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

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Outline

1. Introduction
   - Using Modtran for Validation
   - Forward simulation and inversion problems
2. MODO and MODTRAN® 5
   - Changes in MODTRAN -5
   - Using MODO in Imaging Spectroscopy
   - Recent enhancements
   - Open issues in forward simulation
3. ATCOR and MODTRAN® 5
   - Using atmospheric correction for validation purposes
   - Open issues in atmospheric correction
4. Conclusions and Outlook

Use of Modtran in Imaging Spectroscopy

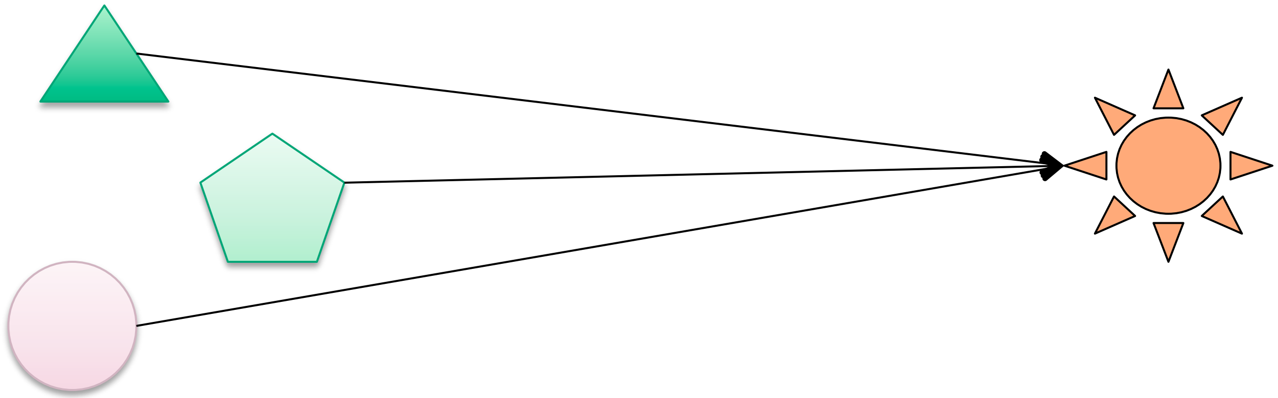
- Atmospheric Gas Retrieval
- Aerosol Retrieval
- Atmospheric correction
- Sensor Design
- Sensitivity Analysis
- Energy Balance Models
- Scene Simulation

and

- **Calibration and Validation**

At-Sensor Radiance Validation

Modtran built for forward simulation:

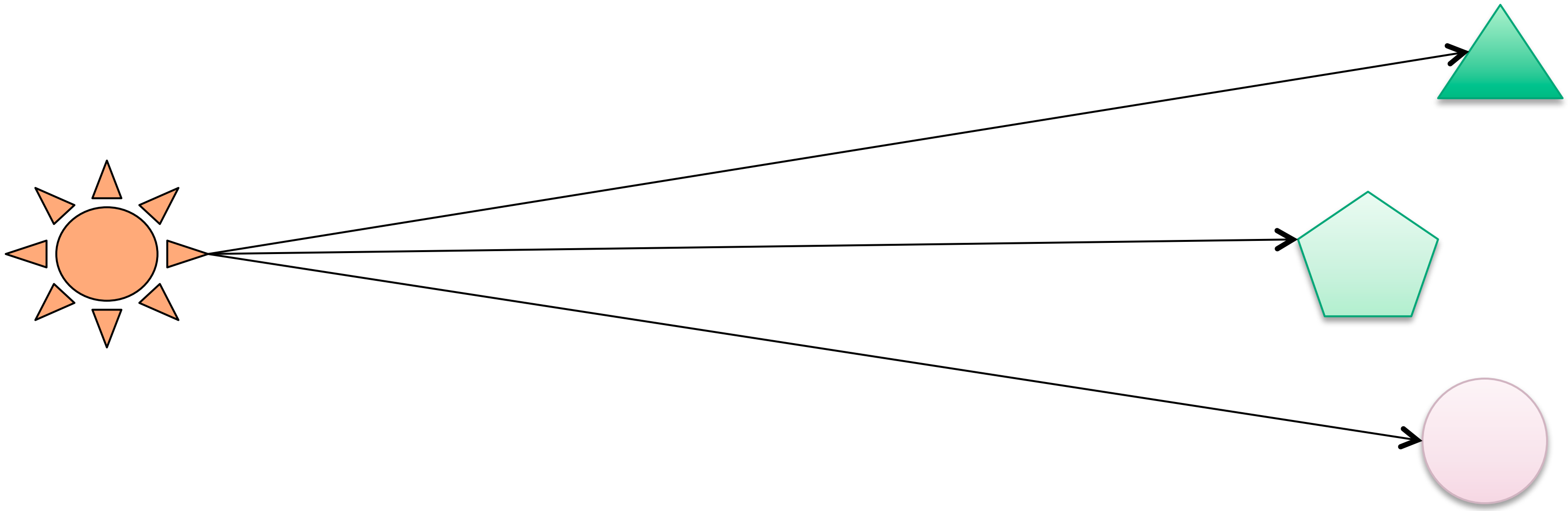


Validation done on at-sensor radiance

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...)

