

Hydrated and Dried Aerosol-Size-Distribution Measurements from the Particle Measuring Systems FSSP-300 Probe and the Deiced PCASP-100X Probe

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ABSTRACT

Comparisons of particle-size distributions measured by Particle Measuring Systems FSSP-300 and PCASP-100X probes through a range of relative humidities reveal that the deiced PCASP-100X probe dries hydrated submicron aerosols before measurement. The FSSP-300 appears to measure the particles in their hydrated state and detects the expected growth in the particle spectrum with increasing relative humidity. Calibration changes for refractive-index changes with hydration are not applicable to the deiced PCASP-100X probe but are for the FSSP-300. The combined use of the two probes with their differing responses to hydrated aerosols may provide information related to the chemical composition of the aerosol.

1. Introduction

The measurement of atmospheric aerosol-size distributions has advanced significantly in the past decade with new technological advances in electronics and laser detection systems. A family of probes designed and manufactured by Particle Measuring Systems, Inc., (PMS) has been used extensively by the scientific community, particularly for airborne measurements. There have been a number of studies of the response of this family of instruments that have appeared in scientific literature. Most of these studies have focused on size calibration of the instruments, including the absolute accuracy and resolution limits, the effect of Mie resonances, and the response to differing refractive indexes and adsorbing particles (Pinnick and Auverman 1979; Garvey and Pinnick 1983; Soderholm and Salzman 1984; Yamada et al. 1986; Szymanski and Liu 1986; Knollenberg 1989; Pueschel et al. 1990). Liu et al. (1992) have recently reported on the effect of aerosol shape on the response of the airborne probes. Still, in spite of the increases in diameter due to deliquescent growth of atmospheric aerosols at typical relative humidities, which in many cases is a much larger effect than those noted in the above studies, there has been little discussion of the potential humidifying or dehumidifying of particles by the probes' sampling technique. Biswas et al. (1987) has discussed some consequences of condensation and evaporation from the particle surfaces during sampling by some optical par-

ticle counters. Kim and Boatman (1990) have assumed that the ASASP-100X (nondeiced version) measures the undisturbed aerosol-size distribution, and they suggest modifications to the size calibration for refractive indexes more representative of hydrated aerosols. Leitch and Isaac (1991) have reported on tropospheric aerosol-size distributions over eastern North America using a deiced ASASP-100X. Based on laboratory experiments and the observation that clear-air aerosol distributions show no variation attributable to relative humidity, they contend that the probe dries the aerosol before sampling. It is therefore imperative to determine the direct effect of the probes on the humidity of the sampled air before meaningful interpretation of their measurements of size distributions of hygroscopic atmospheric aerosol can be achieved. This article provides the first direct evidence of the effects noted by Leitch and Isaac by comparing size distributions determined by a deiced PMS PCASP-100X probe to those of a nonobtrusive PMS FSSP-300 probe.

During the period of 20 March–29 April 1990, the Atmospheric Environment Service organized and conducted the Canadian component of the Second Eulerian Model Evaluation Field Study (EMEFS II), designed to collect air and cloud chemistry data to support the evaluation of regional acid-deposition models. The Institute for Aerospace Research (IAR) Twin Otter research aircraft was instrumented for chemical and microphysical measurements, including a PCASP-100X and, on three occasions, a FSSP-300. These probes were mounted under the same wing of the aircraft, separated by about 2 m. During these occasions, the aircraft was flown from the bottom to the top of a well-mixed boundary layer through a range of relative humidities.

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One of these cases will be examined below in order to examine the response of the probes to hygroscopic growth of the aerosol and to help understand the effects of drying by the deiced PCASP-100X on sampled aerosols. Although data from only one profile is examined, a similar behavior was observed in all three of the flights on which these two probes were together.

2. Instrument description

The PMS ASASP-100X is an airborne version of the wide-angle open-cavity laser spectrometer, housed in an aerodynamic canister and normally mounted on the exterior of the aircraft. A new version of the probe, the passive cavity aerosol spectrometer probe (PCASP-100X), moved the sensing area external to the laser in order to improve stability and sensitivity. The ASASP-100X and PCASP-100X probes measure particle spectra in 15 channels in the nominal size ranges of 0.12–3.0 and 0.10–3.0 μm in diameter, respectively, although Liu et al. (1992) have found that the lower detection limits of the probes used here are closer to 0.18 and 0.12 μm , respectively. Of particular interest here are the identical sampling inlet systems. Air is forced through a nose cone by the forward motion of the aircraft and decelerated into a collection chamber. A constant volume pump then pulls nominally $1\text{ cm}^3\text{ s}^{-1}$ of air through a needle inlet 150 μm in diameter into the interior of the probe canister. Some probes are equipped with deicing heaters, which are intended to keep the sampling inlets ice free when supercooled cloud is encountered. The probe is normally operated with these heaters activated continuously during each flight, regardless of whether cloud is expected. There are several factors that may change the relative humidity of the sampled air in probes: the deceleration of the air before ingestion, the heated inlet needle and nose cone on the deiced probes, the heating of the interior of the canister by probe electronics, and the interaction with the dry focusing sheath flow. All of these factors could be active in drying or partially drying hydrated aerosol before sizing by the probe. The residence of a particle in the PCASP/ASASP is estimated at 0.1–0.3 s. Calculations of the evaporation of solution droplets using the model described in Leaitch et al. (1986), assuming the relative humidity inside the probe is less than 30%, indicate that 12- and 15- μm droplets will dry completely in 0.5 and 0.6 s, respectively. Thus, it is believed that the residence time in the PCASP/ASASP is sufficient to dry most droplets less than 10 μm but that larger droplets may only partially evaporate.

