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CIRRUS MICROPHYSICS OBSERVATIONS MADE DURING FIRE II: SMALL PARTICLES, HIGH CONCENTRATIONS, AND PROBE COMPARISONS

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Abstract

Aircraft observations of cirrus cloud microphysics were made near Coffeyville, Kansas during November and December 1991. Cloud microphysics measurements were made using both a PMS 2DC probe and an ice particle replicator, both mounted on the UND Citation aircraft. Intercomparison is made of the size, area, and ice mass spectra determined from these probes. The PMS 2DC undercounts particles with D < 70 μm and the replicator oversizes particles with D > 150 μm, at least when column rosettes are encountered. High concentrations of particles with D < 50 μm are noted in selected portions of the 22Nov91 replicator data set. Relations between the maximum dimension of a crystal and its shadow area (known as area dimensional relationships) are computed from the PMS data. Area and mass dimensional relationships are used to give a simple analytical expression for computing the wavelength dependent absorption coefficient averaged over a size bin. Calculations based upon the replicator data show that crystals with D < 50 μm contribute significantly to the solar extinction and infrared absorption coefficients during some time intervals.

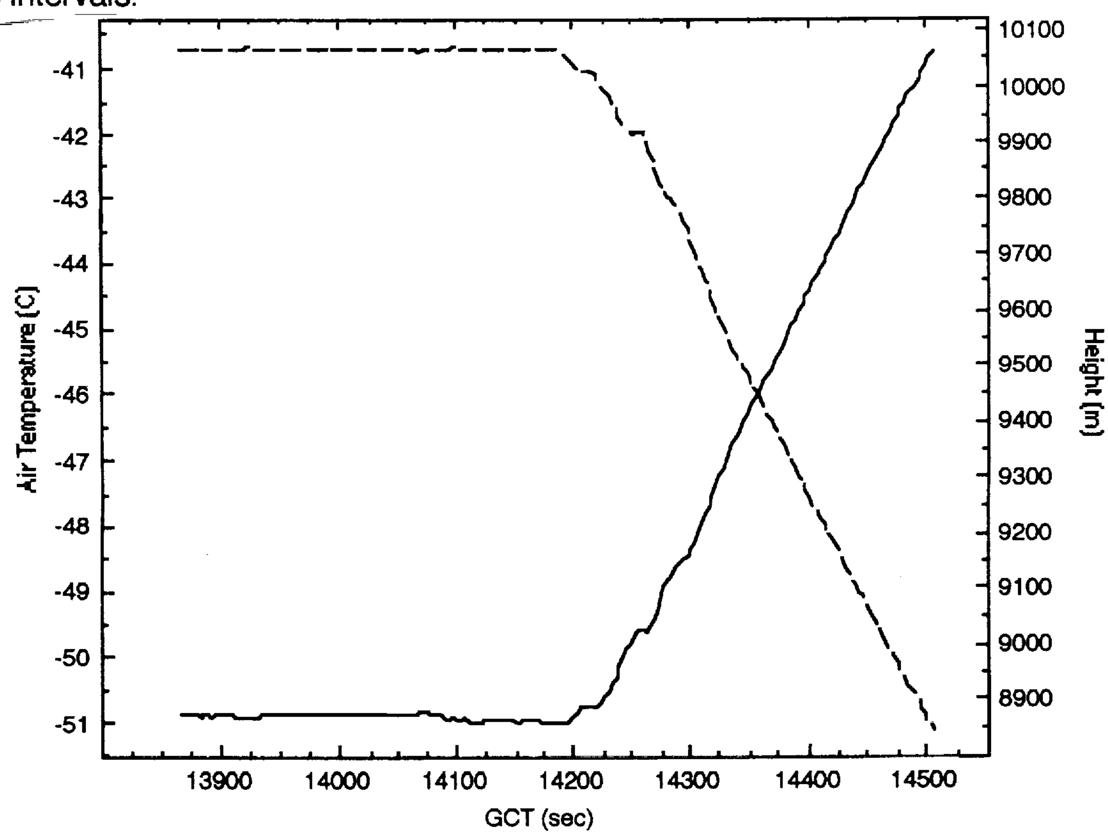

Figure. 1 Air temperature (solid) and aircraft height (broken).

