Comparison of AIRS Radiance PDF's with ERA Re-analysis Simulated PDFs

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AIRS STM
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Overview

- NASA HQ: How Achieve CLARREO Objectives? (They don't like retrievals.)
- Can we make "climate" measurements with well characterized errors?
- Approach: avoid retrievals "as long as possible"
- Data Analysis Approach: PDFs (Probability Distribution Functions)
- Concentrate on *one* AIRS channel: 1231 cm^{-1}
- Compare AIRS measurements to reanalysis products, including cloud fields.
- Long term: build a climate data set with operational sensors

AIRS+CrIS = CLARREO IR??

CLARREO "Cancelled"

1. CLARREO cancelled after recommendation of National Academy of Sciences and NASA Decadal Survey
2. NASA HQ to CLARREO Team: "Explore cost-effective alternatives for achieving some portion of the CLARREO objectives"
3. What can be achieved with AIRS + CrIS?

AIRS+CrIS ≈CLARREO IR??

- Use existing sensors: (AIRS + CrIS), IASI
- AIRS: 9+ years (15 possible?)
- IASI set for 15 years
- CrIS looks good, some minor liens + needs extended cal/val
- All three sensors already agree to ~0.1-0.2K, AIRS stability $<$0.005K/yr?

Hyperspectral IR Climate Record from AIRS/CrIS/IASI

Many Issues (but potentially manageable)

- Relative accuracy of sensors. Need a "tie point".
- Many instrument lineshape issues
- AIRS and IASI stability are excellent
- AIRS: ν calibration, relative accuracy among detector arrays
- IASI: ν calibration, scene dependent data loss
- CrIS: poor ICT emissivity past 1600 cm^{-1}

This Talk: Climate Level Measurements with AIRS

- Excellent stability (previous talks, see Aumann's talk)
- Stable orbit: is diurnal really needed?
- CLARREO approach: **Average Radiances**
- Better approach: **Radiance binning + PDFs**
- 10 years too short for climate response (not forcings)
- Examine ENSO events
- Compare AIRS to Re-analyses (heavily used by climate modelers)

Data Analysis Approach

- Use radiances directly to perserve accuracy: climate trending and extremes
- Use full AIRS spatial resolution
- Convert to geophysical units as "late as possible"
- Easier to assign error estimates to radiances than to L2 products
- Do not average radiances, information lost
- Exploring PDF time series approach to understand trends
- Compare to re-analysis to understand results, understand model and RTA limitations
- Just look at one channel, 1231 cm^{-1} (surface, clouds)
- Connect to fluxes later, maybe using just a few AIRS channels, and only for time derivatives, not absolute

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.

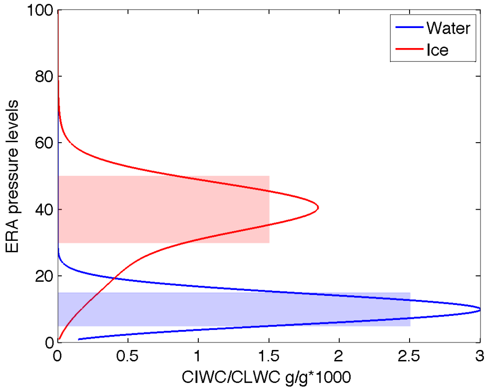
Data set is two AIRS FOVs, on each side of nadir (2/90 sampling).

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.)

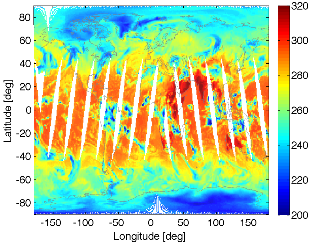
Cloud Field Simplification

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

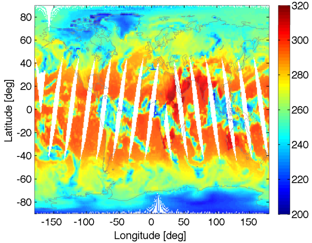


Global NWP Comparisons: (all scan angles, 1/2 day)

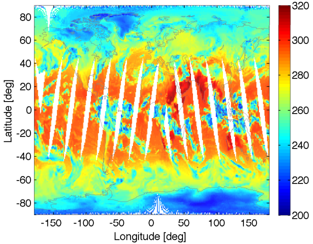
AIRS



ERA Reanalysis



ECMWF Forecast

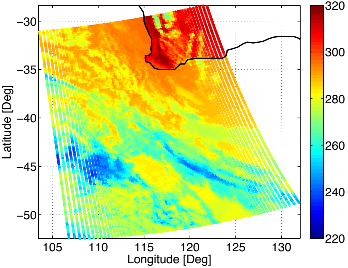


Large scale feature agree between OBS and NWP Calcs.

