Handling Clouds for Hyperspectral Infrared Radiance Assimilation

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Motivation

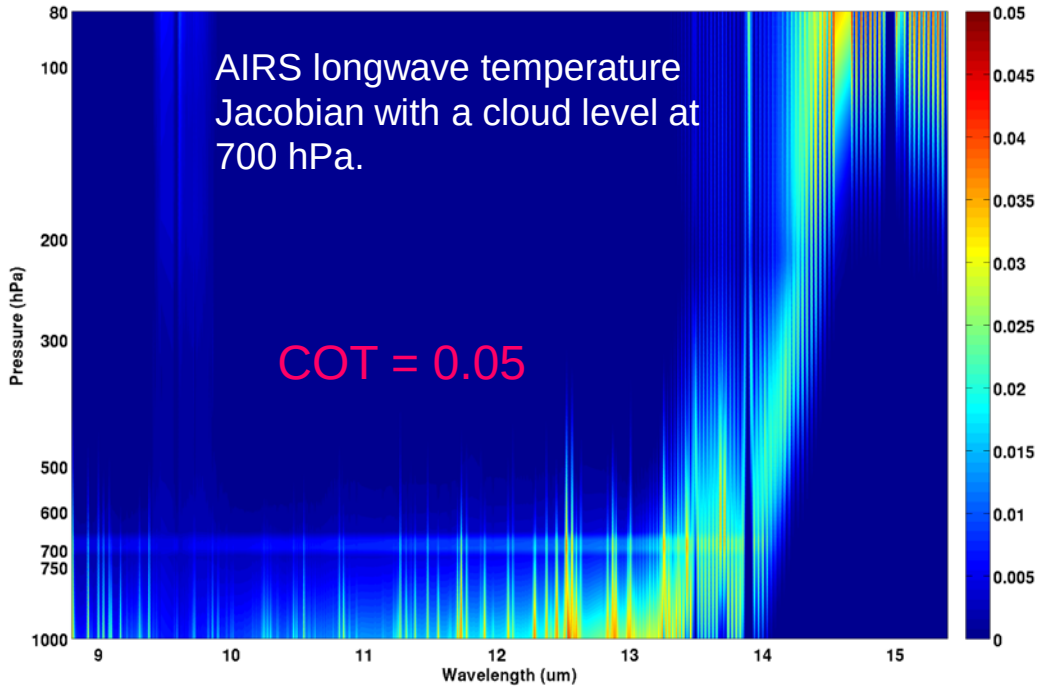
- Question 1: Is direct assimilation of cloudy IR radiances in NWP realistic?
- Question 2: How does cloud detection impact IR sounder radiance assimilation?
- Question 3: How to assimilate thermodynamic information in cloudy situation?

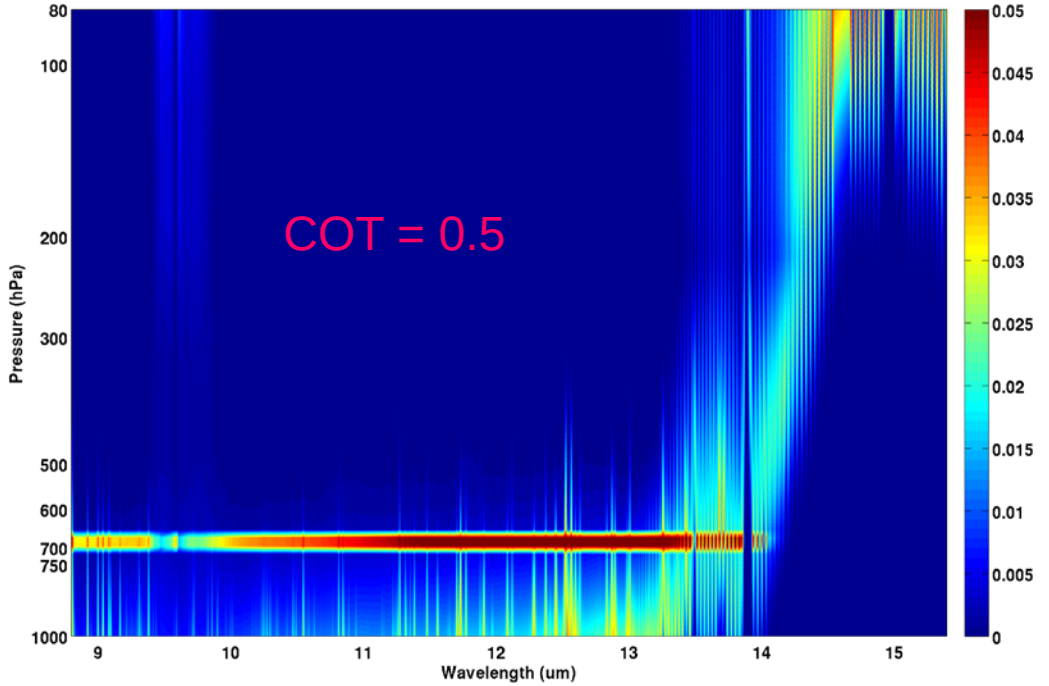
Q: Is direct assimilation of cloudy IR radiances in NWP realistic?

A: Very challenging because:

(1) Both NWP and RTM have larger uncertainty;

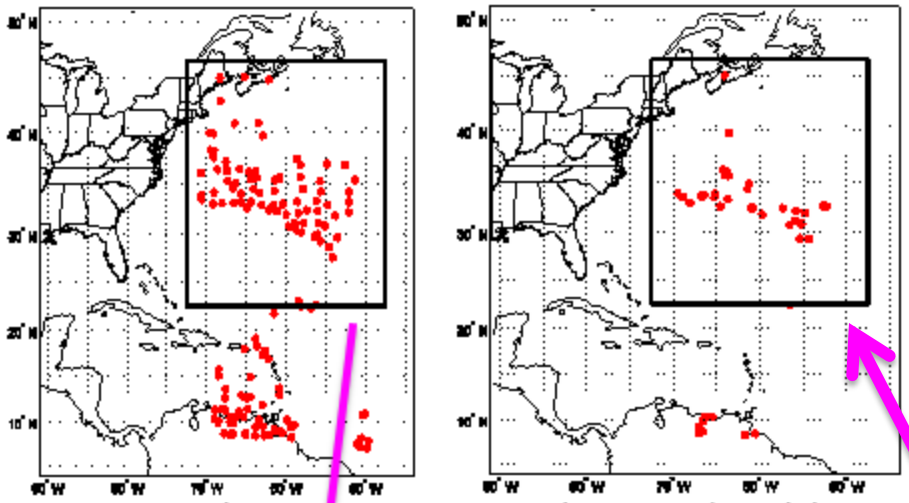
(2) Big change of Jacobian at cloud level.





