Radiance Trending Using PDFs of AIRS with Comparisons to ERA Re-Analysis

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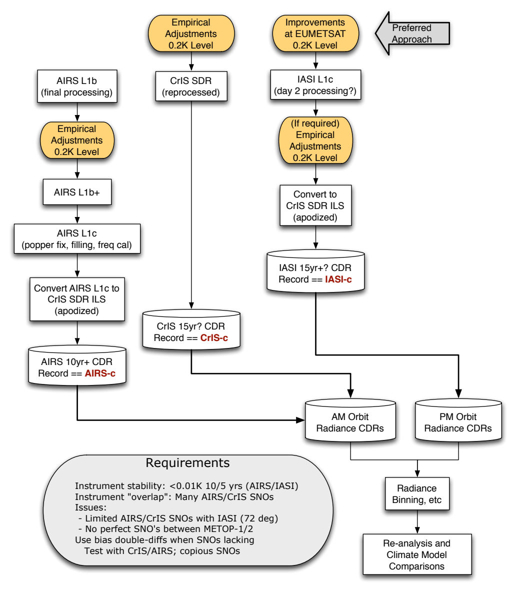
Overview

- What can we learn from long-wave operational sounder hyperspectral record?
- Create uniform radiance record: AIRS, IASI, CrIS
- Instrument stability (AIRS)
- Connecting AIRS with CrIS
- Enhance detection capability, lower accuracy requirements with PDF-based approach
- Comparison of AIRS 10-year record with ERA re-analysis using UMBC’s SARTA RTA for radiances simulation

Framework for Radiance Climate Data Record

Using AIRS, IASI, CrIS

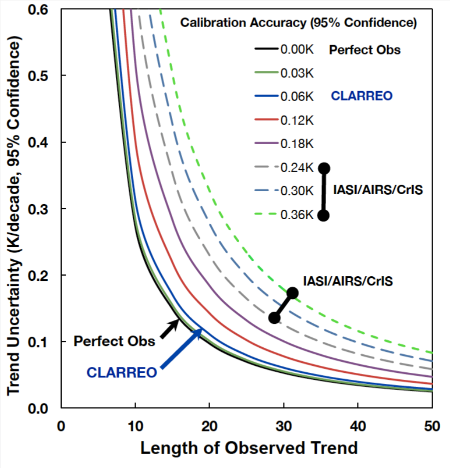


AIRS-c, IASI-c, CrIS-c are individual instrument products converted to a common spectral response (SRF).

Requires:

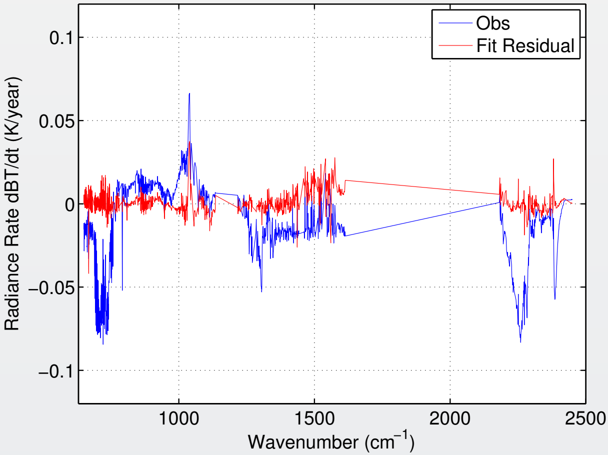
- Instrument stability (CrIS?)
- Instrument overlap (AIRS/CrIS with IASI?)
- SRF conversion algorithms
- Hopefully, B(T) differences dominated by on-board blackbody differences
- Cooperation among instrument teams, and ???

CLARREO LongWave Requirements



- Can we lower AIRS/CrIS effective calibration accuracy? Yes?
- Is the Trend Uncertainty (mean radiance change) the proper metric? Use PDF/quantile analysis to enhance detection.