The PMS forward-scattering spectrometer probe (FSSP-300) was developed specifically to improve measurements of polar stratospheric cloud (PSC) particles (Dye et al. 1990). The probe is similar to the PMS FSSP-100, measuring individual particles by de-

tecting the light they scatter while passing through a focused laser beam. The probe is configured to measure from nominally 0.3–20 μm (for a refractive index of 1.585) in 31 size channels. Of particular importance here is the fact that the FSSP-300 measures aerosol in a size region overlapping the PCASP-100X but is much less obtrusive. Particles pass through the laser detection area by the forward motion of the aircraft and are subject to only minor flow perturbations by the probe geometry (Norment 1988).

3. Results and discussion

The data are from a flight on the afternoon of 24 April 1990 near North Bay, Ontario. Conditions were partly cloudy with small cumuli based at approximately 1800 m MSL. Figures 1a,b illustrate measurements during an ascent from near the surface at the Egbert monitoring station to the top of the boundary layer from 1852 to 1859 UTC. As the relative humidity increases from approximately 40% to near 100% near the top of the layer, the water vapor mixing ratio and the equivalent potential temperature remained nearly constant (Fig. 1a), indicative of a well-mixed surface layer. The corresponding vertical profiles of the FSSP-300 and PCASP-100X total number concentrations are shown in Fig. 1b. The FSSP-300 total number concentration increased with height (relative humidity), consistent with hygroscopic growth of small particles past the lower detection limit of the probe. In contrast, the PMS PCASP-100X total number concentration remains nearly constant, indicative of both a well-mixed layer and drying of the aerosol by the probe. The well-mixed nature of the boundary layer and the increase in relative humidity make this an excellent case to investigate the effects of relative humidity on aerosol measurements from these probes. Note that above the 810-mb level, the PCASP concentration drops sharply, while the FSSP-300 concentration increases to be much higher than that of the PCASP. The positive correlation of the FSSP-300 with the relative humidity suggests that this is consistent with hygroscopic growth of small particles. The results from this particular level are not treated in the following analysis because the uncertainty in the relative humidity is $\pm 5\%$ and, as discussed in the subsequent section, the growth factors for particles are very steep functions of the relative humidity above about 90%.

a. Aerosol composition and deliquescence properties

The concentrations of water-soluble ions in the boundary-layer aerosol, as measured on a triple-stage filter pack exposed for 90 min from 1730 to 1900 UTC at Egbert, Ontario, are summarized in Table 1. The well-mixed nature of the boundary layer indicates that similar concentrations should be expected throughout