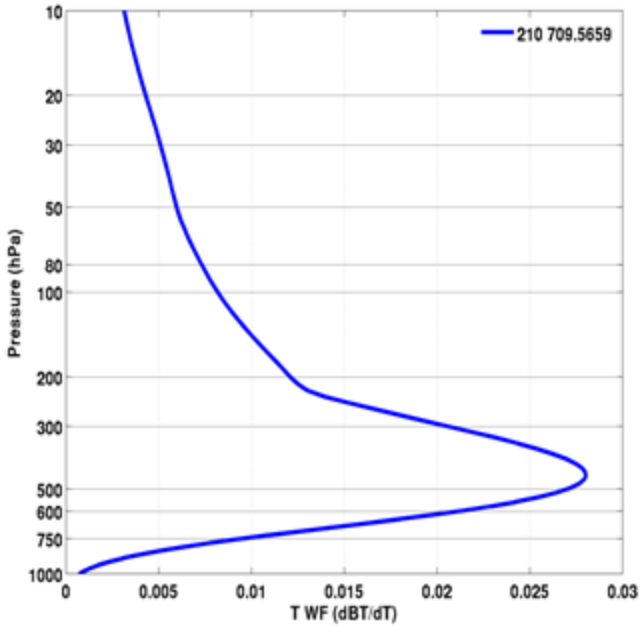
AIRS stand-alone cloud detection

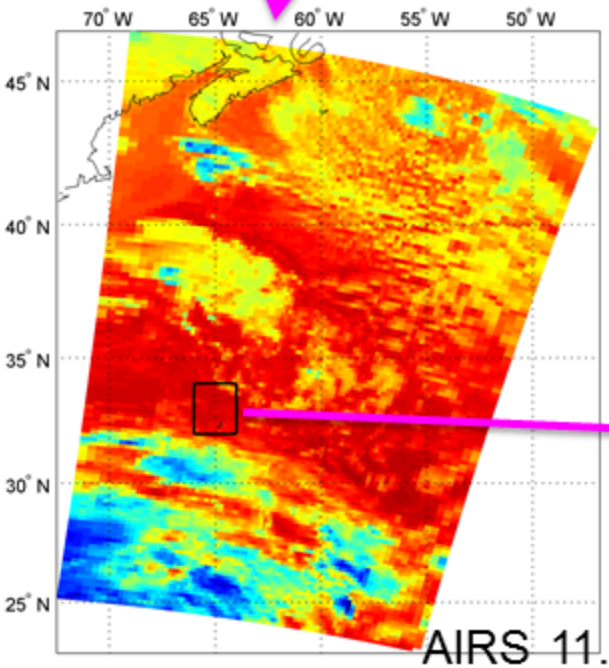
MODIS cloud detection



AIRS data at 06 UTC 25 October 2012 (Sandy)

Channel Index 210, Wave number 709.5659

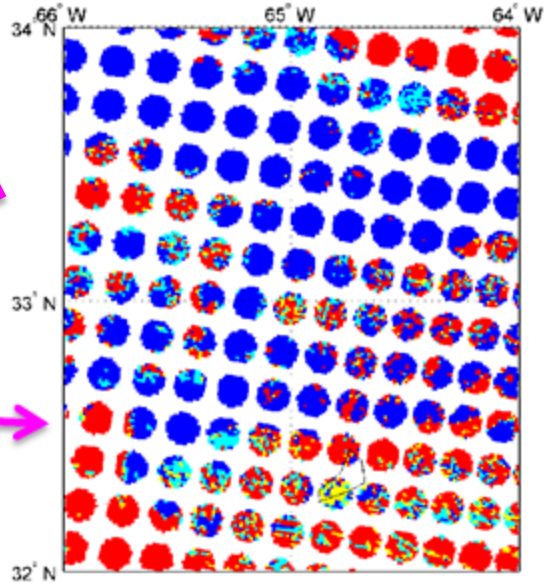




AIRS 11.3 μm BT (K)

