UNIT 7 CLIMATE VARIABILITY AND EXTREME WEATHER EVENTS

Structure

7.1 Introduction
7.2 Objectives
7.3 Climate Change
7.4 Extreme Weather Events
7.5 Drought
7.6 Extreme Heat
7.7 Extreme Precipitation
7.8 Tropical cyclones/Hurricanes
7.9 Extratropical storms/Tornadoes
7.10 Wildfires
7.11 Let Us Sum Up
7.12 Key Words
7.13 Suggested Further Reading/References
7.14 Answers to Check Your Progress

7.1 INTRODUCTION

It has been observed that in recent years, there has been an increase in frequency and magnitude of extreme weather events. These weather events are considered extreme if they differ from similar weather events of that area by 90-95%. Further, to identify the weather events of a region, their historical record of weather is examined. Examples include unusually high or low temperature, precipitation, winds or any other parameters such as wildfires, droughts and floods.

With rising awareness about climate change due to both natural and human-induced factors, it has been projected that global warming would cause and increase in hot temperature extremes and occasional lower temperature extreme on daily as well as seasonal time scales. Under RCP8.5 (Representative Concentration Pathway), by the end of the 21st century, a current 20-year high temperature event will occur more frequently on land and a current 20-year low temperature event will become very rare.

A new scientific approach known as 'extreme event attribution' is being practiced where computer models are used to simulate weather conditions and different scenarios are compared to identify how global warming or any other factor has affected extreme weather events. Attribution scientists aim to quantify the extent of human-induced climate change alters the likelihood and intensity of extreme weather events. An example of extreme event

attribution of Hurricane Harvey in Texas in 2017 is very high rainfall of 60 inches that worsened the flooding and increased the likelihood of storm.

The website Carbon Brief has published an update of its attribution studies titled "Attribution of Extreme Weather Events in the Context of Climate Change" (Fig. 7.1) that have looked into the impact of climate change on extreme weather events around the world. The vertical axis corresponds to the confidence in attribution science and the horizontal axis indicates the level of understanding of how climate affects that type of event.

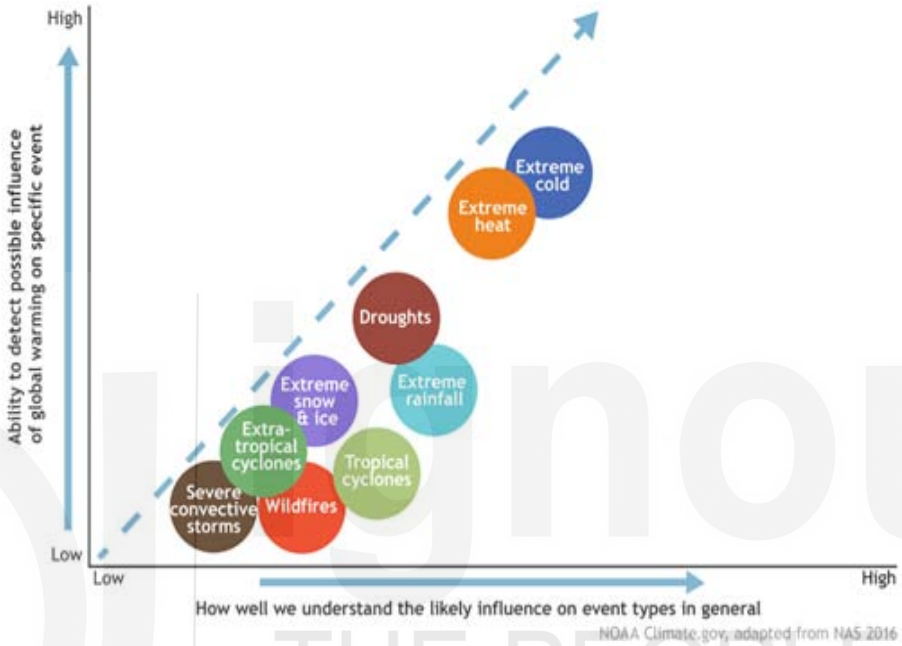

Fig. 7.1: Attribution of Extreme Weather Events in the Context of Climate Change (Source: NAS, 2016)

