

Optimal cloud-clearing for AIRS radiances using MODIS

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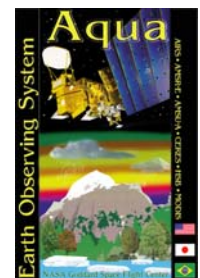
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Presented by *Chian-Yi Liu*

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Using MODIS for AIRS Cloud-Clearing

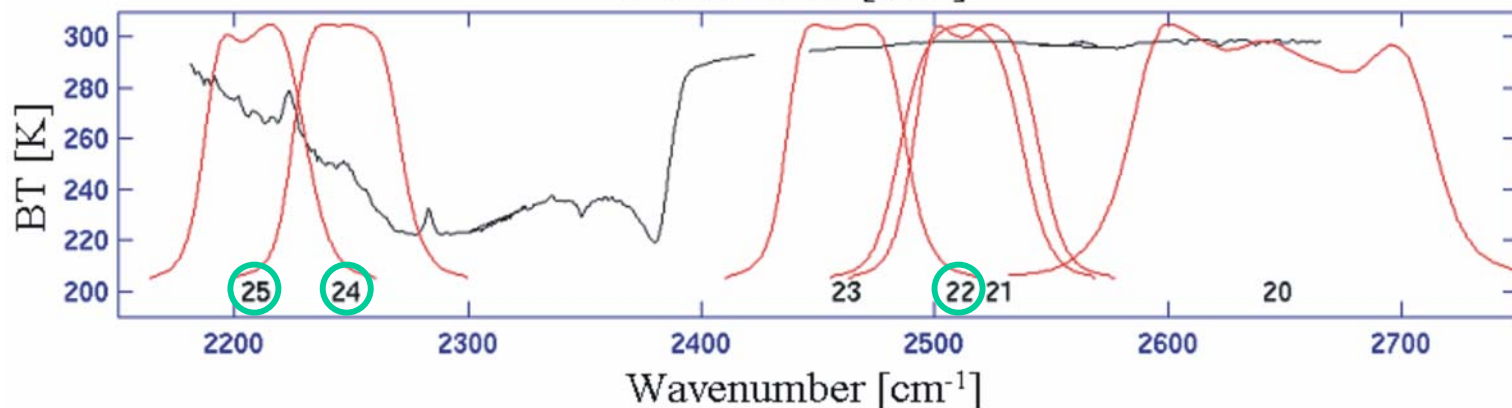
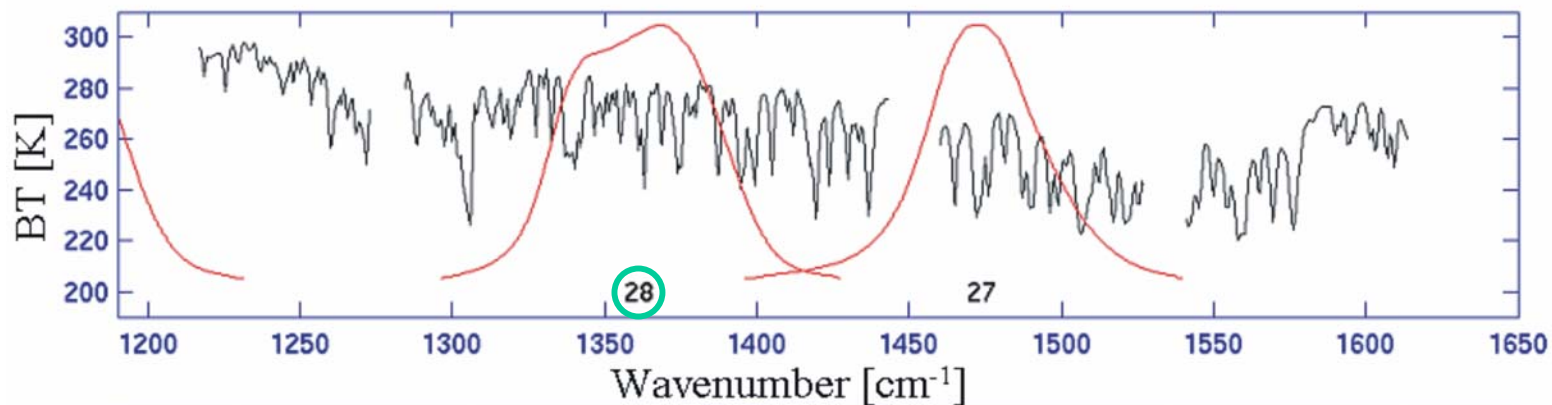
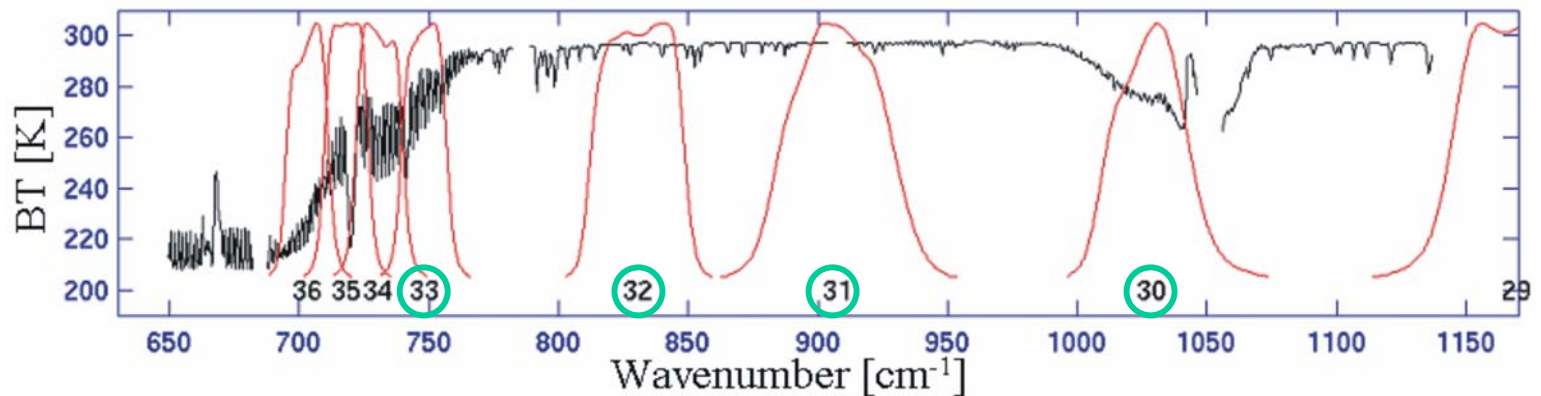
Why cloud_clearing?

- AIRS clear footprints are less than 5% globally.

Why use MODIS for AIRS cloud-clearing?

- Many AIRS cloudy footprints contain clear MODIS pixels; it is effective for N^* calculation and Quality Control for CC radiances
- Cloud-clearing can be achieved on a single footprint basis (hence maintaining the spatial gradient information);
- There is a direct relationship between MODIS and AIRS radiances because they see the same spectra region.

Aqua MODIS IR SRF Overlay on AIRS Spectrum



Direct spectral relationship between IR MODIS and AIRS provides unique application of MODIS in AIRS cloud_clearing !

How to do MODIS/AIRS Cloud-Clearing ?

- (1) Use MODIS cloud mask to identify the MODIS clear pixel within each AIRS footprint
- (2) Optimal MODIS/AIRS cloud-clearing algorithm (Li et al. 2005, IEEE Transactions on Geoscience and Remote Sensing, June issue)
- (3) MODIS clear radiances for QC
- (4) Use nearby AIRS clear radiances to verify the algorithm
- (5) Also use sounding retrievals from CCR to evaluate the CC algorithm

Optimal Cloud-Clearing for AIRS Radiances Using MODIS

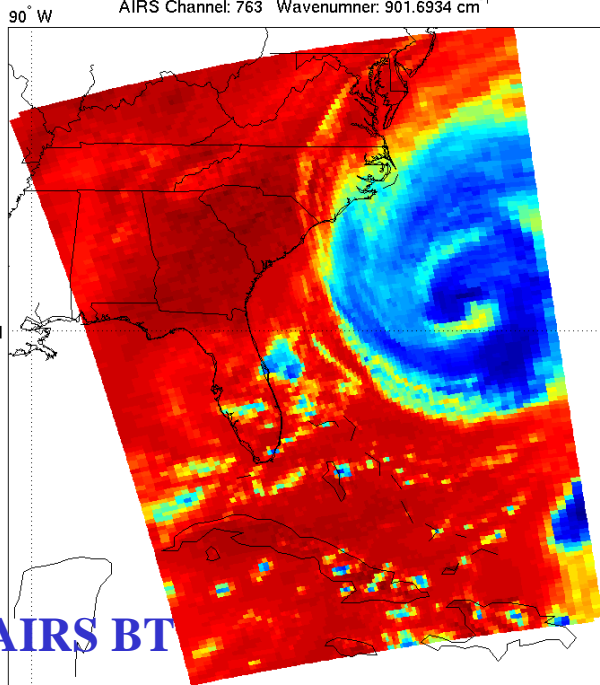
Jun Li, Chian-Yi Liu, Hung-Lung Huang, Timothy J. Schmit, Xuebao Wu, W. Paul Menzel, and James J. Gurka

