Characterizing the Size and Composition of Cloud Condensation Nuclei (CCN) and Ice Cloud Nuclei (IN) over the North Slope of Alaska

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Single Particle Mass Spectrometer - SPLAT II

SPLAT II on board of Convair-580

- Provides in *real-time* the size and internal composition of individual particles in 50 nm to 3 µm size range
- Measures refractory and non-refractory aerosol fractions in each particle
- Yields size distributions *(d_{va})* and number concentrations
- Sampling rate: sizes up to 2000 p/sec, 20-50 of which are also chemically characterized
- High sensitivity: detects 40% of 100 nm particles, and at least 1 p/sec for an aerosol sample of 1p/cm^3 with d>100 nm
- Provides *real-time* information about particle asphericity
- Yields densities for particle classes with different internal compositions

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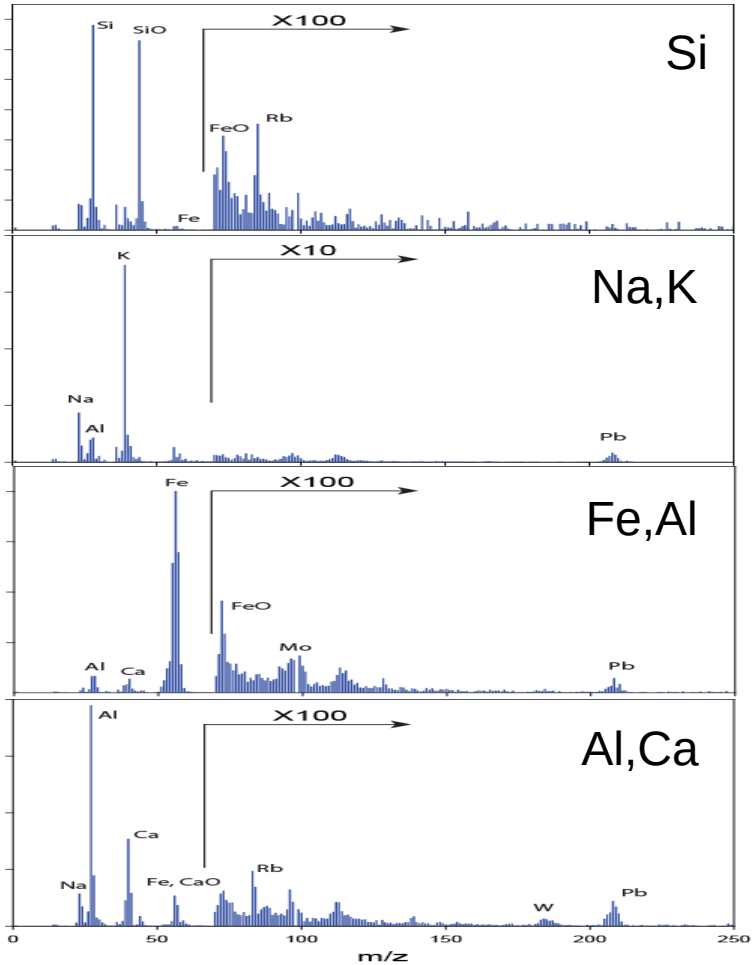
SPLAT II - ISDAC Data

- SPLAT II participated in all 27 flights (over 100 hrs)
- 10s of millions particles were sized and over 3 million of them chemically characterized
- SPLAT II was sampling particles alternately through the aerosol inlet, to characterize the composition and size of the overall aerosol population, and through the CVI inlet to characterize the composition and size of particles that served as CCN and IN.
- SPLAT II measured a wide range of particle compositions, including sulfates and nitrates mixed with organics, processed and freshly emitted sea-salt, dust, metallic particles, and a significant number of biomass burning particles, transported from Asia. Many of these particle types appeared in horizontal and vertical filamentous layers.
- *Previously presented data: April 19, Flight 25 & 26 (highly polluted day)*

SPLAT II - ISDAC Data



Example of a few particles that served as ice nuclei

- In addition to characterization of the overall aerosol population SPLAT II provided information on composition and size of particles that served as CCN and IN.
- *Previously presented IN data: April 19, Flight 25 & 26 and April 1, Flight 9*
- Preliminary analysis of the data on IN revealed a number of interesting findings. SPLAT II has shown that for the large fraction of IN particles are either metallic or composed of dust and that a significant fraction of these particles are as small as 100 nm in diameter. We have also detected episodes during which copper particles, as small as 50 nm, serve as IN.
- *Today's example: April 26, Flight 31*

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Flight 31 flight track
Mixed phase cloud over the ocean
2nd Golden day with single-layer stratocumulus

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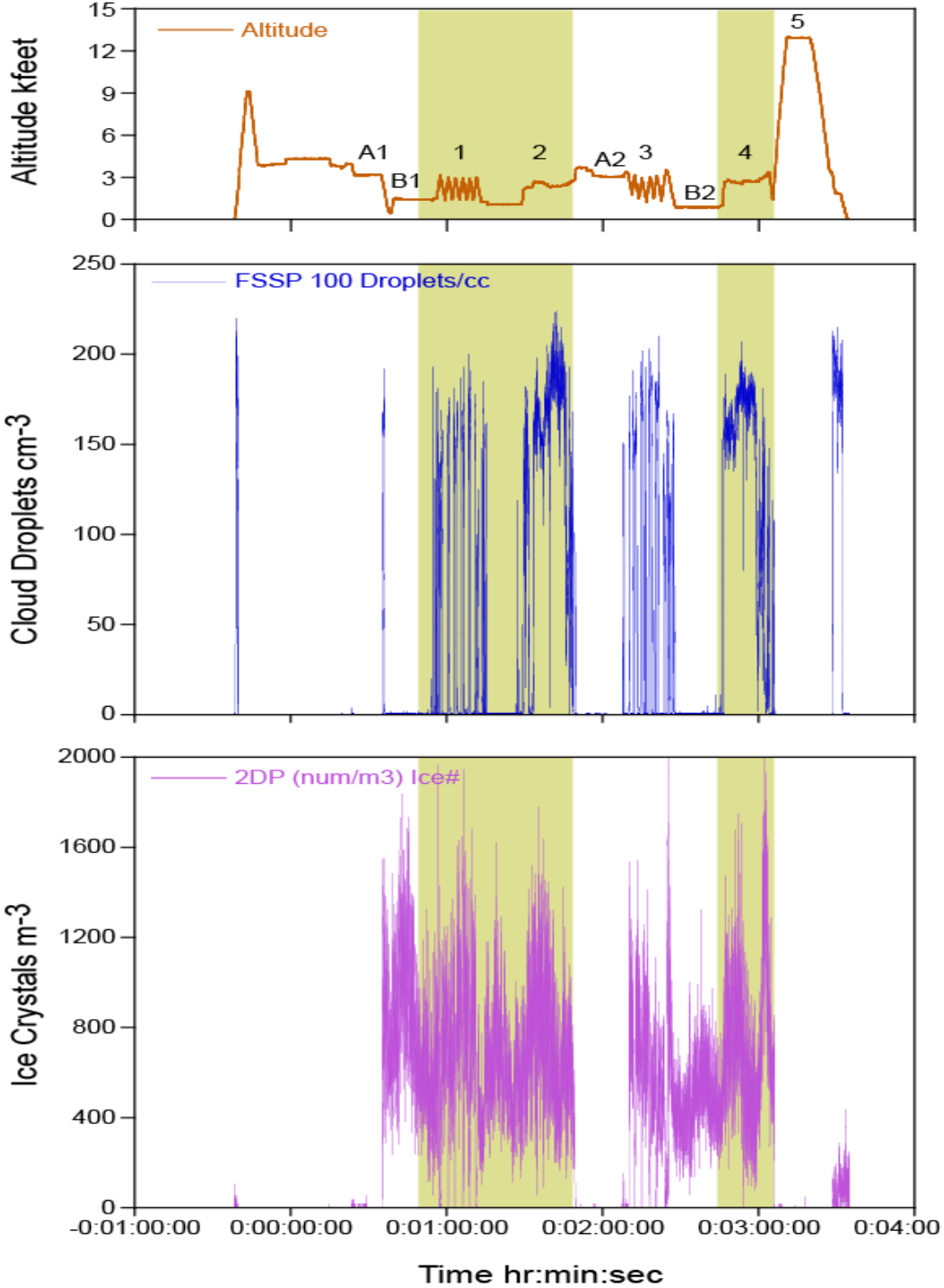

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- Four in-cloud characterization segments, three of which through the CVI 1, 2, 4 (cream colored areas) and once with no CVI, 3.
- Segments 1, 2, 4 provide data on CCN, and 3 can be used to find out which particles do not get activated.
- Segments A1, A2, B1, B2 are used to get information about particles above and below the clouds.
- Segment 5 provides a view of particles at higher altitudes.
- Ice particle concentrations were >1000 lower than droplet concentrations - too low to characterize IN

