8 Year Radiance trends from AIRS and Comparison to ERA-Interim Reanalysis

L. Larrabee Strow, Sergio De-Souza Machado, and Paul Schou

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

CLARREO STM
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Overview

NASA HQ: How Achieve CLARREO Objectives?

- Use existing sensors: AIRS, IASI, CrIS??
- Start with AIRS: 9 years now, maybe 15 years total?
- Use AIRS to test data analysis methodologies

AIRS Analysis

- How stable is AIRS?
- Examine AIRS trends: (a) Clear scenes, (b) Cloudy scenes
- Compare to ERA-Interim Reanalysis

Approach

- Use radiances directly to perserve accuracy
- Convert to geophysical units as “late as possible”
- Examine the competition: Reanalyses

Long Term

AIRS will not last long enough for CLARREO objectives

Diurnal Cycle

- AIRS only samples diurnal cycle twice per day
- Can IASI provide two more samples? (3 identical instruments planned)
- Producing a homogenous radiance record (AIRS + IASI): Difficult, but maybe not hopeless?

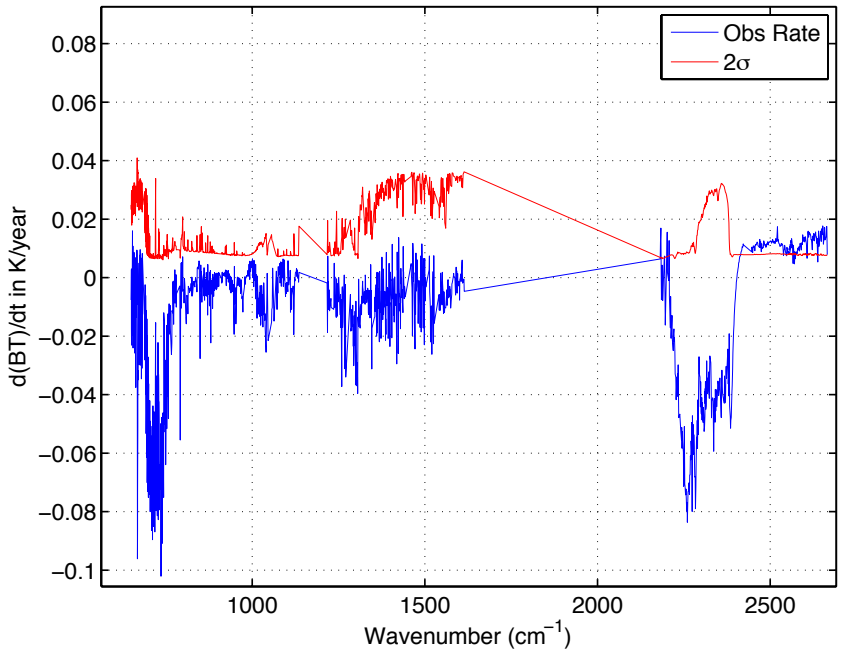
AIRS $\longrightarrow$ CrIS

- Expect AIRS + CrIS to overlap in time, space
- Can their radiance records be "patched" together? Will have *many* SNO's. *NO* SNO's for IASI-1 vs IASI-2!
- Will CrIS be stable enough? Will NOAA get to build CrIS2, CrIS3?
- Can AIRS and CrIS be combined into a homogeneous record?

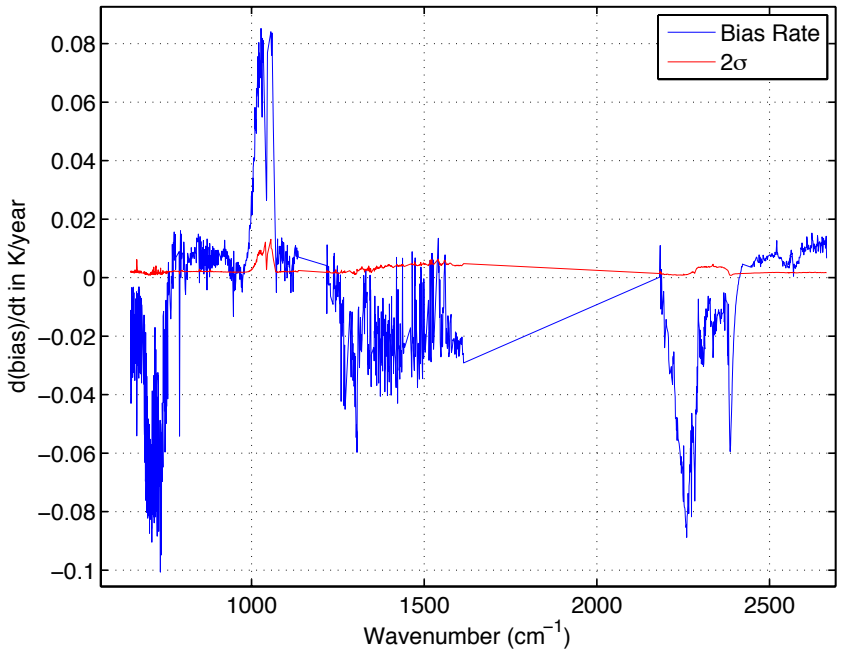
AIRS Stability

A. Compare to ERA-Interim Reanalysis (and SST)

Clear Scene BT Rates



Clear Scene Bias Rates

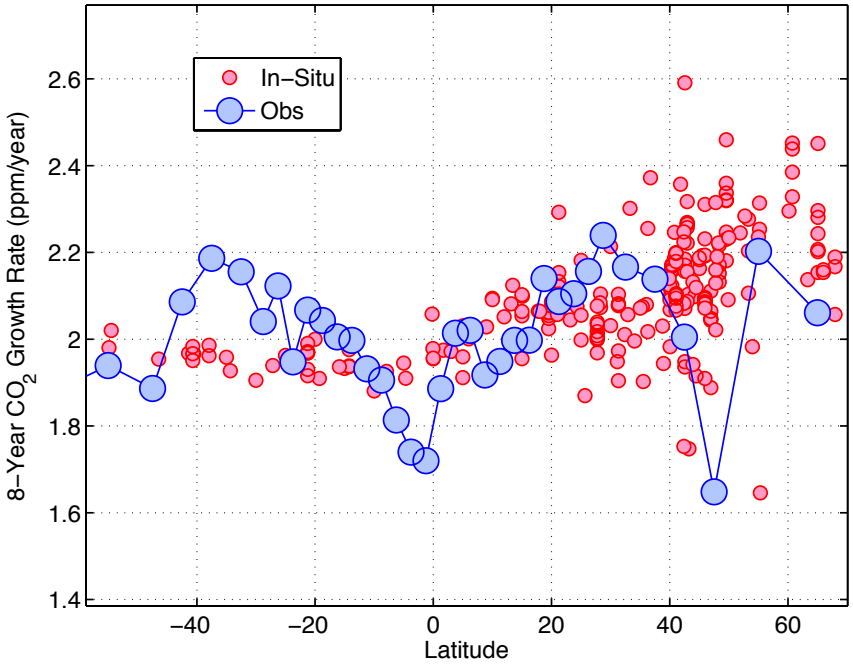


These are tropical ocean scenes. Uncertainty dominated by atmospheric variability (H_2O, QBO in stratosphere).

Bias rate uncertainty far lower, ERA-Interim removes atmospheric variability. If believe ERA (SST) AIRS stable to 3-7 mK/year.

