

2011 Langley ISCCP recalibration effort

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May 16, 2011, LaRC, Hampton, VA

Outline

- LaRC ISCCP calibration approach
- Use Aqua-MODIS as reference for absolute calibration
- Calibration methodologies
 - MODIS/GEO or AVHRR/GEO ray-matching calibration transfer
 - Deep Convective Cloud (DCC) invariant target calibration
 - Desert invariant target calibration
 - Spectral Correction using SCIAMACHY hyper-spectral radiances for each method
 - McIDAS half hourly 4km vs ISCCP B1U 3-hourly 8km comparison for each method
- GEO calibration examples
- GEO/AVHRR calibration examples
- Some outstanding issues
 - Band solar constants and solar incidence spectra
 - Nonlinear sensors

LaRC ISCCP calibration strategy

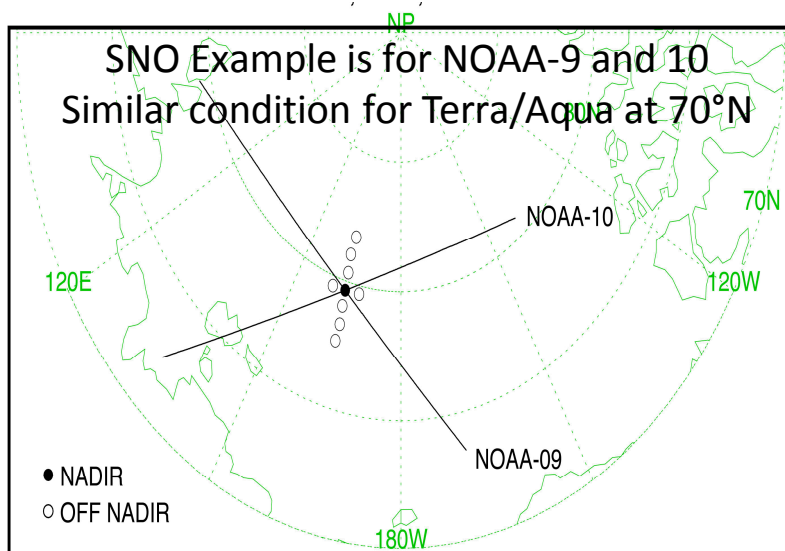
(completely reworked since Feb 2010)

- Use Aqua-MODIS as the absolute calibration reference
- Calibrate each GEO independently, using MODIS/GEO ray-matching, DCC and deserts
 - The DCC and desert models are based on Aqua-MODIS
 - 1985-1999 GEOs are based on DCC and desert only
- Transfer the calibration of all the simultaneous GEOs with a given NOAA AVHRR
 - All GEO cross calibrations should yield the same AVHRR sensor degradation
 - Perform DCC and desert calibration within in the limits of the orbit degradation
- Compare with ISCCP and other published calibration coefficients

Select which MODIS as absolute reference

- Use stability of record, verify with DCC and desert
- Not based on length of record, magnitude of absolute calibration
- Use Terra/Aqua simultaneous nadir overpass (SNO) to radiometrically scale one to the other

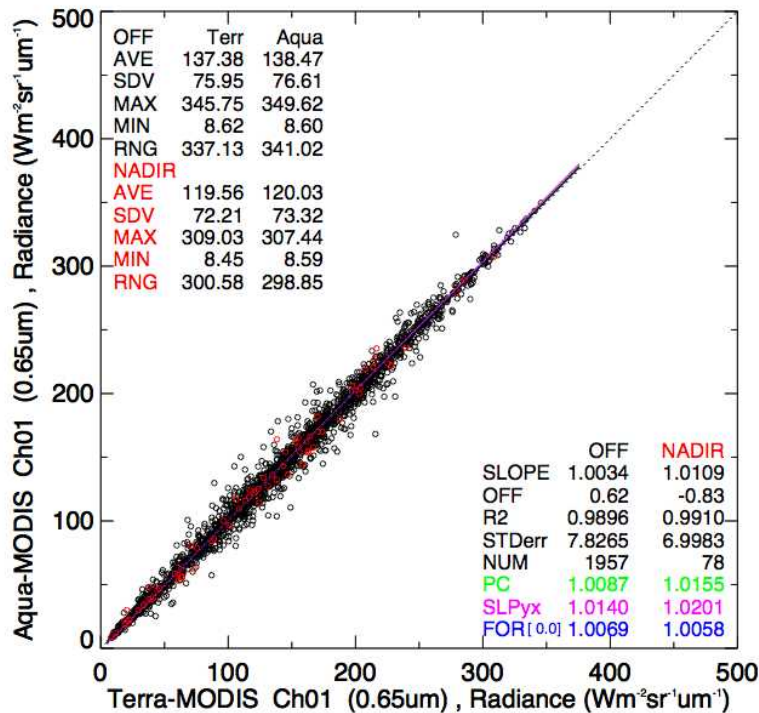
SNO



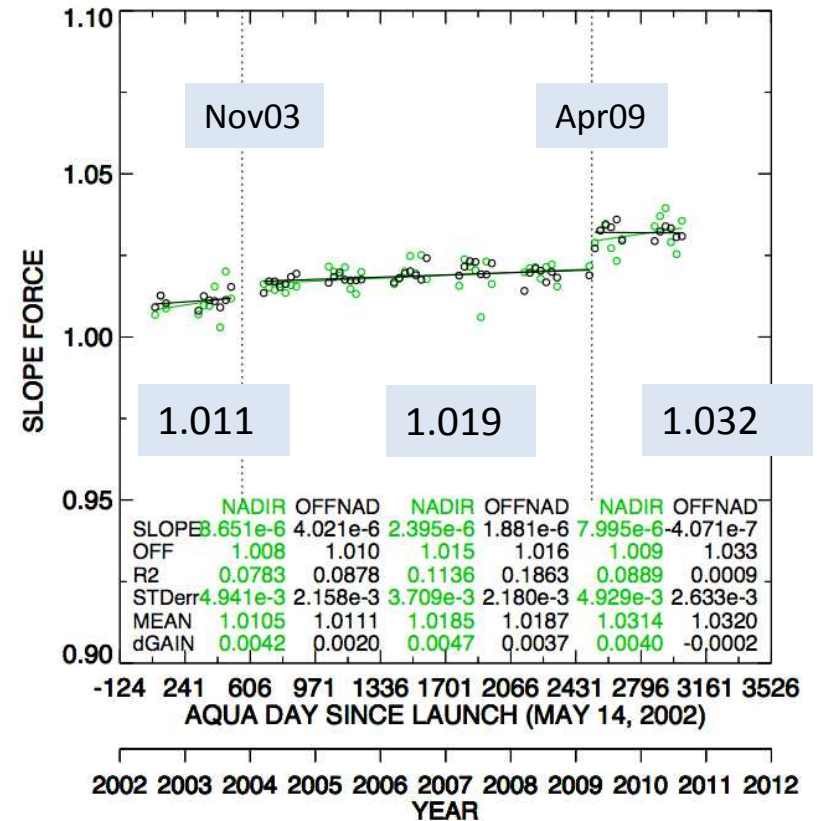
- Terra and Aqua ground track transects are ~15 minutes apart, ratio $\cos(\text{SZA})$ of obs
- Mitigate advection effects by using 50 km radii regions and low spatial sigma regions
- Increase number of observations by using off nadir regions (open circles)
- Off nadir regions that lie in the North-South have identical VZA and are at solar noon and have similar relative azimuth angles

Terra/Aqua SNO

Terra vs Aqua MODIS
NP_2002_07, 0.65um, nadir&off-nadir

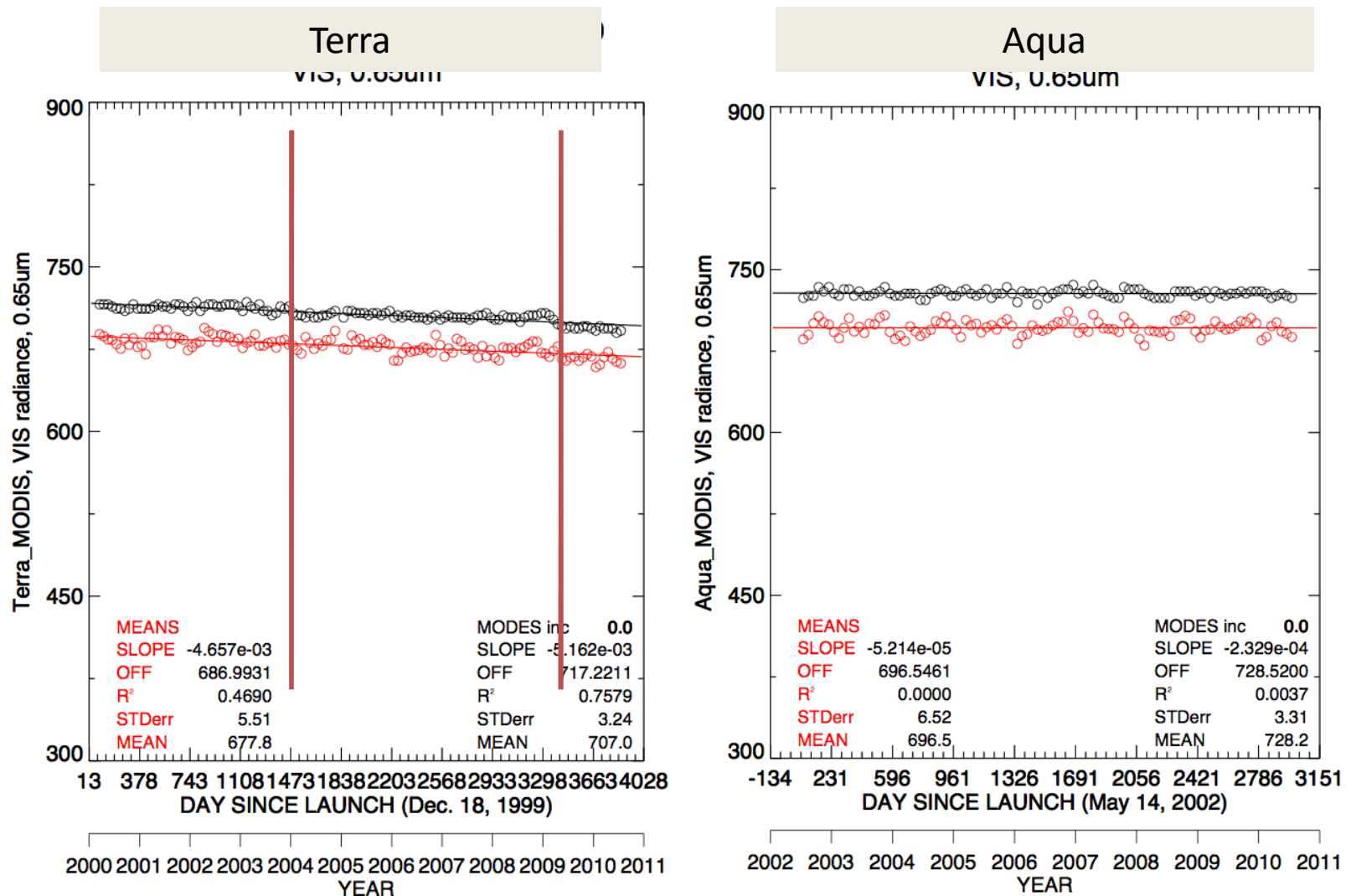


Multiple Terra by these factors to convert to Aqua



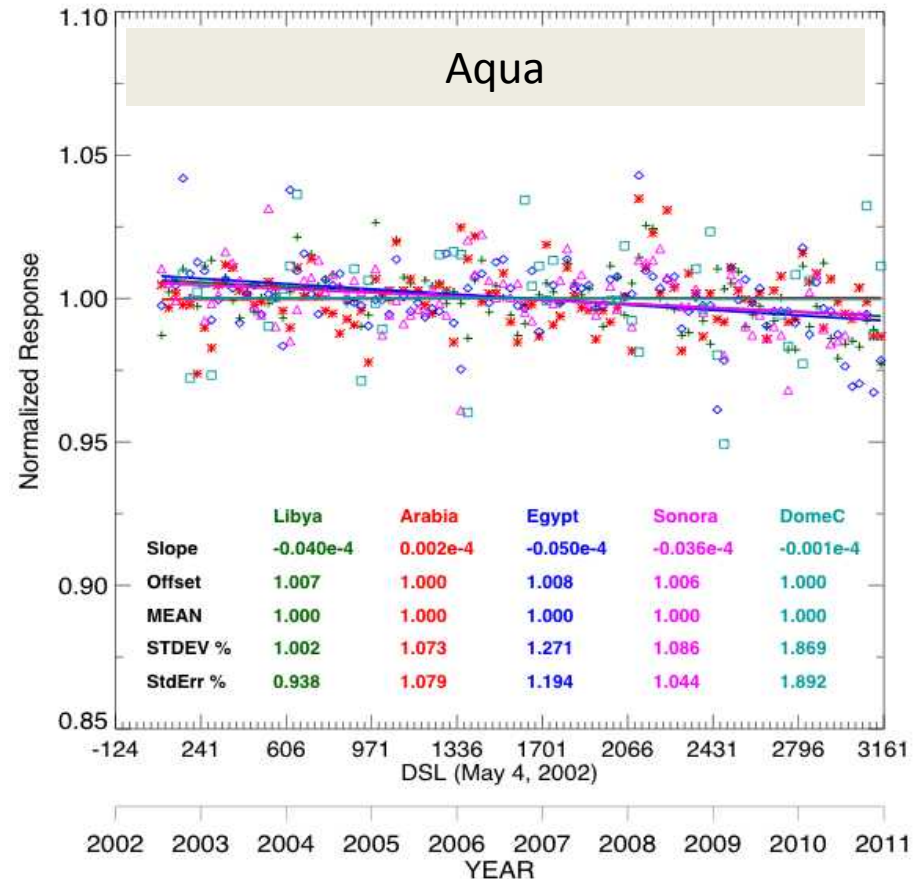
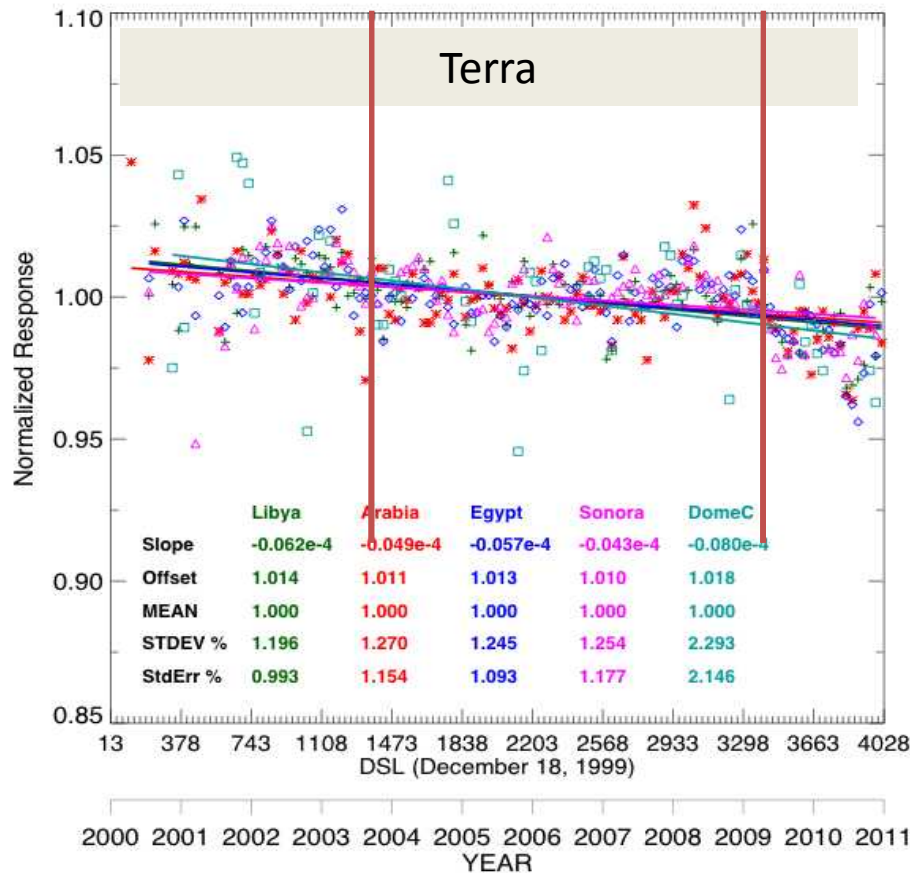
- Terra/Aqua relative calibration indicates at least a 2.1% change over 10 years based on simultaneous nadir measurements (SNO)

DCC nadir radiances



- Deep convective clouds (DCC) are stable invariant targets
- Terra DCC indicate a 2.7%/10years drop, and Aqua a 0.1%/10years drop

