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Important Terms

Rain

Liquid precipitation in the form of water drops of radius between about 500 and 2500 µm.

Shower

Solid or liquid precipitation from a vertically developed cloud is designated a shower and is distinguished from the precipitation, intermittent or continuous, from layer clouds. Showers are often characterized by short duration and rapid fluctuations of intensity (by convention, with radius of water drops more than 2500 µm).

Hail

Solid precipitation in the form of balls or pieces of ice (hailstones) with diameters ranging from 5 to 50 mm or even more.

Thunderstorm

One or more sudden electrical discharges manifested by a flash of light (Lightning) and a sharp rumbling sound (thunder).

Dust storm

An ensemble of particles of dust or sand energetically lifted to great heights by a strong and turbulent wind.[1]

Climate Change

The increase in greenhouse gases in the atmosphere causes climate change which has significantly influenced the water balance by causing changes in evapotranspiration rates, temperature, and rainfall. As the earth's temperature and rainfall continues to rise, one can expect a significant impact on our fresh water supplies with the potential for devastating effects on these resources.[2]

Flash Flood

Flash floods are short-term events, occurring within 6 hours of the causative event (heavy rainfall, dam break, levee failure and rapid snowmelt) and often within 2 hours of the start of high intensity rainfall. A flash flood is characterized by a rapid stream rise with depths of water that can reach well above the banks of the river, carrying with it large amounts of debris and causing high damage due to its suddenness. Flash flood damage and most fatalities tend to occur in areas immediately adjacent to the river where they weaken the soil and cause mud slides, damaging homes, roads and property.[3]

Urban Flooding

As urbanisation leads to developed catchments which increases the flood peaks from 1.8 to 8 times and flood volumes by up to 6 times. Consequently, flooding occurs very quickly due to faster flow times, sometimes in a matter of minutes. Urban areas are centres of economic activities with vital infrastructure which needs to be protected 24x7. Urban flooding has sometimes resulted in loss of life, damage to property and disruptions in transport and power, bringing life to a grinding halt, causing untold misery and hardships. Even the secondary effects of possible epidemics and exposure to infection takes further toll in terms of loss of livelihood, human suffering, and, in extreme cases, loss of life.

[1] http://imd.gov.in/section/nhac/termglossary.pdf
[2] https://www.mdpi.com/2306-5338/5/1/12/pdf
[3] http://www.ssdma.nic.in/Home/ContentFor?MenuID=4&ContentFor=Content_SubMenu

Introduction

A special feature in India is that we have heavy rainfall during monsoons. There are other weather systems also that bring in a lot of rain. Storm surges can also affect coastal cities/ towns. In addition, the urban heat island effect has resulted in an increase in rainfall over urban areas. Global climate change is resulting in changed weather patterns and increased episodes of high intensity rainfall events occurring in shorter periods of time. Then the threat of sea-level rise is also looming large, threatening all the coastal cities. Cities/towns located on the coast, on riverbanks, upstream/ downstream of dams, inland cities and in hilly areas can all be affected.[4]

A research conducted by Singh, Sharma, Singhal and Kaur, 2018 –
Trend Analysis of Rainfall: A Climate Change paradigm, stated that climate change related issues are at an alarming rate. Changes in rainfall patterns, intensity and extreme events are some of the impacts of climate change. Increasing urbanization and unplanned developmental activities, the air quality is deteriorating. The research mainly focused on the rainfall variability due to increasing level of greenhouse gases. Rainfall data of 65 years (1951-2015) of Safdarjung station of Delhi was collected from Indian Meteorological Department and analysed using Mann-Kendall test for time-series data analysis. Through this analysis it can be projected that there will be increase in pre-monsoon rainfall than the actual monsoon season. Pre monsoon rainfall causes cooling effect and results in drier monsoon season. This will increase the vulnerability of communities towards Climate Change and effect related developmental activities.[5]

