04 EXTREME WEATHER EVENTS

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Extreme weather events in the context of climate change

There has been evidence since 1950 of changes in climate extremes.[1] Observed changes in climate extremes reflect the influence of anthropogenic climate change in addition to natural climate variability, with changes in exposure and vulnerability influenced by both climatic and non-climatic factors. Changes in climate extremes vary across regions with each region having unique vulnerabilities and exposure to hazards.

The increase in extreme weather events has been observed in various parts of the world – heat wave frequency and warm days and nights across Europe, hurricanes in the US and Caribbean, flash floods in Nairobi, Kenya, sea level rise in tropical Small Island Developing States, droughts in West Africa, droughts and wildfires over the US and floods in Brazil and Uganda are just some examples. Also recorded were gradual impacts of climate change which were accompanied by less drastic changes, such as the hottest summer recorded in Australia and the warmest June and August recorded in many parts of the world. Several events witnessed a departure from what would normally be expected.

The months of April, May, June, August and September of 2014 were the warmest months on record since record keeping began in 1880. June 2014 was 0.72°C (1.3°F) above the 20th-century average of 15.5°C (59.9°F) – the highest on record. For August 2014 the surface temperature reached 16.35°C (61.45°F) above the 20th-century average of 15.6°C (60.1°F). September 2014 was found to be 0.8°C (1.4°F) above the 1951 to 1980 average, breaking a previous record in 2005. The year 2013, tying with 2003, was also considered the fourth warmest year globally since records began in 1880.

Changing extreme events at global level

Some key findings from the IPCC report[2] on climate extremes are as follows:

- Observations since 1950 show changes in some extreme events, particularly daily temperature extremes, and heat waves.
- It is likely that the frequency of heavy precipitation will increase in the 21st century over many regions.
- It is virtually certain that increases in the frequency of warm daily temperature extremes and decreases in cold extremes will occur throughout the 21st century on a global scale. It is very likely – the probability is 90 to 100 per cent – that heat waves will increase in length, frequency, and/or intensity over most land areas.
- It is likely that the average maximum wind speed of tropical cyclones (also known as typhoons or hurricanes) will increase throughout the coming century, although possibly not in every ocean basin.
- However it is also likely – in other words there is a 66 to 100 per cent probability – that overall there will be either a decrease or essentially no change in the number of tropical cyclones.
- There is evidence, providing a basis for medium confidence, that droughts will intensify over the coming century in southern Europe and the Mediterranean region, central Europe, central North

America, Central America and Mexico, northeast Brazil and southern Africa. Confidence is limited because of definitional issues regarding how to classify and measure a drought, a lack of observational data and the inability of models to include all the factors that influence droughts.

- It is very likely that the rise in average sea level will contribute to upward trends in extreme sea levels in extreme coastal high-water levels.
- Projected precipitation and temperature changes imply changes in floods, although overall there is low confidence at the global scale regarding climate-driven changes in magnitude or frequency of river related flooding, due to limited evidence and because the causes of regional changes are complex.

Trends in disaster losses

- Total economic losses from natural disasters are higher in developed countries.
- Economic losses expressed as a proportion of Gross Domestic Product (GDP) are higher in developing countries.
- Deaths from natural disasters occur much more in developing countries. From 1970 to 2008, for example, more than 95 per cent deaths from natural disasters were in developing countries.

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Table 1: Global scenario of climate extreme: observed changes, attribution and projected changes[4]

