GOVERNMENT OF INDIA
MINISTRY OF EARTH SCIENCES
LOK SABHA
STARRED QUESTION NO. *270
TO BE ANSWERED ON FRIDAY, 6TH AUGUST, 2021

EXTREME WEATHER CONDITIONS

***270. SHRI RAJIV PRATAP RUDY:**

Will the Minister of EARTH SCIENCES be pleased to state:

(a) whether it is a fact that incidence of extreme weather conditions has increased in India and also globally in the last decade;

(b) if so, the details of extreme weather events recorded in the country during the last decade along with the number of casualties/fatalities and estimated property damage occurred therefrom, event-wise;

(c) whether the Government has taken any steps to improve adaptation and mitigation in extreme weather events;

(d) if so, the details thereof; and

(e) whether India is considered more vulnerable to climate change and if so, the details of areas in the country most vulnerable to extreme weather events?

ANSWER
THE MINISTER OF STATE (INDEPENDENT CHARGE) FOR
MINISTRY OF SCIENCE AND TECHNOLOGY
AND EARTH SCIENCES
(DR. JITENDRA SINGH)

(a) to (e): A Statement is laid on the Table of the House.

STATEMENT LAID ON THE TABLE OF THE LOK SABHA IN REPLY TO (a) to (e) of STARRED QUESTION NO. *270 REGARDING "EXTREME WEATHER CONDITIONS" TO BE ANSWERED ON FRIDAY, AUGUST 6, 2021

(a)-(b) Yes Sir. Associated with the global warming, increase in various extreme weather conditions such as heavy rainfall, floods, droughts, cyclones, heat waves and cold wave conditions have been observed in the country in line with increase in the extreme events observed over various other parts of the globe in the last decade.

Details of extreme weather events recorded in the country during the last decade along with the number of casualties/fatalities are given in the **Annexure-I**. The statistics of State wise mortality due to extreme weather events are given in **Figs. 1 & 2**.

(c)-(d) To minimize the adverse effect of the hazardous weather events, India Meteorological Department (IMD) is effectively functioning in the country maintaining accurate weather forecasting services alongwith monitoring services for early detection of severe weather events such as, heavy rainfall, extreme temperature, thunderstorms, cyclones etc.

During the past few years, IMD has been continuously improving weather prediction services in terms of accuracy, lead time and associated impact. There have been significant improvements in forecasting accuracy with respect to severe weather events including tropical cyclones, heavy rainfall, fog, heat wave, cold wave, thunderstorm. In general, there has been 20 to 40 percent improvement in forecast accuracy of severe weather events in recent five years (2016-2020) as compared to previous five years (2011-15).

The forecasts and warnings are issued by IMD at the national, State and district levels. It has a network of State Meteorological Centres for better coordination with State and district level agencies. With the upgradation of observations and prediction system noticeable improvements have been made in the recent past in the skill of prediction, especially with respect to heavy-rainfall, heat-wave, thunderstorm and cyclones.

IMD issues forecast & warnings for the weather elements for five days with an outlook for another two days as per usual practice. From National Weather Forecasting Centre (NWFC), IMD forecasts are given in sub-divisional scale whereas the Regional Weather Forecasting Centre (RWFC) and State Weather Forecasting Centre (SWFC) issue forecast and warning in district level and station level.

The initiatives taken by IMD for the improvement of forecast of different disastrous weather phenomena follow:

(i) Flood and drought warning are not the responsibilities of IMD. However, IMD supports flood warning services of Central Water Commission (CWC) by providing observed and forecasted rainfall. Heavy rainfall events lead to floods over different river basins of the country. River basin floods are dealt by CWC, Ministry of Water Resources. In order to meet specific requirements of flood forecasting, which is provided by CWC, IMD operates Flood Meteorological Offices (FMOs) at fourteen locations viz., Agra, Ahmedabad, Asansol, Bhubaneswar, Guwahati, Hyderabad, Jalpaiguri, Lucknow, New Delhi, Patna, Srinagar, Bengaluru, Thiruvananthapuram and Chennai. Apart from this, IMD also supports Damodar Valley Corporation (DVC) by providing Quantitative Precipitation Forecast (QPF) for Damodar river basin areas for their flood forecasting activities. Flood Meteorological Offices (FMO) operated by IMD provide meteorological support to the CWC for issuing flood warnings well in advance in respect of 153 river basins. CWC issues flood forecasts 6 hrs. to 30 hrs. in advance using QPF received from FMOs of ESSO-IMD and in-situ hydrometeorological data.

