Cloud Spectrum Measurements

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By David Delene

Forward Scattering Spectrometer Probe (FSSP) On the Left Wing of the King Air 200 Research Aircraft



Optical Path of the FSSP



- The beam splitter divides the scattered light onto two photodetectors.
- One photodector is optically masked to not receive scattered light from near the laser beam's center of focus.
- Droplets are rejected as being out of the depth of field when the signal from the masked detector exceeds that from the unmasked detector.

FSSP schematic is taken from Dye and Baumgarnder, [1984]

FSSP Effective Sample Volume

Sample Volume = TAS*DOF*BD*(Tc/Ts)

- TAS Aircraft True Air Speed (~100 m/s)
- DOF FSSP Depth of Field (~2.9 mm)
- BD Laser Beam Diameter (~0.2 mm)
- Tc Number of Droplets Sized (Total Counts)
- Ts Number of Droplets within the DOF (Total Strobes)



Laser Beam

Laser Beam Fraction Correction Effective Laser Beam Diameter (Tc/Ts)

Total Counts (Tc) Total Strobes (Ts)

- The effective laser beam diameter is the fraction of the total diameter where droplets are within the laser beam long enough so they can be sized.
- A running average of droplet transit time through the beam is maintained. If the droplet time within the laser beam is less than the average, it is rejected from sizing but included in the running average.

FSSP Velocity Acceptance Ratio





The velocity acceptance ratio is based on the ratio of total FSSP counts to total FSSP strobes. Dye and Baumgarnder [1984] state that the theoretical velocity acceptance ratio is 62%.

Coincidence and Deadtime Corrections

$$cf = \frac{1}{1 - 0.73 * F_a}$$

cf – Correction factor

F_a – Activity Fraction

The 0.73 constant is an empirical factor found from computer simulations which takes into account particles which are still in the beam at the end of a reset delay period. This factor is described by Baumgardner [1983] and Baumgardner et al [1985].

FSSP Particle Loss Correction



Percentage of particle losses based on the measured FSSP activity.

Theoretical Loss Correction



Plot of the expected loss of the NCAR Research Aviation Facility's FSSP probe flying at 100 m/s. Figure taken from the NCAR Research Aviation Facility Bulleting No. 24.

FSSP Mie Function



FSSP Mie Function is taken from Dye. and Baumgarnder, [1984]

FSSP Calibration Procedure



The FSSP is calibrated to determine the instruments depth of field, laser beam diameter, and channel size boundaries. The channel counts obtained from measurements on beads of known size are used to determine the FSSP channel boundaries.

FSSP Bead Calibration Check



January 29, 2008 FSSP calibration check at 8:40:28 using 15 μm beads.

Why Measure Liquid Water Content?

- Determines the Potential of Enhancing Precipitation using Cloud Seed Techniques (Mali, Saudi Arabia)
- Basic Cloud Parameter (MPACE)
- Icing Studies (WISP04, Sikorsky)
- Comparison with Remote Sensing Measurements (THORpex, IOP1)

Liquid Water Content Calculation

The ¶amount of liquid water for a given volume of air may be determined through mass integration of the cloud droplet distribution.

$$LWC = (\frac{\P}{6}) \rho_{w} \sum_{i=1}^{m} N_{i} d_{i}^{3}$$

- $\rho_{\rm w}$ Density of Water
- $N_{\rm i}$ Concentration of droplets in size channel i
- d_i Droplet diameter in size channel i
- m Total number of channels

March 10, 2004 Citation Flight



4 Hz averaged FSSP (Black line) and King Probe (Red Line) cloud liquid water content data.

September 24, 2004 Citation Flight



4 Hz averaged FSSP (Black line) and King Probe (Red Line) cloud liquid water content data.

How well do they Compare?

March 10, 2004



How well do they Compare?

September 24, 2004



Ice Contamination



The FSSP LWC calculations assume spherical water droplets.

Rapid Visualization of Data



One Last Plot



Conclusions

- Beam fraction, coincidence, and dead time corrections need to be applied to the FSSP data to obtain accurate LWC measurements; however, apparently no airspeed correction has to be applied to the FSSP data.
- The FSSP liquid water content agrees with the King Probe LWC in ice free conditions. Cases from two different field programs found FSSP to King ratios of 0.96 and 1.20.
- Well written software can automatically post process the FSSP data to provide accurate plots of the FSSP measurements during field projects.

Future Work (Assignment)

- Compare the M300 real time processing of FSSP number concentration data with the post-processed FSSP number concentration data.
- Use the January 10, 2008 flights for comparison.
- Present results on March 5, 2008 at 1:00 p.m.
 - Mark it on the calendar, "FSSP data processing comparison"

Any Questions?

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