NASA-Langley satellite cross-calibration, deep convective cloud calibration, and MTSAT case study

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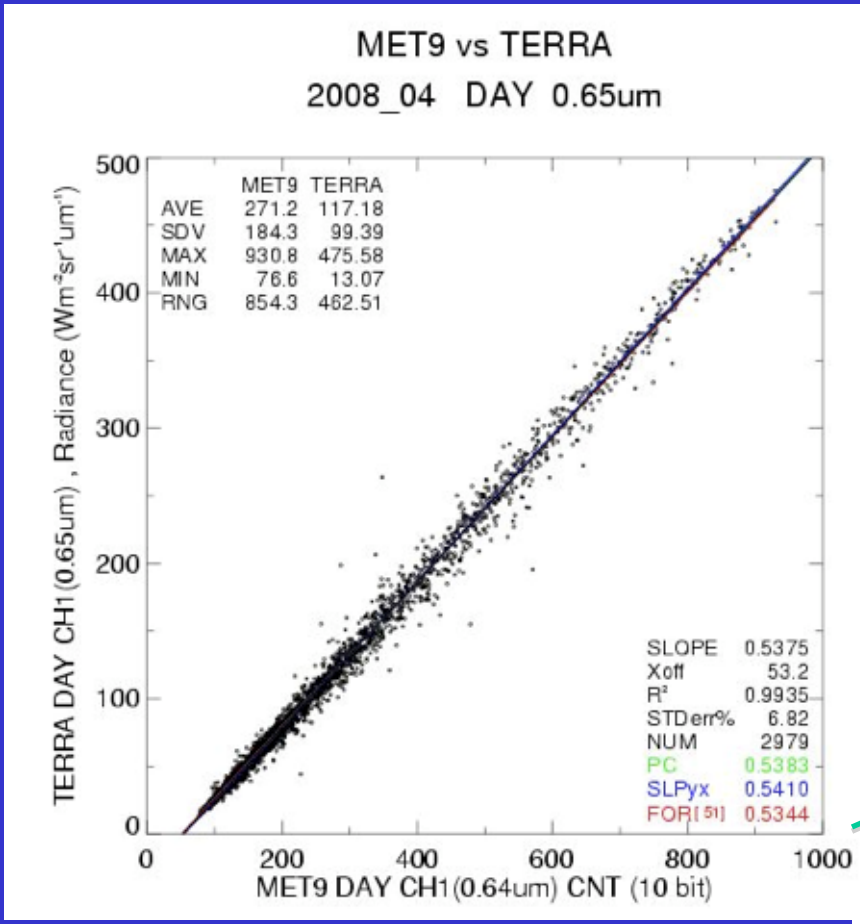
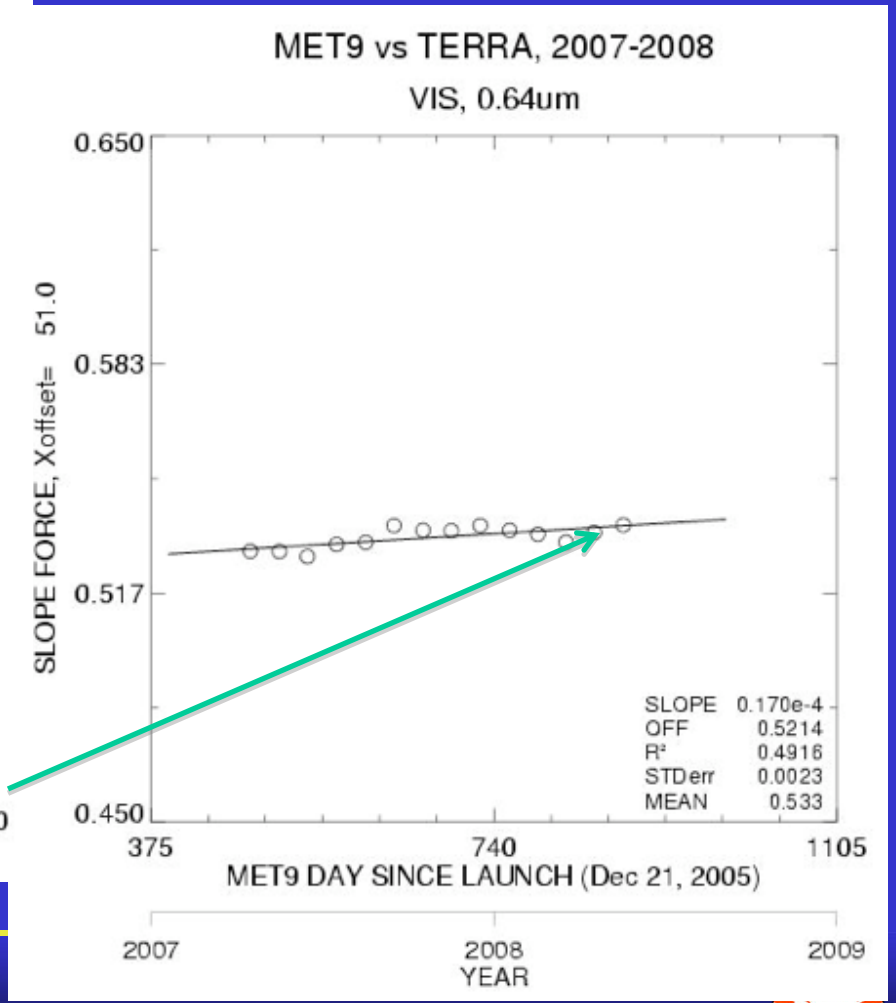
GEO to MODIS Cross-Calibration Method

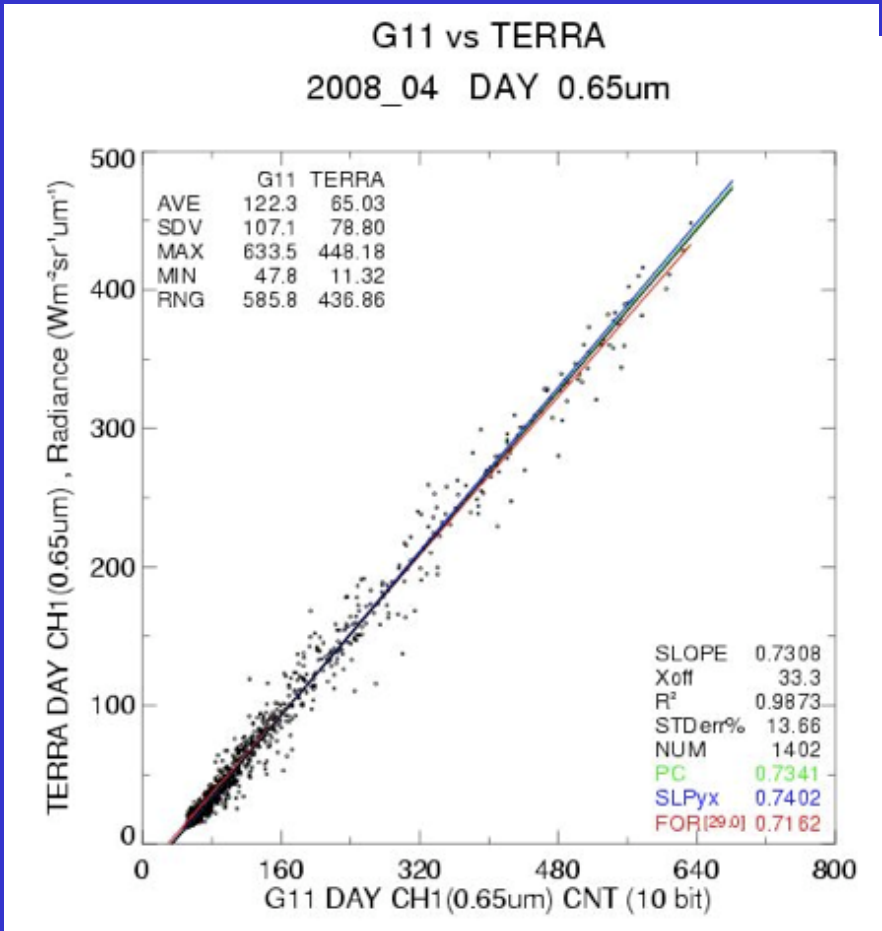
- None of the GEO visible sensors have onboard calibration
- Ray-match GEO counts (proportional to radiance) and MODIS radiances within a 0.5° ocean regions using selection constraints
  - ΔSZA< 5° (15 minutes), ΔVZA<10° , ΔRAZ < 15° , no sunglint
  - Domain ±20° E,W and ± 15° N,S near sub-satellite point to maximize coincident matches
  - Use Terra-MODIS as reference
  - The calibrated GEO radiances will have a MODIS equivalent radiance regardless of spectral response
  - Normalize all solar channels to a common solar constant and SZA
- Perform monthly linear regressions and derive monthly gains
  - Use published offsets
- Compute timeline trends from monthly gains

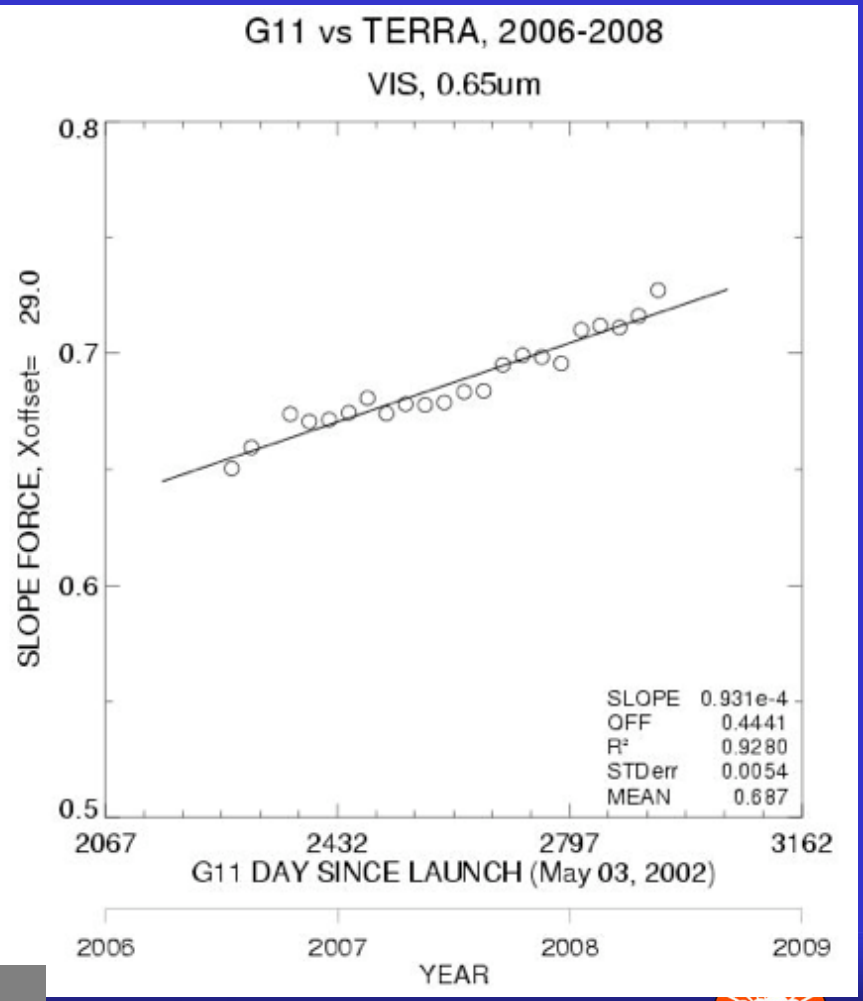
MET9 (0° E)/MODIS cross-calibration





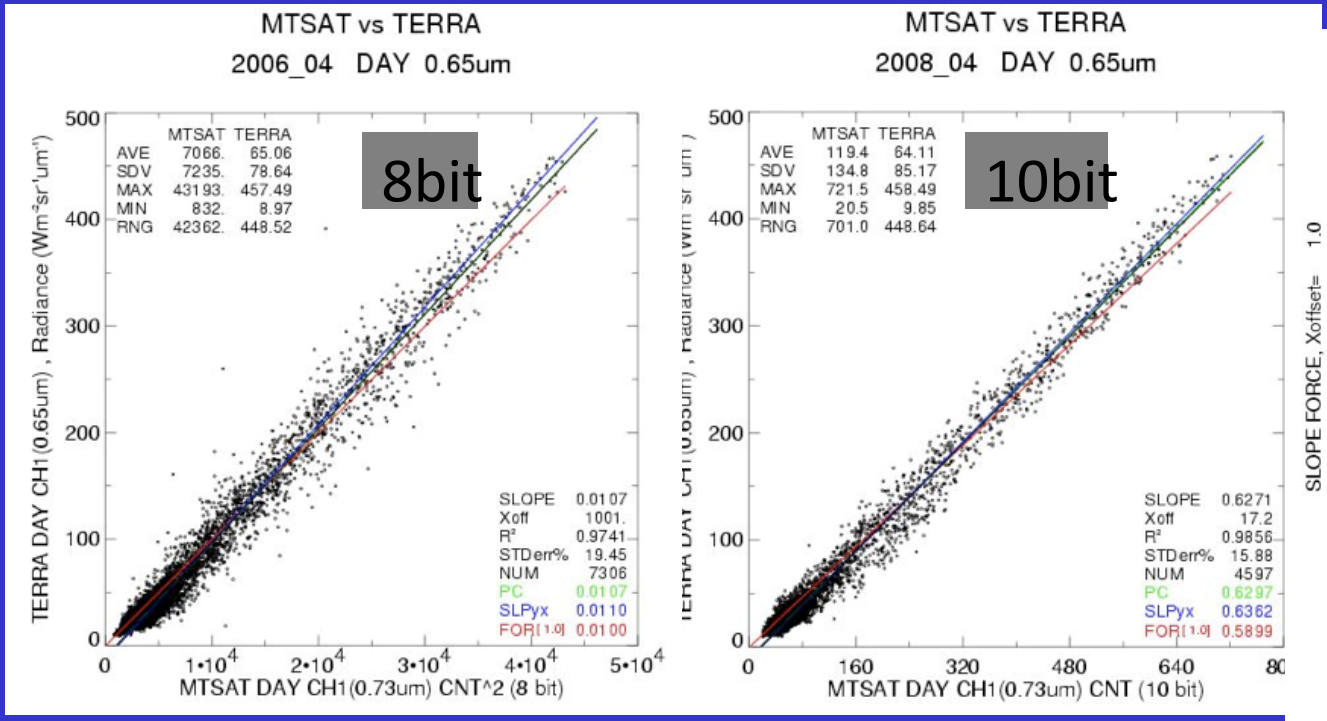
GOES-11 (145° W)/MODIS cross-calibration

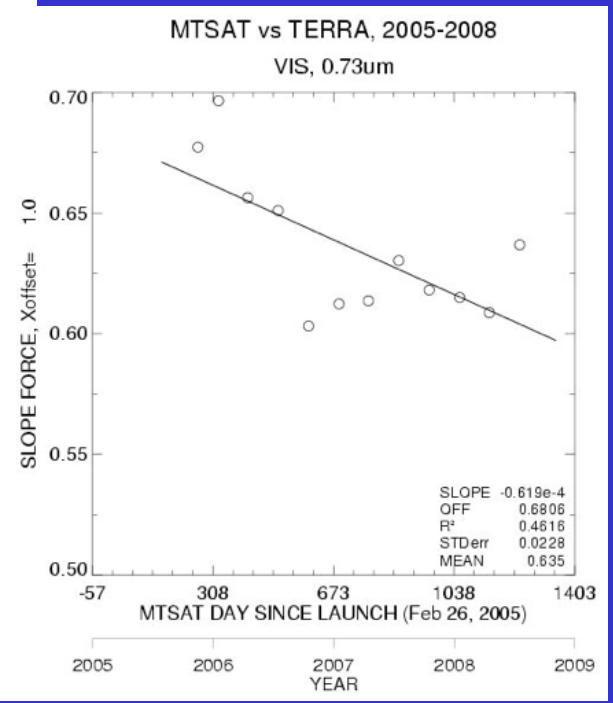




• Similar linearity is seen for MET-5, MET-7, MET-8, GOES-8, GOES-9, GOES-10, GOES-12, GMS-5

