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LIDAR OBSERVATIONS AT 0.7 μ M AND 10.6 μ M WAVELENGTHS
DURING DUSTY INFRARED TEST I (DIRT-I).
ADDITIONAL RESULTS.

JUL 80

12 83

9 Test results dated 1/8/83

BY
10 J. S. / RANDHAWA

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White Sands Missile Range, NM 88002

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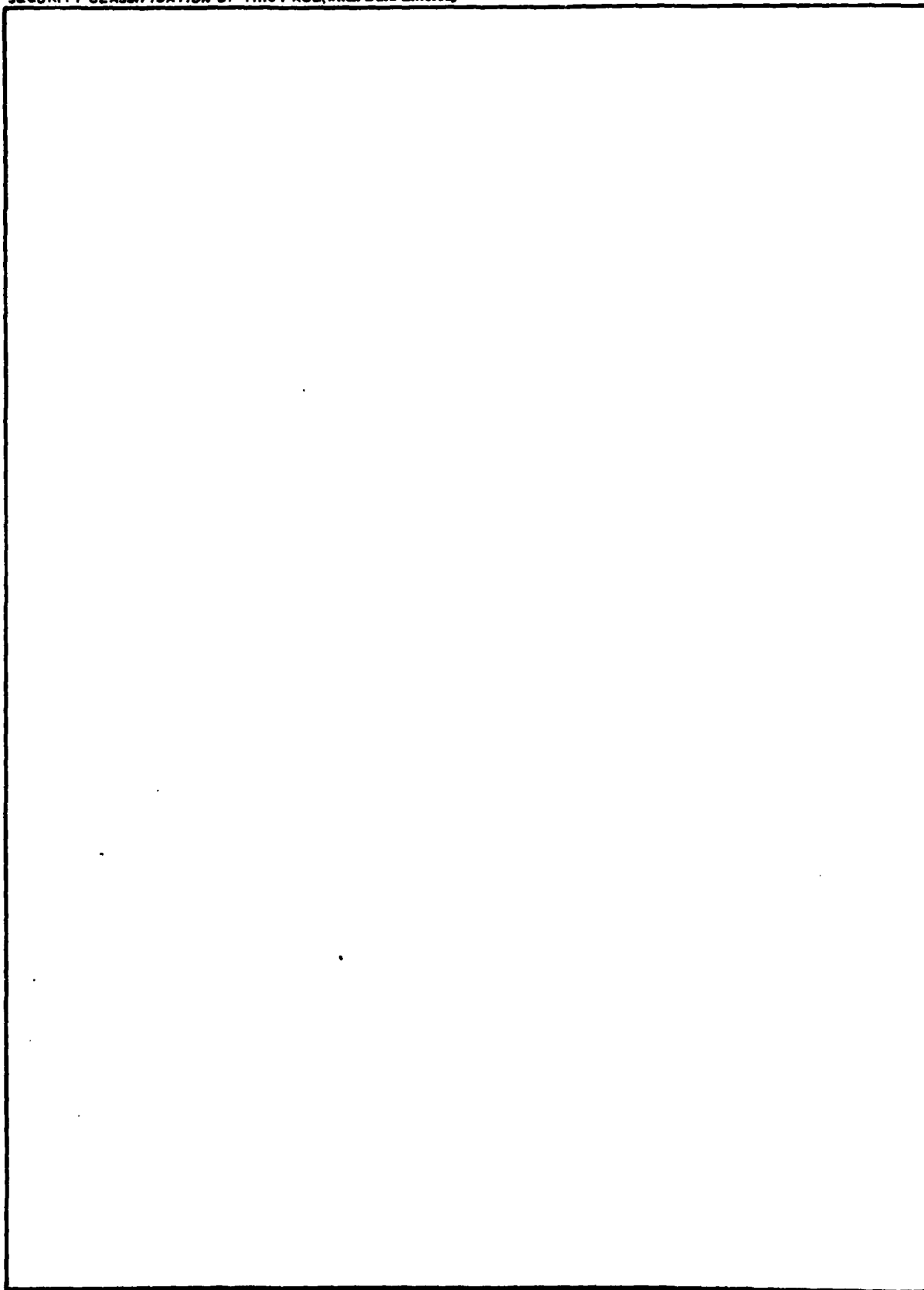
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Two wavelength lidar measurements were made during the Dusty Infrared Test-I (DIRT-I) program conducted at White Sands Missile Range (WSMR) in October 1978. This report contains the additional results obtained during the test but not published in an earlier report.		

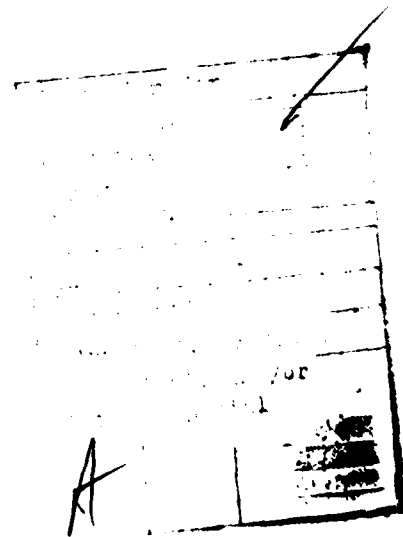
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1. INTRODUCTION

The Dusty Infrared Test I (DIRT-I) was held at White Sands Missile Range (WSMR) in October 1978 to evaluate various techniques to measure physical and optical properties of battlefield dust. Since lidar technique represents one of the most promising techniques, two lidar systems: 10.6 μm wavelength (ASL-lidar) and 0.7 μm Ruby lidar system (Mark IX), were operated over a common 2-km optical path during this test. Primary lidar backscatter data for both wavelengths were recorded on magnetic tape by using Mark IX lidar data system¹ while independent 10.6 μm lidar transmission data were recorded on strip chart in the ASL lidar van. Photographs were also taken every 30 to 60 seconds during each event of range-resolved 10.6 μm backscatter amplitude data (A-Scope presentation). In an earlier report² a few results were described along with the experimental setup, calibration and operating procedures, and analysis technique. This report contains the rest of the results obtained during the test.

2. EXPERIMENT

The two lidar systems were positioned as shown in figure 1. Static TNT charges, artillery rounds, live artillery barrages, and an oil and rubber fire generated dust and smoke cloud in a test zone midway (1 km) between the lidar systems and a beam-stop lidar target.³ Specifications for the 10.6 μm lidar are given in table 1. Table 2 is an inventory and summary of the data collected during the DIRT-I program. In addition to the above data, television video records (video tape) of the lidar optical path were made during each event.

3. DATA

Data gathered by the two lidar systems are presented in figures 2 through 74. Data from October 2 through October 12 show only 10.6 μm lidar backscatter and transmission, with the exception of event C-2 which shows the difference between the Ruby and CO₂ optical depths. Data taken on October 13 and 14 are presented under three categories for each event: (a) 10.6 μm backscatter, (b) percent transmission as observed by the two-wavelengths system, and (c) optical depth difference (Ruby and CO₂).

¹E. E. Uthe and R. J. Allen, 1975, "A Digital Read Time lidar Data Recording, Processing, and Display System," Optical and Quantum Electronics, 7:121

²Jan E. Van der laan, 1979, Lidar Observations at 0.7 μm and 10.6 μm Wavelengths during Dusty Infrared Test-I (DIRT-I), ASL-CR-79-0001-2, US Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM

³James D. Lindberg, 1979, Measured Effects of Battlefield Dust and Smoke on Visible, Infrared and Millimeter Wavelength Propagation: A Preliminary Report on Dusty Infrared Test-I (DIRT-I), ASL Technical Report 0021, White Sands Missile Range, NM

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4. CONCLUSIONS

Results of the DIRT-I program as presented in the earlier report indicate that the broad particle size distribution present in the dust generated at White Sands produces little if any wavelength-dependent transmission effects. The few observed exceptions, where greater 10.6 μ m transmission is indicated, generally can be explained by the presence of wavelength-dependent smoke (which was also generated by the detonations) along the optical path.

TABLE 1. ASL LIDAR SPECIFICATIONS

System Component	Specification	Comments
<u>Transmitter</u>		
Manufacturer	Lumonics Research Ltd., Model TEA-101-2	No nitrogen gas mix
Type	CO ₂	
Wavelength	10.6 μm	
Beam diameter	3.1 cm	
Beam divergence	1.2 mrad	
Operation	pulsed	
Energy	250 mJ	
Pulsewidth	75 ns (FWHM)	
PRF (maximum)	1 pps	
<u>Receiver</u>		
Telescope	12-inch (30 cm), Newtonian	LN ₂ -cooled
Field of view	1.23 mrad	
Detector	Honeywell Associates; HgCdTe photodiode; $D^* = 1.3 \times 10^{10} \text{ cmHz}^{\frac{1}{2}}\text{W}^{-1}$; 100 MHz BW	
Postamplifier	Linear: 26 dB gain, 100 MHz BW	
	Log: tangential sensitivity -111 dBr; ±0.5 dB linearity over 80-dB range; 15-ns rise time	

TABLE 2. LIDAR DATA INVENTORY

Date	Event	Data*					Comments
		1	2	3	4	5	
Oct. 2	A-1	X	✓	✓	✓	✓	X = not available; Mark IX not on site ✓ = data available
	A-2	X	✓	✓	✓	✓	
	A-3	X	✓	✓	✓	✓	
	A-4	X	✓	✓	✓	✓	
Oct. 3	B-1	+	✓	✓	✓	✓	+ = 0.7 μ m data only; two-wavelength inter- face not complete
	B-2	+	✓	✓	✓	✓	
	B-3	+	✓	✓	✓	✓	
	B-4	+	✓	✓	✓	✓	
	B-5	+	✓	✓	✓	✓	
	B-6	+	✓	✓	✓	✓	
	B-7	+	✓	✓	✓	✓	
	B-8	+	✓	✓	✓	✓	
Oct. 5	C-1	✓	✓	✓	✓	✓	
Oct. 6	D-1	✓	✓	✓	✓	X	X = not available; ASL lidar digitizer malfunction
	D-2	✓	✓	✓	✓	X	
	D-3	✓	✓	✓	✓	X	
	D-4	✓	✓	✓	✓	X	
Oct. 10	C-2	✓	✓	✓	✓	✓	
Oct. 11	E-1	✓	✓	✓	✓	✓	
	E-2	✓	✓	✓	✓	✓	
	E-3	✓	✓	✓	✓	✓	
	E-4	✓	✓	✓	✓	✓	
Oct. 12	F-1	✓	✓	✓	✓	X	X = not available ASL lidar digitizer malfunction
	F-2	✓	✓	✓	✓	X	
	F-3	✓	✓	✓	✓	X	
	F-4	-X	-X	-X	-X	-X	
Oct. 13	F-5	✓	✓	✓	✓	✓	-X (F-4) = live 155 mm rounds missed test zone
	F-6	✓	✓	✓	✓	✓	
	F-7	✓	✓	✓	✓	✓	
	F-8	✓	✓	✓	✓	✓	
Oct. 14	E-5	✓	✓	✓	✓	✓	
	E-6	✓	✓	✓	✓	✓	
	E-7	✓	✓	✓	✓	✓	
	E-8	✓	✓	✓	✓	✓	
	E-9	✓	✓	✓	✓	✓	
Oct. 14	G-1	✓	✓	X	✓	✓	

- * 1. Digitized 0.7 and 10.6 μ m range-resolved backscatter data; 9-track magnetic tape.
 2. 10.6 μ m target return amplitude data; strip chart recordings.
 3. 10.6 μ m digitized target return data; IBM card/tape format.
 4. 10.6 μ m energy output; strip chart recordings.
 5. 10.6 μ m range-resolved backscatter; (A-scope) photographs; polaroid sequence.

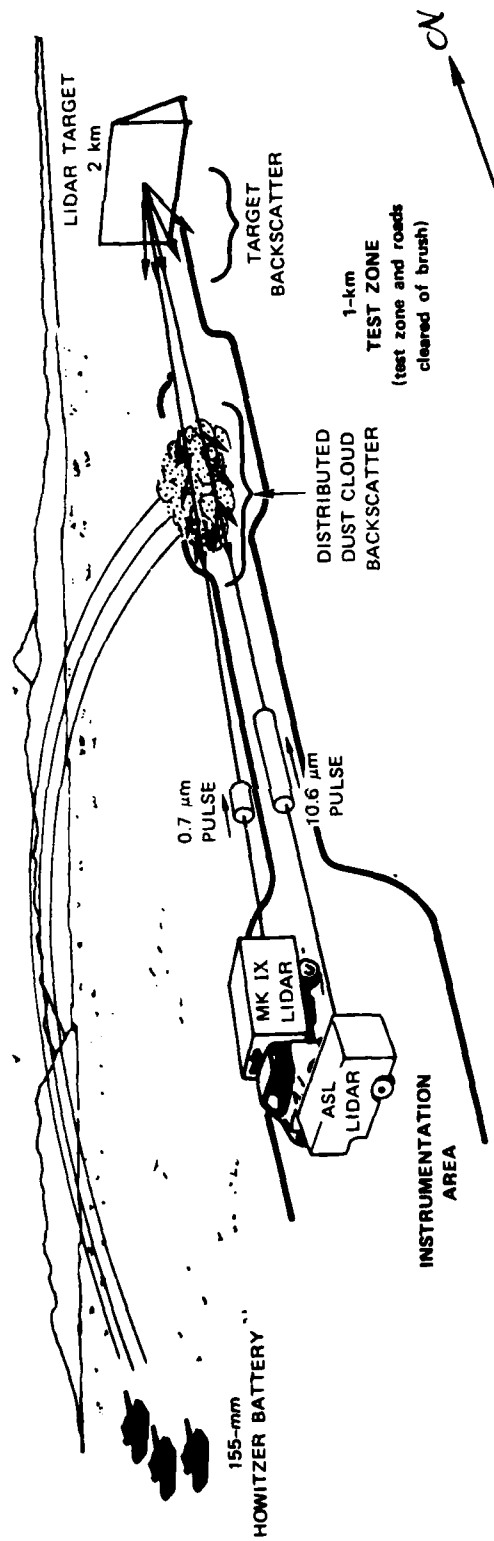


Figure 1. Experimental configuration for two-wavelength lidar observations - DIRT-1.

2 OCTOBER 1978 T = 0707 00 MDT

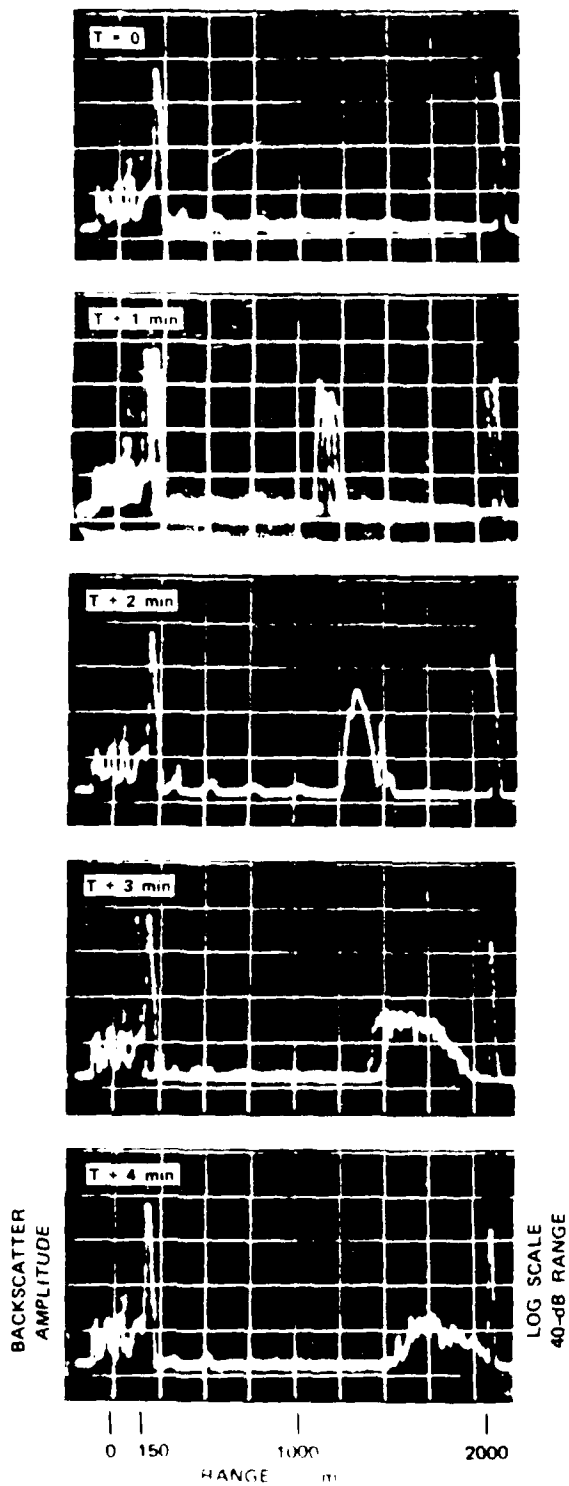


Figure 2. Event A-1 10.0 μ m backscatter data.

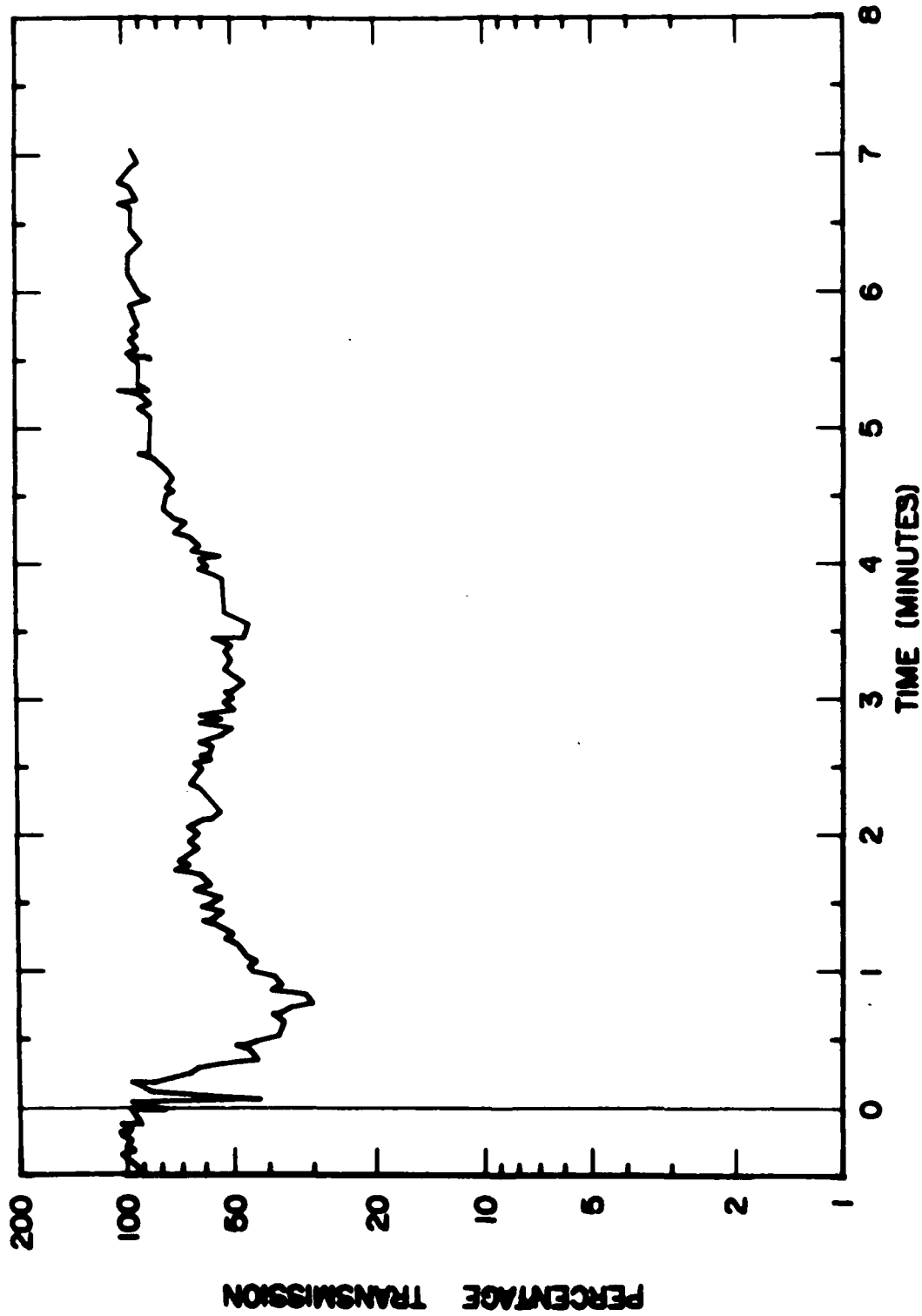


Figure 3. Event A-1 10.6 μ m transmission.

2 OCTOBER 1978 T - 0716 30 MDT

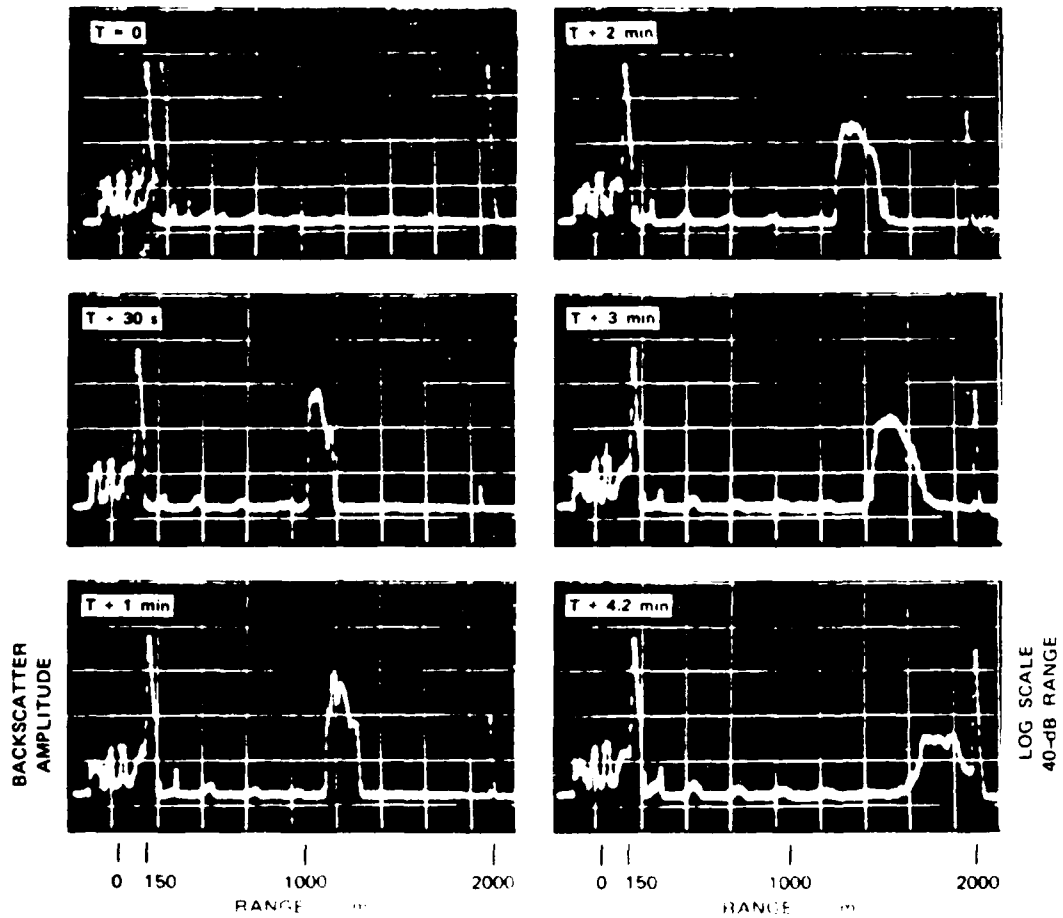


Figure 4. Event A-2 10.6-m backscatter data.

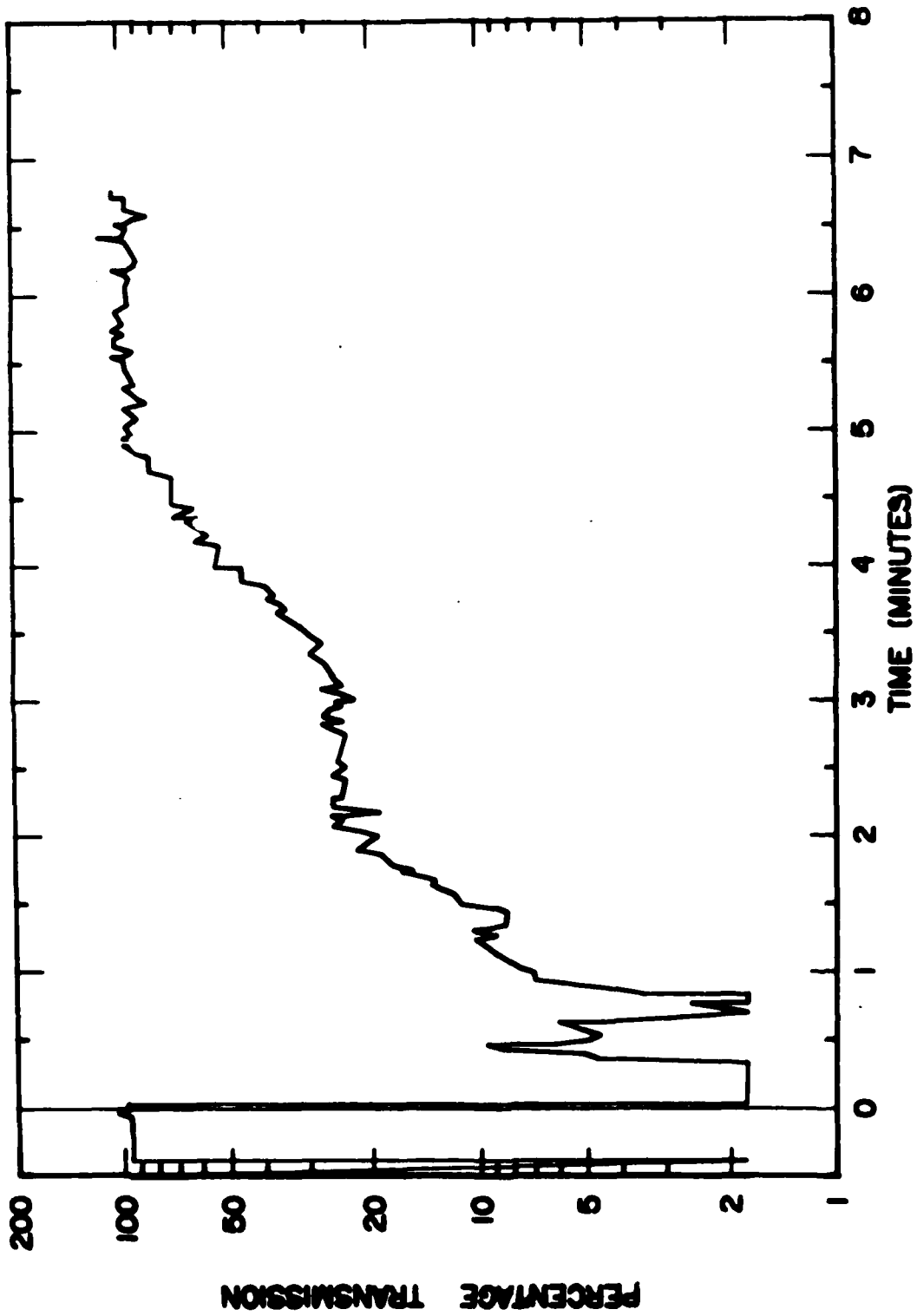


Figure 5. Event A-2 10.6 μ m transmission.

2 OCTOBER 1978 T = 0729 00 MDT

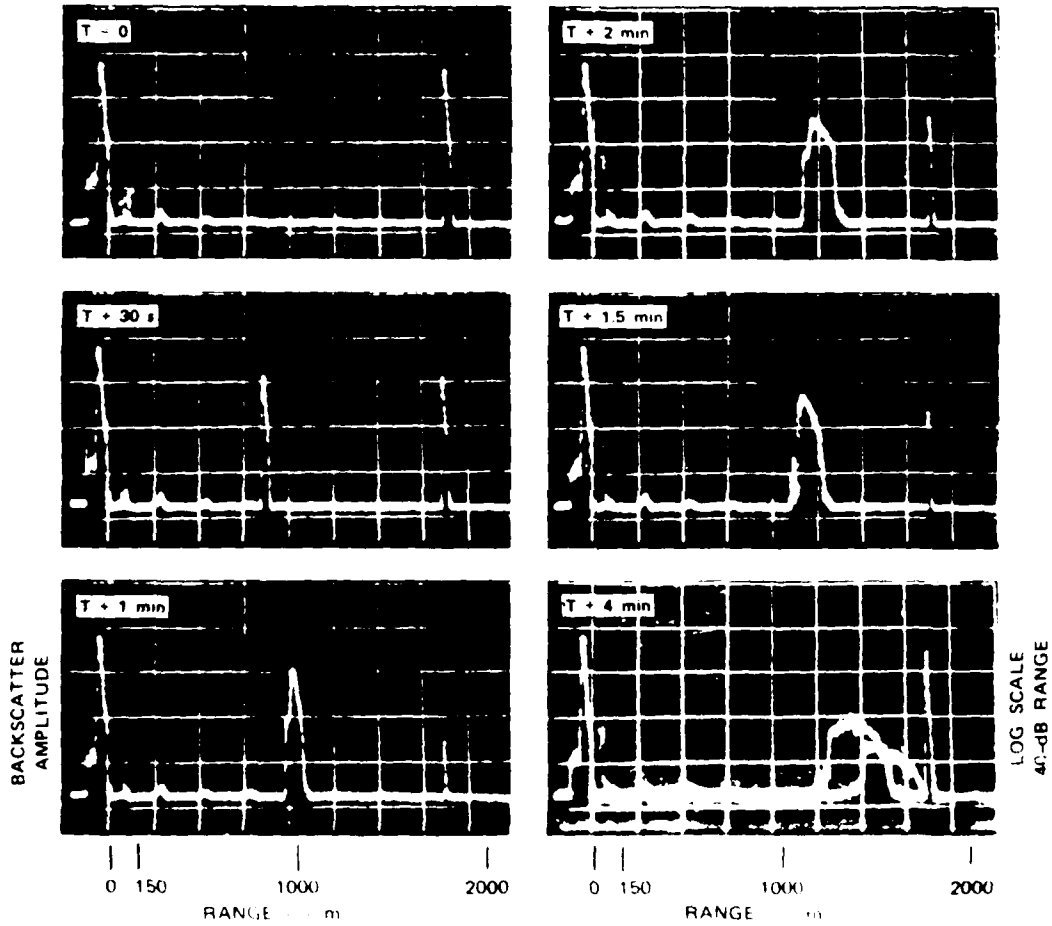


Figure 6. Event A-3 10.6 m backscatter data.

