User's Guide for

UNL–VRTM

A UNified Linearized Vector Radiative Transfer Model

Version 1.3

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1 Getting Start

1.1 Obtaining the UNL-VRTM source code and necessary data

Model packages including source code and run directories are available upon request from the webpage:

`http://eas.unl.edu/~xxu/unlvrtm`

Usually an email will automatically sent back to indicate download links for source code as well as necessary data.

Please do not distribute copies of the code at this time; you may refer such requests to Richard or Jun.

1.2 Directory Structure Overview

The radiative transfer model consists of several subdirectories. If you are in the root directory, a *ls* command should give you:

```
run/  src/  /util
```

The followings are the short description of each subdirectory.

- The *src* is the subdirectory for the source code. It also includes the Fortran libraries of linearized Mie/T-Matrix code and VLIDORT (version of 2.5) model.
- The *run* is used to run the model, which contains the model namelist file.
- The *util* folder consists some analysis tools for the model outputs, including IDL routines.

In addition, the model needs input of a set of ancillary data, such as the line parameters, and cross section of the trace gases, which are stored in a *data* folder. Users needs to obtain those data from the model developer, and specify the path for *data* in a *namelist* file.

1.3 Compilation

The model is compiled in *src* directory by a Makefile. Currently, we have compiled the model only with Intel fortran compiler (ifort). Type 'make -f Makefile' to compile, and 'make clean' to clear the compiled modules.

1.4 Running

To run the model, just move/copy the generated executable file *unlvrtm.exe* by compilation to the *run* directory, and run it with the specification of file *namelist.ini*

2 Input Files

This chapter describe the input and output files of the model. The users need to use the input file, *namelist.ini* located in the *run* directory, to run their specific cases. Once the results is generated, the users also need to access the output for their analysis. In the following, we will discuss these files in more detail.

2.1 Input file: *namelist.ini*

The model puts all the input options and switches into a single input file, *namelist.ini* which located in the *run* directory. In this file, you may specify most options for the radiative transfer simulation, including wavelength, atmospheric profiles, air molecular optics, aerosol physical and optical property, surface property, and diagnostics to save to disk, etc.

Note that the *namelist.ini* file is grouped into menus, as following the style and logic from the input file of GEOS-Chem model. Each menu controls the options for a particular aspect of the model. Below is a list of menus and the options which they control.

- CONTROL MENU. Specifies the wavelength, and atmosphere type, and directory information.
- GEOMETRY MENU. Specifies the sun-earth-viewer geometry.
- RTM MENU. Specifies the simulation options for the VLIDORT model.
- JACOBIAN MENU. Specifies options for Jacobian calculations.
- SURFACE MENU. Specifies surface for simulation.
- AEROSOL MENU. Specifies the optical and physical properties of aerosol.
- TRACE-GAS MENU. Specifies the information of each trace gas, including name, molecular weight, and the individual switch.
- RAYLEIGH MENU. Specifies the Rayleigh scattering calculation.
- DIAGNOSTIC MENU. Specifies which variables are saved to output.
- DEBUG MENU. Switches of debugging some aspect of the model.

Each of these menus is described in more detail below. Note that the line numbers are not part of the *namelist.ini* file, but have been included for the convenience of interpretation.

2.1.1 The CONTROL Menu

```
1 %%% CONTROL MENU %%%    :
2 Start & end lamda [nm]  : 755 775
3 Spectra step[nm or #/cm]: 1.0
4 Atmos. type [1-6,or -1] : 2
5 # of atmos. layers      : -1
6 Run    directory        : ./
7 Data   directory        : /work/jwang7/xxu/rtm_data/data/
8 Output directory        : ./results/
```

Description:

1. Title for this menu.

2. Specifies the wavelength range in the units of nanometer. User can specify either single or multiple wavelengths. It should be noted that, for multiple spectrum, the wavelengths should be in an ascending sequence.

