Single Field of View Cloudy Retrievals

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Outline

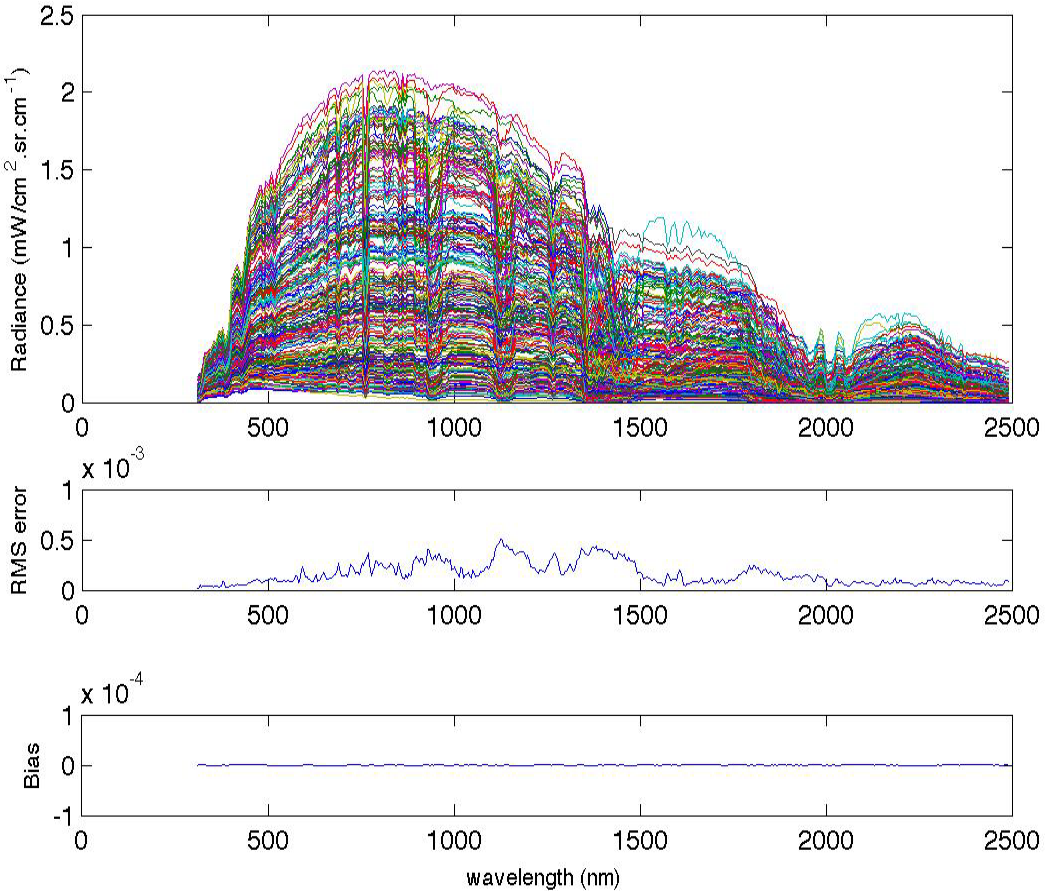
- Recent updates on cloudy radiative transfer modeling
- Single Field of View Retrieval Under All-sky Conditions
- Errors analysis on clouds, T, H_2O, and trace gases Retrievals
- Examples of single FOV retrievals on IASI, CrIS and ATMS
- Summary and Conclusions

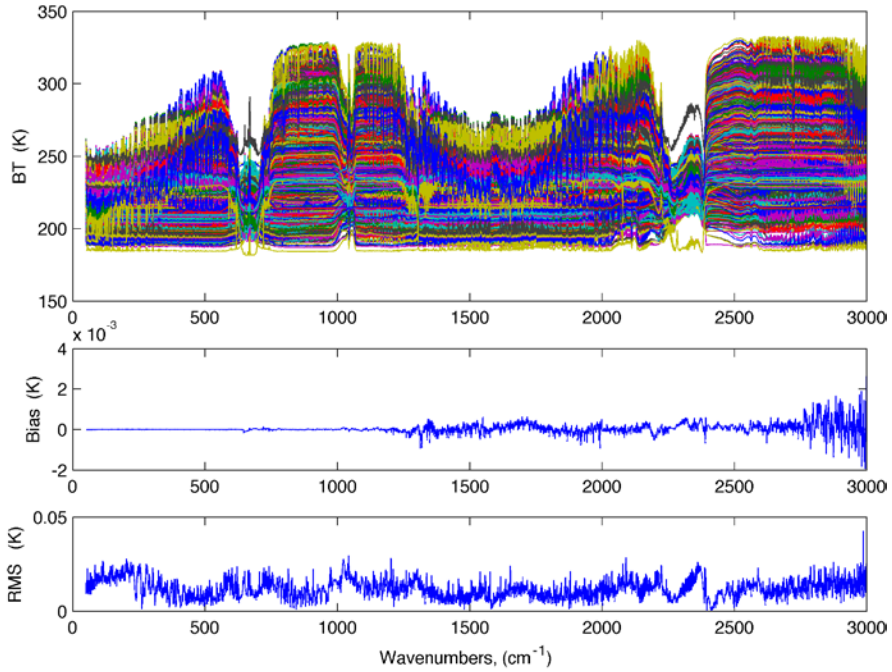
Recent Updates on Cloudy Radiative Transfer Model Development

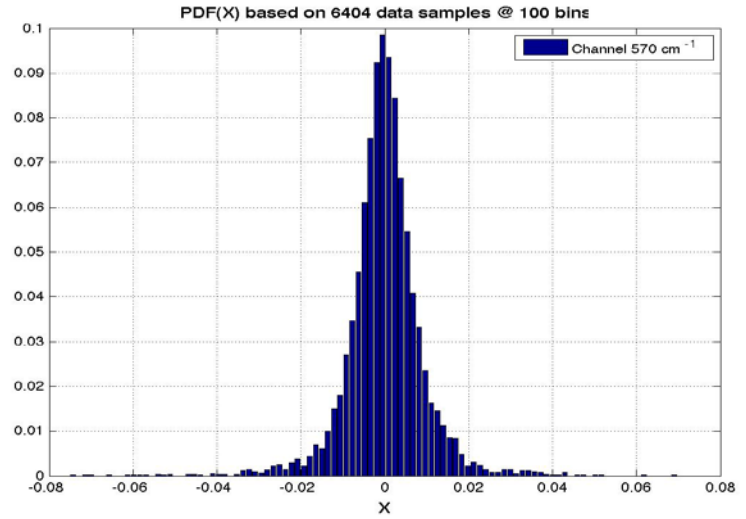
- PCRTM has been extended to far infrared and UV-Vis spectral regions
  - Several methods has been developed (Liu et al. App. Optics, 2016, Yang et al. Optic Express 2016, Liu et al, 14 presentations at CLARREO science team meetings, 2011-2017, more than 20 conference presentations and papers)
- Very fast parameterizations
  - Needed for hyperspectral data analysis
  - Achieved by both reduction in spectral domain and in multiple scattering domain
  - A few miliseconds per spectrum in IR
  - 3 orders of magnitude faster than MODTRAN in solar spectral region
- Very accurate relative to reference models
  - Better than 0.03 K accuracy from far-IR to near-IR
  - Better than 0.02% accuracy from near-IR to UV-vis
- Recent intercomparisons done with other RT models
  - Sergio et al. submitted to AMT 2017
  - Aunman et al. submitted to JGR 2017
- Applications of PCRTM to different problems
  - Wu et al 2017, Chen et al 2013, Seiji et al 2011, 2014, Liu et. al 2009, 2017, Huang et. al. 2014. Pan et al. 2015, 2017, Feldman et al.2013, 3014, 2015, 2017, Bantges et al. 2016, Rose et al. 2013

PCRTM covers spectral range from 0.3 μm to 100 μm, added multiple scattering in the presence of solar radiation