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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 dabase updates, including the calibrated Fontenla solar radiation model (provided at 0.1 cm^{-1} resolution).
- Using recompiled HITRAN-2008 database of molecular absorption.
- Potential to include any absorbing molecule available in the HITRAN datase.
- 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)

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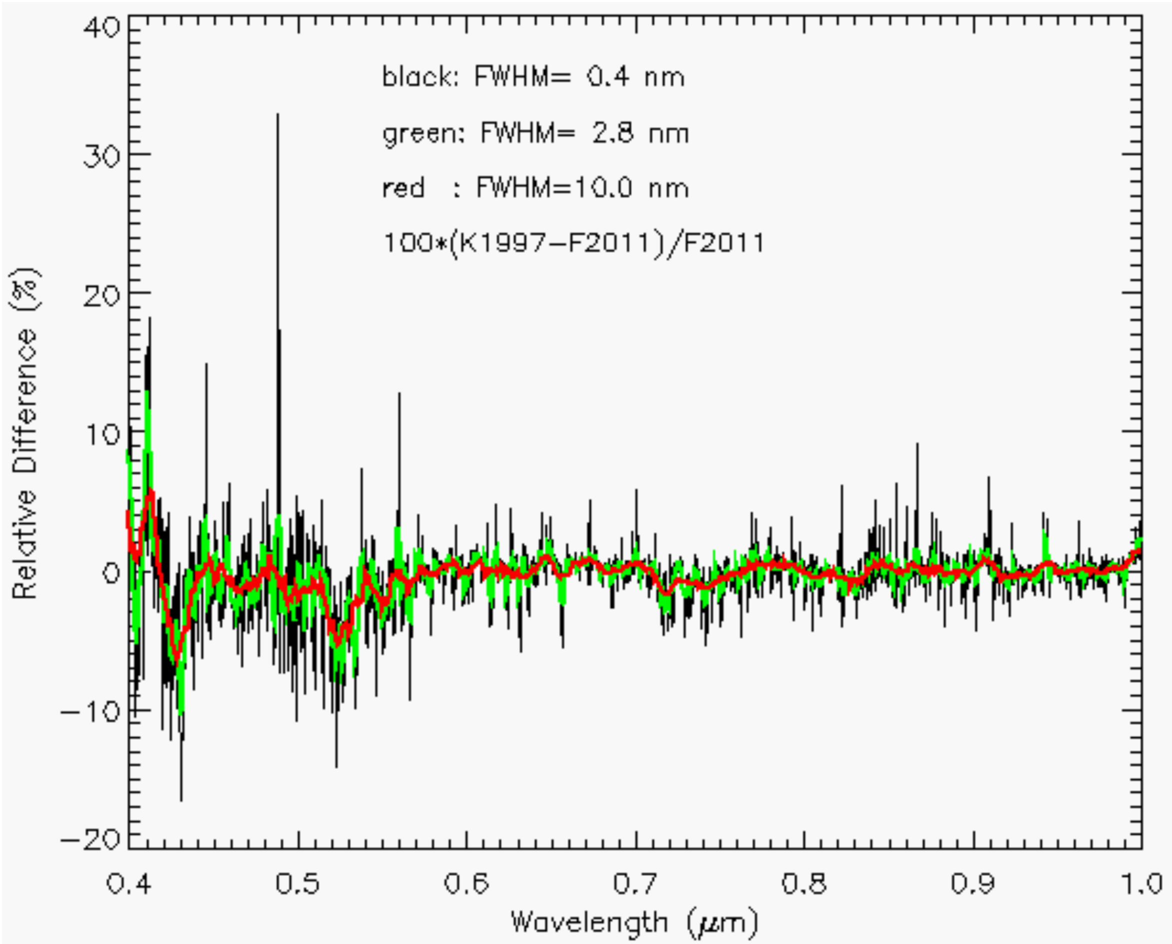
Solar Function VNIR
(Kurusz 1997 vs. Fontenla 2011)



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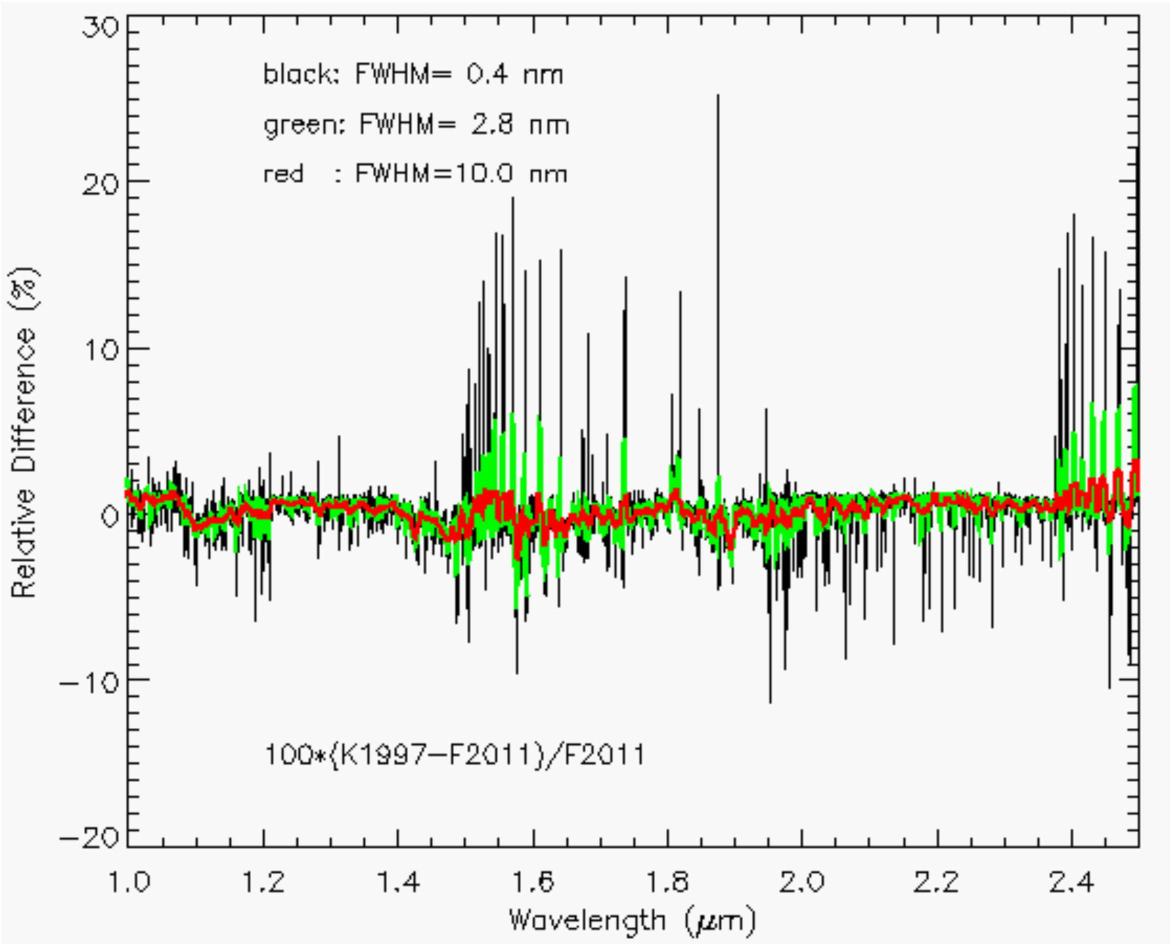
Solar Function SWIR