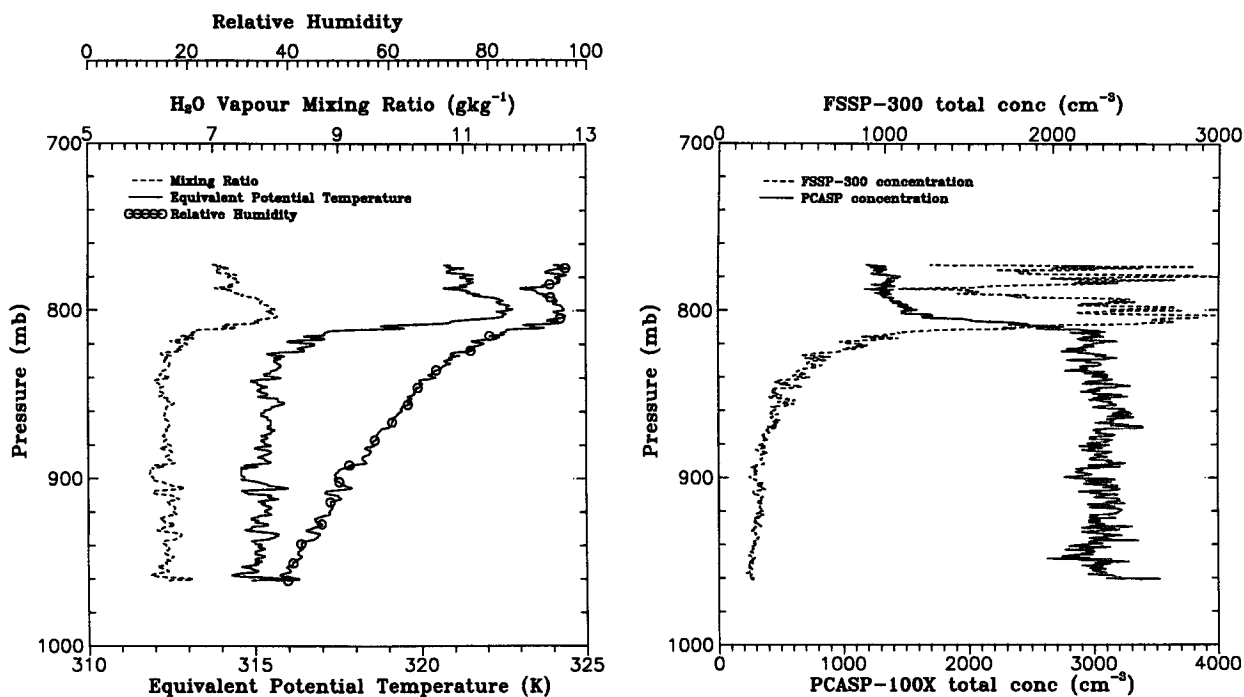


FIG. 1. Vertical profiles of equivalent potential temperature, water vapor mixing ratio, and relative humidity (a), and of FSSP-300 and PCASP-100X total particle concentrations (b) for an ascent through the boundary layer at 1852:03–1859:14 UTC 24 April 1990.

the boundary-layer depth during this period. These results show that the concentrations of major ions in the boundary layer are consistent with a dominance of ammonium sulfate, a small fraction of a NO_3^- salt, and a significant fraction of probably relatively weakly hygroscopic calcareous soil-derived salts. Measurements of the acidity of the aerosol revealed very small H^+ concentrations relative to the other ions. Impactor samples impregnated with BaCl and nitron, and exposed within the boundary layer, were analyzed for the existence of SO_4^{2-} and NO_3^- on individual particles following the techniques of Mamane and De Pena (1978) and Mamane and Pueschel (1980). The observed reaction rings confirmed the presence of SO_4^{2-} on most

particles and NO_3^- on only a small fraction of particles and indicated little evidence of H_2SO_4 droplets. These observations are consistent with the dominance of the fine aerosol by $(\text{NH}_4)_2\text{SO}_4$. Certainly the aerosol was hygroscopic and should hydrate with increasing relative humidity.

Tang and Munkelwitz (1977) and Tang (1980) have described the hygroscopic growth of pure NH_4HSO_4 and $(\text{NH}_4)_2\text{SO}_4$, which deliquesce at relative humidities of 39% and 79%, respectively, and grow rapidly at higher relative humidities (Fig. 2). In the case of decreasing relative humidity, the aerosol does not immediately revert to its dry size as the relative humidity drops through the deliquescence point, but a hysteresis effect is observed with a continuous decrease along an extrapolation of its previous trend (Fig. 2). In this study, although the aerosol is predominantly $(\text{NH}_4)_2\text{SO}_4$, the growth behavior of the aerosol is complicated by the coexistence of small amounts of particulate nitrate (pNO_3^-). The hygroscopic growth properties of NH_4NO_3 have also been described by Tang (1980), who found that the aerosol hydrated at relative humidities of 30%, well below the theoretical 62% deliquescence point. Consequently, the growth properties of the 24 April aerosol are expected to be dominated by those of $(\text{NH}_4)_2\text{SO}_4$, that is, rapid growth at relative humidities greater than 79% and little or no growth less than 79%. Small effects of pNO_3^- could also be present, causing some growth at relative humidities

TABLE 1. Concentrations of water-soluble ions from aerosol filter samples taken at the Egbert surface site directly below the boundary-layer profile of Fig. 1, 1730–1900 UTC 24 April 1990.

	($\mu\text{g m}^{-3}$)	($\eta\text{eq m}^{-3}$)
NH_4^+	5.45	302.8
SO_4^{2-}	16.22	337.9
NO_3^-	3.60	58.1
Cl^-	0.12	3.4
Na^+	0.08	3.5
Ca^{++}	4.10	204.5
Mg^{++}	0.48	39.5
Total	30.1	

