

Table S1 Classification criteria of sampled particle types, mixing states and their possible sources in the snow/atmosphere samples

Particle types	Featured composition	element	Mixing properties	Sources	References
Mineral dust	Si, Al, Fe, Ca, Mg-rich, such as clay, quartz, feldspar, albite, with minor calcite, and other oxides.		Reacted minerals aggregated with soot and salt (MCS, nitrite, etc.).	Desert sand and crustal surface soil.	Shao et al., 2007 Laskin et al., 2005 Dong et al., 2017;
Soot (BC)	C (dominant) and O-rich.		C-rich materials mixed with organic, S, and K-rich particles.	Fossil fuels and biomass burning.	Li et al., 2014
Fly ash	Si, Al, Fe, S, and Ti-rich.		Fly ash mixed with salt (NaCl, sulfate), metals (Fe ₂ O ₃ , MnO ₂), silicate containing minor Fe, Mn, Ti and other metals.	Coal-fired power plants, heavy industries, and oil refinery.	Shi et al., 2003 Li et al., 2014
Organic matter	C (dominant), O, Si-rich, and regular spherical organic particles.		Mixed with mineral, S-rich and K-rich pollutants particles.	Biological particle, fossil fuels and biomass burning.	Hand et al., 2005; Chakrabarty et al., 2006
Sulfate	S- (dominant) rich and mixing sulfate cation (K, Ca, Na, and Mg).		Mixed cation sulfate, (HN ₄) ₂ SO ₄ , and often coated with mineral, soot, and organic particles.	Fossil fuels emission and secondary particles formed by SO ₂ and NO _x .	Li et al., 2014 Li and Shao, 2009b Niemi et al., 2006;
Nitrite	N (dominant), O, K, and Na-rich.		Coated and mixed with other type particles (sulfate, mineral, soot, and organic).	Fossil fuels and secondary particles formed by NO _x .	Niemi et al., 2006 Adachi and Buseck, 2008
NaCl	NaCl rich salt.		Cubic NaCl particle, often coated by NaNO ₃ and Na ₂ SO ₄ .	Sea salt from the Indian Ocean and other seas, salt from arid dust regions.	Li et al., 2014 Vester et al., 2007
Ammonium	(HN ₄) ₂ SO ₄ and (HN ₄) ₂ NO ₃ .		Mixed with MCS, nitrite and minerals.	Fossil fuels and secondary particles formed NH ₃ .	Li et al., 2014