# AIRS+ Radiance PDFs for Climate Trending

L. Larrabee Strow and Sergio De-Souza Machado

Physics Department and
Joint Center for Earth Systems Technology
University of Maryland Baltimore County (UMBC)

AIRS STM
November 2012

# Overview

- AIRS L2 oriented to weather, T(p), Q(p) via 1D-var retrievals
- Clouds introduce significant sampling errors, makes L3 difficult to interpret
- Cloud-clearing introduces large scene-dependent errors (relative to climate requirements)
- AIRS observations contain many cloud, trace gas, aerosol, surface emissivity, surface temperature information that are difficult to stabilize in 1D-var simultaneous retrievals
- Climate trending requires traceability to calibration for error bounds
- AIRS+ radiance calibration accuracy can provide stringent bounds on climate trends
- Examine climate trending in context of radiances, and radiance probability distribution functions (PDFs).

# Framework for Radiance Trending

## Hyperspectral IR Observing Systems

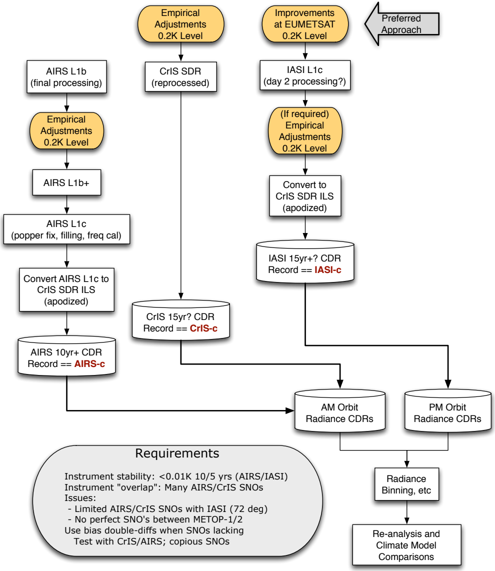
- NASA-AIRS 10 years+ (20??), CrIS will extend record
- IASI up 5+ years, first follow-on working well, IASI NG in development
- All agree to 0.1-0.2K level on "Day 1"
- Nominal 4 observations/day for diurnal mapping
- CLARREO delayed indefinitely.

## Subjects Addressed

- Climate level trending with AIRS+; Use radiances, move to geophysical units "as late as possible"
- Can AIRS+ provide CLARREO equivalent longwave radiance product?
- Examine utility of radiance PDFs trends, relationships
- "Validation" of re-analysis products

# Framework for Radiance Climate Data Record

## Using AIRS, IASI, CrIS

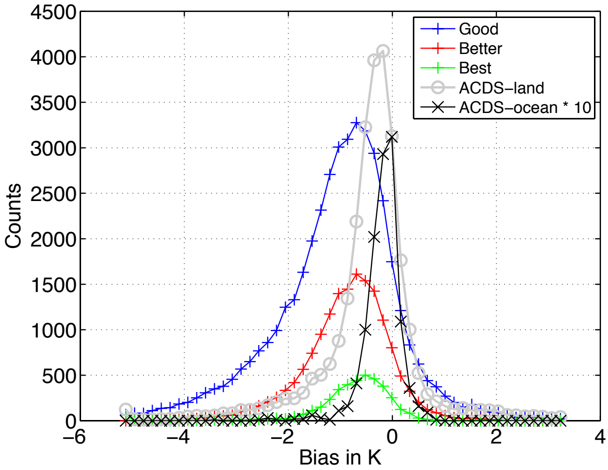



AIRS-c, IASI-c, CrIS-c are individual instrument products converted to a common spectral response (SRF).

Requires:

- Instrument stability (CrIS?)
- Instrument overlap (AIRS/CrIS with IASI?)
- SRF conversion algorithms
- Hopefully, B(T) differences dominated by on-board blackbody differences
- Cooperation among instrument teams, and ???

