A rugged and field deployable multi-laser resonance Single Particle Mass Spectrometer: Ship-based detection of trace metal-containing aerosols in the atmosphere of the Indian Ocean

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Abstract

A newly developed aerosol Single-Particle Mass Spectrometer (SPMS) employs advanced resonant laser ionization processes, enabling highly sensitive detection of transition metals (Passig et al., 2020) and organic molecules, such as polycyclic aromatic hydrocarbons (Schade et al., 2019). The technology, however, uses three laser pulses for laser desorption (IR laser), Resonance-Enhanced Multi-Photon Ionization (REMPI) of organic molecules (UV laser) and Laser/Desorption Ionization (LDI) with focused UV-laser pulses (i.e., plasma ionization). By using a back-reflection and re-focusing concept both ionization processes (LDI and REMPI) could be performed by the same laser (Schade et al., 2019). This development paved the way to develop a compact and rugged SPMS system, which now can be deployed to remote areas (e.g., high-altitude mountain stations) or on long cruises aboard on research vessels. Here we present preliminary data from particle-resolved measurements during a ship cruise with research vessel RV SONNE across the Indian Ocean in late 2024 in the framework of the GEOTRACES project. Atmospheric aerosol deposition is an important source of iron and other essential micronutrients in open ocean regions where their scarcity limits primary production, influencing marine ecosystems and oceanic carbon sequestration (Mahowald et al., 2018). In general, desert dust is the dominant source of trace metals by mass, but their bioavailability in dust is very low. Anthropogenic sources release e.g., pyrogenic iron with higher bioavailability, and these emissions are believed to be an important source of aerosol micronutrients in many regions. Significant uncertainties arise due to the lack of methods for assessing metal solubility at low aerosol concentrations and the scarcity of field data. Throughout the cruise, the new SPMS unit analyzed hundreds of thousands of individual particles. While sea salt aerosol was the dominant particle class, thousands of Fe-containing particles from long-range transport were also detected. Among them were numerous transition-metal-rich particles from mining activities in Australia, observed in the open ocean several hundred kilometers off the coast (see Fig. 1). Most metal-containing particles showed a high variability in the composition of secondary particle components, indicating different sources, transport pathways and aging mechanisms. Since the

SPMS detects internal mixtures of trace metals with solubility-modulating components such as chlorine, sulfate, or dicarboxylic acids, it proves highly suitable for assessing particle sources and the bioavailability of contained metals. In general, the measurements in this sparsely investigated region showed a surprisingly high contribution of anthropogenic sources to iron-containing aerosol in relation to desert dust, highlighting a potentially underestimated pathway in biogeochemical cycles. Finally, we have demonstrated that the newly developed SPMS unit is ruggedized enough to be applicable for months-long ship-based measurement campaigns in rough seas.

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Biography - Aleksandrs Kalamasnikovs

I am a PhD student at the University of Rostock in Germany, working towards a degree in Natural Sciences. Prior to studying in Rostock, I graduated from Riga Technical University in Latvia with a Bachelor's and Master's degree in Environmental Science. My current research focuses on developing novel real-time techniques for the physical and chemical characterization of ambient aerosols. Day-to-day, I mostly work with Single Particle Mass Spectrometers in various configurations and environments, for the non-destructive laser desorption of molecules.

Keywords

Marine aerosols, Single particle mass spectrometry, Indian Ocean, Long-range transport, Ship-based