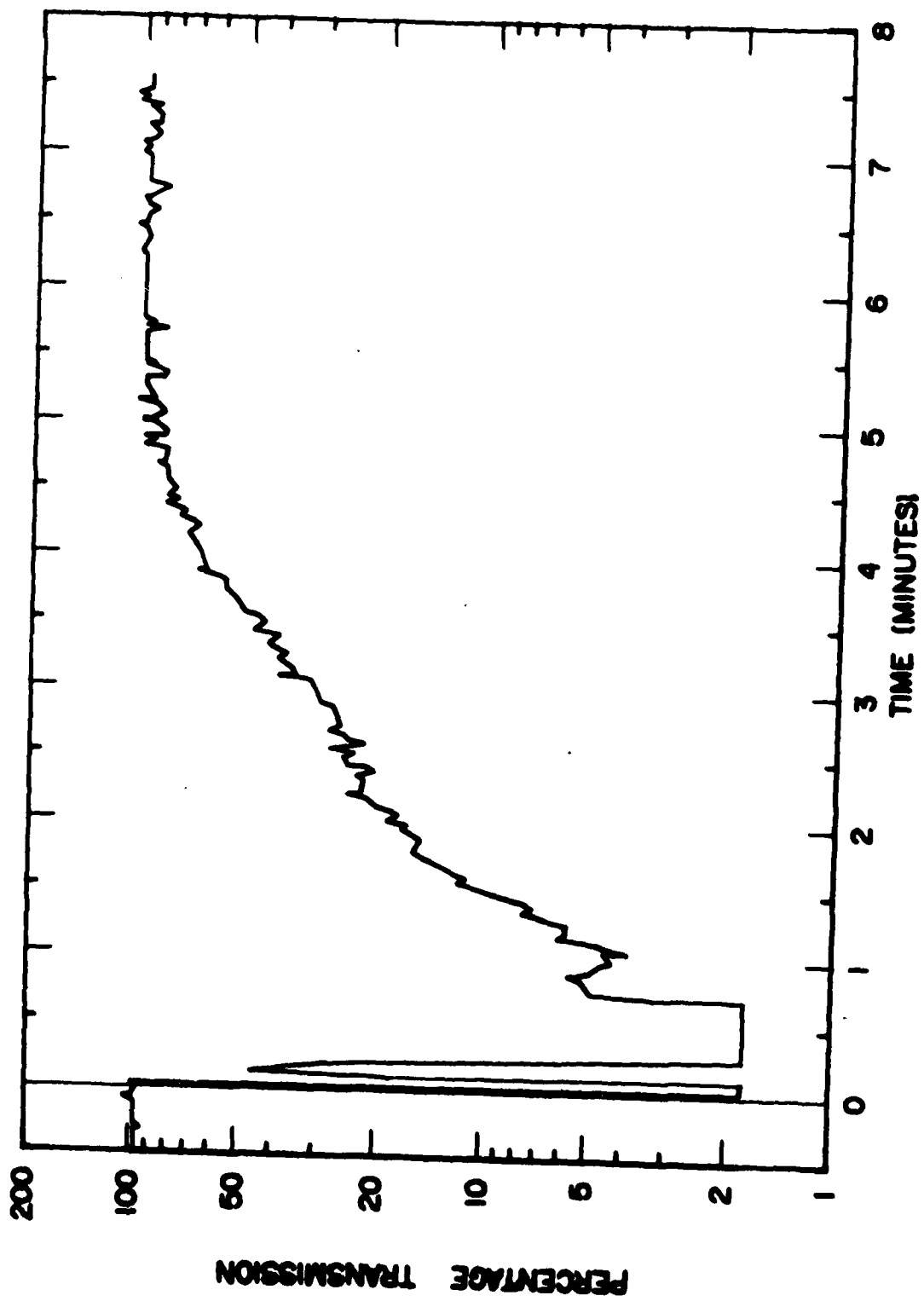


Figure 7. Event A-3 10.6 μ m transmission.

2 OCTOBER 1978 T = 0739 56 MDT

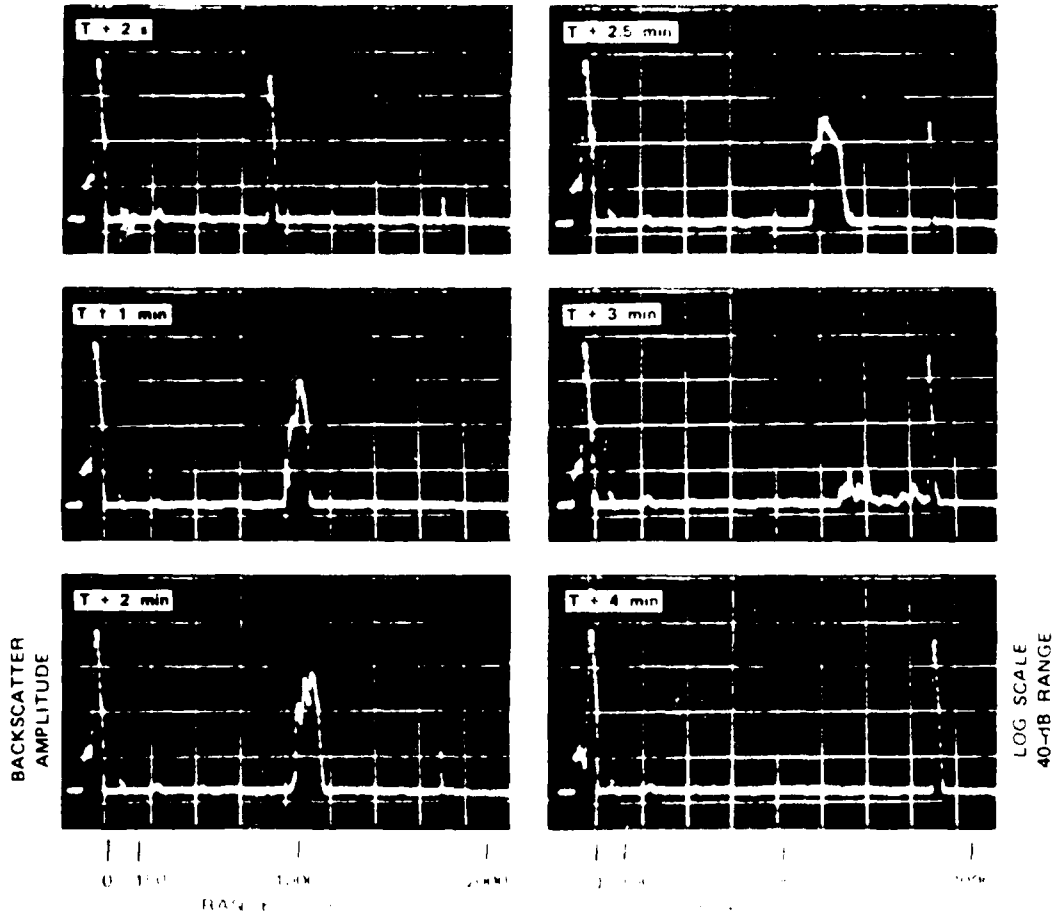


Figure 8. Plot of A-4, 10, 6, m. Data collected on 2 Oct 1978.

3 OCTOBER 1978 T - 0710 00 MDT

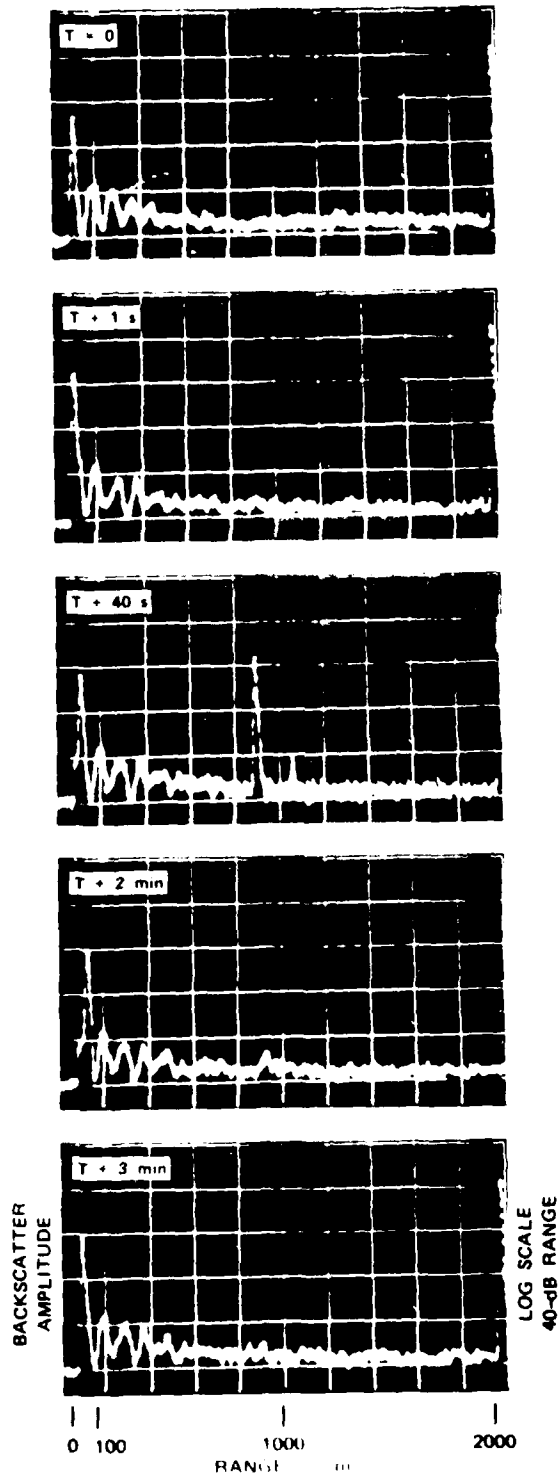


Figure 9. Event B-1 10.6 m backscatter data.

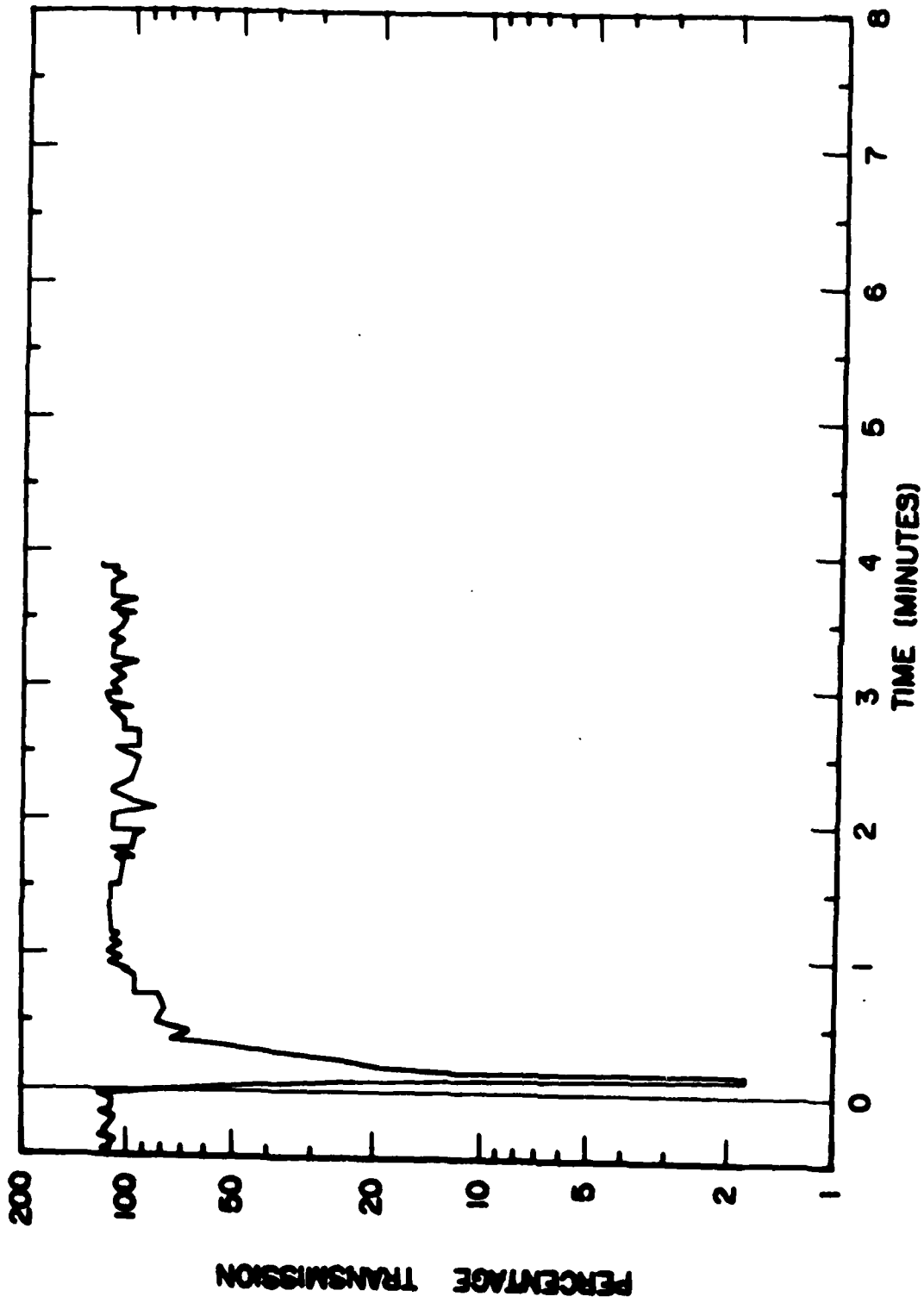


Figure 10. Event B-1 10.6 μ m transmission.

3 OCTOBER 1978

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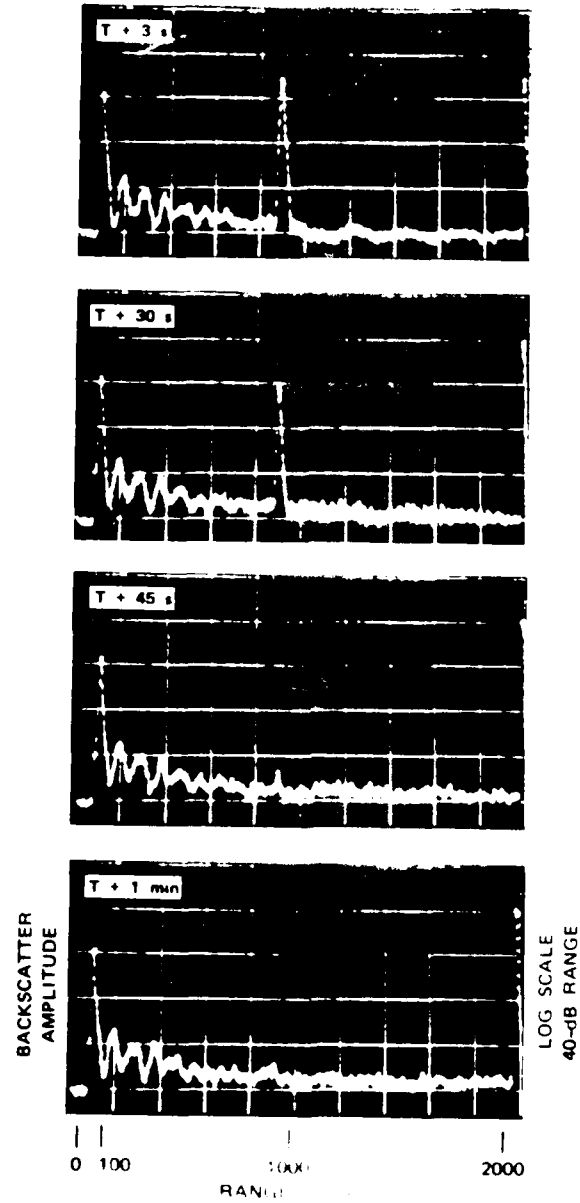


Figure 11. Event Backscatter backscatter data.

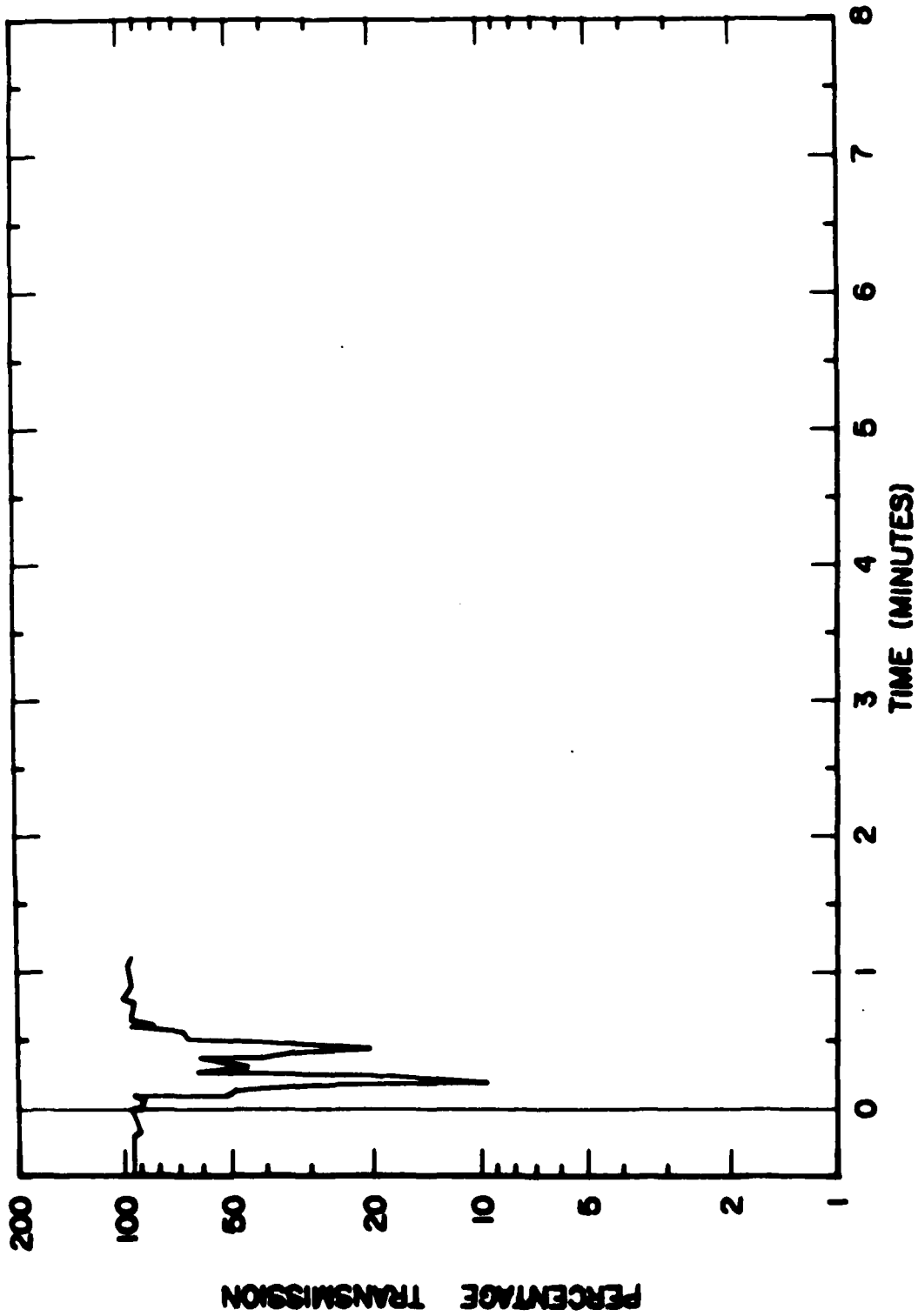


Figure 12. Event B-2 10.6 μ m transmission.

3 OCTOBER 1978 T = 0731.00 MDT

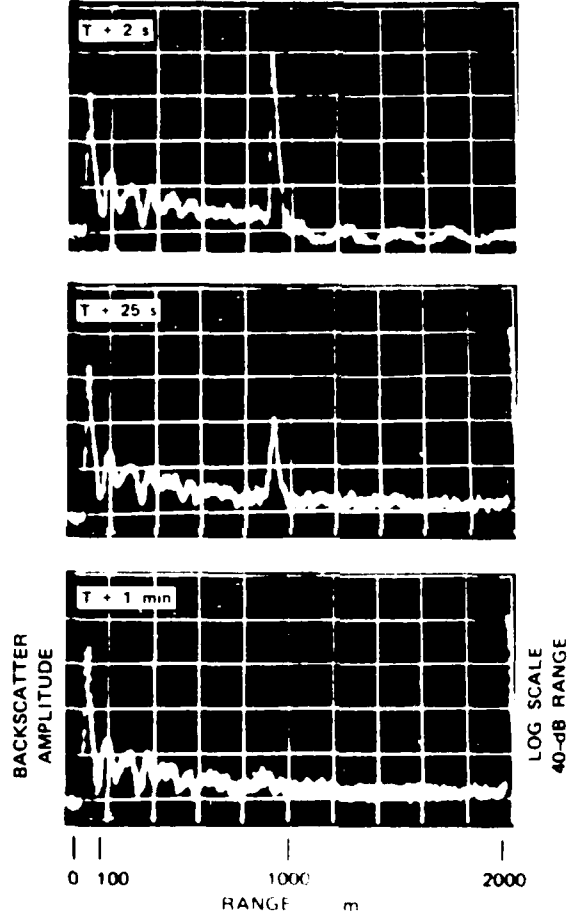


Figure 13. Event B-3 10.6 μ m backscatter data.

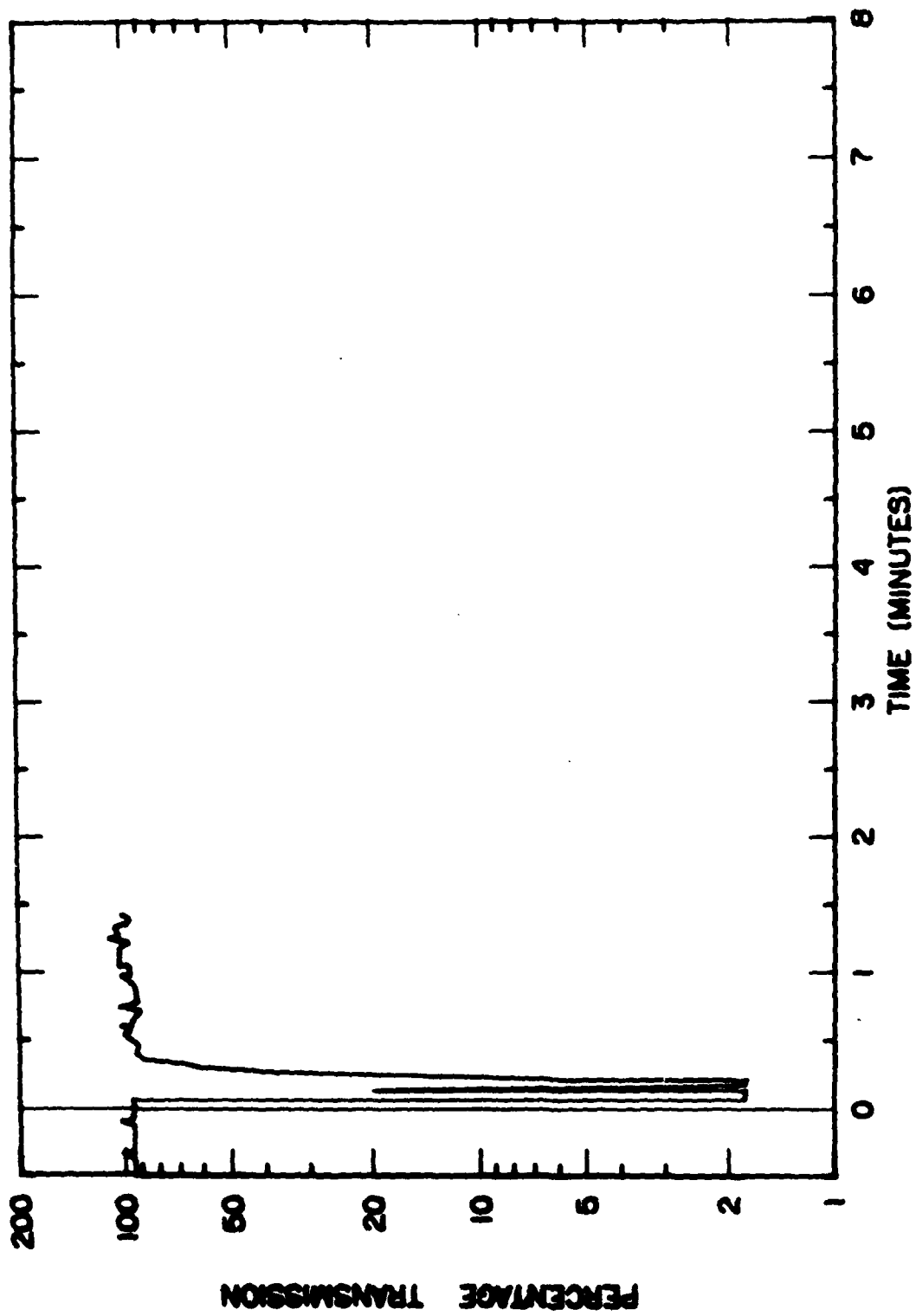


Figure 14. Event B-3 10.6 μ m transmission.

3 OCTOBER 1978 1 - 0741 10 MDT

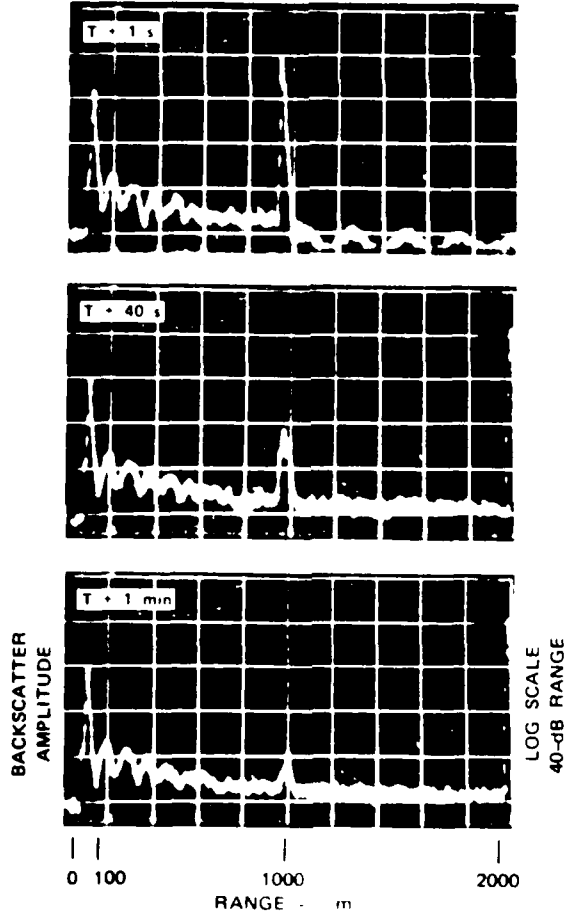


Figure 15. Event B-4 10.6 μ m backscatter data.

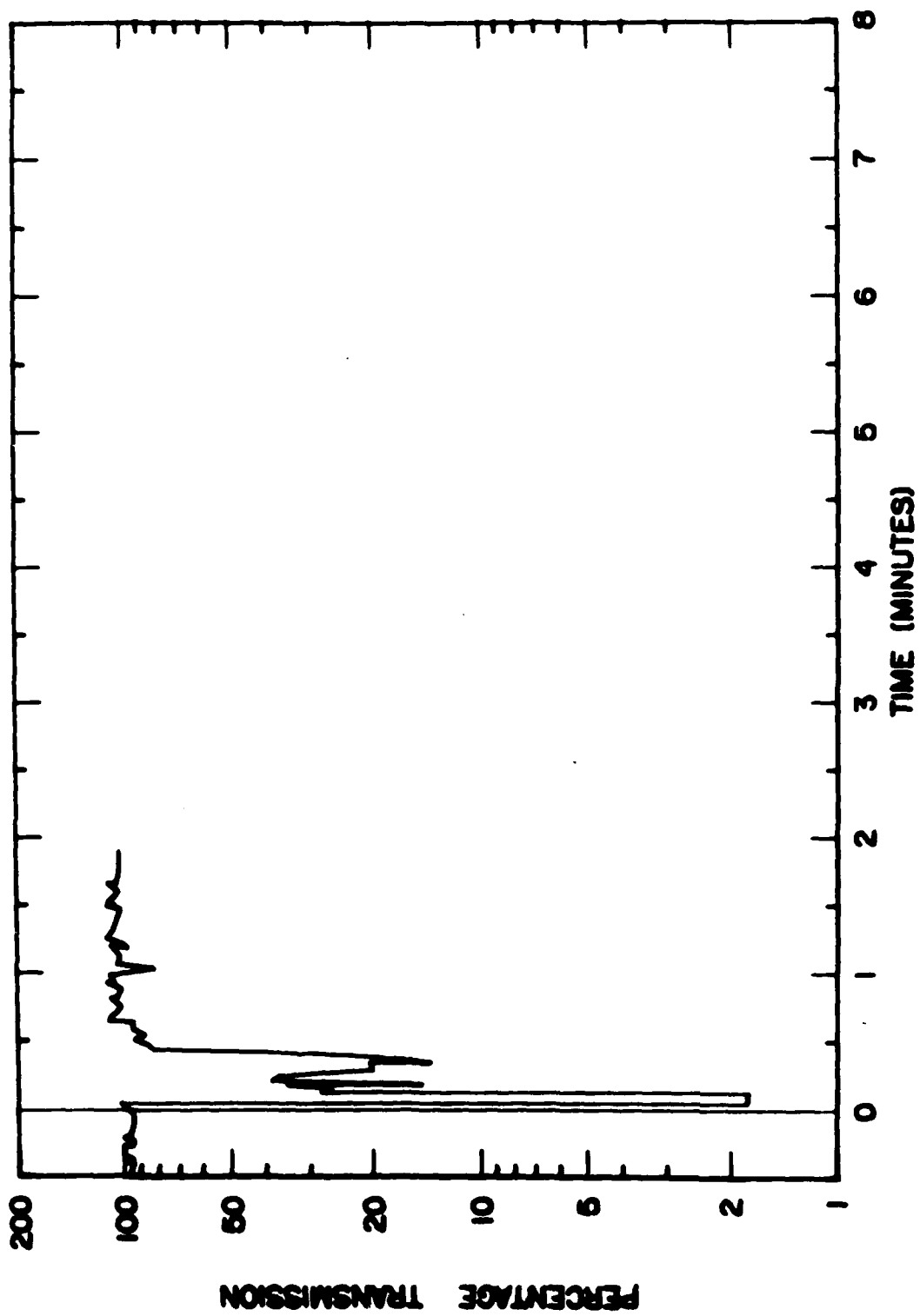


Figure 16. Event B-4 10.6 μ m transmission.

3 OCTOBER 1971

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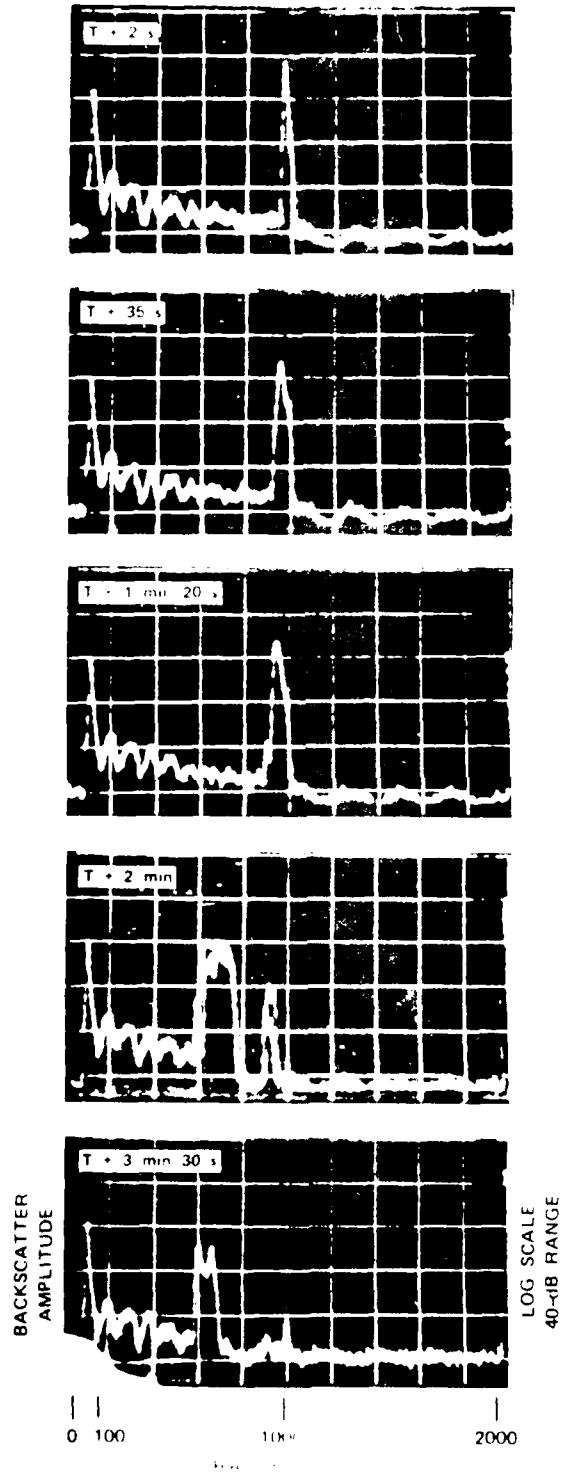


Figure 1. Backscatter data.

