Towards IR Clarreo using AIRS, IASI, and CrIS

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Overview

Hyperspectral IR Observing Systems

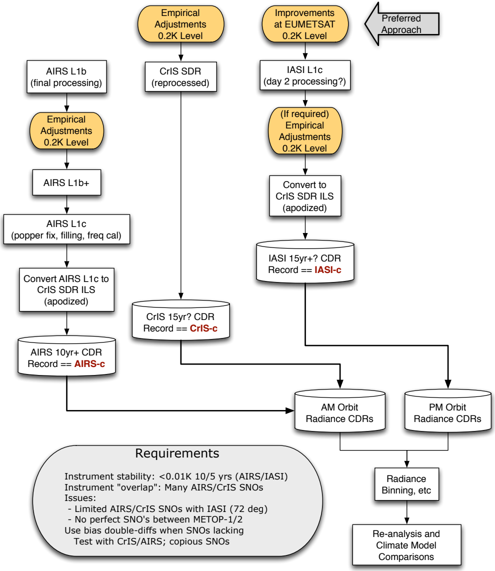
- NASA-AIRS up 10 years (but a calm 10 years)
- AIRS –> NOAA JPSS CrIS should provide 20+ years
- (AQUA + AIRS could last 15+ years)
- IASI up 5+ years, 2 follow-ons built, IASI-NG in planning
- All agree to 0.1-0.2K level on “Day 1”
- CLARREO delayed indefinitely. For now must rely on operational sensors for long-term IR radiance record.

Subjects Addressed

- Can a case be made for an IR CLARREO-like product from existing IR hyperspectral sensors?
- IR hyperspectral analysis, and trends, using PDF’s

Framework for Radiance Climate Data Record

Using AIRS, IASI, CrIS

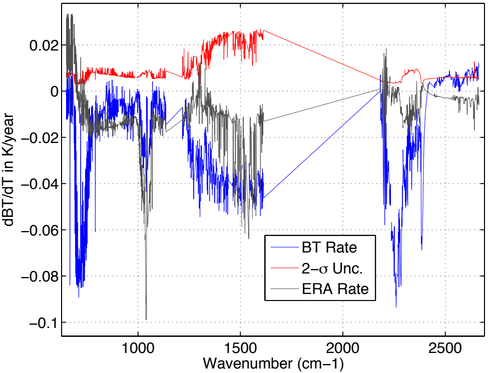


AIRS-c, IASI-c, CrIS-c are individual instrument products converted to a common spectral response (SRF).

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 ???

AIRS/IASI Stability: Use SST and CO_2 to Test



AIRS Clear Scene Subset

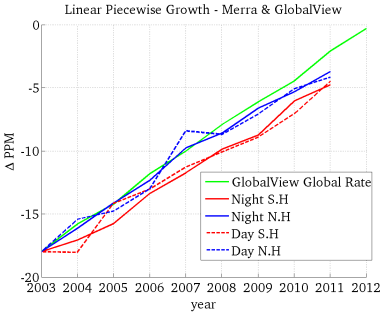
- From NASA/GSFC DAAC
- Nominally clear scenes
- Tropics only
- Linear growth rate: 9 years
- Trop. CO_2 growth evident
- Strat CO_2 growth cancelled by decreasing T

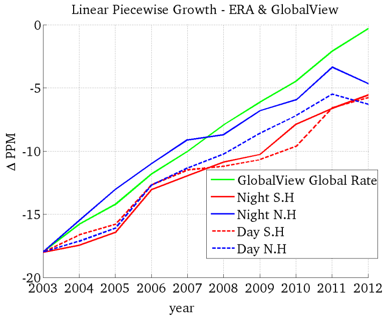
Clear Ocean Scene Linear Rates:

- 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

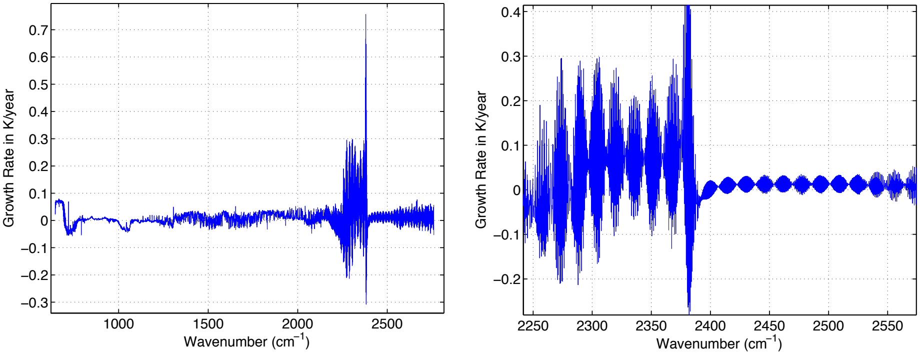




Reanalysis used for temperature
CO_2 retrieved using 791 cm^{-1} line
CO_2 rate dependent on re-analysis "stability" and AIRS stability
Data derived using 1-day per month
Merra compared to in-situ imples AIRS/Merra stability < 0.01K/year

IASI Stability: Observed 5-year BT Rates

Raw Observed Rates: dB(T)/dt (K/year)

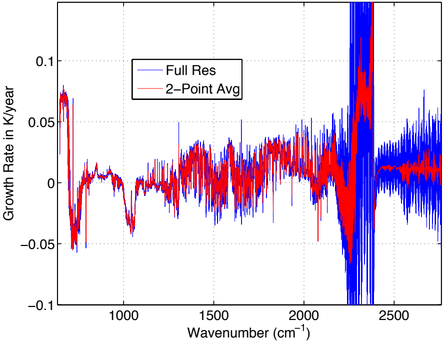


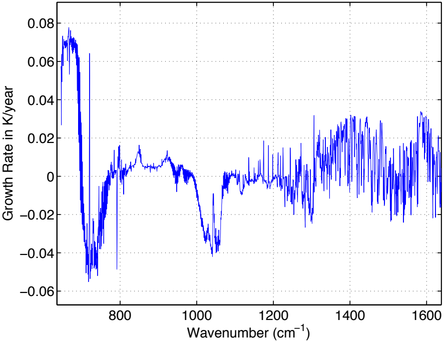
Left: Full spectrum of dB(T)/dt (K/year)
Right: Zoom

Ringing in spectra changed with “Day-2” processing
Easy to avoid with 2-point averaging

IASI Stability: Observed 5-year BT Rates

Two point averaging removes changes to ringing



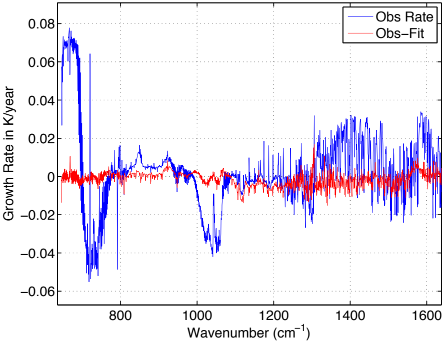


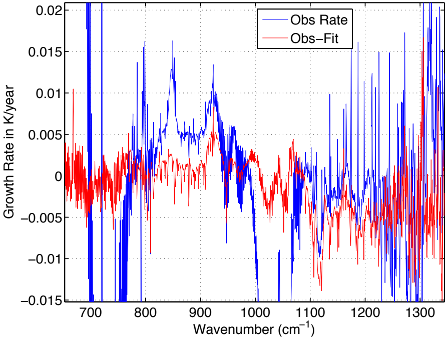
Left: Full resolution, and 2-point averaging
Right: Zoom of 2-point averaged rates

