

Prem Shankar Goel · Rasik Ravindra  
Sulagna Chattopadhyay *Editors*

# Climate Change and the White World

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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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Sulagna Chattopadhyay

# Contents

## Part I Arctic and Antarctic

- Emerging Traits of Sea Ice in the Atlantic Sector of the Arctic** ..... 3  
Mats A. Granskog, Philipp Assmy, and Nalan Koç
- Indian Arctic Multisensory Moored Underwater Observatory** ..... 11  
R. Venkatesan, M. A. Atmanand, and G. Latha
- The Arctic Ocean: Advances in Geopolitics and Geoscience** ..... 19  
Walter R. Roest and Richard T. Haworth
- Glacial Sediments of Schirmacher Oasis, East Antarctica  
and their Characteristics** ..... 31  
Rasik Ravindra

## Part II Climate Change and Adaptation

- Adaptation to Climate Change: A Fishery Technology Perspective** ..... 61  
C. N. Ravishankar and V. R. Madhu
- Potential Technologies for Climate Resilient Agriculture  
in the Indian Himalayan Region** ..... 77  
Latika Pandey and Ayyanadar Arunachalam
- Need for Reorienting Climate Change Research  
in the Himalaya: Balancing the Approach** ..... 87  
Shyamal K. Nandi, Vikram S. Negi, and Ranbeer S. Rawal

## Part III Himalayan Cryosphere and Climate Change

- High-Resolution Dynamic Downscaling of Winter Climate  
over the Himalaya** ..... 101  
S. C. Kar, Sarita Tiwari, and Pushp Raj Tiwari

<b>Glacier Stress Pattern as an Indicator for Climate Change . . . . .</b>	<b>119</b>
Ashit Kumar Swain	
<b>Glacier Response to Climate in Arctic and Himalaya During Last Seventeen Years: A Case Study of Svalbard, Arctic and Chandra Basin, Himalaya . . . . .</b>	<b>139</b>
Parmanand Sharma, Lavkush Kumar Patel, Ajit T. Singh, Thamban Meloth, and Rasik Ravindra	
<b>Implications of Changing Climatic Pattern on the Geopolitical Situation of North Western Himalaya, India . . . . .</b>	<b>157</b>
Ashwagosha Ganju and H. S. Negi	
<b>Glacier Melt Water Characteristics of Hamtah Glacier, Lahaul and Spiti District, Himachal Pradesh, India . . . . .</b>	<b>169</b>
S. P. Shukla, Rakesh Mishra, and Ajai Kumar	
<b>Responses of Indian Summer Monsoon Dynamics and Late Quaternary Fluvial Development: Records from Yamuna River Valley, NW-Himalaya . . . . .</b>	<b>187</b>
Sharat Dutta, S. A. I. Mujtaba, R. Bhavani, Mohammad Atif Raza, R. Chunchekar, and Mohd Sadiq	
<b>An Appraisal of Spatio-Temporal Characteristics of Temperature and Precipitation Using Gridded Datasets over NW- Himalaya . . . . .</b>	<b>219</b>
H. S. Negi and Neha Kanda	

# 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	<i>Code of Conduct for Responsible Fisheries</i>
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

# List of Figures

## Emerging Traits of Sea Ice in the Atlantic Sector of the Arctic

Fig. 1	Monthly mean and modal sea ice thickness in the Fram Strait. Gaps in the time-series indicate missing data. (Updated from data in Hansen et al. 2013. Data available at <a href="http://www.mosj.no/">http://www.mosj.no/</a> ) .....	4
Fig. 2	Schematic view of the sea-ice ridge habitat, with macro porosity in the keel that allows for different ice associated algae to thrive in the interstitial spaces and surface of ice blocks. (Modified from Fernández-Méndez et al. 2018) .....	7
Fig. 3	Schematic view of how a heavy snow load on thinner sea ice allows flooding of the ice/snow interface that can be a new habitat for algae, with stable conditions and avoidance by grazers. (Modified from Fernández-Méndez et al. 2018) .....	7