Normalized Desert radiances



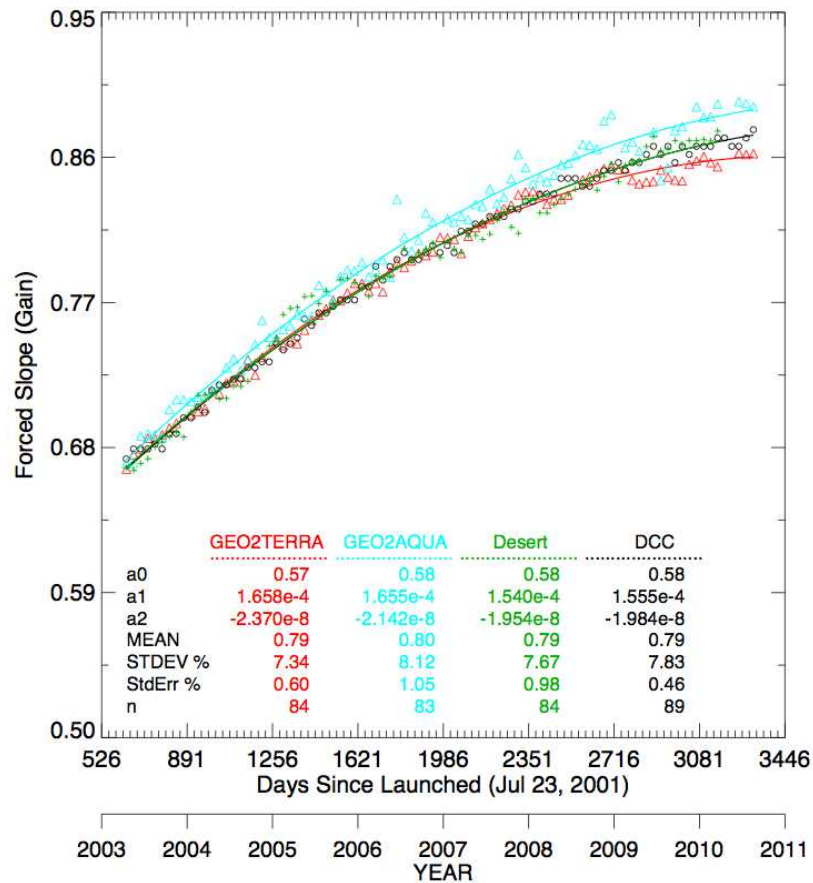
- Invariant desert and snow targets indicate a 1.6 to 2.9%/10years drop for Terra and 0.0 to 1.8% drop for Aqua

CONCLUSION:

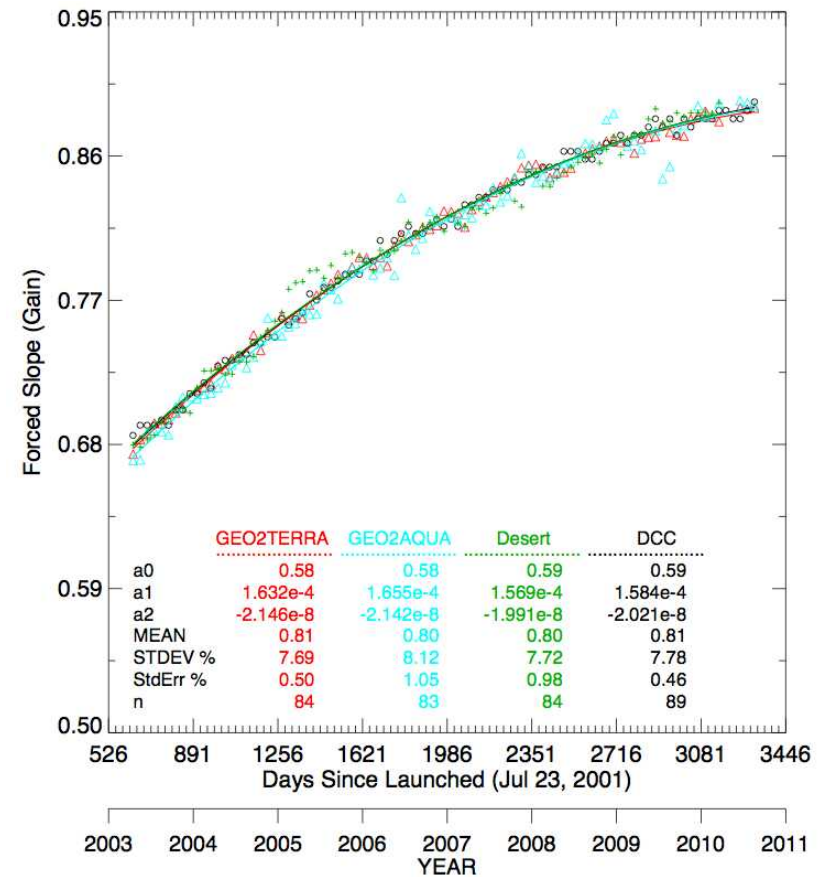
Both DCC and deserts verify that Aqua is more stable
Radiometrically scale Terra-MODIS radiances to Aqua

GOES-12/MODIS Collection 5

Before Terra to Aqua adjustment



After Terra to Aqua adjustment

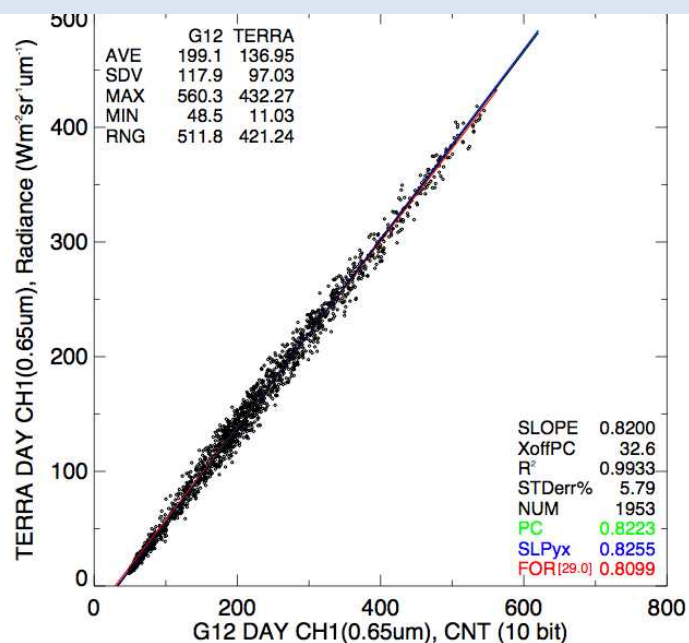


DCC and deserts normalized to Terra

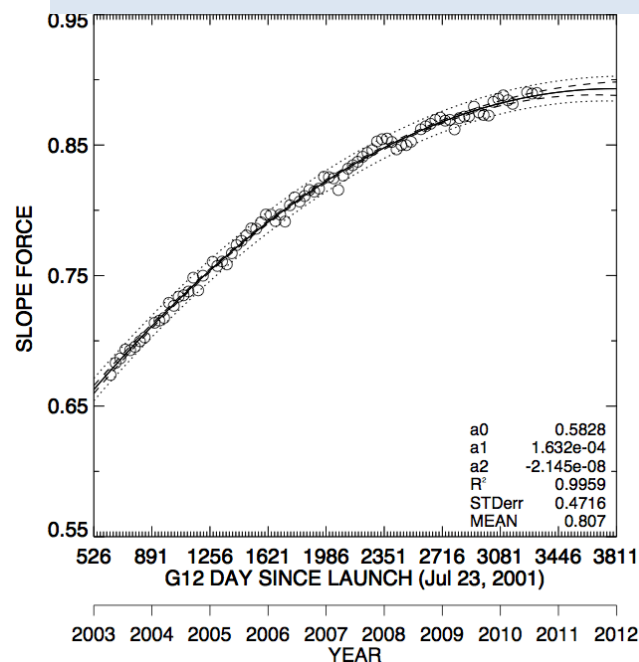
Ray-matching to reference sensor

- Ray-match coincident GEO counts, radiances and MODIS radiances averaged over a 50^2 km ocean grid near the sub-satellite point ($\pm 15^\circ$ lat by $\pm 20^\circ$ lon area)
- Use GEO provided space count offset
- Perform monthly regressions to derive monthly gains
- Compute timeline trends from monthly gains

G12 (10bit McIDAS)/Terra(scaled to Aqua)
June 2006



G12/Terra(scaled to Aqua)
Timeline gain

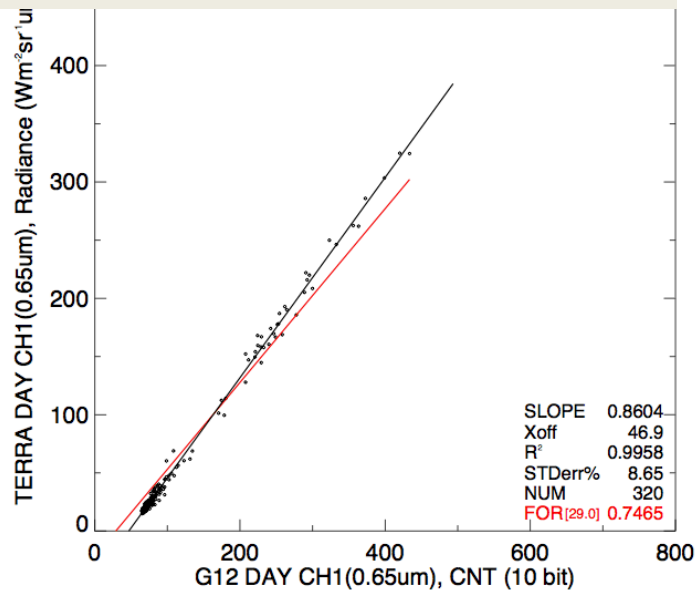


Ray-matching spectral adjustment

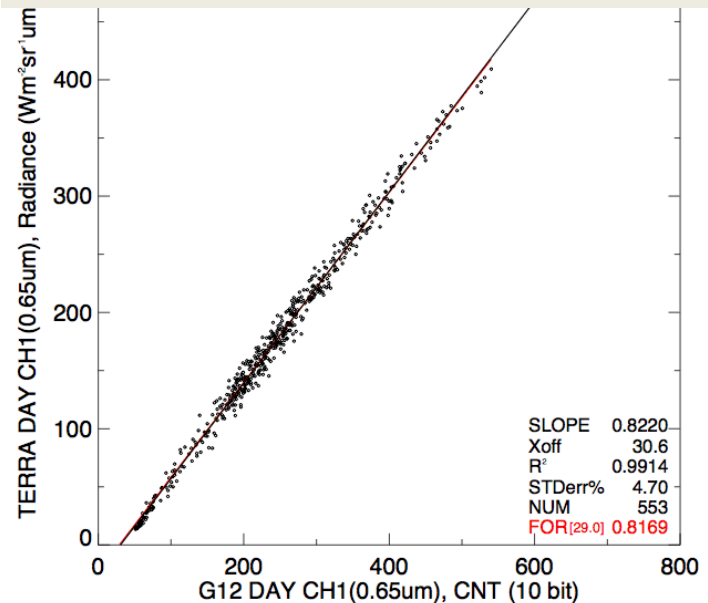
- Use SCIAMACHY pseudo derived GOES-12 and Aqua-MODIS radiances to adjust the GOES-12 radiance as if it had Terra-MODIS spectral response
- Validate by adjusting GOES-12 radiances to Terra-MODIS over ocean and land and the gains should converge

No spectral correction

GOES-12/Terra, Sep 2009, Land



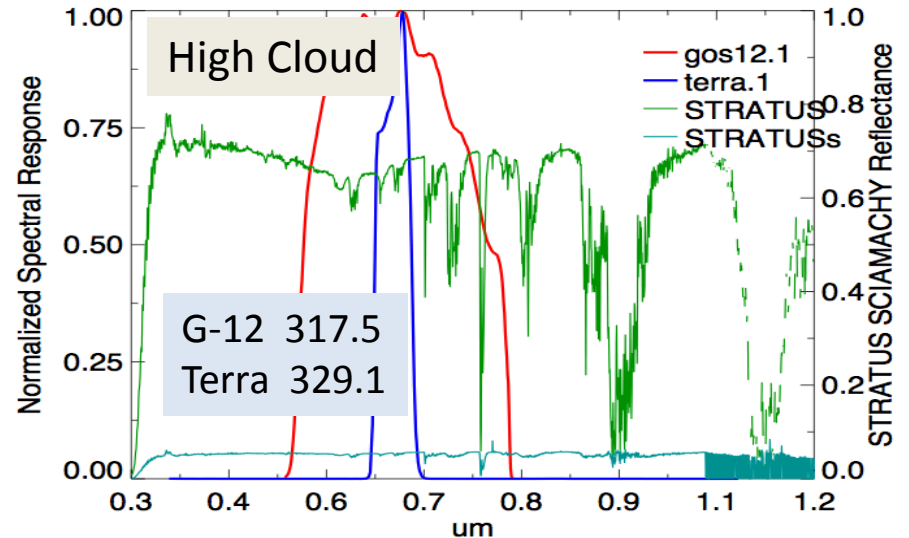
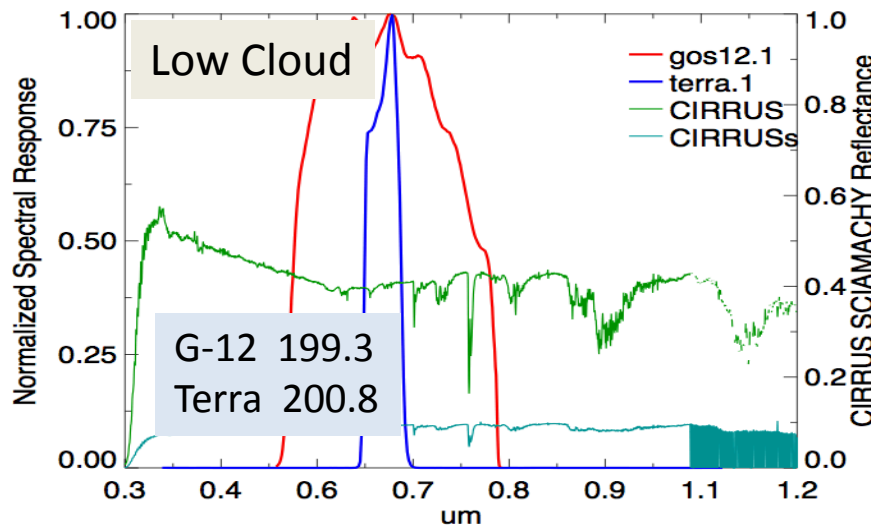
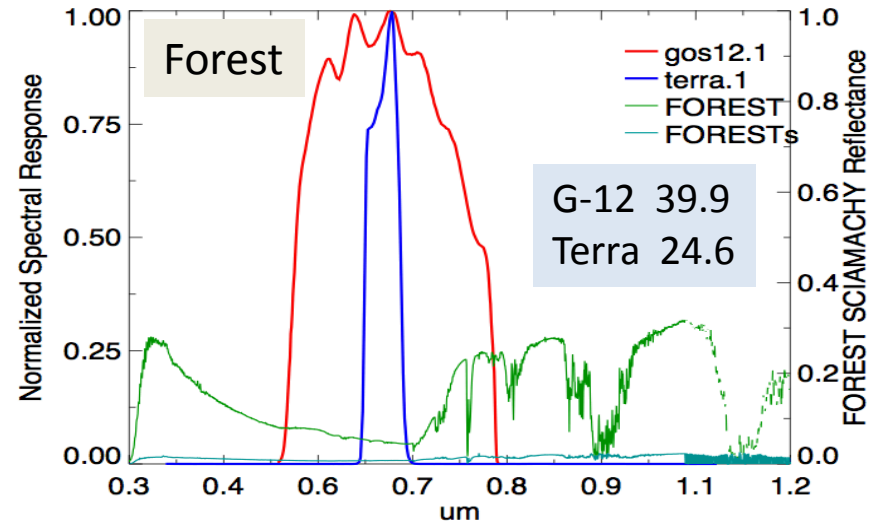
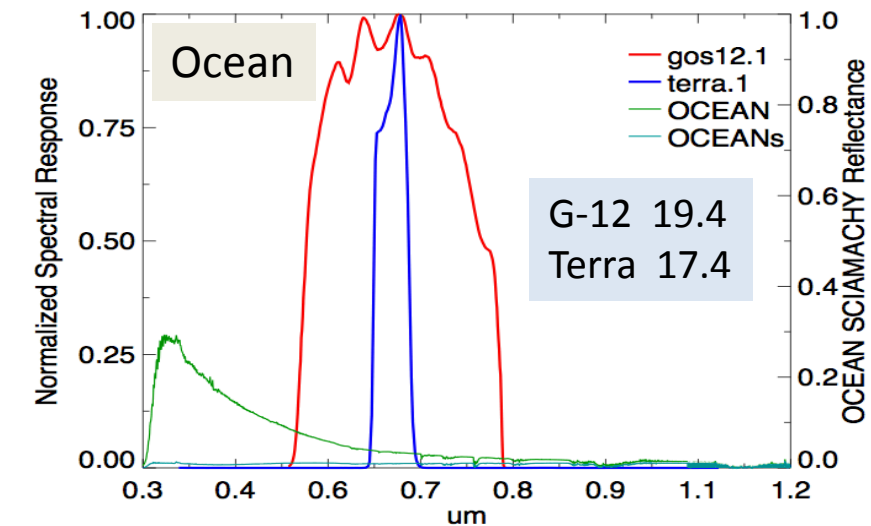
GOES-12/Terra, Sep 2009, Ocean



