Comparison of ERA Re-Analysis Computed Radiance PDF's to AIRS PDF's

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
April 2012

Overview

Three basic topics addressed, concentrating on (2) and (3). Topic (1) addressed in earlier talks.

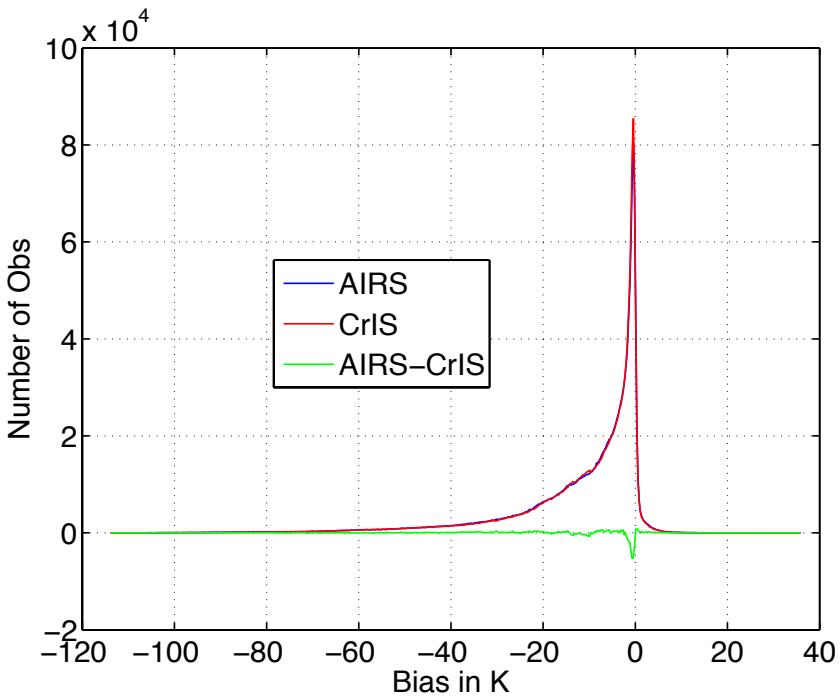
1. NASA HQ: How Achieve CLARREO Objectives?
2. Data Analysis Approach: PDFs (Probability Distribution Functions)
3. NWP Model Comparisons to AIRS PDFs

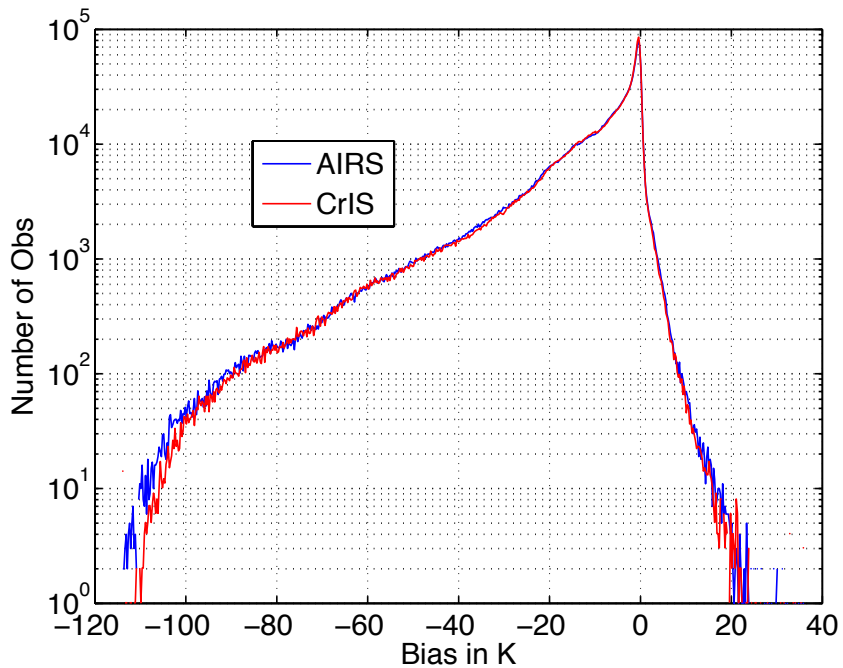
NASA HQ: How Achieve CLARREO Objectives?

- Use existing sensors: (AIRS + CrIS), IASI
- AIRS: 9+ years (15 possible).
- CrIS appears to be working well, hopefully only minor liens that are fixable
- Possibility of gap between CrIS-1 and CrIS-2.
- IASI potential for 15+ years in 9:30 orbit
- We have $<$0.2K agreement between AIRS, IASI, (CrIS?). Stability of $<$0.005K.
- Many ILS issues, AIRS relative calibration offsets (arrays vary), etc.
- Details presented at last CLARREO STM
- Need to emphasize the liens on this approach for CLARREO justification.

Preliminary: CrIS vs AIRS PDFs

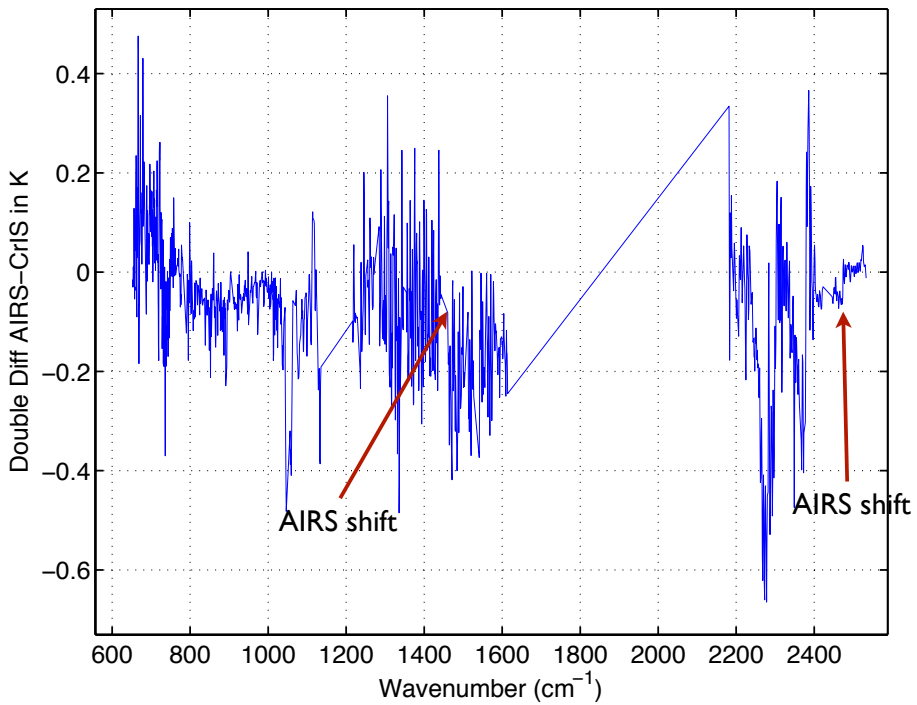
Compare CrIS and AIRS PDFs for same day. Use clear scene bias from NWP, ocean, night to account for scene differences. Cold tails are cloudy scenes.





Preliminary: AIRS vs CrIS using Bias Double-Diffs

Difference of AIRS NWP Bias and CrIS NWP Bias for tropical clear scenes. (a) Using a *very* appoximate AIRS to CrIS ILS operator, (b) the AIRS radiances have *not* been frequency corrected.