MTSAT(140˚ E)/MODIS cross-calibration





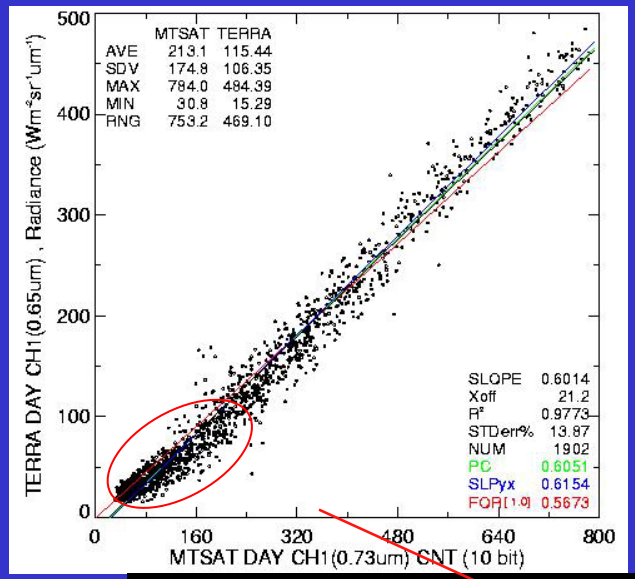
- Same ray-matching technique as the other satellites
- Note the departure from linearity in the low part of the dynamic range
- 8bit from Nov 2005 until October 2007 from McIDAS (degraded the 10bit to 8bit squared)

MTSAT visible calibration

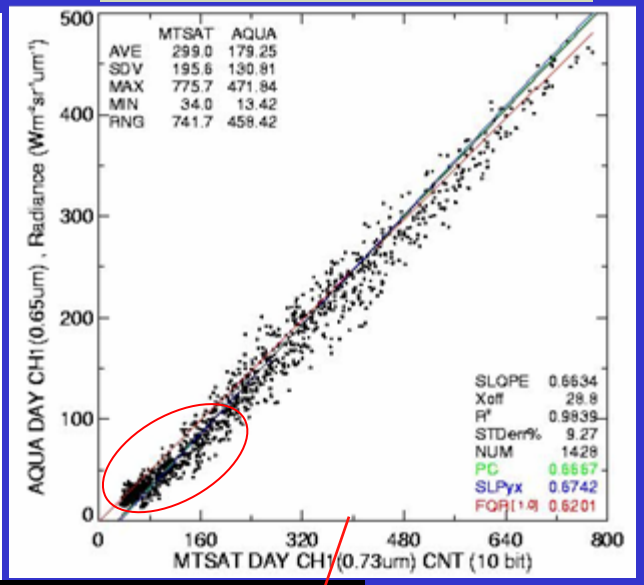
- Reference satellite
- Instrument
- Source
- Navigation
- Space Count
- Spectral response
- Polarization
- Is there any error in my methodology??

Reference? MTSAT 10bit visible calibration, Sep 2007

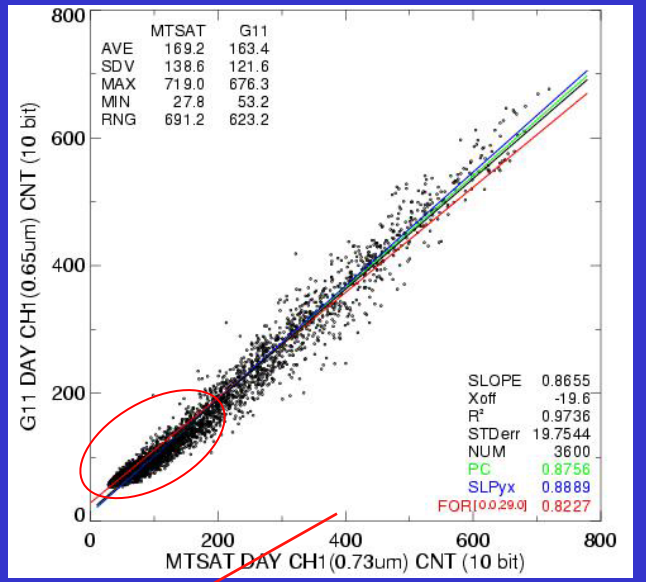
MTSAT/Terra (10:30AM)

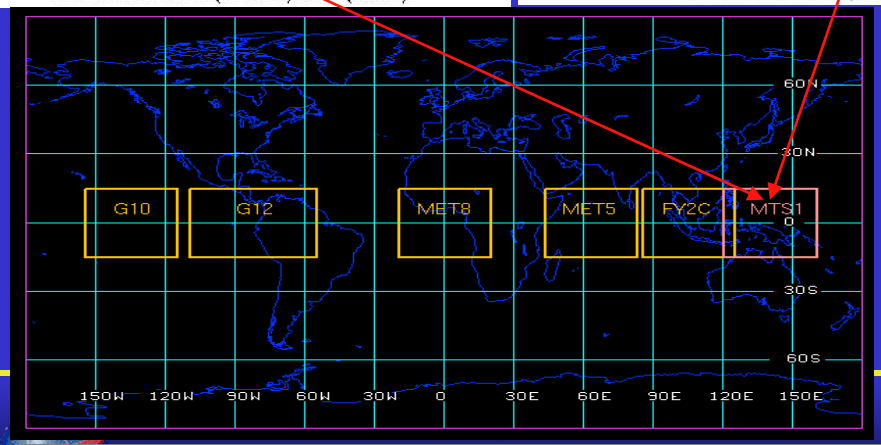


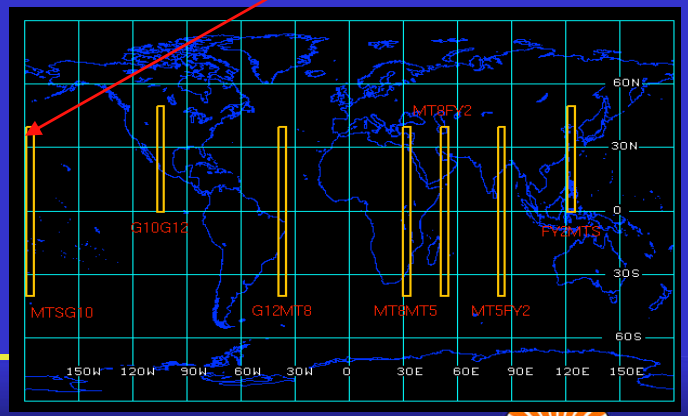
MTSAT/Aqua (1:30PM)



MTSAT/GOES11 (noon)



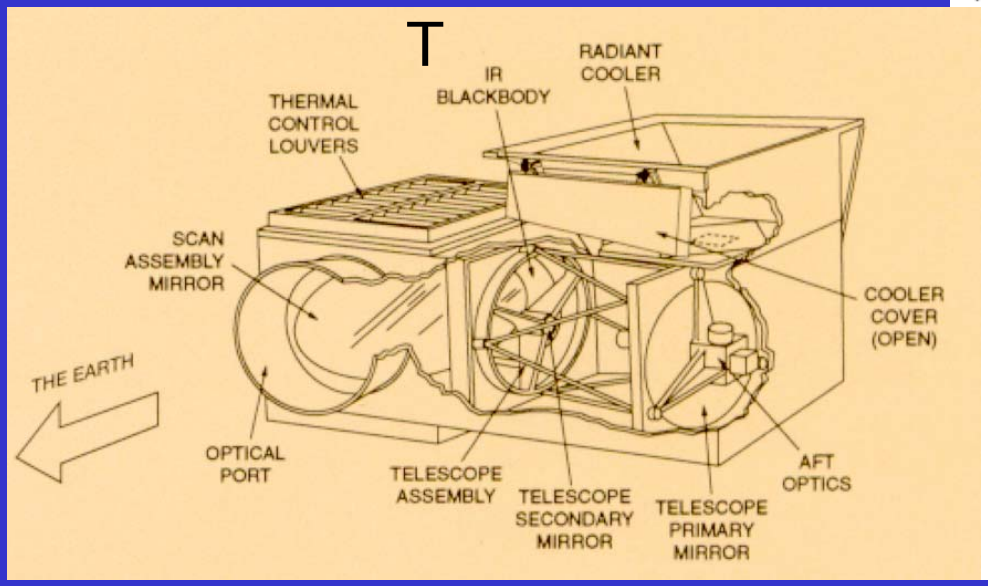




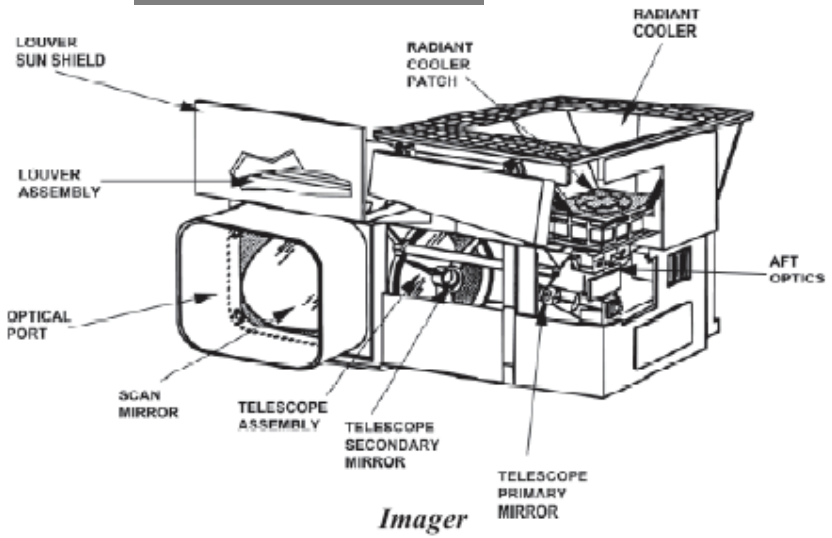
- Note that the nonlinearity exists for Terra, Aqua and GOES-11

Instrument Schematic

MTSA



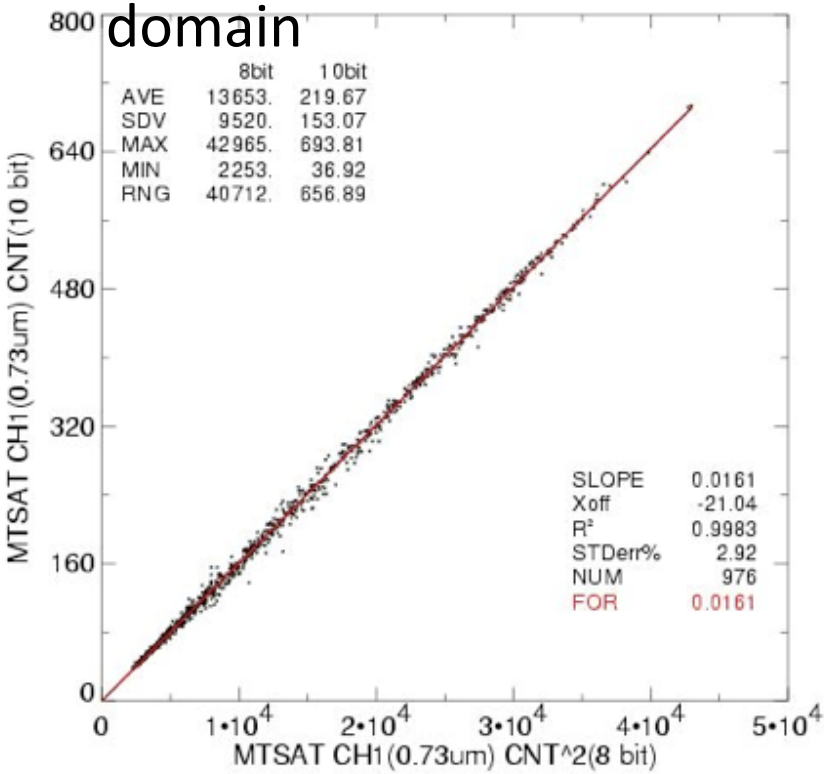
GOES-11



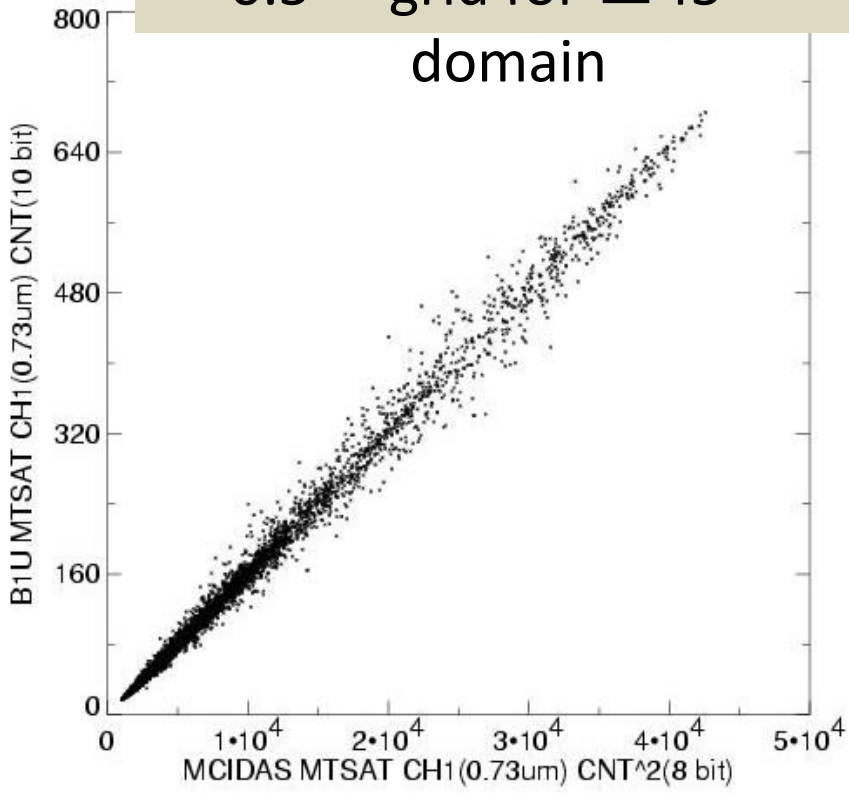
- It seems that GOES-11 has a sun shield, whereas MTSAT does not
- ITT built both the GOES 8-12 series and MTSAT

