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ICICLE 2019 Data Guide: Aerosol

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Ver. 1.0

National Research Council Canada | Conseil national de recherches Canada

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LIST OF ABBREVIATIONS

ARC	Aerospace Research Center
CCNc	Cloud Condensation Nuclei Counter
CPC	Condensation Particle Counter
CPI	Constant Pressure Inlet
DAS	Data Acquisition System
DMT	Droplet Measurement Technologies Inc.
ECCC	Environment and Climate Change Canada
FRL	Flight Research Laboratory
LWC	Liquid Water Content
NRC	National Research Council of Canada
PI	Primary Investigator
SP2	Single Particle Soot Photometer
TWC	Total Water Content
UHSAS	Ultra-High Sensitivity Aerosol Spectrometer

1.0 DATASET OVERVIEW

1.1 Introduction

In this data release, we included the aerosol data collected during the ICICLE field campaign, between the months of January and March 2019. ECCC instruments (i.e. SP2, CCNc, CPC, UHSAS-G) were installed in the aircraft cabin (Fig. 1). An isokinetic laminar flow was sampled by the instruments through a heated inlet, on top of the aircraft fuselage (Fig. 2). Utilizing this setup, the instruments sampled the total aerosol concentration (consisting of the combined interstitial and residual particles). In addition, in flights F26 – F30, NRC's UHSAS was installed on the wingtip. The sampling locations are illustrated in Fig. 3.

The Cabin UHSAS [1], SP2 [2], and CCNc [3] were calibrated and integrated at the NRC FRL facility. Parameters such as aerosol size distribution, total aerosol concentration, CCN concentration, and black carbon content were derived from the measurements. Data were checked for availability and corrected for time synchronization. NRC intends to continue the analysis of aerosol data and to publish a laboratory technical report. The result and the associated publications will be shared with ICICLE partners.

1.1.1 Aerosol Sampling Biases

The sampling of aerosol in clouds was significantly affected by the presence of hydrometeors. In the aerosol dataset, we included Nevzorov-based in-cloud masking to facilitate isolation of the clear air periods.

Low pressure at high altitude is another source of bias, in particular for CPC [4] and CCNc (despite the constant pressure inlet set at 600 mbar [5]), for this reason we included the ambient pressure variable with this dataset.

Figure 1. Aerosol rack in the cabin.

Figure 2. Heated aerosol sampling inlet.

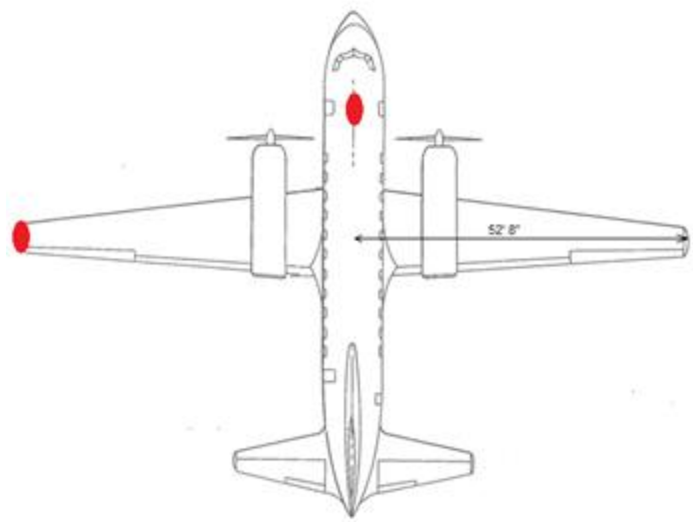

Figure 3. Aerosol sampling location indicated in red on NRC's Convair-580 schematics.

1.2 Spatio-Temporal Information

Flight Campaign Time Period: January 18 to April 25 2019

Total Number of Flights: 31

Aerosol data included: February 27 to March 08 2019 (F02 – F30)

Flight Campaign Regions: Southern Ontario Canada, North-Eastern USA

1.3 Dataset Source and Contact Information

Preparation Agency: National Research Council of Canada (NRC)

Agency Subdivision: Aerospace Research Center (ARC), Flight Research Laboratory (FRL)

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2.0 AEROSOL INSTRUMENTATION DESCRIPTION

2.1 Ultra-High Sensitivity Aerosol Spectrometer (cabin UHSAS, DMT)

Description:

