Methodology of Prediction of Fog

➢ **Time to time trends from Surface parameters and Upper Air observations and Satellite fog products**
- Trend in surface met parameters winds, Ta-Td, RH etc and lower level inversion
- Monitoring sky conditions
- Time to time location based Radiance and reflectivity values and spatial Fog coverage from RPAID based RGB products INSAT 3D at 30-minute gap

➢ **Climatological data based Threshold and checklist**
- Threshold table using surface and UA at the location (TA, Td, RH and Wind) with Upper air Inversion depth and intensity
- Min temp vis-à-vis dense fog occurrences curve

➢ **Process based using Synoptc-Analogues method and pattern matching both using synoptic charts and NWP analysis and forecast upto 5 days**
✓ **Radiation fog at local scale occurring in Nov and Feb**
- Dew point depression(Ta-Td)
- Calm/light winds, clear skies, inversion
✓ **Large-scale Episodic dense fog occurring in peak winter period of Dec-Jan**

➢ **The NWP consensus guidance from various regional and global numerical prediction models including WRF, GFS, GEFS, NCUM, UMEPS, UM Regional etc (both analysis and day 1 to day 5 forecsat)**
- On wind weakening and remaining light/calm across IGP along with building up or persistence of lower level anticyclone/ridge along IGP
- Approach/passage of WD phase or long gap between two WDs
- RH status in the region
- Inversion and Temperature trends
✓ Easterly wave, Cyclone at south Bay etc.

➢ **Objective based fog forecast using fog Models**
❖ **IMD Empirical Fog model of intensity and duration based fog forecast System**
❖ **Dynamical Fog forecast systems based NWP models(samples are shown in Fig**
✓ Experimental spatial and Airport based intensity based NCUM Global/Regional spatial Visibility based fog forecast map from NCMRWF for 24, 48, 72 hours and further validity
✓ Probability NEPS Fog forecast valid for 2 days
✓ NCUM 12KM Global fog model from NCMRWF valid for 10 days
✓ NCUM 4KM Regional fog model from NCMRWF valid for 3 days
✓ NCMRWF 330m Delhi fog model -Valid for 2-days
✓ NCMRWF all_times_DM_Chem-cities.php-1.5km NW India fog- -Valid for 2-days
✓ IITM WRF chem Products spatial and Airport based Visibility based Fog Model at 4 Km resolution Delhi

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IMD Present Airport, sub-City, District and state based fog warning system operational

➢ Fog forecast and warning are issued as multi-hazard color code map upto day 5 at both national level from NWFC IMD HQ as well as state MC/RWFC level at met sub-division wise and at district wise for dense fog
➢ Airport wise fog warning updated at each 6-hourly intervals operational valid for 36-hours available for **12 airports at Delhi, Lucknow, Jaipur, Amritsar**
➢ Similar fog warning system available upto 7-days for major cites

Fog Warning Dissemination:
✓ All fog information (fog as observed and all forecast/warnings of fog) are uploaded in IMD WEB page at IMD main website as well as each MC website
✓ In OLBS for Airports and SMS
✓ Live RVR
→ NDMA, Airlines, Airport operators, ATC and other aviation users, Railway and Highway authority Disaster authorities, States & districts, Indian Railway, Road transport etc. by email.
→ Social Media: Facebook (www.facebook.com/India.Meteorological.Department) & Twitter handles of IMD (@Indiametdept) and NDMA and WhatsApp Groups
→ Through Electronic and Print media warnings are disseminated.
→ Through national IMD website (https://mausam.imd.gov.in) and different regional IMD offices websites.
→ Multi-media messages every Thursday (www.youtube.com/channel/UC_gxTReoq07UVARm87CuyQw).