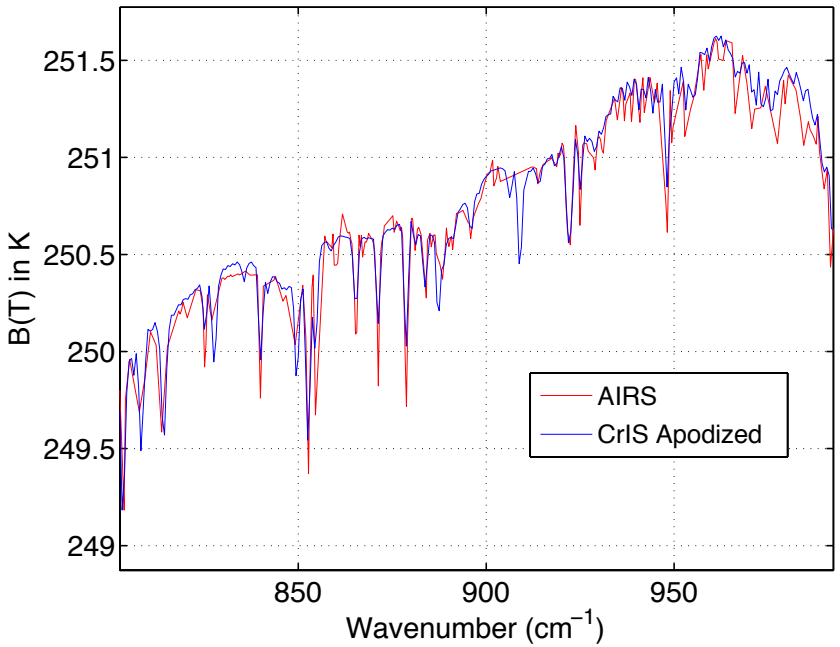


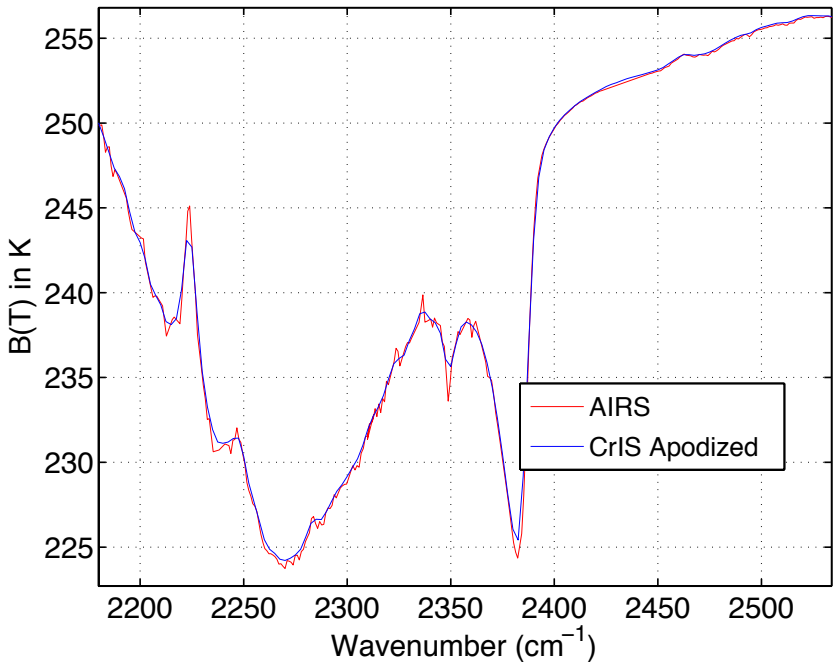
Arrows denote boundaries between two sets of AIRS detector arrays. These offsets relative to AIRS have been seen with IASI DD's and SNOs.

Excellent agreement in the window regions.

CrIS 9 FOVs ILS corrections agree to the 0.03-0.04K level (after in-orbit calibration).

Preliminary: AIRS vs CrIS:SNO's

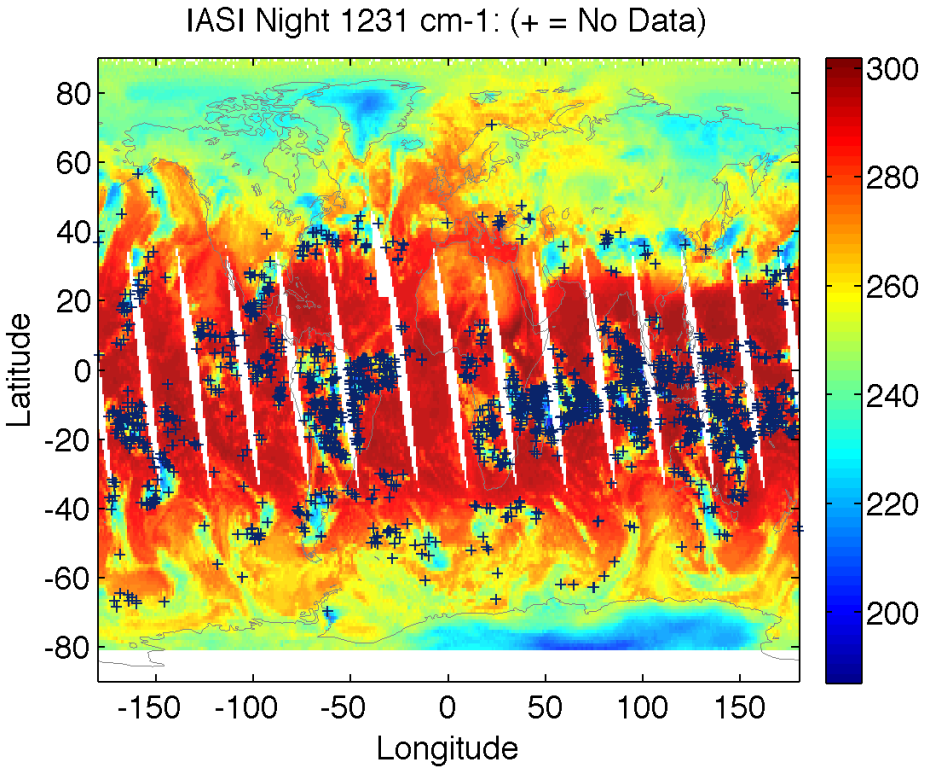


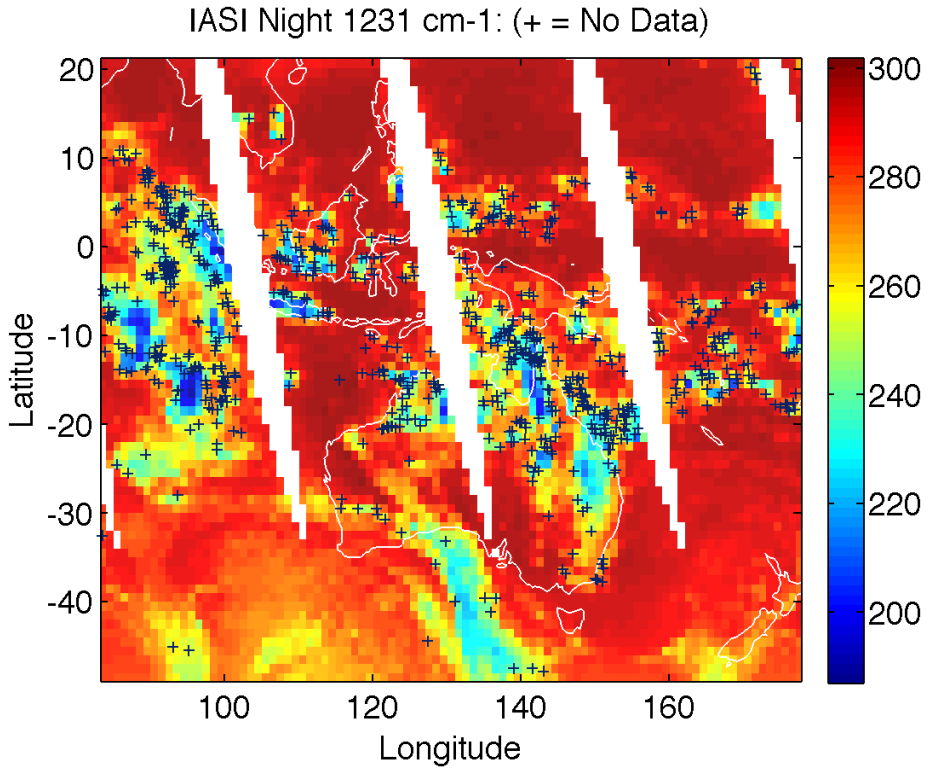


Agreement appears to be in the 0.1K or better range. STD and better statistics awaits conversion of AIRS to CrIS SRF/ILS.

