Input documentation for SBDART (summer 2002 release)

This file documents input parameters for SBDART, (Santa Barbara DISORT
Atmospheric Radiative Transfer). SBDART is a software tool that computes
plane-parallel radiative transfer in clear and cloudy conditions within the
Earth's atmosphere and at the surface. For a general description and review
of the program please refer to Ricchiazzi et al 1998. (Bulletin of the
American Meteorological Society, October 1998).

SBDART's main input file is called INPUT. This file contains a single
NAMELIST input block also named INPUT. A significant advantage of NAMELIST
input is that not all elements of an input block need be specified by the
user. Since most of the code inputs have been initialized with reasonable
default values, new users can start by specifying just a few interesting
input parameters. The default state of input parameters may be determined
by removing INPUT from the current working directory. When SBDART detects
the absence of file INPUT, it will print the default settings of all input
parameters. This output may be redirected to a file for editing.

The default configuration of INPUT is as follows:

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=========================================================================

 &INPUT
  idatm   = 4          ,  amix    = 0.0        ,  isat    = 0          ,
  wlinf   = 0.550      ,  wlsup   = 0.550      ,  wlinc   = 0.0        ,
  sza     = 0.0        ,  csza    = -1.0       ,  solfac  = 1.0        ,
  nf      = 2          ,  iday    = 0          ,  time    = 16.0       ,
  alat    = -64.7670   ,  alon    = -64.0670   ,  zpres   = -1.0       ,
  pbar    = -1.0       ,  sclh2o  = -1.0       ,  uw      = -1.0       ,
  uo3     = -1.0       ,  o3trp   = -1.0       ,  ztrp    = 0.0        ,
  xrsc    = 1.0        ,  xn2     = -1.0       ,  xo2     = -1.0       ,
  xco2    = -1.0       ,  xch4    = -1.0       ,  xn2o    = -1.0       ,
  xco     = -1.0       ,  xno2    = -1.0       ,  xso2    = -1.0       ,
  xnh3    = -1.0       ,  xno     = -1.0       ,  xhno3   = -1.0       ,
  xo4     = 1.0        ,  isalb   = 0          ,  albcon  = 0.0        ,
  sc      = 1.0,3*0.0  ,  zcloud  = 5*0.0      ,  tcloud  = 5*0.0      ,
  lwp     = 5*0.0      ,  nre     = 5*8.0      ,  rhcld   = -1.0       ,
  krhclr  = 0          ,  jaer    = 5*0        ,  zaer    = 5*0.0      ,
  taerst  = 5*0.0      ,  iaer    = 0          ,  vis     = 23.0       ,
  rhaer   = -1.0       ,  wlbaer  = 47*0.0     ,  tbaer   = 47*0.0     ,
  abaer   = -1.0       ,  wbaer   = 47*0.950   ,  gbaer   = 47*0.70    ,
  pmaer   = 940*0.0    ,  zbaer   = 50*-1.0    ,  dbaer   = 50*-1.0    ,
  nothrm  = -1         ,  nosct   = 0          ,  kdist   = 3          ,
  zgrid1  = 0.0        ,  zgrid2  = 30.0       ,  ngrid   = 50         ,
  zout    = 0.0,100.0  ,  iout    = 10         ,  deltam  = t          ,
  lamber  = t          ,  ibcnd   = 0          ,  saza    = 180.0      ,
  prnt    = 7*f        ,  ipth    = 1          ,  fisot   = 0.0        ,
  temis   = 0.0        ,  nstr    = 4          ,  nzen    = 0          ,
  uzen    = 20*-1.0    ,  vzen    = 20*90      ,  nphi    = 0          ,
  phi     = 20*-1.0    ,  imomc   = 3          ,  imoma   = 3          ,
  ttemp   = -1.0       ,  btemp   = -1.0       ,  spowder = f          ,
  idb     = 20*0
 /

=========================================================================
```

NOTE: Unfortunately, many fortran compilers produce rather cryptic error
      messages in response to improper NAMELIST input files. Here are
      three common NAMELIST error messages and their meaning:

    1. ERROR MESSAGE: invalid reference to variable in NAMELIST input

        MEANING: you misspelled one of the NAMELIST variable names

    2. ERROR MESSAGE: too many values for NAMELIST variable

        MEANING: you specified too many values for a variable,
                        most likely because you separated variables by
                        more than one comma.

    2. ERROR MESSAGE: end-of-file during read
                        or
                      namelist block INPUT not found

        MEANING: There are two possibilities:
                        A) you didn't include a NAMELIST block specifier
                           (INPUT, DINPUT or END) or you misspelled it; or
                        B) You used the wrong character to signify a
                           namelist block name. FORTRAN90 expects the
                           namelist blocks to start with &<name> and end
                           with /, but most FORTRAN77 compilers used the
                           $<name>, $END convention.

Other input files are sometimes required by SBDART:

atms.dat   -- atmospheric profile   (see input quantity IDATM)
aerosol.dat -- aerosol information   (see input quantity IAER)
albedo.dat   -- spectral surface albedo   (see input quantity ISALB)
filter.dat   -- sensor filter function   (see input quantity ISAT)
solar.dat   -- solar spectrum   (see input quantity NF)
usrcld.dat   -- cloud vertical profile   (see input quantity TCLOUD)

SBDART usually lists computational results directly to the standard
output device (i.e., the terminal, if run interactively). However,
some warning messages are written to files named SBDART_WARNING.??
where the question marks indicate a warning message number. When
running SBDART iteratively over many inputs, the SBDART_WARNING files
will only be created once, on the first iteration that generated the
warning condition. The warning files contain a warning message and a
copy of the input file that triggered the warning.

```
                General options (NAMELIST &INPUT):
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          WAVELENGTH LIMITS, FILTER FUNCTION SPECIFICATION
          ================================================



    NF:            SOLAR SPECTRUM SELECTOR

          -2 = use TOA solar irradiance read from CKTAU file when
               kdist=-1.  NF=-2 is not a valid input when kdist.ne.-1

          -1 = read from file solar.dat (user supplied)
               data file, "solar.dat" is read from the current
               working directory. This ASCII file is read with the
               following free format read statements:

                   read(13,*,end=100) (wlsun(i),sun(i),i=1,5000)
               100   continue

               where, wlsun    wavelength sample points (microns)

                       sun      direct normal solar irradiance at the
                                top of the atmosphere (W/m2/micron)

               The number of wavelength sample points read from
               solar.dat should be less than or equal to 5000

               Old versions of SBDART used a different
               format for spectral input files albedo.dat,
               filter.dat and solar.dat.  A perl script 'newform'
               is available from
               ftp::/ftp.icess.ucsb.edu/pub/esrg/sbdart to
               convert old data files to the new format.

           0 = spectrally uniform

           1 = 5s solar spectrum
               0.005 micron resolution,  .25 to 4 micron

           2 = LOWTRAN_7 solar spectrum  (default)
               20 cm-1 resolution,      0. to 28780 cm-1
               10 cm-1 resolution,   28780. to 57490 cm-1

           3 = MODTRAN_3 solar spectrum
               20 cm-1 resolution,      100 - 49960 cm-1


    ISAT:          FILTER FUNCTION TYPES

          -4  Guassian filter, WLINF-2*WLSUP to WLINF+2*WLSUP
          -3  Trianglar filter, WLINF-WLSUP to WLINF+WLSUP
          -2  Flat filter, WLINF-.5*WLSUP to WLINF+.5*WLSUP
          -1  USER DEFINED, read from filter.dat
```

```
 0  WLINF TO WLSUP WITH FILTER FUNCTION = 1      (default)

    NOTE: if ISAT=0 and KDIST=-1, then the values of
          WLINF and WLSUP only have an effect if they
          have been changed from their default values
          such that WLINF .ne. WLSUP.  Otherwise the
          wavelength sample points are as specified in
          the CKTAU file.


 1  METEO
 2  GOES(EAST)
 3  GOES(WEST)
 4  AVHRR1(NOAA8)
 5  AVHRR2(NOAA8)
 6  AVHRR1(NOAA9)
 7  AVHRR2(NOAA9)
 8  AVHRR1(NOAA10)
 9  AVHRR2(NOAA10)
10  AVHRR1(NOAA11)
11  AVHRR2(NOAA11)
12  GTR-100 ch1
13  GTR-100 ch2
14  GTR-100 410nm channel
15  GTR-100 936nm channel
16  MFRSR 415nm channel
17  MFRSR 500nm channel
18  MFRSR 610nm channel
19  MFRSR 665nm channel
20  MFRSR 862nm channel
21  MFRSR 940nm channel
22  AVHRR3 (nominal)
23  AVHRR4 (nominal)
24  AVHRR5 (nominal)
25  Biological action spectra for DNA damage by UVB radiation
26  AIRS1 380-460nm
27  AIRS2 520-700nm
28  AIRS3 670-975nm
29  AIRS4 415-1110nm


    NOTE: If ISAT=-1 a user supplied filter data file
          "filter.dat" is read from the current working
          directory. This ASCII file is read with the
          following free format read (numbers may be
          separated by spaces, commas or carriage returns);

          read(13,*,end=100) (wlfilt(i),filt(i),i=1,huge(0))
      100 continue

          where, wlfilt    wavelength sample points (microns)

                 filt      filter response value (unitless)