Abstract—The Atmospheric Infrared Sounder (AIRS) onboard the National Aeronautics and Space Administration's Earth Observing System's (EOS) Aqua spacecraft, with its high spectral resolution and radiometric accuracy, provides atmospheric vertical temperature and moisture sounding information with high vertical resolution and accuracy for numerical weather prediction (NWP). Due to its relatively coarse spatial resolution (13.5 km at nadir), the chance for an AIRS footprint to be completely cloud free is small. However, the Moderate Resolution Imaging Spectroradiometer (MODIS), also on the Aqua satellite, provides collocated clear radiances at several spectrally broad infrared (IR) bands with 1-km spatial resolution; many AIRS cloudy footprints contain clear MODIS pixels. An optimal cloud-correction or cloud-clearing (CC) algorithm, an extension of the traditional single-band N^* technique, is developed. The technique retrieves the hyperspectral infrared sounder clear column radiances from the combined multiband imager IR clear radiance observations with high spatial resolution and the hyperspectral IR sounder cloudy radiances on a single-footprint basis. The concurrent AIRS and MODIS data are used to verify the algorithm. The AIRS

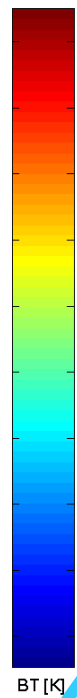
the potential application of this method to the operational processing of hyperspectral IR sounder cloudy radiance measurements when the collocated imager IR data are available. The use of a high spatial resolution imager, along with information from a high spectral resolution sounder for cloud-clearing, is analogous to instruments planned for the next-generation Geostationary Operational Environmental Satellite (GOES-R) instruments—the Advanced Baseline Imager and the Hyperspectral Environmental Suite. Since no microwave instruments are being planned for GOES-R, the cloud-clearing methodology demonstrated in this paper will become the most practical approach for obtaining the reliable clear-column radiances.

Index Terms—Atmospheric Infrared Sounder (AIRS), Geostationary Operational Environmental Satellite (GOES)-R, Moderate Resolution Imaging Spectroradiometer (MODIS), N^* cloud-clearing (CC), optimal cloud-clearing.

AIRS Channel: 763 Wavenumber: 901.6934 cm⁻¹

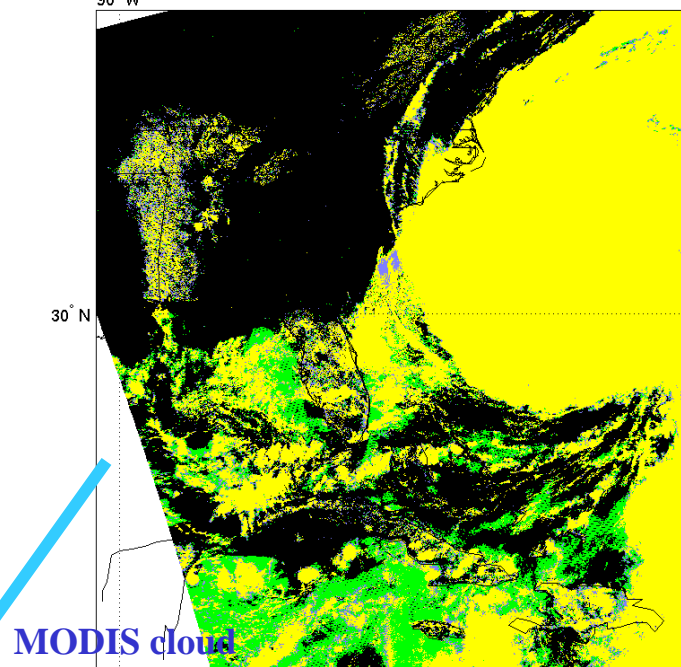


AIRS BT

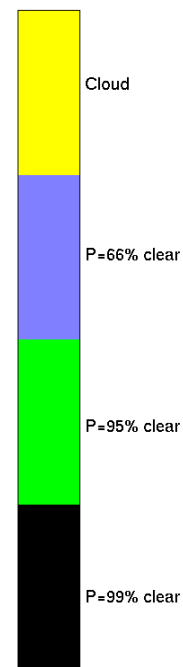


BT [K]

MODIS Cloud Mask [1 Km]



MODIS cloud mask (1 km)



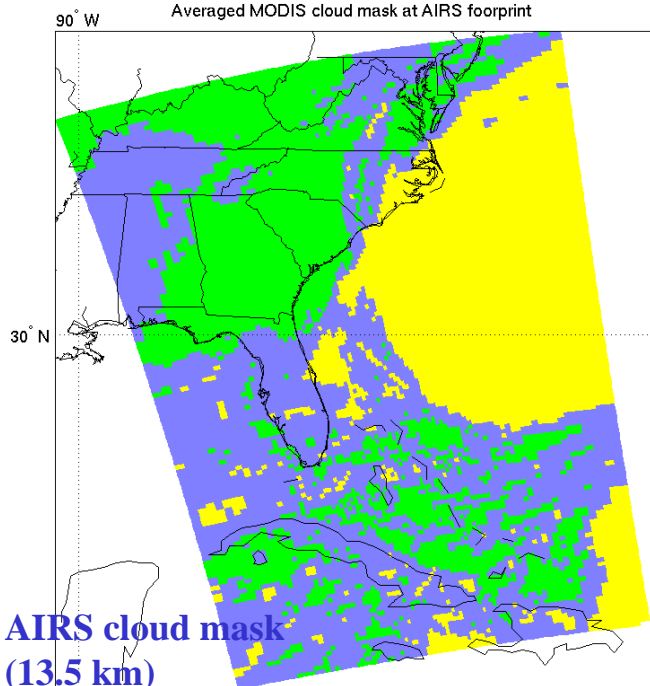
Cloud

P=66% clear

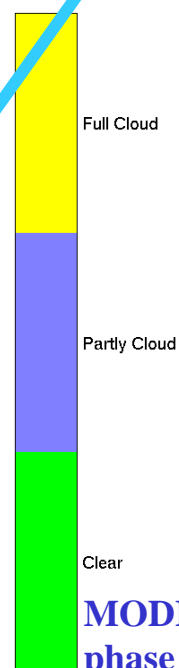
P=95% clear

P=99% clear

Averaged MODIS cloud mask at AIRS footprint



AIRS cloud mask (13.5 km)

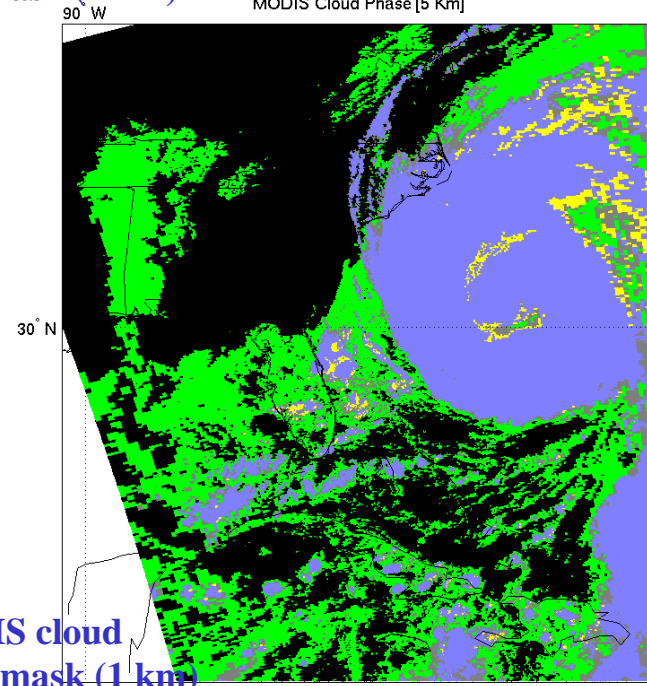


Full Cloud

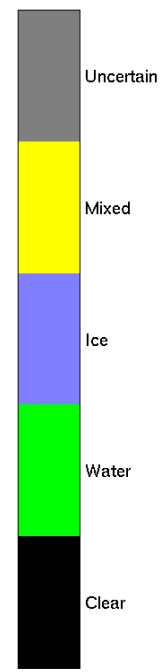
Partly Cloud

Clear

MODIS Cloud Phase [5 Km]



MODIS cloud phase mask (1 km)