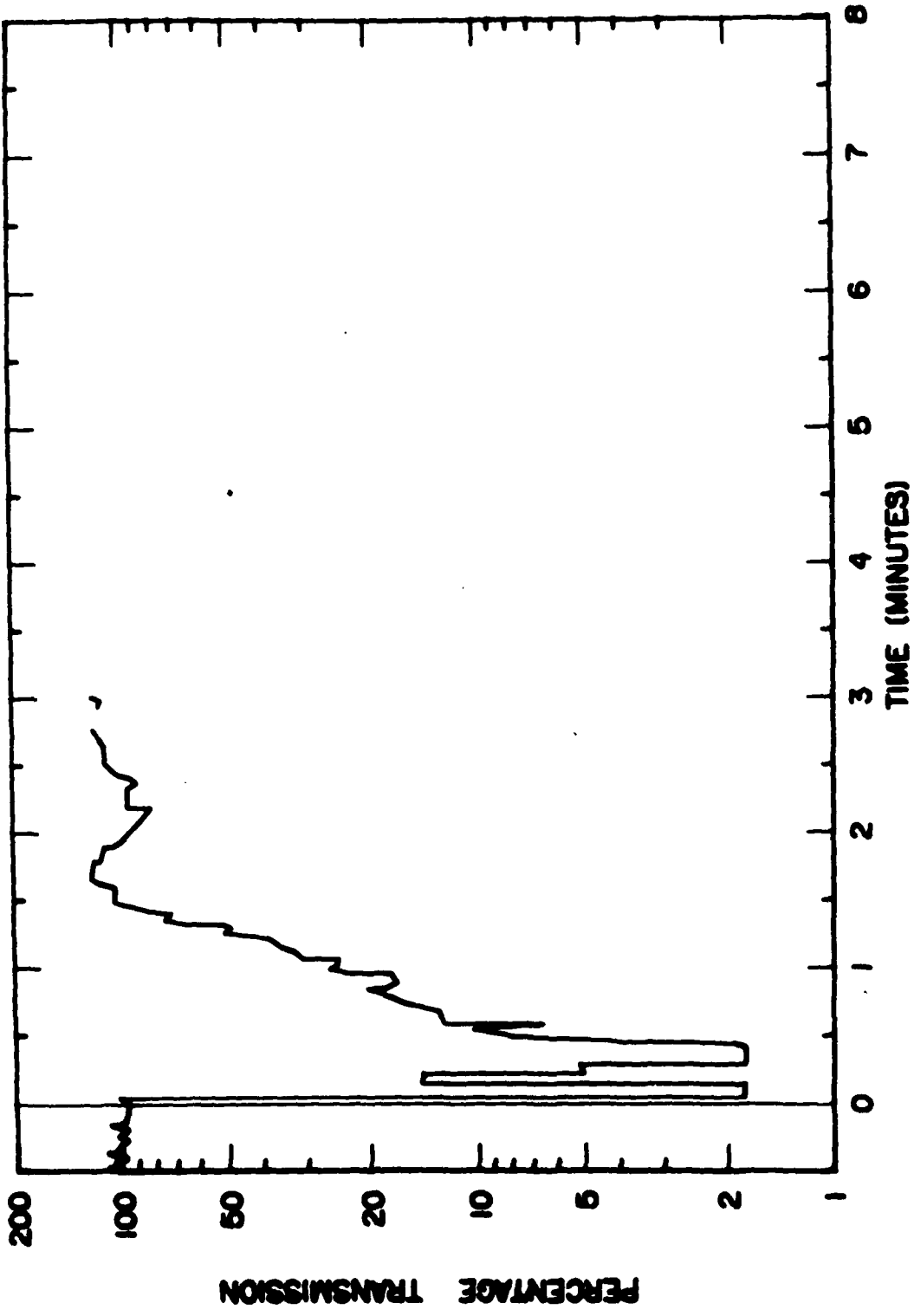


Figure 18. Event B-5 10.6µm transmission.

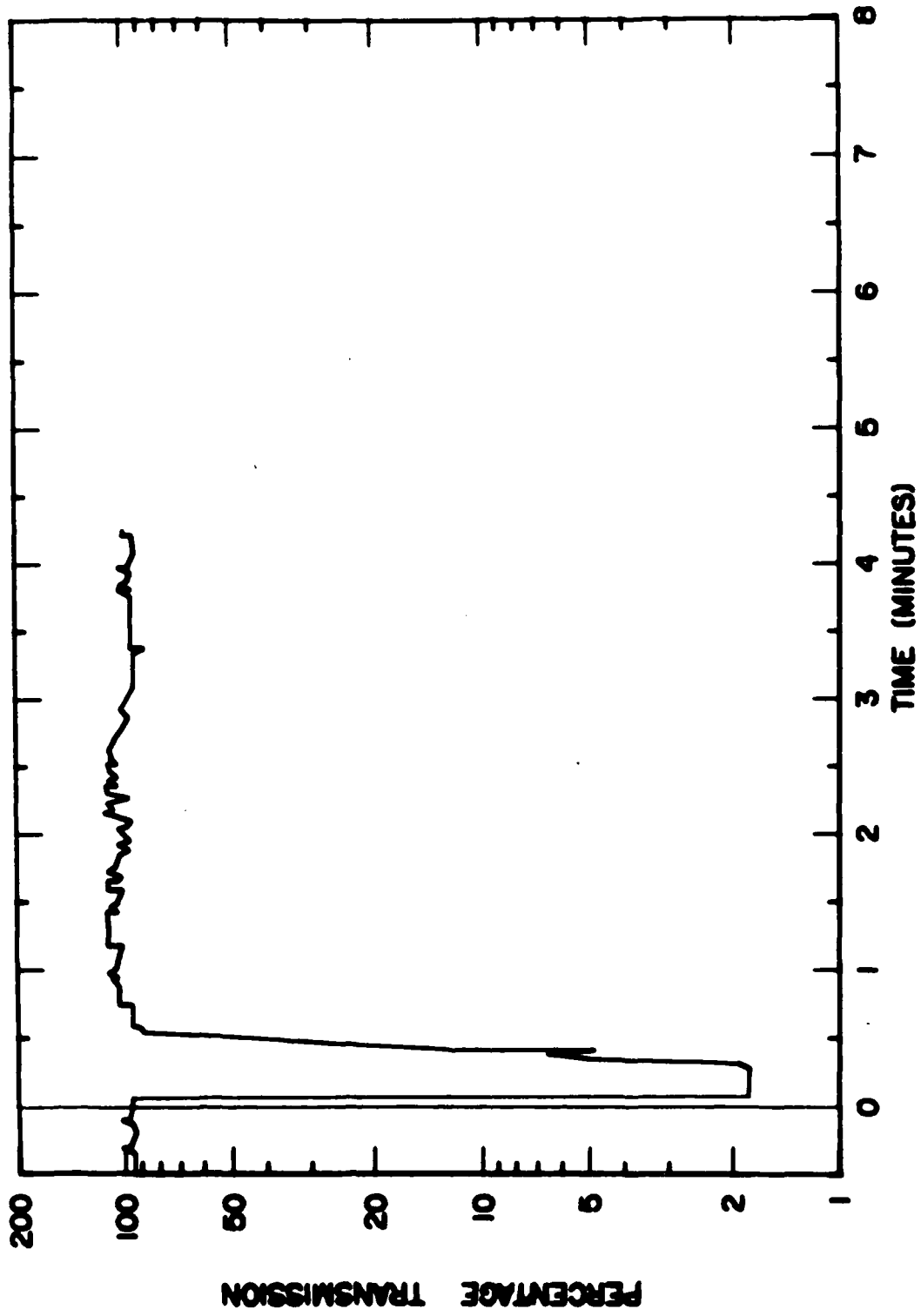
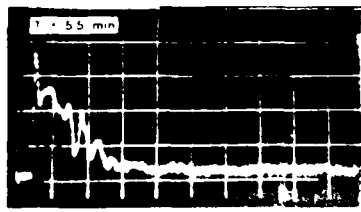
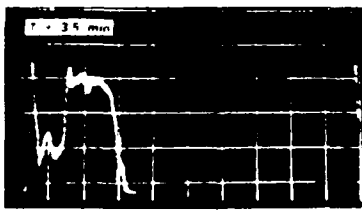
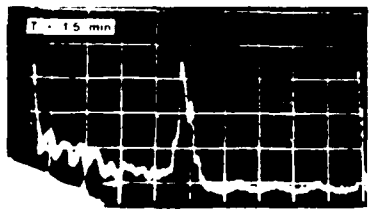
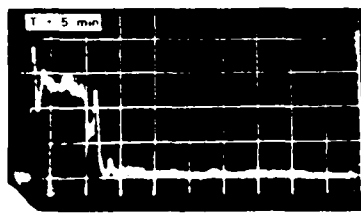
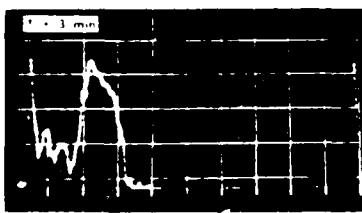
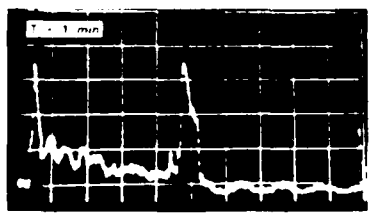
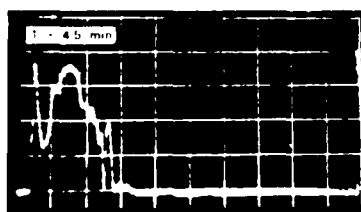
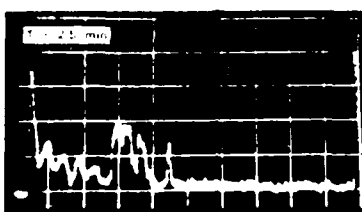
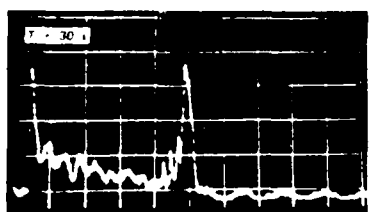
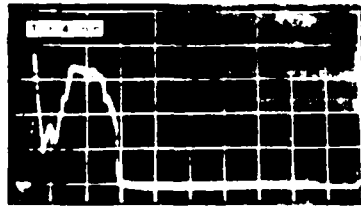
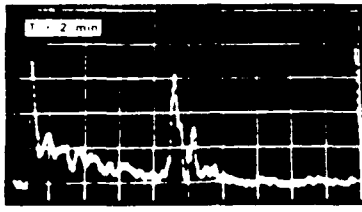
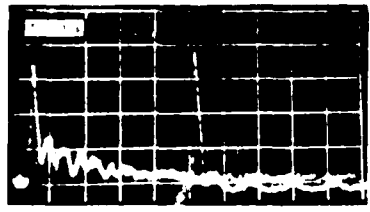


Figure 19. Event B-6 10.6µm transmission.

3 OCTOBER 1968 T = 0815:00 MDT



WAVELENGTH

WAVELENGTH

WAVELENGTH

SPECTRAL INTENSITY

SPECTRAL INTENSITY

Figure 1. Spectral intensity versus wavelength for various times.

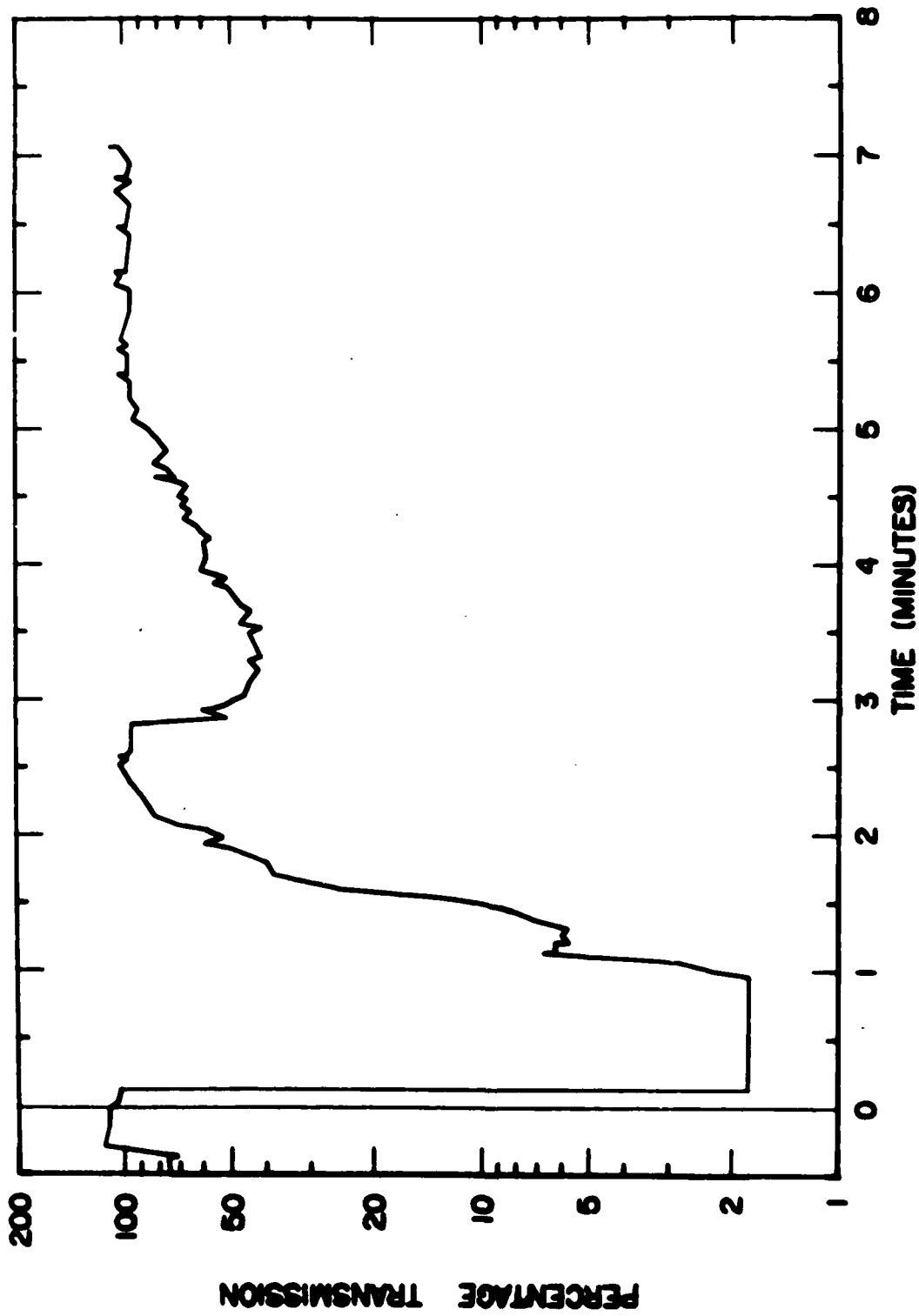
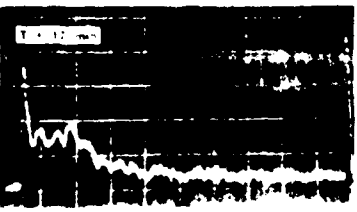
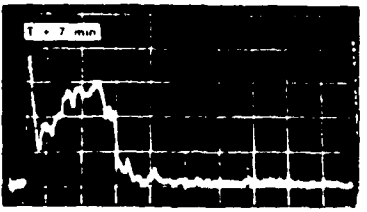
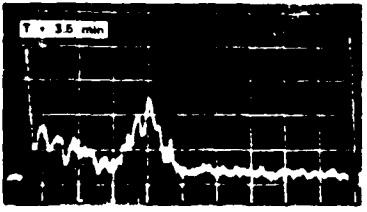
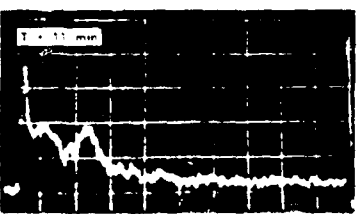
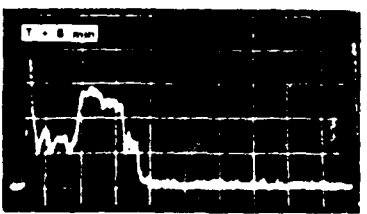
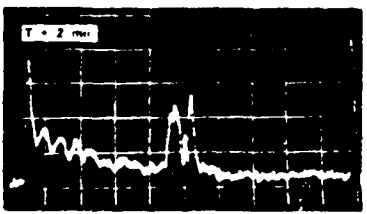
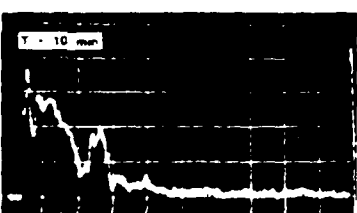
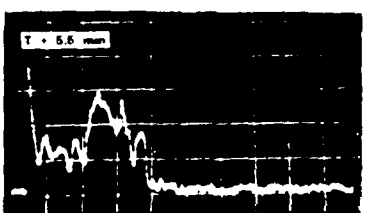
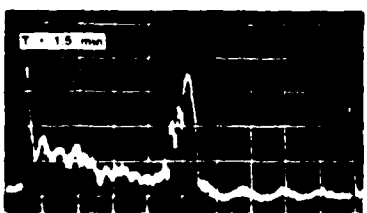
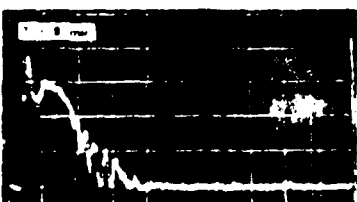
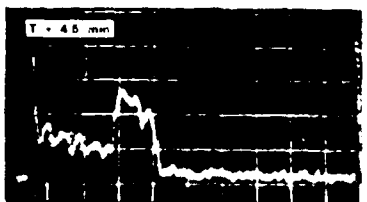
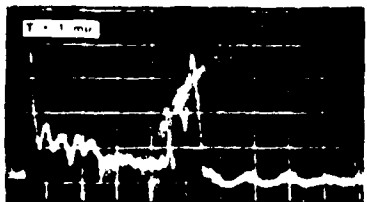
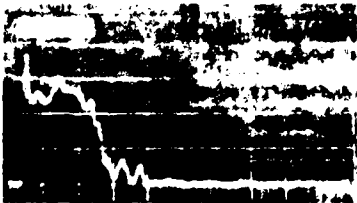
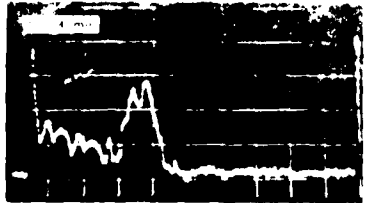


Figure 21. Event B-7 10.6µm transmission.

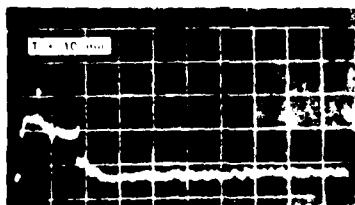
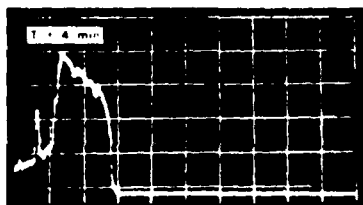
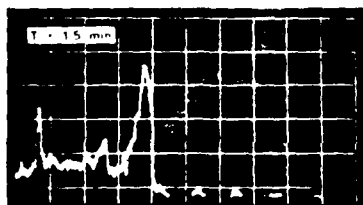
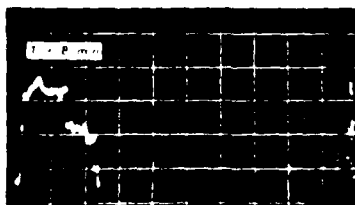
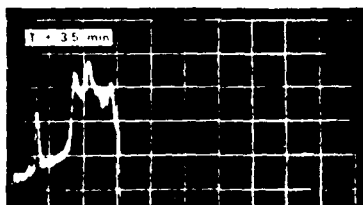
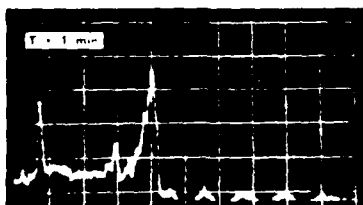
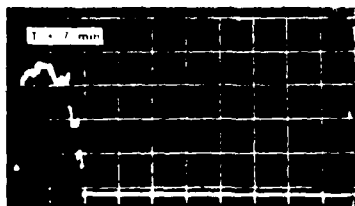
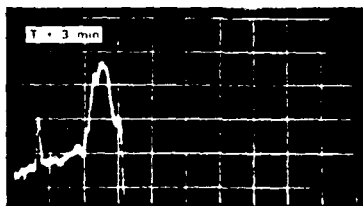
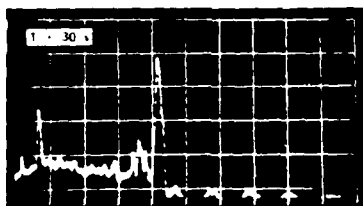
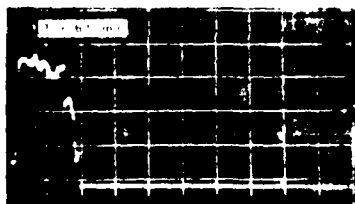
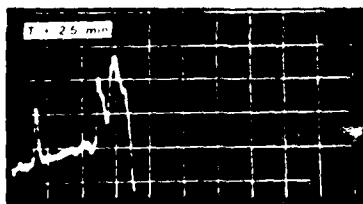
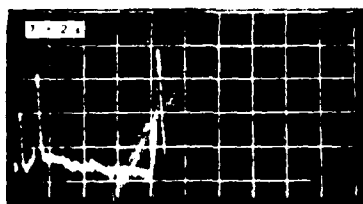
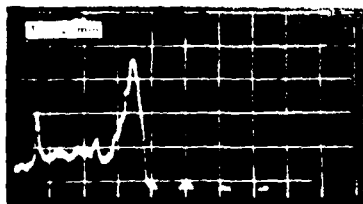
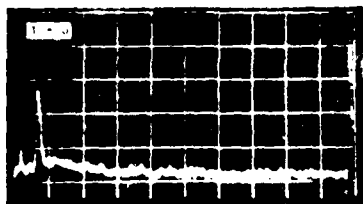
3 OCTOBER 1988 T = 0828.45 UT



KSCA
AMPLIT. 1

1.00

UN TOBE 1978 T = 0712 4 M27



BACKSCATTERED AMPLITUDE

0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

Figure 1. Backscattered amplitude vs. time for various times.

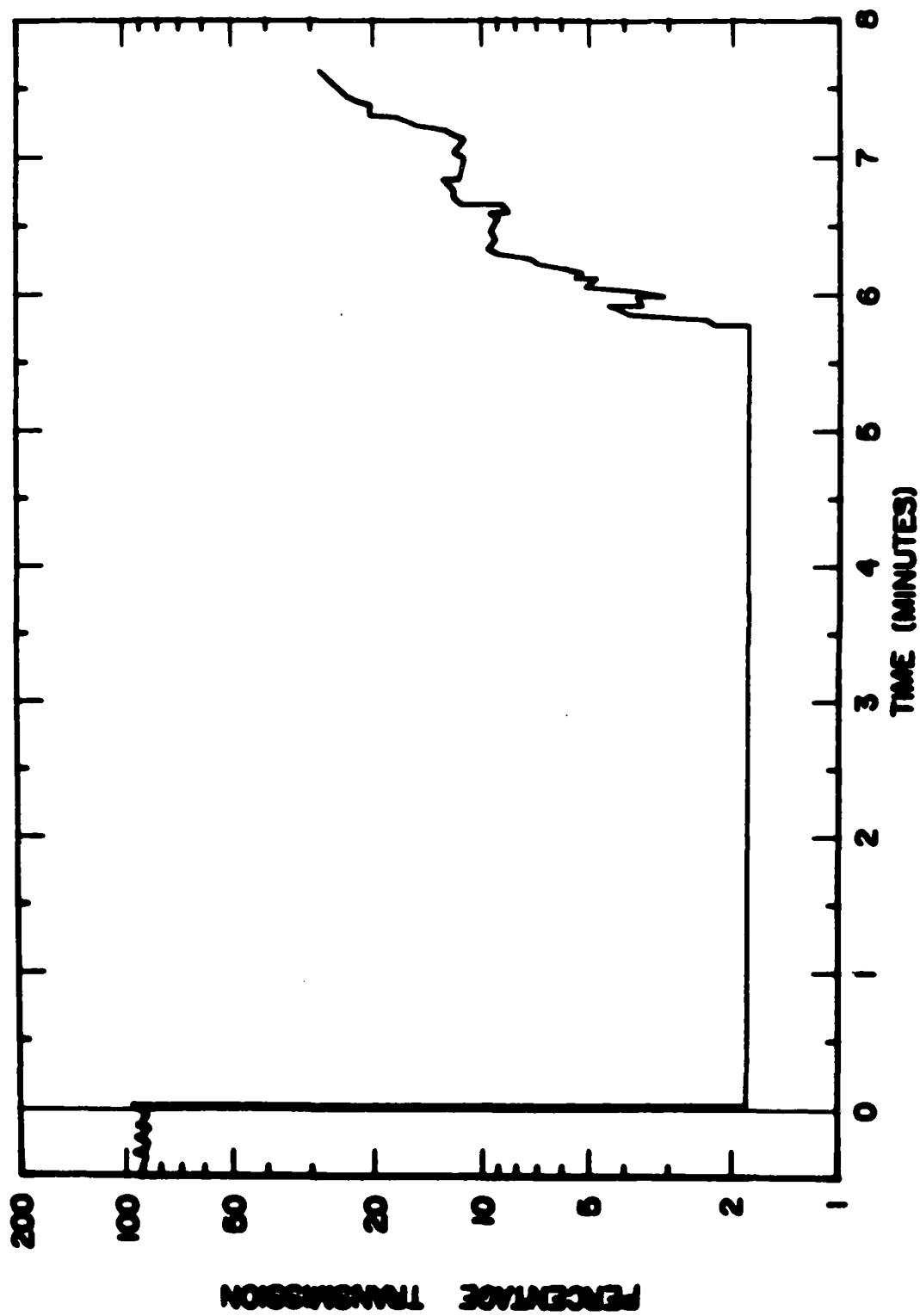


Figure 24. Event C-1 10.6 μ m transmission.

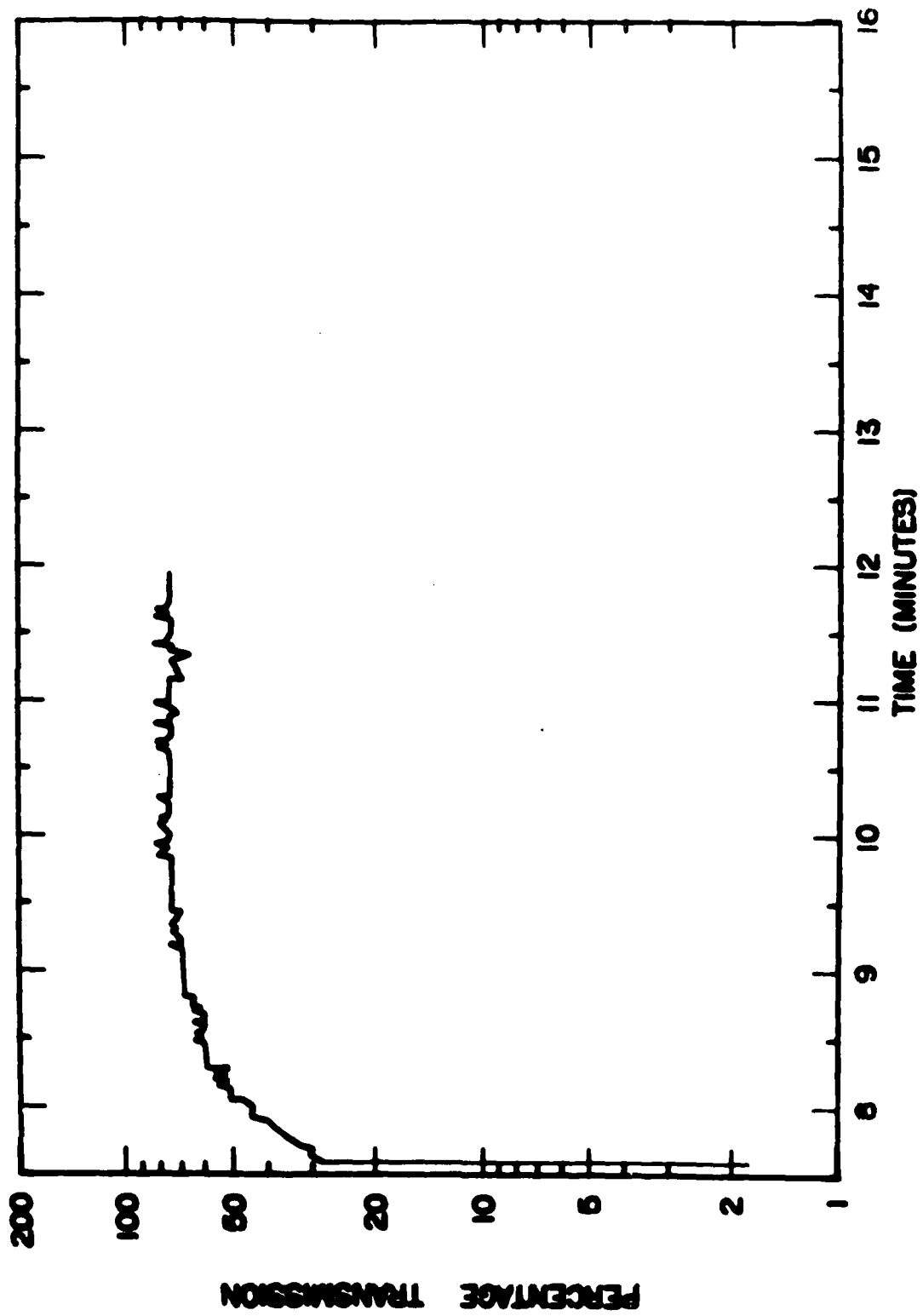


Fig. 25 (cont)

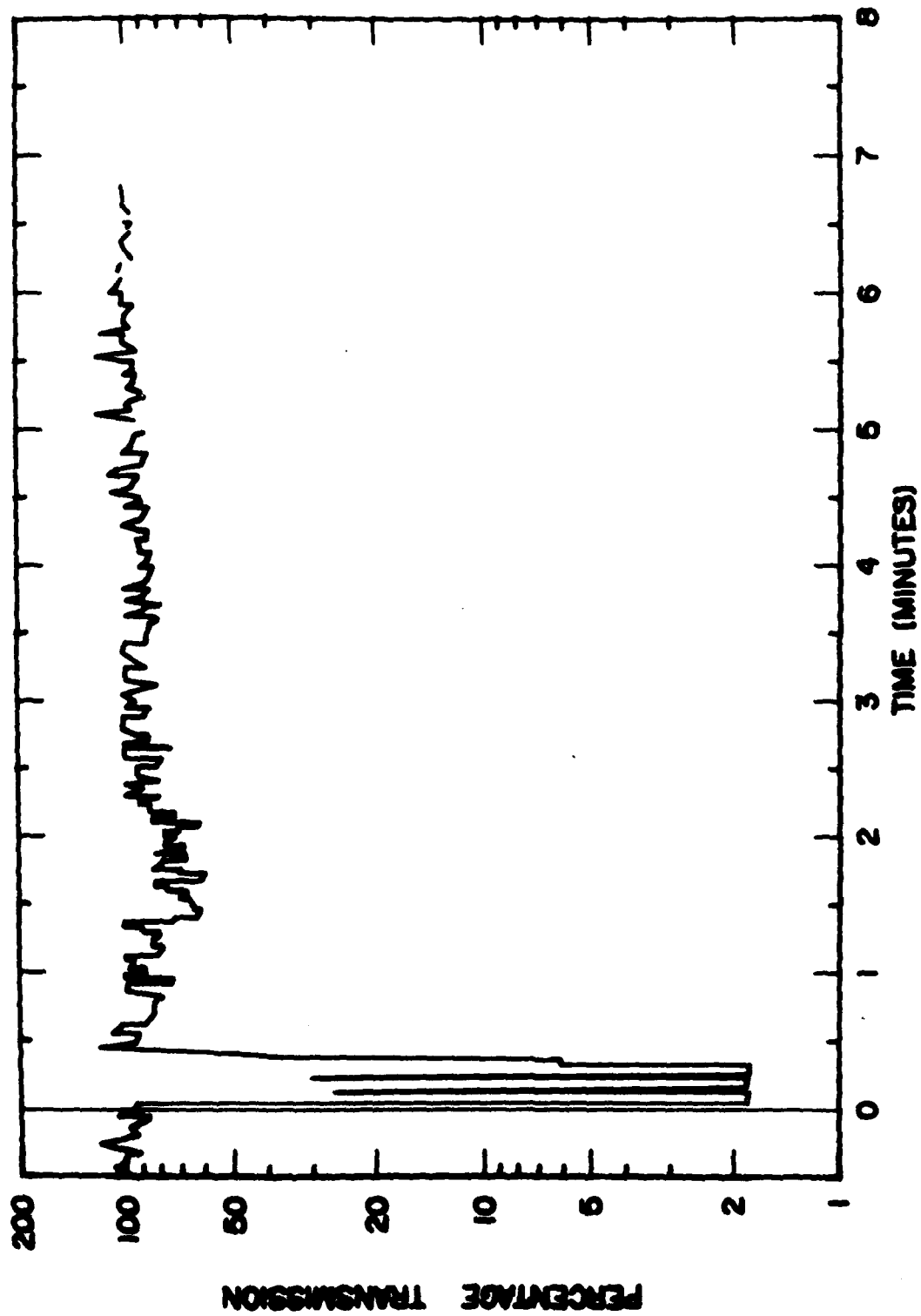


Figure 26. Event D-1 10.6 μ m transmission.

