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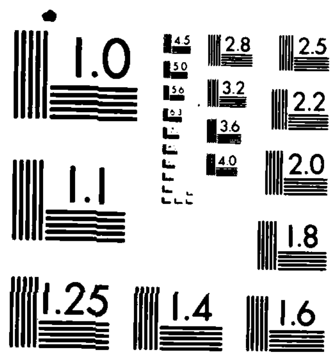
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AFGL-TR-85-0015

A USER'S GUIDE TO THE AFGL/VISIDYNE HIGH ALTITUDE INFRARED RADIANCE MODEL COMPUTER PROGRAM

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A.P. D'Agati

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AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
HANSCOM AFB, MASSACHUSETTS 01731

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This report describes the input data and control statements required to run the AFGL/Visidyne High Altitude Infrared Radiance Model, which computes infrared radiances for an earth's limb viewing geometry. Several sets of model atmosphere data, based on the U.S. Standard Atmosphere Supplement, 1966, have been added to the data set. Recent additions to the model are described briefly.

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1. INTRODUCTION

The Air Force and other Department of Defense agencies have for many years supported the development and improvement of infrared radiance and transmission models of the atmosphere. These models are designed to simulate the radiative properties of the atmosphere to provide predictions for Air Force and other Department of Defense system design and surveillance programs. Comparison with available experimental measurements provides greater understanding of the atmosphere and serves to check the adequacy of the models.

This report is intended to provide a User's Guide to such a radiance model, the AFGL/Visidyne High Altitude Infrared Radiance Model. This model is designed to partially simulate the earth's atmospheric radiance in an earth's limb viewing geometry. The nominal spectral interval included at present lies between 2.0 and 40 micrometers. Emphasis is placed on radiation originating between 60 and 250 km, although the model has been used to provide approximate radiance values for tangent heights as low as 50 km and as high as 500 km.

Various versions of this model have been described by Degges[1,2] and by Degges and Smith [3]. Degges[1] gave a listing of the program with a very brief description of program logical flow. This model was restricted to altitudes above 60 km altitude, and included the infrared active gasses, methane, carbon dioxide, water vapor, nitrous oxide, nitric oxide, and ozone. The spectral region covered was between five and twenty-five micrometers, and only a few vibrational levels were included for each species. At the time of this report, there were very few experimental observations of the abundance of infrared emmitting molecules at the altitudes required by the program. This work included an additional computer program to estimate diurnal variation in the chemical species of interest, to investigate the effects of changes in assumed eddy mixing coefficients, and to estimate the effects of new determinations of chemical rate coefficients. This work on the chemistry has not been updated since, and we currently prefer to rely on more up-to-date published calculations and observational determinations of chemical species abundances.

The principal areas of research and program revision reported by Degges[2] and Degges and Smith[3] included a further study of band radiance modeling and the effects of the line shape on radiance computations. In addition to some exploratory calculations using a Voigt line profile instead of a Doppler line shape, some asymptotic analytical results were obtained which provided an estimate of the accuracy of the numerically obtained band functions at large optical thicknesses. It was found that when a Voigt profile is used, the connection between the band models and functions for a single line is more readily seen than when a Doppler line shape is used. The program described here continues to be based on a model with Doppler line shape. This restricts the lower altitude for accurate quantitative results to about 60 km.

Since that work, there have been several modifications to the computer program. Additional carbon dioxide and ozone bands have been added, the option of computing radiative cooling (or heating) rates has been added, and some aspects of the computational method used in computing carbon dioxide and ozone vibrational populations have been revised. The addition of the carbon dioxide bands was straight-forward, but more effort was required in adding ozone bands to the ten to twelve micrometer "window" region.

In addition to model changes, we have used the U.S. Standard Atmosphere Supplements, 1966[4] to provide a set of atmospheric input data which can be used to demonstrate some of the large scale effects of temporal and latitudinal variations of the atmosphere. Section 2 presents this atmospheric data set. Section 3 provides a description of use of the computer implementation of the model on the AFGL computer system. Section 4 describes the effort to expand the ozone radiance part of the model.

2. DATA FOR MOLECULAR CONCENTRATIONS AND INFRARED RADIANCES

The principal data required for calculation of non-equilibrium infrared radiances include the concentrations of atmospheric species, the rate coefficients for collisional excitation of infrared emitting vibrational levels and infrared band strengths and solar flux values. In previous work we have usually used one of the U.S. Standard Atmospheres (1962[5] or 1976[6]) for information on molecular nitrogen and oxygen and atomic oxygen, and other sources for the concentration of the infrared emitting species. We follow this practice here, in providing a number of data sets for the principal atmospheric species and what is essentially a single set of concentrations for CO_2, H_2O, NO, O_3, and CO. We retain the use of concentrations based on the U.S. Standard Atmosphere, 1976[6], and supplement it with 24 other data sets based on the U.S. Standard Atmosphere Supplements, 1966[4].

The U.S. Standard Atmosphere Supplements, 1966[4] provides model atmospheres for altitudes up to 120 km at 15 degree latitude intervals between 15 and 60 degrees north latitude. The tropic model at 15 degrees latitude is assumed constant year round. Winter and summer models are provided for the other latitudes, and a spring or fall model is added at 45 degrees. High altitude atmospheres are given for combinations of winter, summer, or spring/fall conditions and exospheric temperatures between 500 and 2500 K to simulate variations in the solar cycle. We have selected a set of these upper atmosphere models (600, 1000, 1500 K exospheric temperatures) to make possible calculations that can illustrate aspects of atmospheric variability. We use temperature profiles and sea level pressure to compute concentrations of N_2 and O_2 up to 90 or 110 km, assuming constant mixing up to 110 km and match the high altitude profiles with the computed lower atmosphere concentrations.

Table 1 lists temperature profiles below 90 km for eight atmospheres from the 1966 Supplements. Table 2 lists nine high altitude temperature and concentration profiles, again from the 1966 Supplements. Table 3 gives the temperature profiles for the 24 atmospheres produced by combining the information in Tables 1 and 2, as well as the 1976 Standard Temperature Profile[6]. Table 4 gives day and night atomic oxygen profiles for the nine atmospheres of Table 2. These are the same as those used with the 1976 Standard Atmosphere up to 120 km. Table 5 lists high altitude concentrations for the 1976 Standard Atmosphere.

For the other species, we use the model of Degges and Smith[3] except for water vapor and carbon monoxide mixing ratios from the calculations by Allen et al.[7]. This model assumes a constant mixing rate for CO_2 up to 110 km, with diffusive equilibrium above that altitude. This results in daytime concentrations that are too large, probably by a factor of two or more above 150 km. Our nitric oxide concentrations are based on the twilight measurements of Baker et al.[8] and on the calculations of Oran et al.[9]. The "Day Time" nitric oxide concentrations are better described as referring to high latitude conditions. The "Night Time" ones are closer to mid-latitude conditions.

Below 60 km, we use the ozone model in the U. S. Standard Atmosphere, 1976. Above that altitude, our models rely heavily on measurements by Llewellyn and Witt[10] and Hays and Roble[11]. The calculations of Thomas and Bowman[12] have been used as a guide to predict diurnal variations in abundances. Diffusive equilibrium is assumed above 100 km.

These concentration profiles should be viewed as models, and not considered to represent current knowledge of the atmosphere. Work is in progress at AFGL to provide better concentration profiles based on the Mesospheric Explorer Satellite data. The current models will then be revised to reflect this new experimental information.

Some rates for collisional de-excitation of vibrational levels have been taken from Taylor[13, 14]. We continue to use the nitric oxide quenching by atomic oxygen rates given by Glanzer and Troe[15]. The water vapor calculations have been revised to use the quenching rates of Hovis and Moore[16] and Finzi et al.[17]. We use new rates suggested by R. Sharma[18] for CO_2 15 μm bands.

Tables 6 through 10 list the molecular bands and related physical data now included in the programs. Band strengths for water vapor, carbon dioxide, ozone, and carbon monoxide are those used in the AFGL absorption line atlas first described by McClatchey et al.[19]. Band strengths for nitric oxide are approximately those of Abels and Shaw[20] and Schurin and Ellis[21]. Infrared solar fluxes at band centers are interpolated from the tabulation of Johnson[22].

TABLE 1. DEFINING ALTITUDES, TEMPERATURES, AND SEA LEVEL PRESSURE FOR LOWER ALTITUDE MODEL ATMOSPHERES.

```
TEMP 15 ANNUAL  001        U.S. STND. ATM. 1966
    0.00  299.65    2.26  286.15    2.51  286.95   16.58  193.15
   23.13  215.15   47.46  270.15   51.53  270.15   59.69  254.15
   82.24  177.15   90.48  177.15  101.84  199.15  112.21  270.65
  119.70  410.90
PRES 15 ANNUAL  001
   1013.25

TEMP 30 JANURY  002        U.S. STND. ATM. 1966
    0.00  287.15    2.00  281.15   12.04  216.15   17.07  203.15
   18.08  203.15   22.11  213.15   32.21  233.15   47.42  269.15
   51.48  269.15   59.64  253.15   80.11  191.15   89.36  191.15
  101.74  233.15  112.10  290.85  119.82  355.90
PRES 30 JANURY  002
   1021.00

TEMP 30 JULY    003        U.S. STND. ATM. 1966
    0.00  301.15    1.00  293.65    6.01  266.15   15.06  203.15
   16.06  203.15   21.10  214.15   32.21  236.15   47.42  272.15
   51.48  272.15   59.64  256.15   82.16  172.55   90.39  172.55
  101.74  198.95  112.10  283.25  119.82  410.90
PRES 30 JULY    003
   1013.50

TEMP 45 JANURY  004        U.S. STND. ATM. 1966
    0.00  272.15    3.01  261.65   10.02  219.65   19.06  215.15
   27.11  215.15   32.16  219.15   47.35  265.65   52.43  265.65
   64.65  241.65   85.12  199.65   91.29  199.65  101.60  227.65
  111.94  282.25  120.00  355.90
PRES 45 JANURY  004
   1018.00
```

TABLE 1. DEFINING ALTITUDES, TEMPERATURES, AND SEA LEVEL PRESSURE FOR LOWER ALTITUDE MODEL ATMOSPHERES.

```
TEMP 45 JULY     005         U.S. STND. ATM. 1966
    0.00  294.15     2.00  285.15     6.01  261.15    13.03  215.65
   17.05  215.65    27.11  227.65    32.16  238.15    47.35  275.65
   52.43  275.65    62.61  250.65    82.05  165.15    90.26  165.15
  101.60  200.35   111.94  295.25   120.00  410.90
PRES 45 JULY     005
   1013.50

TEMP 45 SP/FAL   006         U.S. STND. ATM. 1966
    0.00  288.15    11.02  216.65    20.06  216.65    32.16  228.65
   47.35  270.65    52.43  270.65    61.59  252.65    69.76  220.65
   79.99  190.65    91.29  190.65   101.60  210.65   111.94  254.25
  120.00  382.24
PRES 45 SP/FAL   006
   1013.25

TEMP 60 JANURY   007         U.S. STND. ATM. 1966
    0.00  257.15     1.00  259.15     3.50  251.15     8.50  217.15
   15.02  217.15    25.07  211.15    34.15  220.15    50.33  260.15
   54.39  260.15    59.48  251.15    69.67  246.15    90.15  202.15
  101.46  226.35   111.79  273.15   120.15  355.90
PRES 60 JANURY   007
   1013.50

TEMP 60 JULY     008         U.S. STND. ATM. 1966
    0.00  287.15     5.00  260.15    10.00  225.15    23.05  225.15
   32.12  238.65    43.24  271.65    48.30  277.15    53.38  277.15
   59.48  265.15    81.94  161.75    90.15  161.75   101.46  200.25
  111.79  303.45   120.15  410.90
PRES 60 JULY     008
   1010.00
```

TABLE 2. TEMPERATURE AND MOLECULAR NUMBER DENSITIES OF HIGH ALTITUDE MODEL ATMOSPHERES.

WINTER MODEL, 600 K EXOS.TEMP

120.00	333.50	5.7943E+11	1.1350E+11	9.6383E+10
125.00	361.60	3.3806E+11	6.2087E+10	6.8549E+10
130.00	386.80	2.0654E+11	3.5727E+10	5.0234E+10
135.00	408.90	1.3122E+11	2.1429E+10	3.7844E+10
140.00	428.90	8.5704E+10	1.3274E+10	2.8445E+10
145.00	446.60	5.7412E+10	8.4333E+09	2.2751E+10
150.00	462.80	3.9174E+10	5.4828E+09	1.7989E+10
160.00	490.70	1.9099E+10	2.4322E+09	1.1641E+10
170.00	513.30	9.7724E+09	1.1376E+09	7.7804E+09
180.00	532.10	5.1761E+09	5.5463E+08	5.3333E+09
190.00	547.60	2.8249E+09	2.7861E+08	3.7325E+09
200.00	561.00	1.5740E+09	1.4322E+08	2.6424E+09
225.00	587.20	3.9264E+08	2.9512E+07	1.1722E+09
250.00	593.70	1.0593E+08	6.6222E+06	5.5208E+08
275.00	596.90	2.9309E+07	1.5276E+06	2.6424E+08
300.00	598.40	8.2414E+06	3.5892E+05	1.2794E+08
350.00	599.60	6.7764E+05	2.0701E+04	3.0690E+07
400.00	599.90	5.8210E+04	1.2503E+03	7.5509E+06
450.00	600.00	5.1761E+03	7.8806E+01	1.8967E+06
500.00	600.00	4.7643E+02	5.1761E+00	4.8641E+05
600.00	600.00	4.4875E+00	2.5119E-02	3.3806E+04
700.00	600.00	4.8306E-02	1.4191E-04	2.5410E+03

TABLE 2. TEMPERATURE AND MOLECULAR NUMBER DENSITIES OF HIGH ALTITUDE MODEL ATMOSPHERES.

WINTER MODEL, 1000 K EXOS.TEMP

120.00	334.10	5.7943E+11	1.1376E+11	9.6383E+10
125.00	407.20	3.0974E+11	5.7148E+10	6.1944E+10
130.00	472.00	1.8621E+11	3.2584E+10	4.3451E+10
135.00	527.80	1.2134E+11	2.0277E+10	3.2434E+10
140.00	577.90	8.3176E+10	1.3366E+10	2.5177E+10
145.00	621.60	5.9429E+10	9.2045E+09	2.0137E+10
150.00	661.20	4.3652E+10	6.5313E+09	1.0444E+10
160.00	728.10	2.5235E+10	3.5318E+09	1.1535E+10
170.00	782.30	1.5488E+10	2.0464E+09	8.4528E+09
180.00	826.70	9.9312E+09	1.2417E+09	6.4121E+09
190.00	863.10	6.5760E+09	7.7983E+08	4.9774E+09
200.00	893.20	4.4668E+09	5.0350E+08	3.9264E+09
225.00	949.70	1.8155E+09	1.8155E+08	2.2856E+09
250.00	983.30	7.9616E+08	7.1121E+07	1.4060E+09
275.00	991.70	3.6475E+08	2.9242E+07	8.9743E+08
300.00	995.90	1.6982E+08	1.2218E+07	5.7943E+08
350.00	999.00	3.7844E+07	2.1979E+06	2.4547E+08
400.00	999.80	8.6497E+06	4.0738E+05	1.0568E+08
450.00	999.90	2.0277E+06	7.7625E+04	4.6132E+07
500.00	1000.00	4.8417E+05	1.5171E+04	2.0370E+07
600.00	1000.00	2.9512E+04	6.1944E+02	4.1210E+06
700.00	1000.00	1.9454E+03	2.7733E+01	8.7096E+05

TABLE 2. TEMPERATURE AND MOLECULAR NUMBER DENSITIES OF HIGH ALTITUDE MODEL ATMOSPHERES.

WINTER MODEL, 1500 K EXOS.TEMP

120.00	333.30	5.8076E+11	1.1376E+11	9.6605E+10
125.00	429.00	2.9648E+11	5.4828E+10	5.9156E+10
130.00	516.30	1.7620E+11	3.0974E+10	4.0551E+10
135.00	594.50	1.1508E+11	1.9409E+10	2.9923E+10
140.00	666.60	7.9799E+10	1.3002E+10	2.3121E+10
145.00	732.60	5.7943E+10	9.1411E+09	1.8493E+10
150.00	793.60	4.3451E+10	6.6681E+09	1.5136E+10
160.00	901.60	2.6363E+10	3.8371E+09	1.0780E+10
170.00	995.60	1.7179E+10	2.3823E+09	8.0910E+09
180.00	1077.00	1.1749E+10	1.5596E+09	6.2951E+09
190.00	1147.80	8.3176E+09	1.0617E+09	5.0350E+09
200.00	1209.20	6.0674E+09	7.4645E+08	4.1115E+09
225.00	1329.70	2.9992E+09	3.3884E+08	2.6363E+09
250.00	1420.00	1.6106E+09	1.6749E+08	1.7989E+09
275.00	1452.00	9.2683E+08	8.0536E+07	1.2972E+09
300.00	1471.20	5.4576E+08	4.8978E+07	9.5280E+08
350.00	1489.70	1.9634E+08	1.5276E+07	5.2966E+08
400.00	1496.30	7.2946E+07	4.9204E+06	2.9992E+08
450.00	1498.70	2.7606E+07	1.6255E+06	1.7219E+08
500.00	1499.50	1.0641E+07	5.4576E+05	9.9770E+07
600.00	1499.90	1.6444E+06	6.4714E+04	3.4356E+07
700.00	1500.00	2.6792E+05	8.1658E+03	1.2190E+07

TABLE 2. TEMPERATURE AND MOLECULAR NUMBER DENSITIES OF HIGH ALTITUDE MODEL ATMOSPHERES.

SUMMER MODEL, 600 K EXOS.TEMP

120.00	380.00	3.1623E+11	5.7943E+10	6.4565E+10
125.00	413.00	1.9498E+11	3.3729E+10	4.7206E+10
130.00	441.20	1.2589E+11	2.0654E+10	3.5810E+10
135.00	464.20	8.4333E+10	1.3152E+10	2.7861E+10
140.00	483.90	5.7943E+10	8.6298E+09	2.2080E+10
145.00	499.80	4.0738E+10	5.7810E+09	1.7783E+10
150.00	513.60	2.8973E+10	3.9446E+09	1.4488E+10
160.00	535.00	1.5276E+10	1.9099E+09	9.8855E+09
170.00	550.20	8.3368E+09	9.5940E+08	6.9024E+09
180.00	561.10	4.6559E+09	4.9431E+08	4.9091E+09
190.00	568.20	2.6485E+09	2.6002E+08	3.5318E+09
200.00	574.10	1.5171E+09	1.3804E+08	2.5645E+09
225.00	587.20	3.9264E+08	2.9512E+07	1.1722E+09
250.00	593.70	1.0593E+08	6.6222E+06	5.5208E+08
275.00	596.90	2.9309E+07	1.5276E+06	2.6424E+08
300.00	598.40	8.2414E+06	3.5892E+05	1.2794E+08
350.00	599.60	6.7920E+05	2.0701E+04	3.0690E+07
400.00	599.90	5.8210E+04	1.2503E+03	7.5509E+06
450.00	600.00	5.1761E+03	7.8886E+01	1.8967E+06
500.00	600.00	4.7753E+02	5.1880E+00	4.8529E+05
600.00	600.00	4.4978E+00	2.5119E-02	3.3806E+04
700.00	600.00	4.8306E-02	1.4191E-04	2.5410E+03

TABLE 2. TEMPERATURE AND MOLECULAR NUMBER DENSITIES OF HIGH ALTITUDE MODEL ATMOSPHERES.

SUMMER MODEL, 1000 K EXOS.TEMP

120.00	379.30	3.1405E+11	5.7412E+10	6.4269E+10
125.00	469.20	1.7418E+11	3.0200E+10	4.1976E+10
130.00	547.80	1.0940E+11	1.8113E+10	3.0061E+10
135.00	614.20	7.4131E+10	1.1830E+10	2.2961E+10
140.00	671.90	5.3088E+10	8.1658E+09	1.8239E+10
145.00	720.20	3.9446E+10	5.8884E+09	1.4928E+10
150.00	761.90	3.0130E+10	4.3652E+09	1.2503E+10
160.00	826.60	1.8707E+10	2.5586E+09	9.2045E+09
170.00	872.90	1.2246E+10	1.5885E+09	7.0469E+09
180.00	906.30	8.2985E+09	1.0233E+09	5.5590E+09
190.00	930.10	5.7544E+09	6.7764E+08	4.4566E+09
200.00	947.10	4.0551E+09	4.5499E+08	3.6224E+09
225.00	968.80	1.7742E+09	1.7742E+08	2.2387E+09
250.00	983.30	7.9616E+08	7.1121E+07	1.4060E+09
275.00	991.70	3.6475E+08	2.9242E+07	8.9743E+08
300.00	995.90	1.6982E+08	1.2218E+07	5.7943E+08
350.00	999.00	3.7844E+07	2.1979E+06	2.4547E+08
400.00	999.80	8.6497E+06	4.0832E+05	1.0568E+08
450.00	999.90	2.0277E+06	7.7625E+04	4.6132E+07
500.00	1000.00	4.8417E+05	1.5171E+04	2.0370E+07
600.00	1000.00	2.9512E+04	6.1944E+02	4.1115E+06
700.00	1000.00	1.9454E+03	2.7733E+01	8.7096E+05

TABLE 2. TEMPERATURE AND MOLECULAR NUMBER DENSITIES OF HIGH ALTITUDE MODEL ATMOSPHERES.

SUMMER MODEL, 1500 K EXOS.TEMP

120.00	379.80	3.1261E+11	5.7148E+10	6.4121E+10
125.00	499.50	1.6520E+11	2.8642E+10	3.9628E+10
130.00	607.80	1.0186E+11	1.6982E+10	2.7669E+10
135.00	704.40	6.9024E+10	1.1117E+10	2.0797E+10
140.00	791.40	4.9774E+10	7.7625E+09	1.6406E+10
145.00	868.40	3.7497E+10	5.6885E+09	1.3397E+10
150.00	937.30	2.9174E+10	4.3251E+09	1.1220E+10
160.00	1051.00	1.8923E+10	2.6853E+09	8.3560E+09
170.00	1141.00	1.3092E+10	1.7824E+09	6.5464E+09
180.00	1211.20	9.4624E+09	1.2388E+09	5.2966E+09
190.00	1266.80	7.0307E+09	8.8920E+08	4.3853E+09
200.00	1310.60	5.3456E+09	6.5313E+08	3.6898E+09
225.00	1383.10	2.8576E+09	3.2137E+08	2.5235E+09
250.00	1420.00	1.6106E+09	1.6749E+08	1.7989E+09
275.00	1452.00	9.2683E+08	8.9536E+07	1.3002E+09
300.00	1471.20	5.4450E+08	4.8978E+07	9.5499E+08
350.00	1489.70	1.9634E+08	1.5276E+07	5.2966E+08
400.00	1496.30	7.2946E+07	4.9204E+06	2.9992E+08
450.00	1498.70	2.7606E+07	1.6255E+06	1.7219E+08
500.00	1499.50	1.0617E+07	5.4576E+05	9.9770E+07
600.00	1499.90	1.6444E+06	6.4714E+04	3.4356E+07
700.00	1500.00	2.6792E+05	8.1658E+03	1.2218E+07

TABLE 2. TEMPERATURE AND MOLECULAR NUMBER DENSITIES OF HIGH ALTITUDE MODEL ATMOSPHERES.

