PCRTM
(*Principal Component Radiative Transfer Model)*
Spectral Longwave Simulations with 5 Years of SSF and MOA Data Compared to CERES Observed Broadband Nadir Radiances

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Outline

- PCRTM Model
  - Accuracy
  - Description of Simulation
- Survey of Results
  - Monthly Variability
  - Daily variability example
- Comparisons to CERES Nadir broadband LW radiance
- Radiative kernels
  - CO2 Forcing and possible feedback examples
- Summary

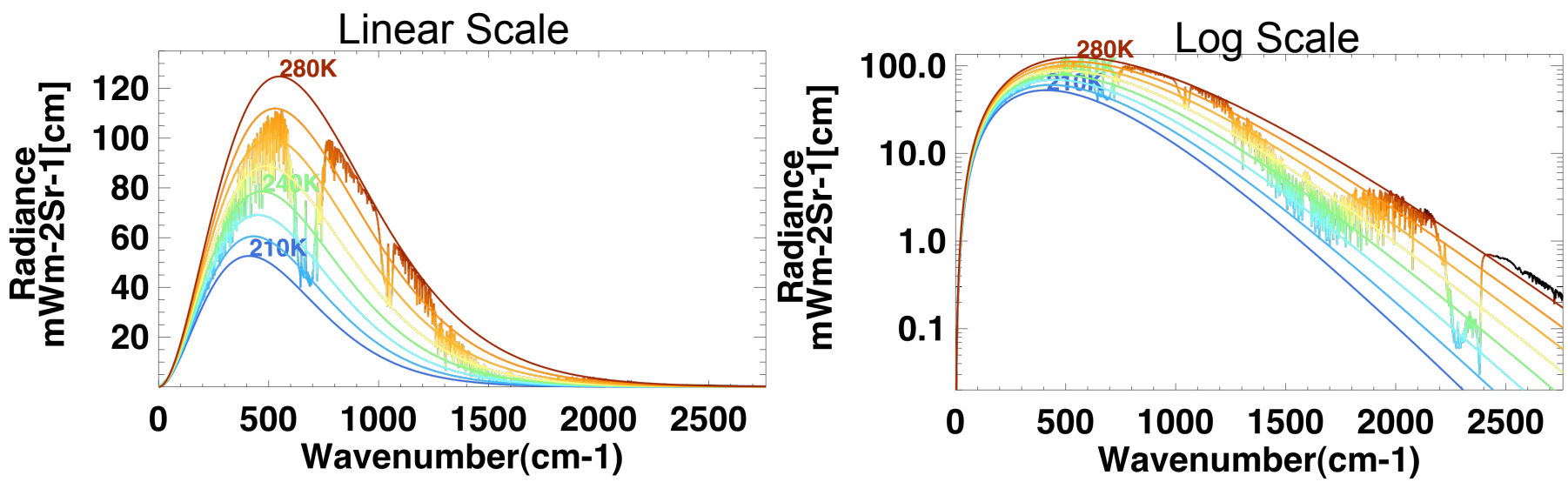
PCRTM

- Principal Component Radiative Transfer Model
  - Xu Liu, William L. Smith, Daniel K. Zhou, and Allen Larar
    - Applied Optics Vol 45, No. 1, 1 Jan 2006
- Spectral longwave radiance (50 -2760 cm^{-1})
- 0.5cm^{-1} effective resolution
  - obtained using 280 principal components (FAST !!!)
- Cloud properties (P. Yang)
  - Optical depth, Particle size, Phase ,Effective height
- Includes Multiple Scattering
- Variable Gases: **H_2O, O_3**

  - CO_2, CH_4, N_2O, CO can vary in PCRTM but not in this simulation.

  - Other minor trace gas concentrations fixed example: CFC's
- IGBP based (coarse /12 band) surface spectral emissivity
- No Aerosol in this simulation

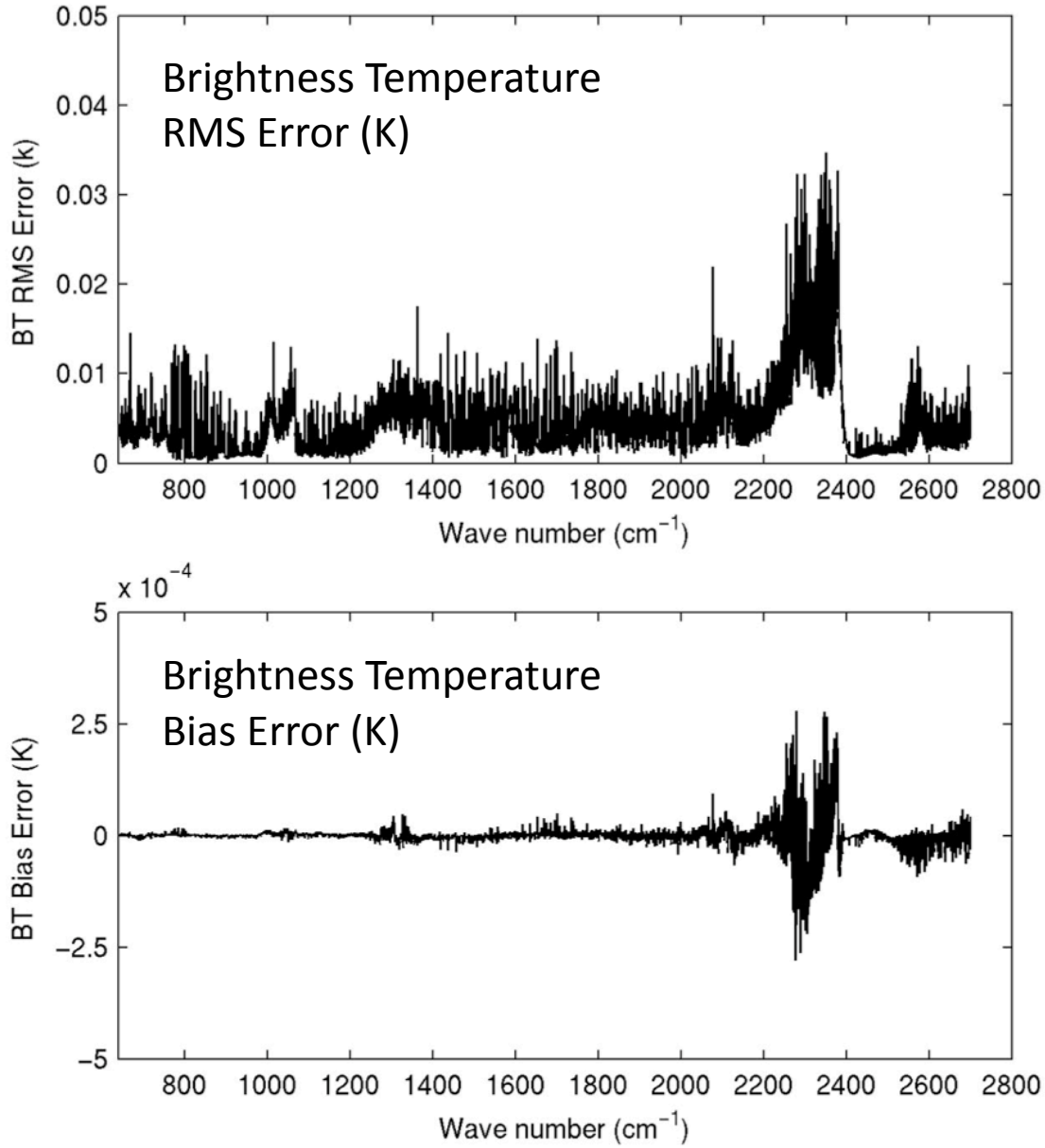
Radiance & Brightness Temperature



•An example longwave radiance spectra color coded by brightness temperature
•Plank functions overlaid

•Brightness temperature is convenient to highlight variability in spectral regions where emitted radiant energy is small.

PCRTM Accuracy

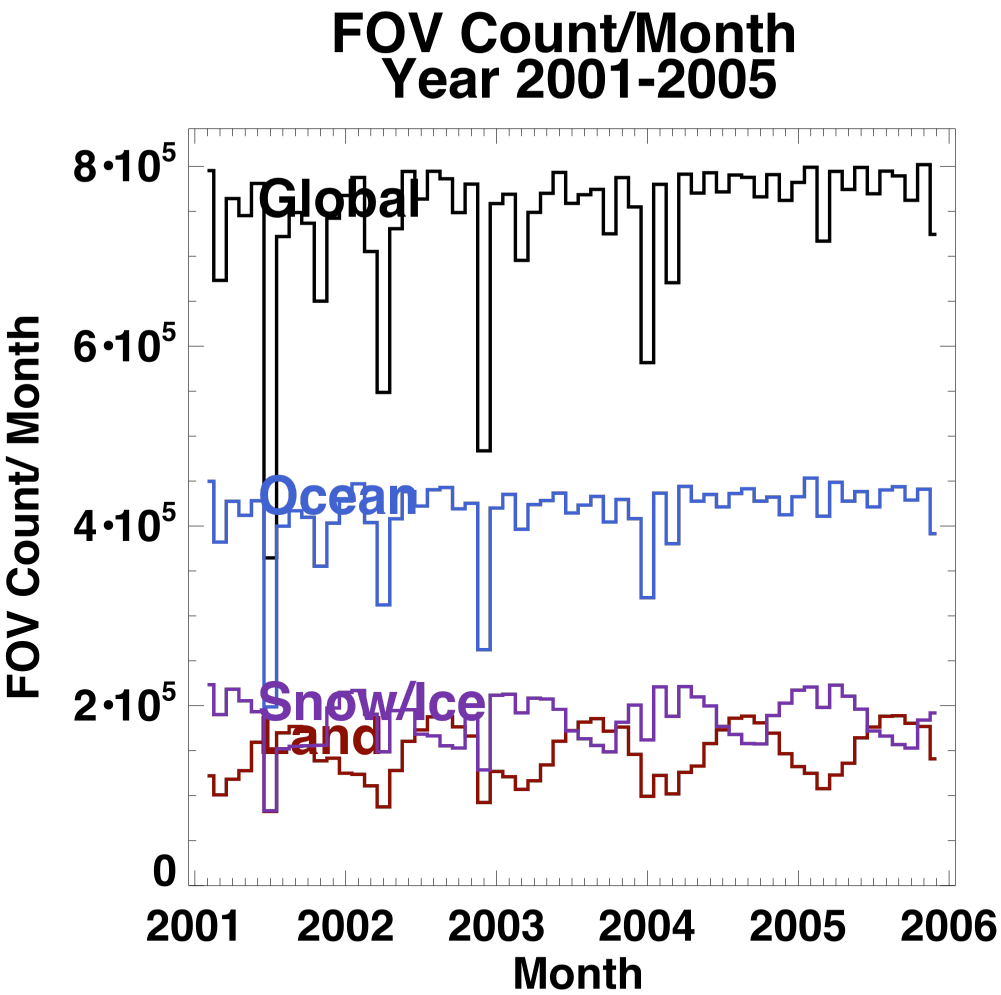


- PCRTM compared to LBLRTM
- Used 52 ECMWF diverse atmosphere profiles
- Fig 4. Applied Optics (Xu et al 2006)

