Development of the MTSAT1R visible footprint point spread function

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Background

- For CERES processing performed MTSAT1R/Aqua-MODIS 0.65μm channel inter-calibration

- The individual MTSAT-1R/Aqua-MODIS radiance pairs revealed a non-linear relationship
  - Presented at the 2009 Annual GSICS meeting at JMA
  - Derived a linear relationship using SZA adjustment factor

- Requested coincident MTSAT-2 commissioning and MTSAT-1R operational images
  - Obtained images in July 2011 from Arata Okuyama
  - 3 days of coincident images during Dec 21-23, 2010

- Analyzed coincident images and found an increase in the clear-sky radiances near bright clouds
  - Developing a point spread function to subtract a small contribution over a large field of view
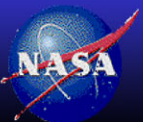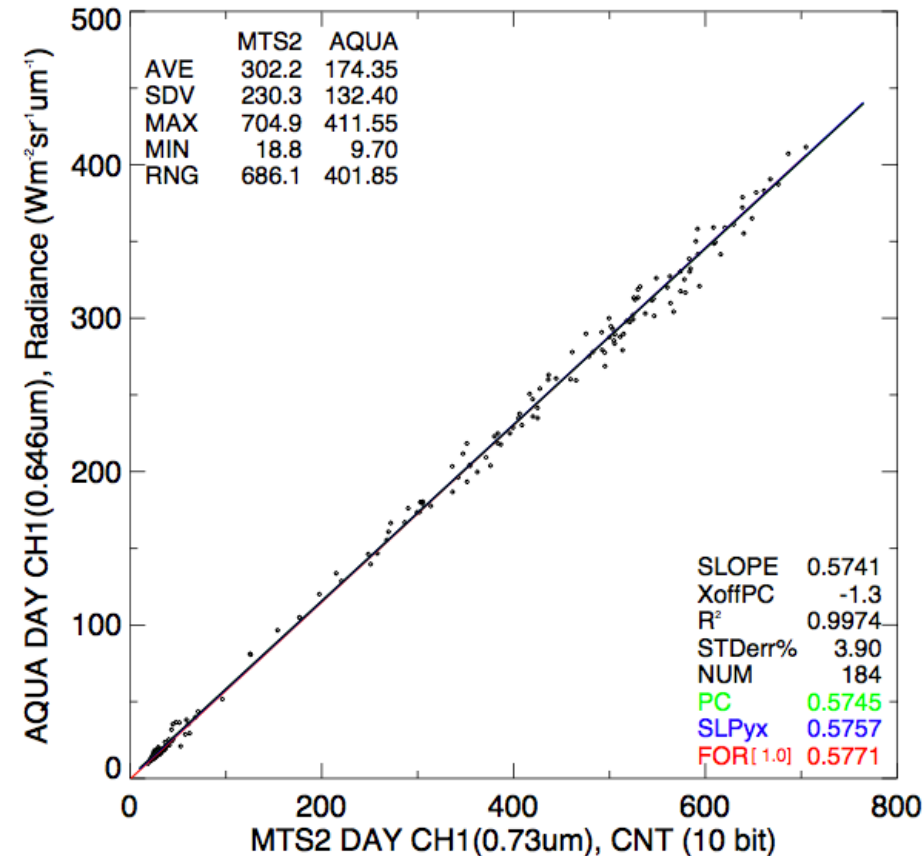
GEO to MODIS Cross-Calibration Method

- None of the GEO visible sensors have onboard calibration
- Ray-match GEO counts (proportional to radiance) and MODIS radiances within a 0.5° ocean regions using selection constraints
  - ΔSZA< 5° (15 minutes), ΔVZA<10°, ΔRAZ < 15°, no sunglint
  - Domain ±20° E,W and ± 15° N,S near sub-satellite point to maximize coincident matches
  - Use Aqua-MODIS Collection 6 as reference
  - Use a SCIAMACHY spectral band adjustment factor derived from all SCIA footprints over the same equatorial region
  - Normalize the cosine solar zenith angle
- Perform monthly linear regressions and derive monthly gains
  - Use published offsets
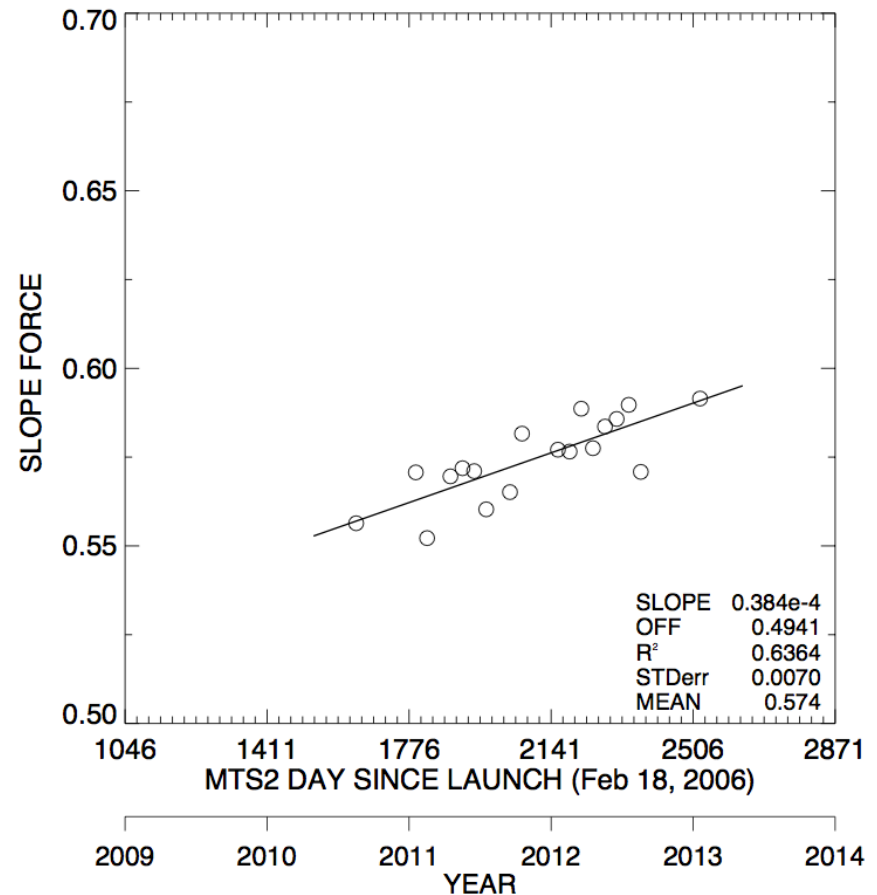- Compute timeline trends from monthly gains

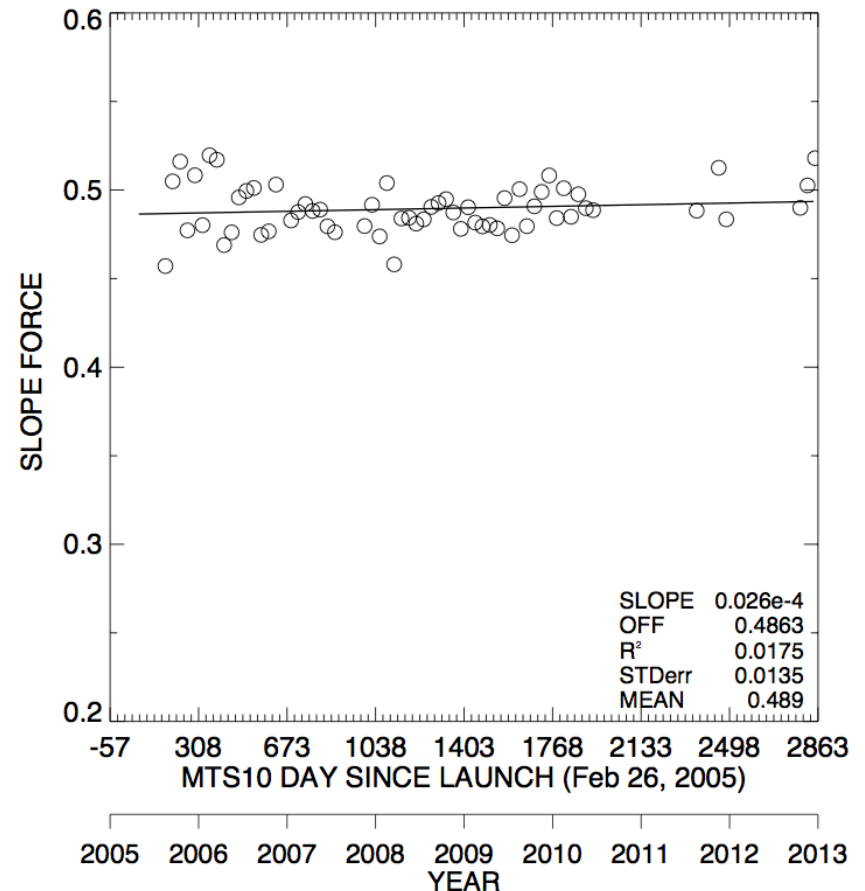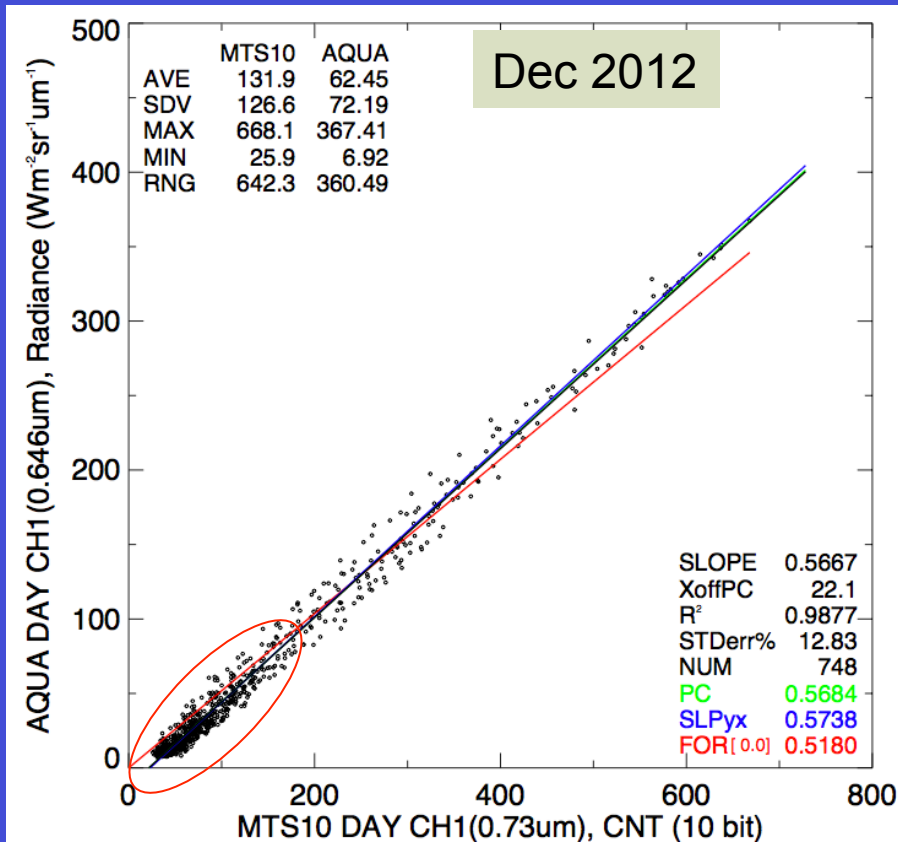# MTSAT-2/Aqua-MODIS ray-match inter-calibration

