Algorithms for Processing Cloud Microphysical Data Acquired by Atmospheric Radiation Measurement Program Unmanned Aerospace Vehicle Applications to TWP-ICE

M. Freer and G. McFarquhar
University of Illinois
Urbana, Illinois

G. Kok
Droplet Measurement Technologies
Boulder, Colorado

B. McCoy and T. Tooman
Sandia National Laboratories
Livermore, California

Introduction

The Atmospheric Radiation Measurement (ARM) Program's Unmanned Aerospace Vehicle program currently maintains and operates a complete suite of cloud probes that provide in situ measurements of the size and shape distributions of ice crystals over a wide range of sizes and bulk measurements of extinction (βe) and ice water content (IWC).

Processing programs, developed in MatLab, allow users to easily obtain, view and plot higher level data products using a graphical user interface (GUI). This allows quality control immediately after the data is downloaded from the aircraft.

Cloud Particle Images and Size Distributions

For the Cloud Aerosol Precipitation Spectrometer (CAPS), a code converts the measured particle counts into size distributions (SDs), total concentration, IWC and βe. Figure 1 shows the GUI used to plot data from all in-situ probes, including the CAPS. Particle images from the Cloud Imaging Probe (CIP) are displayed in Figure 2. Matlab routines determine each particle's diameter, area, axis ratio, circularity, and habit. In Figure 3, number concentrations from the CIP and Cloud Aerosol Spectrometer (CAS), components of the CAPS, are shown.