It is pertinent to mention that many scientists are of the opinion that global climate change has led to increase in frequency and magnitude of extreme weather events such as heat waves, droughts, floods, storms etc. Further, anthropogenic role in climate change has further aggravated the occurrence and intensity of extreme weather events. For example, sea level rise due to climate change adversely affects the coastal storms. Further, rising global temperatures due to global warming pose additional stress on areas affected by drought due to higher temperatures. All these examples point towards the role of climate change in increasing the intensity and frequency of extreme weather events. Through this unit, we would be discussing climate variability and extreme weather events.

7.2 OBJECTIVES

After studying this unit, you should be able to:

- define the extreme weather event; and
- discuss the extreme weather events.

7.3 CLIMATE CHANGE

Climate change refers to the change in the normal weather patterns around the world for an extended period of time. Many evidences such as rising sea level, shifting of tree lines, loss of sea ice, increased frequency of heat waves and drought, shrinking of glaciers and so on, indicate towards changing climate of the Earth. The United Nations has set up an organization known as Intergovernmental Panel on Climate Change (IPCC) for assessing the science related to climate change. IPCC is of the opinion that the extent of climate change effects on individual regions will vary over time depending on the adaptation capacity of the community as well as the environment of that region. Further, the temperature increase forecasted by IPCC is 1-3°C all over the globe, which would be beneficial for some regions while disadvantageous for a few. However, the disadvantages far outweigh the positive effects of climate change.

Further, it is projected that global climate will continue to change even beyond this century depending on the amount of greenhouse gases emitted globally, that heat up the earth's atmosphere by preventing passage of longwave radiations back to the space; and also, by earth's response to those greenhouse gas emissions.

7.4 EXTREME WEATHER EVENTS

The definition of an extreme event is quite varied depending on the impacts caused by these events or on the basis of magnitude and intensity of these events. It may range from droughts, tsunamis and earthquakes to epidemics or explosion as well. These extreme events have been gaining greater attention in the last few years due to increase in frequency and magnitude of extreme weather and climate events; as well as due to increase in vulnerability due to high population growth, lifestyle changes and urbanization in regions which should ideally have been buffer zones during the onset of disaster such as floods. Examples include building settlement areas on river banks or in coastal regions prone to tsunamis or cyclones.

If we look at the chronology of the development of the term 'extreme event', it was first used for rainfall intensity and frequency in a report by the National Weather Service, earlier known as U.S. Weather Bureau (U.S. Weather Service, 1959). The word 'extreme' has been derived from the Latin 'extremus' meaning "utmost" while 'event' originates from the Latin 'evenire' meaning "to come" (Weekley, 1921). Thus, extreme refers to the process of rare occurrence or of low probability or as outliers to the normal condition; while event describes a non-stationary situation. Thus, an extreme weather event refers to the occurrence of a very high or very low value of a weather variable as compared to its threshold level in a specific region. This is illustrated in the form of extreme weather and climate events such as heat waves and drought which are a manifestation of climate change. Over the last

three decades, the world has witnessed prolonged droughts, excessive precipitation, frequent floods, fewer colder days and higher temperatures. This is often attributed to human-induced climate changes. Many factors influence extreme weather events.

Various mechanisms have been developed all over the world to assess the extreme weather events. For example, U.S Records is a tool that lists daily, monthly and all-time data for weather stations located across the United States. Besides, the National Climate Extremes Committee (NCEC) was established in 1997 in US to study the extreme events and ponder upon the meteorological measurements by NOAA (National Oceanic and Atmospheric Administration) and State Climate Extremes Committee (SCEC) in 2006 to evaluate the climatological records of individual states in US. International Best Track Archive for Climate Stewardship (IBTrACS) provides information pertaining to the distribution, frequency, and intensity of tropical cyclones worldwide. Also, various reports such as Special Reports on Extreme Climate Events and Global Hazards Report focus on extreme events around the world. NOAA's National Centres for Environmental Information (NCEI) hosts and provides public access to abundant environmental information on Earth that includes atmospheric, coastal, oceanic and geophysical data.

