Sensitivity study of the MODIS cloud top property algorithm to CO_2 channel spectral response functions

Hong Zhang*, Richard Frey* and Paul Menzel+

* *Cooperative Institute for Meteorological Satellite Studies, Space Science and Engineering Center, University of Wisconsin, Madison, WI USA*

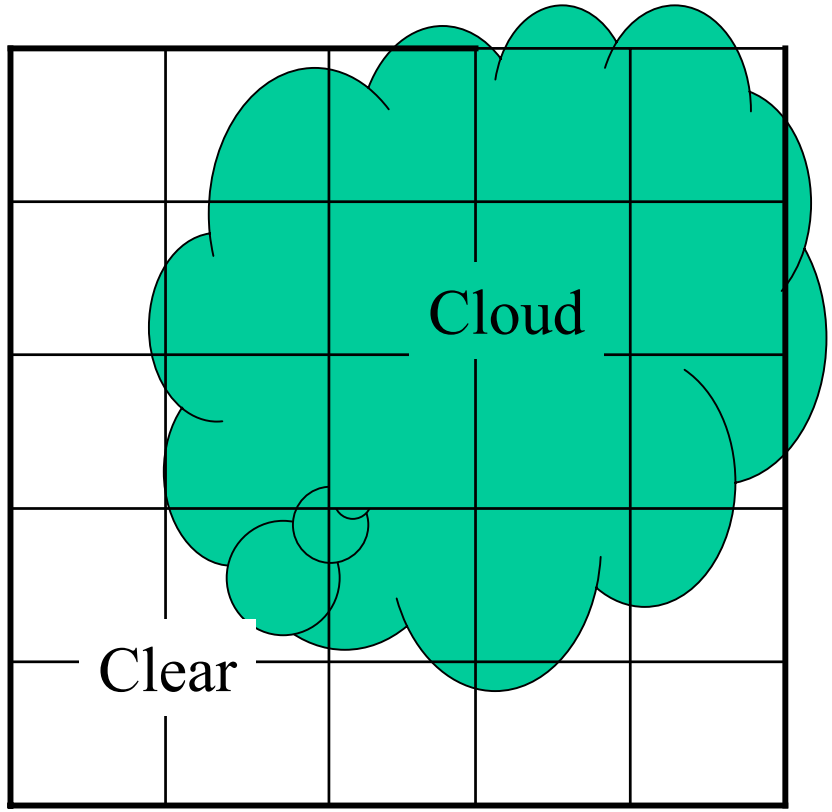
\+ *Office of Research and Applications, NOAA/NESDIS, Madison, WI USA*

ITSC-14 2005, Beijing, China, 26 April, 2005

Outline of presentation

- CO_2 slicing approach -- MODIS cloud top property algorithm
- Intercalibration with AIRS suggests spectral shifts for the MODIS CO_2 channels
- Preliminary cloud top property results with shifted Spectral Response Function
- Summary

Radiation Transfer Equation in CO_2 Slicing Algorithm



Radiance from a partly cloudy FOV

$I_\lambda = \eta\varepsilon_\lambda I_\lambda^{bcd} + (1 - \eta\varepsilon_\lambda) I^{clr}$ where $\eta\varepsilon_\lambda$ = effective cloud amount (ECA)

$I_\lambda^{bcd} = B_\lambda[T(Pc)]$ where B_λ= Planck function,
T(Pc) = temp at cloud top pressure Pc

Two unknowns: $\eta\varepsilon_\lambda$ and Pc

Two unknowns require two equations

$$\frac{(I_{\lambda 1}-I_{\lambda 1}^{clr})}{(I_{\lambda 2}-I_{\lambda 2}^{clr})} = \frac{\eta\varepsilon_{\lambda 1}\int_{p_s}^{p_c}\tau_{\lambda 1}\,dB_{\lambda 1} + (1-\varepsilon_s)\tau_{s(\lambda 1)}B_{s(\lambda 1)} - \int_{0}^{p_s}B_{\lambda 1}(T(p))\,d\tau^{\downarrow}}{\eta\varepsilon_{\lambda 2}\int_{p_s}^{p_c}\tau_{\lambda 2}\,dB_{\lambda 2} + (1-\varepsilon_s)\tau_{s(\lambda 2)}B_{s(\lambda 2)} - \int_{0}^{p_s}B_{\lambda 2}(T(p))\,d\tau^{\downarrow}}$$

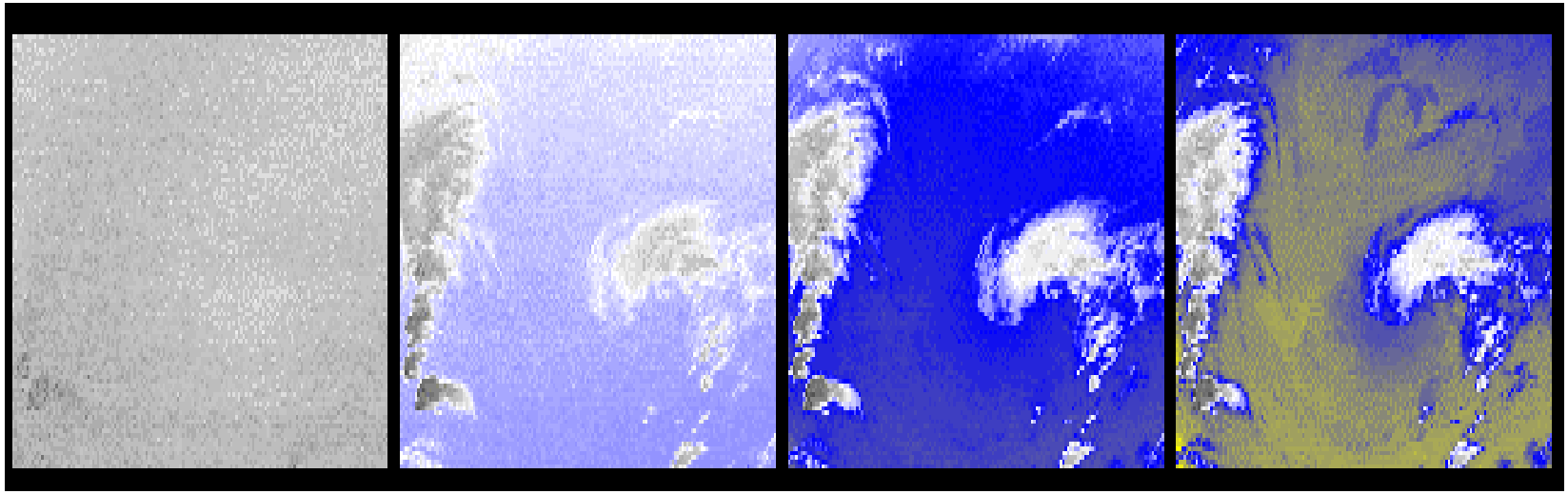
Different ratios reveal cloud properties at different levels

