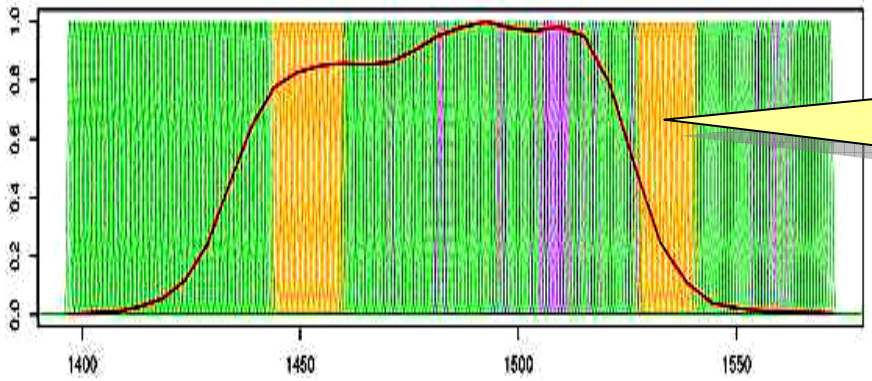
Advanced GEO Radiance Estimation from Hyper Sounder Data and Preparation for MTSAT Intercalibration in JMA

February 2008

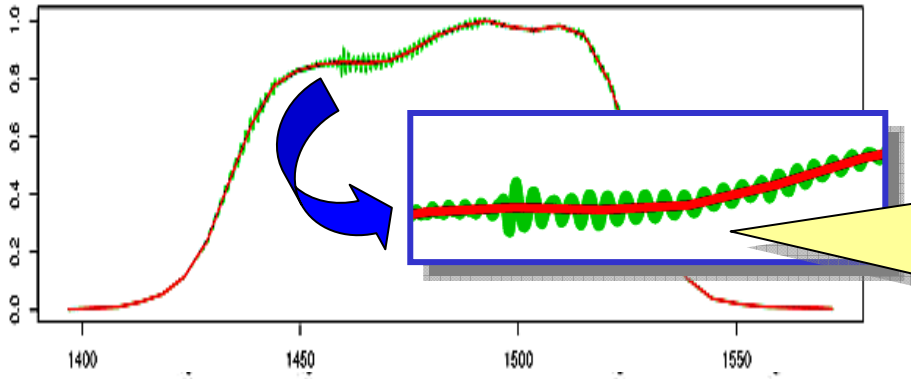
Yoshihiko Tahara
Koji Kato

Meteorological Satellite Center
Japan Meteorological Agency

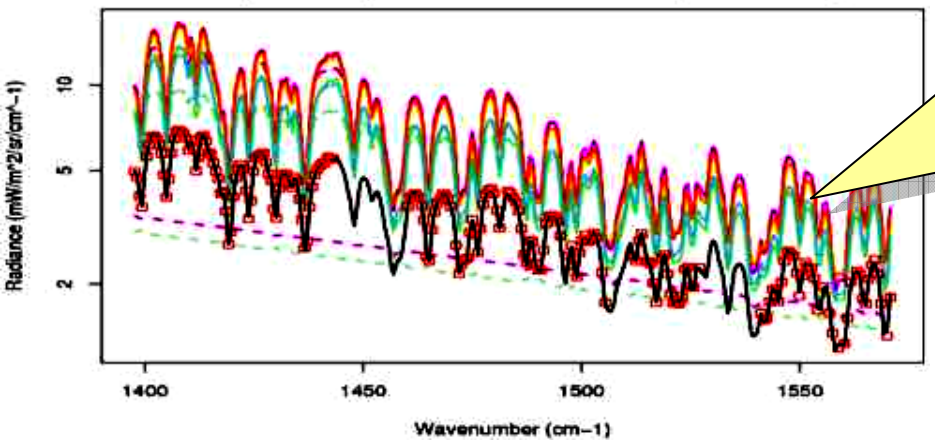
GEO Radiance Estimation from Hyper Sounder Data



1. "Gap channels" introduced
To fill the spectral gaps of a LEO hyper sounder

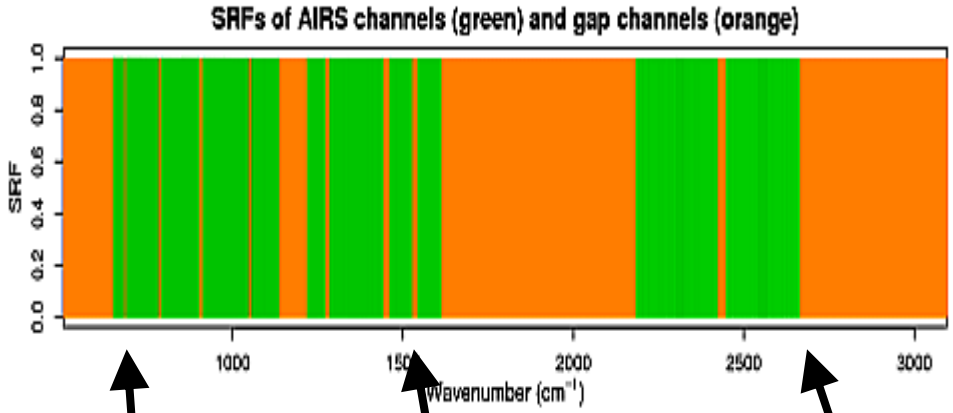


2. "Super channel" generated
To imitate a GEO channel from the hyper and gap channels by the "constraint method"

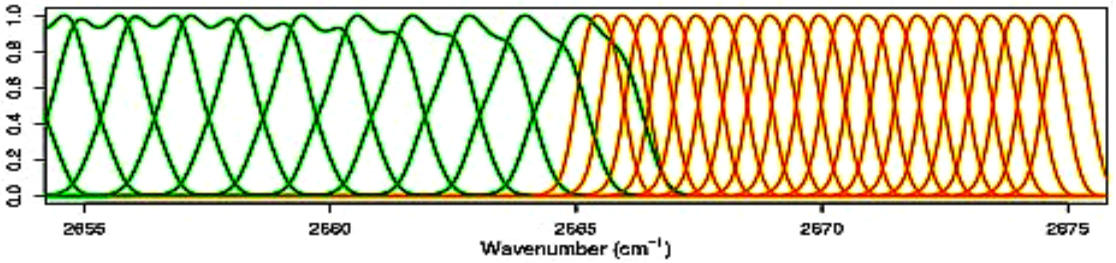


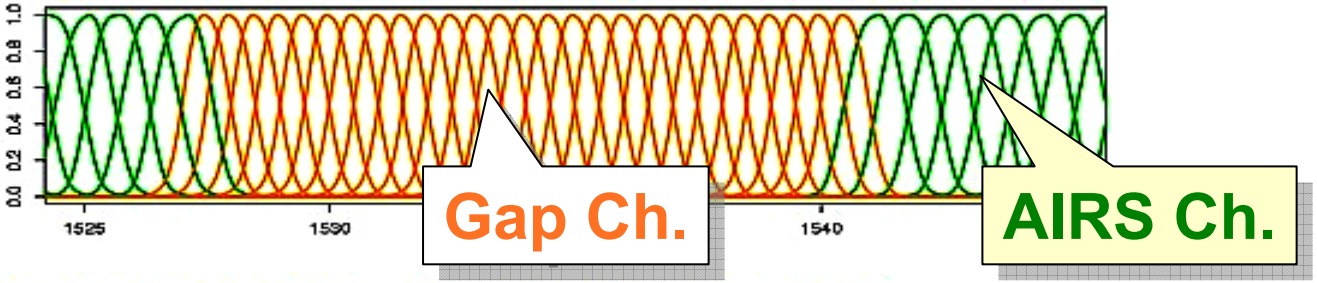
3. Radiances of missing hyper and gap channels estimated
by using valid hyper channel observations and beforehand simulated radiances for 8 profiles

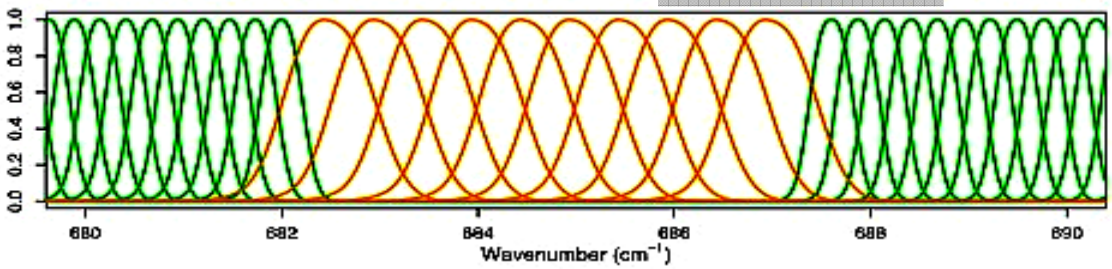
AIRS Gap Channels



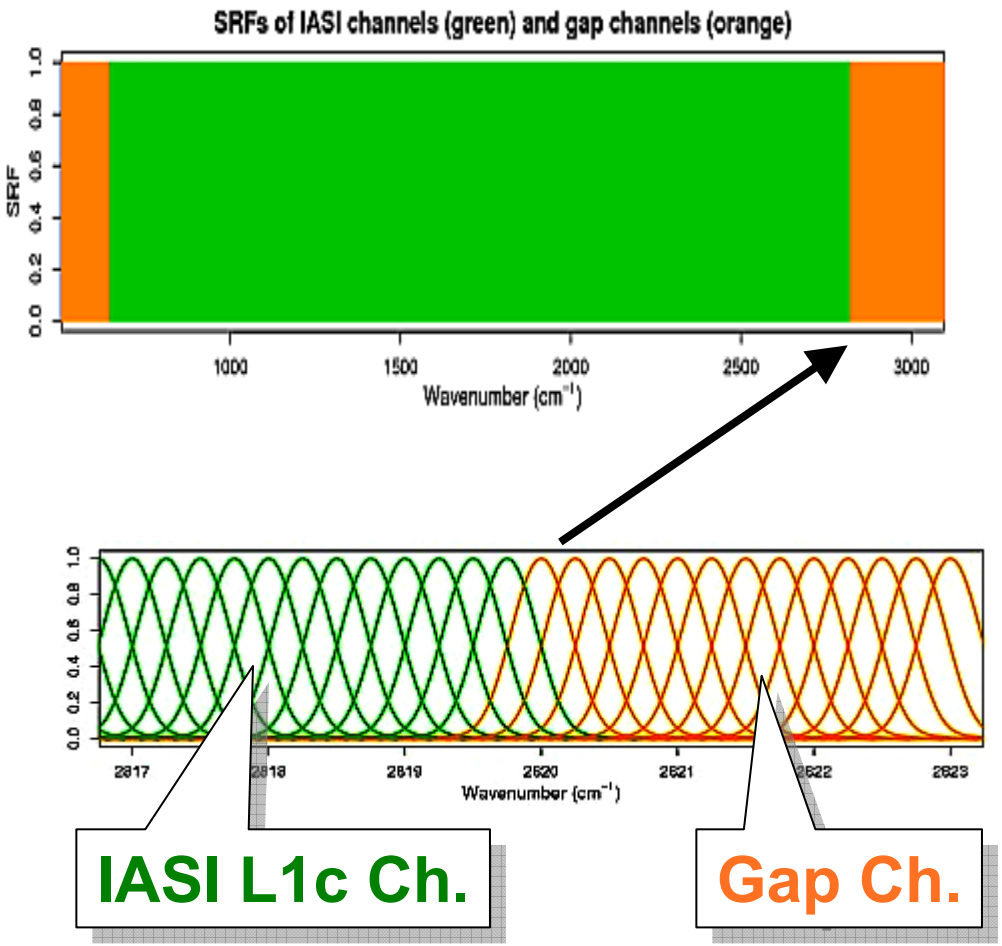
- Unique SRF for all AIRS gap channels
- Gaussian curve of sigma = 0.5 cm^{-1}
- 0.5 cm^{-1} intervals







IASI Gap Channels



- No gaps in IASI spectral
- But bands of some GEO NIR channels are not covered by IASI fully

"IASI gap channels"

- The same intervals (0.5 cm^{-1}) as IASI L1c
- The same SRF as IASI L1c

The gap channel can be treated as a member of hyper channels, and its observation is failed

Super Channel by Constraint Method

Radiance observed by a broadband channel is

$$I_b = \int S_b(\nu) I(\nu) d\nu, \qquad \text{where} \qquad \int S_b(\nu) d\nu = 1.$$

Radiance of a super channel (linear combination of sounder radiances) is

$$I_b \approx \sum_i w_i I_i = \int \left\{ \sum_i w_i S_i(\nu) \right\} I(\nu) d\nu.$$

$$I_i = \int S_i(\nu) I(\nu) d\nu$$

$$\int S_i(\nu) d\nu = 1$$

They should be approximately equal for any $I(\nu)$, then

$$S_b(\nu) \approx \sum_i w_i S_i(\nu)$$

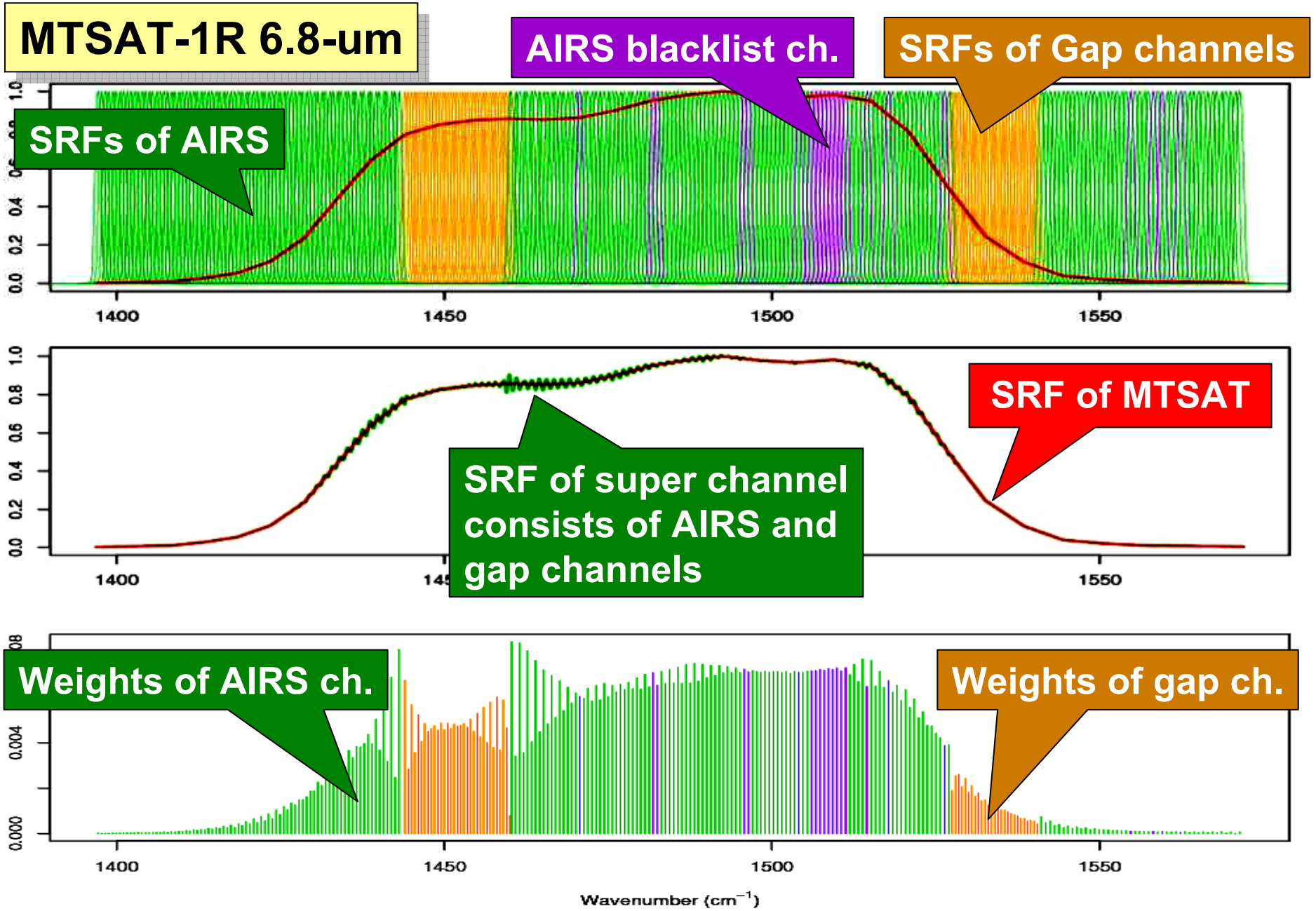
To obtain optimized w_i, solve

$$\text{argmin} \;\; J(w_1, w_2, \cdots) = \int \left\{ S_b(\nu) - \sum_i w_i S_i(\nu) \right\}^2 d\nu.$$

where

$$\frac{\partial J}{\partial w_k} = \int 2 S_k \left\{ S_b(\nu) - \sum_{i=1}^{n} w_i S_i(\nu) \right\} d\nu.$$

