PROJECT REPORT

(BSCC3151)

On

Monitoring of fog in Indo-Gangetic plain with INSAT-3DR data

& Channel differencing method performance for Night time Fog

Submitted in Partial Fulfilment of the Requirement for the degree of
B.Sc. (Hons) Chemistry

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May 2022

GALGOTIAS UNIVERSITY

(Established under Galgotias University Uttar Pradesh Act No. 14 of 2011)

School of Basic and Applied Science

CERTIFICATE

This is to Certify that **Ms. Kalash Sharma** has carried out his/her project work entitled "***Monitoring of fog in Indo-Gangetic plain with INSAT-3DR data & Channel differencing method performance for Night time Fog***" under my supervision. This work is fit for submission for the award of Bachelor Degree (Hons) in Chemistry.

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This is to certify that Ms. Kalash Sharma has carried out her major project work entitled "Monitoring of fog in Indo-Gangetic plain with INSAT-3DR data & Channel differencing method performance for Night time Fog" under my supervision from 13th January to 31st May-2022. This work is fit for submission for the award of Bachelor's Degree in Chemistry.

I wish her all the best for her upcoming career.

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Candidate Declaration

I hereby declare that the dissertation entitled "Monitoring of fog in Indo-Gangetic plain with INSAT-3DR data & Channel differencing method performance for Night time Fog" submitted by me in partial fulfilment for the degree of B.Sc. (Hons) Chemistry to the Division of Chemistry, Department of Basic Sciences, School of Basic and Applied Science, Galgotias University, Greater Noida, Uttar Pradesh, India is my original work. It has not been submitted in part or full to this University of any other Universities for the award of diploma or degree.

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Kalash Sharma

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Notations

INSAT-3D: Indian National Satellite

INSAT-3DR: Indian National Satellite 3D

BTD: Brightness Temperature Difference

METAR: Meteorological Terminal Aviation Routine Weather Report

IMD: Indian Meteorological Department

VIS: Visible

SWIR: Short Wave Infrared

MIR: Middle Infra-Red

TIR: Thermal Infra-Red

NCUM: National Centre for Medium Range Weather Forecasting Unified Model

GOES: Geostationary Operational Environmental Satellite

SATMET: Satellite Meteorological

UTC: Universal Time Coordinated

PBL: Planetary Boundary Layer

Abstract

Fog during winter season over Indo-Gangetic plains is very common and sometimes it creates hazardous situation and disrupts the life. Fog intensity and its spread forecast is challenging task. Most of the techniques available are mainly based on the remote sensing observation which is available on continuous bases and fills data gaps. To forecast precisely we need to validate the fog intensity or spatial extent during day and night. This work is mainly focuses on the night time fog monitoring with the help of satellite derived fog products. This product during night time is obtained through channel differencing (MIR-TIR1) of INSAT-3D /3R channels. Normal threshold was -2.5 degree C or K for fog pixels, but this work shows that this threshold does not hold good for entire IGP or Indian region, in the case of radiation fog. The different cases of the season 2020-21 (December-January) have been analyzed with different thresholds and found that other threshold ranges also significant for fog occurrences over the area.

Key words: INSAT-3D, INSAT-3DR, Remote Sensing, remote sensing techniques, Indo-Gangetic Region.

1.0

INTRODUCTION

1.0 Introduction

Fog is the most common weather hazard during winter period (December-January) over the Indo-Gangetic plain due to favorable meteorological conditions. It causes a number of health hazards and also leads to economic losses. It affects the transportation and it has been reported that every year almost over 38,700 vehicle crashes occur in during fog period [1]. Fog formation occurs when water vapours present in the air forms water droplets. These water droplets get suspended in the air, hence decreasing the visibility. When the air near the surface becomes saturated, either by cooling it to its dew point temperature or by adding moisture to it, Fog occurs. Depending on how the condensation was created, fog can form in a variety of ways. The Indo-Gangetic (IG) plains are predominantly affected by radiation fog and advection fog due to varying local conditions.

Due to increase in air pollution in Indo-Gangetic region, occurrence of Fog has become very frequent. It has been reported that Maximum occurrence of fog over northwest India is about 48 days every year with atmospheric visibility less than 1000 m, during the months of December to February and over the Indo-Gangetic Plain regions, the frequency of fog occurrence has increased during winter months in the last four decades [2]. Aerosols are important for fog, as they act as the substrate on which water condenses and fog droplets form. The droplet growth rate is dependent on the initial aerosol size and their solubility. The presence and nature of cloud condensation nuclei (CCN) in the atmosphere also help to sustain the fog activity. The fog occurrence is also depending on may other factors such as wind spped, humidity, radiation cooling, presence of upper-level weather system, sinking of dry air and moisture convergence mostly over Indo Gangetic Plains (IGP). To detect and monitor Fog and its dissipation needs further information about (PBL) and its flux mixing rate accurately. On the other hand, it is also important to study the relationship between fog and Aerosol's concentrations [3][4][5]. A two-way relationship was found between aerosol concentration and fog occurrence based on the nature of the aerosols (hygroscopic /hydrophobic) [4].

There are many implications to the society during the time of persistent fog occurrence. Persistent Fog can cause accidents due to low visibility and the economic loss, especially in aviation flight diversion and delay. It also affects the maximum temperature during winter period and gets slowed down and can cause harmful effect in our health both in mentally as well as psychologically. It has been observed from the study in the past that over Delhi maximum temperature falls during Foggy day's 5 to 6 degree °C below normal [6]. For the formation of Fog, it has been observed that generally the air temperature should be between 3–13°C, relative humidity >87%, wind speed <2 m/s and elevation <300 m. [7].

Fog prediction is really a challenging task because its occurrence is affected by the interaction starting from PBL to upper troposphere (mid latitude) weather systems. Fog can be spatially monitored with the help of Geostationary images and data which is available in every 15 minutes (staggering mode) in India. We know that fog can be detected or monitored using visible (based on the reflectivity difference) and combined image of infrared and visible, short-wave Infrared (SWIR) and Infrared channels during day time but there are limitations during the night we do not have visible channels. Hence, fog detection and monitoring during night is a challenging and especially the time period between dawn and dusk. Therefore, brightness temperature difference, Mid Wave Infrared and Infratred-1 (MIR-TIR-1) is used to detect night time fog. It is important to measure an accurate threshold radiance to improve forecasting of fog and also to study its dissipation rate. The dissipation rate depends on the changes in the meteorological parameters (temperature, humidity, sun-shine and winds) which modifies the boundary layer characteristics. When the difference between the brightness temperature of smaller wavelength and larger wavelength is >0 °C, it indicates presence of fog whereas BTD< 0 indicates high clouds.[8] IMD used 2.5 °K as threshold value but in recent studies (TIR-1-MIR) it is found that for many cases 1.5 °K is more accurate (opposite in the case of MIR-TIR-1 Brightness temperature differences). Therefore, in this study, we will compare the different brightness temperature thresholds values and compare with the visibility data for New Delhi, Amritsar, Varanasi and Lucknow stations in order to get an accurate threshold value over different regions in India.

