

A New MODTRAN® Integration Method for SMART and SMARTI

Vincent Ross, M.Sc.
Aerex Avionics Inc.

Prepared By:
Aerex Avionics Inc., 324 St-Augustin, Beakeyville (Québec), Canada, GOS 1E1
Contractor's Document Number: AEREX Report 2013-125216-AT3-001
PWGSC Contract Number: W7701-125216
Technical Authority: Denis Dion, Defence Scientist

Disclaimer: The scientific or technical validity of this Contract Report is entirely the responsibility of the Contractor and the contents do not necessarily have the approval or endorsement of the Department of National Defence of Canada.

Contract Report
DRDC-RDDC-2016-C273
December 2013

- © Her Majesty the Queen in Right of Canada, as represented by the Minister of National Defence, 2016.
- © Sa Majesté la Reine (en droit du Canada), telle que représentée par le ministre de la Défense nationale, 2016.



324, Saint-Augustin Avenue, Breakeyville (Québec), Canada, G0S 1E1
Phone: (418) 832-1040, Fax: (418) 832-9831, E-mail: info@aerex.ca

AEREX Report No: 2013-125216-AT3-001

A New MODTRAN® Integration Method for SMART and SMARTI

CONTRACT LETTER REPORT

delivered to

Dion Denis
DRDC, Valcartier Research Center
2459, De la Bravoure Road
Québec (Québec)
Canada, G3J 1X5

in the framework of contract
W7701-125216/001/QCL

authored by :
Vincent Ross, M.Sc.

The scientific or technical validity of this Contract Report is entirely the responsibility of the Contractor and the contents do not necessarily have the approval or endorsement of the Department of National Defence of Canada.

This document was reviewed for Controlled Goods by DRDC Valcartier

December 2013

This page intentionally left blank.

© Sa majesté la reine du Canada, représentée par le ministre de la Défense nationale, 2015

© Her Majesty the Queen, as represented by the Minister of National Defence, 2015

A New MODTRAN® Integration Method for SMART and SMARTI

[Subject]

AEREX Report No: 2013-125216-AT3-001

Version: 1.0

This document was reviewed for Controlled Goods by AEREX Avionics Inc. using the Guide to Canada's Export Controls.

The scientific or technical validity of this Contract Report is entirely the responsibility of the contractor and the contents do not necessarily have the approval or endorsement of the Department of National Defence of Canada.

L'entrepreneur est entièrement responsable de la validité scientifique ou technique de ce rapport de contrat et le contenu de ce rapport n'est pas nécessairement approuvé ni entériné par le ministère de la défense du Canada.

Principal author: (Original signed by) December 2013
Vincent Ross, M.Sc. (date)
Physicist

Publication reviewed by: (Original signed by) December 2013
Paul Lacasse, ing. MBA (date)
Senior Project Manager

Publication approved by: (Original signed by) December 2013
Daniel Pomerleau, Eng. (date)
President, AEREX Inc.

This page intentionally left blank.

Background

The radiative transfer codes SMART (Suite for Multi-resolution Atmospheric Radiative Transfer) and SMARTI (SMART Interface) rely on MODTRAN[®][1] for the parameters required to describe the atmosphere optically. These parameters have an altitude dependence (but are constant within a layer of the atmosphere) and a spectral dependence. These include among others:

- The total extinction coefficients expressed in terms of Correlated-Ks;
- The molecular scattering coefficients;
- The aerosol extinction coefficients;
- The aerosol scattering coefficients;
- The scattering coefficients of different types of clouds (water, ice and cirrus);
- The scattering coefficients of rain; and
- The Legendre phase function expansion coefficients

These quantities are all intermediate variables used within the MODTRAN program, but these are not normally made available to the user through output files. To remedy this, earlier versions of SMART and SMARTI would run the MODTRAN process as a debugger (MODTRAN being the debuggee). This would let SMART and SMARTI access the internal memory of MODTRAN, and thus be able to extract all the necessary quantities required for atmospheric propagation calculations.