AIRS Stability

B. CO_2 Growth Rate Comparisons



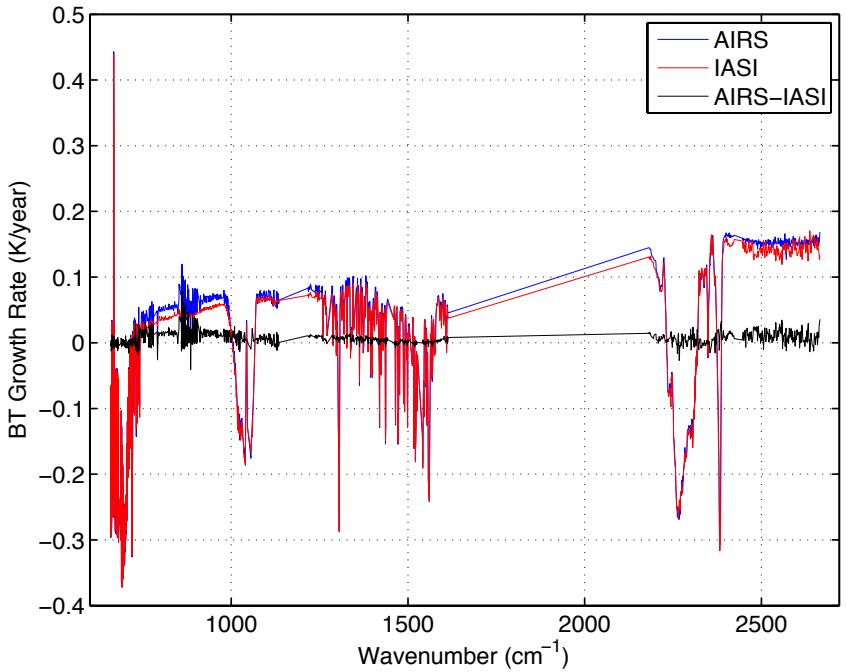
OEM Fit of Radiance Rate

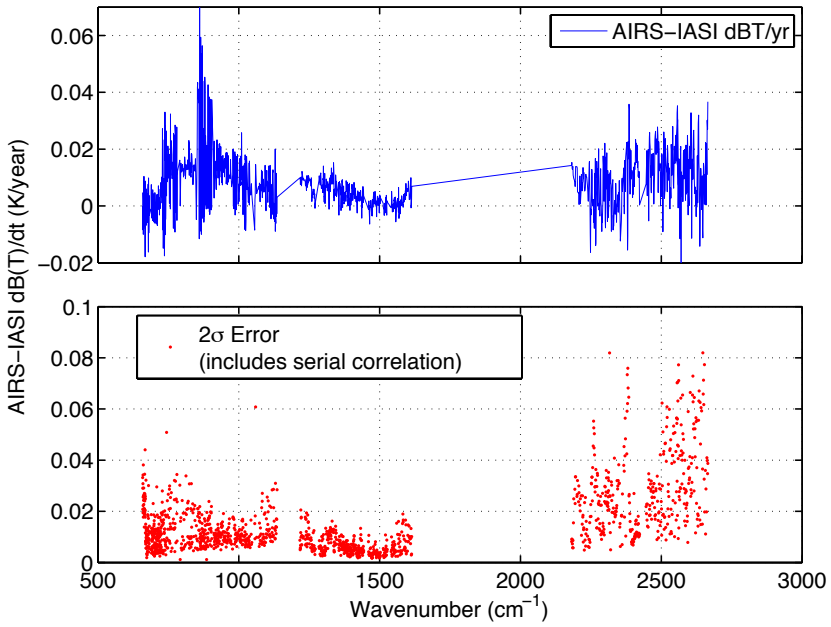
- OEM fit: CO_2, N_2O, CH_4, H_2O profile, T profile
- Regularization: L1 derivative smoothing for H_2O, T profiles.
- AIRS frequency calibrated and adjusted.

- Agreement very good, much less than $\sim$ 0.01K/year.
- No apriori information.
- Kernel function for CO_2 suggests H_2O is helping get the right CO_2 rates.
- If fit ERA-Interim biases for CO_2 you get the **wrong** answer, about 1.7 ppm/year.

AIRS Stability

C. Relative to IASI.





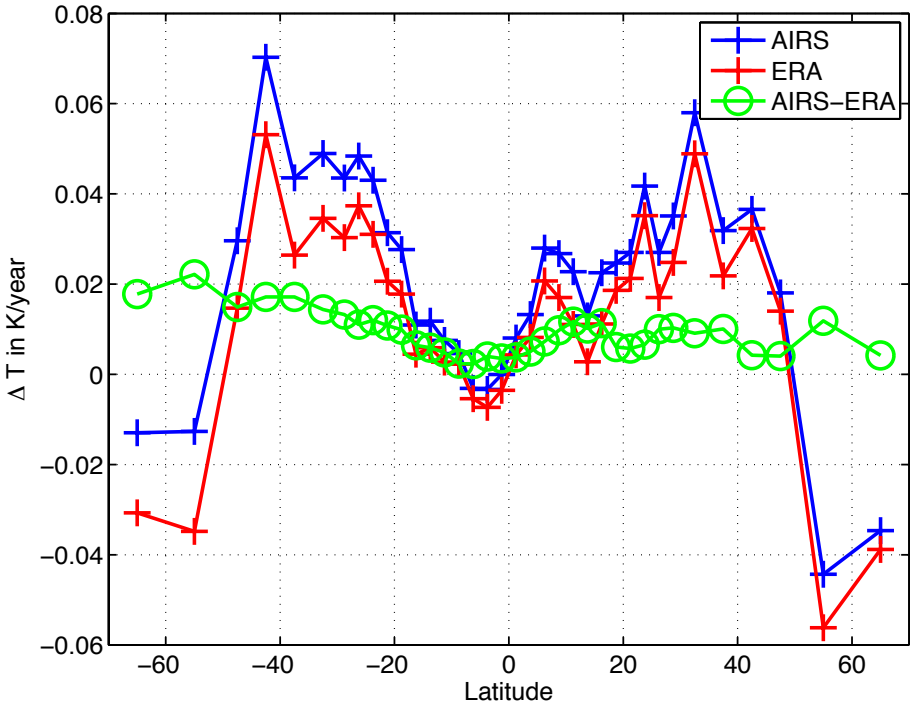
Use 4-years of AIRS/IASI SNO's

- Showing N. Hemisphere SNO Rates: +74 Deg. N.
- Strat cooling, trop getting warmer
- AIRS and IASI relatively stability < 0.01K/year
- Small issues with AIRS window channels (A/B detectors)

AIRS Stability

D. Relative to ERA-Interim (T-profile).

T-profiles rates averaged from 250 mbar to the surfce.



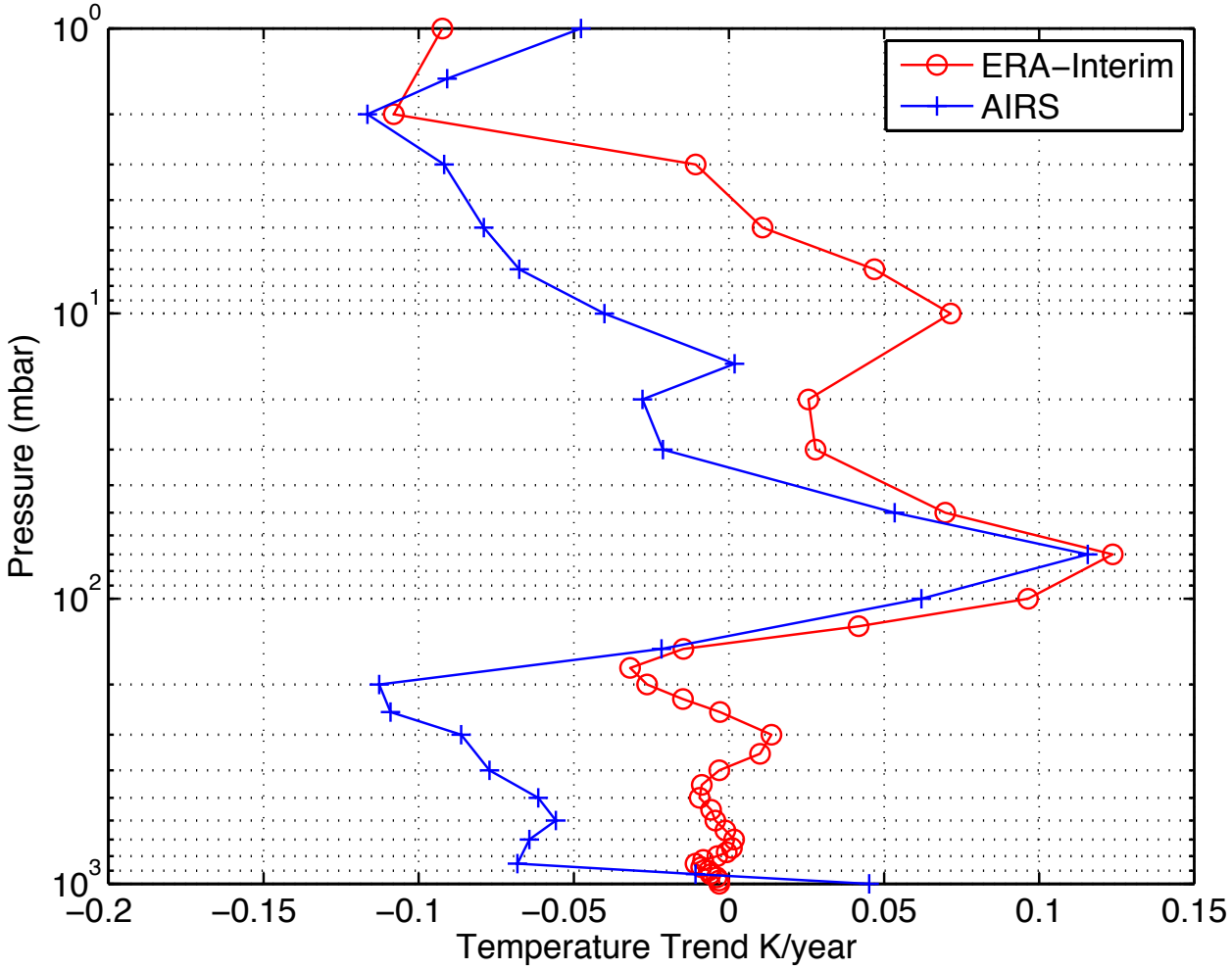
OEM Fit (discussed earlier)

- No apriori (L1 profile smoothing)
- CO_2, etc fit at same time, or removed using in-situ data
- Clear sky bias, but matched ERA to observations
- Persistent 0.01-0.02K difference

Observed minus ERA in strat is same magnitude, opposite sign.