## Indian Arctic Multisensory Moored Underwater Observatory

Fig. 1	IndARC deployment location .....	13
Fig. 2	Deployment of Ambient noise measurement system with two hydrophones.....	15
Fig. 3	Temperature profile of IndARC mooring during the period July 2014 to July 2016.....	16
Fig. 4	The Spectrogram of bubbling noises as observed in 2016 summer .....	17

## The Arctic Ocean: Advances in Geopolitics and Geoscience

Fig. 1	Maritime jurisdiction and maritime boundaries (established or potential) in the Arctic. (Source: IBRU, Durham University 2015. See <a href="http://www.durham.ac.uk/ibru/resources/arctic">http://www.durham.ac.uk/ibru/resources/arctic</a> for details).....	23
Fig. 2	Bathymetric map of the Arctic Ocean, showing the major geological features, and notably the complex ridges and basins that make up the seafloor.	



(Source: Executive Summary of the Submission made by Denmark together with the government of Greenland to the CLCS: [http://www.un.org/depts/los/clcs\\_new/submissions\\_files/dnk76\\_14/dnk2014\\_es.pdf](http://www.un.org/depts/los/clcs_new/submissions_files/dnk76_14/dnk2014_es.pdf))..... 25

Fig. 3 Magnetic anomaly map of the Arctic Ocean with magnetic domain boundaries. The magnetic domains represent regions that share a common pattern of anomalies. (From Saltus et al. 2011) ..... 26

Fig. 4 Bathymetry/topography of the Alpha-Mendeleev complex. The white outline represents the High Arctic Magnetic High. *AB* Amundsen Basin, *AX* Axel Heiberg Island, *CB* Chukchi Basin, *CG* Cooperation Gap, *ELI* Ellesmere Island, *NB* Nautilus Basin, *NS* Nautilus Spur, *NWR* Northwind Ridge, *MB* Makarov Basin, *MS* Marvin Spur, *PB* Podvodnikov Basin, *SB* Stefansson Basin, *SS* Sever Spur. (From Oakey and Saltus 2016, see publication for more details)..... 27

Fig. 5 Multichannel profile crossing some of the most important features of the Arctic Ocean, from the Barents-Kara shelf to the Canada Basin. This composite profile was collected by Russian and other scientific teams. (Source: Revised submission by the Russian Federation to the CLCS: [http://www.un.org/depts/los/clcs\\_new/submissions\\_files/rus01\\_rev15/2015\\_08\\_03\\_Exec\\_Summary\\_English.pdf](http://www.un.org/depts/los/clcs_new/submissions_files/rus01_rev15/2015_08_03_Exec_Summary_English.pdf))..... 28

**Glacial Sediments of Schirmacher Oasis, East Antarctica and their Characteristics**

Fig. 1 Location of Schirmacher Oasis, CDML, East Antarctica..... 32

Fig. 2 Glacial till and rock clasts broken by the weathering processes..... 34

Fig. 3 Schematic map of different phases of glacial deposits across the Schirmacher Valley. The numbers denote the sample locations ..... 35

Fig. 4 Lithological section showing sediment variation with respect to depth..... 36

Fig. 5 3D cross-sections showing lithological section of shallow pits..... 36

Fig. 6 Map showing sample locations for trace metal analysis. (After Ravindra et al. 2001) ..... 37

Fig. 7 Pie-diagram of sand-silt-clay percentage of samples numbered as 1, 2, 3B, 4 and 5..... 38

Fig. 8 Bar Diagram illustrating comparative (a) sand-silt-clay percentage, and (b) concentration of organic carbon (OC), inorganic carbon (IC) and carbonate (CaCO<sub>3</sub>) in percentage for different samples (ST1-NH)..... 42

Fig. 9 Trace metal concentrations (PPM) of all the soil samples of Schirmacher Oasis..... 43

Fig. 10 Variation of Co and Ni concentrations of all the Schirmacher soil samples..... 44

