A Comparison of Fast Hyperspectral Radiative Transfer Models

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Motivation

- To assess the clear sky AIRS RTA by comparing it to other well tested fast models

- Support retrieval developments that incorporate clouds by determining current cloudy RTA capabilities

- Develop both clear and cloudy forward model expertise at NASA JPL

Radiative Transfer Models

SARTA

- *Stand-Alone Radiative Transfer Algorithm*
- Developed at UMBC
- Line-by-line model : KCARTA
- PCSLAM scattering code

CRTM v2.1.3

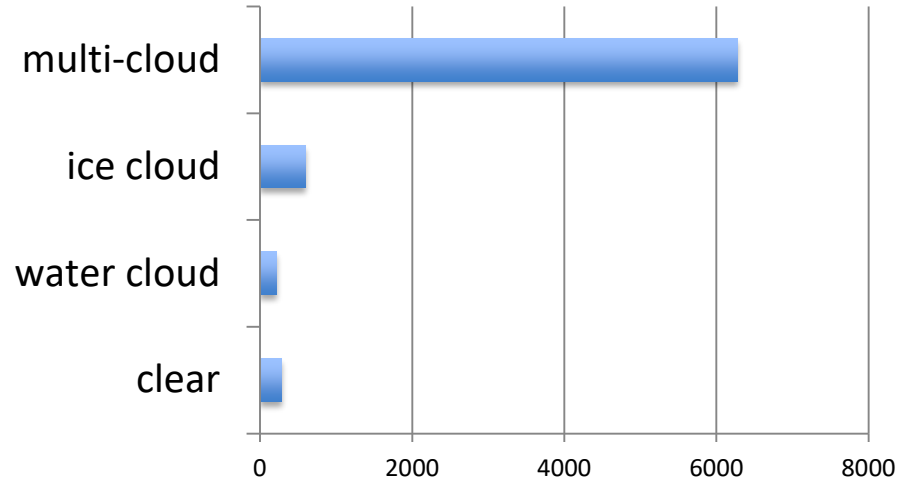
- *Community Radiative Transfer Model*
- Developed by NOAA
- Scattering: Adding Doubling or Successive order of interaction
- Line-by-line model : LBLRTM

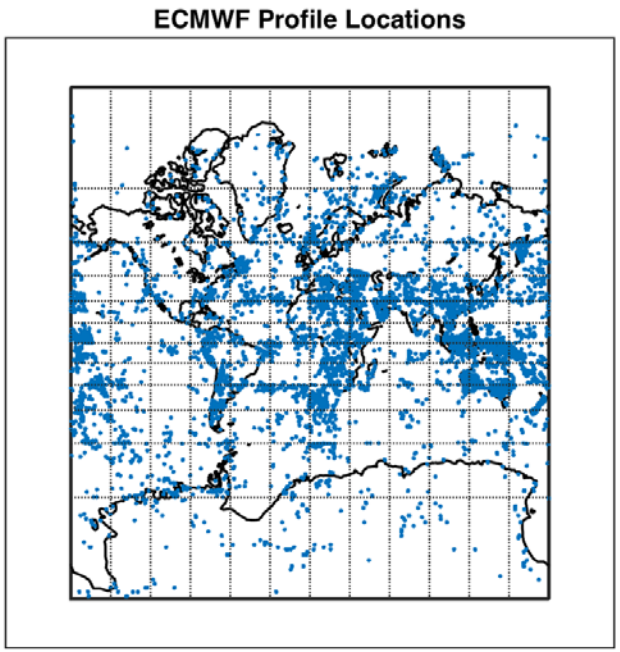
RTTOV v11.4

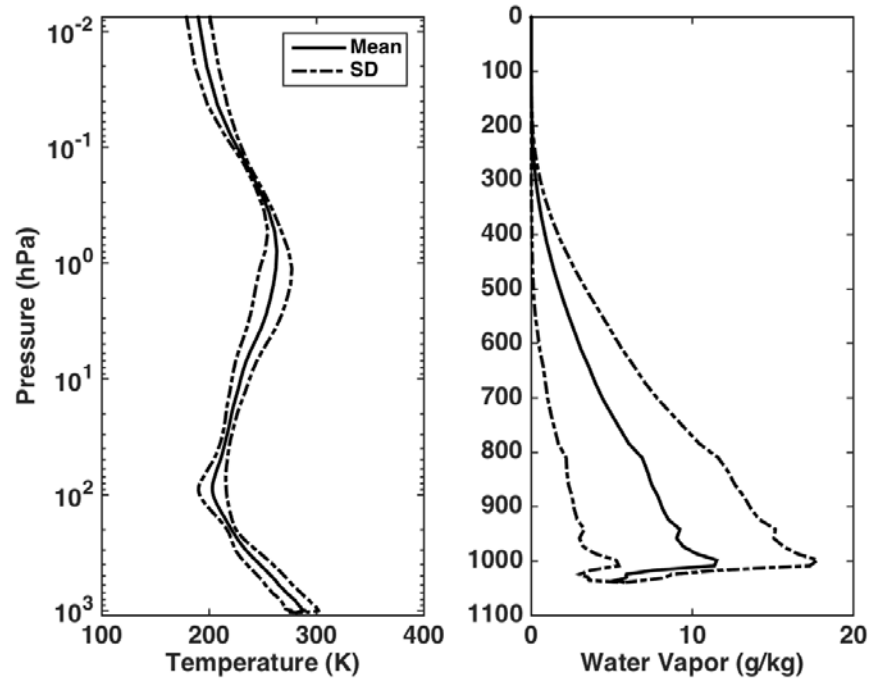
- *Radiative Transfer for TOVS*
- Developed by Eumestat
- Scattering is parameterized rather then treated explicitly