2.0

LITERRATURE REVIEW

2.0 Literature review

During winter months fog becomes a major threat for transportation. For minimizing the consequences of fog, it's critical to improve fog detection and anticipate dissipation rates. Over a period of time many numerical models, remote sensing techniques and artificial intelligence has been designed and advanced to predict fog accurately.

2.1 Numerical Prediction Models

For many years, numerical prediction models have been employed to forecast meteorological conditions. A global numerical weather prediction (NWP) model was formed to analyse and forecast the conditions that are favourable for radiative fog formation over northern plains i.e., Indo-Gangetic (IG) plains of India. NCUM is capable in indicating the spatial extent of the occurrence of fog three days in advance over most part of Indo-Gangetic plain. [9].

2.2 Remote Sensing techniques

In the recent past, Remote Sensing techniques using Satellites has been used widely to detect fog. The water droplets clouds show low emissivity in the SWIR wavelengths but they show higher emissivity in the LWIR wavelengths [10]. The Brightness Temperature Difference between these two Wavelengths helps in detecting Fog by differentiating them from the clouds. Using this difference various techniques and methods are formulated to detect Fog. Gary P. Ellrod proposed using GOES multispectral infrared (IR) data to identify fog and low clouds at night in 1995. Fog is recognised with this technique by subtracting and enhancing brightness temperature data from IR window channels with wavelengths of 3.9 and 10.7μ–11.2 μ. This technique is useful to detect low clouds and fog but it fails in detecting shallow layers of fog because of the poor resolution of the GOES (13.8) [11]. In 1998, A. I. Anthis, used data from AVHRR and METEOSAT to detect fog and forecast the fog dissipation over Thessalia lowland area, located in the mainland of Central Greece. Three infrared AVHRR channels were employed in this study to identify fog at night. To detect fog or low stratus from land and sea, the difference between channels 4 and 3 was used. For detection of fog at night time, A threshold value of 2.5 K was calculated and used [12]. The shortest SWIR channel offered the best night time low cloud detection, according to an analysis of MODIS bi-spectral pictures utilising three distinct SWIR bands. [13]. In 2010, Chauarasia et. al, formulated an algorithm to detect night time fog using MODIS satellite data to study fog episodes over the North Indian plains (2009-2010). The bi-spectral thresholding technique was utilised in the algorithm, which utilizes the brightness temperature difference (BTD) between two spectral channels (3.9 and 10.75 m). They used a constant BTD threshold of 5.0–7.5 K between the 3.9 μm and 10.75 μm channels which successfully detected the night time fog for the 2009 and 2010 winter seasons over the Indo-Gangetic plain. This threshold technique was later used to monitor fog episodes using data from the geostationary satellite INSAT-3D [14]. Using a fixed threshold leads to false detection. Hence to overcome this problem an objective method for detecting night time fog based on bi-spectral difference of 3.9µm and 11µm channel brightness temperature has been developed. The thresholds used in this are dynamically derived, based on the data and have been tested with MODIS AQUA/TERRA data for December 2012-January 2013 and December 2013-January 2014 winter season over northern India.[15] In 2014, Rizwan Ahmed et.al, used bi-spectral brightness temperature difference (BTD) technique for detecting night time fog over Indo-Gangetic plain region during the fog episodes of 2010–2011. They examined the reliability of the threshold value (2.5 K) in their study by comparing satellite data to ground-based measurements from four stations. (Amritsar, New Delhi, Lucknow and Varanasi). For total 393 cases, while using 2.5 K threshold, accuracy for detection of fog was 83.9%. When the BTD threshold is reduced to 1.5 k, the accuracy rises to 88.3 percent. They also studied the effect of aerosols concentration on fog droplet number concentration and visibility degradation. In the Indo-Gangetic Basin, it was discovered that a minimum fog droplet number concentration of 3.23 cm^3 was necessary to reduce visibility below 1 km in the presence of aerosols at 95 percent relative humidity. This result implies that fog can be formed even when fog droplet no. concentration is low because of the presence of aerosols. This study points out the importance of further study of aerosols which will be helpful in improving forecasting of fog formation and dissipation. [16]. Fog and low clouds detection was done using both ceilometer and INSAT3D over New Delhi Station. It was observed that ceilometer is more effective than INSAT3D for detection during multi-layer clouds but for the spatial coverage of fog, Satellite is more effective [17]. Fog Stability Index was formulated to detect day time. It is based on the meteorological information available from the vertical temperature, humidity profiles and the wind speed information, [18]. Chaurasia et.al calculated FSI to detect fog over IG plains [19]. Choudhury, S et al. 5(2007) used NOAA-AVHRR data to map and analyze fog for the Indo-Gangetic plain for three years (2002–2005). They presented a model for the forecast of future fog using meteorological data [20]. SBDART (Santa Barbara DISORT Radiative Transfer) model was used for this study to simulate brightness temperatures (BT). A BTD threshold of >5 K accurately detected night time fog over IGP. [21]. An MSG-SEVIRI SatFog algorithm has been formulated and used to detect daytime fog. It is found to be helpful in providing the indication of the presence of fog in near real time and at the high spatial resolution of the HRV channel [22]. By using GOES-12 observations and screen temperature data, a warm fog detection (air temperature > −5°C) algorithm was formulated and it was observed that it has an average relative forecasting accuracy of 59% [23]. By taking photos from a moving vehicle, a fog detection technology is being developed to aid in the reduction of road accidents. The purpose is to offer the essential information to the driver about the density of the fog and the maximum visibility distance on the particular road segment [24]. To detect night time fog BTD of two channels is useful but in case of day time Fog this method cannot be used. To detect day time Fog benndix et.al. used images of Goes satellite to Form new strategies [25].

