MICROPHYSICAL OBSERVATIONS IN SUPPORT OF THE CONVECTION AND MOISTURE EXPERIMENT (CAMEX-4)

by

Andrew Heymsfield and Aaron Bansemer
NCAR
Boulder, Colorado
(heyms1@ncar.ucar.edu, bansemer@ncar.ucar.edu)

1. Overview

This report documents our activities during the first year of our funding for CAMEX-4. The goals of our project were two-fold:

- Make measurements of particle size distributions, from several microns to cm size, measure directly the condensate (liquid and ice) mass, and determine the shapes and properties of the hydrometeors sampled from the NASA DC-8 aircraft during CAMEX-4 and KAMP.

- Develop a suite of parameterizations that can be used directly in modeling studies to produce more physically estimates of condensate and precipitation. Algorithms for retrieving cloud microphysical properties from radar are also to be developed.

The text and figures that follow summarizes our progress during CAMEX-4. Section 2 describes the instruments we used to collect microphysical data from the DC-8 aircraft, Section 3 describes the types and extent of data we acquired, and Section 4 presents examples of the hurricane data that we acquired, Section 5 presents our plans for future analysis, and Section 6 identifies the data we have provided to the CAMEX-4 archive.

2. Data Acquisition

During CAMEX-4, we acquired particle size distribution and habit data, using a number of instruments. The majority of data were collected from Droplet Measurement Technology's (DMT) cloud and precipitation imaging probes (CIP and PIP). These 2D-type optical array probes (Fig. 1) collect particle size and low-resolution shape data, over sizes from about 25 to 1600 microns and from 100 to 6400 microns, respectively. Additional particle size distribution information was obtained from a DMT-modified forward

scattering spectrometer probe (SPP-100), measuring in the size range from about 3 to 45 microns. High-resolution particle imagery was acquired from a Stratton Park Engineering Company (SPEC) cloud particle imager (CPI) probe. A counterflow virtual impactor (CVI) probe, owned by the University of Stockholm and operated by us on the DC-8, provided information on the "residual aerosol" population—those particles that were left over from the liquid and ice particles--- above about 8 microns that entered into the CVI--, were evaporated in air filled with dry nitrogen. The size distributions of these residuals were measured directly with optical probes. A portion of the residuals were collected on filters and are available for analysis—to obtain the composition of the constituent aerosols. The capability to measure condensate mass by the CVI probe was largely non-functioning during CAMEX. However, we acquired direct measurements of condensate mass with a Nevzorov total water content probe. We also installed a SPEC high volume spectrometer probe (HVPS) on the DC-8. This probe measures size distributions in the diameter range 200 microns to above 5 cm.

Fig. 1: CIP (2D-C) probe used on the NASA DC-8 aircraft during CAMEX-4

3. Data Quality

After overcoming design problems that were inherent in the DMT CIP and PIP probes during the early part of CAMEX-4, we then acquired excellent CIP and PIP data for most periods of most flights throughout the month of September. This included the acquisition of excellent data from Hurricanes Humberto and Erin, and from Tropical Storm Gabrielle. Data from the FSSP probe are excellent for most periods of all flights throughout CAMEX-4. After a full-time effort by SPEC engineers during the month of August and during early September to get the CPI probe operational, we collected good CPI data after about the 12th of September. Excellent residual aerosol size distributions and filter samples from the CVI probe are available throughout CAMEX. Nevzorov total water content data are available during the early periods of many of the flights. Graupel (small hail) particles often destroyed the sensing elements during the hurricane flights. Although SPEC engineers worked to get the HVPS probe operational continuously throughout CAMEX-4, it appears from our efforts that there was no usable HVPS data.

4. Results

We use the excellent data acquired during the flights into Hurricane Humberto to illustrate some of the results of our efforts. Figure 2 shows images of ice particles obtained from the CIP probe on 24 September during an eyewall penetration. An animation of the sequence of images during this penetration appears on the CAMEX-4 website. There was evidence of riming (collection of supercooled liquid water) on the particle surfaces but generally they were single crystals and aggregates. Higher resolution imagery from the CPI probe during this penetration also revealed that the particles did not have characteristic simple shapes (Fig. 3). This particular example comes from the penetration on 23 September.