          The number of wavelength sample points read from
          filter.dat should be less than or equal to 1000
```

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This file format is new. Previous versions of SBDART used a different format for spectral input files albedo.dat, filter.dat and solar.dat. A perl script 'newform' is available from ftp::/ftp.icess.ucsb.edu/pub/esrg/sbdart to convert old data files to the new format.

WLINF: lower wavelength limit when ISAT=0   (WLINF > .250 microns)
                central wavelength when ISAT=-2,-3,-4

WLSUP: upper wavelength limit when ISAT=0   (WLSUP < 100.0 microns)
                equivalent width when ISAT=-2,-3,-4

                NOTE:

                If ISAT eq -2, a rectangular filter (constant with
                wavelength) is used, with central wavelength at WLINF
                and an equivalent width of WLSUP (full width = WLSUP)

                If ISAT eq -3, a triangular filter function is used with
                the central wavelength at WLINF and an equivalent width of
                WLSUP (full width = 2*WLSUP) (filter function is zero at end
                points, and one at WLINF).

                If ISAT eq -4, a gaussian filter function is used with
                the central wavelength at WLINF and an equivalent width of
                WLSUP (full width = 4*WLSUP)

                If output is desired at a single wavelength, set
                WLINF=WLSUP and ISAT=0. In this case, SBDART will
                set WLINC=1 (the user specified value of WLINC is ignored)
                and the output will be in units of (W/m2/um) for
                irradiance and (W/m2/um/sr) for radiance.

WLINC: This parameter specifies the spectral resolution of the
                SBDART run. Though the spectral limits of the calculation
                are always input in terms of wavelength, the spectral
                step size can be specified in terms of constant
                increments of wavelength, log(wavelength) [same as
                constant increment of log(wavenumber)] or wavenumber.
                Which one to choose depends on where in the spectral
                bandpass you want to place the most resolution.

                Since SBDART is based on LOWTRAN7 band models, which
                have a spectral resolution of 20 cm-1, it would be extreme
                overkill to allow spectral step size less than 1 cm-1. On
                the other hand a spectral resolution coarser than 1 um
                is also pretty useless. Therefore the way WLINC is
                interpreted depends on whether it is less than zero,
                between zero and one, or greater than 1.

              * WLINC = 0 (the default) => wavelength increment is
                equal to 0.005 um or 1/10 the wavelength range, which

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ever is smaller. If the WLINF=WLSUP then WLINC=.001

* WLINC < 0 => wavelength increment is a constant fraction
  of the current wavelength. WLINC is interpreted as
  a specified value of delta(lambda)/lambda and the
  wavelength steps are adjusted so that wavelength step is
  approximately the product of the current wavelength and
  WLINC.

  Specifying the wavelength increment as a fractional
  step size is useful when the wavelength range extends
  over more than an decade of wavelength. For example,
  if the wavelength range is 0.5 to 20.0, specifying a
  constant wavelength increment of .01 microns tends to
  under-resolve the low wavelengths and over-resolve the
  long wavelengths. Setting WLINC = -.01 causes the
  code to use a wavelength increment of about .005
  microns in the visible and about .2 micron in the
  thermal infrared, which is a better compromise of
  resolution and computer time.

* 1 >= WLINC > 0   => WLINC is the wavelength step size (um)

  if WLINC > 1 then WLINC is the step size in inverse
  centimeters. If maximum fidelity is required and
  gaseous absorption is the primary influence on the
  output, then WLINC should be set to 20, which is the
  wavenumber resolution of the LOWTRAN7 band models.

  The total number of wavelength steps, nwl, is given by

   nwl = 1+ln(wlsup/wlinf)/|wlinc| wlinc < 0

   nwl = 1+(wlsup-wlinf)/wlinc   1 >= wlinc > 0

   nwl = 1+10000*(1/wlinf-1/wlsup)/wlinc   wlinc > 1

SOLAR GEOMETRY
==============

SZA: solar zenith angle (degrees) (default = 0.)
              Solar input may be turned off by setting sza>90
              SZA is ignored if CSZA is non-negative or IDAY is non-zero.

CSZA: Cosine of solar zenith angle. If CSZA > 0, solar
              zenith angle is set to acos(CSZA) (default = -1.)

SAZA: solar azimuth angle (degrees) (default = 0.)
              SAZA is ignored if IDAY is non-zero. Setting SAZA=180.
              will cause the forward scattering peak to appear near
              phi=0 (see below).

IDAY: If IDAY > 0, the solar illumination angles (SZA, SAZA)
              are computed from the specified time and geographic

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                  coordinates using an internal solar ephemeris
                  algorithm (see subroutine zensun). IDAY is the number
                  of days into a standard "year", with IDAY=1 and the
                  1st of January and IDAY=365 on the 31st of December
                  if IDAY > 365, IDAY is replaced internally by
                  mod(IDAY-1,365)+1.

                  If IDAY < 0, the code writes the values of abs(iday),time,
                  alat,alon,sza,azm, and solfac to standard output and exits.

    TIME:         UTC time (Grenwich) in decimal hours
    ALAT:         latitude of point on earth's surface
    ALON:         east longitude of point on earth's surface

                  NOTE: TIME, ALAT and ALON are ignored if IDAY .eq. 0


    SOLFAC:       solar distance factor.  Use this factor to account
                  for seasonal variations of the earth-sun distance.
                  If R is the earth-sun distance in Astronomical Units
                  then SOLFAC=1./R**2.  SOLFAC is set internally when the
                  solar geometry is set through IDAY, TIME, ALAT and ALON.
                  In this case SOLFAC is set to,
                                                            -2
                  SOLFAC = ( 1.-eps*cos(2*pi*(IDAY-perh)/365) )

                  where eps  = orbital eccentricity = 0.01673
                  and   perh = day of perihelion    = 2          (jan 2)

                  NOTE: seasonal variations in earth-sun distance
                        produce a +/-3.4% perturbation in the TOA solar
                        flux.  This factor should be included when
                        making detailed comparisons to surface
                        measurements.

    NOSCT:        aerosol scattering mode used for boundary layer aerosols:
                  0    normal scattering and absorption treatment
                  1    reduce optical depth by (1-ssa*asym), set ssa=0
                  2    set ssa=0
                  3    reduce optical depth by (1-ssa), set ssa=0

                  where ssa=single scattering albedo, and asym=asymmetry factor

                  nosct does not affect the stratospheric aerosol models or
                  the iaer=5 boundary layer model.


                   SURFACE REFLECTANCE PROPERTIES
                   ==============================

    ISALB:         SURFACE ALBEDO FEATURE

                  -1 -spectral surface albedo read from "albedo.dat"
                   0 -user specified, spectrally uniform albedo set with ALBCON

                   1 -snow
                   2 -clear water
                   3 -lake water
```

```
   4 -sea  water
   5 -sand              (data range 0.4 - 2.3um)
   6 -vegetation        (data range 0.4 - 2.6um)


   7 -ocean water brdf, includes bio-pigments, foam, and sunglint
     additional input parameters provided in SC.


   8 -Hapke analytic brdf model. additional input parameters
     provided in SC.


   9 -Ross-thick Li-sparse brdf model. additional input
     parameters in SC.


NOTE: isalb = 7, 8, 9 causes sbdart to use a non-Lambertian
      surface reflectance. Since the reflectance BRDF
      must first be expanded in terms of orthogonal
      functions, this mode of operation is somewhat
      more time consuming than the normal Lambertian
      reflectance models, In some cases flux
      calculations may be accurately computed in
      Lambertian mode by using directional albedo
      computed from the brdf, assuming all the
      incomming radiation is along the solar beam
      direction.  Of course this approach will
      probably fail in cases where the solar direct
      beam doesn't dominate the downwelling radiation
      (e.g., in the infrared or under clouds).  SBDART
      may be run with directional albedos by setting
      isalb to -7, -8 or -9.


10 -combination of snow, seawater, sand and vegetation
    partition factors set by input quantity SC


NOTE: If ISALB=-1 a user supplied spectral reflectance
      file "albedo.dat" is read from the current working
      directory. This ASCII file is read with the
      following free format read (numbers may be
      separated by spaces, commas or carriage returns);

         read(13,*,end=100) (wlalb(i),alb(i),i=1,huge(0))
     100 continue

         where, wlalb   wavelength sample points (microns)
                alb     spectral albedo (unitless)

         The number of wavelength sample points read from
         albedo.dat should be less than or equal to 1000



The user specified reflectance may cover any
wavelength range and have arbitrarily high resolution.
This contrasts with the standard reflectance models
(sand, vegetation, lake water and sea water) which are
only specified in in the range .25 to 4 um at 5nm
resolution.

Prior to version 2.0, SBDART used a different format
```

```
                   for spectral input files albedo.dat, filter.dat and
                   solar.dat.  A perl script 'newform' is available from
                   ftp::/ftp.icess.ucsb.edu/pub/esrg/sbdart to convert
                   old data files to the new format.

                   NOTE: A large collection of spectral reflectance
                   data is available from the JPL Spectral library:

                          http://speclib.jpl.nasa.gov/


                   The jpl spectral files may be used by sbdart after
                   processing with this one line perl command:

perl -lane 'print "$F[0] ",$F[1]/100 if /^ *[0-9]/' < jplfile > albedo.dat

                   where jplfile is the name of the spectral library file.



    ALBCON:        ISALB=0 --  a spectrally uniform, surface albedo

    SC:            surface albedo specification parameters used for
                   isalb=7, 8 and 10


                   ---------- isalb=7 ----------

                   SC specifies ocean reflection model parameters:

             SC(1): Oceanic pigment concentration in mg/m3.
                    Pigment is assumed to consist of Chlorophyll a +
                    Pheophytin a.  Pigment concentration affects the ocean
                    brdf in the wavelength range from 0.4-0.7um (Default = 0.01)
                    Turn off the subsurface contribution by setting SC(1)=0
                    (Note that subsurface contribution is set to a non-zero
                    constant for 0 < pigment_concentration < 0.0001.  I.e.,
                    the subsurface contribution does not approach zero
                    continuously as sc(1) goes to zero.)


             SC(2): Wind speed over ocean in m/s. Wind speed affects the
                    sunglint and foam contributions to the ocean brdf
                    (Default=5 m/s)

             SC(3): Oceanic salinity in parts per thousand.  Salinity affects
                    the Fresnel reflectivity of the ocean surface (Default=34.3)

                    NOTE: The oceanic brdf model is nearly the same as the
                    one used in the 6s radiative transfer model.  The only
                    difference is that the brdf in SBDART does not depend
                    on the wind direction.   The brdf dependence on wind
                    direction was eliminated by averaging the 6s reflectance
                    model over 360 degrees of wind azimuth.

                    Note: The 6s model does not include any provisions for
                    wave facet shading, so results for shallow
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illumination or viewing directions may be incorrect.
Additional information is available from "Second
Simulation of the Satellite Signal in the Solar
Spectrum (6S), user's guide" by Vermote, E., D. Tanre,
J.L. Deuze, M. Herman, and J.J. Morcrette (1995).

---------- isalb=8 ----------

SC specifies Hapke analytic brdf model parameters:

SC(1): Single scattering albedo of surface particles
SC(2): Asymmetry factor of scattering by surface particles
SC(3): Magnitude of hot spot (opposition effect)
SC(4): Width of hot spot

NOTE: This model is based on Hapke, 1981

       also see P. Pinet, A. Cord, S. Chevrel and Y. Daydou,
       (2003): 'Experimental determination of the Hapke parameters
       for planetary regolith surface analogs'

       Generic vegetation (actually clover), may be described
       with sc=0.101,-0.263, 0.589, 0.046.
       (From Pinty and Verstraete, 1991).

       Snow may be described with
       sc=0.99, 0.6, 0.0, 0.995.
       (From Domingue et al., 1997; and Verbiscer and Veverka, 1990).

---------- isalb=9 ----------

SC specifies the Ross-thick Li-sparse brdf model parameters

SC(1)=isotropic coefficient
SC(2)=volumetric coefficient
SC(3)=geometric shadowing coefficient
SC(4)=hot spot magnitude
SC(5)=hot spot width

(Ross, 1981; Li and Strahler, 1992).

---------- isalb=10 ----------

SC specifies mixing ratios snow, ocean, sand and vegetation

Composite albedo fractions (applies only when ISALB=10)
SC(1): fraction of snow
SC(2): fraction of ocean
SC(3): fraction of sand
SC(4): fraction of vegetation

NOTE: SC(1)+SC(2)+SC(3)+SC(4) need not sum to 1.
       Thus, it is possible to use the SC factor to
       boost the overall reflectance of a given
       surface type. For example, SC=0,0,2,0 yields

results for a surface with spectral reflectivity
twice that of sand. Beware, total reflectance
greater than one will produce unphysical results.

MODEL ATMOSPHERES
=================

IDATM:	ATMOSPHERIC PROFILE:	default water vapor (g/cm2)	ozone(atm-cm) total	below_10km
	------------------	-------------------	-------------	
0	User Specified			
1	TROPICAL	4.117	0.253	.0216
2	MID-LATITUDE SUMMER	2.924	0.324	.0325
3	MID-LATITUDE WINTER	0.854	0.403	.0336
4	SUB-ARCTIC SUMMER	2.085	0.350	.0346
5	SUB-ARCTIC WINTER	0.418	0.486	.0340
6	US62	1.418	0.349	.0252
-n	List to standard out			

If IDATM = 0, a user supplied atmospheric profile,
"atms.dat", is read from the current working
directory. This ASCII file is read with the following
free format read statements (input values may be
separated by spaces, commas or carriage returns);