SPRING/FALL MODEL, 600 K EXOS.TEMP

120.00	355.00	3.9994E+11	7.4989E+10	7.6033E+10
125.00	387.10	2.3878E+11	4.2170E+10	5.4576E+10
130.00	415.00	1.4997E+11	2.5003E+10	4.0644E+10
135.00	439.30	9.7949E+10	1.5488E+10	3.1046E+10
140.00	460.30	6.5615E+10	9.8855E+09	2.4210E+10
145.00	478.60	4.5082E+10	6.4714E+09	1.9231E+10
150.00	494.60	3.1550E+10	4.3251E+09	1.5453E+10
160.00	520.40	1.6144E+10	2.0230E+09	1.0304E+10
170.00	539.90	8.6099E+09	9.9312E+08	7.0958E+09
180.00	554.60	4.7315E+09	5.0350E+08	4.9774E+09
190.00	565.70	2.6607E+09	2.6122E+08	3.5481E+09
200.00	574.10	1.5171E+09	1.3804E+08	2.5645E+09
225.00	587.20	3.9264E+08	2.9512E+07	1.1722E+09
250.00	593.70	1.0593E+08	6.6222E+06	5.5208E+08
275.00	596.90	2.9309E+07	1.5276E+06	2.6424E+08
300.00	598.40	8.2414E+06	3.5892E+05	1.2794E+08
350.00	599.60	6.7920E+05	2.0701E+04	3.0761E+07
400.00	599.90	5.8210E+04	1.2503E+03	7.5509E+06
450.00	600.00	5.1761E+03	7.8886E+01	1.8967E+06
500.00	600.00	4.7753E+02	5.1880E+00	4.8641E+05
600.00	600.00	4.4978E+00	2.5119E-02	3.3806E+04
700.00	600.00	4.8306E-02	1.4191E-04	2.5410E+03

TABLE 2. TEMPERATURE AND MOLECULAR NUMBER DENSITIES OF HIGH ALTITUDE MODEL ATMOSPHERES.

SPRING/FALL MODEL, 1000 K EXOS.TEMP

120.00	355.00	3.9994E+11	7.4989E+10	7.6033E+10
125.00	439.50	2.1627E+11	3.8282E+10	4.8865E+10
130.00	513.00	1.3274E+11	2.2439E+10	3.4594E+10
135.00	576.90	8.0308E+10	1.4322E+10	2.6062E+10
140.00	632.30	6.1944E+10	9.6828E+09	2.0464E+10
145.00	680.50	4.5290E+10	6.8391E+09	1.6558E+10
150.00	722.40	3.4041E+10	4.9774E+09	1.3740E+10
160.00	790.40	2.0559E+10	2.8314E+09	9.8855E+09
170.00	841.80	1.3152E+10	1.7140E+09	7.4645E+09
180.00	880.50	8.7297E+09	1.0814E+09	5.7943E+09
190.00	909.80	5.9704E+09	7.0307E+08	4.6026E+09
200.00	931.90	4.1591E+09	4.6666E+08	3.6983E+09
225.00	966.30	1.7783E+09	1.7783E+08	2.2439E+09
250.00	983.30	7.9616E+08	7.1121E+07	1.4060E+09
275.00	991.70	3.6475E+08	2.9242E+07	8.9743E+08
300.00	995.90	1.6982E+08	1.2218E+07	5.7943E+08
350.00	999.00	3.7844E+07	2.1979E+06	2.4547E+08
400.00	999.80	8.6497E+06	4.0832E+05	1.0568E+08
450.00	999.90	2.0277E+06	7.7625E+04	4.6132E+07
500.00	1000.00	4.8529E+05	1.5171E+04	2.0370E+07
600.00	1000.00	2.9512E+04	6.1944E+02	4.1210E+06
700.00	1000.00	1.9454E+03	2.7733E+01	8.7096E+05

TABLE 2. TEMPERATURE AND MOLECULAR NUMBER DENSITIES OF HIGH ALTITUDE MODEL ATMOSPHERES.

SPRING/FALL MODEL, 1500 K EXOS.TEMP

120.00	355.00	3.9994E+11	7.4989E+10	7.6033E+10
125.00	466.40	2.0654E+11	3.6644E+10	4.6345E+10
130.00	566.90	1.2474E+11	2.1184E+10	3.1989E+10
135.00	657.70	8.2985E+10	1.3583E+10	2.3768E+10
140.00	739.60	5.8884E+10	9.3325E+09	1.8578E+10
145.00	813.60	4.3652E+10	6.7143E+09	1.5031E+10
150.00	880.40	3.3497E+10	5.0234E+09	1.2474E+10
160.00	995.00	2.1184E+10	3.0269E+09	9.1201E+09
170.00	1088.50	1.4322E+10	1.9634E+09	7.0146E+09
180.00	1164.70	1.0139E+10	1.3366E+09	5.5976E+09
190.00	1226.70	7.4302E+09	9.4189E+08	4.5814E+09
200.00	1277.30	5.5590E+09	6.8077E+08	3.8194E+09
225.00	1366.50	2.8973E+09	3.2659E+08	2.5586E+09
250.00	1420.00	1.6106E+09	1.6788E+08	1.7989E+09
275.00	1452.00	9.2683E+08	8.9536E+07	1.2972E+09
300.00	1471.20	5.4576E+08	4.8978E+07	9.5280E+08
350.00	1489.70	1.9634E+08	1.5276E+07	5.2966E+08
400.00	1496.30	7.2946E+07	4.9317E+06	2.9992E+08
450.00	1498.70	2.7606E+07	1.6255E+06	1.7219E+08
500.00	1499.50	1.0641E+07	5.4702E+05	9.9770E+07
600.00	1499.90	1.6444E+06	6.4863E+04	3.4356E+07
700.00	1500.00	2.6792E+05	8.1658E+03	1.2190E+07

TABLE 3. TEMPERATURE PROFILES FOR MODEL ATMOSPHERES.

TEMP 15 ANNUAL 001 U.S. STND. ATM. 1966

SUMMER MODEL, 600 K EXOS.TEMP

0.00	299.65	2.26	286.15	2.51	286.95	16.58	193.15
23.13	215.15	47.46	270.15	51.53	270.15	59.69	254.15
82.24	177.15	90.48	177.15	101.84	199.15	112.21	270.65
118.00	360.00	120.00	390.00	125.00	413.00	130.00	441.20
135.00	464.20	140.00	483.90	145.00	499.80	150.00	513.60
160.00	535.00	170.00	550.20	180.00	561.10	190.00	568.20
200.00	574.10	225.00	587.20	250.00	593.70	275.00	596.90
300.00	598.40	350.00	599.60	400.00	599.90	700.00	600.00

PRES 15 ANNUAL 001

1013.25

TEMP 15 ANNUAL 001 U.S. STND. ATM. 1966

SUMMER MODEL, 1000 K EXOS.TEMP

0.00	299.65	2.26	286.15	2.51	286.95	16.58	193.15
23.13	215.15	47.46	270.15	51.53	270.15	59.69	254.15
82.24	177.15	90.48	177.15	101.84	199.15	112.21	270.65
118.00	360.00	120.00	390.00	125.00	469.20	130.00	547.80
135.00	614.20	140.00	671.90	145.00	720.20	150.00	761.90
160.00	826.60	170.00	872.90	180.00	906.30	190.00	930.10
200.00	947.10	225.00	968.80	250.00	983.30	275.00	991.70
300.00	995.90	350.00	999.00	400.00	999.80	700.00	1000.00

PRES 15 ANNUAL 001

1013.25

TEMP 15 ANNUAL 001 U.S. STND. ATM. 1966

SUMMER MODEL, 1500 K EXOS.TEMP

0.00	299.65	2.26	286.15	2.51	286.95	16.58	193.15
23.13	215.15	47.46	270.15	51.53	270.15	59.69	254.15
82.24	177.15	90.48	177.15	101.84	199.15	112.21	270.65
118.00	360.00	120.00	390.00	125.00	499.50	130.00	607.80
135.00	704.40	140.00	791.40	145.00	868.40	150.00	937.30
160.00	1051.00	170.00	1141.00	180.00	1211.20	190.00	1266.80
200.00	1310.60	225.00	1383.10	250.00	1420.00	275.00	1452.00
300.00	1471.20	350.00	1489.70	400.00	1496.30	450.00	1498.70
500.00	1499.50	600.00	1499.90	700.00	1500.00	800.00	1501.00

PRES 15 ANNUAL 001

1013.25

TABLE 3. TEMPERATURE PROFILES FOR MODEL ATMOSPHERES.

TEMP 30 JANURY 002 U.S. STND. ATM. 1966
WINTER MODEL, 600 K EXOS.TEMP

0.00	287.15	2.00	281.15	12.04	216.15	17.07	203.15
18.08	203.15	22.11	213.15	32.21	233.15	47.42	269.15
51.48	269.15	59.64	253.15	80.11	191.15	89.36	191.15
101.74	233.15	112.10	290.85	118.00	333.00	120.00	333.50
125.00	361.60	130.00	386.80	135.00	408.90	140.00	428.90
145.00	446.60	150.00	462.80	160.00	490.70	170.00	513.30
180.00	532.10	190.00	547.60	200.00	561.00	225.00	587.20
250.00	593.70	275.00	596.90	300.00	598.40	350.00	599.60
400.00	599.90	700.00	600.00	500.00	600.00	600.00	600.00

PRES 30 JANURY 002
1021.00

TEMP 30 JANURY 002 U.S. STND. ATM. 1966
WINTER MODEL, 1000 K EXOS.TEMP

0.00	287.15	2.00	281.15	12.04	216.15	17.07	203.15
18.08	203.15	22.11	213.15	32.21	233.15	47.42	269.15
51.48	269.15	59.64	253.15	80.11	191.15	89.36	191.15
101.74	233.15	112.10	290.85	118.00	333.00	120.00	334.10
125.00	407.20	130.00	472.00	135.00	527.80	140.00	577.90
145.00	621.60	150.00	661.20	160.00	728.10	170.00	782.30
180.00	826.70	190.00	863.10	200.00	893.20	225.00	949.70
250.00	983.30	275.00	991.70	300.00	995.90	350.00	999.00
400.00	999.80	450.00	999.90	700.00	1000.00	600.00	1000.00

PRES 30 JANURY 002
1021.00

TEMP 30 JANURY 002 U.S. STND. ATM. 1966
WINTER MODEL, 1500 K EXOS.TEMP

0.00	287.15	2.00	281.15	12.04	216.15	17.07	203.15
18.08	203.15	22.11	213.15	32.21	233.15	47.42	269.15
51.48	269.15	59.64	253.15	80.11	191.15	89.36	191.15
101.74	233.15	112.10	290.85	118.00	333.00	120.00	333.30
125.00	429.00	130.00	516.30	135.00	594.50	140.00	666.60
145.00	732.60	150.00	793.60	160.00	901.60	170.00	995.60
180.00	1077.00	190.00	1147.80	200.00	1209.20	225.00	1329.70
250.00	1420.00	275.00	1452.00	300.00	1471.20	350.00	1489.70
400.00	1496.30	450.00	1498.70	500.00	1499.50	600.00	1499.90
700.00	1500.00	800.00	1501.00	900.00	1502.00	100.00	1503.00

PRES 30 JANURY 002
1021.00

TABLE 3. TEMPERATURE PROFILES FOR MODEL ATMOSPHERES.

TEMP 30 JULY 003 U.S. STND. ATM. 1966
SUMMER MODEL, 600 K EXOS.TEMP

0.00	301.15	1.00	293.65	6.01	266.15	15.06	203.15
16.06	203.15	21.10	214.15	32.21	236.15	47.42	272.15
51.48	272.15	59.64	256.15	82.16	172.55	90.39	172.55
101.74	198.95	112.10	283.25	118.00	335.00	120.00	380.00
125.00	413.00	130.00	441.20	135.00	464.20	140.00	483.90
145.00	499.80	150.00	513.60	160.00	535.00	170.00	550.20
180.00	561.10	190.00	568.20	200.00	574.10	225.00	587.20
250.00	593.70	275.00	596.90	300.00	598.40	350.00	599.60
400.00	599.90	700.00	600.00	500.00	600.00	600.00	600.00

PRES 30 JULY 003
1013.50

TEMP 30 JULY 003 U.S. STND. ATM. 1966
SUMMER MODEL, 1000 K EXOS.TEMP

0.00	301.15	1.00	293.65	6.01	266.15	15.06	203.15
16.06	203.15	21.10	214.15	32.21	236.15	47.42	272.15
51.48	272.15	59.64	256.15	82.16	172.55	90.39	172.55
101.74	198.95	112.10	283.25	118.00	335.00	120.00	379.30
125.00	469.20	130.00	547.80	135.00	614.20	140.00	671.90
145.00	720.20	150.00	761.90	160.00	826.60	170.00	872.90
180.00	906.30	190.00	930.10	200.00	947.10	225.00	968.80
250.00	983.30	275.00	991.70	300.00	995.90	350.00	999.00
400.00	993.80	450.00	999.90	700.00	1000.00	600.00	1000.00

PRES 30 JULY 003
1013.50

TEMP 30 JULY 003 U.S. STND. ATM. 1966
SUMMER MODEL, 1500 K EXOS.TEMP

0.00	301.15	1.00	293.65	6.01	266.15	15.06	203.15
16.06	203.15	21.10	214.15	32.21	236.15	47.42	272.15
51.48	272.15	59.64	256.15	82.16	172.55	90.39	172.55
101.74	198.95	112.10	283.25	118.00	335.00	120.00	379.80
125.00	499.50	130.00	607.80	135.00	704.40	140.00	791.40
145.00	868.40	150.00	937.30	160.00	1051.00	170.00	1141.00
180.00	1211.20	190.00	1266.80	200.00	1310.60	225.00	1383.10
250.00	1420.00	275.00	1452.00	300.00	1471.20	350.00	1489.70
400.00	1496.30	450.00	1498.70	500.00	1499.50	600.00	1499.90
700.00	1500.00	800.00	1501.00	900.00	1502.00	100.00	1503.00

PRES 30 JULY 003
1013.50

TABLE 3. TEMPERATURE PROFILES FOR MODEL ATMOSPHERES.

TEMP 45 JANURY 004 U.S. STND. ATM. 1966
WINTER MODEL, 600 K EXOS.TEMP

0.00	272.15	3.01	261.65	10.02	219.65	19.06	215.15
27.11	215.15	32.16	219.15	47.35	265.65	52.43	265.65
64.65	241.65	85.12	199.65	91.29	199.65	101.60	227.65
111.94	282.25	118.00	321.00	120.00	333.50	125.00	361.60
130.00	386.80	135.00	408.90	140.00	428.90	145.00	446.60
150.00	462.80	160.00	490.70	170.00	513.30	180.00	532.10
190.00	547.60	200.00	561.00	225.00	587.20	250.00	593.70
275.00	596.90	300.00	598.40	350.00	599.60	400.00	599.90
700.00	600.00	500.00	600.00	600.00	600.00	700.00	600.00

PRES 45 JANURY 004
1018.00

TEMP 45 JANURY 004 U.S. STND. ATM. 1966
WINTER MODEL, 1000 K EXOS.TEMP

0.00	272.15	3.01	261.65	10.02	219.65	19.06	215.15
27.11	215.15	32.16	219.15	47.35	265.65	52.43	265.65
64.65	241.65	85.12	199.65	91.29	199.65	101.60	227.65
111.94	282.25	118.00	321.00	120.00	334.10	125.00	407.20
130.00	472.00	135.00	527.80	140.00	577.90	145.00	621.60
150.00	661.20	160.00	728.10	170.00	782.30	180.00	826.70
190.00	863.10	200.00	893.20	225.00	949.70	250.00	983.30
275.00	991.70	300.00	995.90	350.00	999.00	400.00	999.80
450.00	999.90	700.00	1000.00	600.00	1000.00	700.00	1000.00

PRES 45 JANURY 004
1018.00

TEMP 45 JANURY 004 U.S. STND. ATM. 1966
WINTER MODEL, 1500 K EXOS.TEMP

0.00	272.15	3.01	261.65	10.02	219.65	19.06	215.15
27.11	215.15	32.16	219.15	47.35	265.65	52.43	265.65
64.65	241.65	85.12	199.65	91.29	199.65	101.60	227.65
111.94	282.25	118.00	321.00	120.00	333.30	125.00	429.00
130.00	516.30	135.00	594.50	140.00	666.60	145.00	732.60
150.00	793.60	160.00	901.60	170.00	995.60	180.00	1077.00
190.00	1147.80	200.00	1209.20	225.00	1329.70	250.00	1420.00
275.00	1452.00	300.00	1471.20	350.00	1489.70	400.00	1496.30
450.00	1498.70	500.00	1499.50	600.00	1499.90	700.00	1500.00

PRES 45 JANURY 004
1018.00

TABLE 3. TEMPERATURE PROFILES FOR MODEL ATMOSPHERES.

TEMP 45 JULY 005 U.S. STND. ATM. 1966
SUMMER MODEL, 600 K EXOS.TEMP

0.00	294.15	2.00	285.15	6.01	261.15	13.03	215.65
17.05	215.65	27.11	227.65	32.16	238.15	47.35	275.65
52.43	275.65	62.61	250.65	82.05	165.15	90.26	165.15
101.60	200.35	111.94	295.25	118.00	360.00	120.00	380.00
125.00	413.00	130.00	441.20	135.00	464.20	140.00	483.90
145.00	499.80	150.00	513.60	160.00	535.00	170.00	550.20
180.00	561.10	190.00	568.20	200.00	574.10	225.00	587.20
250.00	593.70	275.00	596.90	300.00	598.40	350.00	599.60
400.00	599.90	700.00	600.00	500.00	600.00	600.00	600.00

PRES 45 JULY 005
1013.50

TEMP 45 JULY 005 U.S. STND. ATM. 1966
SUMMER MODEL, 1000 K EXOS.TEMP

0.00	294.15	2.00	285.15	6.01	261.15	13.03	215.65
17.05	215.65	27.11	227.65	32.16	238.15	47.35	275.65
52.43	275.65	62.61	250.65	82.05	165.15	90.26	165.15
101.60	200.35	111.94	295.25	118.00	360.00	120.00	379.30
125.00	469.20	130.00	547.80	135.00	614.20	140.00	671.90
145.00	720.20	150.00	761.90	160.00	826.60	170.00	872.90
180.00	906.30	190.00	930.10	200.00	947.10	225.00	968.80
250.00	983.30	275.00	991.70	300.00	995.90	350.00	999.00
400.00	999.80	450.00	999.90	700.00	1000.00	600.00	1000.00

PRES 45 JULY 005
1013.50

TEMP 45 JULY 005 U.S. STND. ATM. 1966
SUMMER MODEL, 1500 K EXOS.TEMP

0.00	294.15	2.00	285.15	6.01	261.15	13.03	215.65
17.05	215.65	27.11	227.65	32.16	238.15	47.35	275.65
52.43	275.65	62.61	250.65	82.05	165.15	90.26	165.15
101.60	200.35	111.94	295.25	118.00	360.00	120.00	379.80
125.00	499.50	130.00	607.80	135.00	704.40	140.00	791.40
145.00	868.40	150.00	937.30	160.00	1051.00	170.00	1141.00
180.00	1211.20	190.00	1266.80	200.00	1310.60	225.00	1383.10
250.00	1420.00	275.00	1452.00	300.00	1471.20	350.00	1489.70
400.00	1496.30	450.00	1498.70	500.00	1499.50	600.00	1499.90
700.00	1500.00	800.00	1501.00	900.00	1502.00	100.00	1503.00

PRES 45 JULY 005
1013.50

TABLE 3. TEMPERATURE PROFILES FOR MODEL ATMOSPHERES.

```
TEMP 45 SP/FAL  006      U.S. STND. ATM. 1966
SPRING/FALL MODEL,  600 K EXOS.TEMP
    0.00  288.15   11.02  216.65   20.06  216.65   32.16  228.65
   47.35  270.65   52.43  270.65   61.59  252.65   69.76  220.65
   79.99  190.65   91.29  190.65  101.60  210.65  111.94  254.25
  118.00  330.00  120.00  355.00  125.00  387.10  130.00  415.00
  135.00  439.30  140.00  460.30  145.00  478.60  150.00  494.60
  160.00  520.40  170.00  539.90  180.00  554.60  190.00  565.70
  200.00  574.10  225.00  587.20  250.00  593.70  275.00  596.90
  300.00  598.40  350.00  599.60  400.00  599.90  700.00  600.00
PRES 45 SP/FAL  006
   1013.25
```

```
TEMP 45 SP/FAL  006      U.S. STND. ATM. 1966
SPRING/FALL MODEL, 1000 K EXOS.TEMP
    0.00  288.15   11.02  216.65   20.06  216.65   32.16  228.65
   47.35  270.65   52.43  270.65   61.59  252.65   69.76  220.65
   79.99  190.65   91.29  190.65  101.60  210.65  111.94  254.25
  118.00  330.00  120.00  355.00  125.00  439.50  130.00  513.00
  135.00  576.90  140.00  632.30  145.00  680.50  150.00  722.40
  160.00  790.40  170.00  841.80  180.00  880.50  190.00  909.80
  200.00  931.90  225.00  966.30  250.00  993.30  275.00  991.70
  300.00  995.90  350.00  999.00  400.00  999.80  450.00  999.90
  700.00 1000.00  600.00 1000.00  700.00 1000.00  800.00 1501.00
PRES 45 SP/FAL  006
   1013.25
```

```
TEMP 45 SP/FAL  006      U.S. STND. ATM. 1966
SPRING/FALL MODEL, 1500 K EXOS.TEMP
    0.00  288.15   11.02  216.65   20.06  216.65   32.16  228.65
   47.35  270.65   52.43  270.65   61.59  252.65   69.76  220.65
   79.99  190.65   91.29  190.65  101.60  210.65  111.94  254.25
  118.00  330.00  120.00  355.00  125.00  466.40  130.00  566.90
  135.00  657.70  140.00  739.60  145.00  813.60  150.00  880.40
  160.00  995.00  170.00 1088.50  180.00 1164.70  190.00 1226.70
  200.00 1277.30  225.00 1366.50  250.00 1420.00  275.00 1452.00
  300.00 1471.20  350.00 1489.70  400.00 1496.30  450.00 1498.70
  500.00 1499.50  600.00 1499.90  700.00 1500.00  800.00 1501.00
PRES 45 SP/FAL  006
   1013.25
```

TABLE 3. TEMPERATURE PROFILES FOR MODEL ATMOSPHERES.