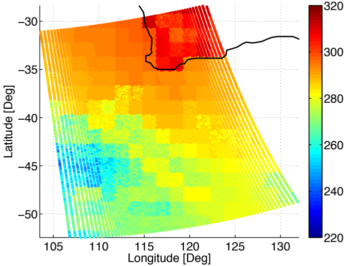
Observations are a mix of day and night.

2011/03/10 : Zoom: West of Australia

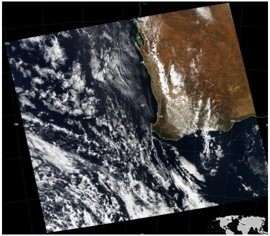
AIRS



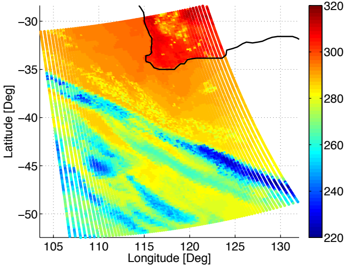
ERA Reanalysis



MODIS

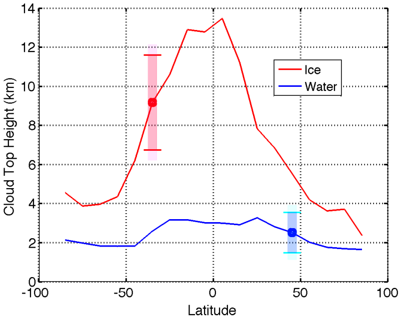


ECMWF Forecast

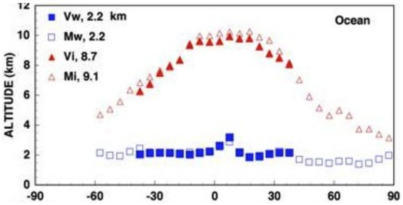


Zonal Climatology :Cloud Top

UMBC CTOP (km)



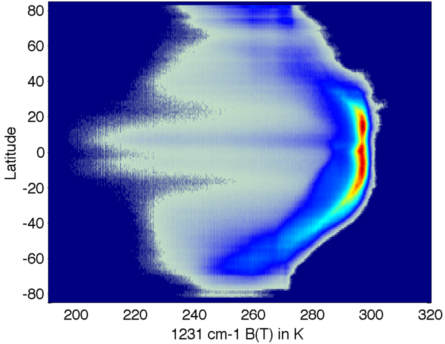
MODIS/VIRS CTOP (km)

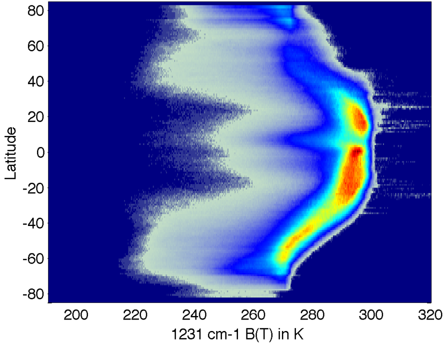


Overview Obs vs ERA Calcs

Ocean, night. SST well known.

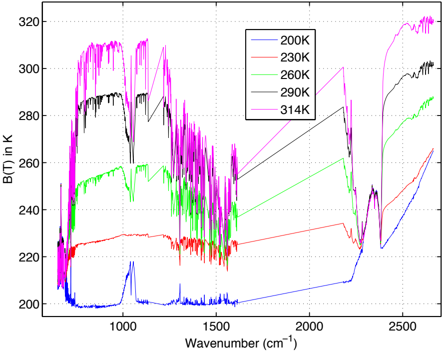
OBS ERA CALC





PDF Measurement Approach

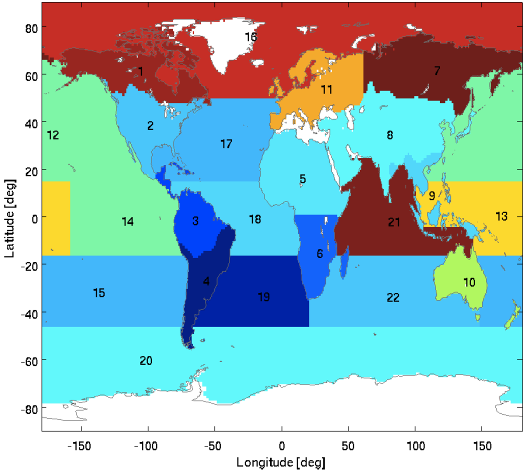
Do not average all-sky radiances.



