Morphology of Diesel Soot Residuals from Supercooled Water Droplets & Ice Crystals

Objective: Investigate changes in morphology of diesel soot particles that participated in cold cloud processes. Assess the effects of morphology on optical properties

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Summary of progress:

- Cold cloud processing of freshly formed diesel soot particles was simulated by allowing them to form supercooled water droplets at -20 ^{o}C and ice crystals at -40 ^{o}C.
- The supercooled droplets and ice crystals (> ~4 μm) were separated from interstitial particles using a pumped counterflow virtual impactor and passed through a diffusion dryer to collect dry residuals.
- Morphologies of nascent soot and soot residuals were characterized using electron microscopy.
- Optical properties of nascent soot and soot residuals were simulated using the discrete dipole approximation (DDA-DDSAT7.3) code.

Results

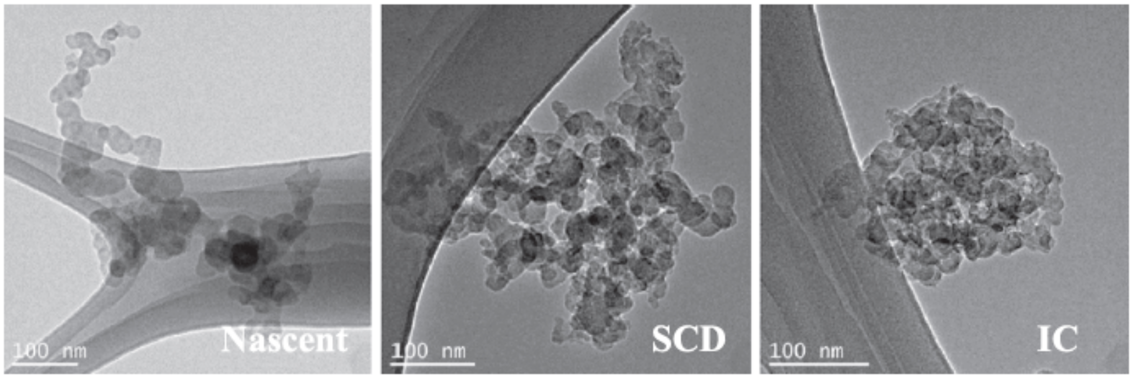

Figure 1. Examples of TEM images of nascent soot (left panel), supercooled droplet (SCD) residuals (middle panel) and ice crystal (IC) residuals (right panel).

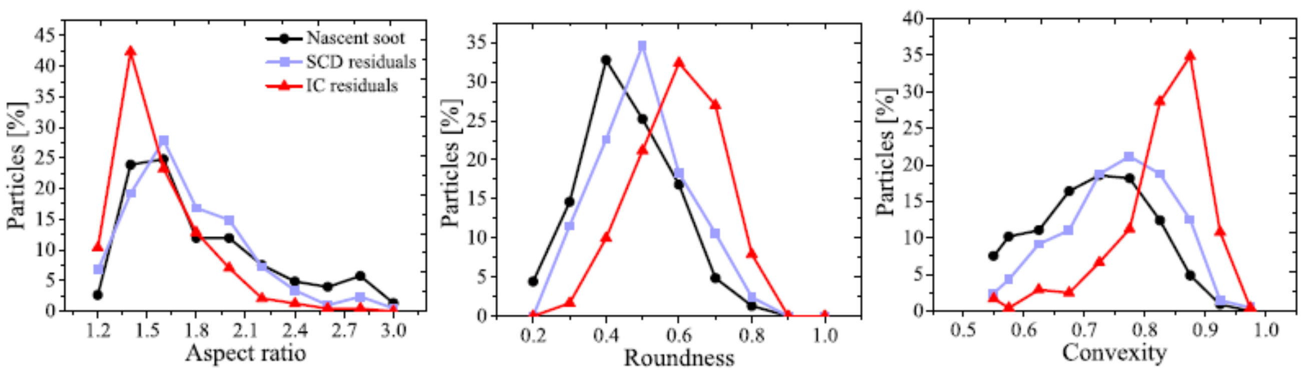

Figure 2. Distributions of aspect ratio (left panel), roundness (middle panel) and convexity (right panel) for nascent soot (black), soot from supercooled droplet (SCD) residuals (light blue) and ice crystal (IC) residuals (red). Number of particles analyzed for nascent soot, supercooled and ice crystal residuals were 226, 208 and 241, respectively.