TEMP 60 JANURY 007 U.S. STND. ATM. 1966
WINTER MODEL, 600 K EXOS.TEMP

0.00	257.15	1.00	259.15	3.50	251.15	8.50	217.15
15.02	217.15	25.07	211.15	34.14	220.15	50.33	260.15
54.39	260.15	59.48	251.15	69.67	246.15	90.15	202.15
101.46	226.35	111.79	273.15	118.00	318.00	120.00	333.50
125.00	361.60	130.00	386.80	135.00	408.90	140.00	428.90
145.00	446.60	150.00	462.80	160.00	490.70	170.00	513.30
180.00	532.10	190.00	547.60	200.00	561.00	225.00	587.20
250.00	593.70	275.00	596.90	300.00	598.40	350.00	599.60
400.00	599.90	700.00	600.00	500.00	600.00	600.00	600.00

PRES 60 JANURY 007
1013.50

TEMP 60 JANURY 007 U.S. STND. ATM. 1966
WINTER MODEL, 1000 K EXOS.TEMP

0.00	257.15	1.00	259.15	3.50	251.15	8.50	217.15
15.02	217.15	25.07	211.15	34.14	220.15	50.33	260.15
54.39	260.15	59.48	251.15	69.67	246.15	90.15	202.15
101.46	226.35	111.79	273.15	118.00	318.00	120.00	334.10
125.00	407.20	130.00	472.00	135.00	527.80	140.00	577.90
145.00	621.60	150.00	661.20	160.00	728.10	170.00	782.30
180.00	826.70	190.00	863.10	200.00	893.20	225.00	949.70
250.00	983.30	275.00	991.70	300.00	995.90	350.00	999.00
400.00	999.80	450.00	999.90	700.00	1000.00	600.00	1000.00

PRES 60 JANURY 007
1013.50

TEMP 60 JANURY 007 U.S. STND. ATM. 1966
WINTER MODEL, 1500 K EXOS.TEMP

0.00	257.15	1.00	259.15	3.50	251.15	8.50	217.15
15.02	217.15	25.07	211.15	34.14	220.15	50.33	260.15
54.39	260.15	59.48	251.15	69.67	246.15	90.15	202.15
101.45	226.35	111.79	273.15	118.00	318.00	120.00	333.30
125.00	429.00	130.00	516.30	135.00	594.50	140.00	666.60
145.00	732.60	150.00	793.60	160.00	901.60	170.00	995.60
180.00	1077.00	190.00	1147.80	200.00	1209.20	225.00	1329.70
250.00	1420.00	275.00	1452.00	300.00	1471.20	350.00	1489.70
400.00	1496.30	450.00	1498.70	500.00	1499.50	600.00	1499.90
700.00	1500.00	800.00	1501.00	900.00	1502.00	100.00	1503.00

PRES 60 JANURY 007
1013.50

TABLE 3. TEMPERATURE PROFILES FOR MODEL ATMOSPHERES.

```
TEMP 60 JULY     008       U.S. STND. ATM. 1966
SUMMER MODEL,   600 K EXOS.TEMP
    0.00  287.15     5.00  260.15    10.00  225.15    23.05  225.15
   32.12  238.65    43.24  271.65    48.30  277.15    53.38  277.15
   59.48  265.15    81.94  161.75    90.15  161.75   101.46  200.25
  111.79  303.45   118.00  361.00   120.00  380.00   125.00  413.00
  130.00  441.20   135.00  464.20   140.00  483.90   145.00  499.80
  150.00  513.60   160.00  535.00   170.00  550.20   180.00  561.10
  190.00  568.20   200.00  574.10   225.00  587.20   250.00  593.70
  275.00  596.90   300.00  598.40   350.00  599.60   400.00  599.90
  700.00  600.00   500.00  600.00   600.00  600.00   700.00  600.00
PRES 60 JULY     008
  1010.00
```

```
TEMP 60 JULY     008       U.S. STND. ATM. 1966
SUMMER MODEL,  1000 K EXOS.TEMP
    0.00  287.15     5.00  260.15    10.00  225.15    23.05  225.15
   32.12  238.65    43.24  271.65    48.30  277.15    53.38  277.15
   59.48  265.15    81.94  161.75    90.15  161.75   101.46  200.25
  111.79  303.45   118.00  361.00   120.00  379.30   125.00  469.20
  130.00  547.80   135.00  614.20   140.00  671.90   145.00  720.20
  150.00  761.90   160.00  826.60   170.00  872.90   180.00  906.30
  190.00  930.10   200.00  947.10   225.00  968.80   250.00  983.30
  275.00  991.70   300.00  995.90   350.00  999.00   400.00  999.80
  450.00  999.90   700.00 1000.00   600.00 1000.00   700.00 1000.00
PRES 60 JULY     008
  1010.00
```

```
TEMP 60 JULY     008       U.S. STND. ATM. 1966
SUMMER MODEL,  1500 K EXOS.TEMP
    0.00  287.15     5.00  260.15    10.00  225.15    23.05  225.15
   32.12  238.65    43.24  271.65    48.30  277.15    53.38  277.15
   59.48  265.15    81.94  161.75    90.15  161.75   101.46  200.25
  111.79  303.45   118.00  361.00   120.00  379.80   125.00  499.50
  130.00  607.80   135.00  704.40   140.00  791.40   145.00  868.40
  150.00  937.30   160.00 1051.00   170.00 1141.00   180.00 1211.20
  190.00 1268.80   200.00 1310.60   225.00 1383.10   250.00 1420.00
  275.00 1452.00   300.00 1471.20   350.00 1489.70   400.00 1496.30
  450.00 1498.70   500.00 1499.50   600.00 1499.90   700.00 1500.00
PRES 60 JULY     008
  1010.00
```

TABLE 3. TEMPERATURE PROFILES FOR MODEL ATMOSPHERES.

TEMP 45 STND76 009 U.S. STND. ATM. 1976

0.00	268.15	11.02	216.65	20.06	216.65	32.16	228.65
47.35	270.65	51.41	270.65	71.80	214.65	86.00	186.87
90.00	186.87	92.00	186.98	94.00	187.74	96.00	189.31
98.00	191.72	100.00	195.08	102.00	199.53	104.00	205.31
106.00	212.89	108.00	223.29	110.00	240.00	120.00	360.00
122.00	383.55	124.00	406.22	126.00	428.04	128.00	449.04
130.00	469.27	134.00	507.48	138.00	542.90	142.00	575.73
146.00	606.17	150.00	634.39	160.00	696.29	170.00	747.57
180.00	790.07	190.00	825.31	200.00	854.56	220.00	899.01
240.00	915.78	260.00	950.99	300.00	976.01	350.00	990.06
400.00	995.83	500.00	999.24	600.00	999.85	700.00	999.97

PRES 45 STND76 009
1013.25

TABLE 4. ATOMIC OXYGEN CONCENTRATIONS FOR MODEL ATMOSPHERES.

WINTER MODEL,	600 K EXOS.TEMP							
OATM 45 STDATM		01						O 01 01
0.0	1.00E-06	60.0	1.00E+06	70.0	1.00E+08	80.0	1.00E+10	
86.0	8.60E+10	88.0	1.51E+11	90.0	2.44E+11	92.0	3.43E+11	
94.0	4.16E+11	96.0	4.47E+11	98.0	4.48E+11	100.0	4.30E+11	
102.0	4.01E+11	104.0	3.62E+11	106.0	3.19E+11	108.0	2.75E+11	
110.0	2.30E+11	112.0	1.89E+11	114.0	1.56E+11	116.0	1.30E+11	
118.0	1.10E+11	120.0	9.28E+10	125.0	6.60E+10	130.0	4.84E+10	
135.0	3.64E+10	140.0	2.74E+10	145.0	2.19E+10	150.0	1.73E+10	
160.0	1.12E+10	170.0	7.49E+09	180.0	5.14E+09	190.0	3.59E+09	
200.0	2.54E+09	225.0	1.13E+09	250.0	5.32E+08	275.0	2.54E+08	
300.0	1.23E+08	350.0	2.95E+07	400.0	7.27E+06	450.0	1.83E+06	
500.0	4.68E+05	600.0	3.25E+04	700.0	2.45E+03	800.0	1.73E+05	
OATM 45 STDATM		02						O 02 01
0.0	1.00E+02	20.0	1.00E+06	30.0	1.00E+08	40.0	3.00E+09	
50.0	8.00E+09	60.0	1.20E+10	70.0	2.00E+10	80.0	6.00E+10	
86.0	8.60E+10	88.0	1.51E+11	90.0	2.44E+11	92.0	3.43E+11	
94.0	4.16E+11	96.0	4.47E+11	98.0	4.48E+11	100.0	4.30E+11	
102.0	4.01E+11	104.0	3.62E+11	106.0	3.19E+11	108.0	2.75E+11	
110.0	2.30E+11	112.0	1.89E+11	114.0	1.56E+11	116.0	1.30E+11	
118.0	1.10E+11	120.0	9.28E+10	125.0	6.60E+10	130.0	4.84E+10	
135.0	3.64E+10	140.0	2.74E+10	145.0	2.19E+10	150.0	1.73E+10	
160.0	1.12E+10	170.0	7.49E+09	180.0	5.14E+09	190.0	3.59E+09	
200.0	2.54E+09	225.0	1.13E+09	250.0	5.32E+08	275.0	2.54E+08	
300.0	1.23E+08	350.0	2.95E+07	400.0	7.27E+06	450.0	1.83E+06	
500.0	4.68E+05	600.0	3.25E+04	700.0	2.45E+03	800.0	1.73E+05	

TABLE 4. ATOMIC OXYGEN CONCENTRATIONS FOR MODEL ATMOSPHERES.

WINTER MODEL, 1000 K EXOS.TEMP

DATM 45 STDATM 01 — O 01 01

0.0	1.00E-06	60.0	1.00E+06	70.0	1.00E+08	80.0	1.00E+10
86.0	8.60E+10	88.0	1.51E+11	90.0	2.44E+11	92.0	3.43E+11
94.0	4.16E+11	96.0	4.47E+11	98.0	4.48E+11	100.0	4.30E+11
102.0	4.01E+11	104.0	3.62E+11	106.0	3.19E+11	108.0	2.75E+11
110.0	2.30E+11	112.0	1.89E+11	114.0	1.56E+11	116.0	1.30E+11
118.0	1.10E+11	120.0	9.28E+10	125.0	5.96E+10	130.0	4.18E+10
135.0	3.12E+10	140.0	2.42E+10	145.0	1.94E+10	150.0	1.58E+10
160.0	1.11E+10	170.0	8.14E+09	180.0	6.17E+09	190.0	4.79E+09
200.0	3.78E+09	225.0	2.20E+09	250.0	1.35E+09	275.0	8.64E+08
300.0	5.58E+08	350.0	2.36E+08	400.0	1.02E+08	450.0	4.44E+07
500.0	1.96E+07	600.0	3.97E+06	700.0	8.39E+05	800.0	1.73E+05

DATM 45 STDATM 02 — O 02 01

0.0	1.00E+02	20.0	1.00E+06	30.0	1.00E+08	40.0	3.00E+09
50.0	8.00E+09	60.0	1.20E+10	70.0	2.00E+10	80.0	6.00E+10
86.0	8.60E+10	88.0	1.51E+11	90.0	2.44E+11	92.0	3.43E+11
94.0	4.16E+11	96.0	4.47E+11	98.0	4.48E+11	100.0	4.30E+11
102.0	4.01E+11	104.0	3.62E+11	106.0	3.19E+11	108.0	2.75E+11
110.0	2.30E+11	112.0	1.89E+11	114.0	1.56E+11	116.0	1.30E+11
118.0	1.10E+11	120.0	9.28E+10	125.0	5.96E+10	130.0	4.18E+10
135.0	3.12E+10	140.0	2.42E+10	145.0	1.94E+10	150.0	1.58E+10
160.0	1.11E+10	170.0	8.14E+09	180.0	6.17E+09	190.0	4.79E+09
200.0	3.78E+09	225.0	2.20E+09	250.0	1.35E+09	275.0	8.64E+08
300.0	5.56E+08	350.0	2.36E+08	400.0	1.02E+08	450.0	4.44E+07
500.0	1.96E+07	600.0	3.97E+06	700.0	8.39E+05	800.0	1.73E+05

TABLE 4. ATOMIC OXYGEN CONCENTRATIONS FOR MODEL ATMOSPHERES.

WINTER MODEL, 1500 K EXOS.TEMP

OATM 45 STDATM	01							0 01 01
0.0	1.00E-06	60.0	1.00E+06	70.0	1.0 E+08	80.0	1.00E+10	
86.0	8.60E+10	88.0	1.51E+11	90.0	2.44E+11	92.0	3.43E+11	
94.0	4.16E+11	96.0	4.47E+11	98.0	4.48E+11	100.0	4.30E+11	
102.0	4.01E+11	104.0	3.62E+11	106.0	3.19E+11	108.0	2.75E+11	
110.0	2.30E+11	112.0	1.89E+11	114.0	1.56E+11	116.0	1.30E+11	
118.0	1.10E+11	120.0	9.28E+10	125.0	5.68E+10	130.0	3.90E+10	
135.0	2.87E+10	140.0	2.22E+10	145.0	1.78E+10	150.0	1.45E+10	
160.0	1.04E+10	170.0	7.77E+09	180.0	6.05E+09	190.0	4.84E+09	
200.0	3.95E+09	225.0	2.53E+09	250.0	1.73E+09	275.0	1.25E+09	
300.0	9.15E+08	350.0	5.09E+08	400.0	2.88E+08	450.0	1.65E+08	
500.0	9.58E+07	600.0	3.30E+07	700.0	1.17E+07	800.0	1.73E+05	
OATM 45 STDATM	02							0 02 01
0.0	1.00E+02	20.0	1.00E+06	30.0	1.0 E+08	40.0	3.00E+09	
50.0	8.00E+09	60.0	1.20E+10	70.0	2.0 E+10	80.0	6.00E+10	
86.0	8.60E+10	88.0	1.51E+11	90.0	2.44E+11	92.0	3.43E+11	
94.0	4.16E+11	96.0	4.47E+11	98.0	4.48E+11	100.0	4.30E+11	
102.0	4.01E+11	104.0	3.62E+11	106.0	3.19E+11	108.0	2.75E+11	
110.0	2.30E+11	112.0	1.89E+11	114.0	1.56E+11	116.0	1.30E+11	
118.0	1.10E+11	120.0	9.28E+10	125.0	5.68E+10	130.0	3.90E+10	
135.0	2.87E+10	140.0	2.22E+10	145.0	1.78E+10	150.0	1.45E+10	
160.0	1.04E+10	170.0	7.77E+09	180.0	6.05E+09	190.0	4.84E+09	
200.0	3.95E+09	225.0	2.53E+09	250.0	1.73E+09	275.0	1.25E+09	
300.0	9.15E+08	350.0	5.09E+08	400.0	2.88E+08	450.0	1.65E+08	
500.0	9.58E+07	600.0	3.30E+07	700.0	1.17E+07	800.0	1.73E+05	

TABLE 4. ATOMIC OXYGEN CONCENTRATIONS FOR MODEL ATMOSPHERES.

SUMMER MODEL, 600 K EXOS.TEMP

OATM 45 STDATM 01 — O 01 01

0.0	1.00E-06	60.0	1.00E+06	70.0	1.00E+08	80.0	1.00E+10
86.0	8.60E+10	88.0	1.51E+11	90.0	2.44E+11	92.0	3.43E+11
94.0	4.16E+11	96.0	4.47E+11	98.0	4.48E+11	100.0	4.30E+11
102.0	4.01E+11	104.0	3.62E+11	106.0	3.19E+11	108.0	2.75E+11
110.0	2.30E+11	112.0	1.89E+11	114.0	1.56E+11	116.0	1.30E+11
118.0	1.10E+11	120.0	9.28E+10	125.0	6.78E+10	130.0	5.15E+10
135.0	4.00E+10	140.0	3.17E+10	145.0	2.56E+10	150.0	2.08E+10
160.0	1.42E+10	170.0	9.92E+09	180.0	7.06E+09	190.0	5.08E+09
200.0	3.69E+09	225.0	1.68E+09	250.0	7.94E+08	275.0	3.80E+08
300.0	1.84E+08	350.0	4.41E+07	400.0	1.09E+07	450.0	2.73E+06
500.0	6.98E+05	600.0	4.86E+04	700.0	3.65E+03	800.0	1.73E+05

OATM 45 STDATM 02 — O 02 01

0.0	1.00E+02	20.0	1.00E+06	30.0	1.00E+08	40.0	3.00E+09
50.0	8.00E+09	60.0	1.20E+10	70.0	2.00E+10	80.0	6.00E+10
86.0	8.60E+10	88.0	1.51E+11	90.0	2.44E+11	92.0	3.43E+11
94.0	4.16E+11	96.0	4.47E+11	98.0	4.48E+11	100.0	4.30E+11
102.0	4.01E+11	104.0	3.62E+11	106.0	3.19E+11	108.0	2.75E+11
110.0	2.30E+11	112.0	1.89E+11	114.0	1.56E+11	116.0	1.30E+11
118.0	1.10E+11	120.0	9.28E+10	125.0	6.78E+10	130.0	5.15E+10
135.0	4.00E+10	140.0	3.17E+10	145.0	2.56E+10	150.0	2.08E+10
160.0	1.42E+10	170.0	9.92E+09	180.0	7.06E+09	190.0	5.08E+09
200.0	3.69E+09	225.0	1.68E+09	250.0	7.94E+08	275.0	3.80E+08
300.0	1.84E+08	350.0	4.41E+07	400.0	1.09E+07	450.0	2.73E+06
500.0	6.98E+05	800.0	4.86E+04	700.0	3.65E+03	800.0	1.73E+05

TABLE 4. ATOMIC OXYGEN CONCENTRATIONS FOR MODEL ATMOSPHERES.

SUMMER MODEL, 1000 K EXOS.TEMP

OATM 45 STDATM 01 — 0 01 01

0.0	1.00E-06	60.0	1.00E+06	70.0	1.00E+08	80.0	1.00E+10
86.0	8.60E+10	88.0	1.51E+11	90.0	2.44E+11	92.0	3.43E+11
94.0	4.16E+11	96.0	4.47E+11	98.0	4.48E+11	100.0	4.30E+11
102.0	4.01E+11	104.0	3.62E+11	106.0	3.19E+11	108.0	2.75E+11
110.0	2.30E+11	112.0	1.89E+11	114.0	1.56E+11	116.0	1.30E+11
118.0	1.10E+11	120.0	9.28E+10	125.0	6.06E+10	130.0	4.34E+10
135.0	3.32E+10	140.0	2.63E+10	145.0	2.16E+10	150.0	1.81E+10
160.0	1.33E+10	170.0	1.02E+10	180.0	8.03E+09	190.0	6.44E+09
200.0	5.23E+09	225.0	3.23E+09	250.0	2.03E+09	275.0	1.30E+09
300.0	8.37E+08	350.0	3.54E+08	400.0	1.53E+08	450.0	6.66E+07
500.0	2.94E+07	600.0	5.94E+06	700.0	1.26E+06	800.0	1.73E+05

OATM 45 STDATM 02 — 0 02 01

0.0	1.00E+02	20.0	1.00E+06	30.0	1.00E+08	40.0	3.00E+09
50.0	8.00E+09	60.0	1.20E+10	70.0	2.00E+10	80.0	6.00E+10
86.0	8.60E+10	88.0	1.51E+11	90.0	2.44E+11	92.0	3.43E+11
94.0	4.16E+11	96.0	4.47E+11	98.0	4.48E+11	100.0	4.30E+11
102.0	4.01E+11	104.0	3.62E+11	106.0	3.19E+11	108.0	2.75E+11
110.0	2.30E+11	112.0	1.89E+11	114.0	1.56E+11	116.0	1.30E+11
118.0	1.10E+11	120.0	9.28E+10	125.0	6.06E+10	130.0	4.34E+10
135.0	3.32E+10	140.0	2.63E+10	145.0	2.16E+10	150.0	1.81E+10
160.0	1.33E+10	170.0	1.02E+10	180.0	8.03E+09	190.0	6.44E+09
200.0	5.23E+09	225.0	3.23E+09	250.0	2.03E+09	275.0	1.30E+09
300.0	8.37E+08	350.0	3.54E+08	400.0	1.53E+08	450.0	6.66E+07
500.0	2.94E+07	600.0	5.94E+06	700.0	1.26E+06	800.0	1.73E+05

TABLE 4. ATOMIC OXYGEN CONCENTRATIONS FOR MODEL ATMOSPHERES.

SUMMER MODEL, 1500 K EXOS.TEMP　　　　　　　　O 01 01

OATM 45 STDATM 01

0.0	1.00E-06	60.0	1.00E+06	70.0	1.00E+08	80.0	1.00E+10
86.0	8.60E+10	88.0	1.51E+11	90.0	2.44E+11	92.0	3.43E+11
94.0	4.16E+11	96.0	4.47E+11	98.0	4.48E+11	100.0	4.30E+11
102.0	4.01E+11	104.0	3.62E+11	106.0	3.19E+11	108.0	2.75E+11
110.0	2.30E+11	112.0	1.89E+11	114.0	1.56E+11	116.0	1.30E+11
118.0	1.10E+11	120.0	9.28E+10	125.0	5.74E+10	130.0	4.00E+10
135.0	3.01E+10	140.0	2.37E+10	145.0	1.94E+10	150.0	1.62E+10
160.0	1.21E+10	170.0	9.47E+09	180.0	7.67E+09	190.0	6.35E+09
200.0	5.34E+09	225.0	3.65E+09	250.0	2.60E+09	275.0	1.88E+09
300.0	1.38E+09	350.0	7.67E+08	400.0	4.34E+08	450.0	2.49E+08
500.0	1.44E+08	600.0	4.97E+07	700.0	1.77E+07	800.0	1.73E+05

OATM 45 STDATM 02　　　　　　　　O 02 01

0.0	1.00E+02	20.0	1.00E+06	30.0	1.00E+08	40.0	3.00E+09
50.0	8.00E+09	60.0	1.20E+10	70.0	2.00E+10	80.0	6.00E+10
86.0	8.60E+10	88.0	1.51E+11	90.0	2.44E+11	92.0	3.43E+11
94.0	4.16E+11	96.0	4.47E+11	98.0	4.48E+11	100.0	4.30E+11
102.0	4.01E+11	104.0	3.62E+11	106.0	3.19E+11	108.0	2.75E+11
110.0	2.30E+11	112.0	1.89E+11	114.0	1.56E+11	116.0	1.30E+11
118.0	1.10E+11	120.0	9.28E+10	125.0	5.74E+10	130.0	4.00E+10
135.0	3.01E+10	140.0	2.37E+10	145.0	1.94E+10	150.0	1.62E+10
160.0	1.21E+10	170.0	9.47E+09	180.0	7.67E+09	190.0	6.35E+09
200.0	5.34E+09	225.0	3.65E+09	250.0	2.60E+09	275.0	1.88E+09
300.0	1.38E+09	350.0	7.67E+08	400.0	4.34E+08	450.0	2.49E+08
500.0	1.44E+08	600.0	4.97E+07	700.0	1.77E+07	800.0	1.73E+05

TABLE 4. ATOMIC OXYGEN CONCENTRATIONS FOR MODEL ATMOSPHERES.