- The gain difference is .8169 for ocean and 0.7465 for land, a 9.4% difference
- The space count is 30.6 for ocean and 46.9 for land, a 16 count difference

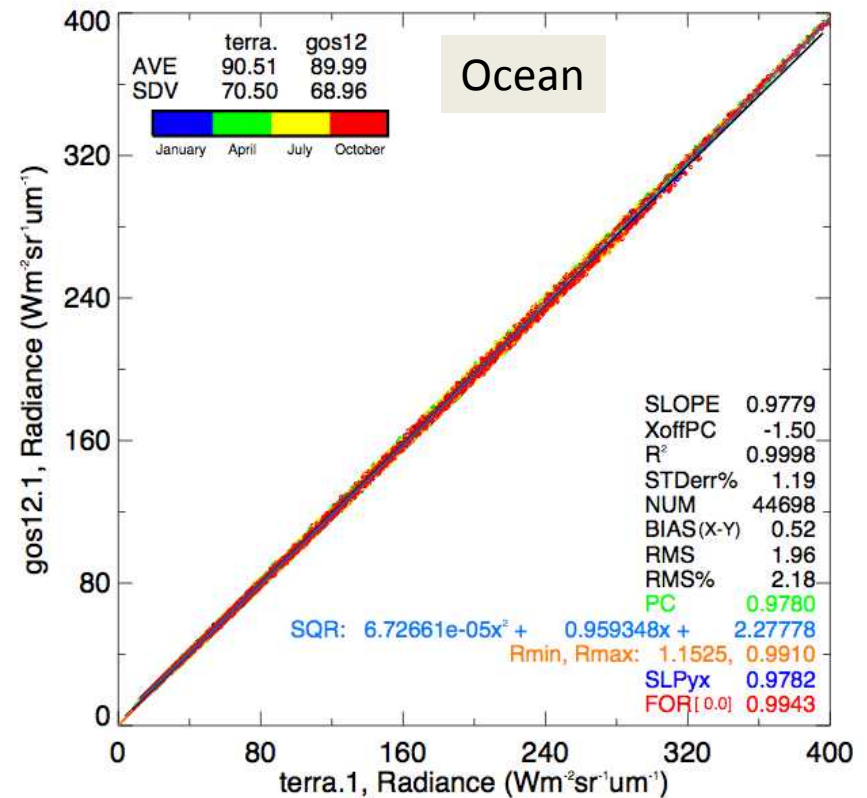
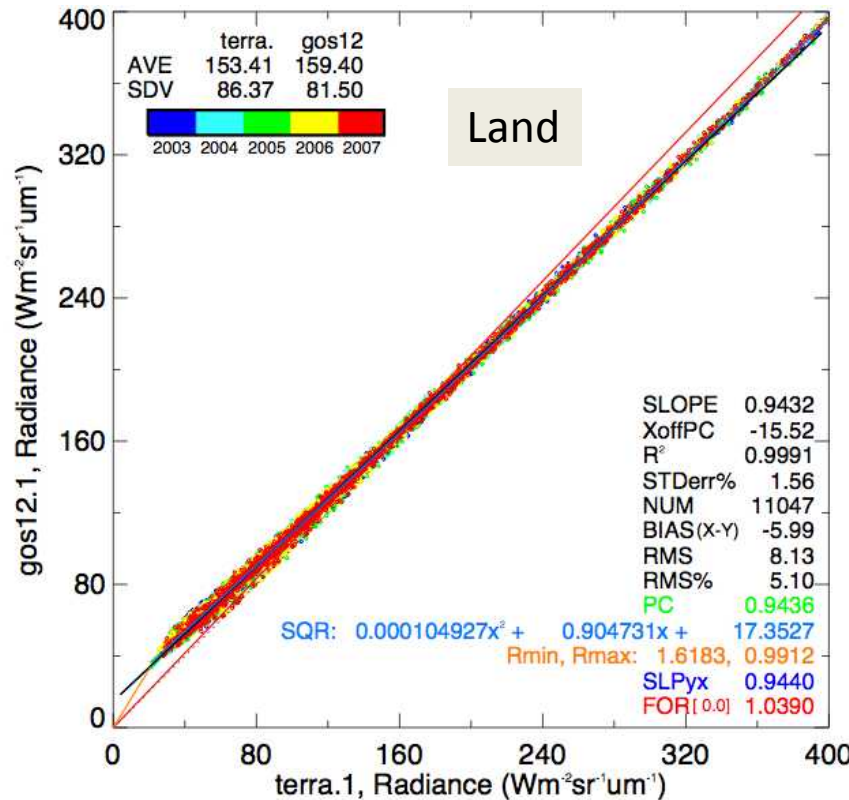
SCIAMACHY reflectances

- SCIAMACHY pseudo radiances in blue



SCIAMACHY Pseudo Radiances

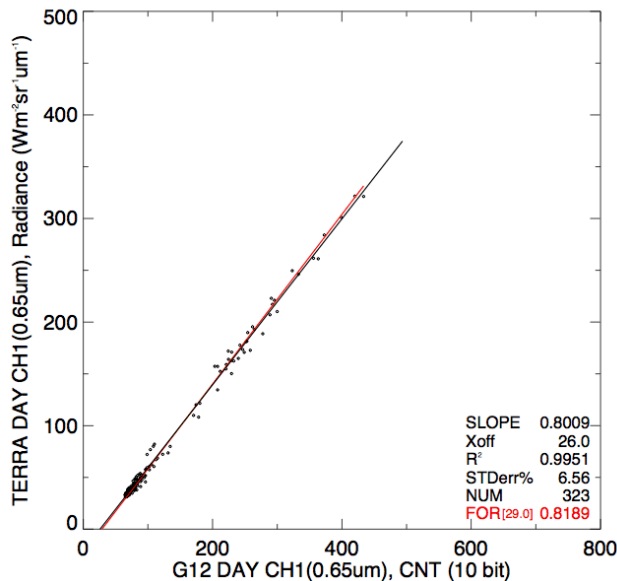
- Use all SCIAMACHY footprint that fall within the GEO/LEO equatorial domain
- Derive spectral correction using cubic fit for land and ocean separately



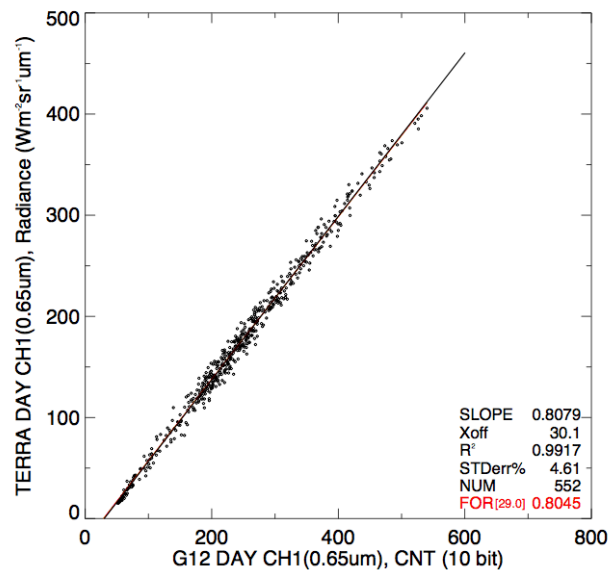
Ray-matching spectral adjustment

With spectral correction

GOES-12/Terra, Sep 2009, Land



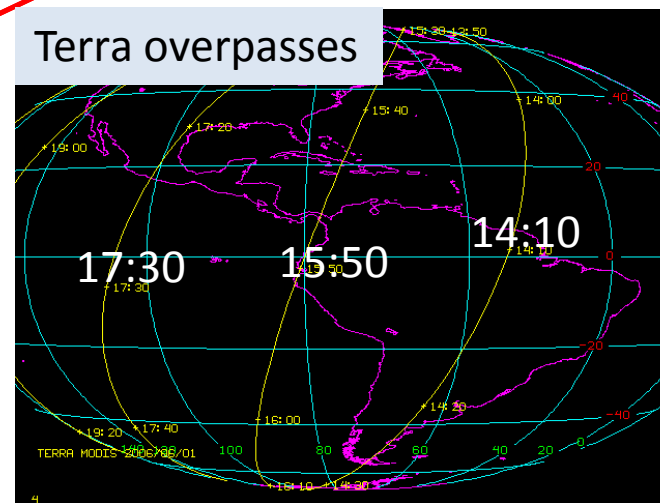
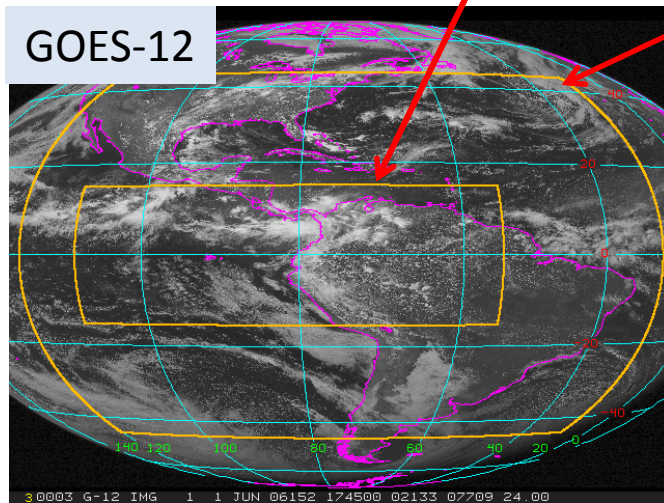
GOES-12/Terra, Sep 2009, Ocean



- The gain difference is .8045 for ocean and 0.8189 for land, ~1.7% difference
- The space count is 30.1 for ocean and 26.0 for land, ~ 4 count difference

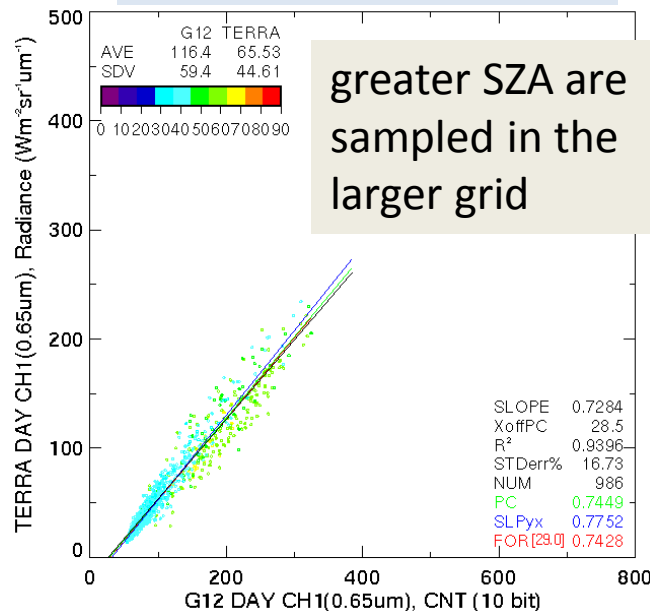
- Only use ocean geo-type for ray-matching, since the spectral correction is minimal

