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On the Variability of Giant Sea-Salt Size Distributions as Observed from Aircraft during the VOCALS Campaign: Relationship to Marine Stratocumulus, Cold Pools and Implications for Drizzle Formation

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This study presents a quantum leap in the observations of marine sea-salt size distributions. The observations are obtained with a new instrument, the Giant Nucleus Impactor (GNI), which consists of polycarbonate slides exposed in the free airstream outside an aircraft, followed by storage in desiccated test tubes. The slides are subsequently analyzed in the laboratory, using a humidified automatic optical digital microscope system. The instrument has been extensively characterized in terms of uncertainty.

450 slides, each with typical sample volumes of 300 liters and ~50,000 particles per slide, were exposed from the NSF/NCAR C-130 research aircraft during the 2008 VOCALS campaign over the Pacific Ocean off the coast of Chile. The observed particle size range is 0.7 μm – 12 μm dry radius range for relatively low wind speeds of 1-14 m/s in the marine boundary layer.

Figure 1 shows the aerosol mass loading as a function of wind speed for 286 slides that were exposed within a narrow altitude range 120 – 180 m above the sea surface. All slides obtained within a single flight are shown with the same symbol. The figure shows a general trend of higher mass loading with increasing wind speed, but at the same time a clustering of the measurements obtained within a given day. This suggest that wind speed is not the sole determinant of the giant sea salt mass loading, but the action of other factors, possibly cold pools or wave fields that are not in balance with the wind at the time of the slide exposures.

The implications for drizzle precipitation formation are considerable. The concentration of the largest of the giant sea-salt particles are related to the observations of drizzle drops in the VOCALS stratocumulus in the vicinity of the exposed slides. In-cloud observations of cloud droplet size spectra as well as drizzle drop spectra shows two important conclusions:

In lightly drizzling clouds (low drizzle drop concentrations of a few per litre), the drizzle drop concentrations can be explained if drizzle drops form on all particles larger than about 4 μm dry radius.

In more intense drizzling clouds (drizzle drop concentrations of about 100 per litre), almost all giant sea-salt particles with dry radius > 1 μm dry radius are needed to explain the observed drizzle drop concentrations. Even so, these intensely precipitating clouds are also characterized by large cloud droplets.

The implementation of giant sea-salt particles as nuclei for warm rain in large-scale models is implemented using a "toss-box" model, which includes both condensational and coalescence growth.