SRF of Super Channel



Radiance Estimation for Missing Hyper Channels

- **Formulation** $\log I_i^e = c_0 + \sum_k c_i \log I_i^k$

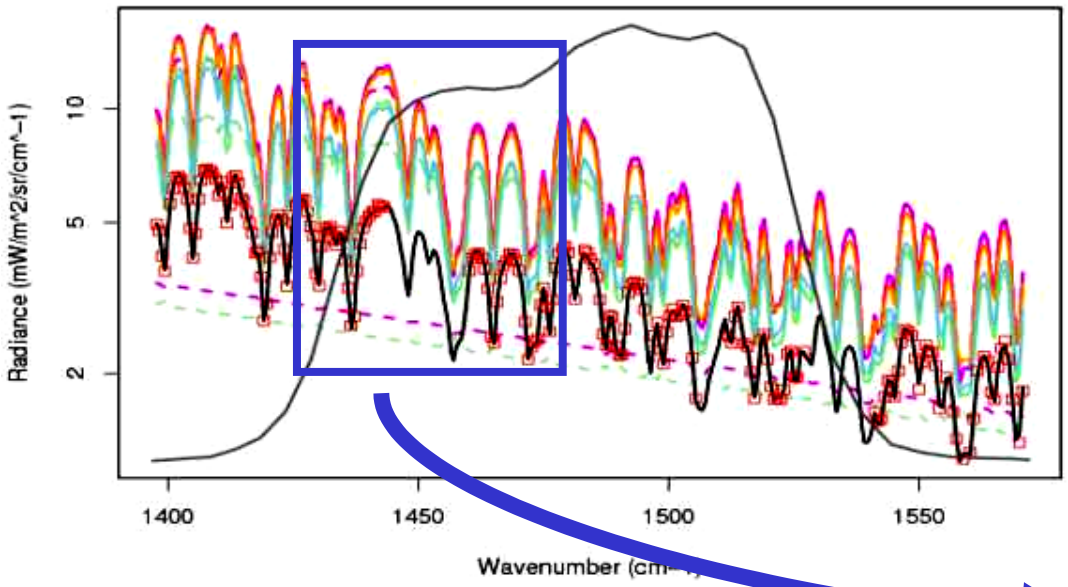
  Estimated radiance of blacklist channel and gap channel i

  Simulated radiance of channel i for model profile k

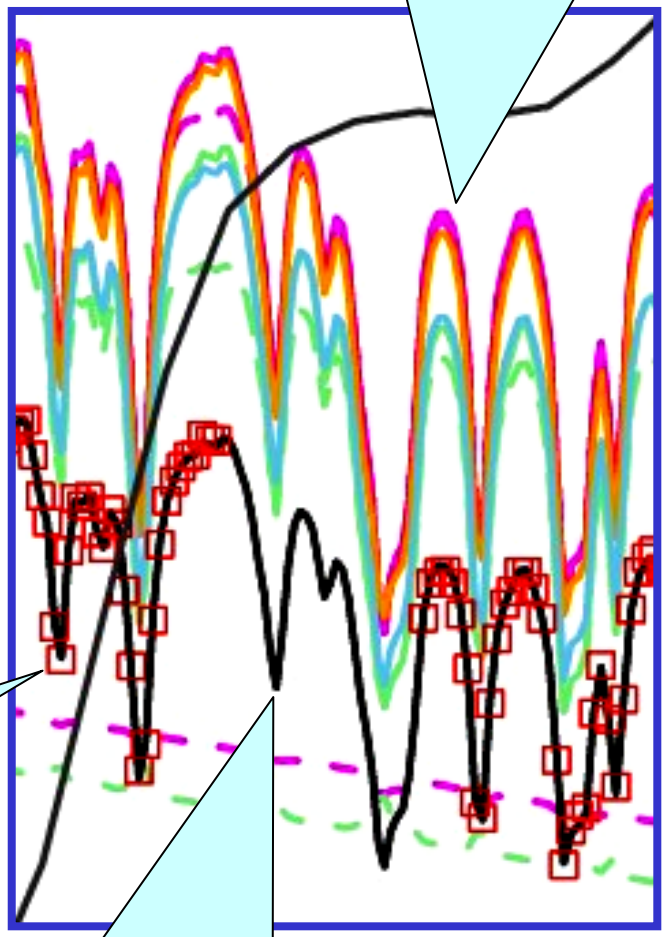
  - For each GEO channel and each hyper sounder observing pt.
  - Log radiance estimated for better fitting
- **Simulated radiances for 8 model profiles**
  - Tropic, US standard, Mid-latitude winter and summer profiles
  - Thick cloud at 500 hPa and 200 hPa for Tropics and US std.
- **Coefficients computation**
  - Solving least square problem by applying valid hyper sounder observations and corresponding simulated radiances
- **No NWP fields and no RT computation in operation**