- Optically measures aerosols in the aerosol diameter range 60 nm < D_p< 1 µm
- Sizing accuracy at 1 – 2 % of particle diameter
- 1054 nm laser eliminates sizing uncertainty frequently associated with scattering spectrometers that measure sizes larger than the excitation wavelength.
- Particles size distributions collected in up to 100 size bins
- Can output size distributions at rates up to 10 Hz
- Counts up to 3,000 particles s^{-1}
- Uses two detection systems: a primary, highly sensitive Avalanche Photo-detector (APD)-based system to size smaller particles, and a secondary PIN photodiode system to size larger particles

Model: UHSAS-G, Serial Number: 1210-039

Instrument Location: Aircraft Cabin

Primary Measured Parameters: Diameter, Concentration

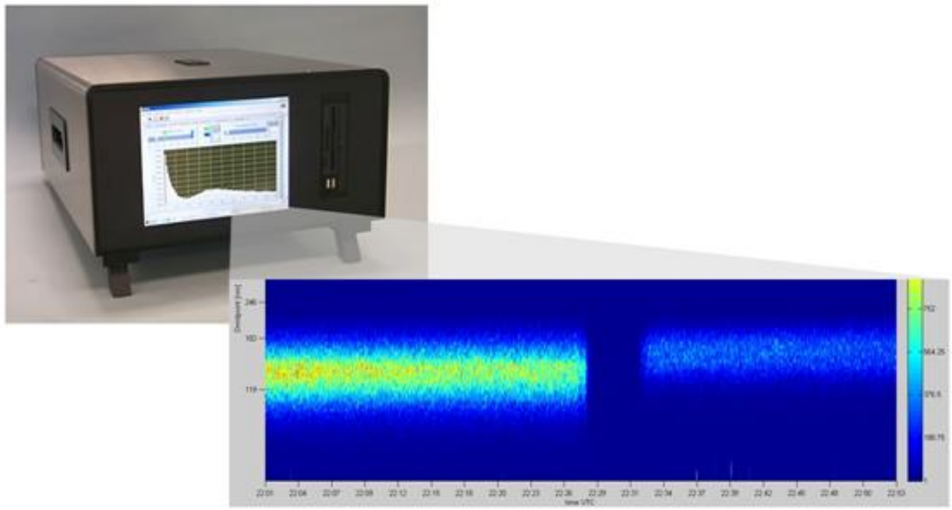

Figure 4. Cabin UHSAS picture, with displayed particle size distribution time series.

2.2 Ultra-High Sensitivity Aerosol Spectrometer (wing UHSAS, DMT)

Description: same as in section 2.1. For more details see [6].

Model: UHSAS-A, Serial Number: 1710-011

Instrument Location: Canister wing tip

Primary Measured Parameters: Diameter, Concentration

Figure 5. Wing UHSAS.

2.3 Cloud Condensation Nuclei counter (CCNc, DMT) with Constant Pressure Inlet (CPI, DMT)

Description:

The CCNc draws the aerosol through a column preconditioned with supersaturated water vapor, which can condense onto aerosol particles. Particles that are activated and grown larger as they pass through the column, are counted by an optical particle counter and sized by forward light scattering detection. Thus, activated ambient aerosol particle number concentration as a function of set supersaturation is measured. The instrument can operate in a scanning or in a constant supersaturation mode.

The CCNc was equipped with a CPI, to maintain a constant pressure sampling set at 600 hPa. The constant pressure was maintained with a 0.020 critical orifice up to about 4.5 km altitude (Appendix-B in [5]). At higher flight altitude 4.5 - 7 km, the CPI pressure reached lower values, down to 480 hPa, affecting the quality of the CCN measurements. In these cases, measured concentration at set supersaturation require additional corrections [5].