In order to cater the services of hydro-meteorological events occurring in short duration of time, IMD is issuing Flash Flood Guidance (FFG) by which a diagnostic value within a watershed required to produce flooding at the outlet of the catchment is estimated, to support the flood warning services.

Similarly, IMD provides actual and forecast rainfall information in different spatial and temporal scale like districts, States & meteorological subdivisions level and daily, weekly & seasonal scale to the Ministry of Agriculture for drought monitoring.

(ii) Heat wave is one of the severe weather phenomena for which IMD issues early warning. In the country, appreciable rise in maximum temperatures as well as heat waves are found to be more in the months of April, May & June. As an initiative IMD is issuing Seasonal Outlook for temperatures for the months of April, May & June in the last week of March for planning purpose. This outlook brings out the expected scenario of heat waves also during the period.

As an adaptive measure, IMD in collaboration with local health departments have started heat action plan in many parts of the country to forewarn about the heat waves and also advising action to be taken during such occasions. Heat action plan became operational since 2013.

The Heat Action Plan is a comprehensive early warning system and preparedness plan for extreme heat events. The Plan presents immediate as well as longer-term actions to increase preparedness, information-sharing, and response coordination to reduce the health impacts of extreme heat on vulnerable populations. NDMA and IMD are working with 23 states prone to high temperatures leading to heat-wave conditions to develop heat action plans.

IMD has started Forecast Demonstration Project (FDP) on heat waves for the hot weather season under which a detailed daily report including realized data of heat waves, weather systems leading to the occurrence of heat waves, diagnosis on the basis of Numerical Model outputs and forecast and warnings for five days is prepared. This bulletin is disseminated to all concerned including health departments.

(iii) During the cold season, associated with the passage of Western Disturbances, the north & northwest India and adjoining central India are frequently affected by adverse weather elements like fog, Cold Wave to Severe Cold Wave and Cold Day to Severe Cold Day conditions.

By the end of November, IMD issues Press-Release regarding Seasonal Outlook for the Temperatures during December to February which brings out the temperature scenario with respect to mean temperature, mean minimum & maximum temperatures during the cold weather season. During the cold weather season, IMD also issues Press-Releases whenever any place or region is likely to experience cold/severe cold waves.

In addition to these, a Forecast Demonstration Project (FDP) for winter weather systems has been initiated from 2016 and it has brought together several institutes other than IMD also to enhance the monitoring and forecast of weather elements during cold weather season. Accordingly a FDP bulletin is prepared and issued during November to February on daily basis.

From November 2020 onwards, IMD started issuing a special bulletin related to winter weather systems (All India Multihazard Winter Warning Bulletin) which provide the details of colour coded warning for five days for the adverse weather elements, along with present weather scenario related to cold wave, cold day etc.

(iv) To mitigate the casualties due to thunderstorm and associated severe weather phenomena, IMD issues three hourly nowcasts for severe weather including thunderstorm and associated weather phenomena for about 1084 stations and all districts in India on regular basis utilizing Radar and satellite data as well as ground based observations. These nowcasts are provided in real time to the users through the Website of India Meteorological Department. Additionally, in case of possibility of severe thunderstorms and associated severe weather phenomena, warnings are issued through SMS and e-mail to the Disaster Management authorities and mass media like All India Radio, TV and social media.

(v) In order to cater to the needs of Cyclone Warning Services and Marine weather services, there are seven established Warning Centers covering the east & west coasts of our country. Among these, three are Area Cyclone Warning Centres (ACWCs) located at Chennai, Mumbai and Kolkata and remaining four are Cyclone Warning Centres (CWCs) located at Ahmedabad, Thiruvananthapuram, Visakhapatnam and Bhubaneswar. Area of responsibility of ACWCs and CWCs is shown in the Table below.