Lien on IASI: Correlated Missing Data

IASI has 0.2-0.3% of scenes flagged bad when cannot find ZPD.
CrIS doesn't lose fringes, so not an issue.





Note in zoom that IASI errors are "near" colder scenes.

Work needs to be done to determine importance of these missing data for climate using IASI.

Data Analysis Approach

- Use radiances directly to perserve accuracy
- Operational sensors provide copious measurements
- Do not average radiances, information lost
- Exploring PDF time series approach to understand trends
- Convert to geophysical units as “late as possible”

Model Comparisons

- Sanity check
- Examine the competition: Re-analyses
- Use clear-sky NWP calculations to derive instantaneous cloud radiative forcing (future work)
- Using radiances that go with each BT bin, attempt to derive geophysical rates for each bin (future work).

Concentrate on 1231 cm^{-1} channel for now. AIRS channel with the most variability since it is the (longwave) channel with the lowest transmission to space.

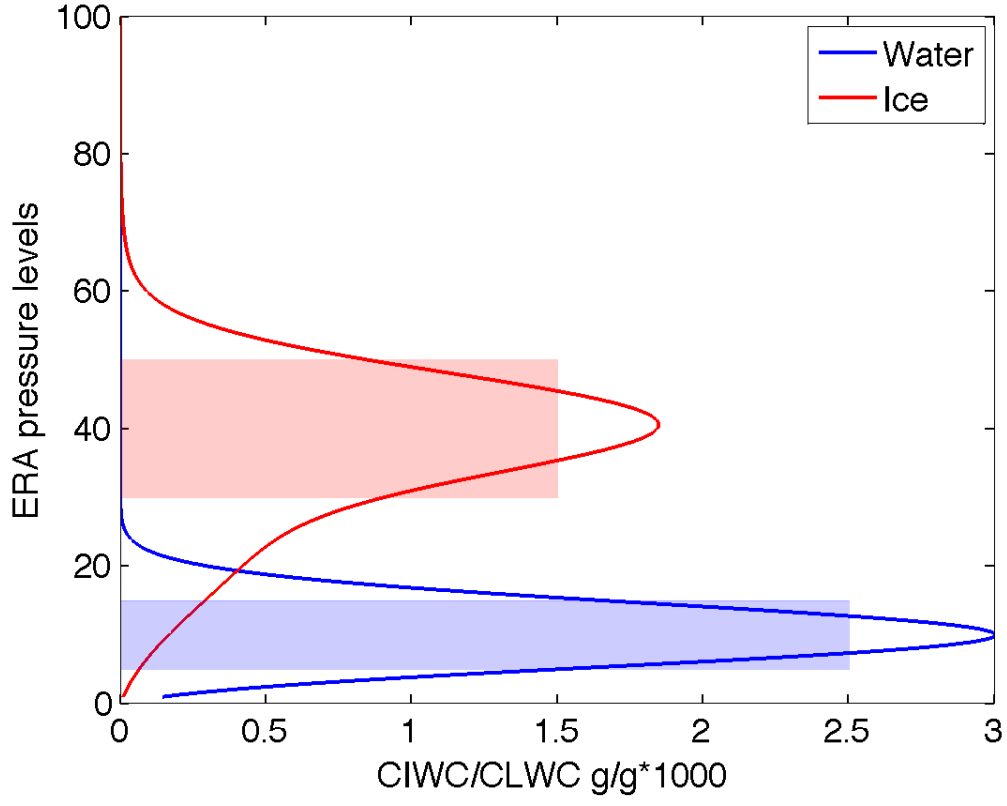
Data set is two AIRS FOVs, on each side of nadir (2/90 sampling).

SARTA CLOUDY

- SARTA-CLEAR used in AIRS L2, NOAA extended products
- Spectroscopy in SARTA has been extensively validated using AIRS measurements and radiosonde campaigns
- SARTA-CLOUDY uses the "Parameterization for Cloud Longwave Scattering for use in Atmospheric Models" (PCLSAM) by Chou, Lee, Tsay and Fu *J.Climate* (1999) + NLTE + reflected solar
- Scattering paramters parameterized into effective cloud optical depth $\tau_{scatter}(\nu) = f(ext(\nu), \omega(\nu), g(\nu))$
- Which can be combined with gas absorption $\tau_{total}(\nu) = \tau_{gas}(\nu) + \tau_{scatter}(\nu)$
- Has been validated for dust storms (MODIS/PARASOL/OMI)
- Emphasis on speed, but
- SARTA-CLOUDY can only handle two slab scattering layers (any combination of aerosols, ice/water clouds.)

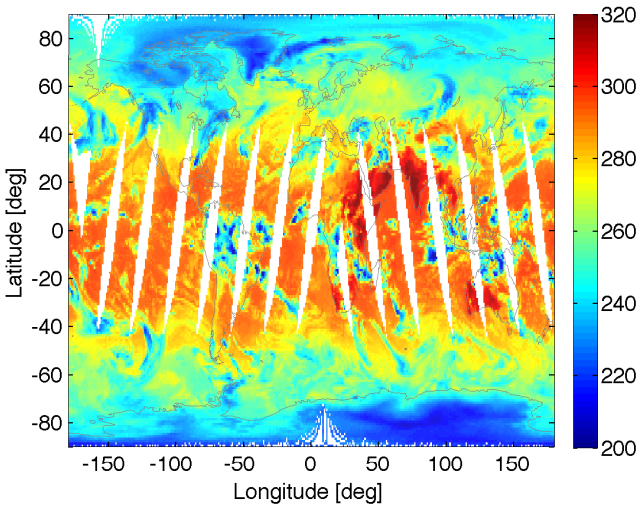
Cloud Field Simplification

- Modify CIWC and CLWC so together they occupy at most two independant slabs
- Random cloud overlap

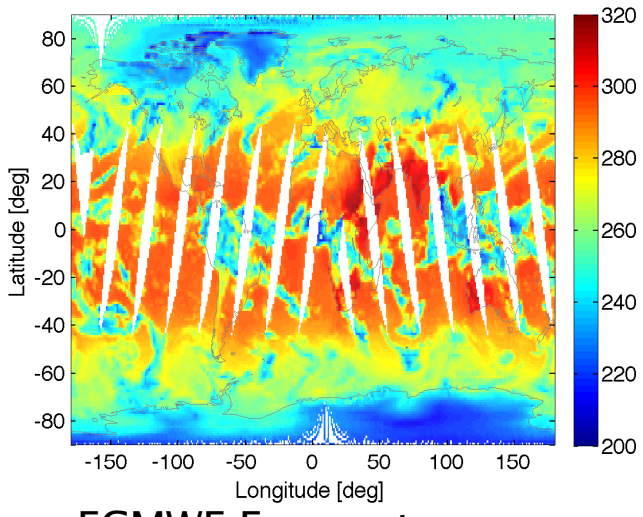


Global NWP Comparisons: (all scan angles, 1/2 day)