Retain more information: PDF rates, not Radiance Rates

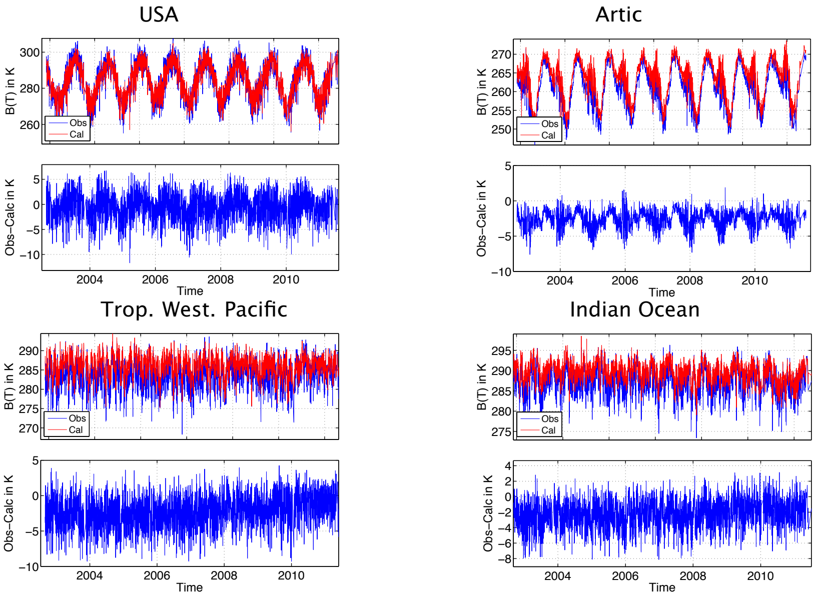
- Averaging clear with cloudy scenes destroys information
- Bin (create PDFs) versus variable related to cloudiness
- I used 1231 cm^{-1} channel B(T): clearest window channel
- Data Set: 8+ years of AIRS, only FOVs on each side of nadir
- Bins of B(T) 1231 cm^{-1}, from 190:1:320K
- Mean BT spectra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

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



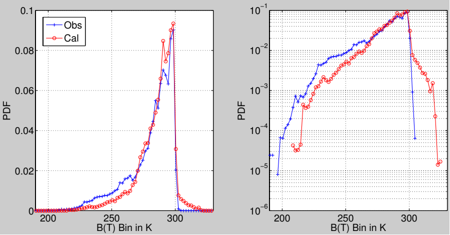
$$PDF(t) = a + R * t + \sum_{n=1}^{4} c_n sin(2n\pi t/\tau + \phi_n), R = PDF\ Rate$$

