

# Climate change, Environmental impacts and Sustainable development

U.S. De<sup>1</sup> and D.M. Rase<sup>\*2</sup>

<sup>1</sup>Visiting Faculty, India Meteorological Department, Pune

<sup>2</sup>India Meteorological Department, Pune

\*Corresponding Author: drdineshrase@gmail.com

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## ABSTRACT

It has been revealed by proxy data that terrestrial and extra terrestrial factors were mainly responsible for paleoclimatic changes. However, since the industrial revolution during the past one hundred fifty years, the climate change is driven by anthropogenic factors, in addition to natural. The impacts of the climate changes, during the last hundred years on our environment are found to be detrimental in many ways. The paper presents some of these aspects and the international efforts to face the challenges of anthropogenic involvement in climate change. A way forward could be sustainable development by arresting negative factors that are adding to degradation of our environment, including uncontrolled use of non renewable natural resources.

**Key words:** Global warming, Climate change, Paleoclimate, Mitigation, conference of parties (COP).

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## INTRODUCTION

Climate of our planet is a display of the long term balance between incoming solar radiation and outgoing long wave radiation from earth-atmosphere system. The temperature of the earth varies from equator to the poles and supports different types of vegetation and lives in the biosphere. These form the rich biodiversity of the planet earth (Juniper, 2007). Any change in the climate of earth over long periods of time were slow enough but the flora and fauna on the earth varied their evolutionary mechanism faster to adapt to changes to the paleoclimate due to various natural phenomena, as seen in fossil records and other geo indicators. Irrespective of such an evolutionary trend the changes witnessed were in no way as significant as noticed in the geological recent past.

In recent years rapid anthropogenic climate change is mainly forced due to enhanced emission of Green House Gases (GHGs) and aerosols linked with industrial development, which started nearly 200 years back. Studies during twentieth century showed that an anthropogenic climate change has raised the average global temperature from 1860 till date at different rates. Jones and Bifra (1998) found that the last decade of the past century, 1991-2000, was the warmest during the past 140 years. Rupakumar et al., (1994); De and Mukhopadhyay (1998) have studied the temperature data for the Indian region to have a better understanding of this global problem with data at local and regional level.

The present century has also evidenced so far the same trend albeit at a steeper rate. WMO's Climate Research Program (WCRP) focused on the climate change issue leading to a global attention on the urgent matter. The governments took interest and the Inter Governmental Panel on Climate

Change (IPCC) and United Nation Framework Convention on Climate Change (UNFCCC) were established. Studies on impacts of Global Warming showed that impacts can be reduced only by controlling emission and by adapting measures linked with sustainable development path ways advocated in United Nation Convention on Environment of Development (UNCED) or Rio - 1995.

These efforts and initiatives were useful in making "Global Warming" a matter of concern for global community. It stepped up the awareness among nations to act to combat global warming. However, despite years of concerted efforts at global, regional and national levels the momentum for future development on focused sustainable path has not gained significant acceptance from all the developed and developing countries due to lack of understanding between different stakeholders. Efforts are needed to meet future needs of the planet by moving on a sustainable path, which seems to be the proper answer to contain global warming.

## Data, observations and impacts

Global data show various signatures of climate change. Some signatures (Rosser (2008)) are listed below:

- a. Significant (Nearly 30-40 %) reduction in the aerial extent of mountain glaciers and snow cover during the last century.
- b. A trend that supports continuous rise in average global temperature from the base line value of 1860. The rate of increase in temperature in recent decades after 1980's, showing a steeper trend. As on 1995 the increasing rate was between 0.38° and 0.6°C, compared to the average during last century. The updated trend, taking in to consideration the total data, during the last hundred year period, 1906-2005, is found to be 0.74°C.