Fig. 11	Variation of Zn, Pb and Cu concentrations of all the Schirmacher soil samples .....	45
Fig. 12	SEM microphotographs for glacial surface ST-1.....	46
Fig. 13	SEM microphotographs for glacial surface ST-2.....	47
Fig. 14	SEM microphotographs for glacial surface ST-3a.....	48
Fig. 15	SEM microphotographs for glacial surface ST3b.....	49
Fig. 16	SEM microphotographs for glacial surface ST3b.....	50
Fig. 17	SEM microphotographs for glacial surface ST4.....	51
Fig. 18	SEM microphotographs for glacial surface ST5.....	52
Fig. 19	SEM microphotographs for glacial surface NH1a and NH13a .....	53
Fig. 20	Fluvial channel deposit showing perfectly rounded to sub- rounded pebbles and boulders of varying lithologies and sizes. Note the interstitial spaces filled by small sized pebbles of similar composition.....	54
 <b>Adaptation to Climate Change: A Fishery Technology Perspective</b>		
Fig. 1	Changes in the different categories of vessels in India (Source: MoA and CMFRI 2012).....	64
Fig. 2	Present and optimum marine fleet recommended for Indian fisheries. (Source: Kurup and Devaraj 2000).....	65
Fig. 3	Comparison of the CO <sub>2</sub> released per tonne of live-weight of marine fish landed. (Source: Tyedmers et al. 2005; Vivekanandan et al. 2013).....	68
Fig. 4	FV Sagar Harita, a multi-purpose deep sea fishing vessel developed by ICAR-CIFT. (Photo credit: ICAR-CIFT).....	69
Fig. 5	Solar powered fishing boat developed by ICAR-CIFT. (Photo credit: ICAR-CIFT).....	70
Fig. 6	Semi-pelagic trawl system that operates off-bottom with reduced bottom impact. (Source: CIFT 2011).....	72
 <b>High-Resolution Dynamic Downscaling of Winter Climate over the Himalaya</b>		
Fig. 1	Two nested domains (Domain-1 and Domain-2) of the WRF model used in the present study. The topography of the domain-1 at 24 km and domain-2 at 8 km horizontal resolution are also shown.....	104
Fig. 2	Observed and the WRF mode simulated climatology for DJF period. (a) CRU surface temperature (°K); (b) GPCP precipitation (mm/d); (c) WRF temperature at 2 m (°K) and (d) precipitation (mm/d) .....	105
Fig. 3	(a) The WRF model simulated snow water equivalent (SWE) climatology (mm/d) during DJF; (b) Ratio (%) of snowfall to total precipitation .....	107
Fig. 4	Latitude-pressure vertical cross-section of the WRF model simulated temperature (T), zonal wind and meridional wind (v) averaged over (a–c) for western Himalaya; (d–f) eastern Himalaya .....	108

