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Tracing the Evolution of Marine Aerosols: A Single-Particle Investigation across the South China Sea to the Eastern Indian Ocean

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Marine aerosols play a critical role in Earth's radiative forcing and cloud dynamics, yet their physicochemical properties vary significantly from remote ocean to coastal areas. This study investigated marine aerosol particles collected during a scientific cruise from the South China Sea to the eastern Indian Ocean, spanning diverse marine environments including remote Indian Ocean, the Malacca Strait, the South China Sea, and Sanya port. Combining advanced single-particle techniques including SEM-EDX, NanoSIMS, and Raman spectroscopy, we analyzed the morphology, chemical composition, and mixing states of marine aerosol particles across four size fractions (>2.5 μm, 1–2.5 μm, 0.5–1 μm, 0.25–0.5 μm), to explore the sources and evolution mechanisms of tropical marine aerosols.

Marine aerosols exhibited significant spatial variability, as revealed by SEM-EDX analysis. In the South China Sea region, the finest particles (0.25–0.5 μm) contained a high proportion of sea spray aerosol mixtures (36.4%) and sulfate particles (41.9%), indicating strong anthropogenic influence. In contrast, sulfate levels in the corresponding fraction from the remote Indian Ocean were much lower (12.7%). Additionally, the coarse fraction (>2.5 μm) at the Sanya port was dominated by biological particles (38.2%), reflecting substantial local biological activity.

SEM-EDX and Raman spectroscopy revealed that marine aerosols in coastal and strait regions likely underwent notable chemical transformations. The detection of sodium nitrate species clearly indicates that NO_x-driven reactions with sea-salt are primarily responsible for the observed increase in nitrogen content and the depletion of chloride. NanoSIMS measurements revealed significant variations in sulfur isotopes ($\delta^{34}S$) of individual particles, which suggest diverse sulfur sources and complex sulfur transformation pathways during aerosol aging.

These results offer insights into the chemical evolution of marine aerosols driven by environmental conditions and anthropogenic inputs. Future work will expand sampling and refine isotopic analyses to further elucidate aerosol transformation processes.