2.3 Artificial Intelligence

Artificial Intelligence has been used for past years for the prediction and detection of fog. As a result of the advancement of computational abilities, CNN (Convolution Neural Network), RNN (Recurrent Neural Network), and ANN (Artifical Neural Network) [26] [27] [28] are emerging as promising tools for Fog detection. A neural-network approach for the short-range visibility forecast was firstly implemented in 1995 [26]. A similar study was done where ANN's applicability to predict Fog was tested over the Canberra International Airport (YSCB) (2007) [27]. A similar approach was also implemented to nowcast the spatial visibility during fog over the airport of Kolkata ANN model [28].

Objective

- Analyse the visibility data taken from METAR for the cases with visibility less than 800m.
- To calculate brightness temperature difference of TIR1 and MIR for using satellite data.
- Analyse the data by comparing the values for multiple ranges of BTD.
- Examining and comparing the accuracy of different threshold values with respect to visibility data for these stations; New Delhi, Amritsar, Varanasi and Lucknow.

3.0
DATA AND METHODOLOGY

3.0 Data and Methodology

We have taken INSAT-3DR data from India Meteorological Department (IMD) to analyses fog events. The brightness temperature data set was generated and then a difference between MIR and TIR-1 channels has been carried out to detect the fog during night time. During day time other satellite images or data like visible data time RGB etc. has been used to monitor the areal extent of fog. INSAT-3DR Imager has six channels Imager and provides data in different resolutions both during day and night. The spectral channels of INSAT-3DR Imager are in Short Wave Infrared (SWIR), Mid Infrared (MIR), Thermal Infrared (TIR-1 & TIR–2), Water vapour (WV) and Visible regions of electromagnetic spectrum. Brightness Temperature Difference (BTD) has been carried out New Delhi, Amritsar, Varanasi and Lucknow stations from the Imager data. For BTD values, two thermal infrared channels TIR and MIR (with 11.0 and 3.9 µm) are used.

The other data set of visibility data has been extracted from Meteorological Reports (METARS), during winter time, December and January (2020-2021) for four stations (New Delhi, Amritsar, Varanasi and Lucknow).

In this study, we have taken visibility data of four stations during December 2020 and January 2021 and filtered it with the requirement of visibility to be less than 800m. The BTD values were calculated for this data. The data is then grouped by different threshold ranges for BTD viz. 0 to -2.5, 0 to -1.5, 0 to 2.5 and < -2.5.

Table 1. The specifications of INSAT-3DR 19 channel sounder.

Detector	Ch. No.	λ_c(mm)	υ_c (cm-1)	NEΔT @300K	Principal absorbing gas	Purpose
Long wave	1	14.67	682	0.17	CO_2	Stratosphere temperature
	2	14.32	699	0.16	CO_2	Tropopause temperature
	3	14.04	712	0.15	CO_2	Upper-level temperature
	4	13.64	733	0.12	CO_2	Mid-level temperature
	5	13.32	751	0.12	CO_2	Low-level temperature
	6	12.62	793	0.07	Water vapour	Total perceptible water
	7	11.99	834	0.05	Water vapour	Surface temp., moisture
Mid wave	8	11.04	906	0.05	Window	Surface temperature
	9	9.72	1029	0.10	Ozone	Total ozone

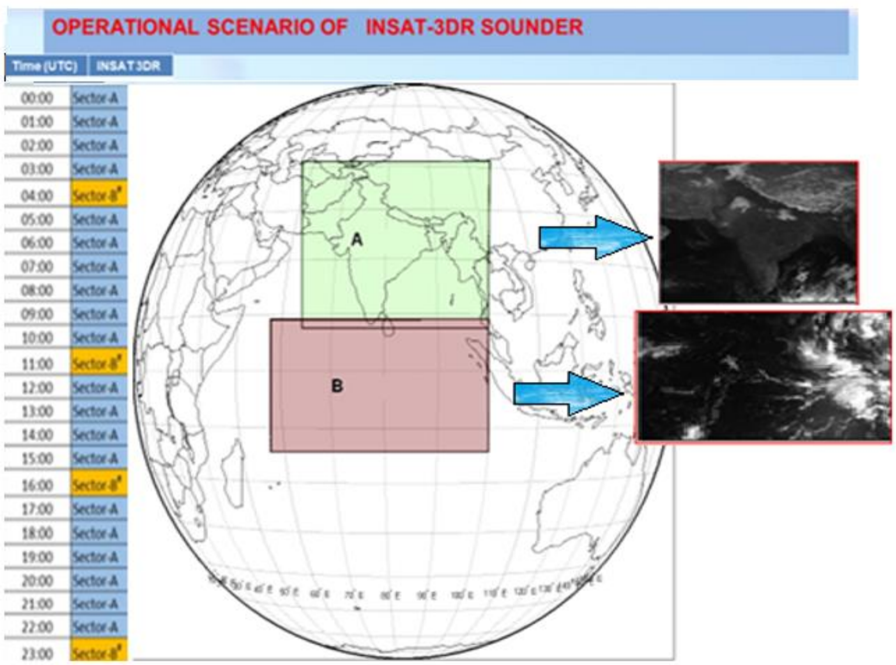
	10	7.44	1344	0.05	water vapour	Low-level moisture
	11	7.03	1422	0.05	Water vapour	Mid-level moisture
	12	6.53	1531	0.10	Water vapour	Upper-level moisture
Short wave	13	4.58	2184	0.05	N2O	Low-level temperature
	14	4.53	2209	0.05	N2O	Mid-level temperature
	15	4.46	2241	0.05	CO2	Upper-level temperature
	16	4.13	2420	0.05	CO2	Boundary-level temp.
	17	3.98	2510	0.05	Window	Surface temperature
	18	3.76	2658	0.05	Window	Surface temp., moisture
Visible	19	0.695	14367	-	Visible	Cloud

Source:https://www.isro.gov.in/insat-3d/geo-physical-parameters-gpr-derived-insat-3d-imager-and-sounder

Table 2. Channel Wavelength

Spectral Band	Wave length (μm)	Ground Resolution
VIS	0.55 – 0.75	1km
SWIR	1.55 – 1.70	1 km
MIR	3.80 – 4.00	1 km
WV	6.50 – 7.10	8 km
TIR-1	10.3 – 11.3	4 km
TIR-2	11.5 – 12.5	4 km

Source:https://www.isro.gov.in/insat-3d/geo-physical-parameters-gpr-derived-insat-3d-imager-and-sounder



Scheme 1: Scanning Strategy. Source:https://www.isro.gov.in/insat-3d/geo-physical-parameters-gpr-derived-insat-3d-imager-and-sounder

4.0

RESULT AND DISCUSSION

4.0 Result and Discussion

Fog can be a hazard during winter time every year and need an accurate prediction both spatial and temporal domain. It is monitored day & night with the help of INSAT 3D /3DR Imager data and derived products. During day time satellite images in the visible region, day time microphysics, RGB images and blended imaged are utilized operationally by the forecasters and end users. They will be found very useful to monitor the spatial extent of the fog. Although its generation and persistency also depend on the frequency and occurrences of mid latitude weather systems approached during winter season frequently from west called western disturbances (WD) & ahead of the WD generally fog occurs.

