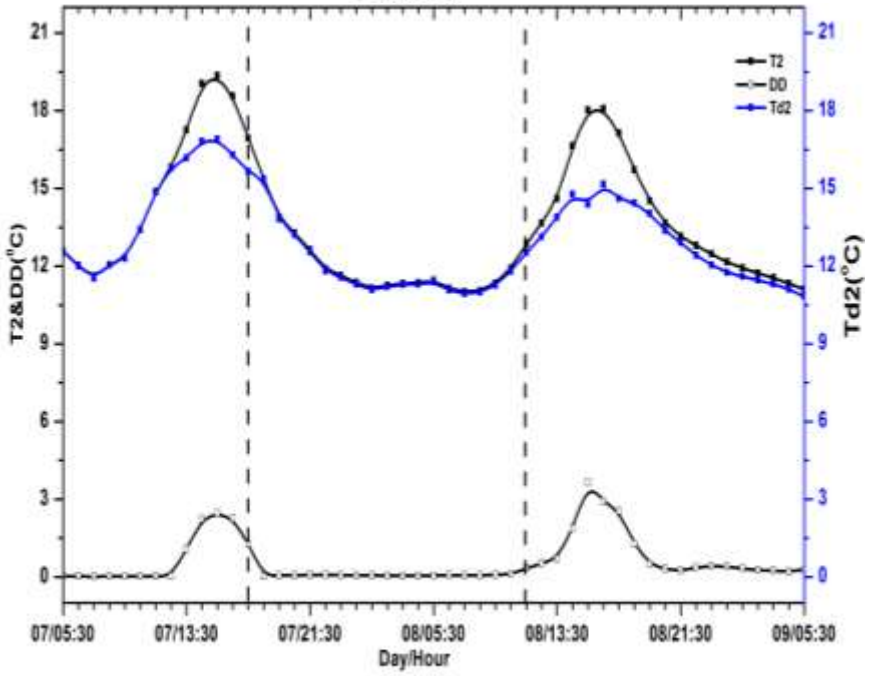




T and Td profiles observed from MWR and tower observations during fog and non-fog events

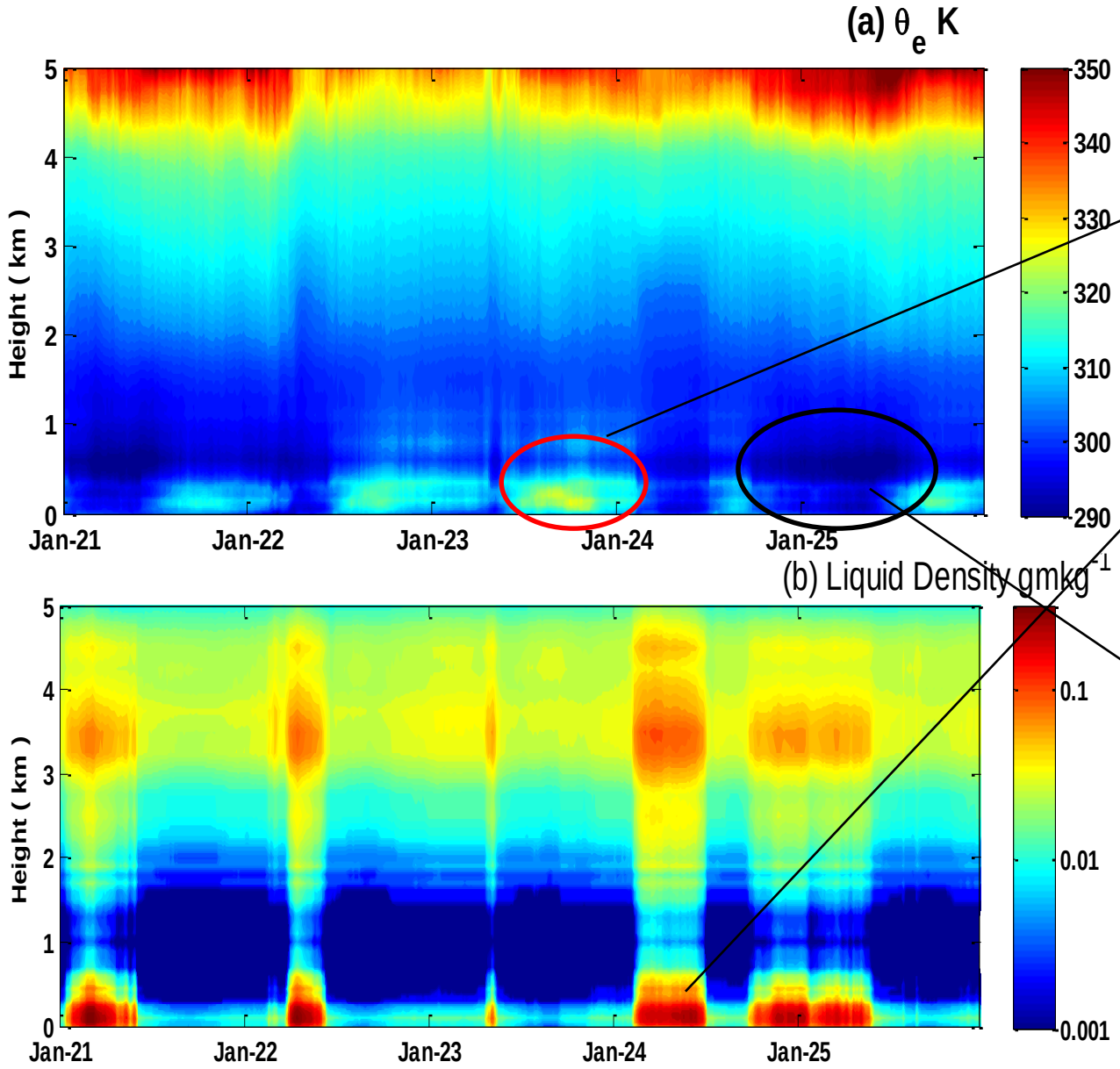






Dew point Depression: close to zero triggers fog

Θ_E and LWC profiles observed from MWR during 21-25 Jan



High Θ_E prior to all fog events

Imminent fog could be identified 2-3 hours prior to event

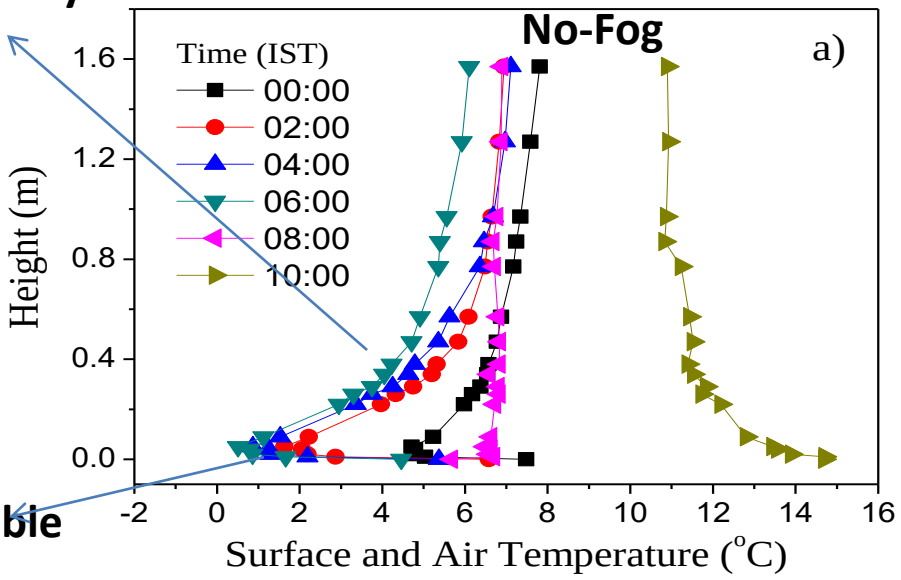
Vertical layer of fog could also be assessed

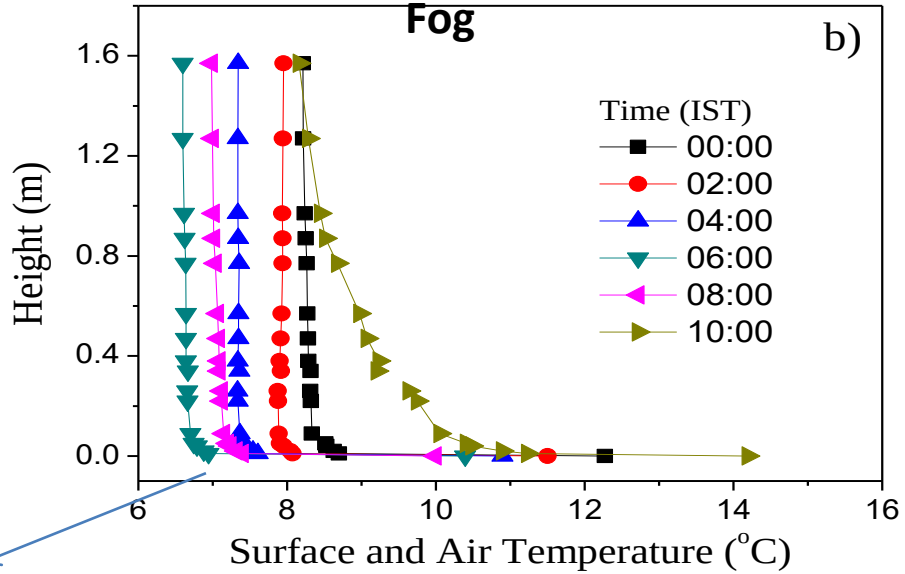
Mini convective boundary layer structure sustaining turbulence at top and bottom of the fog layer

