UTILIZATION OF REMOTE SENSING DATA IN THE EVALUATION OF AIR POLLUTION CHARACTERISTICS IN THE SOUTH COAST/SOUTHEAST DESERT AIR BASIN

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SUMMARY

Lidar aircraft data were collected in July 1981 by EPA (McElroy et al, 1982) in conjunction with the Southeast Desert Transport Study (Smith et al, 1983). The lidar aircraft was flown on 10 days during the study period. The flight schedule was coordinated with the tracer releases for the Transport Study. On eight of the flight days, one or two flights were made on the day of the tracer release, followed by a morning flight on the following day to evaluate the pollutant carry-over in the desert.

The present report represents the first opportunity for analysis of the lidar data in conjunction with the data obtained during the Transport Study. The analyses and data used in the previous study were of very great value in interpretation of the lidar data.

The EPA aircraft lidar system in 1981 was relatively new and the system operation improved substantially during the 10-day program, particularly with respect to noise. The lidar system operates on two different wave lengths, the present analyses were performed using the green portion of the system.

The aircraft flew at about 3000 m-msl during the flight program. The lidar is mounted to direct its beam vertically toward the ground. Back-scatter returns from aerosols within the 3000 m layer are recorded as a function of distance below the aircraft. The data were subsequently processed by EPA into a gray-scale representation (McElroy et al, 1982) and a digital format using bin averages 150 m deep and one km along the flight path.

In contrast to radar operations, techniques for quantitative calibration of the lidar system have not been developed. The size distribution of the aerosols is also not known for realistic atmospheric targets. Attenuation of the lidar signals due to heavy aerosol loading is an additional limitation on the quantitative analysis of the data. In spite of these limitations, semi-quantitative comparisons between lidar back-scatter measurements and visibility on b_{scat} observations were reasonably satisfactory.

The principal value of the lidar data for the present

study was to provide information on relative aerosol concentrations aloft where measurements from the surface were either not available or not possible. Unique data on the presence of upslope flow along the San Gabriel Mts., of convergence zones and of layers aloft were provided by the lidar observations. Of particular interest were cross sections through the San Fernando Valley and Elsinore Convergence Zones which graphically illustrate these two important mechanisms for removal of pollutants from the Los Angeles basin.

A number of lidar aircraft flights were made through the passes which form additional exit routes from the basin into the Southeast Desert Air Basin. Estimates of the aerosol loadings were calculated from the lidar data by summing the bin-averaged back-scatter values within the mixed layer for each traverse through the pass. These data are presented as a function of time of day. Results when grouped according to the individual pass clearly show that San Gorgonio Pass carried by far the heaviest aerosol loading during the flight measurement period.

Data taken on the desert side of San Gorgonio and Cajon Passes show the top of the aerosol layer descending rapidly with distance traveled into the desert. This results in a shallow layer at the entrance points into the desert which frequently breaks up into a deeper convective layer because of the strong surface heating.

The most interesting case of carry-over into the desert occurred on the morning of July 31. Substantial transport into the desert had occurred during the previous afternoon. Heavy aerosol loadings were observed by the lidar on the 31st in the Coachella Valley. Reported visibilities were reduced to 5-7 miles during the forenoon. It is speculated that high humidity in the desert may have contributed to these unusual values.

Within the South Coast Air Basin lidar aircraft observations would be particularly useful in studying upslope flow, convergence zones, recirculation of pollutants, pollutant transport through passes and total aerosol burden. All of these problems involve pollutant concentrations aloft which are not easily observed by other means. The lidar observations may therefore be extremely valuable both as a data source and an analytic tool when applied to complex photochemical models. Interpretation of the lidar data requires sufficient upper wind information to reconstruct possible source regions of the aerosols. It is also suggested that repeated flight paths during the day over the same geography would help greatly in defining the time evolution of such processes as the convergence zones and upslope flows.

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1.0 INTRODUCTION

During the period of July 8 to August 11, 1981 a major field study was conducted in the Southeast Desert Air Basin under the sponsorship of the California Air Resources Board (CARB). Principal purpose of the study was to investigate and document the transport of pollutants from the South Coast Air Basin into the Southeast Desert Air Basin. An additional objective was to examine the relative contribution of local sources and previous day's precursors to the morning oxidant increase in the SEDAB. A final report (Smith et al, 1983) was prepared to describe the results of the study.

The CARB field program was supplemented on 10 days by lidar measurements made in a downward-pointing mode by an EPA aircraft. The flight patterns covered much of the South Coast Air Basin and the adjacent desert areas. The patterns were coordinated with the CARB program to obtain maximum utility from the lidar data. These data are presented in a data report (McElroy et al, 1982) but have not been analyzed for informational content.

The objective of the present study has been to examine the three-dimensional structure of pollutants in the South Coast and Southeast Desert Air Basins through the use of the lidar data in conjunction with the data base already generated for the CARB study. A secondary objective was to evaluate the potential uses of the lidar aircraft measurements as a tool for air pollution investigations.

The bulk of the report is descriptive in nature. The lidar observational data were treated in terms of individual days so that a perspective on variations from day-to-day could be gained. Descriptions and examples of the observational data obtained on each day are supported by meteorological data and by proposed operative mechanisms. More objective treatments of particular pollutant characteristics are given later in the report. These include analyses of mixing heights, visibility and pollutant fluxes. Recommendations for future use of the lidar aircraft complete the report.

Dr. James McElroy of the EPA Environmental Monitoring Systems Laboratory (Las Vegas, Nev.) provided the lidar data in visual and digital form and was most helpful in interpreting the data during the analysis period.

2.0 DATA SOURCES AND TREATMENT

2.1 Lidar Data

The EPA lidar aircraft flew on 10 days during mid to late July 1981. Following is a schedule of flight days and times:

Table 2.1
Schedule of EPA Lidar Aircraft Flights

Date	Time (PDT)
7/ 9/81	1800-2120
7/14/81	1510-1815
7/15/81	0840-1030
7/18/81	1400-1730
	1800-1940
7/19/81	0830-1220
7/22/81	1440-1800
	1910-2120
7/23/81	0640-1040
7/27/81	1420-1810
	2000-2320
7/30/81	1430-1800
	1950-2320
7/31/81	0850-1220

A total of 14 flights was made in the 10 day period, each of 3 to 4 hours duration. The flights were scheduled to coincide with intensive, tracer sampling days within the CARB study. July 9, 14, 18, 22, 27 and 30 are such tracer release days. Flights on July 15, 19, 23 and 31 were carried out during the mornings following the tracer releases and were intended to study the question of carry-over of pollutants from the previous day.

The tracer releases on intensive measurement days, were supported by data from the routine meteorological and air quality networks, by supplemental ozone and wind observational sites, by several upper wind (pibal) stations and by an air quality aircraft which provided measurements aloft of key air pollution parameters including ozone, nitrogen oxides, b_{scat}, sulfur dioxide and temperature. In addition, an experimental ozone-measuring instrument was flown by JPL (Grant, 1982) on several of the study days.

The lidar aircraft flew at approximately 3000 m (msl) on all flights. The lidar signals can be considered to represent the relative degree of backscatter from aerosols if effects due to extinction and multiple scattering are considered to be negligible. These data were processed by EPA (McElroy et al, 1982) into a pictorial, gray-scale representation of the intensity of the back-scatter signal as a function of height along the flight path. Fig. 2-1 is an example of a flight path and the data obtained by the EPA aircraft. The flight on July 30 originated at 2014 PDT at Palm Springs and followed a path to downtown LA, Palmdale, San Bernardino, Ontario, Santa Ana, Corona and back to Indio/Palm Springs. A final segment of the flight was carried out from San Bernardino to Big Bear Lake. The depth of the ground-based aerosol layer and the height of the terrain are shown in cross-section form.

The lidar data were subsequently processed into digital form for a more quantitative perspective on the concentrations in various layers. The lidar reflectivity data were averaged in separate volume bins 150 m deep and 1 km in length along the flight path, the third dimension being the width of the beam. These date were processed by McElroy and furnished to the present study program.. During the course of the analysis, it became apparent that the 1 km averaging distance along the flight path was not adequate to remove many of the random fluctuations which might be expected with a relatively inhomogeneous aerosol distribution. Consequently, the 1 km bins were further averaged into 5 km bins along the flight path for the purposes of most of the following analyses. This additional averaging helped greatly to smooth out the random signal fluctuations.

In many of the data presentations which follow, there is clear evidence of aerosol layers aloft, with apparently stronger back-scatter signals than are observed near the surface. Although such layers are common in the Los Angeles Basin, some of the layering may be more apparent than real. A comparison of back-scatter intensity vs. surface visibility (Section 4) indicated that attenuation of the lidar signal may be occurring under conditions of heavy particulate loading (visibility 2-3 miles or less). Under these conditions an apparent "layer" aloft occurred due to attenuation in the top of the aerosol layer. On many occasions, however, the aerosol layering is undoubtedly real.

The relative magnitudes of the quantitative back-scatter data can only be compared on a within-day basis. The lidar was set up somewhat differently on each flight day so that

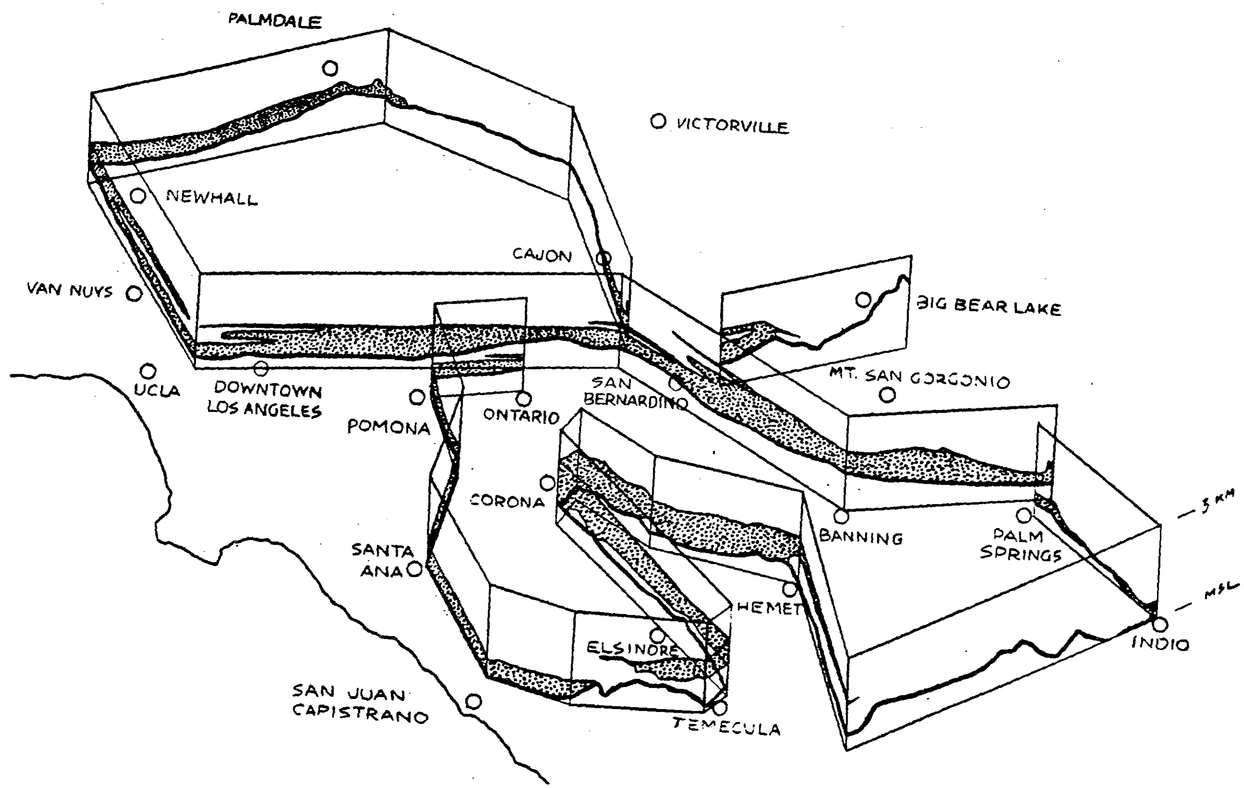


Fig. 2-1 SCHEMATIC VIEW OF LIDAR AIRCRAFT FLIGHT PATH
July 30,1981 (2014 - 2258 PDT)

the beam intensity and aperture setting varied from day-to day. This precludes any quantitative comparison of data between days. Relative intensity of back-scatter is plotted in later figures.

The operation of the lidar system improved markedly during the three-week period of flight operations. The data collected on July 27 and 30 were not only of the best quality during the program (particularly with respect to noise) but also, fortunately, coincided with some of the most interesting observational opportunities.

Finally, it should be kept in mind that the EPA aircraft lidar system was still in a developmental stage during the summer of 1981. The results obtained during this period may not necessarily be representative of the ultimate potential of the system.

2.2 Characteristics of the Lidar System

The following description of the aircraft lidar system is excerpted from a report by McElroy et al (1982).

The lidar system in the aircraft emits a short pulse of laser light in a vertical, down-pointing direction. The light is scattered back toward the receiver in the aircraft as it strikes air molecules, aerosols in the atmosphere and finally the ground itself.

The laser system transmits light simultaneously at two frequencies (.532 µm-green and 1.064 µm-near infrared). The pulse length is 17 billionths of a second. A 36 cm Newtonian telescope serves as a receiver for the scattered light returned to the aircraft. The transmitter and receiver are not located on a common vertical axis so that the transmitted beam is not within the full view of the telescope for the first 150 m below the aircraft. The return light collected by the telescope passes through two dichroic mirrors that separate it into two frequencies and direct it into two photo multiplier tubes.

The laser signals are preprocessed in an electronics subsystem. The signals are corrected for range (distance from the aircraft) and known multiplier tube characteristics. The signals are then digitized and recorded on magnetic tape.

The laser pulse rate can be adjusted in a range from 0.1 per second to 10 pulses per second. The maximum pulse rate, together with the typical ground speed for the aircraft, determines a minimum horizontal resolution of about 10 m along the flight path.

There were several problems in the 1981 lidar data which should be kept in mind in their interpretation.

1. False signal returns appeared frequently near the top of the lidar pictures. An example is shown in Fig. 3-14. The apparent layer at the top of the picture is an artifact which may have been due to reflected sunlight entering the telescope.

2. There were occasional drop-outs of data during many of the flights. These produce vertical lines extending downward into the aerosol layer. An example of these dropouts also appears in Fig. 3-14. The vertical streakiness of the picture results from occasional loss of data in the system and not from any vertical striations in the aerosol layer.

3. When the aircraft banks the effective range indicated for the aerosol targets increases but returns to the correct value when horizontal flight is resumed. Two examples of this are shown in the middle of Fig. 3-18 and at the left hand side of Fig. 3-19.

None of these problems seriously affected the value of the data for the present study. It should be noted in the following sections that the aerosol returns are represented as white areas while the clear regions appear to be black.

2.3 Area Maps

The lidar aircraft flights covered a wide range of geography in Southern California during the 10 day flight program. It has been necessary therefore to refer to a large number of locations and terrain features in order to describe the results of the program. In order to make the report somewhat easier to interpret maps showing the locations of most of these areas have been constructed. Fig. 2-2 is a map of the major terrain features described in the text. Locations of most of the points referred to in the report are shown in Fig. 2-3.

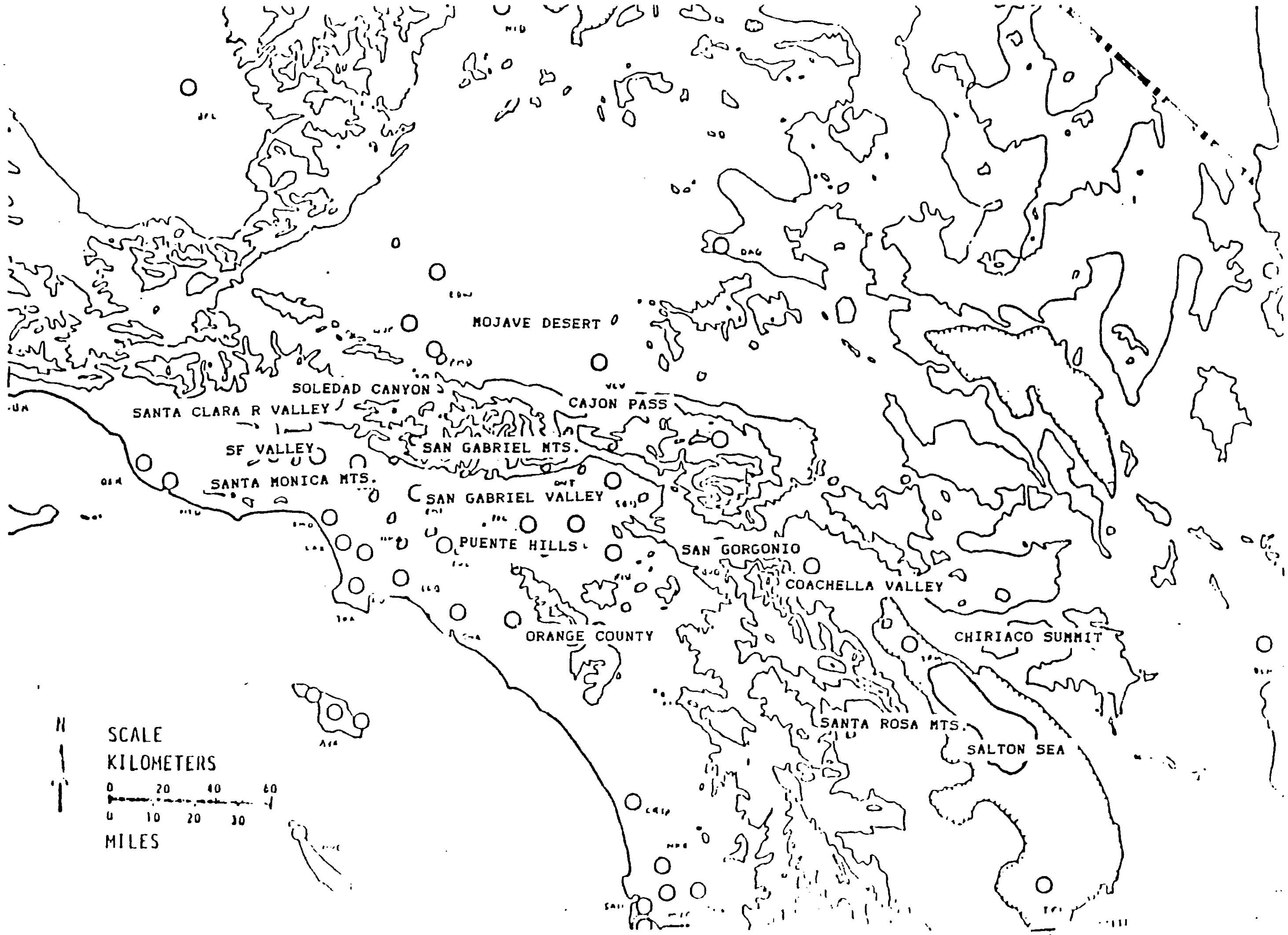


Fig. 2-2 GEOGRAPHICAL LOCATIONS

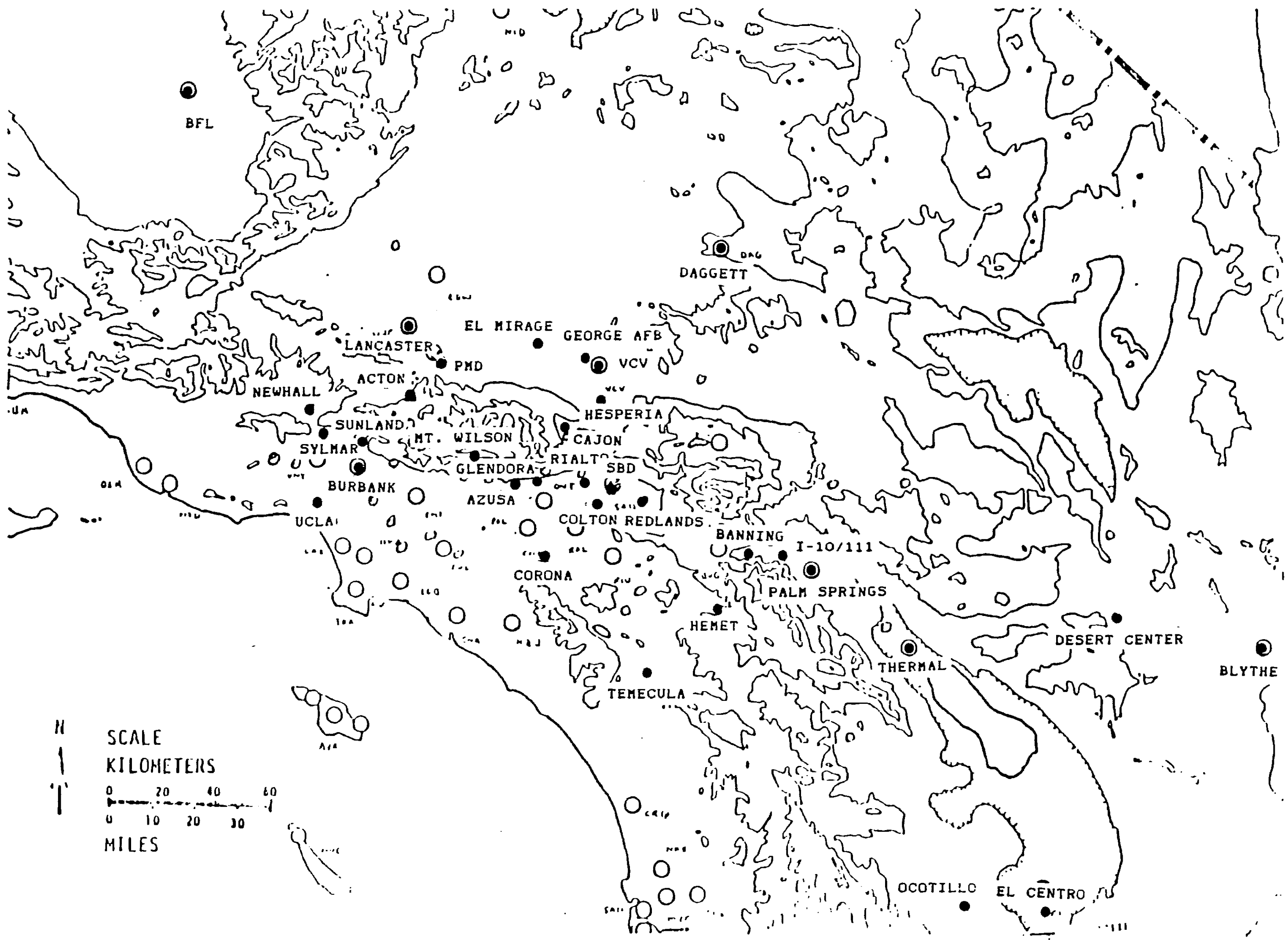


Fig. 2-3 SITE LOCATIONS

3.0 OBSERVATIONAL RESULTS

Significant features of the pollutant structure observed by the lidar aircraft are given in the following paragraphs. Descriptions of a number of the sampling days are presented in this section of the report. Summaries of some of the characteristic features are given in Section 4.

July 14, 1981

Meteorological conditions in the southwestern U. S. were dominated by a stagnant high pressure system aloft and a substantial high pressure ridge extending from the Pacific Ocean into Washington, Oregon and northern California.

Meteorological parameters of interest on July 14 are given in Table 3.1:

Table 3.1

Meteorological Parameters
July 14, 1981

850 mb Temperature (UCLA)	23.4° C
Pressure Gradients (08 PDT)	
LAX-Daggett	1.1 mb
LAX-Bakersfield	-0.2
Maximum Surface Temperatures	
Ontario	101° F
Palm Springs	106
Mixing Heights	
UCLA (12 PDT)	400 m-msl (250 m-agl)
Ontario (1430 PDT)	1020 m-msl (730 m-agl)

The day was characterized by rather warm temperatures aloft, by weak pressure gradients, by shallow mixing heights and by warm surface temperatures inland.

Peak hourly ozone concentrations on July 14 were observed at Fontana (31 pphm) and San Bernardino (32 pphm). These peak concentrations occurred at 16 and 17 PDT, respectively.

A tracer release was made from Sylmar on July 14 and the most interesting pollutant features were observed from

Palmdale-Newhall-El Monte as a result of the concentration of observations in that area.

Perhaps the best example of the injection of aerosol from the ground-based polluted layer into the inversion layer is provided by the lidar cross section from 1639 to 1647 PDT (Fig. 3-1) which extended from west of Newhall to Burbank on July 14. The upper part of the figure is a copy of the gray scale representation of the lidar data (McElroy et al, 1982). The bottom portion was constructed from digitized lidar data. White areas represent aerosol concentrations.

As indicated by the terrain in the figure, the flight leg originated in the Santa Clara River Valley and the high terrain near the betinning of the leg represents the aircraft crossing into the western San Fernando Valley. To the woutheast (right) in the figure there is an aerosol layer in the San Fernando Valley with a well-defined top at about 600 m-msl. At the western end of the Valley there is a vertical plume of aerosol being injected upqard to a height of 1400 m-msl where it stabilized into a layer about 600 m deep which was transported toward the east. The UCLA sounding (12 PDT), reporduced in the figure, shows that the flat layer in the San Fernando Valley was contained within the low-level mixing layer but that the elevated plume was injected into the stable layer above the inversion base.

An analysis of the surface wind field (Fig. 3-2) at the time of the transect shows that the San Fernando Convergence Zone (Edinger and Helvey, 1961) stretched across the valley just west of the flight path and appears to be the mechanism lofting the surface aerosol layer. Upper level winds at Sylmar (16 PDT) were from 230 to $240^{o}40^{o}$ at 3.5 to 5 m/s within the layer containing the elevated plume. These winds should have carried the layer aloft through Soledad Canyon towards Palmdale.

Fig. 3-3 shows an aircraft sounding made at a location about 5 mi. west of Palmdale at 1740 PDT. An elevated ozone layer is present from 1400 to 2200 m-msl with a peak value of 17 pphm. Upper winds measured at Acton (in Soledad Canyon) at 1805 PDT omdocate tyhat this layer was moving from the west-southwest at a velocity of 7-9 m/s. It issuggested that this layer originated in the San Fernando Convergence Zone and the convergence and higher surface terrain in Soledad Canyon resulted in a further

TX-2

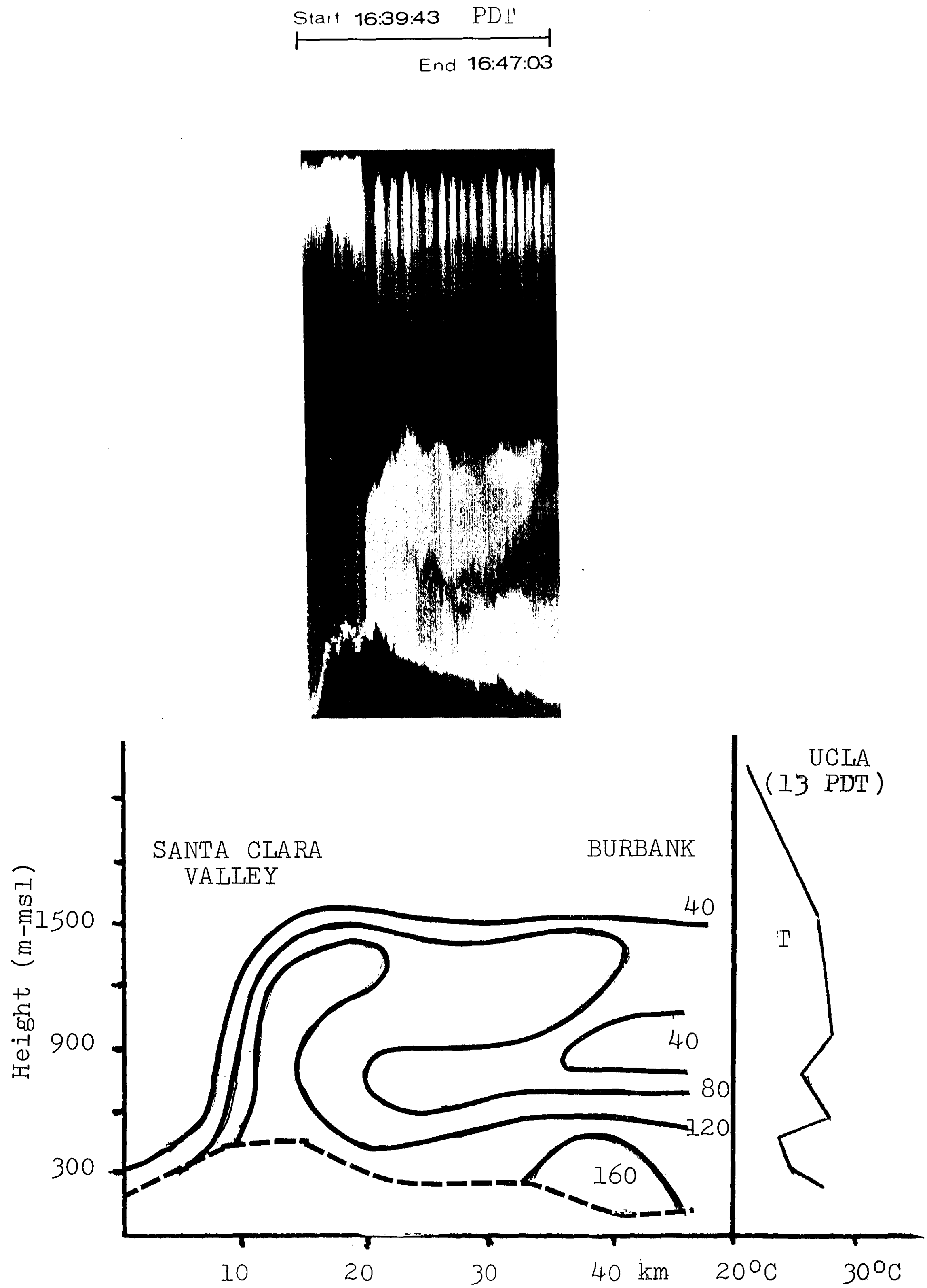


Fig. 3-1 CROSS SECTION FROM
SANTA CLARA RIVER VALLEY TO BURBANK

July 14, 1981

Fig. 3-2 STREAMLINE MAP - July 14,1981 (16 PDT)

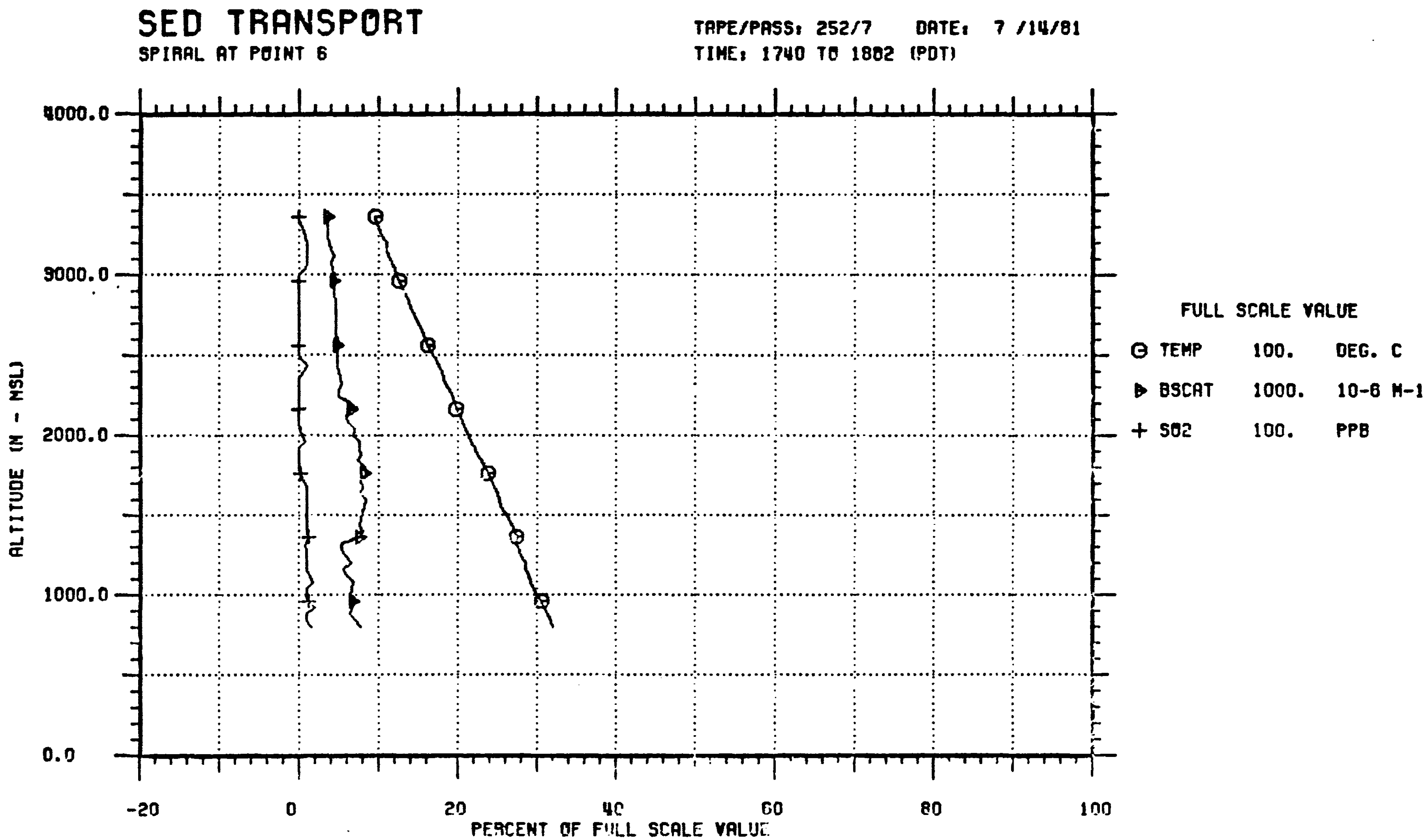


Fig. 3-3 AIRCRAFT SOUNDING % MI W OF PALMDALE
July 14,1981

600925.1
02:12:09

elevation of the layer relative to sea level.

Fig. 3-4 was constructed from a transect from near El Monte to El Mirage between 1647 and 1659 PDT. The track of the aircraft was from the southwest (left side of figure) to the northeast, passing nearly over Mt. Wilson. Upslope flow is indicated in the figure, starting from a layer top over the valley of about 500 m-msl. Upslope flow extended upward along the slope to a level of 1200 m-msl with some fingers of aerosol at higher levels. The main part of the upslope plume stabilized into a layer with a top of 1100 m-msl but extended southwestward over the basin. Winds in this layer, as measured at Sylmar, were from the southwest so that the upslope flow was sufficiently strong to divert the wind flow near the slope and transport aerosols back over the basin against the prevailing winds.

Fig. 3-5 shows another portion of the southern slopes of the San Gabriel Mts. at a later time on July 14. The transect was flown from Palmdale to Burbank between 1755 and 1803 PDT. The flight path was oriented from north-northeast (left of figure) towards the south-southwest. The slopes on the right of the figure are in the vicinity of Sunland/Tujunga.

The structural features in Fig. 3-5 are similar to those shown somewhat more clearly in Fig. 3-4. There is a shallow upslope layer along the slopes leading to an elevated layer with a top of about 1200 m-msl. The top of the layer is at about the same altitude as the terrain and there appears to be little transport across the ridge in spite of the southwesterly winds. It is apparent in both Fig. 3-4 and 3-5 that the top of the elevated layer is near but within the stable inversion layer as measured by the 12 PDT sounding at UCLA.

July 18, 1981

On July 18 a weak surface pressure trough existed in Nevada with surface pressures rising in the Pacific Northwest during the period July 17-19. A minor pressure ridge aloft moved into Southern California on July 18, resulting in weak, upper level winds over the area. The normal, inland surface pressure trough was not as well developed as normal during the summer.