```
      read(13,*) nn
      do 10 i=1,nn
        read(13,*) z(i),p(i),t(i),wh(i),wo(i)
10    continue
```

where nn is the number atmospheric layers
        nn should be less or equal to than MXLY,
        a parameter used in SBDART (see params.f)
        to set the maximum number of levels in the
        vertical grids.

        z   is the layer altitude in km
            (z must be monotonically decreasing)
        p   is the pressure in millibars
        t   is the temperature is Kelvin
        wh water vapor density g/m3
        wo ozone density g/m3

If IDATM is set to a negative number in the range -1
to -6 SBDART prints the atmospheric model
corresponding to abs(idatm) to standard out, and then
quits. The output atmospheric profile will reflect
any modifications caused by input parameters
UW, UO3, O3TRP, PBAR, ZPRES, RHCLD, and KRHCLR.

AMIX: weighting factor, when positive this factor controls
               how much of the atms.dat atmospheric profile to mix in
               with one of the standard internal profiles selected by
               IDATM. For example IDATM=1 and AMIX=.7 specifies a
               70% weighting of atms.dat and a 30% weighting of
               profile TROPIC. No (default=-1)

```
UW:             integrated water vapor amount (G/CM2)

UO3:            integrated ozone concentration (ATM-CM)
                above the level ZTRP.  The default value of ZTRP=0,
                so UO3 usally specifies the total ozone column.
                If UO3 is negative the original ozone density is used.
                (default=-1)

        NOTE: 1 atm-cm = 1000 Dobson Units

        NOTE: Use UW or UO3 to set the integrated amounts of water
              vapor or ozone in the model atmosphere.  Aside from
              multiplicative factors the vertical profile will be
              that of the original model atmosphere set by IDATM.
              The original unmodified density profile is used when
              UW or UO3 is negative.

O3TRP:          integrated ozone concentration (ATM-CM) in troposphere.
         i.e., for z.lt.ZTRP.  The original tropospheric density
              (set with IDATM) is used when O3TRP is negative.
              (default=-1.)

ZTRP:           The altitude of the tropopause.  The parameters UO3 and
          O3TRP sets the total column ozone in the stratosphere
          and troposphere, respectively.  Note: since the default
          value of ZTRP is zero, UO3 normally sets the integrated
              ozone amount of the entire atmosphere (default=0).


XN2:         volume mixing ratio of N2   (PPM,  default = 781000.00 )
XO2:         volume mixing ratio of O2   (PPM,  default = 209000.00 )
XCO2:        volume mixing ratio of CO2  (PPM,  default =    360.00 )
XCH4:        volume mixing ratio of CH4  (PPM,  default =      1.74 )
XN2O:        volume mixing ratio of N2O  (PPM,  default =      0.32 )
XCO:         volume mixing ratio of CO   (PPM,  default =      0.15 )
XNH3:        volume mixing ratio of NH3  (PPM,  default =    5.0e-4)
XSO2:        volume mixing ratio of SO2  (PPM,  default =    3.0e-4)
XNO:         volume mixing ratio of NO   (PPM,  default =    3.0e-4)
XHNO3:       volume mixing ratio of HNO3 (PPM,  default =    5.0e-5)
XNO2:        volume mixing ratio of NO2  (PPM,  default =    2.3e-5)

          NOTE: Setting any of these factors to -1 causes that
                atmospheric component to retain its nominal
                mixing ratio defined in the US62 atmosphere
                (as listed above).

                The volume mixing ratio (VMR) of a given species
                is adjusted by specifying the surface value of
                its VMR in PPM.  The entire altitude profile is
                multiplied by the ratio of the user specified
                VMR and the nominal surface VMR.

                There are no further re-normalizations of the
                VMR.  Thus, the total of all the VMRs may be
                greater or less than 10^6. By the way, the
```

default set of VMRs do not add up to 10^6
because of the exclusion of the noble gases
which do not have any radiative effects.

XRSC: sensitivity factor for Rayleigh scattering (default=1)
                This factor varies the strength of Rayleigh scattering
                for sensitivity studies.

XO4   sensitivity factor to adjust strength of absorption by
                oxygen collisional complexes (default=1, see comments
                in subroutine o4cont)

PBAR: surface pressure in millibars.

                PBAR > 0 causes each pressure to be multiplied by the
                factor (PBAR/P0) where P0 is the surface pressure of the
                original atmosphere. The absorption due to mixed gases
                is affected, but absorption by ozone and water vapor is not
                (they are separately controlled by UW and UO3). The
                Rayleigh scattering optical depth is proportional to the
                PBAR/P0 factor.

                PBAR = 0 disables Rayleigh scattering and all atmospheric
                absorption (including water vapor and ozone). Scattering
                by aerosols or clouds is not affected.

                PBAR < 0, causes the original pressure profile to be used.
                (this is the default)

                NOTE: PBAR has no effect of the CKTAU optical depths.

ZPRES: Surface altitude in kilometers.
                This parameter is just an alternate way of setting the
                surface pressure, and should not be set when PBAR is
                specified. When ZPRES is set PBAR is obtained by
                logarithmic interpolation on the current model's
                atmosphere pressure and altitude arrays. Changing
                ZPRES does not alter other parameters in the
                atmospheric model in any way. Note that setting a
                large value of ZPRES may push the tropopause (where
                dT/dz=0) to an unrealistically high altitude.

SCLH2O: Water vapor scale height in km.

                If SCLH2O .gt. 0, then water vapor is vertically
                distributed as exp(-z/SCLH2O)

                If SCLH2O .le. 0, then the original vertical profile
                is used. Changing SCLH2O has no effect on the total
                water vapor amount.

```
             CLOUD PARAMETERS
             ================


  ZCLOUD:     Altitude of cloud layers (km) (up to 5 values), Cloud
              layers may be specified in two ways. To specify separate
              cloud layers, set ZCLOUD to a sequence of monotonically
              increasing altitudes.  A cloud layer with optical depth
              TCLOUD(j) will start at the highest computation level
              for which z(i).le.ZCLOUD(j)+.001  and will extend to the
              next higher level, z(i+1).