hi - 14.2/13.9
mid - 13.9/13.6
low - 13.6/13.3

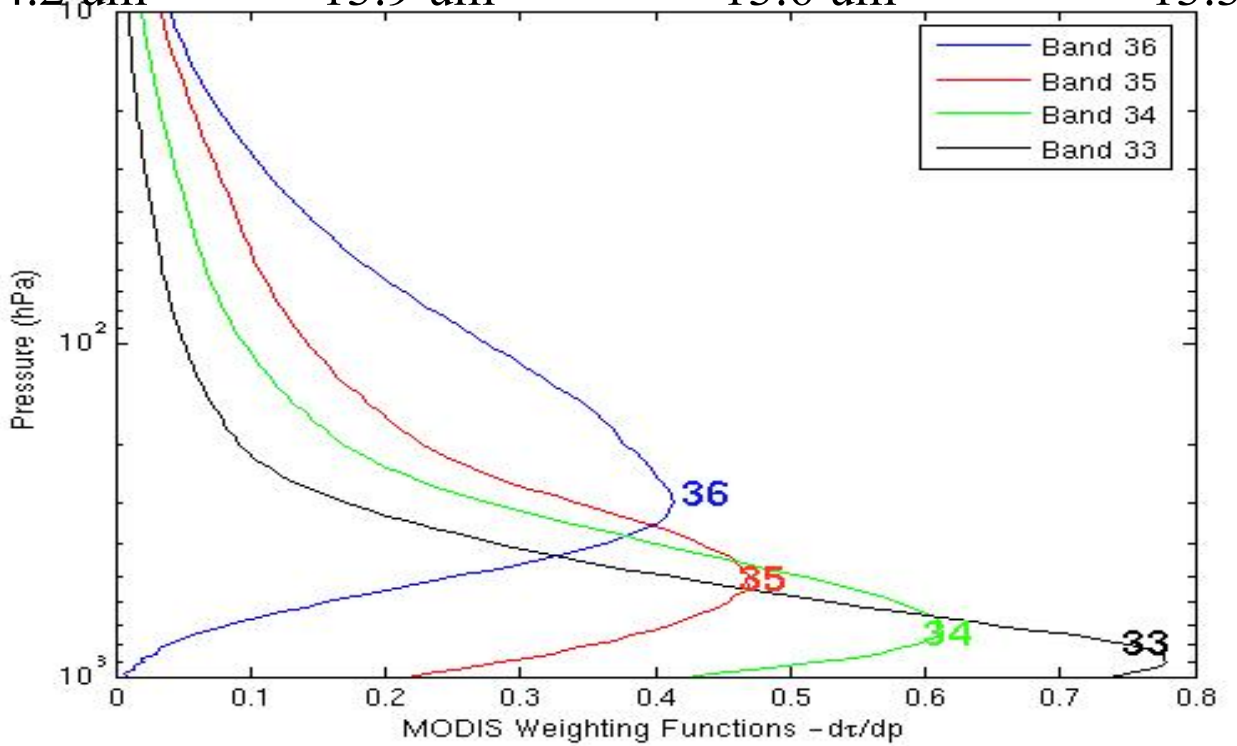
ECA is evaluated from the infrared window (IRW) band

$$ECA = \eta\varepsilon_{c(w)} = \frac{(I_{IR}-I_{IR}^{clr})}{(I_{IR}^{bd}-I_{IR}^{clr})}$$

CO_2 channels see different levels in the atmosphere



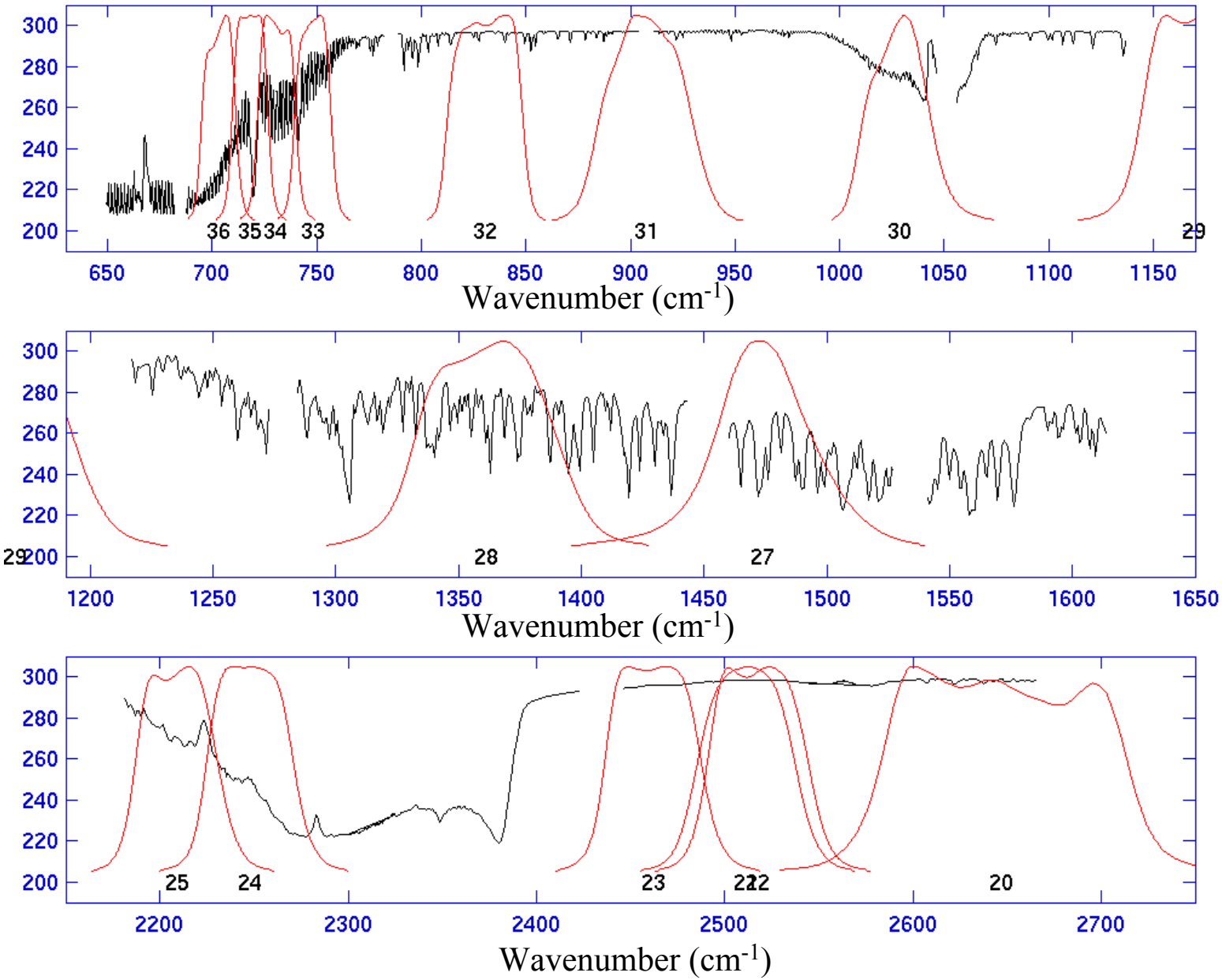
14.2 µm 13.9 um 13.6 um 13.3 um



Outline of presentation

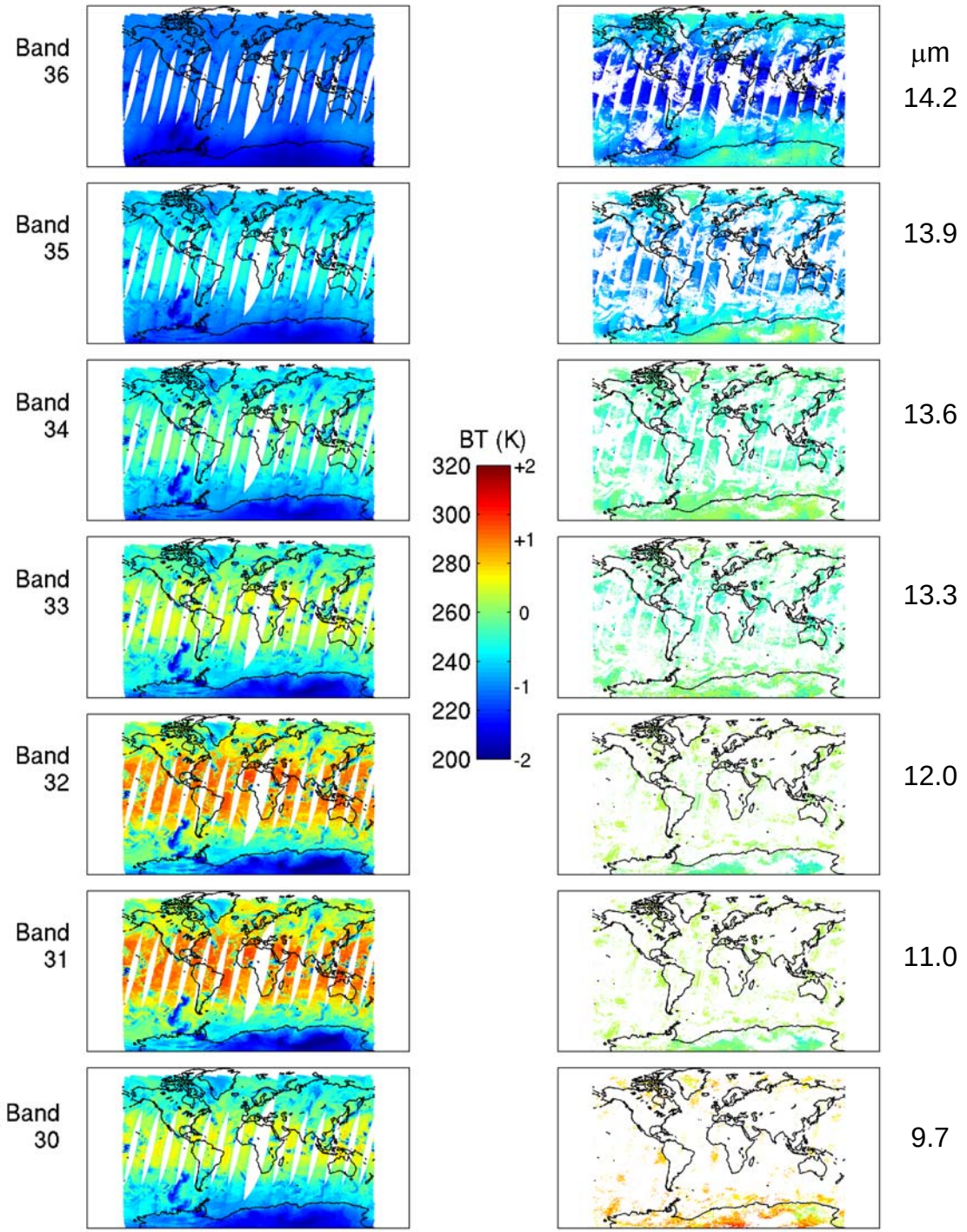
- **CO_2 slicing approach -- MODIS cloud top property algorithm**
- **Intercalibration with AIRS suggests spectral shifts for the MODIS CO_2 channels**
- **Preliminary cloud top property results with shifted Spectral Response Function**
- **Summary**

