Journal of Basic and Applied Engineering Research
p-ISSN: 2350-0077; e-ISSN: 2350-0255; Volume 3, Issue 1; January-March, 2016, pp. 79-83

http://www.krishisanskriti.org/Publication.html

# Impact of Climate Change on Heat Wave Related Deaths in India: Past, Present and Future

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**Abstract—***Climate change has brought about possibly permanent alterations to our planet's geological, biological and ecological systems. These changes have led to the emergence of large-scale environmental hazards to human health, among which deaths due to overheating of human body i.e. heat wave deaths are remarkable. To date, much less research has been conducted on the impacts of climate change on human health than on the geophysical changes related to global warming. Heat waves are expected to intensify around the globe in the future, with potential increase in heat stress and heat-induced mortality in the absence of adaptation measures. India has significant exposure to heat waves, and with limited adaptive capacity, impacts of increased heat waves might be quite severe. In this context, this paper presents the past, present and future scenario of heat wave related deaths in India and assesses Coupled Model Inter-comparison Project 5 (CMIP5) ensemble-based annual temperature change (°C) projected for 2030s, 2060s and 2080s relative to the pre-industrial baseline (1880s) for the four Representative Concentration Pathways (RCPs) over India. Discussing the governmental efforts to combat this situation, this study concludes with recommendations that can be adopted to quantify the magnitude of the problem and to design appropriate public health interventions.*

**Keywords***: Climate Change, Health, Heat Waves, Mortality, Coupled Model Inter-comparison Project 5, Representative Concentration Pathways.*

## 1. INTRODUCTION

Weather extremes can have significant impact on public health. Frequency of extreme weather events, including extreme precipitation, drought, tropical cyclones, and flooding has been increasing in recent years at global level, consistent with anthropogenic climate change. As climate change becomes more pronounced, these trends, which exhibit significant regional variability, are expected to continue in future. Indian government's assessment on climate change projects increasing temperatures for India through the 21st century, including increasing extreme heat events. Extreme temperatures are a major underlying climate related cause of mortality in many parts of the world. Heat related mortality can be due to either direct or indirect effects. Direct effects include heat illness ranging from heat exhaustion to heat stroke; the indirect effects occur when heat exposure stresses underlying physiological systems and results in other specific manifestations such as renal insufficiency, acute cerebrovascular disease, and exacerbations of pulmonary disease [1]. A heat wave is a prolonged period of unusually and excessively hot weather, sometimes accompanied by high humidity [15]. The US National Oceanic & Atmospheric Administration (NOAA) defines a heat wave as a period of abnormally and uncomfortably hot and unusually humid weather lasting two or more days and advisories are issued when these conditions are forecast. According to the definition provided by the India Meteorological Department (IMD), a heat wave in India is declared when either there is an excess of 5°C over a normal daily historical maximum temperature (30 year average) of less than 40°C. If the actual maximum temperature is above 45°C, is a heat wave is declared irrespective of the normal historical maximum temperature [1]. Due to the urban heat island effect cities and urban areas experience higher levels of heat exposure than surrounding rural areas, whereby temperatures in urban areas are on average 3.5–12°C higher than the country sides. Urbanization can exacerbate heat exposures for residents of urban core areas. However, this on-going development also provides opportunities for municipalities to implement specific and targeted actions to mitigate the impacts of rising temperatures range.

India has had several historic heat waves. In May 1998, India experienced a severe heat wave over a 2-week period. A similar event occurred in 1999 when north-west and central India. experienced unprecedented heat in April, with maximum temperatures of 40°C or above for more than 14 days [1]. Heat wave in 2003 caused more than 3,000 deaths in Andhra Pradesh. In May 2010, Ahmedabad experienced a heat wave. The most recent heat wave of 2015 claimed almost 2500 lives all over India.

While the health impacts of heat waves, particularly impacts on mortality, have been done for many regions of the world, there is relatively little information on specific impacts and characteristics of the relationship between excess heat

exposure and health impacts in India. Heat health promotion strategies in India have only recently been made a matter of policy at the city government level. In this context, the objective of this study is to relate climate change with the past, present and future scenario of heat wave induced deaths in India.

