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FINAL REPORT OF IGI AIRPORT, NEW DELHI, INDIA

(AvRDP: Prediction of Fog and Thunderstorms, MET-ATM impact analysis and Future Plans)

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Summary

Indian civil aviation sector has witnessed rapid growth in the last 10 years and it is expected to emerge as third largest aviation sector in the world by 2025 after the USA and China. India's domestic air traffic nearly doubled to 117 million passengers in 2017. The number of civil airports in the country as per AAI 2017-18 annual report is presently 129 and the number is expected to increase to 190 by 2025.The Report discusses the major weather Hazards affecting the IGI, New Delhi airport and the initiatives taken by Ministry of Earth Sciences (MoES) under Aviation research demonstration project (AvRDP).

Introduction

Airport information:

Name of the airport - Indira Gandhi International Airport (IGIA), New Delhi, India

Air traffic service provider-Airport Authority of India (AAI), A public sector of Govt of India.

Airport Operator-Delhi International Airport Limited (A Private Public Partnership (PPP) of AAI and GMR and other private enterprises in consortium agreement operating since 2007) for Air Side Operation and Management, Terminal and other Ground management and services

Meteorological Service Provider- Meteorological Watch office (MWO), India Meteorological Department (IMD)

Regulator-Director General of Civil aviation (DGCA), Govt of India

Mandates and MET Facilities of Meteorological Weather Office (MWO), IMD IGIA New Delhi

Major mandates of MWO, IGI airport, Delhi are

i) To provide Live Met data/actual weather conditions at its three RWYs of IGIA and their nowcast/forecast of deterioration or improvement if any e.g. weather warnings, fog conditions etc. to nearly 1300 flights presently operating each day round the clock through IGI Airport

ii) To provide aerodrome forecast and local forecast of IGI Airport and Significant weather information (SIGMET) of the Delhi FIR region from time to time for their safety operation.

iii) To brief about prevailing weather parameters and their forecast at various national and international routes at various altitudes for their smooth flying

iv) To keep a 24X7 aviation weather watch in the Delhi FIR region for smooth flight operation.

v) To keep close watch of time to time weather conditions at Eighteen other airport meteorological offices/Airport Met Stations functional in Delhi FIR under IMD and coordinate with HQ to provide technical guidance and training to these Met offices

vi) To provide weather information for their en-route airports and destination airport whether it is a domestic flights operating to any airport in India or international flight operating to any airport over the globe

vii) To prepare technical documents on occurrences of high impact weather event in case it affects the airport e.g. dense Fog, Intense Rainfall, severe thunder squalls, etc. and carry out R & D for improvement of their forecast/nowcast

viii) To monitor performance of instruments (RVR), verification of aviation forecast products, warnings and fog forecast including performance of dissemination systems like Automatic Message Switching System (AMSS)

MWO, New Delhi at IGIA has all modern computer and infrastructural facilities e.g. DWR, satellite and NWP products receiving work stations, Decision support system (MFI)-analysis and forecasting work station and other various in-house products. All Runways have an aviation weather observing systems and instruments for RVR. There are 12 Automatic Weather Stations over the Delhi region within 50 km radius, to keep 24x7 hours watch on weather developments in and around IGI airport.

India Meteorological Department

India Meteorological Department (IMD), under the Ministry of Earth Sciences (MoES), Government of India, is the apex weather agency providing National Meteorological services at the airports. One of the main mandates of IMD is to provide aviation meteorological service for the civil aviation in 88 airports in India. IMD maintains a dense network of current weather and synoptic surface observation network, automatic weather stations (AWS), upper air observations through RadioSonde & RadioWind observatories, Doppler Weather Radar network (DWR), Satellite data products besides running numerical weather prediction (NWP) models at various locations to meet the current weather requirements as well as forecast services for these airports.

