CHAPTER XII. ATMOSPHERIC SOUNDINGS

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A. INTRODUCTION

During the period 18-23 August 1994, atmospheric soundings have been obtained to characterize the wind, temperature, and humidity profiles over the Little Washita watershed for the WASHITA-94 experiment. The launch site is located 3.2 miles south of US-177 and about 3 miles due north of Rocky Ford in extreme western Grady county (98° 5.19′ W; 34° 50.43′ N). The site is situated approximately in the center of the Little Washita river catchment on high ground (elevation 434 m MSL) in a freshly mowed field of hay stubble, and has excellent exposure and a panoramic view of the watershed from northwest, through west, through south as well as to the northeast. This siting has facilitated the acquisition of soundings that reasonably represent the state of the atmospheric boundary layer over the central portion of the watershed in all wind regimes.

This atmospheric sounding data complements and provides corrections for other measurements of radiance and soil moisture from space- and airborne platforms and ground transects. The soundings also provide a context for interpreting sensible and latent heat fluxes deduced from an array of specially instrumented surface sites, and are suitable for initializing and validating sophisticated numerical Large Eddy Simulation (LES) and mesoscale models of the atmospheric boundary layer.

B. INSTRUMENTATION

Soundings have been obtained with the Mobile Cross-chain Loran (Long-range aid to navigation) Atmospheric Sounding System (M-CLASS), based on CLASS technology developed by NCAR (Lally and Morel 1985; Lauritzen et al. 1987) and converted for mobile operation by the NSSL (Rust et al. 1990). The CLASS system is rack-mounted in a van equipped with an auxiliary power generator for fully autonomous operation. The system uses Vaisala RLS-80 sondes that receive LORAN navigation for tracking the balloon and calculating horizontal winds. The LORAN signals are retransmitted with pressure, temperature, and humidity data to the ground station for processing and archival. Geopotential height is derived from the hypsometric equation, while range, azimuth, and elevation of the sonde is derived from the LORAN data. The CLASS system provides the capability to monitor the progress of individual soundings in real time, while the mobile capability provides ease and flexibility in siting the balloon launches. Infrequent missing or noisy data can easily be detected in the CLASS data records (and the bad data removed) using quality numbers for pressure, temperature, humidity, and wind data values. The manufacturer's specifications of the performance of the pressure, temperature, and humidity sensors of the sonde are presented in Table S-1.

The mobile laboratory is also equipped with a suite of instruments to measure temperature, derived dewpoint, pressure, winds, and vehicle position (Fredrickson et al. 1995). Data values are based on 6-second averages of a set of three 2-second samples. Global Positioning System (GPS) navigation receivers provide information on vehicle position. Winds are measured with an R. M. Young Wind Monitor; relative humidity is measured by a VAISALA solid-state capacitive chip sensor; and atmospheric pressure is measured by a VAISALA solid-state barometer. Temperature measurements are obtained from two sources: 1) a "slow" temperature sensor housed within the relative humidity sampling volume; 2) a YSI temperature sensor exposed to the ambient air (ie. faster response). Care has been exercised to ensure that measurements are decoupled from vehicle and wind effects by using a specially designed wind-insensitive pressure port and by locating the various sensors at optimal heights above the vehicle.

C. MESOSCALE WEATHER SUMMARY

Table S-2 summarizes key mesoscale weather events that have influenced the boundary layer evolution in general and the soundings in particular. A series of intense thunderstorms develop and cross the Little Washita watershed on the afternoon and evening of 17 August and the early morning hours of 18 August. These thunderstorms leave cold outflows in low levels and bring heavy rainfall. A small, short-lived thunderstorm west of Cyril on the morning of 19 August is followed by a cold frontal passage on the morning of 20 August. Light-to-moderate rainfall accumulates in central Oklahoma during and after the frontal passage, with minor accumulations over the Little Washita watershed. The boundary layer is strongly capped and influenced by cold advection with northeast surface winds on August 20th. Winds gradually veer out of the southeast and become lighter and more variable as temperatures rise during the period of 21-23 August.

To assist in interpreting the soundings, which reveal boundary layer evolution that is forced in part by soil moisture variability, the mesoscale convective rainfall is examined using WSR-88D observations. It is assumed that soil moisture patterns can be inferred from the radar measurements, allowing for the well-known limitations of reflectivity-rainfall rate relationships.