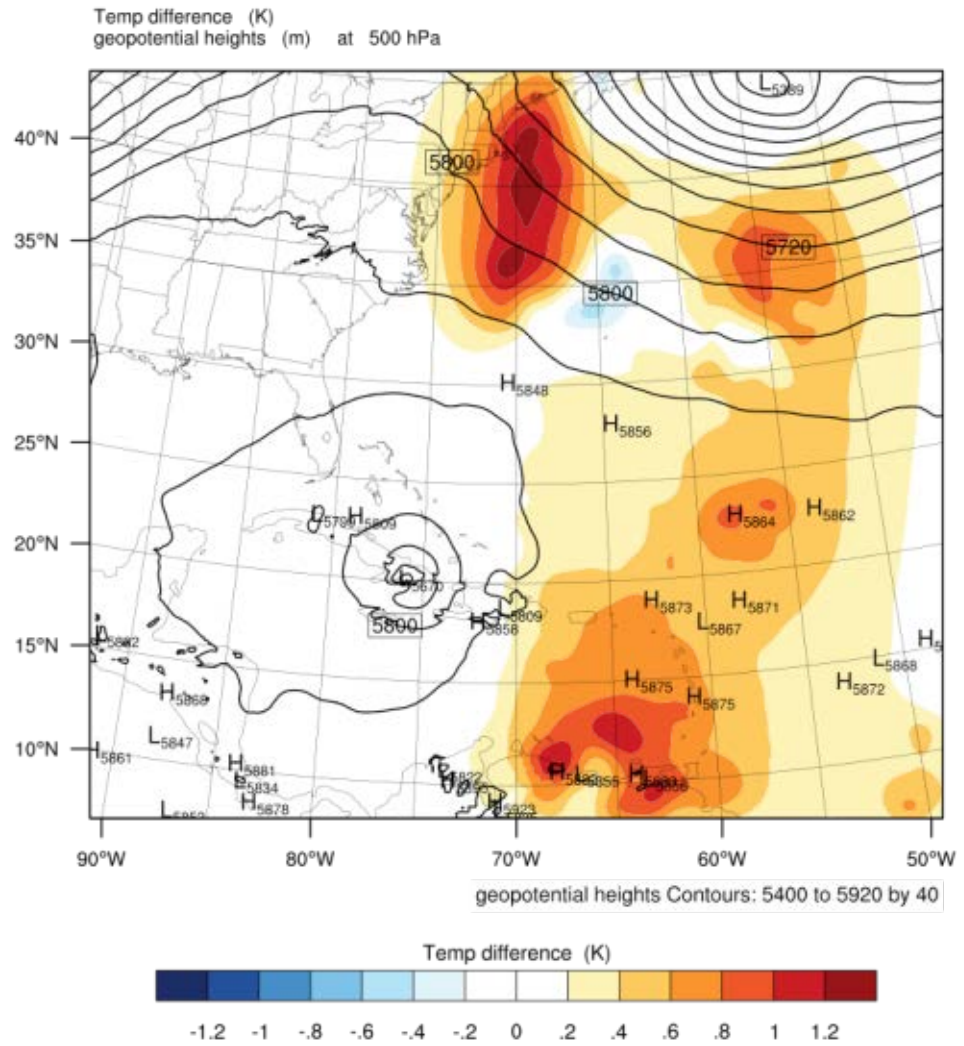
230 240 250 260 270 280 290 300

Wang et al. (2014, GRL)



AIRS sub-pixel cloud detection with MODIS

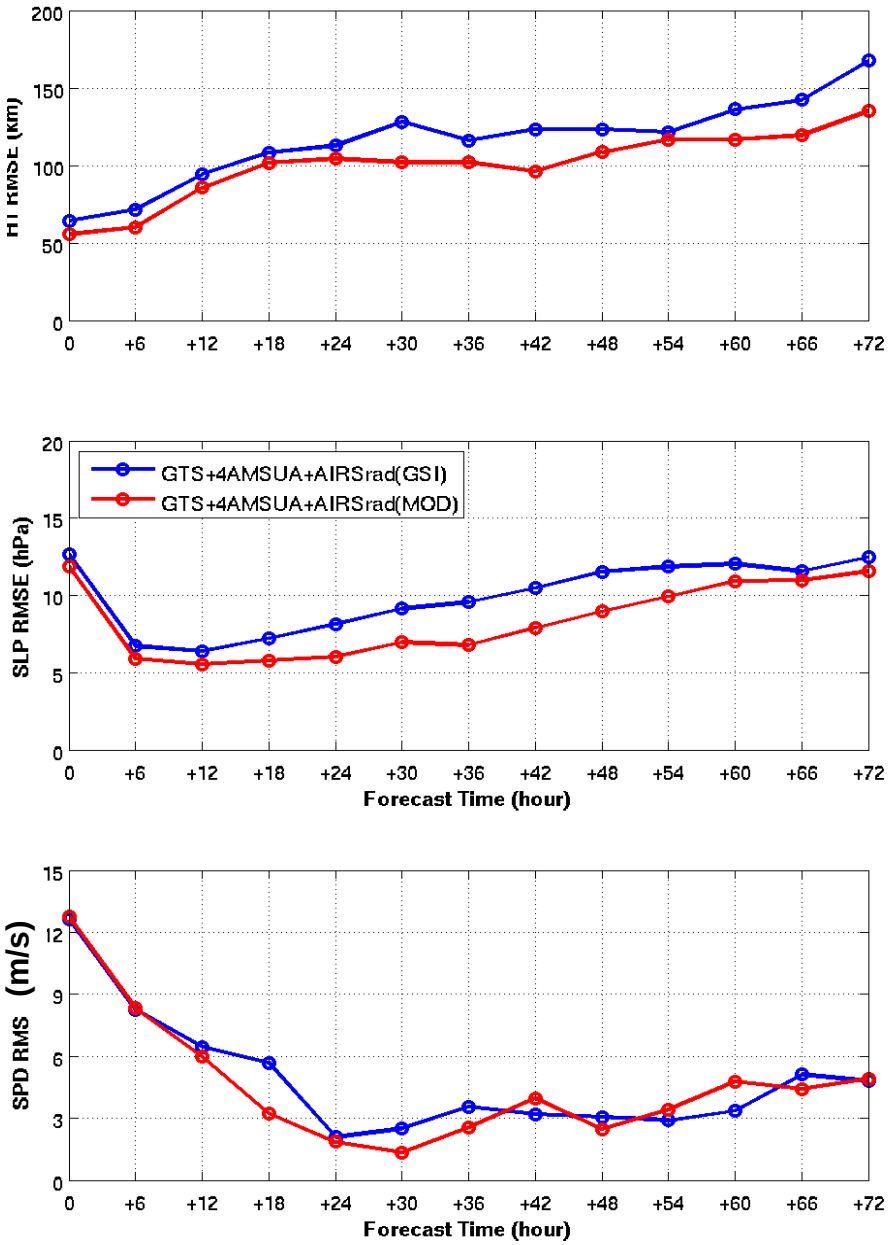
Confident Clear | Probably Clear | Uncertain | Cloudy



500 hPa temperature analysis difference

(AIRS(MOD) - AIRS(GSI))