Model: CCNc-100 with Controlled Pressure Inlet, Serial Number: 1110-0098

Instrument Location: Aircraft Cabin

Primary Measured Parameters: Concentration of activated droplets, Size

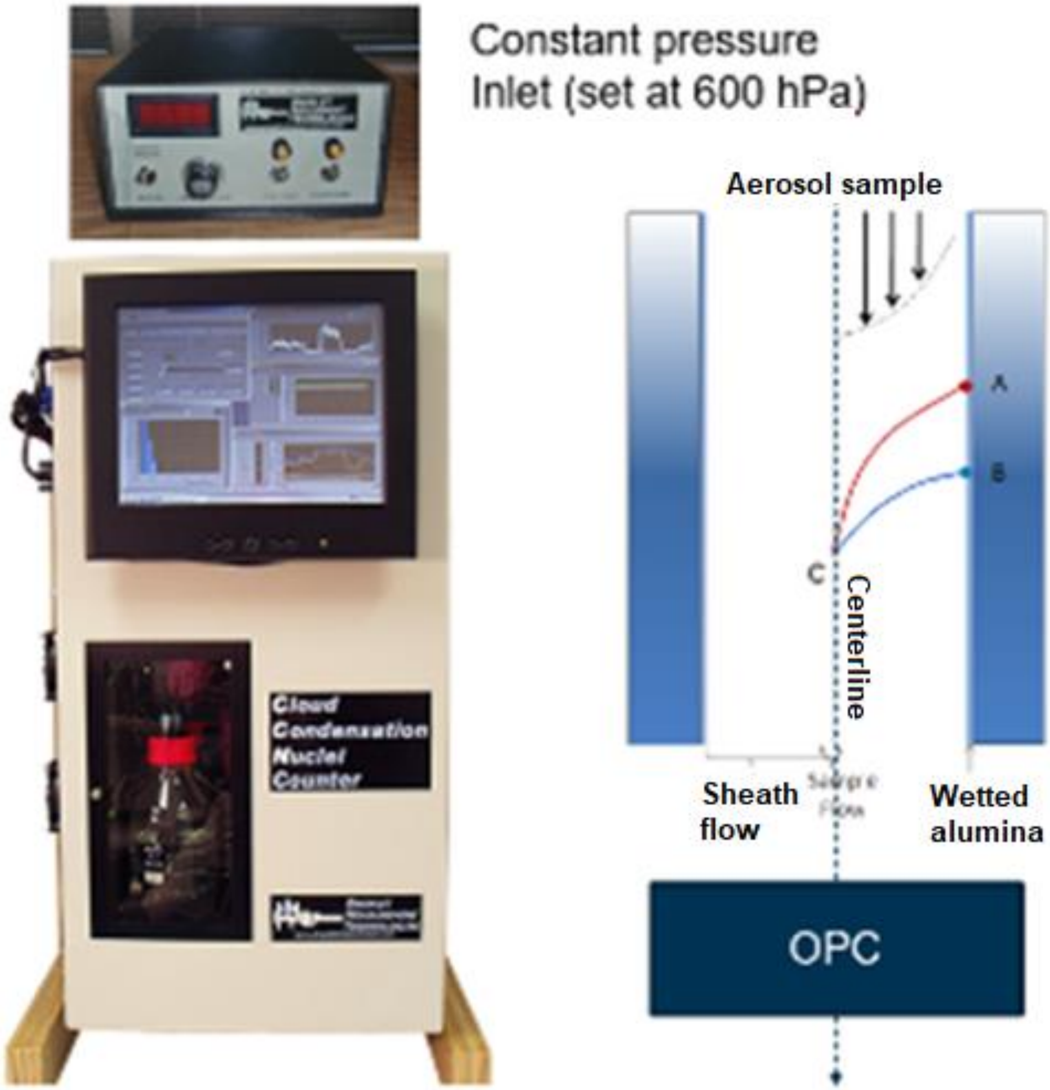

Figure 6. CCNc-100 with constant pressure inlet set at 600hPa, image adapted from manufacturer's website.

2.4 Condensation Particle Counter (CPC, TSI)

Description: Condensation Particle Counter 3775 is a general-purpose counter that detects airborne particles down to 4 nm. It provides highly accurate measurements over a wide concentration range from 0 to 10^7 particles cm^{-3}. With the built-in high vacuum pump, the CPC is capable of operating at altitude up to 2 km or inlet pressures down to ~750 hPa. During the ICICLE field campaign, the aircraft occasionally climbed up to 7 km (reaching a minimum static air pressure of 410 hPa). The reduced pressure will essentially have an impact on the flow through the internal critical orifice and reduce the 1-butanol saturation ratio in the internal condenser. Therefore, altitude dependent bias in counting efficiency was inevitable. Furthermore, the instrument uses liquid butanol reservoir and it is therefore sensitive to tilting e.g. during pitch and roll maneuvers.