Format? 8bit vs 10bit relationship

October 2007, McIDAS
0.5° grid over ±15°
domain



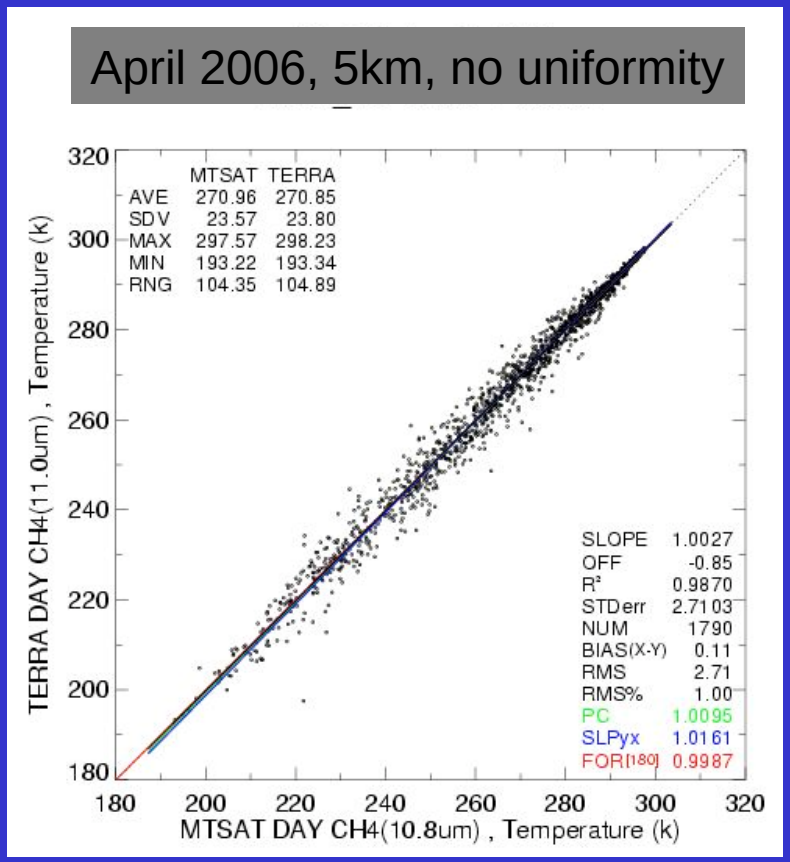
B1U, Nov 2005
0.5° grid for ±45°
domain



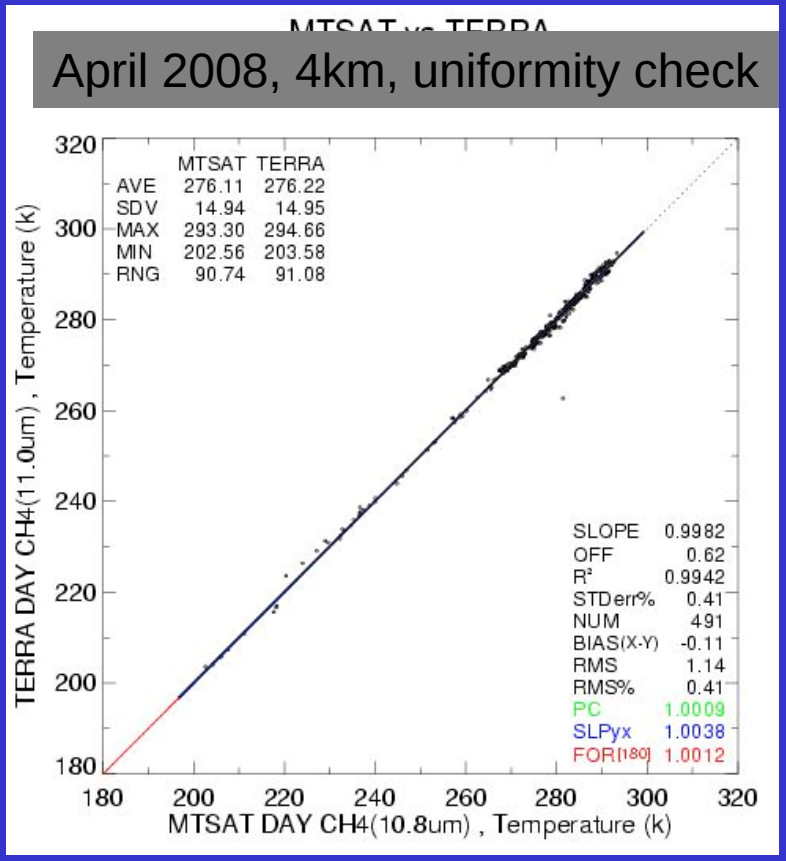
- There is a linear relationship between 8bit and 10bit, so the 8 and 10 bit gains can be merged during the record
- ISCCP source is 10bit for the entire record, We are downloading the ISCCP B1U (8km nominal, 3-hourly resolution) from NCDC (Ken Knapp) when McIDAS is 8bit
- **FORMAT INDEPENDENT**

Navigation? MTSAT/Terra IR (11µm)

April 2006, 5km, no uniformity



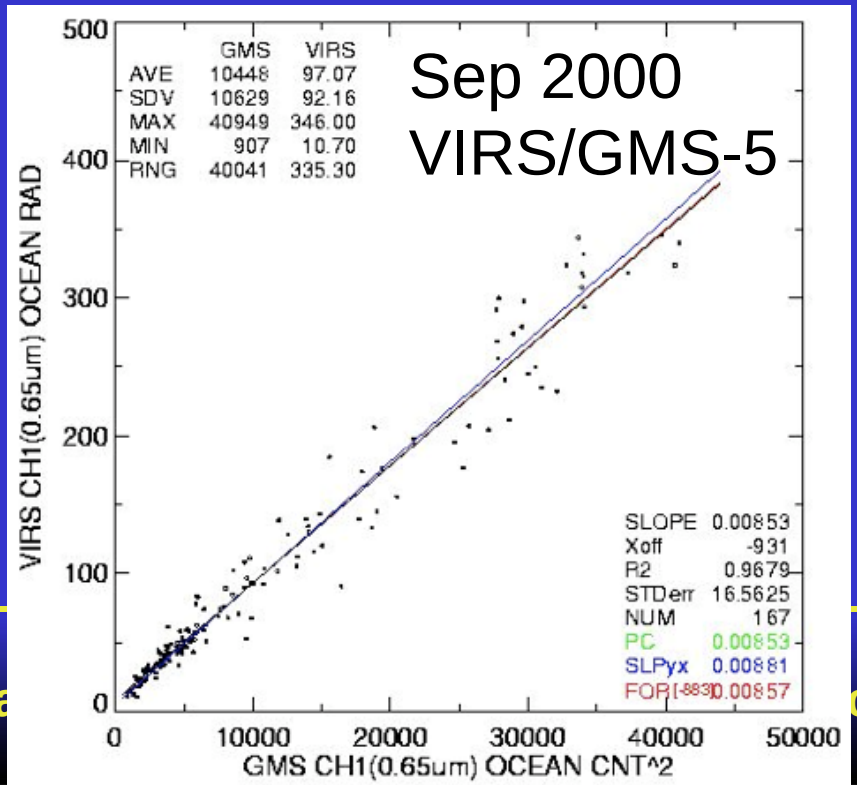
April 2008, 4km, uniformity check



- The McIDAS ingester tried to fit the MTSAT image (1100x1100, 4km) into a GMS-5 (850,850, 5km) image using JPEG compression, and the visible from 10bit to 8bit squared for transmission
- The IR comparison indicates good navigation and points to the issue to the visible detectors
- **GOOD NAVIGATION**

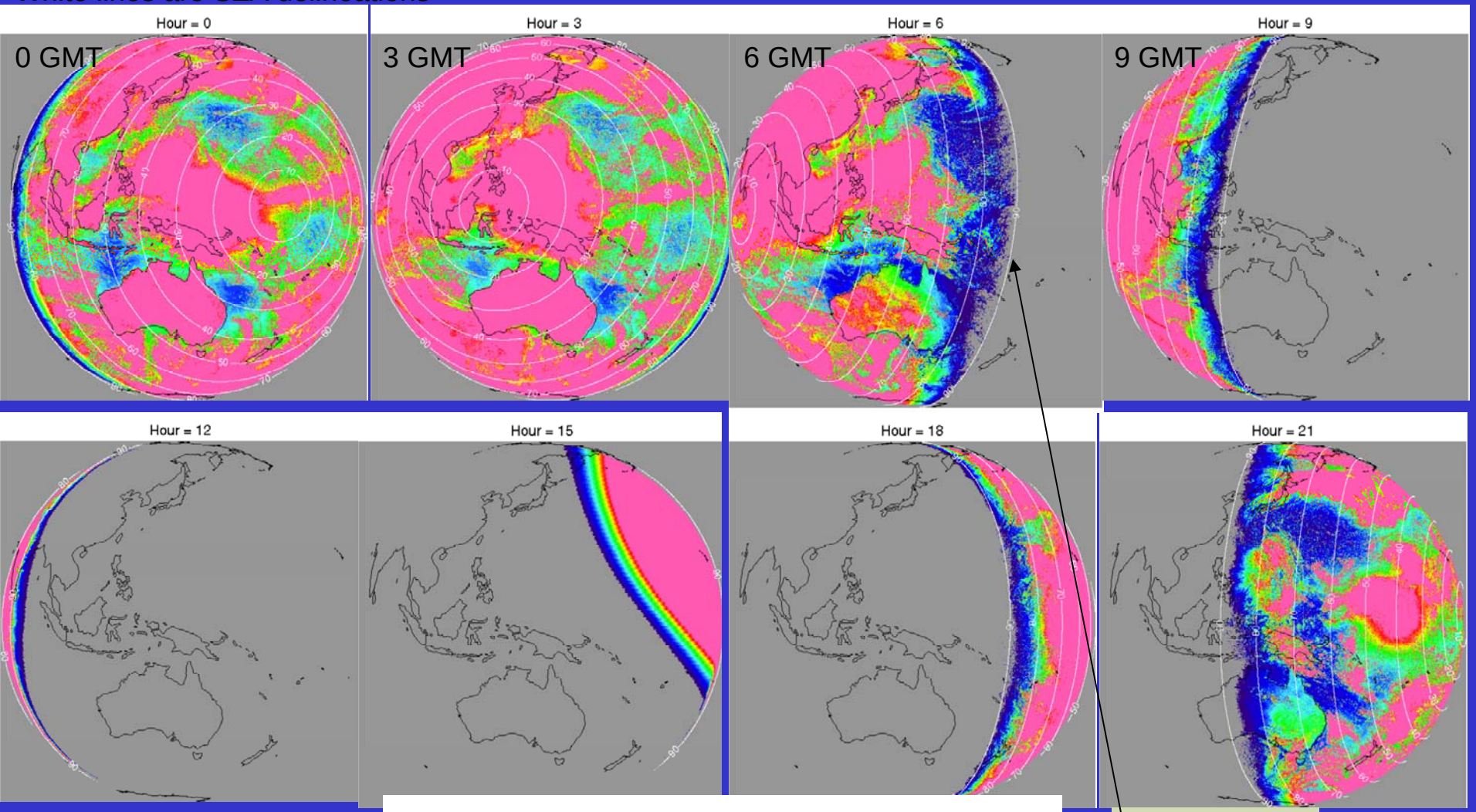
Space Count?

- MTSAT has an offset of 0, where as all the other GEOs have a space clamp that sets the offset>0
  - Space count of 29 for GOES and 51 for MET
  - GMS-5 also had a offset of 0,
  - Any calibration error could result in negative space counts, thereby truncating any counts



