Experimental Objectives for the Characterization and Detection of Convective Turbulence

This document is written in conjunction with the "Convective Turbulence Data Collection Program for Characterization and Detection System Development" written by William Bresley, Allied Signal, hereafter referred to as the "Operations Plan". The purpose of this auxiliary document is to give more details of the experimental procedures and plans that are anticipated to be executed during the field program and data collection.

Conduct of Operations

1. Upper air soundings

Each day, the Mobile CLASS sounding crews will take a sounding at 11:00 a.m. such that the data obtained can be used for the weather briefing conducted at noon by the Weather Analyst. This sounding will be taken at the CHILL radar site (or nearby if that site is not suitable).

Subsequent soundings will be taken by driving the Mobile CLASS van to appropriate locations, depending on the evolving weather conditions, as directed by the Test Director or Weather Analyst.

Soundings will be displayed on a Web site after being communicated back to the RAP computers via a modem or spectrum radio link. The url for the Web page is http://www.rap.ucar.edu/projects/nasa_turb/turb.html. The latest CLASS and Denver soundings will be displayed.

Communications with the Mobile CLASS van will be conducted with a cellular phone. That phone number is (303) 870-7892.

2. Ground based radars

The CHILL and Pawnee radars will be operational slightly before noon to enable the weather briefers to examine the state of the atmospheric boundary layer. This information, coupled with the morning sounding, is extremely useful when formulating a prediction for the day's events.

The radars will operate in unsynchronized surveillance scans after the noon briefing. A timed, dual Doppler scan will be conducted every half hour such that the wind field within the boundary layer may be derived. The radars will operate in this mode until the onset of convection.

Once storms begin to form and the aircraft have been launched, dual Doppler sector scans will be conducted. These scans will cover the area of the storm to be penetrated as well as the region between the storm and the two following aircraft. The Weather Analyst or the CHILL Operator will be in radio contact with the Pawnee operator to coordinate the scan start times via radio. A dual Doppler scan optimization program will be run at both radars to assist in the scan determination. Azimuth limits will be adjusted manually as the storms move.

A second mode for the ground-based radars will have the Pawnee radar maintaining the sector scan while the CHILL radar does a "tracking" scan that follows the aircraft of interest (generally the T-28). This scan does a small sector centered on the aircraft with about 5 elevation angles. The center elevation angle will be positioned on the aircraft altitude.

Typically, during aircraft penetrations, dual Doppler scans will be conducted before and after penetration. As the aircraft enter the storm, the tracking scan will be used at CHILL. This mode of operation will ensure the safety of the aviation crews, particularly in mature or intensifying storms having reflectivity values at or above 40 dBZ.

However, if storms are in very early stages of development or if the storm is dissipating (reflectivity values considerably below 40 dBZ), dual-Doppler sector scans may be conducted during penetrations, if the Aircraft Coordinator is in agreement. Storm evolution must be closely watched to ensure aviation safety standards are maintained.

Dual-polarization data may be used during the dual Doppler or tracking scan, depending on conditions. The need for rapid dual Doppler scan completion may necessitate turning off the dual polarization data. For aviation safety, dual-polarization data will be collected for the tracking scans and for other penetration scans.

A set of "canned" scans will be devised prior to the start of the field program to define the basic characteristics of each scan type. Canned scans for surveillance mode, dual Doppler mode, and RHI modes will be devised. The scan optimizer allows these scans to be optimized during operations.

Figure 1 shows a map of the dual-Doppler area for the CHILL and Pawnee radars. The unhatched areas within the dual Doppler lobes are primary regions for the conduct of field operations due to the lack of conflicts with airways, terrain, beam blockage, or the dual Doppler baseline. The eastern lobe is particularly suitable. Arrival and Departure corridors for the Denver International Airport and the Cheyenne Airport are shown with the green, bold lines. Regions of high terrain and a 15 degree sector that has low-level blockage from CHILL are indicated by the red hatching. These areas are considered secondary for experimental objectives due to the difficulty of conducting aircraft operations over high terrain and to the difficulty in deriving the wind field because of the beam blockage. The region of the dual-Doppler baseline is hatched blue and is also a secondary region since the wind field cannot be determined in this region.