Radiance Estimation of Missing Hyper Channels

MTSAT-1R 6.8-um region



simulated AIRS radiances

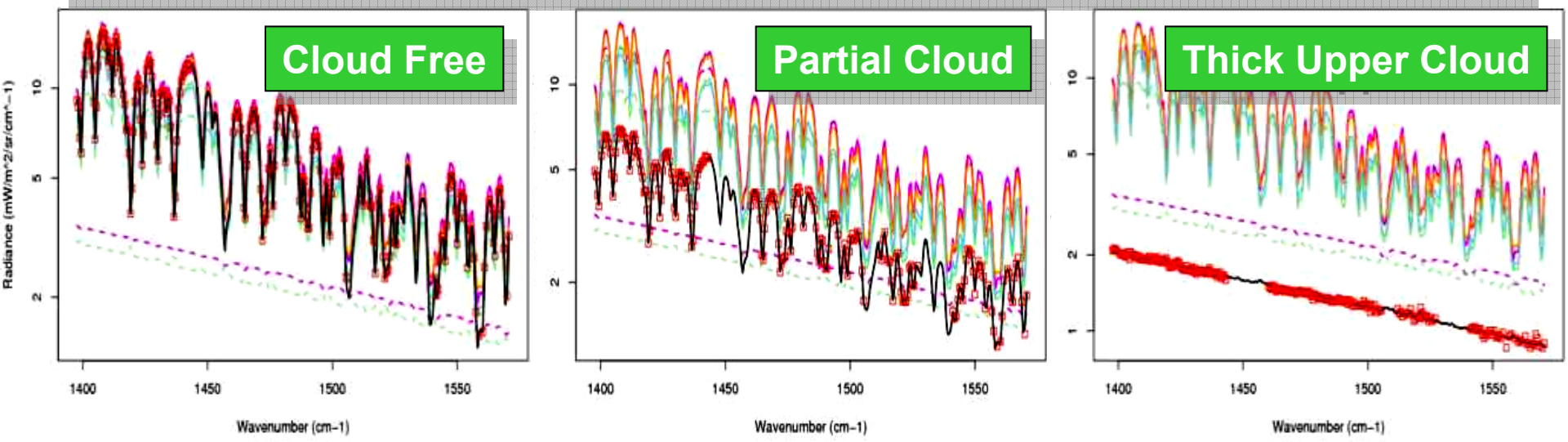


observed AIRS radiances

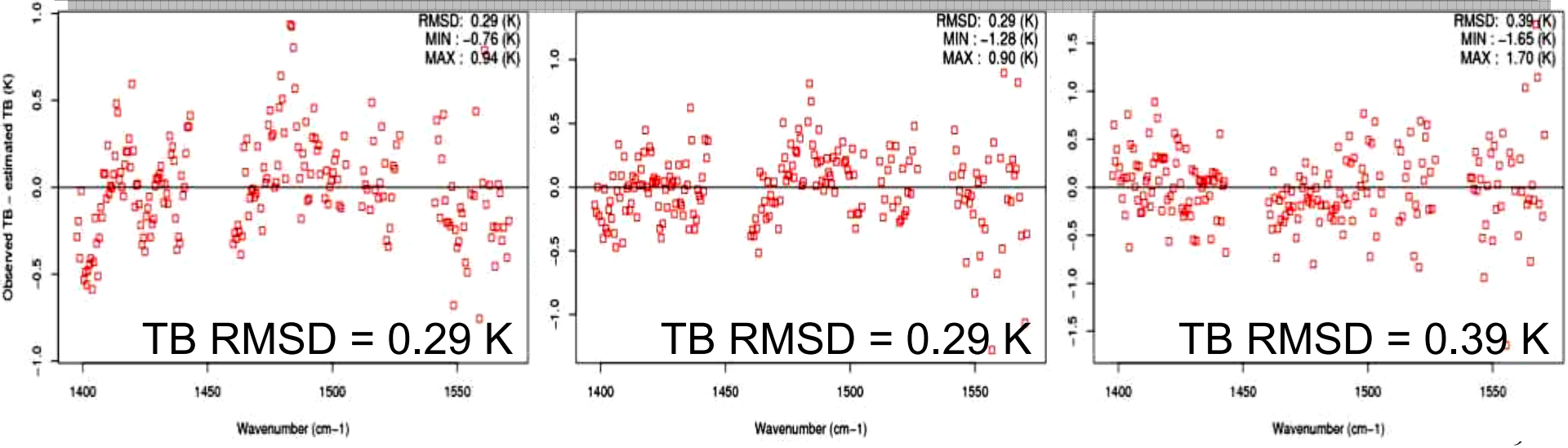
estimated AIRS radiances

AIRS Radiance Estimation over MTSAT 6.8-um

Estimated AIRS radiances

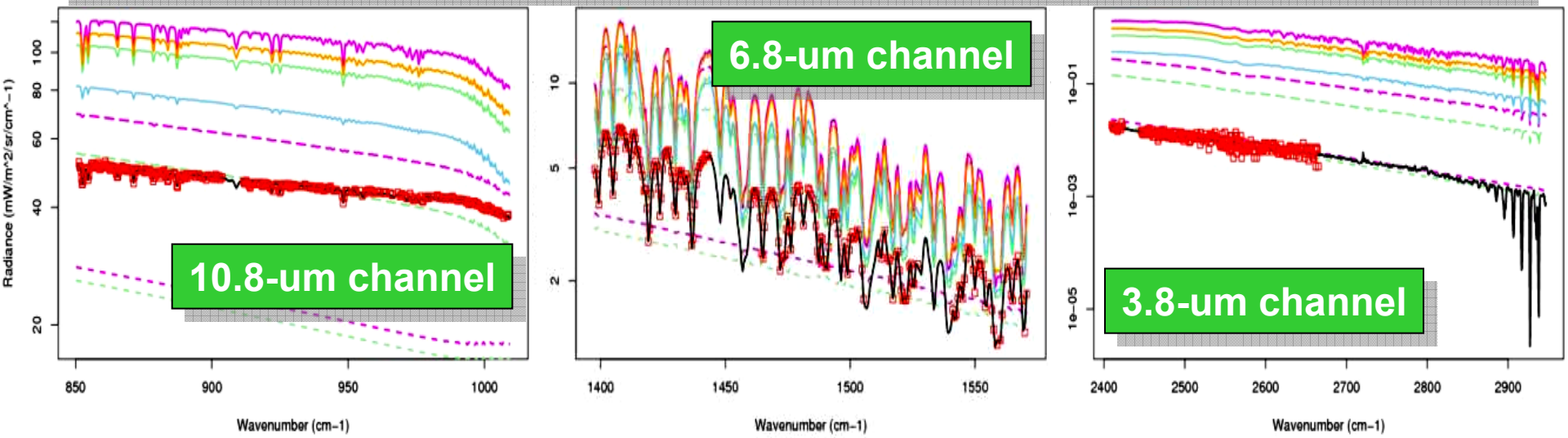


TB differences between AIRS observations and estimations

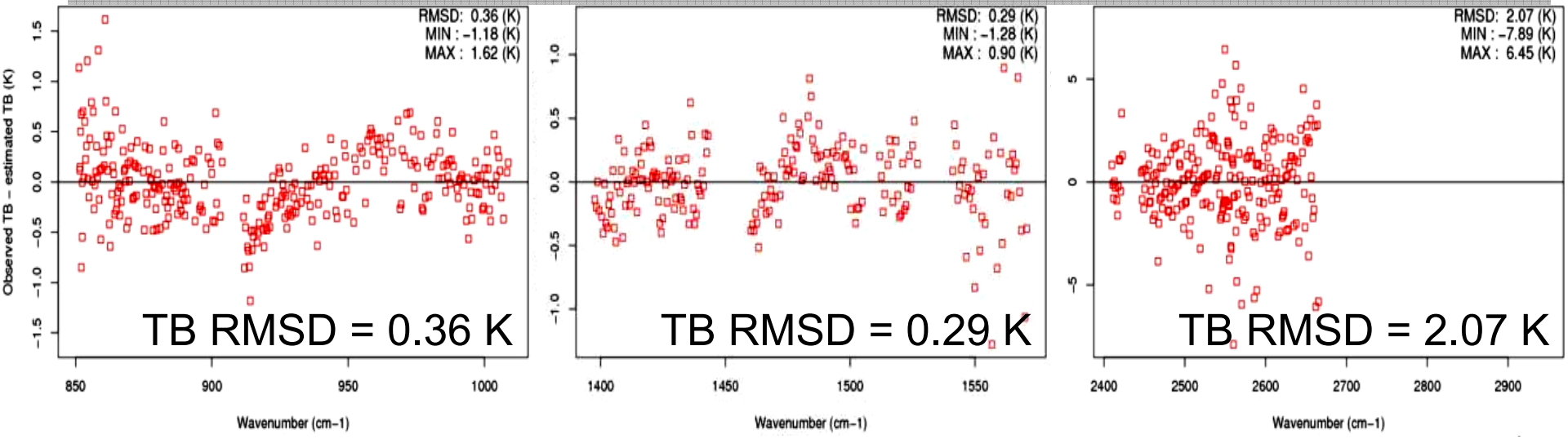


AIRS Radiance Estimation for MTSAT Channels

Estimated AIRS radiances

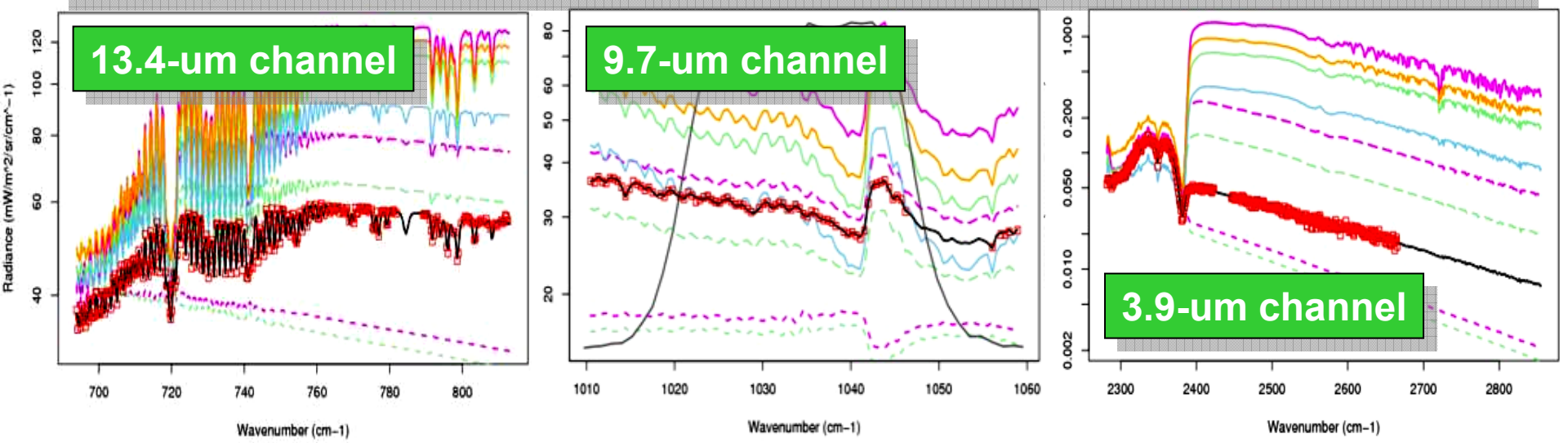


TB differences between AIRS observations and estimations

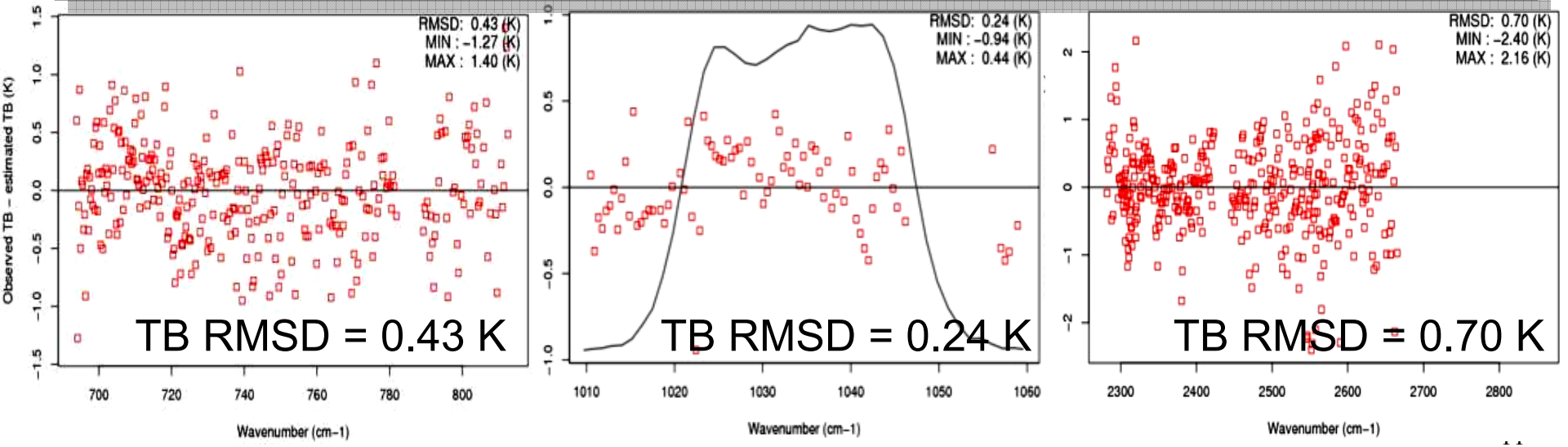


AIRS Radiance Estimation for Meteosat Channels

Estimated AIRS radiances

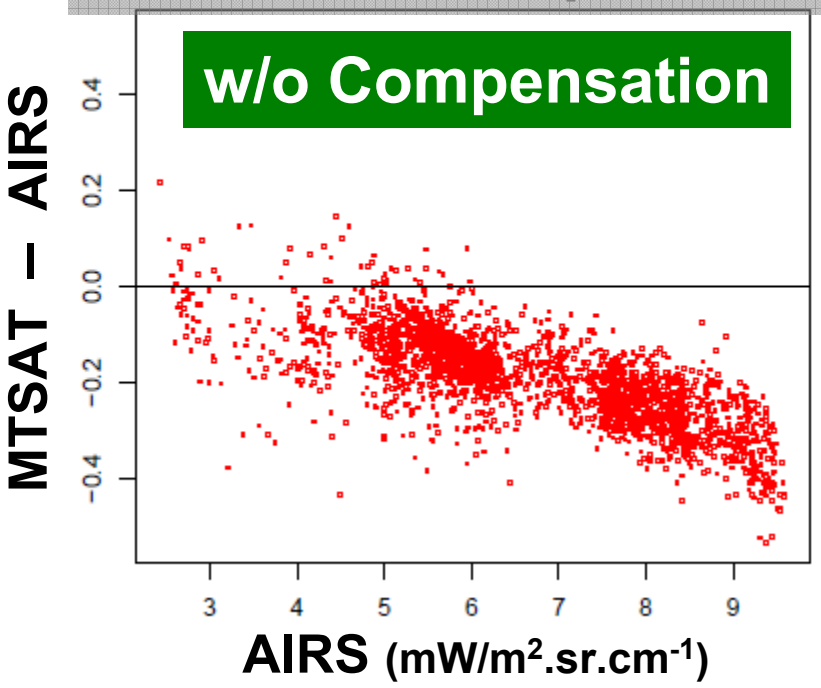


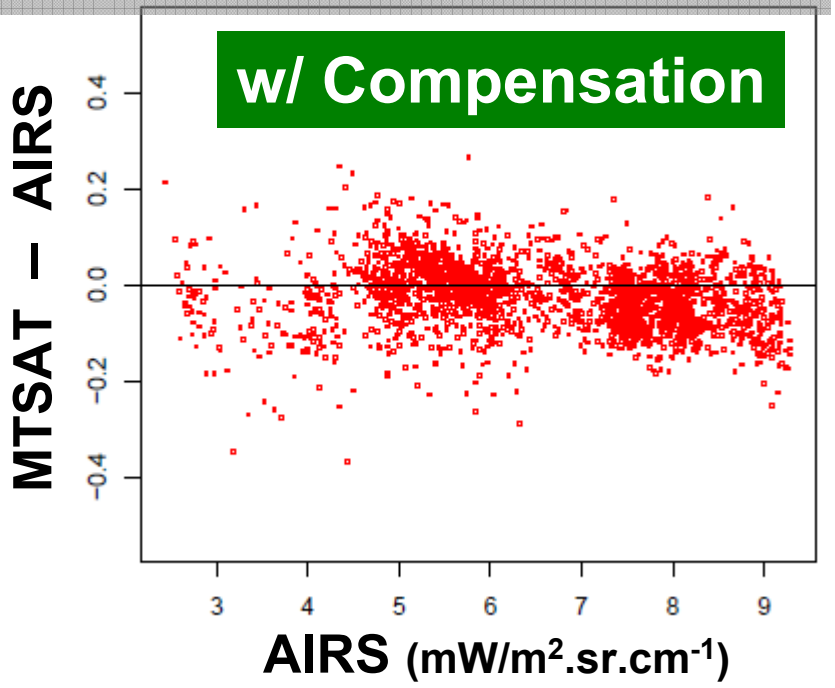
TB differences between AIRS observations and estimations



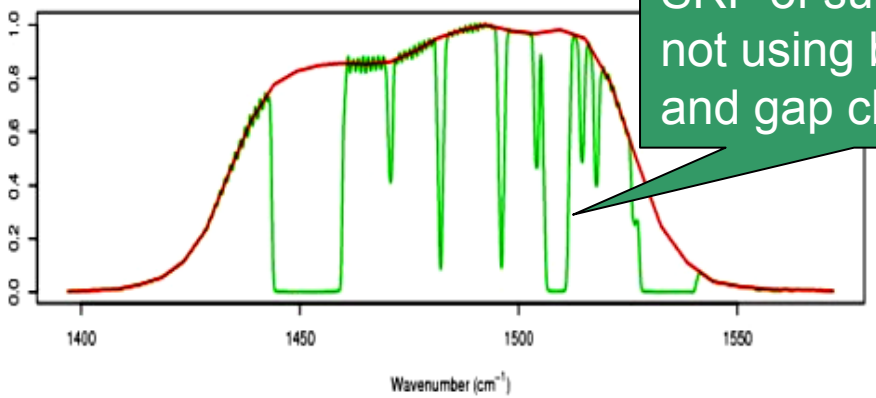
Compensation vs. No Compensation

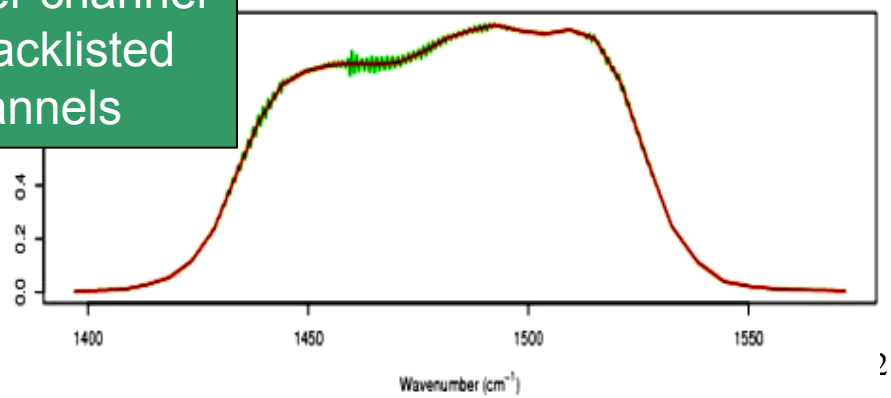
Radiance comparison of MTSAT1R 6.8-um and AIRS





