Solar (+ Thermal) Radiance Mode with ISAACS' or Conservative Scattering, `I4` = 2 or 4 (IEMSCT = 2 or 4) and `L1` = 'F' (DIS = 'F')

```
 DO I8 = 1, J2
     READ(UNIT=I1, IOSTAT=I9)R80,R81,R82,R83,R84,                        &
&      R85,R86,R87,R88,R89,R90,R91,R92,R93,R94,R95
 ENDDO
```

The mapping of inputs to <*rootname*>.tp7 file columns is as follows:

`R80`	FREQ	`R81`	TOT_TRANS	`R82`	PTH_THRML	`R83`	THRML_SCT
`R84`	SURF_EMIS	`R85`	SOL_SCAT	`R86`	SING_SCAT	`R87`	GRND_RFLT
`R88`	DRCT_RFLT	`R89`	TOTAL_RAD	`R90`	REF_SOL	`R91`	SOL@OBS
`R92`	DEPTH	`R93`	DIR_EM	`R94`	TOA_SUN	`R95`	BBODY_T[K]

Solar/Lunar Irradiance Mode with DISORT Scattering `I4` = 2 or 4 (IEMSCT = 2 or 4) and `L1` = 'T' (DIS = 'T')

```
 DO I8 = 1, J2
     READ(UNIT=I1, IOSTAT=I9)R100,R101,R102,R103,R104
 ENDDO
```

The mapping of inputs to <*rootname*>.tp7 file columns is as follows:

`R100`	FREQ	`R101`	TRANS	`R102`	SOL TR	`R103`	SOLAR
`R104`	Unlabeled						

4.11.5 *How does one read a MODTRAN®5 <rootname>*_b.tp8 *binary output file*?

The structure of the <*rootname*>_b.tp8 binary output files is quite complicated. For these binary files, unlike all the others, it is recommended that one run M5_bn2as to convert the file to ASCII first, and then read the data from the ASCII file. If it is truly necessary to read the binary <*rootname*>_b.tp8 file directly, it is recommended that the user modify the M5_bn2as.f file for this purpose. Any questions regarding details of the M5_bn2as.f source code can be sent to modtran@spectral.com.

5. Geometry

5.1 *Are there figures illustrating the MODTRAN geometry inputs*?

MODTRAN geometry inputs are illustrated in Figures 5.1A and 5.1B. Figure 5.1A contains the CARD3 line-of-sight (LOS) inputs. These inputs all lie within a plane defined by 3 points: the center of the Earth, the sensor (observer), and the final altitude. Two LOS's, with a common observer location and view angle, and with the same final altitude (**H2ALT** = **H2ALT′**) are illustrated; primes (′) are appended to the longer path variable names. Generally, 4 geometry inputs (one being **RAD_E**, the Earth radius) define a slant path (CARD 1 input ITYPE = 2), although only specific combinations are allowed. The full set of MODTRAN line-of-sight inputs are

- **H1ALT** Observer altitude above sea level (km),
- **H2ALT** Path final altitude above sea level (km),
- **OBSZEN** Observer path zenith angle (deg),
- **HRANGE** Refracted path slant range (km),
- **BETA** Earth center angle (deg),
- **LENN** Short (0) vs. long (1) path range switch,
- **RAD_E** Earth radius (km), and
- **BCKZEN** **H2ALT** to **H1ALT** zenith angle (deg).

As Figure 5.1A illustrates, ambiguity arises when the observer zenith angle (**OBSZEN**) exceeds 90°, the observer altitude (**H1ALT**) exceeds the final altitude (**H2ALT**) and the LOS does not intersect the Earth; these inputs are consistent with both a short and long path – the long path passes through the tangent height ($H_{TANGENT}$). The input **LENN** selects which of these 2 paths should be used. Note that the same ambiguity arises for the slant path is defined by the input set (**BCKZEN**, **H2ALT**, **H1ALT**) when **BCKZEN** > 90° and **H2ALT** > **H1ALT**; this case also requires specification of input **LENN**.