Uncertain

Mixed

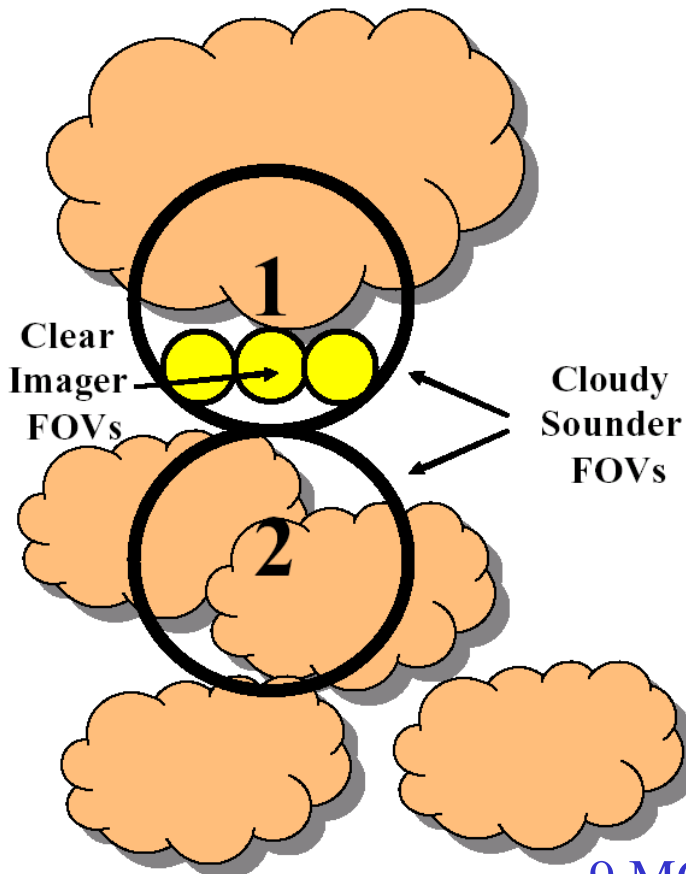
Ice

Water

Clear

Optimal imager/sounder cloud-clearing Methodology

(Li et al. 2005; *IEEE Trans. On Geoscience and Remote sensing*, June issue).



$$J(N^*) = \sum_i \frac{1}{\sigma_i} [(R_{M_i}^{clr} - f_i(R_v^{cc}))]^2$$

$$R_v^{cc} = \frac{R_v^1 - R_v^2 N^*}{1 - N^*}$$

N^* is solved by minimizing $J(N^*)$!

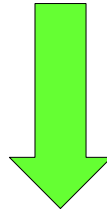
9 MODIS band (22, 24, 25, 28, 30, 31, 32, 33, 34) are used

Optimal imager/sounder cloud-clearing Methodology

(Li et al. 2005; *IEEE trans. On Geoscience and Remote sensing*, June issue).

N^* then can be analytically solved from minimizing
the cost function

$$\frac{\partial J(N^*)}{\partial N^*} = 0$$



An extension of single band N^*
method (Smith et al. 1968, 2004) !

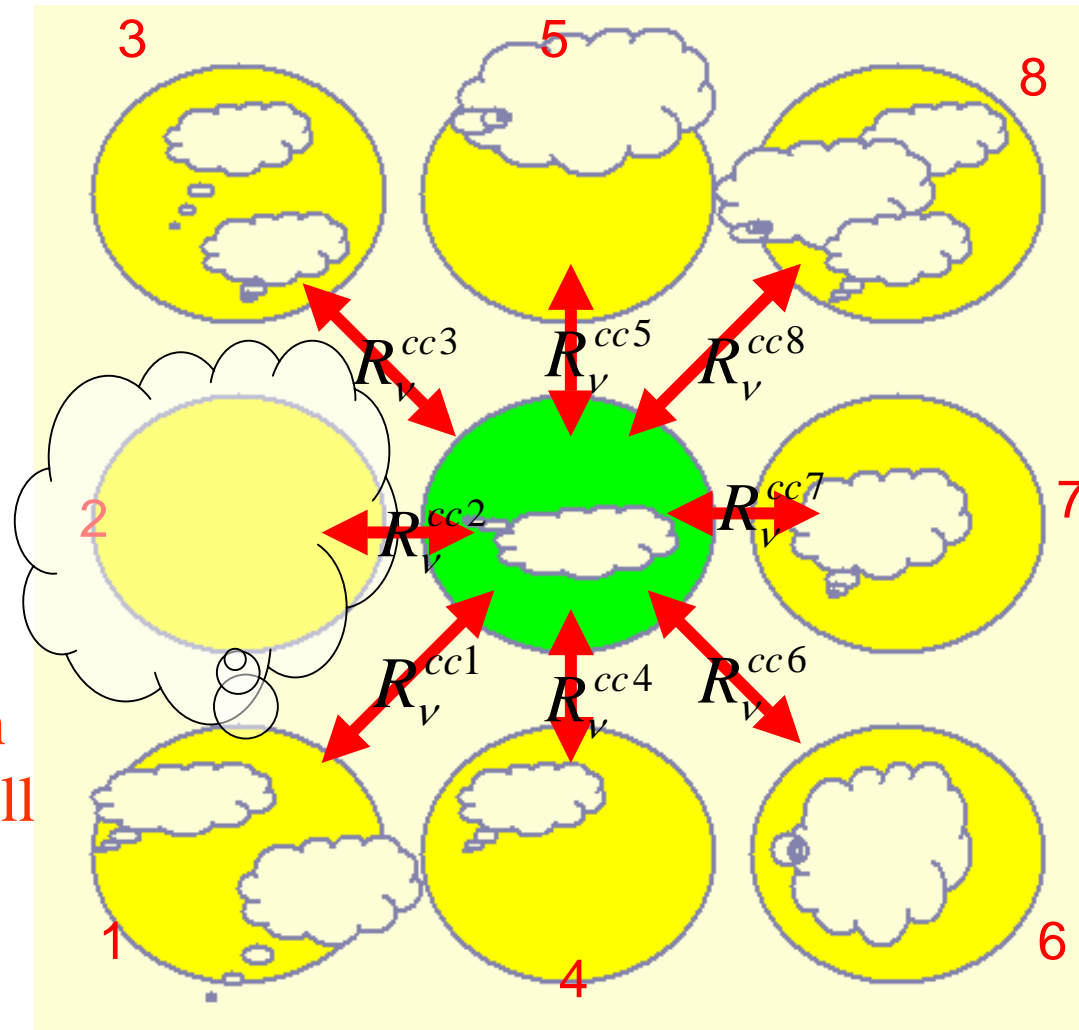
$$N^* = \frac{\sum_i \frac{1}{\sigma_i^2} [f_i(R_v^1) - R_{M_i}^{clr}] [f_i(R_v^1) - f_i(R_v^2)]}{\sum_i \frac{1}{\sigma_i^2} [f_i(R_v^2) - R_{M_i}^{clr}] [f_i(R_v^1) - f_i(R_v^2)]}$$

