Prem Shankar Goel · Rasik Ravindra
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Preface

The current book Climate Change and the White World is the outcome of the 4th Conference on Science and Geopolitics of Himalaya, Arctic and Antarctic (SaGHAA IV 2017) held at the Convention Centre, Jawaharlal Nehru University, New Delhi, India, on November 30 and December 1, 2017. The Arctic, Antarctica and the third Pole-Himalaya have drawn the attention of scientists and researchers in the last few decades like never before due to the unprecedented changes in the environment and morphology of cryospheric regions. The region also has seen the emergence of political interventions and strategic scientific developments especially in view of the claims of coastal states to continental shelves beyond their exclusive economic zones and on the issues of Antarctic Treaty System.

The year 2018 has been ranked fourth warmest on record. As per a recent report of NASA, 18 of the 19 warmest years have occurred since 2001. The global warming and associated climate variability that scientists had been warning about are no longer a myth. The increasing evidences in the form of extreme weather events, viz. increase in flash floods, cloud bursts, hurricane, storms, etc., point towards an alarming reality. In fact, the current trends in the rise of temperatures are faster than that envisaged by climate models. Though climate change is a natural process and evidences of earth's past periods of warming are recorded in the form of alternating interglacial and glacial periods, that anthropological factors have accelerated the rate of global warming due to an infusion of greenhouse gases into the atmosphere is now globally accepted. The rate at which changes are occurring is a serious cause of concern, whether in the form of rise in average air temperature or the sea level rise, glacial retreat, etc. The worst affected regions facing the brunt of global warming are the cryospheric regions of the world – Arctic, Antarctic and the mountain glaciers such as the Alpine, Andes, Alaska, Himalayan and Patagonian.

The Arctic region is transforming fast as the change in climate has increased melting of sea ice and opened accessibility in the otherwise frozen Arctic Sea. The year 2018 saw Arctic winter ice at its lowest. The magnitude of temperature increase in the Arctic is twice as much as the global increase. The effect of Arctic climate change will have profound local, regional and global implications. In the first half of 2010, air temperatures in the Arctic were 4 °C warmer than between 1968 and

1996. Satellite data show that over the past 30 years, Arctic sea ice cover has declined by 30%. Satellite data also shows that snow cover over land in the Arctic has decreased and glaciers in Greenland and Northern Canada are retreating. In addition, frozen ground in the Arctic has started to thaw. There have been reports that the world's northernmost weather station located at the tip of Northern Greenland experienced warmer temperature than London and Zurich for unusual long spells.

A growing demand for energy resources has encouraged exploitation in these parts, raising environmental concerns. The loss of ice shelves, though differentially in different parts of Antarctica, has increased over the past few decades. Calving of great portions of Larsen ice shelf and disintegrating glaciers in western Antarctica has demonstrated the impact of global warming on sensitive ecological parts of our Earth. Himalaya – the third pole, analogous to polar regions – needs increased attention as nearly 1.3 billion people depend upon its resources, especially water, for sustenance. Three of the world's major rivers – the Indus, the Ganges and the Brahmaputra – originate in the Himalaya. Any major stress on water availability either under the climate change scenario or because of an increased demand can only lead to conflict between countries sharing the resources. The decreasing snow and ice cover and the impact on the regional climate due to teleconnections between the distant parts of the earth have demonstrated that what happens in one region has implications for other parts too.

The wide variation in the content and the geographical spread covered in the book *Climate Change and the White World* demonstrate the effort put in by the organizers, Learning in Geography, Humanities, Technology and Science (LIGHTS), to provide a networked platform to evolve a synergy between scientists and social, political and legal experts working in the cryosphere of three polar regions. The volume has also covered the adaptation strategies especially for sustainability in densely populated Himalayan region.

This book is an effort of many scientists who care for Earth and its environment and sustainability of mankind. It is hoped that this effort will be yet another small step towards bringing awareness amongst policy-makers, heads of states, etc. The development at the cost of environment is already palpable in the rapidly changing white world. The editors would like to place on record the assistance of experts in glaciology, climate change research and geopolitics in reviewing the papers. The help provided by the LIGHTS secretariat, especially, Rajoli Ghosh, Nilesh Kumar and others, is gratefully acknowledged.

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Introduction

Climate change is forcing visible impacts onto the sensitive polar regions which are seen in the form of depleting sea ice in the Arctic and consequently the opening up of new maritime routes, melting and breaking of ice shelves in Antarctica, deteriorating health of Himalayan glaciers, etc. The need to assess the changing face of the cryosphere in the polar regions including the Himalaya; discuss the extreme events, climate modelling and teleconnections of climate between polar region and Indian summer monsoon; and develop adaptation strategies led to the 4th Conference on Science and Geopolitics of Himalaya, Arctic and Antarctica (SaGHAA IV) near the end of the year 2017. The conference was in continuation of the SaGHAA biannual series held in 2011, 2013 and 2015. The present volume, therefore, can be seen as a publication in line and in continuation to an earlier volume *Science and Geopolitics of the White World: Arctic-Antarctic-Himalaya* published in 2017 by Springer.

