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Guest Editorial

Recent Antarctic Research in India: The National Committee Report to SCAR (2017)

Antarctica, the remote continent, having spectacular landscapes, has been playing major role in modulating global climate. During each winter, Antarctica grows nearly double to its size of summer, owing to an increase in seasonal sea ice extent. It has been recognized that the recent accelerated loss of ice over Antarctica can affect sea level as well as atmospheric and ocean circulations. India has been very active in Antarctica research since 1983, however it got a major boost during the last decade. During this period, the successful launch of the first expedition to the South Pole, setting up of the third station, 'Bharati' along with ground station for receiving satellite data at the Larsmann Hills on the East Antarctica coast, intensifying research in the Southern Ocean, and setting up advanced laboratories in the Antarctica and at ESSO-NCAOR, have resulted in improved understanding of Antarctica. Hence, this special issue was planned to look at the achievements, to identify gap areas and information needs. As the science agenda depend on information needs and thus this issue can help, both policy makers and researchers.

Considering the importance of the Antarctica, the Scientific Committee on the Antarctica Research (SCAR) had organized the 1st SCAR Antarctic and Southern Ocean Horizon Scan Retreat in 2014 to identify science questions to address the information and knowledge needs (Antarctic Science, 2014, 1-16, DOI:10.1017/S0954102014000674; Nature, 512:23-25). India had participated very actively and contributed significantly to develop the scientific questions, some of them are directly relevant to India.

The infrastructure available at 'Maitri' and 'Bharati' has enabled Indian researchers to contribute to many global research experiments planned under SCAR. The Indian Antarctic program is an example of long-term research efforts in a collaborative and coordinated manner. The major areas comprise, geoscience including paleoclimate, biology, oceanography, cryosphere studies, atmospheric and environmental sciences.

Antarctica was keystone of Gondwana and older super continents. Decoding history of the geological terrains hidden below ice is essential to understand how the super continent assembled and broke up in the past. The accurate topographical and geological mapping is the critical element for the advancement of many aspects of geo-science including this fragmentation process. High-resolution topographical and geological maps have been published for the Central Dronning Maud Land and Larsmann Hills. Geological studies conducted by India have helped to decipher the extension of the East African Orogeny in the Schrimacher Oasis and Humboldt Mountains based on the geochronology of granulated-facies rocks from the Schirmacher Oasis. Based on the GPS data collected from the Maitri (1997 onwards) and other sites on the Antarctica showed northward velocity of about 8 mm per year. At other places, the velocity varies between 4-20 mm per year and rotational movement has been estimated.

The study of proximal marine sediments revealed the geology of provenance, sedimentary processes on the continental rise and fluctuations of the East Antarctic Ice Sheet (EAIS) during Pliocene and late Miocene. The overall characteristics and composition of sediments in epi-shelf lakes of the Schhirmacher Oasis provided information on source rock composition, sediment transportation, depositional processes and weathering.

A focused Antarctica ice-core program was initiated since 2006 leading to recovery and study of several ice cores (up to 100 m) from coastal Antarctica. Ice-core proxy records provide information about climate variability at decadal,

**Author for Correspondence: E-mail: shailesh@moes.gov.in*

centennial and millennial scales. This study revealed a substantial warming of 0.6 to 1 degree C per century. The intimate relations between the Southern Hemisphere climate variability and Antarctic climate reconstructed from ice records - Southern Annular Mode (SAM) and ENSO played a major role in past changes in temperature, wind strength and sea ice extent. Integrating the proxy temperature data, it was observed that an overall cooing trend during last two thousand years. Such information is useful in validating climate models as well.

Lake sediments from the Schirmacher Oasis and Larsmann Hills offered great potential to reconstruct the past climate and environmental conditions. The lake sediments of the Schirmacher Oasis, indicated that this region has been ice-free for last 50,000 years or so. Paleo-climatic reconstruction from the Larsmann Hills and the Vestfold Hills revealed paleo-productivity fluctuations during the Holocene.