This method had the major benefit that an original and unmodified version of a MODTRAN executable could be used directly. The user of SMART(I) did not have the burden to modify MODTRAN correctly in order to output these quantities, which facilitated the use SMART(I) considerably.

The major drawback of the method was that only the official (precompiled) executable of a single version of MODTRAN (MODTRAN 4 version 3 release 1) could be used. This is because even the slightest change in the MODTRAN executable (by as little as one single bit) would change the mapping in memory of the information used by MODTRAN. This memory mapping is hardcoded in SMART(I) and is thus only good for a fixed executable version. Any recompilation of the MODTRAN source code with a different compiler or different compilation options would break the MODTRAN integration in SMART(I). Furthermore, as newer versions of MODTRAN were released, MODTRAN 4 version 3 release 1 became harder to obtain, while SMART(I) was unable to benefit from the updates (updated band model databases for example).

A new MODTRAN integration method

In order to resolve this issue, a new method of integrating any version of MODTRAN 4 or 5 with SMART(I) was devised. Although this method requires more involvement on the part of the SMART(I) user, it is still relatively straightforward.

Upon receiving new releases of the EOSPEC library (of which SMART(I) is part), the users will also receive a script called “smart_MODTRAN_patch.bat” that relies on a C++ program called smartModer. In order to use this script, the user must possess an original (unmodified) MODTRAN source code for any version of MODTRAN 4 or 5. Note that MODTRAN is usually distributed along with its source code.

The MODTRAN source code directory location is provided to the script as input. The script then copies the entire MODTRAN source code to a temporary location, modifies the appropriate source files, and if the Intel Fortran compiler is located on the system, goes on to compile the modified MODTRAN source to produce a MODTRAN executable that is compatible with SMART(I). In order to be compatible with SMART(I) the executable creates a new output file with the .smt extension along with the other MODTRAN output files. To speed the calculations of SMART(I), significant portions of the computations in the modified version of MODTRAN are bypassed. Because of this, the modified version of MODTRAN is not adequate for use in other applications.

In order to modify the MODTRAN source code, the script attempts to locate patterns of text within the source files, and use the appropriate variable names and types to insert proper code at specific location. As MODTRAN has evolved through multiple versions and releases, the code has changed somewhat, so it is a challenge to support every possible version. The current script has been tested and should work correctly on at least the following versions of MODTRAN:

- A) MODTRAN 4 version 1 release 1 (released April 2000);
- B) MODTRAN 4 version 3 release 1 (released May 2003);
- C) MODTRAN 5 version 2 release 3 (released May 2004);
- D) MODTRAN 5 version 2 release 4 (released August 2004);
- E) MODTRAN 5 version 3 release 3 (released January 2005);
- F) MODTRAN 5 version 2 release 14 (aka 5.1b) (released February 2008);
- G) MODTRAN 5 version 3 release 5 (released February 2008);
- H) MODTRAN 5.3.0.0 (released January 2010);
- I) MODTRAN 5.2.1 (released May 2011); and
- J) MODTRAN 5.3.1.1 beta (released March 2012)

It is assumed that most other versions of MODTRAN 4 or 5 will also be compatible with the script.

In the rare cases where the modified version of MODTRAN should fail to compile, the user can search the modified source directory for the “driver.f” file as well as the “loop.f” file (MODTRAN 4 and early versions of MODTRAN 5) or “d_loop.f” (more recent versions of MODTRAN 5) and locate the modified code segments. Modified code segments are easily recognizable since they are between preprocessor directives like

```
#ifdef SMART_OUTPUT
...
#endif
or
#ifdef SMART_OUTPUT
...
#endif
```

These preprocessor directives also provide a mechanism that allows the modified code to be compiled as an original version of MODTRAN by not defining SMART_OUTPUT for the preprocessor. Any error in the code introduced by the script should be relatively trivial to fix by hand.

