Advances in Remote Sensing Data Processing Using the Modtran®5-Enhanced MODO and ATCOR Software

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Outline

1. Introduction
   - Using Modtran for Remote Sensing
   - Forward simulation and inversion problems
2. MODO and MODTRAN® 5
   - Using MODO in Imaging Spectroscopy
   - Recent enhancements
   - Open issues in forward simulation
3. ATCOR and MODTRAN® 5
   - Overview of the ATCOR code family
   - Aspects of atmospheric correction
   - Open issues in atmospheric correction
4. Conclusions and Outlook

Remote Sensing Related Use of Modtran®

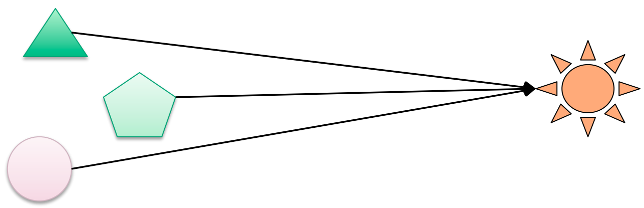
- Atmospheric Gas Retrieval
- Aerosol Retrieval
- Atmospheric correction
- Sensor Design
- Sensitivity Analysis
- Energy Balance Models
- Scene Simulation

and many more…

… how to design add-ons to MODTRAN for Remote Sensing?

Forward Simulation?

Modtran built for forward simulation:



MODO being a helper to ease this part.

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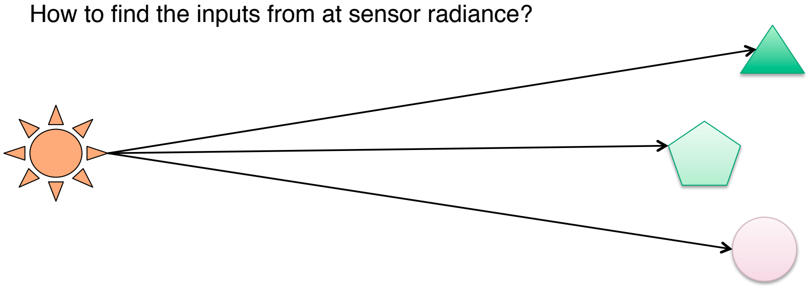
Inversion?

How to find the inputs from at sensor radiance?



ATCOR being one of the solutions for that part...

MODO

'Modtran Organizer'

MODO - Goals

GOAL:

Create a tool for scientists to ease the use of MODTRAN for remote sensing.

i.e.:

- Translate the original tape5's,
- Create a bridge to remote sensing sensors,
- Support typical research tasks such as at-sensor radiance simulation and sensitivity analyses,
- Provide an open, programmable system.

MODO - Development

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
2010:	Update to Version 4 for Modtran4 and in parallel Version 5 for Modtran5
soon:	Release of the new versions including Modtran5

(Beta versions are available upon request,
but without Modtran 5 components)

Dealing with Tape5's

'Scientific Approach':

- Don't hide the tape5's given structure.
- Show as many options as possible
- Allow to use the original Modtran documentation manual efficiently
- Support import/export for batch processing
- Read/support all possible options (but not all are editable by GUI)

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FF 8F 5 3

1 0

100.000

1 2

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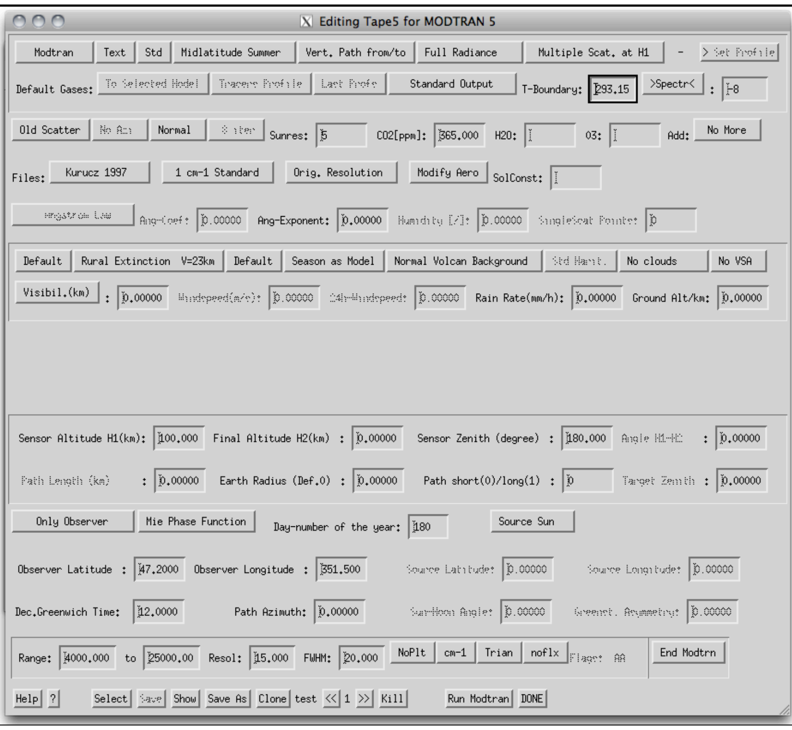
0



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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
- Bridge to ENVI spectral libraries