Near surface air temperature profiles on clear and foggy day

Stable layer

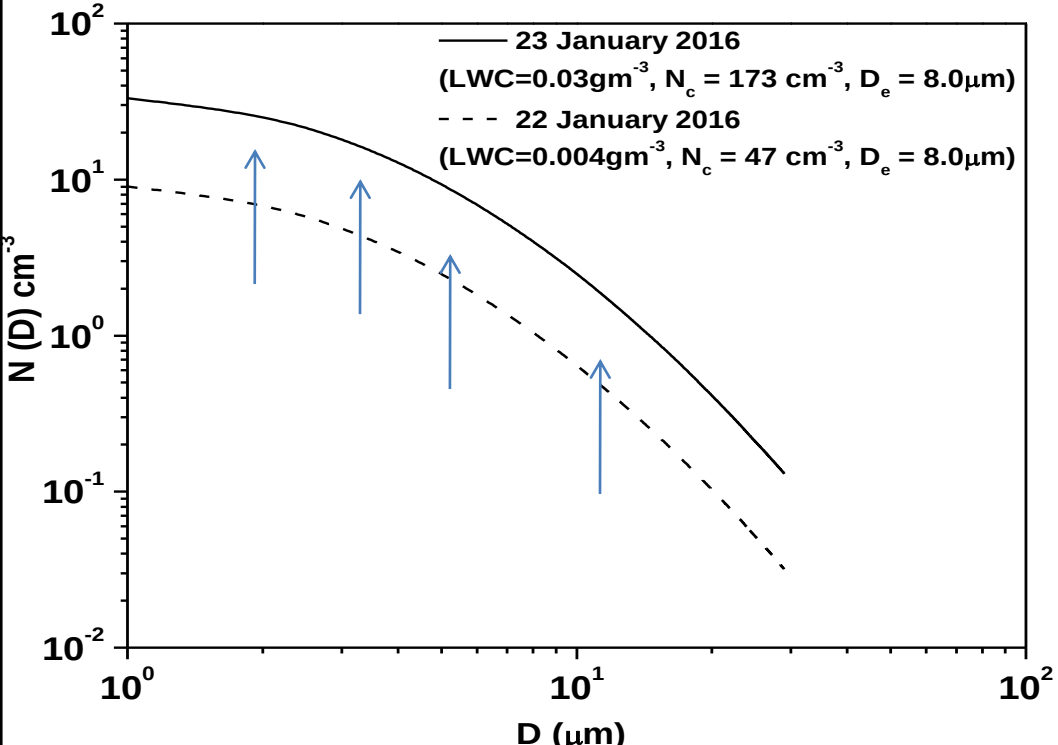
Thin unstable layer

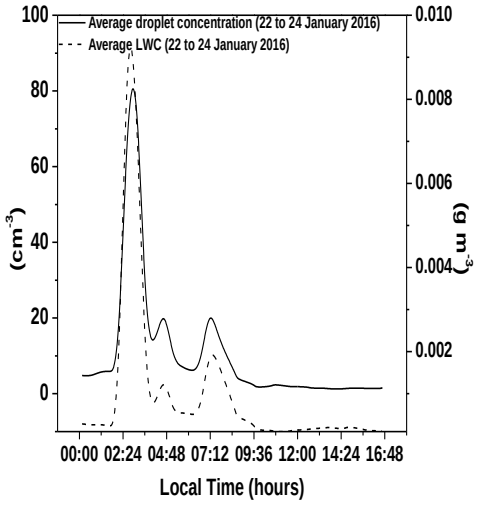


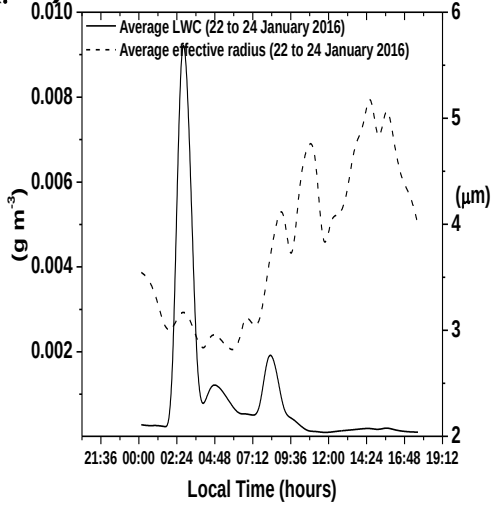


Sharp cooling lower few centimetre

Fog droplet size distribution on 22-23 January 2016



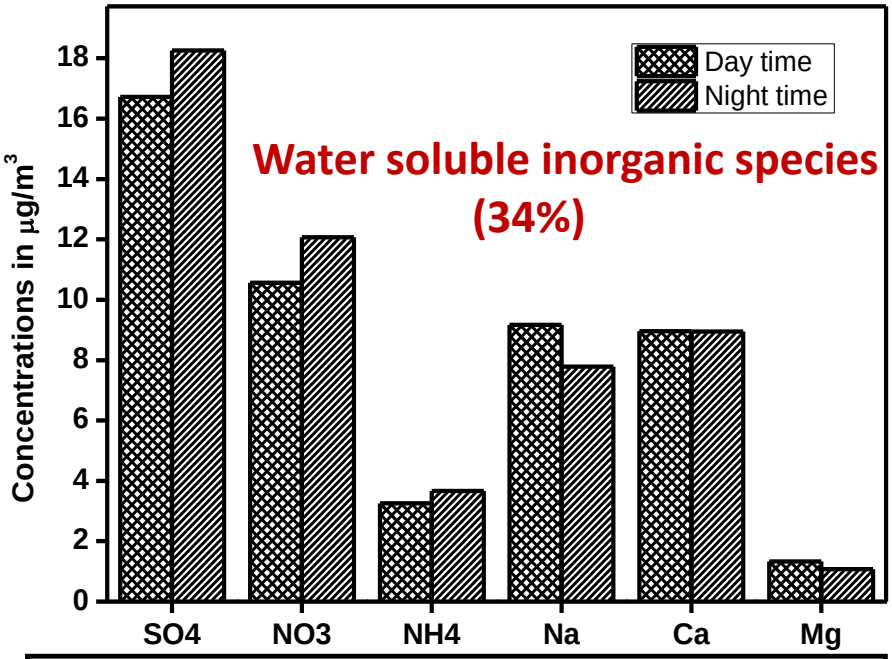


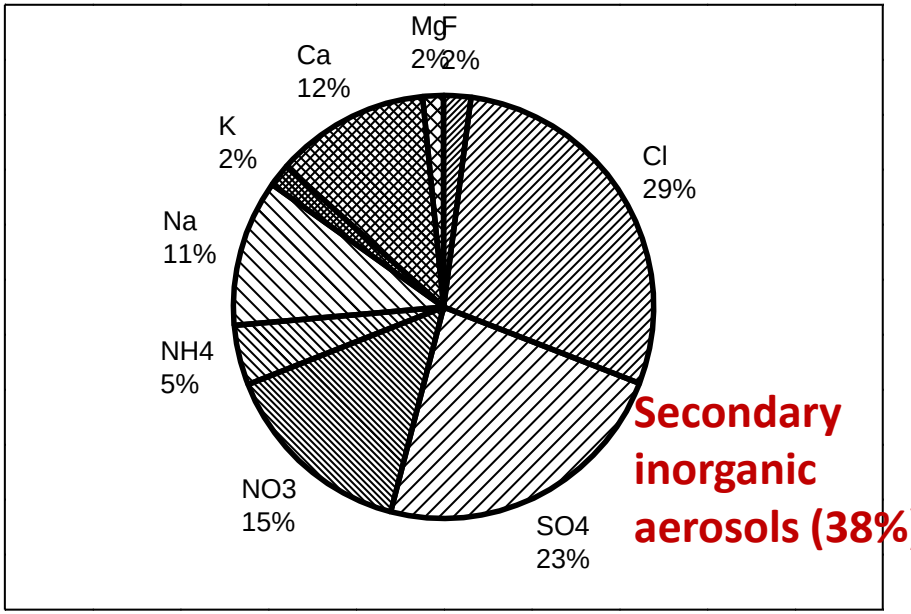


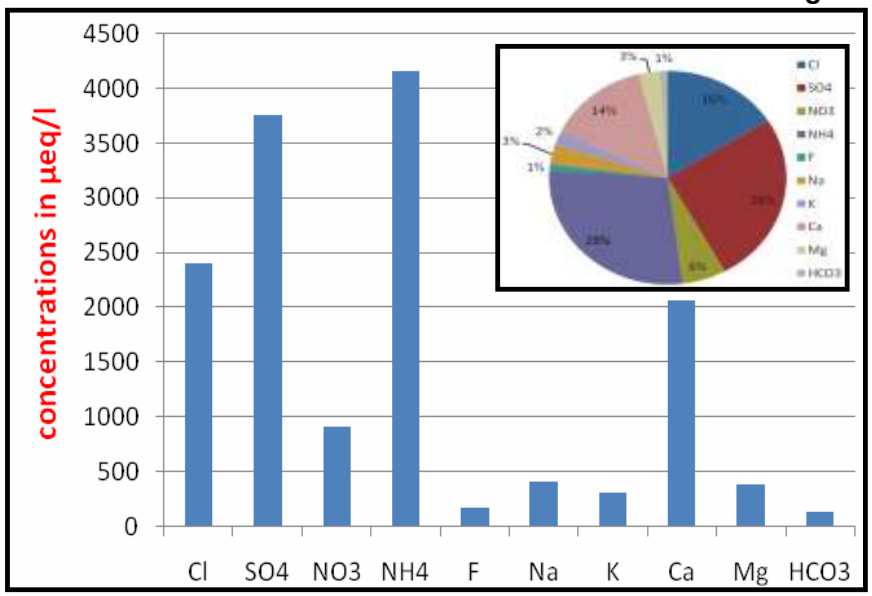
Very large particles are form during fogy conditions