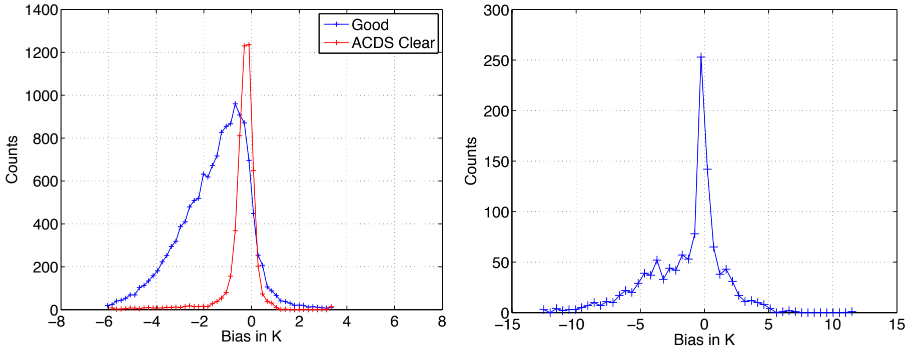
# Liens on Cloud-Cleared Radiances Used for Products
## Ocean, ±60 deg lat Bias PDFs: Add ACDS Land



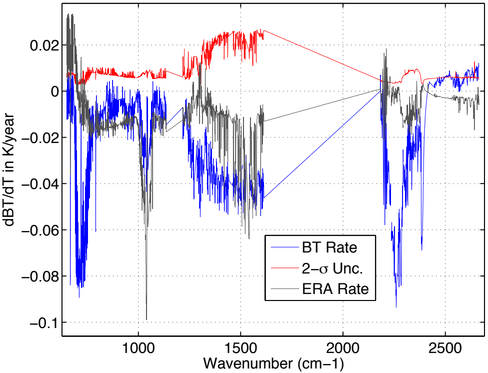

ACDS land clear not bad reltiave to ECMWF land surface temperatures!

# Liens on Cloud-Cleared Radiances Used for Products, con'td
## Ocean, 30-60 deg (N/S) lat PDFs

Left: Ocean, 30-60 deg (N/S) lat PDFs
Right:Ocean, 30-70 deg (N/S) lat PDFs for 25-50% Clouds



# AIRS/IASI Stability: Use SST and $CO_2$ to Test




## AIRS Clear Scene Subset

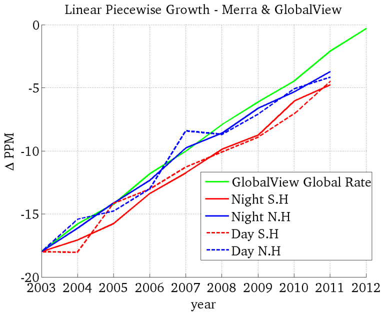
- From NASA/GSFC DAAC
- Nominally clear scenes
- Tropics only
- Linear growth rate: 9 years
- Trop. $CO_2$ growth evident
- Strat $CO_2$ growth cancelled by decreasing T

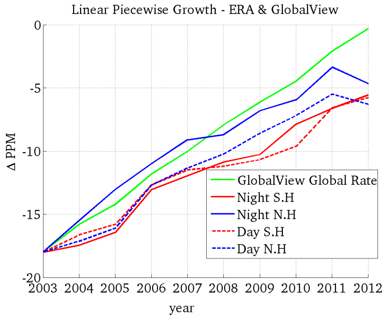
## Clear Ocean Scene Linear Rates:

- AIRS vs SST products: 1231 $cm^{-1}$: 5.6 ± 8.1 mK/yr
- AIRS vs $CO_2$ in-situ trends: 6.9 mK/yr (error?)
- IASI vs SST, and $CO_2$, 5 years, implies stability < 0.01K/year

