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L E T T E R S

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RECENT ADVANCES IN COMMUNICATION INFRASTRUCTURE OF IMD FOR EARLY WARNING SYSTEM

1. All disaster emergencies and crisis events are by nature chaotic and highly dynamic, creating physical, emotional and social disorder. In such crisis events and emergencies, timely communication of information to all stakeholders is critical during all phases of disaster management. Communications during disaster weather events incorporates a wide range of measures to manage risks to communities and the environment. Timely communication of information from various meteorological data sources that include observations like surface, upper air and remote sensing based (satellites and radars) etc. is very vital for early warnings. Before disasters strike, telecommunications can be used as a conduit for disseminating information about the impending danger thus, making it possible for government agencies and people to take the necessary precautions and measures to mitigate the impact of the hazards.

India has been traditionally vulnerable to weather related natural disasters on account of its unique geo-climatic conditions. Floods, droughts, severe thunderstorms, cyclones, earthquakes and landslides have been recurrent phenomena. As per Report by National Disaster Management Division (NDMD, 2004) about 60% of the landmass is prone to earthquakes of various intensities; over 40 million hectares is prone to floods; about 8% of the total area is prone to ease and 68% of the area is susceptible to drought.

In the recent years, the heat wave casualties have increased over India. During the years 1995, 2005, 2015 and 2016 the casualties are reported to have crossed 1000. The worst was in 2015 when 2300 deaths were reported, making it the fifth highest in world history in terms of number of deaths (Pai *et al*., 2013). Most of the deaths were concentrated in Andhra Pradesh, Telangana, Punjab, Odisha and Bihar (FDP, 2019). To save lives of people, starting from the year 2016, IMD is issuing summer and winter forecasts with heat wave and cold wave warnings.

Tropical Cyclones (TCs) are one of the natural hazards that affect India almost every year causing losses of lives and property. India has a coastline of about 7516 km of which 5400 km is along the mainland. The entire coast is affected by TCs with varying frequency and intensity.

Although the North Indian Ocean (the Bay of Bengal and Arabian Sea) generates only about 7% of the world's TCs (5-6 TC's per year according to IMD) (Mohapatra *et al*., 2011), their impact is comparatively high and devastating, especially when they strike the coasts bordering the north Bay of Bengal. Thirteen coastal states and Union Territories (UTs) in the country are affected by TCs. Four states (Tamil Nadu, Andhra Pradesh, Odisha and West Bengal) and one UT (Puducherry) on the east coast and one state (Gujarat) on the west coast are more vulnerable to TC hazards (Antonio, 2004). The detailed damage potential of TCs is given in 'Damage Potential of Cyclones' published by IMD (2002). It is being used by IMD to mention the 'expected damages and suggested actions by the disaster managers in its three hourly bulletins issued during the period of TC. IMD is the nodal government agency as well as Regional Specialized Meteorological Centre (RSMC) - RAII that provides weather services related to TCs in India as well as south Asia and adjoining countries. IMD identifies the districts as per TC tracks for which cyclone warnings are to be issued. For the purpose of better TC disaster management in the country, it is necessary to define TC to identify TC prone coastal districts and probable damage due to TC. It is also necessary to decide degree of probable hazard of a district by considering TC parameters so that mitigation measures are prioritized.

In the present era of digital communication, the internet provides a useful platform for disaster mitigation communications. Well-designed and informative website/ mobile apps are very cost-effective means of making an intra-national and international presence felt. It provides a new and potentially revolutionary option for the rapid, automatic, and global dissemination of disaster information for taking necessary measures by respective authorities/ individuals for its mitigation to minimize the losses. Online social networking services and social media like Twitter, Facebook, Google Currents etc. plays very important role to solve many problems during natural disasters. All the conventional communications generally stop functioning at this time interval while social media or networking services stay active.

2. *Data flow for observational data exchange*- IMD used different tools and instruments to gather information, which help weather forecasters to analyze synoptic and dynamic conditions of weather. IMD issue weather warnings when hazardous weather is expected called early warning system, which comprises of observations, analysis, Numerical weather modelling, Forecasting, early warning products, presentations which