MTSAT-1R/Aqua-MODIS ray-match inter-calibration

Dec 2012

	MTS10	AQUA
AVE	131.9	62.45
SDV	126.6	72.19
MAX	668.1	367.41
MIN	25.9	6.92
RNG	642.3	360.49

SLOPE	0.5667
XoffPC	22.1
R²	0.9877
STDerr%	12.83
NUM	748
PC	0.5684
SLPyx	0.5738
FOR[0.0]	0.5180

SLOPE	0.026e-4
OFF	0.4863
R²	0.0175
STDerr	0.0135
MEAN	0.489

- The MTSAT-1R an has a space count of zero
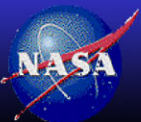
MTSAT-1 Ed2 nonlinear calibration

MTSAT-1/Terra April 2006
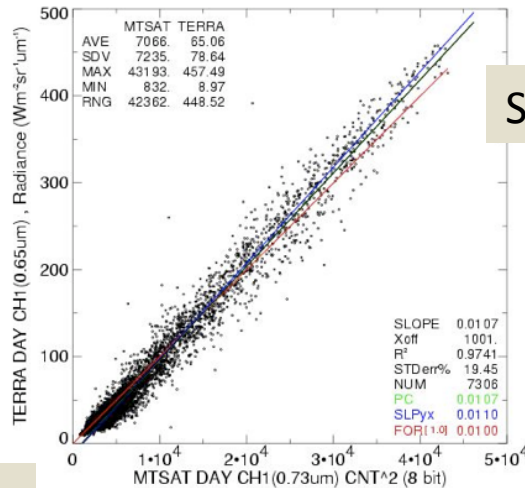
MTSAT-1/VIRS

Stratified by SZA
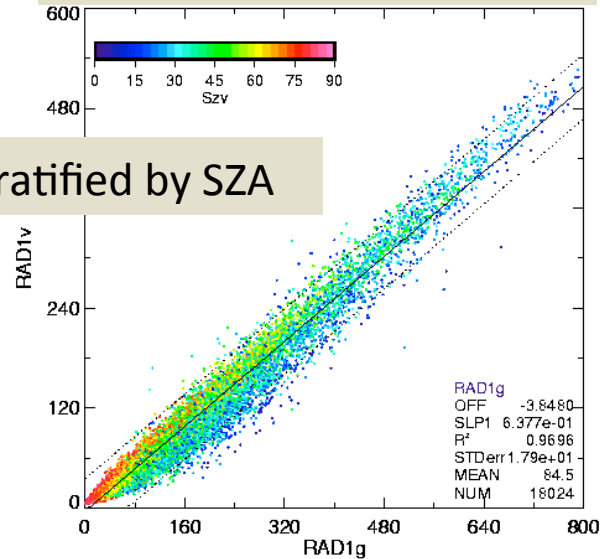
MTSAT-1 nonlinear gain

GEO-derived Broadband fluxes
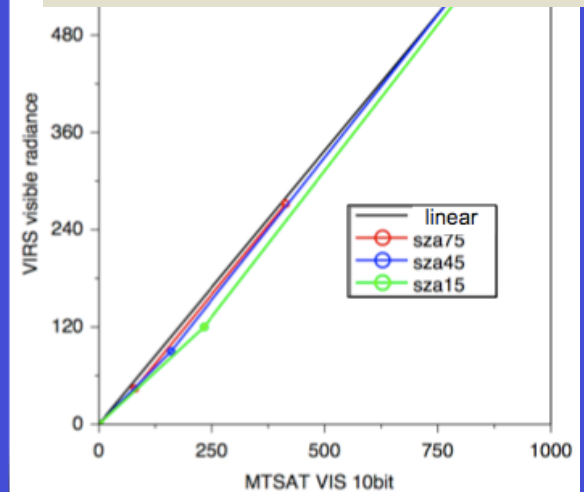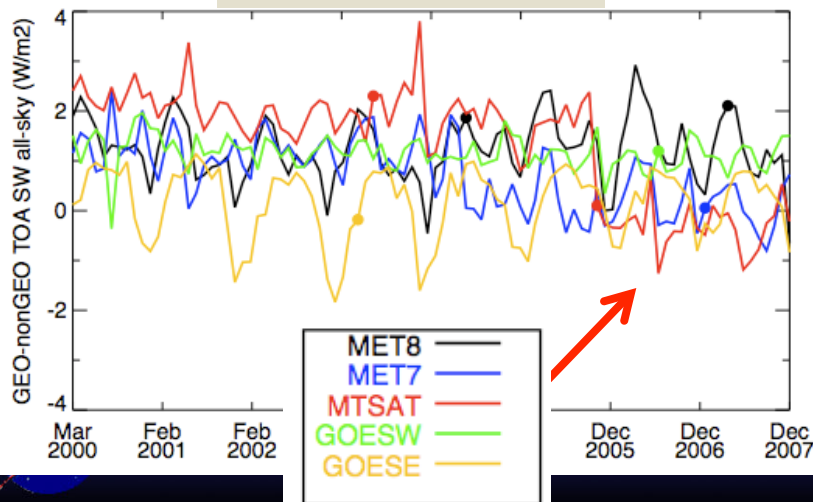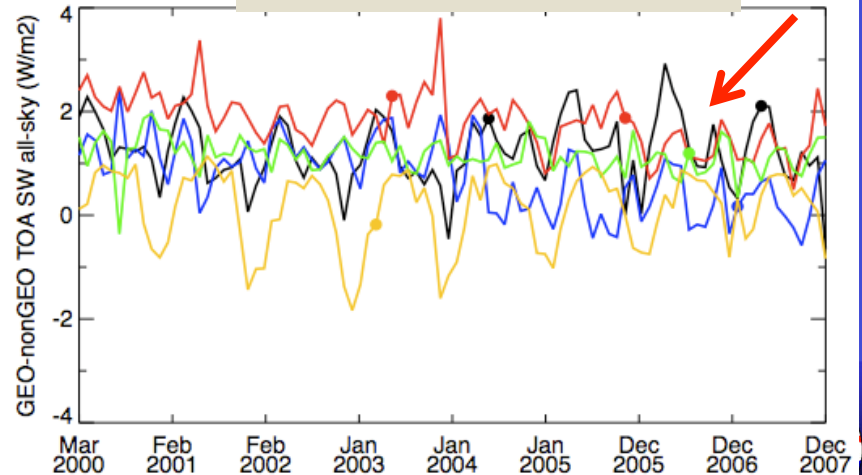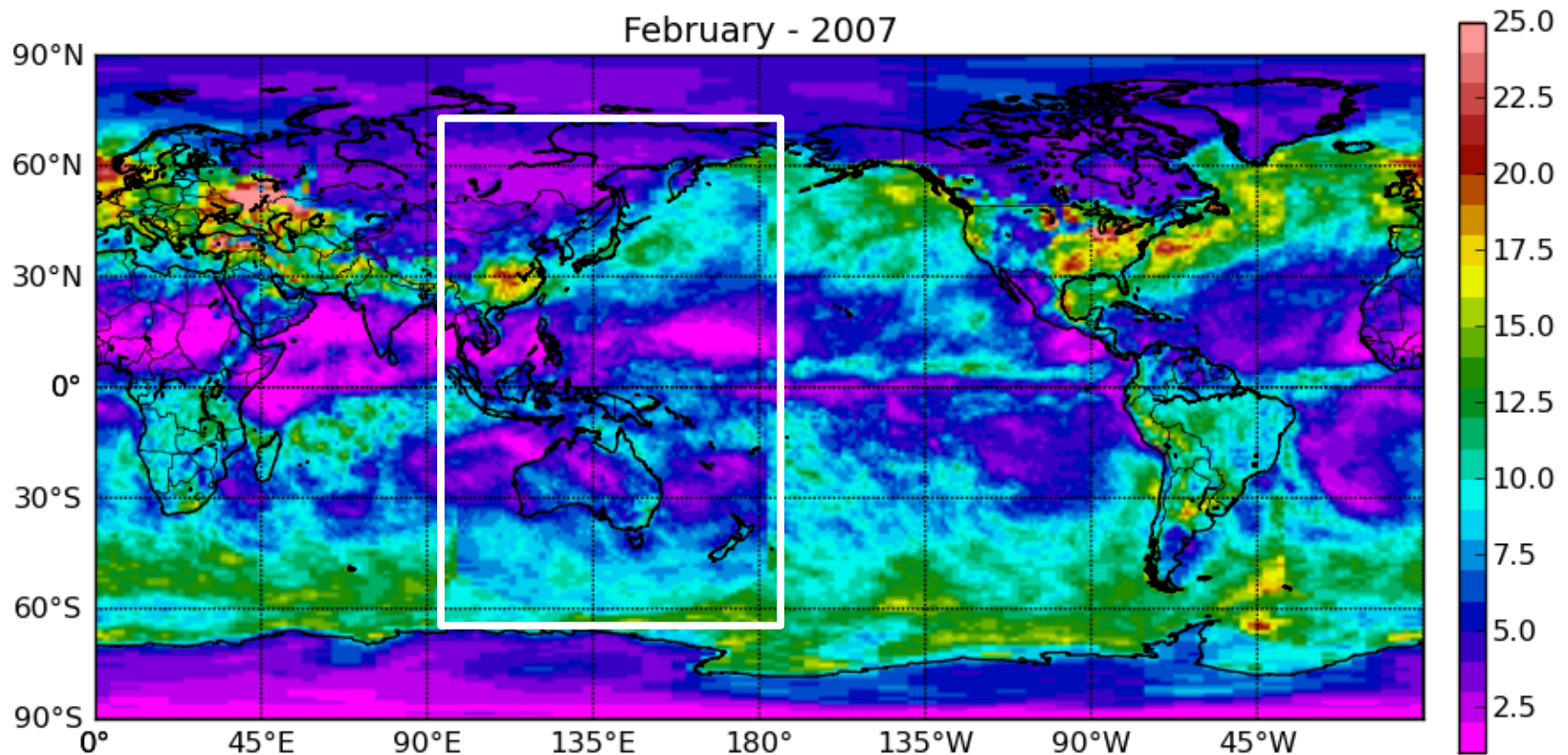
Linear calibration

