

MICROPHYSICS AND OPTICS IN TRADE-WIND CUMULUS

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Cotton and Cumuli



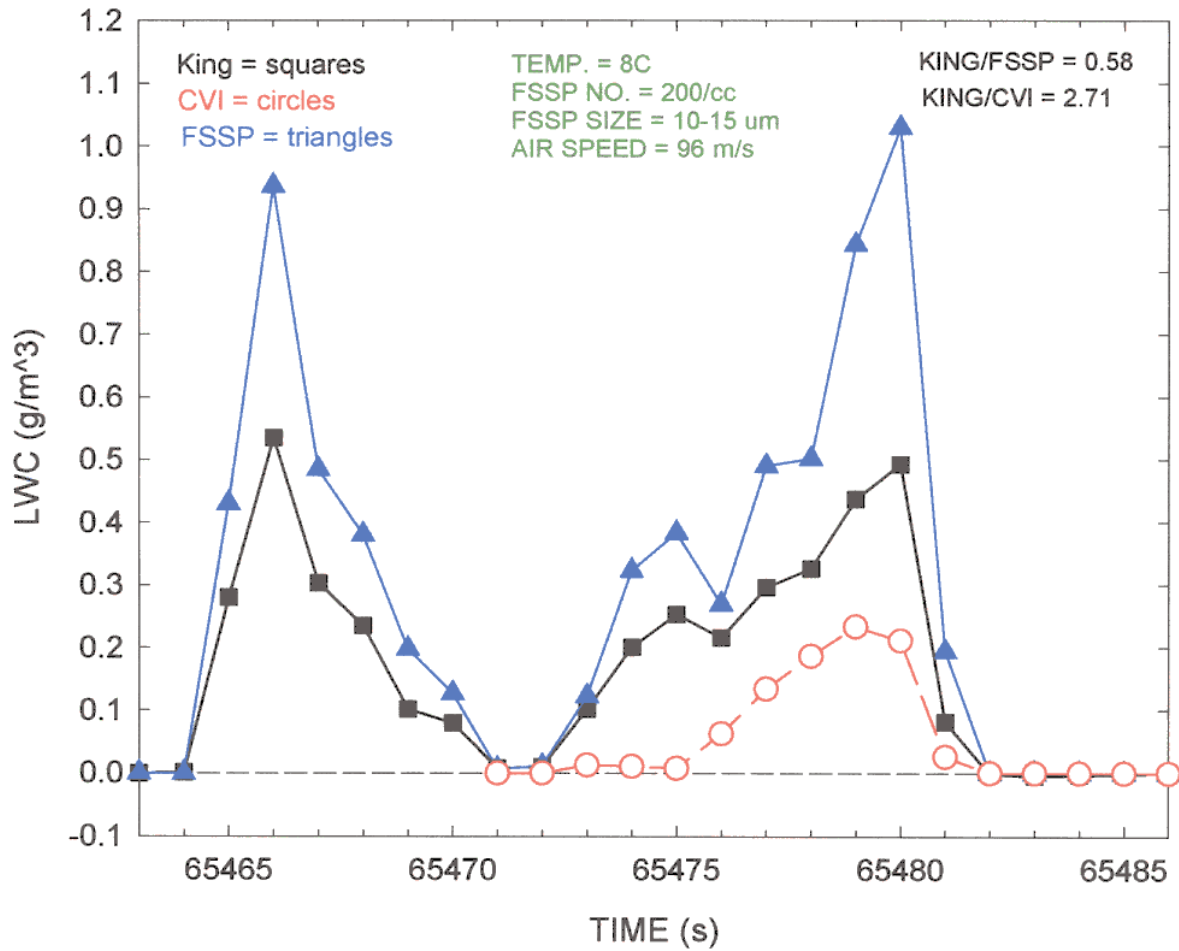
(from Rodts, S., 2001: Shallow cumulus dynamics: observations and parameterizations. IMAU.)

