Effects of Cloud Scavenging on Aerosol Single-Scattering Albedo

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The magnitude, and even the sign, of the climate forcing by aerosol particles is strongly dependent upon the aerosol single-scattering albedo, which is the fraction of the aerosol light extinction that is due to scattering. Long-term monitoring at a variety of surface sites reveals a systematic decrease in aerosol single-scattering albedo as the aerosol loading decreases, i.e., aerosols are "blacker" in the cleanest air. One hypothesis for this behavior is that clouds preferentially scavenge scattering aerosols more effectively than absorbing aerosols, which is what would be expected if the absorbing component of the aerosol is dominated by hydrophobic black carbon and the scattering component is dominated by hygroscopic species like sulfates. As a test of this hypothesis, continuous measurements of aerosol light scattering and absorption were made during July 2003 at Mt. Åreskutan in central Sweden. Aerosol properties in clear air prior to and after cloud events were compared with the properties of the unscavenged (interstitial) particles when clouds were present. An integrating nephelometer and particle/soot absorption photometer (PSAP) were used to measure aerosol light scattering and absorption coefficients, respectively. Cloud extinction coefficient was estimated every minute using a digital camera ("cloudcam") that viewed a range of black and white targets. The cloudcam system was developed as a simple approach to monitoring the presence or absence of clouds when the site was unattended.

Aerosol concentrations dropped to near or below the detection limits of the nephelometer and PSAP when clouds were present, which indicates nearly complete scavenging of all optically important particles by the cloud droplets. For this analysis, the key question is whether the few remaining particles were relatively enriched in absorbing material. The figure shows the variation in aerosol single-scattering albedo, calculated as the aerosol light scattering coefficient divided by the sum of the scattering and absorption coefficients. Values of single-scattering albedo larger than unity are physically impossible and indicate the difficulty of measuring this quantity when the primary measurements are at or near their detection limits. Nevertheless, it is clear that the majority of in-cloud observations have single-scattering albedos that are substantially lower than the observations made in cloud-free air. This is particularly true for the observations on July 26 and 27, when the intersitial aerosol light scattering and absorption coefficients were slightly higher than during the cloudy periods at the beginning and end of the study.

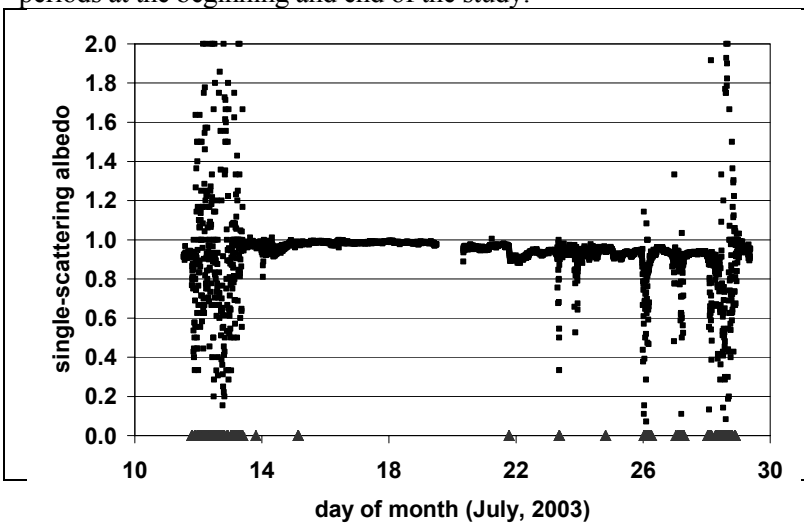

Figure 1. Variation of aerosol single-scattering albedo during July, 2003. Periods when clouds were detected by the cloudcam are indicated by the black triangles along the abscissa.