MTSAT VIS, Sept 17, 2007

White lines are SZA delineations

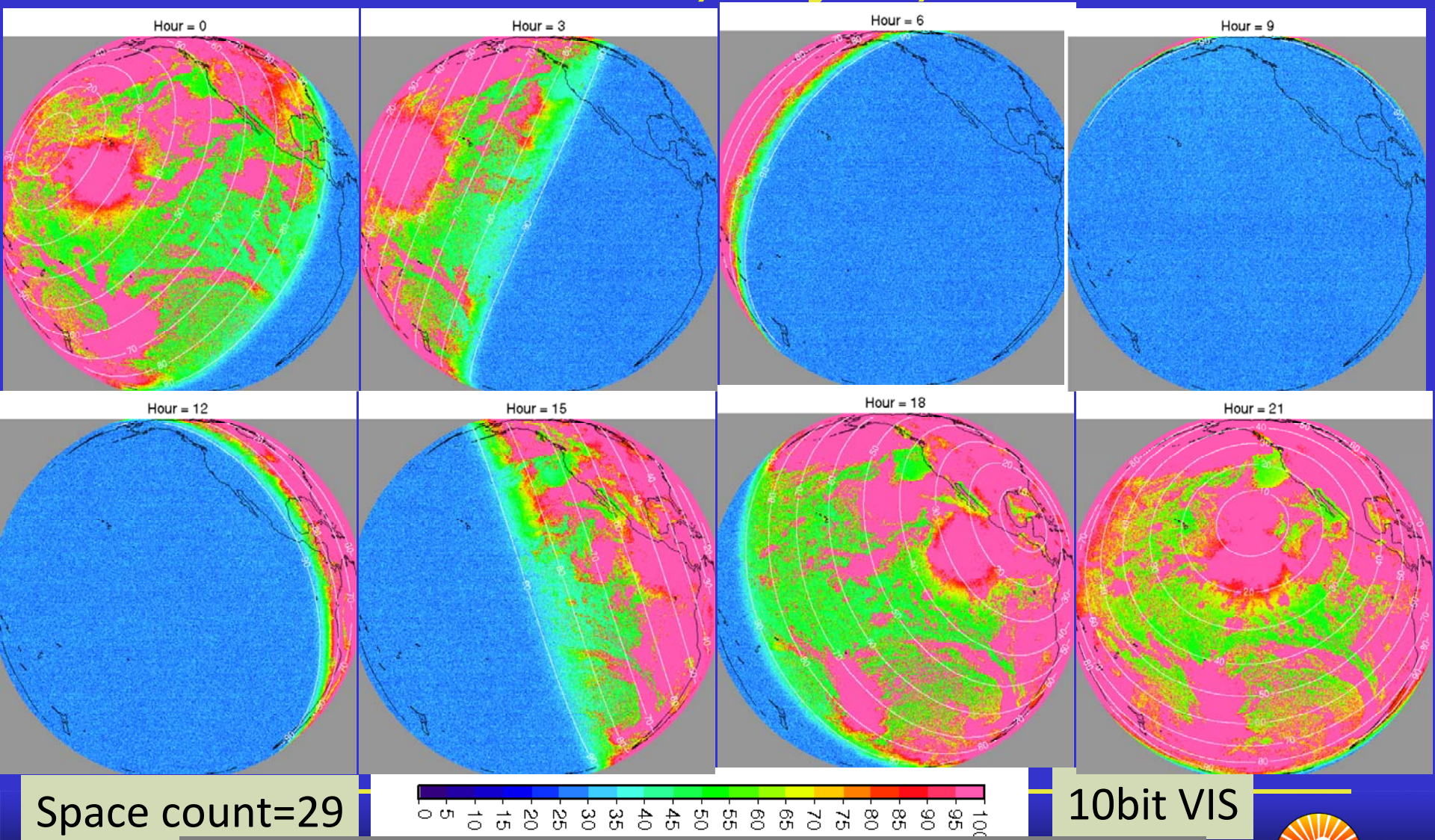


Space count=0

10bit VIS

- Note that many terminator MTSAT pixels have counts of 0 when the SZA<90˚

GOES11 VIS, July 18, 2006

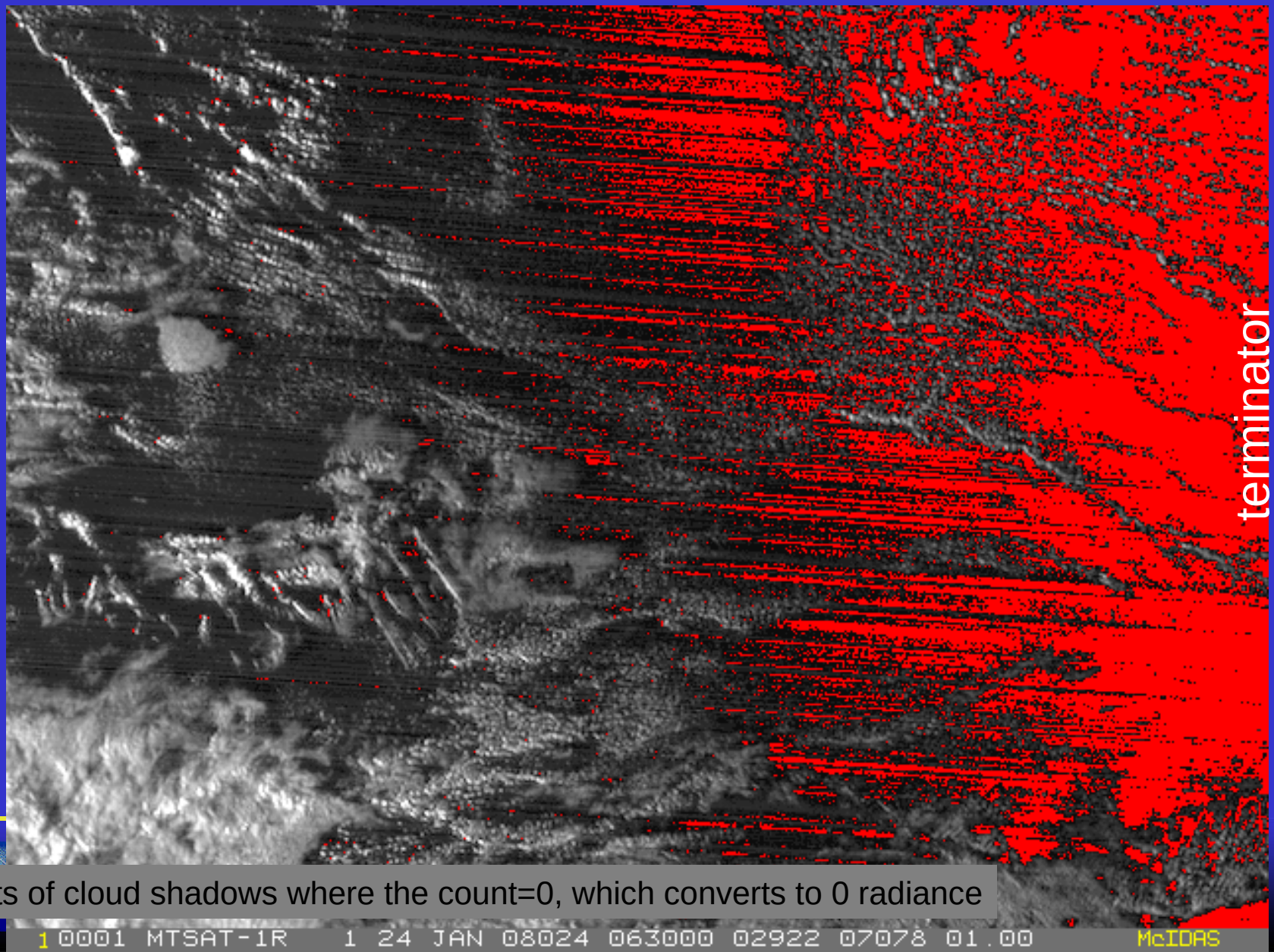


Space count=29

10bit VIS

Note the sunlit part of the disc is greater than 29 and clearly delineated

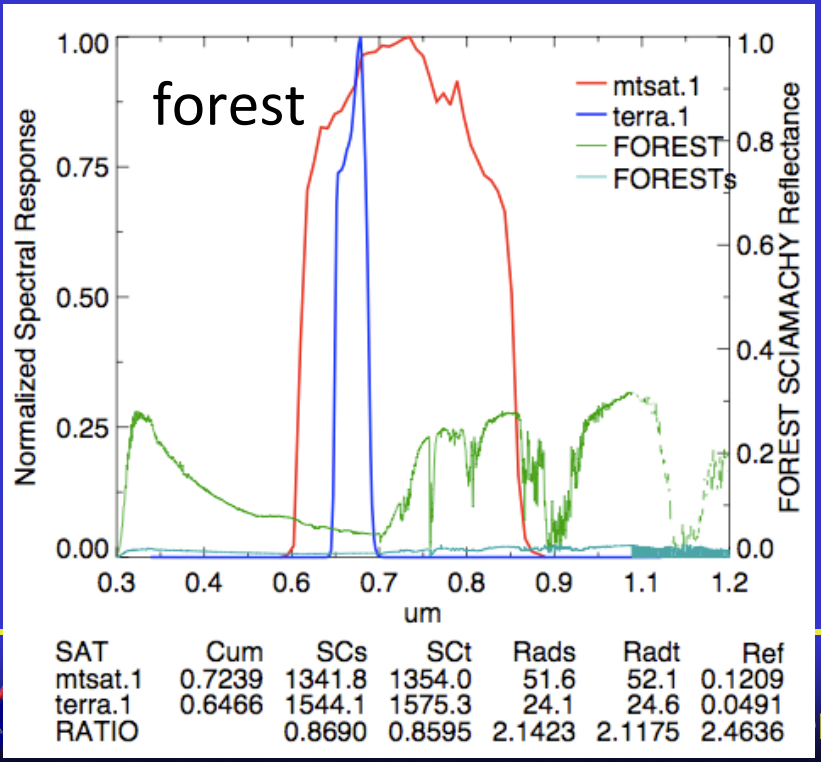
MTSAT, VIS, 1km, Jan 24, 2008 6:30 GMT



Lots of cloud shadows where the count=0, which converts to 0 radiance

Spectral Response?

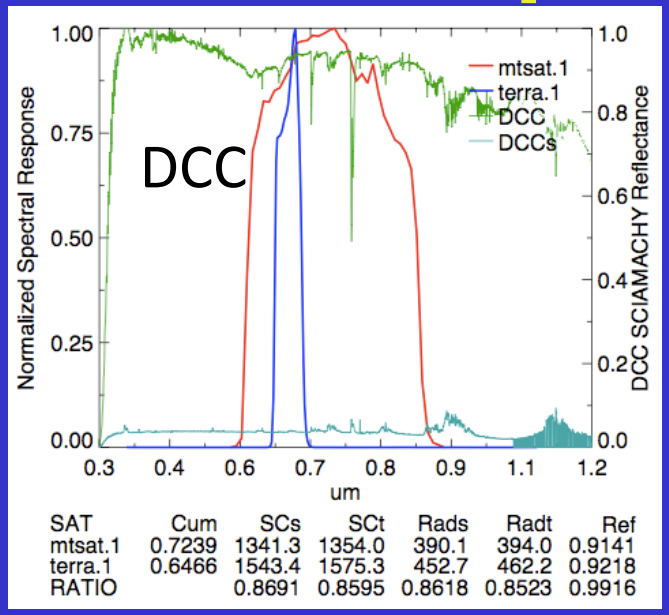
- MTSAT spectral response is centered in the near-infrared
- MODIS, VIRS, MET8,9 are in the red
- Older GEO are almost BB
- Use SCIAMACHY high spectral resolution data to determine reflectances for various cloudy ocean scenes



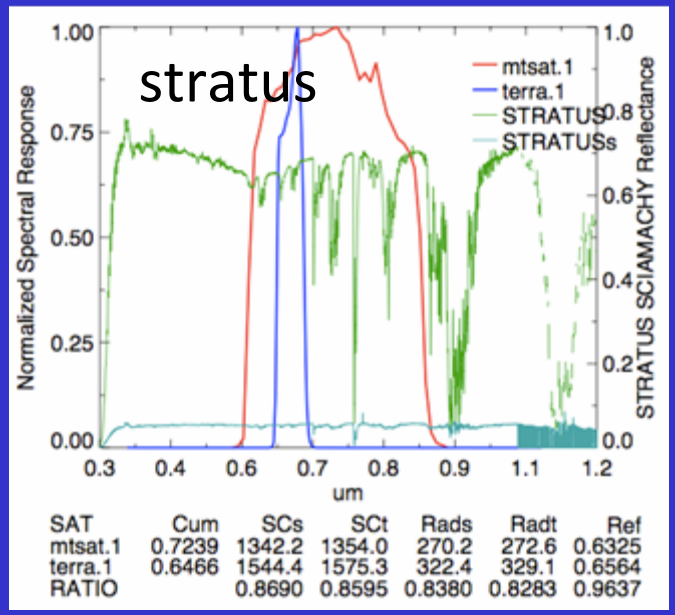
SAT	Cum	SCs	SCt	Rads	Radt	Ref
mtsat.1	0.7239	1341.8	1354.0	51.6	52.1	0.1209
terra.1	0.6466	1544.1	1575.3	24.1	24.6	0.0491
RATIO		0.8690	0.8595	2.1423	2.1175	2.4636

• SCIAMACHY data courtesy of Costy Loukachine and the SCIAMACHY project

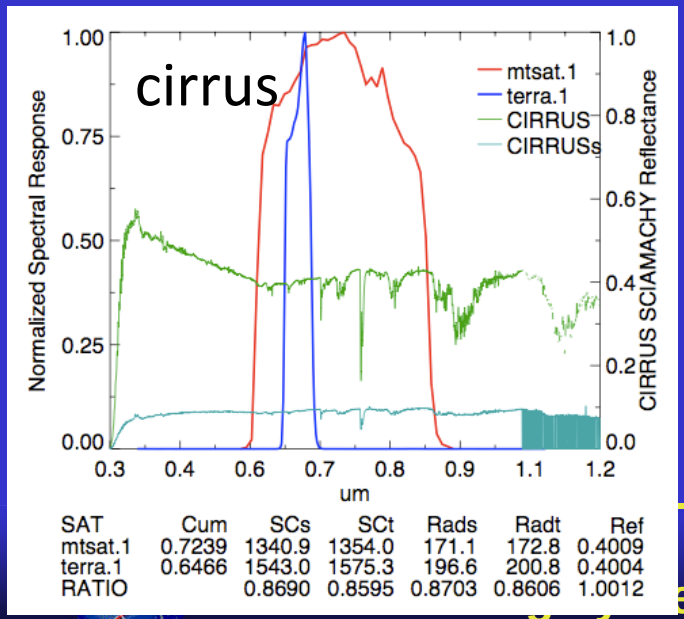
Spectral Response



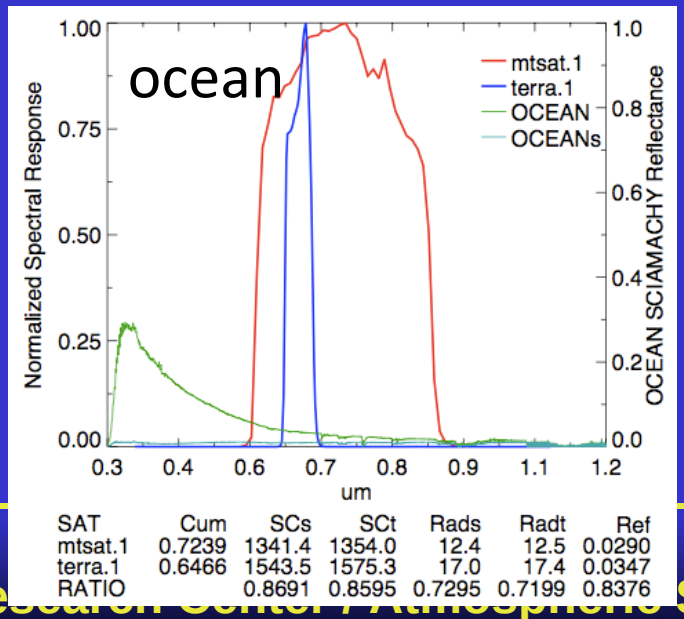
SAT	Cum	SCs	SCt	Rads	Radt	Ref
mtsat.1	0.7239	1341.3	1354.0	390.1	394.0	0.9141
terra.1	0.6466	1543.4	1575.3	452.7	462.2	0.9218
RATIO		0.8691	0.8595	0.8618	0.8523	0.9916



SAT	Cum	SCs	SCt	Rads	Radt	Ref
mtsat.1	0.7239	1342.2	1354.0	270.2	272.6	0.6325
terra.1	0.6466	1544.4	1575.3	322.4	329.1	0.6564
RATIO		0.8690	0.8595	0.8380	0.8283	0.9637



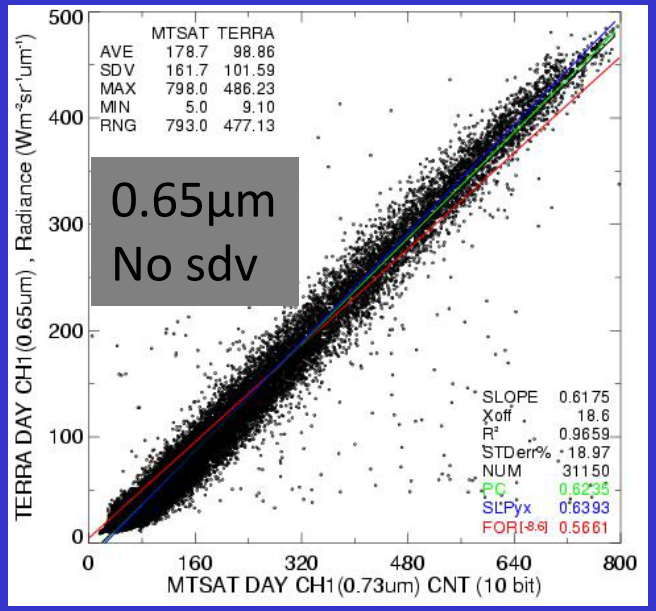
SAT	Cum	SCs	SCt	Rads	Radt	Ref
mtsat.1	0.7239	1340.9	1354.0	171.1	172.8	0.4009
terra.1	0.6466	1543.0	1575.3	196.6	200.8	0.4004
RATIO		0.8690	0.8595	0.8703	0.8606	1.0012

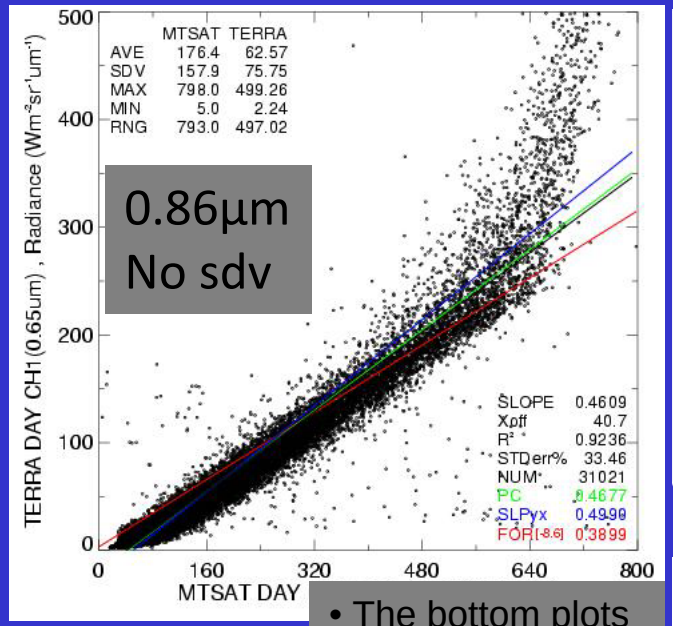


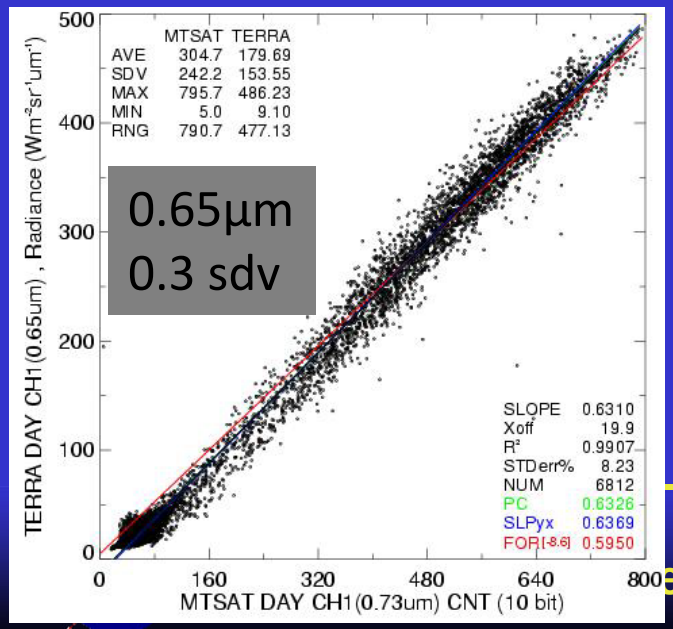
SAT	Cum	SCs	SCt	Rads	Radt	Ref
mtsat.1	0.7239	1341.4	1354.0	12.4	12.5	0.0290
terra.1	0.6466	1543.5	1575.3	17.0	17.4	0.0347
RATIO		0.8691	0.8595	0.7295	0.7199	0.8376

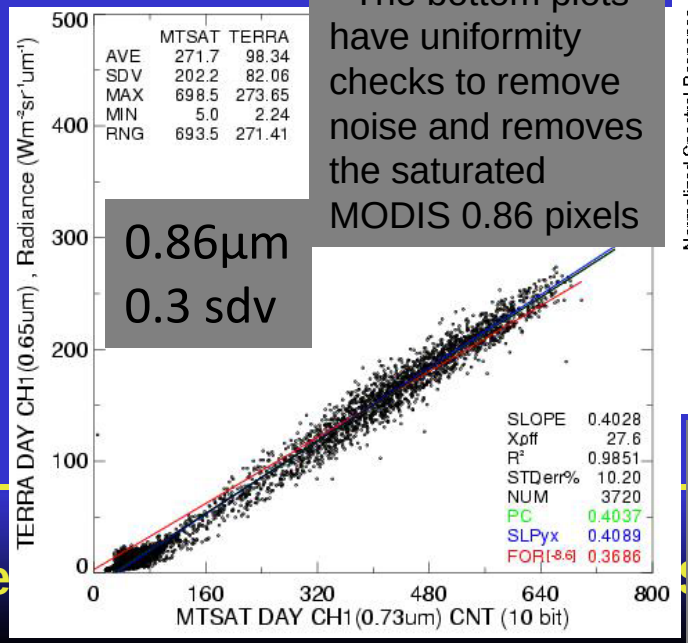
- Clouds are nearly flat between 0.6-0.9µm
- Clear ocean small has a much smaller radiance than cloud scenes
- Avoid clear land scenes, only inter-calibrate over ocean scenes