The service provisions are regulated by the DGCA, India through CAR Series ‘M’, ICAO Annex 3 and other relevant WMO/ICAO documents. IMD provides this service in association with Airports Authority of India and for these purposes it has established four MET Watch Offices (MWO) and more than 85 Aeronautical Meteorological Stations (AMS) and Aerodrome MET Offices (AMO) across the country. The service broadly comprises of following:

I. Observation and reporting of Airport and Runway specific meteorological parameters.

II. Area, Route Forecast and Warning for the airport and the controlled area.

III. Briefing, consultation and documentation to Pilots

IV. In flight services like SIGMET, VOLMET, ATIS broadcast.

V. Search and rescue services.

The services provided by IMD fits into three broad classifications based on the functional and operational requirements of international and domestic aviation services as laid by International Civil Aviation Organisation (ICAO). In India there are four flight information regions (FIR) viz., Delhi, Mumbai, Kolkata and Chennai which are served by 4 Meteorological Watch Offices (MWO). The forecasting and warning requirements are catered to by 18 Aerodrome Meteorological Offices (AMO) which includes the 4 collocated MWOs as well. These AMOs have current weather observations for their own and cater to forecasting and warning requirements of Aeronautical Meteorological Stations (AMS) attached to them. The AMS have current weather observations mostly for domestic aviation operations. However, in India, international flights are also taking place at many of the AMS. There are 70 AMS functioning in India.

Impacting Weather

Fog

The Indira Gandhi International (IGI) Airport of Delhi (one of the largest megacities of South Asia), is one of the busiest airports in the country in terms of both passengers and cargo traffic. Delhi IGI Airport was ranked as the 25th busiest airport in the world in 2015 where more than 900 flight operations occur per day (Fig.1). Fog, thunderstorms, squalls, dust storms and heavy rainfall are the worst aviation weather hazards for IGI Airport and other airports in the region.

Compared to other areas of the world, fog events observed over northern region of India form rapidly, are largest in coverage area and longest in duration. Combinations of these factors introduce formidable challenges for fog forecasting over the region. Dense fog affects aviation severely at IGI Airport and flight operations are often hindered due to delays, diversions, or cancellations, causing significant economic losses. Dense fog in the early morning or evening hours creates more loss to the airlines than if it occurs at midnight or in the late morning hours. Fog season in Delhi covers four months mainly from November to February. Most of the days in December and January are affected by moderate fog, reducing the visibility to less than 1000 m. On an average 8 days in December and 13 days in January are affected by dense fog, reducing the visibility to less than 200m.On an average December and January account for almost 70-80% of the occurrences. The transition months i.e. Nov and Feb both normally have only 1-3 days of dense fog mornings, with a shorter period life (Table 1).

Recent studies have shown that there has been an increase in the frequency and intensity of fog over the northern parts of the country during the winter season, and morning poor visibility days have increased significantly during the last five decades.

An increase in dense fog hours at an airport will affect more flight operations and can create more economic losses to the airlines due to the increased diversion, delay, and cancellation of flights. When fog occurs, (1) air traffic on the ground slows down due to a reduced taxiing speed and (2) runway occupancy time (ROT) increases. Air traffic controllers (ATCs) may have to increase the spacing between each aircraft landing and takeoff to ensure safe operations, which can reduce airport capacity by 40% compared to its normal capacity. Additionally, ATCs must protect landing system signals for an aircraft arrival at two nautical miles from touchdown. For this to occur, previous arrivals and departures must be cleared from these areas. Because of this, a scheduled flight may be held at its origin, diverted back to the other airport, or in the worst-case scenario it may be cancelled.

The Directorate General of Civil Aviation, Government of India (DGCA), the Indian Meteorology Department (IMD), and the Airports Authority of India (AAI) prepared strict guidelines for better preparedness for landing, technical management, and training for the pilots in 2014 for all flight landings at IGI Airport during periods of fog. A study, undertaken for the first time in India by Kulkarni et.al in 2019 has evaluated the impact of dense fog at IGI Airport on economic losses which occurred during the winter season between 2011 and 2016. A total of 653 hours of dense fog between 2011 and 2016 at IGI Airport caused economic losses of approximately 3.9 million USD (248 million Indian rupees) to the airlines. The analysis further found that from 2014–2015 onwards, there has been a reduction in the number of flight delays, diversions, and cancellations by approximately 88%, 55%, and 36%, respectively, due to the strict implementation of guidelines to facilitate the Category (CAT)-III landing for aircraft during dense fog.

The presence of heavy and extended period fog in the northern regions of India is one of the major weather hazards, impacting aviation, road transportation, economy and public life in the world's most densely populated region. Maximum fog occurrence over the Northwest India is about 48 days (visibility < 1000m) per year, and occurs mostly during the December-February time period. All India annual morning poor visibility days (PVD <4 km) has increased from 6.7 to 27.3 % days. Recent studies on fog in India during the past 10-15 years have prompted significant socio-economic concern due to increase in frequency, persistence and intensity of fog occurrence over the northern parts of the country. Land use changes and increasing pollution in the region are responsible for growing Fog occurrence. We need a reliable forecasting system for Fog occurrence. Improved understanding on the physical and chemical characteristics of fog, meteorological factors responsible for its genesis, sustenance, intensity and dissipation is required. Similarly, meteorological conditions like humidity, wind and synoptic conditions need to be studied for better fog forecasting. Improved understanding on above aspects is required to develop reliable forecasting models and observational techniques for accurate prediction of Fog events.