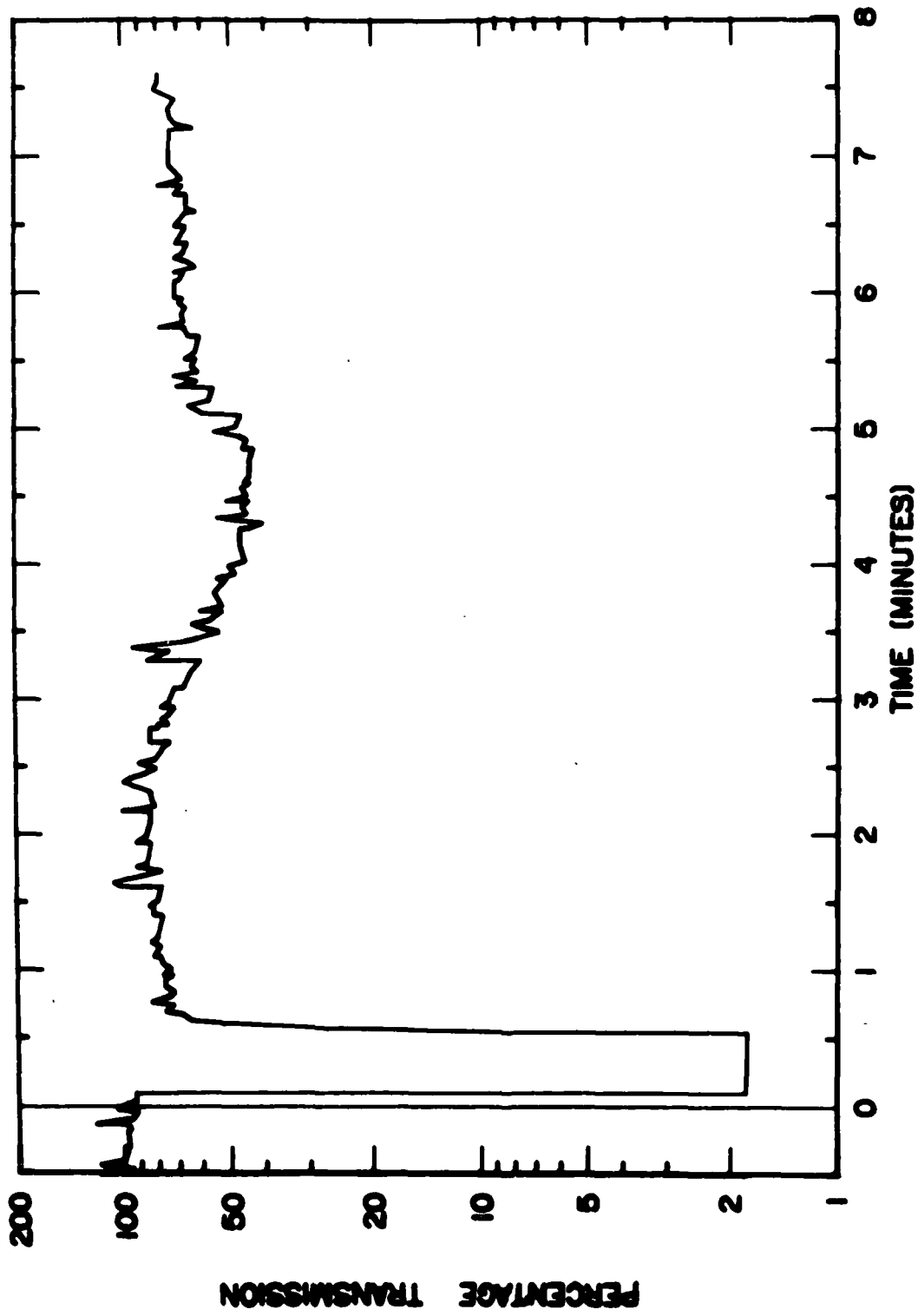


Figure 27. Event D-2 10.6 μ m transmission.

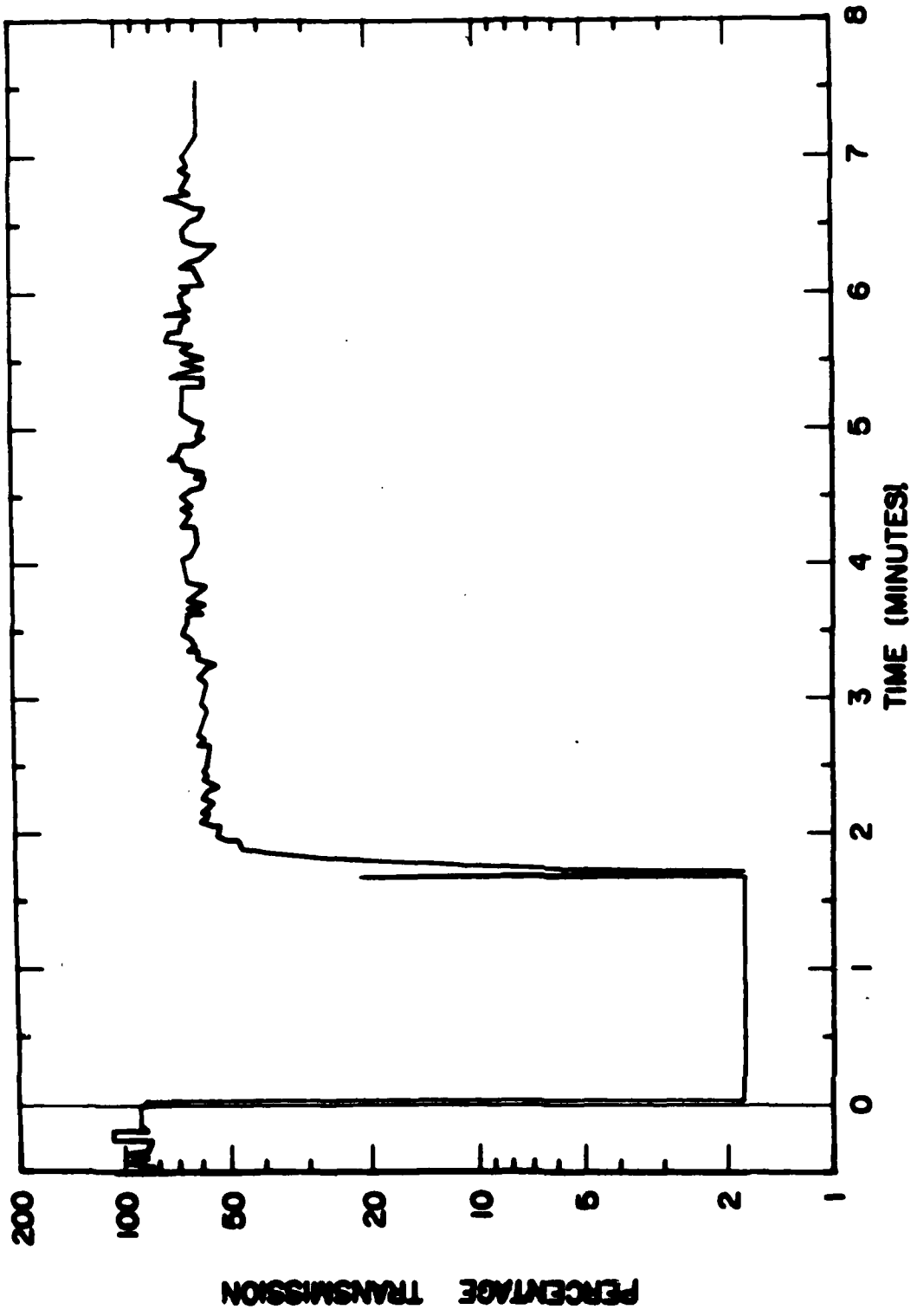


Figure 28. Event D-3 10.6 μ m transmission.

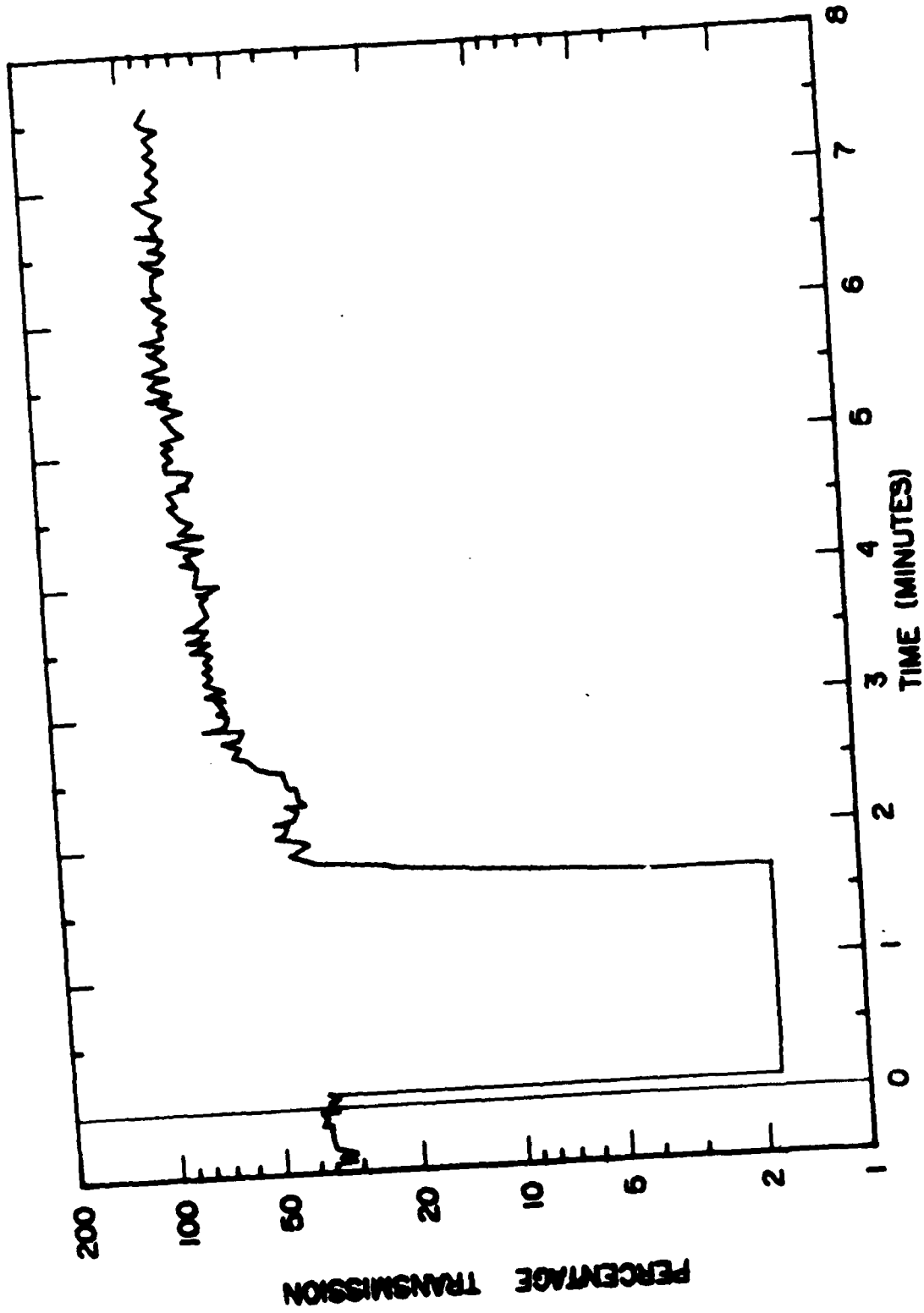


Figure 29. Event D-4 10.6 μ m transmission.

10 OCTOBER 1971 11:00 MET

BACKSCATTER
AMPLITUDE

Y-axis SCALE
X-axis RANGE

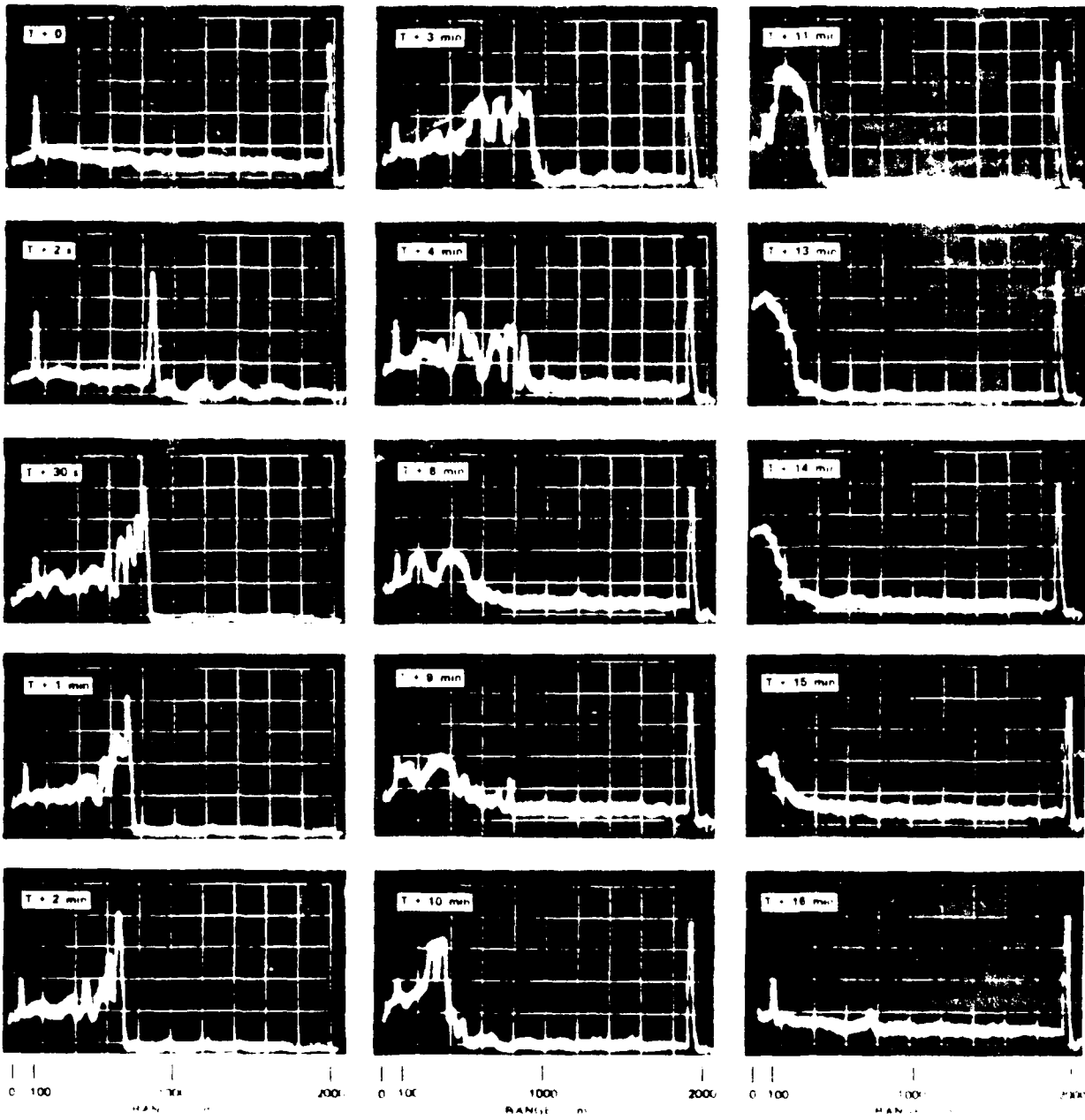


Figure 1. Backscatter amplitude (dBZ) vs. range (km) for the 10 October 1971 storm.

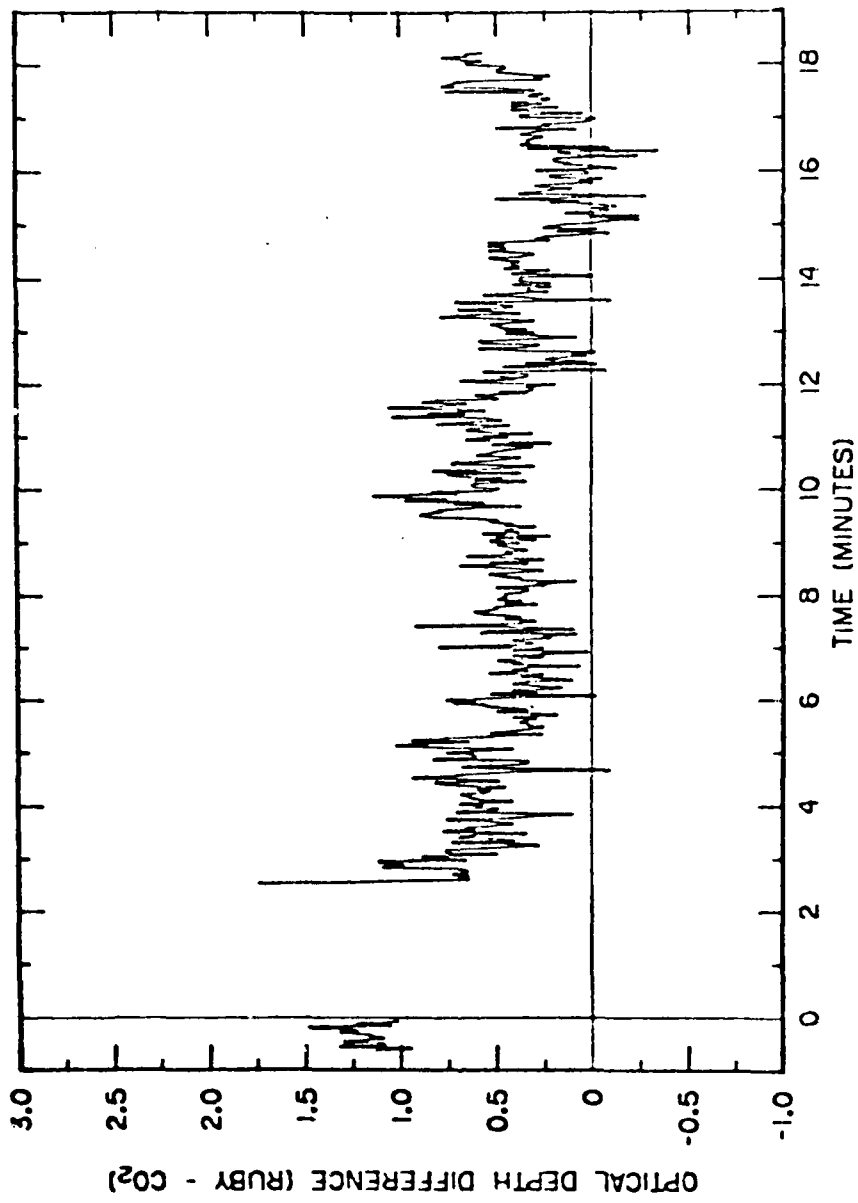


Figure 31. Difference between Ruby and CO₂ optical depths (C-1).

11 OCTOBER 1978

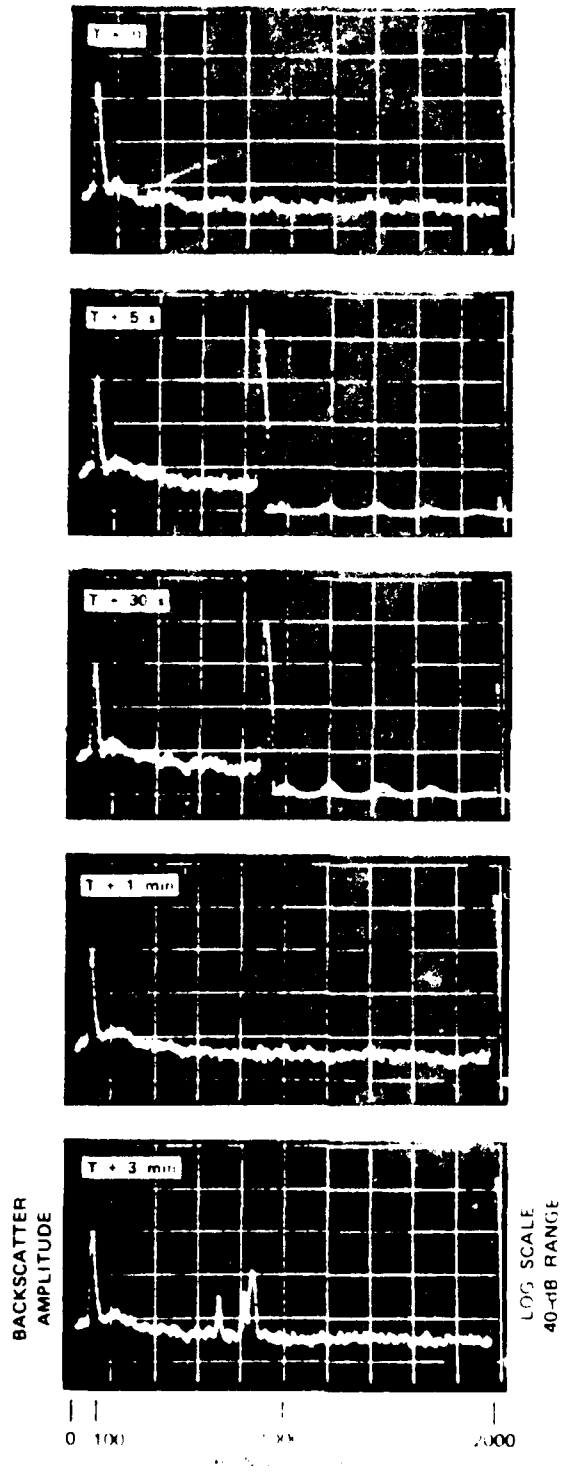


Figure 3. Backscatter amplitude vs. log scale range data.

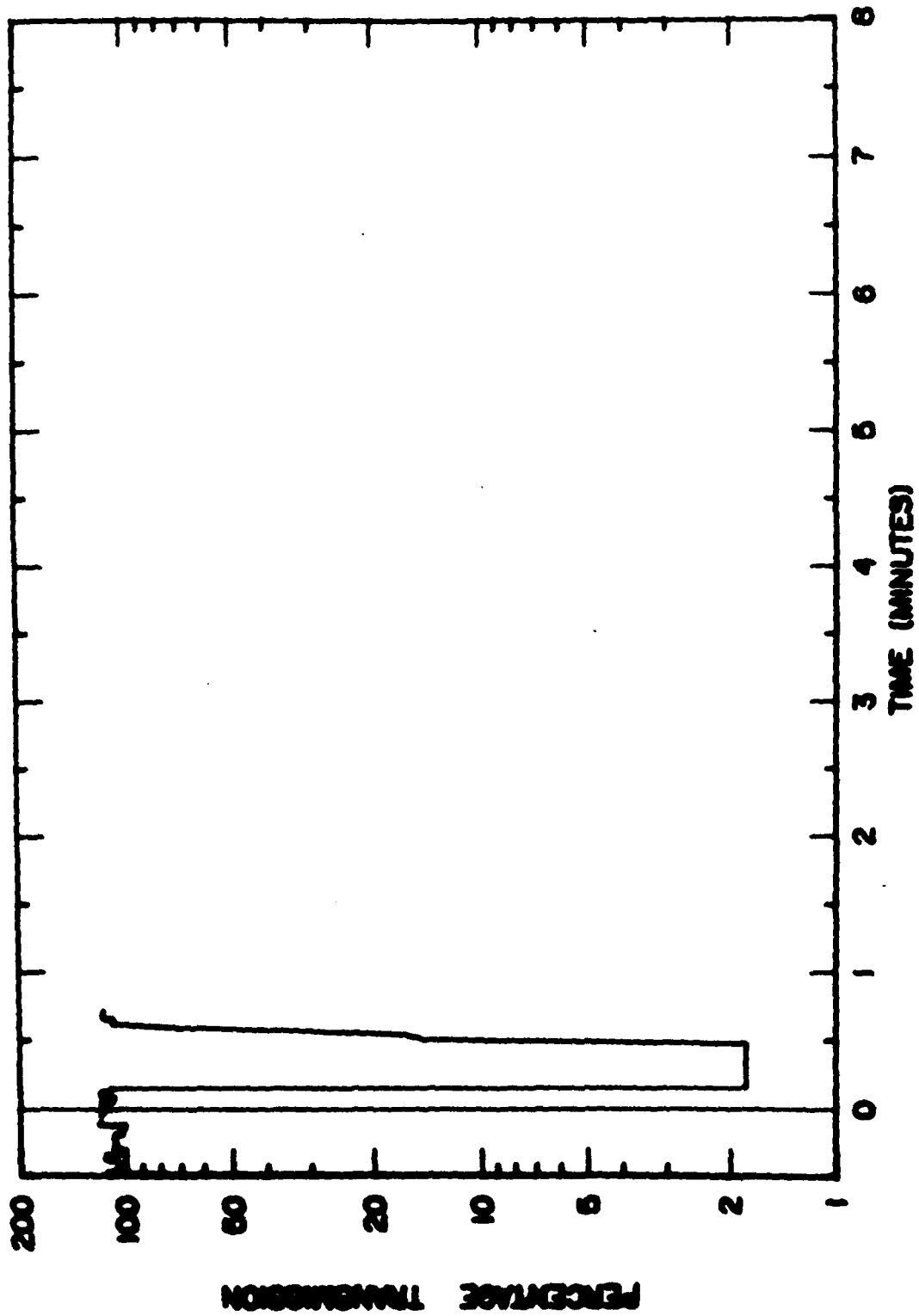


Figure 33. Event E-1 10.6µm transmission.

11 OCTOBER 1978 T = 0 57 10 MDT

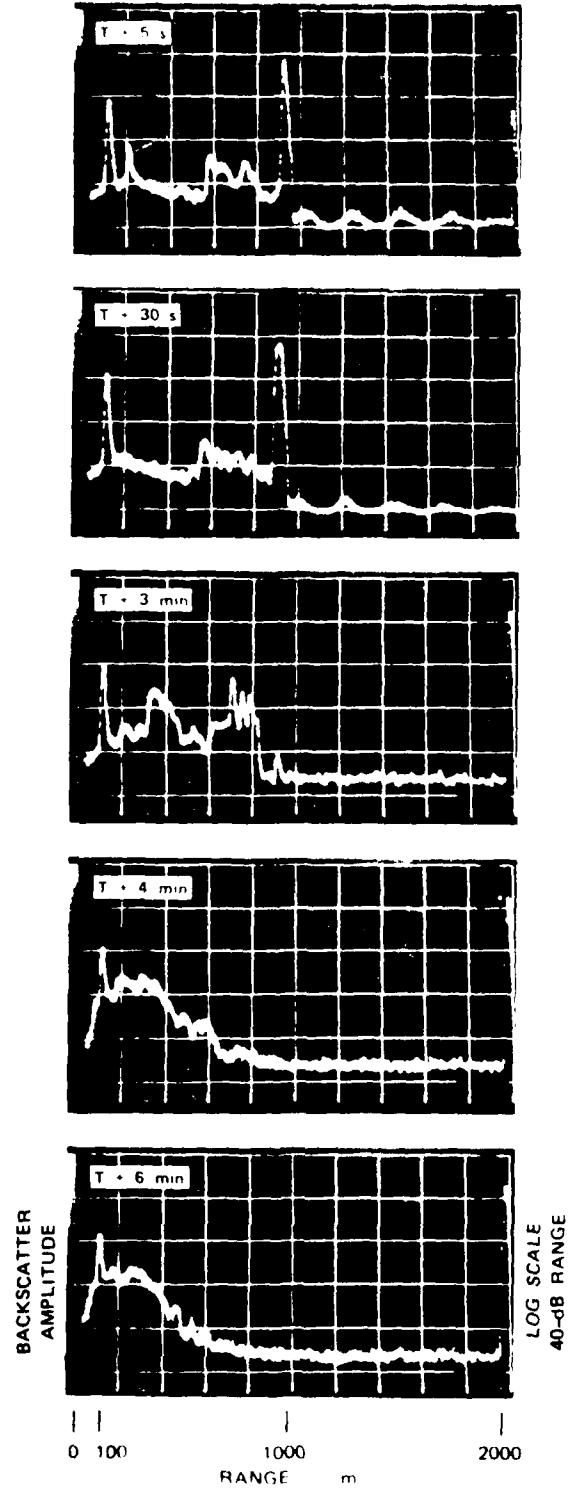


Figure 34. Event E-2 10.6 m backscatter data.

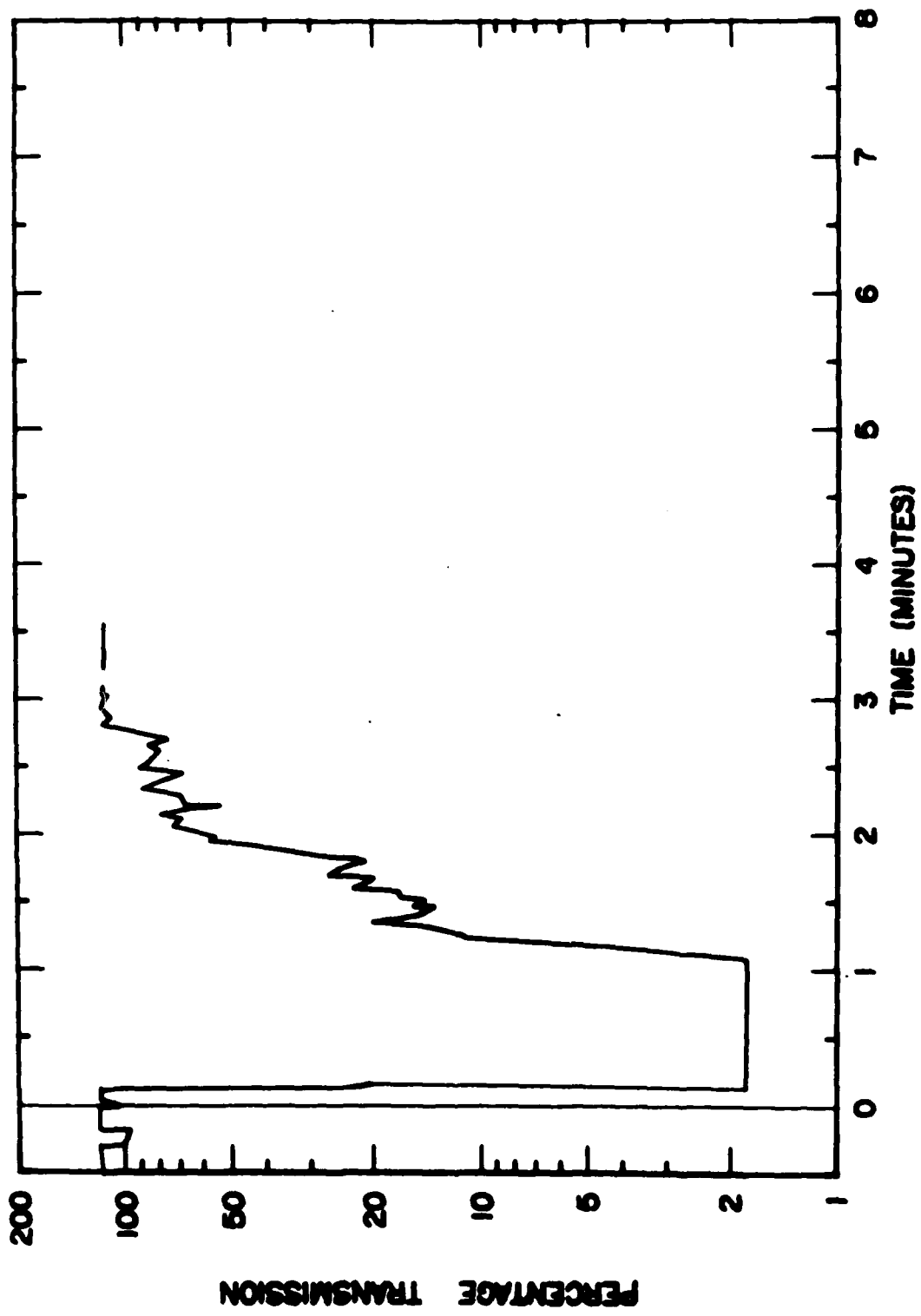


Figure 35. Event E-2 10.6 μ m transmission.