AIRS Stability: Clear Subset Radiance Rate Fits

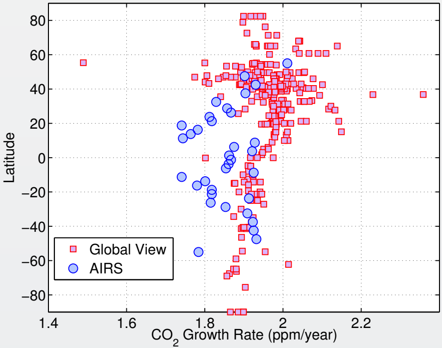


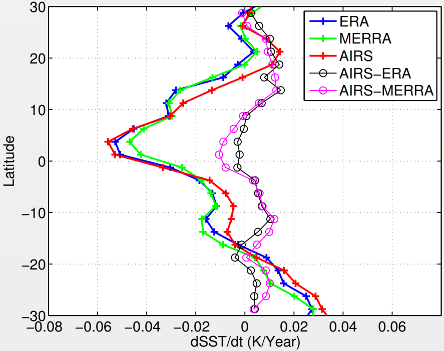
10-Year linear rates

Not frequency corrected, no L1c

OEM Fit Results

All a priori = 0, covariance = ~3X nominal variability

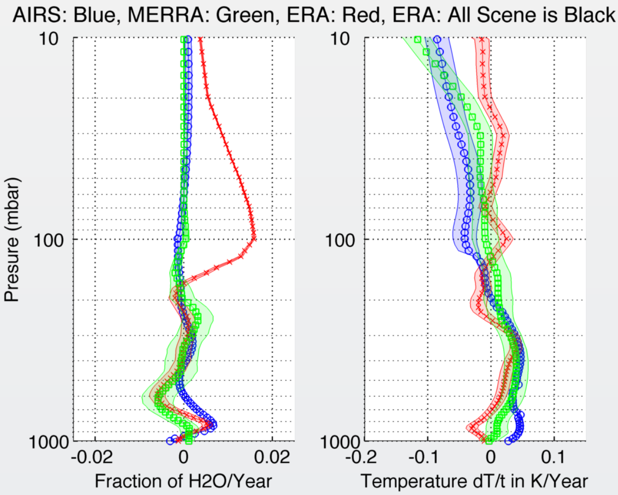




AIRS SST - SST CDR: +0.004 ± 0.006 K

AIRS CO_2 - In-Situ CO_2: -0.004 ± 0.004K

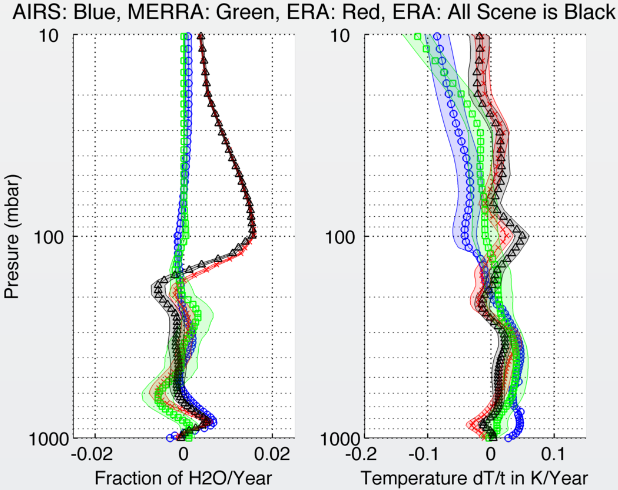
OEM Profile Fits, N. Mid Lats: Reasonable Agreement



Blue is OEM retrieval. Green, blue are linear rates derived directly from MERRA, ERA model fields matched to AIRS clear observations.