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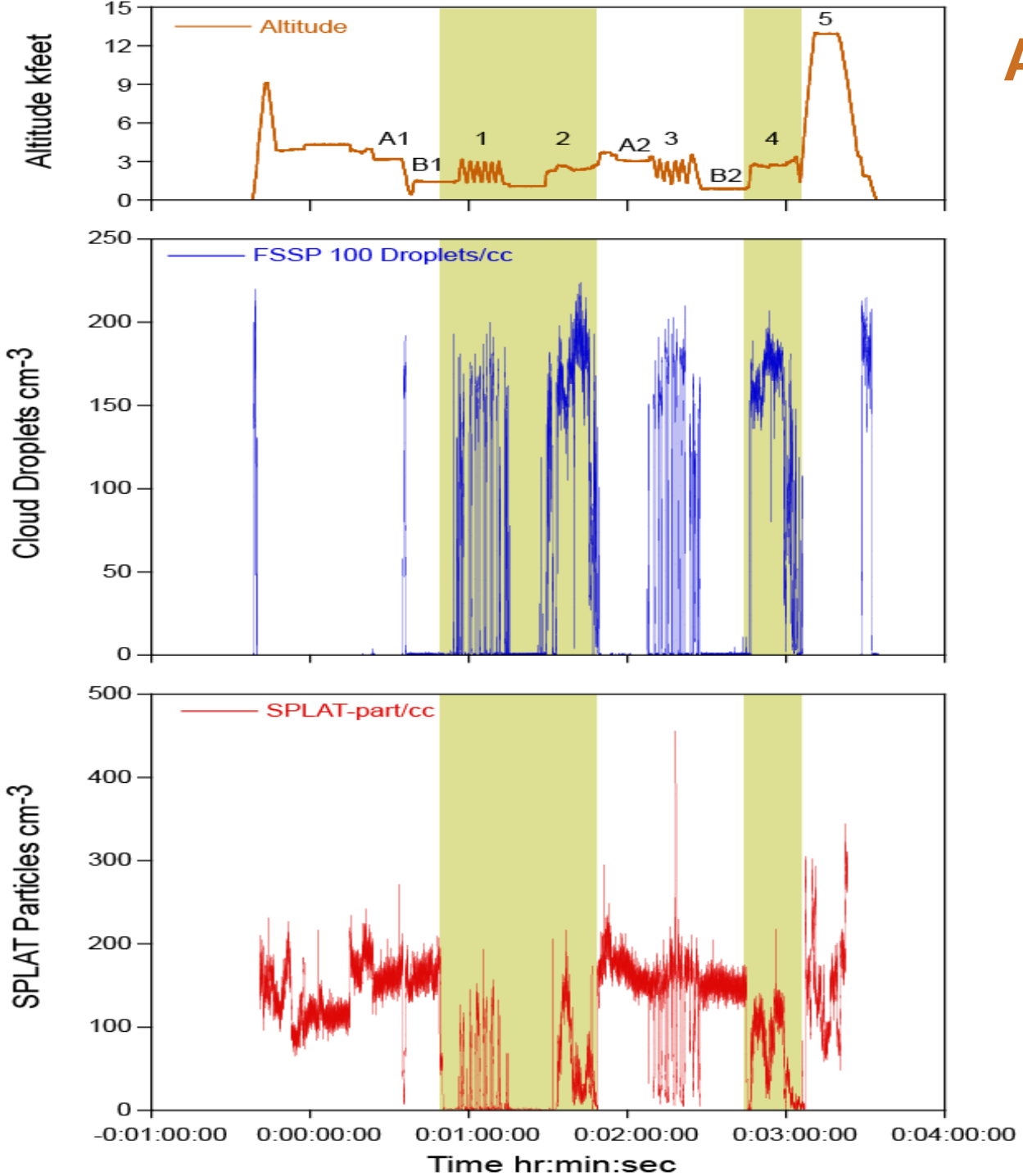

SPLAT II measured number concentration of particles during the same flight

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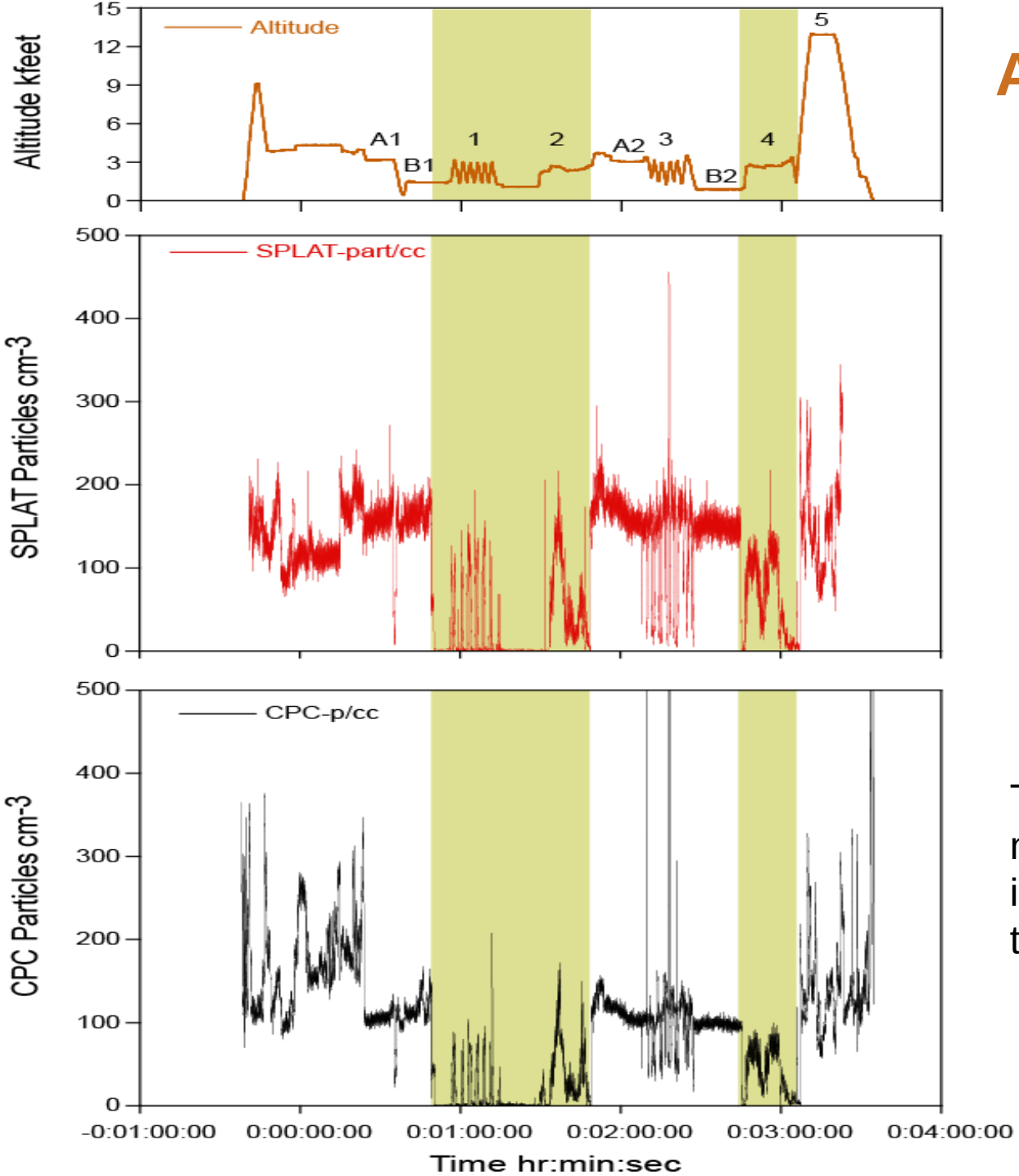

The SPLAT measured number of particles/cc are in excellent agreement with the CPC counts

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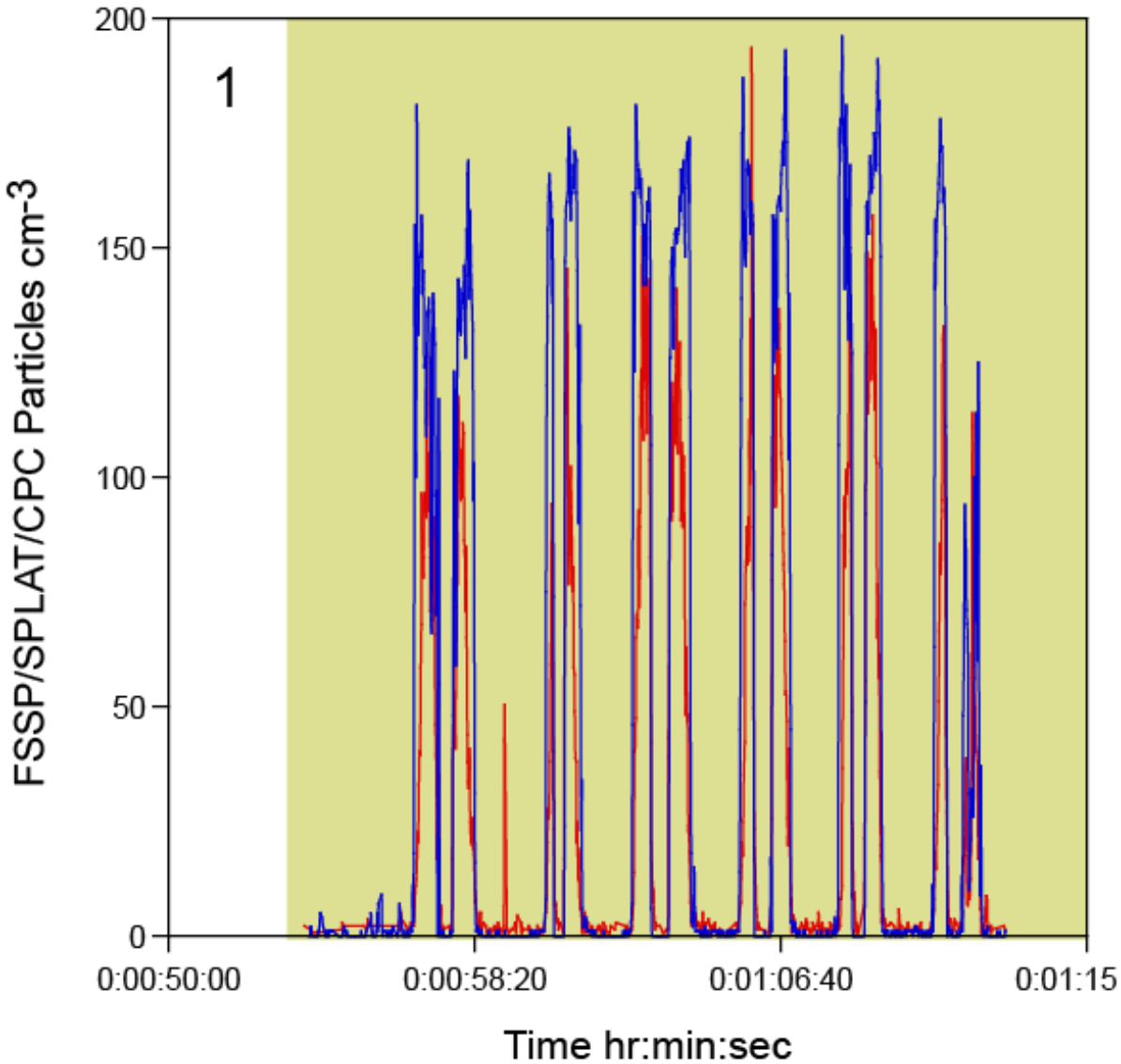
Sampling CCN



Segment 1 involved cloud characterization by purposing through the cloud and sampling through the CVI. The number of particles detected by SPLAT (red) is in perfect correlation with the FSSP count (blue).

