The isothermal haze chamber with discontinuous flow: a new experimental device for CCN measurements at low supersaturation

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Abstract

An isothermal haze chamber (IHC) has been designed, incorporating results from the tests of earlier instruments held at the 1981 Reno (NV) workshop. This instrument, named isothermal haze chamber with discontinuous flow (IHCDF), periodically discontinues the flow through the haze chamber in order to form a well-defined region of 100% RH in the center of the chamber. Indeed, tests performed with our conventional continuous flow IHC showed a poorly defined 100% RH field in the chamber, mainly due to an unsteady laminar air flow through the chamber during measurement.

Experiments with polydisperse NaCl aerosol showed that a supersaturation spectrum could be obtained within a growth time of 300 s, over a supersaturation range of 0.01–0.1%.

The instrument is suitable for field use. It is contained in a package 1.4 m high and weighs 5 kg. Three minutes is required to collect the air sample and 5 min for drop growth, thus permitting the analysis of seven samples per hour. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Isothermal haze chamber with discontinuous flow; Supersaturation; Aerosol

1. Introduction

The atmospheric aerosol and clouds are important to the earth radiative balance, and the aerosol is an important component of the atmospheric chemical balance. The atmospheric aerosol is composed of a large variety of materials (Heintzenberg, 1989;
Solomon et al., 1989; Saxena and Hildeman, 1996) including water, crustal dust, nitrate, sulfate, chloride, ammonium, sodium, black carbon, organic compounds and biologically derived substances. Aerosol is involved in many processes of tropospheric heterogeneous chemistry, oxidation reaction (see for example Chungtai et al., 1991), rain chemistry (Lacaux et al., 1992) and condensed vapors partitioning gas at low saturation vapor pressure (Pankow, 1987; Goss and Eisenreich, 1997).

Hobbs (1993) considers the role of the aerosol in global warming. Atmospheric aerosol has direct effects with scattering, back scattering to space and absorption of solar radiation and indirect effects by influencing earth cloud cover and cloud albedo. Clouds may be considered as both source and sink for atmospheric aerosol (Hegg et al., 1991; Radke and Hobbs, 1991). Particles nucleating or sorbed into cloud droplets, that are precipitated, form an atmospheric aerosol sink. Particles released during cloud evaporation have enough different properties to consider the cloud as an atmospheric aerosol source. This is a significant source of tropospheric aerosol and annual emissions should be around 3000 Tg yr\(^{-1}\) (Jaenicke, 1993) (see Table 1). Particles produced by cloud evaporation have specific granulometric, morphological and chemical characteristics different from those of the aerosol that initiates cloud droplets. This means that modified aerosol properties will modify cloud radiative properties and that cloud evaporation processes modify aerosol radiative properties.

The relationship between clouds and atmospheric aerosol is not well known because of the complexity of the heterogeneous chemistry reaction. The main criterion that characterizes a particle’s capacity to condense water vapor is the critical supersaturation \(S_c\). \(S_c\) is the water vapor supersaturation required to activate cloud condensation nuclei (CCN). The estimation of \(S_c\) is therefore indispensable to understand and quantify cloud droplet formation. The measured CCN concentration in various types of atmospheric air mass is generally described by the formula of Twomey (1959):

\[
N = CS^k
\]  

(1)

where \(S\) is atmospheric supersaturation expressed as a percentage, \(N\) is CCN concentration for a supersaturation equal to \(S\) (in cm\(^{-3}\)), \(C\) is CCN concentration for \(S = 1\%\) and

<table>
<thead>
<tr>
<th>Source</th>
<th>Strength (Tg yr(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Widespread surface sources</strong></td>
<td></td>
</tr>
<tr>
<td>Ocean and fresh water bodies</td>
<td>~ 1000–2000</td>
</tr>
<tr>
<td>Crust and cryosphere</td>
<td>~ 2000–</td>
</tr>
<tr>
<td>Biosphere and biomass burning</td>
<td>~ 450–</td>
</tr>
<tr>
<td>Volcanoes</td>
<td>~ 15–90</td>
</tr>
<tr>
<td><strong>Spatial sources</strong></td>
<td></td>
</tr>
<tr>
<td>Gas-to-particle conversion</td>
<td>~ 1300</td>
</tr>
<tr>
<td>Clouds</td>
<td>~ 3000</td>
</tr>
<tr>
<td>Extraterrestrial</td>
<td>~ 10</td>
</tr>
</tbody>
</table>
Table 2
Empirical parameters for the CCN concentration calculated with Twomey’s formula (Hegg and Hobbs, 1992)

