

Scanning flow CCN measurements were conducted at the Bodega Bay Marine Laboratory (BML) as part of the Calwater2 campaign. This document provides an overview of these measurements, the Calwater2 study, and the calibration and use of this dataset.

All valid data from the study is included in the “data” directory. Metadata with descriptions of file format is included in the “Metadata.txt” file.

STUDY MEASUREMENT OVERVIEW

Calwater2 took place between January and March of 2015. Data utilized in this study were gathered between 23 January and 5 March, during which a DMT CCNc and TSI 3010 CPC were operational as parts of the scanning flow CCN system. Size distribution measurements from a TSI 3936 SMPS with a 3080 DMA column were utilized for calibration of the CCNc supersaturation using ammonium sulfate.

All aerosol measurements used here were made from within the CSU mobile lab, deployed to BML, and kept stationary approximately 200 m from the coast (approximately 38.32°N latitude and 123.07°W longitude). Air was sampled through several ½” stainless steel tube inlets routed through the roof of the mobile lab to a height of approximately 5 m, before the flow was split and sent to various instruments described further below.

SCANNING FLOW CCN MEASUREMENT METHODOLOGY

Measurements of CCN activity across a range of environmental supersaturations were conducted. A scanning flow CCN system (sfCCN) was used to measure total CCN number concentration as supersaturation was ramped between approximately 0.08% and 1.1% supersaturation. The system used a DMT CCNc instrument that had been modified by

connecting a voltage modulated proportional flow valve to the bottom of the column to precisely control flow. The flow rate was slowly increased from 0.2 to 1.2 lpm through the CCN column while holding the temperature gradient constant, thereby scanning peak column supersaturation as a function of flow rate and column temperature gradient (Moore and Nenes, 2009). A TSI 3010 Condensation Particle Counter (CPC) was placed in parallel to the CCNc to measure total particle number concentration (CN). Each approximately 5-minute scan was repeated three times, after which the temperature gradient was changed to scan a different range of supersaturations. As the column temperatures took several minutes to stabilize, the first scan of each three-repetition set was considered invalid.