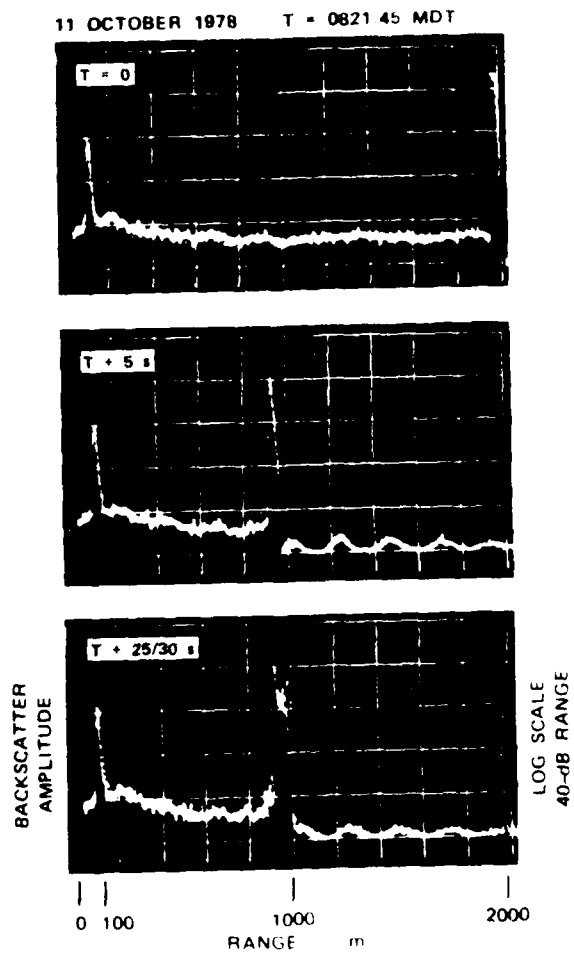


Figure 36. Event E-3 10.6 m backscatter data.

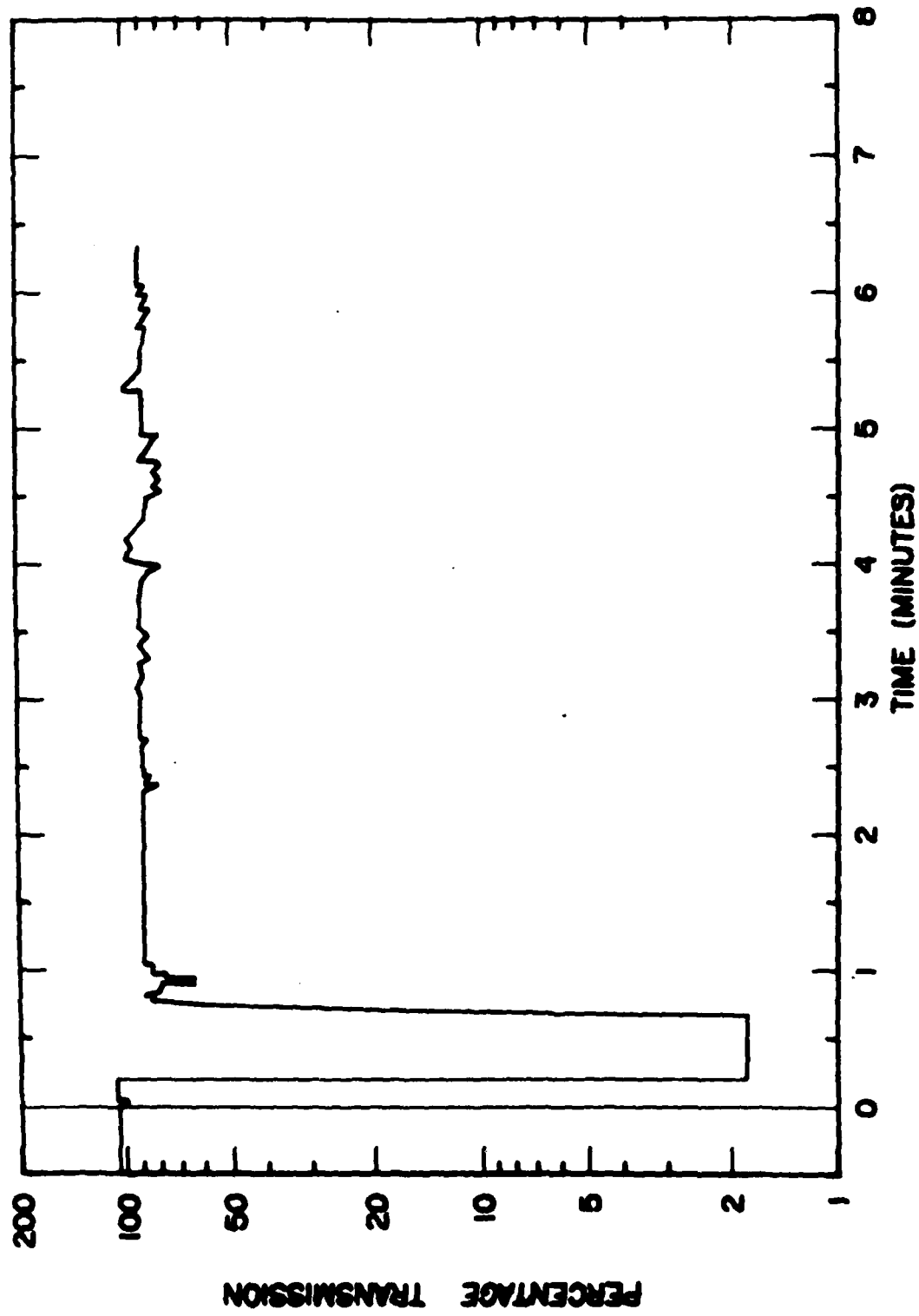


Figure 37. Event E-3 10.6 μ m transmission.

11 OCTOBER 1978 T = 0829 05

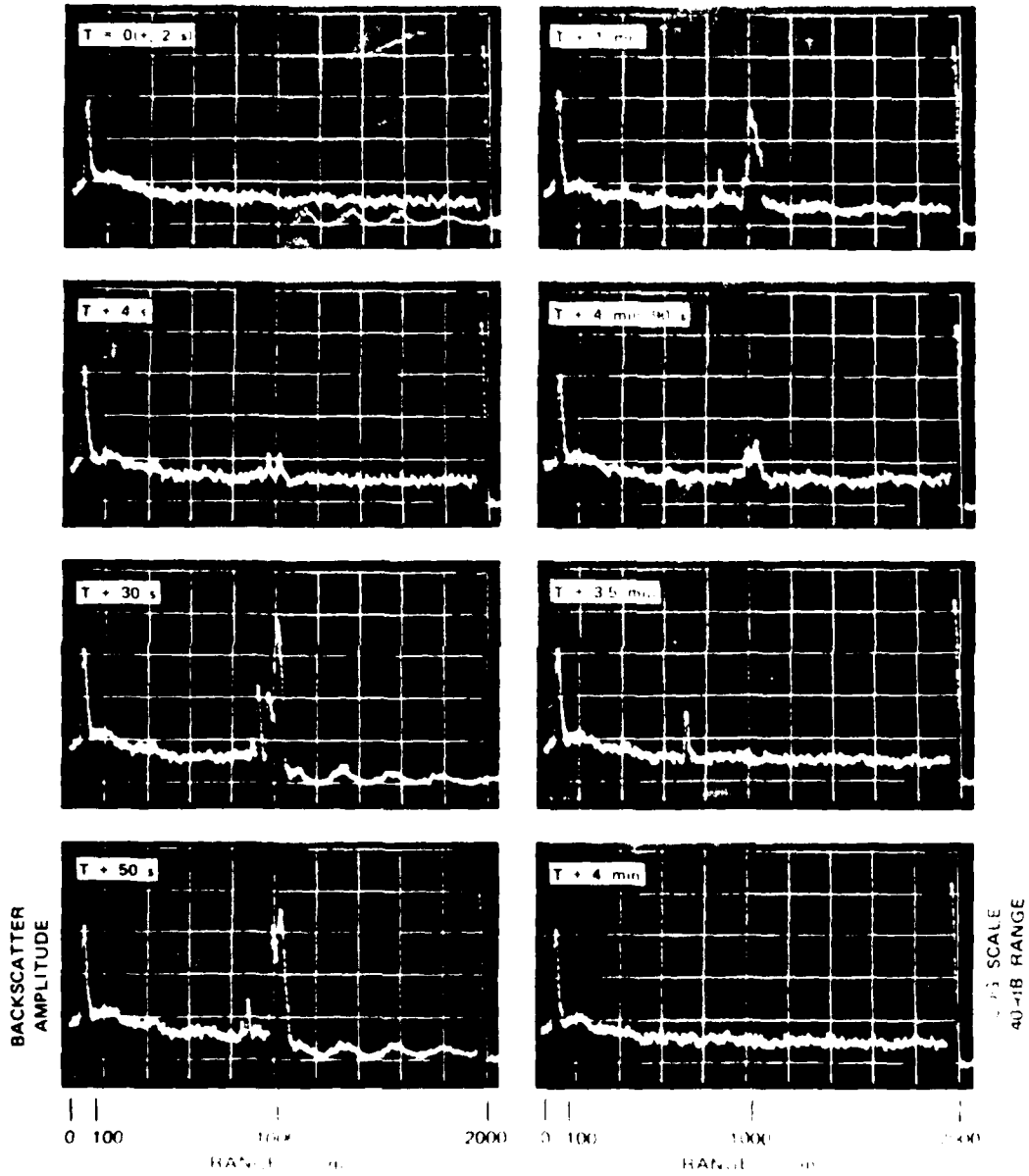


Figure 1. Backscatter data from F-5 10,000 ft. alt.

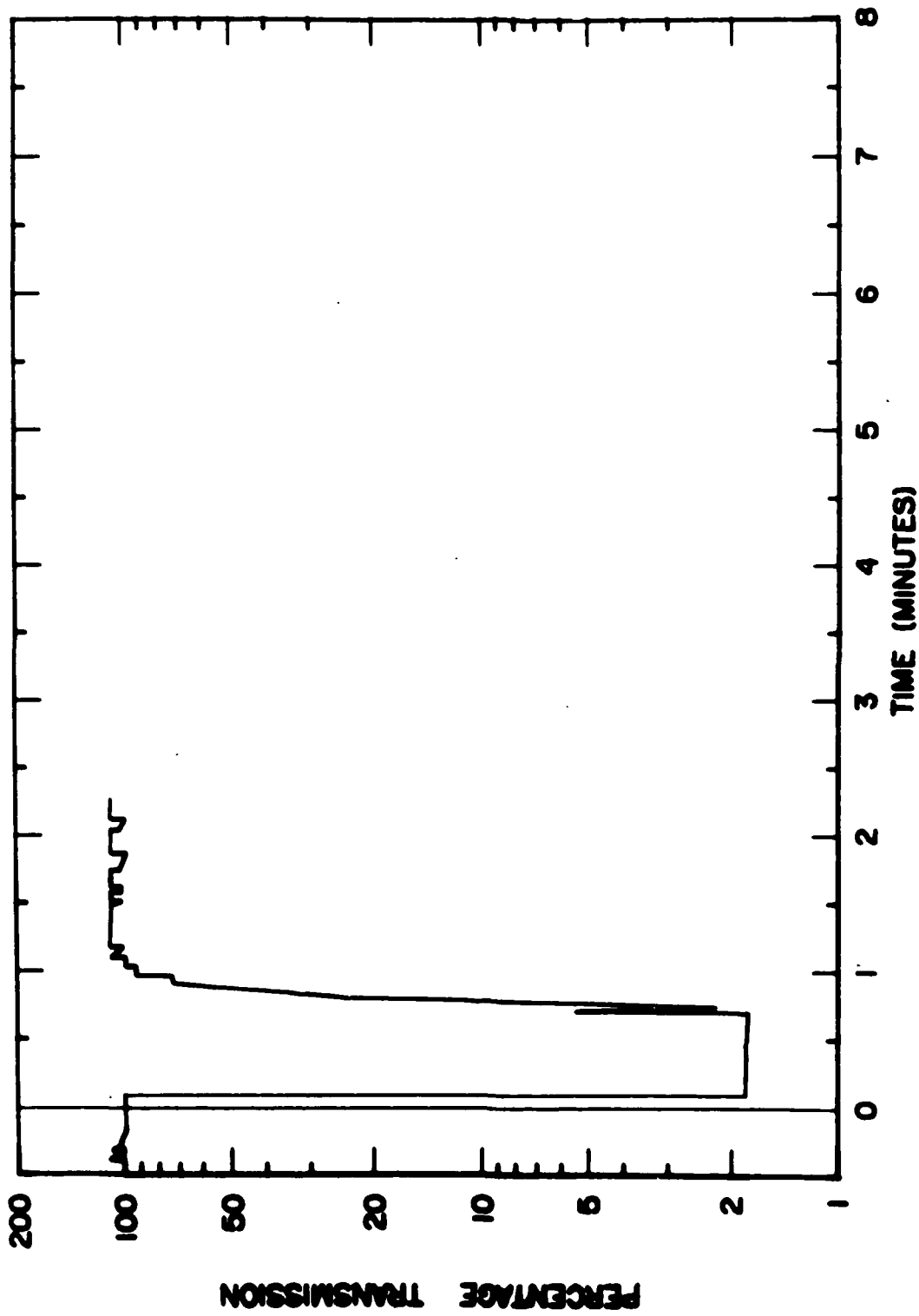


Figure 39. Event E-4 10.6 μ m transmission.

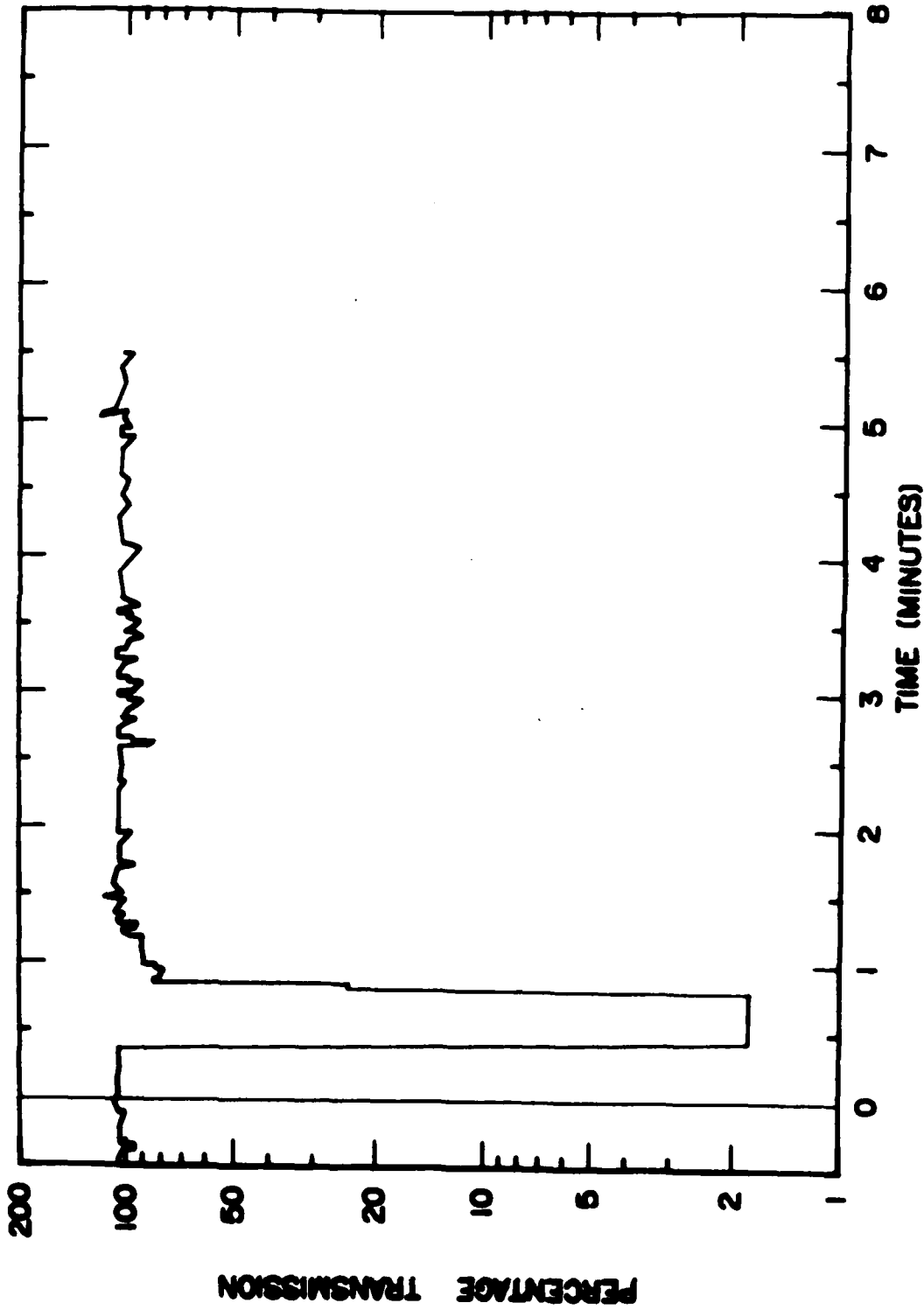


Figure 40. Event F-1 10.6 μ m transmission.

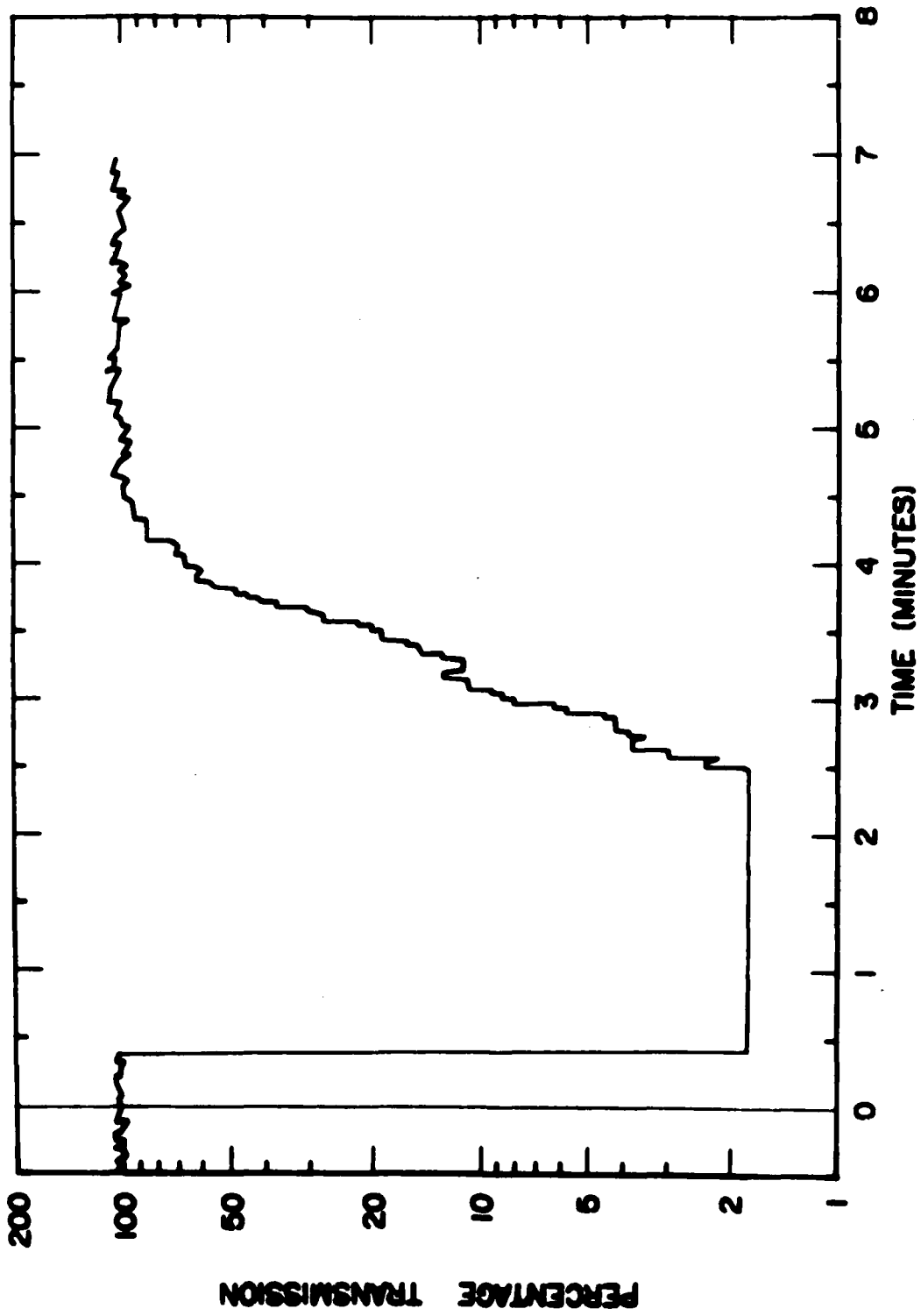


Figure 41. Event F-2 10.6µm transmission.

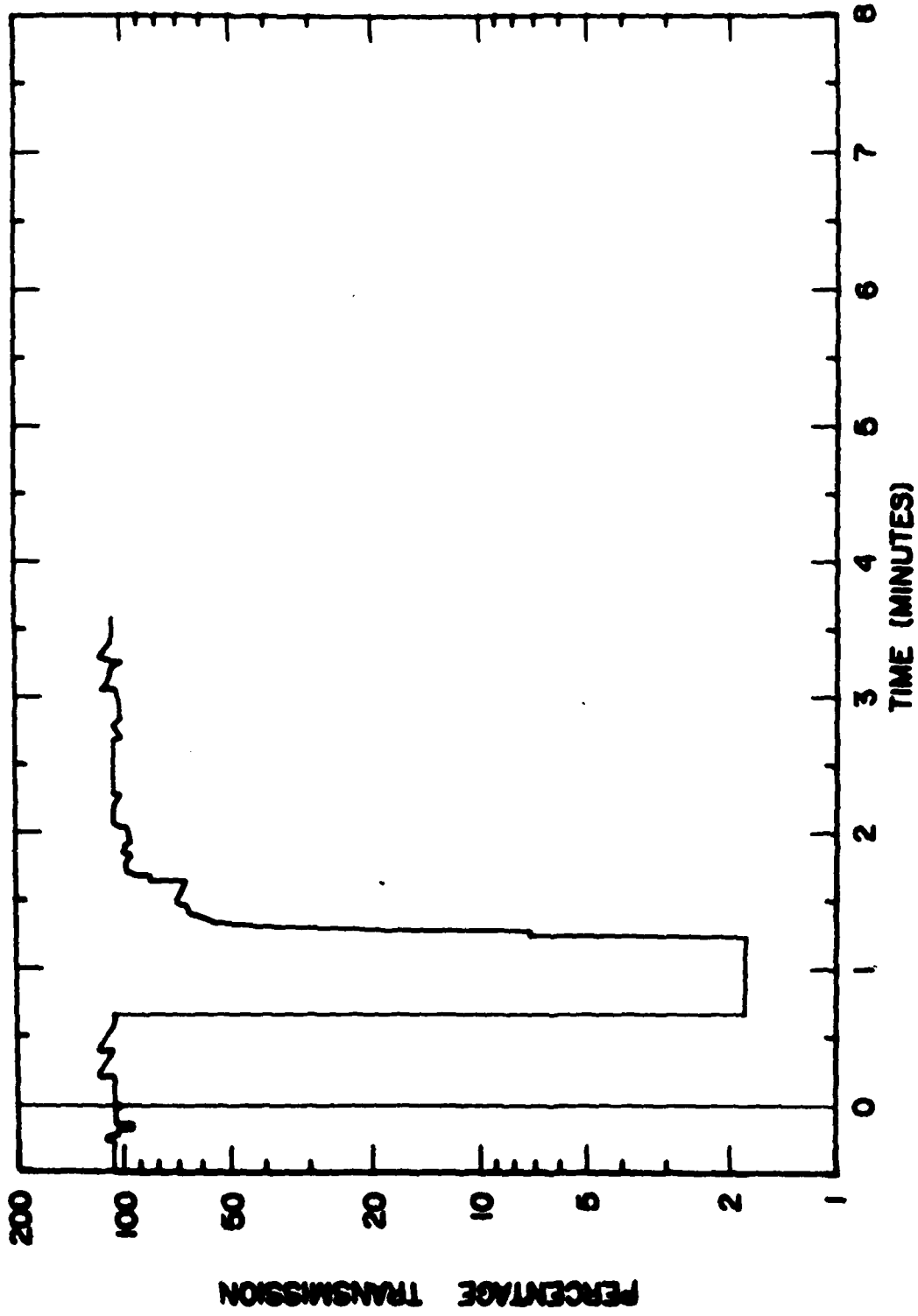
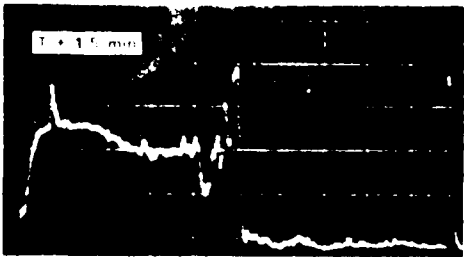
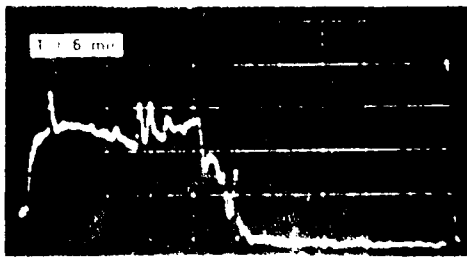
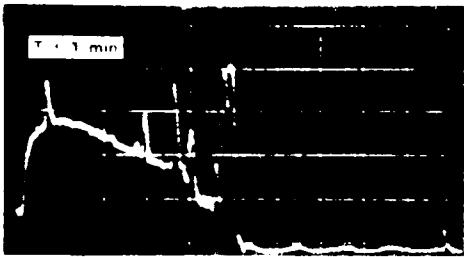
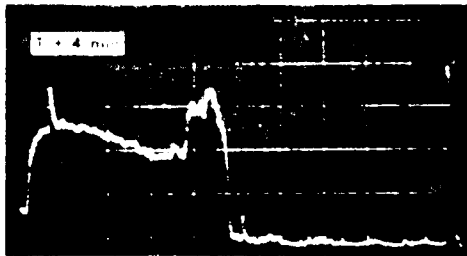
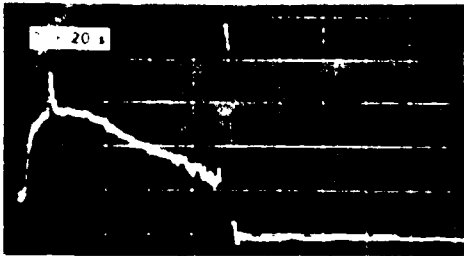
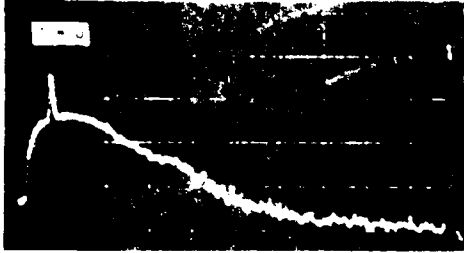


Figure 42. Event F-3 10.6µm transmission.

13 OCTOBER 1978 07:48 4.17

BACKSCATTER
AMPLITUDE



0 100 2000

0 100 2000

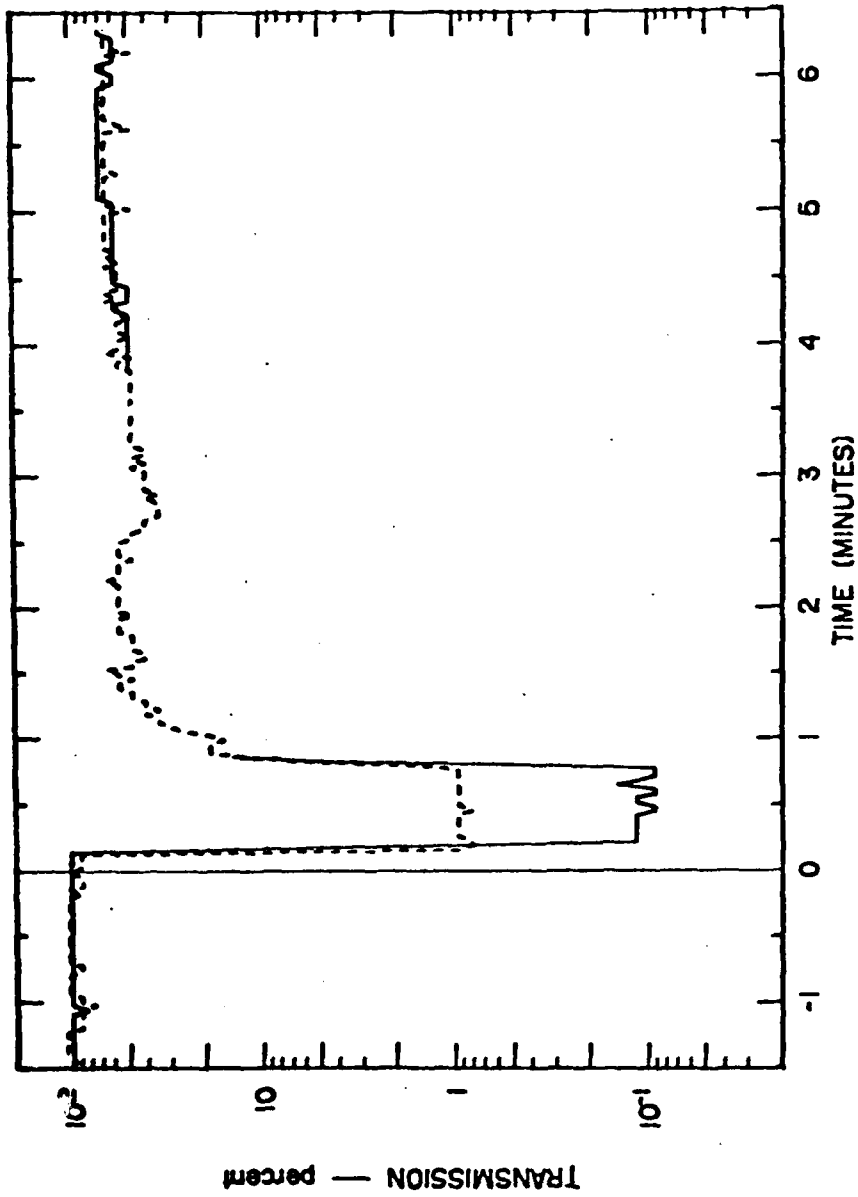


Figure 44. Transmission observed by the two-wavelength lidar system (F-5).