3. Specifies the sampling step for the spectrum in wavelength [nm] or wavenumber [#/cm]. A positive value is for wavelength, while a negative value will indicate wavenumber.
   There are various options for specifying spectrum with above two lines:

   - If only one wavelength is specified in line 2, or value of zero is in line 3, model then does the simulation on a single wavelength.
   - If two wavelengths are specified in line 2, and a POSITIVE interval specified in line 3, model will simulate multi-spectrum from start wavelength to end wavelength with equal wavelength of the interval value. With above sample settings, the model will do simulation in the O2-A band (755 - 775 nm) with equal interval of 1 nm.
   - If two wavelengths are specified in line 2, and a NEGATIVE interval specified in line 3, model will simulate multi-spectrum from start wavelength to end wavelength with equal wavenumber of the interval value.
   - If three or more wavelength values are specified, simulation will be on these wavelength while specified interval value does not take effects.

4. Specifies the index of atmospheric type for the meteorological and air density profile. Number of 1 to 6, or -1 indicate 6 different atmospheric profile types, or user specified profile (under development).

- 1: Tropical
- 2: Mid-latitude summer
- 3: Mid-latitude winter
- 4: High-latitude summer
- 5: High-latitude winter
- 6: US standard
- -1: User specified

5. Specifies the number of atmospheric layers. Those built-in atmospheric types are 49 layers and options for this number are:

   - 49: Full standard atmospheric profile with 49 layers.
   - Any number from 1 to 48: Uses the specified number of bottom layers.
   - -1: 33 atmospheric layers, by aggregating a few stratospheric layers.
   - -2: 26 atmospheric layers, by aggregating a more stratospheric layers.
   - -3: 3 atmospheric layers, with 2 layers in troposphere and 1 in stratosphere.

6. Specifies the model run directory. Generally, it is ./ which is the current directory.

7. Specifies the directory where the ancillary data is placed.

8. Specifies the subdirectory in the run directory where the model output will be saved.

2.1.2 The GEOMETRY Menu

```
1 %%% GEOMETRY MENU %%%   :
2 Solar zenith angle      : 30 45
3 Viewer zenith angle     : 45 60 75
4 Relative azimuth angle  : 60 120
```

Description:

1. Title of geometry menu

2. Specifies solar zenith angles. You may list a single or two angles in the units of degree. The maximum number of angles is 2.

3. Specifies viewing zenith angles, number of which is up to 5.

4. Specifies the relative azimuth angles, number of which is up to 2.

However, it should be noted that user can increase, if needed, those maximum numbers for each type of angles by modifying codes and updating the library of VLIDORT. And this will be discussed in Chapter 4.

2.1.3 The VLIDORT Menu

```
1 %%% RTM MENU %%%        :
2 Turn on RTM (VLIDORT)?  : T
3 # of Stokes components  : 3
4 # of dsicrete streams   : 15
5 # of P Legendre terms   : 180
6 Receptor levels         : 0
7 Receptor direction      : -1
8 Index of SSC scenario   : 1
```

Description:

1. Title for VLIDORT menu.

2. Switch to turn on/off the VLIDORT calculation

3. Specifies the number of Stokes vector components [*I, Q, U, V*]. By setting 1, the model will be only calculating *I*. By setting 3, model calculate *I,Q,U*, and similarly, model calculates full Stokes vector if 4 is set.

4. Specifies number of streams in the hemisphere.

5. Specifies number of Legendre expansion terms for Greek Matrix. Current maximum is 180, but user can increase it (see Chapter 4).

6. Defines on which levels you want to calculate the radiance. The maximum number of levels is 2. Note that level is 0 to N from the top-of-atmosphere (TOA) to the bottom-of-atmosphere (BOA) in VLIDORT. Therefore, **0 represents TOA level**. For the convenience, you may also use -1 to indicate the BOA level.

7. Specifies the direction of beam to the viewer. **-1 and 1 represent upward and downward**, respectively.

8. Specifies the scenario of the single scattering correction in VLIDORT. Please check the code *vlidort_mod.f* for detail. 0 is recommended for Rayleigh only atmosphere; while 1 is recommended if aerosol scattering involves.