Skill of fog warning at IGI airport improved by 30-40% during 2008-2019

Impact based Fog Forecast
Operational since winter of 2020-21 at district and state levels(below is only impact of highest severity given as red)

Fog Information and Warning Services
India Meteorological Department
Ministry of Earth Sciences
Government of India

Mission

-To monitor and timely report visibility based fog conditions at each surface observatories and airport locations using visibility land marks, RVR instruments, satellite data
-To provide Airport based Visibility and fog conditions at half an hour gap and its timely early warnings to Aviators for safe flight operations and optimize its disruption.
- To report, area wise/route wise, station based visibility and fog conditions and also to prepare and issue spatial level fog forecast covering district, city and met sub-division wise by MC, RWFC and NWFC respectively using synoptic, satellite and objective based fog forecast system upto 5 days in advance, for use by general public, Highway transport, Railway and other users
- Preparation of intensity and duration based Fog Climatology and its vulnerability.
- Research studies and development of tools to improve the Fog monitoring, forecasting and dissemination Systems
-To conduct special observational fog campaign like WIFEX 2015-21 conducted at IGI Airport, in order to understand fog formation process and its micro-physics and improving dynamical fog forecasting system.

Classification of Fog into different Types based on General Visibility:

Fog Types	General Visibility Range (in meters)
Shallow	Visibility fall upto 500m
Moderate	Upto 200m
Dense	Upto 50m
Very dense	< 50 m
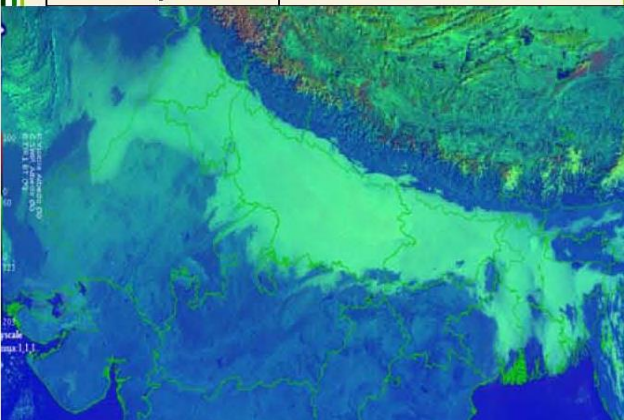
Fog blanket as detected by INSAT 3D at 0830 Hours of IST of 5 Jan 2018 and extensively covered large part of Indo-Gangetic plains(IGP)

Criteria for Airport Category based landing conditions :-

Visibility/Fog Types	Approx. General Visibility	Low Visibility and CAT-Types as per corresponding RVR ranges as per ICAO	Types of IGI service affected
Shallow to/Moderate Fog	1000m-200m	Low Visibility Procedures(850-1200)	Helicopters and small flights severely affected
		CAT-1(>=550m)	Bigger Flight which are not CAT Compliances severely affected
		CAT-II(>=275m)	
Dense fog (CAT-III)	<200m	CAT-IIIA(>=175m) CAT-IIIB->=75m/50m CAT-IIIC-<50m}	All flights which are CAT-IIIB Compliances can operate upto RVR >=75m/50m and Airport is closed when RVR<50m

## Climatological characteristics and Trends of fog

➤ Indo-Gangetic plains(IGP) of India is most vulnerable for fog occurrences. Fog also occurred over northern parts of central and eastern and northeastern parts of India

➤ Study of fog events across IGP region for 1997-2021 using satellite fog coverage data, airport current weather and synoptic station data show that major episodic dense fog spells lasting for weeks formed during peak winter months of Dec-Jan across vast areas of Indo-Gangteic plains. It is linked to large-scale wind and temperature patterns. Fog during Nov and Feb are of occasional occurrences. The former types are of large-scale in terms of aerial coverage, duration of the spell and are combination of Radiation and advection types while latter are of localized formation and are of meso-scale or synoptic scale, shorter duration and lasted for 1-2 mornings and called radiation fog which normally occurred after passage of WDs and rain events following with clam winds and clear skies.

