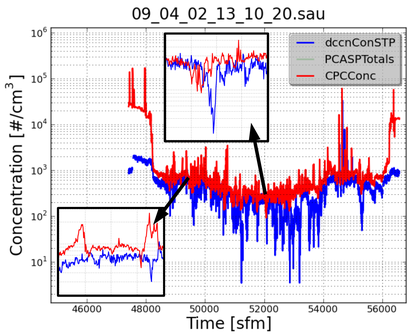
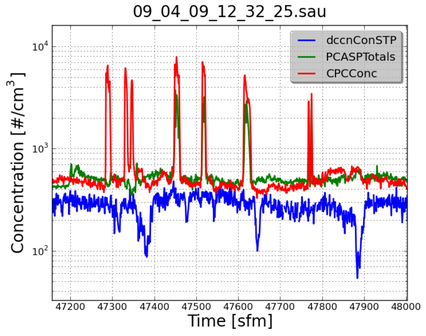
Analysis of Airborne Cloud Condensation Nuclei, Condensation Nuclei, and Optical Aerosol Measurements Made During the Spring 2009 Saudi Arabia Field Project

Gökhan Sever (gokhan.sever@und.edu) and David Delene (delene@aero.und.edu) Department of Atmospheric Sciences, University of North Dakota, Grand Forks, North Dakota, USA

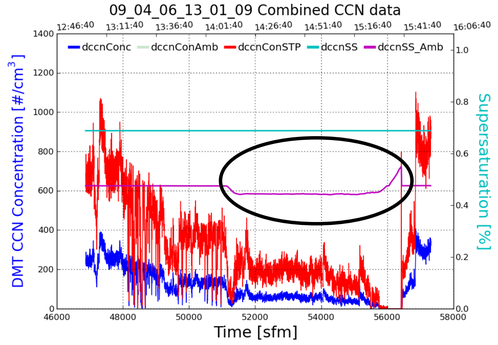
This study analyzes 13.5 hours (6 flights) of data collected by a Droplet Measurement Technologies - Cloud Condensation Nuclei Counter (DMT-CCNC), a Passive Cavity Aerosol Spectrometer Probe (PCASP-100X), a TSI – Condensation Particle Counter (CPC-3772), and a Hot-wire Liquid Water Content (LWC) probe during the Spring 2009 Saudi Arabia Precipitation Enhancement field campaign in Riyadh, Saudi Arabia. The main objective of this work is to study aerosol-cloud interactions. Analysis started by conducting quality assurance on the data set that is very important due to the intrinsic measurement errors associated with the instruments used for this study.



The figure shows that there is a time difference between the DMT-CCN and CPC concentration measurements. The lower left box inside this plot references the 49200-49400 sfm time range, whereas the upper box references the 52200-52400 sfm range. The lower-left box indicates a 20 seconds lag, while from the latter box the lag is seen as 24 seconds. The CPC concentrations were four seconds shifted backwards, and the PCASP concentrations are hidden to ease the view.



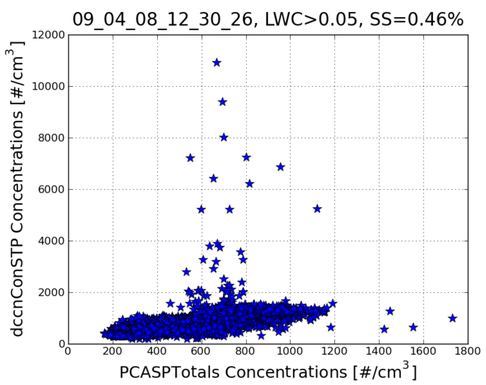
The second figure shows a section of the time-series from the April 09 flight that is originally in the range of 45181 to 52097 sfm (~ 1 hours 55 minutes). Here the PCASP measures higher concentration values than the CPC does, which is beyond reality since PCASP only measures within a subset of CPC detectable sizes.



