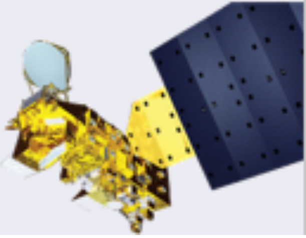
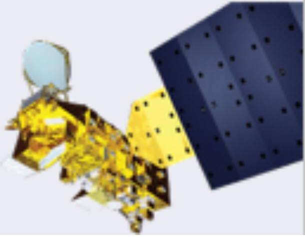


Cloudy Radiative Transfer Model Status Report

H. H. Aumann, Sergio DeSouza-Machado, Xu Liu, Evan Manning, Evan Fishbein, Bill Irion, Mathias Schreier, Chris Wilson

AIRS Science Team Meeting

24 March 2016



Why are we working on a RTM with clouds

Development of a test data set

Comparison of two clear RTM under clear conditions

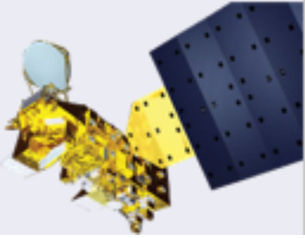
Comparison of two RTM with clouds

Comparison of two RTM with clouds with collocated AIRS cloudy data

International community involvement

Plans

Some early conclusions



An accurate and fast Radiative Transfer Model (RTM) is the foundation of the accurate interpretation and assimilation of hyperspectral infrared sounder data.

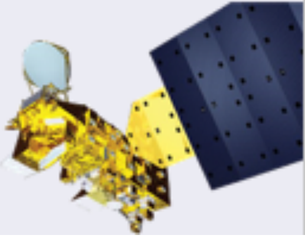
Assimilation and single footprint retrievals of cloudy spectra requires an accurate and fast RTM for clouds. See the status report by Sergio Machado (UMBC) and Bill Irion (JPL).

There are many clear RTM

- **SARTA (UMBC)**
- **PCRTM (LARC)**
- **NOAA (CRTM)**
- **AER (LBLRTM)**
- **UKMetOffice (RTTOVS)**
- **UW, U.Michigan, and more**

The RTM with clouds is always imbedded in a clear RTM

In October 2015 the AIRS project started to evaluate cloudy RTMs. Following is a status report.

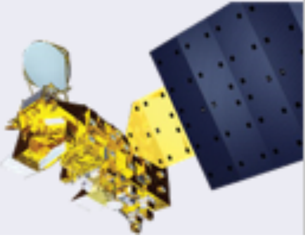


We created a global set of 7377 atmospheric states based on AIRS spectra.

These states were matched up (time and space interpolation) to the nearest ECWMF definition of T(p), q(p) etc in 62 layer, including clouds.

The international community was invited to exchange spectra calculated for AIRS.
Sergio Machado is the interface into the ITOVS community.

As a test of the data set and an analysis methodologies we used the March 2016 versions of SARTA_cloud (UMBC , Sergio) and PCRTM_cloud (LARC , Xu Liu).

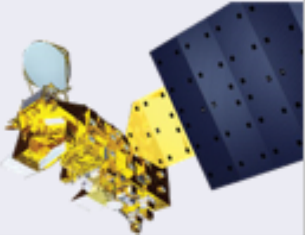


Several methods have been used to validate fast cloudy RTMs.

1) Compare results from different cloudy RTMs.
Interesting, but these comparisons don't reveal who is more right.
Assumptions regarding scattering, particle size distribution
and cloud overlap largely cancel.

2) Compare the results with spectra calculated with observed spectra from field campaigns.
Not globally representative.

3) Compare the results with spectra calculated using LBLRTM and DISORT.
Interesting, but LBLRTM_DISORT does not qualify as a fast RTM.
LBLTRTM_DISORT is impractical for globally representative conditions and hyperspectral data.
Shared assumptions regarding scattering, particle size distribution and cloud overlap cancel.



We use a variant of the previously used methods.

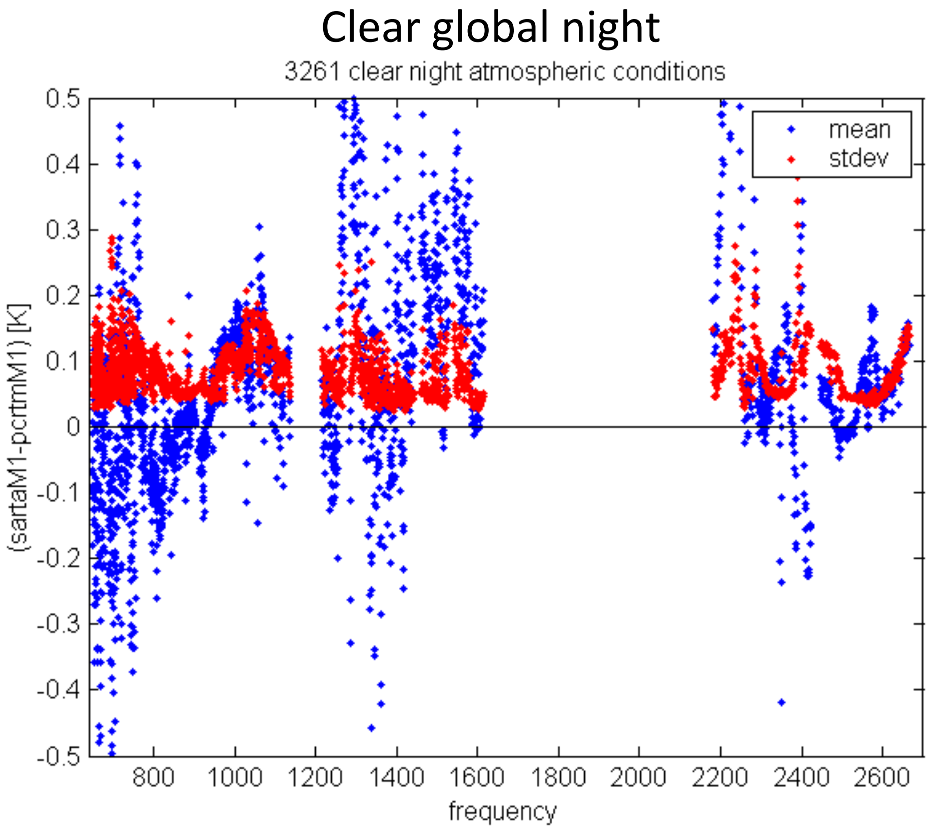
We analyzed the mean and stdev of (PCRTM-SARTA) under clear and cloudy conditions