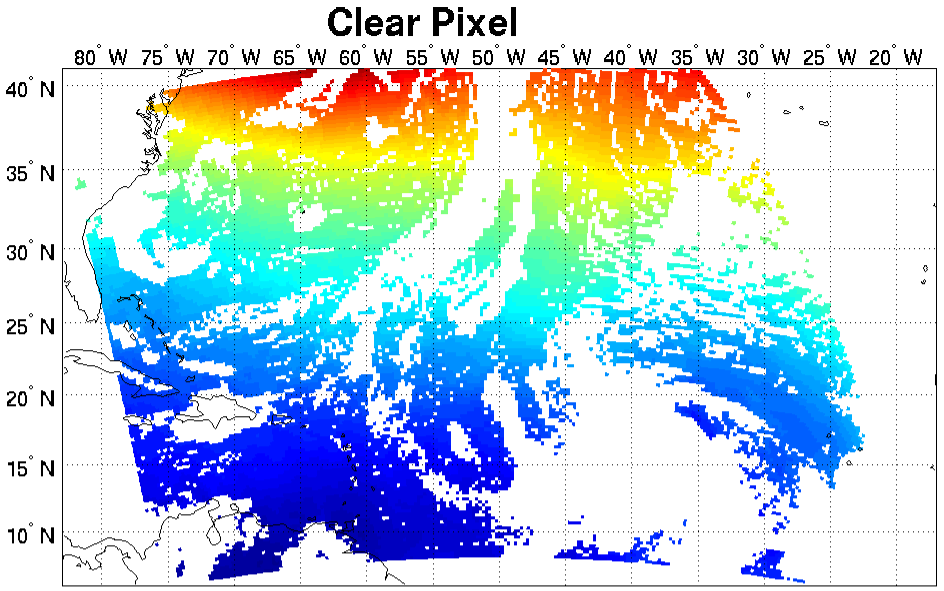
Hurricane Sandy (2012) forecast RMSE



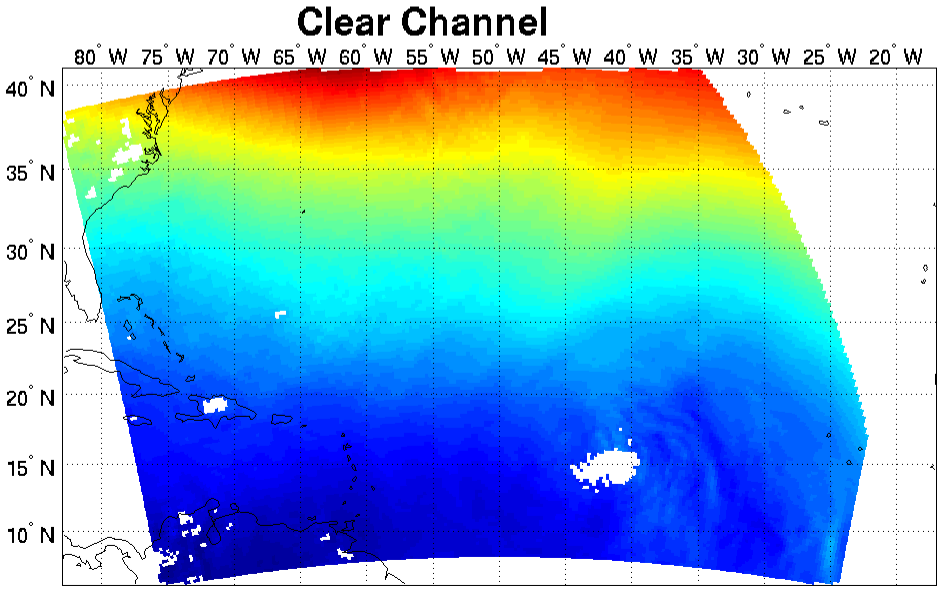
72-hour forecasts of Sandy from 06z 28 to 00z 30 Oct, 2012

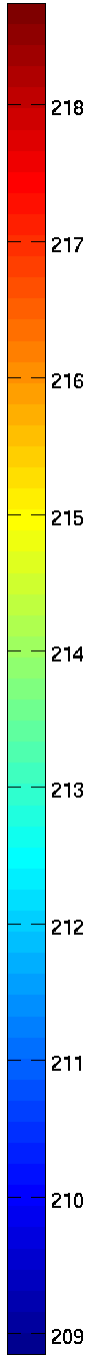
Poster: 11p.09 (Jinlong Li):

Near real time satellite data assimilation system (http://cimss.ssec.wisc.edu/sdat)



15.36 μm

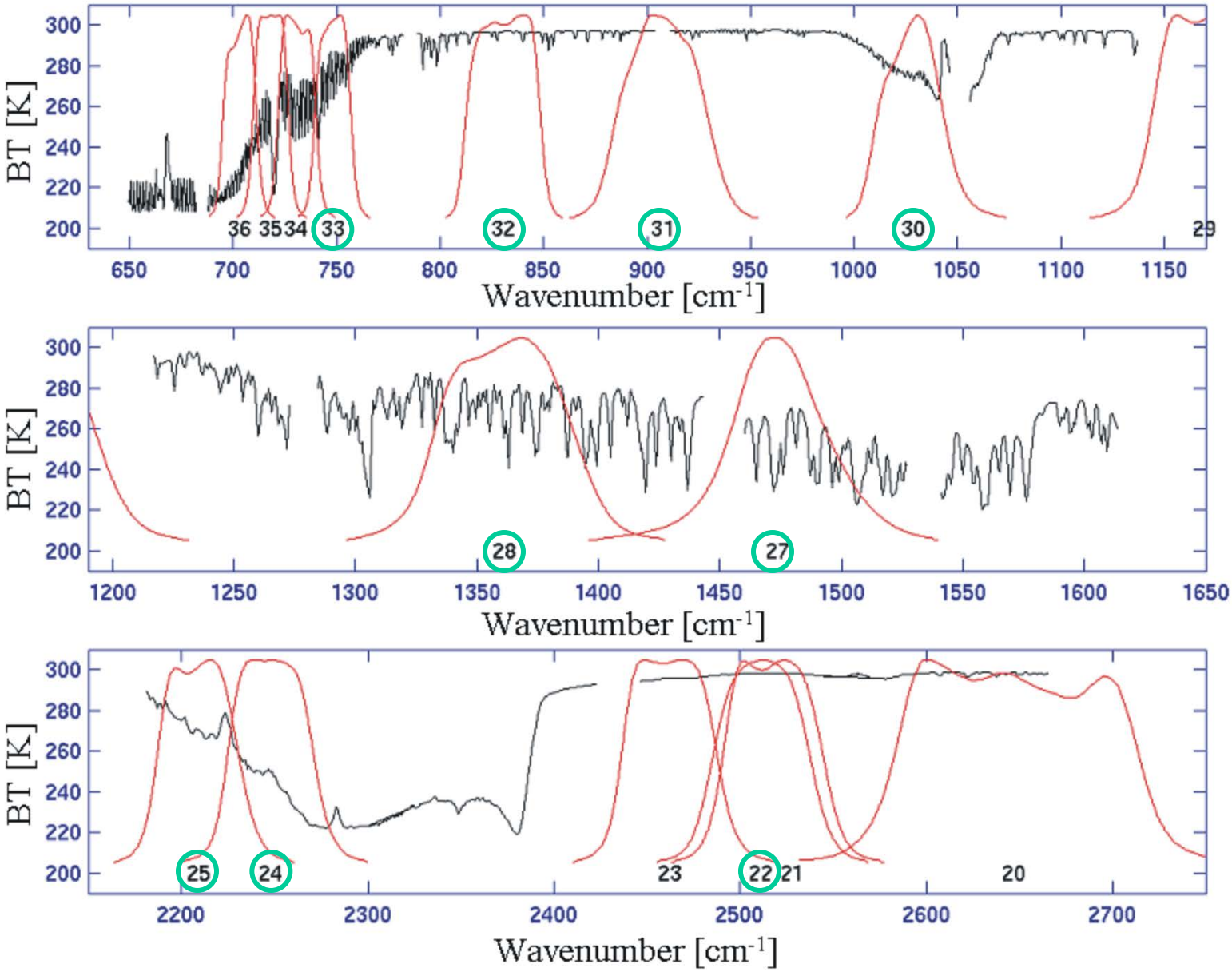




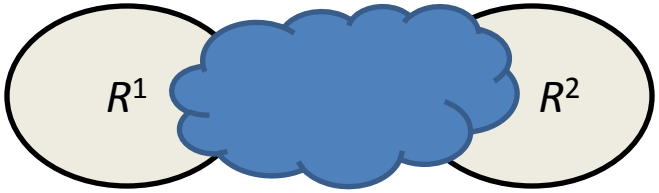
Poster: 11p.07

(Zhenglong Li)

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 !



