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ABSTRACT

Satellite derived information play an important role in weather forecasting. Both INSAT-3D/3DR and Global Navigation Satellite System (GNSS) derived products utilizing operationally at India Meteorological department (IMD) daily. These products are operationally available at 15 minutes intervals from INSAT-3D/3DR Imager and GNSS. INSAT3D/3DR Imager derived blended imagery, Day /Night Time Microphysics (DMP/NMP), Outgoing Long Wave Radiation (OLR), RGB Imagery and clear sky Wind Index from INSAT-3DR Sounder (hourly) were analysed for recent thunderstorm over Delhi NCR region on 30th May-2022. GNSS derived Integrated Precipitable Water Vapour (IPWV) shows a gradual building up 3 to 4 hours prior to the event. Therefore, with the supports of INSAT products the weather events can be monitored prior to its occurrence and suitable inputs were supplied to the decision support system of forecasting in IMD. Thereafter the information is value added based on other inputs from Numerical Weather Prediction Models (like Rapid Refresh Weather research Forecast, Ensemble forecast, Global Forecast System etc), Radar, and surface or upper air etc. before giving the information to the general public and end users.

Keywords: *INSAT-3D/3DR, IPWV and thunderstorm*

INTRODUCTION

Convective growth of clouds especially pre-monsoon (March to May) season is rapid and generally associated with thunder showers & rain along with strong winds (Manohar et al., 1999, Manohar and Keserkar., 2003, 2004). Role of satellite images and derived products are useful in monitoring and short term weather forecasting by critical monitoring and tracking the cloud growth in satellite images. INSAT-3DR have Imager payload of six spectral bands (spatial resolutions are given in brackets), visible (1.0 x 1.0 km), shortwave infrared (1.0 x 1.0 km), mid-wave infrared (4.0 x 4.0 km), thermal infrared-1 (4.0 x 4.0 km), thermal infrared -2 (4.0 x 4.0 km) & water vapour (8.0 x 8.0 km). Satellite based monitoring of thunderstorm activities related work was earlier done by many authors (Goyal et al., 2017, Goyal et al., 2016, Goyal et al., 2014, Tyagi., 2007, Tyagi et al., 2012) in the past. Global Navigational Satellite System (GNSS) derived Integrated Preicipitable Water Vapour (IPWV) is utilized by many researchers in the recent past to nowcast the convective thunderstorm activities over India and globe (Yadav et., 2021, 2020, Puviarasan et al, 2014, 2020). The total zenith delay from dual frequency receiver of GNSS stations is the sum dry and wet zenith delays of troposphere. The dry part is easily modelled by the pressure and temperature values at the station but the wet zenith delay is variable and difficult to estimate. This wet zenith delay is determined from zenith total delay by subtracting zenith dray delay and by adjusting the moisture by mean layer temperature at the station (Bevis et al., 1992 & Businger et al., 1992). The IPWV values derived from GNSS shows gradual increase in PWV at least 4-5 hours prior to the occurrence of thunderstorm. This information is very useful to the forecasters to issue the warnings or advisories over and around the station in advance.

Depending on the geographical locations the importance of GNSS, IPWV data have its own importance. For example if the GNSS stations are near to the airport area then it will help to issue the

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nowcasting well in advance during the time of take-off and landing of aircraft operations. If the stations near the coast then it will support in value addition of the forecast or warning related to coastal area and regions nearby. Similarly, at plains the IPWV information is very useful to the famers during pre-monsoon season as this is the season of harvesting and most of the crops are ready for storage. The information in time can save the crops and adversity related duststorm, thunderstorms and high winds. Therefore, satellite derived products and GNSS IPWV together are very helpful in monitoring the weather events and gives a clue in advance for coastal regions, aviation's, farmers and monsoon onset, active and withdrawal from the country. Severe weather records like thunderstorms compilation both national as well as international are very important to investigate vulnerable areas for future (IMD, 1905, Brooks., 1925).