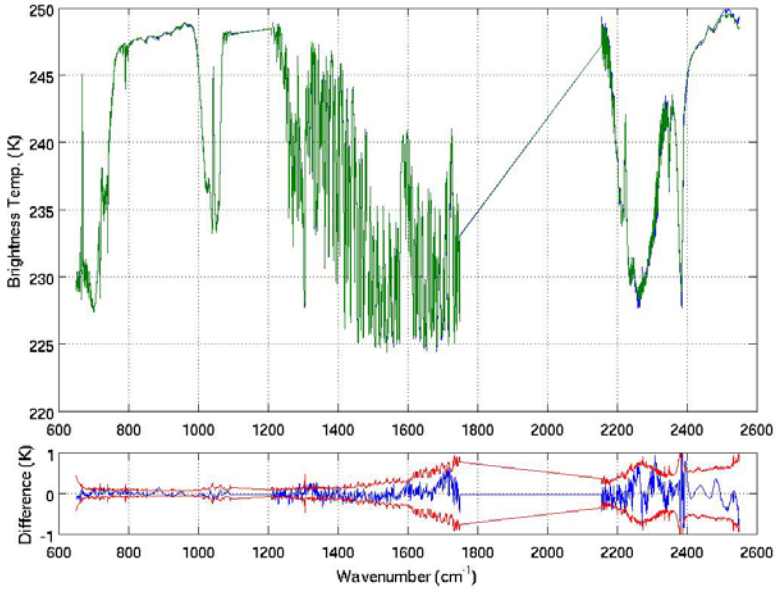
- Bias error relative to LBL is typically less than 0.002 K
- The PDF of errors at different frequencies are Gaussian distribution
- RMS error < 0.03K for IR and < $5x10^{-4}$ $mW/cm^2/sr/cm^{-1}$ for solar (< ~0.02%)

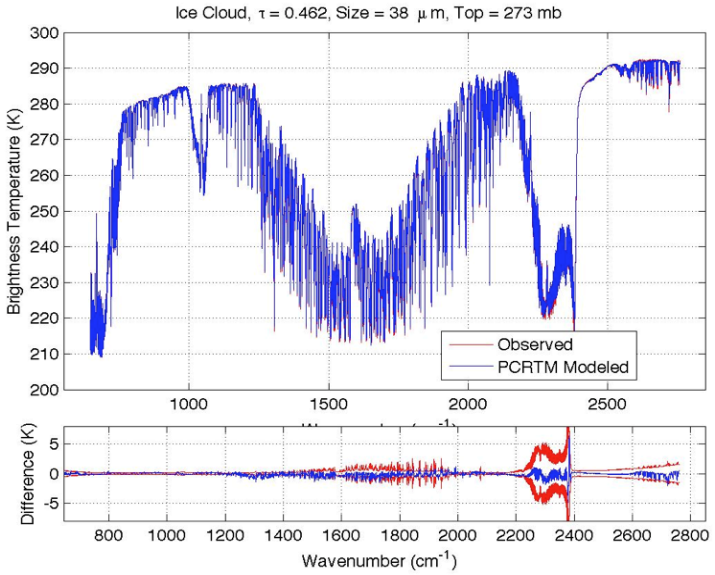


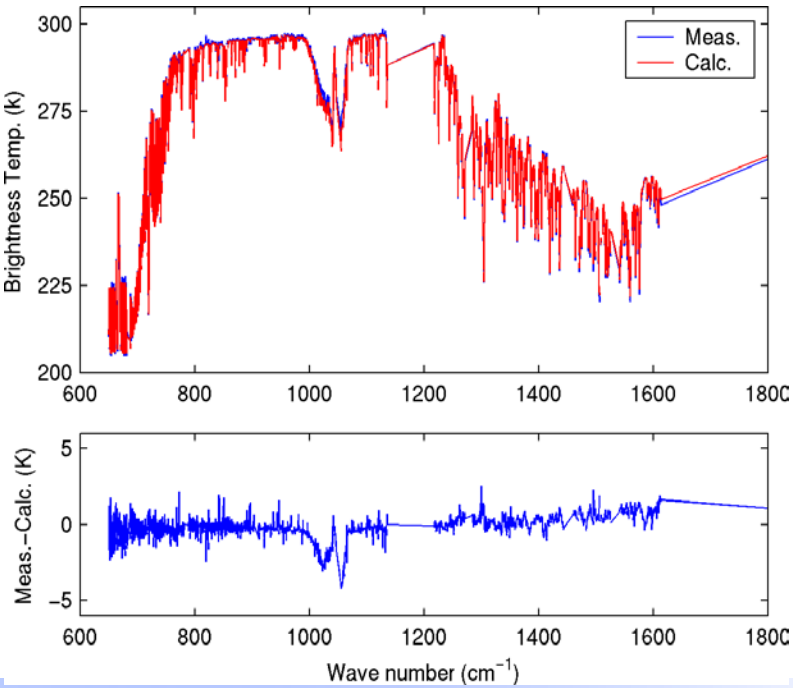


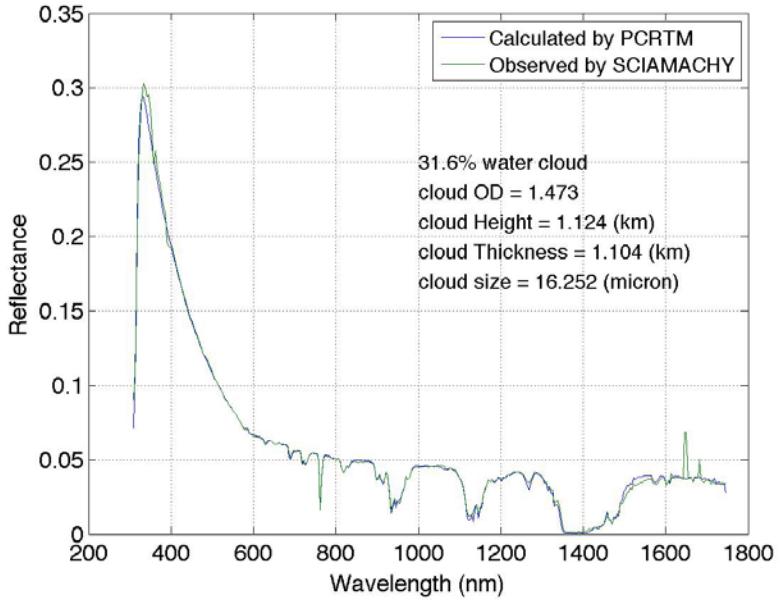


Examples of PCRTM Simulations of CrIS, IASI, AIRS, NAST-I, and SCIAMACHY real data