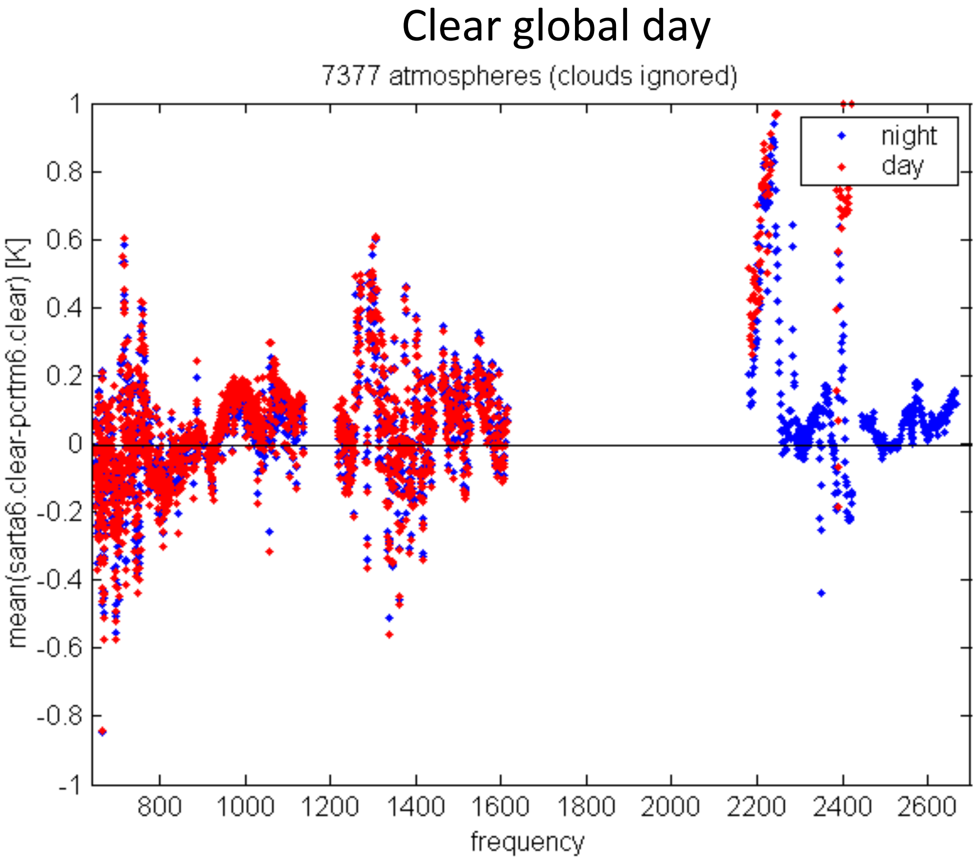
We analyze the mean and stdev of (PCRTM-AIRS) and (SARTA-AIRS) under cloudy conditions.

The 7377 set of conditions is large enough to analyze day/night, global and regional statistics.

The analysis method can be applied to spectra calculated by other interested parties.

