Consistent Pre-2000 GEO Visible Calibration Record Based on Deep Convective Clouds and Desert Targets

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Outline

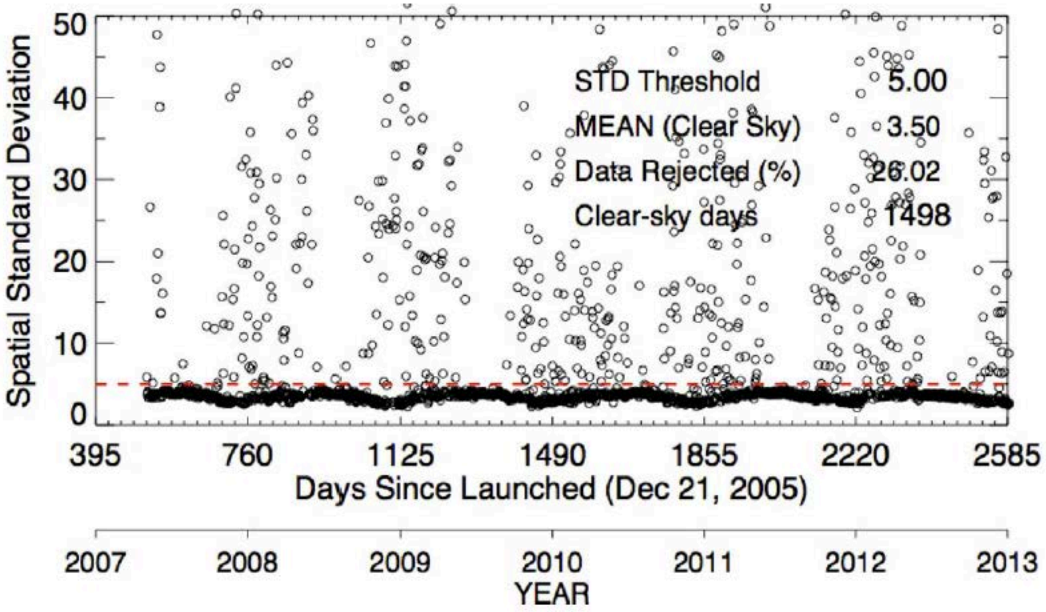
- Describe the geostationary (GEO) calibration methods
  - Desert calibration
  - Deep convective cloud (DCC) calibration
  - Spectral band adjustment factors (SBAF)
- Compare the method calibration method gains
  - Examine method calibration discrepancies to understand the individual GEO sensors

Desert invariant target method for GEOs

- The GEOs have had consistent scanning schedules and equatorial positions for 40 years
  - ISCCP coordinated 3-hourly synchronized imagery among the GEO operational centers for the ISCCP B1U dataset
- This allows deserts to be observed with the same daily angular conditions year after year
- A Daily Exoatmospheric Radiance Model (DERM) is constructed from a reference GEO that has been inter-calibrated with Aqua-MODIS C6 radiances
  - Clear-sky is determined using a spatial homogeneity filter
  - The inter-annual variability of the atmospheric column is assumed to be small
- The DERM clear-sky predicted radiance is used to calibrate either historical or future GEO sensors
  - Spectral Band Adjustment Factor are applied to the reference GEO and is used to account for GEO sensor spectral band differences

