Functional Data Analysis of Temperature and Rainfall Observations for the Regional Indexing of Climate Change Severity in India

A THESIS

Submitted for the degree of

DOCTOR OF PHILOSOPHY

in the School of Basic Sciences

by

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September, 2017

Dedicated to

My Family

Declaration by the Research Scholar

I hereby declare that the entire work embodied in this Thesis is the result of investigations carried out by me in the School of Basic Sciences, Indian Institute of Technology Mandi, under the supervision of Dr. Sarita Azad, and that it has not been submitted elsewhere for any degree or diploma. In keeping with the general practice, due acknowledgments have been made wherever the work described is based on finding of other investigators.

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Declaration by the Research Advisor

I hereby certify that the entire work in this Thesis has been carried out by Pankaj Narula, under my supervision in the School of Basic Science, Indian Institute of Technology Mandi, and that no part of it has been submitted elsewhere for any degree or diploma.

Signature:

Name of the Guide: **Dr. Sarita Azad**

Acknowledgements

First and foremost, I offer my sincere gratitude to the almighty. Next, I am very grateful for the opportunity I have been given to do a PhD at the School of Basic Sciences at IIT Mandi. I would like to thank my supervisor Dr. Sarita Azad who, with great enthusiasm and knowledge introduced me to the interesting and challenging field of climate change and its impacts. I appreciate all the support and help during the work and the way she has supervised me so that I could become an independent researcher.

I am also grateful to the other members of my doctoral committee: Dr. Rajendra K. Ray, Dr. Syed Abbas, Dr. Manoj Thakur and Dr. Kaustav Sarkar for their valuable suggestions and to my teachers who encouraged me to pursue higher studies. I would like to express my gratitude to Dr. Kaustav Sarkar for his constant support and guidance in this work. I am also thankful to my friends, Manoj Kumar, Kunal Sharma, Bhupesh Phutela, Rajeev Prashar, Preetinder Singh Sandhu and Jyoti Prakash Kataria for their continuous support.

Furthermore, I appreciate the support and help given by staff members of IIT Mandi. I would like to extend my thanks to the colleagues, Suraj S. Meghwani, Mohit Sharma, Sandeep Sharma, Sharad Gupta, Abhay Guleria, Sachin Kumar, Rajan Kumar, Parvinder Kumar, Subit Kumar Jain, Deepak Kumar, and Pravat Jena for their support and great memories.

Financial support from University Grants Commission is also acknowledged. Finally, I take this opportunity to convey my gratefulness to my family whom I am really proud of. Without them I would never have enjoyed so many opportunities. Thank you both for giving me strength to reach for the stars and chase my dreams.

Pankaj Narula

Abstract

The persistence of global warming and its impact on various facets of human life is indubitable. Particularly, India is among the countries which are most vulnerable to the influence of climate change. Thus, identification of spatial and temporal course of climate change events in India is crucial to develop the optimal adaption and mitigation strategies. The present work aims to identify the footprints of temperature change in Indian context by analyzing monthly temperature data pertaining to the period of 1901-2005. Functional data analysis (FDA) has been implemented for the detection of mean change-years in Indian temperature. The technique is more robust than conventional multivariate analysis and provides more information about the data. The estimated change-years have been observed to largely pertain to the latter half of 20th century and fall in close proximity of widely reported global change-years. The all-India temperature shift is estimated to be 0.53°C during 1901-2005. An index, consolidating the results of FDA such as change-years and temperature rise, has been developed to quantify the temperature change severity. Based on the spatial distribution of index values, the hot-spots have been found to cluster over the north-central and eastern parts of the country. These findings have been validated against actual conditions. The approach has also been employed to understand the manifestation of significant changes in maximum and minimum temperatures. It is observed that maximum temperatures have undergone frequent changes during the period 1901-1970, whereas continual changes are observed in minimum temperatures during post 1970. The values obtained from the developed index suggests that change in minimum temperature is more severe and wide spread than change in maximum temperature.

Further, changing patterns of climate have substantially altered the frequency of different rainfall events. To investigate the issue, firstly regional rainfall observations have been converted into smooth curves using FDA. Subsequently, wet spells for Indian homogeneous regions have been estimated from their corresponding smooth curves. Thereafter, decadal distribution of moderate, heavy and extremely heavy rainfall events have been computed during the estimated wet spells. It has been found that frequency of extremely heavy rainfall events have increased in every region due to the warmer climate.

Buildings are fundamental components of infrastructure and play a crucial role in the dynamics of climate change. To assess the joint impact of wind and rain endured by vertical building facades, annual driving rain index ($aDRI$) is computed on gridded scale. The $aDRI$ values have been estimated using gridded daily records of wind and rainfall pertaining to the sixty-year period of 1951-2010. The study compares the quality of $aDRI$ estimates as a function of the temporal resolution of gridded data by evaluating total, non co-occurring and averaging errors. An $aDRI$ map for India at $1^\circ \times 1^\circ$ (lat./long.) resolution has been constituted and the dominant directions of driving rain have been identified. The discourse concludes with a trend analysis of yearly driving rain index values.

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