AIRS/MODIS cloud-clearing (Li et al.2005)

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

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

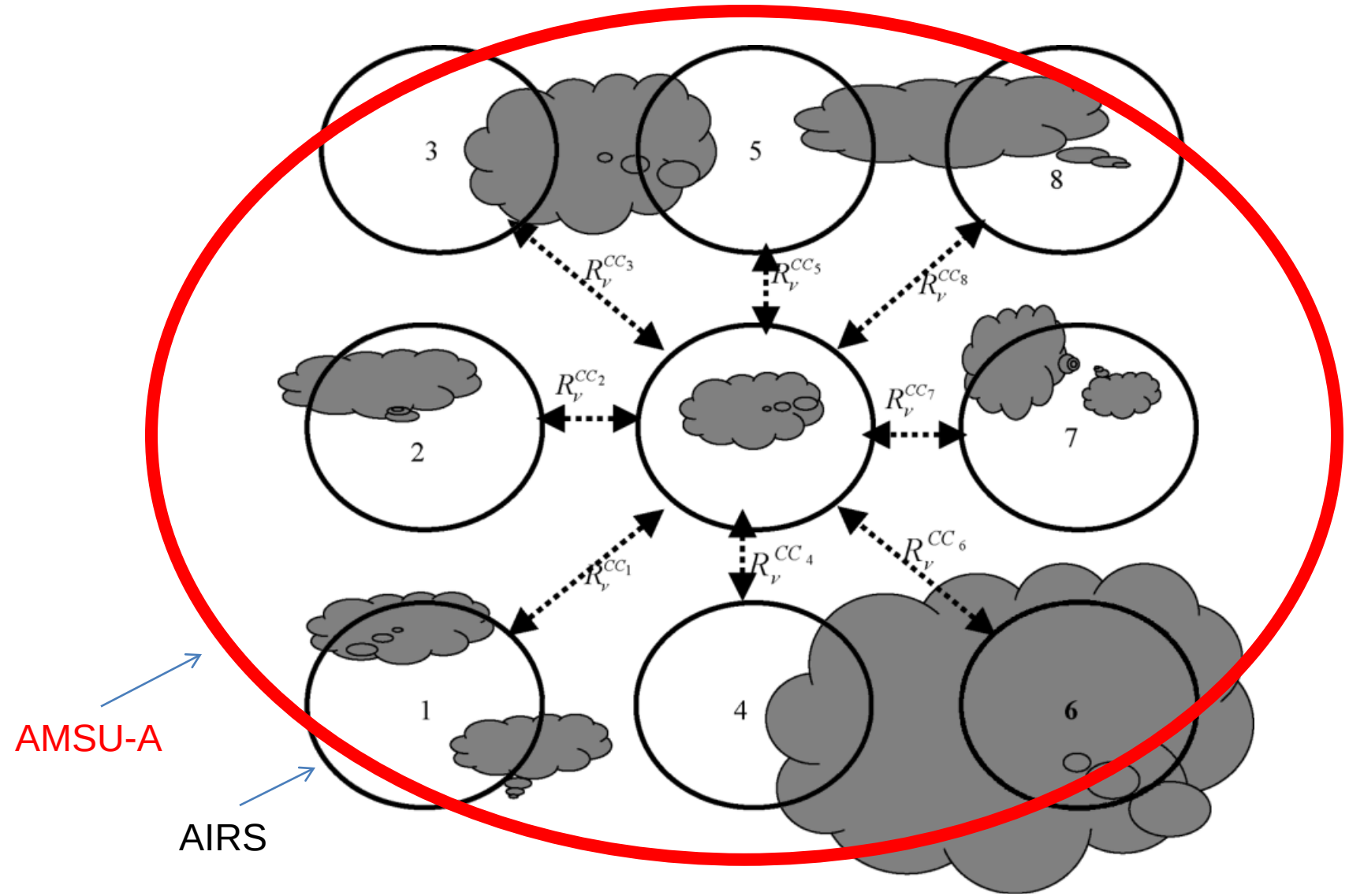
σ_i is NEdR for MODIS band

solve $\dfrac{\partial J(N^*)}{\partial N^*} = 0$ ⇒ $N^* = \dfrac{\sum_i \frac{1}{\sigma_i^2}[f_i(R_\nu^1) - R_{M_i}^{clr}][f_i(R_\nu^1) - f_i(R_\nu^2)]}{\sum_i \frac{1}{\sigma_i^2}[f_i(R_\nu^2) - R_{M_i}^{clr}][f_i(R_\nu^1) - f_i(R_\nu^2)]}$

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

(1) For each cloudy AIRS FOV, 8 pairs are used to derive 8 AIRS CC radiance spectra;