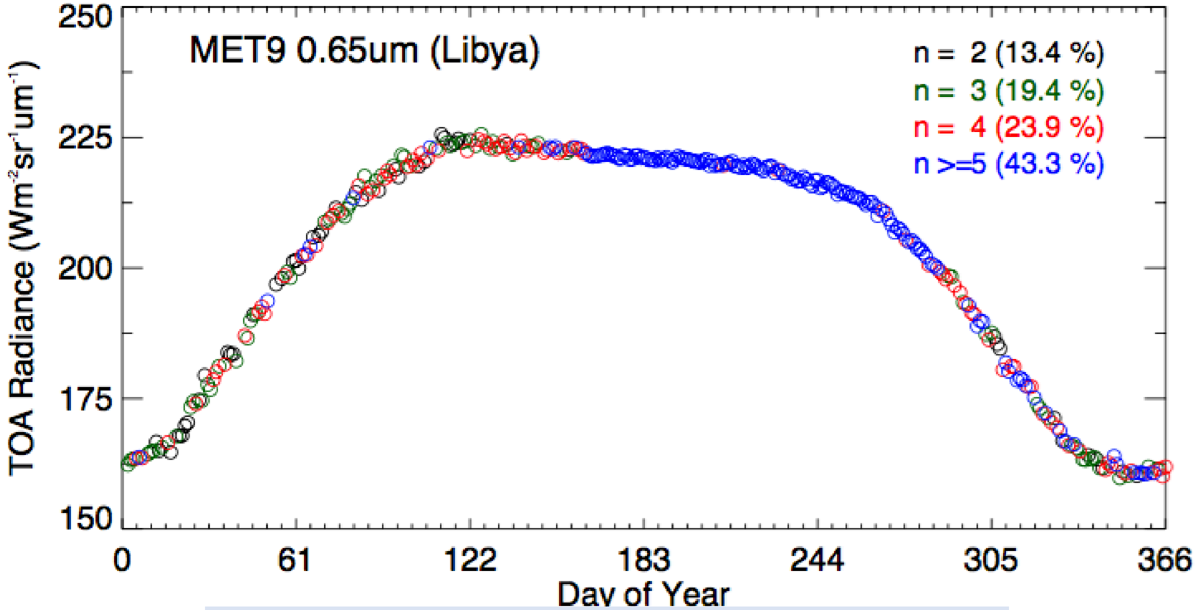
Met-9 Libya-4 DERM

Libya-4 Daily spatial standard deviation

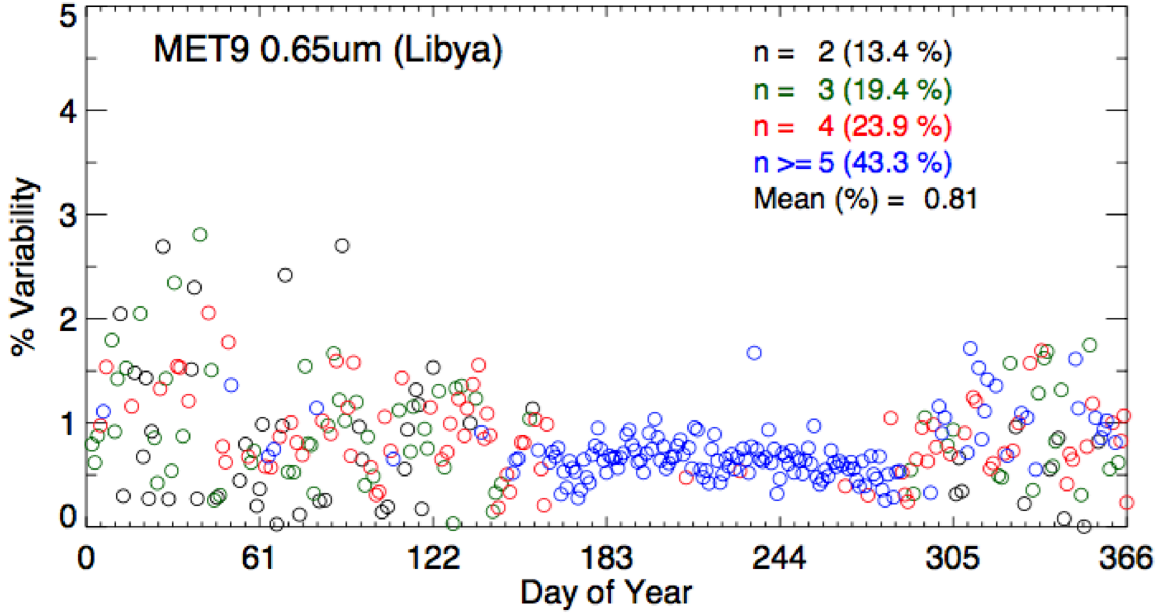


- Although the DERM has a large seasonal cycle the inter-annual variability is very small
- The daily inter-annual standard deviation is mostly under 2% and on average is 0.81% for Libya-4
- The monthly inter-annual standard deviation is ~0.5%