➤ The former types are of large-scale in terms of aerial coverage, longer spells and are combination of Radiation and advection types while latter are of meso-scale or synoptic scale, shorter duration and lasted for 1-2 mornings are radiation fog types and mostly occurred after passage of WDs and rain events following with clam winds and clear skies.

➤ Normally, around 30-40(18-22 days) of General fog<1000m (Dense Fog<200m) for 8-10-hours(6-7hours) in Dec-Jan. Delhi being more polluted, it records more of fog days compared to others(refer Table). Season to season, it shows very high variability with extreme fog of 25-35 days/200-285 hours of dense (2017-18)while some has hardly any dense fog events(, 2007-08).

➤ IGP fog is the fastest in formation, largest in areas and longest in duration, if compared to any other fog areas of the world and, so also in terms of magnitude of its severe impact as it spreads over such world's mostly densely populated region.
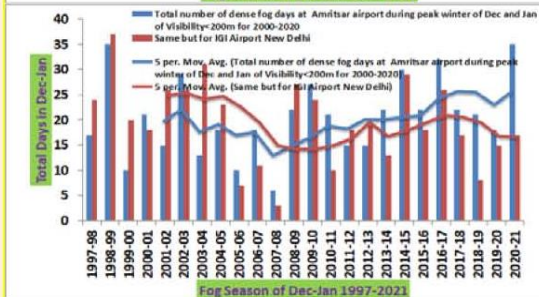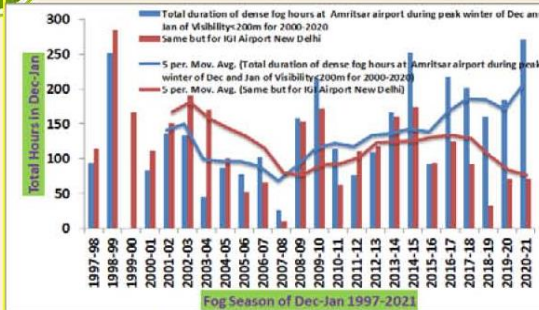
Season wise variation and trends of dense fog occurrences (Days and Duration) at Amritsar and IGI Airport Delhi 1997-2021
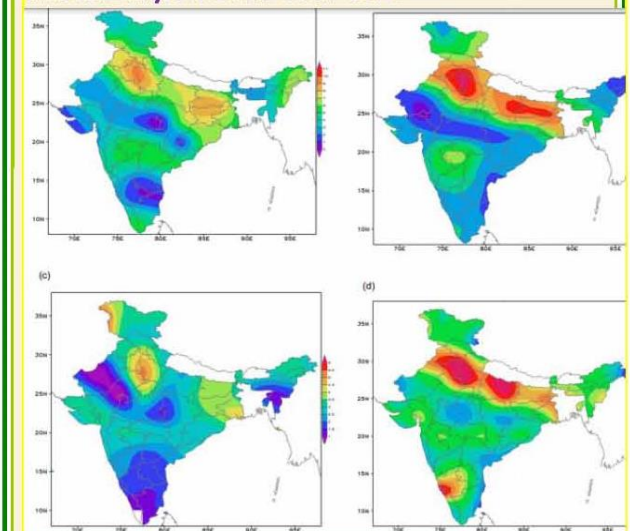
Average number of days with fog having visibility < 1000 m for the period 1971-2000 (a) December, (b) January, (c) February and (d) Season

## Airport Visibility based fog climatological information system:

Average Fog hours duration and days of various intensity of fog occurrences using hourly data 1991-2021(31-years) IGI Airport, New Delhi

Months/ Types of fog	Duration			
	<1000	<500	<200	<50
Nov	151.3	29.3	4.5	1
Dec	277.8	102.3	41.3	25.3
Jan	289.6	127.2	66.3	38.3
Feb	104.9	36.2	13.8	5.9
Total	823.6	295	125.9	70.5
	Days			
Nov	17	4.8	1	0.5
Dec	26	15	7	5.2
Jan	26.1	17.9	11.4	8.2
Feb	18.5	9.5	4.0	2.1
Total	87.6	47.2	23.4	16