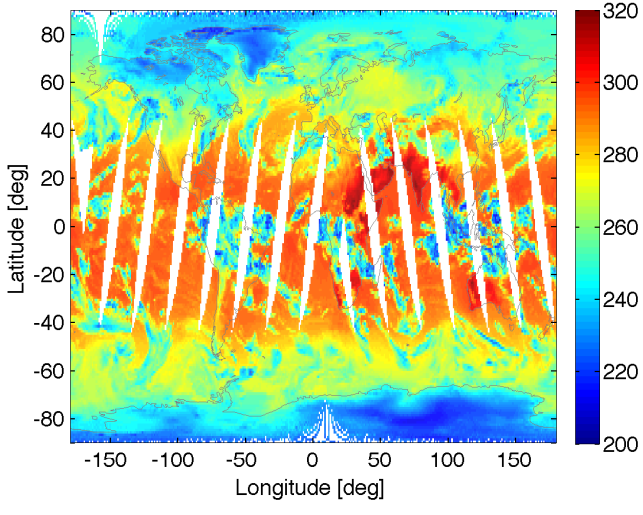
AIRS



ERA Reanalysis



ECMWF Forecast

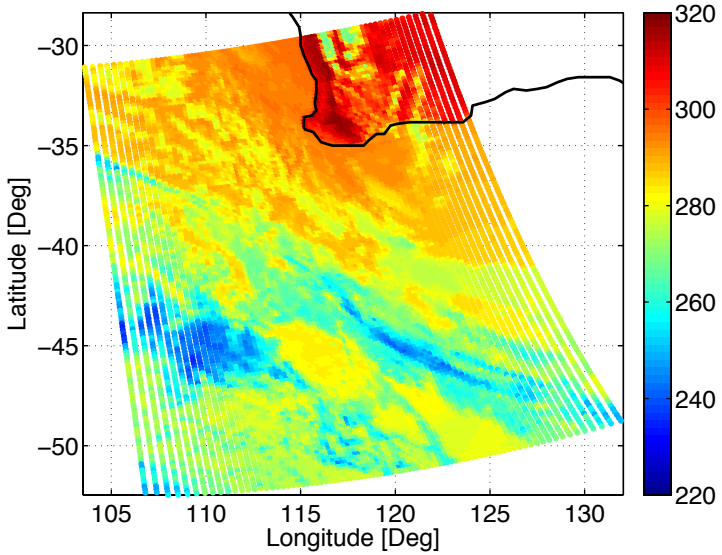


Large scale feature agree between OBS and NWP Calcs.

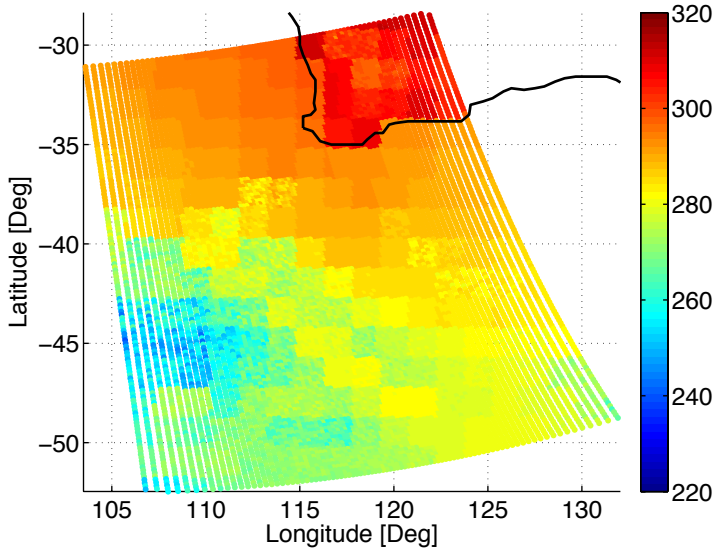
Observations are a mix of day and night.