Time Series of Averaged Obs/Cal

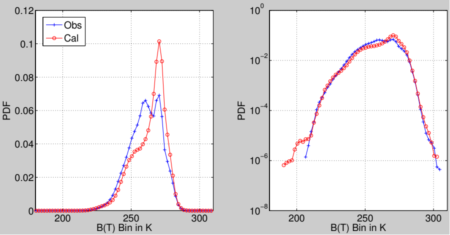


PDF Comparisons: Night

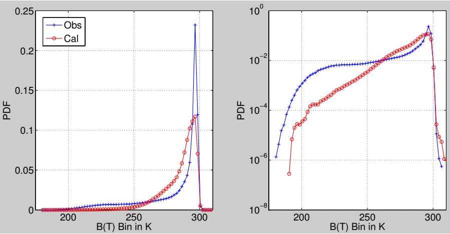
USA



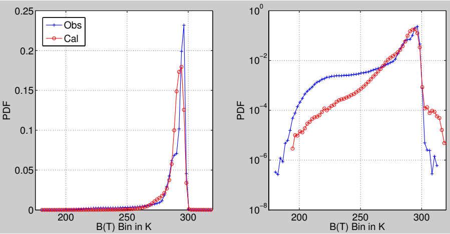
Artic



Western Tropical Pacific

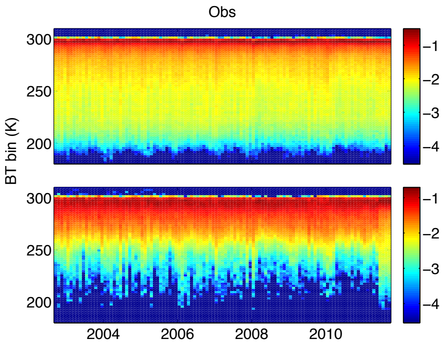


Eastern Tropical Pacific

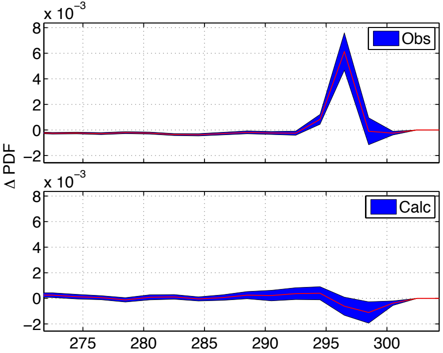


Tropical Western Pacific

BT Bins Populations



dPDF/dt

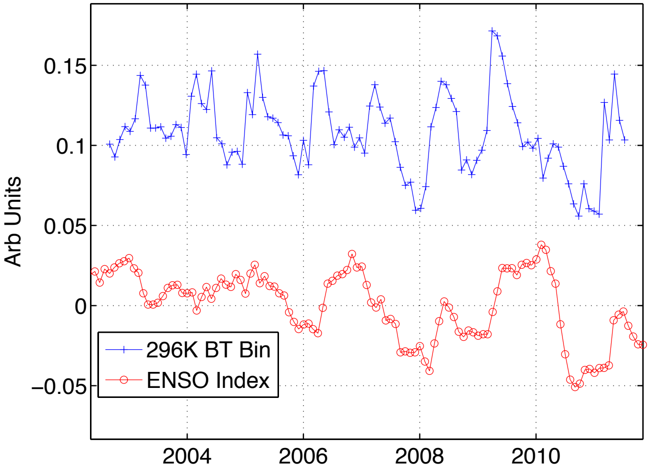


Bootstrap approach used for dPDF/dt error bounds.

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

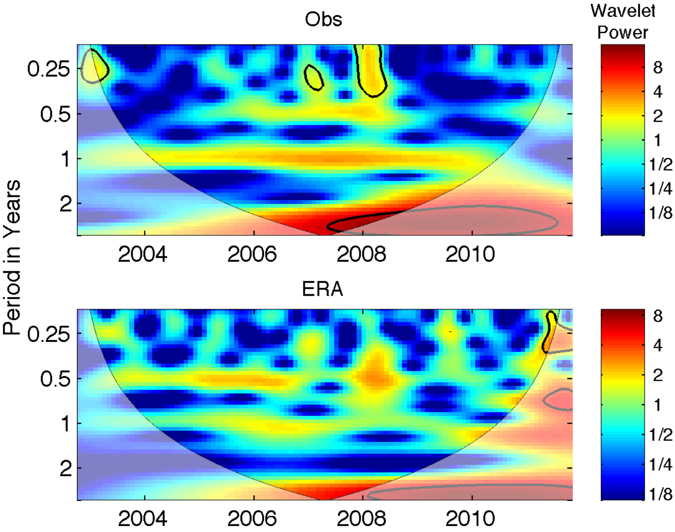
Tropical Western Pacific: PDF time series

PDF appears to follow ENSO. Have not removed annual cycle from observed PDF.



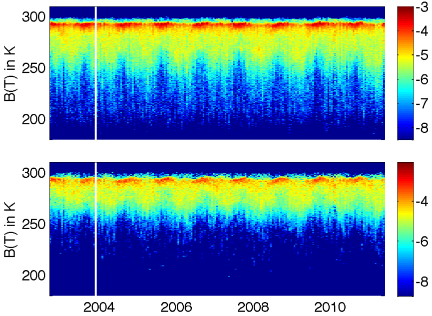
Wavelet Analysis: Tropical Western Pacific

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.