RTA Input

- 7377 ECMWF profiles
- T,P,q,O_3,CO,N_2O,CO_2,CH_4,clw c,ciwc,cloud coverage
- Emissivity, reflectivity, surface temperature

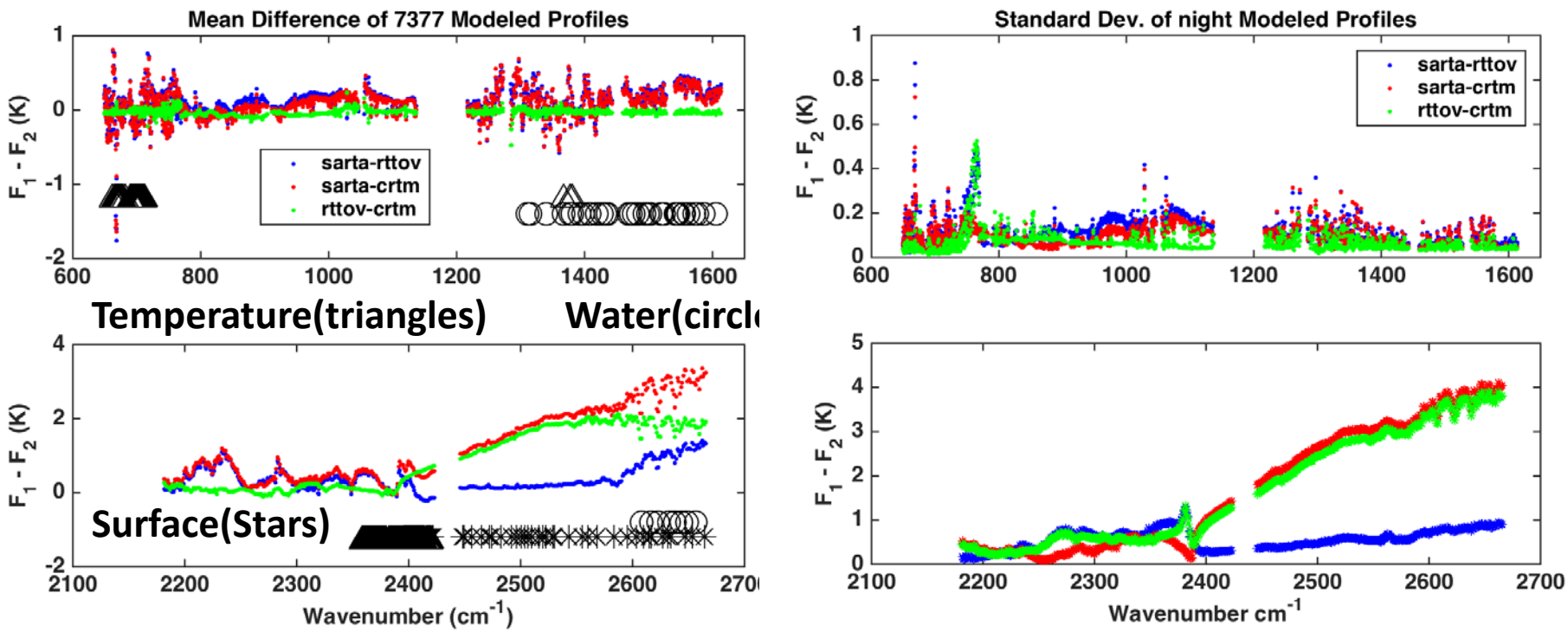






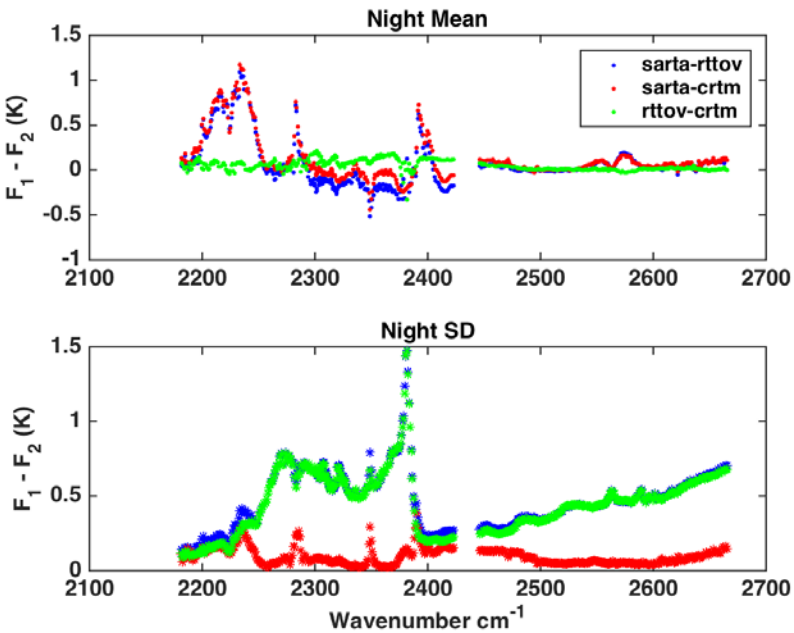
All Clear Cases

- CRTM, RTTOV, and SARTA were run using the same 7377 ECMWF profiles
- Agreement in 2 RTA's helps with understanding differences in the third RTA
- RTTOV and CRTM are nearly identical in the longwave
- Different foundational Line-by-Line models likely leading to the small differences between SARTA and RTTOV/CRTM
- RTTOV/SARTA have Large differences (>1k) from CRTM in the shortwave