Some of the key papers presented in the SaGHAA-IV were invited for publication titled *Climate Change and the White World*. Fourteen papers were selected and divided in three parts/sections, viz. Arctic and Antarctic, climate change and adaptation and Himalayan cryosphere and climate change, encompassing nearly all the themes that were discussed in the technical sessions of SaGHAA IV. The papers selected cover a wide range of subjects varying from current topics of interest in Arctic and Antarctic and geopolitical advances in the Arctic Region to adaptation strategies in the Himalayan Region in response to climate change and glaciological research in the Himalaya in the light of global warming.

The first part dealing with Arctic and Antarctic has four papers, namely, Emerging Traits of Sea Ice in the Atlantic Sector of the Arctic by Nalan Koç and her co-workers; Indian Arctic Multisensory Moored Underwater Observatory by Atmanand and his research group; The Arctic Ocean: Advances in Geopolitics and Geoscience by Walter Roest and Richard Haworth; and Glacial Sediments of Schirmacher Oasis, Central Dronning Maud Land, East Antarctica and their characteristics by Rasik Ravindra.

The first paper *Emerging Traits of Sea Ice in the Atlantic Sector of the Arctic* by Nalan Koç, Mats A. Granskog and Philipp Assmy summarizes the results from the Arctic Region, showing that not only has the sea ice cover of Arctic changed drastically over decades but also its thickness. The warmer Arctic is changing the Northern Hemisphere's weather patterns. The authors stress that the following questions need to be answered: What melts the ice? How the thinner ice responds to atmospheric forcing? What are the effects of the changing sea ice system on ice-associated ecosystem? The paper reviews the Norwegian Young Sea Ice Cruise expedition to the Arctic in 2015 and documents its main findings that include the following: unexpected thick snow cover, new and growing ice formed with little snow, storms slowing ice growth, ocean heat flux, early phytoplankton blooms below thick snow covered sea ice, etc.

M. A. Atmanand, R. Venkatesan and G. Latha in their paper *Indian Arctic Multisensory Moored Underwater Observatory* cover a wide spectrum of subjects, viz. the need for the Arctic mooring, nature of the mooring system, parameters measured, analysis, etc. Datasets collected on temperature/salinity, ambient noise and corrosion from Arctic using 'IndARC I, II, III and IV' for 3 years are presented and described in detail. The results from spectrogram and iceberg cracking/calving and those from anthrophony and biophony are also discussed.

Walter Roest and Richard Haworth in their paper *The Arctic Ocean: Advances in Geopolitics and Geoscience* discuss the advances in geopolitics and scientific exploration with reference to the Arctic Ocean. In their scholarly article, they discuss the major changes that have occurred in the Arctic area: first, being the opening of new sea routes, the northeastern and the northwestern routes, and, second, the coming in force of the UN Convention on the Law of the Sea (UNCLOS) which defines different sovereignty regimes for the oceans. The authors discuss data types required for mapping continental shelf beyond 200 nautical mile, collaboration and cooperation being paramount to the success of the exploration in geoscientific fields in the Arctic Ocean.

The last paper of this part, authored by Rasik Ravindra, deals with the characteristics of glacial sediments collected from various glacial and periglacial environments of the Schirmacher Oasis of East Antarctica. The author discusses the provenance, the geochemistry and the micro textures developed on the quartz grains and deduces the palaeoclimate of Schirmacher Oasis from this study.

Part II comprises three papers that deal with climate change and the adaptations to this changing scenario. These are *Adaptation to Climate Change: A Fishery Technology Perspective* by C.N. Ravishankar and V. R. Madhu, *Potential Technologies for Climate Resilient Agriculture in the Indian Himalayan Region* by Latika Pandey and Ayyanadar Arunachalam and *Need for Reorienting Climate Change Research in the Himalaya: Balancing the Approach* by Shyamal K. Nandi, Vikram S. Negi and Ranbeer S. Rawal.

The first paper describes the many ways in which fisheries may be impacted by climate change, such as shifts in productivity, displacement or migration of species and more. The authors deal with issues of over-exploitation and suggest that interventions with fishery technologies and development of models for adaptation may assist the mitigation of the immediate concerns.