Major weather systems

Southwest Monsoon

Southwest monsoon (also known as Summer Monsoon) season (June-September) is the main rainy season in India during which the country receives over 70 to 75 per cent of its annual rainfall. The regions which receive the largest rainfall are along the west coast of India, north-eastern states, West Bengal and coastal Orissa. Heavy rainfall is a day-to-day occurrence during this season. In India, urban flooding is mostly due to heavy rainfall during this season. Embedded in monsoon system, there are other synoptic systems such as vortices (lower/mid-tropospheric cyclonic circulation, off-shore vortices along the west coast, low pressure areas, depressions and cyclones), troughs (monsoon trough, off-shore trough along the west coast, north-south troughs over peninsular India during break monsoon conditions) and east-west wind shear zone in the lower troposphere that largely enhance the monsoon rainfall activity. Besides monsoon systems, orography plays a very crucial role in enhancing rainfall distribution. Heavy rainfall associated with each of these individual systems, by and large, follows a set pattern.

Northeast Monsoon

After the retreat of southwest monsoon, northeast monsoon (also known as Winter Monsoon) starts around the middle of October, causing significant amount of rainfall over southern parts of peninsular India covering South Andhra Pradesh, Tamil Nadu, Puducherry, Kerala, South Karnataka, Andaman & Nicobar Islands and Lakshadweep. Heavy rainfall is a common occurrence over these areas during this period of northeast monsoon covering middle of October to end of December.

Depressions and Cyclones

Depressions are low pressure systems around which wind blows in an anti-clockwise manner in the Northern Hemisphere and where wind speed is between 31 km/h and 49 km/h over the sea. In India, a depression may originate over the sea or land and may cause copious rainfall along its path. Some depressions originating over the ocean may develop into tropical cyclones where wind speed in the circulation is 62 km/h or more. The tropical cyclone can intensify and move towards land. These are associated with hazards like very strong winds, very heavy rainfall and storm surges. After crossing the coast, they weaken into depressions and move across the land providing heavy to very heavy rainfall along its path over much of the land it covers.

[4] https://ndma.gov.in/images/guidelines/management_urban_flooding.pdf
[5] http://granthaalayah.com/Articles/Vol3Iss9/08_IJRG15_B09_79.pdf

Western Disturbances

Western disturbances are extra-tropical weather systems (low pressure areas) which move from west to east, regularly, causing widespread rainfall over the extra-tropical areas (covering the states of Haryana, Himachal Pradesh, Jammu & Kashmir, Punjab, Delhi, Rajasthan and Uttarakhand) round the year. Their frequency and intensity vary from season to season. These are more frequent and more intense between November and March.

Thunderstorms

Thunderstorms are are localized short duration transient weather phenomena. These weather systems can also cause localized heavy to very heavy rainfall sometimes leading to local flooding. Thunderstorms are very frequent and sometimes very severe in summer, especially over north-east India causing heavy rainfall and floods. Thunderstorms during the monsoon season, though less frequent, greatly enhance the quantity of rainfall locally and are the major source of short duration heavy rainfall leading to flash floods/ flooding.

Cloudburst

Cloudburst is a disastrous weather event in which, heavy rainfall occurs over a localized area at a very fast rate. The rate of rainfall may be of the order of 100 mm/hr. Cloudburst in India occurs during the monsoon season over the orographically dominant regions like Himalayan region, north-eastern states and Western Ghats and in other areas as well. Associated convective clouds can extend upto a height of 15 km. [6]

Table 1.4: Description Terms for the Spatial Distribution and Intensity of Rainfall

I. Spatial Distribution of Rainfall		
Distribution	**No. of Places**	**Description**
Isolated	One or two places	<25% of stations gets rainfall
Scattered	At a few places	(26–50)% of stations gets rainfall
Fairly Widespread	At many places	(51–75)% of stations gets rainfall
Widespread	At most places	(76–100)% of stations gets rainfall
Dry	-	No station reported rainfall
II. Intensity of Rainfall		
Descriptive Term used	**Rainfall amount in mm (24 hours)**	
No Rain	0.0	
Very Light Rain	0.1- 2.4	
Light Rain	2.5 – 7.5	
Moderate Rain	7.6 – 35.5	
Rather Heavy	35.6 – 64.4	
Heavy Rain	64.5 – 124.4	
Very Heavy Rain	124.5 – 244.4	
Extremely Heavy Rain	>244.5	
Exceptionally Heavy Rain	When the amount is a value near about the highest recorded rainfall at or near the station for the month or season. However, this term will be used only when the actual rainfall amount exceeds 120 mm.	