2011/03/10 : Zoom: West of Australia

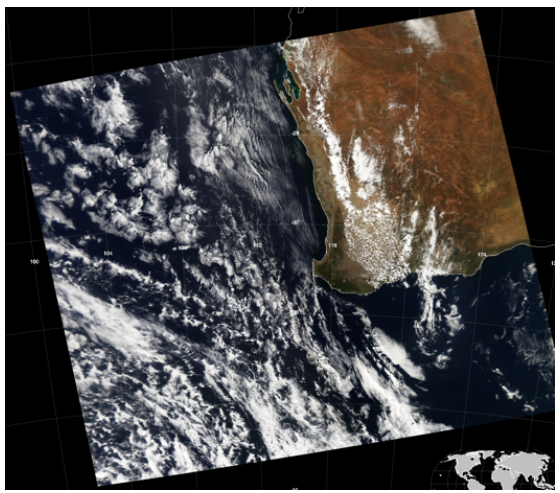
AIRS



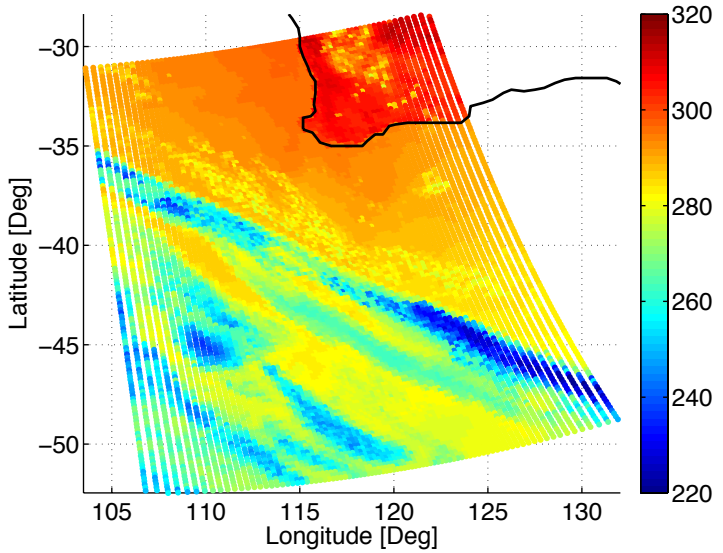
ERA Reanalysis



MODIS

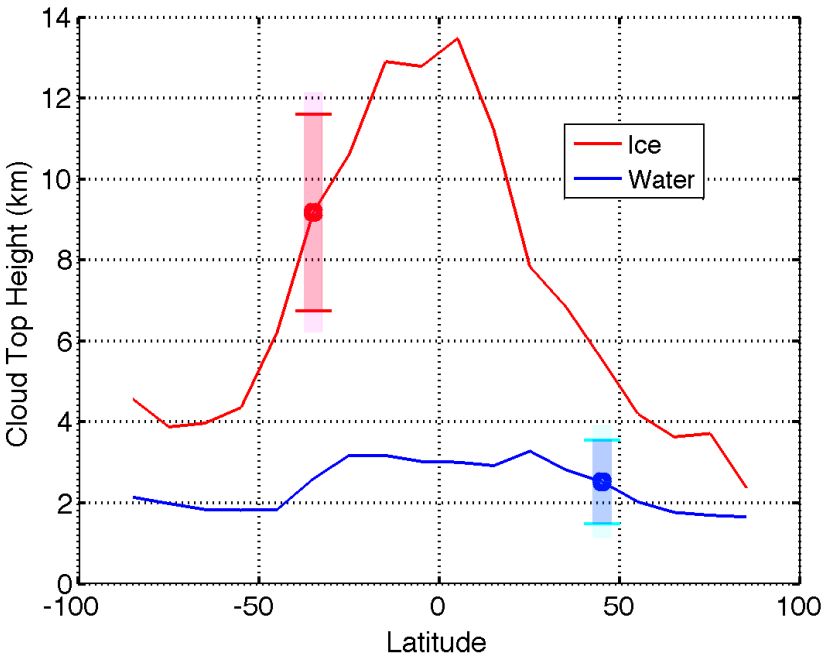


ECMWF Forecast

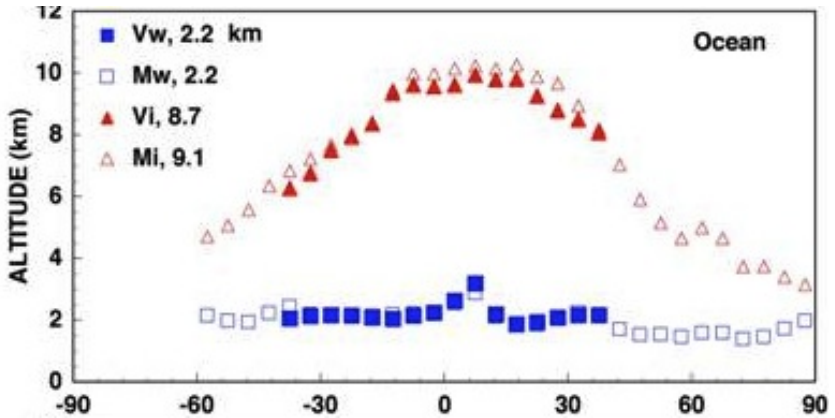


Zonal Climatology :Cloud Top

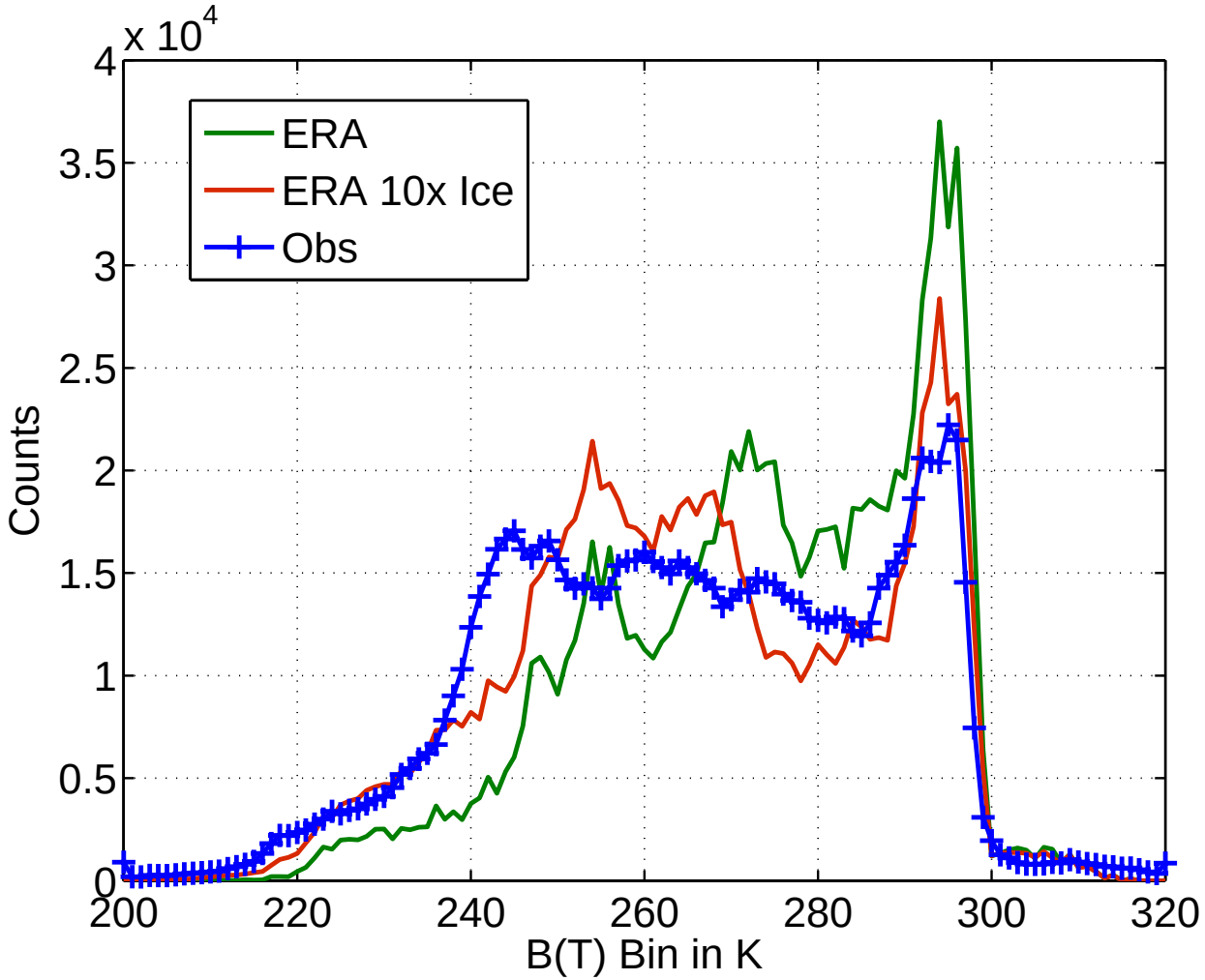
UMBC CTOP (km)



MODIS/VIRS CTOP (km)

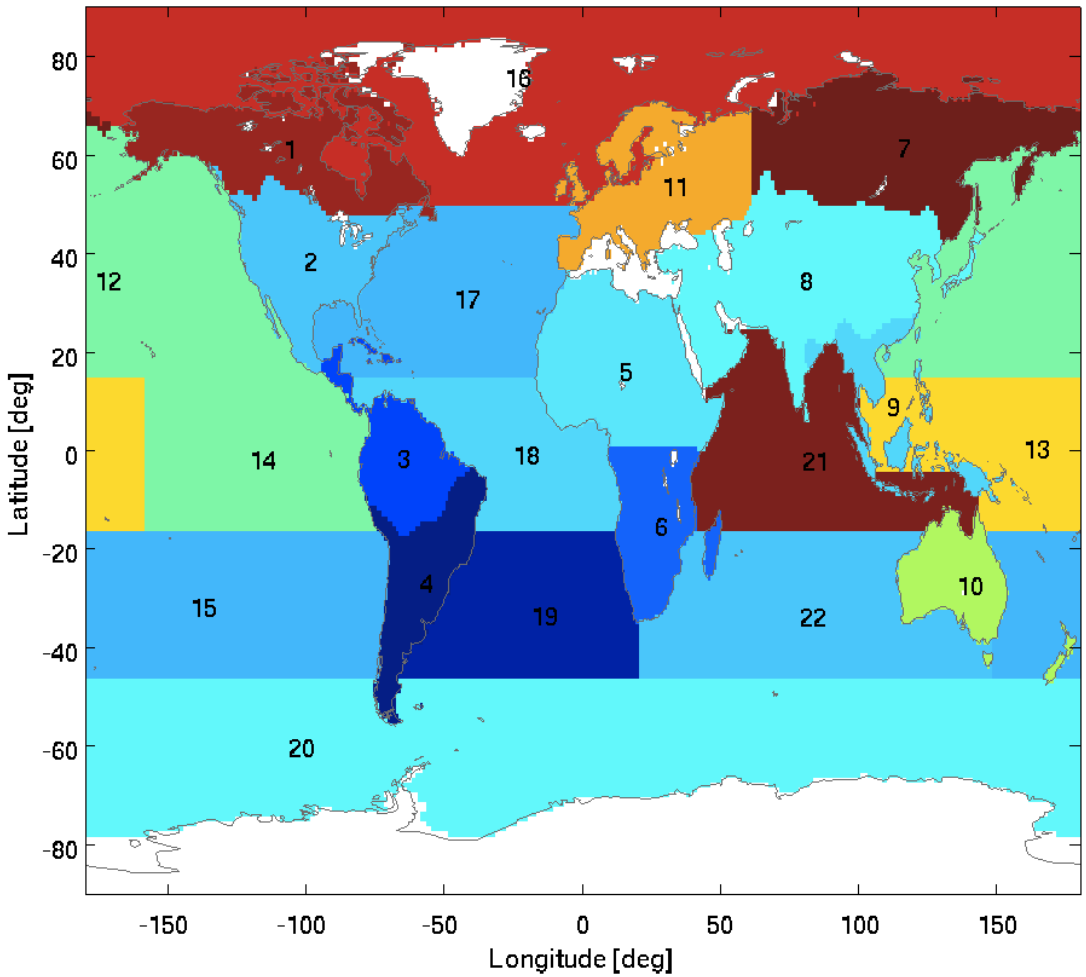


ERA Ice Amount Too Low?