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





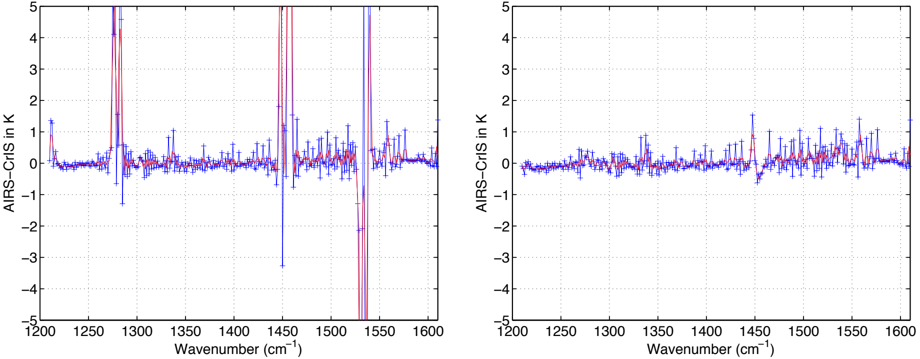
Optimal estimation fit for gas amounts, T(z), Q(z)
Heavily smoothed profiles, L1-type
Zoom on right shows feature at 1020 cm^{-1} not removed in fit

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

Very Preliminary



- 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

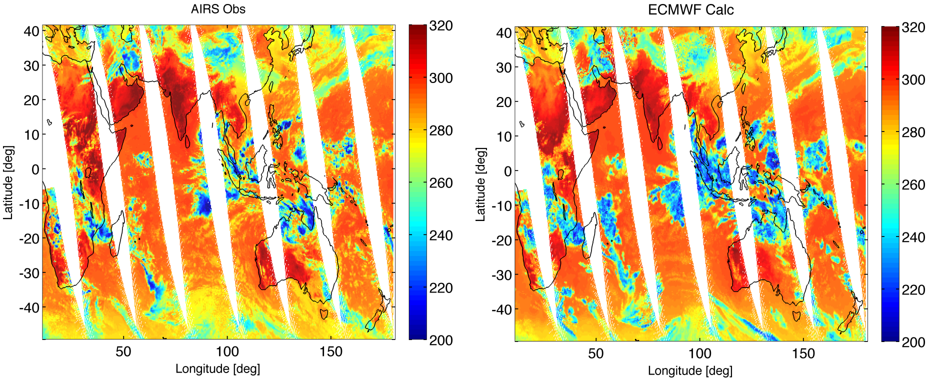
Detail of Data Set and RTA

Details given at last CLARREO meeting.

- 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

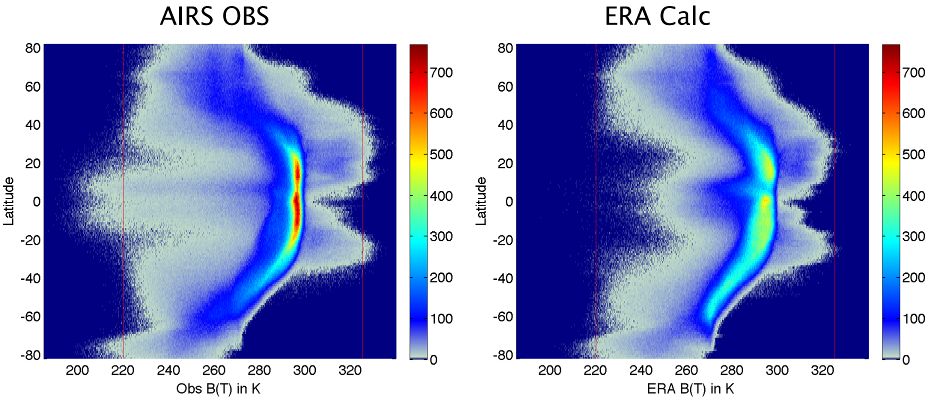
Snapshot Comparison: AIRS to ECMWF via SARTA RTA

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.

