**Naval Research Laboratory**
**Washington, DC 20375-5320**

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# Atmospheric Transmittance Between 1.0 and 2.0 μm

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J. A. Welch

*Applied Optics Branch*
*Optical Sciences Division*

June 30, 1993



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Calculated high resolution extinction plots at sea level are presented for the spectral region between 1 and 2 μm using a mid-latitude summer atmospheric model.

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# ATMOSPHERIC TRANSMITTANCE BETWEEN 1.0 AND 2.0 μM

G.L. Trusty and J.A. Welch

## INTRODUCTION

In the design of EO systems that operate in the infrared the most important aspect for outdoor use is the choice of wavelength. Because of molecular absorption by atmospheric gases, there are few locations in the infrared spectrum that provide sufficiently high transmission for a system to perform successfully. For laser-based systems, the high complexity of the spectrum usually requires a calculation for each proposed wavelength.

In 1983, primarily driven by calculations required for the HF-DF laser, two members of this section at NRL (Leslie and Lebow) produced a report[1] that provided calculated plots of high-resolution molecular absorption spectra of the composite atmospheric gases from 2.0 to 5.0 μm. These plots were of sufficiently high resolution (40 $cm^{-1}$ total on each 7-inch-long graph) that all spectral structure at one atmosphere of pressure, i.e., at sea level, was readily discernable by the reader. That report proved to be extremely useful; in fact, after these ten years it is still regularly referred to for laser and system choices in that spectral region.

## THE CALCULATIONS

In the past several years, new laser developments and new requirements revitalized interest in atmospheric propagation. Over that time we have found many wavelengths being investigated that fall between 1.0 and 2.0 μm. Due to the durable value of the original report we deemed it worthwhile to provide a similar atlas for this new spectral region.

As an historical note the calculations for the first report were done in 1983 on a DEC PDP-11/40 minicomputer. The computer program used at the time was a version of a HITRAN-like code that was written by one of the current authors (Trusty) while a graduate student at Ohio State University. He had brought the code with him to NRL where S. Hanley and K. Haught each added significant improvements to it as it became an integral part of the section operation.

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Today we do the calculations on a PC, using a commercial product[2], which is a version of the AFGL(AirForce Geophysical Laboratory, now Phillips Laboratory) FASCODE[3]. Thus, this report, unlike the original, is not based on an NRL-produced calculational capability. It is presented, instead, as a result of NRL's continued interest in high-resolution propagation issues. Except for the spectal region, the output product here is essentially the same as that of the first report; the primary improvement is probably in the accuracy of the more recent AFGL Absorption Atlas[4] data, the basis of all HITRAN-like codes.

Note that most of the atmospheric absorption in this spectral region comes from water vapor, and therefore, the actual transmittance of a particular laser line can vary significantly with a change in humidity. By necessity, the plots in the report give results for only one value of humidity. Thus, they are only to provide a quick check on applicability to propagation through the atmosphere to determine if further study is required.

For consistancy with the earlier report, we have chosen the AFGL Mid-Latitude Summer model[5] for the atmospheric conditions. At sea level, which these current calculations represent, this gives a temperature of 21 °C and a water vapor pressure of 14 torr. While the earlier report considered only molecular absorption, here, primarily because of the larger scattering contribution at these shorter wavelengths, we have included aerosol scattering. We used the Maritime 23Km-Visibility aerosol model in the calculations. The low-resolution LOWTRAN[6] plot in Fig. 1 shows the resultant total transmittance for the entire spectral region as well as the transmittance for the aerosol scattering contribution.

## THE COMPUTED HIGH-RESOLUTION SPECTRA

The high-resolution plots are given in the Appendix. Each page shows a plot of the extinction coefficient of the atmosphere, for the conditions given above, over the 40-$cm^{-1}$ spectral region noted by the X-axis. Because each plot does show a labeled X-axis noting the spectral region, figure numbers and figure captions seemed redundant and are not included.

## REFERENCES

1. D.H. Leslie, and P.S. Lebow, "Computed Survey Spectra of 2-5$\mu$ Atmospheric Absorption", NRL Memorandum Report 5168, August 31, 1983

2. ONTAR Corporation, PC-LnTRAN, Version 2.1, 129 University Rd., Brookline, MA 02146

3. S.A. Clough, F.X. Kneizys, L.S. Rothman, W.O. Gallery, "Atmospheric Spectral Transmittance and Radiance: FASCOD1B," SPIE 277, Atmospheric Transmission (1981)

4. L.S. Rothman, et al.,"The HITRAN database: 1986 edition", Applied Optics, 26, No. 19, p 4058, 1 Oct 1987

5. G.P. Anderson, S.A. Clough, F.X. Kneizys, J.H. Chetwynd, E.P. Shettle, "AFGL Atmospheric Constituent Profiles" (0-120 km), ERP Report No. 954, AFGL-TR-86-0110, 15 May 1986

6. ONTAR Corporation, PC-TRAN, 129 University Rd., Brookline, MA 02146

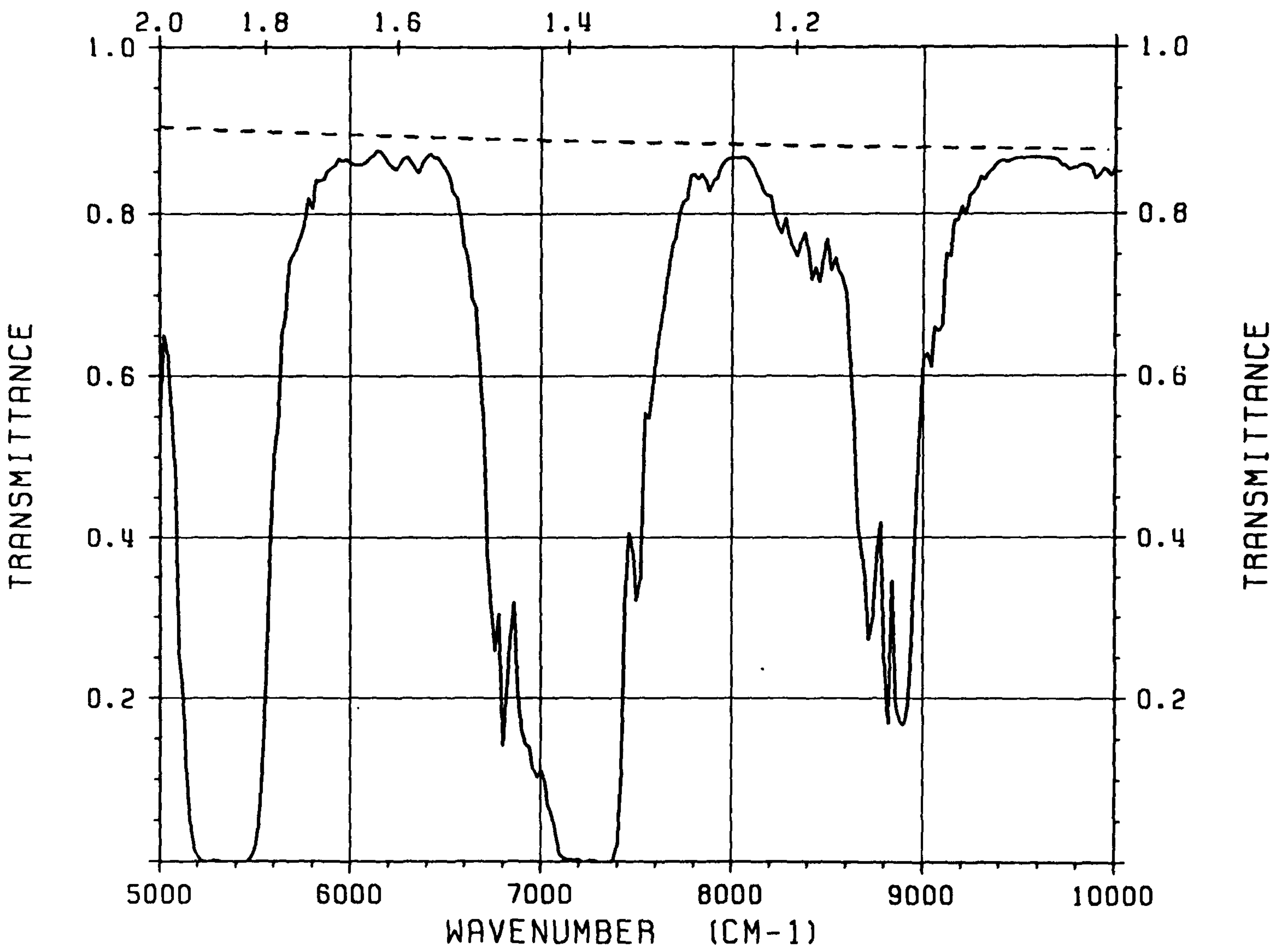
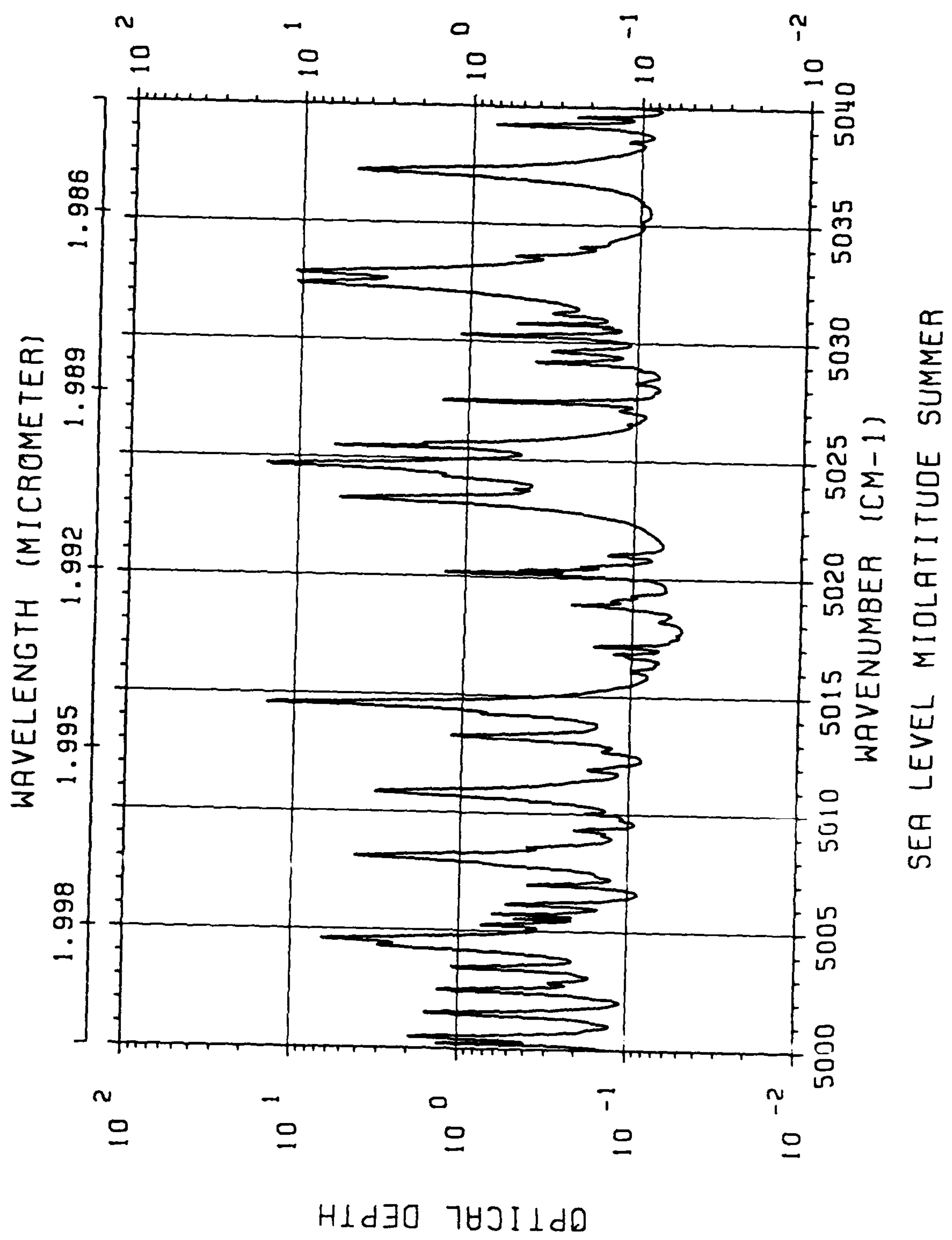



Figure 1. Low-resolution plot of transmittance between 1.0 and 2.0 $\mu$m

# APPENDIX

# THE COMPUTED HIGH-RESOLUTION SPECTRA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1.995
1.992
1.989
1.986
OPTICAL DEPTH
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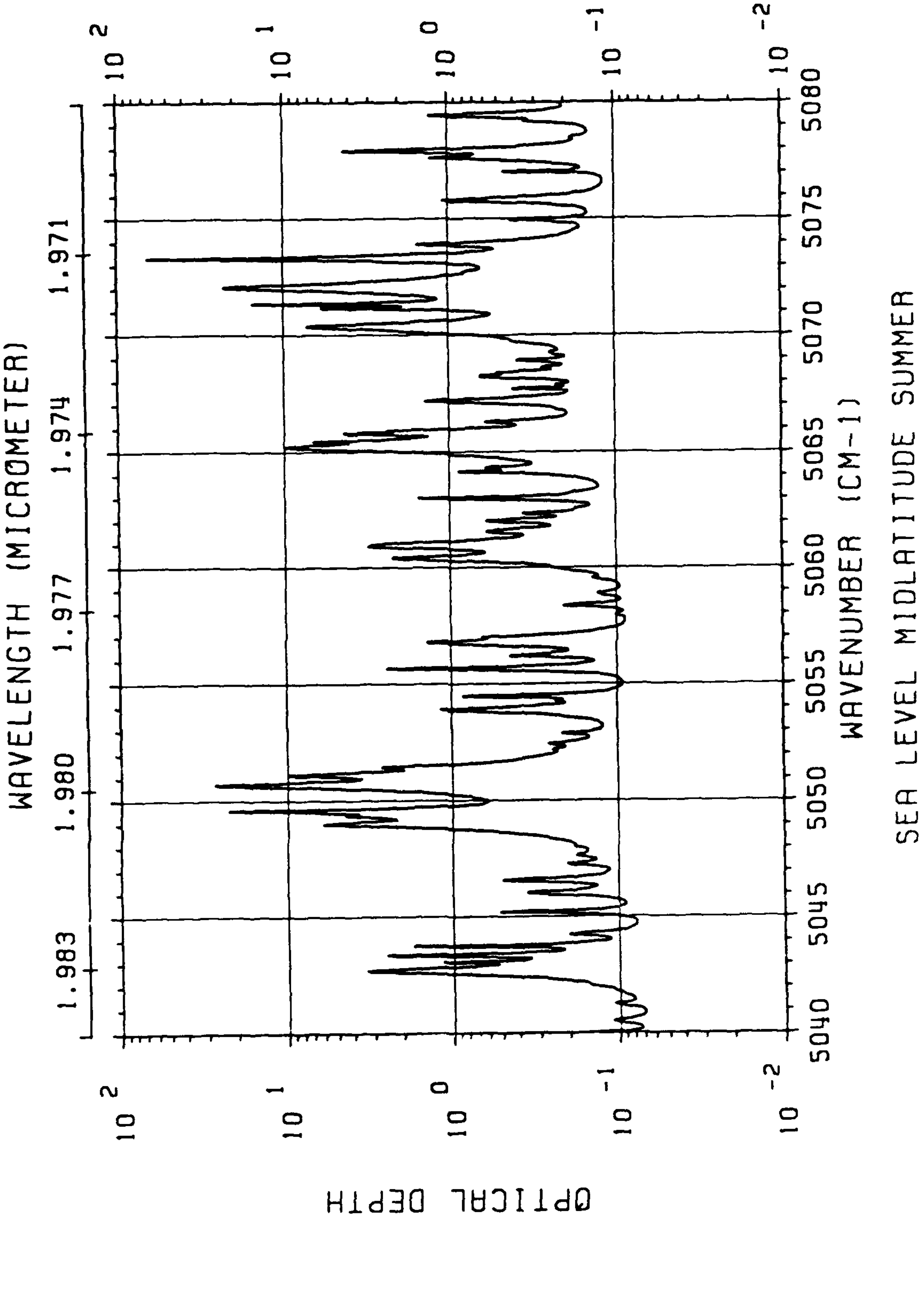
10 1
10 0
10 -1
10 -2
5000
5005
5010
5015
5020
5025
5030
5035
5040
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER



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1.980
1.977
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1.971
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5045
5050
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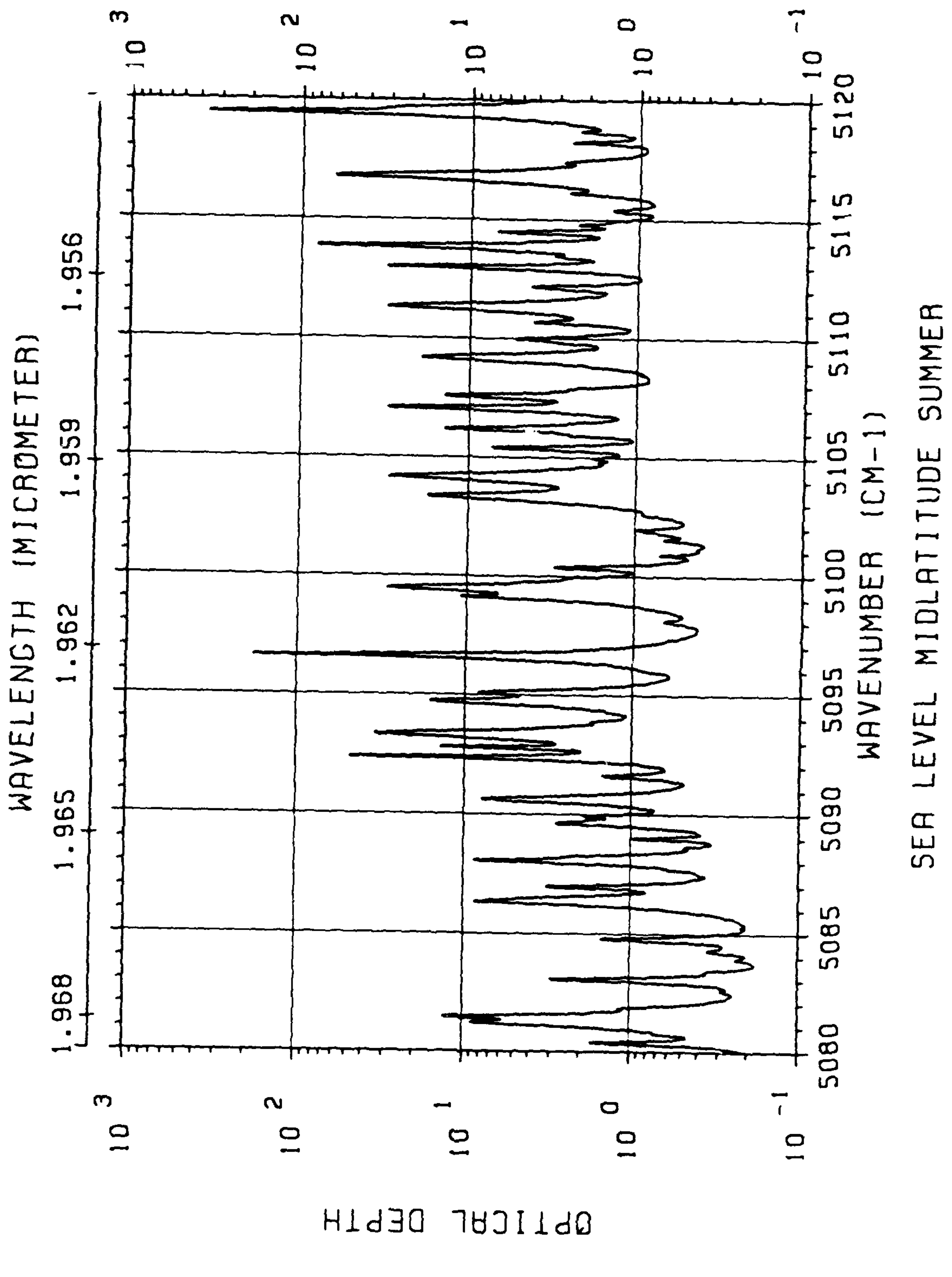
5060
5065
5070
5075
5080
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH



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1.962
1.959
1.956
WAVENUMBER (CM-1)
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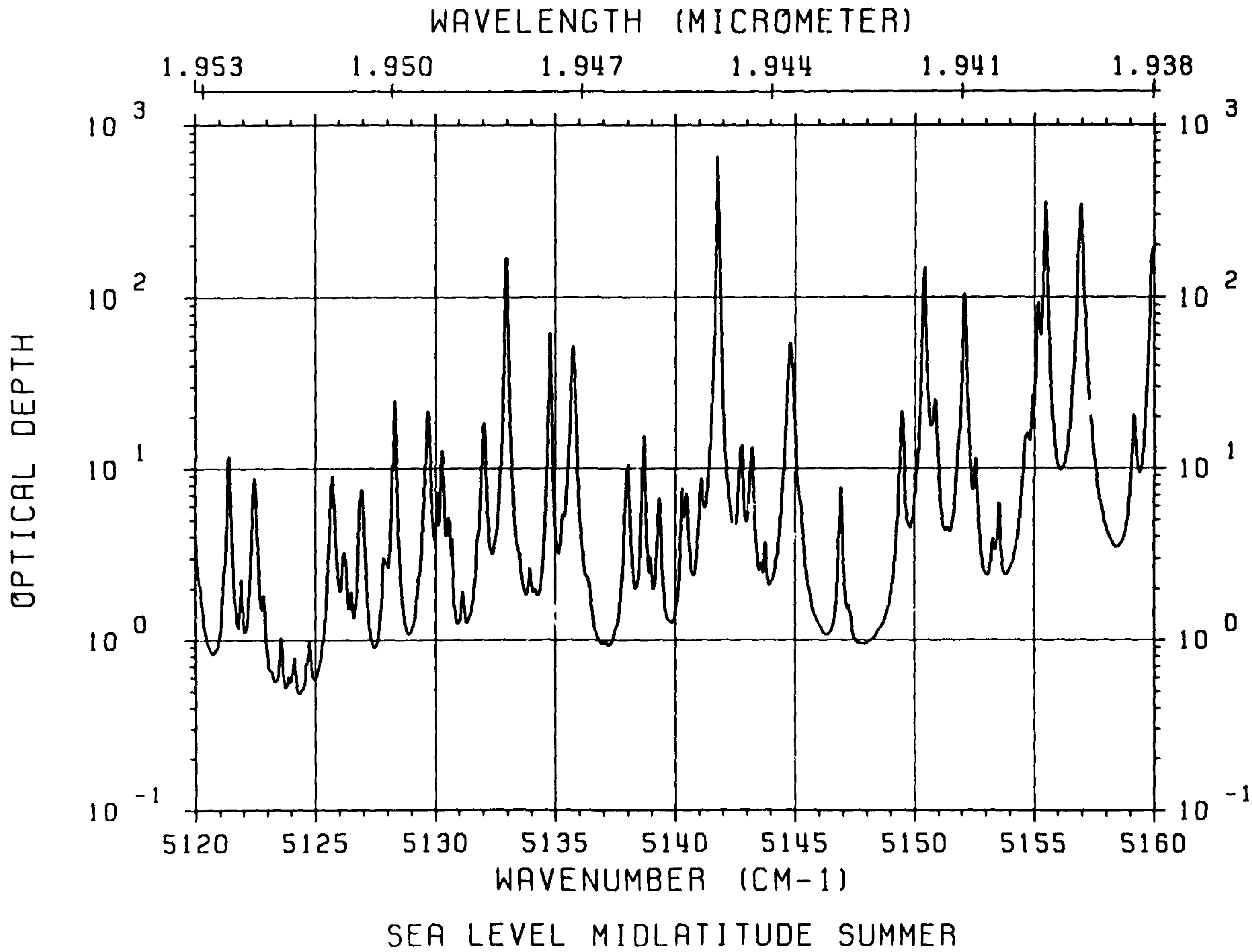
5085
5090
5095
5100
5105
5110
5115
5120
OPTICAL DEPTH
$10^{-1}$
$10^{0}$
$10^{1}$
$10^{2}$
$10^{3}$
SEA LEVEL MIDLATITUDE SUMMER



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1.947
1.944
1.941
1.938
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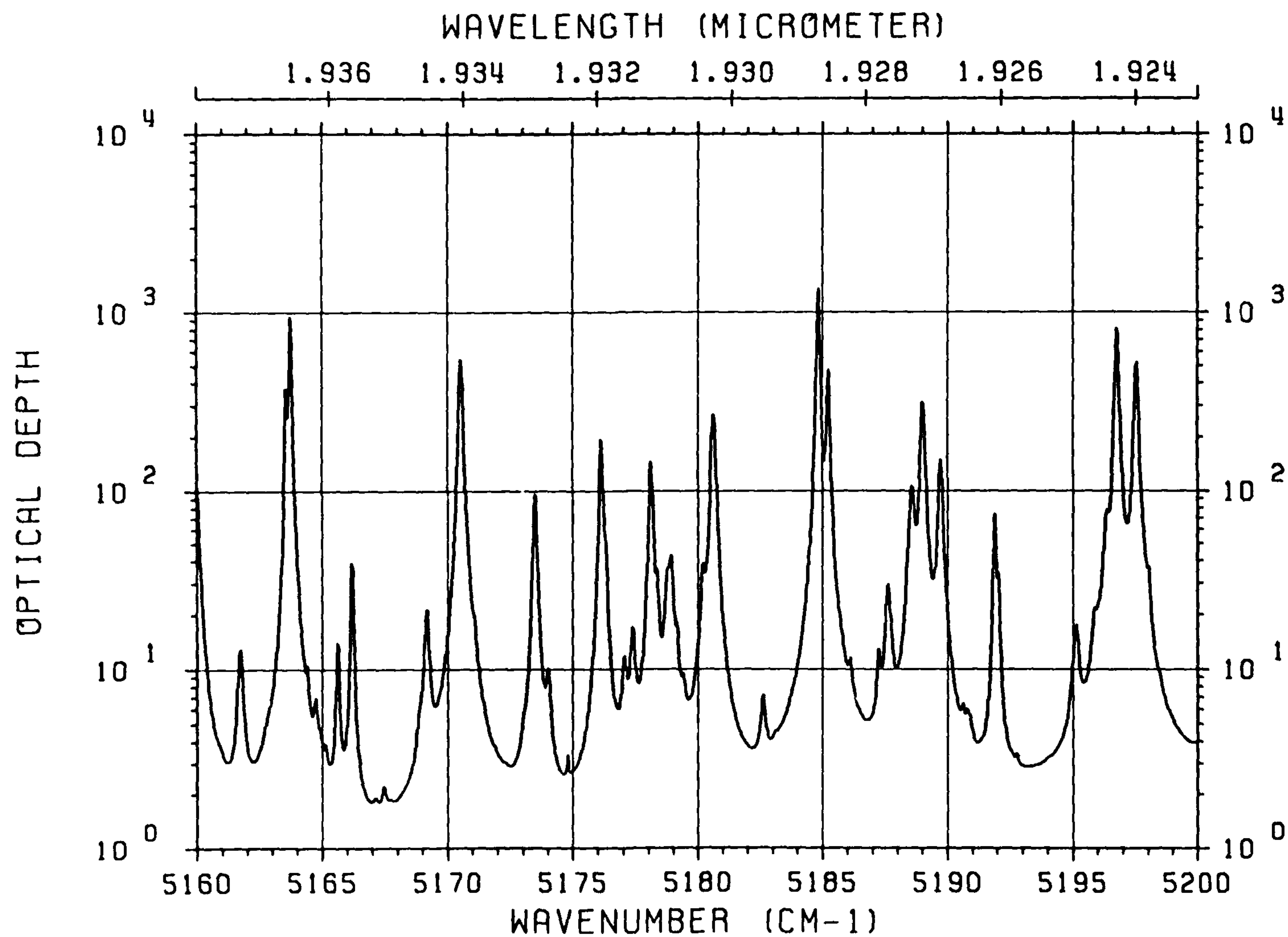
$10^{2}$
$10^{1}$
$10^{0}$
$10^{-1}$
5120
5125
5130
5135
5140
5145
5150
5155
5160
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER

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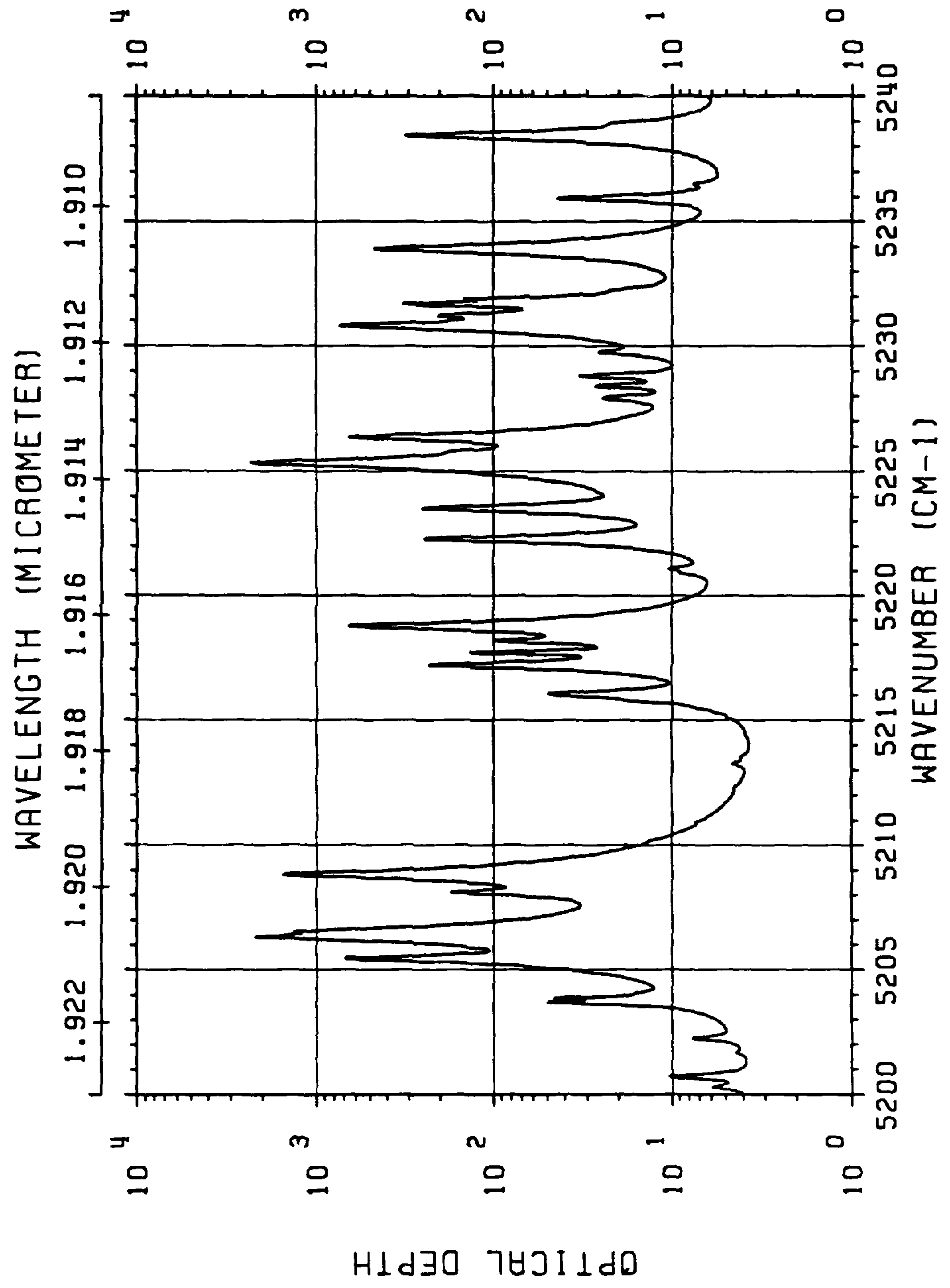


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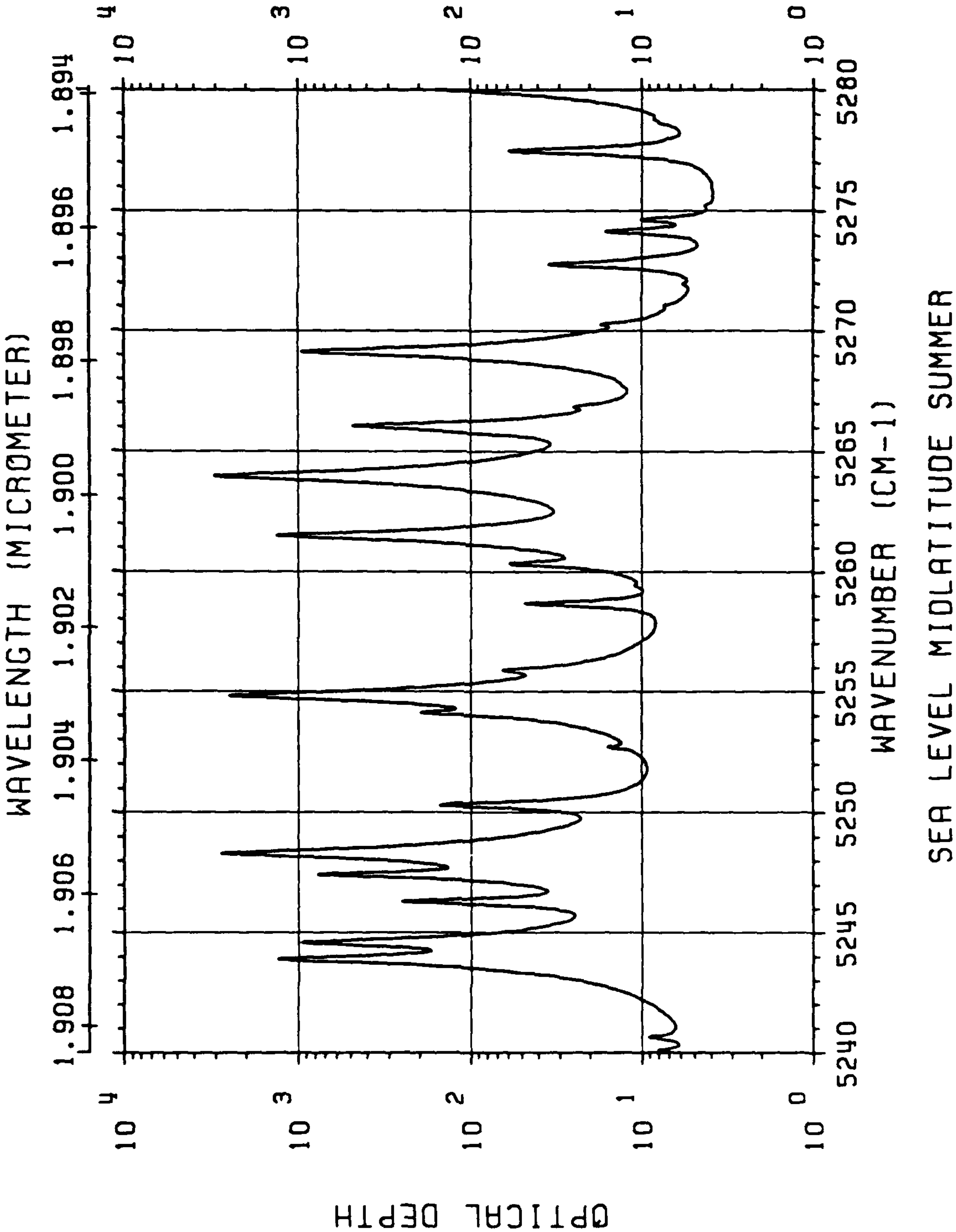
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1.906
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1.902
1.900
1.898
1.896
1.894
WAVENUMBER (CM-1)
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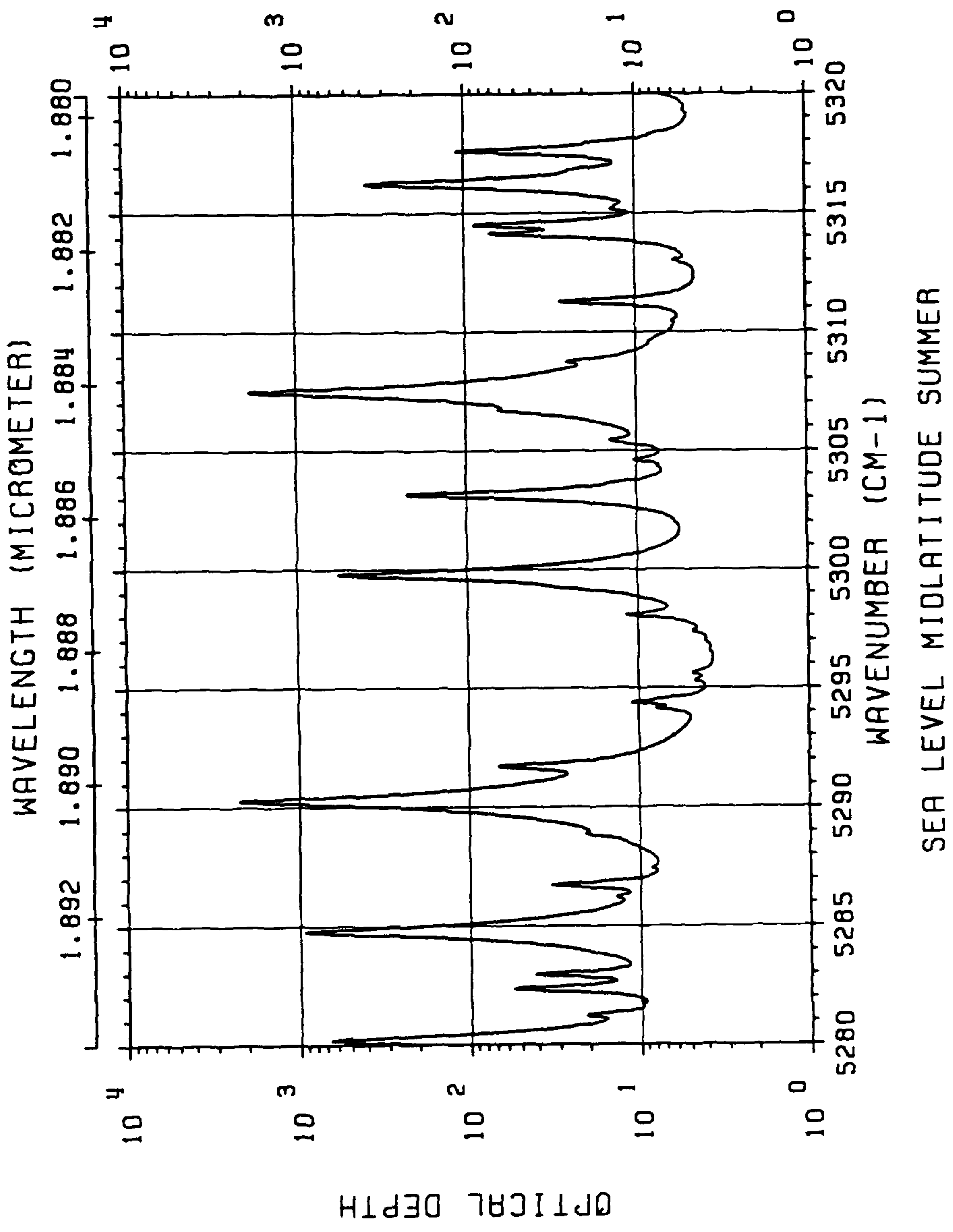
5245
5250
5255
5260
5265
5270
5275
5280
OPTICAL DEPTH
SEA LEVEL MIDLATITUDE SUMMER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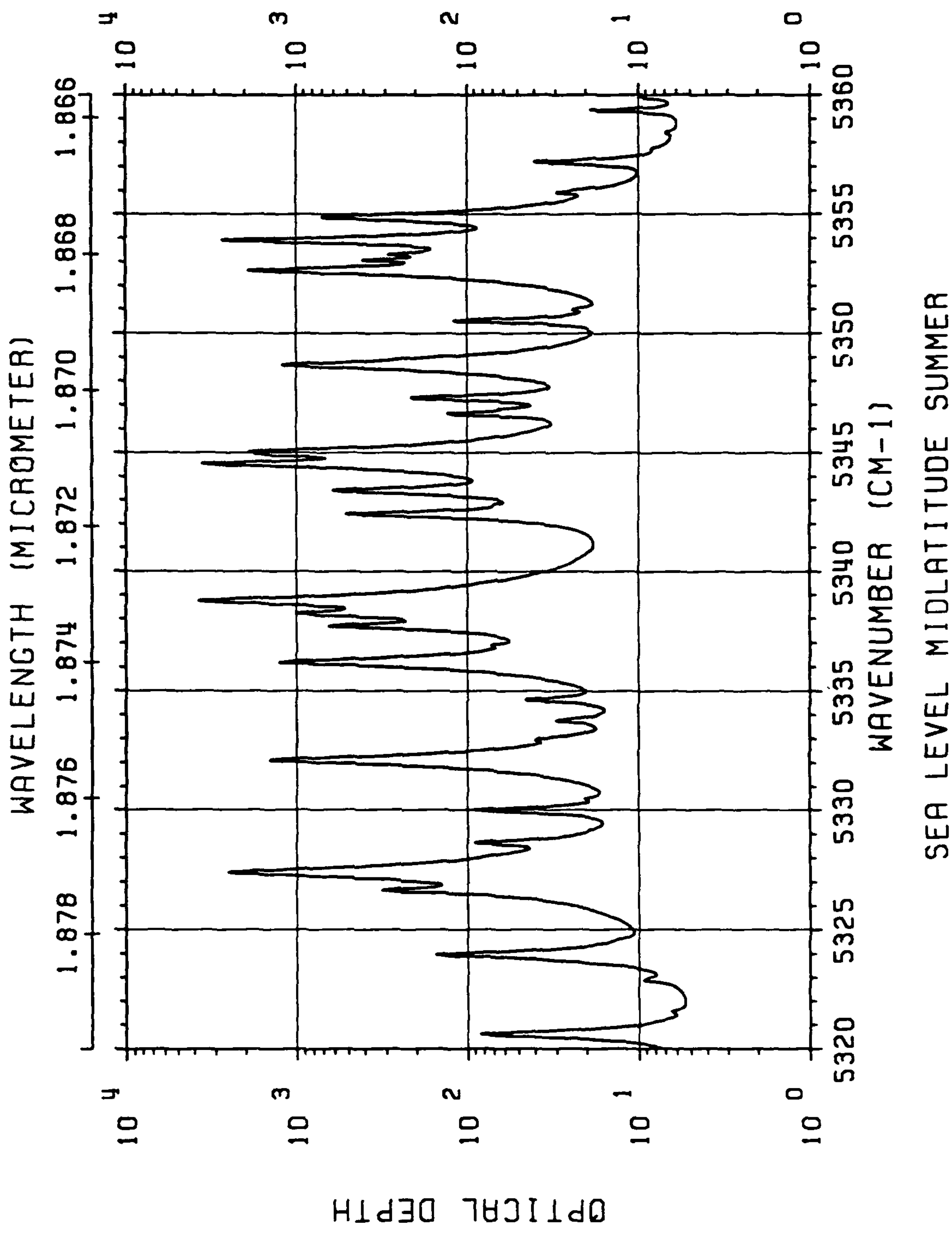
1.888
1.890
1.892
5280
5285
5290
5295
5300
5305
5310
5315
5320
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH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1.868
1.870
1.872
1.874
1.876
1.878
WAVENUMBER (CM-1)
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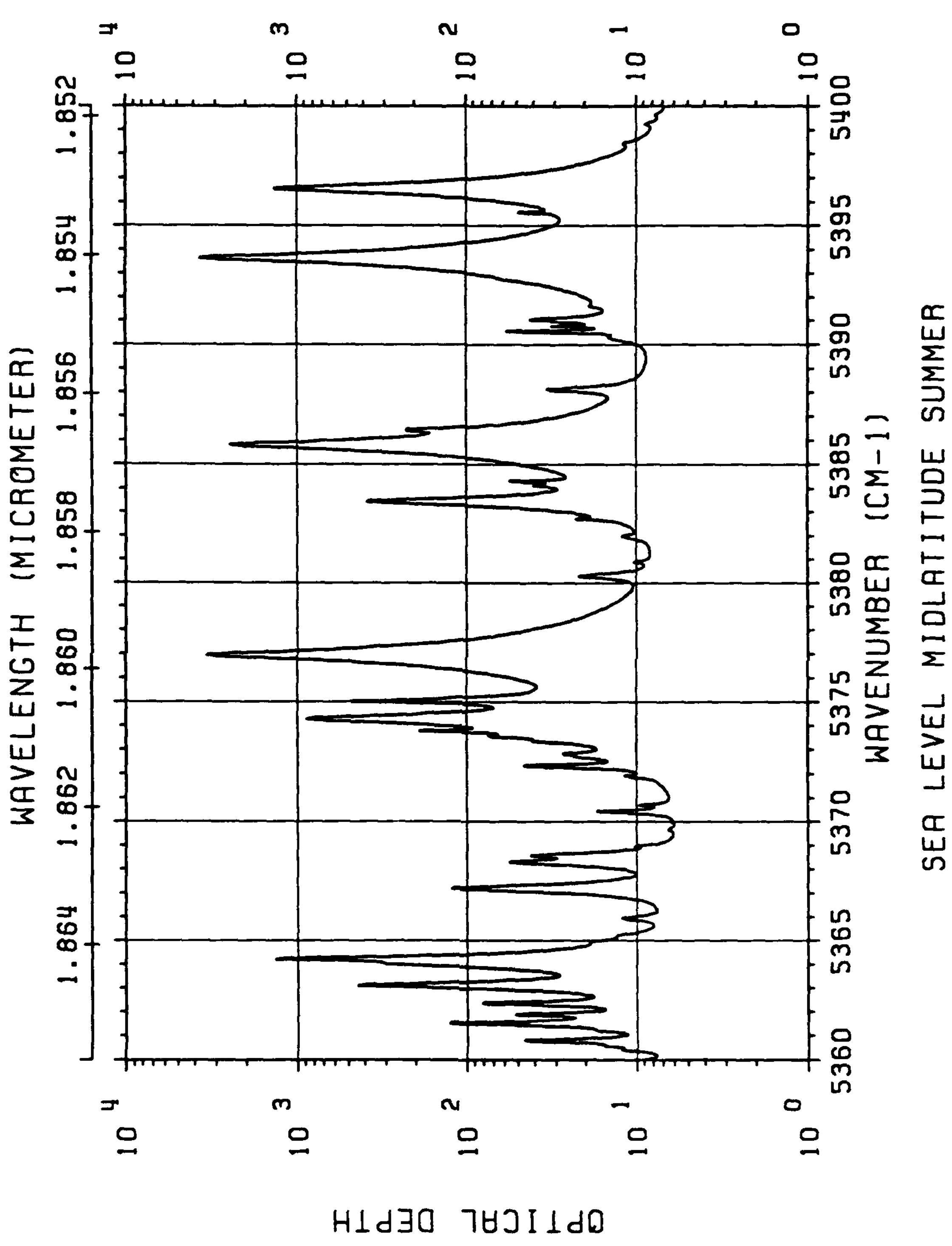
5325
5330
5335
5340
5345
5350
5355
5360
OPTICAL DEPTH
SEA LEVEL MIDLATITUDE SUMMER



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1.856
1.858
1.860
1.862
1.864
WAVENUMBER (CM-1)
5360
5365
5370
5375
5380
5385
5390
5395
5400
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH
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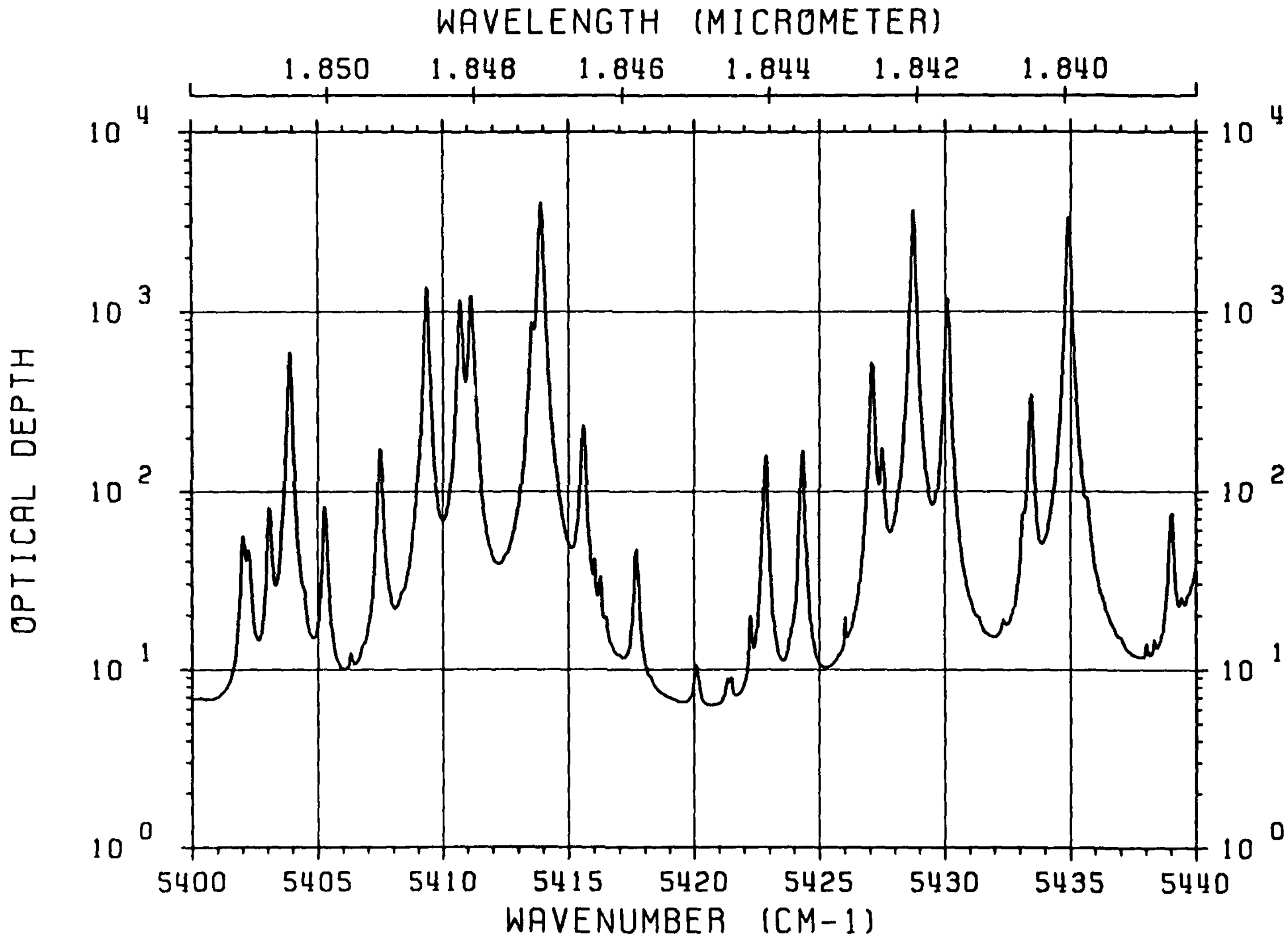
$10^1$
$10^2$
$10^3$
$10^4$