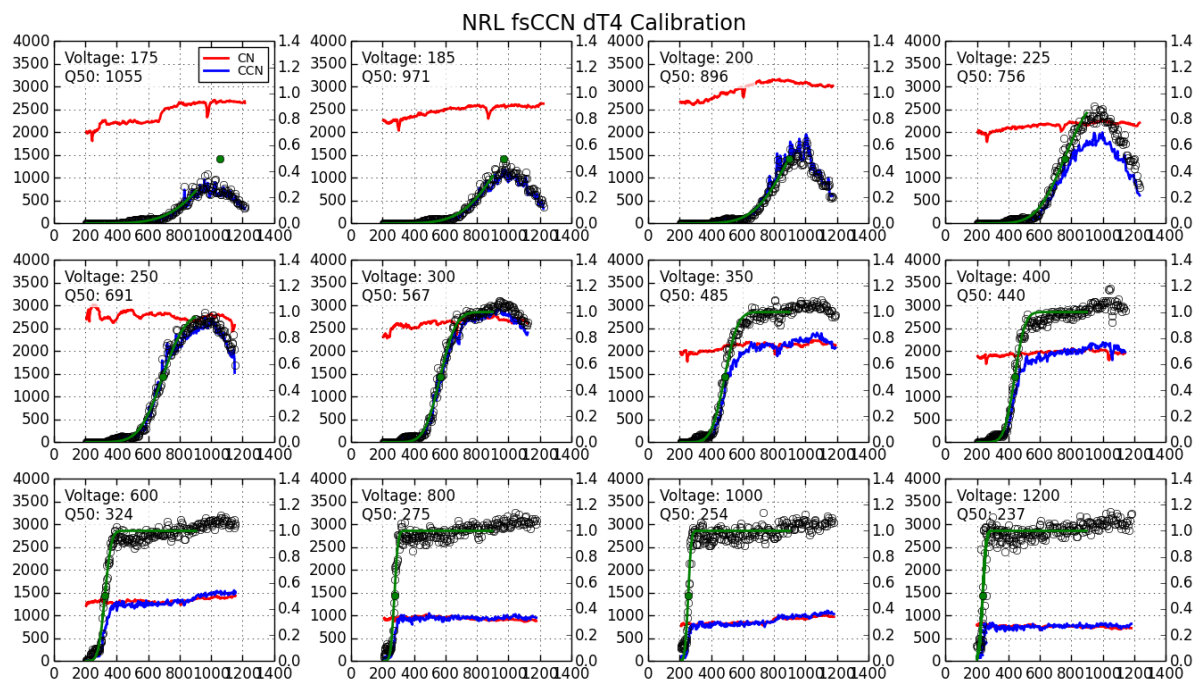


Figure 1 Calibrations conducted for the dT4 (4 K column temperature gradient) setting in the sfCCN system. Each plot shows a flow scan for a specified DMA voltage that was then translated into a monomodal ammonium sulfate population in the calibration analysis.

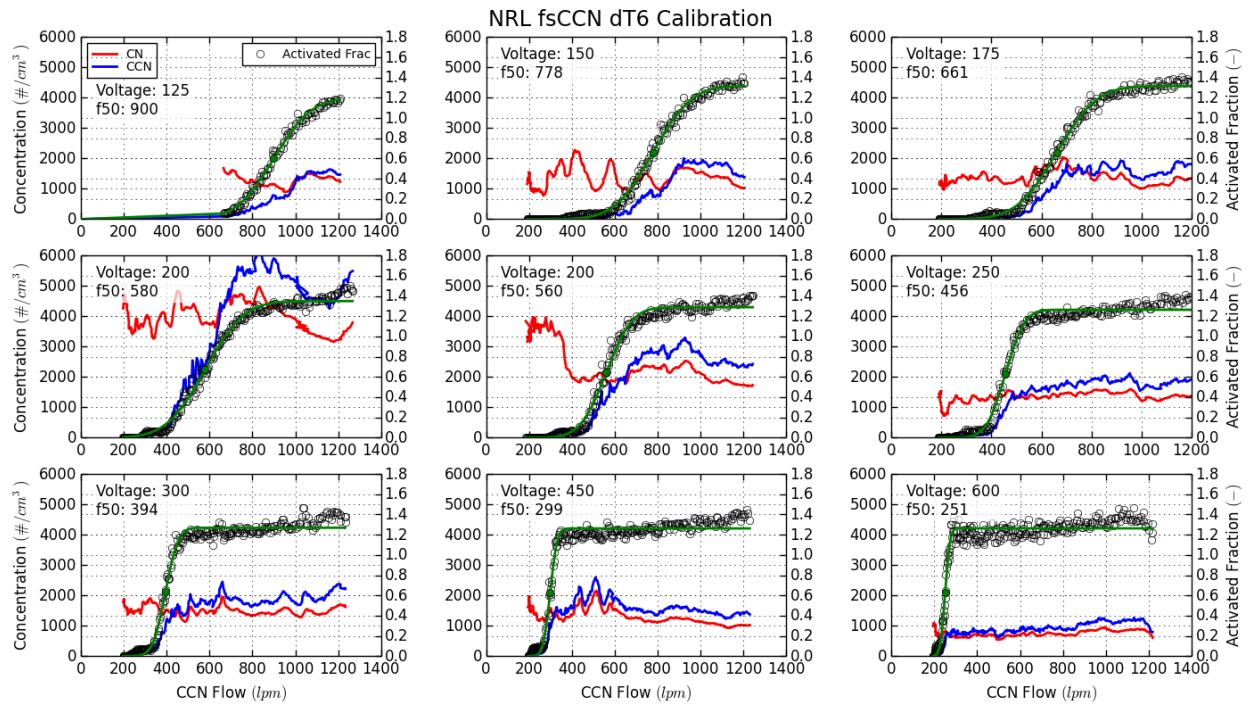


Figure 2 Similar sfCCN system calibrations for the dT6 (6 K gradient) setting.