3. Other weather information

Web access to sites containing near real-time weather information will be used in the operations center to monitor regional conditions.

Flight Plans

This section details the flight plans that can be selected for the horizontal or vertical mapping of the distribution of convective turbulence. Hand-drawn "storms" are superimposed over the flight track to suggest possible aircraft penetration scenarios. Interior contours suggest regions of higher radar reflectivity within the storm, with no indication of the maximum values. For those examples where the flight tracks are shown entering the "highest" regions of reflectivity, the maximum reflectivity represented by the contour will be no higher than the limits imposed for each aircraft.

1. Reverse Heading

The reverse heading (Fig. 2) will be used for penetrations of clouds and storms. However, with three aircraft this flight plan is difficult to perform and is recommended to be used with only 1 aircraft.

2. Tear Drop or Rosette

The tear drop flight plan (Fig. 3a) will be used for cloud and storm penetrations when there are 2 or 3 aircraft in formation. Turns will be made in the clear air. The Convair and Sabreliner aircraft will maintain ±1000 ft separation in the vertical from the altitude of the T-28.

The rosette pattern (Fig. 3b) is similar to the tear drop pattern, but with multiple passes. The pattern is performed with consistently right or left turns when outside the storm to continually work around the storm in one direction. This pattern will map the distribution of turbulence over multiple directions within the cloud or storm. Again, the trailing aircraft will maintain ±1000 ft separation in the vertical from the T-28 altitude.

3. Zig-zag pattern

For larger areas, the zig-zag pattern (Fig. 4a) may be used to map the horizontal distribution of turbulence. Turns will be made in the clear air. The trailing Convair and Sabreliner aircraft will maintain ±1000 ft separation in the vertical from the altitude of the T-28.

For smaller areas, the zig-zag pattern could be used to map the horizontal distribution of turbulence as the aircraft work their way from the outside of the storm towards the inside of the storm (Fig. 4b). Turns will be made in the clear air. The trailing Convair and Sabreliner aircraft will maintain ±1000 ft separation in the vertical from the altitude of the T-28.

4. Vertical mapping

With 2 or 3 aircraft, one of which is the T-28, vertical mapping (Fig. 5) will be accomplished by making constant altitude passes through the storm or cloud, climbing to the next altitude in the clear air, and making a reverse pass through the storm. The T-28 will lead with the Convair and Sabreliner stacked and in tail, separated by several miles horizontally and ±1000ft vertically. This pattern will be flown between cloud base and about 21 kft. Incremental steps in altitude could range from 1000-3000 ft.

If the T-28 is not available for flight, the Convair and the Sabreliner will be able to do vertical mapping at higher altitudes (Fig. 6). The aircraft will be separated by several miles horizontally and 1000 ft vertically. Altitudes of operation will be between 20 and 30kft, or the maximum operating altitude of the aircraft.

A special case of the vertical mapping is to fly over developing cumulus in order to map the turbulent field (Fig. 7). This flight plan must be done early in the convective development to succeed in flying over cloud tops.

Scientific Experiments

1. Updraft/downdraft boundaries

Regions near the boundary between the updraft and the downdraft are areas that can be characterized as having turbulence. Flight plans for the Reverse Heading, the Tear Drop, and Vertical Mapping can be used, as appropriate.

2. Lee side of convective cells

Regions in the lee of convective cells have been known to have turbulent flow. Penetration of this region of the storms can be done with the Tear Drop and Reverse Heading Patterns. Vertical mapping of this region of the storm can be done as well.

3. Storm boundaries

The lateral boundaries of a storm may contain turbulent flow. During the horizontal and vertical mapping of the storm, turns will be made in the clear air such that this region will be sampled by the aircraft.