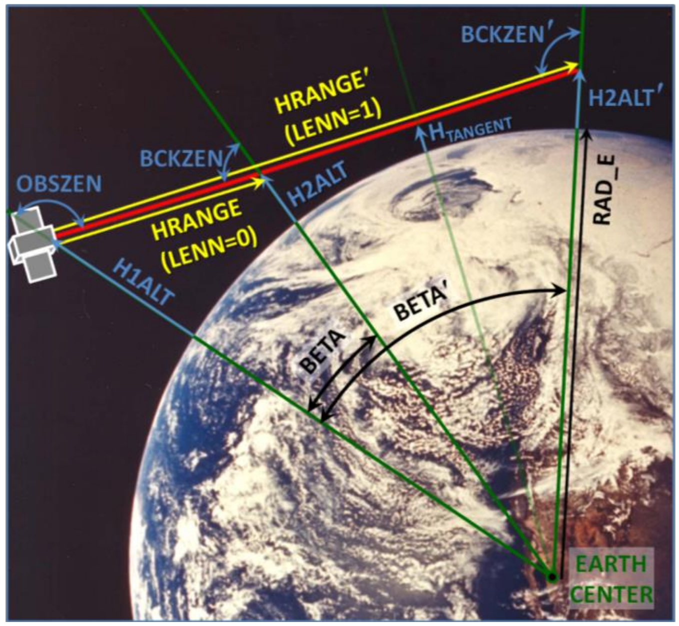

Figure 5.1A. MODTRAN (CARD 3) line-of-sight geometry inputs. When the observer (sensor) zenith angle exceeds 90°, the observer altitude (**H1ALT**) exceeds the final altitude (**H2ALT** = **H2ALT′**), and the path does not intersect the Earth, both a shorter (**LENN** = 0) and a longer (**LENN**=1) path are possible. Input **LENN** distinguishes these two possibilities.

MODTRAN also includes an option to have the line-of-sight specified as a path to space or ground (CARD 1 input ITYPE = 3). For these paths, there are only 3 input options: (**H1ALT**, **OBSZEN**), (**H1ALT**, **H2ALT**) and (**H2ALT**, **BCKZEN**). It is important to remember that when the (**H1ALT**, **H2ALT**) option is used, the input **H2ALT** defines tangent height ($H_{TANGENT}$), not a final path altitude, and that **H1ALT** must exceed **H2ALT**. Also, note that input **RAD_E** is used if provided; otherwise, a default value is selected based on the chosen model atmosphere (CARD 1 input MODEL).

A second set of MODTRAN geometry inputs (CARDs 3A1 and 3A2) defines the solar (or lunar) geometry as illustrated in Figure 5.1B. The direction of incident radiation is specified from the perspective of either the sensor (CARD 3A1 input IPARM equal 0, 1, or 2) or the path end point (IPARM equal 10, 11 or 12). Whichever frame of reference is used, the solar direction is ultimately defined in terms of solar zenith and relative solar azimuth angles. The solar zenith angle is the angle between the vertical at the reference point and the refracted path solar direction (yellow ray) at that point. The relative azimuth is the angle between two vertical planes at the reference point, one containing the line-of-sight (green ray in left image; red ray in right image) and the second containing the solar path.

If the two solar angles are not entered directly via IPARM equal 2 or 12, the required inputs are the latitude and longitude of the reference point along with **TRUEAZ**, the true path azimuth (degrees East of North) at the reference point. In addition, the absolute angular location of the sun from the Earth's perspective must be determined either by directly entering the solar latitude and longitude (IPARM equal 0 or 10) or from temporal data by specifying the day of year (CARD 3A1 input IDAY) and Greenwich Mean Time (CARD 3A2 input GMTIME). For all cases, the Earth to Sun distance is determined from the day of year (IDAY).