Aqua MODIS IR SRF overlaid on AIRS Spectrum

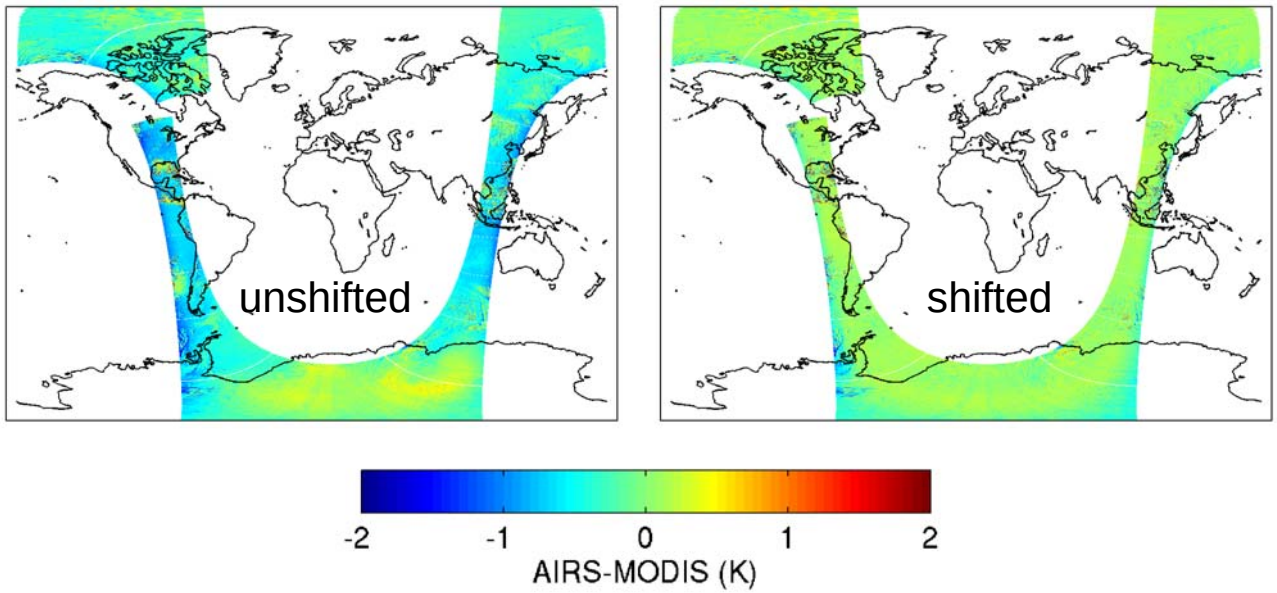


Images of 6 Sep 2002 descending MODIS brightness temperatures (left panels) and AIRS minus MODIS brightness temperature differences (right panels) for bands 36 thru 30.

From Tobin et al 2005

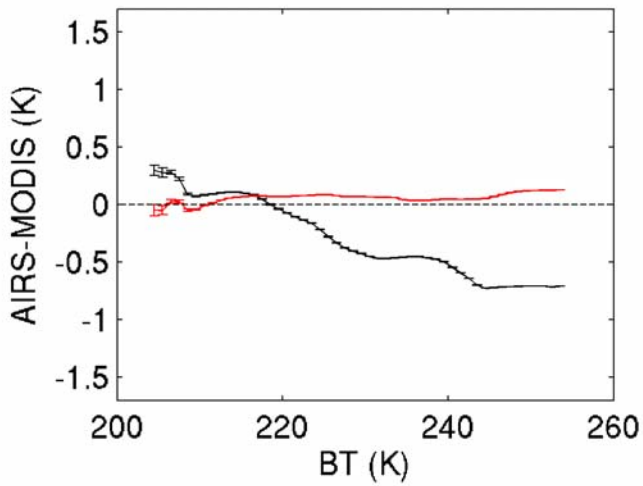


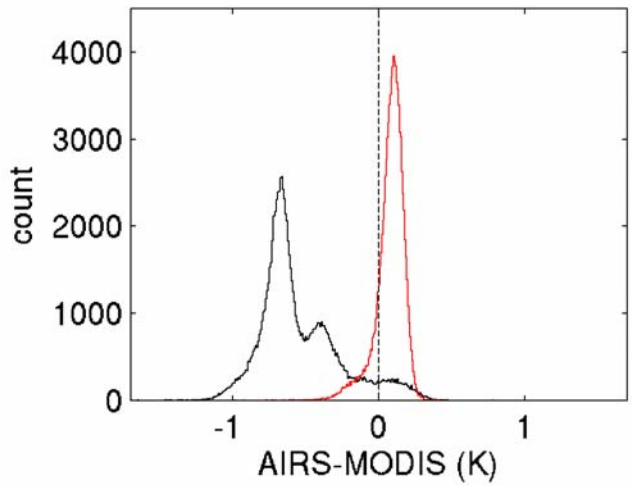
MODIS band 35 (13.9 μm) brightness temperature differences using original SRF (black) and using MODIS SRF shifted +0.8 cm $^{-1}$ (red)
From Tobin et al 2005



SRF shifted for CO_2 channels

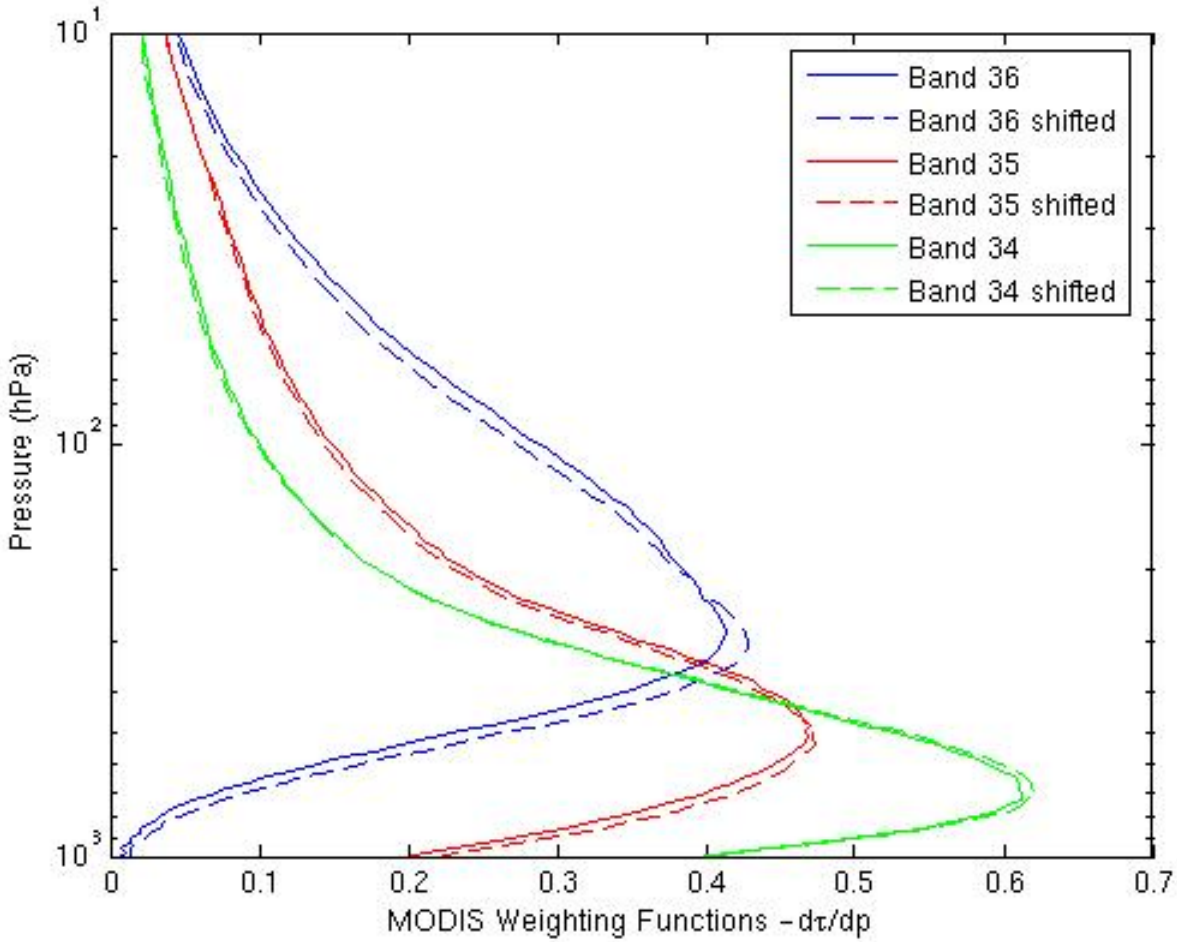
band 36: +1.0 cm $^{-1}$
band 35: +0.8 cm $^{-1}$
band 34: +0.8 cm $^{-1}$
band 33: -0.15 cm $^{-1}$





