The Energy and Resources Institute
Creating Innovative Solutions for a Sustainable Future

Climate Science for Regional Policy Planning: **High Resolution Modelling at TERI**

© THE ENERGY AND RESOURCES INSTITUTE, 2019

All rights reserved | For private circulation only

No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, without prior permission in writing to The Energy and Resources Institute, New Delhi, India, or as expressly permitted by law, or under terms agreed with the appropriate organizations. Enquiries concerning reproduction should be sent to TERI.

Authors

Muhammed Irfan, Project Associate, Centre for Climate Modelling, TERI

Saurabh Bhardwaj, Fellow, Centre for Climate Modelling, TERI

Santosh Kumar Muriki, Associate Fellow, Centre for Climate Modelling, TERI

ACKNOWLEDGEMENTS:

We would like to thank Indian Meteorological Department (IMD) for providing the observational datasets. Climate scenarios used for this work were from the NEX-GDDP dataset, prepared by the Climate Analytics Group and NASA Ames Research Center using the NASA Earth Exchange, and distributed by the NASA Center for Climate Simulation (NCCS).

Designed by

Mr Sudeep Pawar, Graphic Designer, TERI

DISCLAIMER:

This publication is prepared by The Energy and Resources Institute (TERI) after carefully analyzing and processing the data and the information collected from primary and secondary sources. All opinions expressed, as well as omissions and eventual errors are the responsibility of the authors.

SUGGESTED FORMAT FOR CITATION:

Irfan Muhammed, Saurabh Bhardwaj, Santosh K. Muriki (2019) Climate Science for Regional Policy Planning: High Resolution Modelling at TERI. TERI, (New Delhi: The Energy and Resources Institute)

PUBLISHED BY:

The Energy and Resources Institute (TERI)
Website: www.teriin.org

FOR MORE INFORMATION:

Saurabh Bhardwaj, Fellow and Area Convenor,
Centre for Climate Modelling, TERI, Darbari Seth Block,
India Habitat Centre, Lodhi Road,
New Delhi – 110 003

Tel: +91 11 2468 2100/11
Fax: +91 11 2468 2144/45
Email : saurabh.bhardwaj@teri.res.in | cc@teri.res.in

Table of Contents

Background

The changing climate is one of the major global challenges of the 21st century, having adverse effects on all spheres of human activity. Over the past few decades, the world has experienced increasing frequency and intensity of hazards and disasters such as droughts, intense rainfall events, heat waves, storm surges etc. The frequency and intensity of such disasters are expected to further accelerate due to climate change. It is reported that impacts due to such events would be substantially aggravated due to other combined effects such as population growth and urbanization. Climate and disaster risk will have its greatest effects on the lives and livelihoods of vulnerable communities, destroying their capacity to cope and undermining the possibilities of sustainable development. The changing climate also poses potentially severe threats to the financial markets and affects financial stability. In recognition of the current and future climate change scenarios, it is imperative that we prepare and develop multifaceted strategies and initiatives for the mitigation of risks associated with the increased number of extreme events, along with the measures to adapt and expand the local/regional disaster risk reduction efforts.

The Centre for Climate Modelling at TERI attempts to work on this objective to improve existing capacities in regional climate risk assessment via the creation of user customisable and decision relevant timely information to assist regional policy planning. The work at TERI also emphasises the generation of high-resolution climate risk data via dynamically downscaled high-resolution regional climate and impact models in national, and sub-national (zonal, city level) scales.

Some of the notable climate outlooks done by TERI are presented below:

National Level:

India is a peninsular country with an area of about 3.28 million km^2 and an estimated population of about 1,210.2 million (Census of India, 2011). As per Koppen's Classification, India mainly experiences 4 types of climate: the whole of the peninsular region experiences tropical savanna; the West Coast is basically a tropical rainforest; northern India's climate is warm with dry winds; and western India is dry steppe. Generally, the Southwest Indian Monsoon is predominant during June to September months and the North-East Winter Monsoon controls the Indian climate during the October – December season.

Agriculture and other allied sectors are the major source of livelihood for nearly two-thirds of the population. About 40% of the total agricultural production is obtained from 60% of the net sown area, which is rain fed. Since agriculture and allied sectors are highly sensitive to climate variability, temperature and rainfall directly affect the farm production and output. The higher rainfall variability, less diversified agricultural practices, increasing frequency of droughts and floods directly come to bear on food production and supply. Thus the change in rainfall and increase in temperature would remarkably affect the Indian agriculture and allied sectors. Hence, it's very important to assess the recent climate trends and the changing pattern, especially during the past 30 –40 years.

The study conducted by TERI, using the observation datasets provided by the Indian Meteorological Department (IMD) during the period 1980 – 2016, shows an annual trend of 0.011°C, 0.015 °C and 0.017 °C for area averaged minimum, mean and maximum temperatures respectively which is shown in Figure 4, 5 and 6. Mean and Maximum temperatures show increasing trends at 99.9% significance and minimum temperature at 95% significance. Figures 1, 2 and 3 depict the spatial pattern of annual mean, minimum and maximum trends of Indian region during the period 1980 – 2016.