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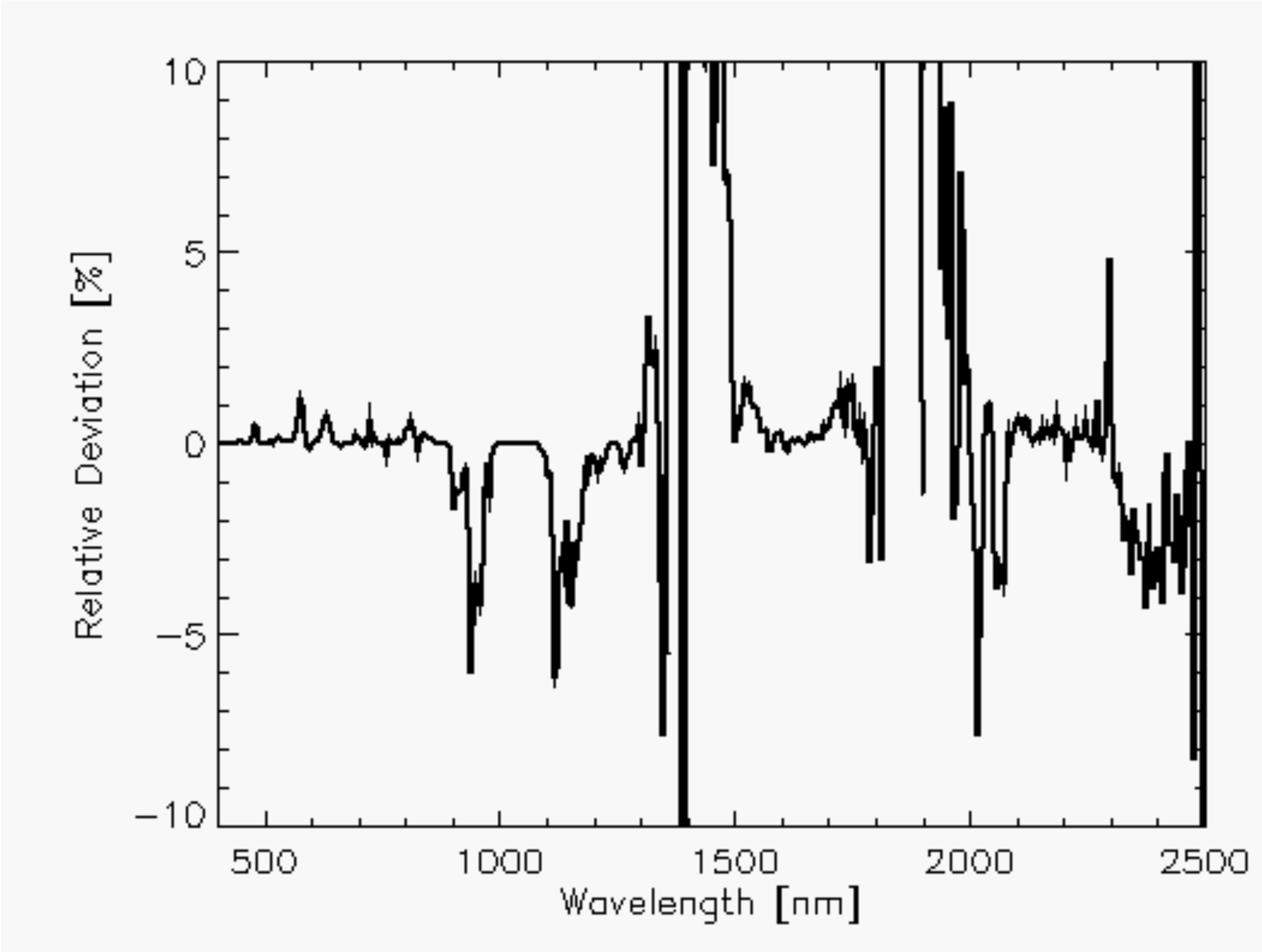
Transmittance – Modtran5

