MEASUREMENTS OF COMPLETE CCN SPECTRA

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The Desert Research Institute (DRI) cloud condensation nuclei (CCN) spectrometers (Hudson 1989) participated in six field projects over the last four years. One of these, RICO (tropical maritime) is the subject of another paper at this conference (Mishra and Hudson 2006). Three of the other projects were continuous surface measurements--ARM-IOP (May 2003 in Oklahoma; polluted), Korea (May 2004; polluted) and SUPRECIP2 (Feb.-Mar. 2006 in California; polluted). The other two were, like RICO, airborne measurements—AIRS2 (Nov-Dec. 2003 Great Lakes area; continental) and MASE (off the central California coast; modified maritime).

Most previous CCN measurements have been limited to supersaturations (S) above 0.1%. Thus S discrimination is limited to the Aitken size range (diameter < 0.1 μm). The S range of the DRI instruments extends down to 0.01%, which thus usually includes most of the Large Nuclei (LN) size range (0.1-1 μm diameter). The S range needs this extension because:

1) many clouds form at S < 0.1%;
2) LN may be precipitation embryos;
3) difficult giant nuclei measurements can be more credible if interfaced with LN;
4) cloud droplet spectral width, which is important for precipitation, may depend on full CCN spectra;
5) concentrations of more massive (lower S nuclei) need to be considered for static CCN closure (comparisons of particle size and composition with CCN);
6) since the lower S nuclei condense the most water they need to be considered for dynamic CCN closure (comparisons of predicted cloud droplet concentrations from CCN and updraft with measured cloud droplet concentrations);
7) wide CCN spectra are needed to determine CCN sizes.

As in many previous projects (e.g., Hudson and Yum 2002) both of the DRI CCN spectrometers operated in all six projects. This was done

1) for redundancy;
2) to better accommodate in flight calibrations;
3) to do measurements of cloud droplet residual particles from a CVI with one instrument while the other continues to monitor ambient;
4) similarly to do volatility measurements;
5) similarly to do size versus S measurements
6) to operate each over different S ranges to optimize the measurements
7) to check each instrument in the overlapping S range.

The latter helps to validate the measurements over the entire S range, especially the instrument operating at the higher (larger) S range, which is more challenging. Agreement of the lower S portion (which is the most challenging) of the higher S range instrument with the upper portion of the S range (which is least challenged) of the lower S range instrument provides confidence (e.g., Fig. 1). Since the DRI instruments have so many S channels it is possible to plot data differentially (e.g. Figs. 2) as well as the traditional cumulative plots. Differential plots provide a better test of instrument comparisons in the overlapping S range.

Figure 3 shows typical vertical profiles measured in AIRS2 where clean concentrations decrease from polluted to clean with altitude. Figure 4 shows the layer of high concentrations that was consistently measured above the stratus clouds off the California coast (e.g., Hudson and Frisbie 1991). Table 1 shows examples of comparisons between CCN spectra and cloud droplet concentrations.

Figure 5 shows the relationship between critical S (S_c) particle size. This is consistent with Hudson and Da (1996) where CCN are larger in more polluted air masses. In clean air the particles are mostly purely soluble substances such as NaCl or ammonium sulfate. In more polluted air masses the CCN are probably internal mixtures of soluble and

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insoluble (e.g., soot) material. Volatility measurements in all projects were consistent with sulfate rather than NaCl for the vast majority of CCN.

Figure 6 shows the average diurnal trend of CCN concentrations at the California foothills location. The lower concentrations during March compared to February reflect the much greater storm frequency in March compared to mostly fair weather conditions in February.

References:

Hudson, J.G., 1989: An instantaneous CCN spectrometer. *J. Atmos. & Ocean. Techn.,* **6,** 1055-1065.

Hudson, J.G. and X. Da, 1996: Volatility and size of cloud condensation nuclei. *J. Geophys. Res.,* ***101***, 4435-4442.

Hudson, J.G. and P.R. Frisbie, 1991: Cloud condensation nuclei near marine stratus*.* *J. of Geophys. Res.,* **96***,* D11, 20,795-20,808.

