

Air-snow interaction of nitrogen species in the polar regions

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The previous studies in the polar regions have frequently compared ion concentration of nitrogen species in snow and aerosol, neglecting to discuss the fact that snow could also scavenge chemical compounds in the gas phase. Further, Peroxyacetyl nitrate ($\text{PAN}_{(g)}$) which is a reactive nitrogen oxide and constitutes $\sim 90\%$ of the total NO_y in the higher altitudes has very scarce measurements in Antarctica and higher altitude areas. The present study reports the interaction of gaseous $\text{PAN}_{(g)}$ and $\text{HNO}_{3(g)}$ species with NO_3^- in aerosols and surface snow, in different meteorological conditions at both Antarctic and Arctic regions. Trace gases were sampled through the denuder tubes followed by a Teflon filter to collect the aerosol species and analyzed through the Ion Chromatography technique. Simultaneous snow measurements were also carried out near the air sampling site, close to the Polar Indian research stations. Samples were collected over a period of 15 days in January-February, 2014 in Larsemann Hills, East Antarctica, and 9 days during April, 2012 in Ny-Ålesund, Arctic.

Observations suggest that during high temperature, high radiation and high humidity conditions $\text{HNO}_{3(g)}$ concentration decrease with a simultaneous increase in aerosol NO_3^- [NO_3^- (A)] in both the regions. It implies that $\text{HNO}_{3(g)}$ converts to NO_3^- (A) probably through the reaction with sea-salt aerosols leading to the formation NO_3^- in aerosols. Further, the NO_3^- aerosol-snow interaction is also strong in these conditions. Such associations suggested that, dry deposition of nitrate aerosol could be a source of snow nitrate [NO_3^- (S)]. Further, a decrease of $\text{PAN}_{(g)}$ concentration with a simultaneous increase in NO_3^- (A) suggested that $\text{PAN}_{(g)}$ undergoes photolytic conversion to form $\text{NO}_{2(g)}$ and $\text{HNO}_{3(g)}$, which may further hydrolyze to form NO_3^- (A) due to high humidity conditions. However, this mechanism was not dominant during low temperature and low radiation conditions in both the regions, rather a direct gaseous exchange was found to influence the NO_3^- (S) concentration. Since, $\text{HNO}_{3(g)}$ is a highly water soluble and strong acid with a strong affinity to ice, the increasing humidity facilitates the adsorption of $\text{HNO}_{3(g)}$ on the snow surface, thereby, increasing the NO_3^- (S). In such conditions, $\text{PAN}_{(g)}$ concentration also decreased with a simultaneous increase in NO_3^- (S) indicating that direct $\text{PAN}_{(g)}$ adsorption on surface snow could be an additional source of NO_3^- (S). $\text{HNO}_{3(g)}$ being a more sticky gas than any other gaseous nitrogen species was scavenged more than $\text{PAN}_{(g)}$ on the snow surface. The precipitation events in the Antarctic and Arctic regions increases the concentration of NO_3^- (S) nearly 2-10 fold, with a simultaneous decrease of NO_3^- (A) and gaseous $\text{HNO}_{3(g)}$ and $\text{PAN}_{(g)}$ concentration. This strongly suggests that during precipitation events gaseous as well as particulate scavenging of nitrogen species could be significant. This study suggests that apart from the dry deposition of aerosol species on the snow surface and the outward fluxes of gaseous species from the snow surface, the direct gaseous adsorption of trace gases on the snow surface also needs to be critically evaluated, before computing the nitrogen budget in the polar regions.