# AIRS Stability: Comparison to Reanalysis

## Compare to NASA/GMAO Merra, EMMWF ERA

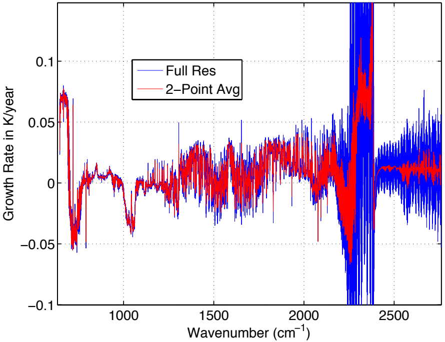


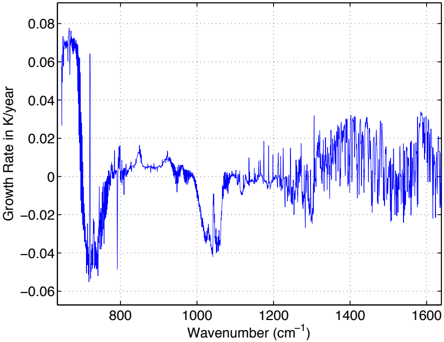




Reanalysis used for temperature
$CO_2$ retrieved using 791 $cm^{-1}$ line
$CO_2$ rate dependent on re-analysis “stability” and AIRS stability
Data derived using 1-day per month
Merra compared to in-situ imples AIRS/Merra stability < 0.01K/year

# IASI Stability: Observed 5-year BT Rates

## Two point averaging removes changes to ringing



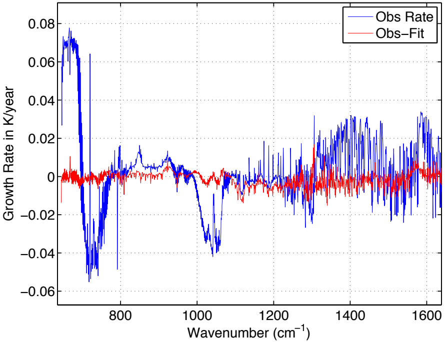



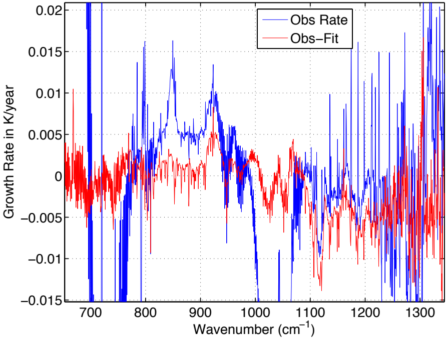

Left: Full resolution, and 2-point averaging
Right: Zoom of 2-point averaged rates

Tropospheric -0.06K/year due to $CO_2$ evident
Increase in $O_3$
Decrease in CFCs

# IASI Stability: Observed 5-year BT Rates

## Compare to $CO_2$ in-situ, Tropical SST



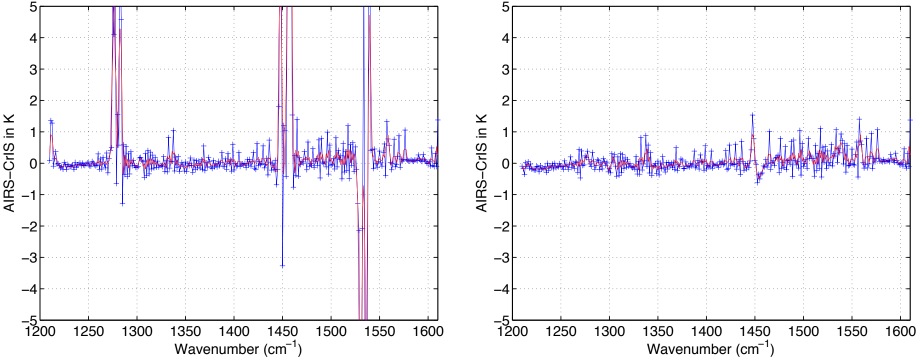

Optimal estimation fit for gas amounts, T(z), Q(z)
Heavily smoothed profiles, L1-type
Zoom on right shows feature at 1020 cm$^{-1}$ not removed in fit

MLO in-situ $CO_2$ rate: 1.99 ppm/year, Fitted rate: 1.99 ppm/year
ERA SST rate: -5 $\times$ $10^{-4}$ K/year, Fitted rate: 0.006K/year

Both of these results imply stability of 0.01K/year or better

# Conversion of AIRS to CrIS SRF: Using L1c!

## Very Preliminary, Main Point: ~0.2K agreement between AIRS and CrIS




Observations are SNOs Channel centers and SRFs for CrIS and AIRS very different
Working on approaches to convert AIRS to CrIS
Use AIRS L1c to fix HdCdTe popping and to fill gaps