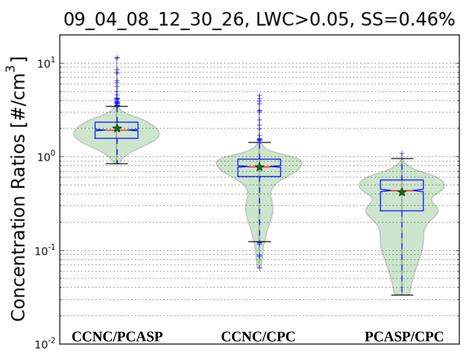
The black encircled section in this figure depicts a supersaturation fluctuation in the DMT-CCNC due to the internal pressure destabilization of the counter when the aircraft went beyond the 425 mB Inlet Pressure Controller (IPC) set pressure threshold. For the ease of view dccnConAmb that stands for the CCN concentrations that are corrected for ambient pressure and temperature levels is not shown.

Out of Cloud (LWC < 0.05 g/m^3)

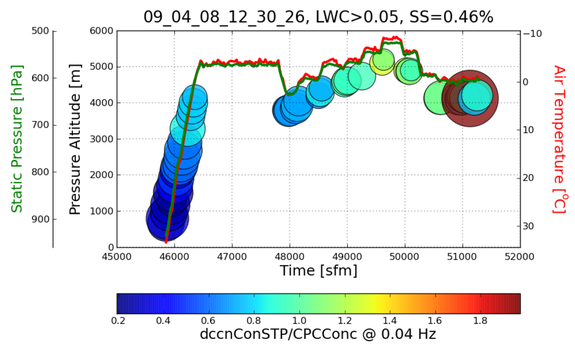
In Cloud



The relation between the PCASP measured aerosol concentrations and the CCN concentrations are shown in these scatter plots.



Concentration ratios are given in the middle with box-and-whisker plots, stars representing the averages of these ratios. Light green envelopes are kernel density estimations of the ratios using a Gaussian kernel.



The CCN activation efficiency in varying time scale. To lower the number of circles the CCN-to-CPC concentration ratio was plotted at 25 second intervals. The colors of the circles vary with the change in the activation ratio, whereas the sizes illustrate the amount of CCN concentration on a given point.

Conclusions

- In the quality control and quality assurance phase of the data analysis having auxiliary instrument data helps to make correct decisions about the nature of the measurements.
- In the case of the DMT-CCNC even if flying with an IPC to control sample pressure fluctuations, the whole system should frequently be tested for its leak tightness. (A leak-proofed system should have less than 1 mB per minute pressure drop to ensure reliable measurements)
- Before any airborne campaign deployment the counter should be calibrated to eliminate supersaturation deviations possibly owing to device transportation issues.
- Overall, all device performances should be checked daily as well as the collected data for various artifacts and to determine any instrument malfunctions.
- The April 8, 2009 flight is one of the flights that the CCN and PCASP concentrations show a relatively good agreement with each other. It is expected to see that this agreement can also be shown using calculated CCN concentrations instead of measured ones.
- For out-of-cloud cases, of all six analyzed flights the highest median (1.59) of the CCN-to-PCASP ratio was obtained on the April 8, 2009 flight. Only except the April 06 morning flight, the highest average ratio value (2.01) is also seen from this analysis.
- Likewise, the maximum median of the CCN-to-CPC ratio occur on this day with a value of 0.78. The highest average activation ratio, 0.77, is also from this day. The April 2nd flight results follow with 0.71 average ratio.
- Similar trends are also apparent for in-cloud cases when average and median ratios are compared among the six flights. CCN-to-PCASP mean = 1.54, median = 1.45, CCN-to-CPC mean = 0.96, median = 0.85.

Future Work

- Devise a way to correct the CPC measurements. Since the CPC flow-rate varies with varying pressure levels, the delay in the CPC measurements must be calculated as a function of pressure instead of having a constant time shift.
- Include measurements that were taken on the ground to see the concentration variations in between airborne and ground measurements.
- Extract cloud bases using balloon soundings and the FSSP (Forward Scattering Spectrometer Probe) measurements to assess the source of aerosol layer, and repeat the analysis for these refined cases.

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