Pandey and Arunachalam in their paper drive home the point that changing climatic conditions have impacted weather events, further exacerbating the frequency and intensity of various climatic disasters, affecting the Himalayan ecology and livelihood security. The authors have described the attempts made under the National Mission for Sustaining the Himalayan Ecosystem (NMSHE) to face new challenges and provide opportunities to enhance the quality of life of the farmers by utilizing the locally available resources and introducing important modern tools and technologies to generate a sustainable source of livelihood vis-à-vis climate resilience. On a similar note, the final paper of the section by Nandi and co-workers have emphasized a need for reorienting and balancing the research in the field of climate change in the Himalaya.

The third section includes seven papers dealing with the Himalayan cryosphere and climate change. It presents findings of a few Himalayan glaciers together with high-resolution dynamic downscaling of winter climate and the response of Indian summer monsoon dynamics to Late Quaternary fluvial deposits.

Kar, Sarita Tiwari and Pushp Raj Tiwari in their paper *High-Resolution Dynamic Downscaling of Winter Climate over the Himalaya* show the results of dynamic downscaling simulations using a high-resolution WRF model and a regional climate model (RegCM) with enlightened sensitivity of cloud microphysics schemes in the WRF model. This allows for the simulation of snowfall over the high mountain top or on the slopes.

Ashit Kumar Swain in his paper *Glacier Stress Pattern as an Indicator for Climate Change* discusses the relation of climate change to glacier stress patterns. He describes the result of ice thickness measurements using GPR and discusses different types of forces such as traction, stresses and strains as studied in Vestre Broggerbreen glacier of Svalbard. Similar studies carried out in a part of Antarctica are also discussed.

Parmanand Sharma, and his group in their paper *Glacier Response to Climate in Arctic and Himalaya During Last Seventeen Years: A Case Study of Svalbard, Arctic and Chandra Basin, Himalaya,* presents the results on different glacial parameters such as ice density, annual/cumulative mass balance, mean annual temperature and precipitation, etc. obtained from different glaciers in Chandra Basin, Himachal Pradesh (India) and Svalbard (Arctic). They conclude that though the Arctic glaciers and ice caps are losing more glacier mass as compared to the Himalaya, the rate of melting of the Himalayan glaciers is significantly higher than those in the Arctic.

Ganju and Negi in their paper *Implications of Changing Climatic Pattern on the Geopolitical Situation of NW Himalaya, India* have cautioned that the changing pattern of climate may prove disastrous in some regions where the regolith is loose and dry. The rapid erosion from mountain slopes would give rise to unprecedented hazards downstream. The prediction with a view to offer reasonable solutions in the context of an increasing frequency of extreme weather events will continue to be the future research area of work in the Himalaya.

In a paper *Glacier Melt Water Characteristics of Hamtah Glacier, Lahaul and Spiti District, Himachal Pradesh, India* based on field investigations of a Himalayan glacier, Shukla, Rakesh Mishra and Ajai Kumar analyse the hourly melt water discharge data collected using area-velocity technique, during the August-September period spanning between 2000 and 2007. The studies indicate close linkages with temperature and surface ice ablation.

Sharat Dutta and his co-workers in their paper on *Responses of Indian Summer Monsoon (ISM) Dynamics and Late Quaternary Fluvial Development: Records from Yamuna River valley, NW Himalaya,* describe three to four major periods of sediment dispersal and aggradation in the Yamuna Valley under warm climatic conditions. They report enhanced ISM activity during these phases and conclude that the continuation of palaeo-floodplain across MCT and MBT suggests profound climate control of sediment generation, dispersal and aggradations.

In the final paper *An Appraisal of Spatio-temporal Characteristics of Temperature and Precipitation over NW Himalaya Using Gridded Datasets*, Negi and Neha validate the performance of eight gridded datasets, over NW Himalaya (NWH) within the Indian subregion and then study spatio-temporal variability of climate through the use of these selected datasets. They find that ERA-I and CRU-TS datasets capture the spatial distribution of temperature and precipitation well. They further add that temperature and precipitation trends pre- and post-year 2000 reveal comparative slowdown in warming/rate of precipitation decline after year 2000 which is linked with increased snow cover area and comparatively less negative glacier mass budget in westerly dominated areas like NWH.

Overall, the book *Climate Change and the White World* provides a comprehensive overview of scientific studies conducted by researchers in different areas related to impact of climate change on Antarctic, Arctic and the Himalaya and on people around. However, a lot more scientific attention is needed to substantially comprehend the complex interplay of manmade interventions with the natural world.