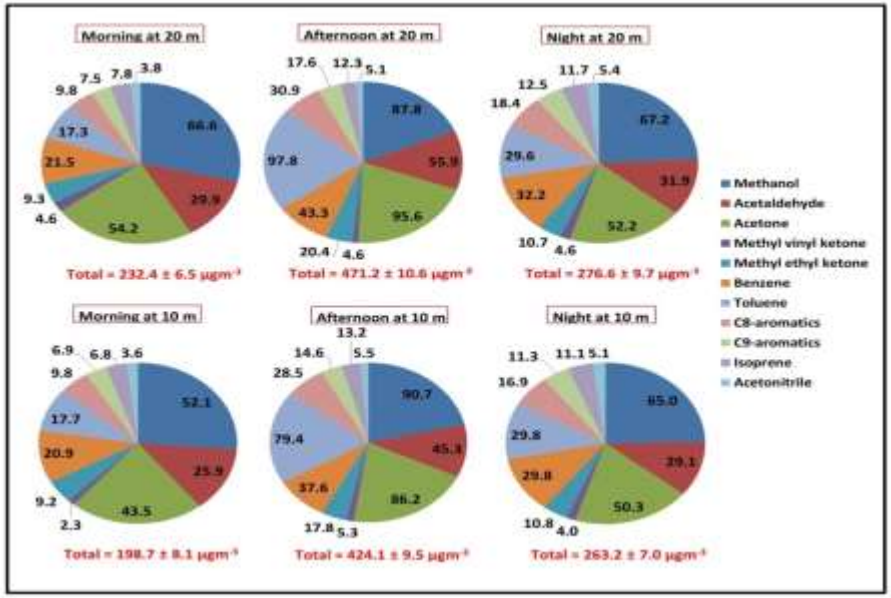
Number concentration increases uniformly along entire spectrum and fog particle grew Larger from non-foggy to foggy day

Chemical composition ($PM_{2.5}$, fog water and VOC's)









Current Science, 2017

IITM_Experimental WRF Forecast for WIFEX 2016-17

IITM_GEFS 12.5km and WRF 2km

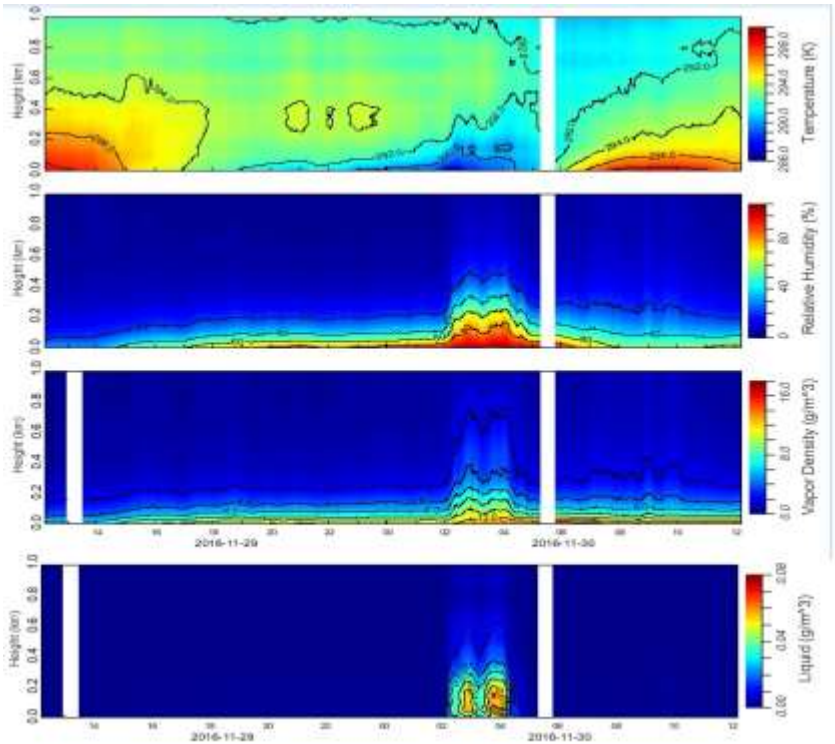
Different Model Physics used for simulations in hind cast mode

- **Micro_Phy** : Lin,WSM3,**WSM6,WDM6**,WDM5,Thompson
- **Radiation (Long,Short wave)** : RRTM, RRTMG, Dudhia, **CAM**
- **PBL** : **MYNN2.5**,QNSE,Boulac,UW,MYJ,Y SU, ACM2 TEMF,GBMS
- **Surface Layer** : **MM5**, QNSE
- **Land Surface** : NOAH, NOAH_MP, **Pleim-Xiu**, RUC

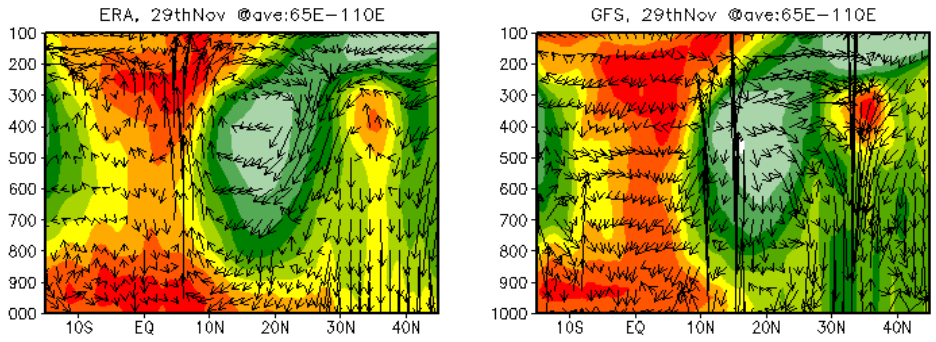
Different Model simulations used in hind cast mode

- ❖Spin-up simulations : 06,12,24,48hr
- ❖Domain : single and Nested
- ❖Resolution : 2km and 4km
- ❖IC/BC : ECMWF, GFS, IITM_HRGFS, NCUM
- ❖Nudging : Grid point and Observational
- ❖Model configuration : Every day re initialization
- ❖Grid Number/Domain Size : 440*220, 220*110 (for 2km and 4km)
- ❖Vertical levels : 27,50 and 60