**Table 1.** Extreme Weather Events in India.

| Year | Weather Events and area/region affected   | Extent of damage   |
|------|---|--|
| 2002 | i) Severe heat wave in Andhra Pradesh, Rajasthan, West Bengal and Orissa.<br>ii) During this year the first all India drought during SW monsoon was witnessed, after 1987.  | i) 800 lives lost, out of which 600 deaths were in Andhra Pradesh alone.<br>ii) 12 out of 36 subdivisions of the country came under the grip of moderate to severe drought.  |
| 2003 | i) Severe cold wave over most parts of north India during January.<br>ii) Heat wave over Andhra Pradesh during 2 <sup>nd</sup> fortnight of May and 1 <sup>st</sup> fortnight of June.  | i) 1300 lives lost.<br>ii) More than 1400 died.  |
| 2004 | i) Floods and heavy rains over various parts of the country, especially over Assam, Bihar and Gujarat.  | More than 1500 lives lost.   |
| 2005 | i) SW monsoon witnessed heavy rains and cloud bursts over many parts of the country.<br>ii) Mumbai (Santa Cruz) and Thane in Maharashtra state received a record rainfall of 94 cm. and 72 cm. respectively in 24 hour on 27 July 2005.<br>iii) NE monsoon Floods and heavy rains during the season.<br>iv) Heat wave swept across northern parts of the country and Maharashtra state in different periods during April, May and June.<br>v) A Bay of Bengal cyclone hit the north Andhra coast during 17-21 Sept.<br>vi) This was a weak El-Nino year | i) 2051 human lives lost, apart from loss of large number of live stock. Extensive damage to public/private property<br>ii) Mumbai city and neighborhood was 4 to 5 ft. under water. Many buildings collapsed and it alone took a toll of 425 human lives. Estimated loss exceeded 1000 crores of Rupees.<br>iii) 328 died due to floods and heavy rain.<br>iv) 588 succumbed to heat waves.<br>v) 64 human lives lost and extensive damage to public / private property.<br>vi) Rainfall was deficit by 20% in north east India and 9% in north west India. |
| 2006 | i) Floods and heavy rains during summer monsoon of 2006.<br>ii) Cyclonic storm 'OGNI' during 29-30 <sup>th</sup> October 2006 crossed Andhra Pradesh coast on 30 <sup>th</sup> October.   | i) 1758 human lives lost apart from loss of large number of livestock. Extensive damage to public/private property.<br>ii) Loss of 28 human lives, 35000 livestock and crops in thousands of hectares in Prakasham, Guntur and Krishna districts of Andhra Pradesh.  |
| 2007 | Floods and heavy rains during Summer monsoon of 2007.   | 1287 human lives lost, apart from loss of large number of livestock and extensive damage to public/private property.   |
| 2008 | Cyclonic Storm 'NISHA' during 25-27 November 2008 crossed Tamil Nadu coast north of Karaikal.   | Loss of 100 human lives and extensive damage to paddy crops in 55,250 hectares.  |
| 2009 | i) The Cyclonic Storm 'AILA' which developed during 23-26 May 2009 over the Bay of Bengal crossed Indian coast close to Sagar Islands as severe cyclonic storm on 25 <sup>th</sup> .<br>ii) This is a moderate El Nino year   | i) Loss of 100 human lives in West Bengal and also caused extensive damage to crops and property.<br>ii) Country received deficient rainfall (78 % of long term averaged (89cm) ). 46% of country was under moderate drought (i.e. rainfall deficiency 26% to 50%)   |
| 2010 | i) A cloud burst on 6 <sup>th</sup> August in Leh (J&K).<br>ii) Severe Cyclonic Storm 'JAL' over Bay of Bengal crossed north Tamil Nadu – south Andhra Pradesh coast near Chennai on 7 <sup>th</sup> November.  | i) 150 lives lost and 500 people were reported missing.<br>ii) 16 lives lost in Andhra Pradesh and Tamil Nadu. Extensive damage to crops and public property reported.   |
| 2011 | The Severe Cyclonic Storm 'THANE' over the Bay of Bengal near Lat. 11.00N/ Long. 87.50E at 1800 UTC during 25-31 December crossed North Tamil Nadu coast between Cuddalore and Puducherry on 30 <sup>th</sup> December.   | It took a toll of 46 persons in Tamil Nadu, Puducherry and Kerala. Extensive damage to crops and property reported. Estimated damage worth Rs. 1300 to 1500 crore Rupees.  |