Non-Linear calibration

MTSAT-1R derived optical Depth

CERES_SYN1deg-Month_Terra-Aqua-MODIS_Ed3A

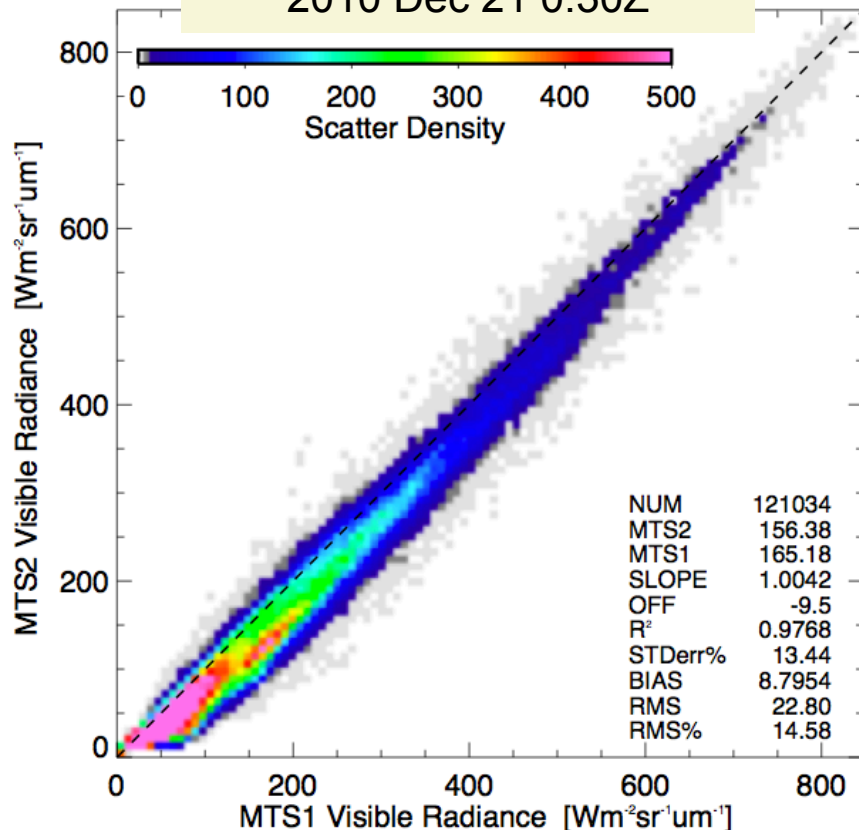Cloud Visible Optical Depth - Total clouds (1)

February - 2007

Generated at http://ceres.larc.nasa.gov

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MTSAT-1R vs MTSAT-2 comparisons

- Compare coincident 1° x 1° lat/lon gridded radiances

VIS MTSAT-1/MTSAT-2
2010 Dec 21 0:30Z

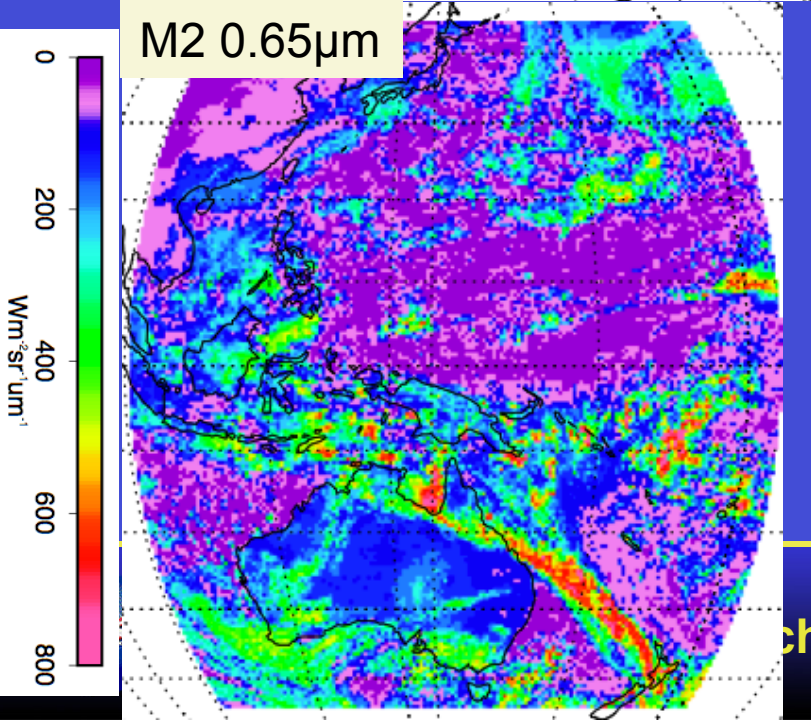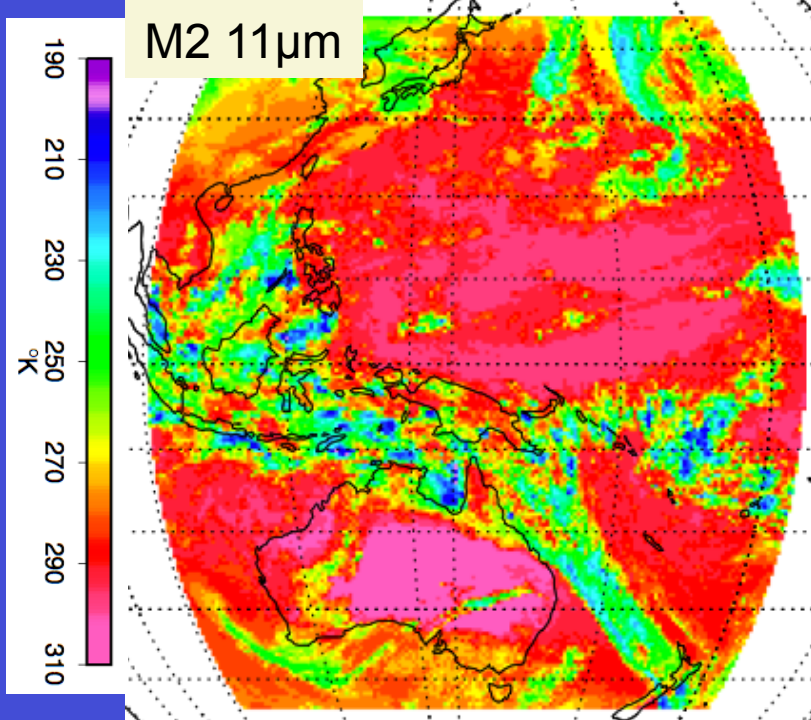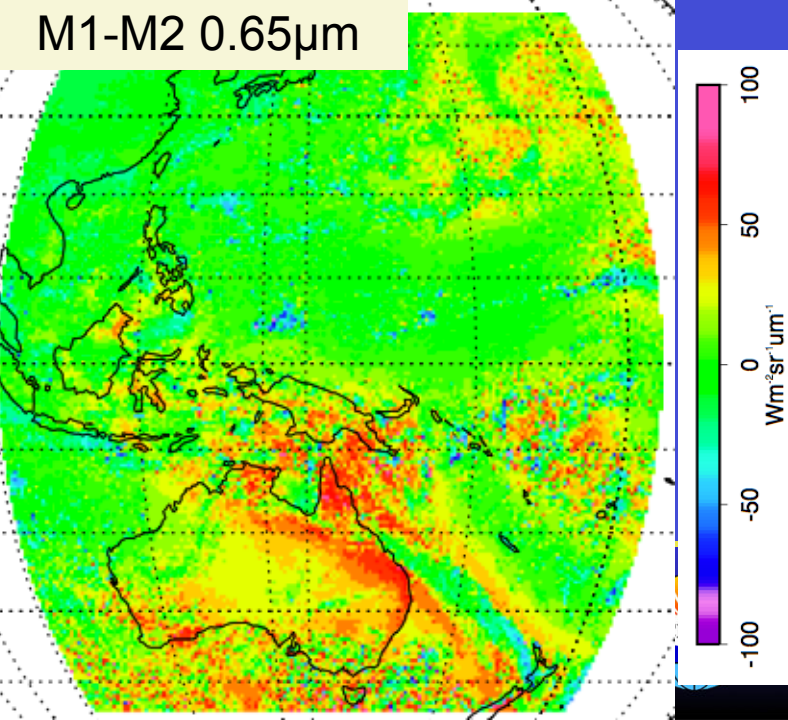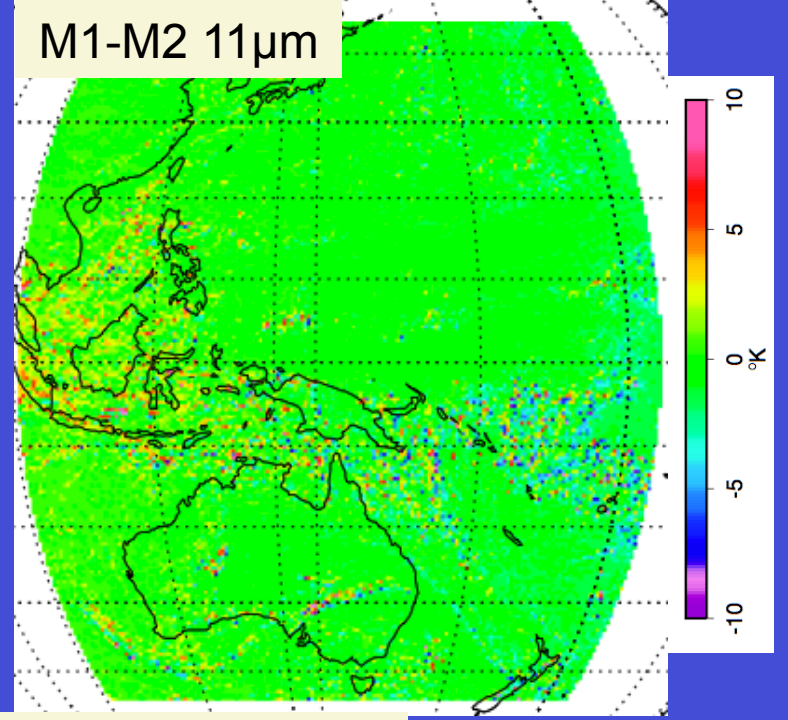IR MTSAT-1/MTSAT-2
2010 Dec 21 0:30Z

