

## Research Highlight

The mixing of the chemical constituents within individual atmospheric particles can influence the way they interact with water vapor and radiation. The term “mixing state” has long been used to describe how chemical species are distributed within individual particles. Until recently, particle mixing state was a purely qualitative term. Recent theoretical work has led to the implementation of entropy metrics to provide researchers with a simple parameter,  $\chi$  (chi), to define mixing state quantitatively. Under this parameterization, if all particles have identical compositions  $\chi = 100\%$  and if all particles consist of a single species,  $\chi = 0\%$ , such a metric can be applied to characterize and compare aerosol mixing state in different environments. The metric also may prove useful for developing parameterizations of aerosol mixing state for large scale climate models. A collaborative team led by researchers at the University of the Pacific has used the mixing state parameterization to characterize internal heterogeneity of atmospheric particles collected as part of the Carbonaceous Aerosols and Radiative Effects Study (CARES), sponsored by the U.S. Department of Energy’s Office of Biological and Environmental Research.

University of the Pacific scientists worked with others at national laboratories and universities to employ two different chemical imaging methods to provide a large experimental data set of particle mixing state during the CARES study. Results show that a very small fraction of particles have only one species per particle ( $\chi = 0\%$ ), and the overwhelming majority of the particles are mixed with other species with  $\chi$  between 40 and 90% for both techniques. The mixing state for the urban site located in the Sacramento metropolitan area was driven by the introduction of particles containing black carbon. Mixing of carbonaceous and non-carbonaceous inorganic species was characterized using scanning transmission X-Ray microscopy (STXM), which provides the spatial distribution of organic carbon, black carbon, and non-carbonaceous inorganic species within the particles. The mixing-state evolution in this analysis was driven by emissions of sea spray and sulfates from refineries in the San Francisco Bay Area. These measurements provide the first characterizations of mixing state under this framework and are useful for constraining atmospheric models.

Work related to this project is underway for samples collected for the GOAmazon campaign. Methods are being developed that will allow data from multiple imaging techniques to be combined into a unified data set. Furthermore, efforts to incorporate morphology and other physical properties into this parameterization are currently being considered. This will allow for a much more complete and comprehensive evaluation of the mixing state of particles sampled at multiple geographic locations.

## Reference(s)

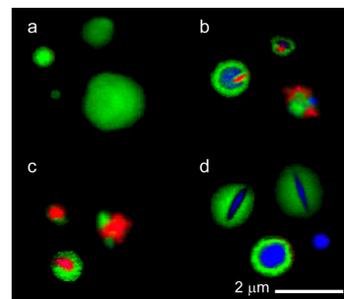
O'Brien RE, B Wang, A Laskin, N Riemer, M West, Q Zhang, Y Sun, X Yu, P Alpert, DA Knopf, MK Gilles, and RC Moffet. 2015. "Chemical imaging of ambient aerosol particles: Observational constraints on mixing state parameterization." *Journal of Geophysical Research – Atmospheres*, 120, JD023480, doi:10.1002/2015JD023480.

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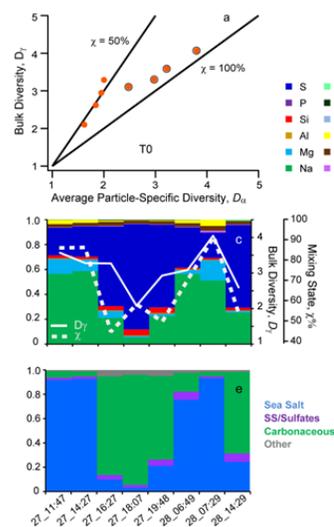
## Working Group(s)

Aerosol Life Cycle



Organic (OC)  
Inorganic (IN)  
Soot/Black Carbon (BC)

Soft X-ray microscopy images of different particle mixing states observed during CARES.



Variations in mixing state parameters (top), elemental mass fractions (middle), and particle types (bottom) during CARES.