Impact of Fog

➤Dense fog severely Impact Aviation, Railway and Highway transports, River/Costal ferry services, It also affect the agriculture e.g. crop at growth stage, Flowering stage and at seed formation stage, It causes fatal Road accidents and data shows in an extreme fog season like of 2016-18, Around 120(159) Lives lost Dec-Jan 2016-17(2017-18).
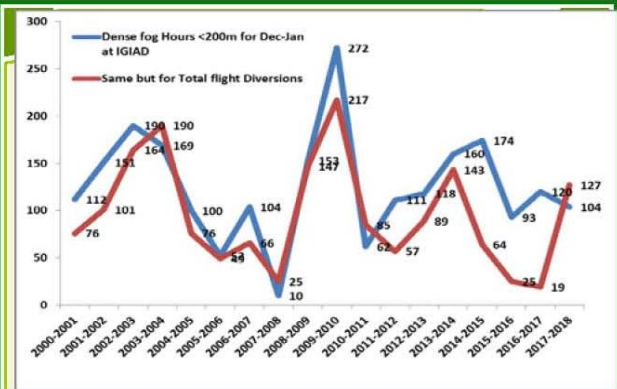
Total hours of Dense fog reported and flight diverted at IGI Airport Delhi for months of Dec-Jan for the period of 2000-2018
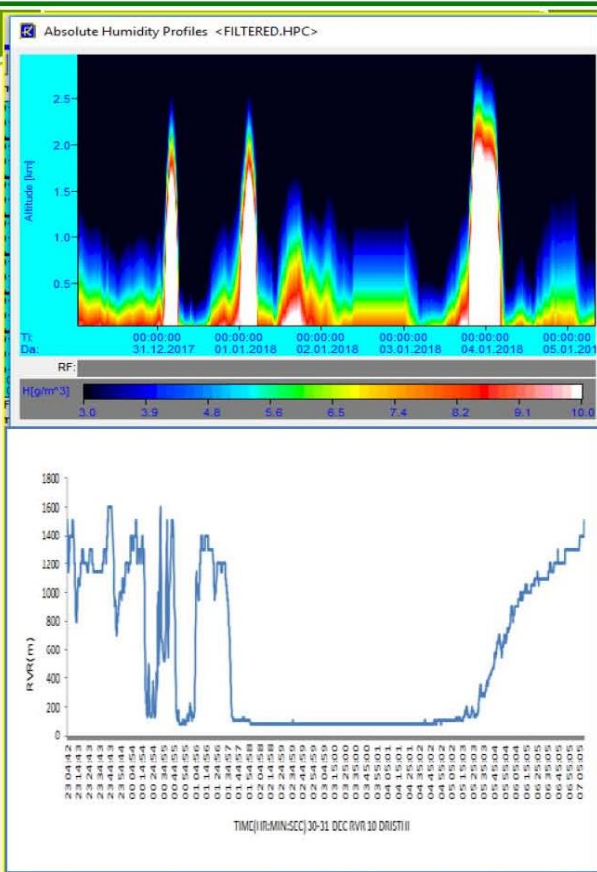
Monitoring of Fog

Location based fog information

-Airport fog conditions based upon Visibility report and RVR at RWY. Available at around 120 airports at 10 second to 1-h update
-Depth of the fog layer by Radiometer
- Station's based Synoptic observations at each 3-h gap from around 250 stations

Aerial based Fog information

-RGB Day-night fog mapping by INSAT 3D at 15-30 minute gap(refer Fog map in Page 3)
- Surface visibility based fog maps at each 3- h gap

Live RVR IGI Airport from 10 different locations of its three RWYs

Fog layer as detected by Radiometer(top) and RVR based fog variation at each 10 second (middle) and surface Visibility map at each 3-h updated(below)