In the following section, let's study some extreme weather events arising out of climate change.

7.5 DROUGHT

Drought is a climate anomaly characterized by temporary reduction in water or moisture availability significantly below the normal amount for a specific period. This could be due to a single factor of insufficient or irregular rainfall, or a higher water need or a combination of multiple factors. The reason for concern of drought is that if it persists for longer periods, it can cause adverse effects on humans, vegetation, livestock as well as ecological systems that undergo drought. Globally, drought is the second-most geographically extensive hazard after floods of the earth's land area. The percent of area affected by serious drought has doubled since 1970. In recent years, droughts have been occurring frequently, and their impacts are being aggravated by the rise in water demand and the variability in hydro-meteorological variables due to climate change.

In general, four types of drought are recognised: meteorological drought, hydrological drought, agricultural drought and socioeconomic drought. Meteorological drought is defined as a lack of precipitation over a region for a period of time. Hydrological drought is related to a period with inadequate surface and subsurface water resources for established water uses of a given water resources management system. Agricultural drought, usually, refers to a period with declining soil moisture and consequent crop failure. This does not include any reference to surface water resources A decline of soil

moisture depends on several factors which are affected by meteorological and hydrological droughts along with differences between actual evapotranspiration and potential evapotranspiration. Socio-economic drought is associated with failure of water resources systems to meet water demands and thus associating droughts with supply of and demand for water. Socio-economic drought occurs when the demand for water exceeds supply as a result of a weather-related shortfall in water supply. In rainfed areas, drylands are more prone to 'drought'. Severe drought can affect livestock and crops in agriculture; leading to food price instability, famine; water transport system; roadways; increase the probability of wildfires; scarcity of hydropower and thus additional energy stress coupled with increased electricity demand. Resilience towards drought can be built by conserving water, enhancing water efficiency, stormwater management, emergency planning for drought, and planting drought-resistant crops.

Various mechanisms have been explained regarding contribution of climate change to drought. The first and foremost factor in this is the erratic monsoon patterns and its deviation from the normal or predicted rainfall. Further, lesser rainfall coupled with higher temperatures create moisture stress in plants due to increased evapotranspiration. As a result, the amount of water needed for evapotranspiration exceeds the total amount of moisture available in soil. Further, it has also been hypothesized that droughts can persist through a "positive feedback," where dry soils and reduced plant cover can further hamper precipitation in an already dry area.

Further, it is estimated that relatively wet places, such as the tropics, and higher latitudes will get wetter, while relatively dry places in the subtropics will become drier. The recent studies on droughts in United States indicate that 81% of area suffered severe economic drought.

In the Indian context, every year since 2015, the country has faced severe drought in many states. It has been estimated that during the last year (2019), about 42% of geographical area of the country faced severe drought and about 50 million people were severely affected by drought. According to the Drought Early Warning System, Rajasthan, Bihar, Jharkhand, Gujarat, Maharashtra, Tamil Nadu and Telangana were the states worst affected by drought. In 2019, 44% of India's area was under drought of one type or the other due to scanty rainfall, delay in monsoons and increased heatwaves. Even in 2020, almost one-fifth of India's districts faced drought-like conditions as per reports by India Meteorological Department (IMD).

7.6 EXTREME HEAT

It has been observed that all over the world, the frequency and intensity of hot days has been increasing in the last few decades; while the number of cold days annually has been decreasing. Further, if greenhouse gas emissions are not significantly reduced, the coldest and warmest daily temperatures are expected to increase by at least 5 degrees F in most areas of United States.

The National Climate Assessment estimates the annual number of days with a heat index above 100 degrees F will double, and days with a heat index above 105 degrees F will triple, nationwide, when compared to the end of the 20th century. Figure 7.2 represents the projected changes in the number of days per year in United States with a maximum temperature above 90°F and a minimum temperature below 32°F. Changes are the difference between the average for mid-century (2036–2065) and the average for near-present (1976–2005) under the higher scenario (RCP8.5). This map depicts a weighted multi-modal mean of 32 climate model projections.