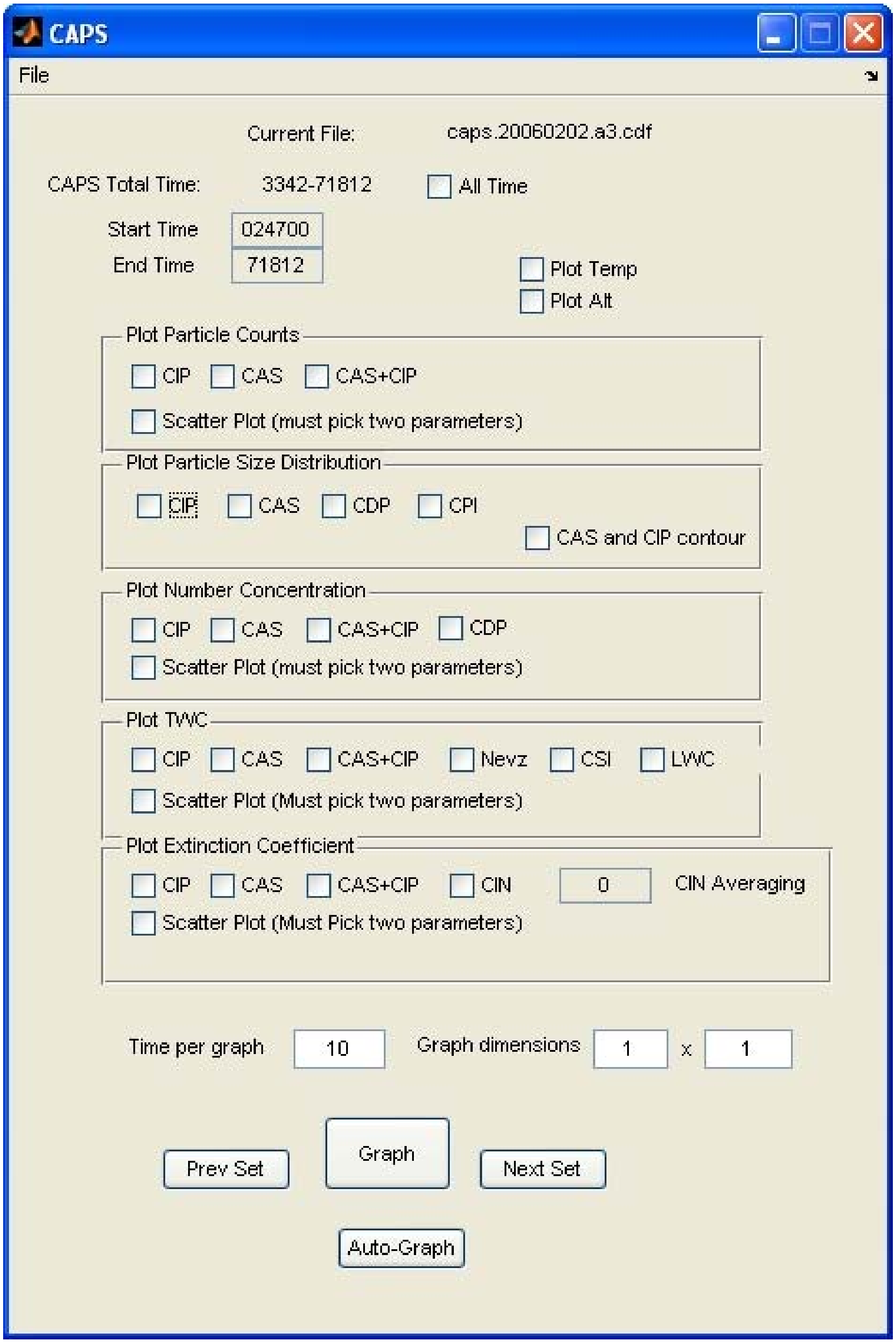

Figure 1. Example of GUI.

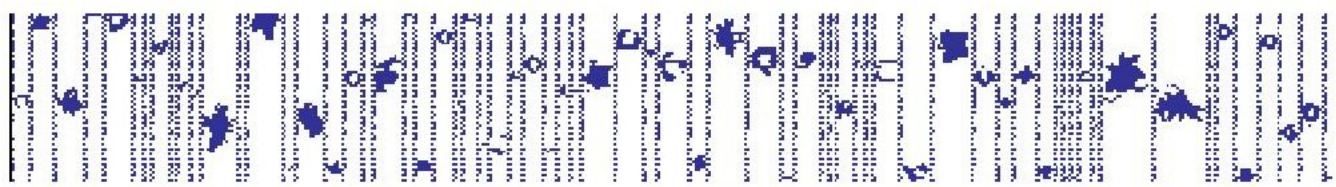

Figure 2. CIP particle images plotted using CAPS processing routine. Vertical bars denote timing bar needed for concentration calculation in Matlab.