In Indian domain the time of occurrence of thunderstorm events differs place to place in some regions these events occurs in the early moring (Bihar and North East regions) an late afternoon (NW, Central Southern parts of India) and night. Therefore, forecasters /researchers in the past thought to know the diurnal cycle of these events (Whipple, 1929, Williams, 2009). In aviation services many flights get cancelled, diverted from their route and met an accidents also due to the intense thunderstorm activities during their route or near airport area. Therefore, it's monitoring through space, surface or NWP based guidance is essential and forecasting /warning in advance can save the lives and property. The other associated risk or we can say a silent killer which is nowadays are increasing is the lightning associated with such mesoscale thunder events. Normally all thunderstorms cloud development reached above freezing level and therefore mixed types of clouds phases (warm as liquid and cold as ice phase) will present and intermixing through upward and downward motions of moisture can produce severe turbulence , poor visibility , lightning, hail and shear at lower levels. To cope with such disasters satellite remote sensing play an important role. INSAT-3DR derived like blended imager of Infrared channel, day time microphysics (DMP), night time microphysics (NMP), wind Index from sounder and IPWV from GNSS can provide a clue to forecasters and end users to take safe decisions. The subsequent portions of this work are data & methodology, analysis and discussions, concluding remarks and references.

DATA AND METHODOLOGY

The IPTWV and INSAT-3DR data utilised for this work has been taken from satellite division of India Meteorological Department (IMD) Mausam Bhawan, Lodi Road, New Delhi. The online web-application tool known as Real time Analysis of Product and Information Dissemination (RAPID) was jointly developed by Indian Space Research Organisation, Space Applica Centre (ISRO-SAC) for operational use at IMD also utilized for real time INSAT-3DR data analysis. The concept behind the work was that thunderstorm activities during pre-monsoon season were developed due to sudden convective heating. It may be purely localized convection based on the available moisture of the surrounding area or induced by other sources like Arabian Sea or Bay of Bengal and usually carried by mid-latitude weather systems (known as west urn disturbances). The proposed convection was much more localized and associated with weak eastward moving system passing over that area. The wind gust potential was monitored by wind index a derived parameter from INSAT-3DR data sounder data sets. INSAT-3DR imager blended images (brightness temperature over thermal infrared image), outgoing long wave radiation (proxy of convection) and a combination of visible, infrared red or mid infrared images etc. were also utilised to map and monitor the convection.

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RESULTS AND DISCUSSION

Figure 1 is the blended image of INSAT-3DR imager and it indicates the areas of expected severe convection with the help of brightness temperatures (BTs) lying over the infrared (IR) image of the Imager. Near Delhi NCR region noticed a short duration severe thunderstorm event confined in a short region and caused damages of building, uprooted the trees at several places due to strong winds. This convection is clearly seen in figure (1) by red arrow around Delhi NCR. There is wind confluence generated from northwest and southerly direction which made the convection confinement over NCR region. The similar situation is seen in Figure (2) in da time microphysics product of INSAT-3DR generated every half an hour operationally at satellite division of IMD.

Figure (3) indicated the wind gust associated > 45 knot at 1600 IST and it suggests the wind convergence building up around NCR approximately 2 hours prior to the actual occurrence of thunderstorm. The wind index products is available for cloud free pixels only and therefore during the time thunderstorm it was retrieved over Delhi due to the presence of clouds. This product is routinely available every hour in public domain through dedicated website of IMD for general public, end users, forecasters and researchers. The high index value depicted around NCR indicates that convection is developing and it can accompanying with rain and strong winds. The severity of the convection can also be determined with the help of outgoing longwave radiation (OLR) data operationally available every 15 minutes (in staggering mode of INSAt-3D & 3DR). On 30th May this convection shows around 112 watt/m2 (Figure 4) which indicated severe to very severe convection around the area. It will further develop by releasing the latent heat of condensation and buoyant will continues going up and move forward with the wind. This will develop the intense convection over larger area and hence its impact. Figure 5 shows the IPWV rise of about 15 mm (25 to 40 mm) 3 to 4 hour prior to the actual occurrence of the thunder event. Therefore, main precursors like convection, wind, moisture availability etc of convective events can easily be monitored with the help of satellite remote sensing observations.