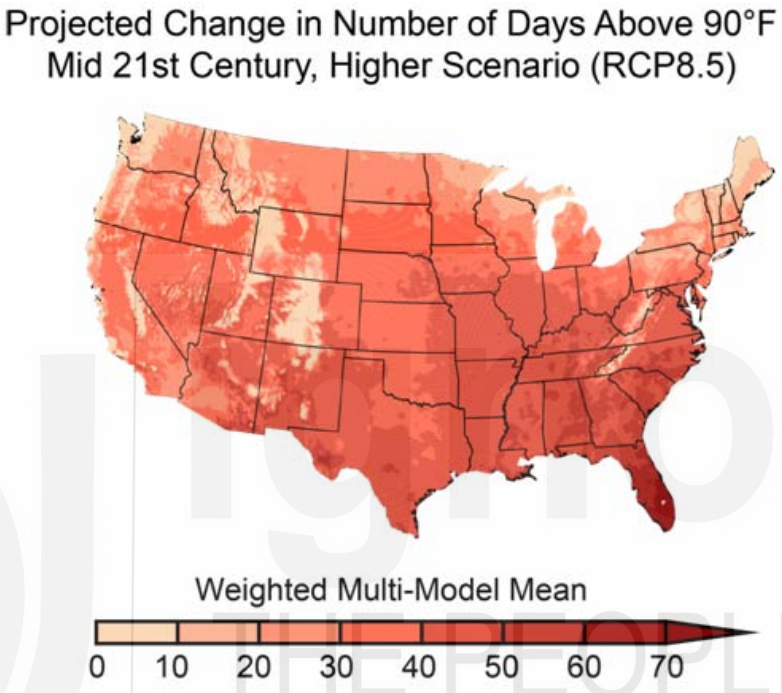

Fig. 7.2: Projected changes in the number of days per year in United States (CICS-NC and NOAA NCEI by Russel Vose, available in Climate Science Special Report).

In the Indian context, extreme heat events have been occurring frequently in the last decade. Various heat events have been recorded that have been linked to anthropogenic reasons contributing to climate change. Last year in the month of May and June (2019), a severe heat wave was recorded in India with highest temperatures reaching 50.8°C in Churu, Rajasthan. Many casualties were reported in Northern and eastern cities of India during summer season due to these heat waves. This led to severe drought and extreme water scarcity in many parts of India. Some other examples include heat wave in Ahmedabad in 2010 that killed about 1000 people and another heat wave in 2015 caused about 2300 casualties in whole of India. In the same year, a huge heat wave killed thousands of people in Andhra Pradesh and Telangana. So far, the highest temperatures during extreme heat waves have been recorded in the year 2016 with temperatures reaching 51°C in Phalodi in north-western India.

The threats posed by extreme heat waves include increase in frequency and intensity of droughts; wildfires; heat island effect in urban areas due to

elevated temperatures in built-up areas of cities; impact on human health such as dehydration, diarrhoea, fatigue, heat stroke, heat stress, unconsciousness and even death, cardiovascular and respiratory symptoms; economic losses and increase in pollution levels, thus, affecting the air quality. This is particularly damaging to crop productivity, livestock, higher energy consumption due to excessive use of air-conditioners and refrigerators.

As a result, it becomes imperative to chalk out resilience pathways for minimising the heat impacts. These include:

- Creating heat preparedness plans;
- Recognising populations vulnerable to extreme heat;
- Installing cool and green roofs and cool pavement to reduce the urban heat island effect;
- Increasing land area under plantation to reduce the temperature of urban area; and
- Utilizing energy efficiency to reduce electricity demand.

