Title: Correction methods on SMPS sample flow rate and CCNC water supersaturation under low air pressure conditions

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(1) Pressure dependence of sample flow rate of SMPS

The SMPS consists of Electrostatic Classifier platform (EC or DMA) and Condensation Particle Counter (CPC). The CPC (model 3772) requires external diaphragm pump to sample the air. In order to examine the pressure dependence of the sample flow rate of SMPS, we set up the system in the laboratory shown in Fig. 1. Inlet and outlet of the air for the system were connected to a buffer tank, so it was a closed system. We had several mass flow meters (MFMs) between the devices. The pressure of the buffer tank can be controlled to be reduced, and we measured each flow rate every about 100 hPa from the ground level.

The experiment result was shown in Fig. 2. On the ground level, we set the volumetric flow rate of 0.63 [lpm] as the sample flow rate. We found that the sample flow rate which converted to volumetric unit (Sample Flow2') was almost constant up to 400 hPa level.

The number concentrations from SMPS measurements are obtained as a unit of [#/cc] in the M300 text data. However, it was calculated from the original impact flow rate during the flight, which was not constant under low pressures. Thus, the number concentration [#/cc] should be corrected by multiplying the original impact flow rate [lpm], then dividing by 0.63[lpm]. The number concentration as a unit of [#/scc] (at standard conditions for temperature and pressure) can be calculated from absolute pressure and sheath air temperature of EC house-keeping data, that were recorded during the flight.

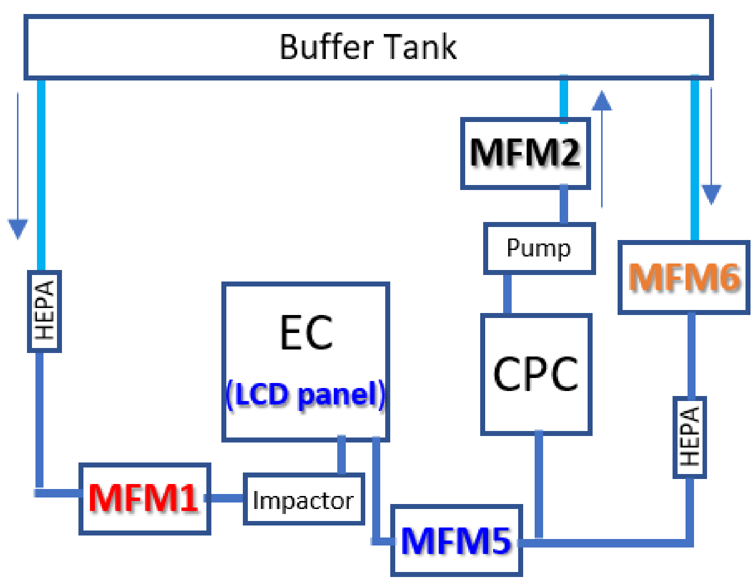

Fig. 1. Piping diagram for SMPS flow rate measurements in a depressurization test.