Hudson, J.G., and S.S. Yum, 2002: Cloud condensation nuclei spectra and polluted and clean clouds over the Indian Ocean. *J. Geophys. Res.*, **107(D19), 8022,** doi:10.1029/2001JD000829.

Mishra, S. and J.G. Hudson, 2006: Characterizing CCN spectra to investigate the warm rain process. (This conference)

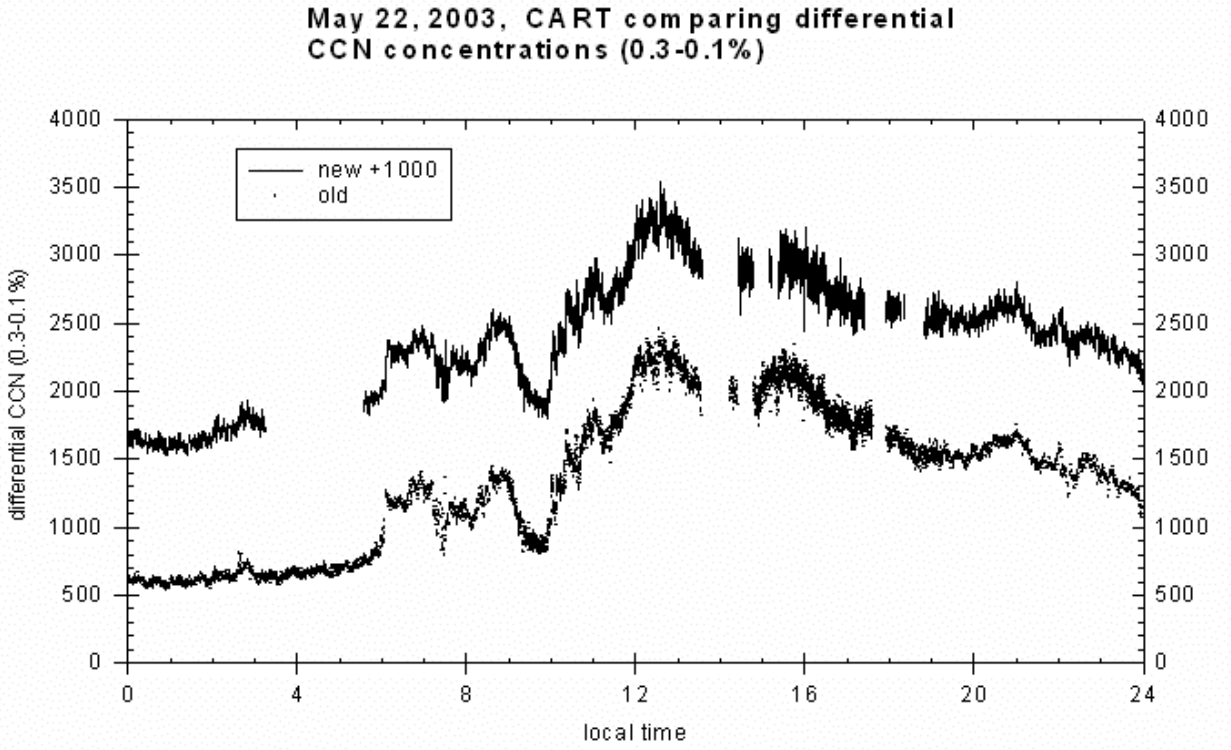