Centre	Coastal area*	Maritime State/UT
ACWC Kolkata	State: West Bengal UT: Andaman & Nicobar Islands	State: West Bengal UT : Andaman & Nicobar Islands
ACWC Chennai	State: Tamil Nadu UT: Puducherry	State: Tamil Nadu UT: Puducherry
ACWC Mumbai	State: Maharashtra & Goa	State: Maharashtra & Goa
CWC Thiruvananthapuram	State: Kerala & Karnataka UT: Lakshadweep	State: Kerala & Karnataka UT: Lakshadweep
CWC Ahmedabad	State: Gujarat UT: Dadra & Nagar Haveli, Daman & Diu	State: Gujarat UT: Dadra & Nagar Haveli, Daman & Diu
CWC Visakhapatnam	State: Andhra Pradesh	State: Andhra Pradesh
CWC Bhubaneshwar	State: Odisha	State: Odisha

*Coastal strip of responsibility extends upto 75 km from the coast line.

In the present scenario, India is second to none, not only among the developing Nations, but across the world in early warning services as well as in managing the disasters associated with Cyclones. India Meteorological Department has demonstrated its capability to provide early warning for Cyclones with high precision. With the help of such early warnings, the Government is able to mobilise evacuation operations in a timely manner, thereby saving lives & livelihood. The cyclone forecast accuracy has significantly improved in recent years as has been demonstrated during cyclones Phailin (2013), Hudhud (2014), Vardah (2016), Titli (2018), Fani & Bulbul (2019), Amphan, Nisarga & Nivar (2020) and Tauktae & Yaas (2021). During recent years, the loss of life has been drastically reduced being limited to double digit figure in the recent years.

The annual average track forecast errors in 2020 have been 72 km, 85 km and 111 km, respectively for 24, 48 and 72hrs against the past five years average error of 80, 125 and 177 km based on data of 2016-2020. The errors have been significantly lower during last year (2020) as compared to long period average (2015-19) for all lead periods upto 120 hours.

Further, the Government of India has initiated the National Cyclone Risk Mitigation Project (NCRMP) with a view to address cyclone risks in the country. The overall objective of the Project is to undertake suitable structural and non-structural measures to mitigate the effects of cyclones in the coastal states and UTs of India. National Disaster Management Authority (NDMA) under the aegis of Ministry of Home Affairs (MHA) will implement the Project in coordination with participating State Governments and the National Institute for Disaster Management (NIDM). The Project has identified 13 cyclone prone States and Union Territories (UTs), with varying levels of vulnerability.

It is being planned to further enhance the accuracy of weather forecasts and their timely dissemination by improving the observational network and numerical modeling capability.

(vi) Along with early detection of impending hazardous weathers, early and fast dissemination is also very necessary for taking mitigation action. Regarding well in advance broadcasting / dissemination of weather forecasts and warnings, IMD is always in a continuous process of improvement through implementation of latest tools and technology. At present the forecasts and warnings are broadcasted or disseminated to users including disaster managers by e-mail on regular basis. In addition to this, WhatsApp groups are created including disaster managers and IMD officials through which these forecasts & warnings are disseminated. The forecasts & warnings are uploaded in social media & website for reference by all concerned. The nowcasts related to Severe Weathers are also disseminated through SMS to the registered users.

In addition to this, as and when the situation arises, Press Releases are issued by IMD and the same is also disseminated by all the platforms mentioned above.

IMD has taken various initiatives in recent years for improvement in dissemination of weather forecast and warning services based on latest tools and technologies. In 2020, IMD has launched seven of its services (Current Weather, Nowcast, City Forecast, Rainfall Information, Tourism Forecast, Warnings and Cyclone) with '**UMANG**' mobile App for use by public.

Moreover, in 2020, India Meteorological Department had developed mobile App '**MAUSAM**' for weather forecasting, '**Meghdoot**' for Agromet advisory dissemination and '**Damin**i' for lightning alert.

(vii) IMD is issuing Impact Based Forecast (IBF) for all districts for past two years against all types of server weather events in the recent past. Impact Based Warning contains guidelines to the general public while getting exposed to the severe weather. These guidelines are finalized by NDMA (National Disaster Management Authority) in coordination with IMD and the same is being issued for the adverse weather elements during different seasons.