The use of various proxies such as microfossils (diatom and foraminifera), magnetic susceptibility, marine sedimentary records, oxygen isotopes, etc. have been handy to reconstruct the past productivity and ice-sheet dynamics. Such information is very useful in understanding atmospheric carbon dioxide variations.

The areas under snow and ice are least studied component of the Earth system due to paucity of observations, remoteness, challenging field conditions and limited time-window. Increasing imbalance in the mass budget has been observed during the last two decades. Accurate measurement of ice sheet and glacier features and variability lead to improved predictive modelling of ice loss. The monitoring of the snout of the Dakshin Gangotri (DG) and polar ice sheet along the Schirmacher Oasis showed continued recession. Many other glaciers show horizontal velocities varying between 1.9 to 10.9 m per annum to the north-north-East based on GPS measurements. The annual mass balance of glaciers is negative indicating impact of warming.

Digital elevation models for the Larsmann Hills and Schrimacher Oasis have been prepared using interferometric and photogrammetric techniques for monitoring ice sheets having an accuracy of ~ 25 cm. The use of such models for monitoring changes in the ice sheets are very useful.

An integrated study involving glaciology, bio-geochemical processes and ice core records from all polar regions was initiated for reconstructing, monitoring and predicting the variability of the global cryosphere system. An image album of the showing various cryosphere features using CARTOSAT-2 images have been made and further improved using RISAT-1 data. Using high-resolution temporal data, areas of snowmelt and freeze have been identified and monitored. Such information is very valuable as a baseline data.

Sea ice plays key role in modulating energy balance and thus impact atmospheric and oceanic circulations. Sea ice trend analysis using scatterometer (QUICKSAT and OSCAT) data and modelling have provided insight into sea ice response and forcing. The Antarctica sea ice shows both positive and negative anomalies, unlike Arctic which shows continuous retreat. These studies also revealed global tele connections - most frequently showing influence on the Indian monsoon and Indian Ocean Dipole. Sea ice variability is influenced by SAM and ENSO. A climatic dataset of Climatic Sea Ice Probability (SIOP) and sea ice type data generated based on microwave radio meter and scatterometers are routinely used for safe navigation as well as to understand variability in sea ice extent and likely causes.

The changes in polar atmosphere can alter planetary energy budget, moderate temperature gradient between the Equator and poles, and regulate variability in atmospheric circulation and thus influence global weather and climate. Studies of the Antarctic atmosphere are essential for the forecasting weather conditions and to understand the chemical processes taking place high in the stratosphere above Antarctica that result in ozone hole. Long-term continuous meteorological, electrical and ozone measurements at Maitri has provided a database on the Antarctic climate variability. Surface temperature, pressure, winds and blizzards show decreasing trend around the Maitri station.

Antarctica provide an excellent opportunity to study aerosols. Aerosol studies during last decade or so, revealed spatial heterogeneities associated with long-range transport and local influences. Energy balance studies at different snow/ice surfaces using

remote weather station and satellite remote sensing revealed temporal and spatial heterogeneity. High sublimation rate of ice sheet has been attributed to high katabatic winds (8 m per second) and warmer temperatures. Most of the such studies had been short-term campaigns. Questions related to patterns and trends, and physical and chemical processes involved in phenomena have not been addressed. It is necessary to augment systematic, continuous, automated and long-term observations, followed by modelling.

Antarctica is one of the best places to study 'geospace' the region where the Earth's atmosphere interacts with the solar wind, a supersonic stream of charged particles emitted from Sun's corona. The interaction of the solar wind with Earth's magnetic field creates the aurora australis as well as a wide range of other effects including geomagnetic storms, disruption in short-wave radio communications and power surges in long electricity transmission lines. Two decades of experimental Geomagnetism revealed that Maitri is ideally suited for now casting geospace weather, inter-planetary weather as well as core-mantle processes. Cosmic noise absorption (CNA) measured using imaging rio meter provide insight into D-region ionospheric conditions and dynamics.

