Climate Change Projection for Bhutan

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Abstract

New hottest temperatures have been reported almost every year since 2014, breaking previous records. The year 2024 is the warmest year ever recorded. The warming is unprecedented and inching closer to the global target for limiting rise in global temperature below 1.5°C. Climate change is believed to impact every aspect of existence and Bhutan is highly vulnerable to the impacts of climate change. There is a trend of increasing temperature in Bhutan, especially since the 1990s. Extremes like heavy rainfall and associated floods and landslides are on the rise. Climate change is projected to increase both the temperature and the frequency of high intensity rainfall.

The climate projection report of the National Centre for Hydrology and Meteorology Bhutan projects increase in both temperature and rainfall across different scenarios and time scales. The results are based on downscaling of selected Global Climate Models to 1km resolution for Bhutan.

The results indicate increase in the maximum and minimum temperatures with more increase in the northern and central places. Likely rise in temperature ranges from 1.5°C to 5°C in different scenarios and timescales. Intensification of the water cycle and increase in rainfall is expected across many countries. Increase in rainfall could be in the form of short duration heavy rainfall extremes, causing floods. Rainfall in Bhutan is projected to increase with more increase likely for the north, western, and south-western regions of the country while a few places in the eastern and south-east regions may also experience decrease. Adaptation is critical for Bhutan to reduce the loss and to build resilience to climate change.

Introduction

The year 2024 was the warmest year on record. The global temperature in 2024 was 1.46°C above the pre-industrial (1850-1900) average (NOAA,

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2024). The global average land and oceans temperature in 2024 was 1.29°C above the 20th century average from the National Oceanic and Atmospheric Administration's (NOAA) 1850-2024 record (NOAA, 2024). It was warmer than 2023, which was the previous warmest on record. The Intergovernmental Panel of Climate Change (IPCC) fifth assessment report concludes that the warming in the climate system is unequivocal and limiting climate change requires substantial and sustained reductions in greenhouse gas (GHG) emissions (IPCC, 2013). The CO2 concentration has set a new record at 420 ppm at Mauna Loa, Hawaii, where observation began in 1958, Figure 1 (NASA, 2024). Figure 1 shows CO2 levels for thousands of years in the past reconstructed from air bubbles trapped in ice sheets and glaciers (NASA, 2024).

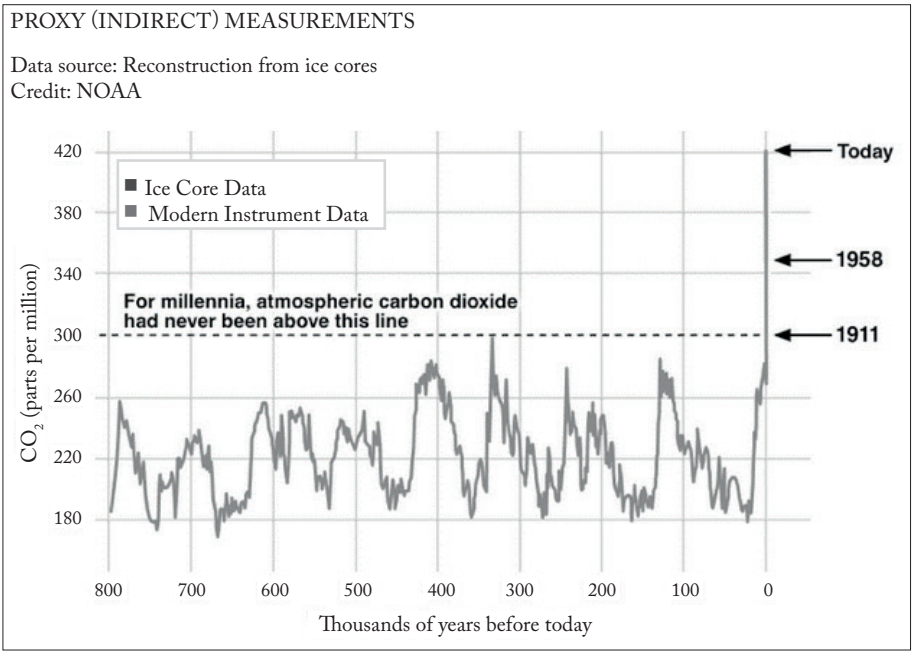

Figure 1 CO2 concentration

Bhutan is a small land locked country located in the south eastern Himalayas with a fragile mountain geology. More than 60 percent of the total population of over 700,000 people reside in rural areas depending primarily on agriculture (NSB, 2024). Bhutan is a carbon negative country and has pledged to remain carbon neutral at all times. The country is located in the Eastern Himalayas bio diversity hotspot and more than 70

percent of its land under forest cover and more than 50 percent under protected areas. Bhutan has achieved this as a result of conscious efforts of the visionary leadership of the country.