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Abbreviations

ABNJ	Areas Beyond National Jurisdiction
ADCP	Acoustic Doppler Current Profiler
AGCM	Atmosphere-Only General Circulation Models
AIS	Automatic Identification System
AMS	Accelerato Mass Spectrometry
CC	Climate Change
CCRF	*Code of Conduct for Responsible Fisheries*
CDML	Central Dronning Maud Land
CH	Central Himalaya
CLCS	Commission on the Limits of the Continental Shelf
CMIP5	Coupled Model Intercomparison Project Phase 5
COP	Common Observation Period
CORDEX	Coordinated Regional Climate Downscaling Experiment
CRU	Climate Research Unit
CRU-TS	Climate Research Unit Time Series
CTD	Conductivity, Temperature, Depth
DO	Dissolved Oxygen
DTR	Diurnal Temperature Range
EAO	East African Orogeny
ECMWF	European Centre for Medium-Range Weather Forecasts
ED	Equivalent Dose
EEZ	Exclusive Economic Zone
FAO	Food and Agriculture Organization
FLNTUS	Fluorescence and Turbidity
FYI	First Year Ice
GAAP	Global Aquaculture Advancement Partnership
GCM	General Circulation Models
GH	Great Himalaya
GHG	Greenhouse Gas
GPCC	Global Precipitation Climatology Centre
GPR	Ground Penetrating Radar

GSSI	Geophysical Survey Systems, Inc.
HALIP	High Arctic Large Igneous Province
HAMH	High Arctic Magnetic High
HFT	Himalayan Frontal Thrust
HHC	Higher Himalayan Crystalline
HKH	Hindu Kush Himalaya
HKKH	Hindu Kush Karakoram Himalaya
IAE	Indian Antarctic Expedition
IAV	Interannual Variability
ICAR	Indian Council of Agricultural Research
ICTP	International Centre for Theoretical Physics
IFS	Integrated Farming System
IGP	Indo-Gangetic Plain
IHR	Indian Himalayan Region
IMD	India Meteorological Department
INCCA	Indian Network on Climate Change Assessment
INCOIS	Indian National Centre for Ocean Information Services
IPCC	Intergovernmental Panel on Climate Change
IR	Infrared
IRSL	Infrared Stimulated Luminescence
ISM	Indian Summer Monsoon
ISUS	In Situ Ultraviolet Spectroscopy
IUU	Illegal, Unreported and Unregulated
KH	Karakoram Himalaya
LEFM	Linear Elastic Fracture Mechanics
LFT	Local Fan Terraces
LGM	Last Glacial Maximum
LH	Lower Himalaya
LIFDCS	Low-Income Food-Deficit Countries
LOI	Loss on Ignition
MAE	Mean Absolute Error
MBT	Main Boundary Thrust
MCS	Monitoring Control and Surveillance
MCT	Main Central Thrust
MPA	Multi-satellite Precipitation Analysis
MS	Magnetic Susceptibility
MSL	Mean Sea Level
MW	Microwave
MYI	Multi-Year Ice
NAPCC	National Action Plan on Climate Change
NCAOR	National Centre for Antarctic and Ocean Research
NCAP	National Center for Atmospheric Prediction
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NCPOR	National Centre For Polar and Ocean Research

NHSI	Northern Hemisphere Summer Insolation
NIOT	National Institute of Ocean Technology
NMSHE	National Mission for Sustaining the Himalayan Ecosystem
NPI	Norwegian Polar Institute
NSIDC	National Snow and Ice Data Centre
NWH	North Western Himalaya
OOS	Ocean Observation Systems
OSL	Optically Stimulated Luminescence
PAR	Photosynthetically Active Radiation
PFZ	Potential Fishing Zones
QCLOUD	Cloud Liquid Water (g/kg)
QICE	Ice (g/kg)
QRAIN	Rainwater (g/kg)
QSNOW	Snow (g/kg)
RCP	Representative Concentration Pathways
RegCM4	Regional Climate Model
RMSE	Root Mean Squared Error
RSB	Raised-Sunken Bed
SAR	Synthetic Aperture Radar
SASE	Snow and Avalanche Study Establishment
SCA	Snow Cover Area
SEM	Scanning Electron Microscopy
SOPIM	Schirmacher Oasis-Polar Ice Sheet Margin
SPCM	Single-Point Current Meter
SRM	Standard Reference Materials
SRTM	Shuttle Radar Topographic Mission
SUNA	Submersible Ultraviolet Nitrate Analyser
SWE	Snow Water Equivalent
SYI	Second Year Ice
TKS	Traditional Knowledge Systems
TP	Tibetan Plateau
TRMM	Tropical Rainfall Measuring Mission
UHMWPE	Ultrahigh-Molecular-Weight Polyethylene
UNCLOS	United Nations Convention on the Law of the Sea
USCGC	US Coast Guard Cutter
WDs	Western Disturbances
WRF	Weather Research and Forecast
YRT	Yamuna River Terrace

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