show better agreement with AIRS for all temperatures

MODIS Weighting Functions with/without SRF shift (U.S. Standard Atmosphere)

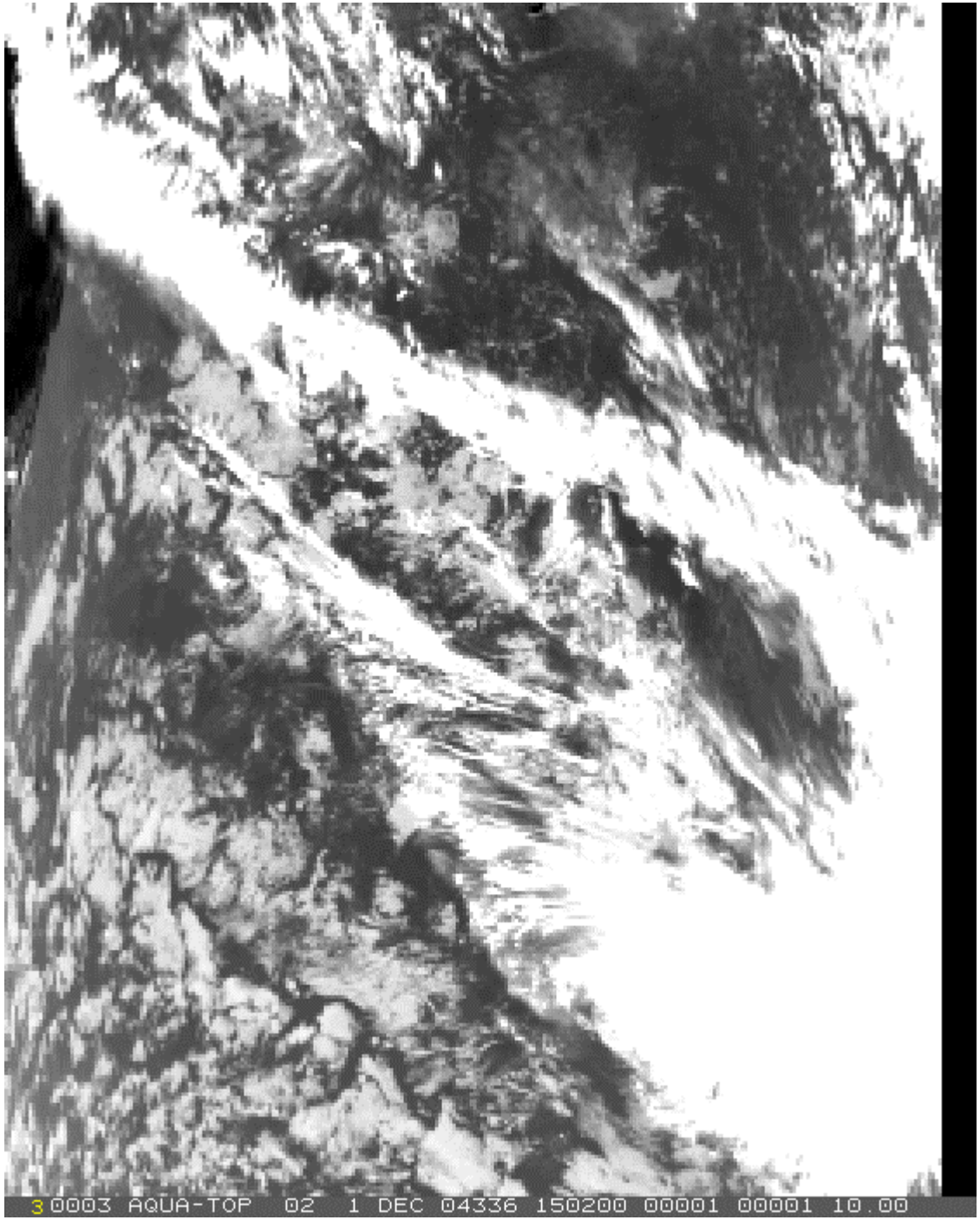


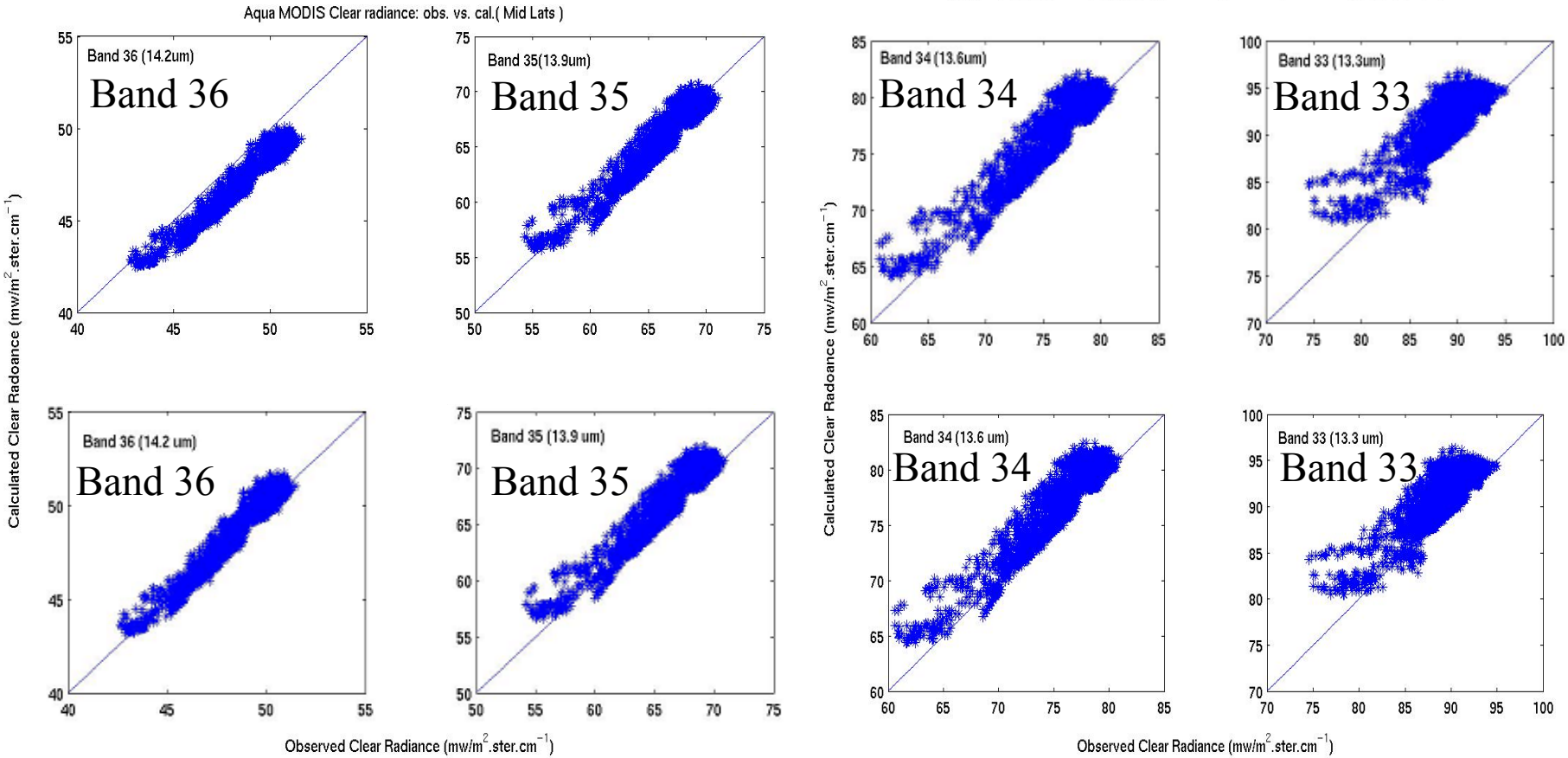
Outline of presentation

- **CO_2 slicing approach -- MODIS cloud top property algorithm**
- **Intercalibration with AIRS suggests spectral shifts for the MODIS CO_2 channels**