Equatorial and large GEO grid

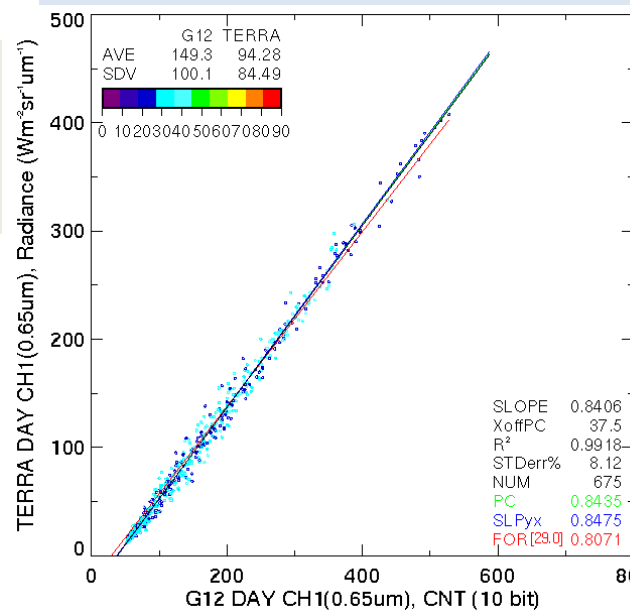


- Large domain relies on many overpasses
- Equatorial domain only one or two

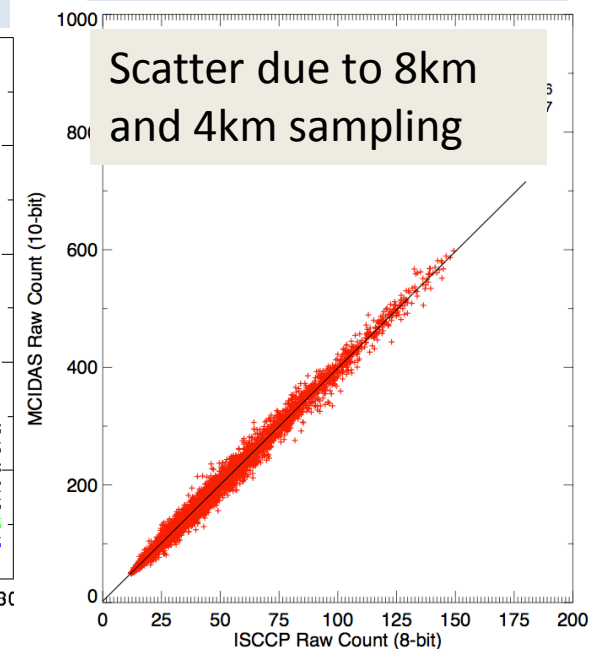
B1U 3-hourly sampling



McIDAS 0.5 hourly sampling



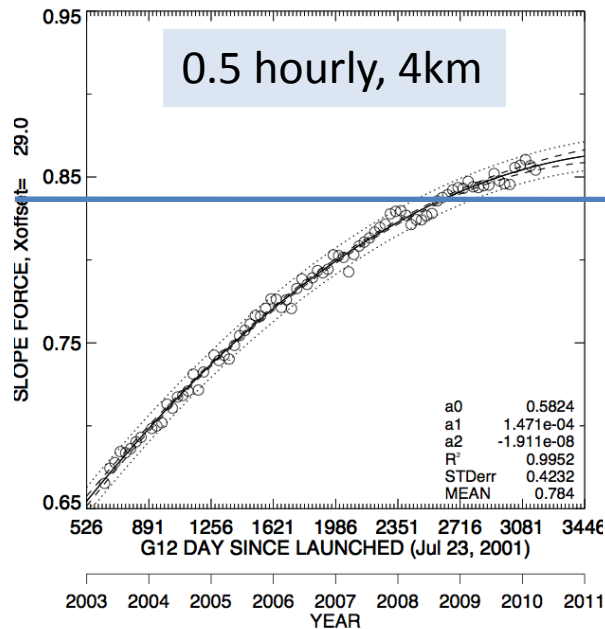
McIDAS vs B1U counts



Terra/G12 B1U vs McIDAS

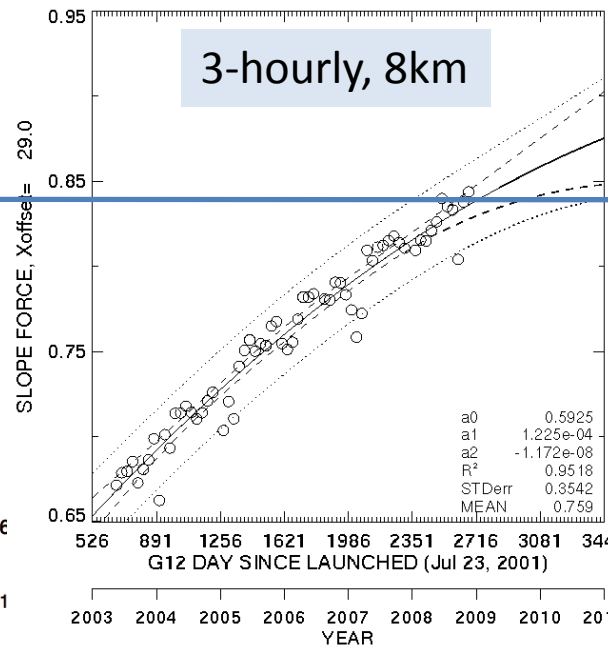
McIDAS equatorial domain

0.5 hourly, 4km



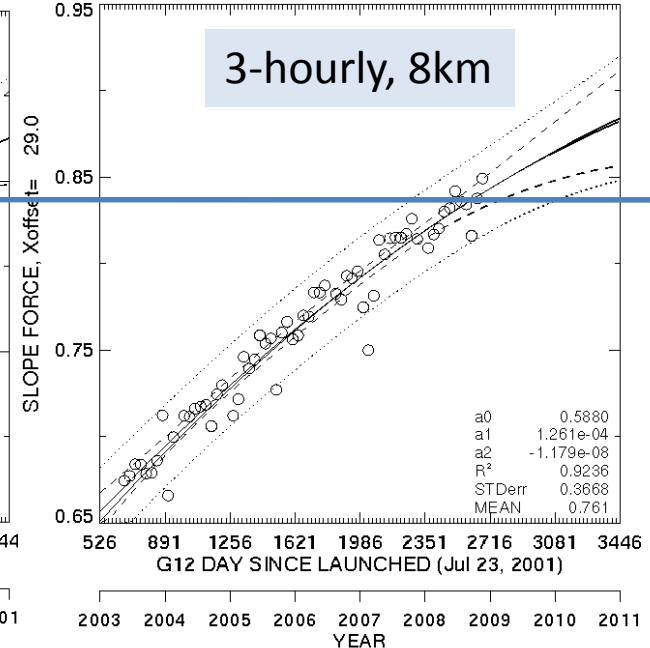
ISCCP B1U large domain

3-hourly, 8km



McIDAS large domain

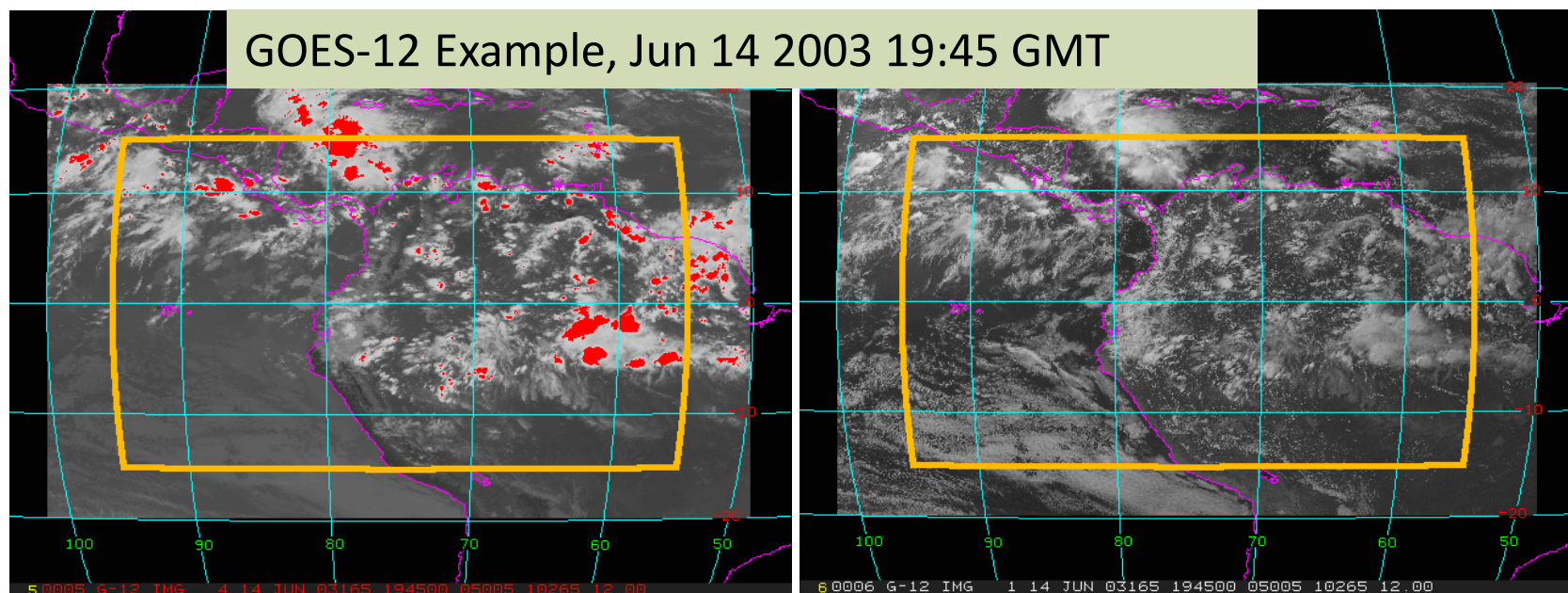
3-hourly, 8km



- Although the confidence bounds of the regression have expanded the coefficients are similar

LaRC DCC Methodology

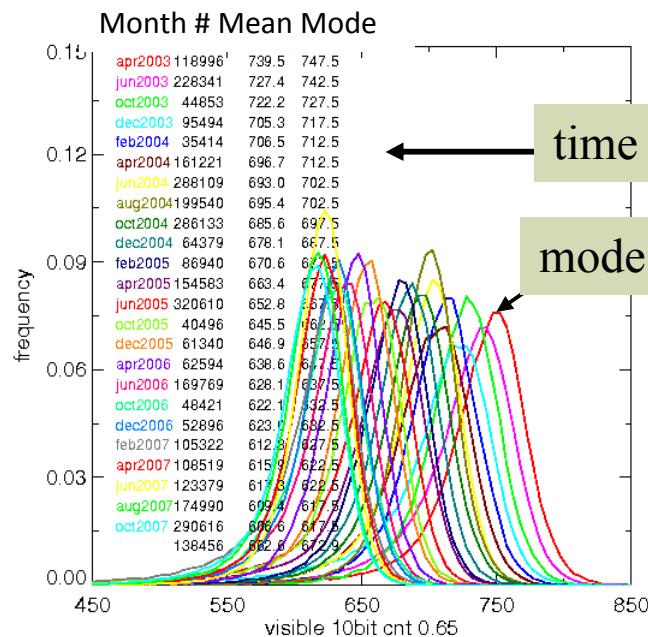
- DCC are cold, bright, stable, tropopause level, and nearly isotropic targets located near the equator and are observed by all GEO and LEO satellites
- Identify DCC pixels by $T(11\mu\text{m}) < 205^\circ\text{K}$, $\sigma T(11\mu\text{m}) < 1^\circ\text{K}$, $\sigma(0.65\mu\text{m}) < 3\%$ thresholds
 - ~0.5% of all tropical pixels are identified as DCC
 - Relies on good IR and VIS co-registration, good navigation not necessary
- Apply CERES DCC bidirectional model to convert radiance to overhead sun
- Methodology described in Minnis et al 2008, JTECH March 2000



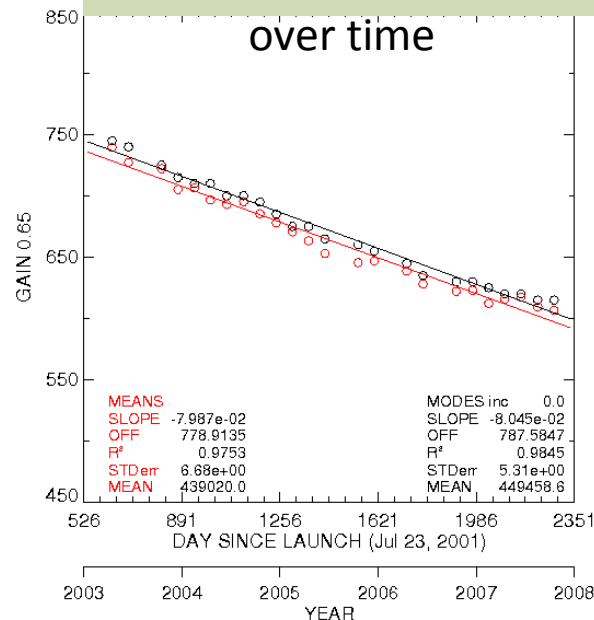
2003-2007 GOES-12 DCC

- Plot the monthly nadir DCC radiance, track the mode and mean over time
- Compare the DCC relative gain with G12/Terra-MODIS ray-matched gain

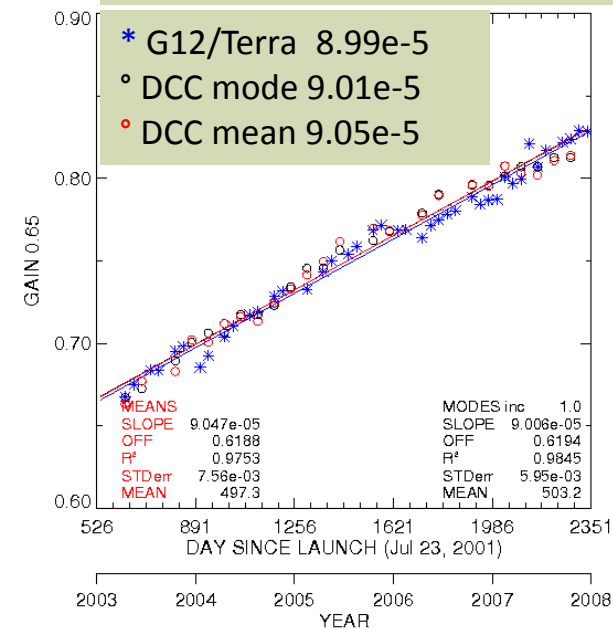
Monthly PDFs



Monthly PDF
mean/mode counts
over time

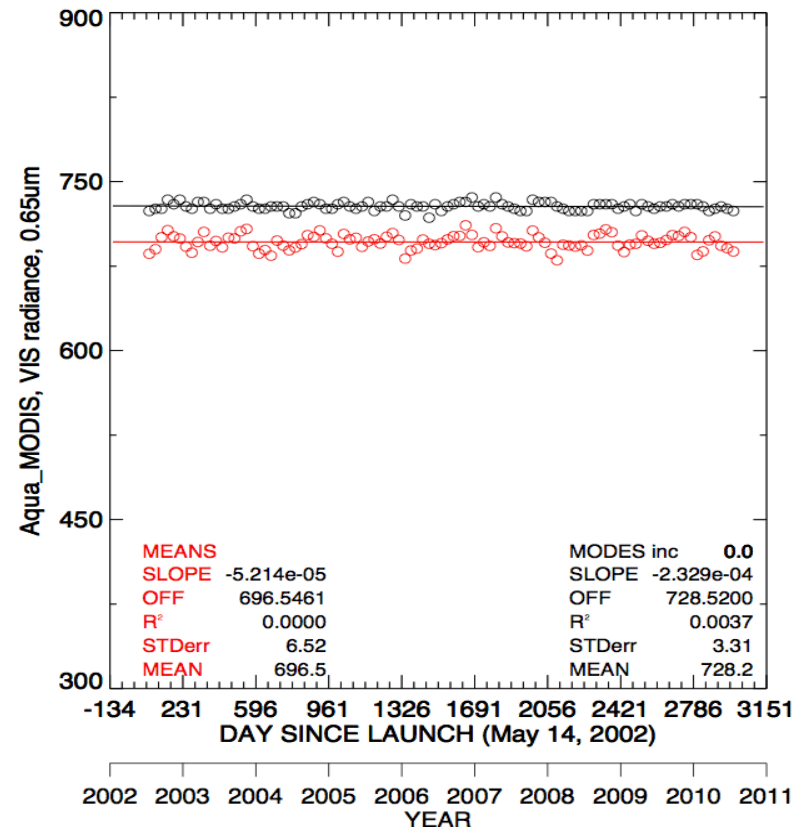
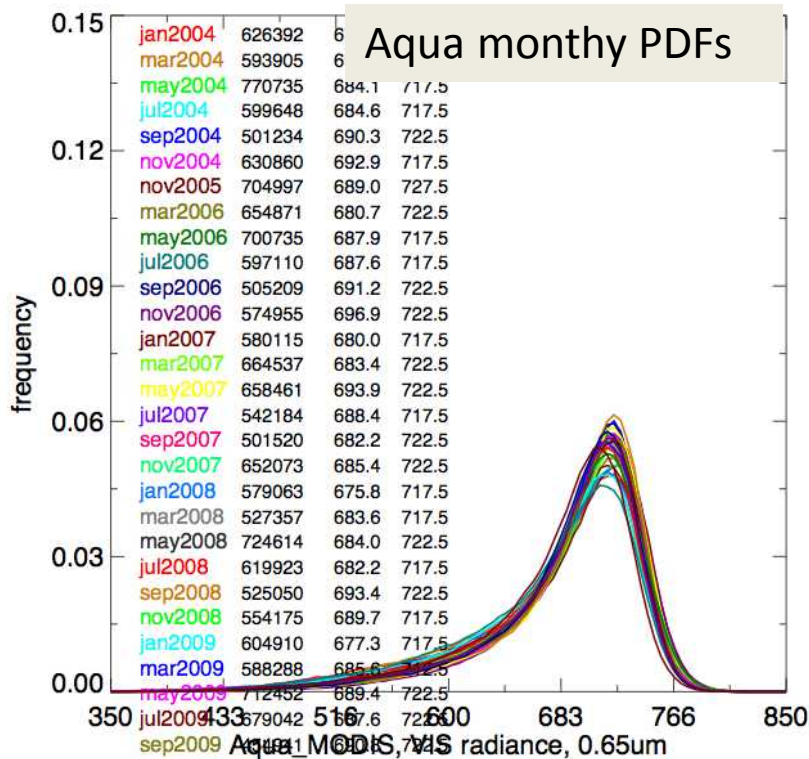


DCC relative and
G12/Terra gain



- It is remarkable the gain trends are within 0.7%

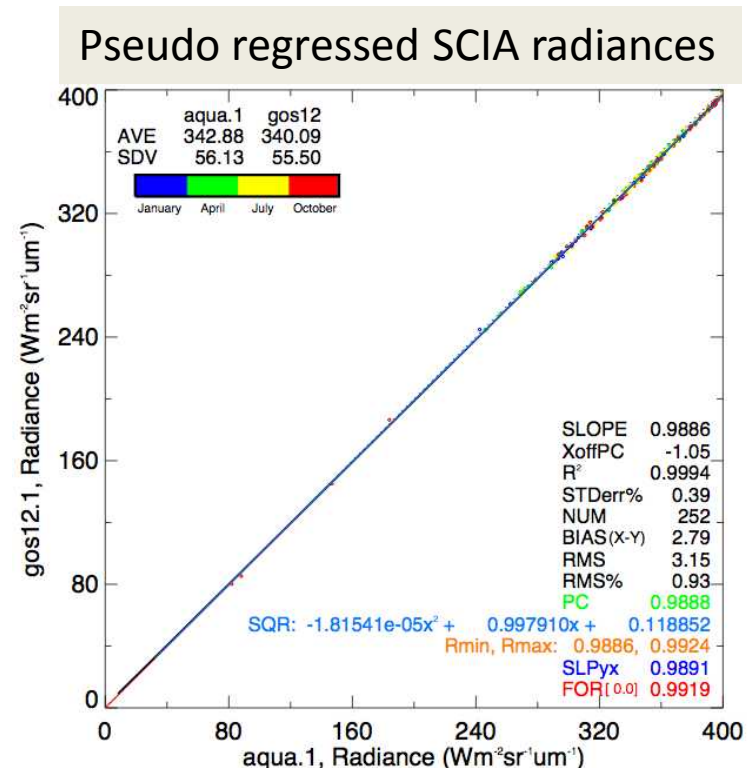
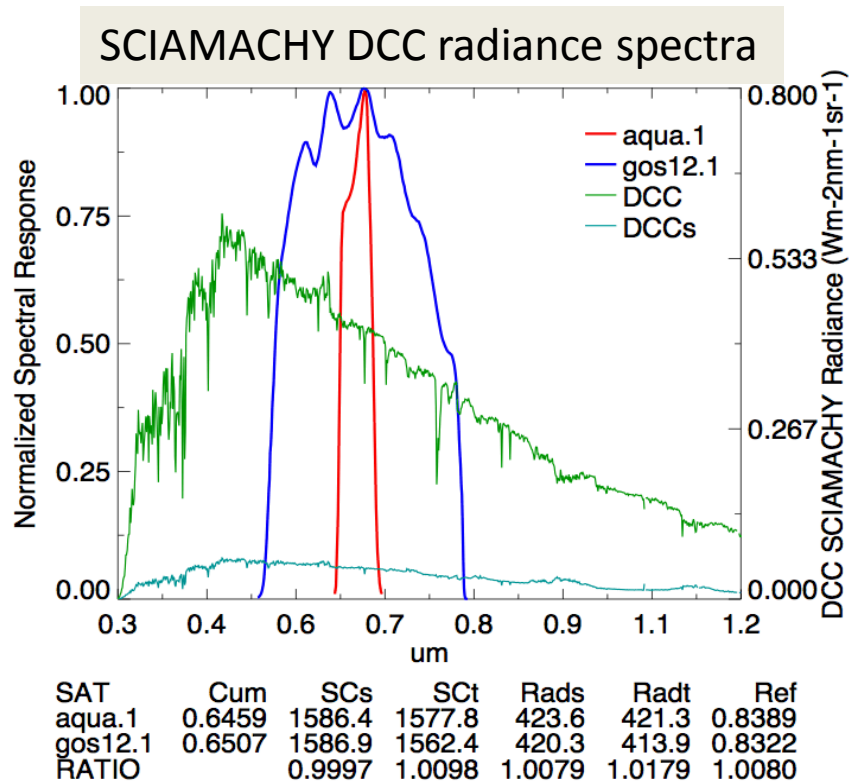
2002-2010 Aqua-MODIS DCC trends