4. Regions of vertical shear

Regions of vertical shear of the horizontal wind are known to have turbulent flow. Vertical shear may be found near the top of the outflow boundary, and within mid-level entrainment of environmental air within storms, to name a few. Again, flight plans for the horizontal and vertical mapping of the region of turbulence can be used to sample regions of interest.

5. Over developing cloud tops

Regions near and above cloud top are suspected to be turbulent, on occasion. To sample this region, aircraft must be deployed early in the lifecycle of convective development before cloud tops are excessively high. Redeveloping cumulus along the flanking line of thunderstorms are also candidates for this experiment.

6. Regions near the top of updrafts

During the VORTEX experiment, an encounter with severe turbulence occurred at the exit region of an updraft. With the Convair and the Sabreliner, it may be possible to penetrate this region of a storm, with the qualification that turbulence levels must not be severe. Altitude constraints and safety considerations may make it difficult to probe this region for mature convective storms, however, it may be attainable with developing convective clouds.

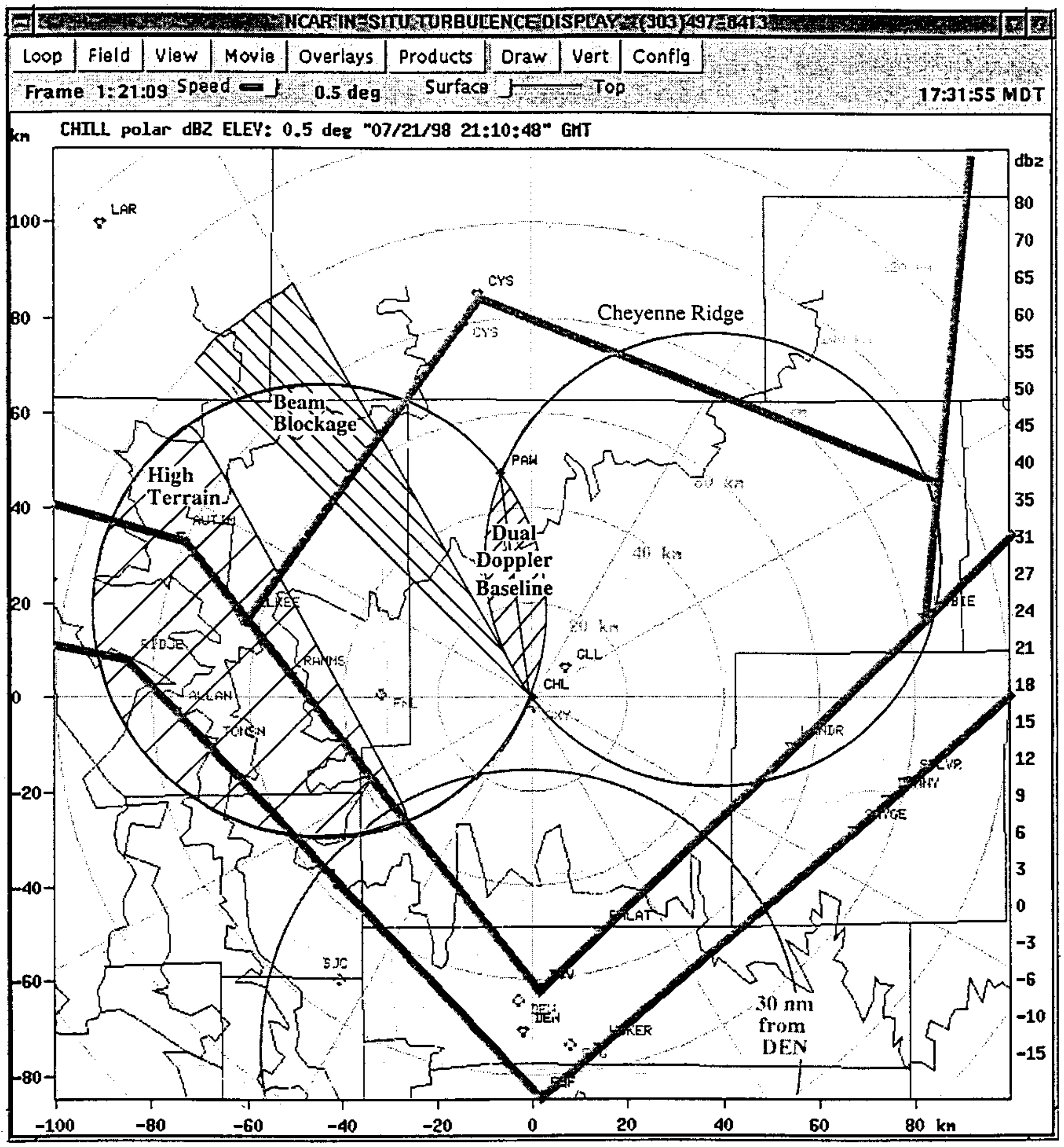


Figure 1. A map of the CHILL-Pawnee dual Doppler lobes.

Horizontal Mapping of the Distribution of Turbulence

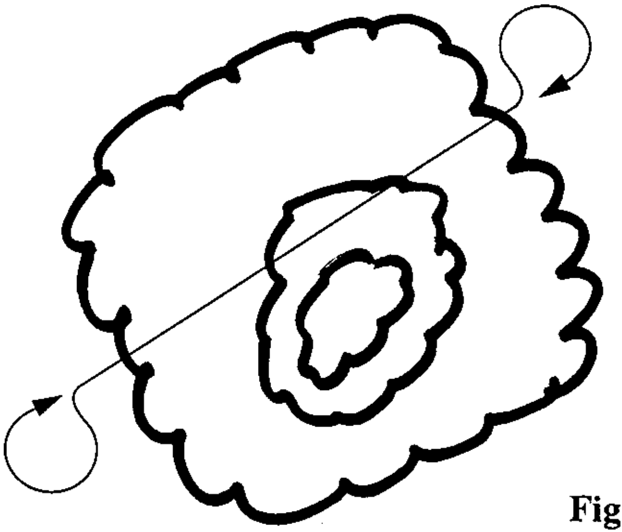


Figure 2. Reverse Heading
(Difficult with >1 aircraft)