<table>
<thead>
<tr>
<th>c (cm⁻³)</th>
<th>k</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>125</td>
<td>0.3</td>
<td>Maritime (Australia)</td>
</tr>
<tr>
<td>53–105</td>
<td>0.5–0.6</td>
<td>Maui (HI)</td>
</tr>
<tr>
<td>100</td>
<td>0.5</td>
<td>Atlantic, Pacific Oceans</td>
</tr>
<tr>
<td>190</td>
<td>0.8</td>
<td>Pacific</td>
</tr>
<tr>
<td>250</td>
<td>1.3–1.4</td>
<td>North Atlantic</td>
</tr>
<tr>
<td>145–370</td>
<td>0.4–0.9</td>
<td>North Atlantic</td>
</tr>
<tr>
<td>100–1000</td>
<td>–</td>
<td>Arctic</td>
</tr>
<tr>
<td>140</td>
<td>0.4</td>
<td>Cape Grim (Australia)</td>
</tr>
<tr>
<td>250</td>
<td>0.5</td>
<td>North Atlantic</td>
</tr>
<tr>
<td>25–128</td>
<td>0.4–0.6</td>
<td>North Pacific</td>
</tr>
<tr>
<td>27–111</td>
<td>1</td>
<td>North Pacific</td>
</tr>
<tr>
<td>400</td>
<td>0.3</td>
<td>Polluted North Pacific</td>
</tr>
<tr>
<td>100</td>
<td>0.4</td>
<td>Equatorial Pacific</td>
</tr>
<tr>
<td>600</td>
<td>0.5</td>
<td>Continental</td>
</tr>
<tr>
<td>2000</td>
<td>0.4</td>
<td>Continental (Australia)</td>
</tr>
<tr>
<td>3500</td>
<td>0.9</td>
<td>Continental (Buffalo, NY)</td>
</tr>
</tbody>
</table>

$k$ is a measurement adjusting coefficient to Twomey’s formula. Necessary parameters for Twomey’s formula calculation are shown in Table 2 (Hegg and Hobbs, 1992).

Hudson (1993) pointed out the importance of CCN study at $S_c < 0.1\%$ because this supersaturation is present in stratiform type clouds (Mason, 1971; Hudson, 1983). Stratiform clouds are considered to have the largest impact on global atmospheric albedo and this points out the necessity of having a reliable CCN measurement device for this important supersaturation range.

2. Review of CCN measurement devices

There are two predominant types of experimental devices to measure CCN. The first type is composed of the diffusion cloud chambers (Saxena and Kassner, 1970). The geometry, operating principles and droplet detection methods are described in Rea (1981). Diffusion cloud chambers require several independent measurements to determine the supersaturation spectrum. These diffusion cloud chambers work with continuous or discontinuous flow (Hudson and Squires, 1973, 1976; Rogers and Politovitch, 1981; Serpolay, 1981) and the available supersaturation range is about 0.1–3%. CCN spectrometers (Hudson 1993; Hudson et al., 1981) determine the supersaturation spectrum within a single sample in order to avoid the problems due to the time and space variability of the aerosol source. The available supersaturation range is 0.01–3% (Fukuta and Saxena, 1979; Radke et al., 1981; Hudson, 1989).

The continuous flow isothermal haze chambers (IHC) are the second type of experimental device for CCN measurement. They have been specially designed to operate at small critical supersaturations, in the range 0.01–0.1% (Alofs and Trueblood,
Latkionov (1972) presented an original method for CCN measurement with \( S_c \) ranging from 0.01% to 0.1%: starting with the equilibrium radius \( r_{100} \) of a droplet constituted from a particle in a 100% RH atmosphere, he linked \( r_{100} \) with \( S_c \) according to the following formula:

\[
S_c(\%) = \frac{200a}{3\sqrt{3}} \frac{1}{r_{100}}
\]

(2)

where \( a = 2M\sigma/\rho RT \), \( M \) is the molar mass of pure water, \( \sigma \) is the surface tension of pure water, \( \rho \) is the density of pure water, \( R \) is the perfect gas constant and \( T \) is the temperature in Kelvin. At 293 K, we have:

\[
S_c(\%) = \frac{0.041}{r_{100}(\mu m)}
\]

(3)

Eq. (3) allows the calculation of the supersaturation spectrum of an aerosol with a single measurement by means of an optical particle counter. It is not necessary to know the initial diameter of the particles, nor their chemical composition. Eq. (3) allows us to define the size spectrum range for the droplet, between 0.41 and 4.1 \( \mu \)m in radius, to obtain a supersaturation spectrum in the range of 0.01–0.1%.