Fig. 5	(a) Interannual variability of seasonal mean precipitation (mm/d); (b) correlation of precipitation over Karakoram region with the neighboring regions and (c) time-series of seasonal mean precipitation (mm/d) for the area averaged over 70°E–79°E and 33°N–38°N.....	110
Fig. 6	Composite difference of (a) T2 m (°C) and (b) precipitation (mm/d) between excess and deficit years .....	111
Fig. 7	Difference in vertical structure of temperature (°C), zonal (u) and meridional (v) components of wind (m/s) averaged between 70°E and 79°E between excess and deficit precipitation years.....	112
Fig. 8	Same as Fig. 7, but for the WRF model simulated hydrometeors (a) cloud liquid water QCLOUD (g/kg); (b) rain water (QRAIN, g/kg), (c) snow (QSNOW, g/kg) and (d) ice (QICE, g/kg).....	114
Fig. 9	(a) Observed precipitation (b) climatology (1982–2009) from IMD gridded data; (b) the GCM simulated hindcast and (c) RegCM4 simulated downscaled precipitation for the same period .....	114
Fig. 10	Year-wise precipitation anomalies (mm/d) from 1982 to 2009 from IMD gridded data; GCM (T80 model) and RegCM4 (with forecast and observed sea surface temperatures).....	115
Fig. 11	Composite of omega (pa/s) during excess years (a) NNRP2 (b) GCM (T80 model) and (c) RegCM4 model forced with the T80 model.....	116
<b>Glacier Stress Pattern as an Indicator for Climate Change</b>		
Fig. 1	Different components of stress experienced by glaciers and Polar ice sheet, where $\theta$ is the slope of the glacier surface.....	121
Fig. 2	Schirmacher Oasis group of exposed rocky landmass are separated into three distinct zones by different lakes (Lake Zig-zag/ Lake E-1 separates one landmass towards west and Lake Ozhidaniya/ Lake E-10 to the north separates Nadezhdy/Lanka Island from the main Schirmacher Oasis). Two glacial wall types of cliffs are located towards the western and eastern part of the Schirmacher Oasis and represented as Western Wall and Eastern Wall. Study area in this manuscript is represented by a rectangle marked by dashed yellow lines .....	122
Fig. 3	Multiple Low Frequency antennas with 16–80 MHz centre frequency based Ground Penetrating Radar studies attached to a snow scooter for Polar ice sheet estimation.....	124
Fig. 4	A profile over Polar ice sheet to the south of Schirmacher Oasis showing bedrock-Polar ice sheet interface varying between 10 m and 80 m.....	126

Fig. 5 Topographic map of Schirmacher Oasis with contour lines of Polar ice sheet to the south of it along with spot heights of different places in and around the Schirmacher Oasis. The yellow dashed rectangular box inserted in the map is the study area, where detail investigation was carried out. (Source: Topographic map of the Schirmacher Oasis (1:25000) published in Leningrad, USSR (1972), on the basis of aerial photographs taken in 1961) ..... 129

Fig. 6 (a) Elevation map showing gradually lowering of the Polar ice sheet from southwest to northeast of the study area plotted over the Toposheet. (b) Surface slope map of the Polar ice sheet in the study area showing a large flat area towards south and the steep slope towards the northern part, which is plotted over the Toposheet. (c) Ice thickness map of the Polar ice sheet in the study area plotted over the Toposheet showing an overall increase in the thickness from north towards south. The area lying close to the Schirmacher Oasis – Polar ice sheet margin (SOPIM) has less ice thickness, but the area is very less as compared to its southern continuation where the thickness of the ice increases abruptly. (d) Bed elevation map of the Polar ice sheet in the study area plotted over the Toposheet showing an overall increase in the elevation of the bedrock from northeast to southwest. The area lying close to the Schirmacher Oasis – Polar ice sheet margin (SOPIM) has bedrock elevation less than 100 m amsl, while that towards southwestern part has the highest bedrock elevation of 384 m amsl. (e) Bedrock slope map of the Polar ice sheet in the study area plotted over the Toposheet showing an overall increase in the bedrock slope from northeast to southwest. The area lying close to the SOPIM is virtually flat with less than 2° slope, whereas that towards the southwestern part of the study area has the steepest slope “of 12.6°. (f) Stress map of the Polar ice sheet in the study area plotted over the Toposheet showing a large area under less stress zone upto 53 mPa. However, a linear zone of a moderate stress is located towards the north-central part of the study area. A small area towards the southwestern part of the study area and lying close to the Veteheia nunatak shows a zone of moderate stress of about 100 kPa..... 130

Fig. 7 Crevasse map of the Polar ice sheet to the south of the Schirmacher Oasis showing orientation and population of the crevasses. Snow cover on the Polar ice sheet are marked by white coloured patches..... 132

Fig. 8 (a) Model 1 showing the scenario which will happen during a cooling phase. Note the increase in the surface slope  $\theta$  due

to more accumulation in the upper reaches as compared to that of the lower portions of a glacier. The surface slope of the glacier before the cooling phase is expressed in terms of a dashed red line. **(b)** Model 2 showing the scenario which will happen during a warming phase. Note the increase in the surface slope  $\theta$  due to more ablation in the lower reaches as compared to that of the upper portions of a glacier. The surface slope of the glacier before the warming phase is expressed in terms of a dashed red line ..... 133

