Climatically sensitive 'Arctic': Another scientific frontier for India

According to the recent Intergovernmental Panel on Climate Change report[1], climate change is set to impact every continent and threaten nearly a third of the world's species with extinction. Effects on the earth's weather systems from increasing greenhouse gases will change rainfall pattern, punch-up the power of storms and boost the risk of droughts, flooding and stress on water supplies.

Therefore, economic planners are in the quest of predictive models of such climatic change. It has now become a global responsibility to understand the climate change, on both short and long timescales as a global phenomenon, with different parts of the earth responding to the climatic change with a time lead–lag and by different orders of magnitude. Though the exact cause of climatic change on earth is still unknown, the time lead–lag in climatic change in different parts of the earth helps in understanding the role of various regions in triggering (?) or enhancing the climatic change. Deciphering and inter-comparing the climatic history of different geographic regions can help to better understand the possible role of different geographic regions in global climatic variations[2].

The Arctic region is critical for studying global change because it impacts the entire earth system through powerful feedback processes involving the atmosphere, cryosphere, land surface and ocean. The Arctic Ocean and the surrounding regions are one of the most important areas that not only govern the earth's present climate, but also serve as a repository of climate change. The stronger signals or clues that signify climate change in the Arctic than elsewhere on the planet, make this an ideal region to understand future changes. The thermohaline circulation that originates in the northern Atlantic and southern Arctic is the major force that drives not only the global oceanic circulation, but also regulates the global climate. Possible changes in this global circulation can pose a threat to the Arctic region and thereby the global climate. Any change in extreme northern hemisphere (Arctic region) can affect the global climate, sea level, biodiversity, etc.

The Arctic region will experience the effects of global warming first and will amplify its effects within the earth system. Rapid changes are being observed in the Arctic region, which may be considered as the barometer of global climatic change. The Arctic Ocean continental margins serve as the interactive transformation zone between the shelf and deep basin regions. These margins are the main avenues for boundary currents and the overall large-scale ocean circulation to transport heat, salt, freshwater, biogeochemical properties and sediments around the Arctic Ocean. Understanding the key processes regulating interactions across margins and gateways is vital for modelling the past, present and future of the Arctic ecosystem. The Arctic region and its ecosystem serve an area of active research, because it is particularly sensitive to climate change[3,4] and also because climatically induced environmental changes can induce further changes of global consequence. Palaeoenvironmental scientists working in the Arctic region have made major contributions to understanding its climate dynamics and environmental response that are crucial to understanding the climate system.

The Arctic system is not only an amplifier of variability in the global climate, but also of the effects of greenhouse forcings. It is one of the most sensitive regions to natural and human-induced environmental changes. The observational records of environmental changes in the Arctic region are short and geographically sparse.

Few climate stations that have records extending back beyond 50 years, indicate that the Arctic region warmed up by about 1–2°C between 1910 and 1945. A number of stations showed further warming over the past two decades[5]. This observed increase in the Arctic temperature is greater than that of the northern hemisphere as a whole and indicates an amplification of global climate change in the region. However, it remains open to debate whether the warming in recent decades is an enhanced greenhouse warming signal or natural decadal and multidecadal variability[6,7]. Existing instrumental and palaeoclimatic records also show that the Arctic region experienced significant environmental variations at different temporal and spatial scales[8]. Such variation, driven by natural and anthropogenic factors, is anticipated to also occur in the future.

To better understand futuristic climatic trends, we need to know the past climatic changes and their linkages with changes that occurred in other geographically distinct regions. Although the instrumental record provides evidence of significant temporal and spatial variability associated with recent Arctic environmental changes, the records are insufficient to identify the full potential range of variations that the Arctic region has experienced in the past or may experience in the future.

Palaeoclimatic records can be obtained by investigating Arctic lakes, wetlands, tree-ring sites, ice cores and marine sediment cores. These palaeoenvironmental records of past Arctic changes are the only means of extending the records back in time and increasing their spatial coverage in order to describe and understand the full range of temporal and spatial variability. These proxies demonstrate that both the magnitude and spatial extent of 20th century Arctic warming may be unprecedented over the past 400 years[9].