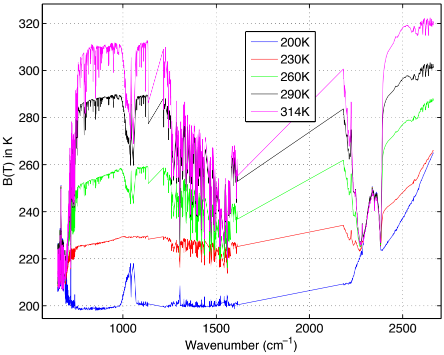
Use impulse deconvolution of AIRS, then covert to CrIS

# Detail of Data Set For PDF Trending Study

- Using only 2 FOVs on either side of nadir, ~2% of data.
- Matched to closest ERA-Interim re-analysis grid point ==> relatively large time offsets
- Simulated radiances computed using UMBC SARTA RTA.
- Simple algorithm to convert re-analysis vertical mass profiles to scattering layers: needs improvement
- Time series analysis used daily averages for region of interest.
- Concentrate on 1231 $cm^{-1}$ AIRS channel. Least amount of $H_2O$ in thermal region. Mostly a surface + cloud channel.
- Often show data in one geographic region using TRANSCOM definitions, ie Tropical Western Pacific

# PDF Measurement Approach

Do not average all-sky radiances.

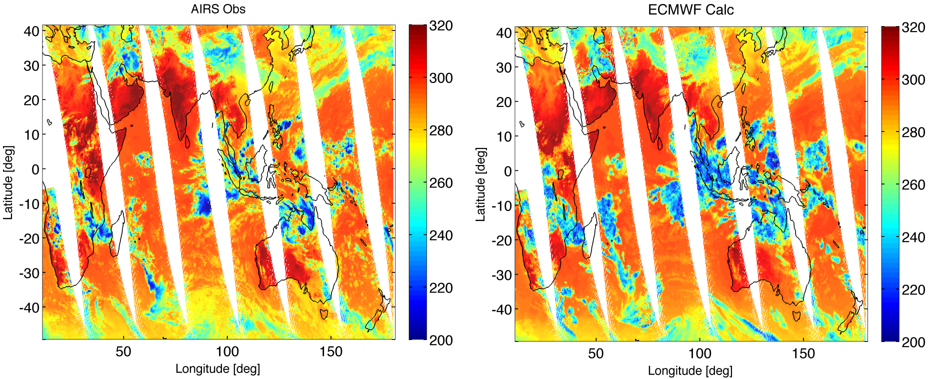



## Retain more information: PDF rates, not Radiance Rates

- Averaging clear with cloudy scenes destroys information
- Bin (create PDFs) versus variable related to cloudiness
- I used 1231 cm$^{-1}$ channel B(T): clearest window channel
- Data Set: 8+ years of AIRS, only FOVs on each side of nadir
- Bins of B(T) 1231 cm$^{-1}$, from 190:1:320K
- Mean BT spectra in each bin are stable versus time
- All the information is in the PDFs in each bin

# Snapshot Comparison: AIRS to ECMWF via SARTA RTA

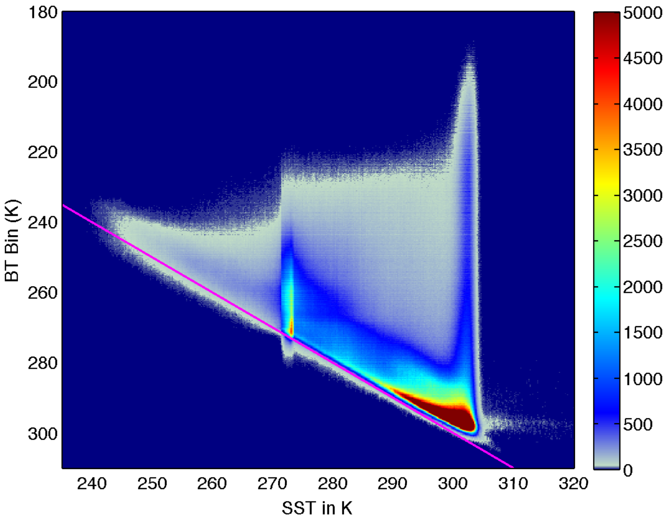
## Image of 1231 $cm^{-1}$ channel B(T), March 10, 2011