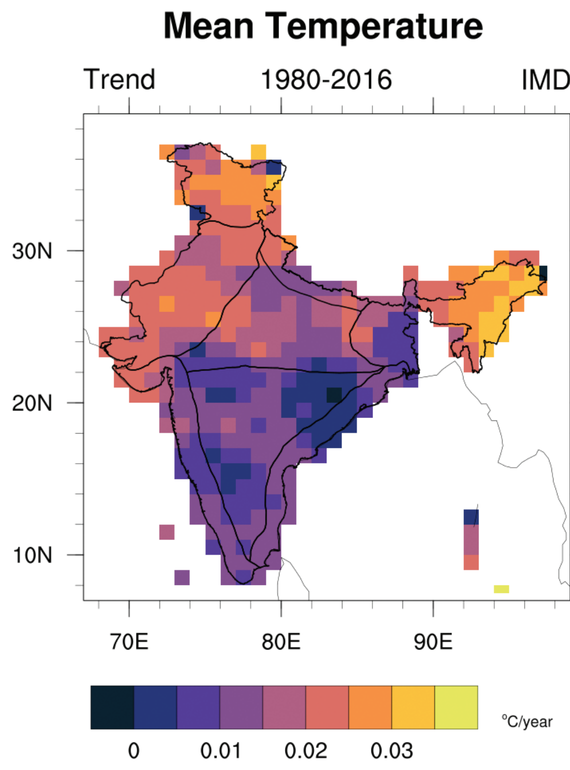


Figure 1: Annual Mean Temperature Trend

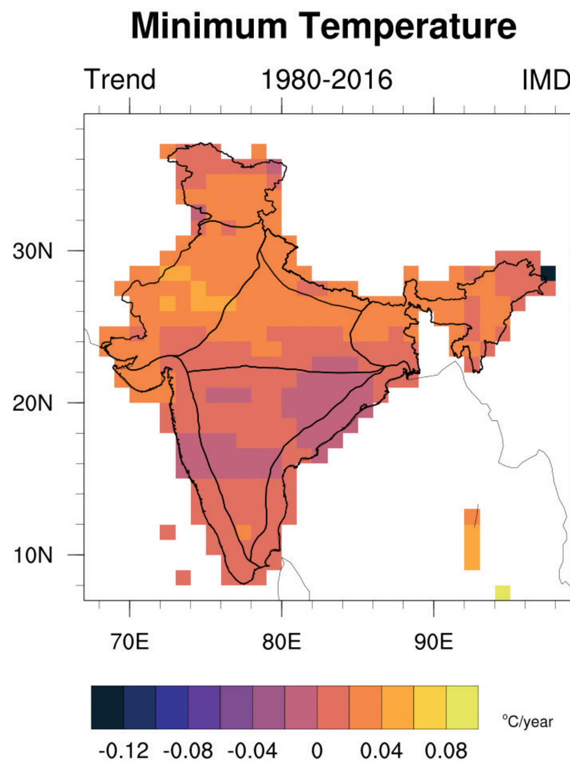


Figure 2: Annual Minimum Temperature Trend

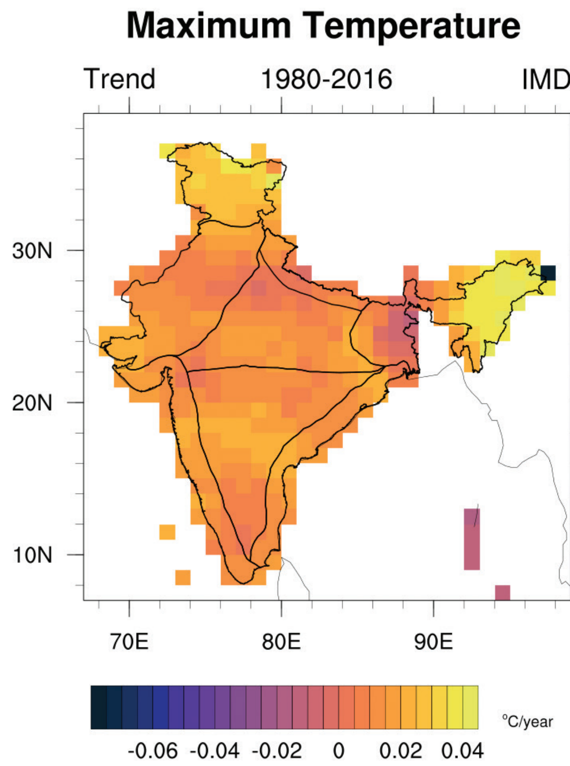


Figure 3: Annual Maximum Temperature Trend

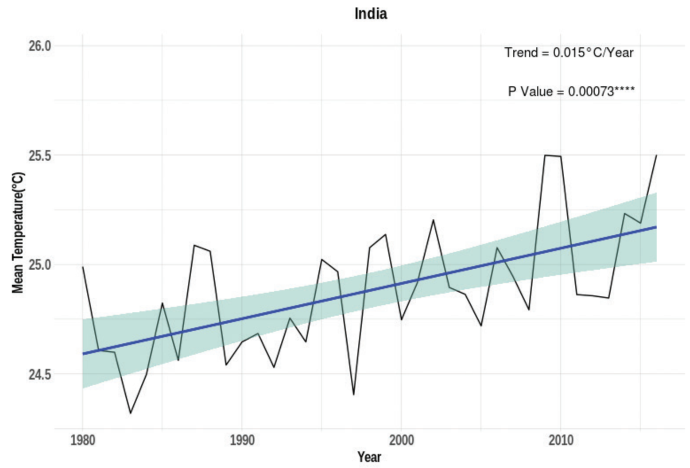


Figure 4: Area Averaged Annual Mean Temperature Trend
(**** Significant at 99.9% Confidence Interval)