SPRING/FALL MODEL, 600 K EXOS. TEMP

DATM 45 STDATM 01 — O 01 01

0.0	1.00E-06	60.0	1.00E+06	70.0	1.00E+08	80.0	1.00E+10
86.0	8.60E+10	88.0	1.51E+11	90.0	2.44E+11	92.0	3.43E+11
94.0	4.16E+11	96.0	4.47E+11	98.0	4.48E+11	100.0	4.30E+11
102.0	4.01E+11	104.0	3.62E+11	106.0	3.19E+11	108.0	2.75E+11
110.0	2.30E+11	112.0	1.89E+11	114.0	1.56E+11	116.0	1.30E+11
118.0	1.10E+11	120.0	9.28E+10	125.0	6.66E+10	130.0	4.96E+10
135.0	3.79E+10	140.0	2.95E+10	145.0	2.35E+10	150.0	1.89E+10
160.0	1.26E+10	170.0	8.66E+09	180.0	6.08E+09	190.0	4.33E+09
200.0	3.13E+09	225.0	1.43E+09	250.0	6.74E+08	275.0	3.23E+08
300.0	1.56E+08	350.0	3.75E+07	400.0	9.22E+06	450.0	2.31E+06
500.0	5.94E+05	600.0	4.13E+04	700.0	3.10E+03	800.0	1.73E+05

DATM 45 STDATM 02 — O 02 01

0.0	1.00E+02	20.0	1.00E+06	30.0	1.00E+08	40.0	3.00E+09
50.0	8.00E+09	60.0	1.20E+10	70.0	2.00E+10	80.0	6.00E+10
86.0	8.60E+10	88.0	1.51E+11	90.0	2.44E+11	92.0	3.43E+11
94.0	4.16E+11	96.0	4.47E+11	98.0	4.48E+11	100.0	4.30E+11
102.0	4.01E+11	104.0	3.62E+11	106.0	3.19E+11	108.0	2.75E+11
110.0	2.30E+11	112.0	1.89E+11	114.0	1.56E+11	116.0	1.30E+11
118.0	1.10E+11	120.0	9.28E+10	125.0	6.66E+10	130.0	4.96E+10
135.0	3.79E+10	140.0	2.95E+10	145.0	2.35E+10	150.0	1.89E+10
160.0	1.26E+10	170.0	8.66E+09	180.0	6.08E+09	190.0	4.33E+09
200.0	3.13E+09	225.0	1.43E+09	250.0	6.74E+08	275.0	3.23E+08
300.0	1.56E+08	350.0	3.75E+07	400.0	9.22E+06	450.0	2.31E+06
500.0	5.94E+05	600.0	4.13E+04	700.0	3.10E+03	800.0	1.73E+05

TABLE 4. ATOMIC OXYGEN CONCENTRATIONS FOR MODEL ATMOSPHERES.

SPRING/FALL MODEL, 1000 K EXOS.TEMP

OATM 45 STDATM 01 — 0 01 01

0.0	1.00E-06	60.0	1.00E+06	70.0	1.00E+08	80.0	1.00E+10
86.0	8.60E+10	88.0	1.51E+11	90.0	2.44E+11	92.0	3.43E+11
94.0	4.16E+11	96.0	4.47E+11	98.0	4.48E+11	100.0	4.30E+11
102.0	4.01E+11	104.0	3.62E+11	106.0	3.19E+11	108.0	2.75E+11
110.0	2.30E+11	112.0	1.89E+11	114.0	1.56E+11	116.0	1.30E+11
118.0	1.10E+11	120.0	9.28E+10	125.0	5.96E+10	130.0	4.22E+10
135.0	3.18E+10	140.0	2.50E+10	145.0	2.02E+10	150.0	1.68E+10
160.0	1.21E+10	170.0	9.11E+09	180.0	7.07E+09	190.0	5.62E+09
200.0	4.51E+09	225.0	2.74E+09	250.0	1.72E+09	275.0	1.10E+09
300.0	7.07E+08	350.0	3.00E+08	400.0	1.29E+08	450.0	5.63E+07
500.0	2.49E+07	600.0	5.03E+06	700.0	1.06E+06	800.0	1.73E+05

OATM 45 STDATM 02 — 0 02 01

0.0	1.00E+02	20.0	1.00E+06	30.0	1.00E+08	40.0	3.00E+09
50.0	8.00E+09	60.0	1.20E+10	70.0	2.00E+10	80.0	6.00E+10
86.0	8.60E+10	88.0	1.51E+11	90.0	2.44E+11	92.0	3.43E+11
94.0	4.16E+11	96.0	4.47E+11	98.0	4.48E+11	100.0	4.30E+11
102.0	4.01E+11	104.0	3.62E+11	106.0	3.19E+11	108.0	2.75E+11
110.0	2.30E+11	112.0	1.89E+11	114.0	1.56E+11	116.0	1.30E+11
118.0	1.10E+11	120.0	9.28E+10	125.0	5.96E+10	130.0	4.22E+10
135.0	3.18E+10	140.0	2.50E+10	145.0	2.02E+10	150.0	1.68E+10
160.0	1.21E+10	170.0	9.11E+09	180.0	7.07E+09	190.0	5.62E+09
200.0	4.51E+09	225.0	2.74E+09	250.0	1.72E+09	275.0	1.10E+09
300.0	7.07E+08	350.0	3.00E+08	400.0	1.29E+08	450.0	5.63E+07
500.0	2.49E+07	600.0	5.03E+06	700.0	1.06E+06	800.0	1.73E+05

TABLE 4. ATOMIC OXYGEN CONCENTRATIONS FOR MODEL ATMOSPHERES.

SPRING/FALL MODEL, 1500 K EXOS.TEMP | | | | | | | | O 01 01
OATM 45 STDATM 01

0.0	1.00E-06	60.0	1.00E+06	70.0	1.00E+08	80.0	1.00E+10
86.0	8.60E+10	88.0	1.51E+11	90.0	2.44E+11	92.0	3.43E+11
94.0	4.16E+11	96.0	4.47E+11	98.0	4.48E+11	100.0	4.30E+11
102.0	4.01E+11	104.0	3.62E+11	106.0	3.19E+11	108.0	2.75E+11
110.0	2.30E+11	112.0	1.89E+11	114.0	1.56E+11	116.0	1.30E+11
118.0	1.10E+11	120.0	9.28E+10	125.0	5.66E+10	130.0	3.90E+10
135.0	2.90E+10	140.0	2.27E+10	145.0	1.83E+10	150.0	1.52E+10
160.0	1.11E+10	170.0	8.56E+09	180.0	6.33E+09	190.0	5.59E+09
200.0	4.66E+09	225.0	3.12E+09	250.0	2.20E+09	275.0	1.58E+09
300.0	1.16E+09	350.0	6.46E+08	400.0	3.66E+08	450.0	2.10E+08
500.0	1.22E+08	600.0	4.19E+07	700.0	1.49E+07	800.0	1.73E+05

OATM 45 STDATM 02 | | | | | | | | O 02 01

0.0	1.00E+02	20.0	1.00E+06	30.0	1.00E+08	40.0	3.00E+09
50.0	8.00E+09	60.0	1.20E+10	70.0	2.00E+10	80.0	6.00E+10
86.0	8.60E+10	88.0	1.51E+11	90.0	2.44E+11	92.0	3.43E+11
94.0	4.16E+11	96.0	4.47E+11	98.0	4.48E+11	100.0	4.30E+11
102.0	4.01E+11	104.0	3.62E+11	106.0	3.19E+11	108.0	2.75E+11
110.0	2.30E+11	112.0	1.89E+11	114.0	1.56E+11	116.0	1.30E+11
118.0	1.10E+11	120.0	9.28E+10	125.0	5.66E+10	130.0	3.90E+10
135.0	2.90F+10	140.0	2.27E+10	145.0	1.83E+10	150.0	1.52E+10
160.0	1.11E+10	170.0	8.56E+09	180.0	6.83E+09	190.0	5.59E+09
200.0	4.66E+C3	225.0	3.12E+09	250.0	2.20E+09	275.0	1.58E+09
300.0	1.16E+09	350.0	6.46E+08	400.0	3.66E+08	450.0	2.10E+08
500.0	1.22E+08	600.0	4.19E+07	700.0	1.49E+07	800.0	1.73E+05

TABLE 5. HIGH ALTITUDE MOLECULAR NUMBER DENSITIES FOR U.S. STANDARD ATMOSPHERE, 1976

U. S. STANDARD ATMOSPHERE, 1976

86.00	1.1300E+14	3.0310E+13	8.6000E+10
88.00	7.9150E+13	2.1200E+13	1.5130E+11
90.00	5.5470E+13	1.4790E+13	2.4430E+11
92.00	3.8860E+13	1.0270E+13	3.4340E+11
94.00	2.7150E+13	7.0600E+12	4.1590E+11
96.00	1.8940E+13	4.8010E+12	4.4710E+11
98.00	1.3200E+13	3.2300E+12	4.4760E+11
100.00	9.2100E+12	2.1510E+12	4.2980E+11
102.00	6.5080E+12	1.4300E+12	4.0070E+11
104.00	4.6090E+12	9.4340E+11	3.6190E+11
106.00	3.2730E+12	6.1890E+11	3.1880E+11
108.00	2.3270E+12	4.0450E+11	2.7480E+11
110.00	1.6410E+12	2.6210E+11	2.3030E+11
112.00	1.1580E+12	1.7060E+11	1.8890E+11
114.00	8.4220E+11	1.1560E+11	1.5650E+11
116.00	6.2850E+11	8.1200E+10	1.3050E+11
118.00	4.7940E+11	5.8920E+10	1.0960E+11
120.00	3.7260E+11	4.3950E+10	9.2750E+10
122.00	2.9470E+11	3.3600E+10	7.9250E+10
124.00	2.3680E+11	2.6250E+10	6.8400E+10
126.00	1.9300E+11	2.0870E+10	5.9560E+10
128.00	1.5920E+11	1.6830E+10	5.2290E+10
130.00	1.3260E+11	1.3750E+10	4.6250E+10
132.00	1.1160E+11	1.1340E+10	4.1180E+10
134.00	9.4600E+10	9.4440E+09	3.6880E+10
136.00	8.0800E+10	7.9270E+09	3.3200E+10
138.00	6.9470E+10	6.7020E+09	3.0040E+10
140.00	6.0090E+10	5.7020E+09	2.7290E+10
142.00	5.2250E+10	4.8810E+09	2.4890E+10
144.00	4.5650E+10	4.1990E+09	2.2780E+10
146.00	4.0070E+10	3.6310E+09	2.0920E+10
148.00	3.5310E+10	3.1530E+09	1.9270E+10
150.00	3.1240E+10	2.7500E+09	1.7800E+10
160.00	1.7740E+10	1.4600E+09	1.2380E+10
170.00	1.0700E+10	8.2770E+08	8.9960E+09
180.00	6.7400E+09	4.9210E+08	6.7470E+09
190.00	4.3850E+09	3.0310E+08	5.1810E+09
200.00	2.9250E+09	1.9180E+08	4.0500E+09
220.00	1.3730E+09	8.1450E+07	2.5730E+09
240.00	6.7780E+08	3.6530E+07	1.6950E+09
260.00	3.4590E+08	1.7000E+07	1.1430E+09
280.00	1.8060E+08	8.1100E+06	7.8340E+08
300.00	9.5930E+07	3.9420E+06	5.4330E+08
350.00	2.0690E+07	6.8500E+05	2.2490E+08
400.00	4.6690E+06	1.2520E+05	9.5840E+07
450.00	1.0860E+06	2.3680E+04	4.1640E+07
500.00	2.5920E+05	4.6070E+03	1.8360E+07
550.00	6.3230E+04	9.1960E+02	8.2000E+06
600.00	1.5750E+04	1.8800E+02	3.7070E+06
650.00	4.0030E+03	3.9320E+01	1.6950E+06
700.00	1.0380E+03	8.4100E+00	7.8400E+05
800.00	7.3770E+01	4.1050E-01	1.7320E+05
900.00	5.6410E+00	2.1770E-02	3.9890E+04
1000.00	4.6260E-01	1.2510E-03	9.5620E+03

TABLE 6: WATER VAPOR BAND DATA

VIBRATIONAL TRANSITION		BAND CENTER WAVELENGTH (μm)	BAND STRENGTH AT 296°K ($mol^{-1} cm^2 cm^{-1}$)	SOLAR FLUX AT BAND CENTER (photons $cm^{-2} \mu m^{-1}$)
UPPER STATE	LOWER STATE			
010	000	6.27	1.06(-17)*	5.60(15)
020	000	3.17	6.58(-20)	3.50(16)
100	000	2.73	3.62(-19)	5.10(16)
001	000	2.66	7.99(-18)	5.40(16)
020	010	6.42	8.61(-21)	5.70(15)
100	010	4.85	8.90(-23)	1.20(16)
001	010	4.63	4.90(-22)	1.50(16)
030	010	3.26	7.99(-23)	3.30(16)
110	010	2.75	1.50(-22)	5.00(16)
011	010	2.68	3.30(-21)	5.40(16)
030	020	6.60	7.00(-24)	4.90(15)
030	000	2.14	2.00(-22)	9.30(16)
110	000	1.91	1.83(-20)	1.20(17)
011	000	1.88	9.16(-19)	1.25(17)

*Number in parentheses is power of ten.

TABLE 7: CARBON DIOXIDE BAND DATA

VIBRATIONAL TRANSITION		BAND CENTER WAVELENGTH	BAND STRENGTH AT 296°K	SOLAR FLUX AT BAND CENTER
UPPER STATE	LOWER STATE	(μm)	($mol^{-1}cm^2cm^{-1}$)	(photons $cm^{-2}\mu m^{-1}$)
01101	00001	14.98	8.26(-18)*	4.60(14)
10002	01101	16.18	1.44(-19)	3.70(14)
02201	01101	14.98	6.49(-19)	4.60(14)
10001	01101	13.87	1.85(-19)	5.80(14)
11102	00001	5.17	1.06(-21)	9.45(15)
11102	10002	15.45	2.22(-20)	4.20(14)
11102	02201	16.74	5.21(-21)	3.35(14)
11102	10001	18.37	2.72(-22)	2.55(14)
03301	02201	14.97	3.82(-20)	4.60(14)
11101	00001	4.81	4.87(-21)	1.15(15)
11101	10002	12.64	1.12(-21)	7.00(14)
11101	02201	13.48	7.90(-21)	6.30(14)
11101	10001	14.52	1.49(-20)	5.00(14)
00011	00001	4.26	9.60(-17)	1.60(16)
00011	10002	9.40	9.03(-22)	1.78(15)
00011	10001	10.41	6.87(-22)	1.31(15)
01111	01101	4.28	7.66(-18)	1.60(16)
10012	00001	2.77	1.04(-18)	4.95(16)
10012	10002	4.30	1.93(-19)	1.60(16)
02211	02201	4.30	3.08(-19)	1.60(16)
10011	00001	2.69	1.50(-18)	5.35(16)
10011	10001	4.30	1.18(-19)	1.60(16)
20013	00001	2.06	8.07(-21)	1.02(17)
20013	10002	2.80	3.38(-21)	4.80(16)
20012	00001	2.01	3.50(-20)	1.07(17)
20012	10002	2.71	4.24(-21)	5.20(16)
20012	10001	2.79	1.78(-21)	4.90(16)
20011	00001	1.96	1.12(-20)	1.14(17)
20011	10001	2.69	3.50(-21)	5.30(16)

*Number in parentheses is power of ten

TABLE 8: NITRIC OXIDE BAND DATA

VIBRATIONAL TRANSITION UPPER STATE	LOWER STATE	BAND CENTER WAVELENGTH (μm)	BAND STRENGTH AT 296°K ($mol^{-1}cm^{2}cm^{-1}$)	SOLAR FLUX AT BAND CENTER (photons $cm^{-2}\mu m^{-1}$)
1	0	5.32	5.0×10^{-18}	8.7×10^{15}
2	0	2.68	8.5×10^{-20}	5.4×10^{16}
2	1	5.41	1.27×10^{-21}	8.4×10^{15}

TABLE 9: OZONE BAND DATA

VIBRATIONAL TRANSITION UPPER STATE	VIBRATIONAL TRANSITION LOWER STATE	BAND CENTER WAVELENGTH (μm)	BAND STRENGTH AT 296°K ($mol^{-1}cm^2cm^{-1}$)	SOLAR FLUX AT BAND CENTER (photons $cm^{-2}\mu m^{-1}$)
010	000	14.27	6.28×10^{-19}	5.30×10^{14}
001	000	9.60	1.29×10^{-17}	1.68×10^{15}
100	000	9.07	6.71×10^{-19}	1.97×10^{15}
020	000	14.32	4.16×10^{-20}	5.20×10^{14}
011	000	5.79	5.37×10^{-20}	7.50×10^{15}
011	010	9.75	4.50×10^{-19}	1.60×10^{15}
110	000	5.57	2.27×10^{-20}	7.70×10^{15}
110	010	9.13	1.10×10^{-20}	2.25×10^{15}
002	000	4.86	1.11×10^{-19}	1.12×10^{16}
002	001	9.84	1.74×10^{-19}	1.55×10^{15}
101	000	4.74	1.13×10^{-18}	1.20×10^{16}
101	001	9.36	3.22×10^{-21}	1.80×10^{15}
101	100	9.92	6.15×10^{-20}	1.50×10^{15}
200	000	4.54	3.00×10^{-20}	1.35×10^{16}
200	100	9.11	6.30×10^{-21}	1.92×10^{15}
111	000	3.59	2.32×10^{-20}	2.55×10^{16}
111	010	4.80	3.85×10^{-20}	1.16×10^{16}
111	001	5.74	1.52×10^{-22}	7.10×10^{15}
111	100	5.94	2.65×10^{-22}	6.50×10^{15}
111	011	9.45	1.65×10^{-22}	1.75×10^{15}
111	110	10.11	2.50×10^{-21}	1.43×10^{15}
003	000	3.29	1.11×10^{-19}	3.20×10^{16}
003	001	5.00	2.23×10^{-21}	1.04×10^{16}
003	002	10.17	1.96×10^{-21}	1.41×10^{15}
004	003	10.50	2.12×10^{-23}	1.38×10^{15}
005	004	10.85	2.66×10^{-25}	1.38×10^{15}
006	005	11.20	3.61×10^{-27}	1.38×10^{15}
007	006	11.60	5.48×10^{-29}	1.38×10^{15}
008	007	12.02	9.50×10^{-31}	1.38×10^{15}
009	008	12.47	1.87×10^{-32}	1.38×10^{15}

TABLE 10: CARBON MONOXIDE BAND DATA

VIBRATIONAL TRANSITION UPPER STATE	VIBRATIONAL TRANSITION LOWER STATE	BAND CENTER WAVELENGTH (μm)	BAND STRENGTH AT 296°K ($mol^{-1}cm^{2}cm^{-1}$)	SOLAR FLUX AT BAND CENTER (photons $cm^{-2}\mu m^{-1}$)
1	0	4.67	9.70×10^{-18}	1.25×10^{16}
2	0	2.35	6.99×10^{-20}	7.40×10^{16}
2	1	4.72	5.80×10^{-22}	1.20×10^{16}

3. USING THE COMPUTER MODEL

The high altitude radiance program consists of four program sets. The first includes five programs that compute vibrational populations, BGND2 for CO_2, BGND3 for H_2O, BNGD4 for NO, BNGD6 for O_3, and BNGD7 for CO. The other three are BGND9, SPCTRA and TRYPEN. Each program may be run separately or in appropriate combination with one or more of the others. A general flow chart for the high altitude radiance program is given in Figure 1, which shows the basic routines of the computer program. We use the water vapor program BGND3 to illustrate use of the first group. Program BGND3 ($H_2Ø$) computes vibrational populations and total unit volume band radiances at 2 km intervals between Ø and 15Ø km, and at 1Ø km intervals between 15Ø and 7ØØ km. Program BGND9 integrates radiance values, mean temperature, and total number of molecules per square centimeter in each vibrational level along the line-of-sight for two endo-atmospheric viewing levels: vertical (Ø°) and horizontal (9Ø°) and for exo-atmospheric limb viewing. The computations include modifications necessary for the effects of optical thickness along the line-of-sight. Program SPCTRA computes spectral radiances, corresponding to the total band radiances outputted by BGND3 ($H_2Ø$) and BGND9, between 25Ø and 6ØØØ wavenumbers. The last program TRYPEN plots the output of SPCTRA for a maximum of five altitudes, one at a time.

The following is a user oriented discussion and description concerning the mechanism and input data required to make a successful program run. A detailed flow chart of each program is also included. For calculating vibrational populations the flow chart for the $H_2Ø$ molecule program (BGND3) is used. Only those variables which pertain to input data are listed and derived. A complete list of the variables used in the four programs and their related subroutines is given by Degges and Smith[3].

Subroutines BNRAD2 (carbon dioxide program BGND2) and BNRAD6 (ozone program BGND6) call a linear equation solver, LEQTIF. This is a subroutine from the IMSL library,

This library is licensed for use at AFGL only, and we cannot supply it with the programs. The IMSL handbook references the similar subroutines DECOMP, SOLVE, and SING listed and described by Forsythe and Moler [24]. These or any other linear equation solvers may be used with these programs.