2.1.4 The JACOBIAN Menu

```
 1 %%% JACOBIAN MENU %%%   :
 2 Turn on atmos. Jacob.?  : T
 3   - wrt Gas?            : F
 4   - wrt AOD?            : F
 5   - wrt SSA?            : F
 6   - wrt aerosol mass?   : T
 7   - wrt mode fraction?  : F
 8   - wrt refractivity?   : T
 9   - wrt shape factor?   : F
10   - wrt size dist?      : T
11   - wrt profile?        : F
12 Non-variation of mass?  : T
13 Non-variation of AOT?   : F
14 Turn on surface Jacob.? : T
15   - wrt BRDF factor?    : T
16   - wrt BRDF parameter? : F
17 Do FD verication?       : F
```

Description:

1. Title for Jacobian menu.

2. Switch to turn on/off the calculation for Jacobian for atmospheric trace gas or aerosol parameters. If set false, all the atmospheric Jacobian calculations will be turned off.

3. Switch to turn on/off the calculation of Jaocbian of Stokes components with respect to total gas absorption optical depth.

4. Switch to turn on/off the calculation of Jaocbian of Stokes components with respect to aerosol optical depth.

5. Switch to turn on/off the calculation of Jaocbian of Stokes components with respect to aerosol single scattering albedo.

6. Switch to turn on/off the calculation of Jaocbian of Stokes components with respect to aerosol mass.

7. Switch to turn on/off the calculation of Jaocbian of Stokes components with respect to aerosol modal mass fraction.

8. Switch to turn on/off the calculation of Jaocbian of Stokes components with respect to aerosol refractive indices.

9. Switch to turn on/off the calculation of Jaocbian of Stokes components with respect to aerosol shape factor (with T-Matrix code turned on).

10. Switch to turn on/off the calculation of Jaocbian of Stokes components with respect to aerosol size distribution parameters.

11. Switch to turn on/off the calculation of Jaocbian of Stokes components with respect to aerosol vertical profile parameters.

12. If true, keep the mass constant (but varying AOD) in the Jacobian calculation.

13. If true, keep AOD as a constant (but varying mass) in the Jacobian calculation. Only and must one of this and above one should be true.

14. Switch to turn on/off the calculation of Jaocbian of Stokes components with respect to surface reflectance.

15. Switch to turn on/off the calculation of Jaocbian of Stokes components with respect to BRDF amplitude factor of each kernel.

16. Switch to turn on/off the calculation of Jaocbian of Stokes components with respect to BRDF kernel parameters.

17. Switch to turn on/off the finite difference verification for the Jacobian calculation of VLIDORT model (current not useful, may be removed later!).

2.1.5 The SURFACE Menu

```
1 %%% SURFACE MENU %%%    :
2 Do Lambertian surface?  : F
3   - surface reflecetance: 0.1
4 Do BRDF surface?        : T
5   - # of BRDF kernels   : 3
6   - BRDF kernel entries : Name      Index  Factor  #PARS  PAR(1)  PAR(2)  PAR(3)
```

```
7           ==> kernel#1 : Lambertian  1    0.18    0      0.0     0.0     0.0
8           ==> kernel#2 : Ross-thick  3    0.10    0      0.0     0.0     0.0
9           ==> kernel#3 : Li-sparse   4    0.03    2      2.0     1.0     0.0
```

Description:

1. Title for the Surface Menu.
2. Switch to turn on/off the Lambertian surface.
3. Define the Lambertian surface reflectance value. A decimal value between 0 and 1 (include 0 and 1) indicates a specified surface reflectance value. Alternatively, by set a integer number from 2 (currently up to 3), the model will use its built-in reflectance spectrum library. 2 is for tap water surface, and 3 is green grass surface.
4. Switch to turn on/off the BRDF surface. **Only and must one of Lambertian and BRDF should be set true.**
5. Define number of used BRDF kernels (maximum is 3).
6. BRDF entry titles.
7. From line 7 are the parameters for each kernel (Table 2.1 here lists the available kernels, but more details are referred to VLIDORT User's Guide): (1) Kernel names, (2) kernel index, (3) amplitude of the kernel, (4) number of parameters, (5) kernel parameters up to 3.

Table 2.1 Summary of available BRDF kernels (from VLIDORT User's Guide).

