A Comparison of the Characteristics of Cirrus and Anvils Observed During CRYSTAL-FACE Derived from Ground-Based and Aircraft data: Selected Case Studies

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Introduction: Upper tropospheric cloud systems that are either directly or indirectly associated with convection compose a substantial fraction of the earth's cloud cover and consequent radiative forcing. While observations of these cloud types exist in satellite data sets and through measurements conducted by ARM and during the TOGA COARE and CEPEX programs, no coordinated measurement campaign that combines the essential elements of ground-based, satellite and in situ had been conducted until CRYSTAL-FACE. The combination of platforms and payloads deployed in Crystal-FACE allows us to address fundamental questions that extend from basic science to issues that relate to algorithm development and product validation.

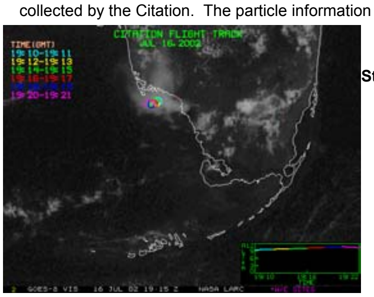
Motivation: Our participation in the CRYSTAL-FACE effort has been motivated by multiple scientific objectives. We will concentrate on two of these objectives in this poster

- **Algorithm Parameter Specification**: A large amount of remote sensing data currently exists in the form of ground based radar and lidar data collected at the tropical ARM sites. While algorithms for converting the measurements into cloud properties currently exist, their applicability to convectively generated cirrus is uncertain because parameters that have been derived empirically using data collected in the middle latitudes may not be applicable to tropical or convective cirrus. We will use the CRYSTAL-FACE data to examine this problem.

- **Active Remote Sensing of Cirrus From Space:** In 2004, the Cloudsat and Calipso satellites will begin generating the first space borne coordinated cloud radar and lidar data sets. Creation of these data sets will certainly be a watershed event in our understanding of clouds in the atmosphere. Lidar and millimeter radar flew on the ER2 for the first time during [redacted] based on the ER2.

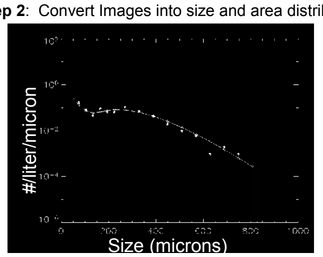
Methodology:

Goal: Use data collected *in situ* to fine tune our ability to retrieve cloud properties from remotely sensed data by deriving **mass-dimensional** and **terminal velocity-dimensional** power laws. We have found that cloud property retrieval algorithms are *extremely* sensitive to the choice of such parameters. We attempt to define these relationships using *in situ* data. Here we use data collected by the Citation. The particle information is provided by the PMS 2DC (provides area and number distribution) and the counter flow virtual impactor (CVI) that provides ice water content.

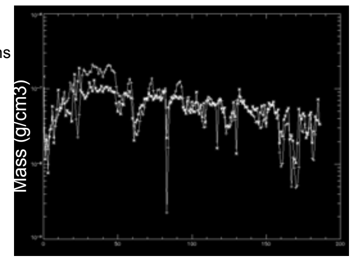


Step 1: Identify a flight segment. Here the Citation spirals through an anvil remnant that just passed over the western ground site on July 16.

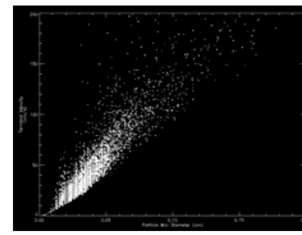
Step 2: Convert Images into size and area distributions



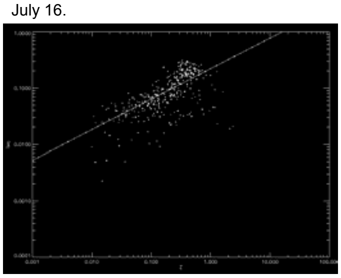
Step 3: Fit the distributions with bimodal (gamma and exponential) functions for mathematical analysis of the distributions.