Figure 1a

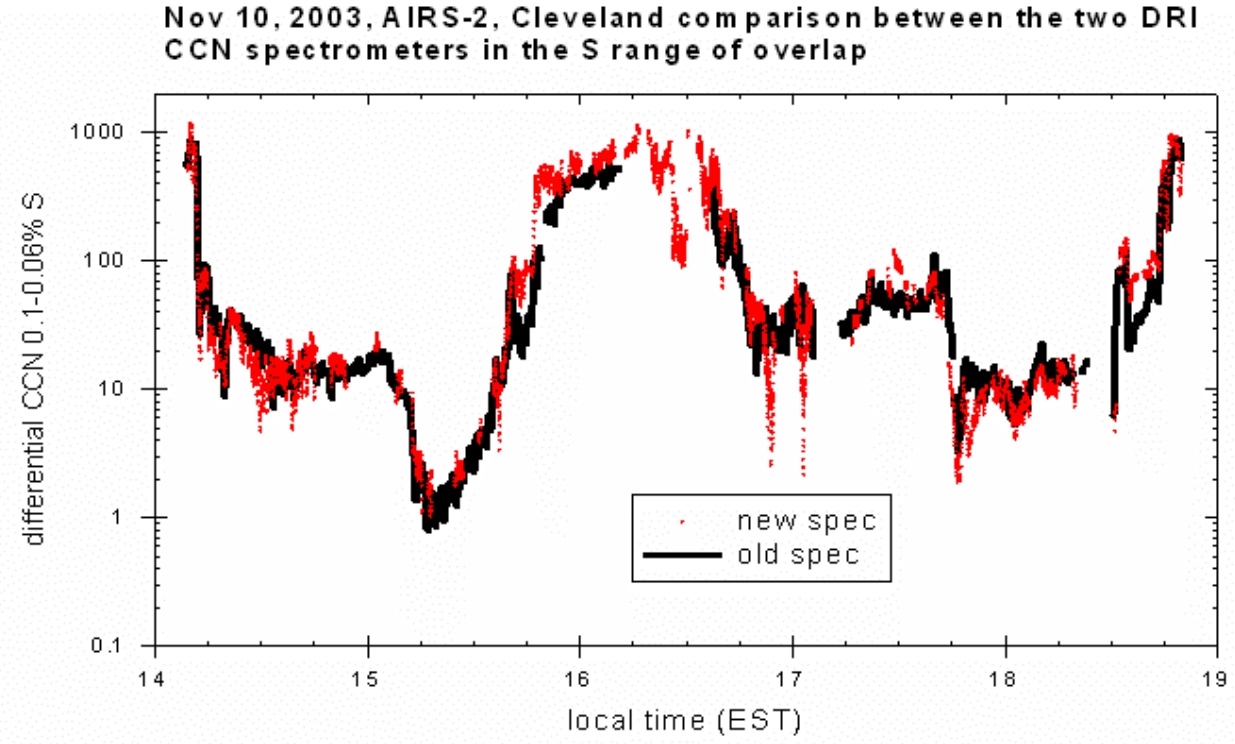

Figure 1b

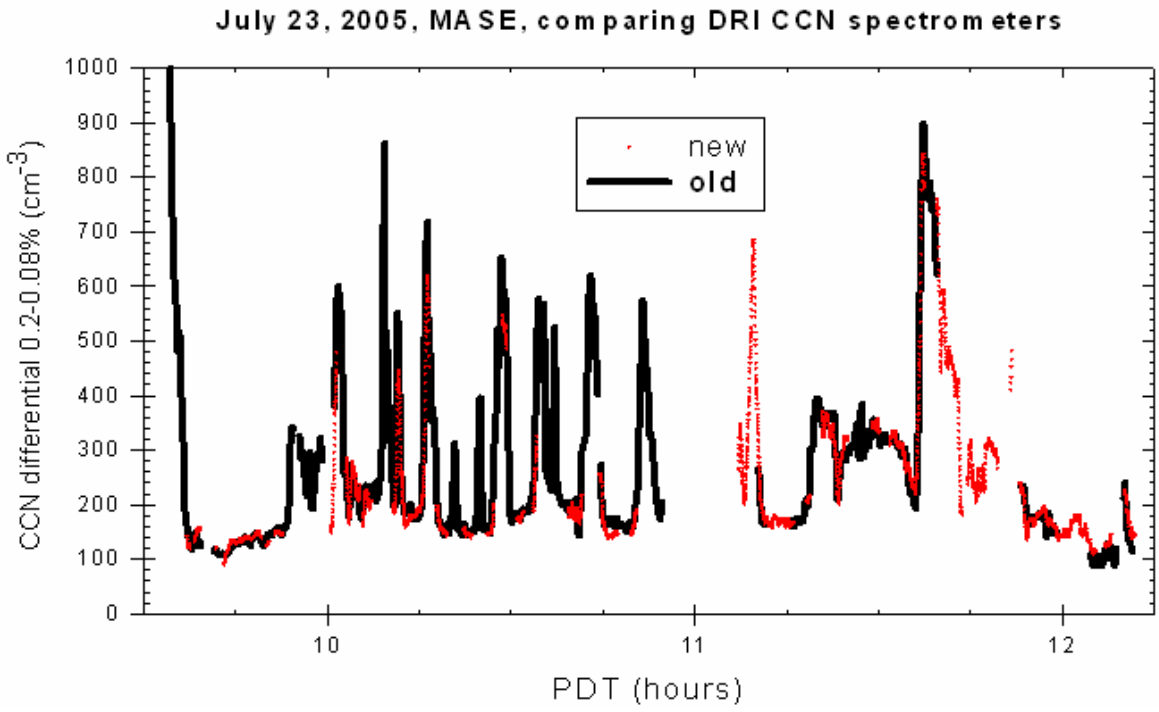

Figure 1c

Figure 1 a, b, c: Time plots of differential concentrations within the same overlapping S range as obtained simultaneously by the two DRI CCN spectrometers each operating over different S ranges.