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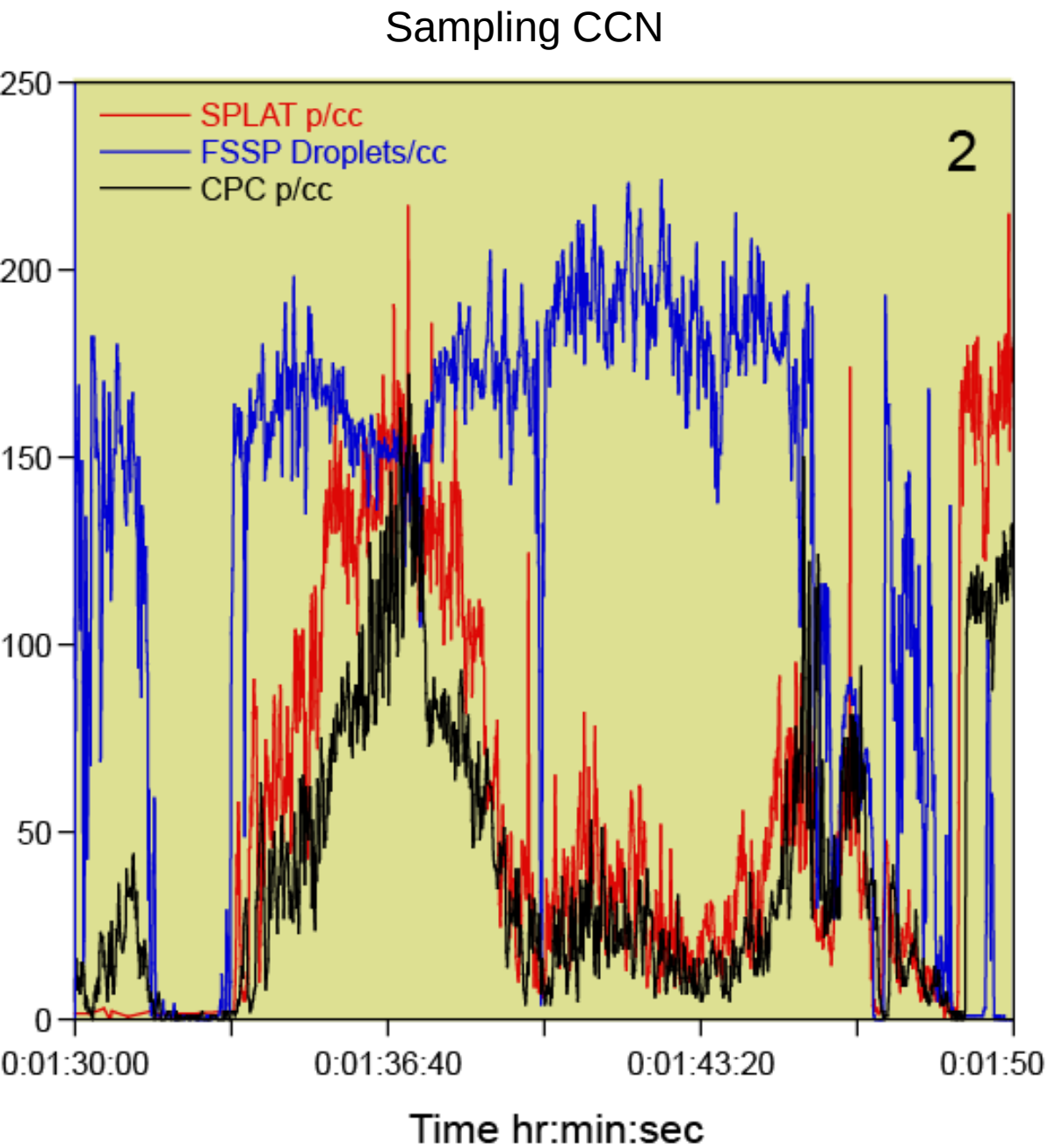

Segment 2 involved cloud characterization at constant altitude and sampling through the CVI.

The number of particles detected by SPLAT (red) is not correlated with the FSSP count (blue), but it is perfectly correlated with the CPC.

This indicates that the cloud droplets sizes varied through the cloud and a significant fraction was not transmitted by the CVI.

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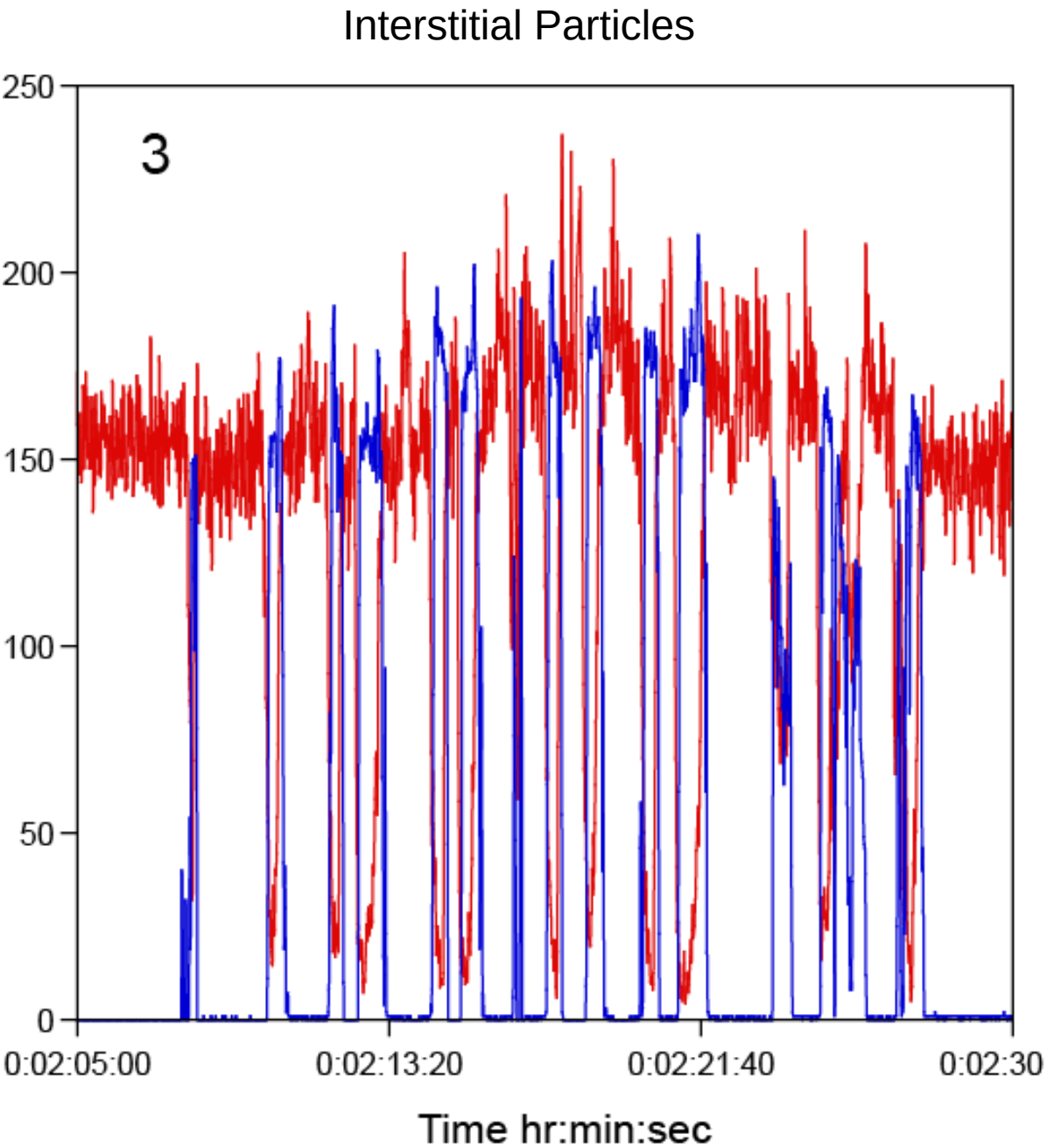

Segment 3 involved cloud characterization by purposing and sampling without the CVI. The number of particles detected by SPLAT (red) is perfectly anti-correlated with the FSSP count (blue).

Note that close to 90% of the particles are activated and by looking at the compositions of un-activated particles at the valleys one gets a direct information on interstitial particles.

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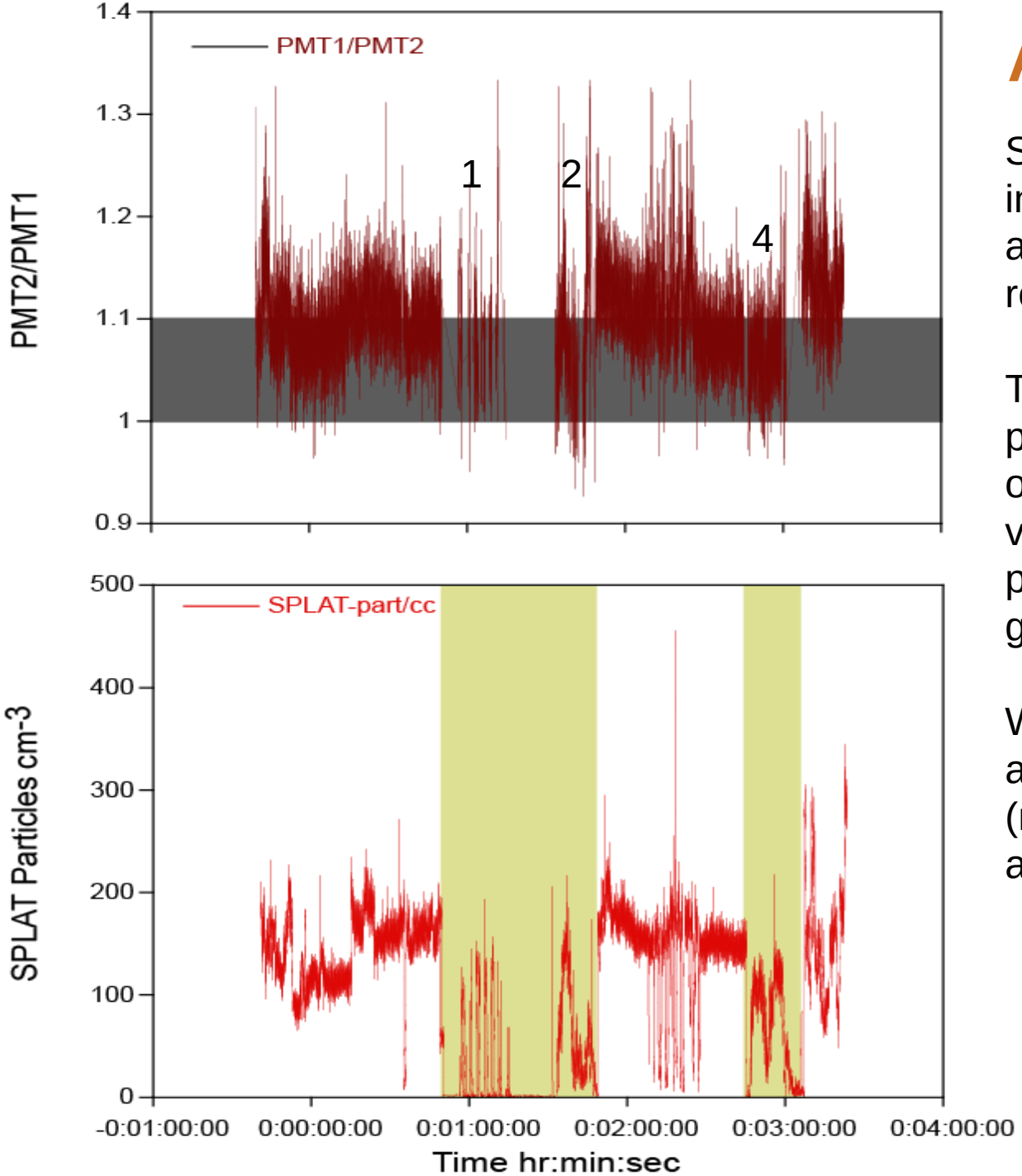