Slice and dice up the shortwave

- RTTOV/CRTM has a 1k mean difference from SARTA at 2200-2250
- SARTA/CRTM ~ .7K SD difference from RTTOV at 2250-2400
- SARTA/CRTM .2-.5K different from RTTOV at 2450-2600



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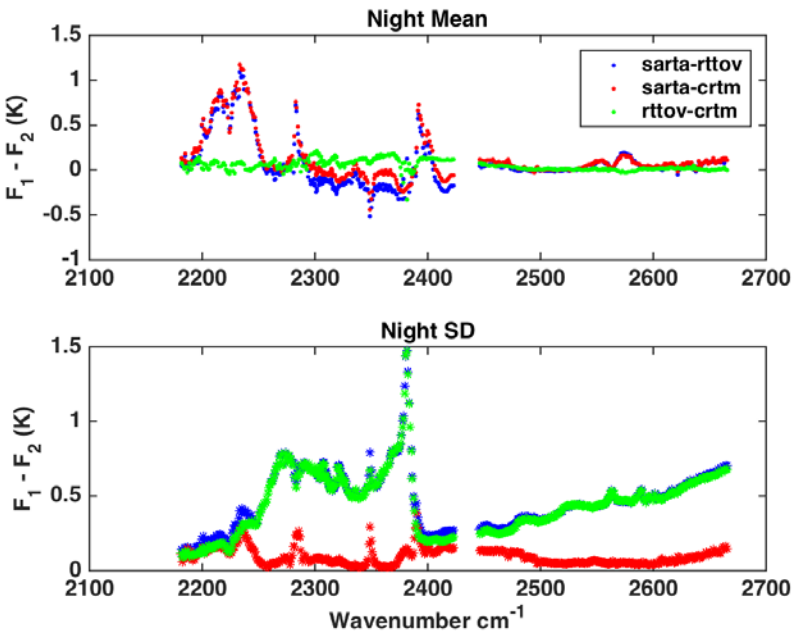
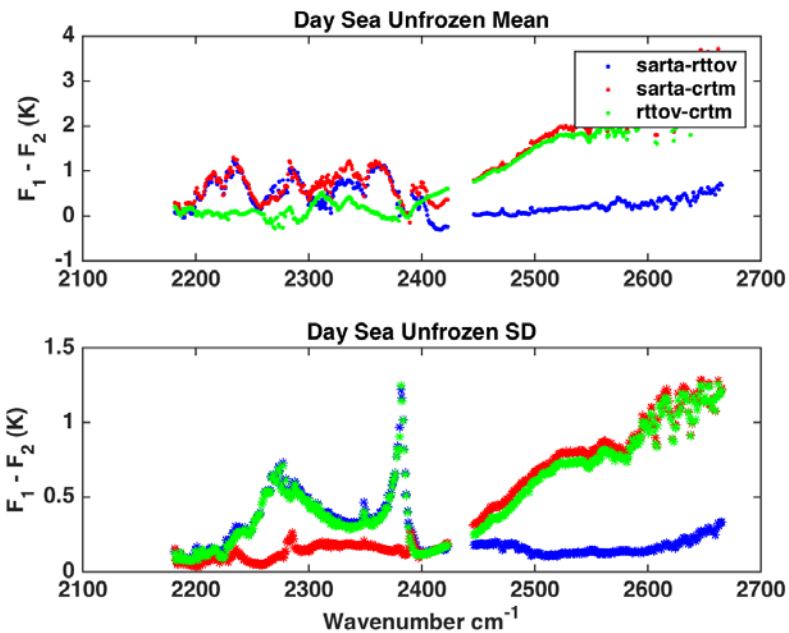
- SARTA has approximately a 1K bias from CRTM/RTTOV between 2200-2400
- Daytime switches the CRTM to a poor agreement from 2450-2600
- No day/night difference in RTTOV's .5K SD disagreement at 2250-2400