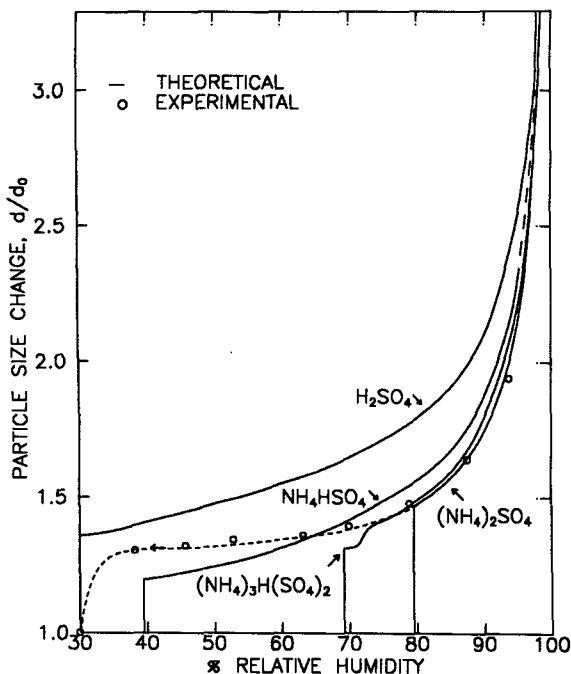


FIG. 2. Deliquescence properties of common sulfate aerosols, reproduced from Tang (1980). Theoretical growth curves are shown in solid. The observed hysteresis effect for lowering relative humidity with $(\text{NH}_4)_2\text{SO}_4$ is shown in open circles and approximated with the dotted line.

less than 79% and possibly augmenting $(\text{NH}_4)_2\text{SO}_4$ growth rates. In addition we cannot discount the possibility that some acidic sulphates with lower deliquescence points were also present. The hysteresis effect for lowering relative humidities could also mean that hydrated aerosol previously deliquesced at higher relative humidities may remain hydrated at humidities lower than 79%.

b. Observed spectral growth

The total number concentrations measured by the FSSP-300 (Fig. 1b) show a moderate increase from near the surface (~ 960 mb) to ~ 850 mb, after which concentrations increase very rapidly with relative humidity. This occurs at a relative humidity of roughly 65%, not far from the deliquescence point of 79% for pure $(\text{NH}_4)_2\text{SO}_4$. These observations are consistent with a dominance $(\text{NH}_4)_2\text{SO}_4$ and small fractions of other hygroscopic aerosol components or the hysteresis effect noted above.

The actual 30-s average variations of the PCASP-100X and FSSP-300 size distributions with height (relative humidity) are shown in Fig. 3. The manufacturer's calibration for nonabsorbing aerosol of refractive index 1.585 has been used for the PCASP-100X. The FSSP-300 channel diameters are similar to those rec-

ommended by the manufacturer ($r = 1.585 + 0i$), but some channels have been grouped together in the highly resonant region of the Mie-scattering curve to avoid multivalued response. These groupings have very little effect on interpretation of the distributions reported here. The first observation from Fig. 3 is that the FSSP-300 distributions shift to larger diameters with increasing relative humidity, consistent with hygroscopic growth of the aerosol. The proximity of the FSSP-300 distributions at lower relative humidities suggest that the aerosol at 40% relative humidity is approaching its dry size. The PMS PCASP-100X distributions, in contrast, are nearly identical throughout the range of relative humidities. The most likely explanation of this behavior is that the PCASP-100X has dried the aerosol before measurement. It is also evident that the overlap is poor between the PCASP-100X spectra and the driest FSSP-300 spectrum; this observation will be discussed in section 3d.

c. The effect of refractive-index changes with deliquescence

The growth of the FSSP-300 spectrum with increasing relative humidity implies a shift in refractive index of the particles, from the nominal 1.585 used by the manufacturer to a value approaching 1.33 for greatly hydrated particles. Since the manufacturer's calibration assumes a constant refractive index of 1.585, one would

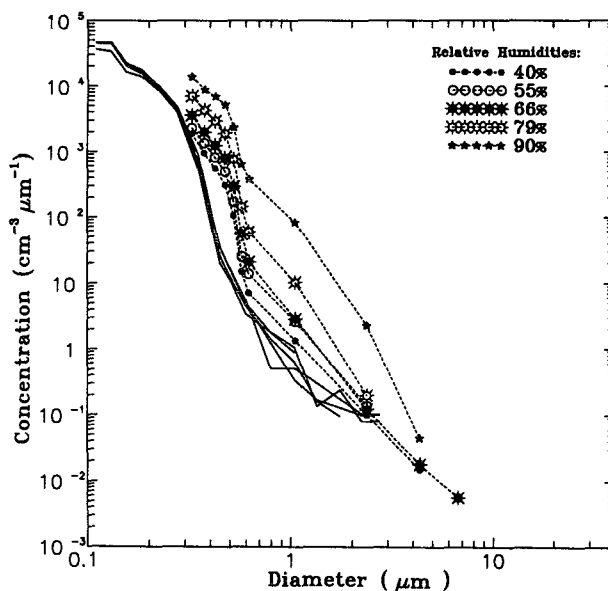


FIG. 3. Comparisons of aerosol-particle-size spectra observed by a PMS PCASP-100X probe (solid) and a PMS FSSP-300 probe (dotted) in a well-mixed boundary layer at relative humidities of 40%, 55%, 66%, 79%, and 90%. PCASP-100X spectra are uncorrected for size calibrations. FSSP-300 spectra use the manufacturer's calibration for aerosol refractive index of $1.585 + 0i$. All spectra are normalized to standard temperature and pressure.