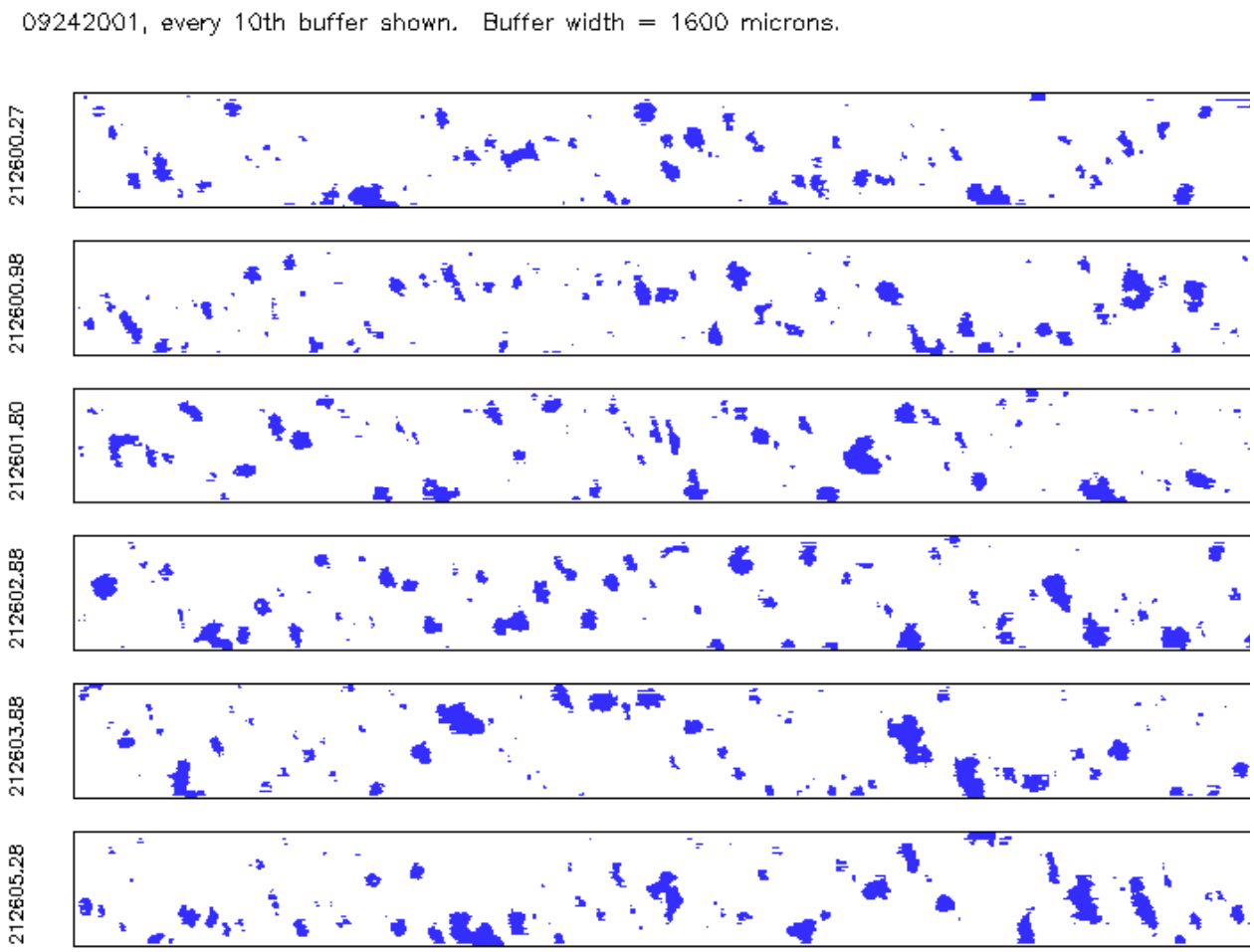

Fig. 2. Examples of 2D images of particles sampled by the CIP probe on 24 September 2001 in eyewall during penetration through Hurricane Humberto.The distance between the horizontal lines represents a particle size of 1 mm.