In an effort to gain insight into these questions, the Ministry of Earth Sciences (MoES), Government of India had taken up a multi-institutional initiative to conduct an intensive ground-based measurement campaign at the Indira Gandhi International Airport (IGIA), Delhi, to understand different physical and chemical features of Fog and factors responsible for its genesis, intensity and duration. Winter Fog Experiment (WIFEX) was conducted in a pilot mode at IGIA during 2016 and 2017 winter. The main scientific objective of this project was to study the characteristics and variability of fog events and associated dynamics, thermodynamics and fog microphysics, with the aim to achieve better understanding of fog life cycle and ultimately improve capability in fog prediction. Extensive sets of comprehensive ground-based instrumentation, including remote sensing platforms, are deployed at the Indira Gandhi International Airport (IGIA), New Delhi. Major in-situ sensors are deployed to measure surface micro meteorological conditions, radiation balance, turbulence, thermo-dynamical structure of the surface layer, fog droplet and aerosol microphysics, aerosol optical properties, real time sky images, and aerosol and fog water chemistry to describe the complete environmental conditions in which fog develops. Ghude et al. (2017) provide an overview on the instruments, experimental set-up and summarizes the preliminary results on fog physical, chemical and optical properties, fog droplet size distribution, microphysics and dynamics under the WIFEX Project.

Winter Fog Experiment (WIFEX) has helped in better now-casting (next 6 hours) and forecasting of winter fog on various time and spatial scales, and thus reduce its adverse impact on aviation, transportation and economy, and loss of human life due to accidents. The measurements will form the basis for understanding the some of the key questions on fog formation and dispersion. With these measurements, modelling efforts are also made with the ultimate aim to improve the prediction skill. These observations from intense campaign will be further used to validate model forecasts and to improve model capability. The model was made operational for Fog forecast in the winter season of 2018.

Thunderstorms

IGIA normally has an average of 51 thunderstorms (TS) per annum which include all types of thunderstorms (as per data of 2006-2017) of which 90% occur in March-September (Table.2). Out of all these, on an average, 16 are associated with squalls and Dust storms (DS) with squally wind and gusting speed as high as 140 kmph hase been recorded (Table.3&4). Their occurrences have strong seasonal behaviour with most of them (90%) occurring in Pre monsoon and monsoon covering March-Sept. Though, only 20% of these total annual local storms occurred at IGIA during peak local summer (April-June), but 70-80% were accompanied with squalls. They regularly have affected flight operation severely in each summer and their severity cause diversions upto 100s in some season at IGIA.

On 13 May 2018, severe Thunderstorm/Squall affected air traffic at IGIA during 0433-0830pm and diverted 78 flights, which is a record highest number of flights diverted in the recent past. The event delayed upto 100 flights by upto 3-6 hours. Keeping into account the Diversions/devastations caused by the severe thunderstorms during pre-monsoon months of March-April-May in 2018, over different parts of India and particularly the northern and northwestern region, Ministry of Earth Sciences took a time targeted development work under the chairmanship of Secretary, MoES. A working group (STORM) was formed to develop the tools of predicting thunderstorm occurrence, as well as lightning flash, lightning probability, heavy rain, gusty wind etc. with a 24 hour lead time and outlook with a 48 hour lead time.

Under this new initiative, scientists from various MoES Institutes worked together in coordination and a holistic tool for nowcast up to 1 hour and a 24 hour forecast from high resolution regional model and 48 hour outlook from high resolution global model with customized thunderstorm specific products, were developed.

For improving the nowcast of thunderstorm location and associated lightning, the high resolution satellite observations, lightning sensor observations (from IITM and IAF) and the RADAR observations have been merged to develop a user friendly high spatio-temporal frequency based operational product. For 24 hour ahead prediction, high resolution mesoscale models of IITM and IMD have been utilized to develop thunderstorm specific products and provide the guidance at district level. To get 48 hour ahead thunderstorm guidance, the Global Forecast System (at 12.5 km spatial resolution), has been utilized to develop several thunderstorm specific products.