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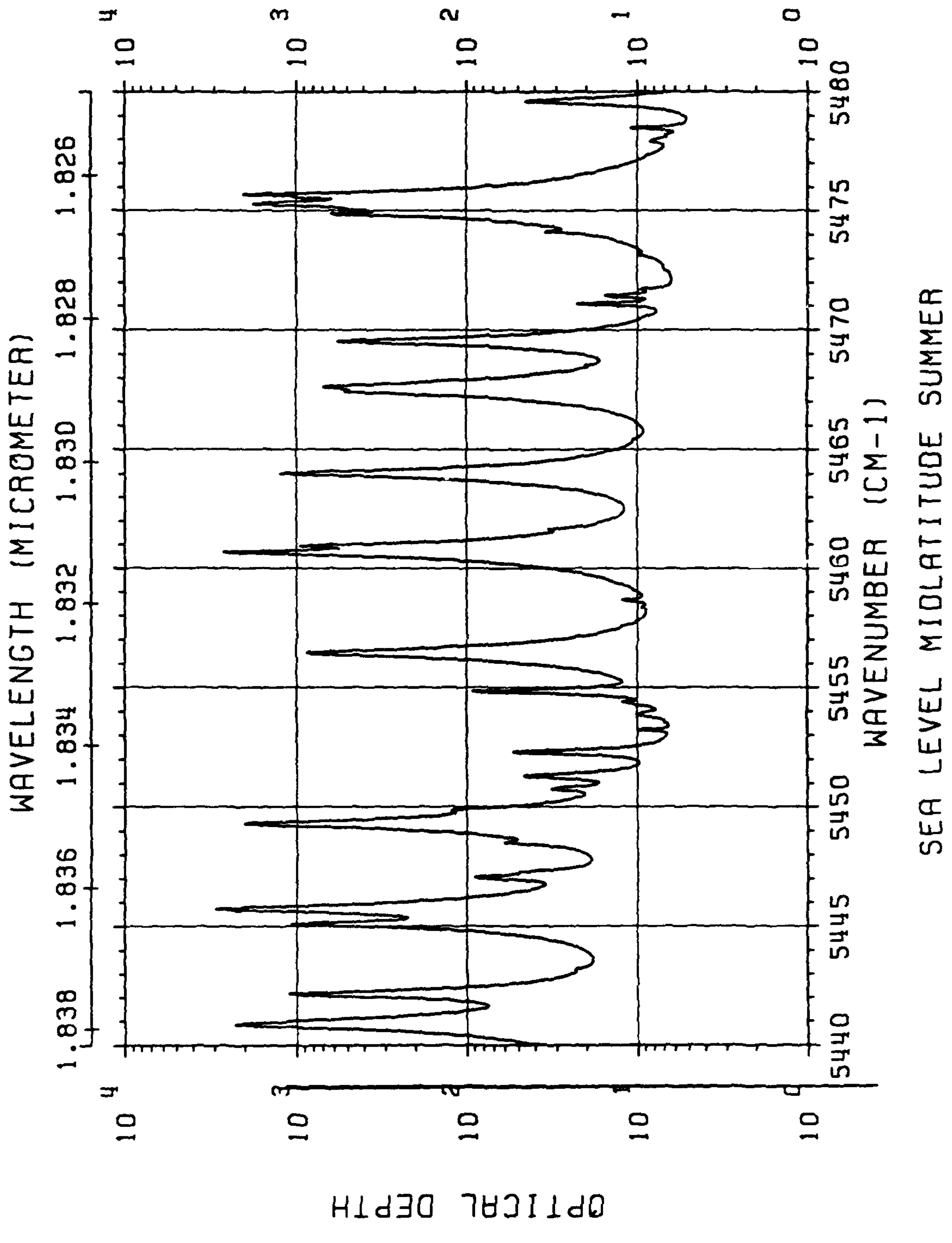
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1.828
1.830
1.832
1.834
1.836
1.838
10^4
10^3
10^2
10^1
10^0
OPTICAL DEPTH
5440
5445
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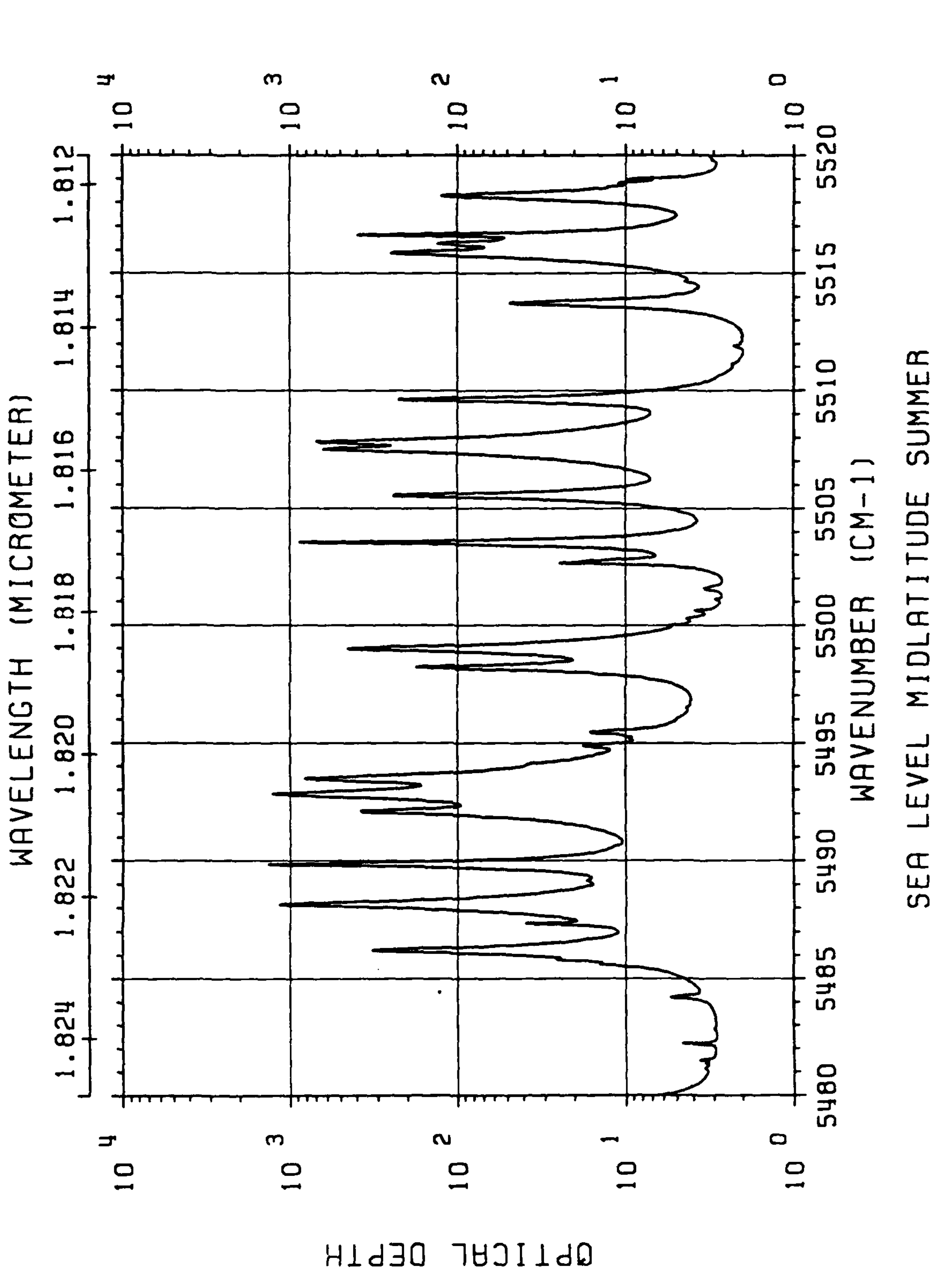
5455
5460
5465
5470
5475
5480
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER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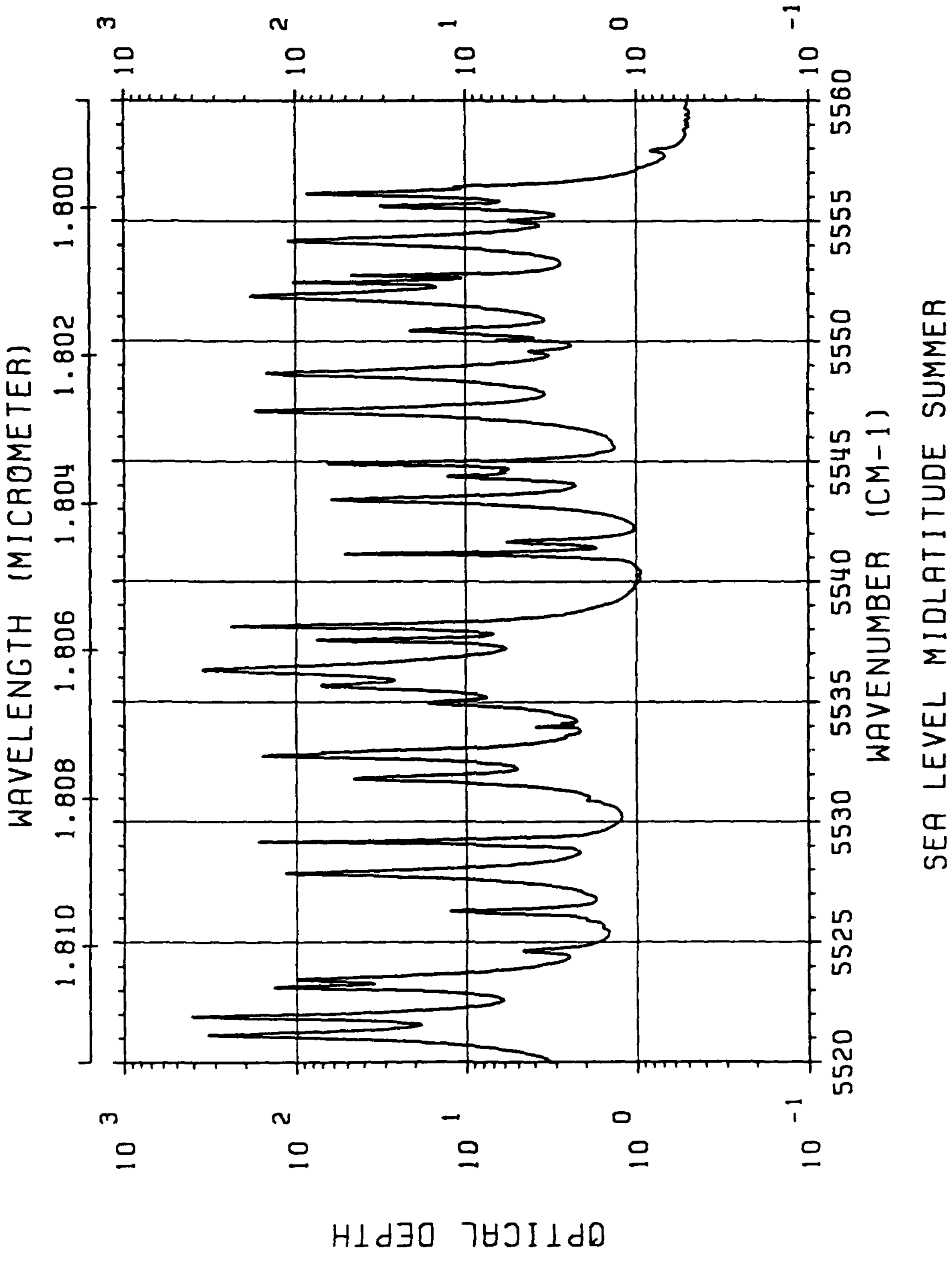
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH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1.806
1.804
1.802
1.800
WAVENUMBER (CM-1)
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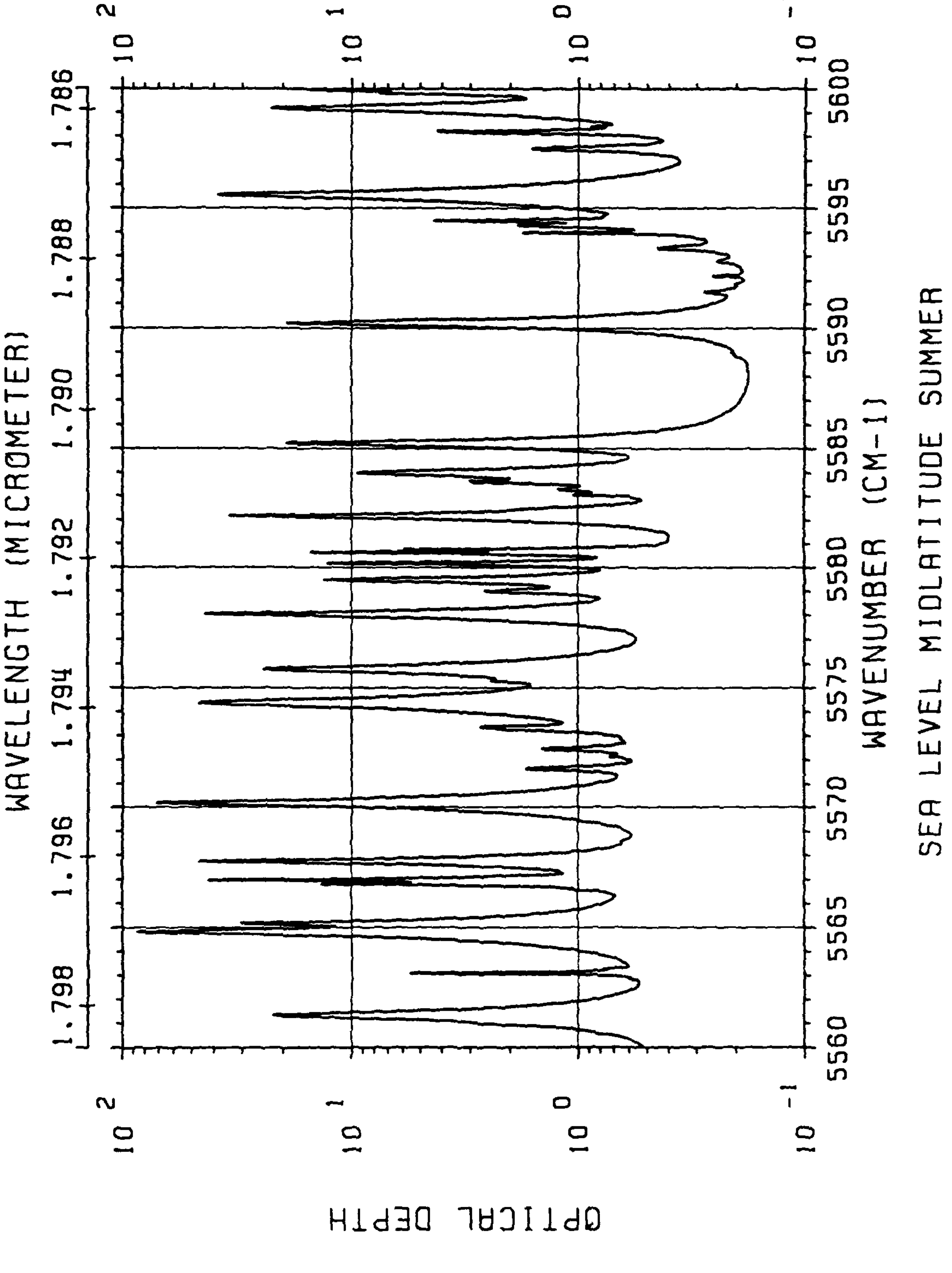
5525
5530
5535
5540
5545
5550
5555
5560
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH
10^3
10^2
10^1
10^0
10^-1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1.792
1.794
1.796
1.798
WAVENUMBER (CM-1)
5560
5565
5570
5575
5580
5585
5590
5595
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SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH
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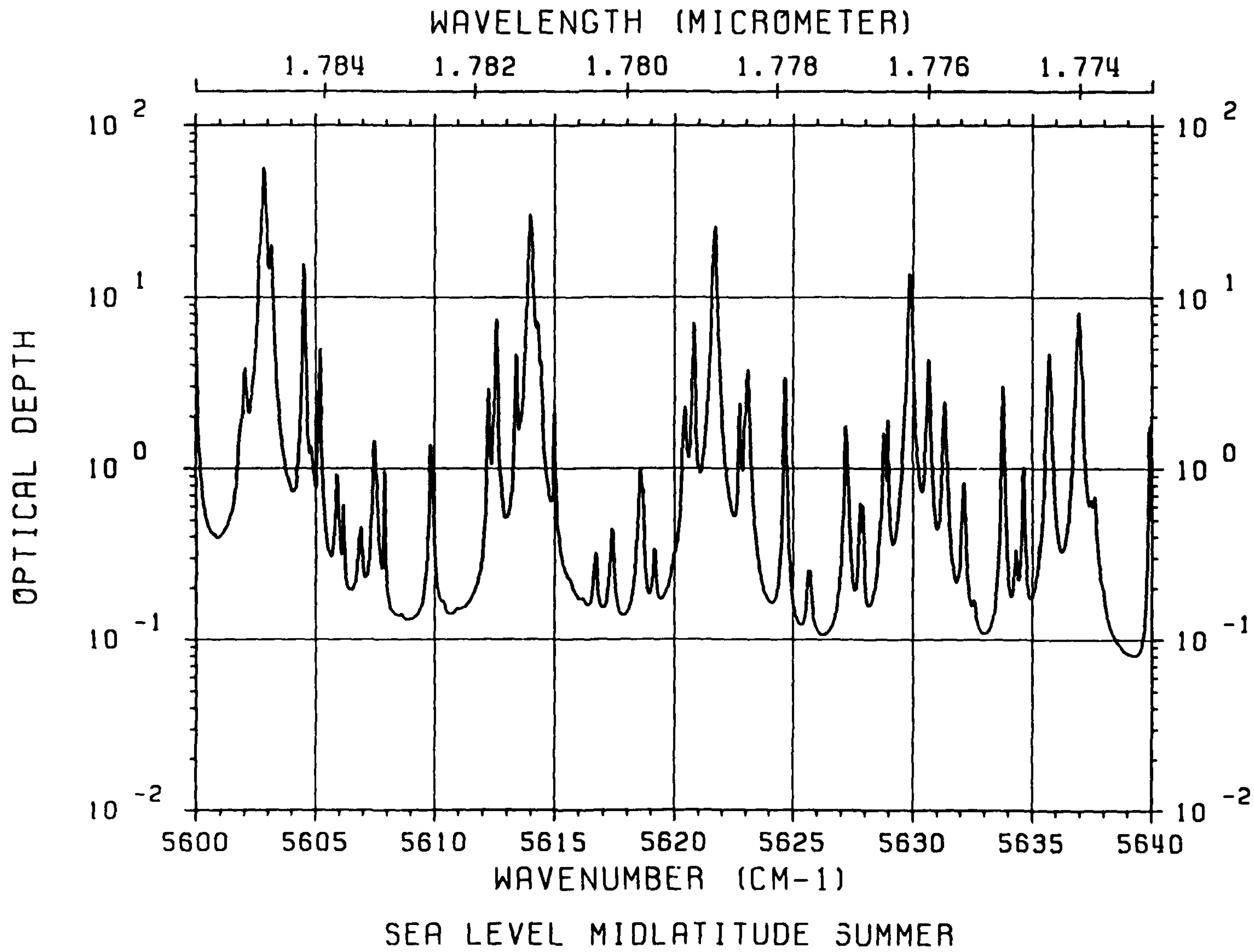
$10^{1}$
$10^{0}$
$10^{-1}$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1.778
1.776
1.774
OPTICAL DEPTH
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$10^{1}$
$10^{0}$
$10^{-1}$
$10^{-2}$
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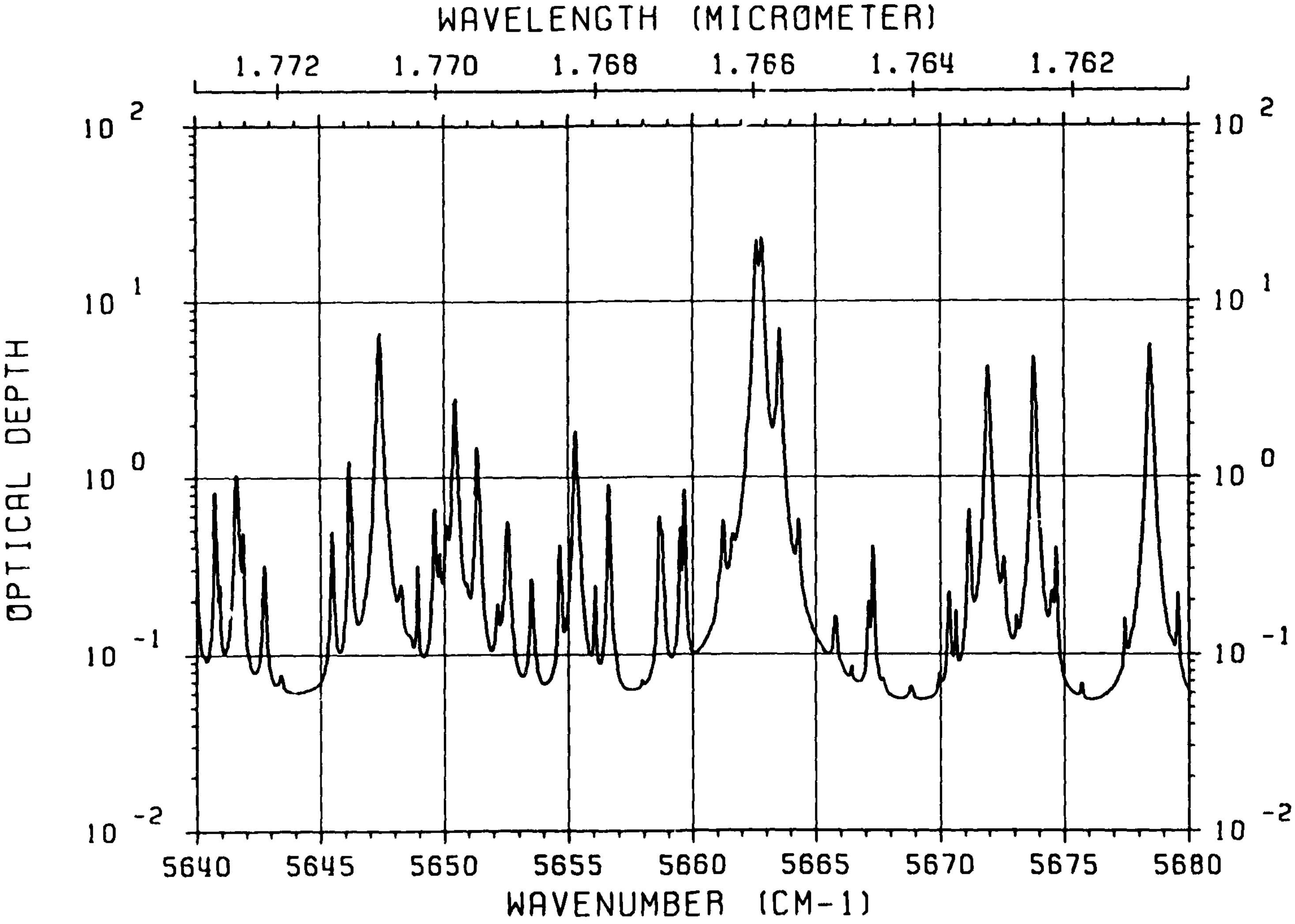
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER

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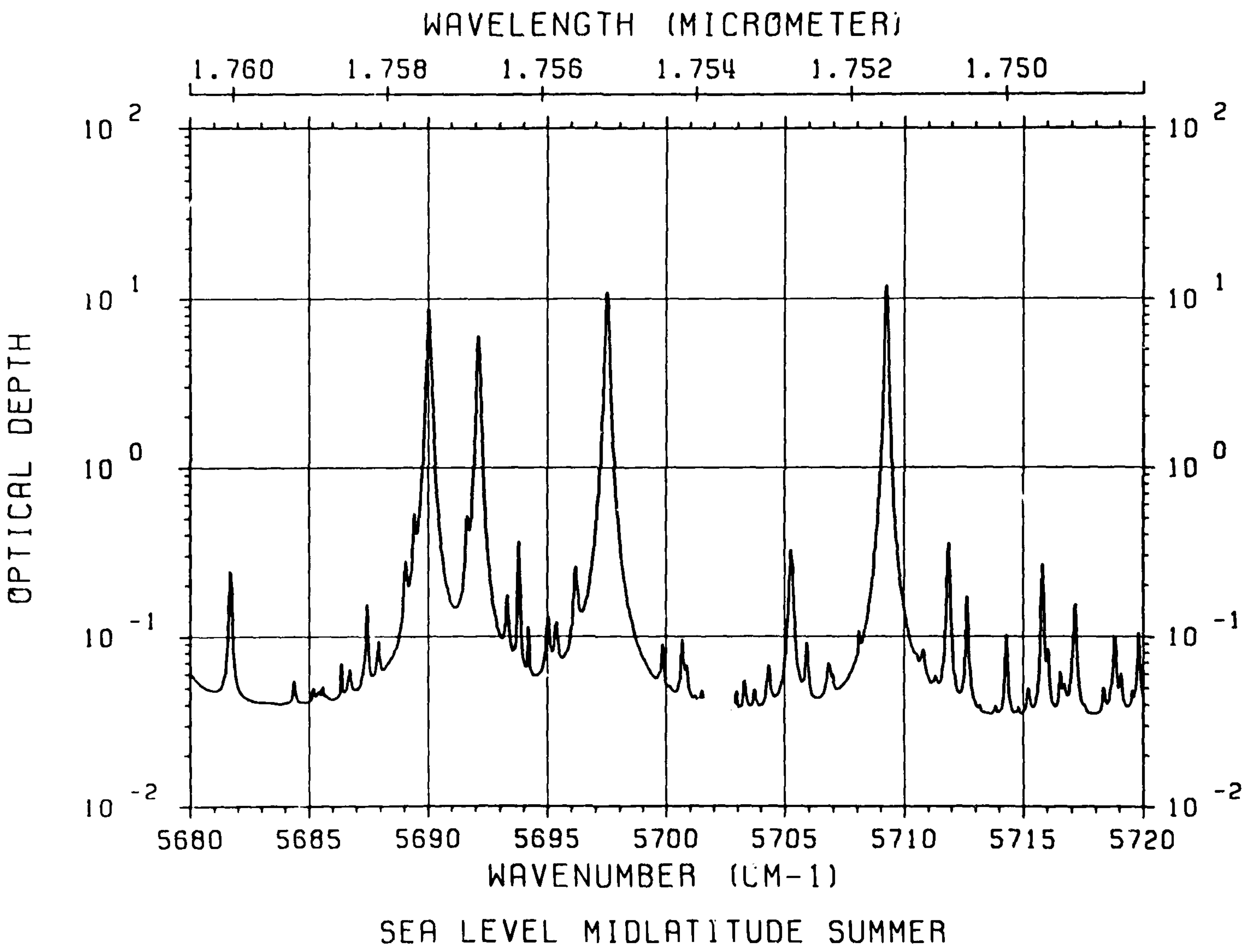

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1.758
1.756
1.754
1.752
1.750
OPTICAL DEPTH
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10 1
10 0
10 -1
10 -2
5680
5685
5690
5695
5700
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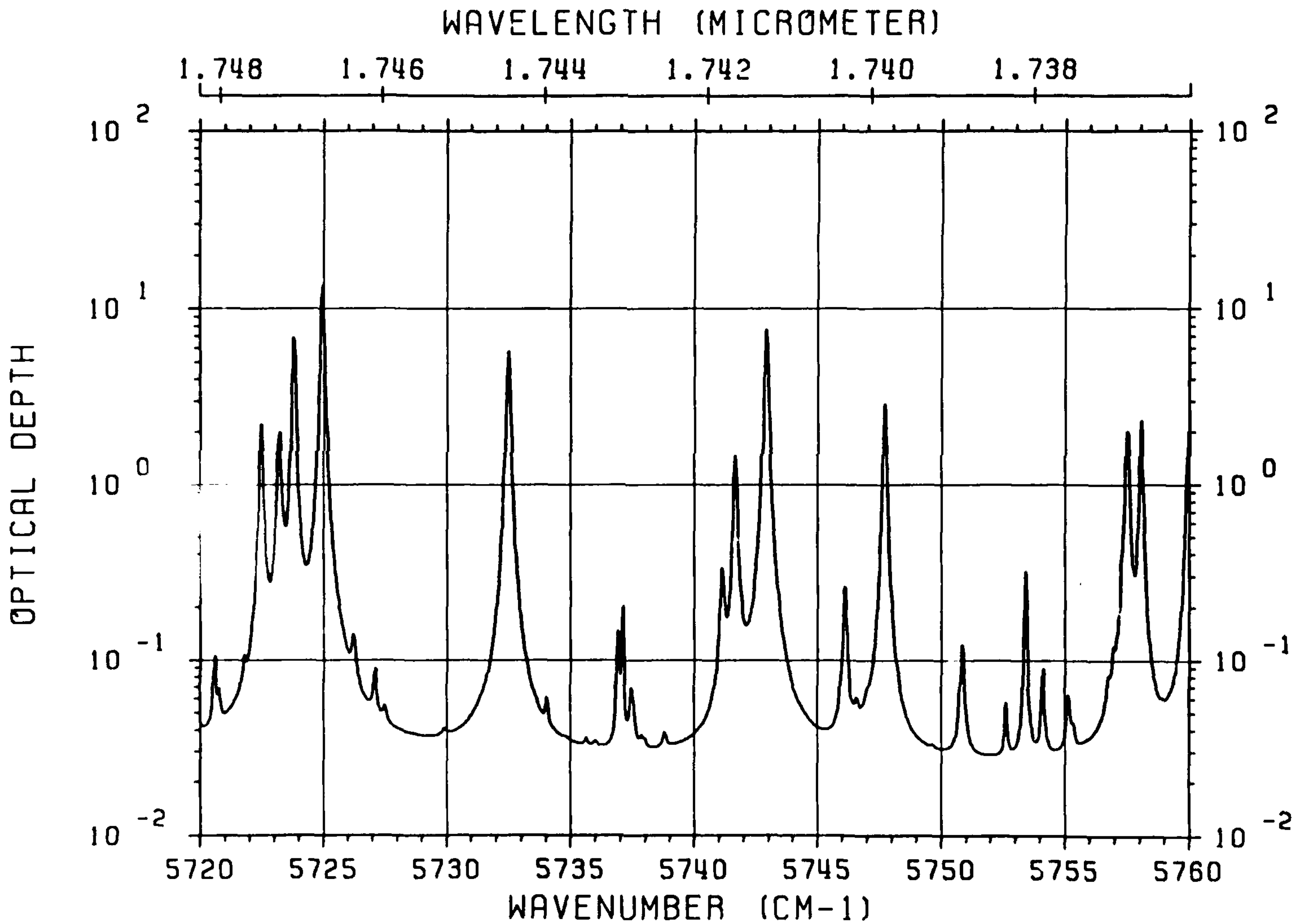
5710
5715
5720
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER

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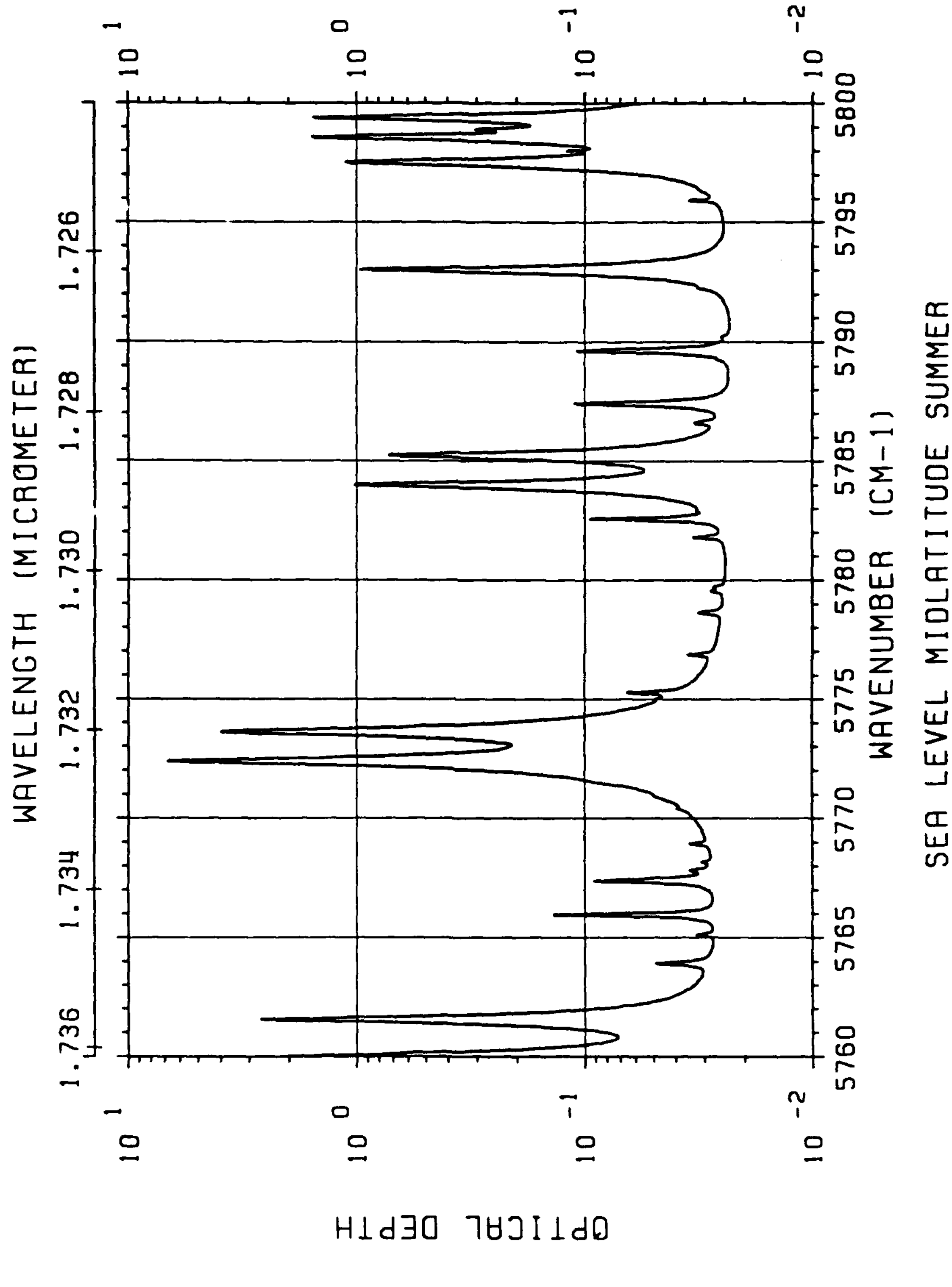
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1.734
1.732
1.730
1.728
1.726
OPTICAL DEPTH
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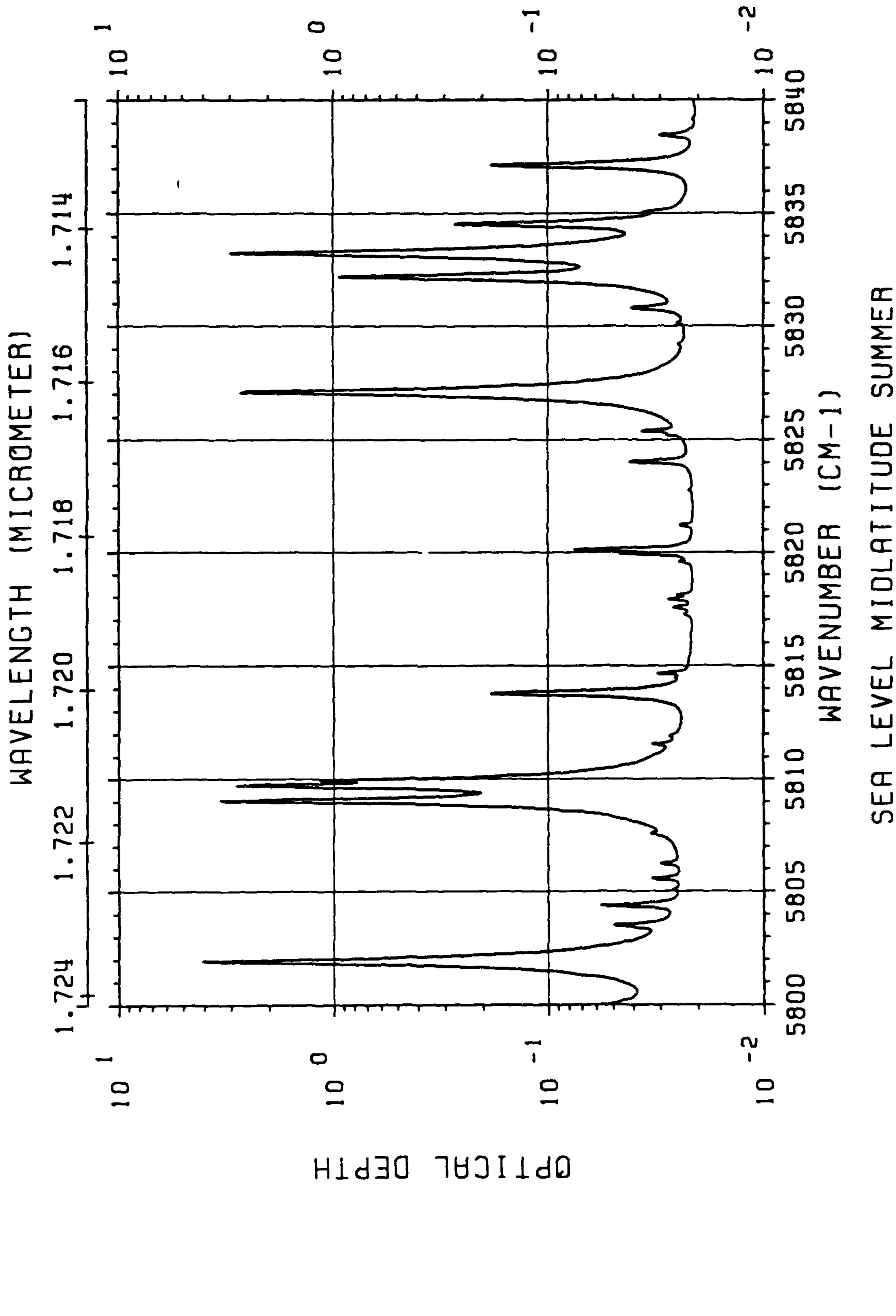
10^0
10^-1
10^-2
5760
5765
5770
5775
5780
5785
5790
5795
5800
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER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$10^{0}$
$10^{-1}$
$10^{-2}$
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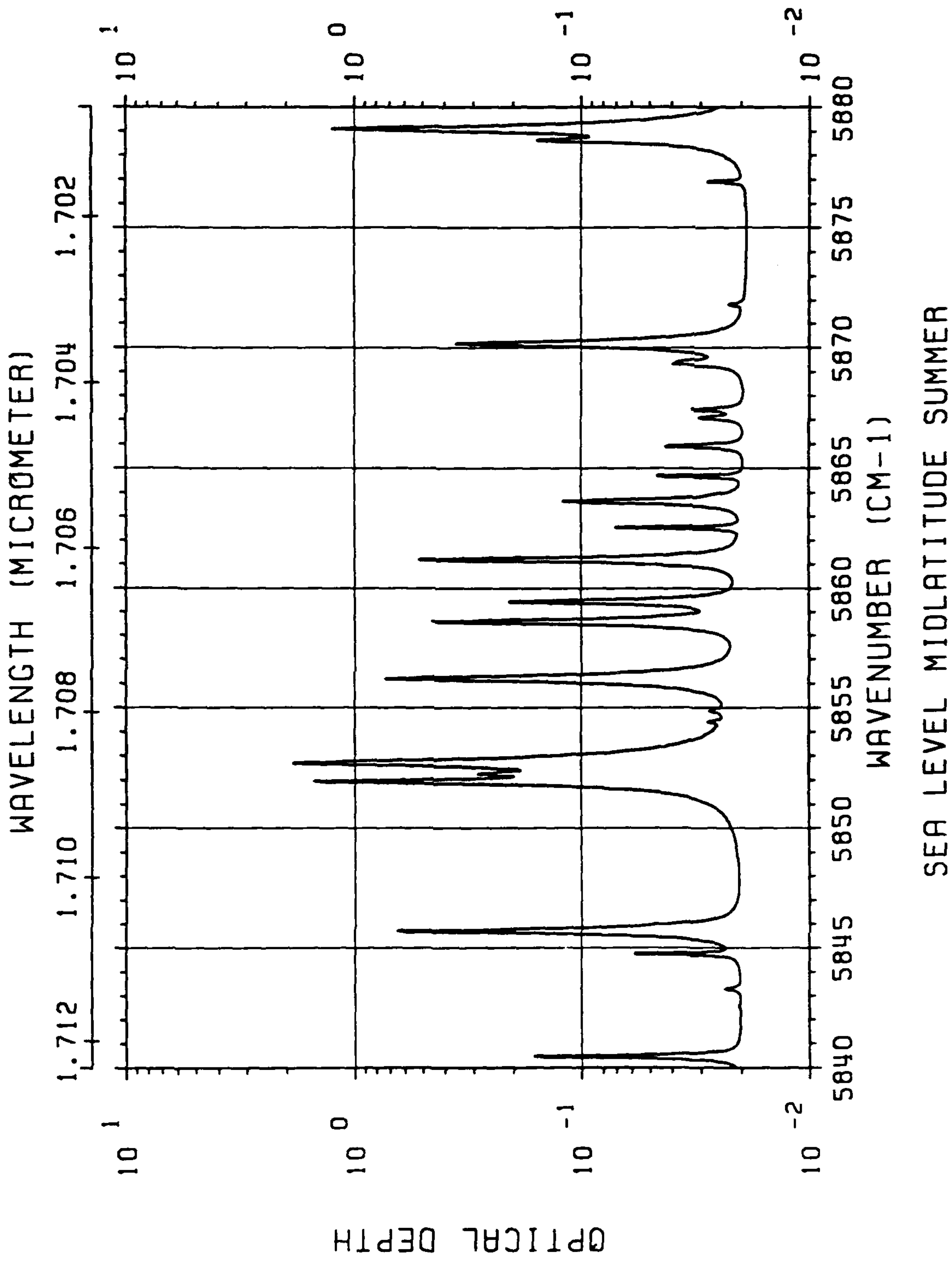
5830
5835
5840
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER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$10^{0}$
$10^{-1}$
$10^{-2}$
5840
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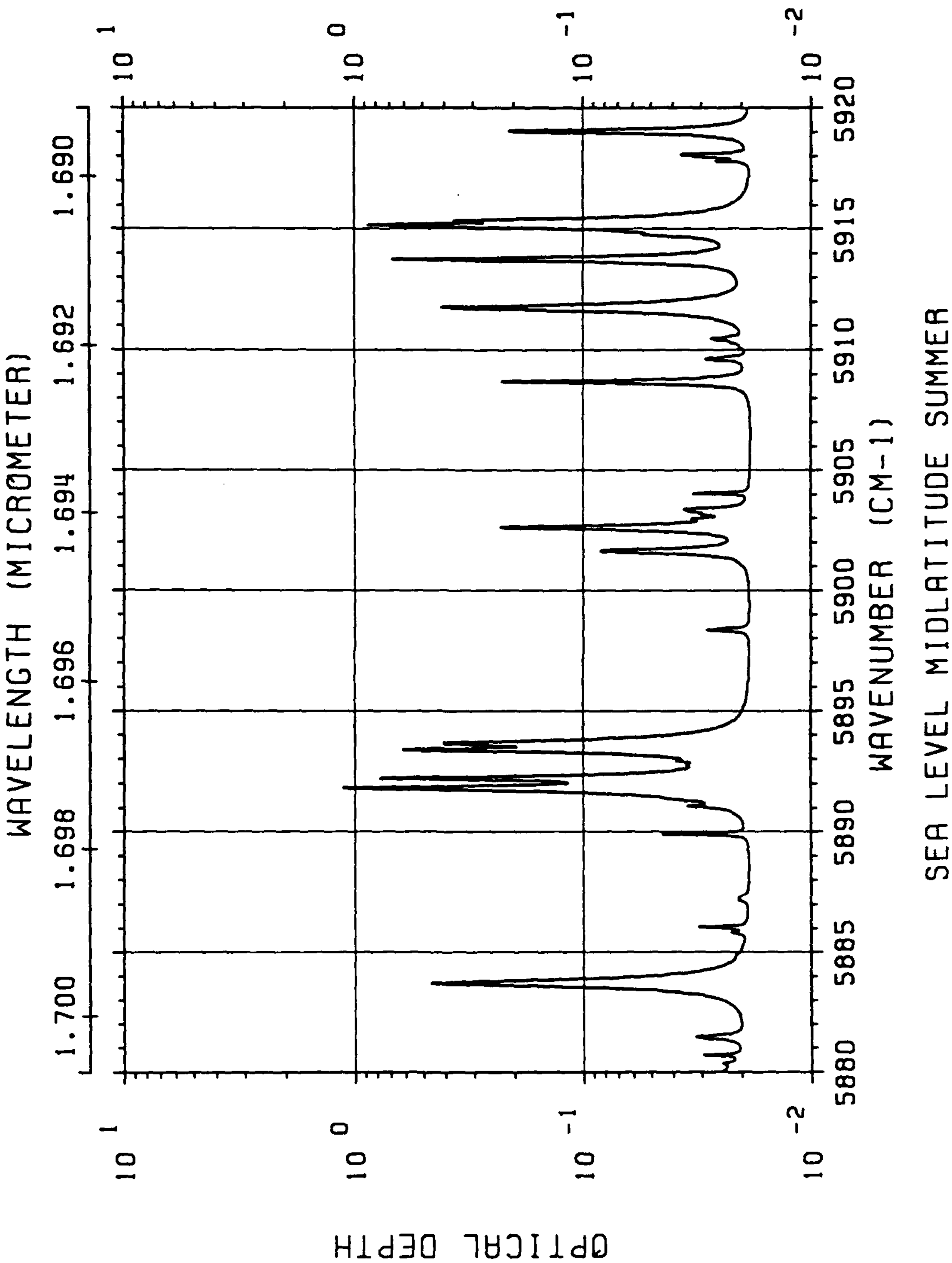
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER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WAVENUMBER (CM-1)
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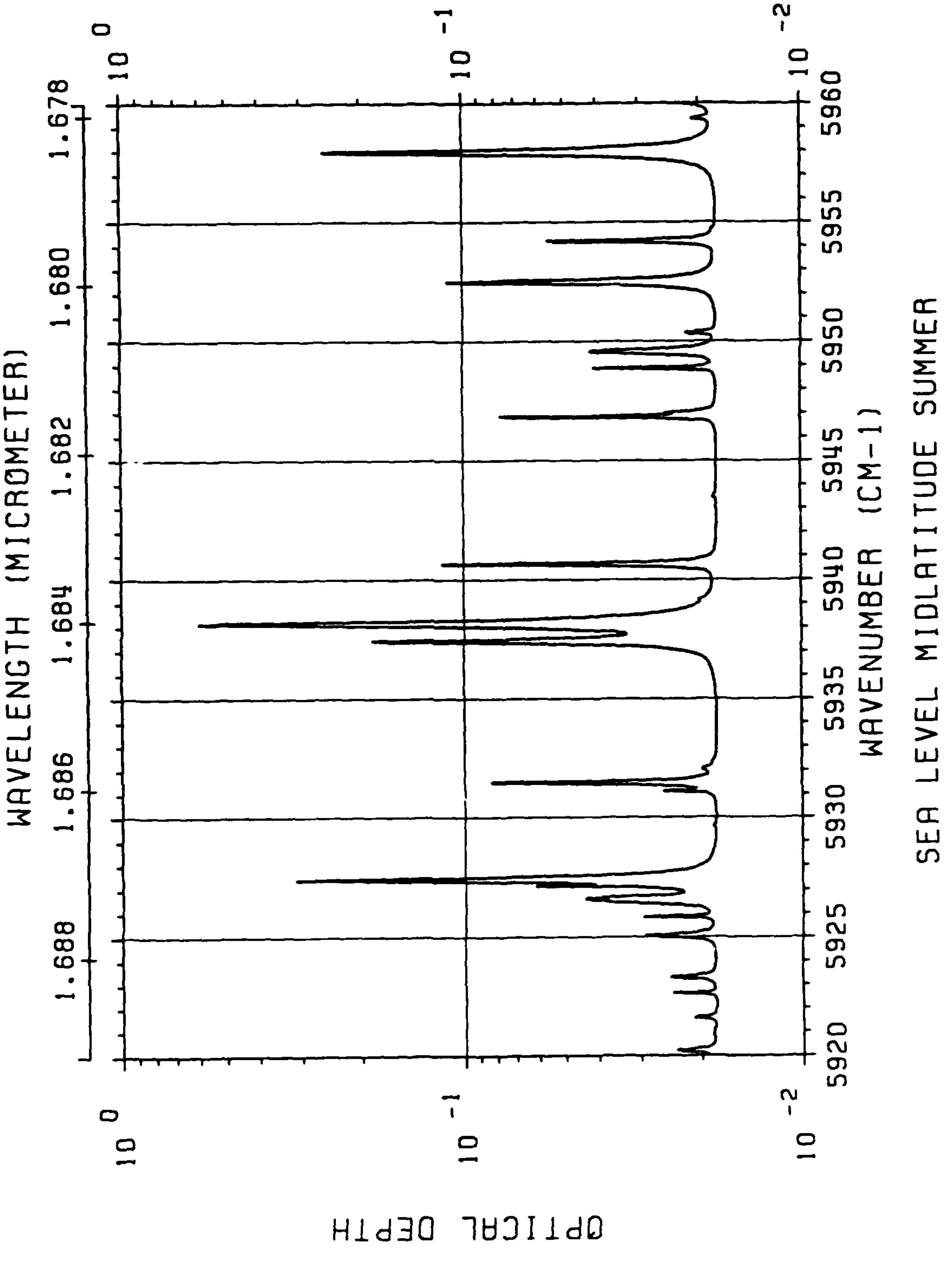
5885
5890
5895
5900
5905
5910
5915
5920
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH
$10^{1}$
$10^{0}$
$10^{-1}$
$10^{-2}$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5955
5950
5945
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5920
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH
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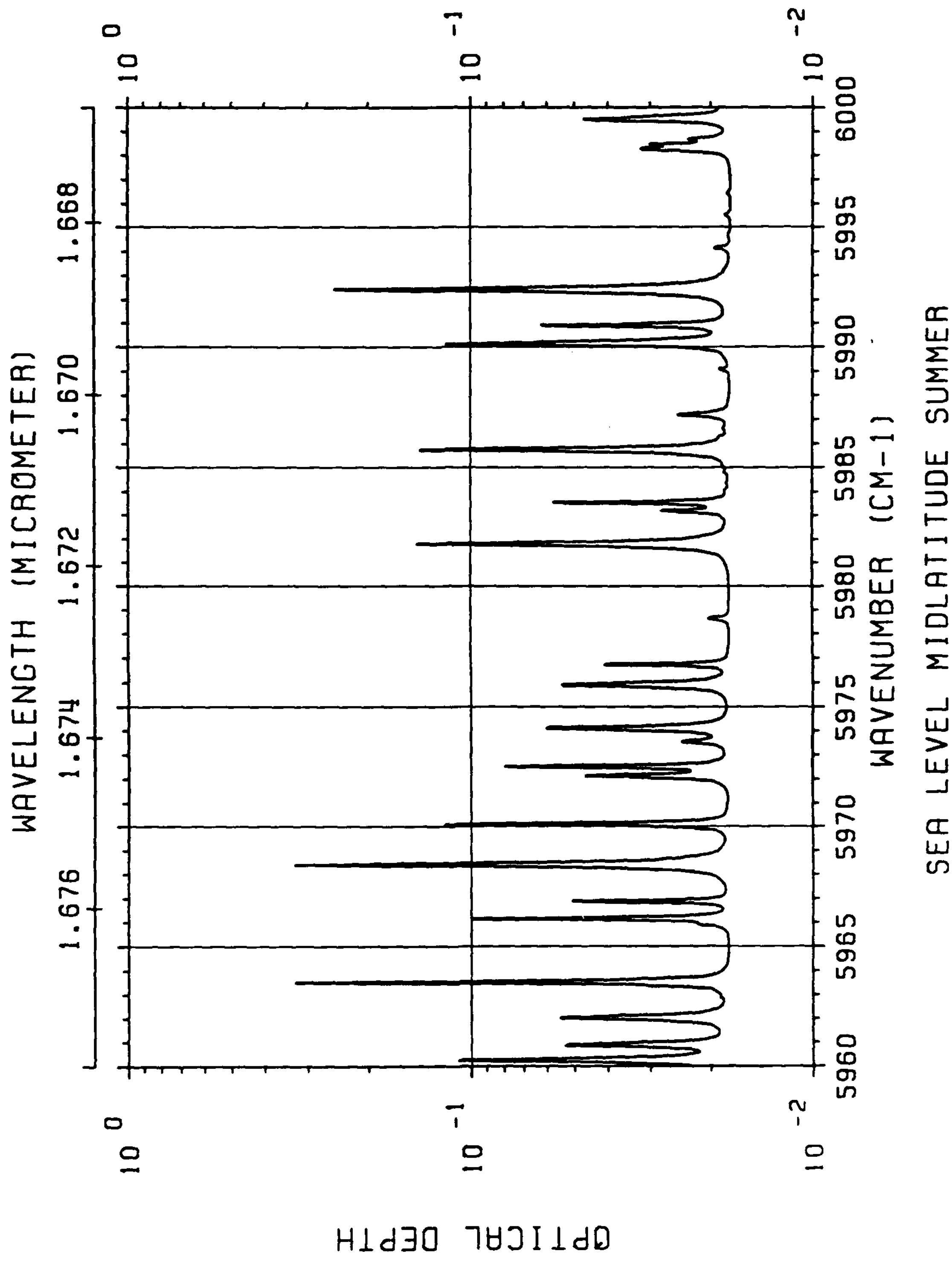
$10^{-1}$
$10^{-2}$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WAVENUMBER (CM-1)
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5970
5975
5980
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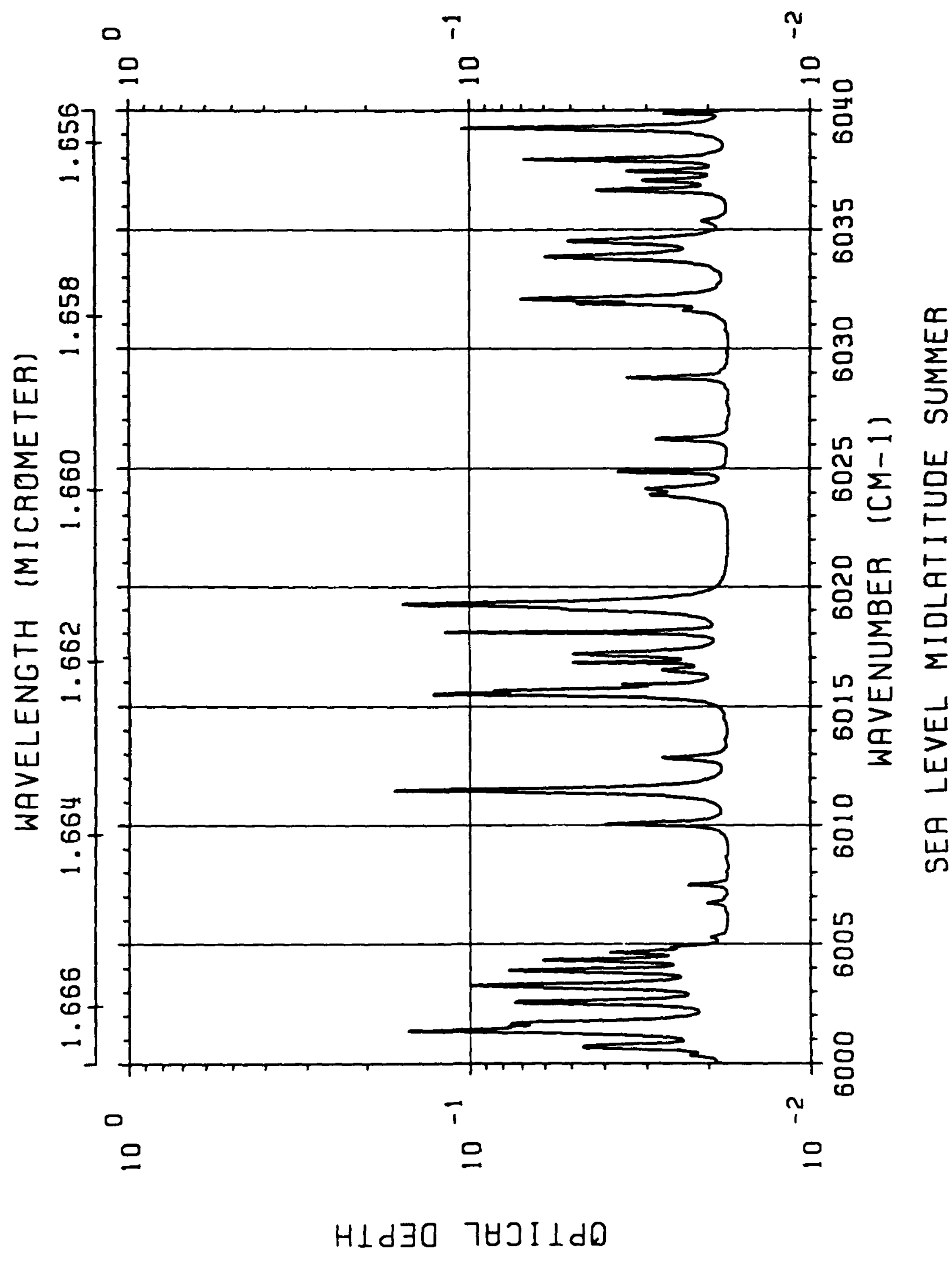
5995
6000
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH
$10^{0}$
$10^{-1}$
$10^{-2}$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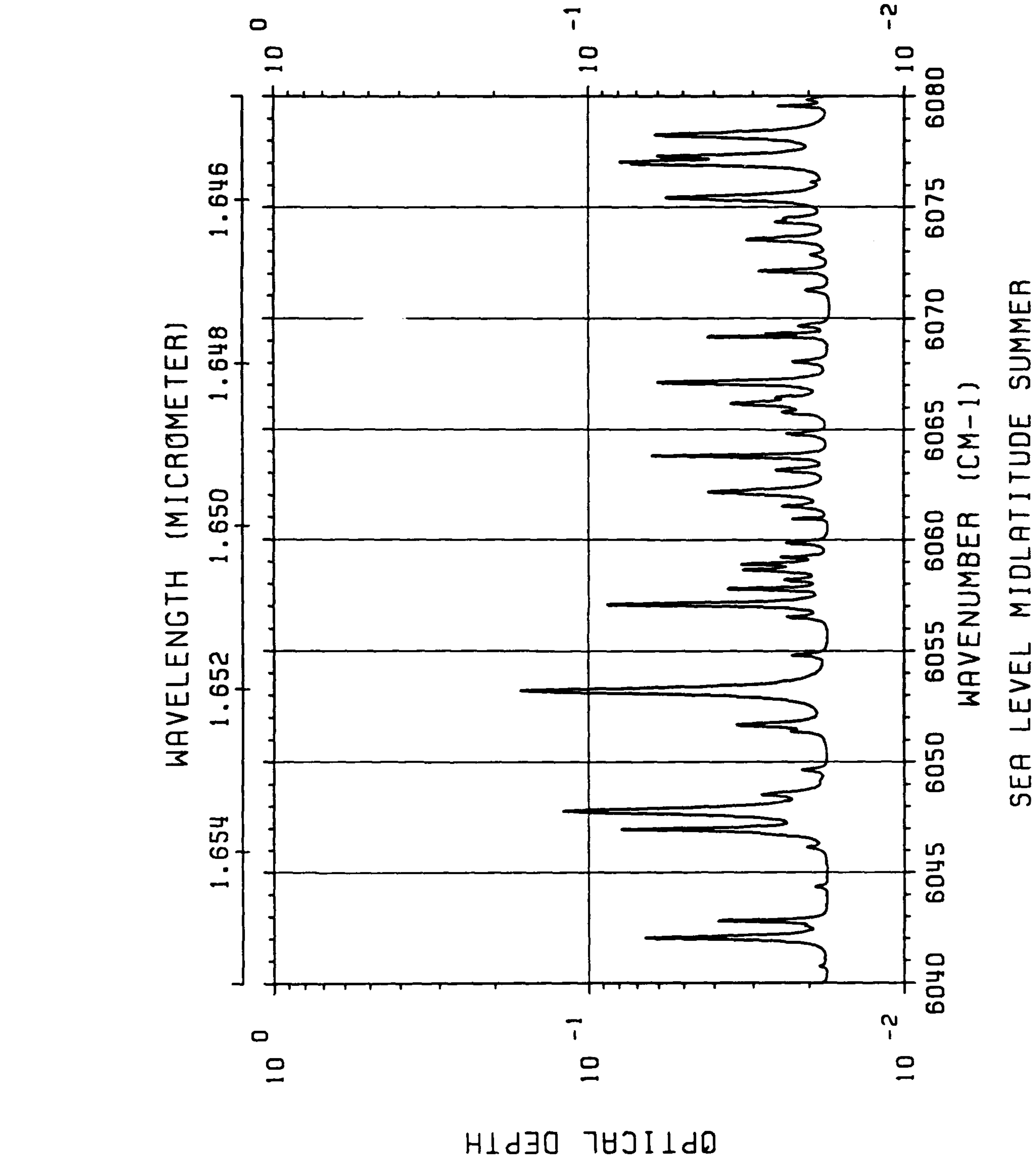
6025
6030
6035
6040
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
10^0
10^-1
10^-2
OPTICAL DEPTH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1.654
WAVENUMBER (CM-1)
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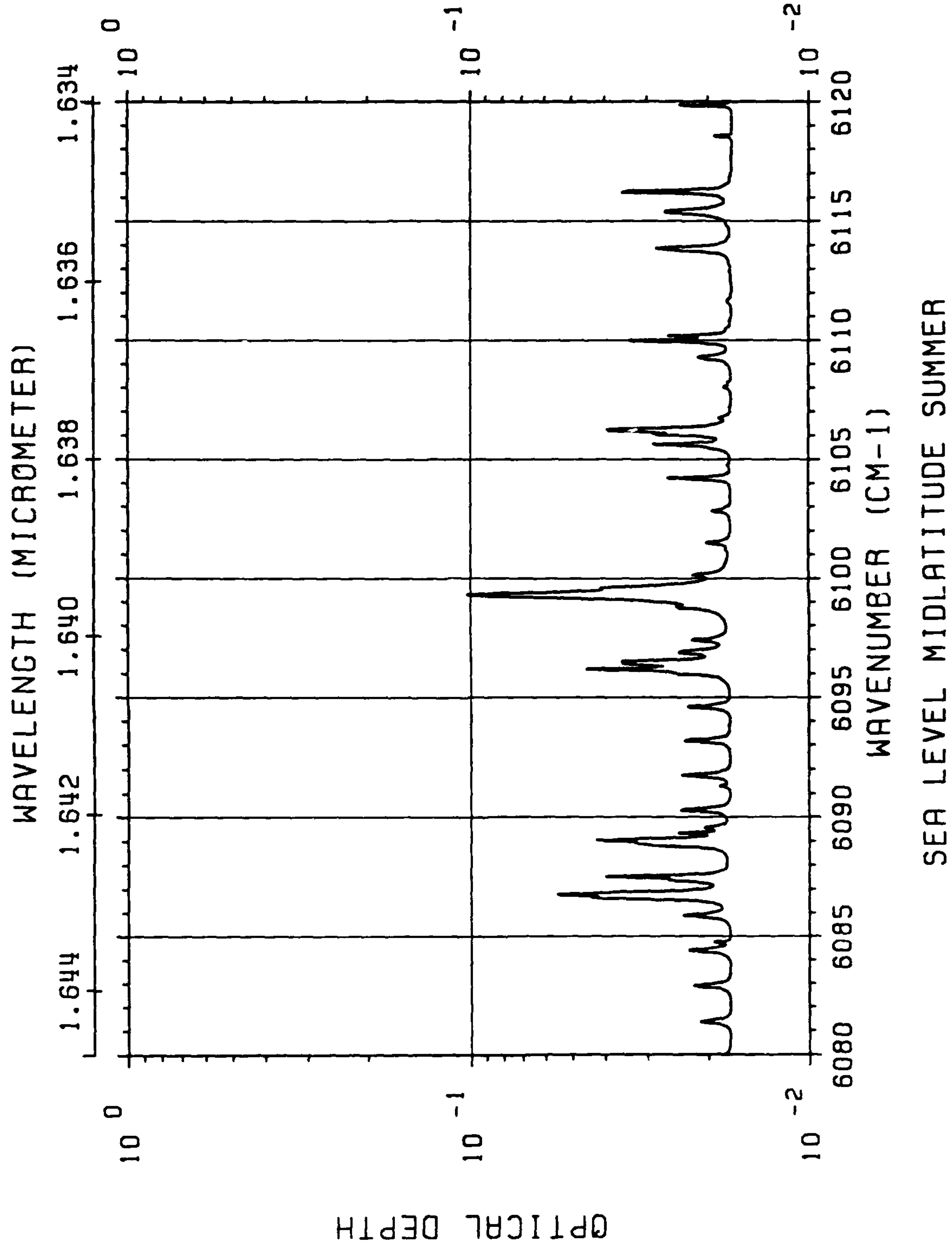
6075
6080
OPTICAL DEPTH
SEA LEVEL MIDLATITUDE SUMMER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1.644
WAVENUMBER (CM-1)
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6085
6090
6095
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6110
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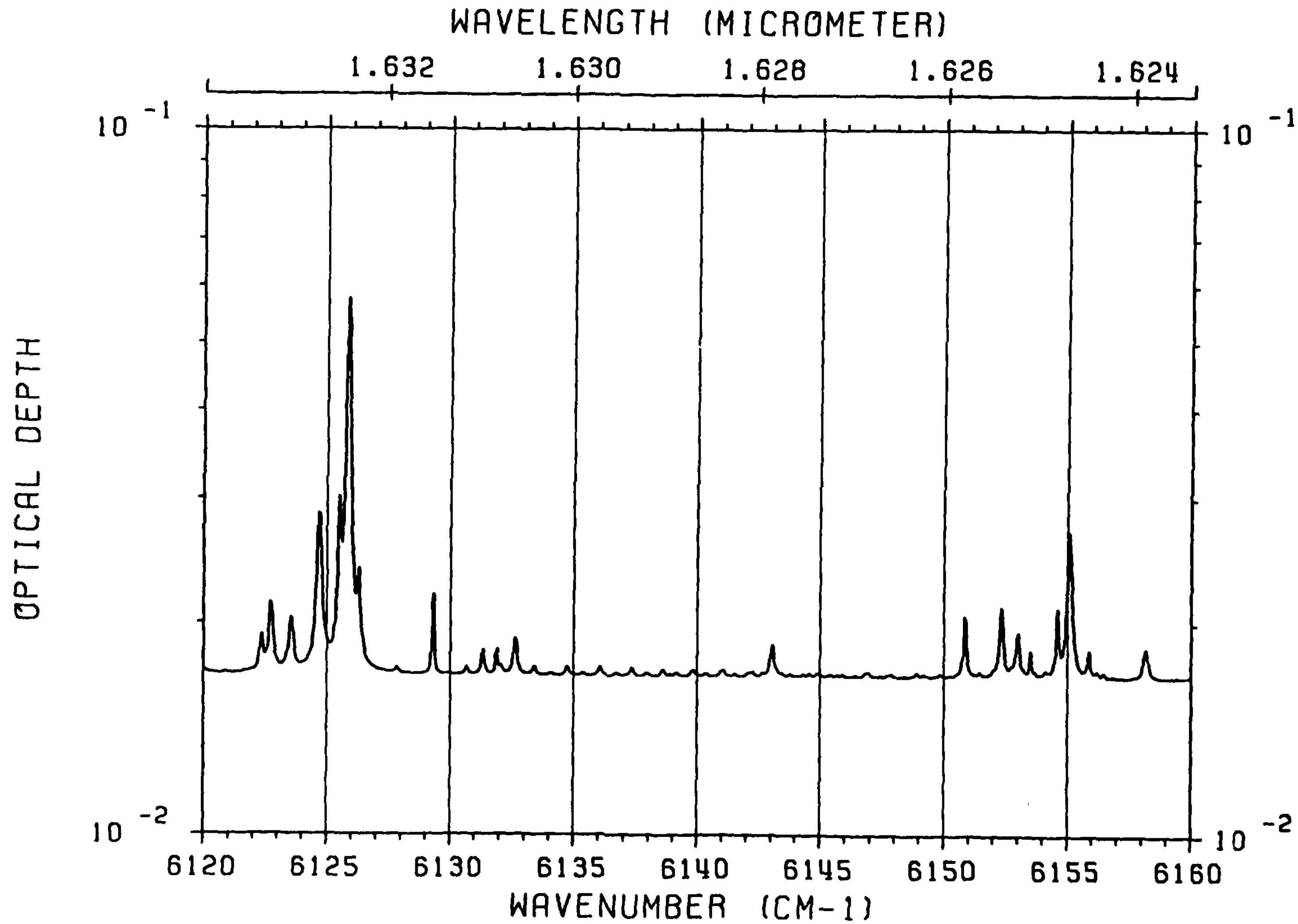
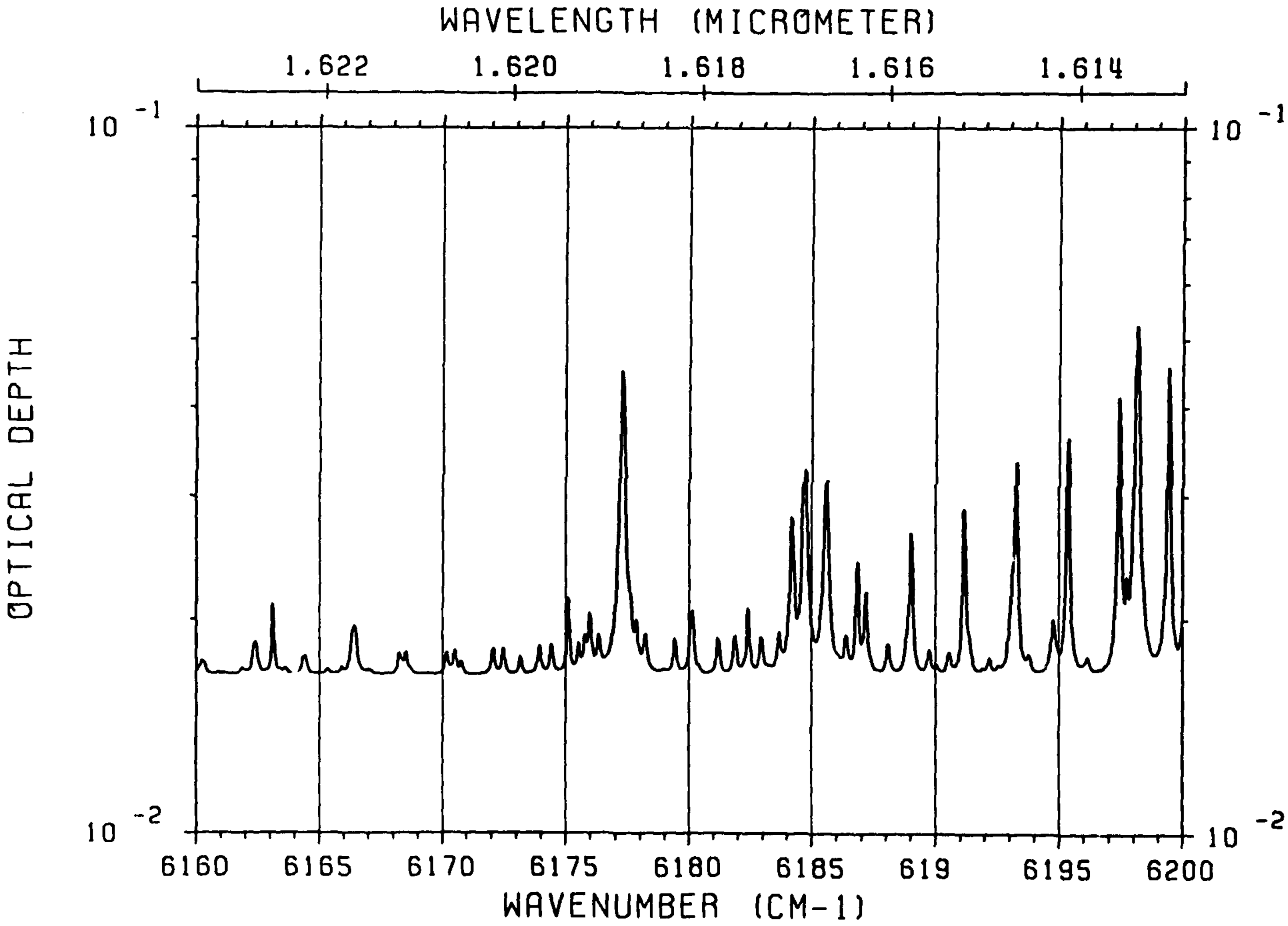
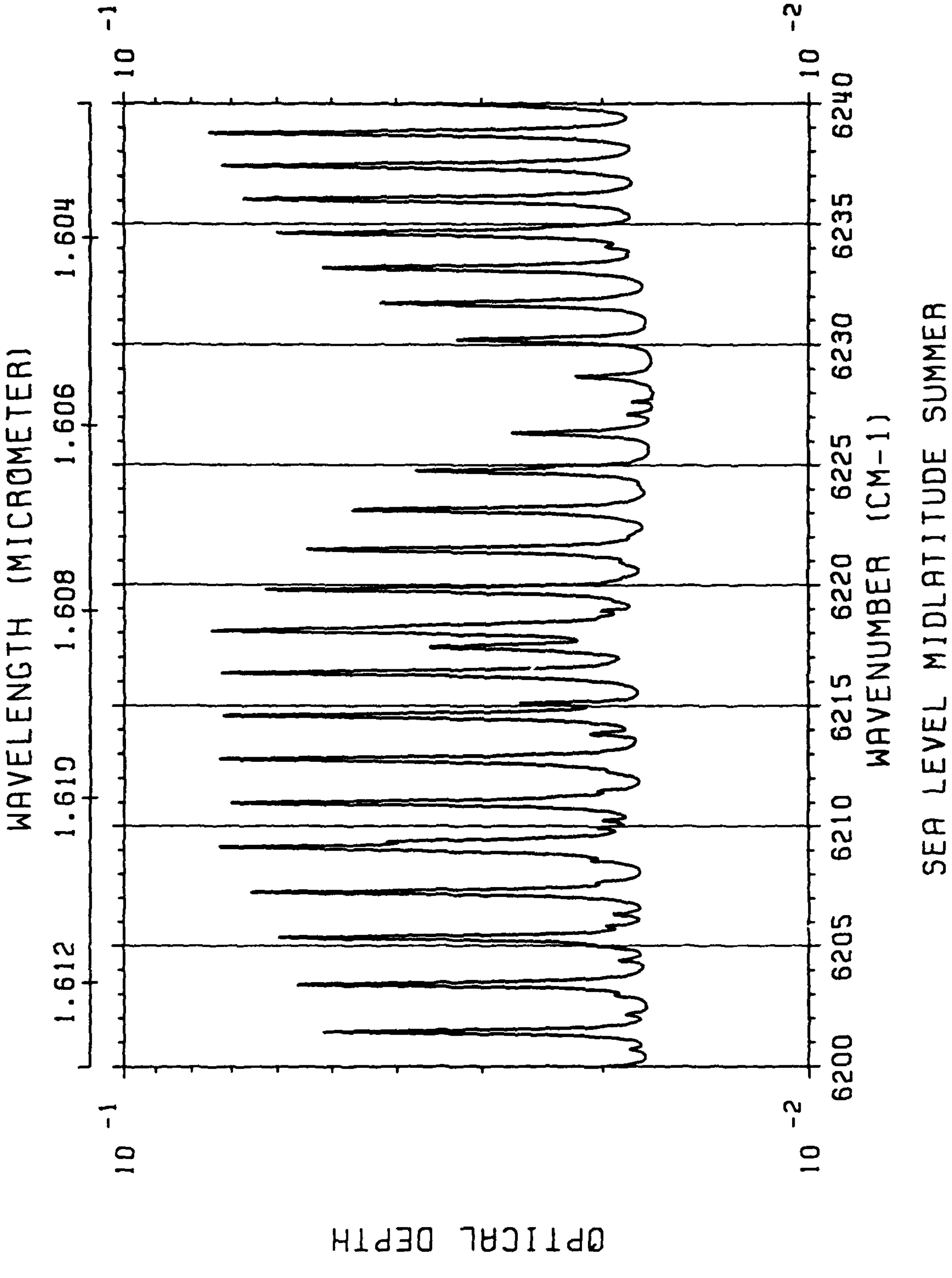
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH
10^0
10^-1
10^-2

