This study makes important contributions to the understanding of present-day seasonal and spatial variations in snow chemistry and stable isotope records in the East Antarctic snowpack as well as delineating the factors influencing these variations. Two sectors within the East Antarctic region – the central Dronning Maud Land (cDML) and the Princess Elizabeth Land (PEL) regions that are ~2000 km apart comprising entirely different geographical and meteorological scenarios were studied in detail. A coastal to inland transect of snow coring was carried out in each region. About 42 snow cores (~1 m long) were collected and sub-sampled, with total samples accounting to 750. Various glaciochemical ions and stable isotopes were measured and analysed to determine the major source regions, transport pathways and environmental conditions, besides providing an insight into the factors influencing their depositional processes and implications on the past environmental records on the Antarctic ice sheet. The major findings of the present investigation of snow samples are as follows:

- The chemistry of snow pack in coastal section of Antarctica are influenced primarily by sea-salt ions (Na⁺, Cl⁻, Mg²⁺ and K⁺) from sea spray during summer and sea-ice surface during winter.

- Snow in the coastal section was also influenced by the presence of non-sea-salt aerosols such as Ca²⁺, an indicator of crustal material derived from remote continents, as well as the ice-free coastal landmass of Larsemann Hills during summer in PEL and from the Schirmacher Oasis and nunataks throughout the year in cDML.
• The chemistry of snowpack in the mountainous section in cDML region was influ-
enced strongly by the ice-free mountain chains and nunataks. Snowpack chemistry in this region was dominated by the strong association of Ca$^{2+}$ and SO$_4^{2-}$. The pre-
ence of evaporite salt crusts of gypsum (CaSO$_4$ $\cdot$ 2 H$_2$O) and calcite (CaCO$_3$) in the nunataks apparently influence the snow chemistry in this section of the transect.

• The snowpack chemistry of inland region in cDML was predominantly influenced by aerosols in finer size ranges (<0.1 µm), such as MSA and nssSO$_4^{2-}$. These aerosols are known to have longer atmospheric residence times and as a result, travel further inland, constituting the major component of snowpack next to NO$_3^-$ in the interior region.

• Glaciochemistry of the snowpack in the interior section of PEL transect was mainly influenced by sea-salt aerosols unlike cDML region. This is attributed to the ab-

cence of physical barriers (such as nunataks and mountain chains along cDML tran-
sect and ice shelves) causing the sea-salt source region to being closer to the interior region. As a result of these regional differences in geographical set-up, the marine aerosol influence was obvious even in interior sites of the PEL transect.

• The steep escarpment in the coastal section of PEL showed a strong depletion of Cl$^-$ resulting in a very low Cl$^-$/Na$^+$ ratio when compared with the bulk sea-water ratio. Such Cl$^-$ depletion was observed throughout the year, indicating that it is a factor more likely to be a permanent feature in this region. Multiple regression model showed that the surface slope factor contributed significantly to the snow chemistry modification in the coastal section of PEL. The low values of Cl$^-$/Na$^+$ ratios are either due to possible excess accumulation of Na$^+$ as a result of wind redistribution at steep slopes, or due to the loss of Cl$^-$ or a combination of these factors.
• This study demonstrated for the first time that a major fraction of NO$_3^-$ in Antarctica could be attributed to the chemical interactions with dust particles transported from mid-latitudes. About 75% of such dust-bound NO$_3^-$ was observed in the coastal section of both cDML and PEL transects. In the interior region, about 15–50% of NO$_3^-$ was long-range transported nitrate, while the rest was in the form of HNO$_3$. Backward and forward trajectory model analyses supported the theory that majority of Ca$^{2+}$ rich dust was sourced from Southern South America. The Ca$^{2+}$ rich dust while carried by the Westerlies, react with atmospheric HNO$_3$ and deposit in Antarctica in the form of calcium nitrate, resulting in a strong association between nssCa$^{2+}$ and NO$_3^-$ in snow.

• Trace element distribution along the cDML and PEL transects showed signs of significant local contamination (with high input of Pb, Cu, Zn and Cr) at the coastal sections. This could be ascribed to the ever expanding footprints of human activities in these regions, where station-related activities are high throughout the year. Further, trace element distribution in the snowpack is significantly influenced by exposed nunataks in the mountain section of cDML.