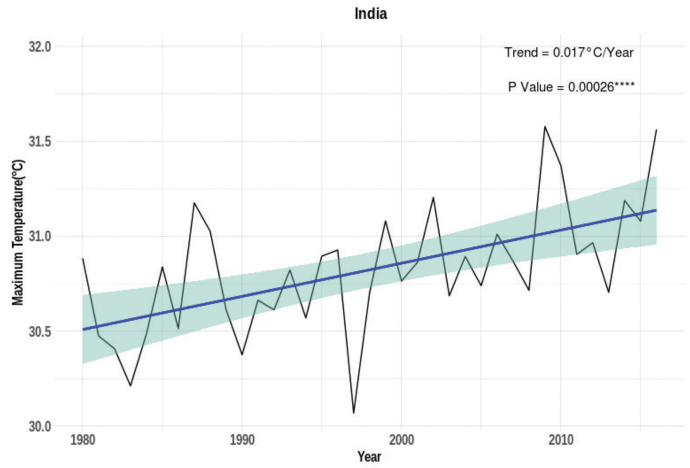


Figure 5: Area Averaged Annual Maximum Temperature Trend
(**** Significant at 99.9% Confidence Interval)

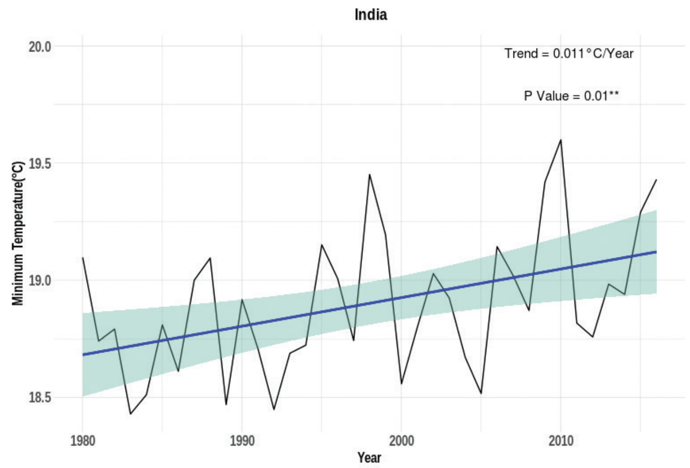


Figure 6: Area Averaged Annual Minimum Temperature Trend
(** Significant at 95% Confidence Interval)

Zonal Level:

Due to the large expanse of India in both north-south and west-east, different parts of the country experience different temperature and rainfall levels even in the same month or season. To assess the historical climate profile of different regions, the Indian region is divided into seven climatologically and geographically homogenous zones such as Central, East Coast, West Coast, Inner Peninsula, North East, North West and North as shown in Figure 7. The analysis using IMD observation datasets show that the maximum and minimum temperatures over all the regions have been increasing significantly during the past 40 years. The Northern region shows the highest increasing trend for the maximum temperature followed by North East, East Coast and Central India. Figures 8 and 9 show the trend of zonal area averaged minimum temperatures in which East Coast has the highest increasing trend.