South American Tropical: Amazon

BT Bins Populations



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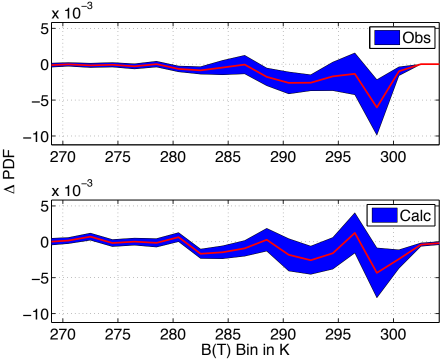
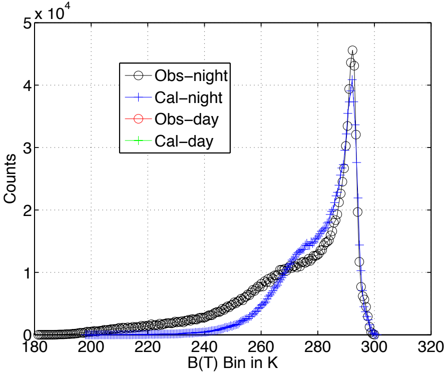
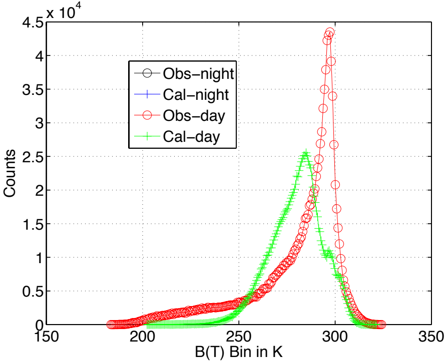


South American Tropical: Day vs Night

Night PDFs



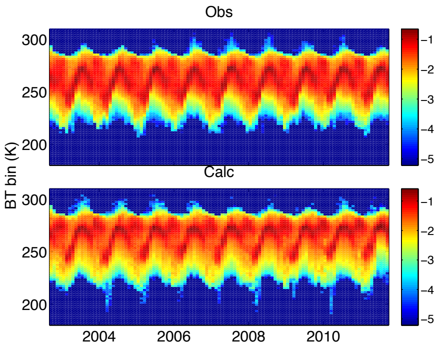
Day PDFs



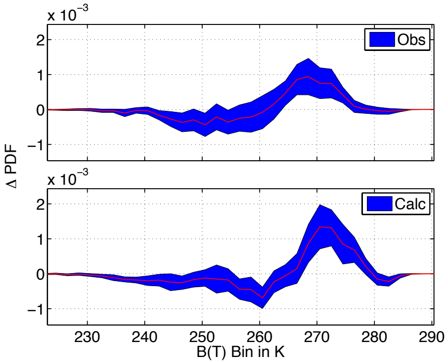
Besides deep convective clouds, large differences in daytime. AIRS "hotter" implies cloud fraction differences. Real broken clouds result in higher BTs.