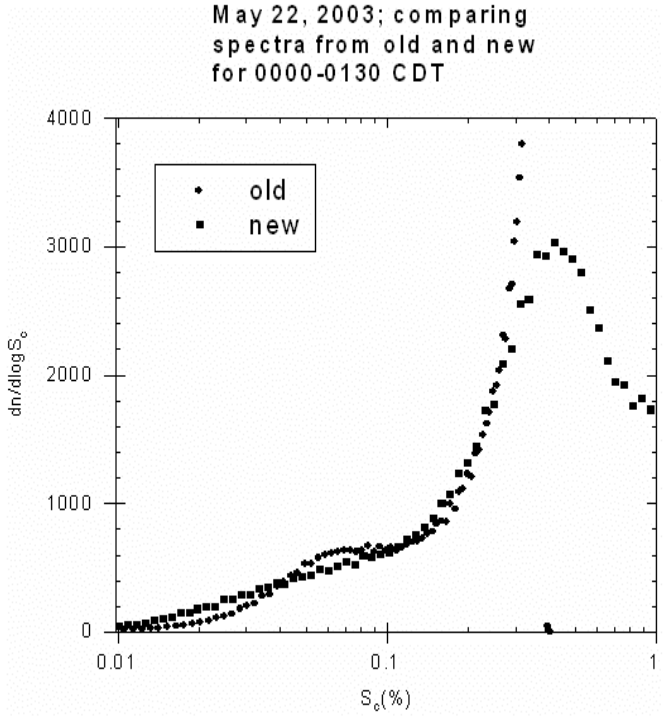

Figure 2a

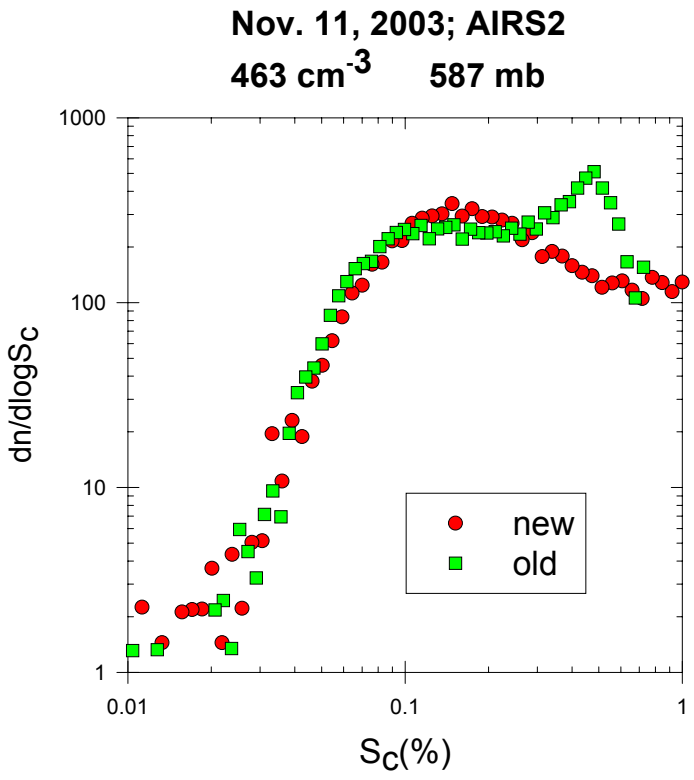

Figure 2b

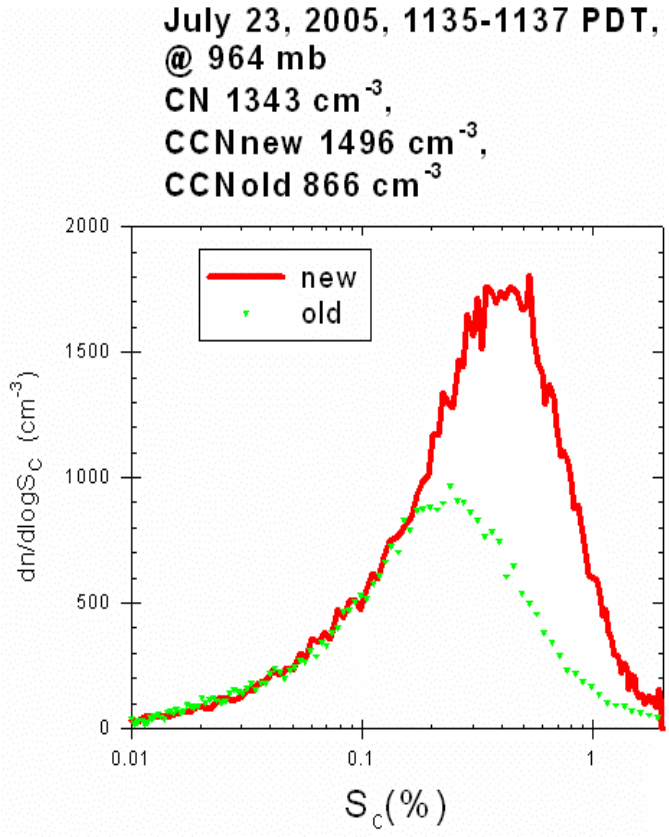

Figure 2c

Figure 2 a, b, c: Differential plot of comparison of the two DRI CCN spectrometers. Here New operated over the higher (larger S range up to 1% whereas old operated only up to 0.3%.