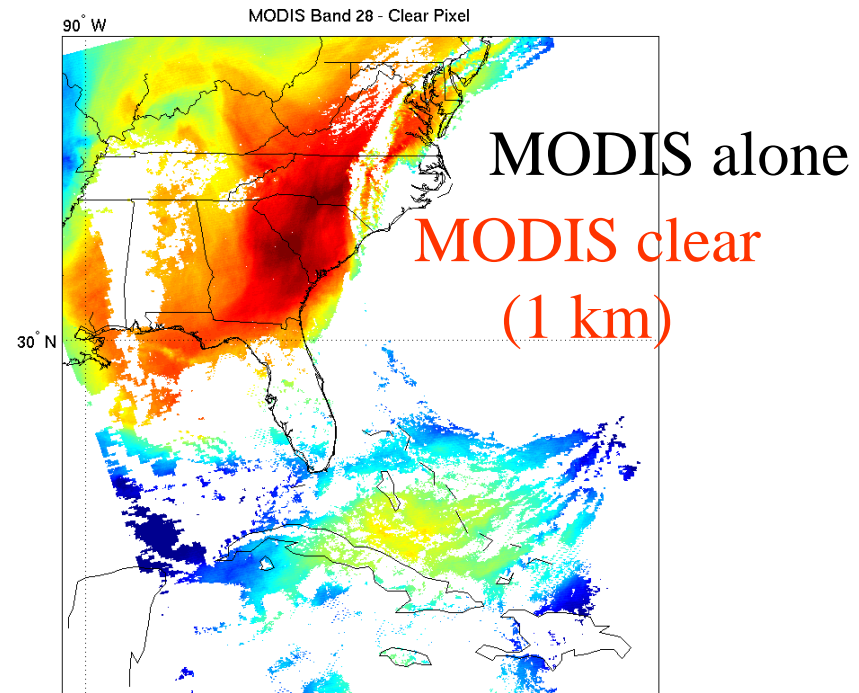
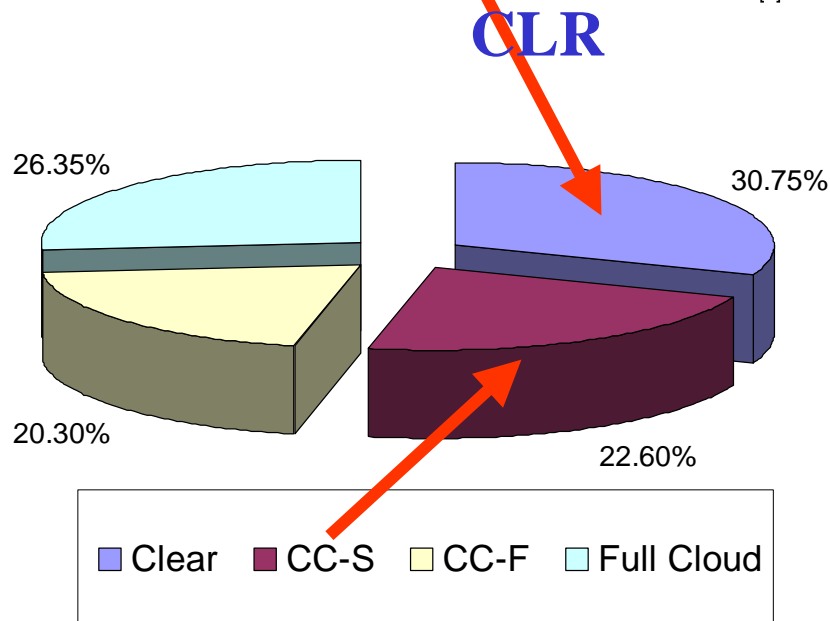
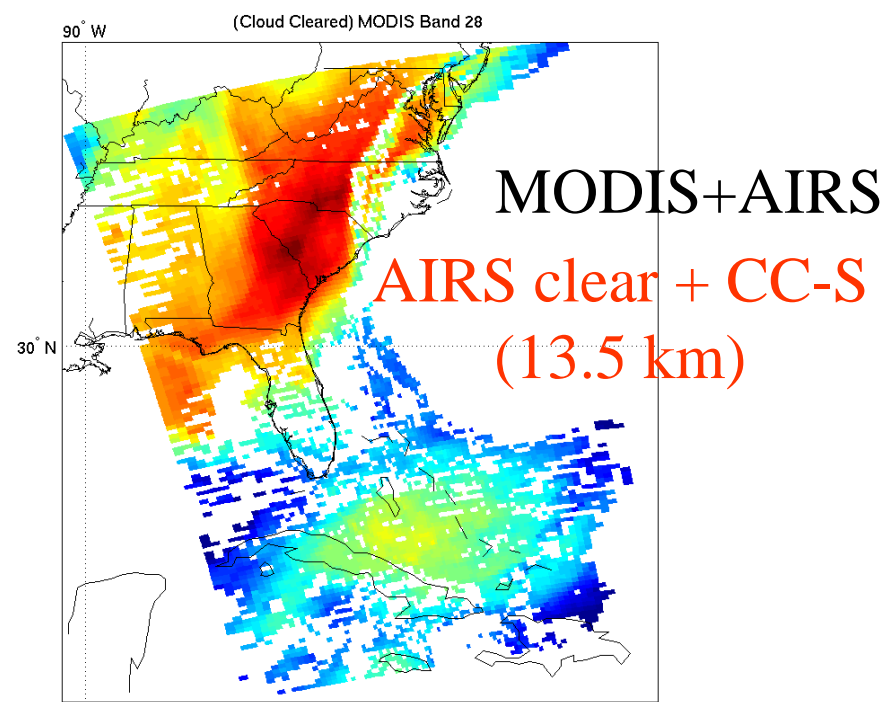
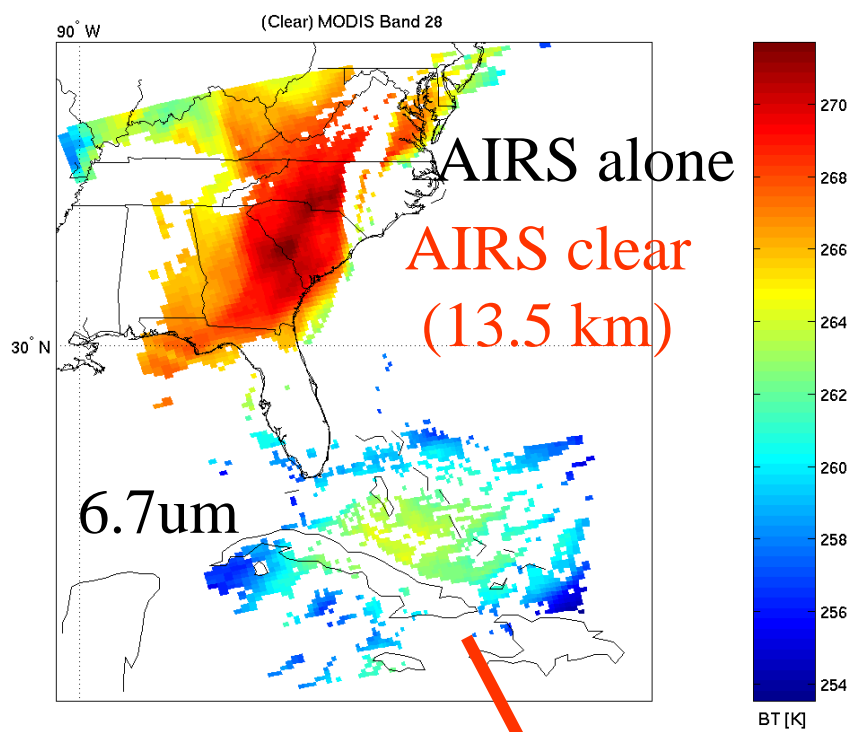
Step 1: Get cloud-cleared AIRS radiances for Principal and supplementary footprints.

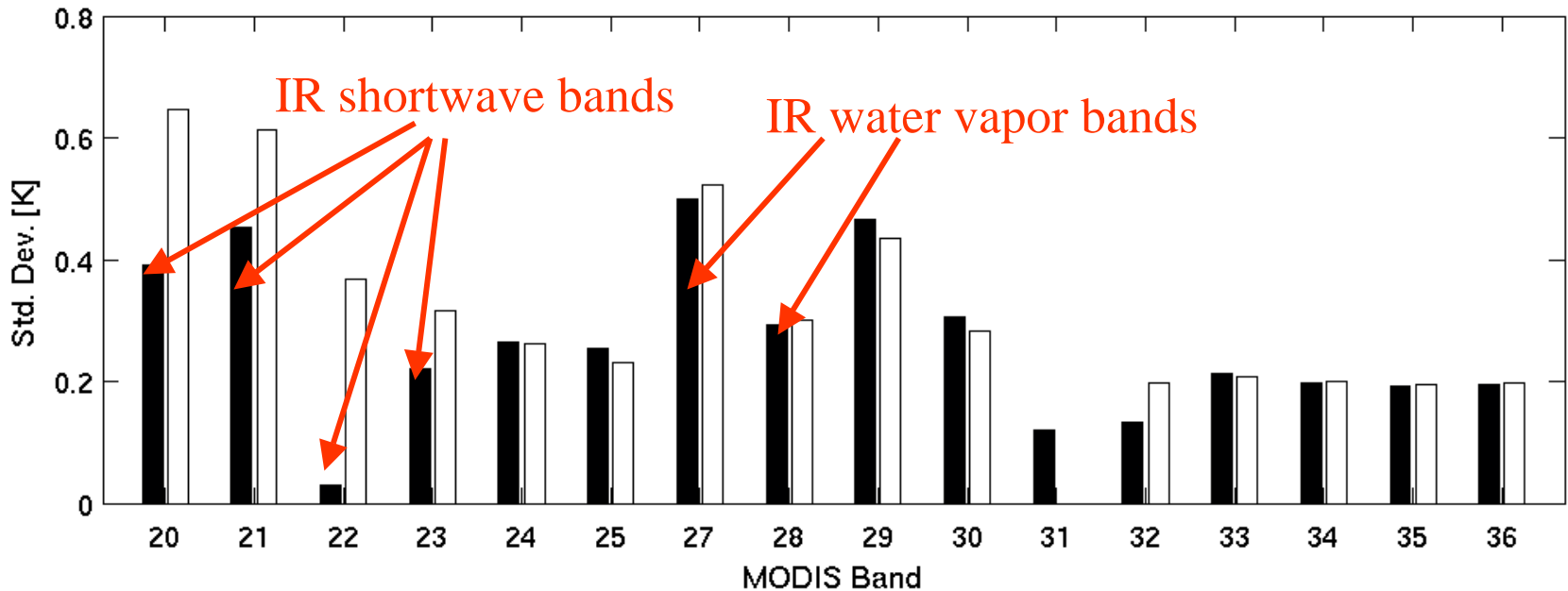
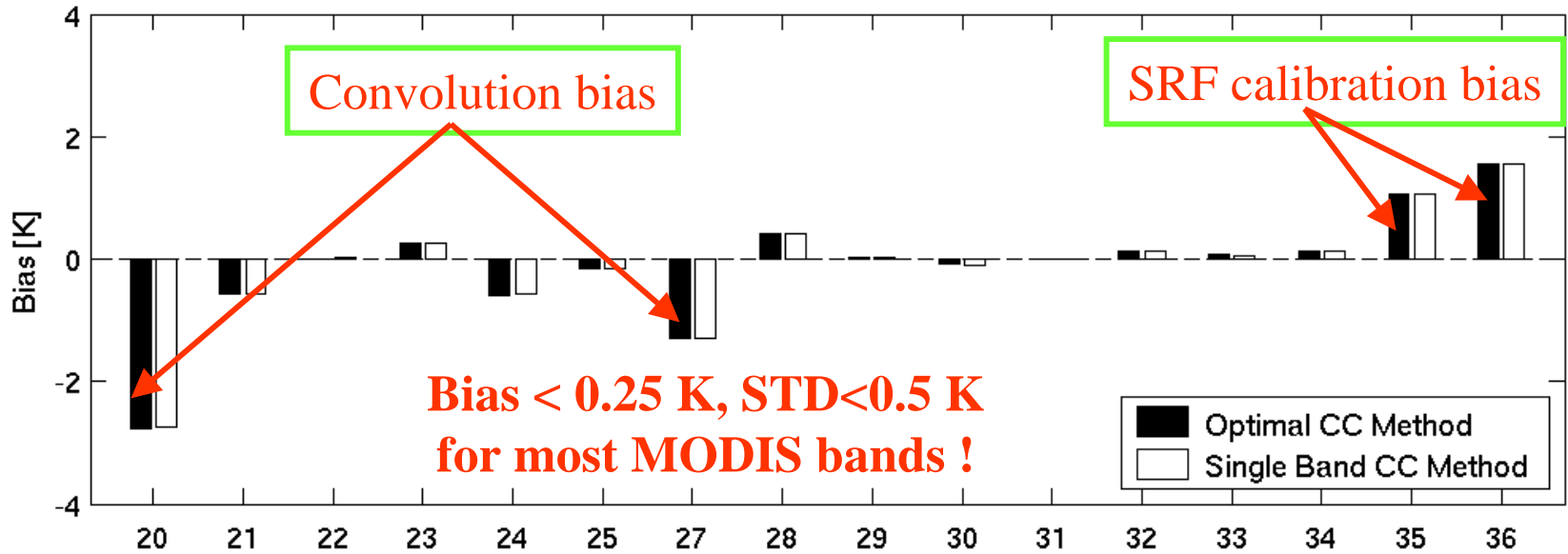
Step 2: Find best R^{cc} by comparing with MODIS clear radiances observations in the principal footprint.