Five Year PCRTM/SSF/MOA Inputs

- Jan 2001 : Dec 2005 (60 Months)
  - Instantaneous NADIR ONLY FOVs (ie Clarreo simulation)
- Subset SSF : Terra-FM1-MODIS_Edition2B
  - Cloud (Fraction, Optical Depth, Height, Phase , Re/De)
  - Clear Sky and up to 2 Cloud Conditions per SSF FOV
  - Skin Temperature, IGBP type
- MOA: DAO-GEOS4
  - 6 hourly profiles of Temperature, Humidity (Surface to 0.4 hPa)
  - Daily SMOBA Ozone profile
- Processed on AMI : IBM X86 64 node cluster
  - ~45 Million Instantaneous Nadir Only FOVs
  - 100^{+} Million Clear and Cloudy PCRTM spectra calculations
  - Output data: 60 month 10degLat PCscore output ~ 6Mb

Monthly Sampling

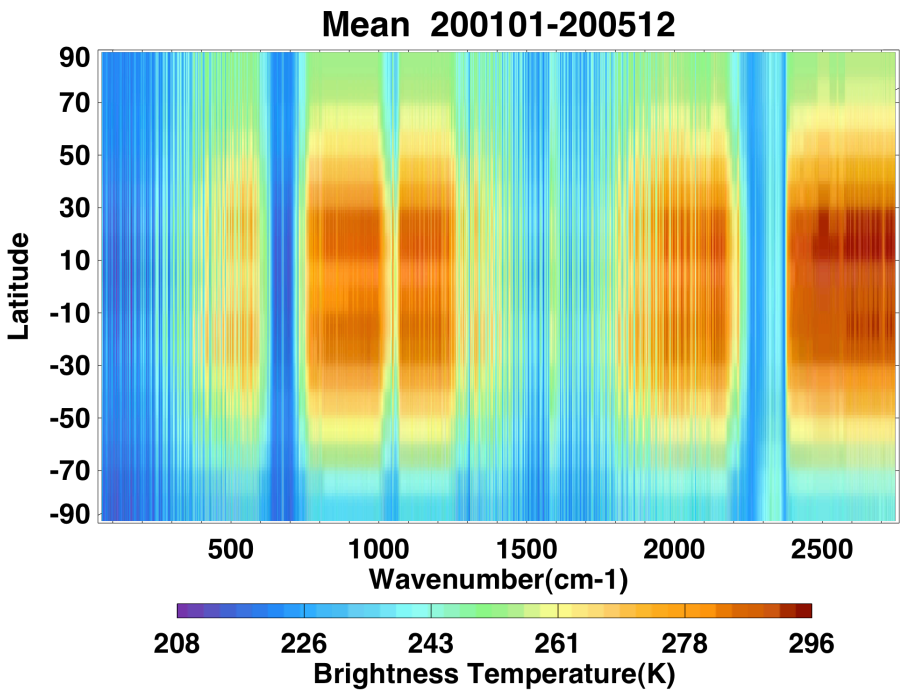


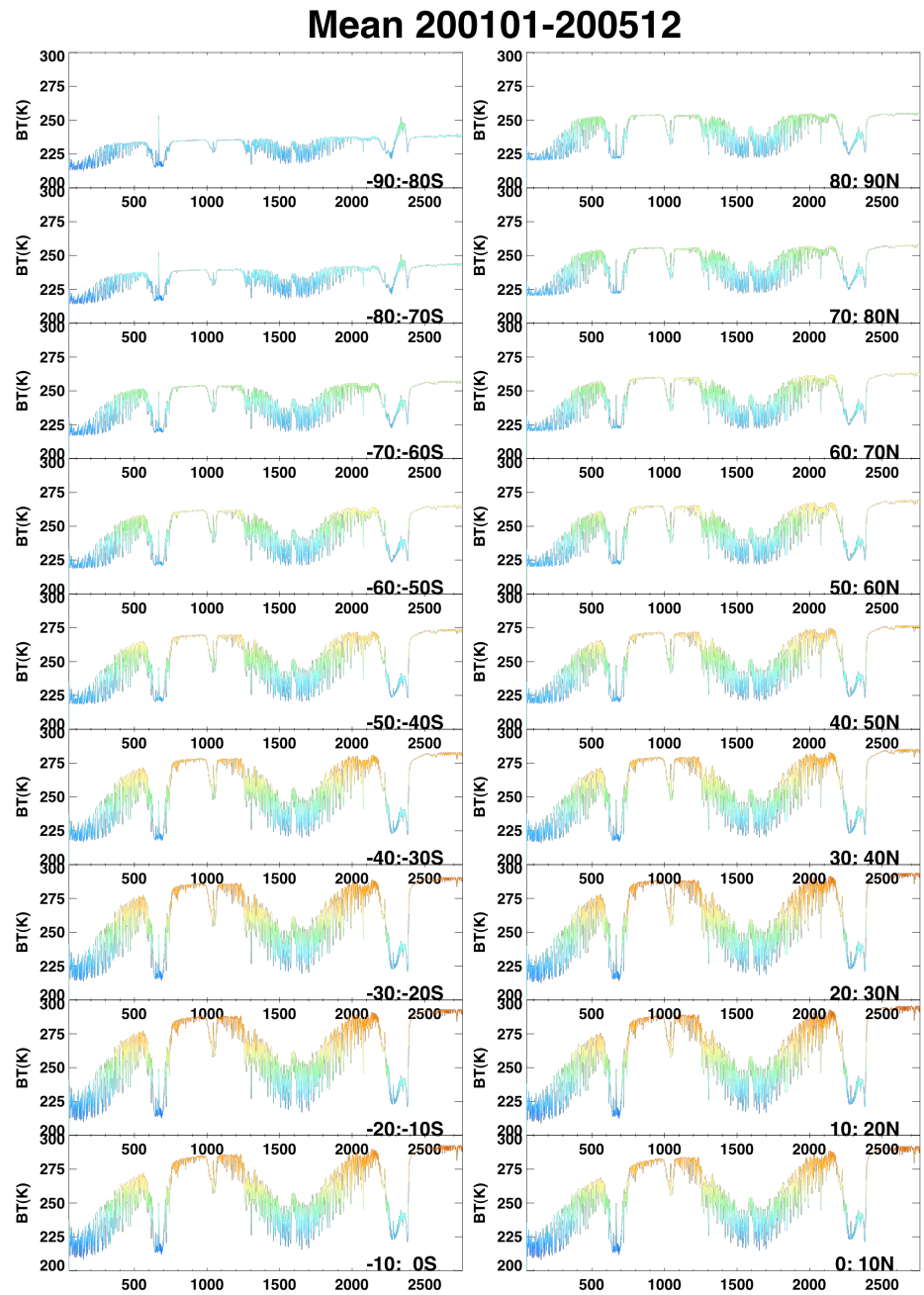
- Typically
  750,000 Global FOV/month
  400,000 Ocean
  200,000 Snow/Ice
  150,000 Land

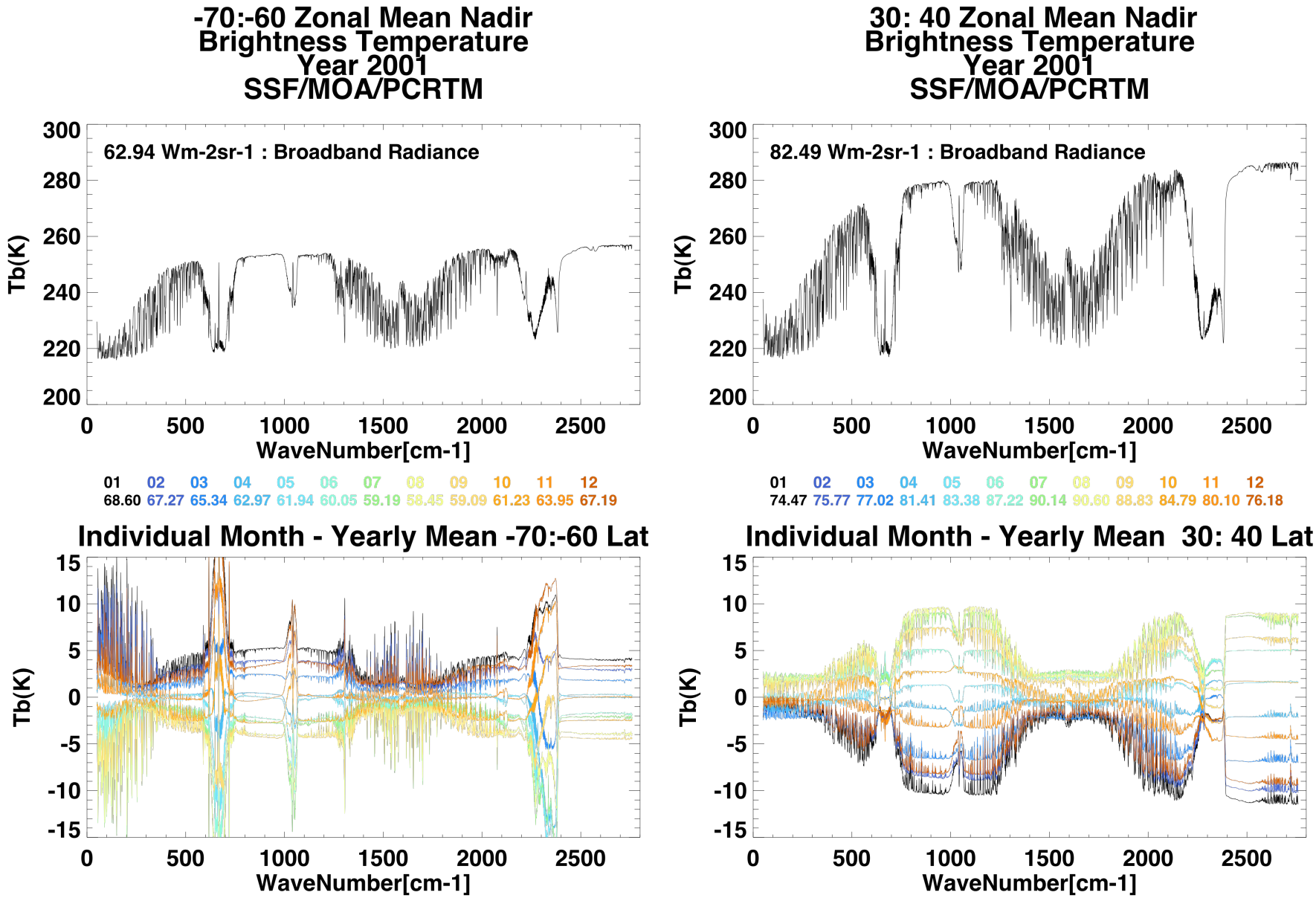
- June 2001 : MODIS issue
  15 days missing