              To specify a range of altitudes which will be filled
              by cloud, tag the second element of the range with a
              minus sign.  In this case the element of TCLOUD that
              corresponds to the negative element of ZCLOUD specifies
              the gradient of the optical depth.  Setting this element
              of TCLOUD to 1 causes a uniform opacity between the
              lower and upper limits of the cloud layer. See description
              of TCLOUD input.  Consider,

              zcloud=1,-3,10,-15
              tcloud=4, 1, 8,  1
              nre   =6, 6, 10,  20

              In this example two continuous cloud layers are
              defined, the lower one extends from 1 to 3 km and has
              a total optical depth of 4 and an effective radius of
              6um.  The upper cloud layer extends from 10 to 15 km,
              has a total optical thickness of 8 and a sliding value
              of effective radius which starts 10um at the bottom of
              the cloud and ramps up to 20um at 15km  The ramping
              function is logarithmic, i.e.,
                 nre(12km)=10*(20/10)**((12-10)/15-10)).
              Note that the actual location of the cloud layers is
              determined by the resolution and placement of vertical
              grid points in SBDART, as explained below.

              SBDART puts the i'th cloud layer at the highest vertical
              grid point, k, such that

                 z(k) .le. abs(ZCLOUD(i)+.001)

              NOTE: A cloud with a nominal altitude equal to that of
              one of the computational layer altitudes, Z(K),
              actually extends from Z(k) to the next higher grid
              point.  For example, a cloud layer at Z(k) will not
              affect the direct beam flux at Z(k+1) (one layer
              above) but will strongly affect it at Z(k).  (You can
              check this out your self by setting IOUT=10 and
              ZCLOUD=1 and messing around with ZOUT to get outputs
              just above or below the cloud).

              Suppose the bottom of your computational grid looks like

               k          z(k)
               ...        ...
               6          2.5
```

```
5          2.0
4          1.5
3          1.0
2          0.5
1          0.0
```

Consider this input,

```
ZCLOUD=1.0, -6.0,  4.0, -9.0
TCLOUD=50.,  1.0, 10.,  1.0
NRE   = 8.,    8, 20.,  20.
```

Here two overlapping cloud decks are specified, one
extending from 1 to 6 km with a total optical
thickness of 50, and the other from 4 to 9 km with a
total thickness of 10. Since the total cloud optical
thickness is spread over the total altitude range we
would have 10 optical depths per km for the lower cloud
deck and 2 optical depths per km for the second. The
code adds the effects of both cloud decks in the
region of overlap. Scattering parameters (e.g., single
scattering albedo) in the overlap region are given by
the weighted averages of the values computed from the mie
scattering database using effective radius appropriate to
each cloud deck, and weighting according to the opacity
contributed by each cloud deck.

	cloud optical depth	opacity (km-1)	scattering parameters
6-9 km	6	2	mie(20)
4-6 km	24	12	[mie(10)*10+mie(20)*2]/12
1-4 km	30	10	mie(10)
total	60		

If you have any doubt about where the code is putting
the cloud, set IDB(5)=1 (see below) to get a diagnostic
print out of cloud optical depth.

NOTE: do not try to put an ice cloud (NRE < 0) in a
      cloud layer range which includes water cloud
      (2 le NRE le 128). In other words this specification
      won't work:

```
ZCLOUD = 1,-4
TCLOUD = 1, 1
NRE    = 8,-1
```

TCLOUD: Optical thickness of cloud layer, (up to 5 values)

TCLOUD specifies the cloud optical depth at a
wavelength of 0.55um.   The cloud optical depth at
other wavelengths is computed using the relation,

tau = TCLOUD*Q(wl)/Q(0.55um),

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where Q is the extinction efficiency, which is a
function of effective radius and wavelength (see
discussion of LWP for a definition of Q). The code
contains a look-up table of Q that covers effective
radii in the range 2 to 128um for water clouds and for
a single effective radius of 106um for ice clouds.
The wavelengths range is 0.29 to 333.33 um for water
clouds and .29 to 20 um for ice clouds.

When specifying an optical depth for a range of grid
levels, the second TCLOUD entry corresponding to the
cloud top altitude is usually set to one. This
produces a uniform distribution of opacity over the
altitude range.

For example,

```
ZCLOUD= 1 ,-5,0,0,0    # uniformly distributed opacity
TCLOUD= 10, 1,0,0,0    # for a cloud of extent 4 km
NRE=    10,20          # 2.5 optical depths per km
                       # effective radius ramps from
                       # 10 to 20 between 1 and 5km
```

A linearly varying opacity distribution can be
obtained by setting the second TCLOUD entry to a
factor which represents the ratio of the opacity in
the highest layer to that in the lowest layer

For example,

```
ZCLOUD= 1 ,-5,0,0,0    # linearly distributed opacity
TCLOUD= 10, 4,0,0,0    # for a cloud of extent 4 km
                       # between tau(1-2km)=1
                       # between tau(2-3km)=2
                       # between tau(3-4km)=3
                       # between tau(4-5km)=4
                       #
                       # tau(total)=10
                       # tau(4-5km)/tau(1-2km)=4
```

NOTE: if r is the ratio of the top to bottom and t
      is the average opacity per level then,

          tau(top_level)=t*2r/(1+r)

          tau(bot_level)=t*2/(1+r)

NOTE: a linear increase in opacity, starting from zero
      at the cloud bottom, is obtained by setting,

          r=1 + 2*zdiff/dz

      where dz is the grid spacing and zdiff is the total
      altitude range over which the cloud extends. This
      formula assumes constant grid spacing over the
      cloud altitude range. Thus, if dz=1 then
      ZCLOUD= 1,-5 and TCLOUD= 10,7 yeilds a linear

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increase from zero.

      NRE: Cloud drop effective radius (microns).   (up to 5 values)
                   Default value of NRE=8.

                   The absolute value of NRE should be a floating point
                   number in the range 2.0 to 128.0.
                   NRE < 0 selects mie scattering parameters for ice particles
                   NRE > 0 selects mie scattering parameters for water droplets

                   The drop size distribution is assumed to follow a
                   gamma distribution:

$$N(r) = C * (r/Ro)^{(p-1)} e^{(-r/Ro)}$$

                   where C is a normalization constant [C=1./(Ro*gamma(p))],
                   p=7, and Ro=NRE/(p+2)

                   The factor (p+2) relating Ro to NRE follows
                   from the defining equation of NRE:

$$NRE = < r^3 N(r) > / < r^2 N(r) >,$$

                   where the angle brackets indicate integration over all
                   drop radii.

                   Another frequently used parameter to describe the size
                   distribution is the mode radius, Rm, which is defined
                   as the radius at which N(r) is maximized. For our
                   drop size distribution Rm=(p-1)*Ro. Using the relation
                   between Ro and NRE we find that, Rm=(p-1)*NRE/(p+2)

                   NOTE: If the first element of NRE is zero, the
                   values of TCLOUD, ZCLOUD, LWP and NRE are ignored and
                   cloud specification records are read from file usrcld.dat.
                   The first record in this file corresponds to the
                   lowest layer in the atmosphere, that is between the
                   surface and the lowest cell boundary altitude. Each
                   following record sets values for the next higher
                   atmospheric layer in the model atmosphere. usrcld.dat
                   is read with the following fortran statements:

```
                   do i=1,nz-1
                     read(13,*,end=100) lwp(i),re(i),fwp(i),rei(i),cldfrac(i)
                   enddo
             100 continue
```

                   where
                    lwp   liquid water path in layer i.   (g/m2)
                              (default=0)

                    re   effective radius of liquid water   (um)
                              in layer i. (default=8um)

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```
      fwp       frozen water path in layer i.          (g/m2)
                if fwp < 0 then scattering parameters
                are obtained from ccm3 cirrus model
                (see subroutine icepar), if fwp > 0
                then scattering parameters are obtained
                from an internal mie scattering database
                covering ice spheres with effective radii
                between 2 and 128 um. (default=0)

      rei       effective radius of frozen water       (um)
                in layer i.  only active when fwp
                is non-zero.  if fwp.lt.0 and rei.le.0
                then effective radius of ice is taken
                from ccm3 cirrus model (see subroutine
                icepar) (default=-1)

      cldfrac   cloud fraction in layer. this parameter
                reduces cloud optical depth by factor
                cldfrac**1.5 (default=1)

      It is not necessary to provide input records for
      layers above the highest cloud.  In addition, a
      forward slash terminates interpretation of data values
      in a record.  For example, the following records in
      usrcld.dat specify a cloud that extends from 2 to 4 km
      (assuming idatm>0 and no regridding):

      /                    # no cloud between 0-1 km
      /                    # no cloud between 1-2 km
      30 /                 # lwp=30, re=10 between 2-3 km
      60 20 5 30 .2 /      # lwp=60, re=20 fwp=5 reice=30 cldfrac=.2
                           #         between 3-4 km

      Any input quantities that are left unspecified will
      retain their default values of lwp=0. reff=8,
      fwp=0, reice=-1, and cldfrac=1.  The radiative
      properties of ice are computed from a CCM3 model (see
      subroutine ICEPAR).


IMOMC:        Controls the phase function model used in cloud layers:
              1  isotropic scattering
              2  rayleigh scattering phase function
              3  henyey_greenstein [a function of asymmetry factor, g(re)]
              4  haze L as specified by garcia/siewert
              5  cloud c.1 as specified by garcia/siewert

              (default=3)

LWP:          The liquid water path (or frozen water path if nre.le.0)
              of a cloud is specified in units of g/m2.  This is another
              way to specify cloud optical depth.

              A linearly varying opacity distribution can be
              obtained by setting the second LWP entry to a
              factor which represents the ratio of the opacity in
              the highest layer to that in the lowest layer
```

For more details see the discussion of TCLOUD.

NOTE: a 1 mm column of liquid water = 1000 g/m2,

NOTE: LWP and TCLOUD cannot be used at the same time

NOTE: The cloud optical depth is related to LWP by

$$tau = \frac{3 \; Q(wl) * LWP}{4 \; RHO * NRE}$$

where Q is the scattering efficiency and RHO is
the density of liquid water (1 g/cm3). The
value of Q that applies to a distribution of
cloud droplets can be expressed in terms of the
extinction cross-section at a given wavelength and
liquid drop radius.