SRF of super channel not using blacklisted and gap channels

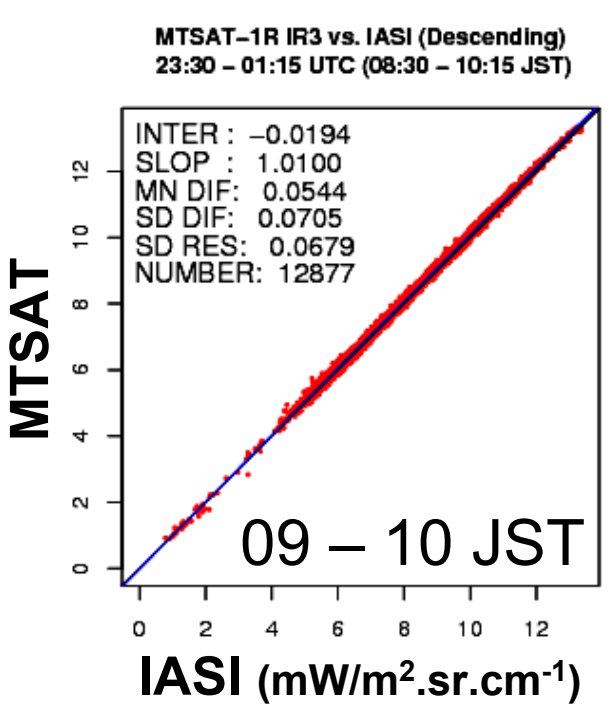


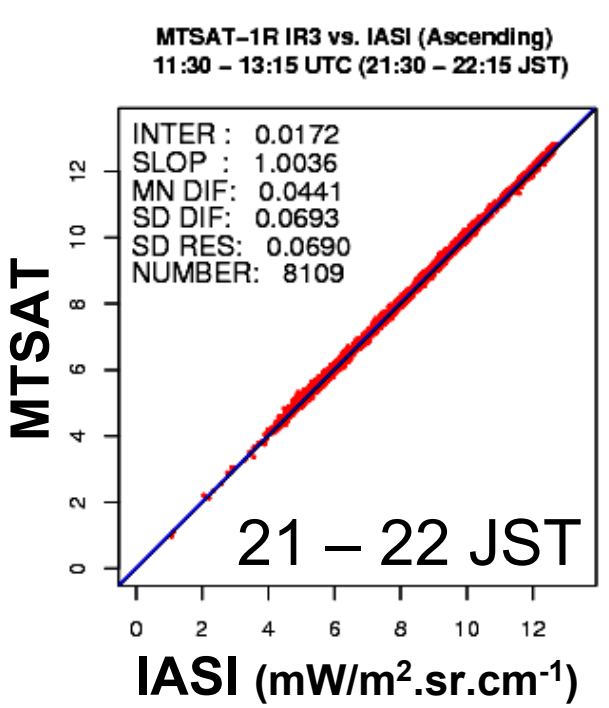


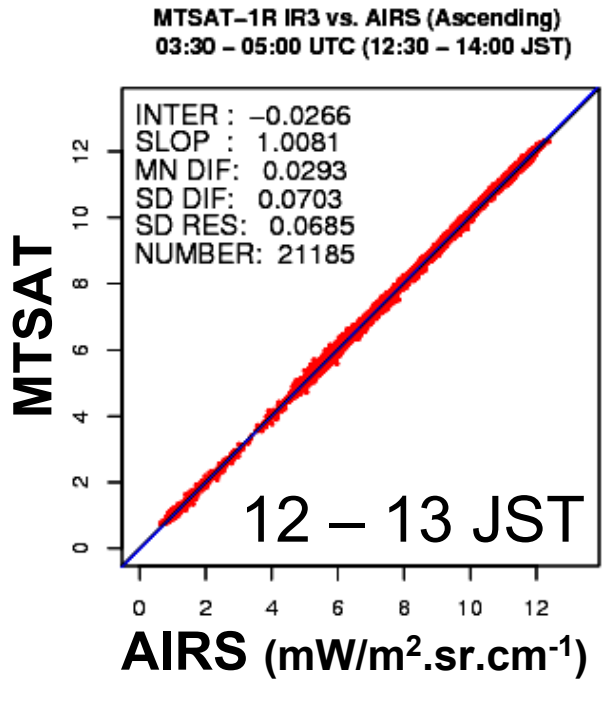
MTSAT-1R 6.8-um vs. AIRS/IASI

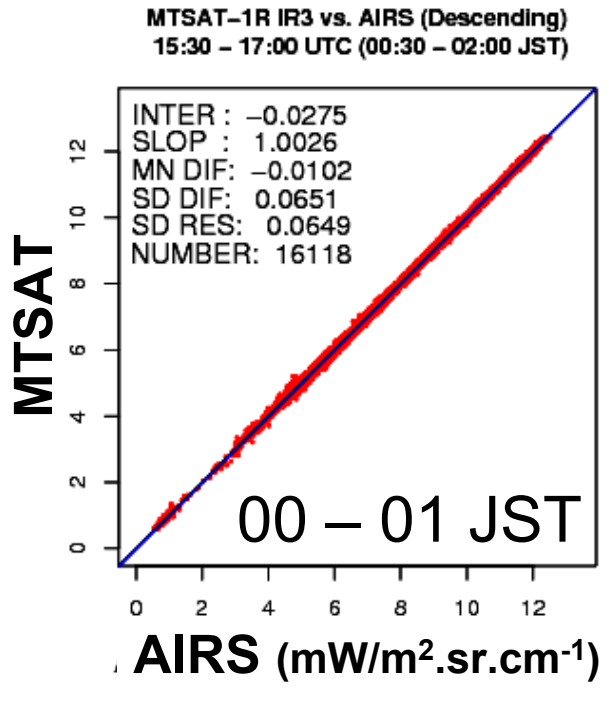
August 2008

* Compensation applied to AIRS super channel computation





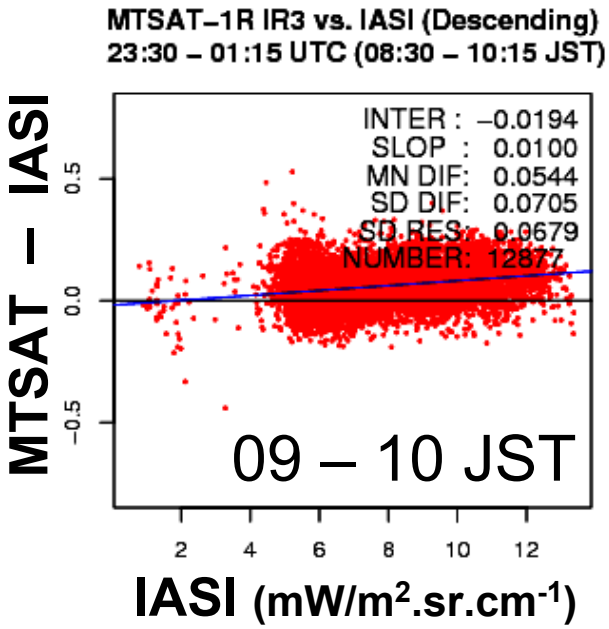


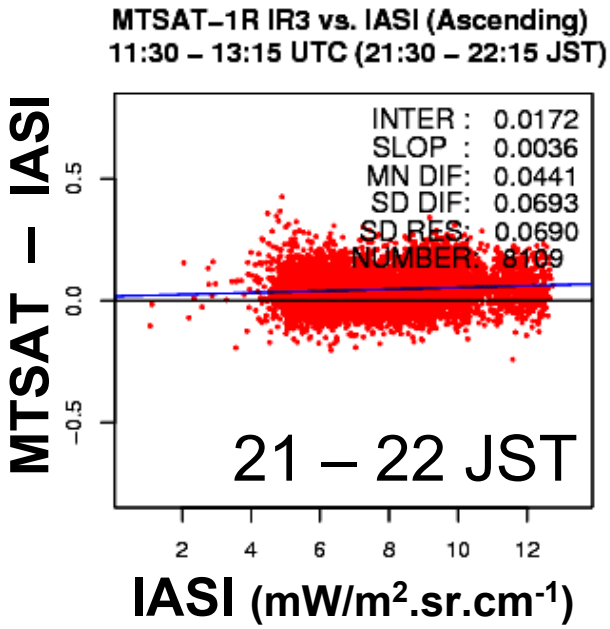


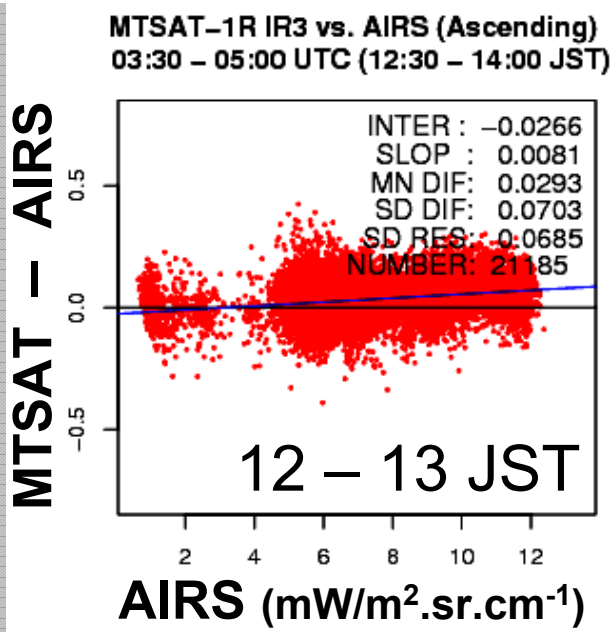
MTSAT-1R 6.8-um vs. AIRS/IASI

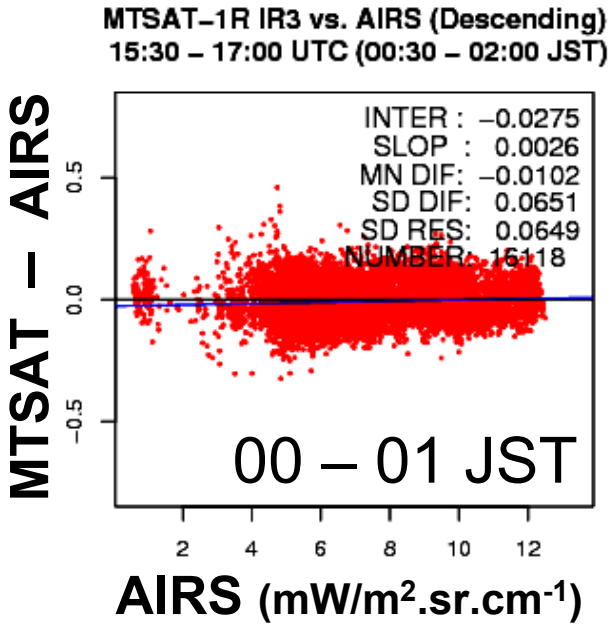
August 2008

- Daytime comparisons against AIRS & IASI show the same result
- Only midnight AIRS comparison shows different from others, that might indicate unknown solar effect on MTSAT



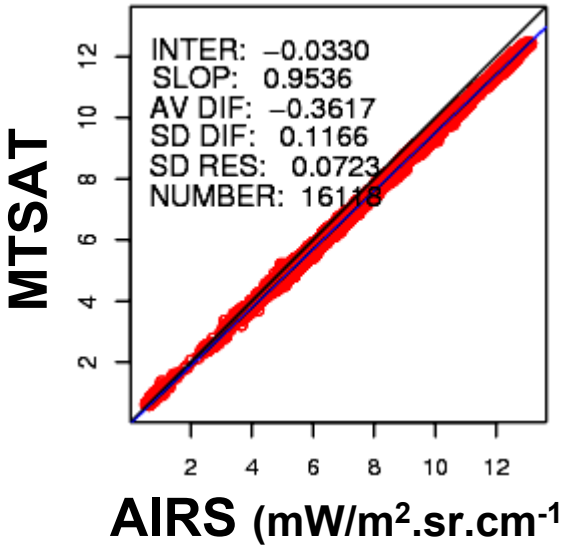




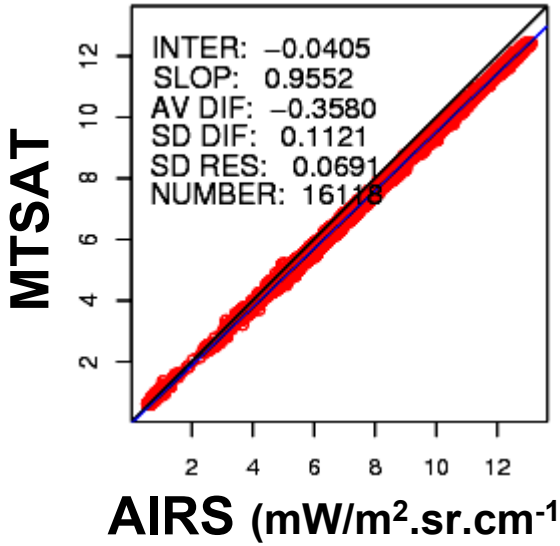


Comparison between Compensation Methods

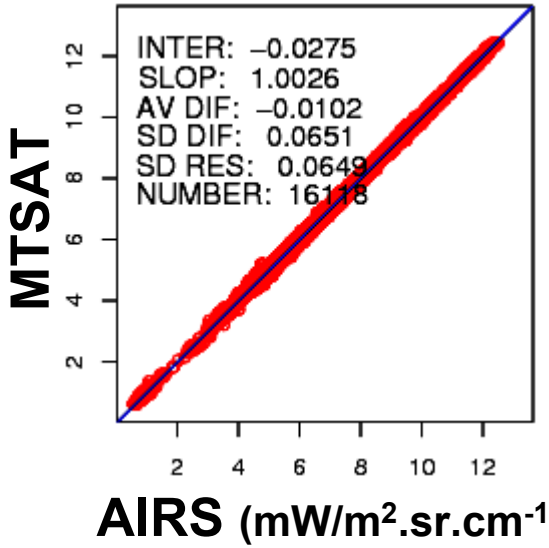
Radiance comparison of MTSAT1R 6.8-um and AIRS



Convolution channel Kato/Wu compensation (GSICS version 1 code)



Convolution channel Gunshor compensation (GSICS version 1 code)



Constraint channel New compensation

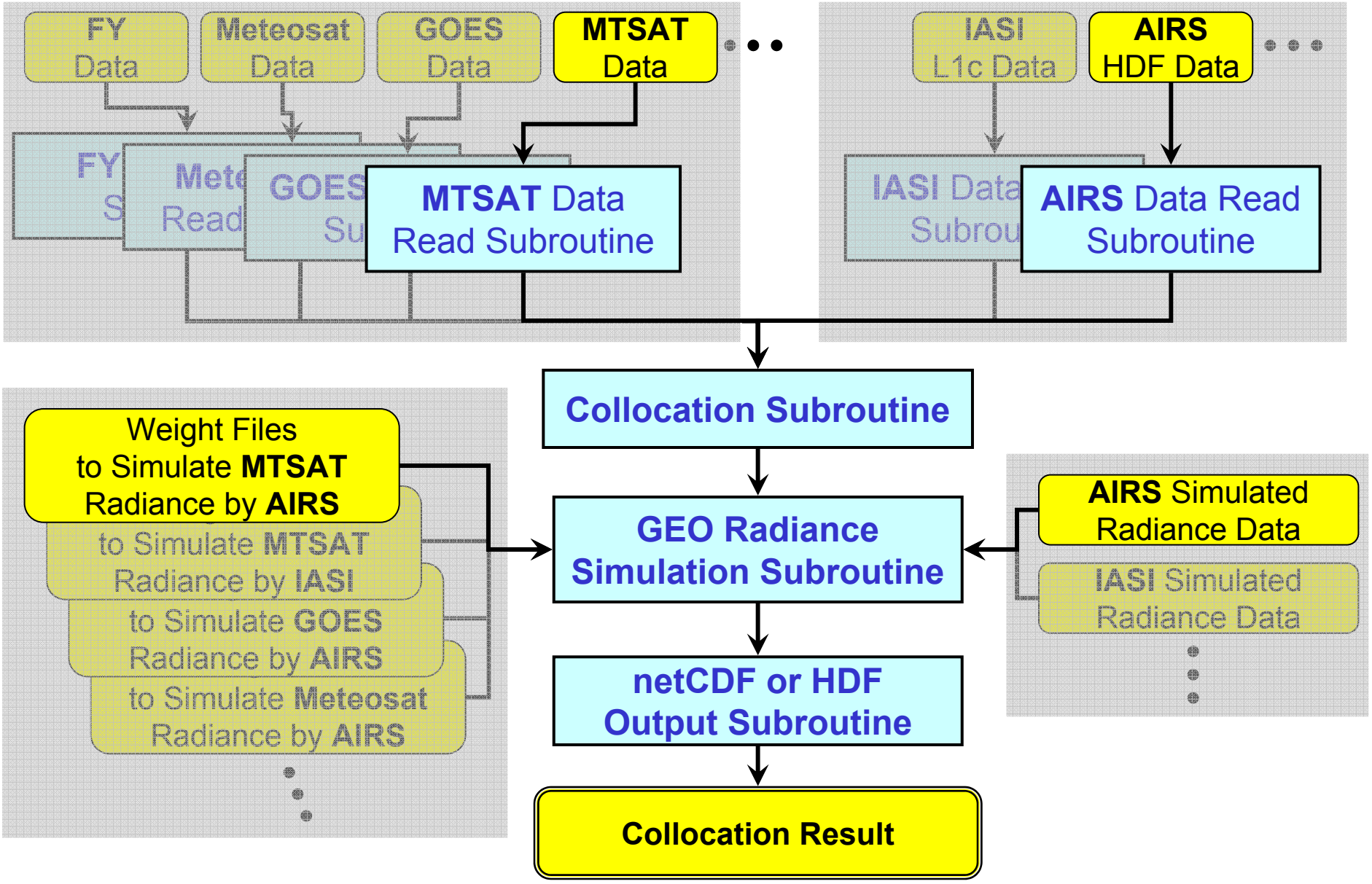
Preparation for Operation of MTSAT-1R Infrared Intercalibration

- **Preparation for AIRS/IASI data download**
  - Examined to download AIRS data from NASA GES DISC and IASI data from NOAA/NESDIS CLASS via the Internet
    → Data volume and download time acceptable
  - Automatic AIRS/IASI data download script
    → Only AIRS data from NASA supported currently
    → Written in Pearl script
    → Details will be reported in GDWG session
  - **Issue is we don't know where to download IASI data**
- **Implementation of GSICS version 1 code**
  - AIRS, IASI, MTSAT/GMS data access
  - NetCDF and HDF5 output
  - Fortran90 code
  - No change on the original algorithm
  - New GEO radiance estimation implemented in addition

JMA Intercalibration Code

- **Fortran90 modules to ease maintenance and introduction of new satellite and algorithm**
  - GEO module, LEO module, collocation module, GEO radiance simulation module, NetCDF/HDF5 output modules
- **Structure variable control to keep code intelligible**
  - type(GeoData_Def) :: geo *! GEO data*
  - type(LeoData_Def) :: leo *! LEO data*
  - type(Colloc_Def) :: colloc *! collocation information*
- **No change on GRWG algorithm version 1**
  - New GEO radiance estimation algorithm implemented in addition to the GRWG version 1 algorithm
- **Access to IASI and MTSAT native data besides AIRS**
  - IASI PFS L1c data
  - AIRS HDF L1b data
  - MTSAT/GMS native data (using JMA original library)