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SPLAT can be used to get information on particle asphericity with ~1 sec time resolution.

The data here show that the particles are either spherical or nearly spherical. (the values for perfectly spherical particles are marked with the gray area).

When flying through cloud and sampling through the CVI (marked 1, 2, 3) the particles are nearly perfectly spherical!

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Particle Compositions

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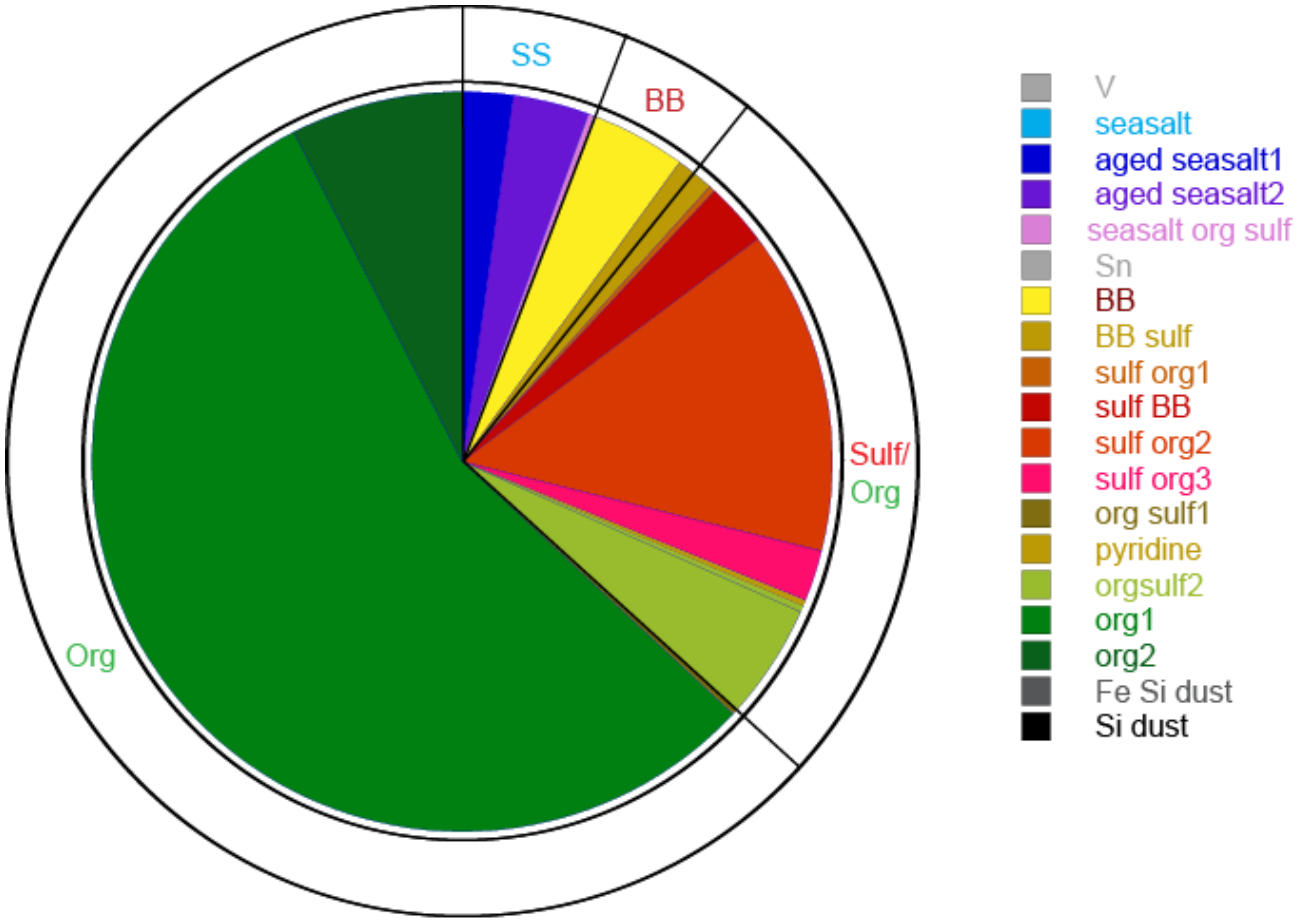

all data

An overall picture of the particle compositions. The data show that most particles are organics (green), the next population are sulfates mixed with organics, BB, and sea salt. Very few dusty particles like Si, Al, etc. were observed.

Particle Compositions
Time evolution

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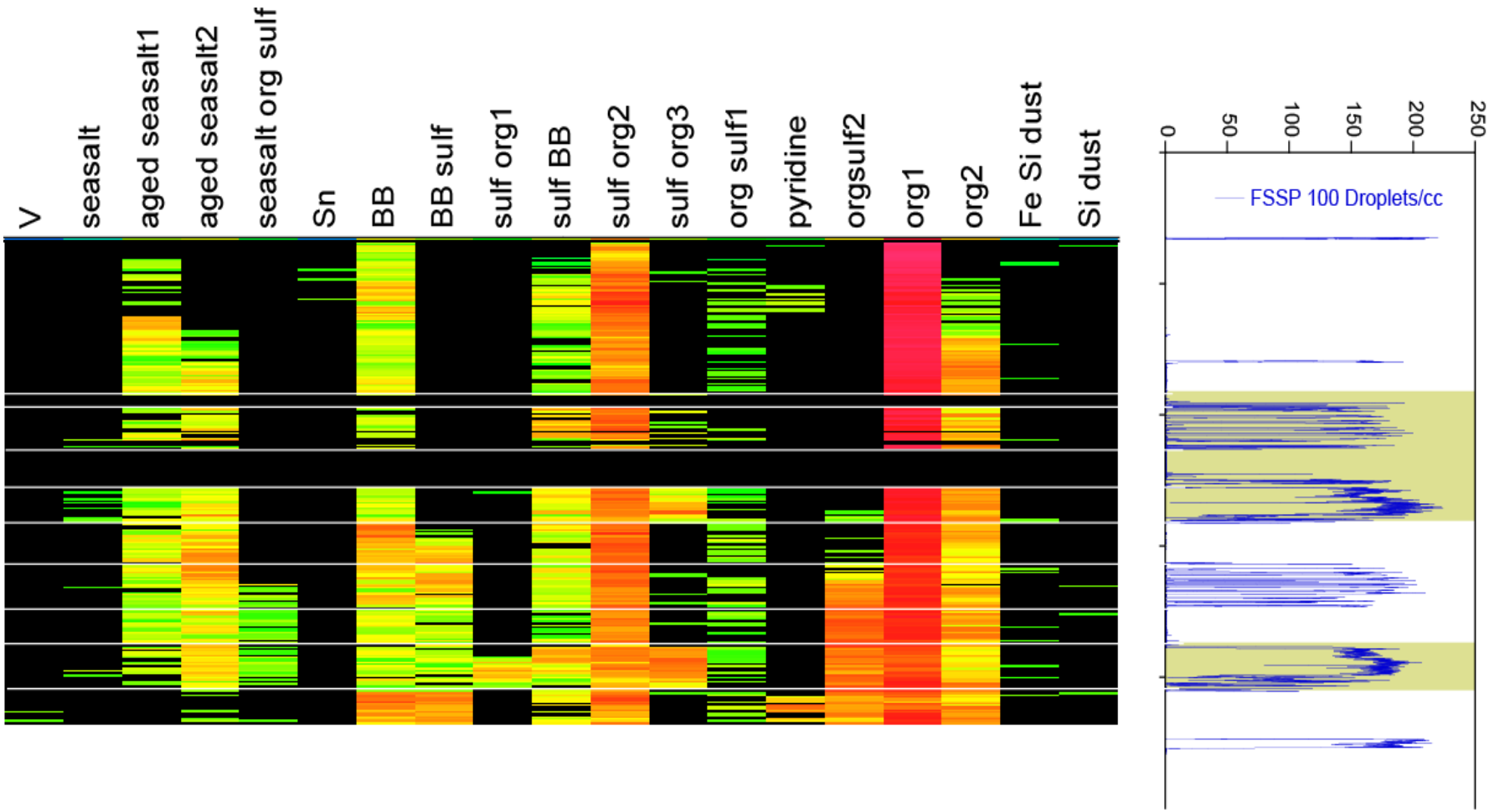

A movie of particle population in 19 composition classes as a function of time. For orientation a plot of the FSSP data is shown on the right.