Let   sigma = extinction cross-section at a given
                 wavelength and drop radius

         $q = sigma/(pi*r^2)$ (dimensionless)

                where $(pi*r^2)$ is the geometrical
                cross-section of the cloud drop

then Q is a weighted average over drop radius,
given by:

$$Q = < r^2 \; q \; N(r) > / < r^2 \; N(r) >$$

for visible light Q is typically about 2
(dimensionless).

For example:
NRE = 10um and LWP= 200g/m2 = 0.2mm =>   tau = 30

RHCLD: The relative humidity within a cloud layer (a floating point
              value between 0.0 and 1.0). RHCLD<0 disables the adjustment
              of relative humidity, in which case the relative humidity in
              the cloud layer is unchanged (it varies with the temperature
              and water vapor density of the initial model atmosphere).
              This parameter has no effect when KDIST<0

KRHCLR: If zero, water vapor mixing ratio in clear layers is
              proportionately reduced to maintain the water vapor
              path specified by WH. This option has no effect if
              RHCLD is negative or TCLOUD is zero. if KRHCLR=1, the
              relative humidity in clear layers is unchanged. (default=0)

              NOTE: if KRHCLR=1 and clouds are present, the actual
              water vapor path will differ from that specified by WH.
              On the other hand, if KRHCLR=0, the normalization procedure

may drive the water vapor in clear layers to zero and still
be unable produce a given WVP. This parameter has no
effect when KDIST<0

STRATOSPHERIC AEROSOLS (LOWTRAN 7 model)
==

JAER: 5 element array of stratospheric aerosol types

                0-no aerosol
                1-background stratospheric
                2-aged volcanic
                3-fresh volcanic
                4-meteor dust

ZAER: altitudes (above the surface) of stratospheric aerosol
                layers (km) Up to 5 layer altitudes may be specified.
                NOTE: even though these models are for stratospheric
                aerosols, the scattering layer may be placed anywhere
                within the numerical grid. See ZCLOUD for a discussion
                of how aerosol (cloud) layers are positioned within
                SBDART's computational grid.

TAERST: optical depth (at 0.55 microns) of each stratospheric
                aerosol layer. Up to 5 layer optical depths may be
                specified.

BOUNDARY LAYER AEROSOLS (BLA)
============================

IAER: Boundary layer aerosol type selector

              -1-read aerosol optical depth and scattering parameters
                 from aerosol.dat. See subroutine AEREAD.

                the file format is readable by the following Fortran code:

                read(11,*) nn, moma
                do k=1,huge(0)
                  read(11,*,end=100) wl(k)
                  do i=nz-nn+1,nz
                    read(11,*) dtau(i,k),waer(i,k),pmom(1:moma,i,k)
                  enddo
                enddo
            100 continue

                where
                  nn   is the number of atmospheric levels for
                                which aerosol information is specified.

                  moma   number of phase function moments

                  wl(k)   is the wavelength [wl(k) < wl(k+1)]

dtau(i,k)   is the optical depth increment within
                              level i at wavelength k, information is
                              specified in top-down order.

                 waer(i,k)   is the single scattering albedo

                 pmom(m,i,k) are legendre moments of the phase function.
                              Note that zeroeth moment is not read, it
                              is assumed to be 1.

                   NOTE: Layers are read from top to bottom
                              starting from layer nz-nn+1, i.e., the
                              lowest nn levels in the atmosphere. A single
                              forward slash may be used to indicate levels
                              with zero aerosol optical depth.

           0-no boundary layer aerosols (all BLA parameters ignored)

           1-rural

           2-urban

           3-oceanic

           4-tropospheric

           5-user defined spectral dependence of BLA

             The wavelength dependence of the aerosol scattering
             parameters are replaced by those read in from input
             parameters wlbaer, tbaer, wbaer and gbaer. Between
             1 and 47 spectral values may be specified.

           NOTE: the spectral dependence of the boundary layer aerosol
                 models (IAER=1,2,3,4) vary with relative humidity.
                 See subroutine AEROSOL for details.

           NOTE: Don't be mislead by the term "boundary layer
                 aerosol". The BLA models, IAER=1,2,3,4
                 were originally developed to describe aerosols
                 in the lower atmosphere. However in SBDART, the
                 default vertical density of BLA falls off
                 exponentially, and affects regions above the
                 normal extent of the boundary layer. The
                 vertical influence of these aerosols may be
                 confined to a specified boundary layer altitude
                 with the optional parameters ZBAER and DBAER.

     RHAER: The spectral dependence of the boundary layer aerosol
                   scattering parameters are sensitive to relative humidity.
                   Use input parameter RHAER to set the relative humidity
                   used in the boundary layer aerosol model. Set RHAER=-1
                   (the default value) to use the ambient surface relative
                   humidity computed from the temperature and water vapor
                   density of the current model atmosphere. RHAER has no

                                  21

```
              effect when IAER = 5.

   VIS:        (Horizontal Path) Visibility (km) at 0.55 microns
               due to boundary layer aerosols.  This parameter does
               not set the optical depth for the user defined aerosol
               model (IAER=5), but does affect that model through
               the vertical structure (see below).


               NOTE: unlike the stratospheric aerosols, the boundary
                     layer aerosols have predefined vertical density
                     distributions.  These vertical structure models
                     vary with visibility.  (see discussion of ZBAER
                     and DBAER)

               NOTE: The boundary layer aerosol optical depth
                     (absorption + scattering) at 0.55 microns
                     is given by

                     tauaero(0.55um) = 3.912 * integral ( n(z)/n(0) dz) / VIS

                     where n(z) is the vertical profile of aerosol
                     density.  For the 5 and 23 km visibility models
                     the indicated integral is 1.05 and 1.51 km,
                     respectively. So,

                     tauaero(0.55um) = 3.912*(1.05*w+1.51*(1-w))/vis

                     where w is a weighting factor between the two
                     extremes and is given by

                        (1/vis-1/23)
                      w = ----------          ,     5 < vis < 23
                         (1/5-1/23)


                      w = 1                   ,     vis < 5

                      w = 0                   ,     vis > 23

               NOTE: Visibility is defined as the horizontal distance
                     in km at which a beam of light at 0.55um is
                     attenuated by a factor of 0.02.

                     n(0)*sigma*VIS = -ln(.02), or

                     VIS = 3.912/(n(0)*sigma)

                     where sigma is the aerosol absorption+scattering
                     cross-section at 0.55 microns.  See Glossary of
                     Meteorology, American Meteorology Society, 1959

   ZBAER:      Altitude grid for custom aerosol vertical profile (km)
               Up to MXLY altitude points may be specified.  ZBAER is
               active for all positive values of IAER.

   DBAER:      Aerosol density at ZBAER altitude grid points, active for
```

all positive values of IAER. Up to MXLY density values
may be specified. The number of density values must
match the number of ZBAER. The units used to specify
aerosol density is arbitrary, since the overall
profile is scaled by the user specified total vertical
optical depth. The aerosol density at all
computational grid points is found through logarithmic
interpolation on the ZBAER and DBAER values. The
normal vertical profile from 5s is used when DBAER is
unset.

For example

    ZBAER=0,1,100
    DBAER=1000,500,1

specifies a aerosol density profile that drops by a
factor 2 (exponential fall off) between 0 and 1km altitude
and then by a factor of 500 between 1 and 100 km.

If DBAER is set but ZBAER is not set, then the elements
of DBAER are used to set the aerosol density for each
computational layer, starting from the bottom layer.

For example,

    DBAER=10,0,1,0

puts aerosol in the first and third layer.

If neither ZBAER or DBAER are set, the boundary layer
aerosols are assumed to follow a pre-defined vertical
distribution which drops off exponentially with a
scale height between 1.05 and 1.51 km depending
visibility (see VIS). Thus, even if visibility is not
used to set the vertical optical depth it can affect
the result through the vertical profile. Note that
ZBAER and DBAER do not affect the total vertical
optical depth of aerosols. (See discussion for VIS).

TBAER: Vertical optical depth of boundary layer aerosols nominally
            at 0.55 um. TBAER input is significant for all values of IAER.
            When IAER=1,2,3,4 the specified value of TBAER
            supersedes the aerosol optical depth derived from
            input parameter VIS (but VIS still controls vertical
            structure model unless DBAER and ZBAER are set).

QBAER: QBAER is the extinction efficiency. QBAER is only active
            when IAER=5. When TBAER is set, QBAER sets the spectral
            dependence of the extinction optical depth as,

                tau= tbaer * Qext(wave_length)/Qext(0.55)

            where Qext(wave_length) = QBAER interpolated to wave_length
            and wl_reference is 0.55 um unless modified by WLBAER

            If TBAER is not set, then the values of QBAER are interpreted

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as extinction optical depths at each wavelength WLBAER.

For example, the Multi Filter Rotating Shadowband
Radiometer (MFRSR) installed at the Southern Great
Plains ARM site is able to retrieve aerosol optical
depth in 6 SW spectral channels. This information may
be supplied to SBDART by setting,

```
  wlbaer= .414,  .499,  .609,  .665,  .860,  .938
  qbaer= 0.109, 0.083, 0.062, 0.053, 0.044, 0.041
  wbaer=6*.9
  gbaer=6*0.8
```

This spectral information is iterpolated or extrapolated to
all wavelengths using logarithmic fitting on QBAER and
linear fitting on WBAER and GBAER. Many aerosol types
display a power law dependence of extinction efficiency on
wavelength. The logarithmic interpolation/extrapolation on
QBAER will reproduce this behavior if it exists in the
input data. QBAER need not be specified when aerosol
information is provided at a single wavelength.

WLBAER: Wavelengths points (um) for user defined aerosol spectral
               dependence. Only used when IAER=5. WLBAER (and QBAER) need
               not be specified if a single spectral point is set. In this
               case the aerosol optical depth is extrapolated to other
               wavelengths using a power law (see ABAER). If only one
               value of WLBAER is set (and IAER=5), that value is used
               as the reference wavelength at which the value TBAER,
               WBAER, and GBAER or PMAER applies. If WLBAER is not set
               then the reference wavelength defaults to 0.55um

WBAER: Single scattering albedo used with IAER=5.