## 2. DATA SOURCE AND METHODOLOGY

The CMIP5 model has been used to project the future temperature change over India, so that the impact of temperature on the health of people can be predicted. In this study, CMIP5 has given preference over CMIP3 because, CMIP5 contains more models than CMIP3 and the CMIP5 models are more advanced, consisting of higher resolution compared to their CMIP3 counterparts. Apart from reasonably projecting the all India mean annual temperature, CMIP5 ensemble is also able to broadly capture the observed spatial distribution patterns of temperature over India. The IPCC's Fifth Assessment Report (AR5) is based primarily on results from the CMIP5 modelling using Representative Concentration Pathways (RCPs). CMIP5 model ensemble based temperature change projections for short- (2030s), medium-(2060s) and long-term (2080s) scenarios of RCP2.6, RCP4.5, RCP6.0 and RCP8.5. Similar way to assess the temperature projection has been adopted in this study. The naming convention reflects socioeconomic pathways that reach a specific radiative forcing by the year 2100. For example, RCP8.5 leads to a radiative forcing of 8.5 Wm–2 by 2100 [3].

Data on heat wave related death have collected from the report, Statistics Related to Climate Change, India-2015 released by Ministry of Statistics and Programme Implementation, in order to prepare a graphical representation. However, this report is giving data only upto 2008.

On the basis of available data and results produced by the model CMIP5, a generalized assessment has done regarding the impact of climate change on the past, present and future scenario of heat waves and related deaths in India.

## 3. HOW HEAT WAVES ARE FORMED?

Generally heat waves develop in the north-western parts of India and from this area they progress to neighbouring subdivisions of the country. On some occasions, heat waves also develop in situ. The favourable factors responsible for severe heat waves are:

i. There should be a region of warm dry air and appropriate flow pattern for transporting hot air over the region.

ii. Sparser pre-monsoon season showers, which bring less moisture than normal to the area, leaving large parts of the country arid and dry.

iii. Sudden end of pre-monsoon rain showers.

iv. The sky should be practically cloudless to allow maximum insolation over the region;

v. The lapse rate should approach dry adiabatic;

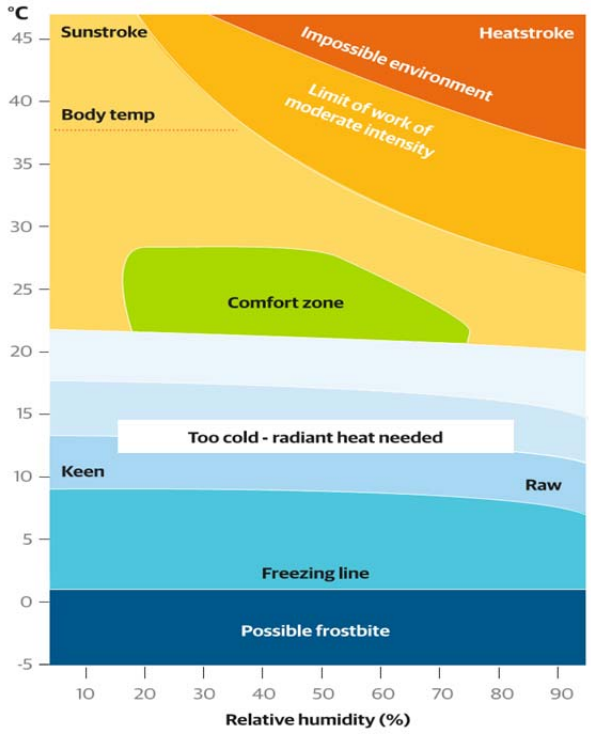
vi. The El Niño effect, which often increases temperatures in Asia, combined to create the record high temperatures.

vii. Finally, there should be a large amplitude anticyclonic flow or the thickness values should be considerably above normal in all layers.

## 4. IMPACT OF HEAT WAVE ON PUBLIC HEALTH

Due to environmental heat exposure with lack of thermoregulation, heat wave leads to fatal heat stroke which is a severe heat illness with a body temperature greater than 40.6 °C (105.1 °F) which can even culminate into death (Fig. 1).