It is believed that in 2003, the European heat wave killed about 35000-70000 people. In India, most of the heat waves occur during the summer months of May and June. In 2015, it was estimated that heat waves caused death toll of more than 2400 people in the country. This number has been increasing ever since with India seeing the hottest 32 days during May-June months in 2019. In 2020, Churu in Rajasthan state recorded the highest temperatures (50°C) during summertime. The Indian Meteorological Department had categorized Core Heatwave Zones (CHZs) that included Rajasthan, Punjab, Haryana, Delhi, Madhya Pradesh, Uttar Pradesh, Coastal Andhra Pradesh and Orissa besides other regions of the country.

7.7 EXTREME PRECIPITATION

Extreme precipitation events have become more common since the 1950s in many regions of the world. It is predicted that with increasing global warming, the trend of extreme precipitation would continue since warmer air can hold greater amount of water vapour. This would probably lead to more moisture retention by warmer air and further lead to intense precipitation. However, intense precipitation may or may not lead to increase in total precipitation. Various climate models predict a decrease in rainfall and increase in length of dry periods. The heavy events are defined as the top 1% of all daily events.

Many climate models project that all over the globe, the wet places would get wetter while the dry ones would become even drier due to spatial and temporal variability in extreme precipitation events. Further, these models also indicate a relatively widespread intensification of heavy precipitation events in response to global warming and increase in greenhouse gases.

However, the complexities of extreme events should be kept in mind while studying these models since they tend to simplify these processes due to assumptions in these models.

Threats posed by heavy precipitation

Some of the most imminent threats posed by heavy precipitation is the prospect of flooding. This is further exacerbated in urban areas where stormwater flow pollutants like heavy metals, pesticides and other nutrients such as nitrogen and phosphorus increase and runs off into sewerage and aquatic ecosystems, thus, damaging the water quality. It is estimated that from 1980 to 2009, floods caused more than 500,000 deaths and affected more than 2.8 billion people all over the world. Some recent examples include heavy rains in Maryland in July 2016 of about six inches falling during two hours, and a year's worth of rainfall (17 inches) was received in Colorado in September 2013 causing severe economic losses. India is one of the worst floods affected countries, being second in the world and accounts for one fifth of global death count due to floods. India receives 75% of rains during the monsoon season (June to September). As a result, almost all the rivers are flooded during this time resulting in sediment deposition, drainage congestion, invading into the main land. More than 8 million hectares of land in India are annually affected by floods. The flood prone area in India constitutes about 40 million hectares. Other examples include Uttarakhand floods due to cloudburst that caused great loss to life and property in June 2013. Every year during monsoons, the city of Mumbai gets flooded due to very old drainage network system and increase in impermeable surfaces due to heavy construction of roads, pavements and buildings in the city. According to meteorological records from the Santacruz Observatory in Mumbai, this year, 82.5 inches of rain fell in the city between July 10 and August 7, 2020.

Various types of floods have been recognised:

- Flash floods: These can be caused by short-duration intense precipitation, dam or levee failure, or collapse of debris and ice jams. The flash floods in Uttarakhand in June 2013 due to multiple cloud bursts in a single day caused massive landslides and has been known to be the worst disaster in the country after 2004 tsunami incident.

- Urban flooding: Caused by immediate runoff from impervious surfaces such as roads, pavement, parking lots, and buildings by short-duration very heavy precipitation. Flash floods and urban flooding are directly linked to heavy precipitation and are expected to increase as a result of increases in heavy precipitation events.

- River flooding: It occurs when surface water as a result of precipitation drained from a watershed into a stream or a river exceeds channel capacity, overflows the banks and inundates adjacent low-lying areas.

- Coastal flooding: It is predominantly caused by storm surges as a result of increase in heavy rainfall and sea level rise that push seawater towards the shore. Storm surge can cause inland flooding leading to deaths, damage to infrastructure, and severe beach erosion.

In addition to flooding, heavy precipitation also increases the risk of landslides. Every year, the states of Himachal Pradesh and Uttarakhand face landslides due to heavy rains in the region. The Garhwal Himalayas tragedy of 16-17 June, 2013 was one of the worst disasters of the last century owing to unprecedented rainfall. The extreme rainfall coupled with bursting of moraine-dammed Chorabari lake caused heavy floods in Mandakini river that led to flash floods and devastation in downstream areas of Kedarnath, Rambara and Gaurikund.