MTSAT/Terra SEP07-APR08



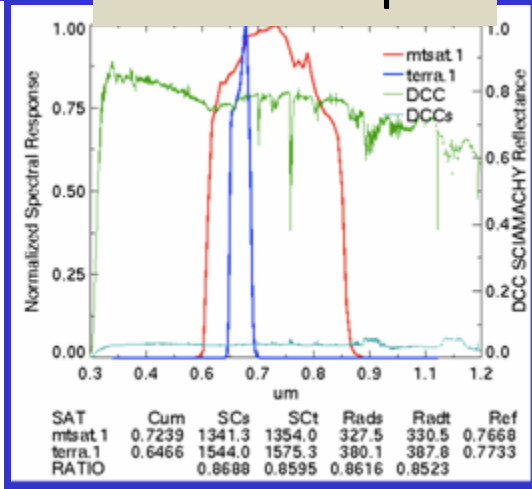




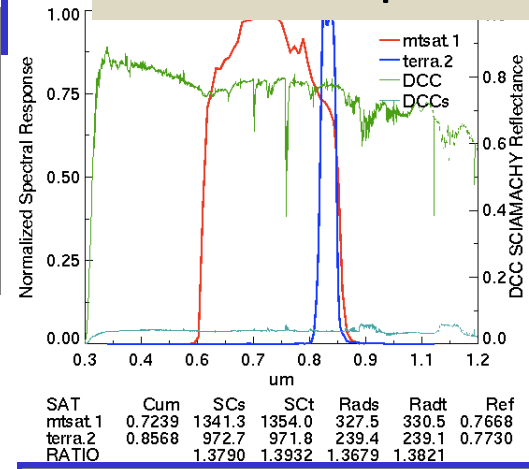


• The bottom plots have uniformity checks to remove noise and removes the saturated MODIS 0.86 pixels

Terra 0.65µm



Terra 0.86µm

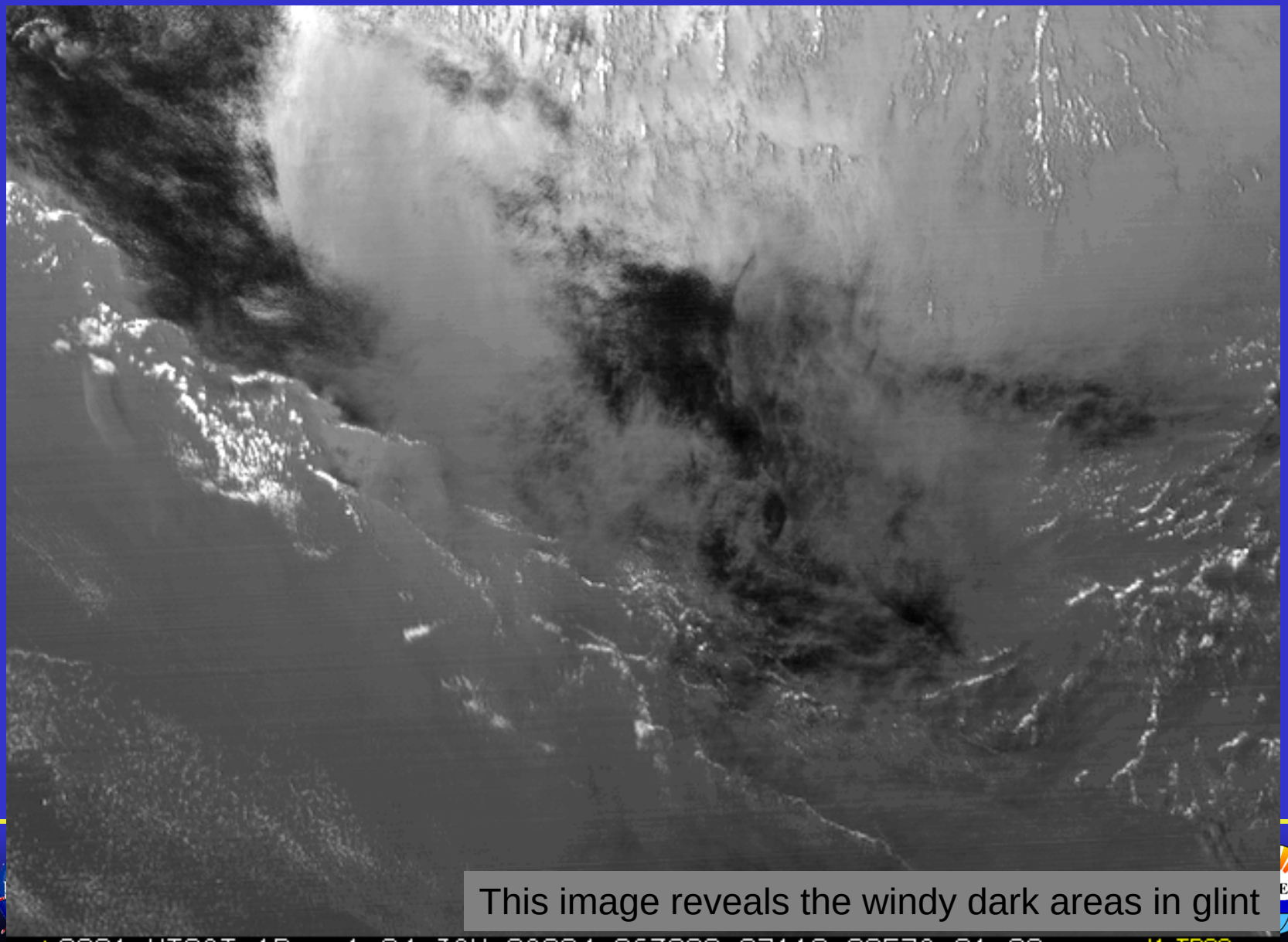


• The nonlinear regression appears to be both in the 0.65 and 0.86µm channels, which removes spectral response as a factor

Sunglint?

- The ray-matched domain is near glint
- A glint check is used that eliminates pixels in large glint probabilities
  - It works for all other GEOs
- Glint is bright in the near IR
  - Compare matched radiances near glint and outside of glint
  - Small grid = near sub-satellite ±15° latitude and ± 20° longitude gird
  - Large grid = ±45° latitude and ± 45° longitude grid minus the small grid

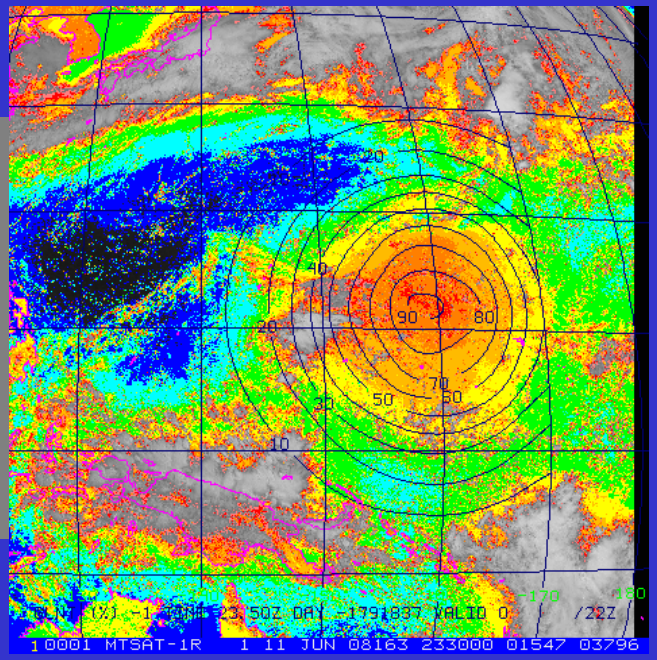
Point 7 mag=1, red=0

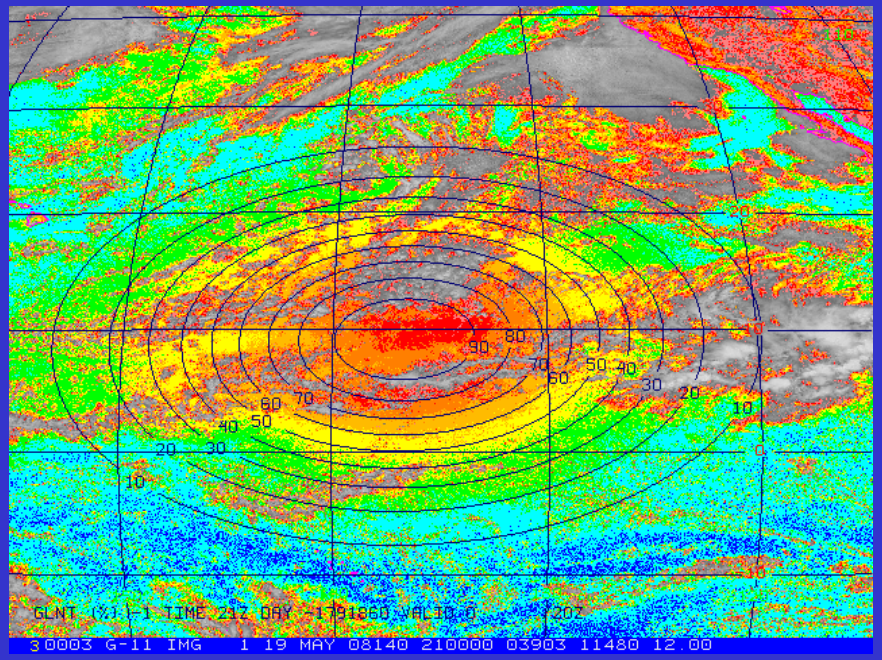


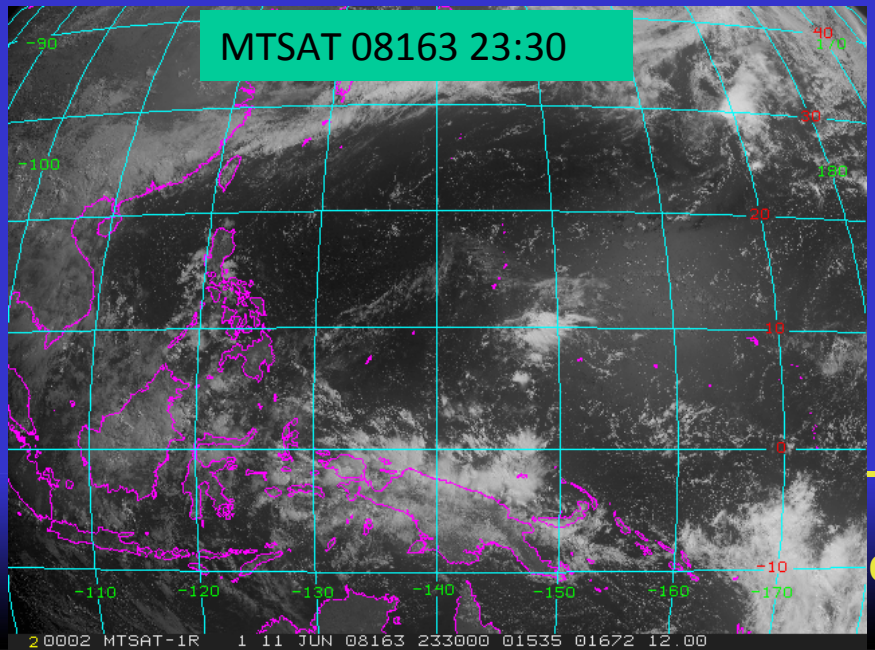
This image reveals the windy dark areas in glint

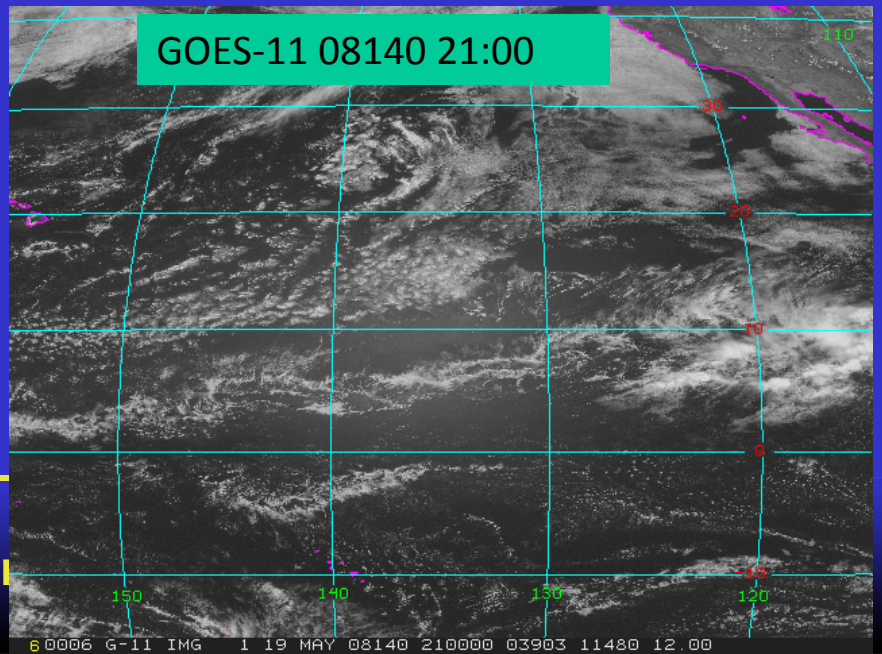
Comparison of glint probability

- Lines denote glint probability
- Color coded according to visible count
- High counts are in the glint centers