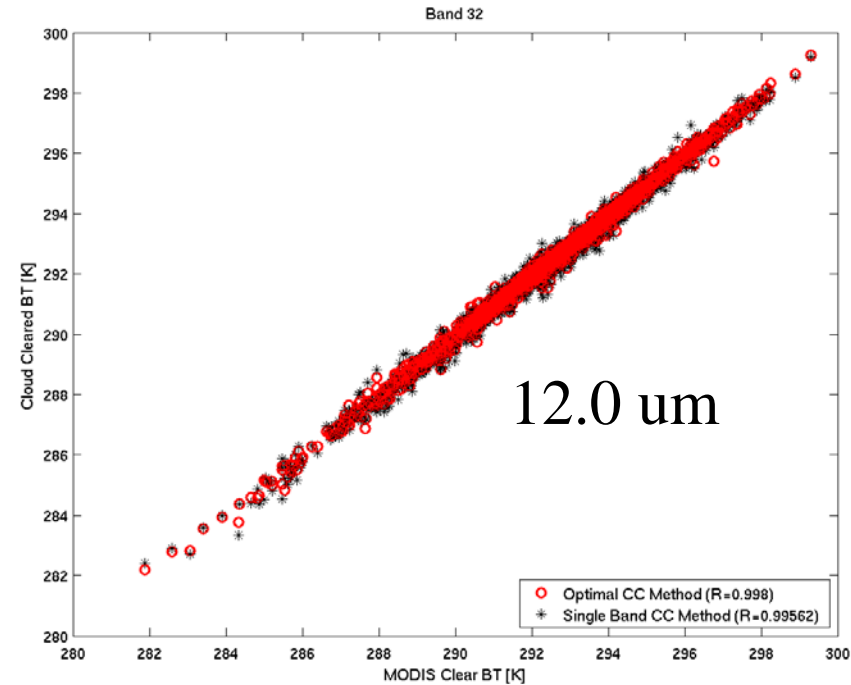
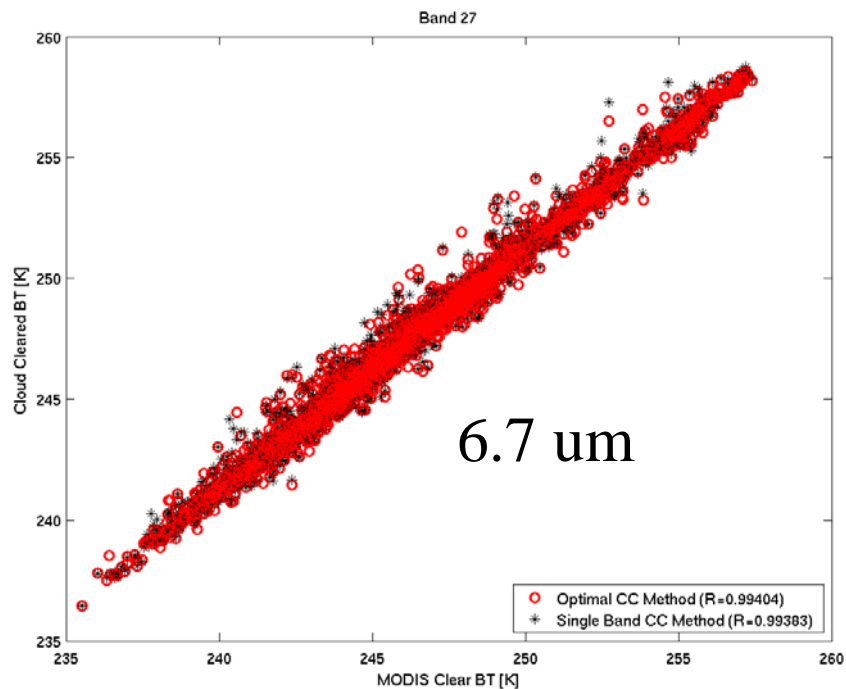
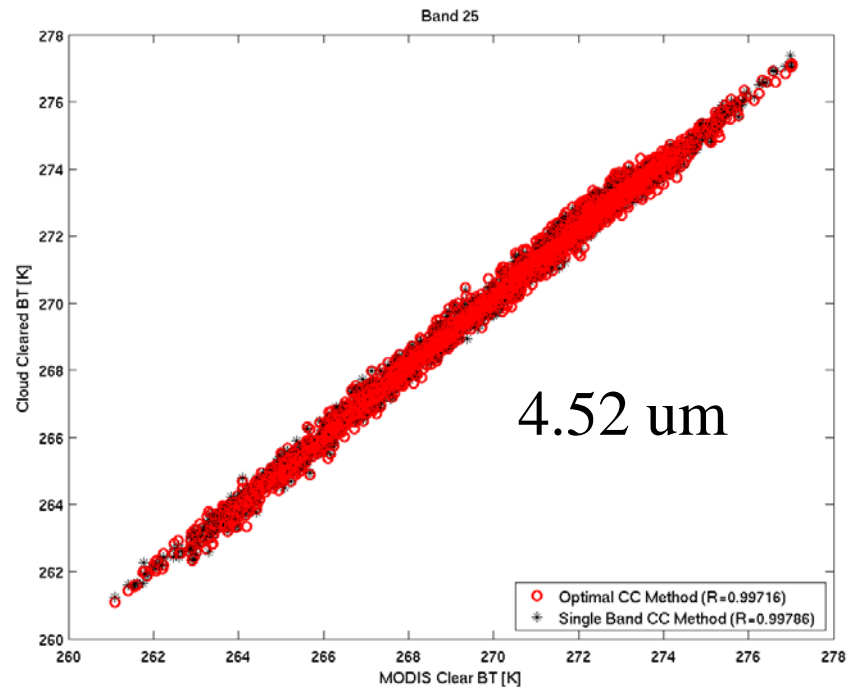
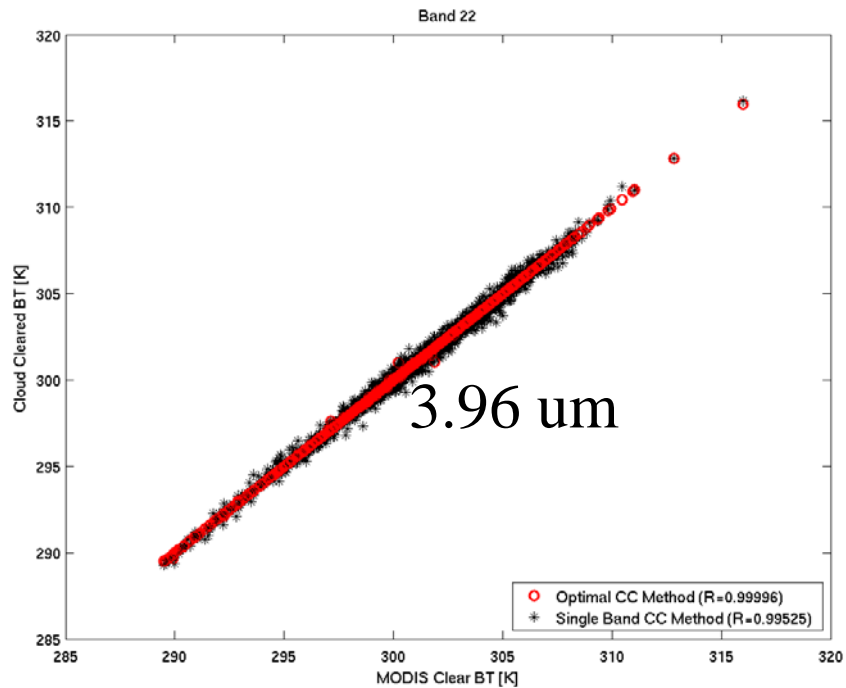
(1) Principal footprint has to be partly cloudy, while the supplementary footprint can be either partly cloudy or full cloudy.