Stefan Rodts, 2001: “Models are an imitation of reality. It is wise to continue to check the accuracy of the modeling results with measurements.”

issue #1:

ACCURATE LIQUID WATER CONTENT

CRYSTAL-FACE
CITATION; CVI vs King vs FSSP; 11 July, PM



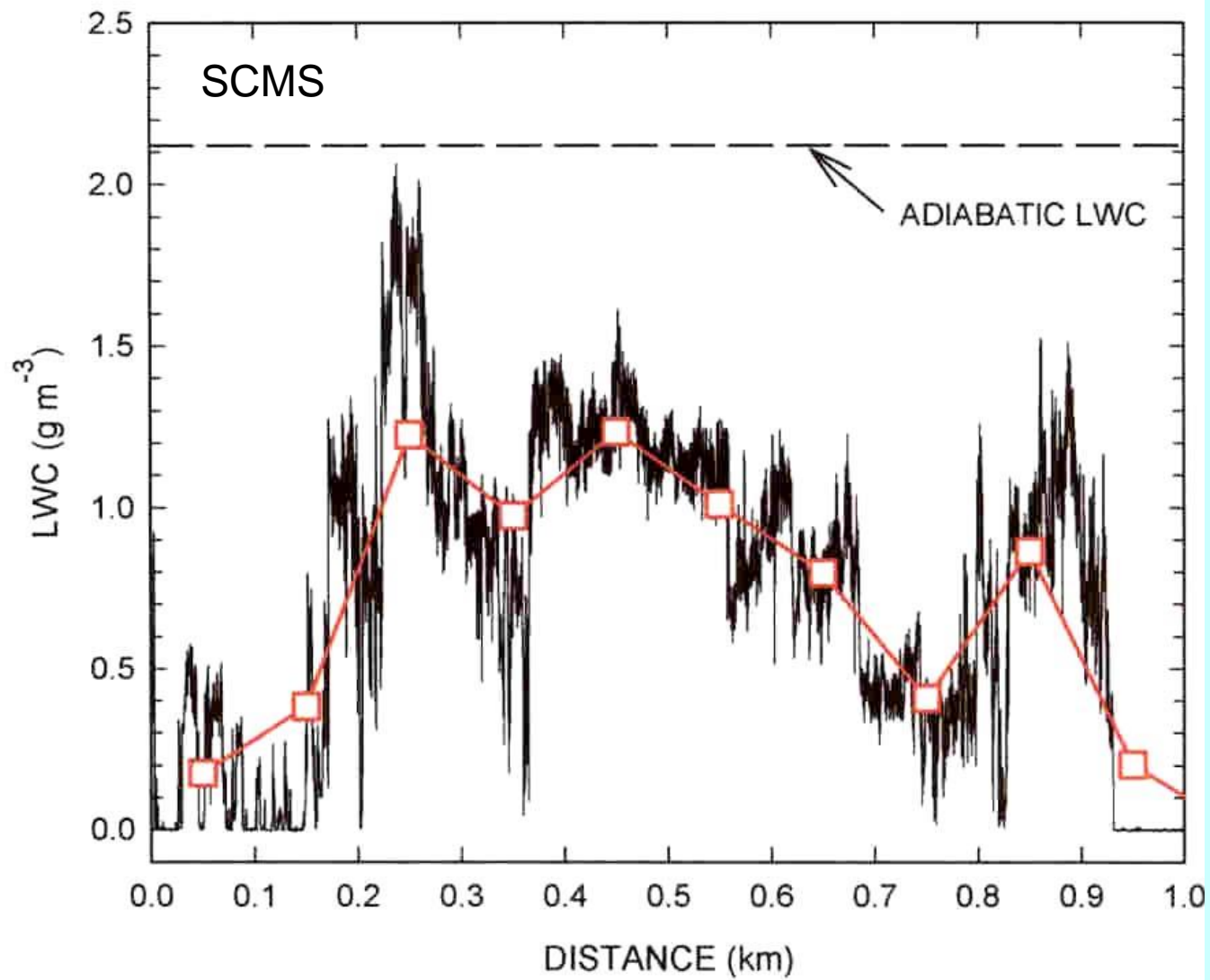
“CLASSIC ADIABATIC CORES” IN Cu

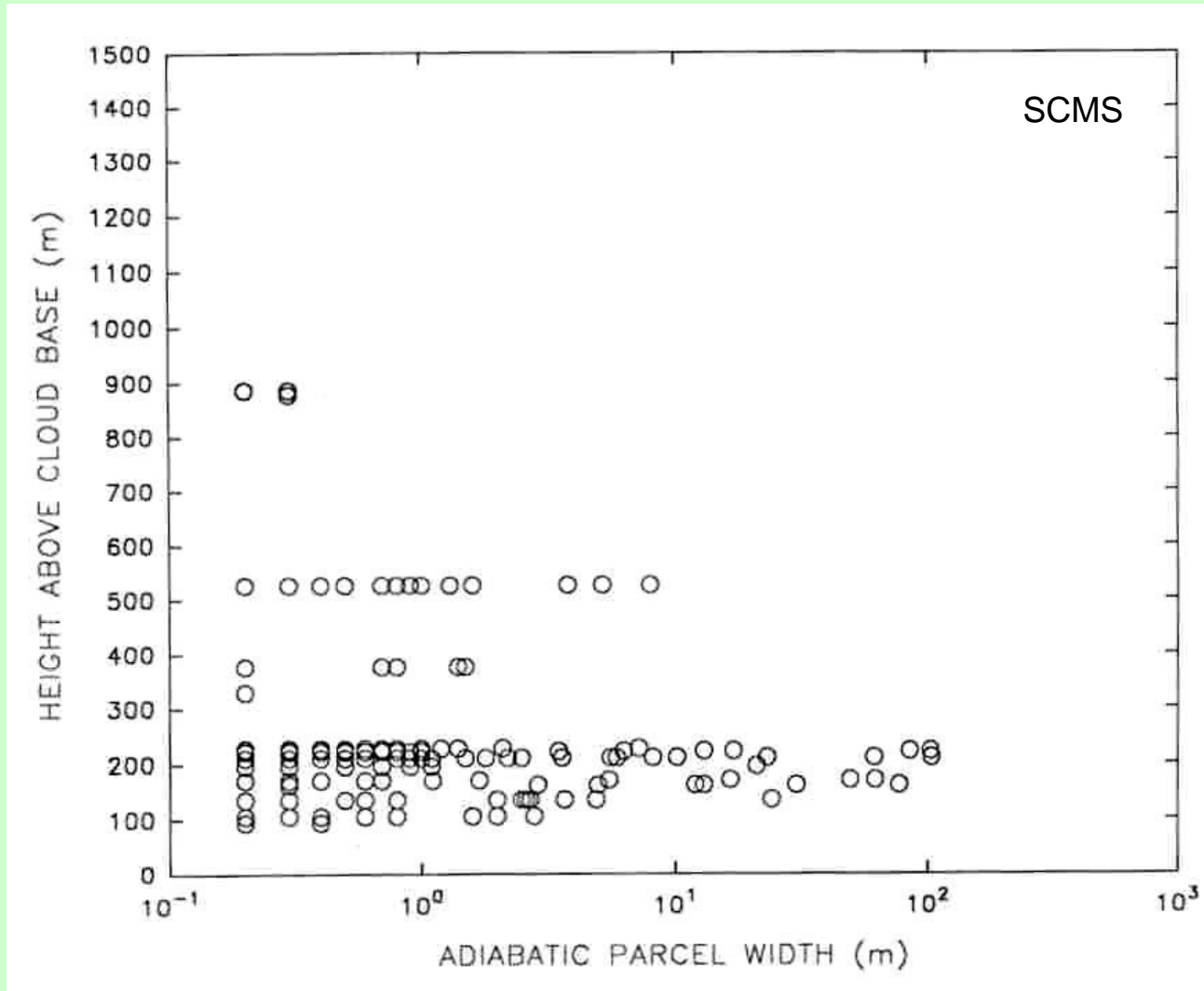
YES

- Cooper (1978, Rpt. AS119)
- * Heymsfield et al. (1978, J.A.S.)
- Paluch (1979, J.A.S.)
- Boatman and Auer (1983, J.A.S.)
- Jensen(1985, Ph.D Thesis)
- * Jensen(1985, J.A.S.)
- Pontiks et al. (1987, J.A.S.)