MTSAT-1 overestimates MTSAT-2
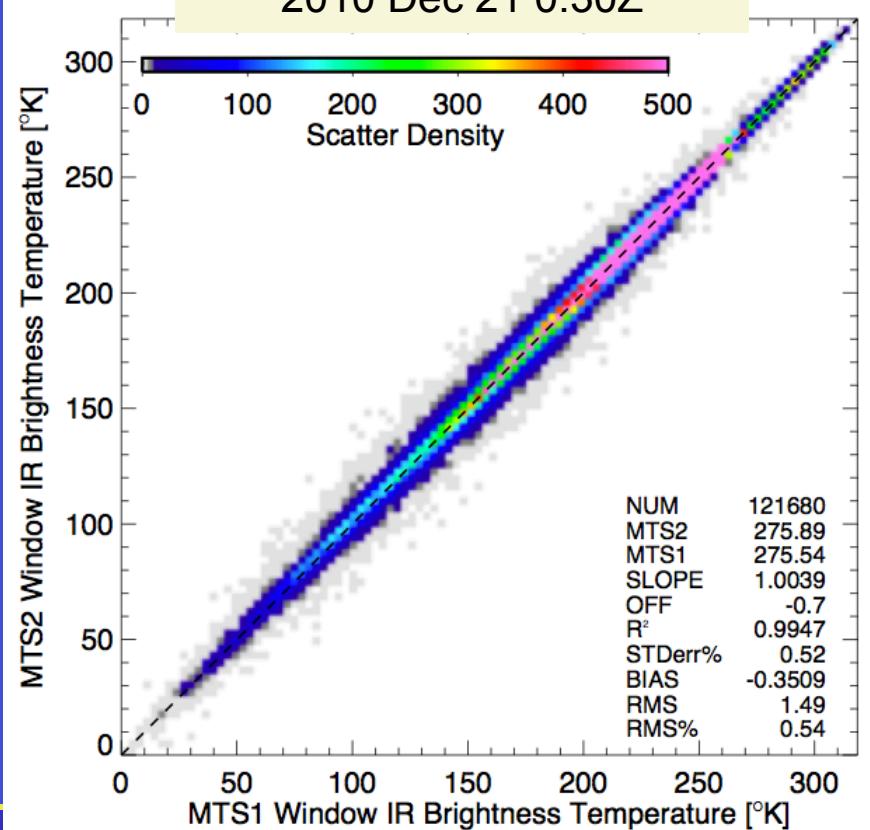
IR demonstrates good navigation
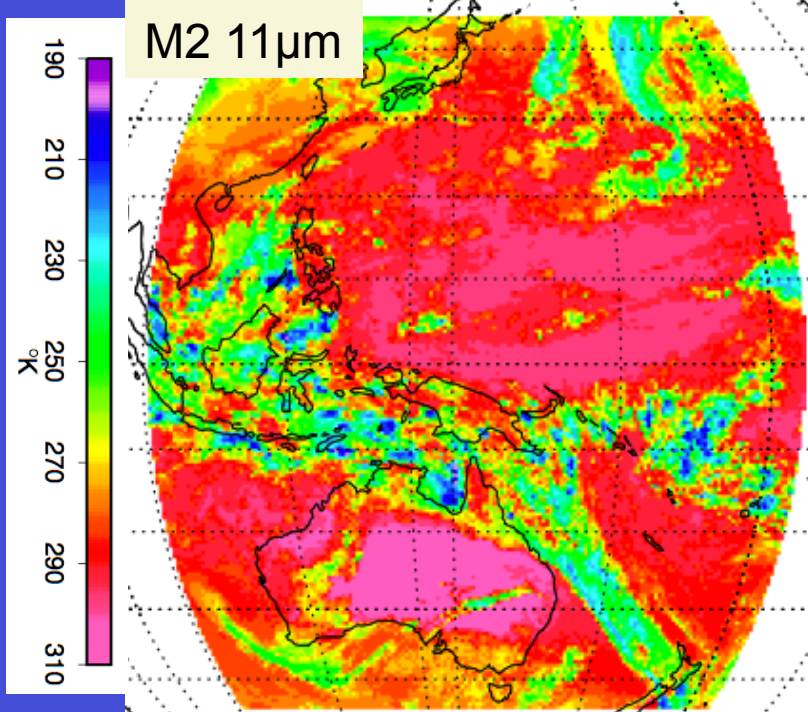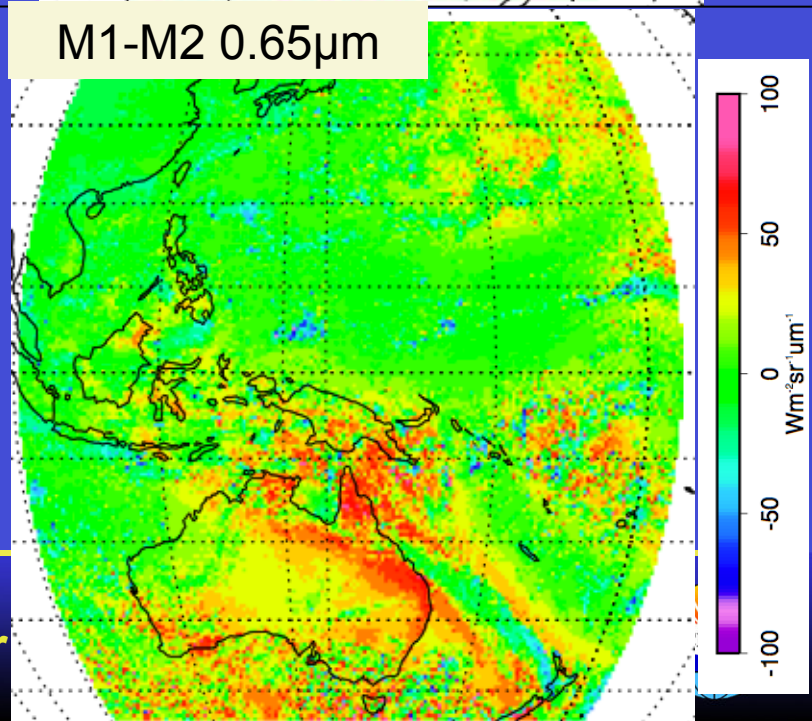
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MTSAT1 – MTSAT2 comparison
2010 Dec 21 0:30Z

M2 11μm

M1-M2 11μm

M2 0.65μm

M1-M2 0.65μm

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M2 11μm

(M1-M2)/M2 0.65μm (%)

MTSAT1 – MTSAT2 comparison
2010 Dec 21 0:30Z

M2 0.65μm

M1-M2 0.65μm

°K

Percent

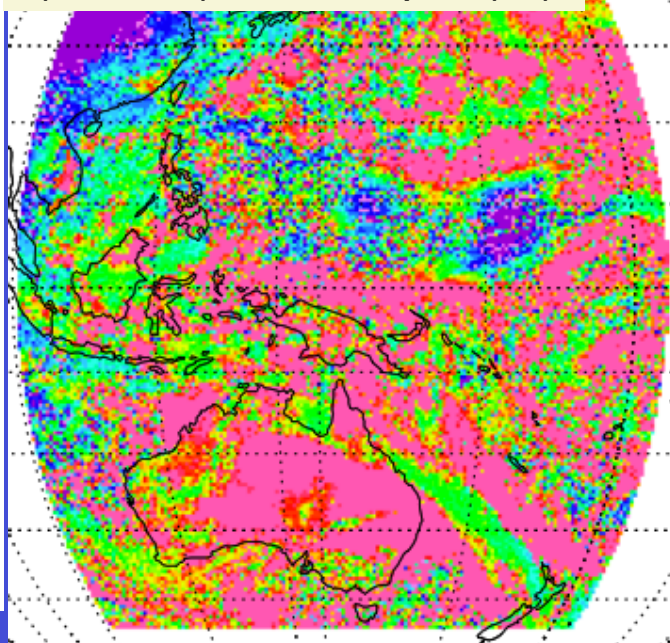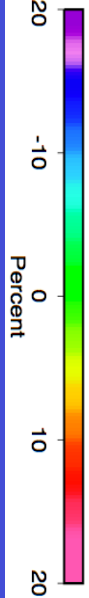Wm⁻²sr⁻¹um⁻¹