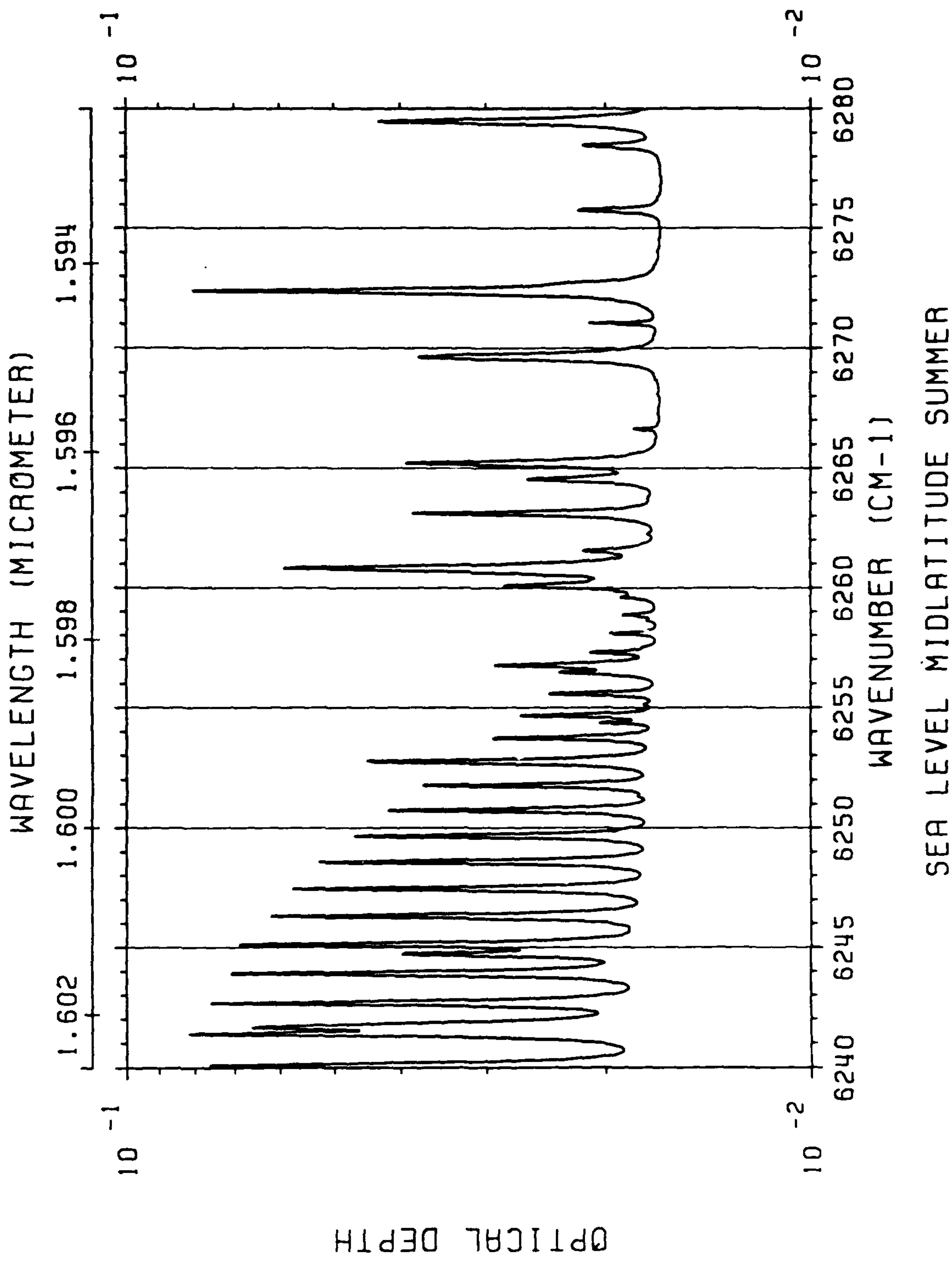



SEA LEVEL MIDLATITUDE SUMMER

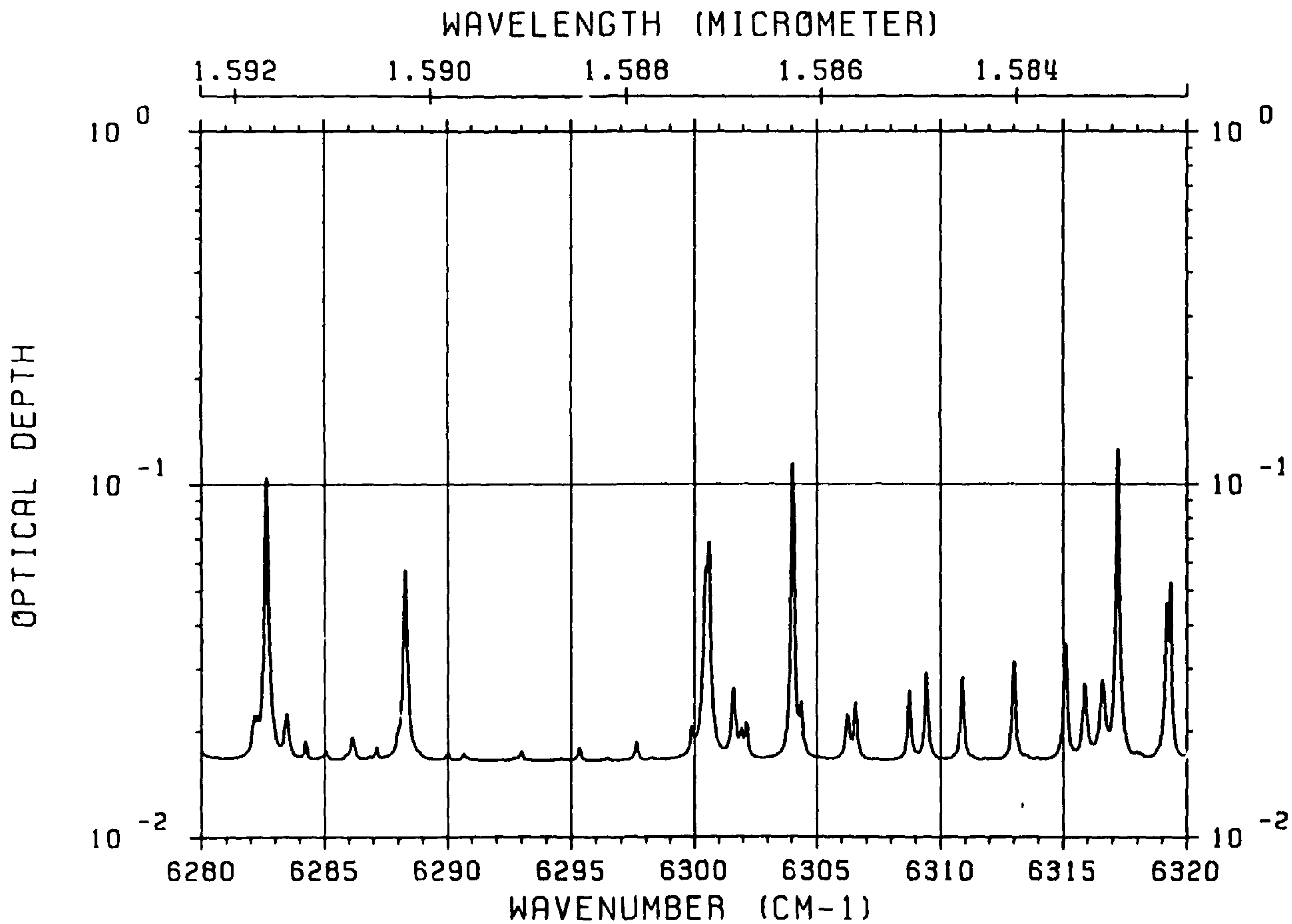



SEA LEVEL MIDLATITUDE SUMMER

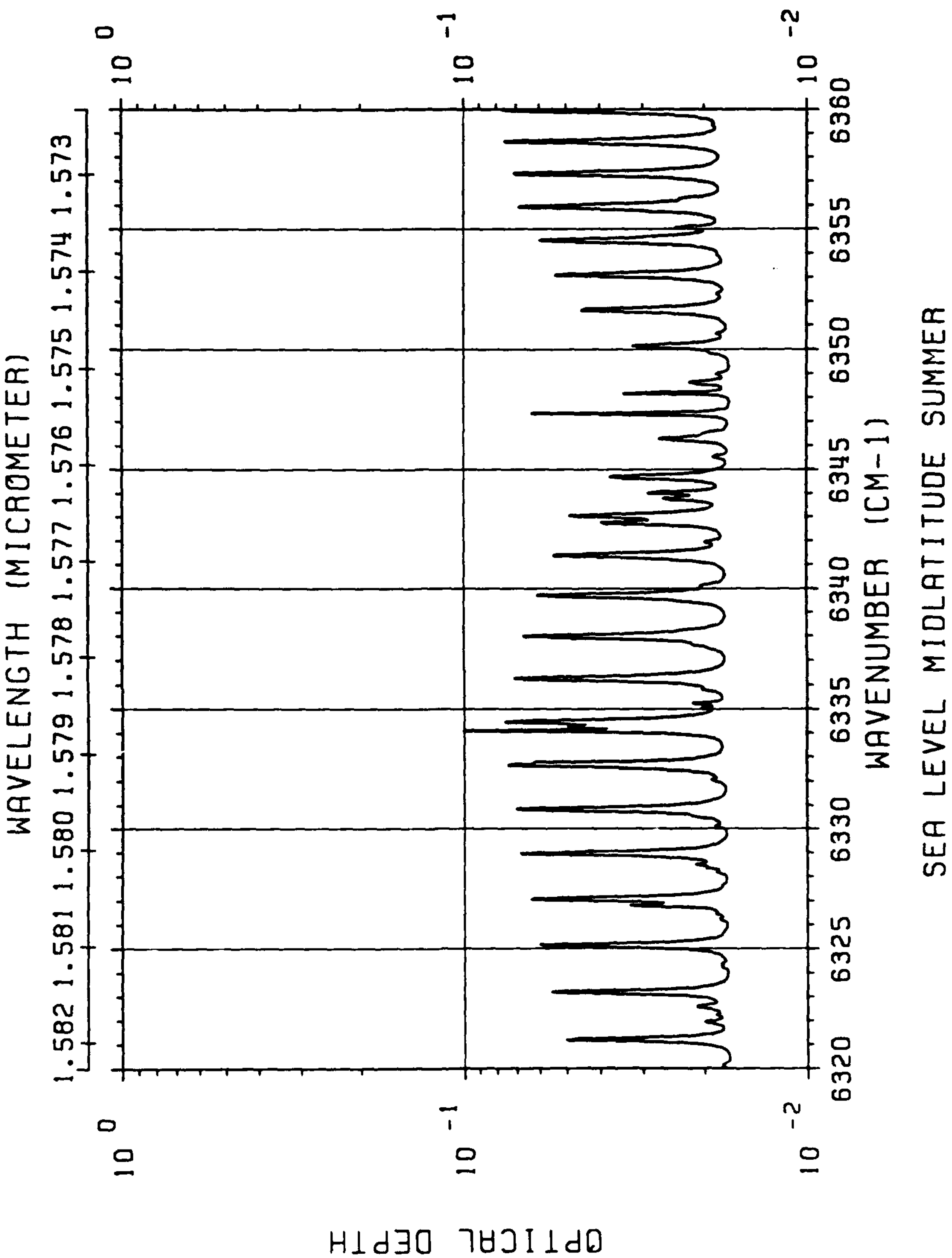

WAVELENGTH (MICROMETER)
1.604
1.606
1.608
1.610
1.612
10^-1
10^-2
6200
6205
6210
6215
6220
6225
6230
6235
6240
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH

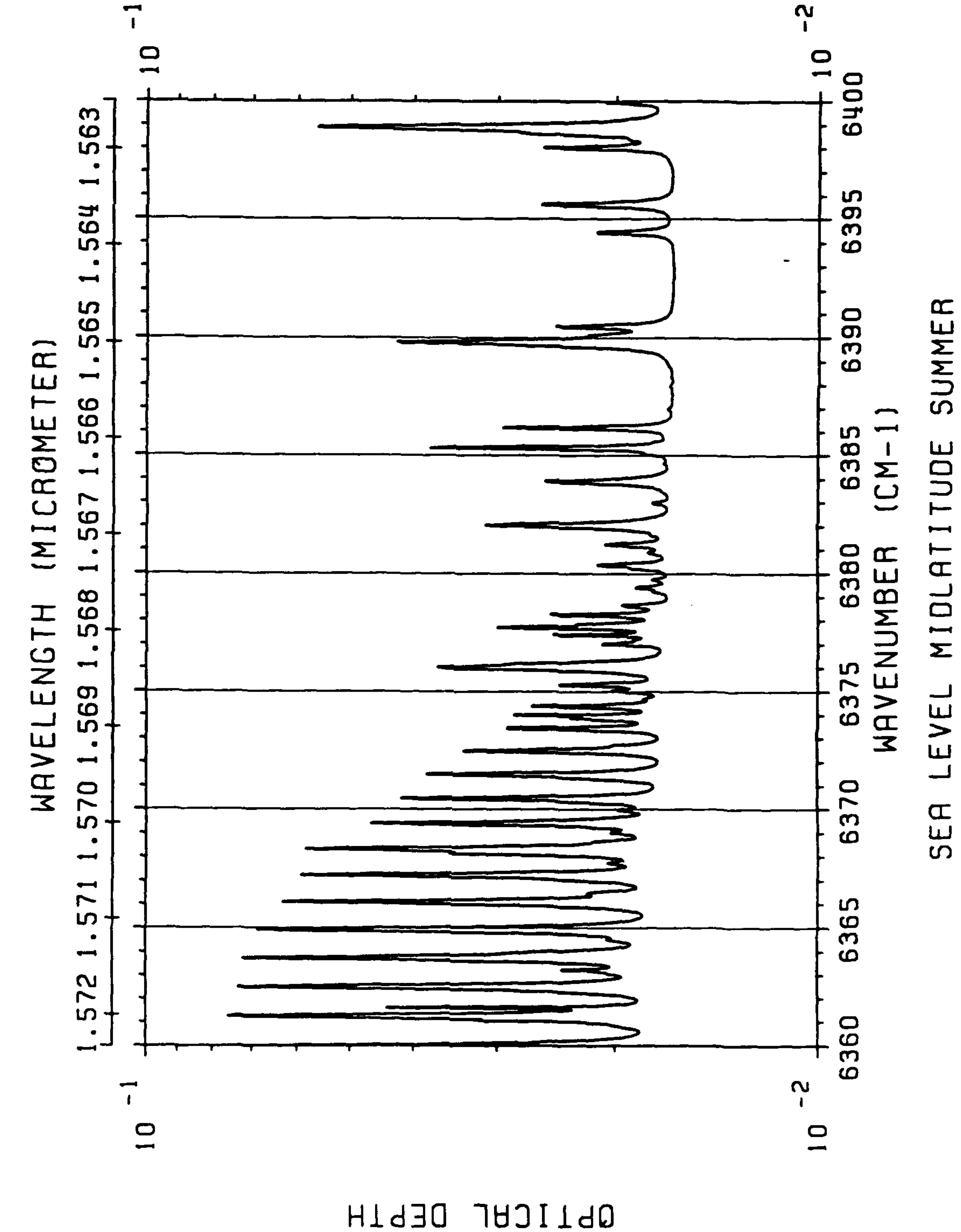


WAVELENGTH (MICROMETER)
1.594
1.596
1.598
1.600
1.602
OPTICAL DEPTH
10 -1
10 -2
WAVENUMBER (CM-1)
6240
6245
6250
6255
6260
6265
6270
6275
6280
SEA LEVEL MIDLATITUDE SUMMER

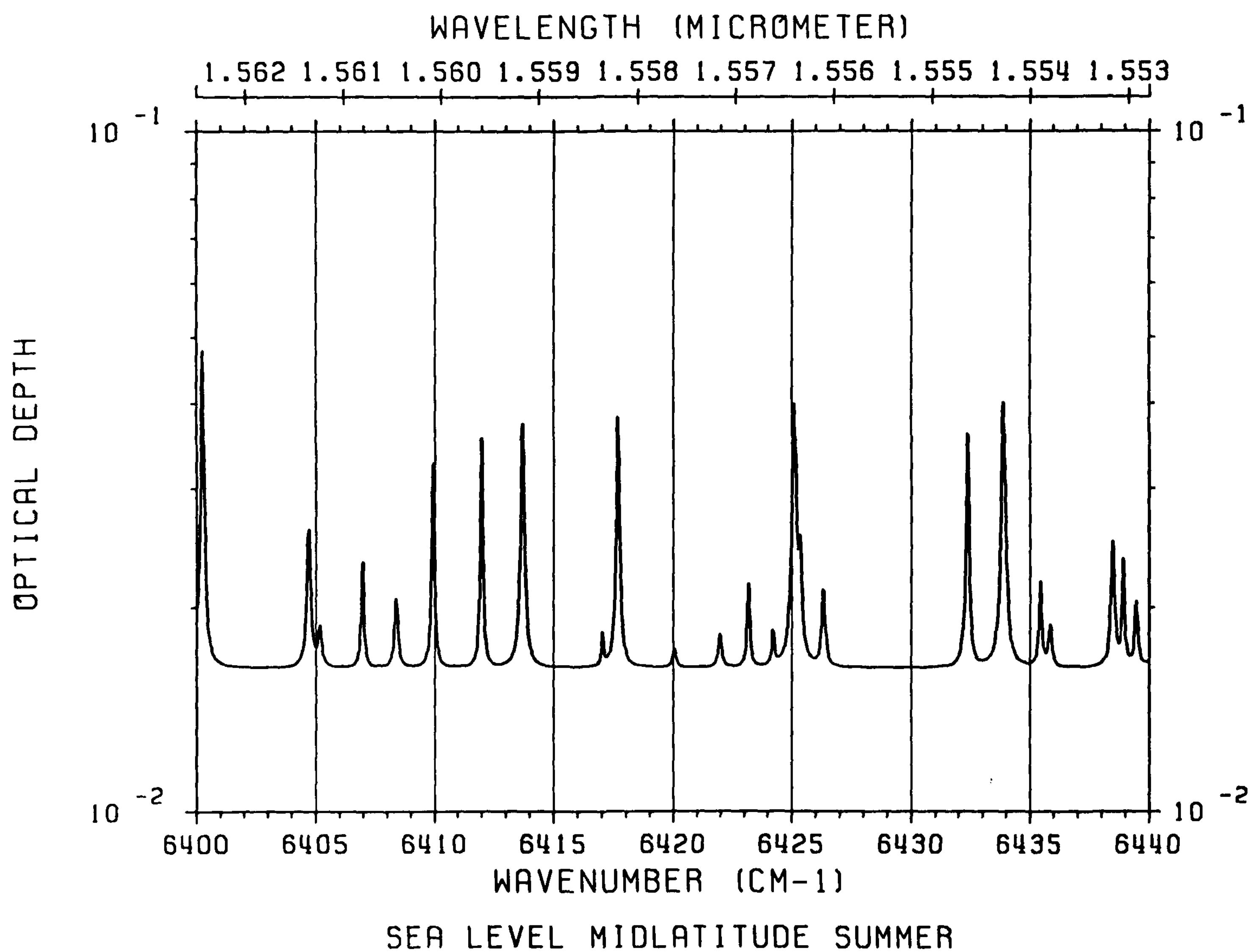


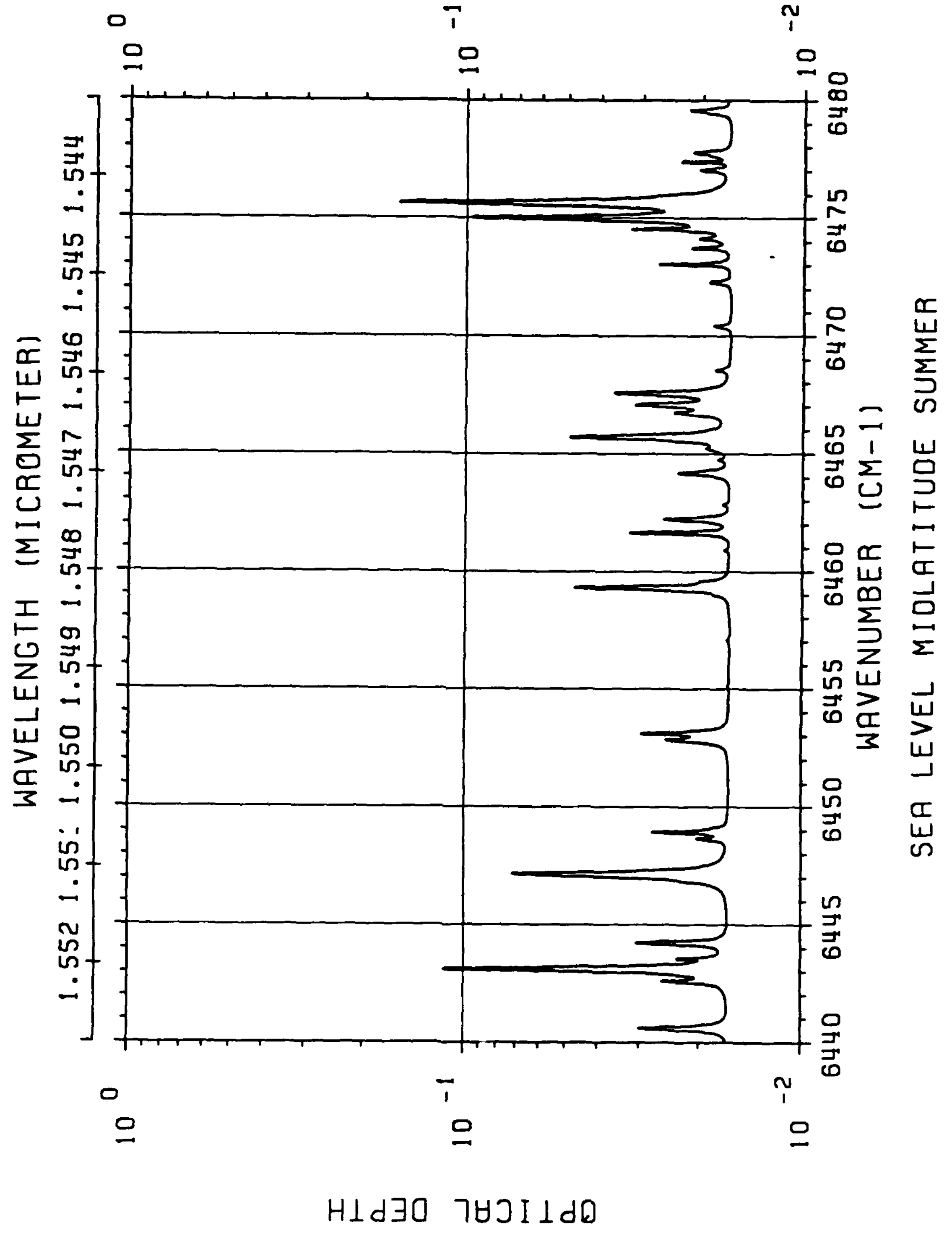

SEA LEVEL MIDLATITUDE SUMMER

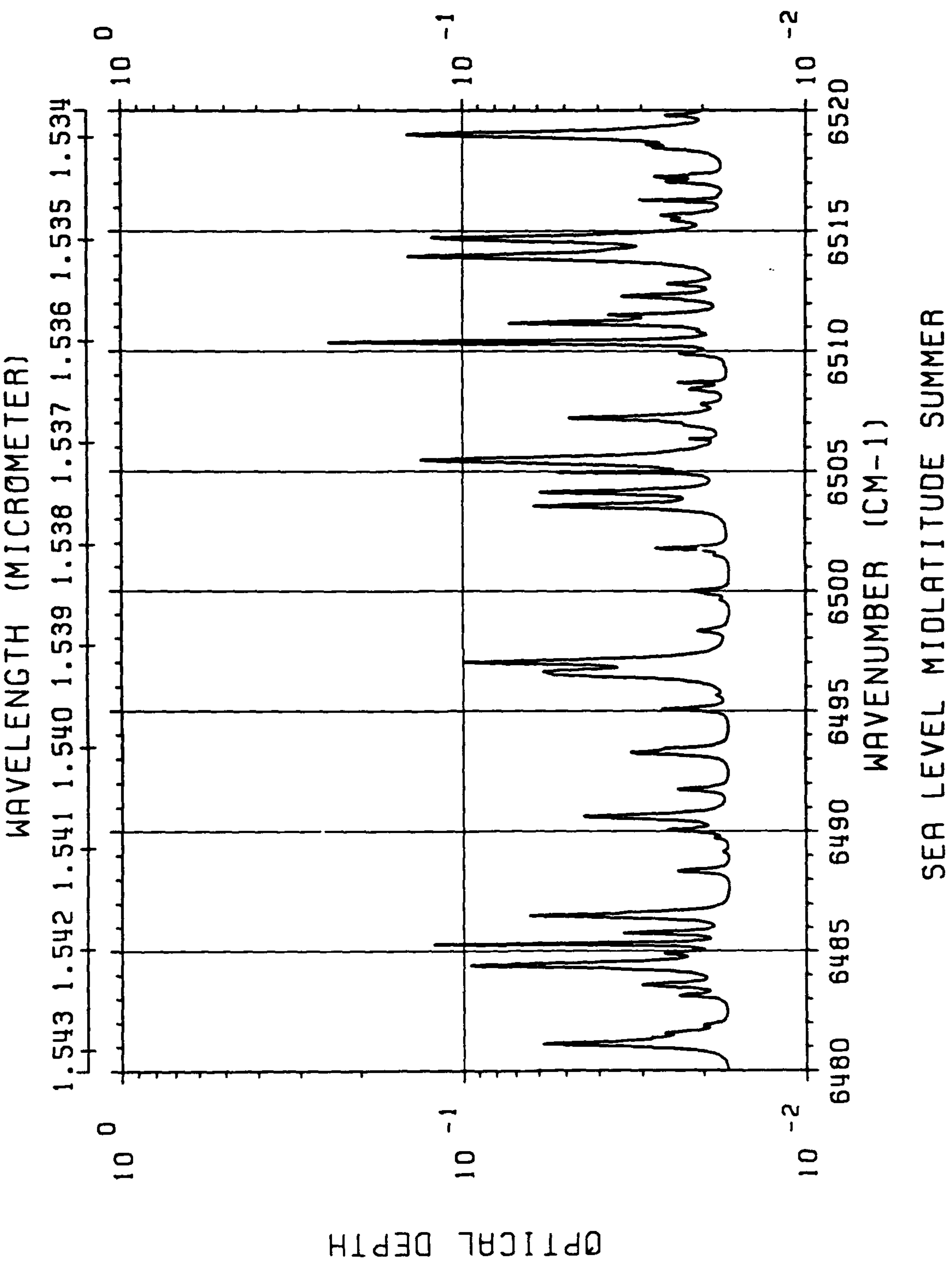

WAVELENGTH (MICROMETER)
1.582 1.581 1.581 1.580 1.580 1.579 1.578 1.578 1.577 1.577 1.576 1.576 1.575 1.575 1.574 1.573
WAVENUMBER (CM-1)
6320 6325 6330 6335 6340 6345 6350 6355 6360
OPTICAL DEPTH
$10^{0}$ $10^{-1}$ $10^{-2}$
SEA LEVEL MIDLATITUDE SUMMER

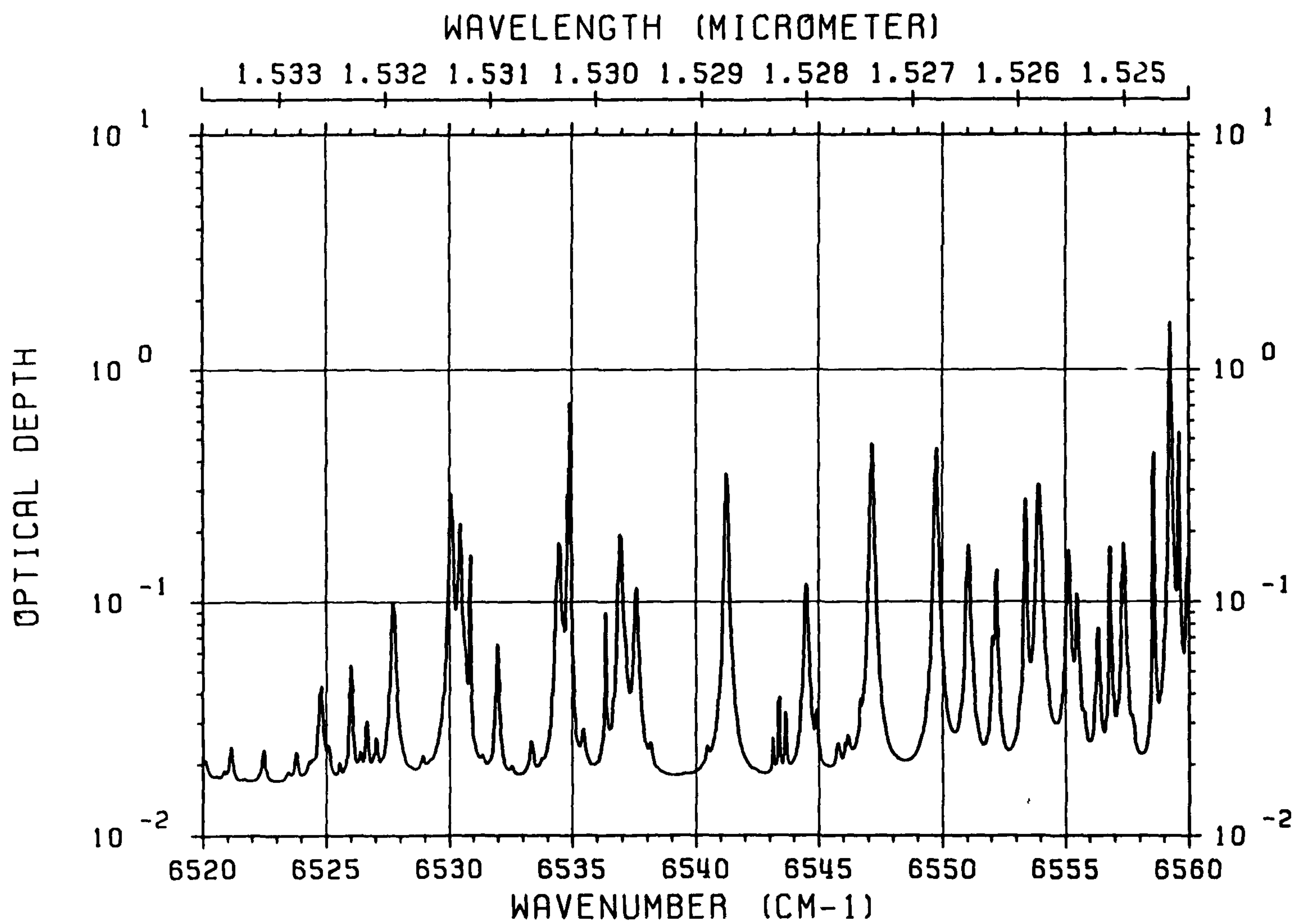


WAVELENGTH (MICROMETER)
1.572 1.571 1.570 1.569 1.568 1.567 1.566 1.565 1.564 1.563
WAVENUMBER (CM-1)
6360 6365 6370 6375 6380 6385 6390 6395 6400
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH
10 -1
10 -2

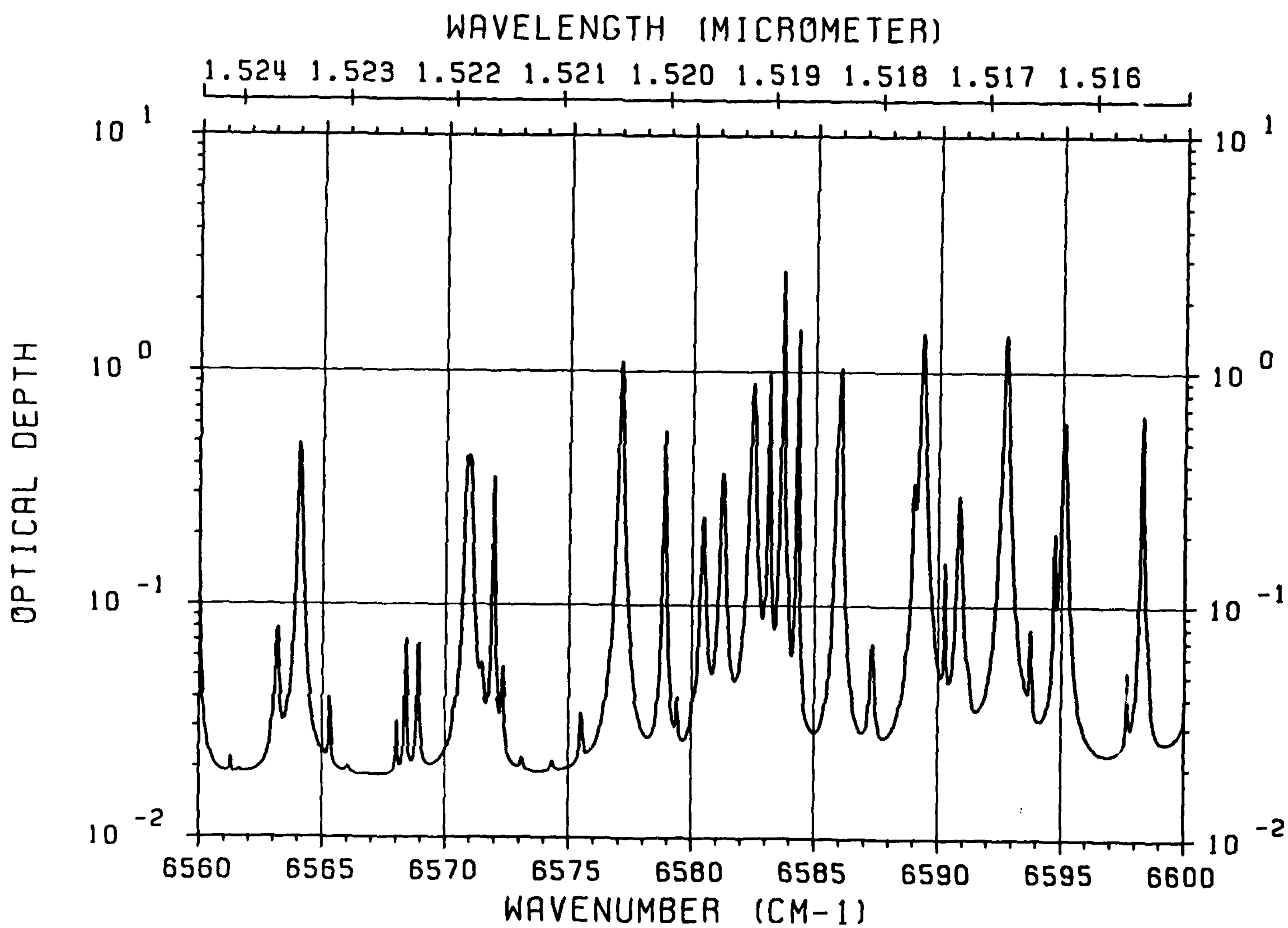

WAVELENGTH (MICROMETER)
1.562 1.561 1.560 1.559 1.558 1.557 1.556 1.555 1.554 1.553
OPTICAL DEPTH
10 -1
10 -2
6400 6405 6410 6415 6420 6425 6430 6435 6440
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER


WAVELENGTH (MICROMETER)
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH

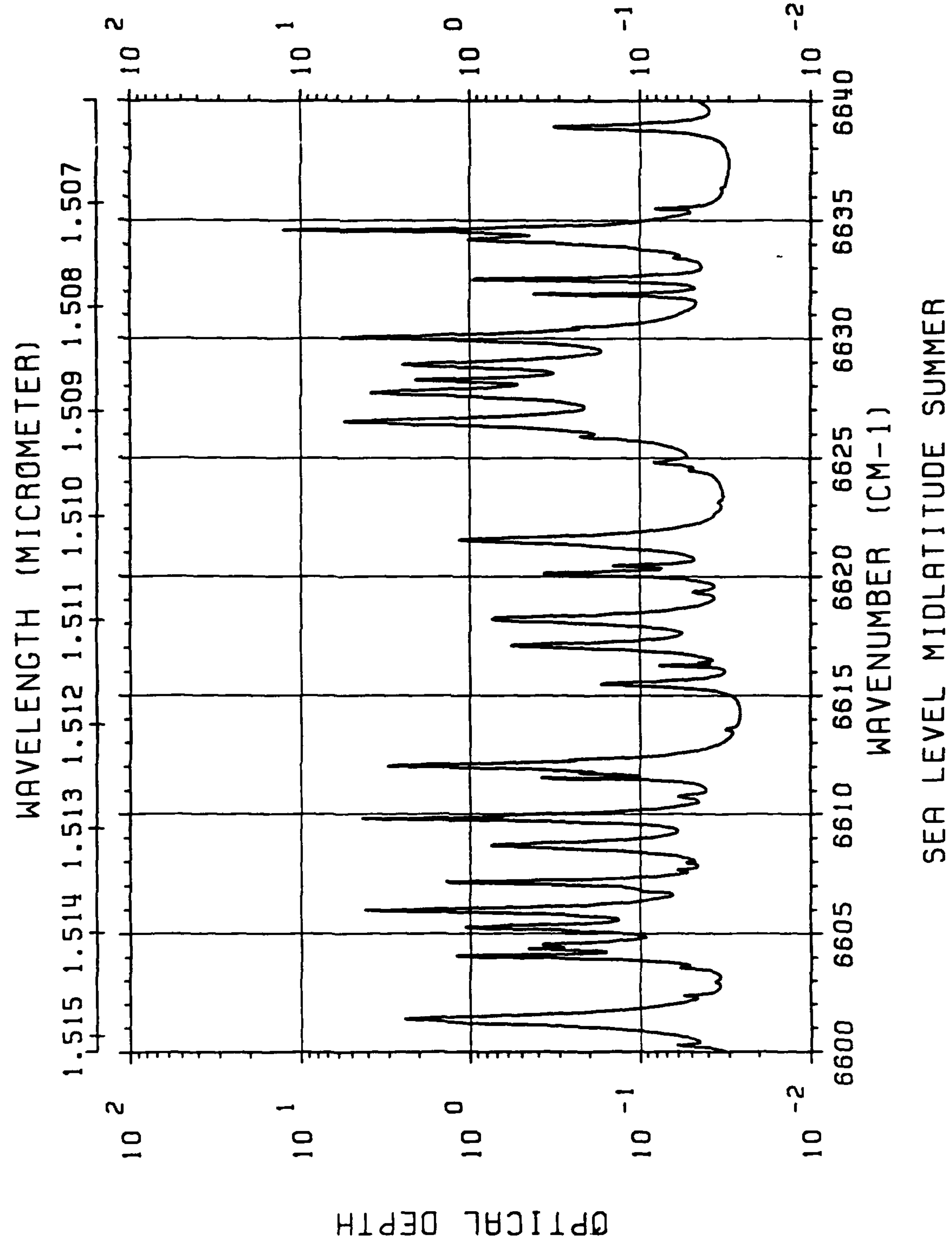

WAVELENGTH (MICROMETER)
1.543 1.542 1.541 1.540 1.539 1.538 1.537 1.536 1.535 1.534
WAVENUMBER (CM-1)
6480 6485 6490 6495 6500 6505 6510 6515 6520
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH
10^0 10^-1 10^-2

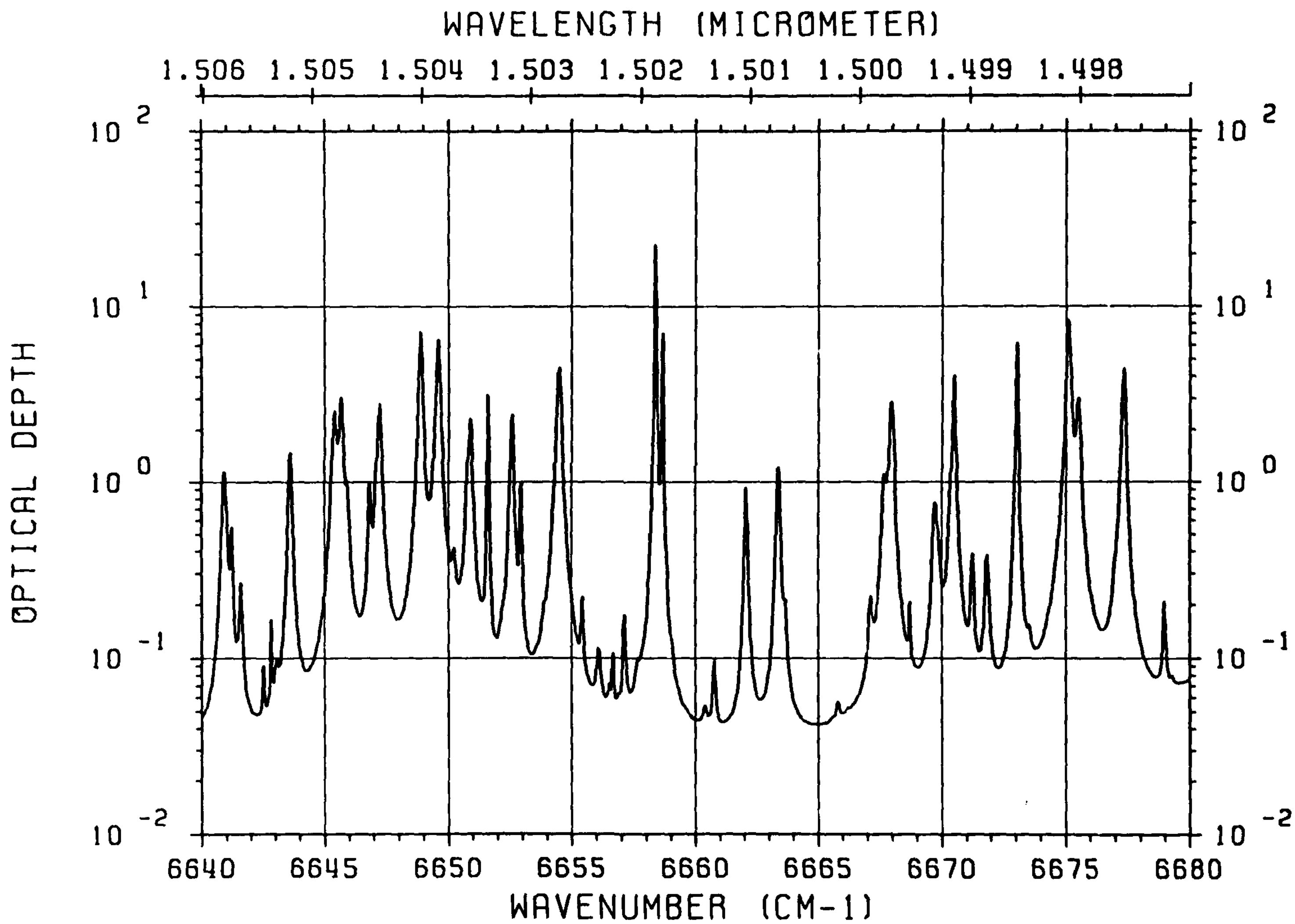



SEA LEVEL MIDLATITUDE SUMMER

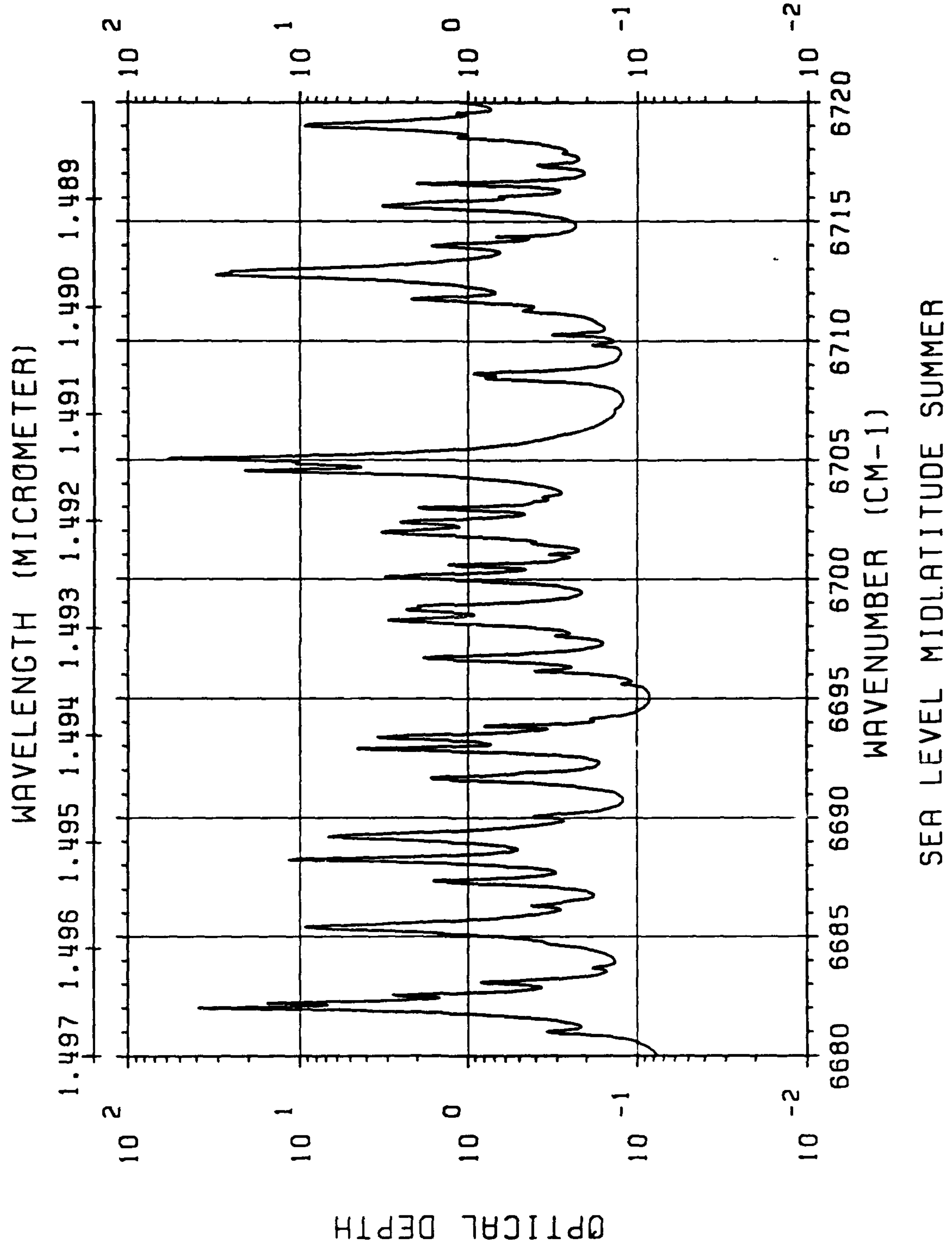


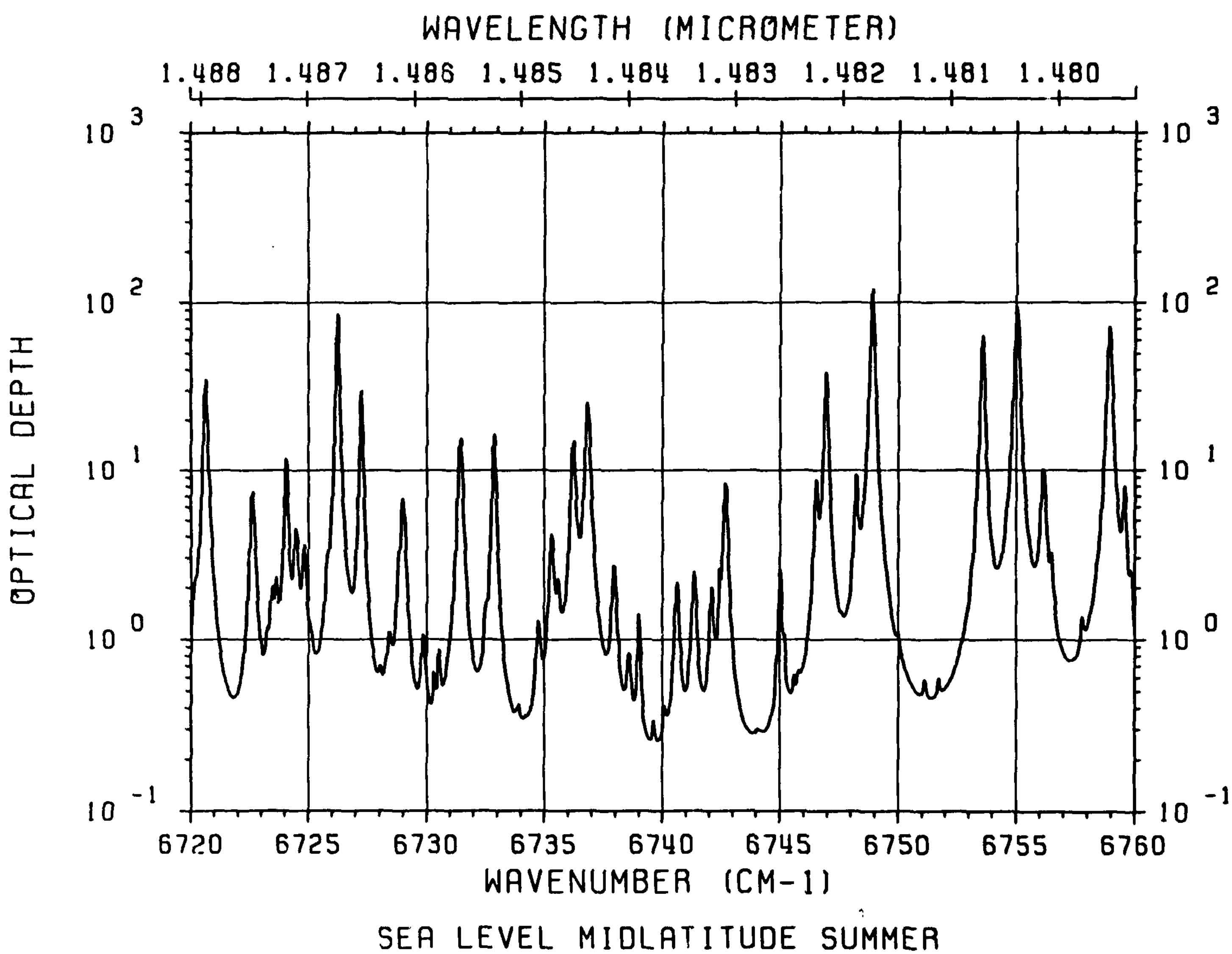

SEA LEVEL MIDLATITUDE SUMMER

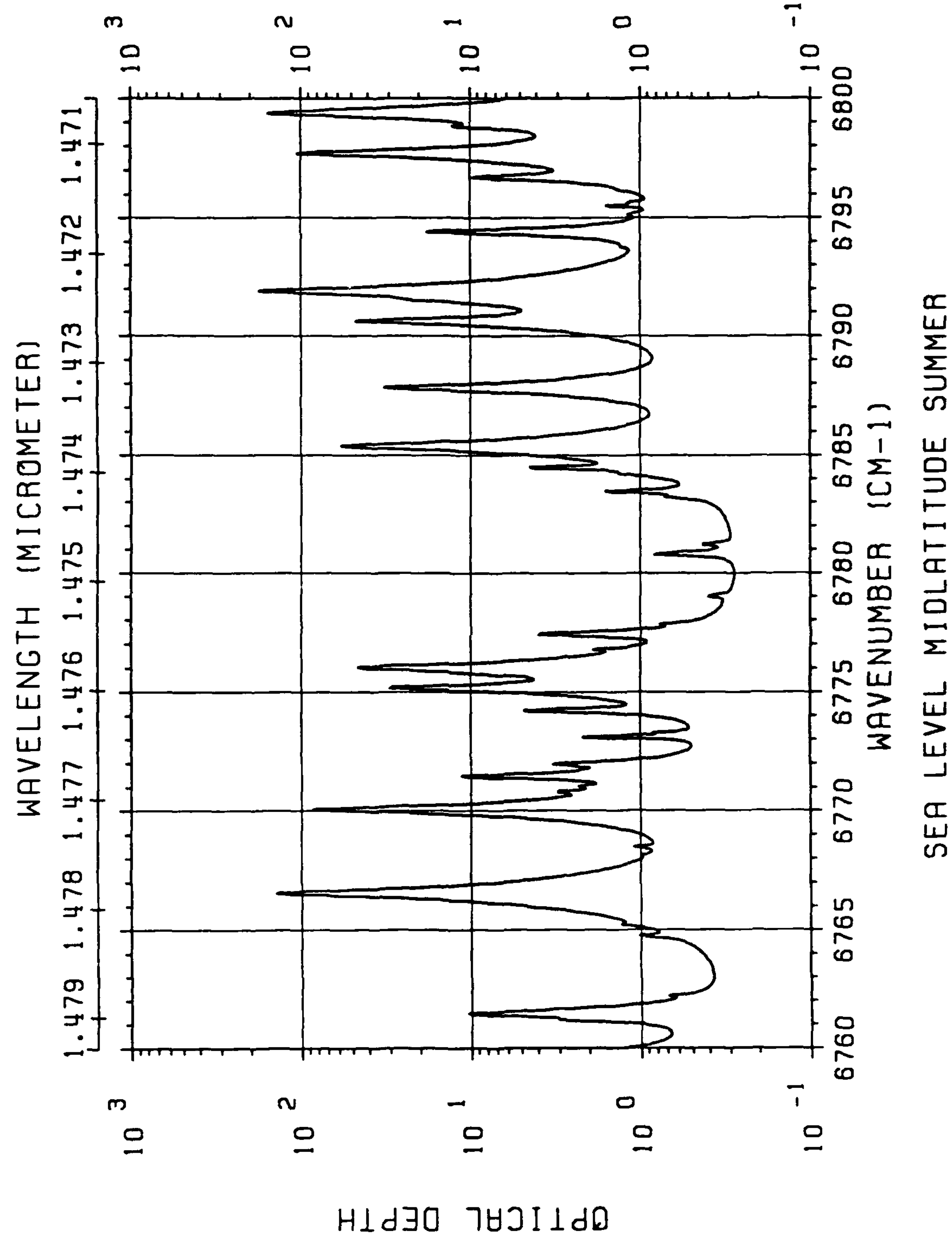

WAVELENGTH (MICROMETER)
1.515 1.514 1.513 1.512 1.511 1.510 1.509 1.508 1.507
WAVENUMBER (CM-1)
6600 6605 6610 6615 6620 6625 6630 6635 6640
OPTICAL DEPTH
10^2 10^1 10^0 10^-1 10^-2
SEA LEVEL MIDLATITUDE SUMMER

