Implications and caveats of using MODTRAN-5 for inflight Validation and Calibration

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Outline

1. Introduction
   o Using Modtran for Validation
   o Forward simulation and inversion problems

2. MODO and MODTRAN® 5
   o Changes in MODTRAN -5
   o Using MODO in Imaging Spectroscopy
   o Recent enhancements
   o Open issues in forward simulation

3. ATCOR and MODTRAN® 5
   o Using atmospheric correction for validation purposes
   o Open issues in atmospheric correction

4. Conclusions and Outlook
Use of Modtran in Imaging Spectroscopy

- Atmospheric Gas Retrieval
- Aerosol Retrieval
- Atmospheric correction
- Sensor Design
- Sensitivity Analysis
- Energy Balance Models
- Scene Simulation

and

- Calibration and Validation
At-Sensor Radiance Validation

Modtran built for forward simulation:

Validation done on at-sensor radiance
MODO being a helper to ease this part.
Validation of surface reflectance quantities

Inversion of the radiative transfer code

Validation on HDRF-type reflectances.

(ATCOR being one of the solutions for that part...)
Modtran® 5 - what's new?

- Reformulating the band models for resolutions down to 0.1 cm\(^{-1}\) (from 1 cm\(^{-1}\)), i.e. 0.06 nm instead of 0.6 nm at 2500 nm.
- Solar database updates, including the calibrated Fontenla solar radiation model (provided at 0.1 cm\(^{-1}\) resolution).
- Potential to include any absorbing molecule available in the HITRAN database.
- Increased accuracy and speed of DISORT aerosol scattering algorithms.
- Fine tuning of aerosol scattering function through Angstrom coefficients.
- Side outputs for atmospheric correction purposes (i.e. spherical albedo and diffuse transmittance)
Solar Function VNIR
(Kurusz 1997 vs. Fontenla 2011)

black: FWHM= 0.4 nm
green: FWHM= 2.8 nm
red : FWHM=10.0 nm

$100 \times (K1997 - F2011) / F2011$
Solar Function SWIR

black: FWHM = 0.4 nm
green: FWHM = 2.8 nm
red: FWHM = 10.0 nm

100*(K1997-F2011)/F2011

EUFAR JWG Edinburgh 2011, Daniel Schläpfer, daniel@rese.ch
Transmittance – Modtran5

Difference of Modtran-4 Simulation (2001 Hitran) to Modtran-5 (5nm):

![Graph showing relative deviation of Modtran-4 and Modtran-5 simulations over wavelengths.](image-url)
Radiance – Modtran 5

Difference of Modtran-4 Simulation (2001 Hitran) to Modtran-5 (5nm):

- red: total rad,
- black: path rad
Radiance – Modtran 5

Difference of Modtran-4 Simulation (2001 Hitran) to Modtran-5 (10nm):

red: total rad,
black: path rad
MODO with MODTRAN-5

"MODTRAN Organizer" software

1994: Development started in 1994
1996: First version available
2000: New Foundation 2000 (for Modtran 3)
2004: Release of Version 3 for Modtran 4
       License from AFRL for inclusion of Modtran 4
2011: Update to Version 4 for Modtran4 and in parallel Version 5
       for Modtran5

Designed with Imaging spectroscopy data validation and sensitivity analysis in mind.
Sensor Simulation

Remote Sensing Specialists approach:

- Hide unnecessary Modtran options
- Use SI units common to remote sensing (i.e. $W/(m^2 \text{ sr} \text{ nm})$)
- Include common sensor systems and characteristics
- Extract the total radiance
- Feed ground characteristics from external sources
Forward-Simulation Summary

Pro's:
- Full control of all MODTRAN Parameters
- "Only" calibrated imagery required (no preprocessing)
- Single spectrum processing feasible

Con's:
- Adjacency difficult to model
- Meteorological data input required
- Processing on single spectra (difficult statistics)
SACO – Simple Atmospheric Correction

Uses the *.acd output of Modtran® 5 directly for an atmospheric correction.

Restrictions:
• No angular dependencies
• No terrain correction
• One set of parameters per spectral band

Advantages:
• Very fast processing.
• Baseline atmospheric correction for evaluation of atmospheric correction developments and fast validation purposes.
SACO Calculation

\[ \rho = \frac{\rho^*}{\tau_{tot} + \tau_{dif} + \rho^* \cdot s} \]

Surface ‘reflectance’ (directional)
(bottom of atmosphere reflectance)

\[ \rho^* = \frac{\left[ \left( \text{DN} \cdot c_1 + c_0 \right) - L_{path} \right] \pi d^2}{E_0 \cos \theta} \]

Apparent at-sensor reflectance

\[ L_{path} = L_{atm,0} + \frac{\tau_{dif,d} \cdot E_0 \cos \theta \cdot \tau_{dir,u} \rho}{\pi d^2 \left( 1 - \bar{\rho} s \right)} \]

Total path radiance
## ATCOR - SACO

<table>
<thead>
<tr>
<th>ATCOR</th>
<th>SACO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fully automatic inputs</td>
<td>User-defined inputs</td>
</tr>
<tr>
<td>6-D look-up Table</td>
<td>1 Parameter set per scene</td>
</tr>
<tr>
<td>Terrain, viewing angle</td>
<td>Nadir conditions only</td>
</tr>
<tr>
<td>30’ for 1000x3000x160 bands</td>
<td>15x faster</td>
</tr>
<tr>
<td>Processing chain component</td>
<td>Simple scientific test tool</td>
</tr>
<tr>
<td>Validated and broadly used</td>
<td>Non-validated</td>
</tr>
<tr>
<td>Side outputs (aerosol, water vapor, emissivity, …)</td>
<td>No side outputs.</td>
</tr>
</tbody>
</table>
Hyspex Atmospheric Correction
SACO-Results

HYSPEX Imaging Spectrometer Processing

Black: ATCOR 4 Output
Brown: SACO Output
(both unfiltered, single pixels)
Inversion Simulation Summary

Pro's
- Validation on full imagery
- Atmospheric parameters from imagery
- Consistency check between variety of spectra
- Full inclusion of adjacency effects

Con's
- No BRDF correction
- Limited atmospheric LUTs
- Differences between methods
Conclusions

• Significant differences between MODTRAN-5 and MODTRAN-4

• Reliable forward simulation is feasible through MODO/ MODTRAN-5 also for high resolution instruments.

• Validation of imaging spectroscopy data shall be done on both radiance level or reflectance level depending on validation question.

• Simple atmospheric inversion is suitable to get a first impression about data quality (but not for operational atmospheric correction)
Thanks!

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