		Observed changes (since 1950)	Attribution of observed changes	Projected changes (up to 2100) with respect to the late 20th century
Weather and climate variables	Temperature	Very likely decrease in number of unusually cold days and nights at the global scale. Very likely increase in number of unusually warm days and nights at the global scale. Medium confidence in increase in length or number of warm spells or heat waves in many (but not all) regions. Low or medium confidence in trends in temperature extremes in some sub-regions due either to lack of observations or varying signals within sub-regions.	Likely anthropogenic influence on trends in warm/cold days/nights at the global scale. No attribution of trends at a regional scale with a few exceptions.	Virtually certain decrease in frequency and magnitude of unusually cold days and nights at the global scale. Virtually certain increase in frequency and magnitude of unusually warm days and nights at the global scale. Very likely increase in length, frequency and/or intensity of warm spells or heat waves over most land areas.
	Precipitation	Likely statistically significant increases in the number of heavy precipitation events (e.g., 95th percentile) in more regions than those with statistically significant decreases, but strong regional and sub-regional variations in the trends.	Medium confidence that anthropogenic influences have contributed to intensification of extreme precipitation at the global scale.	Likely increase in frequency of heavy precipitation events or increase in proportion of total rainfall from heavy falls over many areas of the globe, in particular in the high latitudes and tropical regions, and in winter in the northern mid-latitudes.
	Winds	Low confidence in trends due to insufficient evidence.	Low confidence in the causes of trends due to insufficient evidence.	Low confidence in projections of extreme winds (with the exception of wind extremes associated with tropical cyclones).
Phenomena related to weather and climate extremes	Monsoons	Low confidence in trends because of insufficient evidence.	Low confidence due to insufficient evidence.	Low confidence in projected changes in monsoons, because of insufficient agreement between climate models.
	El Niño and other Modes of variability	Medium confidence in past trends toward more frequent central equatorial Pacific El Niño-Southern Oscillation (ENSO) events. Insufficient evidence for more specific statements on ENSO trends. Likely trends in Southern Annular Mode (SAM).	Likely anthropogenic influence on identified trends in SAM. Anthropogenic influence on trends in North Atlantic Oscillation (NAO) are about as likely as not. No attribution of changes in ENSO.	Low confidence in projections of changes in behavior of ENSO and other modes of variability because of insufficient agreement of model projections
	Tropical cyclones	Low confidence that any observed long-term (i.e., 40 years or more) increases in tropical cyclone activity are robust, after accounting for past changes in observing capabilities.	Low confidence in attribution of any detectable changes in tropical cyclone activity to anthropogenic influences (due to uncertainties in historical tropical cyclones record, incomplete understanding of physical mechanisms and degree of tropical cyclone variability).	Likely decrease or no change in frequency of tropical cyclones. Likely increase in mean maximum wind speed, but possibly not in all basins. Likely increase in heavy rainfall associated with tropical cyclones.
	Extra tropical cyclones	Likely pole-ward shift in extratropical cyclones. Low confidence in regional changes in intensity.	Medium confidence in an anthropogenic influence on Pole-ward shift.	Likely impacts on regional cyclone activity but low confidence in detailed regional projections due to only partial representation of relevant processes in current models. Medium confidence in a reduction in the numbers of mid-latitude storms. Medium confidence in projected pole-ward shift of mid-latitude storm tracks.
Impacts on physical environment	Droughts	Medium confidence that some regions of the world have experienced more intense and longer droughts, in particular southern Europe and West Africa, but opposite trends also exist.	Medium confidence that anthropogenic influence has contributed to some observed changes in drought patterns. Low confidence in attribution of changes in drought at the	Medium confidence in projected increase in duration and intensity of droughts in some regions of the world, including southern Europe and the Mediterranean region, central Europe, central North