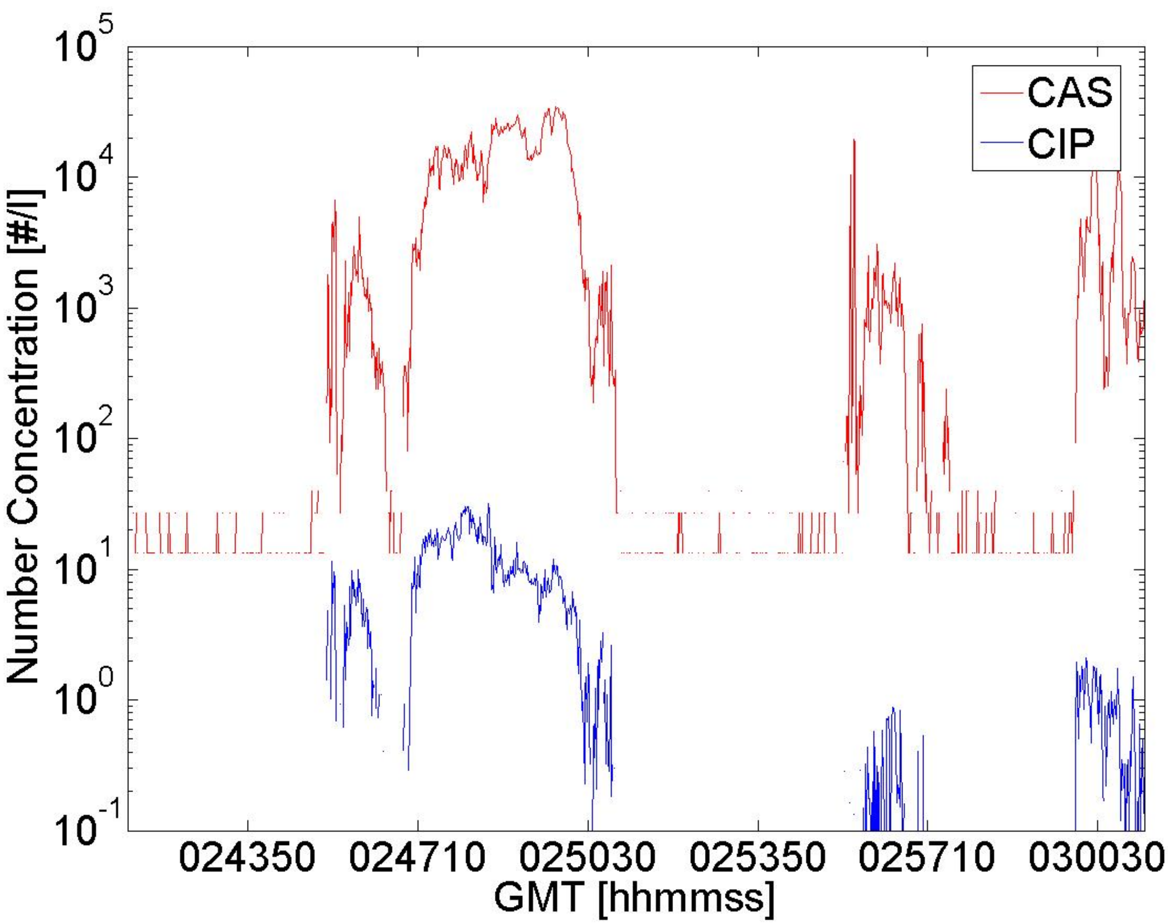

Figure 3. Total number concentration measured by the CIP and CAS during the first spiral in an anvil on February 2 during Tropical Warm Pool-International Cloud Experiment (TWP-ICE).

The Proteus also carried a Cloud Particle Imager (CPI). Particle images and SDs are generated using CPIView, developed by The Stratton Park Engineering Company Inc. The Matlab code imports the CPI SDs and combines them with the CAS and CIP SDs. Figure 4 shows example SDs from the CPI and CAPS.