Horizontal Mapping of the Distribution of Turbulence

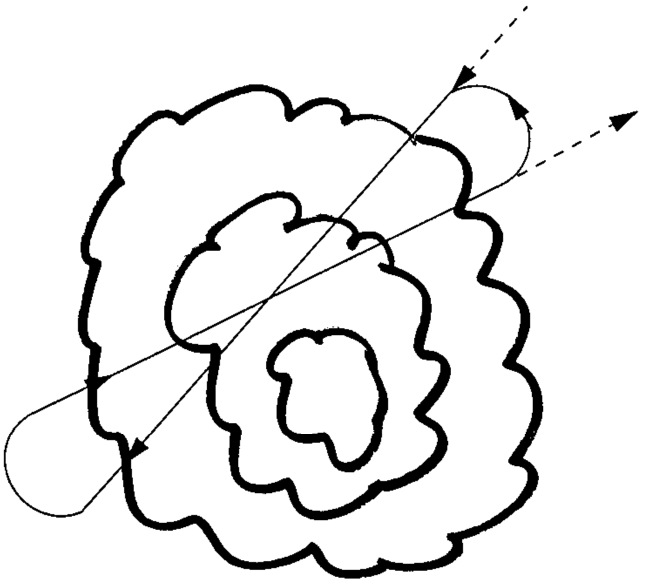