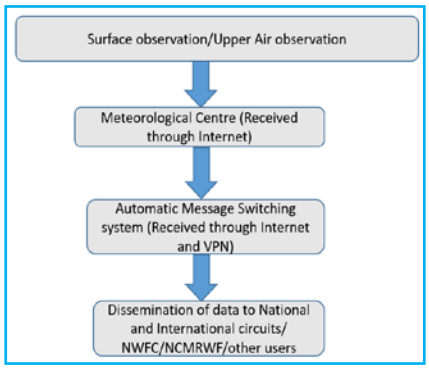


Fig. 1(a). Data flow chart of Surface and upper air observations

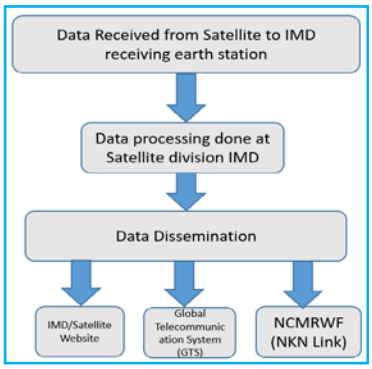


Fig. 1(b). Data flow chart of Satellite data

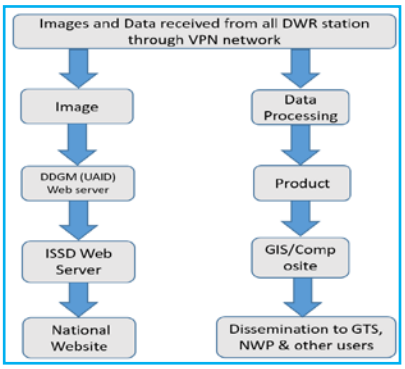


Fig. 1(c). Data flow chart of Radar Data

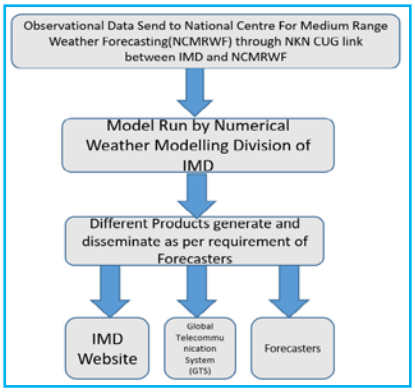


Fig. 1(d). Data flow chart of Numerical weather Modelling

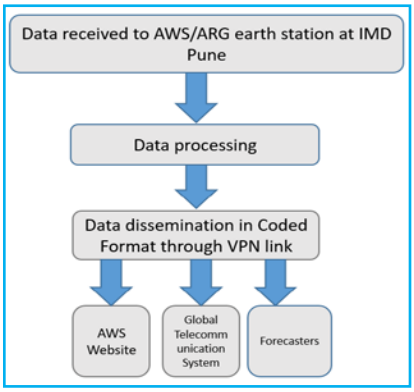


Fig. 1(e). Data flow of AWS/ARG Data

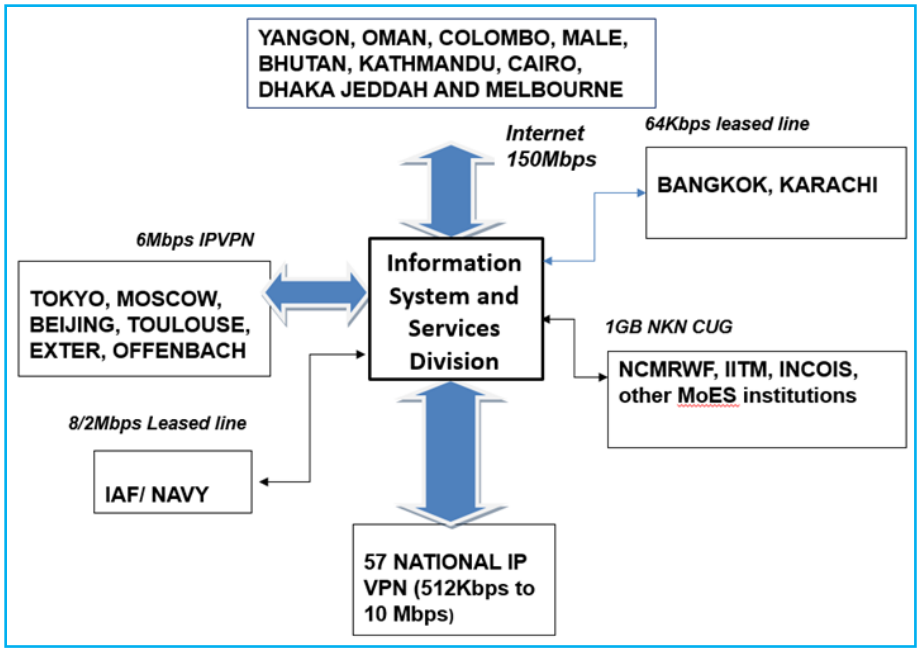


Fig. 2. Communication Links established with other Countries/Organizations

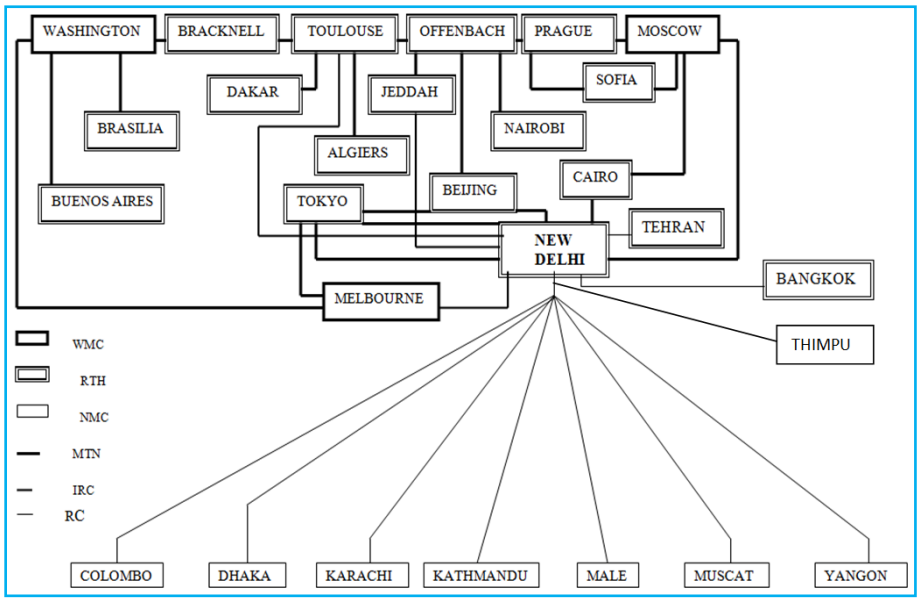


Fig. 3. Network Configuration of GTS

results to dissemination of warning. Figs. 1. (a-e) shows data flow chart of surface and upper air observations, Satellite data observations, Radar data, Numerical weather modelling and AWS/ARG data respectively

Data flow from various tools are totally automatic and have less manual intervention which are required in generation, display and transmission of the end product.

3. *Telecommunication Infrastructure* - GTS links with Regional Telecommunication Hub (RTH), New Delhi consist of 18 international circuits. It manages 6Mbps Internet Protocol Virtual Private Network (IPVPN) links with Tokyo, Moscow, Beijing, Toulouse, Exter and Offenbach. Links with Yangon, Oman, Colombo, Male, Bhutan, Kathmandu, Cairo, Dhaka, Jeddah and Melbourne are through 150 Mbps internet (at New Delhi end). Other international links with Bangkok and Karachi are operating at 64 Kbps leased lines. Communication links established at RTH, New Delhi are shown in Fig. 2 and Network configuration of GTS is shown in Fig. 3.