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



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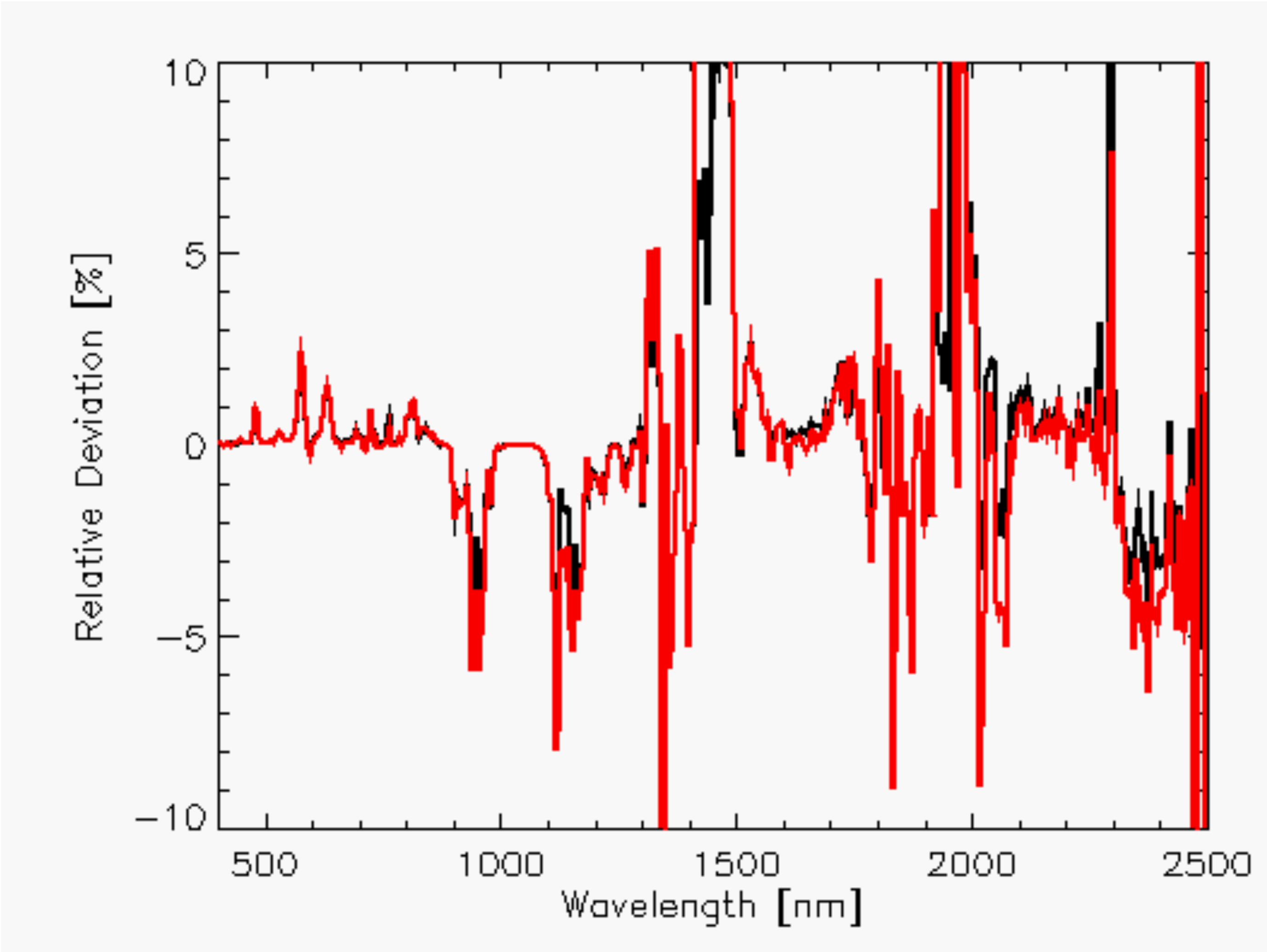
Radiance – Modtran 5

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



red: total rad,

black: path rad

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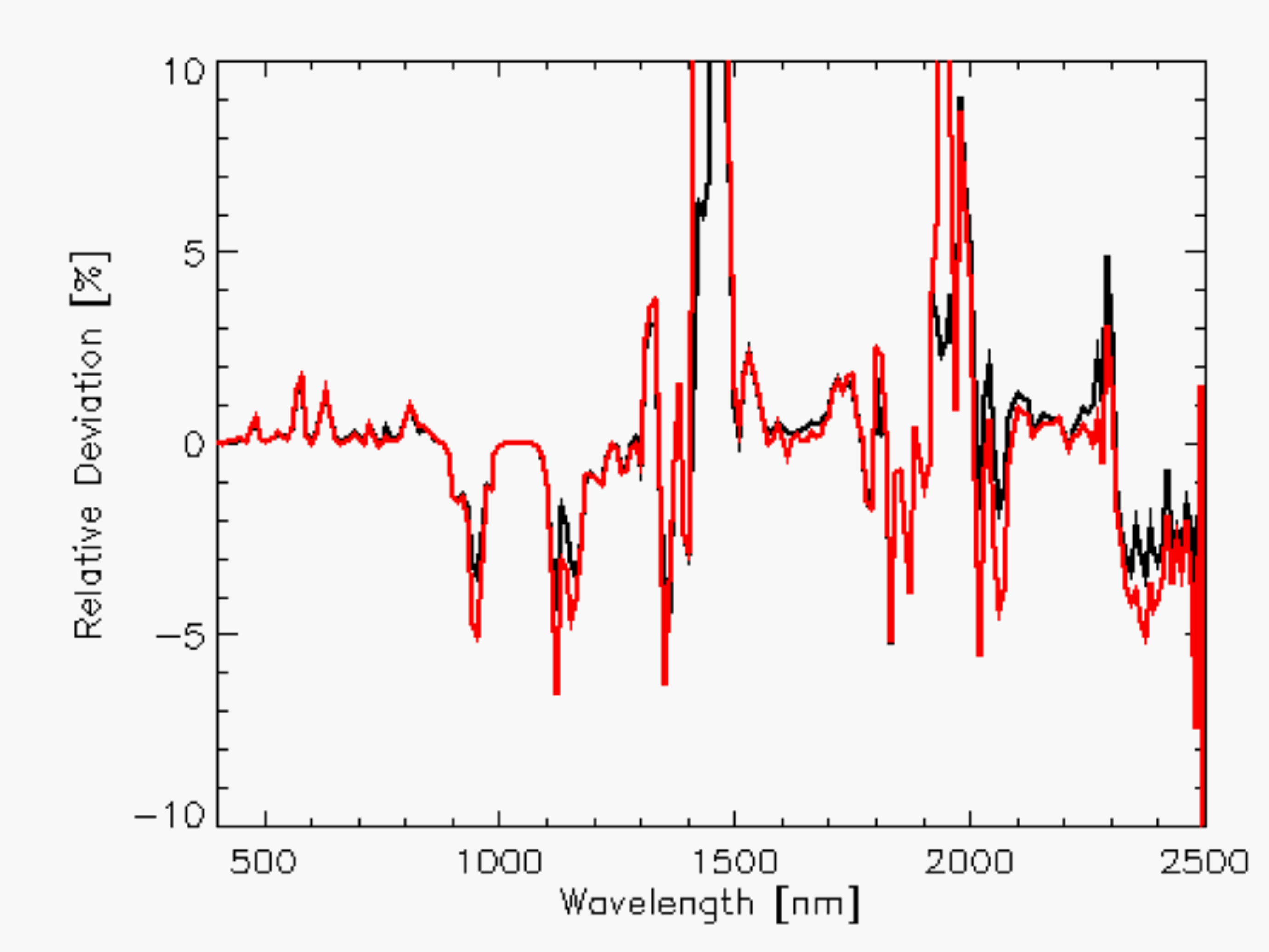
Radiance – Modtran 5

