PCRTM updates and validation using SCIAMACHY data

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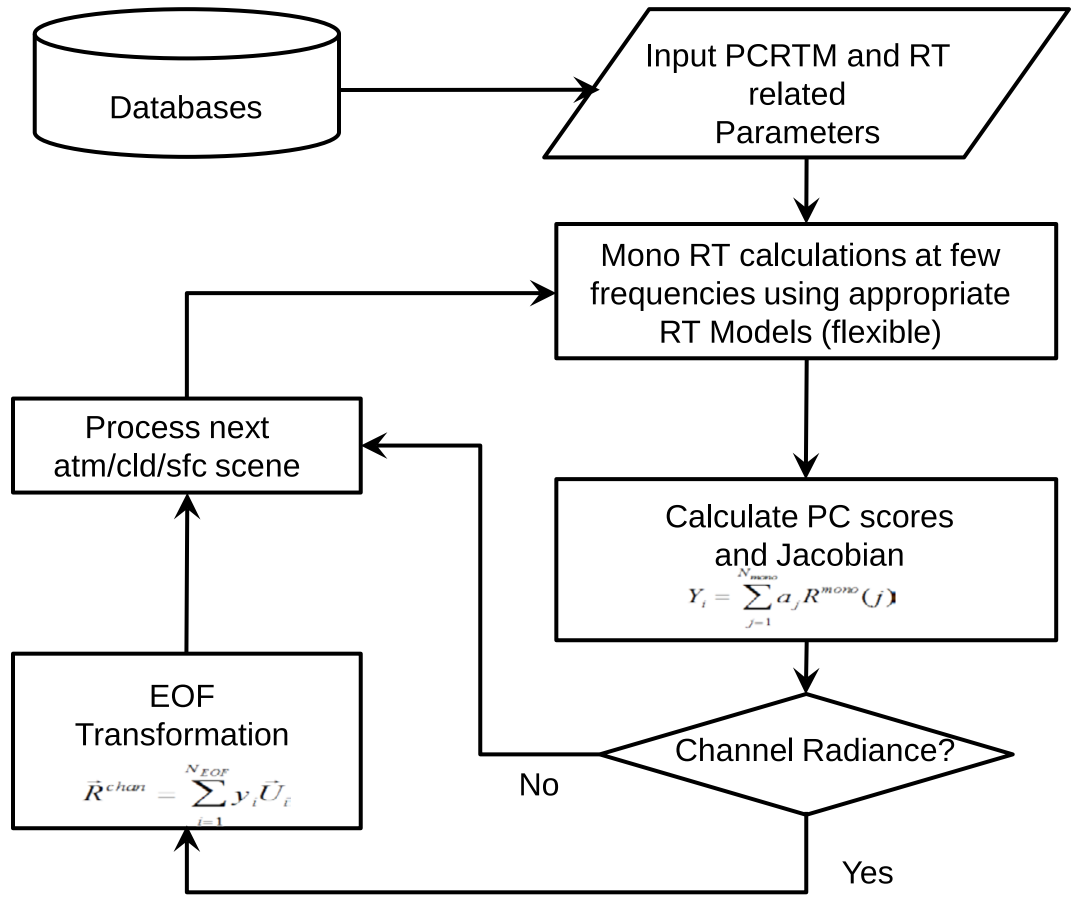
Outline

- Introductions
- Updates on the PCRTM
- Analyzing SCIAMACHY hyperspectral data using PCRTM
- Summary and Conclusions

Introduction

- RT model is one of the key components to a satellite mission
  - Instrument trade studies
  - OSSE
  - Sensitivity studies
  - Tool for L1 & L2 algorithm development
- PCRTM explores spectral correlations in the hyperspectral data
  - Mono RT done rigorously
  - 2-900 times faster than channel-based RT models
  - Reduce dimensionality of original spectrum by a factor of 10-90
  - Accurate relative to full RT calculations
- It covers 0.31 μm-200 μm spectral range
  - Panchromatic OSSE
  - Trace gases, atmospheric, clouds, aerosols, various surface emissivity and BRDF..

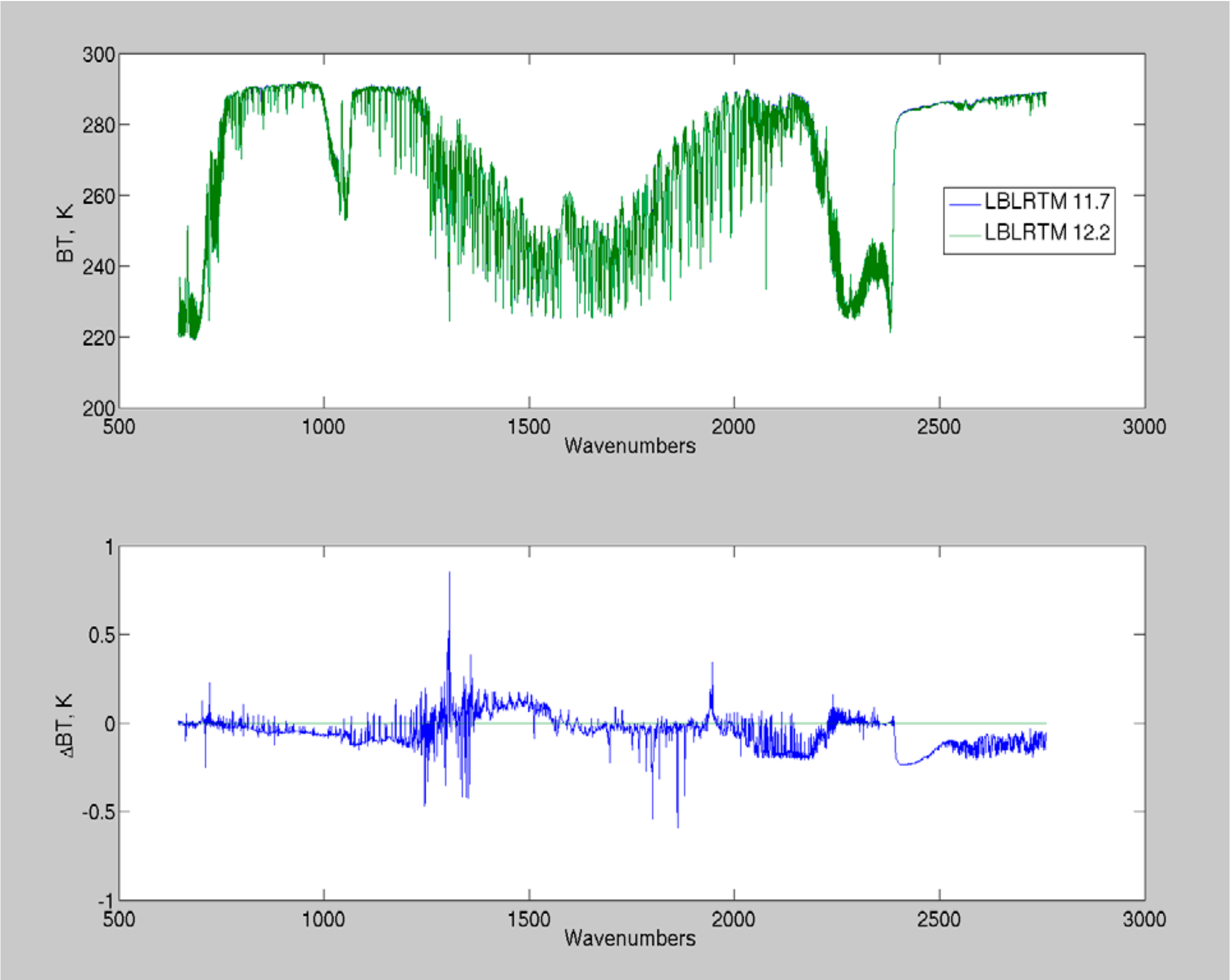


Updates since last Science Team Meeting

- PCRTM in infrared spectral region
  - Updated the spectroscopy using the latest LBLRTM
  - The old version PCRTM can be updated simply by replacing the appropriate database files
  - Updated the cloud lookup table for both ice and water clouds (from Ping Yang)
  - Implement faster cloudy radiative transfer calculations -- on going collaboration Ping
  - Added two more sensors to the PCRTM
- PCRTM in solar spectral region
  - Added shortwave PCRTM with 4 nm Gaussian instrument function to mimic a grating instrument
  - Trained another version of PCRTM with 10 nm spectral resolution
    - Improved the computational speed even further
  - Adapted the new version of PCRTM to Berkeley's OSSE frame work
  - Explored SCAMACHY data using PCRTM

LBLRTM 12.2 vs. LBLRTM 11.7

- The goal is to validate an accurate RT model based on real observations and the state of art RT models
- Usually variations in the LBL model and spectroscopy are larger than the PCRTM trained accuracy