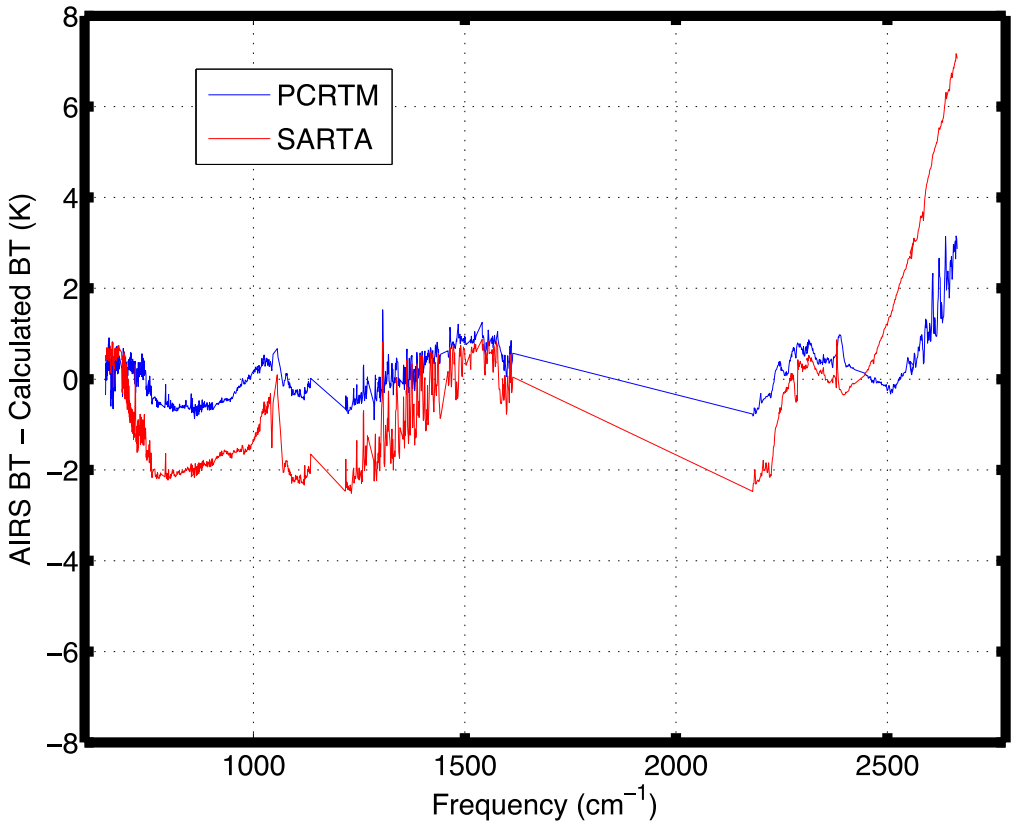


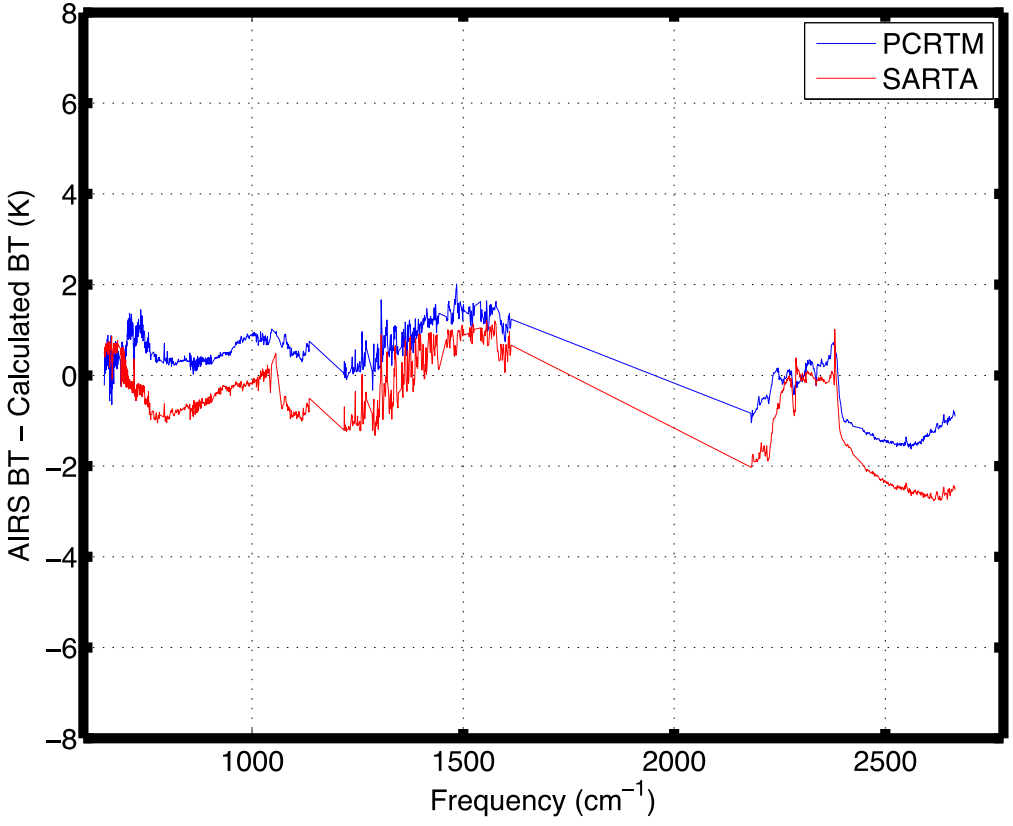






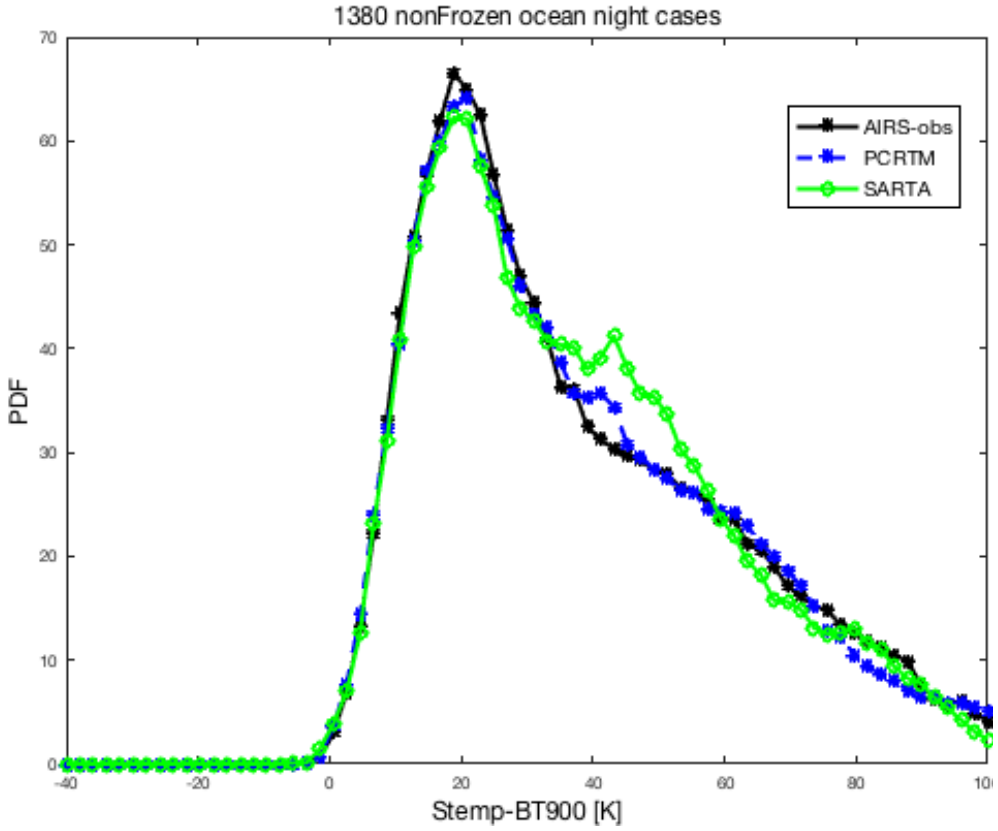
Recent Results on Simulating AIRS spectra in the using ECMWF cloud fields (Aunman and Sergio et al)

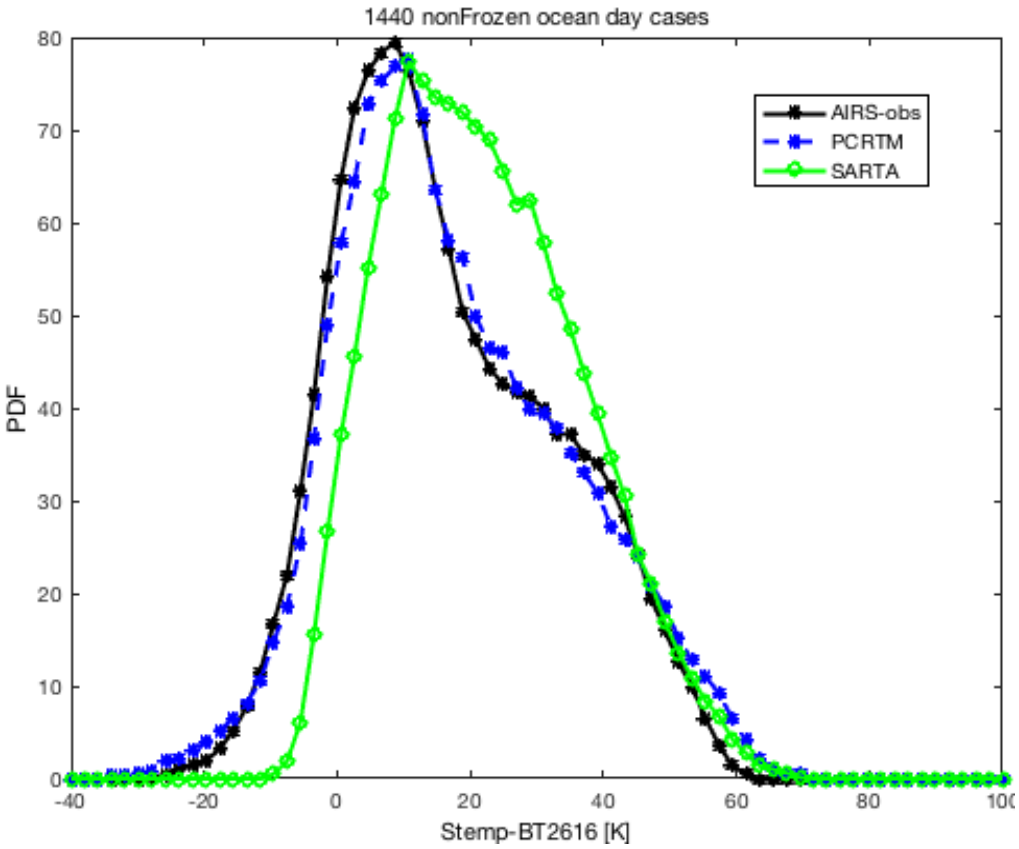




Thanks to Sergio and Aunman for providing the ECMWF model outputs, matched AIRS radiances, and SARTA results!