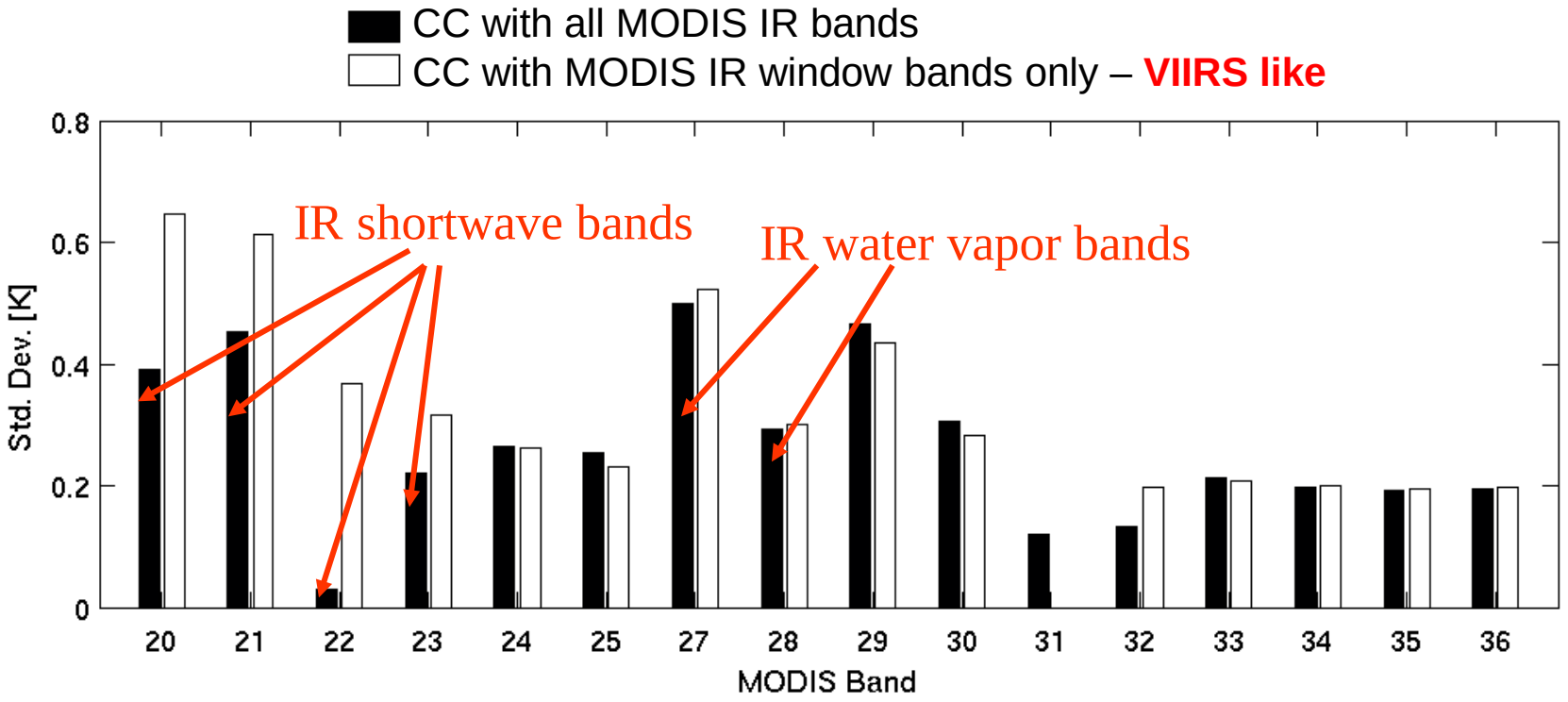
(2) Compare AIRS CC radiances with MODIS clear radiance observations within the AIRS FOV, find the best pair and the corresponding CC radiance spectrum.



Sounding bands imager are very important in IR/Imager cloud-clearing

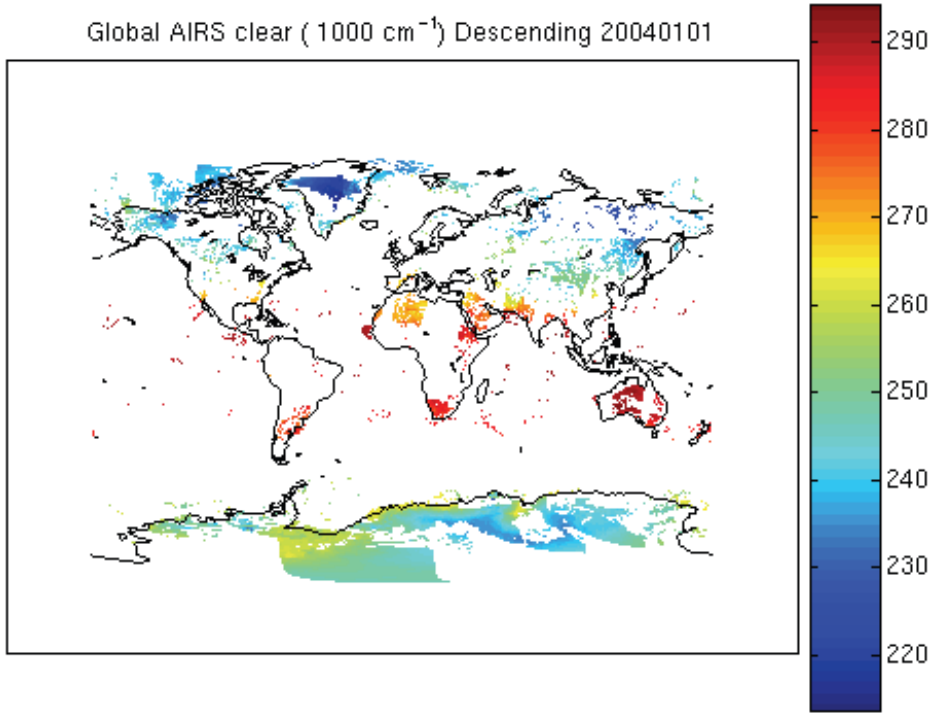
AIRS cloud-cleared BT standard deviation (STD) compared with MODIS clear BT measurements

Bias < 0.25 K, STD<0.5 K at most MODIS bands.

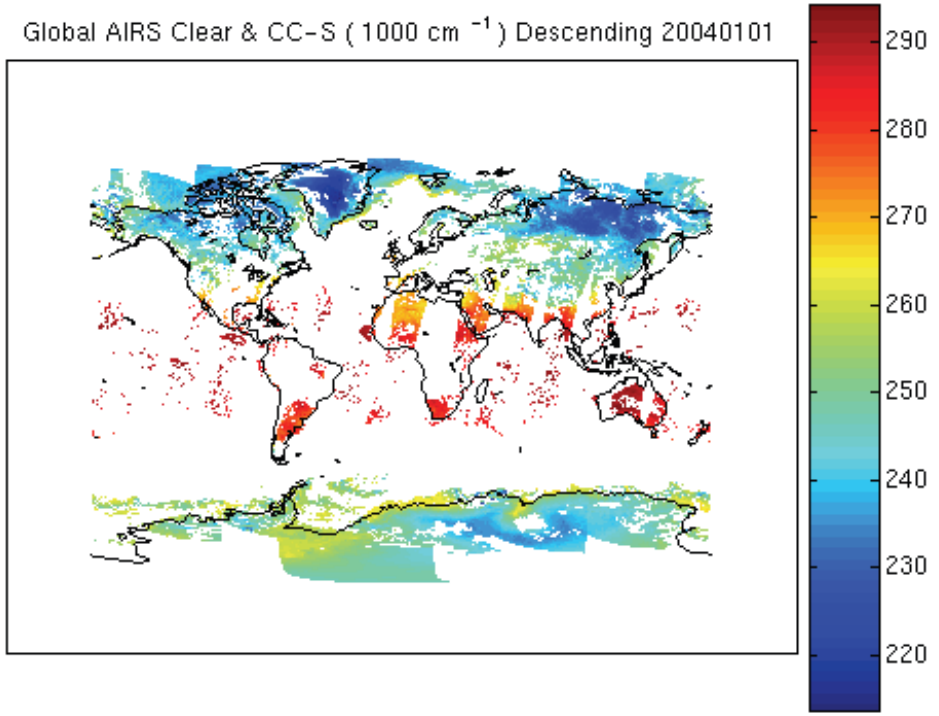


The precision of AIRS/MODIS cloud-cleared radiances high rely on MODIS spectral and radiometric calibration.