Under clear night conditions SARTA and PCRTM agree within 0.1K at night

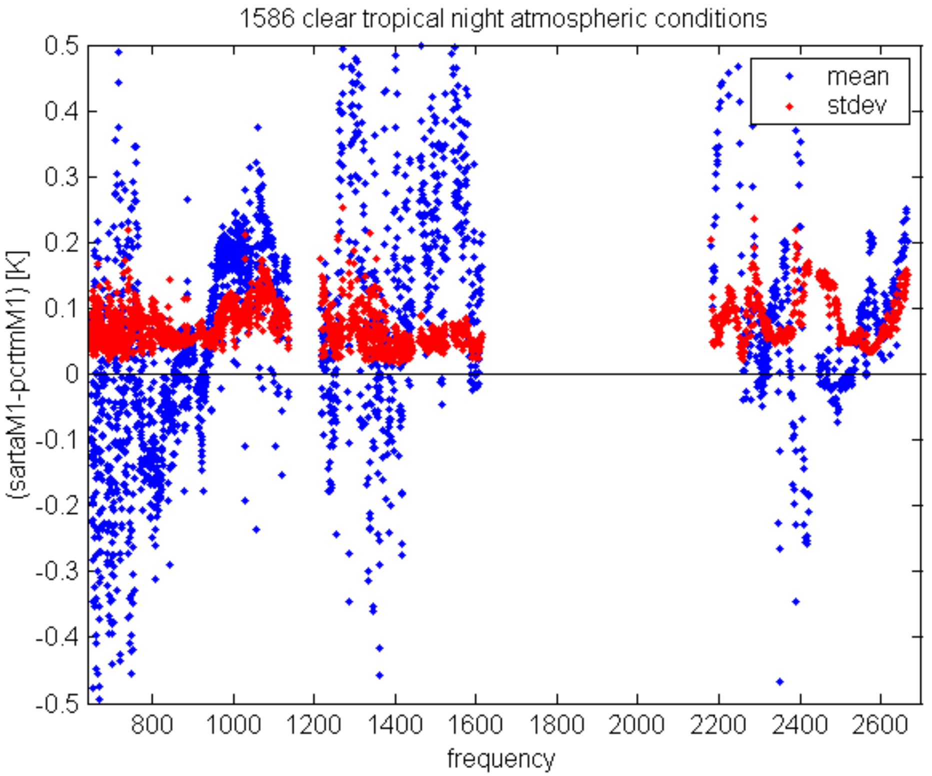




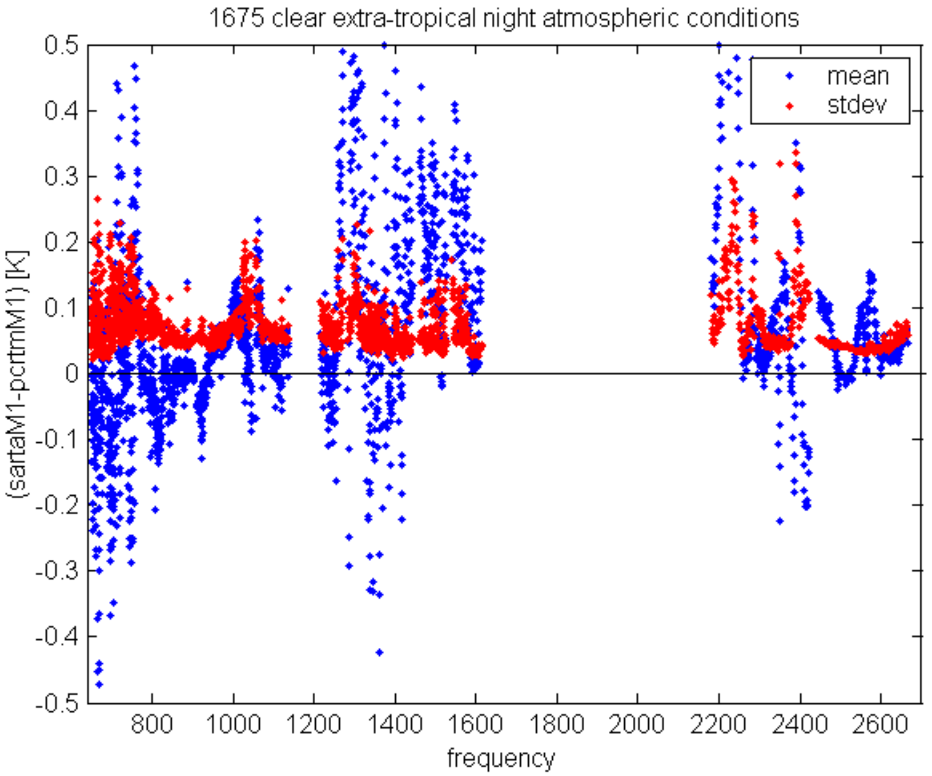
During the day SARTA and PCRTM agree within 0.1K in the long-wave channels. The version of PCRTM available for our test did not implement daytime non-LTE. In the following we focus on the longwave channels.

The mean(SARTA-PCRTM) is zone dependent

Clear night tropical



Clear night extratropical



Zonal bias is seen in the CO2, water channels and ozone.

RTM with clouds

The most accurate RTM for cloudy spectra is widely assumed to be LBLRTM with DISORT (1988). The clouds are defined in many layers (ECMWF uses 61 layers) in terms of liquid water and ice water content, particle size and distribution, and cloud fraction. LBLRTM_DISORT is computationally impractical. It is unlikely that the complexity of the cloud prescription which can be handles by LBLRTM_DISORT can actually be retrieved.