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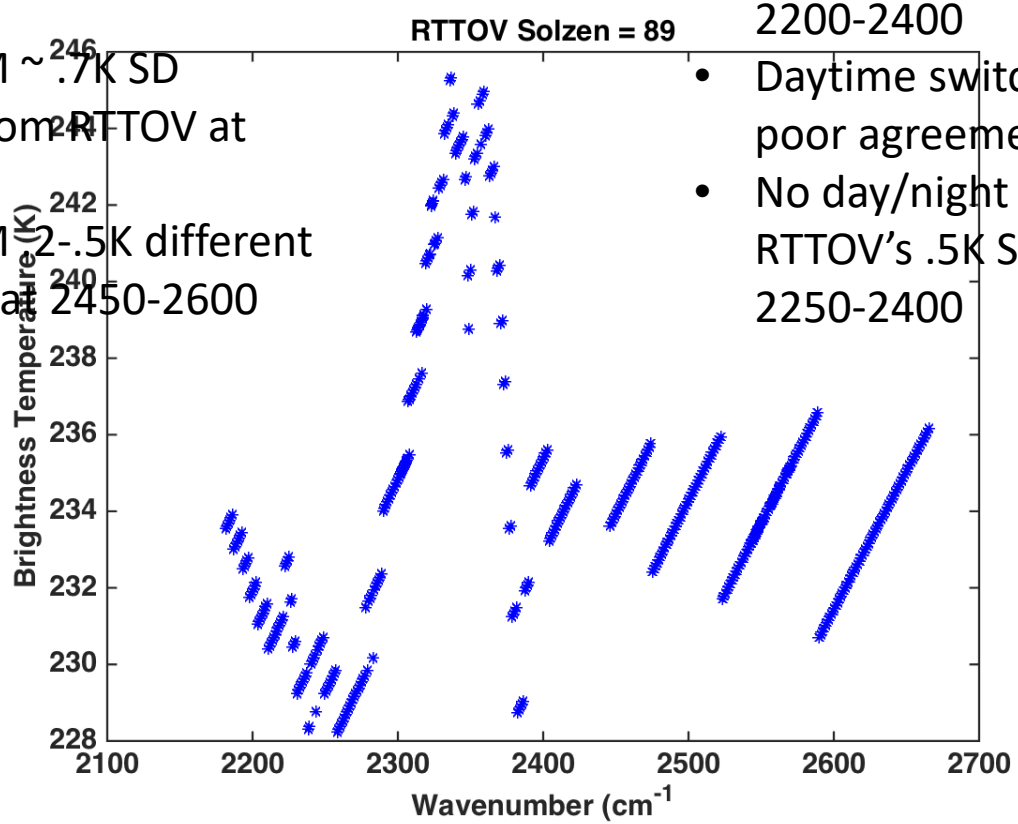
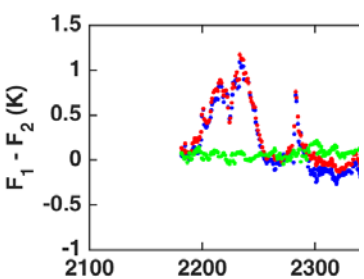
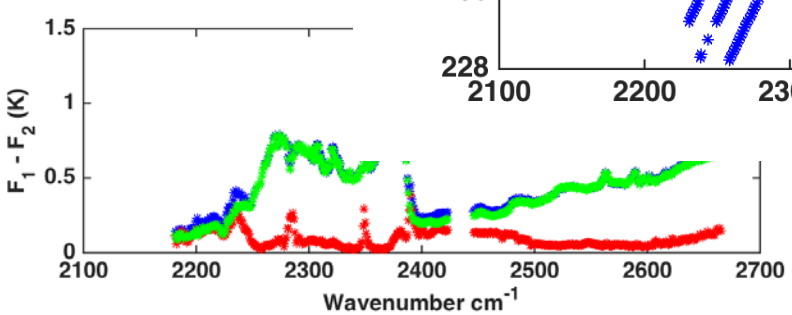
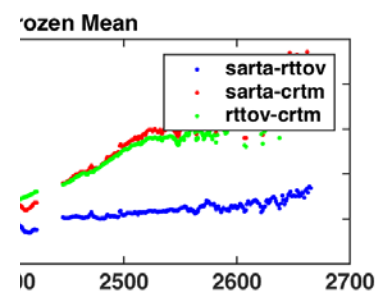
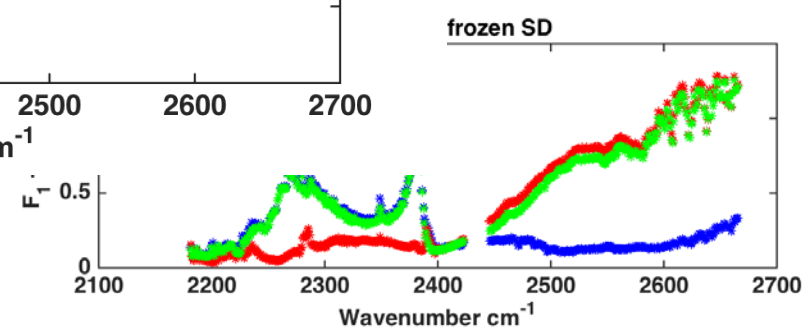
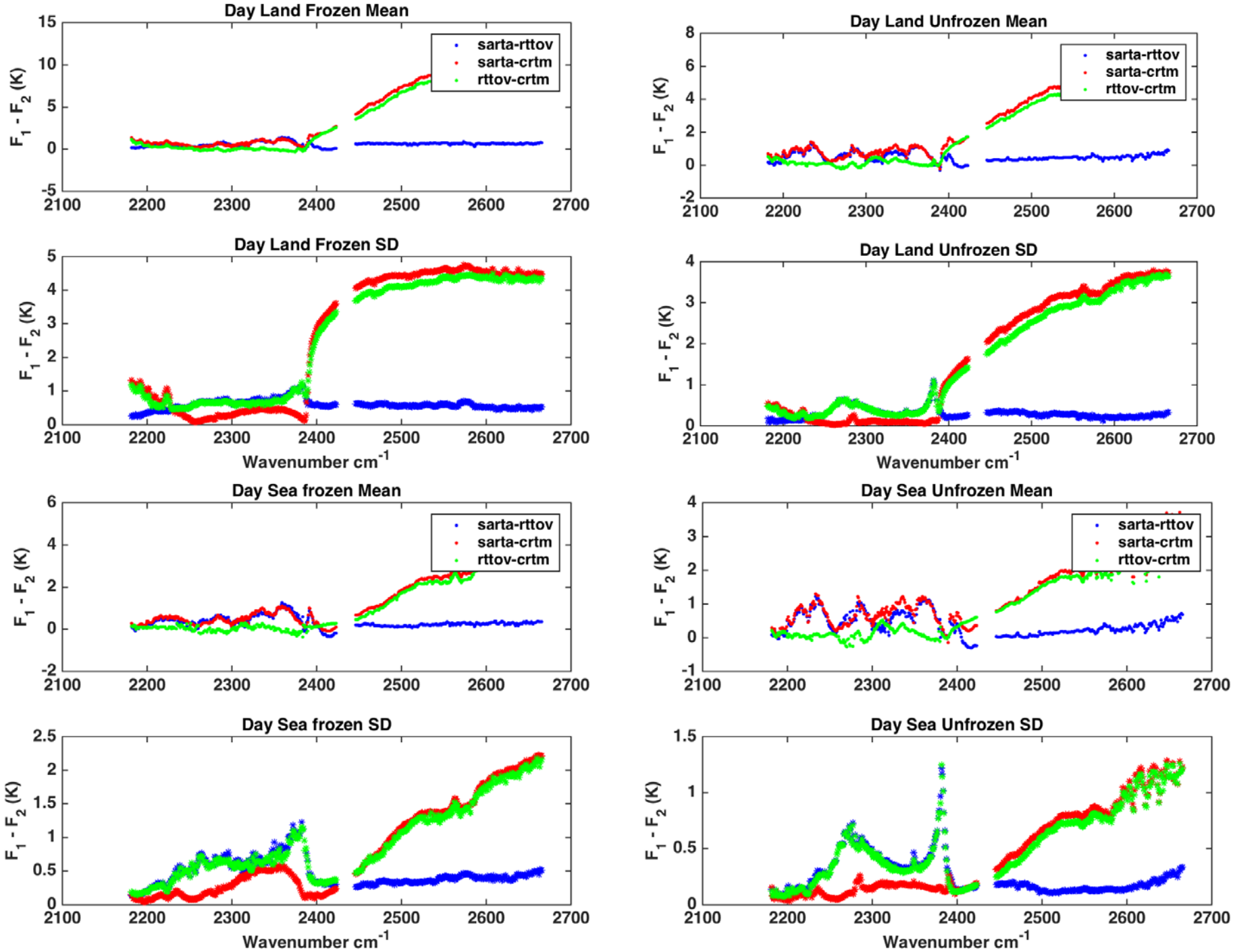