Source: *India Meteorological Department*

[6] https://ndma.gov.in/images/guidelines/management_urban_flooding.pdf

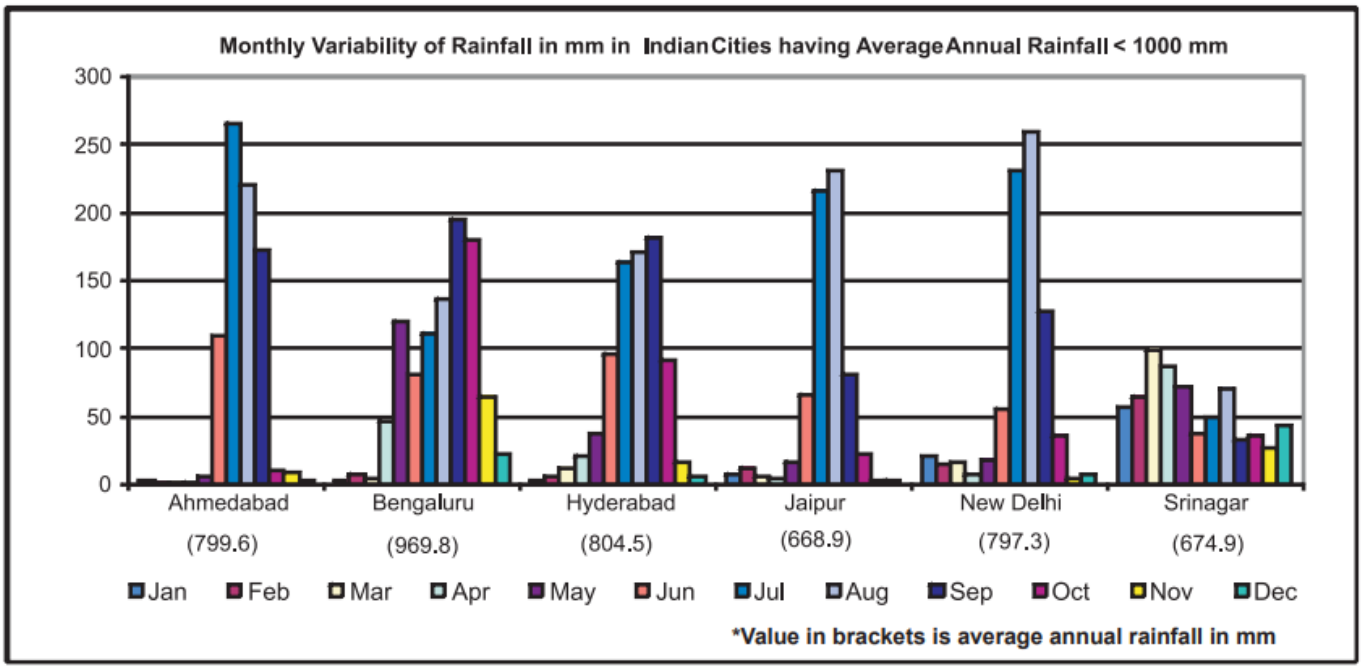

Fig. 1.1 Monthly Variability of Rainfall in some important Indian Cities (Compiled on the basis of IMD Data)
Note: Different scales are used for rainfall for different categories of cities

Methodology

The rainfall statistics is computed based on the receipt of rainfall data from about 3500 stations spread over the entire country. Based on daily rainfall data of these stations, the rainfall of all the districts are computed and using the rainfall of the districts, rainfall statistics for the Meteorological (Met.) Subdivisions, states, the four broad regions and for the whole country have been computed. The statistics is provided on monthly, 4 seasons i.e. Winter (Jan-Feb), Pre-Monsoon (Mar-May), Southwest (SW) Monsoon (Jun-Sep) and Post-Monsoon (Oct-Dec), and on annual basis.