The visibility data of Delhi, Amritsar, Lucknow and Varanasi extracted from METAR data from each airport has been analyzed and extracted the cases whenever the visibility was less than 1.0 km (as per the definition standard of ICAO). These low visibility phenomena in which the visibility is less than 1.0 km were comes under the category of fog. These events were further categorized into moderate, intense, very intense depending on the further deterioration of visibility (Table 3) [29]. The visibility data of fog cases is shown in figures (1,2,3,4,5,6,7,8). Based on the visibility the number of cases reported in the month of December in case of Delhi is more as compared to January-2021.

Table 3. Types of fog associated with general visibility range.

Fog types	General visibility range (m)
Shallow fog	1000–500
Moderate fog	500–300
	350–200
Dense fog	200–50
Very dense fog	<50

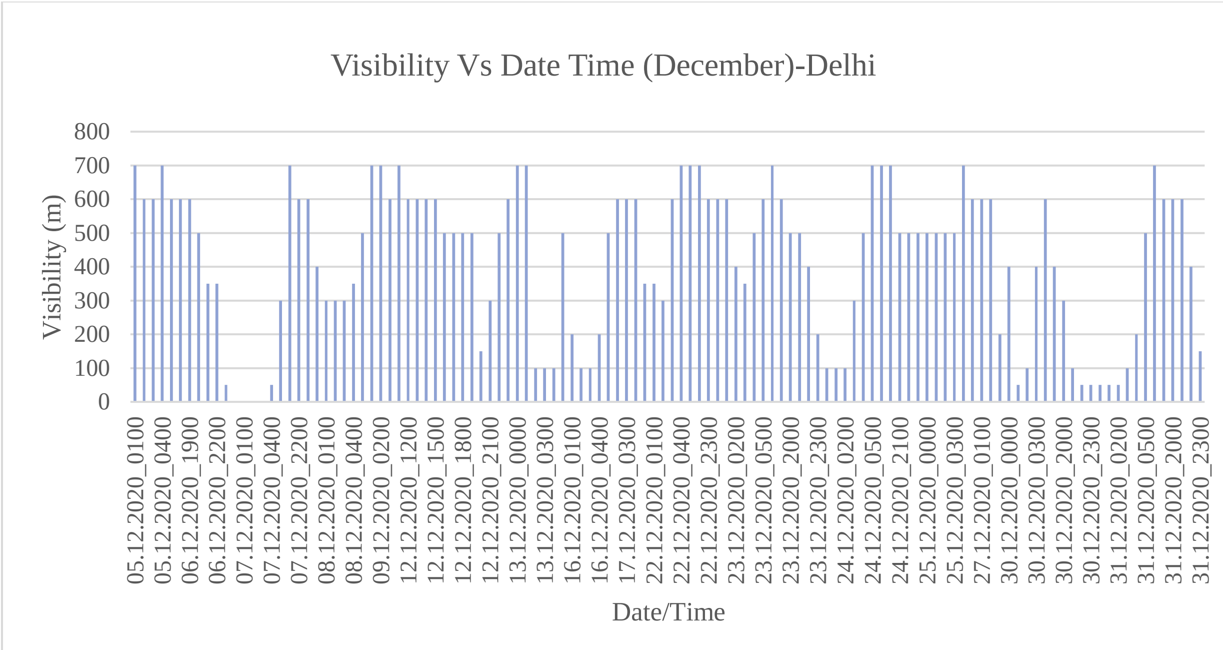


Fig.1 Visibility Vs Date Time (December)-Delhi

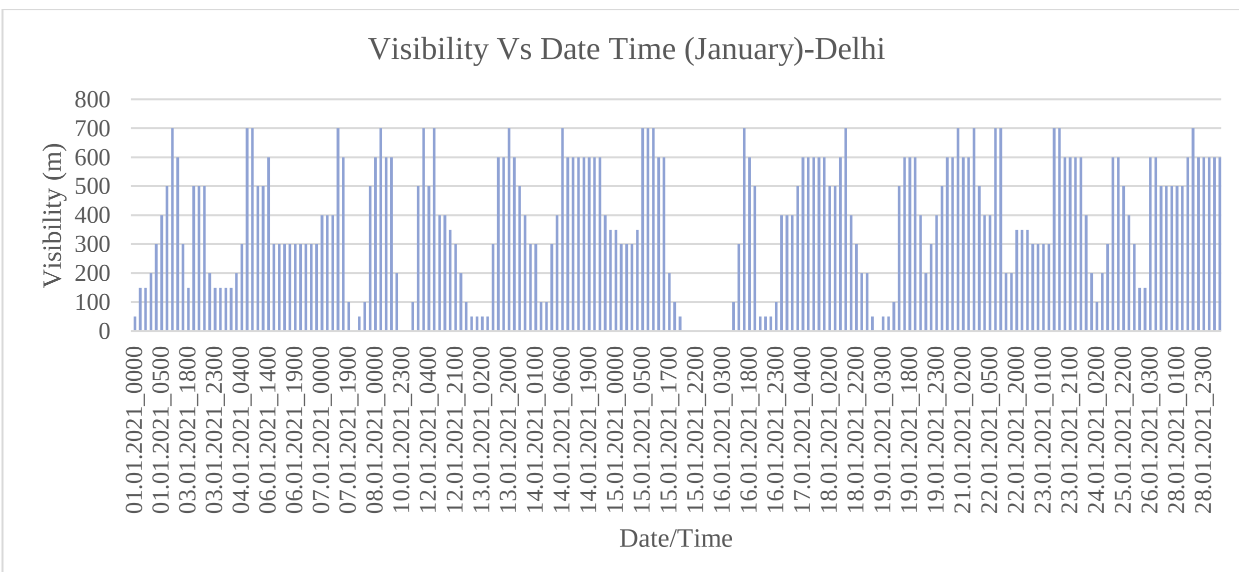


Fig. 2 Visibility Vs Date Time (January)-Delhi

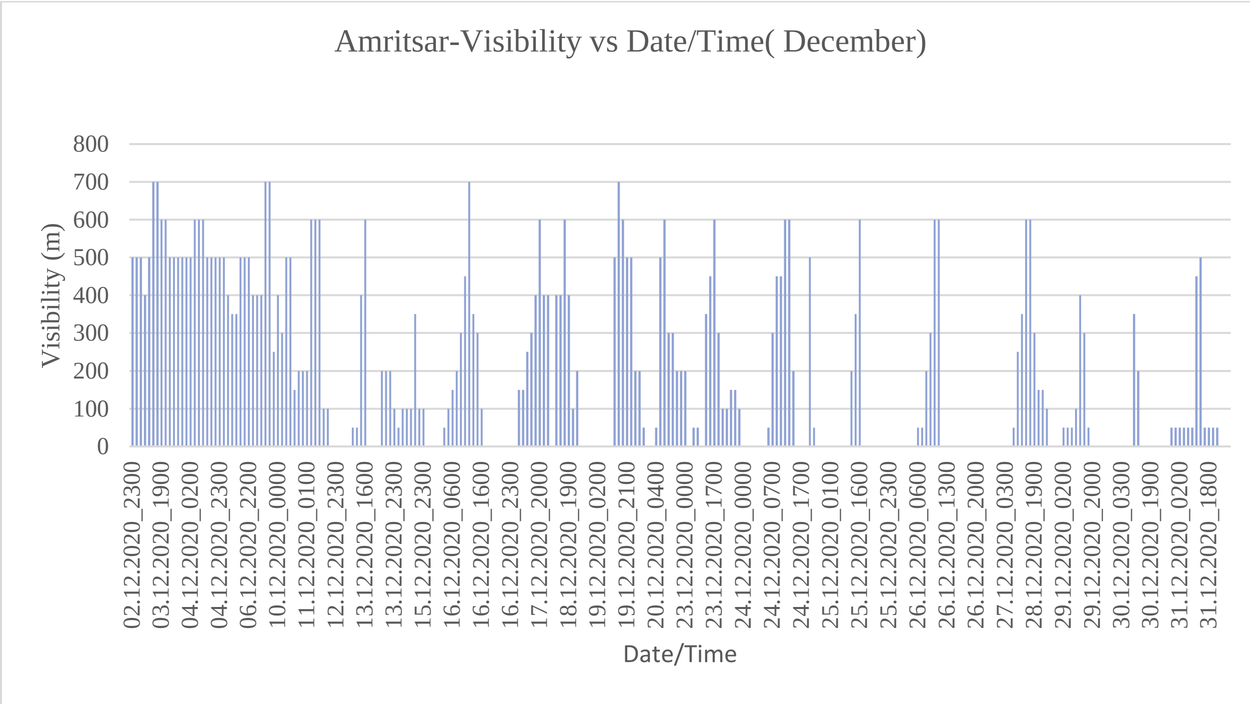


Fig. 3 Amritsar-Visibility vs Date/Time (December)

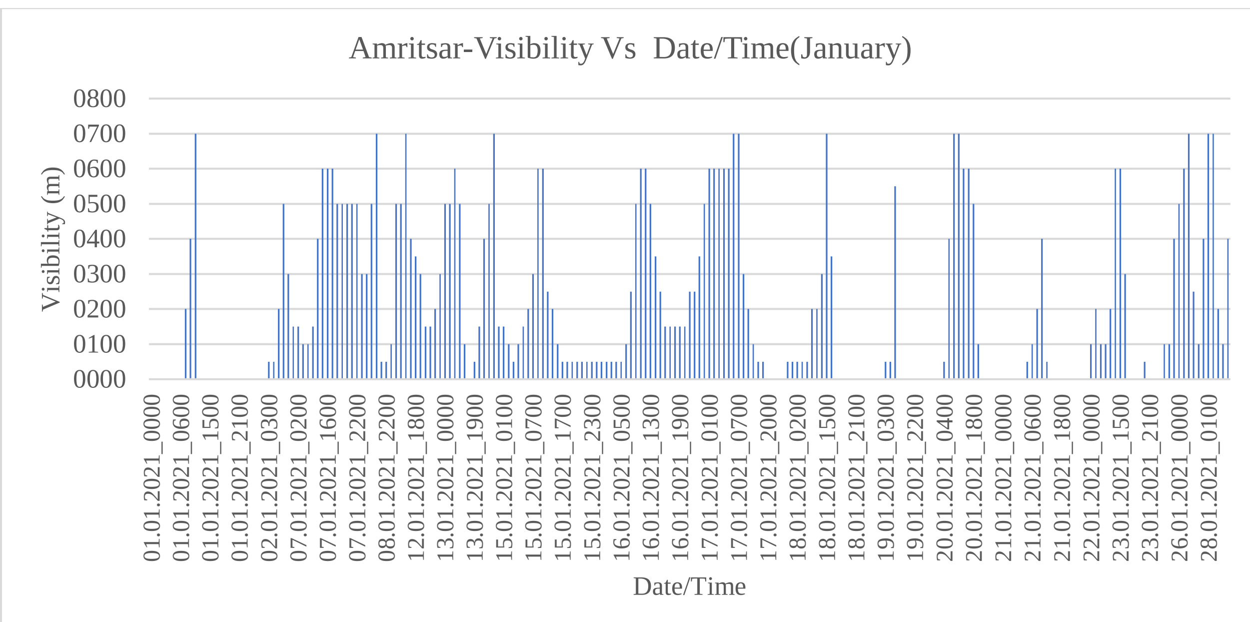


Fig. 4. Amritsar-Visibility Vs Date/Time (January)