PDF of AIRS observed and RTM Simulated BT at two difference spectral regions

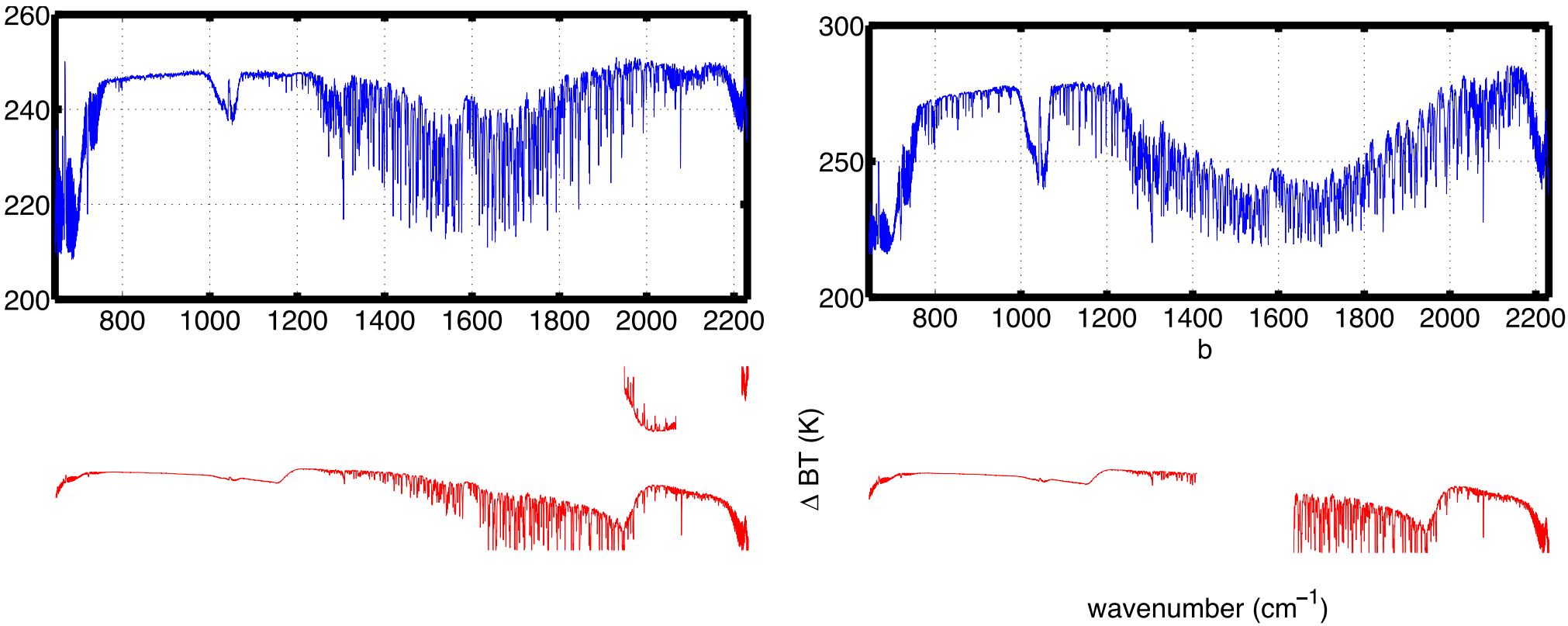




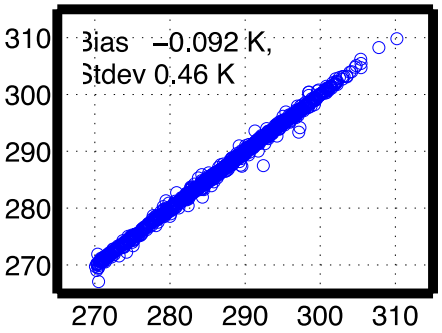
Recent Updates on Single FOV Cloudy Retrievals

- PCRTM Retrieval Algorithm (PCRTM-RA) performs single FOV retrieval of the following properties:
  - cloud phase, effective cloud height, cloud microphysical properties
  - atmospheric temperature, water vapor and trace gas profiles
  - Surface skin temperature and emissivity spectra
- PCETM-RA algorithm updates
  - Improved the capability to include microwave sensors to improve performance below thick clouds
  - Improved minimizations scheme
- Performed sensitivity studies on the PCRTM-RA in the presence of clouds
- Performed error analysis
  - Rigorous optimal estimation error estimates
  - Simulation retrieval studies
- Validate the retrieval performance using CALIPSO and ECMWF data

Cloud phase discerning



End-to-end simulation study
Tskin & cloud retrieval



ud Vis. Opt. Dep.

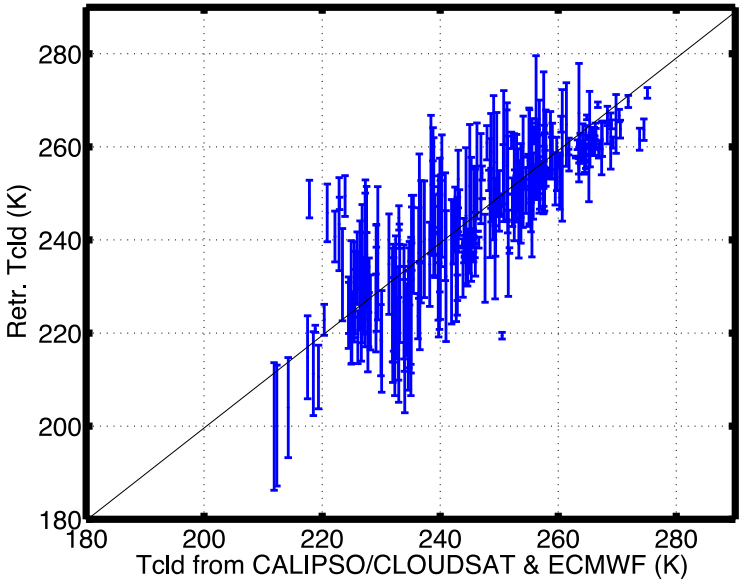
Bias –0.017,
Stdev 0.13

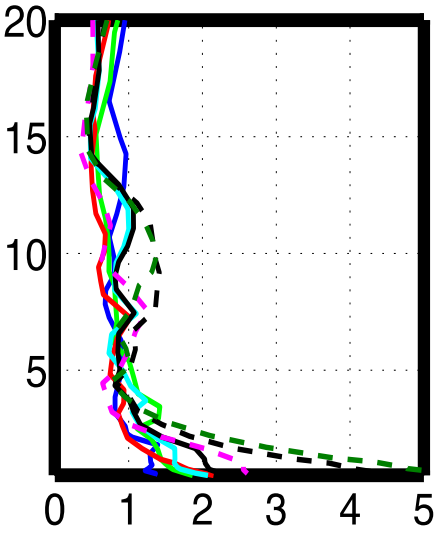
CONFUSION MATRIX FOR CLOUD PHASE RETRIEVAL