OEM Profile Fits

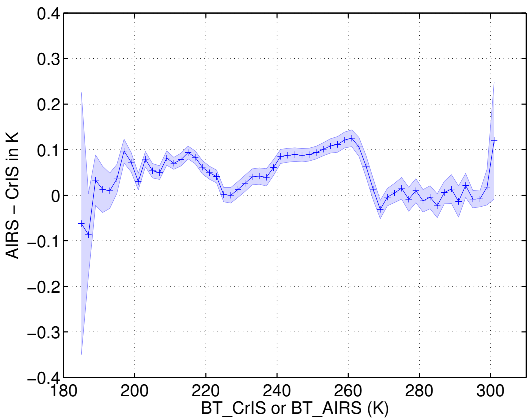
All-Scene ERA Result Shown



Black is ERA using all model fields, not just those co-located to AIRS clear subset.

Connect AIRS to CrIS: SNO Comparisons at 900 cm^{-1}

Ensure agreement versus scene temperature

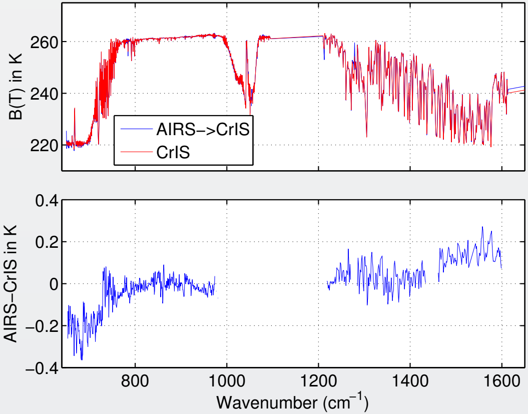


More work needed (Univ. Wisc. SSEC has an extensive effort). For CLARREO, relevant number is difference if uncorrected, is standard deviation *if* well-defined offsets can be derived.

H. Motteler: AIRS -> CrIS ILS Conversion

Robust approach uses AIRS Measured ILS functions.

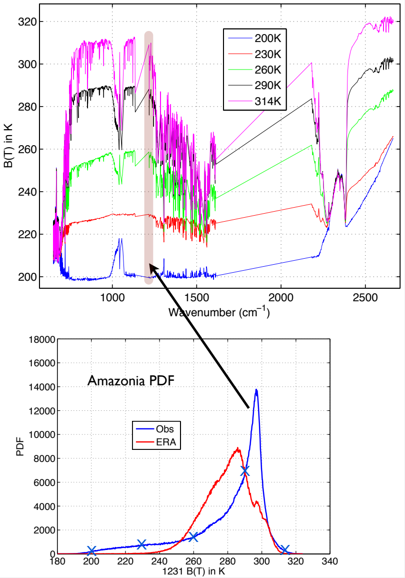
Convert AIRS ILS to CrIS for long-term radiance record.



This comparisons shows SNO intercomparisons for 1 day, Oct. 1, 2012. A key part of this work is JPL AIRS Project L1c product, removing effects of popping channels.

PDF Measurement Approach

Do not average all-sky radiances.

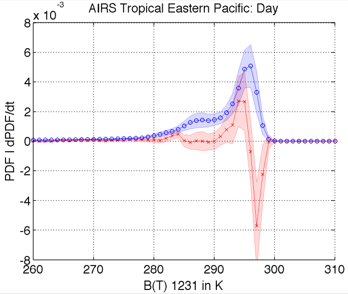


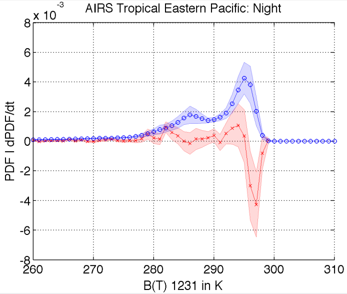
Retain more information: PDF rates, not Radiance Rates