- Nov 2002 : SMOBA ozone
  10 days missing

5 Year MEAN Zonal/Spectrum

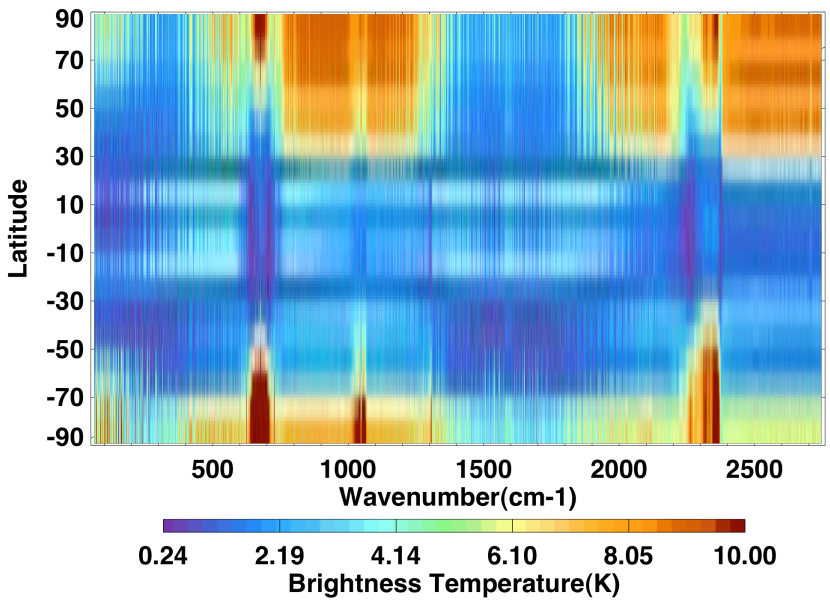


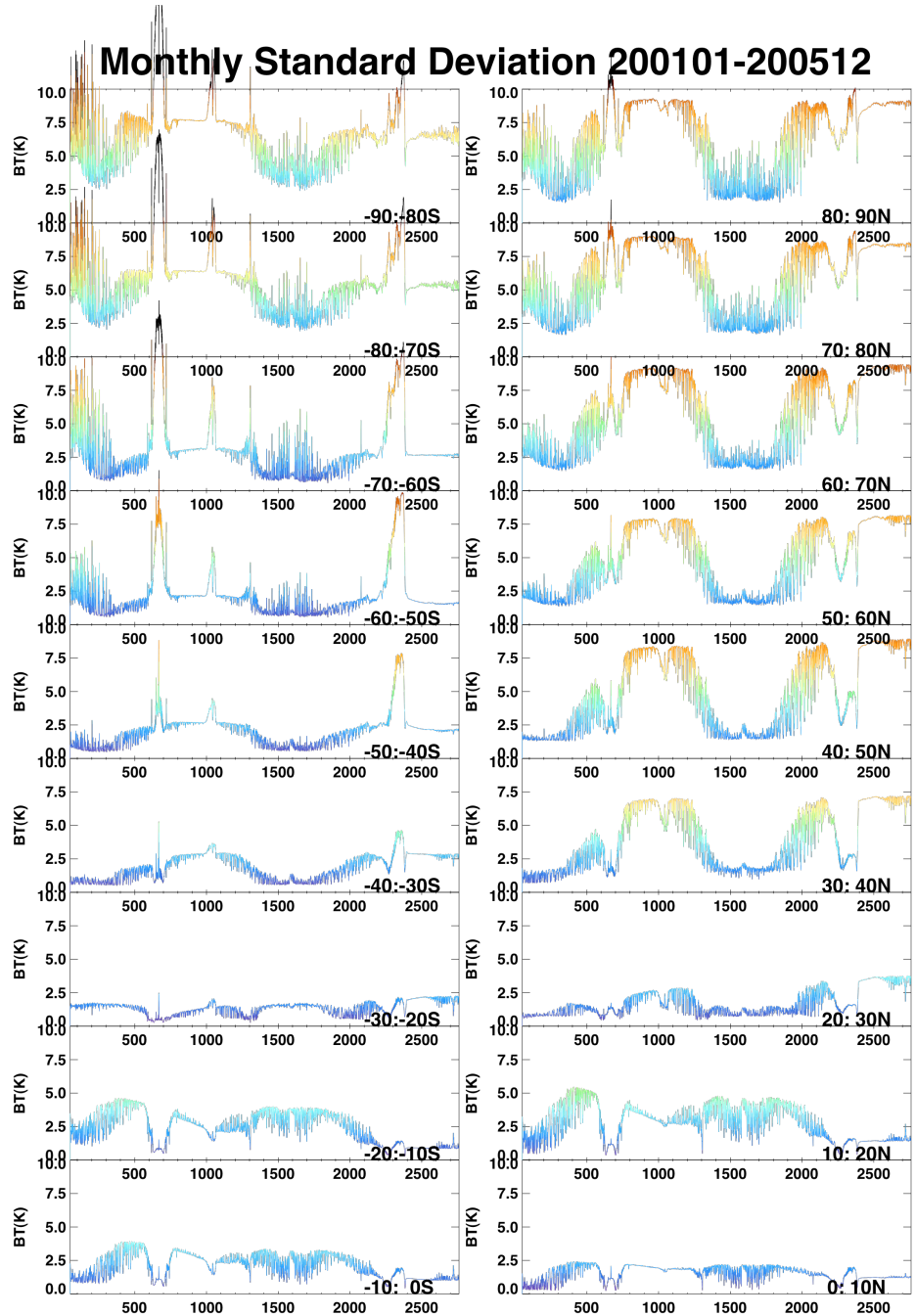



-70:-60 Zonal Mean Nadir
Brightness Temperature
Year 2001
SSF/MOA/PCRTM
62.94 Wm-2sr-1 : Broadband Radiance
Tb(K)
WaveNumber[cm-1]
01 02 03 04 05 06 07 08 09 10 11 12
68.60 67.27 65.34 62.97 61.94 60.05 59.19 58.45 59.09 61.23 63.95 67.19
30: 40 Zonal Mean Nadir
Brightness Temperature
Year 2001
SSF/MOA/PCRTM
82.49 Wm-2sr-1 : Broadband Radiance
Tb(K)
WaveNumber[cm-1]
01 02 03 04 05 06 07 08 09 10 11 12
74.47 75.77 77.02 81.41 83.38 87.22 90.14 90.60 88.83 84.79 80.10 76.18
Individual Month - Yearly Mean -70:-60 Lat
Tb(K)
WaveNumber[cm-1]
Individual Month - Yearly Mean 30: 40 Lat
Tb(K)
WaveNumber[cm-1]

Standard Deviation of Monthly Data(200101-200512)

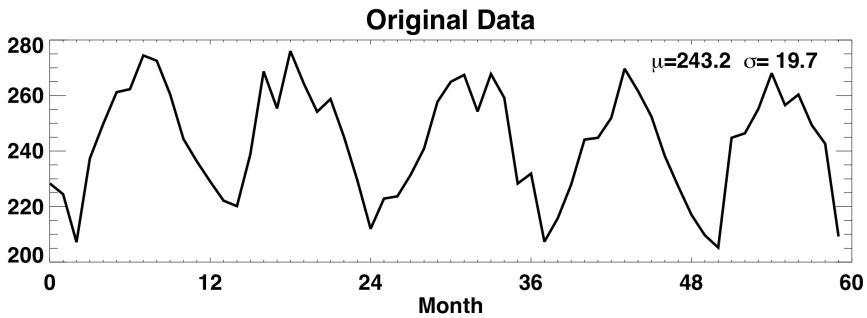
Seasonal Variability



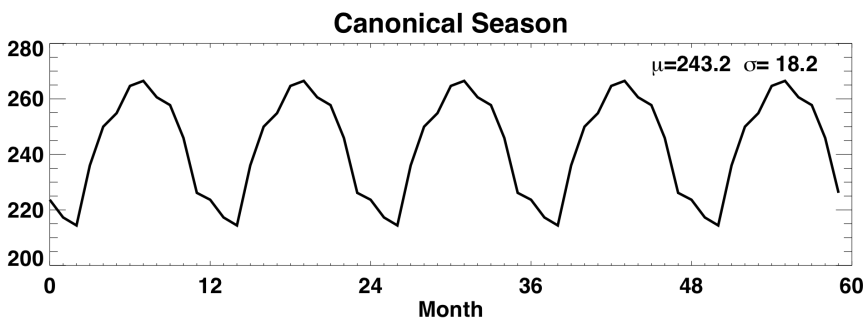


Deseasonalized Anomaly : What is it ?

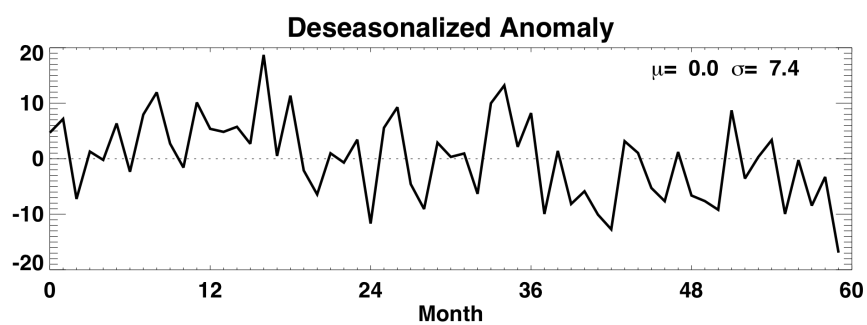
Example using made up temperature data



Original Data is 5 years of monthly data with a large apparent seasonal component



Canonical Season is the mean of each individual month (Jan , Feb.. Dec) over all available years. In this case 5 years.