The constant ‘\( a \)’ represents properties of pure water and may be affected by the chemical composition of the CCN. Some compounds present in the atmosphere act as surfactants, which may significantly modify the droplet surface tension (Andrews and Larson, 1993). Corradini and Tonna (1979) studied the Laktionov relation according to the electrolyte composition of continental and maritime aerosol and the variation of the Laktionov formula does not exceed 6%. The minimal amount of necessary soluble material in the dry particle to prevent any deviation from the Laktionov formula is around 5% in mass (Hoppel and Fitzgerald, 1977). Finally, at 20°C, a variation of ± 10°C in the temperature induces an error of ± 5% for \( S_c \).

The Reno workshop compared the performances of four different models of IHC (Fitzgerald et al., 1981). The results show that two IHC out of four agreed as near as 40% over the whole range of critical supersaturation. The third IHC is in agreement at small critical supersaturation values, but departs by a factor 2 at greater supersaturation. The fourth IHC could not be compared with the others because of the use of a different type of optical particle counter. Fitzgerald et al. (1981) explained the differences in the results obtained with the four IHC. Firstly, \( r_{100} \) is dramatically sensitive to the RH value inside the IHC. For example, a NaCl nucleus with initial radius of 0.2 \( \mu \)m, a growth in a 99.99% RH atmosphere will induce an 8% relative error in the critical supersaturation. This error will reach 90% with growth in 99.9% RH! The difference shown by the University of Colorado IHC (Hindman, 1981) is probably due to this reason. Secondly, the residence time of droplets in a 100% RH atmosphere must be long enough to allow them to reach their equilibrium radius \( r_{100} \). This time is theoretically about 7 min (Fukuta and Walter, 1970; Latkionov, 1972; Robinson and Scott, 1980).

In addition to this discussion, tests performed with the IHC designed by the Observatoire de Physique du Globe du Puy de Dôme (Garmy, 1985; Garmy and...
Serpolay, 1986) showed two major problems, mainly due to an unsteady laminar air flow through the chamber during measurement (Legrand, 1996). Firstly, the transfer time of the droplet is too short in the IHC, between 30 s and 5 min, instead of the 8.5-min theoretical transfer time. Furthermore, measurements are not reproducible without changing the experimental procedure. This problem may result from the flow velocity in the IHC. At low speed, the laminar flow seems to be unsteady, thus introducing a doubt about the RH field value (Legrand, 1996). Secondly, the time needed to obtain a homogeneous aerosol concentration in the IHC is 30 min. This induces problems in associating the supersaturation spectrum with the aerosol concentration source when this source varies with time.

The available instruments, including thermal diffusion chambers and IHC, allow the measurement of supersaturation spectra in an approximate range between 0.01% and 3% of $S_r$. This range represents the most important part of atmospheric supersaturations. However, the IHC problems highlighted by Fitzgerald and Legrand seem to originate from the inhomogeneity of the RH field value. As a consequence, it seemed necessary to conceive a new type of isothermal haze chamber with discontinuous flow (IHCDF). With the use of discontinuous flow, definitely reaching a 100% RH atmosphere becomes possible in the center of the IHC.

3. Technical description of the IHCDF

The operation of the IHCDF is based on Laktionov’s formula (3). A theoretical model taking into account the heat and mass transfer was elaborated in order to define the physical characteristics of the IHCDF. This model is based on the droplet growth equation (Fukuta and Walter, 1970), on the RH field equation inside the chamber, on the sedimentation velocity equation of droplets inside the chamber and on constraints in using the optical particle counter (airflow velocity, inlet diameter . . . ). Several thermodynamic parameters, such as temperature, incoming air humidity, temperature difference between incoming air and chamber interior wall, were separately studied. Fig. 1 shows a description of the IHCDF. The IHCDF is a PVC tube of height 1.1 m and 72 mm diameter, with an inner wall covered with a synthetic cloth constantly moistened during the measurement. With these dimensions and when the airflow is switched off inside the chamber, the theoretical time to obtain 99.999% RH in the center of the chamber is approximately 100 s.