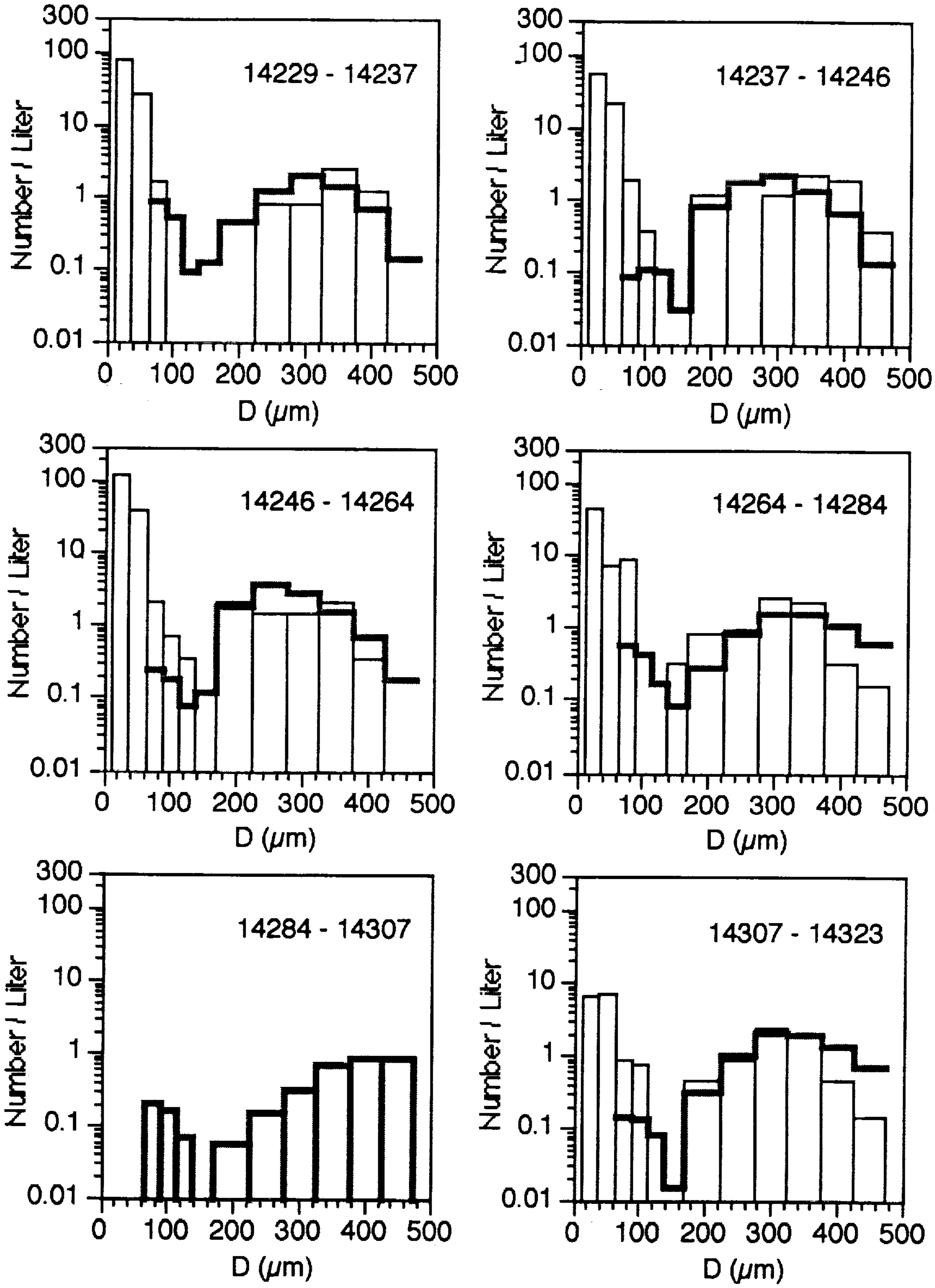

Figure 2. Representative ice crystal size distribution for the replicator (solid line) and PMS 2DC (shadowed line) as a function of time. The time interval in seconds is indicated in each graph.