The region is also of special significance to the Indian subcontinent, as several studies have shown that there exists a tele-connection between the northern polar region and Indian monsoon intensity, which forms the backbone of the Indian economy. The exact mechanism by which this tele-connection exists is still open to debate and is a topic of ongoing research[10]. Though limited, a few studies have explored the possible influence of tropical Pacific Ocean on the climatic changes in the Indian Ocean region. Similar comparisons have also been made between the climatic changes in the Atlantic regions and the Arabian Sea. Recently, based on oxygen isotopic and elemental analysis of planktic foraminifera, similarities in equatorial Indian Ocean sea-water changes and Antarctic temperatures over the last ~140,000 years have been deciphered. Previously, signatures of major ice-rafting episodes called Heinrich events[11], first noticed in the northern Atlantic marine records, have also been recovered from the Arabian Sea[12]. The results of inter-comparison studies are in contrast with a few studies supporting the lead role of tropical oceans in global climatic changes, and others suggesting that polar regions trigger global climatic changes. A further debated topic is the timing of climatic changes in the northern and southern hemispheres, with increasing support for the see-saw pattern in climatic changes in the northern and southern polar regions.

A comprehensive study comprising detailed palaeoclimatic reconstruction from selected sites in both the northern and southern high latitudes and tropical Indian Ocean can help understand the possible role of northern and southern high latitudes in tropical Indian Ocean climatic changes. In view of the limited studies from the northern high latitudes, it is imperative to decipher climatic history of the northern high latitudes on different timescales. Till date no systematic study has been undertaken by the Indian scientific community in the Arctic region.

Additionally, attempts should be made to understand the causes of Arctic warming and its feedback to the global climate system as a whole. Accordingly, high-resolution (annual to decadal) Holocene palaeoevironmental records that span at least 2000 years and extend through the 20th century need to be generated. Such proxy records of climate may also decipher periodic changes (if any) in Arctic climate and address issues with regard to the causal linkages vis-à-vis their interrelation with the global climate system.

Research should be initiated to decipher the past climatic changes from the Arctic region on the following timescales.

1. Last two glacial–interglacial cycles (~150,000 yrs).
2. Last glacial–interglacial transition (~20,000 yrs).
3. Holocene (last 10,000 yrs).

A key challenge is to develop the observational basis and theory to understand the full range of modes of environmental variability in the Arctic region, their relation to climate states at lower latitudes, and the degree to which they are predictable. Climatic history over the last two glacial–interglacial transitions will help understand the occurrence and possible lead–lag relationship between major climatic changes in the Arctic region and the tropical Indian Ocean, especially the warmer stage 5e, as reported from the tropical Indian and polar ice-core records[13,14].

The last glacial–interglacial transition is one of the most widely reported events in all palaeoclimatic records. However, climatic shift, especially temperature change during this period is still being debated. Reconstructing the climatic history of the Arctic region during this time period will help in not only understanding better the temperature shift in the northern high latitudes over glacial–interglacial transitions, but also to infer the lead–lag relationship between northern high-latitude climatic changes and those in the tropical Indian Ocean region.

High-resolution climatic history of the selected northern high-latitude sites for the Holocene period will help resolve the possible anthropogenic influence on the global climatic changes, and the timing and amplitude of short-term climatic changes (e.g. medieval warming, little ice-age, etc.) in the northern high latitudes and tropical Indian Ocean. Climatic history of northern high latitudes on the above-mentioned timescales will further help to compare the timing and amplitude of climatic changes in the southern and northern polar regions. Longer records spanning the entire Holocene (last 10,000 yrs) at centennial resolution also need to be investigated to assess whether the millennial-scale variability identified elsewhere in the Arctic region is a widespread feature of Holocene climate.

The use of satellites for remote sensing of ice coverage and thickness, ocean colour, and tracking marine mammals and seabirds should be attempted to provide enhanced coverage of the Arctic region, coupled with validation of measurements during the field programme. Considering the apparent thinning of the Arctic sea ice in recent decades and melting in Greenland, there is an urgent need to understand the Arctic warming and its global impact.