|      |   |  |
|------|---|--|
| 2012 | Heat wave conditions prevailed over some parts of the country.  | 729 human lives lost, out of which 366 from Andhra Pradesh, 142 from West Bengal and 104 from Jharkhand.   |
| 2013 | i) Heat wave conditions prevailed over Northeastern, Central and Peninsular parts of the country.<br><br>ii) During 14-18 June heavy to very rainfall/flash floods/cloudbursts/massive landslides and avalanches reported at several segments of Uttarakhand, North India.. | i) Over 1400 human lives lost, out of which 1393 were from Andhra Pradesh alone.<br><br>ii) More than 5,000 died. Widespread damage to public/private property and cash crops, especially apple. It was one of the most devastating natural disasters in the state.  |
| 2014 | i) Floods and heavy rains during summer monsoon. A massive landslide on 5 <sup>th</sup> August due to heavy rains.<br><br>ii) Severe cold wave prevailed over plains of north India during January and December.<br><br>iii) Moderate drought year                          | i) About 940 lives lost. It completely buried a village "Malin" (District Pune, Maharashtra). Around 200 people lost their lives in the landslide. During the second week of September, over 200 lives were lost due to floods. More than 4 lakh people were stranded. Widespread damage to the agriculture and public/private property, in the state of J & K.<br><br>ii) Due to cold wave 200 lives lost from northern parts of the country.<br><br>iii) Of the four homogeneous regions, the rainfall was below normal over north west India (-21.4%), East and northwest India (-11.8%). |
| 2015 | i) Heat wave conditions prevailed over Northeastern, Central and Peninsular parts of the country.<br><br>ii) This was a very strong El Nino year.   | i) Over 2000 human lives were lost, out of which 1422 were from Andhra Pradesh and 584 lives were from Telangana.<br><br>ii) The deficient rainfall received in west and east Uttar Pradesh and Marathwada (was more than 40% of its Long Period Average-LPA during monsoon season (June to Sept).<br><br>Of the four homogeneous regions the rainfall was below normal over north west India (-17%), Central India (-16%) and Peninsular India (-15% )  |

- c. The melting of snow cover and glaciers has resulted in the sea level rise ranging between 10-25 cm, since last century.
- d. Increase in the intensity and frequency of extreme weather events such as tropical Cyclones, cloudbursts and heavy rainfall, floods, droughts, heat and cold waves at global, regional and local levels.
- e. Increase in the number of frost free days and shift of permanent snow line to higher altitudes. This has led to significant impact on the vegetation and crops in these belts.
- f. Early flowering of trees in these belts and increase in the length of the growing season.
- g. Increase in the acidity of sea water since 1961 show that the temperature of global oceans up to a depth of at least 3000 ft. has been increasing.
- h. Concentration of all major Green House Gases has increased since 1860. The concentration of CO<sub>2</sub> has risen by almost 100 ppm (260-379 ppm) since 1860. It is now almost certain that these recent aspects of global warming are very likely to be associated with anthropogenic causes of rising Green House Gases concentration (IPCC 2012), which was 1.95 ppm/year during 1995-2005 (WMO, 2016, Bulletin v.65, no.2).

As mentioned earlier, the frequency of extreme weather events and their intensity have increased in the recent times. In this context the high impact of summer of 2003 killed more than 30,000 in Europe. In France alone 14002 people died from the scorching heat (Larson 2003). Similarly, unprecedented droughts of 2002 and 2009 in the Indian subcontinent bear testimony to these findings. Latest data from the India Meteorological Department's Climate Monitoring Centre, Pune show that February 2017 as the warmest February during the past 100 years. De et al., (2005) have listed major extreme weather events in India till 2001. Table 1, gives a list of such events in India from 2002 till date and Table 2 elsewhere in the world. These have resulted in large scale losses.

With emission of Green House Gases (GHGs) from anthropogenic activities growing unabated, the impacts are also growing. Non-climatic factors such as growth of population and rural population's migration to urban locations and unsustainable development has added to the severity of the impacts (WMO, 2016). De and Sinha Ray (2000) and De and Dandekar (2001) have shown how urban areas are becoming more vulnerable. The deluge in Mumbai, India, on 27<sup>th</sup> July 2005 due to unprecedented rainfall (De et al., 2006); the hurricane Katrina (2004)