Arctic

BT Bins Populations



dPDF/dt

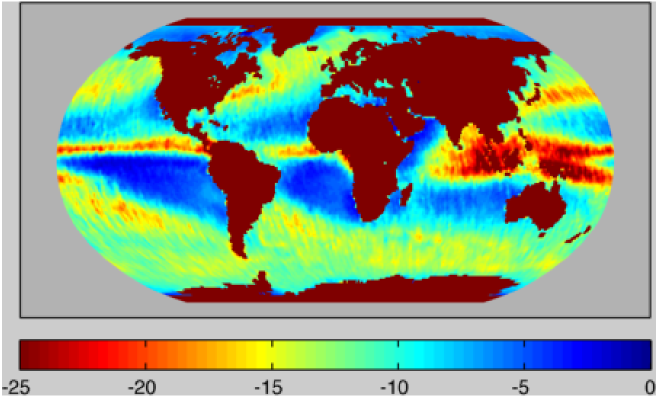


Liens on PDF Approach and NWP Comparisons

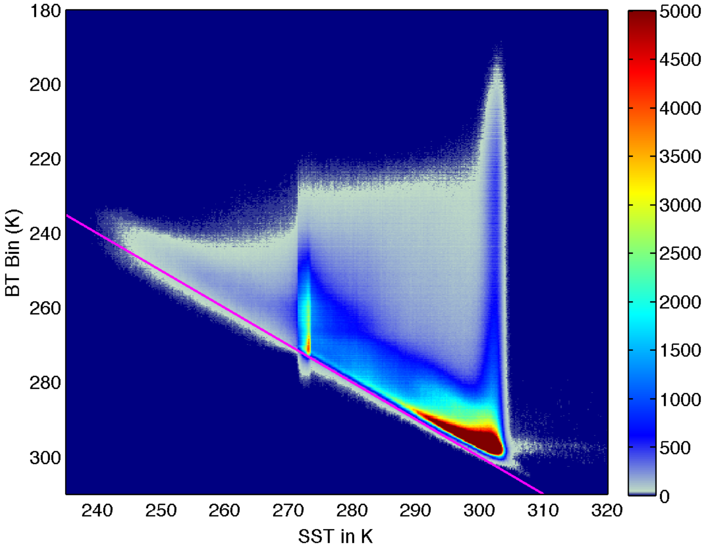
- Modify re-analysis SST to include diurnal variability and evaporative cooling.
- Variable bin widths (near surface for 1231 cm^{-1} channel)
- Start geophysical rate retrievals from full binned spectra

Longwave Cloud Forcing

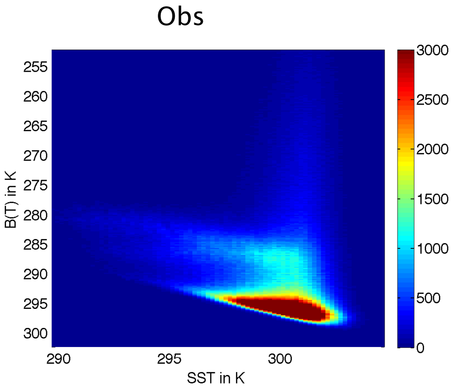
ERA reanalysis extremly accurate for T,Q and is available everywhere all the time. Can use BT_cal minus BT_obs to compute forcing at 1231 cm^{-1} very accurately for ocean where SST well known.

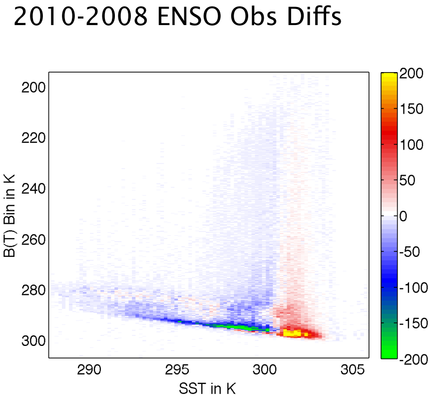


Global 1231 cm^{-1} PDFs (PDF's area weighted.)



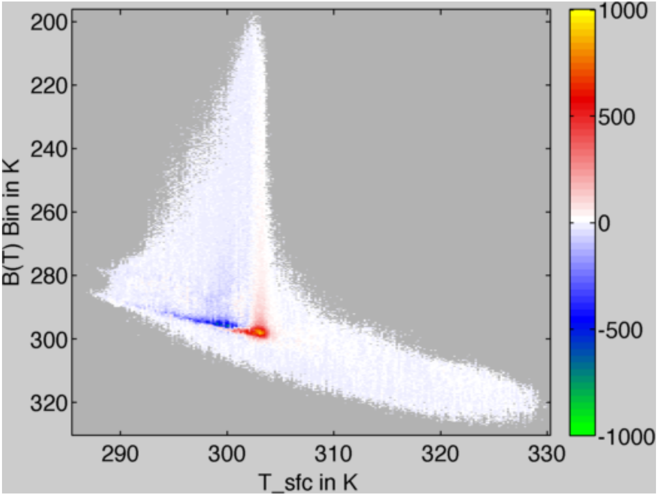
PDF Regional Subsets: Tropical Western Pacific





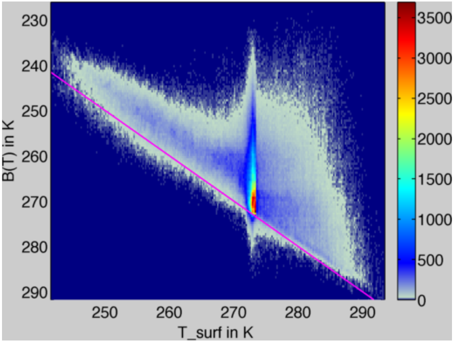
PDF Regional Subsets: Tropical Land + Ocean