Studies should also be focused on the coupled ocean–ice–atmosphere system and its importance for the global climate by conducting field measurements and numerical simulations related to oceanic circulation, transport of substances and energy in polar seas and the polar atmosphere, as well as to the influence of these processes on the global climate system. While oceanographic studies should concentrate on modification of water masses in the polar seas and on the spreading of deep and bottom waters into the world ocean, atmospheric studies need to be undertaken to understand climate-relevant processes on different scales in space and time. Variations in the concentration of climate-forcing trace gases and aerosols and their impact on the earth's radiation balance related to tropical regions could be another area of interest for Indian scientists.

We must describe and understand the range of natural environmental variability in the Arctic region at temporal and spatial scales relevant for anticipating future changes and determine the sensitivity of the region to altered forcing, both natural and anthropogenic. Similarly, history and controlling mechanisms of biogeochemical cycling of nutrients and environmentally sensitive species should be established.

In order to determine the causes and consequences of the past warm episodes on the Arctic climate, acquisition and analysis of high-temporal-resolution palaeoclimatic records for the natural modes of climate variability that have impacted the Arctic region over the past 2000 years and beyond should be attempted coupled with climate models by studying marine, terrestrial and biological systems of the Arctic region on well-known periods of warmer-than-present conditions.

To begin with, the following thrust areas should be addressed as far as research in the Arctic region is concerned.

- Characterization of sea ice in the Arctic region using satellite data through active and passive microwave observations.
- Comprehensive glaciological studies of the Arctic region.
- Dynamics and mass budget of Arctic glaciers.
- Arctic biodiversity.
- Ice cores from the Arctic region for high-resolution records of past climatic changes.
- Isotopic, chemical and micropalaeontological studies on the sediments from the Arctic Ocean to decipher their response and feedback to past climate changes.
- Carbon cycling in the Arctic near-shore sediments.
- Tele-connections between the Arctic climate and Indian monsoon intensity.
- Arctic microbes and their bioprospecting.

Undoubtedly, we have established our capability to undertake Antarctic explorations at par with other global partners and contributed significantly during the last 25 years. The Indian Antarctic Programme has become a multi-institutional, multidisciplinary and internationally visible scientific programme. We have acquired expertise both in Antarctic science and logistics. Like many developed or developing countries, India is also an active partner in Antarctic explorations under the umbrella of various international governing bodies like ATCM, COMNAP, SCALOP, SCAR, etc. True to the spirit of the Antarctic Treaty System, the Indian Antarctic Programme is embarking upon mutually beneficial scientific collaborations with various Treaty nations.

Having gained sufficient expertise in organizing annual Antarctic expeditions for the last 25 years, it is most appropriate at this juncture to venture into the northern hemisphere, i.e. the Arctic region to undertake the aforesaid scientific studies. There is a pressing need for establishing bi-hemispheric approach in understanding the vital issues related to environment/climatic changes. The Svalbard Treaty may offer a unique opportunity to India to explore the possibilities of carrying out various scientific activities using the facilities at Svalbard Island as a research station. This correspondence does not necessarily speak on any policy with regard to the Arctic programme. It only points to the scientific wealth that the region can offer India.

1. The fourth Assessment Report (AR4), United Nations Intergovernmental Panel on Climate Change, 2007.
2. Rajan, S. and Khare, N., In Proceedings of the National Seminar on Four Decades of Marine Geosciences in India – A Retrospective, Geological Society of India, 2002, pp. 70–76.
3. MacDonald, G. M. *et al., Quat. Res.*, 2000, **53**, 302–311.
4. Overpeck, J. *et al., Science*, 1997, **278**, 1251–1256.
5. Manabe, S. and Stouffer, R. J., *Quat. Sci. Rev.*, 2000, **19**, 285–299.
6. Polyakov, I. V. and Johnson, M. A., *Geophys. Res. Lett.*, 2000, **27**, 4097–4100.
7. Polyakov, I. V., Johnson, M. A., Colony, R. L., Bhatt, U. and Alekseev, G. V., *Geophys. Res. Lett.*, 2002, **29**, 1878.
8. Stein, R. *et al., Quat. Sci. Rev.*, 2004, **23**, 1485–1511.
9. Outridge, P. M., Stern, G. A., Hamilton, P. B., Percival, J. B., McNeely, R. and Lockhart, W. L., *Geochim. Cosmochim. Acta*, 2005, **65**, 4881–4894.
10. Knutti, R., Meehl, G. S., Allen, M. R. and Stainforth, D. A., *J. Climate*, 2006, **19**, 4224–4233.
11. Cortijo, E., Duplessy, J.-C., Labeyrie, L., Duprat, J. and Paillard, D., *C. R. Geosci.*, 2005, **337**, 897–907.
12. Leuschner, D. C. and Sirocko, F., *Quat. Sci. Rev.*, 2000, **19**, 243–254.
13. McDowell, P. F. and Edwards, M. E., *Quat. Sci. Rev.*, 2001, **20**, 63–76.
14. Funder, S., Hjort, C. and Kelly, M., *Quat. Int.*, 1991, **10–12**, 107–122.