Bhutan's climate ranges from hot sub-tropical in the south to cold alpine climate in the north with the altitude ranging from 100 to over 7000 metres above sea level. Owing to the variation in altitude, the temperature is hot in the south and decreases northwards. More than 70 percent of the total annual rainfall is brought by the south-west Indian summer monsoon during the months of June to September. Rainfall also varies widely from being very heavy in the south to a drier north. Owing to this, southern Bhutan is more resilient to incidences of heavy showers whereas similar rains would have caused floods in the northern parts of the country. Bhutan is highly vulnerable to climate impacts like extreme weather, floods, landslides and Glacial Lake Outburst Floods (GLOF). Bhutan's economy is highly dependent on climate sensitive sectors like hydropower and agriculture.

The National Centre for Hydrology and Meteorology (NCHM) aspires to become the centre of excellence in hydrology, meteorology and cryosphere science and services. NCHM is the nodal agency within Bhutan to provide climate change information and services. The latest climate projection report of Bhutan, insights from CMIP6 projections, is developed in collaboration with the technical support of the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) and the National Institute of Environmental Studies (NIES) Japan with the funding from the UNDP National Adaptation Plan.

Future Climate Projection of Bhutan

Observed Trend

There is an increasing temperature trend in Bhutan since 1960 with sharper increase in 1991-2020 (NCHM, 2024). Precipitation has also increased from 1970 with sharper increase since 1990 (NCHM, 2024). NCHM validated the temperature trend with observed station data from 1996-2023. In the 20 dzongkhags, there is an increasing maximum temperature trend as shown in the Figure 2. However, the trend is not so significant.

Given the huge elevation difference and different climate zones, the trend is also analysed dzongkhag wise.

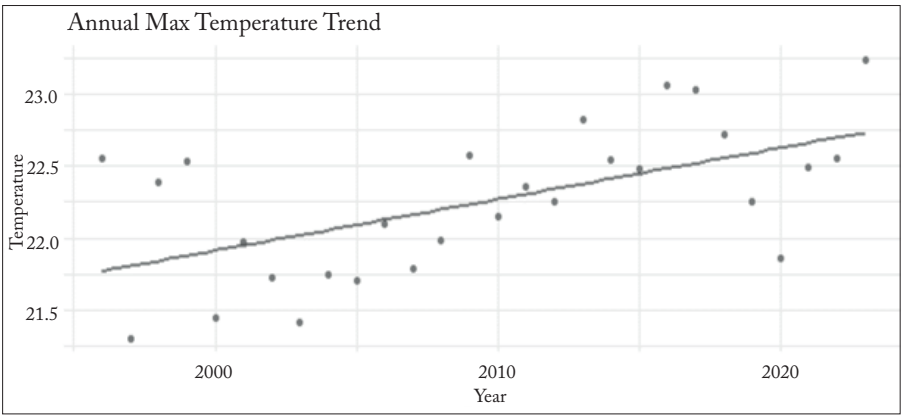

Figure 2 Annual Max temperature trend

The trend differs dzongkhag-wise and these inter dzongkhag variations can be attributed to use of point station data for the analysis in the absence of gridded data. There are very few stations in the northern high-altitude regions, owing to inaccessibility, and a few stations were shifted. Based on the gridded global data sets, the majority of the dzongkhags show an increasing temperature trend as observed globally and in the region. On a daily scale, temperature extremes like the increased number of hot days are also occurring in Bhutan. The increasing daily maximum temperature dataset suggests more frequent or intense short-term warming events, changes in weather patterns, and more frequent extreme events such as heat waves and dry spells.