Resilience to extreme precipitation event

The impacts of heavy precipitation can be reduced by the following steps:

- Building infrastructure on higher platforms so that they are less prone to flooding.
- Applying flood control infrastructure.
- Replacing the use of pavement and concrete with permeable surfaces
- Providing insurance and incentives to the victims affected by floods and landslides.
- Wastewater systems need to be separated from stormwater systems.

Check Your Progress 1

Note: i) Use the space given below for your answers.

ii) Check your answers with those given at the end of the unit.

1) What are potential threats caused by extreme heat event?

……

……

……

……

……

2) How can resilience be built for an extreme precipitation event?

……

……

……

……

……

7.8 TROPICAL CYCLONES/HURRICANES

A hurricane is a low-pressure storm system that develops in the tropics or subtropics; hence, is known as tropical cyclones. In the Northern Hemisphere, these storms rotate counter-clockwise and clockwise in southern hemisphere. Stronger systems are called “hurricanes” or “typhoons,” while weaker tropical cyclones are called “tropical depressions” or “tropical storms.” Tropical cyclones, are known as hurricanes in the Atlantic Ocean or typhoons in the Pacific Ocean. Predicting these cyclones/ hurricanes has been quite uncertain; it is only with the advent of recent remote sensing techniques and satellite data that the study of these cyclones and hurricanes has developed to a great extent.

It is believed by climate scientists that a warmer and moist atmosphere would increase the magnitude and intensity of hurricanes. Further, increased temperatures would lead to sea level rise, and higher rainfall; that would lead to increased coastal storms and thus, flooding. However, the impact of global warming on frequency of hurricane is uncertain. Various factors have been shown to influence these hurricanes as a result of higher local sea surface temperatures, including natural variability, human-induced emissions of heat-trapping gases, and particulate pollution. Quantifying the relative contributions of natural and human-caused factors is an active focus of research.

Further, the cyclones are very sensitive to natural climate variability, that in turn, affects the ocean basins. Modelling the tropical cyclones is a difficult task due to the grid size of numerical climate simulation models ranging from a few tens to several hundred kilometres.

Threats Posed by Hurricanes

- Economic losses due to hurricanes are enormous. Four of the 10 costliest hurricanes on record in the United States occurred in 2017 and 2018. Hurricane Katrina (2005) remains the most expensive hurricane on record costing $168 billion (2020 dollars).
- Risk to property and infrastructure in coastal areas is huge.
- There is a great threat to human lives during a hurricane. About 1800 deaths during Hurricane Katrina and 2981 deaths during Hurricane Maria in 2018 have been reported.
- Besides, hurricanes damage energy systems, water and sewer systems and transportation structures.

In 2020, various hurricanes such as Hurricane Hanna that made landfall in Texas followed by Hurricane Isaias and then Hurricane Laura, Hurricane Sally and Hurricane Eta were the most prominent one besides various tropical storm that occurred in Atlantic Ocean. A total of 30 storms were recorded in 2020 with the strongest storm being Storm Iota with maximum

wind speeds of 260km/hr. Out of these 30 storms, 13 developed into hurricanes with total fatalities of more than 431 and total economic losses of more than $46.906 billion USD have been reported. It is pertinent to mention that the Atlantic Hurricane season started on June 01 and ended on November 30 this year. It was by far the most active and seventh costliest recorded Atlantic hurricane season in terms of economic losses.

Resilience can be built by:

- Preserving coastal wetlands and coral reefs to minimize the impacts of storm surge.
- improving vulnerable buildings to reduce flood damage.
- Developing an evacuation plan to minimize the adverse impacts.

7.9 EXTRATROPICAL STORMS/TORNADOES

Research indicates that storms have increased in frequency and intensity since the 1950s coupled with the intensity and frequency of tornadoes, hail, and thunderstorm. Storms are related to atmospheric circulations which corresponds to temperature difference between the equator and the poles.