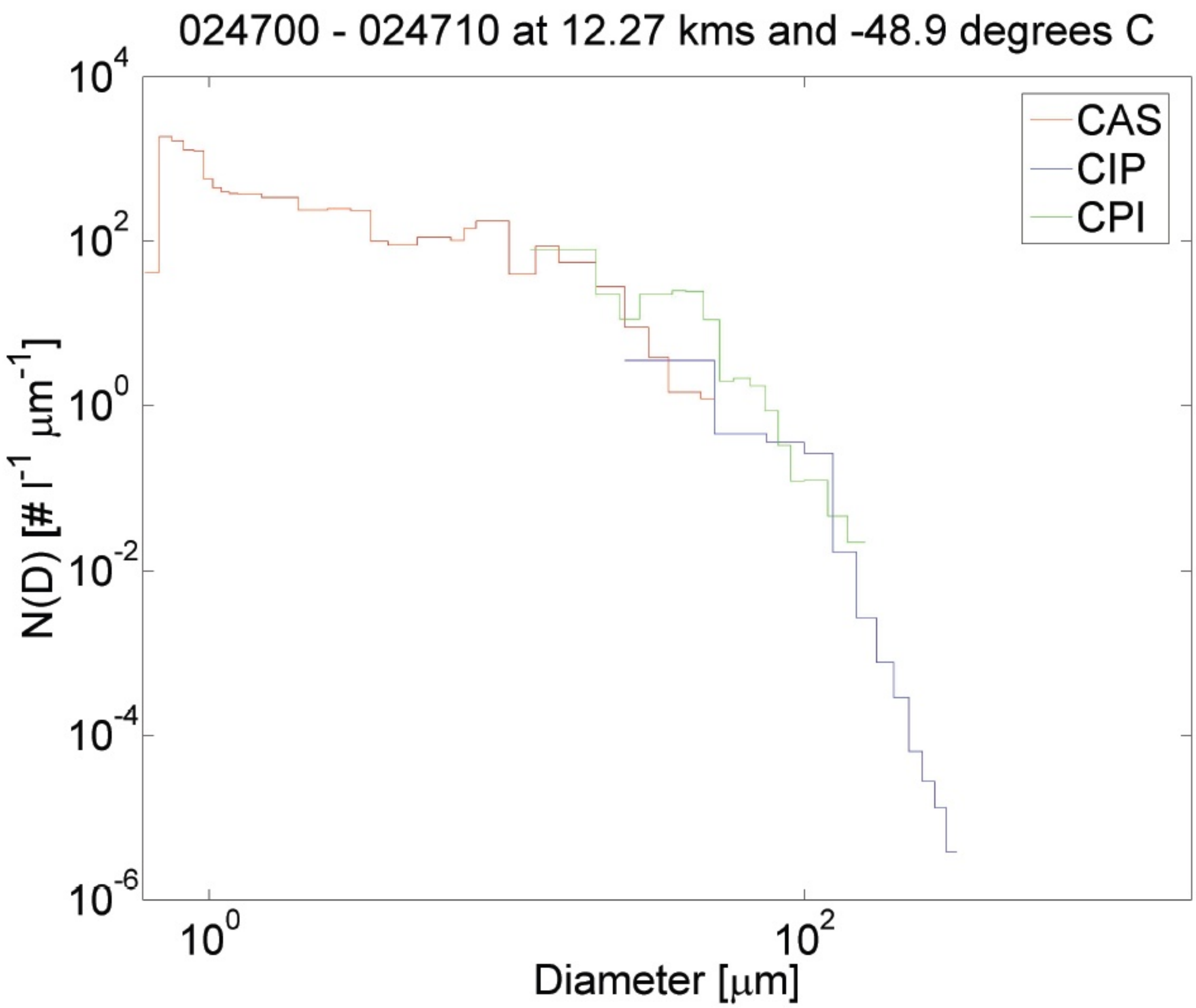

Figure 4. CAPS and CPI SDs from the first spiral on February 2 during TWP-ICE.

Bulk Microphysical Measurements

A bulk measurement of total water content (TWC) is provided by the CSI, whereas channel voltages from the Nevzorov probe are converted to bulk measures of TWC and liquid water content using a point outside cloud to correct for an altitude dependent baseline drift. The Matlab code compares IWC from the bulk probes against that derived from the CAPS SDs (Figure 5).