Fig. 9 **(a)** Relationship between the stress in kPa and ice thickness in m. **(b)** Relationship between the stress in kPa and bedrock slope in degree ( $^{\circ}$ ). **(c)** Relationship between the stress in kPa and surface slope in degree ( $^{\circ}$ )..... 135

**Glacier Response to Climate in Arctic and Himalaya During Last Seventeen Years: A Case Study of Svalbard, Arctic and Chandra Basin, Himalaya**

Fig. 1 Study area **(a)** Ny-Alesund, Svalbard archipelago **(b)** Chandra basin, Himalaya..... 142

Fig. 2 Annual net surface balance of glacier of Svalbard from 2000 to 2016 ..... 146

Fig. 3 Annual net surface balance of glacier of Svalbard from 1967 to 2016 ..... 146

Fig. 4 Mean annual net balance of six glaciers in Chandra basin by National Centre for Polar and Ocean Research (NCPOR) during 2013–2017..... 150

Fig. 5 A comparative study for annual mass balance of Chandra basin, Himalaya and Svalbard (Arctic) glaciers during 2002–2016 ..... 150

Fig. 6 Cumulative mass balance of Svalbard, Arctic and Chandra basin, Himalaya glaciers during 2002–2016..... 151

Fig. 7 Mean annual temperature and precipitation inf Chandra basin, Himalaya during 1900–2015 ..... 152

**Implications of Changing Climatic Pattern on the Geopolitical Situation of North Western Himalaya, India**

Fig. 1 Chain of events in cases of climate change in Himalaya..... 164

**Glacier Melt Water Characteristics of Hamtah Glacier, Lahaul and Spiti District, Himachal Pradesh, India**

Fig. 1 Hamtah glacier in Chandra basin, Lahaul & Spiti district, H.P..... 172

Fig. 2 Emergence of Hamtah glacier meltwater stream from the snout..... 173

Fig. 3 Discharge measurement in Hamtah glacier meltwater stream..... 174

Fig. 4 Hamtah glacier meltwater hydrograph showing discharge variation in total observation period ..... 175

Fig. 5 Average daily discharge of Hamtah glacier in total observation period..... 176

Fig. 6	Variation of Hamtah glacier melt stream discharge with temperature and precipitation in total observation period .....	176
Fig. 7	Scatter plots showing discharge vs temperature and precipitation in Hamtah meltwater .....	177
Fig. 8	Diurnal discharge variation in Hamtah meltwater .....	178
Fig. 9	Hourly discharge variation in first fortnight of July, August and September 2003 .....	179
Fig. 10	Day and night time discharge of Hamtah glacier .....	180
Fig. 11	Fortnightly average daily discharge variation of Hamtah glacier during COP .....	181
Fig. 12	Fortnightly average daily discharge variation of vis-à-vis temperature and precipitation on Hamtah glacier during COP .....	182
Fig. 13	Fortnightly average daily discharge variation of Hamtah glacier during COP .....	183
Fig. 14	Diurnal discharge variation of Hamtah glacier during COP .....	183
Fig. 15	Day and night time discharge of Hamtah glacier during COP .....	184

**Responses of Indian Summer Monsoon Dynamics and Late Quaternary Fluvial Development: Records from Yamuna River Valley, NW-Himalaya**