Inspection of the Storm Precipitation product from the WSR-88D radar KTLX (Twin Lakes, east of Oklahoma City) documents the convective rainfall in central Oklahoma for the system of 17-18 August (Fig. 1). Three northwest-southeast oriented mesoscale precipitation bands with accumulated rainfall in excess of 1 inch are produced by the storm activity in the Little Washita watershed vicinity during the period from 1759 UTC on 17 August to 1203 UTC on 18 August. (All times are Universal Time unless specified otherwise.) The largest rainfall accumulations occur in the central band at the extreme eastern edge of the Little Washita watershed, with maximum radar-estimated precipitation amounts in the 2-3 inch range southwest of Chickasha.

D. SOUNDING AND SURFACE OBSERVATIONS

Launch times and depths of the soundings are summarized in Table S-3. The daytime diurnal cycle is sampled with releases close to the nominal local times of 0600, 0900, 1200, 1500, and

1800 (ie. UTC = LST + 5 hours), except for two soundings canceled due to rain on the morning of 20 August. Soundings have been permitted to continue until or after the balloon bursts, yielding data from the boundary layer through the tropopause and into the lower stratosphere.

With the exception of 20 August when the boundary layer is strongly forced by horizontal advection and light, widespread rainfall, the earliest soundings each day reveal pronounced nocturnal inversions (eg. Figs. 2a, 3a). Under conditions of strong insolation during the late morning and afternoon, the soundings reveal the development of the Convective Boundary Layer (CBL) as illustrated in Figures 2b and 3b. As illustrated in Figure 4, Saturation Point analysis of the afternoon soundings (Betts 1982) confirms that the CBL is well-mixed and may be capped by an Elevated Mixed Layer (EML). Enhanced soil moisture from the heavy thunderstorms on 17 August probably contributes to increase the latent heat fluxes locally and suppress the CBL growth, as compared to the deeper CBL that develops with reduced soil moisture levels on 23 August.

An intriguing aspect of the soundings is the profile of the balloon rise rate, which can be used to infer the vertical air motion profile. The example of an analysis of excess rise rate in Figure 5 is consistent with the notion that vertical air motions within the upward branches of mesoscale circulations in the CBL have been sampled by the sonde. Analogous profiles are observed in other soundings through CBLs during WASHITA-94 (not shown), although with lesser amplitudes with the exception of the 2300 sounding on 23 August. The implied role of fluxes due to organized circulations is helpful for the interpretation of the CBL profiles of wind, temperature, and moisture as revealed by the NSSL M-CLASS sounding system.

E. ACKNOWLEDGEMENTS

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F. REFERENCES

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Table XII-1. Manufacturer specifications of sensor performance for VAISALA RLS-80 sonde. The lag response time is derived for 6 m s^{-1} airflow at 1000 mb pressure.

Measurand	Range (Hi / Lo)	Resolution	Accuracy	Lag
Pressure (mb)	1060 / 3	0.1	±0.5	
Temperature (°C)	+60 / -90	0.1	±0.2	2.3 sec
Relative Humidity (%)	100 / 0	1	±2	1 sec

Table XII-2. Mesoscale weather summary for the Little Washita watershed for the period 18-23 August 1994.

Date	Character of Precipitation	Mesoscale Boundaries
94/08/18	intense Mesoscale Convective Systems	cold thunderstorm outflow
94/08/19	small thunderstorm west of Cyril	localized cold thunderstorm outflow
94/08/20	weak high-based convection	cold front
94/08/21	none	none
94/08/22	none	none
94/08/23	none	none

Table XII-3. Sounding information. Format is as follows: launch time (LST)/atmospheric pressure (mb) at launch/atmospheric pressure (mb) at balloon burst. Problems noted are a generator failure on the 19th (*) and a late release due to a keyboard problem on the 23rd (†). Soundings were canceled on the morning of the 20th due to precipitation at the launch site (re. Table S-2).