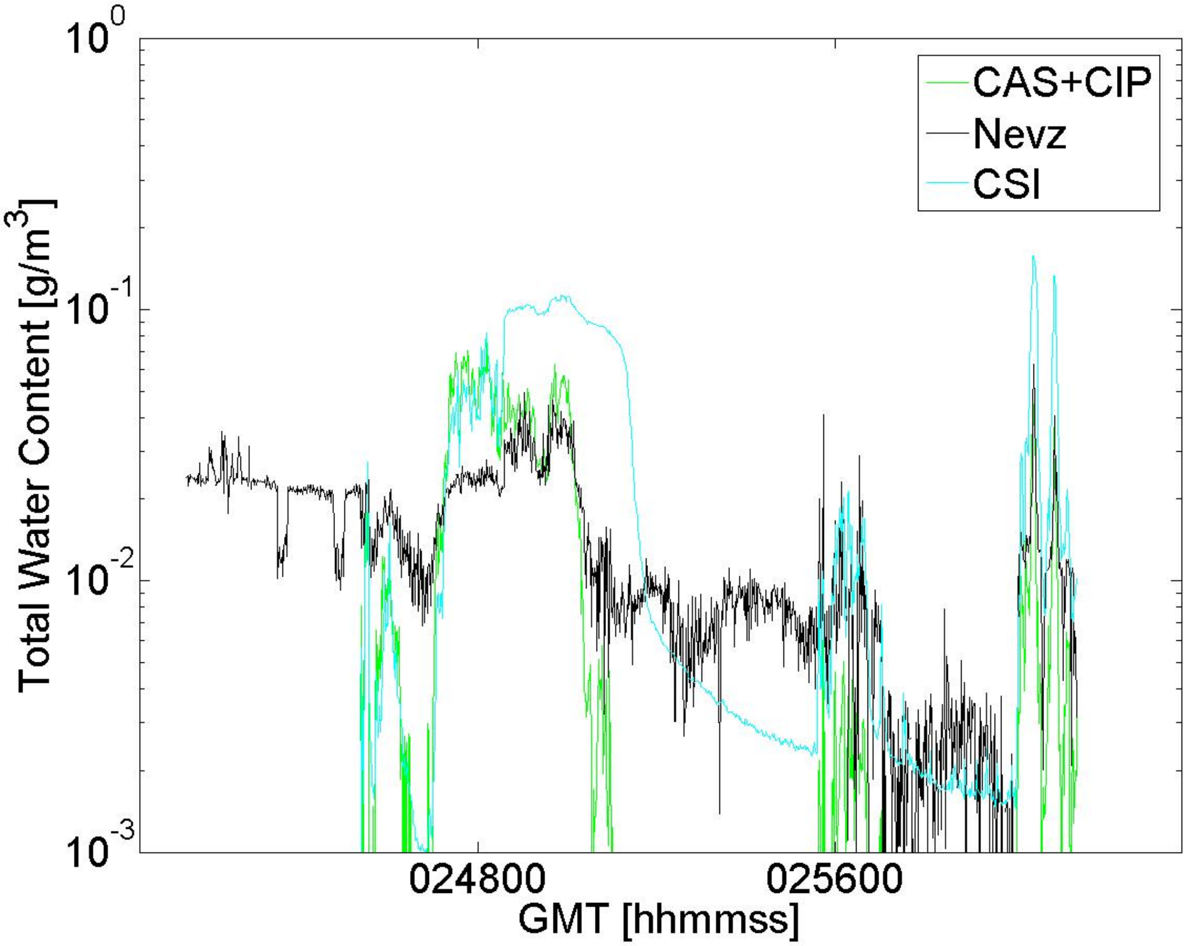

Figure 5. Nevzorov, CSI and derived CAPS derived TWC for the first spiral on February 2 during TWP-ICE.

The Matlab code also calculates bulk measures of βe and asymmetry parameter (g) from the convective inhibition (CIN) with averaging intervals specified by the user. The CIN βe can be compared against βe derived from integrating the CAPS SDs assuming geometric optics (Figure 6).

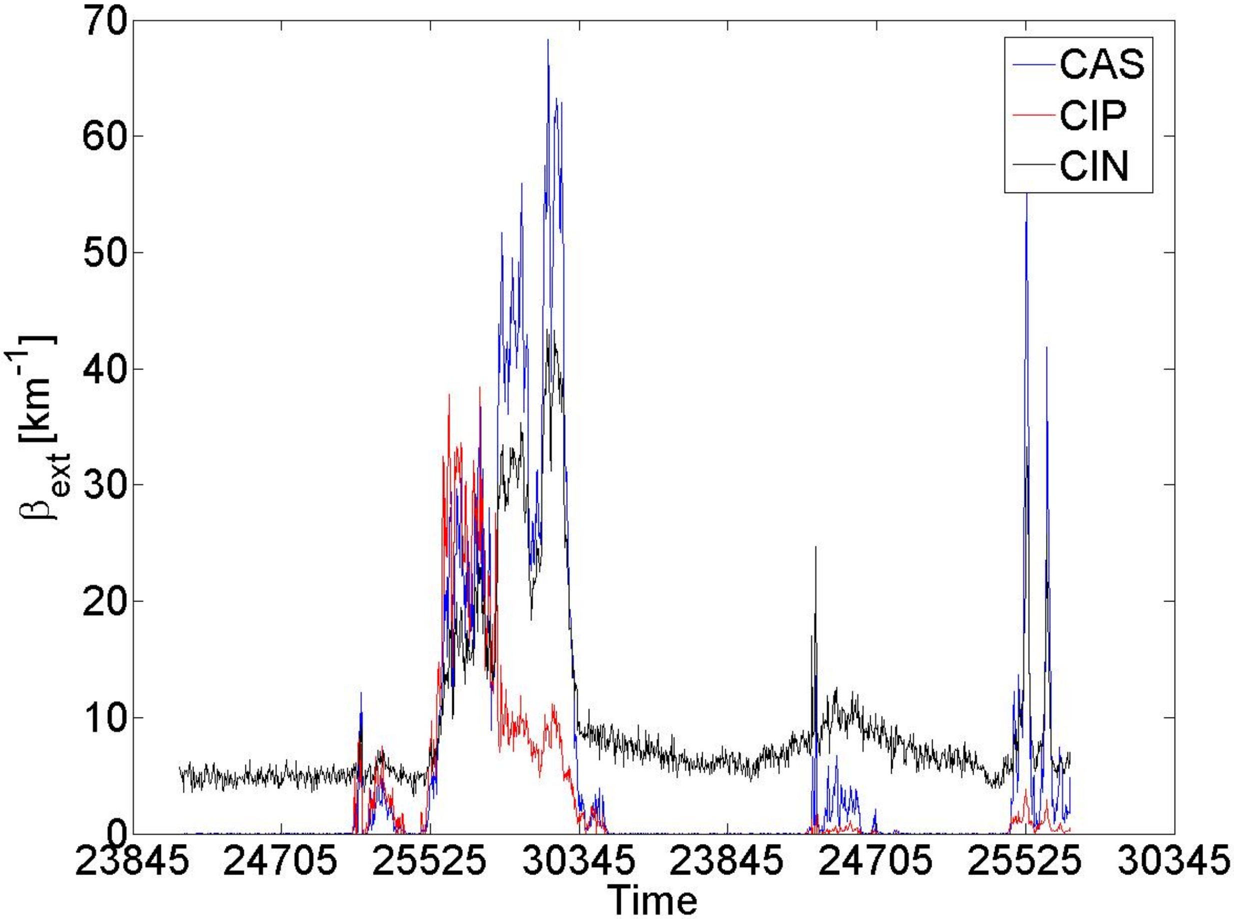

Figure 6. Comparison between CAPS and CIN βe for 1st spiral on February 2 during TWP-ICE.