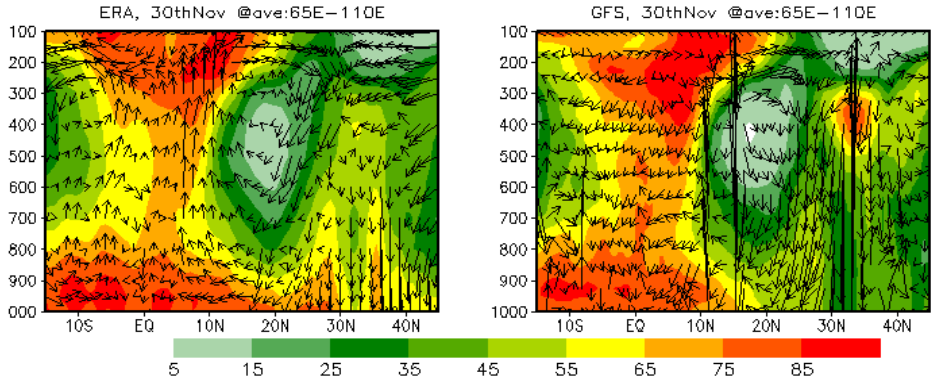
Cyclone NADA

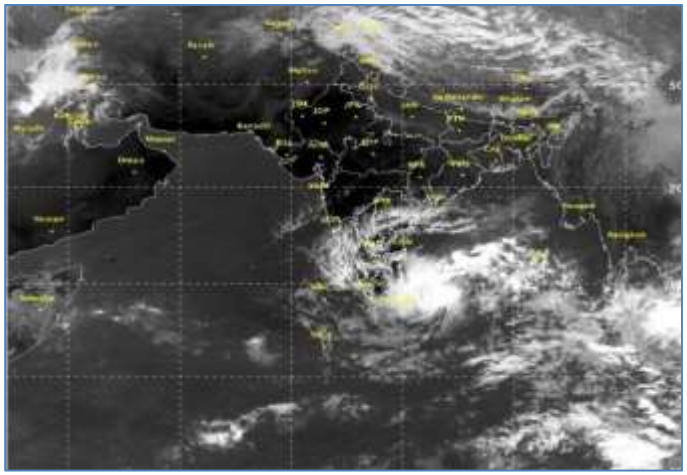


ERA Reanalysis **28th Nov IC/BC 24hr forecast valid for 29th Nov 00UTC**



29th Nov IC/BC 24hr forecast valid for 30th Nov 00UTC



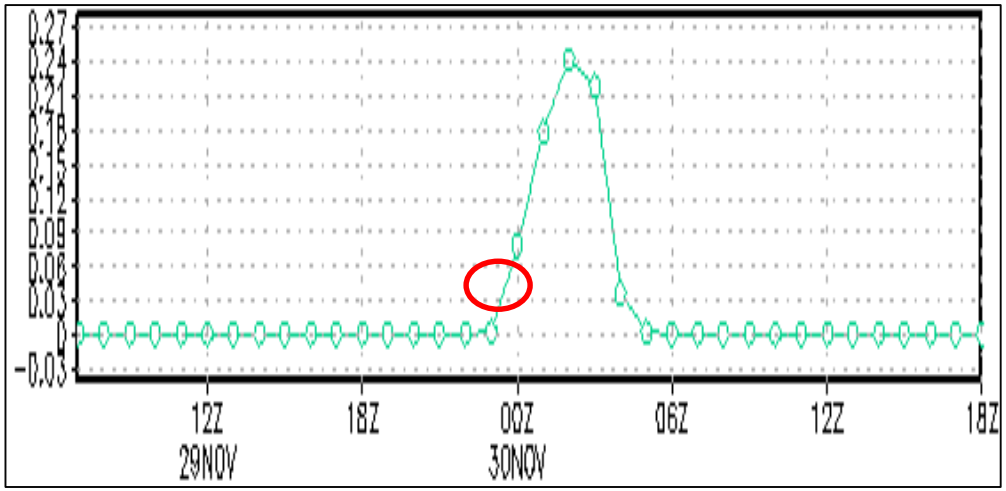


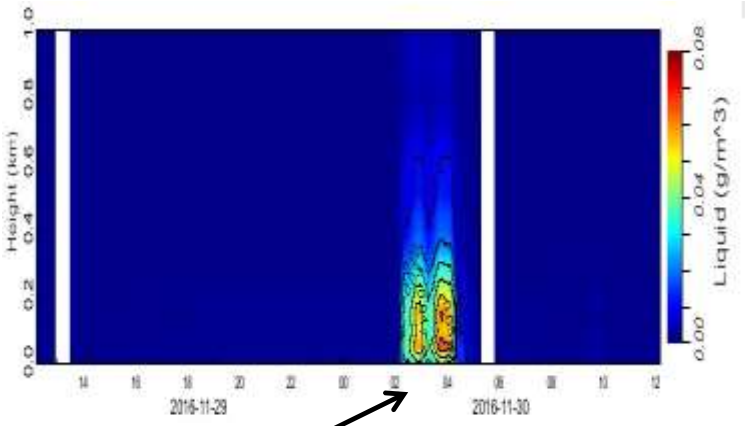
30th Nov

18h Forecast Generated using IITM GFS (12 km) and IITM-WRF (2 km)