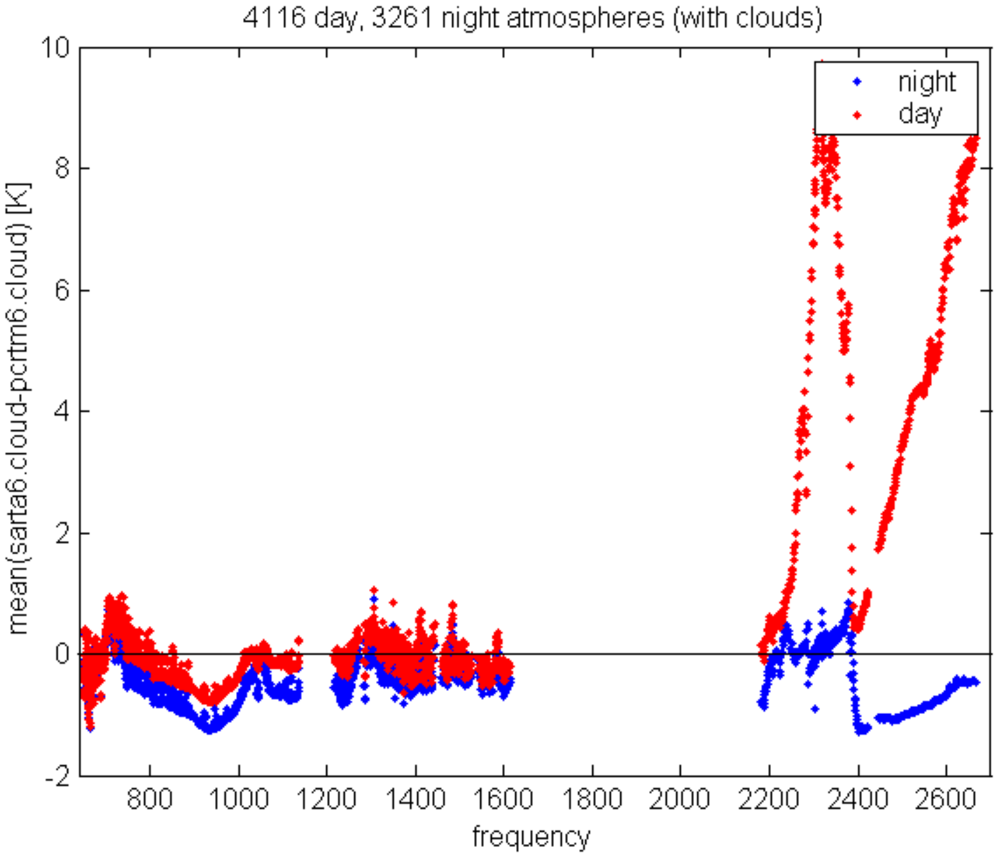
PCRTM_cloud provided by Xu Liu uses Maximum Random Overlap (MRO) and 50 subpixels to handle cloud inhomogeneity. This is computationally stressing. It is unlikely that the complexity of the cloud prescription used by PCRTM can be retrieved.

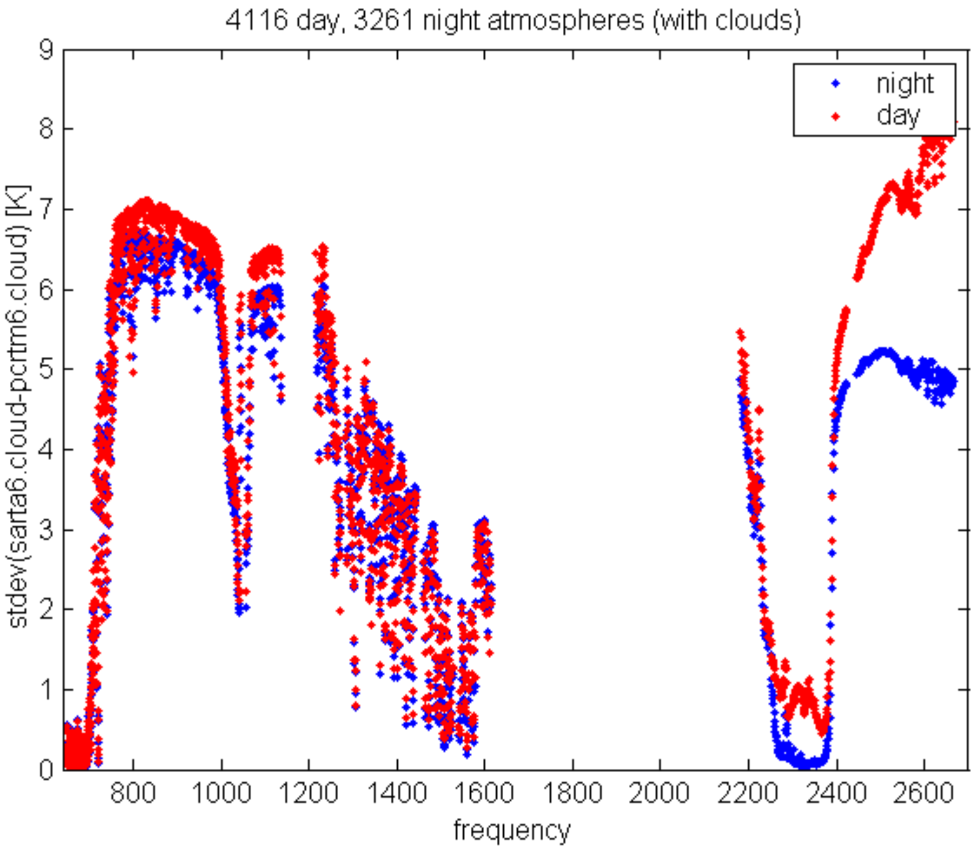
SARTA_cloud collapses the 61 layer ECMWF physical cloud prescription in to six parameters: two thick clouds defined by cloud-top and cloud bottom pressure and two cloud fractions. This is computationally manageable.

For the comparison of spectra calculated with different cloudy RTM the accuracy of the ECMWF prescription is irrelevant.

Difference are due to different methodologies used for converting the ECMWF prescription into radiance spectra.

