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Multi-instrumental characterization of atmospheric nanoparticles entrapped in ancient glacier ice

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Atmospheric mineral nanoparticles entrapped in ancient ice from remote areas are just starting to be explored as, until recently, the size of this class of particles was below the detection limit of the conventional techniques used for dust analysis. These particles, smaller than 200 nanometers, could influence the atmospheric radiative balance directly, by scattering and absorbing the solar radiation, and indirectly by acting as ice nucleating particles that in turn influence the planetary albedo. Recent technological and industrial development is introducing a large number of natural and engineered nanoparticles into Earth's atmosphere. These constitute a concern for human health, mainly due to their very high chemical reactivity. While many atmospheric nanoparticle studies have been performed in modern urban environments, there is essentially no information about their occurrence in a pristine atmosphere. This is critical, as it constitutes an important benchmark of comparison for the modern, anthropogenically affected atmosphere. We have identified and geochemically characterized atmospheric nanoparticles entrapped in several modern and prehistorical ice samples collected from high elevation in the European Alps (Mt. Ortles 3869 m) and in pre-industrial ice sections from the "horizontal ice core" from the remote Taylor Glacier (coastal East Antarctica). A unique set of techniques is employed including Transmission Electron Microscopy (TEM) with Energy Dispersive X-ray Spectroscopy (EDX), Single Particle Inductively Coupled Plasma Quadrupole Mass Spectrometry (spICP-QMS), and spICP-Time of Flight MS to determine nanoparticle sizes, particle number concentrations and chemical composition. We discuss the characterization of these atmospheric nanoparticles in ancient glacier ice as an advanced tool for source identification.