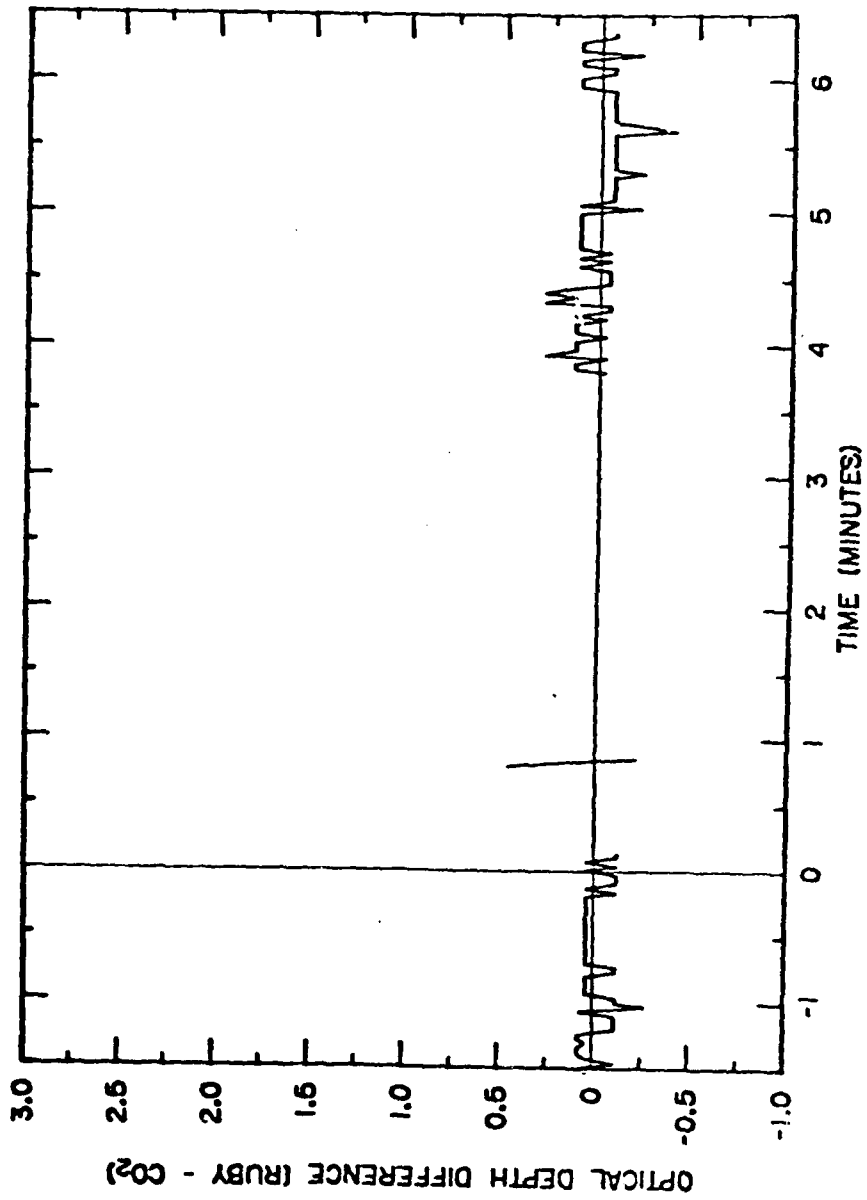


Figure 45. Difference between Ruby and CO₂ optical depths (1-5).

13 OCTOBER 1978 T + 07:51.40 MDT

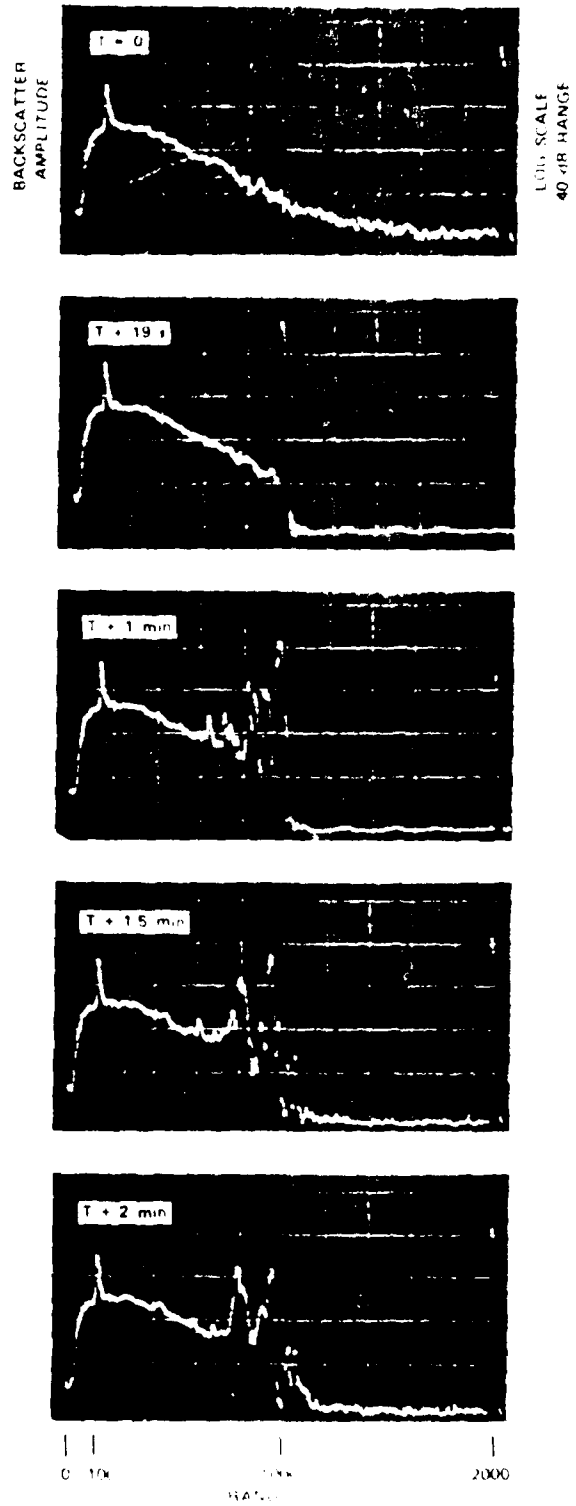


Figure 36. Evolution of backscatter data.

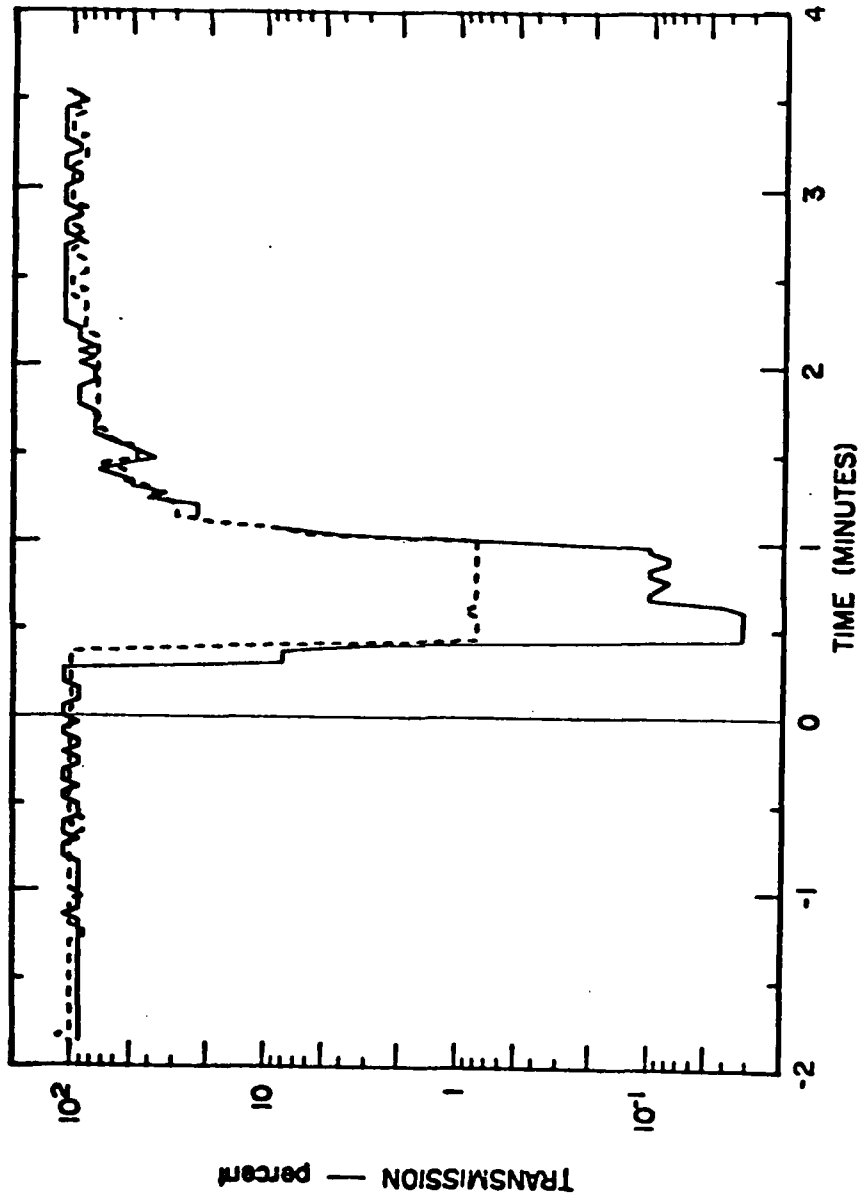


Figure 47. Transmission observed by the two-wavelength lidar system (F-6).

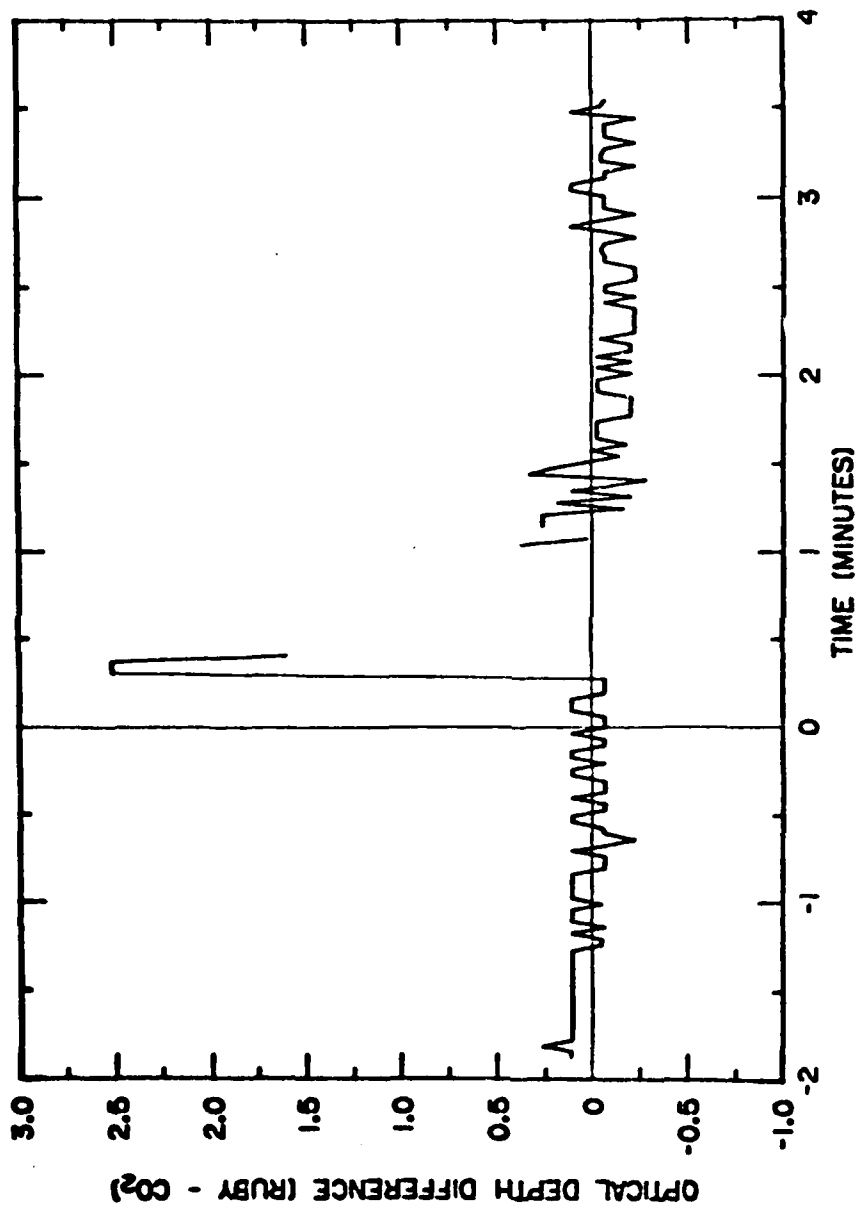
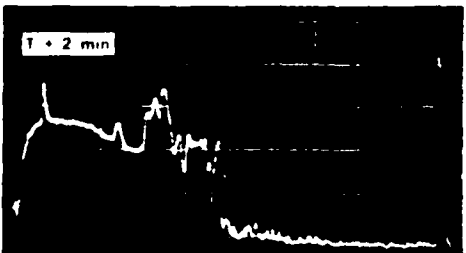
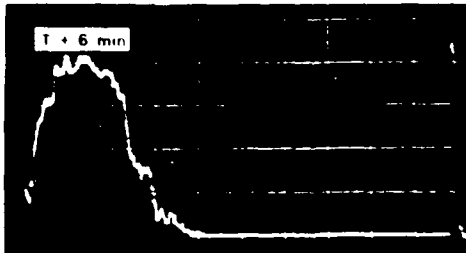
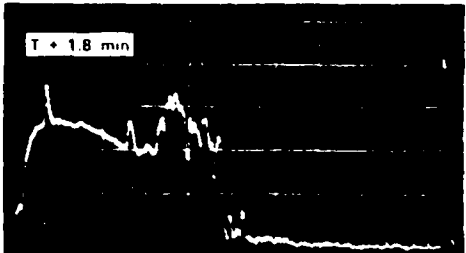
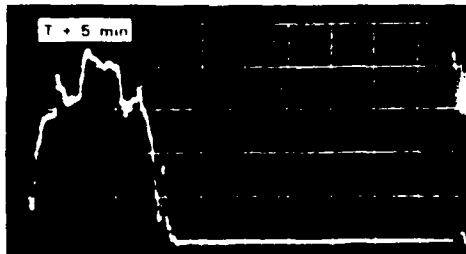
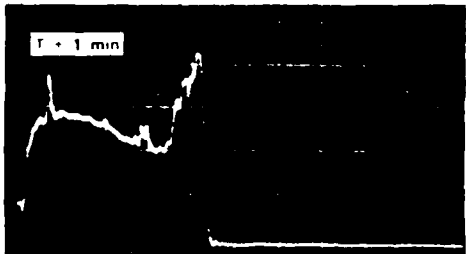
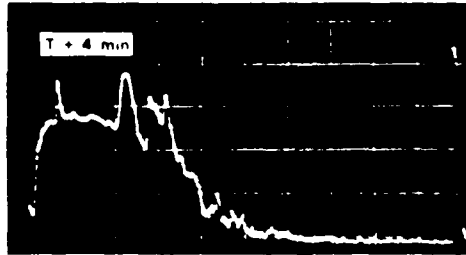
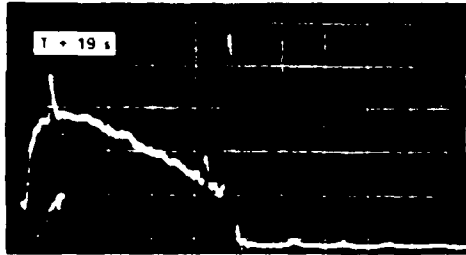
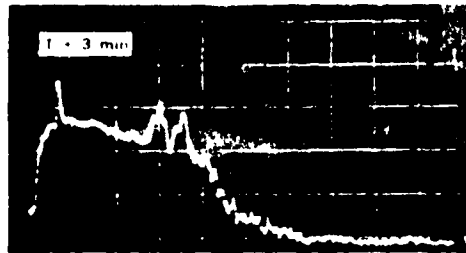
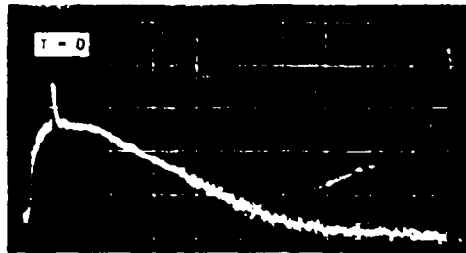


Figure 48. Difference between Ruby and CO₂ optical depths (F-6).

15 OCTOBER 1978 T = 0808 20 MDT

BACKSCATTER AMPLITUDE



0 100 1000 2000
RANGE m

0 100 1000 2000
RANGE m

1000 2000

Figure 1. Backscatter amplitude vs. range at 10.6 μm backscatter laser.

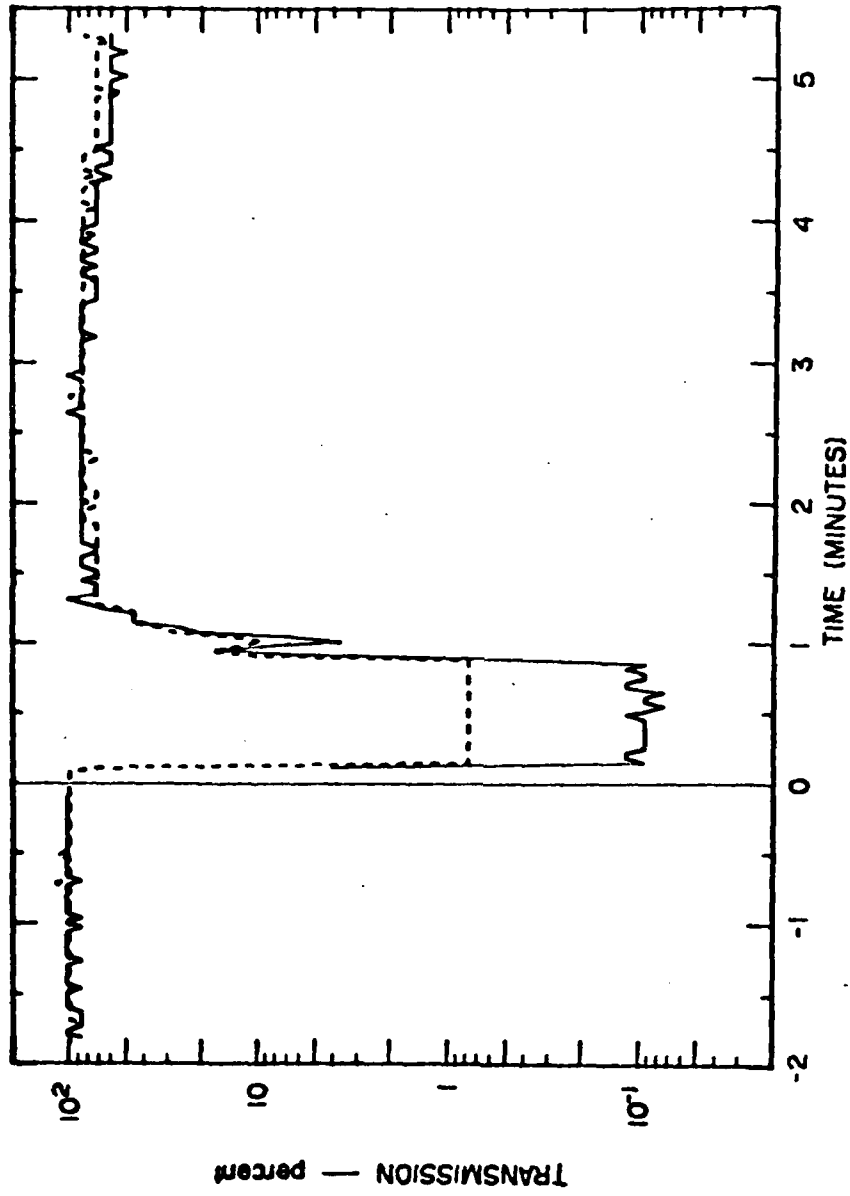


Figure 50. Transmission observed by the two-wavelength lidar system (F-7).

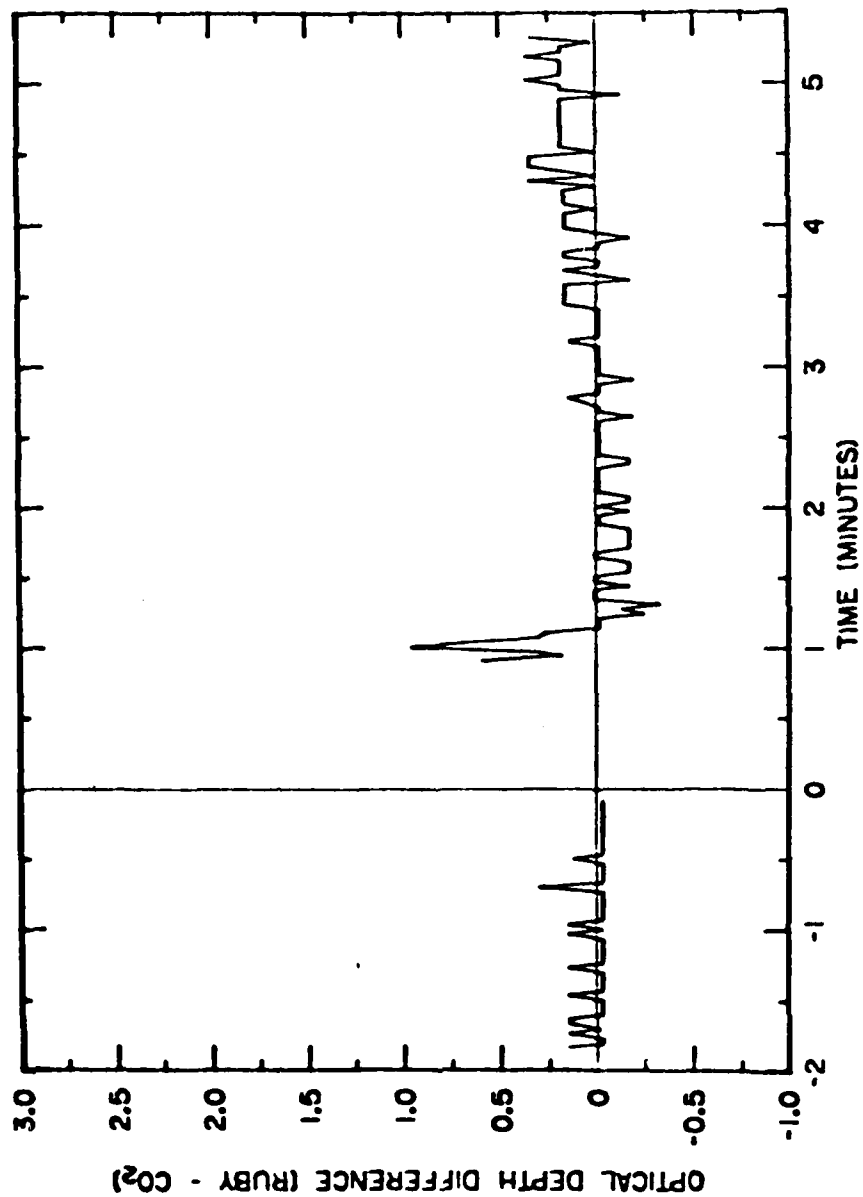
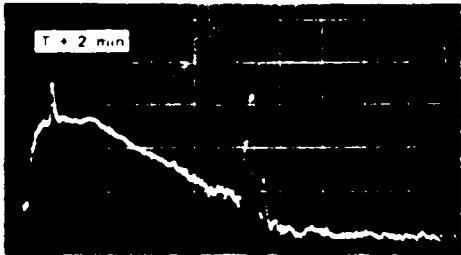
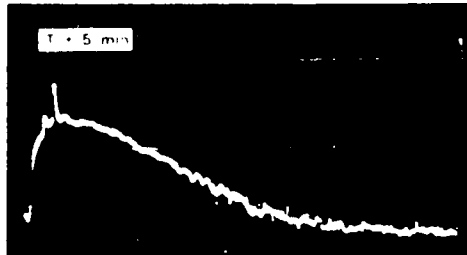
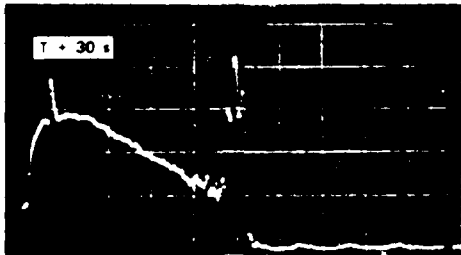
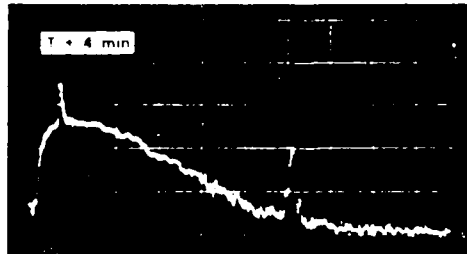
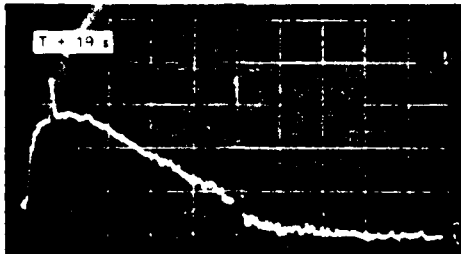
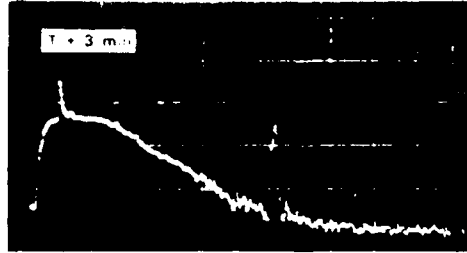
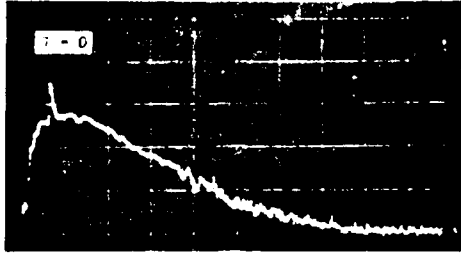


Figure 51. Difference between Ruby and CO₂ optical depths (F-7).

13 OCTOBER 1978 T = 0826 15 AM

BACKSCATTER
AMPLITUDE



0 100 2000

0 100 2000

0 100 2000

0 100 2000

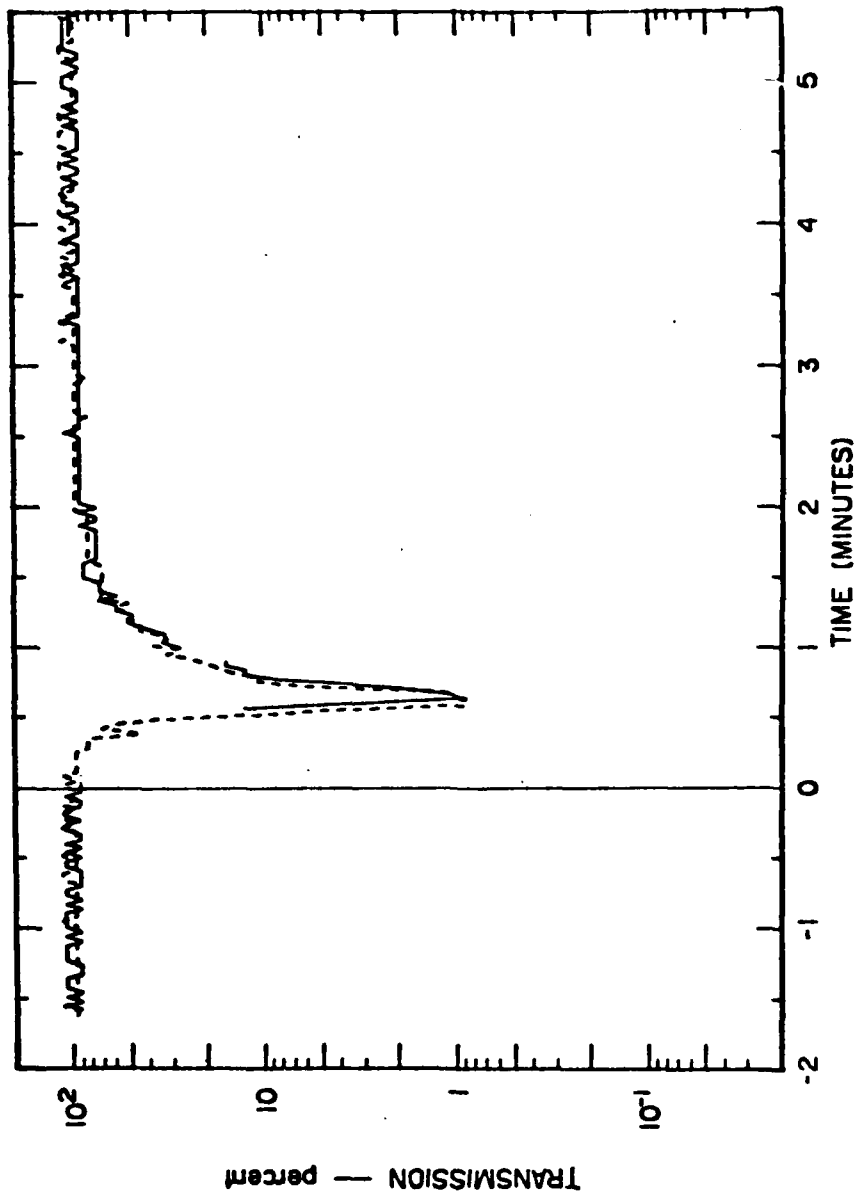


Figure 53. Transmission observed by the two-wavelength lidar system (P-8).

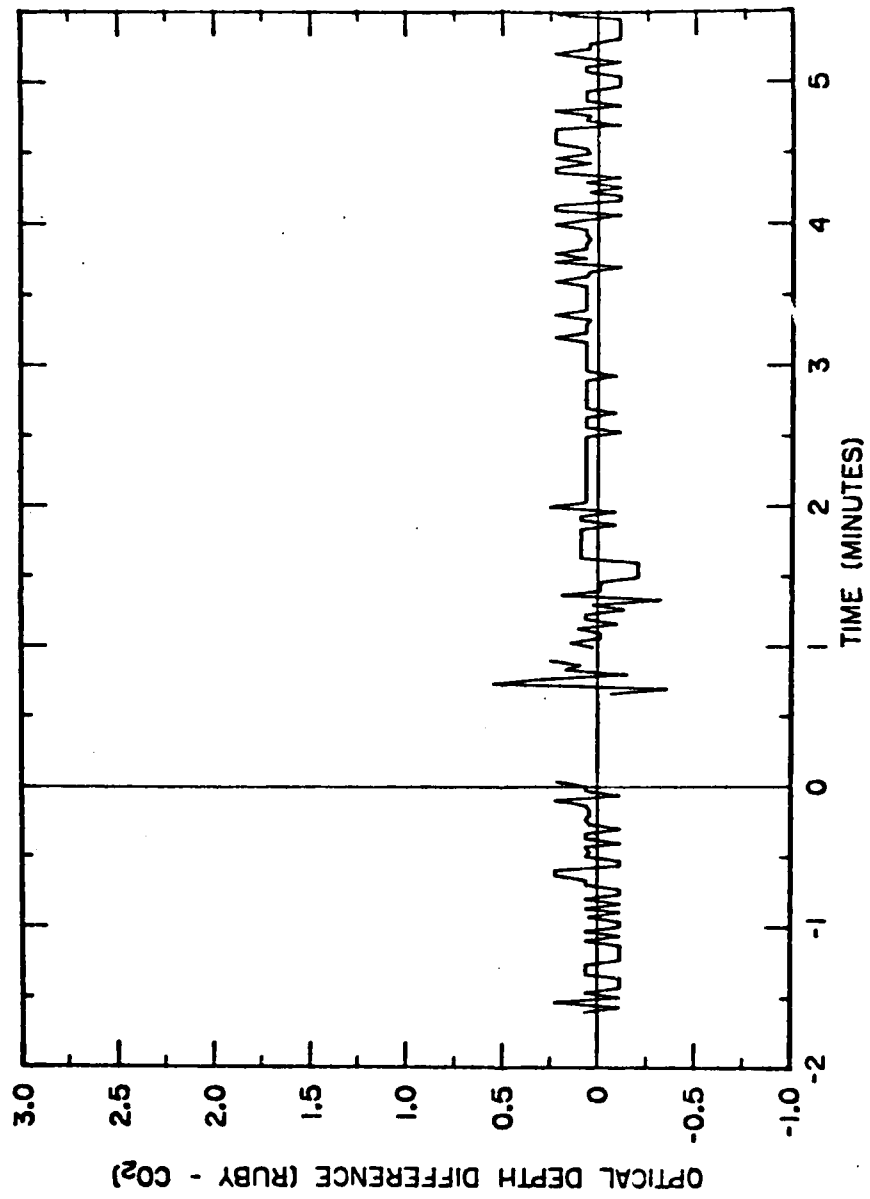


Figure 54. Difference between Ruby and CO₂ optical depths (F-8).