TX-3

Start 16:47:05 PDT

End 16:59:53

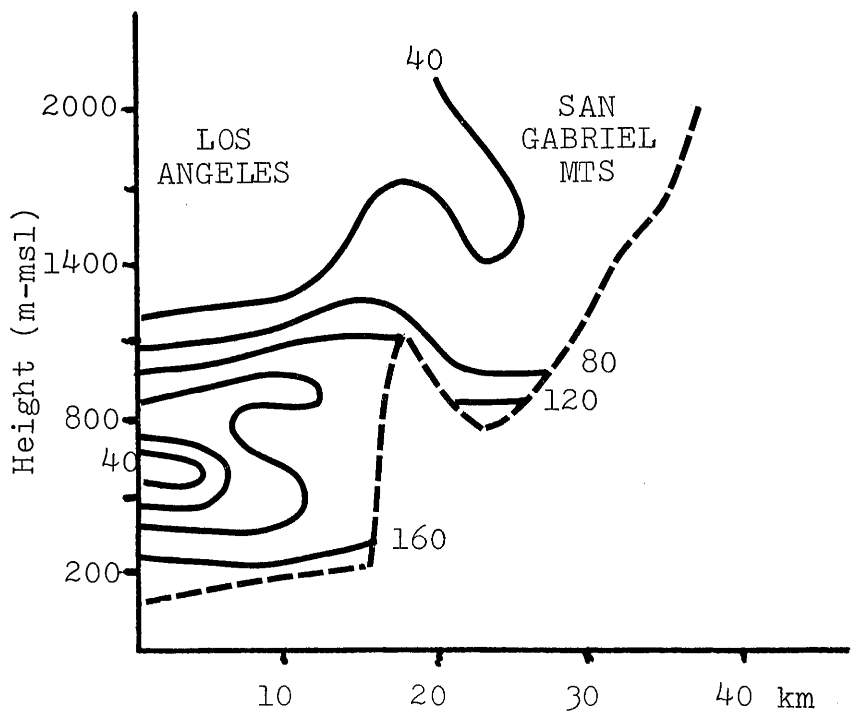


Fig. 3-4 CROSS SECTION OVER SAN GABRIEL MTS.
July 14, 1981

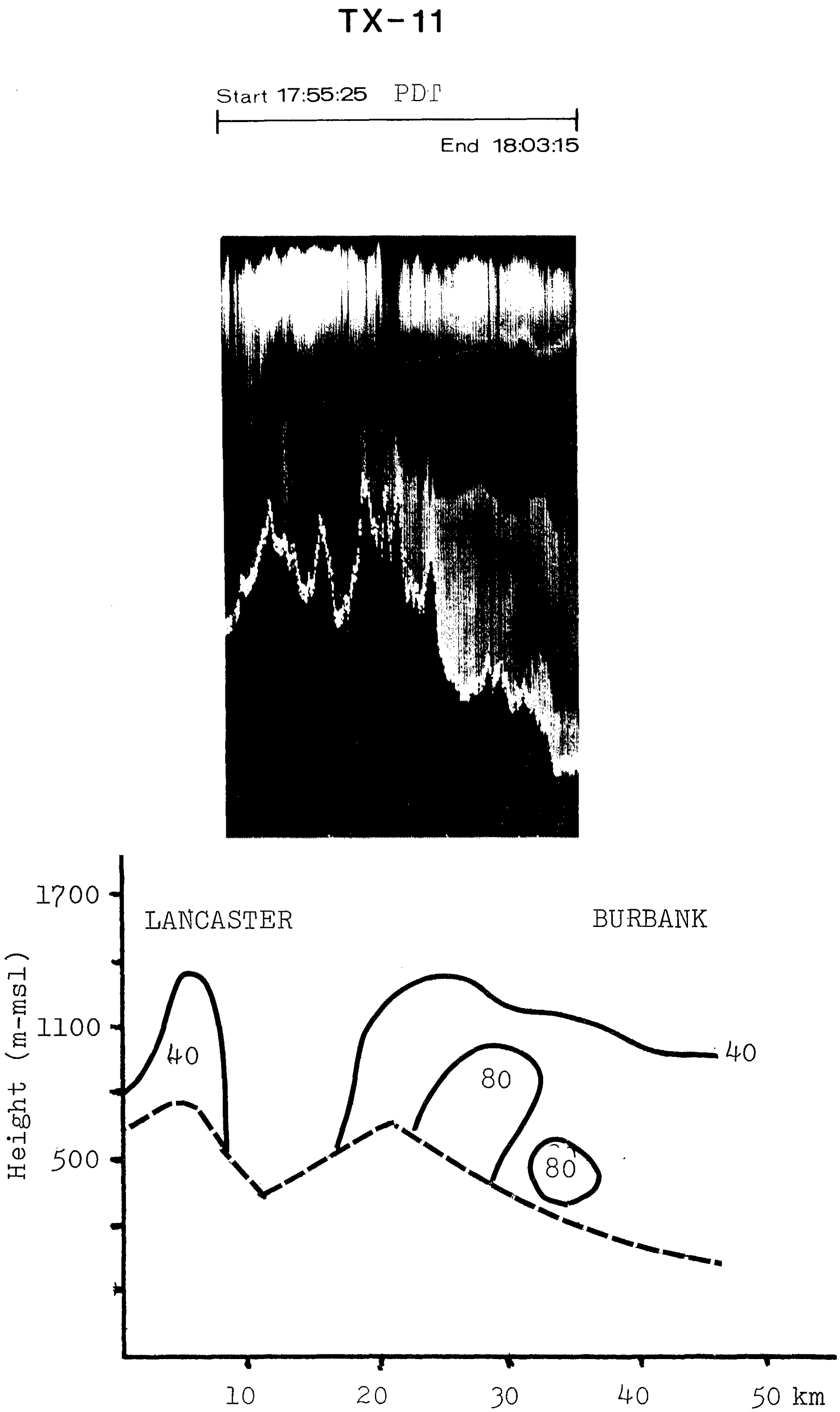


Fig. 3-5 CROSS SECTION FROM DESERT
TO BURBANK
July 14, 1981

Meteorological parameters of interest on July 18 are given in Table 3.2:

Table 3.2

Meteorological Parameters
July 18, 1981

850 mb Temperature (UCLA)	20.6° C
Pressure Gradients (08PDT)	
LAX-Daggett	1.9 mb
LAX-Bakersfield	0.1
Maximum Surface Temperatures	
Ontario	99° F
Palm Springs	110
Mixing Heights	
UCLA (12 PDT)	375 m-msl (225 m-agl)
Rialto (1521 PDT)	1250 m-msl (800 m-agl)

The 850 mb temperature was slightly cooler than average for July. Mixing heights were near or slightly higher than on July 14. The weak surface pressure gradients led to relatively low transport wind conditions. The temperatures at the top of the inversion were several degrees cooler than on July 14. This permitted more vigorous penetrations of the low-layer aerosols into the stable layer than was observed on July 14. Highest ozone concentrations reported in the South Coast Air Basin were 17 pphm and 25 pphm at Fontana and San Bernardino, respectively.

Fig. 3-6 shows a transect from Victorville (left of figure) to downtown Los Angeles between 1501 and 1524 PDT on July 18. The track passed slightly to the east of Mt. Wilson. Apparent returns at high altitude over the desert are an artifact of the instrument system.

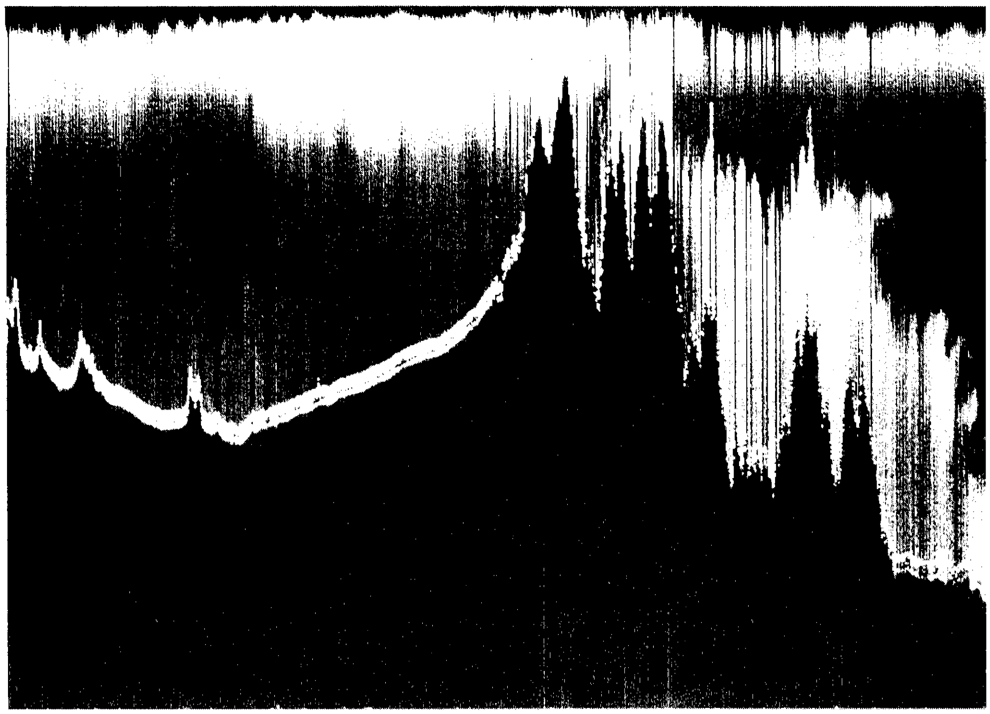
The layer along the slopes stabilized at about 1200 m-msl and there was an indication that backflow over the basin was present at the top of the layer. In general, there appeared to be more vertical development along the slope compared to Fig. 3-4 where the stable lid on the upward convection was more pronounced.

Data in Fig. 3-7 were taken during a flight leg from downtown Los Angeles to San Benardino between 1525 and 1542 PDT. The high terrain in the middle of the figure

TX-1

Start 15:01:17 PDT

End 15:24:01



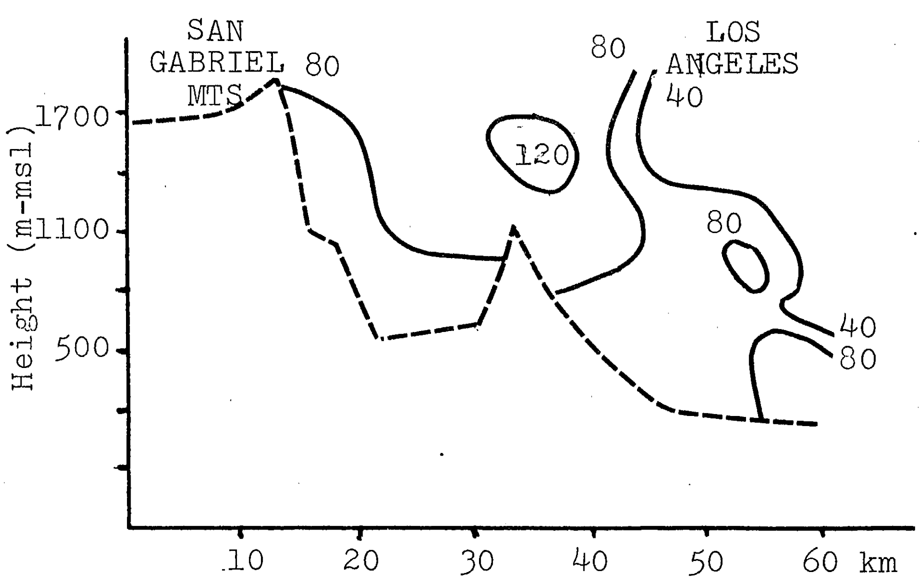


Fig. 3-6 CROSS SECTION OVER SAN GABRIEL MTS

July 18, 1981

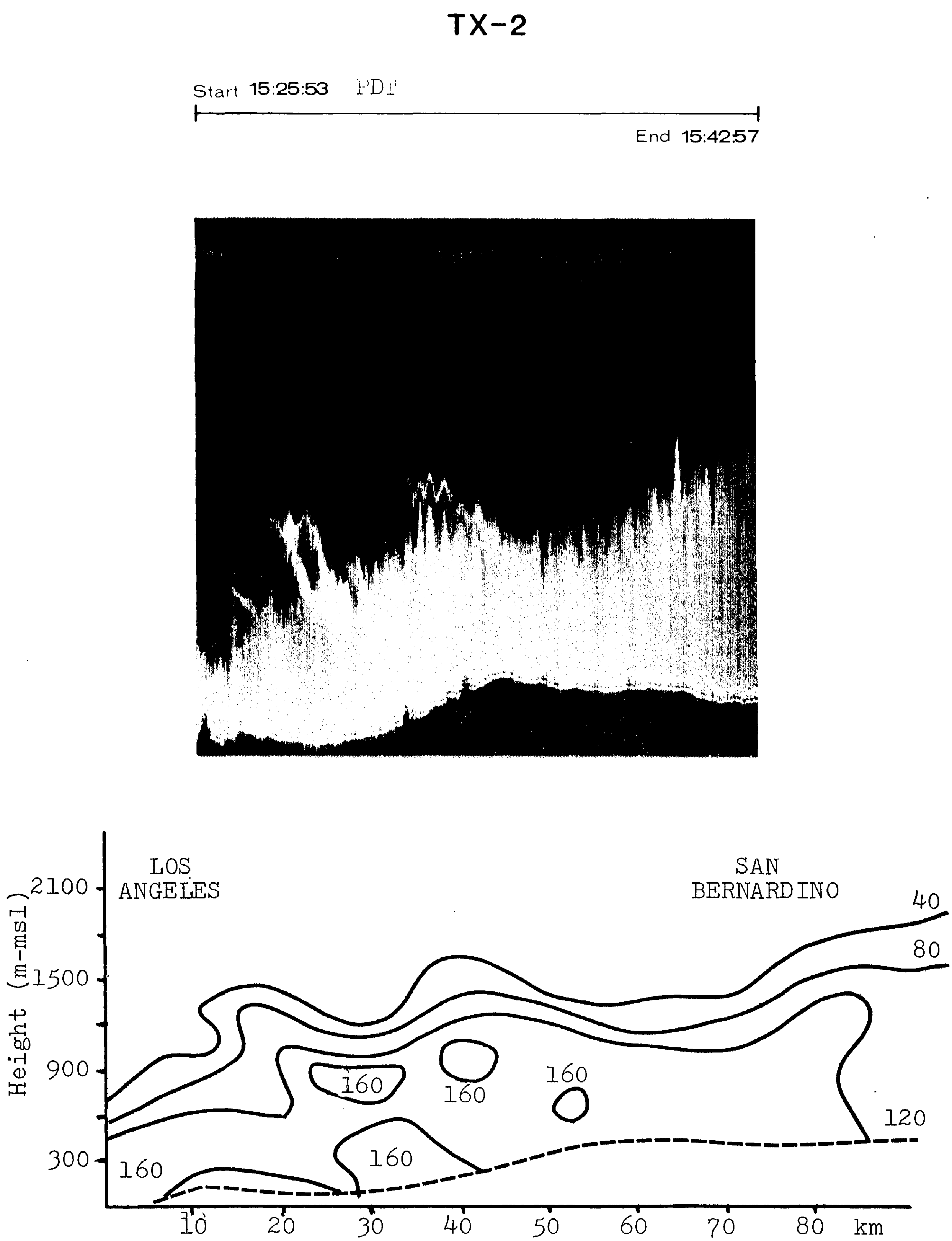


Fig. 3-7 CROSS SECTION FROM LOS ANGELES TO SAN BERNARDINO

July 18, 1981

represents the Puente Hills with the eastern San Gabriel Valley to the right of the figure.

The top of the aerosol layer in Fig. 3-7 is unusually variable, ranging from 500 m-msl over downtown Los Angeles to 1200 m-msl in the middle of the figure and 1400 m-msl in the east. These variations appear to be directly related to 1) the effects of heating over the western slopes of the Puente Hills and 2) higher surface temperatures in the eastern part of the basin.

Two pronounced fingers aloft appear in the left portion of the figure. These represent heating pulses which have broken through the relatively weak inversion which was present on July 18. As indicated in the digital portion of the figure, these fingers appear to extend westward relative to the faster-moving air in the mixed layer below. If drawn to proper horizontal and vertical perspectives they would appear to be relatively flat layers aloft extending to the west.

Fig. 3-8 shows an aircraft sounding taken at 1521 PDT at Rialto, slightly to the north of the flight track. The principal mixing layer top is at 1250 m-msl with layers aloft, probably associated with the slopes to the north. Otherwise, the agreement with the lidar data is good.

Fig. 3-9 was taken during a transect from Victorville through Hesperia to Cajon Pass from 1859 to 1908 PDT on July 18. Hesperia is slightly to the left of the center of the figure. The track through Cajon Pass was made to the south of Cajon Summit from a northeast to southwest direction.

The figure shows an aerosol layer top at about 1100 m-msl at the beginning of the transect near Victorville. The top of the layer increased toward Cajon Pass reaching about 1700 m-msl near the pass. At 13 PDT the surface wind at Victorville shifted to south, continuing in a gusty fashion through 17 PDT. A gradual shift to southwest was recorded after 17 PDT. The visibility (25 miles) at Victorville did not decrease during this period but the dewpoint increased somewhat, reflecting the flow of basin air from the pass. It is of interest to note the strongly descending slope in the layer top from the pass to Victorville. A similar phenomenon is shown later for San

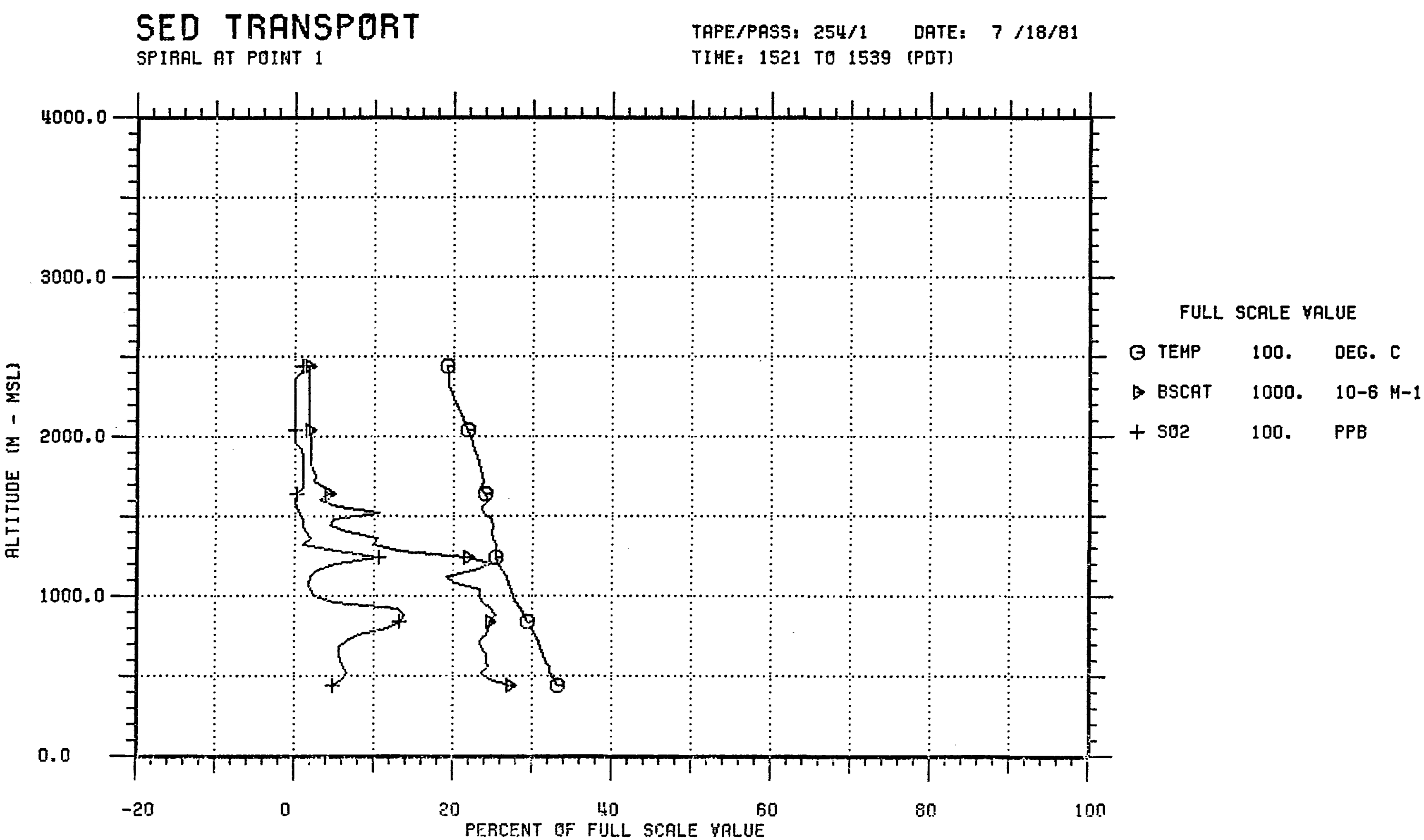


Fig. 3-8 AIRCRAFT SOUNDING AT RIALTO
July 18,1981

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06:43:06

053

TX-12

Start 18:59:29 PDT

End 19:08:39

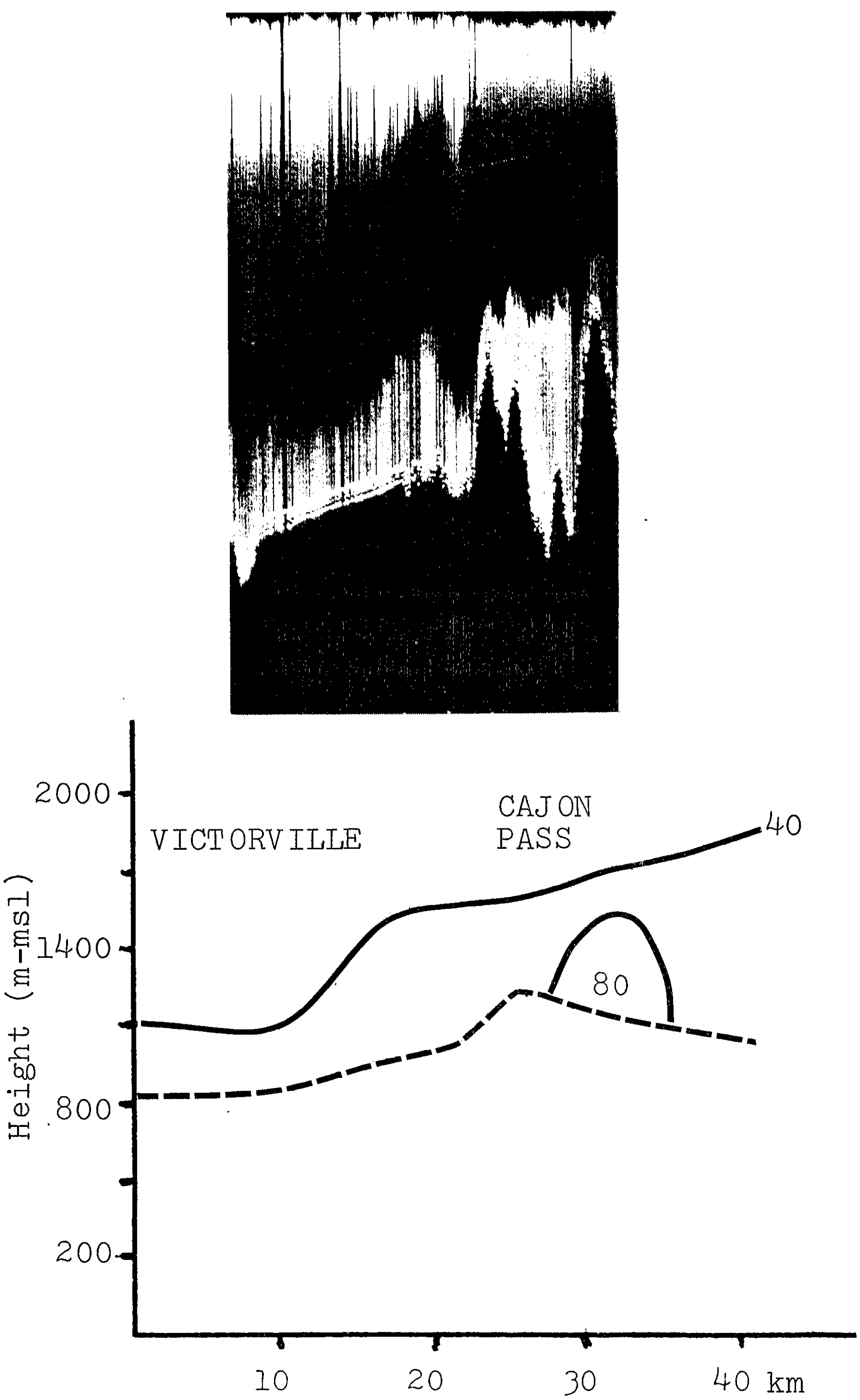


Fig. 3-9 CROSS SECTION
OVER MOJAVE DESERT

July 18, 1981

Gorgonio Pass.

Fig. 3-10 shows a flight leg from west Fontana to downtown Los Angeles between 1910 and 1922 PDT on July 18. Two layers are shown over Los Angeles, merging into one layer near Fontana. The top of the upper layer over Los Angeles is about 1100 m-msl while the top of the lower layer is about 350 m-msl. Over west Fontana the top of the single layer is about 800 m-msl. Between the two layers is a wedge of relatively clean air. A similar cross section was constructed from successive aircraft soundings in Smith et al (1976). This figure is reproduced in Fig. 3-11 for comparison with Fig. 3-10.

Smith et al (1976) have suggested that such a crossection is formed by an undercutting, marine layer which penetrates well inland during the late afternoon. This layer undercuts the existing pollutant layer but brings with it its own shallower layer of pollutant which has been accumulated during the trajectory to the inland areas. The shallow layer extends inland from Los Angeles nearly to Pomona with highest surface aerosol concentrations near the eastern boundary of the layer.

July 19, 1981

High pressure continued to ridge into the western states, resulting in warming temperatures aloft and continued weak surface pressure gradients. Meteorological parameters of interest on July 19 are:

Table 3.3

Meteorological Parameters
July 19, 1981

850 mb Temperature (UCLA)	23.4° C
Pressure Gradients (08PDT)	
LAX-Daggett	1.7 mb
LAX-Bakersfield	0.9
Maximum Surface Temperatures	
Ontario	101° F
Palm Springs	109
Mixing Heights	
UCLA (12 PDT)	380 m
Ontario	N/A

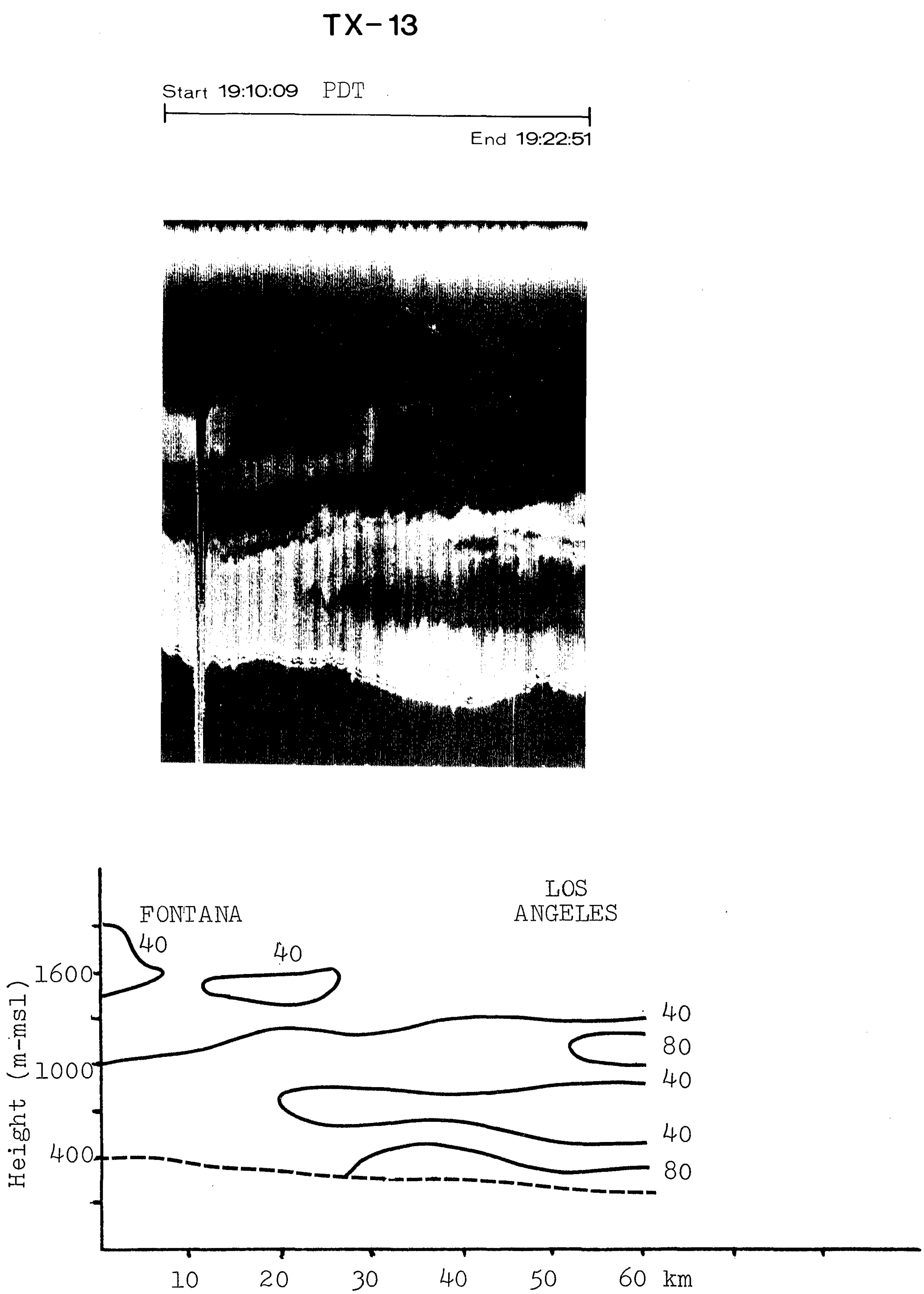


Fig. 3-10 CROSS SECTION IN SOUTH COAST AIR BASIN

July 18, 1981

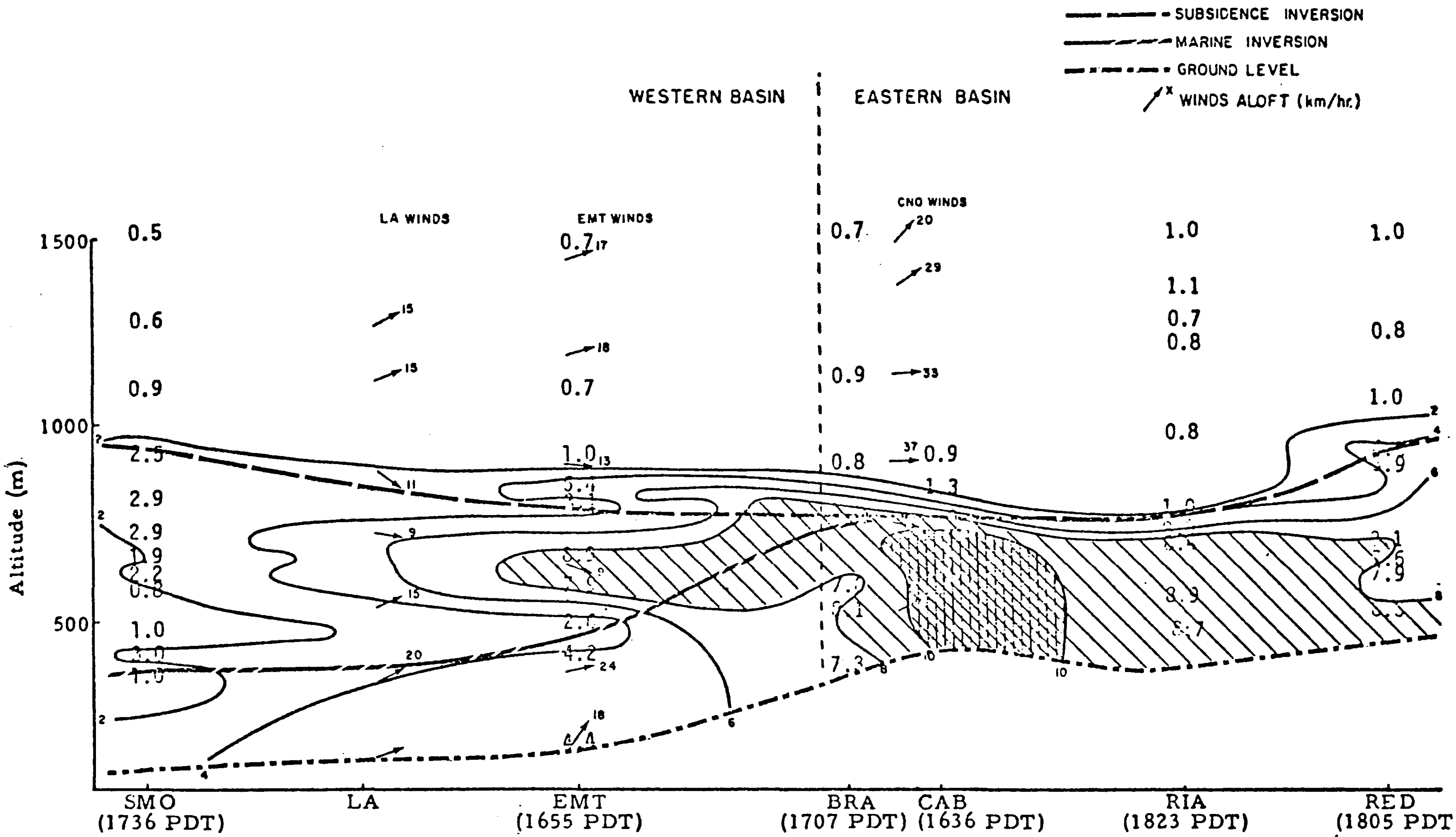


Fig. 3-11
VERTICAL CROSS SECTION OF b_{scat} - July 25,1973

The 850 mb temperature increased over two degrees from the previous day reaching a level about 1.5° C above average for July. The mixing height decreased slightly in keeping with the increased ridging aloft. Maximum ozone reported in the South Coast Air Basin was 22 pphm at San Bernardino and Upland.

Fig. 3-12 is a cross section from Victorville to downtown Los Angeles between 0913 and 0922 PDT. The flight track passed to the east of Mt. Wilson. An aerosol layer is indicated over the desert areas with a ragged top near 1400 m-msl near Victorville increasing somewhat immediately adjacent to the mountain slopes. An earlier air quality aircraft sounding at Victorville (0723 PDT) confirmed the presence of a low-level ozone layer with a top of 1400 m-msl and a peak value near the surface of 10 pphm.

Over the valley (Fig. 3-12) the top of the aerosol layer was about 1000 m-msl. The top of the layer was somewhat higher near the southern slopes of the San Gabriels, reflecting the beginning of the slope heating. Aerosols are shown to have penetrated into an intermediate valley in the San Gabriel Mts. but highest concentrations were observed on the slopes adjacent to the basin.

Fig. 3-13 is a flight leg from downtown Los Angeles to San Bernardino between 0936 and 0956 PDT. Over downtown Los Angeles there was a surface-based aerosol layer with a top of 600 m-msl which followed the terrain along the eastern part of the flight route. Above this layer were extensive aerosol layers with tops ranging from 1100 to 1200 m-msl. These upper layers were imbedded in the stable layer above the morning inversion. Layer tops were about the same height as indicated the previous afternoon along the same flight track (Fig. 3-7). It is suggested that the upper level layer is a carry-over from the previous day with a top representing the maximum vertical mixing depth during the previous afternoon. The top of the upper layer corresponds to a small temperature inversion in the morning UCLA sounding.