Received 16 April 2007; revised accepted 3 December 2007

N. KHARE

National Centre for Antarctic and Ocean Research,
Ministry of Earth Sciences,
Headland Sada,
Vasco-da-Gama,
Goa 403 804, India
e-mail: nkhare@ncaor.org

Isolating diesel-degrading bacteria from air

Air is rich in microorganisms, many of which are important to humans. In the present study, we have devised a method of isolating diesel-degrading bacteria from air, which is a simpler, faster and more efficient method of isolating these microorganisms compared to the conventional method of isolation from diesel contaminated soil[1] or water through enrichment culture techniques.

For isolation of diesel-degrading microorganisms from air, the experiment was set up in 250 ml flasks containing 100 ml Bushnell–Hass medium[2] ($MgSO_4$, 0.20 g/l, $CaCl_2$, 0.02 g/l; K_2HPO_4, 1 g/l; NH_4NO_3, 1 g/l; $FeCl_3$, 0.05 g/l; KH_2PO_4, 1 g/l; pH 7.0), supplemented with increasing concentrations of diesel (2–8%) and left open for isolating strains from air against a blank which was well covered. The flasks were left open for 10 days and manual shaking was done at regular intervals. These cultures were then plated on nutrient agar medium and incubated at 28°C overnight.

Flasks having 2 and 4% diesel concentration indicated observable growth after 4 days. After 6 days, other flasks containing higher percentage of diesel also showed growth and emulsification, which was lesser as compared to the ones with lower concentration (data not shown). The emulsification activity was determined using xylene emulsification method[3]. The temperature at which the experiment was carried out varied between 15°C and 33°C. Isolation from air at such variable temperatures indicated that our strain might have a wide range of thermal tolerance. Plating of the cultures from flasks having variable diesel concentrations on nutrient agar medium gave identical colonies, which indicated the presence of a single strain in all the flasks (Figure 1 *a*). The same isolate when plated on King's medium[4] (peptone, 20 g/l; glycerol, 10 g/l; K_2HPO_4, 1.5 g/l; $MgSO_4{\cdot}7H_2O$, 1.5 g/l; agar, 15 g/l; pH 7.2) showed fluorescence in the short-wavelength (254 nm) ultraviolet light (Figure 1 *b*). A common characteristic of the fluorescent pseudomonads is the production of pigments that fluoresce under short-wavelength ultraviolet light, particularly after growth under conditions of iron limitation.

The isolate was tentatively identified as *Pseudomonas* strain based on morphological and biochemical characteristics. In order to compare the bacterial characteristics of the air isolate with those isolated from diesel-contaminated soils, we selected 50-year-old diesel contaminated sites of the Himachal Pradesh Roadways Transport (HRTC), Shimla, Himachal Pradesh, India. Samples were collected using quadrant method in sterile containers and inoculated into enrichment cultures.

The isolate from air was compared with the 11 strains obtained from diesel-contaminated soil through morphological and biochemical studies. The air isolate along with other isolates obtained from the soil showed indications of belonging to the genus *Pseudomonas*. Further studies to identify these isolates are in progress.

The usefulness of the bacterial strain isolated from air for diesel spill site remediation was evaluated by studying its effect on mineralization of diesel in *in vitro* studies.