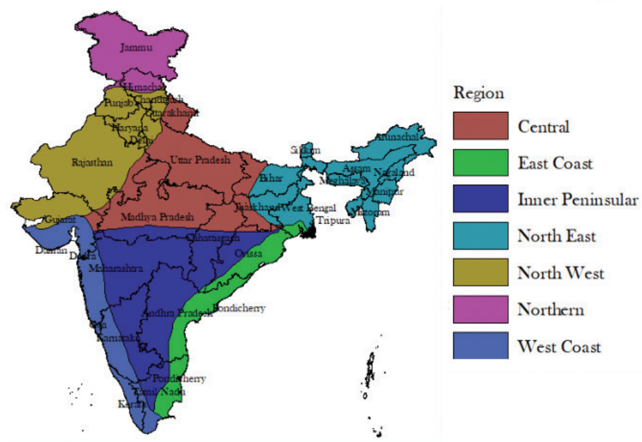


Figure 7: Homogenous regions of India

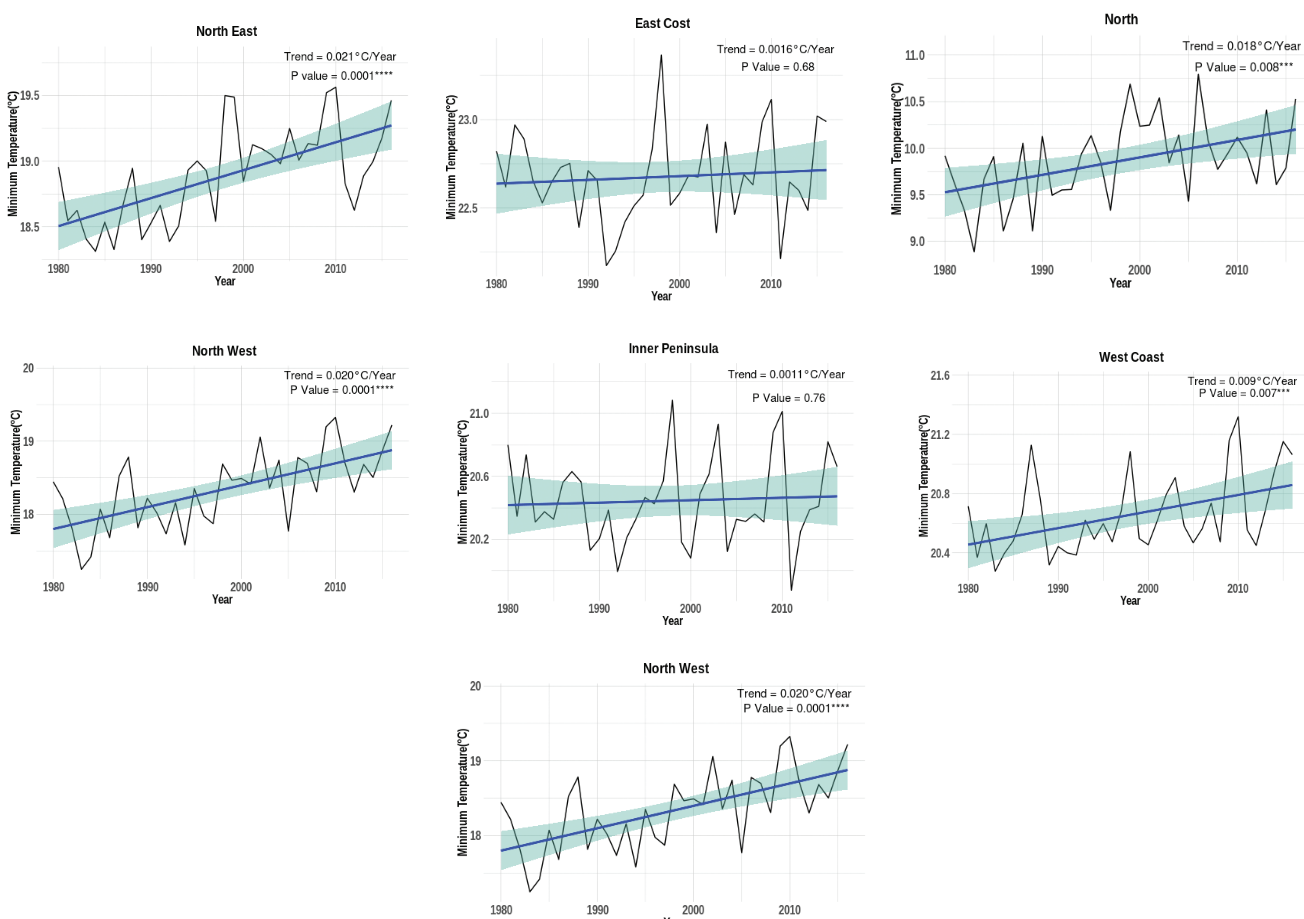


Figure 8: Area Averaged Zonal Minimum Temperature
The trends significant at 90%,95%,99% and 99.9% are marked by *,**,*** and **** respectively

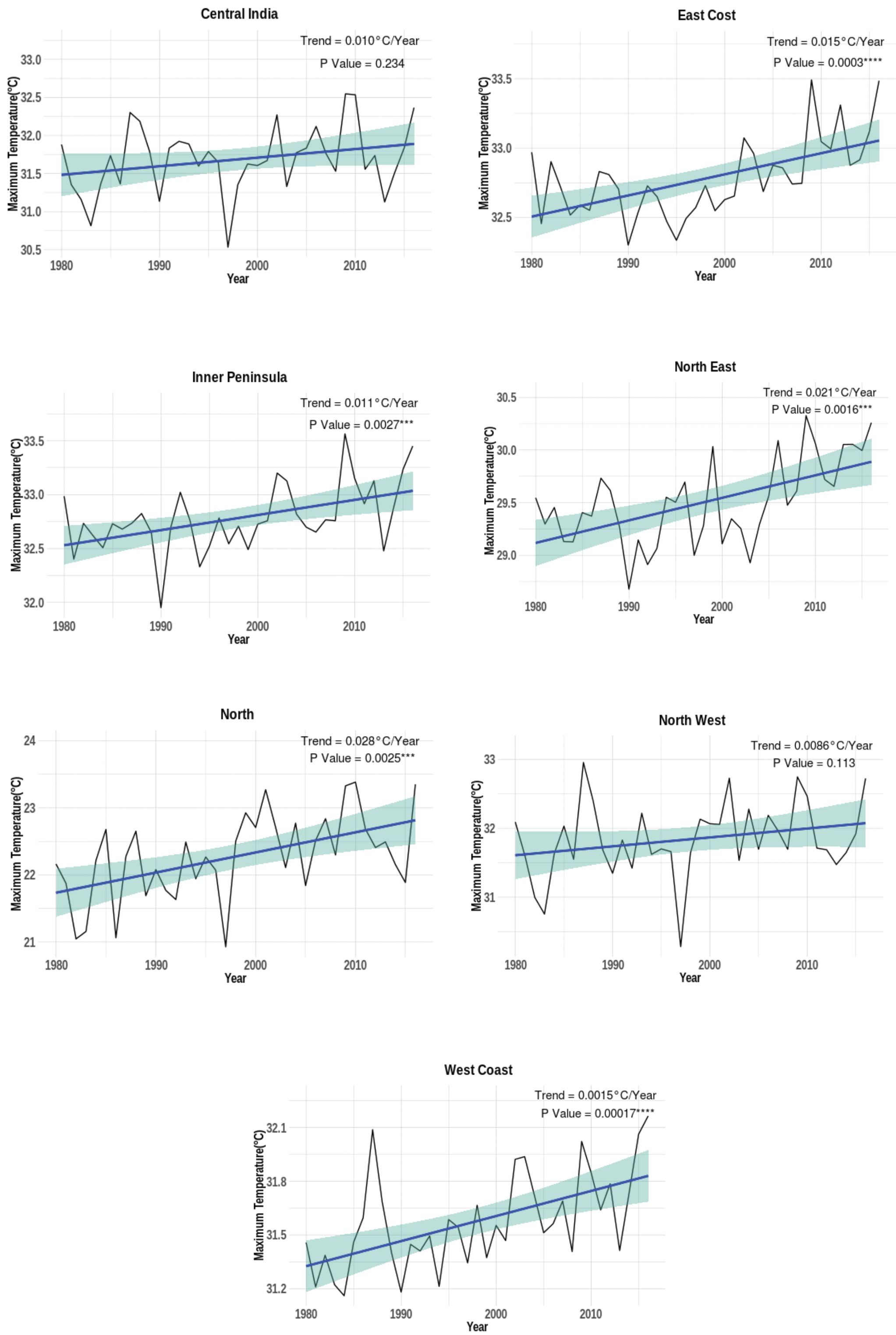


Figure 9: Area Averaged Zonal Maximum Temperature
The trends significant at 90%,95%,99% and 99.9% are marked by *,**,*** and **** respectively