Wm⁻²sr⁻¹um⁻¹

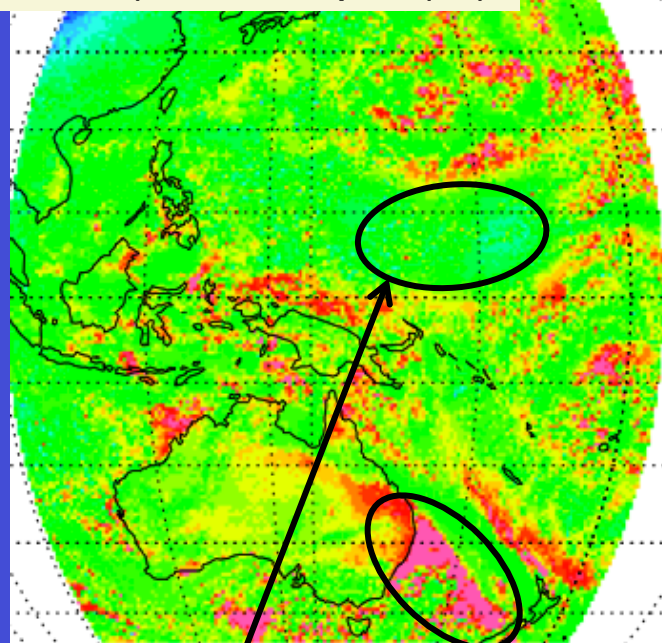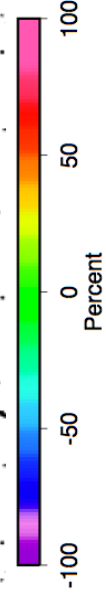ch Center

(M1-M2)/M2 0.65µm (%)

(M1-M2)/M2 0.65µm (%)
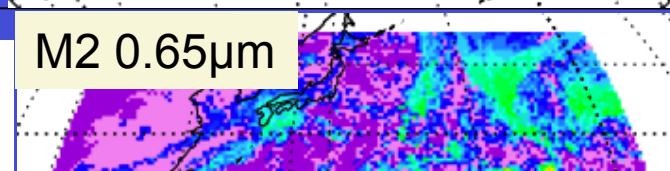
MTSAT1 – MTSAT2 comparison
2010 Dec 21 0:30Z

M2 0.65µm
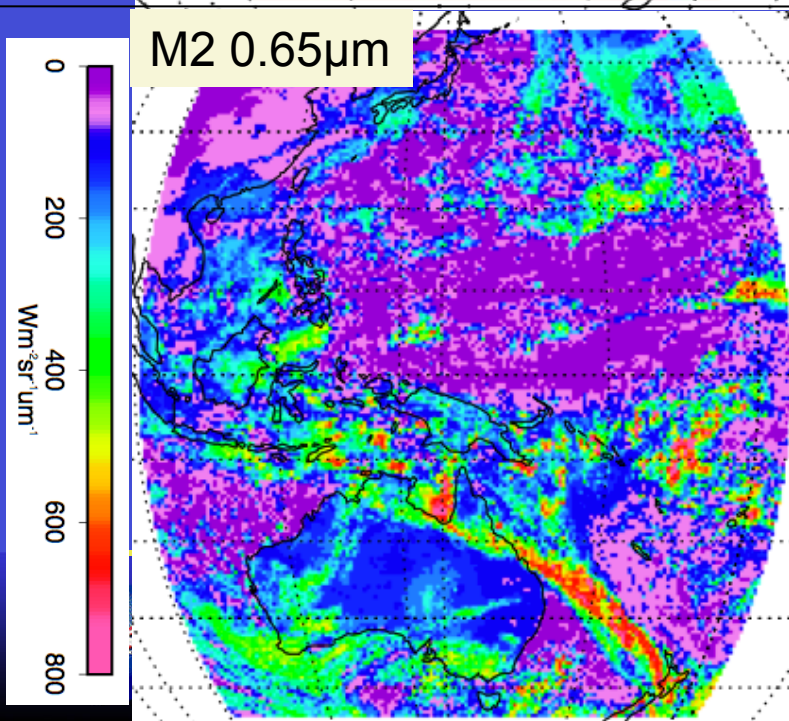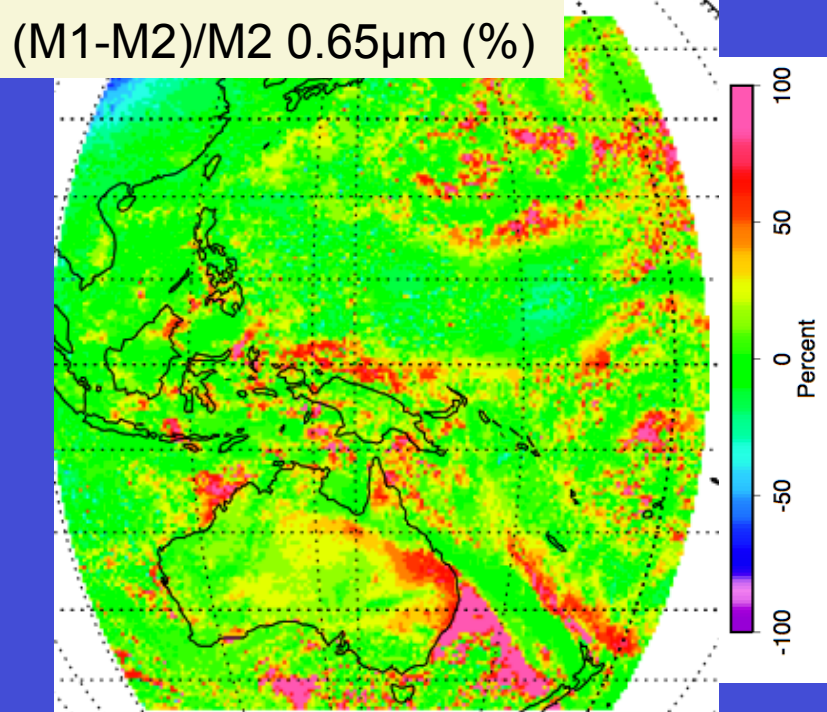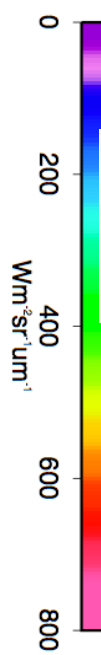
M1-M2 0.65µm
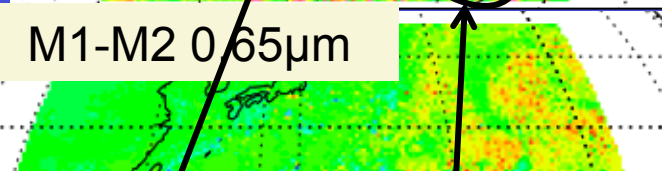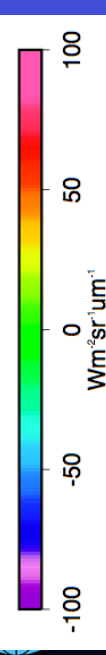
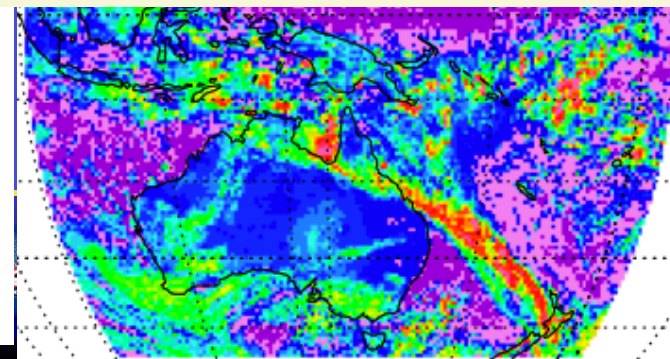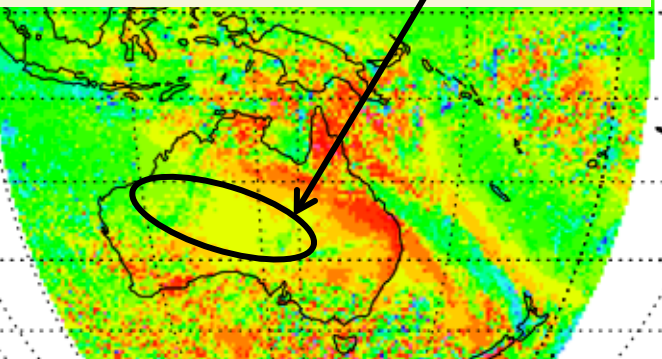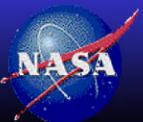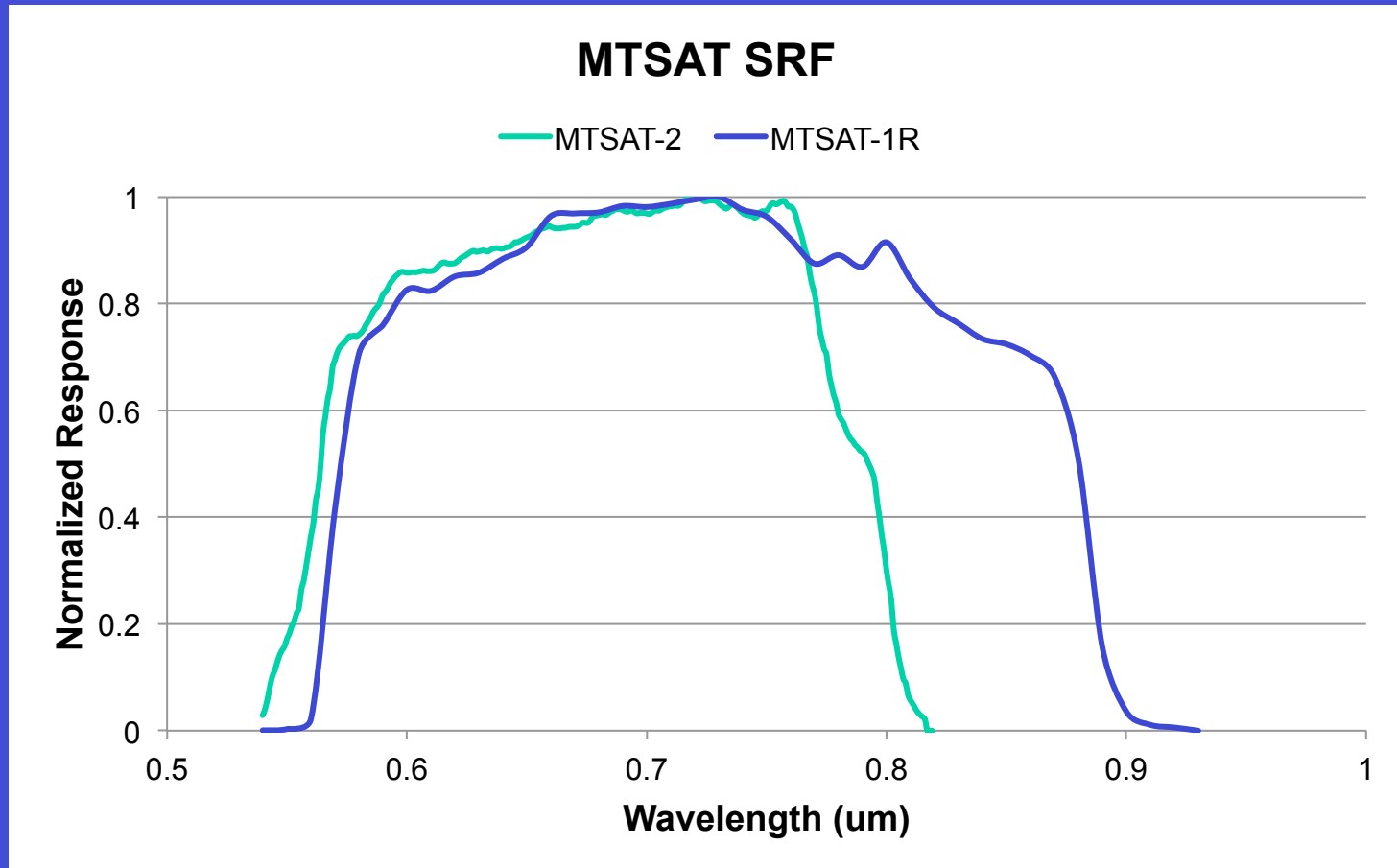Clear-sky ocean near bright clouds can be overestimated by 100%
Clear-sky ocean not surrounded by clouds are not effected
There are spectral response function differences, evident over Australia