Can cause aviation hazard ?

The air route between sources to destination can be monitored with the support of satellite and GNSS based data analysis. IMD provides the aviation forecast for national as well as international flights operating in Indian region.

Severe weather sometimes can cause accident and an aviation accident is defined by the Convention on International Civil Aviation Annex 13 as an occurrence associated with the operation of an aircraft, which takes place from the time any person boards the aircraft with the intention of flight until all such persons have disembarked, and in which a) a person is fatally or seriously injured, b) the aircraft sustains significant damage or structural failure, or c) the aircraft goes missing or becomes completely inaccessible. Annex 13 defines an aviation incident as an occurrence, other than an accident, associated with the operation of an aircraft that affects or could affect the safety of operation.

As per the historical records the first fatal aviation accident was the crash of a Rozière balloon near Wimereux, France, on June 15, 1785, killing the balloon's inventor, Jean-François Pilâtre de Rozier, and the other occupant, Pierre Romain. The first involving a powered aircraft was the crash of a Wright Model A aircraft at Fort Myer, Virginia, in the United States on September 17, 1908, injuring its co-inventor and pilot, Orville Wright, and killing the passenger, Signal Corps Lieutenant Thomas Selfridge.

The first aircraft accident in which 200 or more people died occurred on March 3, 1974, when 346 died in the crash of Turkish Airlines Flight 981. As of

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April 2020, there have been 33 aviation incidents in which 200 or more people died.

The top 10 countries with the highest number of fatal civil airliner accidents from 1945 to 2021 are the United States, Russia, Canada, Brazil, Colombia, UK, France, Indonesia, Mexico, and India. The UK is noted to have the highest number of air crashes in Europe, with a total of 110 air crashes within the time period, and Indonesia is the highest in Asia at 104, followed by India at 95.

The largest loss of life due to severe or bad weather conditions on board a single-aircraft is the 520 fatalities in the 1985 Japan Airlines Flight 123 accident, the largest loss of life in multiple aircraft in a single accident is the 583 fatalities in the two Boeing 747's that collided in the 1977 Tenerife airport disaster, while the largest loss of life overall in a collective incident is the 2,996 fatalities in the coordinated terrorist destruction of airplanes and occupied buildings in the 2001 September 11 attacks.

History says that bad weather conditions for every billion kilometres travelled, trains have a fatality rate that is 12 times higher than that of air travel, and the fatality rate for automobiles is 62 times greater than for air travel. By contrast, for every billion journeys taken, buses are the safest form of transportation; using this measure, air travel is three times more dangerous than car transportation, and almost 30 times more dangerous than travelling by bus.

Concluding remarks

Due to increase the privatisation of aviation services and their growths in the recent past the accurate knowledge of prediction of weather forecast play a major role. The infrastructure required to cater the needs of society safety the role of satellite based information is crucial and important even in data sparse regions. INSAT-3DR or 3D derived products along with the web based analysis tool RAPID has changed the forecast scenario. The satellite data is almost cost effective as compared to other surface and upper air data and available all time. This data also fills the data gaps and utilized in numerical weather prediction (NWP) models for further refinement of prediction. However, this data needs proper validation of the products generates to use them appropriately. In this present case, the thunderstorm event around Delhi NCR have advanced indications of convective development of about 2 to 3hours prior to the occurrence. Although it has the limitations to know the exact area and wind speed or rainfall through satellite measurement. For this purpose we need to integrate RADAR observation and satellite based information together.