Functioning as National Meteorological Telecommunication Centre (NMTC), India Meteorological Department maintains its dedicated networks for exchange of meteorological data/ information with other centers. At present, nationwide main communication link is IPVPN with speed of 10 Mbps at NMTC, New Delhi and 512 Kbps / 1 Mbps at various other centers and Radar stations. Another two leased links, one of 8 Mbps with Indian Air Force (IAF) and the other of 2 Mbps with Indian Navy (IN), have been established to continuously exchange data. In addition, 1Gbps National Knowledge Network (NKN) Closed User Group (CUG) links have been established with National Centre for Medium Range Weather Forecasting (NCMRWF), Indian Institute of Tropical Meteorology (IITM), Indian National Centre for Ocean Information Services (INCOIS) and other institutes of Ministry of Earth Sciences (MoES) for information exchange.

Meteorological data and processed products containing half hourly Indian National Satellite System (INSAT) images, surface and upper air data, aerodrome forecast, weather charts and model outputs etc. are exchanged over Global Telecommunication System (GTS). A receive only Satellite Data Dissemination System (SADIS) is in operation at New Delhi to receive aeronautical meteorological information from International Civil Aviation Organization (ICAO) Centers which are routed to four International Airports of India for National and International flight briefing and for providing data in GRIB/BUFR format for wind/temperature and Significant weather charts. Different Data type used in IMD with format and Data Volume per day (per month) are shown in Table 1.

4. *Existing Communication Infrastructure*.

4.1. *Automatic Message Switching System (AMSS)* - Automatic Message Switching System (AMSS) is the central element in a high technology Meteorological environment. The present AMSS (Transmet) based on cluster Linux solution, is very useful for mission-critical

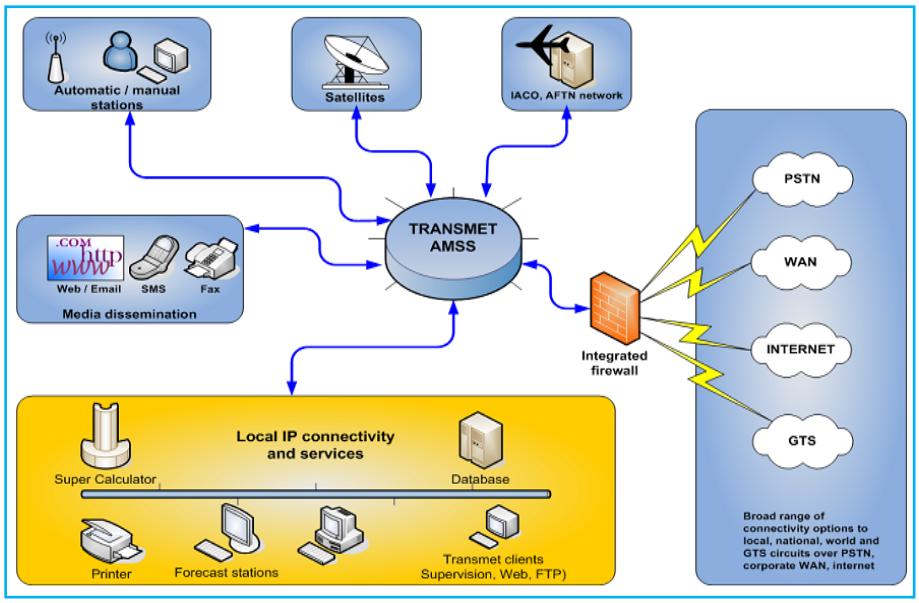


Fig. 4. System Overview of AMSS

TABLE1

Data format and data volume per day (Per Month)

S. No.	Data Type	Data Volume per day (MB)	Volume per month (GB)	Format of Data
1.	Satellite	82172	2407.4	**HDF/BUFR**
2.	Satellite	350	10.3	**GIF/JPEG**
3.	Radar	23552	690	**NETCDF/BUFR**
5.	NWP	17264640	505800	**GRIB**
6.	Cyclone	200	5.9	**TEXT**
7.	Marine	1	0.03	**TEXT**
8.	NWFC	140	4.1	**TEXT**
9.	Observation • Surface • Upper Air • Aviation Data • Buoy Data	500	14.6	**TEXT/BUFR**

meteorological networks. Clusters are based on latest generation HP servers loosely coupled in redundant manner. There are two separate AMSS for national and international operations. AMSS-National manages collection and dissemination of data in India (NMTC functions). AMSS-International manages all the international circuits (RTH functions). AMSS is the heart of meteorological telecommunications. Its main functions are to receive, check and forward automatically, the meteorological data and products according to the WMO standards. With AMSS, we interconnect our Meteorological sub-systems. It is able to handle more than hundred circuits at any speed practically available at present. Cisco firewall has been implemented to safeguard the system from any intrusion / attack / hacking from outside world. An overview of the system is given in Fig. 4.

Latest SADIS 2G receiver has been integrated with the system to receive the SADIS data. Cisco routers and HP switches are installed for interconnecting various subsystems, systems over IMD Local Area Network

(LAN) (*viz*., High performance computing system (HPCS), Synergie, Central information processing system (CIPS), Public Weather System (PWS), Climatological System (CLISYS) etc.) and outside over GTS, Wide Area Network (WAN) and internet etc.

Facilities/ salient features of the system - The system has following advanced features / facilities:

(*i*) *Web tool for easy deployment and setup* : The system includes a web based configuration tool for simplified circuit configuration, routing table modification, circuit supervision, database message search and access, redaction of bulletins (SYNOP, TEMP, TAF, METAR …) and system setup etc

(*ii*) *File switching* : This facility enables the system to switch satellite, radar, and model output etc. data files to predefined destinations as soon as these are received through File Transfer Protocal (FTP). Media (audio-visual) files can also be switched to Regional Meteorological Centre (RMC), Meteorological Centre (MC) etc. through FTP.

