

Climate change scenario

in Indian hot arid region

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Emission of greenhouse gases is increasing since the beginning of Industrial Revolution, and their increasing concentrations in the atmosphere are altering the radiative forcing of the earth. The climate change due to earth's altered energy balance resulted in increasing temperatures and changes in precipitation amounts, frequency of extreme weather events, rise in sea levels, etc. globally. Increase in day and night temperatures was observed in hot arid zone, particularly after 1970s. Consequently, number of hot days in a year is increasing, whereas the number of cool nights is declining. Annual rainfall showed clear increasing trend (9.4 mm yr^{-1}) in Saurashtra and Kutch regions during 1981-2010 and maximum increase was observed in July rainfall (3.2 mm yr^{-1}). Climate models showed that warming would continue in these regions in near future also, but the magnitude may vary depending upon future emission scenario. The impact of climate change on precipitation in arid regions of India, however, is not so clear though there are indications of slight increase.

Key words: Climate change, Greenhouse gases, Hot arid zone

EARTH receives energy from the sun as shortwave radiation and most of it is emitted back in space as longwave radiation. Concentration of heat-trapping gases or greenhouse gases (GHGs) like carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO_2) as well as the water vapour in the atmosphere affects earth's radiative forcing or energy balance and thus its climate.

Similarly, changes to land surfaces like clearing forests for farming, change the surface albedo which also affect the energy balance. Emission of pollutants that affects the amount and type of particles in the atmosphere also affect earth's energy balance.

The change in energy balance causes the climate change. In simple terms, climate change refers to major changes in temperature, precipitation, wind patterns etc. for an extended period of time (over decades or longer).

Global climate change scenario

Atmospheric carbon dioxide (CO_2) concentration remained below 280 parts per million (ppm) about 8,00,000 years before beginning of industrialization. Since the Industrial

Revolution from 1,750 global CO_2 emissions was increasing rapidly due to use of fossil fuel in energy, transport, industry and other sectors. Burning of forests for farming and other land use changes were