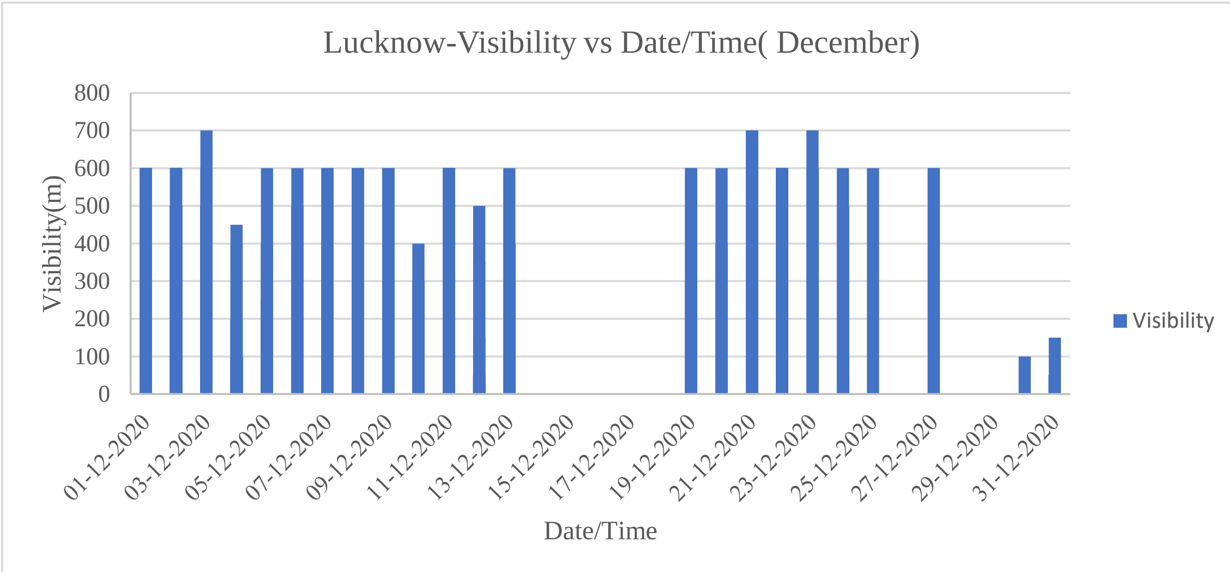


Fig. 5 Lucknow-Visibility vs Date/Time (December)

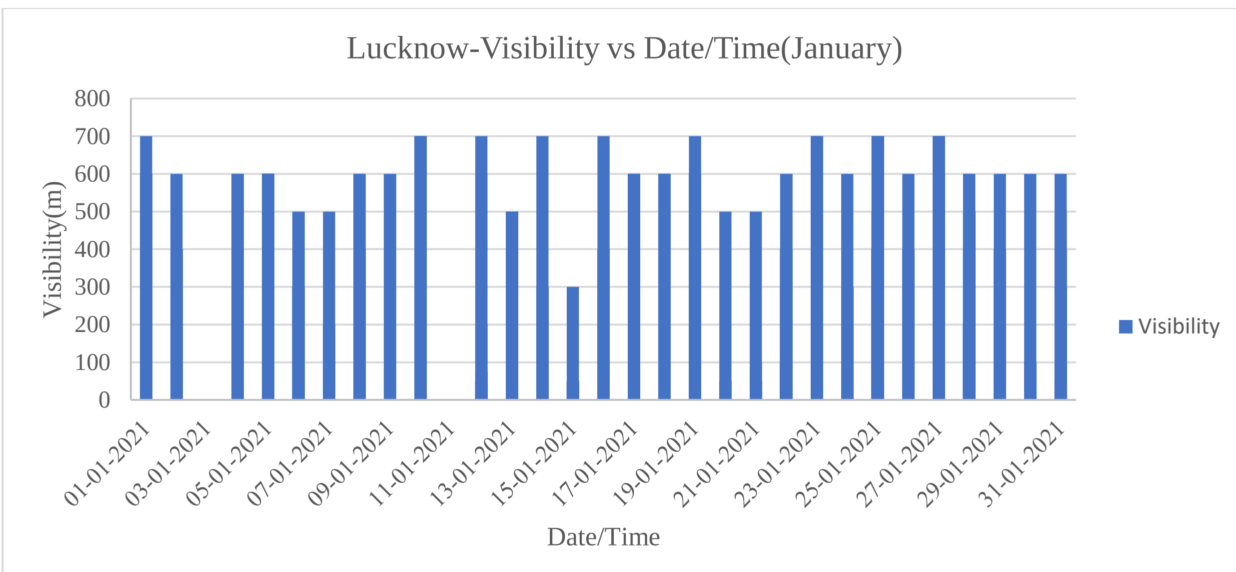


Fig.6 Lucknow-Visibility vs Date/Time (January)

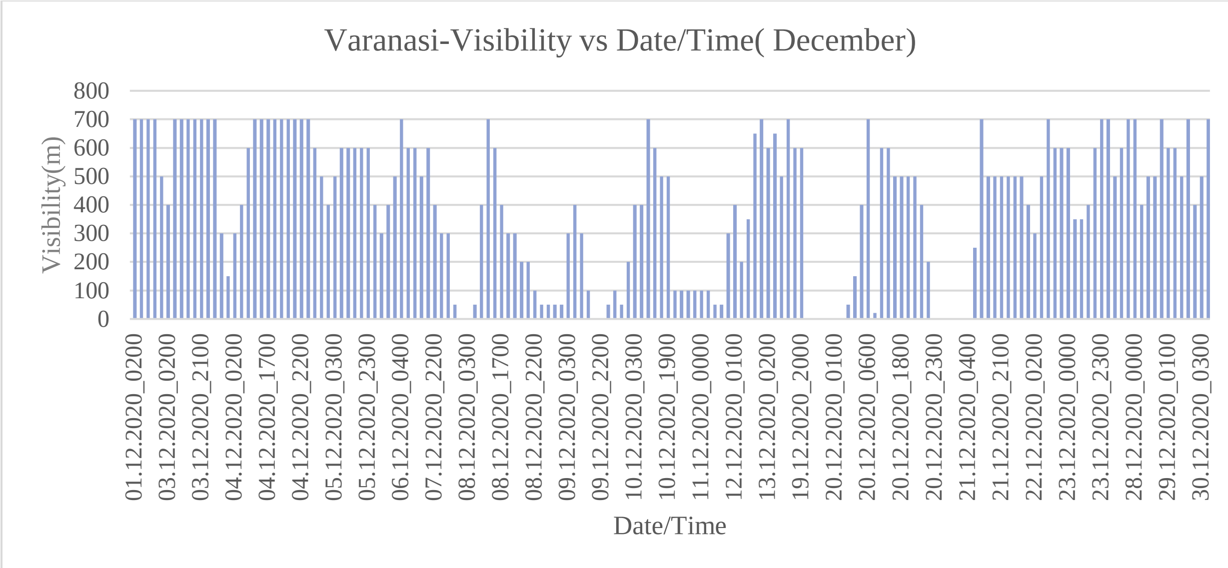


Fig.7 Varanasi-Visibility vs Date/Time (December)