- Blyth et al. (1988), J.A.S.)
- Raga et al. (1990, J.A.S.)
- Hicks et al. (1990, J.A.S.)
- Pontikis et al. (1991, JTECH)
- Cooper et al. (1996, 12th ICCP)
- Paluch et al. (1996, J.A.S.)
- Carpenter et al. (1998, J.A.S.)
- Knight and Miller (1998, J.A.S.)
- Lawson and Blyth (1998, At. Res.)
- Brenguier (1998, AMS Conf.)
- Siebesma (1998, Kluger Acad. Pub.)
- Vaillancourt and Yau (2000, B.A.M.S.)
- Brenguier and Chaumat (2001, J.A.S.)
- Chaumat and Brenguier (2001, J.A.S.)
- Kollias et al (2001, J.A.S.)
- Blyth et al (2003, J.A.S.)

NO

- * Warner (1966, Tellus)
- Warner (1977, J.A.S.)
- Sloss (1977, J.A.S.)
- McCarthy (1974, J.A.S.)
- Gerber (1999, Atm. Res.)
- Gerber (2000, 13th ICCP)
- Zipser (2003, Met. Mono.)





PROPOSED USE OF THE PVM-100A PROBE ON THE NCAR C-130

MEASUREMENTS:

1. 10-cm maximum resolution *LWC* and effective radius *Re*

SCIENCE:

1. determine entrainment locations and scales in Cu
2. determine spatial variability of *LWC*, including adiabatic *LWC_a*
3. calculate fractional entrainment rates based on $q_t(z)$ and $\theta_1(z)$

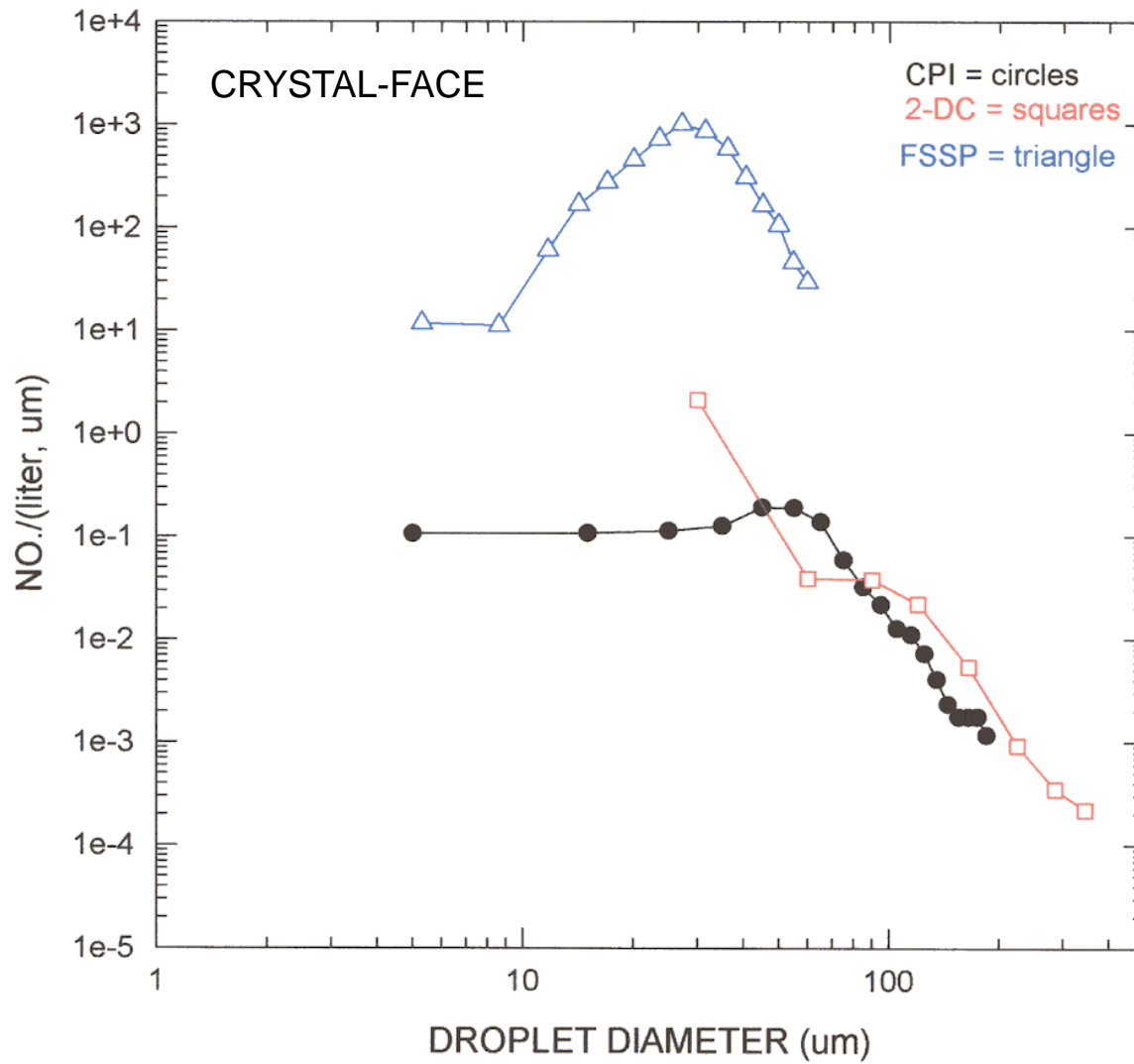
DATA AND OTHER MEASUREMENT REQUIREMENTS:

1. multiple passes at different *z* above cloud base for many Cu
2. 1000-hz PVM-100A measurements (2 channels)
3. measures of *z*, *T*, *P*, *u*, *v*, *w*, q_v , θ (25 hz)
4. forward-looking video

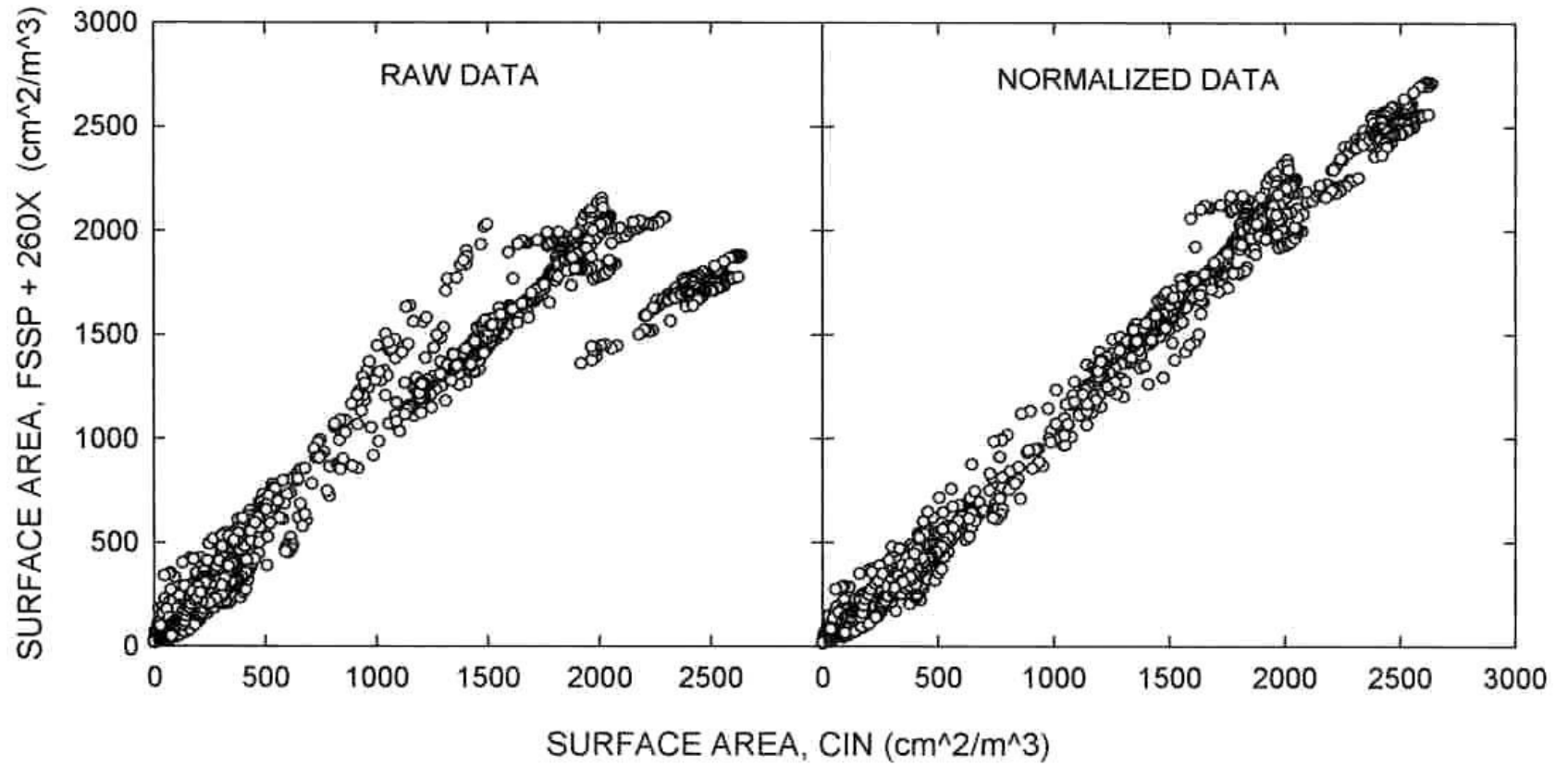
issue #2:

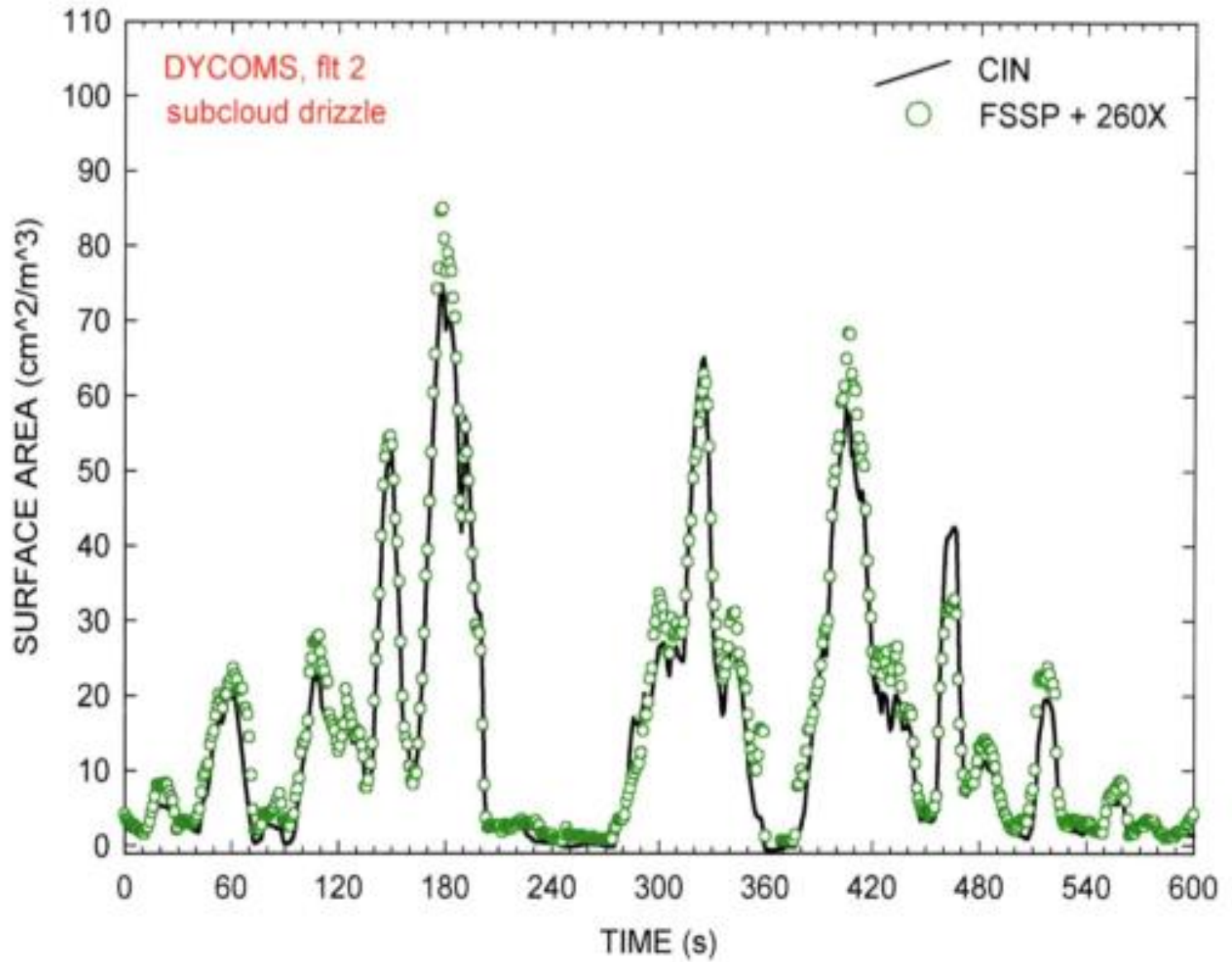
ACCURATE DROPLET SIZE SPECTRA

CITATION; 9 July (69,475s - 69,771s)



DYCOMS-II





CLOUD INTEGRATING NEPHELOMETER (CIN)



PROPOSED USE OF THE CLOUD INTEGRATING NEPHELOMETER (CIN) ON THE C-130

MEASUREMENTS

1. in-situ optical extinction coefficient, asymmetry parameter, total droplet surface area

SCIENCE

1. scaling reference for droplet spectrometers
2. determine relationship between CCN and Cu optics
3. relate Cu optics to remote sensing

DATA AND OTHER MEASUREMENT REQUIREMENTS

1. multiple passes at different z above cloud base for many Cu
2. CIN measurements (4 channels, 25 hz)
3. measure of CCN, visible spectrum remote sensing
4. Integrated droplet surface area concentration from spectrometers

FIGURE CAPTIONS

Fig. 1 - Title slide

Fig. 2 - Being an experimentalist, I couldn't resist showing this figure and caption by Dr. Rodts. While validation of modeling predictions by experimentation is the obvious approach, it is not so obvious if cloud microphysical measurements yet have sufficient accuracy to permit meaningful validations related to the main topic of RICO. The topic being the measure of CCN and their Lagrangian evolution in the tradewind Cu to precipitation size drops. Two major experimental issues need to be addressed to make possible meaningful measurement-modeling comparisons:

Fig. 3 - Issue #1: It is well known in our community that the measure of cloud liquid water content (LWC) has remained error prone, with various measurement techniques rarely, if ever, agreeing even in co-located aircraft measurements. Given the LWC is an important variable in the coalescence mechanism (e.g., see the recent paper by Blyth et al, 2003; JAS), we need to measure LWC with unassailable and improved accuracy to meet RICO objectives.