AIRS Level 3 Trends vs ERA-Interim

Tropics

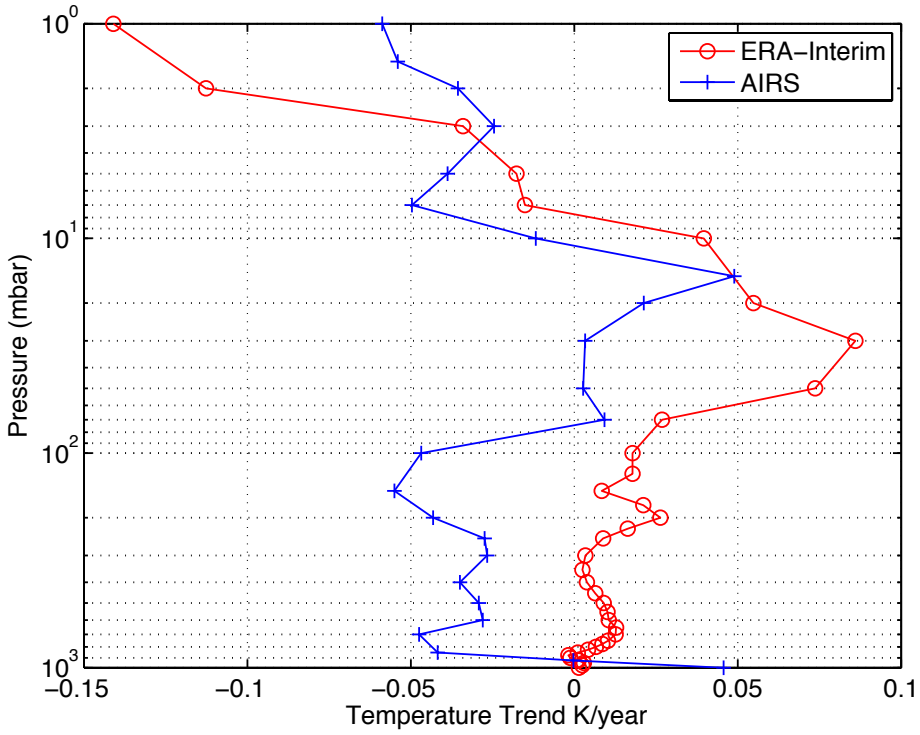


AIRS trends look incorrect in the troposphere. Ringing versus altitude?

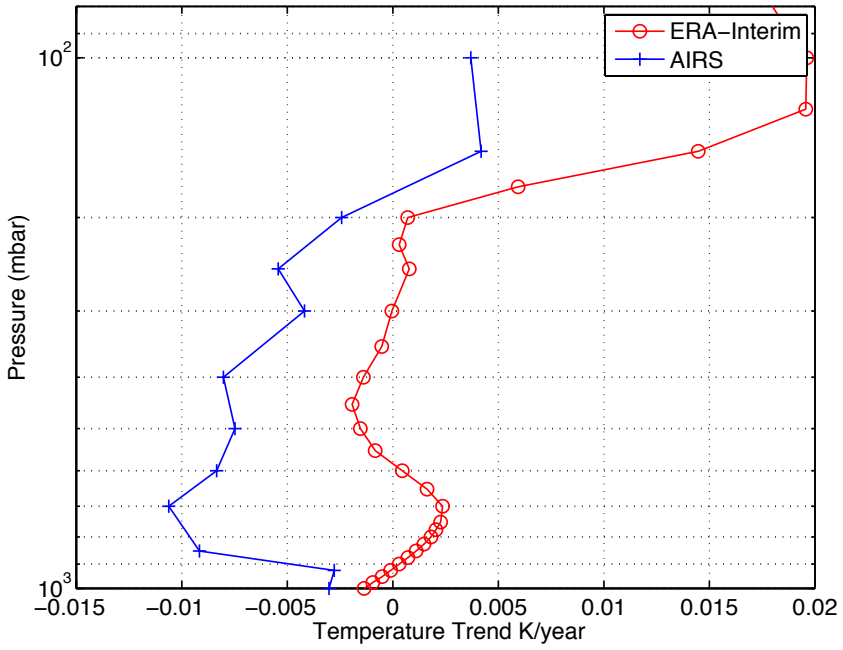
AIRS Level 3 Trends vs ERA-Interim

Mid-latitude, Polar

Mid-Latitude

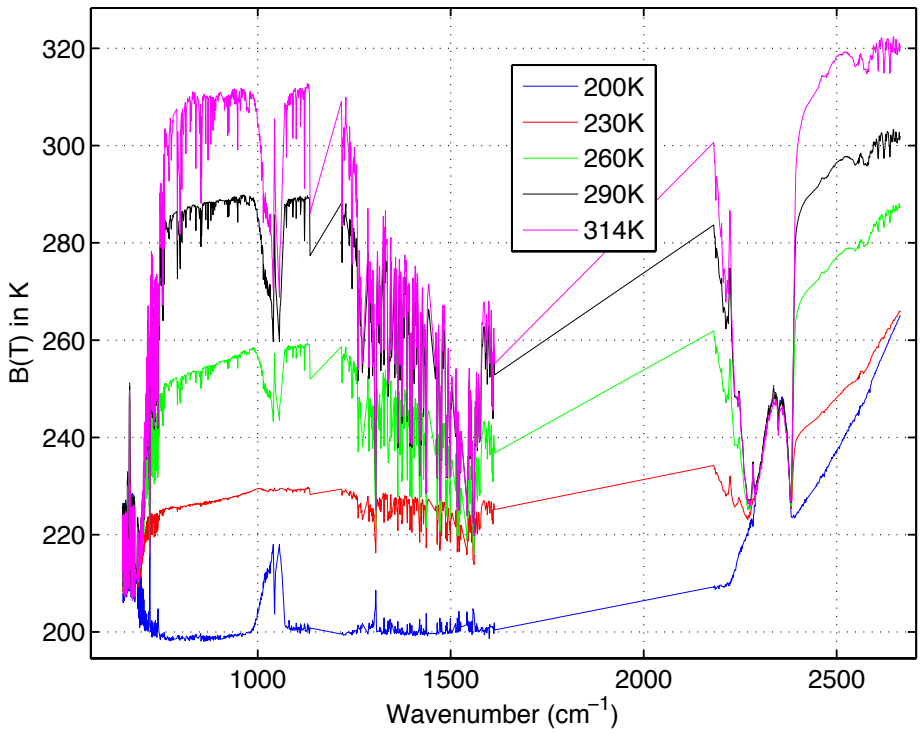


Polar



PDF Measurement Approach

Do not average all-sky radiances.