CALCULATE VIBRATIONAL POPULATIONS

PROGRAM BGND3
(H_2O)

The main program BGND3 reads and checks the input data and transfers control to subroutine BNRAD3 which computes vibrational population, local optical thickness, and volume radiances for all included bands of a single molecular species. The program requires as input the temperature, molecular concentration data, and the concentration and temperature descriptors.

PROGRAM

Carbon Dioxide	BGND2
Water Vapor	BGND3
Nitric Oxide	BNGD4
Ozone	BNGD6
Carbon Monoxide	BNGD7

See Appendix A for the list of the programs and the data on the distribution tape.

PROGRAM SPECIFICATIONS

There is a different program to be used for each molecular species.

PROGRAM INPUT

A. Input data variables or constants to direct program flow to appropriate calculations.

ZFAC Secant of solar zenith angle. This is required to properly treat absorption of incident solar radiative fluxes.

ICHEK Used to print diagnostic informat'~~. Normally zero, must be set to 1 (integer one) for listing of optical thicknesses and results of intermediate radiative transfer calculations.

ICOOL Normally zero, set to integer one to compute and print atmospheric cooling (or heating)rates for each infrared band included in the program.

B. Molecular species data: Temperature, Concentrations, Band, and Level data. See Appendix A. Listed below are the variables and constants in the order in which they are read in.

NLTE Integer variable used to indicate conditions of computations.

= 1 - Local thermodynamic equilibrium

= 2 - Collisional excitation only

= 3 - Night conditions

= 4 - Noon conditions

= 5 - To include high vibrational temperatures for nitrogen

T   Temperature profile (°K)

Molecular concentrations (molecules/cm^3)

CONN2 - Nitrogen

CONO2 - Oxygen

CONO - Atomic Oxygen

CONCH4 - Methane

CONCO2 - Carbon Dioxide

CONH2O - Water Vapor

CONNO - Nitric Oxide

CONN2O - Nitrous Oxide

CONO3 - Ozone

CONCO - Carbon Monoxide

IGAS   Number of molecular species for which data is to be read in.

XID   Array of molecular species names

ICHK   Molecule identifier code

1 - Methane

2 - Carbon Dioxide

3 - Water Vapor

4 - Nitric Oxide

5 - Nitrous Oxide

6 - Ozone

7 - Carbon Monoxide

ALTM	Maximum altitude of the molecular species for which total band radiances are calculated. Also used for calculating the number of altitude levels. The values in (km) are: 120 - Methane 700 - Carbon Dioxide 700 - Water Vapor 700 - Nitric Oxide 150 - Nitrous Oxide 700 - Ozone 700 - Carbon Monoxide
TYPE	Temporary location for species names (See XID)
NLEV	Number of vibrational levels for this species
NBAND	Number of bands for this species
AMAS	Molecular mass of the molecule (g/mole)
DEXT	Rate coefficient at 300°K for vibrational exchange of Nitric Oxide with Nitrogen or Oxygen for the most significant vibrational level (cm^3/sec)
DEXB	Rate coefficient at 300°K for vibrational de-excitation of lowest Nitric Oxide vibrational level (cm^3/sec)
LSC	Integer array containing level type information
LCC	Integer array containing vibrational level coupling to Nitrogen or Oxygen
RCM	Array containing energy level of each band (cm^{-1})
BV	Rotational constant (cm^{-1})
JGAS	See ICHK
JLEVEL	Level number

LBC	Integer array containing information on which levels produce a band
LBU	Integer array containing band type information
STR	Array of band strength for each band ($cm^{-1}(atm\text{-}cm)^{-1}$)
SFLUX	Array of solar flux values for each band
TFLUX	Array containing fluxes from lower altitudes for each band

PROGRAM OUTPUT

Write level and band data to File 4

SUBROUTINE BNRAD3

PROGRAM SPECIFICATIONS

Called by BGND3

INPUT DATA

None (read in)

OUTPUT DATA

Write vibrational populations, unit optical thickness, and volume radiances to file 3

DECK SET-UP

1. Attach program BGND3.
2. Attach required subroutines - PROGLIB.
3. Attach data file.
4. Catalog output, TAPE3, TAPE4.

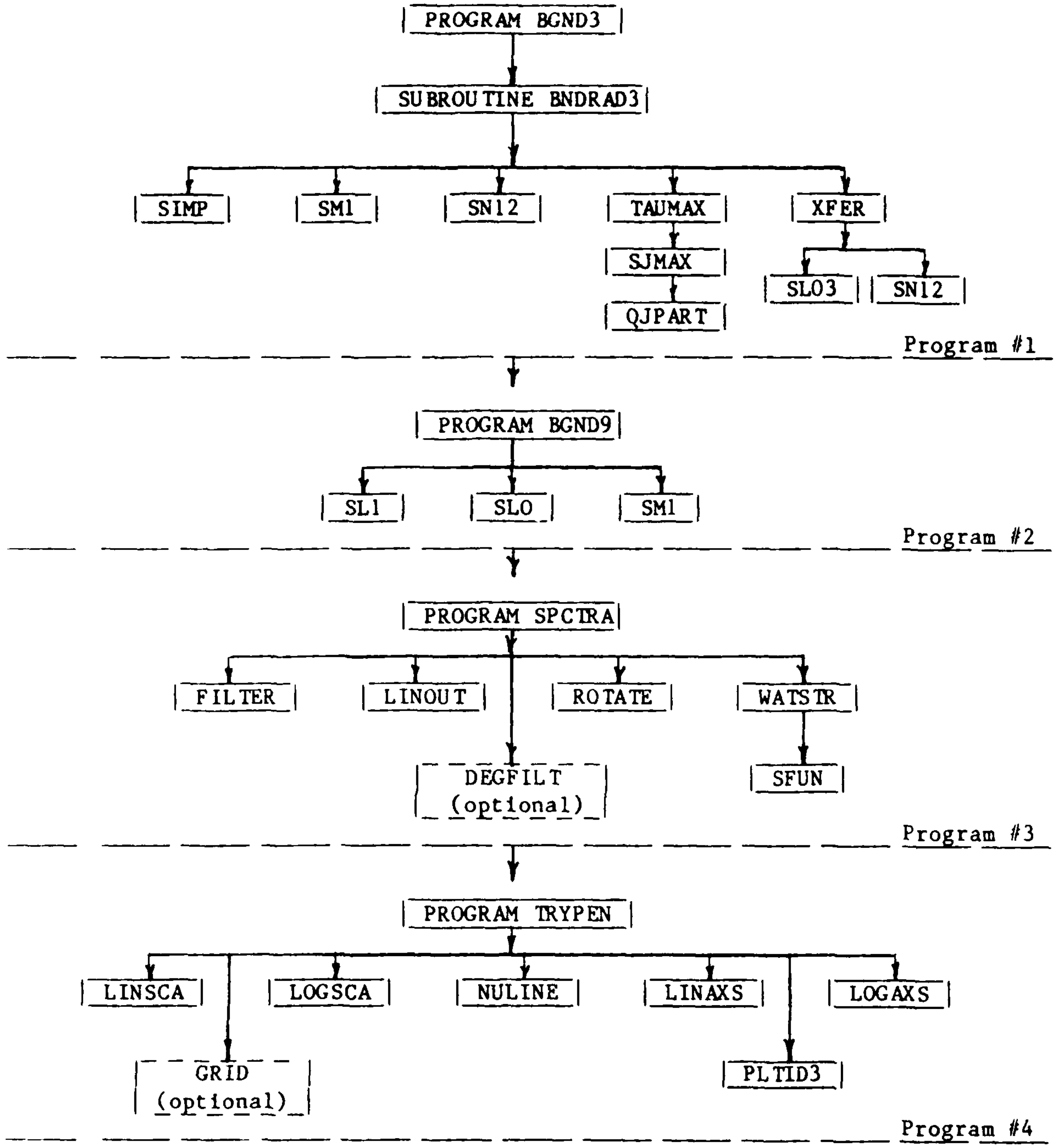

FIGURE 1. General Flow Chart for the High Altitude Radiance Program

PROGRAM BGND3

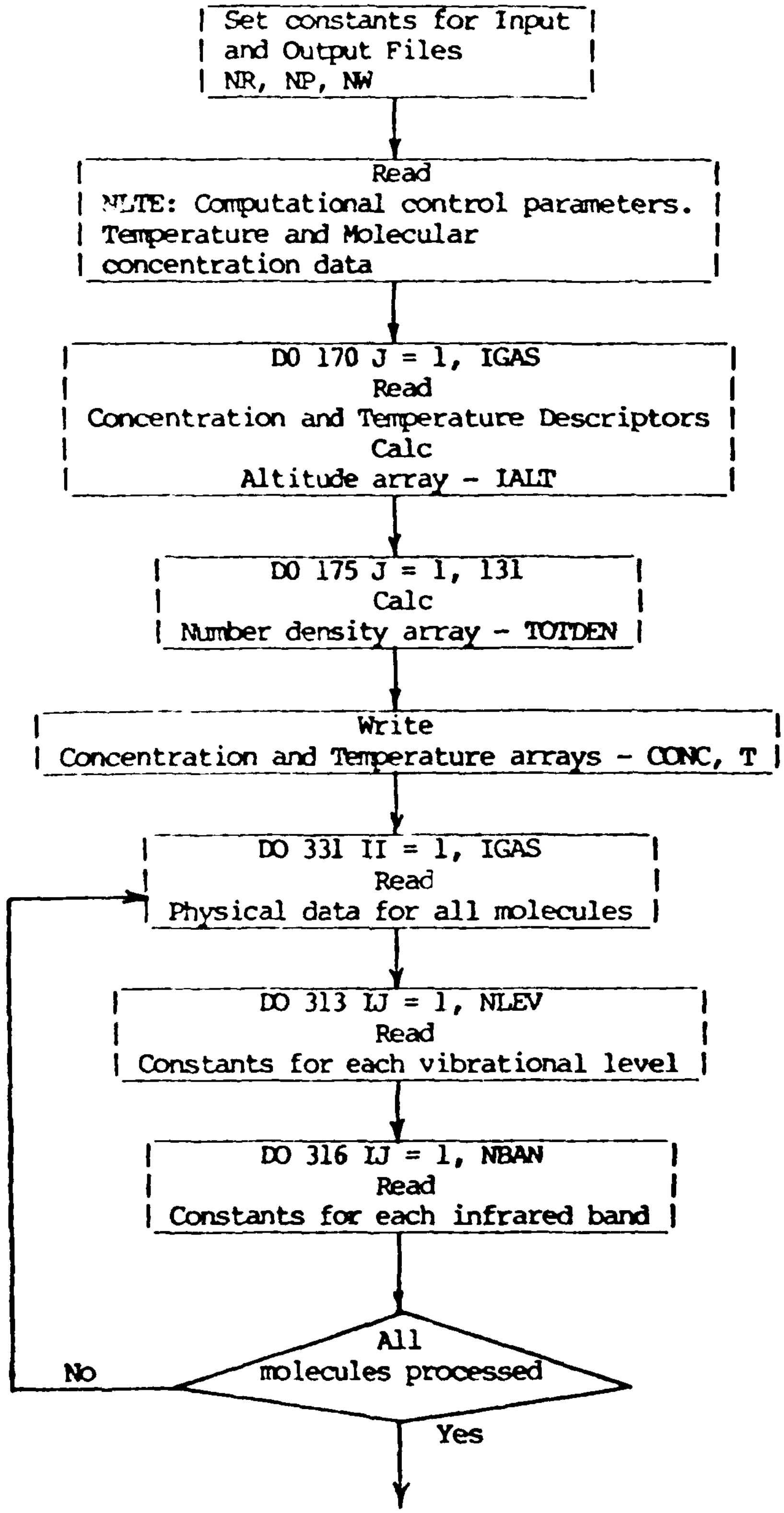

FIGURE 2. Detailed Flow Chart for Program BGND3

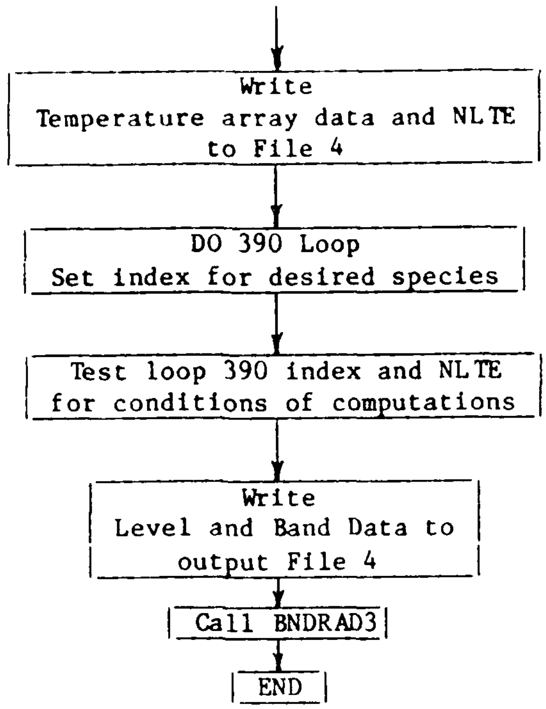

FIGURE 2. Detailed Flow Chart for Program BGND3 (cont'd)

SUBROUTINE BNRAD3

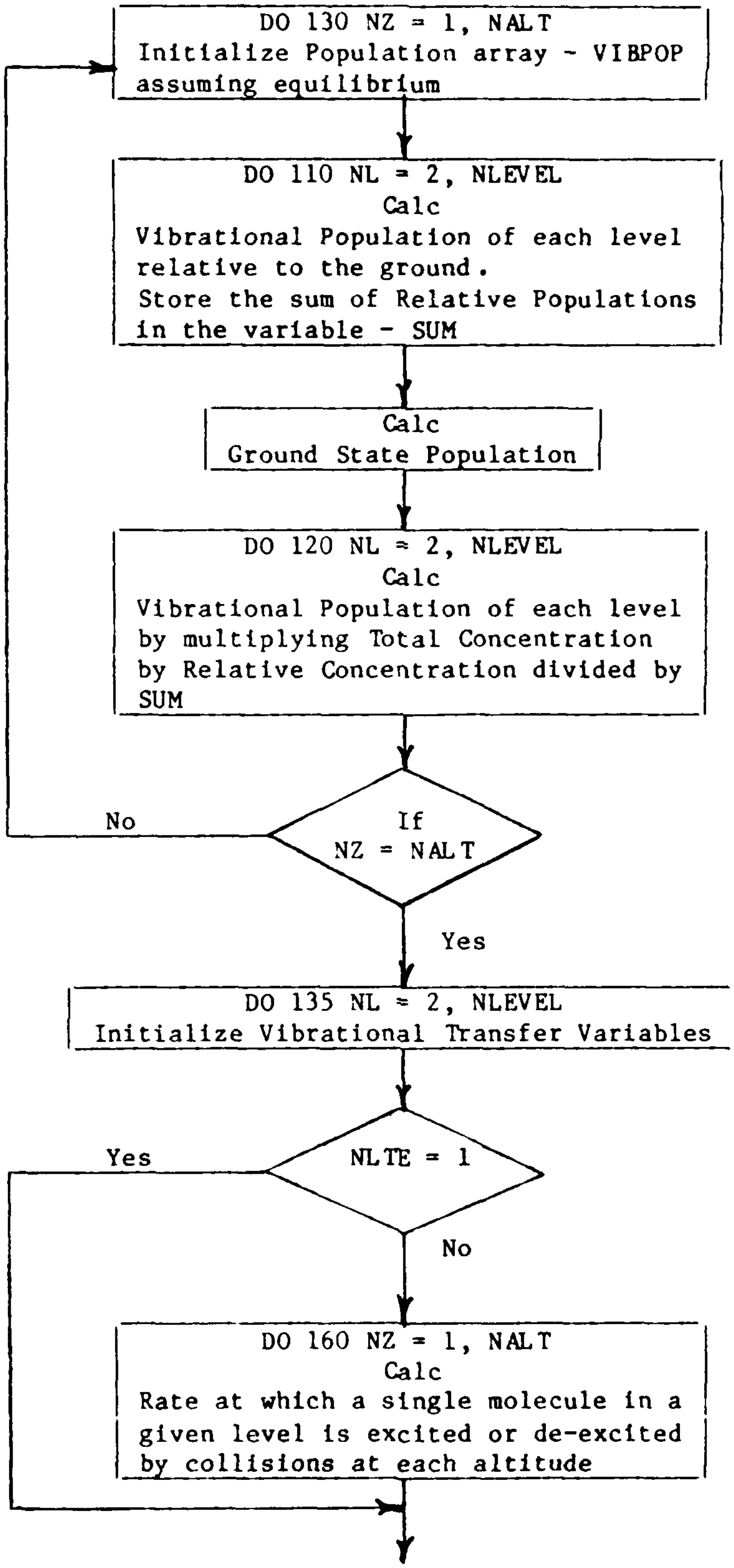

FIGURE 2A. Detailed Flow Chart for Program BGND3

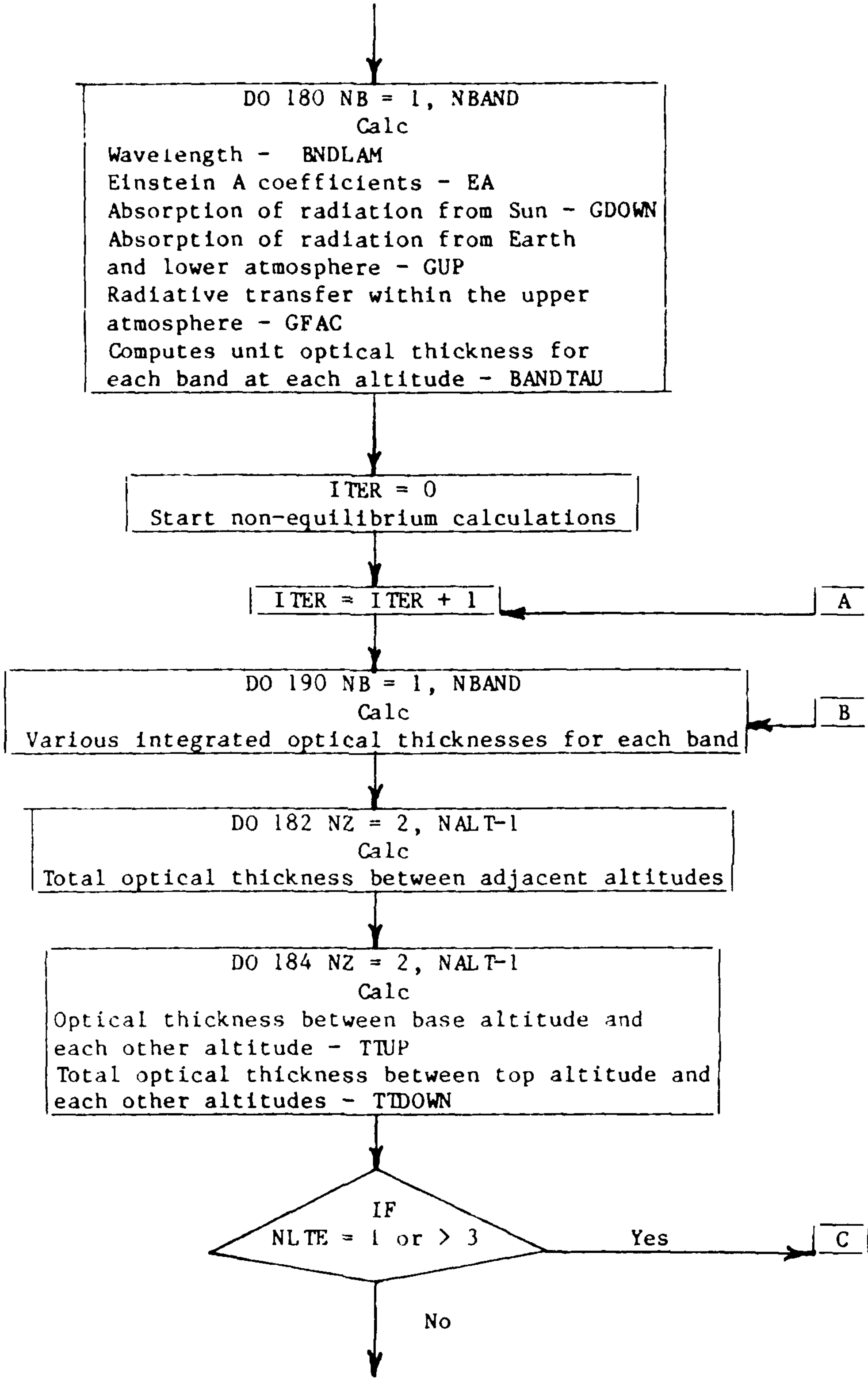

FIGURE 2A. Detailed Flow Chart for Program BGND3 (cont'd)

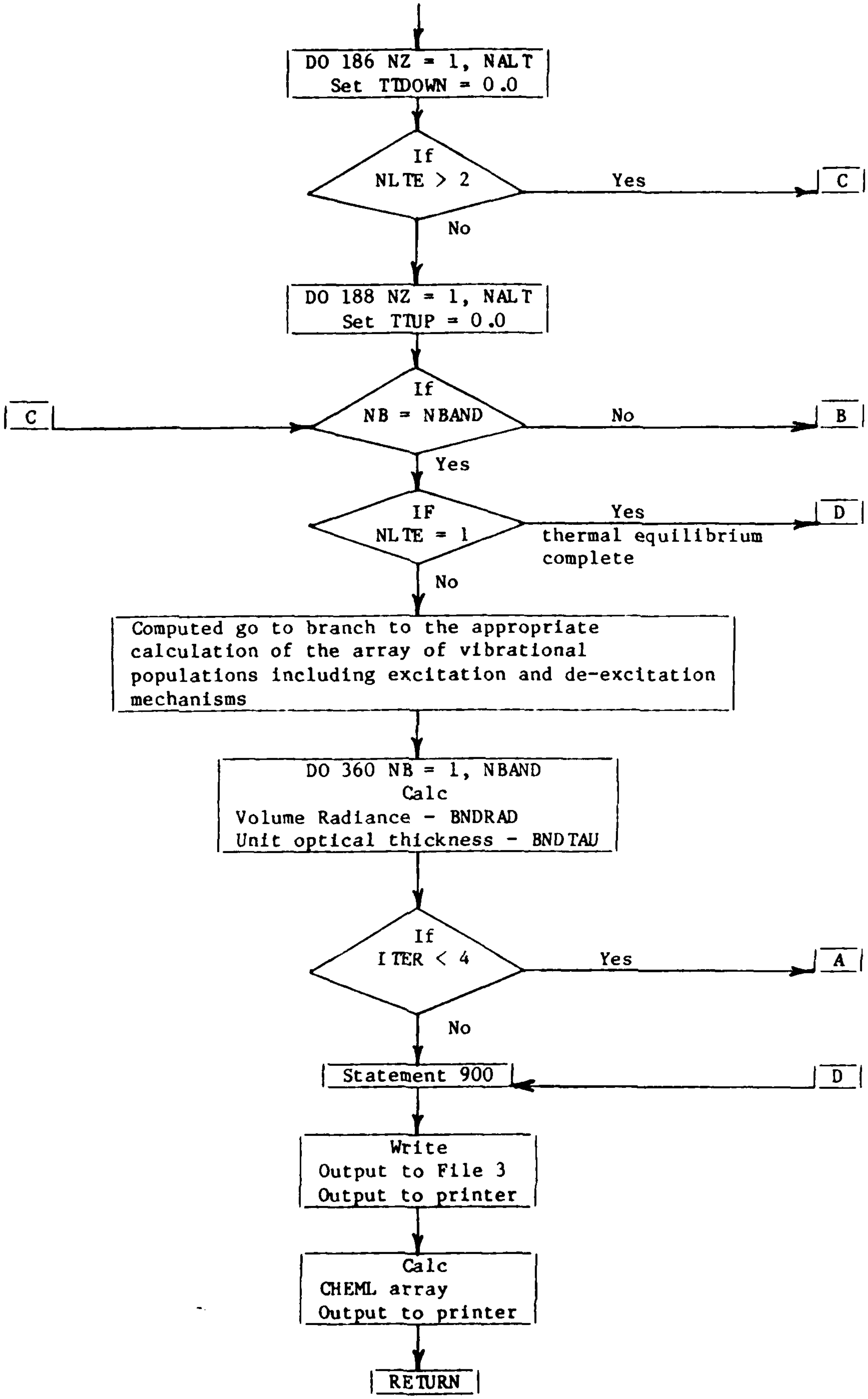

FIGURE 2A. Detailed Flow Chart for Program BGND3 (cont'd)

PROGRAM BGND9

Program BGND9 computes the effective temperature, and the radiance values for two endo-atmospheric viewing levels (horizontal, vertical) and one exo-atmospheric viewing level (limb). In the current version radiance values are computed at 2 km intervals of tangent height up to 150 km and at 10 km intervals above 150 km. The integration of radiance values for each viewing level begins at the viewing level. At each point on the line-of-sight, the contribution of the local volume emission rate to that received at the viewing point is computed.