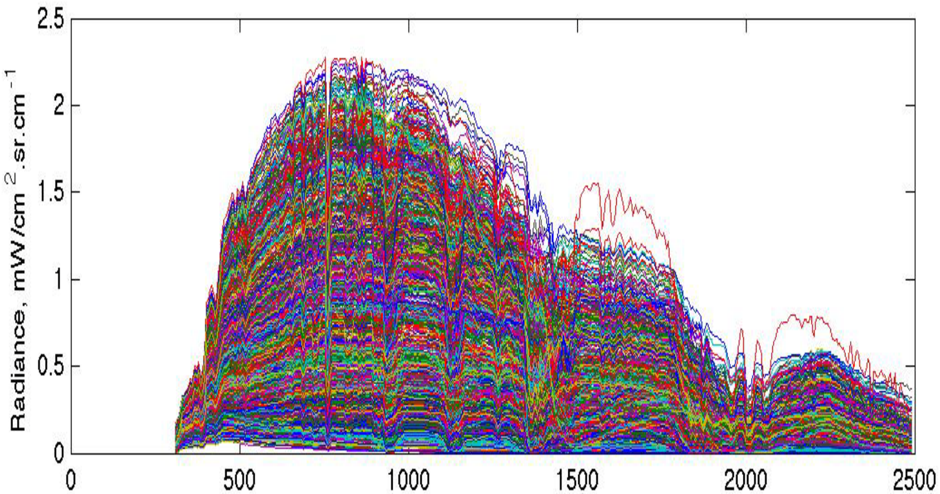
- H2O line positions and intensities for the wavenumber range 10 to 2500 cm^{-1} are from Coudert et al. (2008). This AER line file contains both measured and calculated Coudert et al values, while HITRAN 2008 includes measured values only, which stop at 1750 cm^{-1}
- CO2 line parameters were built using the CO2 line mixing database of Lamouroux et al., 2010. This database takes most of its line positions, intensities, and lower state energies from the HITRAN 2008 database, but the values for air-broadened half-widths and their temperature dependencies are adjusted from the HITRAN 2008 values to be consistent throughout the bands, and the air-induced pressure shifts were added
- CH4 line parameters now include line coupling parameters for the v_3 (3000 cm^{-1}) and v_4 (1300 cm^{-1}) bands of the main isotopologue. The line coupling parameters were calculated using the HITRAN 2008 line parameters and the method of Tran et al., 2006
- The positions and intensities of CO_2 lines have been corrected in to match HITRAN 2008 outside the spectral range 597-2500 cm^{-1}

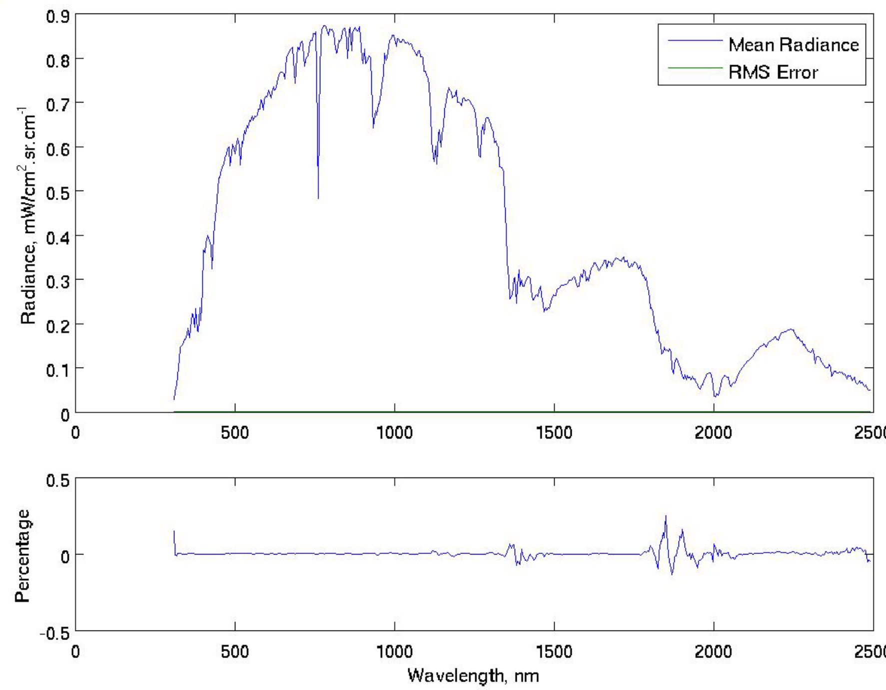
Added more instruments to PCRTM

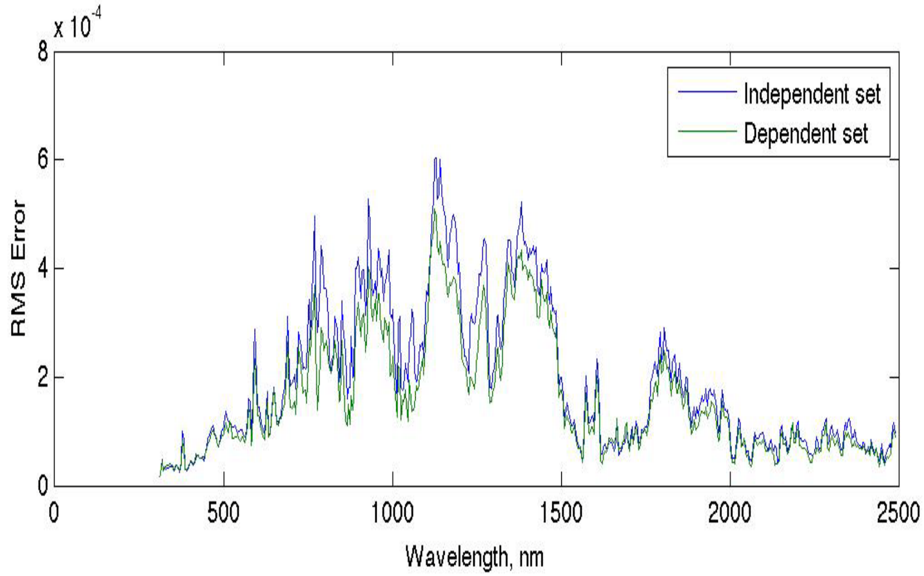
- Retrained many instrument PCRTM using latest LBLRTM
- Added S-HIS PCRTM
- Added full spectral resolution CrIS PCRTM (0.625 cm^{-1} resolution for all 3 bands)
- Takes a small fraction of a second to get a full spectrum

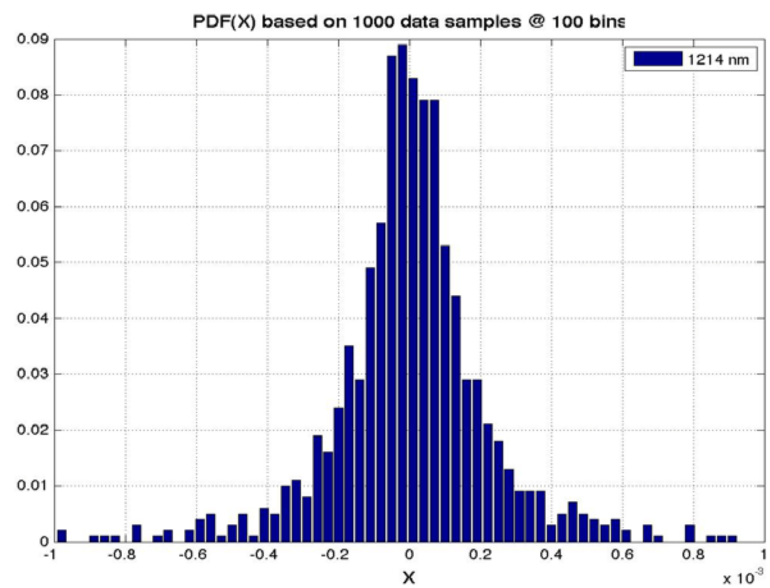
Sensor	Channel Number	PC score (seconds)	PC score + Channel radiance	PC score + PC Jacobian
CLARREO, 0.1 cm^{-1}	19901	0.014 s	0.022 s	0.052 s
CLARREO, 0.5 cm^{-1}	5421	0.011 s	0.013 s	0.039 s
CLARREO, 1.0 cm^{-1}	2711	0.0096 s	0.012 s	0.036 s
IASI, 0.25 cm^{-1}	8461	0.011 s	0.012 s	0.044 s
AIRS, 0.5-2.5 cm^{-1}	2378	0.0060 s	0.0074 s	0.031 s
CrIS, Blackman, 0.625-2.5 cm^{-1}	1317	0.0050 s	0.0060 s	0.021 s
CrIS, Boxcar, 0.625-2.5 cm^{-1}	1317	0.0050 s	0.0060 s	0.022 s
CrIS, Hamming, 0.625-2.5 cm^{-1}	1317	0.0050 s	0.0058 s	0.022 s
NAST-I, 3 bands, 0.25 cm^{-1}	8632	0.010 s	0.013 s	0.045 s
NAST-I, 44 bands, 0.25 cm^{-1}	8632	0.032 s	0.032 s	0.18 s