Program Flow



F90 Modules

New satellite implemented by replacing either GEO module "access_geo" or LEO module "access_leo"

program **geo_leo_intercal_ir**
[variable definition] geo, leo, colloc

call open_geo(geo, GeoFile)
call get_geo_radiance(geo)

call open_leo(leo, LeoFile)
call get_leo_data(leo)

call colloc_geo_leo(geo, leo, colloc)

call get_simgeo_convolution
call get_simgeo_constrain
(geo, leo, colloc)

call write_colloc_netcdf/HDF
(geo, leo, colloc, CollocFile)

call close_geo(geo)
call close_leo(leo)

module **common_constants**
- Basic constants defined

module **access_geo**
- Definition of GEO data structure
- Subroutines to open/close GEO, get GEO data, deallocate arrays

module **access_leo**
- Definition of LEO data structure
- Subroutines to open/close LEO, get LEO data, deallocate arrays

module **collocate_geo_leo**
- Definition of collocation data structure
- Subroutines to collocate GEO-LEO, deallocate arrays

module **simulate_georad_convolution**
module **simulate_georad_constrain**
- Subroutines to estimate GEO radiances from LEO data, deallocate arrays

module **write_colloc**
- Subroutine to write out results

Libraries for Make

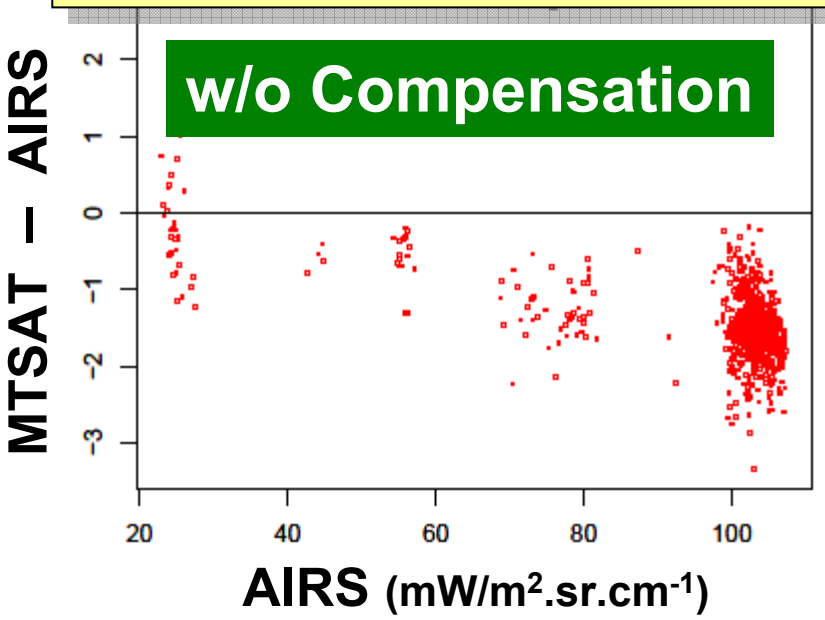
- To read AIRS L1b HDF
  - **HDF4 and HDF5 library**
    - http://hdf.ncsa.uiuc.edu/index.html
  - **HDF-EOS2 libraries**
    - http://hdfeos.org/software.php
- To read IASI PFS L1c
  - **Library in AAPP software**
    - http://www.metoffice.gov.uk/research/interproj/nwpsaf/aapp/
- To simulate GEO radiance by new compensation method
  - **LAPACK** (Fortran interface)
    - http://www.netlib.org/lapack/
- To write out results in NetCDF format
  - **NetCDF library**
    - http://www.unidata.ucar.edu/software/netcdf/

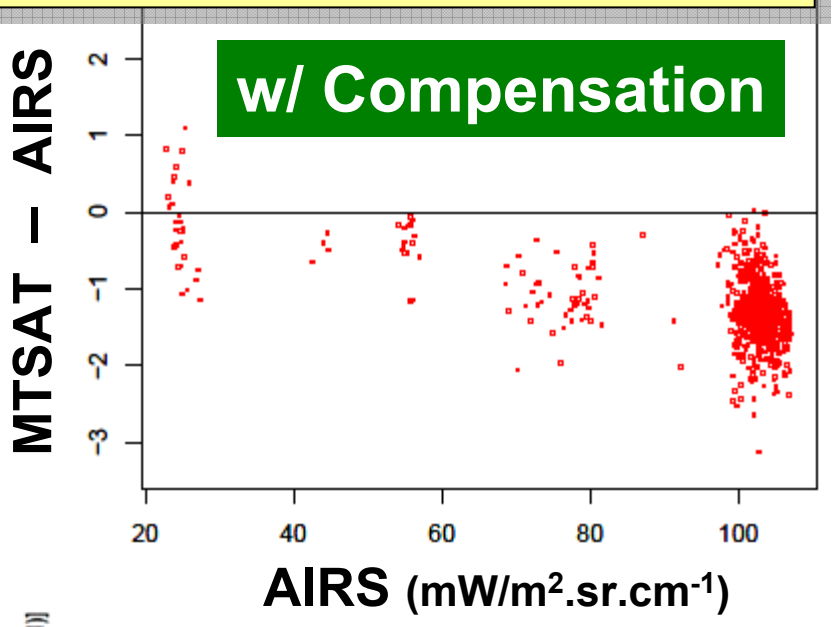
Parameter Files for GEO Simulation

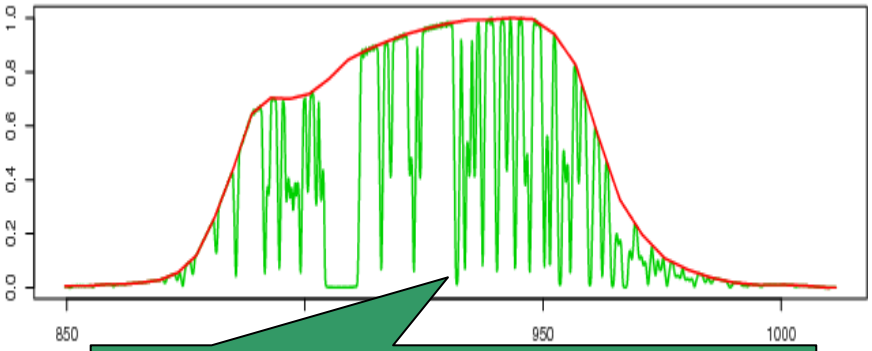
- **LBL radiance files**
  - 0.001 cm^{-1} resolution from 550 cm^{-1} to 3050 cm^{-1}
  - LBLRTM (ver 11.1) with HITRAN2004 including AER updates (ver 2)
  - 8 model profiles (US, Trop, mid-lat summer/winter under clear, cloudy)
- **Hyper sounder simulated radiance files**
  - Radiances of AIRS, IASI and their gap channels for 8 model profiles
  - Computed from the LBL radiances
- **Super channel weight files**
  - Weights computed by the "convolution" and "constraint" methods
    - MTSAT-1R, 2 ←→ AIRS, IASI
    - GOES-10, 11, 12, 13 ←→ AIRS, IASI (for "constraint" only)
    - METEOSAT-8, 9 ←→ AIRS, IASI (for "constraint" only)
- **Code to compute the parameter files**
  - Written in the R language
    (free and powerful statistical tool, http://www.r-project.org/)

Compensation vs. No Compensation

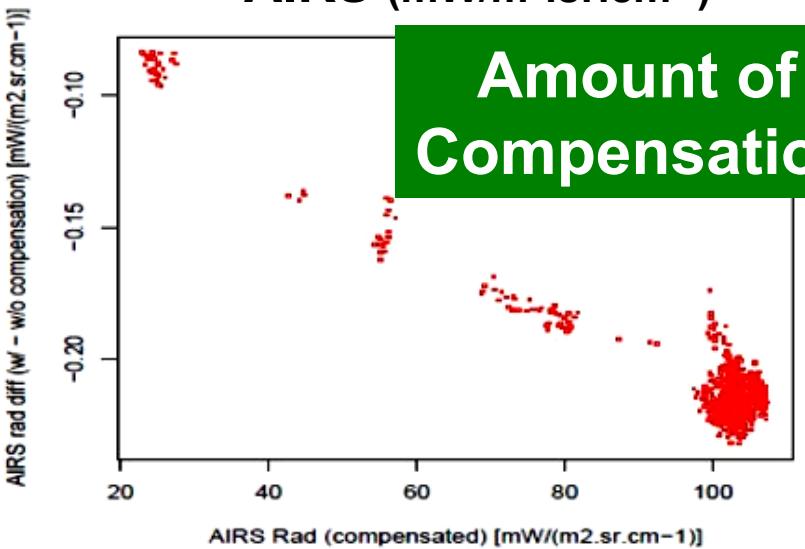
Radiance comparison of MTSAT1R 10.8-um and AIRS







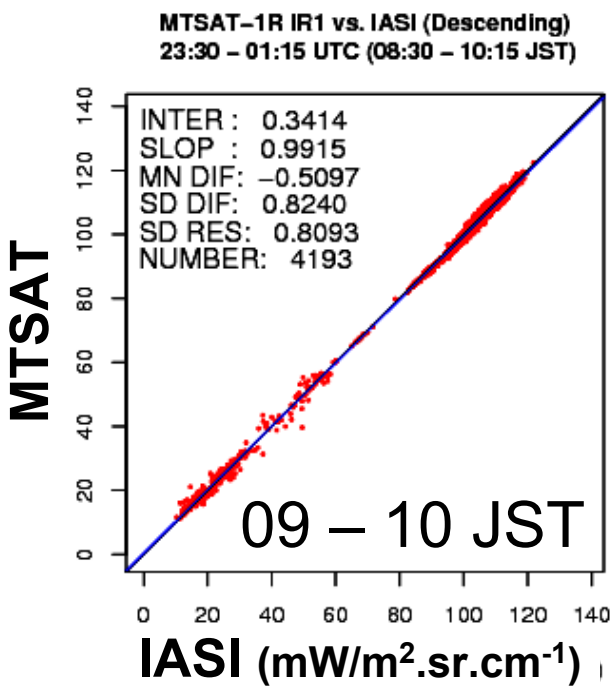
SRF of super channel not using blacklisted and gap channels