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



red: total rad,

black: path rad

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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.

MM 0 2

FF 8F 5 3

1 0

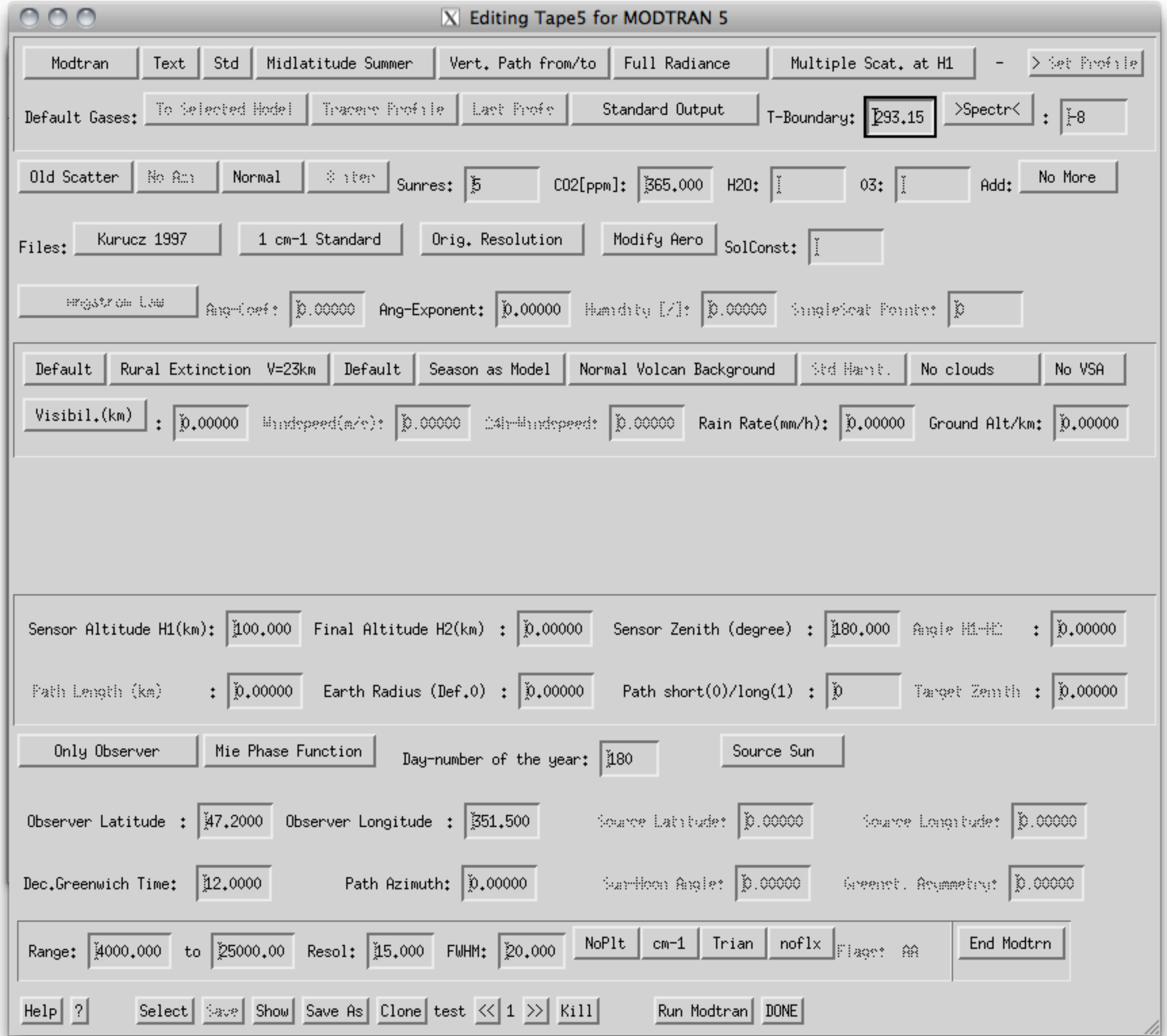
100.000

1 2

47.200

4000.0

0



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Sensor Simulation

Remote Sensing Specialists approach:

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

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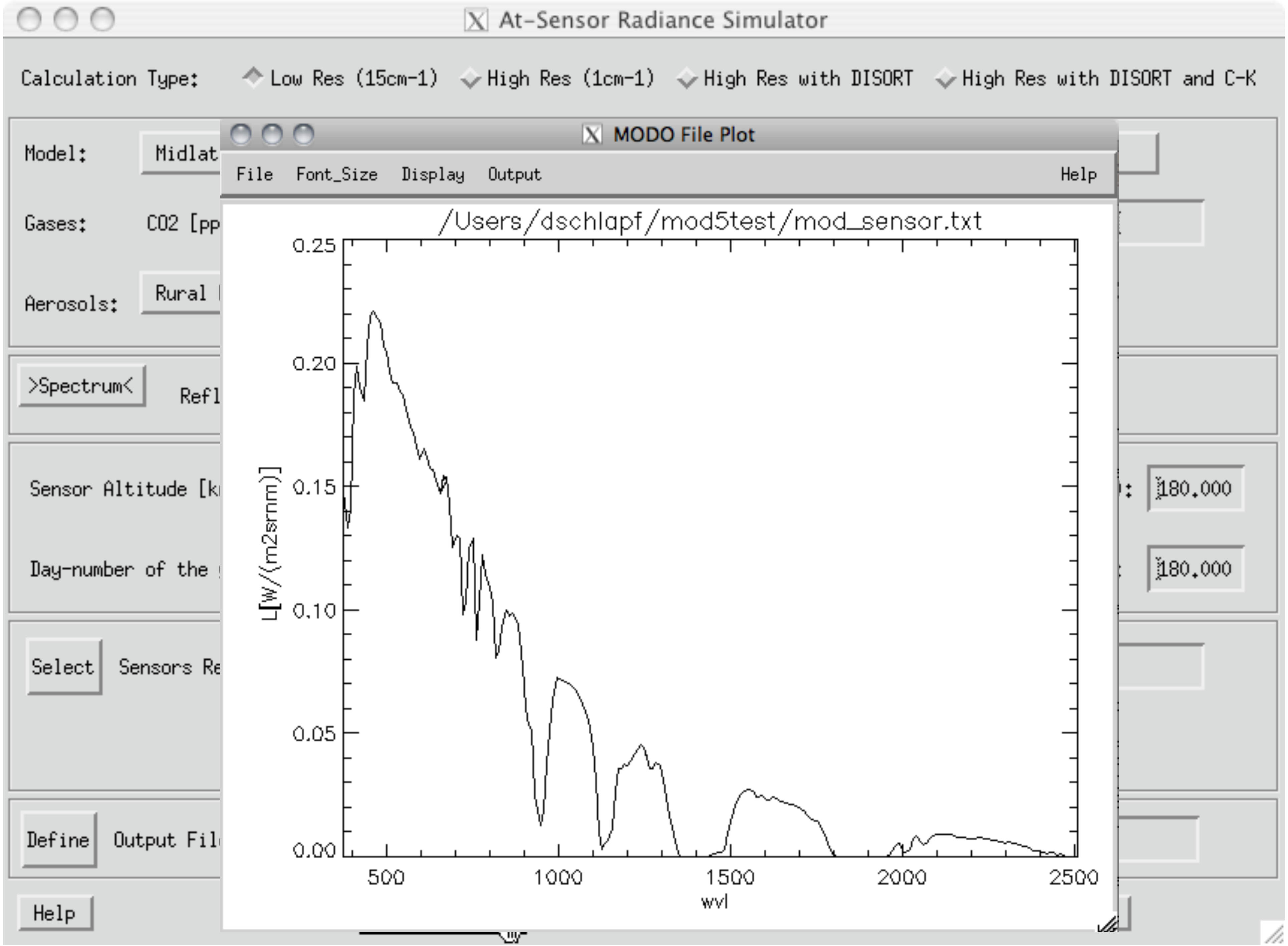
At-Sensor Radiance Simulator
Calculation Type:
Low Res (15cm-1)
High Res (1cm-1)
High Res with DISORT
High Res with DISORT and C-K
Model:
Midlat
Gases:
CO2 [pp
Aerosols:
Rural
>Spectrum<
Refl
Sensor Altitude [k
180.000
Day-number of the
180.000
Select
Sensors Re
Define
Output Fil
Help
MODO File Plot
File
Font_Size
Display
Output
Help
/Users/dschlapf/mod5test/mod_sensor.txt
L[W/(m2srnm)]
0.00
0.05
0.10
0.15
0.20
0.25
500
1000
1500
2000
2500
wvl

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)

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SACO – Simple Atmospheric Correction

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

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SACO Calculation

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

Surface 'reflectance' (directional)

(bottom of atmosphere reflectance)