Under cloudy conditions SARTA and PCRTM agree within 1K in the mean, but stdev(SART-PCRTM) is 6.5K at night, 7K during the day in the 11um window area.





SARTA and PCRTM start with identical ECMWF physical definition of the clouds, both use the same surface emissivity, but differ in the details of how scattering and cloud overlap are handled.

We use AIRS spectra to determine if SARTA or PCRTM is closer to the truth.

The comparison of spectra calculated using the ECMWF prescription with co-located AIRS spectra introduces three errors:

1. The interpolation error. The ECMWF prescription is from a ¼ degree grid every 3 hours. This error should be zero mean, but may contribute to a large stdev.

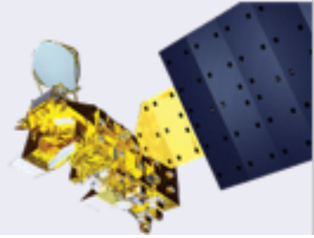
2. The calculation error. This error could create a bias and increase the large stdev.

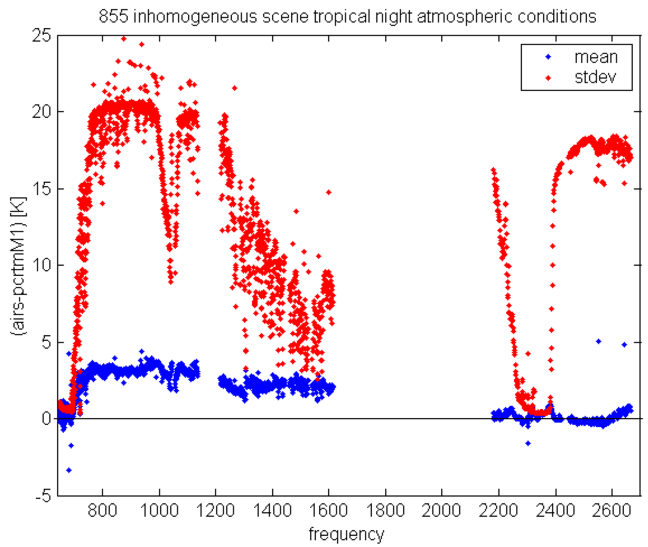
3. The ECMWF error. This error creates a zonal day night bias which relates to cloud-types, which can be seen in the data analysis.

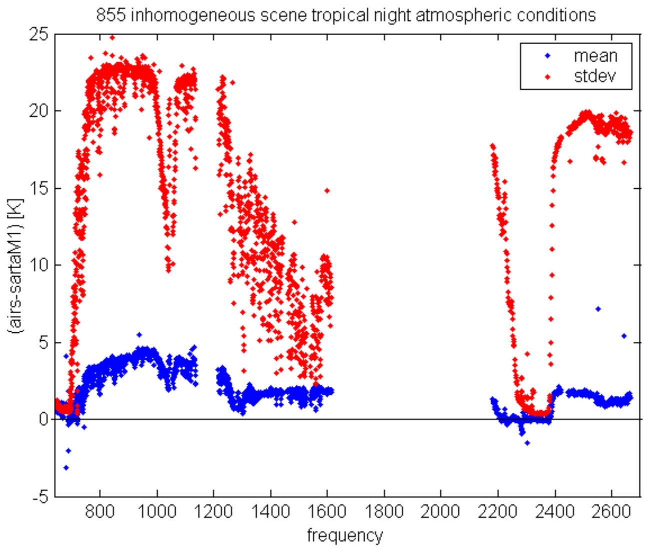
National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Atmospheric Infrared Sounder

Different cloud types create more or less homogeneous scenes. Homogeneous scenes have less interpolation error than inhomogeneous scenes, but the bias switches from -3K to +3K for SARTA and for PCRTM

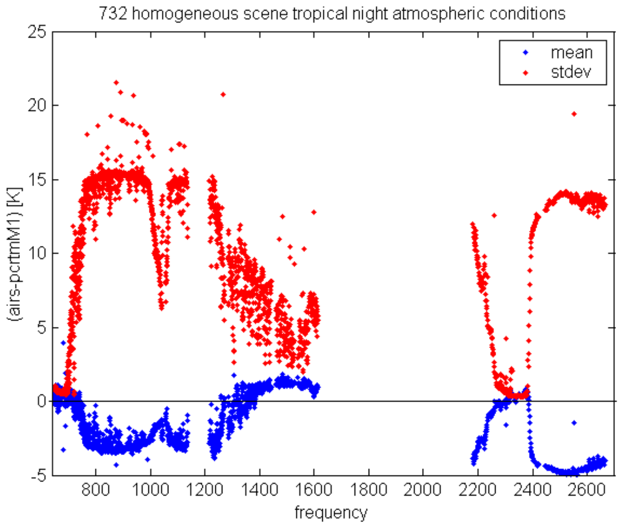


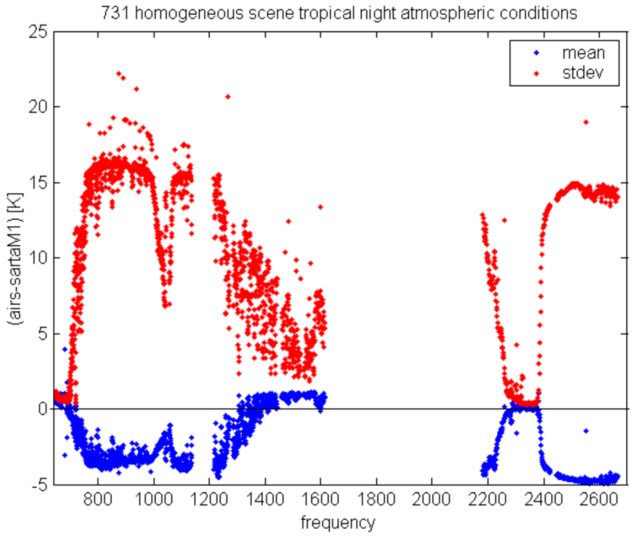




We uses the AIRS Cij effect at the m8m9 and m1m2 boundaries to divide the tropical zone data into homogeneous and inhomogeneous scenes.