(*iii*) *SMS interface* : The system is equipped with dissemination of customized message through SMS to predefined recipients whenever the message with a particular header is received. This facility is quite useful for warning dissemination. Small observational messages can also be submitted to the system through SMS.

(*iv*) *Audio visual warning* : It has the facility of audio visual warning system in case of circuit/ system failure and special message (like tsunami warning, nuclear accident) reception.

(*v*) *Broadcast of GMDSS (Global Maritime Distress and Safety System)* : Broadcast of GMDSS bulletins has been integrated with the system. This facility enables broadcast of sea area bulletins over safety net automatically at predefined times for Met Area VIII (N).

(*vi*) *Message submission through browser* : Remote / part time observatories can submit messages to AMSS directly using web browser.

(*vii*) *E-mail communication* : The system is capable of switching the message through e-mail. The message is switched to predefined users through e-mail when a message with particular header is received. The system has the ability to retrieve message from e-mail and submit the same to GTS.

(*viii*) *Fax interface* : The system is able to divert the warning messages to predefined fax numbers as per routing dictionary using a fax server naming HylaFax. It can deliver the incoming faxes as e-mail messages. Operator (using on-line phone book available) can send automatically from Transmet, or manually from any supervision terminal fax.

4.2. *WMO Information System (WIS)* - The WMO Information System (WIS) is the single coordinated global infrastructure responsible for the telecommunications and data management functions. It is the pillar of the World Meteorological Organization (WMO) strategy for managing and moving weather, climate and water information in the 21stcentury. WIS provides an integrated approach suitable for all WMO Programmes to meet the requirements for routine collection and automated dissemination of observed data and products, as well as data Discovery, Access and Retrieval (DAR) services for all weather, climate, water and related data produced by centers and Member countries in the framework of any WMO Programme (www.wmo.int/pages/prog/www/WIS).

WIS provides routine collection and dissemination service for time-critical and operation-critical data and products and also ensures timely delivery service for data and products. Under WIS framework of WMO, RTH New Delhi acts as a Data Collection or Production Centre (DCPC) in view of its long services rendered as a designated Regional Telecommunication Hub for the Global Telecommunication System (GTS) under the Main Telecommunication Network (MTN). Its role is the collection and dissemination of meteorological data and products within its area of responsibility and also exchange of such data/products with other RTHs (Singh *et al*., 2017)

4.3. *Website of IMD* - The India meteorological department has mainly two Websites with URLs:
http://www.mausam.imd.gov.in and
http://www.rsmc.imd.gov.in containing all the forecast and warning related static & dynamically updated information.

All warnings related to cyclone, heat wave, cold wave are displayed in front page with detailed analysis of warnings. IMD websites contain lot of information for public awareness. All satellite imagery, Radar images, Numerical Weather products (NWP), Nowcast imagery; Cyclone Warning etc. are updated regularly in IMD webpage in order to provide access to the public to the latest updated information at regular intervals.

4.4. *Methods for Early warning message dissemination* - India Meteorological Department (IMD) is using mobile-network-based warning message

dissemination methods in order to make warning messages easily accessible to the coastal residents and field-level disaster management committees/ authorities.

4.4.1. *Interactive Voice Response System (IVRS)* - Popularly known as "Weather on telephone", the Interactive Voice Response System (IVRS) service in IMD is functioning with effect from July, 2000. IVRS is an example of Computer-Telephone Integration (CTI). The most common way for a phone to communicate with a computer is through the tones generated by each key on the telephone keypad. These are known as dual-tone multi-frequency (DTMF) signals. A computer needs special hardware called a telephony board or telephony card to understand the DTMF signals produced by a phone. A simple IVR system only requires a computer hooked up to a phone line through a telephony board and some IVR software. The IVR software allows pre-recording of greetings and menu options that a caller can select using his telephone keypad. More advanced IVR systems include speech-recognition software that allows a caller to communicate with a computer using simple voice commands. Speech recognition software has become sophisticated enough to understand names and long strings of numbers. In the context of mobile governance, the IVRS application is intended to serve the Citizen to Government (C2G) and Government to Citizen (G2C) services within the e-governance domain.

One can access current weather and forecast for major Indian cities by dialing Toll free number 1800 220 161.

4.4.2. *Short Message Service (SMS)* - India Meteorological Department has taken various initiatives in recent years for improvement in dissemination of weather forecast and warning services based on latest tools and technologies. Since 2009 IMD has started SMS based weather and alert dissemination system through AMSS (Transmet) at RTH, New Delhi. To further enhance this initiative, India Meteorological Department has taken the leverage of Digital India Programme to utilize "Mobile Seva" of Department of Electronics and Information Technology (DeitY), Ministry of Communication and Information Technology, Govt. of India; for SMS based Warnings /Weather information for wide range of users through the URL: https://services.mgov.gov.in/logout.do. Services Portal provides three modes of sending SMS depending on the user's needs. These modes are Quick SMS, Group SMS and Bulk SMS.

Quick SMS - The quick SMS facility is used while sending messages to a limited number of persons. Using this facility, SMS can be sent to individuals by entering their mobile numbers separated with commas.

Group SMS - The group SMS facility is used while sending messages to a group or groups of persons. Using this facility, SMS can also be sent to individuals by entering their mobile numbers separated by commas.

Bulk SMS - Bulk SMS is a fast and convenient way to send different messages to different individuals.

In Quick and group SMS, the message being sent to the persons is the same while in bulk SMS, different messages can be sent to a large number of people. Bulk SMS makes this possible by using an excel file, which contains fields for name, mobile number and message. This file can be uploaded to the portal and the messages are sent to the respective recipients as specified in the excel sheet. The user can choose the excel file prepared by him with names, mobile numbers and messages and upload the same using the Choose File button. The user can then save the excel sheet by clicking on the Save File button. Multiple files can be uploaded in this manner for sending bulk SMS. These files can then be used to send SMS.