Date					
94/08/18	0617/961/35	0900/966/47	1153/964/35	1458/962/34	1758/962/85
94/08/19	0606/962/245 *	0857/963/37	1155/962/33	1458/960/26	1757/958/73
94/08/20			1200/963/60	1501/964/32	1759/963/85
94/08/21	0603/966/37	0900/967/34	1159/967/29	1459/965/32	1801/963/54
94/08/22	0610/965/53	0901/966/30	1200/966/47	1505/964/57	1801/962/80
94/08/23	0643/964/70 †	0906/967/64	1202/965/64	1458/965/35	1800/964/41

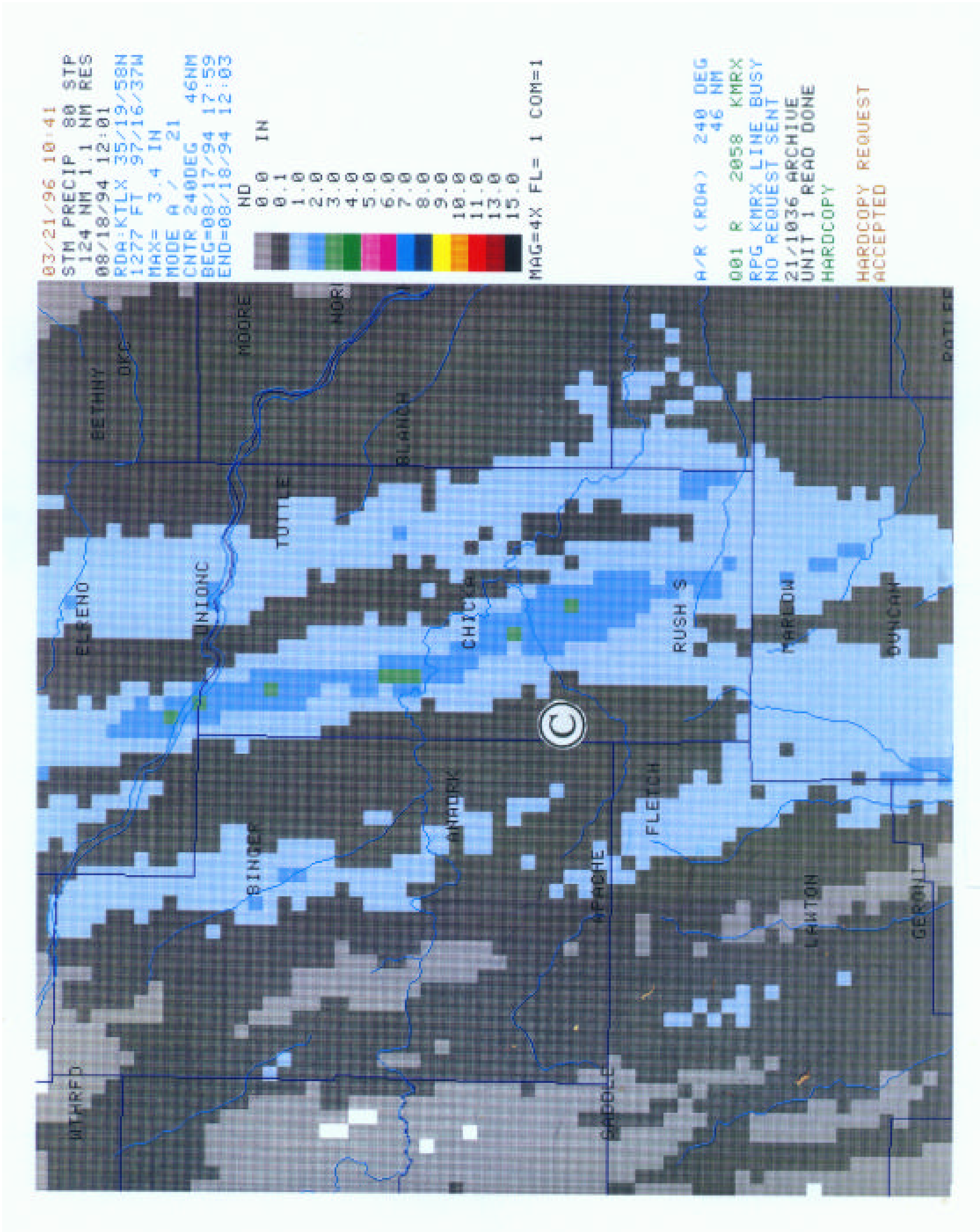

Figure XII-1. Storm Precipitation Product from WSR-88D radar KTLX (near Oklahoma City, Oklahoma) based on radar-derived rainfall composited from 1759 UTC 17 August to 1203 UTC 18 August 1994. The effective spatial resolution is about 1.7 km. The Little Washita watershed is located near the center of the panel southwest of Chickasha, Oklahoma. The circled letter C denotes the location of the NSSL CLASS sounding site.