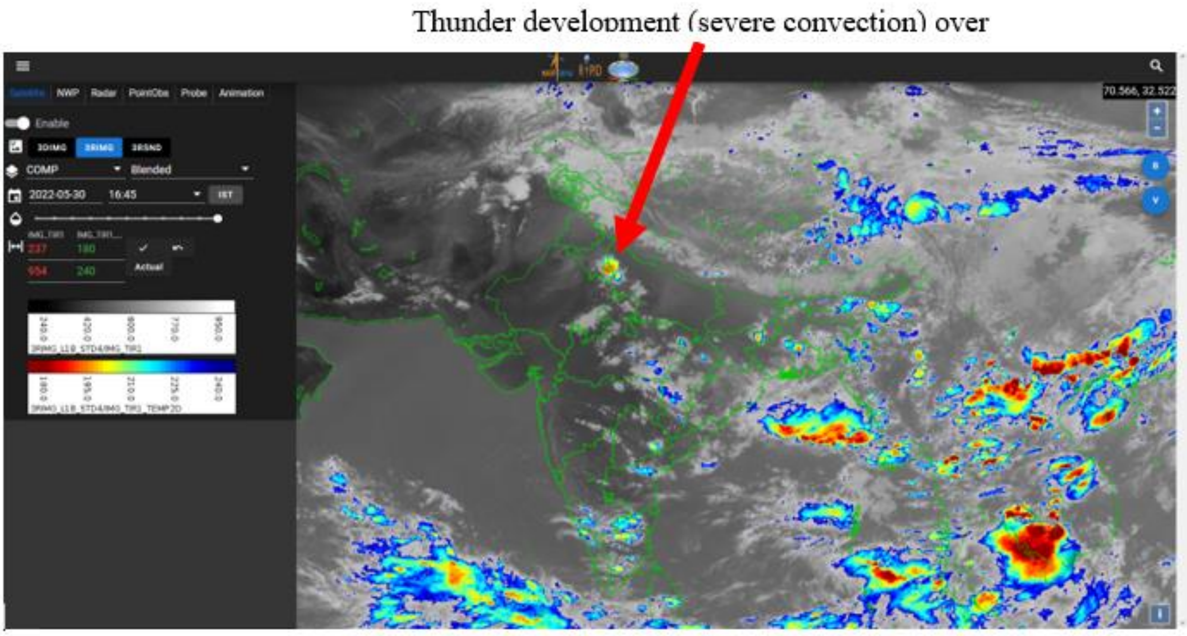

Fig 1: Blended Image (Infrared TIR-1 & BT) of INSAT-3DR at 16:45 IST-30 May-2022 (Thunderstorm noticed at NCR): Intense convection seen around Delhi NCR.