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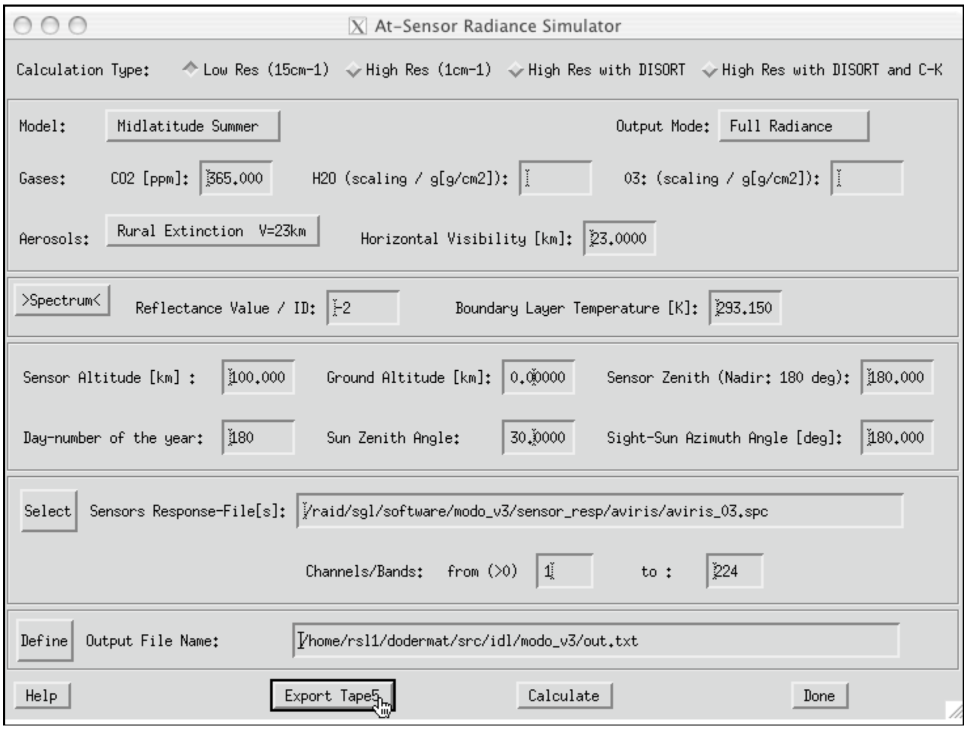
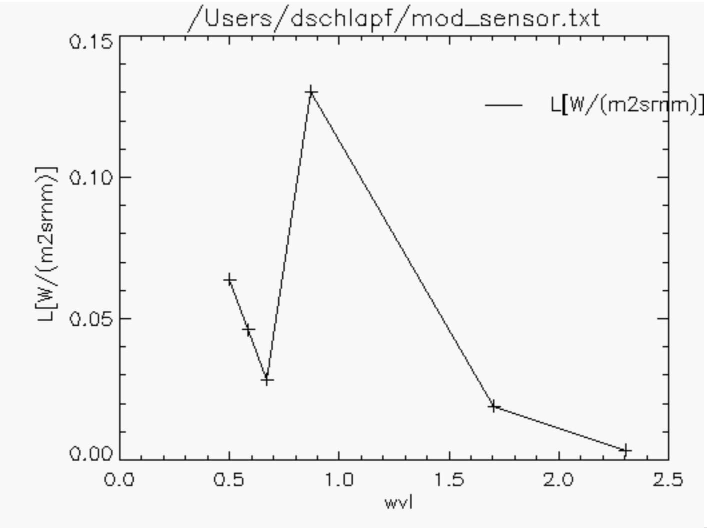