Size distributions were composited for the CIP and PIP probes to yield concentration information over the size range from about 50 microns to 1 cm. An example of one such composite in the eyewall of Hurricane Humberto appears on the CAMEX-4 web page. This and all of our averages were derived over 1 km path. We found that the spectra from the two probes almost always produced continuous size distributions (Fig. 4).

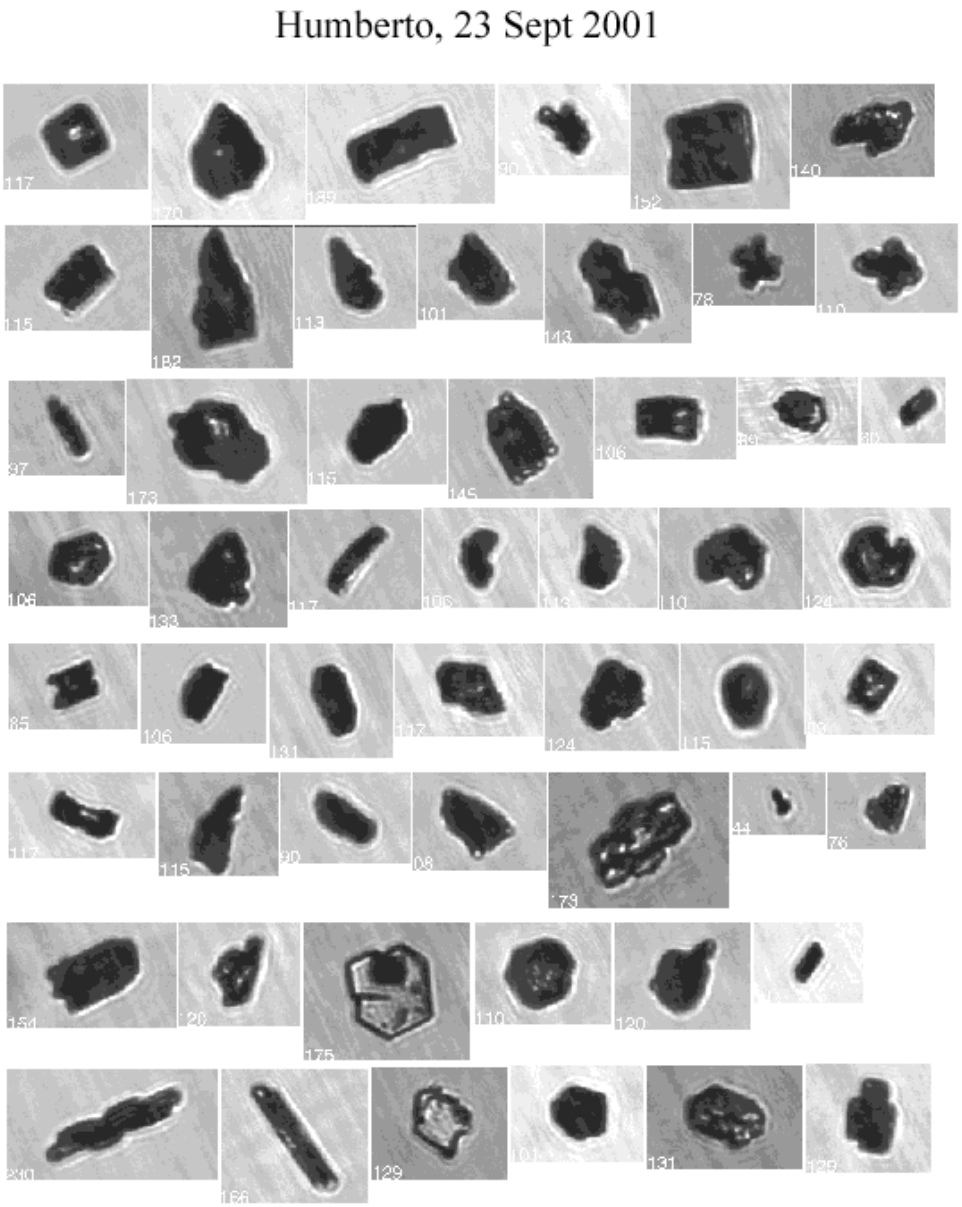

Fig. 3. Examples of CPI images obtained during eyewall penetration into Hurricane Humberto on 23 September 2001. Particles shown are 200 microns and smaller.