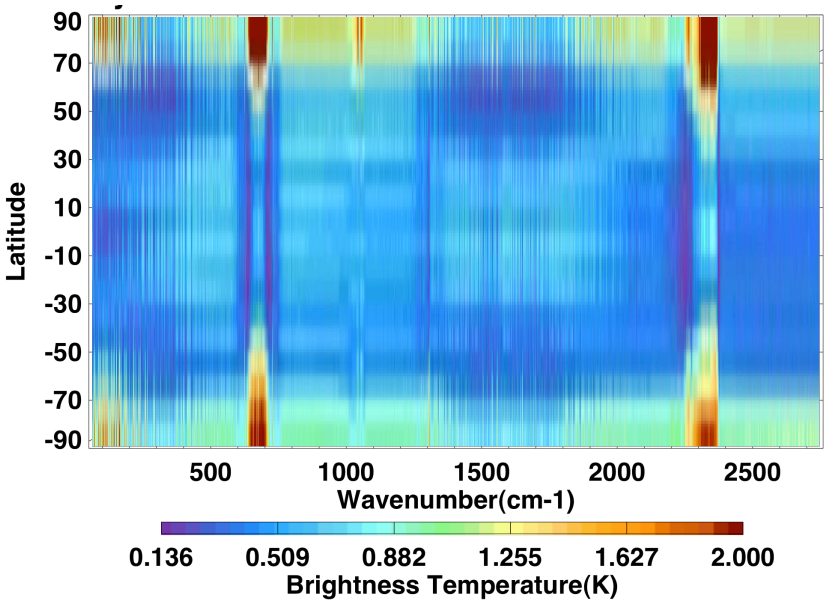


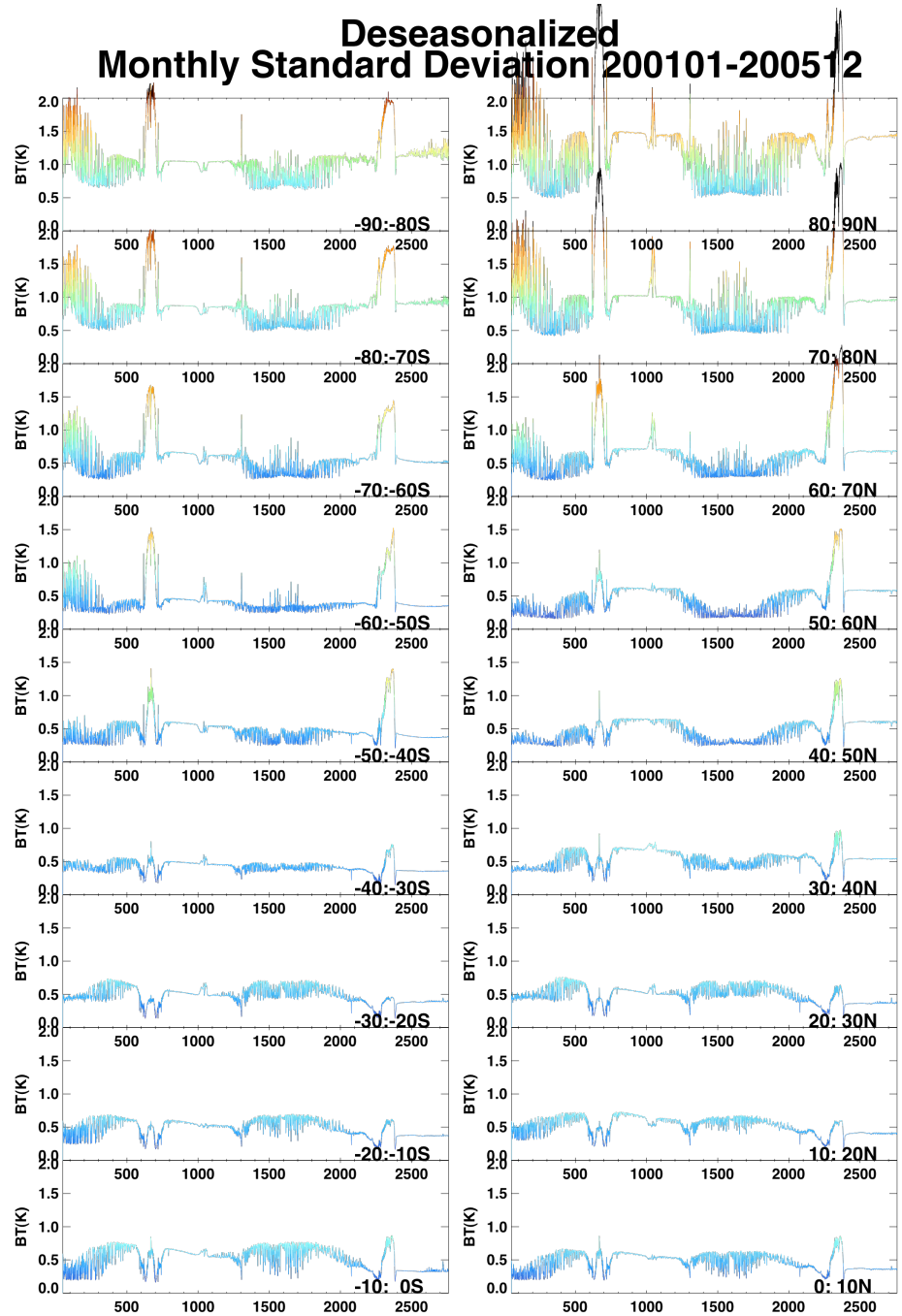
Deseasonalized Anomaly is formed by original data *minus* canonical season

$$\sigma_{Total} = \text{SQRT}(\sigma^2_{Canonical} + \sigma^2_{Anomaly})$$

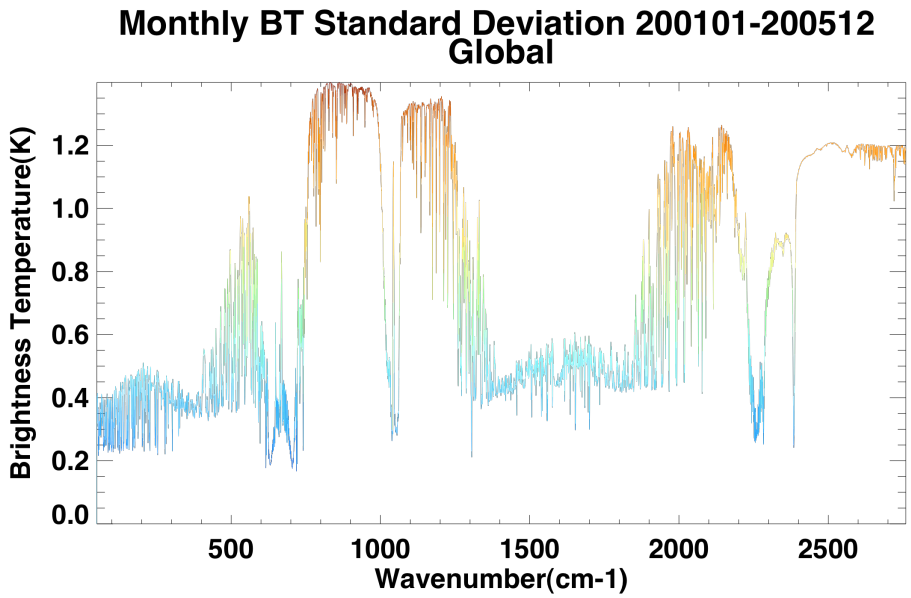
$$19.7 = \text{SQRT} ((18.2)^2 + (7.4)^2)$$

Standard Deviation of Deseasonalized Anomaly (Jan 2001:Dec 2005)