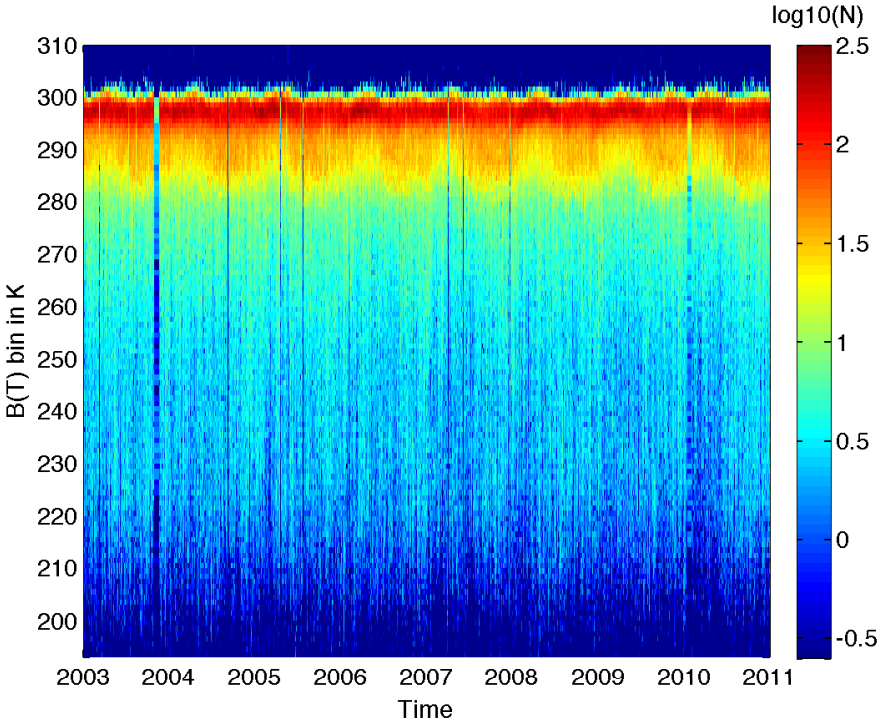


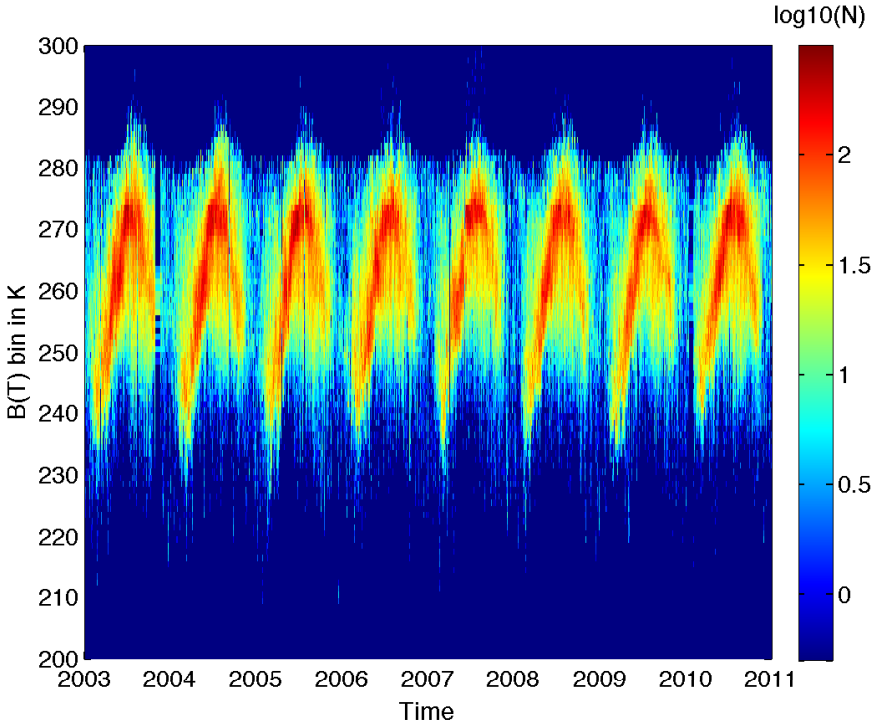
Retain more information: PDF rates, not Radiance Rates

- 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 bin PDFs

Tropical/Polar Ocean PDFs

Zonal Averaging for Now

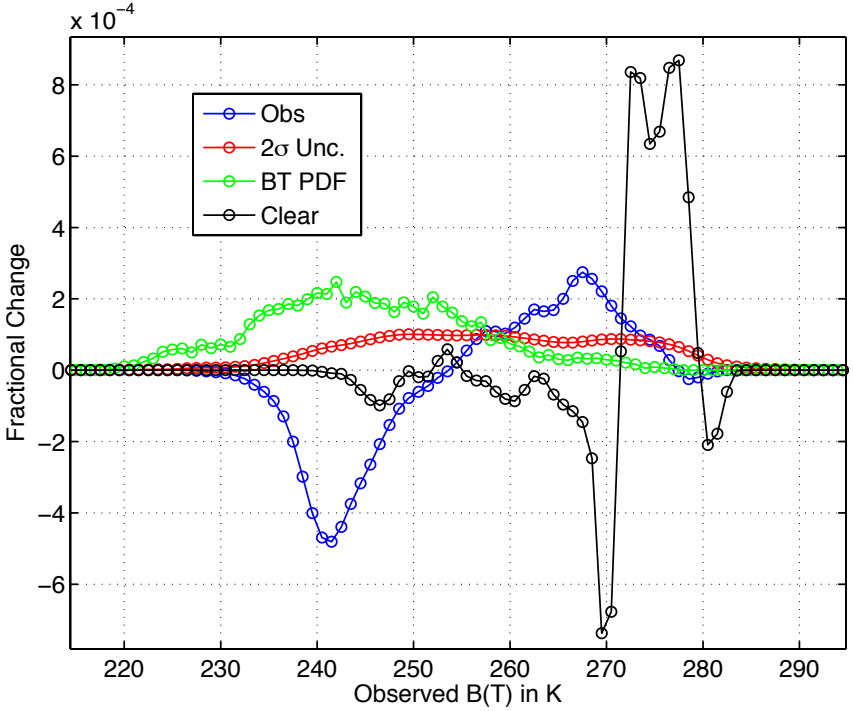




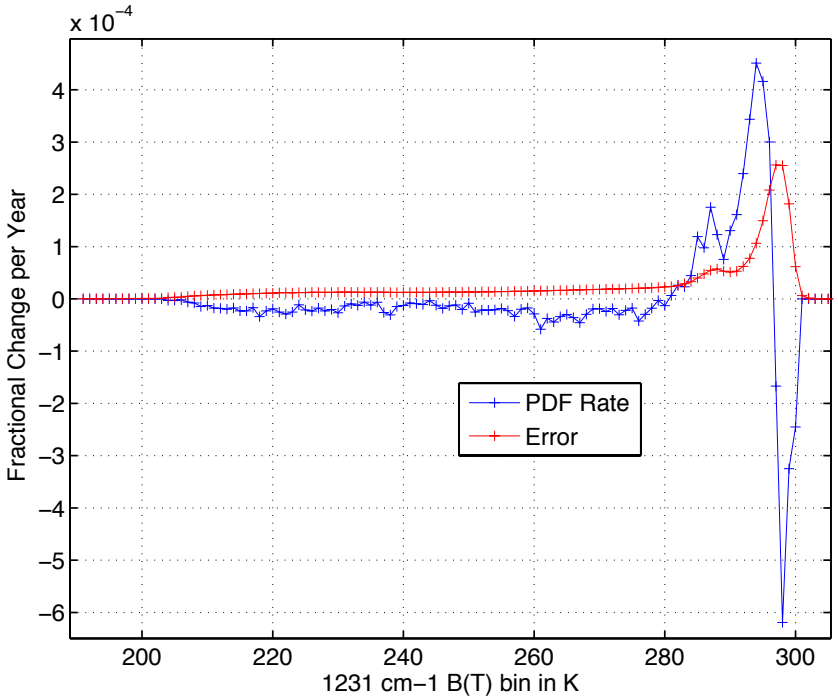
Tropical/Polar Ocean PDFs: Changes with Time

Fit each bin versus time to get a rate.

60-80 Deg. North



±10 Deg



Limited Comparisons to ERA-Interim

No time series comparisons yet for cloudy scenes.

Reanalysis Products are Very Good!