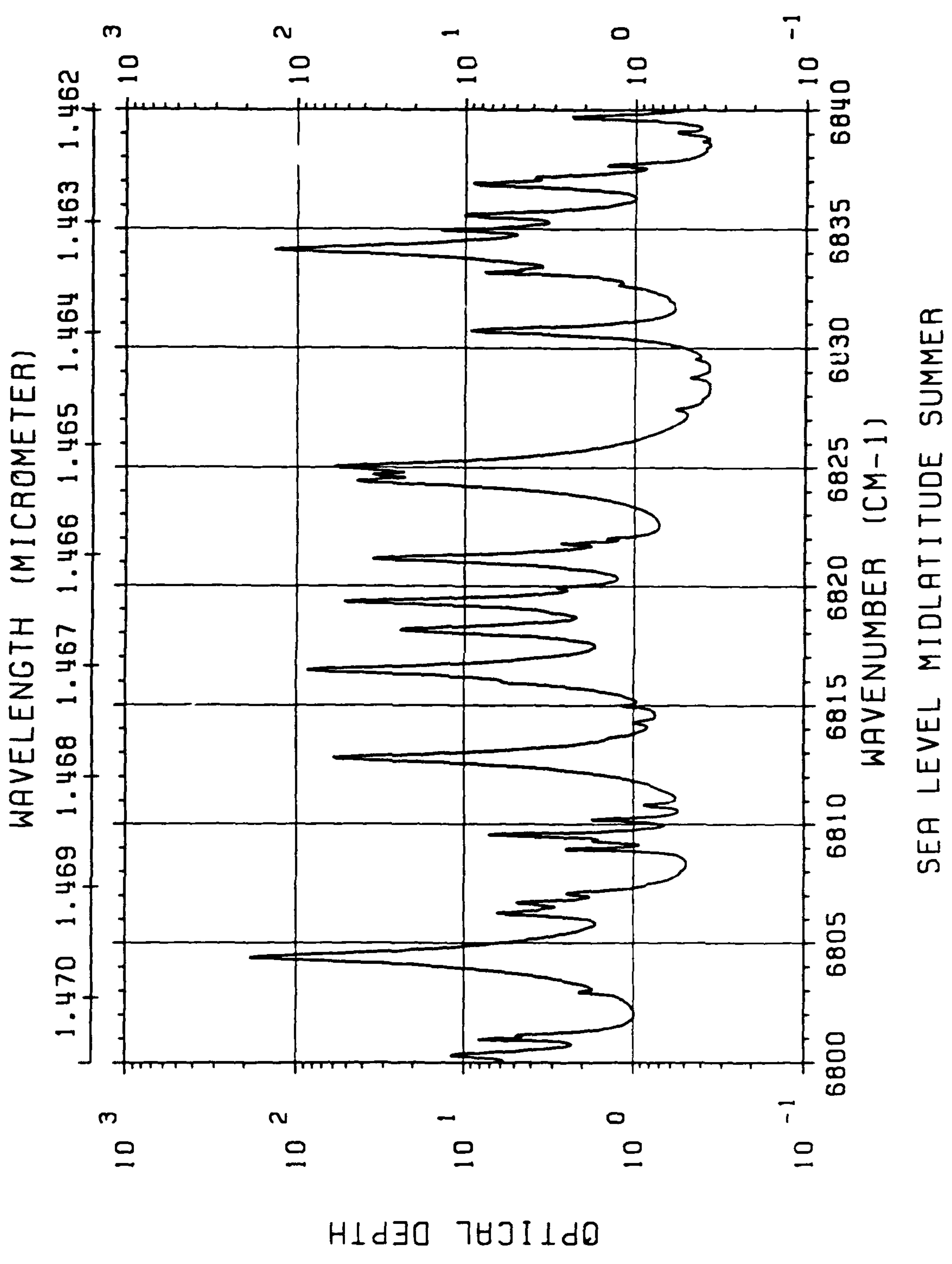


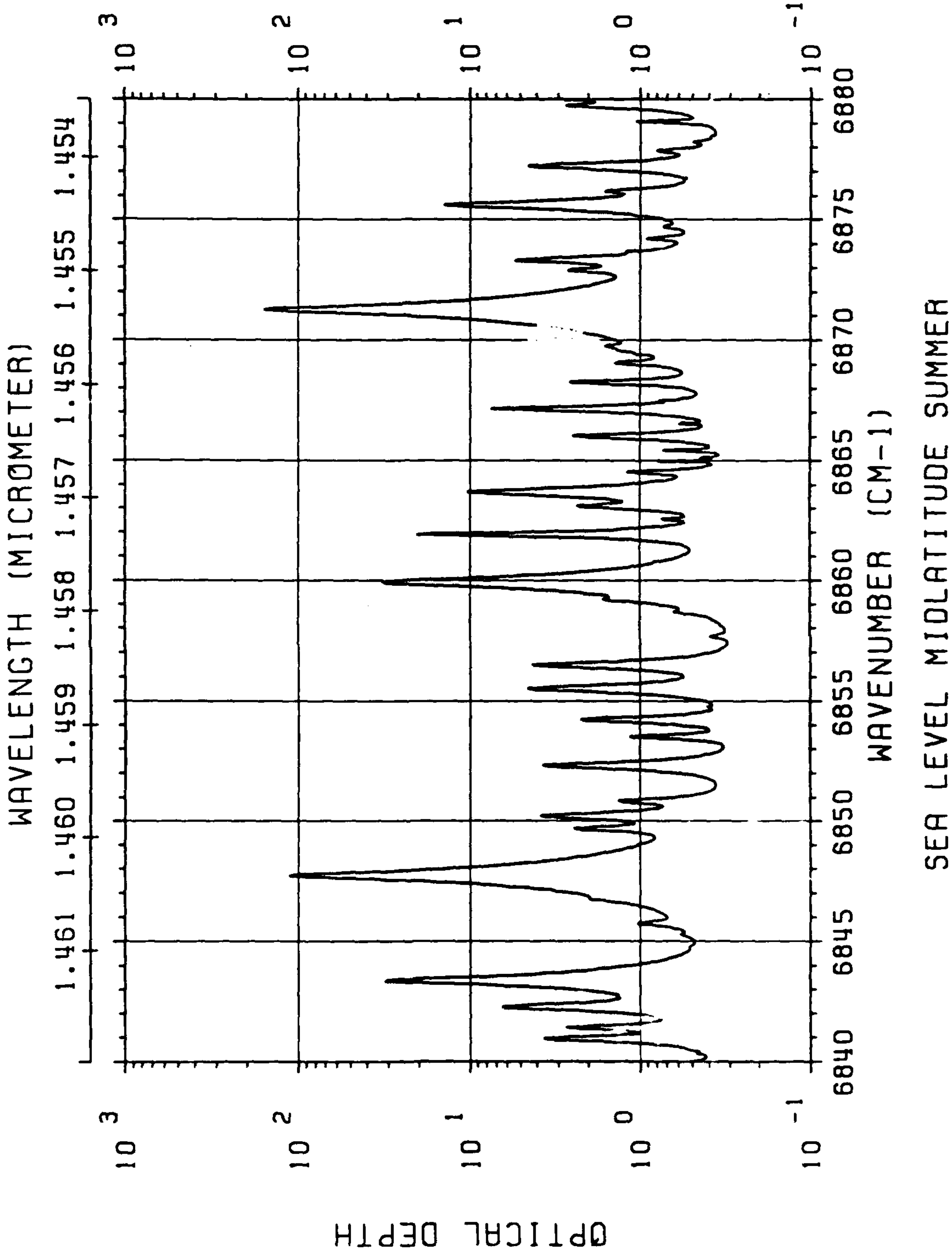

SEA LEVEL MIDLATITUDE SUMMER

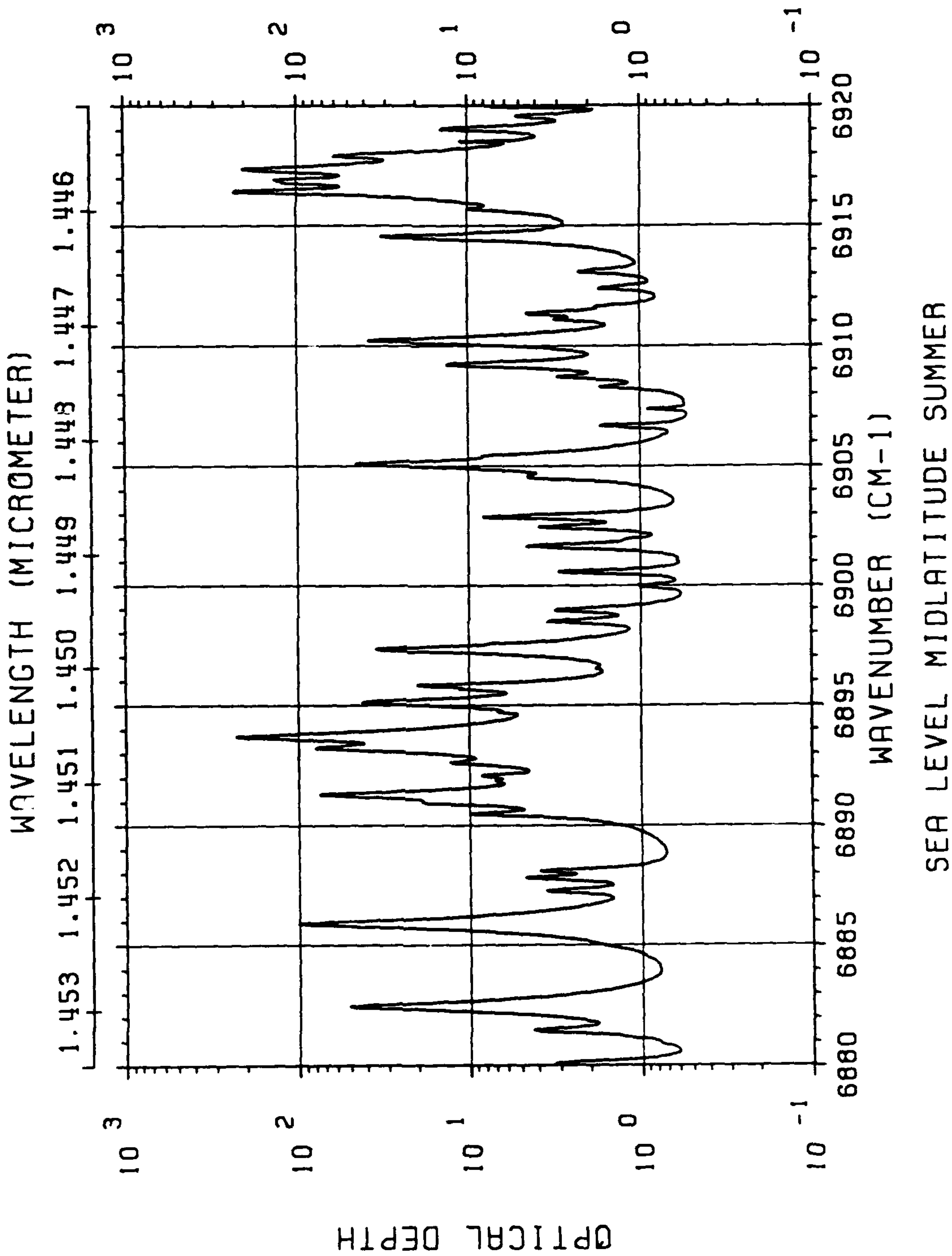

WAVELENGTH (MICROMETER)
1.497 1.496 1.496 1.495 1.495 1.494 1.494 1.493 1.493 1.492 1.492 1.491 1.491 1.490 1.490 1.489
6680 6685 6690 6695 6700 6705 6710 6715 6720
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH
10^2 10^1 10^0 10^-1 10^-2

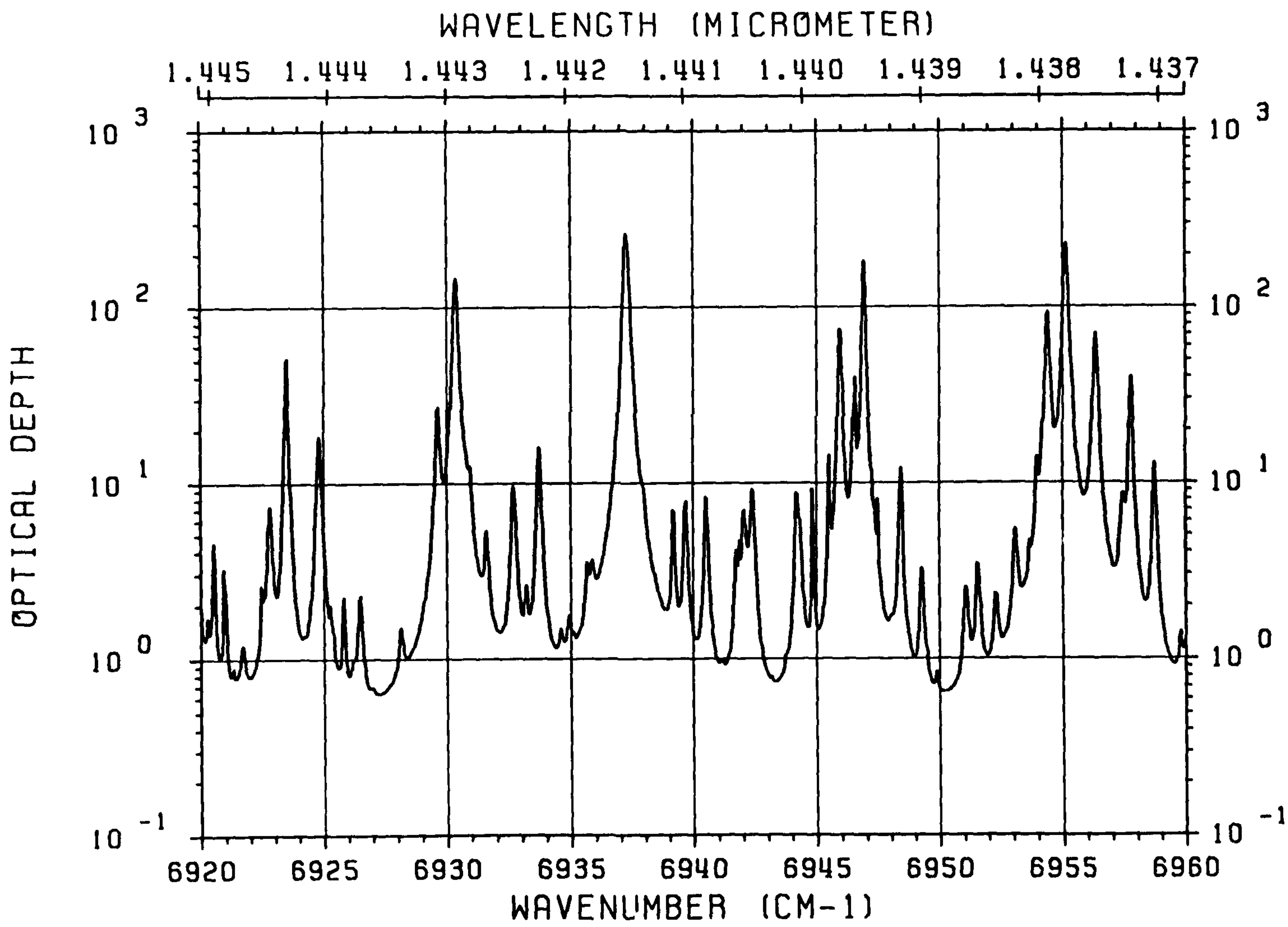

WAVELENGTH (MICRØMETER)
1.488 1.487 1.486 1.485 1.484 1.483 1.482 1.481 1.480
OPTICAL DEPTH
10^3
10^2
10^1
10^0
10^-1
6720 6725 6730 6735 6740 6745 6750 6755 6760
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER


WAVELENGTH (MICROMETER)
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH

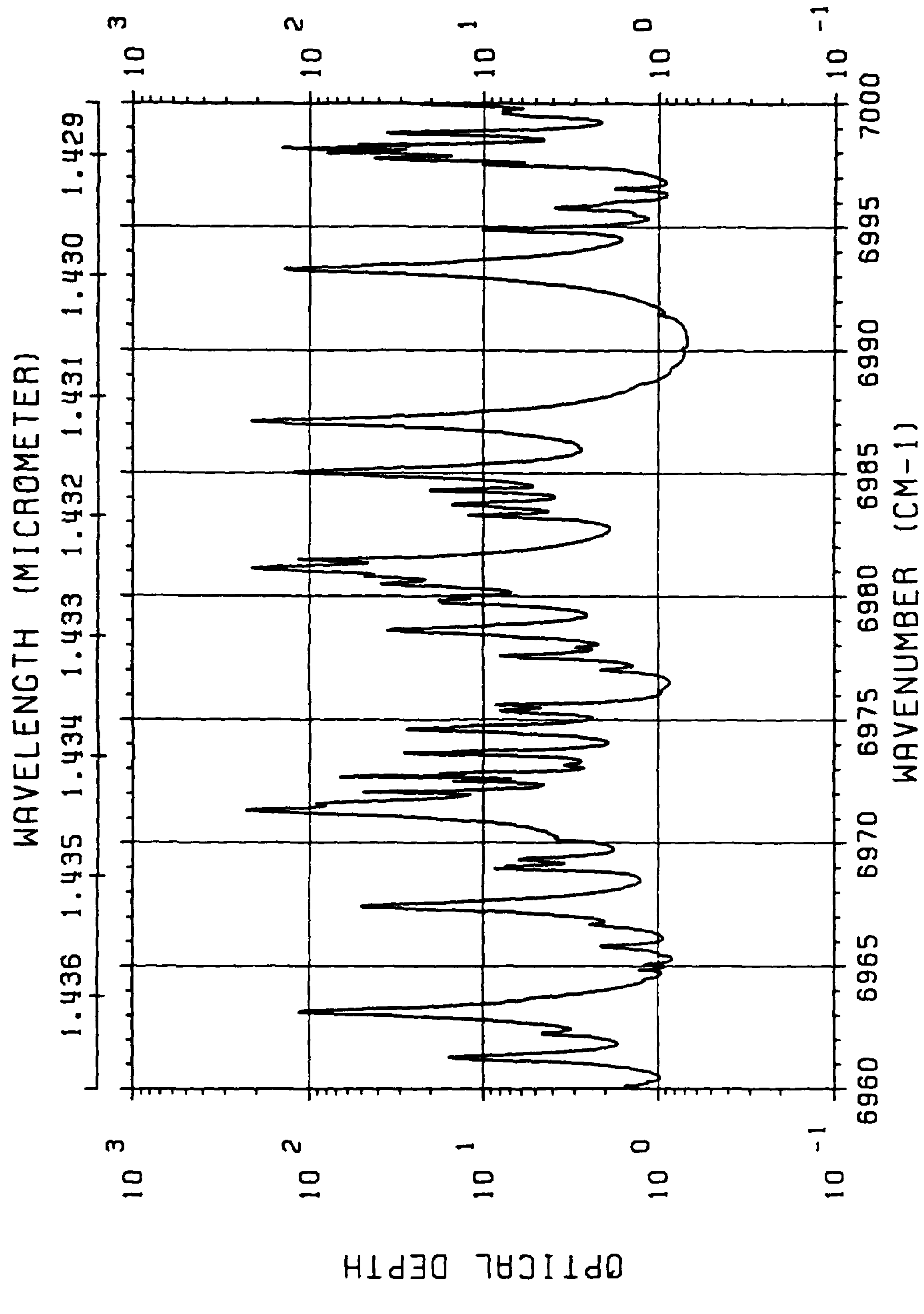

WAVELENGTH (MICROMETER)
1.470 1.469 1.468 1.467 1.466 1.465 1.464 1.463 1.462
6800 6805 6810 6815 6820 6825 6830 6835 6840
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH
10^3 10^2 10^1 10^0 10^-1


WAVELENGTH (MICROMETER)
1.461 1.460 1.459 1.458 1.457 1.456 1.455 1.454
OPTICAL DEPTH
$10^{3}$ $10^{2}$ $10^{1}$ $10^{0}$ $10^{-1}$
6840 6845 6850 6855 6860 6865 6870 6875 6880
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER

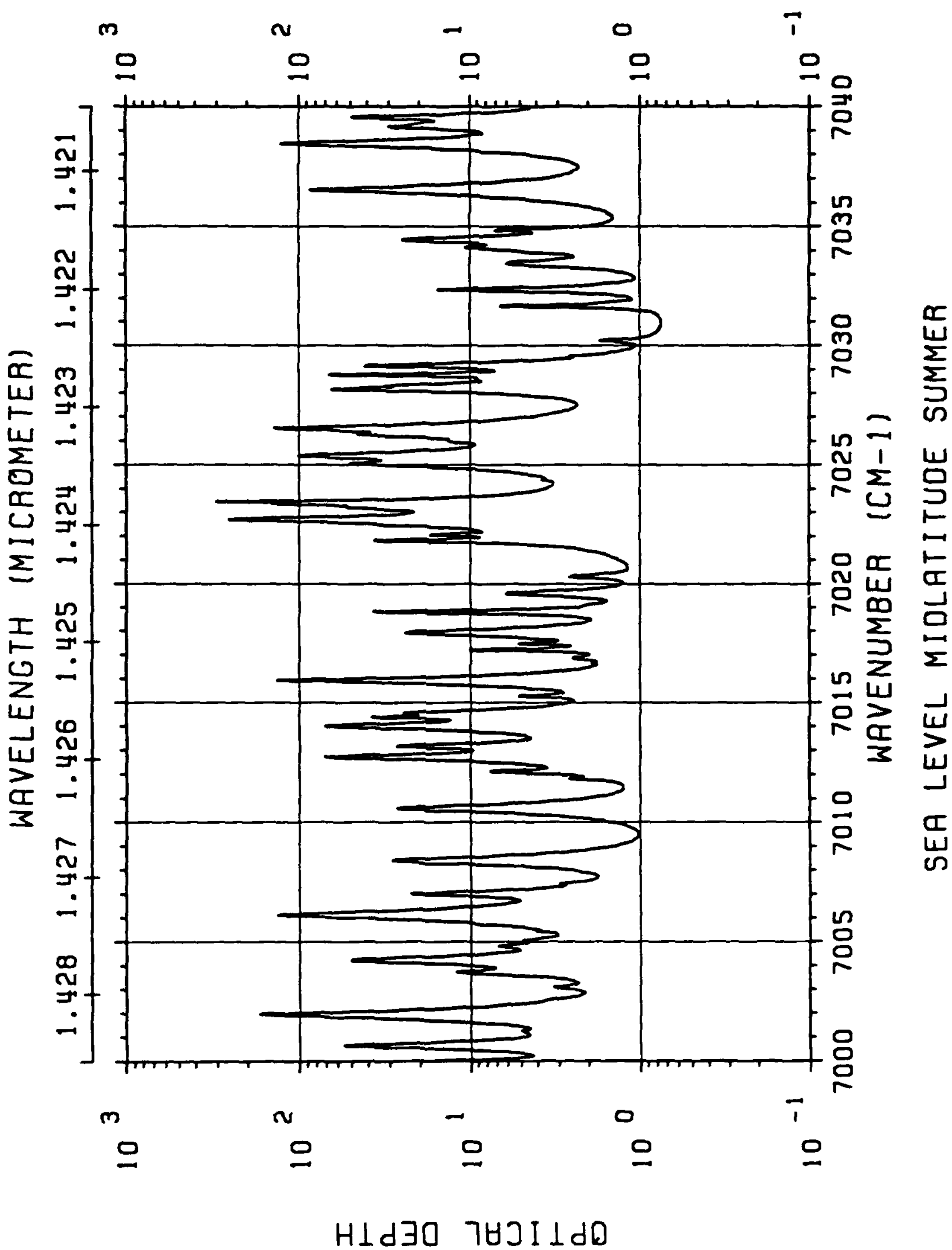

WAVELENGTH (MICROMETER)
1.453
1.452
1.451
1.450
1.449
1.448
1.447
1.446
WAVENUMBER (CM-1)
6880
6885
6890
6895
6900
6905
6910
6915
6920
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH
$10^{-1}$
$10^{0}$
$10^{1}$
$10^{2}$
$10^{3}$

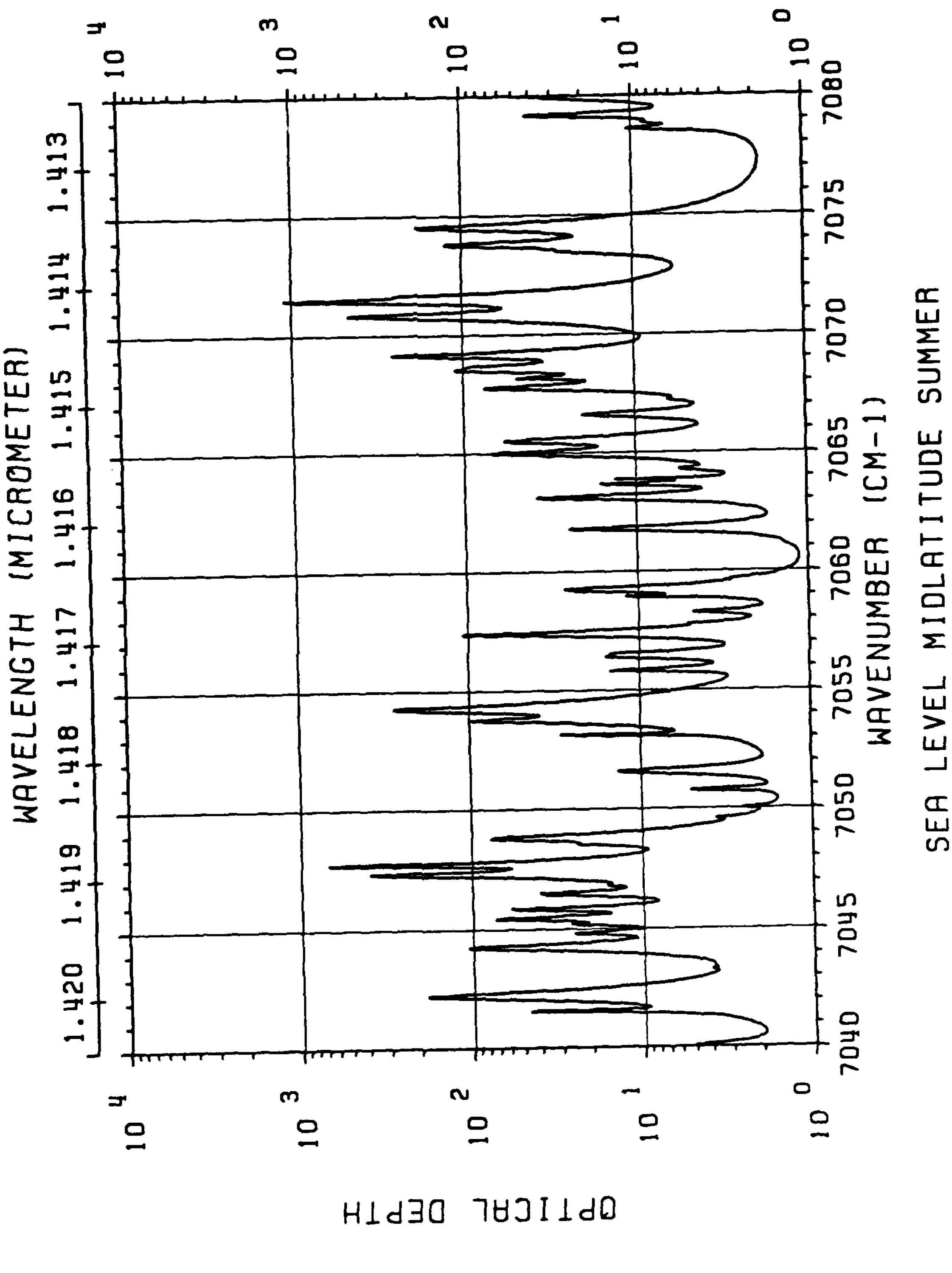


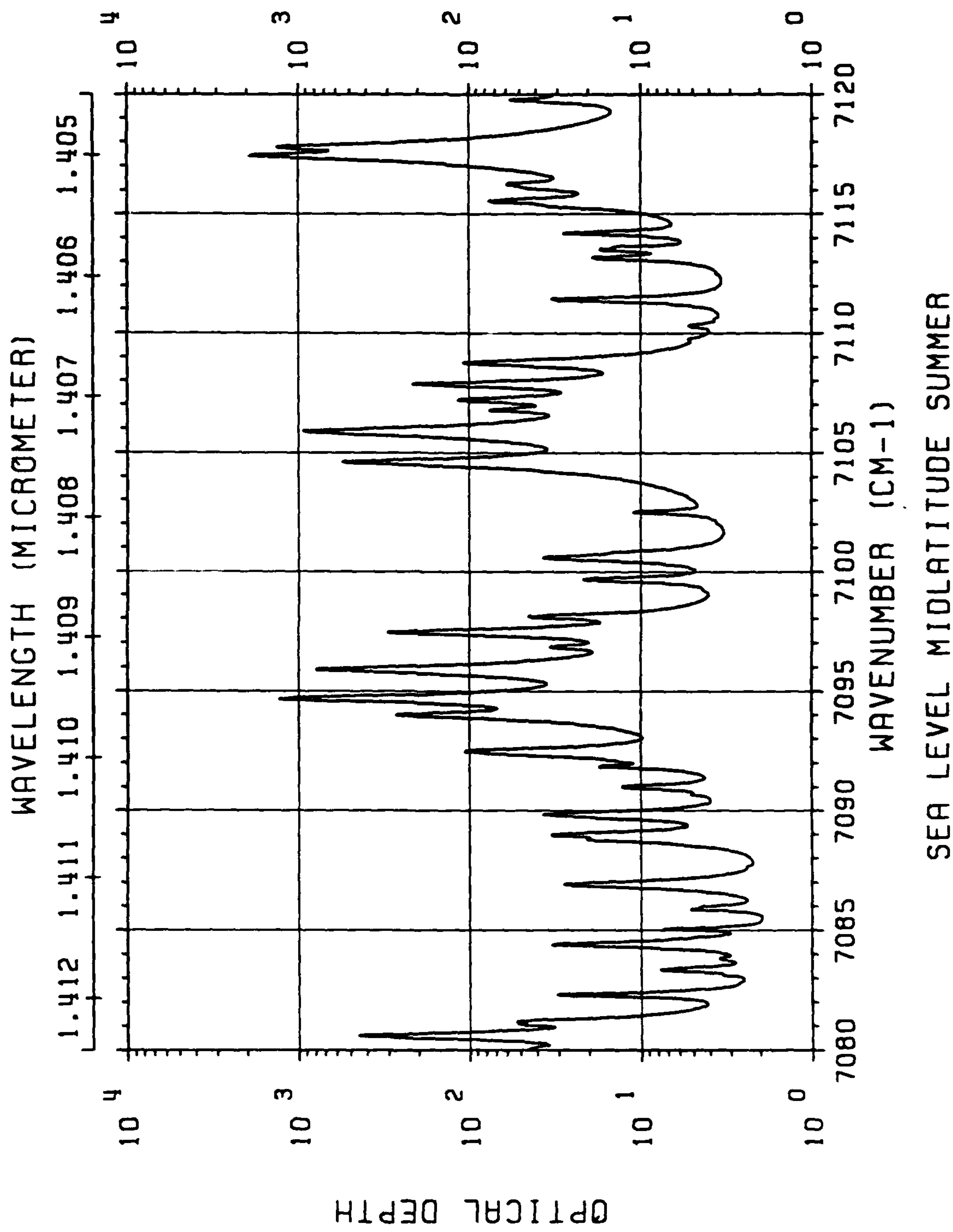

SEA LEVEL MIDLATITUDE SUMMER

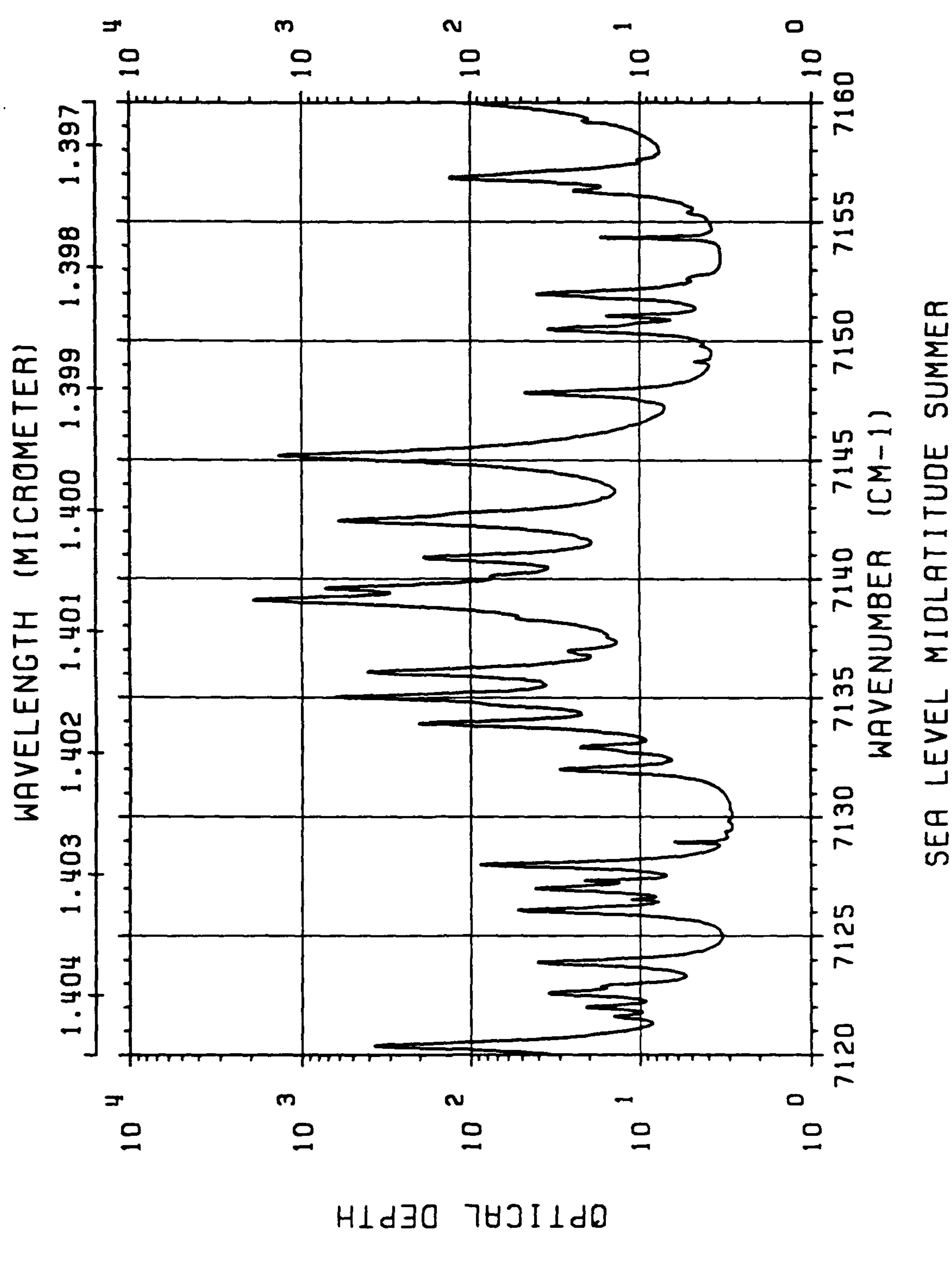


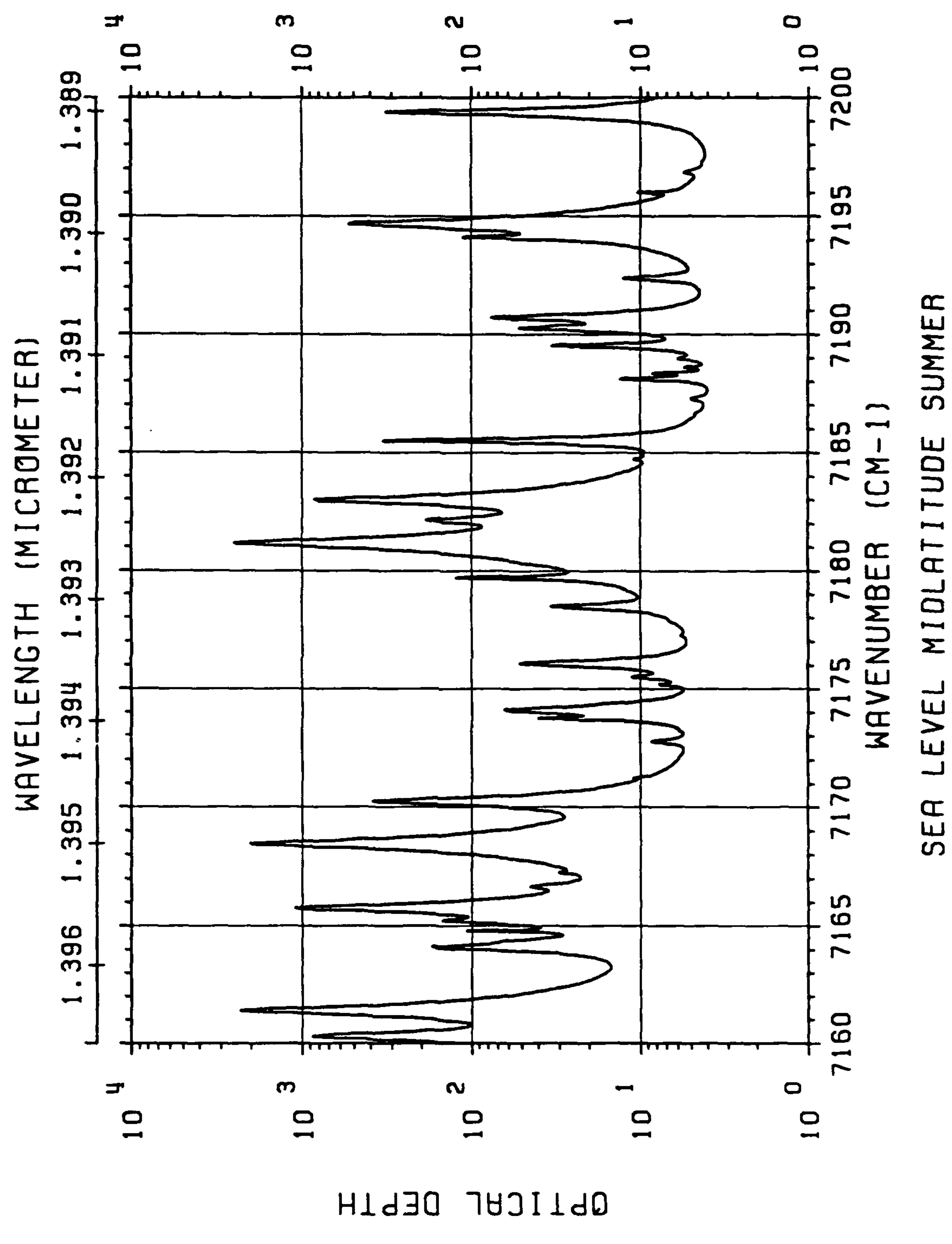

SEA LEVEL MIDLATITUDE SUMMER


WAVELENGTH (MICROMETER)
1.428
1.427
1.426
1.425
1.424
1.423
1.422
1.421
WAVENUMBER (CM-1)
7000
7005
7010
7015
7020
7025
7030
7035
7040
OPTICAL DEPTH
SEA LEVEL MIDLATITUDE SUMMER

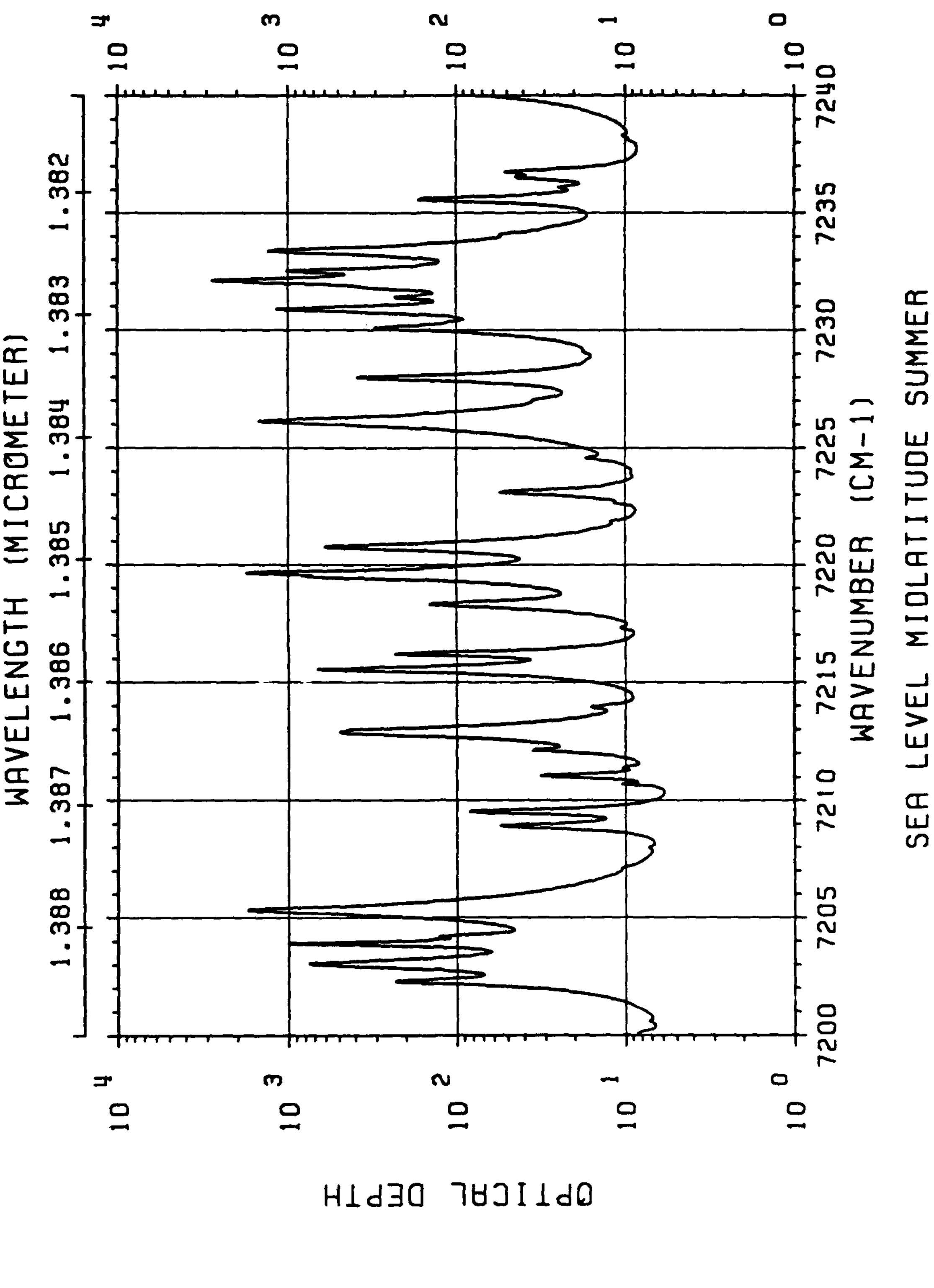

WAVELENGTH (MICROMETER)
1.420 1.419 1.418 1.417 1.416 1.415 1.414 1.413
OPTICAL DEPTH
10^0 10^1 10^2 10^3 10^4
7040 7045 7050 7055 7060 7065 7070 7075 7080
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER

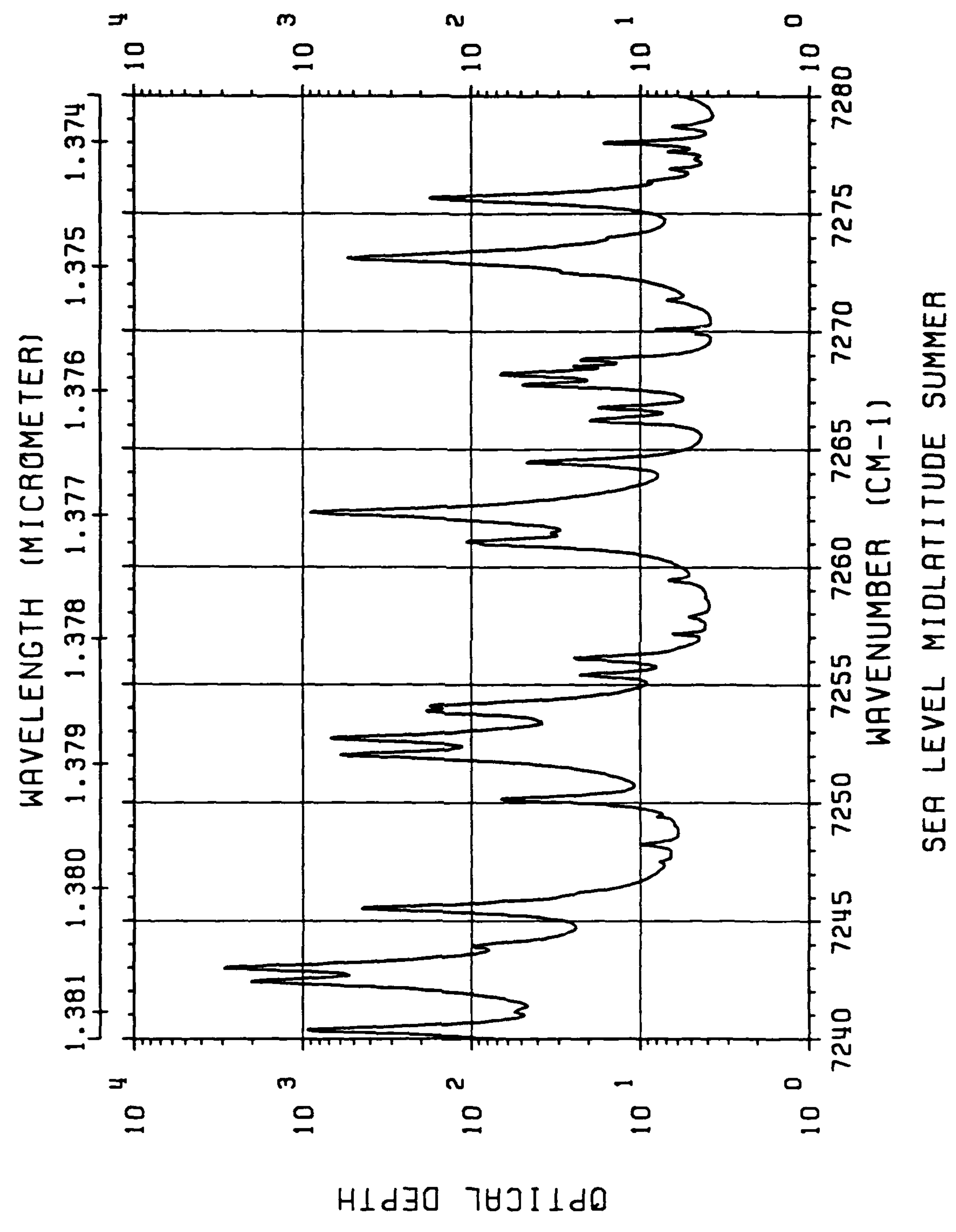

WAVELENGTH (MICROMETER)
1.405
1.406
1.407
1.408
1.409
1.410
1.411
1.412
WAVENUMBER (CM-1)
7080
7085
7090
7095
7100
7105
7110
7115
7120
OPTICAL DEPTH
$10^0$
$10^1$
$10^2$
$10^3$
$10^4$
SEA LEVEL MIDLATITUDE SUMMER

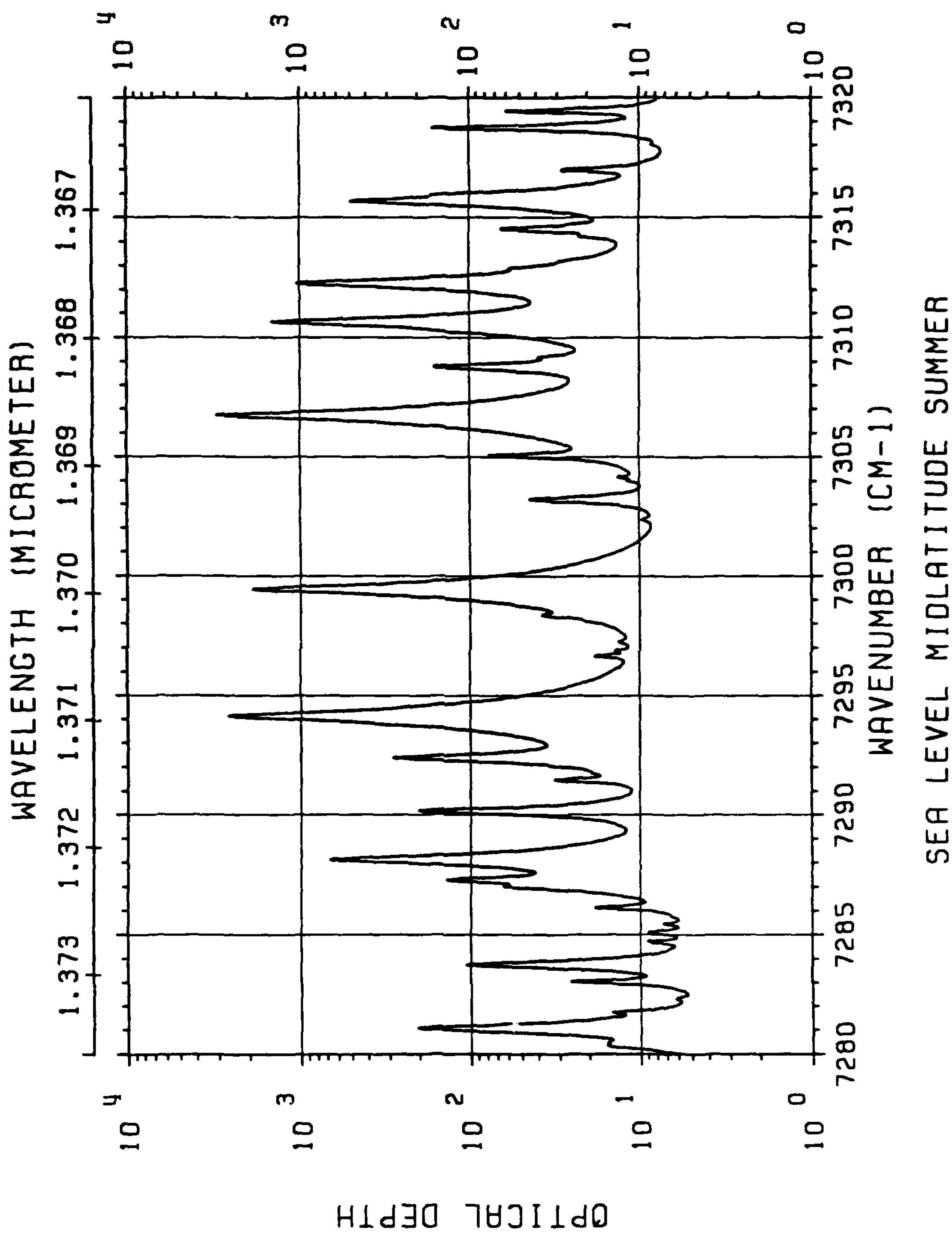

WAVELENGTH (MICROMETER)
1.397
1.398
1.399
1.400
1.401
1.402
1.403
1.404
7120
7125
7130
7135
7140
7145
7150
7155
7160
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
10^0
10^1
10^2
10^3
10^4
OPTICAL DEPTH



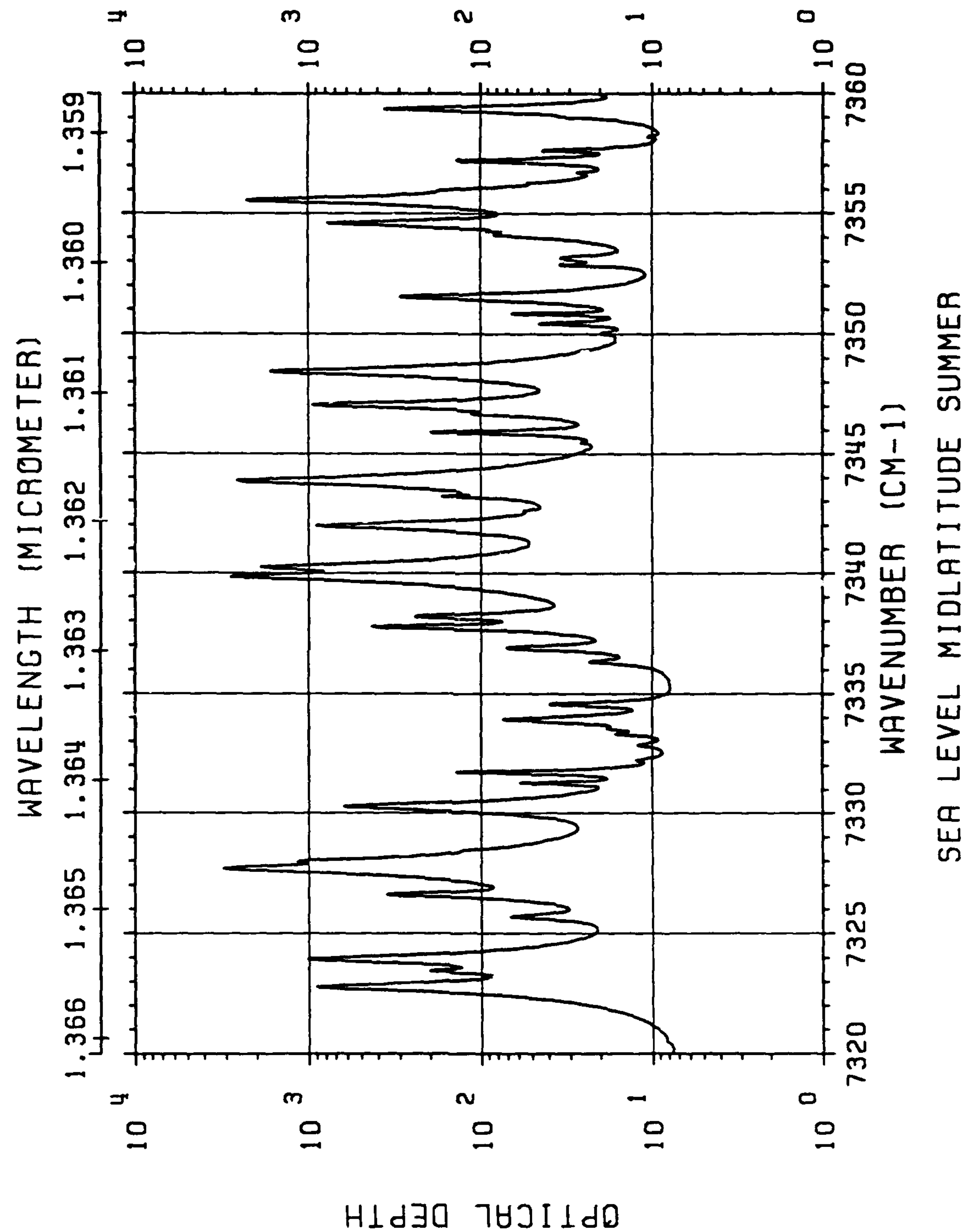
WAVELENGTH (MICROMETER)
1.396
1.395
1.394
1.393
1.392
1.391
1.390
1.389
10^4
10^3
10^2
10^1
10^0
7160
7165
7170
7175
7180
7185
7190
7195
7200
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH

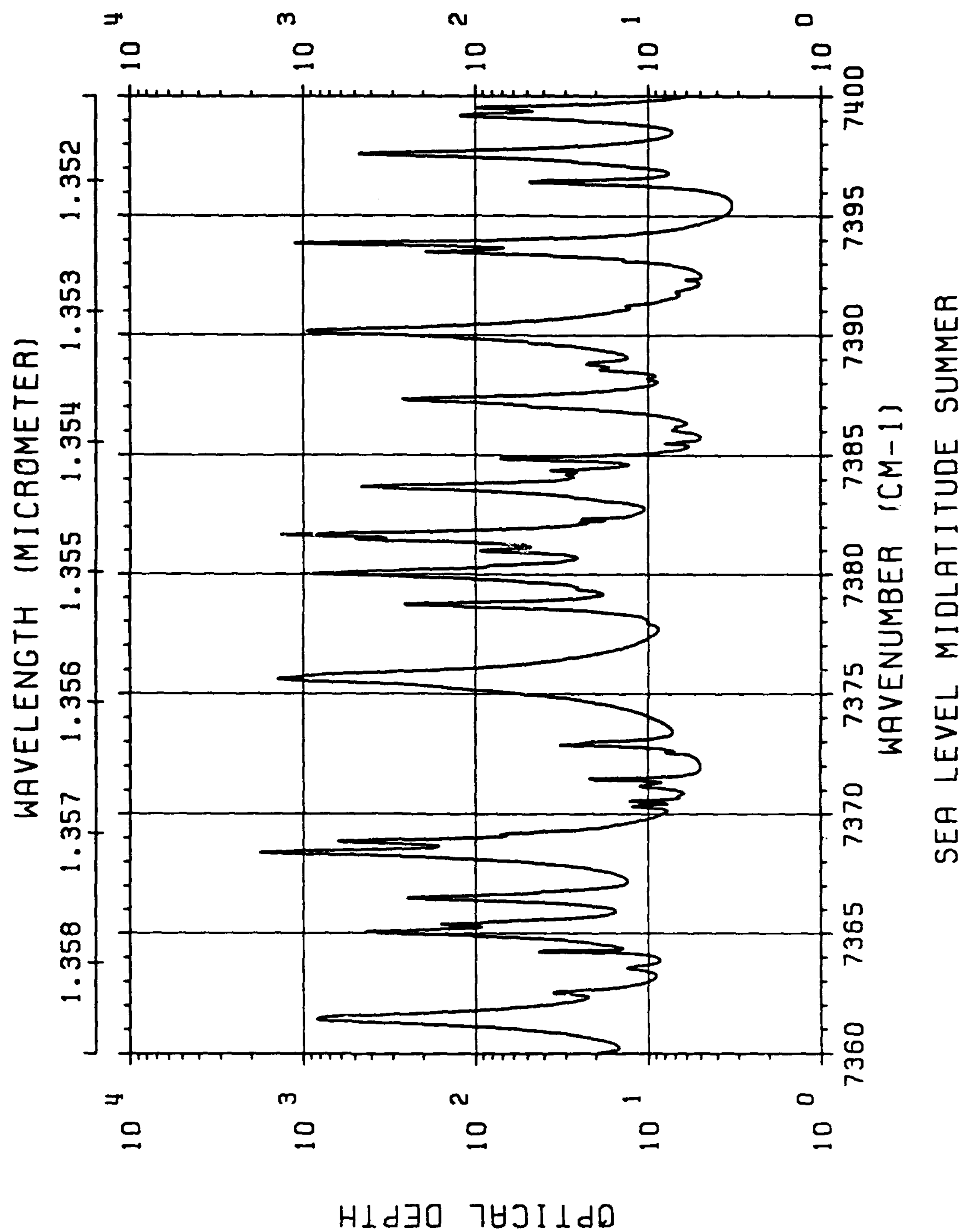

WAVELENGTH (MICROMETER)
1.388 1.387 1.386 1.385 1.384 1.383 1.382
7200 7205 7210 7215 7220 7225 7230 7235 7240
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH
10^0 10^1 10^2 10^3 10^4

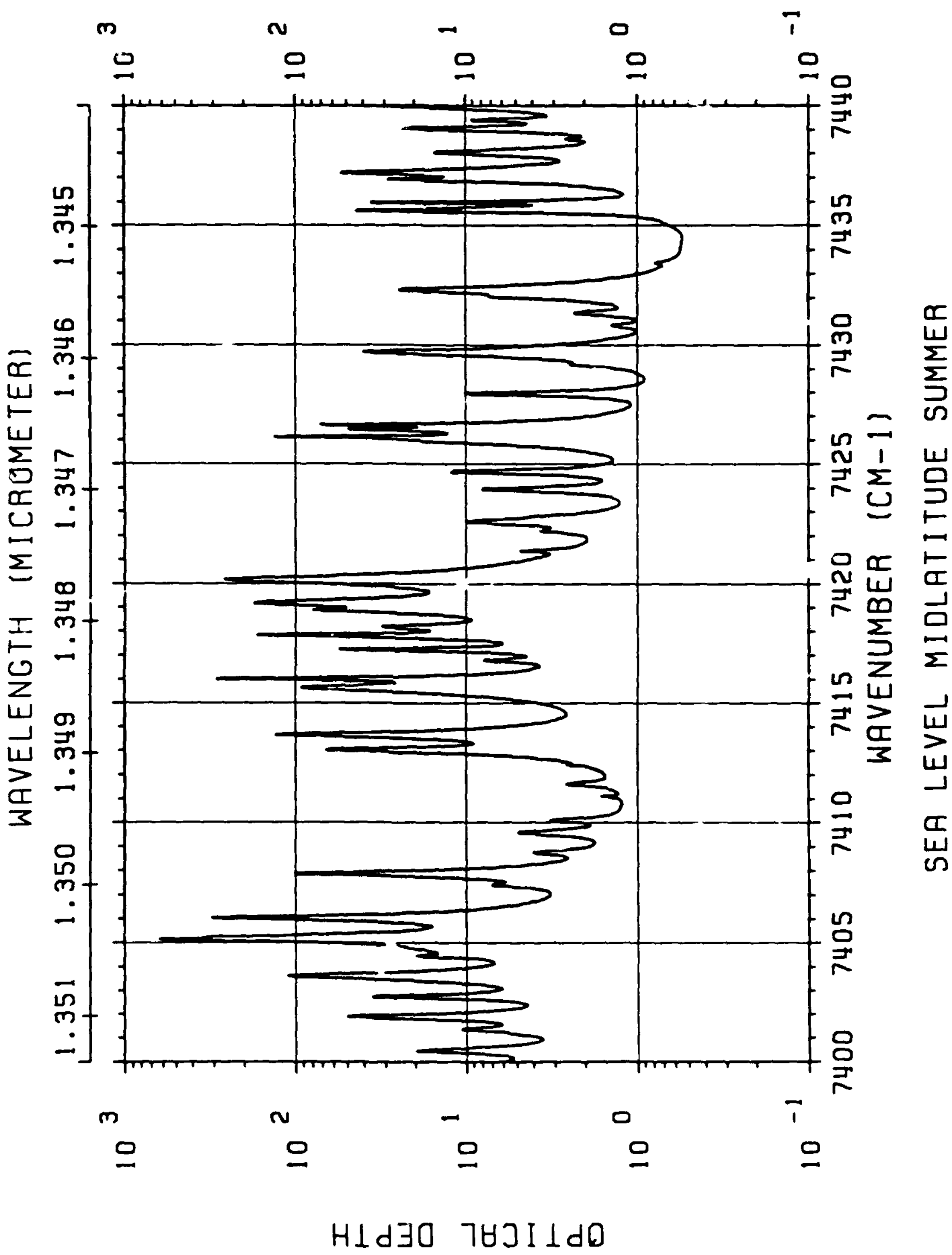

WAVELENGTH (MICROMETER)
1.374 1.375 1.376 1.377 1.378 1.379 1.380 1.381
WAVENUMBER (CM-1)
7240 7245 7250 7255 7260 7265 7270 7275 7280
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH
10^0 10^1 10^2 10^3 10^4