Index	Kernel name	# parameters	Type	Source
1	Lambertian	0	Scalar	
2	Ross-thick	0	Scalar	Wanner et al., 1995
3	Ross-thin	0	Scalar	MODIS
4	Li-sparse	2	Scalar	MODIS
5	Li-dense	2	Scalar	MODIS
6	Roujean	0	Scalar	MODIS
7	Rahman(RPV)	3	Scalar	Rahman et al., 1993
8	Hapke	3	Scalar	Hapke, 1993
9	Cox-Munk	2	Scalar	Cox/Munk, 1954
10	GISS Cox-Munk	2	Vector	Mishchenko/Travis 1997
11	BPDF2009	2	Vector	Maignan et al., 2009

2.1.6 The AEROSOL Menu

```
 1 %%% AEROSOL MENU %%%    :
 2 Turn on aerosol?        : T
 3 Number of aerosol modes : 2
 4 Modal fractions         : 0.65       0.35
 5 Column AOD as input?    : F          1.0
 6 ColMass[kg/m2] as input?: T          0.20E-03
 7 Density of each [kg/m3] : 1.0E+03    1.0E+03
 8 Mie(1) or T-Matrix(2)?  : 1          1
 9 Mode #1 Properties      : ..................Mode#1..................
10   - refractive index    : 1.33E+00   0.006
11   - shape factor        : -1         1.4
12   - monodisperse?       : F          1.0
13   - size range [um]     : 0.01       15
14   - size distribution   : Index      PAR(1)    PAR(2)    PAR(3)
15             ==> Entries : 4          0.1       1.6       0
16   - vertical range[km]  : 0          15
17   - vertical profile    : Index      PAR(1)    PAR(2)
18             ==> Entries : 3          0.5       2.0
19 Mode #2 Properties      : ..................Mode#2..................
20   - refractive index    : 1.53E+00   0.001
21   - shape factor        : -1         1.0
22   - monodisperse?       : F          1.0
23   - size range [um]     : 0.05       15.0
24   - size distribution   : Index      PAR(1)    PAR(2)    PAR(3)
25             ==> Entries : 4          1.00      2.0       0
26   - vertical range[km]  : 0          15.0
27   - vertical profile    : Index      PAR(1)    PAR(2)
28             ==> Entries : 3          2.0       2.0
29 Reference aerosol mode  : ................Mode#REF..................
30   - reference AOD?      : F
31   - wavelength [nm]     : 354
32   - refractive index    : 1.75E+00   0.435
33   - monodisperse?       : F          1.0
34   - size range [um]     : 0.01       10.0
35   - size distribution   : Index      PAR(1)    PAR(2)    PAR(3)
36             ==> Entries : 4          0.01      2.0       0
```

Description:

1. Title for aerosol menu.
2. Set true to include aerosol scattering for the radiance calculation.
3. Specifies number of aerosol modes. 1 for single mode, 2 for bi-mode.

4. Specifies the modal fractions. If single mode, this line is non-effective. Note that these could be either AOD fractions or mass fractions, depending on which is used as loading input in following two lines.

5. Define the column atmospheric aerosol optical depth (AOD). (1) Turn on/off using column AOD as aerosol loading inputs; (2) Column AOD.

6. Define the column aerosol mass in the units of [kg/m2]. (1) Turn on/off using column mass as aerosol loading inputs. (2) Aerosol column mass. NOTE that only one of mass and AOD should be turned on.

7. Specifies the density of modal aerosols.

8. Specifies the used approaches for aerosol optical property calculation, **1 for Mie theory**, and **2 for T-Matrix method**. Two inputs are respectively for each individual modes.

9. Title for mode #1.

10. Refractive index for mode #1, respectively, real and imaginary terms.

11. Shape factor for non-spherical particle when using T-Matrix calculation [to be filled.....]

12. Options for mono-disperse simulation: (1) Turn on/off considering mono-disperse, (2) specify the mono-size in micron

13. Particle size range in micron-meter.

14. Size distribution entries titles

15. Size distribution entries: (1) Size distribution function index, (2)-(4) size distribution parameters, up to 3 parameters. Size distribution functions and their parameters are listed in Table 2.2.