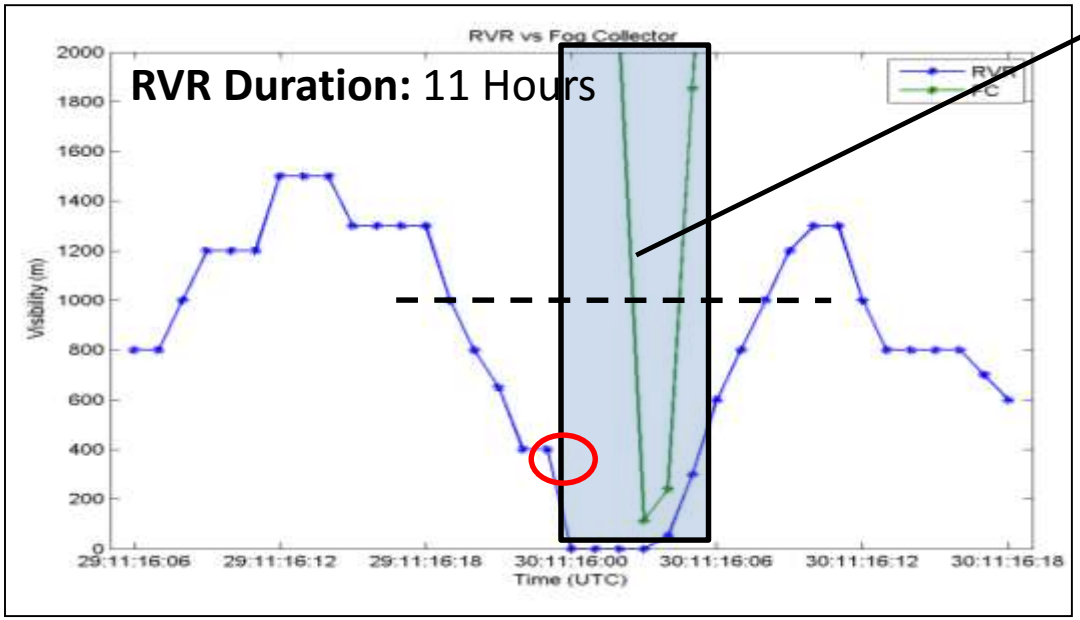
30 November

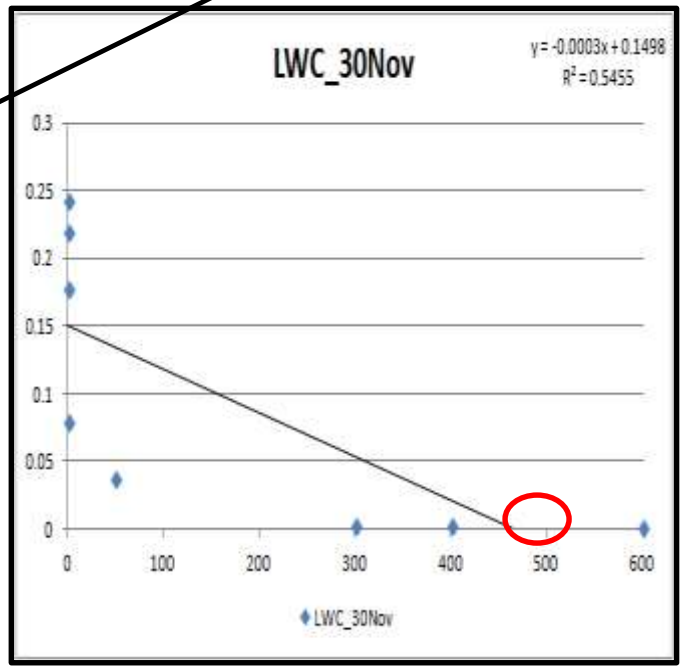
MWR Duration: 2 Hours





RVR Duration: 11 Hours

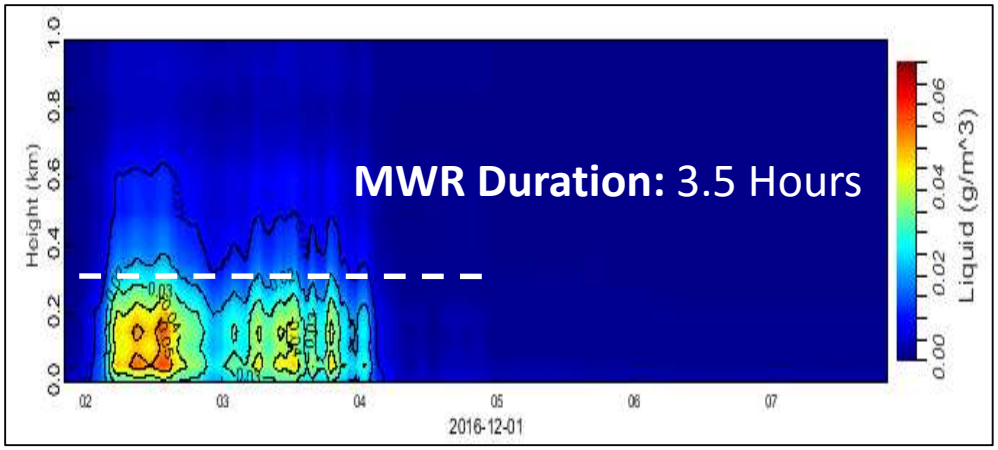


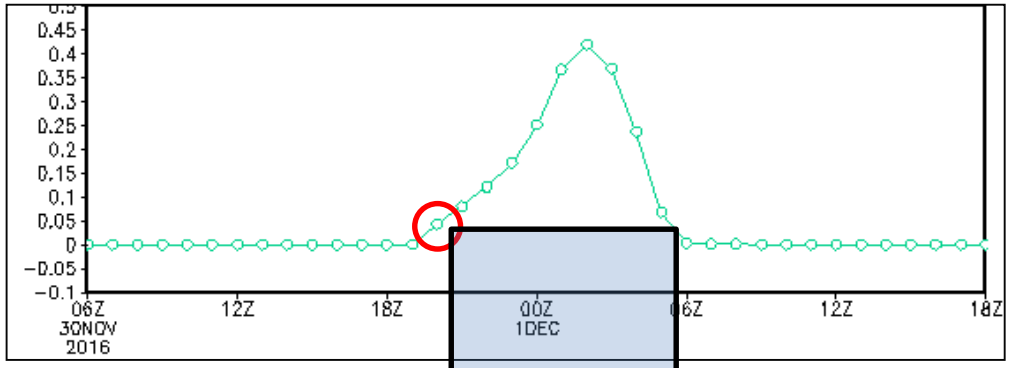


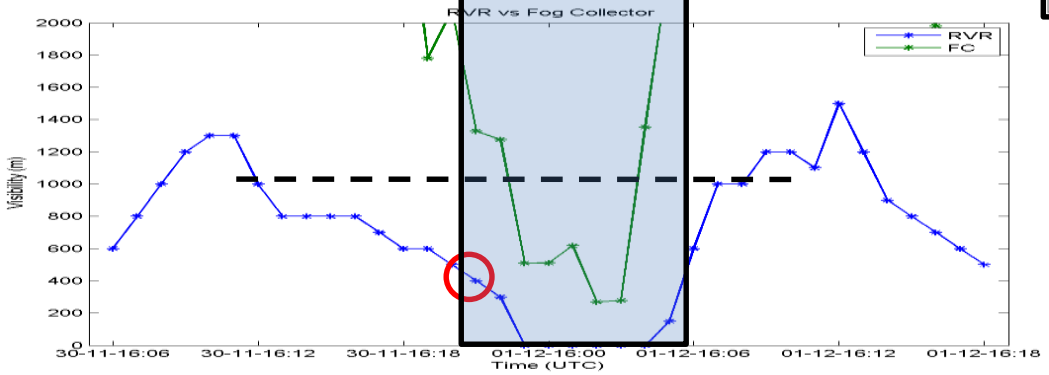
Model Duration: 6 Hours

18h Forecast Generated using IITM GFS (12 km) and IITM-WRF (2 km)