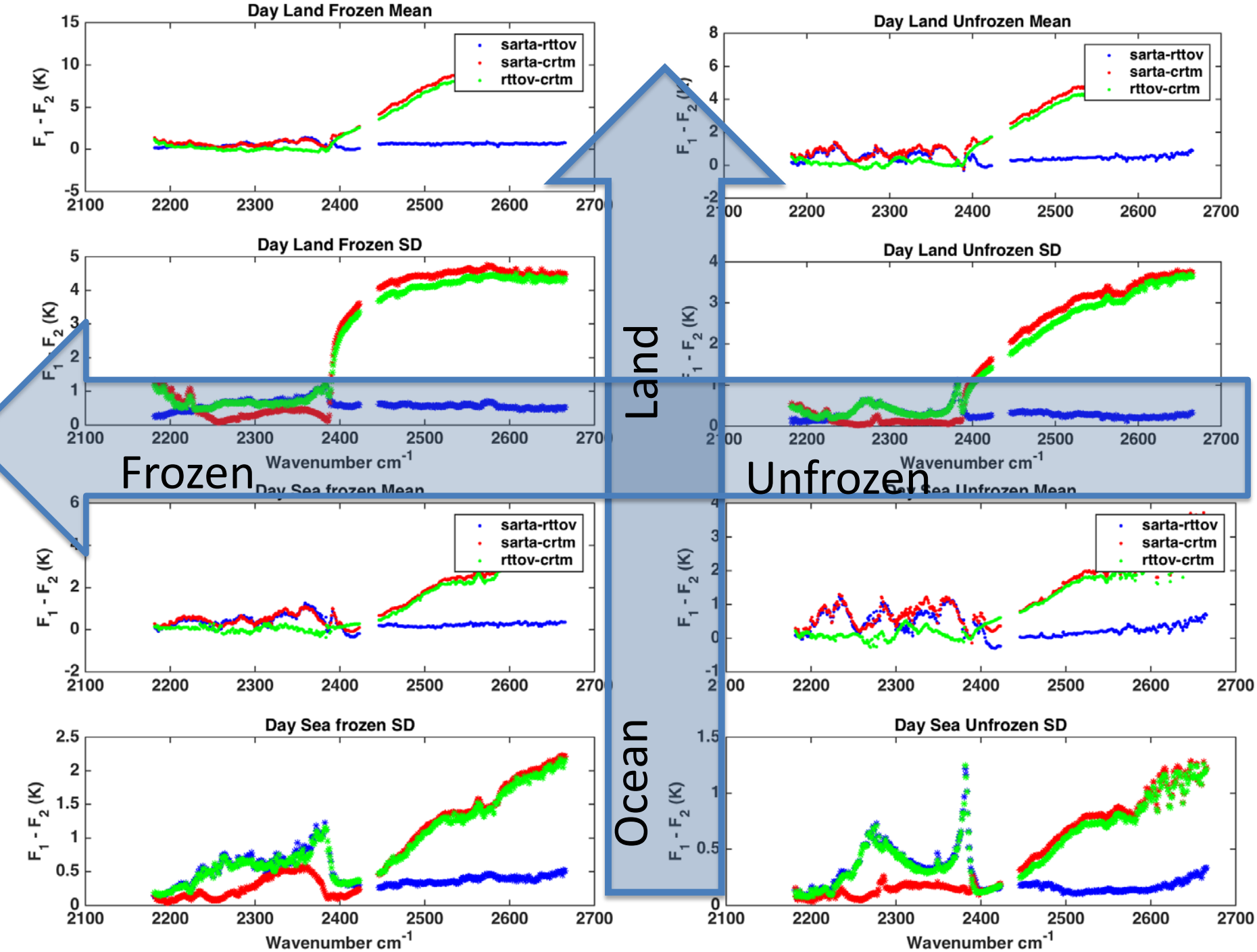









Day Land Frozen Mean
Day Land Unfrozen Mean
Day Land Frozen SD
Day Land Unfrozen SD
Day Sea frozen Mean
Day Sea Unfrozen Mean
Day Sea frozen SD
Day Sea Unfrozen SD
sarta-rttov
sarta-crtm
rttov-crtm
F1 - F2 (K)
Wavenumber cm-1