Under homogeneous scene condition stdev(airs-sartaM1) and stdev(airs-pcrtm) are considerably smaller than under inhomogeneous scene condition. The is expected, since the interpolation error under homogeneous scene conditions should be smaller.





The mean for both airs-sartaM1 and airs-pcrtm switches sign between homogeneous and inhomogeneous scenes. This is most likely do to a change in cloud-type specified by ECMWF

The comparison of spectra calculated using the ECMWF prescription with co-located AIRS spectra is the RSS of the interpolation error, the calculation error, and the ECMWF error.

SARTA and PCRTM share the same interpolation error and ECMWF prescription error.

The stdev(PCRTM_cloudy-AIRS) is consistently less than stdev(SARTA_cloudy-AIRS) .

This means that the more complex cloud description of PCRTM_cloudy fits the AIRS data better than SARTA_cloudy, but the prize is computational complexity.

Summary and Plans

We have created a data set for the analysis of different cloudy RTM.

We have tested the data set and a methodology for the evaluation of cloudy RTM. Interesting facts emerge from the analysis.

At this early state of analysis the 7377 states are good enough for the evaluation.

The ITOVS community has expressed interest in the 7377 atmospheric states and cloudy RTM comparisons: UMBC/LARC/NOAA (RTTOVS?)/ AER/UKMetOffice/UW/U.Michigan/JPL

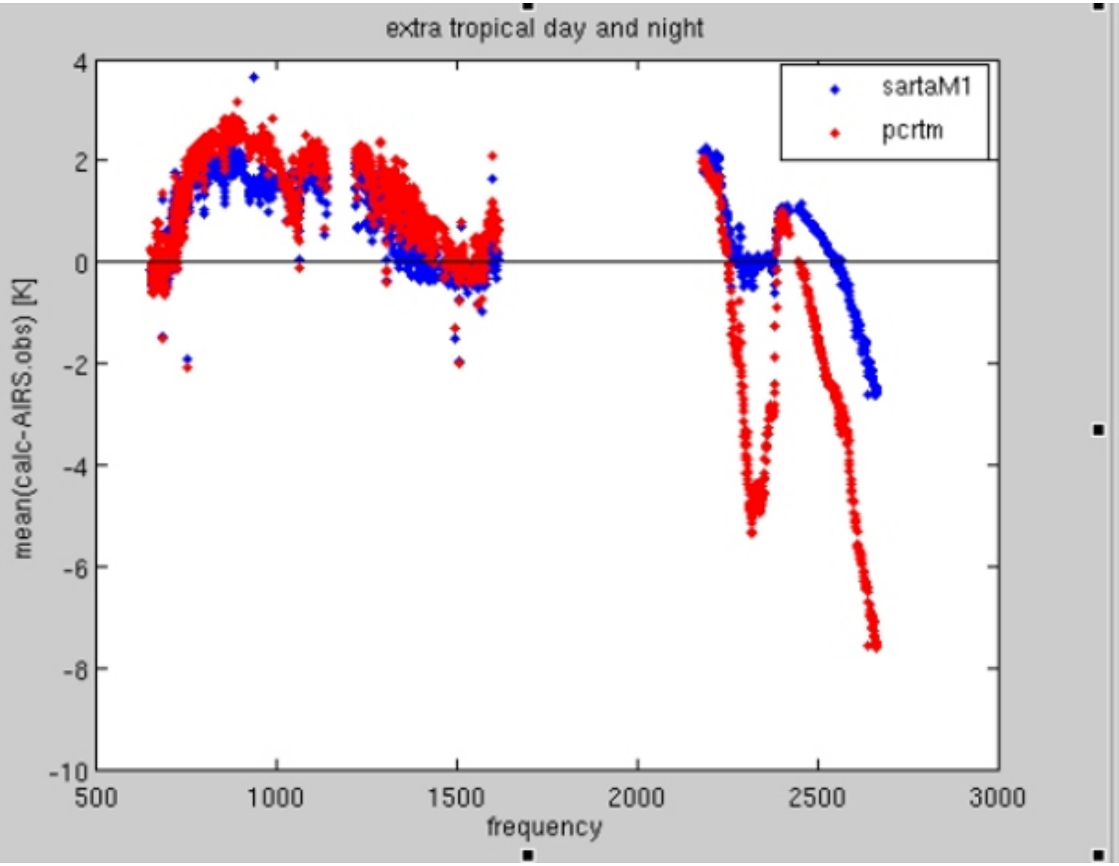
We are ready to distribute the data set. Results with SARTA (March 2016 version) for clear and cloudy will be included in the distribution as examples. The matching AIRS data will be held back.