Cloud Boundaries

The Matlab code applies Wang and Sassen's (2001) cloud detection algorithm to cloud lidar data to determine tops and bottoms for up to 10 cloud layers. The GUI (Figure 7) allows the user to set threshold values for the boundaries and the time domain over which the boundaries should be computed. It can plot the normalized backscatter return, the cloud boundaries (Figure 8) or histograms of the derived cloud heights (Figure 9).

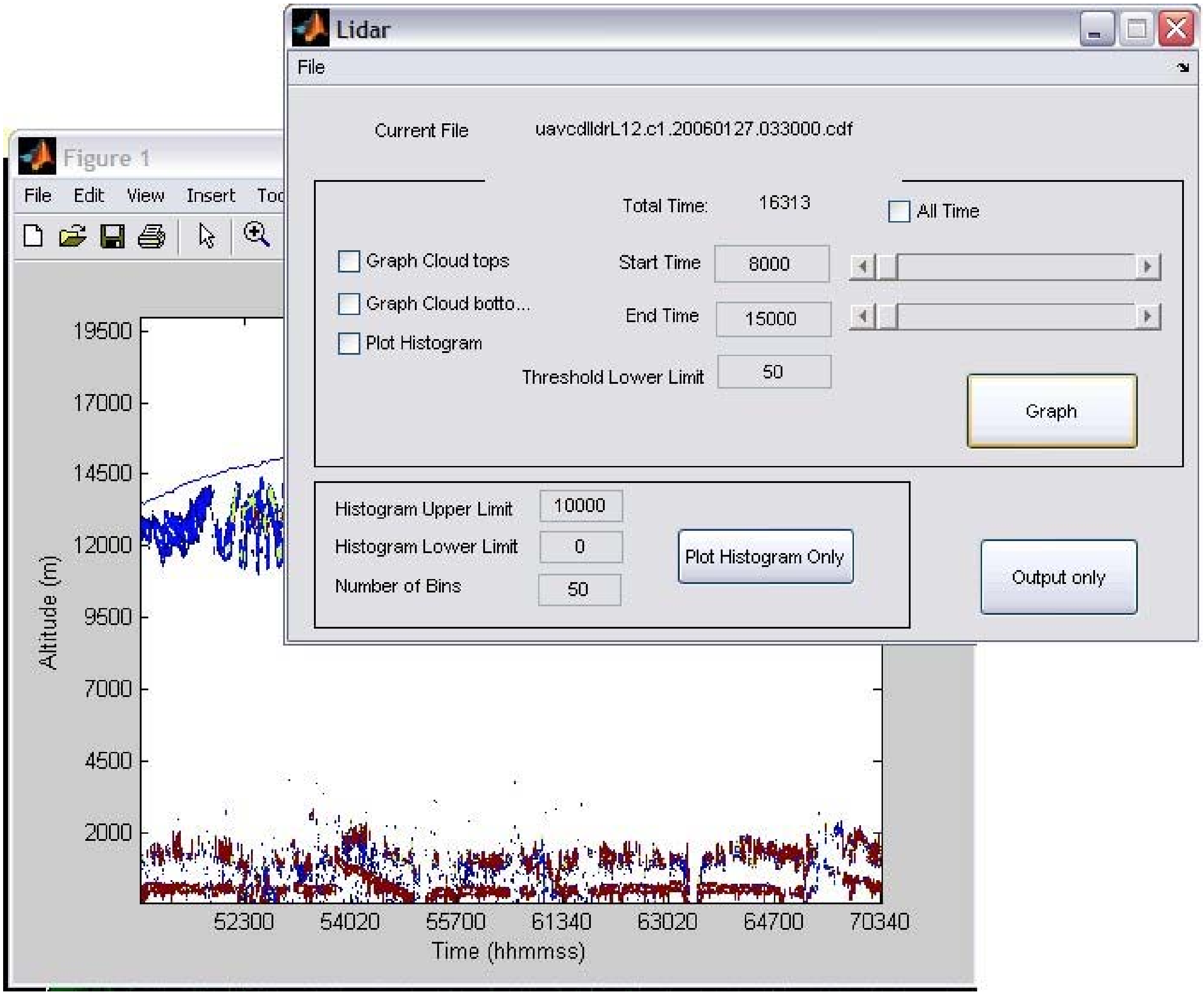

Figure 7. Example of GUI that runs in Matlab for identifying cloud boundaries.