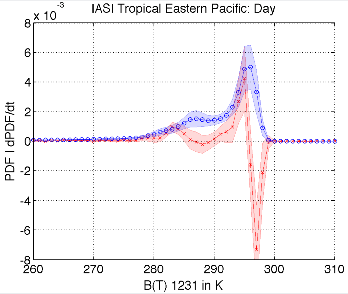
- Averaging clear with cloudy scenes destroys information
- Bin (create PDFs) versus variable related to cloudiness
- I used 1231 cm^{-1} channel B(T): clearest window channel
- Data Set: 10 years of AIRS, only FOVs on each side of nadir
- Bins of B(T) 1231 cm^{-1}, from 190:1:320K
- Mean BT spectra in each bin are stable versus time
- All the information is in the PDFs in each bin

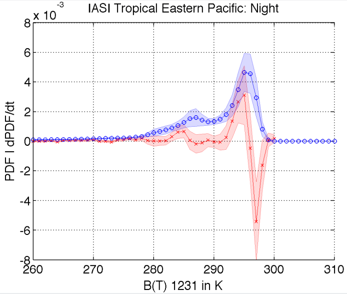
Diurnal Variability of PDF Rates (5-year rates)

PDFs divided by 25; Mean BT Rates (AIRS) -0.03K, -0.08K (IASI) 0.01K, 0.01K, all 2σ ~ 0.15K







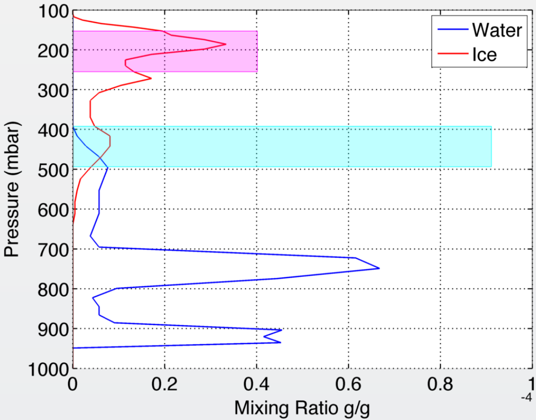


Comparisons to ERA Re-Analysis

Re-Analysis heavily used by climate community

- CLARREO: compare model to observations in radiance space
- SARTA is UMBC RTA, used for AIRS and by NOAA
- Developed mapping of model clouds fields to RTA, 2 scattering layers only for now
- Comparisons to 100-layer cloud overlap models are quite good!

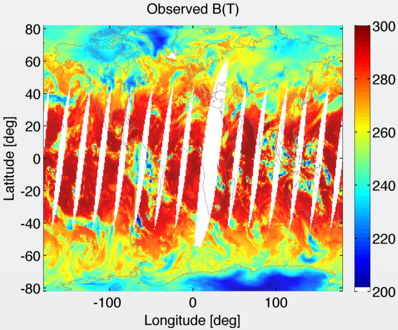
SARTA: 2-cloud layer RTA



100-layer cloud RTA too slow for our purposes. Convert re-analysis cloud fields into two layers (water, ice). Top of cloud where optical depth is near unity. Results very similar to PCRTM (and SARTA 100-layer), far closer than differences to observations.

Overview of SARTA vs Observations: ECMWF, not ERA

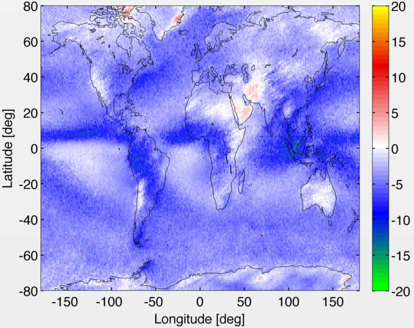
March 11, 2012, 1231 cm^{-1} channel



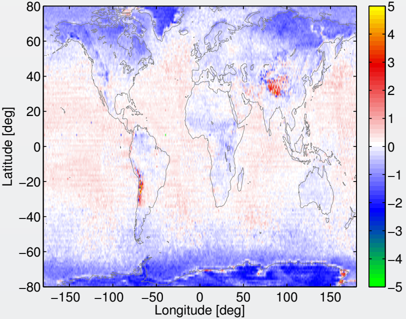
Comparisons quite good at this scale.