- **Preliminary cloud top property results with shifted Spectral Response Function (mid-lat & tropics)**
- **Summary**

Study case 1:
Mid-Lat area
(1500UTC
2004336)

Aqua
Band 31

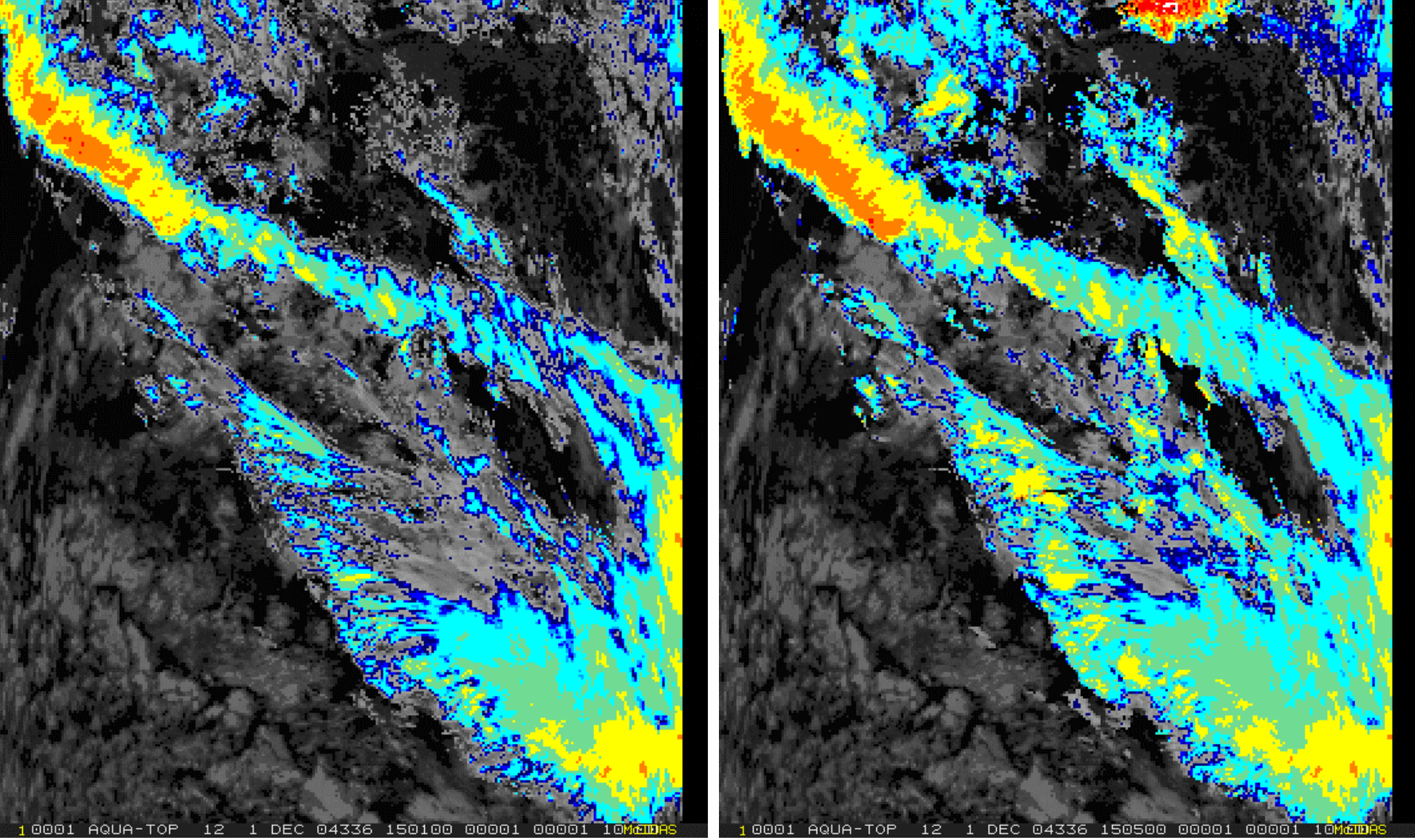




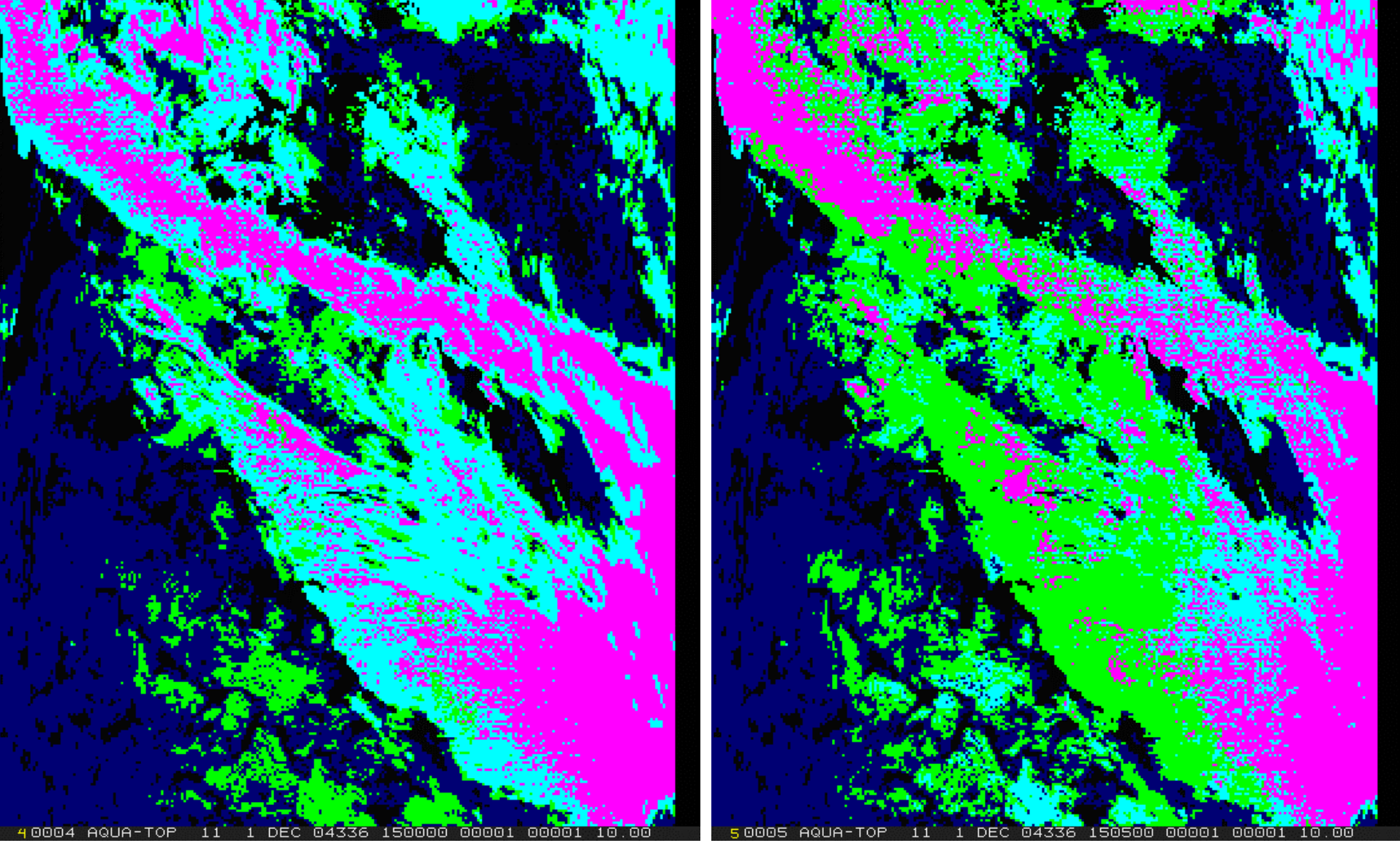
Calculated Clear Radiance vs. Observed Clear Radiance in Mid-Lat. for band 33, 34, 35, and 36