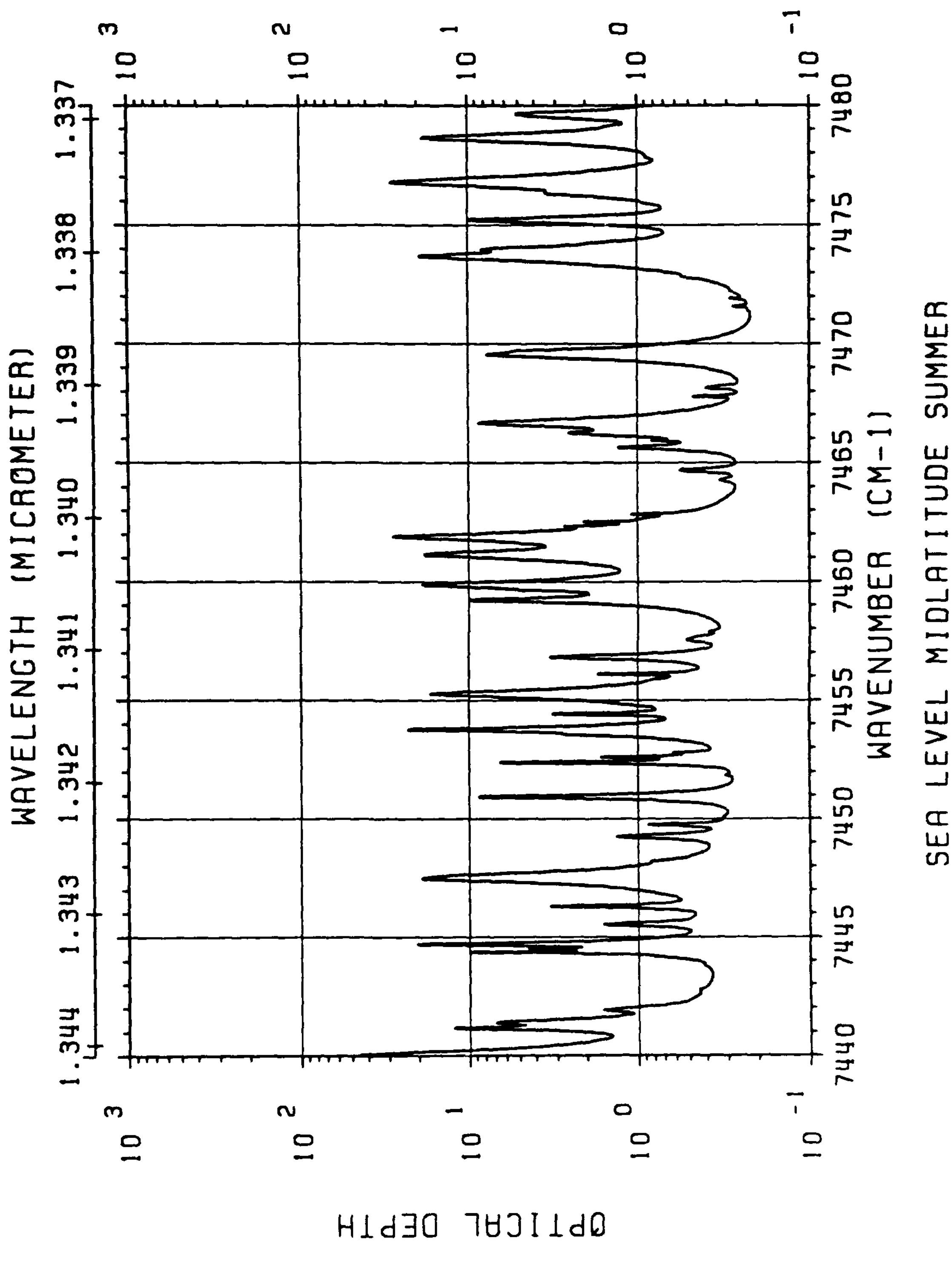


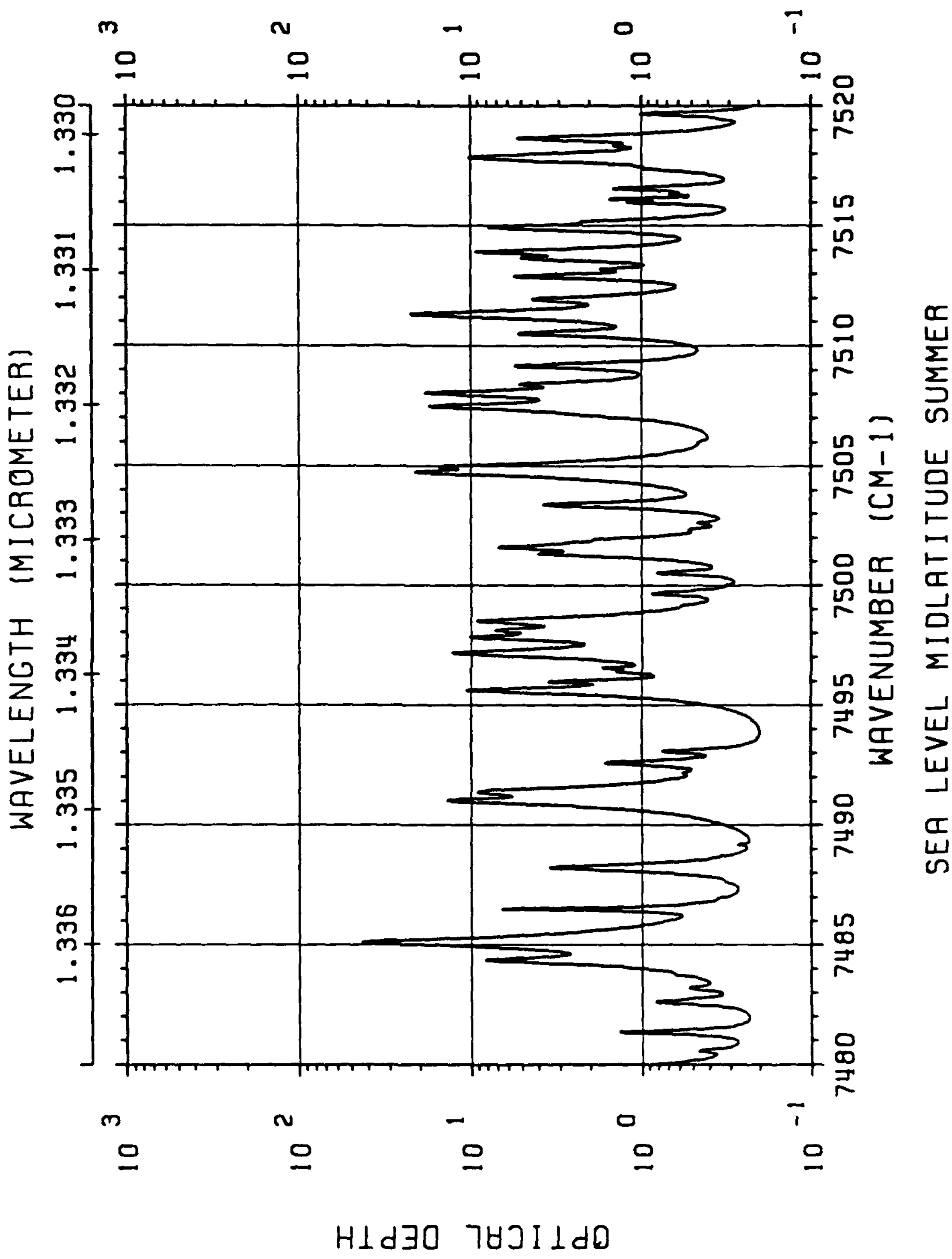
WAVELENGTH (MICROMETER)
1.367
1.368
1.369
1.370
1.371
1.372
1.373
7320
7315
7310
7305
7300
7295
7290
7285
7280
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH

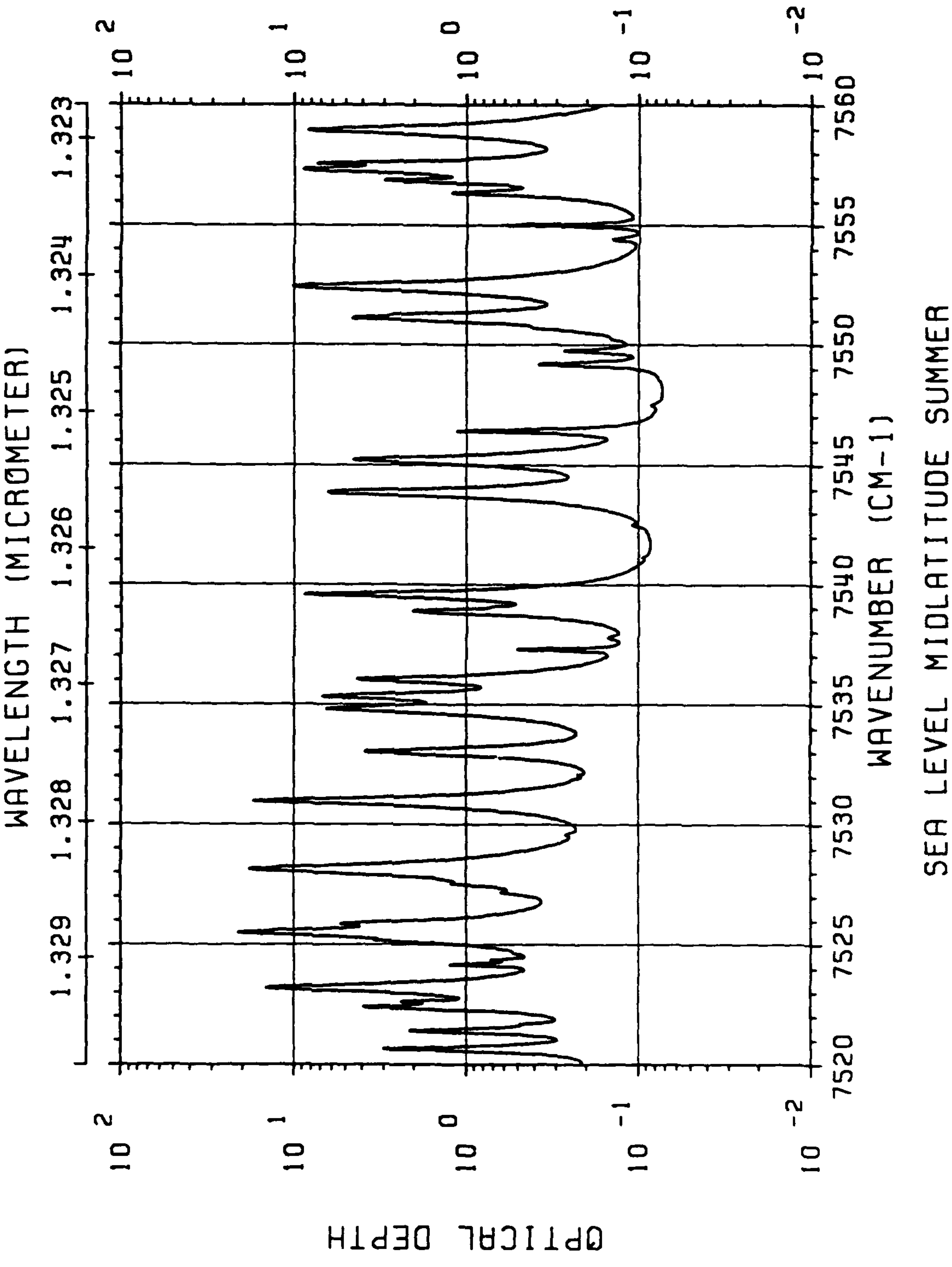

WAVELENGTH (MICROMETER)
1.359
1.360
1.361
1.362
1.363
1.364
1.365
1.366
7320
7325
7330
7335
7340
7345
7350
7355
7360
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH
$10^0$
$10^1$
$10^2$
$10^3$
$10^4$

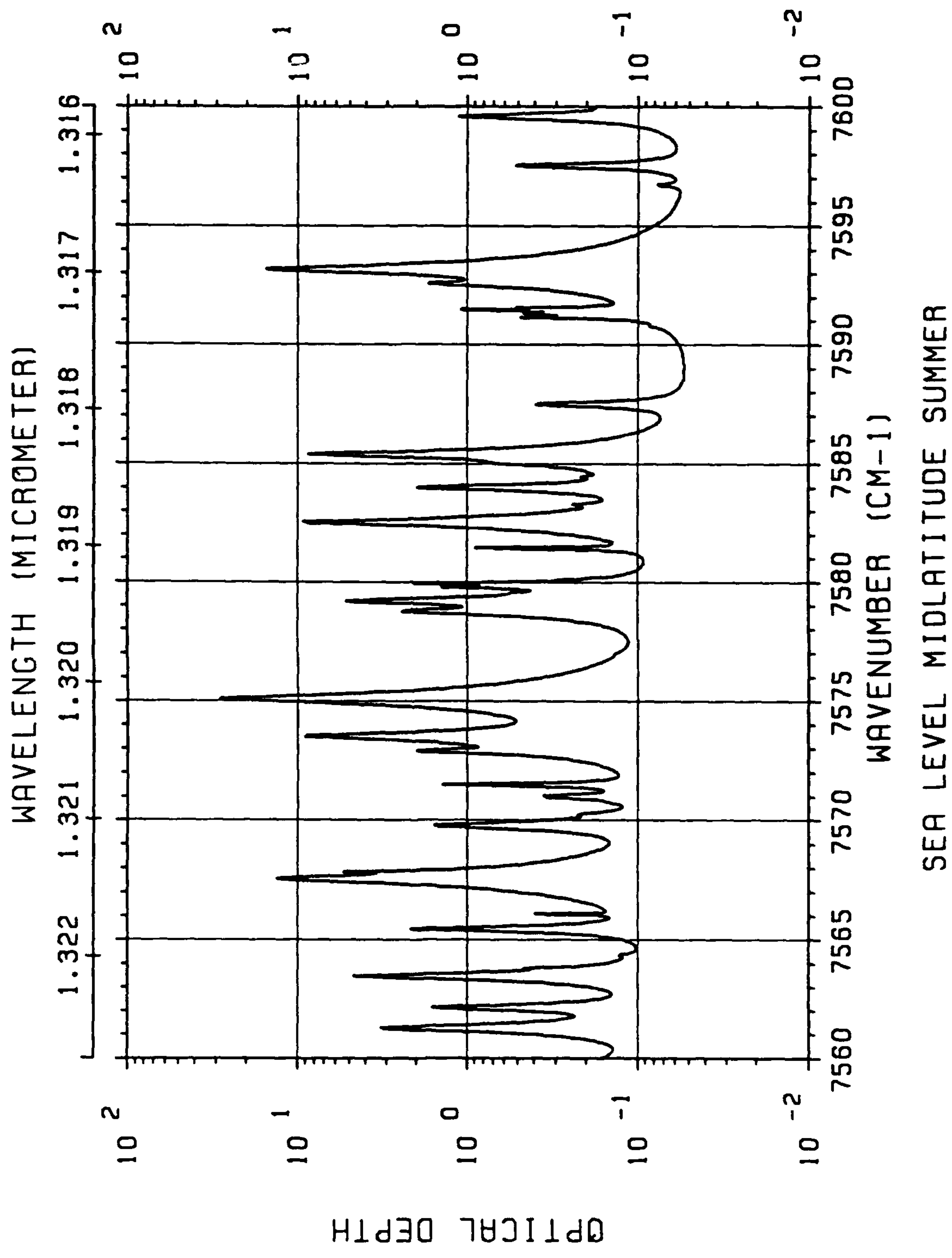

WAVELENGTH (MICROMETER)
1.352
1.353
1.354
1.355
1.356
1.357
1.358
WAVENUMBER (CM-1)
7360
7365
7370
7375
7380
7385
7390
7395
7400
OPTICAL DEPTH
$10^0$
$10^1$
$10^2$
$10^3$
$10^4$
SEA LEVEL MIDLATITUDE SUMMER

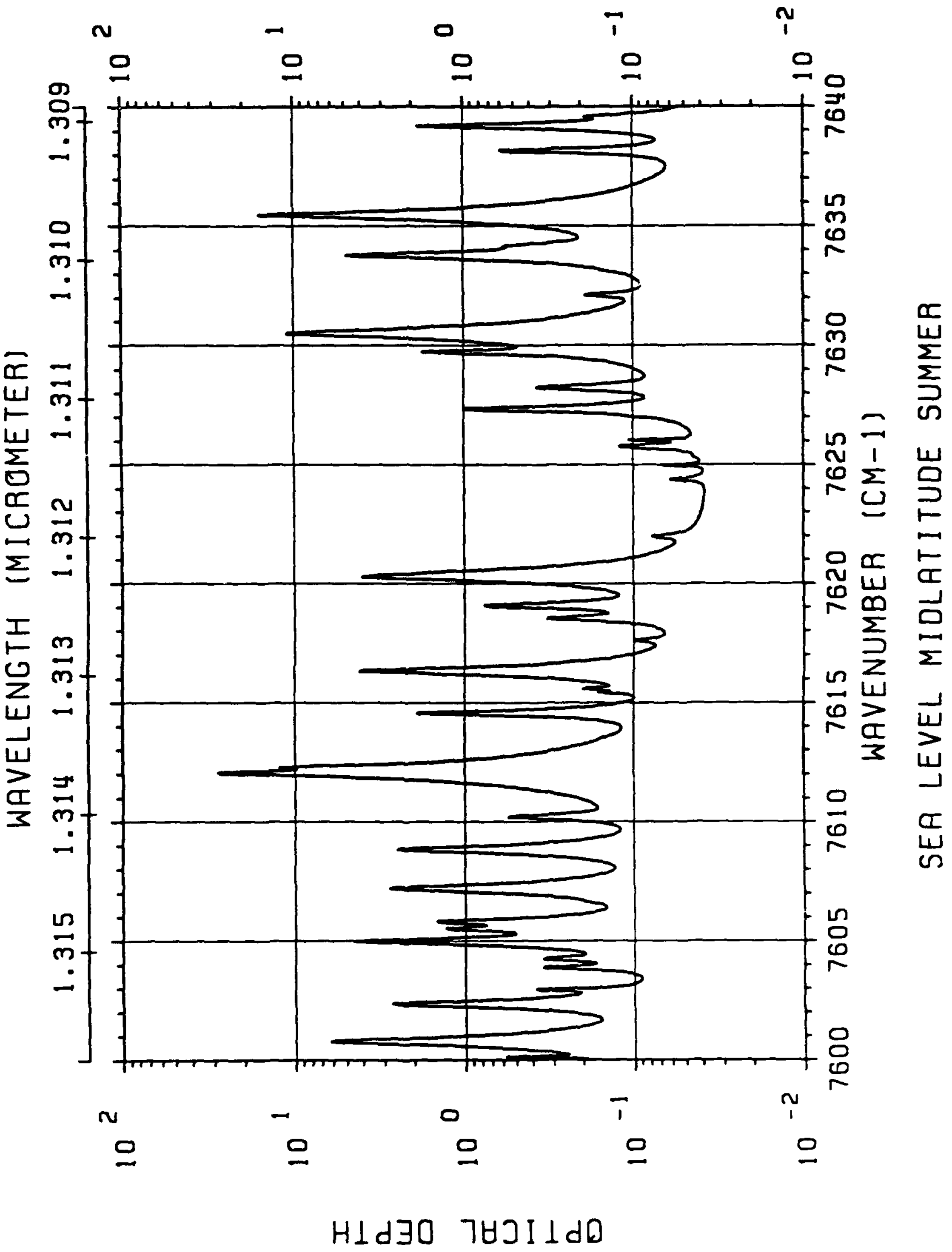

WAVELENGTH (MICROMETER)
1.345
1.346
1.347
1.348
1.349
1.350
1.351
OPTICAL DEPTH
WAVENUMBER (CM-1)
7400
7405
7410
7415
7420
7425
7430
7435
7440
SEA LEVEL MIDLATITUDE SUMMER

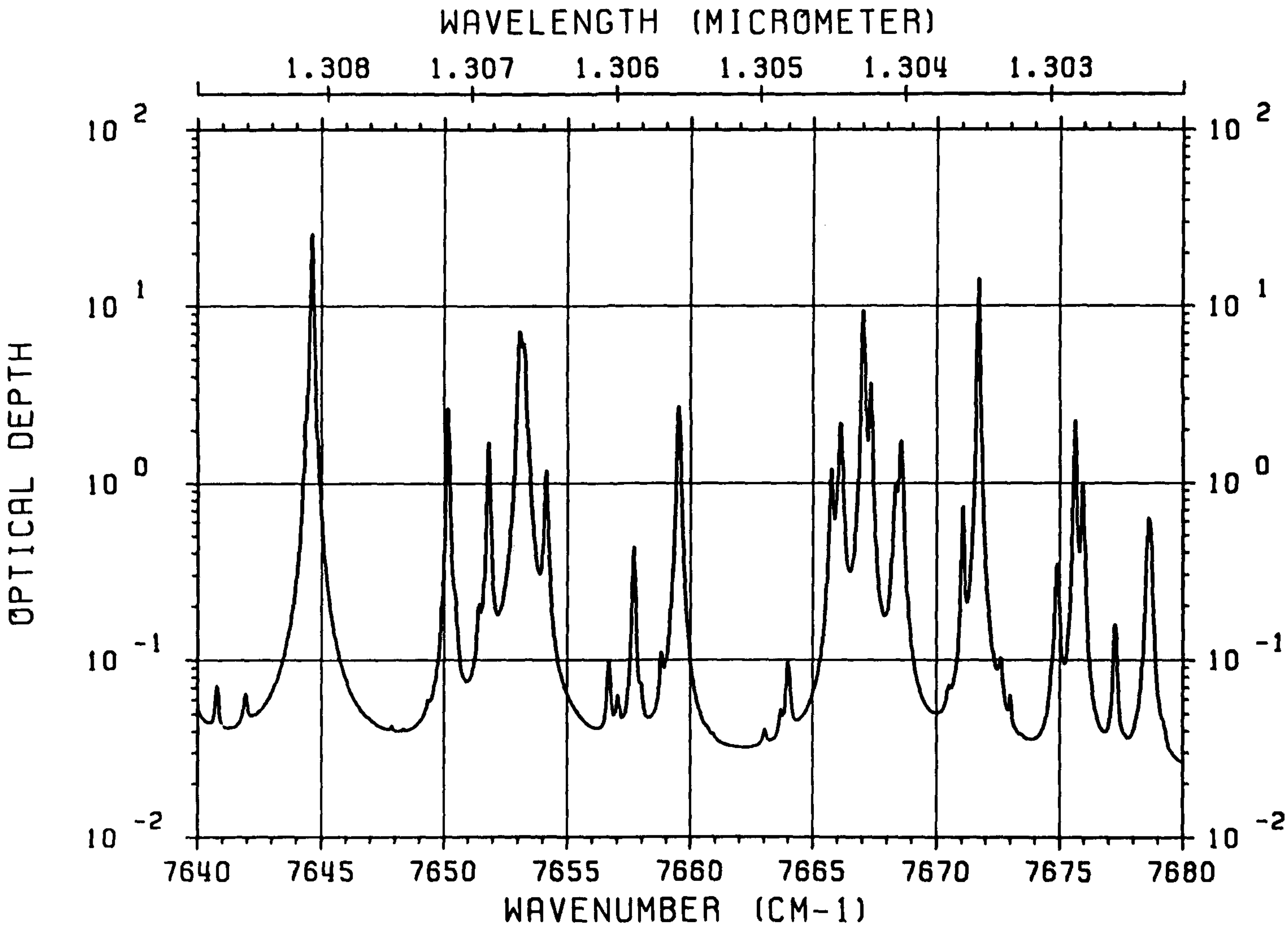

WAVELENGTH (MICROMETER)
1.337
1.338
1.339
1.340
1.341
1.342
1.343
1.344
OPTICAL DEPTH
$10^{3}$
$10^{2}$
$10^{1}$
$10^{0}$
$10^{-1}$
7480
7475
7470
7465
7460
7455
7450
7445
7440
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER


WAVELENGTH (MICROMETER)
1.330
1.331
1.332
1.333
1.334
1.335
1.336
WAVENUMBER (CM-1)
7480
7485
7490
7495
7500
7505
7510
7515
7520
OPTICAL DEPTH
SEA LEVEL MIDLATITUDE SUMMER

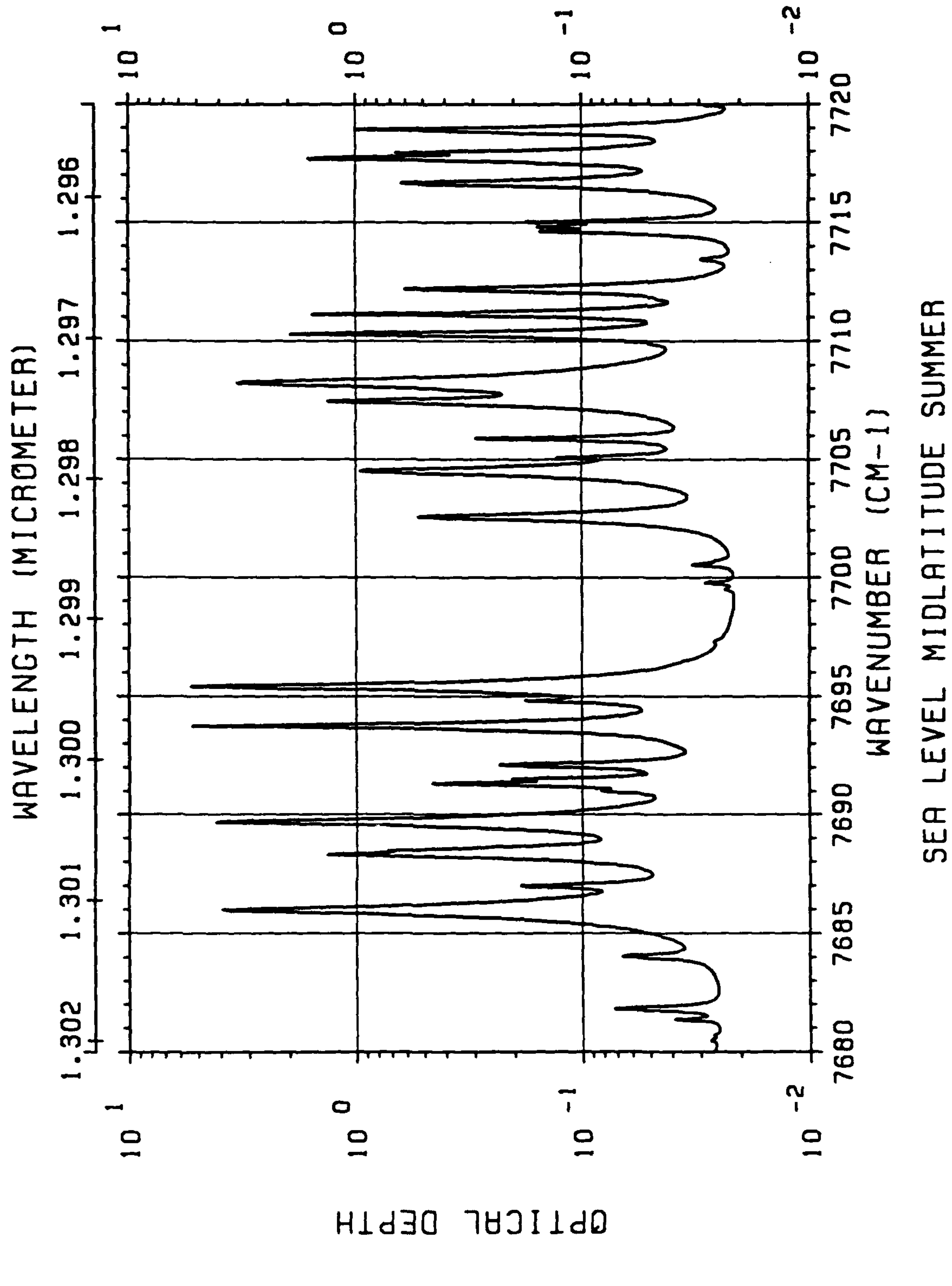

WAVELENGTH (MICROMETER)
1.323
1.324
1.325
1.326
1.327
1.328
1.329
OPTICAL DEPTH
$10^{2}$
$10^{1}$
$10^{0}$
$10^{-1}$
$10^{-2}$
7520
7525
7530
7535
7540
7545
7550
7555
7560
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER


WAVELENGTH (MICROMETER)
1.316
1.317
1.318
1.319
1.320
1.321
1.322
OPTICAL DEPTH
10^2
10^1
10^0
10^-1
10^-2
7560
7565
7570
7575
7580
7585
7590
7595
7600
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER

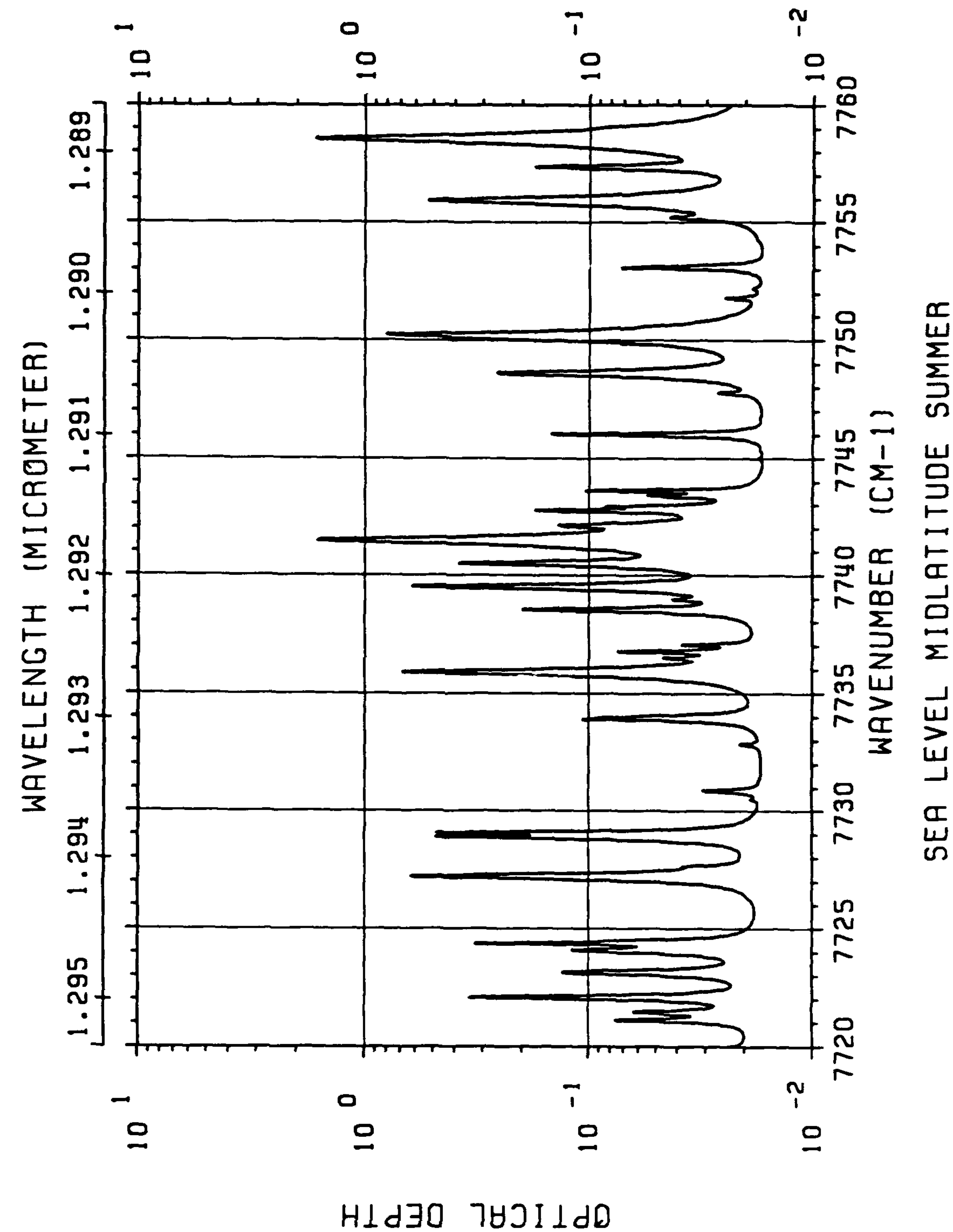

WAVELENGTH (MICRØMETER)
1.315 1.314 1.313 1.312 1.311 1.310 1.309
OPTICAL DEPTH
10^2 10^1 10^0 10^-1 10^-2
7600 7605 7610 7615 7620 7625 7630 7635 7640
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER

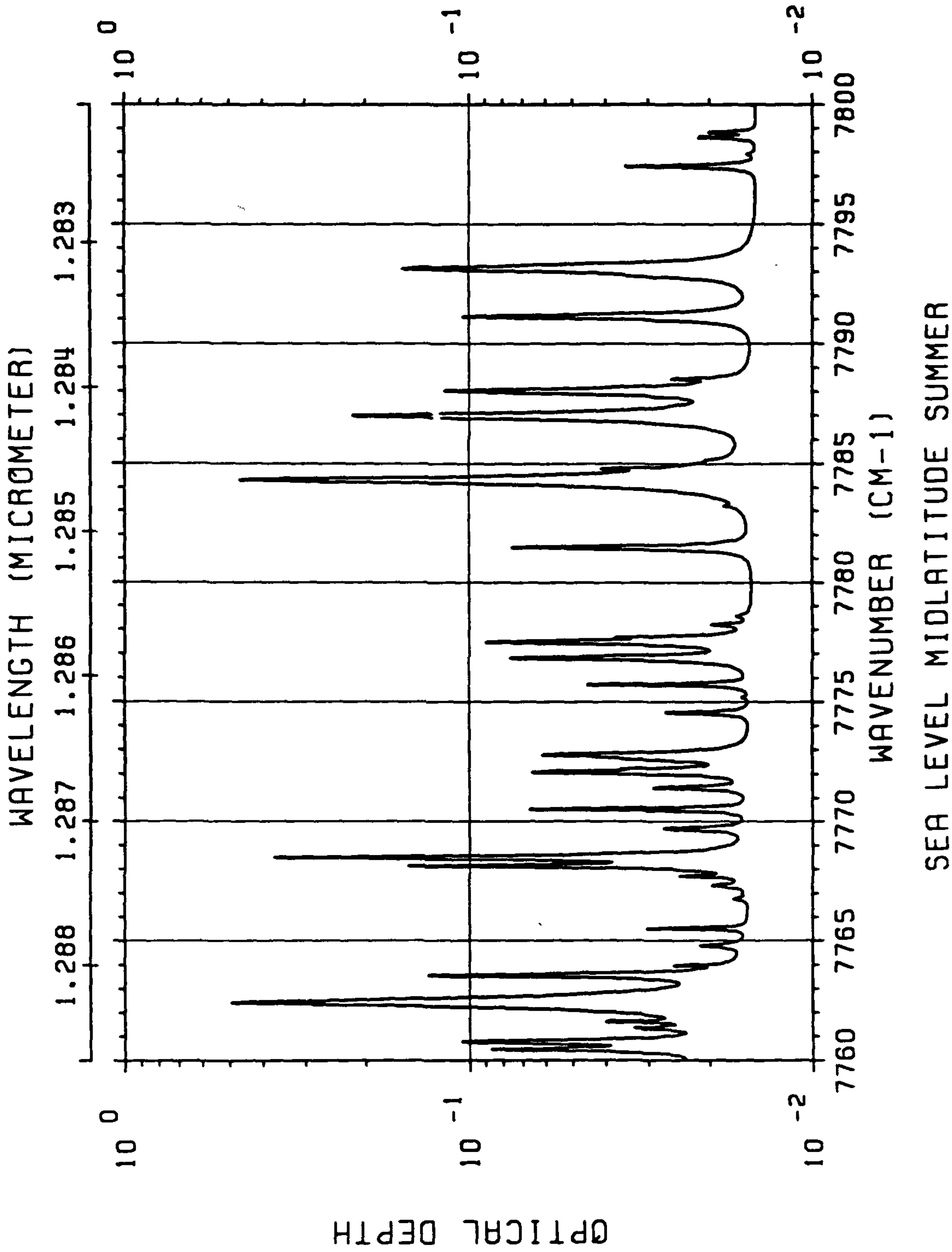


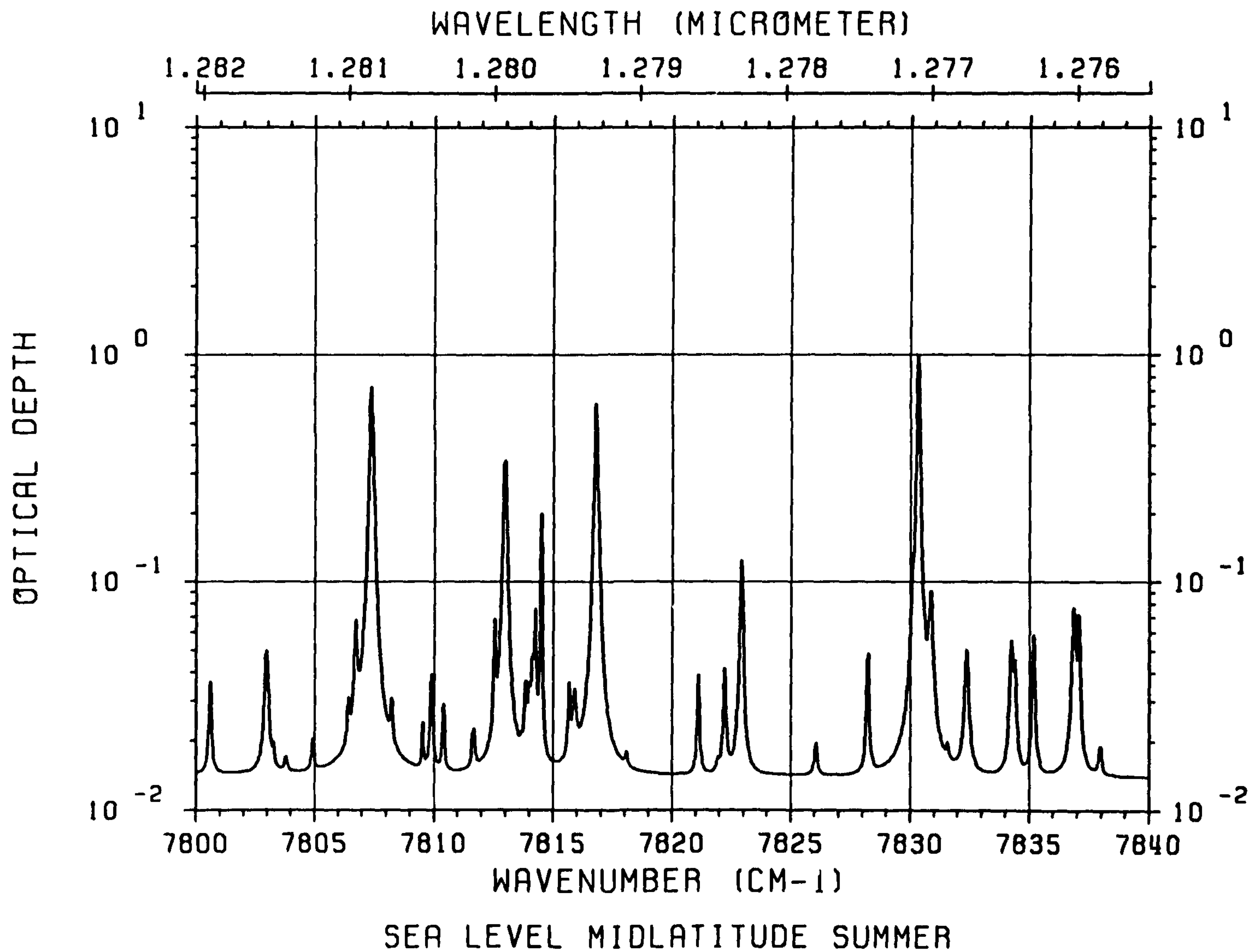

SEA LEVEL MIDLATITUDE SUMMER

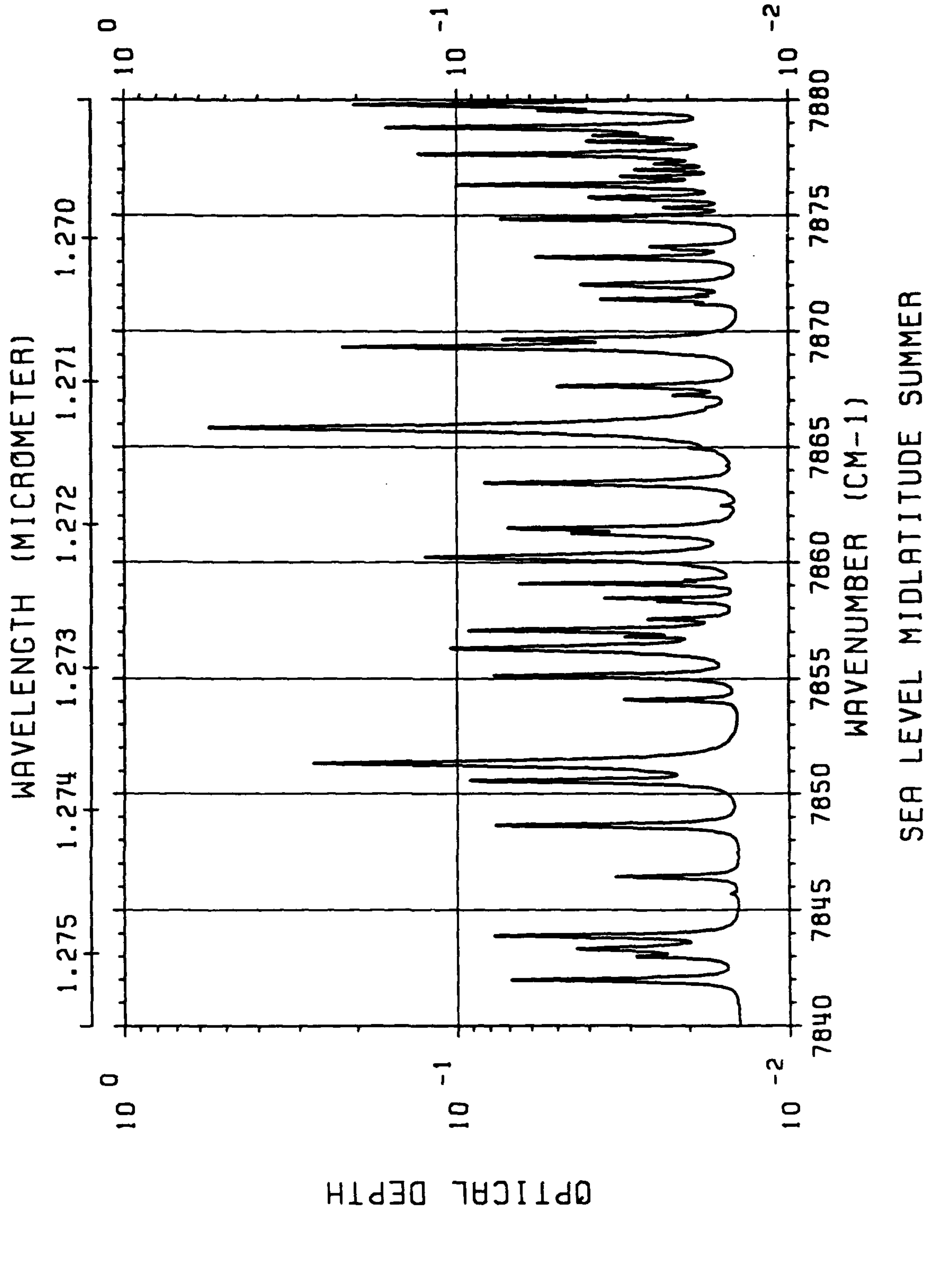


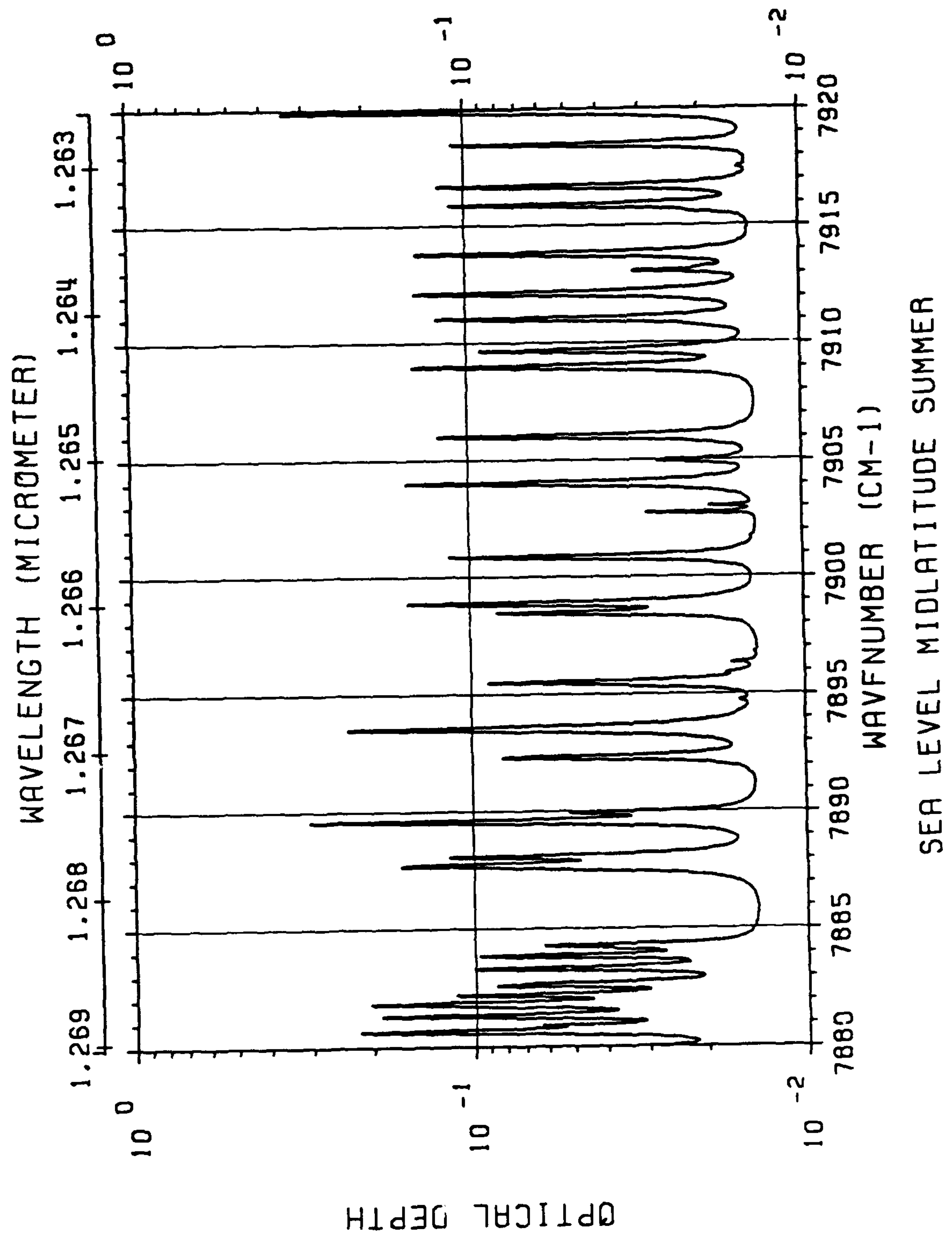
WAVELENGTH (MICROMETER)
1.302
1.301
1.300
1.299
1.298
1.297
1.296
WAVENUMBER (CM-1)
7680
7685
7690
7695
7700
7705
7710
7715
7720
OPTICAL DEPTH
$10^{1}$
$10^{0}$
$10^{-1}$
$10^{-2}$
SEA LEVEL MIDLATITUDE SUMMER

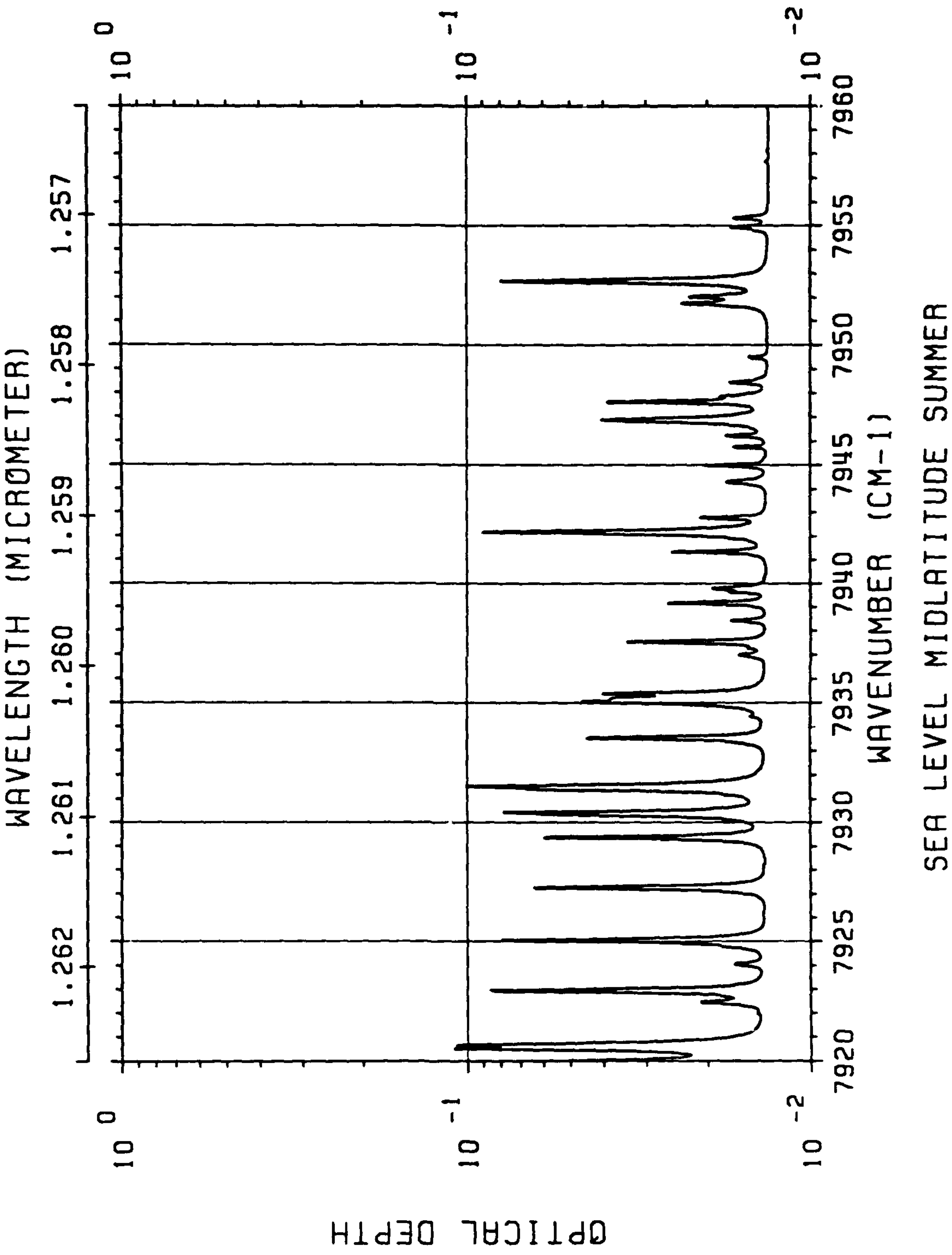

WAVELENGTH (MICROMETER)
1.289
1.290
1.291
1.292
1.293
1.294
1.295
WAVENUMBER (CM-1)
7720
7725
7730
7735
7740
7745
7750
7755
7760
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH
$10^{1}$
$10^{0}$
$10^{-1}$
$10^{-2}$

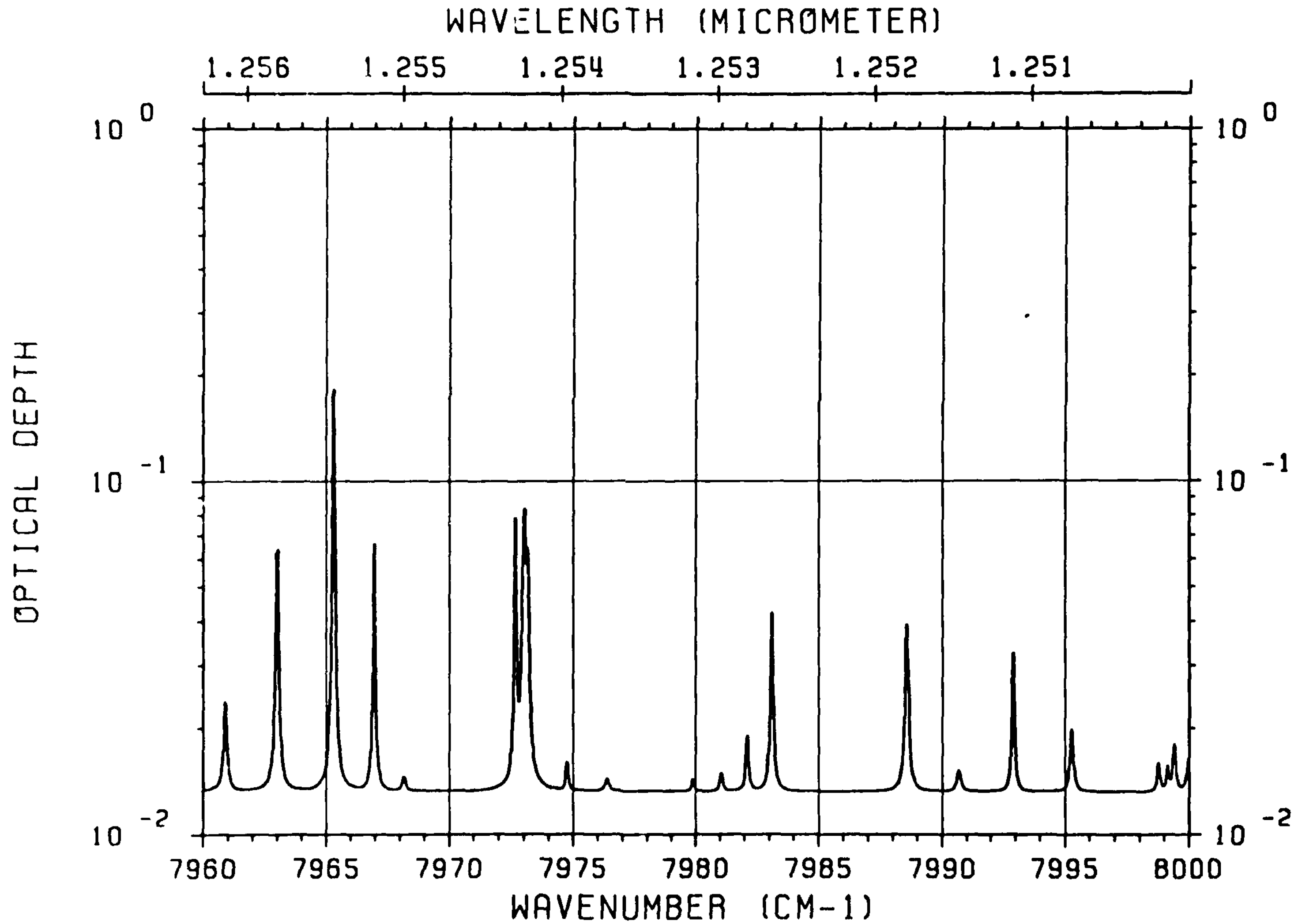

WAVELENGTH (MICRØMETER)
1.283
1.284
1.285
1.286
1.287
1.288
$10^{0}$
$10^{-1}$
$10^{-2}$
7760
7765
7770
7775
7780
7785
7790
7795
7800
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
ØPTICAL DEPTH


WAVELENGTH (MICROMETER)
1.282
1.281
1.280
1.279
1.278
1.277
1.276
OPTICAL DEPTH
10^1
10^0
10^-1
10^-2
7800
7805
7810
7815
7820
7825
7830
7835
7840
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER

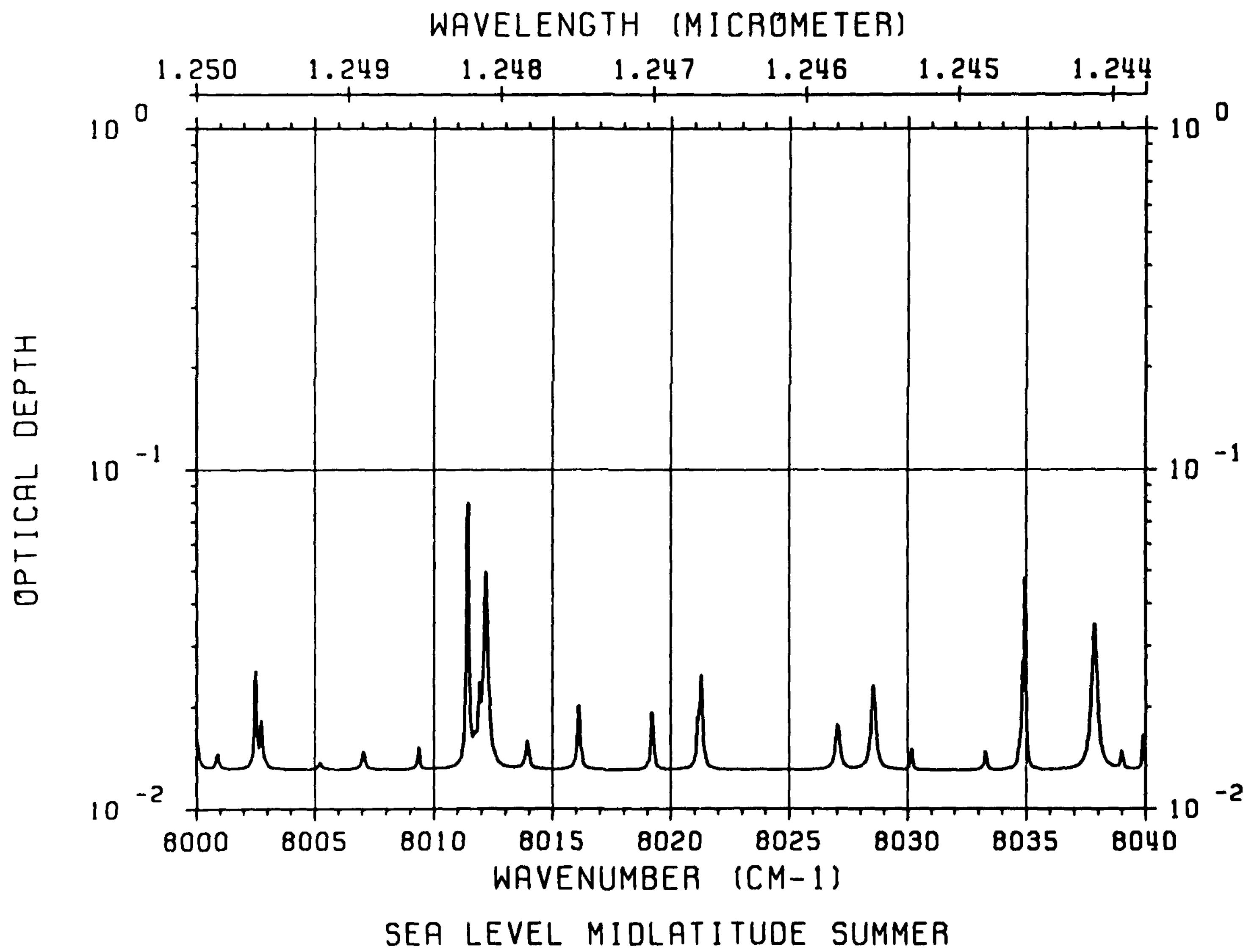

WAVELENGTH (MICROMETER)
1.270
1.271
1.272
1.273
1.274
1.275
WAVENUMBER (CM-1)
7840
7845
7850
7855
7860
7865
7870
7875
7880
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH
$10^{0}$
$10^{-1}$
$10^{-2}$


WAVELENGTH (MICROMETER)
1.263
1.264
1.265
1.266
1.267
1.268
1.269
7920
7915
7910
7905
7900
7895
7890
7885
7880
WAVFNUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
$10^0$
$10^{-1}$
$10^{-2}$
OPTICAL DEPTH

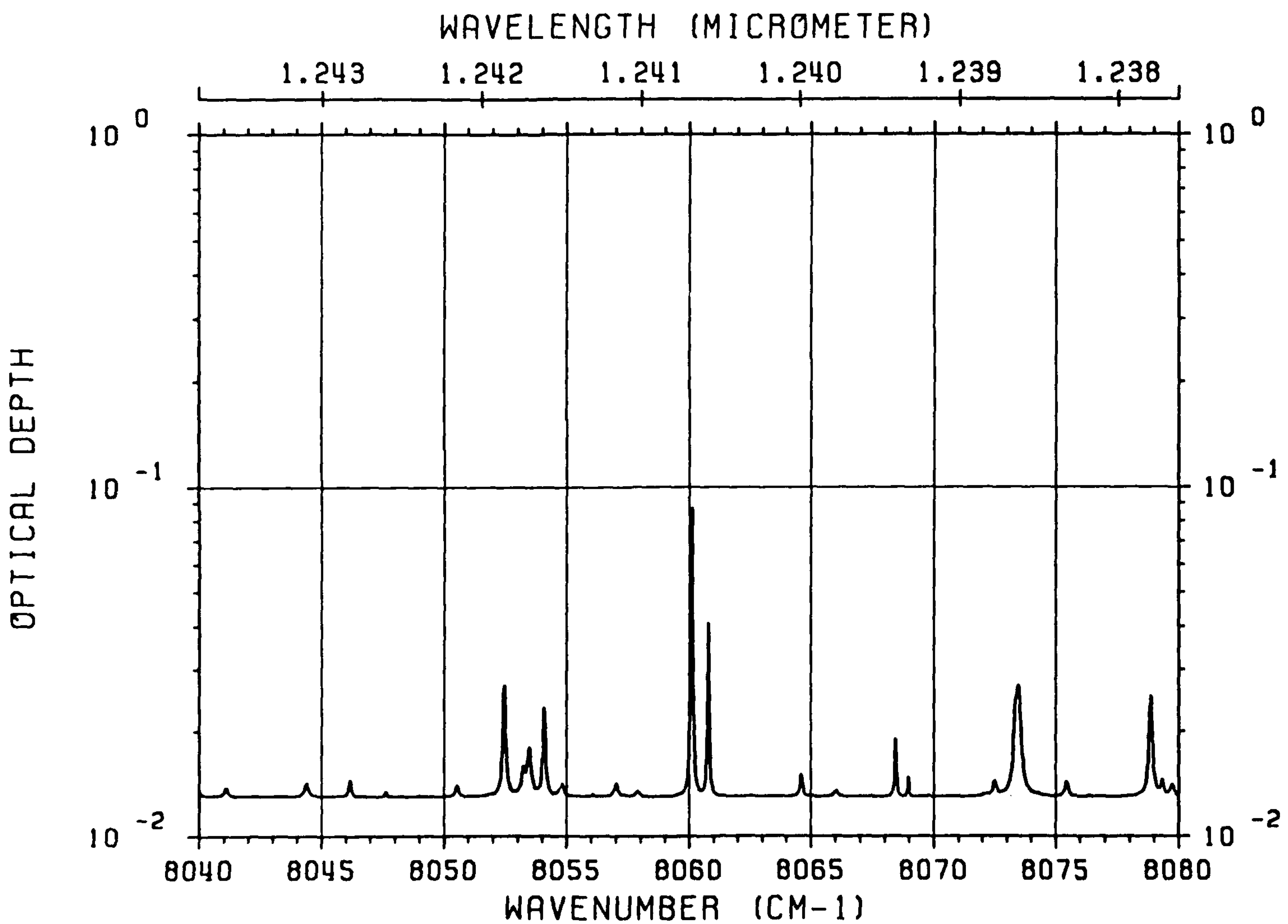

WAVELENGTH (MICROMETER)
1.262
1.261
1.260
1.259
1.258
1.257
WAVENUMBER (CM-1)
7920
7925
7930
7935
7940
7945
7950
7955
7960
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH
$10^0$
$10^{-1}$
$10^{-2}$