               WBAER represents the single scattering albedo of
               boundary layer aerosols at wavelengths WLBAER.

GBAER: Asymmetry factor used with IAER=5

               GBAER represents the asymmetry factor of boundary
               layer aerosols at wavelengths WLBAER. Number of
               values must match the number of WLBAER.

               GBAER is ignored when parameter PMAER is set or when
               IMOMA .ne. 3

PMAER: Legendre moments of the scattering phase function of
               boundary layer aerosols, only active for IAER=5. The
               Legendre moments of the phase function are defined as
               the following integral over the scattering phase
               function, f:

$$pmaer(i) = \int f(mu)\ P(i,mu)\ d\ mu\ \Big/\ \int f(mu)\ d\ mu$$

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```
         /                          /     /
```

where P(i,mu) is the Legendre polynomial, mu is the cosine
of the scattering angle, and the range of the integrals are
from -1 to 1. The Legendre moment for i=0 is always
one. Hence, the zero'th moment is assumed by SBDART and
should not be specified.

Unlike the previous boundary layer aerosol parameters, you
need to specify at least NSTR values for each wavelength
point, for a total of NSTR*NAER values, where NAER is
the number of wavelength points supplied. The order of
specification should be such that wavelength variation is
most rapid. For example, here is a case with 4 wavelengths
and 6 streams:

```
        nstr=6
        wlbaer=.400,.500,.600,.700
        wbaer =0.88,0.89,0.91,0.92
        pmaer= 0.80,0.70,0.60,0.50,
               0.64,0.49,0.36,0.25,
               0.51,0.34,0.22,0.12,
               0.41,0.24,0.13,0.06,
               0.33,0.17,0.08,0.03,
               0.26,0.12,0.05,0.02
```

ABAER: Wavelength (Angstrom model) exponent used to extrapolate
            BLA extinction efficiency to wavelengths outside the
            range of WLBAER [Qext ~ (lambda)^(-abaer)]. This parameter
            is only operative when IAER=5. (default=0)

IMOMA: Controls phase function used for boundary layer aerosol
            The value of IMOMA is ignored when IAER=5 and PMAER is
            specified. Note that an asymmetry factor must be
            specified when IMOMA=3 (default=3).

            1 isotropic scattering
            2 rayleigh scattering
            3 henyey_greenstein(g(re))   <-- default
            4 haze L as specified by garcia/siewert
            5 cloud c.1 as specified by garcia/siewert

SPOWDER: Setting SPOWDER to true causes an extra sub-surface layer
            extending between -1 and 0 km to be added to the bottom of
            the atmospheric grid. This layer may be used to model the
            effects of surface reflection and thermal emission caused
            by a granular surface material (e.g., snow or sand). The
            scattering properties of the surface layer may be specified
            either with the cloud or aerosol inputs. For example, a
            thin water cloud over a snow surface composed of 100um
            snow grains may be modeled with the following input file:

```
 &INPUT
   sza=30,      idatm=4,    spowder=t
   wlinf=.3,    wlsup=2,    iout=1
   tcloud= 10000, 10
   zcloud=    -1,   2
```

```
     nre=      -100,  10
  /
```

Similarly, the scattering properties of the surface and
atmosphere may be read from aerosol.dat with IAER=-1.
To model a semi-infinite granular surface layer the optical
depth of the bottom layer should be made very large, e.g.,
10000, as indicated in the example. However, a smaller
optical depth may also be specified in conjunction with a
given value of sub-surface albedo selected with ISALB.
Thus, in the previous example the effect of a thin snow
layer covering a grass field may be modeled by setting,
tcloud=100,10 and isalb=6

NOTE: When SPOWDER is set, BTEMP no longer sets surface
skin temperature. Rather it sets the temperature of the
sub-surface level below the granular material. At present
there is no way to set the surface temperature (above the
graunual layer) to something other than the atmospheric
temperature of the bottom level.

===

NOTHRM: nothrm=-1 => Thermal emission turned on only for wavelengths
                        greater than 2.0 um (default)

                        (Note: During daylight hours solar
                        radiation is a factor of about 1.e5
                        greater than thermal radiation at 2.0um)

        nothrm=0 => Thermal emission turned on for all wavelengths

        nothrm=1 => No thermal emission

        NOTE: If thermal emission is desired, be sure that the
              temperature steps in the atmospheric model are small
              enough to resolve changes in the Planck function. The
              original version of the DISORT radiative transfer
              module issued a warning message if the temperature
              difference between successive levels in the atmosphere
              exceeded 20 K. All the standard atmospheres violate
              this condition for at least 1 stratospheric layer.
              This warning message has been disabled to avoid
              clutter in SBDART's standard output. If near-IR thermal
              emission from the stratosphere is important to your
              application, you should supply SBDART with a new model
              atmosphere with higher resolution in the stratosphere.
              (see ZGRID1, ZGRID2, an NGRID)

KDIST: KDIST=-1 causes correlated-k optical depths and weighting
              factors to be read from files CKATM and CKTAU. The format
              used to read these files is documented in subroutines
              gasinit and readk, both in file taugas.f.

If WLINF .eq. WLSUP all wavenumbers in the CKTAU file are processed, otherwise only those wavenumbers in the range 10000./WLSUP to 10000./WLINF are used.

NOTE: KDIST=-1 disables the effect of all input parameters that control aspects of the gaseous atmospheric profile. Thus, KDIST=-1 disables input parameters WLINC, AMIX, SCLH2O, UW, UO3, O3TRP, ZTRP, XN2, XO2, XCO2, XCH4, XN2O, XCO, XNO2, XSO2, XNH3, XNO, XHNO3, XO4, RHCLD, KRHCLR, NGRID, ZGRID1, ZGRID2, PBAR, and ZPRES.

KDIST=0 causes the optical depth due to molecular absorption to be set to the negative log of the LOWTRAN transmission function. This approximation is not appropriate for cases in which multiple scattering is important, but is not very wrong when the molecular absorption is weak or the scattering optical depth is small.

KDIST=1 causes SBDART to use the LOWTRAN7 k-distribution model of absorption by atmospheric gases. Since a three term exponential fit is used, SBDART execution times are up to 3 times longer with KDIST > 0 compared to KDIST=0.

KDIST=2 causes the k-fit transmissions to exactly match the LOWTRAN transmission along the solar beam direction. This option may be useful when computing surface irradiance under clouds of optical thickness less than about 10. This is because in this thin cloud case much of the radiation which reaches the surface propagates along the direct beam direction.

KDIST=3 causes the k-fit transmissions to exactly match the LOWTRAN transmission along the solar beam direction for parts of the atmosphere above a scattering layer. As the scattering optical depth increases above 1 the k-fit factors are ramped back to there original LOWTRAN values. The effect of the slant path correction is ramped down to zero for wavelengths greater than 4um, where solar energy input is less important. KDIST=3 is the default.

ZGRID1:   These three parameters can be used to change the grid
ZGRID2:   resolution of the model atmosphere. ZGRID1 controls
NGRID: the resolution near the bottom of the grid while
             ZGRID2 sets the maximum permissible step size (at the
             top of the grid). NGRID sets the number of grid
             points. For example ZGRID1=.5, ZGRID2=30, NGRID=45
             specifies a 45 element grid with a resolution of .5 km
             throughout the lower part of the grid and a largest step
             of 30 km.

             The regridding is performed after the call to
             subroutine ATMS. This allows regridding of the
             standard internal atmospheres as well as user

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specified atmospheres (read with IDATM=0). No matter
how many grid points were used to specify the original
atmosphere, the new regridded atmosphere will contain
NGRID vertical array elements. The default value of
ZGRID1 and ZGRID2 are set to 1 and 30km, respectively.
The default value of NGRID=0, causes the initial un-modified
atmsopheric model to be used. The internal parameter,
MXLY, sets the maximum number of levels allowed. Setting
NGRID>MXLY causes NGRID to be set to MXLY.

If NGRID is negative SBDART terminates execution
after printing out the regridded values of Z,P,T,WH,WO
to standard out. This option can be used to preview the
effect of a given set of ZGRID1,ZGRID2 and abs(NGRID)
values. Note that the regridded atmosphere listed with
negative NGRID will contain the effects of non-default
values of UW, UO3, O3TRP, PBAR, ZPRES, RHCLD, and KRHCLR

OUTPUT OPTIONS
==============

IDB: DIAGNOSTIC OUTPUT SELECTOR (integer array)

The IDB print flag is used to select print diagnostics
for a variety of computational parameters. Setting
IDB(n)=m where m is any non-zero integer, will cause
the diagnostics associated with array index n to be listed.
For some values of n, increasing the value of m (e.g.,
IDB(8)=2) will produce more detailed diagnostics. (default=0)

array
index
idb(1) print an explanation of quantities in IOUT output group

idb(2) prints relative humidity and water vapor density

idb(3) atmospheric profile used in gas absorption diagnostic
       prints z,p,t and correlated-k parameters

idb(4) if iday .ne.0 prints iday,time,alat,alon
       prints sza,solfac, z,p,t,h2o,o3

idb(5) cloud parameters: print wl,z(i),dtauc(i),ssa(i),pmom(i,1:n)
       where z(i) is altitude (the cloud layer extends
       from z(i) to z(i+1), dtauc(i) is the cloud optical
       depth contributed by layer i, ssa(i) is the single
       scattering albedo of cloud layer i, and
       pmom(i,1:n) are the first n moments of the
       scattering phase function of cloud. If idb(5)=1,
       sbdart stops after printing this information for
       the first wavelength encountered. If idb(5)=2 the
       code produces output for all wavelengths specified
       by WLINF WLSUP and WLINC.

idb(6) aerosol single scattering albedo assymetry factor
       optical depth increments of total (taua) and boundary

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```
           layer aerosols (tauab).  The total optical depth
           is displayed on the final line of output.

  idb(7) When kdist ge 0,
           idb(7)=1 for the surface layer only,
                    print wl, wn, tau_h2o, tau_h2o_c, tau_o3,
                        tau_c2o, tau_o3, tau_n2o, tau_co,
                        tau_ch4, tau_o2+n2, tau_trace, tau_totals

           idb(7)=2 same as idb(7)=1 but for all layers

           idb(7)=3 same as idb(7)=2 and add print out of
                    3-term k-distribution terms

         When kdist lt 0,
           idb(7)=1 lists wn(iw),trans(iw)
           idb(7)=2 lists wn(iw),solband(iw)
           idb(7)=3 lists the gwt(iw,ik) and dtauk(iw,ik,iz)

         where
           iw is the wavenumber index
           ik is the k-distribution index
           iz is the layer index
           wl is the wavelength
           wn is the wavenumber
           tau_?? = -log(transmission) of constituent ??
           h2o   = water vapor
           h2o_c = water vapor continuum
           o3    = ozone lines and continuum
           n2o   = nitrous oxide
           ch4   = methane
           o2+n2 = oxygen and nitrogen lines and continua
           trace = no, so2, no2, nh3
           solband is the toa solar irradiance in the band
           gwt is k-distribution weight
           dtauk is the k-distribution optical depth


         Note, to save time, the normal radiative transfer
         quantities are not computed when idb(7) is set.

  idb(8) surface brdf diagnostics for isalb=7,8,9 of -7,-8,-9
         idb(8)=1: the surface brdf function is integrated
         over solid angle to obtain the surface albedo (albedo
         is essentially the ratio of botup/botdn with thermal
         emission turned off) for the given solar zenith angle.
         if isalb is positive (7,8,9) and idb(8)=2: the brdf
         function is output in the same format used to list
         the iout=20 radiance output.  The output slots
         ordinarily filled by botup are filled with the
         directional albedo, assuming incoming radiation is
         parallel to the solar beam direction.


  idb(9) Optical depth due to Rayleigh, aerosols, cloud
         molecular continuum and line, single scattering albedo
         and asymmetry factor. Additional printouts for each
```

```
                    term in the k-fit are produced if KDIST=1.



     ZOUT:          2 element array specifying BOT and TOP altitude
                    points (km) for IOUT output.  For example ZOUT=0,50
                    specifies output information for 0 and 50 km. The
                    surface is always set at zero.  Note that the actual
                    layers for which output is generated is determined by
                    finding the atmospheric layers nearest the chosen
                    value of ZOUT(1) and ZOUT(2).  (default = 0,100)

                    This parameter can be used to determine the amount of
                    radiation absorbed in a particular atmospheric layer.
                    For example, zout=2,3 tcloud=10 zcloud=2 iout=10 will
                    produce flux output just below and above the cloud layer
                    from which the cloud absorption may be computed as
                    topdn-topup-botdn+botup


     IOUT:          STANDARD OUTPUT SELECTOR
          value
          -----
           0.       no standard output is produced, DISORT subroutine
                    is not called, but diagnostics selected by idb in gas
                    absorption or aerosol subroutines are active.

           1.       one output record for each wavelength,
                    output quantities are,

                       WL,FFV,TOPDN,TOPUP,TOPDIR,BOTDN,BOTUP,BOTDIR

                       WL    = wavelength                       (microns)
                       FFV   = filter function value
                       TOPDN = total downward flux at ZOUT(2) km  (w/m2/micron)
                       TOPUP = total upward flux at ZOUT(2) km    (w/m2/micron)
                       TOPDIR= direct downward flux at ZOUT(2) km (w/m2/micron)
                       BOTDN = total downward flux at ZOUT(1) km  (w/m2/micron)
                       BOTUP = total upward flux at  ZOUT(1) km   (w/m2/micron)
                       BOTDIR= direct downward flux at ZOUT(1) km (w/m2/micron)

                       NOTE: The filter function value, FFV, should be used
                             to perform integrations over wavelength intervals.
                             For example if WLINC is set positive (wavelength
                             increment is constant), the total power (w/m2) at
                             the surface in the interval from WLINF to WLSUP
                             would be the sum

                                   WLINC * SUM ( FFV(i)*BOTDN(i))


           5.       nzen+3) records for each wavelength.  Output format:
                       write(*,*) '"tbf'     ; Block id (used in postprocessors)

                        do m=1,nw
                          write(*,*)
                      &     wl,ffv,topdn,topup,topdir,botdn,botup,botdir
```