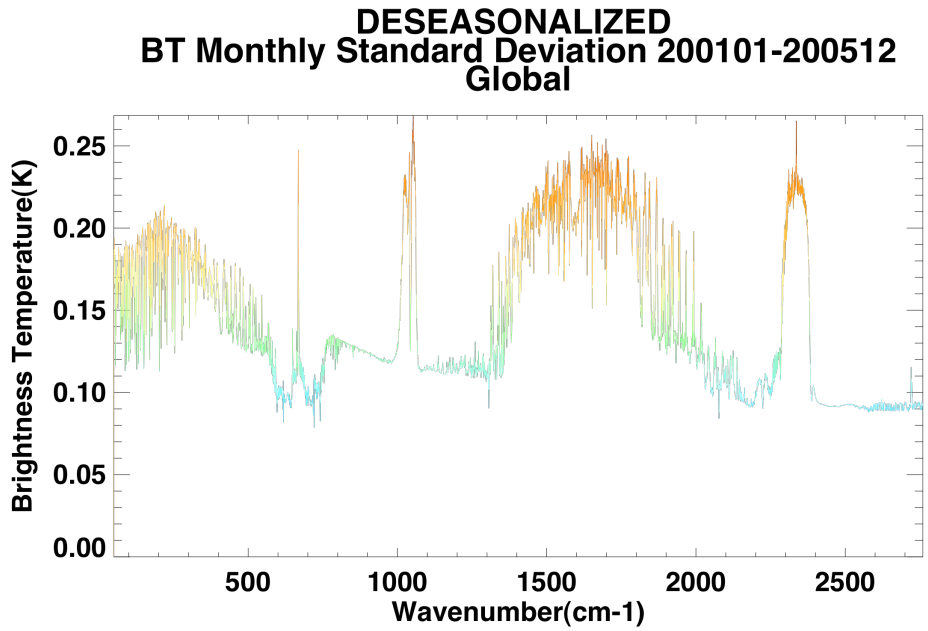




Global Mean LW Spectral Brightness Temperature Variability

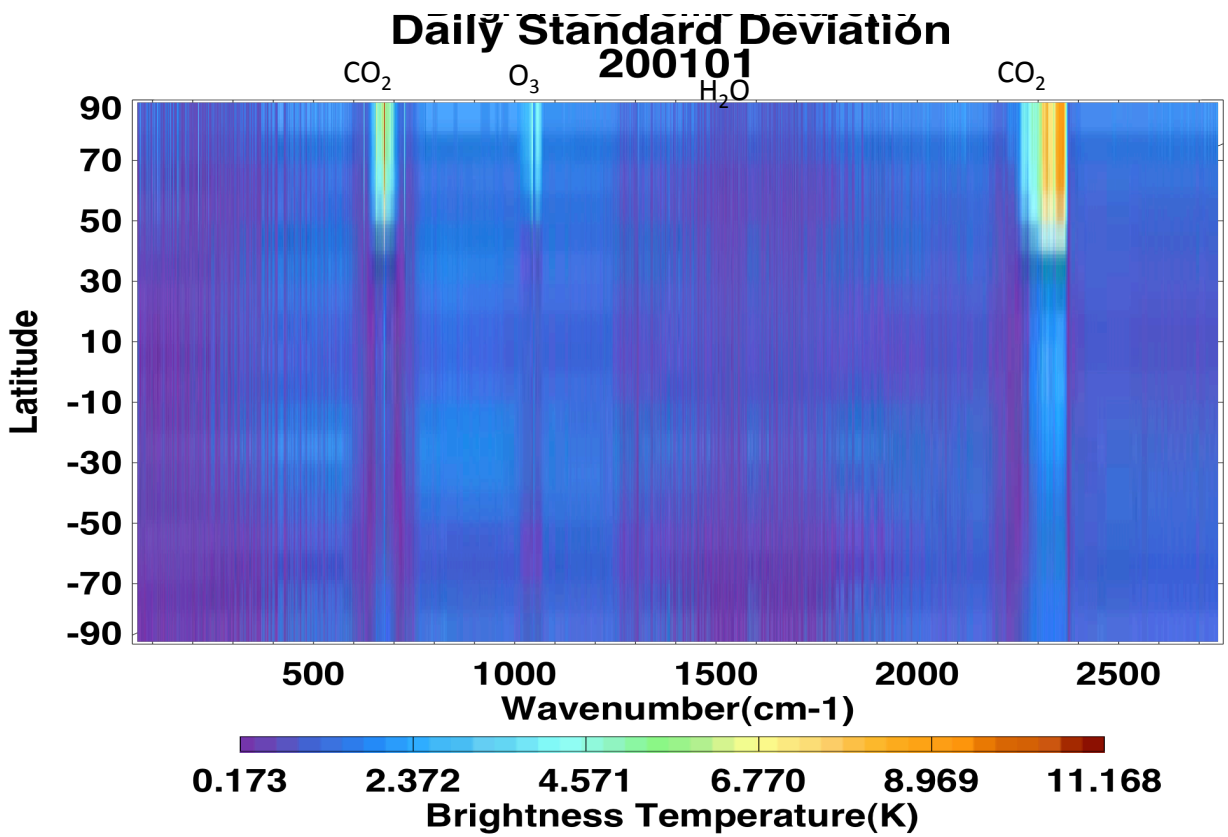


Seasonal variability large in windows surface temperature variability

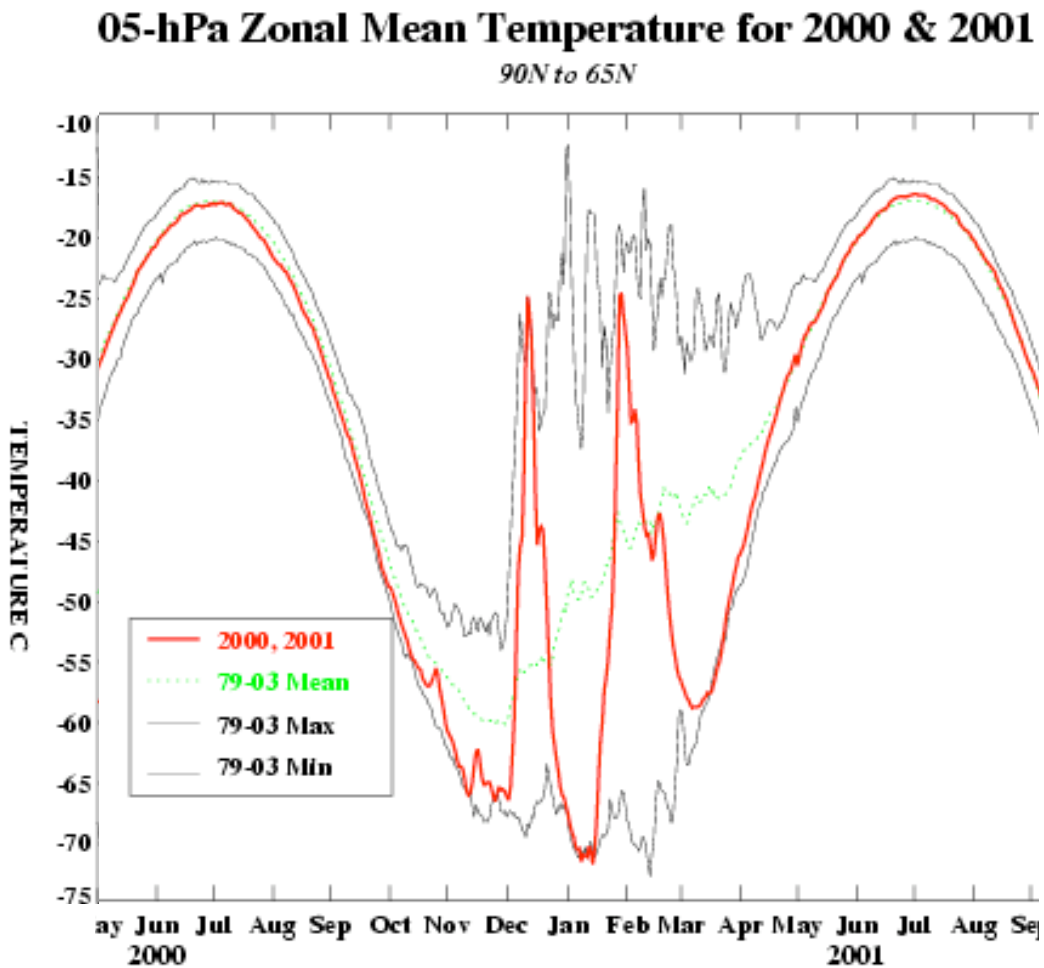


Deseaonalized anomaly variability large in H_2O atmosphere absorption bands

Daily Zonal Mean Variability
Jan 2001



65N -90N Sudden Stratospheric Warming Event Jan-Feb 2001



ΔT during Jan 2001
1hpa +40K
5hpa +45K
30hpa +15K

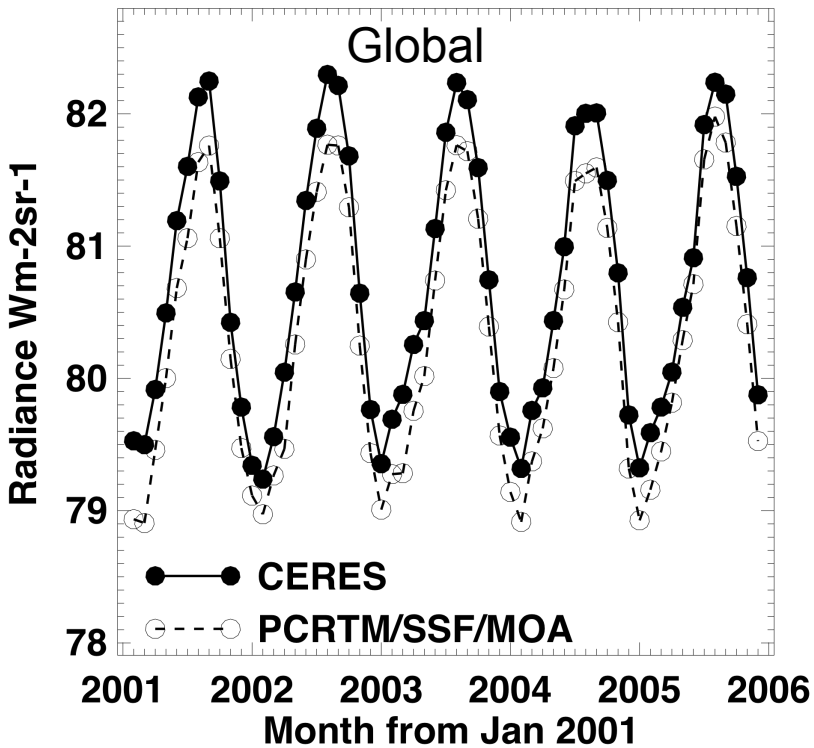
Source http://www.cpc.noaa.gov/products/stratosphere/temperature/

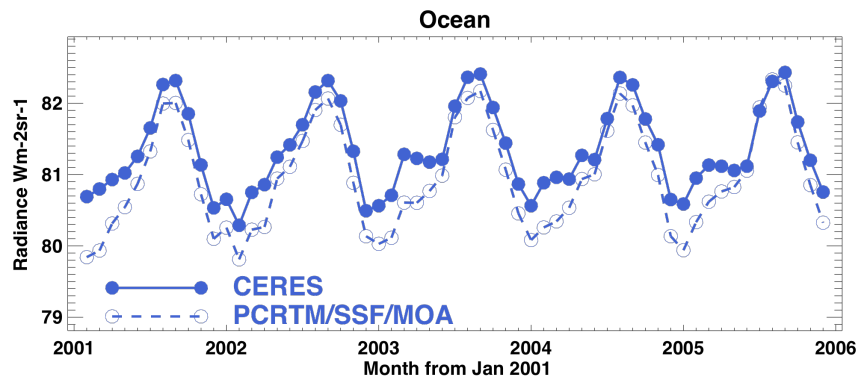
Comparisons of PCRTM simulations to CERES Observations of LW nadir radiances