A similar flight path was flown about two hours later on July 19 (1150 to 1200 PDT). Fig. 3-14 shows a crossection from Victorville to Fontana through the eastern portion of Cajon Pass. The aerosol layer over the basin is shown to rise along the south slopes of the mountains, reaching an altitude of 1400 m-msl for the main layer with fingers extending another 500 m upward. There is little aerosol apparent in the desert areas. Presumably the early

TX-1

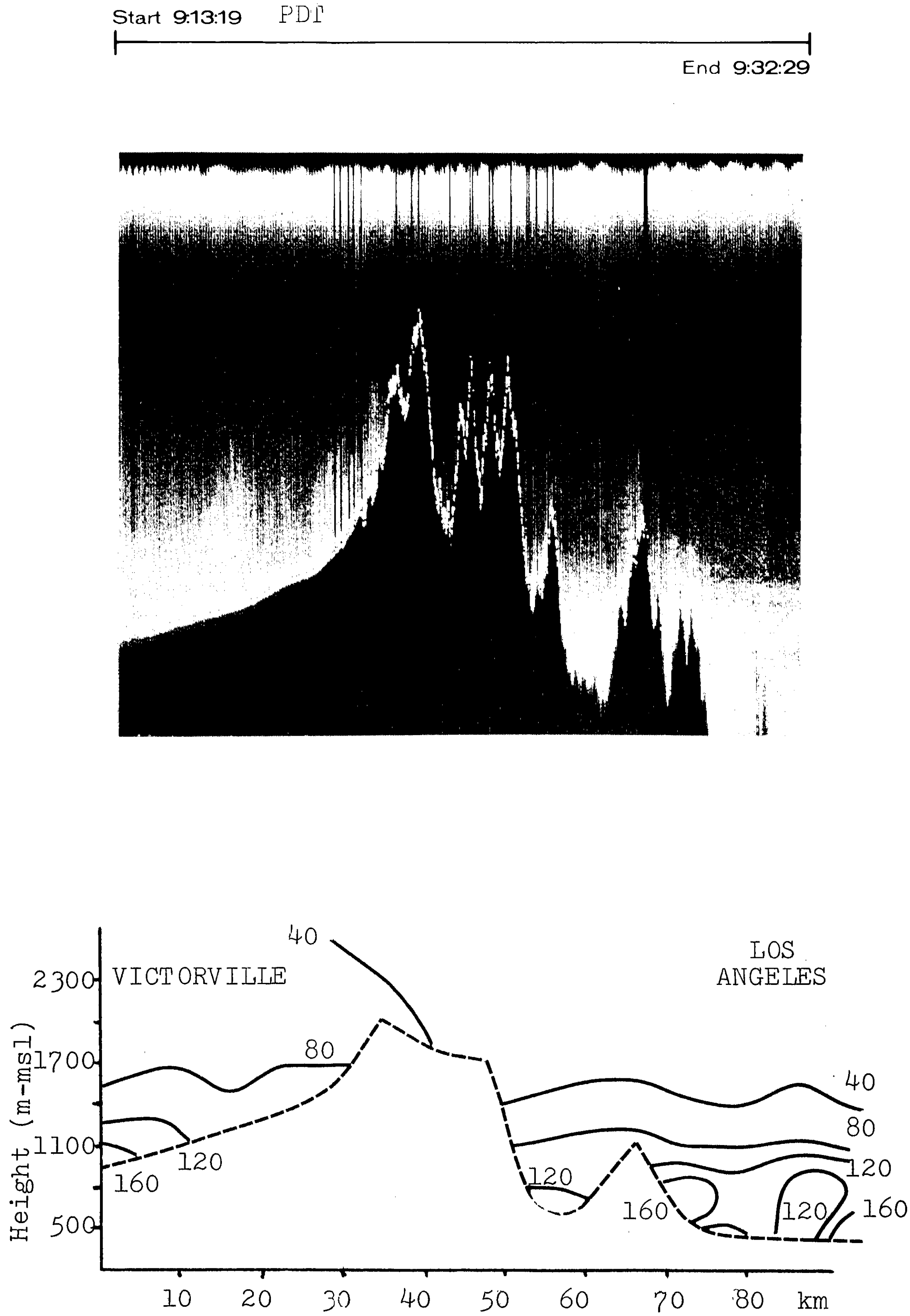
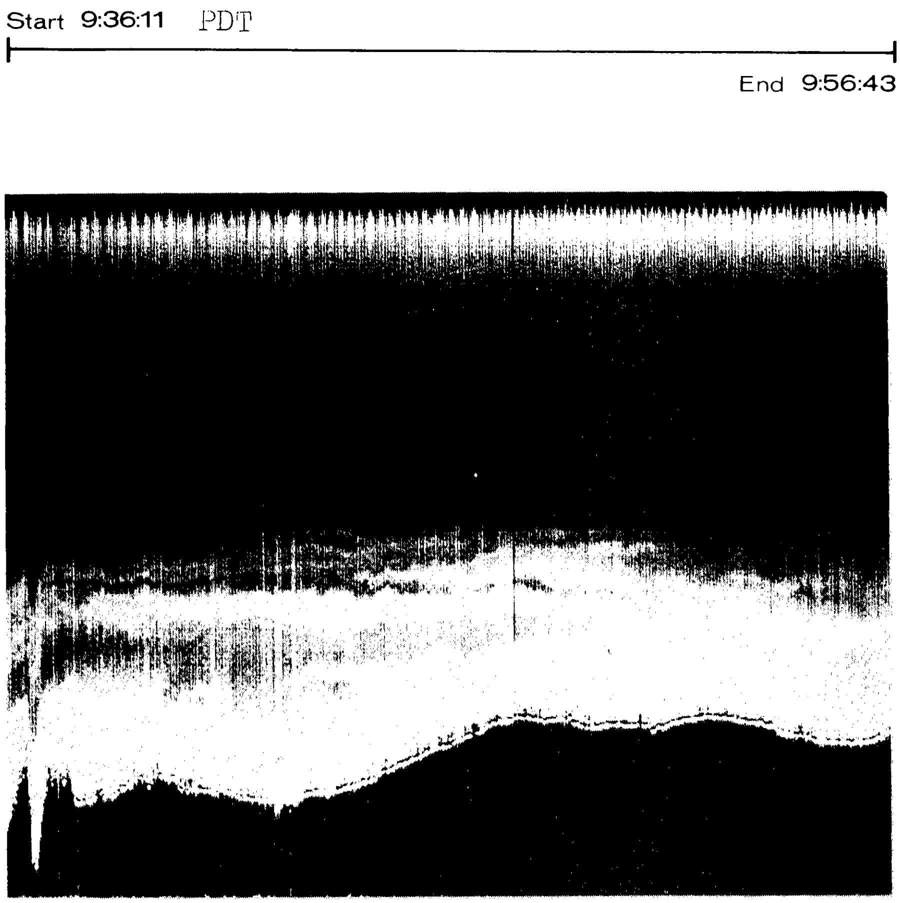


Fig. 3-12 CROSS SECTION OVER SAN GABRIEL MTS
July 19, 1981

TX-2



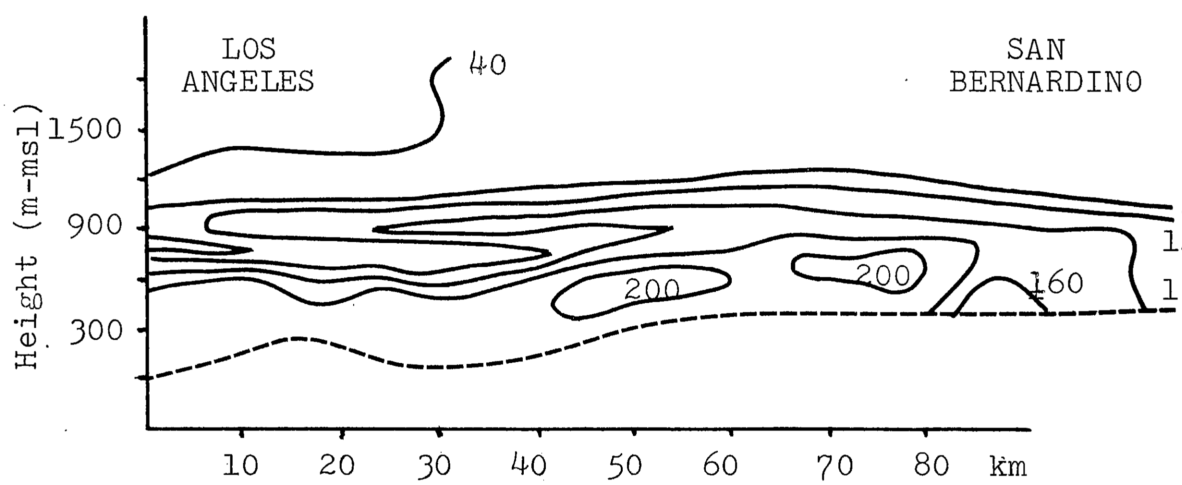


Fig. 3-13 CROSS SECTION IN SOUTH COAST AIR BASIN
July 19, 1981

TX-11

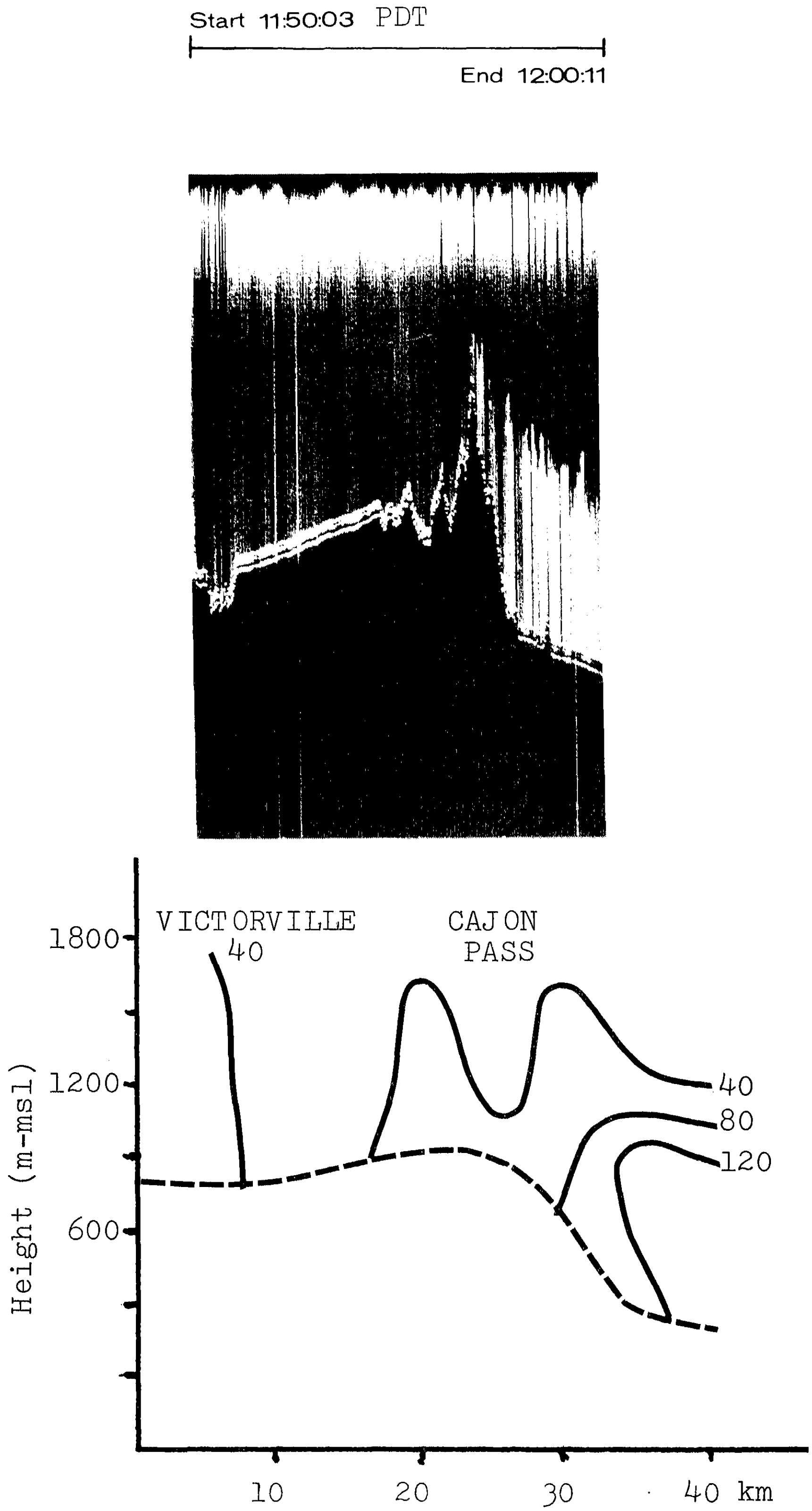


Fig. 3-14 CROSS SECTION OVER CAJON PASS

July 19, 1981

morning layer (Fig. 3-12) has been diluted by vertical mixing.

Fig. 3-15 repeats the flight trajectory of Fig. 3-13 from Fontana to downtown Los Angeles between 1200 and 1216 PDT. The top of the layer was relatively flat at about 1100 m-msl. Horizontal inhomogeneities are apparent in the digital portion of Fig. 3-15. The largest aerosol bulge is located between El Monte and West Covina. The eastern inhomogeneity lies between Pomona and Ontario. The sources of these anomalies are not known. Peak ozone at Pomona occurred at 14-15 PDT and may have been associated with the passage of the largest inhomogeneity observed during the flight path.

July 22, 198

A strong high pressure ridge aloft was present over Southern California for several days prior to July 22. By July 22 the ridge had begun to break down but light, variable winds aloft still dominated the area. A list of pertinent meteorological parameters for July 22 is given in Table 3.4:

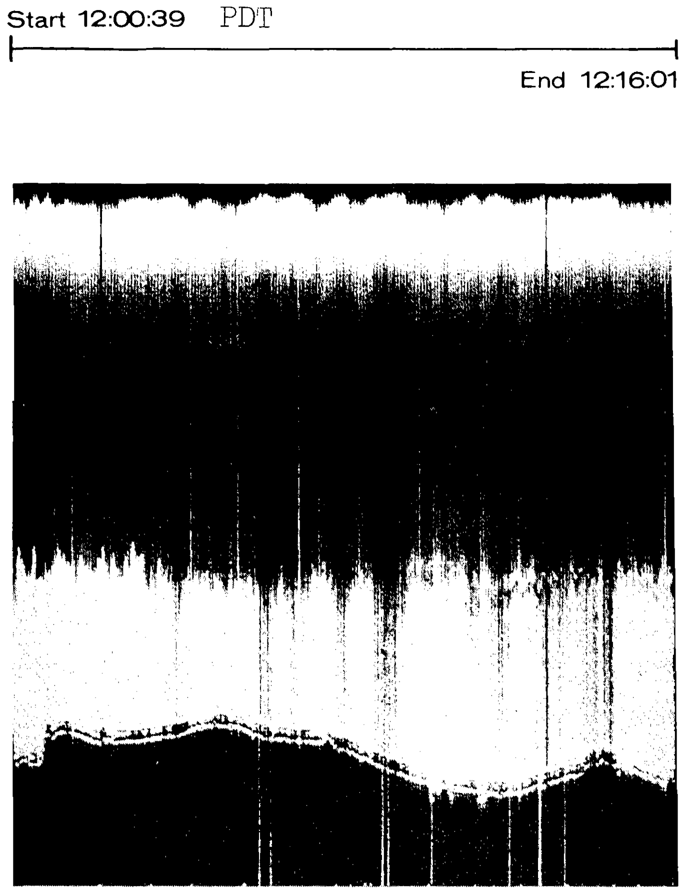
Table 3.4

Meteorological Parameters
July 22, 1981

850 mb Temperature (UCLA)	24.2° C
Pressure Gradients (08 PDT)	
LAX-Daggett	4.4 mb
LAX- Bakersfield	2.7
Maximum Surface Temperatures	
Ontario	96° F
Palm Springs	112
Mixing Heights	
UCLA (12 PDT)	400 m-msl (250 m-agl)
Ontario (1430 PDT)	1040 m-msl (750 m-agl)

The 850 mb temperature was about three degrees warmer than average for July. Pressure gradients were somewhat larger than average for the month, reflecting the warm, inland temperatures. Mixing heights were similar to those observed in previous lidar sampling days. Maximum hourly

TX-12



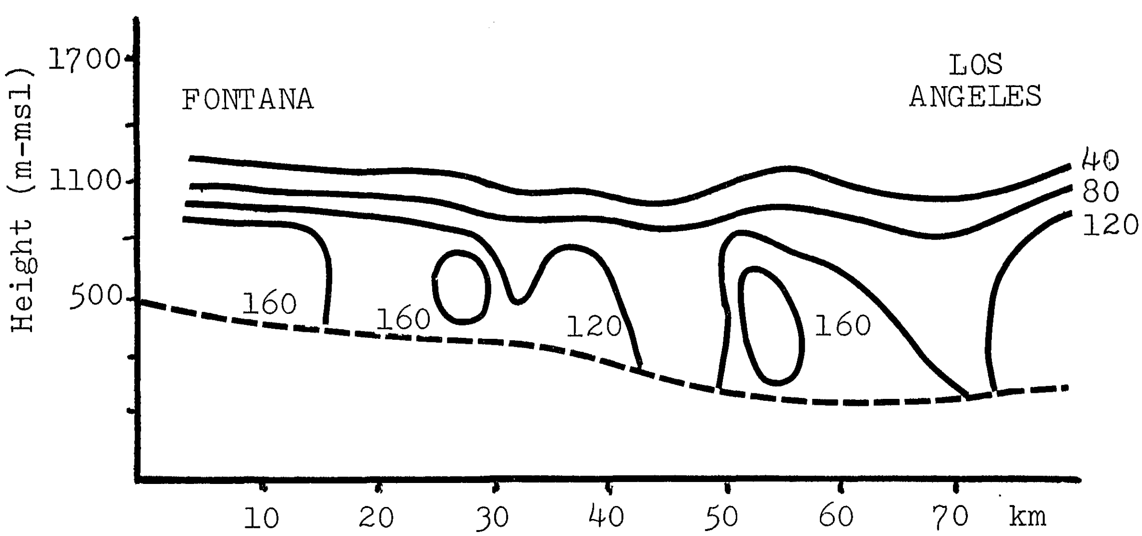


Fig. 3-15 CROSS SECTION FROM FONTANA TO LOS ANGELES

July 19, 1981

ozone concentrations observed in the South Coast Air Basin on July 22 were 25 and 24 pphm at Mt. Baldy and Mt. Wilson, respectively. San Bernardino and Fontana recorded values of 20 and 17 pphm, respectively.

Fig. 3-16 shows a cross section from Victorville to downtown Los Angeles, passing over the San Gabriel Mts. slightly to the east of Mt. Wilson. The flight occurred between 1634 and 1701 PDT. Apparent signal returns at high altitude are artifacts of the instrument system.

A diffuse aerosol layer with ragged top is apparent over the desert areas. The apparent top of the layer was about 1300-1400 m-msl near Victorville without much change as the aircraft approached the northern slopes of the mountains. At Victorville on July 22, the surface wind shifted abruptly at 15 PDT from 290° to 140° and then to 190-210° through 23 PDT. Coincident with the wind shift, the visibility decreased from 20 miles to 10 miles. "Haze all quadrants" was reported at George AFB from 15 PDT through 20 PDT. The incursion of pollution from Cajon Pass appears unmistakable. In contrast to the layers over the South Coast basin, the larger tops over the desert appear ragged and convection-dominated.

On the southern slopes of the San Gabriels (Fig. 3-16), the aerosol layer showed classic upslope motions with a layer developing at 1700 m-msl. Upslope motions close to the slope carried the aerosols as high as 2400 m-msl near the ridge top. Over downtown Los Angeles the top of the aerosol layer was about 1400 m-msl.

Fig. 3-17 shows a cross section from San Bernardino to Cajon Pass from 1718 to 1727 PDT. A deep layer to 2000 m-msl exists over San Bernardino with the top decreasing or becoming more dilute with distance up the slope toward the pass. The upper winds at Fontana (17PDT) were from the west to an altitude of 1000 m-msl becoming SSW at higher altitudes. The inversion was relatively weak on July 22. Peak temperature aloft was 24° at 1300 m-msl. This inversion would have been eliminated by a surface temperature of 93° F at San Bernardino. It seems likely, therefore, that the aerosol layer was carried upslope from San Benardino but diluted extensively by vertical mixing as it passed over the ridge.

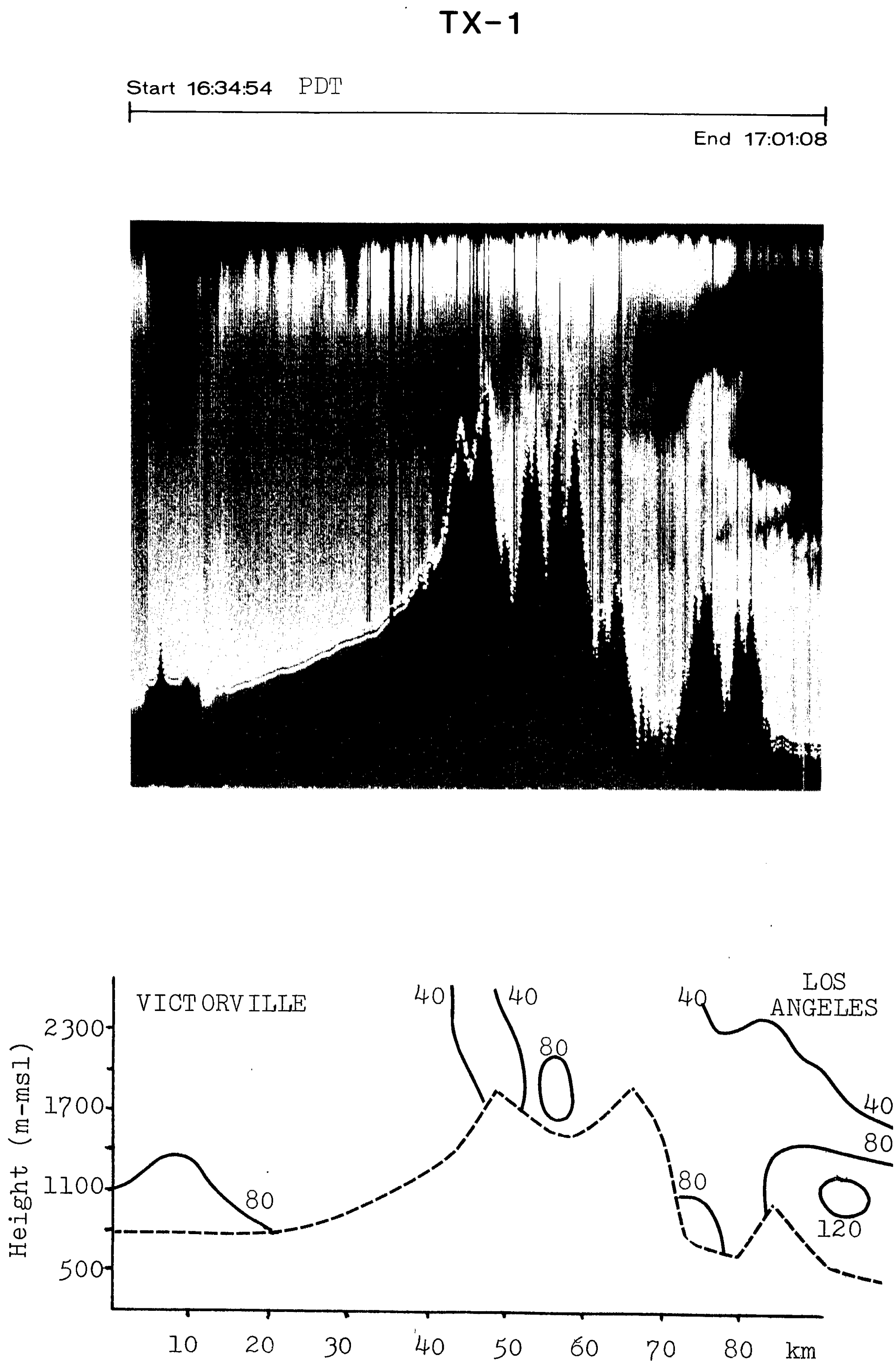
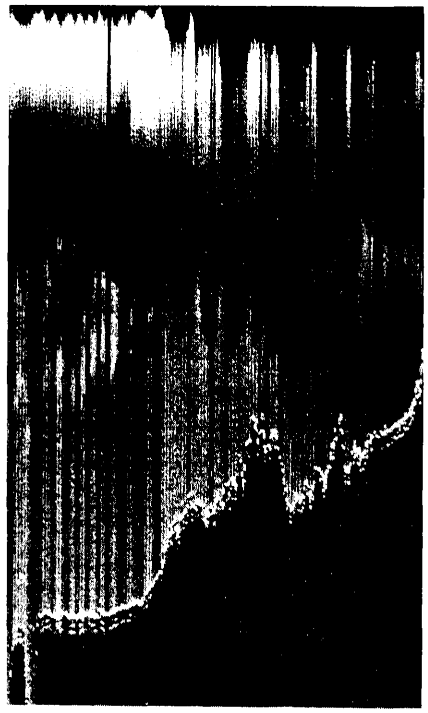


Fig. 3-16 CROSS SECTION OVER SAN GABRIEL MTS
July 22, 1981

TX-3

Start 17:18:00 PDT

End 17:27:40



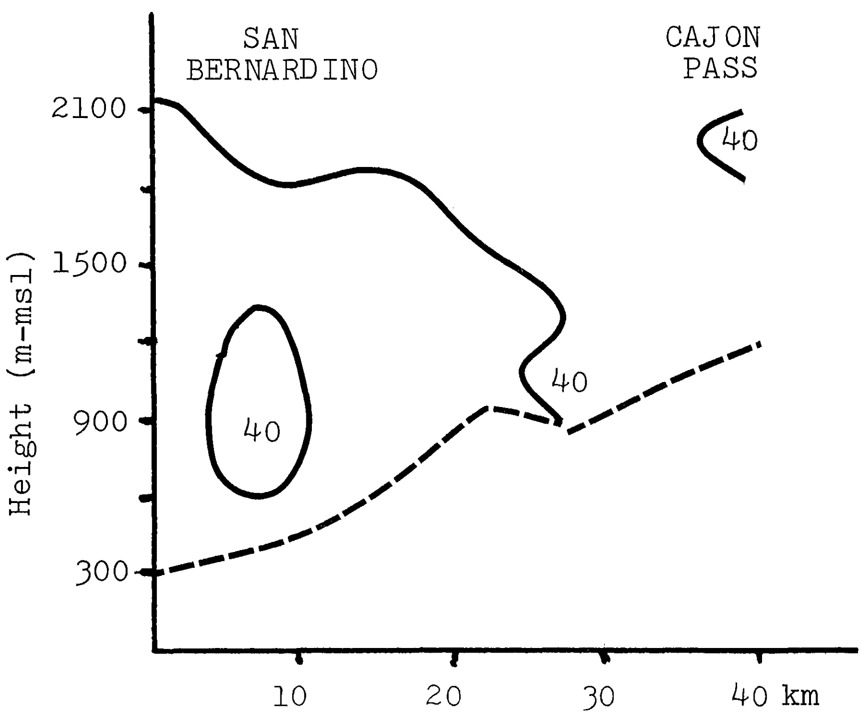


Fig. 3-17 CROSS SECTION ON
SOUTH SLOPE OF CAJON PASS

July 22, 1981

July 23, 1981

The high pressure ridge continued to move eastward, decreasing the temperatures aloft slightly compared to July 22. Characteristic parameters for July 23 are given in Table 3.5:

Table 3.5

Meteorological Parameters
July 23, 1981

850 mb Temperature (UCLA)	23.2° C
Pressure Gradients (08 PDT)	
LAX-Daggett	4.6 mb
LAX-Bakersfield	2.2
Maximum Surface Temperatures	
Ontario	96° F
Palm Springs	114
Mixing Heights	
UCLA (12 PDT)	635 m-msl
Ontario (1430 PDT)	960

The 850 mb temperature was about two degrees warmer than average for July. Pressure gradients to the inland areas continued above average. The noon mixing height at UCLA was higher than previously observed during the lidar flight program. Highest ozone concentration reported in the South Coast Air Basin was 26 pphm at Azusa, Glendora and Mt. Baldy.

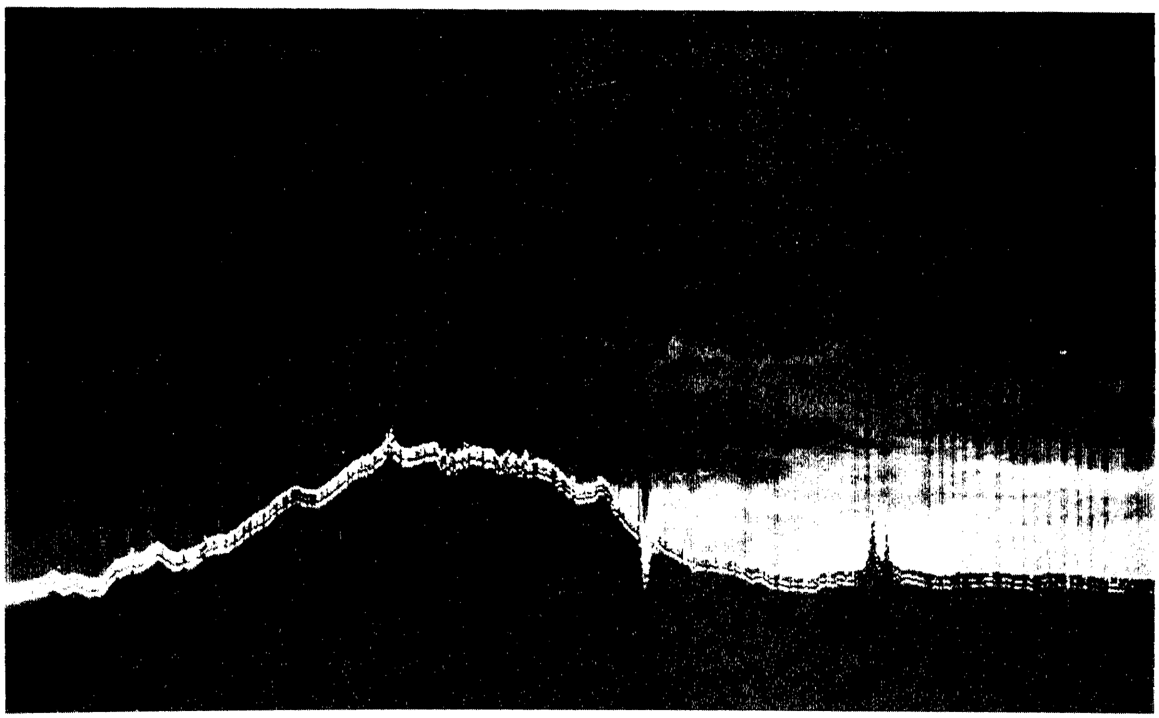
Fig. 3-18 was constructed from a flight path (0713 to 0759 PDT) originating at Palm Springs, passing through San Gorgonio Pass and ending at Pomona. There is little apparent aerosol on the desert side of the pass. There is some indication of a weak layer with a top of 1500 m-msl. Visibility at Palm Springs was reported as 25 miles at 08 PDT. The ozone concentration at 00 PDT in Palm Springs was 10 pphm which suggests that some pollutant carryover may have been present on the following morning.

The aerosol concentrations on the western side of the pass show a marked, layered structure. The top of the structure was at 800 m-msl which was about the same height as the top of the stratus layer in the UCLA morning sounding. An air quality aircraft sounding at Cable Airport (Upland) at 0652 PDT showed a strongly polluted

TX-1

Start 7:13:58 PDT

End 7:39:53



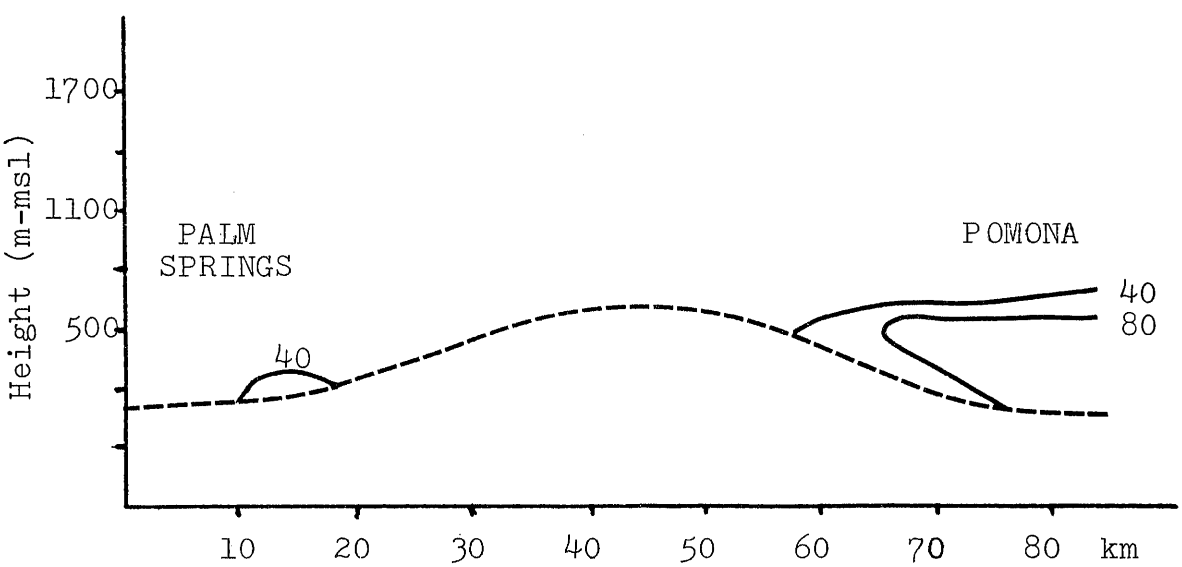


Fig. 3-18 CROSS SECTION THROUGH SAN GORGONIO PASS
July 23, 1981

layer with a top of 700 m-msl but with elevated ozone layers, topping out at 1900 m-msl. As indicated in the discussion for July 22, afternoon mixing occurred to a height of 2000 m-msl near the slopes. Remnants of this deep, mixed layer apparently remained the following morning in the eastern San Gabriel Valley.

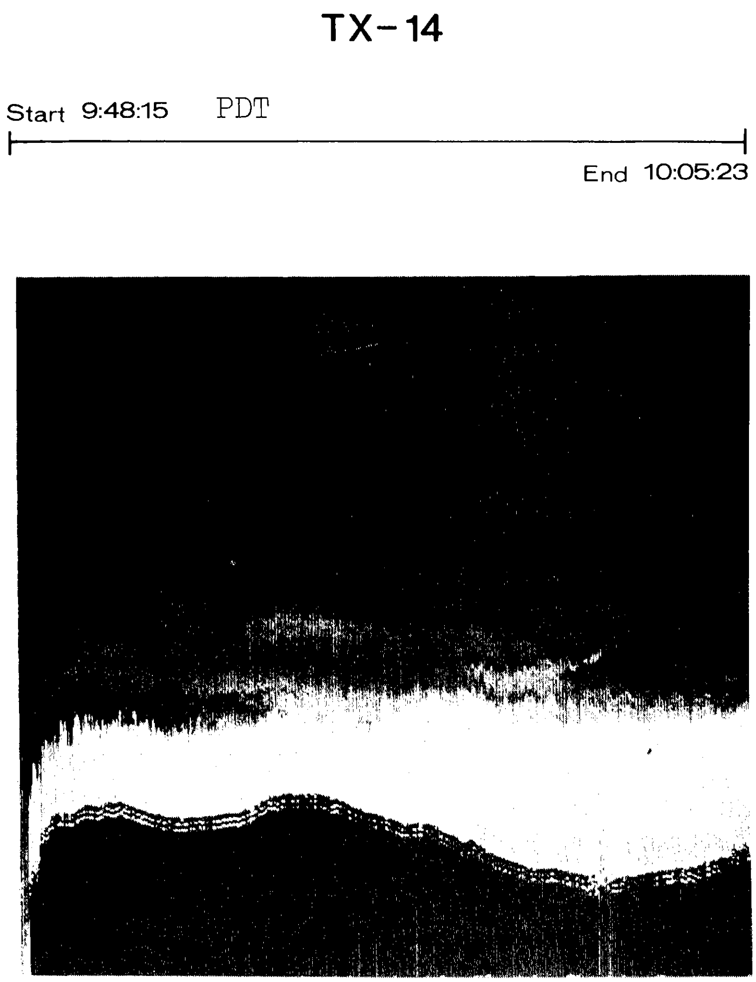
Fig. 3-19 is a cross section from San Bernardino to downtown Los Angeles between 0948 and 1005 PDT, about 2 1/2 hours after the previous figure. The top of the aerosol layer was relatively flat at 800-900 m-msl. The digital crossection in Fig. 3-19 indicates a layer aloft with reduced aerosol concentrations near the ground in the western end of the flight path. Surface visibilities, however, were quite restricted in this area at flight time. La Verne reported 1 1/2 miles in fog and haze while El Monte reported 2 1/2 miles. It is likely, therefore, that the lidar signal was attenuated along this part of the flight path and that higher aerosol concentrations continued all the way to the surface.

July 27, 1981

A well-developed thermal trough was present at the surface on July 27 extending as far north as Washington and Oregon. The flow aloft was dominated by a weak ridge offshore on July 27, moving onshore by July 28. Winds aloft were generally light and variable over the Southern California area. Meteorological parameters of interest on July 27 are given in Table 3.6:

Table 3.6
Meteorological Parameters
July 27, 1981

850 mb Temperature (UCLA)	21.4° C
Pressure Gradients (08 PDT)	
LAX-Daggett	3.5 mb
LAX-Bakersfield	2.4
Maximum Surface Temperatures	
Ontario	92° F
Palm Springs	111
Mixing Heights	
UCLA (12 PDT)	617 m-msl (467 m-agl)
Ontario (1430 PDT)	920 m-msl (630 m-agl)



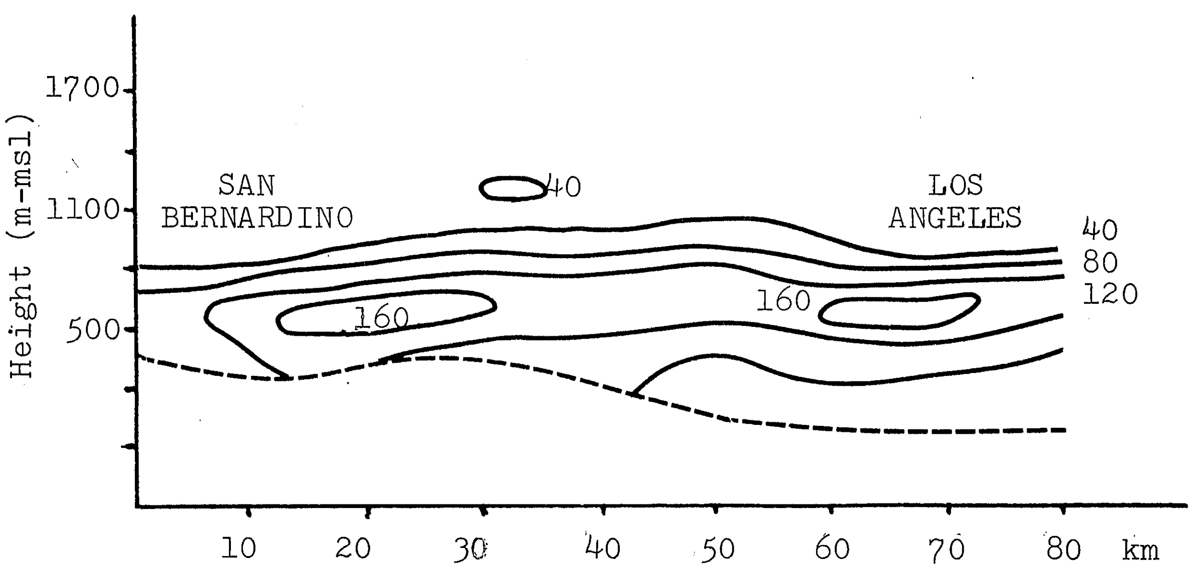


Fig. 3-19 CROSS SECTION IN SOUTH COAST AIR BASIN
July 23, 1981

The 850 mb temperature was near average for the month of July. Onshore pressure gradients were above average Mixing heights were relatively high along the coast but similar to other lidar flight days inland. The Ontario maximum temperature was held down by heavy aerosol concentrations. Visibility at Ontario was generally five miles or less until 20 PDT. Peak ozone concentrations observed on July 27 were 25 and 24 pphm at San Bernardino and Fontana, respectively.

There were two extensive lidar aircraft flights undertaken on July 27 starting at 1520 and 2042 PDT. These flights followed similar paths over central Los Angeles, Orange County and the Coachella Valley.

Fig. 3-20 shows a flight cross section through Cajon Pass to San Bernardino between 1528 and 1536 PDT. The flight track was slightly to the west of the center of the pass. The top of the aerosol layer near San Bernardino was near 1200 m-msl, rising along the slope as a result of slope heating and upslope transport. In comparison with the mixing height data (Table 3.6) this places the top of the aerosol layer within the inversion. There are indications of an aerosol layer extending beyond the pass into the desert but with reduced concentrations. Victorville surface winds shifted to southerly at 16 PDT, continuing through 20 PDT but without any change in visibility.

Fig. 3-21 is a cross section from San Bernardino to downtown Los Angeles between 1536 and 1550 PDT. The top of the aerosol layer was 1000 m-msl over downtown Los Angeles, with a somewhat higher top in the eastern part of the basin. Introduction of aerosol into an upper, stable layer is indicated in the eastern part of the flight path. The digital cross section indicates higher aerosol concentrations aloft during the flight leg. Visibilities along the flight track, however, were 3-4 miles and it appears that attenuation by the heavy aerosol concentrations have reduced the lidar return from the lower layers. An air quality aircraft sounding taken at Rialto at 1619 PDT (Fig. 3-22) shows a sharp layer top at about 1200 m-msl with a well-mixed layer below that level.