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```
              write(*,*)  nphi,nzen
              write(*,*) (phi(j),j=1,nphi)
              write(*,*) (uzen(j),j=1,nzen)
              do i=nzen,1,-1
                write(*,*) (uurs(i,k),k=1,nphi)
              enddo
            enddo
```

where,

```
   WL    = wavelength                      (microns)
   FFV   = filter function value
   TOPDN = total downward flux at ZOUT(2) km  (w/m2/micron)
   TOPUP = total upward flux at ZOUT(2) km    (w/m2/micron)
   TOPDIR= direct downward flux at ZOUT(2) km (w/m2/micron)
   BOTDN = total downward flux at ZOUT(1) km  (w/m2/micron)
   BOTUP = total upward flux at  ZOUT(1) km   (w/m2/micron)
   BOTDIR= direct downward flux at ZOUT(1) km (w/m2/micron)
   NPHI  = number of user azimuth angles
   NZEN  = number of user zenith angles
   PHI   = user specified azimuth angles      (degrees)
   UZEN  = user specified zenith angles       (degrees)
   VZEN  = user specified nadir angles        (degrees)
   UURS  = radiance at user angles at         (w/m2/um/str)
           altitude ZOUT(2) (top)
```

NOTE: The radiance output from SBDART represents
      scattered radiation. It does not include the
      solar direct beam. Also, keep in mind that UURS
      represents the radiance at the user specified
      sample directions. Hence, computing the
      irradiance by an angular integration of UURS
      will not yield BOTDN because of the neglect of
      the direct beam, and it will probably not yield
      (BOTDN-BOTDIR) because of under-sampling.

NOTE: if IDAY is set, then PHI is the actual compass
      direction in which the radiation in propagating

6.   same as IOUT=5 except radiance is for ZOUT(1) altitude
      (bottom)

7.   radiative flux at each layer for each wavelength. This
      output option can produce a huge amount of output if many
      wavelength sample points are used

```
      write(*,*) '"fzw'       ; block id (used in postprocessors)
      write(*,*) nz           ; number of z levels
      write(*,*) nw           ; number of wavelengths

      do j=1,nw
        write(*,*) wl
        write(*,*)
   &    (Z(i),i=nz,1,-1),    ; altitude                (km)
   &    (fdird(i),i=1,nz),   ; downward direct flux  (w/m2/um)
```

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```
     &      (fdifd(i),i=1,nz),   ; downward diffuse flux (w/m2/um)
     &      (flxdn(i),i=1,nz),   ; total downward flux   (w/m2/um)
     &      (flxup(i),i=1,nz)    ; total upward flux     (w/m2/um)
      enddo


10.        one output record per run, integrated over wavelength.
           output quantities are, (integrations by trapezoid rule)

               WLINF,WLSUP,FFEW,TOPDN,TOPUP,TOPDIR,BOTDN,BOTUP,BOTDIR

               WLINF = lower wavelength limit            (microns)
               WLSUP = upper wavelength limit            (microns)
               FFEW  = filter function equivalent width  (microns)
               TOPDN = total downward flux at ZOUT(2) km (w/m2)
               TOPUP = total upward flux at ZOUT(2) km   (w/m2)
               TOPDIR= direct downward flux at ZOUT(2) km (w/m2)
               BOTDN = total downward flux at ZOUT(1) km (w/m2)
               BOTUP = total upward flux at  ZOUT(1) km  (w/m2)
               BOTDIR= direct downward flux at ZOUT(1) km (w/m2)


               NOTE: To get the spectral flux density (w/m2/micron)
                     divide any of these quantities by FFEW

11.        radiant fluxes at each atmospheric layer integrated
           over wavelength. Output format:

               write(*,*) nz,phidw
               do i=1,nz
                 write(*,*) zz,pp,fxdn(i),fxup(i),fxdir(i),dfdz,heat
               enddo

            where,  nz    = number of atmospheric layers
                    phidw = filter function equivalent width(um)
                    zz    = level altitudes                (km)
                    pp    = level pressure                 (mb)
                    fxdn  = downward flux (direct+diffuse)  (W/m2)
                    fxup  = upward flux                     (W/m2)
                    fxdir = downward flux, direct beam only (W/m2)
                    dfdz  = radiant energy flux divergence  (mW/m3)
                    heat  = heating rate                    (K/day)

           NOTE:  dfdz(i) and heat(i) are defined at the layer
           centers, i.e., halfway between level i-1 and level i.

20.        radiance output at ZOUT(2) km.

           Output format:

               write(*,*)  wlinf,wlsup,ffew,topdn,topup,topdir,
              &            botdn,botup,botdir
               write(*,*)  nphi,nzen
               write(*,*)  (phi(i),i=1,nphi)
               write(*,*)  (uzen(j),j=1,nzen)
               write(*,*)  ((r(i,j),i=1,nphi),j=1,nzen)

           The first record of output is the same as format IOUT=10
```

```
      (WLINF,WLSUP,FFEW,TOPDN,TOPUP,TOPDIR,BOTDN,BOTUP,BOTDIR)
      addition records contain:

      NPHI  = number of user azimuth angles
      NZEN  = number of user zenith angles
      PHI   = user relative azimuth angles (nphi values)
      UZEN  = user zenith angles (nzen values)
      R     = radiance array (nphi,nzen) (W/m2/sr)

      NOTE: if IDAY is set, then PHI is the actual compass
            direction in which the radiation in propagating
```

21.   same as IOUT=20 except radiance output at ZOUT(1) km.