Result

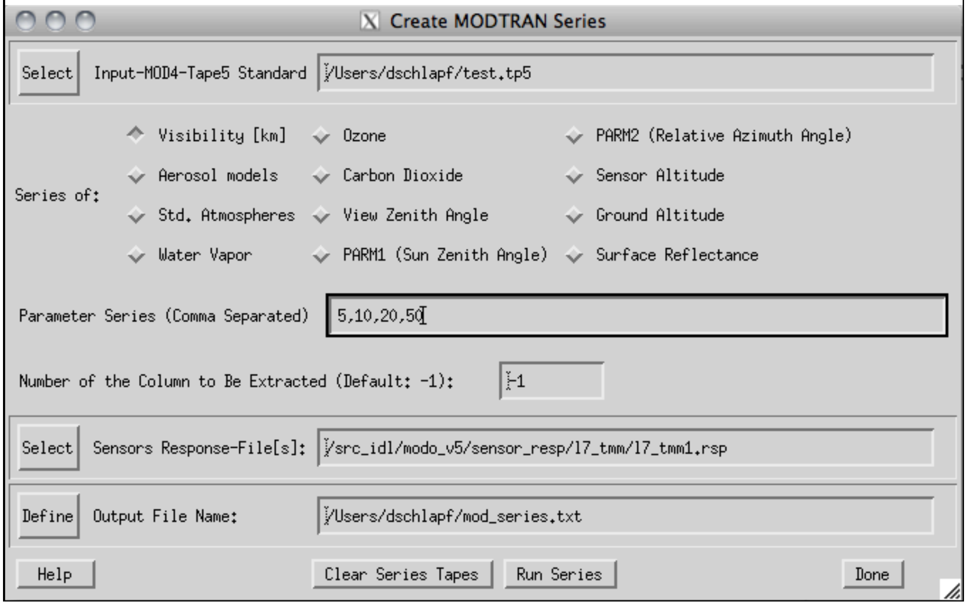


Sensitivity Analyses

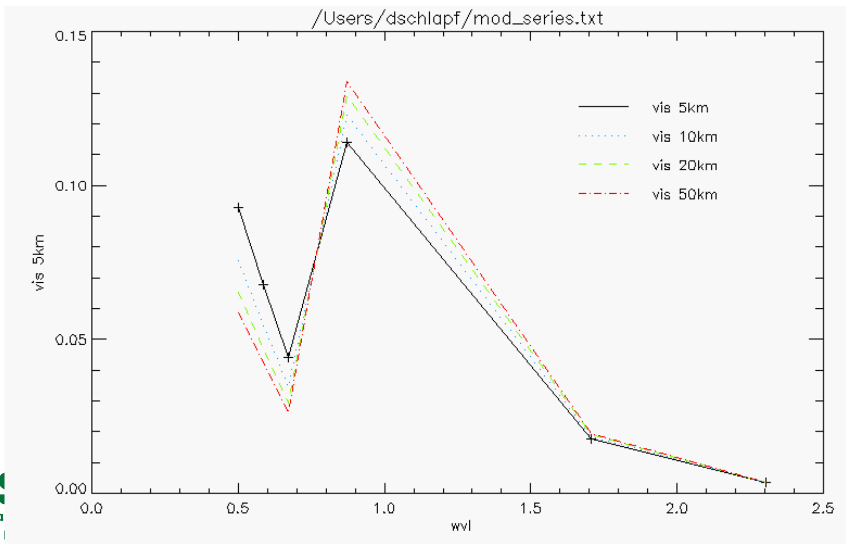
What for:

- Evaluate the discernability of spectral ground reflectance features after atmospheric 'distortions'
- Show the range of impact of various atmospheric parameters
- Search for methods for atmospheric parameter retrieval
- Sensor design question (radiometric range and SNR requirements)

Sensitivity Analysis



Result



Introducing Modtran® 5 in MODO

- Extended internal data structure (naming consistent with Modtran manual)
- Added generic spectral shift analysis tool
- Support for new solar reference data options
- Added support for new Modtran atmospheric correction mode and added simple atmospheric correction tool (SACO)
- API for use of functionality from IDL applications

SACO – Simple Atmospheric Correction

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

SACO Calculation

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

Surface 'reflectance', directional

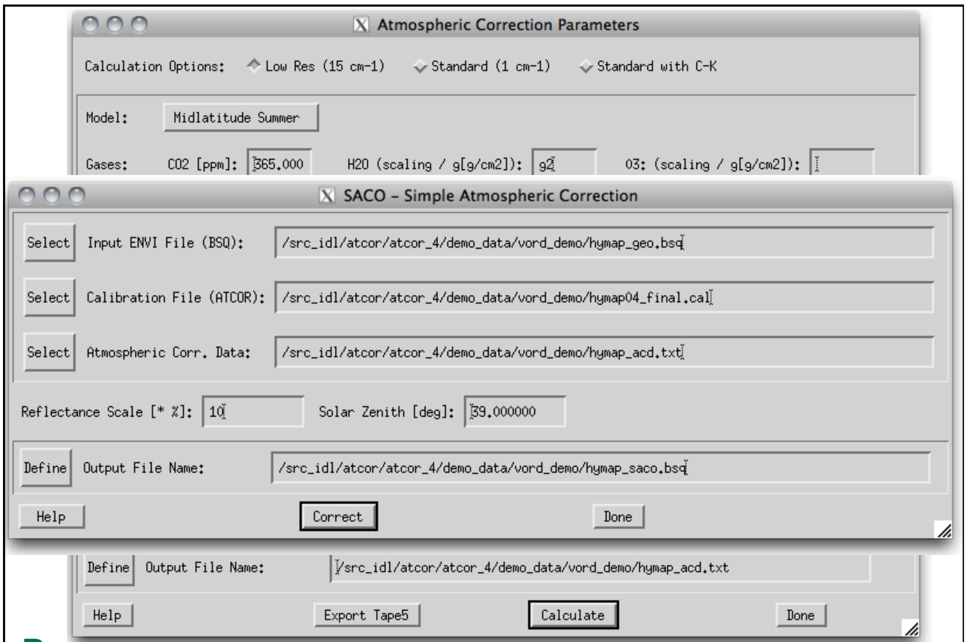
(bottom of atmosphere reflectance)

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

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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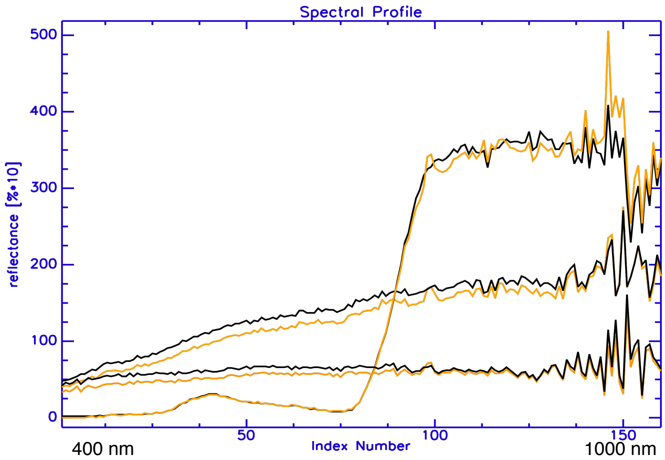
SACO-Results of atmospheric correction



HYSPEX Imaging Spectrometer Processing

Black: ATCOR 4 Output
Brown: SACO Output

(both unfiltered, single pixels)