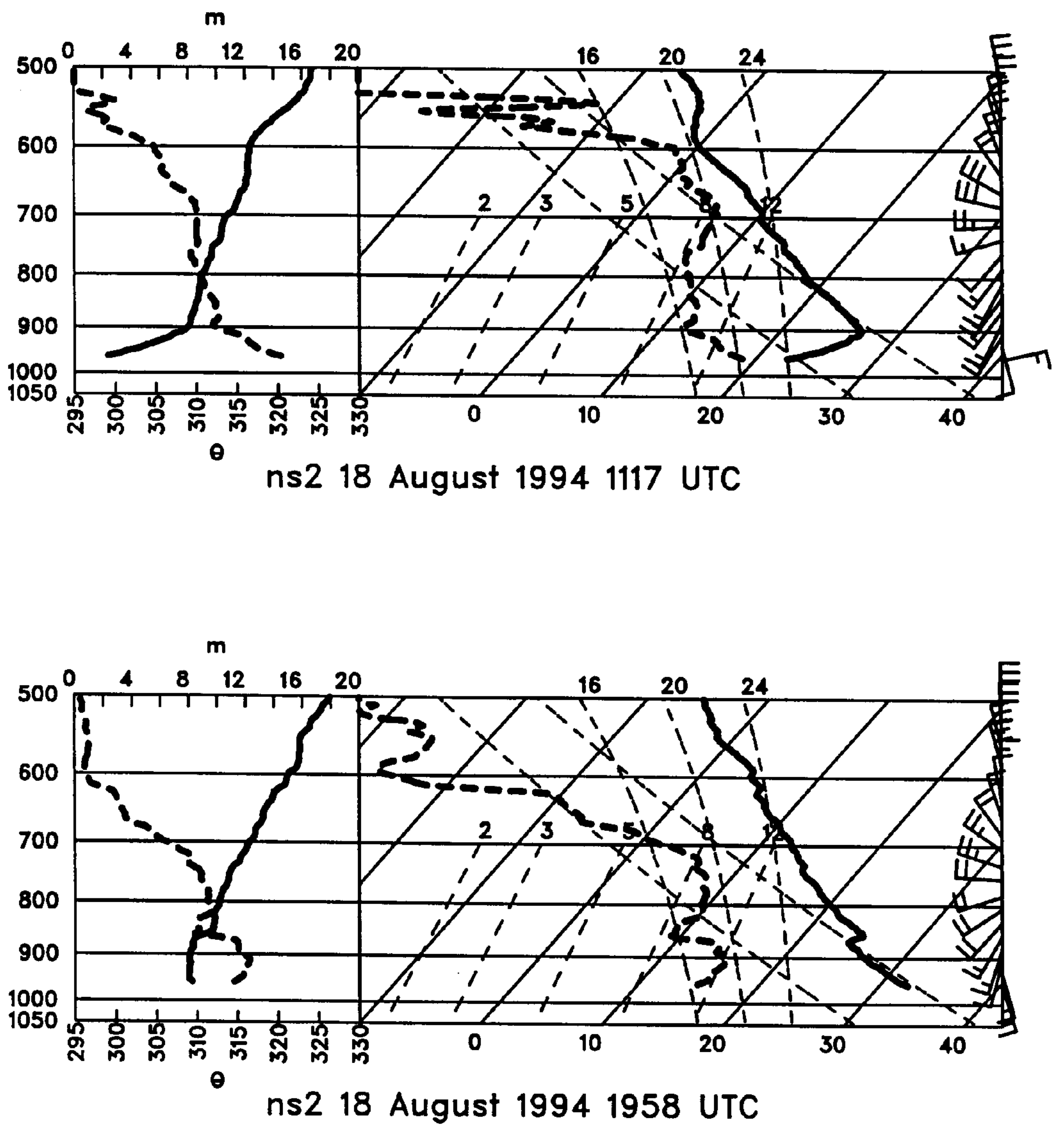

Figure XII-2. Selected NSSL M-CLASS Skew-T Log-P soundings obtained on 18 August 1994 during WASHITA-94: (a) 1117 UTC; (b) 1958 UTC. Inset on left-hand side of diagram depicts the pressure profiles of potential temperature Θ (bottom legend) and water vapor mixing ratio q_v (top legend). Flag symbols along right-hand side denote wind direction (ie. direction from which wind blows) and speed (full barb = 5 m s^{-1}; half barb = 2.5 m s^{-1}).