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

Apparent at-sensor reflectance

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

Total path radiance

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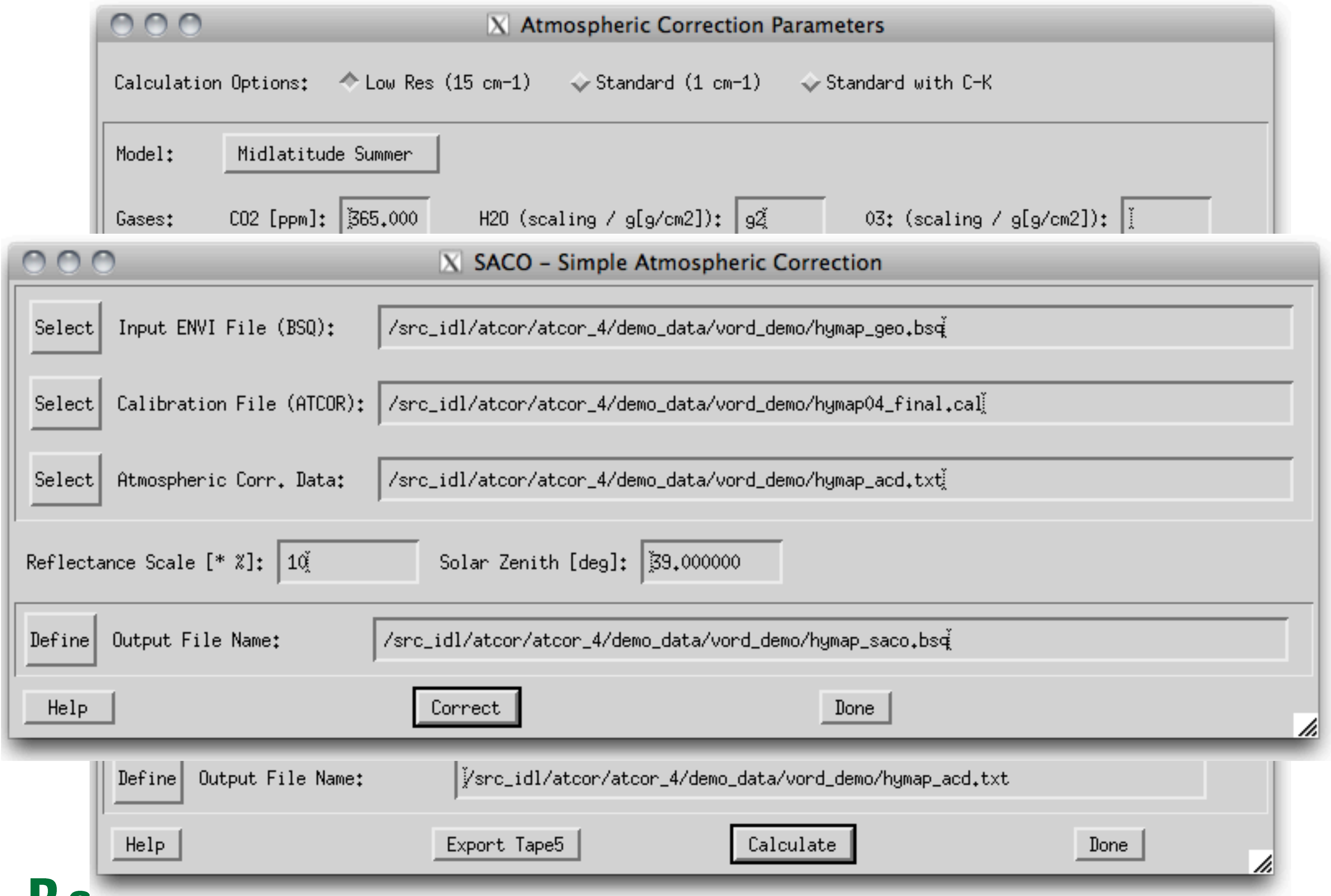

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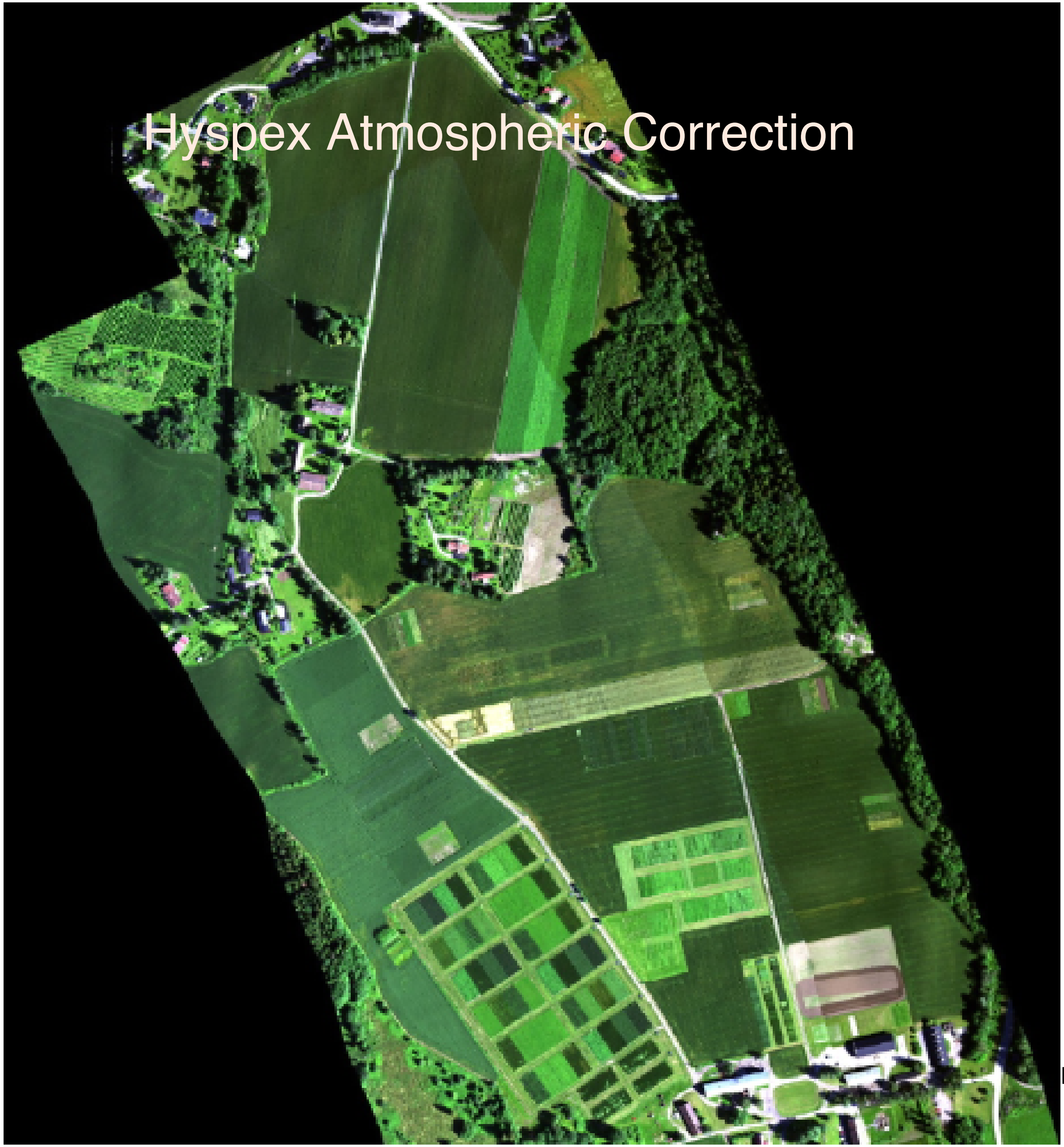
ATCOR - SACO