If we look into the temperature gradient between the poles and the equator, the melting of ice at the poles due to climate change results in greater warming at the poles; thus, decreasing the temperature difference between equator and poles. Further, warming is higher at the top of the troposphere, thus, strengthening the temperature gradient. The difference between the troposphere of upper tropics and the lower Arctic results in the atmospheric dynamics of the mid-latitudes, such as depressions and storms. Climate variability further adds to the formation of storms. However, it is pertinent to mention here that not all depressions turn into storms, hence, further adding to the uncertainty. The impact of atmospheric instability and wind shear on the formation of tornadoes needs to be studied.

Threats posed by tornadoes

The most important threats from tornadoes is the damage due to high speed winds that carry debris along with them. As per the projections of NOAA, about 1,200 tornadoes occur across the country annually. Although the casualties have decreased rapidly in the last few years due to better early warning systems and satellite images; however, the damages caused still need detailed minimization strategies.

Communities can increase their resilience and reduce the impacts from tornadoes by:

- Adopting more stringent building codes in tornado-prone areas.
- Continuing to support research on severe weather forecasts.
- Heeding watches and warnings when they are issued, and ensuring that

individuals can be reached by emergency alert systems.

7.10 WILDFIRES

Many studies have linked an increase in wildfire activity to global warming. In addition, the risk of a fire could depend on past forest management, natural climate variability, human activities, and other factors, in addition to human-caused climate change. Determining how much climate change contributes to extreme weather events such as wildfires continues to be studied.

Climate change has been a key factor either directly or indirectly, in increasing the risk and extent of wildfires in the world. Various factors contribute to increased risk of wildfire, such as temperature, soil moisture, dry conditions, increased drought scenario, presence of vegetation and other potential fuel such as organic matter that burns up easily (e.g., dried leaves, twigs etc.). Some of the examples include frequent bushfires in Australia of which the highest number of deaths and casualties were reported in the 2009 Black Saturday bushfires in the state of Victoria. The most recent examples include burning of the Seshachalam forest area very close to the holy city of Tirupati in South India in March, 2020 and the lightening sparked wildfires in the state of California in August 2020 which has burnt lakhs of acres of land.

The effects of wildfire are manifold:

- Economic aspects: Wildfires cause severe economic losses as funds are required for suppression of fires.
- Public health: Wildfire cause risk to life, property and public health; Smoke reduces air quality and can cause eye and respiratory illness.
- Damage to environment: Wildfires can damage ecosystem and release large amounts of gases such as carbon dioxide into the atmosphere, thus, adding further to climate change.

Resilience towards wildfires can be developed by:

- Avoiding buildings and infrastructure in fire-prone areas.
- Working on increasing the spacing between residential areas and forest areas.
- Including fire-resistant materials in buildings.
- Increasing resources allocated to firefighting and fire prevention and minimizing damage due to fires.

Many of these extreme events are inter-related and cannot be studied in isolation. For example, highest rainfall was recorded from a single event during Hurricane Harvey at Houston in August 2017.

Check Your Progress 2

Note: i) Use the space given below for your answers.

ii) Check your answers with those given at the end of the unit.

1) What are the contributing factors to a wildfire event?

……

……

……

……

……

2) Is it best to study extreme events in isolation or a holistic manner?

……

……

……

……

……

7.11 LET US SUM UP

To sum up, the study of extreme weather events is very challenging due to uncertainties in climate change. Most of the climate models have their own limitations, which in turn, make the study of extreme weather events in relation to climate change a huge scientific challenge. Although attempts are being made all over the world by various research groups for improvement of climate models, increasing the network of observation stations and simulation of extreme events; still a lot needs to be done to improve research output and predictability of extreme events and thus, climate change. Further, every time anthropogenic inputs should not be blamed for every extreme event occurring; many a times nature follows its own course which is beyond the control of humans. However, efforts should be made to minimize the impacts of humans on probability of extreme event.