16. Vertical extending range in [km].

17. Vertical profile entry titles.

18. Vertical profile function index, and parameters. See Table 2.3.

19. Line 19 – 28: Specifies aerosol parameters for mode #2, similar to that of mode #1.

20. Line 29 – 36: Specifies aerosol parameters for a reference aerosol AOD value, similar to that of mode #1. The reference AOD can be used here when one knows the AOD values at certain wavelength and want to conduct simulation on other spectral wavelengths.

Table 2.2 Summary of particle size distribution (PSD) options.

Index	**Description of PSD and parameters**
1	Two parameter GAMMA with ALPHA and B given
2	Two parameter GAMMA with REFF and VEFF given
3	3-parameter Bimodal equal-weight GAMMAS with 2 REFFs + same VEFF
4	Two parameter Lognormal with RG and SIGMA given
5	Two parameter Lognormal with REFF and VEFF given
6	Power-Law with R1, R2 and ALPHA
7	3-parameter Modified-Gamma with ALPHA,GC,GAMMA given
8	3-parameter Modified-Gamma with ALPHA,B,GAMMA given

Table 2.3 Summary of aerosol vertical profile options*.

Index	**Description of PSD and parameters**
1	Uniform profile—aerosol are evenly distributed in the given vertical range
2	Exponentially decreasing profile with scale height H given
3	Generalized Distribution function, given z_{peak} and γ

* Equations for index #2: $\int_{TOA}^{z} \tau(z)dz = \tau_0 \exp(-\frac{z}{H})$, where τ_0 is columnar AOD. The profile #3 follows an "almost-Gaussian" function: $\tau(z) = K\frac{\exp(-\gamma|z-z_{peak}|)}{[1+\exp(-\gamma|z-z_{peak}|)]^2}$, where K is related to the columnar loading, z_{peak} is the height of AOD peak, and γ related to the half-width σ: $\gamma = \ln(3+\sqrt{8})/\sigma$.

2.1.7 The TRACEGAS Menu

```
 1 %%% TRACE-GAS MENU %%%  :
 2 Turn on trace gases?    : T
 3 Full wid.@half max(FWHM): 10.0
 4 Num. of trace gases     : 22
 5 Trace gas Entries   ==> : TR#   Name    M-Weight   Include?  Scaling
 6 Trace gas #1            :   1   H2O     18.015       T       0.15
 7 Trace gas #2            :   2   CO2     44.010       T       1.0
 8 Trace gas #3            :   3   O3      47.998       T       1.25
 9 Trace gas #4            :   4   N2O     44.010       T       1.0
10 Trace gas #5            :   5   CO      28.011       T       1.0
11 Trace gas #6            :   6   CH4     16.043       T       1.0
12 Trace gas #7            :   7   O2      31.999       T       1.0
13 Trace gas #8            :   8   NO      30.010       T       1.0
14 Trace gas #9            :   9   SO2     64.060       T       1.8
```

```
15 Trace gas #10          :  10   NO2     46.010       T       1.8
16 Trace gas #11          :  11   NH3     17.030       F       1.0
17 Trace gas #12          :  12   HNO3    63.010       F       1.0
18 Trace gas #13          :  13   OH      17.000       T       1.0
19 Trace gas #14          :  14   HF      20.010       F       1.0
20 Trace gas #15          :  15   HCL     36.460       F       1.0
21 Trace gas #16          :  16   HBR     80.920       F       1.0
22 Trace gas #17          :  17   HI      127.91       F       1.0
23 Trace gas #18          :  18   CLO     51.450       F       1.0
24 Trace gas #19          :  19   OCS     60.080       F       1.0
25 Trace gas #20          :  20   H2CO    30.030       T       1.0
26 Trace gas #21          :  21   HOCL    52.460       F       1.0
27 Trace gas #22          :  22   N2      28.014       F       1.0
```

Description:

1. Title for trace gas menu.
2. Set true to include trace gas absorption for the radiance calculation.
3. Specifies the gas absorption spectral resolution parameter: full width at half maximum (FWHM).
4. Specifies the total number of considered trace gas. This **must** be 22 in the current version of the model.
5. Entries.
6. Line 6-27 give the tracer number, name, mole weight, switches to turn on/off the inclusion of each gas, and the scalling factor. The scaling factor scale the gaseous columnar amount from the built-in standard atmospheric profile. The value of 1.0 indicating to use the standard profile. And in practical, it is recommend to exclude gases those having zero or negligible absorption in your focused bands, which will considerably speed the model run.