Emergency response system during Gujarat floods 2006

The flood scenario in Surat

Surat district saw one of the worst floods in all of Gujarat in 2006. Surat is located in south Gujarat and Surat city has a most vibrant economy with zero percent unemployment, owing mainly to the textile and diamond industries. It has a population of 2.87 million with a high population density of 21,673 persons per sq km in the old city limits (Census 2001). The city is located by the river Tapi and has a 6 kilometres coastline along the Arabian Sea. It has been prone to floods since centuries. The months of July to September are high-risk periods when rivers and drains swell due to rains in upstream regions. The average annual rainfall (1995-2004) in Surat city is 1255 mm (Source SER, Government of Gujarat 2005-06). The Dangs district has a high average annual rainfall of 2545 mm and the downstream flow usually exacerbates Surat's vulnerability to floods. In Surat city, the 2006 flood was unprecedented. Of the seven municipal zones, six had flood water standing around for at least 3 days. Water logging was one of the main reasons for the severity of damage. Low-lying city outskirts with shops, establishments and shelters built on the flood plain along with either banks of the Tapi were inundated with up to 18 feet of flood waters for several days.

The severity was partly due to a combination of unusual natural occurrences. It rained continuously for three days in catchment areas of river Tapi in neighbouring Maharashtra State, forcing the dam authorities in Maharashtra to release not just 125,000 (1.25 lakh) cusecs of water as originally announced but a total of 800,000 (8 lakh) cusecs of water over a 3-day period. The third day of flooding was a full moon night, the sea was on high tide, and the water could not drain out into the sea. The water at the highest point rose up to 20 feet inside the city. The flood protection wall too collapsed leaving nothing between the fury of the waters and human habitations in those areas. Main administrative areas, which had seen highest flood water levels of 7 feet during earlier floods, did not

anticipate that water would rise up to 10-12 feet and some offices, including that of the District Collector, had to be shifted twice. The other major reason for the destruction was waterlogging, which it is believed, was aggravated by illegal buildings having come up, many of them in the last four years on the natural draining waterways. The administration was unable to gauge the severity of the disaster because it was apparently not able to assess the extent of waterlogging. Its assessment was based on the last severe floods of 2002. On the second day power petered out and with it, the major communication channel - the mobile phones were jammed or became non-functional with no way to recharge batteries. Wireless systems went on a blink and power generators, normally stationed in the basement of buildings lay under water. The city had run out of supplied drinking water and sanitation was a nightmare. With this scenario in a city with an extremely high population density.[7]

Owing to intense cumulative rainfall received from South-West Monsoon in 2006 many parts of Central (Gujarat & Maharashtra), Eastern and Peninsular India was overcast with widespread excess precipitation resulting in flooding. It was forecasted on 21st September 2006, Gujarat's west coastal areas would be affected.

The Village Disaster Management Teams (VDMTs) of three members each, were well prepared to meet any challenge, actually better prepared and equipped, because just four days earlier a mock drill for evacuation to safe shelters had been conducted by the Mamlatdar's office with the help from the UNDP Project Support Officer (PSO). The specified responsibility of each of the seven Disaster Management Teams (DMTs) in Gandvi as in other villages is Early warning and communication;

1. Search and rescue;
2. First aid;
3. Evacuation and temporary shelter;
4. Relief and co-ordination;
5. Water and sanitation; and
6. Damage assessment.