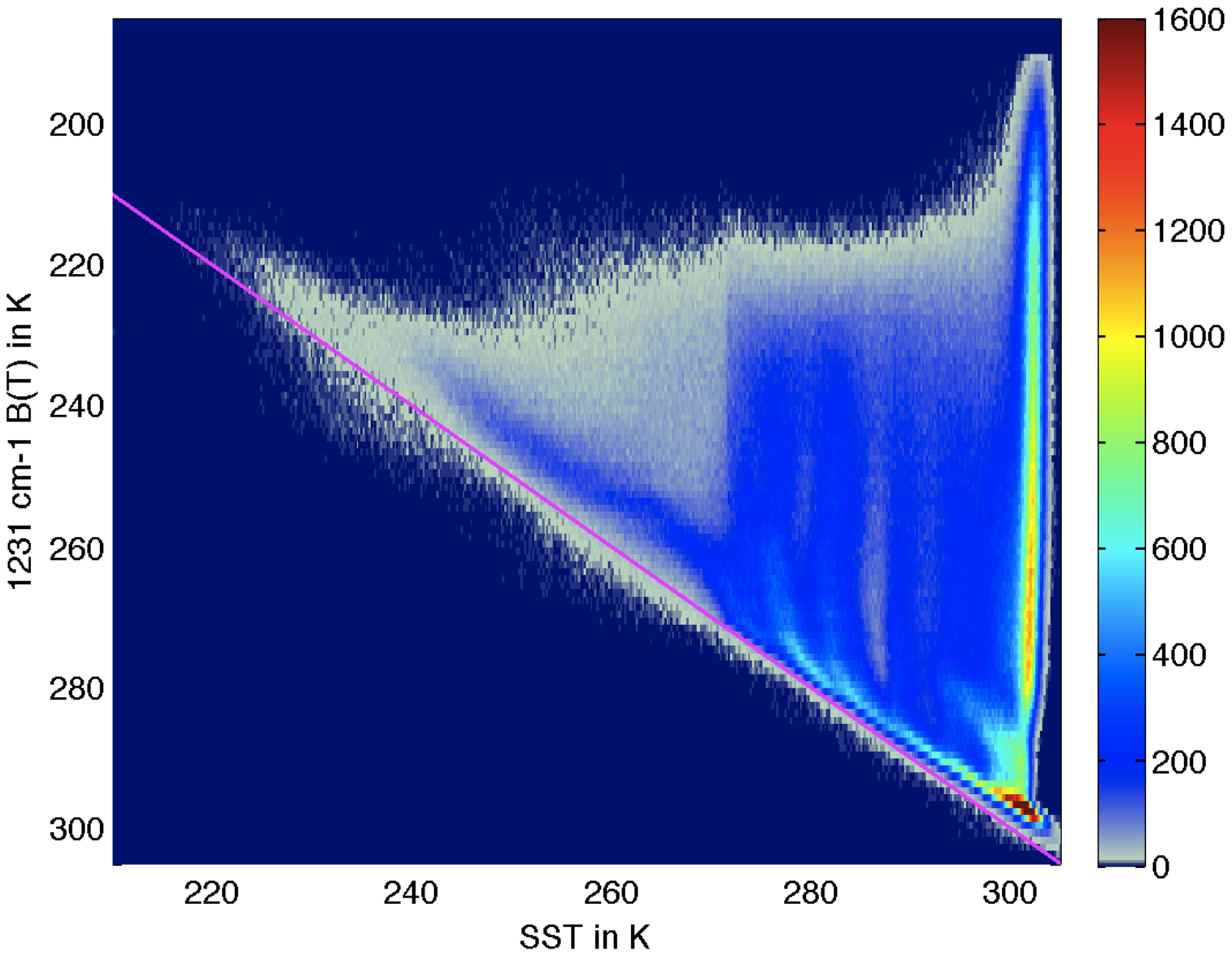
- How good? T/Q fields appear almost climate quality.
- Of course, convection not as good.
- We do RTA calculations using ERA-Interim cloud fields
- We have only started: will show results from 12 days, 1 per month

Radiative Transfer

- Our SARTA model for clear-sky.
- Turn ERA cloud product into two cloud formations, random overlap
- Can have two water clouds or one water and one ice.
- Difficult to determine if Obs-Calc differences are (a) RTA, (b) Scheme to produce RTA compatible cloud fields, or (c) errors in reanalysis clouds.

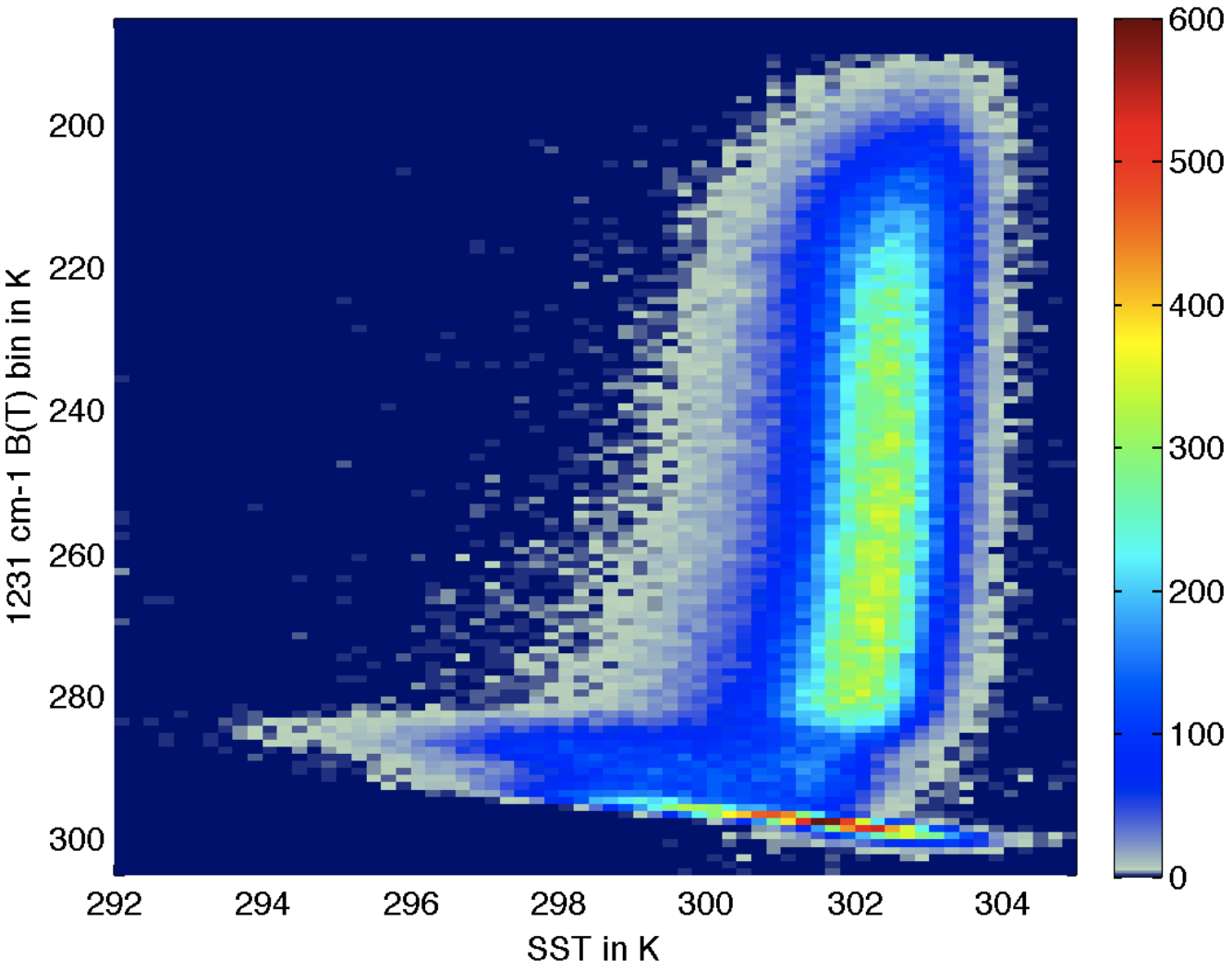
First: 1231 cm^{-1} PDF's vs SST: Ocean, Day