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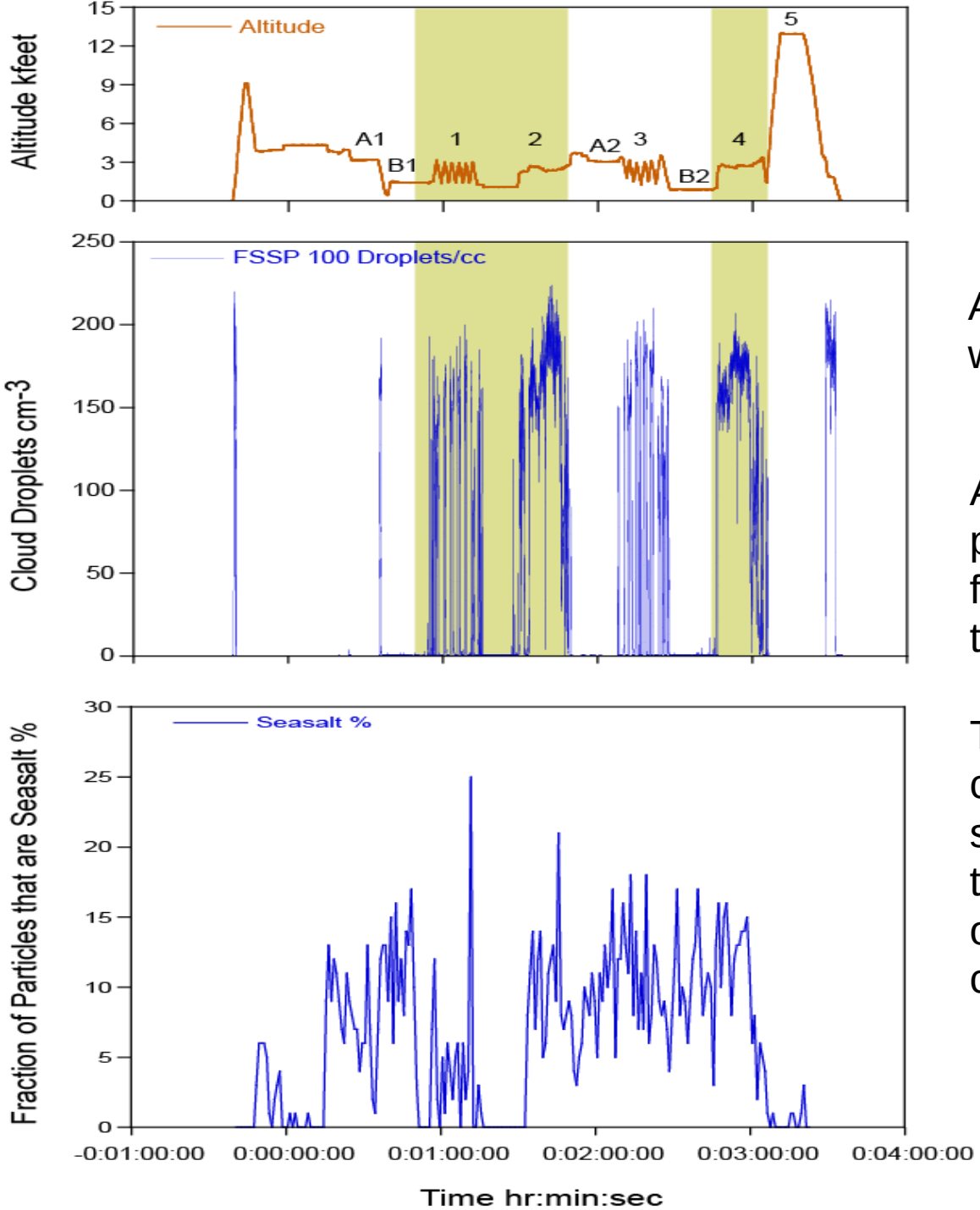

SEASALT Particles

Are seasalt particles correlated with cloud droplets?

A plot of the fraction of particles that are seasalt as a function of time compared with the FSSP count.

There does not seam to be any correlation. In other words, seasalt particles do not appear to be much better than most other particles at making clouds.

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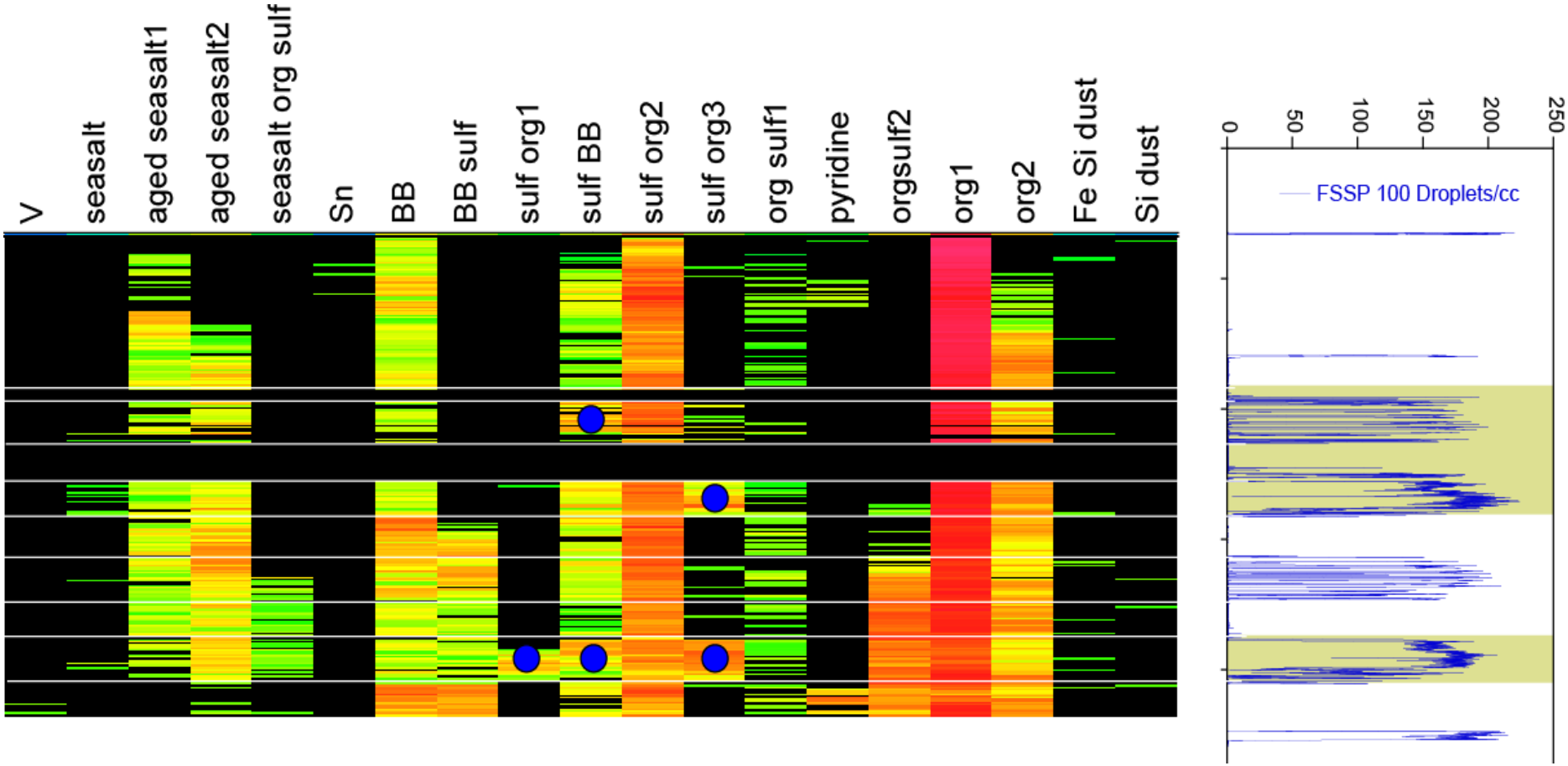
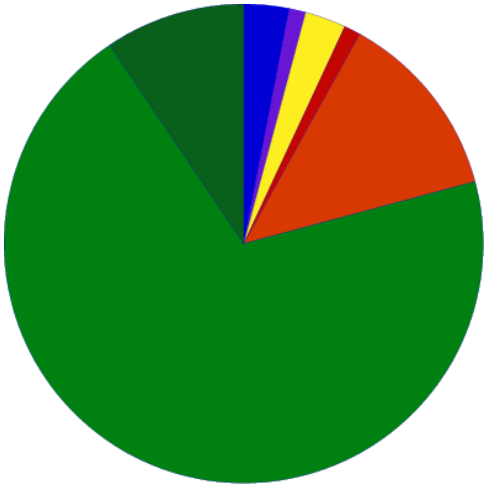
Particle Compositions
Time evolution

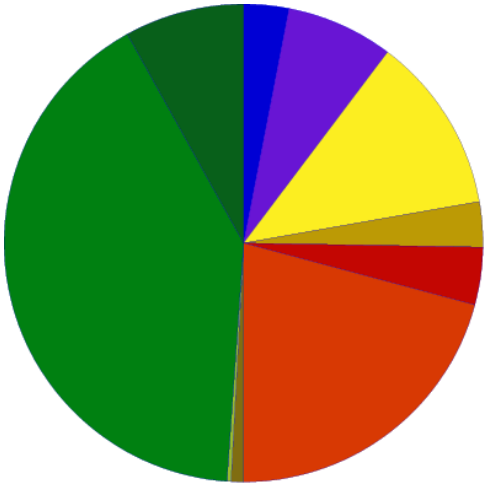


Particle compositions marked in blue circles appear to be correlated with clouds, possibly indicating cloud processing.

Particle Compositions **A**bove and **B**elow the Cloud

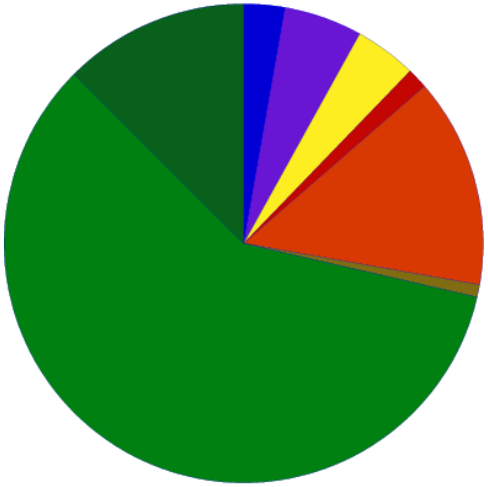


A1

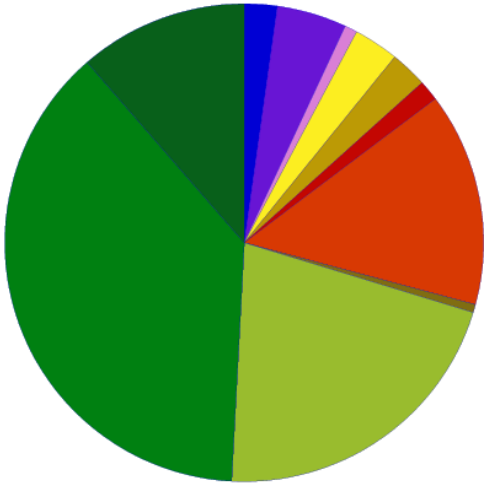


A2

There seem to be bigger differences between the set 1 and 2 than between A and B. The former points to slight changes in particle compositions as a function of time and space rather than small changes in altitude.