Fig. 2 shows the operating principle of the IHCDF. The aerosol is introduced into the IHCDF (Fig. 2a) and the flow is then interrupted. Particles remain static in the chamber (Fig. 2b). The transfer pump is turned on after the necessary delay for the droplets to reach their equilibrium radius ($r_{eq}$) and the droplets are counted in the transfer flow with an optical particle counter (Fig. 2c). At first, we must define three different characteristic times for the IHCDF measurement procedure:

- **The homogenization time** refers to the necessary time for obtaining the same concentration of particles inside and outside the IHCDF. During this time, the sample pump is turned on. The homogenization time is equal to 3 min.
Fig. 1. Description of the isothermal haze chamber with discontinuous flow.

- **During the growth time**, the sample pump is turned off and particles remain inside the IHCDF. The growth time is the necessary time for the droplets to reach their equilibrium radius $r_{equil}$. The growth time value will be defined in Section 4.
- **The sampling time**: after the growth time, the sample pump is turned on and the sampling time is the time of droplet size spectrum measurement performed with the optical particle counter. The sampling time is the beginning of the homogenization time for the following measurement.

Therefore, there are four major phenomena to consider when optimizing the dimensions of the IHCDF prototype.

- Droplet sedimentation while they are in the chamber during the growth time. This can cause larger droplets to disappear before droplet size measurement.
- After the growth time, air humidity inside the chamber is equal to 100% RH. The small depressurization caused in the chamber when switching on the sample pump for droplet size measurement would induce a transient supersaturation by the way of adiabatic pressure drop, leading to an undesired growth of droplets.
Introduction of dry air in the chamber during droplet size measurement, thus causing droplet evaporation.

Difference between atmospheric temperature and IHCDF wall temperature may cause supersaturation inside the IHCDF. In order to avoid this problem, the chamber is mounted inside a second PVC tube. Both cylinders together enclose a volume in which ambient air circulates in order to homogenize the temperature of the device.

The modeling study, taking into account the four phenomena above described, allows us to define the dimensions of the prototype:

- **Total height of the chamber**: 1.1 m. In order to prevent larger droplet \( r = 4.1 \, \mu m \) sedimentation in the lower third of the chamber.
- **Radius of the chamber**: 3.6 cm. To get 99.999% RH in the center of the chamber as soon as possible and a sufficient Reynolds flow number to get a steady laminar flow during droplet size measuring.
- **Sampling flow**: 5.5 l/min. To get a steady laminar flow during droplet size measuring.
- **Sampling time**: 15 s. Sufficient for measurement and highest possible value to ensure sampling in the lower third of the chamber only, without mixing with dry air in order to prevent droplet evaporation.
- **Sampling vent**: \( \varnothing 18 \, mm \) and maximum sampling pipe length: 4 m. Both are mandatory to prevent depressurization in the chamber during droplet size measuring.
4. Experimental validation of the IHCDF

The experimental validation of the IHCDF is performed with a polydispersed NaCl aerosol. First experiments concerned the non-existence of leaks (air and water) inside the chamber and the non-production of particles by the IHCDF itself. These issues will not be dealt with in this paper. Two important points are developed hereafter. Firstly, it is necessary to evaluate depressurization consequences on the droplet growth during the droplet size spectrum measurement. Secondly, we must define the growth time value. This time must be long enough for the droplets to reach their equilibrium radius, and short enough to avoid the sedimentation of the largest droplets.

Fig. 3 shows the experimental device used for the experimental validation of the IHCDF. The aerosol source is a 520-l stainless steel tank, with 12 holes (in order to connect sample pipes). The aerosol is produced by nebulization of a NaCl solution of concentration from 1 to 100 g/l. The nebulization flow rate is 8 l/min and nebulization time is about 15 s. Because the laboratory humidity value is always lower than 70% RH, nebulized droplets quickly evaporate from the tank to leave polydispersed NaCl particles. A continuous flow (8 l/min) pump blows filtered air, allowing a non-contaminated dilution while sampling. Initial concentration is about 10,000 cm⁻³. This source is stable for about 2 h. The output concentration is measured with a TSI 3022 condensation particle counter.