Figure 3a. Tear Drop

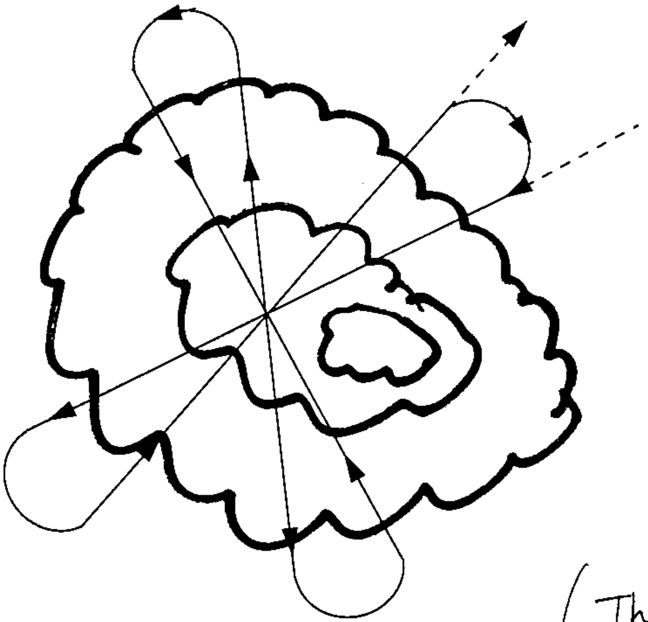
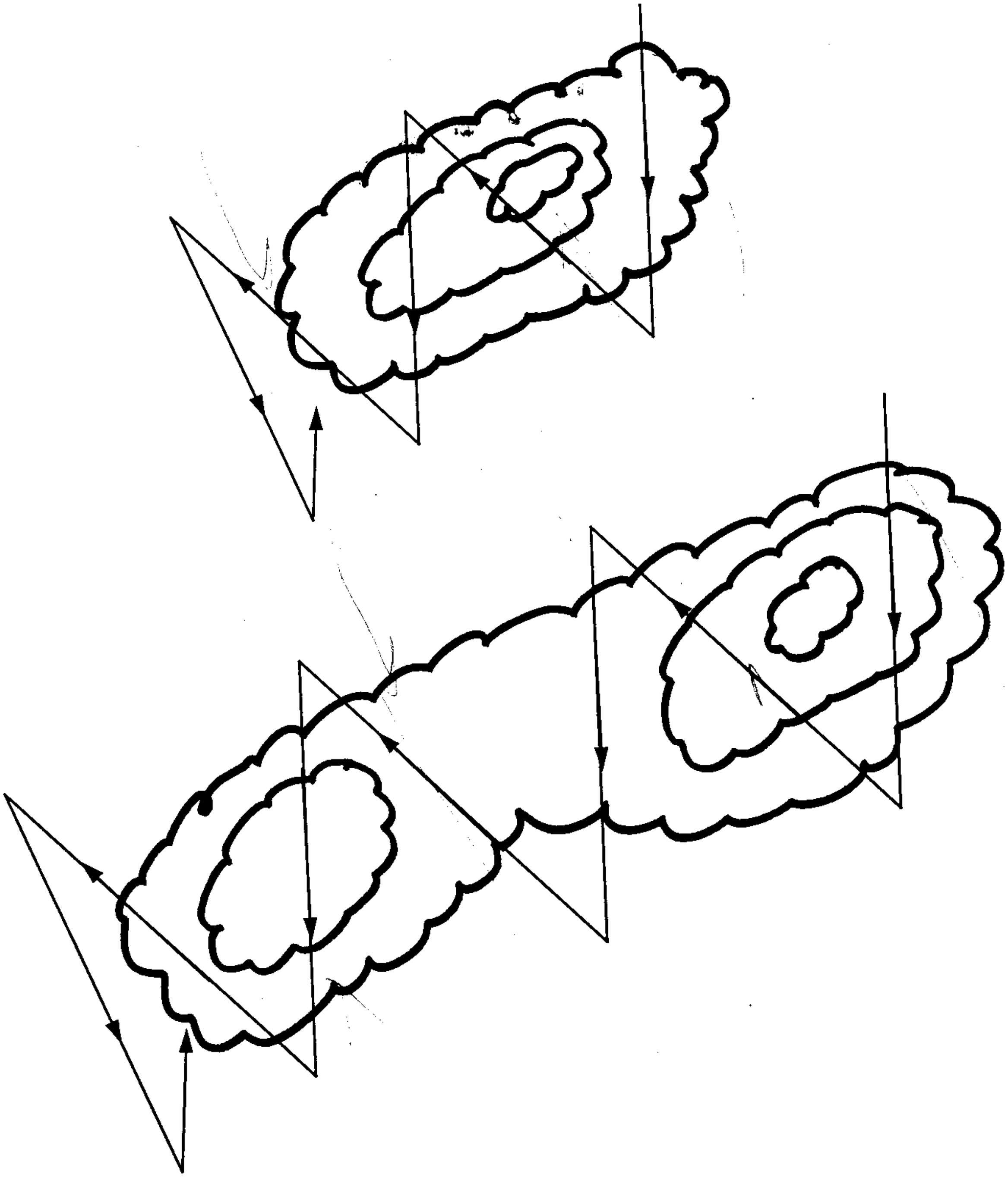