Fig. 1a	Geomorphological map of Yamuna Valley Sector-I; terraces and concomitant OSL sampling and section locations .....	189
Fig. 1b	Geomorphological map of Yamuna Valley Sector-II; terraces and concomitant OSL sampling and section locations .....	190
Fig. 1c	OSL signal data of sample LM-2 showing (i) Shine-down of natural OSL signal; (ii) Growth curve for single aliquot regeneration doses (SAR protocol); and (iii) Equivalent dose distribution. The data shows the well-bleached nature of quartz .....	193
Fig. 2	Geological map of Yamuna Valley (in Himalayan transect) showing study area sector-I & II .....	194
Fig. 3	(a) 'V' - shaped river valley and deep gorge (Sector-I; North of MCT) and (b) Prograded alluvial fan morphology and entrenched feeder channel .....	195
Fig. 4	Longitudinal profile of the Yamuna River, based on Survey of India toposheet at 20 m contour interval. (a) Profile from north of MCT to MBT showing terrace trends in Sector-I & II and OSL chronologies. (b) Longitudinal profile of the Yamuna River from MBT to HFT with palaeofloodplain trends and OSL dates (Vertical exaggeration is 4×) .....	196
Fig. 5	Well preserved T-4 terrace surface at Phoolchatti (right bank of Yamuna River). Note the sloping and flat surface indicating palaeo-gradient of Yamuna River .....	197

Fig. 6	Staircase of terrace surface in Chattanga-Barkot-Phaunti transect. Note the continuous terrace trends parallel to present day Yamuna River .....	197
Fig. 7	Terrace surfaces at Lakhamandal locality. Well preserved four levels of terraces with vertical cut sections .....	198
Fig. 8	(a) Terrace surface at Kharsali. (b & c) sedimentary facies (lithology and photo) and OSL sample location.....	200
Fig. 9	Sedimentary facies association of terrace deposit and OSL sample position at Phoolchatti area.....	201
Fig. 10	Valley morphology, disposition of terrace, litholog and Sedimentary facies of terrace deposit at Ozri village area.....	202
Fig. 11	Valley morphology, disposition of terraces, lithology and sedimentary facies of terrace deposits at Nanger village area. Note the exposed bedrock and overlying sedimentary deposit.....	203
Fig. 12	Valley morphology, disposition of terraces, lithologs of measured sections and sedimentary facies of terrace deposit at Chattanga village area. Multiple cut and fill terraces .....	205
Fig. 13	Valley morphology, disposition of terraces, lithologs of measured sections and sedimentary facies of terrace deposit at Chattanga village area.....	206
Fig. 14	(a) Valley morphology, disposition of terraces near Barkot area. (b) Sedimentary fill near Chattanga (right bank of Yamuna River) and (c, d, e) Sedimentary facies of terrace deposits at Barkot – Chattanga area .....	207
Fig. 15	Valley morphology, disposition of terraces, lithologs of measured sections and sedimentary facies of terrace deposit at Phauntipul (left bank section). (a) channel bar deposit in upper part of section. (b) sedimentary fill in the moddle part of deposit (c) sedimentary fill in lower part of the section. (d) sedimentary facies, chronology and cross section showing terrace morphology .....	209
Fig. 16	Valley morphology, disposition of terraces, lithologs of measured sections and sedimentary facies of terrace deposit at Purola road (right bank section) .....	210
Fig. 17	Valley morphology, disposition of terraces, lithologs of measured sections and sedimentary facies of terrace deposits at Lakhamandal.....	211
Fig. 18	Disposition of terraces at Lakhamandal, sedimentary facies and OSL ages.....	212
Fig. 19	Distribution of late Pleistocene-Holocene aggradation and incision phases in Yamuna valley between north of MCT to MBT (present study), MBT to HFT, Ganga plain and Dun (reference in figure) in relation to MIS stratigraphy after Lisiecki and Raymo (2005) .....	215

**An Appraisal of Spatio-Temporal Characteristics of Temperature and Precipitation Using Gridded Datasets over NW- Himalaya**

Fig. 1 Study area showing various zones of NWH along with locations of manual observatories (S1–S23) established by SASE. Observatories S1, S2, S5–S9 belong to LH, S3, S4 and S10 belong to GH and S11–S23 represent KH climatology..... 222

Fig. 2 Magnitude of wintertime mean temperature as observed and estimated at different climatic zones, i.e. (a) LH, (b) GH, (c) KH; Magnitude of (d) Bias (%), (e) Mean Absolute Error (MAE) and (f) Root Mean Squared Error (RMSE) at LH, GH and KH (Kanda et al. 2019) ..... 225