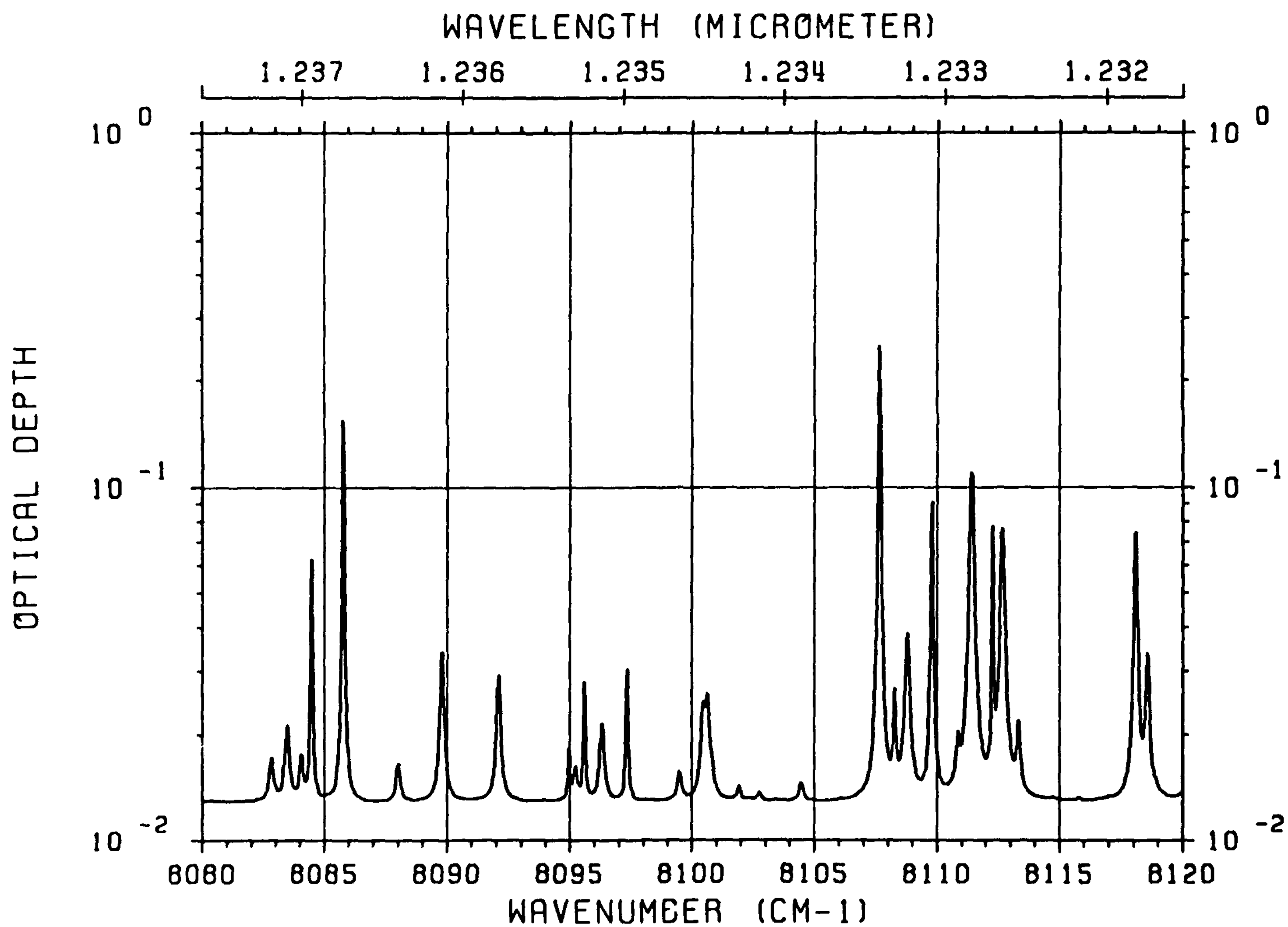

SEA LEVEL MIDLATITUDE SUMMER



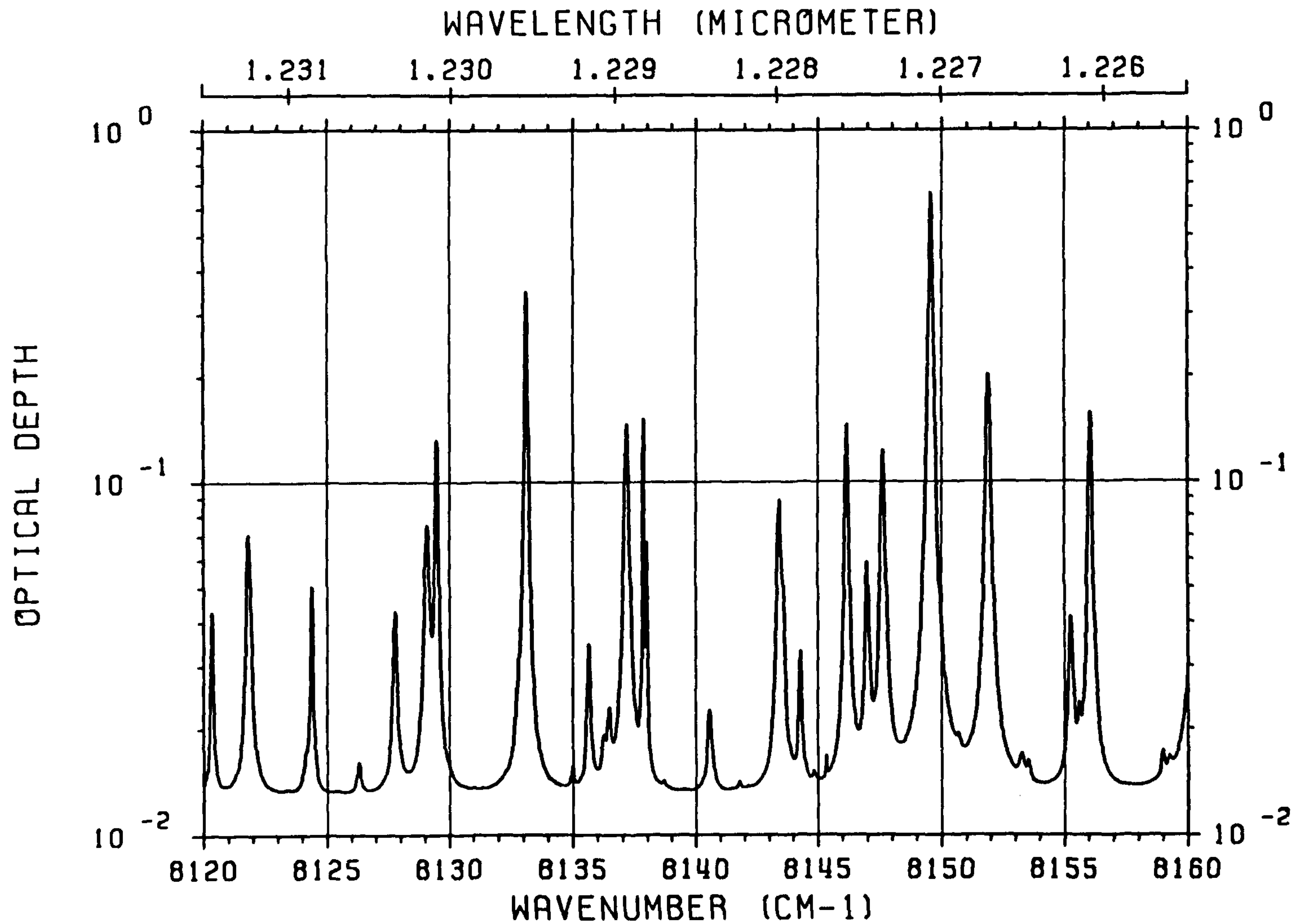
WAVELENGTH (MICROMETER)
1.250
1.249
1.248
1.247
1.246
1.245
1.244
OPTICAL DEPTH
$10^{0}$
$10^{-1}$
$10^{-2}$
8000
8005
8010
8015
8020
8025
8030
8035
8040
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER



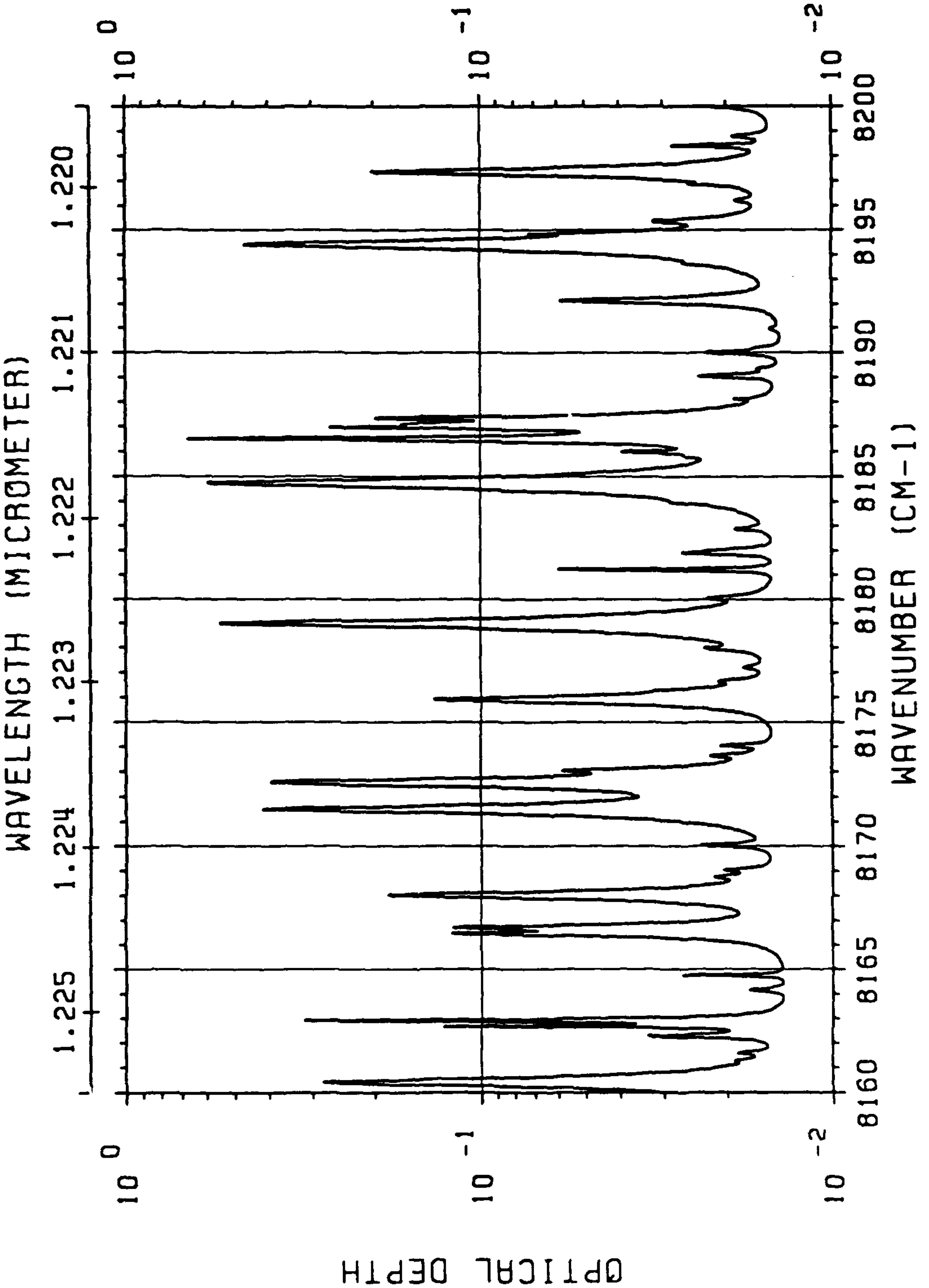

SEA LEVEL MIDLATITUDE SUMMER



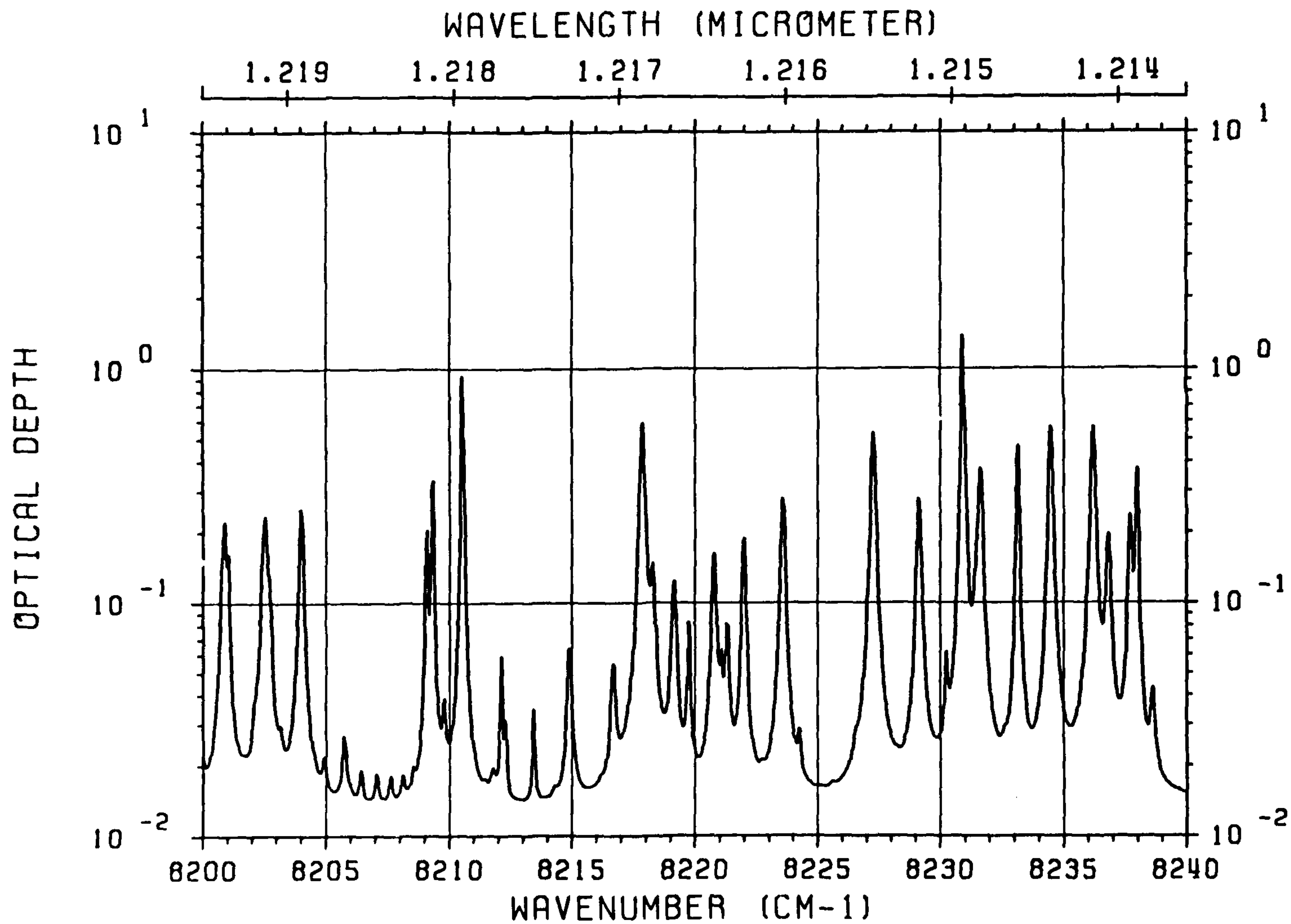

SEA LEVEL MIDLATITUDE SUMMER



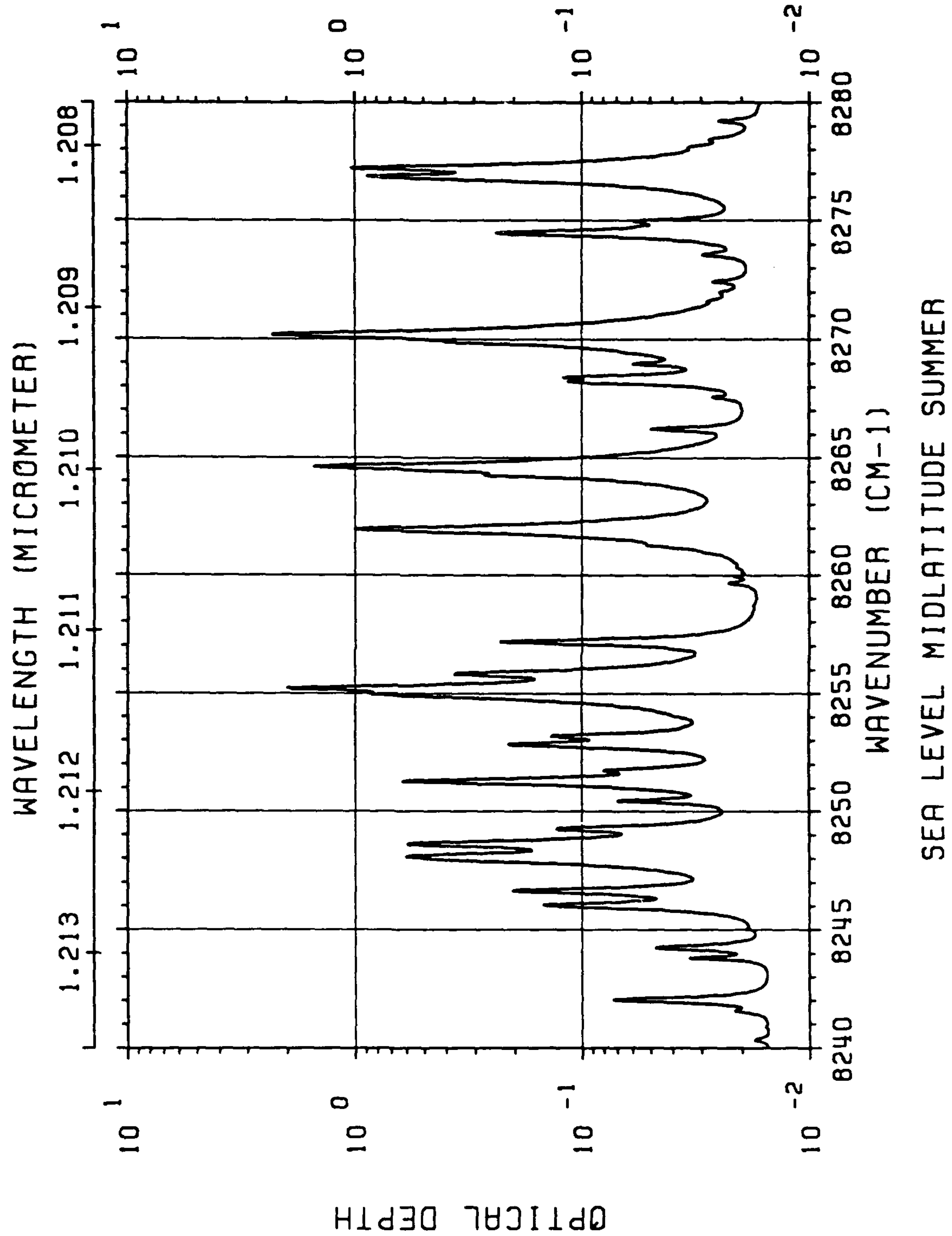

SEA LEVEL MIDLATITUDE SUMMER

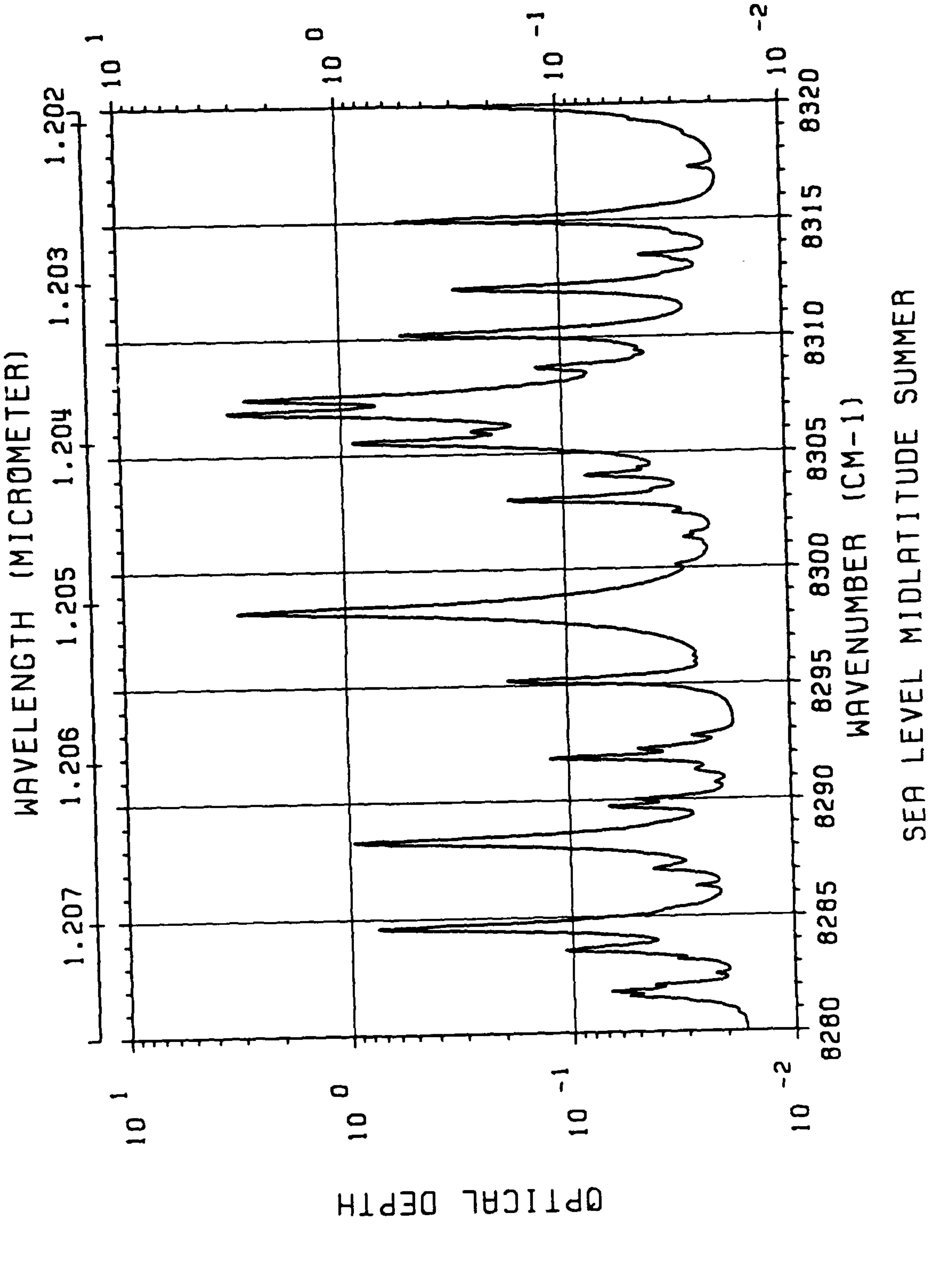


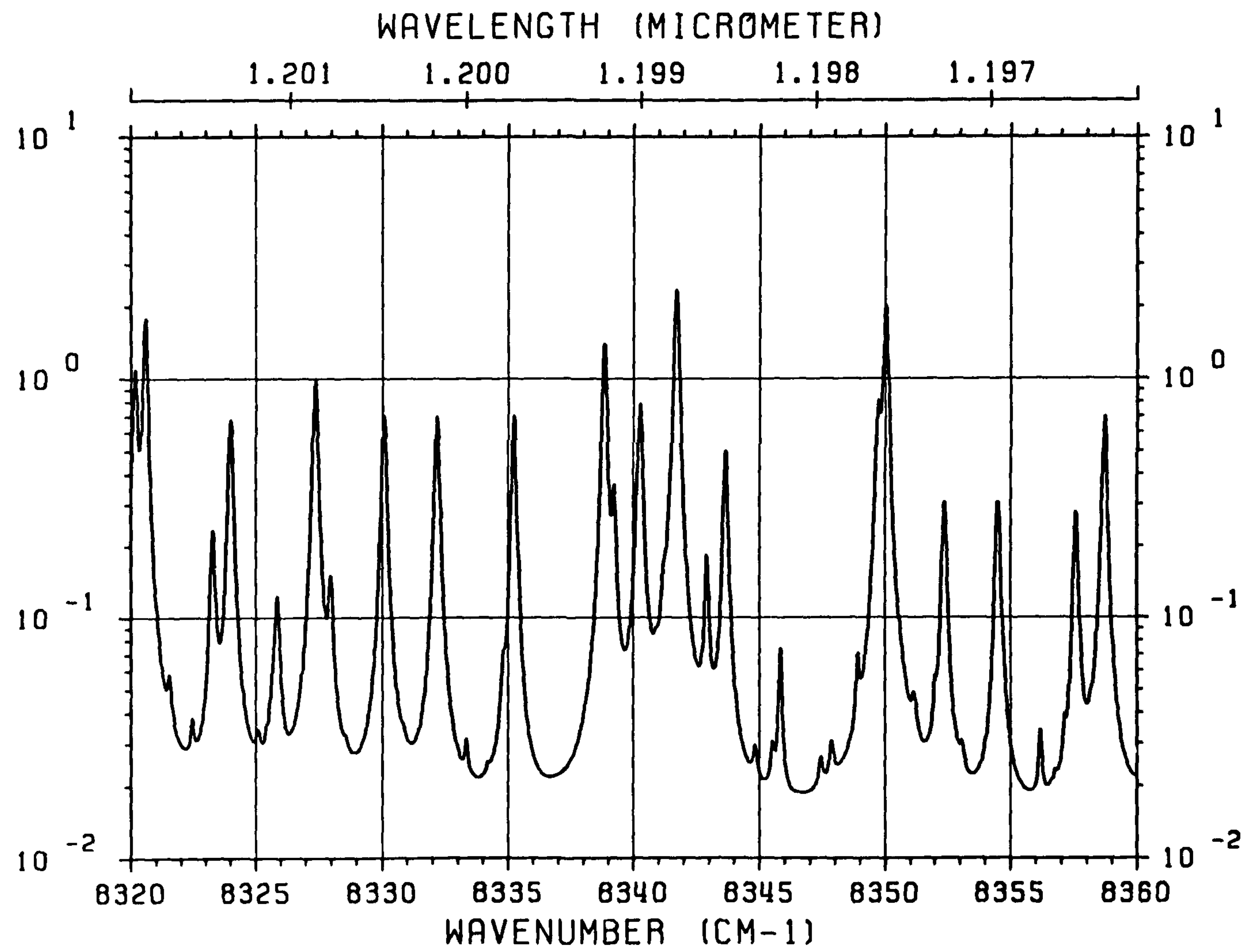

SEA LEVEL MIDLATITUDE SUMMER



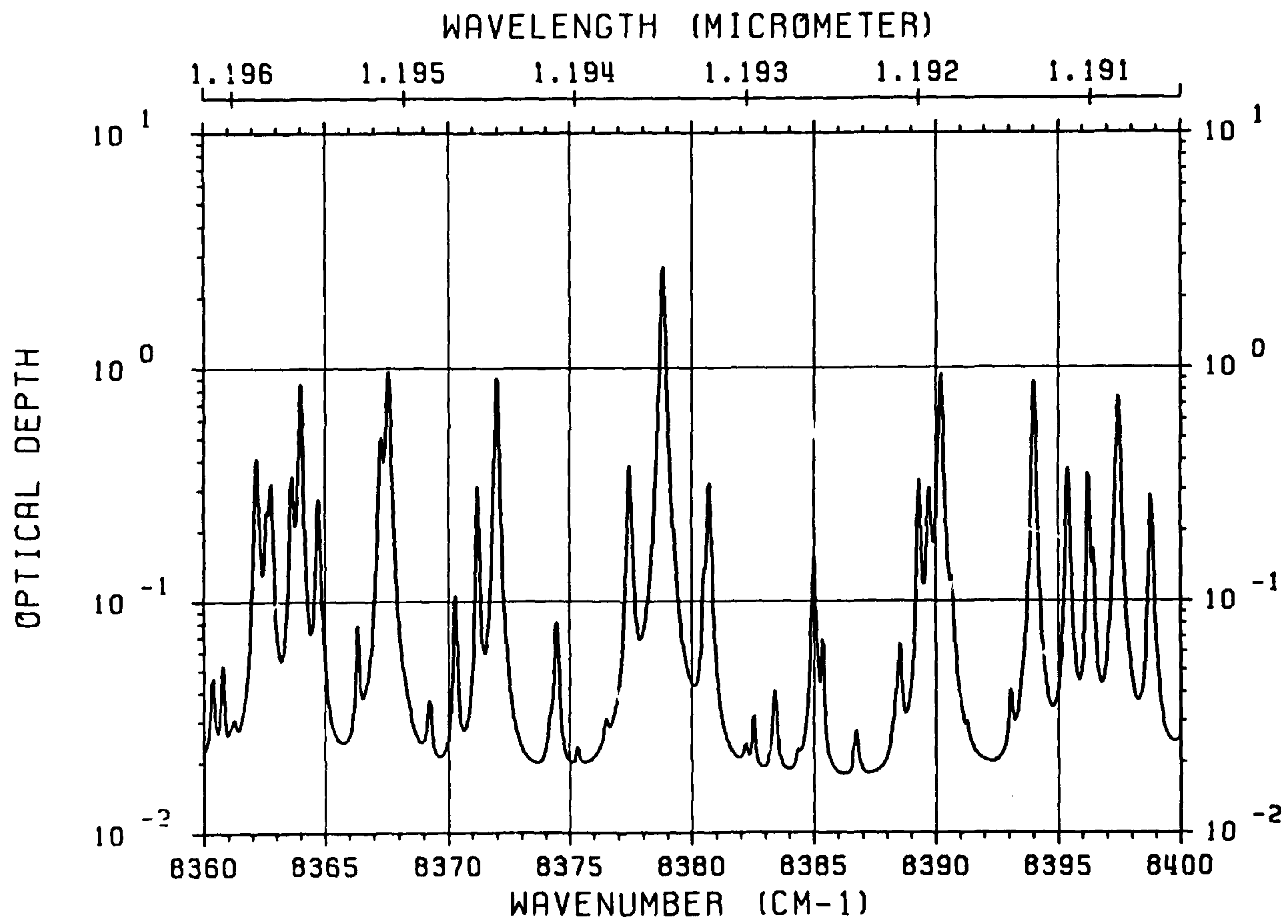

SEA LEVEL MIDLATITUDE SUMMER


WAVELENGTH (MICROMETER)
1.208
1.209
1.210
1.211
1.212
1.213
10^1
10^0
10^-1
10^-2
8240
8245
8250
8255
8260
8265
8270
8275
8280
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH

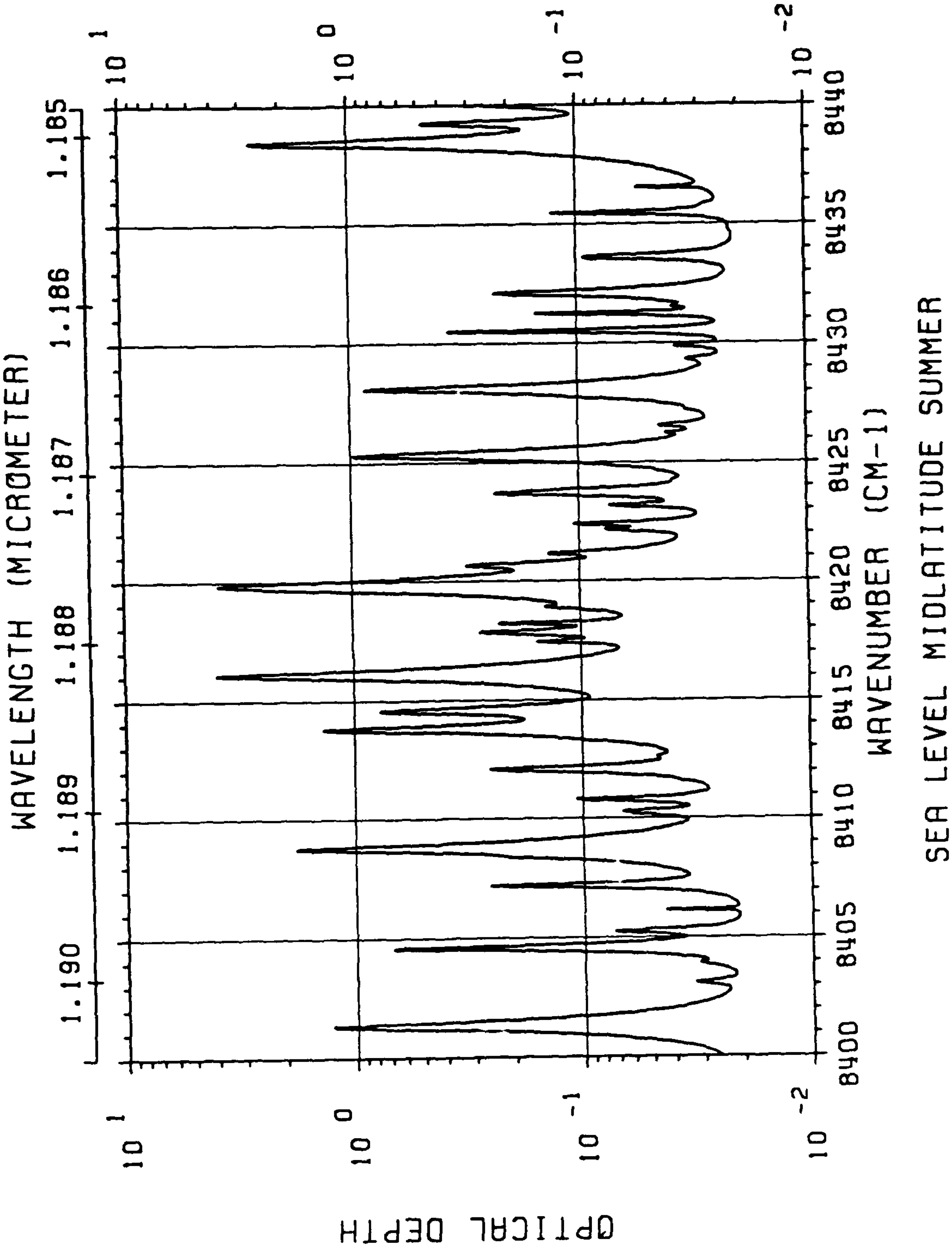

WAVELENGTH (MICROMETER)
1.202
1.203
1.204
1.205
1.206
1.207
10^1
10^0
10^-1
10^-2
8280
8285
8290
8295
8300
8305
8310
8315
8320
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH

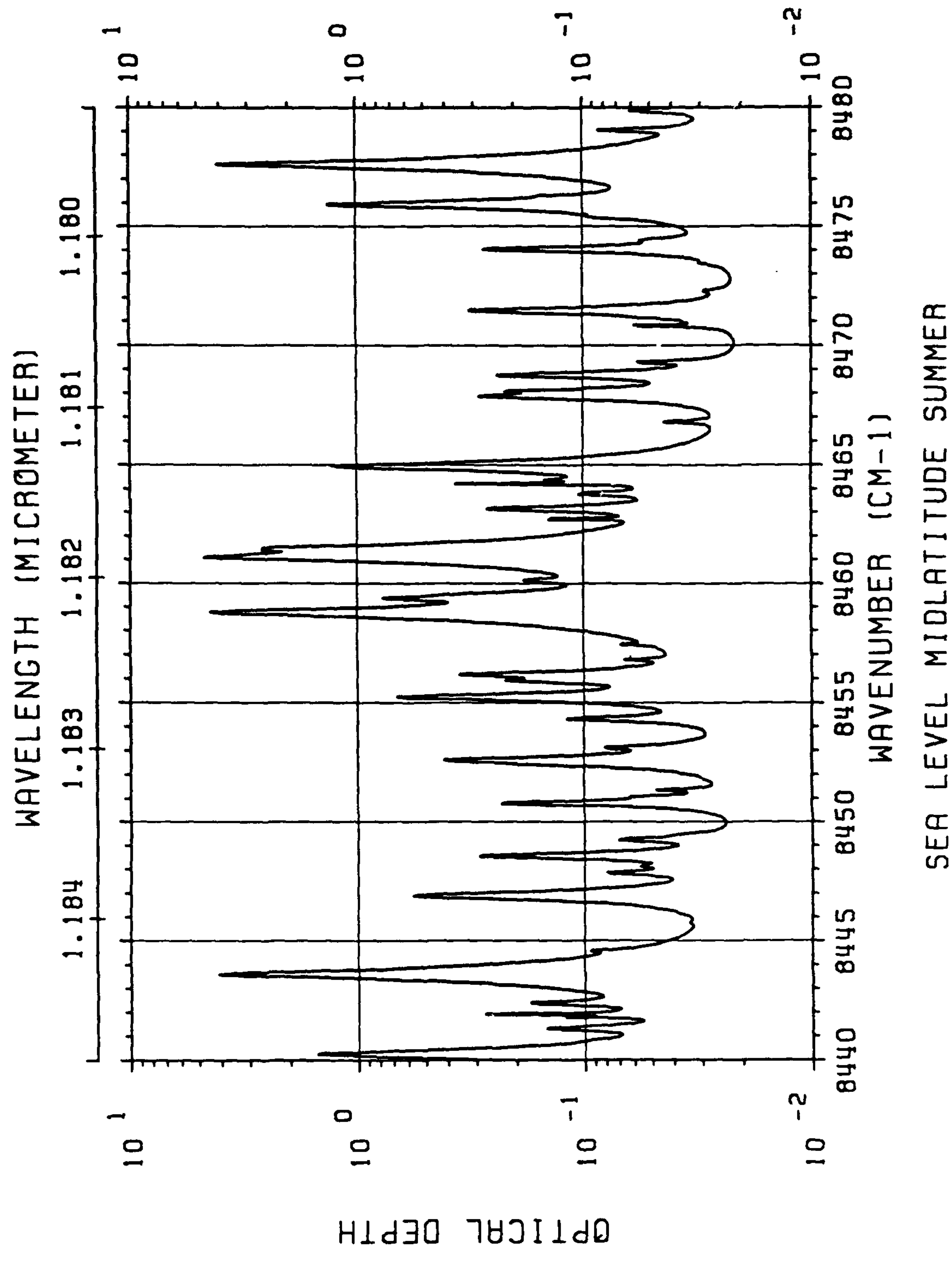



SEA LEVEL MIDLATITUDE SUMMER

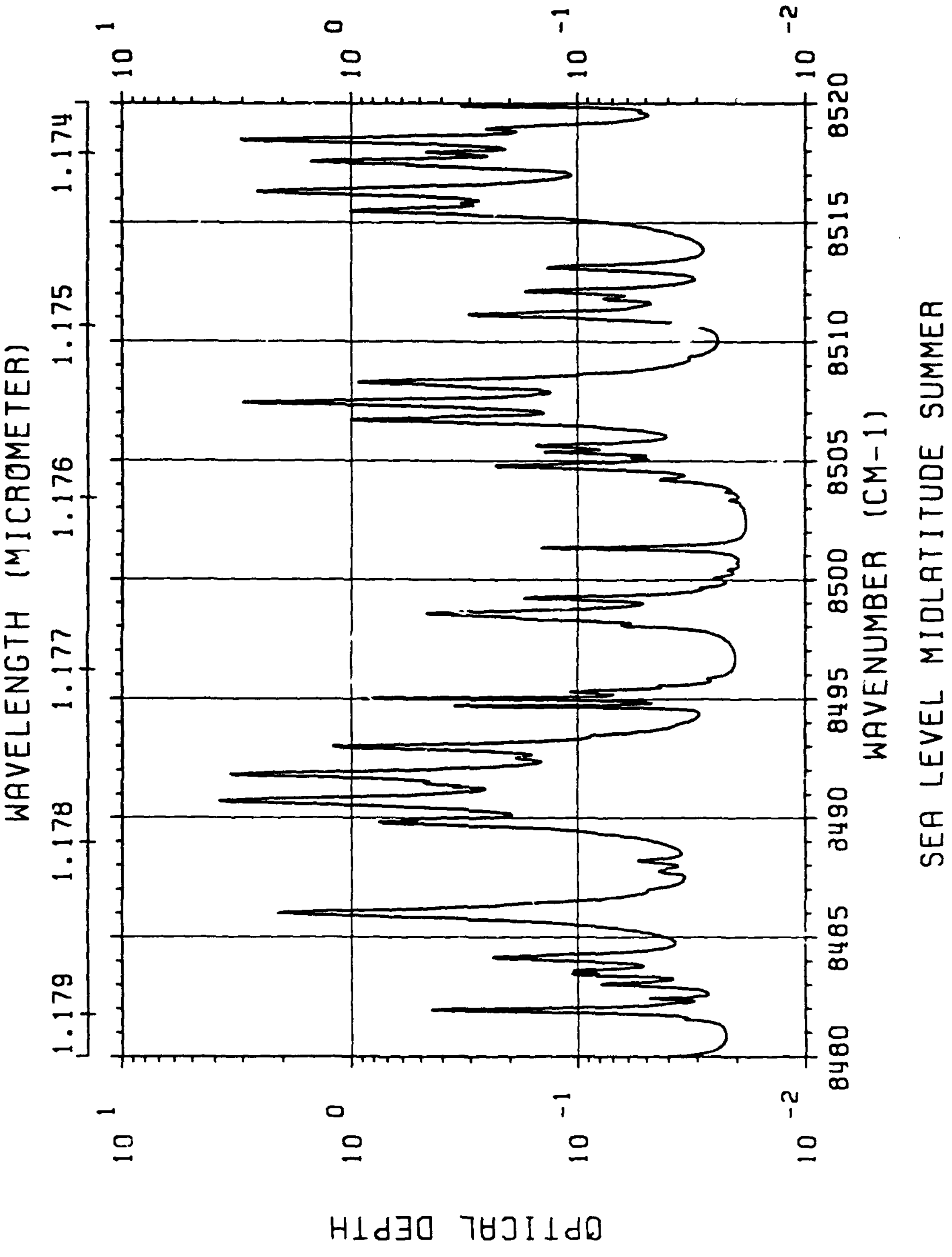


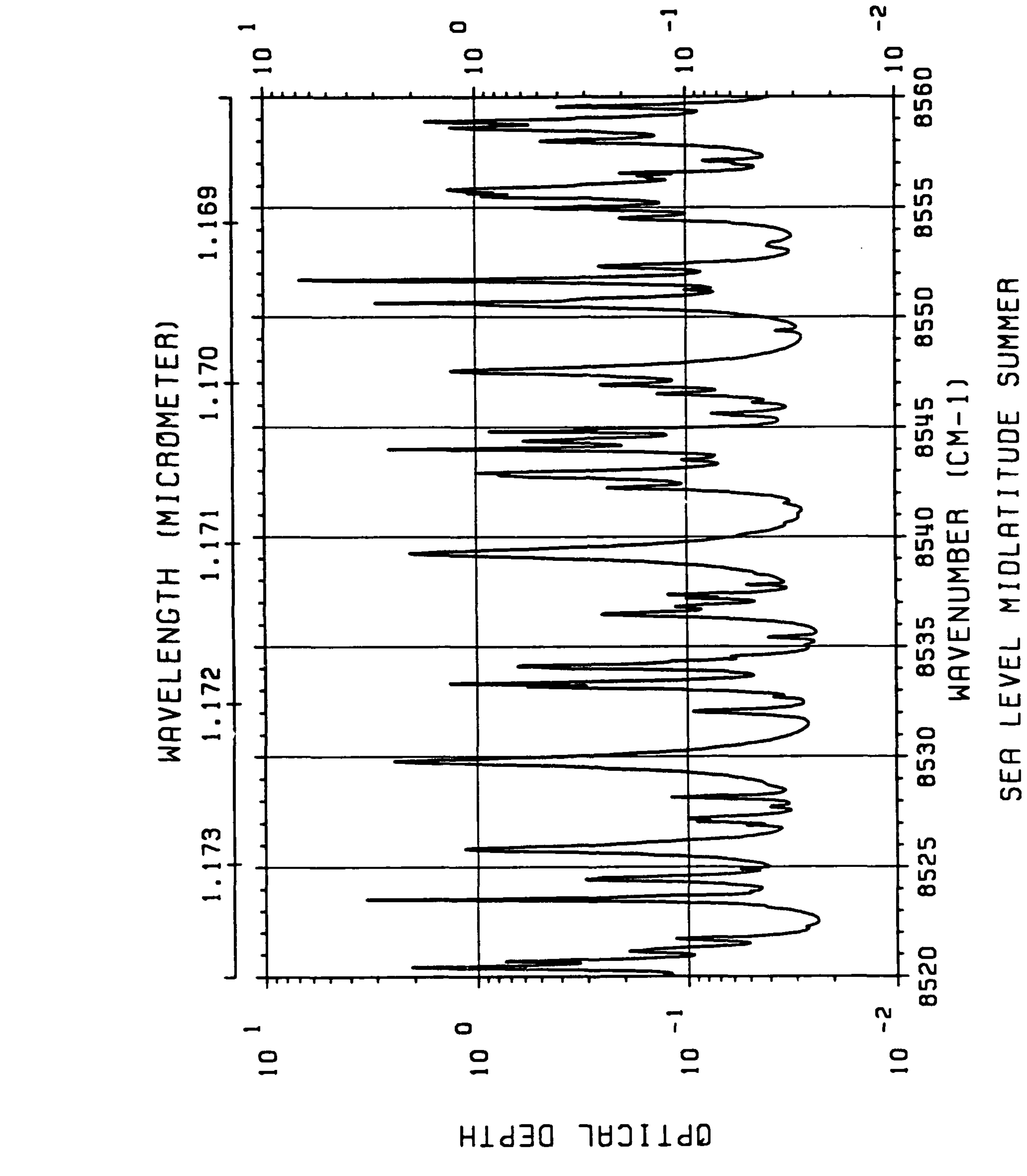

SEA LEVEL MIDLATITUDE SUMMER

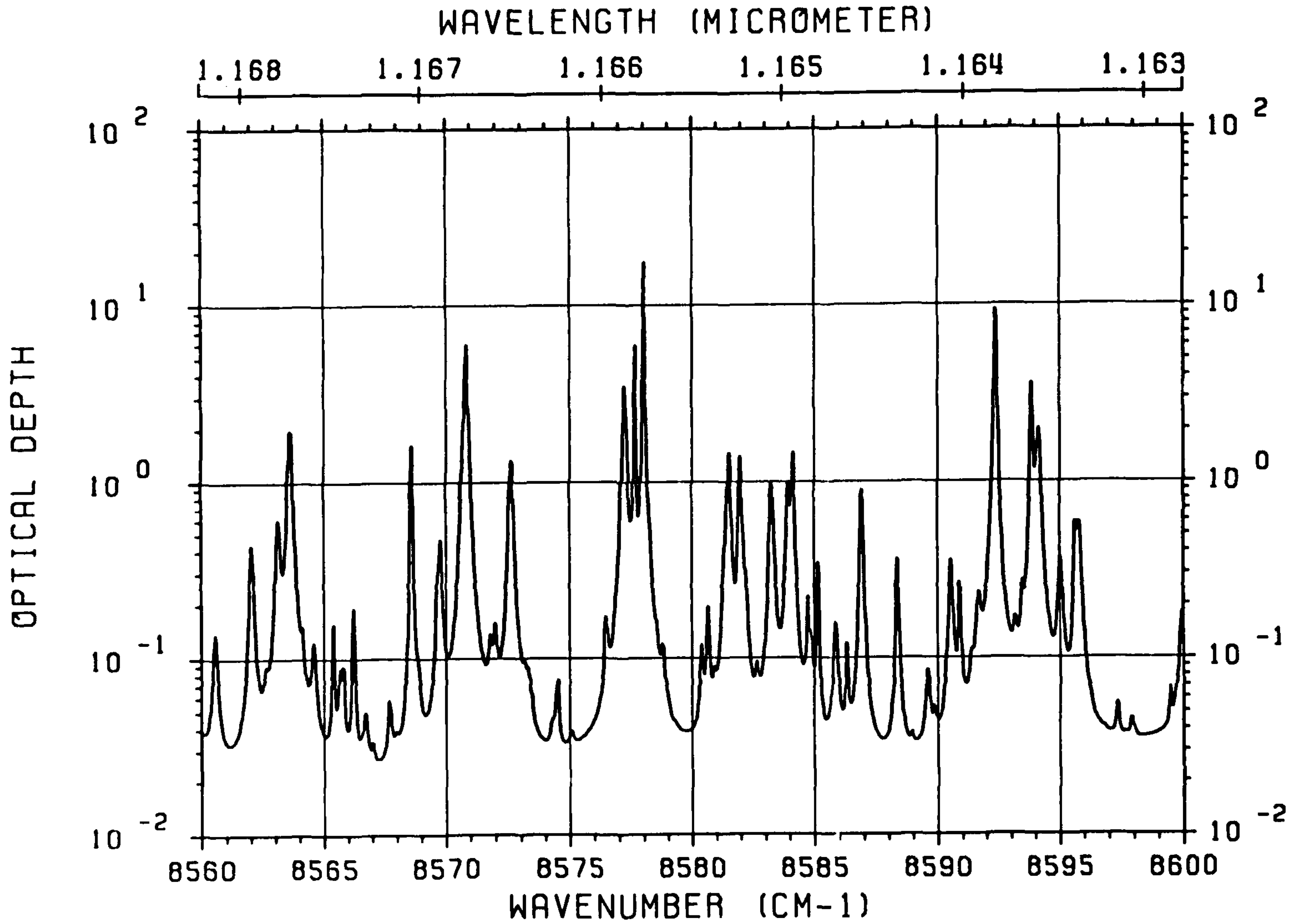

WAVELENGTH (MICROMETER)
1.185
1.186
1.187
1.188
1.189
1.190
OPTICAL DEPTH
$10^{1}$
$10^{0}$
$10^{-1}$
$10^{-2}$
8400
8405
8410
8415
8420
8425
8430
8435
8440
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER



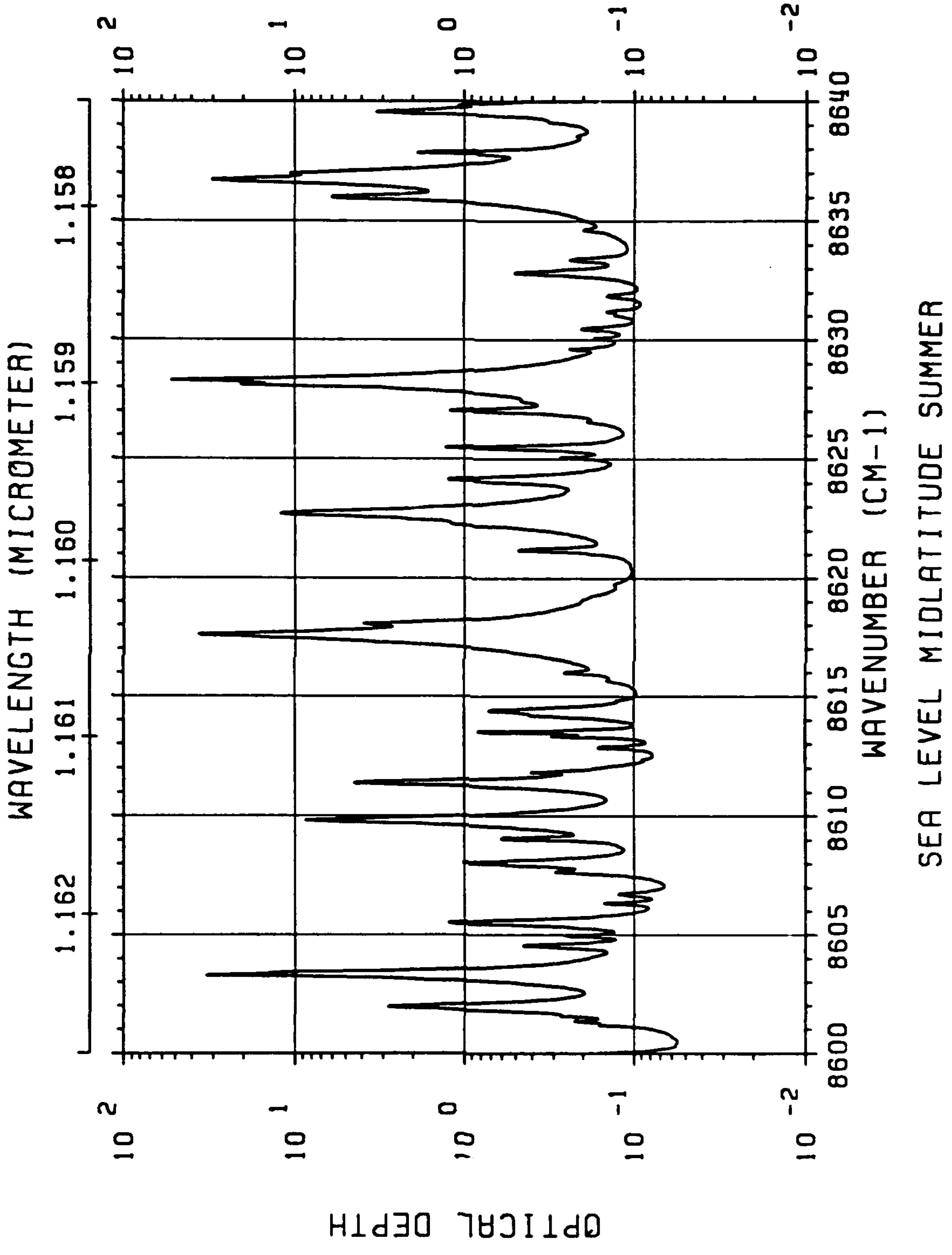
WAVELENGTH (MICROMETER)
1.180
1.181
1.182
1.183
1.184
WAVENUMBER (CM-1)
8440
8445
8450
8455
8460
8465
8470
8475
8480
OPTICAL DEPTH
$10^{1}$
$10^{0}$
$10^{-1}$
$10^{-2}$
SEA LEVEL MIDLATITUDE SUMMER

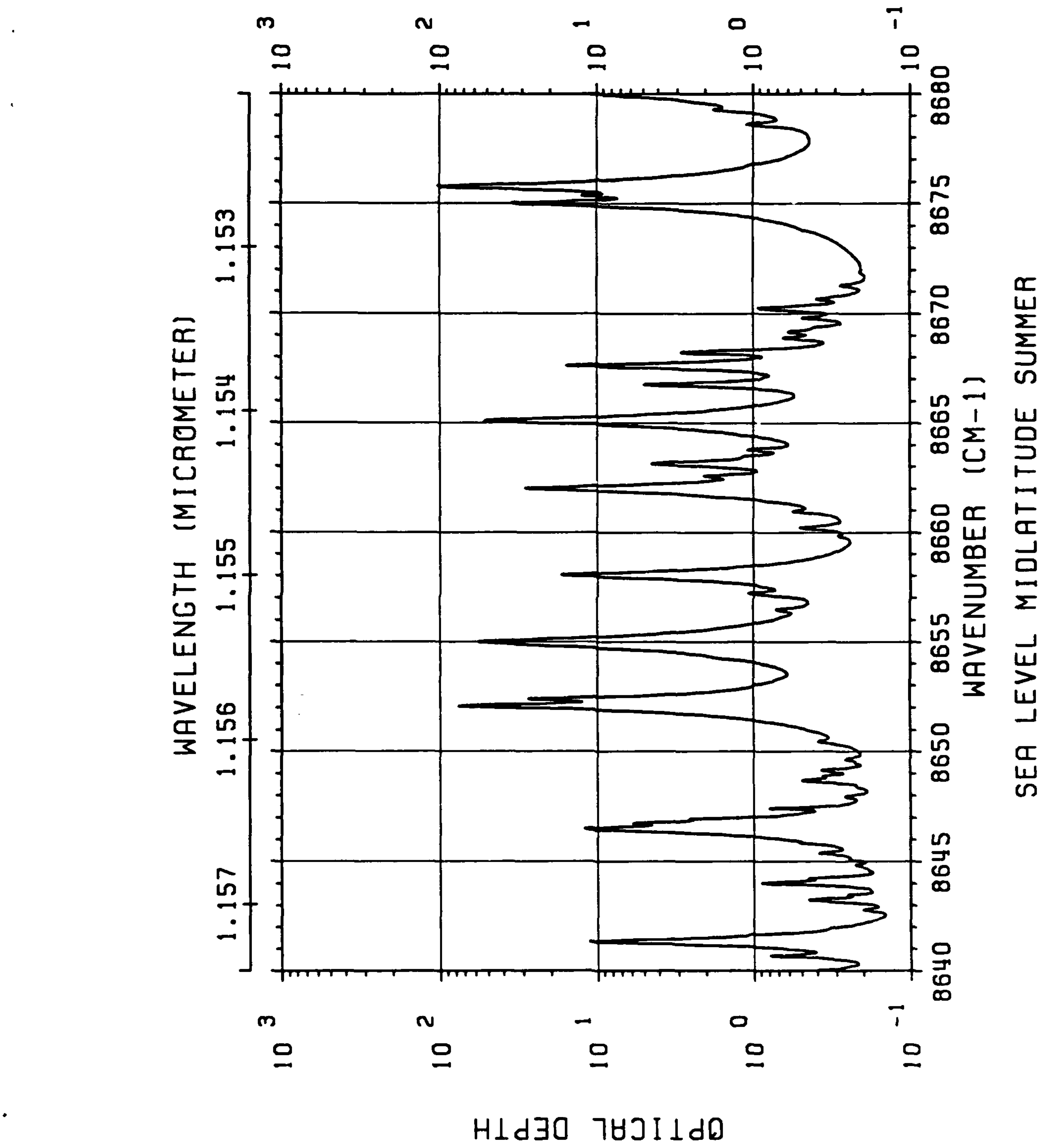

WAVELENGTH (MICROMETER)
1.174
1.175
1.176
1.177
1.178
1.179
OPTICAL DEPTH
$10^{1}$
$10^{0}$
$10^{-1}$
$10^{-2}$
8480
8485
8490
8495
8500
8505
8510
8515
8520
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER

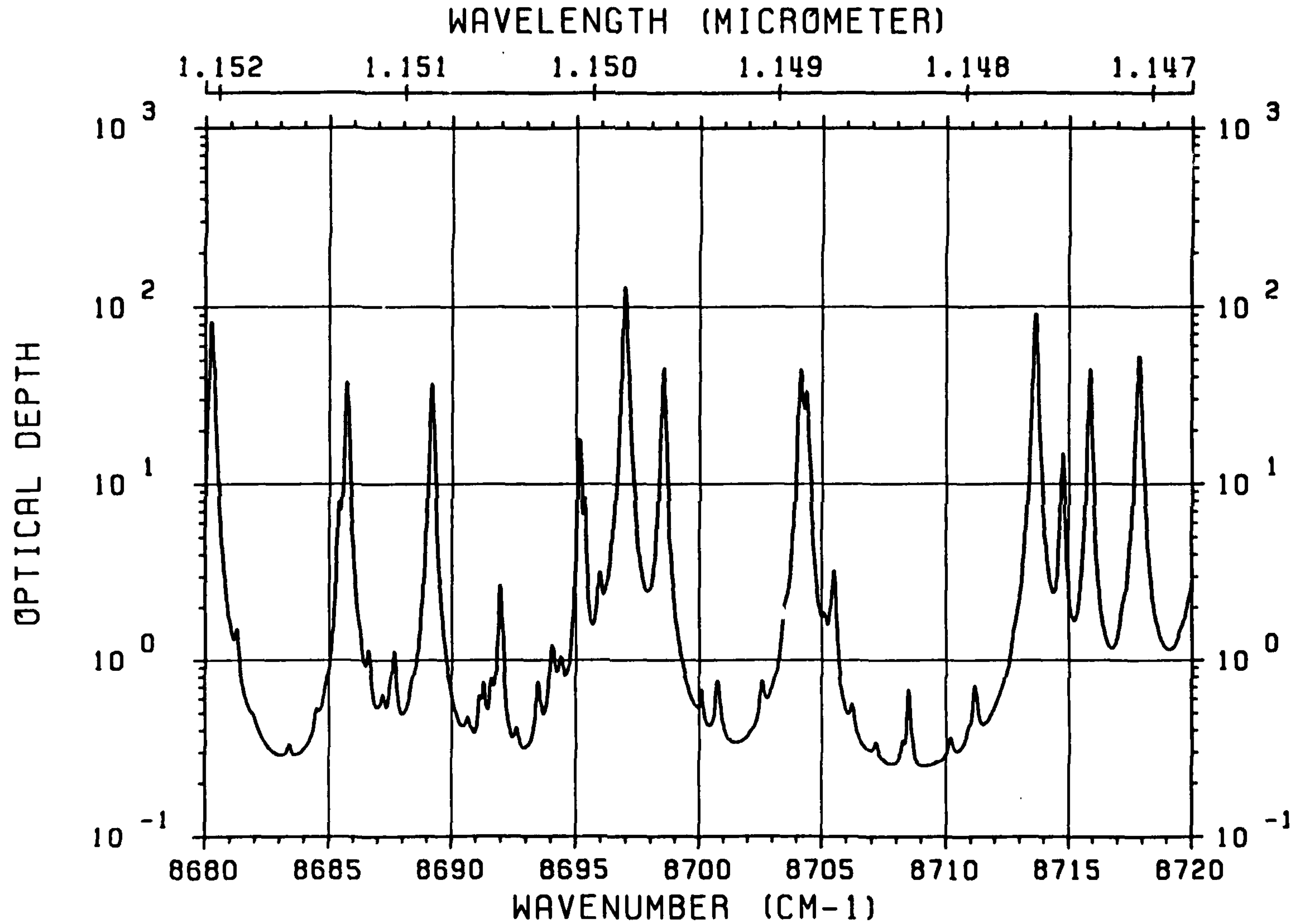

WAVELENGTH (MICROMETER)
1.169
1.170
1.171
1.172
1.173
OPTICAL DEPTH
$10^{1}$
$10^{0}$
$10^{-1}$
$10^{-2}$
8520
8525
8530
8535
8540
8545
8550
8555
8560
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER



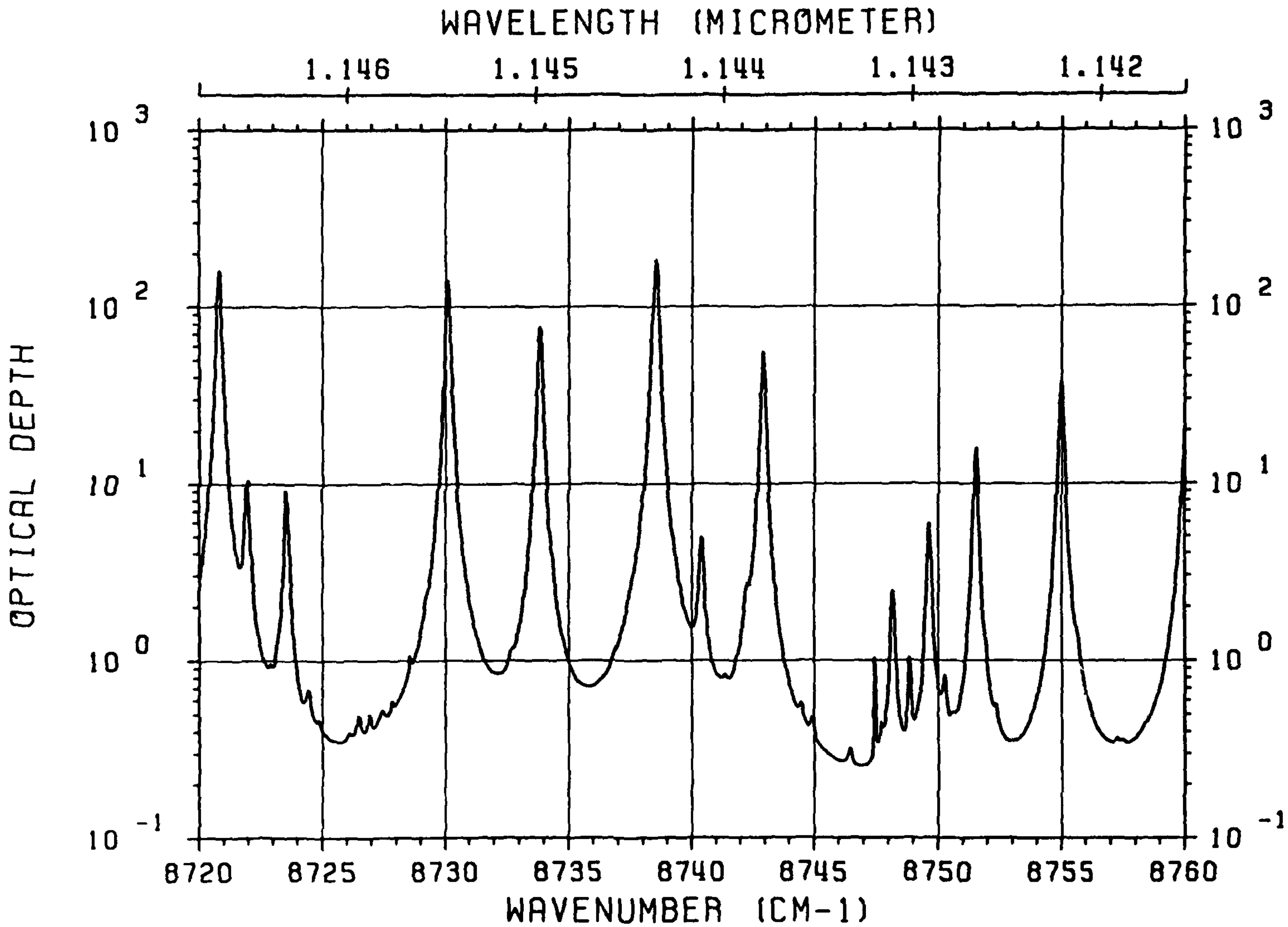

SEA LEVEL MIDLATITUDE SUMMER


WAVELENGTH (MICROMETER)
1.158
1.159
1.160
1.161
1.162
WAVENUMBER (CM-1)
8600
8605
8610
8615
8620
8625
8630
8635
8640
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH
$10^{2}$
$10^{1}$
$10^{0}$
$10^{-1}$
$10^{-2}$