- Aqua-MODIS is stable over 8 years and the monthly PDFs are consistent over time
- Use as a reference for DCC absolute calibration

DCC calibration tied to reference sensor

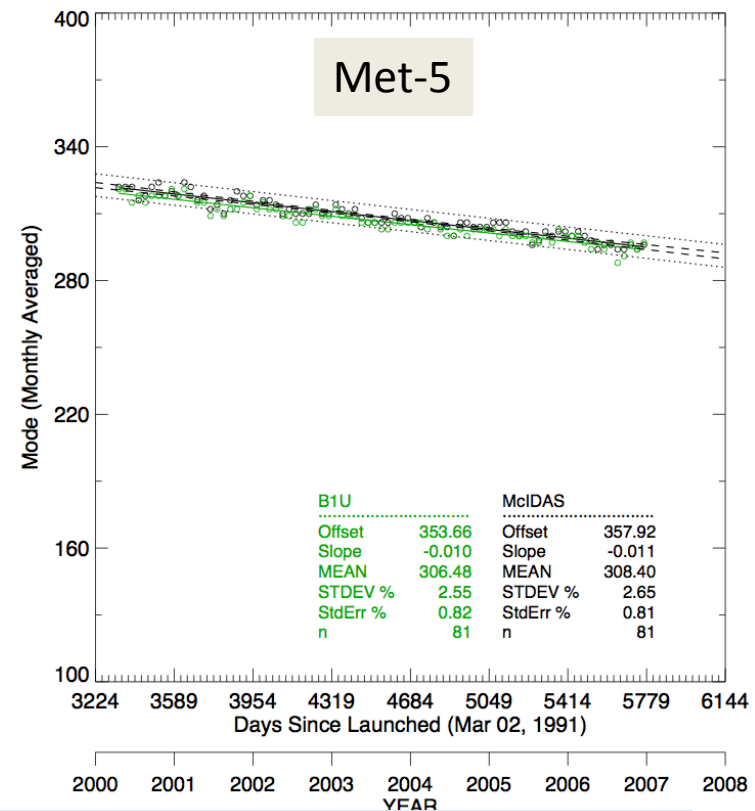
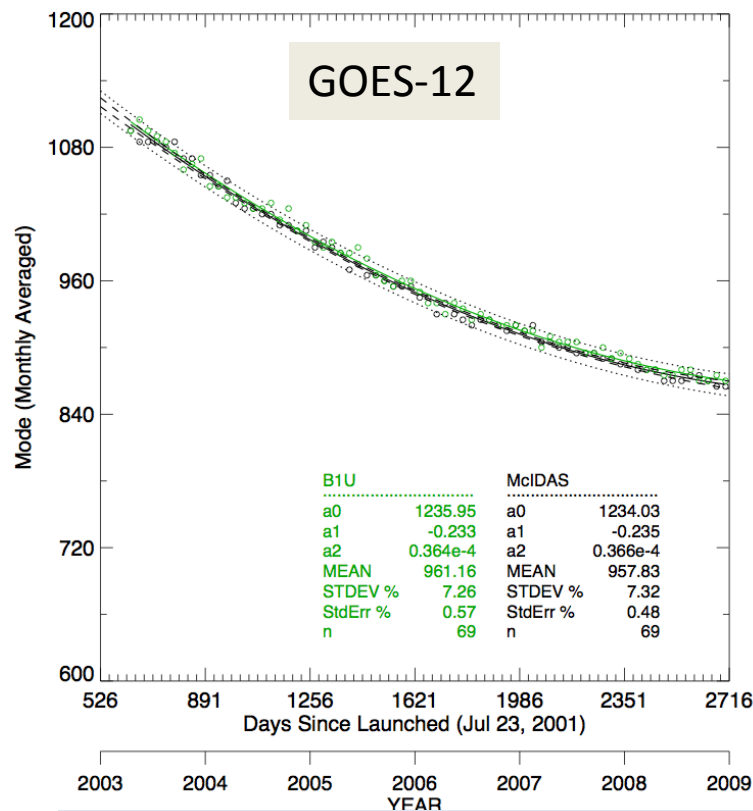
- Use Aqua-MODIS as a reference
- Use SCIAMACHY pseudo derived GOES-12 and Aqua-MODIS DCC radiances to adjust the Aqua-MODIS radiance as if it had GOES-12 spectral response
- The gain is the factor needed to scale GOES-12 DCC counts to the expected GOES-12 DCC radiance



GOES-12 and Aqua-MODIS radiance ratio due to Spectral Response differences is 1.008

ISCCP B1U vs McIDAS DCC calibration

- What effects does 3-hourly, vs noon, 4km vs 8km, and full count vs 8 bit count resolution have on DCC algorithm
- For ISCCP-B1U use all daylight images, the sigma tests on 8km resolution, and the resulting DCC pixel count is much smaller

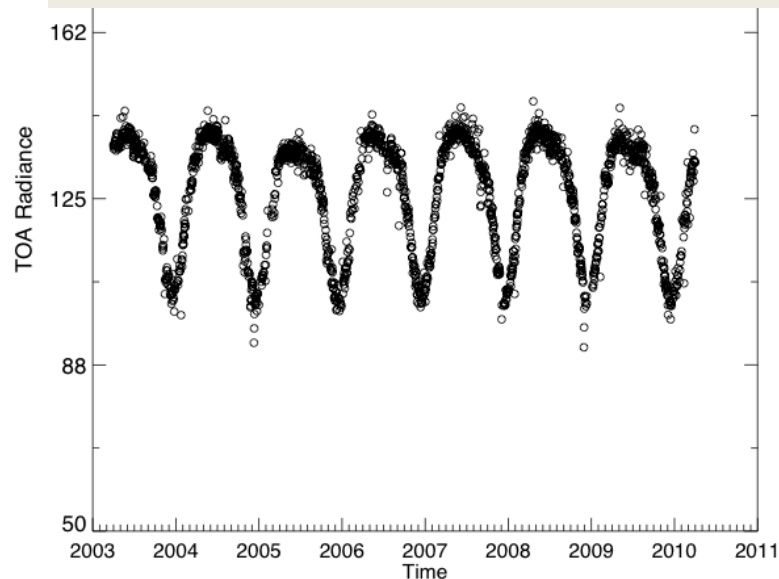


- The ISCCP B1U trends match the full resolution McIDAS trends very well

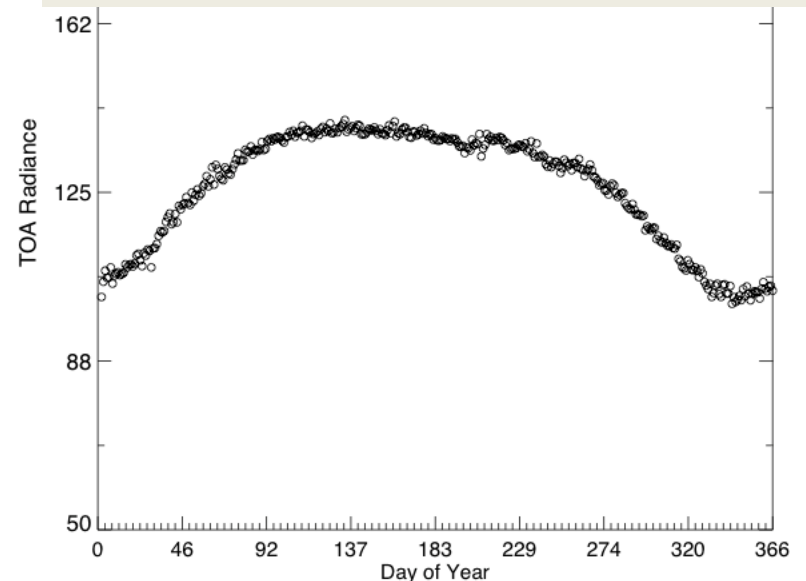
Desert Calibration tied to reference sensor

- Transfer the Aqua-MODIS calibration to the reference GEO instrument using ray-matching
- The GEOs in each position usually have the same scan schedule, so that the daily viewing and solar geometry is identical from year to year
- Locate invariant desert sites for each GEO
- Derive the clear-sky daily noon radiance. Use spatial sigma to determine clear-days
- Derive a daily noon annual radiance model from the lifetime of the reference GEO
- For B1U a near-noon 3-hourly GMT must be chosen

GOES-12 Sonoran radiances based
on Aqua/GOES-12 ray matching
19.5 GMT image, (VZ=56.4)

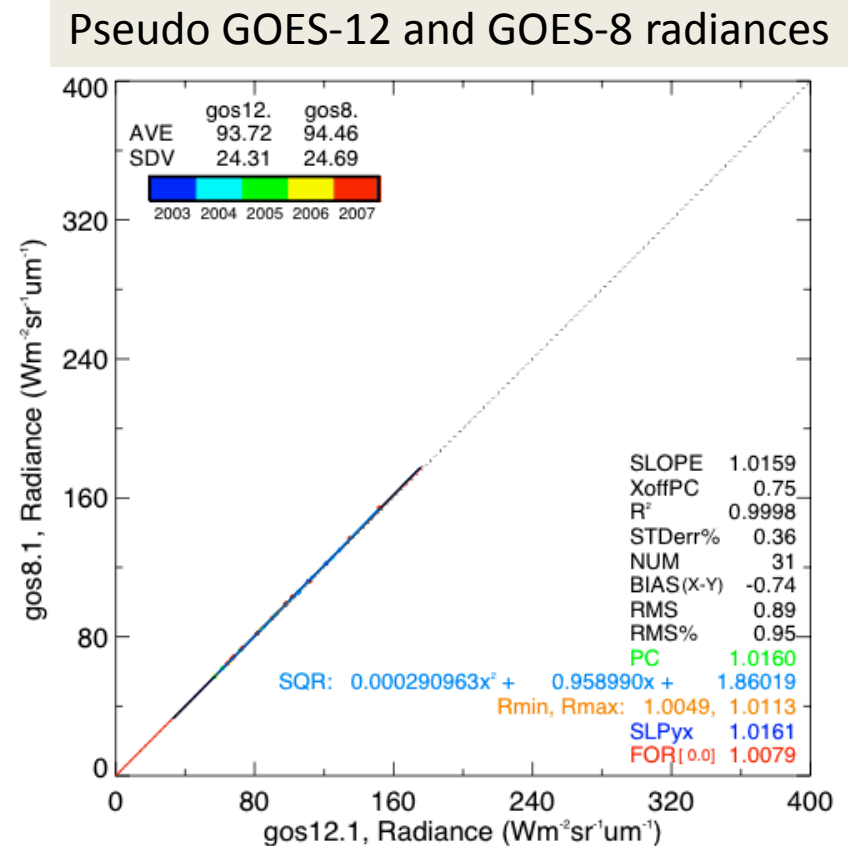
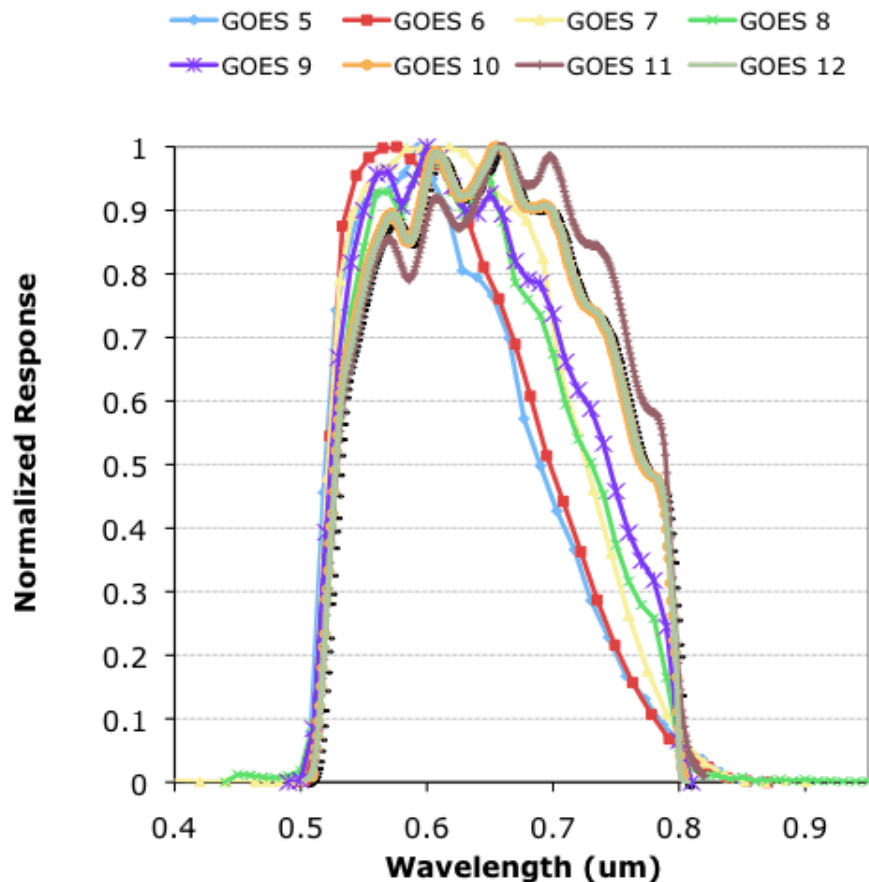


GOES-12 Sonoran daily noon
radiance model
19.5 GMT image, (VZ=56.4)



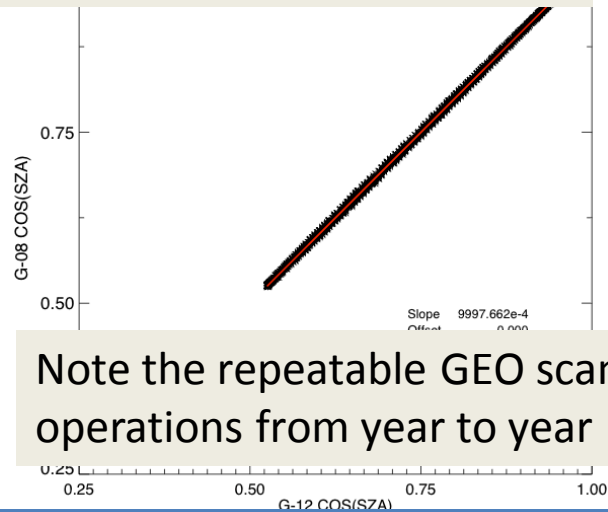
Spectral Band Adjustment

- Use SCIAMACHY pseudo derived reference GOES-12 and target GOES to adjust the GOES-12 model radiance as if it had target GOES spectral response

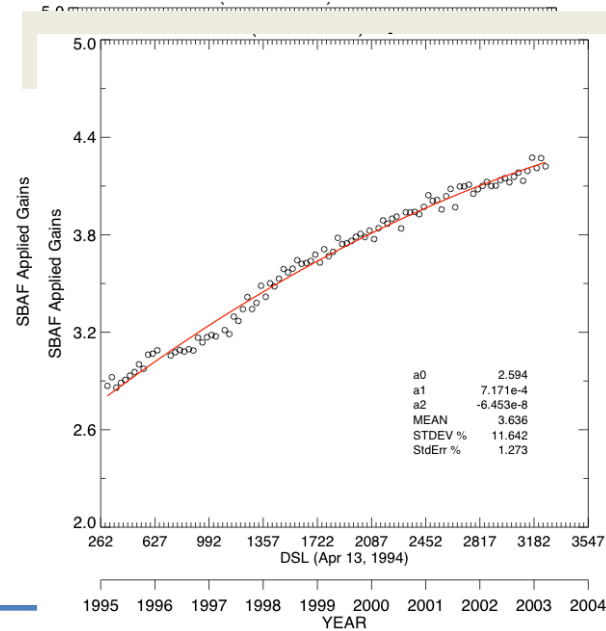


GOES-7/8 desert calibration

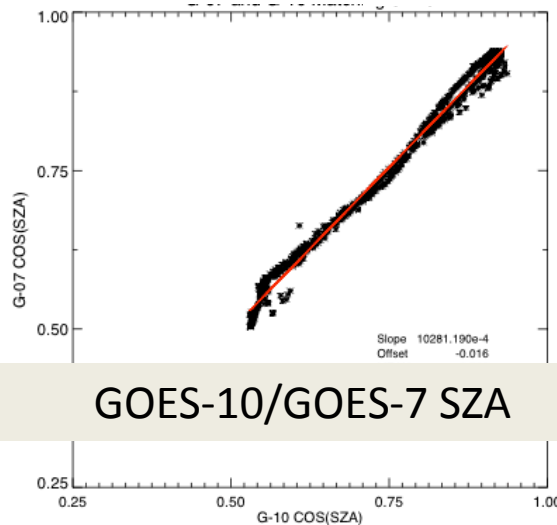
GOES-12/GOES-8 SZA



Note the repeatable GEO scan operations from year to year

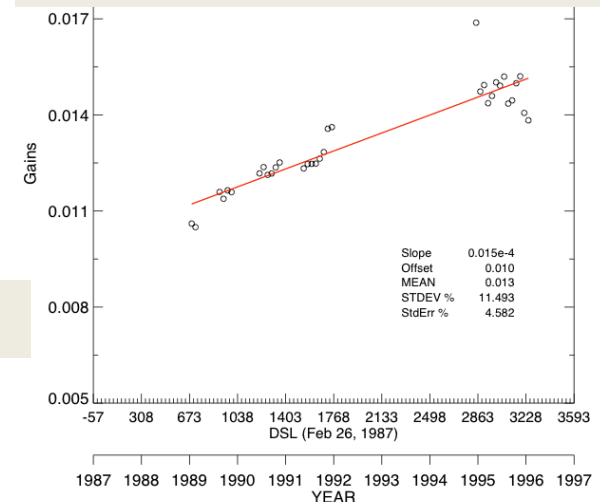


GOES-6 and GOES-7 drifted in location, use ray-matched events with the model and the target GOES within $\Delta SZA < 5^\circ$, $\Delta VZA < 5^\circ$, $\Delta RAZ < 10^\circ$