Heat stroke occurs when thermoregulation is overwhelmed by a combination of excessive metabolic production of heat (exertion), excessive environmental heat, and insufficient or impaired heat loss, resulting in an abnormally high body temperature [14]. Heat stroke can happen in old people, babies or even young people without health problems or medications, most often in athletes or outdoor daily wage laborers or military personnel engaged in strenuous hot-weather activity, or in certified first responders wearing heavy personal protective equipment.




(Image Source: The Guardian, 2015)

**Fig. 1: Effect of Temperature and Humidity on Public Health**

## 5. IMPACT OF CLIMATE CHANGE ON HEAT WAVE RELATED DEATHS IN INDIA

Associated with this warming trend, severe heat wave events that killed thousands of people have occurred in the country. Long-term data obtained from 103 weather stations located all over India have analysed by the IMD, confirming that heat waves are recurring more frequently and with greater intensity with changing climate [6]. Over the past half-century, from 1961 to 2010, these have increased by a third. World Metrological Organisation has declared the decade of 2001-2010 as a "Decade of Climate Change" [7]. Therefore India no doubt showed a significant rise in peak temperatures similar to the rest of the world. From 580 such days per year measured by all these weather stations in the previous decade from 1991-2000, the number rose to 670 days per year [5]. As per IMD, the 25 stations from north, northwest and central India registered major increases in severe heat waves [5] over the past half-century. Many areas of west Rajasthan, Punjab, Haryana, east Rajasthan, Madhya Pradesh, Chhattisgarh, Vidarbha, western Uttarakhand, east Uttar Pradesh, western parts of Jharkhand and Bihar, Gangetic West Bengal, northern parts of Orissa, Telangana, coastal Andhra Pradesh, eastern parts of Rayalaseema and north Tamil Nadu on an average have experienced eight or more heat wave days [5]. Human suffering is more both due to excessive heat as well as scarcity of water in Bihar, Punjab and parts of Maharashtra.

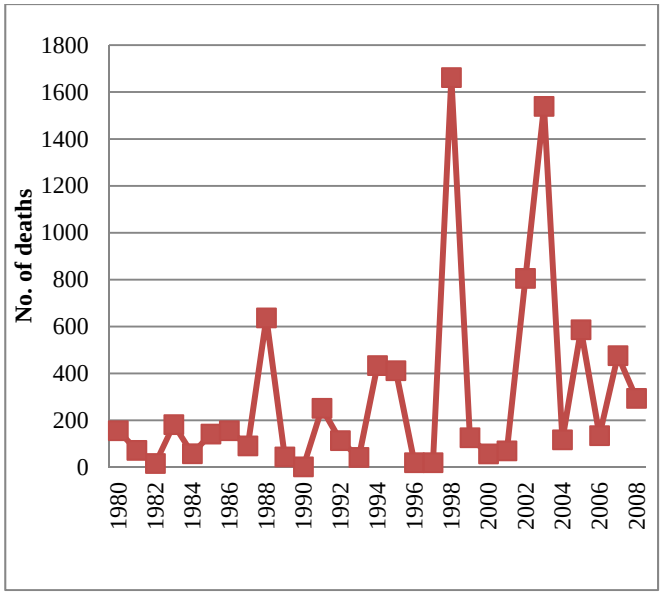
The recent decade (2001-2010) registered the highest number of deaths due to heat wave events compared to previous three decades. Recently in May 2015, The sudden end of pre-monsoon rain showers coupled with the El-Niño effect have resulted in record high temperatures and heat waves followed by the death of more than 2300 people in the country [13]. The hot years following "El-Niño" – the global phenomenon associated with a band of warm ocean water temperatures that periodically develops off the Pacific coast of South America– have many times accentuated mortality in India.

## 6. HEAT WAVES RELATED DEATH SCENARIO IN INDIA

During the period March–July, spells of hot weather occasionally occur over certain parts of India. These spells are often seen to move from one region to another [4]. Hence, this phenomenon is termed as a heat wave. Several deaths are reported when the heat waves become severe. However, there is lack of proper documented data as, government generally collect the death statistics from the media and publish those in reports. Average annual loss of human life due to heat wave over India is 153 [2].