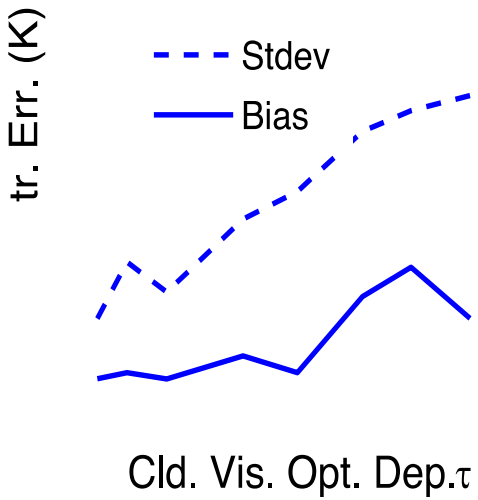
Output Class		Ice Cloud	Water Cloud	
	Ice Cloud	47.98% [1]50.15% [2]47.18% **A**	0.58% [1]0.31% [2]0.68% **B**	Sensitivity 98.81% [1]99.39% [2]98.58% **C**
	Water Cloud	0.91% [1]2.77% [2]0.23% **D**	50.53% [1]46.77% [2]51.91% **E**	Sensitivity 98.24% [1]94.54% [2]99.56% **F**
		Precision 98.15% [1]94.77% [2]99.51% **G**	Precision 98.87% [1]99.34% [2]98.71% **H**	Accuracy 98.52% [1]96.92% [2]99.09% **I**
	Target Class			

[1] over land, [2] over ocean

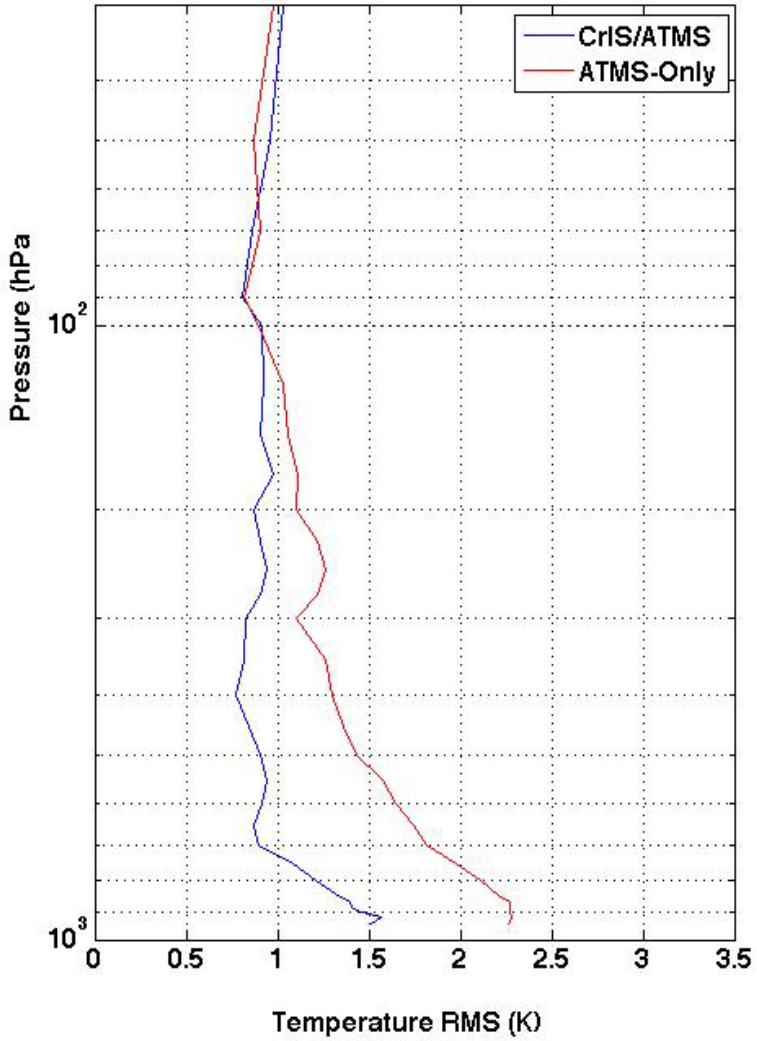
Validation of real data retrieval using ECMWF and CALIOP/CPR data

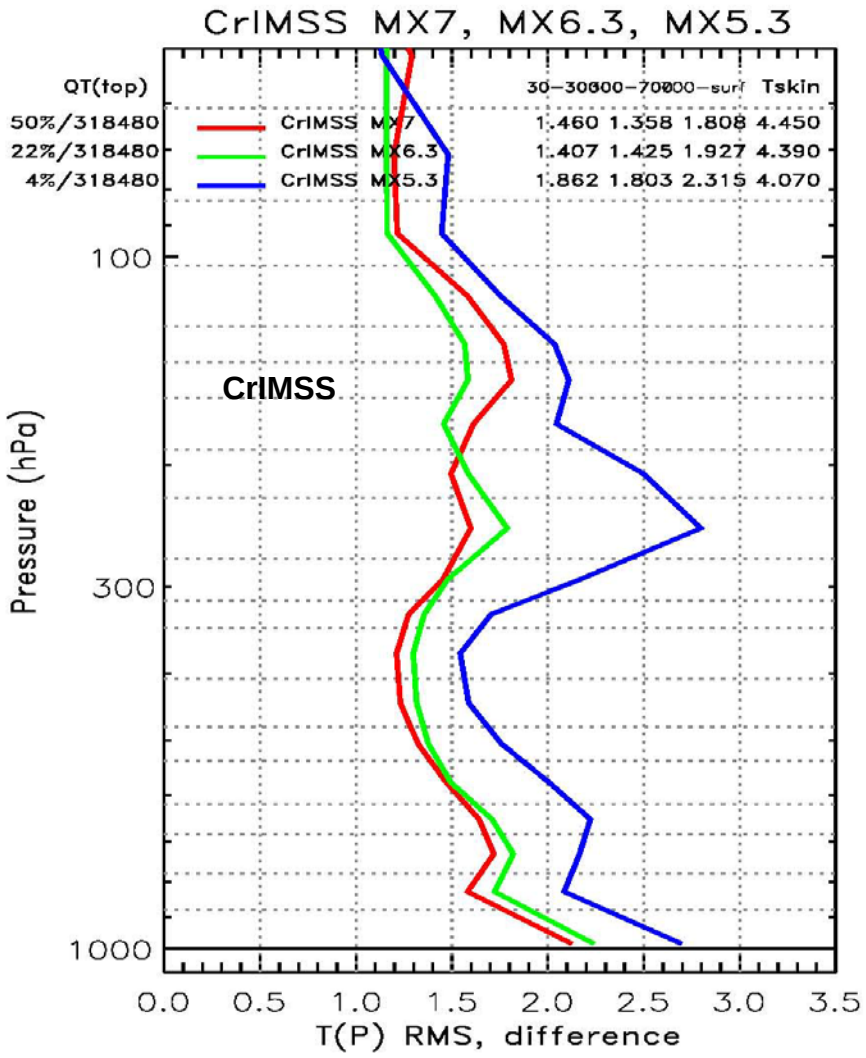




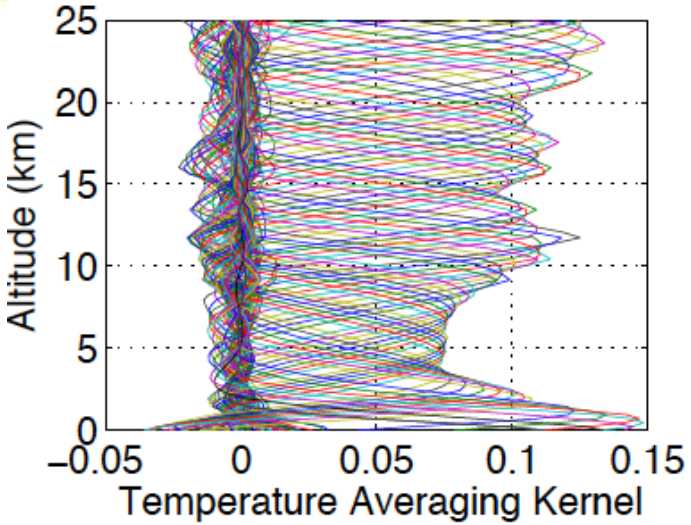


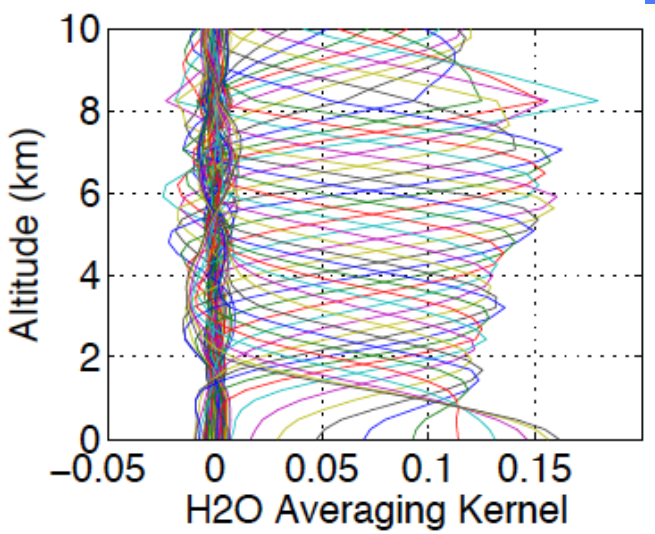
Atmospheric temperature profile retrieval with and without multiple spectral regions