The Polytec HC70G500 optical particle counter measures the size spectrum of droplets in the diameter range 0.7–21 μm in 128 channels. The highest measurable concentration is about 18,000 cm⁻³ with a 5% coincidence. A counting problem is present in the channels 0–39 (0.7–2.38 μm diameter), due to the acquisition software (Legrand, 1996). The data on those channels are to be used cautiously. However, this problem will have no consequence to the experimental study because it will be carried out with comparisons of droplet spectra in a relative mode. Furthermore, this counting problem concerns the smallest droplets, which are the least affected by sedimentation.

Fig. 3. Experimental device for the validation experiment.
and which rapidly reach their equilibrium radius $r_{\text{eq}}$. For absolute measurements (for field studies), the Polytec OPC is now driven by new acquisition software that corrects the counting problem present in the smallest channels.

The TSI 3022 condensation particle counter detects particles of radius greater than 10 nm, at concentrations less than $10^6$ cm$^{-3}$. It is used for aerosol source concentration checking and for normalized size spectra calculation.

4.1. Checking of depressurization consequences

In the first part of this experiment, we are going to evaluate consequences of depressurizations inside the IHCDF during droplet size spectrum measurement. Because of the high humidity value (100% RH) inside the chamber before the droplet size spectrum measurement, a small depressurization will cause a transient supersaturation in the chamber, by the way of an adiabatic pressure loss, when the sample pump is switched on. This transient supersaturation induces new growth of the droplets during droplet size measurement. Because of the short time of the droplet size measurement (15 s), the humidification system of the IHCDF will not be able to maintain the supersaturation and the added growth of droplets will be a function of the NaCl particle concentration introduced into the chamber. Fig. 4 presents the droplet arithmetic mean radius versus the injected concentration of NaCl nuclei for four depressurization values in the chamber: 450, 200, 100 and 50 Pa. The effect of the depressurizations is immediately shown (lined curves): the smaller the concentration of nuclei, the larger the mean radius of the spectrum. This characteristic increases with the importance of the

![Fig. 4: Droplet arithmetic mean radius versus injected NaCl nuclei concentration for four depressurizations (lined curves) and without depressurization (circle) inside the IHCDF. We can note the evolution of arithmetic mean radius with the variation of NaCl nuclei concentration when depressurizations are detected.](image)
depressurization. When the depressurization value is not detectable with our barometer, which is the case in the normal operating mode of the IHCDF, the mean radius does not depend on the nucleus concentration (black circles). In this case, there is no added droplet growth during size spectrum measurement. These results do not allow us to conclude that supersaturation does not increase during droplet size measurement. However, if supersaturation occurred when operating, it remained very low and had no influence on the droplet radius. Consequently, we admit that the depressurization created

Table 3
Summary of growth experiments

<table>
<thead>
<tr>
<th>Experiments</th>
<th>Concentration of the NaCl solution (g/l)</th>
<th>Number of measurements</th>
<th>Growth time studied (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>1</td>
<td>13</td>
<td>0, 0.5, 1, 2, 5, 10</td>
</tr>
<tr>
<td>7, 8, 12, 13, 14</td>
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<td>9, 10</td>
<td>6</td>
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</tr>
<tr>
<td>15, 16, 17, 18, 19</td>
<td>20</td>
<td>64</td>
<td>1, 3, 4, 5, 6, 7, 9, 10, 20</td>
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<td>34</td>
<td>60</td>
<td>38</td>
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<tr>
<td>37</td>
<td>100</td>
<td>7</td>
<td>5, 10, 15, 20</td>
</tr>
<tr>
<td>Total number of measurements</td>
<td>231</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
by the inlet pipe is very low, and does not induce supersaturation in the chamber during droplet spectrum measurement.

4.2. Definition of the growth time value

There is no possibility to directly check the growth time necessary for the droplets to reach their equilibrium radius $r_{100\%}$, because we cannot measure the NaCl nucleus size spectrum of the aerosol source. Consequently, there is no possibility to theoretically calculate the droplet spectrum with 100% RH. On the contrary, we have an aerosol

![Fig. 6. Determination of the growth time value. Experiment performed with a 20-g/l NaCl solution. The gray part represents the non-statistically significant part of the spectrum.](image-url)
source whose concentration is permanently known. To know whether the droplets remained long enough in the chamber to reach $r_{100}$, we have to compare the size spectrum measured according to their growth time in the chamber. The method used to compare the droplet size spectrum according to growth time is explained in Fig. 5. To achieve this comparison, we use the size spectrum normalized by the source concentration in order to take the source dilution into account. Droplets are considered to have reached their equilibrium radius when the normalized spectrum shape is independent of growth time. Several measurements are made during several growth times (three different growth times, and four to five measurements for each growth time). A specific growth time has been selected (5 min) to be used as a reference for all the experiments. Comparison may begin after checking the normalized spectrum statistical validity for each measurement. The mean spectrum for each growth time is calculated. The results are used to calculate the ratio of the mean spectrum for the growth time versus the mean spectrum for the 5-min growth time. Table 3 shows the achieved growth experiments.