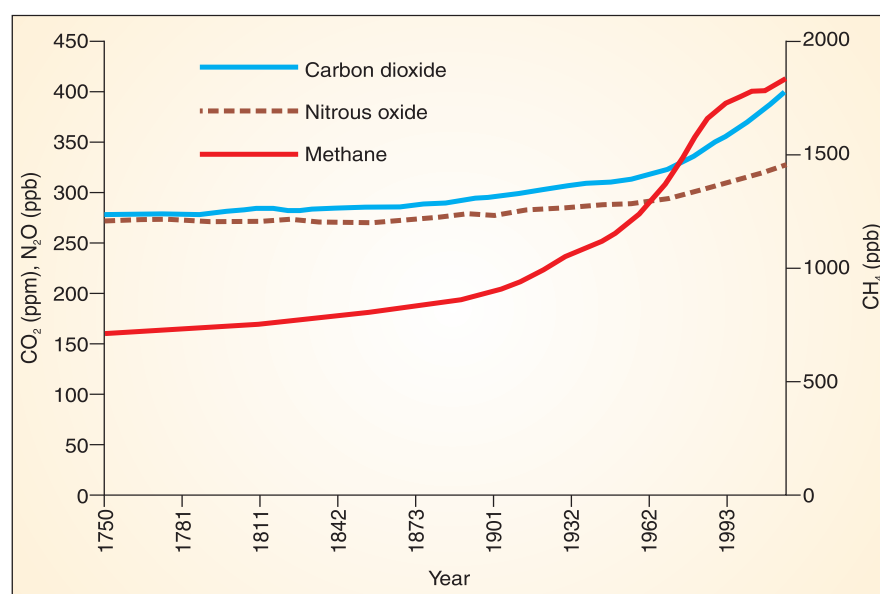


Fig. 1. Atmospheric concentration of three major greenhouse gases

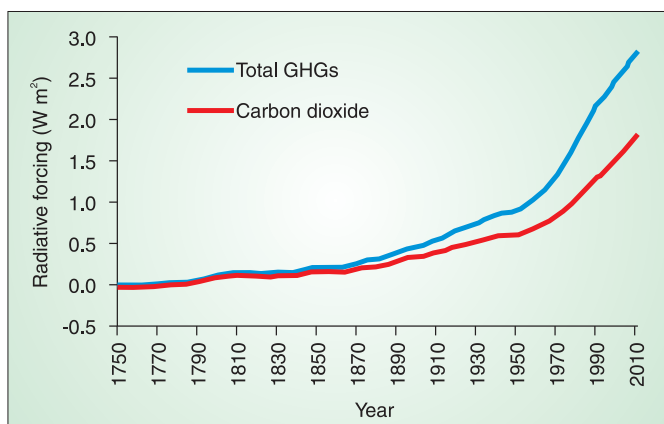


Fig. 2. Radiative forcing of CO₂ and total GHGs

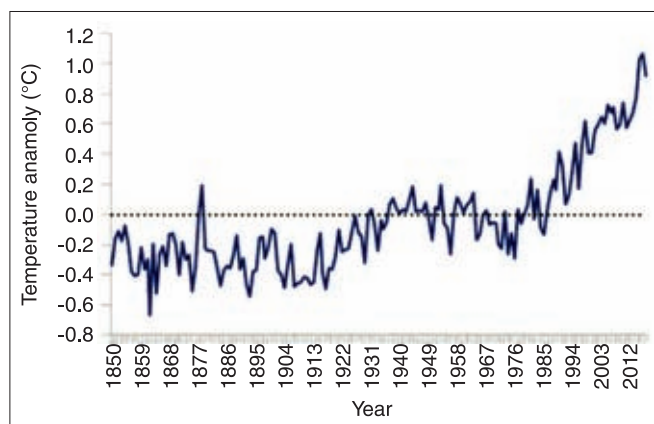


Fig. 3. Temperature anomaly (°C) in northern Hemisphere relative to 1961-1990

contributed to CO₂ emission. About a quarter of the total CO₂ emissions is taken up by the oceans and another quarter by the biosphere, thus reducing the amount of CO₂ in the atmosphere. Despite that, global average atmospheric CO₂ concentration reached 403.3 ppm in 2016. Geological records showed that the last time the earth experienced a comparable concentration of CO₂ was 3 to 5 million years ago.

Emissions of other GHGs like methane (CH₄) and nitrous oxide (N₂O) were increasing through industrial, agricultural and energy sources. In 2016, atmospheric concentration of CH₄ and N₂O were 1853 and 328.9 parts per billion (ppb), respectively. Thus, atmospheric concentrations of CO₂, CH₄ and N₂O were 145, 257 and 122% of pre-industrial levels in 2016 (Fig. 1). Emission of CFCs, however, was declining since 2000.

Prior to 1750, earth's radiative forcing remained relatively stable and scientists calculated subsequent changes over the relative forcing of 1,750. Since then, relative forcing of the five major, well mixed, long-lived greenhouse gases (CO₂, CH₄, N₂O, CFC-12 and CFC-11) increased by 3.06 W m⁻². The increase was more rapid in recent past (Fig. 2) and relative forcing of GHGs increased 41% from 1990 to 2017 (by ~0.90 W m⁻²), CO₂ alone accounted for about 80% of this increase (~0.72 W m⁻²).

The most conspicuous impact of increasing relative forcing was

observed in the form of increasing temperatures. Global average temperature was increased @ 0.13°C since 1957 (Fig. 3). Changes in hydrological-cycle were recorded. Frequency and intensity of storms increased as the warm air is able to hold more water vapor. Changes in annual precipitation were observed with some areas experiencing droughts and others experiencing increased precipitation. Most of the glaciers are decreasing in area and volume, and sea level is rising. Acidification of oceans is also increasing as the oceans absorb about one-fourth of the emitted CO₂.