(2) The 3 by 3 box moves by single AIRS footprint, therefore each partly cloudy footprint has chance to be cloud-cleared

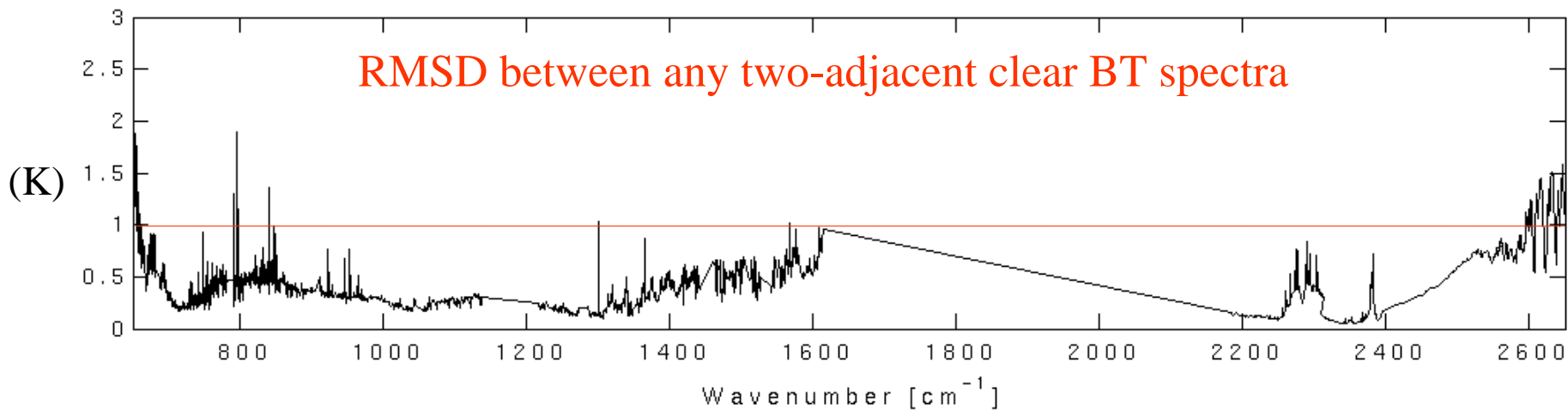
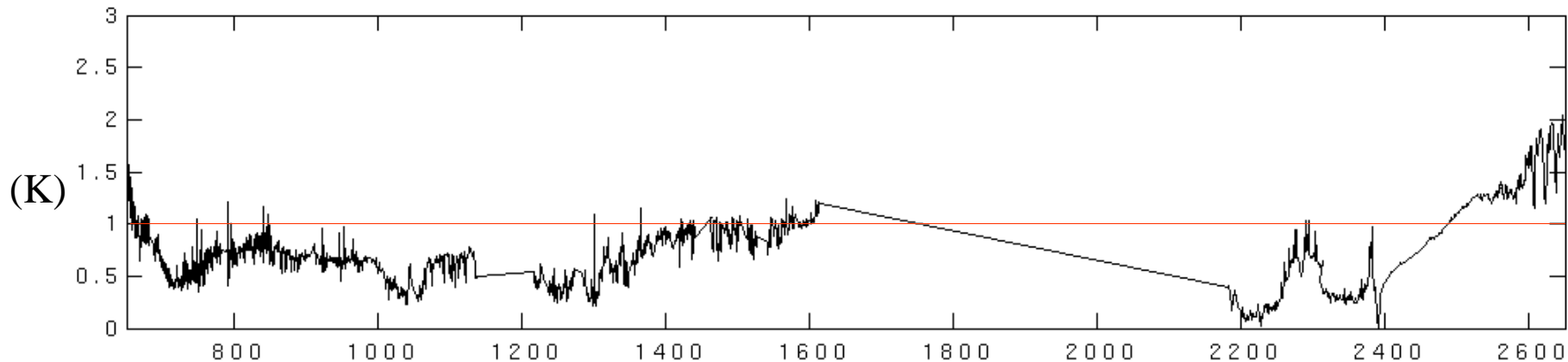






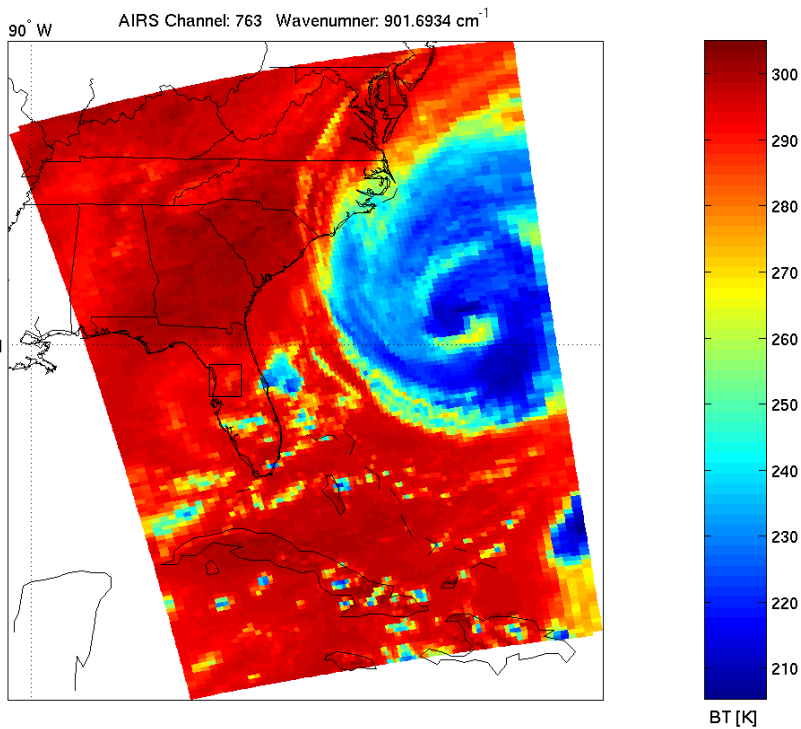
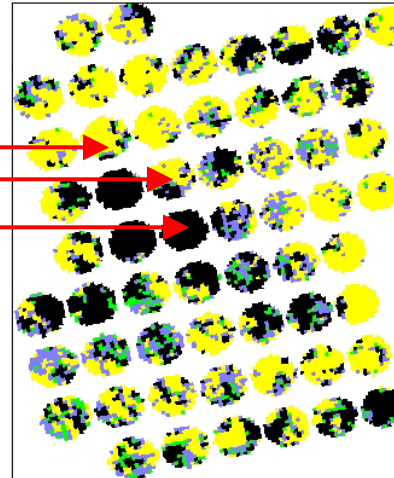


RMSD between CC BT spectra and their nearby clear BT spectra
(930 comparisons, AIRS granule 184 on 17 Sept. 2003)