Training 4 nm PCRTM with a Grating SRF

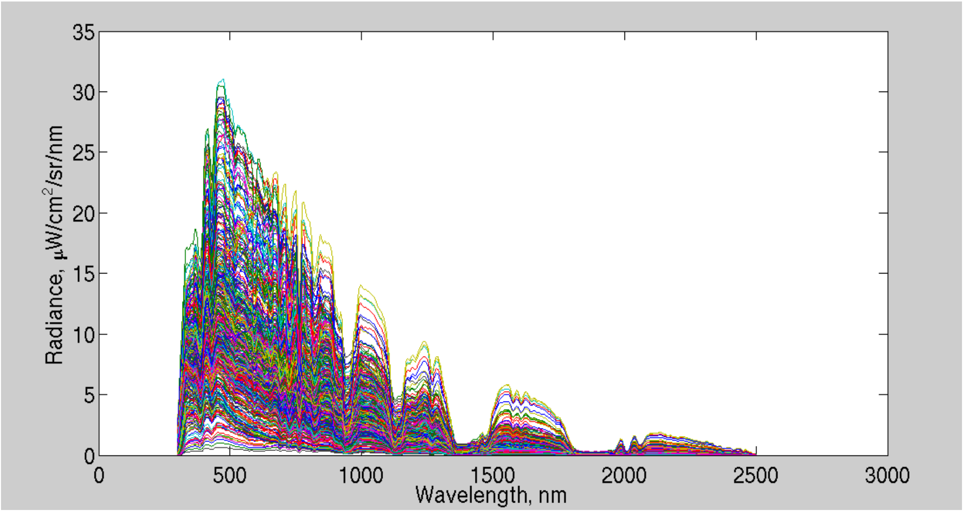


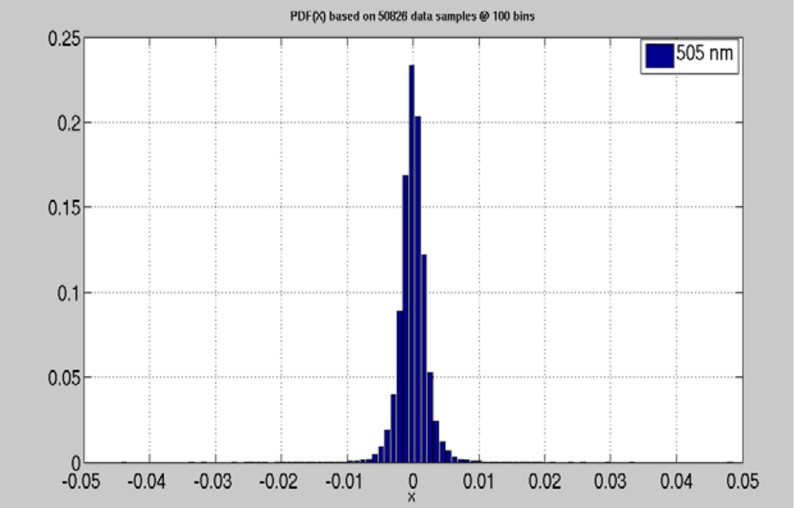


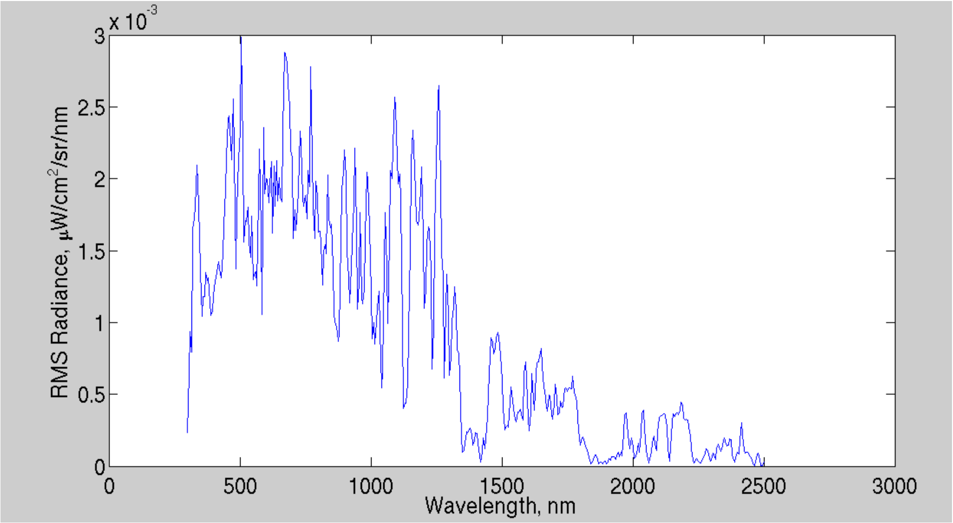




Training 10 nm PCRTM using 15 wavnumber MODTRAN band model







	PCRTM RT	MODTRAN RT	speed up
Ocean $1cm^{-1}$	956	259029	270
Land $1cm^{-1}$	1339	259029	193
Ocean 4nm	279	259029	928
Land 4nm	354	259029	731
Oc/ld 10 nm	109	3079	28

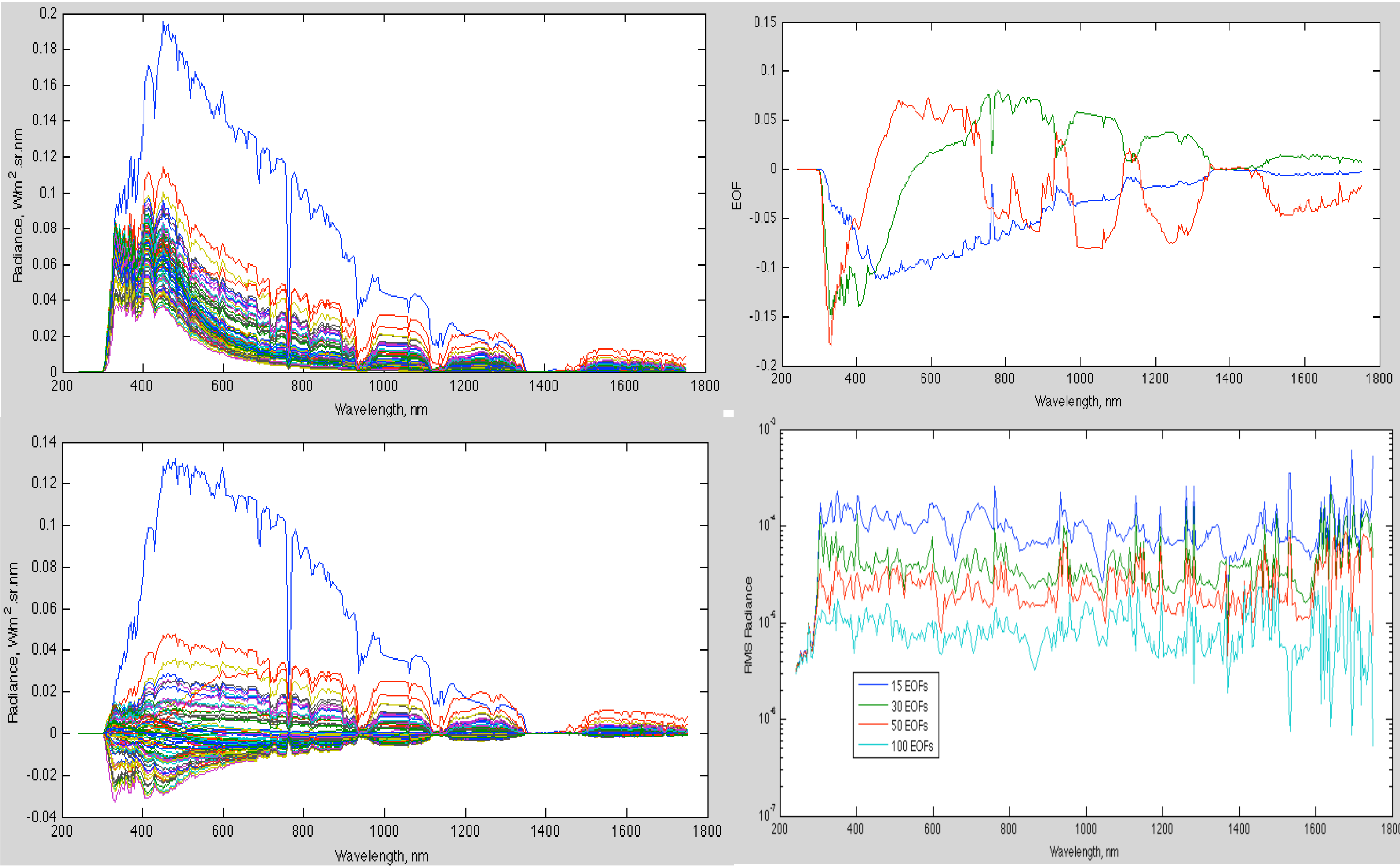
It take about 0.15 s to calculate one spectrum at 10 nm resolution

Analyzing SCIAMAACHY hyperspectral data using PCRTM

- Task performed
  - PCRTM representation of SCIAMACHY data
  - Fitting SCIAMACHY data using PCRTM and CERES atmospheric properties
  - Sensitivity of TOA radiances and reflectances to various atmospheric/cloud/surface parameters

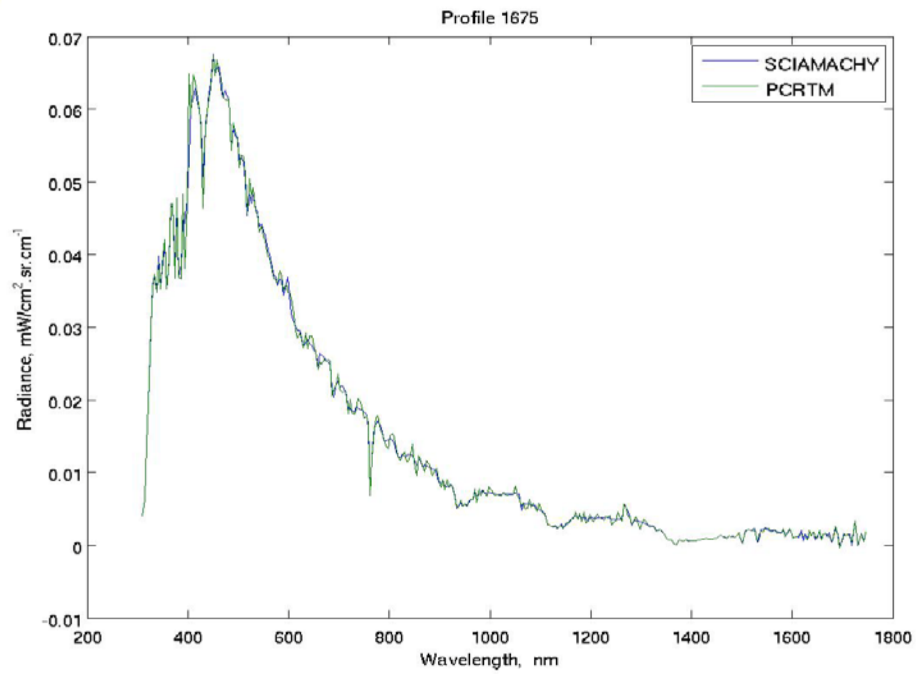
- Goal
  - Be able to simulate both CLARREO IR and RS spectra using one forward model (PCRTM)
  - Be able to extract information of CLARREO spectra using EOF approach