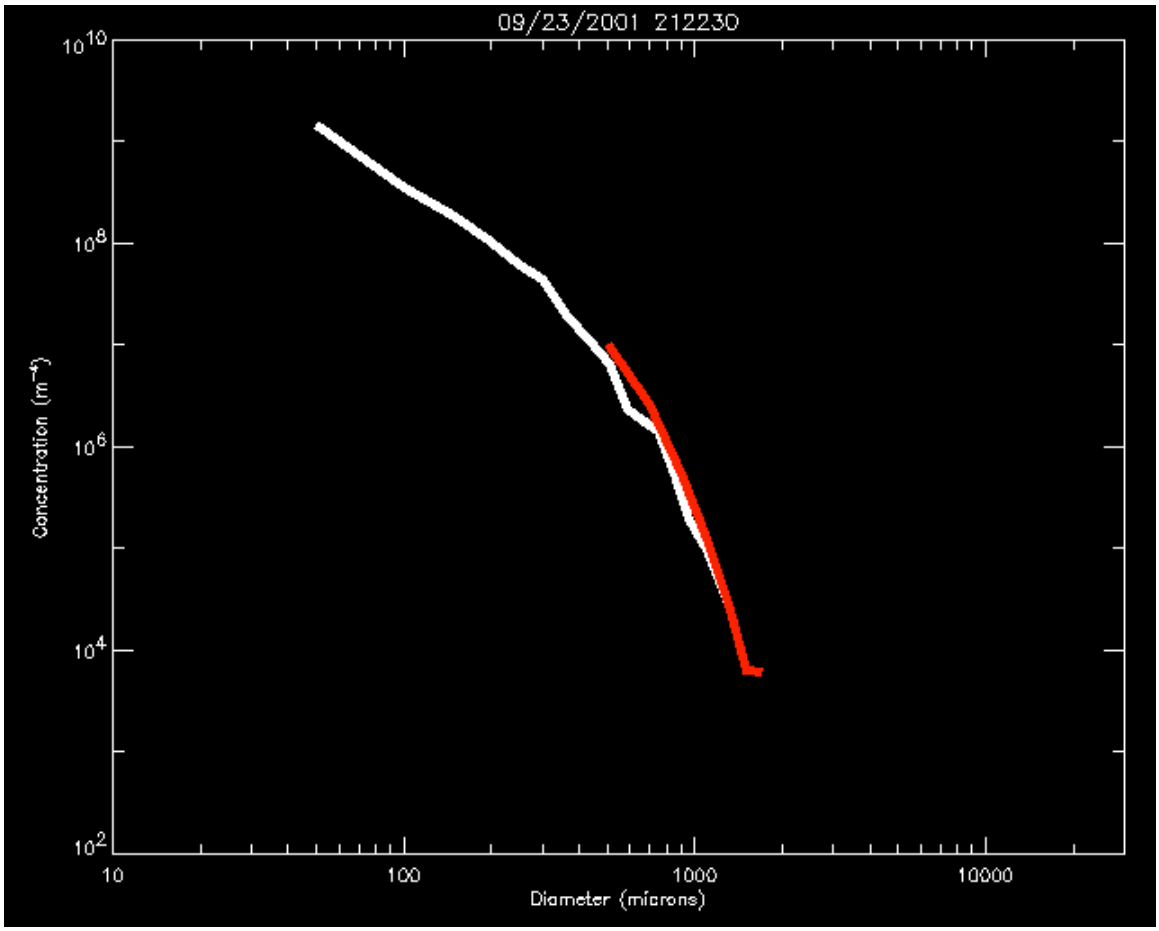

Fig. 4. Size distribution from the CIP (white) and PIP (red) probes over 1 km path during eyewall penetration into Hurricane Humberto.