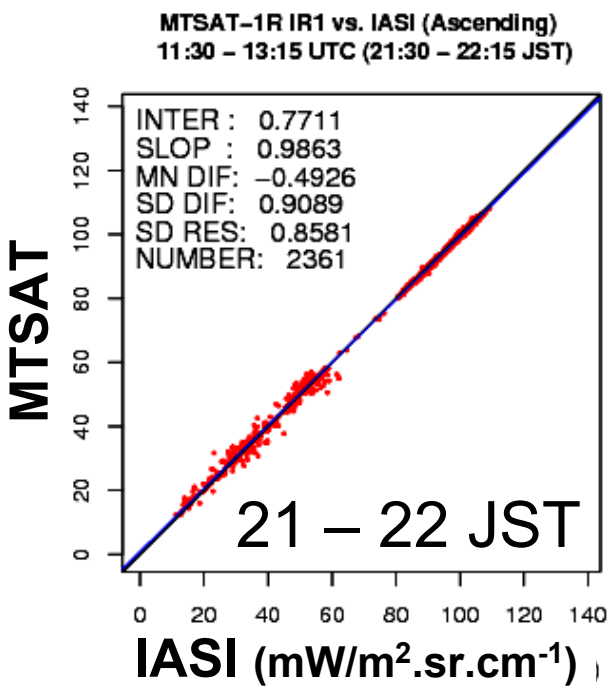


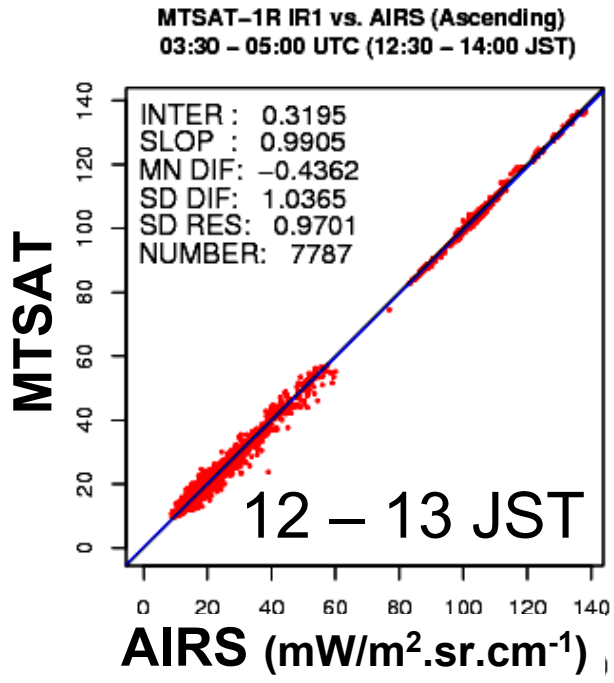
MTSAT-1R 10.8-um vs. AIRS/IASI

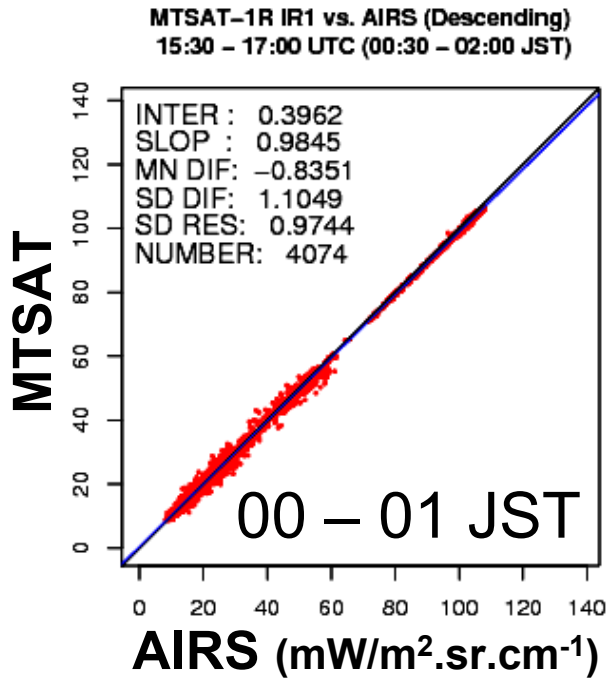
August 2008

* Compensation applied to AIRS super channel computation





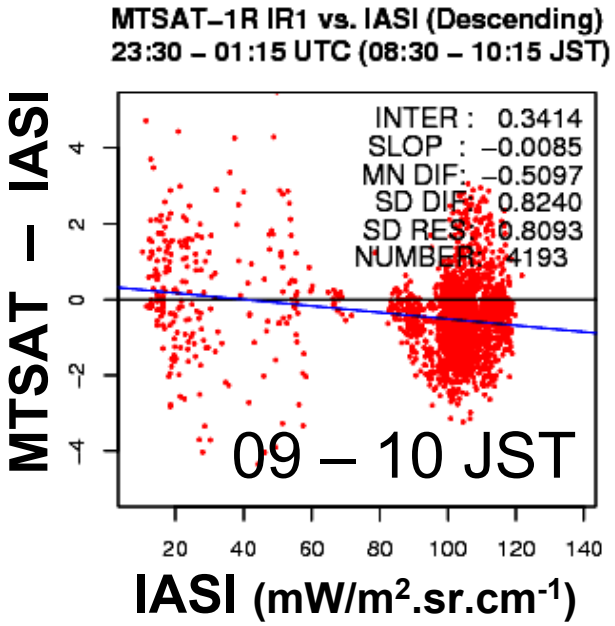


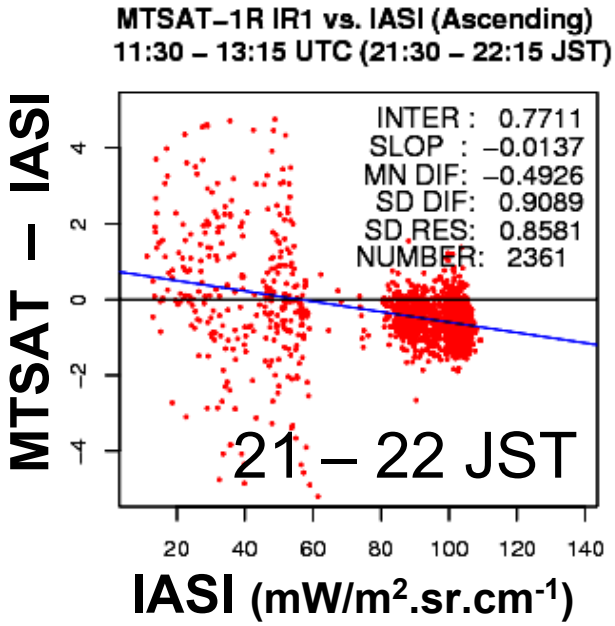


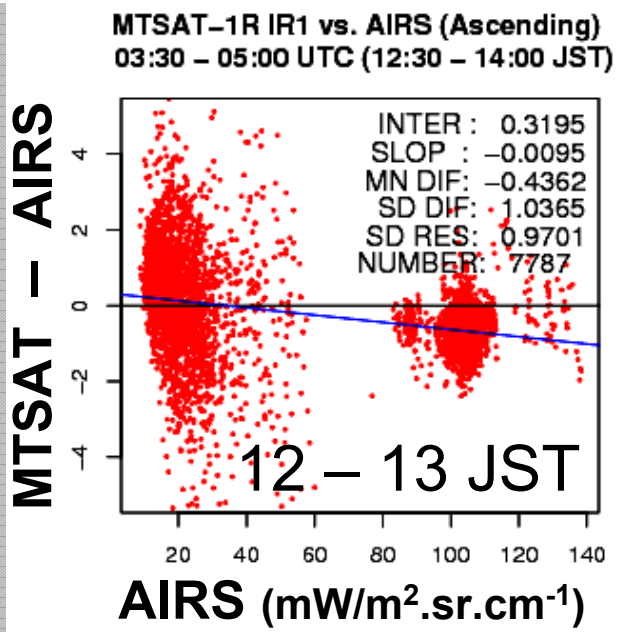
MTSAT-1R 10.8-um vs. AIRS/IASI

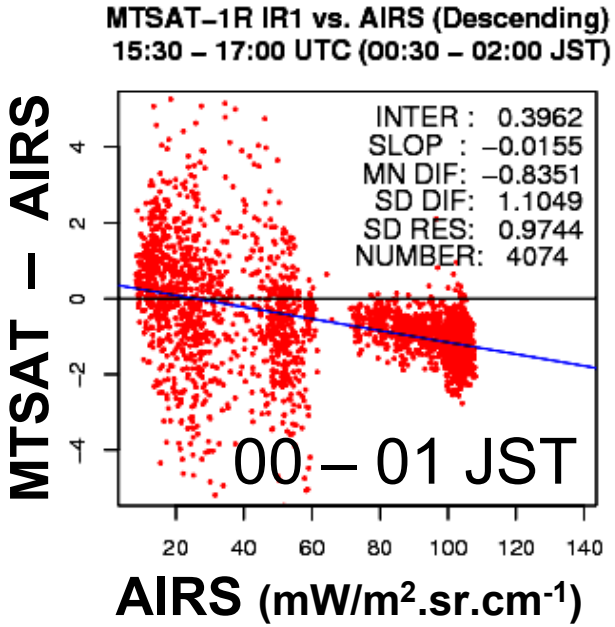
August 2008

- Daytime comparisons against AIRS & IASI show the same result
- Only midnight AIRS comparison shows different from others, that might indicate unknown solar effect on MTSAT





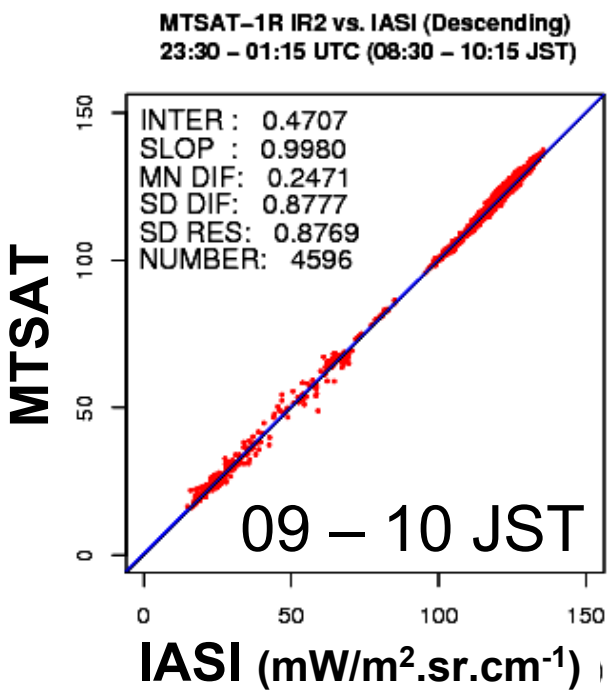


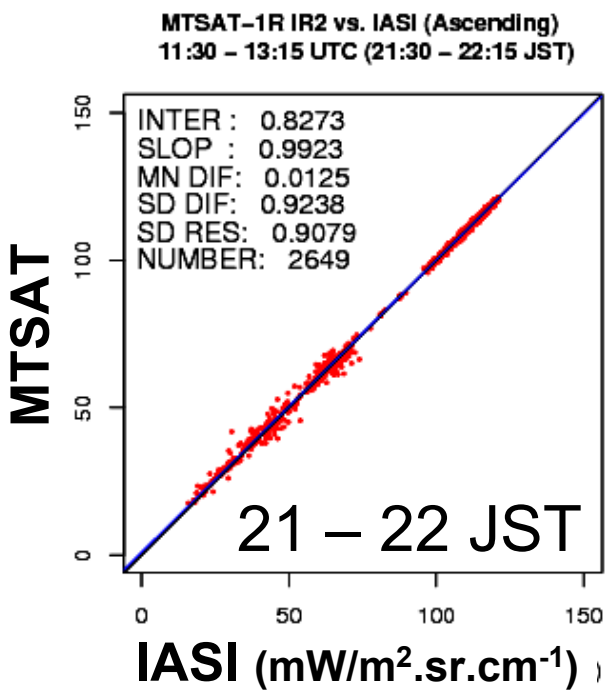


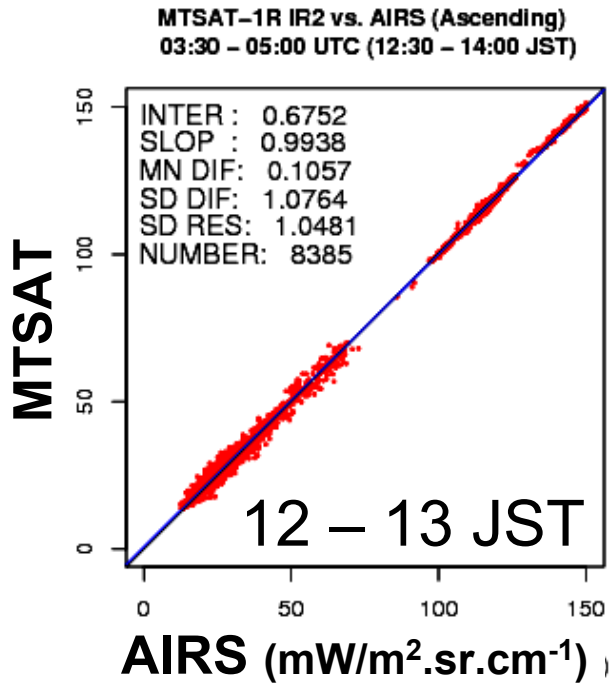
MTSAT-1R 12.0-um vs. AIRS/IASI

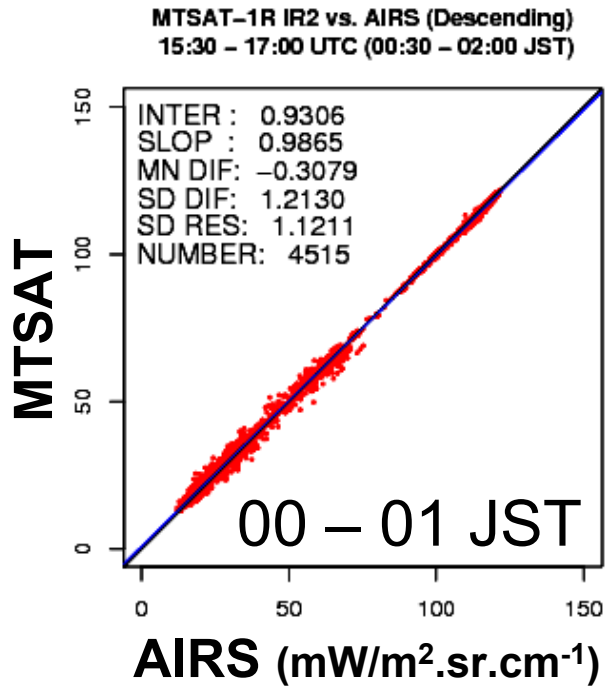
August 2008

* Compensation applied to AIRS super channel computation





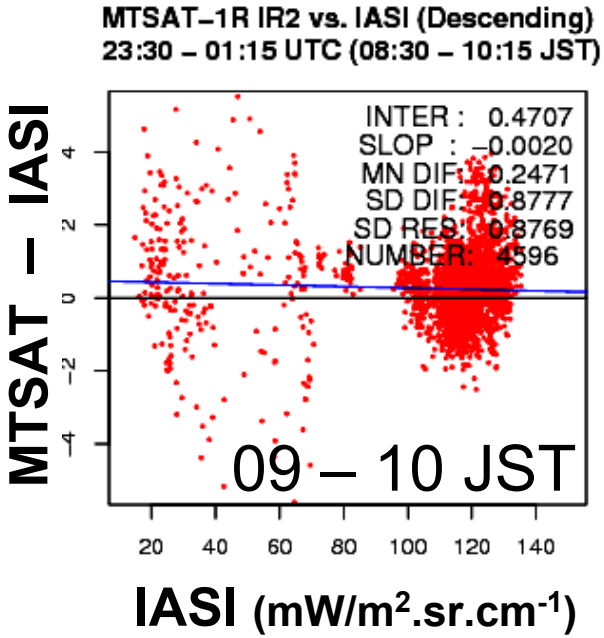


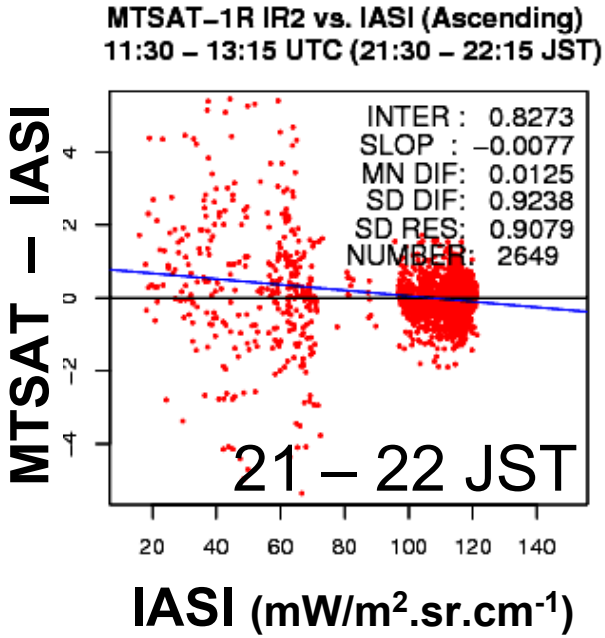


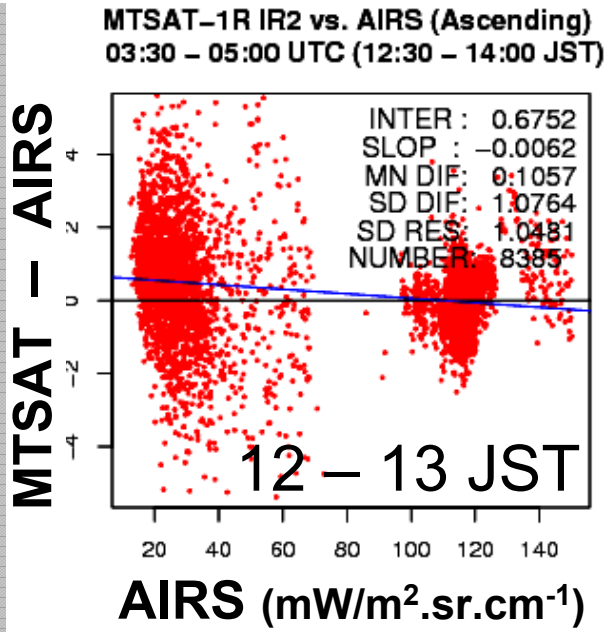
MTSAT-1R 12.0-um vs. AIRS/IASI

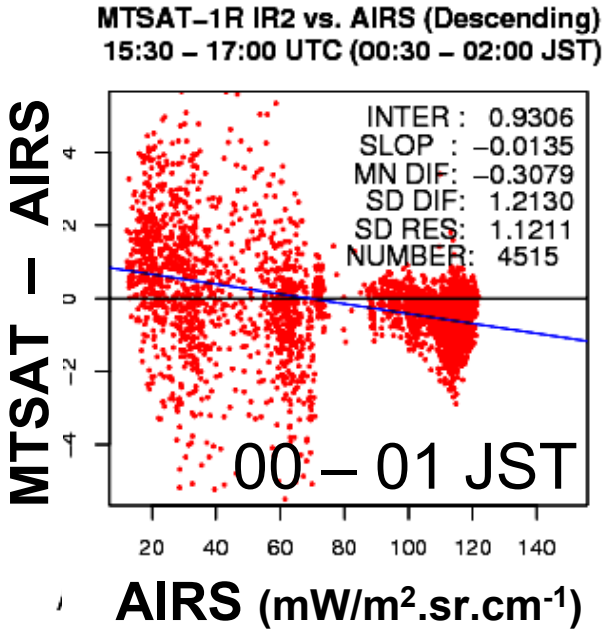
August 2008

- Daytime comparisons against AIRS & IASI show the same result
- Only midnight AIRS comparison shows different from others, that might indicate unknown solar effect on MTSAT