Table 1 indicates the loss of human lives due to heat waves along with their total number of occurrences during the above-mentioned period. It may be noticed that the loss of human lives is maximum in Uttar Pradesh followed by Rajasthan, Maharashtra and Orissa.

Fig. 2 indicates the loss of lives due to heat waves from 1980 to 2008.Within this time period, El Niño years were 1982, 1987, 1997, 2002 and 2004. It can be noticed that casualties are more in the years succeeding the El Niño years over India, which confirms climate change induced El Niño events are chiefly responsible for heat wave and resultant deaths in India.




(Data Source: Statistics Related to Climate Change, India-2015, Ministry of Statistics and Programme Implementation)

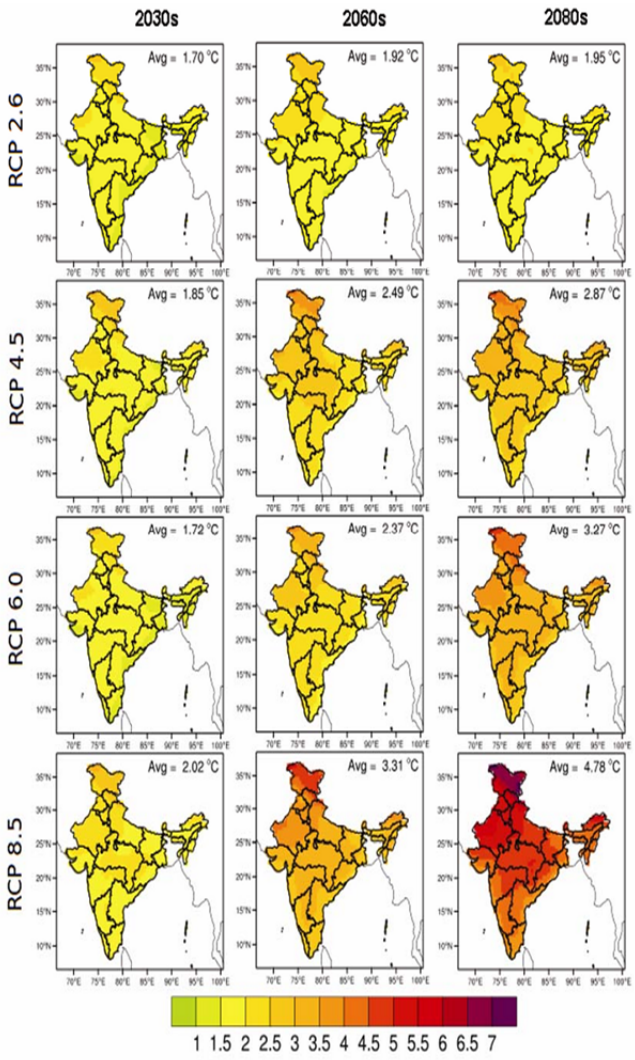
**Fig. 2: Heat Wave Induced Deaths in India (1980-2008)**

**Table 1: State Wise Death Statistics in India (1911-2009)**

| Sl.No. | State | Epochs | | | | |
|---|---|---|---|---|---|---|
| | | 1911-67 | 1968-77 | 1978-99 | 2000-2009 | 1911-2009 |
| 1 | West Bengal | 31 | 2 | 28 | 6 | 67 |
| 2 | Bihar | 76 | 9 | 28 | 4 | 117 |
| 3 | Uttar Pradesh | 105 | 6 | 23 | - | 134 |
| 4 | Rajasthan | 27 | 3 | 42 | 14 | 86 |
| 5 | Gujarat, Saurashtra & Kutch | 43 | 1 | 7 | 2 | 53 |
| 6 | Punjab | - | 2 | - | 6 | 8 |
| 7 | Himachal Pradesh | - | 1 | - | 1 | 2 |
| 8 | Jammu & Kashmir | - | - | - | - | - |
| 9 | Maharashtra | 26 | 5 | 35 | 12 | 78 |
| 10 | Madhya Pradesh | 32 | 4 | 15 | 5 | 56 |
| 11 | Odisha | 25 | 8 | 18 | 22 | 73 |
| 12 | Andhra Pradesh | 21 | - | 3 | 2 | 26 |
| 13 | Assam | - | 4 | 19 | - | 23 |
| 14 | Haryana, Delhi & Chandigarh | - | 1 | 2 | 2 | 5 |
| 15 | Tamil Nadu | 5 | - | 2 | 1 | 8 |
| 16 | Karnataka | 0 | - | - | 1 | 1 |