Rainfall is dependent on inter-annual variability and climate change. Variability like the warming phase (El Nino) causes below-average rainfall over the South Asian region including India and Bhutan. The cooling phase of the cycle (La Nina) brings above-average rainfall with the possibility of rainfall extremes and floods. Other factors like Indian Ocean Dipole and MJO also impact the rainfall. The frequency of rainfall extremes like occurrence of high intensity rainfall is expected to increase due to climate change. In summary, there is an increasing temperature trend over Bhutan, observed since 1996, and no significant trend of total rainfall. Generally, the number of extreme events in Bhutan are on the rise as shown in the Figure 3 (NCHM, 2024).

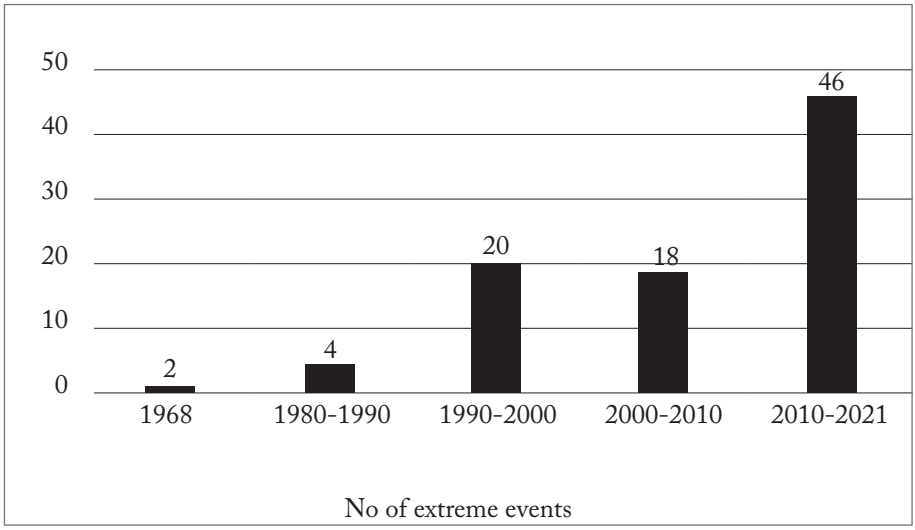

Figure 3 Number of extreme events in Bhutan

Background

The Intergovernmental Panel on Climate Change (IPCC) is an intergovernmental body of the United Nations to advance knowledge about climate change. The IPCC assessment cycles produce reports that are the state-of-the-art science on the understanding of climate change. The sixth assessment report is the current report and planning for the seventh assessment cycle is underway. Coupled Model Inter-comparison Project (CMIP) is a collaborative framework to assess multi models from different modelling groups to understand climate change. The climate projection of Bhutan is based on the sixth assessment report. The Global Climate Models (GCMs) are the tools used for understanding the complex climate system and its behaviour. GCM are numerical models that can simulate global climate features such as atmospheric and oceanic circulation (Zorita & von Storch, 1999). Models are not perfect and a multi-model average is generally preferred to study the climate. The multi-model average was shown to outperform individual models in many climate studies (Gleckler et al., 2008; Hagedorn et al., 2005; Knutti et al., 2010; Reichler & Kim, 2008; Tebaldi & Knutti, 2007).

Selected CMIP6 GCM's were downscaled to 1 km resolution for Bhutan, using a statistical method (NCHM, 2024). Scenarios used were Socio-

economic Pathways (SSPs) which are new scenarios that factor population growth and socio-economic development along with the climate in the future. SSP1 2.6, SSP2 4.5 and SSP3 7.0 were used for this study, representative of policies and pathways best-case, moderate-case and worst-case scenarios. Timescales chosen for this study were baseline (1971-2000), near-term (2021- 2040), mid-term (2041-2060) and long-term (2081-2100). WorldClim historical data is used for bias correction of the CMIP6 model data. 10 climate models from CMIP6 were chosen and used. The monthly global data was downscaled using bilinear interpolation (NCHM, 2024).