Fig. 3-23 was constructed from a similar flight trajectory taken during the evening between 2056 and 2108 PDT (some four hours after Fig. 3-21). The aerosol distribution has taken on a much more layered structure.

TX-2

Start 15:28:36 PDT

End 15:36:24

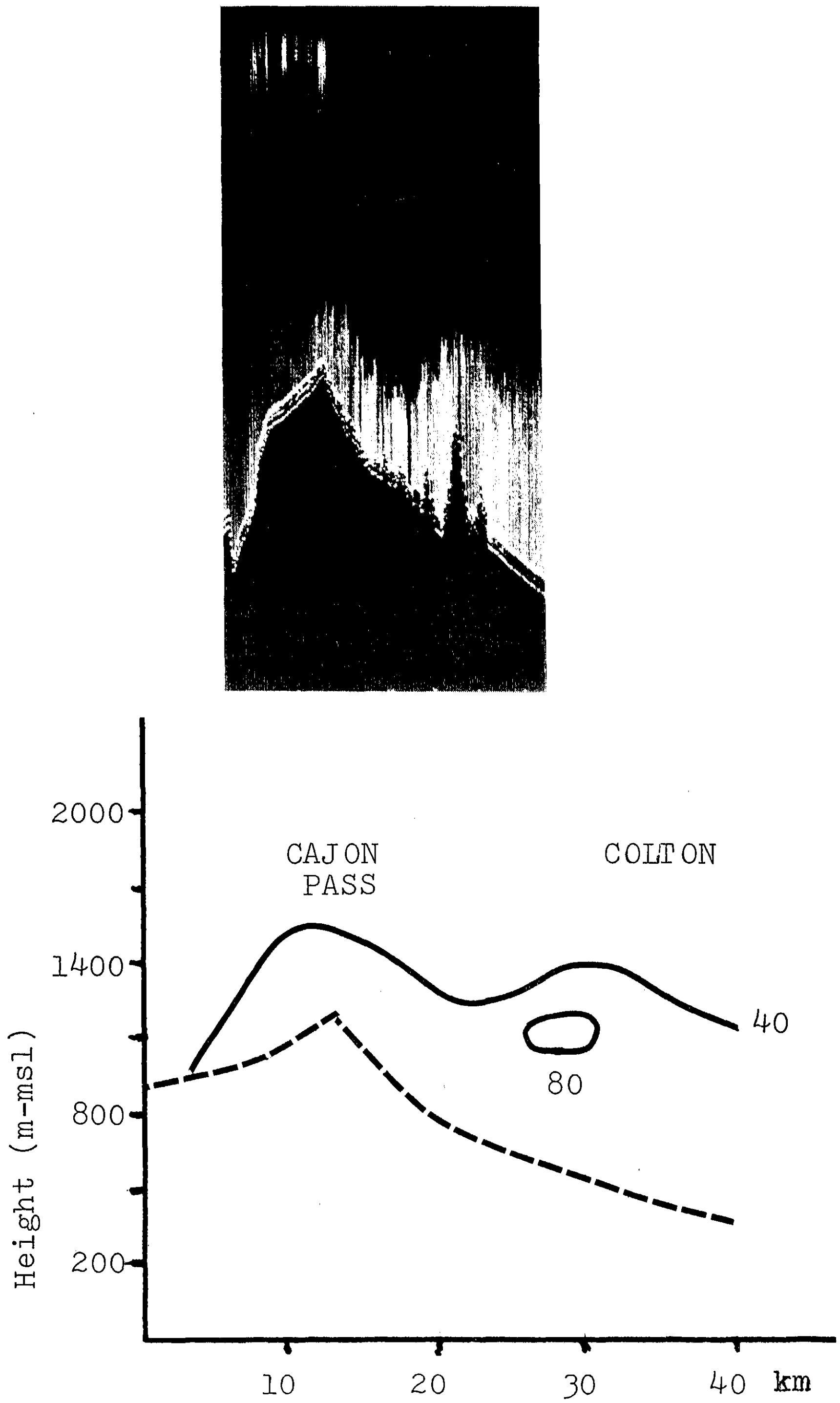
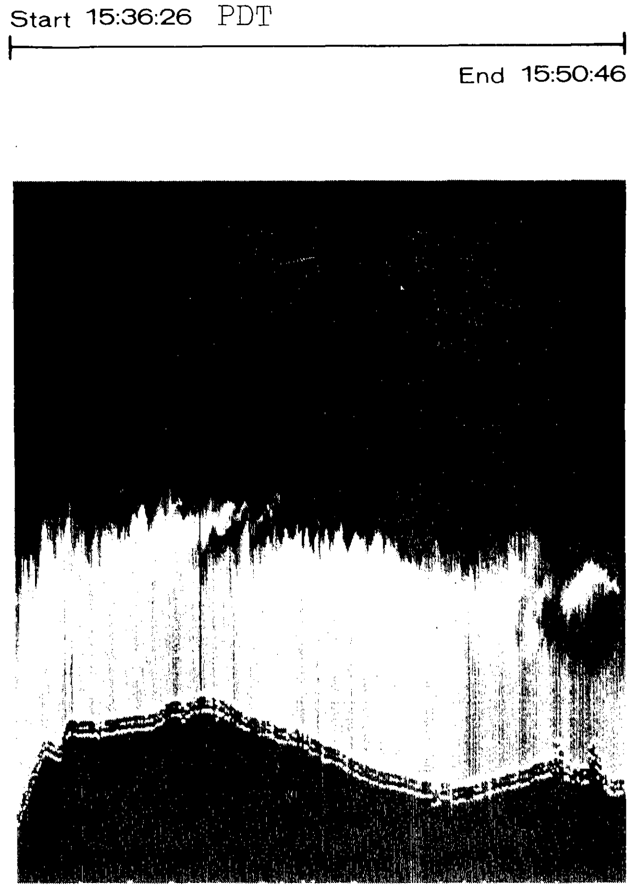


Fig. 3-20 CROSS SECTION ON SOUTH SLOPE OF CAJON PASS

July 27, 1981

TX-3



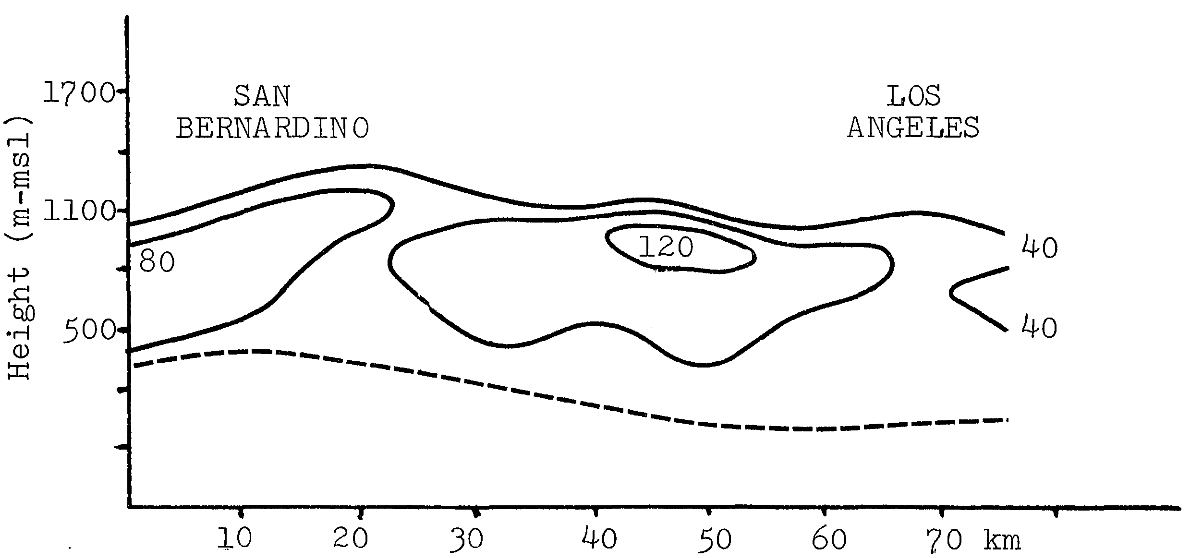


Fig. 3-21 CROSS SECTION IN SOUTH COAST AIR BASIN
July 27, 1981

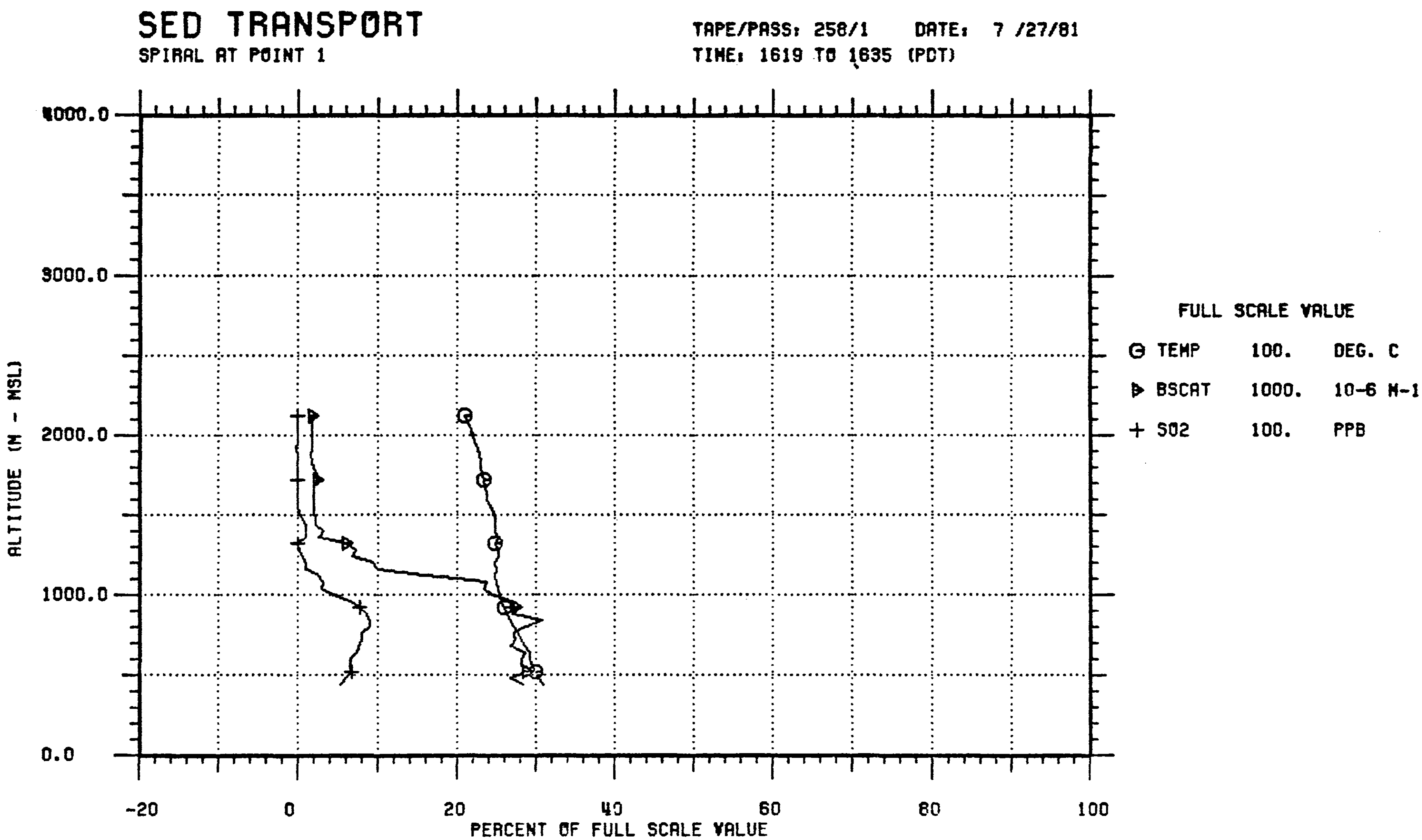
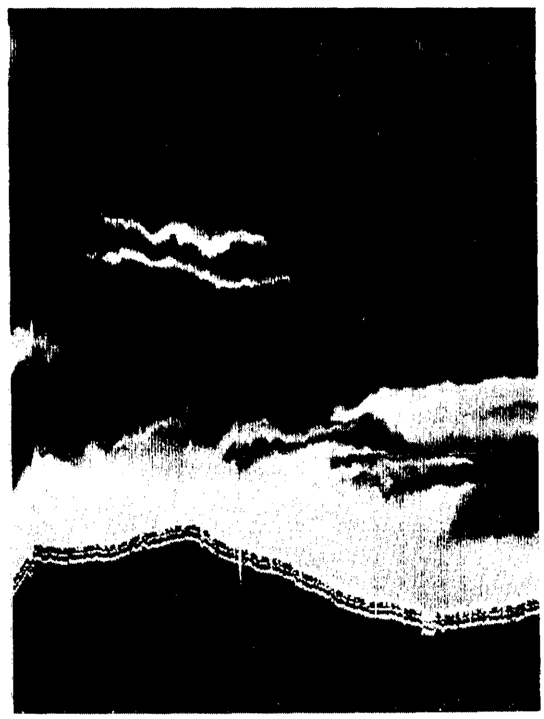


Fig. 3-22 AIRCRAFT SOUNDING AT RIALTO
July 27,1981

TX-4

Start 20:55:40

End 21:08:02



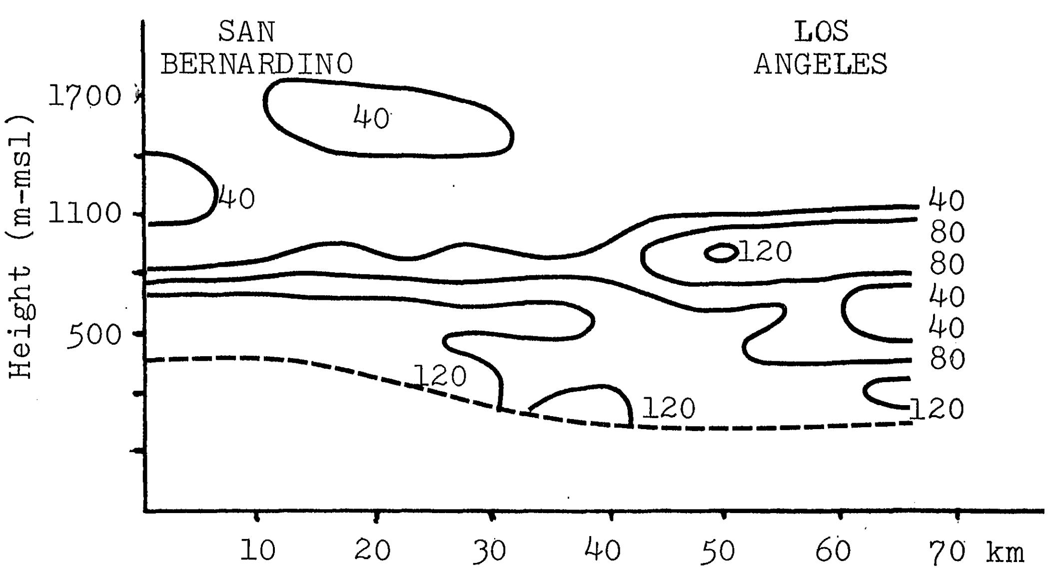


Fig. 3-23 CROSS SECTION IN SOUTH COAST AIR BASIN
July 27, 1981

The top of the highest layer over downtown Los Angeles was 1100 m-msl or the same as shown in Fig. 3-21. A shallow layer (350 m-msl top) has appeared, however, with a relatively clear area between the two layers. As indicated previously on July 18 (Fig. 3-10) this appears to result from an undercutting of a shallow marine layer in the late afternoon. At San Bernardino the top of the aerosol layer was 800 m-msl with indications of layers aloft, possibly from the effects of slope flow.

Fig. 3-24 shows two successive legs of a flight from the Salton Sea to Banning through Palm Springs between 2223 and 2241 PDT. The top of the aerosol layer in the desert was quite ragged, reflecting the convective mixing being encountered. Diffuse tops ranged from 500 m-msl near the Salton Sea to 900 m-msl near Palm Springs.

The surface winds at Palm Springs shifted to northwest at 17 PDT, bringing in polluted air from San Gorgonio Pass. "Haze all quadrants" was reported at the Palm Springs airport at 19, 21 and 22 PDT with visibilities reduced from 30 to 15 miles as a result of the intrusion from the northwest. This layer reached Thermal at 21 PDT so that the aerosol layer between Salton Sea and Palm Springs (Fig. 3-24) was produced largely by the intrusion of air from the northwest. The contrast between the concentrations at the northern end of the valley and those at the southern end is very marked. It appears that a shallow layer intrudes initially from the northwest and that surface heating is the desert subsequently breaks up the shallow layer into a more diffuse aerosol layer from Palm Springs southward.

On the eastern slopes of San Gorgonio Pass the top of the aerosol cloud is shown to decrease markedly from 1300 m-msl to 500 m-msl in the desert area. This type of motion is seen frequently in the lee of the pass (Kauper, 1971 and Smith et al, 1983). This results from lee wave action induced by the flow through the pass. As indicated above, the top of the main aerosol layer over San Bernardino (21 PDT) was about 800 m-msl in contrast to the 1300 m top shown in the pass. This convergence through the pass results in an increase in the top of the layer in the pass and a marked downslope flow (divergence) in the lee of the pass.

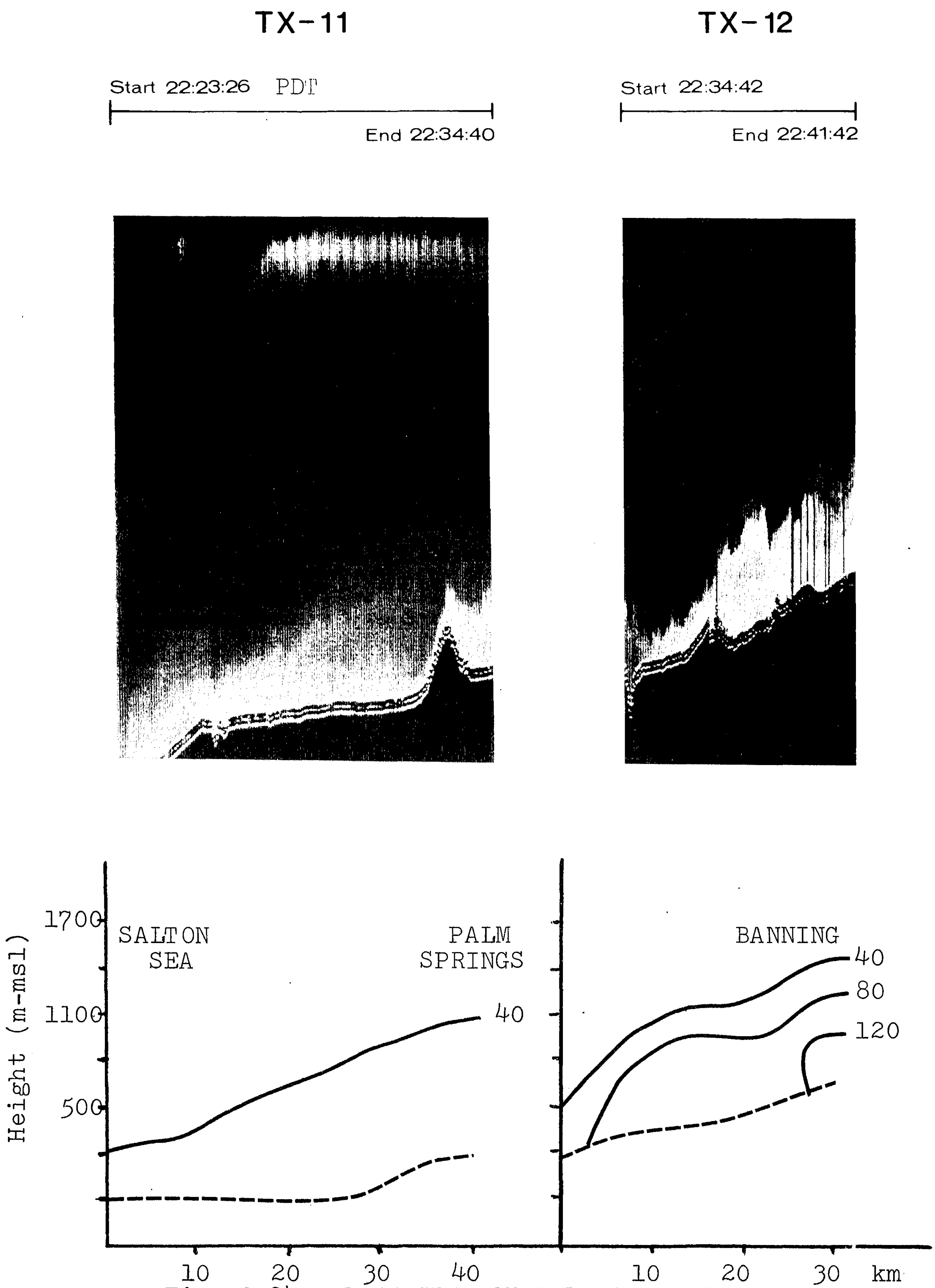


Fig. 3-24 CROSS SECTION THROUGH COACHELLA VALLEY
July 27, 1981

July 30, 1981

A moderate low pressure trough aloft dominated the western part of the U.S. on July 30. Winds aloft over Southern California were from the southwest with the southern portion of the trough remaining offshore. A moderate thermal trough was present at the surface centered in southern Nevada and extending northwestward into northwestern California. Meteorological parameters of interest are shown in Table 3.7:

Table 3.7

Meteorological Parameters
July 30, 1981

850 mb Temperature (UCLA)	21.1° C
Pressure Gradients (08 PDT)	
LAX-Daggett	4.3 mb
LAX-Bakersfield	3.4
Maximum Surface Temperatures	
Ontario	91° F
Palm Springs	106
Mixing Heights	
UCLA (12 PDT)	758 m-msl (608 m-agl)
Ontario (1430 PDT)	930 m-msl (640 m-agl)

The temperature at 850 mb was near average for July but pressure gradients to the inland areas were relatively large. Visibilities at Ontario Airport were restricted to 1-3 miles throughout the day until 22 PDT. This helped to keep the maximum temperature down to only 91° F. Mixing heights were relatively high along the coast but similar to the other sampling days inland. Maximum hourly ozone concentrations in the South Coast Air Basin on July 30 were reported as 27 and 26 pphm at Mt. Wilson and Fontana, respectively.

The flight path of the lidar aircraft on July 30 was similar to that flown on July 27. This covered the area of central Los Angeles, Orange County and the Coachella Valley in two separate flights, about 4 1/2 hours apart.

Fig. 3-25 is a cross section from San Bernardino to downtown Los Angeles between 1547 and 1607 PDT. Top of the aerosol layer in the basin was relatively flat at about 1100 m-msl. Reference to Table 3.7 indicates that the top

TX-3

Start 15:47:39 PDT

End 16:07:11

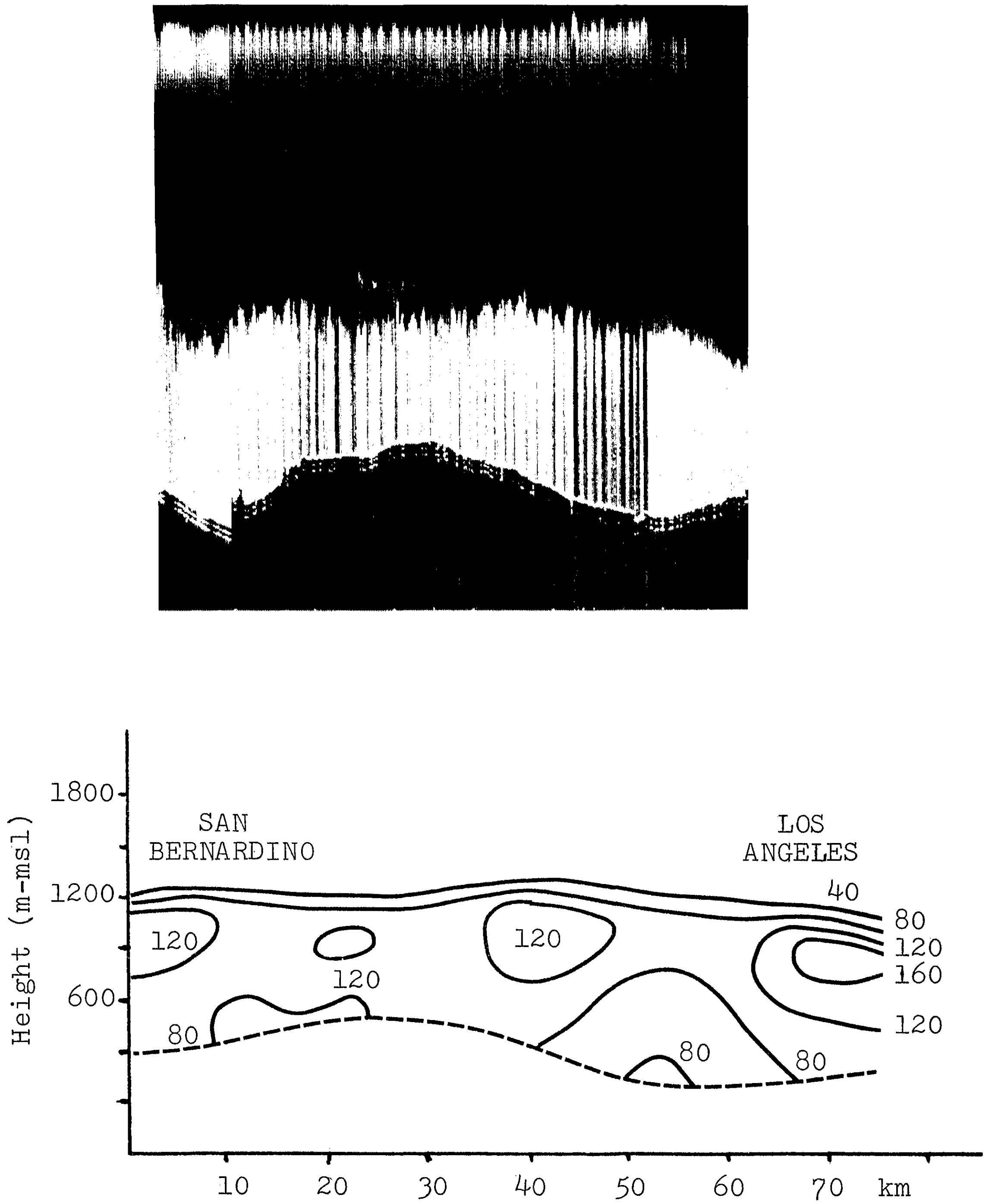


Fig. 3-25 CROSS SECTION IN SOUTH COAST AIR BASIN

July 30,1981

of this layer was in the inversion itself. In Fig. 3-25 the contours indicate an aerosol layer aloft with reduced concentrations near the surface. An air quality aircraft sounding at Redlands at 1626 PDT showed a well-mixed pollutant layer with a top at about 1300 m-msl. With visibility of 3 miles at Ontario at flight time it appears that attenuation by the heavy aerosol layer served to reduce the return from the lower layers.

Fig. 3-26 shows a cross section from Temecula to Corona between 1632 and 1642 PDT. Aerosol concentrations increase markedly along the route toward Corona. This boundary appears to represent the southern boundary of the Elsinore Convergence Zone. A layer aloft extends to the south from the surface location of the zone. The top of the aerosol layer near Corona was 1700 m-msl with the layer aloft to 2100 m-msl extending to the south.

The aircraft then flew from Corona to Hemet (Fig. 3-27) between 1642 and 1653 PDT. The convergence zone appears in the middle of the flight path and is about 15 km wide. Top of the layer in the vicinity of the zone was also 1700 m-msl. A somewhat higher layer extended to the southeast of Hemet.

The Elsinore Convergence Zone is formed by the convergence of air moving southeastward from Riverside County and air moving northeastward through southern Orange County. Streamlines for 16 PDT on July 30 are shown in Fig. 3-28.

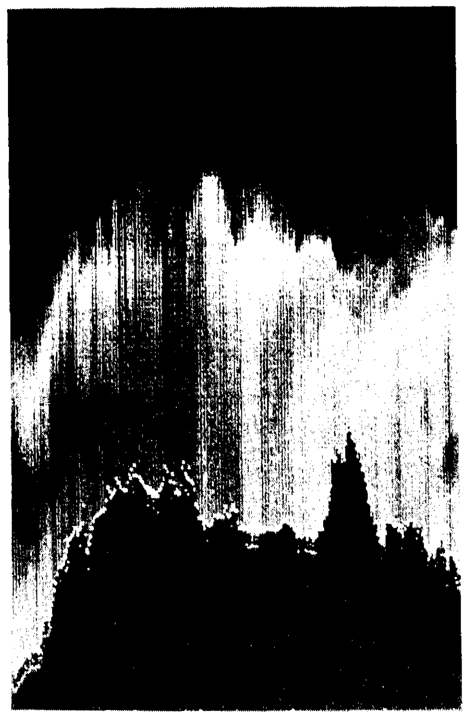
Fig. 3-29 shows the structure of aerosol layers from Palm Springs through San Gorgonio Pass between 1718 and 1739 PDT. Top of the aerosol layer in the pass is about 2000 m-msl while an earlier flight (Fig. 3-25) over the Los Angeles basin indicated a top of 1100 m-msl. Convergence in the pass is again accompanied by downslope flow to the east of the pass with rapidly decreasing layer tops. This downslope flow continued into Palm Springs, reaching there at 18 PDT. An air quality aircraft sounding was made at the intersection of highways I-10/111 at 1818 PDT. This sounding is shown in Fig. 3-30. An ozone layer with a top of 1200 m-msl is indicated at a location about 5 km downwind of the pass.

Fig. 3-29 suggests that an elevated aerosol layer

TX-6

Start 16:32:01 PDT

End 16:42:39



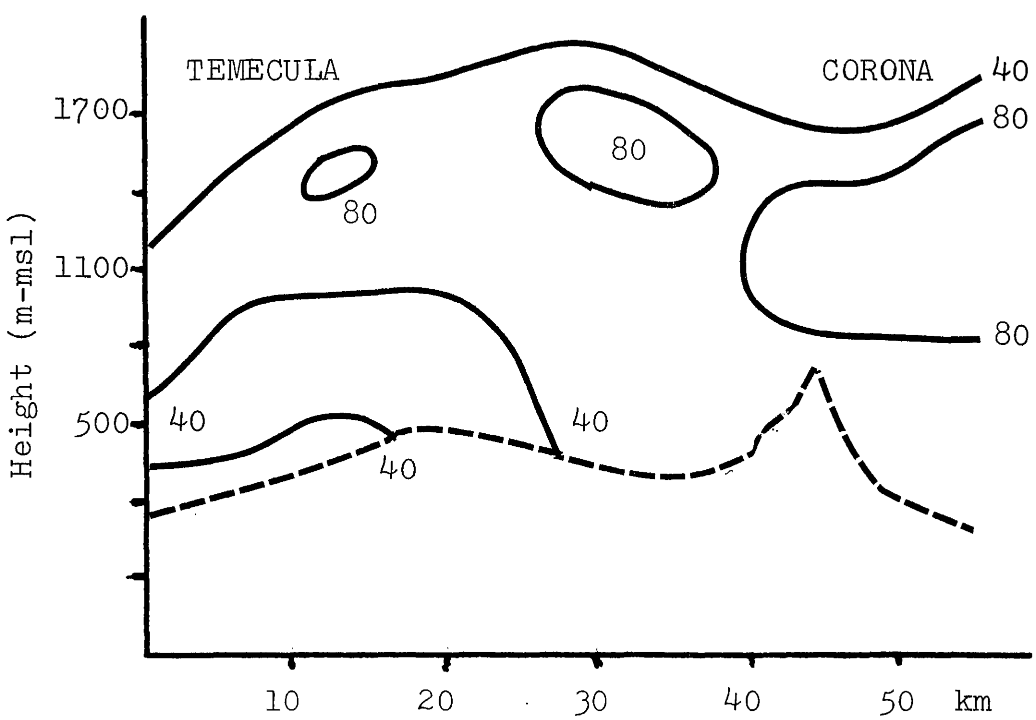


Fig. 3-26 CROSS SECTION FROM TEMECULA TO CORONA

July 30, 1981

TX-7

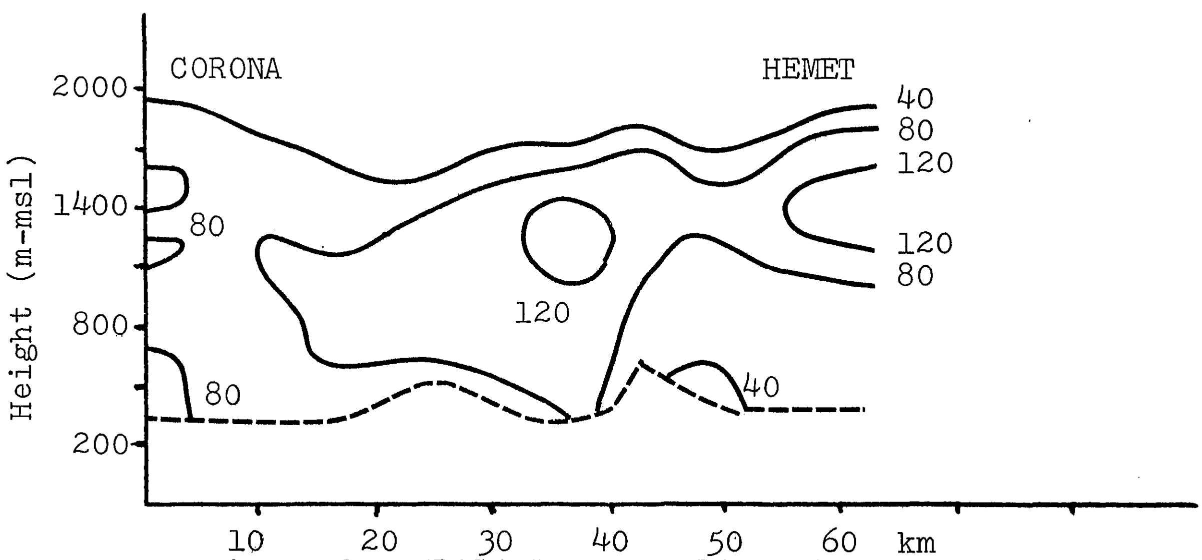


Fig. 3-27 CROSS SECTION FROM CORONA TO HEMET

July 30, 1981

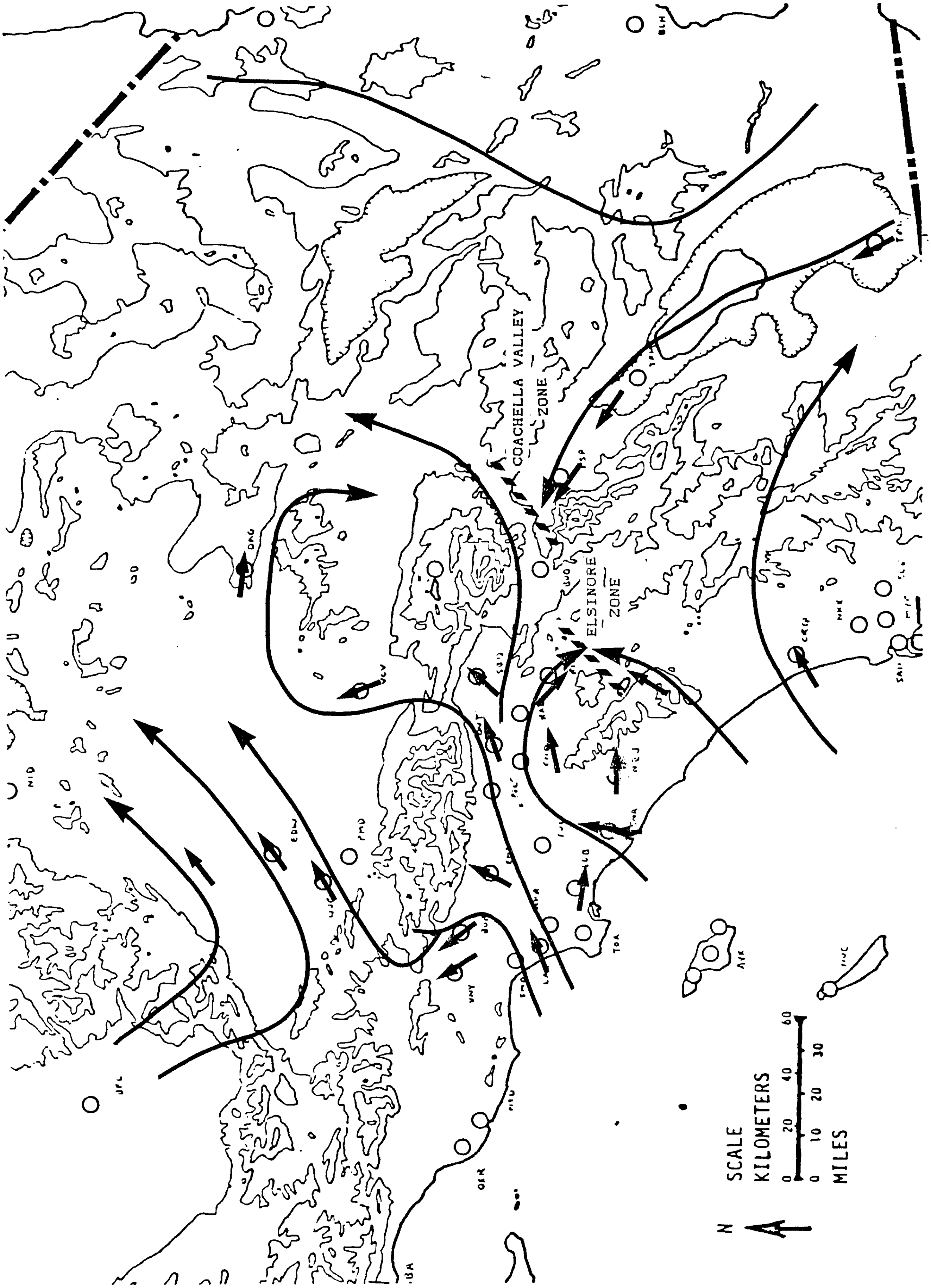


Fig. 3-28 STREAMLINE MAP - July 30,1981 (16 PDT)