Open Items for MODO

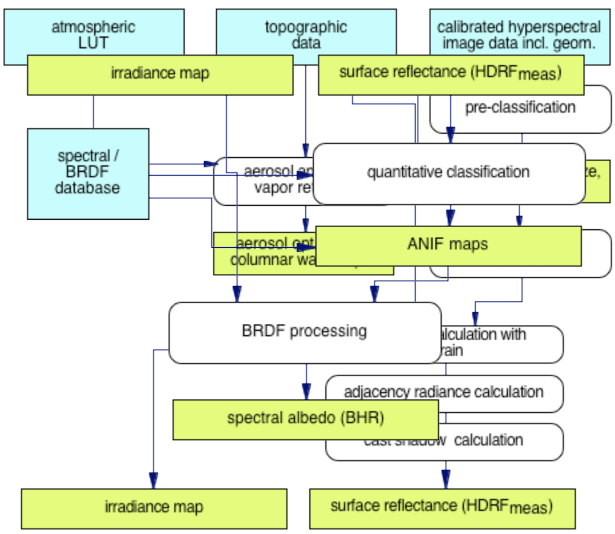
Future enhancement options:

- Scene simulation
- Sensor model inclusion
- Atmospheric profile editor
- BRDF visualisation and support
- LUT generation tools

ATCOR

Atmospheric Correction

Complete atmospheric and radiometric correction



ATCOR - Goals

To develop a complete and self-contained atmospheric correction software on the basis of MODTRAN for remote sensing systems in the VIS/NIR and IR.

ATCOR-2: ‘two dimensional’, i.e. no terrain, multispectral

ATCOR-3: ‘three dimensional’, add terrain influences

ATCOR-4: ‘four dimensional’, add spectroscopy support and view angle dependencies for airborne data

ATCOR - Implementation

Uses a ‘universal’ spectral database (Look-Up-Table) at 0.4 nm resolution

New sensors are introduced by resampling the LUT.
Based on IDL technology for fast prototyping, continuously updated

History:

- Developed originally by Rudolf Richter, DLR:
- Development started in the late 80’s
- Patent held by German Aerospace Agency
- Sub-Licenses granted to ERDAS Imagine and Geomatica
- Original code co-developed and distributed by ReSe since 2002

ATCOR - SACO

ATCOR	SACO
Image-derived inputs (aerosols/ water vapor)	User-defined inputs
6-D Look-up Table	One parameter set per band
Terrain + viewing angle - aware	Nadir conditions only
30’ for 1600x3000x160 bands	15x faster
Processing chain component	Simple scientific test tool
Validated and broadly used	Non-validated
Side outputs (aerosol, water vapor, emissivity, temperature…)	No side outputs.
Haze, cirrus, shadow correction	No spatial variations in correction

Hyspex Atmospheric Correction

HYSPEX:

VIS-NIR hyperspectral sensor,

3.6 nm resolution

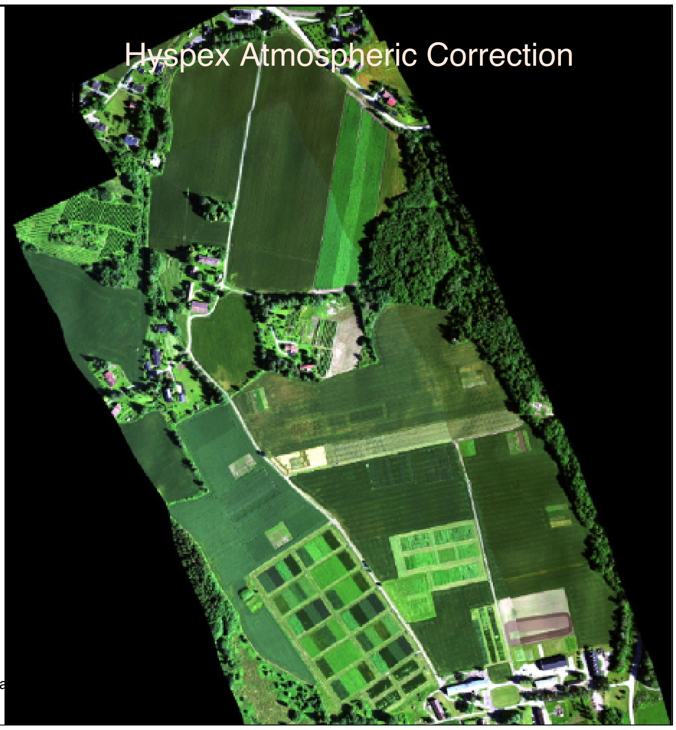
160 bands

400-1000 nm

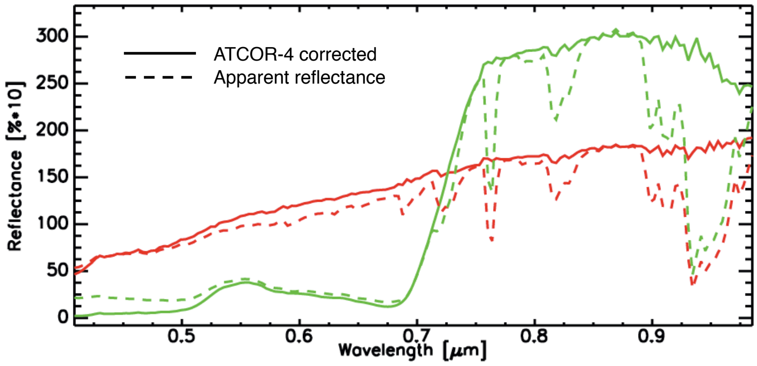
1600pix across track

Courtesy:

NEO, Norway

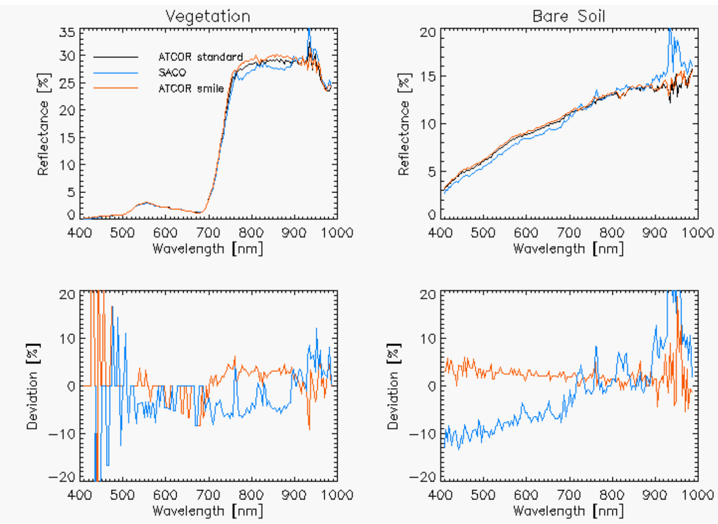


Hyspex Atmospheric Correction

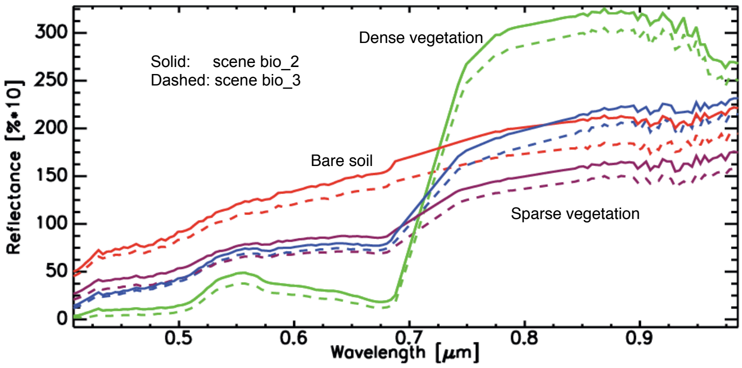


Apparent reflectance (dashed) and corresponding surface reflectance (line) for dense vegetation (green) and bare soil (red); ATCOR-4 correction, no interpolation)

SACO Outputs On HYSPEX



Hyspex Overlap Comparison



HYSPEX reflectance spectra, overlap of two scenes

(all corrections done with ATCOR-4, small atm. features are interpolated, Spectra of 10x10 pixels samples)

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HYMAP BRDF in Overlap

HYMAP data set 'Vordemwald' (Switzerland, 2004). mosaic after orthorectification

- 2400m above ground
- sun zenith: 38°
- 512 across track pixels
- Photogramm. DEM
- FOV: 61.4°

(data in courtesy of RSL, Zürich; PARGE orthorectification)

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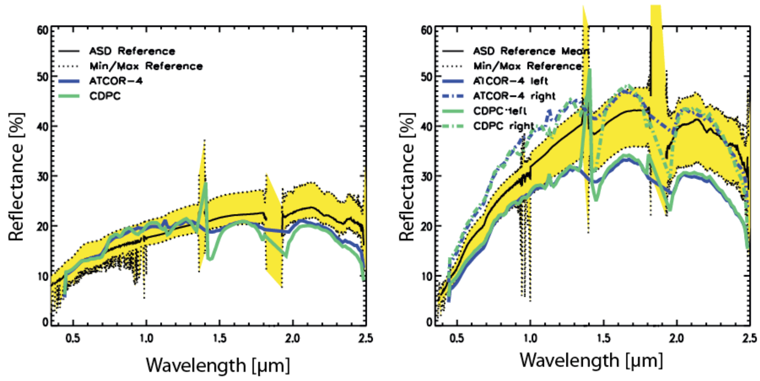
Spectra in Overlap - comparison

No-BRDF influence (Asphalt) Strong BRDF effect (Soil)



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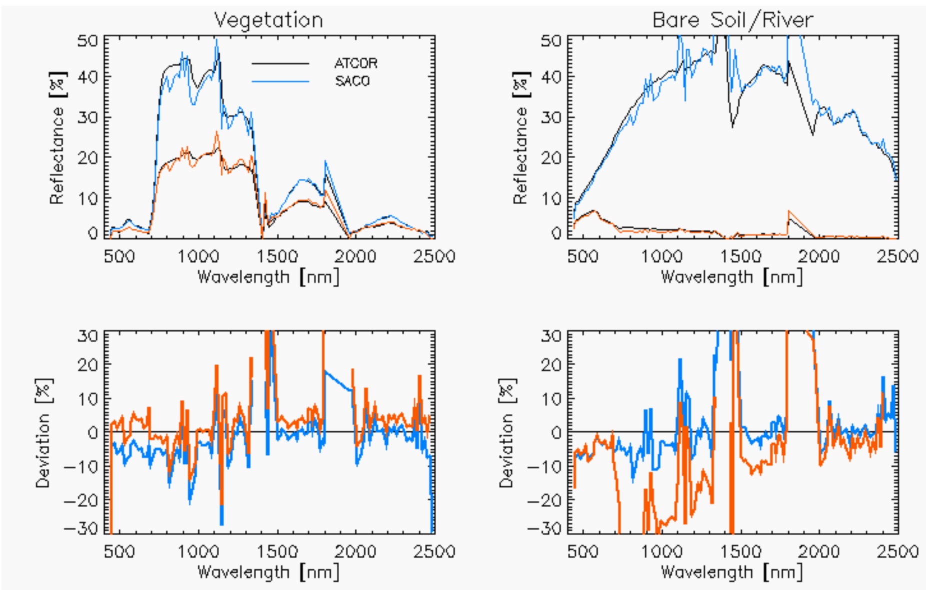
HYMAP ATCOR-SACO



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Solved Problems in Atmospheric Correction

Relying on:

- Data calibration
- Accurate LUT generation or reference (MODTRAN…)

Implemented or used in ATCOR:

- Vicarious radiometric and spectral calibration
- Link of geometric and atmospheric correction
- Aerosol retrieval and haze correction
- Cloud- and cast shadow correction
- Correction of spectral smile
- Water vapor retrieval (over land)
- Topographic illumination correction
- Empirical illumination BRDF correction

Haze and Cirrus Correction

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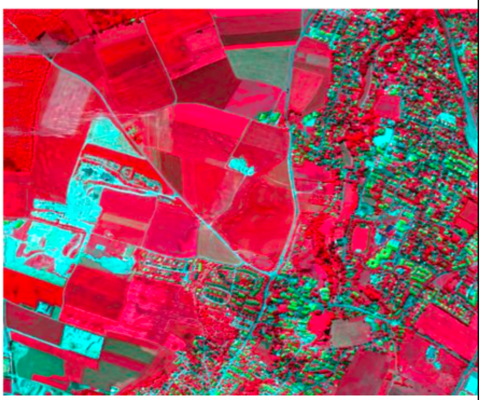
Cloud and Cast Shadow correction



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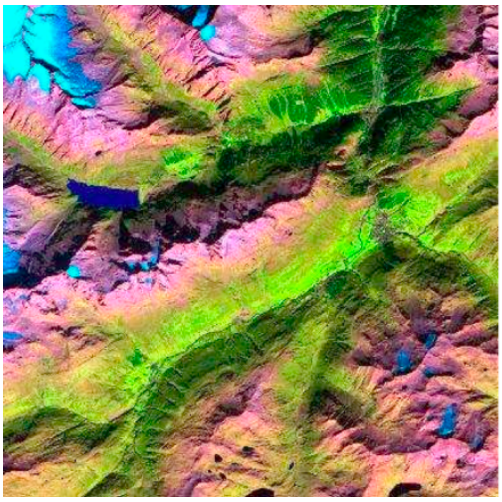
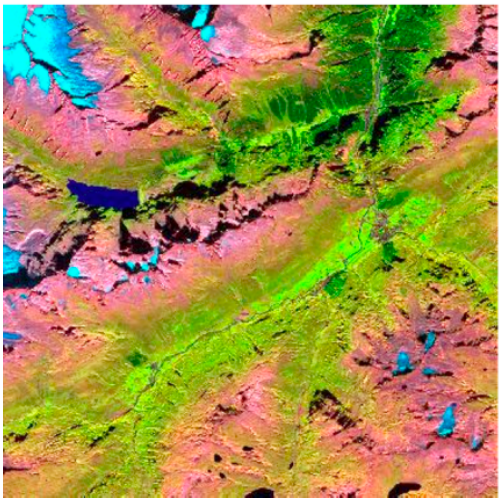
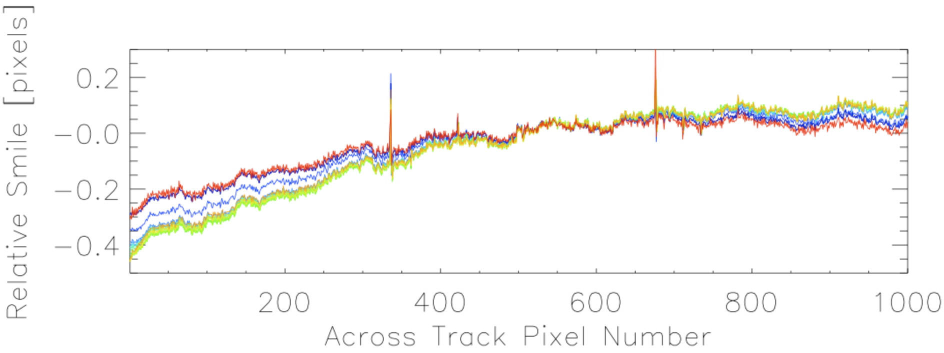
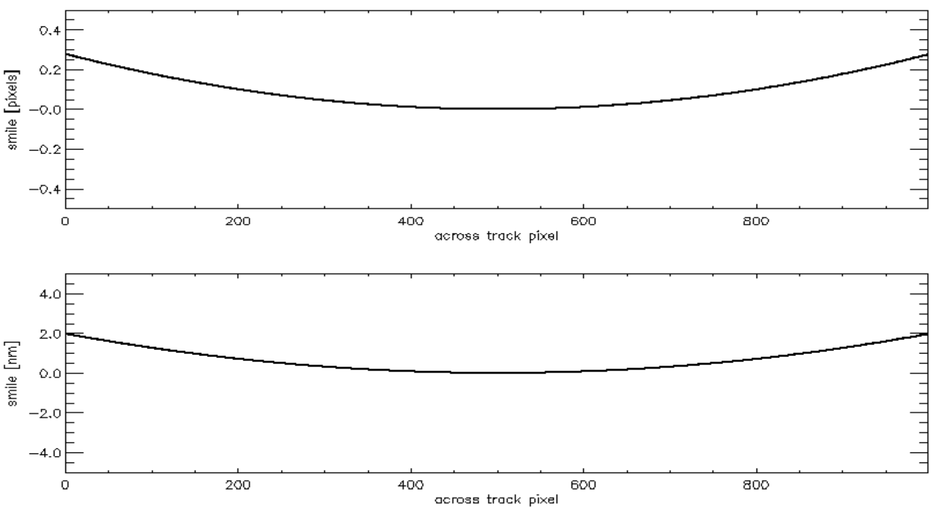
Empirical BRDF Topographic Correction