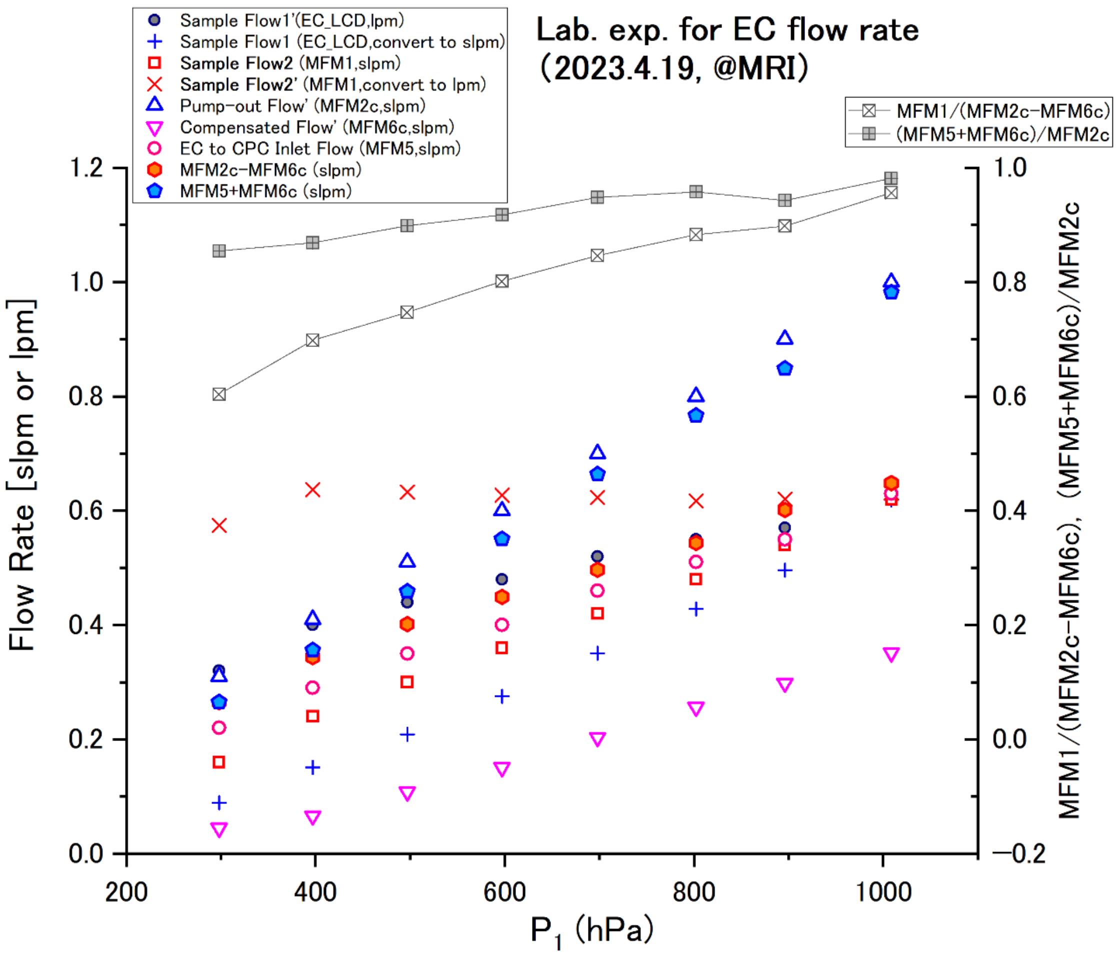

Fig. 2. Comparison of SMPS flow rate measurements in the depressurization test on 2023/4/19.

(2) Pressure dependence of water supersaturation of CCNC

The CCNC (model CCN-200) has dual column to measure CCN concentrations at independently pre-specified water supersaturation (SSw). In order to examine the pressure dependence of the SSw of CCNC, we set up the system in the laboratory shown in Fig. 3. Inlet and outlet of the air for the system were open to the laboratory room. The room air was sampled during this laboratory experiment, being monitored in terms of the total concentration of condensation nuclei (CN). For each column, we measured a CCN spectrum before the depressurization test, and then measured the CCN concentration in every about 100 hPa during the test. The test was conducted at SSw of 0,1, 0.2, 0.5, 0.8, and 1.0%.

The time series of the CCN spectrum measurements and the depressurization test are shown in Fig. 4. The CCN concentration was assumed to be changed according to the CN concentration. Based on the measurement time period at each SSw for each column, the CCN spectra were obtained and curve-fitted as shown in Fig. 5. After corrected by the ratio of the CN concentration between at the test and at the spectrum measurement, the equivalent SSw was estimated from the CCN spectrum in Fig. 5 at each pre-specified SSw for each column, as shown in Fig. 6.

The linear regression of equivalent SSw as a function of pressure is shown in Table. 1. The tendency for column-B at about 400 hPa was different from the linear fitting at higher SSw; the fitting was only applied up to 500 hPa at SSw greater than or equal to 0.5%. When the fitted equivalent SSw was greater than the pre-specified one, we assume the former should be equal to the latter.