Upper: using original Spectral Response Function

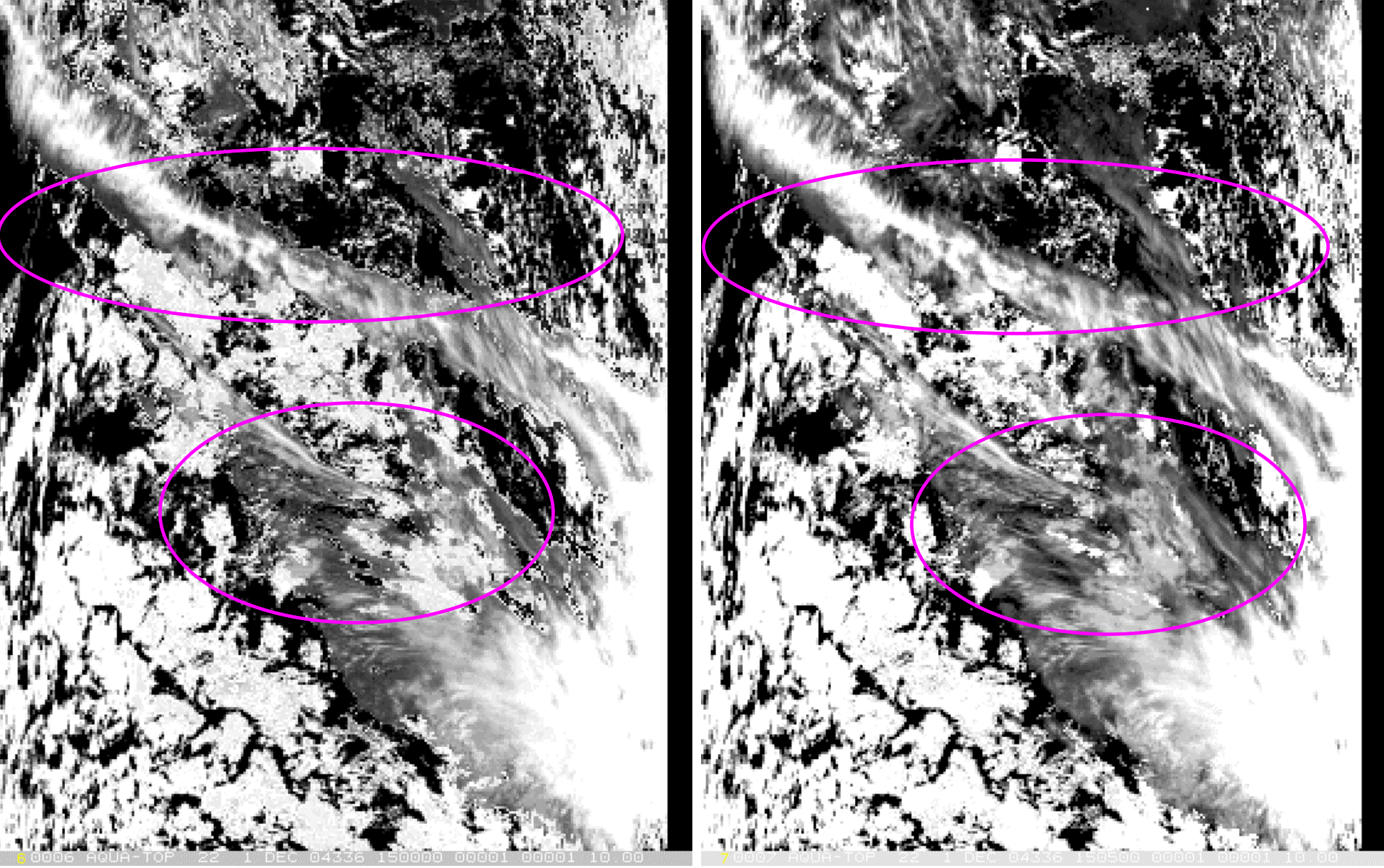
Bottom: using Tobin's shifted Spectral Response Function



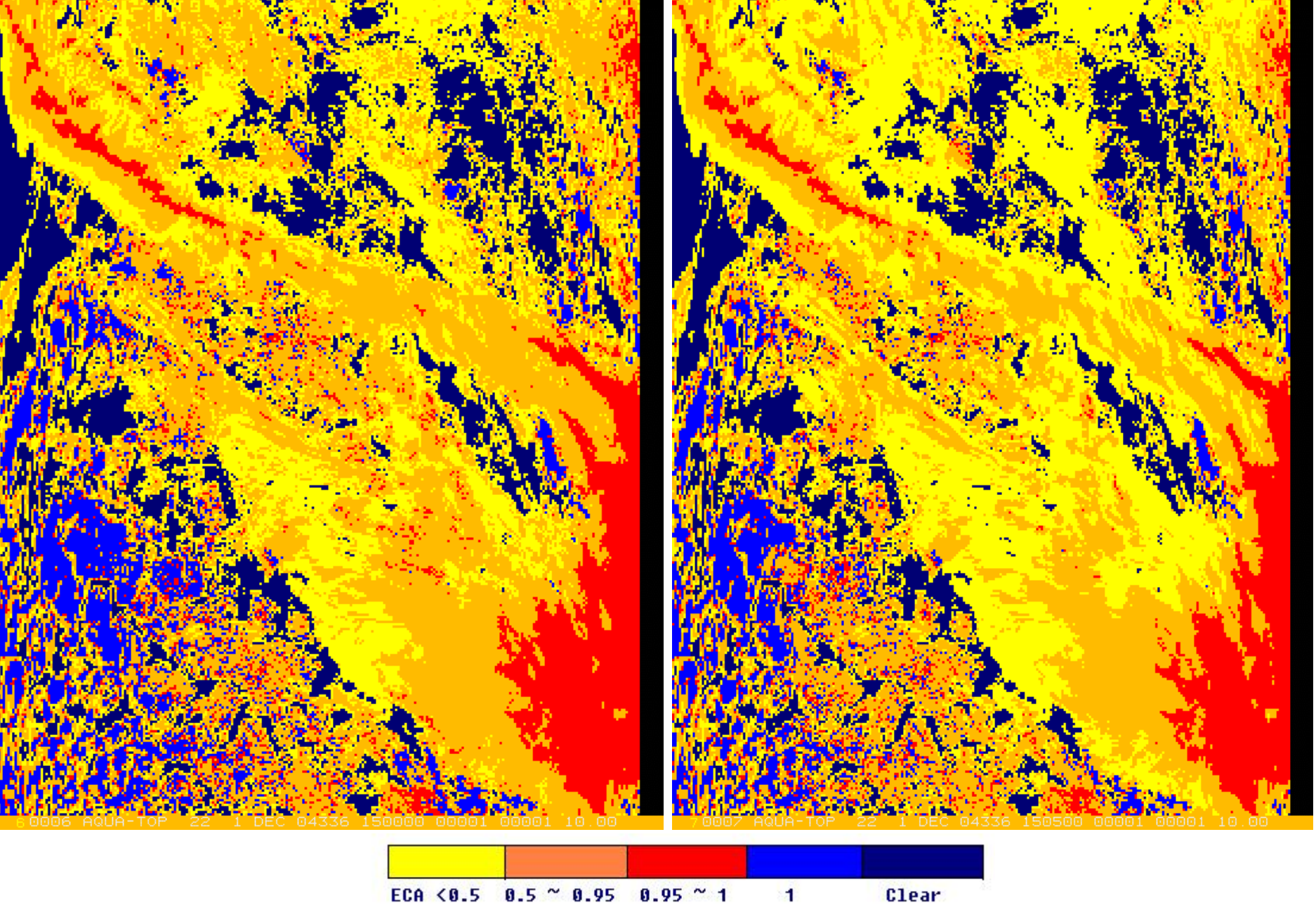
Mid-Lat HI CTP with original SRF (left) and with shifted SRF (right)