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Continue Table 1……

		Observed changes (since 1950)	Attribution of observed changes	Projected changes (up to 2100) with respect to the late 20th century
			level of single regions due to inconsistent or insufficient evidence.	America, Central America and Mexico, northeast Brazil, and southern Africa. Overall low confidence elsewhere because of insufficient agreement of projections.
	Floods	Limited to medium evidence available to assess climate-driven observed changes in the magnitude and frequency of floods at regional scale. Furthermore, there is low agreement in this evidence, and thus overall low confidence at the global scale regarding even the sign of these changes. High confidence in trend toward earlier occurrence of spring peak river flows in snowmelt- and glacier-fed rivers.	Low confidence that anthropogenic warming has affected the magnitude or frequency of floods at a global scale. Medium confidence to high confidence in anthropogenic influence on changes in some components of the water cycle (precipitation, snowmelt) affecting floods.	Low confidence in global projections of changes in flood magnitude and frequency because of insufficient evidence. Medium confidence (based on physical reasoning) that projected increases in heavy precipitation would contribute to rain-generated local flooding in some catchments or regions. Very likely earlier spring peak flows in snowmelt- and glacier-fed rivers.
	Extreme sea level and coastal impacts	Likely increase in extreme coastal high water worldwide related to increases in mean sea level in the late 20th century.	Likely anthropogenic influence via mean sea level contributions.	Very likely that mean sea level rise will contribute to upward trends in extreme coastal high water levels. High confidence that locations currently experiencing coastal erosion and inundation will continue to do so due to increasing sea level, in the absence of changes in other contributing factors.
	Other physical impacts	Low confidence in global trends in large landslides in some regions. Likely increased thawing of permafrost with likely resultant physical impacts.	Likely anthropogenic influence on thawing of permafrost. Low confidence of other anthropogenic influences because of insufficient evidence for trends in other physical impacts in cold regions.	High confidence that changes in heat waves, glacial retreat, and/or permafrost degradation will affect high mountain phenomena such as slope instabilities, mass movements, and glacial lake outburst floods. High confidence that changes in heavy precipitation will affect landslides in some regions. Low confidence in projected future changes in dust activity.

- Economic losses from weather- and climate-related disasters have been heavily influenced by the increasing exposure of people and economic assets to these disasters.

Observed changes in extreme climatic events in South Asia[6]

The increasing tendency in the intensity and frequency of extreme weather events in South Asia over the last century and into the 21st century has been observed.

- **Intense rains and floods:** Serious and recurrent floods in Bangladesh, Nepal and northeast states of India during 2002, 2003 and 2004; a record 944 mm of rainfall in Mumbai, India on 26 to 27 July 2005 led to loss of over 1000 lives with loss of more than US$250 million; floods in Surat, Barmer and in Srinagar during summer monsoon season of 2006; 17 May 2003 floods in southern province of Sri Lanka were triggered by 730 mm rain.
- **Heat waves:** Frequency of hot days and multiple-day heat wave has increased in past century in India; increase in deaths due to heat stress in recent years in India. Record breaking temperatures in Pakistan have claimed hundreds of lives and devastated crops in major heatwave in recent years; in May 2010, temperature in Mohenjo-daro city of Sindh province, Pakistan reached 53.5 ^{0}C (128 ^{0}F), one of the highest temperature ever recorded.
- **Droughts:** 50 per cent of droughts associated with El Niño; consecutive droughts in 1999 and 2000 in

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Table 2: Recent trends of the likelihood and consequences of global extreme weather events[5]

Date and locale	Impact event	Associated climate hazard	Trends relating to likelihood of climate hazard	Trends relating to consequence of climate hazard
Contiguous United States, summer 2012	Agricultural drought, with 57 per cent of cropland and 43 per cent of farms experiencing at least severe drought	Second warmest summer and warmest month (July) in the contiguous USA, and one of the driest March – July periods in the central USA in the 118-year record	Approximately 0.50C warming in summer over the last century, no substantial long-term trend in drought occurrence	Significant growth in area dedicated to soy and maize
Thailand, 2011	Prolonged inundation of urban and industrialised areas; manufacturing losses of about US$32 billion	One of the wettest monsoon seasons on record in middle and upper Chao Phraya Basin, resulting in flooding	No detectable change in precipitation over the basin	• Economic development focused on large industrial estates built in floodplains • Recent spell of political instability • Subsidence from groundwater pumping
European Russia, July – August 2010	Burned area >12,500 km	Record hot days Unusually dry June-August	Trends in temperature, precipitation, humidity, soil moisture and snow cover toward less conducive climatic conditions for fire	• Increased risk from draining of peat bogs in 1960s and earlier • Increased risk from poorly implemented devolution of forest management and forest fire protection in 2007 to regional administrations
Pakistan, July-September 2010	Flooding leading to 2000 deaths; 20 million affected; total loss US$10 billion	Exceptionally high monsoon rainfall over northern Pakistan during July and August	No substantial trend in heavy rainfall event frequency in northern Pakistan in past several decades	Rapid population growth and expansion of formal and informal human settlements • Decreased risk through development of flood and disease warning systems and disaster planning • Increased risk from deforestation on mountainous slopes • Recent unrest in north constrains ability of institutions to deliver basic services
France, summer 2003	Approximately 15,000 excess deaths	Record hot days/heat wave	Increasingly frequent hot days and heat waves in recent decades	• Ageing population, increasing population, trends in marital status • Difficulties staffing health services, undeveloped early warning system