Interpretation of mid-range PDFs difficult, since dependent on cloud fraction and cloud overlap.

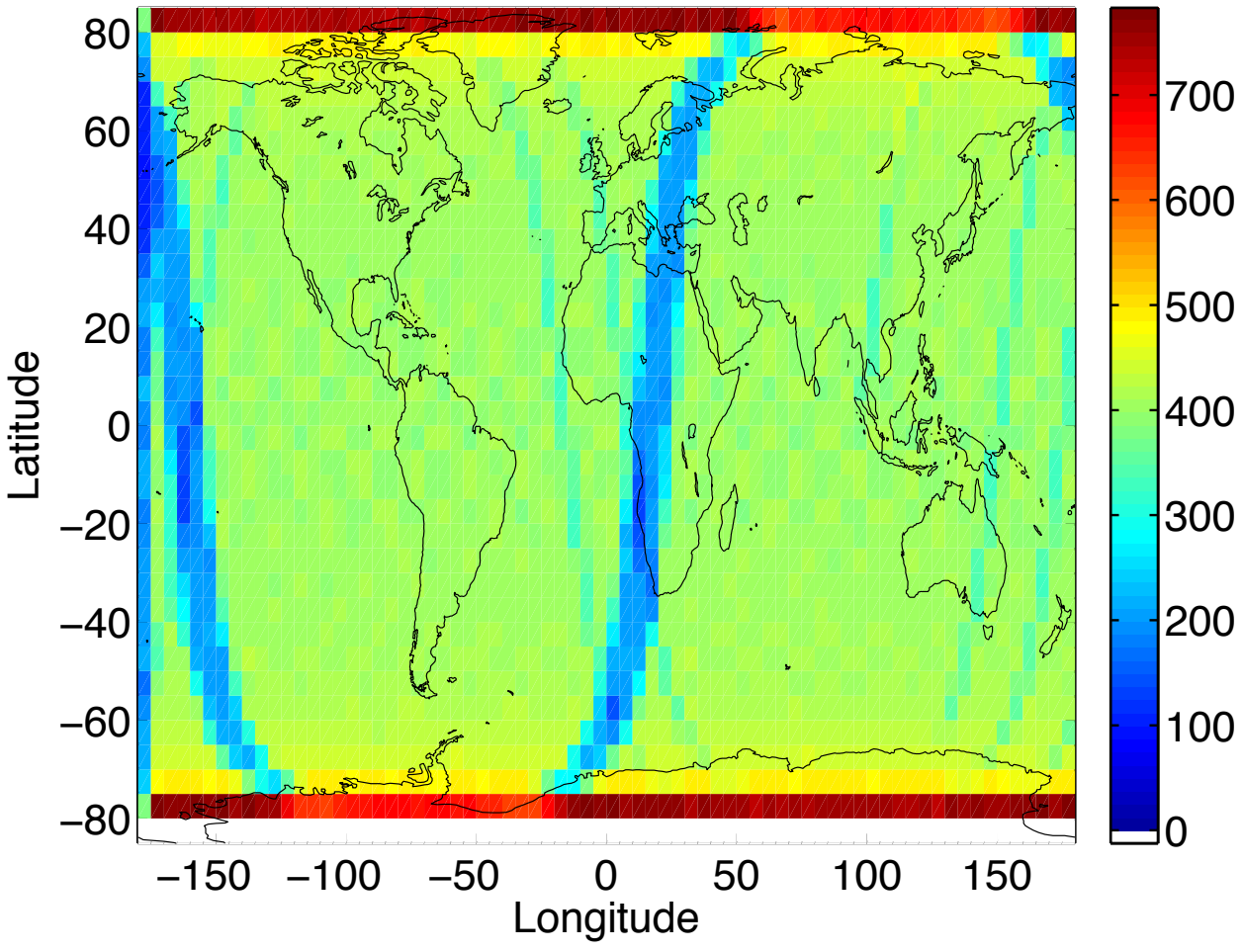
Regional B(T) Binning:TRANSCOM (CO_2 cycle)



$$PDF(t) = a + R * t + \sum_{n=1}^{4} c_n sin(2n\pi t/\tau + \phi_n), R = PDF\ Rate$$

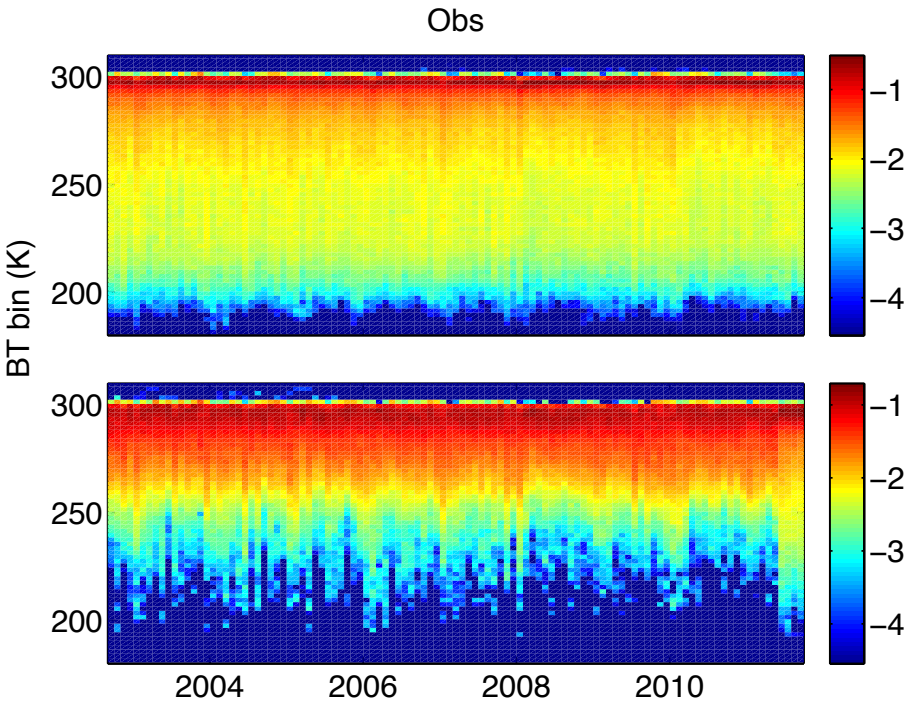
Sampling

Only use two AIRS FOVs on each side of nadir. Coverage over 16 day period for 5-degree bins.