TX-11

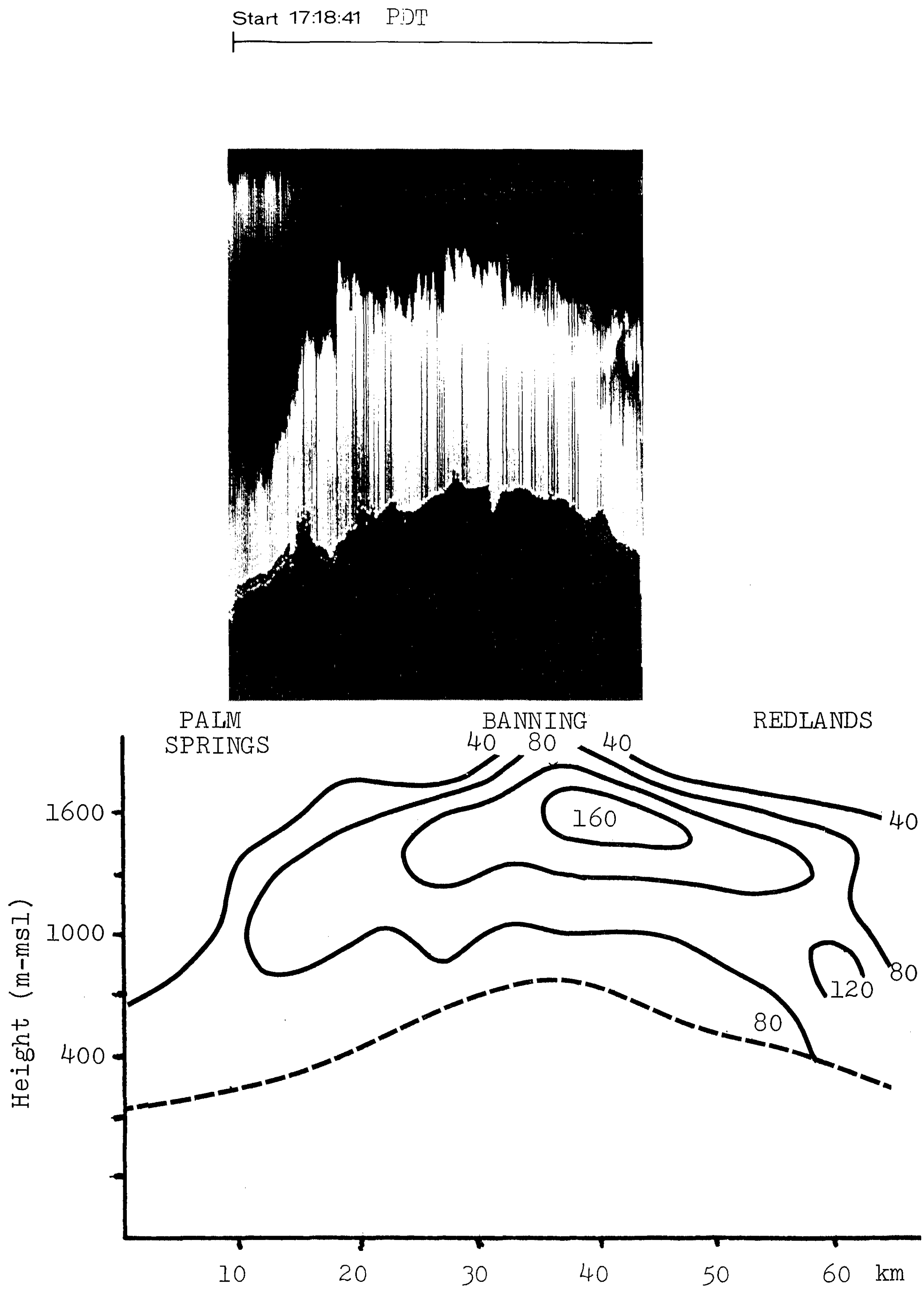


Fig. 3-29 CROSS SECTION THROUGH SAN GORGONIO PASS
July 30, 1981

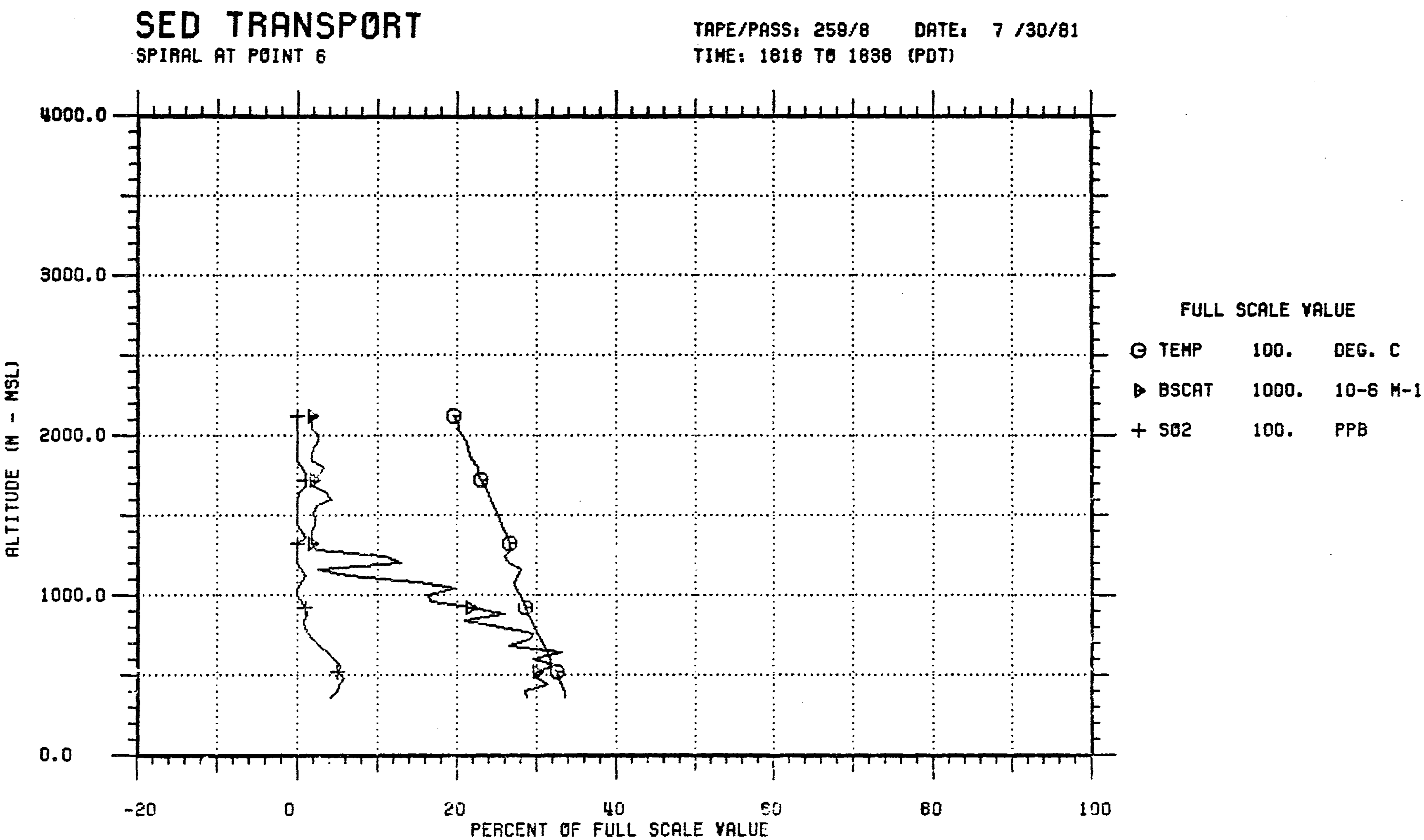


Fig. 3-30 AIRCRAFT SOUNDING AT INTERSECTION I-10/111
July 30,1981

800925.1
21:51:23

existed at an elevation of 1000 m over the terrain in the pass. Since the visibiliby at Beaumont at the time of the flight was reported as 3 miles it is probable that attenuation of the lidar signal contributed to this apparent layer.

Fig. 3-31 is a cross section from Palm Springs through San Gorgonio Pass to downtown Los Angeles between 2014 and 2050 PDT at the beginning of the second flight on July 30. It unquestionably constitutes the most interesting single crossection obtained during the lidar flight program.

From an overall perspective, the cross section shows the following features, starting from left to right (Palm Springs to Los Angeles):

1) Penetration of the marine aerosol layer into the Palm Springs area and a convective break up of the layer which increases the vertical depth markedly.

2) Downslope flow in the lee of the pass leading to dramatically lower layer tops than are present in the pass.

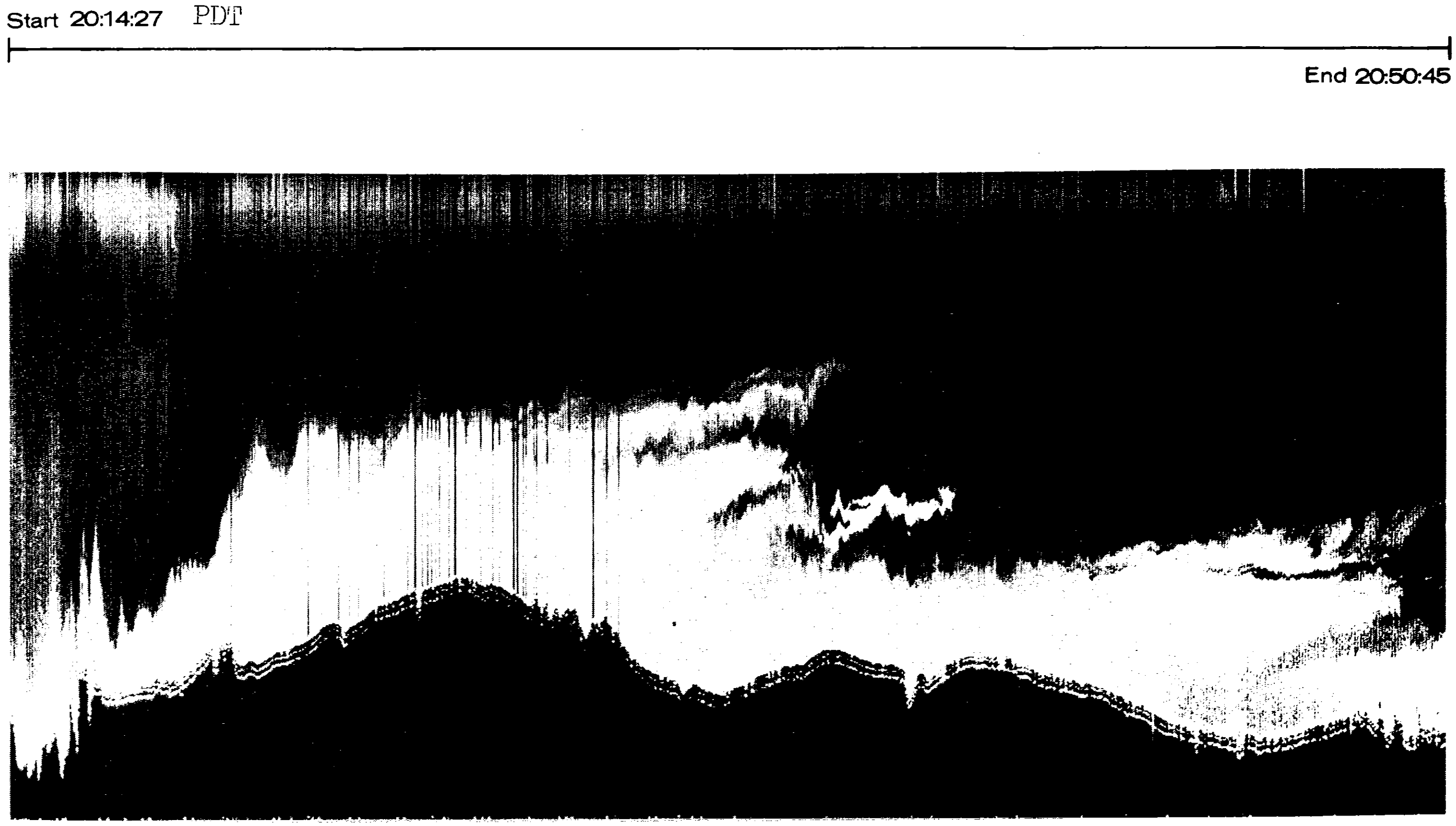
3) Convergence in the pass which lofts the aerosol layer to a top of 1500 m-msl within the pass.

4) In the horizontal, peak aerosol concentrations occurred over the summit of the pass at about 16 PDT (Fig. 3-25). By 20 PDT in Fig. 3-31 the maximum had shifted to the eastern slopes of the pass. The peak ozone concentrations at Palm Springs on July 30 (16 pphm) occurred at 19 and 20 PDT.

5) Incipient layers forming upwind of the pass which represent aerosol concentrations carried upward into the stable layer where the wind velocities are not as strong. They consequently have the appearance of being carried westward relative to the lower, mixed layer. At Redlands (2036 PDT) the upper winds at 1400-1600 m-msl were 1-2 m/s compared to 6-7 m/s in the mixed layer.

6) A relatively flat layer in the middle of the flight leg with a top of 900 m-msl. This is somewhat lower than the previous measurements at about 16 PDT (Fig. 3-25). The top in Fig. 3-31 more nearly corresponds to the

TX-1



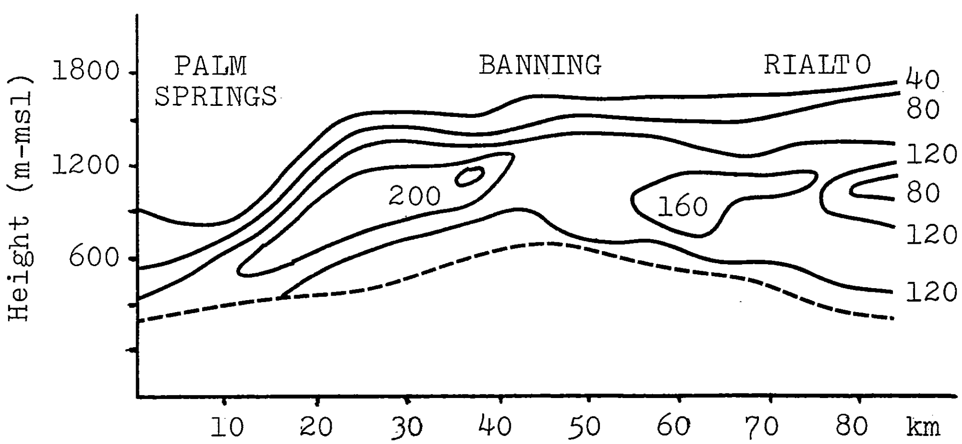


Fig. 3-31a CROSS SECTION THROUGH SAN GORGONIO PASS

July 30, 1981

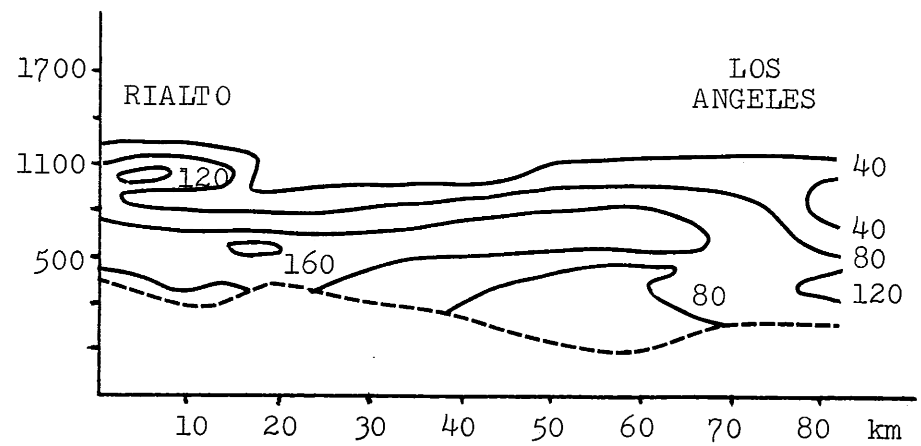


Fig. 3-31b CROSS SECTION IN SOUTH COAST AIR BASIN

July 30, 1981

height of the inversion base.

7) Over downtown Los Angeles there is evidence of an undercutting layer with two elevated layers aloft. The top of the highest layer is at 1200 m-msl which corresponds to the top measured several hours earlier in Fig. 3-25.

Fig. 3-32 is a cross section from Temecula to Corona between 2149 and 2159 PDT. The flight path is similar to that shown in Fig. 3-26 (1632 PDT). The surface features of the Elsinore Convergence Zone have largely broken up and most of the aerosol concentrations are in the layer aloft. It is presumed that this is the normal diurnal history of the zone. Top of the layer is now about 1600 m-msl which is similar to or slightly lower than previously obsrved in the area.

Fig. 3-33 was obtained on a flight from Corona to Hemet (2159-2209 PDT). In this area high concentrations remained near the surface but most of the aerosol seemed to be in an elevated layer with a top of 1500 m-msl. This layer aloft drifted toward the southeast.

A final transect was made through San Gorgonio Pass (2234-2248 PDT) from Palm Springs to Redlands (Fig. 3-34). The general structural features remain the same but the top of the main aerosol layer had been reduced to 1300 m-msl with higher layers to 1700 m-msl. The downslope flow on the east slopes continued but with less significant vertical mixing in the Palm Springs area.

July 31, 1981

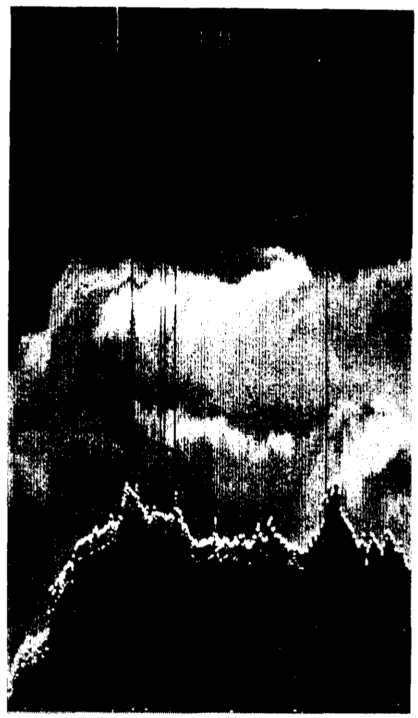
The trough aloft which had been present on July 30 continued to influence the Southern California area. The 850 mb temperature cooled slightly but the 08 PDT onshore pressure gradients also decreased slightly. Afternoon mixing heights were similar to those observed on July 30. Peak ozone concentrations of 29 and 28 pphm occurred at San Bernardino and Fontana, respectively.

Meteorological parameters of interest on July 31 are as follows:

TX-9

Start 21:49:53

End 21:59:25



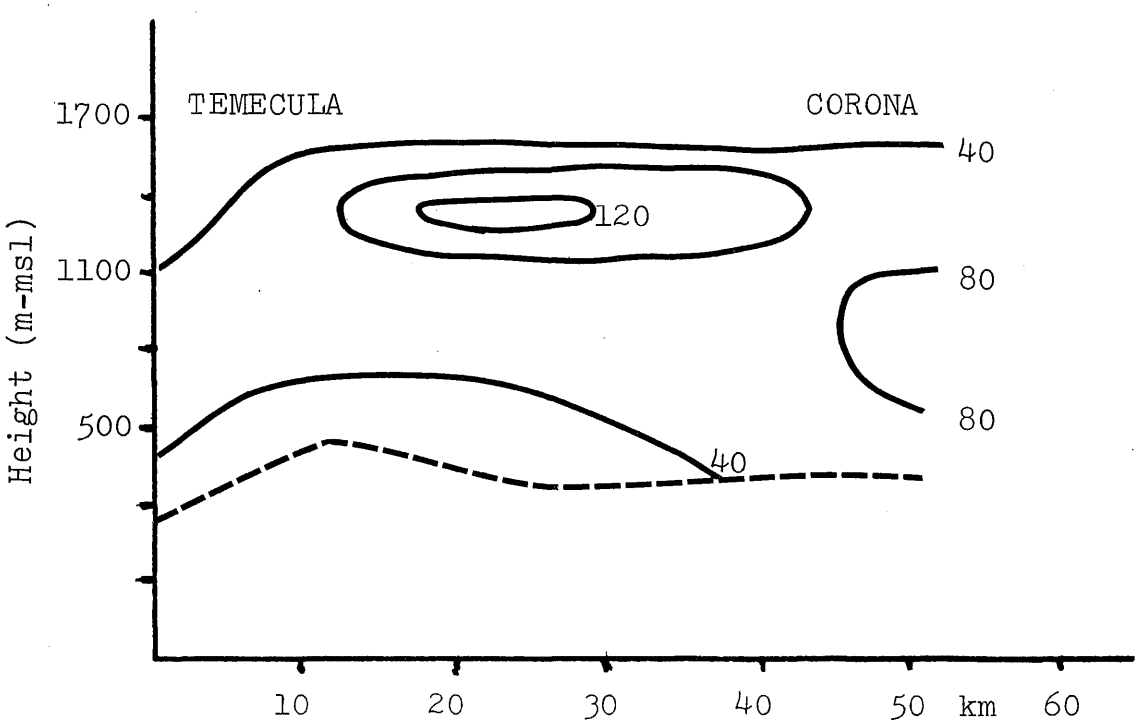


Fig. 3-32 CROSS SECTION FROM TEMECULA TO CORONA

July 30, 1981

TX-10

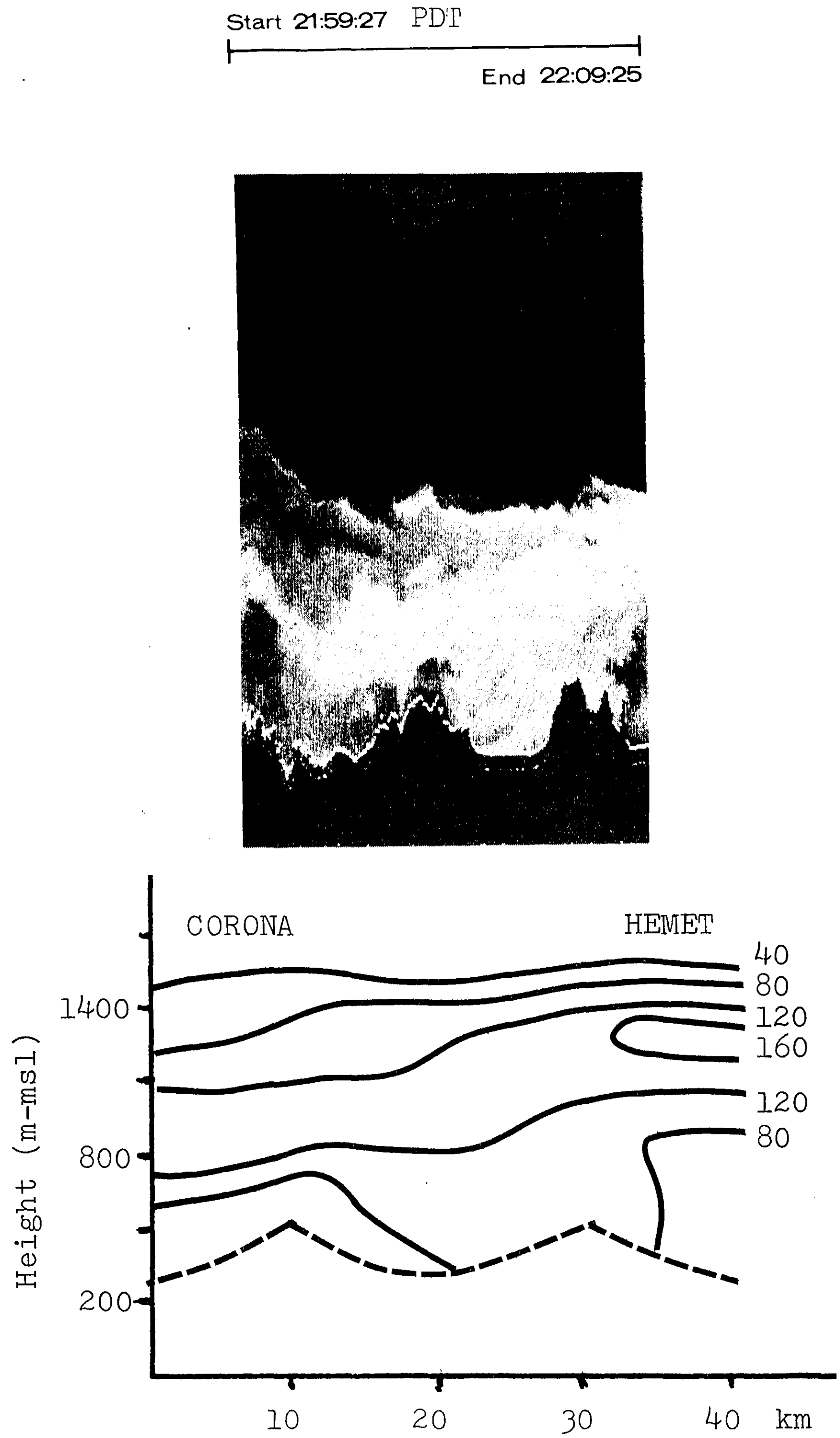
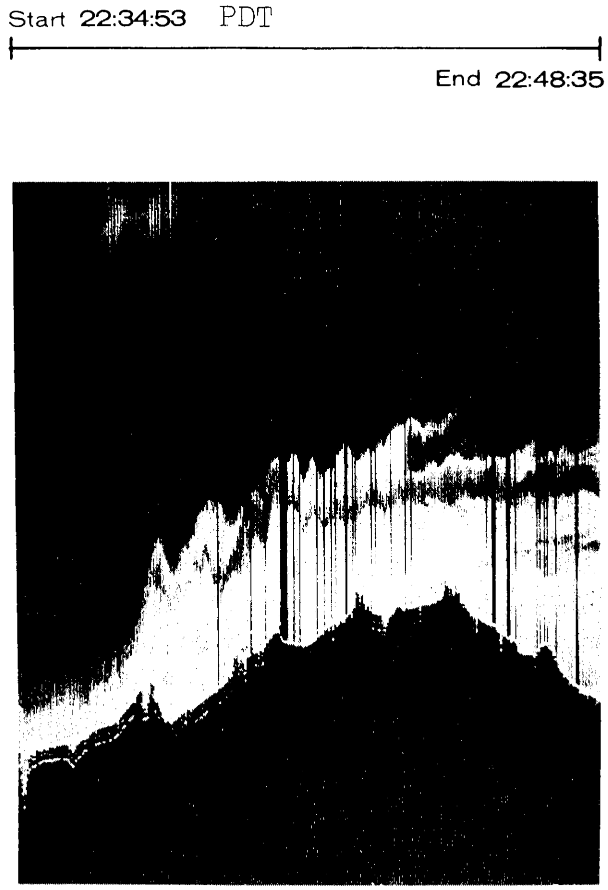


Fig. 3-33 CROSS SECTION FROM CORONA TO HEMET

July 30, 1981

TX-14



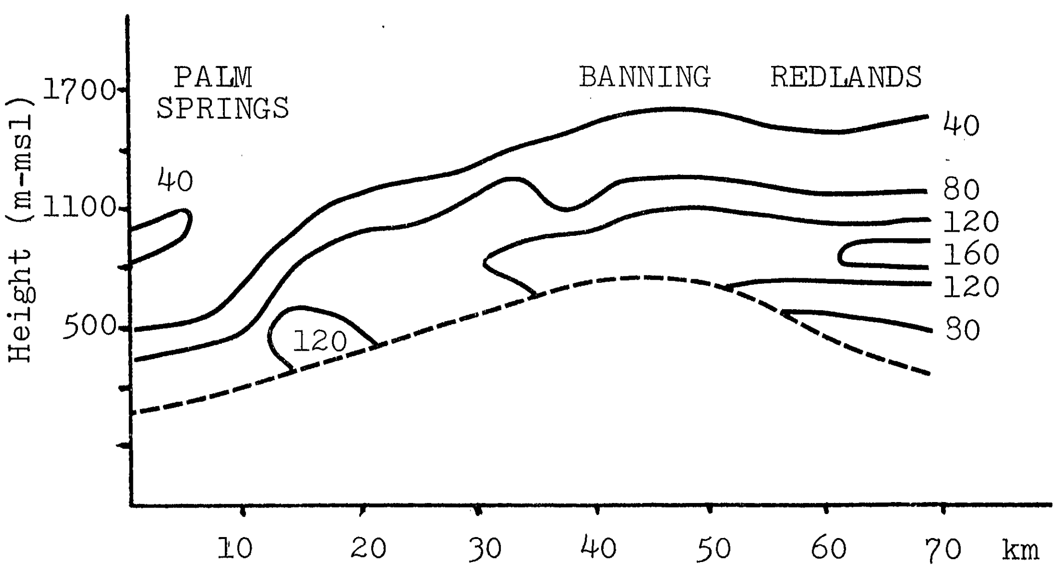


Fig. 3-34 CROSS SECTION THROUGH SAN GORGONIO PASS

July 30, 1981

Table 3.8

Meteorological Parameters
July 31, 1981

850 mb Temperature (UCLA)	20.2^{o} C
Pressure Gradients (08 PDT)	
LAX-Daggett	3.7 mb
LAX-Bakersfield	1.9
Maximum Surface Temperatures	
Ontario	92^{o} F
Palm Springs	109
Mixing Heights	
UCLA (12 PDT)	669 m-msl (419 m-agl)
Ontario (1430 PDT)	950 m-msl (660 m-ag;)

The July 31 flight followed a morning flight pattern from Palm Springs through the Southeast Desert Air Basin back to Las Vegas. It is notable particularly for information on the structure of the desert aerosol layer left over from the previous day's transport into the Basin. For this particular flight the power setting of the system was increased and the aperture opened to provide more sensitivity. This provided much more aerosol information in the desert than was obtained when both desert and South Coast Air Basin sampling was to be accomplished with one sensitivity setting.

Fig. 3-35 represents a cross section from Thermal to Ocotillo (west of El Centro) between 0932 and 0955 PDT. The terrain peak in the figure is the edge of the Santa Rosa Mts. to the west of the Salton Sea. To the south of the Santa Rosa Mts. the height of the aerosol layer decreases markedly from 1300 m-msl to 800 m-msl. The aerosol concentrations were relatively homogeneous horizontally to the north of the Santa Rosa Mts. decreasing substantially near the southern end of the flight path at Ocotillo. The visibility at Thermal at flight time was 7 miles (5 miles at Palm Springs) so that the indicated aerosol concentrations are unusually high.

Although a substantial flow of pollution from the South Coast Basin was observed in the Coachella Valley during the evening of the 30th it does not seem likely that this initial incursion was sufficient to produce such low visibilities on the morning of the 31st. Visibilities at

TX-2

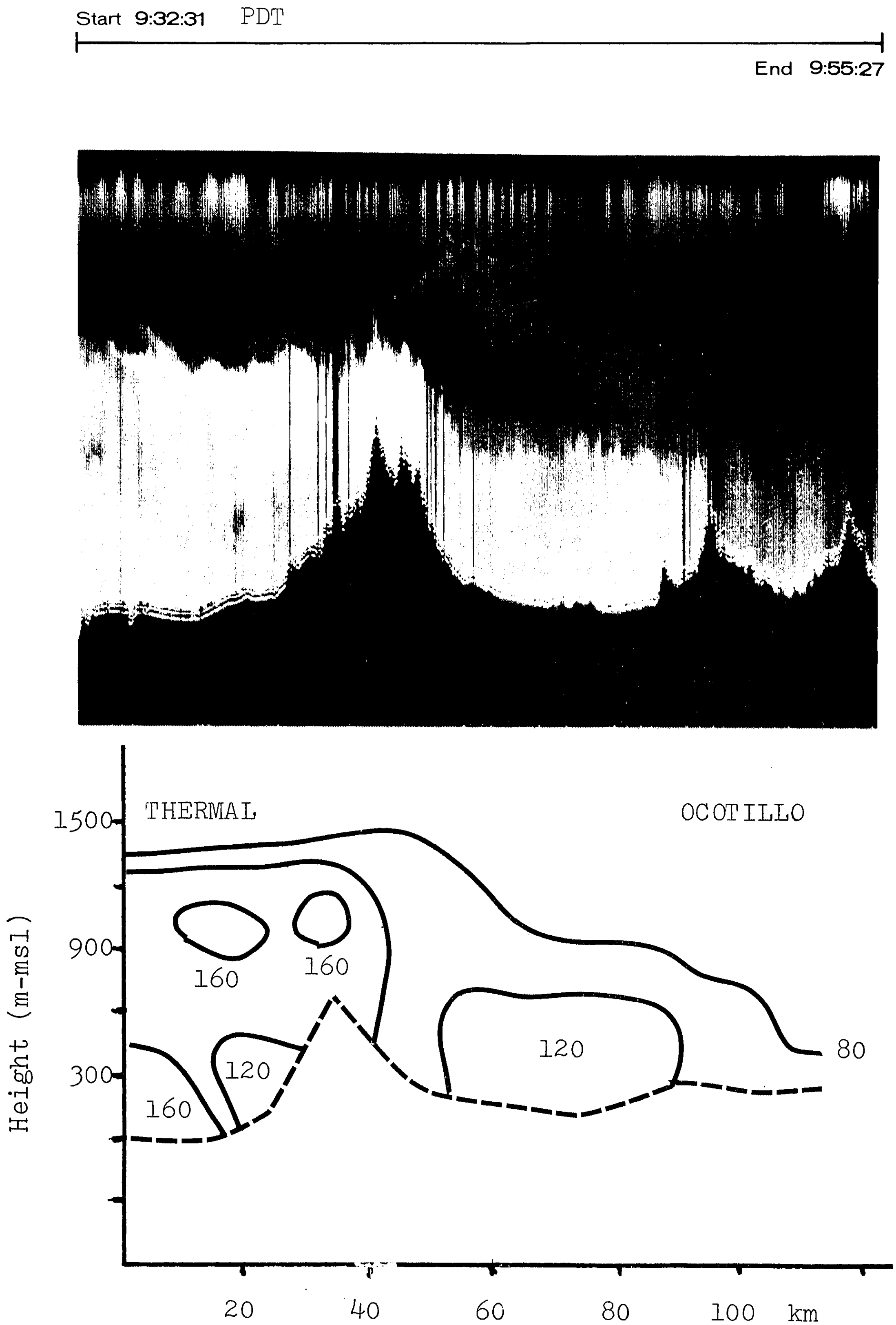


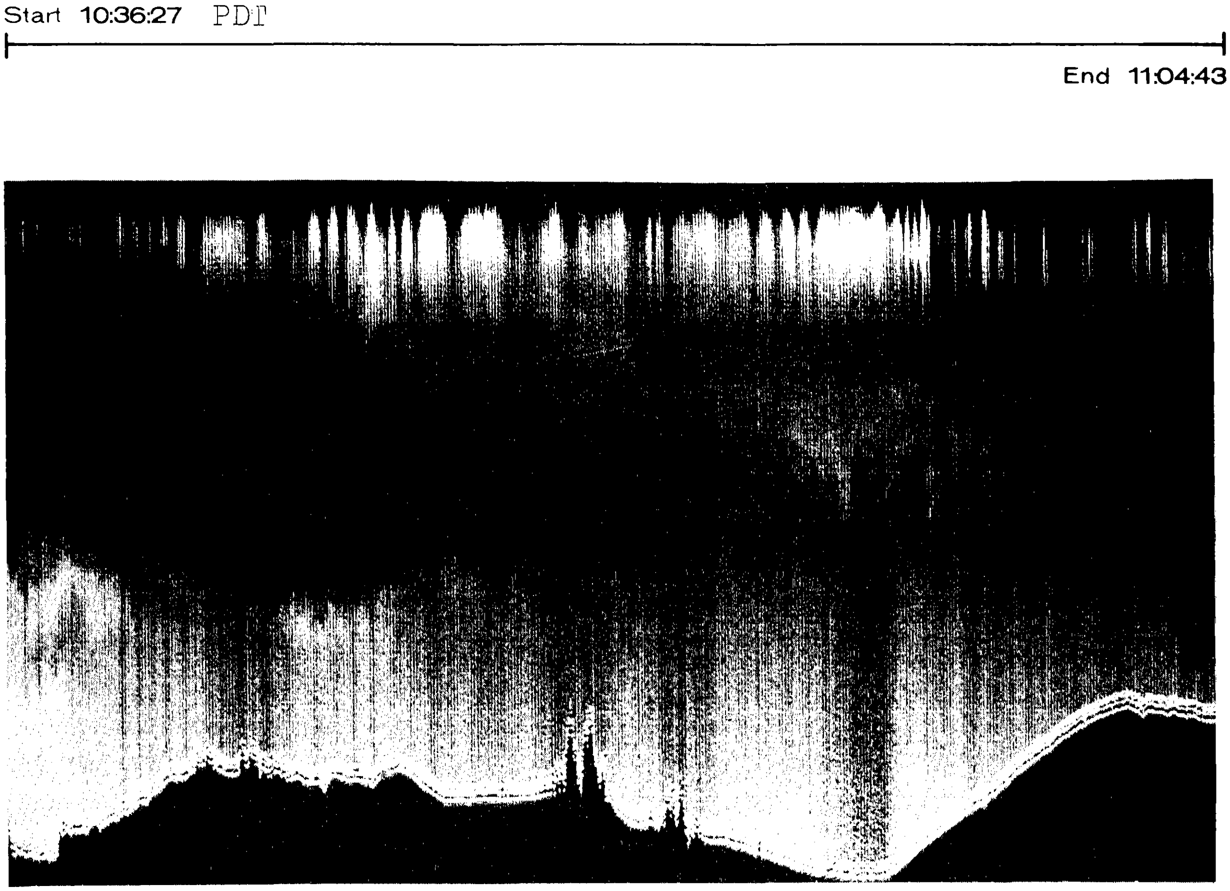
Fig. 3-35 CROSS SECTION THROUGH COACHELLA AND IMPERIAL VALLEYS

July 31, 1981

Palm Springs were 7 miles during the initial appearance of South Coast air, improving later in the evening. The visibility decreased to 5 miles again from 08 to 09 PDT on the 31st. It seems possible that high humidities in the Coachella Valley contributed to these lower visibilities. Dew points during the afternoon of the 30th were in the 70's and much of this moisture must have remained in the area during the night.