Pakistan and N-W India led to sharp decline in watertables; consecutive droughts between 2000 and 2002 caused crop failures, mass starvation and affected approximately 11 million people in the state of Orissa in India; droughts in northeast India during summer monsoon of 2006.

- **Cyclones**: Frequency of monsoon depressions and cyclones formation in Bay of Bengal and Arabian Sea on the decline since 1970 but intensity is increasing causing severe floods in terms of damages to life and property.

Extreme climatic events in India

The year 2014 had monsoon in India marked by high variability. While the India Meteorological Department (IMD) bracketed Punjab, Delhi-Haryana-Chandigarh and the Marathwada regions under the 'scanty rain' category, flash floods and incessant rains in UP, Bihar, Uttarakhand, Orissa, Jammu and Kashmir, Meghalaya and Assam caused heavy destruction of life and property.

Within the last one and half years, in 2013 and 2014, India experienced weather events that covered the entire spectrum ranging from major floods, cyclones to droughts, leading to considerable loss in lives, livelihood and wealth. The country experienced the significant impact of floods in Jammu and Kashmir, Uttarakhand, Assam, Meghalaya, UP and Bihar; a succession of cyclones hit the eastern coasts, particularly in Andhra Pradesh; and intense episodes of

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rainfall in typically dry/arid regions caught communities unawares, leaving them unprepared for the scale of loss and damage that they were subjected to.

Hailstorms

Departing from the normal phenomena, between February and March in 2013, unseasonal rain was accompanied by hailstorm which played havoc with millions of farmers' lives in six Indian states –Punjab, Uttar Pradesh, Rajasthan, Madhya Pradesh, Maharashtra and Andhra Pradesh. The unprecedented event lasted 20 days and it came just as farmers were preparing to harvest crops. According to estimates, 4.65 million hectares of standing crops were ravaged in the worst-hit Maharashtra and Madhya Pradesh alone. More than a hundred farmers reportedly committed suicide in this region due to debt related worries within a month of this event.

Heat waves

In 2014, the unbearable heat waves in the summer were above normal, covering parts of Rajasthan, Odisha and northeastern states of India. The heat waves claimed hundreds of lives across the country, more than 500 deaths in Andhra Pradesh – 169 people reportedly died of intense heat wave in Hyderabad alone – while 12 causalities were reported in Ahmedabad. As many as 73 deaths in just seven days in Delhi from June 1 to 7, 2014

Table 3: Examples of floods in India in 2013-14

Event	Date	Area/People affected / Economic losses (figures given are based on news reports and have been used here just to give an indication)	Lives lost (based on news reports)
Uttarakhand Flash floods	November 2013	110,000 people affected, Rs 7,346 crore worth economic loss	1000+
Assam floods	July 2013	250,000 people, 400 villages in 11 districts affected, 7,000 hectare agriculture land affected	1
Maharashtra floods	August 2013	3000 people, economic losses of Rs 1835 crore	238
Bihar floods	July 2013	1.6 million people displaced, 1,000,000 hectare agriculture land affected	174 people and 299 livestock were killed
Bihar floods	September 2013	6 lakh hectares of farmland was destroyed	201
UP floods	August 2014	8.6 lakh people affected in 1037 villages spread over several districts	89
Orissa floods	July 2014	1.8 million people affected and half-a-million livestock while destroying 15,943 houses, crops over 208,911.9 hectares were damaged and 69,430 people evacuated	47
Monsoon rain Kerala	July 2014	366 people evacuated, crop loss worth Rs 11.20 crore	29
Flood Odisha	August 2014	9.95 lakh people affected, 1,553 villages of 89 blocks in 23 districts affected, paddy crops on 30,659 hectare and jute and vegetable farming on 6,566 hectare damaged 509 villages in 156 gram panchayats	34
Flood Bihar	August 2014	Over 18 lakh people affected, crops worth over Rs 56.44 crore have been damaged by the floods in the 16 districts	34
Flood Uttar Pradesh	September 2014	1.4 million people were affected , 60,000 people in 9 districts bordering Nepal displaced	106
Flood West Bengal	August 2014	319,506 people affected, estimated damage worth Rs 1913.66 lakh	Not available
Flood Assam	September-October 2014	Nearly 12 lakh people hit by floods, economic loss worth Rs 2010 crore due to floods in 2014, average loss of Rs 200 crore is reported every year	44
Flood Meghalaya	September 2014	Properties including road, houses, livestock and agriculture worth about Rs 2,000 crore damaged.	52
Flood Jammu and Kashmir	September 2014	Close to 5 million people are affected by the floods in Jammu and Kashmir – 4.5 million in the Kashmir Valley and half a million in the Jammu region, immediate loss of Rs 5,400-5,700 crore to the state's economy	260