Model: CPC 3775

Instrument Location: Aircraft Cabin

Primary Measured Parameters: Total Concentration

Figure 7. CPC 3775.

2.5 Single Particle Soot Photometer (SP2, DMT)

Description: Measures incandescence and light scattering from single particles [2]. Detects scattering aerosol in the range ~200 – 430 nm, and black carbon particles in the range 60 – 600 nm.

Instrument Location: Aircraft Cabin

Primary calculated Parameters: Black carbon mass and equivalent diameter, Black carbon concentration

Secondary calculated Parameters: Light scattering particle mass and equivalent diameter, light scattering concentration.

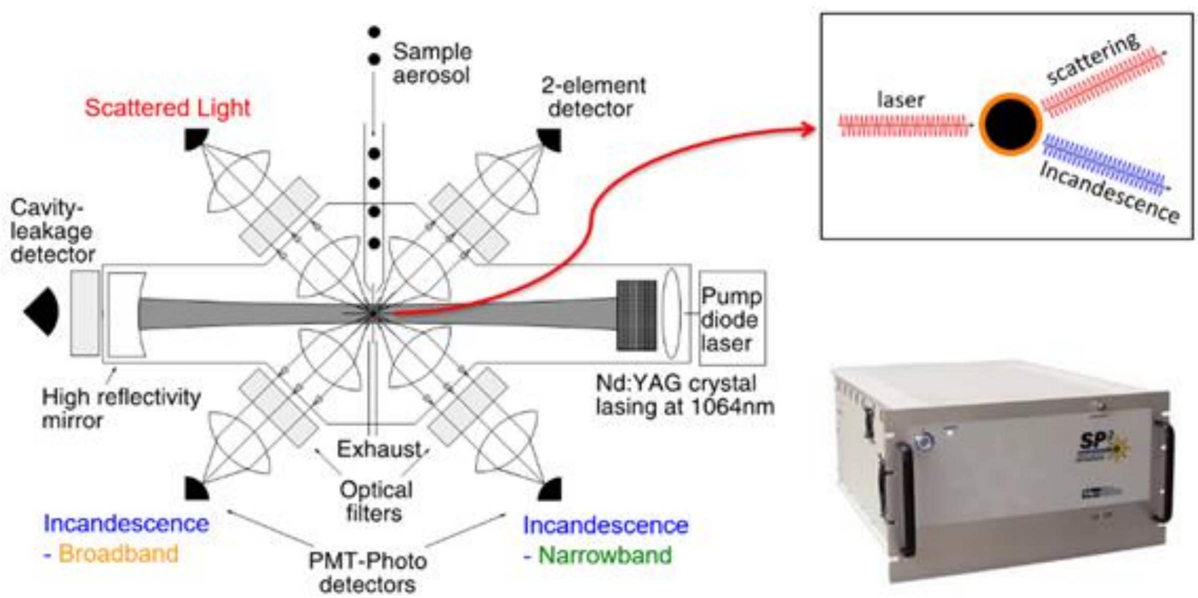

Figure 8. Schematic reproduced from [7].

2.6 Aerosol Measured Parameters

Table 1. A summary of aerosol measured parameters.

Parameter Name	Description	Primary Sources	Secondary Sources
Total concentration [cm^{-3}]	Total aerosol concentration of particles in the range ~ 4 to ~3000 nm.	CPC	UHSAS
CCN concentration [cm^{-3}]	Concentration of activated aerosol at set supersaturation with respect to water.	CCN	
Size distribution	Size distribution in the range 60 – 1000 nm.	UHSAS	SP2
Mass concentration [$ng\ m^{-3}$]	Single particle information of scattering particles: (equivalent diameters of ~200 – 430 nm) and black carbon particles: (equivalent diameters of 60 – 600 nm).	SP2	
Morphology/ mixing state	Scattering and incandescence signal time delays allow to estimate the morphology e.g. core shell, dimer structure.		
Composition	Fraction of black carbon and optically scattering materials.		

3.0 DATA COLLECTION AND PROCESSING

3.1 Description of data collection

Aerosol data collection in each flight started shortly after takeoff and ended few minutes before landing to avoid inlet contamination from the runway. The data was stored internally on instrument HD and rebroadcasted to DAS (Data Acquisition system) for redundancy and time synchronization. Transmitted packets are all collected into one file and then preprocessed.