2.1.8 The RAYLEIGH Menu

```
1 %%% RAYLEIGH MENU %%%   :
2 Turn on Rayleigh?       : T
3 Turn on anisotropy?     : T
```

Description:

1. Title for Rayleigh menu.

2. Set true to include atmospheric Rayleigh scattering for the radiance calculation.

3. Switch to turn on/off the anisotropy effect of atmospheric molecules.

2.1.9 The DIAGNOSTIC Menu

```
 1 %%% DIAGNOSTIC MENU %%% :
 2 Turn on DIAGNOSTIC?     : T
 3 Output NC file prefix   : cntl
 4 DIAG01: Model inputs    : T
 5 DIAG02: Atmos profiles  : T
 6 DIAG03: Linearized Mie  : T
 7 DIAG04: Trace gas       : T
 8 DIAG05: Optic profiles  : T
 9 DIAG06: VLIDORT IOP     : T
10 DIAG07: Radiances       : T
11 DIAG08: Jacobians       : T
```

Description:

1. Title for diagnostic menu.

2. Switch to turn on/off of generating the diagnostic file.

3. Specifies a prefix name for the diagnostic file (netCDF format).

4. Switch to turn on/off of including the model input variables to the diagnostic file. Following lines are similar.

2.1.10 The DEBUG Menu

```
 1 %%% DEBUG MENU %%%      :
 2 Turn on screen print?   : T
 3 Turn on aerosol debug?  : T
 4 Turn on Mie debug?      : T
 5 Turn on Rayleigh debug? : T
 6 Turn on tracegas debug? : F
 7 Turn on VLIDORT  debug? : T
```

Description: Debug menu includes switches to turn on/off screen debug output the calculation.

2.2 Input file: *spectra.dat* (optional)

spectra.dat is an optional input file specifically designed for multi-spectrum simulations. If wavelengths option in Control Menu (in *namelist.ini*) is specified as:

```
%%% CONTROL MENU %%%    :
Start & end lamda [nm]  : -1
```

UNL-VRTM will read wavelengths, aerosol refractive indices, and surface reflectance (Lambertian or BRDF) parameters from*spectra.dat*. And the surface reflectance (or BRDF parameters), as well as the refractive indices, will be replaced by the inputs from file *spectra.dat*.

It is recommended to use *spectra.dat* for multi-spectrum simulations when:

- Aerosol refractive indices varies on the interested wavelengths.
- Surface reflectance varies on the interested wavelengths.

User needs to prepare file *spectra.dat* in fixed format. Here is an example of file *spectra.dat* for my AERONET sky radiance simulations in 4 wavelengths:

```
#1=============================================================================
#2 $id:spectra.dat, specifically for multi-spectral simulations by UNL-VRTM
#3   - first 10 lines are used for comments
#4   - 11th line: specify number of spectrum
#5   - following lines wavelength(nm), n_real, n_img, n_real, n_img,
#6        - column#1  : wavelength(nm)
#7        - column#2-5:  n_real, n_img for 1st mode, and n_real, n_img for 2nd
#8        - column#6-8:  amplification foactor for BRDF model
#9 Version 1.2.0, 4/29/2013, update v1.3, 8/26/13
#10============================================================================
 4
440     1.478  0.0101    1.478  0.0101   0.0739  0.0357  0.0100
675     1.492  0.0071    1.492  0.0071   0.1392  0.0768  0.0202
870     1.493  0.0075    1.493  0.0075   0.1677  0.0894  0.0121
1020    1.488  0.0091    1.488  0.0091   0.1832  0.0764  0.0113
```

2.3 User specified atmospheric profile

This function has not been developed yet in version 1.3.