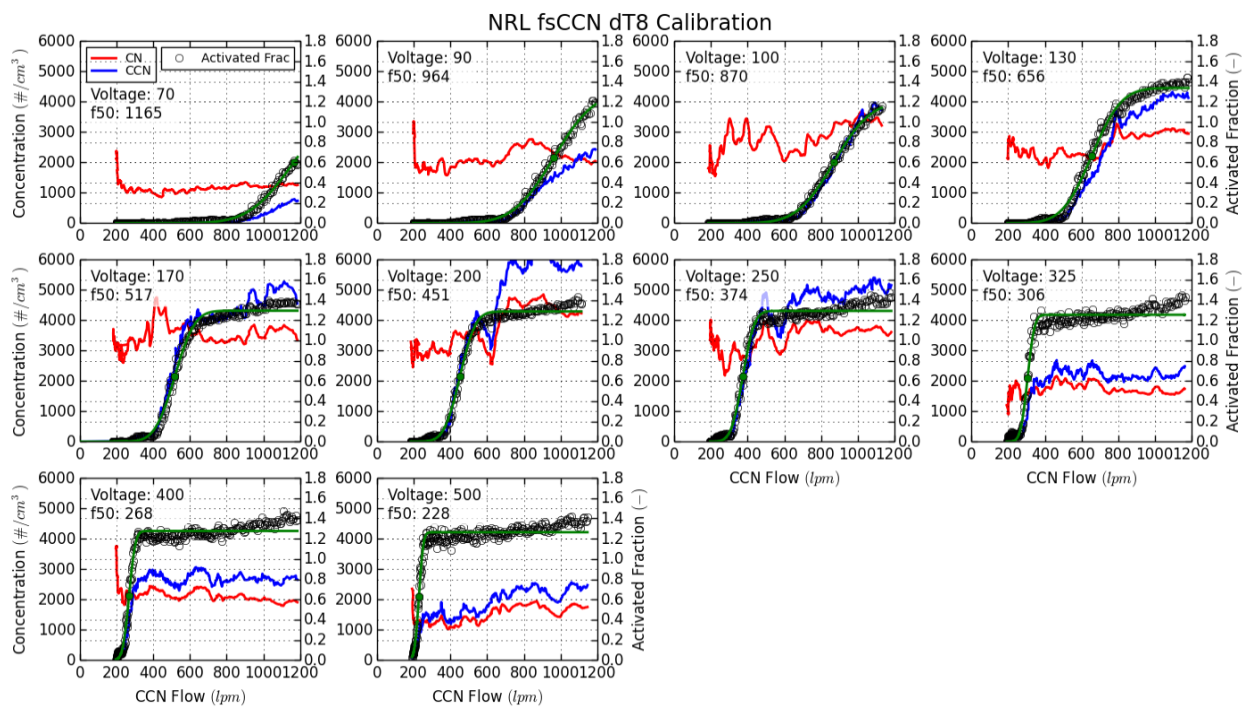


Figure 3 Similar sfCCN system calibrations for the dT8 (8 K gradient) setting.

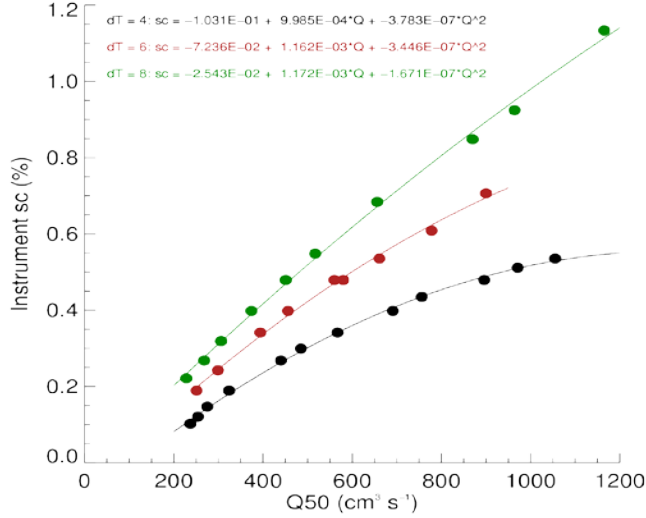


Figure 4 Calibration curves for dT4, dT6, and dT8 sfCCN temperature gradient settings.