Based on all the above products IMD prepares a thunderstorm nowcast guidance and updates in the website. To better communicate the prediction and warning of thunderstorm to public/society and stake holders, a dedicated website has been prepared where all these information is made available with latest update and details.

During 2019 pre-monsoon season of March-April-May, this new prediction tool has been utilized and the thunderstorm forecast guidance over different parts of India has been found to be timely and accurate that has helped in saving public life and property and also helped the aviation sector with an early thunderstorm warning.

Gap Areas

Indian civil aviation sector has witnessed rapid growth in the last 10 years and as per survey by IATA, it is expected to emerge as third largest aviation sector in the world by 2025 after USA and China. India's domestic air traffic nearly doubled to 117 million passengers in 2017. The number of civil airports in the country as per AAI 2017-18 annual report is presently 129 out of which 23 are international, 9 are of custom types, 77 are domestic and 20 are civil enclaves in defence airfields. This number is expected to increase to 190 by 2025. Since weather plays important role in the safety and efficiency of aircraft operations, there has been increasing demand from growing aviation sector for Aviation Met Services as per ICAO and DGCA guidelines.

- Impact based early warning system for Fog and Thunderstorms.
- Runway and aviation sectoral based customized products like wind shear, convective developments, clear air turbulence (CAT), ceiling height, etc, at very high resolution of few meters. Deployment of more sophisticated monitoring systems like Microwave Radiometers, Wind profiler, Terminal Doppler Weather Radar, Doppler LIDAR at airports has become necessary for aviation safety.

- Presently the half-hourly current weather reports at many airports are prepared manually by using data obtained automatically or manually from sensors wherever installed and inserting additional visual observation parameters such as cloud, visibility, weather. An Integrated Automatic Weather Observing System (AWOS) comprising of 10 mt frangible Mast, Pressure, Temperature, Wind, Humidity sensors, RVR, Ceilometer, RVR/Forward Scatterometer, and associated communication, and displays at all airports is required.
- ICAO mandates member countries for conducting periodical QMS audit and valid ISO certification for providing international air navigation services through respective AMO/MWO. This is mandatory for all airports.

Outcomes

Phase 1

1) Major upgradation of Meteorological facilities at all airports was approved under the activity '**Augmentation of Aviation Meteorological Services'** under the Umbrella Scheme ACROSS to meet ICAO and DGCA requirements (2017-2020).The following programmes were taken up under AvRDP

   a) WIFEX:Ministry of Earth Sciences (MoES), Government of India has taken up a multi-institutional initiative to conduct an intensive ground-based measurement campaign at the Indira Gandhi International Airport (IGIA), Delhi, to understand different physical and chemical features of Fog and factors responsible for its genesis, intensity and duration. WIFEX was conducted in a pilot mode at IGIA winter of 2016-2017. The experiment has provided better understanding of fog life cycle and improved capability in fog prediction.

   b) The aviation meteorological requirements, which are precise and demanding in nature, have increased with the increase in frequencies of aircraft operations. Hence, for reaping the benefits of technological advancements in instrumentation, information and telecommunications, IMD has upgraded its online aviation meteorological briefing system (OLBS) through its AMSS computers at four meteorological watch offices (MWO) located at Chennai, Delhi, Kolkata and Mumbai.

Phase II

1) An aviation expert committee was set up by Ministry of Earth Sciences to review current status of Aviation Met Services. The committee after in-depth study of inputs received and extensive deliberations came out with following recommendations for upgrading Aviation Met Services to meet present and emerging requirements of Aviation. The recommendations have been approved for implementation during 2019-2022.

a) International needs of aviation services concerning to gridded products both in charts and GRIB form of various Met parameters essential for safe flight operations, have been mainly served by two World area Forecast centres called WAFC located at London and Washington DC as mandated by ICAO-WMO. However in ICAO service provision, the national Met services if has capability can generate its regional NWP products in a more customized and impact based products for its regional airfields and region for respective aviation met parameters.IMD presently provides analysis and forecast charts of winds and temp of lower levels using WRF 9km model and it has METEOGRAM for some 70 airports and these products have been implemented since 2011. Presently, national SIGWX charts for SWM and SWH are prepared manually by MWO Chennai. As MoES institutions have become global leaders in delivering world class NWP products by adopting major global as well as regional models in recent years, it is recommended to customize some of the high-resolution model products for Aviation Met. Services.