The CCN number concentrations for Column-A are obtained in the M300 text data. Those for Column-B are obtained in the raw data. Firstly, both concentrations should be corrected from absolute pressure of CCNC house-keeping data that was recorded during the flight. Secondly, the CCN spectrum should be analyzed for a target time period in each flight. Finally, the CCN number concentration should be corrected from the analyzed CCN spectrum and the pressure dependency of the equivalent SSw as described in this document.

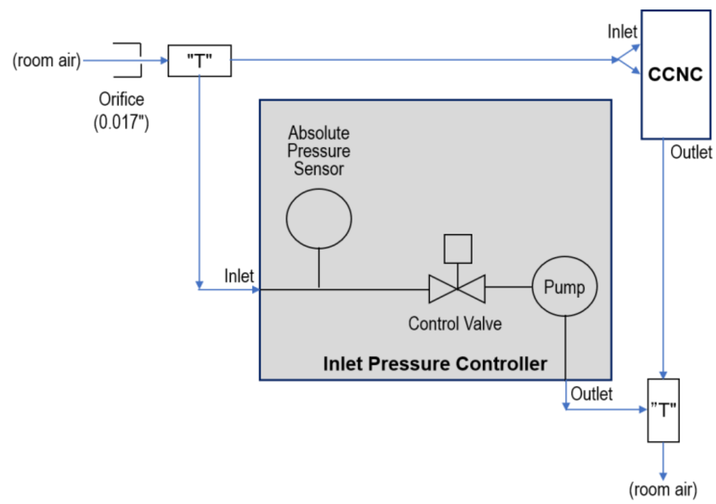

Fig. 3. Piping diagram for CCNC measurements in a depressurization test.

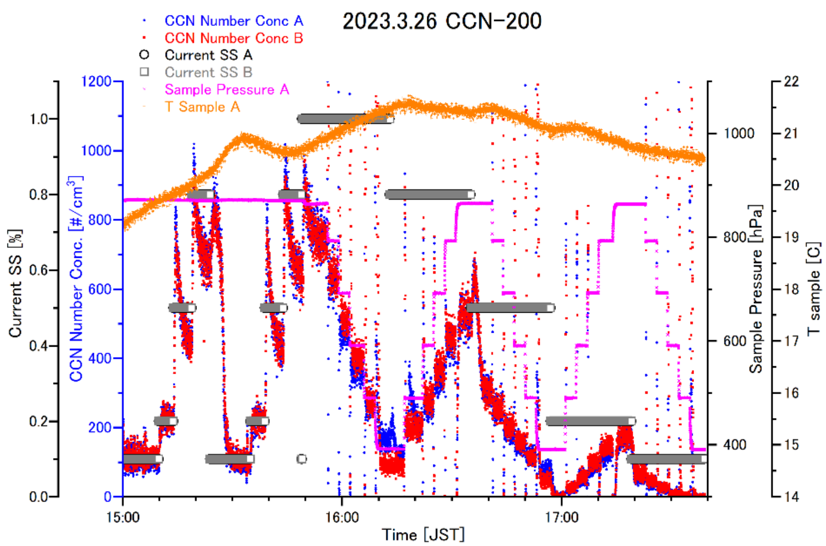

Fig. 4. Time series of the CCN spectrum measurements and depressurization test on 2023/3/26.

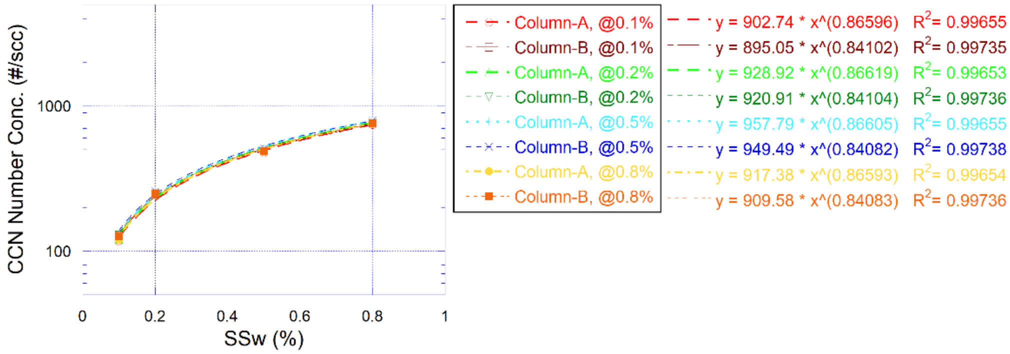

Fig. 5. The CCN spectra obtained on 2023/3/26 and curve-fitted, based on the measurement time period at each pre-specified SSw for each column.