PROGRAM

See Appendix A for program requirements.

PROGRAM MODIFICATIONS

A. If the viewing angles other than horizontal, vertical, and limb are desired, they must be defined within the program. See the variables ANGLE(K), ZANGL, and DZANG in the program.

B. DO 830 Loop controls the tangent height range, currently set for 60 to 250 km. See the equation below the program statement DO 830 K=31, 86 to determine how to calculate the indices to obtain the desired tangent height range.

PROGRAM INPUT

Output files of program BGND3. No other input is required.

PROGRAM OUTPUT

Write integrated radiances, effective temperatures and total number of molecules to file 3.

DECK SET-UP

1. Attach program BGND9.

2. Attach required subroutines - PROGLIB.

3. Attach data file - Output from BGND3.

4. Catalog output, TAPE4.

PROGRAM BGND9

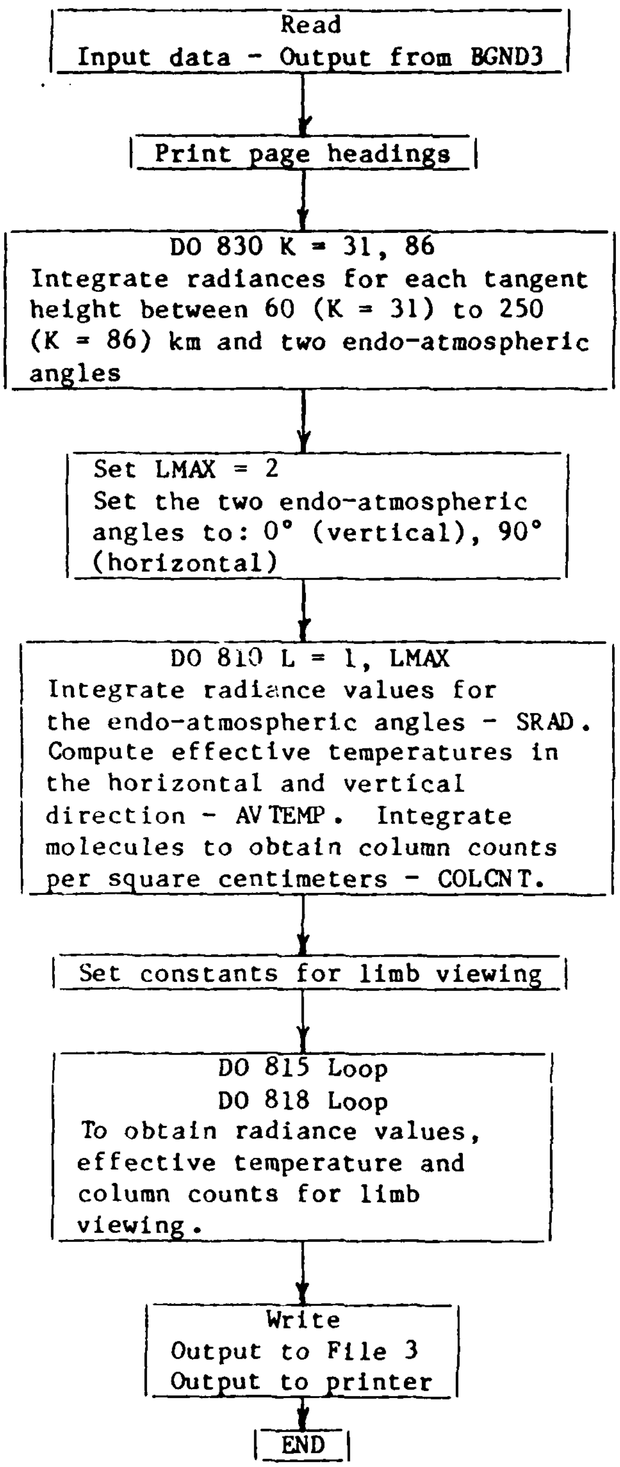

FIGURE 3. Detailed Flow Chart for Program BGND9

PROGRAM SPCTRA

Program SPCTRA computes spectral radiances, corresponding to total band radiances calculated in programs BGND3 and BGND9, between 250 and 6000 wavenumbers. The program in its present form can calculate spectral radiances for only one viewing angle at a time. If required an optional filter subroutine may be attached to the program.

PROGRAM

See Appendix A for the list of the programs on the distribution tape.

PROGRAM MODIFICATIONS

None

PROGRAM INPUT

A. Output files from programs BGND3 and BGND9.

HTS — Altitude (km)

RAD — Total band radiances.

- RAD(1,I) exo-atmospheric limb viewing level
- RAD(2,I) endo-atmospheric vertical viewing level
- RAD(3,I) endo-atmospheric horizontal viewing level

THT — Dummy altitude variable

AVTEMP — Array in which effective temperatures are stored (°K)

- AVTEMP(1,I) Limb viewing
- AVTEMP(2,I) Vertical viewing
- AVETMP(3,I) Horizontal viewing

COLCNT   Array in which column counts in each
            vibrational level are stored.

COLCNT(1,I) Limb viewing

COLCNT(2,I) Vertical viewing

COLCNT(3,I) Horizontal viewing

B. Input data variables or constants to direct program flow to appropriate calculations.

NLTE	See PROGRAM INPUT list of variables for program BGND3
NALT	Number of altitudes for which results are to be returned
JMAX	Number of angles included for each altitude
KALT	Lowest altitude used - first altitude read in
KMAX	Number of spectra to be calculated in each trip through DO Loop 500. Five is maximum.
JTMX	Limit of DO Loop 500.
KLMX	Value of KMAX on the last trip through Loop 500.
JLST	Index of the lowest altitude to have spectra computed.
JLDL	Increment of altitude index.

KA,KB,KC, KD, KE	Indices for selecting the desired viewing level.
= 1	Limb
= 2	Vertical (0°)
= 3	Horizontal (90°)
JLO	Dummy variable. Program sets JLST to JLO.
JHI	Dummy variable. Program sets JHI to JLO + 1
WTLO	Weighting constant = 1.0
WTHI	Weighting constant = 0.0

C. SPECTRAL LINE DATA

Spectral line data is read in subroutine ROTATE. The input data consists of line positions and strengths for vibrational-rotational bands of water, carbon dioxide, ozone, nitric oxide, carbon monoxide, and for the pure rotational spectrum of water. See Appendix B.

PROGRAM OUTPUT

Write spectral radiances for each altitude to File 4.

DECK SET-UP

1. Attach program SPCTRA.
2. Attach required subroutines ~ PROGLIB.
3. Attach data file, output from BGND3 and BGND9.
4. Attach line file.
5. Attach input data file.
6. Catalog output, TAPE7.

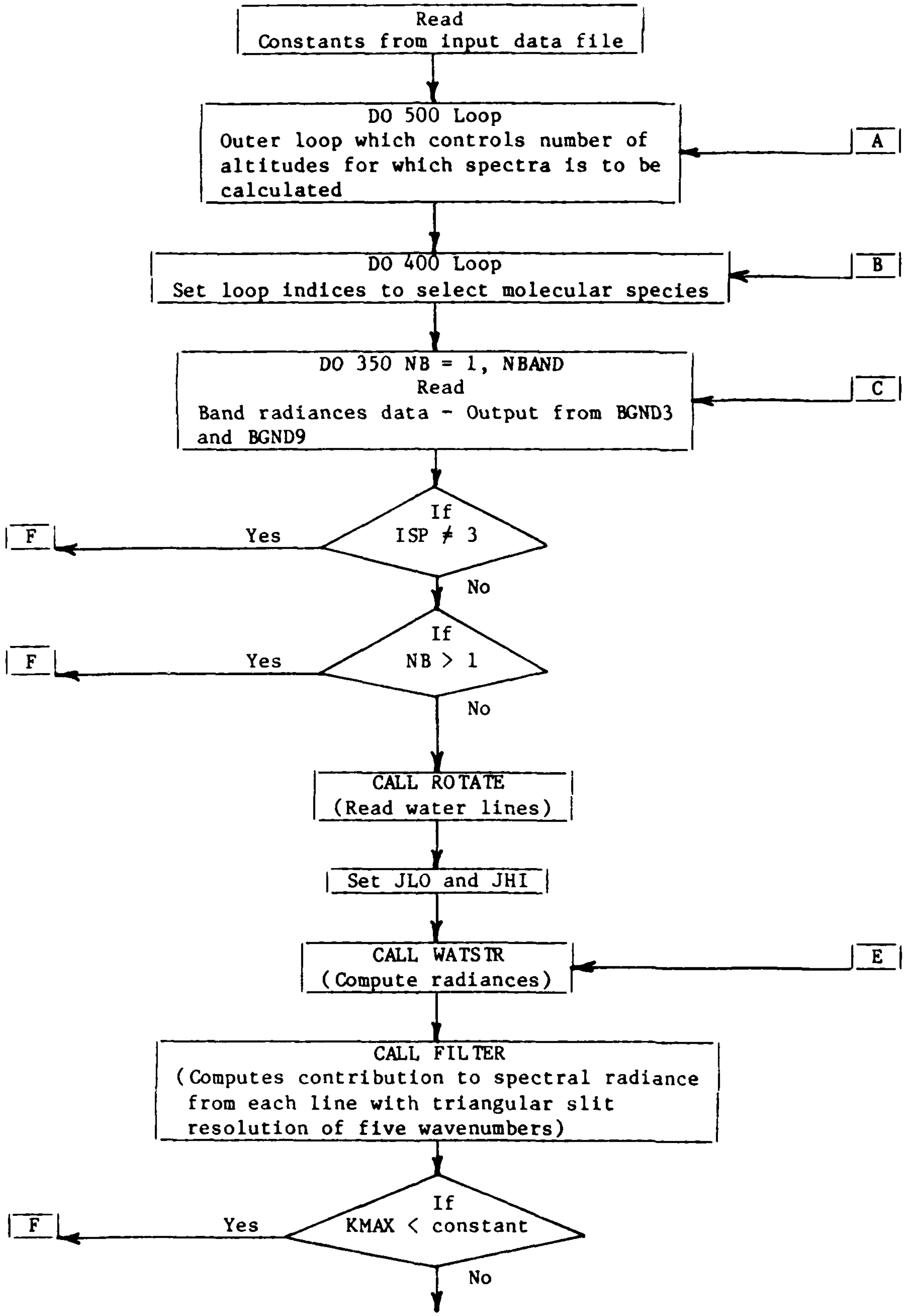

FIGURE 4. Detailed Flow Chart for Program SPCTRA

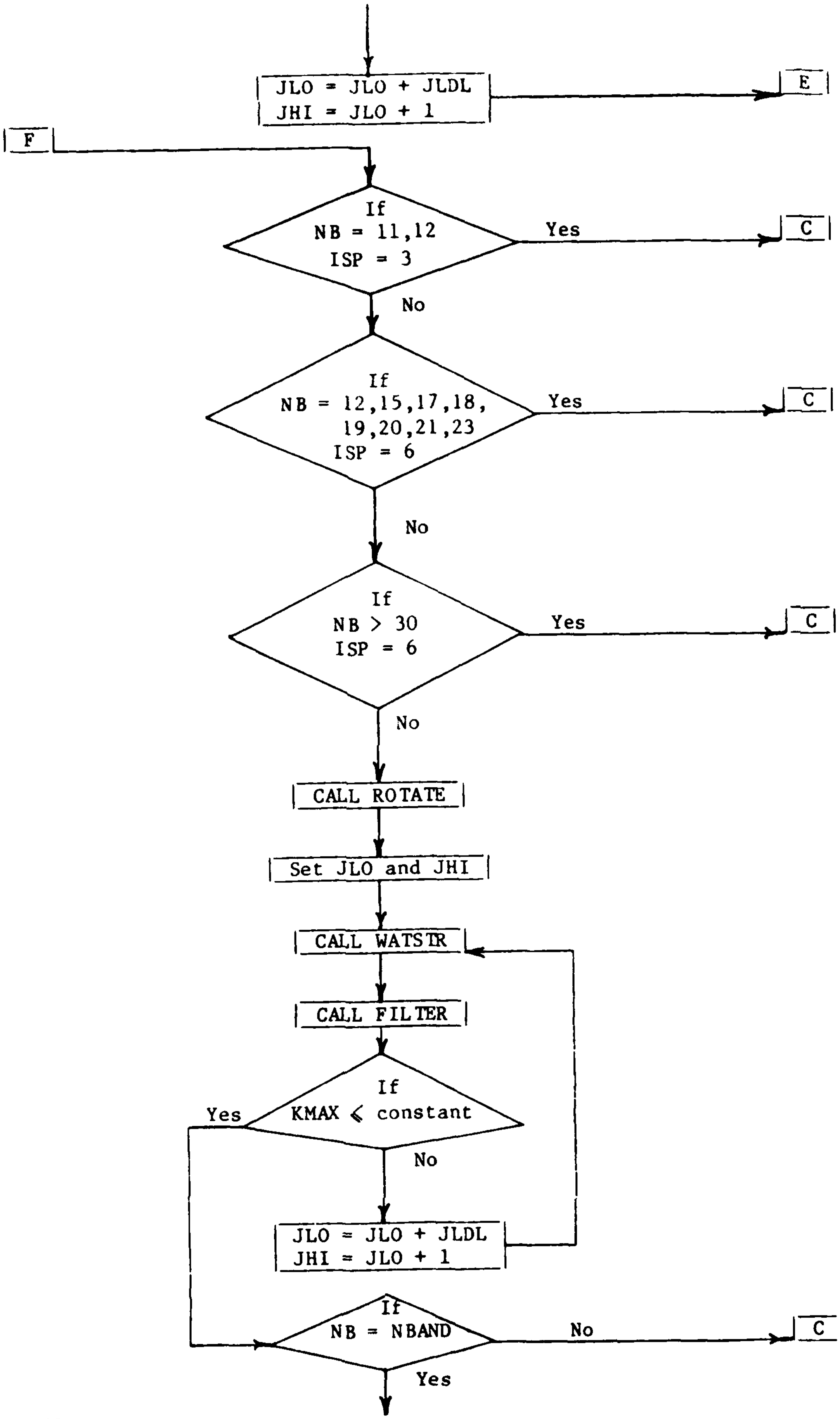

FIGURE 4. Detailed Flow Chart for Program SPCTRA (cont'd)

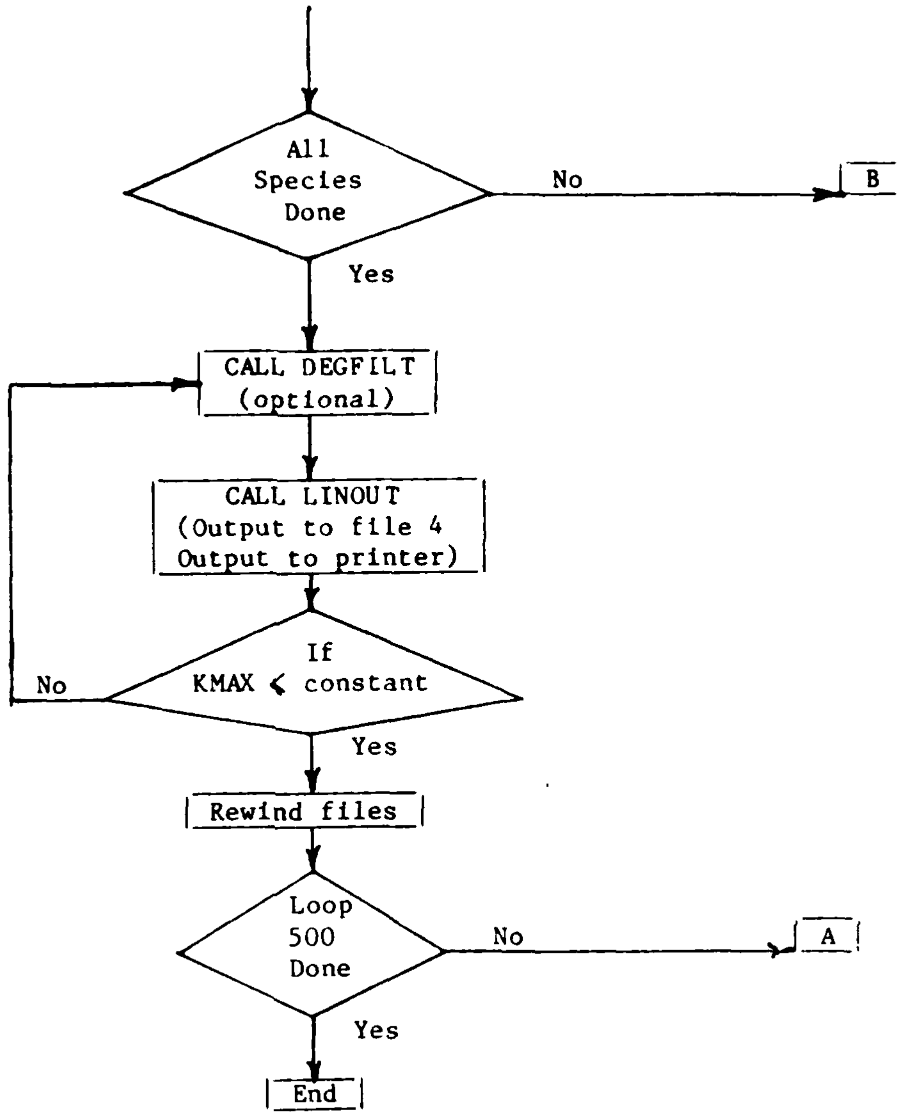

FIGURE 4. Detailed Flow Chart for Program SPCTRA (cont'd)

PROGRAM TRYPEN

The plotting program, TRYPEN, was developed under a previous contract and consists of a main program and six subroutines, LINSCA, LOGSCA, LINAXS, LOGAXS, GRID, and NULINE.

PROGRAM

See Appendix A for program requirements.

PROGRAM MODIFICATIONS

None

PROGRAM INPUT

A. Output from program SPCTRA.

YT	Spectral radiances

B. Input data variables or constants to direct program flow to the appropriate calculations.

JMAX	Number of plots per run. Eleven is maximum.
IDENT	Job name or job identification.
SX	Length of X-axis, inches.
SY	Length of Y-axis, inches
KALT	Lowest altitude plotted.
KDEL	Altitude increment between plotted curves.
LL=0	Logarithmic ordinate. LCYCLE will be the maximum number of cycles on the ordinate scale.
LL=1	Linear ordinate scale. LCYCLE=1, forces scaling of all sets of data at once. LCYCLE=0, scale each set of data separately. Abscissa scale is linear.

LCYCLE		Number of cycles to be plotted on ordinate.
	>0	No more than LCYCLE log cycles will be produced.
	=0	Input value of MIN will be used, unless it is greater than or equal to computed value of MAX.
	<0	Exactly IABS (LCYCLE) log cycles will be used.
LW=0		Abscissa - Wavenumber.
LW=1		Abscissa - Wavelength (micrometers)
LPHOT=0		Ordinate - Power (watts)
LPHOT=1		Ordinate - Quanta (photons) per second
WMIN		Lower wavenumber limit to plot. Minimum is 250.0.
WMAX		Upper wavenumber limit to plot. Maximum is 6000.0.
DELM		Lower extension to plot range.
DELP		Upper extension to plot range.
ISMP		Greater than zero plot JMAX curves on the same plot area
PFAC		Scaling factor for all plots.
NXL		Number of characters in XBCD
XBCD		Abscissa label.
NYL		Number of characters in YBCD.
YBCD		Ordinate label.

C. Attach plot routines.

PROGRAM OUTPUT

Program will generate JMAX number of plots, plotting one curve (altitude) per graph. After JMAX plots have been plotted and labeled, the program will then generate a final plot with JMAX number of curves on one graph.

DECK SET-UP

1. Attach program TRYPEN.
2. Attach required subroutines - PROGLIB.
3. Attach plotting routines.
4. Attach data file, output from SPCTRA.
5. Attach input data file.