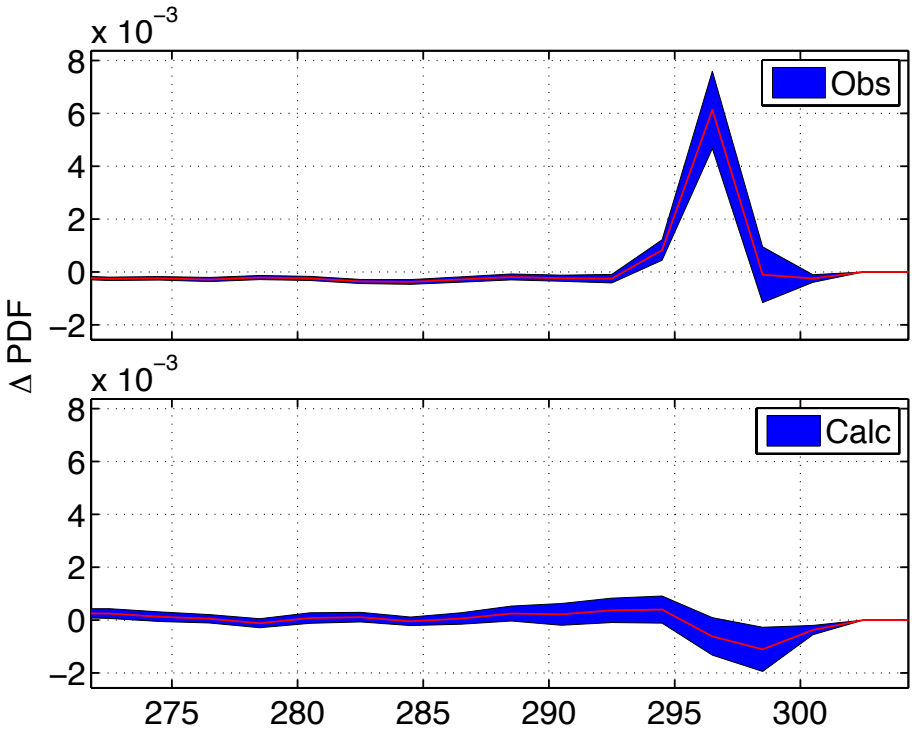


Tropical Western Pacific

BT Bins Populations



dPDF/dt

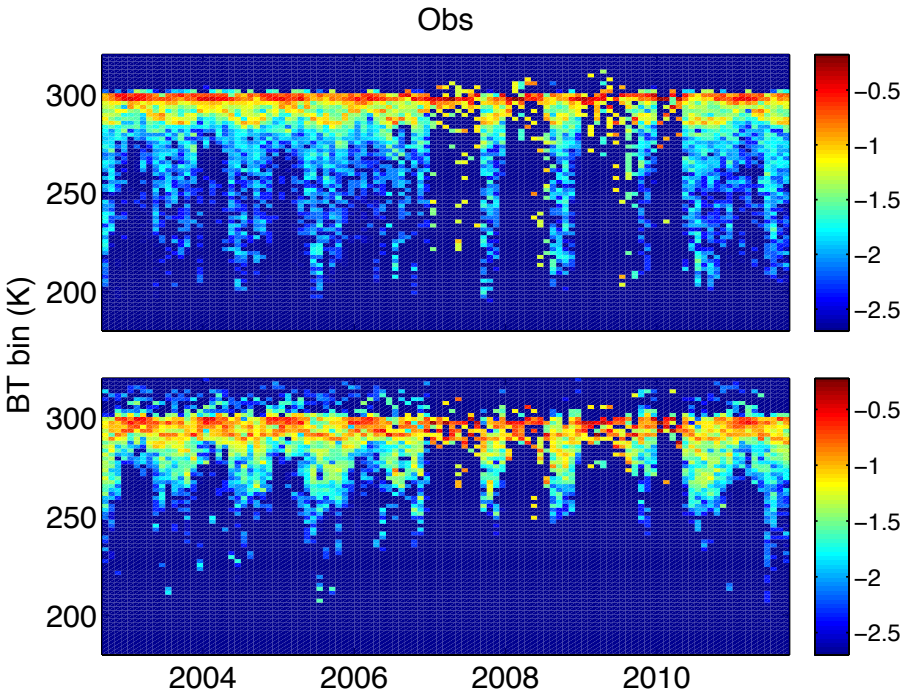


Bootstrap approach used for dPDF/dt error bounds.

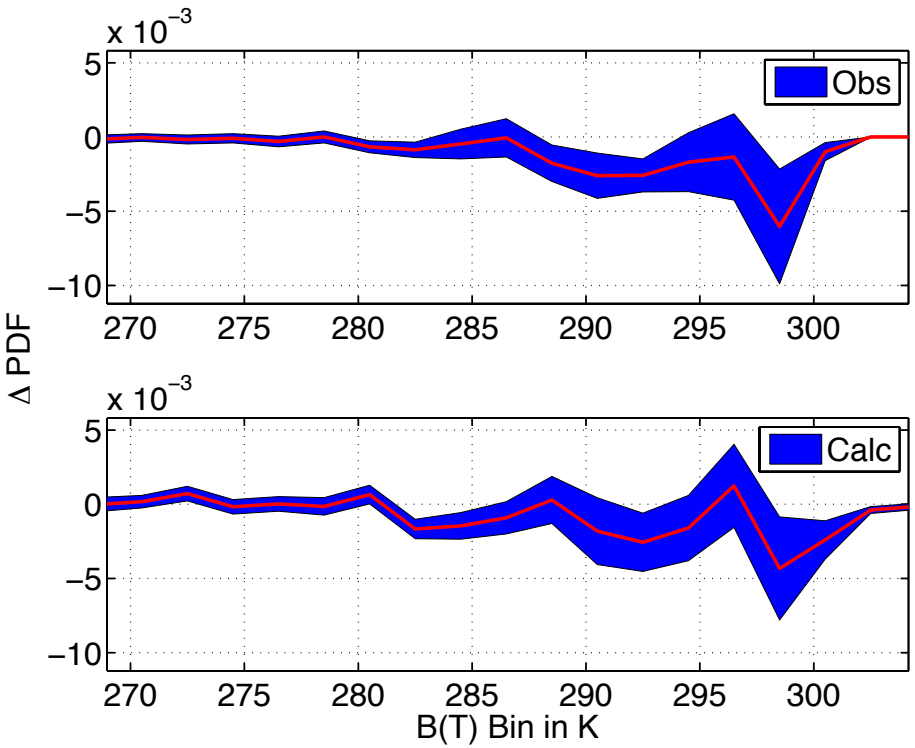
Peak Obs rate corresponds to ~0.04K/year. Can determine if clouds or surface using well known SST.