Abbreviations

USGCRP	U.S. Global Change Research Program
GCMs	General Circulation Models
EBMs	Energy Balance Models
WCRP	World Climate Research Programme
NOAA	National Oceanic and Atmospheric Administration
RCP	Representative Concentration Pathway

NAS	National Academy of Sciences
NCEC	National Climate Extremes Committee
IBTrACS	International Best Track Archive for Climate Stewardship
NCEI	National Centers for Environmental Information

7.12 KEY WORDS

Drought: A period of abnormally dry weather long enough to cause a serious hydrological imbalance. A period with an abnormal precipitation deficit is defined as a meteorological drought. A megadrought is a very lengthy and pervasive drought, lasting much longer than normal, usually a decade or more.

Storm surge: The temporary increase, at a particular locality, in the height of the sea due to extreme meteorological conditions. The storm surge is defined as being the excess above the level expected from the tidal variation alone at that time and place

7.13 SUGGESTED FURTHER READING/REFERENCES

IPCC, 2013: Annex III: Glossary [Planton, S. (ed.)]. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Web Links

- American Meteorological Society – Explaining Extreme Events in 2016 from a Climate Perspective (https://watermark.silverchair.com/bams-explainingextremeevents2016_1.pdf)
- http://www.c2es.org/content/drought-and-climate-change/
- http://www.c2es.org/content/extreme-precipitation-and-climate-change/
- http://www.c2es.org/content/heat-waves-and-climate-change/
- https://nca2014.globalchange.gov/highlights/report-findings/extreme-weather
- https://sites.nationalacademies.org/BasedOnScience/climate-change-global-warming-is-contributing-to-extreme-weather-events/index.htm
- https://sites.nationalacademies.org/BasedOnScience/climate-change-humans-are-causing-global-warming
- https://theconversation.com/yes-climate-change-can-affect-extreme-

weather-but-there-is-still-a-lot-to-learn-136003

- https://www.c2es.org/content/extreme-weather-and-climate-change
- https://www.carbonbrief.org/mapped-how-climate-change-affects-extreme-weather-around-the-world
- https://www.encyclopedie-environnement.org/en/climate/extreme-weather-events-and-climate-change/
- https://www.ncdc.noaa.gov/climate-information/extreme-events
- https://www.pnas.org/content/115/33/8232
- https://www.wcrp-climate.org/images/summer_school/ICTP_2014/documents/presentations/day1/Karoly_Extremes.pdf
- National Academies of Sciences, Engineering, and Medicine – Attribution of Extreme Weather Events in the Context of Climate Change (2016) https://www.nap.edu/resource/21852/Attribution-Extreme-Weather-Brief-Final.pdf
- The Science Behind It: Climate Change - National Academy of Sciences https://thesciencebehindit.org/how-is-earths-climate-changing/
- The Science Behind It: Extreme Weather – National Academy of Sciences (https://thesciencebehindit.org/how-is-climate-change-affecting-heat-waves-floods-hurricanes-and-other-kinds-of-extreme-weather/)
- U.S. Global Change Research Program – Fourth National Climate Assessment (2018) https://nca2018.globalchange.gov/
- U.S. Weather Service (1959). Rainfall intensity-frequency regime. Part 4 – North-eastern United States Hydrologic services division of the U.S. Weather bureau (former name of the national weather service).
- Weekley, E. (1921). Extreme An etymological dictionary of modern English, John Murray, London.

7.14 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1) The threats posed by extreme heat waves include increase in frequency and intensity of droughts; wildfires; heat island effect in urban areas due to elevated temperatures in built-up areas of cities; impact on human health such as dehydration, diarrhoea, fatigue, heat stroke, heat stress, unconsciousness and even death, cardiovascular and respiratory symptoms; economic losses and increase in pollution levels

2) Building infrastructure on higher platforms so that they are less prone to flooding; Applying flood control infrastructure; Replacing the use of pavement and concrete with permeable surfaces; Providing insurance and incentives to the victims affected by floods and landslides.

Check Your Progress 2

1) Contributing factors to wildfire event are forest management, natural climate variability, human activities, and other factors, in addition to human-caused climate change.

2) Many of these extreme events are inter-related and cannot be studied in isolation. E.g., tsunamis are triggered by earthquakes; while floods or landslides are triggered by heavy precipitation.