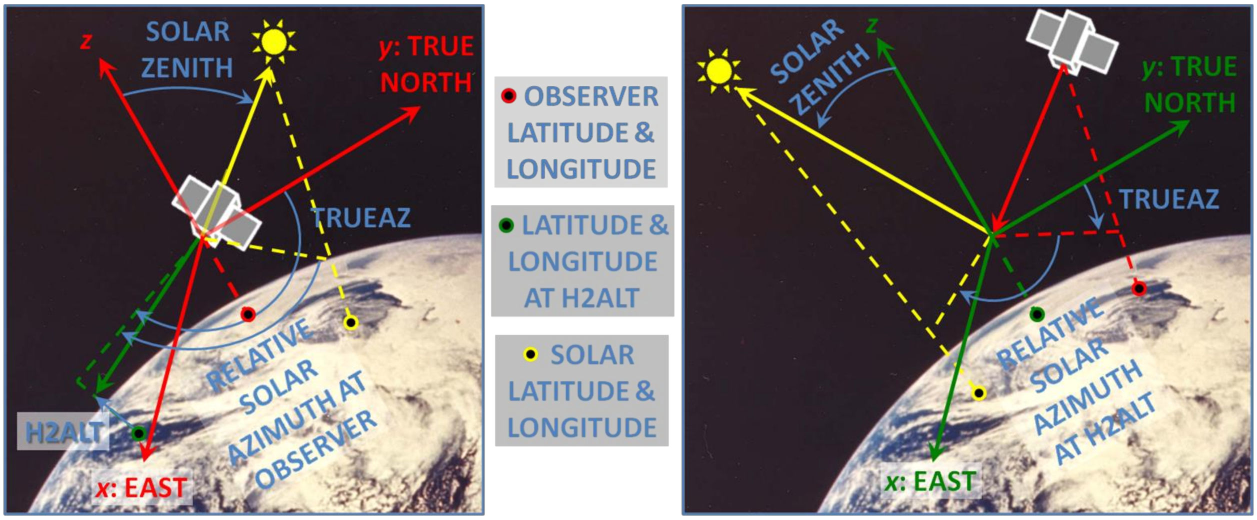

Figure 5.1B. Illustration of Observer (left) and Final Altitude (right) Based MODTRAN Solar Geometry Inputs.

5.2 *What are the limitations of MODTRAN®5's atmospheric refraction algorithm*?

MODTRAN lines-of-sight are defined based on a spherical refractive geometry model. The refractive geometry calculations are performed at a single spectral frequency. More precisely, a single frequency is used to define the index of refraction profile which is input to the refractive geometry model. By default, this frequency is chosen to be the mid-point wavenumber value of the spectral range defined by CARD 4 inputs V1 and V2. However, the user can override the default frequency used to define the refractive index profile by setting CARD 4 input VRFRAC. For most scenarios, the refractive geometry model works well. However, if a user-defined atmosphere is specified which has an excessively large temperature or relative humidity vertical gradient, then an upward directed path can be predicted to bend downward, a phenomenon known as super refraction. MODTRAN is unable to handle this type of refraction, and if it occurs MODTRAN will terminate with an appropriate error message.

6. Specialized Applications

6.1 *Can MODTRAN®5 be used for modeling laser wavelength transmittances*?

Generally, the answer to this question is no. At its finest spectral resolution, MODTRAN can generate 0.1 cm^{-1} spectral bin transmittances. For laser applications, the transmittance at a specific spectral frequency is required. For ground to ground scenarios, it has been argued that MODTRAN's spectral resolution should be sufficient because of the line pressure broadening at the surface. A typical Lorentz line width at 1 Atm pressure (Half-Width at Half Maximum) is ~0.06 cm^{-1}. Thus, the optical depth of a single, off-centered line in a 0.1 cm^{-1} interval will drop by more than half from its peak value. Using a spectral bin averaged transmittance is quite inaccurate. However, if your interval extinction is dominated by continuum sources, such as aerosol extinction, then the MODTRAN bin averaged values may be sufficiently accurate.

6.2 *Does MODTRAN®5 atmospherically correct hyperspectral and/or multispectral imagery*?

If DISORT solar multiple scattering is used (CARD 1 input IEMSCT = 1, 2 or 4; CARD 1 input IMULT = ±1 and CARD 1A input DIS = ′T′) with a downward viewing line-of-sight, and if CARD 1A input DISALB is set to ′T′, MODTRAN will generate an atmospheric correction data (<*rootname*>.acd) output file. This file contains the spectral spherical albedo and both solar and line-of-sight path diffuse and direct transmittance data required for mapping observed radiances into ground reflectances. However, MODTRAN itself does not process radiance imagery to generate surface reflectance maps. A number of software products are available for atmospherically correcting hyperspectral and/or multispectral imagery, most of which rely on MODTRAN radiative transfer to perform the radiance to reflectance mapping. In particular, we recommend the atmospheric correction code FLAASH, developed by Spectral Sciences, Inc. and distributed as an add-on to the ITT ENVI Geospatial Software. For more information, see http://www.ittvis.com/portals/0/pdfs/envi/Flaash_Module.pdf.