Fig. 4 - A typical example of LWCs measured by three co-located and well-known probes in a water cloud in which the droplet sizes are within the range of each probe (CRYSTAL-FACE EXPERIMENT, July 2002). Measured LWC ranges over a factor of about 3.

Fig. 5 - A compilation of literature references dealing with LWC adiabatic cores in Cu. The definition of the "classical adiabatic core" requires that at least a 100-m wide adiabatic core is found at least 1km above cloud base. As this list shows there has been disagreement on this basic cloud parameter for a long time, and it still exists. The adiabatic label requires a lack of entrainment and mixing of out-of-cloud air with the cloud, a factor that undoubtedly influences the evolution of the droplet spectra, if such cores are large and long lived.

Fig. 6 - An example of 1000-Hz LWC measured with the PVM probe on the NCAR C-130 during the SCMS for small Florida Cu. We have learned that high-rate measurements are needed to give us the chance of identifying adiabatic parcels correctly. Often in the past 1-Hz LWC data has been used, which from this figure would lead to missing the two small parcels that approach the predicted adiabatic level. Given that many of the references in the preceding slide are based on 1-hz data, suggests that their "classical adiabatic cores" are likely non-existent and part of the measurement uncertainty for LWC. Jean-Louis Brenguier calls the cores "quasi-adiabatic cores" (quasi meaning "resembling"), which presently seems to be most appropriate.