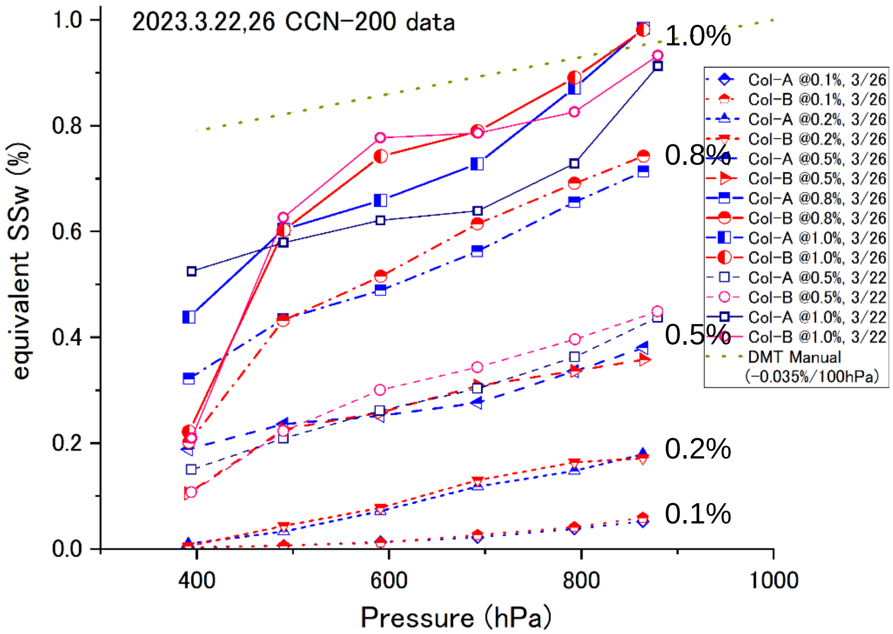

Fig.6. Equivalent SSw at each pre-specified SSw for each column, estimated from the CCN spectra obtained from the measurements on 2023/3/22,26.

Table 1. Linear regression of equivalent SSw as a function of pressure at pre-specified SSw for each column.

Column, pre-specified SSw	linear regression (x: Pressure[hPa], y: equivalent SSw[%])	Remarks (applicable conditions)
Column-A, 0.1%	y = −0.043+0.00010245 ∗ x	x ≥ 400
Column-B, 0.1%	y = −0.050851+0.00011825 ∗ x	x ≥ 400
Column-A, 0.2%	y = −0.14022+0.00036634 ∗ x	x ≥ 400; fixed to y = 0.2 for x ≥ 928.7
Column-B, 0.2%	y = −0.13773+0.0003771 ∗ x	x ≥ 400; fixed to y = 0.2 for x ≥ 895.6
Column-A, 0.5%	y = −0.019298+0.00047277 ∗ x	x ≥ 400
Column-B, 0.5%	y = 0.00016129+0.00046474 ∗ x	x ≥ 500
Column-A, 0.8%	y = 0.020518+0.00079874 ∗ x	x ≥ 400; fixed to y = 0.8 for x ≥ 975.9
Column-B, 0.8%	y = 0.022653+0.00083967 ∗ x	x ≥ 500; fixed to y = 0.8 for x ≥ 925.8
Column-A, 1.0%	y = 0.13197+0.00087464 ∗ x	x ≥ 400; fixed to y = 1.0 for x ≥ 992.4
Column-B, 1.0%	y = 0.23988+0.00080761 ∗ x	x ≥ 500; fixed to y = 1.0 for x ≥ 941.2