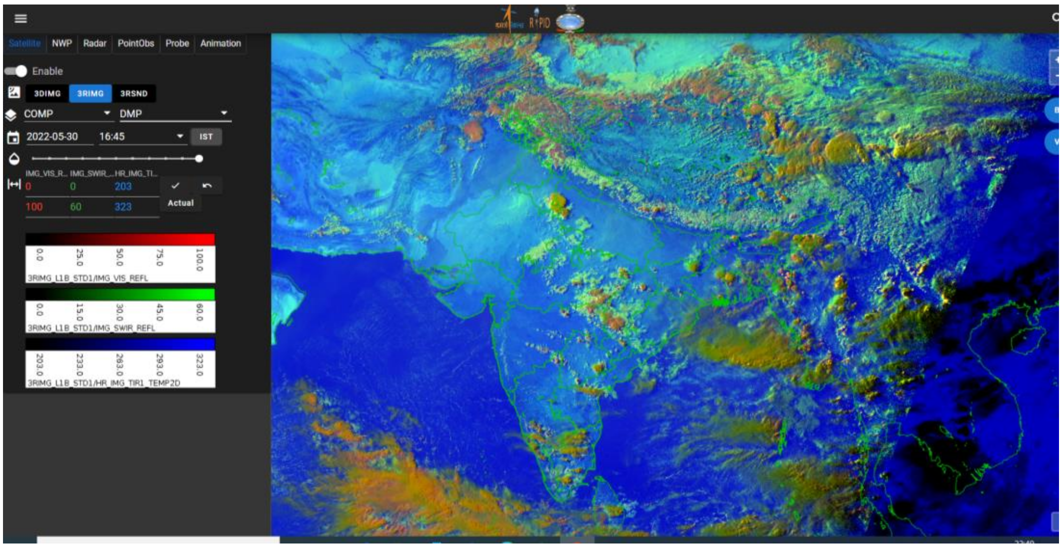

Fig. 2: Day Microphysics (DMP) of INSAT-3DR (Visible + Shortwave Infrared + Thermal Infrared-1) at 16:45 IST-30 May-2022 (Thunderstorm noticed at NCR)

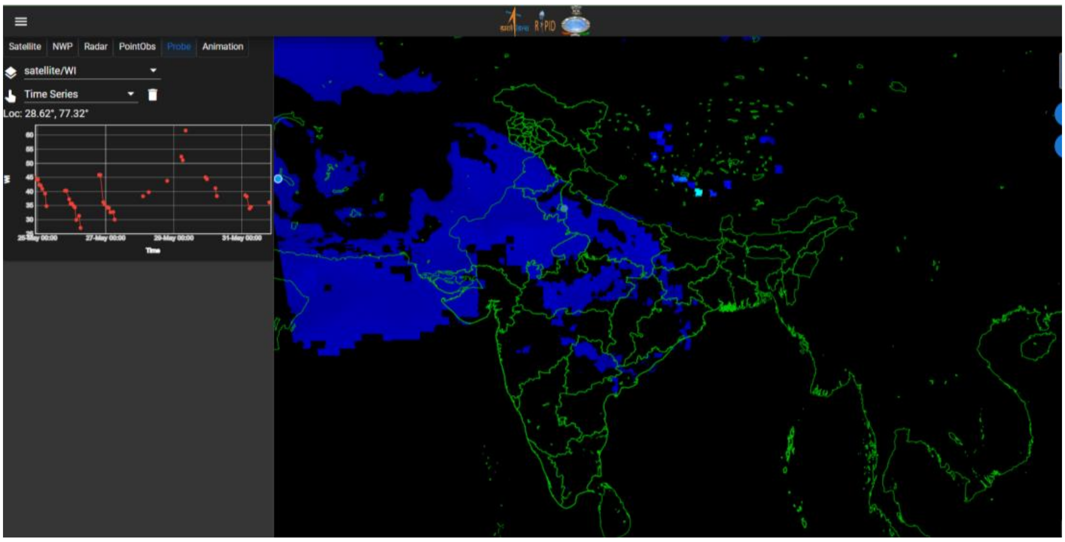

Fig. 3: Wind Index (WI) from INSAT-3DR sounder (> 45 knot) at 100 IST-30 May-2022 (Thunderstorm noticed at 1600 IST in NCR with very high wind speed which caused many trees uprooted).