AIRS clear coverage

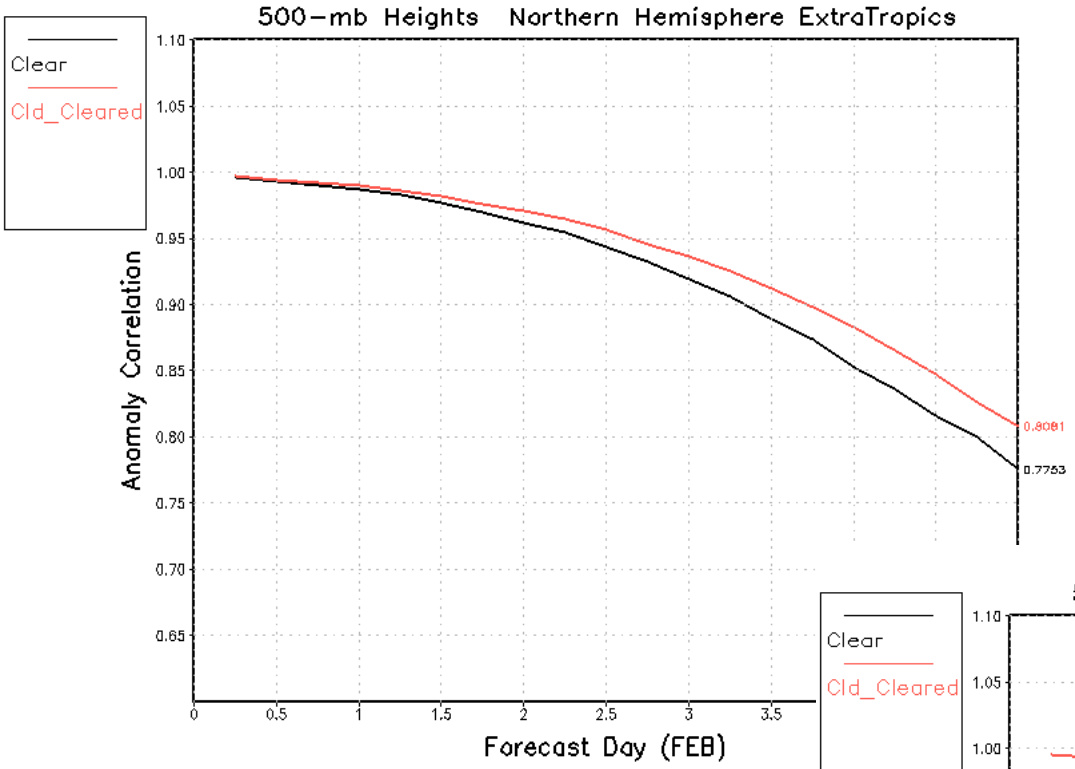


AIRS clear + cloud-clearing coverage

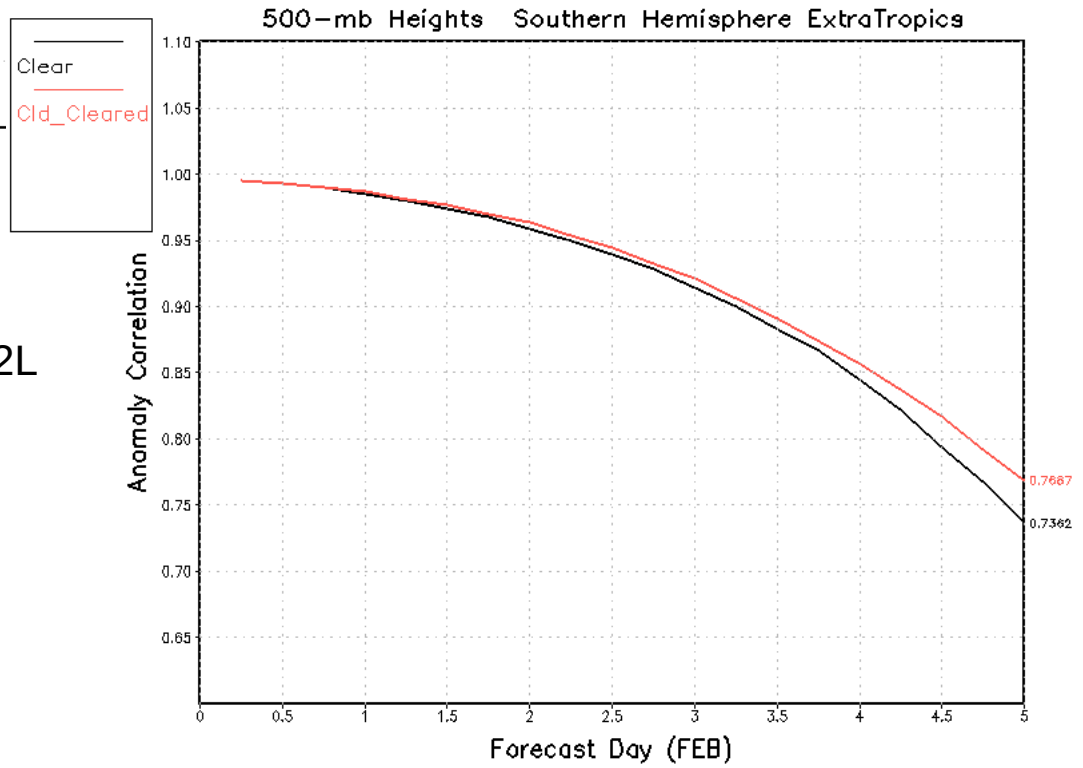


AIRS global clear and cloud clearing brightness temperature (descending) on Jan. 1, 2004.