The size distributions have been analyzed for several of the Humberto eyewall penetrations. These have been composited to yield a depiction of the size distributions through one eyewall penetration (Fig. 5). In the figure, a two-dimensional plot such as that shown in Fig. 4 is color coded such that high concentrations appear towards the red end of the spectrum and low concentrations in blues. The color-coded 2D plot is then projected onto the dimensional axis to yield a line that represents the size distribution. By putting these horizontal lines together we obtained the plot in Fig. 5.

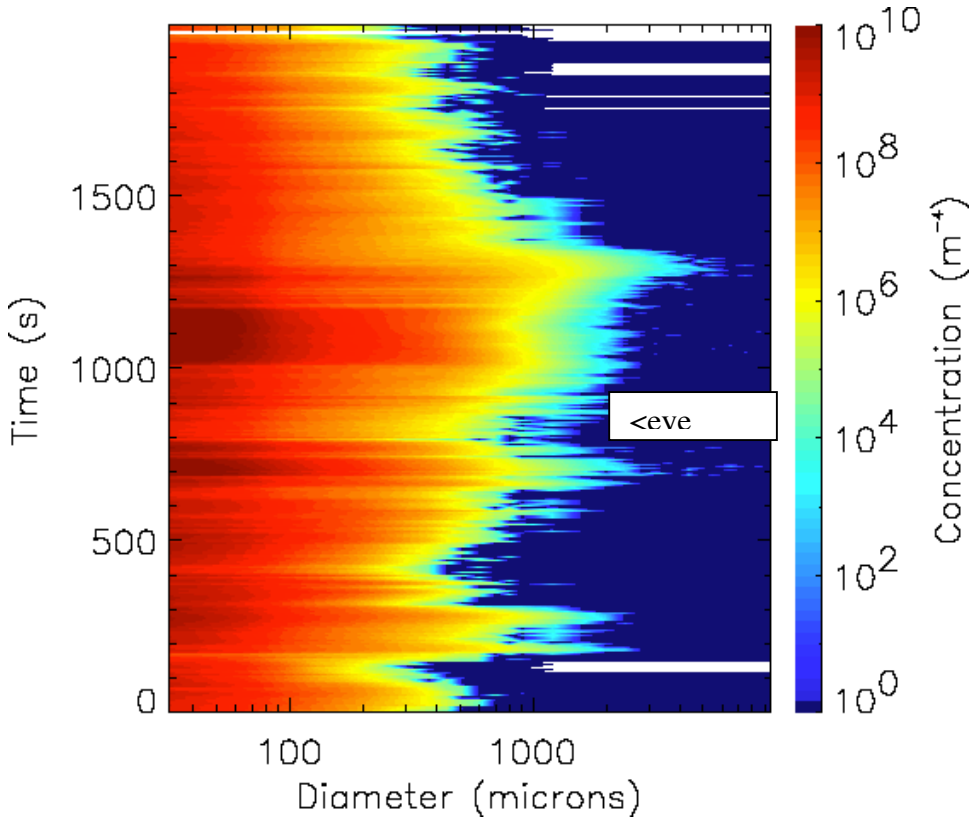

Fig. 5. Plot of size distributions across penetration of Hurricane Humberto on 24 September 2001. Time refers to time or distance along flight path. See text for explanation of figure.

Size distributions were converted into "moments" of the spectra, including the ice water content (IWC) and the snow (or equivalent rain) rate using new techniques developed by the PI. An example showing the ice water content during three penetrations through the eye of Hurricane Humberto is shown in Fig. 6. Note the minima in IWC within the "eye" for each penetration.