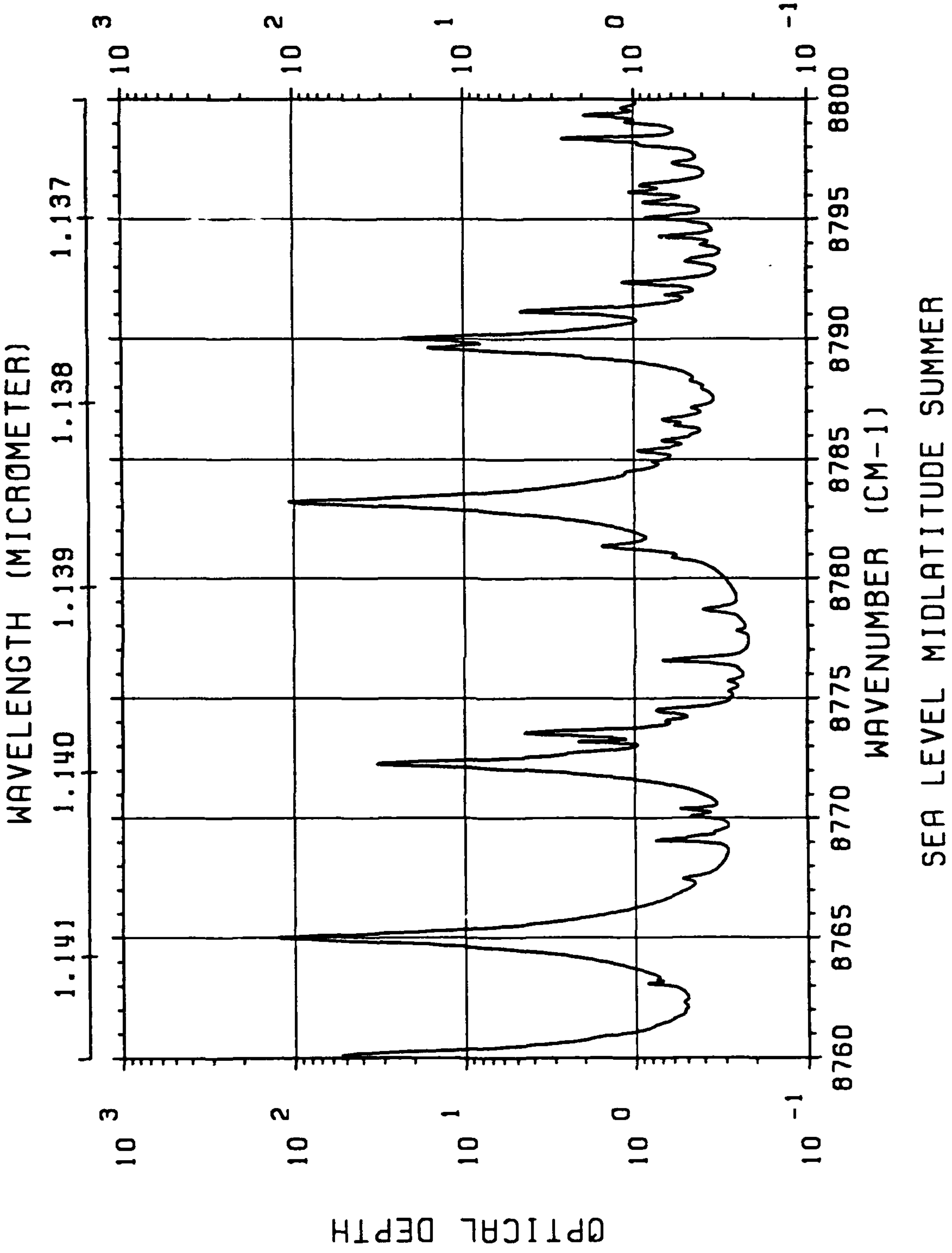

WAVELENGTH (MICROMETER)
1.157
1.156
1.155
1.154
1.153
WAVENUMBER (CM-1)
8640
8645
8650
8655
8660
8665
8670
8675
8680
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH
10^-1
10^0
10^1
10^2
10^3

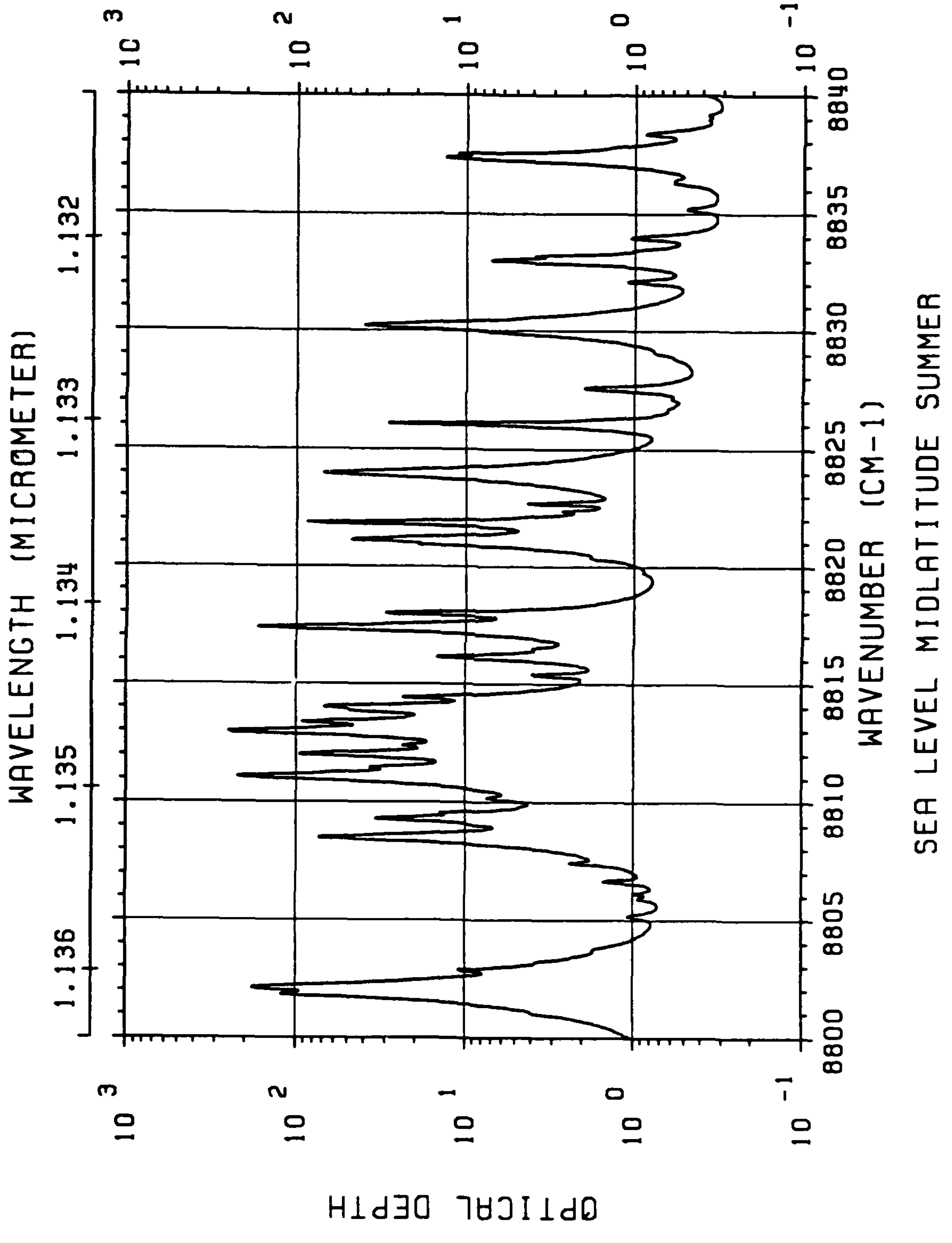


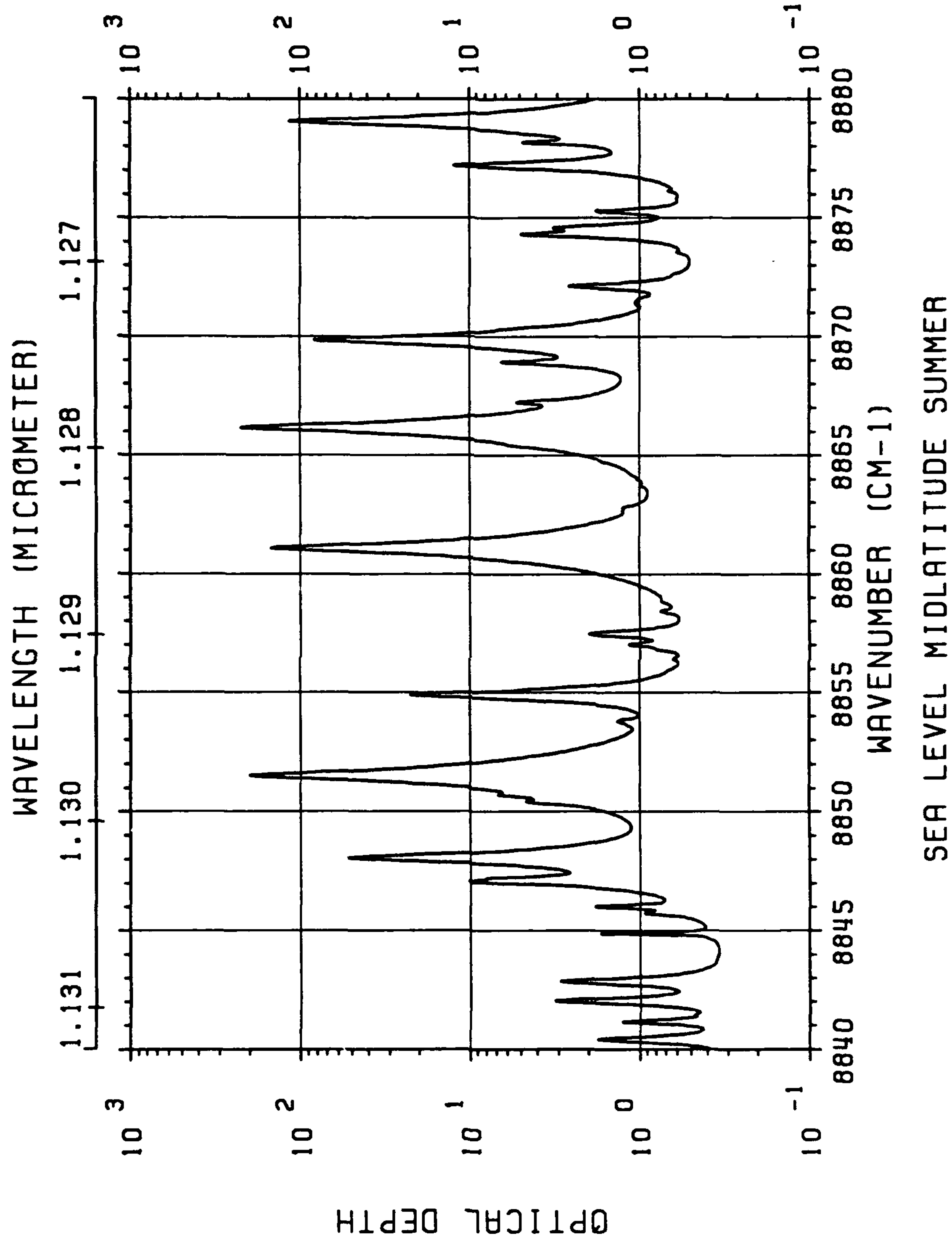

SEA LEVEL MIDLATITUDE SUMMER

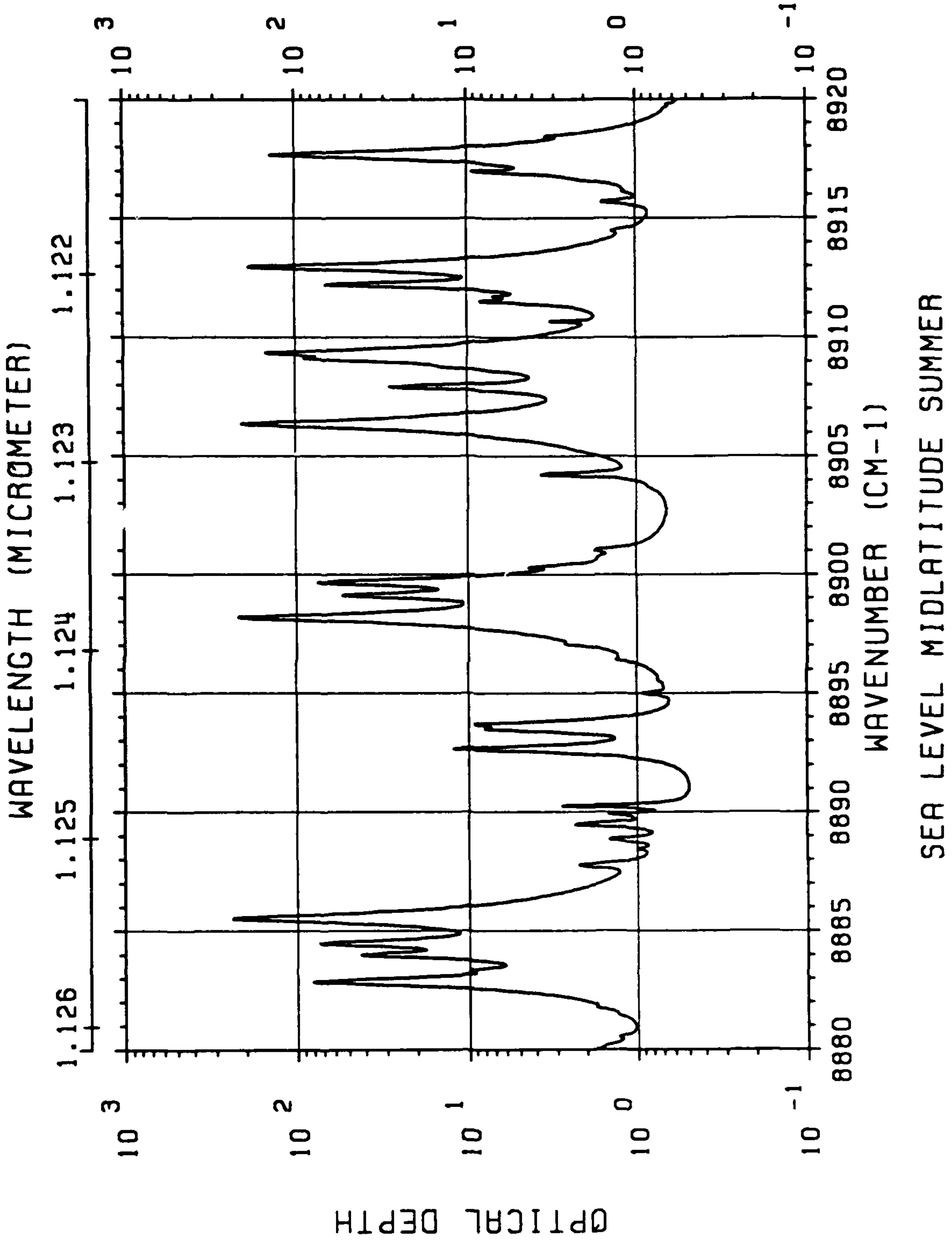


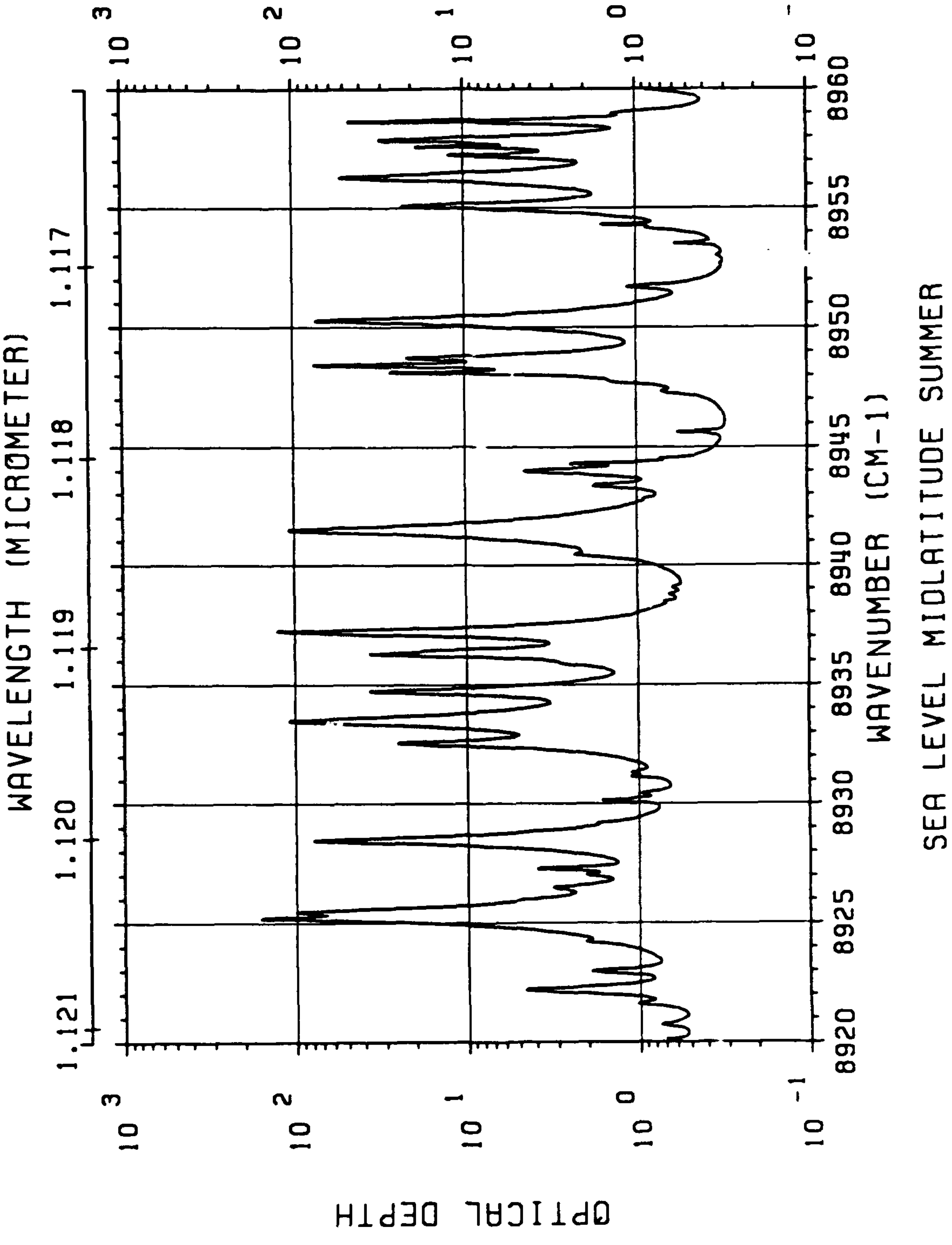

SEA LEVEL MIDLATITUDE SUMMER

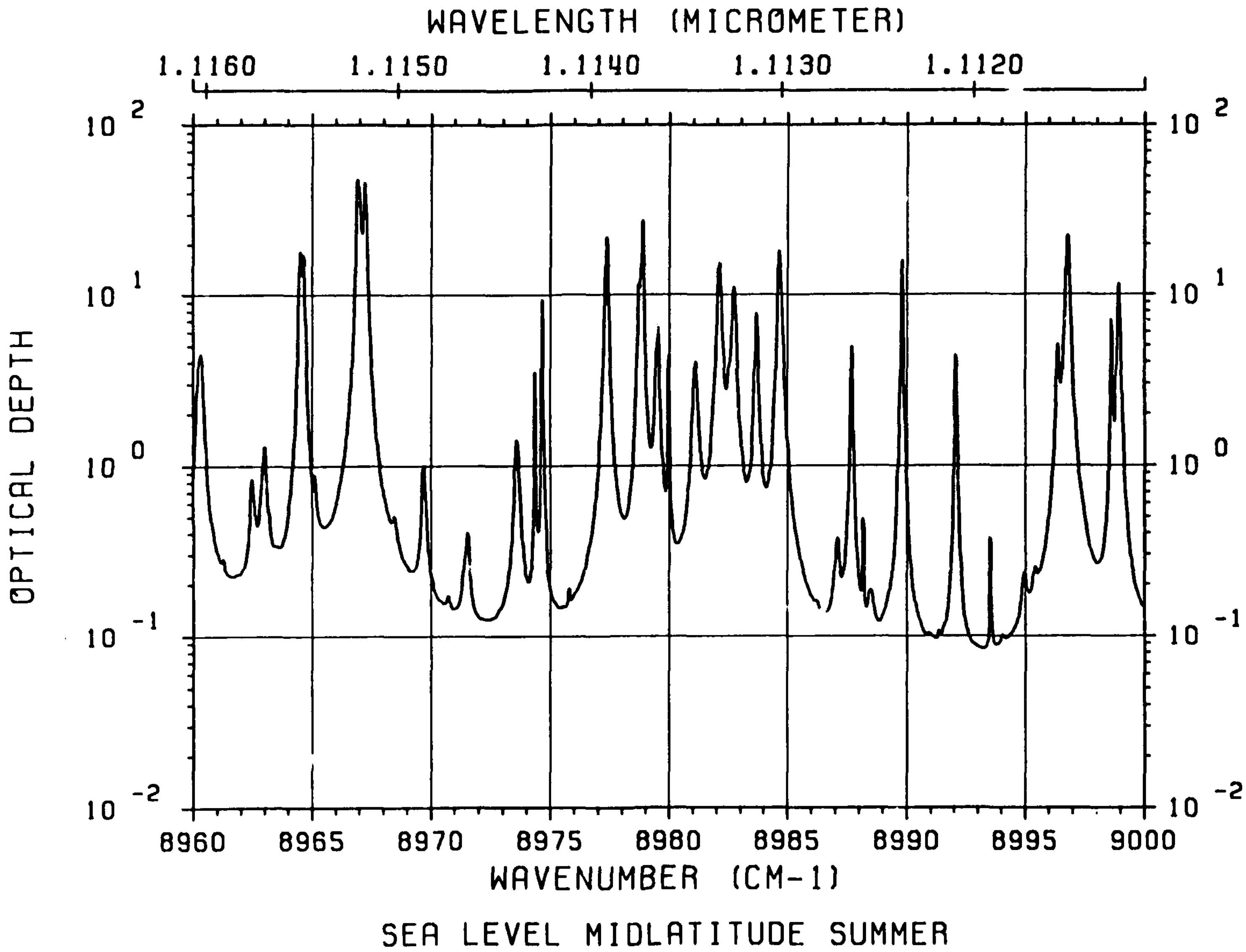

WAVELENGTH (MICROMETER)
1.141
1.140
1.139
1.138
1.137
OPTICAL DEPTH
$10^{-1}$
$10^{0}$
$10^{1}$
$10^{2}$
$10^{3}$
8760
8765
8770
8775
8780
8785
8790
8795
8800
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER

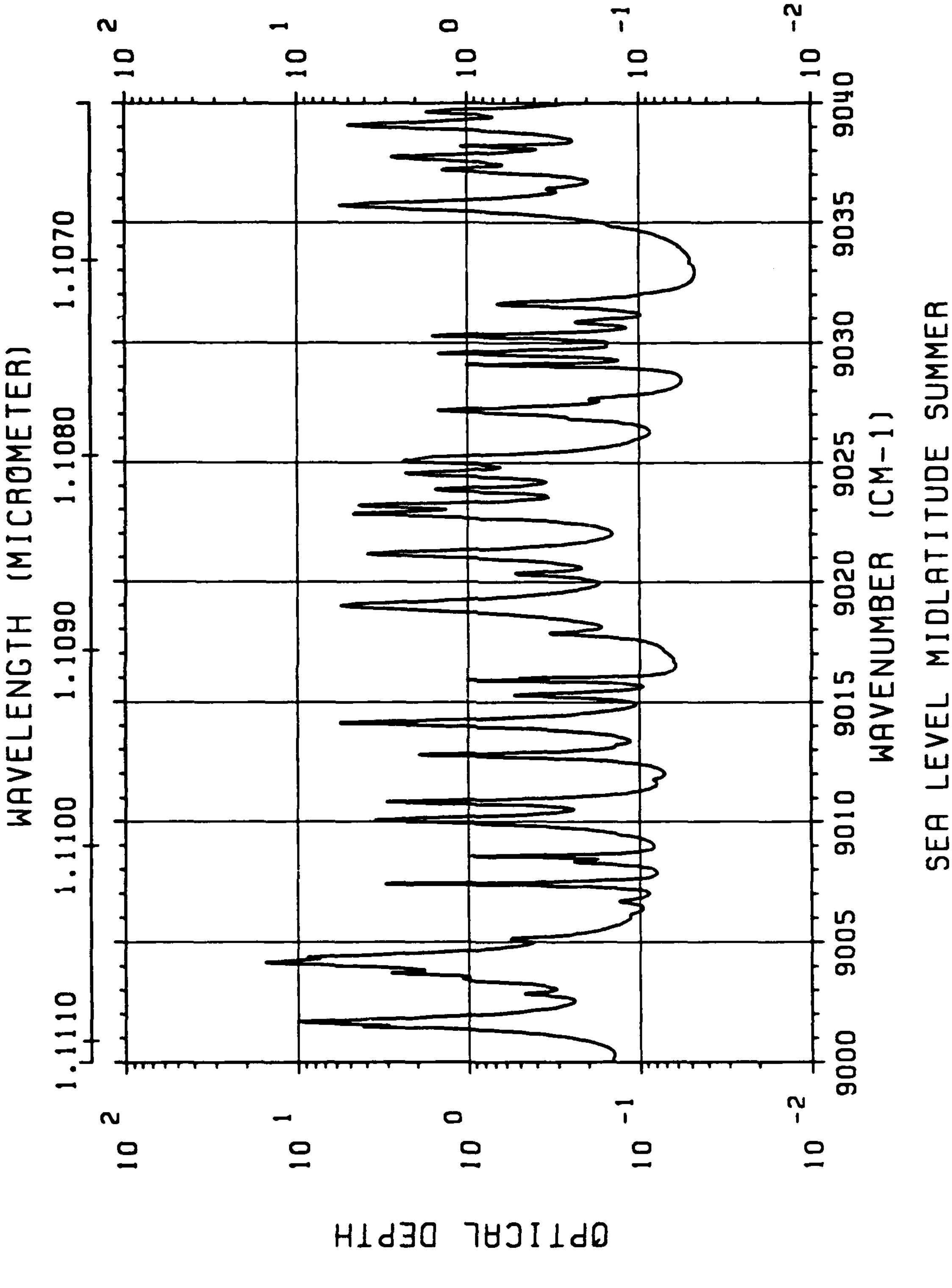

WAVELENGTH (MICROMETER)
1.132
1.133
1.134
1.135
1.136
OPTICAL DEPTH
10^3
10^2
10^1
10^0
10^-1
8800
8805
8810
8815
8820
8825
8830
8835
8840
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER

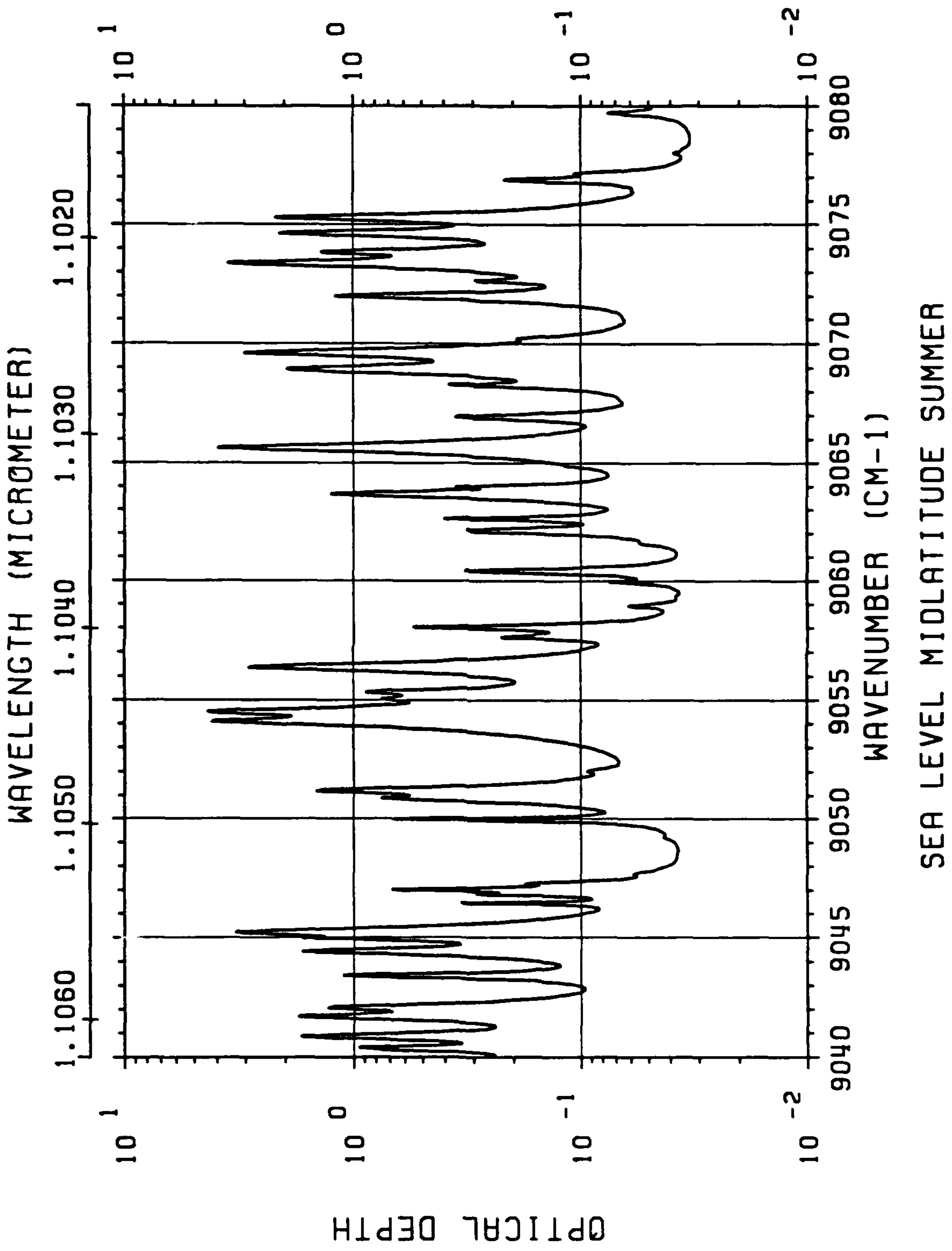

WAVELENGTH (MICROMETER)
1.131
1.130
1.129
1.128
1.127
WAVENUMBER (CM-1)
8840
8845
8850
8855
8860
8865
8870
8875
8880
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH

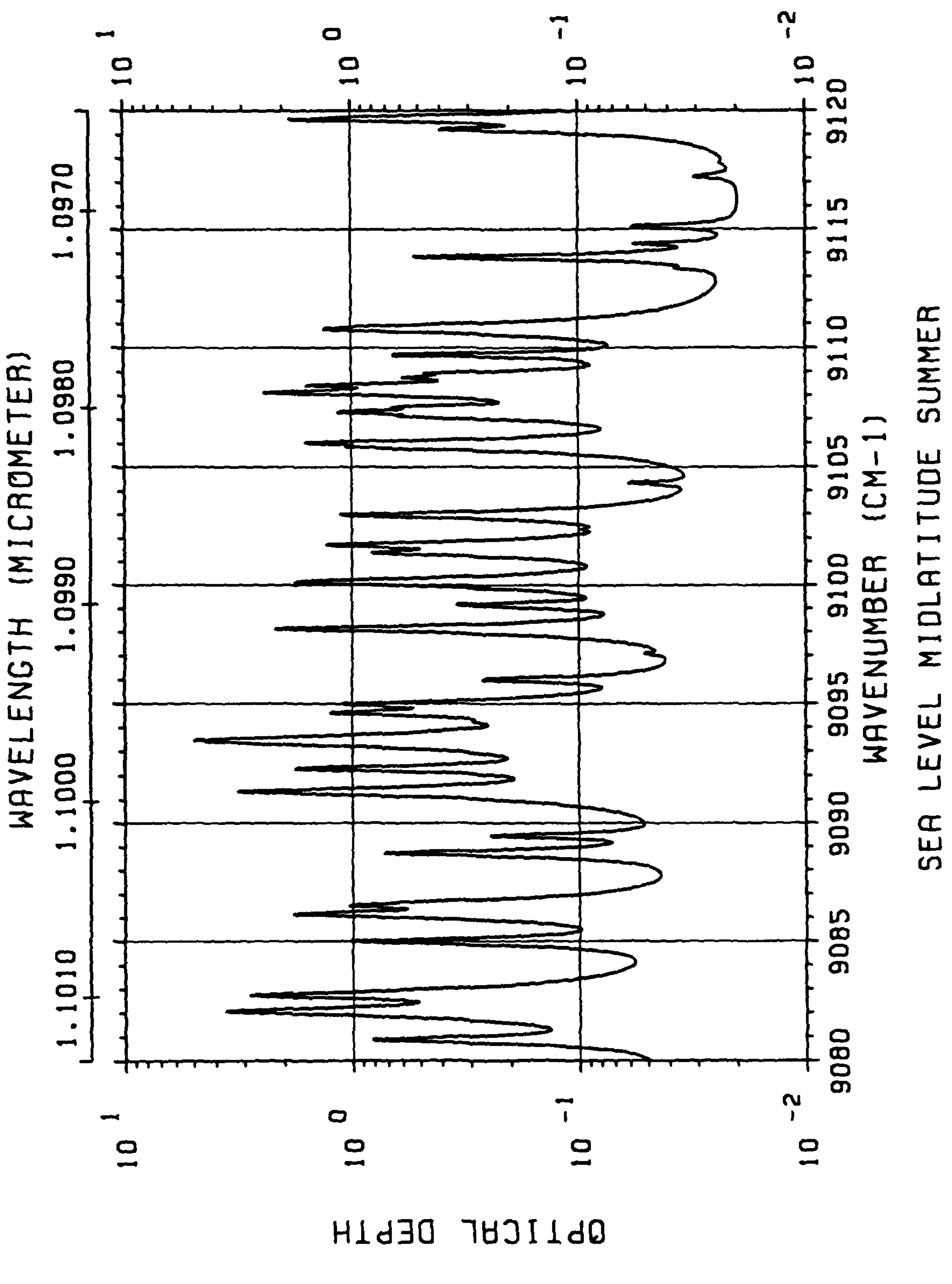

WAVELENGTH (MICROMETER)
1.126
1.125
1.124
1.123
1.122
OPTICAL DEPTH
$10^{3}$
$10^{2}$
$10^{1}$
$10^{0}$
$10^{-1}$
8880
8885
8890
8895
8900
8905
8910
8915
8920
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER

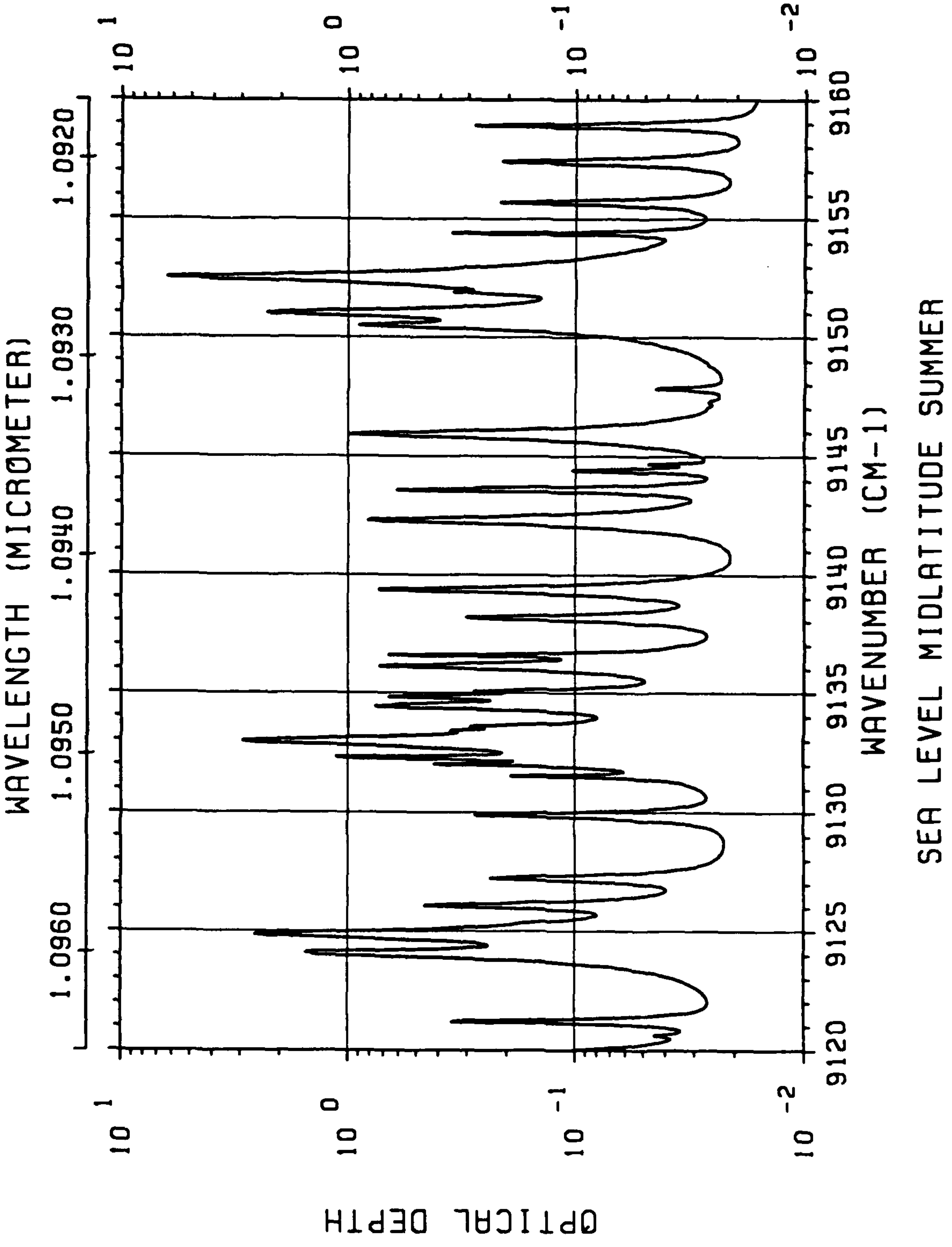

WAVELENGTH (MICROMETER)
1.117
1.118
1.119
1.120
1.121
OPTICAL DEPTH
$10^3$
$10^2$
$10^1$
$10^0$
$10^{-1}$
8920
8925
8930
8935
8940
8945
8950
8955
8960
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER

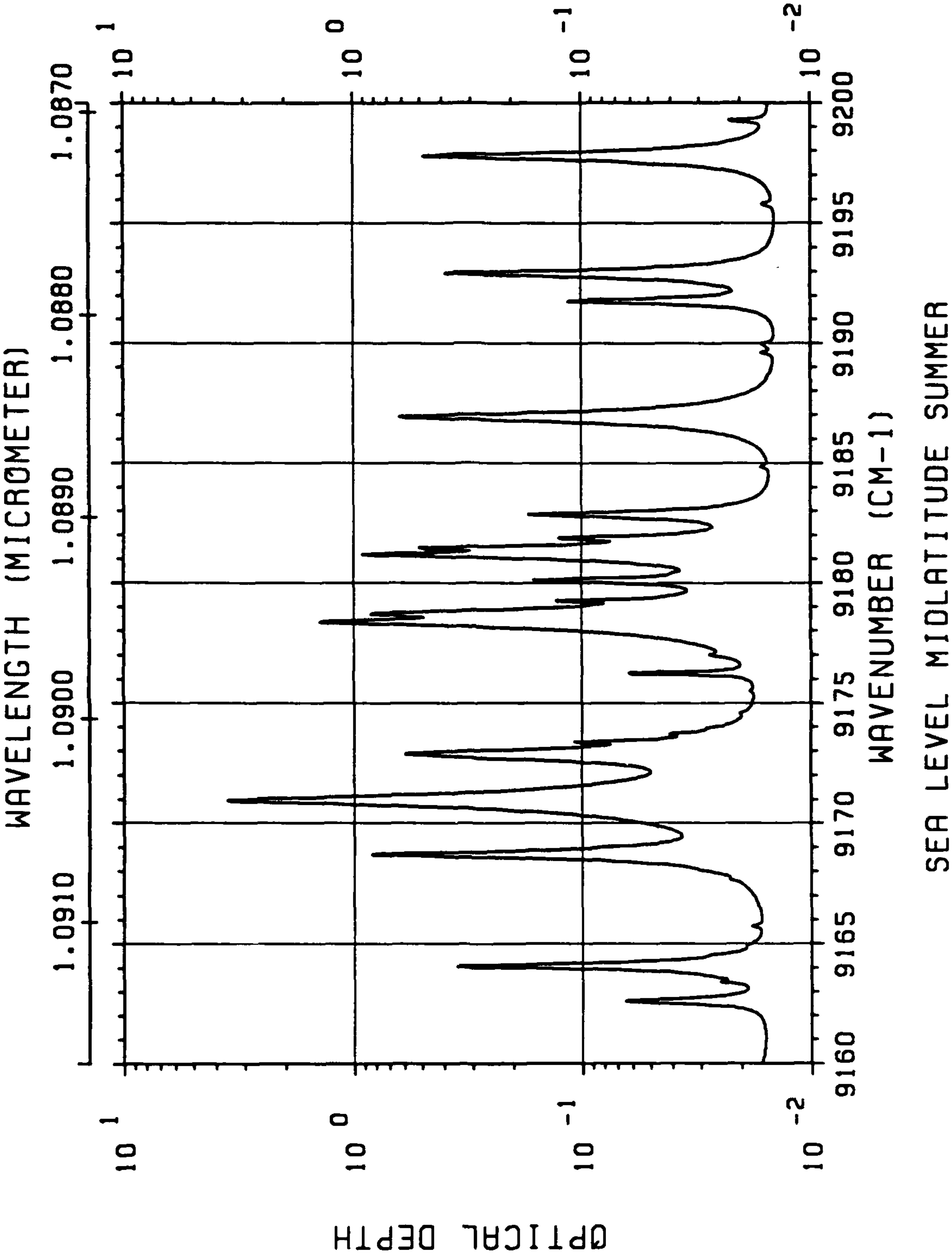

WAVELENGTH (MICROMETER)
1.1160
1.1150
1.1140
1.1130
1.1120
OPTICAL DEPTH
$10^{2}$
$10^{1}$
$10^{0}$
$10^{-1}$
$10^{-2}$
8960
8965
8970
8975
8980
8985
8990
8995
9000
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER


WAVELENGTH (MICROMETER)
1.1110
1.1100
1.1090
1.1080
1.1070
WAVENUMBER (CM-1)
9000
9005
9010
9015
9020
9025
9030
9035
9040
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH
$10^{2}$
$10^{1}$
$10^{0}$
$10^{-1}$
$10^{-2}$

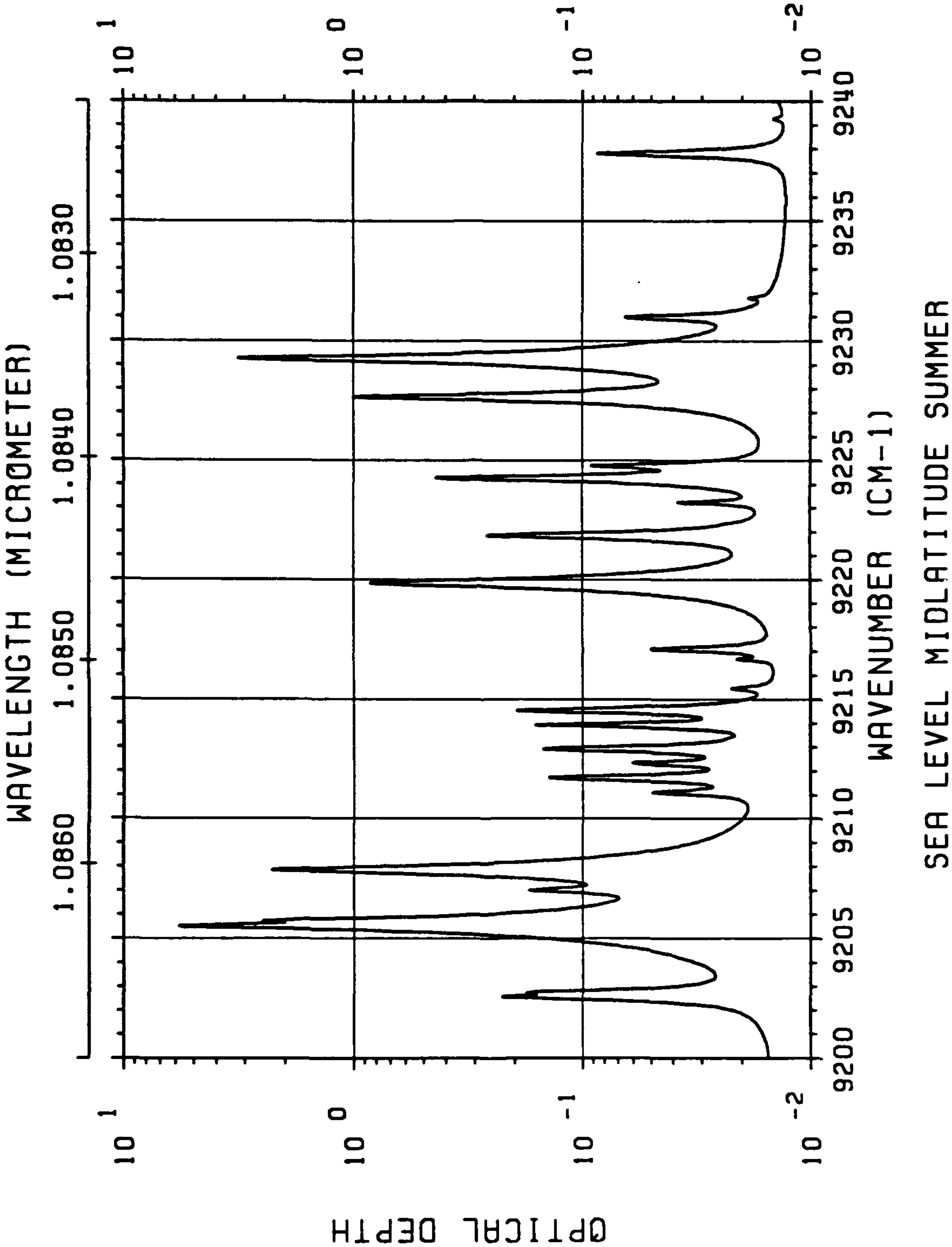

WAVELENGTH (MICROMETER)
1.1020
1.1030
1.1040
1.1050
1.1060
10^1
10^0
10^-1
10^-2
9040
9045
9050
9055
9060
9065
9070
9075
9080
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH


WAVELENGTH (MICROMETER)
1.0970
1.0980
1.0990
1.1000
1.1010
OPTICAL DEPTH
$10^{1}$
$10^{0}$
$10^{-1}$
$10^{-2}$
9080
9085
9090
9095
9100
9105
9110
9115
9120
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER

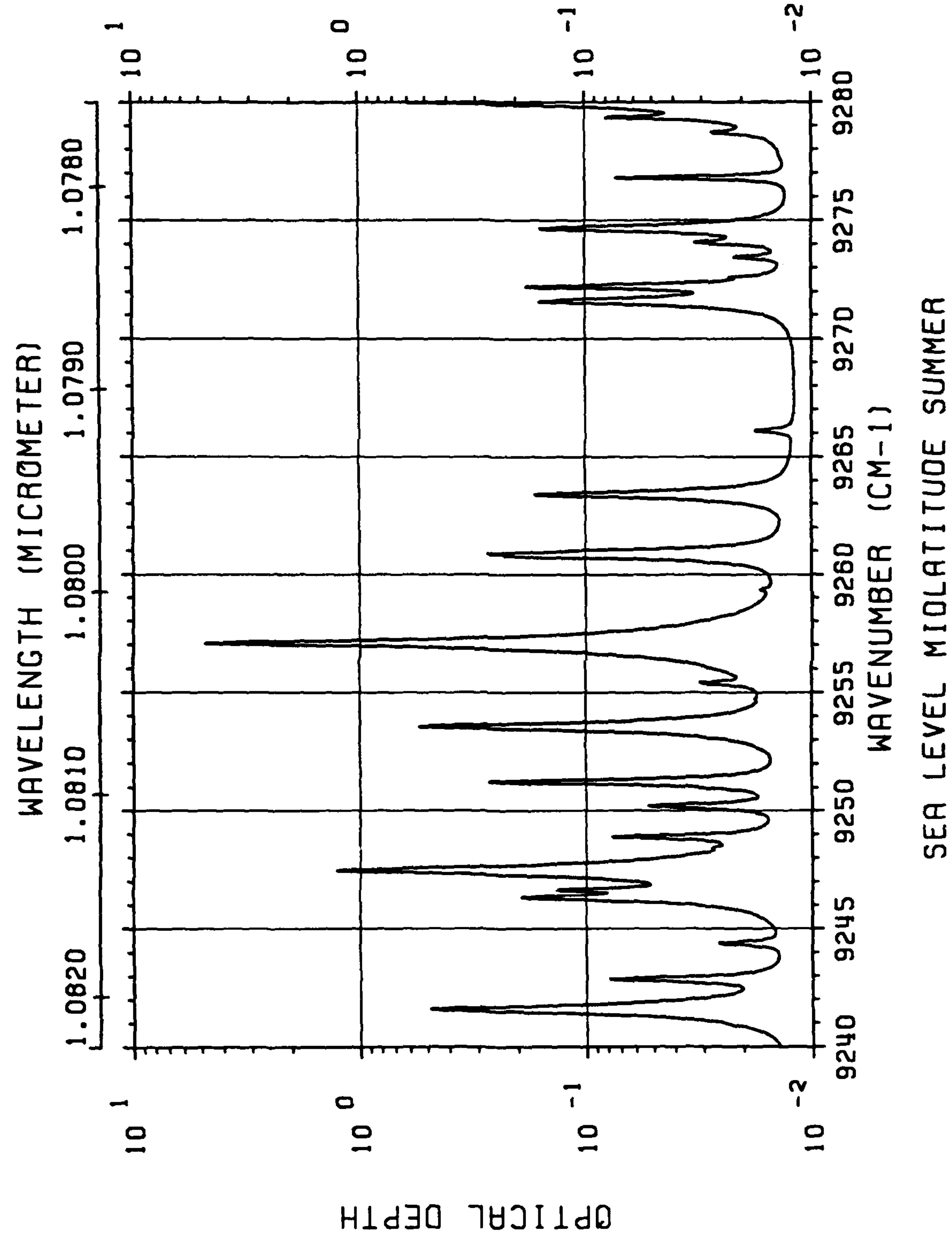

WAVELENGTH (MICROMETER)
1.0920
1.0930
1.0940
1.0950
1.0960
WAVENUMBER (CM-1)
9120
9125
9130
9135
9140
9145
9150
9155
9160
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH

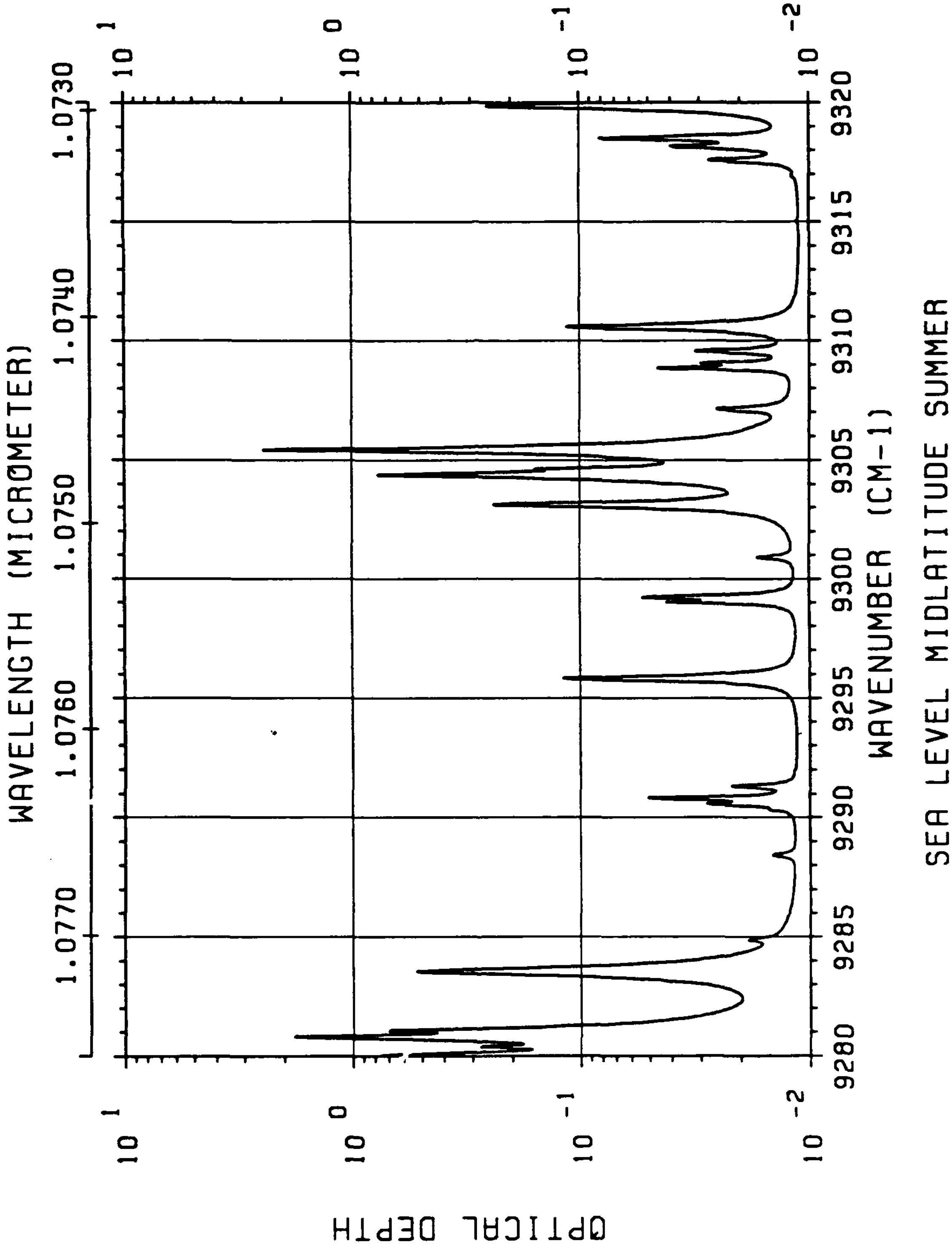


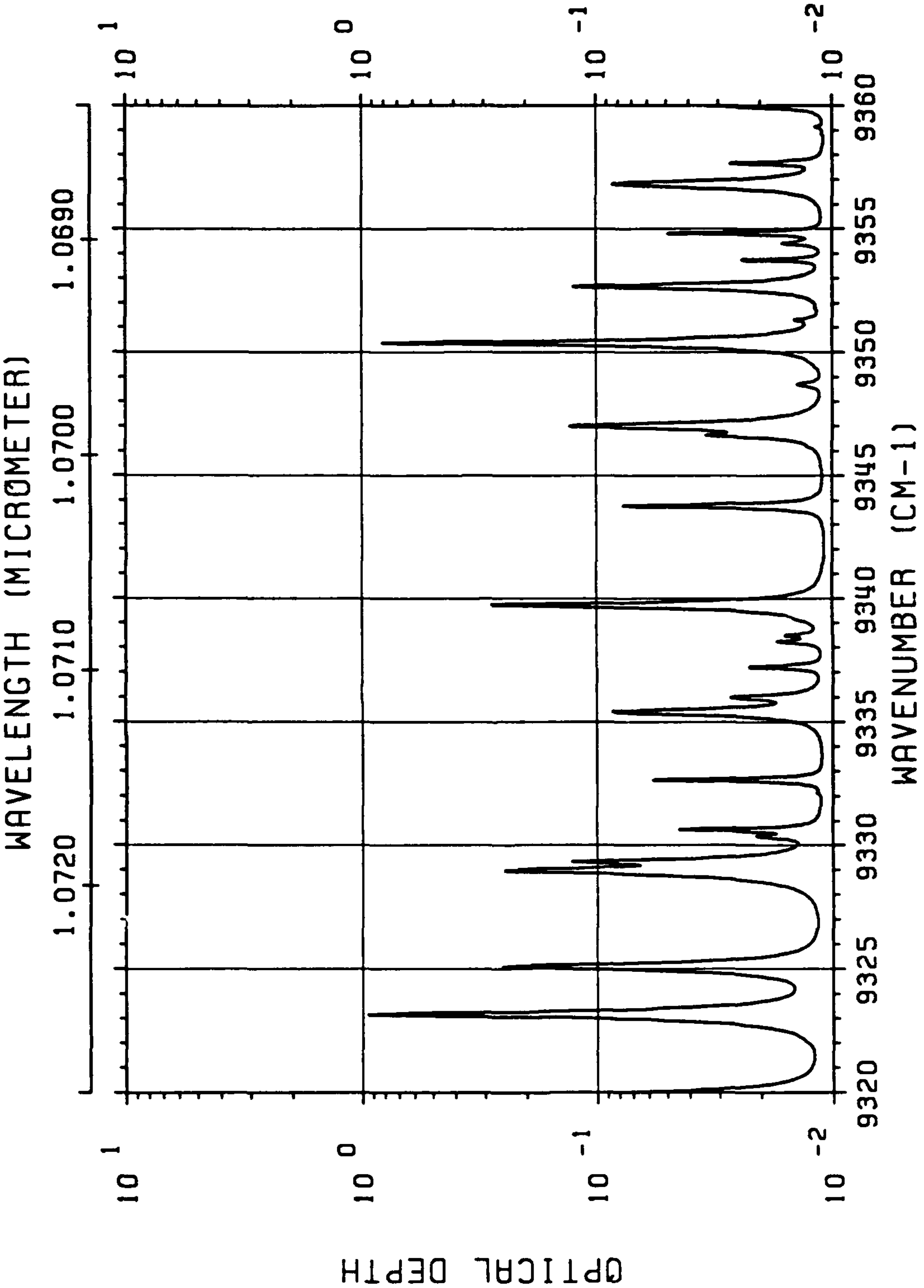
WAVELENGTH (MICROMETER)
1.0910
1.0900
1.0890
1.0880
1.0870
WAVENUMBER (CM-1)
9160
9165
9170
9175
9180
9185
9190
9195
9200
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH



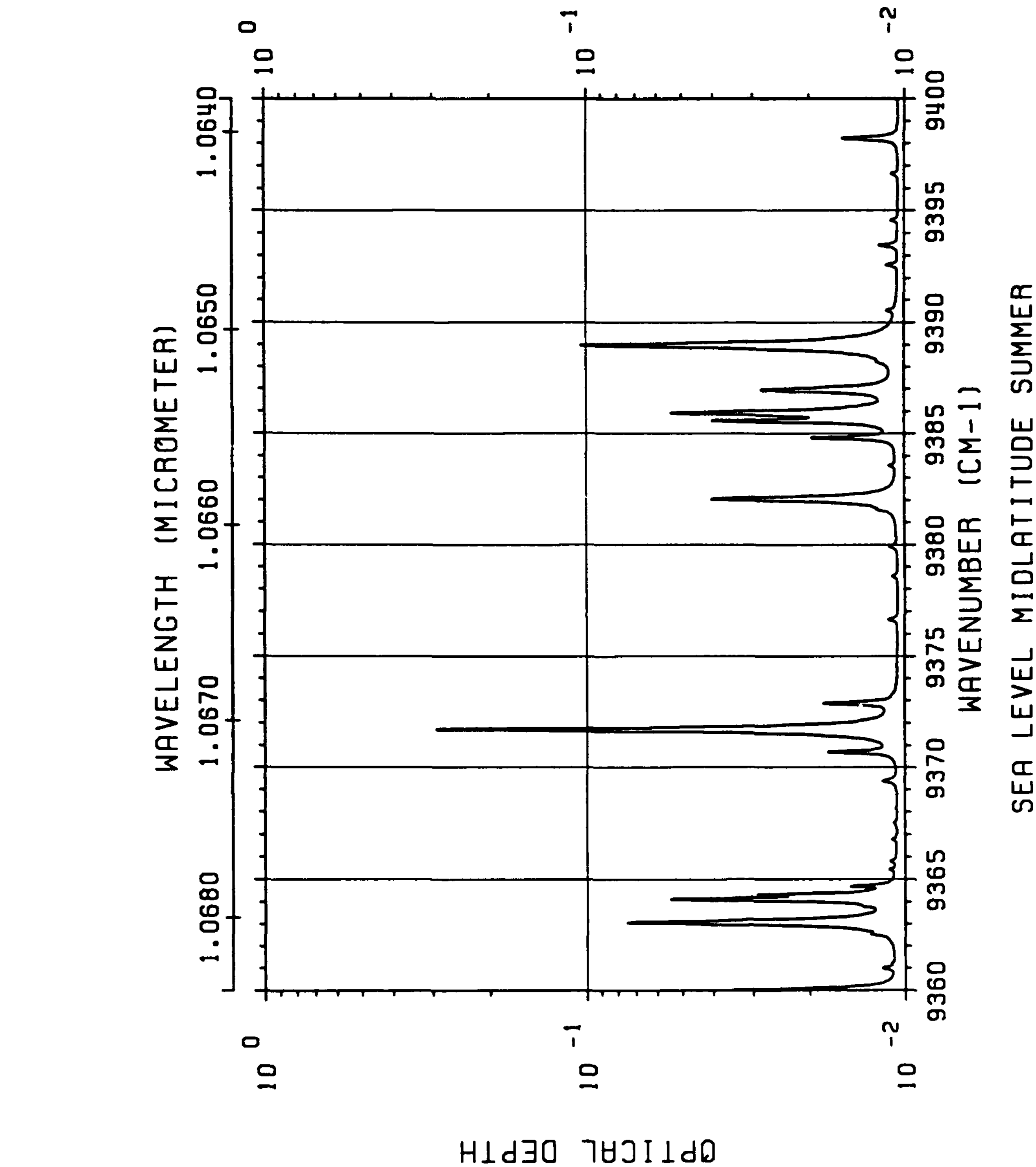
WAVELENGTH (MICROMETER)
1.0830
1.0840
1.0850
1.0860
OPTICAL DEPTH
10^1
10^0
10^-1
10^-2
9200
9205
9210
9215
9220
9225
9230
9235
9240
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER