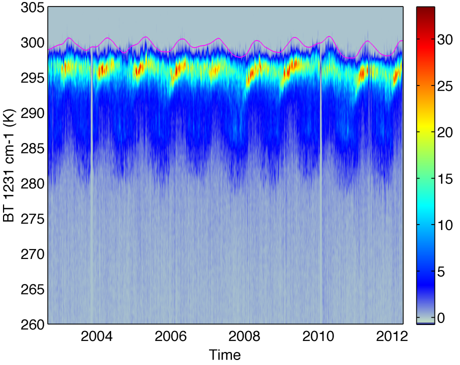
Overview of AIRS vs ERA 1231 cm^{-1} PDFs



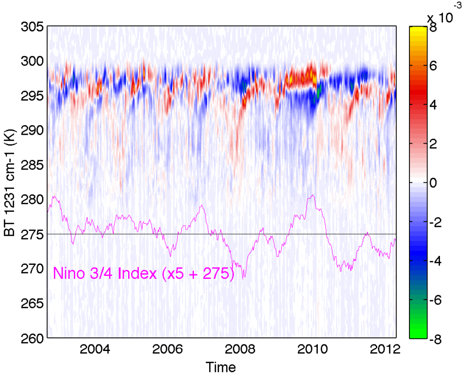
- Data from western tropical pacific
- Reasonable correlation for clear
- Low correlation for deep convective clouds, missing in ERA
- Correlation low for 280-290K, region of broken clouds

Western Tropical Pacific Time PDFs

B(T) and SST (magenta)

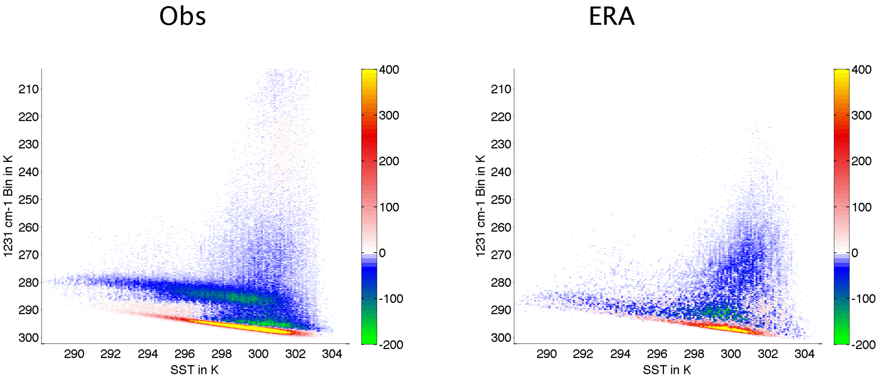


Anomaly PDF



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.

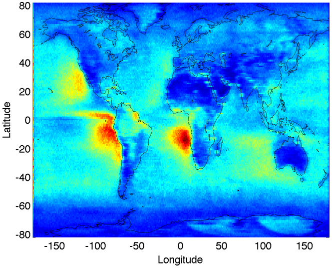
Western Tropical Pacific Time: Day-Night PDFs



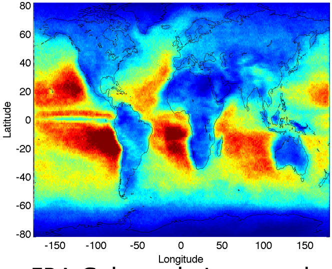
- Mixing all times, with large spatial extent
- Increase in low clouds at night not strong in ERA. Maybe conversion of ERA cloud to RTA grid missed these??

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

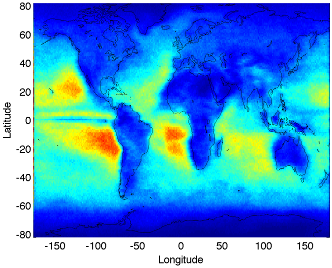
Obs



ERA



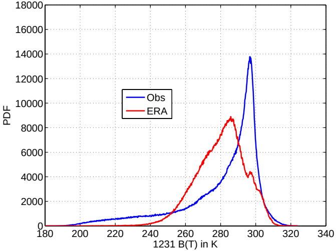
ERA Colorscale Increased



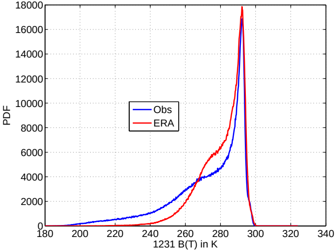
- Low cloud ≡ (2K < B_obs(T) - B_calc(T) < 9K).
- Almost no change if use [3K 8K]
- Using ERA for calc. BUT SST good to 0.2K, and ERA column water very good compared to thresholds.
- If use shortwave, do not need column water, results very similar