Climate characteristic of Indian arid zone

The hot Indian arid zone, confined mainly to north-western Rajasthan, north-western Gujarat and small parts of Punjab and Haryana, faces water scarcity and frequent droughts due to low and erratic rainfall and high potential evapo-transpiration. Geological evidences indicated that earlier this region was semi-arid and the arid phase commenced about 3,000 years back. Like other arid regions, annual rainfall was low and erratic which varied from 100 to 500 mm. About 88 to 93% of the total annual rainfall was received during the south-west monsoon (July to September). The normal onset of monsoon rains is 1 July in eastern parts and 15 July in extreme western parts of Rajasthan. Withdrawal of monsoon rains starts from the western parts by mid-September. Thus, the length of rainy season is 2 to 2.5 months compared to 3-4

months (Jun. to Sep.) in most other parts of India. A small amount of rainfall, constituting about 7 to 10% of the annual, is received during the winter under the influence of western disturbances. Compared to low precipitation amounts, the annual atmospheric water demand (potential evapo-transpiration) is 1,600 to 2,000 mm yr⁻¹, which increased further during drought years. Droughts were common in one or other part of arid zone due to high temporal and spatial variability in rainfall amounts. Droughts occur once in 2 to 4 years in different parts of arid zone. Consecutive droughts of 3 to 4 years are not uncommon. For example, during 1984, 1985, 1986 and 1987, western Rajasthan faced consecutive droughts and Jaisalmer, Bikaner, Barmer, Jodhpur and Jalore districts were worst affected.

Annual and diurnal temperature range was very wide. During winter, mean maximum air temperature varied from 22.4 to 29.0°C and minimum temperatures from 4.1 to 14.3°C, but sub-zero temperatures also occur frequently. Air temperature sharply increased from April onwards and stand highest during May-June till pre-monsoon showers sets in the area. Average maximum temperature during summer varied from 40° to 42°C in different parts, which may occasionally be as high as 47° to 51°C.

General wind direction is south-west during monsoon and north-east during winter. Mean winds speed during winter is low (4-7 km h⁻¹). Wind speed increases during summer and average monthly wind speed

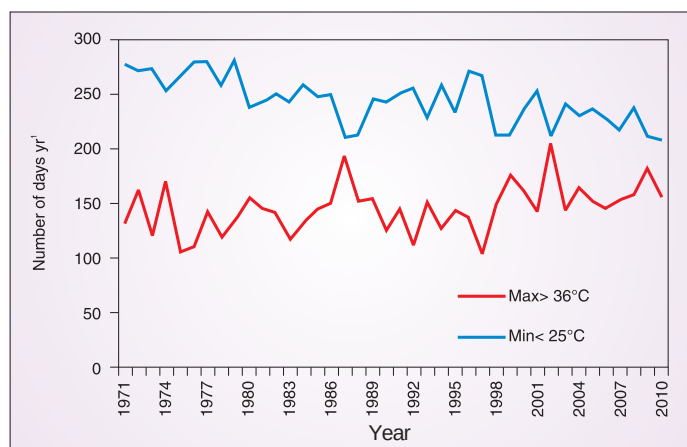


Fig. 4. No. of days/annum with $>36^{\circ}\text{C}$ maximum and $<25^{\circ}\text{C}$ minimum temperatures

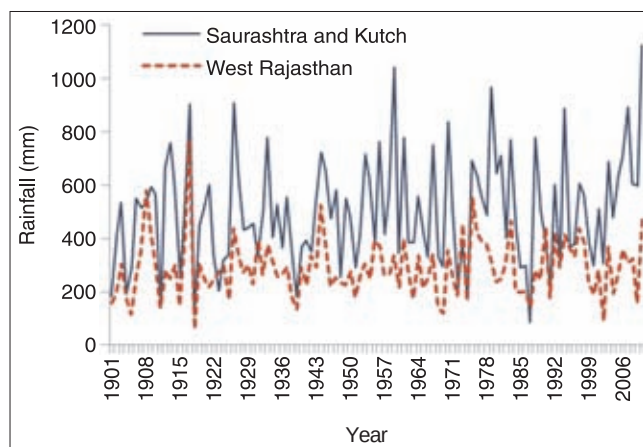


Fig. 5. Annual rainfall (mm) in Saurashtra and Kutch and West Rajasthan met subdivisions

varies from 10 to 18 km h^{-1} . Peak winds occasionally reach as high as 60-80 km h^{-1} during severe dust storms.

Relative humidity remains low from March to May and is often less than 30%. Humidity is highest between July and August when monsoon current brings in high amount of water vapours. The relative humidity drops sharply from October after withdrawal of the monsoon current from the region. Solar radiation is generally high throughout the year ranging from 15 to 26.5 $\text{MJ m}^{-2} \text{d}^{-1}$ in different seasons.