2.4 User specified spectrum response function

This function has not been developed yet in version 1.3.

3 Output Files

Once the code runs properly, results will be saved in a netCDF file, the name of which is *prefix_LAMDAXXXX.nc*, where *prefix* is specified in the *namelist.ini* and *XXXX* is spectrum index. For single spectrum simulation, *XXXX* is *0001*. For multi-spectrum (say 40), one NetCDF file will be generated for each individual spectrum from *0001* to *0040*. Along with the NetCDF output file, up to two ASCII files will be generated with filename of *prefix_LAMDA0001.diaginfo* (and *prefix.diaginfo* if multi-spectrum). In the following, we will discuss these files in more detail.

3.1 Output NetCDF files

The variables saved to the netCDF files are controlled by the Diagnostic Menu in *namelist.ini*. Here we tabulate all the variables could be saved to output NetCDF file in Table 3.1 - 3.9. **It should be noted that variables in Table 3.5 can only be found in file *prefix_LAMDA0001.nc***.

Variables listed in Table 3.2-3.9 may be arrays with at least one dimension. We have not provided the dimension information for each arrays here, user can associate the dimensions (as in Table 3.1) using *ncdump* or other functions.

3.2 File *prefix_LAMDA0001.diaginfo* and *prefix.diaginfo*

prefix_LAMDA0001.diaginfo lists all variables saved in file *prefix_LAMDA0001.nc*; while file *prefix.diaginfo* lists variables saved in the rest netCDF files.

3.3 Other possible output files

Table 3.1 List of dimensions.

Variable	**Long Name**	**Description**
n_sza	number of solar zenith angle	
n_vza	number of viewing zenith angle	
n_raz	number of relative azmith angle	
n_level	number of atmospheric levels	
n_layer	number of atmospheric layers	
maxmol	maximum number of gas tracers	always 39
n_geom	number of geometries	
n_lout	number of levels for radiance output	
n_stok	number of Stokes parameters	
n_jacb	number of control variables for Jacobian	
n_gas	number of gas included	
nval2	value of 2	
nval3	value of 3	
len_gas	length for gas name strings	
len_lpar	length for linaer parameter name strings	
n_jacb_s	number of surface reflectance variables for Jacobian	

Table 3.2 List of DIAG01 variables.

Index	**Variable**	**Units**	**Long Name**
101	IATM	unitless	Atmos Type
102	LAMDA	nm	Current Wavelength
103	SZA	degree	Solar Zenith Angle
104	VZA	degree	Viewer Zenith Angle
105	RAZ	degree	Relative Azimuth Angle
106	R_SFC	unitless	Surface Reflectance
107	LOUTS	unitless	Recptor Levels
108	DIR	unitless	Recptor Direction
109	I_SCENARIO	unitless	Index of SCC Scenario
110	GASNAMES	unitless	Gas Names
111	GASMU	g $mole^{-1}$	Gas Molecular Weight
112	FWHM	nm	Full width of half maximum
113	COLUMN_AOD0	unitless	Specified Column AOD
114	COLUMN_MASS0	kg m^{-2}	Specified Column Mass
115	RMRI	unitless	Refractive Index
116	SIZERANGE	um	Size Range
117	IDIST	unitless	Index of Size Dist Function
118	DISTPAR	um or none	Distribution Parameters
119	MODEFRC	unitless	Aerosol modal mass fraction
120	AERODEN	kg m^{-3}	Aerosol density
121	MONOR	um	Mono-disperse radius
122	SSMODEL	unitless	Single scattering model
123	IDPROF	unitless	Index of vertical profile
124	PROF_RANGE	km	Vertical range
125	PROF_PAR	km^{-1} or km	Profile parameters
126	REFER_LAMDA	nm	Referenced Wavelength
127	REFER_RMRI	unitless	Referenced Refractive Index
128	REFER_SIZERANGE	um	Referenced Aerosol Size Range
129	REFER_IDIST	unitless	Index Ref. Size Distribution
130	REFER_DISTPAR	um or none	Ref. Distribution Parameters
131	REFER_MONOR	um	Ref. Mono-disperse radius

Table 3.3 List of DIAG02 variables.