Amazonia and U.S. PDFs vs ERA

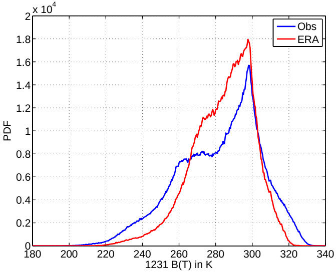
Amazon Day



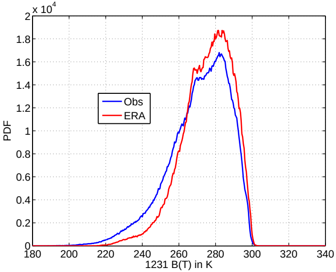
Amazon Night



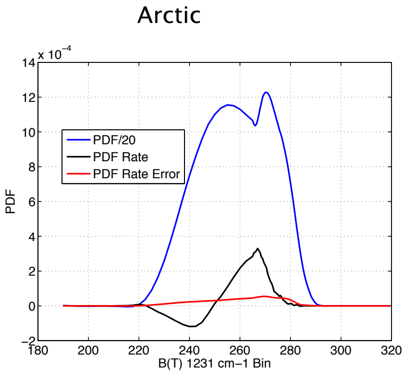
U.S. Day

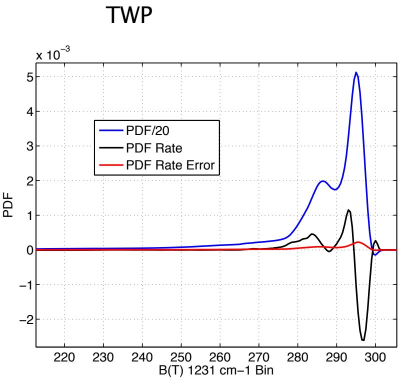


U.S. Night



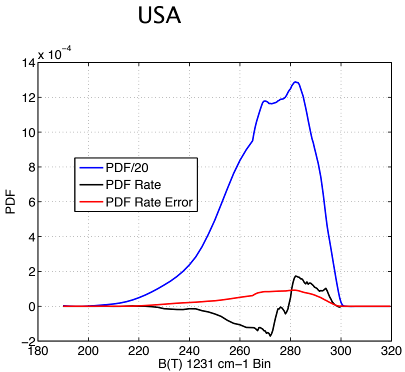
PDF Rates : Arctic, Trop. Western Pacific

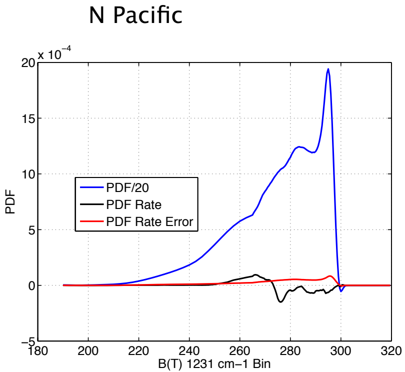




Note: PDF rates are smooth relative to bin width of 0.5K (> 260K)

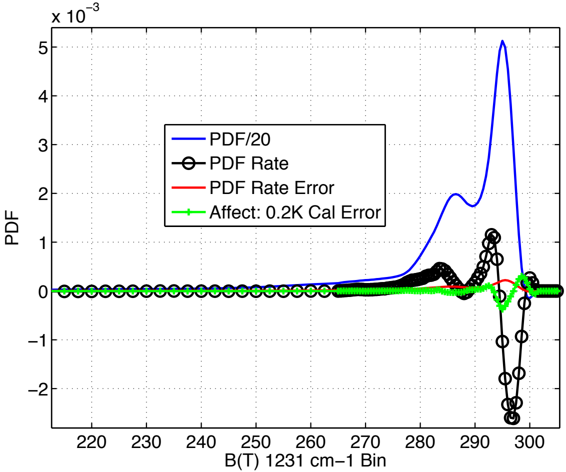
PDF Rates: Continental USA, North Pacific