We are ready to test cloudy versions of the RTM at JPL.

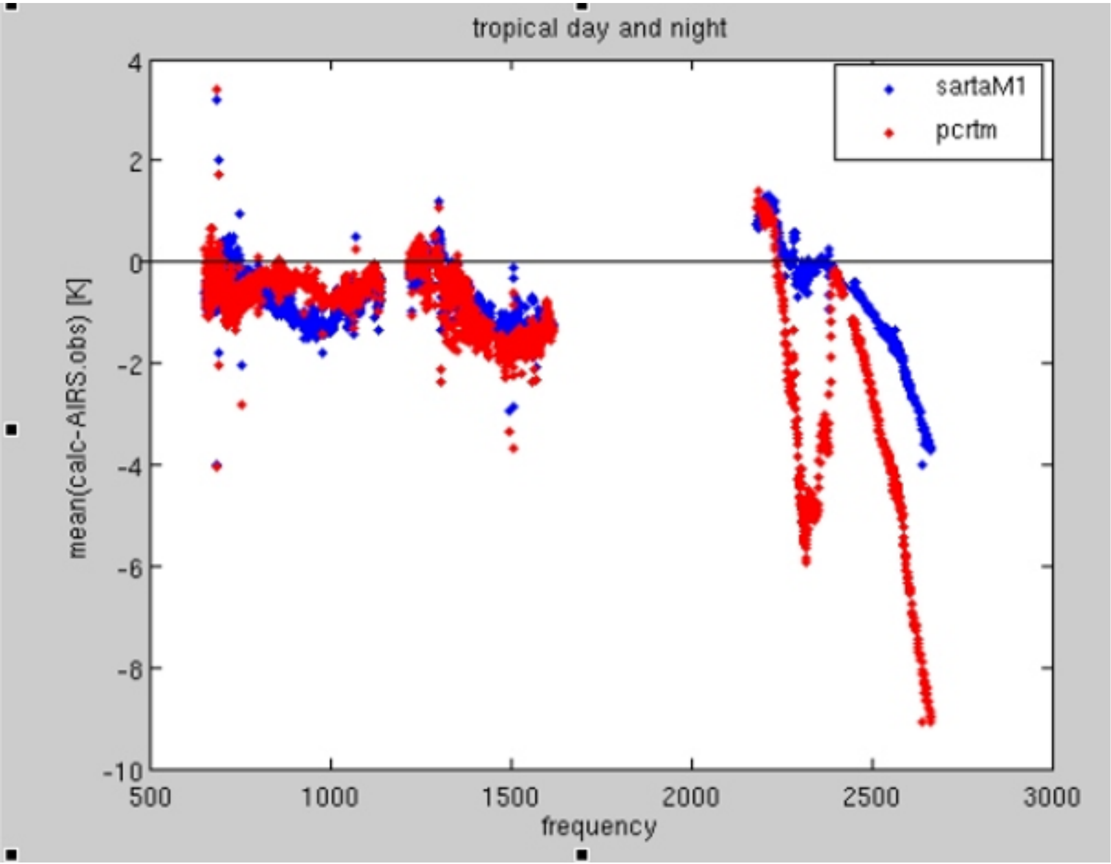
At the first stage of evaluation computer resource requirement are a second order issues.

In the extra-tropical zone AIRS is about 2K colder then SARTA and PCRTM.
In the tropical zone AIRS is 1K warmer than SARTA and PCRTM