Heat Maps

Historical Evidence

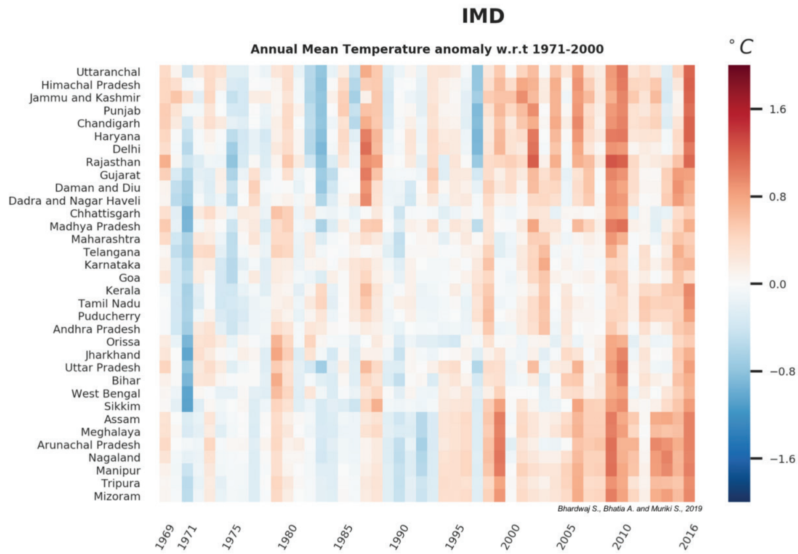


Figure 10: Mean temperature anomaly for states and union territories of India

Figure 10 depicts the regional annual mean temperature anomaly (difference from long term mean) as per the IMD observational data. As can be clearly seen, the regional variations of temperature are profound over India, which shows the vagaries of climate at regional level. However, the recent past years (from 2000 onwards) shows high warming over different states and union territories of India. The recent decade shows more warming as compared to past decades at the regional scale over India.

Future Outlook

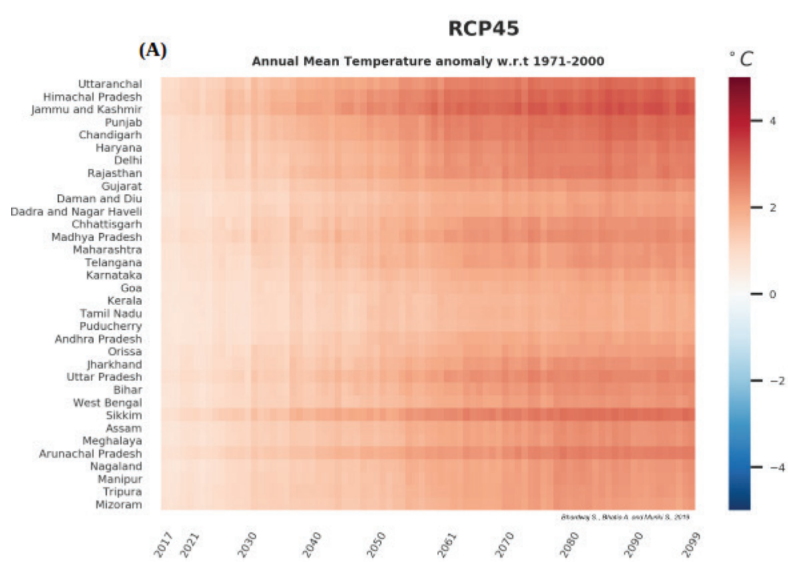


Figure 11: Projected Annual Mean Temperature Anomaly under RCP 4.5 for states and union territories of India

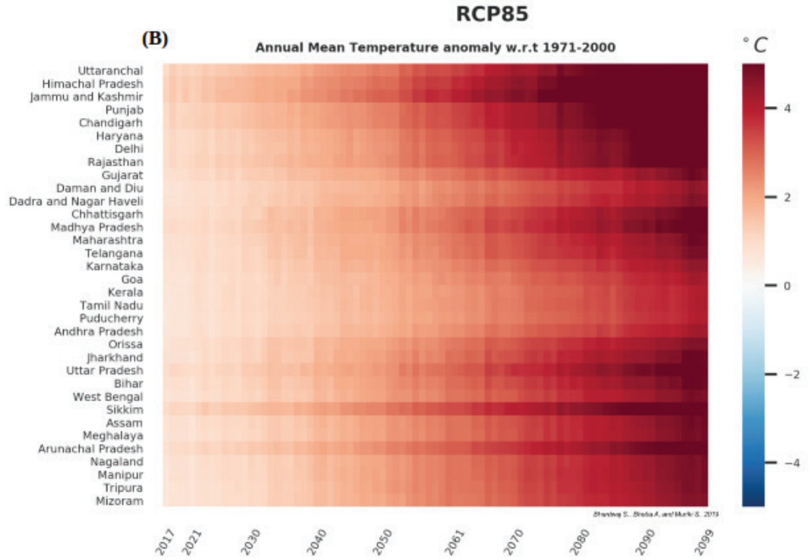


Figure 12: Projected Annual Mean Temperature Anomaly under RCP 8.5 for states and union territories of India