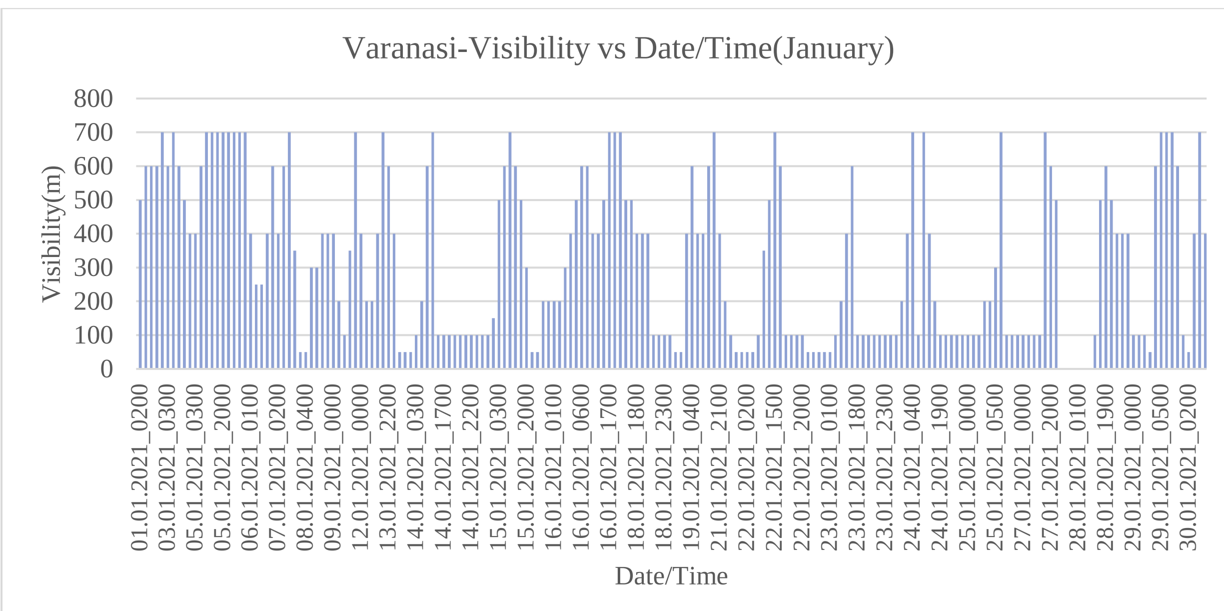


Fig.8 Varanasi-Visibility vs Date/Time (January)

During night visible image is not present so we cannot monitor through visible imagery. Therefore, we have RGB image, night time microphysics and channel differencing products. In this work we have extracted the brightness temperature of Mid Infrared (MIR) and Thermal Infrared -1 (TIR-1) from INSAT-3DR Imager data and then take the difference of brightness temperatures (BTD) to monitor the night time fog events. This brightness temperature difference (BTD) was analyzed with different thresholds of BTD differences. In comparisons with these BTD differences we have taken visibility data as a signature of fog (visibility < 1000 m). It is seen from that study that BTD threshold =2.5 cannot be used universally for all fog evets. Therefore, we have analyzed fog events with other thresholds. The results of other thresholds are given below in the table 4.

Table 4. Number of cases for various stations corresponding to BTD values

Stations		Total no of cases	No of cases BTD 0 to -2.5	No of cases, BTD lesser than -2.5	No of cases BTD 0 to 2.5	No of cases BTD 0 to -1.5
Delhi	Cases In DEC	118	32	30	40	23
	Cases in JAN	204	23		42	20
Amritsar	Cases In DEC	265	26	82	69	22
	Cases in JAN	221	14	62	48	9
Lucknow	Cases In DEC	169	28	43	66	22
	Cases In Jan	238	28	44	68	20
Varanasi	Cases In Dec	162	37	43	49	26
	Cases In Jan	194	24	65	26	12

Similar results were found with channel differencing method satellite data during night time. However, the threshold was not same for all stations and fog observed even after the threshold range (0 to -2.5). The number of cases outside the difference of -2.5-degree K also presented in table (4). Therefore, in this study BTD threshold was classified in different categories to the decide the thresholds at different locations over IGP plain area. It is seen that Delhi no of cases reported in the month of December are 32 with BTD range 0 to -2.5k and in the month of January maximum cases reported are 23 in BTD range 0 to -2.5k.

In Amritsar, no of cases reported in the month of December are 26 with BTD range 0 to -2.5k and in the month of January maximum cases reported are 14 in BTD range 0 to -2.5k.

In Lucknow it is seen that no of cases reported in the month of December are 28 with BTD range 0 to -2.5k and in the month of January maximum cases reported are 28 in BTD range 0 to -2.5k

In Varanasi, no of cases reported in the month of December are 37 with BTD range 0 to -2.5k and in the month of January maximum cases reported are 24 in BTD range 0 to -2.5k

Therefore, thresholds need to revisited with a greater number of data sets at different locations to monitor the night time fog more precisely. After getting the thresholds with more data sets and feedback from the end users, operationally we can generate areas of low, moderate, intense and very intense fog activity. It will help or support to the forecasters, end users, decision makers to formulate their next course of action in advance based on the persistency.

5.0

CONCLUSION

Conclusion

In this study, a technique based on satellite observation is used to detect Fog over IG Plains. For Four stations that are New Delhi, Amritsar, Varanasi and Lucknow cases with visibility less than 800m are studied. For these cases BTD was calculated by differencing of two channels (TIR1&MIR). Using brightness temperature difference (BTD), a threshold value is calculated. For different cases, comparison between BTD and visibility data is done to get an accurate Threshold value. Normal threshold was 2.5 degree C or K for fog pixels, but this work shows that this threshold does not hold good for entire IGP or Indian region, in the case of radiation fog. The different cases of the season 2020-21 (December-January) have been analyzed with different thresholds and found that other threshold ranges also significant for fog occurrences over the area.