(viii) Moreover, various new initiatives, as mentioned below, have been undertaken by IMD, MoES for betterment of prediction and dissemination of warnings of extreme weather events that may cause natural disasters.

1. The observational network of the department is being enhanced with installation of more number of Automatic Weather Stations (AWSs) and Automatic Rain gauges (ARGs) across the country.
2. 29 Doppler Weather Radars are operational across the country to provide adequate warning in the event of approach of Cyclonic Storms, Monsoon Depressions, Thunderstorms etc. DWR network also provides vital information for nowcasting purposes on mesoscale convective weather developments anywhere in the country.
3. Multi-Mission Meteorological Data Receiving & Processing System has been established and dedicated to the nation for augmentation of satellite derived products.
4. 203 new raingauge stations have been added in the District-wise Rainfall Monitoring Scheme taking the total number of stations to 4940.
5. Location specific forecast for 7 days within the capital cities and nowcast for next 3 hours have been extended to 526 and 1084 stations respectively covering 739 districts in the country.
6. NWP Model based gridded rainfall data are provided to Central Water Commission for their flood forecasting model for all 153 river catchments and Extended Range model products for 10 river basins.
7. With operationalization of Flash Flood Guidance system, generation and issue of Flash Flood Guidance has commenced for all watersheds of the country.
8. Common Alert Protocol (CAP) has been implemented as per WMO standard for severe weather warning. It is being utilized for Global Multi-Hazard Alert System of WMO.

(e) Yes. India is also vulnerable to climate change. The latest report on climate change assessment published by Mininstry of Earth Sciences describe the major changes happened in different climate variables over Indian region. It also discusses the areas vulnerable to different extreme weather events in the country. Summary of the report is given as Annexure-II.

Annexure-I

*Number of Deaths due to Extreme Weather Events (2010-2021)												
YEAR	**SNOW FALL**	**COLD WAVE**	**HEAT WAVE**	**SQUALL**	**GALE**	**DUST STORM**	**LIGHTNING**	**THUNDER STORM**	**HAIL STORM**	**FLOODS AND HEAVY RAINS**	**CYCLONIC STORM**	**TOTAL (WHOLE YEAR)**
2021	6	5				5	300	23	1	289	153	**782**
2020	22	162	11	6	12	14	270	594		758	115	**1964**
2019	65	291	495	3	5	25	202	349	2	921	71	**2429**
2018	18	280	33		8	237	342	572	8	1099	157	**2754**
2017	38	51	375	15	10	5	834	287	4	1075	46	**2740**
2016	22	42	510	8	3	11	670	216	28	714	34	**2258**
2015	12	18	2081	1	5	30	498	324	39	917	94	**4019**
2014	62	58	547	9	3	51	352	246	35	953	46	**2362**
2013	30	271	1433	1	3	1	326	327	54	5528	50	**8024**
2012	31	139	729	5	5	5	434	190		395	61	**1994**
2011	14	722	12		4	21	177	331		654	46	**1981**
2010	25	450	269		3	41	431	373	45	1058	22	**2717**