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MTSAT-1R and MTSAT-2 spectral response function

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Background to justify the calculation of PSF

Suppose the blurred MTSAT-1 signal $f_1(t)$ is a convolution of the original signal $f_2(t)$ with a kernel function $K(t)$ representing the unknown PSF:

We assume that $K(t)$ is a nearly perfect response function, Dirac δ-function, but having a weak blurring response in the form of Gaussian function:

Fourier transform of a convolution is a product of the corresponding spectra:
(here $f(\tau) \rightarrow F(\omega)$; $\delta(\tau) \rightarrow 1$; $G(\tau) \rightarrow G(\omega)$)

Because blurring is weak ($G(\omega) \ll 1$) we can approximately rewrite it as:

Taking the inverse Fourier transform we finally obtain that the original signal $f_2(t)$ can be recovered by applying a negative Gaussian response function:

$$f_1(t) = \int f_2(t-\tau) K(\tau) d\tau$$

$$f_1(t) = \int f_2(t-\tau) \left(\delta(\tau) + G(\tau) \right) d\tau$$

$$F_1(\omega) = F_2(\omega) \cdot \left(1 + G(\omega) \right)$$

$$F_1(\omega) \cdot \left(1 - G(\omega) \right) \approx F_2(\omega)$$

$$\int f_1(t-\tau) \left(\delta(\tau) - G(\tau) \right) d\tau \approx f_2(t)$$

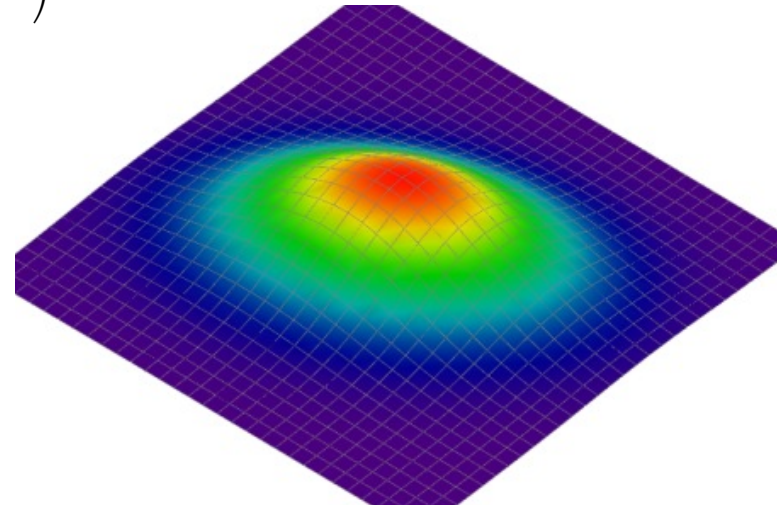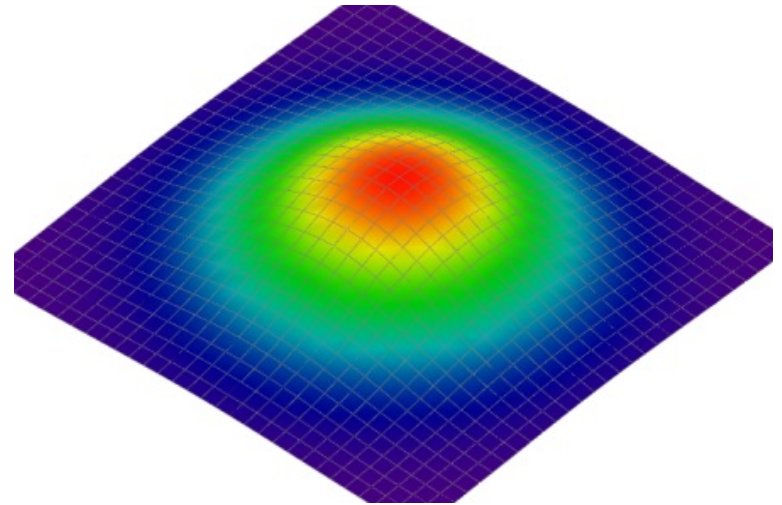Gauss function is defined by 2 unknown parameters: the magnitude **A** and the width σ:
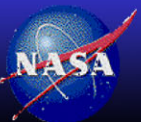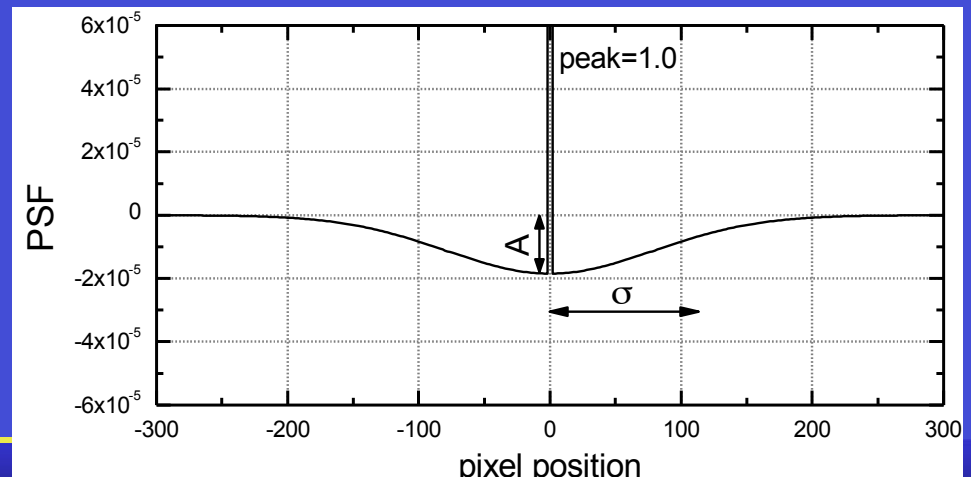
2-Dimensional Case

$$G(x,y) = -\frac{A}{\pi \sigma_x \sigma_y} \exp\left[-\left(\frac{x^2}{\sigma_x^2} + \frac{y^2}{\sigma_y^2}\right)\right]$$

Assuming that $\sigma_x \neq \sigma_y$ we can introduce unknown eccentricity ε and rotation angle θ of the blob.

$$G(x,y) = -\frac{A}{\pi \sigma^2 \sqrt{1-\varepsilon^2}} \exp\left(-\frac{x^2 + y^2 - \varepsilon^2(x\cos\theta - y\sin\theta)^2}{\sigma^2(1-\varepsilon^2)}\right)$$

Finally, the sought shape of the PSF function is defined by the 4 unknown parameters: **A**, σ, ε, and θ.
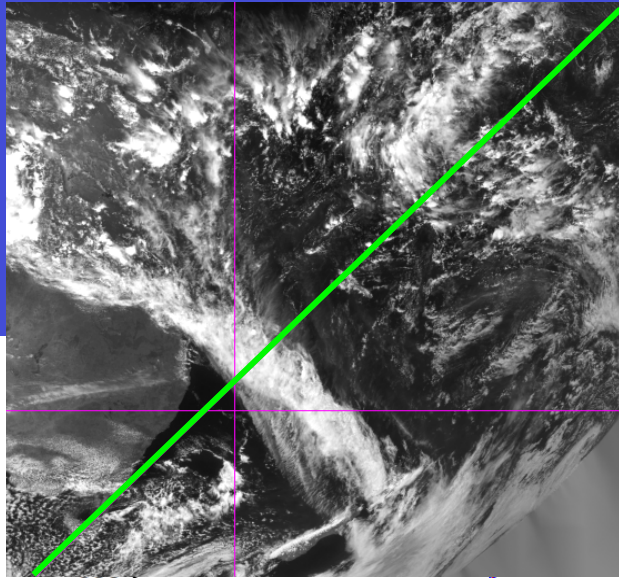
Derivation of PSF-function

1. Detect a piecewise spatial displacement between two images of simultaneous observation of MTSAT-1 and -2 and build a 2D vector map of these displacements. By using this map, the MTSAT-2 image is warped so as to correct for this non-linear displacement. This virtually eliminates any spatial mismatch between the images, which allows us to run a regression analysis reliably on a pixel-by-pixel basis.