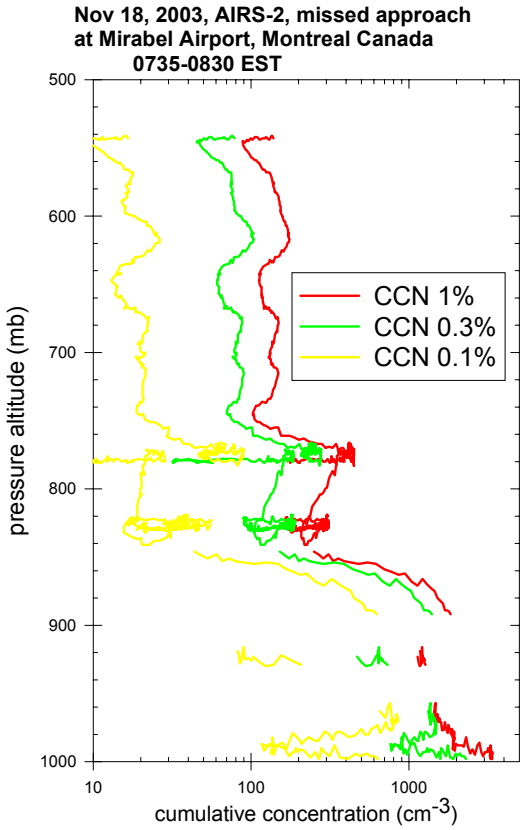

Figure3. Vertical distribution of CCN over North America

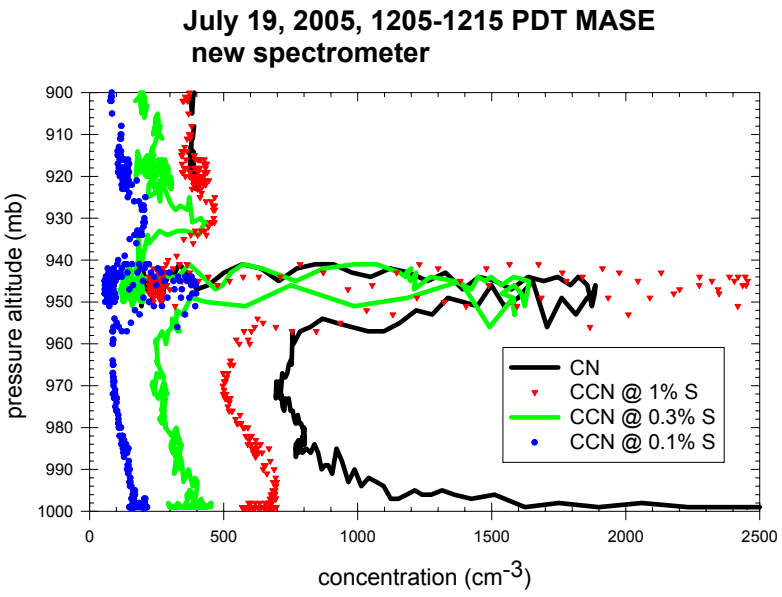

Figure4. Vertical profile of CN and CCN at various S off the California coast with low stratus clouds

Table1. Comparisons of CCN spectra with cloud droplet measurements in AIRS2

date	Cloud time (EST)	CCN time (EST)	Cloud altitude (m)	CCN altitude (m)	Droplet concentration (cm^{-3})	S_{eff}
Nov. 18	1051	1054	892	862	500	0.13%
Nov. 24	1306	1304	3135	3133	200	>2%
Nov 25	1137	1132	1500	1484	300	0.5%
Dec. 1	1425	1419	1503	1490	300	0.5%
Dec. 3	1359	1339	1468	480	200-220	0.31-0.38%
Dec. 4	1057	1052	1112	450	200	0.32%
Dec. 4	1112	1052	1158	450	300-390	0.68-1.04%