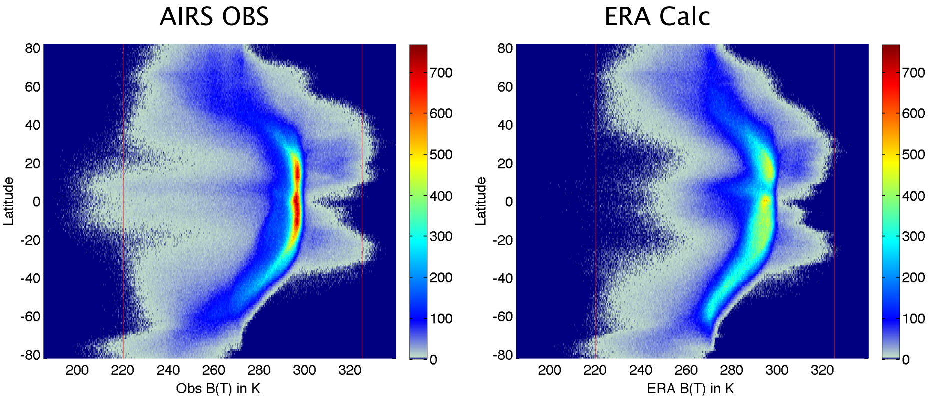

Note: ERA data is lower resolution than ECMWF with 6-hour versus 3-hour time steps.

# Global Ocean 1231 $cm^{-1}$ PDFs (PDF's area weighted.)

Use another good climate observation: SST

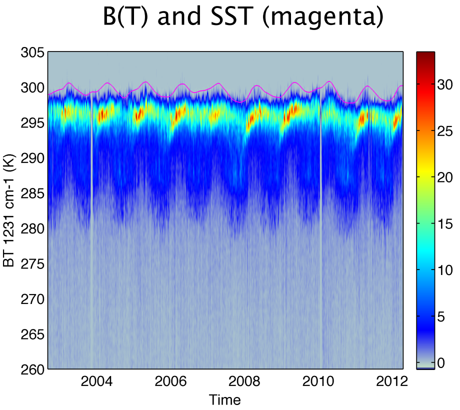


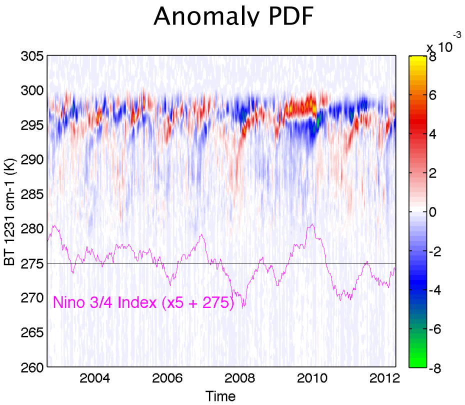
# Overview of AIRS vs ERA 1231 $cm^{-1}$ PDFs




- Data from western tropical pacific
- Reasonable correlation for clear
- Low correlation for deep convective clouds, missing in ERA
- Correlation low for 280-290K, region of broken clouds