Figure 3b. Rosette

(The rosette probably is not drawn correctly, but I gave it my best shot! Cathy)

Horizontal Mapping of the Distribution of Turbulence

Figure 4a. Single Cell or Multiple Cells or Stratus Deck



Horizontal Mapping of the Distribution of Turbulence

Figure 4b. Working from the outside of the storm towards the center

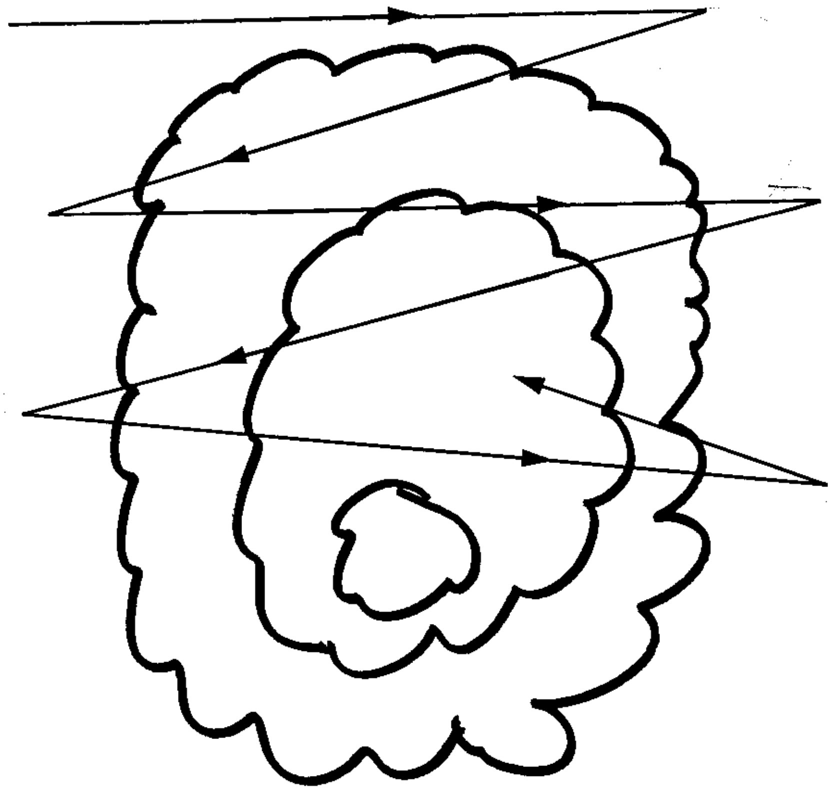


Figure 5. Three Aircraft for Vertical Mapping of the Distribution of Turbulence

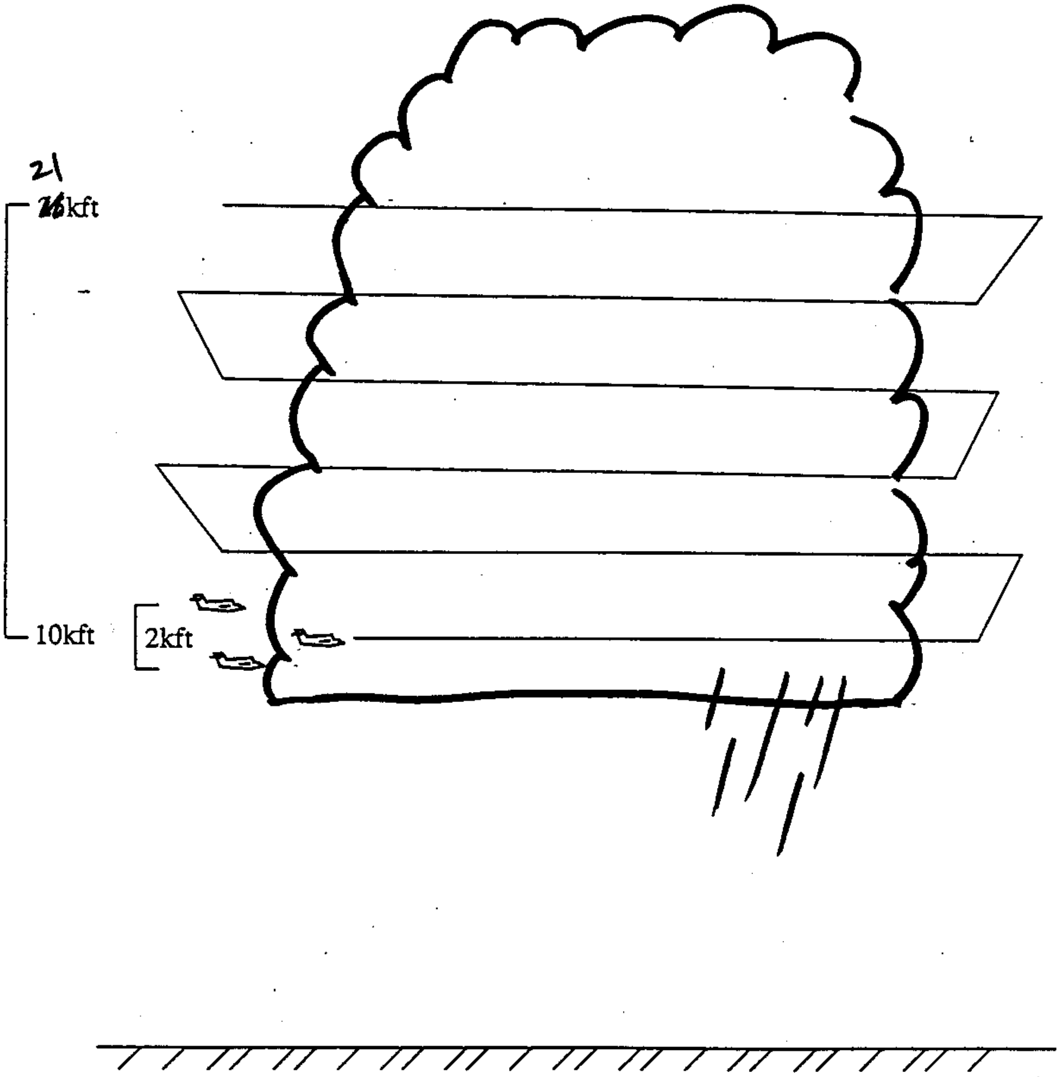