Fig. 3-36 is a cross section from Indio to Blythe from 1036 to 1104 PDT. An aerosol layer is indicated along the entire route with a top in the range of 1100 m-msl. Low-level concentrations were highest in the Coachella Valley, near the Chiriaco Summit at the eastern edge of the Valley, east of Desert Center and west of Blythe. Visibility at Blythe was reported as 40 miles at flight time. An elevated layer centered at 1900 m-msl was observed about 3/4 of the way along the flight track to Blythe.

TX-7



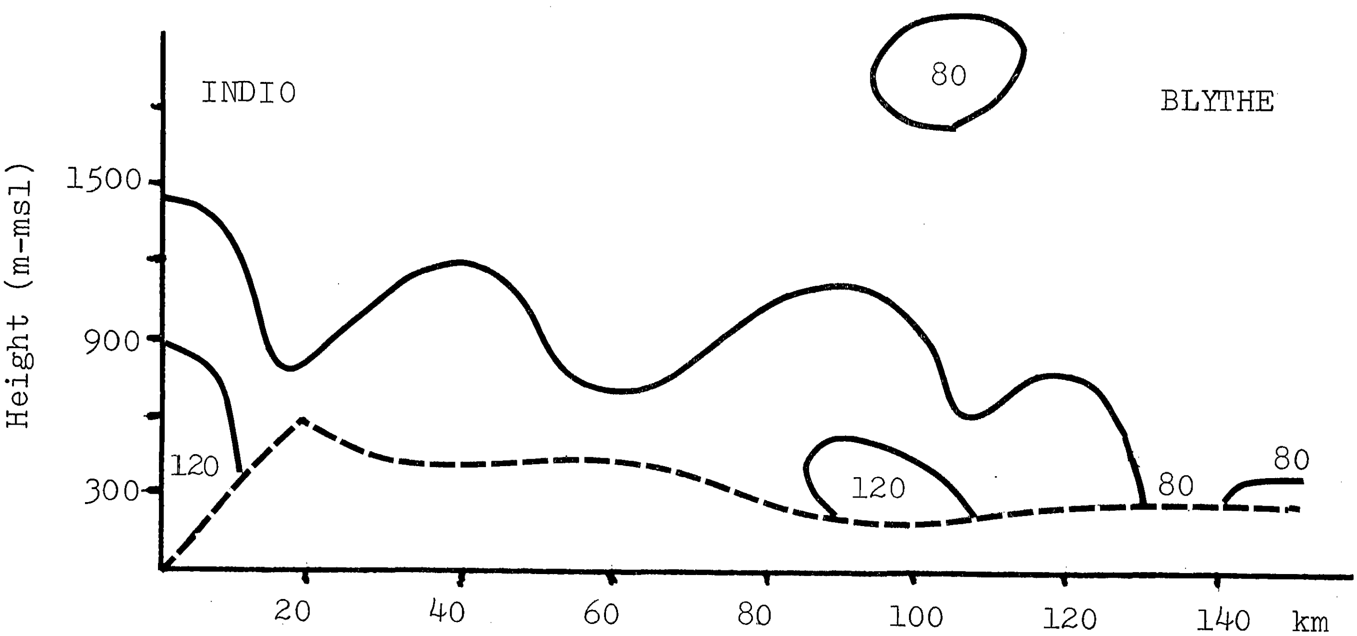


Fig. 3-36 CROSS SECTION FROM INDIO TO BLYTHE
July 31, 1981

4.0 ANALYSIS TOPICS

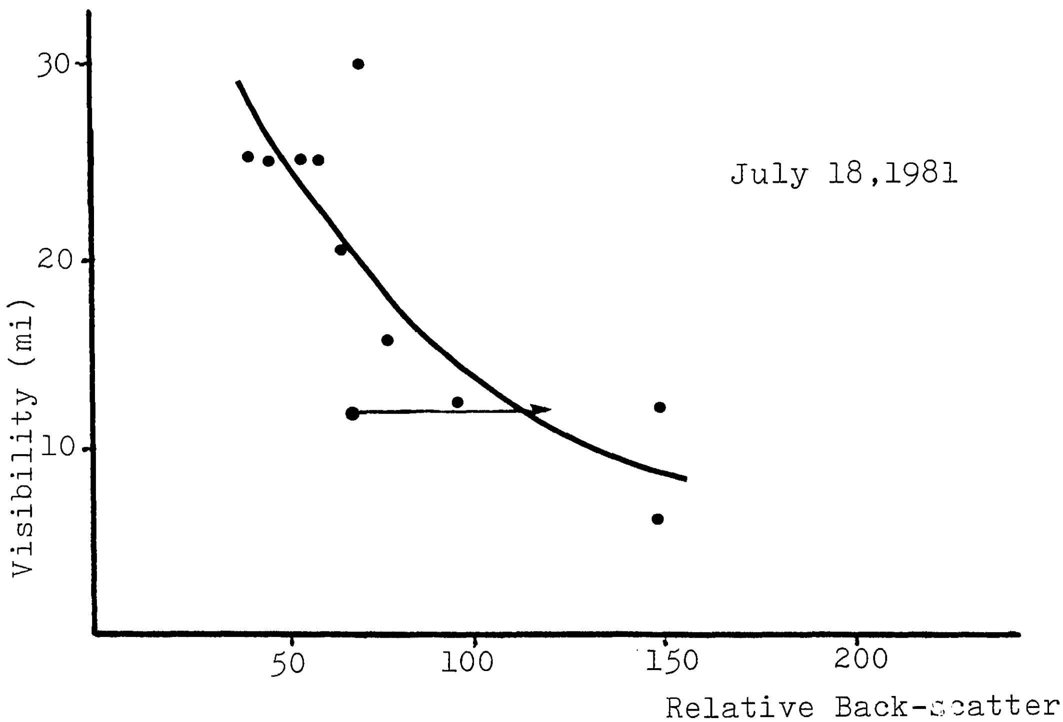
4.1 Comparison of Lidar Data and Observed Visibilities

Both the lidar return signal and the visibility should depend strongly on the mass of aerosol material present in the volume concerned. The lidar return should be a linear function of the aerosol mass, to a first degree, if similarities in particle size distribution and refractive index are assumed. The visibility is an inverse function of aerosol mass (Robinson, 1977) for a given particle size and composition. It is of interest, therefore, to compare lidar data and concurrent visibility data where available.

The lidar flight paths were examined for passages over or near airports where visibility at ground level was reported. In order to obtain a more reliable representation of lidar backscatter, six signal bins were averaged (3 km horizontally and 300 m vertically) in the surface layer to generate an average return which could be compared to the airport visibility. A total of 97 comparison points were obtained during the 10 day flight period. The quality of the data available for comparison varied. The operations of the lidar system improved considerably during the 10-day period, particularly with respect to noise. Locations of the lidar and visibility observations may have been separated by several miles. As noted in Section 3, attenuation of the lidar signal apparently occurs under heavy aerosol loading conditions. Finally, airport visibility reports, in themselves, are relatively imprecise observations, particularly in the high visibility range.

Average lidar return was plotted against concurrent visibility for each day, individually. Sensitivity levels for the lidar changed from day-to-day so that inter-day combinations of the data were not considered useful. There were insufficient comparative data available on July 14-15 to construct adequate comparisons. In addition, the lidar operating system inproved considerably after this date. Comparisons of visibility and relative backscatter for July 18, 19, 22, 23, 27 and 30 are shown in Figs. 4-1 to 4-3.

As expected, the relation between visibility and back-scatter reflects the inverse dependence of visibility



Arrows indicate possible
attenuation errors in lidar signal

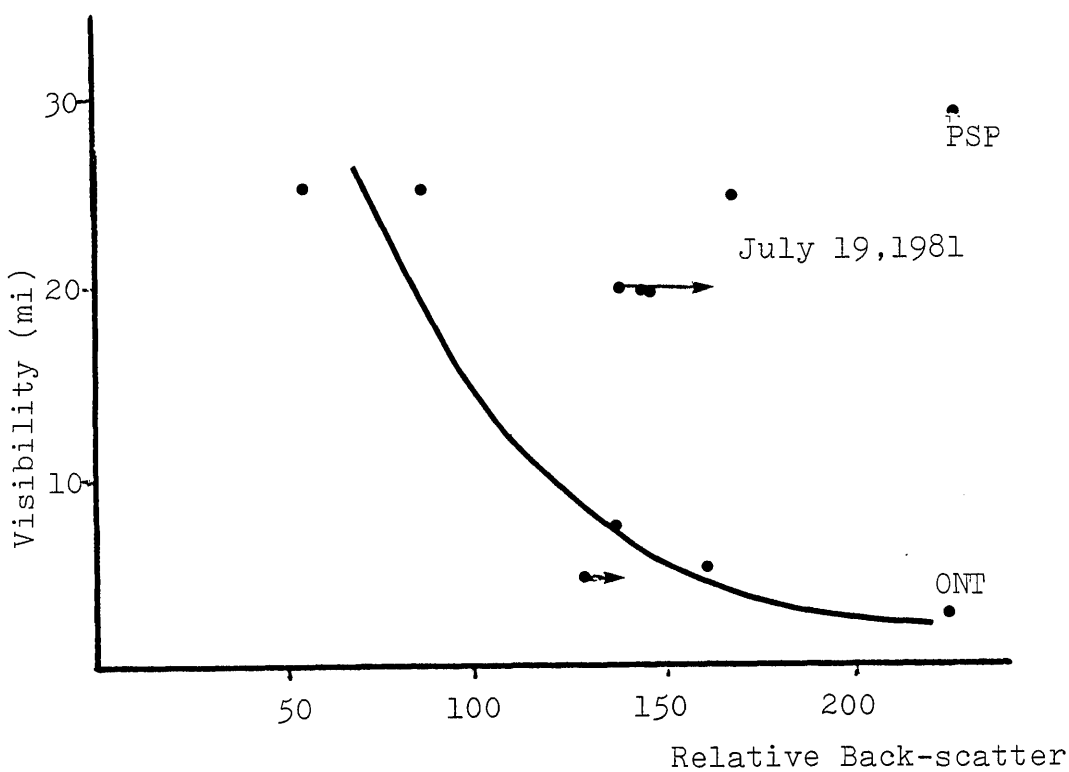
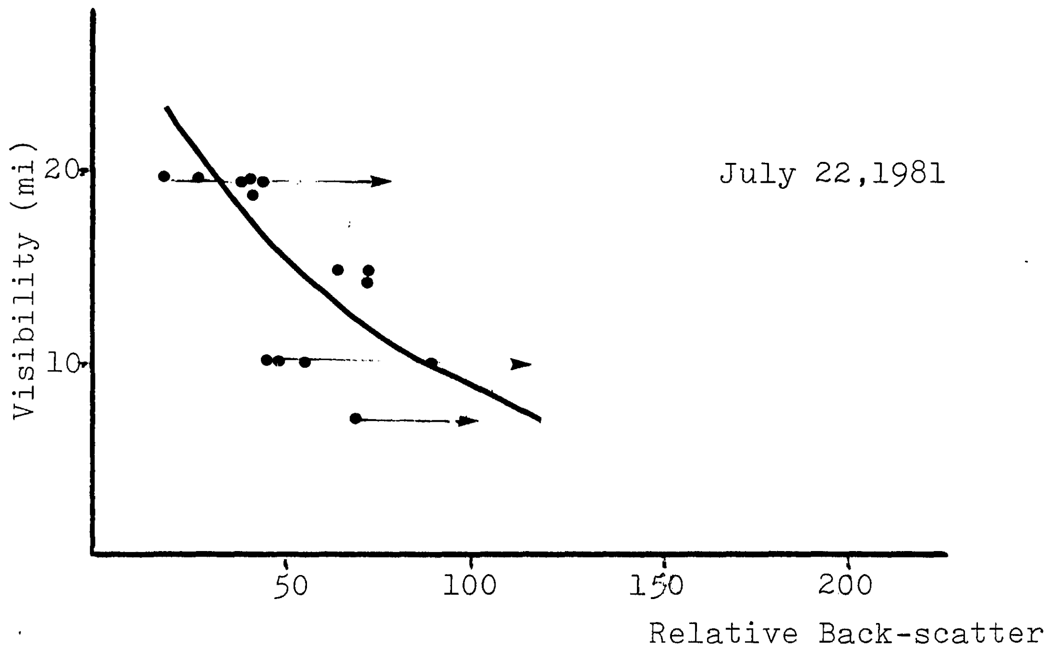


Fig. 4-1 COMPARISON OF VISIBILITIES AND BACK-SCATTER
July 18/19, 1981



Arrows indicate possible
attenuation errors in lidar signal

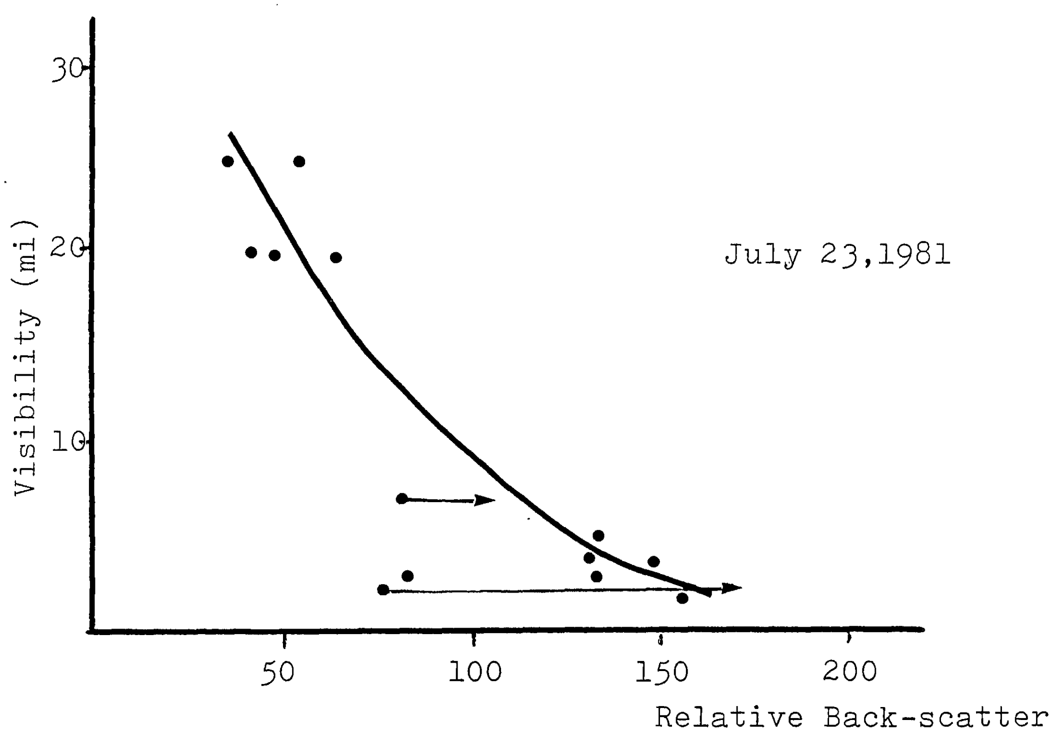
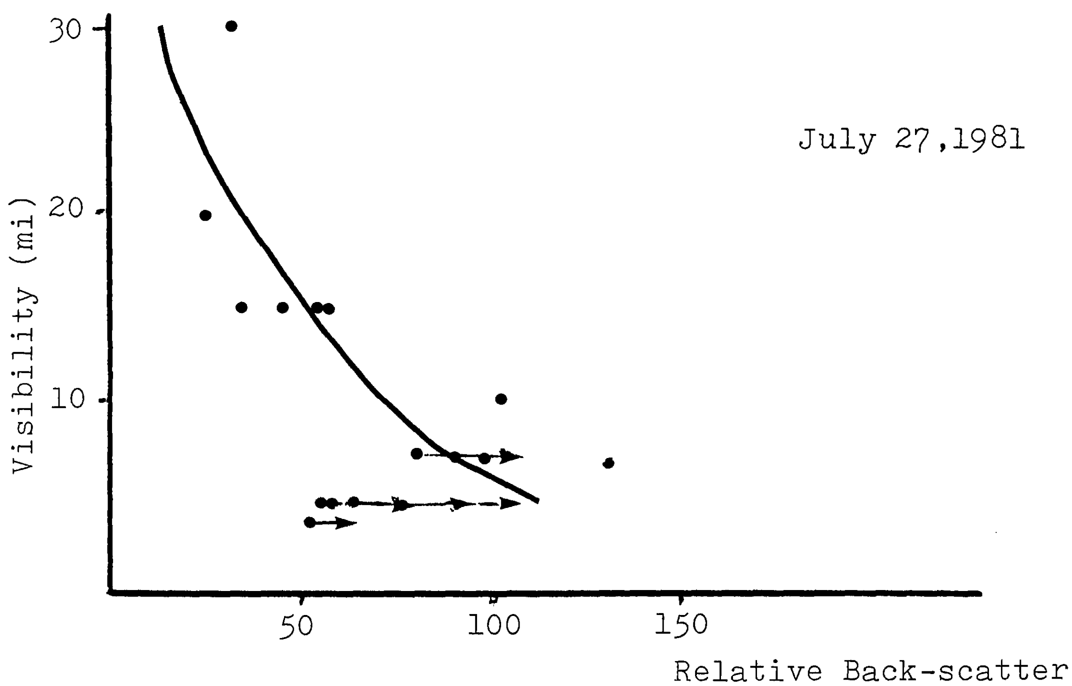


Fig. 4-2 COMPARISON OF VISIBILITIES AND BACK-SCATTER
July 22/23,1981



Arrow indicate possible
attenuation errors in lidar signal

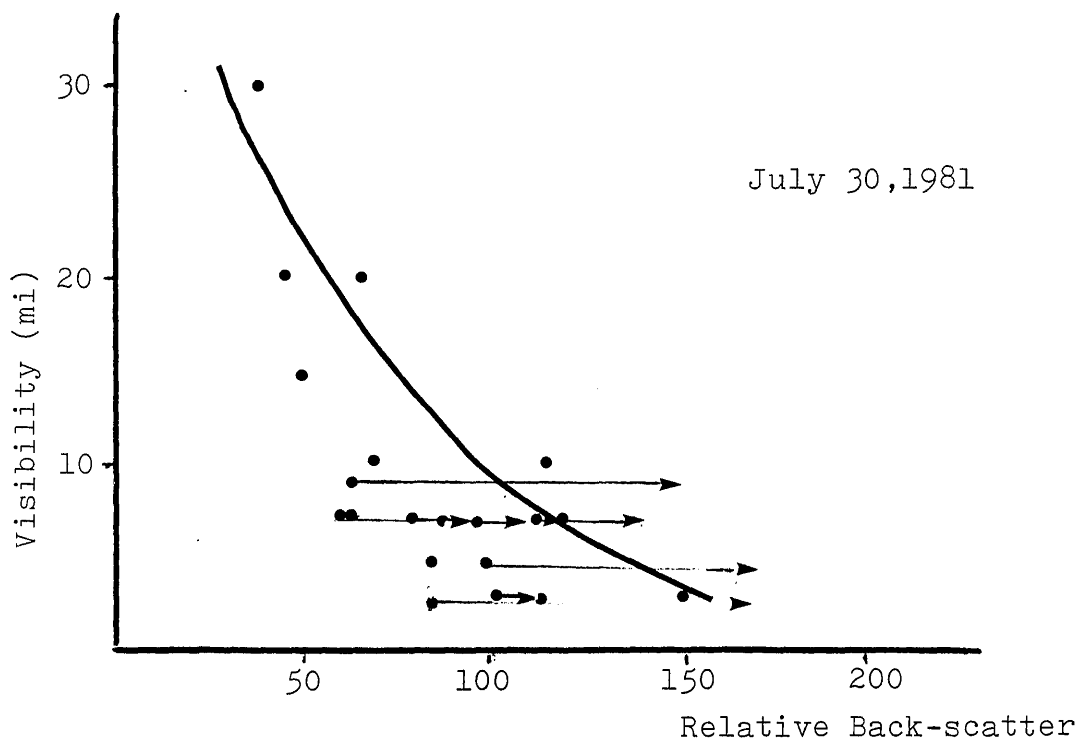


Fig. 4-3 COMPARISON OF VISIBILITIES AND BACK-SCATTER
July 27/30, 1981

on mass while the back-scatter is a direct function. The resultant is an inverse variation of visibility with average volume back-scatter. In all of the cases shown in the figures an increase in back-scatter was associated with a proportionate or slightly greater decrease in visibility. Strict proportionality implies a constant lidar operating system for the duration of the day's flight and consistent or similar aerosol size distributions for all samples. In general, the correlation between visibility and back-scatter, as shown in the figures, is as good as (or perhaps better than) might be expected.

There are several data points on July 18 and 19 which do not fit the relationship suggested by the balance of the data. These occurred at a variety of locations. Such points (to the right of the curve) imply visibilities or back-scatter which were too high for the other associated parameter. In the case of July 19 it is unlikely that reported desert visibilities could be as much in error as indicated by the discrepancies. It seems more likely that a lidar system error was responsible. Note that the lidar return at Ontario (0948 PDT) was about the same as indicated for Palm Springs (1103 PDT) while the difference in visibility was a factor of 10. It is of interest to note that this type of discrepancy did not occur later in the 10-day period when the lidar system operation had improved substantially.

An error to the left of the indicated relationship implies that the back-scatter was not as large as the corresponding visibility suggested. One possible reason for this may be attenuation due to aerosols above the surface layer. In order to check this possibility, the highest average back-scatter return immediately above the surface layer was calculated for those situations where an upper aerosol layer was indicated. The results of this are shown where appropriate in the figures as horizontal arrows with an adjusted datum location. In virtually all of the adjusted cases the agreement with the given relationship was improved. It is concluded that the primary cause of discrepancies to the left of the indicated relationship is attenuation at levels above the surface layer.

The indicated lidar back-scatter/visibility relations are slightly different from one day to the next. In addition to the statistical variability of the data, the system operation was not the same each day (in terms of power and aperture setting) and there may have been significant day-to-day differences in aerosol size distribution.

4.2 Comparison of Lidar with Aircraft Soundings

On a number of days an air quality aircraft sounding was made at about the time and location of one of the lidar aircraft overflights. This provided a means of comparing a vertical spiral sounding with the profile provided by the lidar system. There were 18 such soundings where the two aircraft locations were within 20 km and the time difference between observations was less than one hour. Eight of these soundings with corresponding lidar profiles are given in Figs. 4-4 through 4-11.

Comparisons should be made between b_{scat} as an in situ measurement by a nephelometer with the remote-sensing back-scatter data observed by the lidar. The lidar data were averaged into bins of 150-m depth for use in the present report. There is, therefore, considerably more detail in the air quality aircraft soundings.

In general, the agreement between the nephelometer and the lidar data is quite satisfactory. Quantitative comparisons are not possible due to changes in the lidar system operation. Aerosol layers, however, show good agreement as to altitude and the general trends in the two curves are quite similar. Principal differences seem to result from averaging the lidar data over a 150m deep layer and, possibly, from differences in precise locations where the two observations were made.

4.3 Slope Effects

The best examples of upslope motion of pollutants are reproduced in Figs. 4-12 and 4-13. Temperature profiles are included from nearby stations where appropriate. For July 19 there was no temperature sounding near the time or location of the lidar aircraft path. The contours in the figures were constructed from bin-averaged back-scatter data with a resolution of one km along the flight path and 150 m vertical depth.