Bias cloudy day and night extratropical



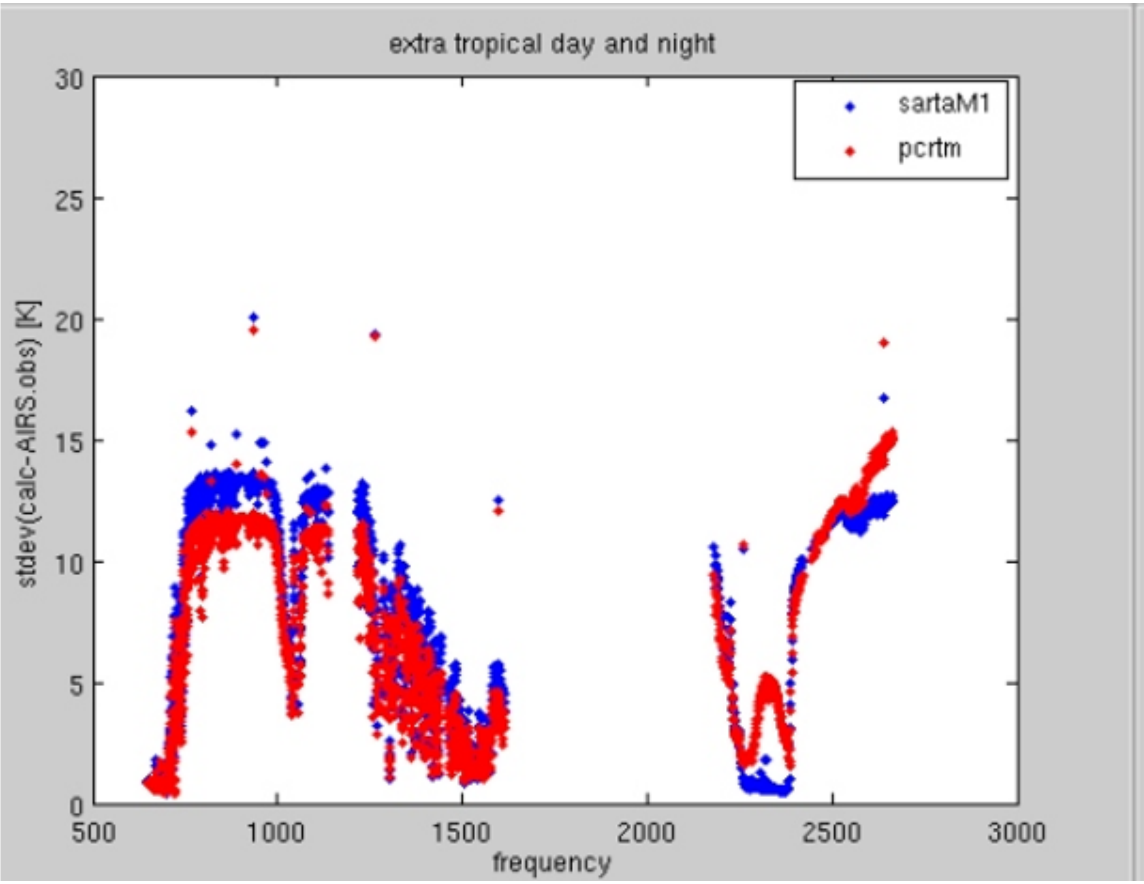
Bias cloudy day and night tropical



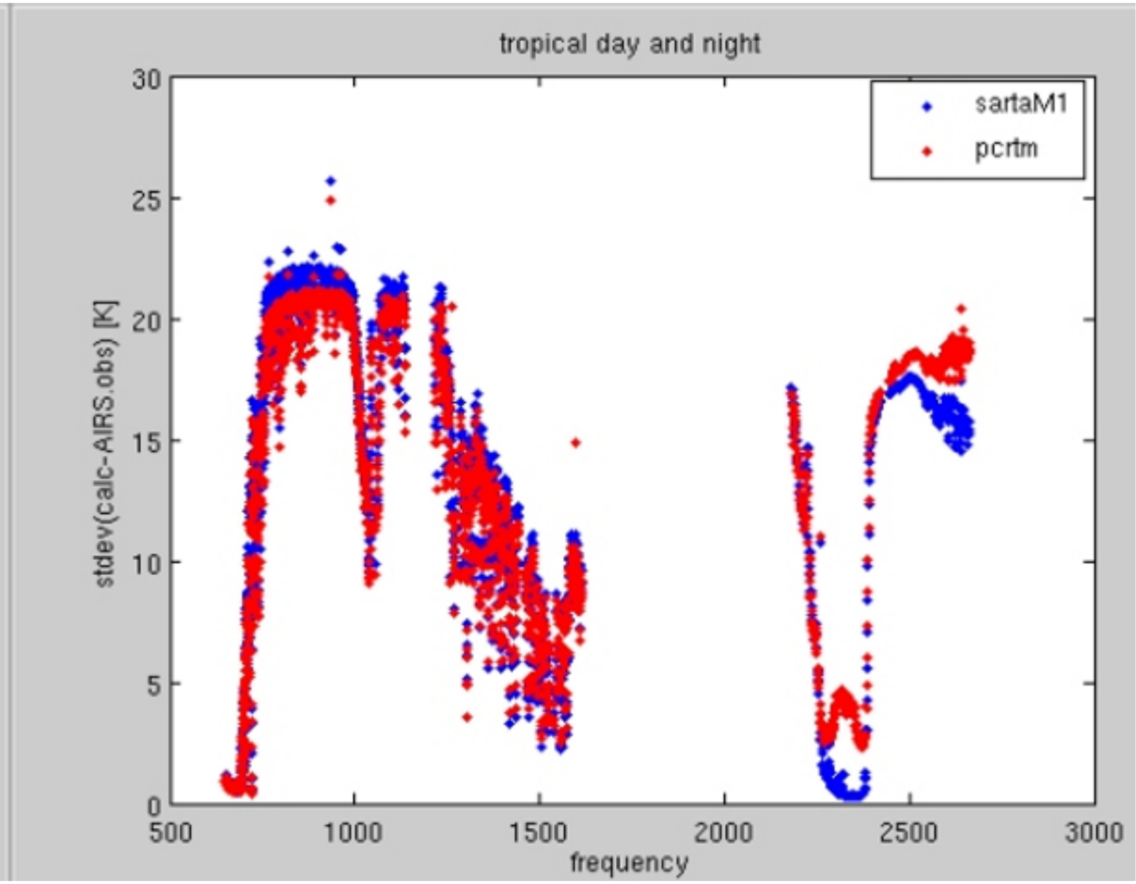
All AIRS channels with nedt250<1K are shown.
The bias of SARTA and PCRTM relative to AIRS are very similar with the same zonal dependence.
This could be an ECMWF prescription issue: Clouds are too thin or too few in the extra-tropical zone.

The stdev of SARTA and PCRTM relative to AIRS is due to the combination of interpolation error, calculation error and ECMWF prescription error

Stdev cloudy day and night extratropical



Stdev cloudy day and night tropical



The stdev(PCRTM-AIRS) is consistently less than stdev(SARTA_AIRS).
Both are consistently smaller in the extratropical zone than on the tropical zone.