***Based on the media reports.**

Figures

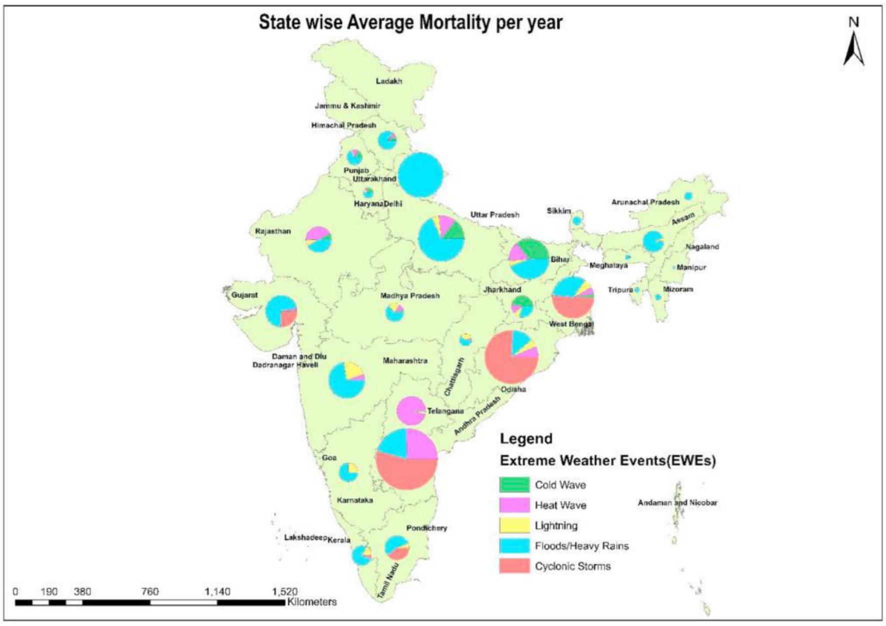

Fig. 1. Extreme weather event (EWE) wise distribution of mortality of various Indian states during 1970–2019. The size of the circle represents the average mortality of each state, while the different sectors of the circle represent mortality due to different EWEs.

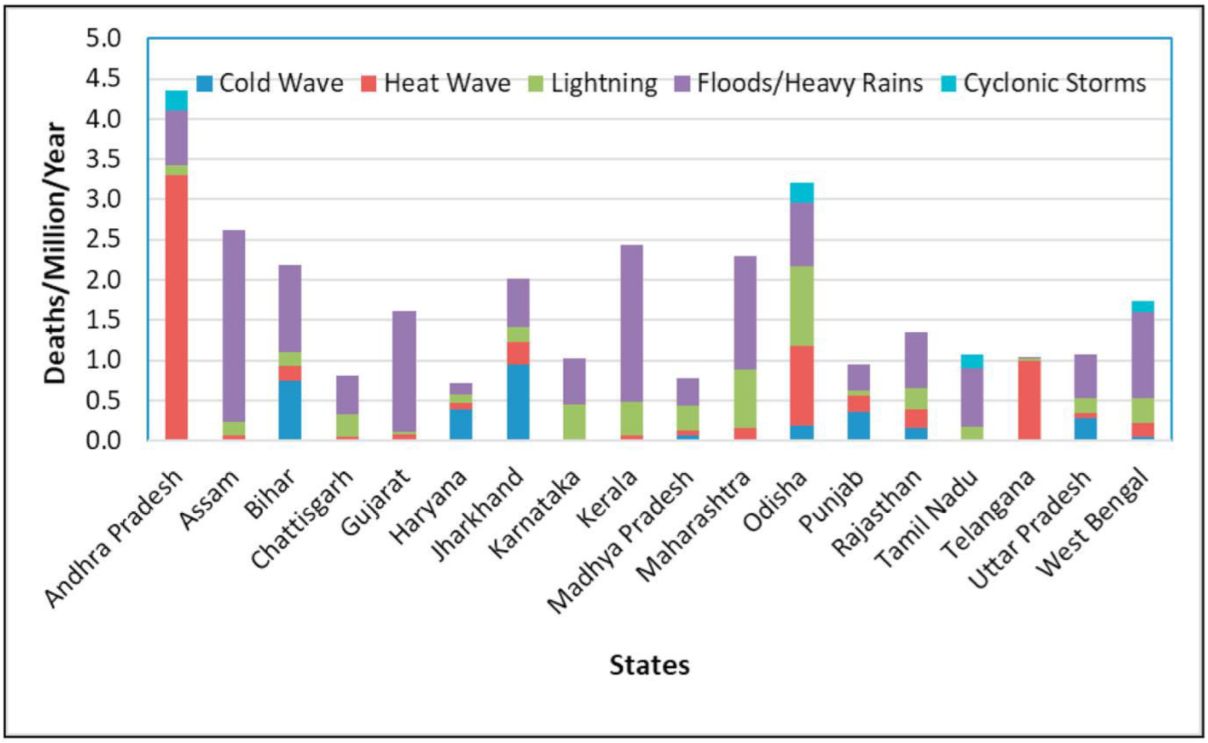

Fig. 2. State-wise and EWE wise distribution of mortality rates (deaths/year/million population) during 2000–2019, for a) states with a population of more than 15 million

Annexure-II

Summary regarding vulnerablility to different extreme weather events

Highlights of the Climate Change Assessment report

The summary on the variability and change of the regional climate system based on the 12 chapters in this book is as follows.