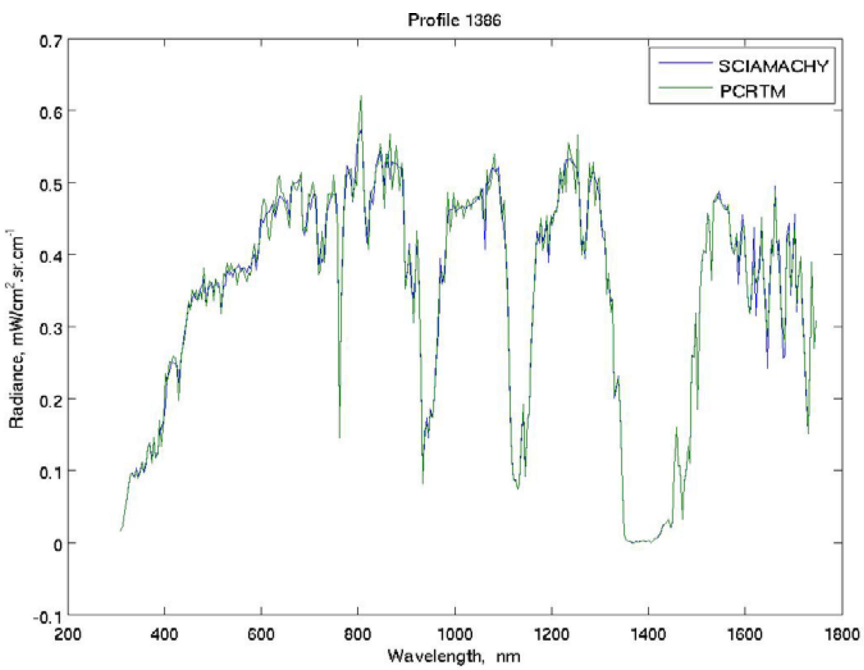
PCA analysis of SCIAMACHY data

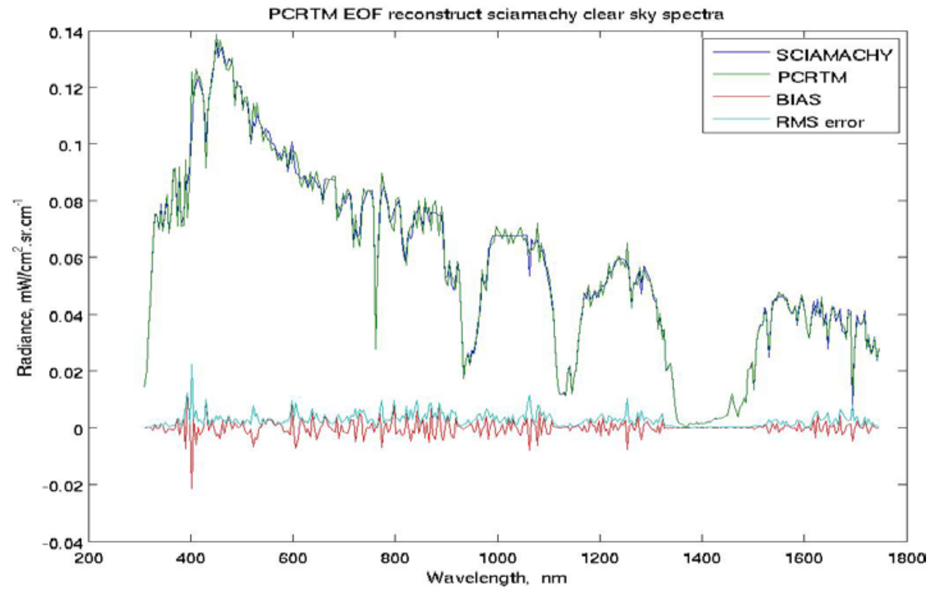


Can PCRTM represent SCIAMACHY data?

- PCRTM was trained with very diverse conditions of various atmospheric, surface ,cloud, aerosol, and solar/satellite geometries
- PCRTM EOF can effectively represent the SCIAMACHY spectral variations