- Fig. 7 - The high-rate LWC data from SCMS also shows that the horizontal length of the unmixed adiabatic LWC parcels decreases rapidly with height, suggesting that even close to cloud base cloud-free air is entrained and modifies the microphysics. It appears from this data that after only one eddy “turn-over height”, which has been thought to be roughly equivalent to the width of the updraft at cloud base, entrained air has already entered the updraft core. These results suggest that the coalescence process occurring mostly several km above Cu base will respond to a long prior Lagrangian history of entrainment, sub-adiabatic LWC, and high turbulence levels that could cause droplet inertial effects to also become important issues.
- Fig. 8 - The main goal of using the PVM probe is to obtain a composite and a high-resolution picture of the trade-wind Cu found during RICO. The degree of attainment of this goal depends on the frequency with which the C-130 traverses the Cu at different levels above cloud base.
- Fig. 9 – Issue #2: The importance of accurately measuring the droplet spectra in the RICO Cu is obvious when the study of CCN/droplet evolution to precipitation initiation is the prime RICO goal. Unfortunately, it is common knowledge that the inaccurate measurement of the spectra with spectrometers has a long-term issue that still exists. The spectrometers have different drop size ranges over which they function; the overlap at the size-range limits are often exceptionally poor, suggesting large measurement errors. While newer spectrometers (e.g., the PDPA; see recent paper by Strapp et al in JTECH, 2003) may improve matters, scaling of spectrometers appears to remain a problem, even if their sizing is done correctly.
- Fig. 10 - The response of three droplet spectrometers in a water cloud with drizzle drops. The spectra show the typically poor spectrometer overlap; and even for the larger droplet sizes the concentration differences between the CPI and 2-DC probes are about one order of magnitude.
- Fig. 11 - A possible remedy for the inaccuracy of spectrometer scaling is to reference the spectrometers to another probe. Here the combined integrated surface area measured by the NCAR FSSP-100 and 260X probes while flying in DYCOMS-II Sc are compared to the surface area measured by the co-located Cloud Integrating Nephelometer (CIN). In this example the contribution to the area was dominated by small droplets measured by the FSSP. On the left are the data from 5 flights, and on the right are the spectrometer data scaled to the CIN. If the CIN can be designated as the reference, then the FSSP scaling has been normalized for those 5 flights.

Fig. 12 - An example of scaling the 260X and FSSP-100 probes to the CIN total surface area for a precipitation episode below Sc base during DYCOMS-II. Here drizzle drops dominated the area. The procedure for scaling the spectrometers' spectra would be to use cloud portions where droplet spectra match the range of a given spectrometer. Once that is done broader spectra with another unscaled spectrometer could be compared to the CIN. This was done for this plot where the FSSP was first scaled as in the preceding figure, and the 260X was then scaled in the present drizzle episode. In this fashion the spectra for both probes showed good overlap. What makes this possible is that the CIN has a broad response (about 5 μ m to 2500 μ m) over which it integrates the droplet area. If the overlap remains poor after such scaling, then the sizing adjustments of the spectrometers are likely off.

Fig. 13 - Cloud Integrating Nephelometer (CIN; see Gerber et al, 2000, JAS). This probe is based on a well-known, and simple principle. The measurement is in-situ, is independent of airspeed and particle size over a large range, and has a 30 cm³ sample volume. It measures the scattering coefficient, asymmetry parameter, and total droplet surface area. The CIN was flown on the NCAR C-130 during DYCOMS-II, and more recently in other field experiments.

Fig. 14 - The most significant aspect of using the CIN on the C-130 during RICO is the possibility of greatly improving the consistency of the spectrometers by scaling their outputs. Improving the accuracy of the spectrometers is also a possibility given a convincing calibration of the CIN. Given the well-known problem with droplet spectrometers, this approach should have a high priority for RICO.