In the processing step, the raw data is converted to NetCDF format, and corrected for any time gaps and anomalies followed by calculation of parameters. The detailed steps are listed below:

- **Conversion to NetCDF:** The data is converted to NetCDF from the raw network packets recorded on the DAS.
- **Time Anomaly Correction:** Timing errors may sometimes arise. This includes issues of timing resets, a transition from 11:59:59PM to 12:00:00AM and more.

- **Resampling:** The time spacing of all parameters is made uniform. This entails interpolation to make the time spacing intervals equal for the whole time series. Resampling in this case is done to 1Hz.
- **Correction of Aerosol Parameters:**
  - **Synchronization:** Each of the four probes was analyzed for any timing delays. The synchronization was done one instrument at a time. The UHSAS was recorded on two different DAS. These two different sources were confirmed to be synchronized, thus confirming that the UHSAS can be used as a reference instrument to validate CPC and CCNc synchronization. Using the UHSAS reference, the CPC was confirmed to be well synchronized. Finally, the standalone CCNc data was corrected for delays, until all three probes were properly synchronized.
  - **Conversion of counts to concentration:** The bin counts were converted from an integer count quantity to a concentration quantity. This was done by dividing the counts per second by the flow per second, going from counts s^{-1} to counts cm^{-3}.

3.2 Description of data products and quality control

Table 2. Processing data levels.

Product level	Data type	Output Data Structure	Note
Level 0	Raw	Delimited/binary	Stored at NRC and typically not distributed
Level 1	NetCDF	Standard UCAR NetCDF Format	Data release (initial QC)
Level 2	NetCDF	Standard UCAR NetCDF Format	Derived parameters are calculated. Documentation on data quality accompanies the data. Basic QC applied to the data.

4.0 DATA REMARKS

4.1 Data Assessment Comments from PI

- Data require further scrutiny and flagging. In particular, ambient pressure and in cloud masking provided in the dataset should be taken into consideration in quantitative analysis.
- More information, including periods of known instrument malfunctioning will be described in a laboratory technical report prepared by NRC.

4.2 Missing Data Periods

Table 3. Data availability is presented in the table below. Last column indicates data gap periods.

		UTC		
Flight	Instruments	data start	data send	gap1
F02	CCN	18:17	21:09	
	UHSASc	18:17	21:09	
	CPC	18:17	21:09	
F03	CCN	20:13	22:58	
	UHSASc	20:13	22:58	
	CPC	20:13	22:58	
F04	CCN	18:07	21:36	
	UHSASc	18:07	21:36	
	CPC	18:07	21:36	
F05	CCN	16:18	20:09	
	UHSASc	16:18	20:09	
	CPC	16:18	20:09	
F06	CCN	12:32	16:17	16:06-16:11
	UHSASc	12:32	14:49	14:49-16:17
	CPC	12:32	16:17	16:06-16:11
F07	CCN	18:05	22:04	
	UHSASc	18:05	22:04	
	CPC	18:05	22:04	
F08	CCN	19:04	22:49	
	UHSASc	19:06	22:49	
	CPC	19:33	22:49	
F09	CCN	18:13	21:57	
	UHSASc	18:12	21:57	
	CPC	18:14	21:57	
F10	CCN	transfer flight		
	UHSASc			
	CPC			
F11	CCN	16:43	18:44	15:07-16:43
	UHSASc	15:57	18:42	15:07-15:57
	CPC	16:44	18:44	15:07-16:44
F12	CCN	11:16	14:58	
	UHSASc	11:16	14:58	
	CPC	11:16	14:58	
F13	CCN	16:59	19:41	
	UHSASc	16:59	19:41	
	CPC	16:59	19:41	
F14	CCN	16:22	20:29	
	UHSASc	16:22	20:29	
	CPC	16:22	20:29	
F15	CCN	19:37	23:55	
	UHSASc	19:37	23:55	
	CPC	19:37	23:55	
F16	CCN	1:21	5:29	
	UHSASc	1:21	5:29	
	CPC	1:21	5:29	