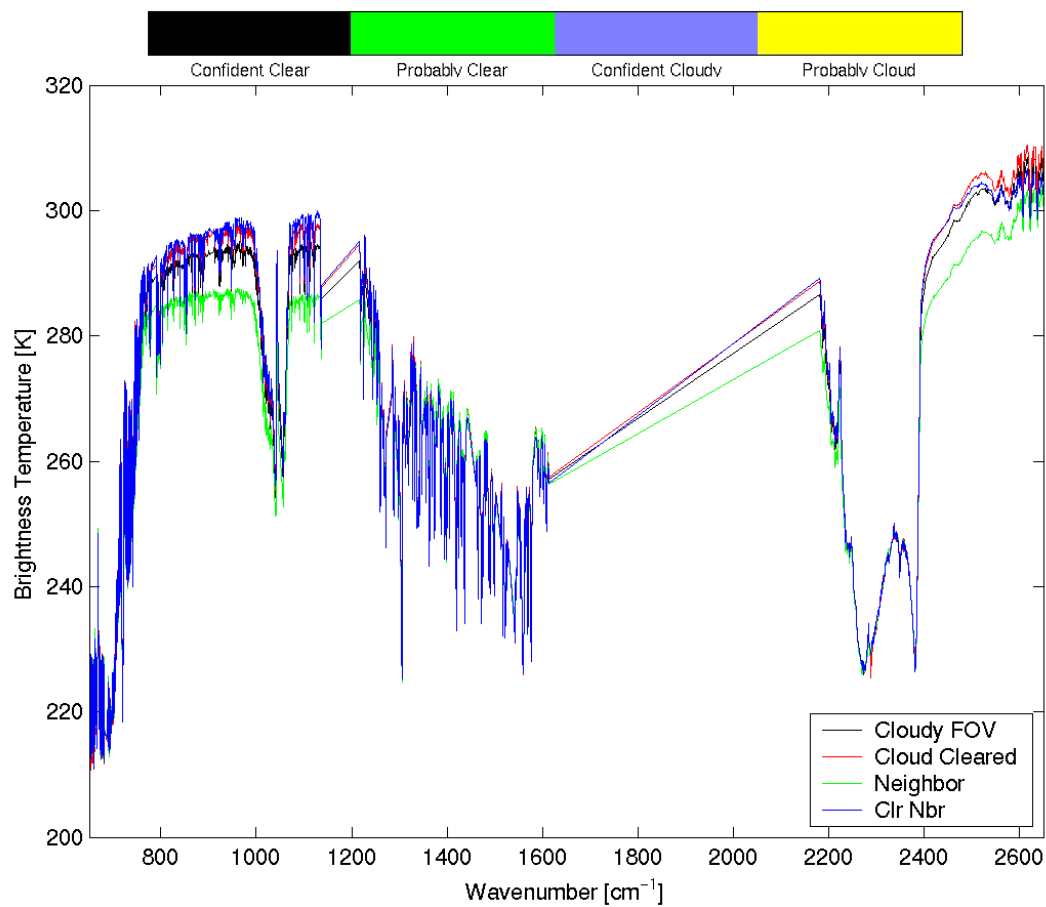


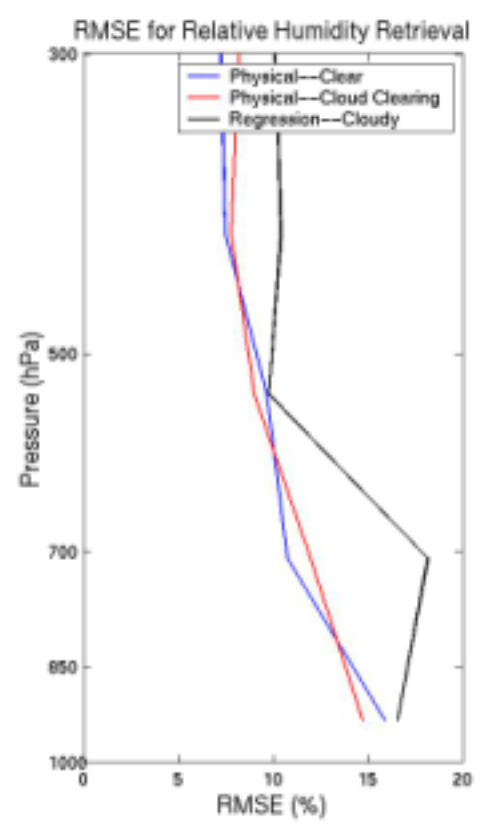
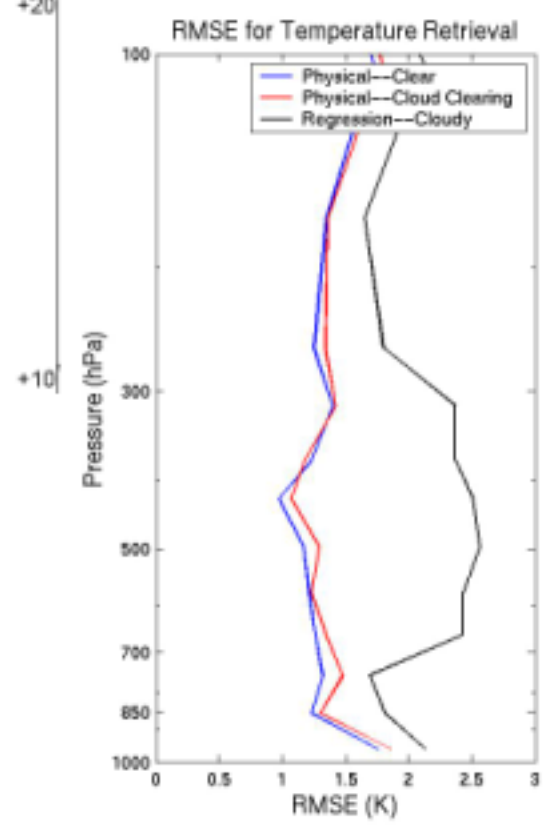
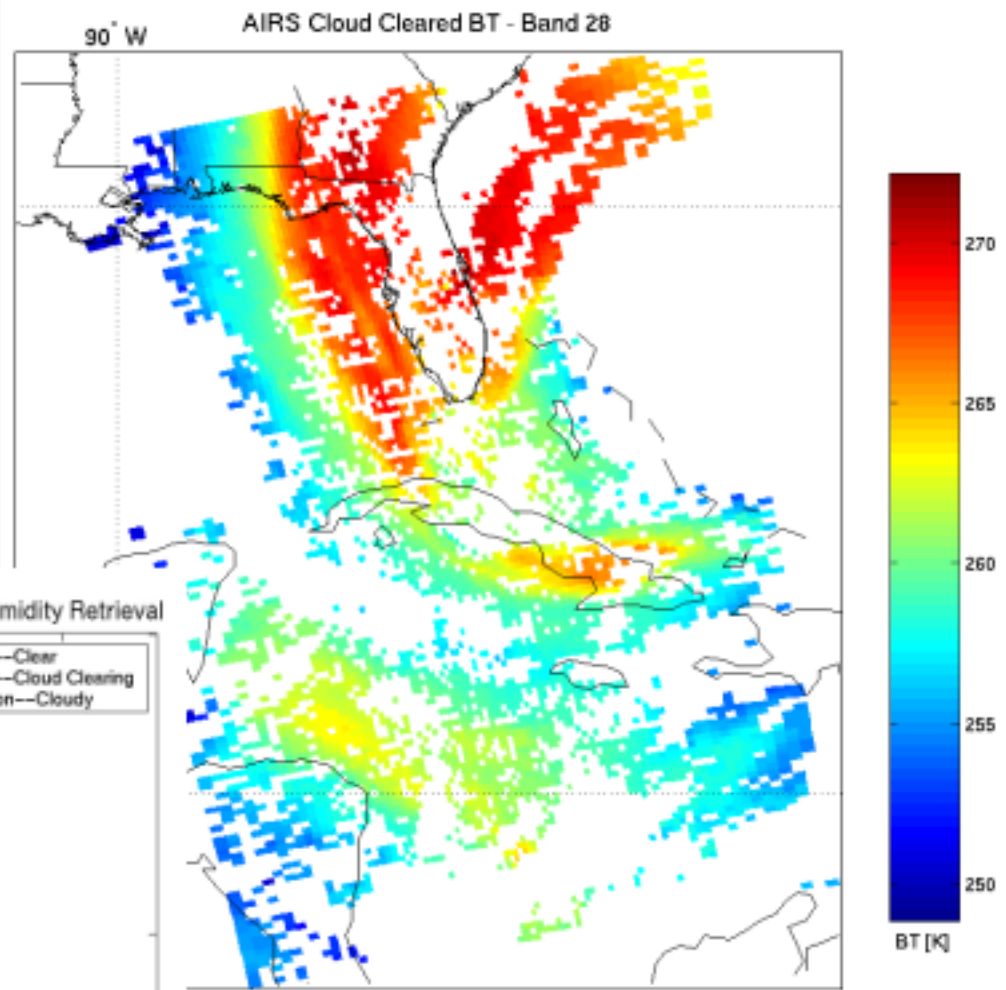
Example of MODIS/AIRS CCR spectrum