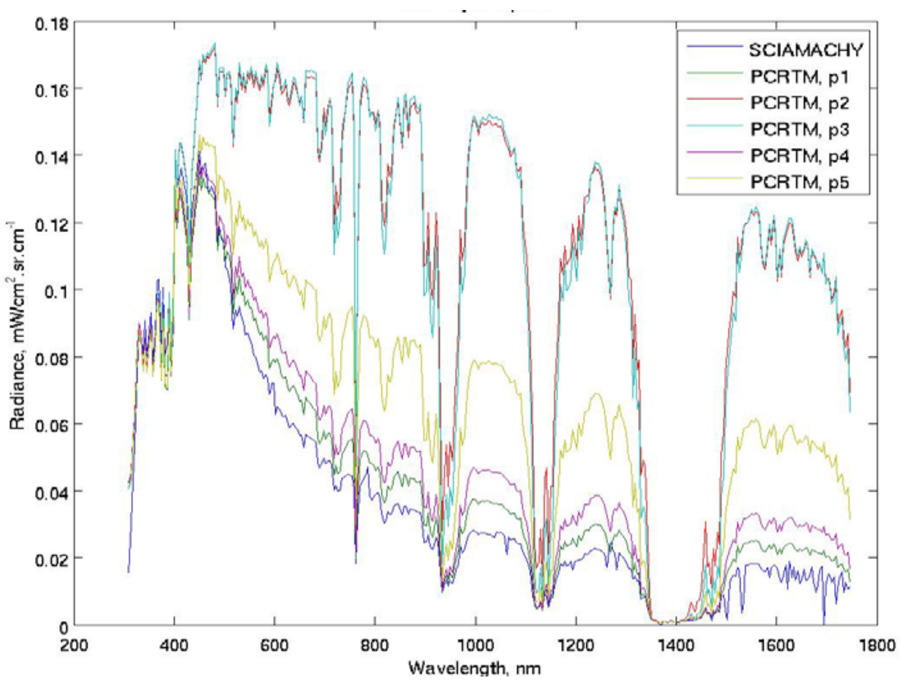


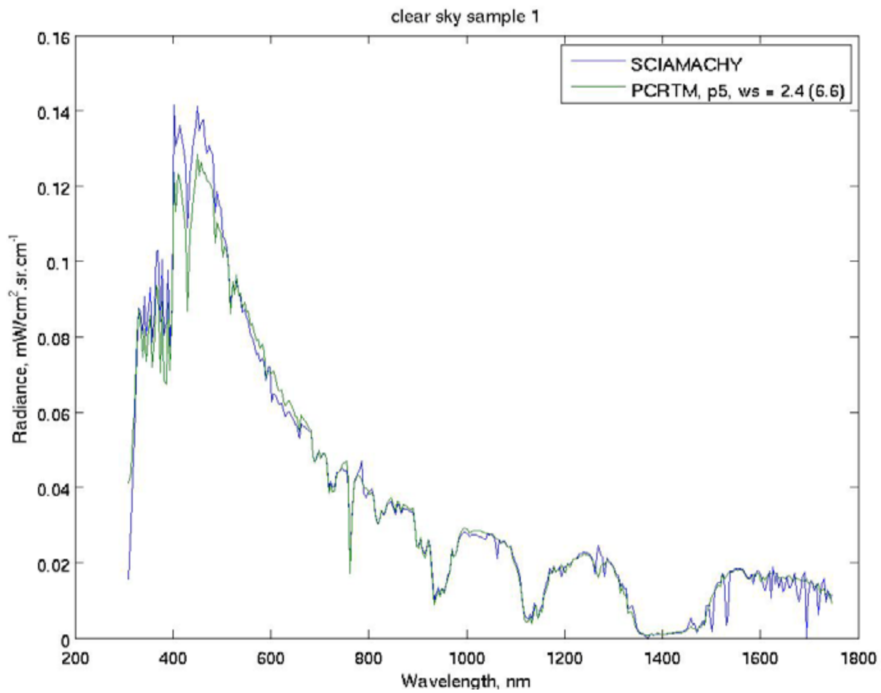




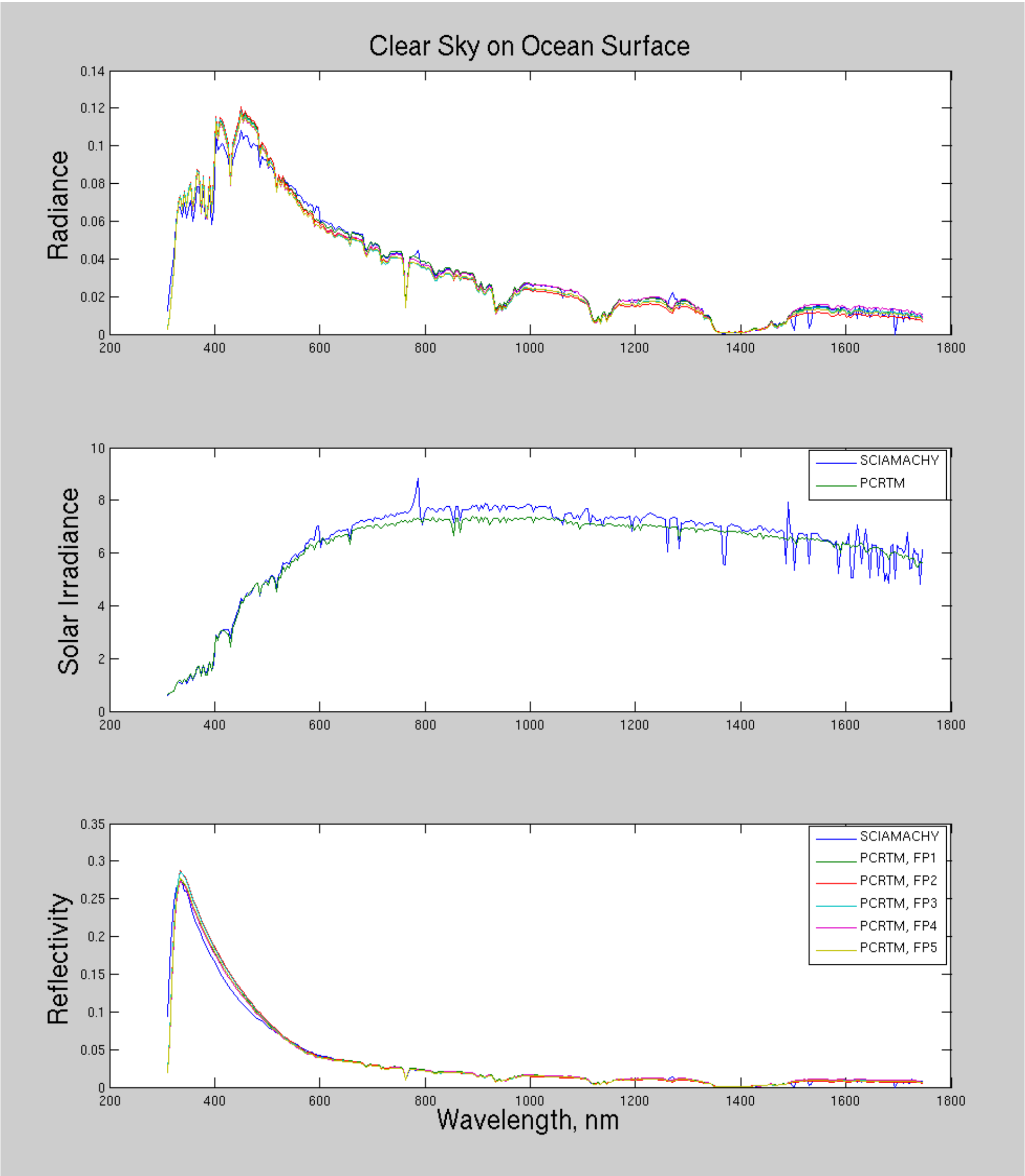
Forward model simulation of SCIAMCHY data using PCRTM model and CERES database

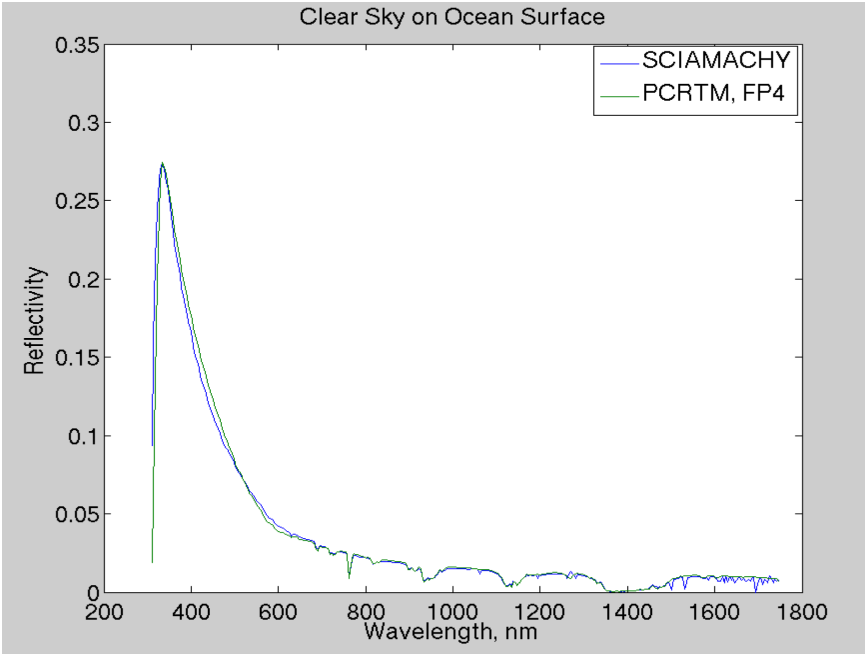
- Five coordinates for each SCIAMACHY footprint
- CERES/MODIS cloud, atmosphere, aerosol, and surface information used as input to PCRTM
- The TOA radiance depends on the geometry significantly for some SCHIAMACHY footprints





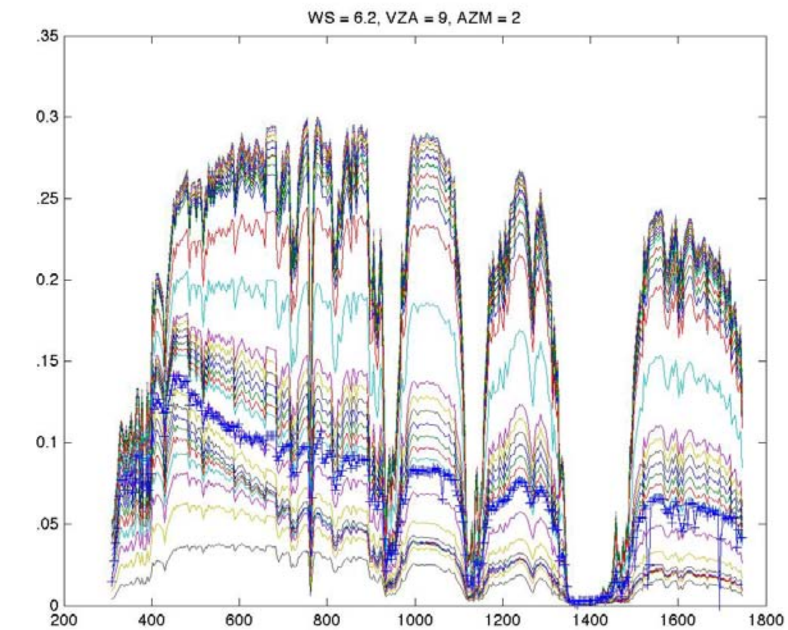
An Example PCRTM simulated spectra and comparison with SCIAMACHY data