2. Mask out all pixels over land and in the areas of sun glint.

3. Calculate the PSF function for a set of the 4 parameters A, σ, ε, and θ.

4. Apply the PSF to the MTSAT-1 image.

5. Degrade the resolution of both images by 4 times by sinc-resampling to reduce differences caused by cloud shadows and due to stereoscopic effect on elevated cloud features.

6. Build a linear regression between corrected MTSAT-1 and MTSAT-2 and calculate the R^2 value.

7. Repeat from step 3 to obtain the optimal set of parameters by means of the Powell's conjugate direction method that minimizes a function in multi-dimensional space.

8. Find the set of 4 parameters for each occurrence of simultaneous observation between MTSAT-1 and -2.
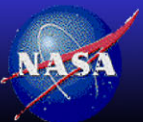
Diagonal Cross Section
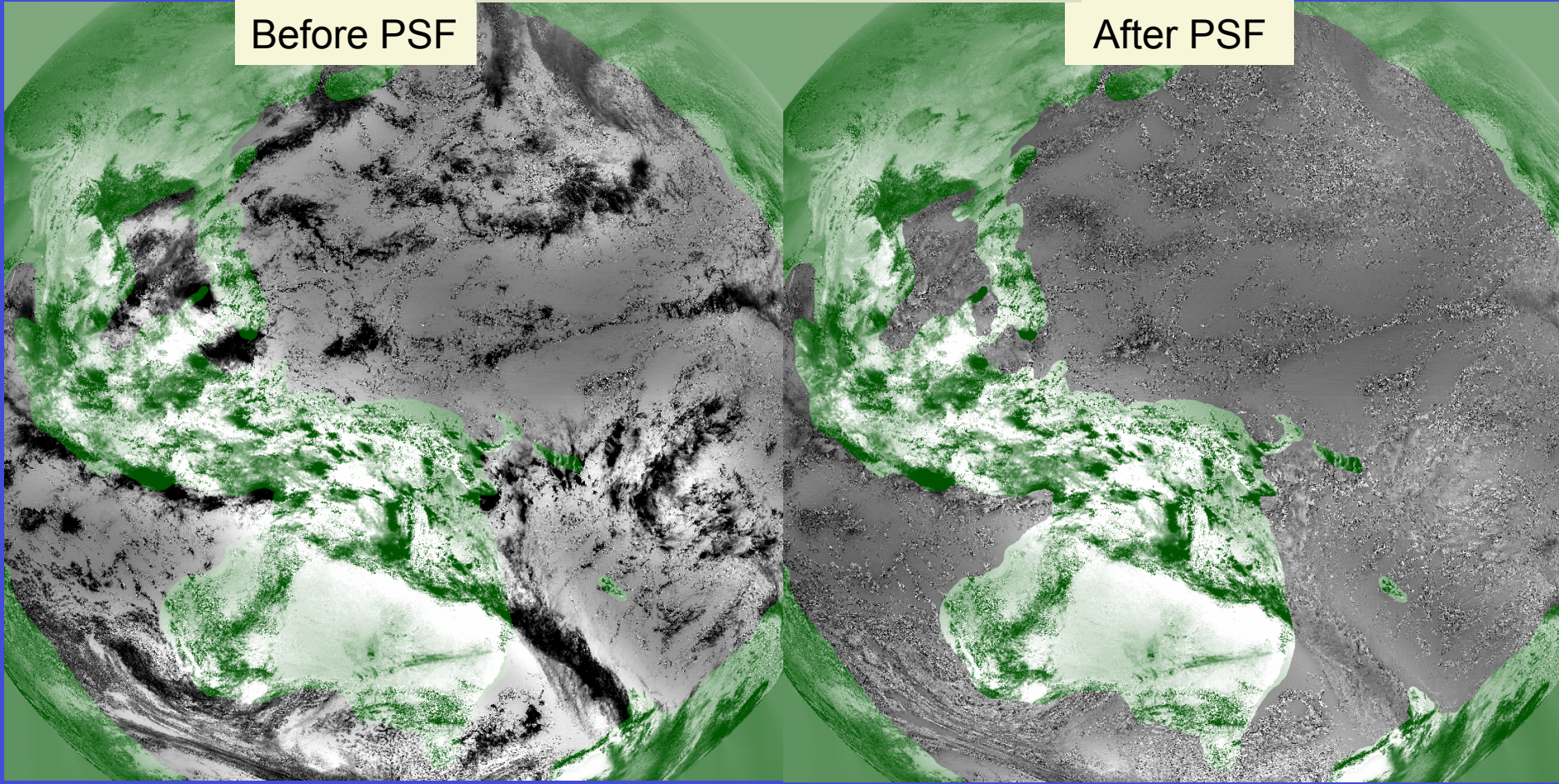

Dec 21, 2010 2:30 GMT

NE

SW
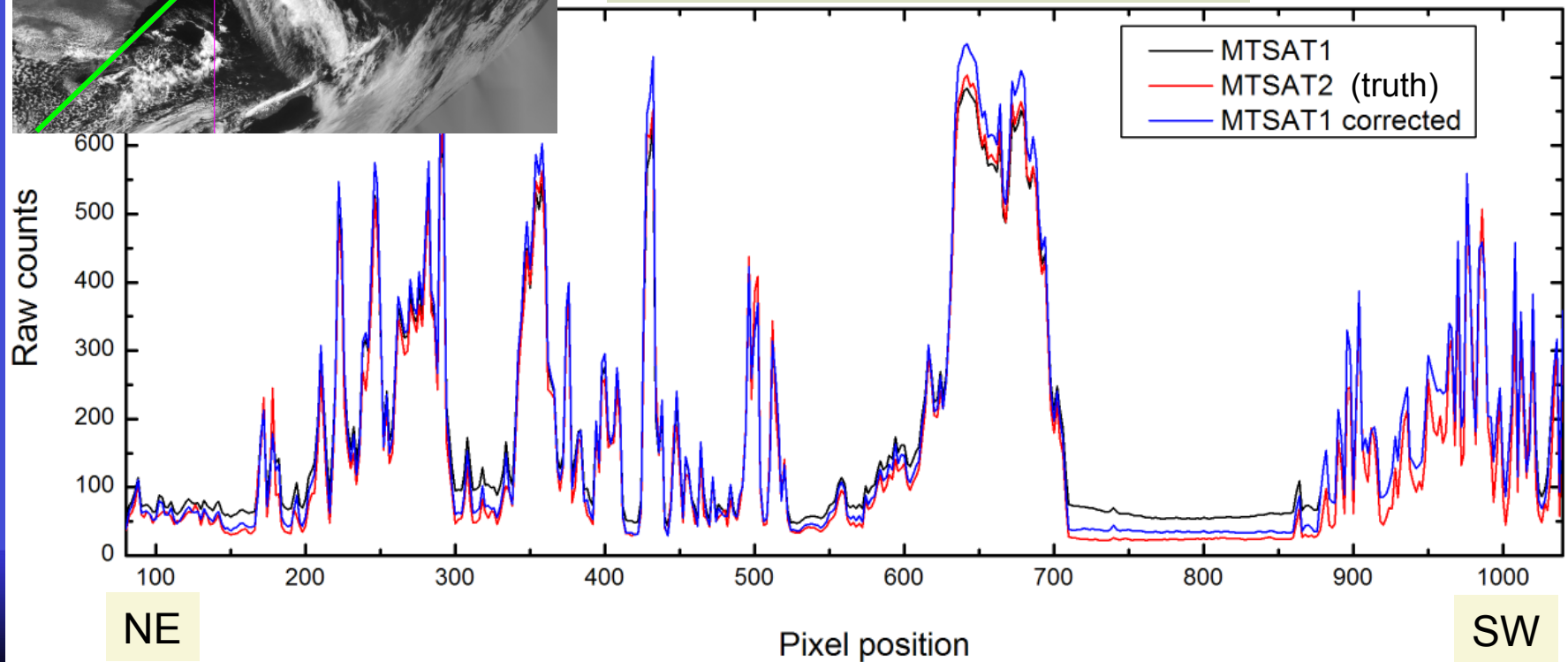
MTSAT1R minus MTSAT2
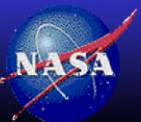
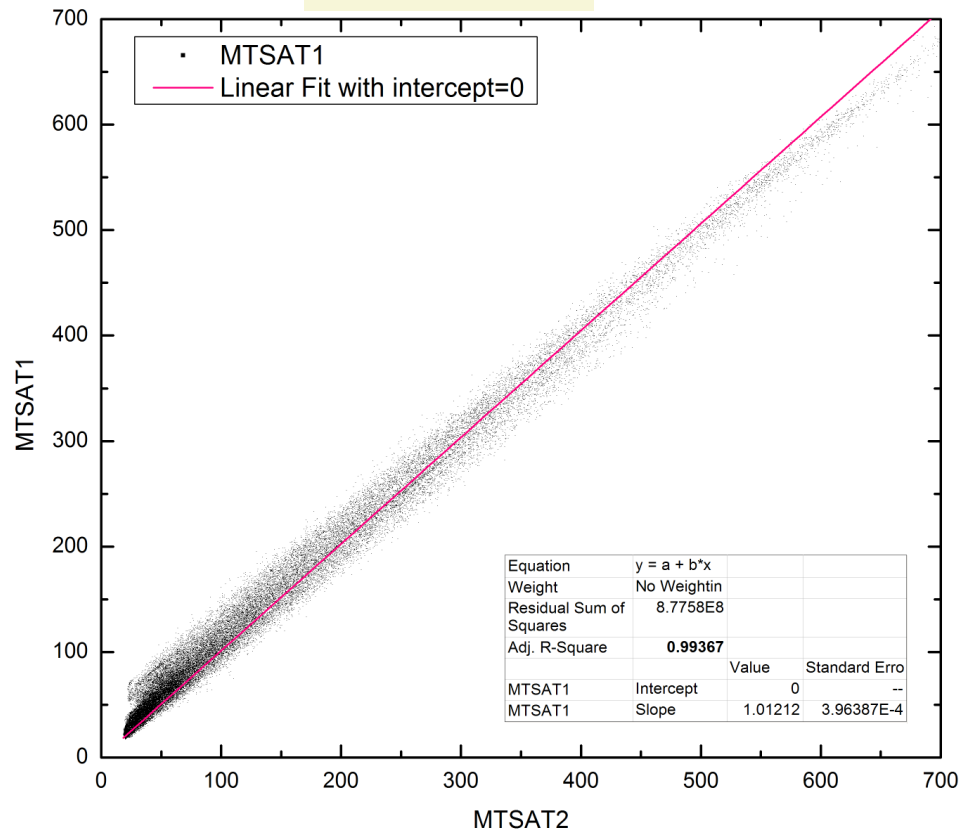Dec 21, 2010 2:30 GMT