SARTA Comparisons to Observations

1231 cm^{-1} Bias

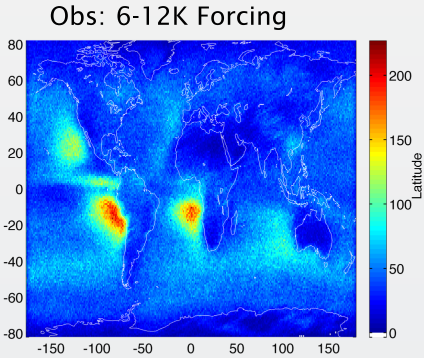


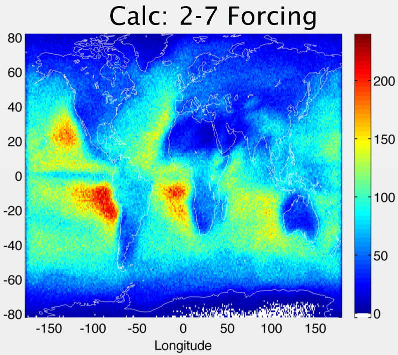
1441 cm^{-1} Bias



High cloud scenes removed for 1441 cm^{-1} bias analysis.

Marine Boundary Layer Cloud: Obs vs ERA

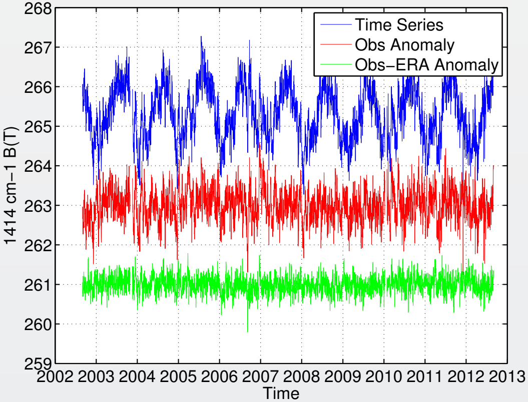




ERA MBL clouds too low. SARTA 2-slab and PCRTM agree, not an issue with 2-slab geometry.

500 mbar Global Water Channel Time Series

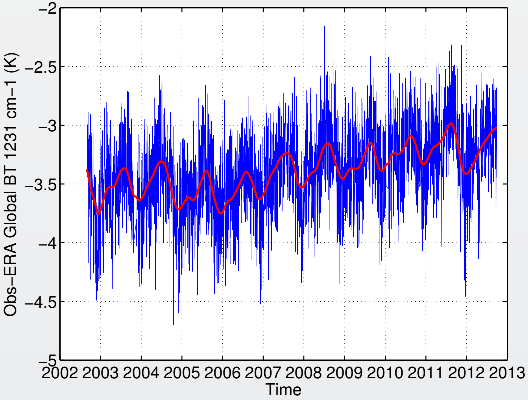
1414 cm^{-1}, No PDF/quantile binning



Global: ERA captures global variability.
Obs: -0.016 ± 0.01 K/year
ERA: -0.014 ± 0.009 K/year

1231 cm^{-1},Global Window Channel Time Series

Simple subtraction of Obs-Calc, daily global binning



Red curve is smoothing. Clear long-term differences.