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Table 4: Examples of droughts in India in 2013-14

Event	Duration	Areas affected/economic losses
Maharashtra drought	June-September 2013	12,000 villages affected, 2,400 crores of economic impact and 18500000 hectares Agricultural land affected
Andhra Pradesh drought	January 2013	234 mandals affected
Kerala drought	April-June, 2013	For the first time, a drought had been declared in every single one of Kerala's 14 districts.
Gujarat drought	March 2013	4,000 villages, mostly in Saurashtra
Bihar drought	June-September 2013	33 districts affected
Tamil Nadu drought	January-February 2013	31 of its 32 districts affected
Gujarat	March 2013	4,000 villages and 17 districts affected, 10 to 15 per cent of the cash crops of the state failed
Karnataka drought	May 2014	28 districts affected
Gujarat drought	May-June 2014	106 villages, Kutch area affected
Uttar Pradesh	September 2014	44 districts affected
Haryana	June-August 2014	18 out of 21 districts affected

due to sweltering summer heat were reported.

Cyclones: The past year and this year saw an unusual amount of cyclone activity, also characterised by erratic storms and rainfall. Some examples are:

- Hudhud struck on October, 2014 in the Andaman and Nicobar Islands, Andhra Pradesh and Odisha, killing more than 46 people and damaging billions of dollars of properties.
- Phailin came on October 12, 2013 in Odisha, Andhra Pradesh, affecting 1,481 villages and claiming more than 45 lives.
- Mahasen came on May 8, 2013 in Andhra Pradesh, affecting 30000 people and claiming 8 lives.
- Helen and Lehar came during November, 2013 in Andhra Pradesh, affecting thousands of people and damaging millions of dollars of properties.

Floods

India received more than its normal share of rains during the monsoons in 2013, leading to devastating floods in some parts of the country, some where such floods were unprecedented; in other parts, the story was just the opposite. The northeastern region, which typically records some of highest rains in the country, received lesser rainfall than usual.

Droughts

The failure or shifting patterns of monsoons result in water shortage which leads to severe droughts in rain-fed areas of India. Also, the El Niño phenomenon further affects rainfall in India. Drought or drought-like situation is a recurrent phenomenon in India. The years 2013 and 2014 have seen various droughts and drought-like situations in various parts of the country.

References

1. Climate Extreme (extreme weather or climate event) has been defined by the Intergovernmental Panel on Climate Change (IPCC) report as the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable.
2. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change, 2012.
3. Note: By 'virtually certain' we mean 99-100 per cent probability; by 'very likely' we mean 90-100% probability; by 'likely' we mean 66-100 per cent probability; by 'about as likely as not' we mean 33 to 66 per cent probability; by 'unlikely' we mean 0-33 per cent probability, by 'very unlikely' we mean 0-10 per cent probability, by 'exceptionally unlikely' we mean 0-1 per cent probability.
4. Source: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change, 2012.
5. Source: Detection and attribution of observed impacts. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change
6. http://www.ipcc.ch/publications_and_data/ar4/wg2/en/ ch10s10-2-3.html