A future outlook of the temperature changes regionally over the different states and union territories of India depicted in figures 11 and 12 shows a clear warming future even regionally with high variation. A multi-model downscaled ensemble of the CMIP5 models, as provided by the NEX-GDDP datasets, show a clear warning signal for future period. The moderate concentration pathway (RCP4.5) projects 1- 3 °C and high concentration pathway (RCP8.5) projects 1-over 4 °C warming over different states and union territories of India for the mean temperature profile for the 2017-2099 time periods. The Himalayan states of India (Uttarakhand, Jammu and Kashmir, Himachal Pradesh) and North Eastern states (Sikkim, Arunachal Pradesh) show relatively more warming than other parts of India under the RCP4.5 concentration pathway. The similar pattern with more warming is also seen over Northern, North East and Himalayan states of India under RCP8.5 concentration pathway as well.

City Level:

Most of the impacts of the changing global and regional climate are felt at much more granular scales viz. at the cities scale. The changing climate and increasing extremes are exacerbating the already stressed urban sprawls by interfering with basic services and their proper functioning, thereby affecting the day to day functioning of city infrastructure and the daily living. Hence, it's extremely important to take mainstreaming climate profiling under the regional and local policy and decision making processes.

TERI has helped local policy establishments and businesses in preparing them to climate proof their development policies. A recent work on climate trends over various cities in India with rapid urbanization rates and which are already facing severe climate change impacts in the recent times are presented here. Figures 13 and 14 show the annual average trend of maximum and minimum temperatures respectively for different cities.

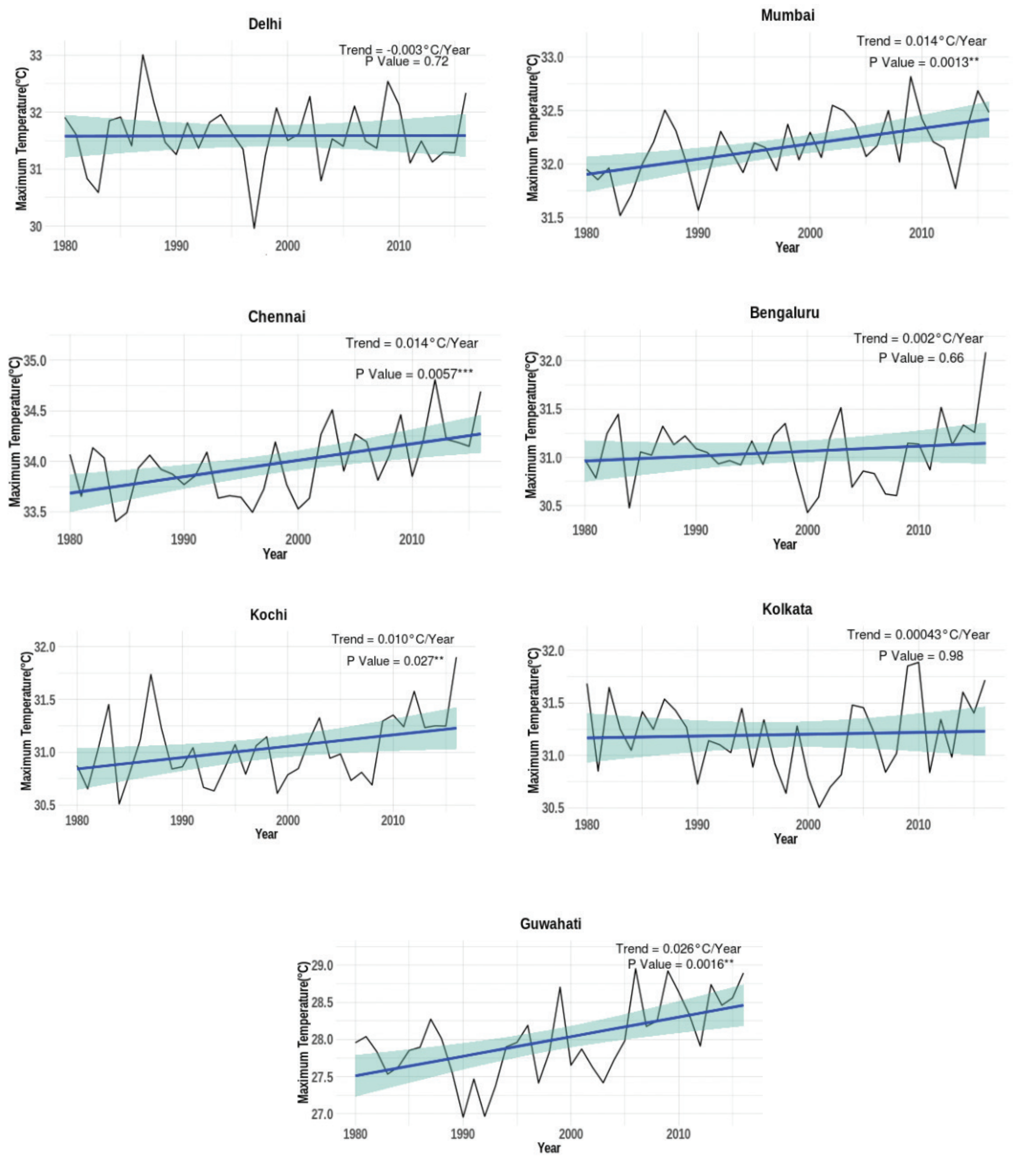


Figure 13: City Level Maximum Temperature Trend
The trends significant at 90%,95%,99% and 99.9% are marked by *,**,*** and **** respectively