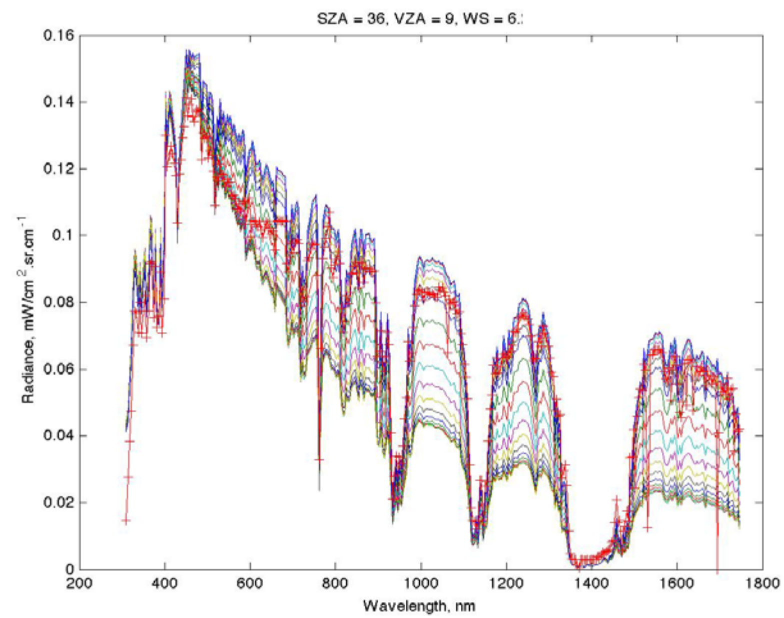


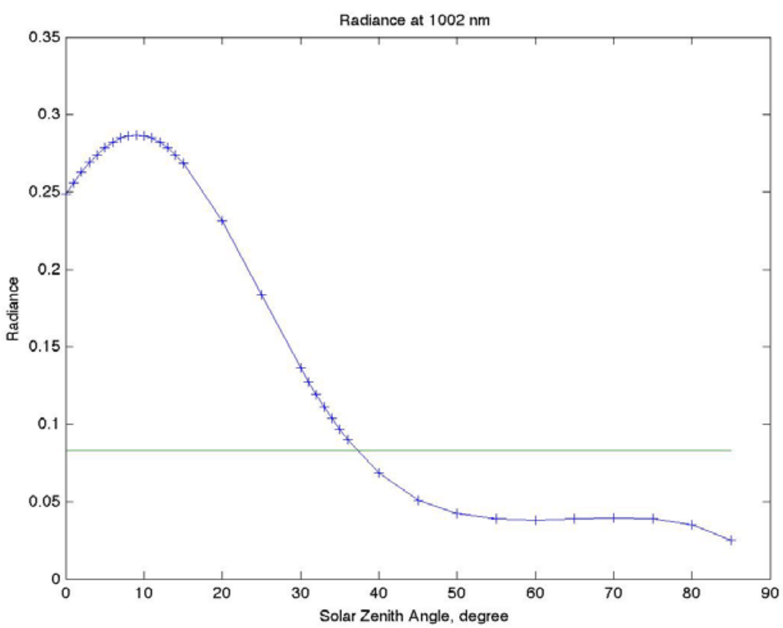


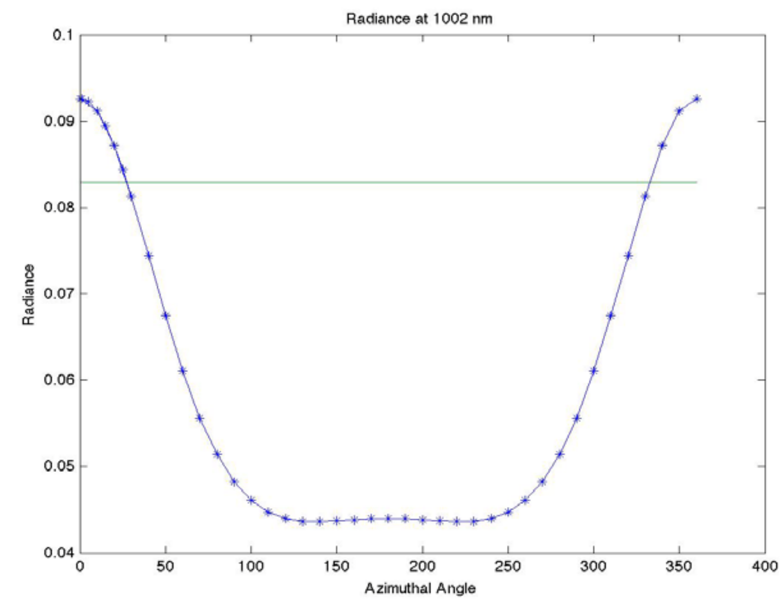
	SZA	VZA	AZM	WS	VAP	AOD
FP 1	44.32	18.29	35.21	1.8	0.768	0.123
FP 2	45.69	1.1	33.53	1.8	0.768	0.123
FP 3	45.69	1.1	33.53	1.4	1.079	0.123
FP 4	44.32	18.29	35.21	1.4	1.079	0.123
FP 5	45.02	9.67	34.34	1.7	0.911	0.124