Quantile vs PDF Approach

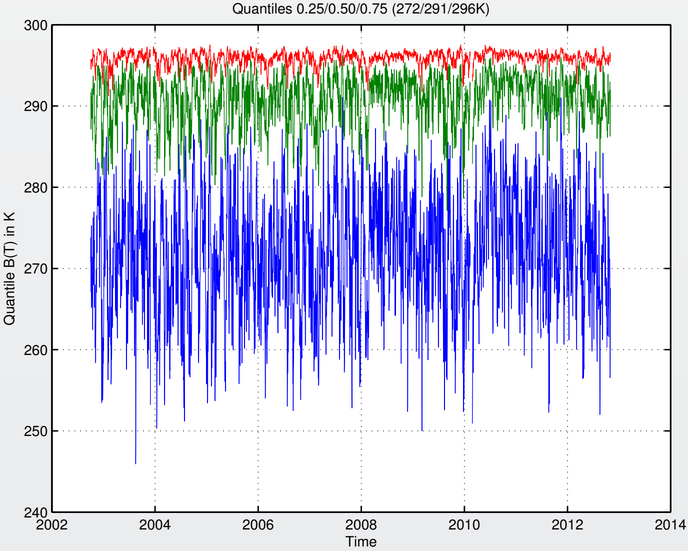
- Previous approach: B(T) 1231 cm^{-1} is independent binning variable: find PDFs of B(T) 1231 since closely correlated with clouds.
- New approach: Make cumulative probability distribution independent variable: find mean value of B(T) 1231 in each "quantile" bin.
- Leads to easier interpetation

Quantiles (cumulative probability distribution): 0:dp:1. Sort B(T) in ascending order and fill bins.

Usually plot B(T) that goes with each dp bin, rather the cumulative probability.

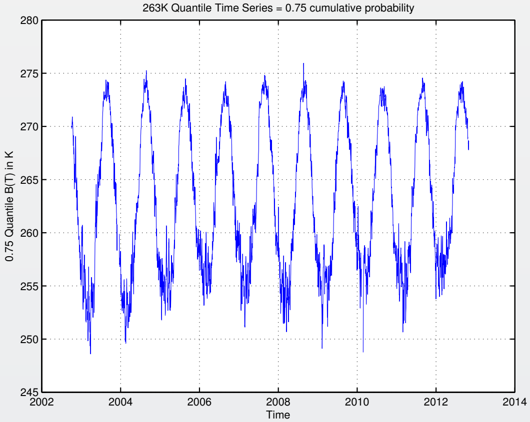
Tropical Western Pacific

Three quantile time series: 0.25, 0.50, 0.75



Arctic

0.75 probability bin

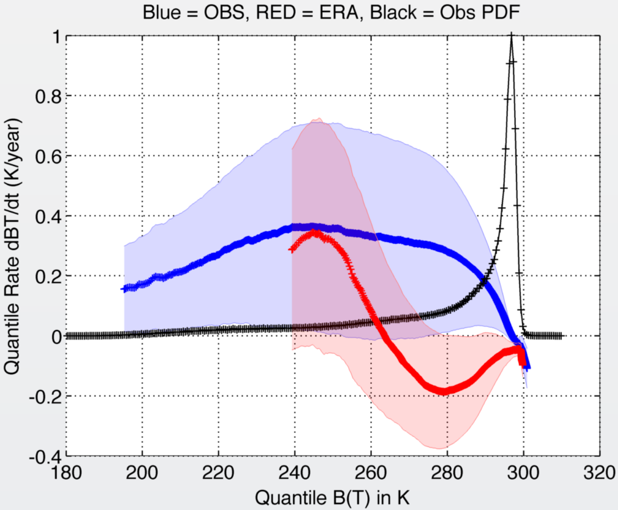


Approach very useful for studying extremes. Note warmer winter radiances.