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

TWO PDFs: Sensitivity to BT Calibration

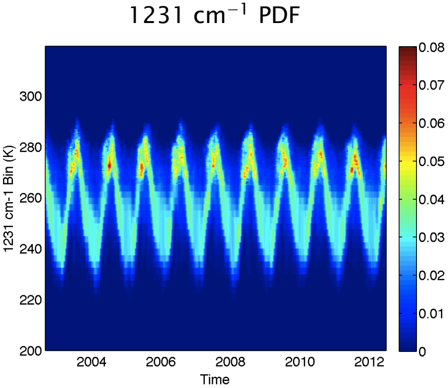


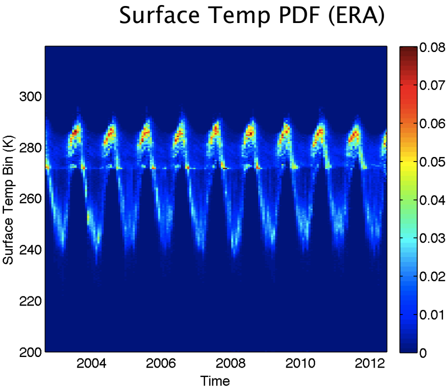
TWP may be worst case for "sharp" dPDF/dt curve

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

PDF rates relatively insensitive to calibration error!

Arctic PDF Time Series Example

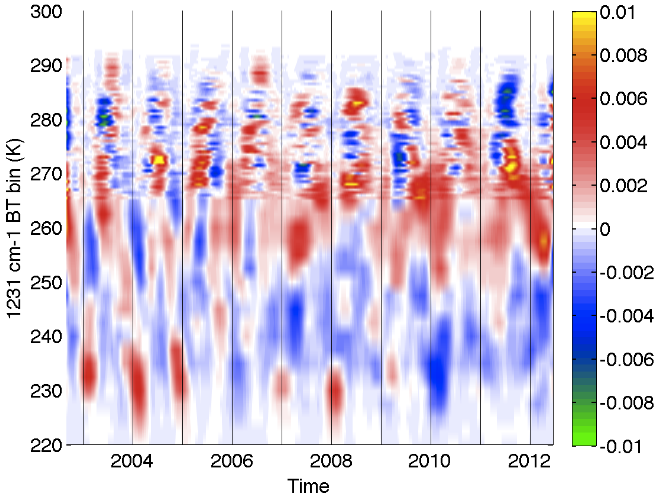




Note: Smoothing not identical in two images

Arctic PDF Anomaly

Linear rate included in anomaly



Increasing PDF's 250-270K, decreasing < 250K

BT 1231 cm^{-1}: Mean Rates (no binning)

Accurate ERA SST Rates. ERA Land T_surf Rates?

BT 1231 Observed Rates

- USA : 0.085 ± 0.021 K/yr
- Arctic: 0.12 ± 0.011 K/yr
- TWP : -0.072 ± 0.011 K/yr

BT 1231 Cloud Forcing (using ERA Surface Temperatures)

- USA: -0.065 ± 0.025 K/yr
- Arctic: -0.012 ± 0.0098 K/yr
- TWP : -0.013 ± 0.012 K/yr

BT 1231 ERA Surface Temperature Rates

- USA : 0.0071 ± 0.0125 K/yr
- Arctic : 0.104 ± 0.007 K/yr
- TWP : -0.071 ± 0.003 K/yr

Conclusions

- Probably need a better RTA and better mapping of ERA clouds to RTA vertical grid before making definitive conclusions.
- PDFs might be useful; rigorous analysis of their utility for climate trend detection remains to be done.
- Other Future Work: (1) examine other channels, (2) derive geophysical rates from binned spectra
- Need temperature pdf's simultaneously with water pdf's in order to interpret.
- Large job of cross-validation and correction between instruments. Can this be done to the precision needed?