Manual Compilation

In the case where the Intel Fortran compiler is not found on the system, the user can compile the source code manually. It is strongly suggested the Intel Fortran compiler be used, as the output file necessary for interfacing with SMART(I) might change format if MODTRAN is compiled with another compiler. In any case, preprocessor definition SMART_OUTPUT must be defined in order for the additional code required by SMART/SMARTI to take effect. Compiling without the SMART_OUTPUT produces an unmodified MODTRAN executable.

Validation

To insure that SMART(I) produces correct results when the modified versions of MODTRAN described above are used, the basic example for the use of SMARTI (source code provided along with SMARTI and EOSPEC) is run with all versions. This example calculates, among other quantities, the band integrated path radiance and average transmittance for a 45 degree ground to space path in the US Standard atmosphere with rural aerosols. Radiance calculations use two-stream DISORT multiple scattering. Both radiance and transmittance are calculated using a triangular sensor filter function on the 3 to 5 micron band at a resolution of 5 cm^{-1} (versions that do not support this band model resolution use 1 cm^{-1}). Radiance and transmittance calculations are also done using the spectral and wideband Correlated-K modes available with SMARTI.

Table 1 shows results for band radiance and transmittance in both spectral and wideband Correlated-K modes of SMARTI using different MODTRAN versions in order to provide optical parameters. MODTRAN versions are referred by the letter designating them in the list above and are in chronological order of release. The reference version is the original memory based version using MODTRAN 4 version 3 release 1. Since different MODTRAN versions use different band model databases and internal algorithms, some variability is expected. It is also expected that when using the reference version of MODTRAN with both memory and file based approaches (bold lines in

Table 1), results should be virtually identical. Here, only the wideband Correlated-K transmittance differs in its last significant digit. This is likely due to round off differences between the two approaches.

Among all file based versions, variability in band radiance between the different versions of MODTRAN tested here is of about plus or minus 1%, while variability in band transmittance is about 0.5%. Note that mean and standard deviation results do not include the reference version. This variability is within expected thresholds so that we are confident of the implementation of the new method for integrating MODTRAN in SMART(I).

Table 1: Band radiance and transmittance in both spectral and wideband Correlated-K modes of SMARTI using different MODTRAN versions in order to provide optical parameters. MODTRAN versions are referred by the letter designating them in the list above. The reference version is the original memory based version.

	Band integrated spectral radiance (W/m ² /sr)	Band averaged spectral transmittance	Wideband CK radiance (W/m ² /sr)	Wideband CK transmittance
Reference	0.261839	0.246021	0.266898	0.242176
A*	0.259714	0.249744	0.265264	0.246464
B	0.261839	0.246021	0.266898	0.242177
C	0.259864	0.246794	0.265022	0.242907
D	0.259864	0.246794	0.265022	0.242907
E	0.258568	0.247841	0.263341	0.243557
F	0.256157	0.248414	0.260315	0.245243
G	0.254214	0.247441	0.259701	0.243010
H	0.254222	0.247418	0.259716	0.242984
I	0.256208	0.248603	0.261249	0.245227
J	0.256207	0.248609	0.261248	0.24523
mean	0.257686	0.247768	0.262778	0.243971
σ	0.002633	0.001101	0.002649	0.001436

* calculated at 1 cm⁻¹ as the 5 cm⁻¹ resolution is not available for this version.

Further Information

For further information on the use of the “smart_MODTRAN_patch.bat” script, please refer to the “readme.txt” file that accompanies its release, or the smarti user guide.

References/Bibliography

- [1] Berk, A., L.S. Bernstein, and D. C. Robertson, “MODTRAN: A Moderate Resolution Model for LOWTRAN7”, Rep. GL-TR-89-0122, *Air-Force Geophysics Lab.*, Bedford, MA, 1989.

Distribution list

AEREX Report No 2013-125216-AT3-001 version 1.0

Internal distribution

Paul Lacasse (AEREX)
Daniel Pomerleau (AEREX)
Denis Dion (DRDC)

Total internal copies: 3

Total copies: 3