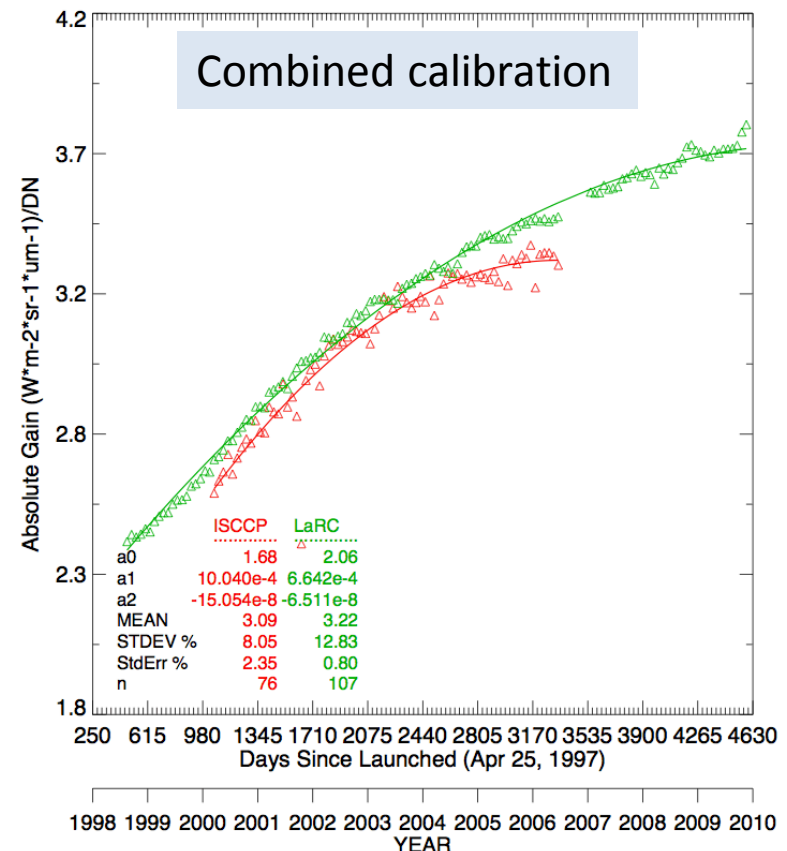
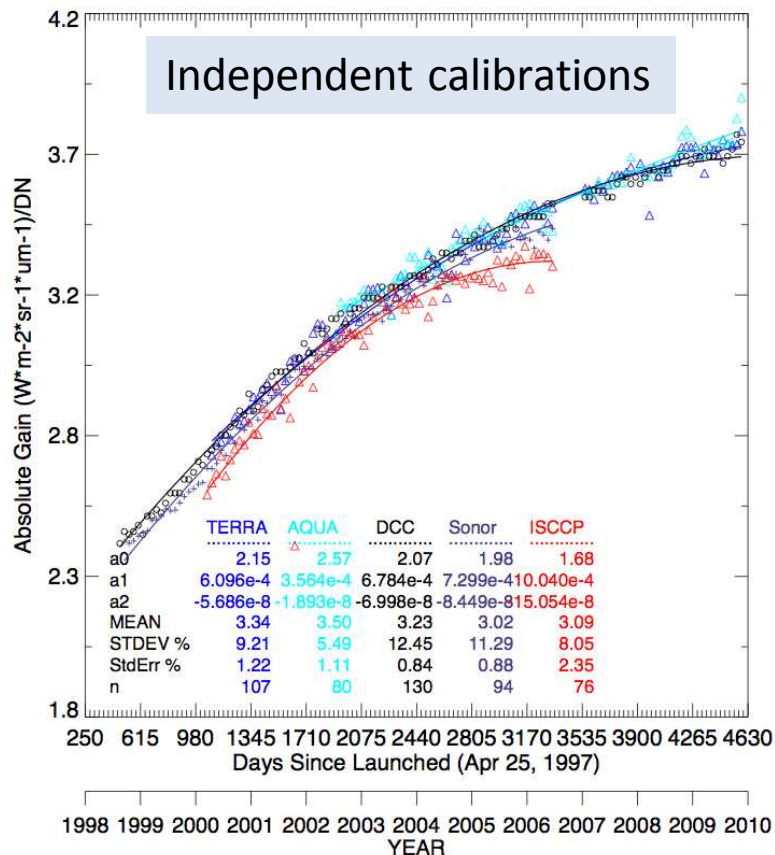
GOES-10/GOES-7 SZA

GOES-7 Sonoran desert gains

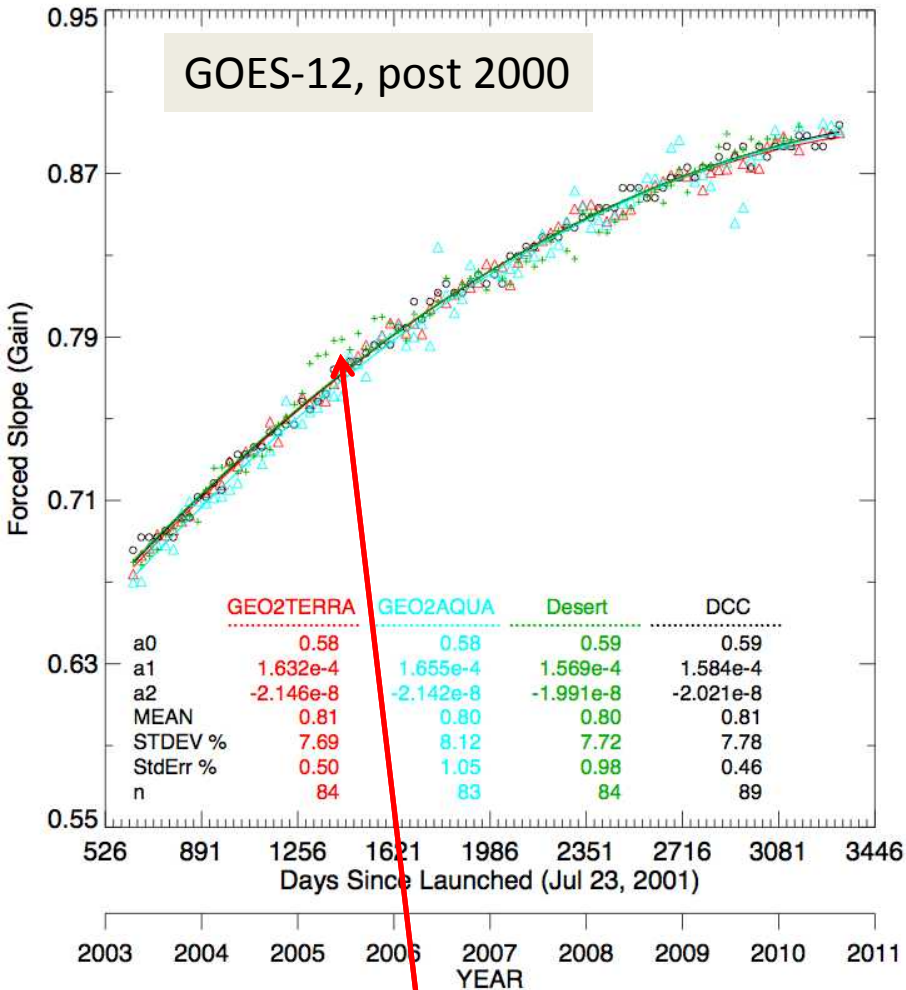


Multi-method GOES-10 calibration

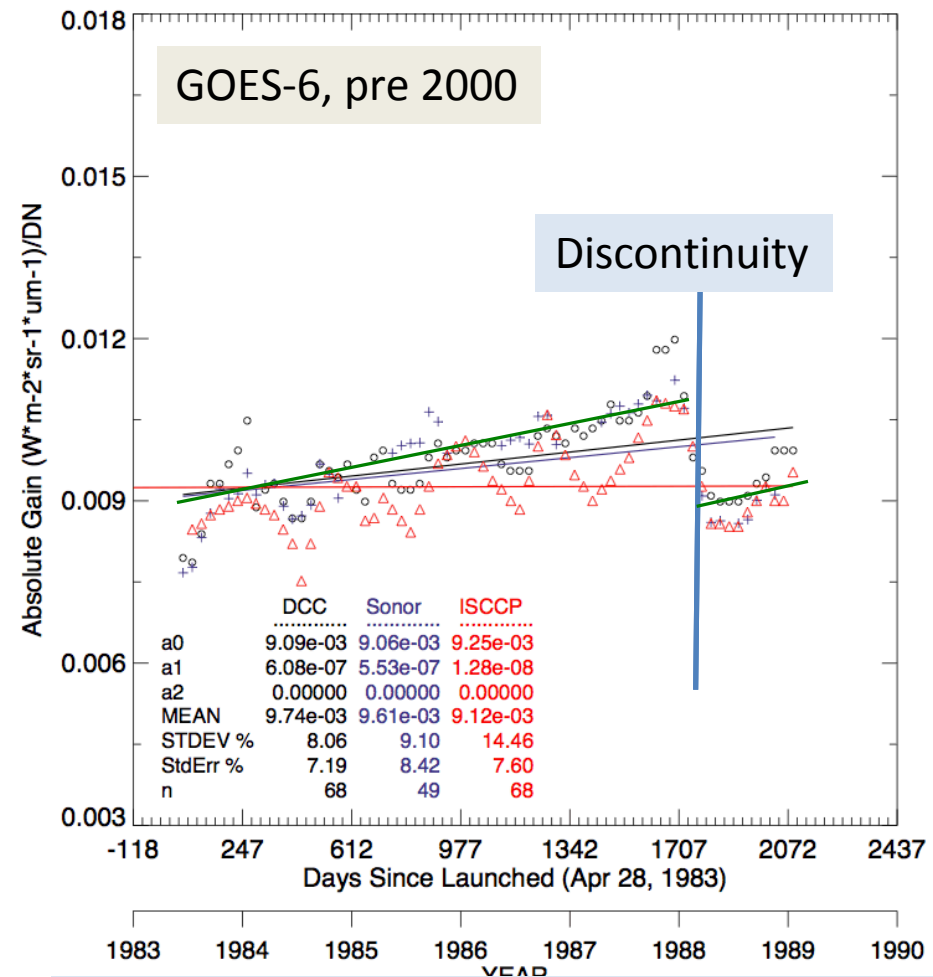
- All methods GOES-12/Terra, GOES-12/Aqua ray-matching, desert and DCC calibration are independent referenced to Aqua-MODIS
- Combine methods by weighting the inverse of the standard error of the regression



Multi-method consistency



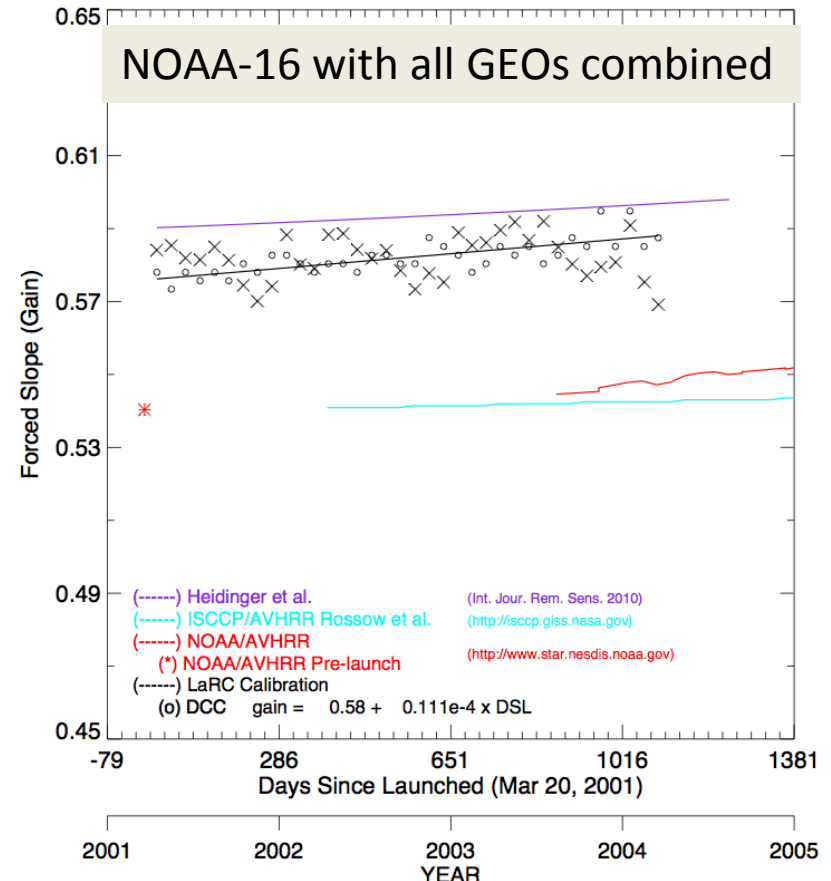
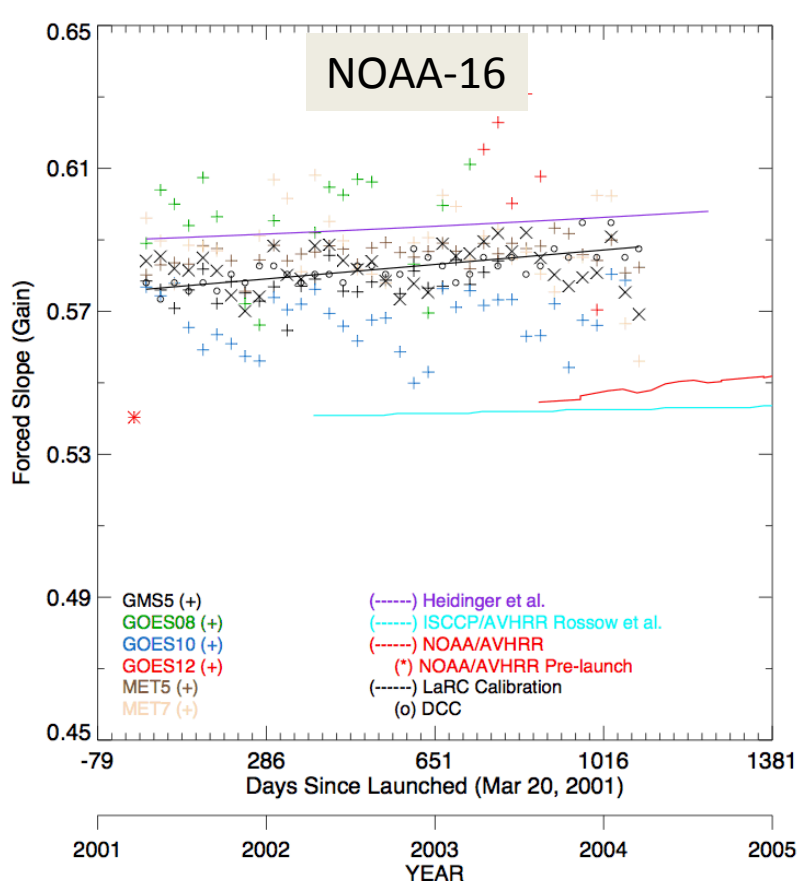
- Note fluctuations of desert around regression