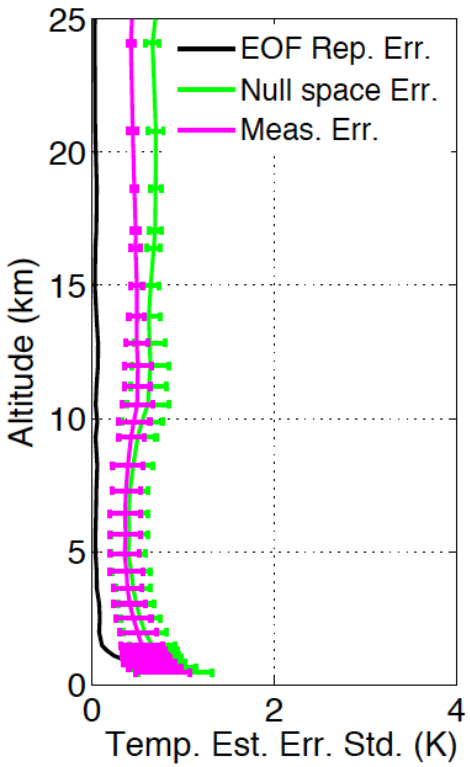


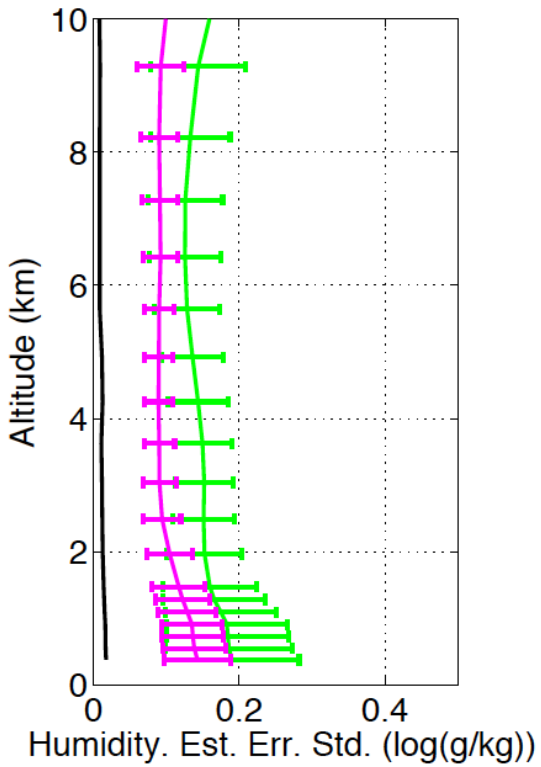


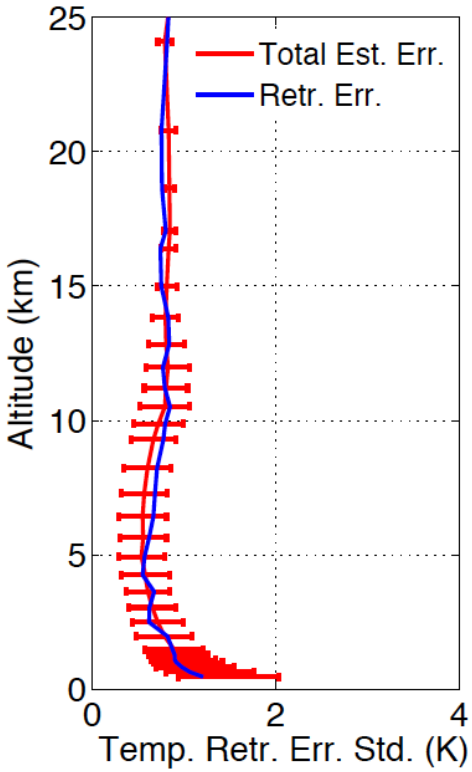
End-to-end simulation study
T and h_2O retrieval