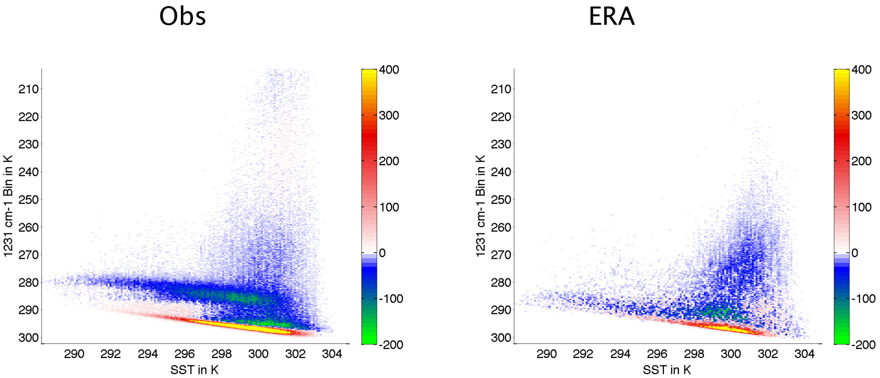
# Western Tropical Pacific Time PDFs




Anomaly PDFs reflect ENSO very nicely. *BUT*, all low-BT structure is mostly due to changes in the surface tempearture, NOT changes in cloud forcing.

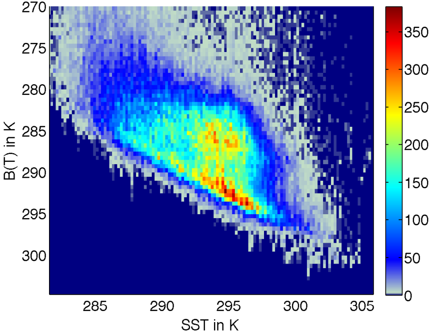
# Western Tropical Pacific Time: Day-Night PDFs



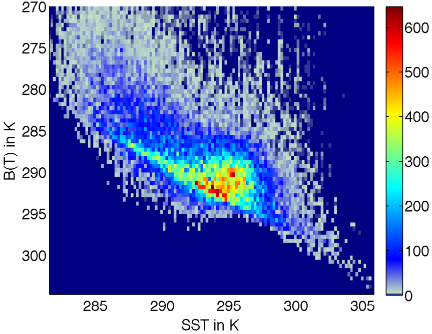

- Mixing all times, with large spatial extent
- Increase in low clouds at night not strong in ERA. Maybe conversion of ERA cloud to RTA grid missed these??

# PDFs off California Coast: Months of JJA

Obs



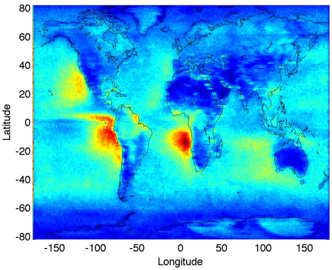

Calcs



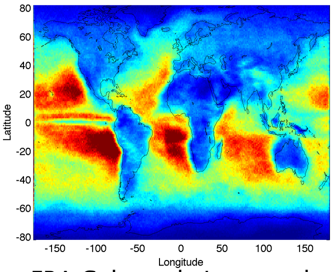

Marine boundary layer clouds detectable. Is RTA or model responsible for lack of clear signal in Calcs?

# Daytime Low Cloud Occurance (ERA? RTA mapping issue?)

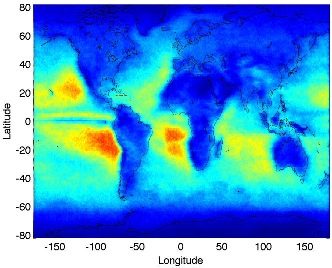
Obs




ERA

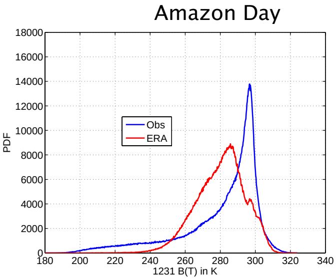


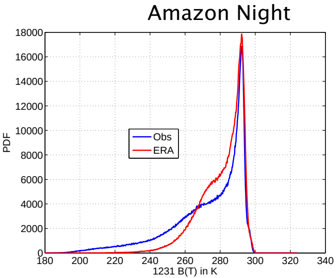

ERA Colorscale Increased

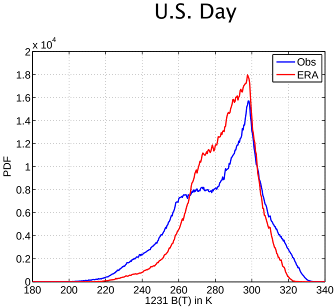


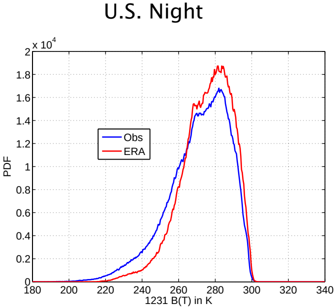

- Low cloud $\equiv (2K < B_{obs}(T) - B_{calc}(T) < 9K)$.
- Almost no change if use [3K 8K]
- Using ERA for calc. BUT SST good to 0.2K, and ERA column water very good compared to thresholds.
- If use shortwave, do not need column water, results very similar