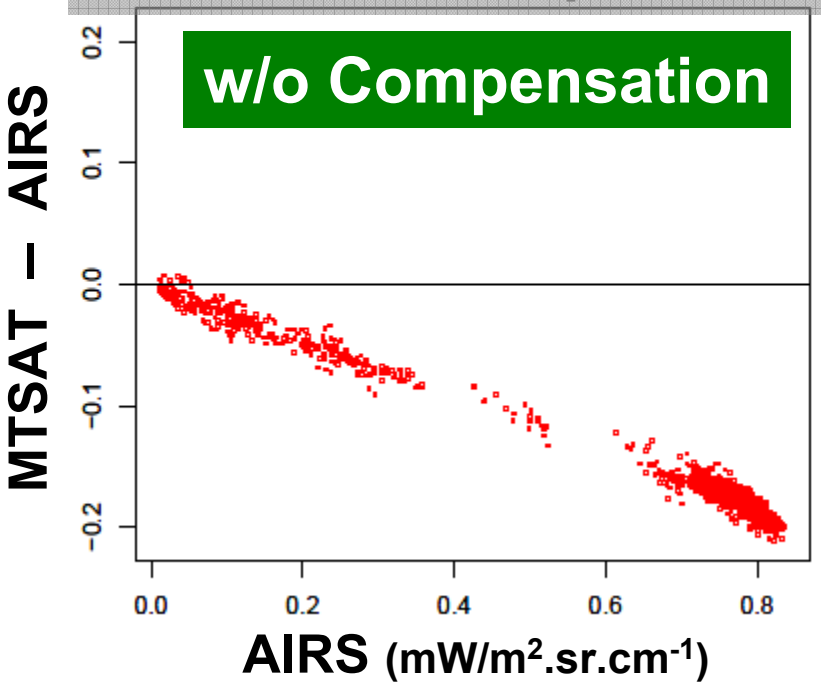


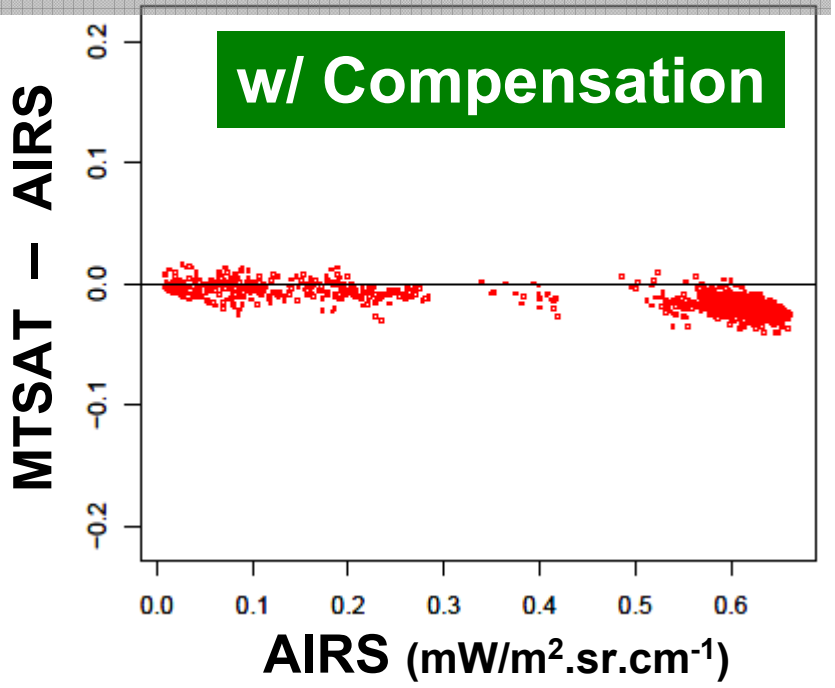


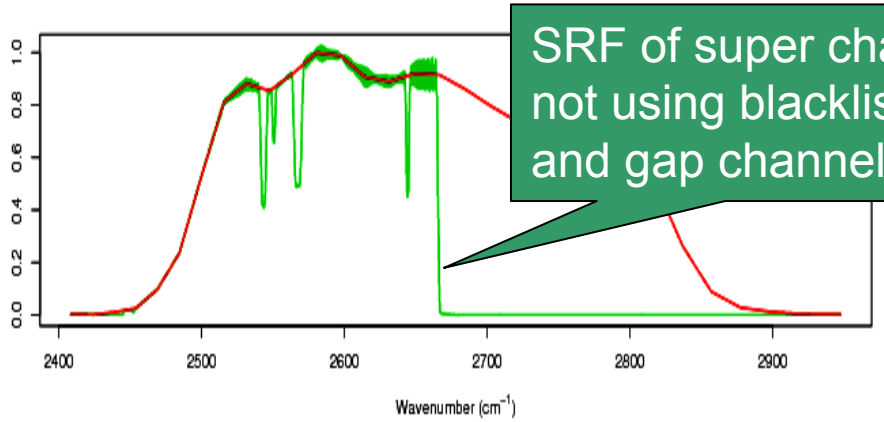


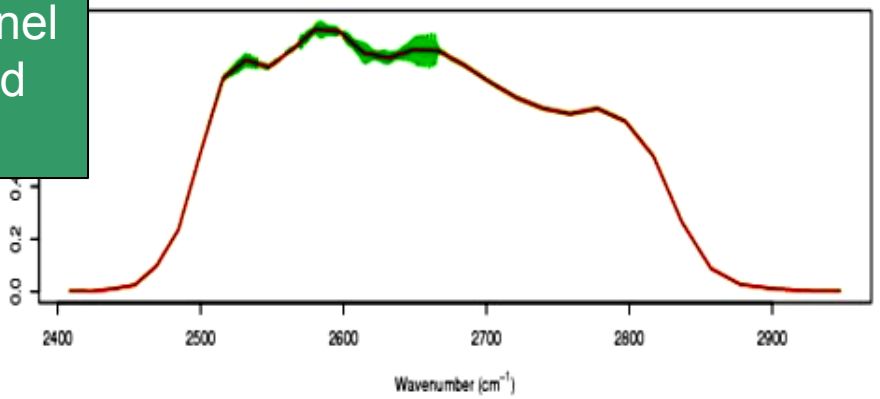
Compensation vs. No Compensation

Radiance comparison of MTSAT1R 3.8-um and AIRS





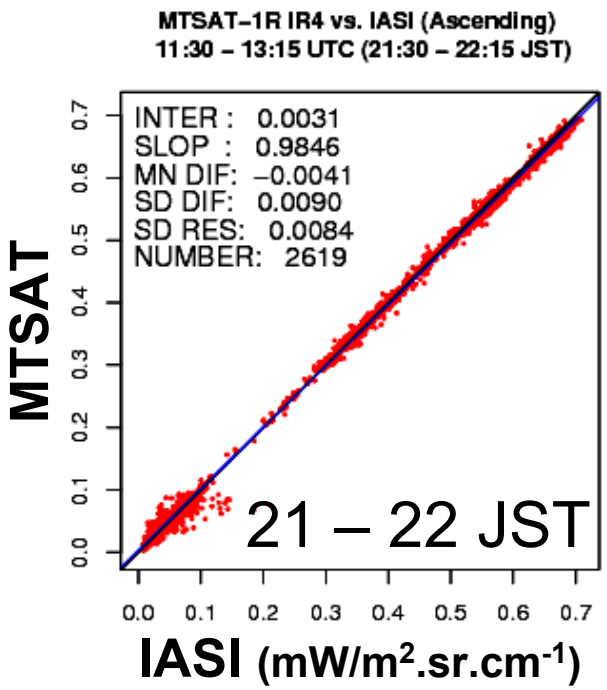


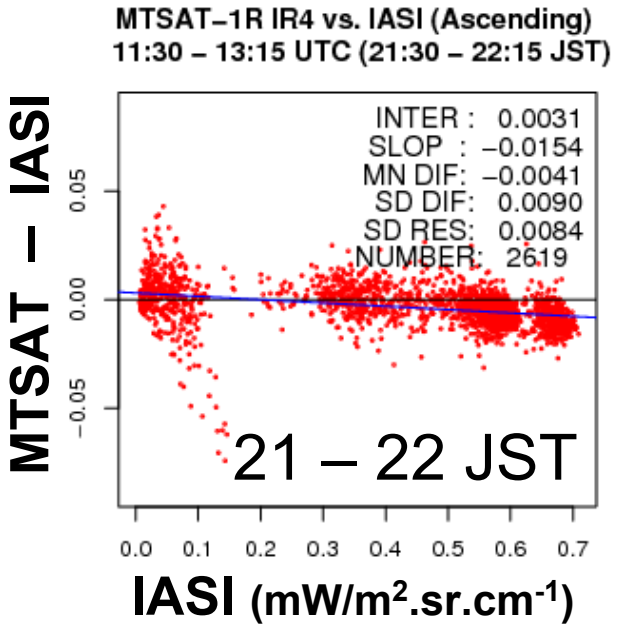


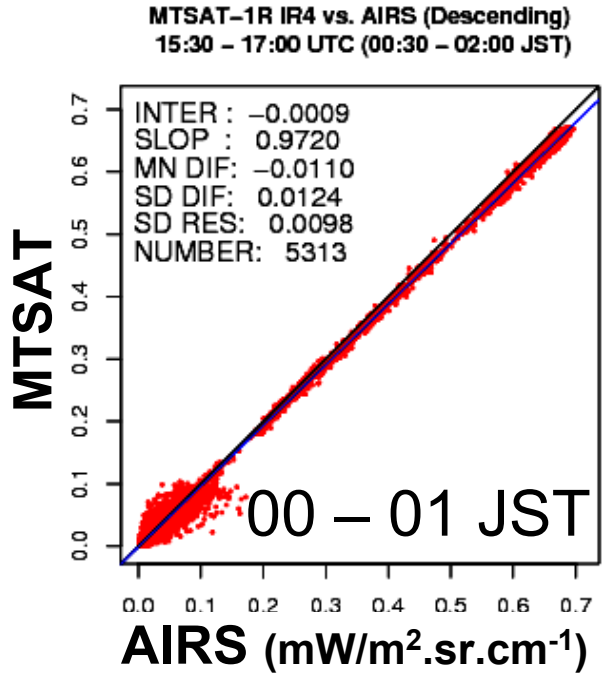
MTSAT-1R 3.8-um vs. AIRS/IASI

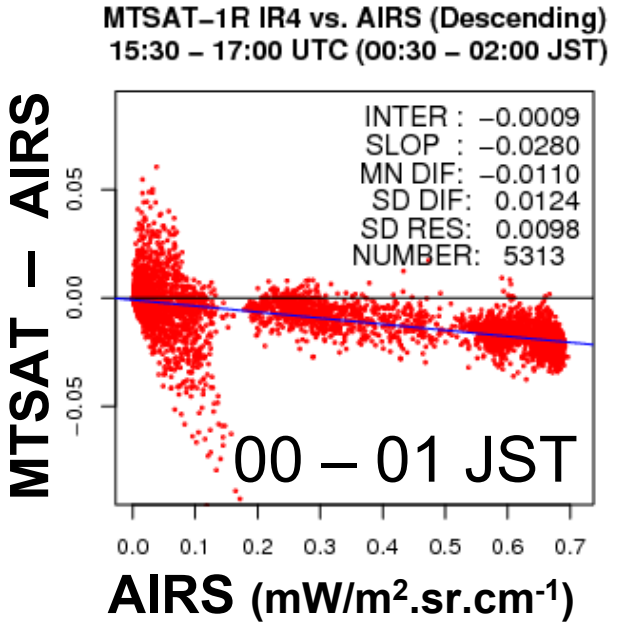
August 2008

* Compensation applied to both AIRS and IASI super channel computation



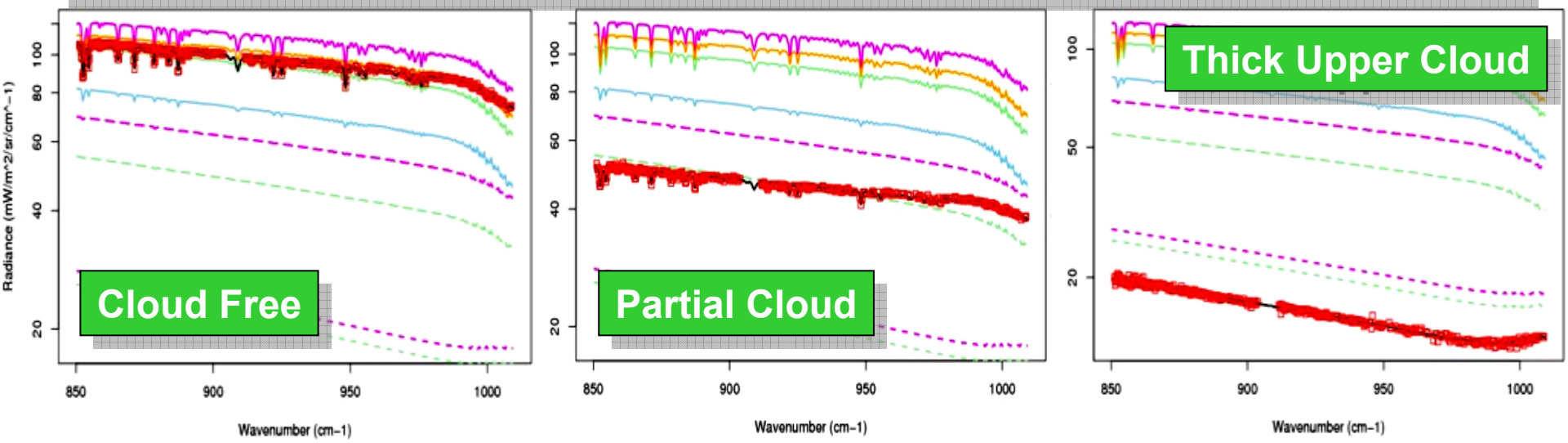




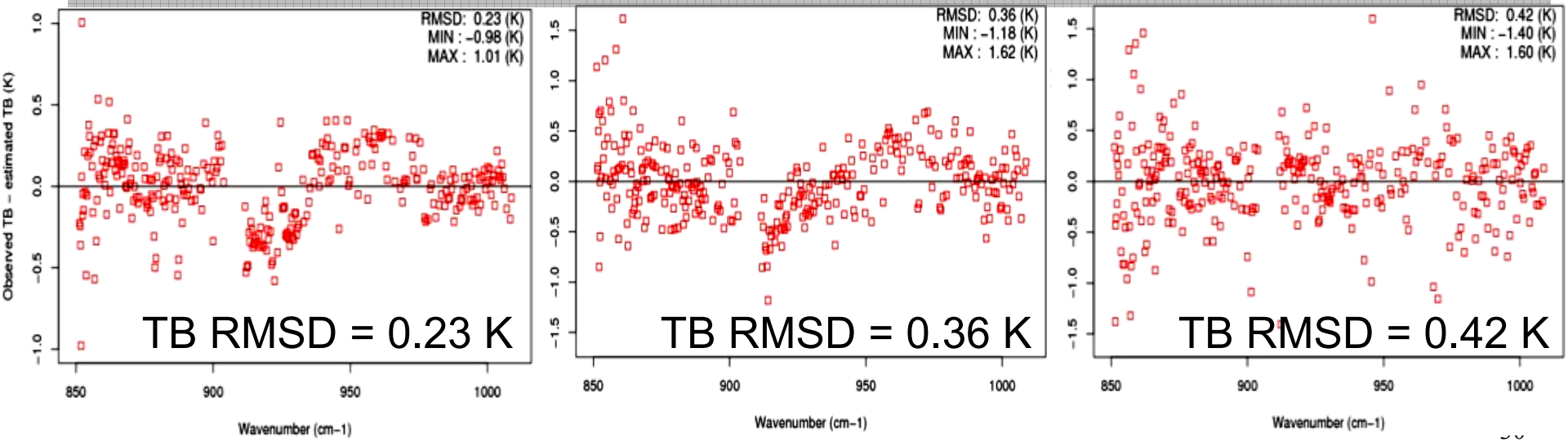


AIRS Radiance Estimation over MTSAT 10.8-um

Estimated AIRS radiances

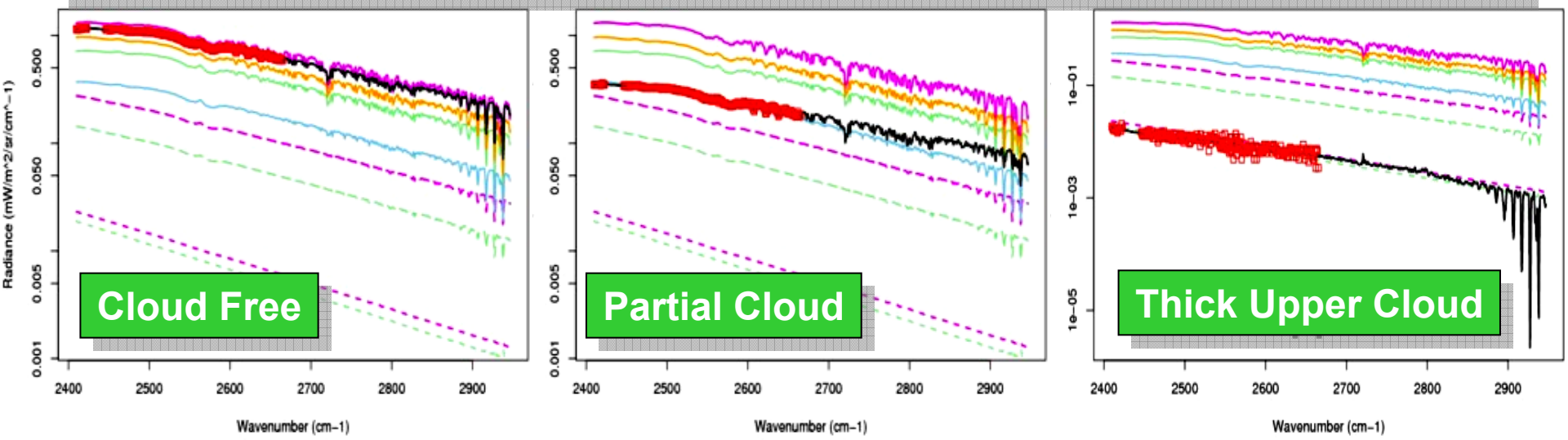


TB differences between AIRS observations and estimations