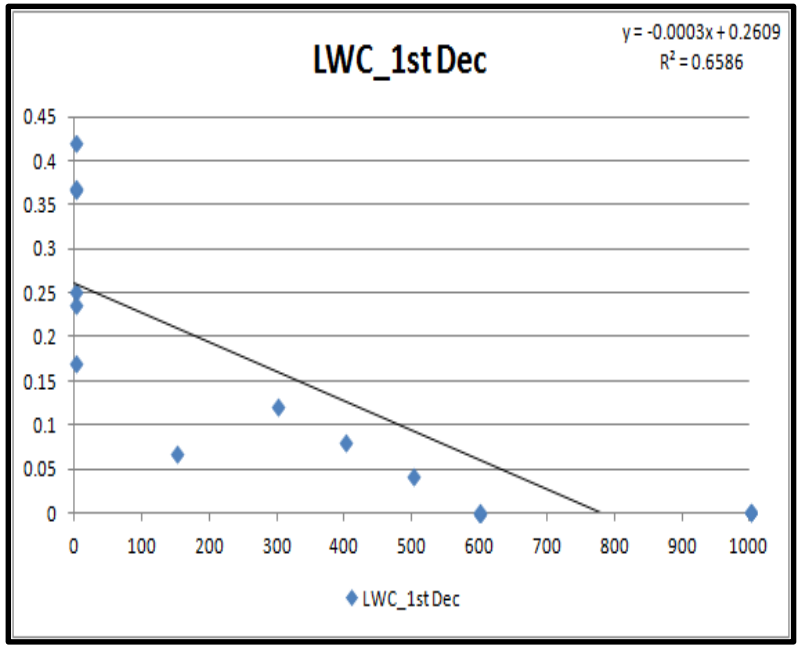
1 December 2017





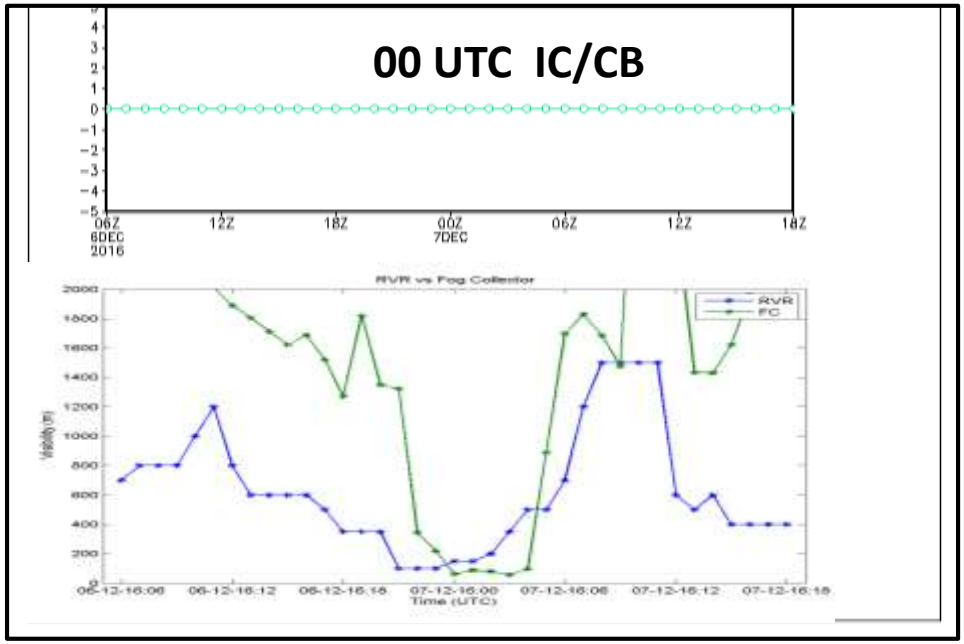


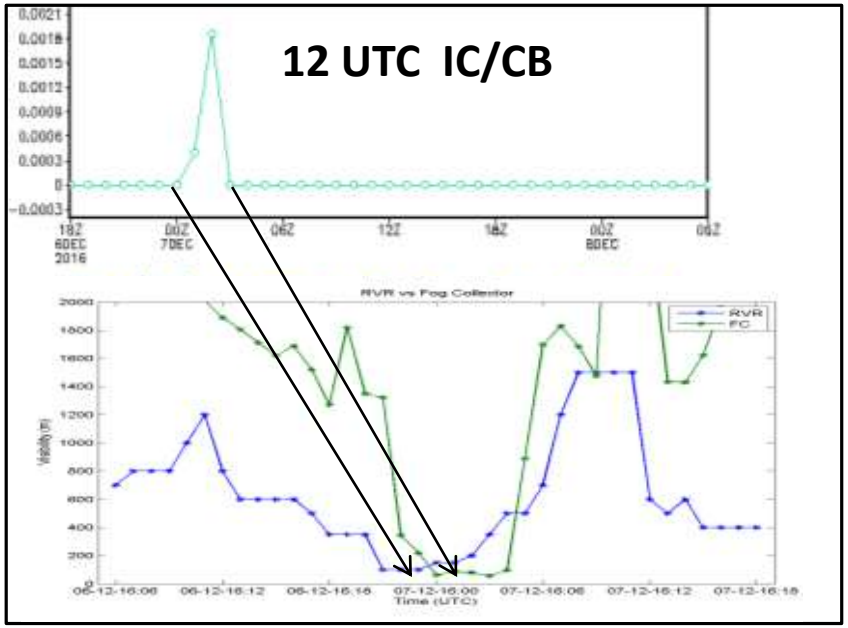
RVR Duration: 11 Hours

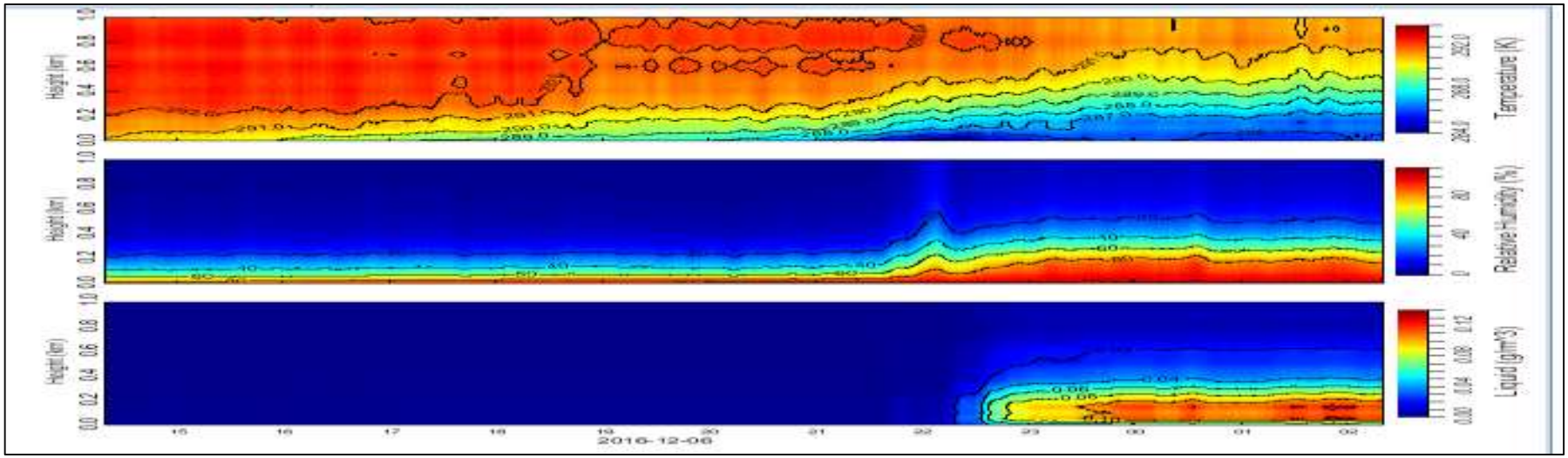


Model Duration: 9 Hours

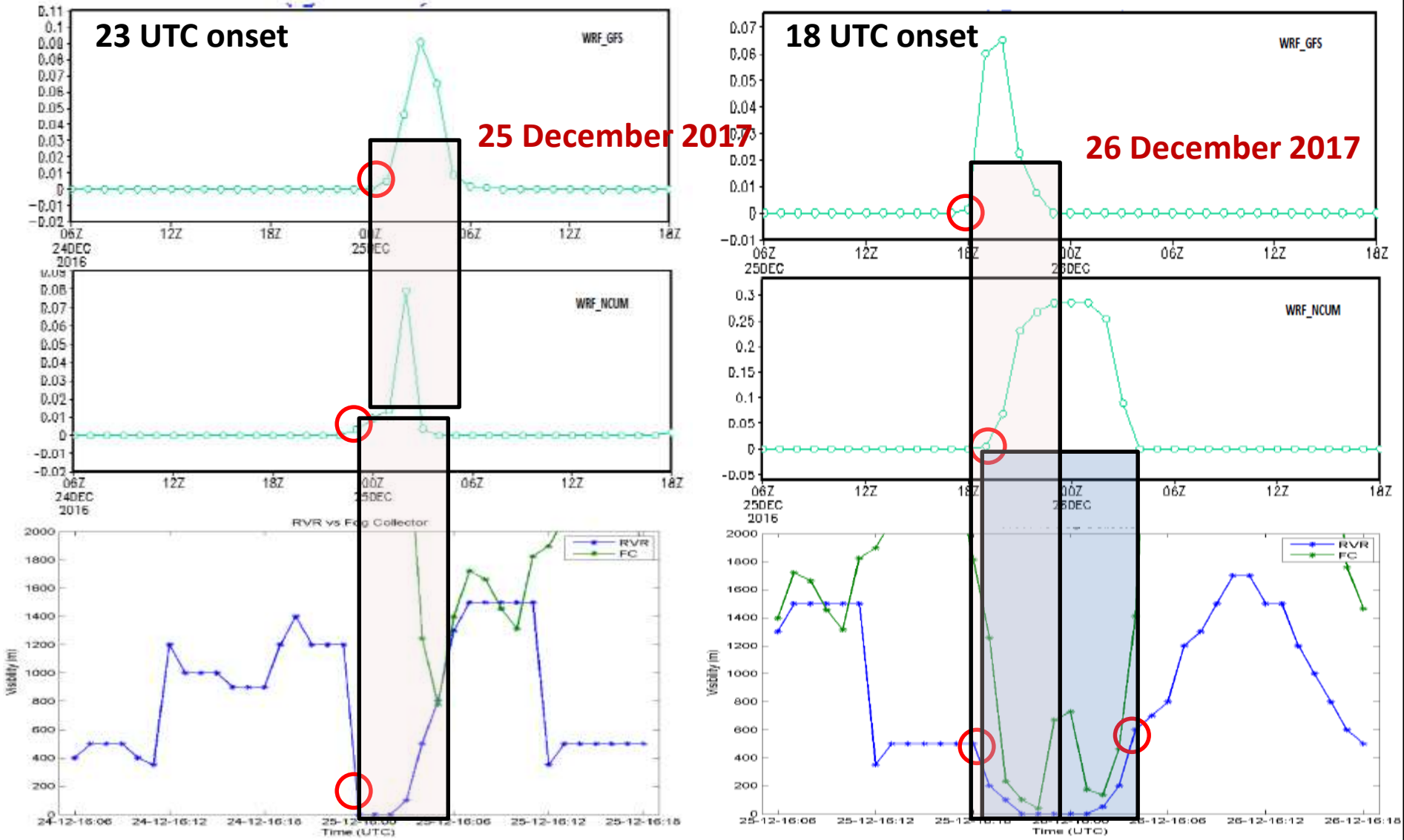
18h Forecast Generated using IITM GFS (12 km) 00 UTC and 12 UTC IC and IITM-WRF (2 km) 7 December 2017





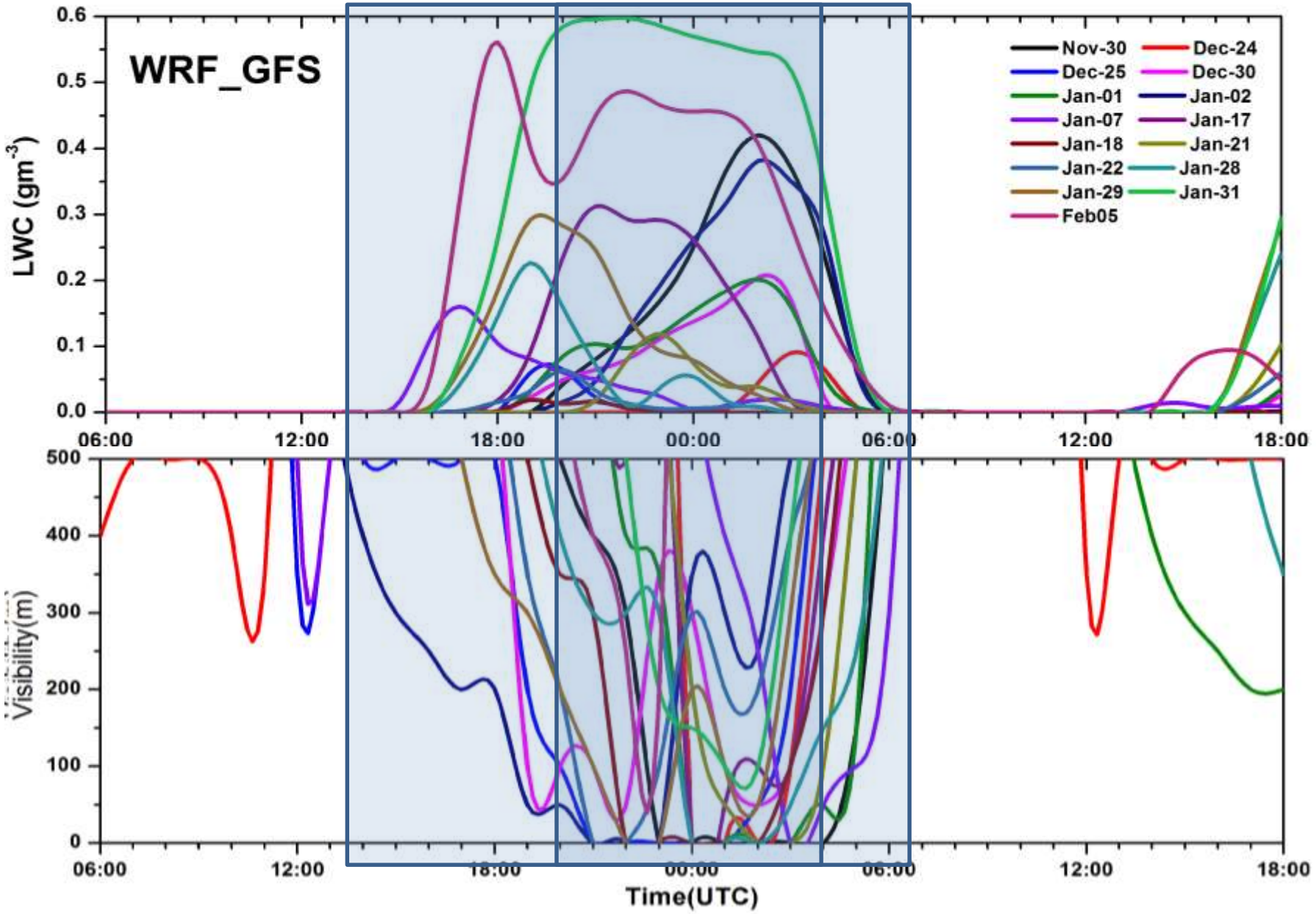


18h Forecast Generated using IITM GFS and NCMRWF NCUM(12 km) and IITM-WRF (2 km)