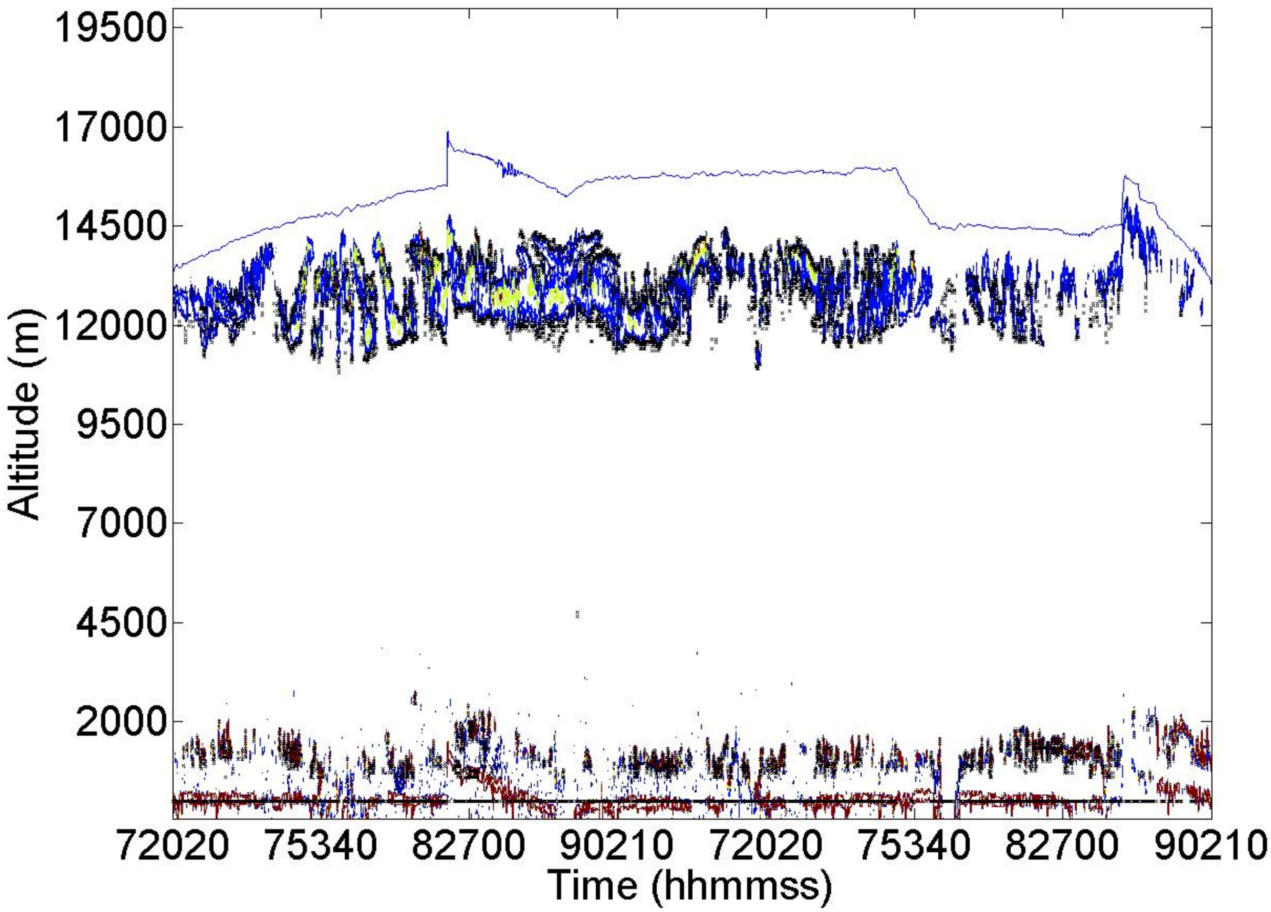

Figure 8. Cloud boundaries determined by applying Wang and Sassen algorithm to lidar signal.