5. *Recent development in early warning dissemination in last 5 years* : 5.1. *Development of National Website* - IMD updated National Website with latest state of the art technology. IMD website introduced many new features like sub-division/District Warnings, Current weather display, Rainfall data in dynamic map , Crowd Sourcing Portal, Latest CAP updates, GIS based cyclone track, Cold wave/Heat wave warnings, Interactive map for Temperature & Heat wave, Interactive map for rainfall & Cloudiness etc.

URL of National Website - https://mausam.imd.gov.in/

Statistics shows that our National website are widely visited and referred by general public, national & state disaster management authority, central & state government agencies, media and other stake holders.

5.2. *Development of Mausam App* - Mausam mobile app has develop for India Meteorological department to help enhance dissemination activity of weather forecast and warning services. Mausam app is dedicated to general public & designed to communicate weather information and forecast in simple manner. Users can access observed weather, forecasts, radar images and warnings of impending weather events. Mausam App updated current temperature, humidity, wind speed and direction for 200 cities updated 8 times a day.

It issues three hourly warnings of localized weather phenomena & intensity for about 800 stations & districts

by state meteorological centres of IMD. App also issues alert twice a day for all districts for the next five days in colour code (Red, Orange and Yellow) to warn citizen of approaching weather.

To get information about lightning occurrence and its forecast by IMD/MoES in your area, users can visit :

(*i*) DAMINI app provides information of Lightning occurrence during the past 15 minutes and forecast for next 30 minutes.

(*ii*) RAIN ALARM app provides rainfall Nowcast around a user's location based on Doppler weather radar.

(*iii*) UMANG app (Unified Mobile Application for New-Age Governance) provides three hours severe weather forecast.

(*iv*) MEGHDOOT app provides three hours severe weather forecast.

(*v*) MAUSAM app provides three hours severe weather forecast.

All the above APPS are available on Android and IOS. You can get auto notifications from MAUSAM, MEGHDOOT, RAIN ALARM app in case of expected weather during next three hours in your area.

5.3. *Up gradation of VPN Links* - A virtual private network (VPN) is a technology that creates an encrypted connection over a less secure network. The benefit of using a VPN is that it ensures the appropriate level of security to the connected systems when the underlying network infrastructure alone cannot provide it (Bibraj *et al*., 2018). IMD has network of 57 VPN stations having bandwidth of 256kb to 10 Mbps. Since data from all sub-offices, DWR stations will come to Telecom Division, New Delhi, so the telecom division, New Delhi is connected to VPN network with a higher bandwidth, 10 Mbps link. VPN also facilitates the interconnectivity between two sub-offices or two Radar stations as all are connected in the same network. The data is send through the communication infrastructure of the VPN service provider through modem and is received at the router in the central server at New Delhi.

5.4. *Up gradation of Video Conferencing infrastructure* - As the beginning of the COVID pandemic unfurled, the working world as we knew it has changed and now video conferencing and media conference technology has become more essential than ever in connecting the modern workforce. Initially, IMD has video conferencing network upto the major sub offices of IMD but now we have video conferencing network and infrastructure upto the observatories level. These video conferencing systems are used for day-to-day discussion/meetings regarding weather forecasting, administrative matters in the country and abroad organizations like WMO and its sub offices.

5.5. *Development of API's* - API stands for Application Programming Interface. It is like messenger that takes our request to a system and returns a response back to us *via* seamless connectivity. IMD has developed API's for Nowcast warning, Rainfall warning, City weather forecast and Current weather. API's of IMD used by various stakeholders to extract data from our server and utilize the same for further applications developed by them. The stakeholders who are using IMD API's are Uttar Pradesh Government, Telangana Government, Kerala Government, Umang App, DD News, NDMA, Incredible India, KRC Network, NITI aayog etc.

The API for district wise Nowcast warnings can be accessed by following link:

https://mausam.imd.gov.in/api/nowcast_district_api.php?id=1

where 1 can be replaced by object id for a particular district and to access data for all districts the below mentioned URL can be used.

https://mausam.imd.gov.in/api/nowcast_district_api.php

5.6. *Introduction to Crowd sourcing Portal* - The India Meteorological Department has launched a public outreach initiative through a website where citizens will be able to record realized weather and can upload their local weather conditions. With this, people will be able to record real-time data. The inclusion of public participation helps IMD in increasing the efficiency, network, verification, and accuracy of the forecasts. The information can further be utilized for improving the department is forecast, especially in the short range.

6. *Results and Discussion* : 6.1. *Public Portal* - IMD has latest state of the art technologies systems like Mobile Seva, IVRS, AMSS, WIS, Website etc. to disseminate information / alerts / warnings etc well in advance during major events like cyclones, heat wave, cold wave and heavy rainfall which helps to minimize loss of lives and property. IMD also has latest state of art Website system, which is more popular, means of dissemination of information and is accessible by public, AMPHAN various stakeholders as well as disaster mitigation authorities. IMD website plays a very important role to update public regularly during cyclones