Supplementary FOV
Principal FOV
Nearby clear FOV



AIRS BT image from 12 μm

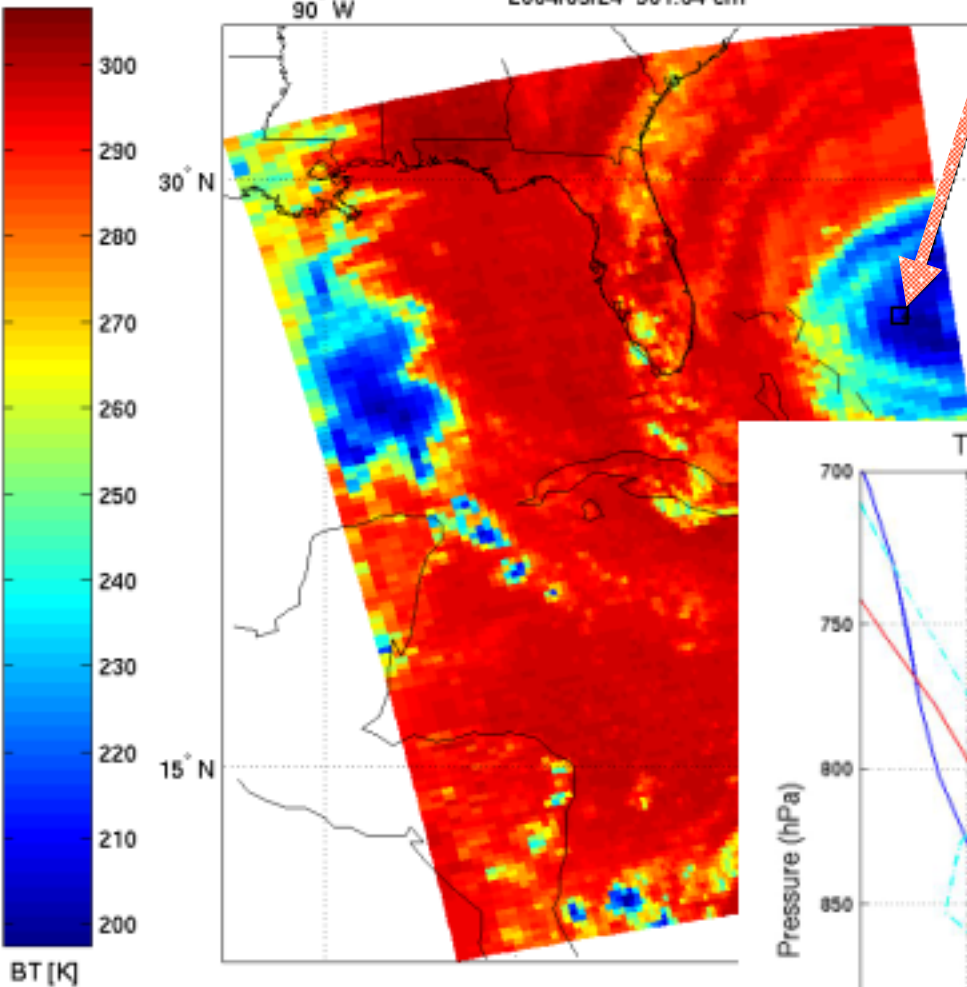




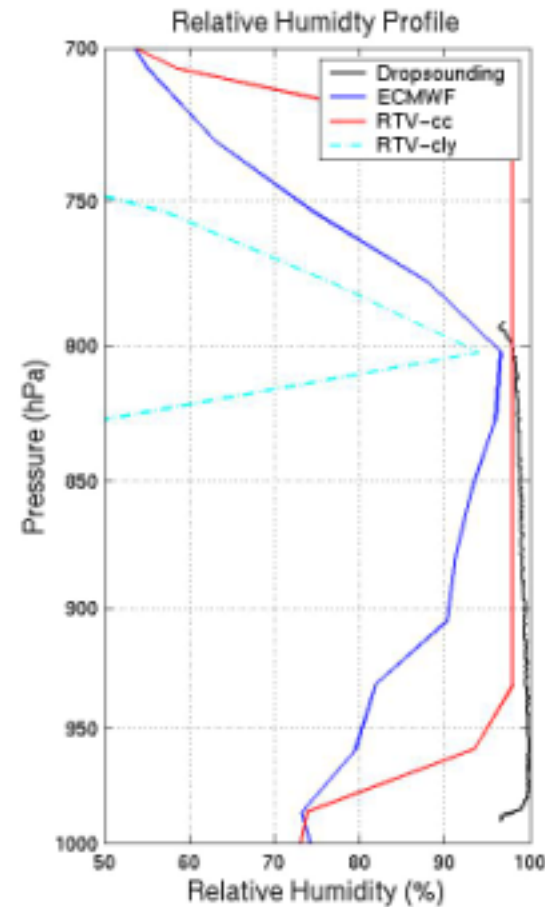
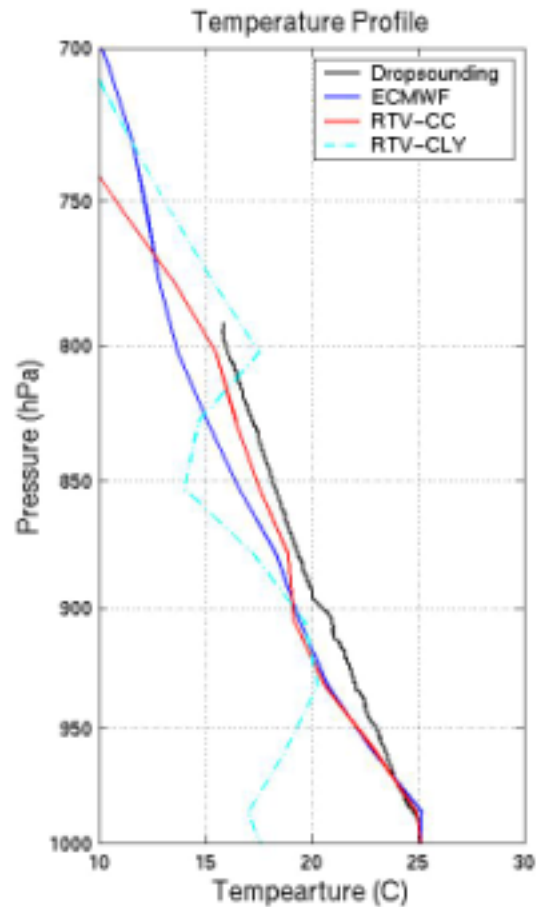
AIRS clr + CC BT
 (convolved to MODIS 6.7 um band)
 AIRS granule 184 of Sept 24, 2004

Dropsonde location

AIRS/ECMWF/Dropsonde
comparison (Sept.24, 2004)



AIRS BT (11.7 um)
image (granule 184)



Dropsonde data courtesy to
Fuzhong Weng

Two-layer cloud-clearing is ongoing !

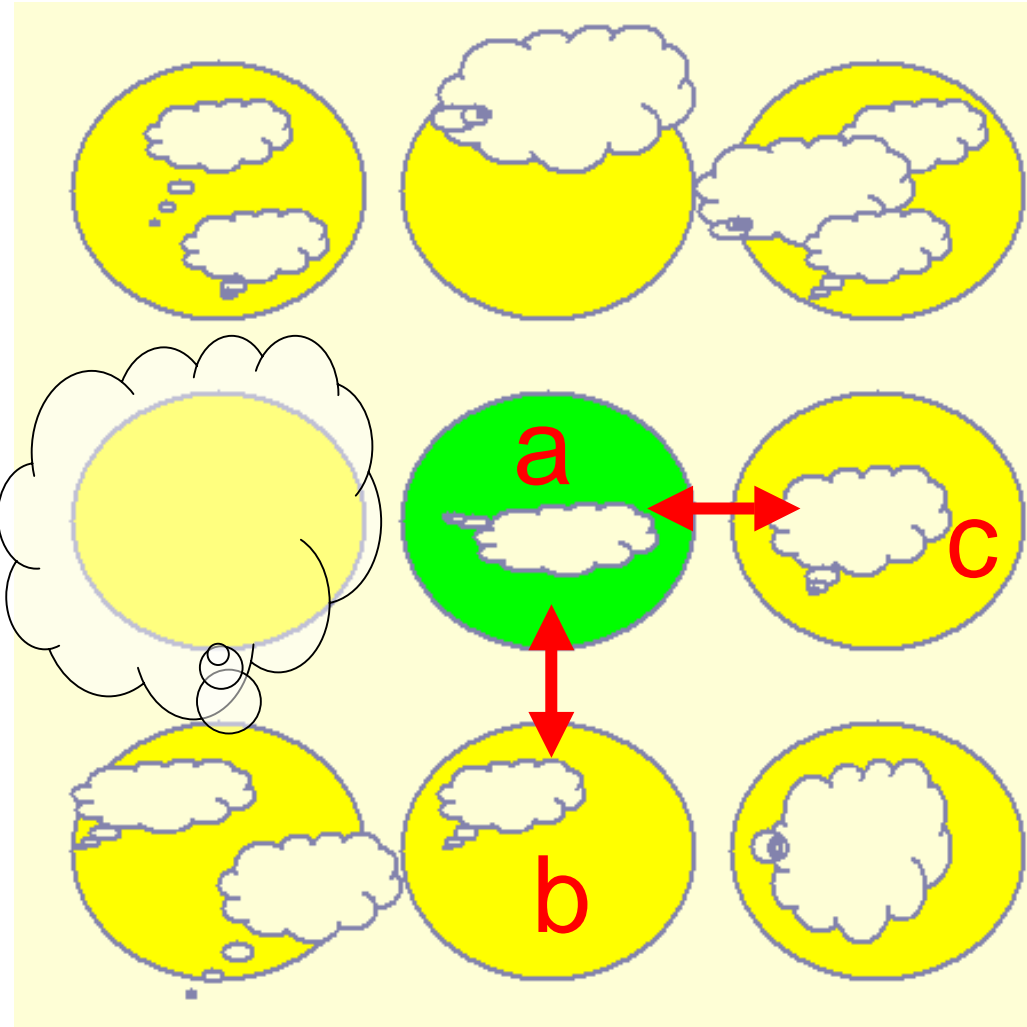
$$R_v^{ccr} = N_a^* R_v^a + N_b^* R_v^b + N_c^* R_v^c$$

Step 1: Using MODIS 9 bands
to solve

$$N_a^*, N_b^*, N_c^*$$

Step 2: Obtaining CCR using
above Equation

Step 2: QC using MODIS
9 spectral bands



Summary

- 1. Combination of MODIS/AIRS is very useful
AIRS cloud-clearing**
- 2. Optimal MODIS/AIRS cloud-clearing provides
good cloud-cleared AIRS radiances with
accuracy better than 0.5 K; more than 22% of
AIRS footprints can be successfully cloud-
cleared according to our study.**
- 3. Sounding retrieval based on CCR is promising.**
- 4. Multi-layer cloud-clearing study is ongoing**
- 5. MODIS/AIRS CC versus AMSU/AIRS CC is
investigated (see next Allen Huang's talk).**