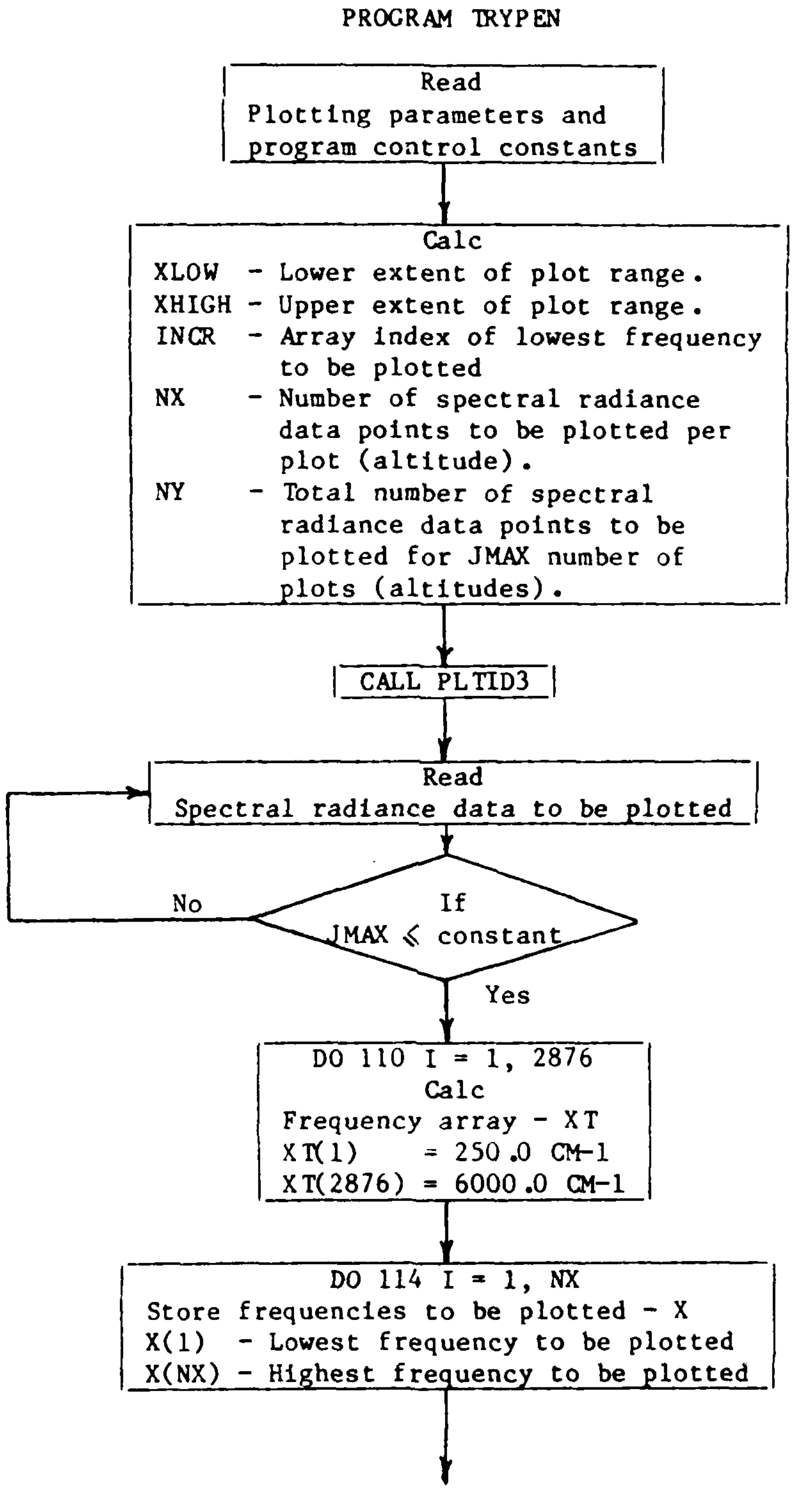

FIGURE 5. Detailed Flow Chart for Program TRYPEN

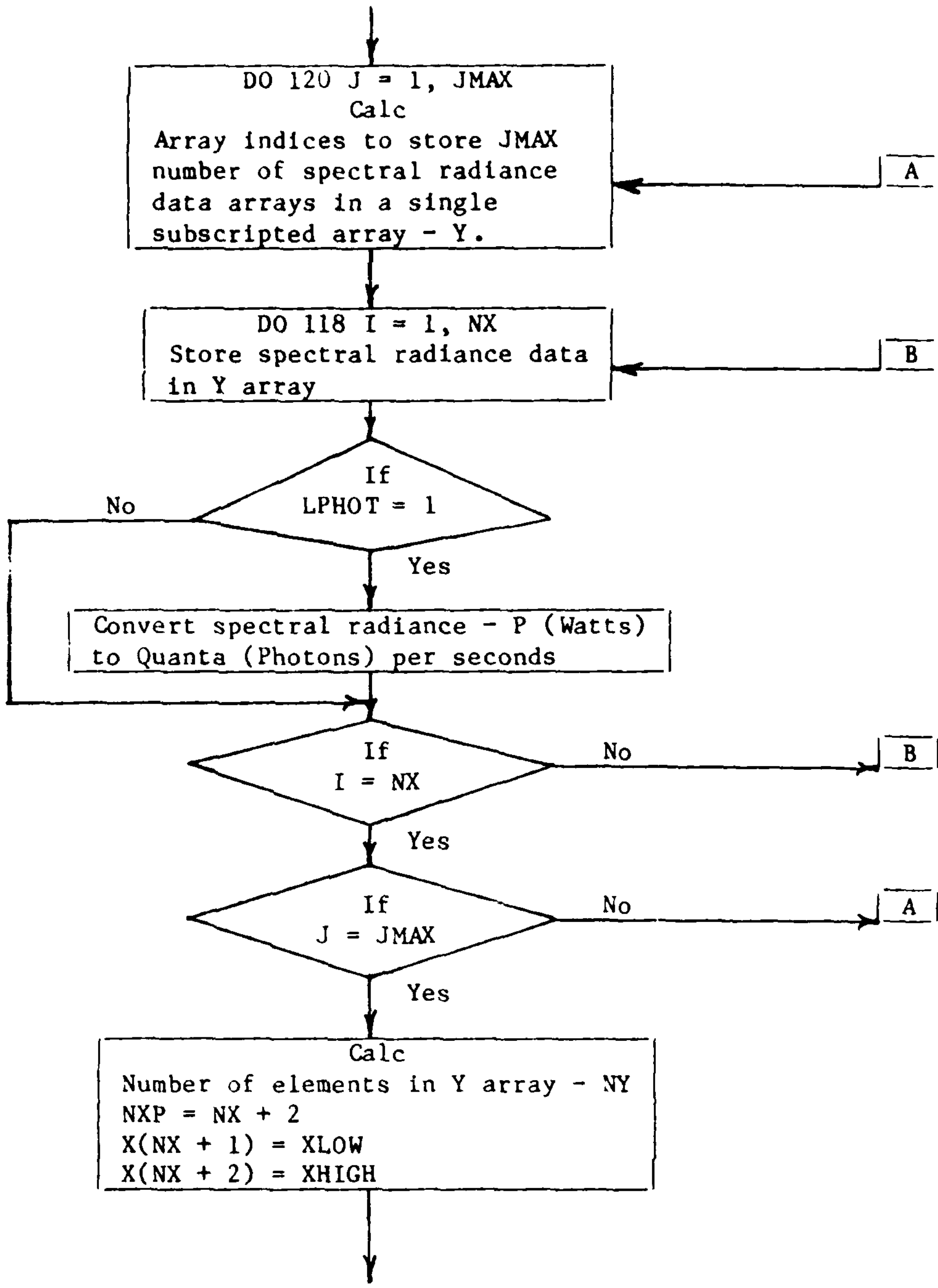

FIGURE 5. Detailed Flow Chart for Program TRYPEN (cont'd)

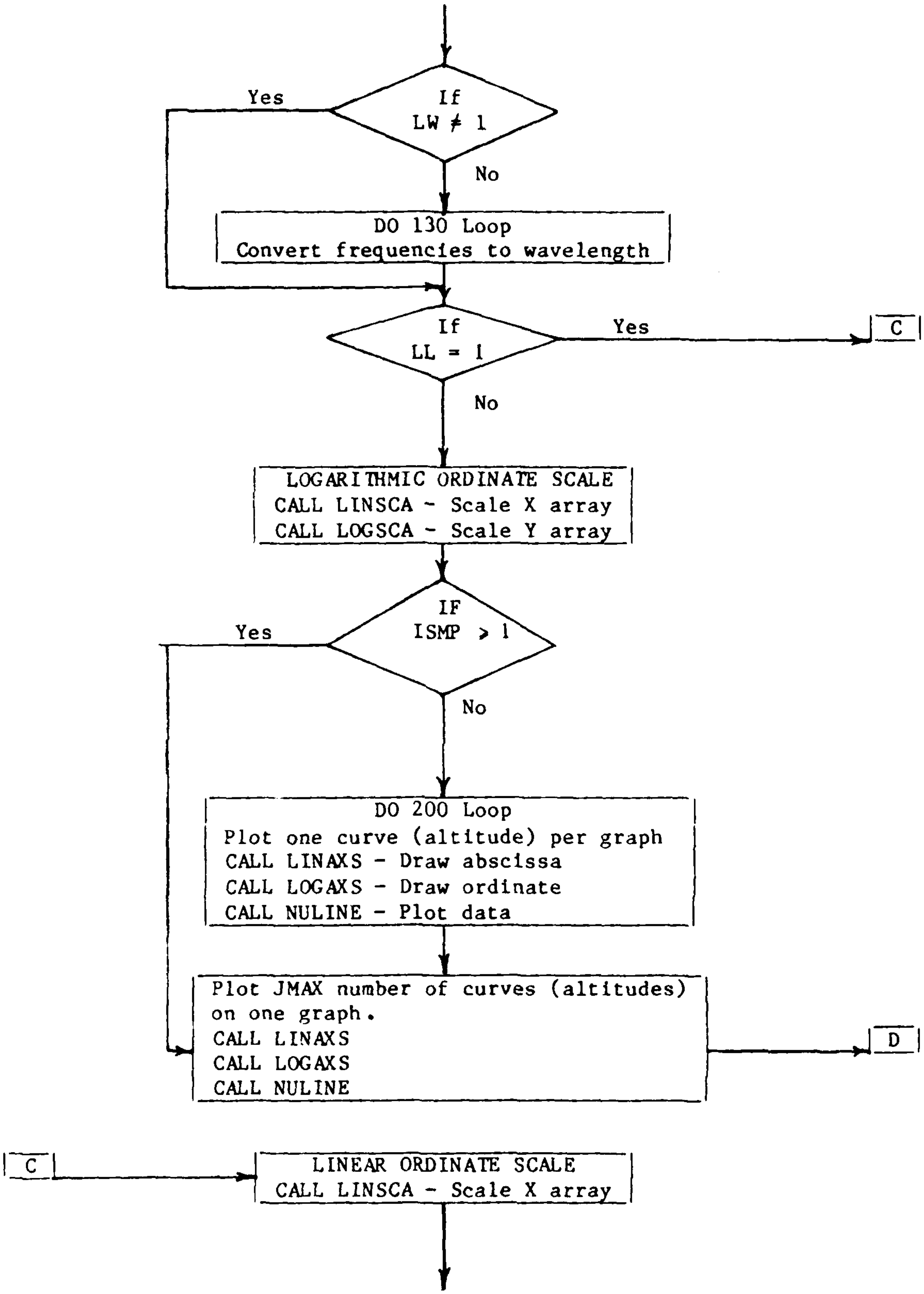

FIGURE 5. Detailed Flow Chart for Program TRYPEN (cont'd)

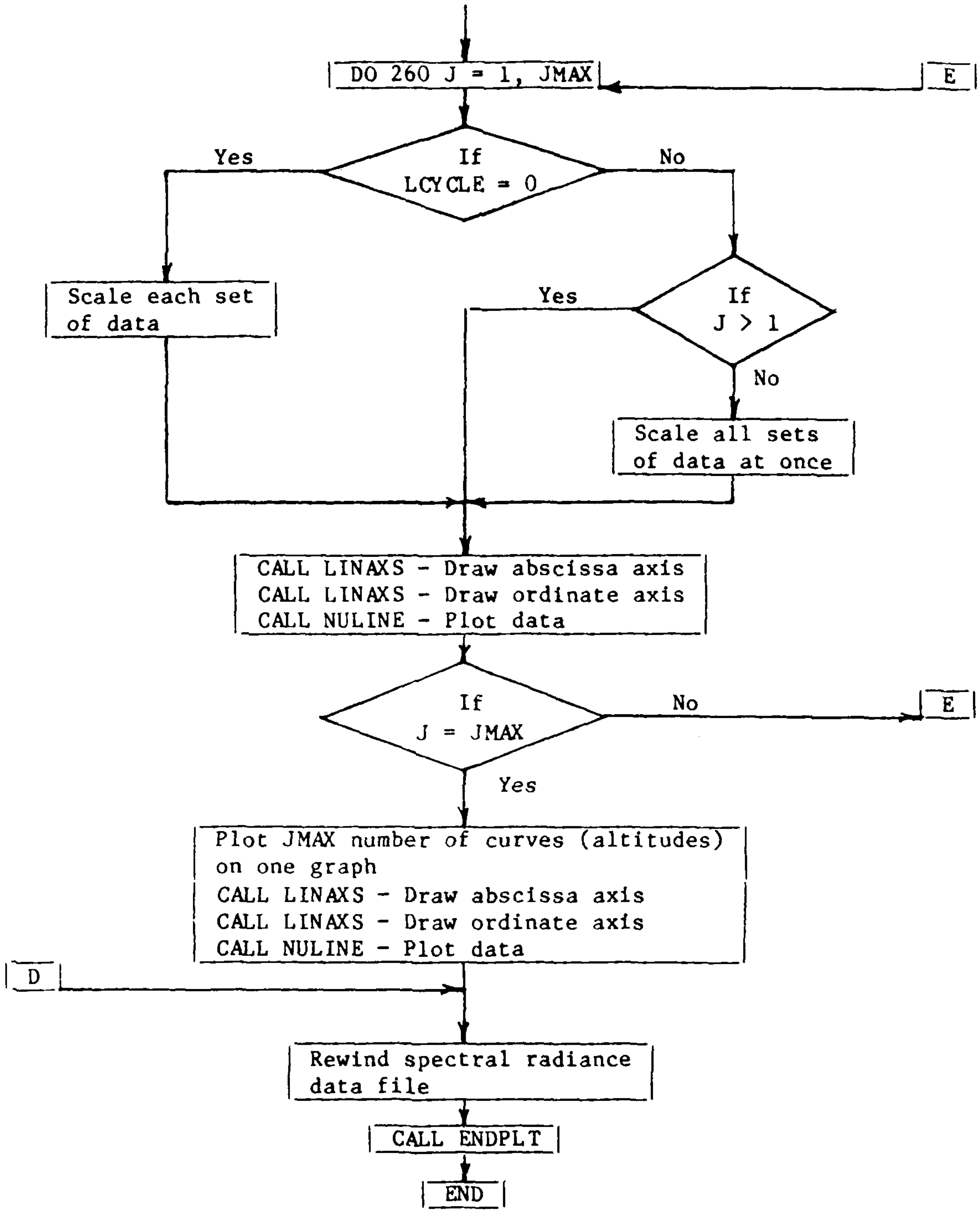

FIGURE 5. Detailed Flow Chart for Program TRYPEN (cont'd)

4. OZONE RADIANCE MODELING

Previous versions of the High Altitude Infrared Radince Model have provided for only one band of ozone, the ν_3 fundamental transition centered at 9.60 micrometers. This band was assumed to be the sole channel for chemiluminescent radiation, and the model calculations agreed with rocket measurements of total radiation in the 9 to 11 micrometer spectral region to within a factor of about two. It has been known for some time, however, that the ozone is formed in excited levels of the ν_3 and other modes in the three body reaction of atomic and molecular oxygen. Radiation from these higher levels falls at longer wavelengths up to about 12 micrometers, partially filling in the "window" region between the strong ozone fundamental radiance at 9.6 micrometers and the CO_2 bands beween 12 and 16 micrometers. Provision for these "hot" bands has been added to the ozone module and the method of calculation is outlined here. While some aspects are given in geater datail than has been done for the other molecules, the sketch below is incomplete and requires reference to earlier work, particularly Ref. 3.

We have relied heavily on Green et al.'s[23] analysis of rocket probe investigations of atmospheric infrared emissions in developing the current ozone radiance model in program BNGD6. The references in the tables to PSI refer to this report. In modeling the infrared radiance field, we have used data from McClatchey et al[19] and subsequent updates. Line strengths and positions are not available for ν_3 mode bands 4-3, 5-4,....and we have included them by extrapolating from the 1-0, 2-1, and 302 data, assuming constant dipole moment, but correcting for altered wavelength. Table 11 lists the vibrational levels included, and Table 12 lists bands used in the model. Note that while all are used in computing vibrational populations, not all are available for spectral radiance calculations. The computational scheme is outlined in equations (1) - (17). We use square brackets [] to indicate concentrations, molecules cm^{-3}. Parentheses are used to enclose vibrational state assignments. (011) indicates no excitation of the ν_1 mode, and one vibrational quantum in each of the ν_2 and ν_3 modes.

$$
\begin{aligned}
[O_3(010)] = \{ & [O_3(000)]\ (TF_{000010} + CR_{000010}) \\
& [O_3(001)]\ CR_{001010} + [O_3(100)]\ CR_{100010} \\
& + [O_3(020)]\ (A_{020010} + CR_{020010}) \\
& + [O_3(011)]\ A_{011010} + [O_3(110)]\ A_{110010} \\
& + [O_3(111)]\ A_{111010} \} / (A_{010000} + CR_{010000} \\
& + CR_{010001} + CR_{010100} + CR_{010020} + TF_{010020} \\
& + TF_{010011} + TF_{010110} + TF_{010111})
\end{aligned} \qquad (1)
$$

Here TF_{000010} is the rate at which a molecule in the ground state (000) is excited to the ν_2 mode (010) by absorption of radiation from the earth's surface, from radiation emitted by other ozone molecules in the 010-000 transition, and (daytime only) from the sun. The collisional excitation rates CR_{lu} and quenching rates CR_{ul} are given in Table 13.

$$
\begin{aligned}
[O_3(001)] = \{ & [O_3(000)]\ (TF_{000001} + CR_{000001} + CX_{000001}) \\
& + [O_3(010)]\ CR_{010001} + [O_3(100)]\ CR_{100001} \\
& + [O_3(002)]\ (A_{002001} + CR_{002001}) + [O_3(101)]\ A_{101001} \\
& + [O_3(111)]\ A_{111001} + [O_3(003)]\ A_{003001} \\
& + CF_{001} \} / (1.0 \times 10^{-11} [O] + A_{001000} \\
& + CR_{001000} + CX_{001000} + CR_{001010} \\
& + CR_{001100} + TF_{001002} + CR_{001002} + TF_{001101} \\
& + TF_{001111} + TF_{001003})
\end{aligned} \qquad (2)
$$

The new symbol CF_{001} introduced here is the rate of formation of ozone in the 001 state, assumed to be

$$2.32 \times 10^{-35} \exp(510/T) \{ [N_2] + [O_2] \} [O_2] [O]$$

The assumed rates for chemical formation in this and other vibrational states are presented in Table 14.

$$
\begin{aligned}
[O_3(100)] = \{ & [O_3(000)]\ (TF_{000100} + CR_{000100}) \\
& + [O_3(010)]\ CR_{010100} + [O_3(001)]\ CR_{001100} \\
& + [O_3(101)]\ (A_{101100} + CR_{101100}) \\
& + [O_3(200)]\ A_{200100} + [O_3(111)]\ A_{111100} \} \\
& / \ (1.0 \times 10^{-11}[O] + A_{100000} + CR_{100000} \\
& + CR_{100010} + CR_{100001} + TF_{100101} \\
& + CR_{100101} + TF_{100200} + TF_{100111})
\end{aligned} \tag{3}
$$

$$
\begin{aligned}
[O_3(020)] = \ & [O_3(010)]\ (TF_{010020} + CR_{010020}) \\
& / \ (1.0 \times 10^{-11}[O] + A_{020010} + CR_{020010})
\end{aligned} \tag{4}
$$

$$
\begin{aligned}
[O_3(011)] = \{ & [O_3(000)]\ TF_{000011} + [O_3(010)](TF_{010011} + CR_{010011}) \\
& + [O_3(001)]\ CR_{001011} + [O_3(111)]\ A_{111011} \} \\
& / \ (1.0 \times 10^{-11}[O] + A_{011000} + A_{011010} + CR_{011010} \\
& + CR_{011111} + TF_{011111})
\end{aligned} \tag{5}
$$

$$
\begin{aligned}
[O_3(110)] = \{ & [O_3(000)]\ TF_{000110} + [O_3(010)](TF_{010110} + CR_{010110}) \\
& + [O_3(100)]\ CR_{100110} + [O_3(111)]\ A_{111110} \} \\
& / \ (1.0 \times 10^{-11}[O] + A_{110000} + A_{110010} + CR_{110010} \\
& + CR_{110100} + TF_{110111})
\end{aligned} \tag{6}
$$

$$
\begin{aligned}
[O_3(002)] = \{ & CF_{002} + [O_3(000)]\ TF_{000002} \\
& + [O_3(001)]\ (TF_{001002} + CR_{001002}) + [O_3(101)]CR_{101002} \\
& + [O_3(003)]\ (A_{003002} + CR_{003002})\} \\
& / \ (A_{002000} + A_{002001} + CR_{002001} + CR_{002101} \\
& + TF_{002003} + CR_{002003} + 1.0 \times 10^{-11}[O])
\end{aligned} \tag{7}
$$

$$
\begin{aligned}
[O_3(101)] = \{ & [O_3(000)]\ TF_{000101} + [O_3(001)](TF_{001101} + CR_{001101}) \\
& + [O_3(100)]\ (TF_{100101} + CR_{100101}) + [O_3(002)]\ CR_{002101} \} \\
& / \ (1.0 \times 10^{-11}[O] + A_{101000} + A_{101001} + CR_{101001} \\
& + A_{101100} + CR_{101100} + CR_{101002})
\end{aligned} \tag{8}
$$

$$
\begin{aligned}
[O_3(200)] = \{ & [O_3(000)\ TF_{000200} + [O_3(100)](TF_{100200} + CR_{100200}) \\
& + [O_3(101)]\ CR_{101200}\} / (1.0 \times 10^{-11}[O] + A_{200000} \\
& + A_{200100} + CR_{200100} + CR_{200101})
\end{aligned} \tag{9}
$$

$$
\begin{aligned}
[O_3(111)] = \{ & [O_3(000)\ TF_{000111} + [O_3(010)]\ TF_{010111} + [O_3(001)]\ TF_{001111} \\
& + [O_3(100)]\ TF_{100111} + [O_3(011)](TF_{011111} + CR_{011111}) \\
& + [O_3(110)]\ (TF_{110111} + CR_{110111}) + [O_3(101)]\ CR_{101111})\} \\
& / (1.0 \times 10^{-11}[O] + A_{111000} + A_{111010} + A_{111001} + A_{111100} \\
& + A_{111011} + CR_{111011} + A_{111110} + CR_{111110} + CR_{111101})
\end{aligned} \tag{10}
$$

$$
\begin{aligned}
[O_3(003)] = \{ & CF_{003} + [O_3(000)]\ TF_{000003} + [O_3(001)]\ TF_{001003} \\
& + [O_3(002)]\ (TF_{002003} + CR_{002003}) + [O_3(004)]\ (A_{004003} + CR_{004003})\} \\
& / (1.0 \times 10^{-11}[O] + A_{003000} + A_{003001} + A_{003002} + CR_{003002} \\
& + CR_{003004})
\end{aligned} \tag{11}
$$

$$
\begin{aligned}
[O_3(004)] = \{ & CF_{004} + [O_3(003)]\ (TF_{003004} + CR_{003004}) \\
& + [O_3(005)]\ (A_{005004} + CR_{005004})\} \\
& / (1.0 \times 10^{-11}[O] + A_{004003} + TF_{004005} \\
& + CR_{004005} + CR_{004005})
\end{aligned} \tag{12}
$$

$$
\begin{aligned}
[O_3(00_5)] = \{ & CF_{005} + [O_3(00_4)]\ (TF_{004005} + CR_{004005}) \\
& + [O_3(00_6)]\ (A_{006005} + CR_{006005})\} \\
& / (1.0 \times 10^{-11}[O] + A_{005004} + TF_{005006} \\
& + CR_{005005} + CR_{005006})
\end{aligned} \tag{13}
$$

$$
\begin{aligned}
[O_3(006)] = \{ & CF_{006} + [O_3(005)]\ (TF_{005006} + CR_{005006}) \\
& + [O_3(007)]\ (A_{007006} + CR_{007006})\} \\
& / (1.0 \times 10^{-11}[O] + A_{006005} + TF_{006007} \\
& + CR_{006005} + CR_{006007})
\end{aligned} \tag{14}
$$

$$
\begin{aligned}
[O_3(007)] = \{ & CF_{007} + [O_3(006)]\ (TF_{006007} + CR_{006007}) \\
& + [O_3(008)]\ (A_{008007} + CR_{008007})\} \\
& / (1.0 \times 10^{-11}[O] + A_{007006} + TF_{007008} \\
& + CR_{007006} + CR_{007008})
\end{aligned} \tag{15}
$$

$$
\begin{aligned}
[O_3(008)] = \{ & CF_{008} + [O_3(007)]\ (TF_{007008} + CR_{007008}) \\
& + [O_3(009)]\ (A_{009008} + CR_{009008})\} \\
& / \ (1.0 \times 10^{-11}[O] + A_{008007} + TF_{008009} \\
& + CR_{008007} + CR_{008009})
\end{aligned}
\tag{16}
$$

$$
\begin{aligned}
[O_3(009)] = \{ & CF_{009} + [O_3(008)]\ (TF_{008009} + CR_{008009}) \\
& / \ (1.0 \times 10^{-11}[O] + A_{009008} + CR_{009008} \\
& + CR_{008007} + CR_{008009})
\end{aligned}
\tag{17}
$$

The excitation and quenching cycles are incomplete in this set of equations. Further, the temperature dependence of the collisional processes is not known.