Main Conclusions

a. Nascent soot particles were least compact (roundness ~0.41)

b. Soot residuals from ice crystals were more compact (roundness ~0.55) than those from supercooled droplets (roundness ~0.45).

c. These results suggest that the atmospheric freeze-drying process may play a role in restructuring of the soot particles.

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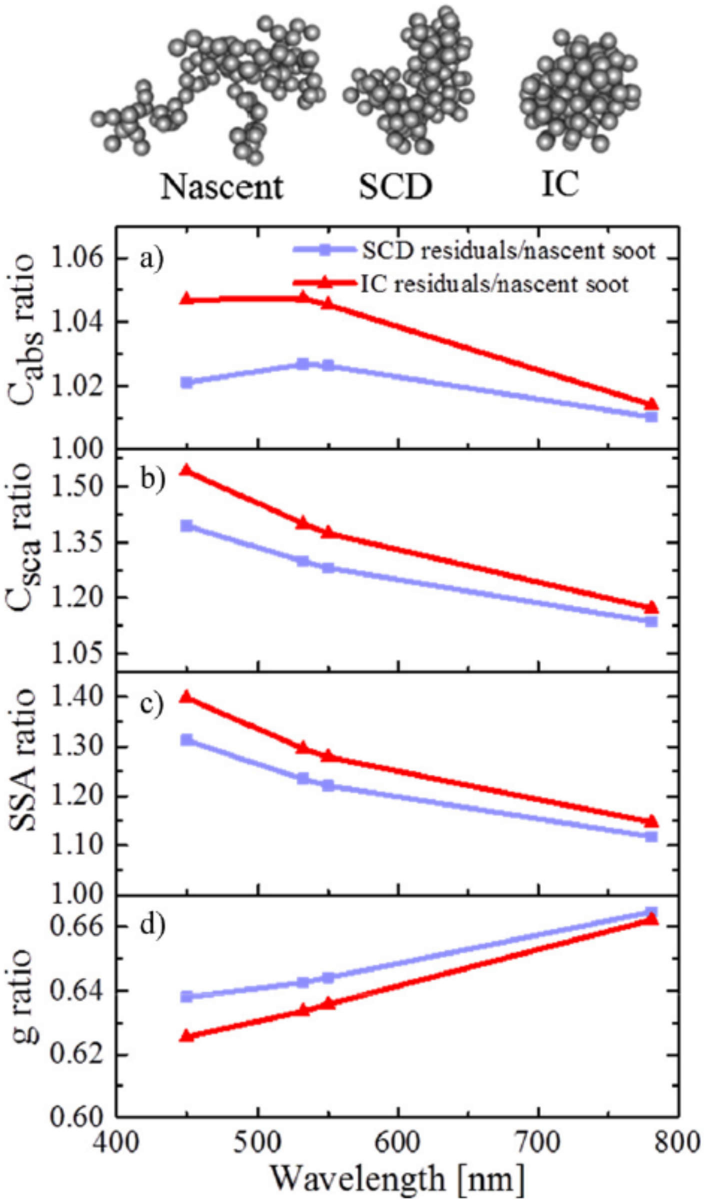
Optical Properties from DDA Simulations



Modeled soot particles were constructed by 100 monomers with 23 nm diameter each and different degrees of compaction to represent the measured morphological values.

Optical cross-sections, SSA and g for SCD and IC soot residuals were normalized by the values obtained for nascent soot.

Main Conclusions:

a) The more compact structure of IC residual enhances single scattering albedo by a factor up to 1.4, thereby reducing the top-of-the-atmosphere direct radiative forcing by ~63%.

b) Climate models should consider morphological evolution of soot due to cold cloud processing to improve the estimate of direct radiative forcing of soot.