Zhang et al. (2010)



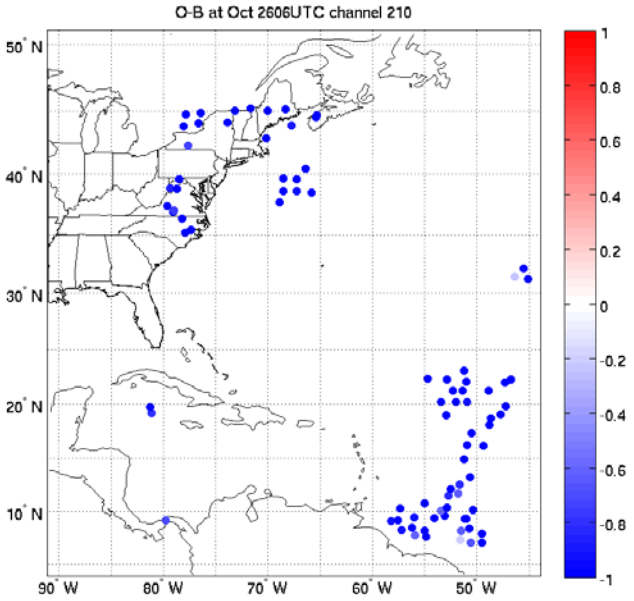
Rienecker et al. (2008): GMAO's Atmospheric Data Assimilation Contributions to the JCSDA and future plans, *JCSDA Seminar*, 16 April 2008.



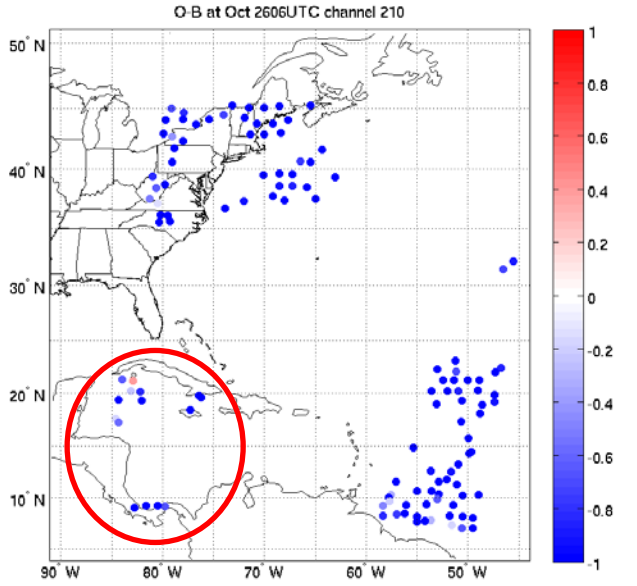
- GEOS-5 model resolution: 1° x1.25° x72L
- Time frame: Jan 01 to Feb 15 2004
- Other Radiance data:
  - HIRS-2/HIRS3 (clear channels)
  - AMSU-A/EOS-AMSU-A
  - AMSU-B/MHS
  - SSM-I
  - GOES Sounders

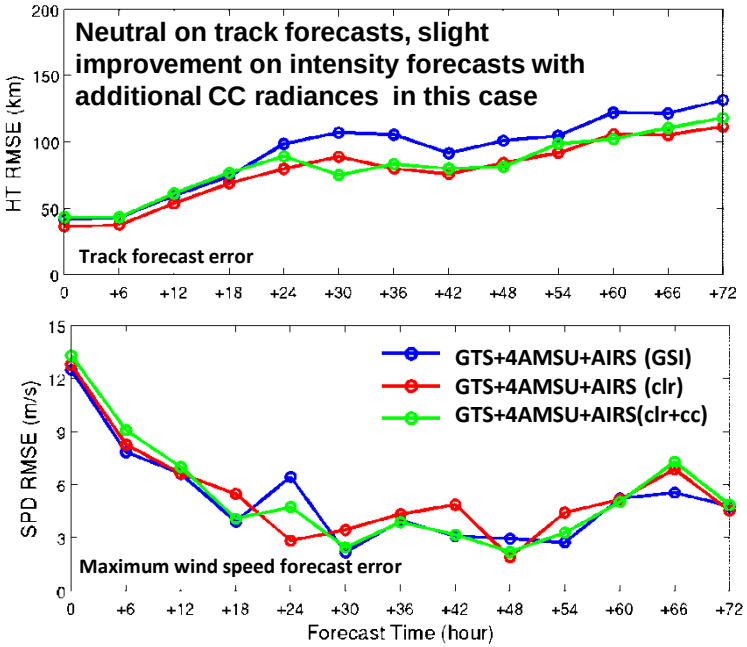
AIRS Channel 210, 2012-10-26-06 Z

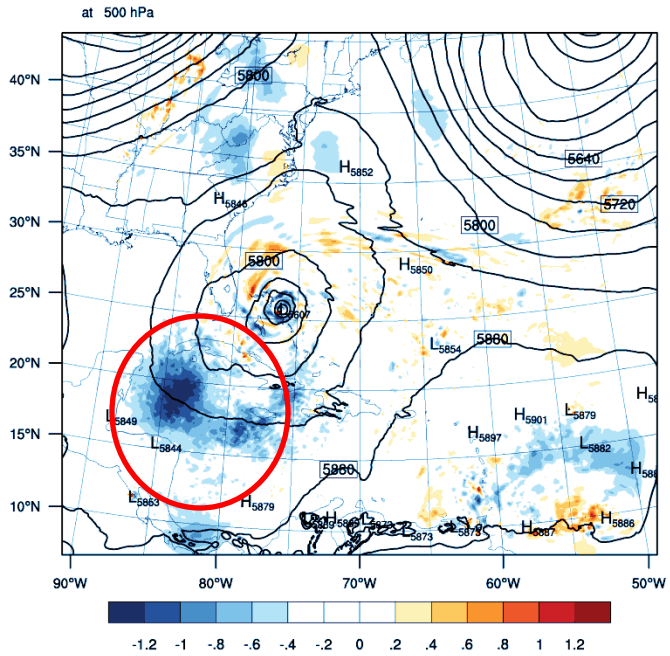
AIRS clr



AIRS clr + AIRS cc







T analysis difference at 500 hPa between AIRS clr+cc and AIRS clr

Summary

- Better cloud detection with high spatial resolution imager leads to significant NWP forecast improvement using GSI and WRF ARW systems;
- The approaches can be applied to NPP/JPSS CrIS/VIIRS and Metop IASI/AVHRR;
- IR sounder cloud-clearing with collocated imager could expand the “clear” coverage for radiance assimilation;
- Future work will focus on assimilating the cloud-cleared radiances (e.g., CrIS/ATMS, AIRS/MODIS, AIRS/AMSU) in NWP.