Day Land Frozen Mean
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Day Land Unfrozen SD
Day Sea frozen Mean
Day Sea Unfrozen Mean
Day Sea frozen SD
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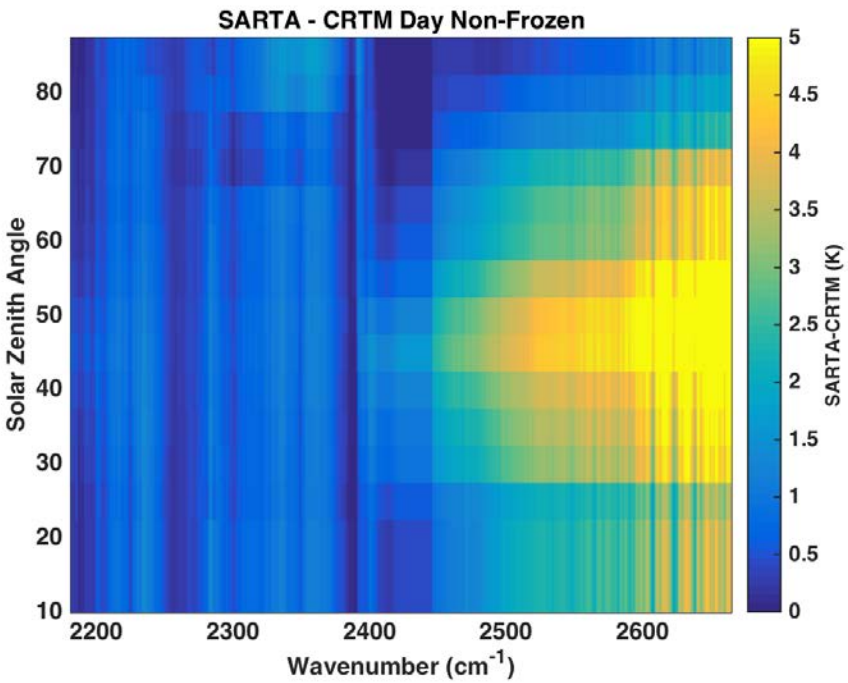
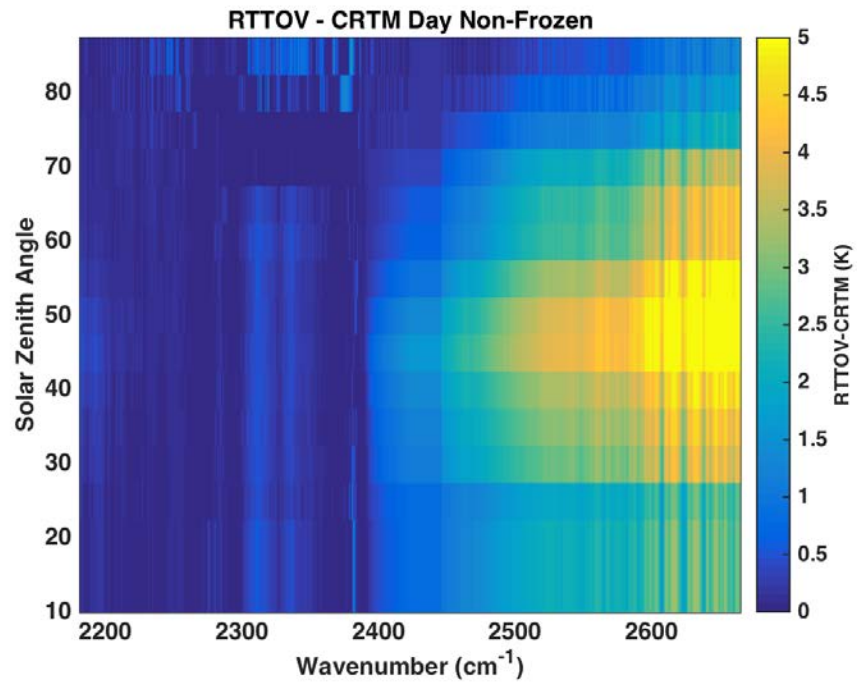
sarta-rttov
sarta-crtm
rttov-crtm
F1 - F2 (K)
Wavenumber cm-1
Land
Ocean
Frozen
Unfrozen

Solar Reflectance

- CRTM differences from SARTA and RTTOV between 2500 and 2650 peaks around solar zenith angles of 45 degrees
- The 2200- 2400 SARTA vs. CRTM/RTTOV differences (~1K) show no dependence on the solar zenith angle





Clear Summary

- CRTM and RTTOV are nearly identical in the longwave, while SARTA has biases ~.5K for certain channels
- CRTM and RTTOV are similar between 2200-2250 while SARTA has a mean difference ~.5K
- SARTA/RTTOV agree in the daytime reflected part (2400-) while CRTM mean differences and SDs vary with surface type **(a few kelvin)**
- **Pay attention to input thresholds for each model.**
- RTTOV has a piece wise step function in the shortwave that creates steps when close to dusk