Observed Changes in Global Climate

The global average temperature has risen by around 1°C since pre-industrial times. This magnitude and rate of warming cannot be explained by natural variations alone and must necessarily take into account changes due to human activities. Emissions of greenhouse gases (GHGs), aerosols and changes in Land Use and Land Cover (LULC) during the industrial period have substantially altered the atmospheric composition, and consequently the planetary energy balance, and are thus primarily responsible for the present-day climate change. Warming since the 1950s has already contributed to a significant increase in weather and climate extremes globally (e.g., heat waves, droughts, heavy precipitation, and severe cyclones), changes in precipitation and wind patterns (including shifts in the global monsoon systems), warming and acidification of the global oceans, melting of sea ice and glaciers, rising sea levels, and changes in marine and terrestrial ecosystems.

Projected Changes in Global Climate

Global climate models project a continuation of human-induced climate change during the twenty-first century and beyond. If the current GHG emission rates are sustained, the global average temperature is likely to rise by nearly 5°C, and possibly more, by the end of the twenty-first century. Even if all the commitments (called the "Nationally Determined Contributions") made under the 2015 Paris agreement are met, it is projected that global warming will exceed 3°C by the end of the century. However, temperature rise will not be uniform across the planet; some parts of the world will experience greater warming than the global average. Such large changes in temperature will greatly accelerate other changes that are already underway in the climate system, such as the changing patterns of rainfall and increasing temperature extremes.

Climate Change in India: Observed and Projected Changes

Temperature Rise Over India

India's average temperature has risen by around 0.7°C during 1901–2018. This rise in temperature is largely on account of GHG-induced warming, partially offset by forcing due to anthropogenic aerosols and changes in LULC. By the end of the twenty-first century, average temperature over India is projected to rise by approximately 4.4°C relative to the recent past (1976–2005 average), under the RCP8.5 scenario. Projections by climate models of the Coupled Model Inter-comparison Project Phase 5(CMIP5) are based on multiple standardized forcing scenarios called Representative Concentration Pathways (RCPs). Each scenario is a time series of emissions and concentrations of the full suite of GHGs, aerosols, and chemically active gases, as well as LULC changes through the twenty-first century, characterized by the resulting Radiative Forcing (A measure of an imbalance in the Earth's energy budget owing to natural (e.g.,volcanic eruptions) or human-induced (e.g., GHG from fossil fuel combustion) changes) in the year 2100 (IPCC 2013). The two most commonly analyzed scenarios inthis report are "RCP4.5" (an intermediate stabilization pathway that results in a Radiative Forcing of 4.5 W/m2 in 2100) and "RCP8.5" (a high concentration pathway resulting in a Radiative Forcing of 8.5 W/m2 in 2100).

In the recent 30-year period (1986–2015), temperatures of the warmest day and the coldest night of the year have risen by about 0.63°C and 0.4°C, respectively.

By the end of the twenty-first century, these temperatures are projected to rise by approximately 4.7°C and 5.5°C, respectively, relative to the corresponding temperatures in the recent past (1976–2005 average), under the RCP8.5 scenario.

By the end of the twenty-first century, the frequencies of occurrence of warm days and warm nights are projected to increase by 55% and 70%, respectively, relative to the reference period 1976-2005, under the RCP8.5 scenario.

The frequency of summer (April–June) heat waves over India is projected to be 3 to 4 times higher by the end of the twenty-first century under the RCP8.5 scenario, as compared to the 1976–2005 baseline period. The average duration of heat wave events is also projected to approximately double, but with a substantial spread among models.

In response to the combined rise in surface temperature and humidity, amplification of heat stress is expected across India, particularly over the Indo-Gangetic and Indus river basins.

Indian Ocean Warming

Sea surface temperature (SST) of the tropical Indian Ocean has risen by 1°C on average during 1951–2015, markedly higher than the global average SST warming of 0.7°C, over the same period. Ocean heat content in the upper 700 m (OHC700) of the tropical Indian Ocean has also exhibited an increasing trend over the past six decades (1955–2015), with the past two decades (1998–2015) having witnessed a notably abrupt rise.