Future climate

Studies have shown that high altitude areas and mountains may have faster change in temperature than lower elevations. Northern Bhutan is likely to experience higher increase in temperature than the southern parts of the country (NCHM, 2024). By 2040, the worst case scenario for Gasa is projected at 1.55˚C and Thimphu at 1.4˚C (NCHM, 2024). By 2060, the projected increase for Gasa is 2.5˚C and Thimphu is 2.3˚C for the worst case scenario. Across the country the increase in minimum temperature (Tmin) is more than the increase in maximum temperature (Tmax) on a given day. By the year 2100, the increase may go beyond 5˚C for both in most places in the worst case scenario (NCHM, 2024).

The projection for summer temperature Tmax is also likely to increase with greater increase in the north and central districts (NCHM, 2024). The summer temperature for northern Bhutan Tmax is likely to increase by 1.3˚C, 1.8˚C and 4˚C in the near term 2040, mid-and-long-term in the worst case scenario. For the southern districts like Samtse, Chhukha, Sarpang, and Samdrup Jongkhar, the Tmax is likely to increase by 1˚C, 1.7˚C, and 3.5˚C in the near term 2040, mid-and-long- term in the worst case scenario (NCHM, 2024). Winter minimum temperature also decreases northwards. Around 2˚C, 3.4˚C, and 4.9˚C increase in the minimum temperature is likely for most central and northern districts in the near term, midterm, and long term in the worst case scenario (NCHM, 2024).

For annual precipitation, by 2040 the north, west, and south-western districts are likely to receive more precipitation and the east and south-eastern districts likely to receive less precipitation (NCHM, 2024). The

signal is similar for 2060 and 2100 indicating higher rainfall for north, west, and central regions.

Bhutan receives more than 70 percent of the annual total rainfall from the Indian summer monsoon from June to September. Changes in the summer monsoon will directly impact Bhutan. Monsoon precipitation is projected to intensify (IPCC, 2013) and changes in the extreme wet and dry spells of South Asian monsoon (Singh et al. 2014). Agriculture will be impacted by the monsoon onset time and the spatial and temporal distribution of rainfall. By 2040, similar to the annual rainfall, monsoons in the eastern districts are likely to decrease under the worst case scenario while it is projected to increase in the rest of the country, Figure 5 (NCHM, 2024). Similarly, by 2060, the monsoon is projected to increase in the central and western parts of the country. Increase across the country is projected by the year 2100 with more increase in the western regions.
Winter precipitation is an important source of water for snow and ground recharge. By 2040, winter rainfall is likely to increase with greater increase in the east and south eastern regions. Winter precipitation is also likely to increase in 2060 and 2100.

Conclusion

There are uncertainties with climate change studies from the socio-economic development, emission pathways, population growth and also inherent in the global climate models. Science and models are evolving and getting better. Climate change is expected to increase the temperature across many countries.

Bhutan is likely to witness faster change in temperature because of the mountainous terrain. Both the maximum and minimum temperatures are likely to increase. The northern and central higher altitude places are expected see a higher increase in the temperature than the lower lying southern foothills. Likely rise in temperature is about 1.5˚C in the near term 2040s, 2.5˚C and beyond 5˚C in the mid-term and long-term under the worst case scenarios. Similarly, summer and winter temperature is projected to increase.

Climate change is projected to increase the temperature and intensify the water cycle, resulting in increase of precipitation. However, research suggests

that the increase in rainfall may be in the frequency of high intensity rainfall. Increasing rainfall will not mean increase in water availability but more high intensity rainfall causing floods and landslides. This holds true for most parts of Bhutan. More increase is likely for the north-western, and south-western regions of the country while a few places in the eastern and south-east regions may also experience decrease. Eastern Bhutan could experience a decrease in rainfall under some scenarios.

Bhutan stands at a crossroads of transformation and economic development. Climate change poses a threat to Bhutan in the areas of agriculture, water security, and health. Risks of extreme weather and disasters have also increased. Climate financing and support is crucial to sustain the efforts of climate mitigation and adaptation in Bhutan. Glacial lake outburst flood (GLOF), increasing extreme weather events like floods and landslides, erratic and high intensity rainfall, and drying of streams are some of the high risk impacts of climate change. Improving weather and flood forecasting, early warning services, and disaster resilience are critical adaptation measures for the extreme weather events. Targeted interventions will be important across all sectors to build resilience to climate change.

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