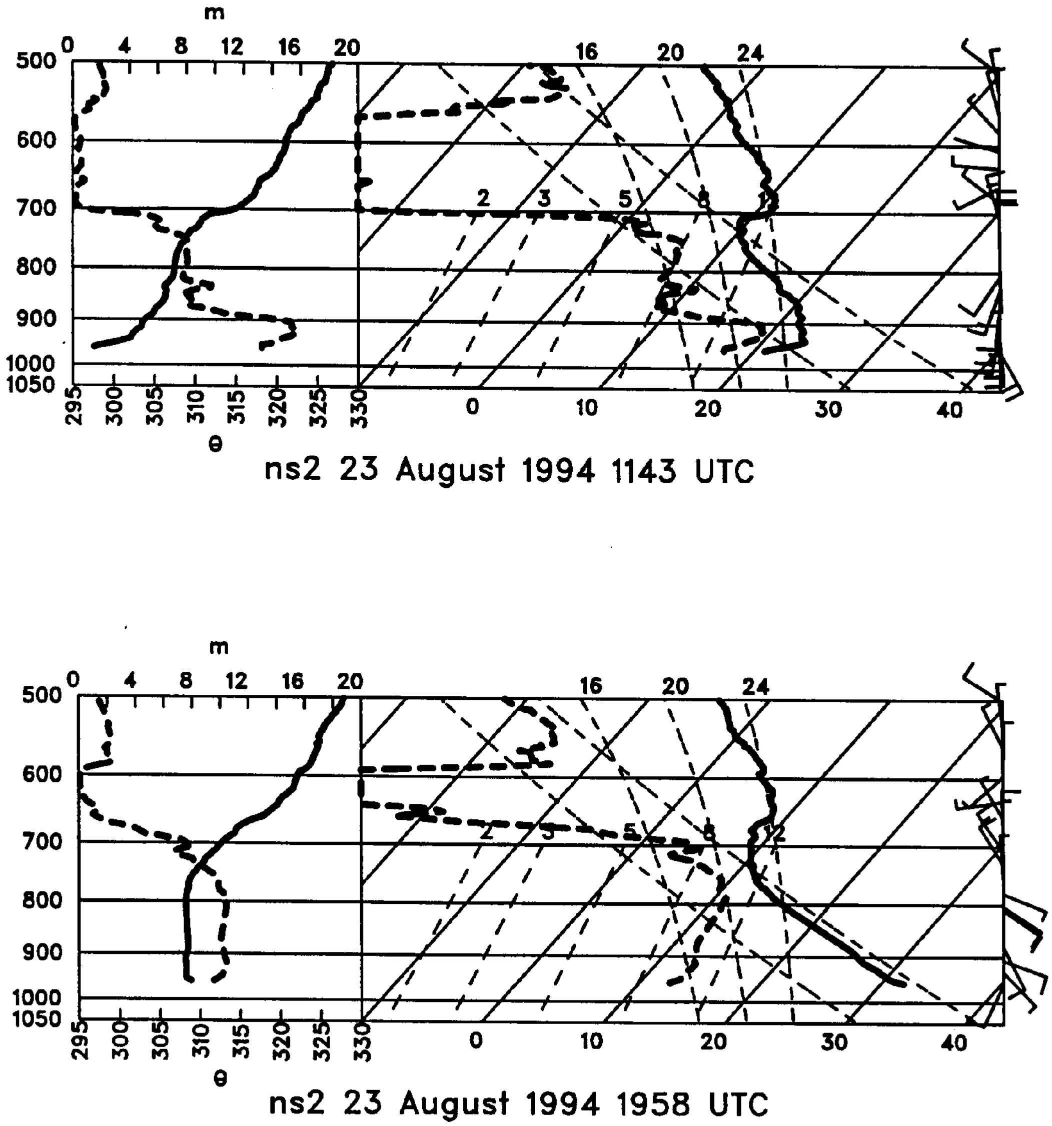

Figure XII-3. Same as in Figure 2, but for M-CLASS soundings on 23 August 1994: (a) 1143; (b) 1958.