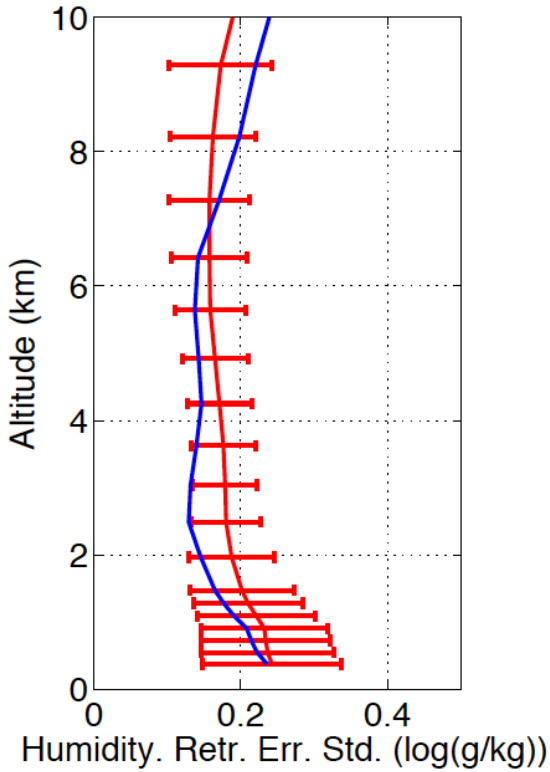






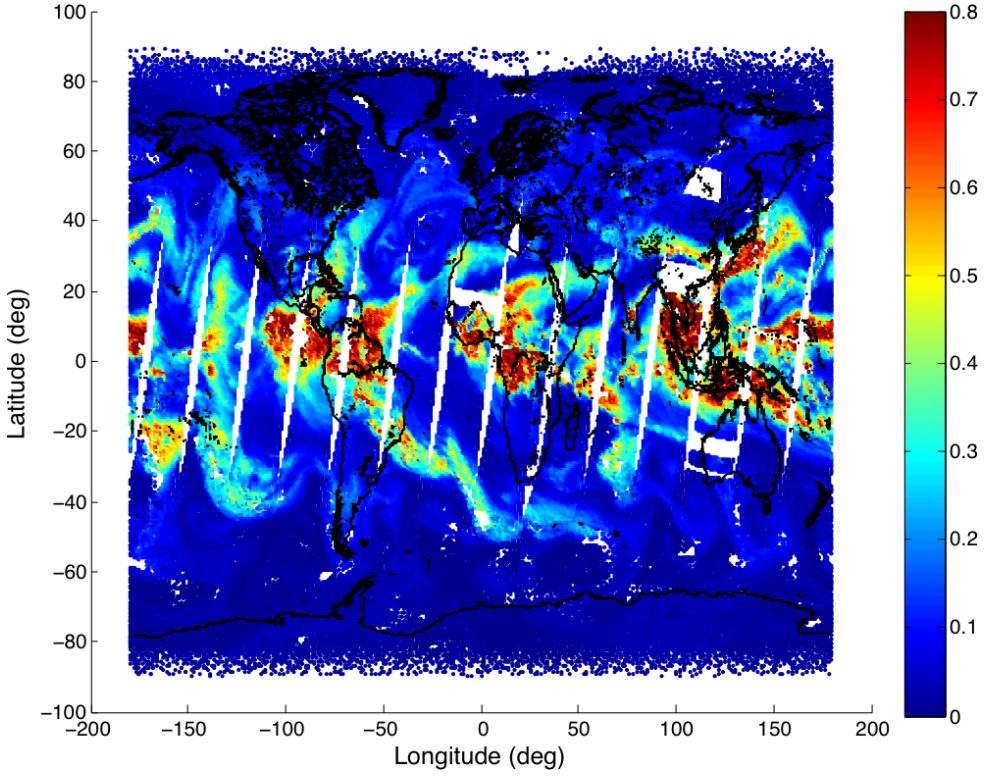




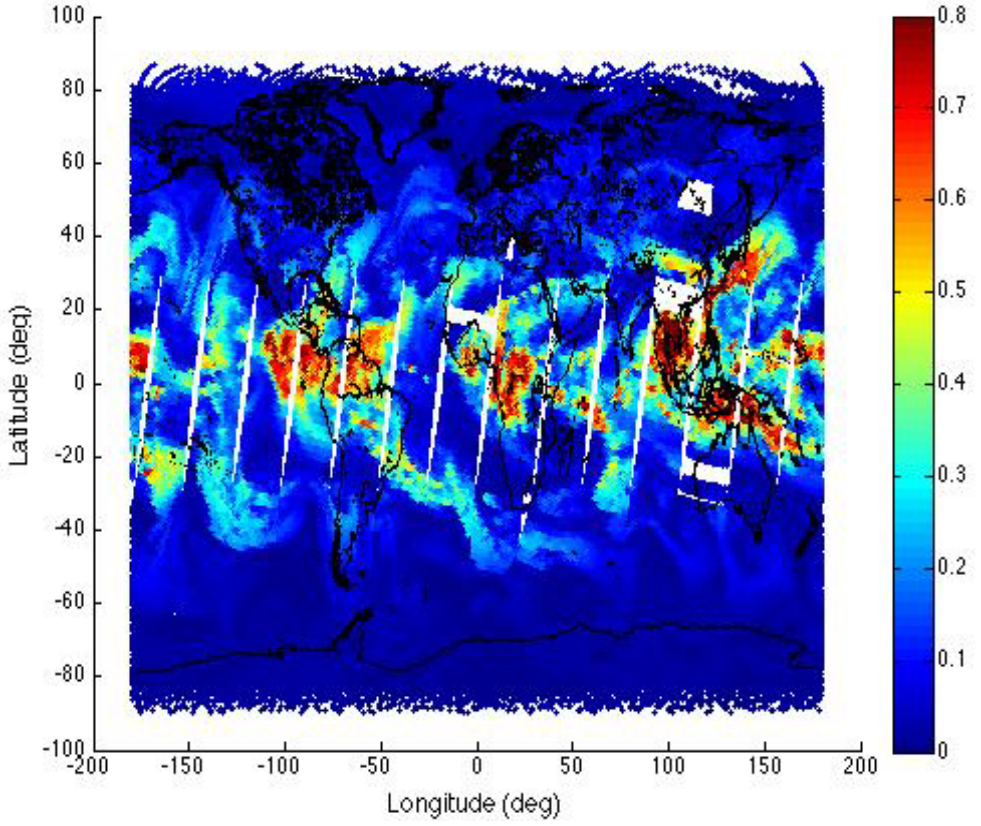


Comparison of PCRTM-RA Retrieved and ECMWF Atmospheric Water Vapor from focus day CrIS/ATMS data

Retrieved 300 hPa from CrIS/ATMS using PCRTM-RA

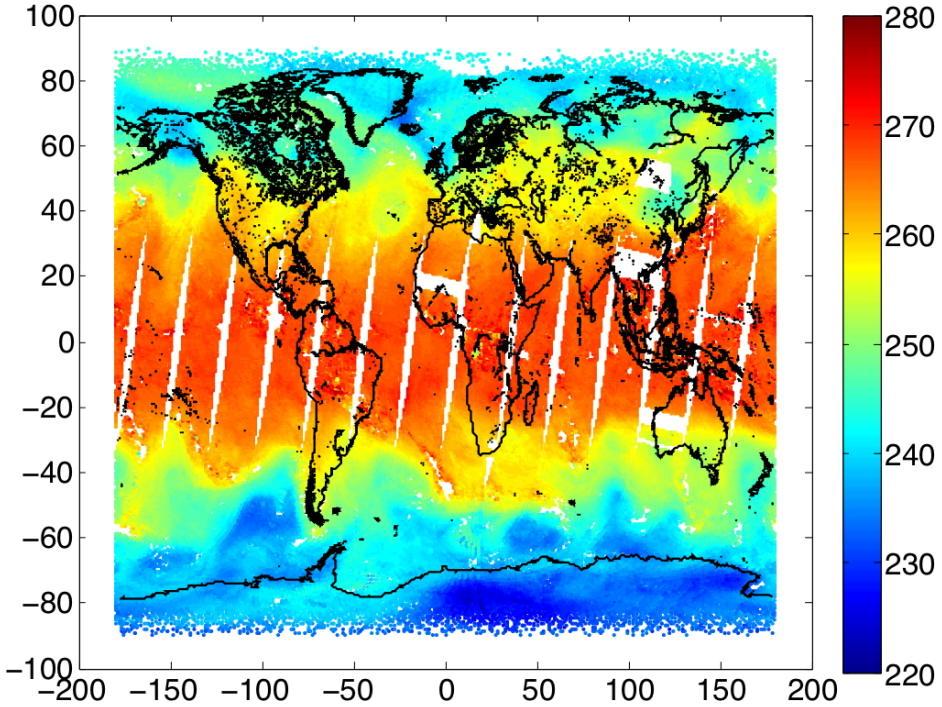


300 hPa from ECMWF

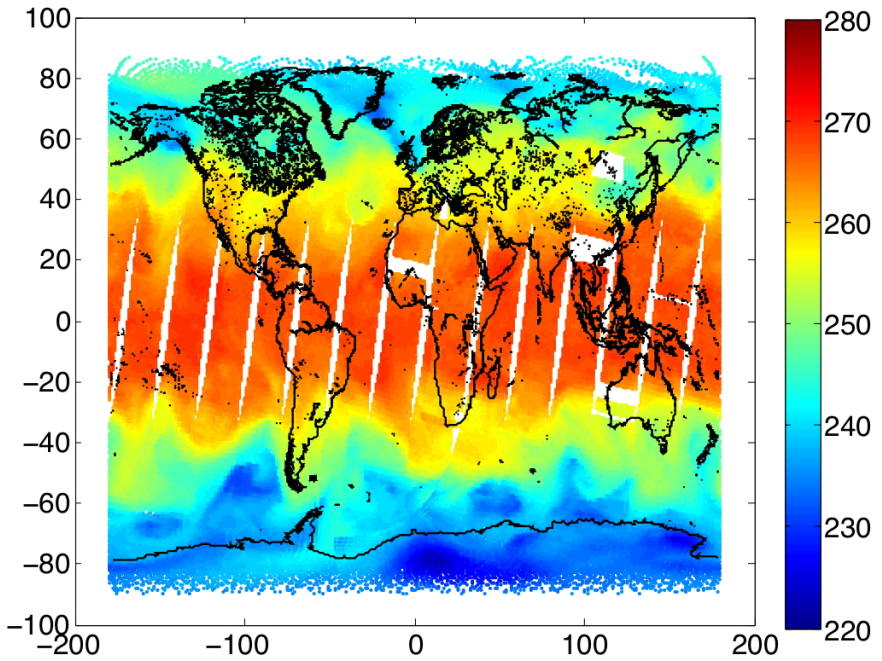


Comparison of PCRTM-RA Retrieved and ECMWF Atmospheric Temperature from focus day CrIS/ATMS data

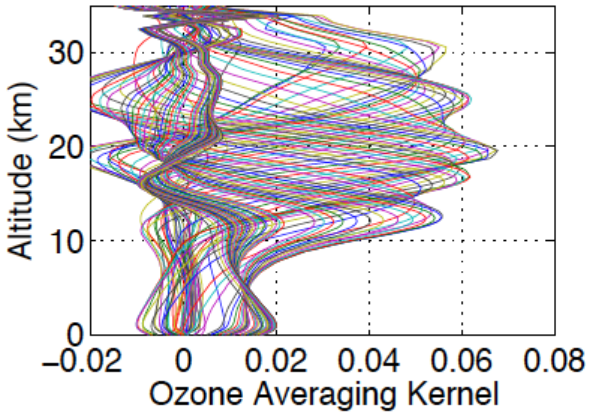
500 hPa Retrieved from ATMS/CrIS using PCRTM_RA