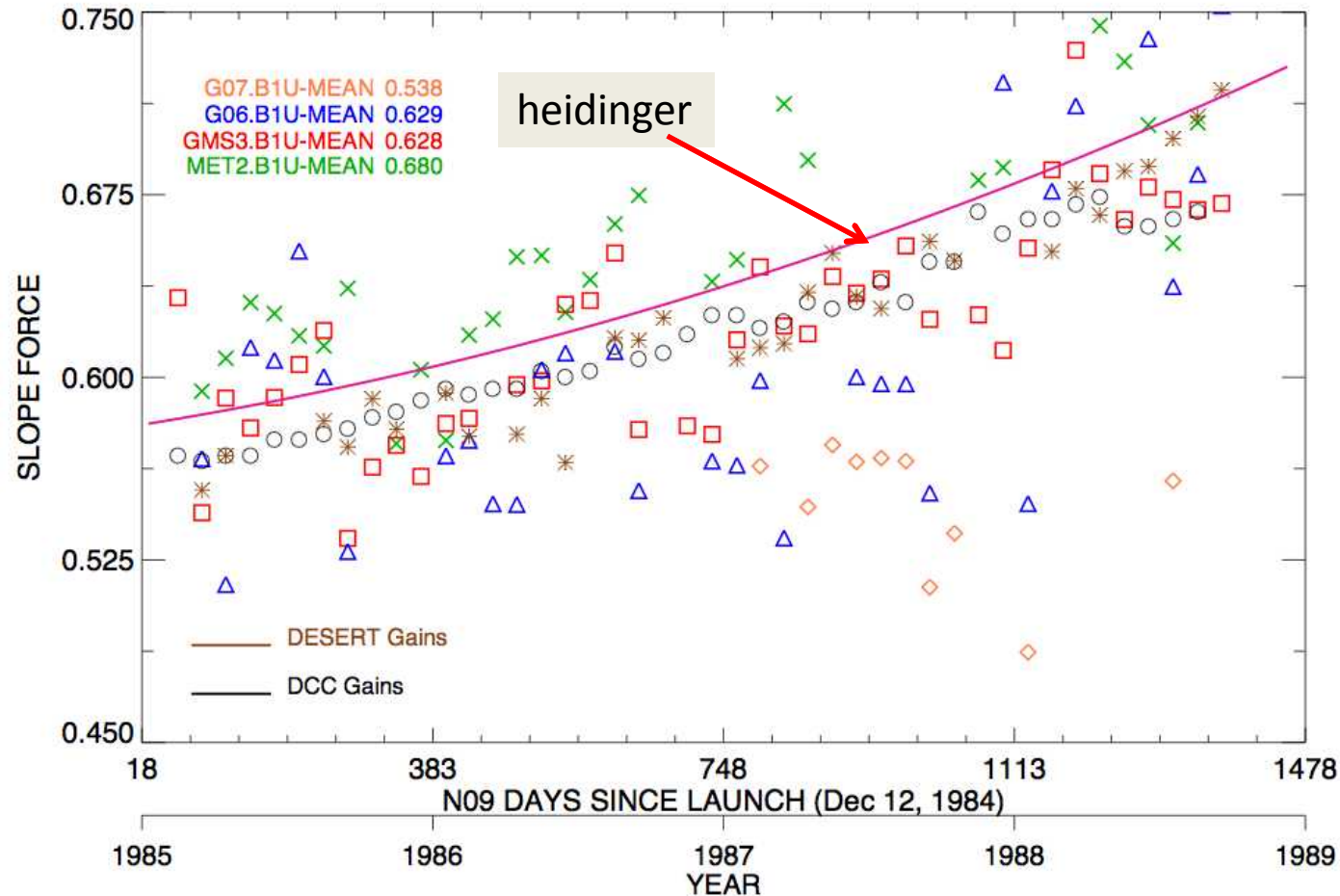
- Note consistency between desert and DCC
- Will have two sets of calibration coefficients for GOES-6

NOAA calibration method

- Use DCC and desert to calibrate NOAA-AVHRR
 - Methods hindered by degradation of NOAA orbits
 - Use VIRS to build desert and DCC models with large SZA
- Use GEO as independent references
 - Ray-match all simultaneous GEOs with a given NOAA AVHRR
 - Compare to known calibration trends



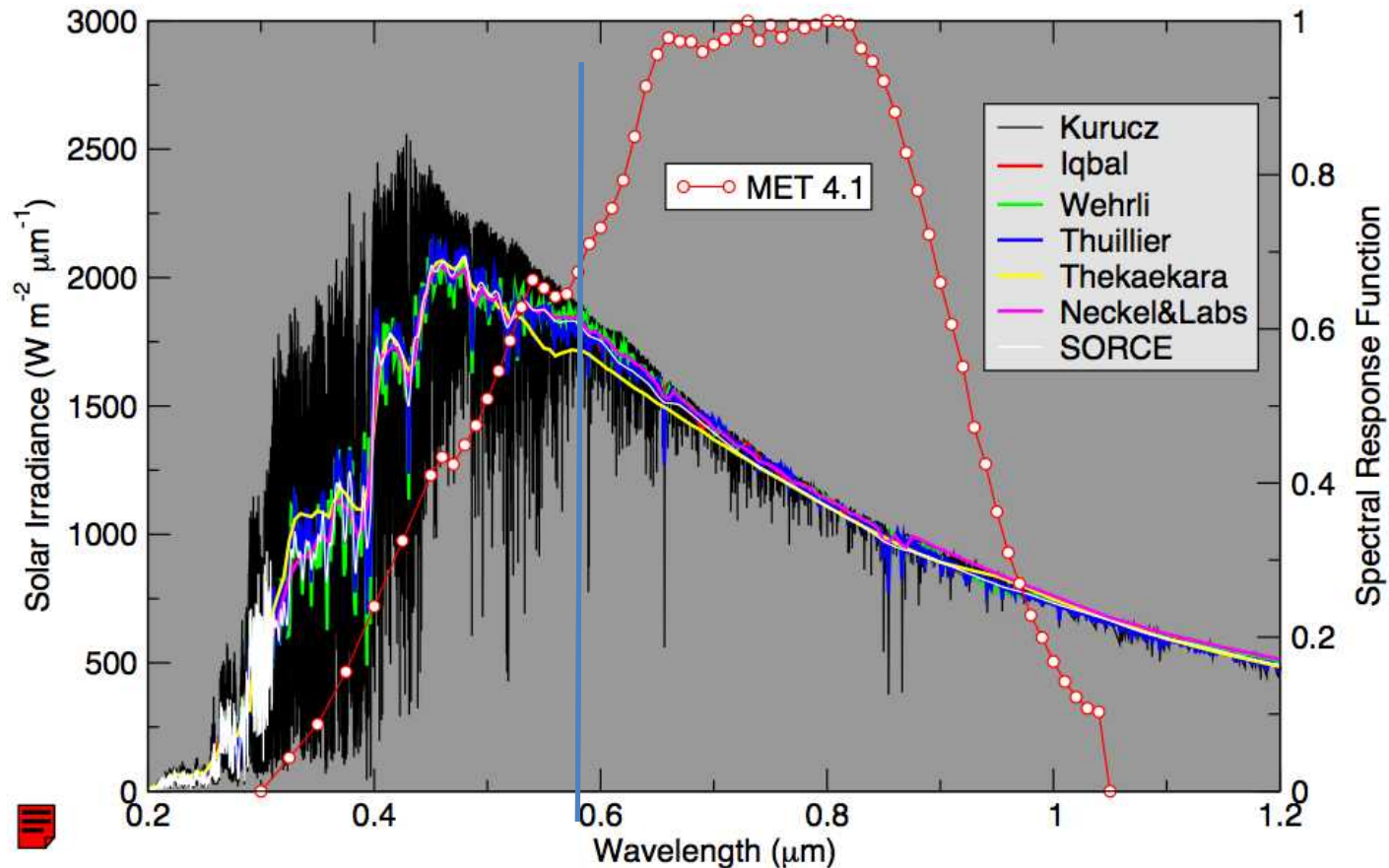
NOAA-9 AVHRR calibration



- Note the consistency between DCC and desert calibration
- Preliminary desert result using VIRS model, DCC to as $SZA < 55^\circ$
- Some GEOs need further investigation

Outstanding Issues

Solar Constant Computation



- Thekaekara not used in this study, Bill told me he uses this spectra
- SORCE is from a very quiet solar minima day (provided by Kopp)
- CEOS uses Thuillier
- What GEO solar constant to provide to the user to convert radiance in reflectance?

ISCCP/Langley solar constant comparison

Integrating interval difference

ISCCP/Langley difference

*Joe's email Nov. 8, 2010

‡ Thuillier is the CEOS standard

Satellite	ISCCP*	Neckel@ Δ Solar	Neckel @ Δ SRF	7 spectra range	7 spectra mean	Thuillier‡
MET-3	620	601 (3.2%)	599 (0.3%)	594-602 (1.3%)	599	597
MET-4	634	594 (6.3%)	597 (0.5%)	588-597 (1.5%)	593	592
MET-5	622	570 (9.1%)	573 (0.5%)	565-572 (1.2%)	569	568
MET-6	574	565 (1.6%)	567 (0.4%)	559-566 (1.3%)	563	562

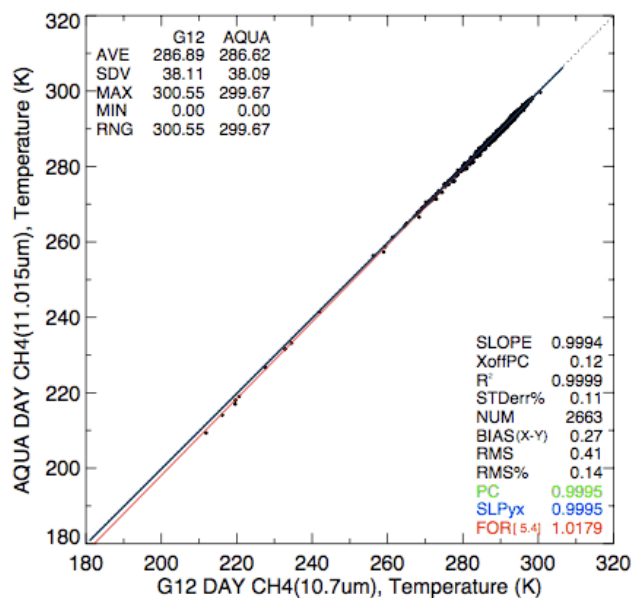
- Langley used the METEOSAT spectral response functions from ISCCP web site
- Langley used the Neckel&Labs provided by Joe

- Incoming solar spectra uncertainty ~1.3%
- Integrating using solar spectra or SRF intervals uncertainty ~0.4%
- ISCCP/Langley solar constants differ more than uncertainties

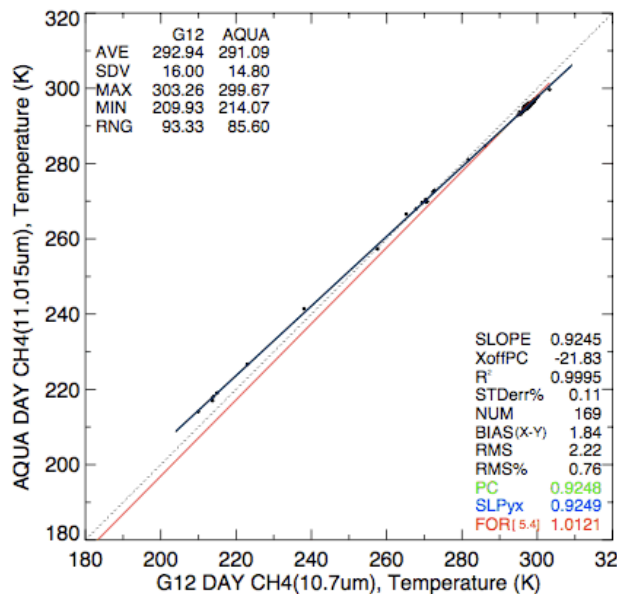
GOES-12 McIDAS vs ISCCP 11 μ m

Jan 1, 2010, 18 GMT

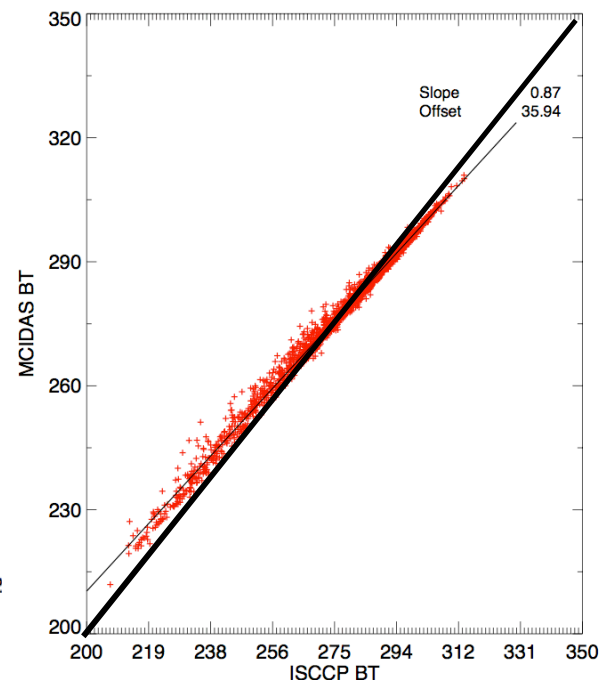
McIDAS vs Aqua



B1U vs Aqua



McIDAS vs B1U BT (10 um)

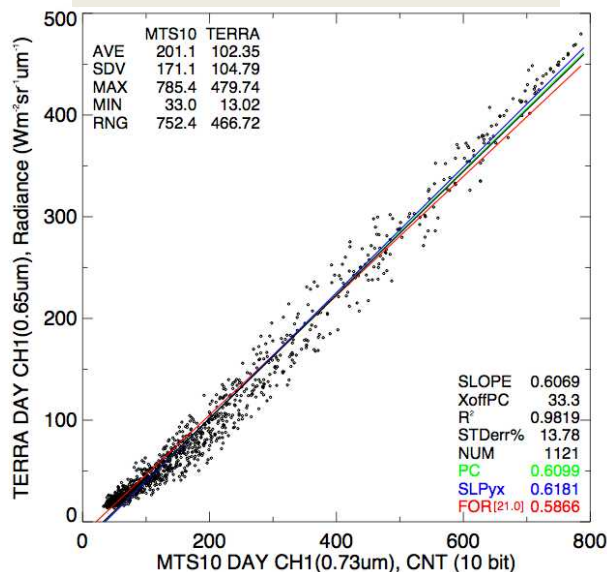


- There should be minimal correction for cold high cloud tops

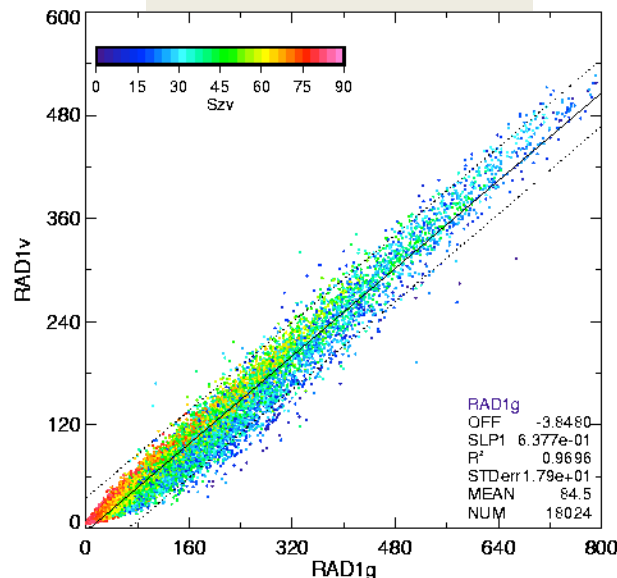
MTSAT sensor nonlinearity

- VIRS is in a 47 day precessionary cycle observing all SZAs every 23 days

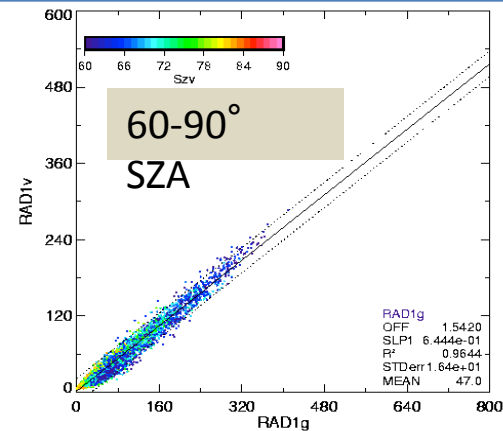
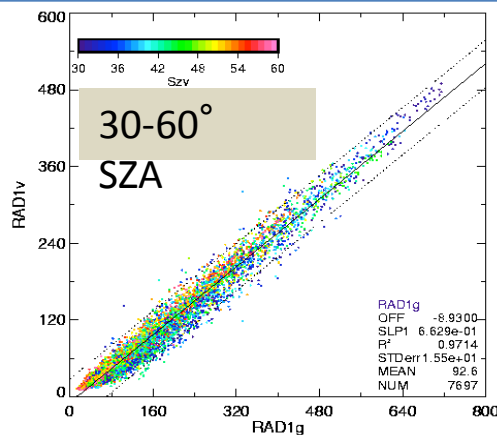
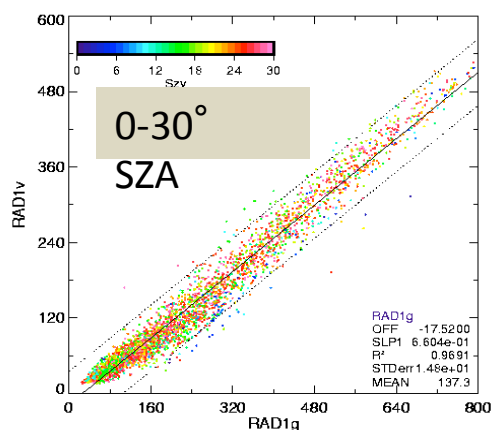
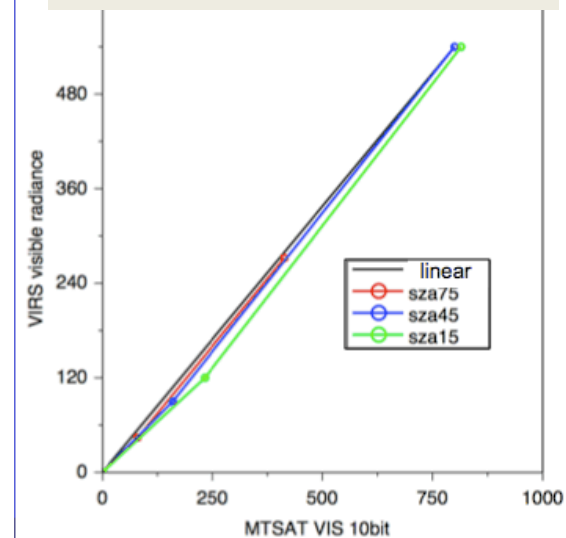
Nov 2007 MTSAT/Terra