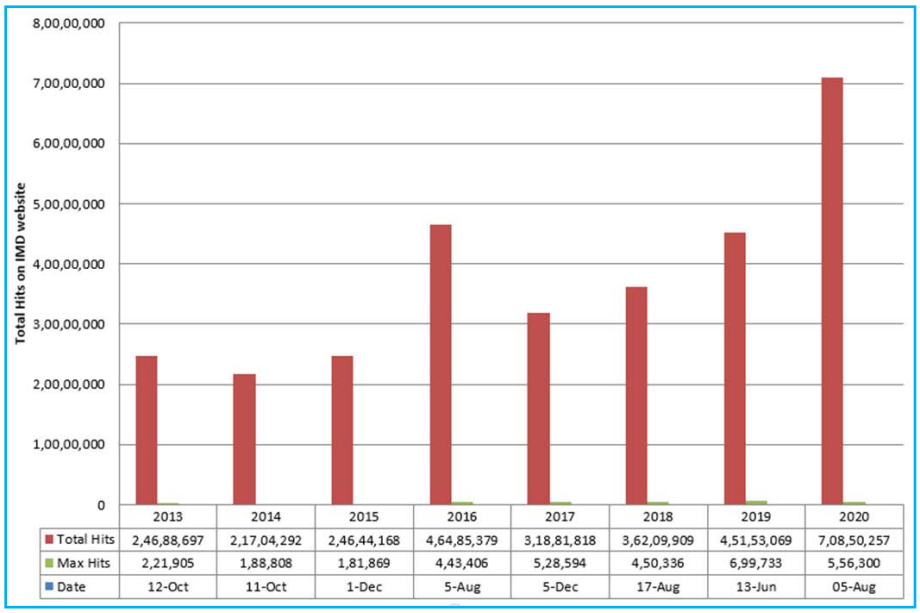


Fig. 5. Number of hits on IMD website during 2013-2020

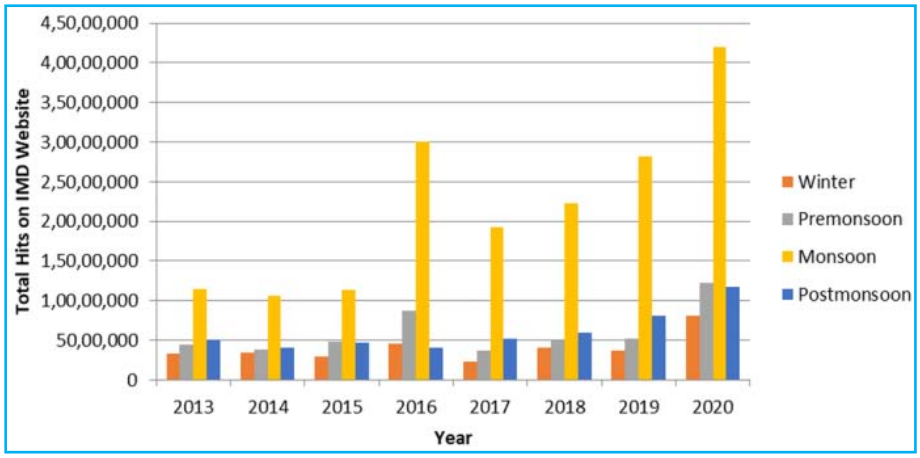


Fig. 6. Total number of hits on IMD website during different seasons

and other severe weather events. During Cyclone, number of hits on the website in a single day normally increases during bad weather or disaster period. Fig. 5 shows the total number of hits during years 2013-2020. It is clear from the figure that the hits are normally increased with years (indicating the increasing public awareness to access IMD website during such disaster and relying on it). The highest hits on a single day were on 12th Oct, 2013 (Cyclone Phalin), 11th Oct, 2014(Cyclone Hudhud), 1st Dec, 2015, 5th Aug, 2016, 5th Dec, 2017 (Cyclone Ockhi), 17th Aug, 2018, 13th Jun, 2019 (Cyclone Vayu) and 5th Aug, 2020 (Heavy rainfall warning over Konkan & Goa including Mumbai). With the help of information available on IMD website public gets authentically informed about warnings related to severe weather events like cyclone and heavy rainfall. Radar imagery, Satellite imagery, NWP products, 7days forecast, Nowcast, Monsoon forecast etc. are also updated regularly on IMD website for deeper analysis and information.

The monsoon rains are vital for farming output and economic growth in India, the world's second-biggest producer of rice, wheat, sugar and cotton. Farm sector shares for about 15% of India's nearly $2.9 trillion economy, Asia's third biggest. Fig. 6 shows the season wise total number of hits on IMD website. It is clear from the figure that number of hits on IMD website increases drastically during monsoon season for all the years. This indicates that public are more concerned about IMD's monsoon season forecasts in general.

Figs. 7(a-d). Hits on IMD website during Cyclone (a) FANI, (b) VAYU, (c) MAHA and (d) AMPHAN

The number of hits on IMD website during major cyclonic storms of 2019-2020 has also been analyzed. Some major cyclones analyzed are Cyclone FANI, Cyclone VAYU, Cyclone MAHA and Cyclone AMPHAN. The analysis details and results of findings are as follows.

On 3 May 2019 around 0230UTC, FANI (26 April-04 May 2019) made landfall near Puri, Odisha as an extremely severe cyclonic storm, with 3-minute sustained winds of 185 km/h (115 mph). The system maintained the cyclonic storm intensity for almost 21 hours even after landfall till 0000 UTC of 4th May. This made FANI the most intense storm to make landfall in India's Odisha state since the 1999 Odisha Super cyclone. The life period (Depression to Depression) of the system was 204 hours (8 days & 12 hours) against long period average (LPA) (1990-2013) of 134 hours (5 days & 14 hrs) for Very Severe Cyclonic Storm/ Extremely Severe Cyclonic Storm (VSCS/ESCS) categories over BOB during pre-monsoon season (Preliminary Report : IMD FANI, 2019). Fig. 7(a) shows Hits on IMD website during FANI cyclone which ran over the city Puri 60 kilometers south of the state capital, Bhubaneswar. IMD received appreciation from United Nations Office for Disaster Risk Reduction (UNDRR), WMO and other national & international scientific community and media for pin point accuracy of forecasts and warnings and excellent services provided during this cyclone.

Very Severe Cyclonic Storm (VSCS) "VAYU" originated from a low pressure area (LPA) which formed over southeast Arabian Sea and adjoining Lakshadweep & east central Arabian Sea (AS) in the morning (0830 IST) of 09th June 2019. It then moved northwards and intensified into a severe cyclonic storm (SCS) in the evening (1730 hrs IST) of the 11th June and into very severe cyclonic storm (VSCS) on the same day around midnight (2330 hrs IST) over the east central AS (Preliminary Report: IMD VAYU, 2019). Due to heavy rainfall warning over Saurashtra and kutch region on 13th &14th June we see maximum number of hits on 13thJune on IMD National website as shown in Fig. 7(b).