therefore predict a calibration change with relative humidity due to the refractive-index change. In order to evaluate the magnitude of this effect, Mie-scattering calculations were performed for a water refractive index of $1.33 + 0i$ and compared to those used by the manufacturer to set up the calibration of the probe for atmospheric aerosol ($1.585 + 0i$). Our calculations produced equivalent output to those of the manufacturer for the same input parameters. The results of the comparisons are plotted in Fig. 4. The calculations display a crossover for the aerosol and water response: at diameters larger than $\sim 1 \mu\text{m}$, water drops are oversized by the FSSP-300 with its standard calibration; at less than $1 \mu\text{m}$, they are undersized. Therefore, as relative humidities increase in Fig. 3, at least part of the change in the observed FSSP-300 spectra could be due to changes in the particles optical properties. A new set of bin diameters were evaluated using the Mie calculations for water, again grouping together channels in the highly resonant region of $1\text{--}6 \mu\text{m}$. Figure 5 compares the spectra for the 90% relative humidity case of Fig. 3 ($r = 1.585 + 0i$) with the redefined size spectrum for water. It is evident that the effect of changing refractive index on probe response is small compared to the observed spread in the FSSP-300 spectra with relative humidity, indicating that this observation is related more to hygroscopic growth of the aerosol and less to a change in optical response. Kim and Boatman (1990) have reported on response changes of a non-deiced ASASP-100X aerosol probe to changes in relative humidity (refractive index). Although their gen-

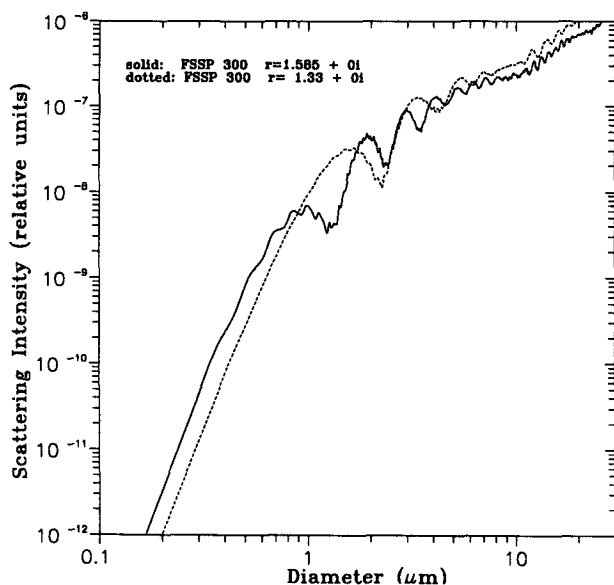


FIG. 4. Mie-scattering calculations for the FSSP-300 for scattering angles between 3° and 15° , comparing the response of particles of refractive index $1.585 + 0i$ (idealized atmospheric aerosol) to those of $1.33 + 0i$ (pure water).

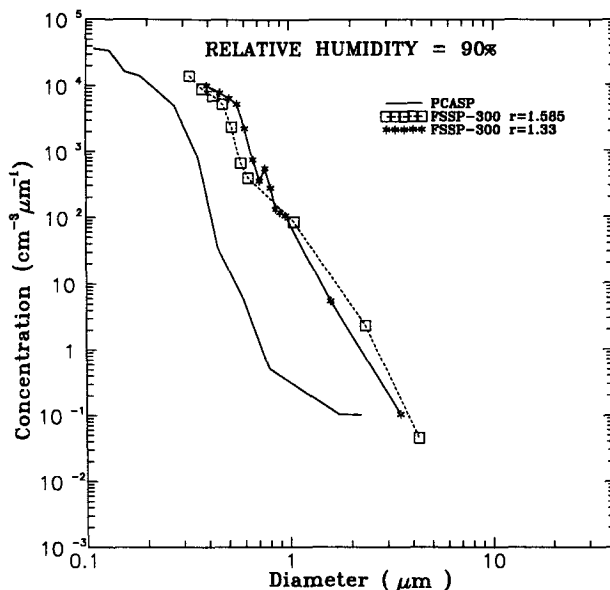


FIG. 5. Comparison of the PMS FSSP-300 particle-size spectrum for the 90% relative humidity case of Fig. 3, for refractive indexes of 1.585 and 1.33. The uncorrected PCASP-100X spectrum is also shown for reference.

eral conclusions of calibration shifts are relevant to the PMS FSSP-300 probe, they are not relevant to our deiced PCASP-100X probe, since the particles are dried before sampling.