b. In order to cater to the increase in services in aviation sector we need to integrate all available meteorological data sources such as radar, satellite, surface observations, lightning, and numerical model data and utilize state-of-the-science, field-proven data analysis and aviation weather hazard detection technologies to meet the specific operational weather monitoring, nowcasting and hazard warning requirements of aviation community. The committee proposed Aviation Weather Decision Support System (AWDSS) to help the forecaster's work and for providing real time inputs for Air Traffic Management (ATM).

c. In view of sectoral specific need-based demand especially with start of C-ATFM systems now operational at AAI Delhi and IGIA, MWO will be equipped with all computer and communication facilities and model expertise to generate required products at the regional and local scale.

d. With the introduction of newer navigational procedures like Performance based navigation (PBN), Trajectory based operation (TBO); continuous descent approach (CDA), the requirement for MET information has also undergone major changes. Now apart from traditional surface-based information, the stakeholders are equally concerned with the parameters like convective & wake turbulence, lightning events, presence and movement of thunderstorm within the controlled zone of an aerodrome etc. While studying at the international best practices adopted at major airports, the committee noted that these airports have deployed an array of additional sensors (Microwave Radiometer, Doppler Lidar, Wind Profiler etc) to detect and nowcast aviation hazards.over and above the basic AWOS to capture and forecast those phenomena which affects or downgrades the capacity of an airport or airspace. Depending upon the prevalence and frequency of such phenomena, the committee recommended additional instruments over and above the AWOS to be deployed at major airports.

e. Aviation meteorological telecommunication requirements for the international and domestic OPMET data exchange in the digital format as prescribed by ICAO (XML/GML/IWXXM format) need to be implemented immediately.

2) A working Group (STORM) was constituted to develop different monitoring and prediction tools for thunderstorms (based on different techniques). The Group was mandated to develop high resolution operational prediction system and to come out with a better strategy for monitoring and predicting thunderstorms .

Future Studies and Plans

National Meteorological Services throughout the world are obliged by law to make meteorological observations and forecast as per the standards and guidelines provided by World Meteorological Organization (WMO) and International Civil Aviation Organization (ICAO). The objective is to contribute towards the safety, economy, regularity and efficiency of air navigation. IMD provides meteorological service to both the national and international civil aviation operators at civil aerodromes, in fulfilment of the specifications prescribed by the

ICAO and the Director-General of Civil Aviation (DGCA), Government of India. Some of the future plans include:

3) Develop a State-of-the-Art Meteorological support System for Aviation Safety with advanced meteorological instruments and advanced forecasting tools for all the civil airports in the country. This will include augmenting observational facilities at all the airports and further improvement of forecasting capabilities including model products.
4) Major upgradation of Meteorological facilities at all airports, to be done to bring it at par with other international airports through very latest state-of-art instruments, display, dissemination facility and full compatibility with the future Air Traffic Management System. Introduction of air-craft based profiler observations, procurement of Doppler Radars, Wind profilers, Radiometers, Lightning detectors, and LIDARs at major airports.
5) Regular training courses to be conducted for Aeronautical IMD Met personnel and from neighbouring countries having common FIR boundaries with India to meet the stringent Quality Management System (QMS) requirements of ICAO.
6) ISO certification of Met Offices at various airports.
7) Extension of MET services at regional and small airports, to improve the connectivity of the remote underdeveloped regions, thereby improving their economic well-being.
8) To develop and commission Multi-Hazard Early Warning System with Impact based forecasts for Tropical Cyclones, Heavy Rainfall events, Fog and Thunderstorms. The forecasts will be based on the impact caused by weather systems to make more actionable item by the user Community.

Road map for GNAP 2016-30 for Indian region

1) Meteorological Information to support enhanced Operational efficiency and Safety (BO-AMET)
2) Better wind information around the Aerodrome in 4 MWOs through commissioning of Wind Lidars (B1-WAKE)

3) Enhanced Operational Decisions through Integrated meteorological information in the form of AWDSS (Aviation Weather Decision Support System)(B1-AMET)
4) Complete integration of MET data with the ATM data under System Wide Information Management (SWIM) environment to make it seamless global ATM, with major upgradation of both observational and communication facilities.