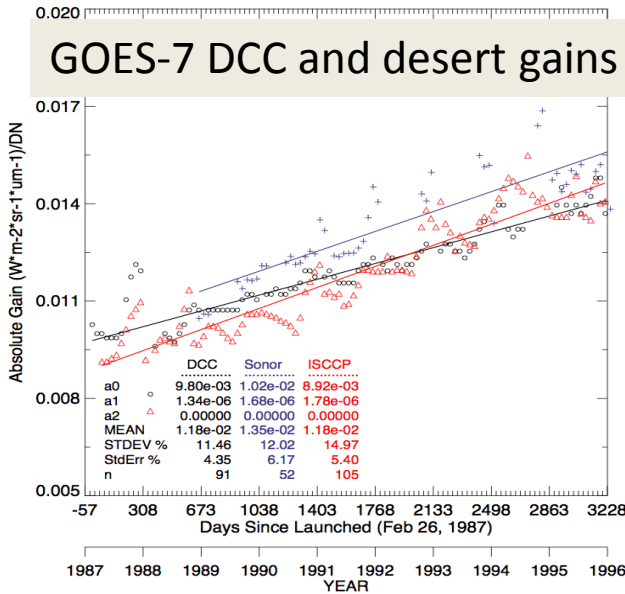
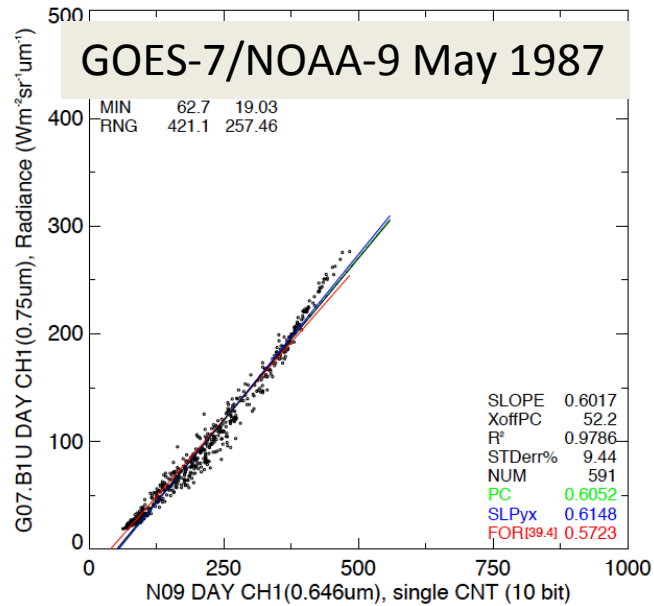
2006 MTSAT/VIRS



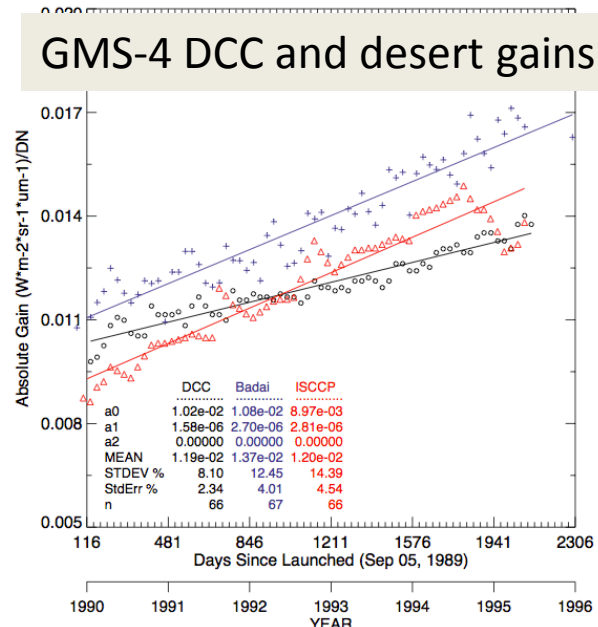
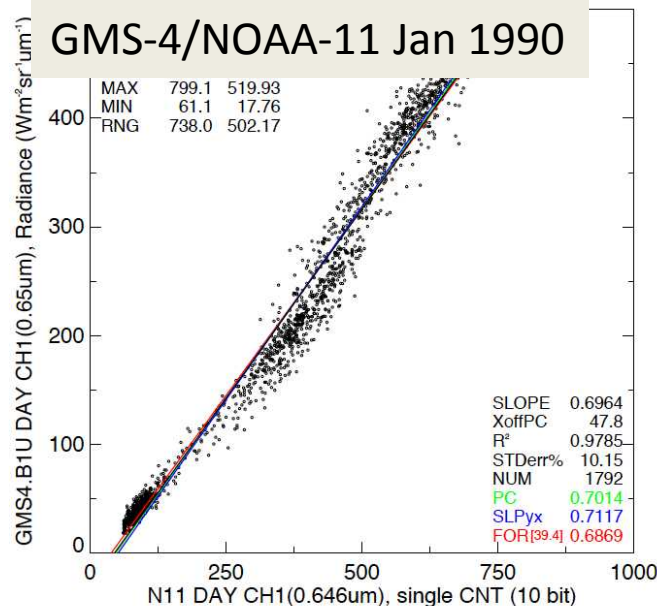
MTSAT nonlinear model, based on VIRS



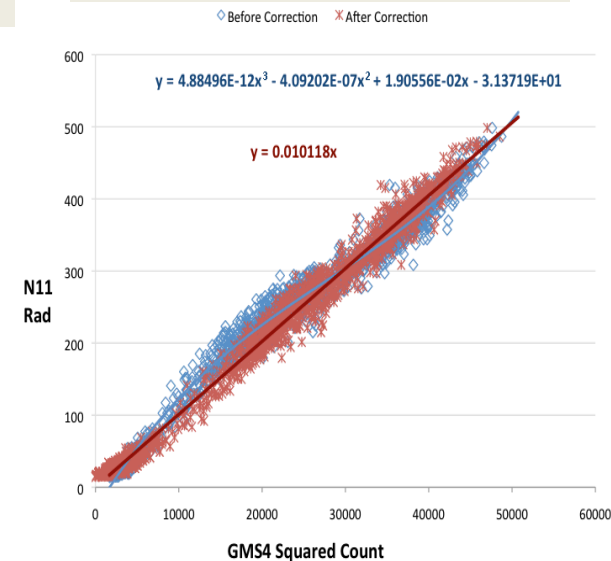
More sensor nonlinearity



- Could the calibration difference between DCC and desert be explained by the sensor nonlinearity?

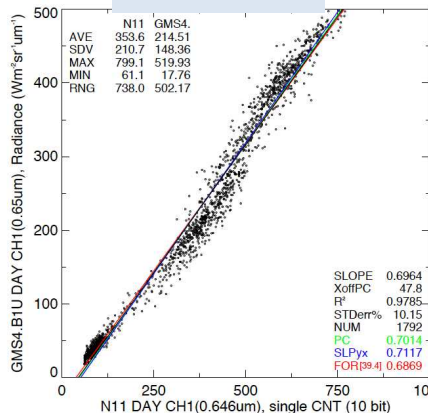


Derive a HMS-4 nonlinear adjustment

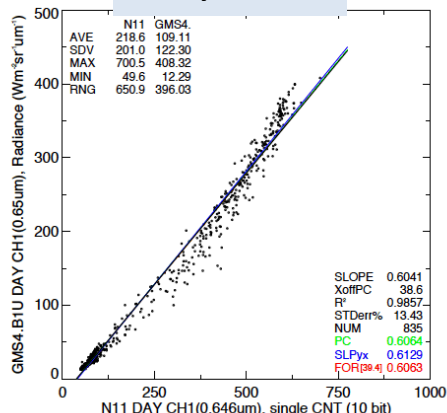


GMS-4 nonlinearity function

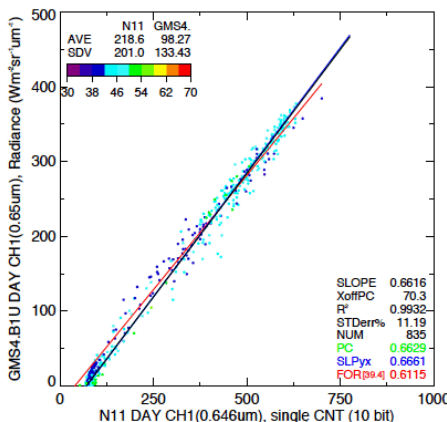
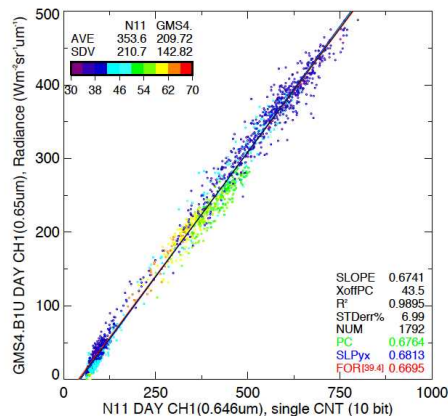
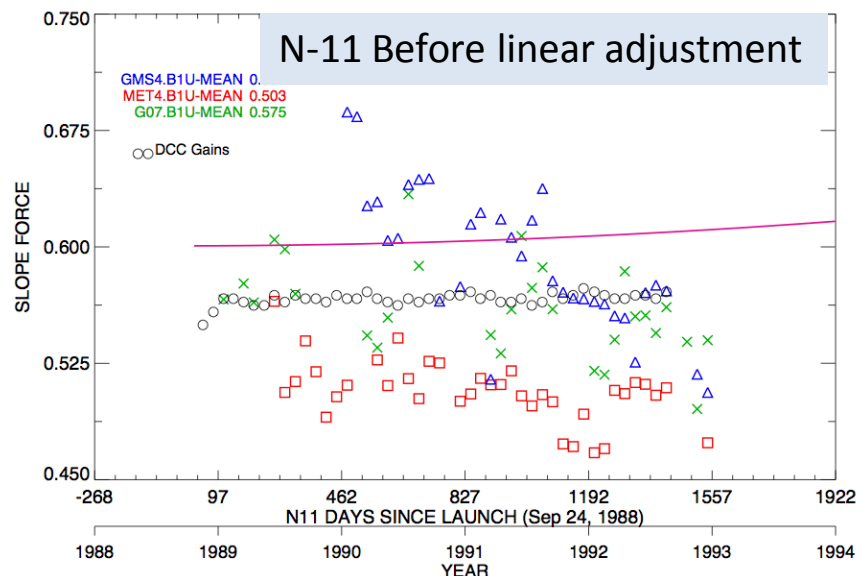
Jan 1990



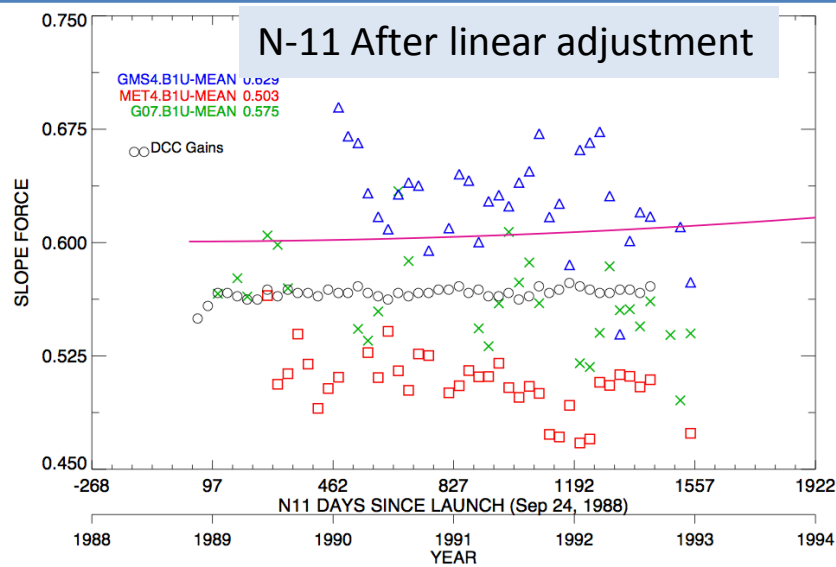
May 1991



N-11 Before linear adjustment

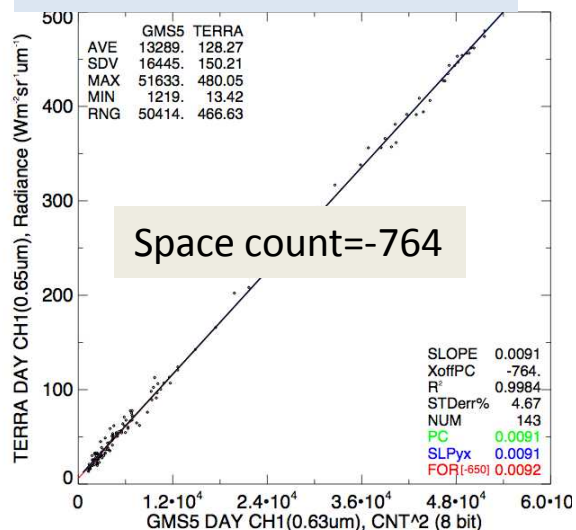


N-11 After linear adjustment

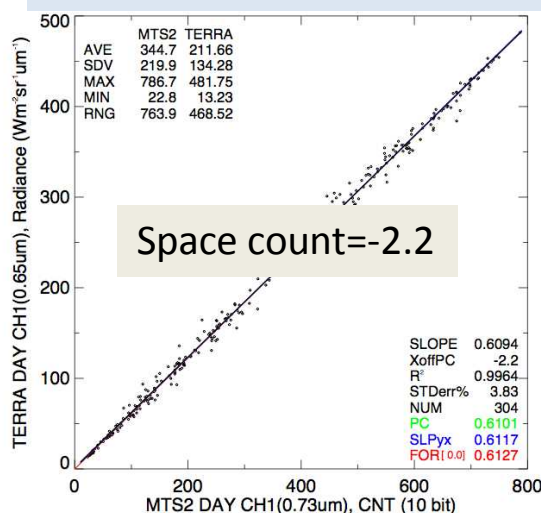


Negative space counts

GMS-5/Terra April 2000

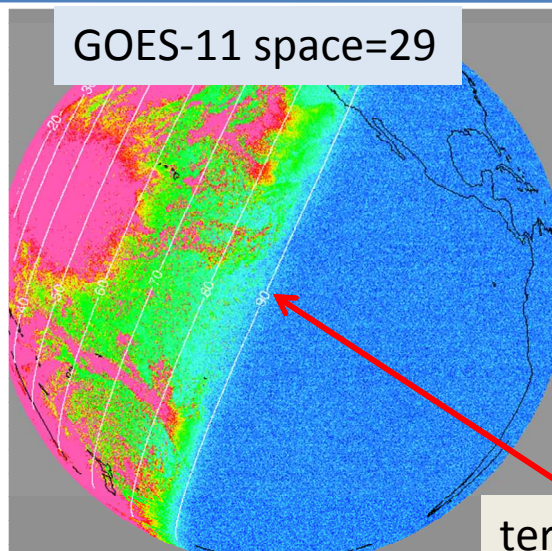


MTSAT-2/Terra Nov 2009



- A negative space count can occur when ever the space count is zero
GOES 8-14 = 29, MET8/9 = 51
GMS 2-5, MTSAT 1-2 = 0

GOES-11 space=29



terminator

MTSAT space=0