Cloudy Concerns

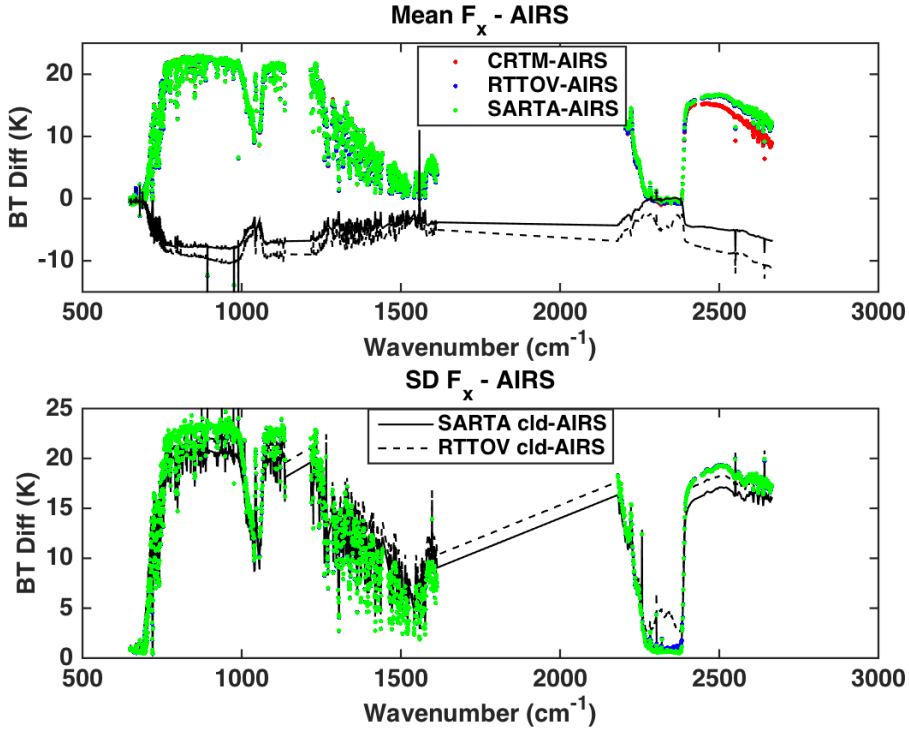
RTTOV

- Requires layered profiles of liquid or ice water content in g/m^3 (from leveled g/g)
- There are 5 choices for water clouds (cumulus, stratus, polluted, ocean/land) and a single ice cloud
- Requires profiles of cloud coverage

CRTM

- Requires layered profiles of clwc and ciwc in kg/m^2
- Requires parameterizations for liquid and ice effective radius
- Assumes complete cloud coverage, so cloud fraction and overlap must be parameterized
- Two different scattering choices available