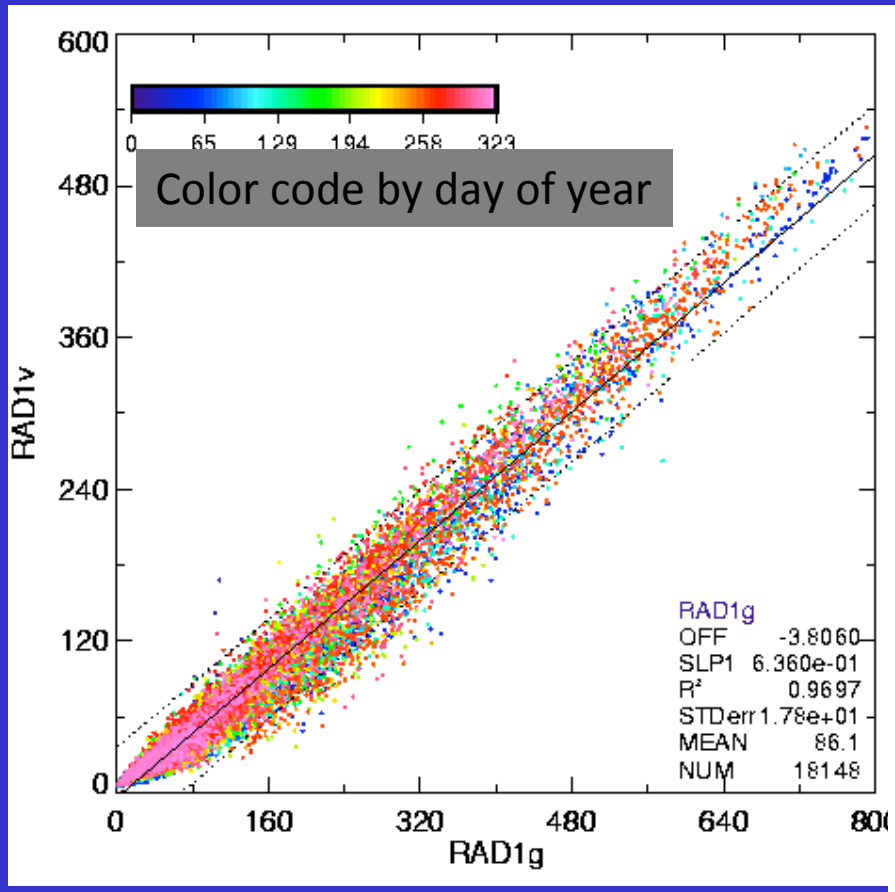


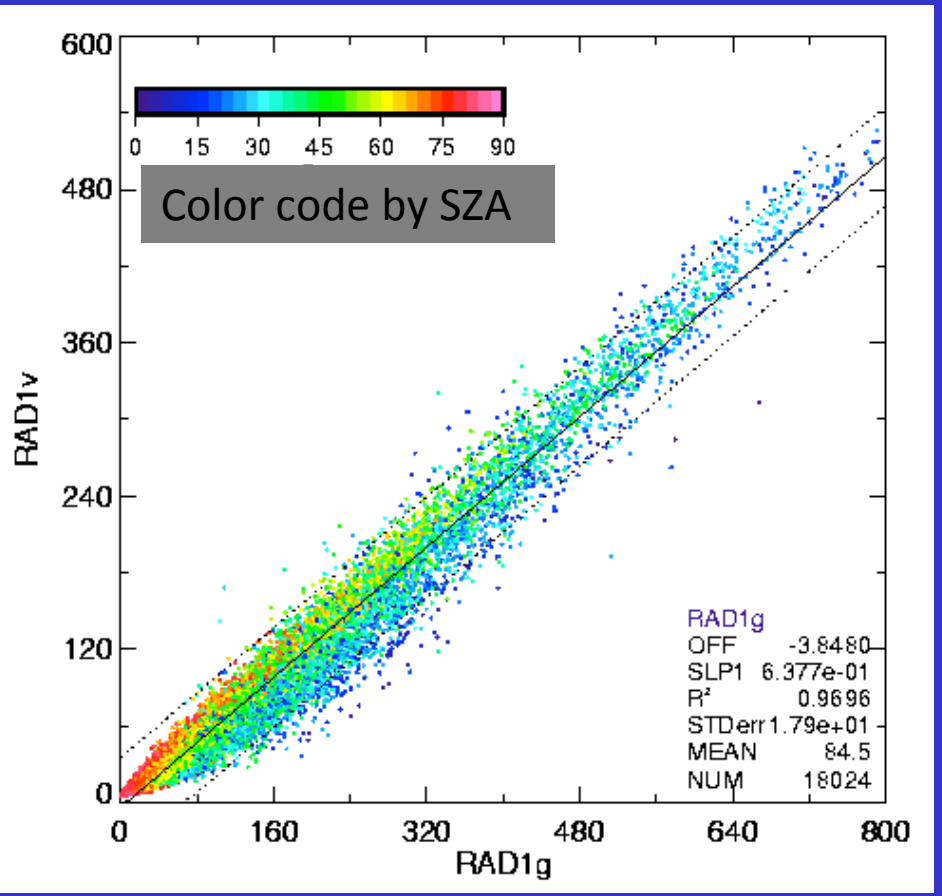


Other ?

- Day to day Calibration shifts
- Viewing geometry, sza, vza, raz, location
- Polarization, function scattering angle
- Diurnal shifts in the calibration

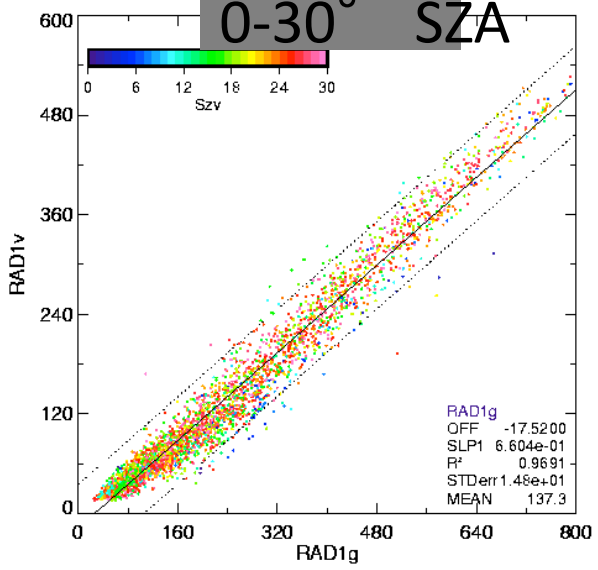
MTSAT/VIRS SEP07-MAR08

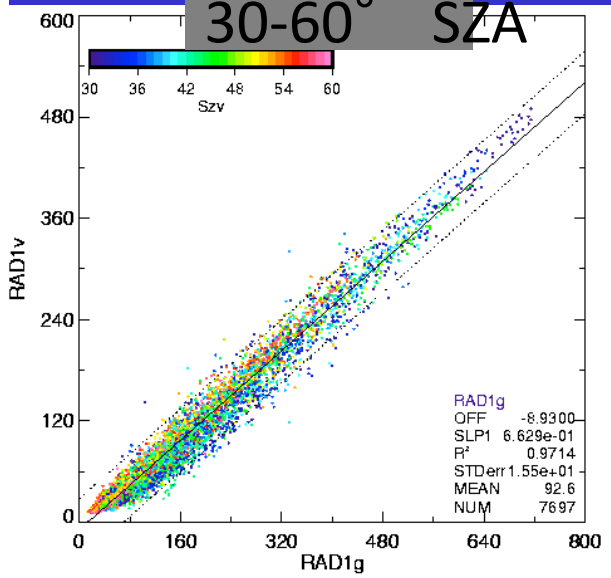


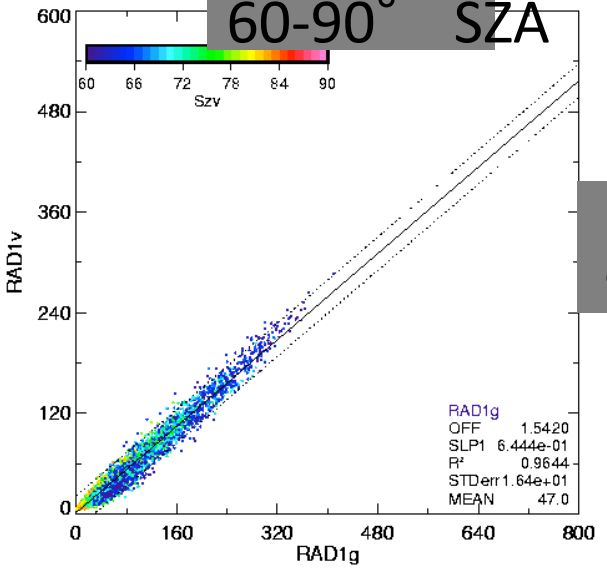


- There is a functionality with SZA in the regression
- VIRS is in a 47 day precessionary cycle

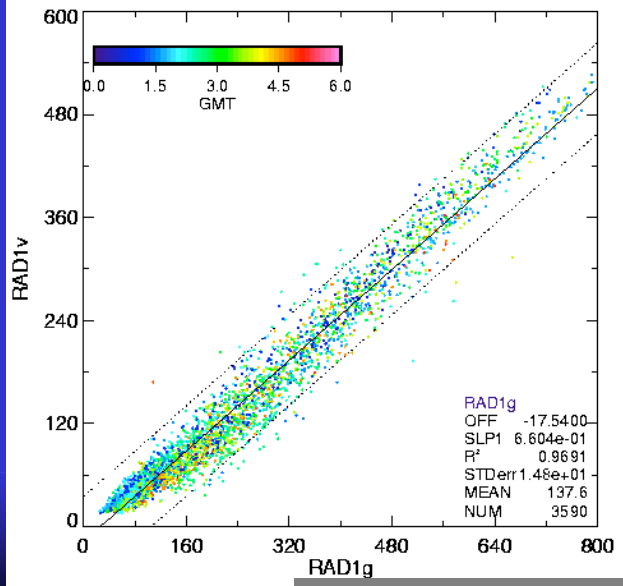
SZA and GMT MTSAT/VIRS comparisons

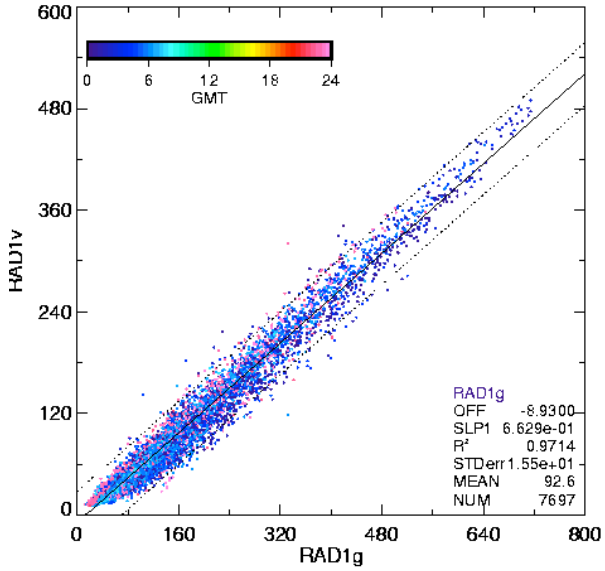


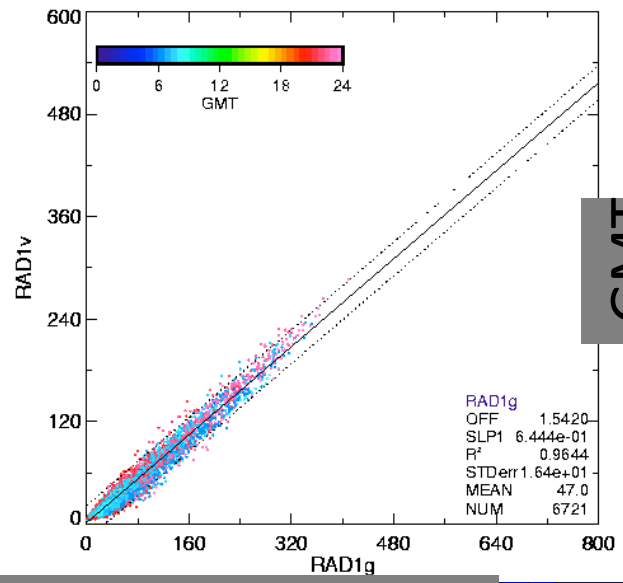




SZA



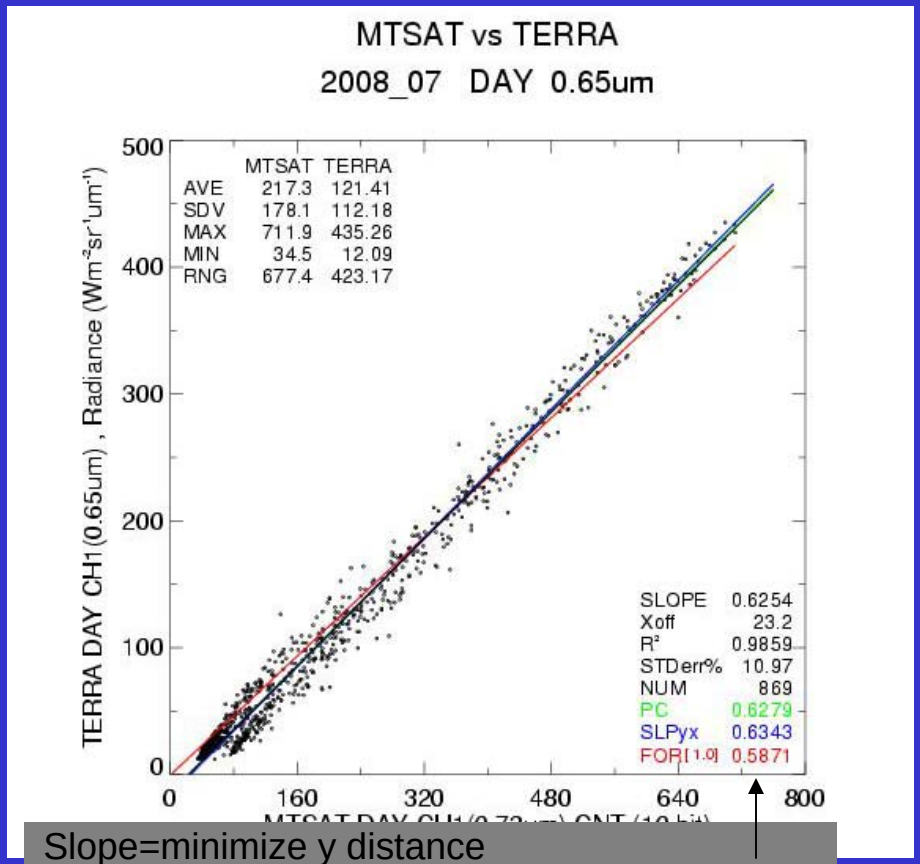




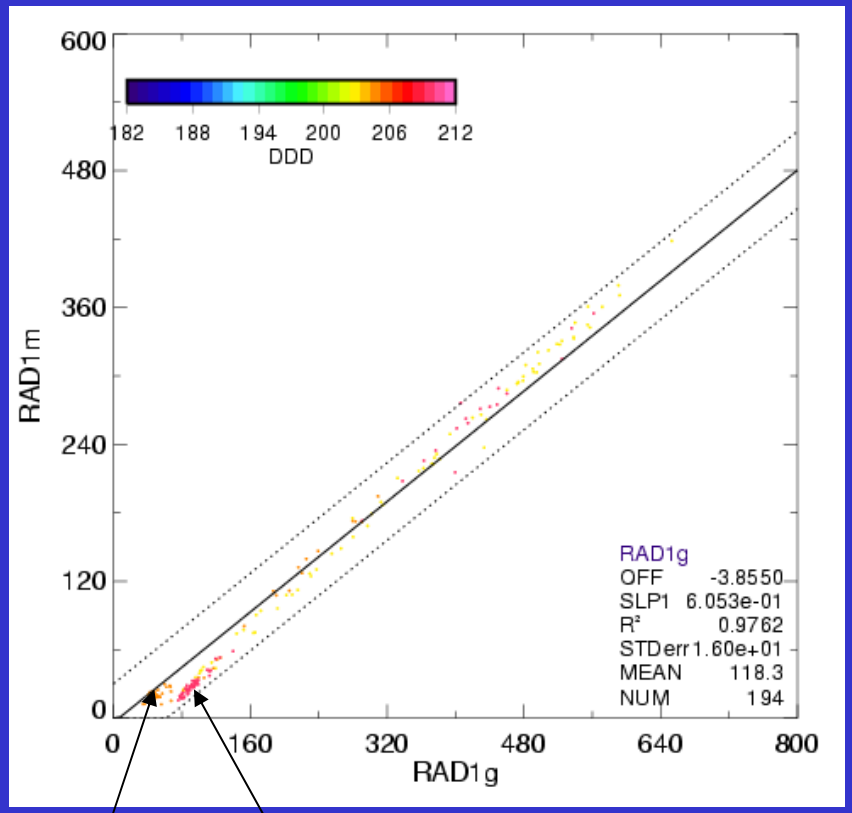
GMT

Based on VIRS results there seems to be a functionality with SZA / GMT

July 2008 MTSAT/Terra large grid



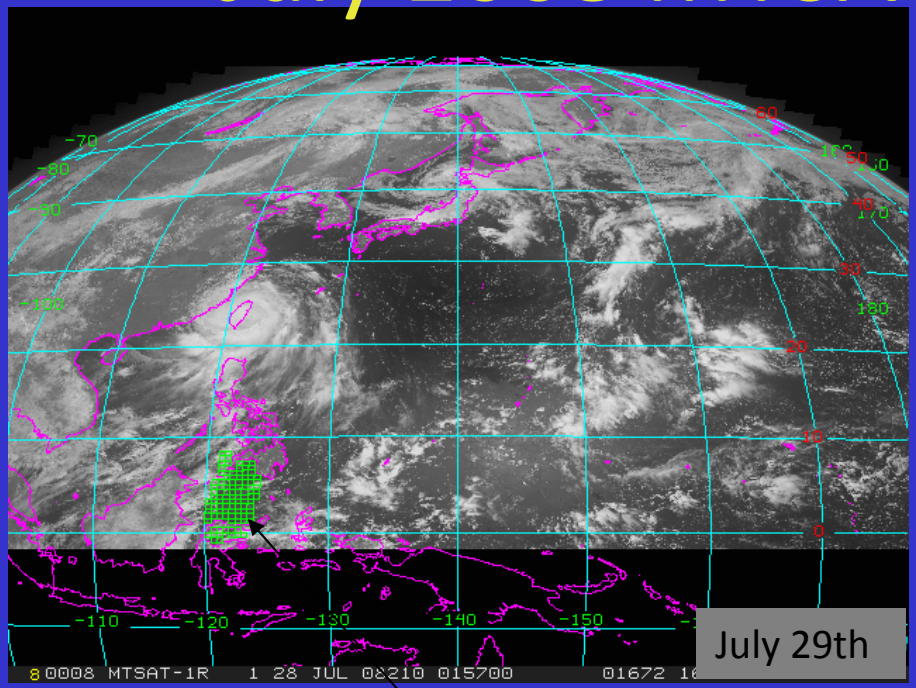
Slope=minimize y distance
SLPyx = minimize x distance
PC = minimize distance to line
FOR = force line through offset