Cloud retrieval method with original SRF (left) and with shifted SRF (right)



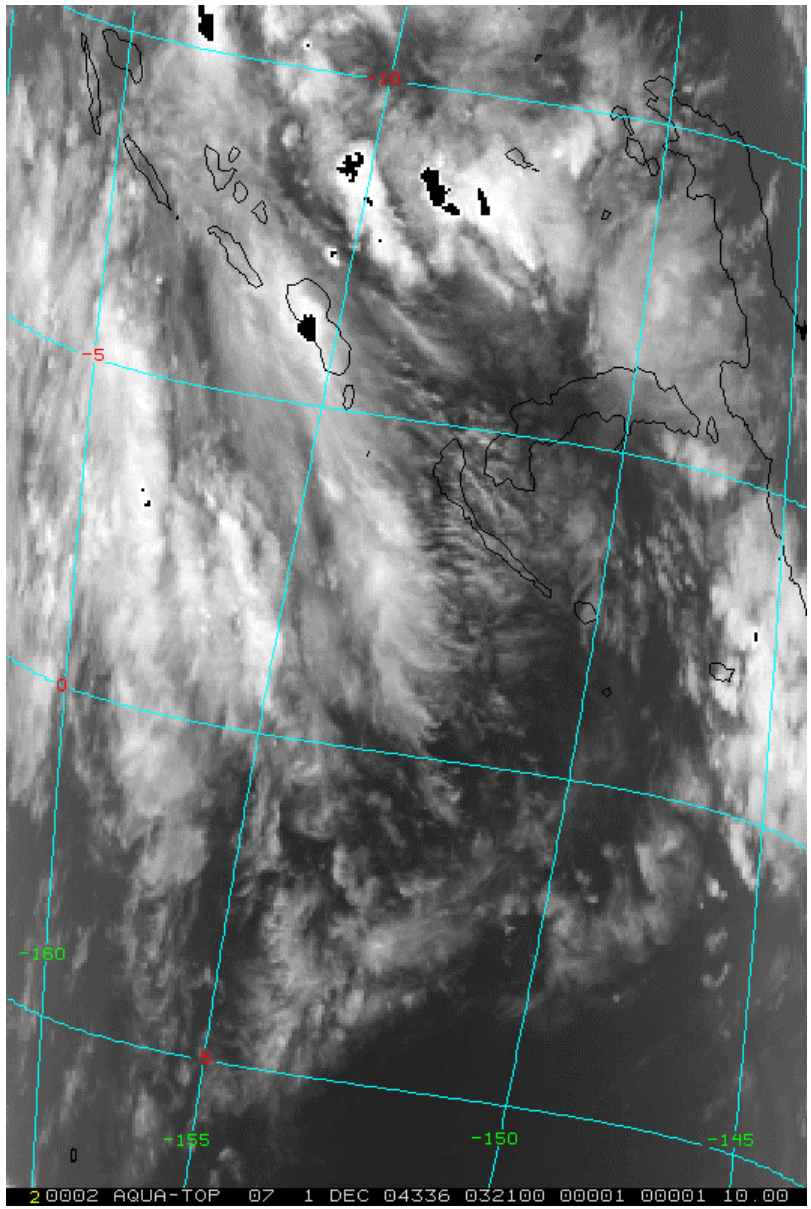
ECA with original SRF (left) and with shifted SRF (right)

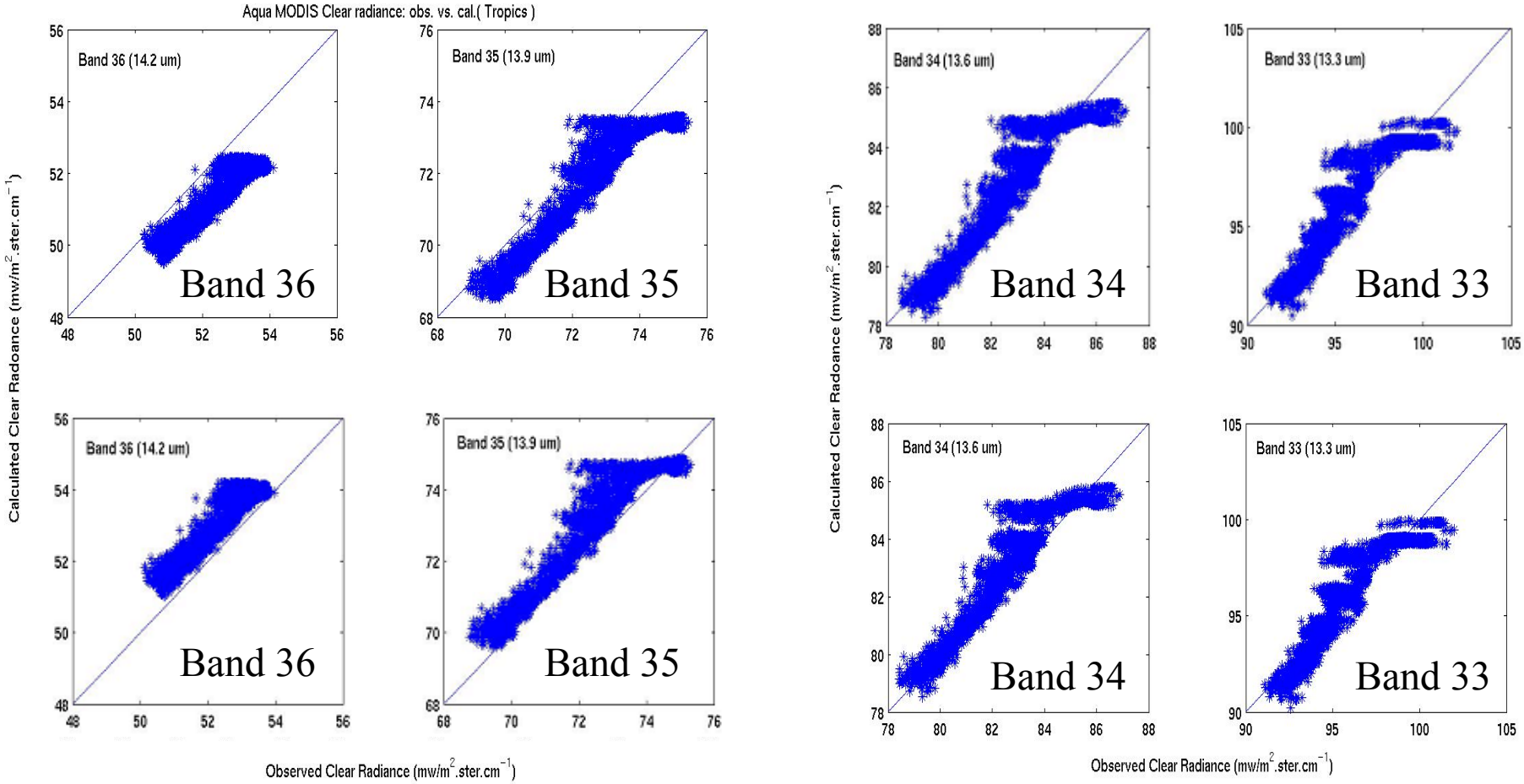


ECA with original SRF (left) and with shifted SRF (right)

Study case 2:
Tropical area
(0320UTC
2004336)