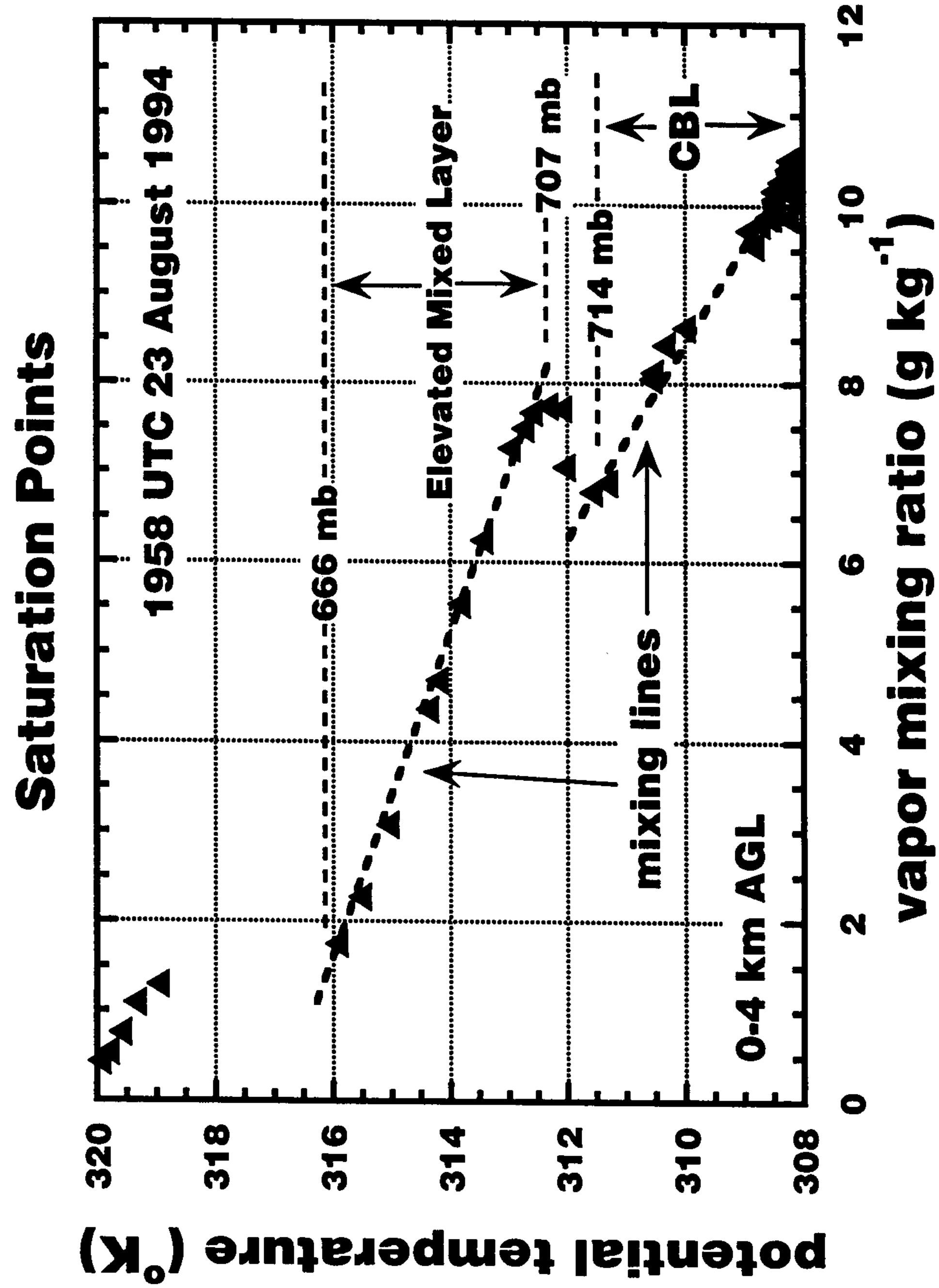

Figure XII-4. Saturation Point (SP) diagram for the M-CLASS sounding at 1958 on 23 August 1994 (see also Fig. 3b). Every observation is plotted (10 s sampling rate), excluding missing or thresholded values. Heavy dashed lines are mixing lines, as discussed in text.