Climate change in recent years

Increase in day and night temperatures was observed in arid zone also, particularly after 1970s. Consequently, number of hot days in a year is increasing, whereas the number of cool nights is declining, as observed at Jodhpur (Fig. 4). This trend is likely to increase the high temperature stress in crops, however, the probability of frost injury to sensitive winter crops and vegetables may decline.

Inter-annual variability in rainfall amounts is wide in hot arid zone as is evident from annual rainfall data of Saurashtra and Kutch, and West Rajasthan met subdivisions. The variability is wider at smaller scale of district or *tehsil*. Annual rainfall showed clear increasing trend (9.4 mm yr^{-1}) in Saurashtra and Kutch region during 1981-2010 (Fig. 5). Maximum increase in rainfall during this period was observed in July (3.2

mm yr^{-1}), followed by August (2.9 mm yr^{-1}), September (2.3 mm yr^{-1}) and June (1.7 mm yr^{-1}). In west Rajasthan also, there was slight increase in annual rainfall (0.9 mm yr^{-1}) during this period.

Average climatic conditions of 11 stations located in hot arid zone (9 in Rajasthan, one each in Gujarat and Haryana), for two blocks of 30 years each viz, 1951-1980 and 1981-2010, were compared. Temperature increased at all the stations from first to second period. Mean annual temperature of all the stations increased by 0.4°C ($0.13^{\circ}\text{C/decade}$), though there were differences in magnitude of increase among different stations. Increase in minimum temperature was more ($0.15^{\circ}\text{C/decade}$) compared to increase in maximum temperature ($0.11^{\circ}\text{C/decade}$). Annual average wind speed declined from 7.9 kmph to 5.6 kmph (29%). Interestingly, number of dust storms also declined from 5.8 to 3.9/annum (32%). Reduction in wind speed was observed in other regions also. Wind speed at Jodhpur was observed to reduce consistently from early 1970s to mid-1990s and no substantial changed were observed for subsequent one- and- a- half-decade (Fig. 6), and the trend was significant for all the months.

Like hot arid zone, temperature in Ladakh region showed increasing trend and the trend was steep and significant for recent period (1991-2013). There was no clear trend in precipitation amount. However, since 1901, negative correlation was

observed between annual precipitation amount and mean temperature of Ladakh region.

Expected climate in near future

Output of 18 General Circulation Models (GCMs), which participated in CMIP5 (Coupled Model Inter-comparison Project-5), for three timelines (2030, 2050 and 2080) and four Representative Concentration Pathways (RCPs), showed increase in temperature in arid Rajasthan with increase in relative forcing and timelines. Mean of prediction of 18 GCMs indicated that the maximum temperature may be higher by 1.6-2.8 $^{\circ}\text{C}$ in 2050 and by 1.7-4.8 $^{\circ}\text{C}$ in 2080 under four representative concentrative pathways. However, the magnitude of increase in minimum temperature was more compared to maximum temperature both for 2050 (1.9-3.3 $^{\circ}\text{C}$) and 2080 (1.8-5.3 $^{\circ}\text{C}$) timeline. There was wider disagreement among models for changes in rainfall amounts. Some models showed increase in rainfall with time while others showed a decreasing trend as showed for three timelines under representative concentrative pathways 6.0 (Fig. 7). Average projection of 18 models indicated 5 to 13% increase in annual and 3 to 9% increase in *kharif* rainfall in arid Rajasthan under four representative concentrative pathways and three timelines.