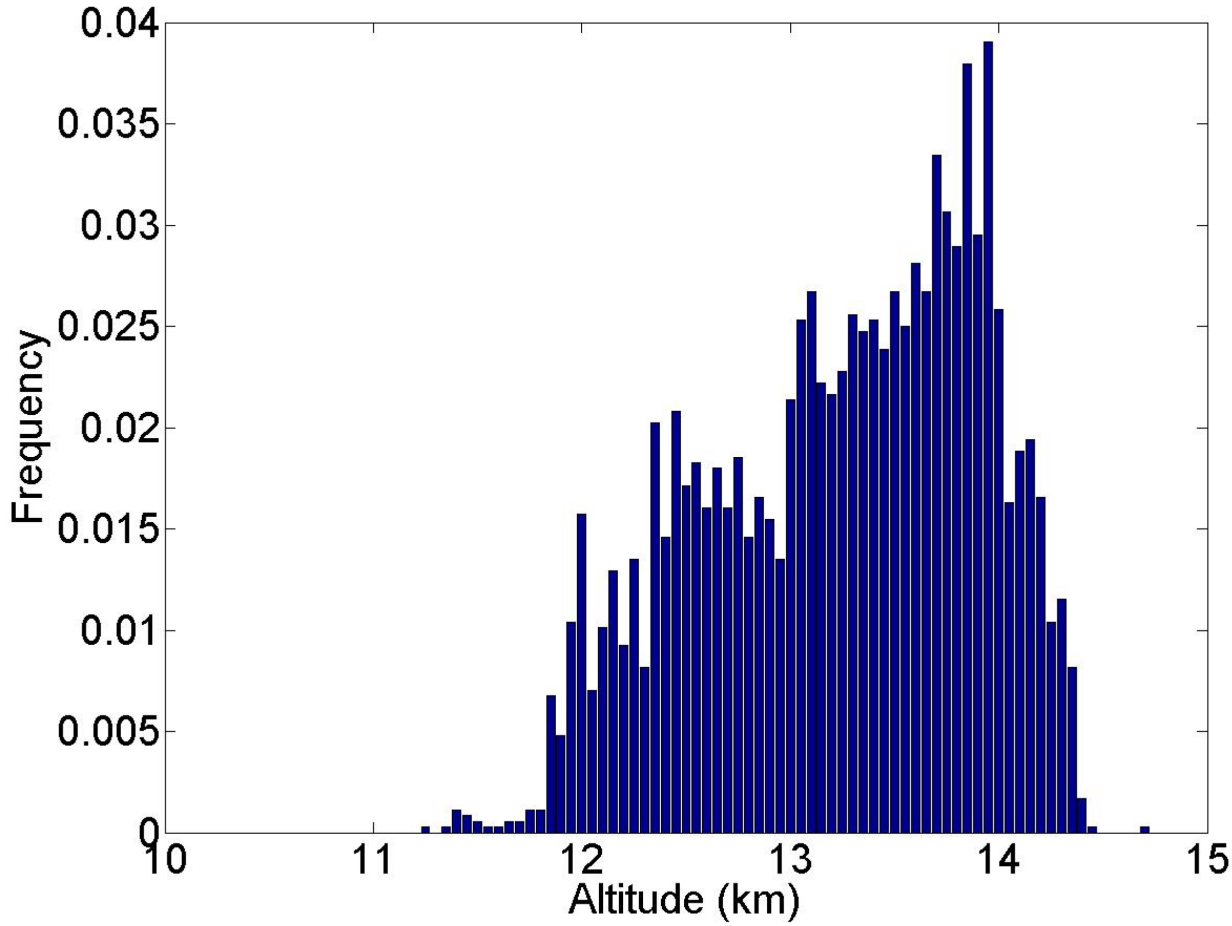

Figure 9. Histograms of normalized frequency of occurrence of cloud heights. Points with aircraft pitch angles > 5 degrees excluded from analysis.

Acknowledgments

This research was supported by the ARM-UAV program and by the Department of Energy ARM Program under grant DE-FG02-02ER63337. Data were obtained from the ARM Program Archive, sponsored by the U.S. Department of Energy, Office of Science, Office of Biological and Environmental Research, Environmental Sciences Division.

References

McFarquhar et al. 2006. Horizontal and Vertical Profiles of In-situ Cloud Properties Measured during TWP-ICE. Presented at the Sixteenth Atmospheric Radiation Measurement (ARM) Program Science Team Meeting. Albuquerque, New Mexico.

Wang, Z, and K Sassen. 2001. "Cloud type and macrophysical property retrieval using multiple remote sensors." *Journal of Applied Meteorology* 41:218-229.