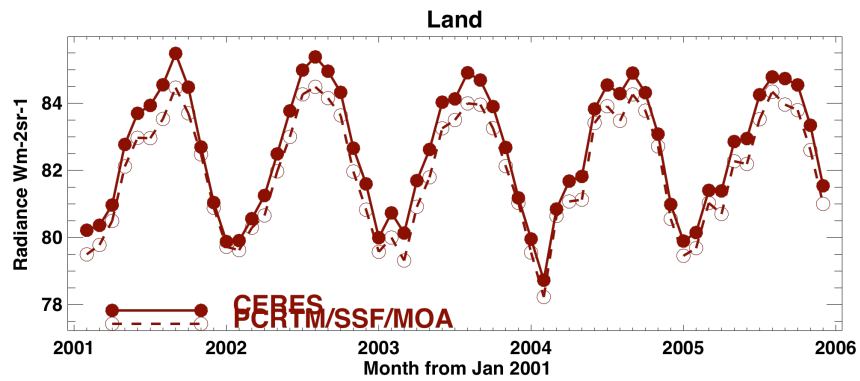
Global Monthly Means

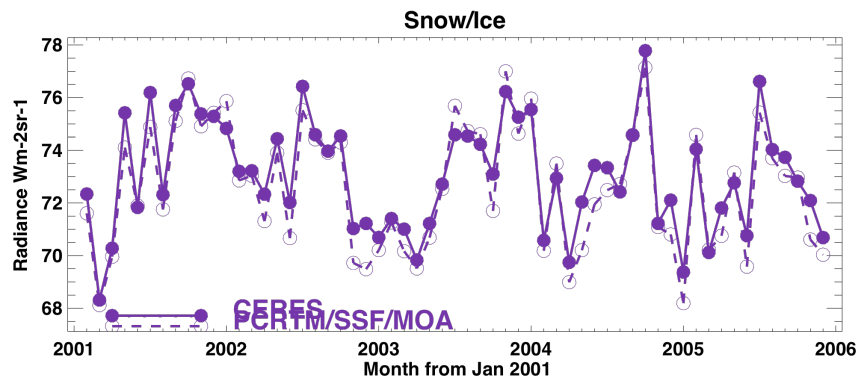
(Seasonal Variability)

Nadir Radiance	PCRTM	CERES	PCRTM -CERES
Global	80.3	80.7	-0.40
Ocean	80.9	81.3	-0.39
Land	81.9	82.5	-0.61
Snow/Ice	72.6	73.1	-0.47





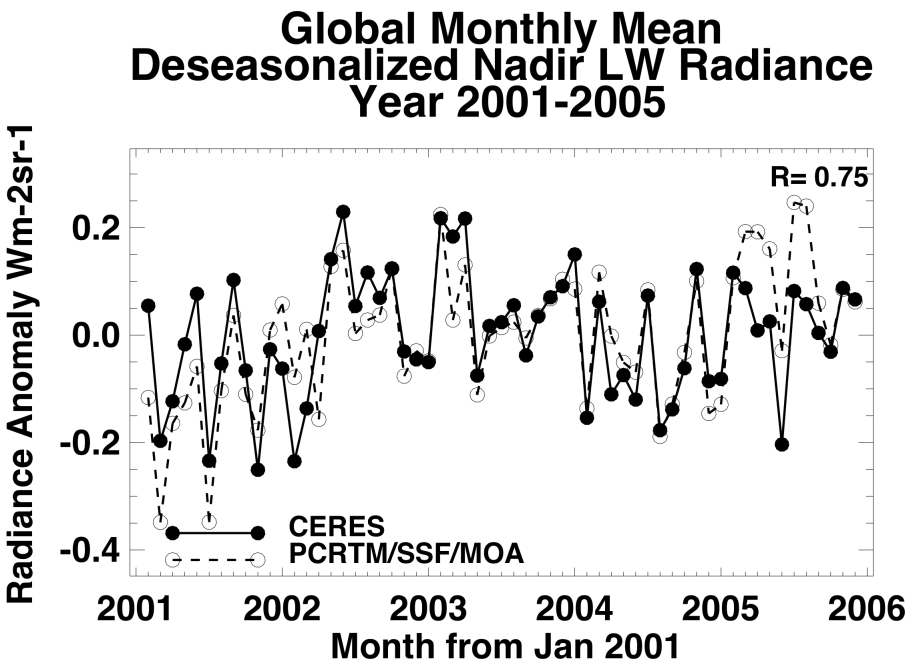


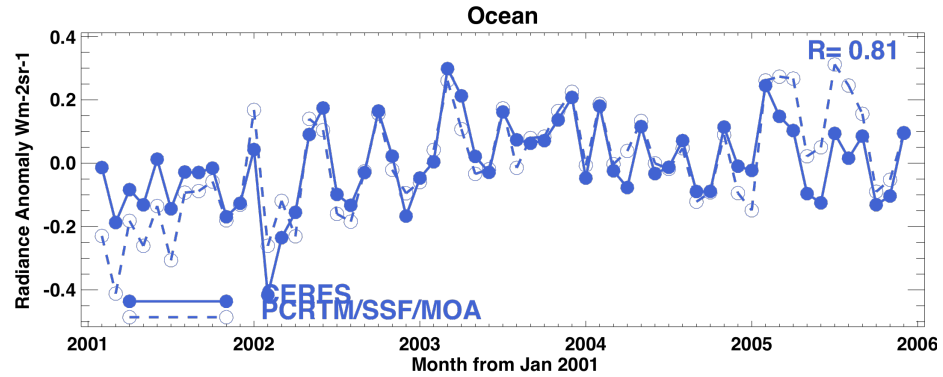


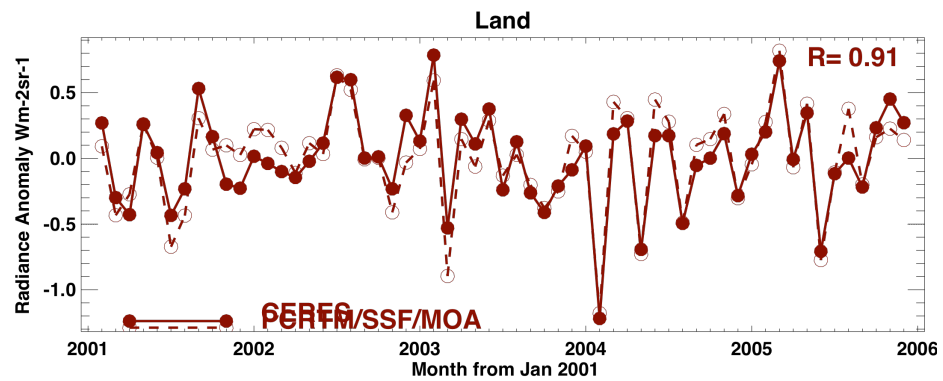
Monthly Mean Anomaly

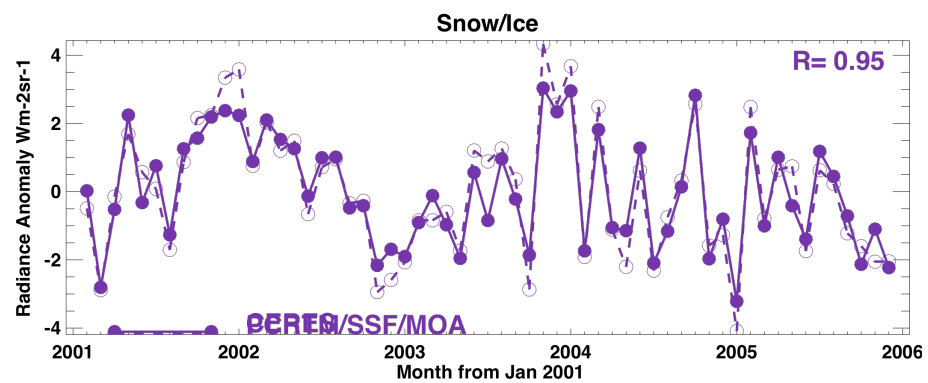
(Inter-annual Variability)

Anomaly Statistics	R^2	PCRTM Stddev	CERES Stddev.
Global	0.75	0.128	0.117
Ocean	0.81	0.162	0.131
Land	0.91	0.379	0.362
Snow/Ice	0.95	1.886	1.600