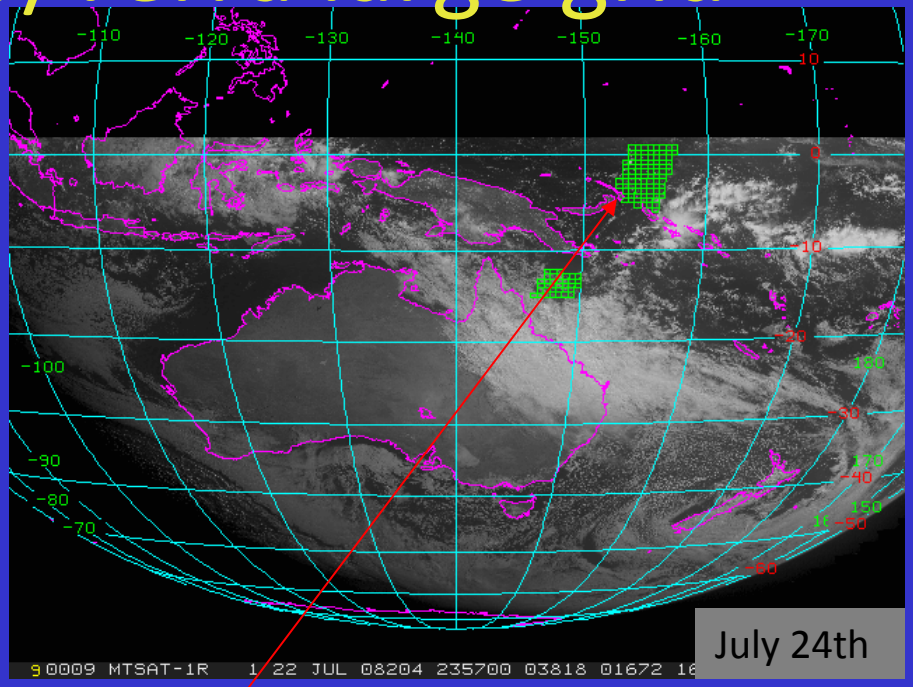


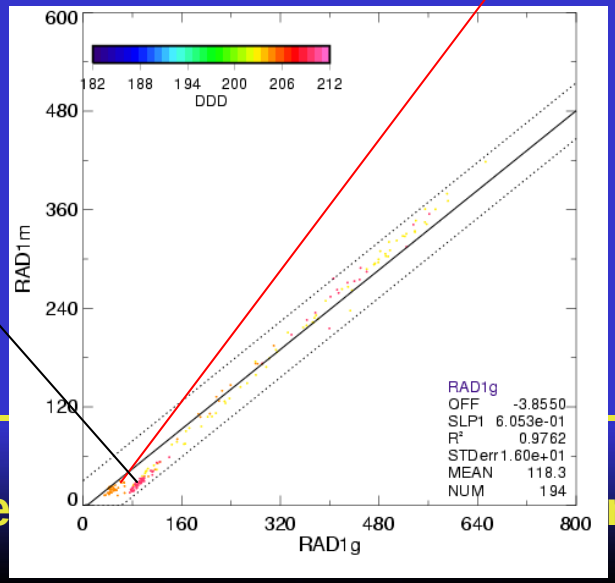
July 24th

July 29th

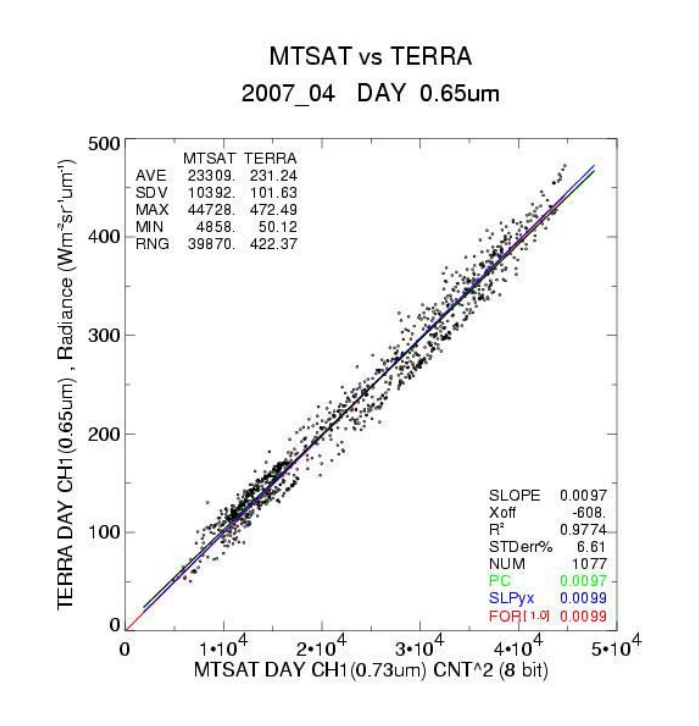
July 2008 MTSAT/Terra large grid





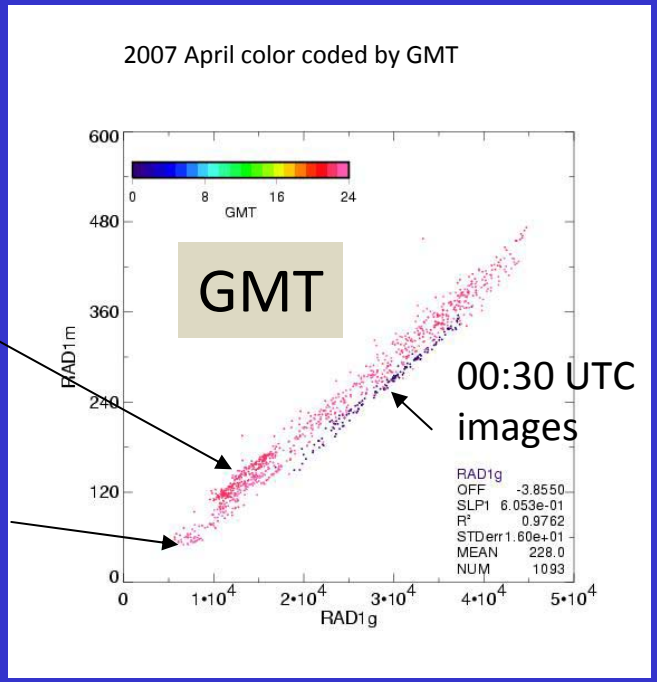


April 2007, MTSAT large grid



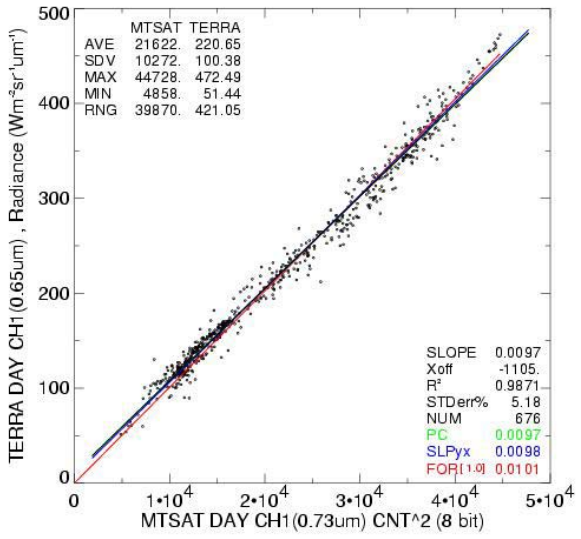
22:30 UTC images

23:30 UTC images

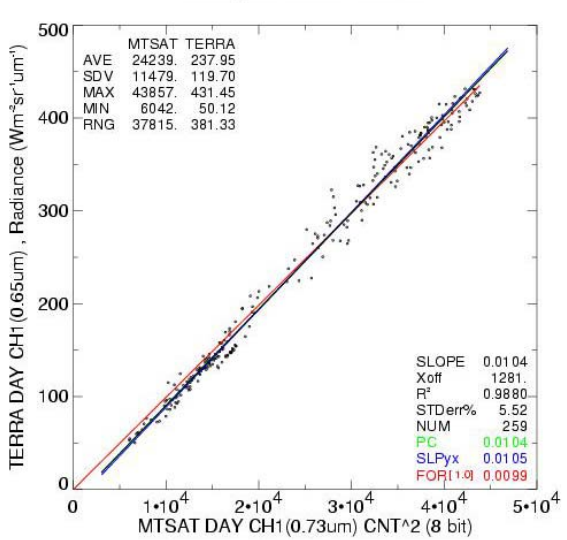


April 2007, MTSAT/Terra large grid

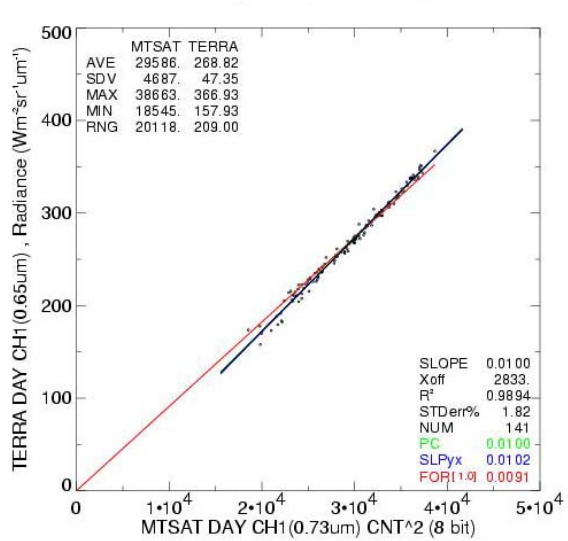
22:30 UTC images



23:30 UTC images



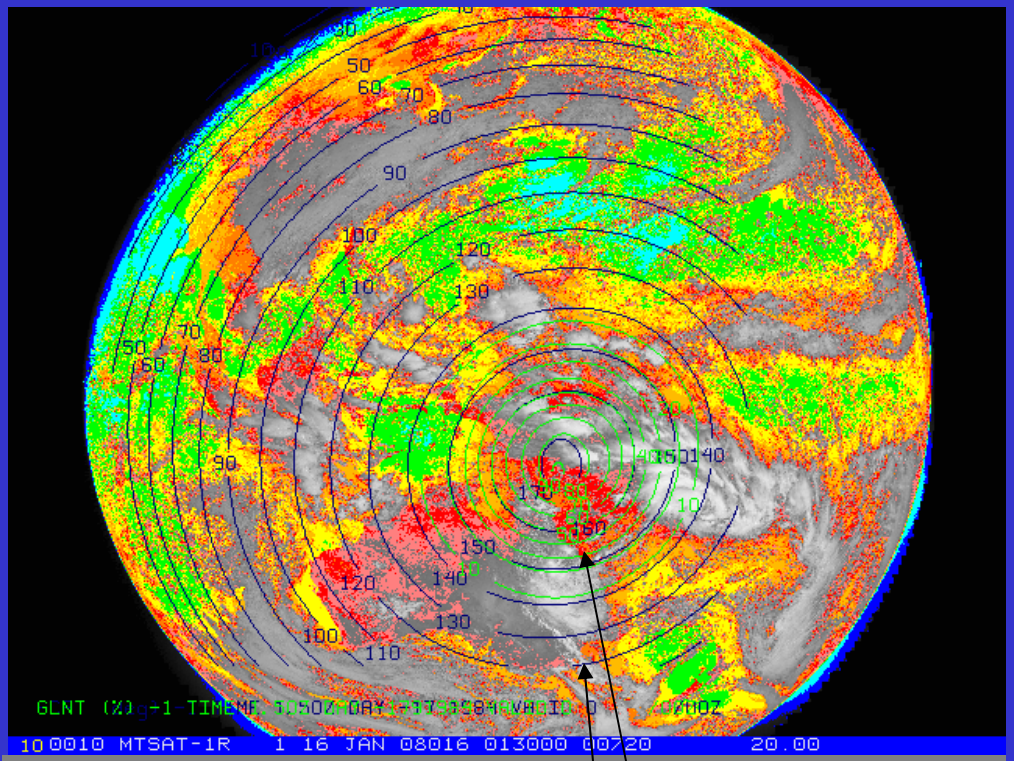
00:30 UTC images



- 3 different slopes for 3 different hourly images for April 2007
- MODIS radiances < 50$Wm^{-2}sr^{-1}\mu m^{-1}$ have been removed

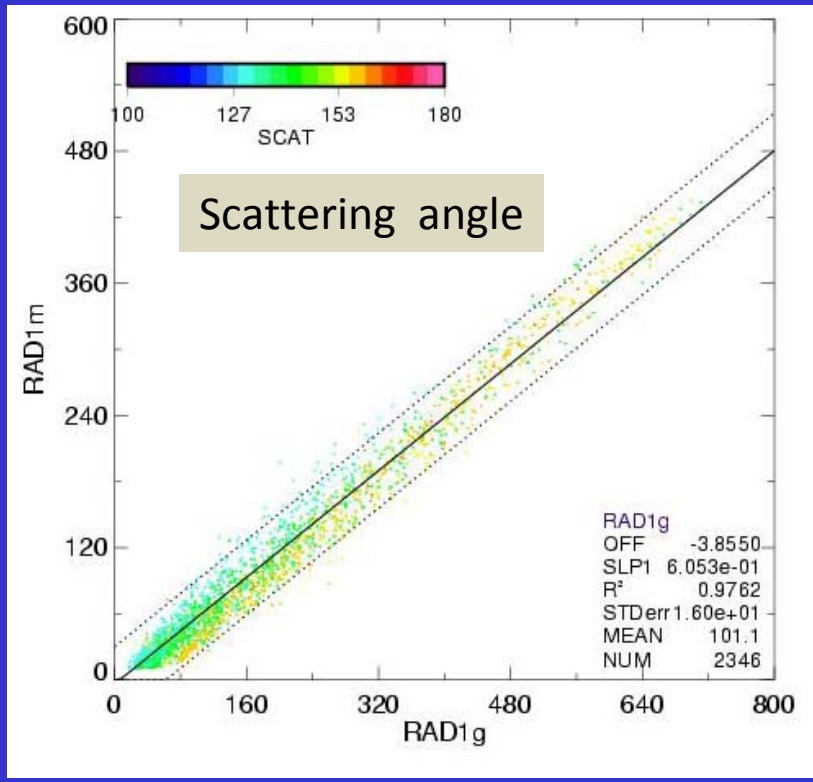
Polarization

Jan 16, 2008, 1:30 GMT



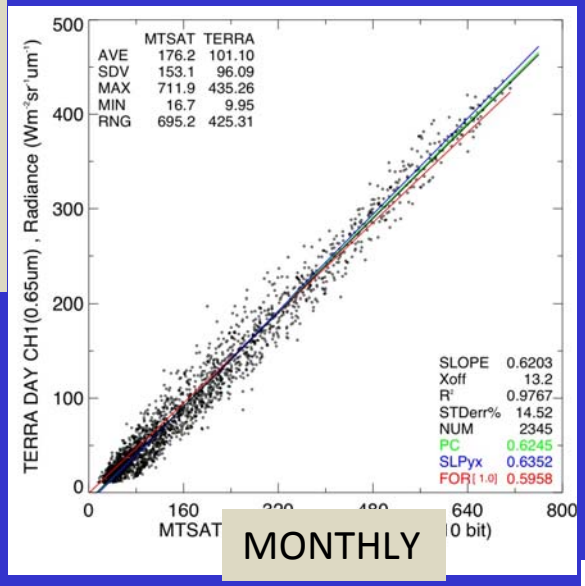
- Green lines are glint probability
- Blue lines are scattering angle
- Image colorcoded by visible count below 100