Quantile Rates

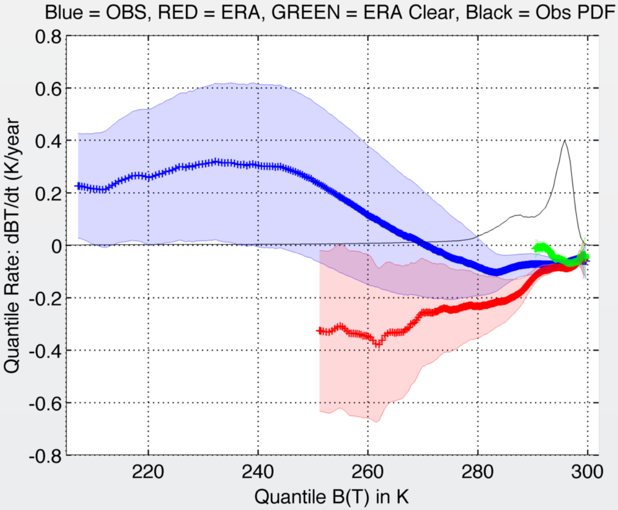
- Subset of some geographic region (TCON regions)
- Determine quantiles for each day in 10-year period
- Fit time series of quantiles for linear growth rate (remove seasonal signals).
- Examine variability versus models (ERA)

Tropical Western Pacific



Mean rate: 0.14K ± 0.04K
However, quantile analysis shows cooling near high-end sensitive to surface.
Model shows more clouds compared to observations, but error bars overlap.

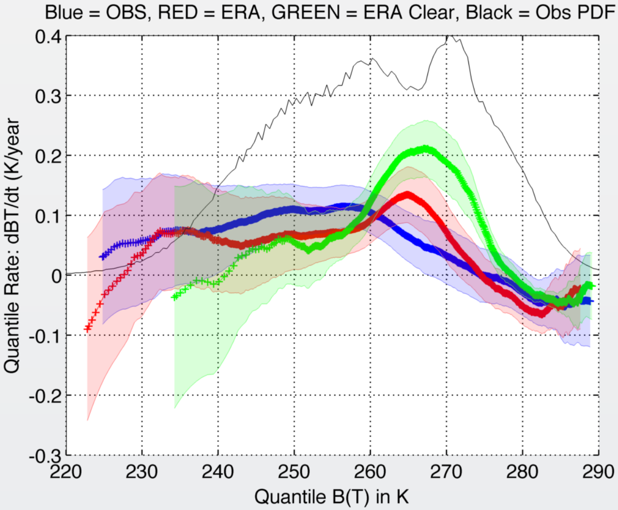
Tropical Eastern Pacific



Mean rate: -0.04K ± 0.02K

Model may have fewer marine-boundary layer clouds over time, but error bars overlap.

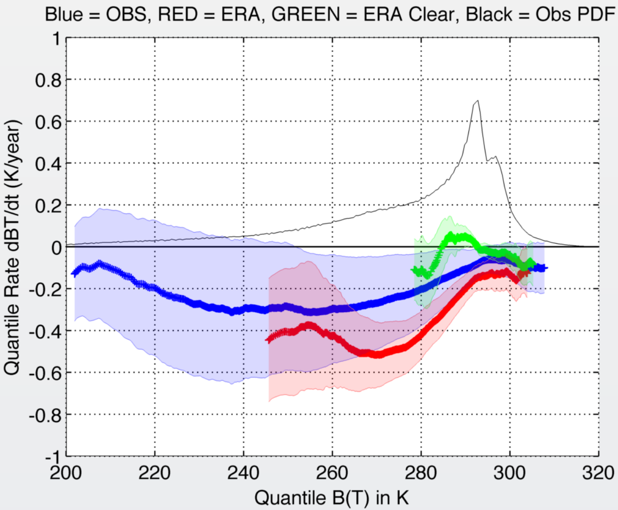
Arctic



Mean rate: 0.12K ± 0.01K

As per Artic time series, warmer winters, slightly cooler for warm observations.

Amazonia



Mean rate: -0.09K ± 0.05K
Good agreement with ERA, lower cloud forcing

Conclusions

- Operational sounders should be able to contribute to CLARREO-like observations
- However, many details need careful attention and peer review, and:
- Different groups need to cooperate!
- A PDF/quantile approach increases information content retrieval compared to mean spectra
- Eventually need to move from analysis of single channels, to retrievals of cloudy spectra