The Extremely Severe Cyclonic Storm (ESCS) 'MAHA' originated as a Low Pressure Area (LOPAR) over Equatorial Indian Ocean off south Sri Lanka coast in the forenoon (0600 UTC) of 28th October. It moved further northwestwards, intensified into a Cyclonic Storm (CS) 'MAHA' in the evening (1200 UTC) of 30th October over Lakshadweep and adjoining Southeast Arabian Sea & Maldives Area and further intensified into a Severe Cyclonic Storm (SCS) in the forenoon (0600 UTC) of 31st October over Lakshadweep and adjoining Southeast Arabian Sea. It moved across Lakshadweep Islands and

emerged into East Central (EC) Arabian Sea on the same day at night (1500 UTC). Moving northwestwards and maintaining intensity of SCS for 75 hours, it further intensified into Very Severe Cyclonic Storm (VSCS) in the afternoon (0900 UTC) of 03rd November over East Central Arabian Sea (EC AS). Then it moved west northwestwards and further intensified into an Extremely Severe Cyclonic Storm (ESCS) in the early morning (0000 UTC) of 04th November over EC & adjoining West central (WC) AS. The sudden increase of alert messages on 6th November due to the bulletin issued at 1210 hrs IST (around 0700 UTC) of 6th November, it was predicted that the system would instead skirt Saurashtra coast as a deep depression/depression and weaken gradually. Hence maximum number of hits were on 6 November, 2019 as shown in Fig. 7(c). Actually, it weakened into a well-marked low pressure area over northeast Arabian Sea and adjoining south Gujarat coast in the evening (1200 UTC) of 7th November. (Preliminary Report: ESCS MAHA over Arabian Sea)

During mid-May, 2020 we found sudden rise of hits on website due to incoming of Super Cyclonic Storm "Amphan". It was the first super cyclone formed in the Bay of Bengal after 1999. India Meteorological Department had predicted this Super Cyclone very accurately which helped to save lot of lives across Odisha and West Bengal coasts. Cyclone was formed on 16th May, 2020 and weakened into well marked low on 21st May, 2020. We can see from Fig. 7(d) that hits on our website are rising tremendously. More than 9 lakhs hits on our National website were seen on 20th May, 2020, the day of landfall of Cyclonic storm (AMPHAN) on West Bengal region.

6.1. *Mobile Seva* - In order to transform the entire ecosystem of public services through the use of information technology, the Government of India has launched the Digital India Programme with the vision to transform India into a digitally empowered society and knowledge based economy. Mobile Seva is an innovative initiative aimed at mainstreaming mobile governance in the country. It provides an integrated whole-of-government platform for all Government departments and agencies in the country for delivery of public services to citizens and businesses over mobile devices.

The meteorologists at IMD formulate warning messages based both on self-produced and numerical-model-generated forecasts received from the Regional Specialized Meteorological Center (RSMC) in New Delhi, India, with most of the emphasis on self-produced forecasts. In cyclone emergency situations, IMD disseminates new warning messages as special weather bulletins, at every hour to three hours depending on the severity and motion characteristics of the approaching TC. Recently, IMD disseminated 3,76,535 special warning SMS during the 10-day lifespan of ESCS MAHA and 7,83,552 special warning SMS during the 09-day lifespan of ESCS FANI. In each warning message, information was added, changed, according to the requirement.

TABLE 2

SMS disseminated during 2019-2020

Year	Cyclone	Number of SMS disseminated during 2019-2020
2019	Cyclone Pabuk (04-08 Jan)	299998
	ESCS Fani (26 Apr - 04 May)	783552
	VSCS Vayu (10-17 Jun)	287575
	Deep depression (06-09 Aug)	167625
	VSCS Hikaa (22-25 Sep)	60142
	SUCS Kyarr (24Oct - 02 Nov)	180820
	ESCS Maha (30 Oct - 07 Nov)	376535
	VSCS Bulbul (05-11 Nov)	434421
2020	Super Cyclonic Storm AMPHAN (16-21 May)	645190
	Severe cyclonic storm NISARGA (01-04Jun)	276595

(*Source* : CDAC SMS services used by IMD https://services.mgov.gov.in/login.jsp)

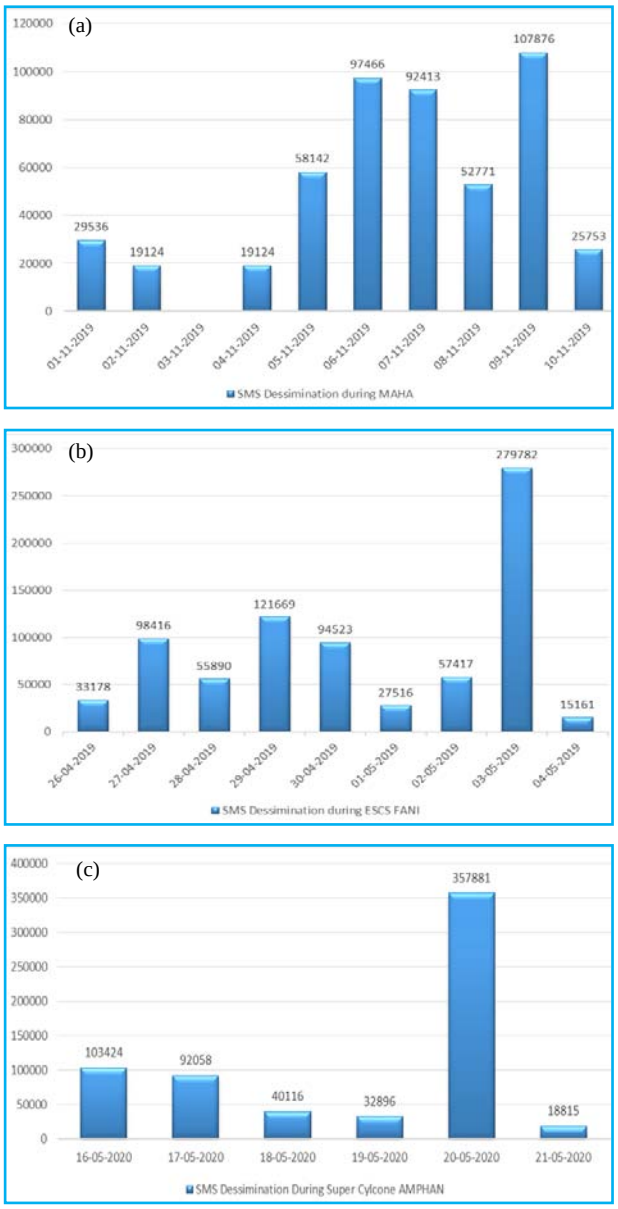
Table 2 shows, Number of SMS disseminated during 2019-2020.