d. The FSSP-300–PCASP-100X spectrum overlap

As noted earlier, there is a noticeable offset between the PCASP-100X ensemble of particle distributions and the lowest relative humidity (40%) FSSP-300 distribution shown in Fig. 3. Problems of statistical counting errors are negligible at smaller sizes ($<1\%$ for particles smaller than $0.3 \mu\text{m}$) but increase to 10% – 20% for particles of approximately $1 \mu\text{m}$. The noisy tails of the FSSP spectra of Fig. 3 reflect the increasing statistical error with increasing size. Uncertainties in the FSSP-300 spectrum lie primarily in the sample area. The value used in computing our concentrations is a theoretical value, and there are presently no generally accepted techniques for experimental verification. Dye et al. (1990) reported an empirically derived FSSP-300 sample volume based on comparisons with an ASASP-100X that was significantly different from the manufacturer's. Based on the results of this article, such an empirical technique could be highly invalid if employed with hygroscopic aerosol. Although sample-area uncertainty could be a contributing factor, it is unlikely to be large enough to explain the offset observed in Fig. 3.

The sample volume of the PCASP-100X is better known than that of the FSSP-300. A constant-volume

pump delivers 1 cm^{-3} through the sampling inlet, independent of pressure. The flow through the inlet was monitored routinely throughout the experiment, and the estimated error is less than 10%. Part of the discrepancy of Fig. 3 could also be due to a size calibration error discovered on the PCASP-100X. Calibrations were performed on the probe several months after the flights with electrostatically classified NaCl and latex particles, as discussed by Liu et al. (1992). Three problems were detected: 1) the sample flow was not properly focused in the center of the laser, resulting in undersizing and undercounting; 2) the calibration gains were not set to the manufacturer's standards; and 3) the detection limit was found to be higher than that indicated by the manufacturer. The sample flow was properly focused, and subsequent calibrations revealed that the probe consistently undersized throughout its range. The calibration effect of the poorly focused sample flow was not resolved, nor was it determined whether it was present on the flight described in this article. Application of new bin intervals based on the calibration, however, brings the PCASP-100X size spectrum much closer to that indicated by the FSSP-300 at low relative humidities, as shown in Fig. 6. Assuming that the FSSP 40% relative humidity spectrum is nearly dry, the overlap between the probes is found to be quite good.

e. Growth calculations

Ideally, it would be appropriate to express the growth of the aerosol distributions in terms of some mean di-

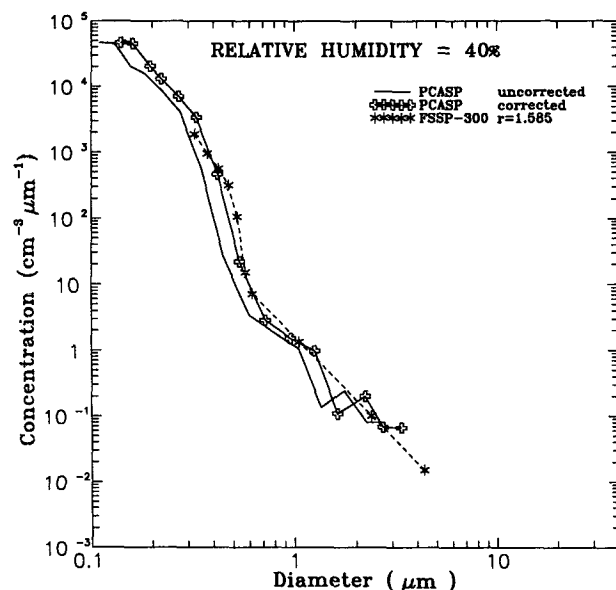


FIG. 6. Comparison of the PMS PCASP-100X particle spectra (uncorrected and corrected for laboratory calibrations) and FSSP-300 spectra for the lowest observed relative humidity. Both probes are suspected to be measuring dry aerosol at this relative humidity.

ameter and to display it as a function of the relative humidity, allowing a direct comparison to the theoretical growth of Fig. 2. Unfortunately, this is not possible with the FSSP-300 spectra, since new particles grow up into the lower detection size of the probes with hydration. Alternatively, the theoretical and experimental results of Tang (1980) provide sufficient information to estimate the growth of $(\text{NH}_4)_2\text{SO}_4$ aerosol-size distributions with relative humidity. The particles are assumed to be composed of an insoluble core and a hygroscopic shell that grows at a rate dependent on composition as described in Fig. 2. From simple geometric arguments, the growth of a composite particle at a particular relative humidity can be expressed as

$$d_{cw} = d_{c0} \left[1 + \frac{\rho_t}{\rho_s} f_2 (f_1^3 - 1) \right]^{1/3},$$