ATCOR	SACO
Fully automatic inputs	User-defined inputs
6-D look-up Table	1 Parameter set per scene
Terrain, viewing angle	Nadir conditions only
30' for 1000x3000x160 bands	15x faster
Processing chain component	Simple scientific test tool
Validated and broadly used	Non-validated
Side outputs (aerosol, water vapor, emissivity, …)	No side outputs.

Hyspex Atmospheric Correction



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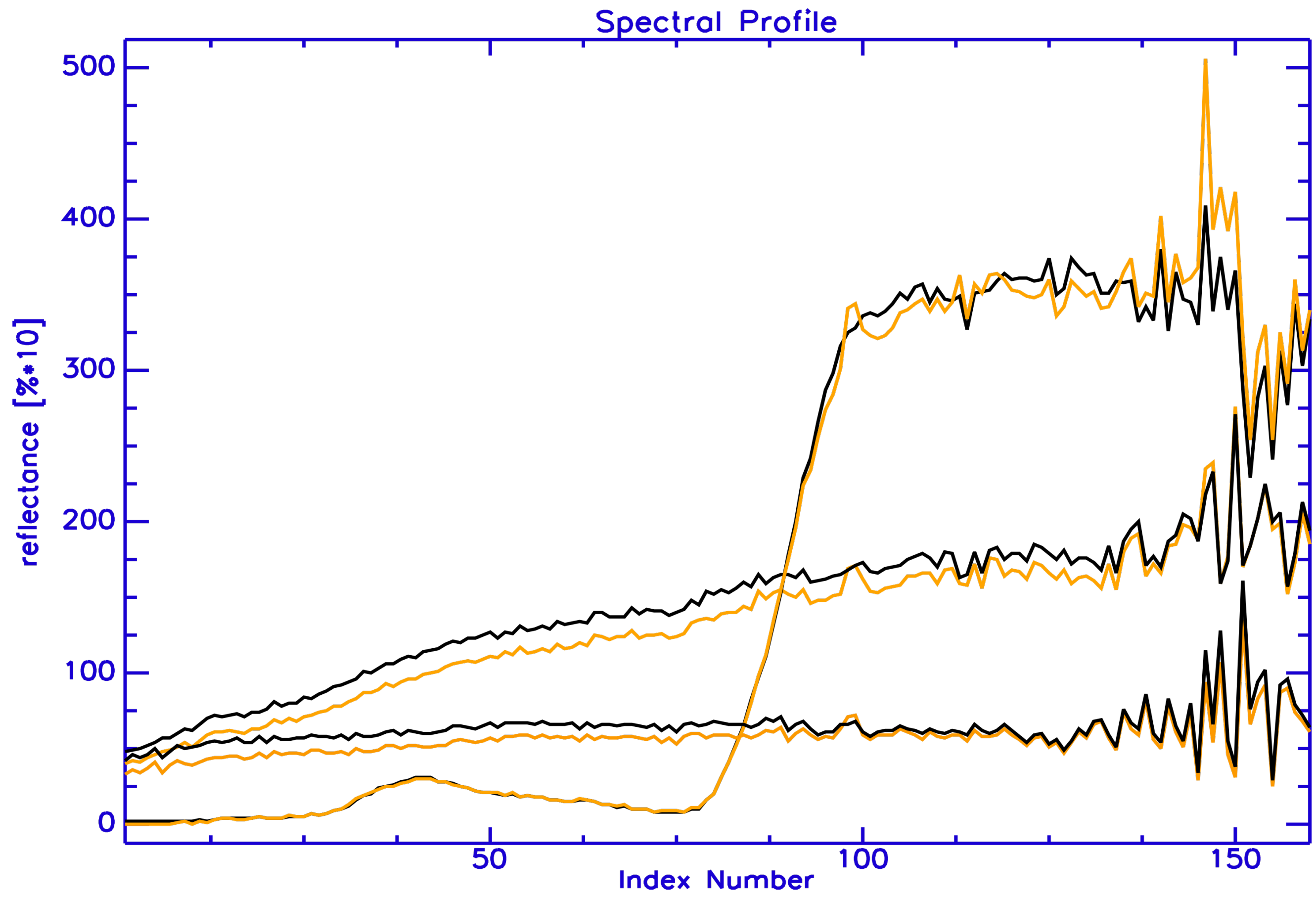
SACO-Results



HYSPEX Imaging Spectrometer Processing

Black: ATCOR 4 Output
Brown: SACO Output

(both unfiltered, single pixels)

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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

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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 spectrosopy 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)

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Thanks!

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