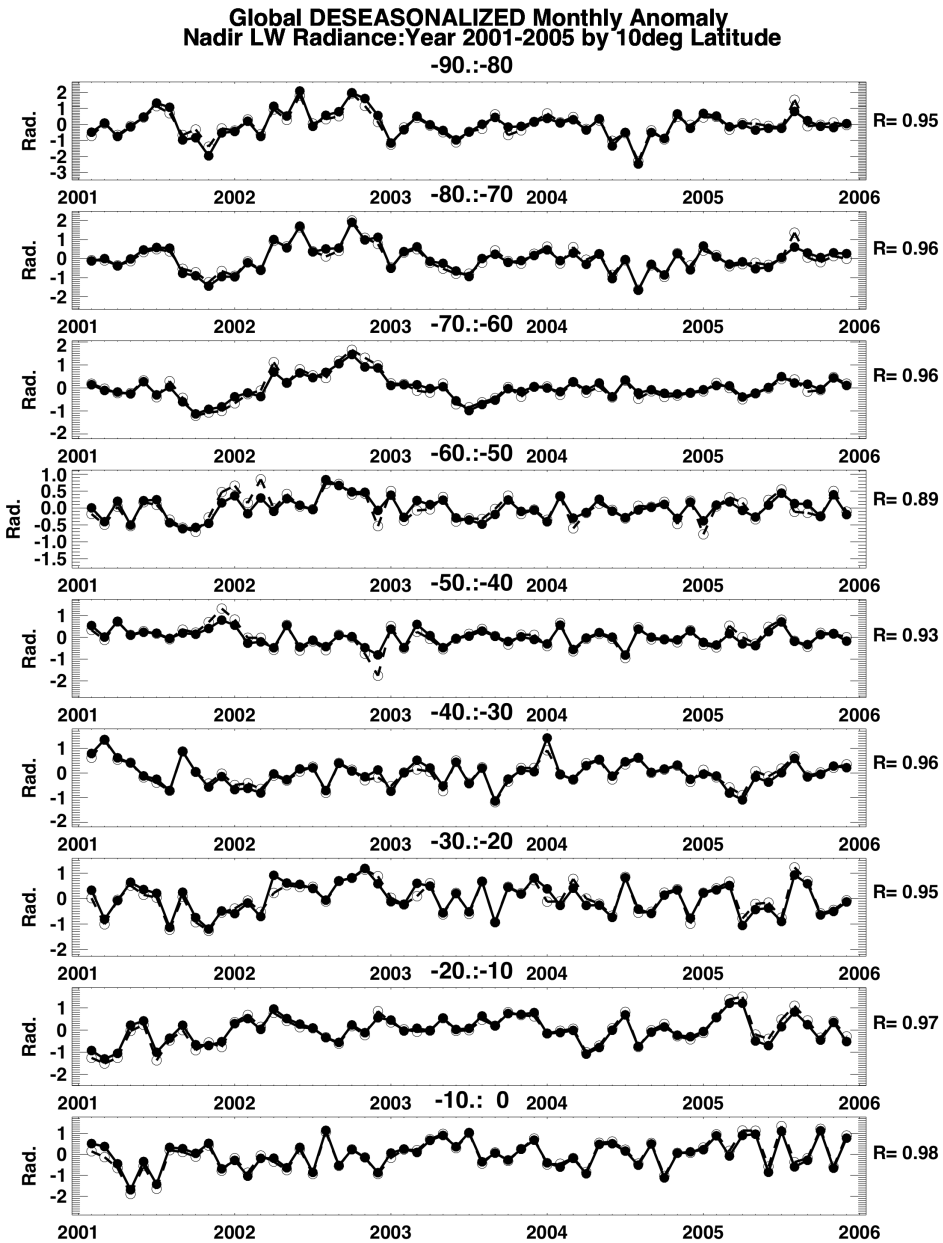


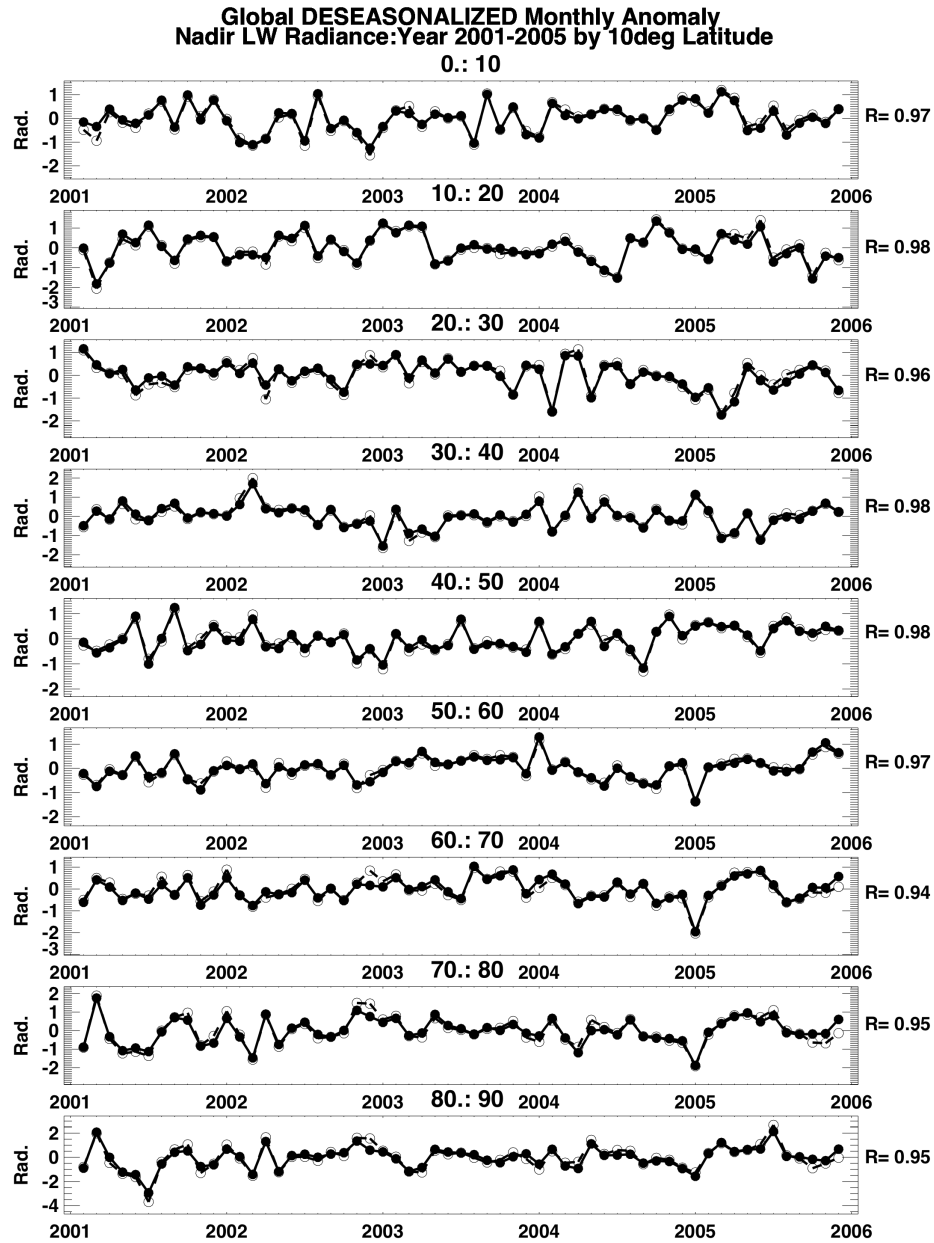






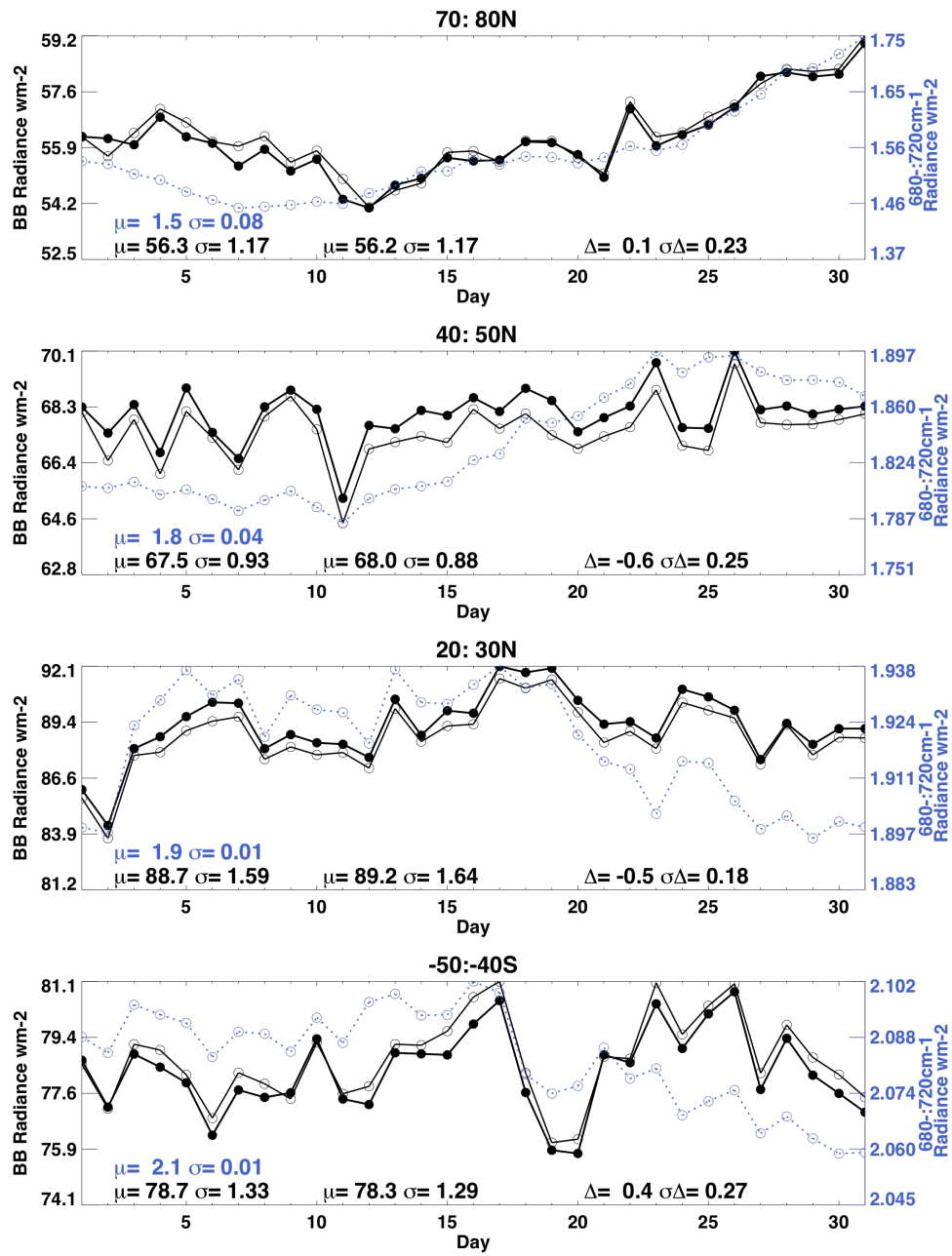
Inter-annual Variability by Lat. Zone





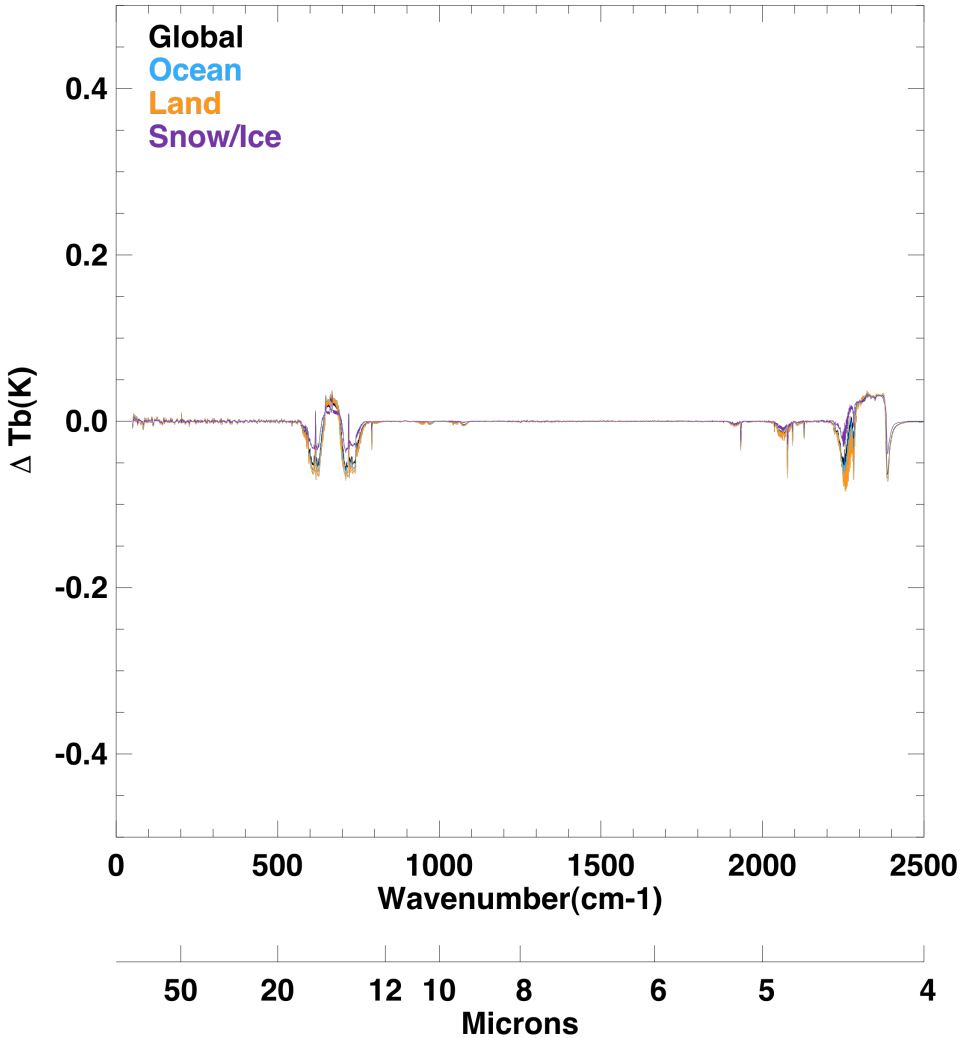
Daily Zonal Mean 200101 & CERES

	75N	45N	25N	45S
CERES BB Wm-2Sr-1	56.2(1.17)	68.0(0.88)	89.2(1.64)	78.3(1.29)
PCRTM BB Wm-2Sr-1	56.3(1.17)	67.5(0.93)	88.7(1.59)	78.7 (1.33)
PCRTM BB-CERES BB	0.1(0.23)	-0.6(0.25)	-0.5(0.18)	-0.5 (0.18)
PCRTM CO2 band 680-720 cm-1	1.5(0.08)	1.8(0.04)	1.9 (0.01)	2.1 (0.01)



PCRTM & CLARREO
Radiative Kernels
(Partial Derivatives of Spectral LW radiances)
and the Attribution of spectral changes over time to physical variables

CO_2 Forcing of LW Spectra



One of upcoming CLARREO mission goals is to detect climate trends.

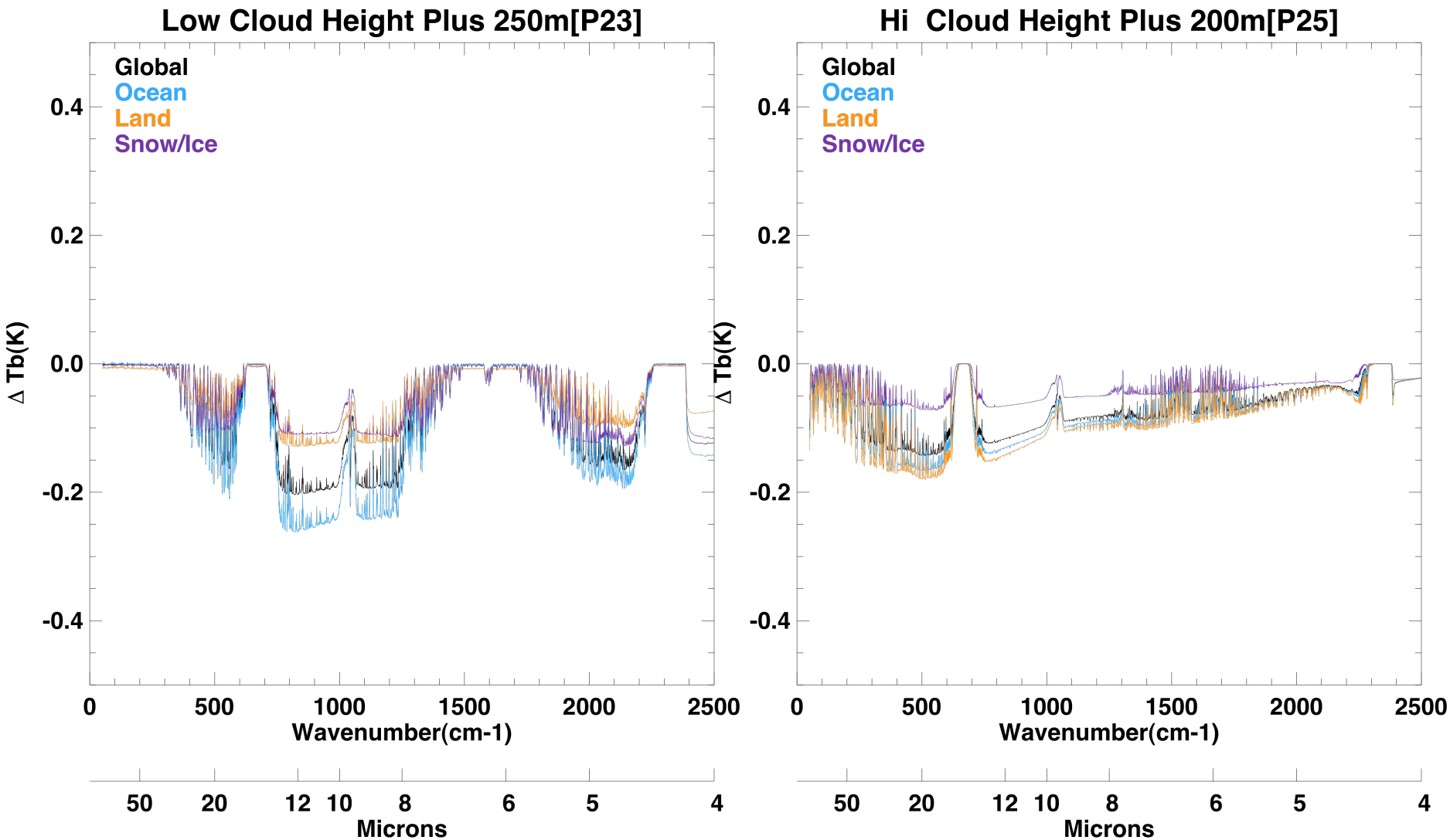