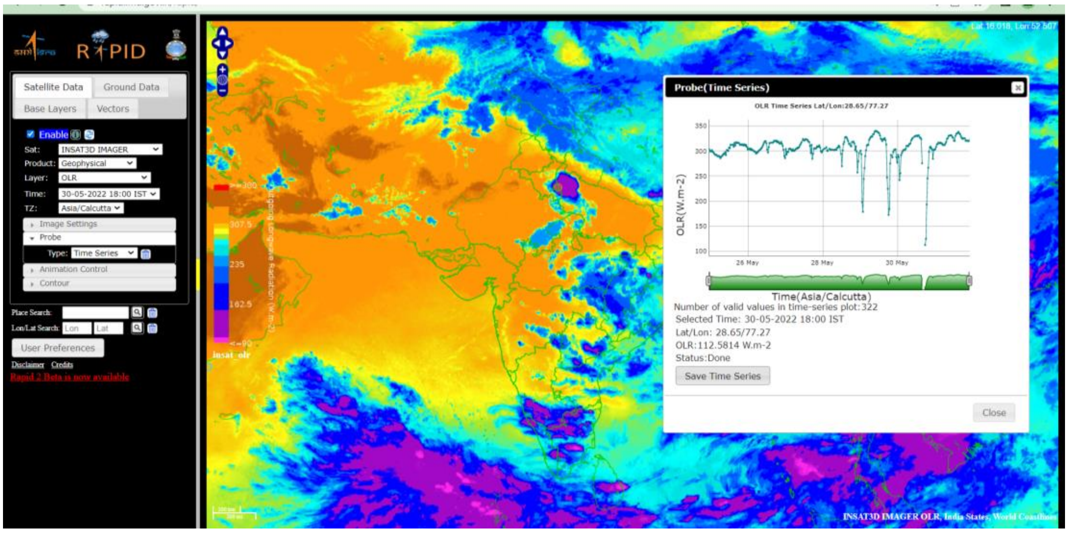

Fig. 4: Outgoing Long Wave Radiation (OLR) in watt /m^2 noticed very intense convection (112 watt /m^2 at 1730 IST-30 May-2022 (Thunderstorm noticed at 1700 IST in NCR)

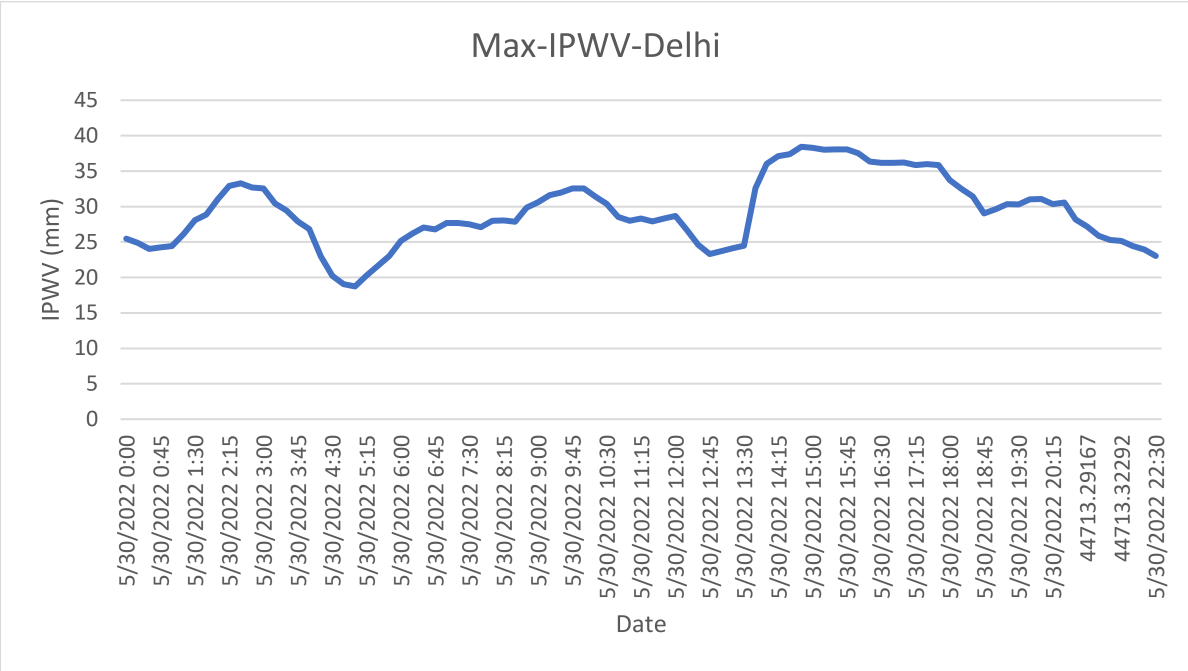

Fig. 5: GNSSS derived IPWV in mm of Delhi from IMD, GNSS Network on 30st May-2022

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