Index	**Variable**	**Units**	**Long Name**
201	Z	km	Level Height
202	P	hPa	Level Pressure
203	T	K	Layer Temperature
204	LAYINT	molec cm^{-3}	Layer Air Number Density
205	LAYMOLS	ppm	Air Molecular Mixing Ratio

Table 3.4 List of DIAG03 variables (all variables contain a dimension for aerosol mode).

Index	**Variable**	**Units**	**Long Name**
301	BULK_AOP	unitless	Mie bulk parameters: 1. Extinction cross-section 2. Scattering cross-section 3. Single scattering albedo 4. Extinction efficiency 5. Scattering efficiency
302	ASYMM	unitless	Asymmetric factor
303	DIST	unitless	Distribution Parameters: 1. Number Density (normalized to1) 2. Cross-section 3. Volume 4. Effective radius 5. Effective variance
304	EXPCOEFFS	unitless	Greek Matrix Expansion Coefficients
305	FMATRIX	unitless	Scattering F-Matrix, and entries are (in order): F11, F33, F12, F34
306	LPSD_BULK	unitless	Linearized Mie Parameters wrt PSD
307	LPSD_DIST	unitless	Linearized Size Parameters wrt PSD
308	LRFE_BULK	unitless	Linearized Mie Parameters wrt RFE
309	LFRC_BULK	unitless	Linearized Mie Parameters wrt MFRC
310	PROF_MASS	kg m^{-2}	Aerosol mass profile of each mode
311	PROF_AOD	unitless	Aerosol AOD profile of each mode
312	PROF_NUM	m^{-2}	Aerosol number profile of each mode
313	LPSD_FMATRIX	unitless	Linearized F-Matrix wrt PSD
314	LRFE_FMATRIX	unitless	Linearized F-Matrix wrt RFE

Table 3.5 List of DIAG04 variables.

Index	Variable	Units	Long Name
401	LAMDAS	nm	Spectral wavelenth
402	XSEC_SAO	cm^2/molec	Absorption Xsec by SAO-Xsec
403	XSEC_HIT	cm^2/molec	Absorption Xsec by HITRAN
404	GAS_XSEC	cm^2/molec	Combined Gas Absorption Xsec
405	XABS_SAO	unitless	Absorption OD by SAO-Xsec
406	XABS_HIT	unitless	Absorption OD by HITRAN
407	GAS_XABS	unitless	Combined Gas Absorption OD

Table 3.6 List of DIAG05 variables.

Index	Variable	Units	Long Name
501	TAUAER	unitless	Aerosol optical depth
502	TAURAY	unitless	Rayleigh scattering OD
503	TAUGAS	unitless	Gas optical depth
504	SSAAER	unitless	Aerosol single scattering albedo
505	TAUGAS_A	unitless	Gas Absorption OD
506	BRDFVAL	unitless	Exact direct BRDF

Table 3.7 List of DIAG06 variables.

Index	Variable	Units	Long Name
601	IOP_TAU	unitless	Ensemble Optical Depth
602	IOP_SSA	unitless	Ensemble SSA
603	LIOP_TAU	unitless	Linearied Ensemble Optical Depth
604	LIOP_SSA	unitless	Linearied Ensemble SSA

Table 3.8 List of DIAG07 variables.

Index	Variable	Units	Long Name
701	STOKES	unitless	Stokes Vector

Table 3.9 List of DIAG08 variables.

Index	**Variable**	**Units**	**Long Name**
801	LPAR_NAMES	unitless	Jacobian Names
802	JCOBIANS_COLUMN	unitless	Column Jacobians
803	JCOBIANS	unitless	Profile Jacobians
804	JCOBIANS_SURF	unitless	Surface Jacobians
805	TAUAER_WFS	unitless	AOD Weighting functions

4 For Advanced Users

4.1 Run the Model Beyond the *namelist.ini* File

To be filled ....

4.2 Making Modifications on the Model

To be filled ...

5 The Useful IDL Programs

There are a few IDL codes in the *util* folder for reading and processing the model results.

More detail to be filled here ...