2010-2008 ENSO Obs Diffs

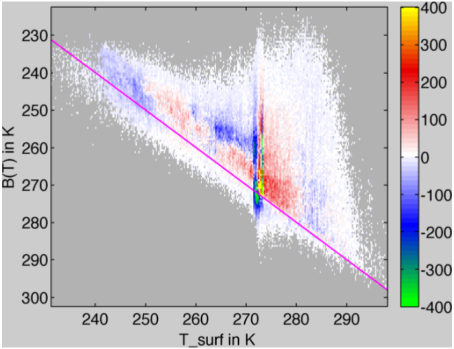


PDF Regional Subsets: Arctic

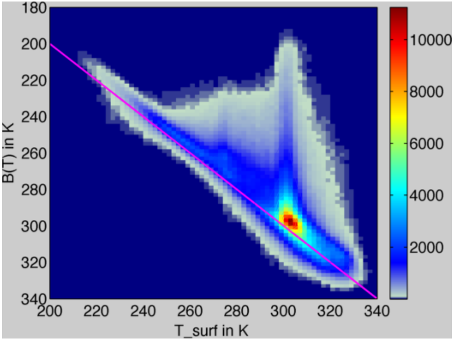
Obs

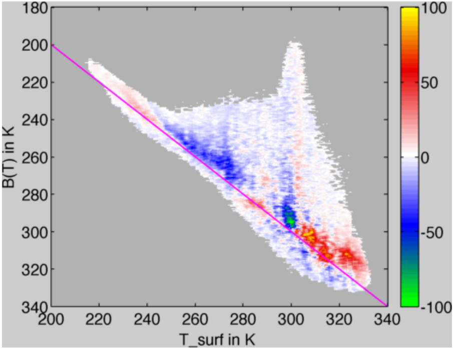


2010-2004 Obs Diffs



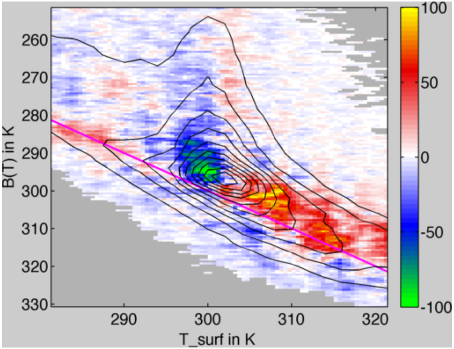
PDF Global Land



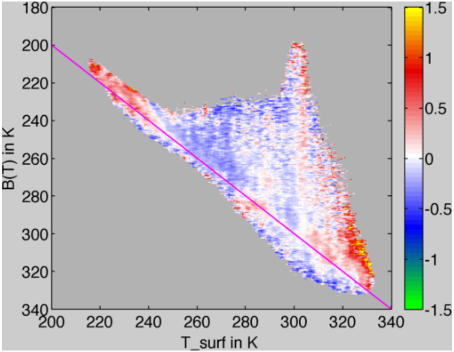


PDF Global Land: Details

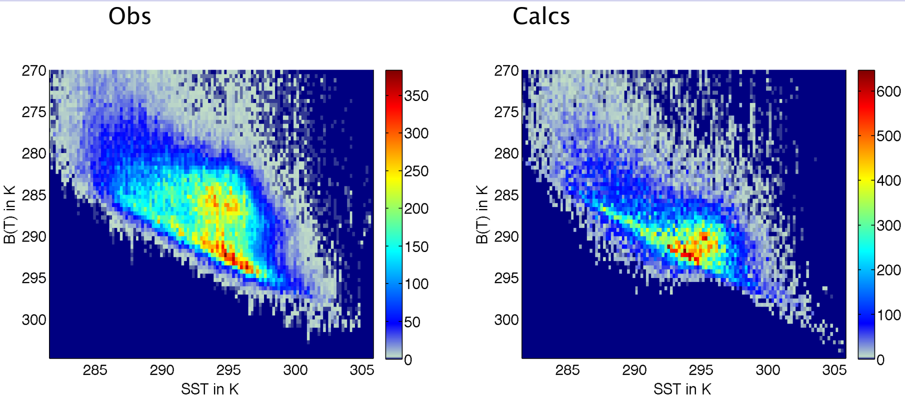
Obs Diffs, Contour Obs



2010-2004 Obs Diffs in Per Bin Fraction



PDFs off California Coast: Months of JJA



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

PDFs off Chile Coast: Months of JJA