SUMMARY

Climate is changing globally but the changes in temperature, rainfall amounts and its distribution pattern

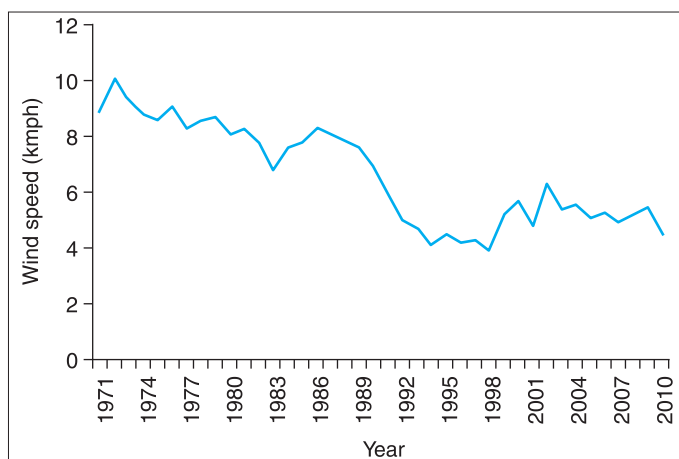


Fig. 6. Annual average wind speed (kmph) at Jodhpur

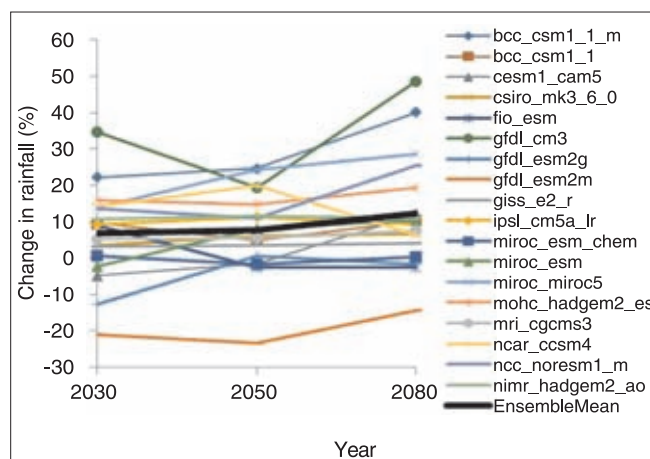


Fig. 7. Prediction of 18 GCMs for change in annual rainfall (%) in arid Rajasthan under RCP 6.0

during the season, extreme weather events, etc. are not similar across the regions. Changes in land use also impact the climate. Introduction of canal and tube-well irrigation in arid parts of Punjab, Haryana and Rajasthan and conversion of grasslands into irrigated cultivated lands resulted in substantial modifications in micro-climate of arid ecosystem. Temperatures were increasing in hot and cold arid regions of India but there was no

clear trend or projection for precipitation. Quantification of changes that occurred in recent past along with GCM outputs for the region, could give fairly good idea of likely climatic conditions people may face in near future. Such information helped in better preparation for adaptation. It was evident that relative forcing due to continued emissions of GHGs will result in warming, but how it will impact global circulation patterns or regional

monsoon systems, is still not well understood.

This is the major cause of concern and replacement of carbon based energy with renewable or clean energy is the only long-lasting solution to the problem of climate change.

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Attracting and Retaining Youth in Agriculture (ARYA)

Realizing the importance of rural youth in agricultural development especially from the point of view of food security of the country, ICAR has initiated a program on "Attracting and Retaining Youth in Agriculture."

The objectives of ARYA project are:

- (i) To attract and empower the youth in rural areas to take various agriculture, allied and service sector enterprises for sustainable income and gainful employment in selected district;
- (ii) To enable the farm youth to establish net work groups to take up resource and capital intensive activities like processing, value addition and marketing; and
- (iii) To demonstrate functional linkage with different institutions and stakeholders for convergence of opportunities available under various schemes/program for sustainable of youth.

ARYA project will be implemented in 25 states through KVKs, one district, 200-300 rural youth will be identified for their skill development in entrepreneurial activities and establishment of related micro-enterprise units in the area of Apiary, Mushroom, Seed processing, Soil testing, Poultry, Dairy, Goatry, Carp-hatchery, Vermi-compost etc. KVKs will involve the Agricultural Universities and ICAR Institutes as technology partners. At KVKs also one or two enterprise units will be established so that they serve as entrepreneurial training units for farmers. The purpose is to establish economic models for youth in the villages so that youths get attracted in agriculture and overall rural situation is improved.

The trained youth groups will function as role model for other youths and will demonstrate the potentiality of the agri-based enterprises which will help in improving their confidence levels and encourage them to pursue farming as profession, generate additional employment opportunities to absorb under employed and unemployed rural in secondary agriculture and service related activities in rural areas.