Step 4: Combine the CVI IWC and 2DC Size functions to determine, using a least squares algorithm, the most appropriate mass-dimensional power law. This figure shows the IWC observations (*) and the derived (+) masses using a coefficient of 0.0138 and an exponent of 2.724 in the dimensional power law equation (cgs units) for the spiral ascents and descents [redacted]

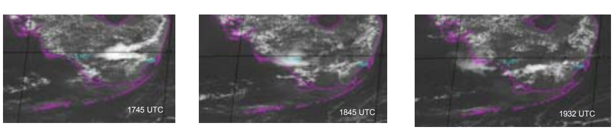


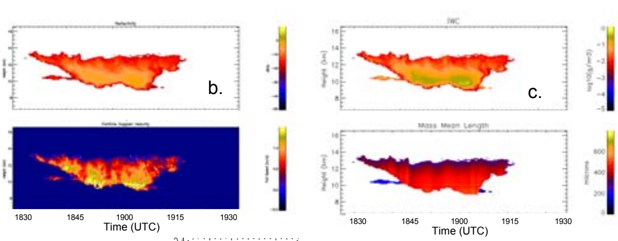
Step 5: Using the mass relationship and the particle areas measured by the 2DC, calculate the particle terminal velocity for individual particles. Fit these with a power law relating the particle maximum dimension to the terminal velocity. The above diagram shows data from the spirals flown on the 16th of July. The power law constant is 11011. and the exponent is 1.6484 in cgs [redacted]

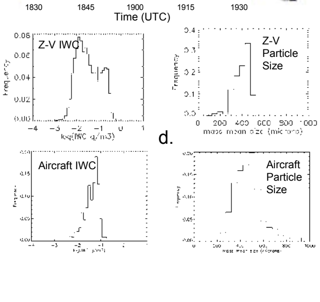


Step 6: Calculate the radar reflectivity from the fitted 2DC distributions and use the CVI IWC to derive an event specific Z-IWC power law. Z-IWC relations are notoriously difficult to specify generally because of case to case variability. However, individual cases allow for a judicious and careful application of the technique. The diagram above shows the Z-IWC relation for the July 16th spirals. The power law coefficient is 0.221 and the exponent is 0.542 (Z in mm^6/m3 and [redacted]

An Example of Ground Site-Aircraft Synergy: 16 July

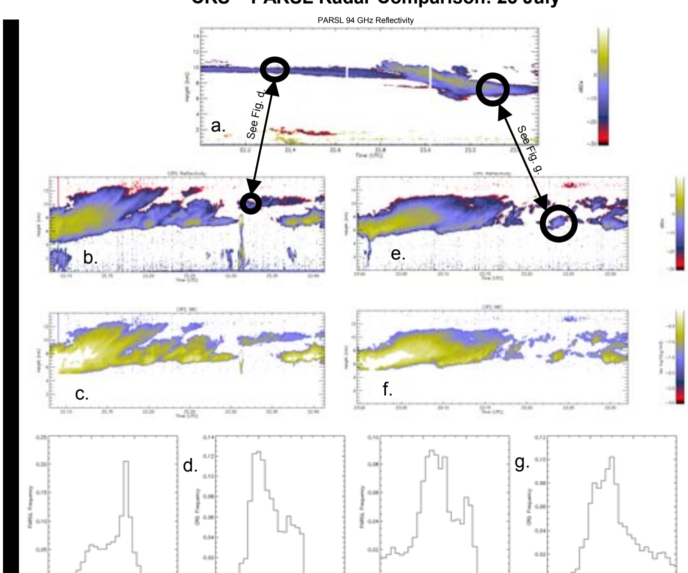






Using the technique outlined above in steps 1-5, we exploit the synergy between the ground -based and *in situ* data with a retrieval algorithm that uses sets of coefficients unique to this cloud system. The satellite data (a.) show the evolution of the anvil from its parent cell north of Miami to where it was sampled by PARSL (b.). The Citation spent 1 hour spiraling in the cloud just after it passed the PARSL site. Using a reflectivity-Doppler velocity retrieval, the properties of the layer are calculated using the model parameters derived from the Citation (c.) The comparison between the aircraft and ground-based cloud system statistics are consistent.

CRS – PARSL Radar Comparison: 23 July



On 23 July, storms near Lake Okeechobee resulted in anvil cirrus extending southwestward over the western ground site. Fig. a. shows the thin anvil that was observed between 22 and 23 UTC by the PARSL 94 GHz radar. The ER2 sampled along the anvil, and the CRS results for two legs that extend from northeast to southwest are shown in Figs. b and e. Water contents derived from Z-IWC relations using coincident Citation data are shown in c. and f. The comparison between the PARSL radar and the CRS for the two overpasses of the ER2 is shown in d. and g. Allowing for differences due to sampling strategy, we find the overall features in the frequency distributions are nearly identical.