Example here is a forcing due to a change in CO2 affecting the longwave spectra with a characteristic shape.

Computed using PCRTM for a single day of SSF 20010115 using a CO2 change of 2 ppmv.

But the Earth is vastly more complicated, feedbacks and natural variability exist….

Possible Feedback Responses

(Many others possible)

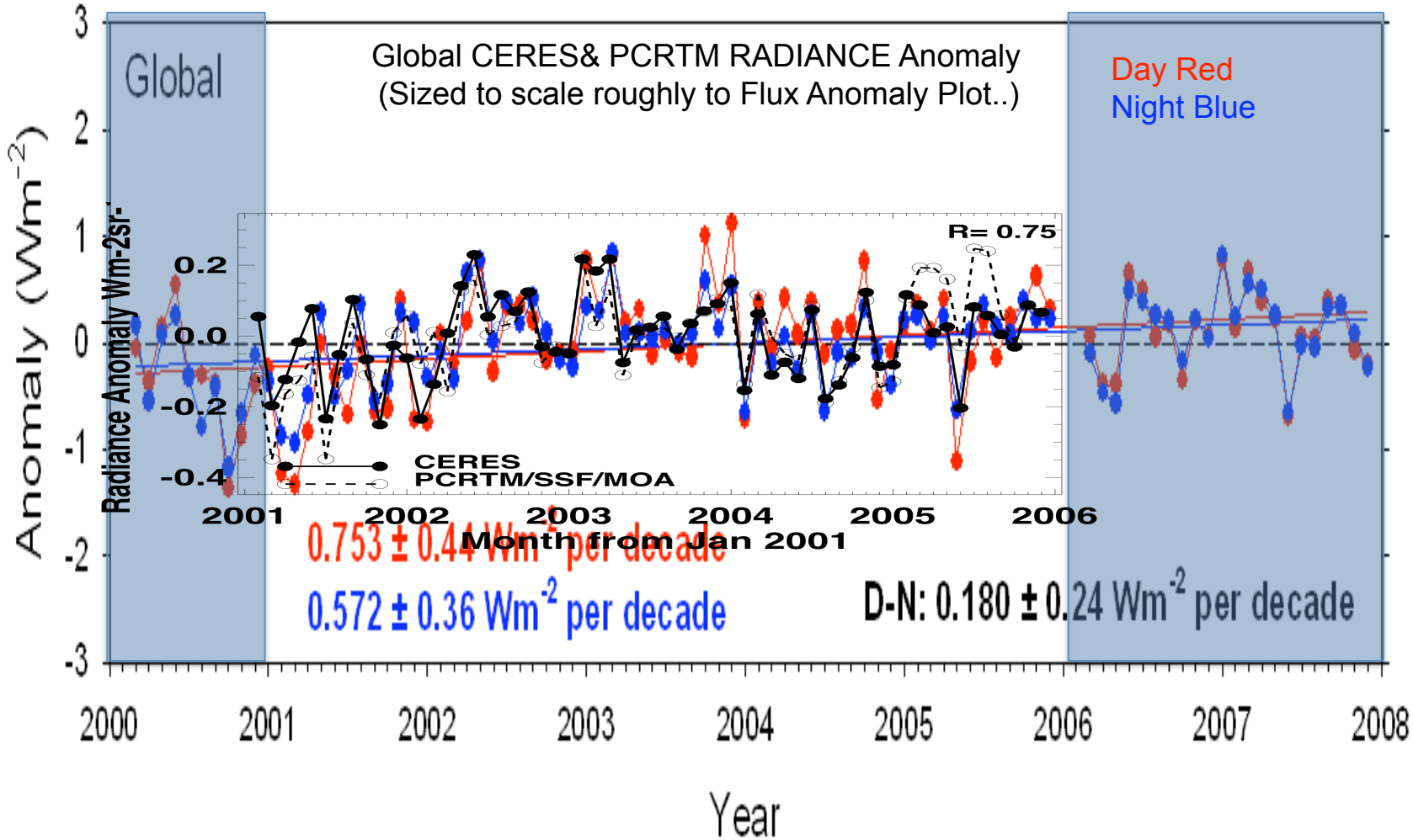


Summary

- PCRTM/SSF/MOA used to simulate nadir LW radiances
  - Use as a tool for CLARREO
- PCRTM/SSF/MOA show much of seasonal and most of deseasoned variance is from stratosphere CO2, O3 bands.
- PCRTM/SSF/MOA simulations match CERES ED2 broadband nadir radiances to -0.4 (Wm-2sr-1) global 5 year mean
  - High correlations of simulation to CERES deseasoned Anomaly

CERES Global LW FLUX Anomaly

(Norman Loeb Provisional Ed3)



Additional Figures

- http://snowdog.larc.nasa.gov/rose/pcrtm/ssf/zgm/