5. Plans for Coming Year

Now that we have developed the tools to process the imaging probe data, we plan to devote our attention to develop the tools to process our other data sets, most importantly the data from the Nevzorov total water content probe, and from the CVI probe measurements of "residual aerosols"--their size distributions and composition. We will also work extensively on the analysis of our data sets, both to analyze the hurricane penetrations and to analyze

data from the KAMP experiment. We also plan to work with Dr. Robert Herman at JPL to analyze supersaturations and possible liquid water at very low temperatures

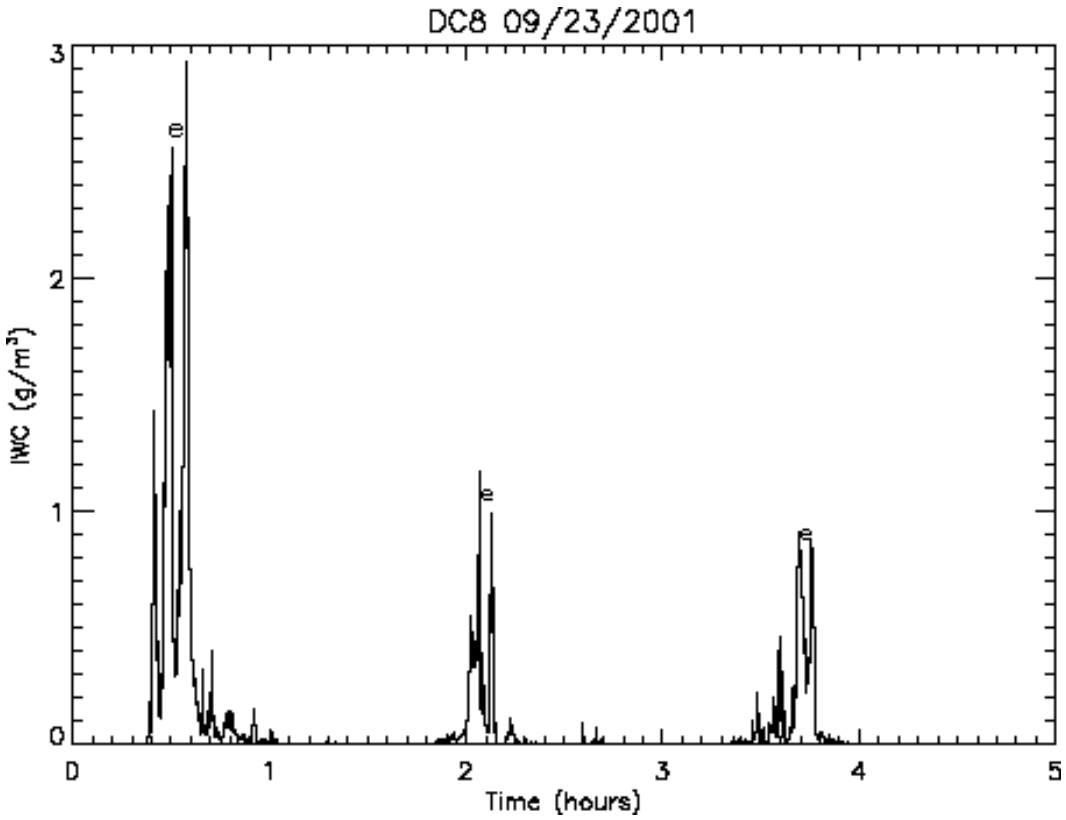

Fig. 6. Ice water content during three penetrations through Hurricane Humberto. The "eye" for each penetration is noted by an "e".

associated with several of the hurricane penetrations. Specifically, we plan to:

- Factor in Nevzorov probe data into our analysis.
- Factor in CVI residual aerosol size distribution data
- Continue analysis of hurricane penetrations, focusing on Hurricanes Humberto, Gabrielle and Erin, where we generally have excellent imaging probe data
- Present our results at the forthcoming Hurricane and Cloud Physics Conferences

- Work with Dr. Robert Herman on the observations of very high (water vapor) supersaturations at very low temperatures.
- Work on case studies with other CAMEX-4 investigators.
- Work on analysis of KAMP data.
- Continue archival of CAMEX-4 and KAMP observations.

6. Archival Activities

At this time most of the imaging probe data from the flights during September, 2001 have been submitted to Dr. Michael Goodman at the CAMEX-4 archive at Marshall Space Flight Center. We will continue to submit data –primarily from the FSSP, Nevzorov and CVI probes—to the archive as we progress on our analysis.