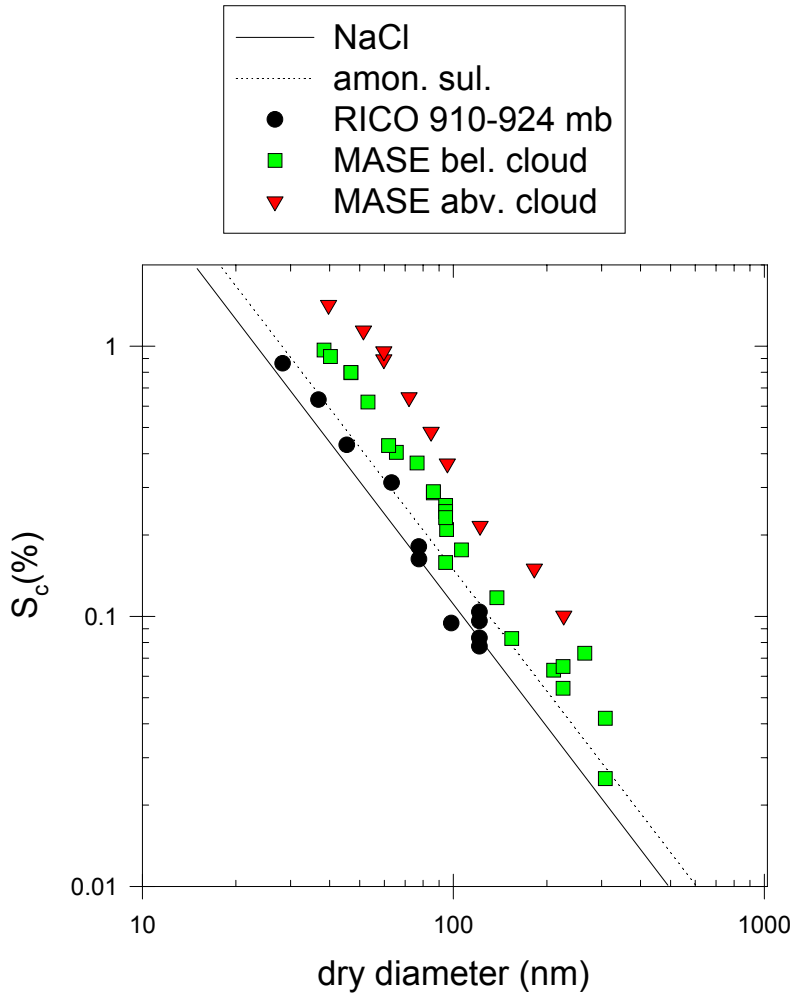

Figure5. Size versus Sc measurements in clean air (RICO) and polluted air (MASE). CCN are larger in more polluted air—i.e., MASE versus RICO