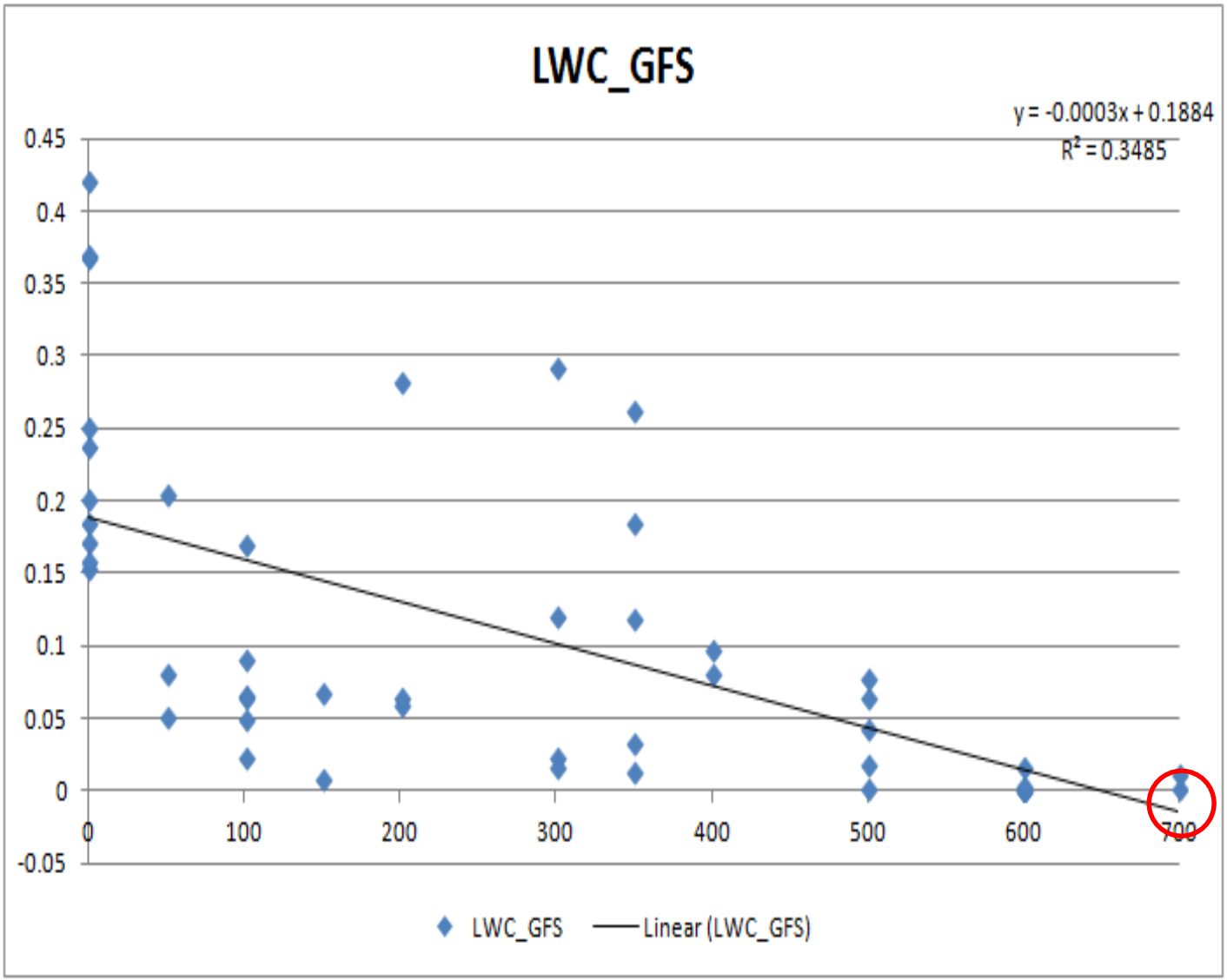


Fog Collector	WRF GFS IC/BC 30th Nov 2016 to 06th Feb 2017	WRF NCUM IC/BC 11th Dec 2016 to 06th Feb 2017
Predicted Fog events	17/25 (68 days)	18/18 (68 days)
Failed Fog events	08	Nil
False alarm	15	34

Simulated LWC and observed visibility during all predicated fog events

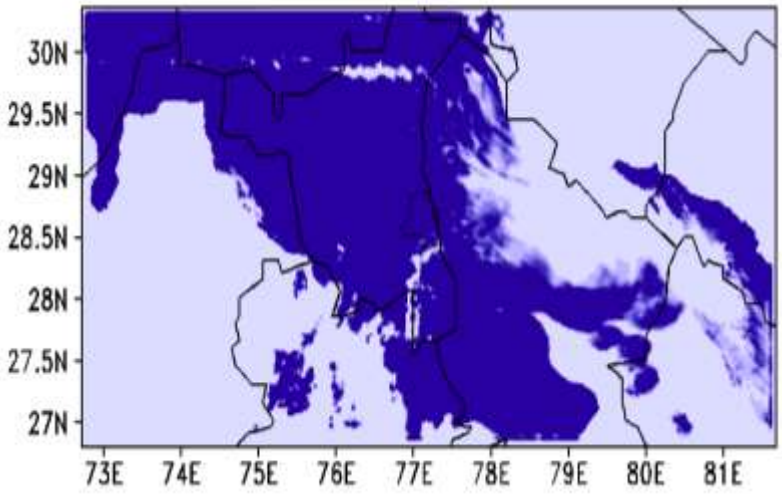


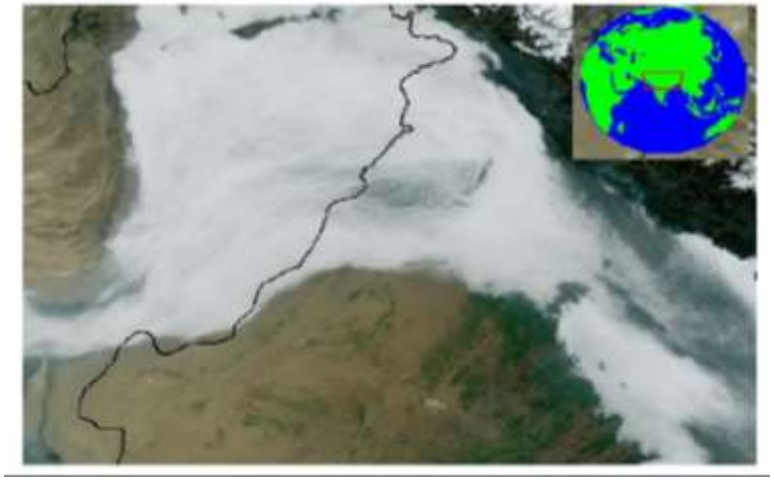
Relationship between simulated LWC and observed visibility during all predicated fog events



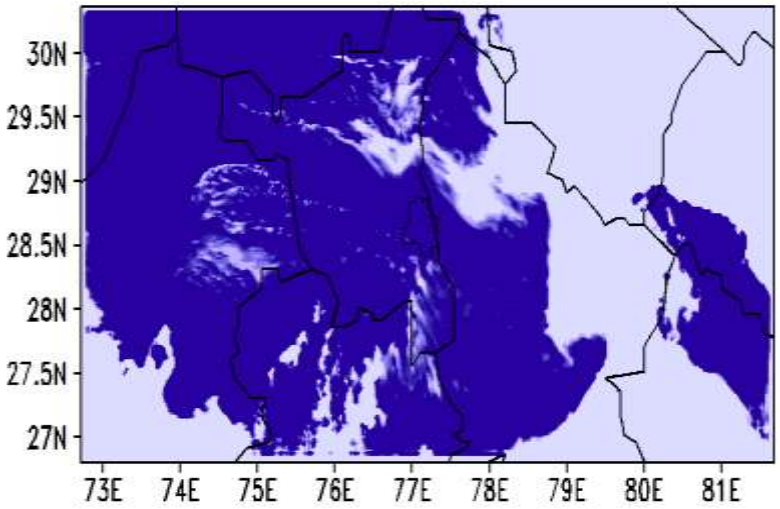
Spatial extent of fog Generated using IITM GFS IC/BC