# Amazonia and U.S. PDFs vs ERA



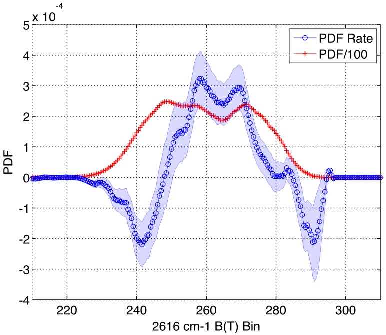



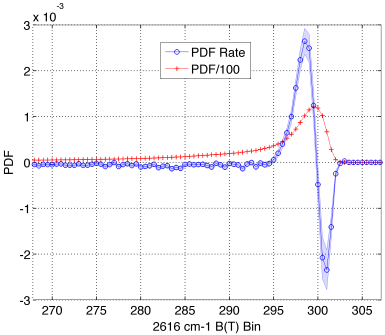



# 10-Year PDF Rates : Arctic, Trop. Western Pacific

Arctic

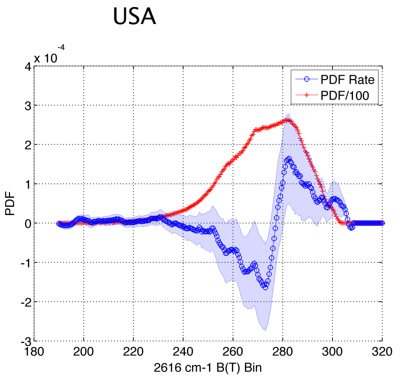


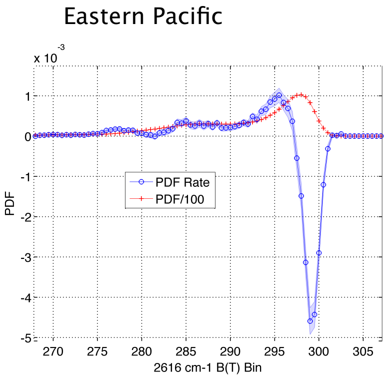

TWP




Note: PDF rates are smooth relative to bin width of 0.5K (> 260K)

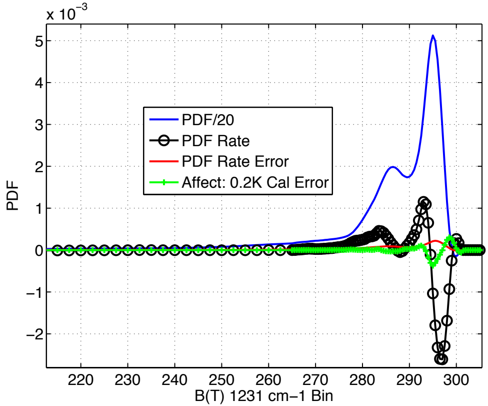
# 10-Year PDF Rates: Continental USA, Eastern Tropical Pacific




Note: PDF rates are smooth relative to bin width of 0.5K

# TWO PDFs: Sensitivity to BT Calibration




TWP may be worst case for “sharp” dPDF/dt curve

Plot shows, in green, PDF rate error for a 0.2K B(T) offset error

PDF rates relatively insensitive to calibration error! AIRS+ good enough for CLARREO objectives??

# Conclusions

- AIRS + IASI + CrIS can potentially provide replacement CLARREO longwave observations.
- Radiance PDF approach can provide information from AIRS now not being used. Allows traceable error bounds.
- Comparison of re-analysis and AIRS observations (and PDFs) should be fruitful for understanding limitations in model clouds