where d_{cw} and d_{c0} are the wet and dry composite diameters, respectively; ρ_t and ρ_s are the total and shell densities of the particle, respectively; f_1 is the growth of the pure salt shell at the particular relative humidity (Fig. 2); and f_2 is the shell fraction of the total particle mass. Heintzenberg (1989) has reported on the average characteristics of urban and nonurban aerosols for a collection of sites throughout the world. He found that the average soluble fraction of the total fine-particle mass was 42% and 52% for urban and nonurban sites, respectively. The PCASP-100X spectra provide an independent estimate of the insoluble fraction. The total aerosol volume average through the descent profile was approximately $17 \times 10^{-12} \text{ cm}^3 \text{ m}^{-3}$, or approximately $31 \mu\text{g m}^{-3}$ for a $(\text{NH}_4)_2\text{SO}_4$ density of 1.78 g cm^{-3} . The average total soluble aerosol mass from the simultaneous ground filter below the descent profile was $30.1 \mu\text{g m}^{-3}$ (Table 1). Although the level of uncertainty in the PCASP-100X derived mass probably exceeds 25%, this comparison nevertheless tends to indicate a small insoluble mass fraction. The aerosol soluble fraction in turn consists of an unknown but significant fraction of weakly hygroscopic calcareous salts, which is unlikely to exceed 50% of the soluble aerosol mass. As will be discussed shortly, the observed growth rates are also consistent with a high soluble fraction.

Therefore, two cases have been chosen for calculation that likely bracket the conditions observed on this day: 1) an original spectrum assumed to be 50% ammonium sulfate by mass with an insoluble core of 50% mass and a total density of 2.0 g cm^{-3} , and 2) an original spectrum assumed to be 100% ammonium sulfate by mass with no insoluble core and a total density of 1.78 g cm^{-3} . The expected equilibrium sizes of pure ammonium sulfate were taken from Fig. 2 as input into simple calculations of the growth of the composite

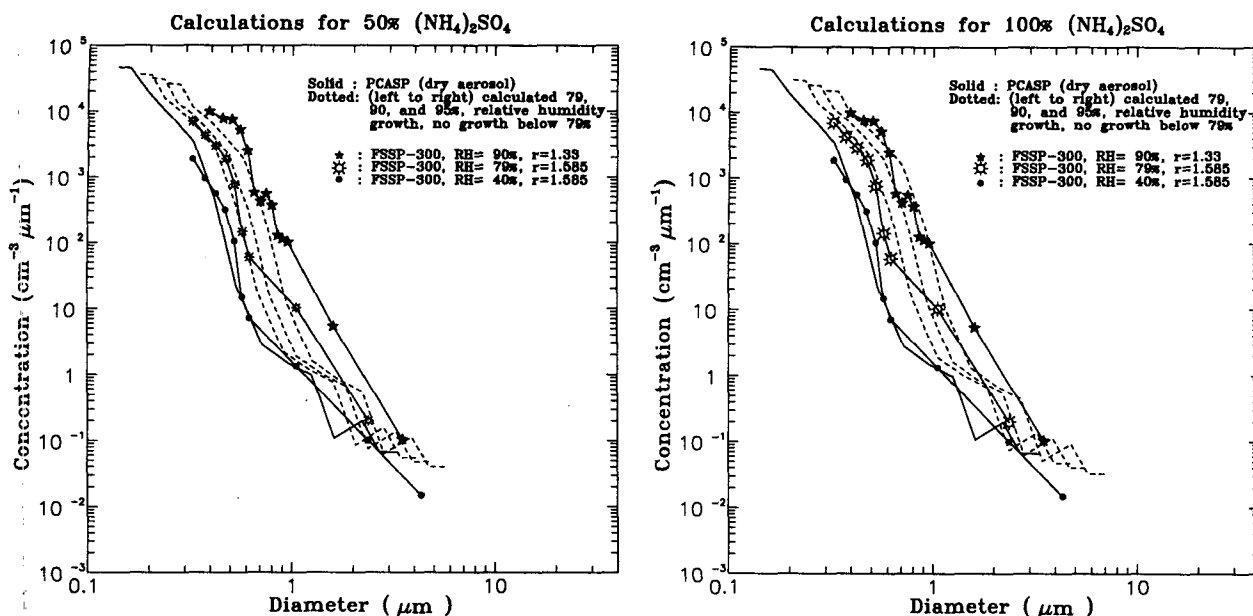


FIG. 7. Calculations (dotted) of the growth of $(\text{NH}_4)_2\text{SO}_4$ particles (a) with a 50% by mass insoluble core and (b) with no insoluble core, at relative humidities of 79%, 90%, and 95% (dotted right to left, respectively). No growth is predicted for the relative humidities of less than 79%. The dry-particle size used as a starting point are those shown in the solid line. A range of observed FSSP-300 spectra from 40% to 90% relative humidity is also shown.

