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Horizontal variability of aerosol optical properties observed during the ARCTAS airborne experiment

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The properties of tropospheric aerosol and gases vary within a satellite grid cell and between ground-based instruments. This hinders comparison between satellite and suborbital measurements of different spatial scales as well as their applications to climate and air quality studies. This paper quantifies the realistic range of the variability in aerosol optical depth (AOD), its Angstrom exponent, in-situ extinction coefficient and carbon monoxide mixing ratio over horizontal distances of 1-30 km, using measurements from the Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS) airborne experiment. The Canada phase in June and July 2008, in which smoke from local forest fires was sampled, likely represents the most heterogeneous of the ambient aerosol environments common over the globe. The relative standard deviation (stdrel) of AOD measured with the 14-channel Ames Airborne Tracking Sunphotometer (AATS-14) has median 19.4% (at 499 nm) among thousands of horizontal 20 km segments. For 6 km segments the analogous median is 9.1%. Another measure of horizontal variability, the autocorrelation (r) of AOD499 across 20 km and 6 km segments is 0.37 and 0.71, respectively. In contrast, the Alaska phase in April 2008, which sampled particles transported from Asia, is presumably among the most homogeneous environments. The median stdrel is 3.0% and r is 0.90, both over 30 km, only slightly different from those for 1 km (stdrel=0.4% and r=1.00). r in the Canada phase is $\sim$0.2 less for in situ extinction coefficient (from a nephelometer and a particle soot absorption photometer) than for the AOD. It is $\sim$0.1 less than for the carbon monoxide mixing ratio. The trends of horizontal variability with distance and aerosol environment are different for the wavelength dependence and the humidity response of light scattering. We discuss challenges in estimating aerosol optical properties, particle size and chemical composition from measurements at a distant location. The statistical parameters thus help interpret existing remote-sensing observations and design future ones.