Experiments made with a 20 g/l NaCl solution are used as an example. Fig. 6 shows the results for 1, 3, 4, 7, 8, 9, 10 and 20 min of growth time.

From this figure, we can determine three results:

- If growth time is shorter than 4 min, we see a lack of larger droplets. Growth time is not long enough to allow larger droplets to reach $r_{100}$.
- If growth time is longer than 9 min, a lack of larger droplets appears again. This is a result of sedimentation.
- When growth time is 4–9 min, the growth is the same in all the experiments. We can note that the growth of larger nuclei is slightly faster than its theoretical value (7 min).

An issue of this experiment is that the concentration of the largest droplets is not large enough to have a statistical validity over all the size range studied (from 0.82 to

![Fig. 7. Mean spectrum ratio at 10, 15 and 20 min of residence time for a 100 g/l NaCl solution. The non-statistically significant part of the spectrum: diameter superior to 13 μm.](image-url)
8.2 μm in diameter corresponding to a supersaturation range from 0.01% to 0.1%. To confirm good growth for the largest droplets, we made an experiment with a 100-g/l NaCl solution. Fig. 7 shows that sedimentation, for a growth time equal to 10 min, is effective for droplets larger than 10 μm, and the ratio ranges between 0.9 and 1.05 for droplets smaller than 10 μm in diameter. Here we see that droplets as large as 10 μm in diameter reach their equilibrium radius and the lower limit of the supersaturation spectrum can be smaller than 0.01% if the concentration of the largest droplets is large enough.

As a result of these experiments, we have chosen a growth time of 5 min to obtain spectra in the standard measurement procedure. This growth time can be set from 4 to 9 min.

Fig. 8a gives an example of field use of the IHCDF in an urban area (Toulouse, France). Measurements were performed on September 1st, 1998, between 03:20 and 16:40 h. The thick curve represents the temporal evolution in CCN concentration at 0.1% supersaturation (CCN (0.1%)) and the thin curve represents the temporal evolution in the total particle concentration measured with the TSI 3022 condensation nuclei counter. Fig. 8b shows an example of a supersaturation spectrum measured at 12:05 h.

![Fig. 8. Application of the IHCDF in urban atmosphere (Toulouse, France). (a) Evolution with time of the CCN (0.1%) concentration (solid thick curve) and of the CN concentration (solid thin curve). (b) Example of supersaturation spectrum performed at 12:05 h. Day September 1st, 1998, 03:20–16:40 h.](image)
With a measurement every 8 min, the temporal resolution of the IHCDF reveals significant variations in CCN (0.1%) concentration during the day, between 350 and 710 cm$^{-3}$. It also shows fluctuations in this concentration within time intervals of about half an hour. All the results obtained during this experiment as well as their interpretation shall be dealt with in a future article.

5. Conclusions

The review of CCN measurement devices has shown that the problem inherent to the isothermal haze chamber with continuous flow is linked to an uncertainty in the RH field value in its center. The isothermal haze chamber with discontinuous flow allows a reliable 100% RH field value to be attained in its whole volume. The necessary time to complete a supersaturation spectrum is 8 min (3 min to collect the air sample and 5 min for drop growth). The short homogenization time (3 min) allows us to have a good time resolution of CCN source fluctuations. However, the main limit of the IHCDF comes from the short sample time available (15 s). As a matter of fact, the optical sample volume after 15 s is only 1.6 cm$^3$ and the CCN concentration must be rather high to get a droplet spectrum statistically significant. In this case, we accumulate several consecutive spectra but this induces a loss of information on the temporal evolution of the CCN source. The IHCDF small dimensions, of 1.4 m height and 10 kg weight, allow easy field use. Moreover, an adapted version of the IHCDF can be designed for aircraft platform instrumentation.

References