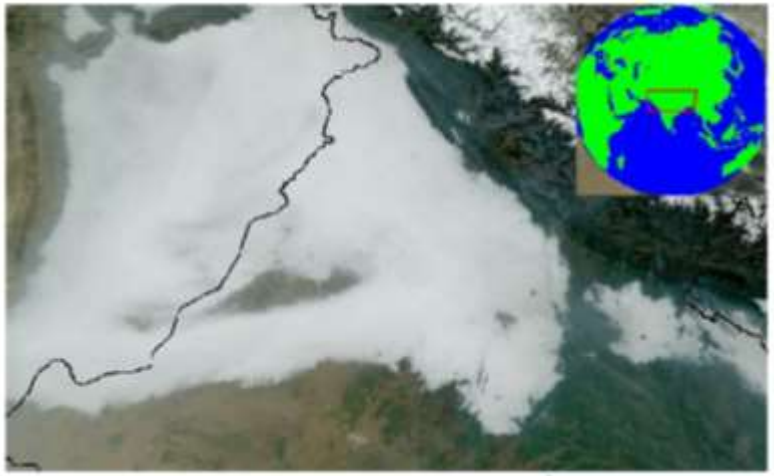
LWC at 22nd Jan 05UTC



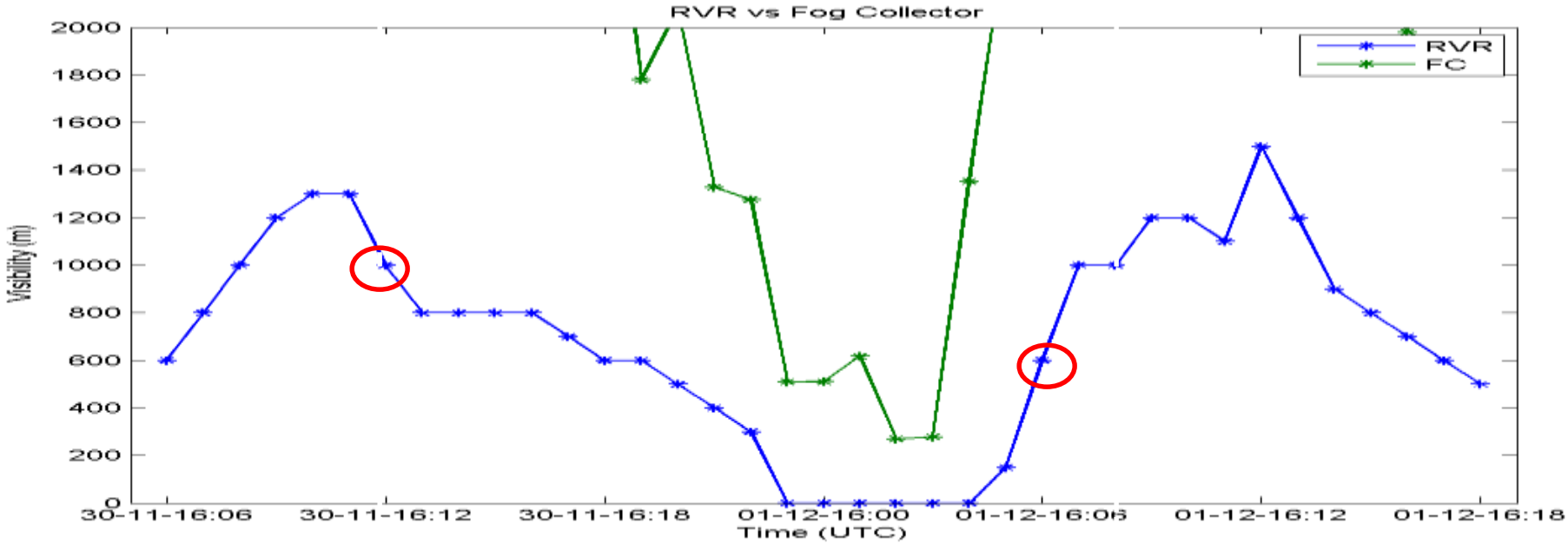


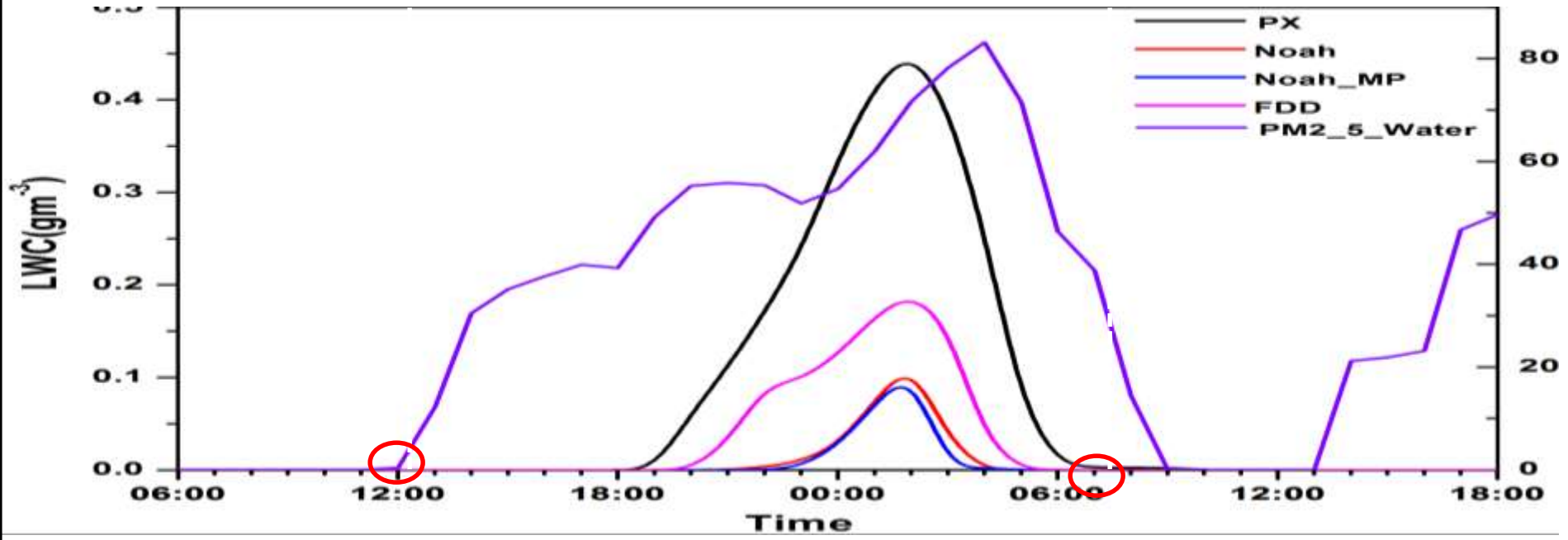
LWC at 24nd Jan 05UTC



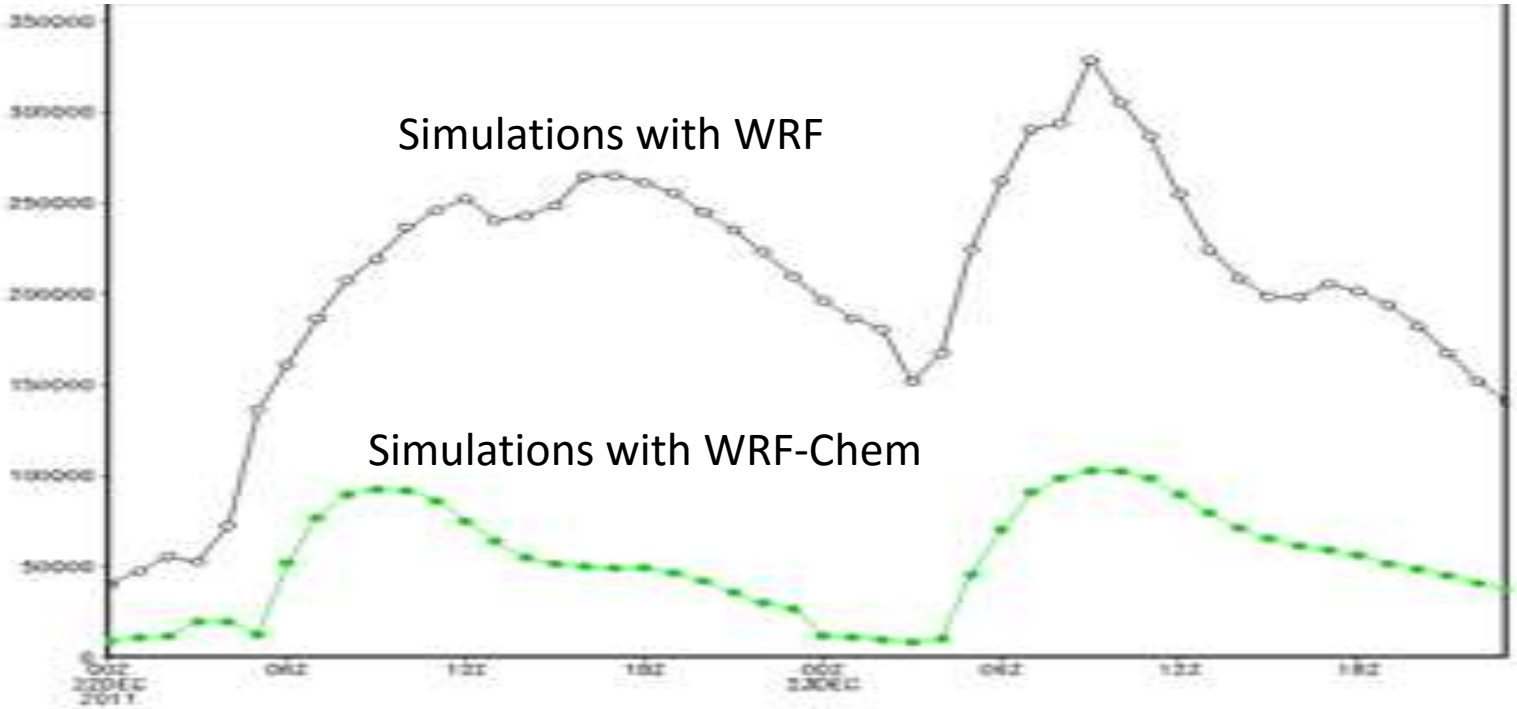


01st Dec Fog Event where model captured





Visibility predictions Using WRF and WRF-Chem



$$vis = -\frac{\ln \varepsilon}{\beta_{\text{tot}}} = \frac{3.912023}{\beta_{\text{tot}}}.$$

$$\text{Vis}_{\text{fi}} = \frac{1.002}{(\text{LWC} \times N_d)^{0.6473}}.$$

$$\beta_{\text{tot}} = \beta_{\text{air}} + \beta(RH, m),$$

Future Modelling Strategy

1. Probabilistic forecast based on

- Initial Conditions GEFS, NCUM
- IC/BC 00 utc, 12 Utc
- WRF-Chem setup

2. Integrated approach Coupling with 1D model and assimilation at local scale?

Winter Fog Experiment (WIFEX) over Indo-Gangetic Region of India: overview and preliminary results

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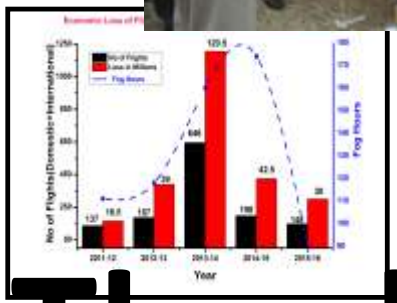

Thank You