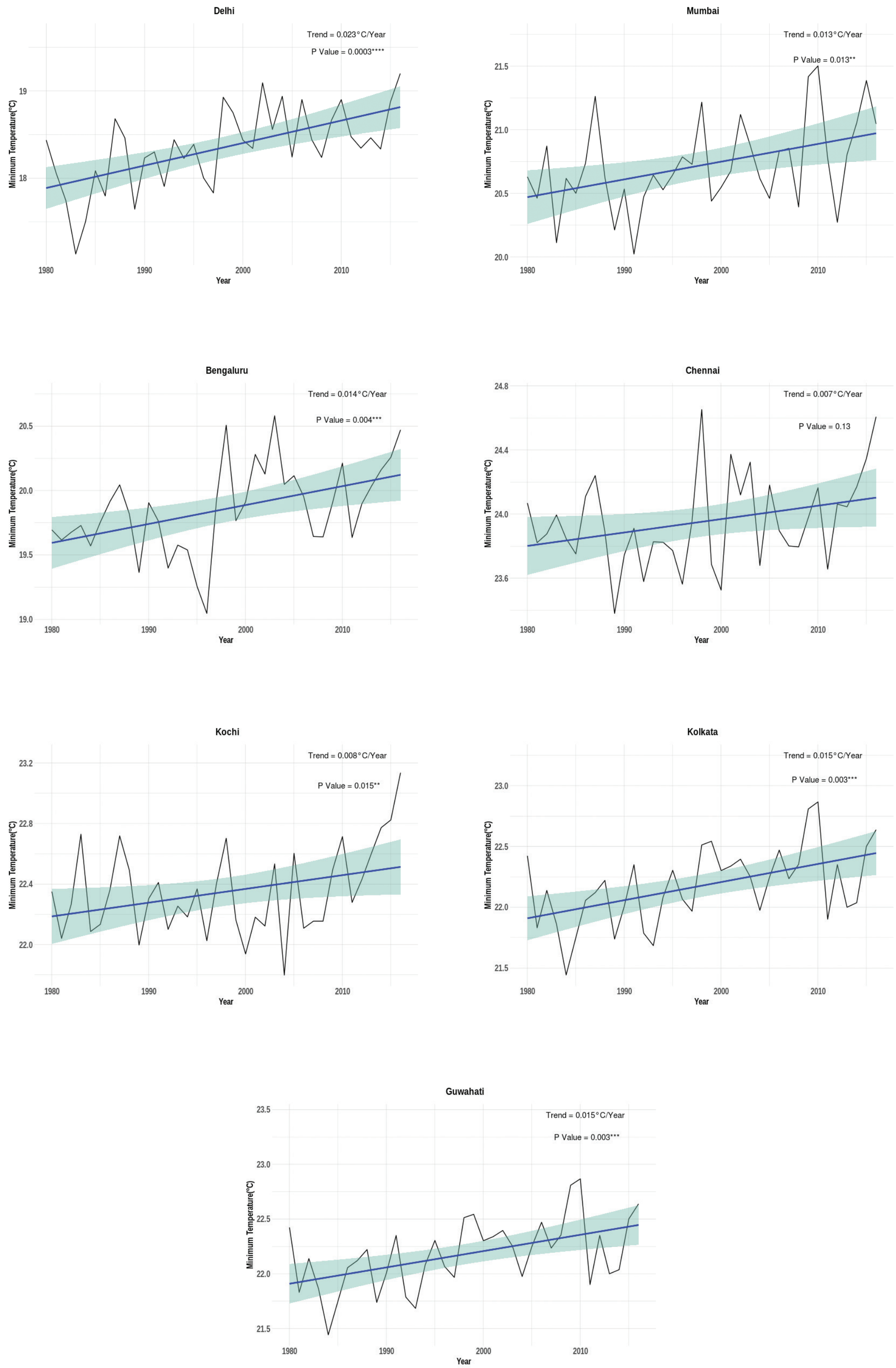


Figure 14: City Level Minimum Temperature Trend
The trends significant at 90%,95%,99% and 99.9% are marked by *,**,*** and **** respectively

The projected future warming rates for different cities are also shown as heat maps.

Future Outlook:

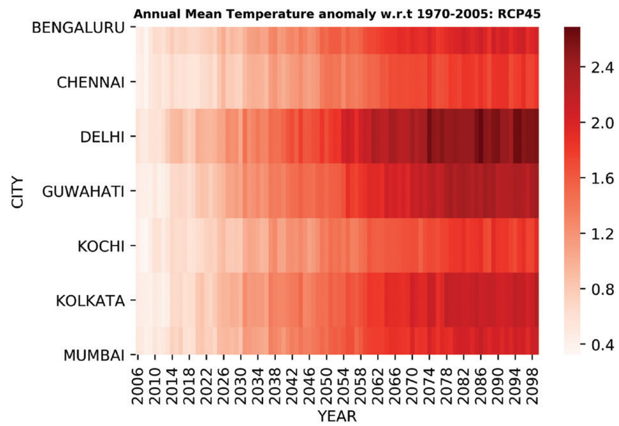


Figure 15: Projected Annual Mean Temperature Anomaly under RCP 4.5 for some selected cities of India