B1



B2

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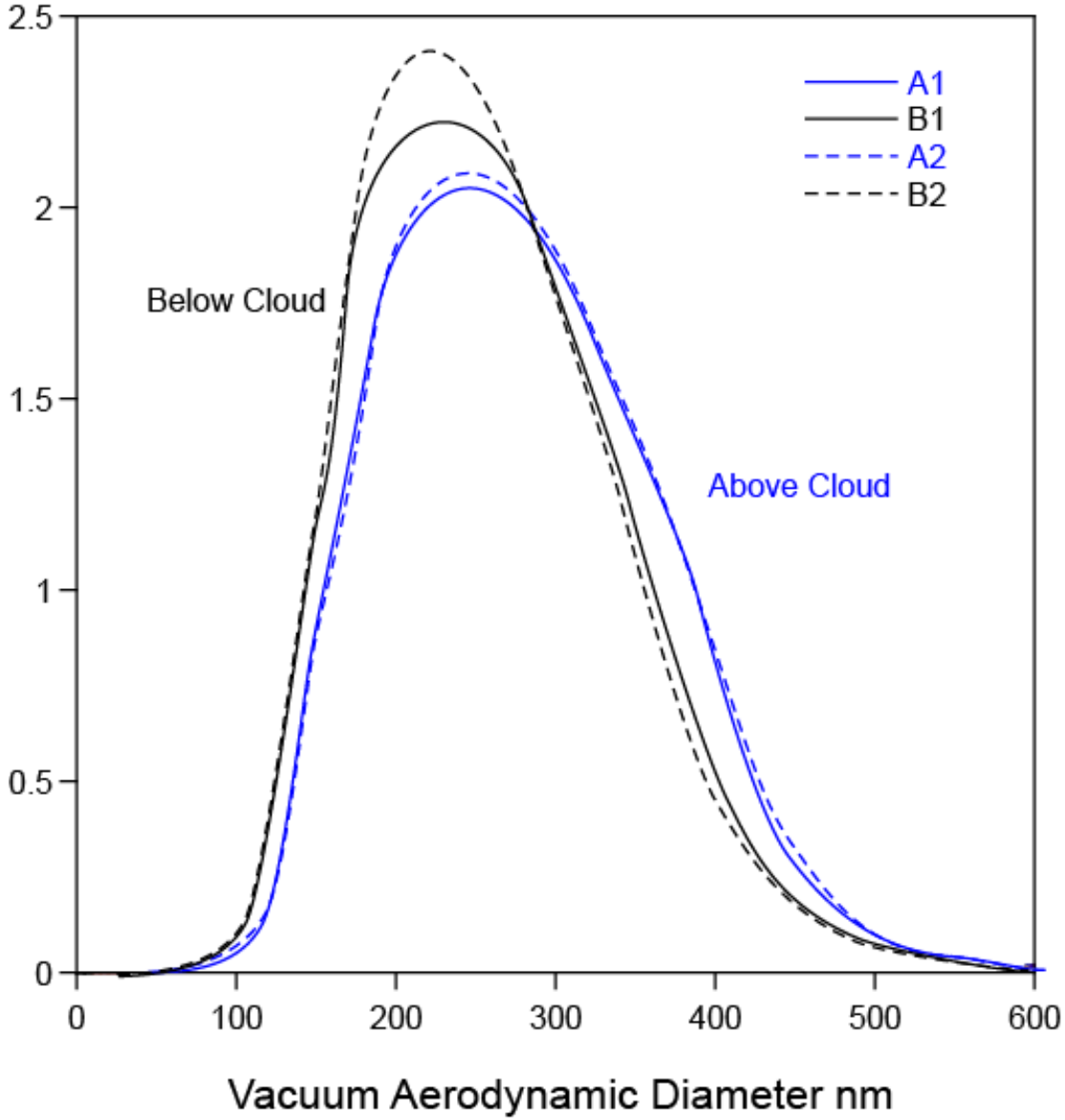
Size distributions of particles above and below clouds



The size distributions of particles above and below the clouds show very small changes.

These data can be used to yield an approximate particle densities of 1.4 for **A** and 1.35 for **B**

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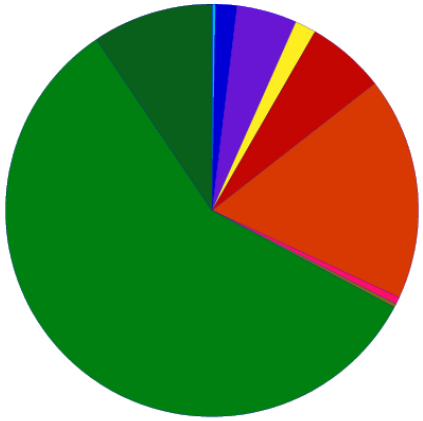
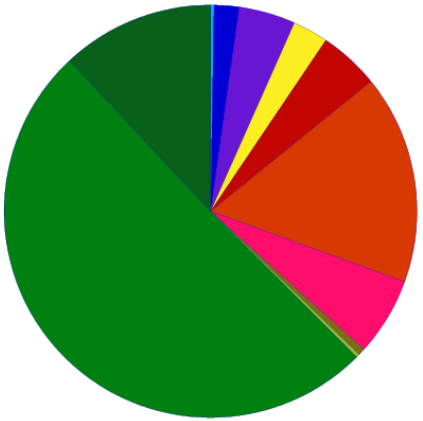
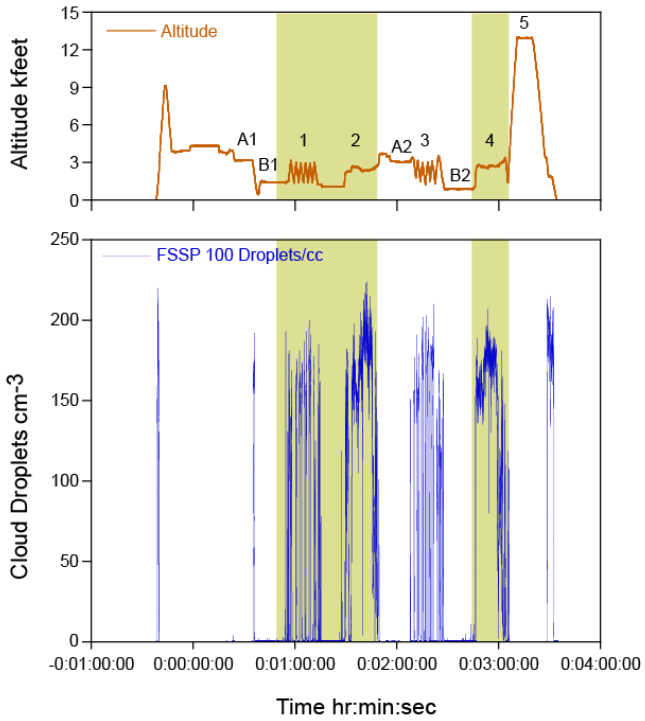
CCN composition

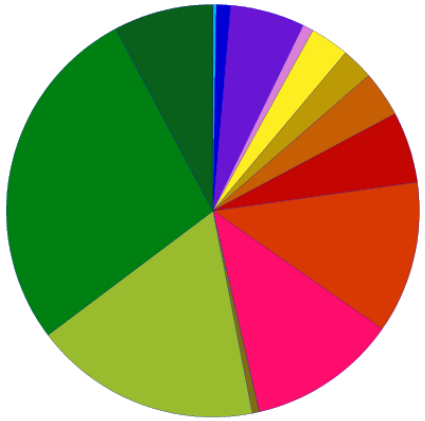


1



2





4

The particles characterized by SPLAT for segments 1, 2, and 4 provide direct information on the compositions and size distributions of CCN