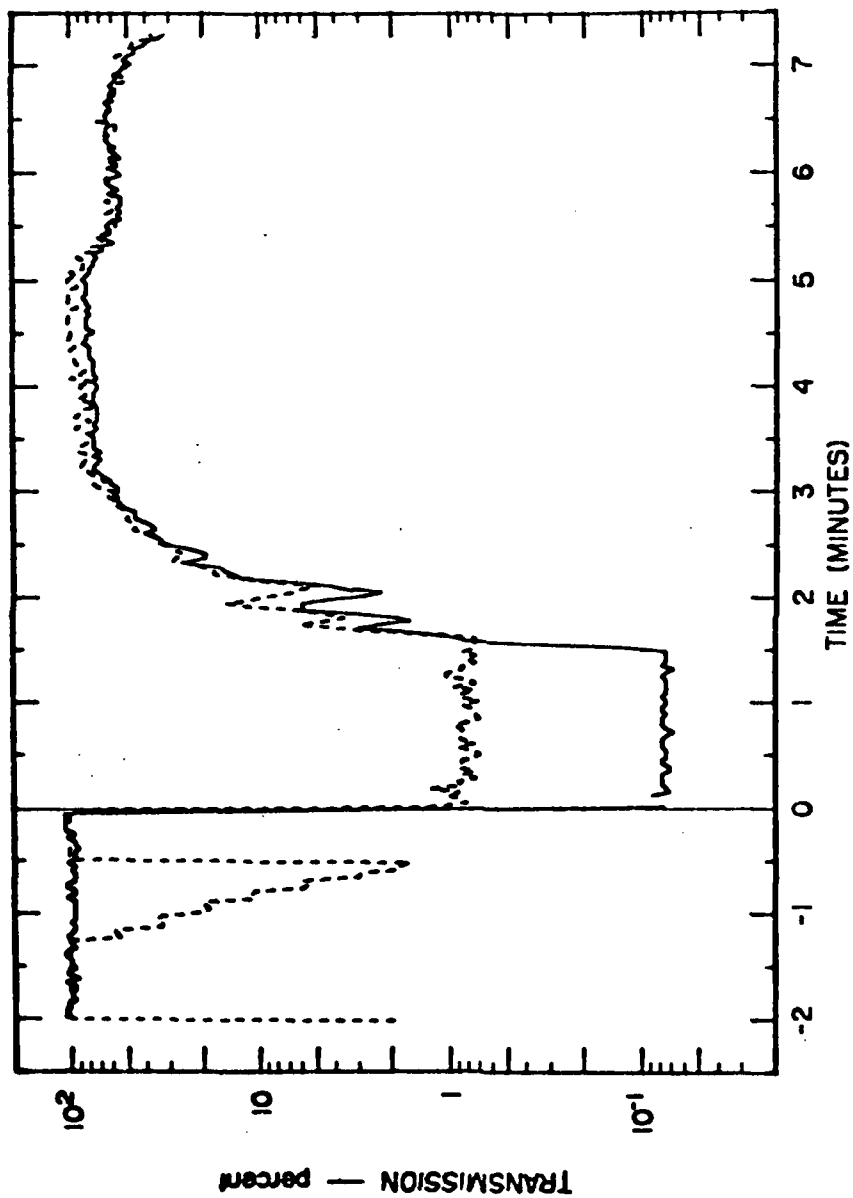


Figure 56. Transmission observed by the two-wavelength lidar system (E-5).

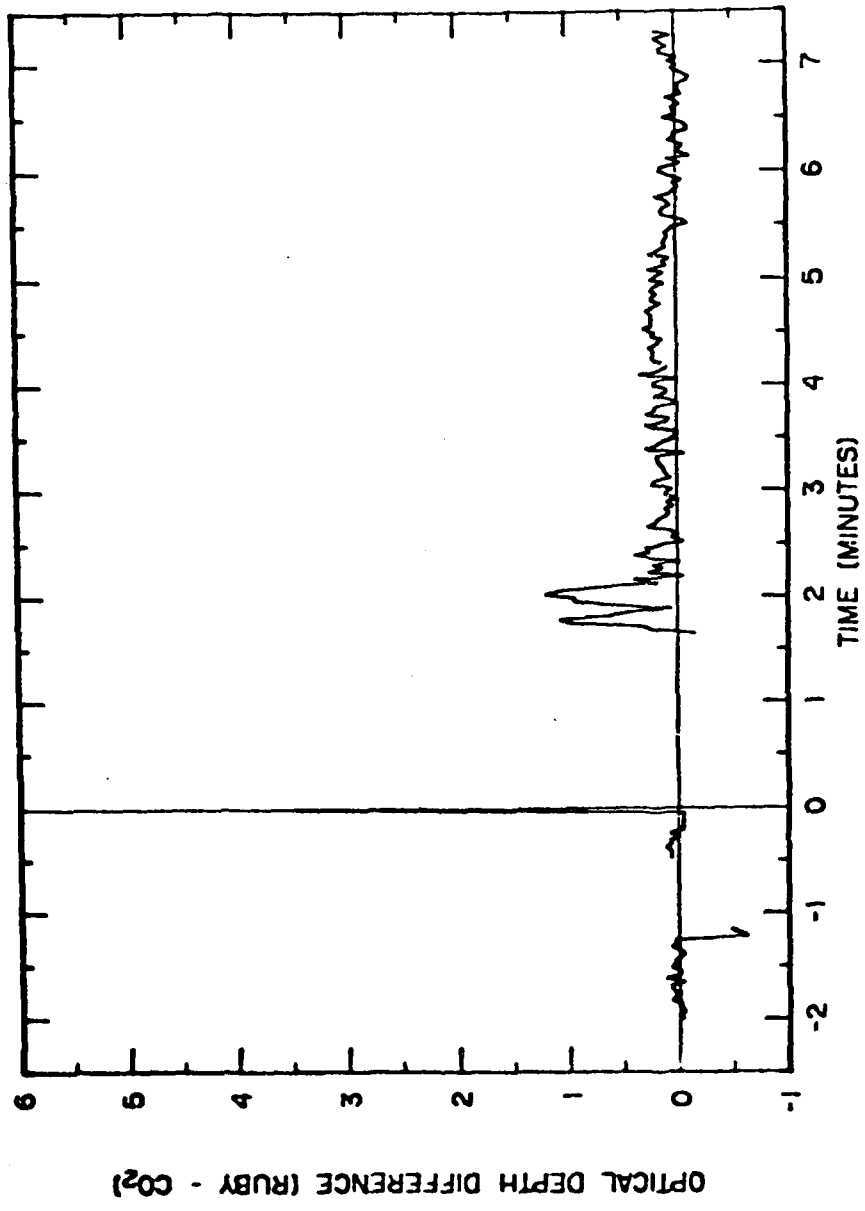


Figure 57. Difference between Ruby and CO₂ optical depths (E-5).

14 OCTOBER 1978 T - 0756 00 MDT

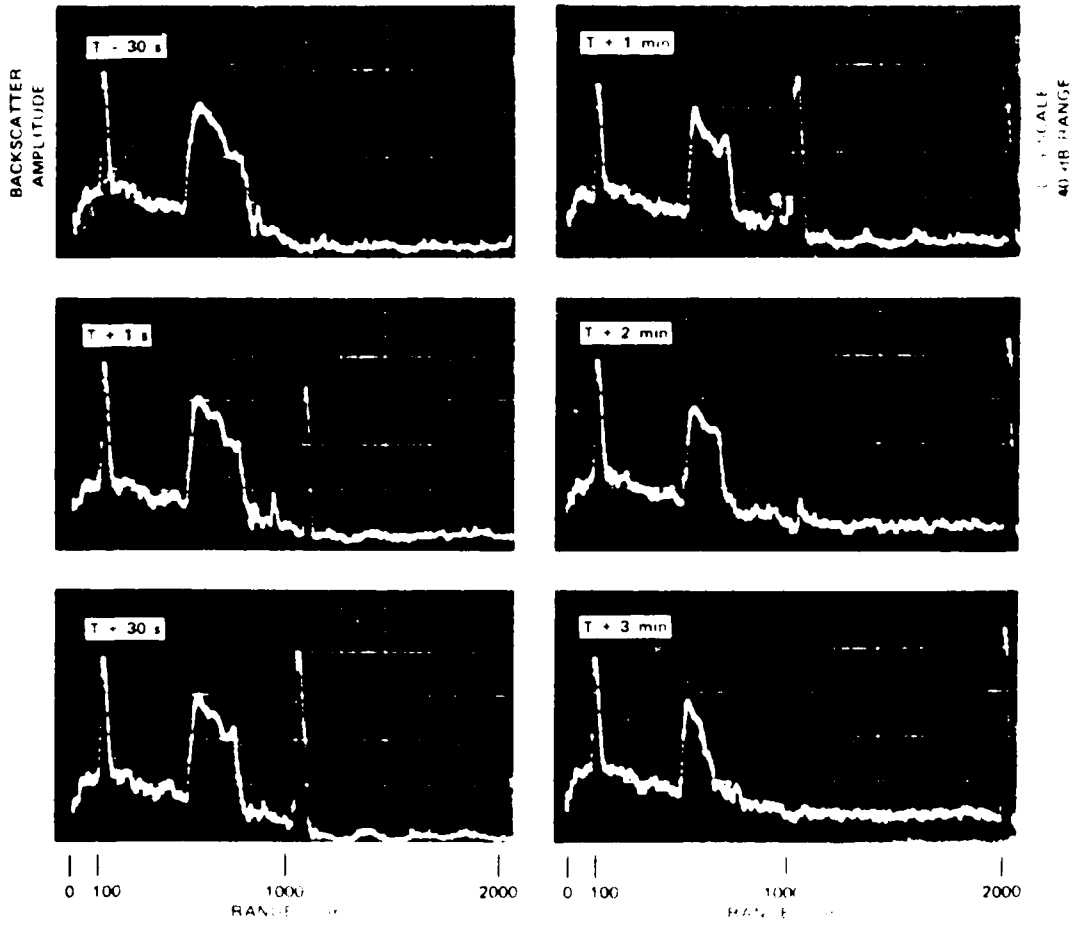


Figure 1. Front E-b. 10.0 m. 10.0 m.

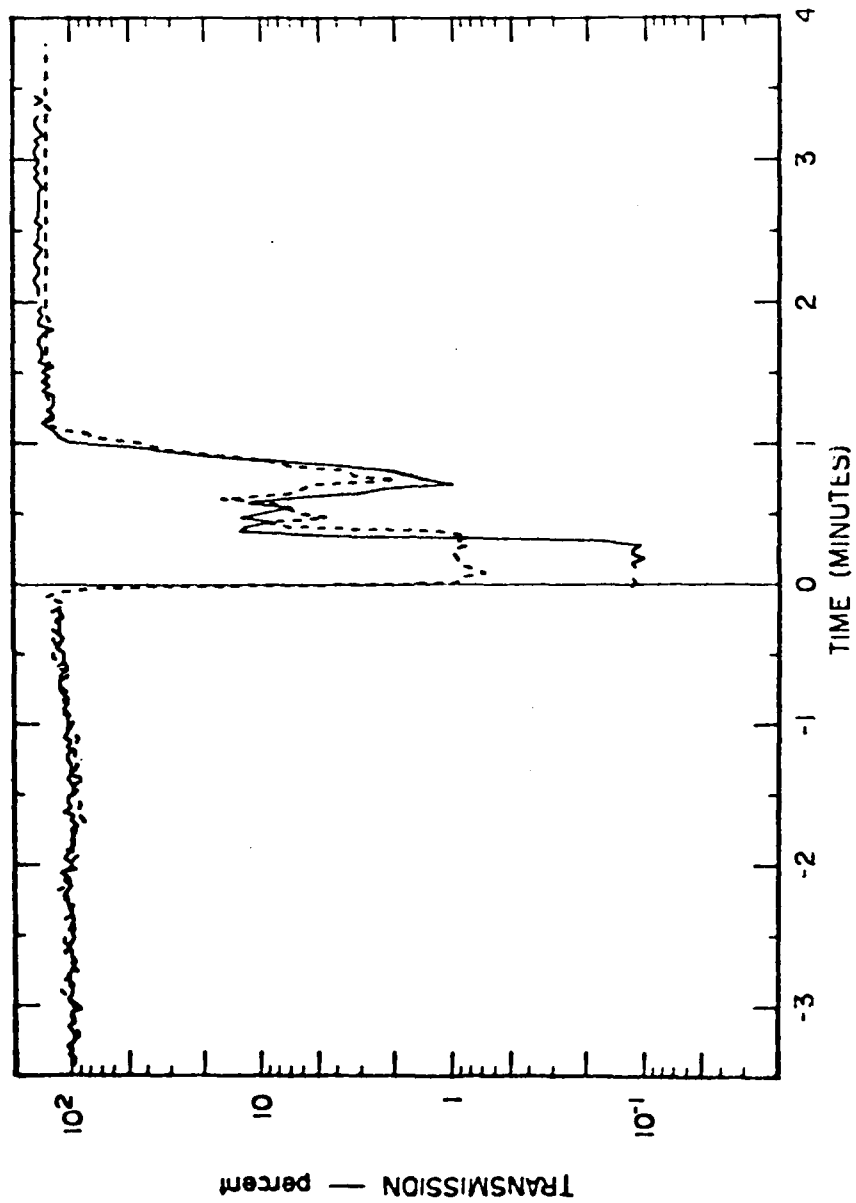


Figure 59. Transmission observed by the two-wavelength lidar system (L-6).

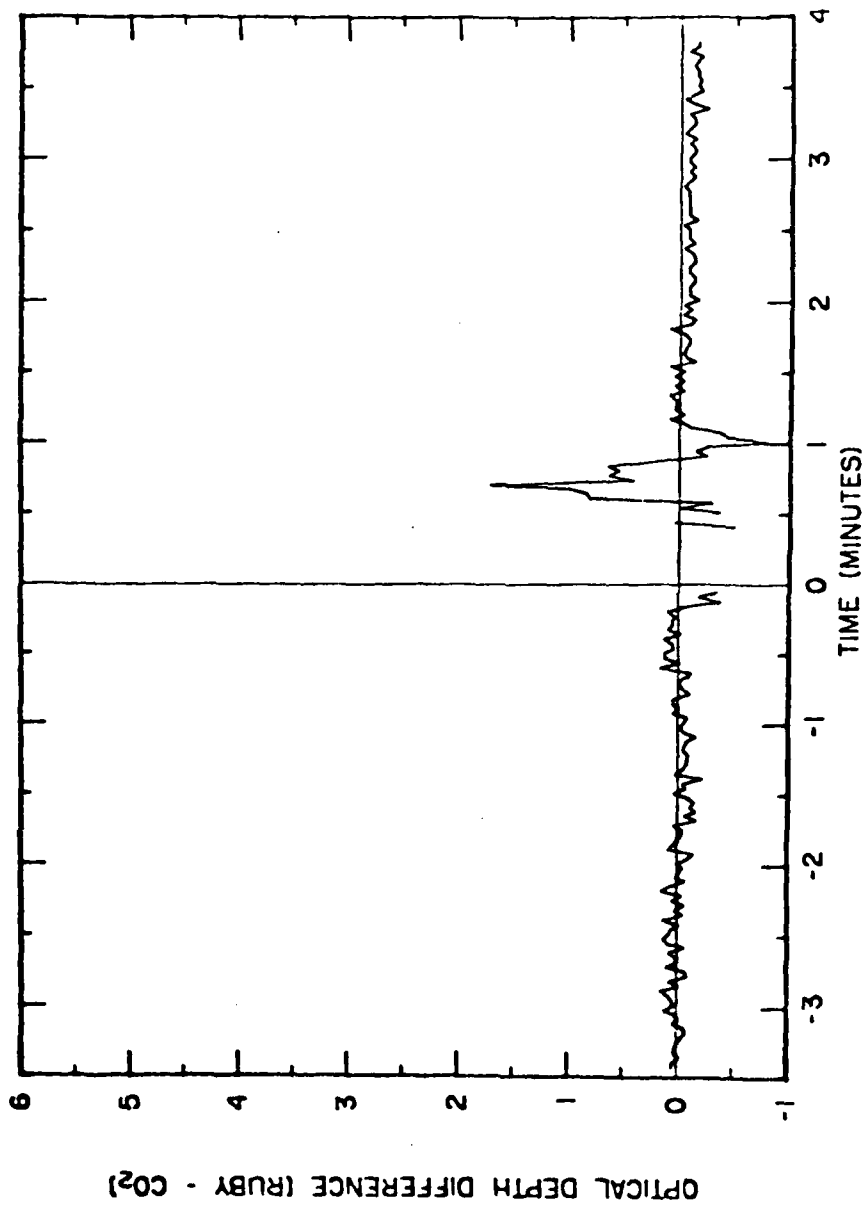
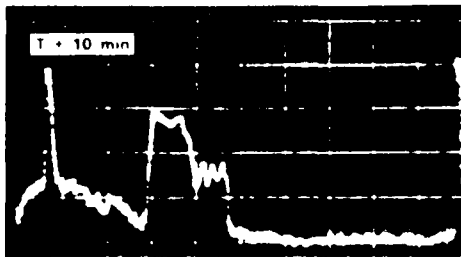
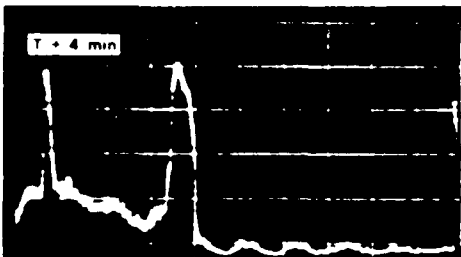
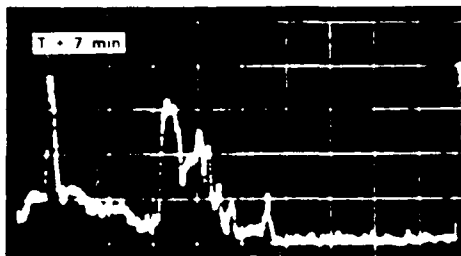
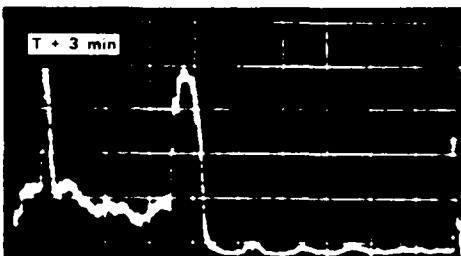
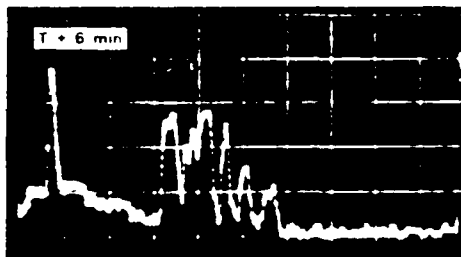
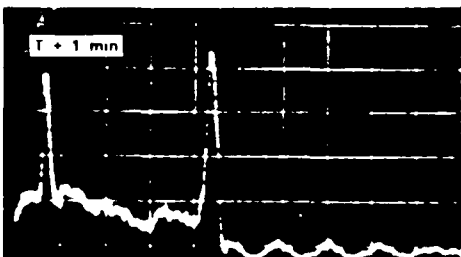
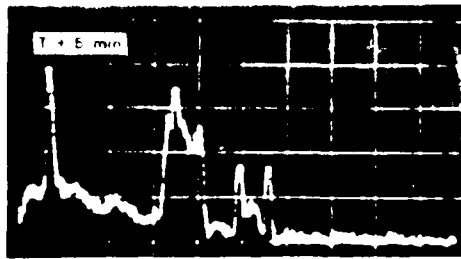
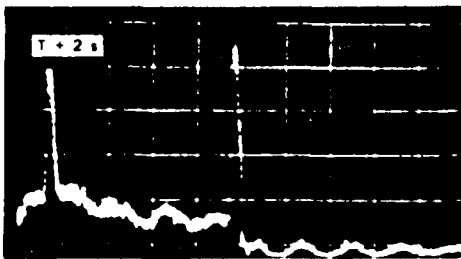


Figure 60. Difference between Ruby and CO₂ optical depths (E-6).

14 OCTOBER 1978 T - 0806 45 MDT

BACKSCATTER
AMPLITUDE



0 100

1000
RANGE - m

2000

0 100

1000
RANGE - m

2000

1000
40 R.A. 14

1000 1000 1000 1000 1000 1000 1000 1000 1000 1000

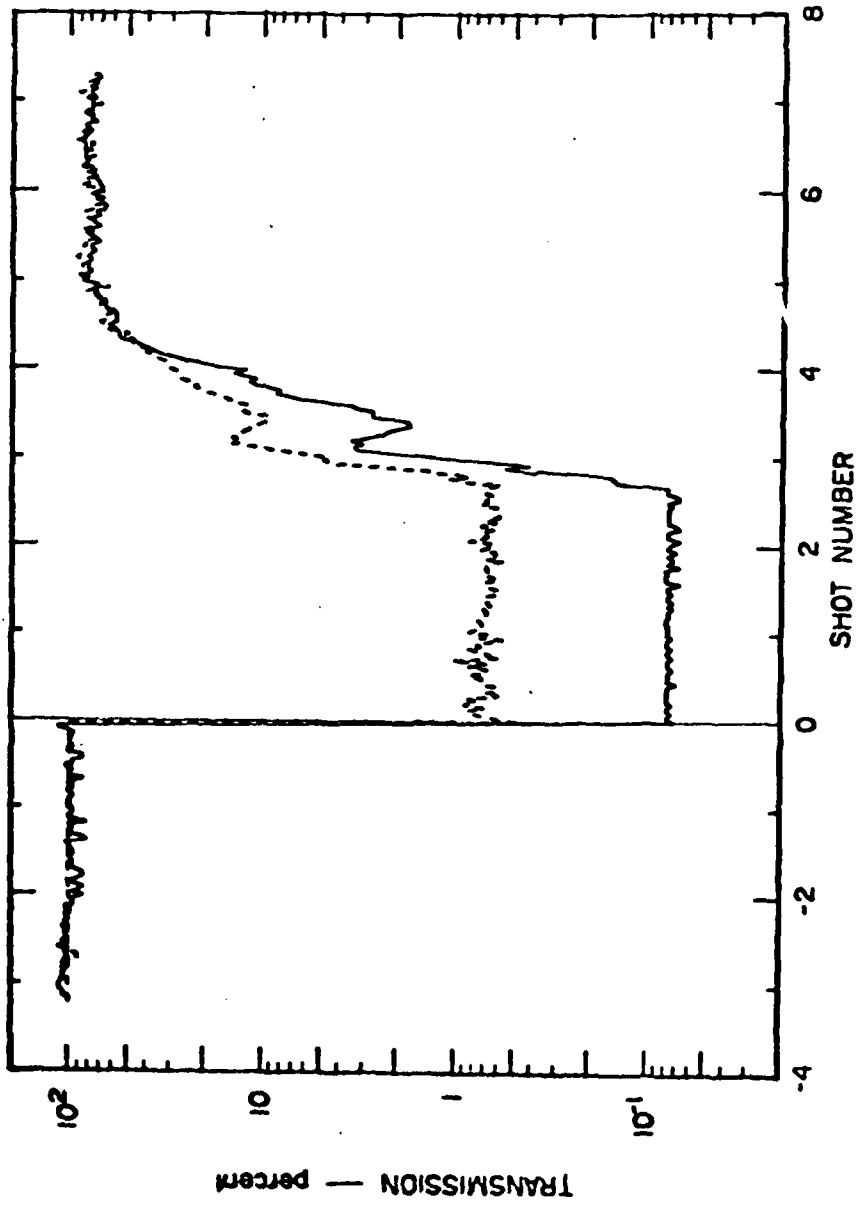


Figure 62. Transmission observed by the two-wavelength lidar system (E-7).

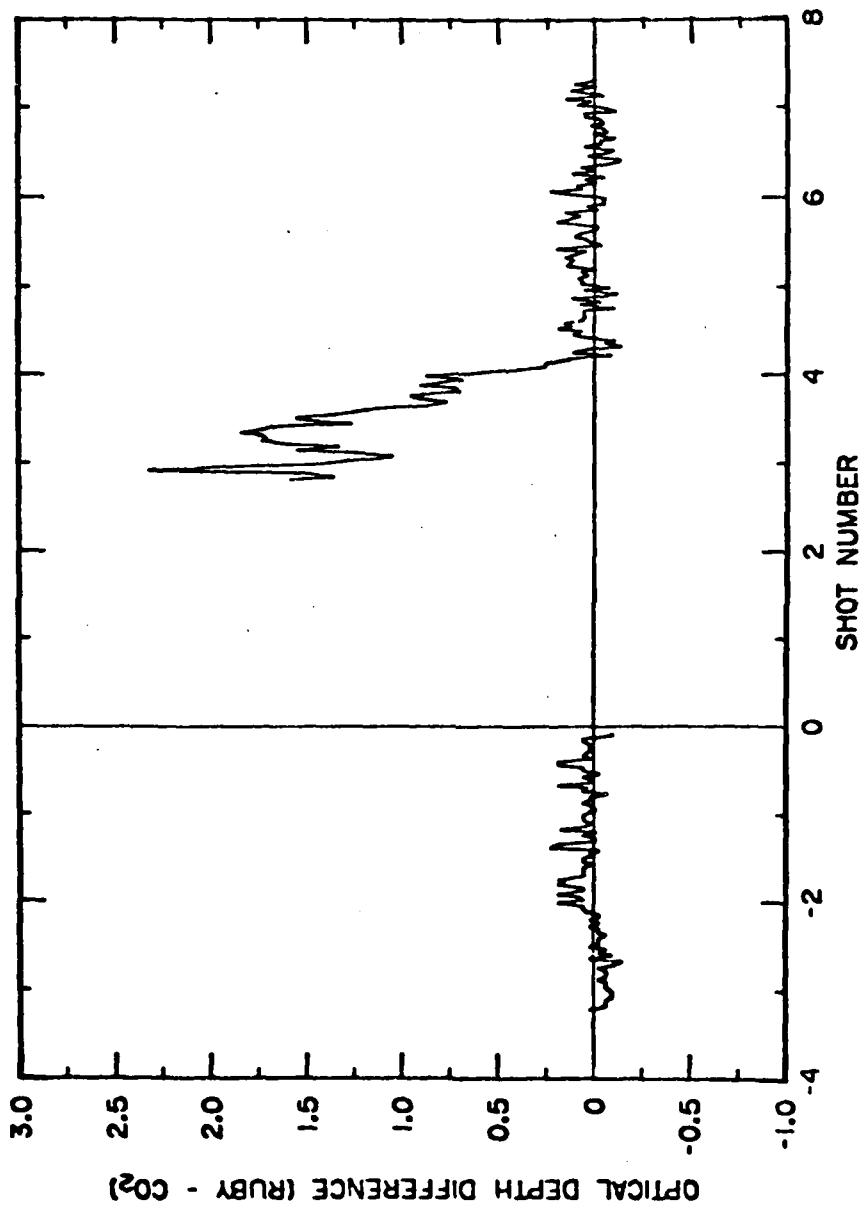
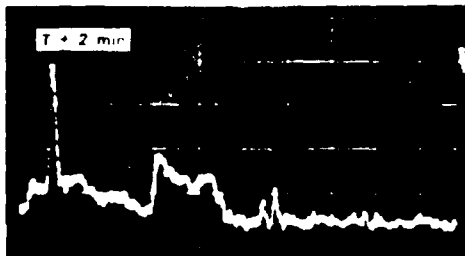
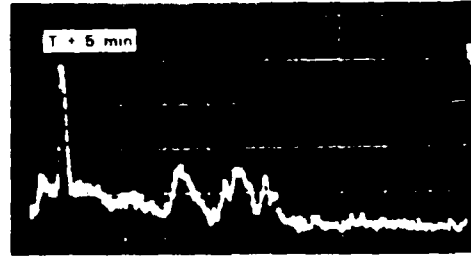
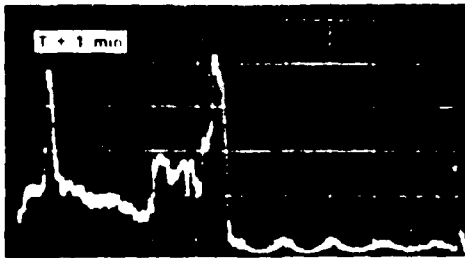
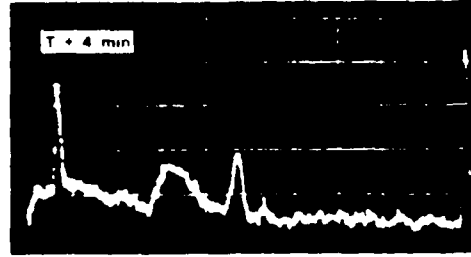
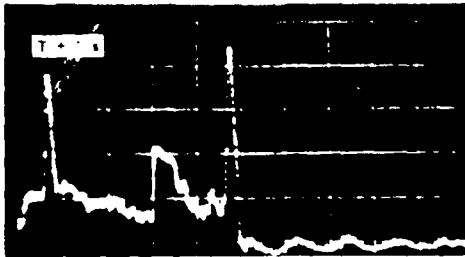
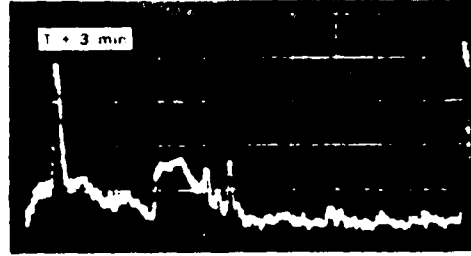
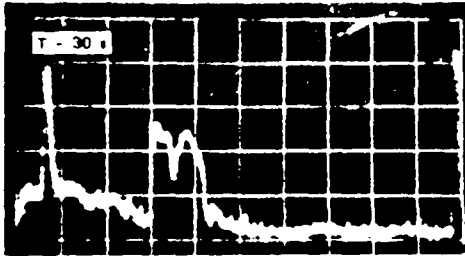


Figure 63. Difference between Ruby and CO₂ optical depths (E-7).

14 OCTOBER 1978 T = 0823.55 MDY

BACKSCATTER
AMPLITUDE



0 100 1000 2000
RANGE m

T C C T
4 MB DATA

Figure 1. Backscatter at 8-10.6mm backscatter data.