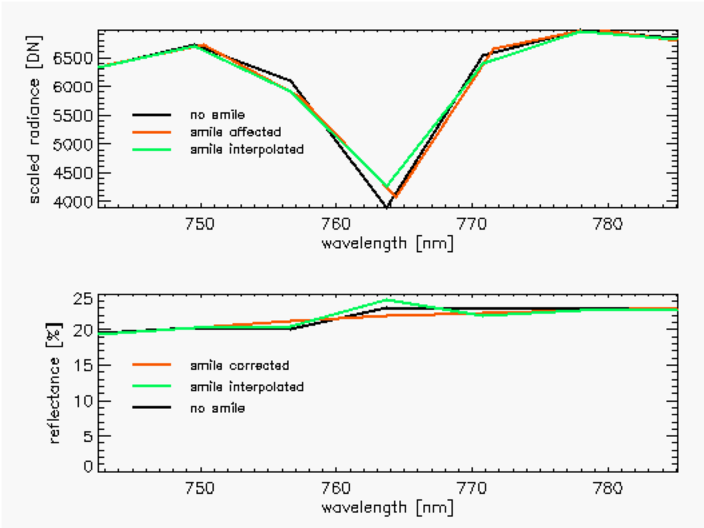


Spectral Smile?





Spectral Smile (2)



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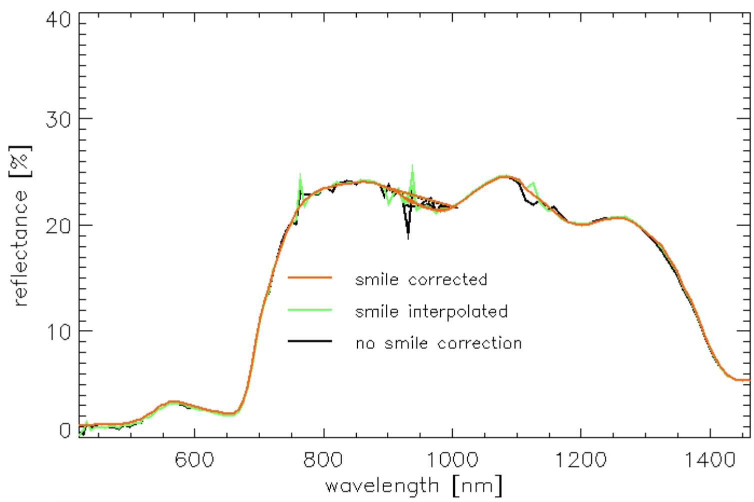
Spectral Smile (3)



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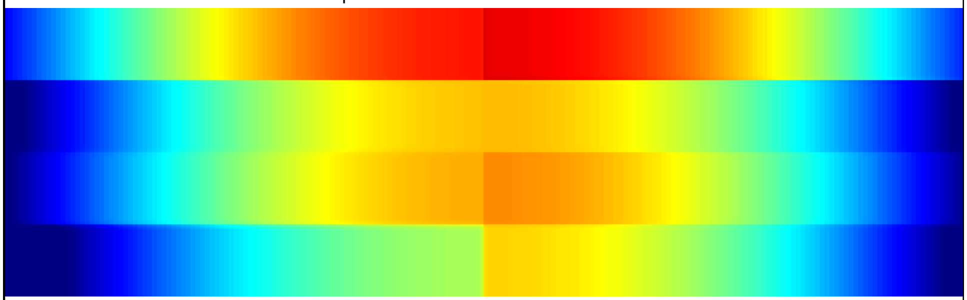
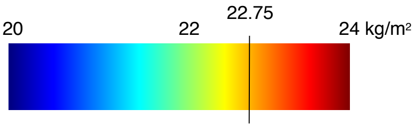
Columnar Water Vapor (1)



Water vapor column simulated ENMAP data

Alfalfa	Conifer
Soil 1	Soil2
Soil 3	Polyethlyene
rho 0.1	rho 0.2



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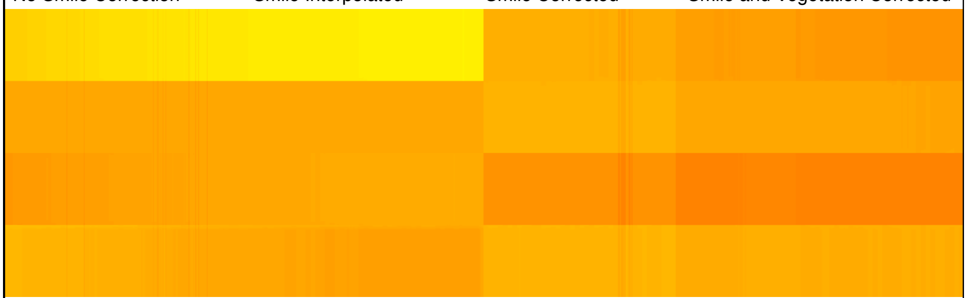
Columnar Water Vapor (1)



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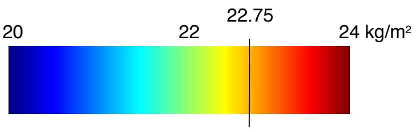