We have analyzed the SMS dissemination during major cyclonic storms MAHA, FANI and AMPHAN of 2019-2020. Also, we analyzed the SMS dissemination during the period November, 2018 to May, 2020. Figs. 8 (a-c) show SMS dissemination during ECS MAHA, ESCS FANI and Super Cyclone AMPHAN.

India Meteorological Department has taken various initiatives in recent years for improvements in the dissemination of weather forecasts and warning services based on latest tools and technologies.

7. *Future Projects of IMD in Telecommunication* :

7.1. *CAP* - Common Alerting Protocol (CAP) is a XML based standard message format especially designed for all-



Figs. 8(a-c). SMS Dissemination during ESCS (a) MAHA, (b) FANI and (c) AMPHAN

Media, All-Hazard, multi-hazard and communications. The message can be targeted to the general public, designated groups such as civic authorities or responders or to specific individuals. CAP defines a digital message format compatible with all kinds of existing and emerging systems - data networks as well as broadcast radio and TV. CAP useful for multilingual and special-needs populations.

7.2. *XML based AMSS* - IMD is proposed to procure XML based automatic data switching system with state of art technology at four airport locations New Delhi, Kolkata, Mumbai and Chennai. The AMSS system as a whole will be WIS (WMO Information System) and WIGOS (WMO Integrated Global Observing System) compliant. The coming system going to have latest technology and functions like handling and generation of ICAO messages, Conversion of ICAO messages into XML format, Generation of Aviation Met bulletins, system capable of handling messages generated under IWXXM and AFTN message handling system etc.

7.3. *Social Media/Mass Media* - Social media is somewhat of a new concept and usage of it dramatically increases during natural disasters like Cyclones, flood, heavy rainfall, bad weather, heat and cold waves etc. IMD intends to hire consultancy services of a credible professional manpower for handling, managing and maintaining all the mass media handles of IMD for outreach of a vast range of IMD services to media, public, disaster managers and stakeholders. IMD continuously share weather updates to public through various social media channels like Facebook, Twitter, Youtube, Webcast etc. To increase the outreach of IMD, hiring of professional manpower is an extraordinary step by IMD.

7.4. *India - Varsamana Project* - The Varsamana Project can be considered as the cornerstone of the IMD modernization program launched on 2006. This includes setting up state of the art and completely integrated information systems at a central level in New Delhi, as well as in 6 Regional Centers, Meteorological Centers and airports. Now, IMD is planning to upgrade this project and include latest development in the system which helps forecasters to forecast weather. The new upgrade system has latest features like fast processing speed of data, better visualization, less dependence on hardware, ability to ingest new formats of data, Cloud based structure etc.

7.5. *NKN facility* - National Knowledge Network project is aimed at establishing a strong and robust Indian network which will be capable of providing secure and reliable connectivity. NKN with its multi-gigabit capability aims to connect all universities, government departments, research institutions, libraries, laboratories, healthcare and agricultural institutions across the county to address such paradigm shift. Presently, IMD has NKN connectivity at IMD H.Q., 6 Regional Met. Centers, CRS Pune and M.C. Bhubneshwar. IMD sends a proposal to NIC to connect all sub offices of IMD with NKN connectivity includes Radar stations, Aerodrome Met Offices, Meteorological centers etc.

7.6. *Central Server and Storage* - IMD regularly upgrading IT infrastructure of the Operational Centre's / Divisions as per requirement and upgrading in technology. IMD procuring Central Server and Storage for the

following functional purposes such as Doppler weather radar data Centre, e-office backup server, Environmental Monitoring and Research Centre archiving data, Hosting of web application for cyclone data and data processing & archival of data for Nowcasting. Managing the Central Server is more effective Instead of hosting and maintain these application individually causes more manpower, hardware requirement, software application etc.

7.7. *Open WIS Project* - WMO information system connects all National Meteorological and Hydrological Services and regions together for data exchange, management and processing. Users with access privileges can easily find and retrieve all the weather, climate and water data and products and visualize in one place. WIS also giving facility to publish data or products. IMD planning to have a web-based user interface so that all researchers, scientist and sub-offices can visualize and accessed the data as per requirement.

7.8. *Uniform Departmental Website* - At present in IMD has more than 16 websites for different RMCs and MCs functioning with the help of NIC and private vendors. All these websites are not uniform and identical with respect to their appearance, background colors, contents outlay etc. As per the Government guidelines the websites should be content managed and it is to be in English, Hindi and Regional language. ISSD taken the initiative to make all departmental websites uniform with National website. There are many advantages of this project such as we can centrally managed the website of all different departments, cost reduction of hardware , automatic updating of data etc.

8. *Conclusion* - There is a fundamental need within meteorology, oceanography, hydrology and climate related sciences for understanding past and present states of the environment. This requires the collection and exchange of very large amounts of data / information. The communication systems of IMD have given a thrust to achieve quick and reliable exchange of large volumes of almost all data types and related products. This is quite useful for forecasters, disaster managers and a large variety of other users. However, responses/feedback on various dissemination systems need to be monitored continuously to provide better services by adopting new technology, upgrading bandwidth as well as systems etc. It is clear from the above discussion that the Meteorological communication system plays a vital role for forecasting and information dissemination to public/ authorities engaged in disaster mitigation to minimize the losses of lives and property.

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