		UTC		
Flight	Instruments	data start	data send	data gap
F17	CCN	12:07	16:02	
	UHSASc	12:07	16:02	
	CPC	12:07	16:02	
F18	CCN	16:58	20:11	
	UHSASc	16:58	20:11	
	CPC	16:58	20:11	
F19	CCN	16:27	21:07	
	UHSASc	16:27	21:07	
	CPC	16:27	21:07	
F20	CCN	12:06	16:05	
	UHSASc	12:06	16:05	
	CPC	12:06	16:05	
F21	CCN	11:59	15:38	
	UHSASc	11:59	15:38	
	CPC	11:59	15:38	
F22	CCN	17:11	20:55	
	UHSASc	17:11	20:55	
	CPC	17:11	20:55	
F23	CCN	17:26	20:44	
	UHSASc	17:26	20:44	
	CPC	17:57	20:44	17:26-17:57
F24	CCN	22:52	2:38	22:45-22:52
	UHSASc	22:45	2:38	
	CPC	22:45	2:38	
F25	CCN	17:56	22:16	
	UHSASc	17:56	22:16	
	CPC	17:56	22:16	
F26	CCN	10:35	14:47	
	UHSASc	10:35	14:47	
	UHSASw	10:28	14:52	
	CPC	10:35	14:47	
F27	CCN	16:14	19:52	
	UHSASc	16:14	19:52	
	UHSASw	16:06	19:53	
	CPC	16:14	19:52	
F28	CCN	11:57	16:17	
	UHSASc	11:57	16:17	
	UHSASw	11:50	16:20	15:55
	CPC	11:57	16:17	
F29	CCN	16:18	21:02	
	UHSASc	16:18	21:02	
	UHSASw	16:15	21:09	
	CPC	16:18	21:02	
F30	CCN	16:06	18:49	
	UHSASc	16:06	18:49	
	UHSASw	16:06	18:49	
	CPC	16:06	18:49	

4.3 Software Compatibility

The NetCDF files are compatible with the NCplot software**.** In addition, interactive html files are provided for every flight. These files are viewable on all common browsers. For best performance, we recommend using Mozilla Firefox. An example of html file is shown in the figure below.

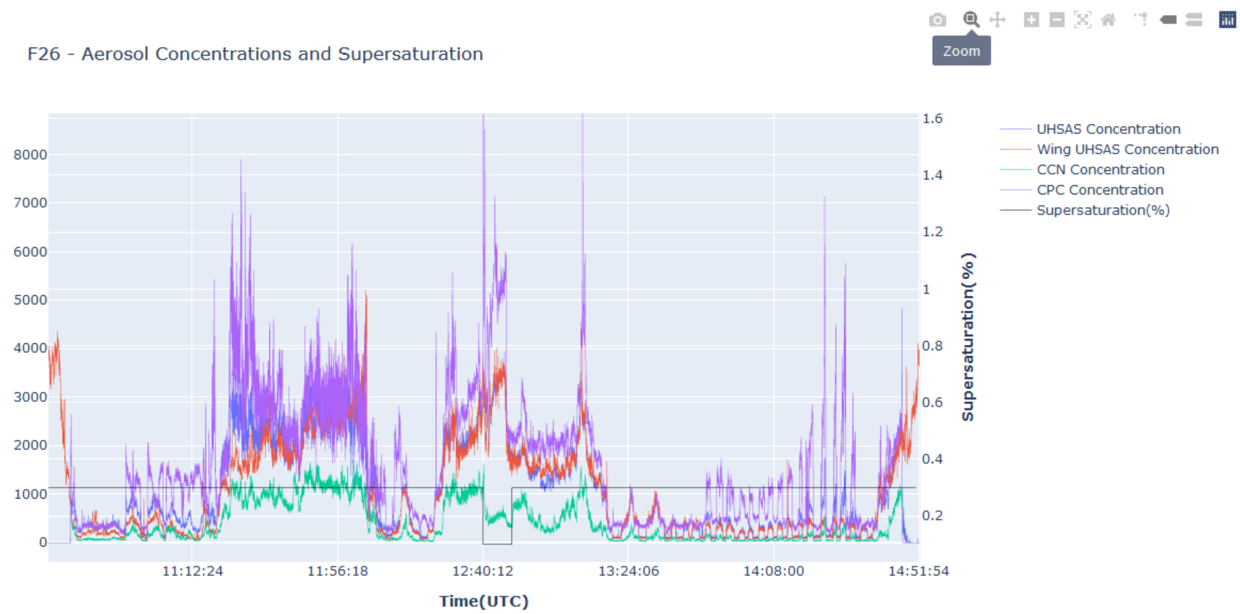

Figure 9. An example of interactive html file (Flight 26).

5.0 REFERENCES

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