Not quantitative, no area averaging, etc. Use ERA-Interim SST for these plots



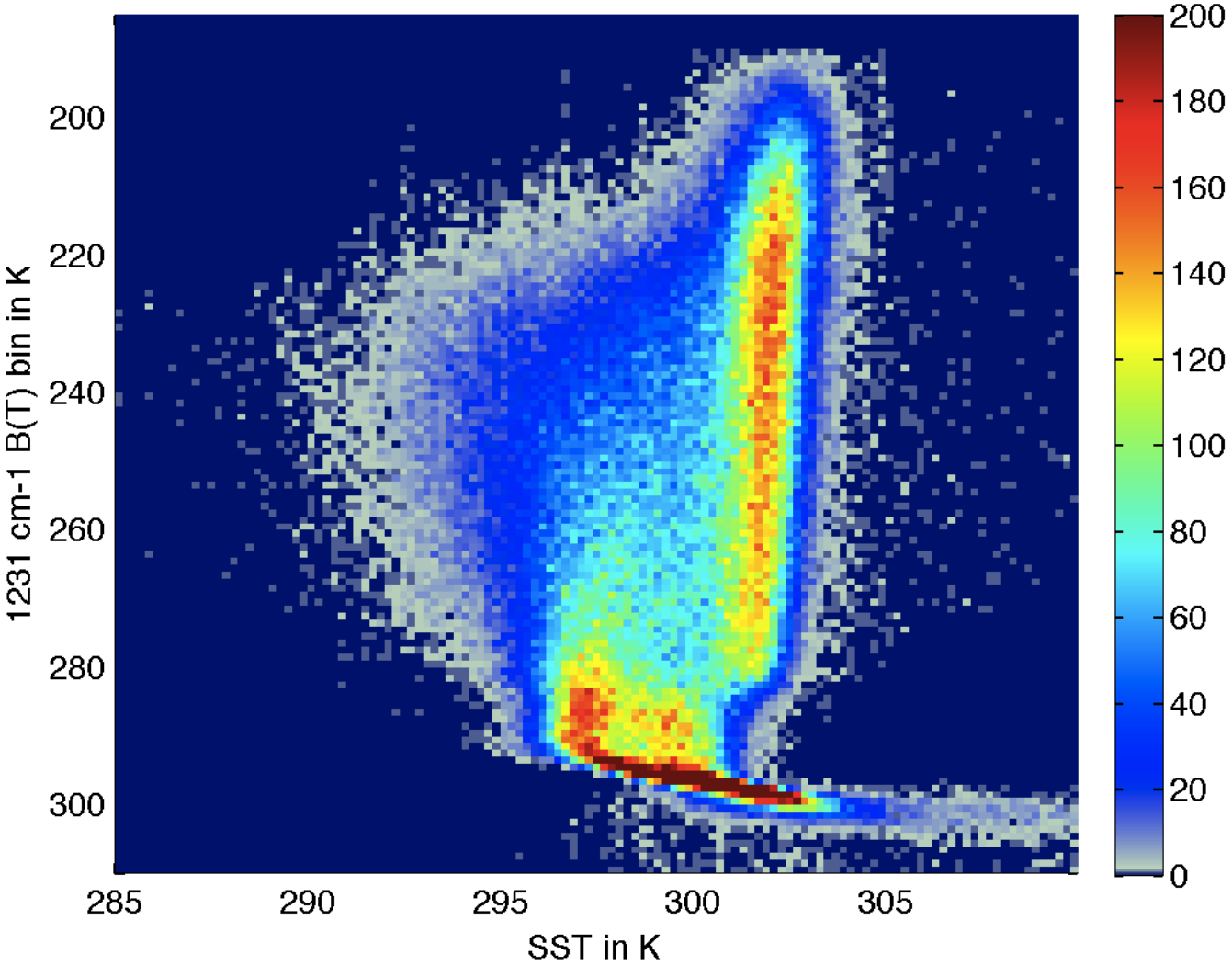
1231 cm^{-1} PDF's vs SST

-5 Deg.Latitude, Ocean, Day



1231 cm^{-1} PDF's vs SST: Mid-Lat

15-25 Deg. North Latitude, Ocean, Day

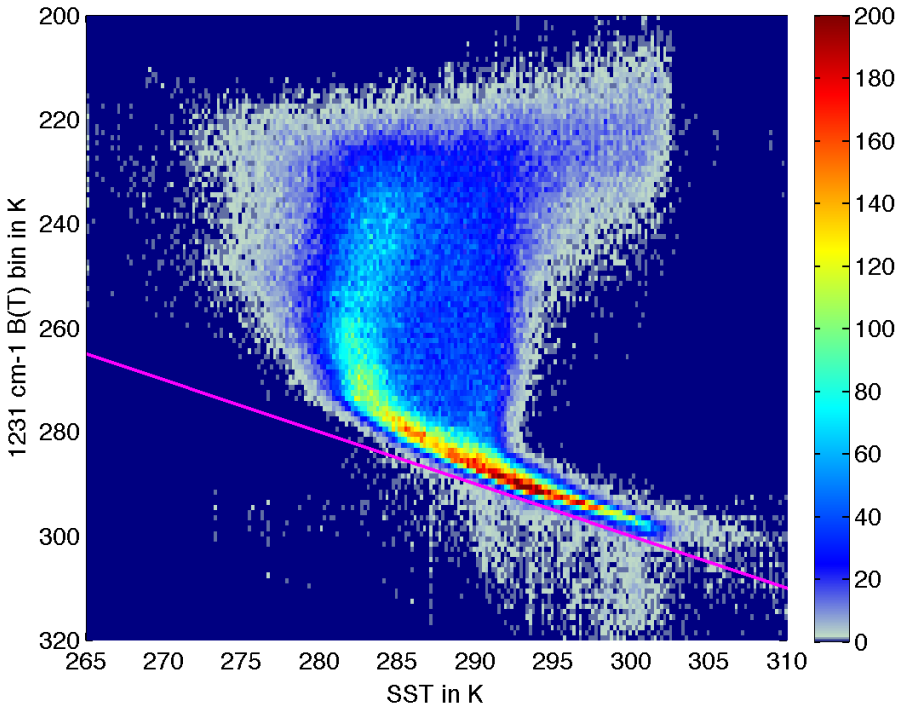


Note high probability of stratus?

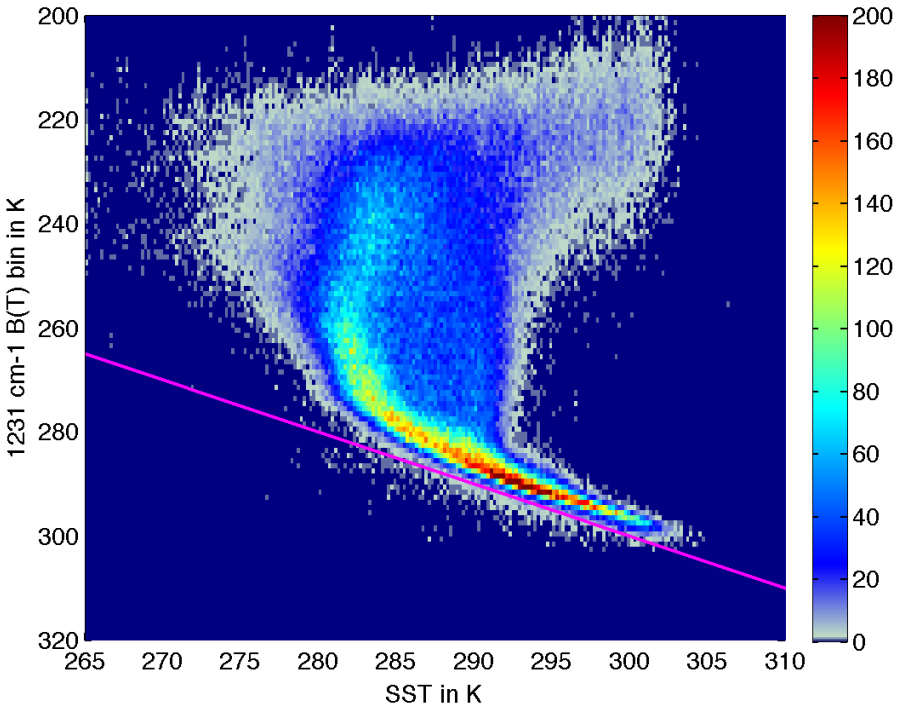
1231 cm^{-1} PDF's vs SST:

35-55 Deg. North Latitude, Ocean, Day + Night

Day



Night

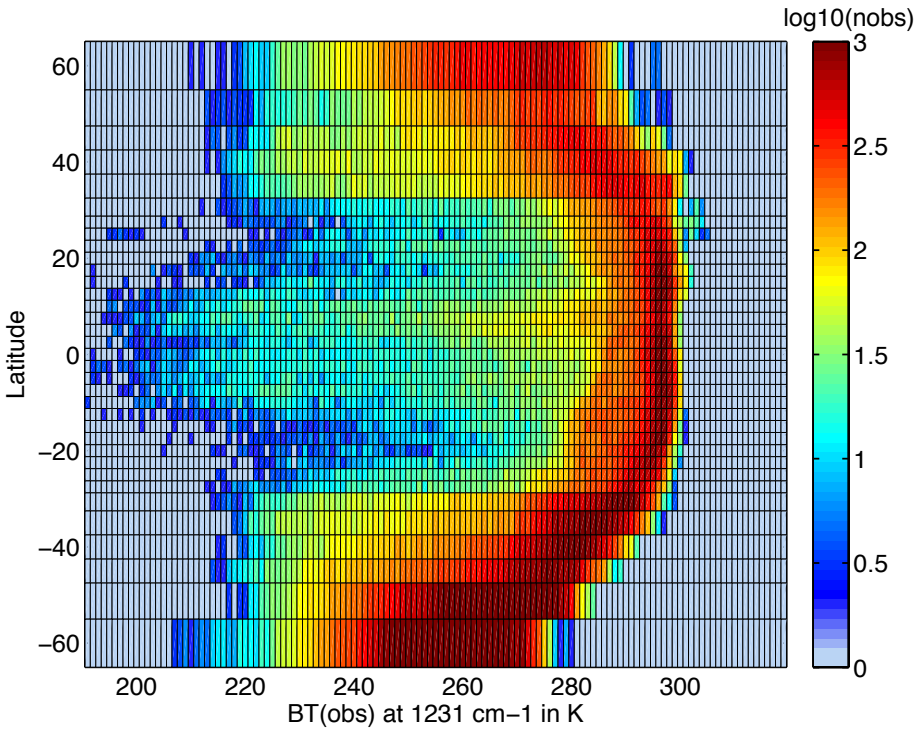


SST problems with ERA during day?