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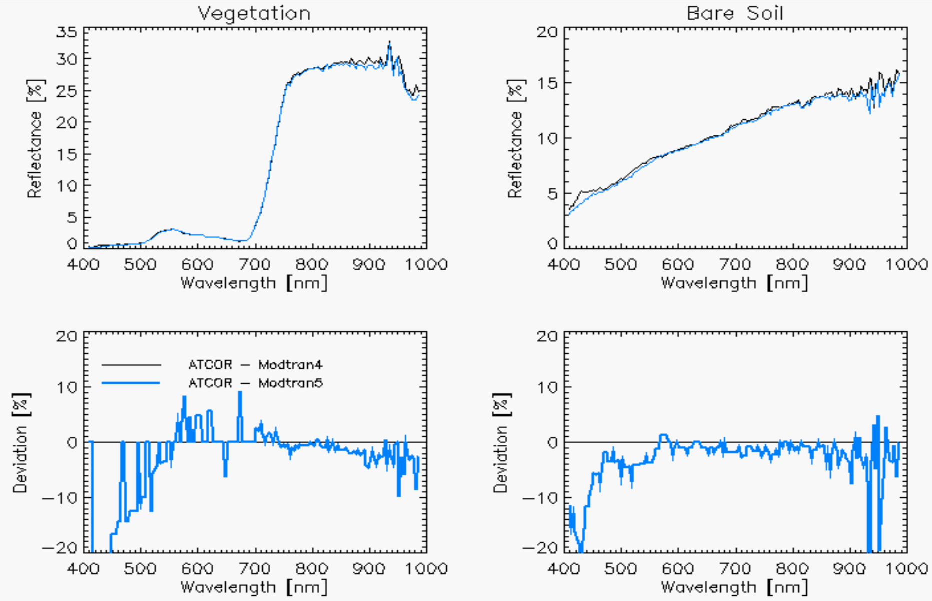
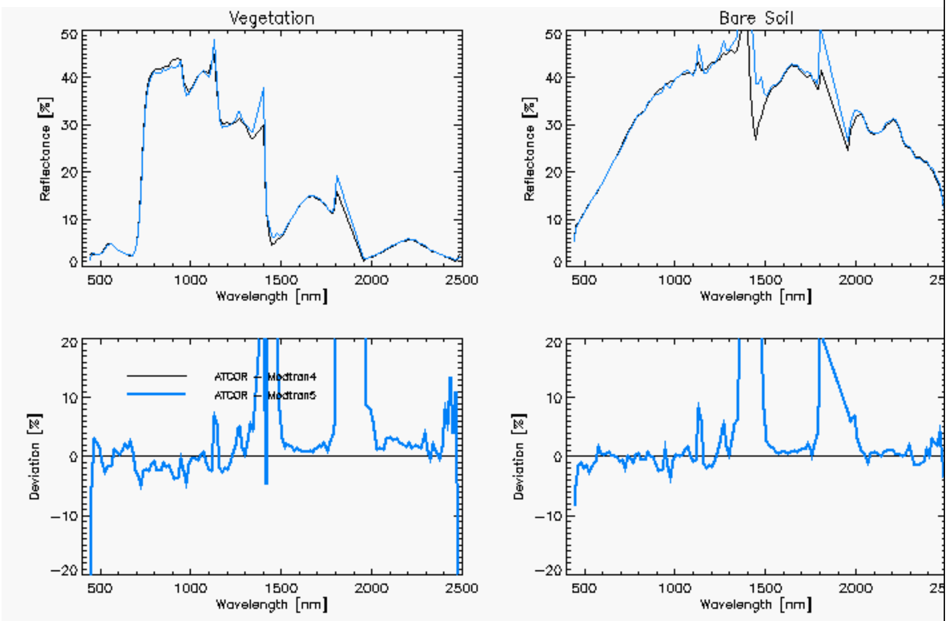
Using Modtran 5 in ATCOR-4

- Completely updated atmospheric database at 0.4 nm internal spectral resolution (in order to support 2nm spectral resolution imaging spectrometers)
- Uses the Kurucz 2005 database as basis (Option to switch solar irradiance function)
- Using Correlated-K with DISORT for all calculations of database,
- Provided with universal 6.2GB database.

Differences: HYSPEX



Differences: HYMAP



Conclusions

Atmospheric and radiometric correction seems to be an ever evolving topic…

Recent advances have been made with respect to

- Coupling of geometric and atmospheric correction (i.e., raw-geometry based atmospheric processing)
- the correction of haze and cirrus,
- the incorporation of spectral smile,
- water vapor retrieval accuracy (including smile)
- automatic processing possibilities (e.g., aerosol type detection)
- spectral resolution

Outlook

Open Challenges

- Water vapor over water and dark objects
- Overcast sky (fully diffuse illumination) correction
- Aerosol size distribution and complete aerosol characterisation
- Inclusion of further gases based from imagery (oxygen, CH4)
- Coupling with water radiative transfer for limnology
- Cirrus correction
- Work on spectral polishing/pushbroom calibration residuals

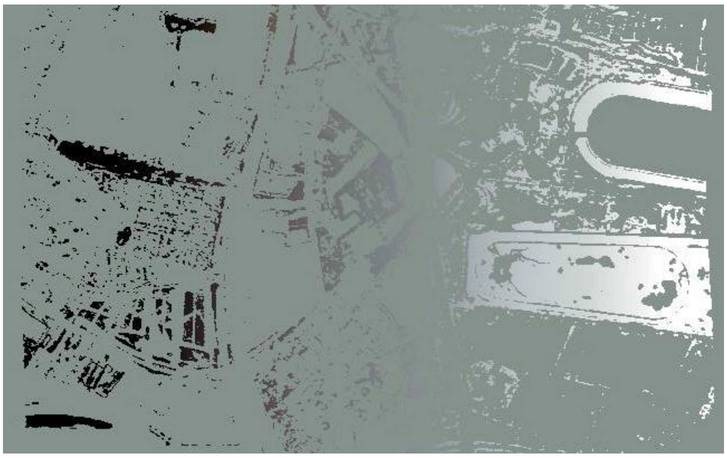
and:

- complete BRDF correction ('BREFCOR')

Model based BRDF correction (BREFCOR)

(see talk of T. Feingersh)

Model based BRDF correction (BREFCOR)



(see talk of T. Feingersh)

Thanks!

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