• The spatial distribution of stable isotope records ($\delta^{18}O$ and $\delta D$) in both cDML and PEL transects decreased systematically from coastal to inland region displaying a classic Rayleigh-type fractionation. The seasonal variations were well marked and summer/ winter periods were determined based on $\delta^{18}O$ values throughout the transect. The deuterium excess values, derived from $\delta^{18}O$ and $\delta D$ values did not show any significant coast-to-inland variation, indicating the absence of moisture source variation, in addition to the absence of significant altitudinal effect. The back-trajectory analyses indicated that most of the airmass in the cDML and PEL
regions were derived from the mid latitudes with the Weddell Sea being the dominant source region.

• The snow accumulation rates in the study region varied significantly between both transects and were primarily influenced by topography of the sampling region. Accumulation was higher at coastal regions of PEL and cDML with comparatively higher moisture availability. Orography provided a physical barrier for precipitation clouds in the cDML region, resulting in higher accumulation rates along the northern section of nunataks. In PEL, the steepest escarpment section near the coast had the largest accumulation, most likely due to the wind redistribution of snow aided by the katabatic winds.

Future Perspectives

Ice cores have become the cornerstone of palaeoclimatic and palaeoenvironmental studies. In order to interpret this information precisely, it is important to understand contemporary variations in the snowpack. The present study aims to provide a better understanding of possible sources, transport pathways and air–snow interactions in the depositional environments of the present-day Antarctic snowpack. For the first time, an additional source for NO$_3^-$ is reported – dust-bound NO$_3^-$ – present in the snowpack throughout the coastal Antarctic region. Significant input of trace metal contamination was also found in the relatively interior sections of the continent, with ever increasing research and tourism related activities that are being archived in the modern-day snowpack.

While this study has made a significant step forward in interpreting snow–air interaction and glaciochemical processes in the present-day snowpack, more work is needed to be undertaken in other parts of Antarctica by integrating the present observations and verifying with ice core data. A deeper firn core that includes the years represented by the snow cores from the present study may be used to delineate variations that occur during
firnification. For instance, the ice core data is primarily used to understand the decadal to millennial scale changes in marine productivity (using MSA\textsuperscript{−} as proxy), change of patterns in atmospheric circulation (using dust as proxy), sea-ice extent (using MSA\textsuperscript{−} and sea-salt ions as proxies), atmospheric temperature (using water isotope proxies) and other proxy parameters. However, the present study shows the complex snow–air processes involved in the response of proxy parameters to environmental conditions. Besides, other studies have also indicated that snowpack undergoes changes from the time of deposition, and some of the species can undergo depositional and post-depositional changes, thereby resulting in a complex scenario for interpreting the ice cores precisely. The next step forward in order to comprehend such complications is to study present-day depositional processes and compare the snowpack chemistry and stable isotope ratio changes of these regions. Such a study would be very important since the snowpack is present with the same environmental conditions and also undergoing firnification several meters below the ground. As a result, it is possible to understand the post-depositional changes, if there are any.

As a result of complexity in the fractionation of stable water isotopes, snowpack records of water isotopes vary spatially and temporally leading to uncertainties while reconstructing the past temperature and moisture conditions. Temperature is the most important factor controlling the spatial variation of stable isotopes ($\delta^{18}O$ and $\delta D$) in the Antarctic ice sheet. In order to understand other factors such as moisture-source changes, physical processes, transport processes, effect of clear sky and cyclonic precipitation on the records and post-depositional processes, an integrated aerosol–snow and ice study is required which could be further verified with a new firn/ice core for evaluating the $\delta$–T relationship. Real-time measurements of air-temperature from nearby research stations could also be compared along with satellite measurements of temperature in moisture-source regions in order to understand the dynamics of stable isotopic fractionation processes. Further, measurements of both stable isotopes in atmospheric vapour in the bound-
ary layer along with measurements from surface snow are important to understand processes involved in precipitation, evaporation/sublimation, moisture transport and post-depositional changes on stable isotope records.

Another important development in the isotope finger-printing is the use of $\Delta^{17}O$ and $^{17}O$-excess records, which provide valuable additional insights on isotopic process during convective events. Since $^{17}O$-excess is sensitive to kinetic fractionation and insensitive to changes in temperature, it can be effectively used as a tracer of relative humidity in regions of evaporation. Such analyses could be extended to vapour, snow, firn and ice to better reconstruct the palaeoclimatic data from Antarctic ice cores.