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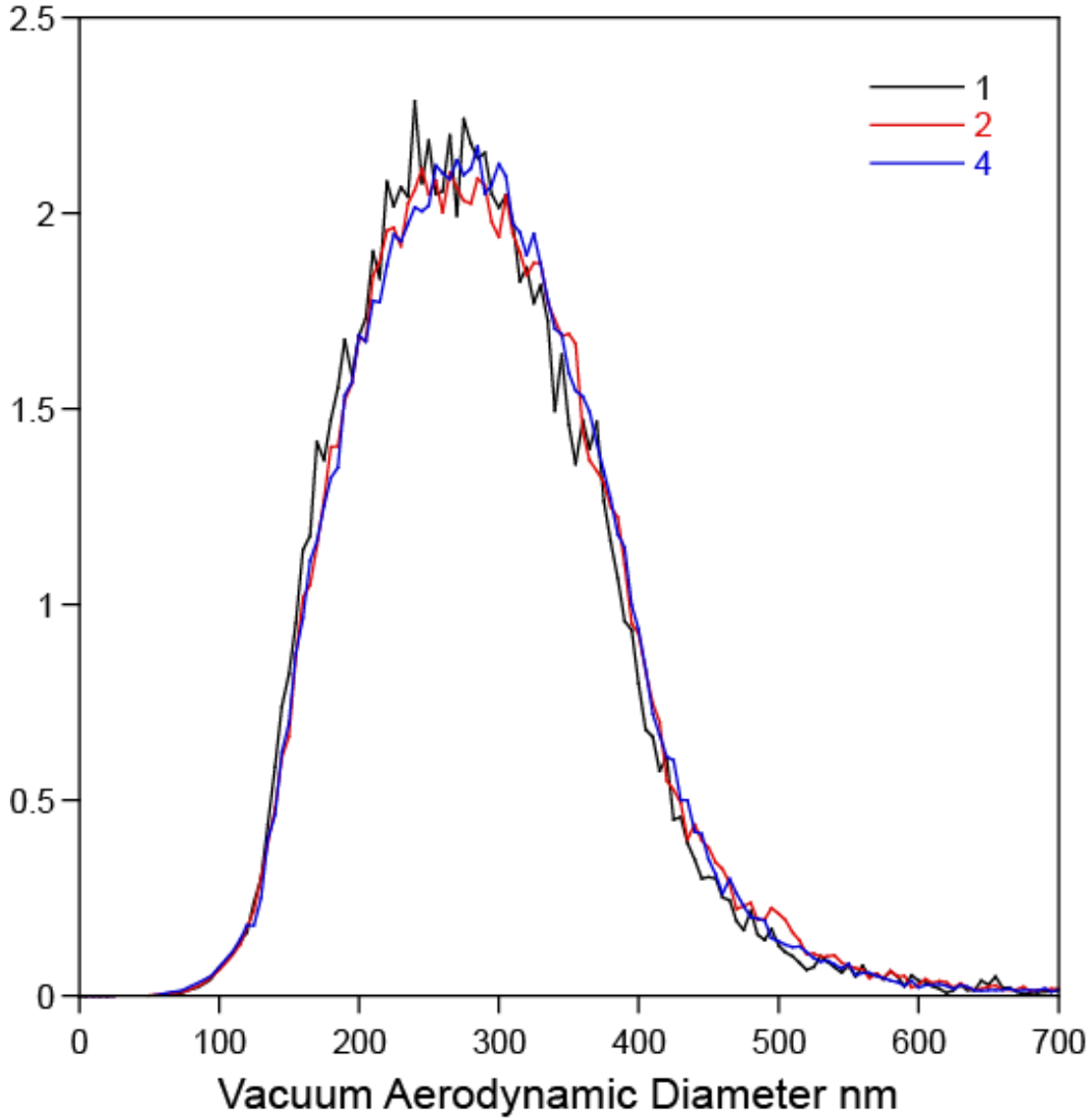
CCN size distribution and density



The size distributions for CCN at the three segments are identical, yielding a density of 1.4.

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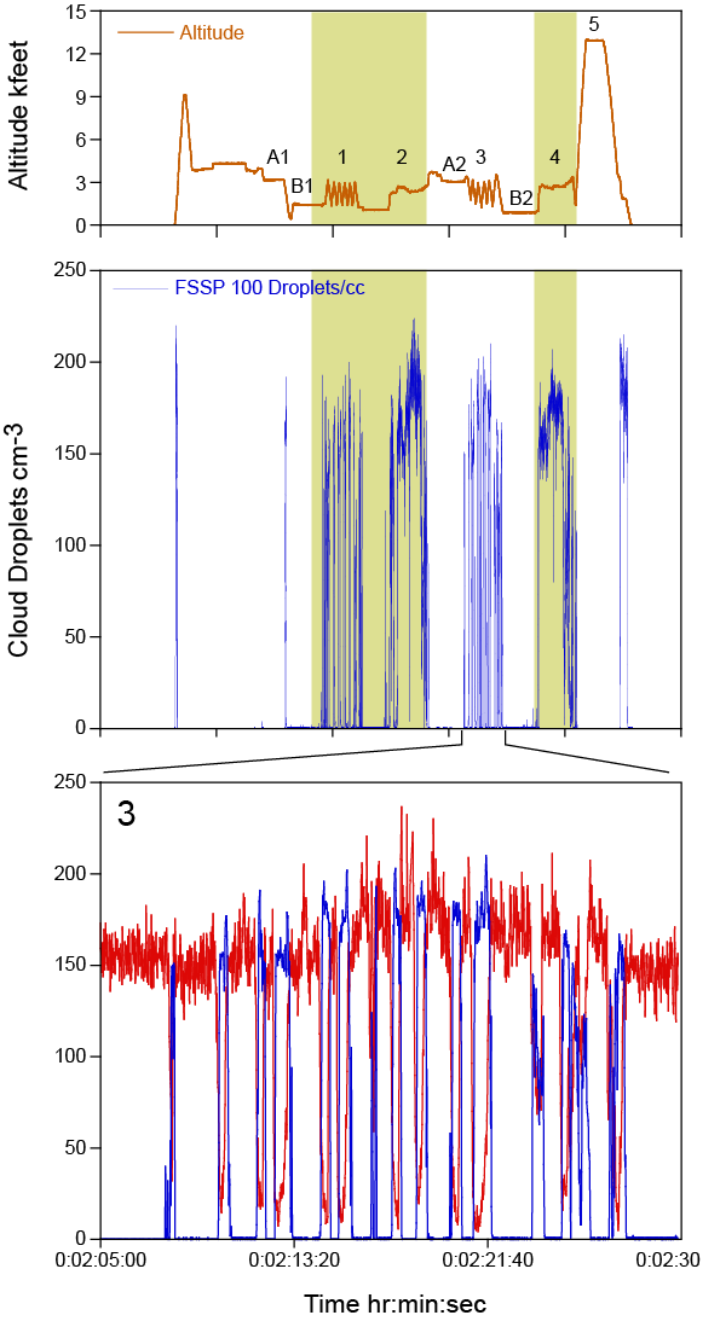
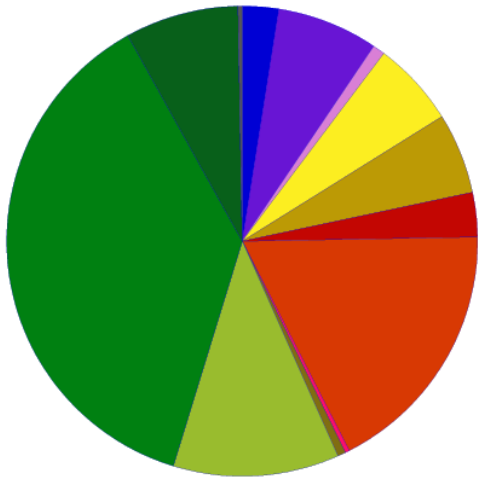
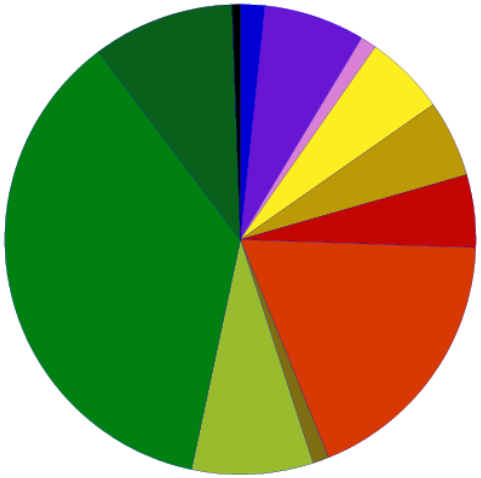
Characterizing interstitial aerosols

April 26, Flight 31





3



Interstisial

The top pie chart is of all the particles characterized in segment 3. It represents the composition of background aerosol.

The bottom pie chart of the ~10% particles that did not get activated in this case.

Note that the two pie charts are virtually identical!

So what is the difference?

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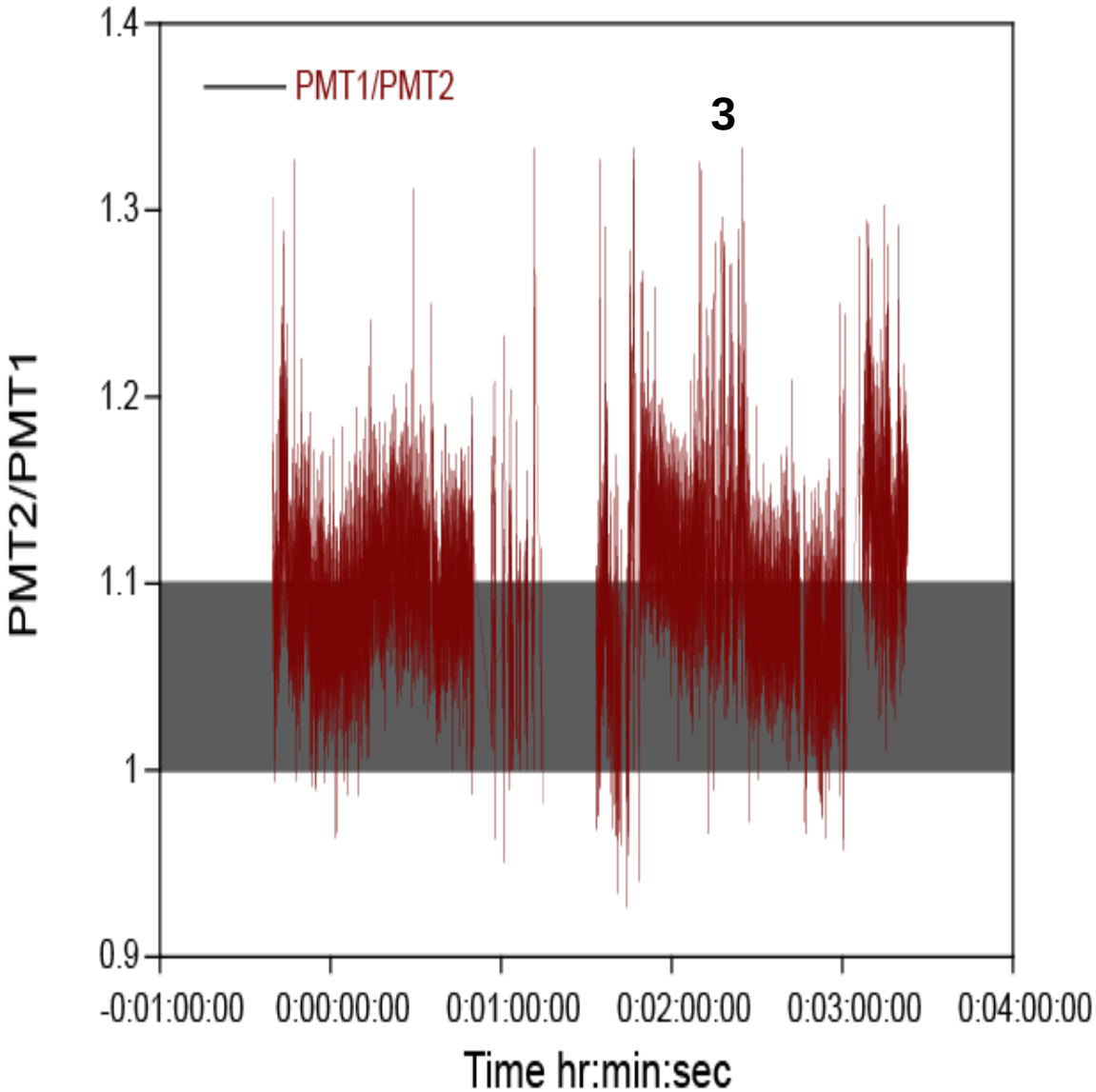
Characterizing interstitial aerosols



The size distributions of the two types of particles encountered in segment 3 : **Red** background aerosols, and **black** ~10% of particles that were not activated as CCN. The **blue** traces represent the size distributions of CCNs.