**Table 2.** Extreme Weather Events- Worldwide.

| <b>Year andMonth</b> | <b>Weather Events and area/region affected</b>  | <b>Extent of damage</b>                          |
|----------------------|---|--|
| 2003, Jun- Jul       | Heat Wave in Europe   | 30,000 lives lost                                |
| 2010, 2011, 2012     | Severe drought in horn of Africa, NW corner of the continent, it includes Somalia, Ethiopia | Caused more than 2,50,000 deaths in Somalia      |
| 2011, Jul -Oct       | Floods in SE Asia   | 800 lives lost , loss of several billion dollars |
| 2012                 | Australia   | Drought  |
| 2012, Oct            | Hurricane Sandy USA and Canada  | Estimated loss US \$ 67 billion                  |
| 2013, Nov            | Typhoon Haiyan, Philippines   | 7800 lives lost                                  |
| 2014                 | Typhoon Halang, Japan,  | 5,70,000 people were displaced                   |
| 2014, Sep            | Riverine floods, Pakistan   | 7,40,000 people were displaced                   |
| 2014 – 2015          | Multi year drought in Brazil, SW USA and India  | Losses of tens of billions of dollars.           |
| 2015, Jun-Sep        | Extended summer in Europe   | Health hazard and deaths.                        |

and the high impact severe snow storm of western Europe during October 1987 etc are some of the examples. Table 1 and Table 2 also display as to how the world has become more vulnerable to these natural weather related hazard.

On the other hand spread of warmer and perhaps wetter climate to higher latitudes has resulted in spread of vector borne diseases such as malaria and Dengue. These impacts of climate change and global warming got accentuated due to non-climatic factors such as unplanned spread of urban areas, encroachment of wet land zones & flood plains and the natural drainage pattern. De (2001) has given an account of regional impacts in Asia from climate change on various sectors such as agriculture etc. De et al., (2013) and Tongadi (2008) have shown the increased risk from floods in urban areas, west coast and north east India.

Singh et al., (2011) studied landslides and flash floods in different parts of India, which also show increasing trend of such events from 1991 to 2005.

The range of temperature rise is between 0.58°C and 0.5°C, during the last 150 years. The data published by the Global Climate Summary (WMO 2016) shows that the last three decades (1981-2010) were warmer than the preceding 14000 years. On the other hand some of the years with recorded high global mean temperature include 1998, 2005, 2009 and 2016, during recent times. On regional and sub-regional scale, Australia had its warmest year in 2013. Similarly, the summer of 2013 was perhaps warmest in Europe (WMO 2016). Over the Indian subcontinent, the year 2015 recorded 0.67°C above the long term mean temperature making it third warmest year since 1901. India recorded abnormally high annual mean temperature during 2009, 2010, 2015, 2003, 2002, and 2014. The warmest 12 years over the country have occurred during the period, 2001-2015 (IMD, 2016).

De et al., (2005) have summarized extreme temperature events for the last hundred years (1901-2000). These observations clearly show that the rising trend in global mean annual temperature is reflected in regional and sub-regional scales as well. In particular the successive years were generally warmer than the previous warmest year. During recent years (2011-2015) the rise of temperature was at a steeper rate being 0.74°C above the level for the period, 1961-90 (WMO, 2016).

The other impacts of climate change (anthropogenic) are: (1) Sea level rise (2) acidification of sea water and (3) increase in intensity and frequency of extreme weather events. Recent observations also support these facts with higher degree of confidence than during the analysis of data sets of the previous century.

Extreme weather events have caused significant social impact and economic losses. In the recent years, some such examples are the rainfall in Mumbai on 27<sup>th</sup> July 2005 and Chennai deluge during November and December 2015. UK floods in 2014 caused a reported loss of US Dollar 646 million. The impact of these extreme weather events were generally felt unevenly with considerable severity in South & South-East Asia and Latin America. Khole and De (2001) have reviewed the socio economic impacts of these losses in development.

### International Efforts

Inter Government Panel of Climatic Change (IPCC) was created to make detailed study of climate change, which gives better scientific understanding and possible steps to combat anthropogenic climate change. Studies by IPCC resulted in various "Assessment Reports". The first Assessment Report was published in the year 1990. The

observations and assessment reports since then have been published at regular intervals. Based on these reports, the Kyoto Protocol was put in place asking for the nations to contain emission of Green House Gases (GHGs), i.e., CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, CFC, HFC and SF<sub>6</sub>.