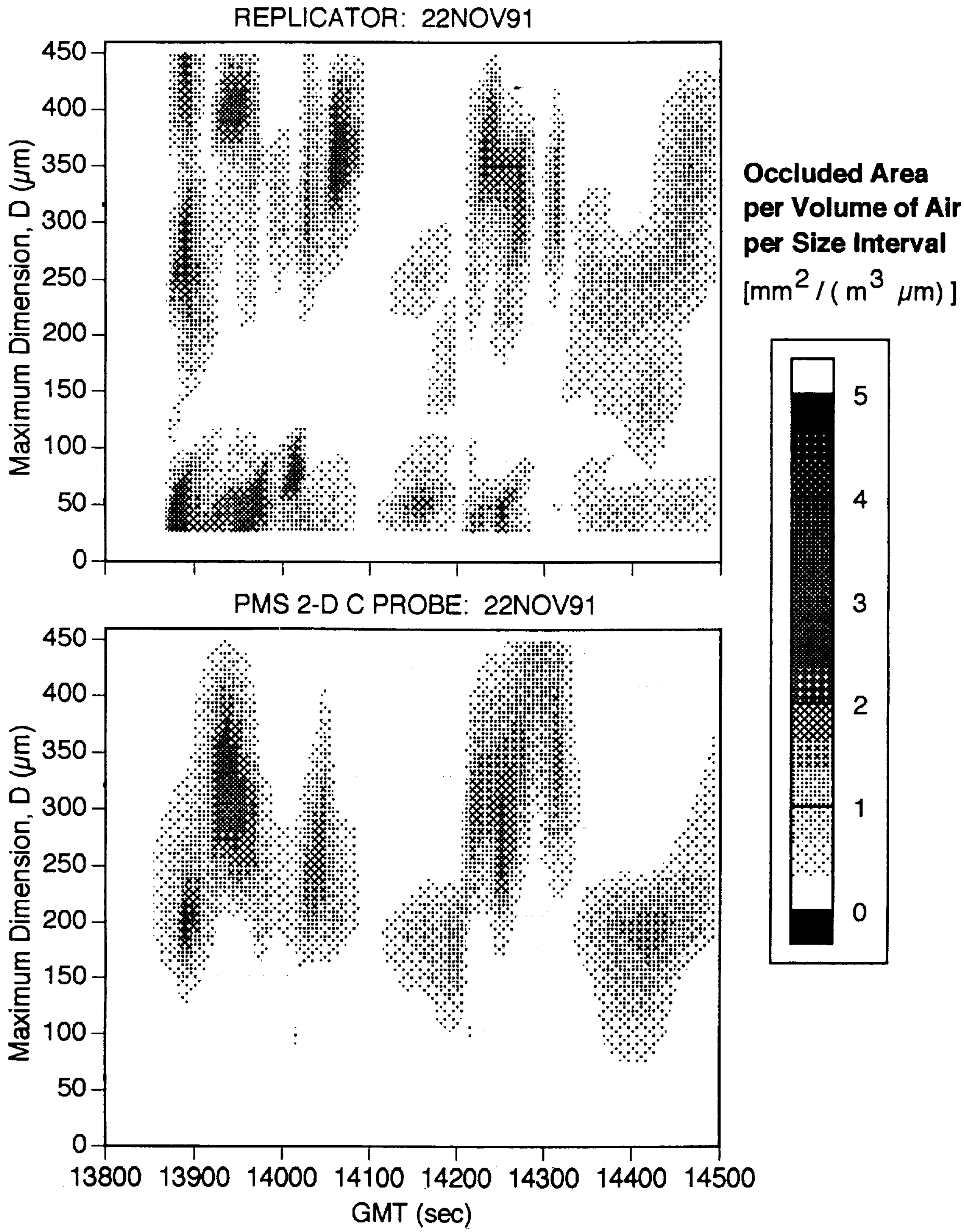

Figure 3. Area distribution of the cloud for replicator and PMS 2DC data. The replicator data shows the contribution of small ice crystals during some time intervals, especially before 13900 GMT.

Small ice crystals can influence the appearance of cirrus clouds from satellites and can be an important component of solar and IR radiative transfer. Small ice crystals have maximum dimensions less than about 60 μm and can affect cloud radiative properties if they occur in sufficient abundance compared with larger crystals. Our calculations for quantifying the radiative importance of small ice crystals used in situ aircraft microphysics data of a particular portion of a cirrus cloud obtained with a probe capable of recording the small particles (the ice crystal replicator). Calculations show that solar extinction and IR absorption coefficients can be predominately due to small ice crystals during some time intervals and in some portions of the cloud. The broader implications and generality of these results are not clear at present.

Cirrus observations were made using the University of North Dakota Citation research aircraft. Figure 1 shows the air temperature (-51 C to -40 C) and aircraft altitude (10100 m to 8850 m). Raman lidar indicated cirrus between 8 km and about 10 km. This portion of the flight occurred during the evening of 21 Nov 1991 from 21:51 to 22:02 local time, or 22 Nov 1991 3:51 to 4:02 Greenwich Mean Time (GMT). The horizontal position of the aircraft had a section of level flight followed by a spiral descent that following the prevailing wind (i.e. Lagrangian descent) to the base. The air speed of the aircraft was usually 120 m/s. The aircraft was equipped with an ice particle replicator manufactured at the DRI and a PMS 2DC optical probe for measuring cloud particle concentrations and sizes. The volume of air sampled per second by the replicator and PMS 2DC are nominally 2 liters per second and 7 liters per second, respectively, though exact numbers depend