July 2008 small grid

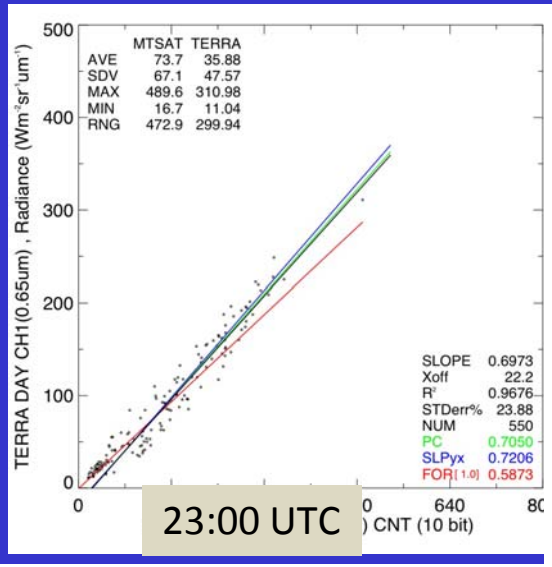


July 2008

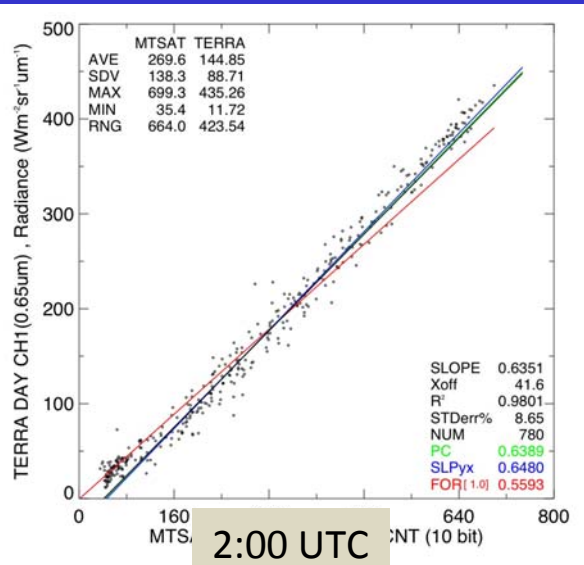
Small grid



MONTHLY

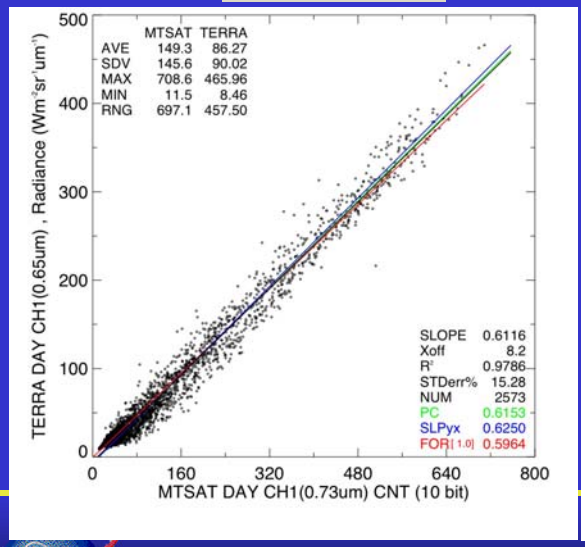


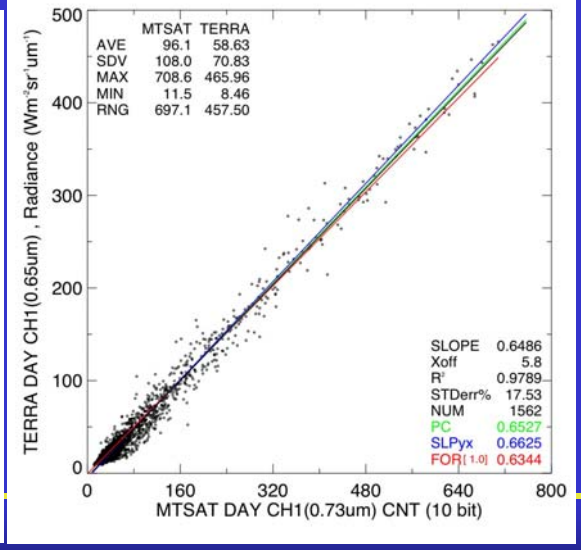
23:00 UTC

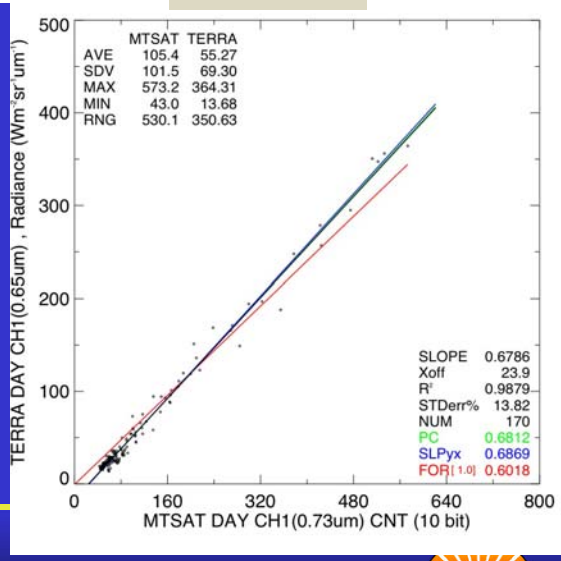


2:00 UTC

Large Grid



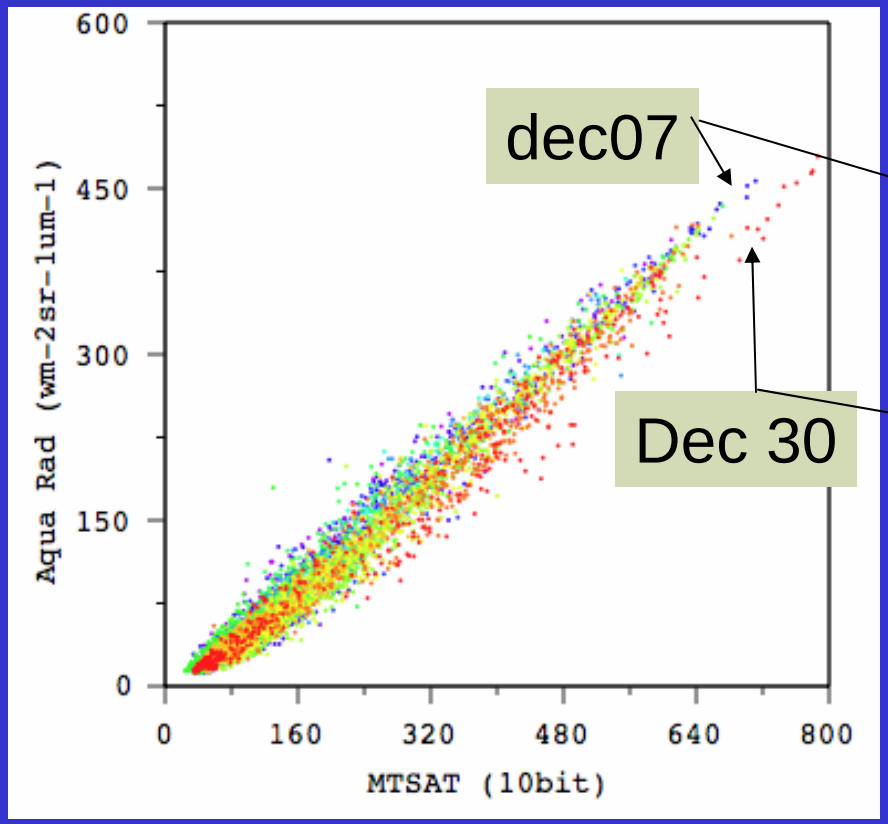


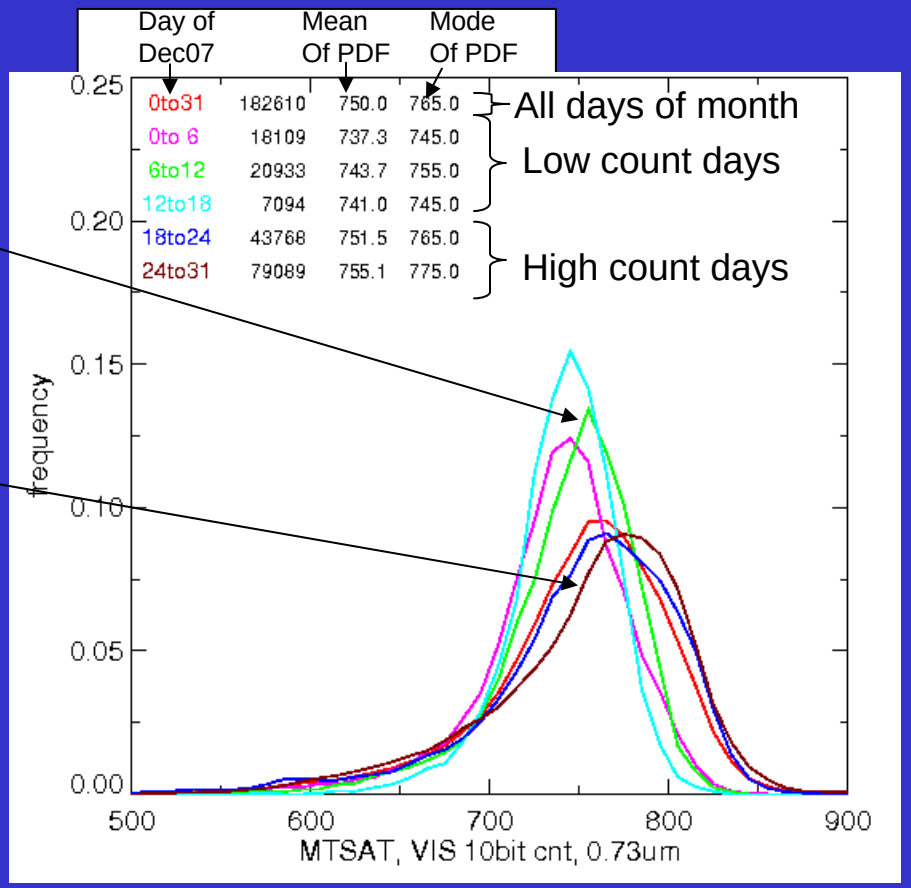


The use of DCC to detect sudden gain shifts, Dec 2007

DCC MTSAT weekly bins

Aqua/MTSAT color by day





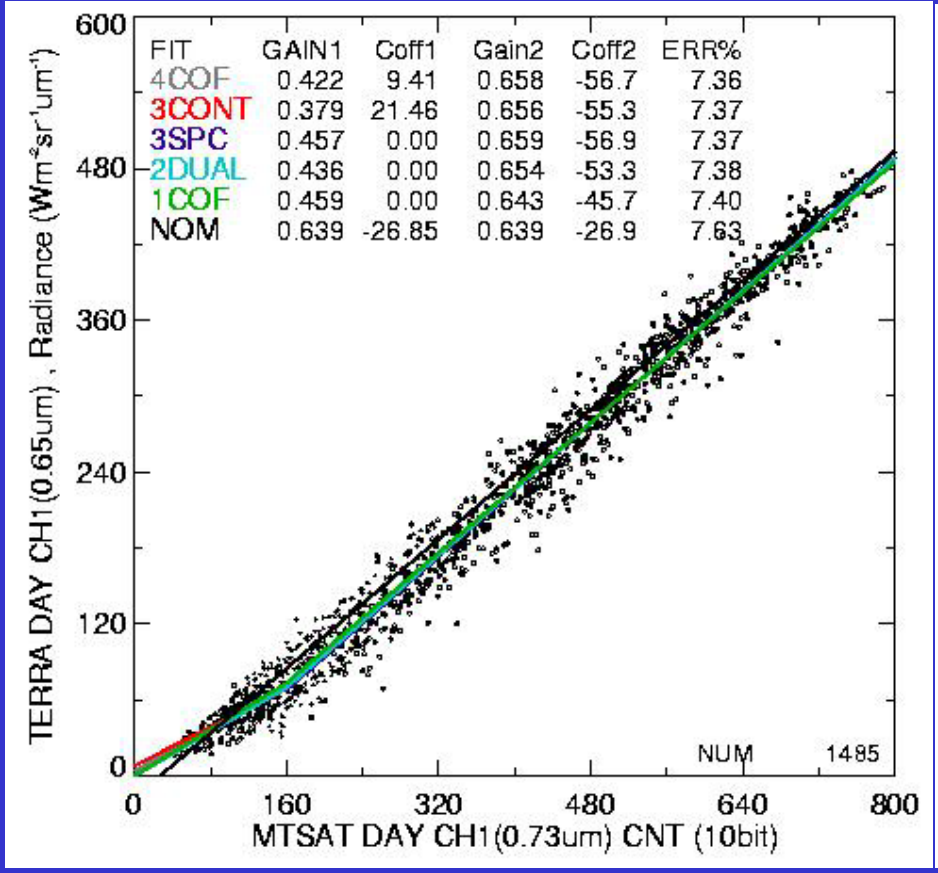
- Seems to be shift in the visible calibration ~ Dec 18, 2007

Conclusions and Future Work

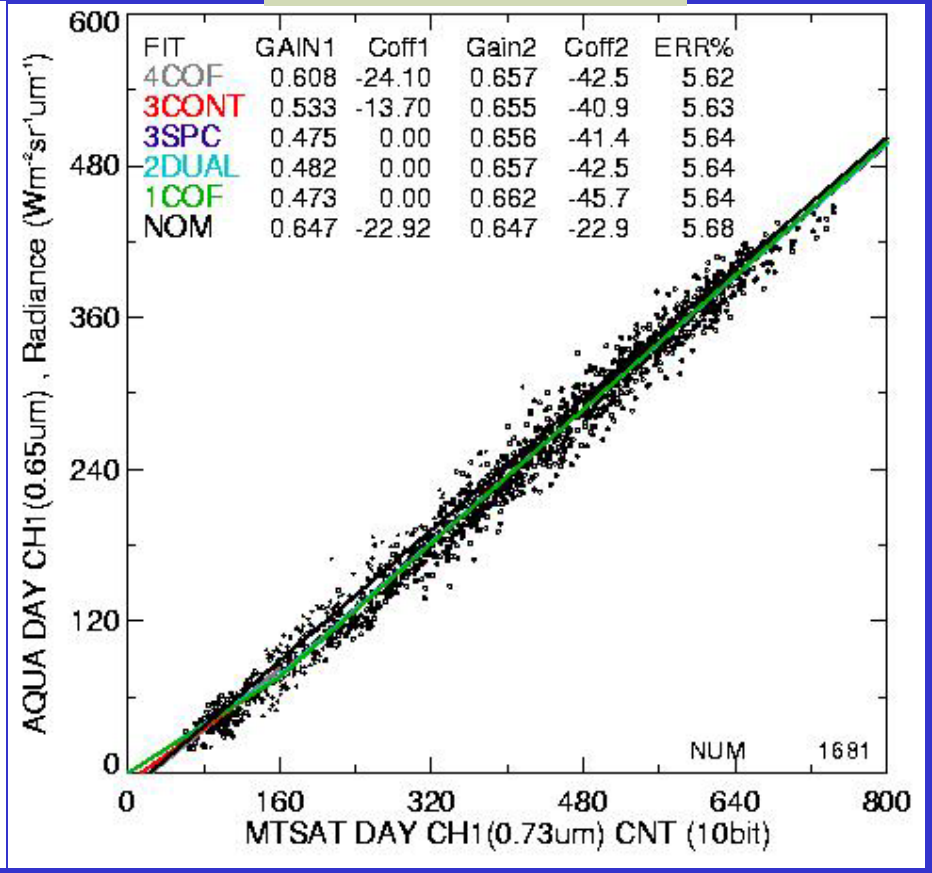
- MTSAT calibration not a function, of navigation, zero offset, spectral response, sunglint
- MTSAT dark radiances have functionality with time, viewing geometry
  - stray light?
  - polarization?
- Based on DCC there seems to be some gain variability
- Calibrate MTSAT bright radiances for stability
- How do you apply the coefficients once you have them?
- Use a dual gain approach?

MTSAT dual fit calibration, Nov 2007

MTSAT/Terra



MTSAT/Aqua



- 2DUAL, force spc=0, breakpoint=160, both gains = breakpoint
- Note very consistent high gains
- Spatial visible standard deviation threshold at 40%

FY2C/Terra Nov07