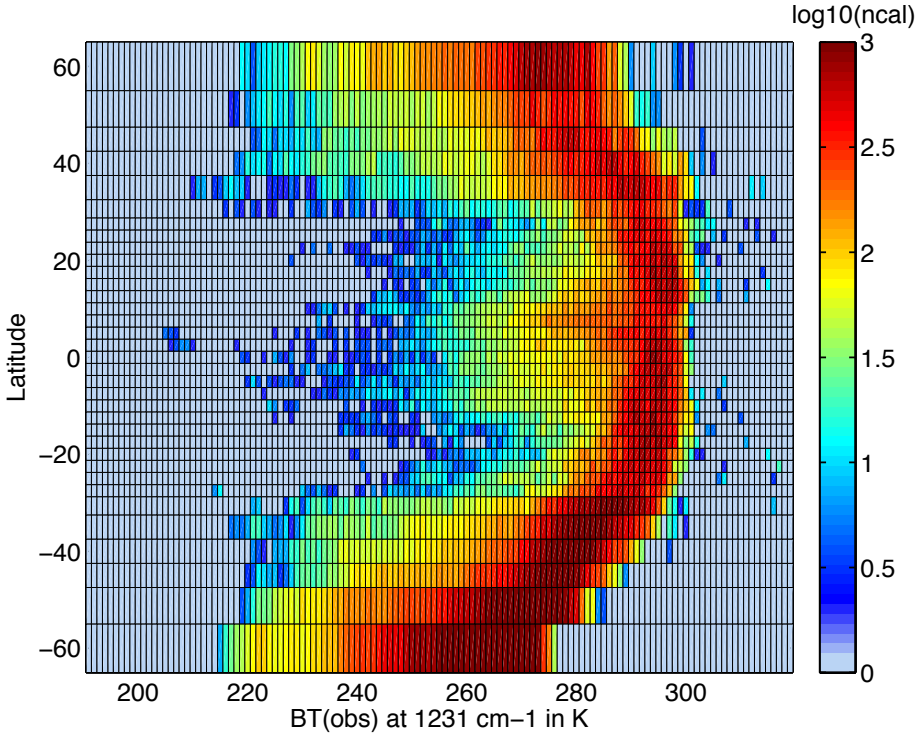
1231 cm^{-1} AIRS vs ERA PDF's

Cloudy RTA Simulations vs Obs

AIRS



ERA Simulated

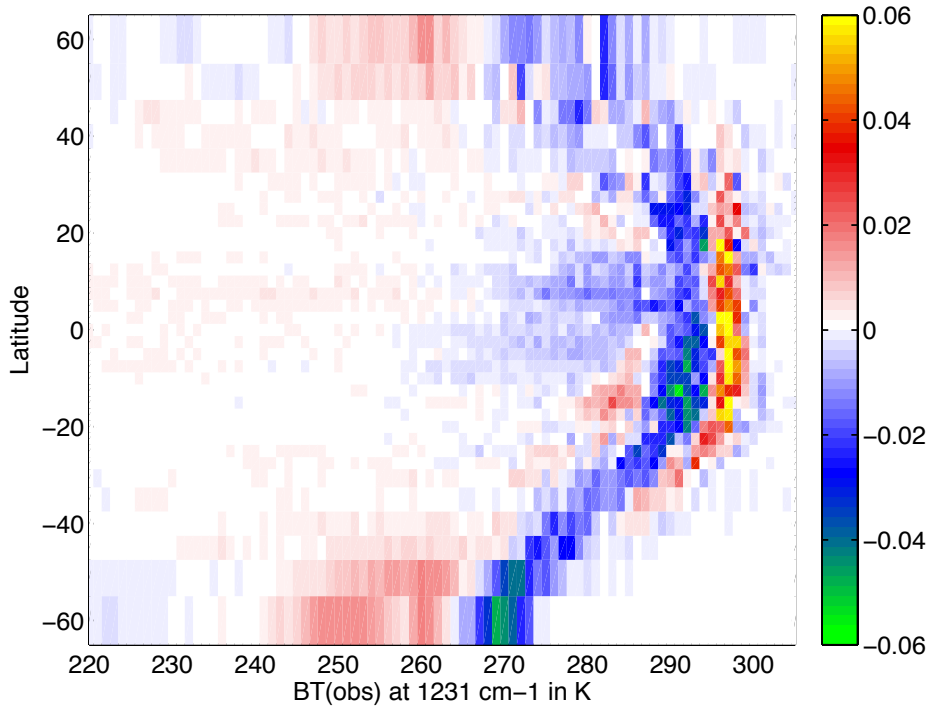


Note log10 scale for Nobs.

Main difference: Lack of deep convective clouds in ERA.

1231 cm^{-1} AIRS minus ERA PDF's

Cloudy RTA Simulations vs Obs



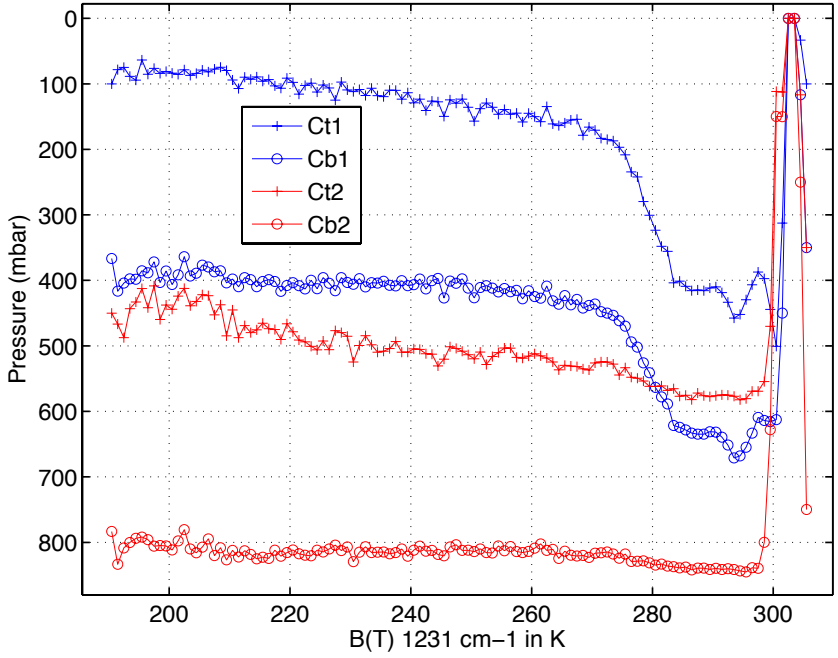
Differences:

- RTA?
- ERA to RTA Cloud Conversion?
- ERA Cloud Model?

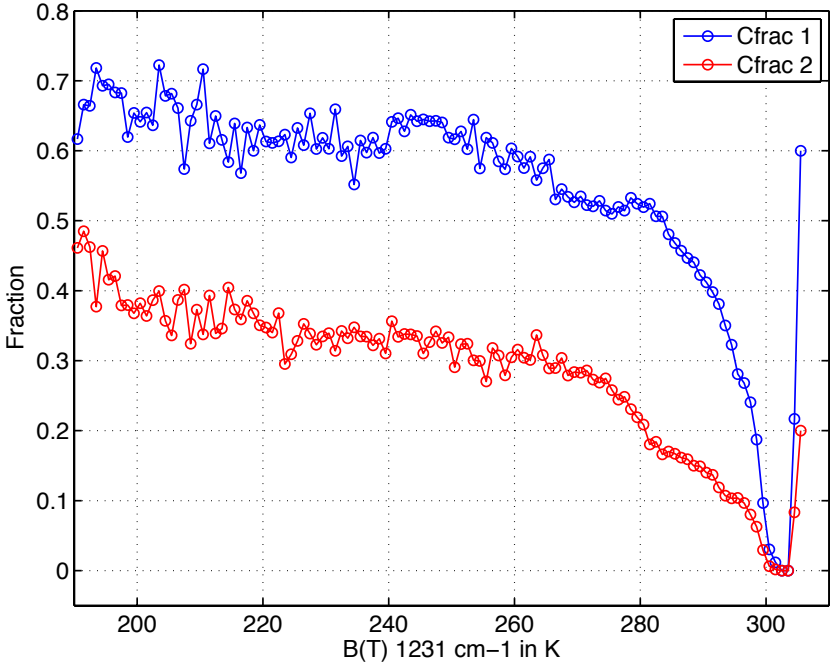
ERA-derived Cloud Boundaries and Fractions