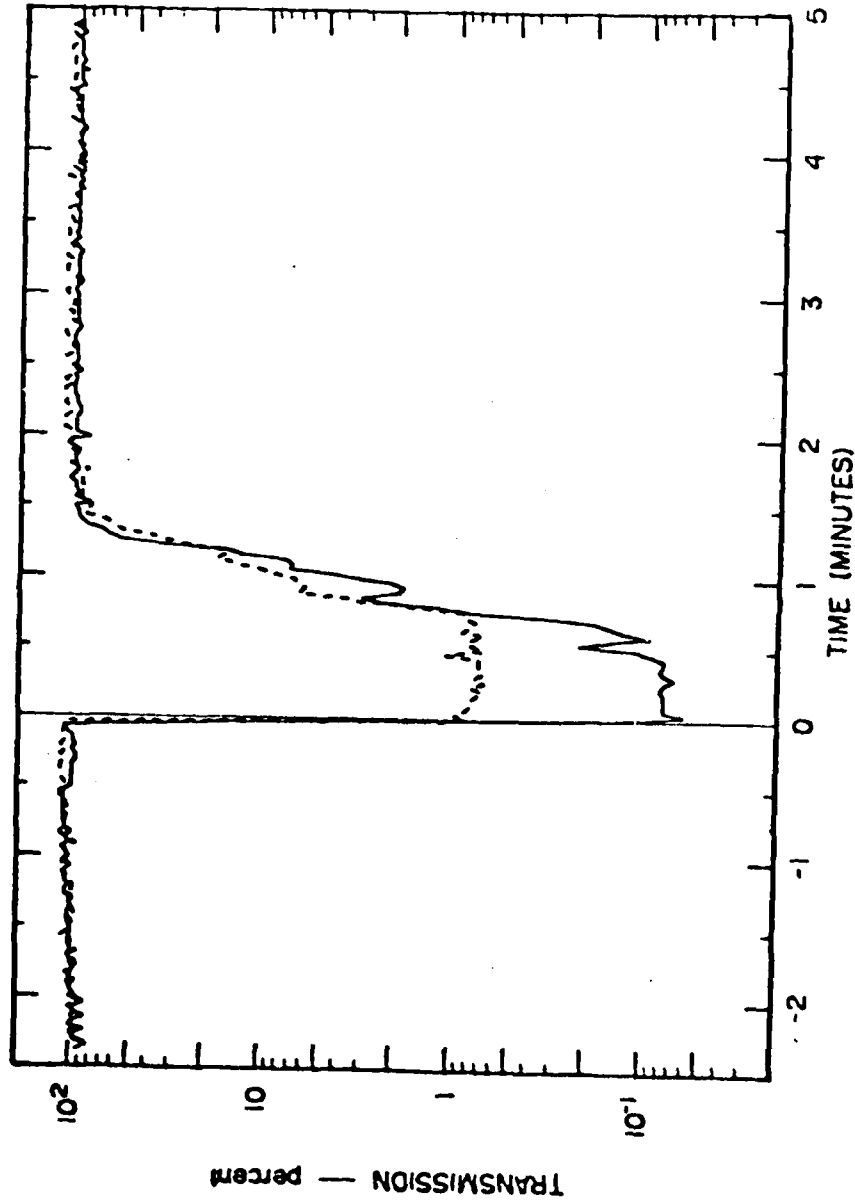


Figure 65. Transmission observed by the two-wavelength lidar system (E-8).

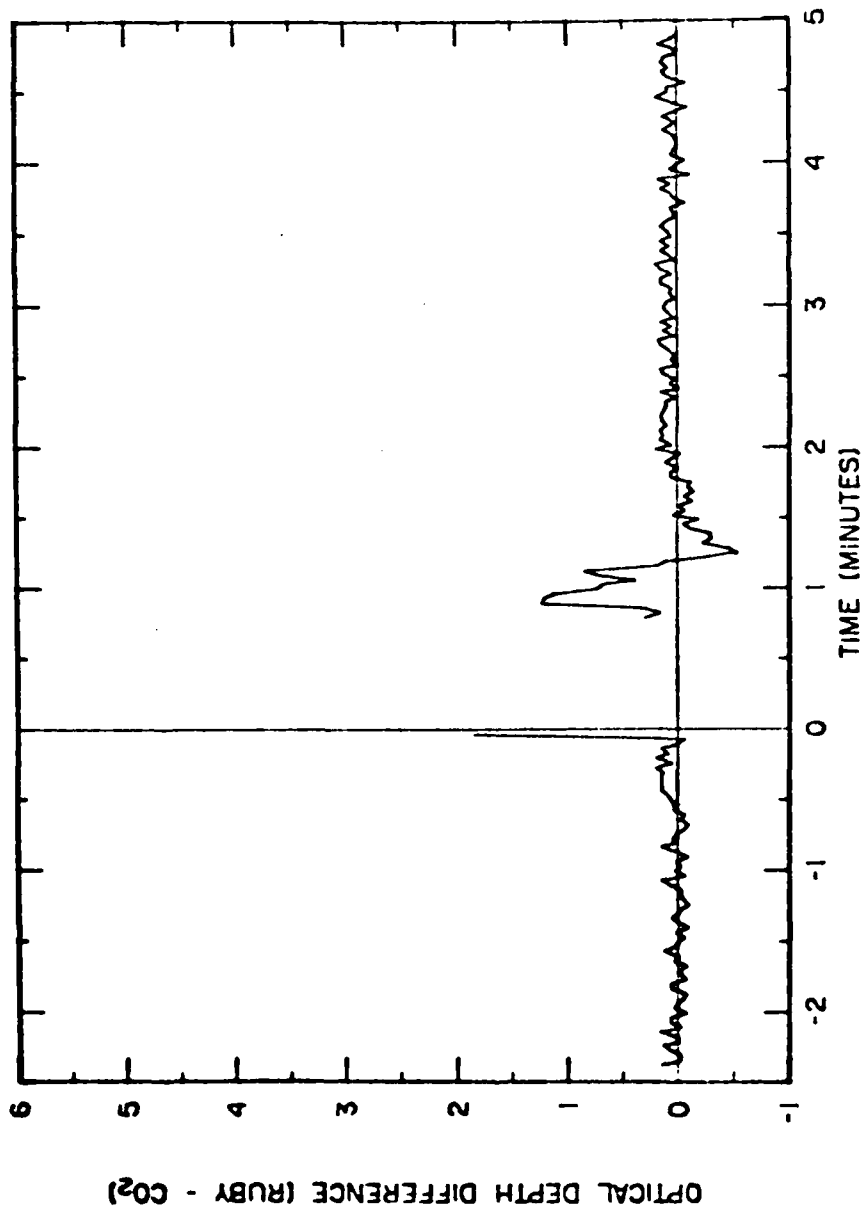


Figure 66. Difference between Ruby and CO₂ optical depths (E-8).

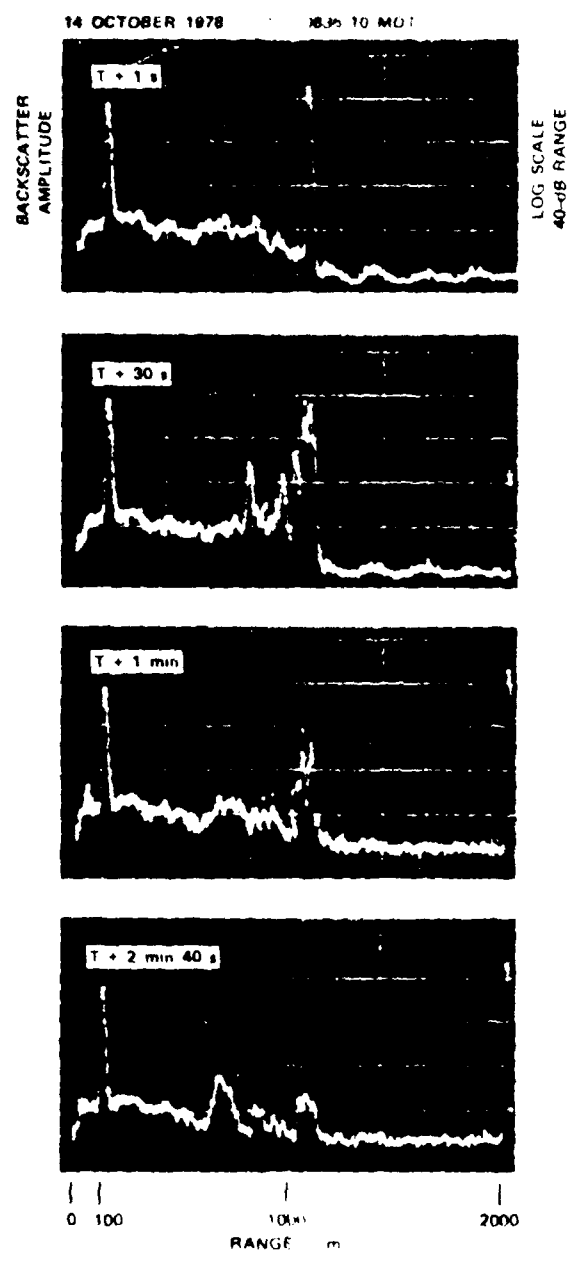


Figure 67. Event 10-11-01 backscatter data.

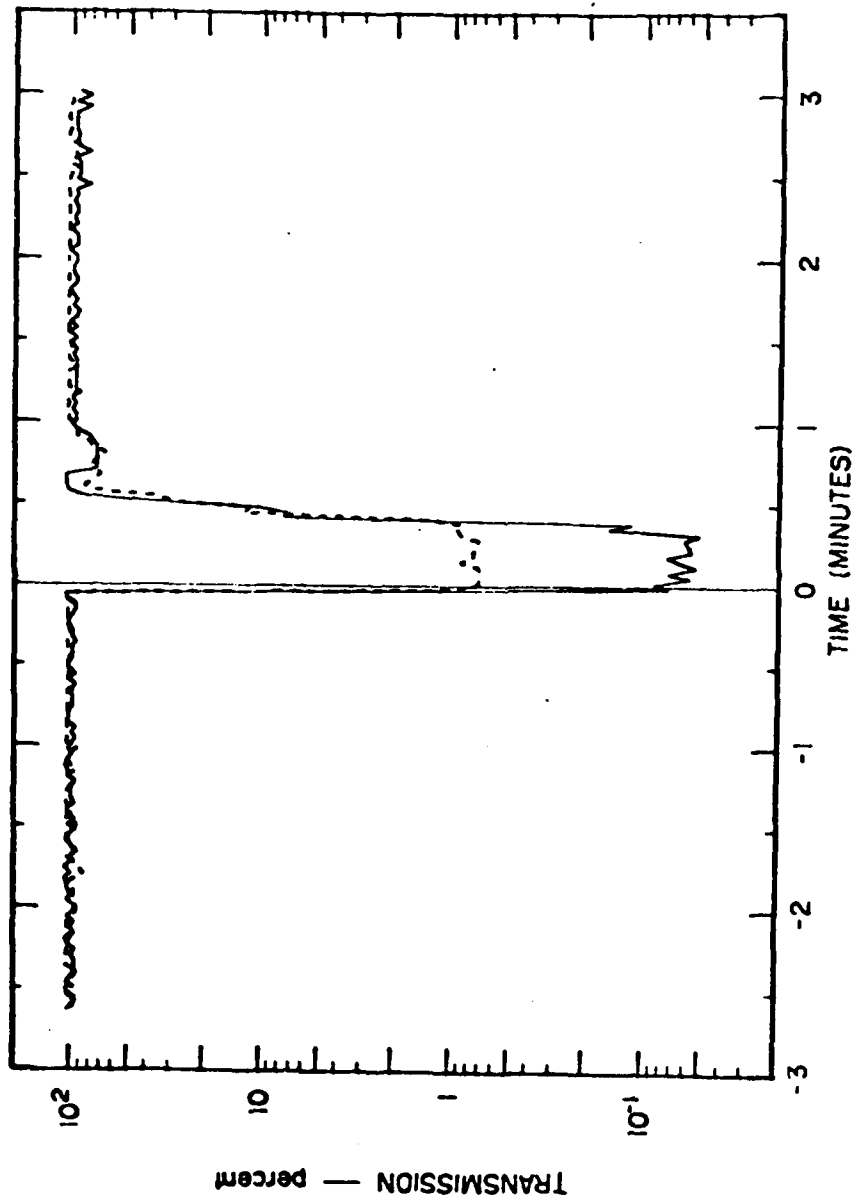


Figure 68. Transmission observed by the two-wavelength lidar system (E-9).

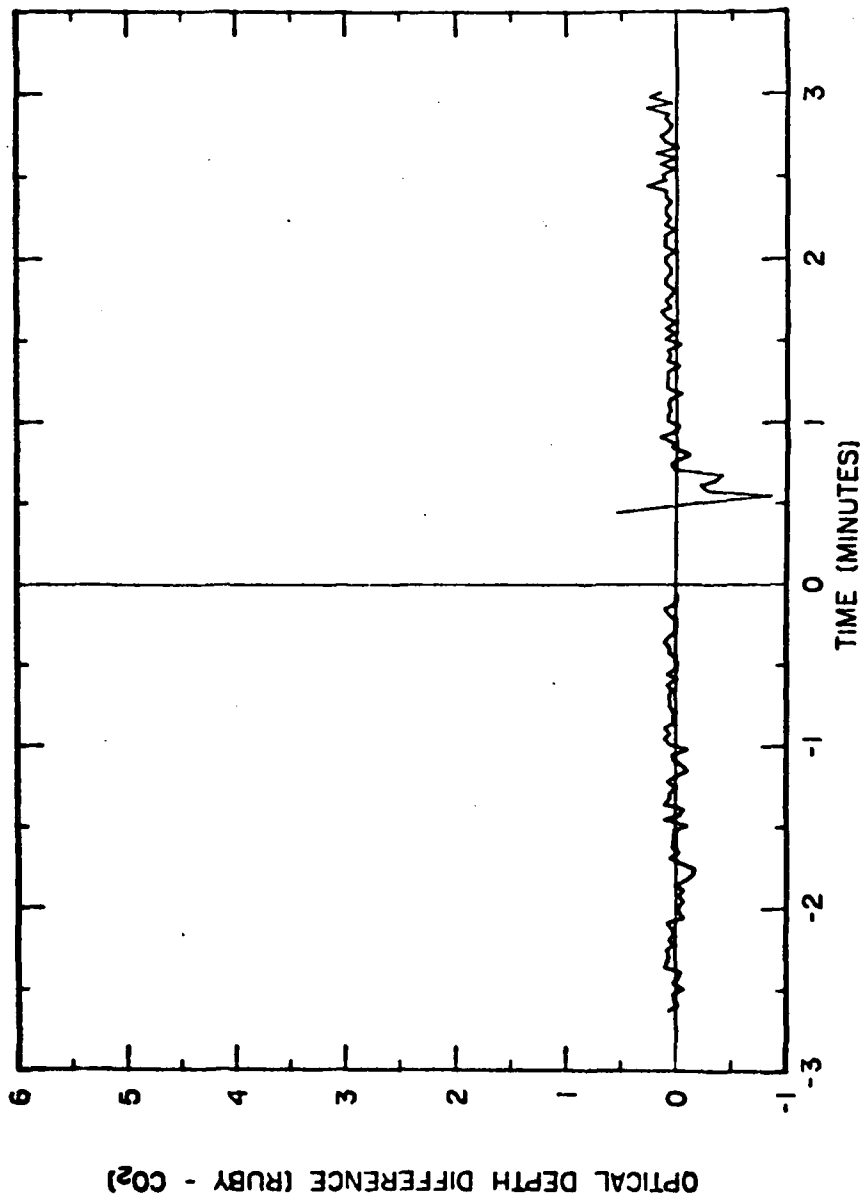
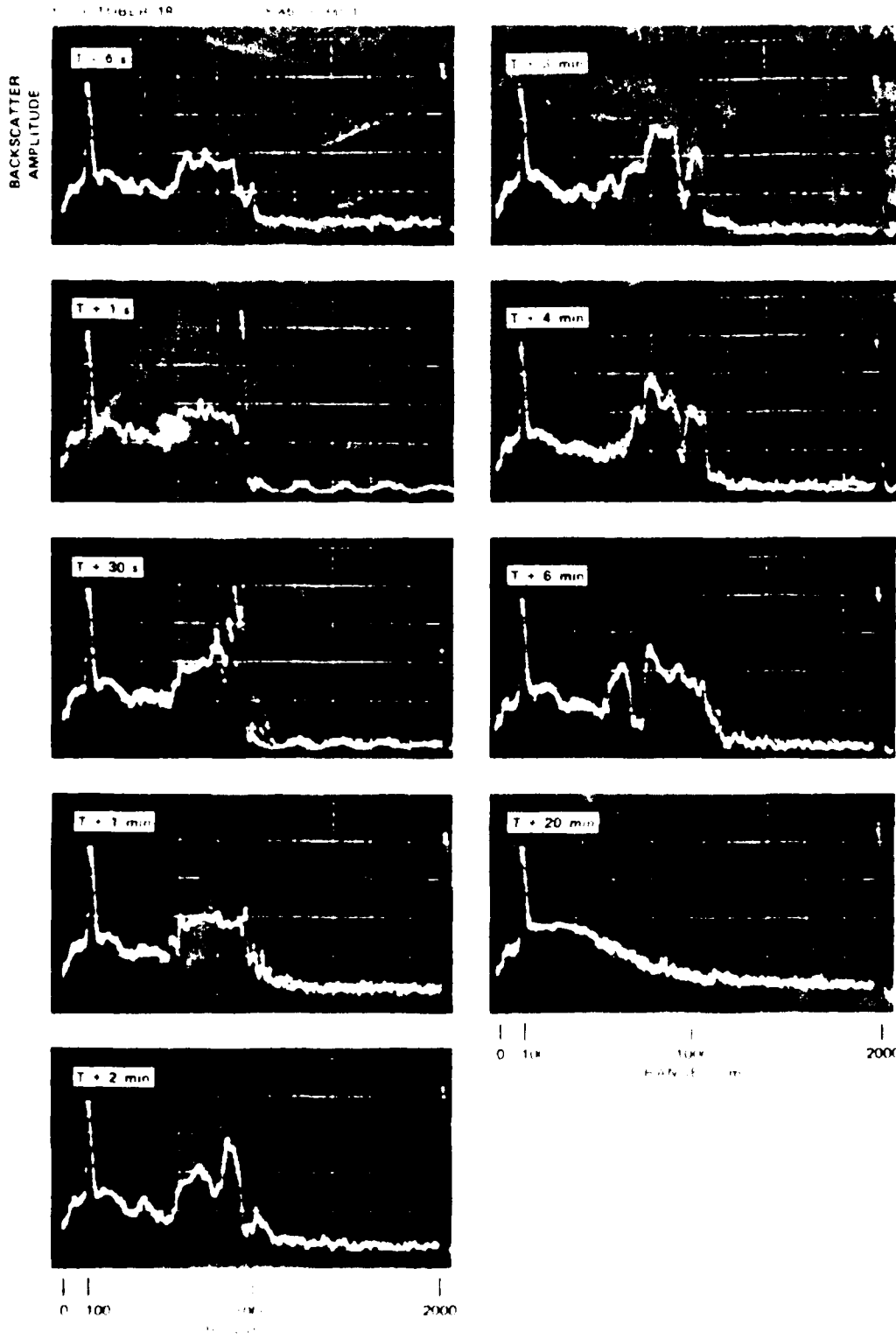


Figure 69. Difference between Ruby and CO₂ optical depths (E-9).



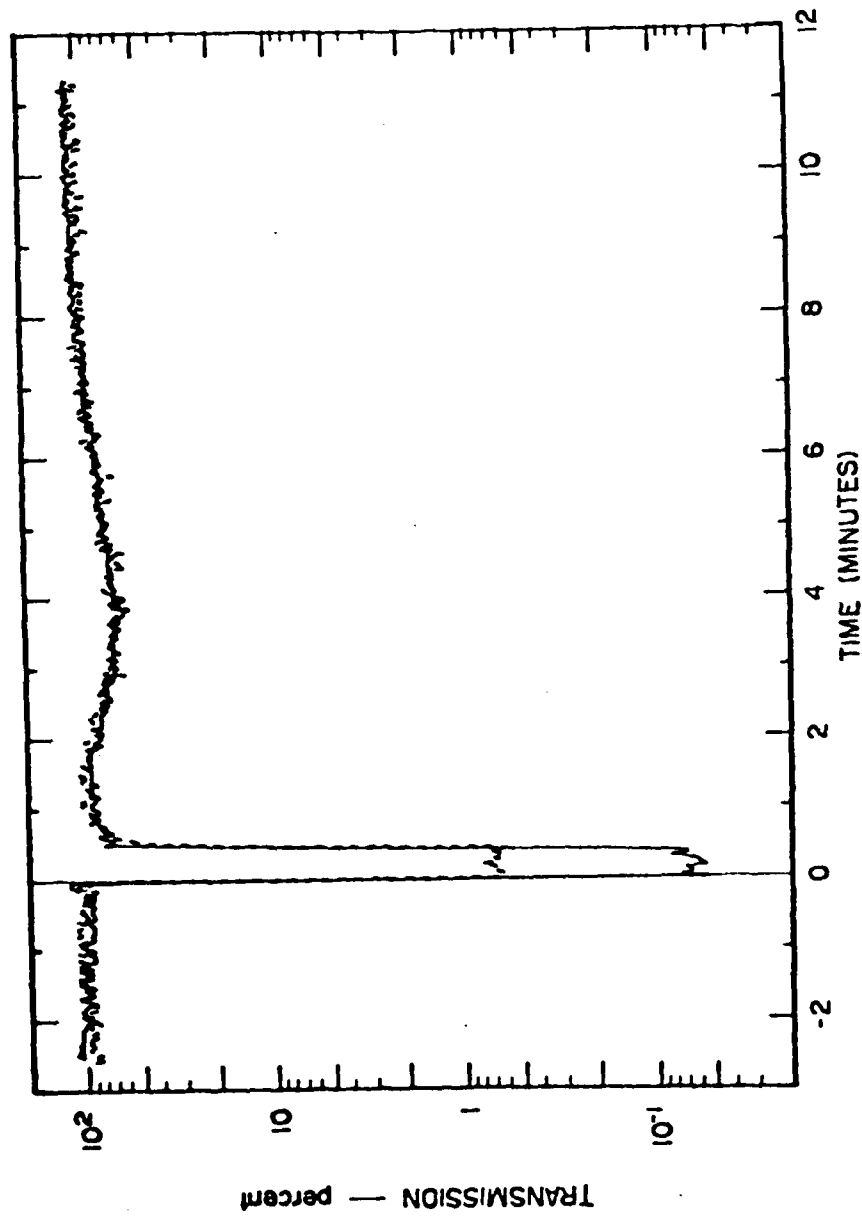


Figure 71. Transmission observed by the two-wavelength lidar system (E-10).

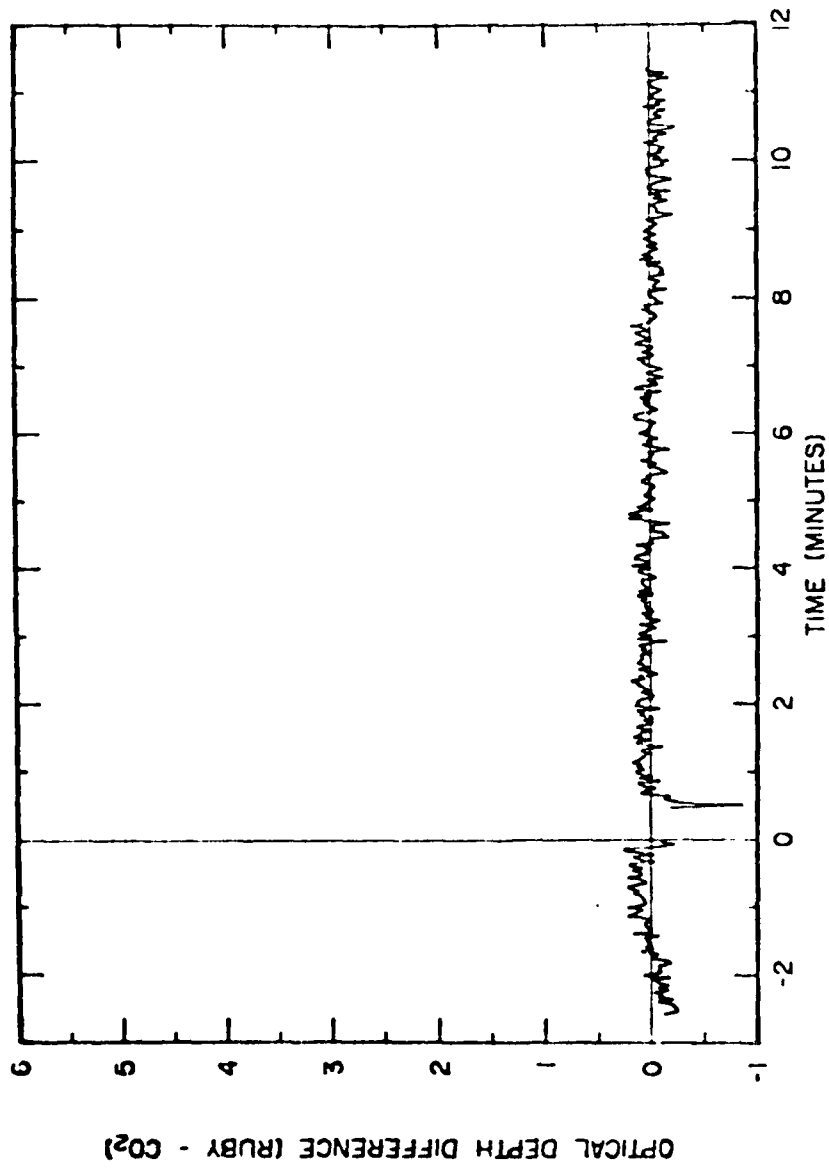


Figure 72. Difference between Ruby and CO₂ optical depths (E-10).

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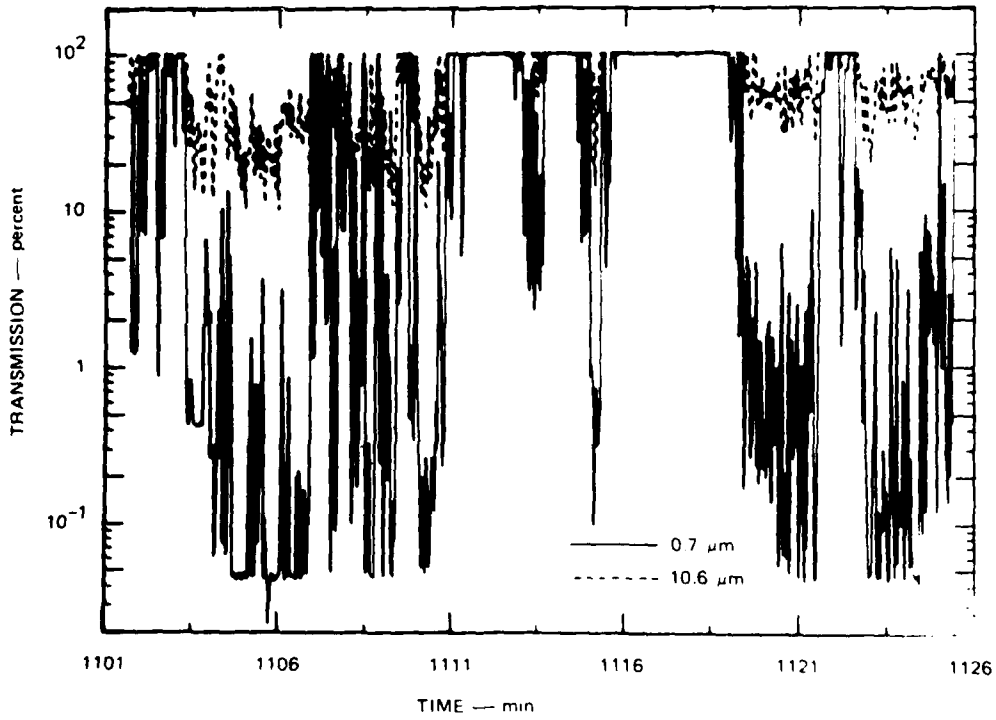
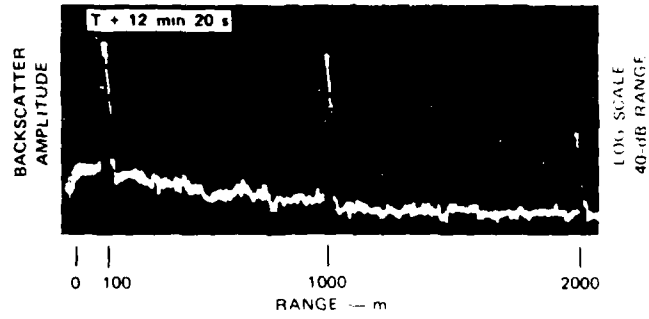


Figure 73. Event G-1 $10.6 \mu\text{m}$ backscatter data and two-wavelength transmission.

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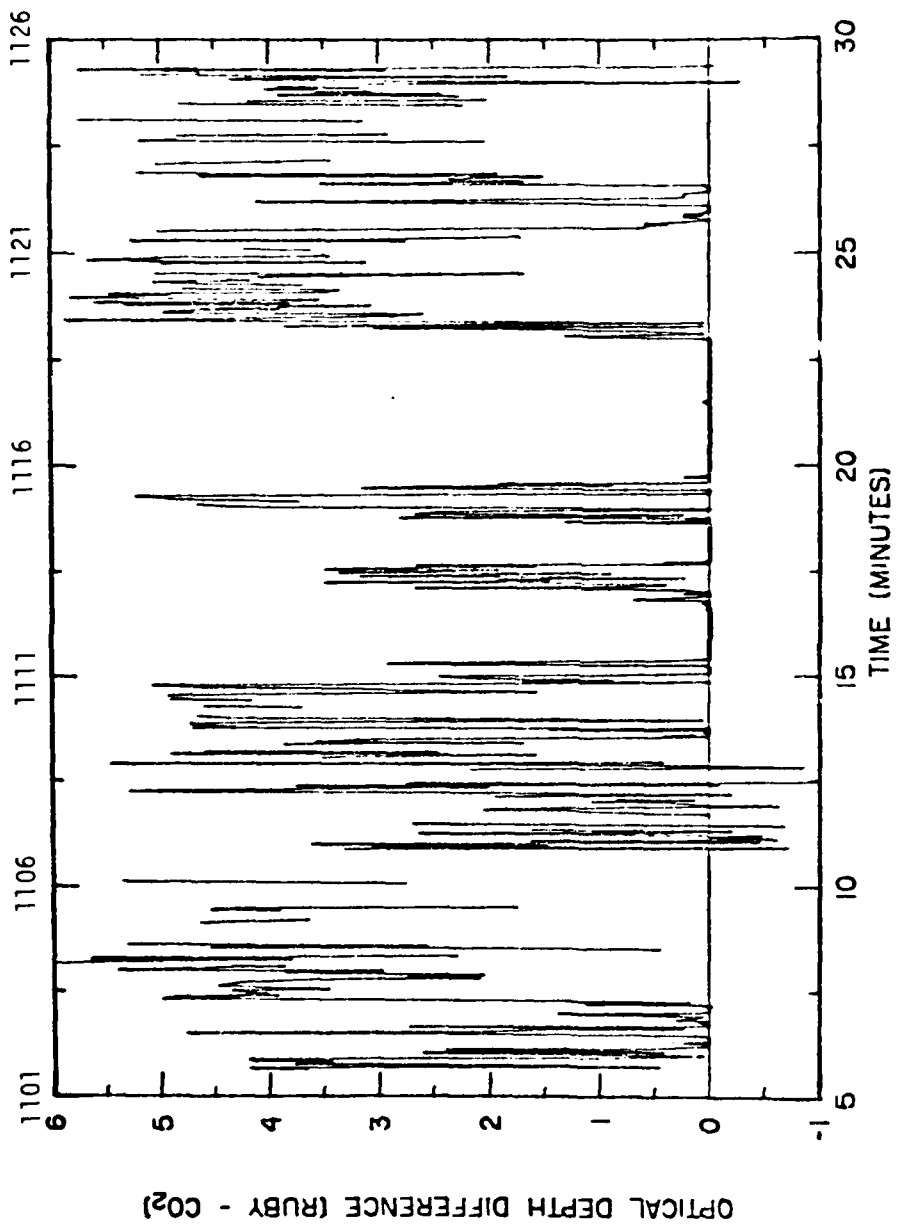


Figure 74. Difference between Ruby and CO₂ optical depths (G-1).

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2. Van der laan, Jan E., 1979, Lidar Observations at 0.7 μ m and 10.6 μ m Wavelengths during Dusty Infrared Test-I (DIRT-I), ASL-CR-79-0001-2, US Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM.
3. Lindberg, James D., 1979, Measured Effects of Battlefield Dust and Smoke on Visible, Infrared and Millimeter Wavelength Propagation: A Preliminary Report on Dusty Infrared Test-I (DIRT-I), ASL Technical Report 0021, US Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM.

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