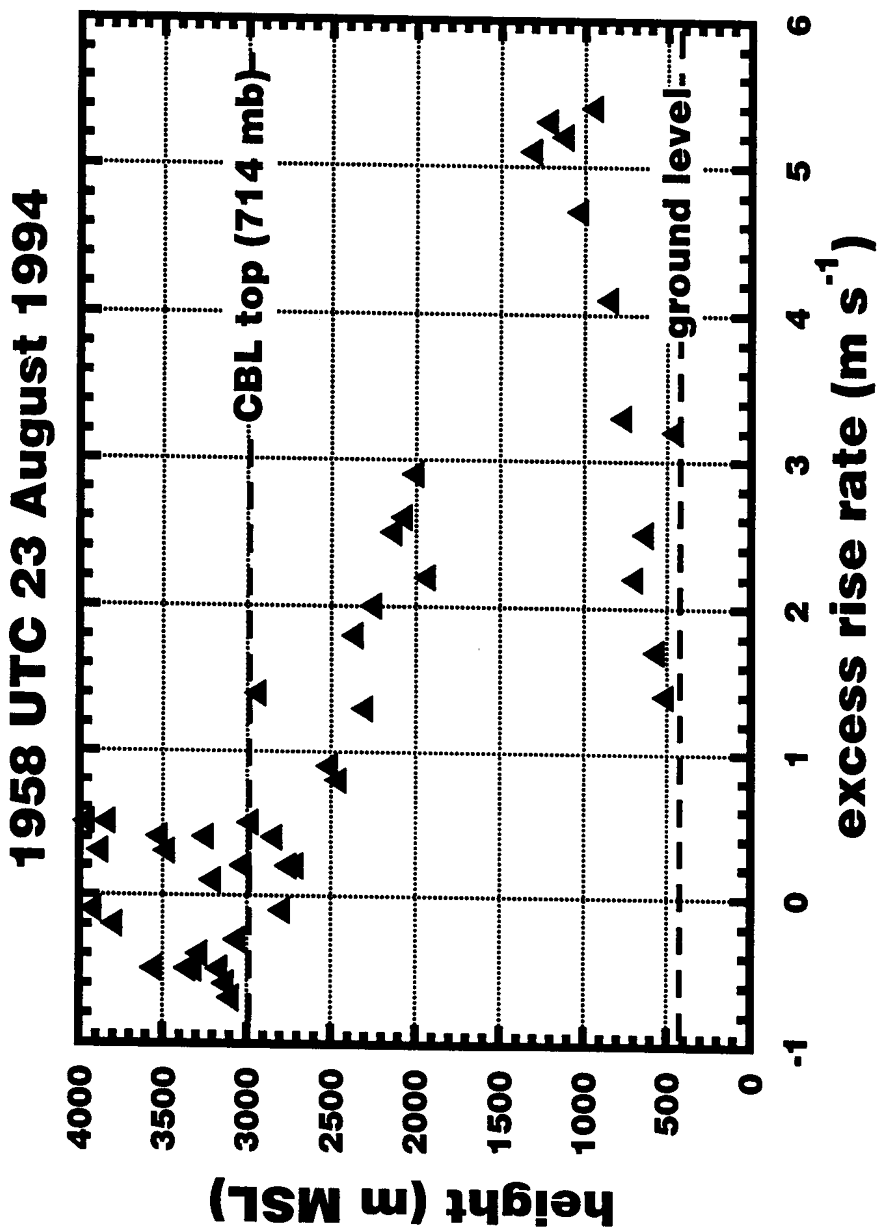

Figure XII-5. Profile of the excess balloon rise rate versus height for the M-CLASS sounding at 1958 on 23 August 1994 (see also Fig. 3b). The excess rise rate, derived by subtracting a nominal rise rate of 4 m s^{-1} in still air from the total rise rate, is an approximate measure of vertical air motion. Convergence toward zero value at the boundary layer top and the ground surface suggest that the vertical air motion is inferred to within an error of ± 1 m s^{-1}. Three outlying values above 3.4 km altitude have been removed prior to display.