Source: Statistics Related to Climate Change, India-2015, Government of India, Ministry of Statistics and Programme Implementation, New Delhi.
(Note: Epochs represent number of heat wave events)

Fig. 3 shows the CMIP5 model ensemble-based annual temperature change (°C) projected for 2030s, 2060s and 2080s relative to the pre-industrial baseline (1880s) for the four RCP scenarios; which show that annual mean temperature increases by 1.7°C–2.02°C by 2030s under different RCP scenarios and, by about 2°C–4.8°C by 2080s, relative to the pre-industrial base. As expected in each of the three time slices RCP 2.6 are associated with the least warming, whereas RCP 8.5 is experiencing with the highest warming. RCP 4.5 and RCP 6.0 are representing the moderate warming scenarios. However, the combined study of all of these four scenarios shows that, the northern part of the country is projected to experience higher warming compared to the southern counterpart. Areas in the Himalayas and Kashmir are particularly vulnerable to intense warming to the tune above 7°C as per RCP 8.5 by the year 2099.




(After Chaturvedi et al. 2012)

**Fig. 3: CMIP5 Based Future Projection of Temperature over India under Four Scenarios**

## 7. ROLE OF GOVERNMENT IN TACKING HEAT WAVE RELATED MORTALITY

Indian State Governments are currently dealing with Heat Wave crisis and have issued guidelines, action plans and Do's & Dont's to alleviate the impact of heat wave [9]. Ahmedabad Heat Action Plan 2015, Andhra Pradesh State Disaster Management Plan and Odisha State Disaster Management Plan (OSDMP) are remarkable.

However, there are some drawbacks also. The IMD definitions underestimate the impacts of extreme heat on health because under the current systems IMD threshold does not formally account for public health effects of extreme heat [11]. Moreover, heat wave induced deaths are not being properly documented [11].

## 8. CONCLUSION AND RECOMMENDATIONS

Associated with this warming trend, severe heat wave events that killed thousands of people have occurred in the country. The recent decade (2001-2010) registered the highest number of deaths due to heat wave events compared to previous three decades. The hot years following El Niño events, are affecting the monsoon and mortality in the country. The effect of global warming and climate change is obvious in India. The Indian Ocean itself is warming rapidly so winds blowing from the ocean are warmer now. Urbanization and deforestation over the last few decades have contributed to things like the intensifying the warming effect. As per IPCC, Asia (including India) is going to experience more frequent and intense heat waves in near future which will increase mortality. In fact, studies say that, heat waves already occur more often now in Asia than they did in 1950. With increasing emission of Green House Gases (GHGs), the warming effect would likely to intensify over India and the heat waves would become more frequent and last longer than they did earlier. Therefore the government, NGOs and the public itself should take precautions and preventive measures to reduce heat wave induced mortality.

From public health point of view, the IMD definition of heat wave should include mortality and morbidity concepts to make it much more useful. Short and medium-range temperature forecasts, early warning systems, measures to build preparedness and response capacity for medical and public health professionals and, simple and easy to understand public awareness campaigns could be used and conducted that might significantly reduce the number of heat-related deaths.

There should be proper arrangement for detail data collection and therefore, information and data sharing channels have to be kept open and active. In addition to early warning systems and preparedness plans, cooperation among various government agencies, NGOs, stakeholders and international partnership regarding knowledge sharing and technical supports need to be developed and maintained to facilitate the

interdisciplinary work and effective implementation of strategies to combat heat wave related mortality in India.

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