Antarctic life was earlier considered as simple and with with low diversity. Though, Antarctica has very harsh climate, during last decade, highly diverse several taxa and ecosystem were recorded. The Antarctic region has record of more than 1500 species of invertebrates and 200 species of vertebrates. Indian scientists have reported 7 new species, first records of 5 families, 25 genera and 92 species of both invertebrate and vertebrate groups. The systematic studies of monitoring seabirds and marine mammals revealed 49 species of sea birds and their abundance increased along higher latitudes. Four species of seals and two penguins were also recoded. Many nesting sites were discovered on the Islands around the Larsemann Hills. Algae, fungal, lichen and mosses are major floristic elements on Antarctica. 69 species of lichens, 109 species of cyanobacteria belonging to 30 genera and 9 families were recorded in the Schirmarcher Oasis and 25 species of lichens in the Larsemann Hills were identified. The discovery of Holocene Moss species, *Pholianutans*, preserved in lake sediments, dates back to 10000 years B. P.

Antarctic bacterial diversity has been studied from diverse habitats including soil, cyanobacterial mats, water, sediments, ephemeral streams, ice core, geothermal vents, orinthogenic soil, etc. Several new genera and species have been discovered. Molecular studies identified genes, responsible for the survival of bacteria at low temperatures. Enzymes from these bacteria have found applications in food processing to bioremediation.

The Southern Ocean plays a key role in the global climate system, being a medium through which critical exchanges of heat, salt, carbon, oxygen and nutrients take place between Antarctica and the rest of the world. The Antarctic Circumpolar Current (ACC) is the key system in the Southern Ocean. The zone of sink and ventilation of CO_2 have been identified in the Indian Sector of the Southern Ocean. Mesoscale eddies have been one of the factors leading to freshening of the Antarctic Intermediate Water (AAIW) and influence plankton community structure. Fast degree of warming and freshening of the Antarctic Bottom water (AABW) - could be due to southward meandering of the Antarctic Circumpolar Current (ACC) as well as glacier melting. Phytoplankton blooms in the coastal and open ocean due to the influence of this melt water. Knowing how the Southern Ocean marine ecosystem evolved will help us to understand evolutionary pathways including possible connection between the Antarctic deep sea benthos and benthic species in other deep oceans. The preliminary hydrographic measurements in coastal Antarctica identified upwelling zones, Circumpolar Deep Water (CDW) and cold fronts. Systematic, long term, multi-platform based observations on physical and biogeochemical processes are lacking and needs to be taken up with automated instruments.

India is a signatory and consultative party to the Antarctic Treaty, and has ratified the Protocol on Environmental Protection to Antarctica Treaty (Madrid Protocol) and carried out all research as per protocols of theTreaty. Maitri and Bharati stations are continuously monitored and many new treatment facilities have been created for maintaining the environmental health of the stations and proximities as per protocols. A study of carbon cycling in Antarctic snow and ice systems revealed that ice hosts significant and diverse type of carbon compounds attributed to microbial action and remote transport processes.

The interface between natural and social science is critical for the policy formulation as well as Antarctic governance. The issues related to the tourism, bioprospecting as well as impacts of climate are required to be addressed. The role of India in social science research needs to be enhanced.

It is important to understand how cryospheric processes contribute to the working of the Earth System and vice versa. The greater understanding of the pivotal role of the Polar regions in the Earth system and it's numerous connections with other physical and biological elements including space weather and Sun-Earth interactions has increased the importance of Polar research.

This is first such volume which provides a birds eye view of the Antarctic Research by India. We hope that these proceedings will help to identify future research areas to be undertaken on the pristine continent and surrounding waters.

Shailesh Nayak
Rahul Mohan
M Ravichandran
Naresh Pant
A Ganju
Satyakumar

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Shailesh Nayak
Chair, National SCAR Committee & Guest Editor