Calibration of the CCNc column

supersaturation for a given flow rate at each temperature gradient setting was conducted generally following the methodology described in Suda et al., (2012). Briefly, a monodisperse ammonium sulfate aerosol was generated by atomizing an ammonium sulfate solution and size selecting using a TSI

3080 Differential Mobility Analyzer (DMA) set to a fixed voltage. Concentrations of CN and CCN were measured as flow rate changed. The flow rate at which 50% of particles had activated (Q_{50}) was calculated by fitting a sigmoid curve to the activation plots for a range of DMA column voltages (Figures 1-3). Given a kappa hygroscopicity parameter of 0.61 (Petters and Kreidenweis, 2007) for the ammonium sulfate particles and the parameters of the DMA, calibration curves for column supersaturation as a function of flow rate and temperature gradient were calculated (Figure 4). Calibrations were conducted for column temperature gradients of 4 K, 6 K, and 8 K (referred to as dT4, dT6, and dT8, respectively). The resulting calibration equations (where Q is the flow rate) were:

$$dT_4: sc = -1.031 * 10^{-1} + 9.985 * 10^{-4} * Q - 3.783 * 10^{-7} * Q^2 \quad (1)$$

$$dT_6: sc = -7.236 * 10^{-2} + 1.162 * 10^{-3} * Q - 3.7446 * 10^{-7} * Q^2 \quad (2)$$

$$dT_8: sc = -2.543 * 10^{-2} + 1.172 * 10^{-3} * Q - 1.671 * 10^{-7} * Q^2 \quad (3)$$

As sampled total number concentration was potentially fluctuating during each scan, the total number concentration from the parallel CPC was utilized to calculate activated fraction at each measured supersaturation. However, as flow increased during each scan, the residence time in the sfCCN system varied. To account for the resulting time delay between equivalent samples in the CCNc and CPC, an adjustment to CPC timestamps was made as a function of flow by measuring the time delay between narrow peaks of particles at specific flow rates. A filter was placed upstream of the split between instruments and then briefly removed, thereby allowing ambient particles to be sampled (Figure 5) by both instruments. The time lag between measurements was then determined for a number of flow rates, shown in Figure 6. A calibration curve was fit to all the aligned time stamps and used to create a CPC timestamp adjustment equation (Equation 4).

$$t_{CPC} = t_{CCN} - 41891 * flow^{-1.2656} \quad (4)$$

where flow is the flow rate in cm^3/min .

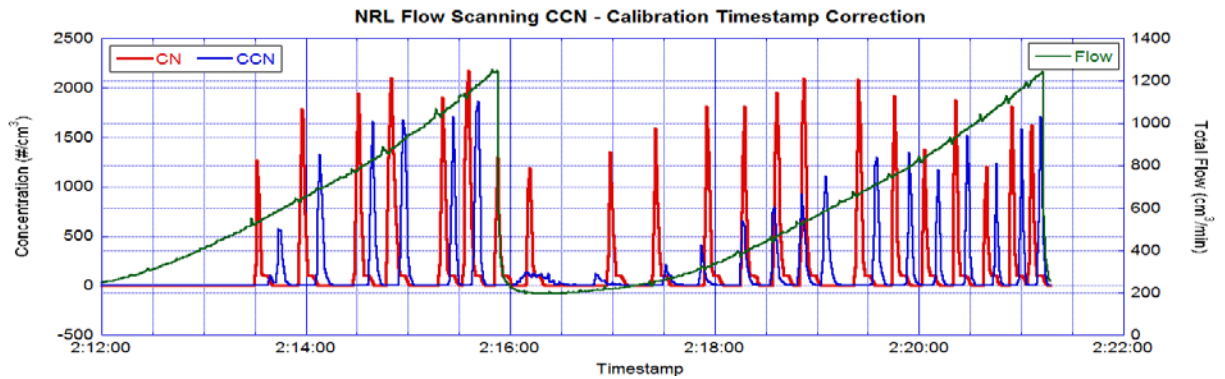


Figure 5 Timestamp correction to account for variable residence time in the sfCCN system as flow changed. Lag between peaks in the CN (red) and CCN (blue) concentrations were dependent of the flow (green) through the sfCCN system.

An example scan with and without the timestamp adjustment is shown in Figure 7. Alignment between CN and CCN peaks was improved by the time stamp adjustment, with corresponding reduction in noise in the calculated activated fraction. Lastly, as the CCNc was observed consistently over-counting as compared to the CPC (e.g. Figures 1-3, 7) at an average ratio of approximately 1.2. Raw CCN concentrations included in the “data” directory files can be divided by 1.2 to account for this discrepancy.