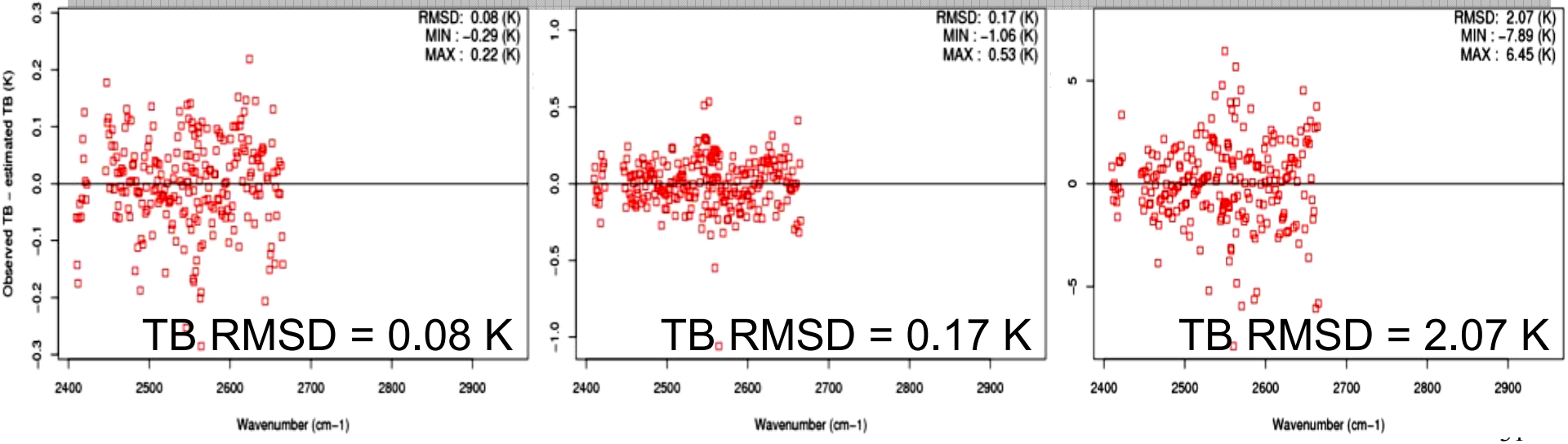


AIRS Radiance Estimation over MTSAT 3.8-um

Estimated AIRS radiances

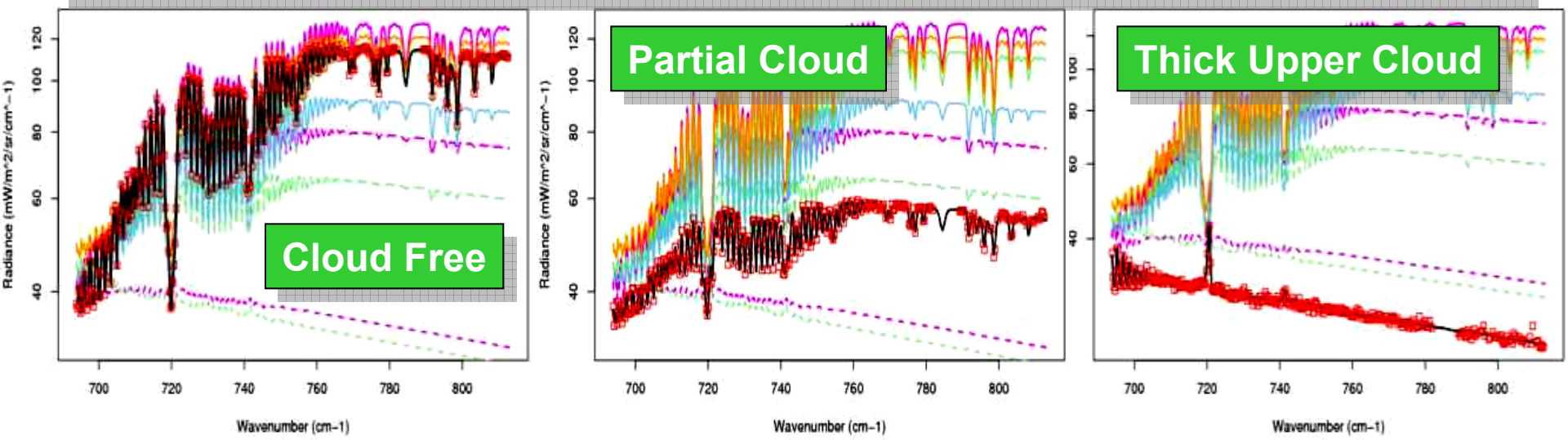


TB differences between AIRS observations and estimations

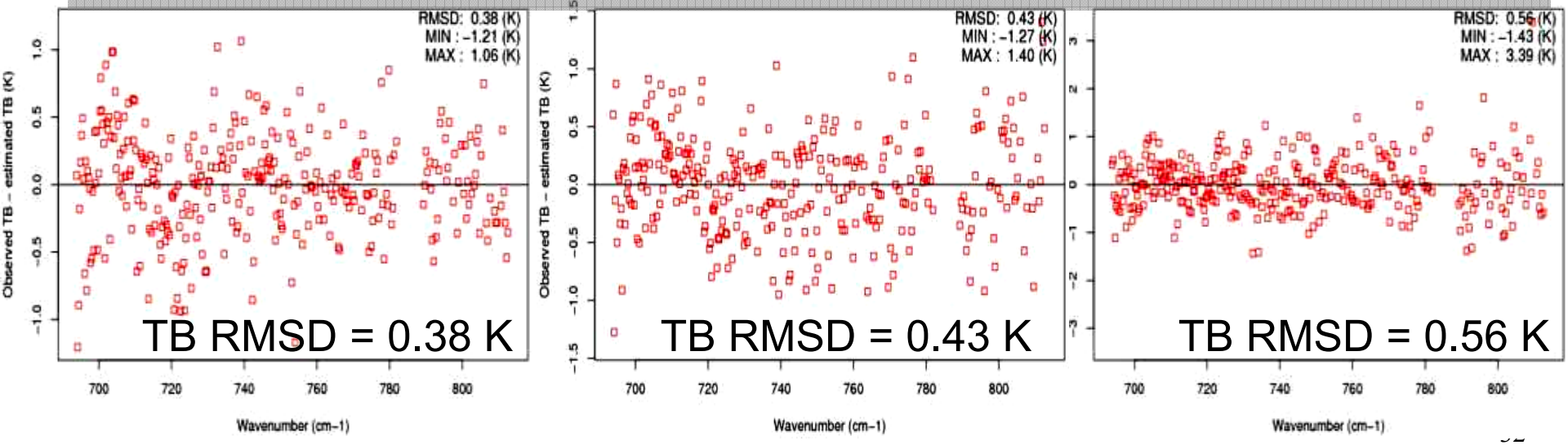


AIRS Radiance Estimation over Meteosat 13.4-um

Estimated AIRS radiances

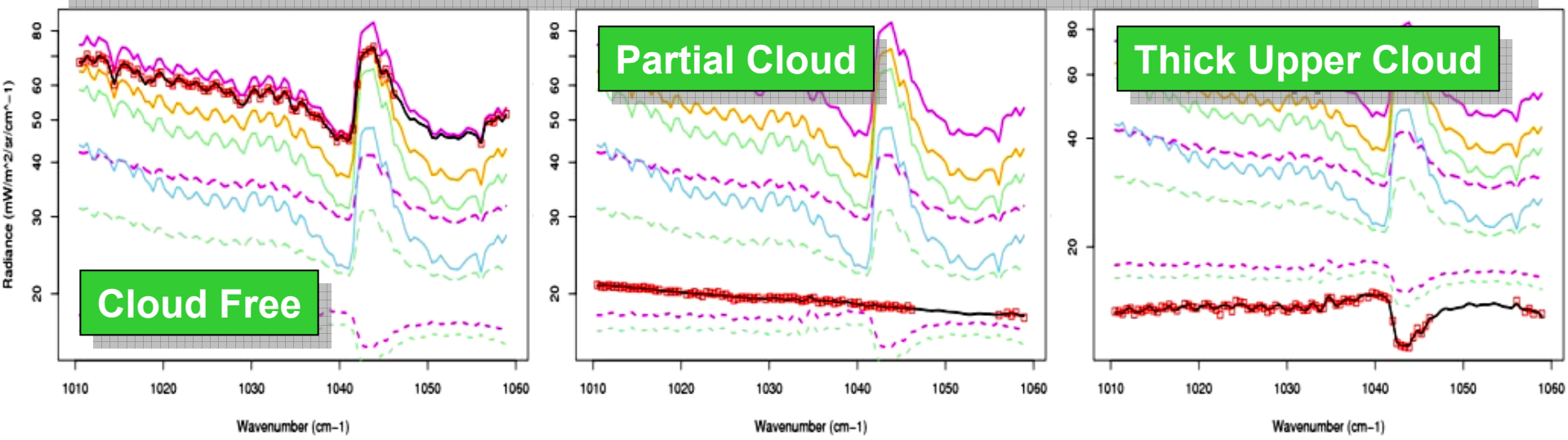


TB differences between AIRS observations and estimations

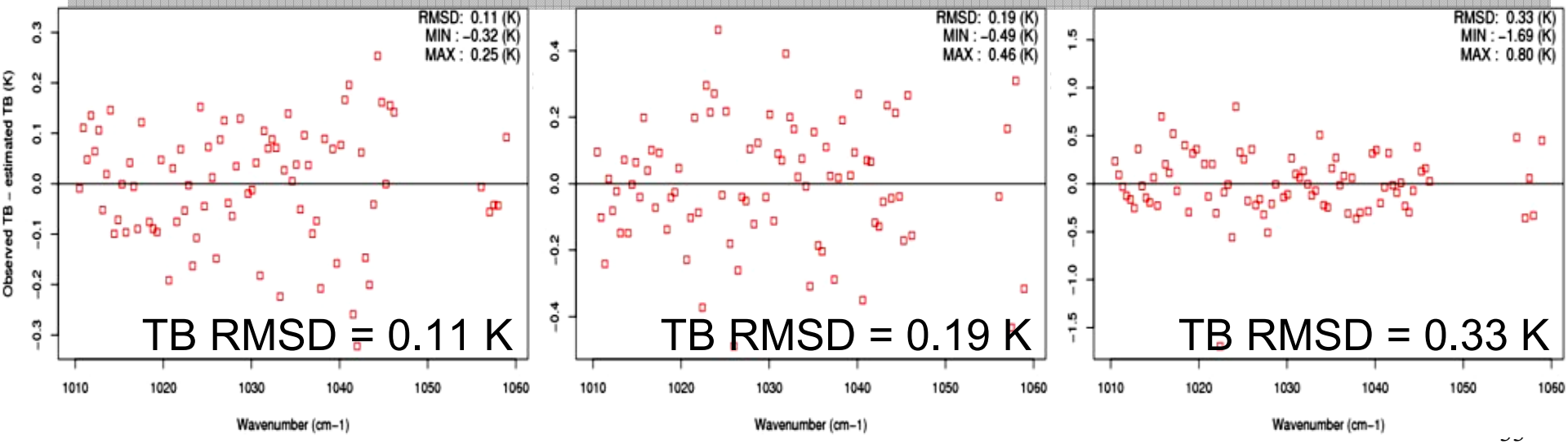


AIRS Radiance Estimation over Meteosat 9.7-um

Estimated AIRS radiances

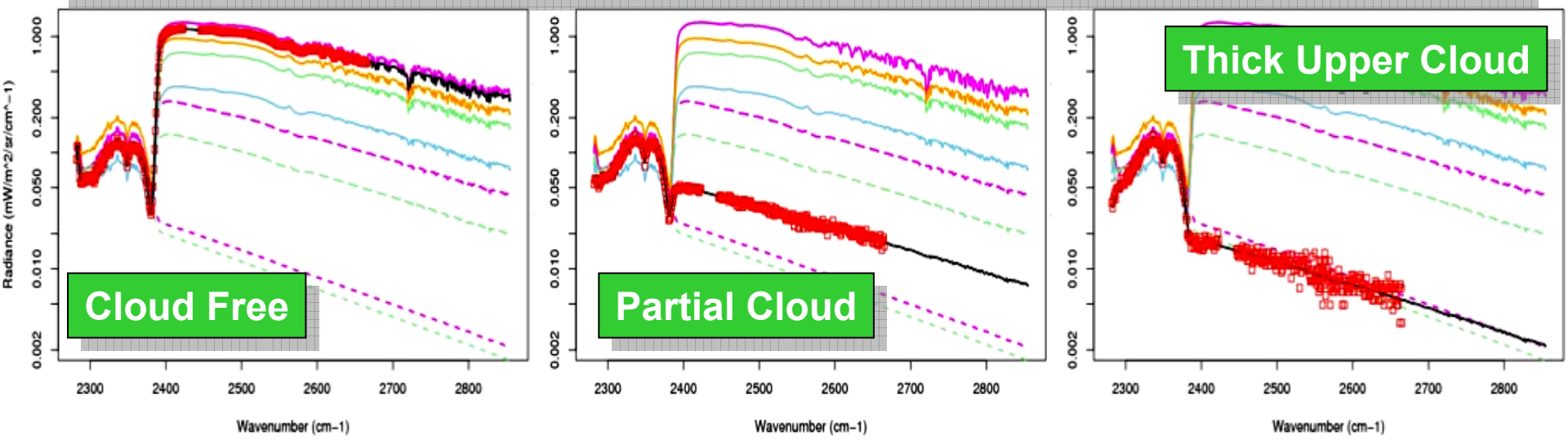


TB differences between AIRS observations and estimations



AIRS Radiance Estimation over Meteosat 3.9-um

Estimated AIRS radiances



TB differences between AIRS observations and estimations