particle. The results for cases 1) and 2) are displayed in Figs. 7a and 7b, respectively. The corrected PCASP-100X spectrum of Fig. 6 has been used as a dry-aerosol starting point, and estimates have been made of the growth of this spectrum for the relative humidities corresponding to Fig. 3. The lower and upper limits of each probe channel were then redefined using the above equation to express the growth of the existing spectrum with relative humidity. The observed spectra are close together at the lower relative humidities and diverge rapidly at relative humidities in excess of 70% (Fig. 3). The calculated spectra show no growth until 79% and then grow rapidly with increasing relative humidity. Comparisons with the observed 79% and 90% relative humidity spectra are also included in Figs. 7a,b. In the case of the 50% insoluble core, the observed 90% spectrum appears to have grown considerably more than calculated. In the case of the pure $(\text{NH}_4)_2\text{SO}_4$, the calculated spectra tend to agree more favorably with the observed, and the spread between the 40% and 90% observed spectra are quite consistent with the calculated spectra. Although the true aerosol composition has been simplified in these calculations, this simple model qualitatively depicts the observed behavior of the FSSP-300 spectra reasonably well and supports the contention that the shift in the FSSP-300 size spectrum with relative humidity is indeed due to hygroscopic growth. The results also tend to support the earlier contention that the aerosol had a small insoluble fraction.

f. Laboratory tests of the PCASP-100X

Laboratory tests of the PCASP-100X were performed to provide further evidence of drying by its deicing heaters. Although the actual conditions encountered by a wing-mounted PCASP-100X could not be exactly duplicated, attempts were made to simulate its airborne configuration. The probe was operated in a cold room near 0°C , and air was drawn through the sampling nose at a flow rate similar to that estimated for the actual operation on the aircraft. An NaCl aerosol was introduced into the room, and the relative humidity was kept near 100%. The effect of the heaters was clear and reproducible, in this case shifting the spectrum mode from channel 5 to channel 3 and steepening the tail of the distribution (Fig. 8). After heaters were turned off, it took approximately 4 min for the distribution to obtain its preheated values. The clear conclusion from these tests is that the deicing heaters have a drying effect on aerosol and that the nondeiced probe has less or no drying effect. The partial drying scenario is particularly disturbing, since recovery of true or dried particle distributions from these data could be exceedingly difficult.

4. Summary and conclusions

The observations of this study indicate a modification of hygroscopic tropospheric aerosol-size distributions measured by the deiced PMS PCASP-100X probe by its delivery system; it dries aerosol in the sub-

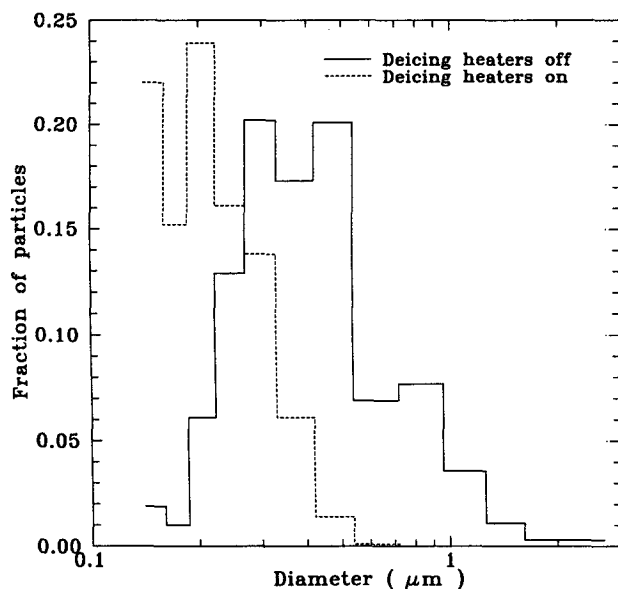


FIG. 8. Laboratory tests of the effects of the deicing heaters on the measurement of greatly hydrated NaCl particles by the PCASP-100X probe.

micron size range before sampling. It is likely that the deiced ASASP-100X, with its identical delivery system, exhibits the same behavior. The probes' deicing heaters, the combined heating of the canister and its contents by the electronics, and the focusing of the sample flow by a dried sheath flow are all possible drying factors, although only the drying effect of the deicing heaters was investigated in this study. These results may not apply to the nondeiced ASASP-100X and PCASP-100X probes, and further tests should be performed on these probes to characterize their behavior and to ensure that partial drying, which could result in irrecoverable data, is not occurring. The effects of the probe drying on the evaporation of cloud droplets and the interpretation of interstitial aerosol measurements also requires further investigation. The FSSP-300 probe spectra displayed changes with relative humidity consistent with the hygroscopic growth of the aerosol and displayed behavior consistent with the aerosol composition. Calibration corrections for refractive index changes with hydration are therefore not applicable to the deiced PCASP-100X or the ASASP-100X probes, but presumably apply to the FSSP-300. Due to their differing responses to hydrated aerosol, a combination of the PCASP-100X and FSSP-300 probes may provide supporting data for diagnosing the state of natural aerosol and its chemical composition.

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