During the twenty-first century, SST and ocean heat content in the tropical Indian Ocean are projected to continue to rise.

Changes in Rainfall

The summer monsoon precipitation (June to September) over India has declined by around 6% from 1951 to 2015, with notable decreases over the Indo-Gangetic Plains and the Western Ghats. There is an emerging consensus, based on multiple datasets and climate model simulations, that the radiative effects of anthropogenic aerosol forcing over the Northern Hemisphere have considerably offset the expected precipitation increase from GHG warming and contributed to the observed decline in summer monsoon precipitation.

There has been a shift in the recent period toward more frequent dry spells (27% higher during 1981–2011 relative to 1951–1980) and more intense wet spells during the summer monsoon season. The frequency of localized heavy precipitation occurrences has increased worldwide in response to increased atmospheric moisture content. Over central India, the frequency of daily precipitation extremes with rainfall intensities exceeding 150 mm per day increased by about 75% during 1950–2015.

With continued global warming and anticipated reductions in anthropogenic aerosol emissions in the future, CMIP5 models project an increase in the mean and variability of monsoon precipitation by the end of the twenty-first century, together with substantial increases in daily precipitation extremes.

Droughts

The overall decrease of seasonal summer monsoon rainfall during the last 6–7 decades has led to an increased propensity for droughts over India. Both the frequency and spatial extent of droughts have increased significantly during 1951–2016. In particular, areas over central India, southwest coast, southern peninsula and north-eastern India have experienced more than 2 droughts per decade, on average, during this period. The area affected by drought has also increased by 1.3% per decade over the same period.

Climate model projections indicate a high likelihood of increase in the frequency (>2 events per decade), intensity and area under drought conditions in India by the end of the twenty-first century under the RCP8.5 scenario, resulting from the increased variability of monsoon precipitation and increased water vapour demand in a warmer atmosphere.

Sea Level Rise

Sea levels have risen globally because of the continental ice melt and thermal expansion of ocean water in response to global warming. Sea-level rise in the North Indian Ocean (NIO) occurred at a rate of 1.06–1.75 mm per year during 1874–2004 and has accelerated to 3.3 mm per year in the last two and a half decades (1993–2017), which is comparable to the current rate of global mean sea-level rise.

At the end of the twenty-first century, steric sea level in the NIO is projected to rise by approximately 300 mm relative to the average over 1986–2005 under the RCP4.5 scenario, with the corresponding projection for the global mean rise being approximately 180 mm.

Tropical Cyclones

There has been a significant reduction in the annual frequency of tropical cyclones over the NIO basin since the middle of the twentieth century (1951–2018). In contrast, the frequency of very severe cyclonic storms (VSCSs) during the post-monsoon season has increased significantly (+1 event per decade) during the last two decades (2000–2018). However, a clear signal of anthropogenic warming on these trends has not yet emerged.

Climate models project a rise in the intensity of tropical cyclones in the NIO basin during the twenty-first century.

Changes in the Himalayas

The Hindu Kush Himalayas (HKH) experienced a temperature rise of about 1.3°C during 1951–2014. Several areas of HKH have experienced a declining trend in snowfall and also retreat of glaciers in recent decades. In contrast, the high-elevation Karakoram Himalayas have experienced higher winter snowfall that has shielded the region from glacier shrinkage.

By the end of the twenty-first century, the annual mean surface temperature over HKH is projected to increase by about 5.2°C under the RCP8.5 scenario. The CMIP5 projections under the RCP8.5 scenario indicate an increase in annual precipitation, but decrease in snowfall over the HKH region by the end of the twenty-first century, with large spread across models.

Conclusions

Since the middle of the twentieth century, India has witnessed a rise in average temperature; a decrease in monsoon precipitation; a rise in extreme temperature and rainfall events, droughts, and sea levels; and an increase in the intensity of severe cyclones, alongside other changes in the monsoon system. There is compelling scientific evidence that human activities have influenced these changes in regional climate.

Human-induced climate change is expected to continue apace during the twenty-first century. To improve the accuracy of future climate projections, particularly in the context of regional forecasts, it is essential to develop strategic approaches for improving the knowledge of Earth system processes, and to continue enhancing observation systems and climate models.

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