These emission control measures were binding on the advanced nations (Annex I countries). The protocol was ratified by several countries. Notable exceptions were US, China and India, while UK and other European Countries ratified it. The protocol was a significant way forward where Annexure-I nations could reduce emission to desired level (pre 1990) through following mechanisms:

- (1) Emission Trading Scheme
- (2) Clean Development Mechanism
- (3) Joint implementation Project.

After 2012, when the Kyoto Protocol period lapsed there have been several attempts to get the fast developing countries such as China, India and others to make commitments to cap their emissions as well. As of now though there is greater awareness about the need to cap the global emission, implemented concrete steps are found to be not sufficient to achieve tangible results.

### Mitigation and Adaptation measures

The first assessment IPCC report published in 1990 made a guarded statement that future climate projection using different emission scenario in models indicate rising temperature with a range of 1 to 4.8°C by the end of 21<sup>st</sup> century. The concentration of CO<sub>2</sub> and other GHGs are increasing, which has a close association with anthropogenic emissions and global warming. Successive IPCC assessment reports gave more conclusive views on the role of anthropogenic emission and global warming and suggested measures to contain it (Houghton, 2004). There was no agreement among the nations regarding the way forward, especially regarding implementation of suggested steps to conclusively lessen greenhouse gas emissions. The Conference of Parties (CoP) in Paris (CoP-21) agreed in December 2015 that each nation would put in place National Declared Contribution (NDC) to emission control, which will be reviewed periodically. The aim of all these national efforts as per the Paris agreement was aimed at reducing the global warming well below 2°C above pre industrial levels [Jonathan and Werani, (2016)], with an effort to limit the increase to 1.5°C by 2050. CoP-22 has put in place measures to ensure greater transparency in monitoring the NDC. Each nation was required to spell out measures to attain their NDC. Recently, in 2017 U.S.A. has expressed its reservations in accepting the Paris agreement, which is disappointing. This has considerably destabilised the Paris agreement.

### Concluding remarks

Mitigation involves reducing emission of GHG. It needs shift to carbon neutral or low carbon technologies in generation of energy for transportation, building design, agriculture and domestic use. Thus any development activity is closely linked with emission scenario, which in turn shapes the future climate and global warming.

Thus shift to sustainable development is a way forward to our future. Huge investment is needed to develop green technologies to make this happen. This shows how development and climate change are interrelated. Lesser and lesser dependence on fossil fuel based energy production and its use is needed in various sectors of global economy. This is difficult but not impossible.

Adaptation is a complementary step to help reduce the impacts of climate change on our daily lives. The progressively increasing losses from natural disasters can be reduced substantially by adaptive measures. These are the local or regional and specific to the problem. Rain harvesting is one such step in areas of variable rainfall. Use of drought resistant crop varieties in drought prone areas is another such step. Rain harvesting and recycling of water, use of carbon neutral technology can be also useful. Thus in making economic decision the impacts of climate change plays a significant role. Our policy makers need to consider this as long term development. Implementation of suggested measures, even though financially affect developing and under developing countries, are needed to ensure sustainability of overall welfare including long term health and environment of this planet.

As stated earlier mitigation efforts as well as adaptation have to go hand in hand. Any opposition or delay on reducing the emission at an agreed level will significantly affect the entire positive measure/ agreement leading to continuation of global warming for several years beyond 2050, causing irrevocable damage to our planet. Since the cost benefit analysis is dependent on precise knowledge of impacts at regional as well as local level (De, 2001), planning adaptation strategies needs to be worked out at local level, taking expert advice from local and international experts. Thus while mitigation efforts need global participation, adaptation can be practiced regionally or locally in different sectors. In both these ways one aims at reducing the negative impact of climate change. Participation of common man is important because of their direct influence in keeping our planet and environment risk free due to various components that affect the climate. Recycling of water, rain harvesting, use of eco-friendly devices and a less consumptive life style can help us in making a sustainable urban environment and better climate for its population (De and Soni, 2009). Reduction

of emission also leads to a cleaner air environment as many Green House gases, including Methane, are also air pollutant.

One of the paradoxes of the present time is that there are many poor in a world of unprecedented prosperity. Inclusive growth can be ensured by following sustainable path way. It may be slow but in long term most beneficial to all living beings of the planet. To say briefly, our future climate depends upon the way we live today.

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#### Compliance with Ethical Standards

The authors declare that they have no conflict of interest and adhere to copyright norms.

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