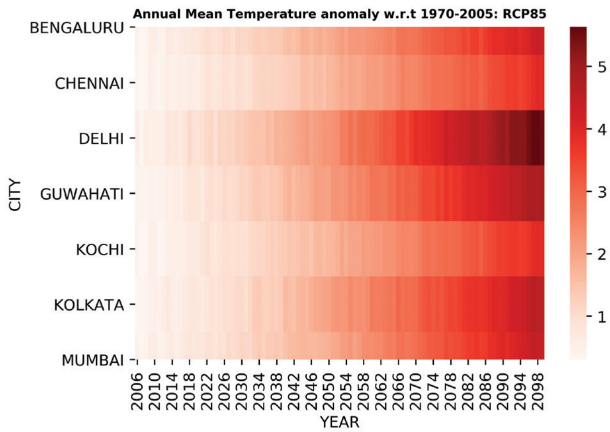


Figure 16: Projected City Level Annual Mean Temperature Anomaly: RCP 4.5 Scenario

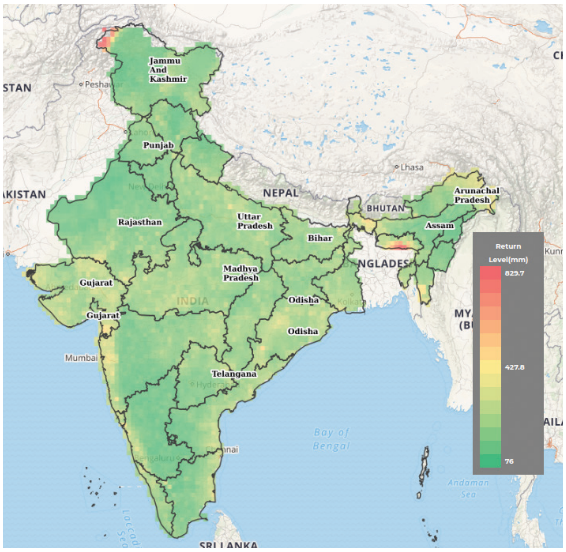
The future outlook of the temperature changes over the different cities of India shown in figures 15 and 16 depicts warming with high variation for future period. The downscaled multi-modal ensemble of the CMIP5 models as provided by the NEX-GDDP datasets show a clear warning signal for future period for the studied cities. The moderate concentration pathway (RCP4.5) projects 0.5 – 2.5 ^{o}C and high concentration pathway (RCP8.5) projects 1 - 5 ^{o}C warming over different cities of India for the mean temperature profile for 2006-2099 time periods. Delhi, Kolkata and Guwahati show relatively more warming rates as compared to other cities under the RCP 4.5 Scenario. The similar pattern with more warming is also seen over Delhi, Kolkata, and Guwahati under RCP8.5 concentration pathway as well.

TERI Climate Tool

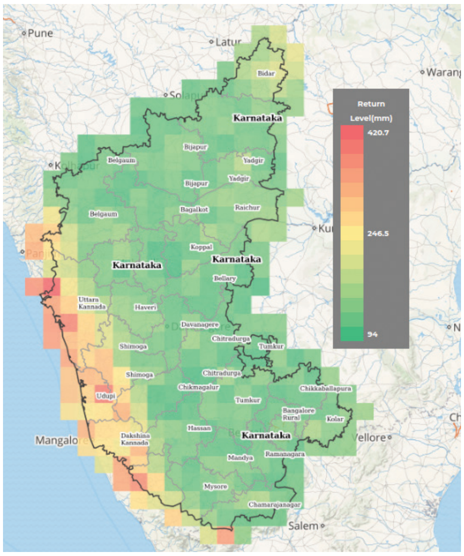
To make decision-makers climate ready, and to assist policy planning at the regional level, TERI has created a climate atlas in the form of a web portal called 'TERI Climate Tool' or TCT, which is a web-based platform to assist in capacity building and knowledge development. The aim of the portal is to provide development practitioners a resource to explore, evaluate, synthesize and learn about climate related vulnerabilities and risks at multiple levels of detail. It enables and helps in the process of developing policies and measures concerning climate impacts by aiding further research. TCT consists of spatially referenced data visualized on multiple web interfaces. Users are able to evaluate vulnerabilities, risks and actions for specific locations on the globe by interpreting climate related data at various levels.

For illustration, a precipitation output showing national, state and city level analysis (pertaining to 50 year return level) of rainfall are presented here:

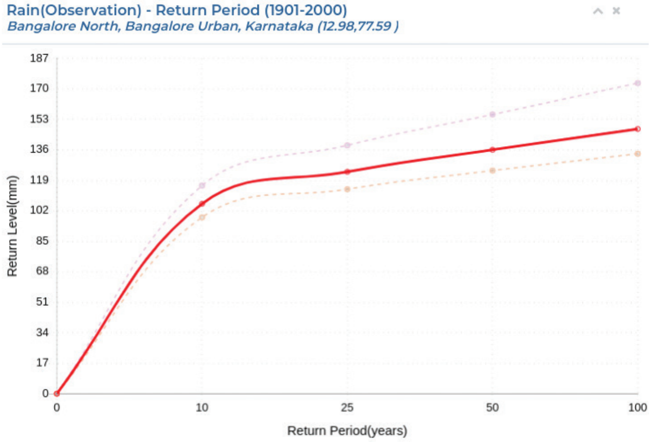
National Level



State Level



City Level



For more information, please visit: **http://www.teriin.org/**

Published by:
The Energy and Resources Institute (TERI)
Darbari Seth Block,
IHC Complex, Lodhi Road,
New Delhi - 110 003, INDIA

Tel: (+91 11) 2468 2100
Fax: (+91 11) 2468 2144, 2468 2145
Web: www.teriin.org