22.   radiance and flux at each atmospheric layer integrated
       over wavelength.

       Output format:

```
      write(*,*) nphi,nzen,nz,ffew
      write(*,*) (phi(i),i=1,nphi)
      write(*,*) (uzen(j),j=1,nzen)
      write(*,*) (z(k),k=nz,1,-1)
      write(*,*) (fxdn(k),k=1,nz)
      write(*,*) (fxup(k),k=1,nz)
      write(*,*) (fxdir(k),k=1,nz)
      write(*,*) (((uurl(i,j,k),i=1,nphi),j=1,nzen),k=1,nz)

     where,  nphi  = number of user specified azimuth angles
             nzen  = number of user specified zenith angles
             nz    = number of atmospheric levels
             ffew  = filter function equivalent width (um)
             phi   = user specified anizmuth angles   (degrees)
             uzen  = user specified zenith angles      (degrees)
             z     = altitudes of atmospheric layers   (km)
             fxdn  = downward flux (direct+diffuse)    (W/m2)
             fxup  = upward flux                       (W/m2)
             fxdir = downward flux, direct beam only   (W/m2)
             uurl  = radiance at each layer            (W/m2/str)

      NOTE: if IDAY is set, then PHI is the actual compass
            direction in which the radiation in propagating
```

23.   same as IOUT=20 except
       lower hemisphere radiance output corresponds to ZOUT(1)
       upper hemisphere radiance output corresponds to ZOUT(2)
       Use this output format to determine radiance above and
       and below a scattering layer. For example, if ZCLOUD=1
       and TCLOUD=10, you can get the scattered radiation field
       above and below the cloud with, IOUT=23, ZOUT=1,2.

```
      NOTE: if IDAY is set, then PHI is the actual compass
            direction in which the radiation in propagating
```

===

                    DISORT options
                    ==============

  DELTAM: if set to true, use delta-m method (see Wiscombe, 1977).
                 This method is essentially a delta-Eddington
                 approximation applied to multiple radiation streams.

                 In general, for a given number of streams, intensities
                 and fluxes will be more accurate for phase functions
                 with a large forward peak if 'DELTAM' is set
                 TRUE. Intensities within 10 degrees or so of the
                 forward scattering direction will often be less
                 accurate, however, so when primary interest centers in
                 this so-called 'aureole region', DELTAM should be set
                 FALSE.(default=true)

  NSTR: number of computational zenith angles used. NSTR must
                 be divisible by 2. Using NSTR=4 reduces the time
                 required for flux calculations by about a factor of 5
                 compared to NSTR=16, with very little penalty in
                 accuracy (about 0.5% difference when DELTAM is set
                 true). More streams should be used with radiance
                 calculations. The default of NSTR depends on the value
                 of IOUT. The default for flux computations (IOUT=1,7,10,11)
                 is NSTR=4. The default for radiance computations
                 (IOUT=5,6,20,21,22,23) is NSTR=20.

  CORINT: When set TRUE, intensities are correct for delta-M scaling
                 effects (see Nakajima and Tanaka, 1988). When FALSE,
                 intensities are not corrected.

                 In general, CORINT should be set true when a beam
                 source is present (FBEAM is not zero), DELTAM is TRUE,
                 and the problem includes scattering. However,
                 CORINT=FALSE runs faster and produces fairly accurate
                 intensities outside the aureole. If CORINT=TRUE and
                 phase function moments are specified with PMAER
                 (IAER=5), or in aerosol.dat (IAER=-1), it is important
                 to specify a sufficient number of phase function
                 moments to adequately model single scattered radiation
                 in the forward direction. Otherwise, if too few moments
                 are provided, the intensities might actually be more
                 accurate with CORINT=FALSE.

                 Default value CORINT=.false.

                 The input value of CORINT is ignored for:
                 1) in irradiance mode, i.e., iout ne (5,6,20,21,22)
                 2) there is no beam source (FBEAM=0.0), or
                 3) there is no scattering (SSALB=0.0 for all layers)

                       Radiance output
                       ===============

```
NZEN:          Number of user zenith angles.  If this parameter is
               specified SBDART will output radiance values at NZEN
               zenith angles, evenly spaced between the first two
               values of input array UZEN.  For example,

                nzen=9,
                uzen=0,80

               will cause output at zenith angles 0,10,20,30,40,50,60,70,80.

UZEN:          User zenith angles.  If NZEN is specified then UZEN is
               interpreted as the limits of the zenith angle range,
               and only the first two elements are required.  If NZEN
               is not specified then up to NSTR values of UZEN may be
               specified.  If neither NZEN nor UZEN is specified and
               a radiance calculation is requested
               (IOUT=5,6,20,21,22,23) a default set of zenith angles
               is used, which depends on the value IOUT as follows:
                      * IOUT=5 or 20:  NZEN=18, UZEN=0,85
                      * IOUT=6 or 21:  NZEN=18, UZEN=95,180
                      * IOUT=22 or 23: NZEN=18, UZEN=0,180

               NOTE: UZEN specifies the zenith angle of at which the
               radiation is propagating:

               UZEN = 0    => radiation propagates directly up
               UZEN < 90   => radiation in upper hemisphere
               UZEN > 90   => radiation in lower hemisphere
               UZEN = 180  => radiation propagates directly down

VZEN:          user nadir angles.  This is just an alternate way to
               specify the direction of user radiance angles, whereby
               uzen=180-vzen

NPHI:          Number of user azimuth angles.  If this parameter is
               specified SBDART will output radiance values at NPHI
               azimuth angles, evenly spaced between the first two
               values of input array PHI.  For example, nphi=7,
               phi=0,180 will cause output at zenith angles
               0,30,60,90,120,150,180

PHI:           User relative azimuth angles.  If NPHI is specified then
               PHI is interpreted as the limits of the azimuth angle range,
               and only the first two elements are required.  If NPHI
               is not specified then up to NSTR values of PHI may be
               specified.  If neither NPHI nor PHI is specified and a
               radiance calculation is requested (IOUT=5,6,20,21,22,23)
               a default set of azimuth angles is used, equivalent to
               the case NPHI=19, PHI=0,180.

               NOTE: If SAZA is set, then PHI=0 represents radiation
               propagating in the Northern direction.  PHI increases
               clockwise looking down on the Earth's surface.
               If SAZA is not set, then PHI is the relative azimuth
               angle from the forward scattering direction.
```

```
        * PHI < 90   => forward scattered radiation
        * PHI > 90   => backward scattered radiation

        For example, if the sun is setting in the West,
        radiation propagating to the South-East has a relative
        azimuth of 45 degrees.

        NOTE: SBDART is currently configured to model radiation
              with at most 40 computational zenith angles and
              40 azimuthal modes.  While these limits may be
              expanded, be aware that running SBDART with a
              much larger number will significantly increase
              running time and memory requirements.  In tests
              performed on a DEC Alpha, the execution time
              scaled roughly with NSTR^2, for NSTR less than
              40.  The code's memory usage also scales roughly
              as NSTR^2.

        NOTE: The default value of the solar azimuth angle, SAZA=180.
              This value of SAZA will cause forward scattered solar
              radiation to appear near PHI=0.



              radiation boundary conditions
              =============================

 IBCND:
      = 0 : general case: boundary conditions any combination of:
             * beam illumination from the top      ( see FBEAM)
             * isotropic illumination from the top ( see FISOT)
             * thermal emission from the top       ( see TEMIS,TTEMP)
             * internal thermal emission sources   ( see TEMPER)
             * reflection at the bottom            ( see LAMBER,ALBEDO,HL)
             * thermal emission from the bottom    ( see BTEMP)
      = 1 : isotropic illumination from top and bottom, in order to get
            ALBEDO and transmissivity of the entire medium vs. incident
            beam angle;
            The only input variables considered in this case are
            NLYR,DTAUC,SSALB,PMOM,NSTR,USRANG,NUMU,UMU,ALBEDO,DELTAM,
            PRNT,HEADER, and the array dimensions.
            NOPLNK,LAMBER are assumed TRUE, the bottom boundary can have
            any ALBEDO.  the sole output is ALBMED,TRNMED.  UMU is
            interpreted as the array of beam angles in this case.
            If USRANG = TRUE they must be positive and in increasing
            order, and will be returned this way; internally, however, the
            negatives of the UMU's are added, so MAXUMU must be at least
            2*NUMU.
            If USRANG = FALSE, UMU is returned as the NSTR/2 positive
            quadrature angle cosines, in increasing order.

 FISOT:     intensity of top-boundary isotropic illumination.  (units
            w/sq m if thermal sources active, otherwise arbitrary
            units).  corresponding incident flux is pi (3.14159...)
            times 'FISOT'.
```

```
    TEMIS:     emissivity of top layer, not used if NOTHRM=1

   BTEMP:      Surface (skin) temperature in Kelvin.  If not set, the
               surface temperature is set to the temperature of the
               bottom layer of the model atmosphere.  The surface
               emissivity is calculated from the albedo (see ISALB and
               ALBCON).  The input value of BTEMP is ignored when
               NOTHRM=1.  When SPOWDER=.true. BTEMP specifies the skin
               temperature of the level just below the granular layer.




            DISORT specific output options:
            ================================
PRNT(k):    k
            1            input variables (except PMOM)
            2            fluxes
            3            intensities at user levels and angles
            4            planar transmissivity and planar albedo
                         as a function solar zenith angle ( IBCND = 1 )
            5            phase function moments PMOM for each layer
                         ( only if PRNT(1) = TRUE, and only for layers
                         with scattering )


===========================================================================
```