References

1. Federal Highway Administration
2. Ghude, S. D., Bhat, G. S., Prabhakaran, T., Jenamani, R. K., Chate, D. M., Safai, P. D., ... & Rajeevan, M. (2017). Winter fog experiment over the Indo-Gangetic plains of India. *Current Science*, 767-784.
3. Gautam, R., Hsu, N. C., Kafatos, M., & Tsay, S. C. (2007). Influences of winter haze on fog/low cloud over the Indo-Gangetic plains. *Journal of Geophysical Research: Atmospheres*, *112*(D5).
4. Safai, P. D., Ghude, S., Pithani, P., Varpe, S., Kulkarni, R., Todekar, K., ... & Rajeevan, M. N. (2019). Two-way relationship between aerosols and fog: A case study at IGI airport, New Delhi. *Aerosol and Air Quality Research*, *19*(1), 71-79
5. Sarkar, S., Chokngamwong, R., Cervone, G., Singh, R. P., & Kafatos, M. (2006). Variability of aerosol optical depth and aerosol forcing over India. *Advances in Space Research*, *37*(12), 2153-2159.
6. Jenamani, R. K. (2007). Alarming rise in fog and pollution causing a fall in maximum temperature over Delhi. *Current Science*, 314-322.
7. Saraf, A. K., Bora, A. K., Das, J., Rawat, V., Sharma, K., & Jain, S. K. (2011). Winter fog over the Indo-Gangetic Plains: mapping and modelling using remote sensing and GIS. *Natural hazards*, *58*(1), 199-220.

8. Eyre JR, Brownscombe JL, Allam RJ. 1984. Detection of fog at night using Advanced Very High-Resolution Radiometer (AVHRR) imagery. Meteorol. Mag. 113: 266–271.
9. ADITI, A., GEORGE, J., Gupta, M. D., Rajagopal, E. N., & Basu, S. (2015). Verification of visibility forecasts from NWP model with satellite and surface observations. *Mausam*, *66*(3), 603-616.
10. Hunt, G. E. (1973). Radiative properties of terrestrial clouds at visible and infra-red thermal window wavelengths. *Quarterly Journal of the Royal Meteorological Society*, *99*(420), 346-369.
11. Ellrod, G. P. (1995). Advances in the detection and analysis of fog at night using GOES multispectral infrared imagery. *Weather and Forecasting*, *10*(3), 606-619.
12. Anthis, A. I., & Cracknell, A. P. (1999). Use of satellite images for fog detection (AVHRR) and forecast of fog dissipation (METEOSAT) over lowland Thessalia, Hellas. *International Journal of Remote Sensing*, *20*(6), 1107-1124.
13. Ellrod, G. P. (2006, January). Evaluation of Moderate-Resolution Imaging Spectroradiometer (MODIS) shortwave infrared bands for optimum nighttime fog detection. Preprints. In *14th Conference on Satellite Meteorology and Oceanography* (Vol. 29).

14. Chaurasia, S., Sathiyamoorthy, V., Paul Shukla, B., Simon, B., Joshi, P. C., & Pal, P. K. (2011). Night time fog detection using MODIS data over Northern India. *Meteorological Applications*, *18*(4), 483-494.

15. Chaurasia, S., & Gohil, B. S. (2016). An objective method for detecting night time fog using MODIS data over northern India. *J. Geomat*, *10*.

16. Ahmed, R., Dey, S., & Mohan, M. (2015). A study to improve night time fog detection in the Indo-Gangetic Basin using satellite data and to investigate the connection to aerosols. *Meteorological Applications*, *22*(4), 689-693.

17. Arun, S. H., Sharma, S. K., Chaurasia, S., Vaishnav, R., & Kumar, R. (2018). Fog/low clouds detection over the Delhi Earth Station using the Ceilometer and the INSAT-3D/3DR satellite data. *International Journal of Remote Sensing*, *39*(12), 4130-4144.

18. Song, Y., & Yum, S. S. (2013). Development and verification of the fog stability index for Incheon international airport based on the measured fog characteristics. *Atmosphere*, *23*(4), 443-452

19. Fog Stability Index: A novel technique for fog/low clouds detection using multi-satellites data over the Indo-Gangetic plains during winter season S. H. Arun, Sasmita Chaurasia, Arundhati Misra & Raj Kumar (3085)

20. Choudhury, S., Rajpal, H., Saraf, A. K., & Panda, S. (2007). Mapping and forecasting of North Indian winter fog: an application of spatial technologies. *International Journal of Remote Sensing*, *28*(16), 3649-3663.

21. Gaurav, S., & Jindal, P. (2018). Radiative transfer model simulations to determine the night time fog detection threshold. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, *42*, 511-517.

22. Nilo, S. T., Romano, F., Cermak, J., Cimini, D., Ricciardelli, E., Cersosimo, A., ... & Viggiano, M. (2018). Fog detection based on meteosat second generation-spinning enhanced visible and infrared imager high resolution visible channel. *Remote Sensing*, *10*(4), 541.

23. Gultepe, I., Pagowski, M., & Reid, J. (2007). A satellite-based fog detection scheme using screen air temperature. *Weather and forecasting*, *22*(3), 444-456.

24. Negru, M., & Nedevschi, S. (2013, September). Image based fog detection and visibility estimation for driving assistance systems. In *2013 IEEE 9th International Conference on Intelligent Computer Communication and Processing (ICCP)* (pp. 163-168). IEEE.

25. Bendix, J., Cermak, J., & Thies, B. (2004, October). New perspectives in remote sensing of fog and low stratus-TERRA/AQUA-MODIS and MSG. In *Third International Conference on Fog, Cape Town* (Vol. 11, No. 15.10).

26. Pasini, A., & Potestà, S. (1995). Short-range visibility forecast by means of neural-network modelling: a case-study. *Il Nuovo Cimento C, 18*(5), 505-516.

27. Fabbian, D., De Dear, R., & Lellyett, S. (2007). Application of artificial neural network forecasts to predict fog at Canberra International Airport. *Weather and forecasting*, *22*(2), 372-381.

28. Dutta, D., Chaudhuri, S. Nowcasting visibility during wintertime fog over the airport of a metropolis of India: decision tree algorithm and artificial neural network approach. *Nat Hazards* **75,** 1349–1368 (2015)

29. Singh, A., George, J. P., & Iyengar, G. R. (2018). Prediction of fog/visibility over India using NWP Model. *Journal of Earth System Science*, *127*(2), 1-13.

Publication

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