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Table 1 Average of Fog occurrences at IGIA Using Longer Period Data 1996-2016

Fog/Dense Fog at IGIA		Nov	Dec	Jan	Feb	Seasonal
General Fog<1000m	Days	10	26	28	15	79
	Hours	85	297	321	110	813
Dense Fog< 200m	Days	1	8	13	3	25
	Hours	3	48	77	12	140

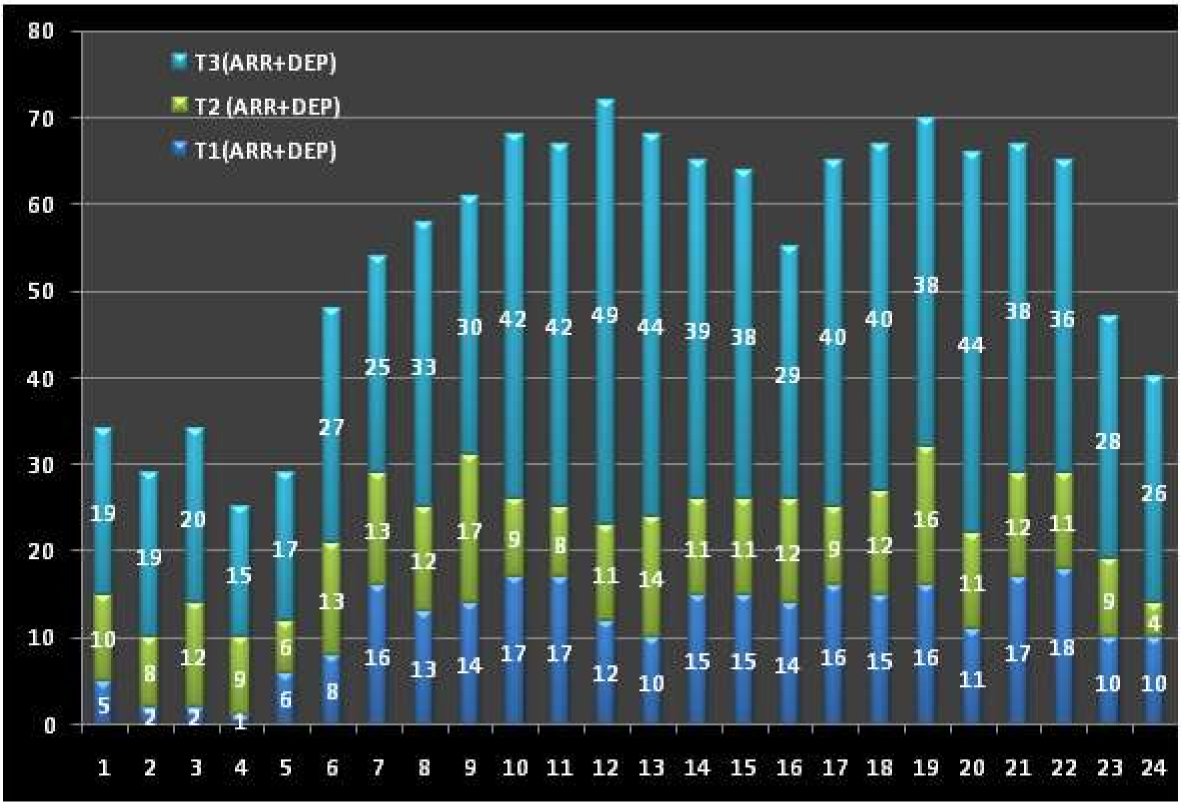

Fig 1 Hourly air traffic at IGIA (Timing in X-Axis is at IST (IST-5 hours and 30 minute is UTC)

Table.2 IGIA Delhi-Climatology of Frequency of TS/DS (2006-2017)

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Freq	1	1	1	4	9	6	8	10	8	1	1	1

Table.3 IGIA Delhi-Climatology of Frequency of Squall (2006-2017)

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Frequency	0.2	0.2	1	2	5	5	2	0.6	0.7	0.3	0.2	0

Table.4 Dates of max winds at IGIA when it crossed 60kts(112.12kmph) in last 18-years for 2001-2018

(The ever highest max wind recorded in 18 years is 75kts (138.9kmph)

Month	**Date**	**Time (IST)**	**Wind direction**	**Wind Speed Kmph**	**Speed (Kt)**	**Duration of Squall (minutes)**
May	24.5.02	1621	270	113	61	One
April	9.4.04	1530	140	118	64	One
April	27.4.05	1741	270	138.9	75	One
June	16.6.06	1606	230	138.1	74	One
May	30.05.14	1654	320	115	62	Two