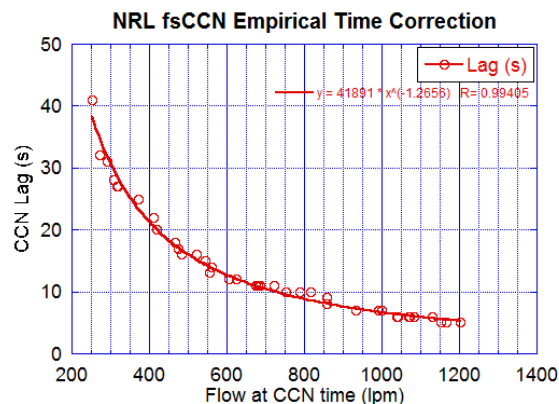


Figure 6 Equivalent CPC time correction function for the sfCCN system.

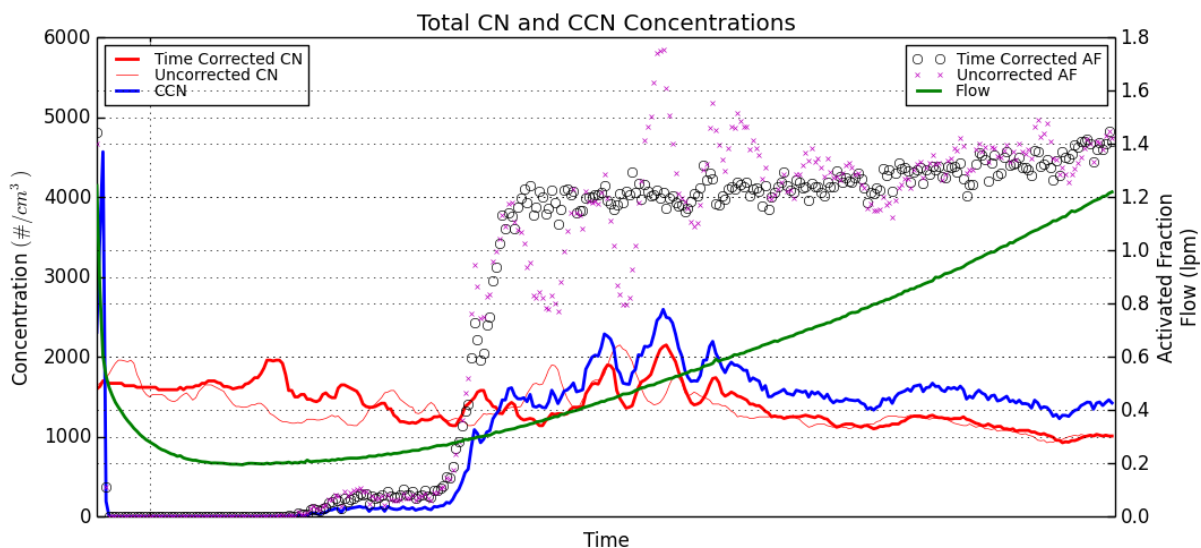


Figure 7 Example sfCCN scan (roughly five minutes in length). CCN concentration is shown in blue, with CN concentration without timestamp correction (thin red) and with the correction (thick red), with the coincident flow through the CCNc column. Concentration peaks show better alignment and noise is reduced for the timestamp corrected activated fraction (black circles) as compared to the uncorrected equivalent (purple Xs).

REFERENCES

Moore, R. H. and Nenes, A.: Scanning Flow CCN Analysis—A Method for Fast Measurements of CCN Spectra, *Aerosol Sci. Technol.*, 43(12), 1192–1207, doi:10.1080/02786820903289780, 2009.

Petters, M. D. and Kreidenweis, S. M.: A single parameter representation of hygroscopic growth and cloud condensation nucleus activity, *Atmos Chem Phys*, 7(8), 1961–1971, doi:10.5194/acp-7-1961-2007, 2007.

Suda, S. R., Petters, M. D., Matsunaga, A., Sullivan, R. C., Ziemann, P. J. and Kreidenweis, S. M.: Hygroscopicity frequency distributions of secondary organic aerosols, *J. Geophys. Res. Atmospheres*, 117(D4), D04207, doi:10.1029/2011JD016823, 2012.