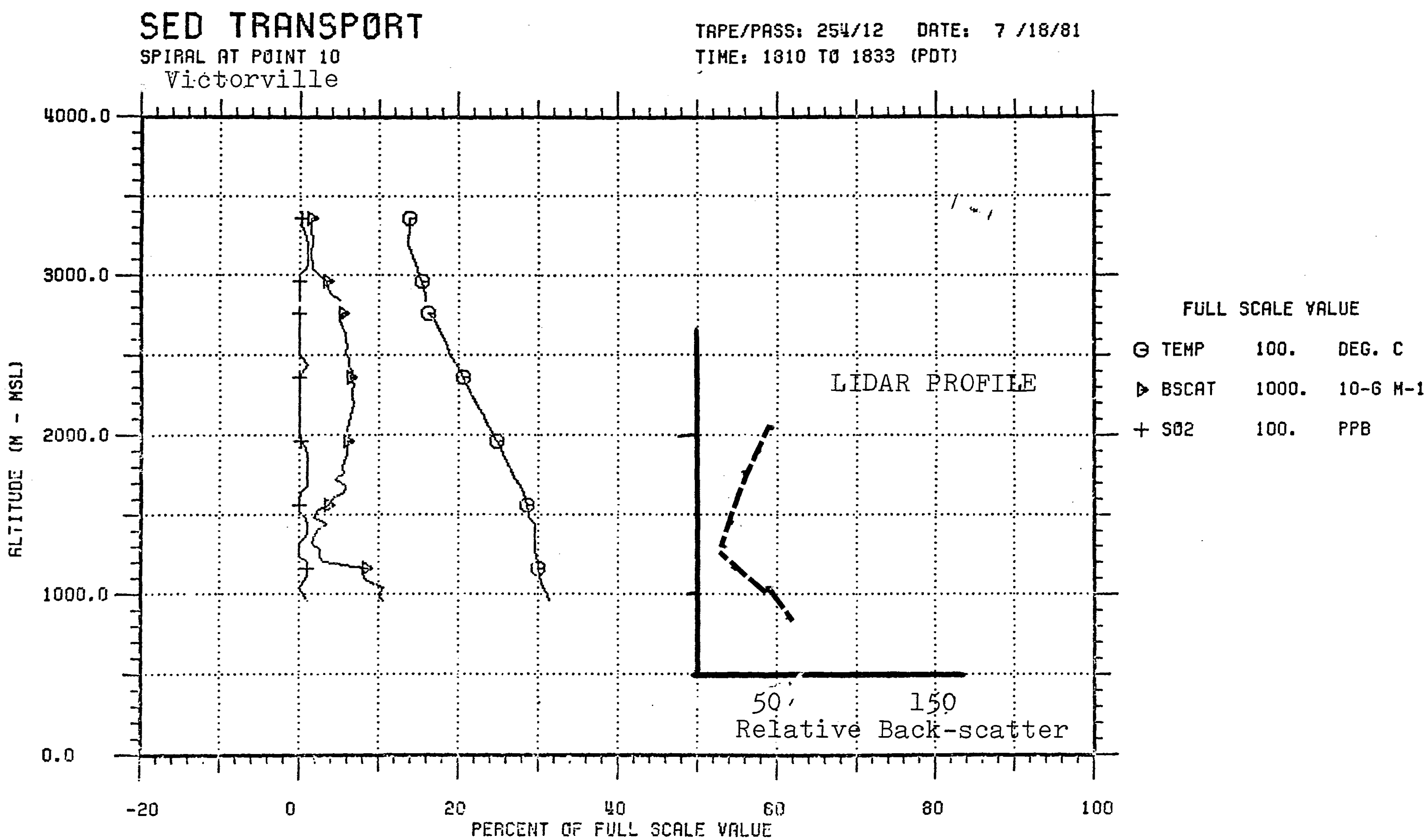


Fig. 4-4 · COMPARISON OF AIR QUALITY AND LIDAR PROFILES
July 18, 1981

811001.1
06:48:06

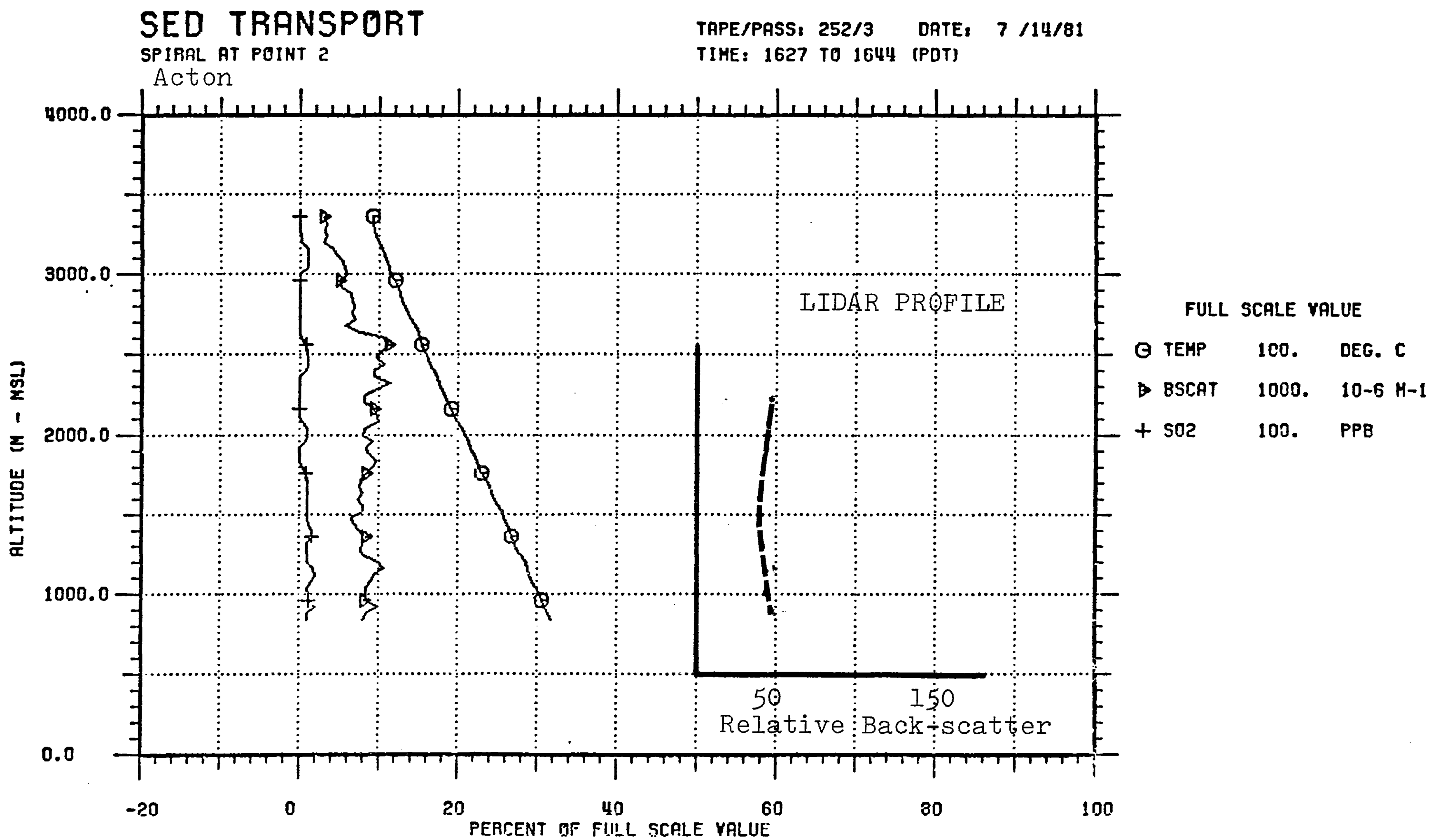


Fig. 4-5 COMPARISON OF AIR QUALITY AND LIDAR PROFILES
July 14,1981

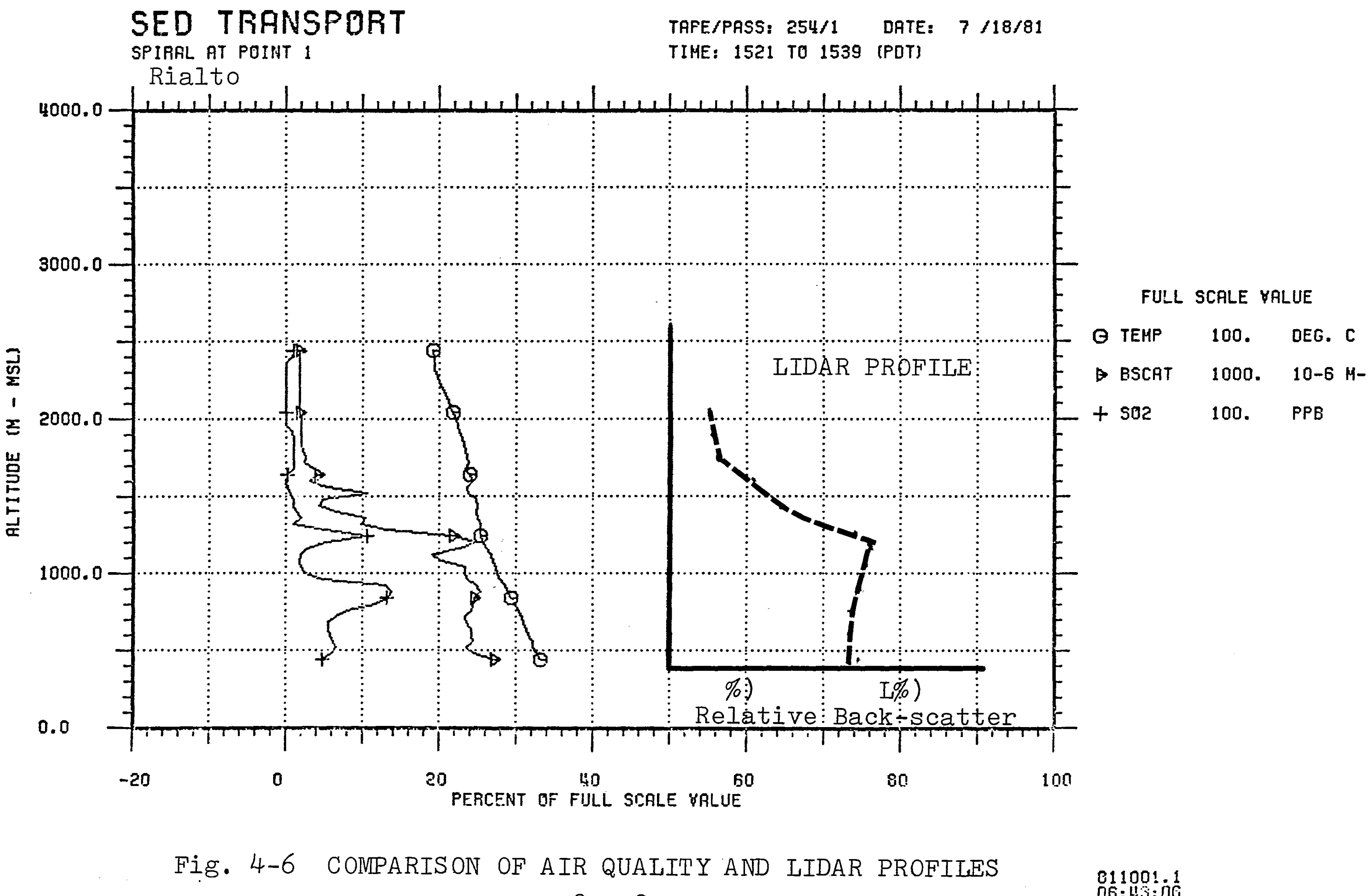


Fig. 4-6 COMPARISON OF AIR QUALITY AND LIDAR PROFILES
July 18,1981

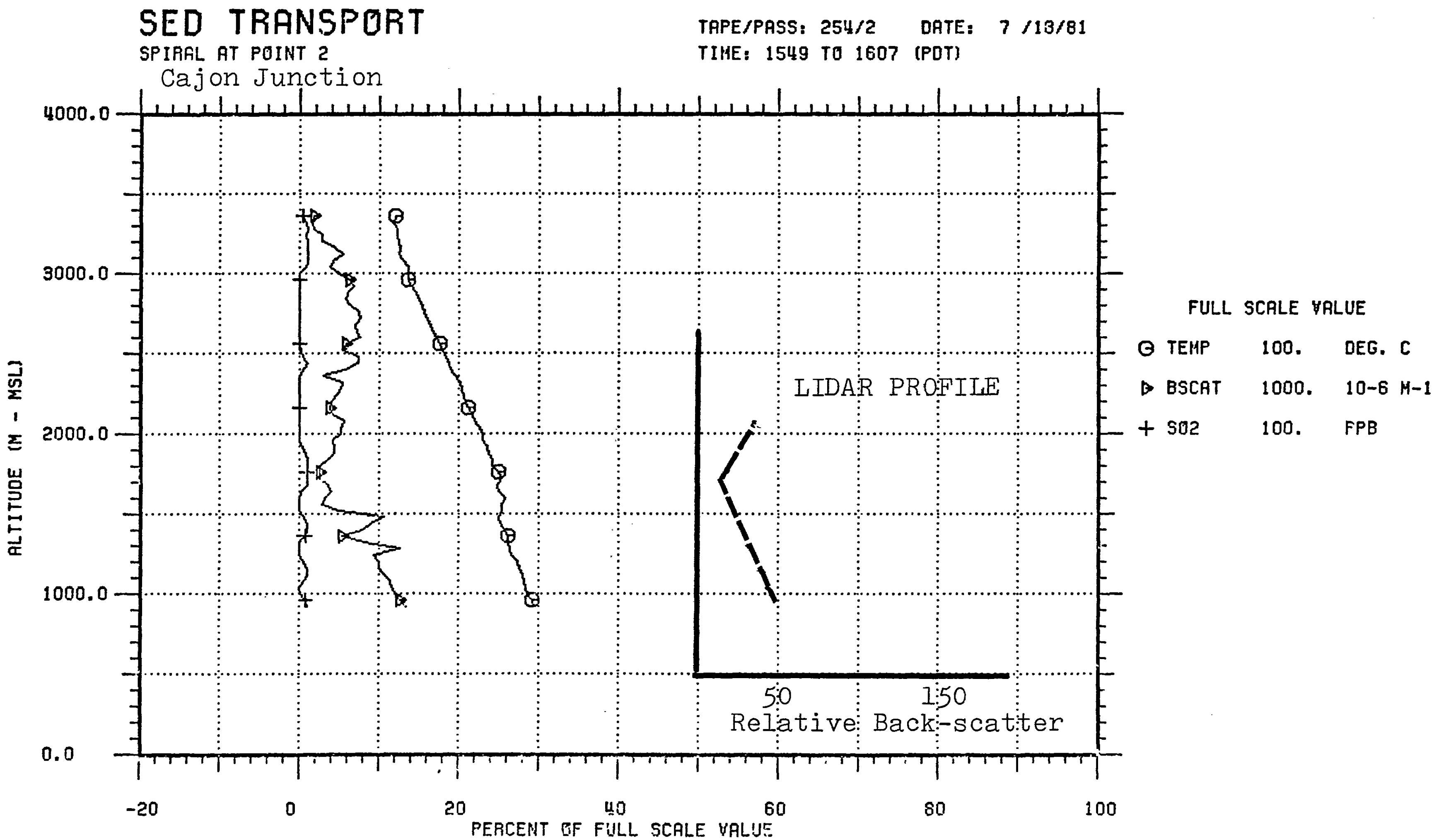


Fig. 4-7 COMPARISON OF AIR QUALITY AND LIDAR PROFILES
July 18,1981

811001.1
06:48:06

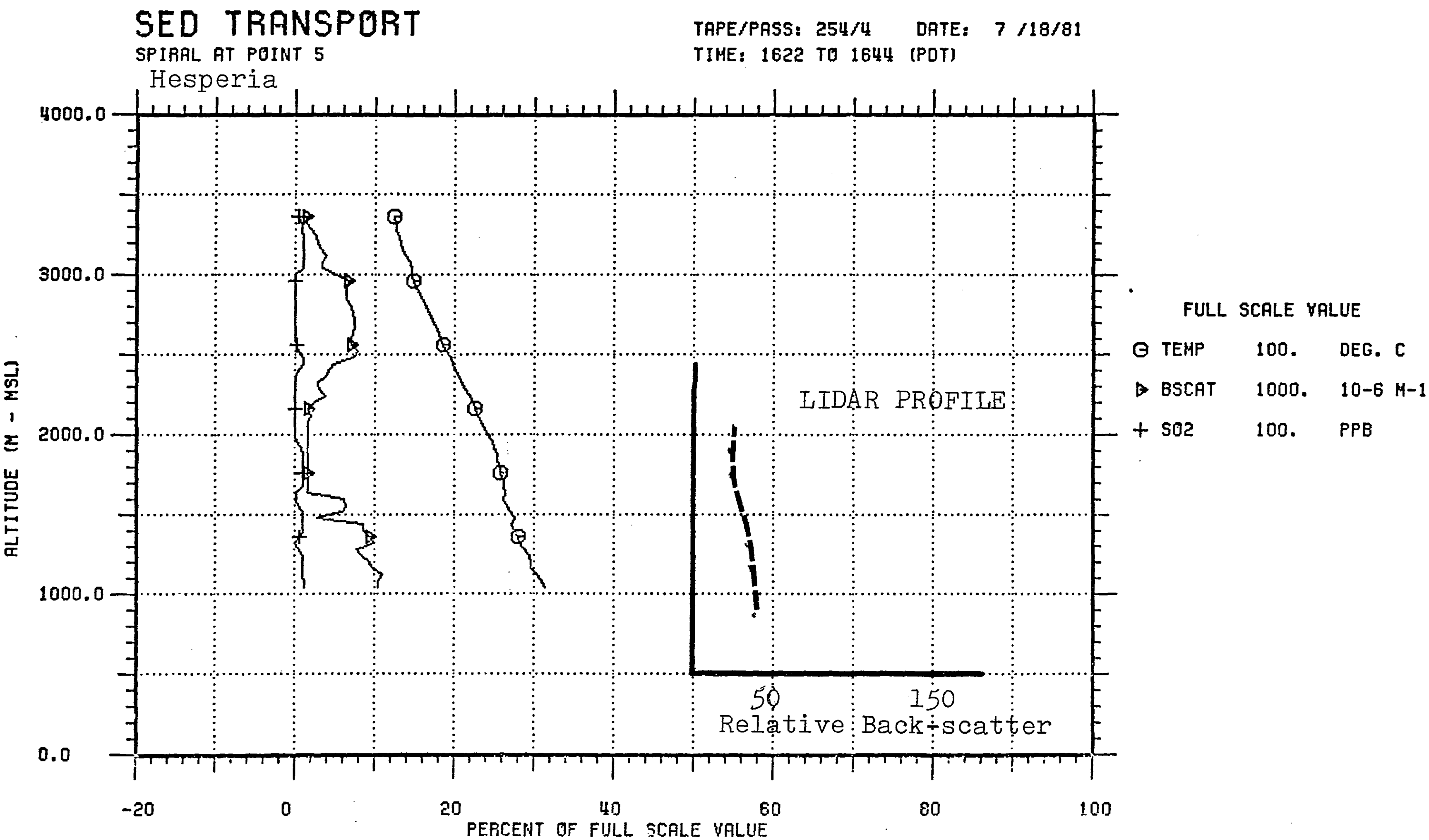


Fig. 4-8 COMPARISON OF AIR QUALITY AND LIDAR PROFILES
July 18,1981

811001.1
06:48:06

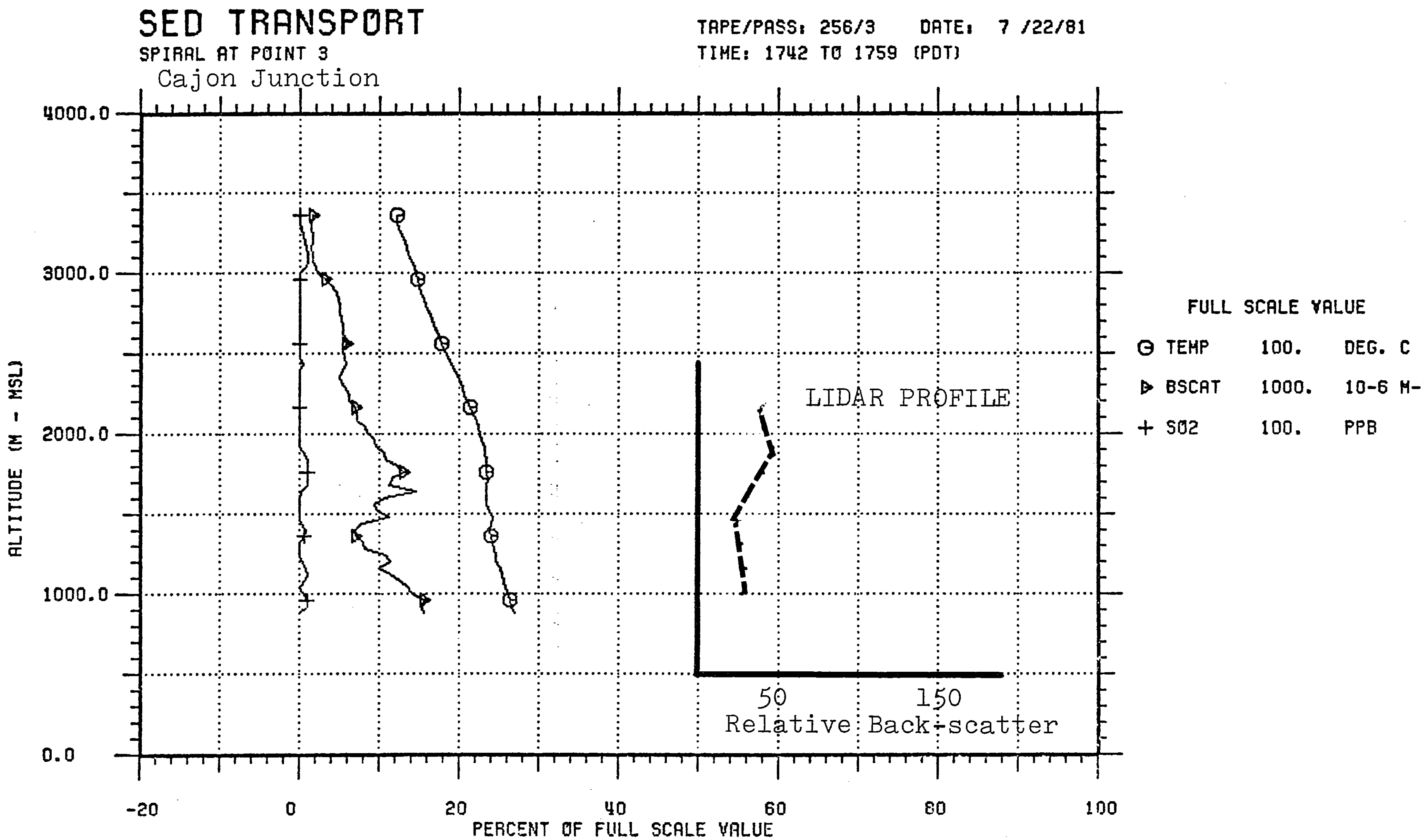


Fig. 4-9 COMPARISON OF AIR QUALITY AND LIDAR PROFILES
July 22,1981

800925.1
19:30:37

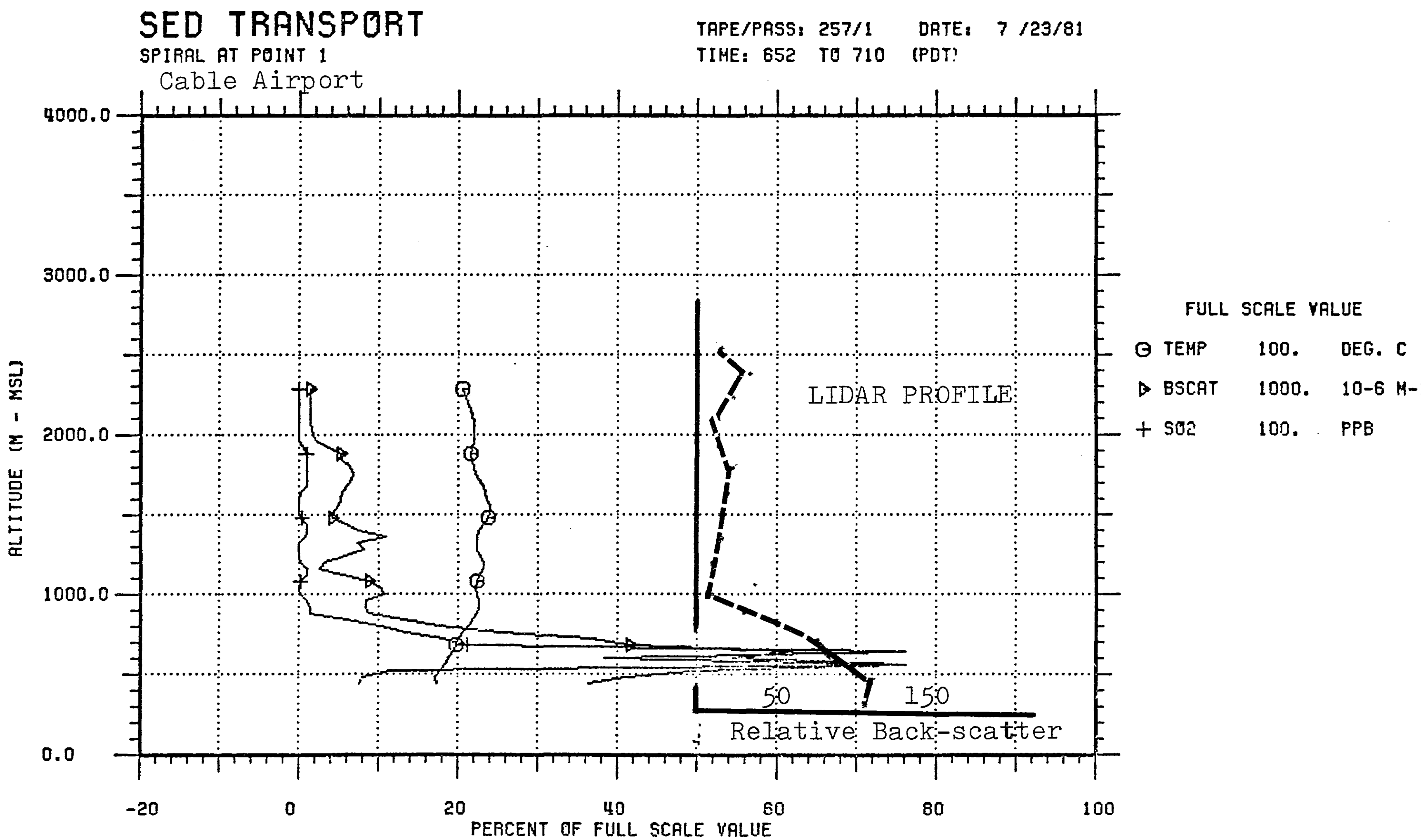


Fig. 4-10 COMPARISON OF AIR QUALITY AND LIDAR PROFILES
July 23,1981

800925.1
20:24:20

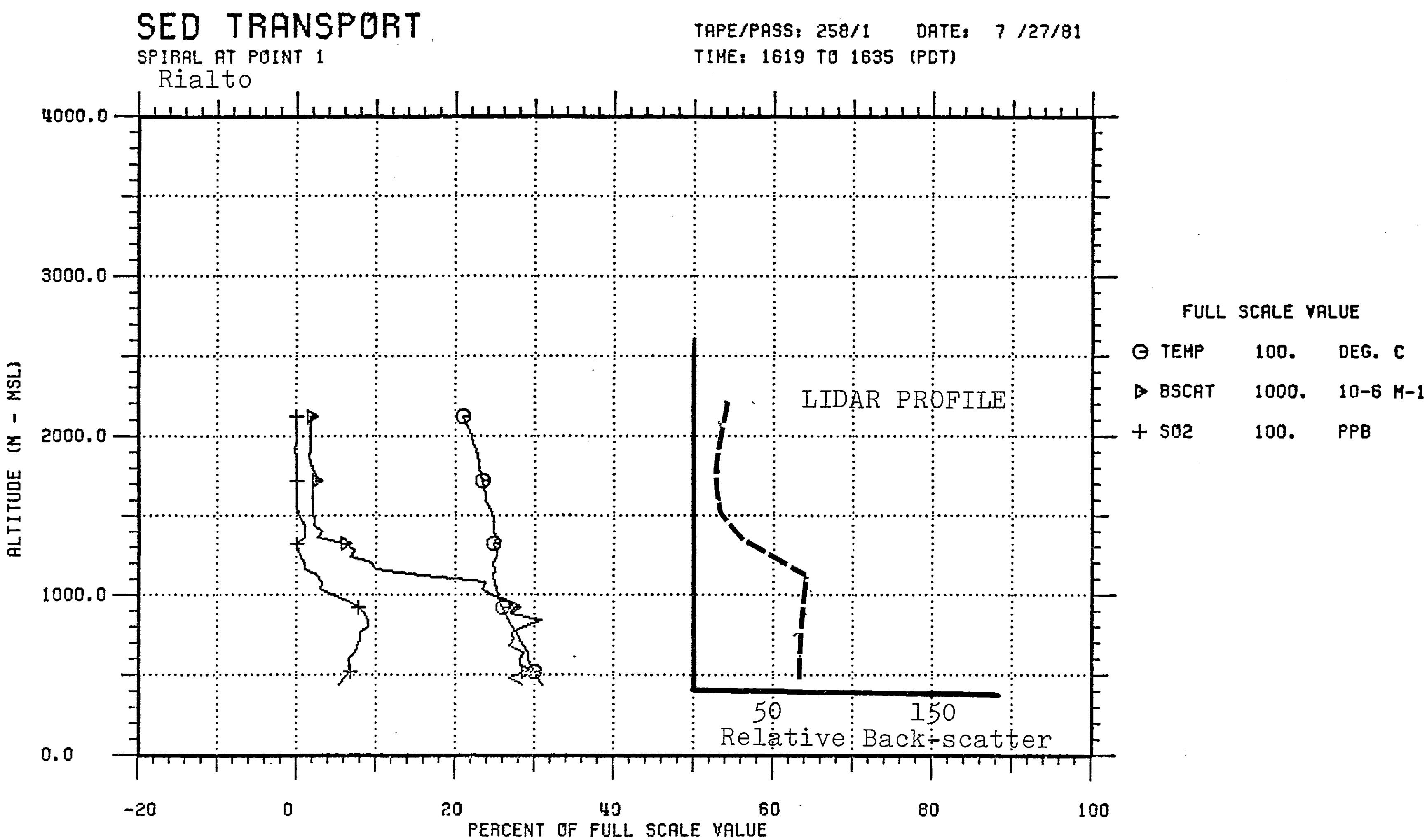


Fig. 4-11 COMPARISON OF AIR QUALITY AND LIDAR PROFILES
July 27,1981

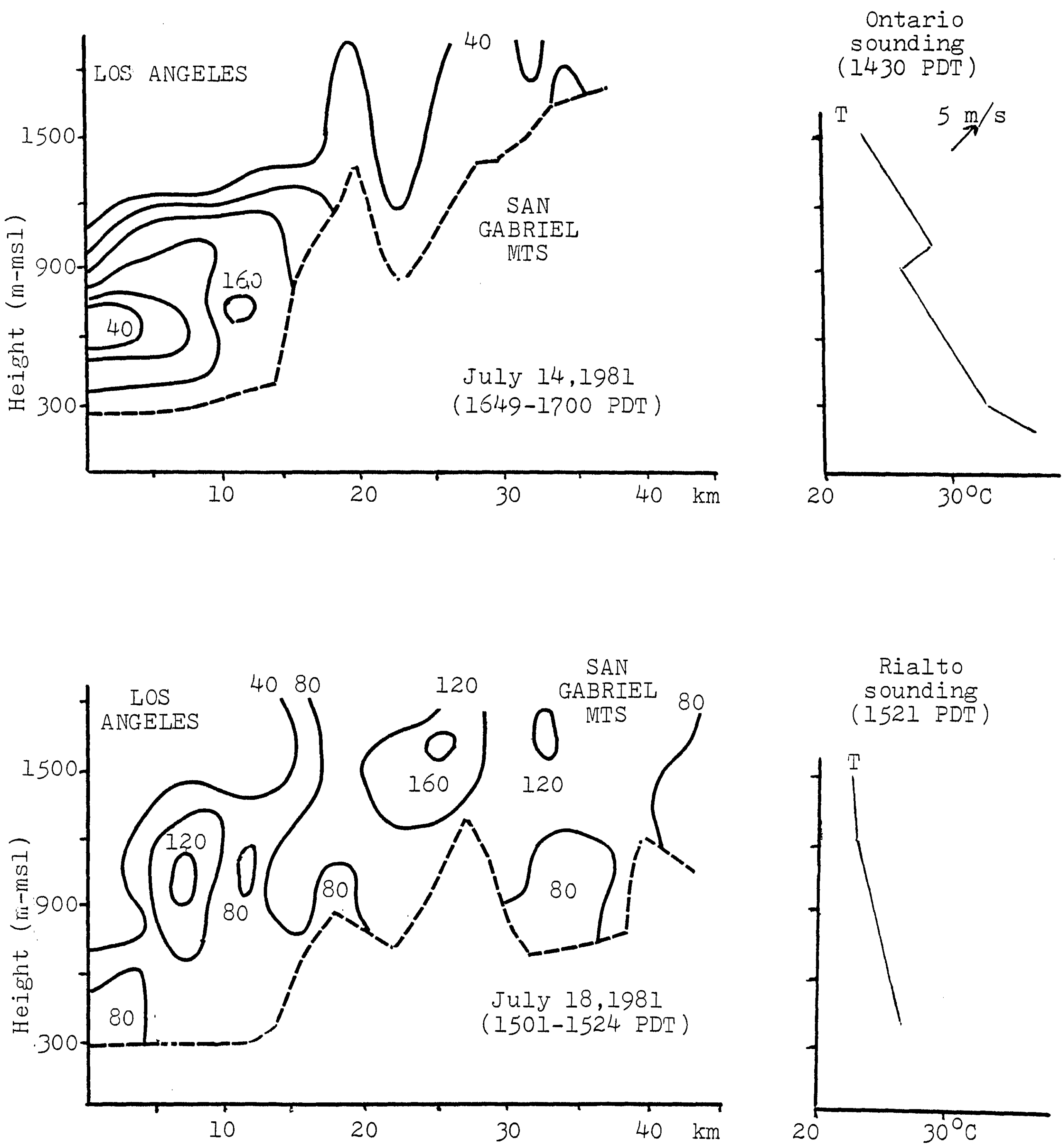
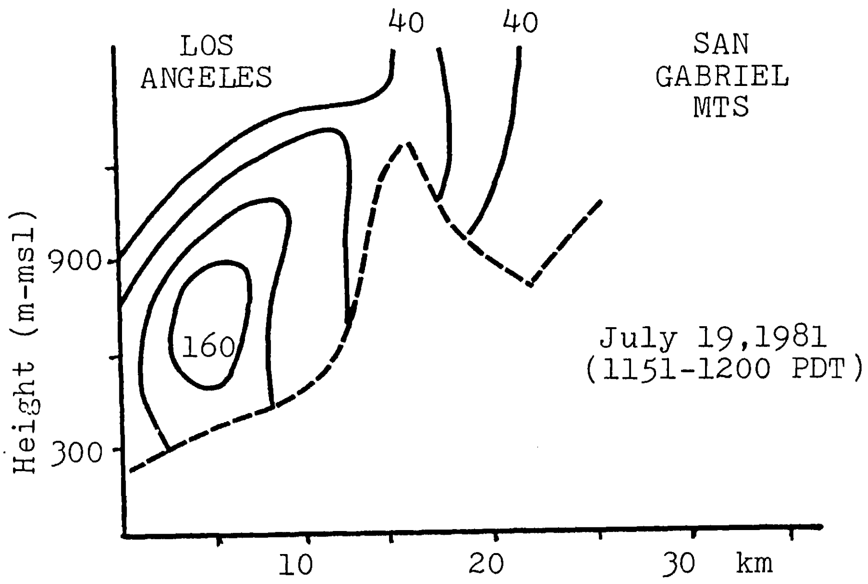


Fig. 4-12 UPSLOPE CROSS SECTIONS



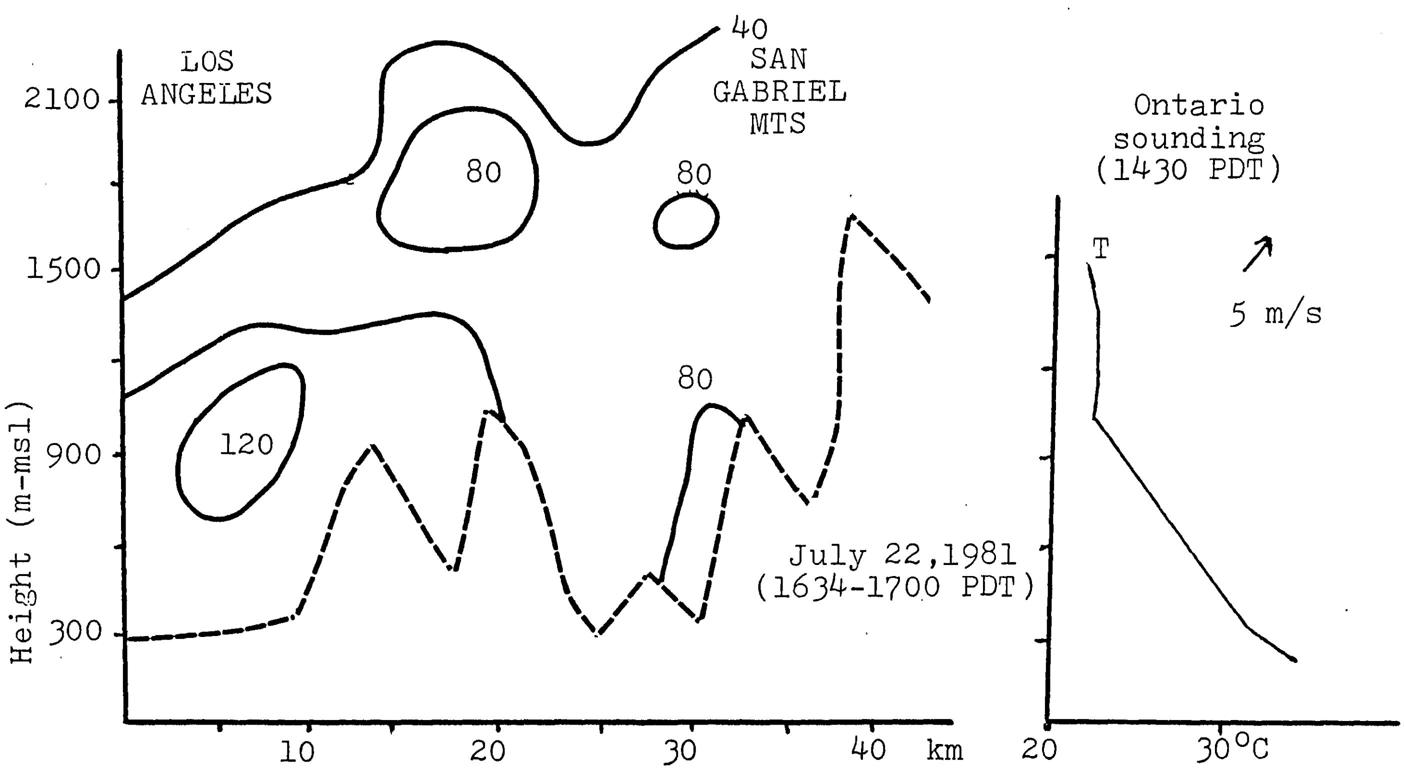


Fig. 4-13 UPSLOPE CROSS SECTIONS

The July 14 cross section (Fig. 4-12) was constructed from a lidar aircraft track beginning at downtown Los Angeles and ending at El Mirage Airport in the Mojave Desert. There was a low aerosol layer top 500-600 m (msl) over the San Fernando Valley and the downtown area (see Figs. 3-1 and 3-4). The valley aerosols appeared to move upslope in a shallow layer with heaviest concentrations within 5 km of the slope (horizontal distance). The bulk of the material appeared to be stopped at a level of about 1100 m-msl which was approximately the height of the upper level inversion over Ontario. The momentum of the upslope flow appears to have carried the aerosol material into the inversion and to the southwest, in spite of the southwest winds aloft. The upslope flow should have been 4 m/s or more in order to accomplish this back flow. A smaller portion of the material continued up the slope and over the first ridge line. Relative back-scatter values of 140 to 160 were prevalent in the surface layers throughout the valley. These concentrations were maintained upslope (or very slightly diluted) to the level of the inversion. The aerosol layer aloft extended over 15 km from the slope with a principal depth of 300-400 m and with slightly lower concentrations (120-150 back-scatter units).

Also shown in Fig. 4-12 is a cross section from Victorville to downtown Los Angeles on July 18, 1981. A gray-scale reproduction of the lidar data is shown in Fig. 3-6. The temperature inversion as measured by the aircraft at Rialto was very weak (1.8^{o} C total temperature differences at UCLA). This weak inversion (about 1200 m-msl) permitted plumes to penetrate the inversion over the basin (see Section 3). It also produced a much different aerosol pattern along the slopes. Highest aerosol concentrations tended to occur at some distance from the slope but the highest elevations experienced greater impacts than indicated in the upper part of the figure.

There are two major pulses of aerosol concentrations shown in the data for July 18. The lower one apparently has broken away from the surface layer but the top is still confined to the top of the mixed layer. The pulse occurred some 8-10 km from the slope in contrast to the pattern of July 14.

The second pulse is at an altitude of about 1600 m-msl over the highest ridge. This indicates penetration well above the mixed layer and then transport over the ridge in southwest winds. Both pulses have the appearance of convective bubbles which may be the principal convective mode along the slopes under weak inversion conditions.

There was a shallow mixed layer over the central part of the basin at the time of the flight path. Top of the layer was about 700 m-msl. Concentrations in the layer were of the order of 140-160 relative back-scatter units. Similar concentrations were observed at the center of each of the bubbles, suggesting an origin in the valley mixed layer.

Fig. 4-13 shows a cross section from Victorville to Ontario on July 19. A gray-scale representation is shown in Fig. 3-14. The flight path began at 1151 PDT where transects in Fig. 4-12 were made during mid-afternoon. There was no applicable temperature sounding but the temperature at 850 mb increased by 1^{o} C from July 18 to July 19, suggesting that the inversion would only be slightly more important than on the 18th.

There was a widespread aerosol layer in the basin at flight time with a top of about 800-900 m-msl. Concentrations of 160-200 relative back-scatter units were prevalent in the layer. The visibility at Ontario Airport was 4 miles in haze and smoke. Some of this layer had begun to move upslope by 12 PDT to a level of 1400 m-msl. The bulk of the aerosols remained as a pulse, similar to July 18, at a distance of 8-10 km from the slope. Maximum concentrations in this pulse were also over 160 relative back-scatter units. It is presumed that this pulse continued up the slope during the afternoon.

Also in Fig. 4-13 is a cross section from Victorville to downtown Los Angeles on July 22 (see Fig. 3-16). This flight path was made during the late afternoon. The temperature sounding at Ontario shows a top of the mixed layer at 1000 m-msl with an isothermal lapse rate above this level.

There was a deep aerosol layer over the basin by 17 PDT with a top of about 1200 m-msl. Aerosol concentrations in the layer were 90-120 relative back-scatter units. Visibility at El Monte Airport was 7 miles.

The top of the main aerosol layer over the southern slopes of the San Gabriel Mts. was about 1300 m-msl, indicating some degree of penetration into the stable layer. Peak concentrations of over 120 units were observed in a pulse centered about 6 km from the slope. There appears to be another, earlier pulse centered at 1800 m-msl and located farther northeast over the ridge. As indicated at Ontario the winds were southwest at that level. Concentrations in the higher pulse were somewhat lower, of the order of 80-90 relative units.

There is a considerable similarity between the cross sections on July 18 and 22. Locations and time were similar. Both apparently show two pulses of aerosol concentrations moving upslope and over the ridge toward the northeast. This is in contrast to the pattern of July 14 which shows a layer forming aloft in association with a more pronounced temperature inversion.

4.4 Convergent Zones

Observations of the San Fernando Convergence Zone on July 14 and the Elsinore Convergence Zone on July 27 and 30 have been discussed in Section 3. The following comments cover additional details of the July 14 and July 27 observations.

July 14, 1981

The San Fernando Convergence Zone (see Figs. 3-1 and 3-2) was encountered about 1640 PDT on a flight path from the upper Santa Clara River Valley through the San Fernando Valley past Burbank. The zone was 8 km wide along the flight path and extended to a height of 1200 m above ground level.

Relative back-scatter values of 120-150 were observed in the central part of the zone, decreasing in the plume which extended for 25 km along the flight path. There was a shallow aerosol layer of about 500 m in depth with back-scatter values of 120-190 along the last half of the flight path, apparently the source of the high values in the zone. This layer is injected into the convergence zone at the rate of 3-4 m/s. Given a 15 km long zone, about $0.8 \times 10^{11} m^3/hr$ can be carried upward in the zone. The volume of the San Fernando Valley (assuming a 500 m deep pollutant layer) is about $2 \times 10^{11} m^3$. The convergence zone, therefore, can be an effective ventilation mechanism for the valley.

July 27, 1981

Two flights were made over the Elsinore Convergence Zone on July 27 at about 17 and 21 PDT. Cross sections from Corona to Hemet for each of these flights are shown in Fig. 4-14. These sections were constructed from bin-averaged data of dimensions 1km horizontal and 150 m vertical. Units shown are in terms of relative back-scatter.

The two diagrams in Fig. 4-14 show the layer aloft created by the convergence zone. None of the flights on the 27th and 30th showed clear indications of the surface roots of the zone. As indicated in the figure the layer aloft tends to be located closer to Hemet than to Corona.

At 1640-1650 PDT the upper layer was about 700-800 m deep and centered about 1500 m-msl. Relative back-scatter values of over 120 were observed near the center of the layer. The principal part of the layer extended at least 35 km along the flight path.

At 2150-2200 PDT the central part of the layer had moved to the southeast, near Hemet. The depth of the layer was about 700 m, centered at 1300 m-msl. Highest back-scatter values were over 160. The horizontal length of the layer was at least 50 km along the flight path. Similar back-scatter values were observed in the surface layers in the eastern San Gabriel Valley earlier in the flight.

Using all of the transect data available for the second flight of July 27, the approximate boundaries of the upper layer have been sketched in Fig. 4-15. The eastern end of the layer is not included since the aircraft did not sample in this area.

The approximate area outlined in Fig. 4-15 is about $2.8 \times 10^9 m^2$. The Los Angeles basin, east of central Los Angeles and not including the San Fernando Valley is of the order of $6 \times 10^9 m^2$. Based on the data for July 27 the volume included in the Elsinore layer aloft is a very appreciable portion of the pollutant volume in the Los Angeles basin. This results from a comparison of areal coverage with similar layer depths and aerosol concentrations.

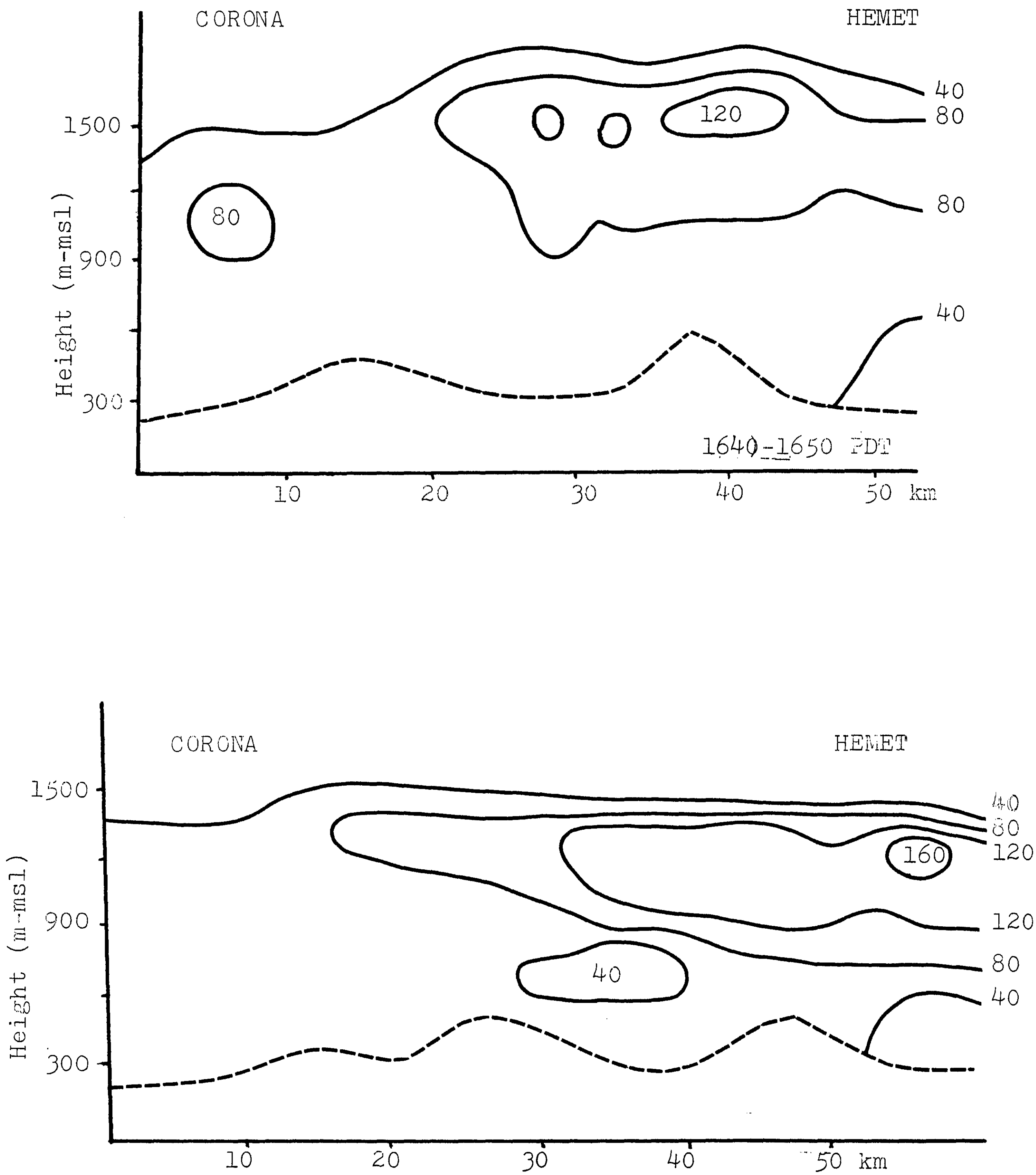


Fig. 4-14 CROSSECTIONS FROM CORONA TO HEMET
July 27,1981

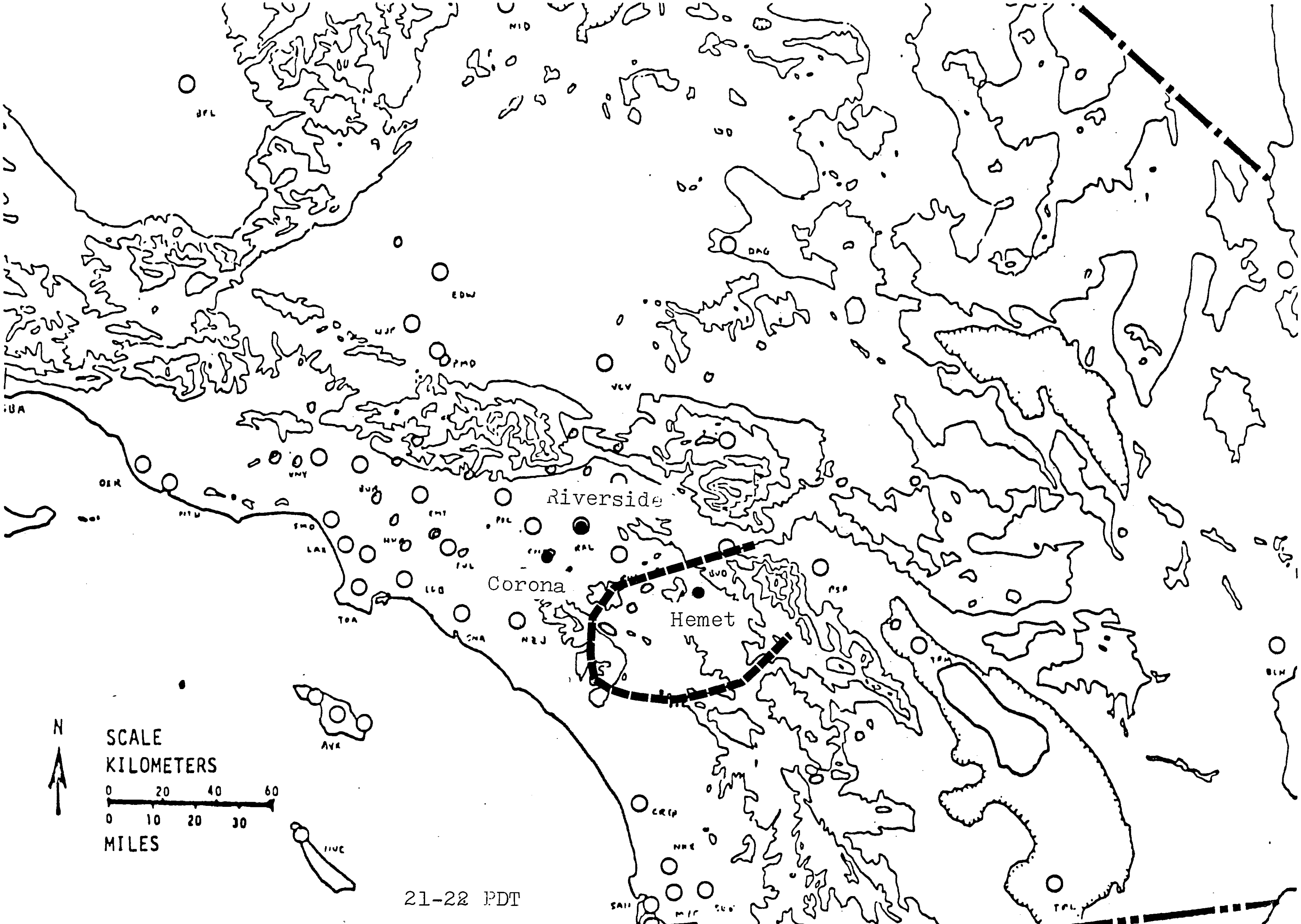


Fig. 4-15 OUTLINE OF UPPER AEROSOL LAYER
July 27,1981

The conclusion must be reached that the Elsinore Zone is a major exit zone for ventilating pollutants out of the surface layers of the basin.