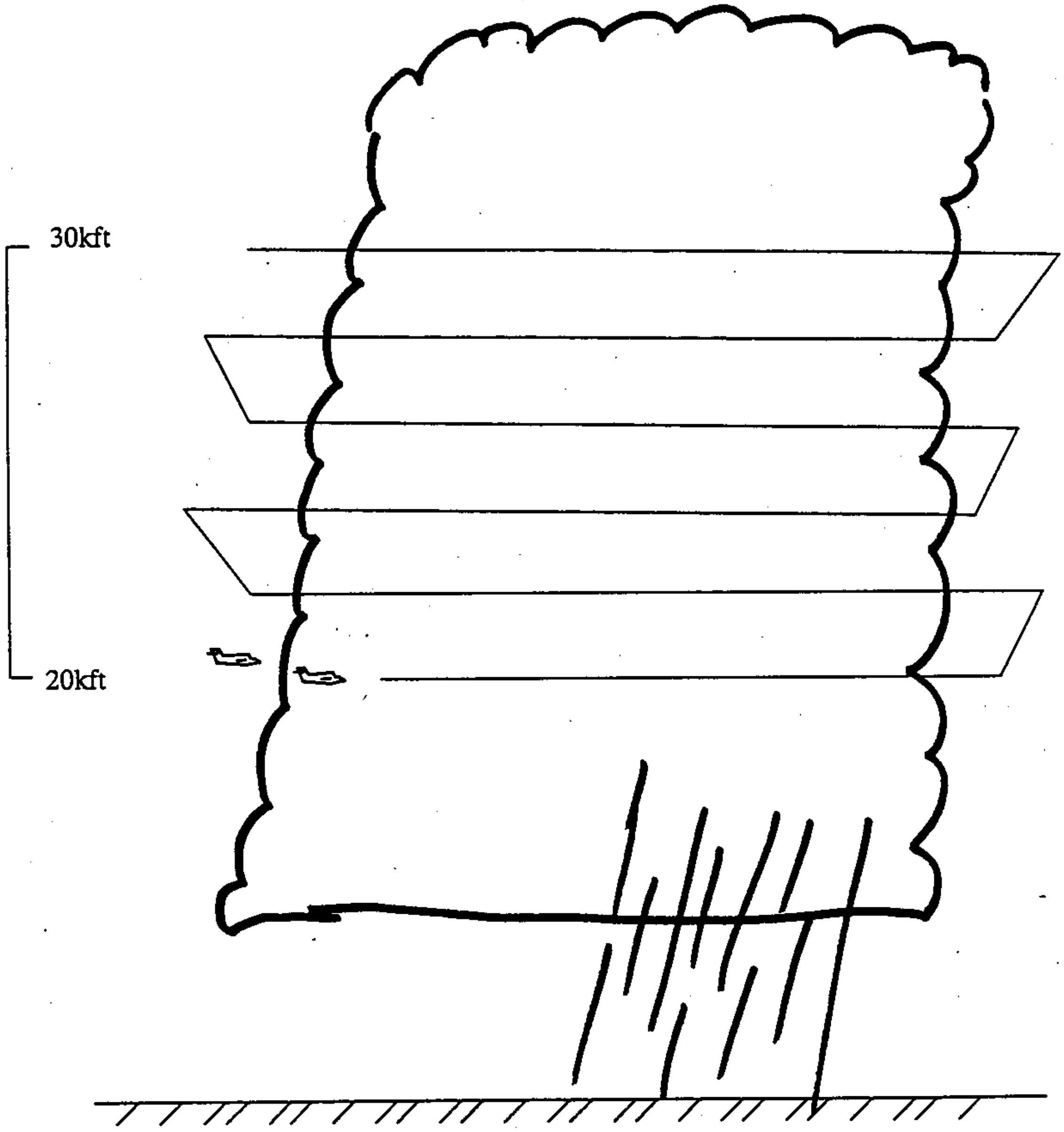


Figure 6. One or Two Aircraft (no T-28) for Vertical Mapping of the Distribution of Turbulence



Horizontal and Vertical Mapping of the Distribution of Turbulence

Figure 7. Line of Cumulus/Cumulus Congestus