WAVELENGTH (MICRØMETER)
1.0820
1.0810
1.0800
1.0790
1.0780
9240
9245
9250
9255
9260
9265
9270
9275
9280
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH
10^1
10^0
10^-1
10^-2

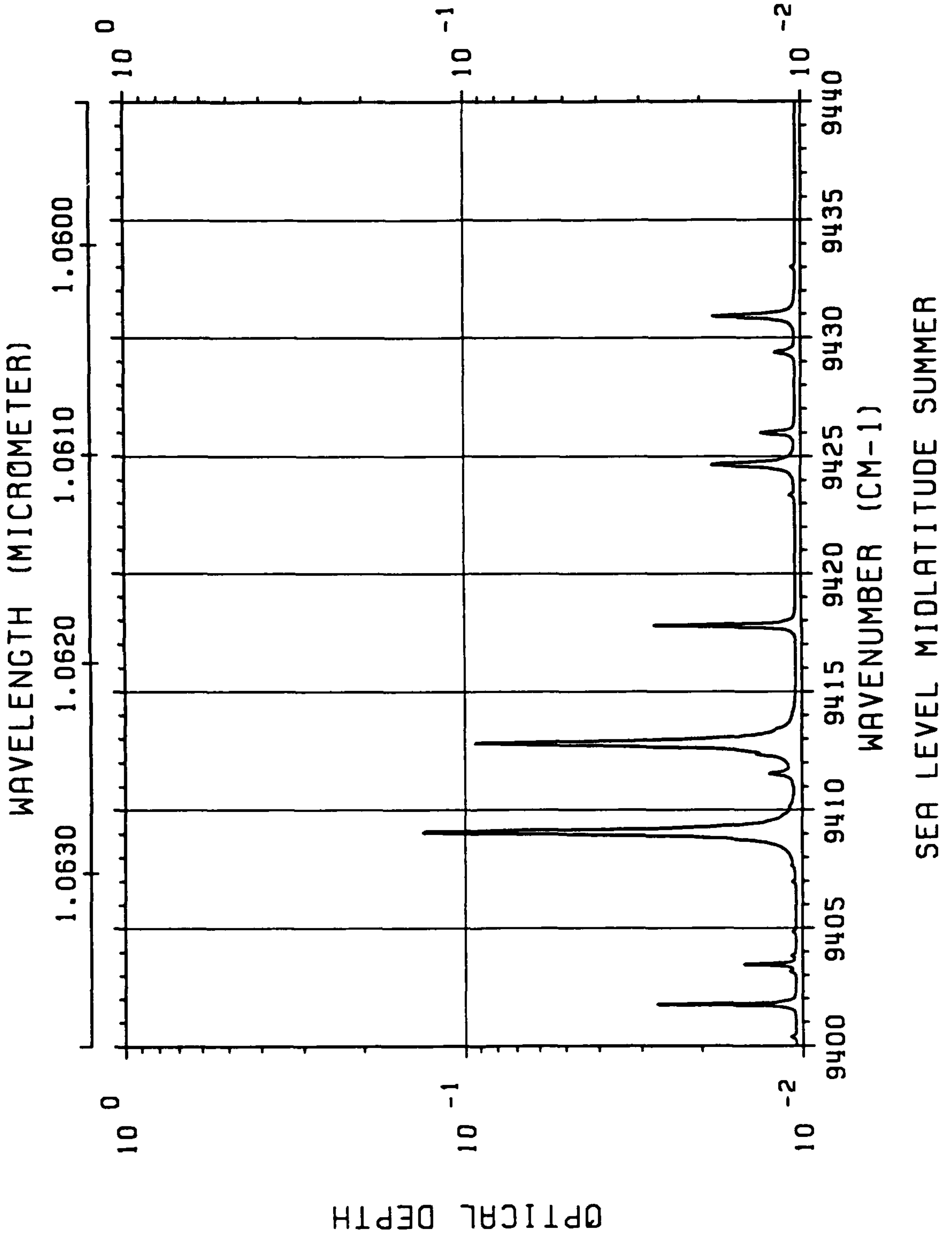

WAVELENGTH (MICROMETER)
1.0730
1.0740
1.0750
1.0760
1.0770
WAVENUMBER (CM-1)
9280
9285
9290
9295
9300
9305
9310
9315
9320
OPTICAL DEPTH
$10^{1}$
$10^{0}$
$10^{-1}$
$10^{-2}$
SEA LEVEL MIDLATITUDE SUMMER

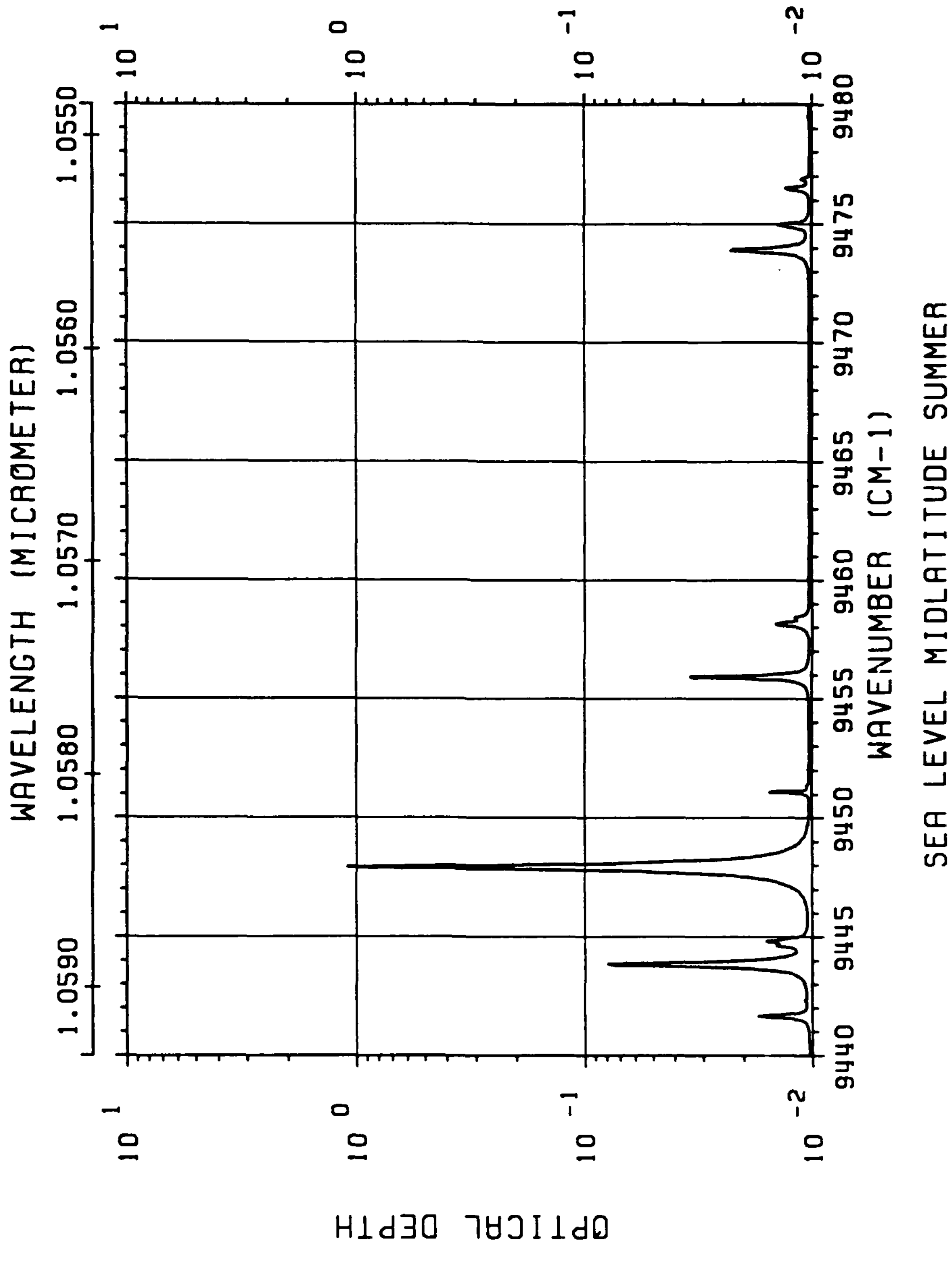


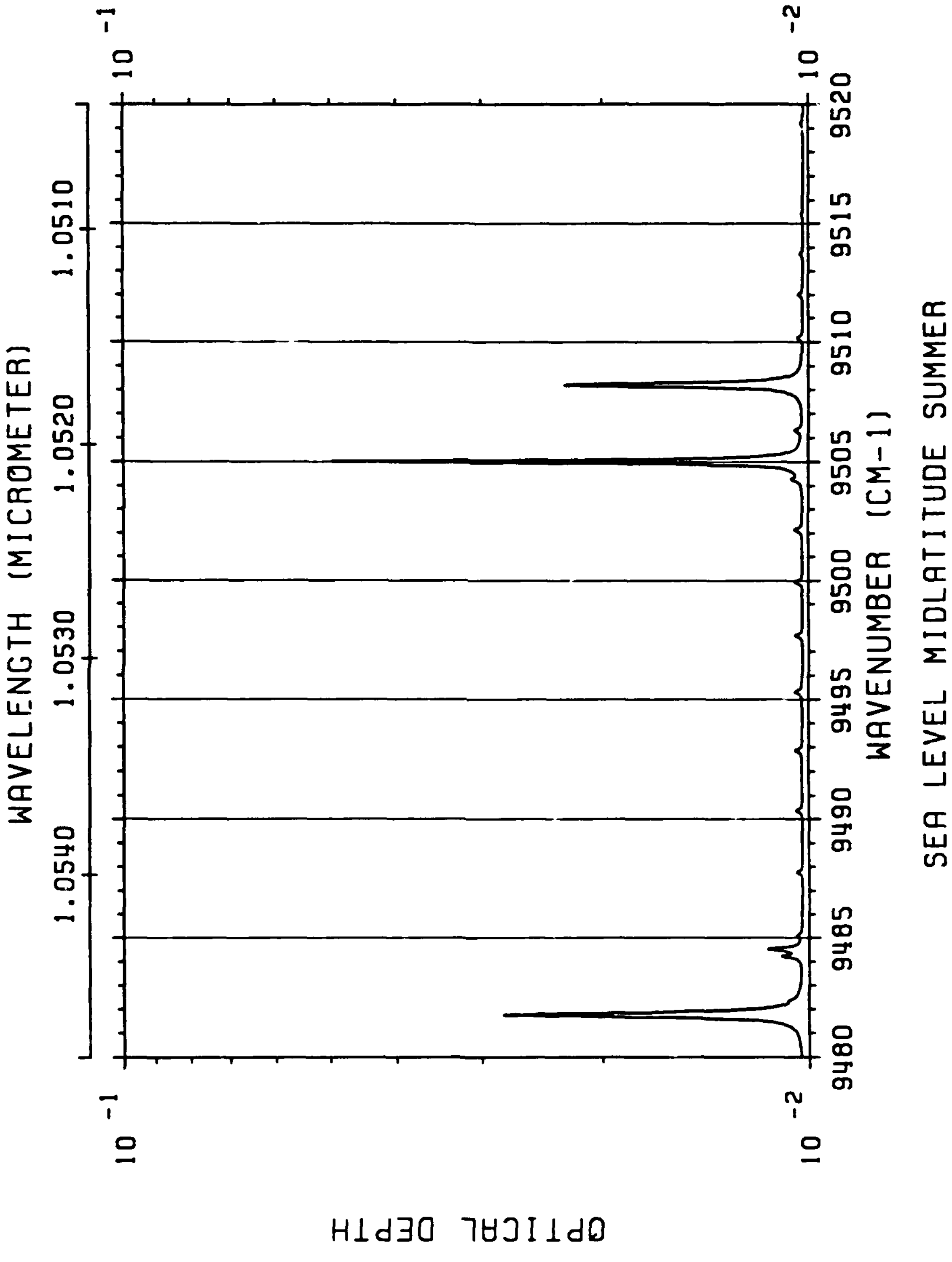

SEA LEVEL MIDLATITUDE SUMMER

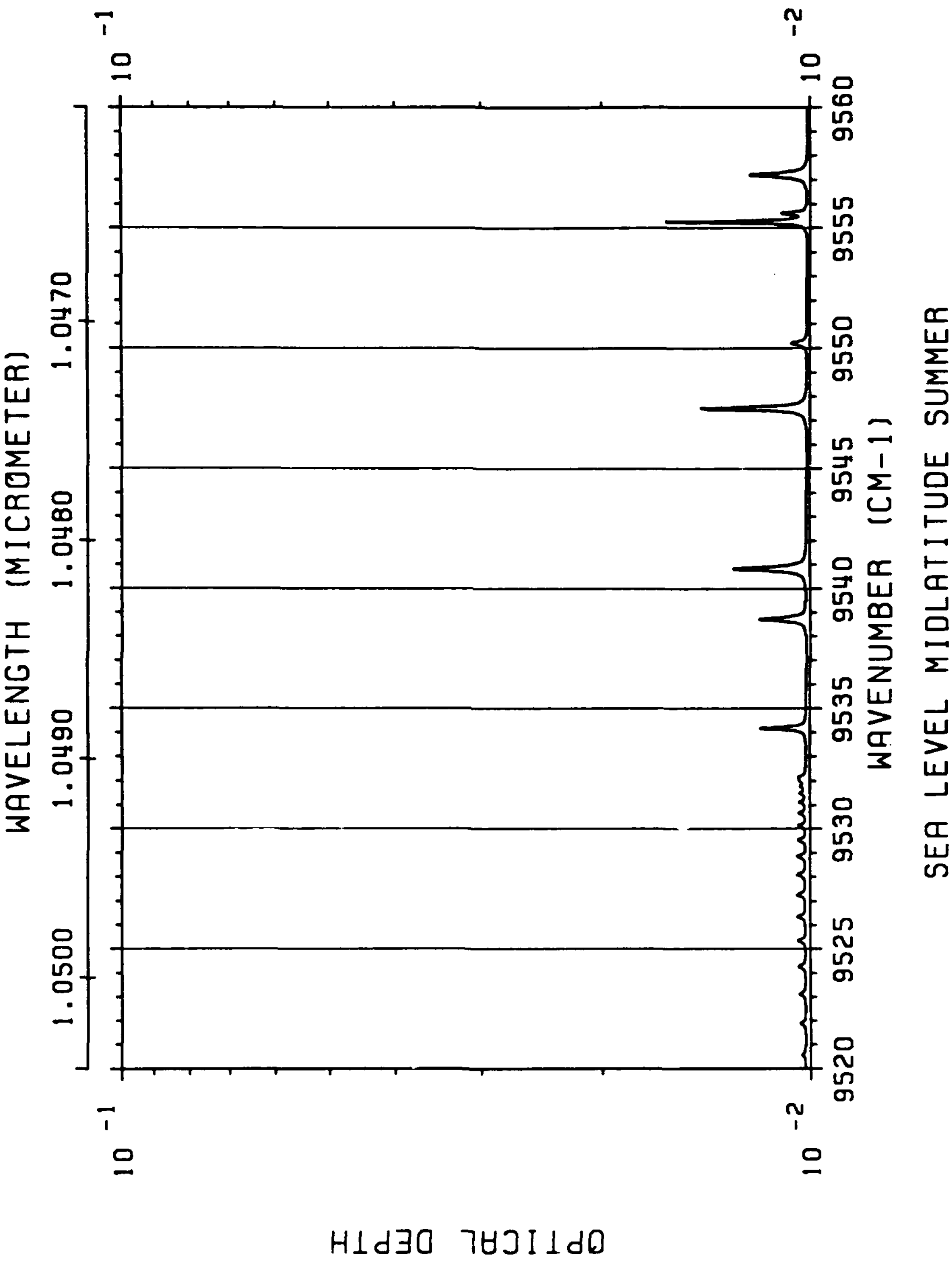


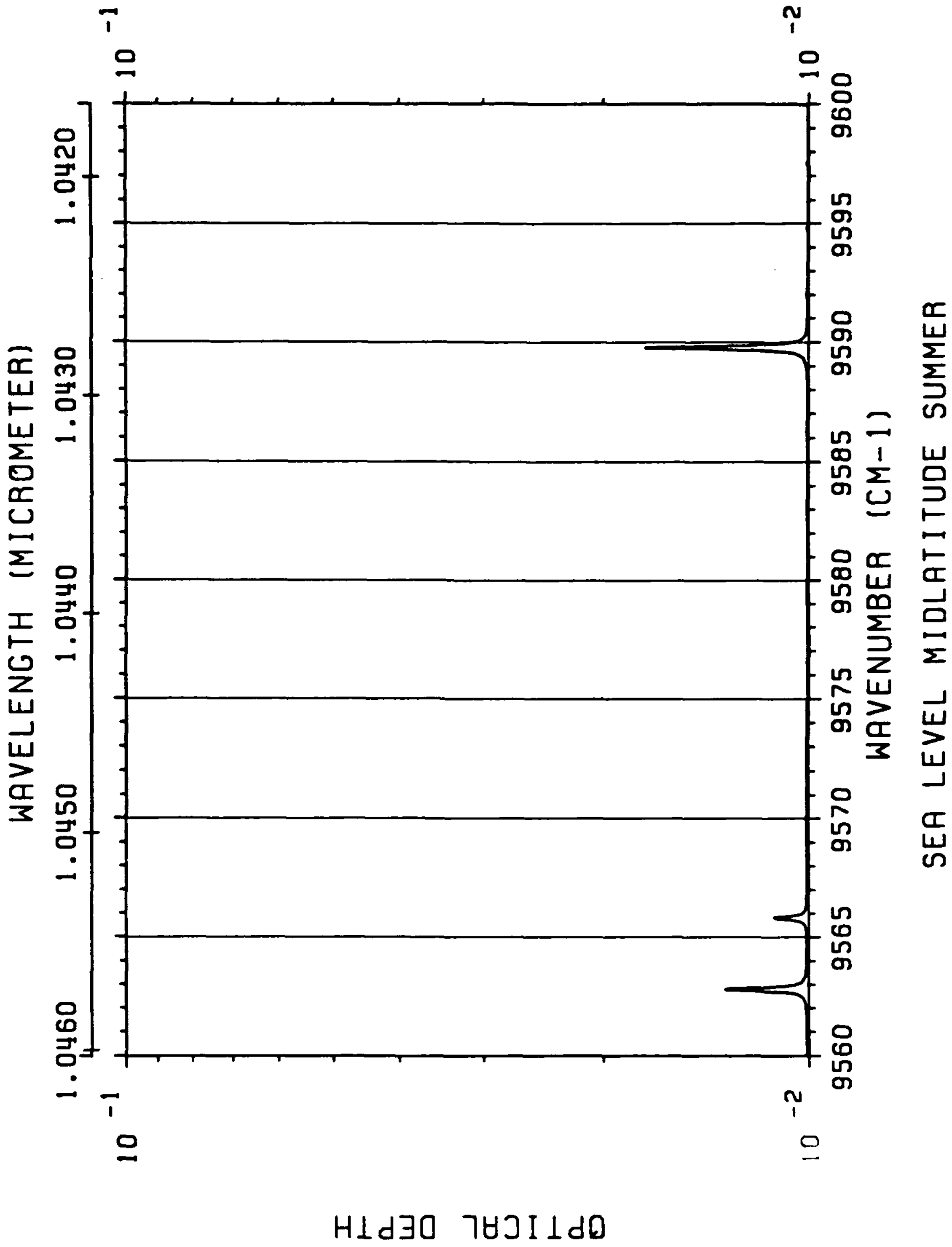
WAVELENGTH (MICROMETER)
1.0640
1.0650
1.0660
1.0670
1.0680
10^0
10^-1
10^-2
9400
9395
9390
9385
9380
9375
9370
9365
9360
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH

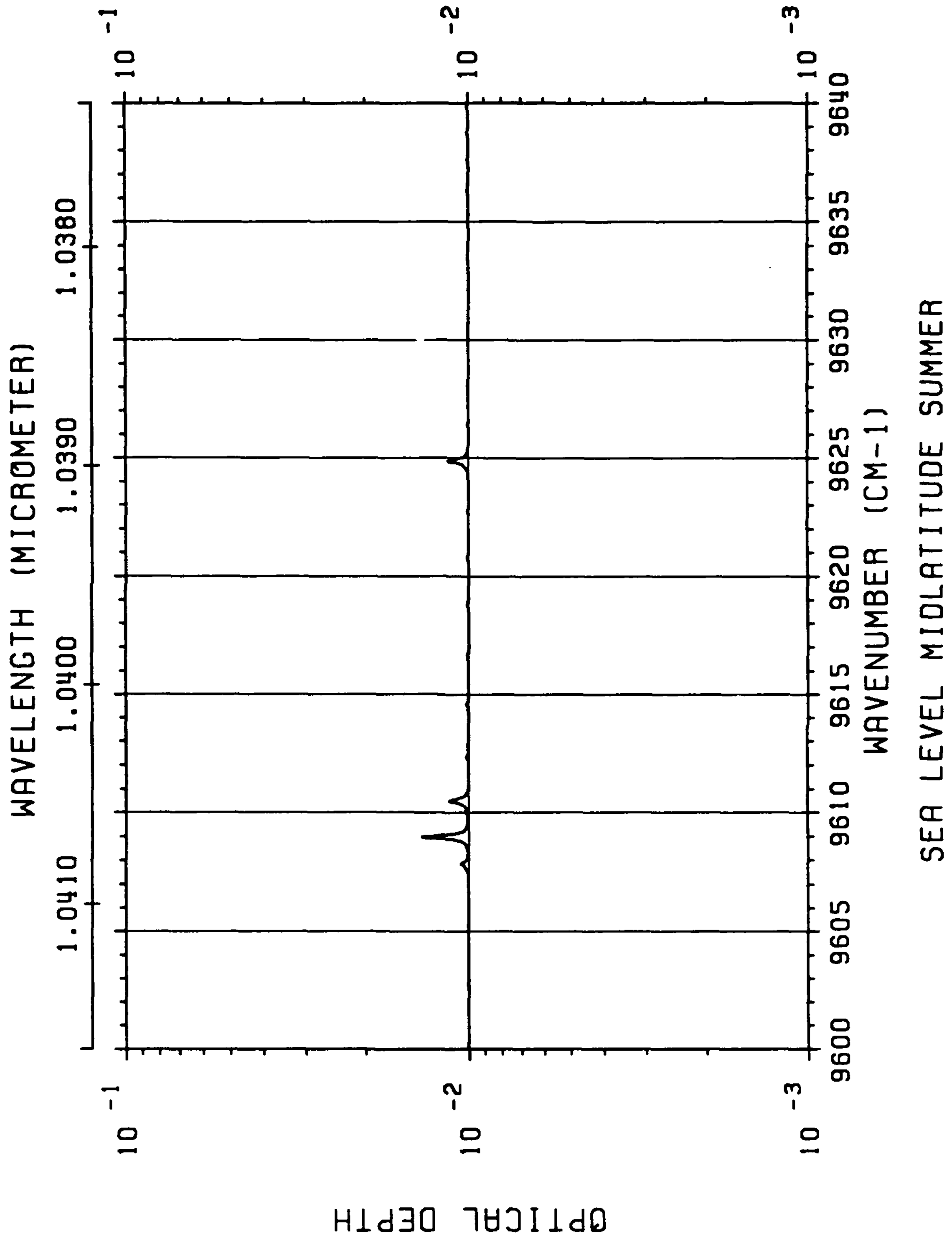

WAVELENGTH (MICROMETER)
1.0600
1.0610
1.0620
1.0630
$10^{0}$
$10^{-1}$
$10^{-2}$
9400
9405
9410
9415
9420
9425
9430
9435
9440
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH

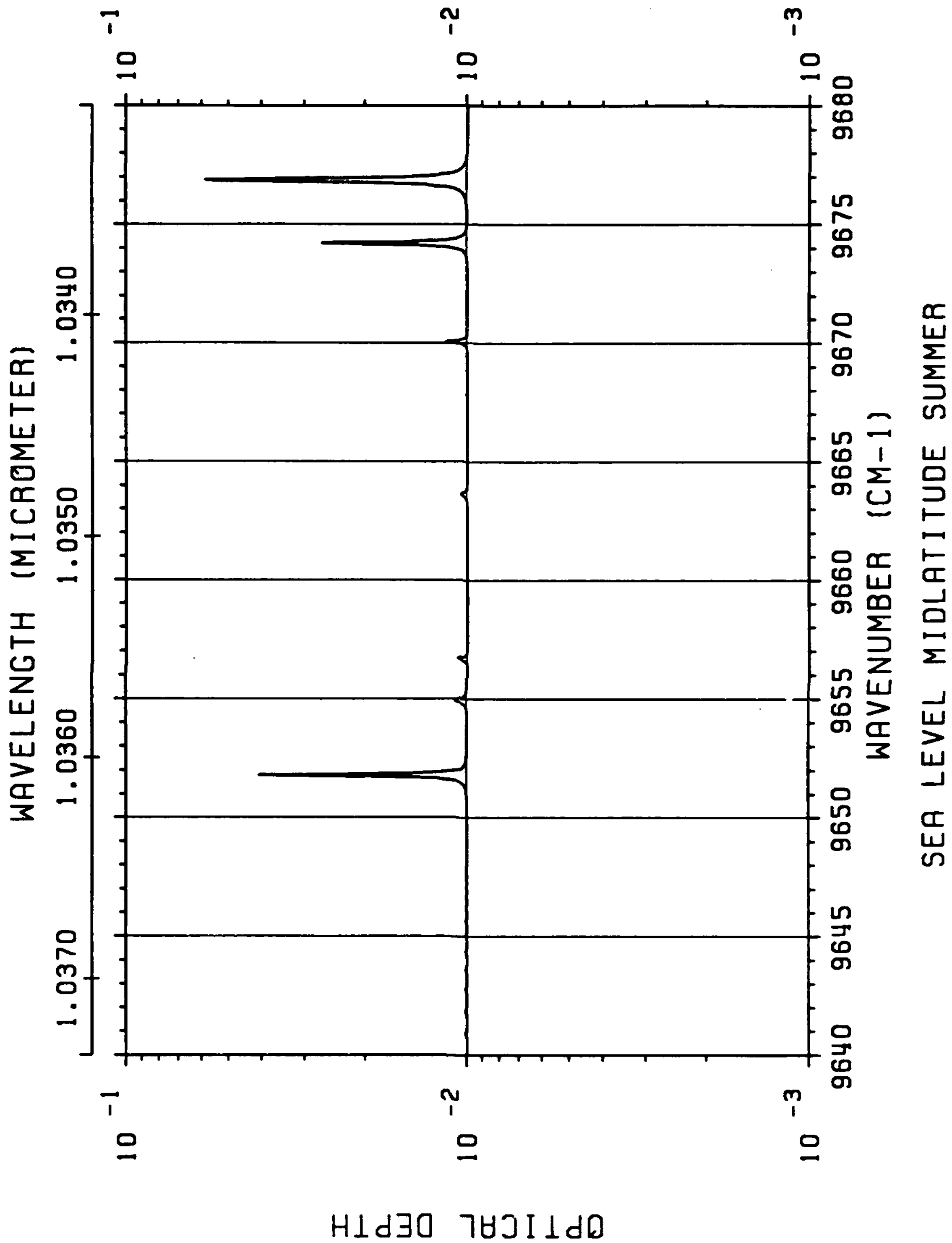

WAVELENGTH (MICROMETER)
1.0550
1.0560
1.0570
1.0580
1.0590
9440
9445
9450
9455
9460
9465
9470
9475
9480
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
10^1
10^0
10^-1
10^-2
OPTICAL DEPTH


WAVELENGTH (MICROMETER)
1.0510
1.0520
1.0530
1.0540
WAVENUMBER (CM-1)
9480
9485
9490
9495
9500
9505
9510
9515
9520
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH
$10^{-1}$
$10^{-2}$

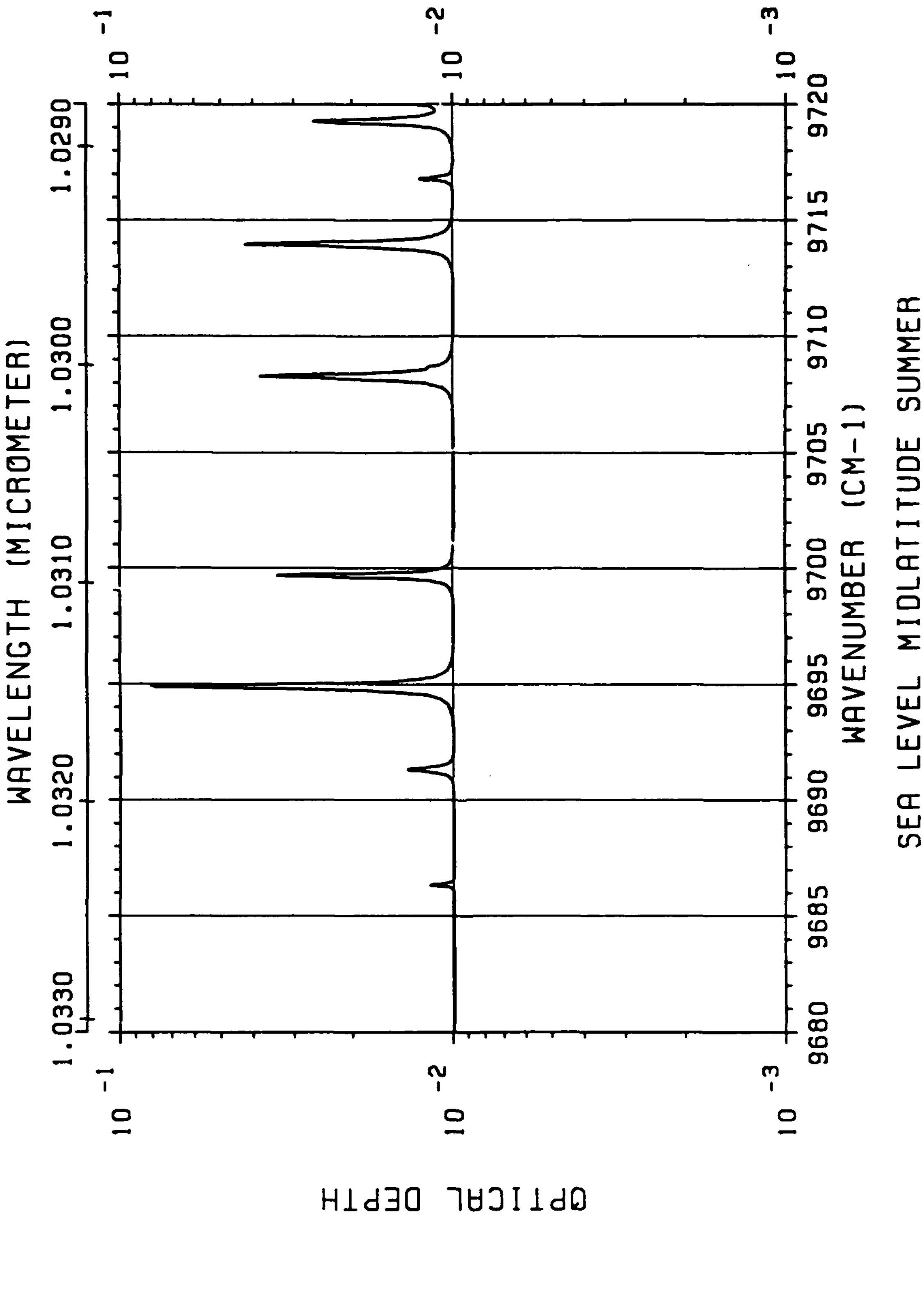

WAVELENGTH (MICROMETER)
1.0500
1.0490
1.0480
1.0470
OPTICAL DEPTH
$10^{-1}$
$10^{-2}$
9520
9525
9530
9535
9540
9545
9550
9555
9560
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER

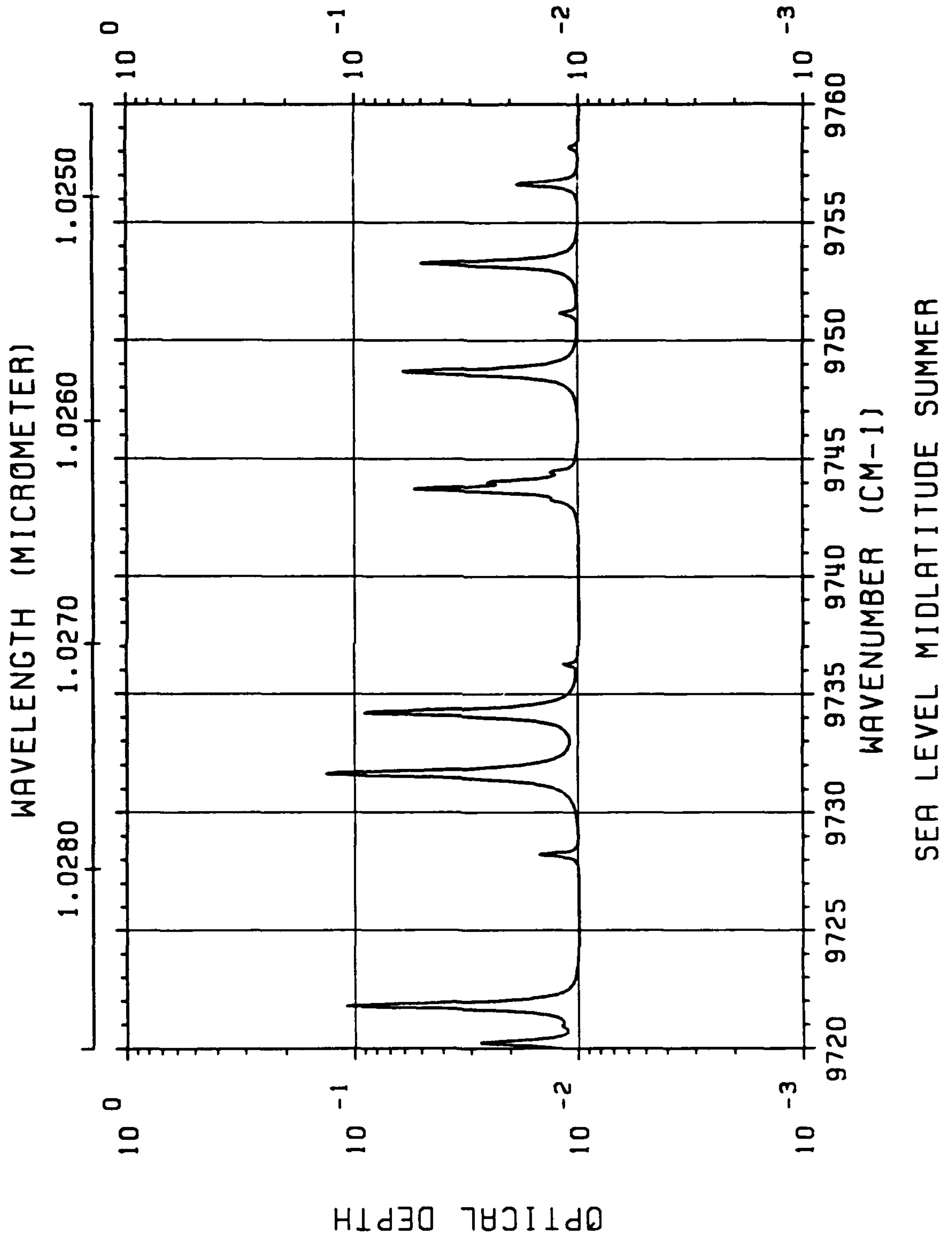

WAVELENGTH (MICROMETER)
1.0420
1.0430
1.0440
1.0450
1.0460
9560
9565
9570
9575
9580
9585
9590
9595
9600
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH


WAVELENGTH (MICROMETER)
1.0380
1.0390
1.0400
1.0410
WAVENUMBER (CM-1)
9600
9605
9610
9615
9620
9625
9630
9635
9640
OPTICAL DEPTH
10^-1
10^-2
10^-3
SEA LEVEL MIDLATITUDE SUMMER

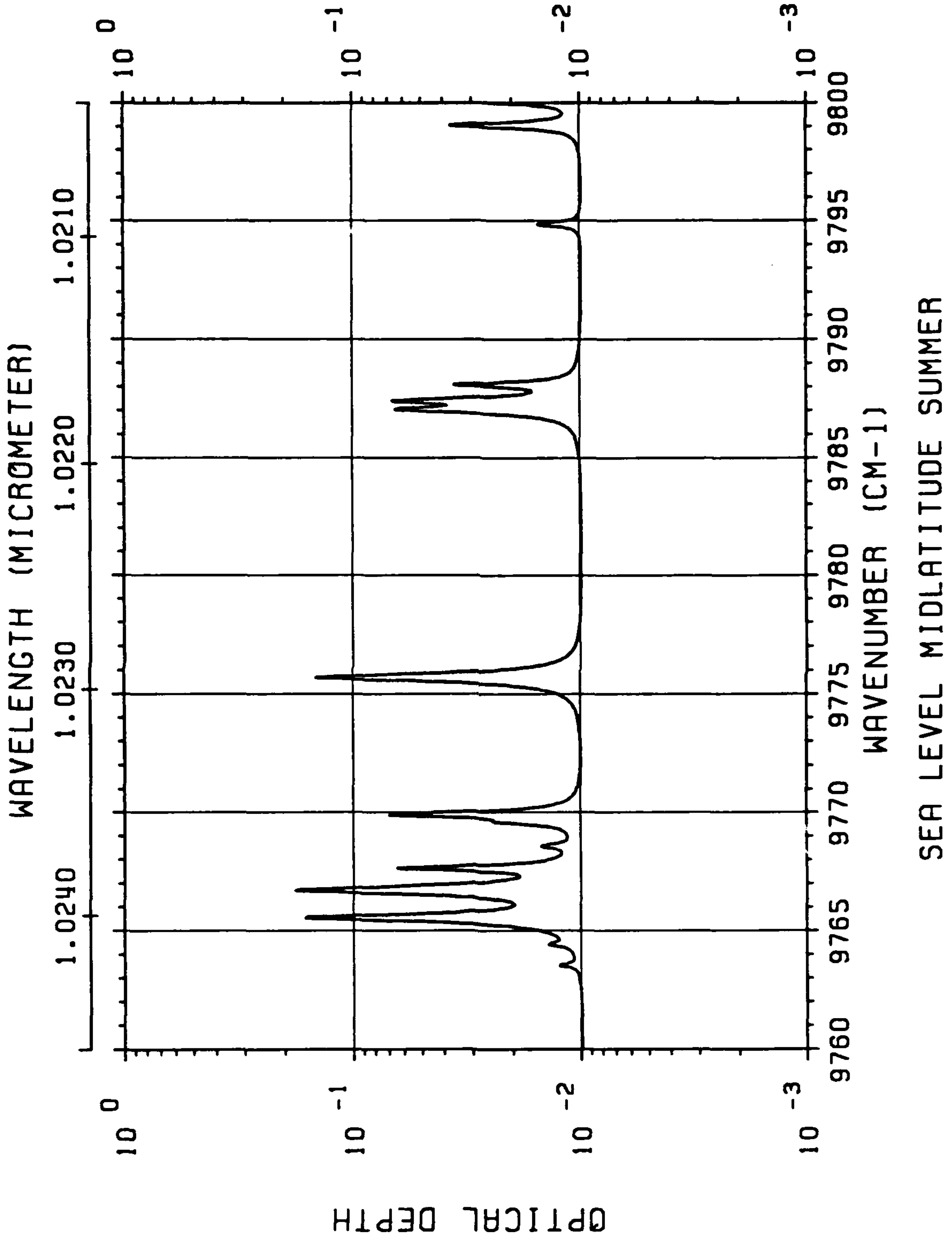


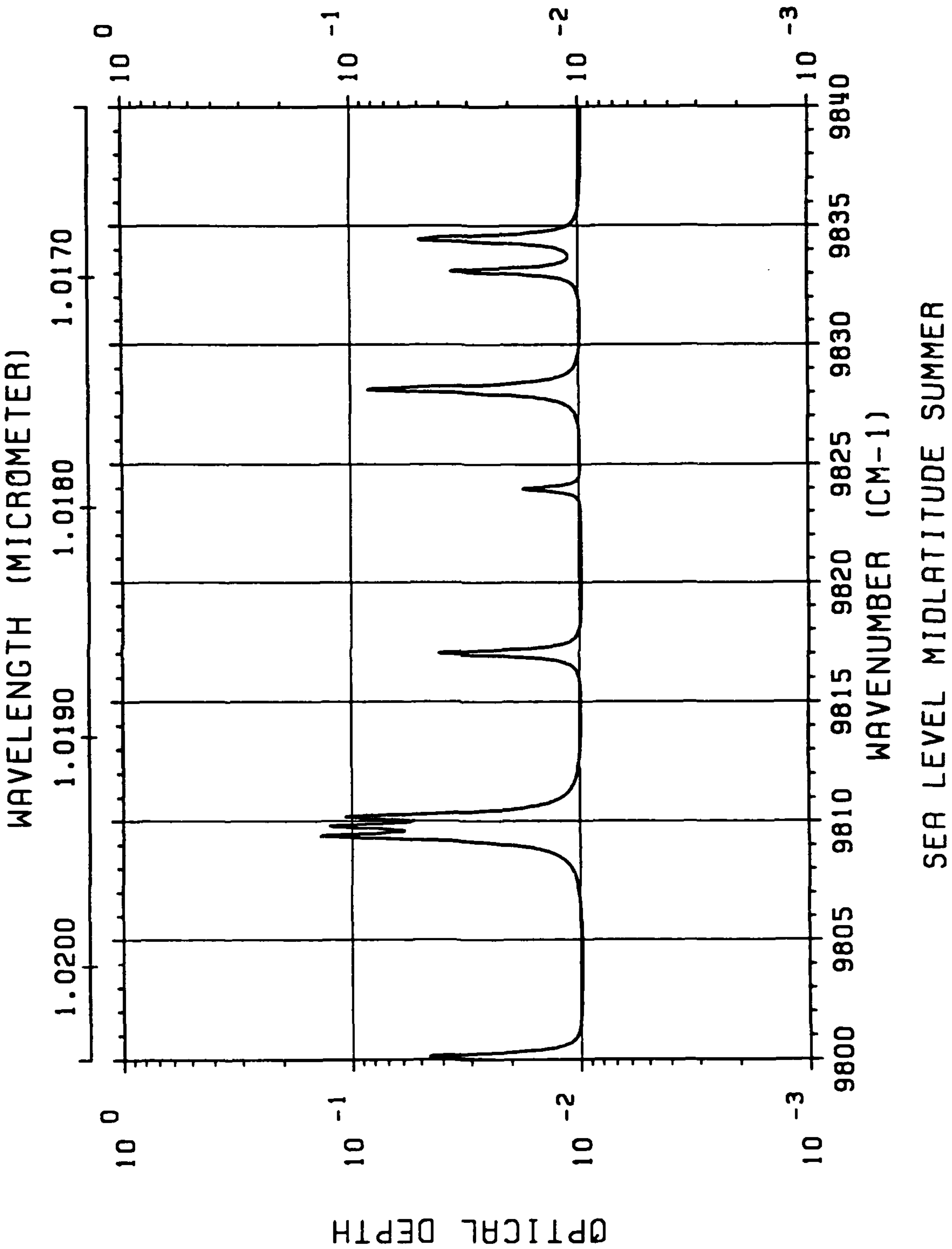
WAVELENGTH (MICROMETER)
1.0340
1.0350
1.0360
1.0370
WAVENUMBER (CM-1)
9640
9645
9650
9655
9660
9665
9670
9675
9680
OPTICAL DEPTH
10 -1
10 -2
10 -3
SEA LEVEL MIDLATITUDE SUMMER


WAVELENGTH (MICROMETER)
1.0290
1.0300
1.0310
1.0320
1.0330
10 -1
10 -2
10 -3
9720
9715
9710
9705
9700
9695
9690
9685
9680
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH

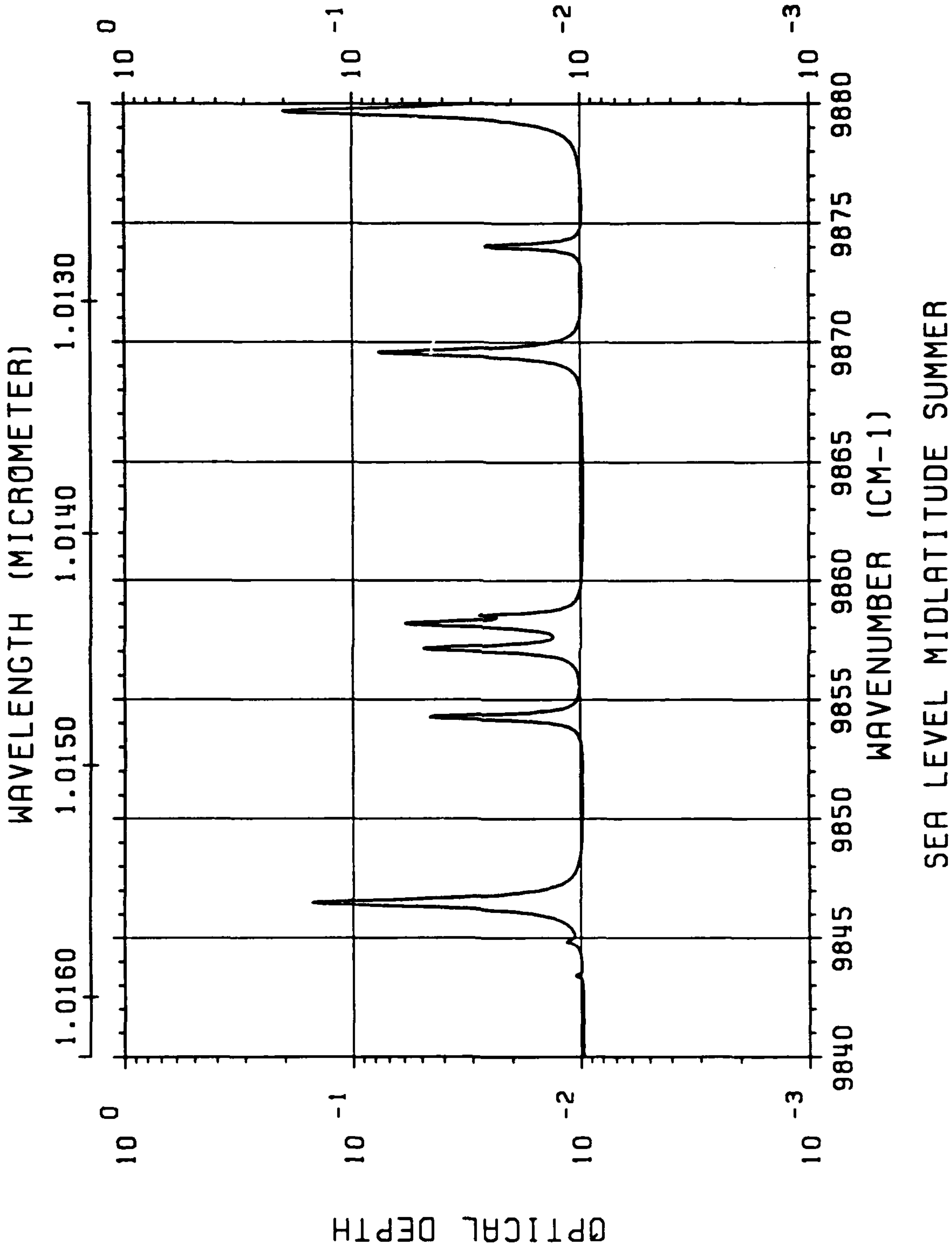


WAVELENGTH (MICROMETER)
1.0250
1.0260
1.0270
1.0280
OPTICAL DEPTH
10^0
10^-1
10^-2
10^-3
9720
9725
9730
9735
9740
9745
9750
9755
9760
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER

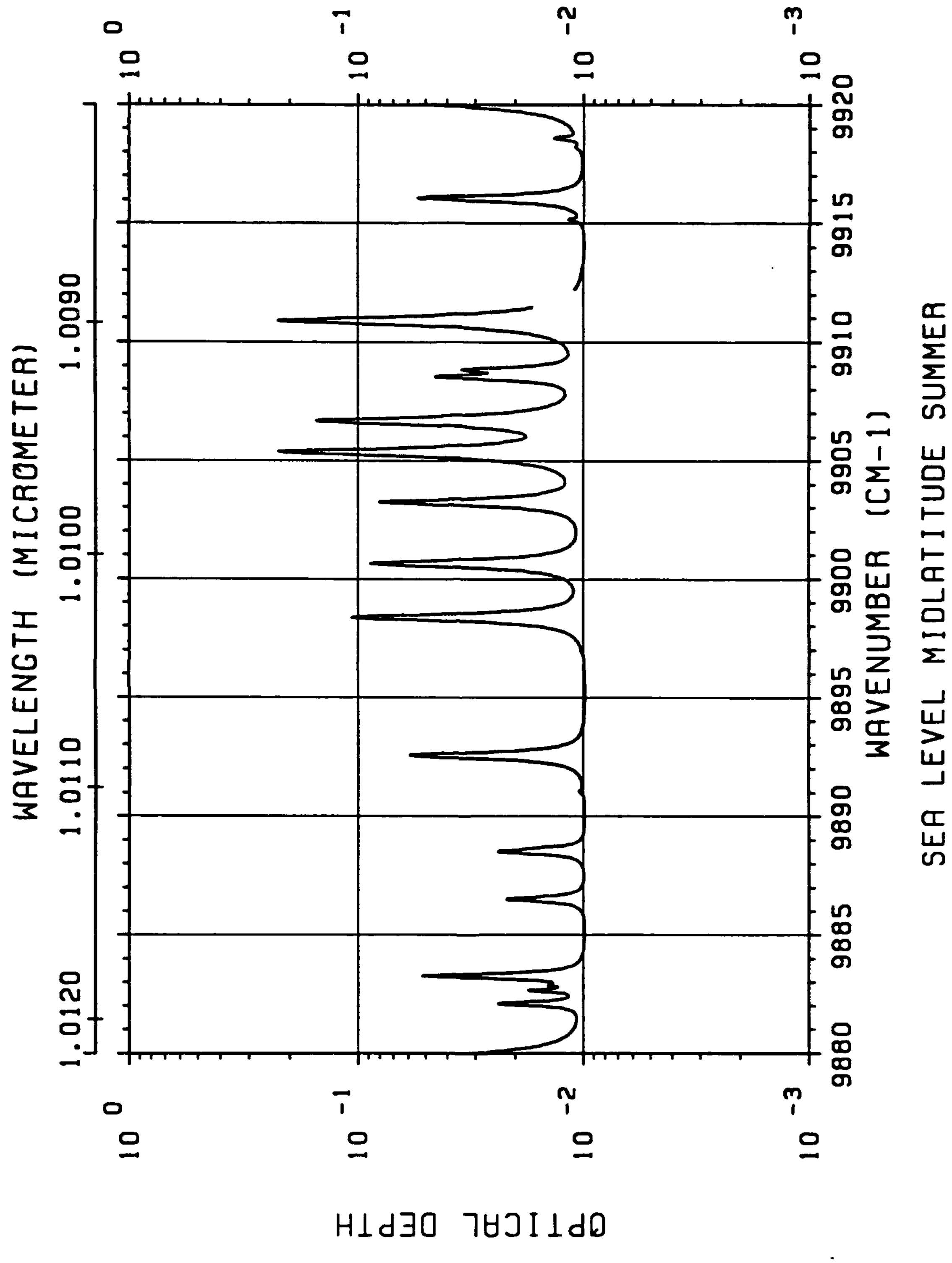

WAVELENGTH (MICROMETER)
1.0210
1.0220
1.0230
1.0240
WAVENUMBER (CM-1)
9760
9765
9770
9775
9780
9785
9790
9795
9800
OPTICAL DEPTH
10^0
10^-1
10^-2
10^-3
SEA LEVEL MIDLATITUDE SUMMER

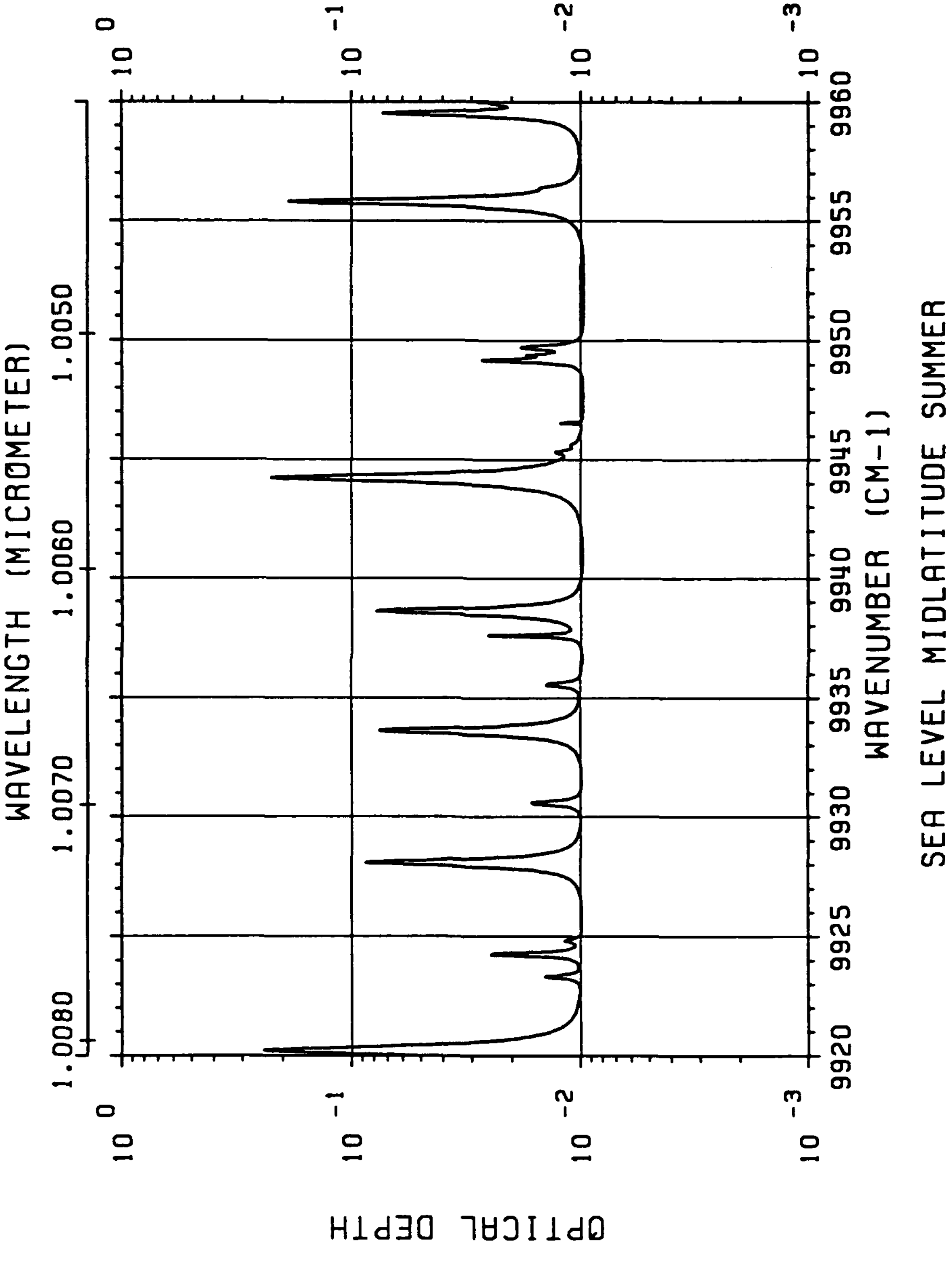


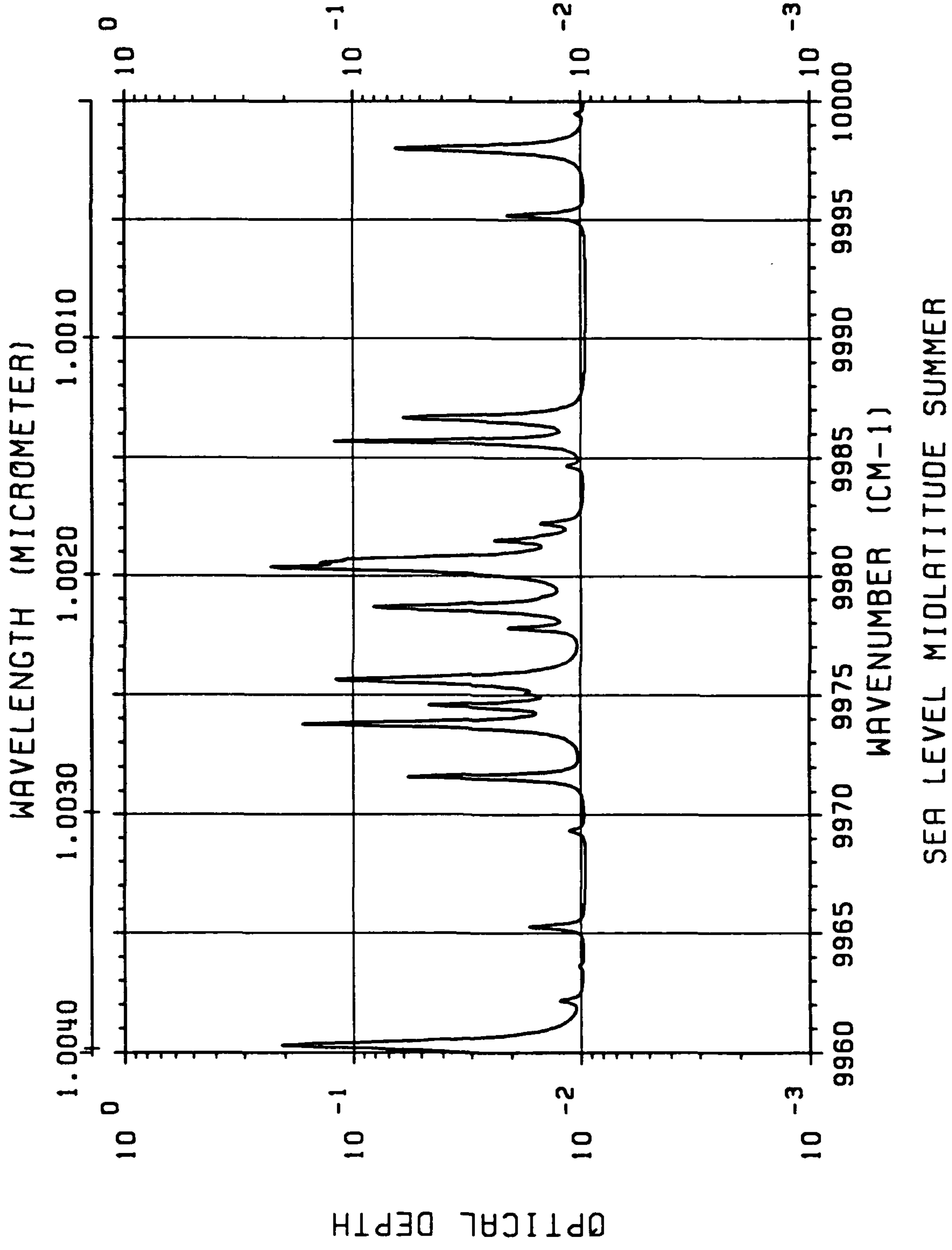
WAVELENGTH (MICROMETER)
1.0170
1.0180
1.0190
1.0200
WAVENUMBER (CM-1)
9800
9805
9810
9815
9820
9825
9830
9835
9840
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH
$10^{0}$
$10^{-1}$
$10^{-2}$
$10^{-3}$



WAVELENGTH (MICROMETER)
1.0130
1.0140
1.0150
1.0160
OPTICAL DEPTH
WAVENUMBER (CM-1)
9840
9845
9850
9855
9860
9865
9870
9875
9880
SEA LEVEL MIDLATITUDE SUMMER


WAVELENGTH (MICRØMETER)
1.0090
1.0100
1.0110
1.0120
10^0
10^-1
10^-2
10^-3
9880
9885
9890
9895
9900
9905
9910
9915
9920
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
ØPTICAL DEPTH


WAVELENGTH (MICRØMETER)
1.0080
1.0070
1.0060
1.0050
OPTICAL DEPTH
10^0
10^-1
10^-2
10^-3
9920
9925
9930
9935
9940
9945
9950
9955
9960
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER


WAVELENGTH (MICROMETER)
1.0040
1.0030
1.0020
1.0010
10^0
10^-1
10^-2
10^-3
9960
9965
9970
9975
9980
9985
9990
9995
10000
WAVENUMBER (CM-1)
SEA LEVEL MIDLATITUDE SUMMER
OPTICAL DEPTH