4.5 Flow Through Passes

During the 10-day observational program the lidar aircraft made a number of flights through the passes leading out of the Los Angeles Basin. There were 12 flights through San Gorgonio Pass, 12 flights through Cajon Pass and four from Newhall to Palmdale through Soledad Canyon. These flights provide an indication of the aerosol mass loading exiting through the passes.

For each of the flights a 5 km section along the flight path and centered on the highest elevation in the pass was considered. The mixing layer within this section was identified and the average back-scatter data were summed layer by layer from the surface to the top of the mixing layer. Thus both the back-scatter values themselves and the depth of the mixed layer contribute to an indication of the total aerosol loading moving through the pass within the mixed layer.

The results of these summations are plotted in Fig. 4-15 as a function of time of day. All flight days are plotted together for each pass. It has been suggested earlier that it is generally not appropriate to combine days in this manner due to possible variations in system operation and aerosol characteristics. However, in this case, the results of combining the data are so striking that they overwhelm the day-to-day variations in back-scatter returns.

It is clear from even a cursory glance at Fig. 4-15 that the aerosol material passing through San Gorgonio Pass dominates the contributions of the other passes. In general, the values in San Gorgonio Pass are of the order of 2-3 times those observed in the other two passes. It is of interest to note that the highest value in San Gorgonio Pass occurred on July 30 in agreement with a previous discussion.

The depth of the mixed layer over the pass was also tabulated in each case with the following results:

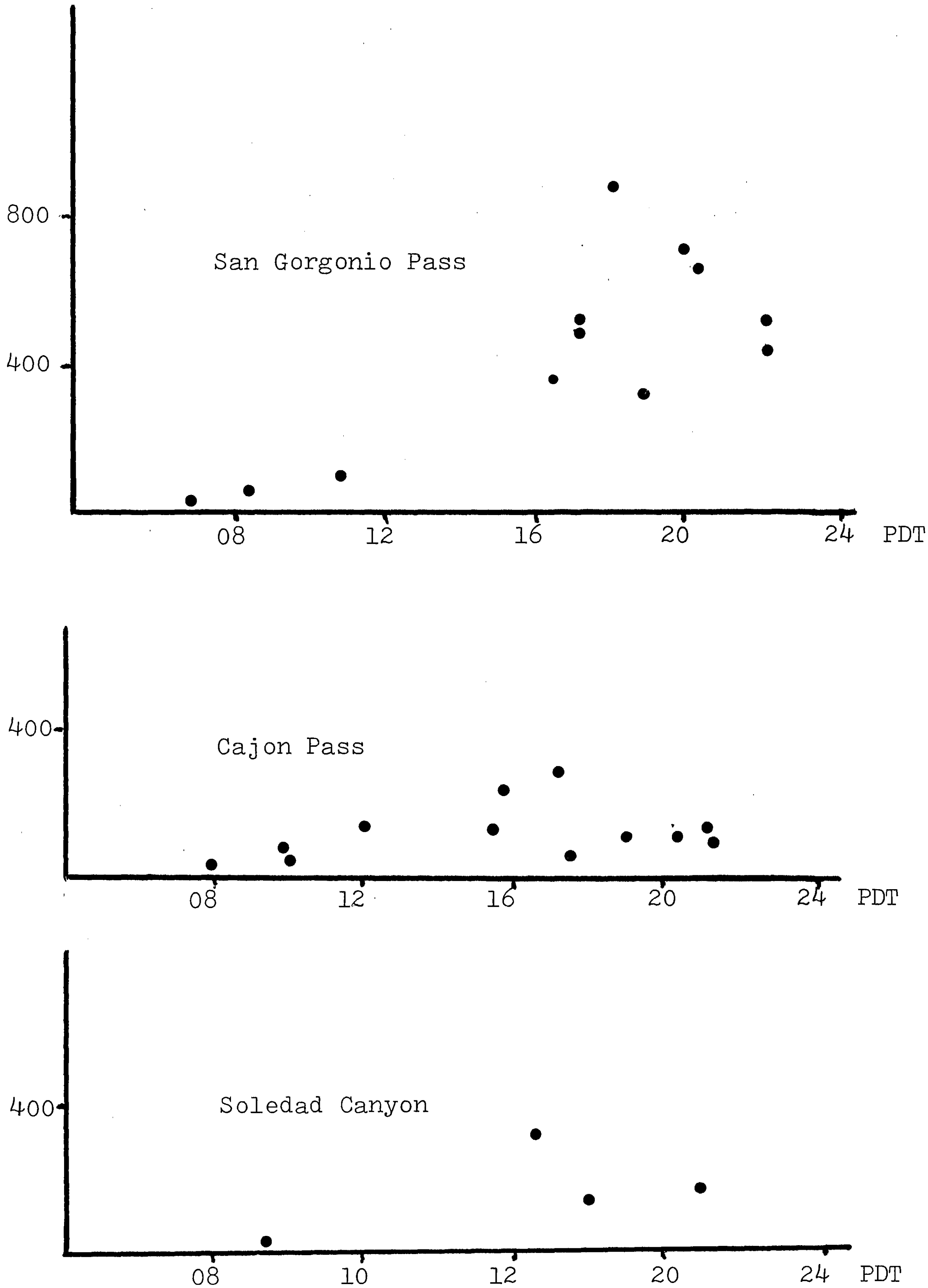


Fig. 4-15 AEROSOL LOADINGS IN PASSES

Location	Top of Mixed Layer
San Gorgonio Pass	100 to 1600 m-agl
Cajon Pass	100 to 1000
Soledad Canyon	350 to 1100

The maximum depth of the flow through San Gorgonio Pass tends to be somewhat greater than observed in the other passes. The convergence through San Gorgonio Pass, leading to high mixing depths through the pass, is well illustrated in Fig. 3-31.

Air fluxes through the passes within the mixed layer were calculated by Smith et al (1983) for all available pibal soundings. Maximum calculated flux through San Gorgonio Pass was of the order of 10,000 m^2/s. This amounts to a total volume flux of 2.9×10^{11} m^3/hr. if an effective crosswind width of 8 km is assumed. The volume of the Los Angeles basin east of central Los Angeles is about 3×10^{12} km^3 if a mixed layer of 500 m is assumed. San Gorgonio Pass may therefore remove some 10% of this volume per hour as a maximum. A realistic figure is probably somewhat less since maximum flux and 500 m deep pollutant layers may not tend to occur on the same day.

4.6 Layers Aloft

The frequent presence of layers aloft in the South Coast Air Basin has been documented by the lidar aircraft data. The existence of such layers has been identified previously (e.g. Smith et al, 1976). The present data provide additional information on the mechanisms for producing such layers.

Beginning with relatively uncomplicated phenomena, the afternoon upslope flow of heated air over the slopes of the basin's peripheral mountain ranges contribute to the layers aloft that are observed to extend southward from the slopes of the San Gabriel Mts. and to the layer aloft detected over the ridgeline of the Santa Ana Mts. Depending on wind direction aloft, the upper aerosol layers appearing at times over Cajon and San Gorgonio Passes also may have their origin on the slopes of the mountains.

Another mechanism capable of venting surface-based aerosol layers into the inversion layer is the convergence of surface winds which can develop as the result of terrain features that deflect and steer the flow. An example is the San Fernando Convergence Zone where sea breezes converge behind the Santa Monica Mts. with southeasterly flow through the San Fernando Valley. Another example is the Elsinore Convergence Zone reflecting convergence between northwesterly wind in Riverside County and southwesterly flow to the south of the Santa Ana Mts. This zone has been well exploited by soaring personnel. Upper layers over Newhall and Soledad Canyon and in the vicinity of Temecula/Corona/Hemet appear to be generated by this mechanism.

The lidar data indicate that aerosol layers can be injected into the inversion at positions over the basin, independent of the slope flow. An example is shown in Fig. 3-7 where plumes from the mixed layer were injected into the inversion layer. Comparisons with the available sounding data suggest that convective motions during the afternoon frequently drive pollutants into the inversion layer, above what would normally be called the mixing layer. When the convective motions which provide the driving force for this action die away in the evening, these pollutants are left unconnected to the lower layer flow and can become layers aloft.

Finally, there is the case shown in Fig. 3-10 in which a shallow layer of marine air apparently moves inland undercutting the existing pollutant layer. Accompanied by cool surface temperatures, a new mixing layer is established, leaving the previous pollutants aloft without surface roots. Thus cut off from the surface layers they become a layer aloft and are subject to a flow regime at an elevated level.

On the basis of the lidar data, the convergence zones and the slope flow would be considered as the most effective mechanisms for creating layers aloft.

4.7 Desert Impact

The lidar data provide an unusual opportunity to examine the evidence for carryover of pollutants in the desert from one day to the next. This results from the extensive areal coverage provided by the aircraft in contrast to the limited area observed by air quality aircraft spirals. Within the 10-day flight program there were four two-day periods when the lidar aircraft sampled in the evening and again the following morning. Comments on each of these periods follow:

July 14-15, 1981

Surface pressure gradients on July 14 were below normal for July. The 08 PDT pressure difference from LAX to Bakersfield was slightly negative. The inversion height was also relatively low. The meteorological conditions on July 14 indicated relatively stagnant wind patterns with below normal transport into the desert.

Ozone intrusions were observed at both Victorville and Palm Springs in the late afternoon or evening. Victorville had an ozone peak of 11 pphm at 17 PST with a southerly wind. Palm Springs had an ozone peak of 14 pphm at 20 PST but without any associated effect on visibility. The evidence suggests a relativley minor impact in the desert on July 14 from the South Coast Air Basin.

Sampling with the lidar aircraft took place in the desert between 17 and 18 PDT on July 14 and from 1000 to 1030 PDT on July 15. No significant aerosol layers were observed on either day. This seems to be the result of 1) sampling in the Coachella Valley before the principal intrusion, 2) the minor importance of the intrusion on July 14 and 3) the lidar system was not operating at full capability until later in the program.

July 18-19, 1981

Weak surface pressure gradients to the inland areas continued through July 19. Wind transport into the desert was also somewhat less than average for July.

Victorville showed an intrusion of ozone with a southerly wind from 16-21 PST and a peak of 14 pphm at 20 PST. Palm Springs experienced a peak ozone value of 15 pphm at 19 and 20 PST, accompanied by west-northwest winds.

Lidar sampling in the Coachella Valley on July 18 occurred prior to the observed ozone pulse at Palm Springs. A weak aerosol layer was present in the valley to a depth of 750 m-agl but with back-scatter values only slightly above the background.

In the Mojave desert sampling from Cajon Pass to Victorville about 19 PDT showed an aerosol layer of 400 m depth over the pass decreasing to 300 m over Victorville. Back-scatter values were only slightly above background.

On the following morning there was a strong aerosol layer (500 m deep) near Victorville. Back-scatter values were very high (120-200) but the surface visibility was reported as 25 miles. This layer broke up later in the morning and was not apparent at 1150 PDT. It is assumed to have been a local influence.

In the Coachella Valley there was also an extensive low-level aerosol layer (600-800 m-agl) at 11 PDT with high back-scatter values in spite of 20-25 mile visibilities at Palm Springs and Thermal. This information is shown in Fig. 4-2 as an anomalous data point in a plotted relationship between visibility and back-scatter.

The intrusion into the desert on July 18 was somewhat more important than on July 14. The possible observations of carryover on July 19, however, were confused by the early morning , anomalous, back-scatter values observed near Victorville and in the Coachella Valley.

July 22-23, 1981

The pressure gradients into the interior increased substantially by July 22. Gradients to both Bakersfield and Daggett were well above normal. Strong transport conditions into the desert were indicated.

Victorville showed an ozone peak of 14 pphm from 14 through 17 PST, associated with moderate southerly winds. Palm Springs also had an earlier ozone peak of 12 pphm at 18 PST with the usual northwest winds. The earlier peaks are presumably the result of the more rapid transport wind conditions. Hazy conditions were reported at George AFB (Victorville) from 15-20 PDT and from 13-16 PDT at Palm Springs.

Aerosol concentrations were observed by the lidar aircraft about 18 PDT in the Coachella Valley and 20 PDT near Victorville. In each case, there were weak aerosol layers present to a level of 500-600 m depth but with back-scatter values only slightly above background.

On the following morning there was evidence of weak aerosol concentrations in the Coachella Valley and eastern Mojave Desert. Depths of 1000-1200 m-agl were observed but with back-scatter values only slightly above background.

The visibility and ozone data confirm effective transport into the desert on July 22. The lidar data supported this evidence with a relatively deep layer of aerosols on the following morning in both desert areas but with low back-scatter values in keeping with the reported morning visibilities of 20 miles.

July 30-31, 1981

Well above average pressure gradients into the inland areas continued on July 30. Transport conditions into the desert were similar to those occurring on July 22.

Victorville showed moderate to strong winds from the south from 10 through 19 PST. The associated peak ozone concentration of 9 pphm was observed at 16 PST and there was no significant effect on visibility.

The only lidar sampling near Victorville took place at about 1540 PDT on the 30th. There was only a weak surface aerosol layer near Victorville but a strong layer to about 900 m depth was encountered during the last half of the path to Hesperia. In the Coachella Valley at 20 PDT there was a strong, shallow (500 m depth) layer near Palm Springs with back-scatter values of 120 to 140 and restricted visibility (7 miles at 18 and 19 PDT). By 2230 PDT the back-scatter values had been reduced to about 100 in the surface layer.

On the following morning (July 31) there were heavy aerosol concentrations in the Coachella Valley, in a 700-800 m deep surface layer and, particularly, in a layer at 1200 m-agl. Back-scatter values were observed at over 180 in both layers. Top of the layer was well-defined at about 1500 m-msl. As indicated in Section 3, two contributing aspects to the high back-scatter values may have been ambient humidity and increased sensitivity of the lidar system. Visibilities at Palm Springs were restricted to 5-7 miles through 13 PDT.

There is little doubt that there was strong transport from the South Coast Air Basin into the Coachella Valley on July 30. In contrast, the intrusion into the Victorville area was much less pronounced. The Coachella Valley experienced very poor visibilities during the forenoon of July 31. Contributors to these heavy aerosol concentrations were carry-over from the previous day, possibly enhanced by high ambient humidities which may have caused increased particle growth.

4.8 Convergence through San Gorgonio Pass

Lidar cross sections (e.g. Fig. 3-31) clearly show the effects of mass convergence through San Gorgonio Pass with marked divergence downwind of the pass. The following is an attempt to estimate the magnitude of these effects.

Figs. 4-17 through 4-20 give the average aerosol loading within the mixed layer and the mixing layer depth for four cross sections through the pass. The top portion of each figure gives the top of the mixed layer (msl) compared to the height of the terrain. The bottom portion shows the average aerosol loading within the mixed layer for 5 km increments along the flight path. Terrain heights are repeated in the bottom portion of the figure for comparison. The average aerosol loading was calculated by summing the relative back-scatter values within the mixed layer for each 5 km segment.

The behavior of both the mixed layer and the average aerosol loading should provide some indication of the convergence/divergence characteristics of the flow through the pass. Unfortunately, only one of the four flights (Fig. 4-19) continued beyond the pass toward Los Angeles. The balance of the flights turned northward toward San Bernardino and Redlands. Indications of convergence were therefore minimal and most of the derived information pertains to the divergence accompanying the flow into the desert.

Table 4-1 shows estimates of the divergence effects for each of the four flights shown in the figures. The estimates are given in terms of the proportionate decrease in mixing height (or aerosol loading) from the crest of the pass to the desert.

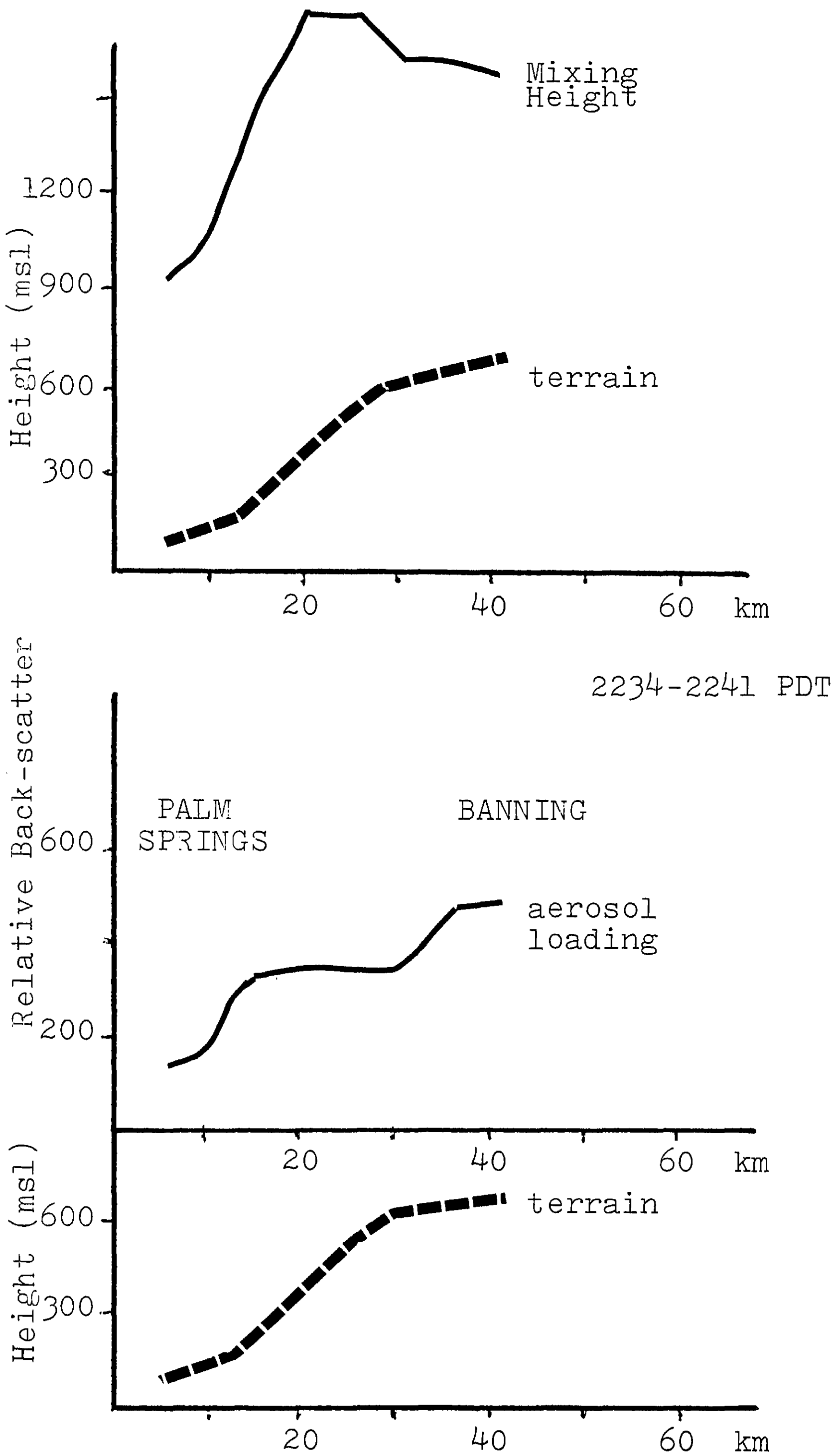


Fig. 4-17 AEROSOL LOADING IN MIXED LAYER
SAN GORGONIO PASS
July 27,1981

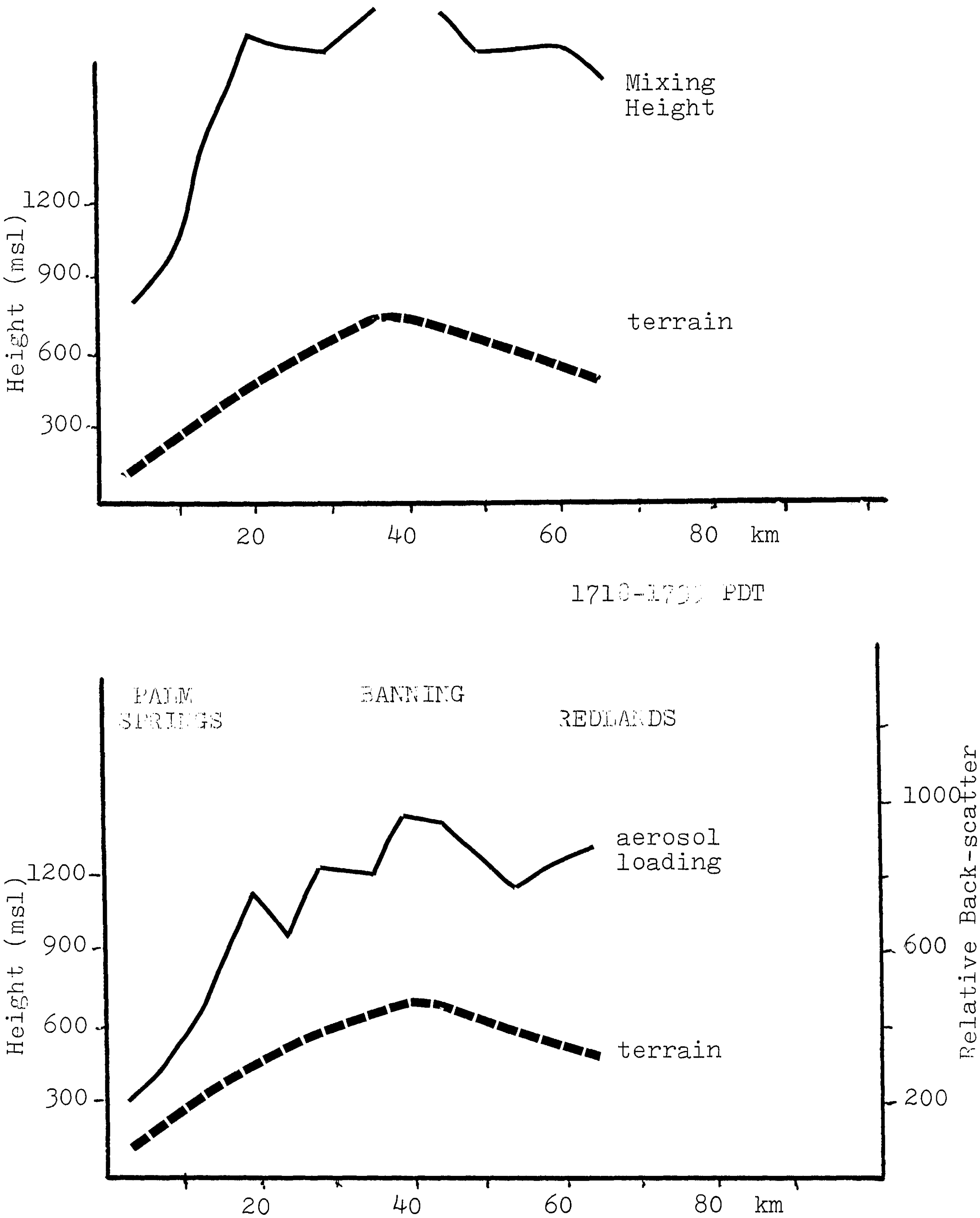


Fig. 4-18 AEROSOL LOADING IN MIXED LAYER
SAN GORGONIO PASS
July 30,1981

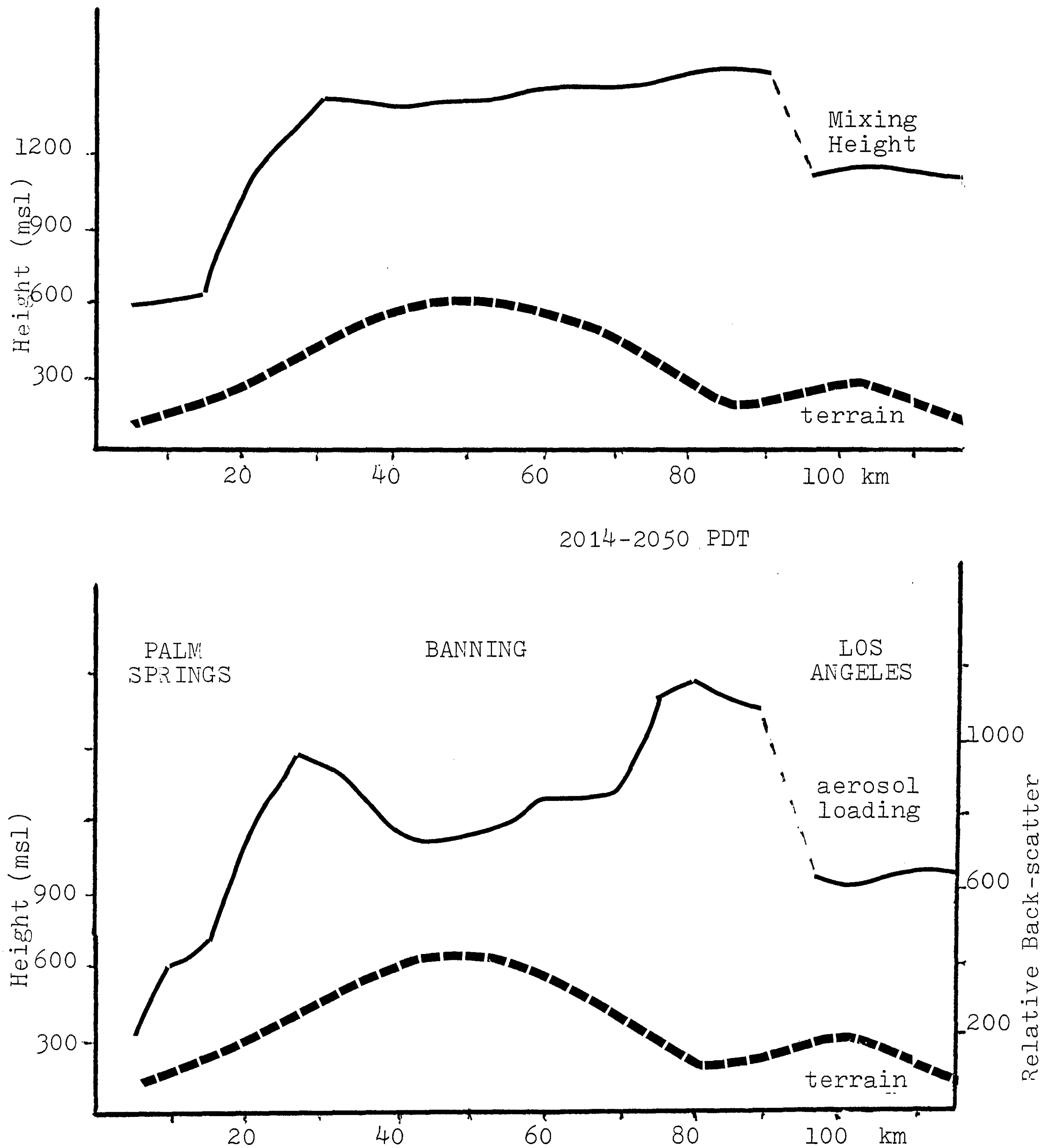


Fig. 4-19 AEROSOL LOADING IN MIXED LAYER
SAN GORGONIO PASS
July 30,1981

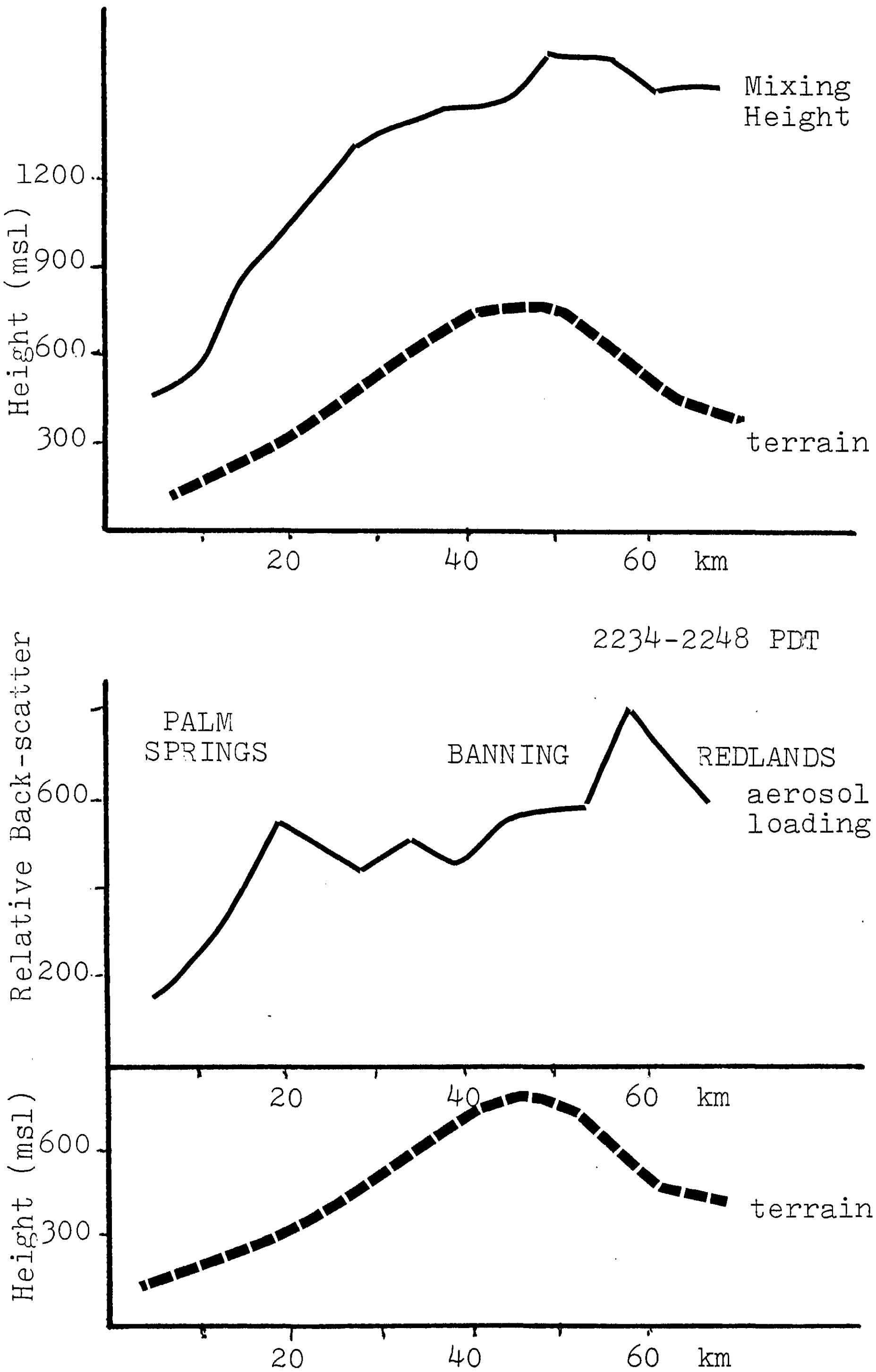


Fig. 4-20 AEROSOL LOADING IN MIXED LAYER
SAN GORGONIO PASS
July 30,1981

Table 4-1

Estimates of Divergence Effects
San Gorgonio Pass

Date	Time	Proportionate Decrease in Mixing Height	Proportionate Decrease in Aerosol Loading
7/27	1728 PDT	0.3	0.67
7/30	1718	0.5	0.75
7/30	2016	0.5	0.7
7/30	2235	0.65	0.75

In each case the proportionate decrease in mixing height was substantially less than the decrease in aerosol loading. This appears to represent the influence of dilution by cleaner, desert air.

Fig. 4-19 represents a cross section from Palm Springs to downtown Los Angeles. In the western portion of the flight route there is an abrupt change in mixing layer depth and aerosol loading. This region indicates that the lower mixing layer heights represent the intrusion of a marine layer (see discussion of Fig. 3-31). Near the eastern boundary of the intrusion both the aerosol loading and the mixing heights appear to increase due to the undercutting of the marine air.

As a result of this intrusion it is difficult to obtain a reasonable measure of the stabilized pollutant layer upwind of the pass. Estimates of the convergence in the pass are consequently not very useful.

5.0 CONCLUSIONS AND RECOMMENDATIONS

This section has been divided into two parts, dealing first with the observational results of the lidar flight program and, secondly, with the potential use of the lidar as an air pollution research tool.

5.1 Observational Results

1. Digital representations of the back-scatter from the lidar were used to compare with concurrent surface visibilities. In spite of variations in lidar system operation and aerosol characteristics the agreement was considered to be good. Indications of attenuation due to heavy aerosol loading were obtained.

2. Satisfactory comparisons were also made between digital back-scatter values and profiles of b_{scat} obtained with an air quality aircraft. Principal differences seemed to be the result of the layer averaging depth for the lidar returns and possible variations due to non-coincident locations.

3. The San Fernando Valley and Elsinore Convergence Zones were identified. The Elsinore zone was considered to be a major exit zone for pollutants in the Los Angeles basin.

4. Upslope flow of aerosols along the south slopes of the San Gabriel Mts. was observed on a number of occasions. The character of the flow appeared to change from a layer or chimney type under strong inversion conditions to a more bubble-like structure with weak inversions.

5. Layers aloft were attributed to upslope flow, convergence zones, convective penetrations into the inversion and low-level marine layer intrusions in the late afternoon.

6. Comparisons of the aerosol loading in the three passes (San Gabriel, Cajon and Soledad Canyon) showed clearly that San Gorgonio Pass tended to carry by far the heaviest aerosol loading during the afternoon.

7. Impact of aerosols into the Mojave Desert and the Coachella Valley from the South Coast Air Basin were observed. Downwind of San Gorgonio and Cajon Passes, the top of the aerosol layer frequently descended markedly as a result of lee-wave flow and divergence. Farther downwind this shallow layer frequently broke up into a deeper, convective layer as a result of surface heating. The morning of July 31, 1981 showed very high aerosol loadings in the Coachella Valley with surface visibilities of 5-7 miles in the forenoon. This followed a strong advection of pollutants from the South Coast Air Basin on July 30. High humidities in the Valley may also have contributed to the large back-scatter values.

8. Estimates of divergence from San Gorgonio Pass into the desert suggest that the depth of the mixing layer decreases proportionately less than does the concurrent aerosol loading. This apparently results from dilution of the pollutant layer with cleaner desert air.

5.2 Potential Use of the Lidar Systems

1. Aircraft lidar data are potentially a very important tool for air pollution research. The aircraft can cover extensive areas with measurements vertically throughout a deep layer. Correlations between back-scatter and visibility and/or b_{scat} suggest that the data can be used semi-quantitatively, at least. Quantitative use of the data was limited by variations in system operation, variations in aerosol size distribution and by the lack of an adequate technique for quantitative calibration of the back-scatter signals. Attenuation of the lidar signals due to heavy aerosol loading was also observed.

2. The problems in the South Coast Air Basin for which the use of lidar aircraft data is particularly suitable are upslope flow, convergence and divergence zones and the recirculation of pollutants into the basin from layers aloft and from offshore locations. Improved understanding of these phenomena should lead to improvements in modeling. These are all problems which are difficult to approach from a surface observational standpoint.

3. The principal difficulty in analysis of the lidar data was the lack of upper wind data to use in interpreting the source of the aerosol concentrations aloft. This

interpretation would also be easier if the flight paths were arranged to follow the approximate wind direction where feasible.

4. Future flight plans might also consider repeated transects over the same route at regular intervals to evaluate the time evolution of such phenomena as the upslope and/or convergence zone flows.

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