The data show that activated particles are slightly larger than background aerosols and that un-activated particles are the smallest.

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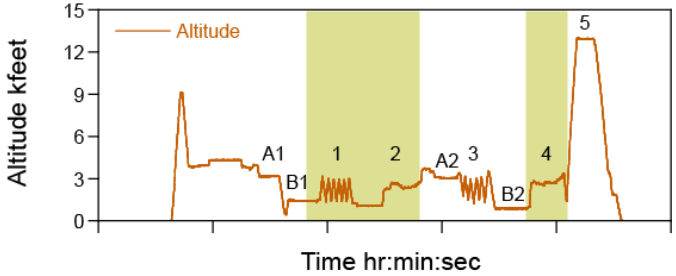
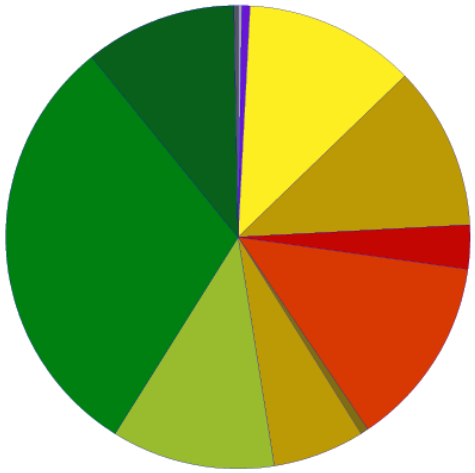
Compositions and size distributions of particles at Higher Altitude





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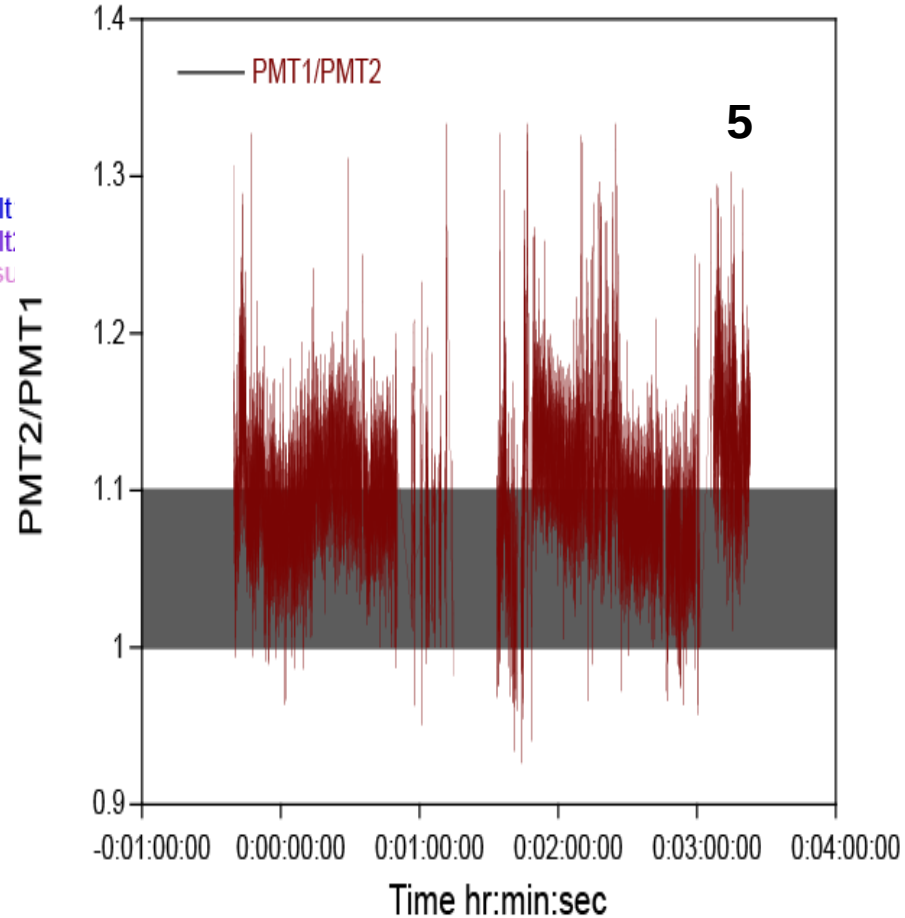

Segment 5 offers the opportunity to characterize particles at higher altitude. The data show that a large fraction of these particles are BB. Their size distribution plotted next to the size distribution of CCN, for scale, shows significantly larger particles. The PMT1/PMT2 ratio shows that a larger fraction of these particles are aspherical.

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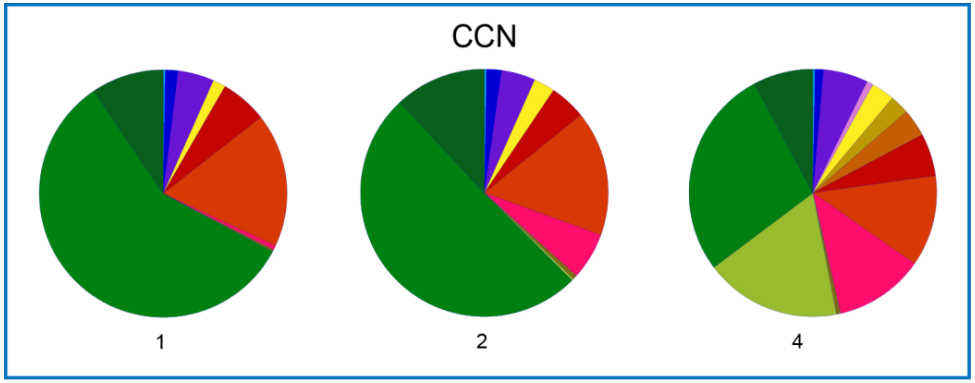

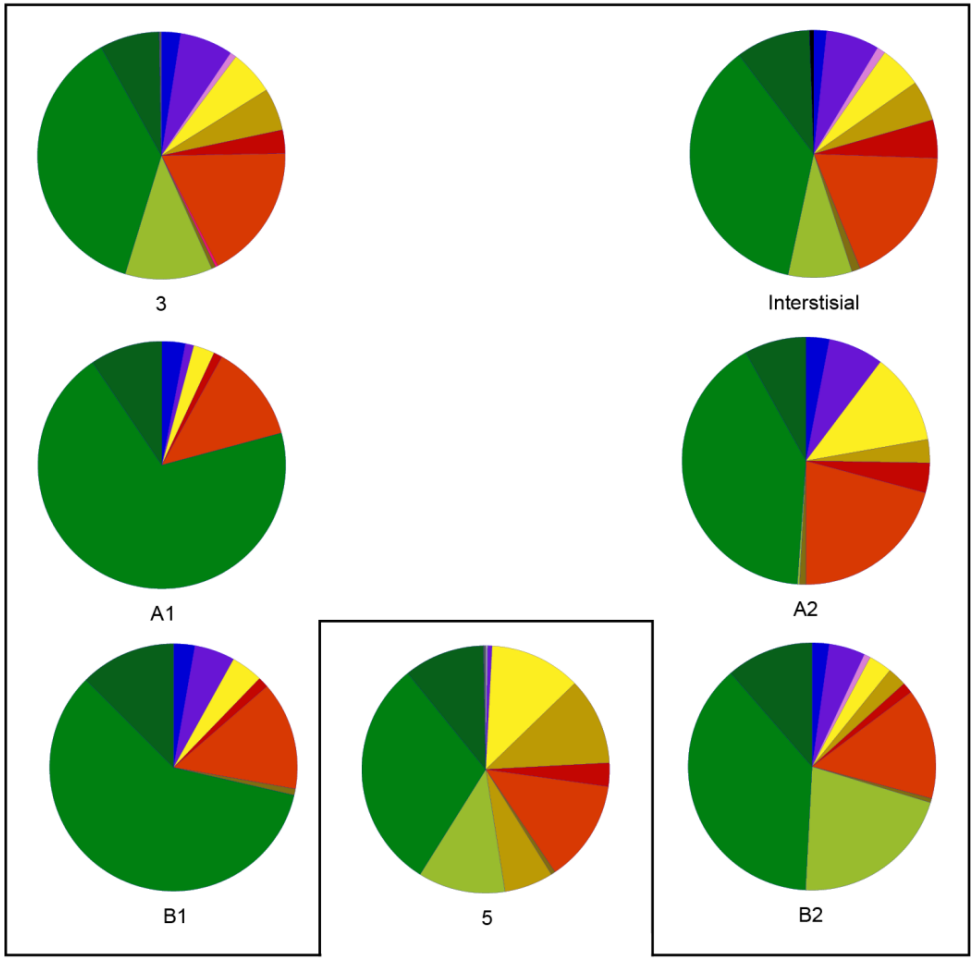

A comparison between the compositions of particles characterized during the 10 flight segments of Flight 31. The three pie charts above show the compositions of CCNs. The lower block shows at the top background aerosols and interstitial particles the other 4 are below and above clouds.

- V
- seasalt
- aged seasalt1
- aged seasalt2
- seasalt org sulf
- Sn
- BB
- BB sulf
- sulf org1
- sulf BB
- sulf org2
- sulf org3
- org sulf1
- pyridine
- orgsulf2
- org1
- org2
- Fe Si dust
- Si dust

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April 26, Flight 31 Conclusion

- The particles during flight 31 were composed of organics, organics mixed with sulfates, BB, and seasalt
- The particle compositions varied slightly with time and location
- Flight 31 provides the opportunity to characterize CCN
- The data show that ~90% of particles get activated
- The most significant difference between activated and un-activated particles is in particle size, with larger particles activating more readily.

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