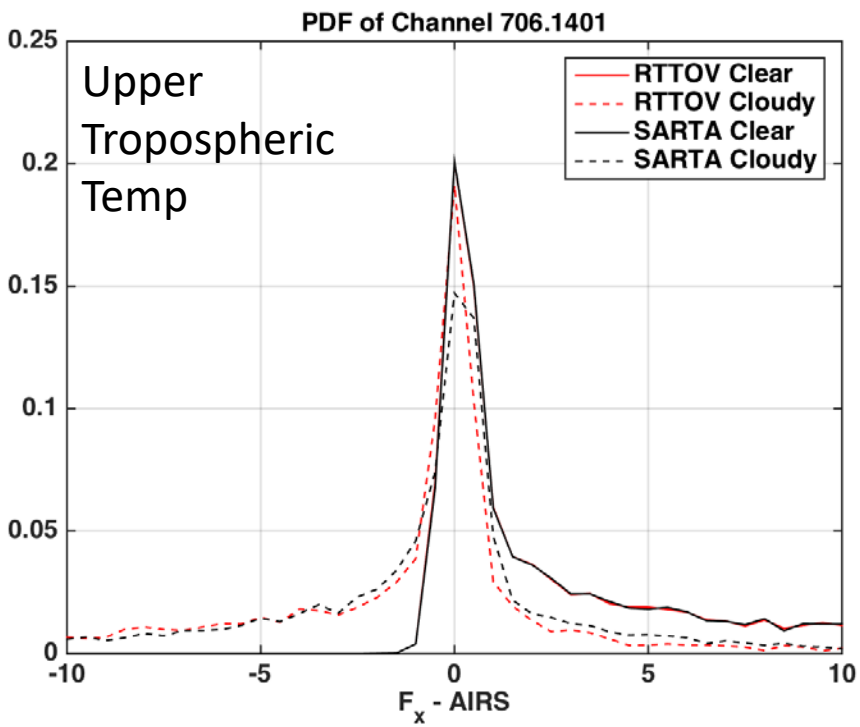
Model-AIRS

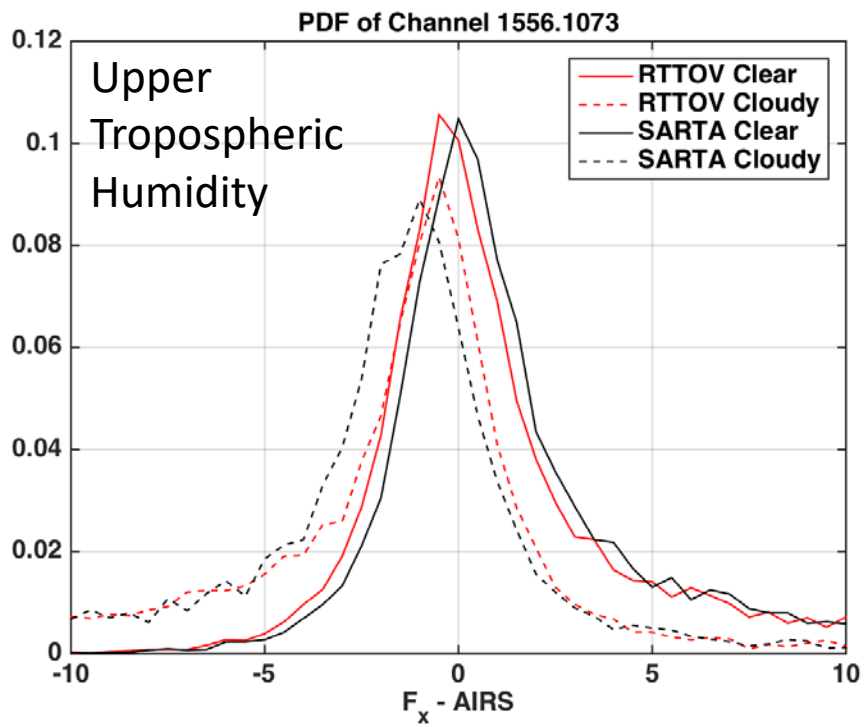


- Colored Lines = Clear Runs
  Black Lines = Cloudy Runs
- Something failed in CRTM and the results were quite poor
- Both SARTA and RTTOV reduce the mean difference in the shortwave and longwave to ~-10K **(still to cold)**
- Standard deviation wasn't noticeable reduced
- Suggests that parameterizations were fit with empirical results from an ensemble of states, rather then with knowledge of cloud microphysics

Channel PDFs

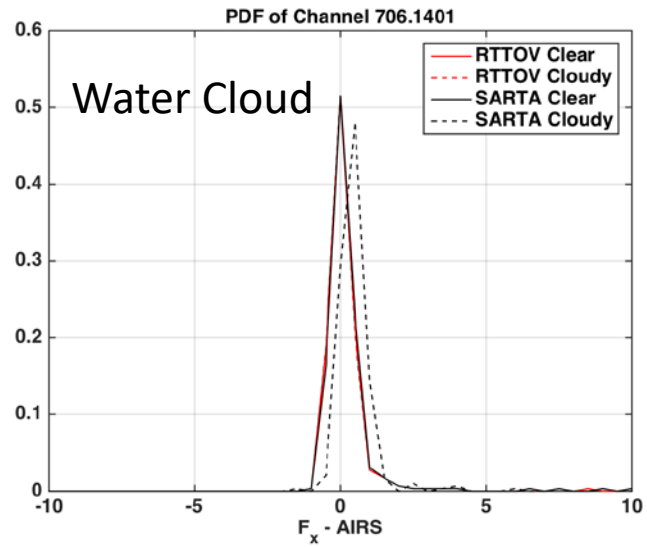
- The upper tropospheric channel was too warm and cloudy model spread the error to the negative tail for both SARTA and RTTOV
- The upper tropospheric humidity channel actually had the peak shifted away from zero to the negative for both SARTA and RTTOV
- Since both SARTA and RTTOV are behaving similarly its fair to question the validity of the cloud geophysical variables produced by ECMWF

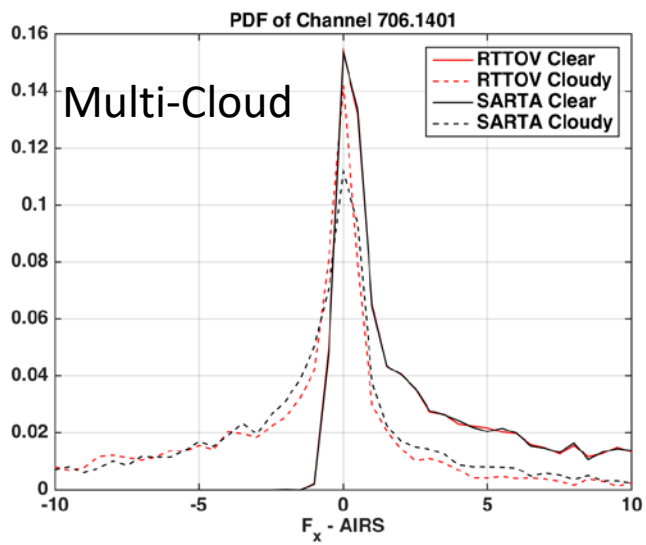


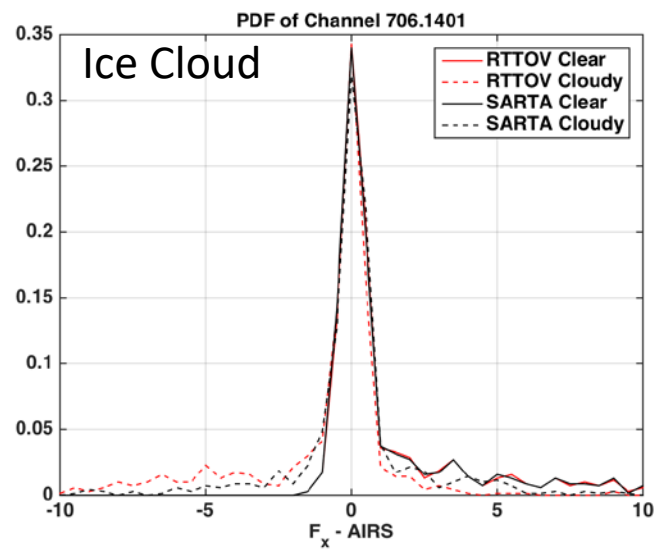


Cloud Scenarios

- Multi-cloud scenario has the largest spread
- Cloud overlap parameter is likely critical in accurate cloudy radiances
- Clear radiative transfer does a decent job for single water clouds







Cloudy Summary

- Created a testbed of RTA codes and input profiles to test cloudy radiative transfer
- CRTM has lots of parameterizations (e.g. overlap and effective radius) to fit the radiances (freedom = danger!)
- RTTOV and SARTA are fixing the bias, but not reducing the spread in the error w.r.t AIRS
- Direct comparisons with AIRS was not possible due to a mismatch with ECMWF