Simplications to ERA Model

Cloud Boundaries



Cloud Fractions

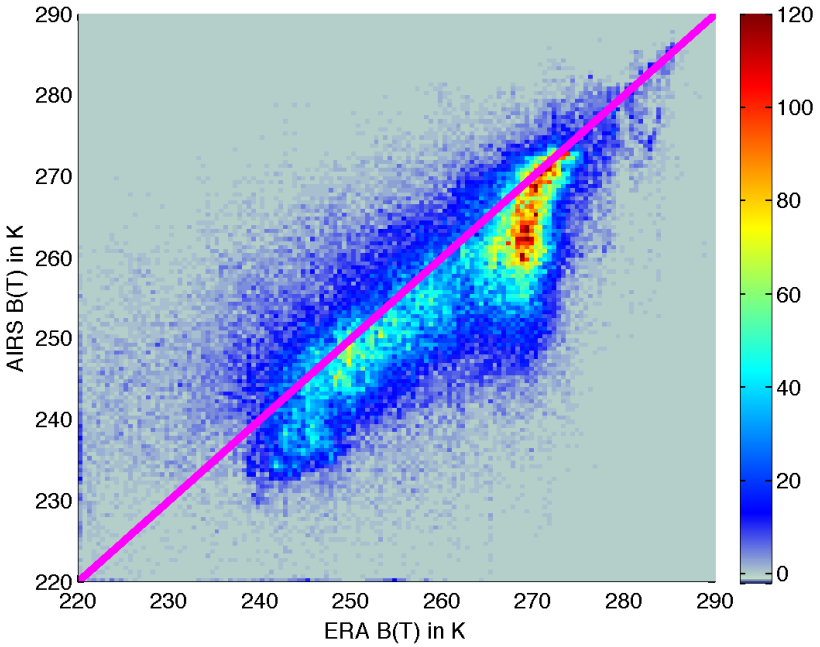


Two cloud approach appears to break down for DCCs. Unsure why cloud boundary goes all the way to zero (bug). However, ERA lacks DCC's anyway.

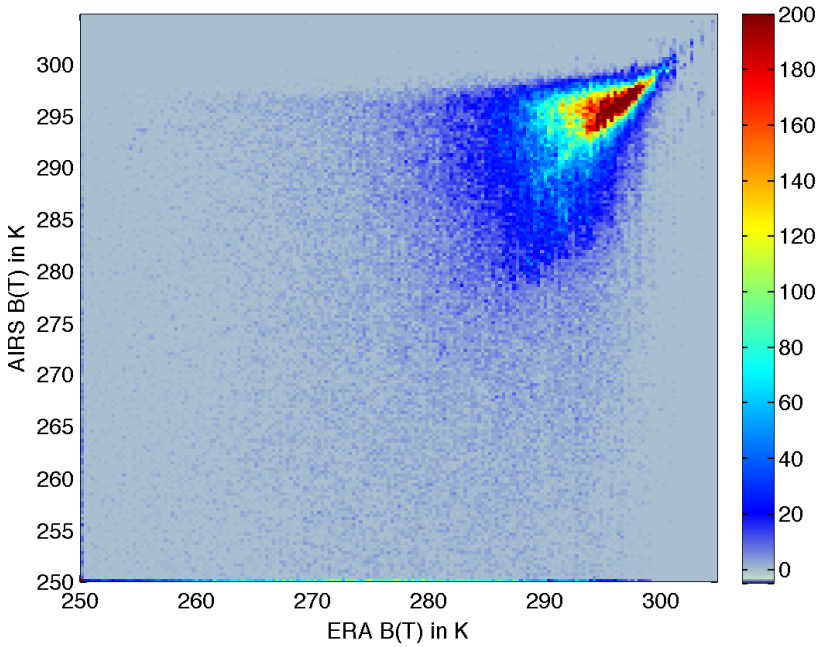
AIRS vs ERA Scatter Diagrams

1231 cm^{-1}

Polar



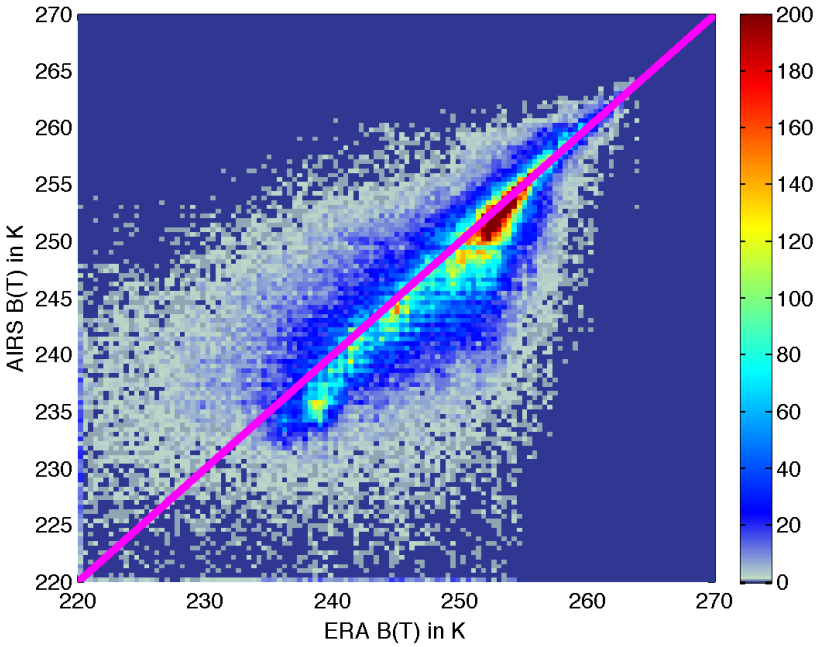
Tropical



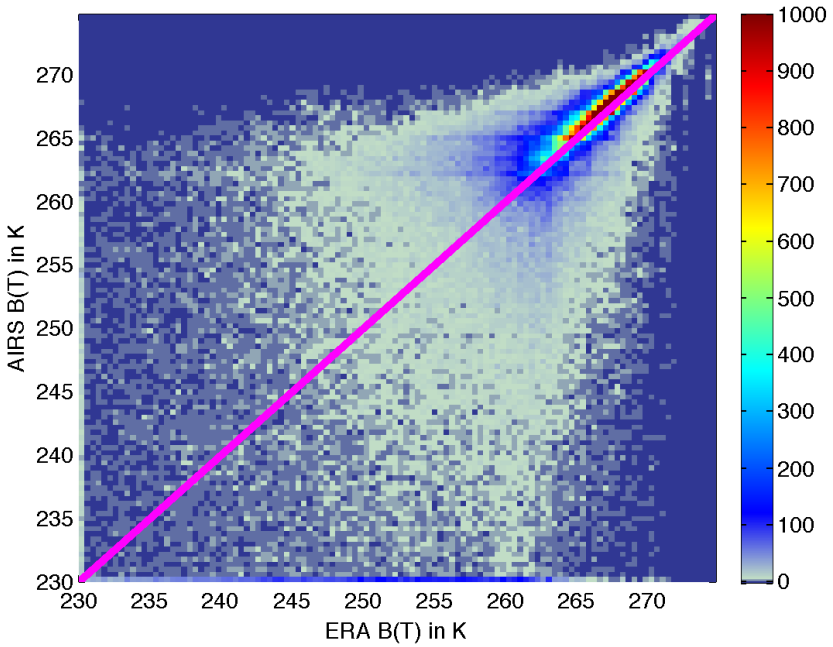
AIRS vs ERA Scatter Diagrams

754 cm^{-1}

Polar



Tropical



Summary

- Strengths and limitation of reanalyses important to understand, provide lower limit of climate model accuracies
- AIRS vs ERA agreement for temperature trends to 0.01K/year level. H_2O differences larger (using BT units).
- CLARREO (and operational sounders?) can be used as independent test of reanalyses, which are heavily used by the climate community.
- Much additional information gleaned by examining PDFs.
- Beginning to demostrate that time dependence of PDFs may be a valid approach for IR climate trending.
- Can we "connect" AIRS to IASI, CrIS? AIRS 2378+ detectors makes this tedious, but not impossible.
- Will CrIS be stable?
- We need to try the above, in order to make the case for CLARREO.