on the aircraft speed and particle size. The PMS 2DC probe was capable of sizing particles in the range of 66-1056 μm with a 33 μm resolution. Generally we find that the PMS 2DC does not record all of the small particles present. The replicator gives an over estimate by roughly 4/3 of the crystals maximum dimension due to flattening of the crystal on impact with the formvar coated film for crystals with $D > 100$ μm.

The extinction coefficient of the cloud for the solar wavelengths is essentially twice the geometric shadow of all crystals in a unit volume of air. Therefore a quick estimate of the relative importance of small ice crystals for the overall solar extinction can be made. The maximum area ratio of 25 μm and 250 μm is 1/100, so the number of 25 μm crystals must be on the order 100 times as great as the number of 250 μm crystals for the 25 μm crystals to contribute significantly to the overall solar extinction coefficient. The replicator data in Figure 2 shows definite time periods when the concentration of small crystals is sufficient that they contribute significantly to the solar extinction coefficient. Figure 3 shows the distribution of crystal area against time and maximum dimension of the crystal for the replicator and PMS data sets. The most important observation of the data set is that during the time interval (13885 - 14000), small ($<$ 75 μm) crystals contribute very significantly to the total area.

Selected time intervals exist where there can be significant numbers of small particles ($D < 60$ μm), and very few larger particles in cirrus. Most of the projected cloud area and IR absorption cross section per volume of cloud is due to the small particles during these intervals. Though small crystals can be expected at cloud margins where they might form from evaporation of larger crystals, or at cloud top, the totality of all possible regions and situations where one might expect large numbers of small crystals is not well investigated.

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