Dependence on solar zenith and relative azimuth angles

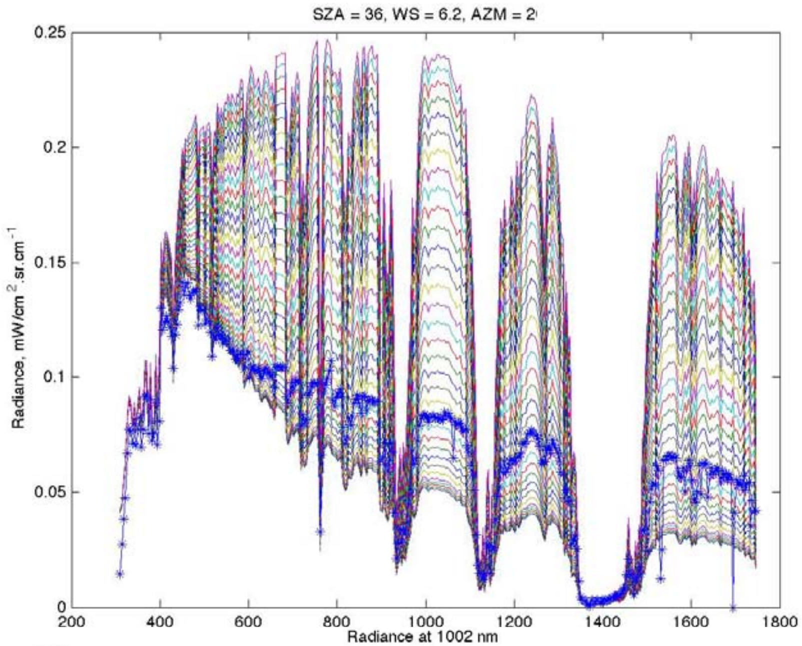


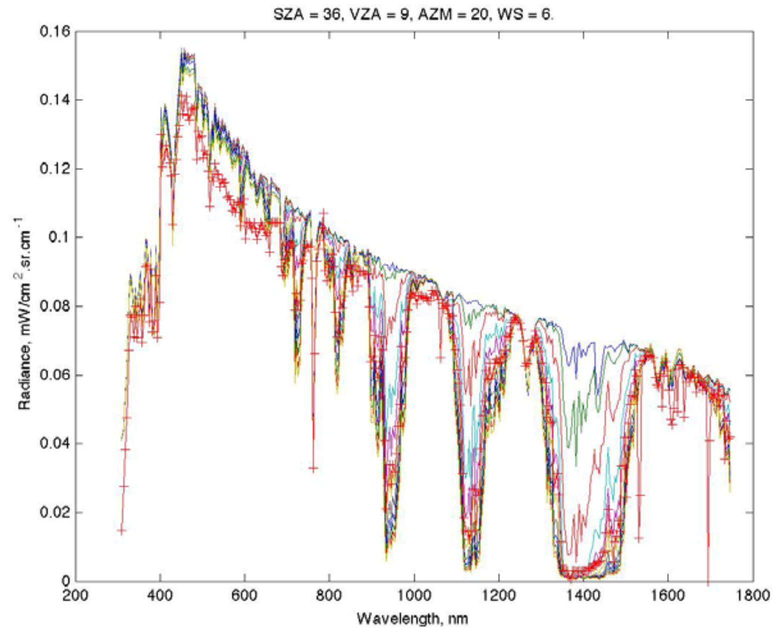


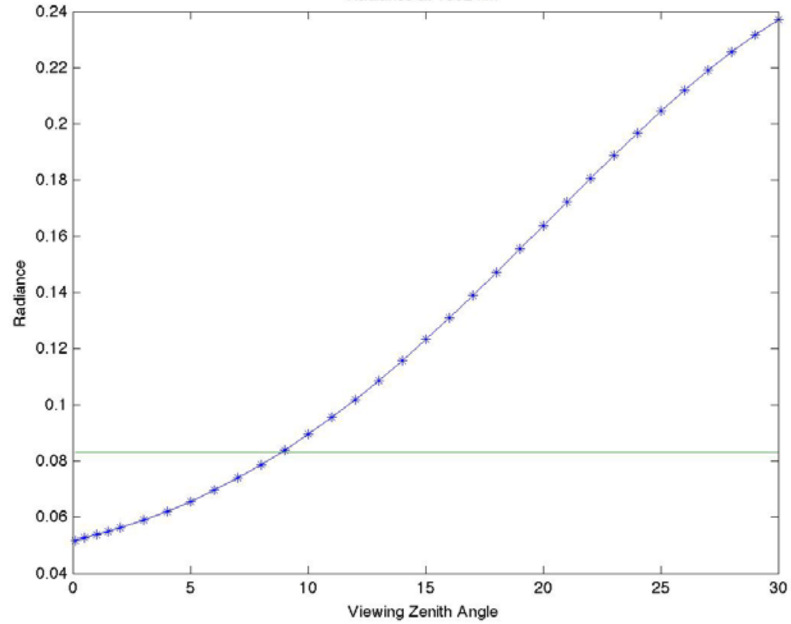


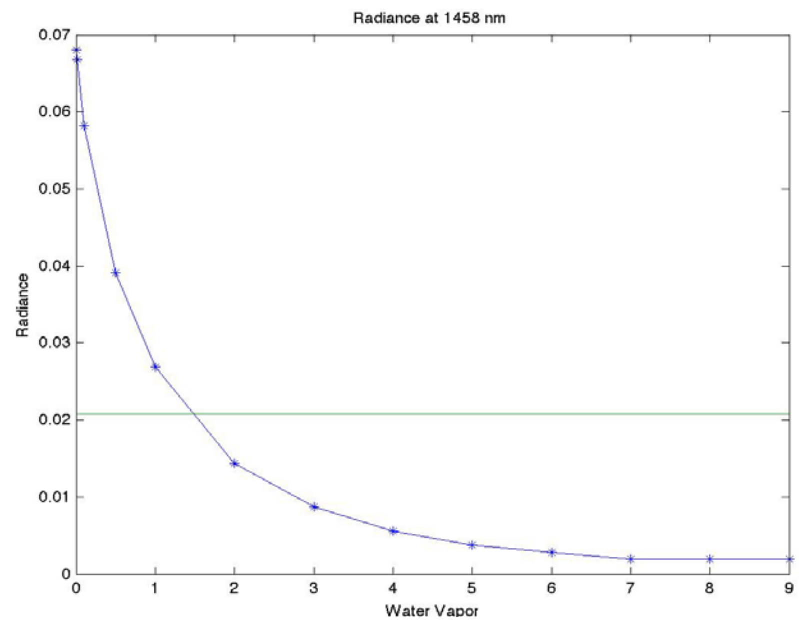


Dependence of the view zenith angle and water column

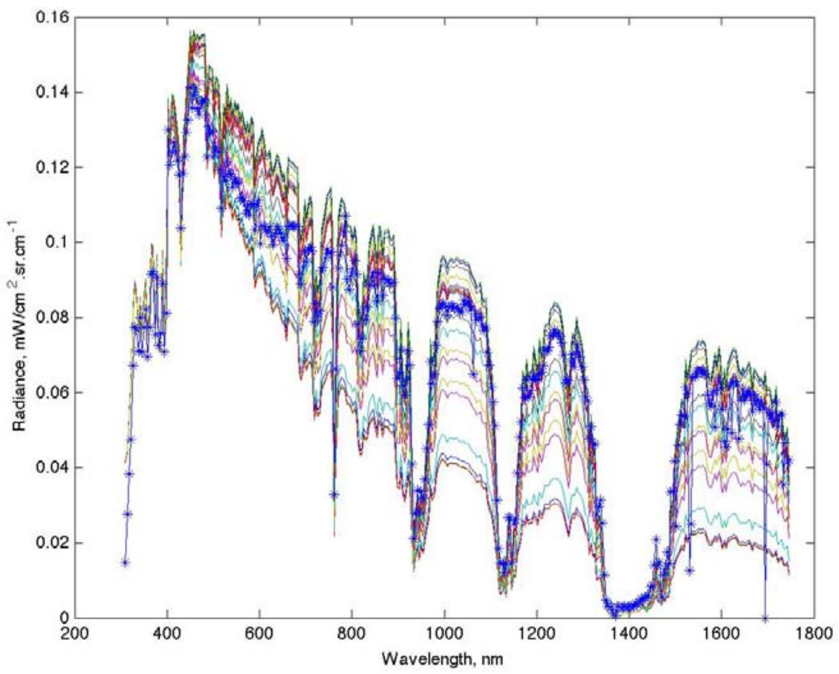




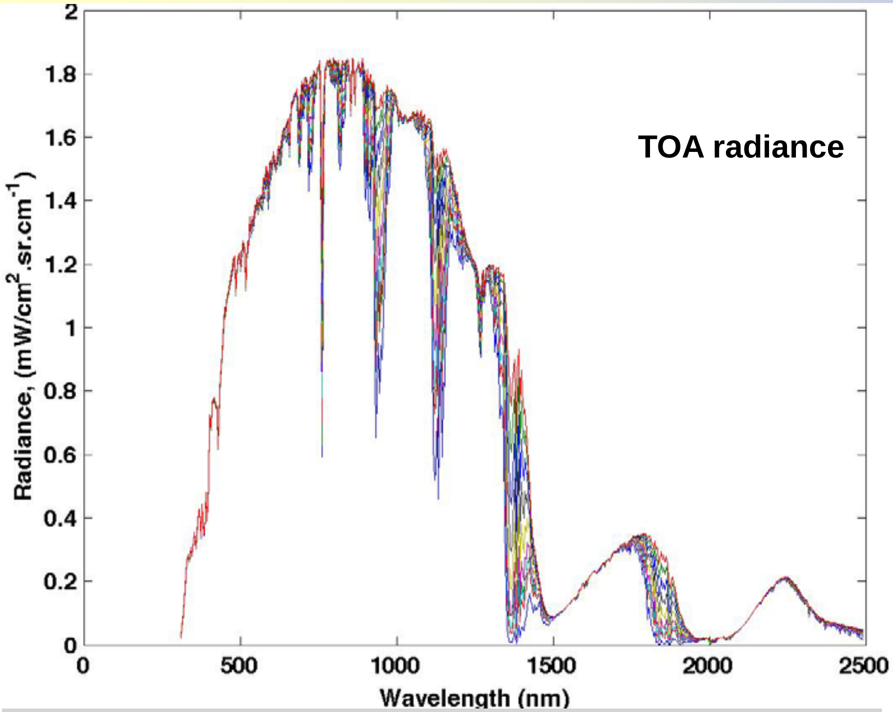


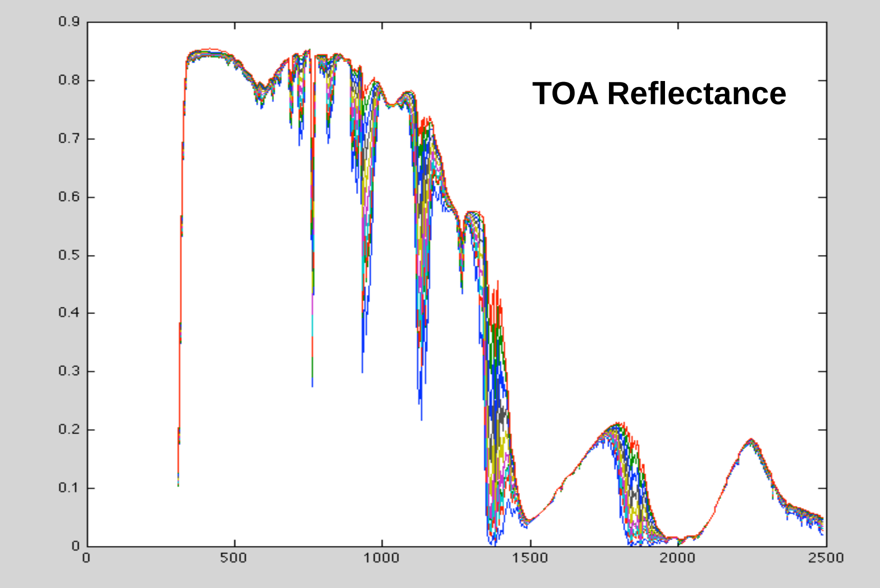


Dependence on wind speed

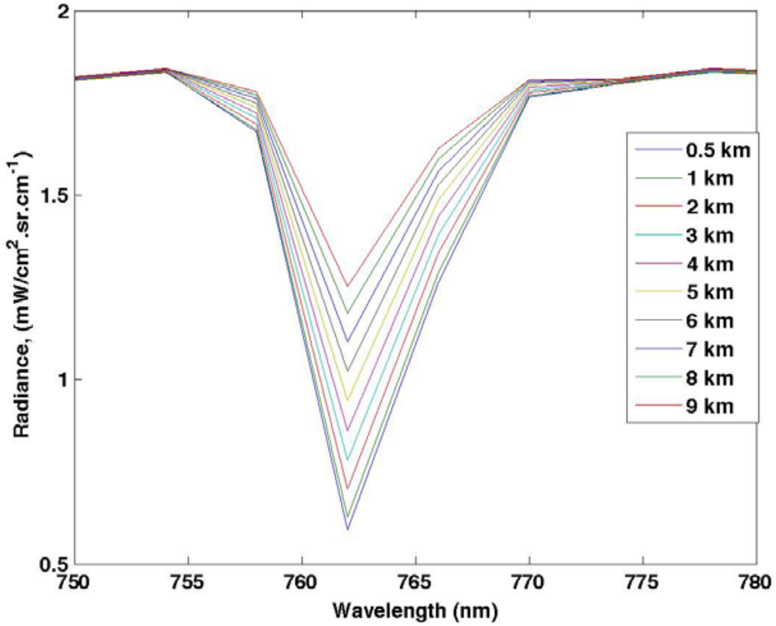


Dependency on cloud height



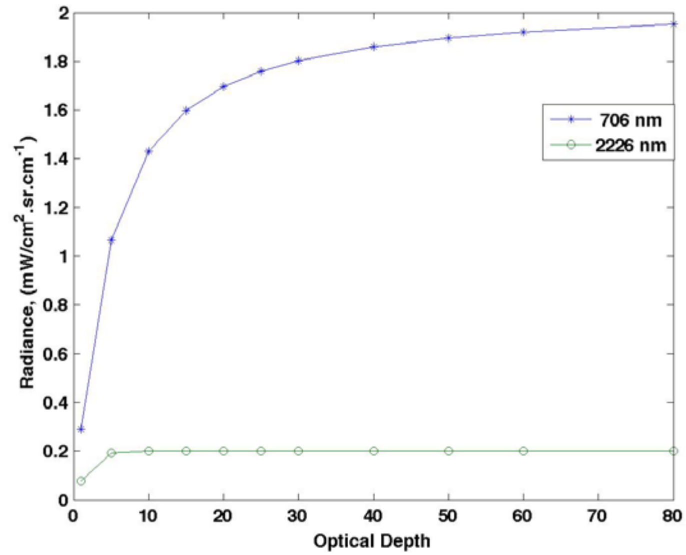


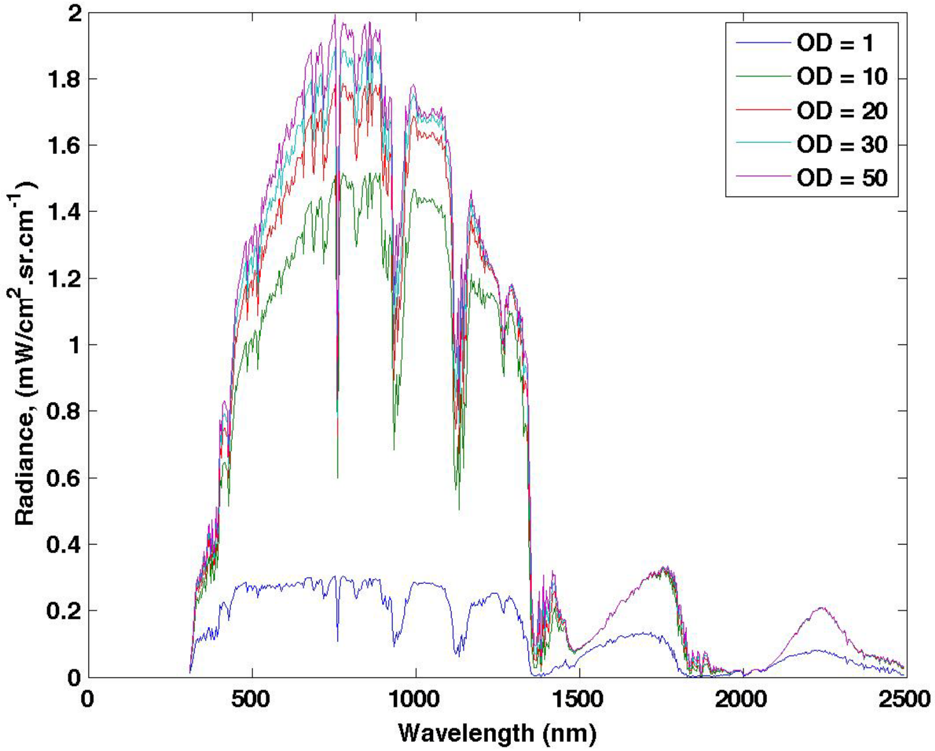
Expanded view of the oxygen A-band spectral variation as a function of cloud height



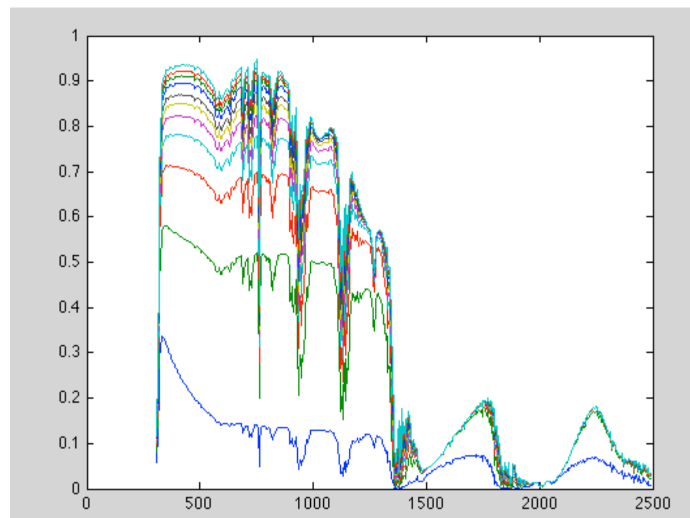
Ice cloud dependency on cloud optical depth

Note different sensitivity of near IR vs visible spectral regions





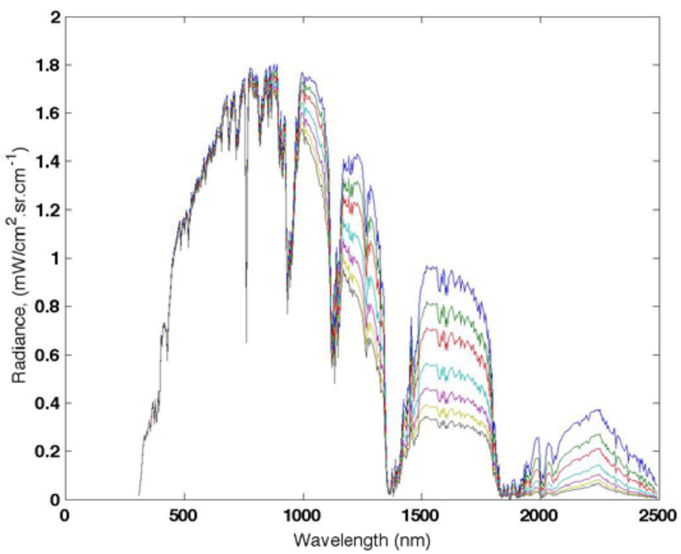
TOA radiance



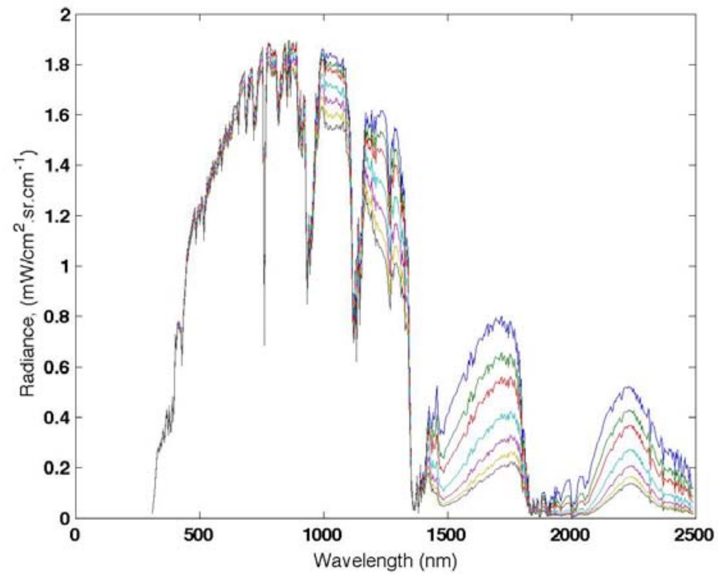
TOA reflectance

Water clouds and Ice clouds have distictive spectral features

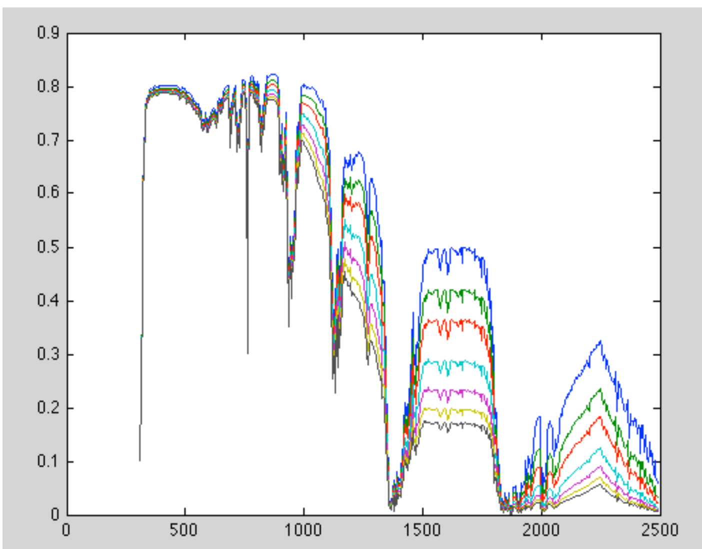
TOA radiance as a function of particle size for water clouds



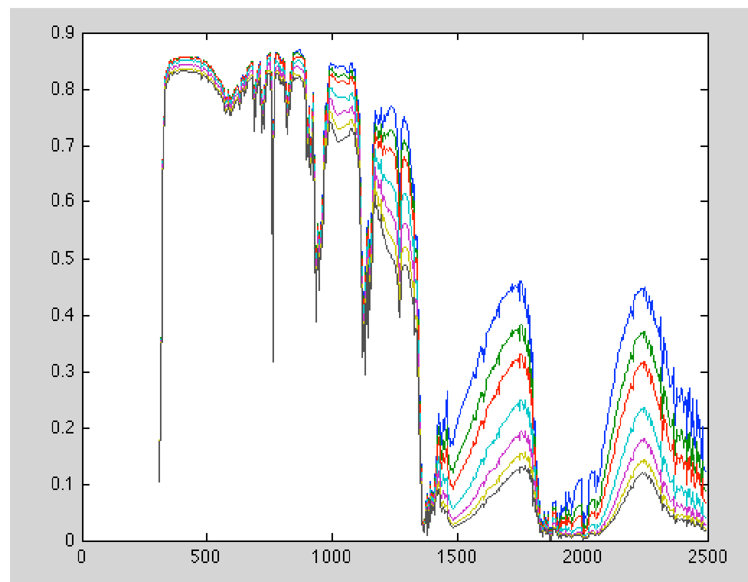
TOA radiance as a function of particle size for ice clouds



TOA reflectance as a function of particle size for water clouds



TOA reflectance as a function of particle size for ice clouds



Summary and Conclusions

- PCRTM has been developed to accurately calculate TAO radiance or reflectance from far-IR to ultraviolet spectral region (0.31 μm-200 μm)
  - Very accurate relative to training model
  - PCRTM Parameters can be easily updated if the LBL or spectroscopy improves
  - The thermal IR PCRTM needs a few millisecond to a fraction of seconds to perform PC scores (or radiance, jacobian) calculations
  - The solar PCRTM enables one to two orders of magnitude speed improvement over the MODTRAN runs (0.15 second for 10 nm shortwave PCRTM)
- CLARREO data have high information content on atmospheric trace gases, clouds, aerosols, and surface
  - Advantageous to have hyperspectral resolution and panchromatic spectral coverage
- PCRTM can be used for
  - Panchromatic spectral simulations and retrieval studies
  - To analyze real satellite data
    - AIRS, CrIS, IASI, SCIAMACHY…..
    - Continuously improve RT model spectroscopy and cloud/aerosol/surface modeling
    - Get ready for real CLARREO data..
- Will continue to support CALRREO science team for various needs