Emergency response from administration

The nearby schools had been converted into rescue centres with sanitation, security and food arrangements. The SMC had activated the flood warning siren from all 36 centres. It had deployed 20 of its powerboats to evacuate people from low-lying slums. Yet many of the community preferred to wait Owing to intense cumulative rainfall received from South-West Monsoon in 2006 many parts of Central (Gujarat & Maharashtra), Eastern and Peninsular India was overcast with widespread excess precipitation resulting in flooding. It was forecasted on 21st September 2006, Gujarat's west coastal areas would be affected.[8]

Do's and Don'ts

1. There is a possibility of spread of water borne diseases after flood, and hence medical treatment should be taken immediately.
2. Do not enter deep, unknown waters.
3. Do not go near the riverbank even after the floodwater has receded.
4. Sprinkle medicines in the stagnant dirty water.
5. Inspect your house for any cracks or other damage. Check all the walls, floor, ceiling, doors and windows, so that any chance of house falling down can be known and you can be aware about the immediate danger.
6. If the floodwater has entered the house or has surrounded the house, then it is advisable not to enter such house.
7. Keep listening to weather forecast on radio and television.
8. Move to your residence only when instructed by the competent authority.
9. Inform the competent authority/officer for restoration of the necessary connections like gas, electricity, telephone, drainage, etc.

[7] https://www.undp.org/content/dam/india/docs/towards_a_disaster_resilient_community_in_gujrat.pdf
[8] https://www.undp.org/content/dam/india/docs/towards_a_disaster_resilient_community_in_gujrat.pdf

10. Beware of the various insects or poisonous snakes that may have been dragged inside the house along with the floodwater.
11. Destroy the food commodities that have been affected by floodwater.
12. Check properly all the electric circuits, floor level furnace, boilers, gas cylinders, or electric equipments like motor pump etc.
13. Check whether any inflammable or explosive item has not entered along with the floodwater.
14. Switch off the main electric supply, if any damage is noticed to the electric equipments.
15. If you find any breakage in the drainage system stop using latrines and do not use tap water.
16. Do not use polluted water.
17. Sewerage system should be checked and any damage should be repaired immediately so as to curtail spread of diseases.
18. Empty the water clogged in the basement slowly with help of water pump so that damage to infrastructure can be minimised
19. Check gas leakage which can be known by smell of gas or by hearing the sound of leakage; immediately open all windows and leave the house. ¾ Boil drinking water before usage and drink chlorinated water.
20. Eat safe food.
21. Rescue work should be undertaken immediately after flood situation as per the instruction. Do not follow any shortcut for rescue work.
22. Do not try to leave the safe shelter to go back home until the local officials declare normalcy after flood and instruction to return home are not given. [9]

What to do before a flood

1. Avoid building in flood prone areas unless you elevate and reinforce your home.
2. Elevate the furnace, water heater, and electric panel if susceptible to flooding.
3. Install "Check Valves" in sewer traps to prevent floodwater from backing up into the drains of your home.
4. Contact community officials to find out if they are planning to construct barriers (levees, beams and floodwalls) to stop floodwater from entering the homes in your area.
5. Seal the walls in your basement with waterproofing compounds to avoid seepage.

If a flood is likely to hit your area, you should:

1. Listen to the radio or television for information.
2. Be aware that flash flooding can occur. If there is any possibility of a flash flood, move immediately to higher ground. Do not wait for instructions to move.
3. Be aware of streams, drainage channels, canyons, and other areas known to flood suddenly. Flash floods can occur in these areas with or without such typical warnings as rain clouds or heavy rain.

If you must prepare to evacuate, you should:

1. Secure your home. If you have time, bring in outdoor furniture. Move essential items to an upper floor.
2. Turn off utilities at the main switches or valves if instructed to do so. Disconnect electrical appliances. Do not touch electrical equipment if you are wet or standing in water.
3. If you have to leave your home, remember these evacuation tips:
4. Do not walk through moving water. Six inches of moving water can make you fall. If you have to walk in water, walk where the water is not moving. Use a stick to check the firmness of the ground in front of you.
5. Do not drive into flooded areas. If floodwaters rise around your car, abandon the car and move to higher ground if you can do so safely. You and the vehicle can be quickly swept away. [10]

[9] http://www.gsdma.org/uploads/Assets/dos-and-donts/flooddos-donts06152017124246671.pdf
[10] https://ndma.gov.in/en/national-plan/66-citizens-corner/natural-disaster/floods/518-do-s-and-don-ts.html