South American Tropical

BT Bins Populations

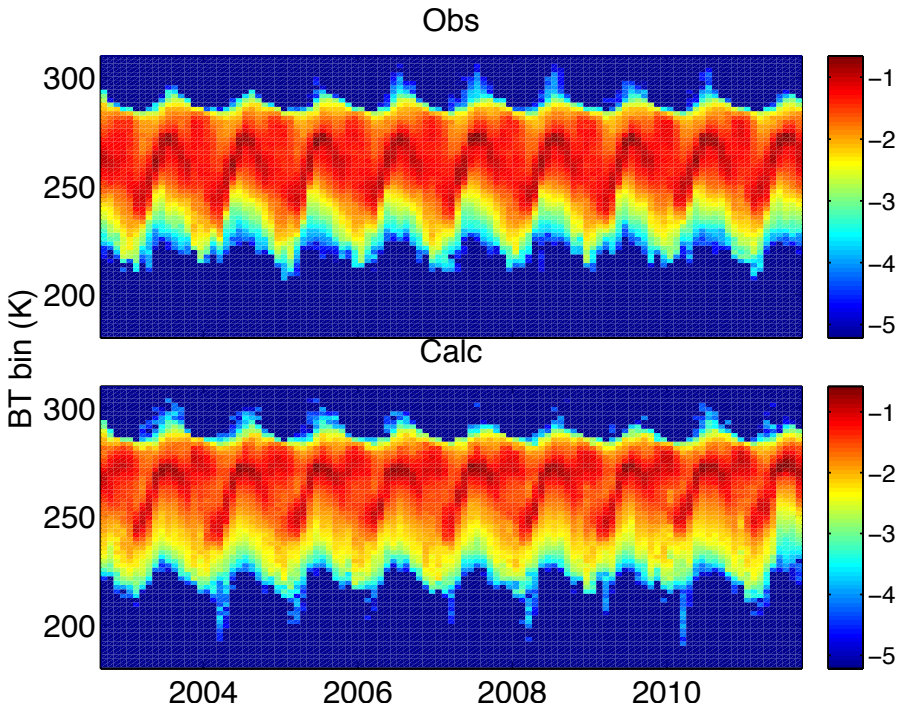


dPDF/dt

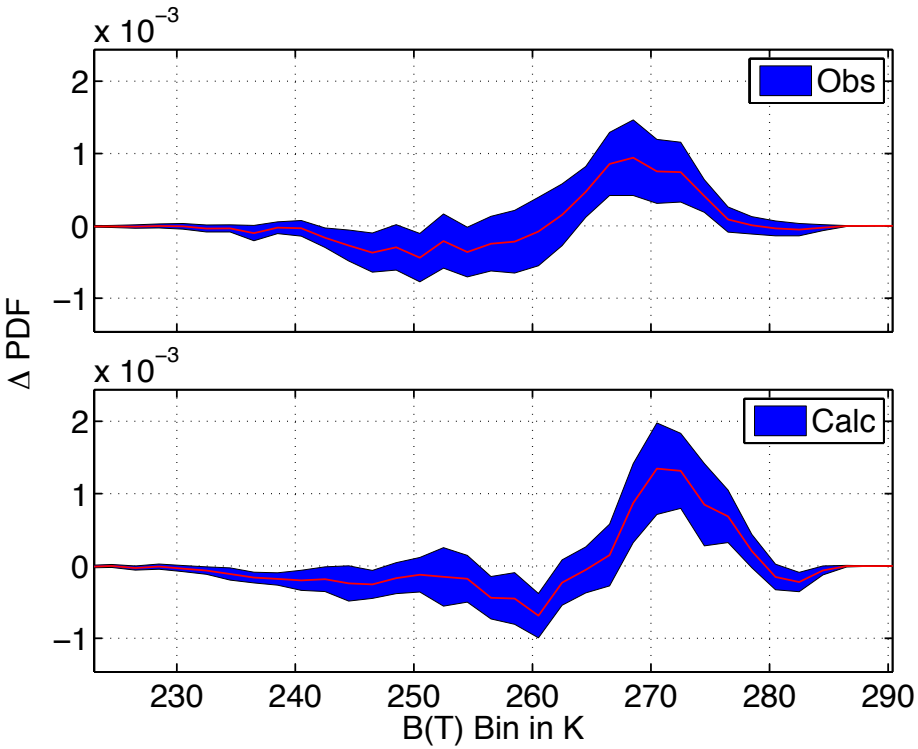


Arctic

BT Bins Populations



dPDF/dt

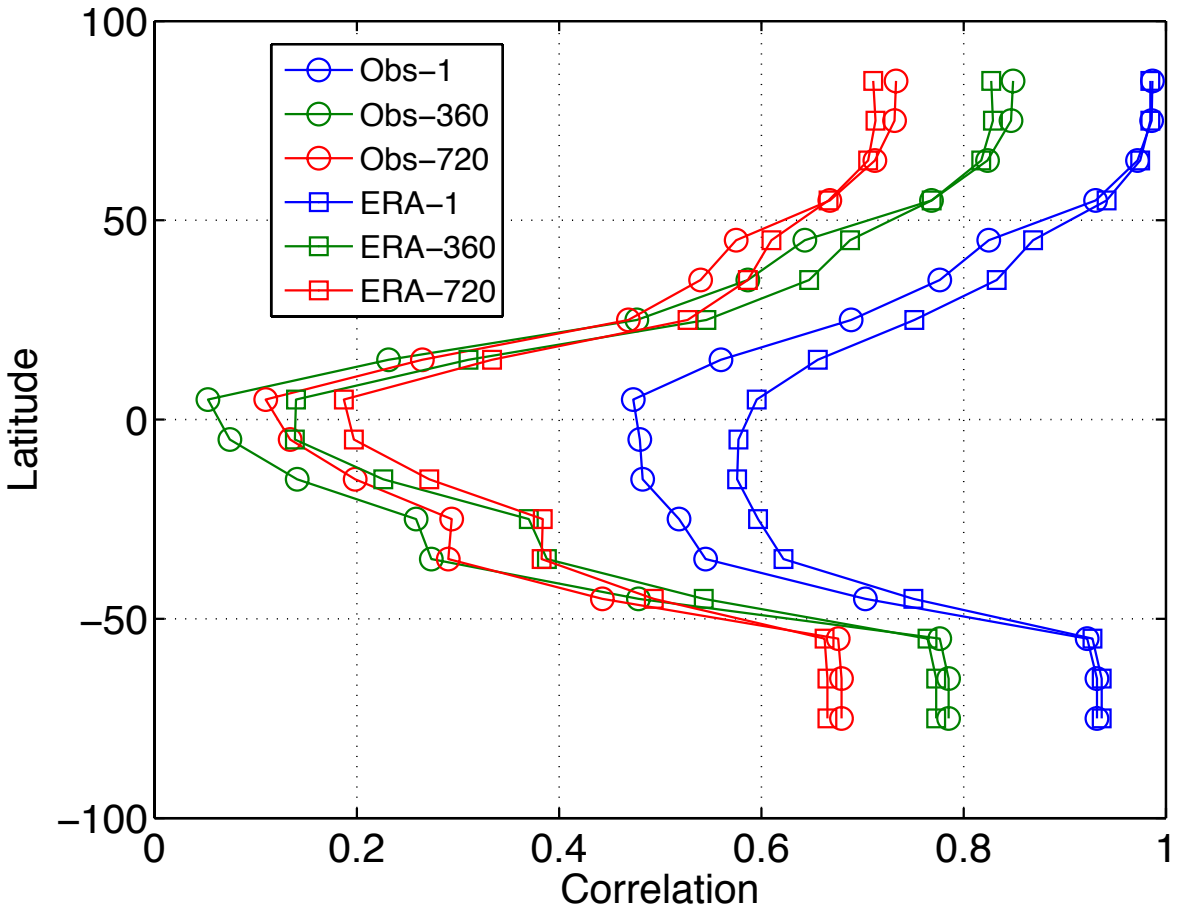


Liens on PDF Approach and NWP Comparisons

- Modify re-analysis SST to include diurnal variability and evaporative cooling.
- Variable bin widths (near surface for 1231 cm^{-1} channel)
- Start geophysical rate retrievals:
  - Start with 1231 cm^{-1} binning, basically cloud amount
  - Bin radiance rate = dPDF/dt * bin_radiance
  - Determine appropriate Jacobian for each bin
  - Retreive change in atmospheric state associated with each bin
  - Full geophysical rate weighted sum of binned retrievals

Time Correlations of 1231 cm^{-1} Radiance Record

Correlations shown for 1 day, 1 year, 2 years.



Note lower correlations for ERA model, related to sub-grid scale cloud variability?

Wavelet Analysis: Tropical Western Pacific

Applied Morlet wavelet analysis (damped sin wave) to 1231 cm^{-1} B(T)'s for the peak BT bin. Shaded areas show where wavelet analysis loses applicability.