Fig. 3 Magnitude of wintertime precipitation (mm) as observed and estimated at different climatic zones,i.e. (a) LH, (b) GH, (c) KH; Magnitude of (d) Bias (%), (e) Mean Absolute Error (MAE) and (f) Root Mean squared Error (RMSE) at LH, GH and KH (Kanda et al. 2019) ..... 226

Fig. 4 Inter-annual variability of wintertime Mean temperature at different zones, (a) LH (b) GH and (c) KH. Black lines depict Observed data and red lines depict estimated values. The values of trend/slope (b; Units: °C/year) for observed and estimated values are also given in same color (Kanda et al. 2019) ..... 227

Fig. 5 Inter-annual variability of wintertime precipitation at different zones, (a) LH (b) GH and (c) KH. Black lines depict Observed data and red lines depict estimated values. The values of trend/slope (b; Units: mm/season) for observed and estimated values are also given in same color (Kanda et al. 2019) ..... 228

Fig. 6 Spatial variability in annual mean temperature (°C) over LH, GH and KH as depicted by (a) ERA-I and (b) CRU-TS ..... 230

Fig. 7 Spatial variability in annual precipitation (mm) over LH, GH and KH as depicted by (a) ERA-I and (b) CRU-TS ..... 231

Fig. 8 Temporal variability in annual temperature (°C) over LH, GH and KH as depicted by ERA-I (a–c) and CRU-TS (d-f). (a) and (d) depict long term (1985–2015) trends in annual temperature by ERA-I and CRU-TS respectively, (b) and (e) depict short term (1985–2000) trends in annual temperature by ERA-I and CRU-TS respectively, (c) and (f) depict short term (2001–2015) trends in annual temperature by ERA-I and CRU-TS respectively. Here solid circles (●) depict statistical significance at  $\alpha = 0.05$  ..... 232



Fig. 9 Temporal variability in annual precipitation (mm) over LH, GH and KH as depicted by ERA-I (**a–c**) and CRU-TS (**d–f**). (**a**) and (**d**) depict long term (1985–2015) trends in annual precipitation by ERA-I and CRU-TS respectively, (**b**) and (**e**) depict short term (1985–2000) trends in annual precipitation by ERA-I and CRU-TS respectively, (**c**) and (**f**) depict short term (2001–2015) trends in annual precipitation by ERA-I and CRU-TS respectively. Here solid circles (●) depict statistical significance at  $\alpha = 0.05$  ..... 233

# List of Tables

## **Indian Arctic Multisensory Moored Underwater Observatory**

Table 1	Operational details of the IndARC moorings .....	13
Table 2	The System Configurations of Different moorings .....	15

## **Glacial Sediments of Schirmacher Oasis, East Antarctica and their Characteristics**

Table 1	Sample locations and their data of different analysed parameters such as sand, silt, clay, organic carbon and carbonate percentage .....	37
Table 2	Vertical sections of sediments from shallow pits (in cm).....	39
Table 3	AMC <sup>14</sup> C dates of the sediments from glacial deposits.....	40
Table 4	Trace Metal concentration in sediment samples from Schirmacher .....	41
Table 5	AMS dates of Lake Core sediments .....	54

## **Potential Technologies for Climate Resilient Agriculture in the Indian Himalayan Region**

Table 1	Potential technologies/intervention for climate resilient hill agriculture.....	80
---------	---	----

## **Need for Reorienting Climate Change Research in the Himalaya: Balancing the Approach**

Table 1	General information about Hindu Kush Himalaya.....	89
---------	--	----

## **Glacier Response to Climate in Arctic and Himalaya During Last Seventeen Years: A Case Study of Svalbard, Arctic and Chandra Basin, Himalaya**

Table 1	Mean annual net balance of studied glacier in Svalbard before 2000.....	145
Table 2	Mean annual net balance of studied glaciers of Svalbard from 2000 onward .....	146