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Effect of Cloud-Processing on Aerosol Radiative Properties: Comparison of Model Predictions with Measurements

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Long-term measurements of aerosol radiative properties at a wide range of locations reveal systematic dependencies on aerosol loadings. Aerosols in the cleanest air at any given location tend to be more highly absorbing and more effective at scattering radiation back to space, i.e., they have the lowest single-scattering albedos and the highest hemispheric backscattering fractions. One hypothesis for this behavior is that the cleanest air is a result of scavenging by clouds followed by removal by precipitation. Cloud scavenging is expected to remove particles larger than ca. 100 nm diameter more efficiently than smaller particles. The smaller, unscavenged particles have lower mass scattering efficiencies and higher backscattering fractions, which would lead to the observed behavior. In addition to the size-dependent effect, there is a composition dependent effect if the particles are externally mixed. Aerosol light absorption is dominated by elemental carbon, which tends to be hydrophobic when initially emitted and therefore less efficiently scavenged than hydrophilic, non-absorbing particles; consequently, the unscavenged particles are relatively enriched in elemental carbon and have a lower single-scattering albedo.

Field studies in a number of locations have shown that the unscavenged particles in clouds indeed have lower single-scattering albedos and higher backscattering fractions than the particles in adjacent, cloud-free air. As a further test of the hypothesis, the statistical behavior of aerosol radiative properties calculated with a global chemical transport model are compared with the long-term observations at sites representative of Arctic, rural continental, marine, and free tropospheric aerosols. The calculations use a version of the GFDL AM2 model, modified to include online aerosols and nudged with the NCEP re-analysis. The results of this measurement-model comparison will be discussed and examined for their implications that the observed systematic dependence of aerosol radiative properties on aerosol amount is caused by cloud scavenging and removal.