and higher altitude in MASE versus lower altitude (see Fig. 3)

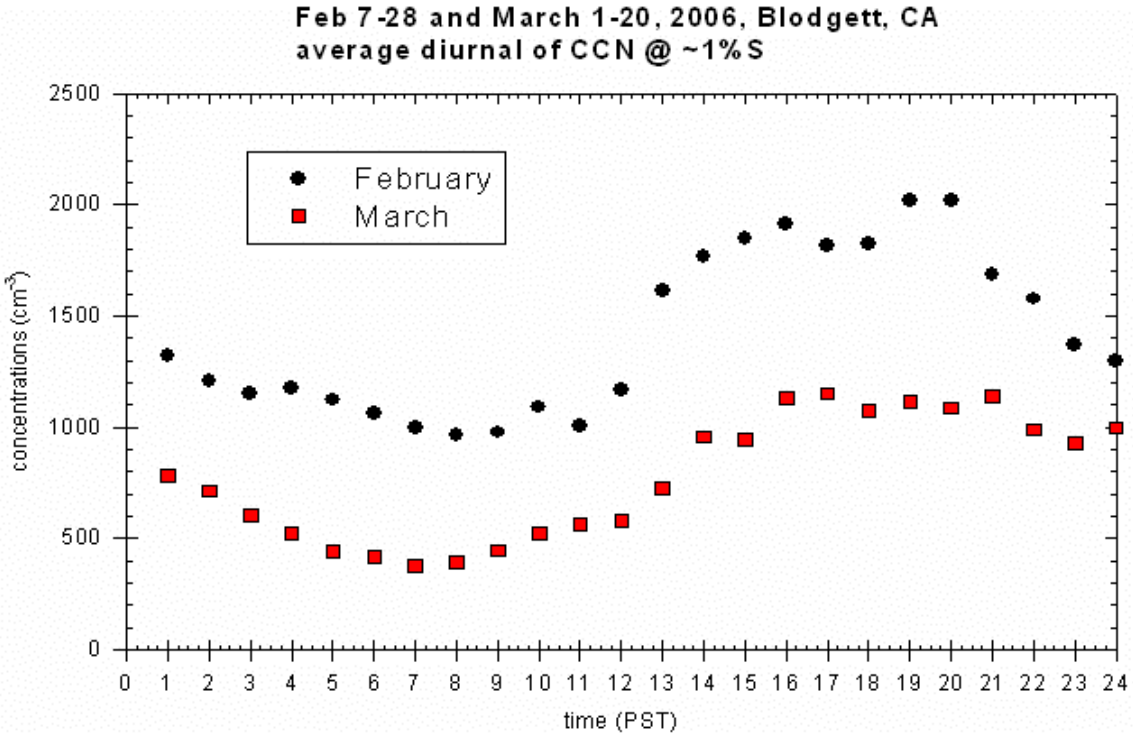

Figure 6. Average diurnal CCN concentrations obtained during SUPRECIP2 project.