Aqua
Band 36

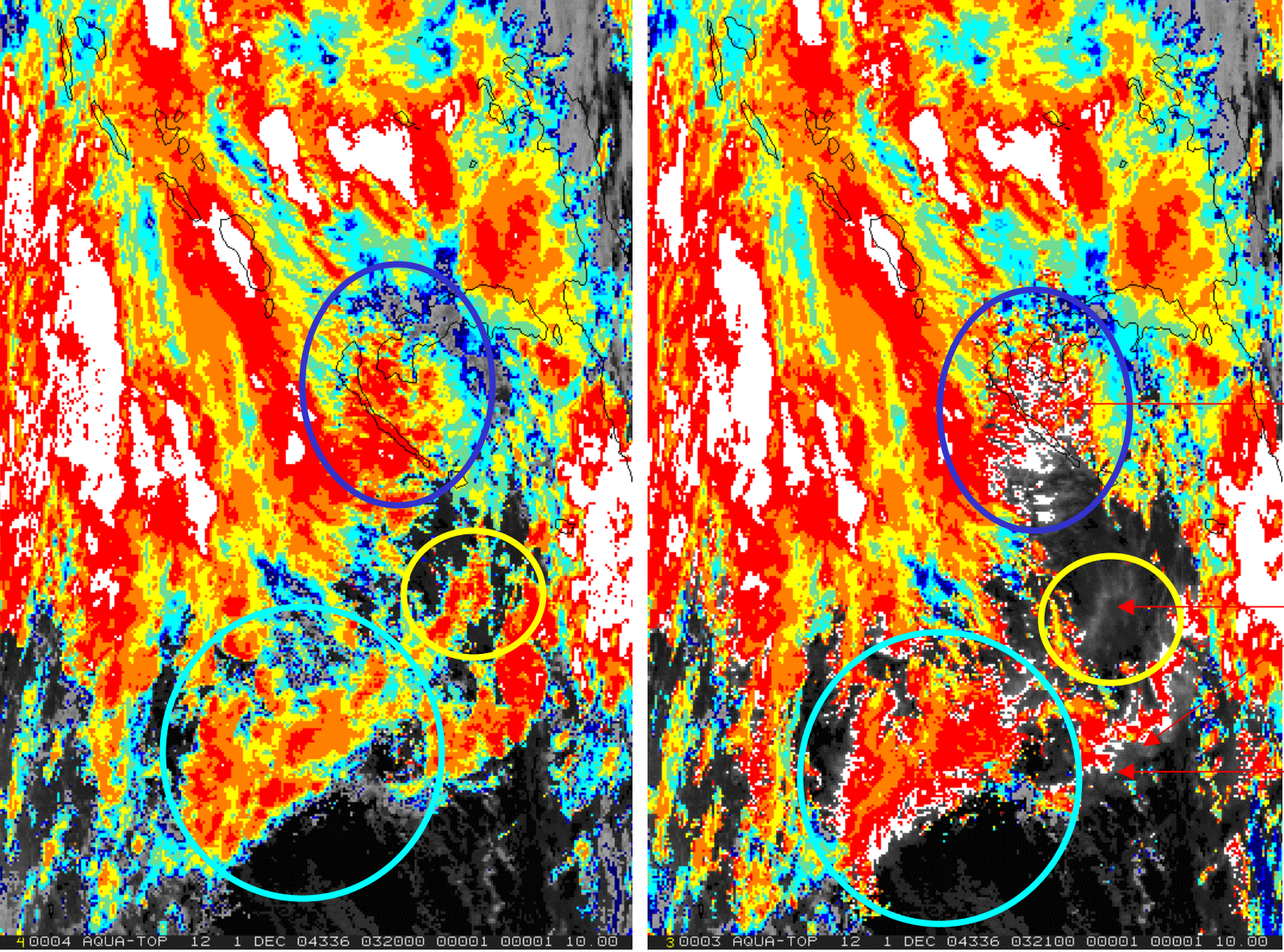




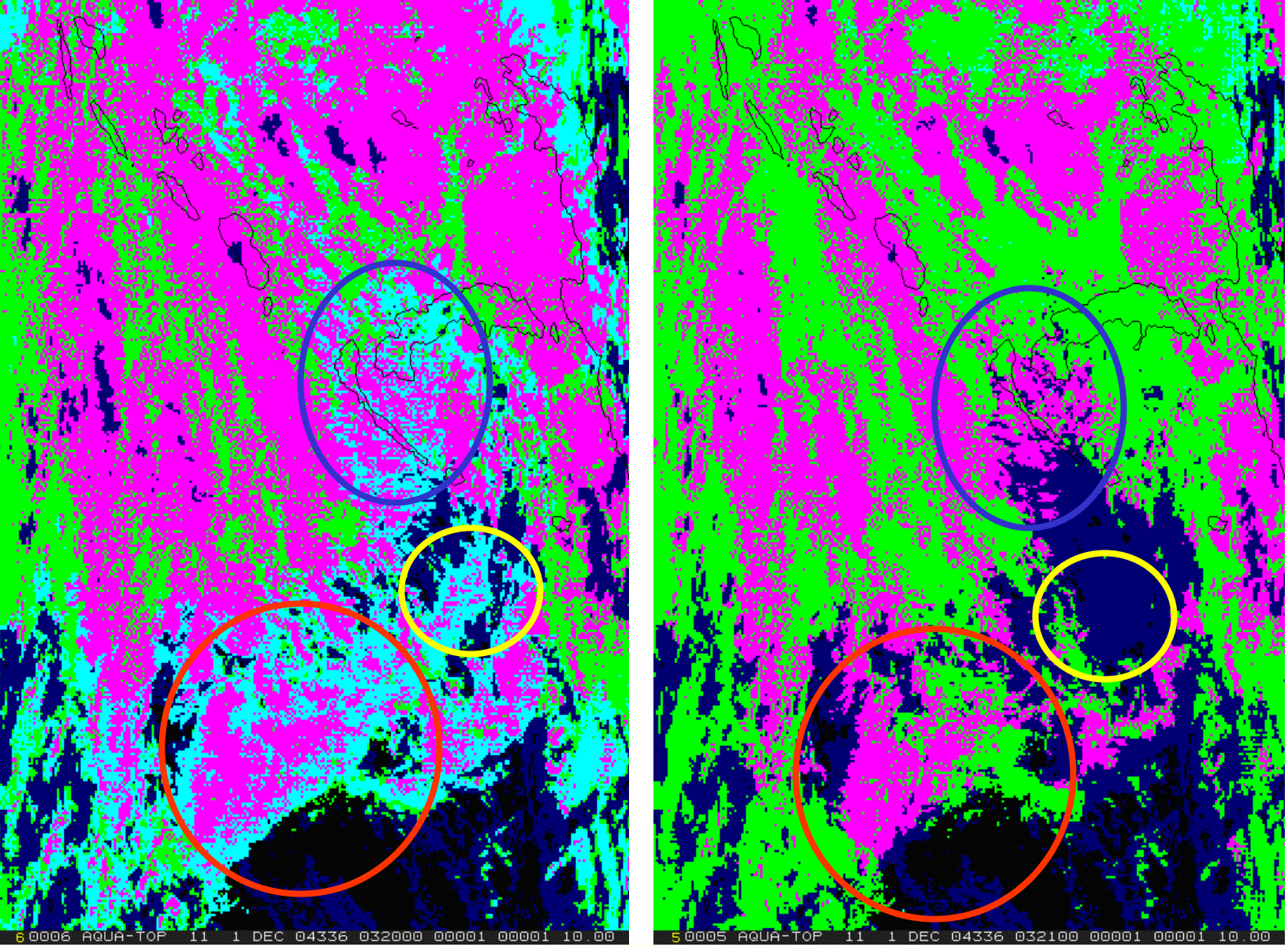
Calculated Clear Radiance vs. Observed Clear Radiance in Tropical area for band 33, 34, 35, and 36

Upper: using original Spectral Response Function

Bottom: using Tobin's shifted Spectral Response Function



Tropics HI CTP with original SRF (left) and with shifted SRF (right)



Cloud retrieval method with original SRF (left) and with shifted SRF (right)

Summary

- Comparisons of AIRS and MODIS radiance observations are applied at MODIS for cloud property retrievals
- Differences for MODIS band 34(13.6 μm), 35(13.9 μm), and 36 (14.2 μm) display clear and significant dependencies on scene temperature, shifted values for band 36: +1.0 cm^{-1}, band 35: +0.8 cm^{-1}, band 34: +0.8 cm^{-1}, and band 33: -0.15 cm^{-1} are tested in MODIS Cloud Top Properties retrievals
- Detection of high thin cirrus is found to be sensitive to CO_2 channel spectral response functions
- In Mid-latitudes, MODIS CTP retrieval with shifted SRF find more high thin clouds, thick cloud edges problem is improved by shifted SRF
- In the tropics, SRF shifted results are not as good – more studies are needed

International TOVS Study Conference, 14th, ITSC-14, Beijing, China, 25-31 May 2005. Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center, Cooperative Institute for Meteorological Satellite Studies, 2005.