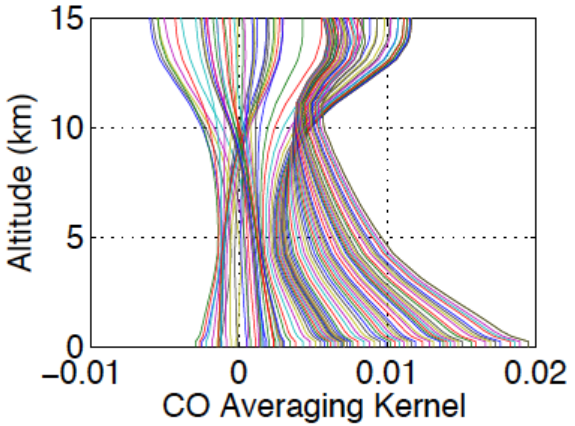


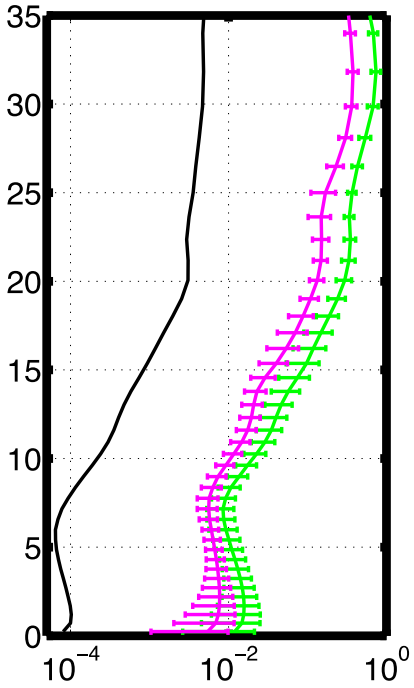
500 hPa Temperature from ECMWF

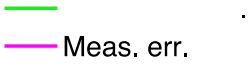


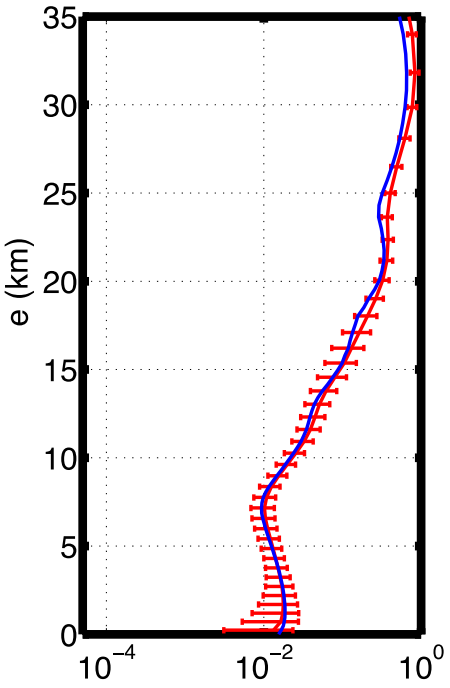
End-to-end simulation study
O_3 and CO retrieval





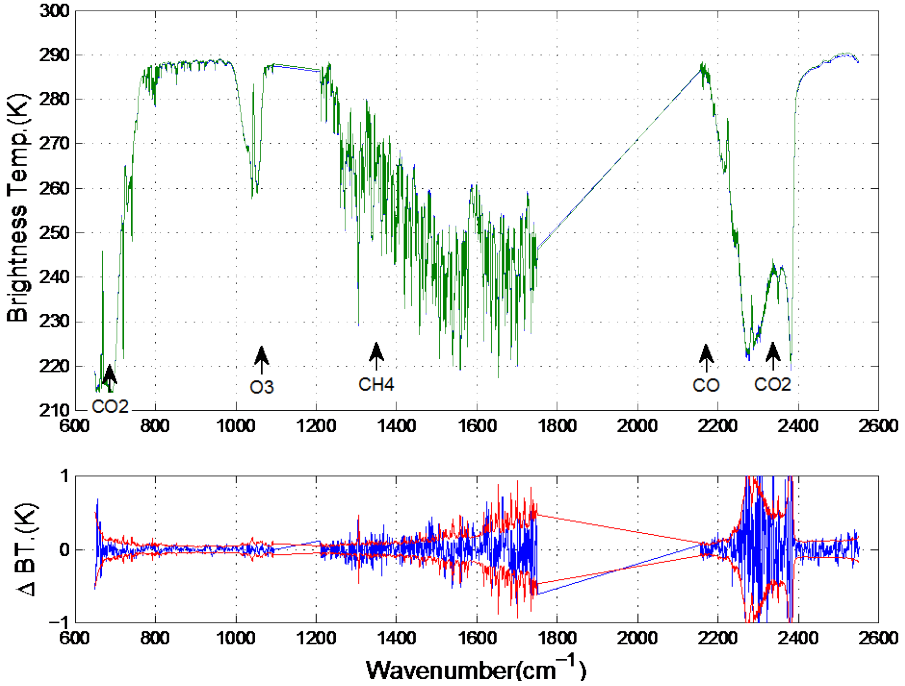


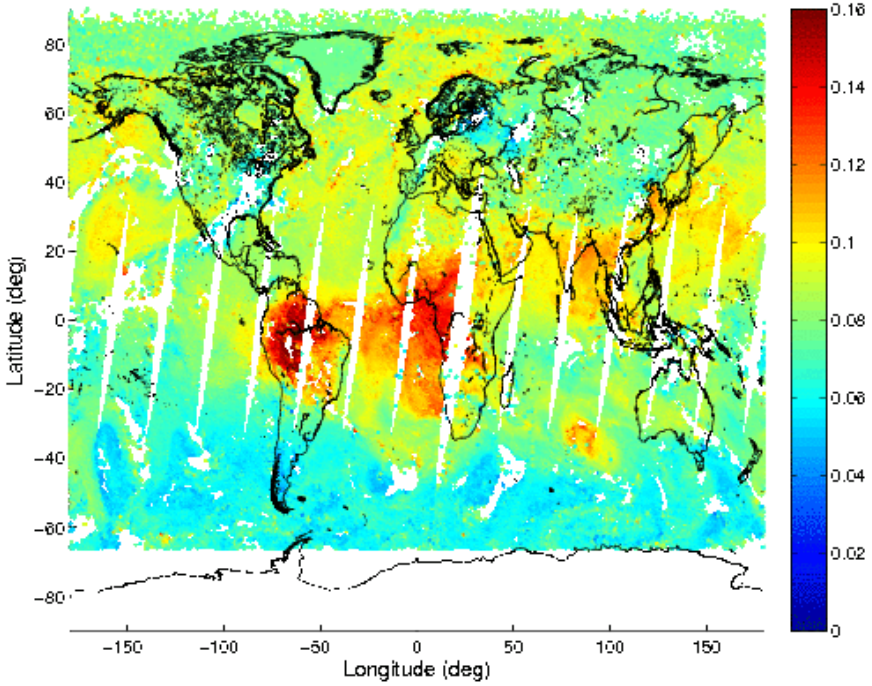




Atmospheric and Surface Property Retrieval using PCRTM

- PCRTM can be used to retrieve
  - Atmospheric temperature, water, trace gas vertical profiles
  - Cloud phase, height, temperature, particle size, optical depth
  - Surface emissivity, skin temperature
- The movie below shows global CO retrievals from December 21-27, 2016
  - CO mixing ratio at 300 mbar
  - Full spectral resolution CrIS data used





Summary and conclusions

- Accurate radiative transfer model capable of handling multiple scattering clouds are needed for the single FOV retrieval algorithm
  - PCRTM has been trained to work from far-IR to UV-Vis spectral regions
  - PCRTM has been updated to handle multiple scattering clouds
  - A few millisecod per spectrum in IR spectral region
  - 3 orders of magnitude faster than MODTRAN in solar spectral region
  - Accurate relative to line-by-line models
- Single FOV cloud retrieval algorithm is capable of retrieving
  - Atmospheric Temperature, Water, CO2, CO, CH4, O3, and N2O profiles
  - Cloud phase, height, temperature, size, optical depth
  - Surface emissivity spectrum and skin temperature
- Will further support NUCAPS product validation under cloudy sky conditions
  - Apply two independent algorithm to handle the same data set
  - With the ultimate goal to improve retrievals under cloudy conditions and obtained cloud microphysical properties