Before PSF

After PSF

Applied only over ocean regions
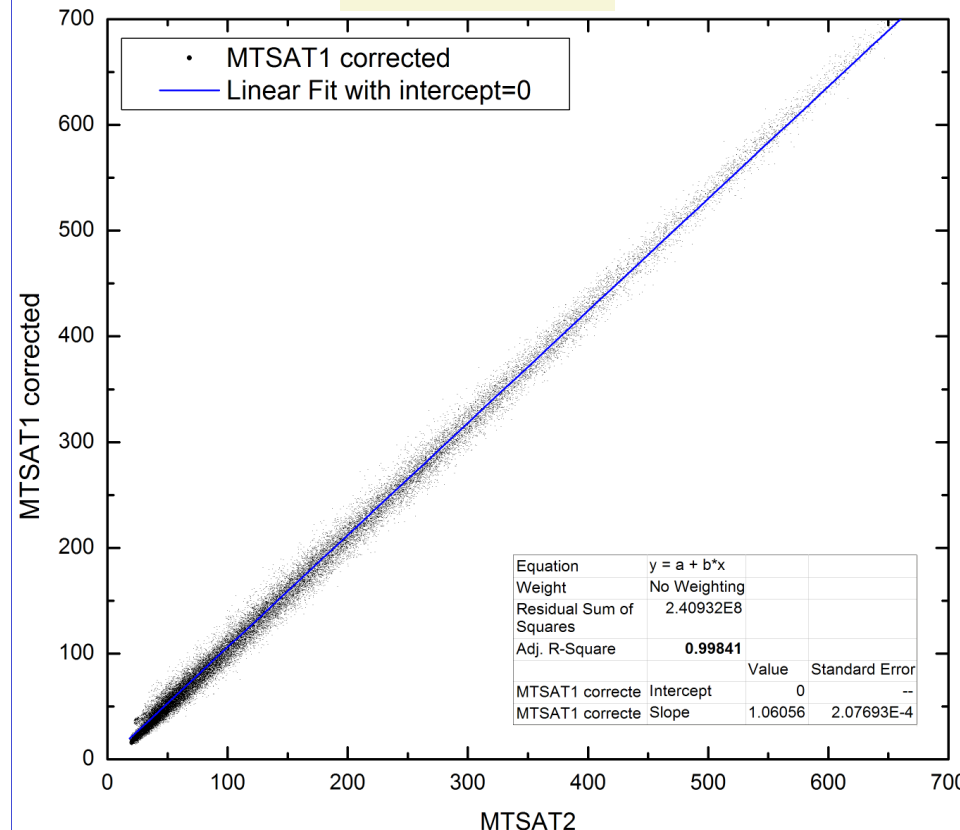
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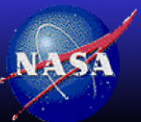
MTSAT1/MTSAT2 pixel pair scatter plot

The PSF weighted radiance pairs have a linear relationship through the space count

Dec 21, 2010 2:30 GMT
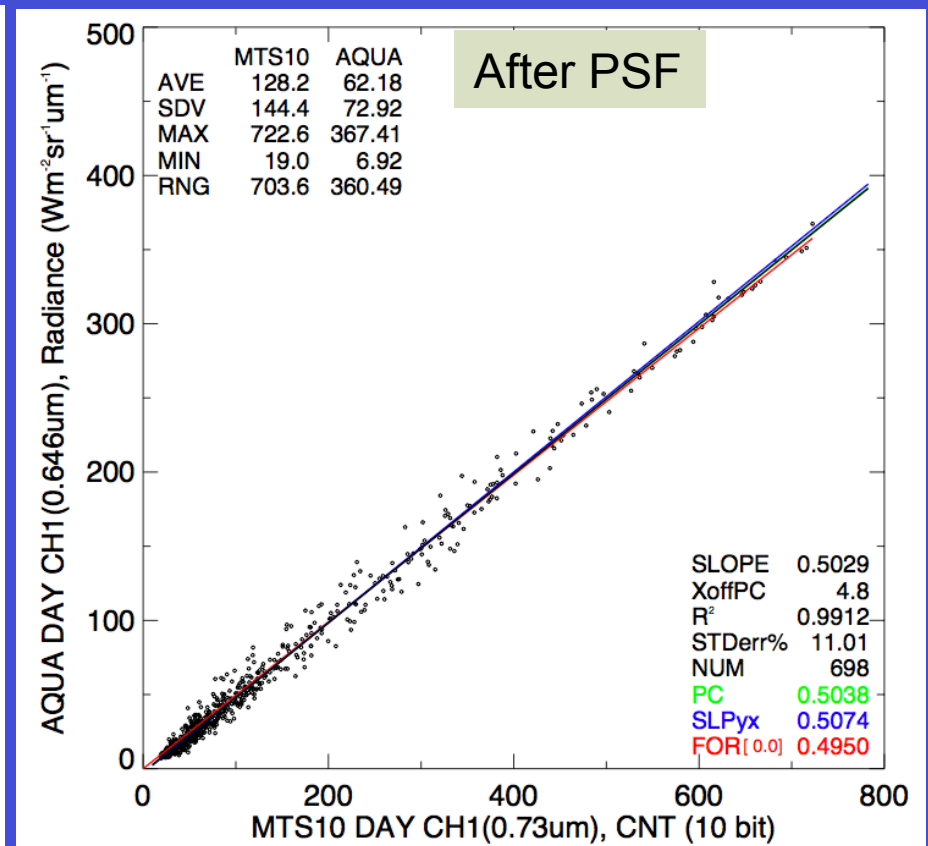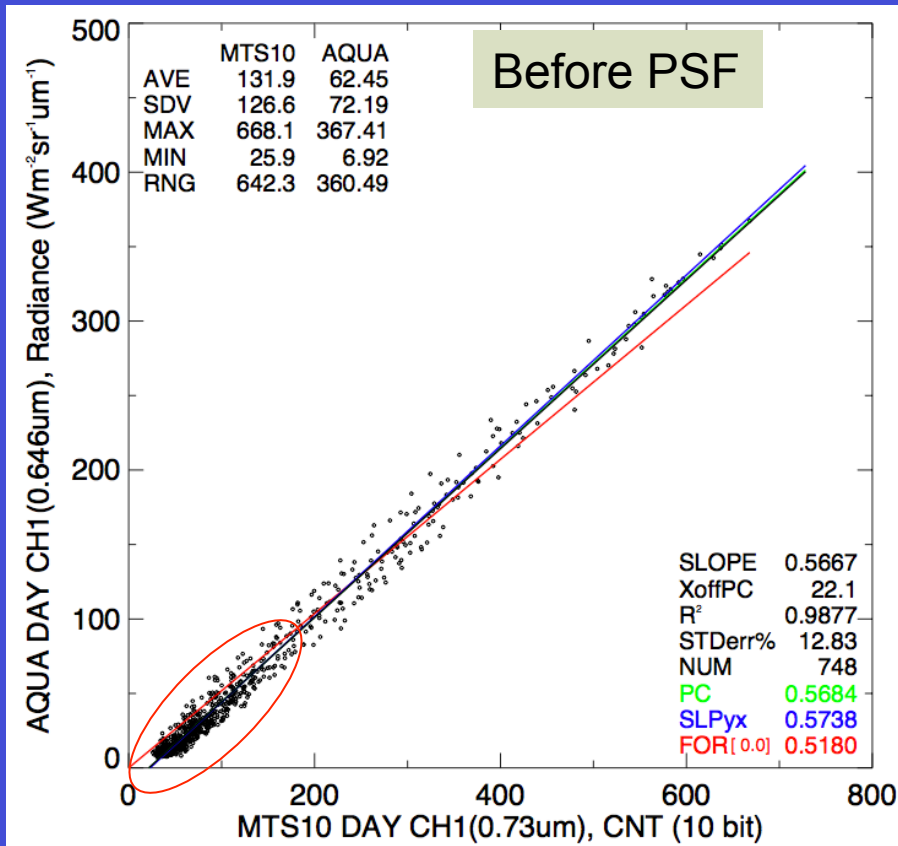
MTSAT-1R/Aqua-MODIS ray-match inter-calibration Dec 2012

• After PSF correction, the MTSAT-1R counts are now proportional to radiance and all linear regressions intersect the space count = 0

Conclusion

- Verifying sensor response over its dynamic range is crucial to obtaining flux and cloud retrievals
  - The MTSAT1/MODIS radiance pair regression is now linear
  - Apply to the whole MTSAT1 record and plot the monthly gain trend over time, the noise in the monthly gains should be greatly reduced
- Redefining the point spread function has greatly improved the science value of the MTSAT-1R imager
  - Apply to all MTSAT-1R images before incorporating them into the future CERES Edition 4 processing
  - Compare before and after MTSAT-1R cloud properties and derived broadband fluxes in the CERES product
- **The development of this algorithm is a GSICS success story!**
  - The interaction between calibrating groups facilitated by GSICS has benefited the entire science community