In the program itself, the notation is different. Instead of using a vibrational level designation such as 011, we use a level number 06. Then the subscripts may be included in a six or seven character name for each rate coefficient. Thus the vibrational excitation rate CR_{002003} is given the FORTRAN name CR0812 and the radiation absorption coefficeint TF_{002003} is called TF0812. Einstein A coefficients are carried in array EA and are numbered in the band sequence of Table 2, so that A_{002003} is EA(24).

TABLE 11. VIBRATIONAL LEVELS INCLUDED IN OZONE RADIANCE MODEL

LEVEL NO.	STATE DESIGNATION	ENERGY, CM^{-1}
1	000	0.000
2	010	700.932
3	001	1042.084
4	100	1003.141
5	020	1399.275
6	011	1726.528
7	110	1796.261
8	002	2057.892
9	101	2110.791
10	200	2201.157
11	111	2785.241
12	003	3041.200
13	004	3988.0
14	005	4910.0
15	006	5803.0
16	007	6665.0
17	008	7497.0
18	009	8299.0

TABLE 12. INFRARED VIBRATION-ROTATION BANDS INCLUDED IN OZONE RADIANCE MODEL

BAND NO.	TRANSITION DESIGNATED	ABSORPTION STRENGTH*	EINSTEIN A COEFFICIENT	BAND CENTER WAVELENGTH, μ
1	010-000	6.283(-19)	0.224	14.27
2	001-000	1.394(-17)	11.00	9.60
3	100-000	6.711(-19)	0.594	9.07
4	020-010	4.164(-20)	0.446	14.32
5	011-000	5.373(-20)	0.116	5.79
6	011-010	4.503(-19)	10.39	9.75
7	110-000	2.266(-20)	0.053	5.57
8	110-010	1.104(-20)	0.291	9.13
9	002-000	1.110(-19)	0.342	4.86
10	002-001	1.743(-19)	20.72	9.84
11	101-000	1.134(-18)	3.673	4.74
12	101-001	3.222(-21)	0.437	9.36
13	101-100	6.152(-20)	9.681	9.92
14	200-000	3.000(-20)	0.106	4.54
15	200-100	6.296(-21)	1.176	9.11
16	111-000	2.320(-20)	0.131	3.59
17	111-010	3.850(-20)	3.669	4.80
18	111-001	1.520(-22)	0.053	5.74
19	111-100	2.650(-22)	0.116	5.94
20	111-011	1.650(-22)	0.593	9.45
21	111-110	2.500(-21)	11.01	10.11
22	003-000	1.110(-19)	0.746	3.29
23	003-001	2.230(-21)	1.026	5.00
24	003-002	1.960(-21)	30.44	10.17
25	004-003	2.120(-23)	36.34	10.50
26	005-004	2.658(-25)	43.08	10.85
27	006-005	3.609(-27)	48.49	11.20
28	007-006	5.485(-29)	52.71	11.60
29	008-007	9.495(-31)	56.12	12.02
30	009-008	1.872(-32)	58.67	12.47

*Units are $CM^{-1}/(MOLECULE\text{-}CM^{-2})$ at 296K. At present, spectra are not available for bands 12, 15, 17, 18, 19, 20, 21, 23 and 24.

TABLE 13. COLLISIONAL DE-EXCITATION AND EXCITATION MECHANISMS INCLUDED IN THE OZONE RADIANCE MODEL.

(1)	$O_3(010) + M \rightarrow O_3(000) + M$ $CR_{010000} = 3.0 \times 10^{-14}([N_2] + [O_2] + [O])$	PSI(14)
(2)	$O_3(010) + M \rightarrow O_3(010) + M$ $CR_{000010} = \exp(-700.932\ C_2/T)\ CR_{010000}$ $C_2 = 1.438786\ K/(CM^{-1})$, SECOND RADIATIOON CONSTANT	PSI(7)
(3)	$O_3(001) + M \rightarrow O_3(000) + M$ $CR_{001000} = 2.9 \times 10^{-15}\ T^{1/2}\ ([N_2] + [O_2])$	PSI(24)
(4)	$O_3(000) + M \rightarrow O_3(001) + M$ $CR_{000001} = \exp(-1042.084\ C_2/T)\ CR_{001000}$	PSI(6a)
(5)	$O_3(001) + M \rightarrow O_3(010) + M$ $CR_{001010} = 5.0 \times 10^{-14}([N_2] + [O_2] + [O])$	PSI(12)
(6)	$O_3(010) + M \rightarrow O_3(001) + M$ $CR_{010001} = \exp(-341.152\ C_2/T)\ CR_{001010}$	PSI(16)
(7)	$O_3(100) + M \rightarrow O_3(000) + M$ $CR_{100000} = 5 \times 10^{-14}([N_2] + [O_2])$	PSI(-)
(8)	$O_3(000) + M \rightarrow O_3(100) + M$ $CR_{000100} = \exp(-1103.141\ C_2/T)\ CR_{100000}$	PSI(-)
(9)	$O_3(100) + M \rightarrow O_3(010) + M$ $CR_{100010} = 5.0 \times 10^{-14}([N_2] + [O_2] + [O])$	PSI(13)
(10)	$O_3(010) + M \rightarrow O_3(100) + M$ $CR_{010100} = \exp(-402.209\ C_2/T)\ CR_{100010}$	PSI(15)
(11)	$O_3(100) + M \rightarrow O_3(001) + M$ $CR_{100001} = 1.0 \times 10^{-11}([N_2] + [O_2] + [O])$	PSI(9)

TABLE 13. COLLISIONAL DE-EXCITATION AND EXCITATION MECHANISMS INCLUDED IN THE OZONE RADIANCE MODEL (Continued).

(12)	$O_3(001) + M \rightarrow O_3(100) + M$ $CR_{001100} = \exp(-61.057\ C_2/T)\ CR_{100001}$	PSI(8)
(13)	$O_3(020) + M \rightarrow O_3(010) + M$ $CR_{020010} = 2CR_{010000}$	PSI(-)
(14)	$O_3(010) + M \rightarrow O_3(020) + M$ $CR_{010020} = \exp(-698.343\ C_2/T)\ CR_{020010}$	PSI(-)
(15)	$O_3(011) + M \rightarrow O_3(010) + M$ $CR_{011010} = CR_{001000}$	PSI(-)
(16)	$O_3(010) + M \rightarrow O_3(011) + M$ $CR_{010011} = \exp(-1025.596\ C_2/T)\ CR_{011010}$	PSI(-)
(17)	$O_3(011) + M \rightarrow O_3(001) + M$ $CR_{011001} = CR_{010000}$	PSI(-)
(18)	$O_3(001) + M \rightarrow O_3(011) + M$ $CR_{001011} = \exp(-684.444\ C_2/T)\ CR_{011001}$	PSI(-)
(19)	$O_3(110) + M \rightarrow O_3(010) + M$ $CR_{011010} = CR_{100000}$	PSI(-)
(20)	$O_3(010) + M \rightarrow O_3(110) + M$ $CR_{010110} = \exp(-1095.329\ C_2/T)\ CR_{110010}$	PSI(-)
(21)	$O_3(110) + M \rightarrow O_3(100) + M$ $CR_{110100} = CR_{010000}$	PSI(-)
(22)	$O_3(100) + M \rightarrow O_3(110) + M$ $CR_{100110} = \exp(-693.120\ C_2/T)\ CR_{110100}$	PSI(-)

TABLE 13. COLLISIONAL DE-EXCITATION AND EXCITATION MECHANISMS INCLUDED IN THE OZONE RADIANCE MODEL (Continued).

(23)	$O_3(002) + M \rightarrow O_3(001) + M$ $CR_{002001} = 2\ CR_{001000}$	PSI(23)
(24)	$O_3(001) + M \rightarrow O_3(002) + M$ $CR_{001002} = \exp(-1015.808\ C_2/T)\ CR_{002001}$	PSI(-)
(25)	$O_3(101) + M \rightarrow O_3(001) + M$ $CR_{101001} = CR_{100000}$	PSI(-)
(26)	$O_3(001) + M \rightarrow O_3(101) + M$ $CR_{001101} = \exp(-1068.707\ C_2/T)\ CR_{101100}$	PSI(-)
(27)	$O_3(101) + M \rightarrow O_3(100) + M$ $CR_{101100} = CR_{001000}$	PSI(-)
(28)	$O_3(100) + M \rightarrow O_3(101) + M$ $CR_{100101} = \exp(-1007.650\ C_2/T)\ CR_{101100}$	PSI(-)
(29)	$O_3(101) + M \rightarrow O_3(002) + M$ $CR_{101002} = 1.0 \times 10^{-11}([N_2] + [O_2] + [O])$	PSI(11)
(30)	$O_3(002) + M \rightarrow O_3(101) + M$ $CR_{002101} = \exp(-52.899\ C_2/T)\ CR_{101002}$	PSI(10)
(31)	$O_3(200) + M \rightarrow O_3(100) + M$ $CR_{200100} = 2\ CR_{100000}$	PSI(-)
(32)	$O_3(100) + M \rightarrow O_3(200) + M$ $CR_{100200} = \exp(-1098.016\ C_2/T)\ CR_{200100}$	PSI(-)

TABLE 13. COLLISIONAL DE-EXCITATION AND EXCITATION MECHANISMS INCLUDED IN THE OZONE RADIANCE MODEL (Continued).

(33)	$O_3(200) + M \rightarrow O_3(101) + M$ $CR_{200101} = CR_{100001}$	PSI(-)
(34)	$O_3(101) + M \rightarrow O_3(200) + M$ $CR_{101200} = \exp(-1090.366\ C_2/T)\ CR_{200101}$	PSI(-)
(35)	$O_3(111) + M \rightarrow O_3(011) + M$ $CR_{111011} = CR_{100000}$	PSI(-)
(36)	$O_3(011) + M \rightarrow O_3(111) + M$ $CR_{011111} = \exp(-1078.713\ C_2/T)\ CR_{111011}$	PSI(-)
(37)	$O_3(111) + M \rightarrow O_3(110) + M$ $CR_{111110} = CR_{001000}$	PSI(-)
(38)	$O_3(110) + M \rightarrow O_3(111) + M$ $CR_{110111} = \exp(-998.980\ C_2/T)\ CR_{111110}$	PSI(-)
(39)	$O_3(111) + M \rightarrow O_3(101) + M$ $CR_{111101} = CR_{010000}$	PSI(-)
(40)	$O_3(101) + M \rightarrow O_3(111) + M$ $CR_{101111} = \exp(-647.450\ C_2/T)\ CR_{111101}$	PSI(-)
(41)	$O_3(003) + M \rightarrow O_3(002) + M$ $CR_{003002} = 3\ CR_{001000}$	PSI(22)
(42)	$O_3(002) + M \rightarrow O_3(003) + M$ $CR_{002003} = \exp(-983.308\ C_2/T)\ CR_{003002}$	PSI(-)
(43)	$O_3(000) + O \rightarrow O_3(001) + O$ $CX_{000001} = 1.0 \times 10^{-11} \exp(-1500/T)[O]$	PSI(6b)

TABLE 13. COLLISIONAL DE-EXCITATION AND EXCITATION MECHANISMS INCLUDED IN THE OZONE RADIANCE MODEL (Continued).

(44) $O_3(001) + O \rightarrow O_3(000) + O$ PSI(-)

$CX_{001000} = \exp(1042.084\ C_2/T)\ CX_{000001}$

(45) $O_3(004) + M \rightarrow O_3(003) + M$

$CR_{004003} = 4\ CR_{001000}$

(46) $O_3(003) + M \rightarrow O_3(004) + M$

$CR_{003004} = \exp\ (-986.8\ C_2/T)\ CR_{004003}$

(47) $O_3(005) + M \rightarrow O_3(004) + M$

$CR_{005004} = 5\ CR_{001000}$

(48) $O_3(004) + M \rightarrow O_3(005) + M$

$CR_{003004} = \exp\ (-922.0\ C_2/T)\ CR_{005004}$

(49) $O_3(006) + M \rightarrow O_3(005) + M$

$CR_{006005} = 6\ CR_{001000}$

(50) $O_3(005) + M \rightarrow O_3(006) + M$

$CR_{005006} = \exp\ (-893.0\ C_2/T)\ CR_{006005}$

(51) $O_3(007) + M \rightarrow O_3(006) + M$

$CR_{007006} = 7\ CR_{001000}$

(52) $O_3(006) + M \rightarrow O_3(007) + M$

$CR_{006007} = \exp\ (-862.0\ C_2/T)\ CR_{007006}$

(53) $O_3(008) + M \rightarrow O_3(007) + M$

$CR_{008007} = 8\ CR_{001000}$

(54) $O_3(007) + M \rightarrow O_3(008) + M$

$CR_{007008} = \exp\ (-832.0\ C_2/T)\ CR_{008007}$

TABLE 13. COLLISIONAL DE-EXCITATION AND EXCITATION MECHANISMS INCLUDED IN THE OZONE RADIANCE MODEL (Continued).

(55) $O_3(009) + M \rightarrow O_3(008) + M$

$CR_{009008} = 9\ CR_{001000}$

(56) $O_3(008) + M \rightarrow O_3(009) + M$

$CR_{008009} = \exp\ (-802.0\ C_2/T)\ CR_{009008}$

TABLE 14. CHEMICAL FORMATION RATES FOR OZONE ν_3 EXCITED LEVELS

(1)	$O + O_2 + M \rightarrow O_3(001) + M$ $CF_{001} = 2.32 \times 10^{-35} \exp(510/T)[O][O_2]([N_2] + [O_2])$	PSI(1b)
(2)	$O + O_2 + M \rightarrow O_3(002) + M$ $CF_{002} = 1.85 \times 10^{-35} \exp(510/T)[O][O_2]([N_2] + [O_2])$	PSI(1c)
(3)	$O + O_2 + M \rightarrow O_3(003) + M$ $CF_{003} = 1.42 \times 10^{-35} \exp(510/T)[O][O_2]([N_2] + [O_2])$	PSI(1d)
(4)	$O + O_2 + M \rightarrow O_3(004) + M$ $CF_{004} = 1.06 \times 10^{-35} \exp(510/T)[O][O_2]([N_2] + [O_2])$	PSI(1e)
(5)	$O + O_2 + M \rightarrow O_3(005) + M$ $CF_{005} = 7.59 \times 10^{-36} \exp(510/T)[O][O_2]([N_2] + [O_2])$	PSI(1f)
(6)	$O + O_2 + M \rightarrow O_3(006) + M$ $CF_{006} = 4.73 \times 10^{-36} \exp(510/T)[O][O_2]([N_2] + [O_2])$	PSI(1g)
(7)	$O + O_2 + M \rightarrow O_3(007) + M$ $CF_{007} = 2.53 \times 10^{-36} \exp(510/T)[O][O_2]([N_2] + [O_2])$	PSI(1h)
(8)	$O + O_2 + M \rightarrow O_3(008) + M$ $CF_{008} = 8.80 \times 10^{-37} \exp(510/T)[O][O_2]([N_2] + [O_2])$	PSI(1i)
(9)	$O + O_2 + M \rightarrow O_3(009) + M$ $CF_{009} = 2.20 \times 10^{-37} \exp(510/T)[O][O_2]([N_2] + [O_2])$	PSI(1j)

During development of the new ozone bands, we made a change in the method of iteration in computing vibrational populations. Instead of using excited state concentrations from previous cycles to compute new vibrational populations, the calculation was recast as a set of simultaneous equations for vibrational populations at a given altitude, and all excited state concentrations at a single altitude are computed simultaneously. This avoids the problem noted earlier for CO_2, that the closely coupled levels may hold each other close to the initial conditions assumed and not reach convergence in a reasonable number of iterations. We have retained the earlier method as comment statements in the program, to porvide a link between the equations above and the present coding of the model.

APPENDIX A

The programs in a FORTRAN V format and the data for calculating vibrational polulations are stored on one magnetic tape. The tape is nine track 1600 CPI, the information is stored as ASCII Code 80 characters per record. There are 60 files on tape. The following is the order in which the programs and data are stored.

File	Program/Data	Destription
1	BGND2	Carbon Dioxide Program
2	BGND3	Water Vapor Program
3	BGND4	Nitric Oxide Program
4	BGND6	Ozone Program
5	BGND7	Carbon Monoxide Program
6	BGND9	See Page 56
7	SPCTRA	See Page 59
8	TRYPEN	See Page 66
9	PROGLIB	Program Subroutines
10	BKNEW	Molecular species data common to all vibrational population programs

For the 25 model atmospheres listed below there are night and daytime conditions for each model. The first model listed is the 1976 standard atmosphere. The remaining 24 models are defined by three exo-atmospheric temperatures: 600°K, 1000°K, and 1500°K. Thus the 1976 standard model requires two files of data storage while the other 24 models require six files of data storage per model.

FILE	MODEL	EXO-ATMOSPHERIC TEMPERATURE
11,12	1976 Standard Atmospheric	1000
13,14	15° Annual	600
15,16	15° Annual	1000
17,18	15° Annual	1500
19,20	30° Summer	600
21,22	30° Summer	1000
23,24	30° Summer	1500
25,26	30° Winter	600
27,28	30° Winter	1000
29,30	30° Winter	1500
31,32	45° Spring/Fall	600
33,34	45° Spring/Fall	1000
35,36	45° Spring/Fall	1500
37,38	45° Summer	600
39,40	45° Summer	1000
41,42	45° Summer	1500
43,44	45° Winter	600
45,46	45° Winter	1000
47,48	45° Winter	1500
49,50	60° Summer	600
51,52	60° Summer	1000
53,54	60° Summer	1500
55,56	60° Winter	600
57,58	60° Winter	1000
59,60	60° Winter	1500

NOTE: The file positions are listed 11,12, etc. The first file number is for the night conditions and the second file number is for the daytime conditions

APPENDIX B

The spectral line data tape "LINE TAPE" contains five files of data.

FILE	
1	Carbon Dioxide
2	Water Vapor
3	Nitric Oxide
4	Ozone
5	Carbon Monoxide

In each file the data is ordered into bands with increasing frequency within each band.

Carbon Dioxide

Band No.	No. Lines	Band No.	No. Lines	Band No.	No. Lines
1	153	11	113	21	99
2	136	12	235	22	92
3	276	13	125	23	83
4	137	14	110	24	81
5	121	15	76	25	89
6	128	16	75	26	81
7	229	17	278	27	79
8	104	18	99	28	85
9	247	19	93	29	81
10	127	20	251		

Water Vapor

Rotational Band - 1581 Lines

Band No.	No. Lines	Band No.	No. Lines	Band No.	No. Lines
1	1773	6	345	11	*
2	1057	7	333	12	*
3	1315	8	662	13	989
4	1727	9	440	14	1233
5	559	10	737		

* Bands 11 and 12 are not on tape.

Nitric Oxide

Band No.	No. Lines	Band No.	No. Lines	Band No.	No. Lines
1	234	2	193	3	160

Ozone

Band No.	No. Lines	Band No.	No. Lines	Band No.	No. Lines
1	6340	11	2165	21	*
2	5813	12	*	22	1575
3	5203	13	1185	23	*
4	4591	14	1530	24	3518
5	1709	15	*	25	1534
6	1544	16	1031	26	1534
7	2137	17	*	27	1534
8	901	18	*	28	1534
9	2164	19	*	29	1534
10	1534	20	*	30	1534

*Band is not on tape

Carbon Monoxide

Band No.	No. Lines	Band No.	No. Lines	Band No.	No. Lines
1	72	2	56	3	26

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