The reference DERM based on Met-9 from 2007-2012



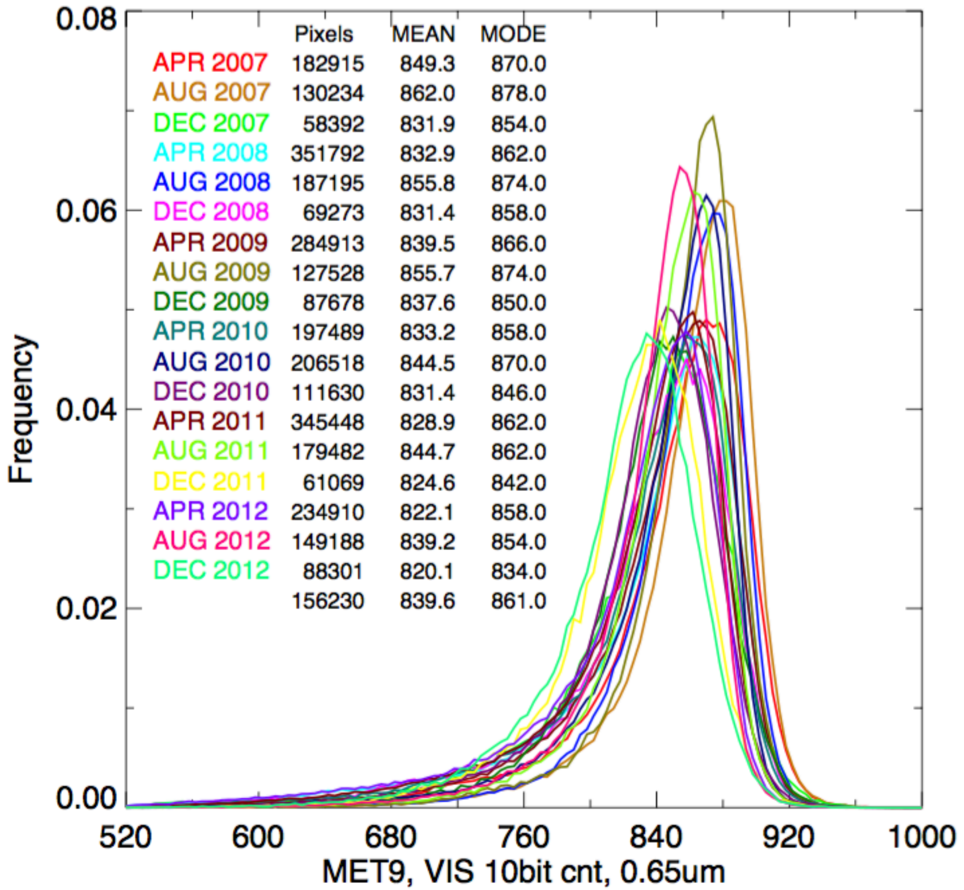
The DERM daily inter-annual variability

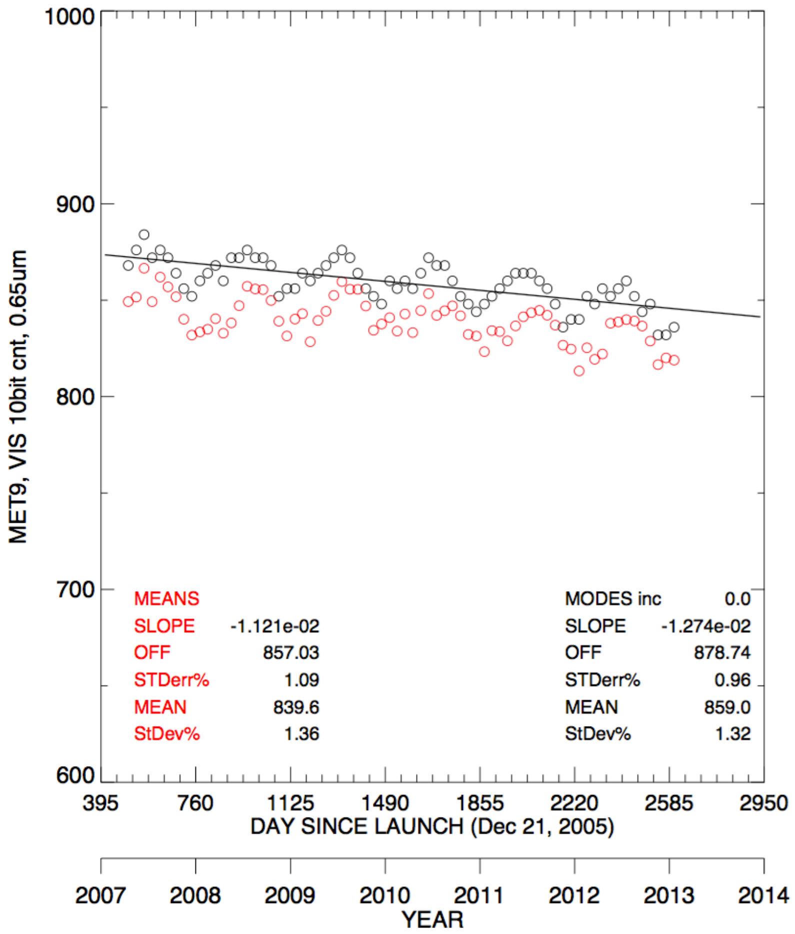


Deep Convective Cloud (DCC) Invariant Target method

- DCC calibration is a large ensemble statistical method that does not rely on a few pristine DCC
- DCC pixels are identified by a BT threshold < 205K, σBT<1K, σVIS<3%, over the tropical domain centered at the GEO sub-satellite point
  - SZA<40°, VZA<40° the more Lambertian part of DCC
- DCC pixel level radiances are corrected to nadir conditions using the Hu DCC BRDF
- DCC are histogrammed monthly and the probability density function (PDF) mode is used to track the stability

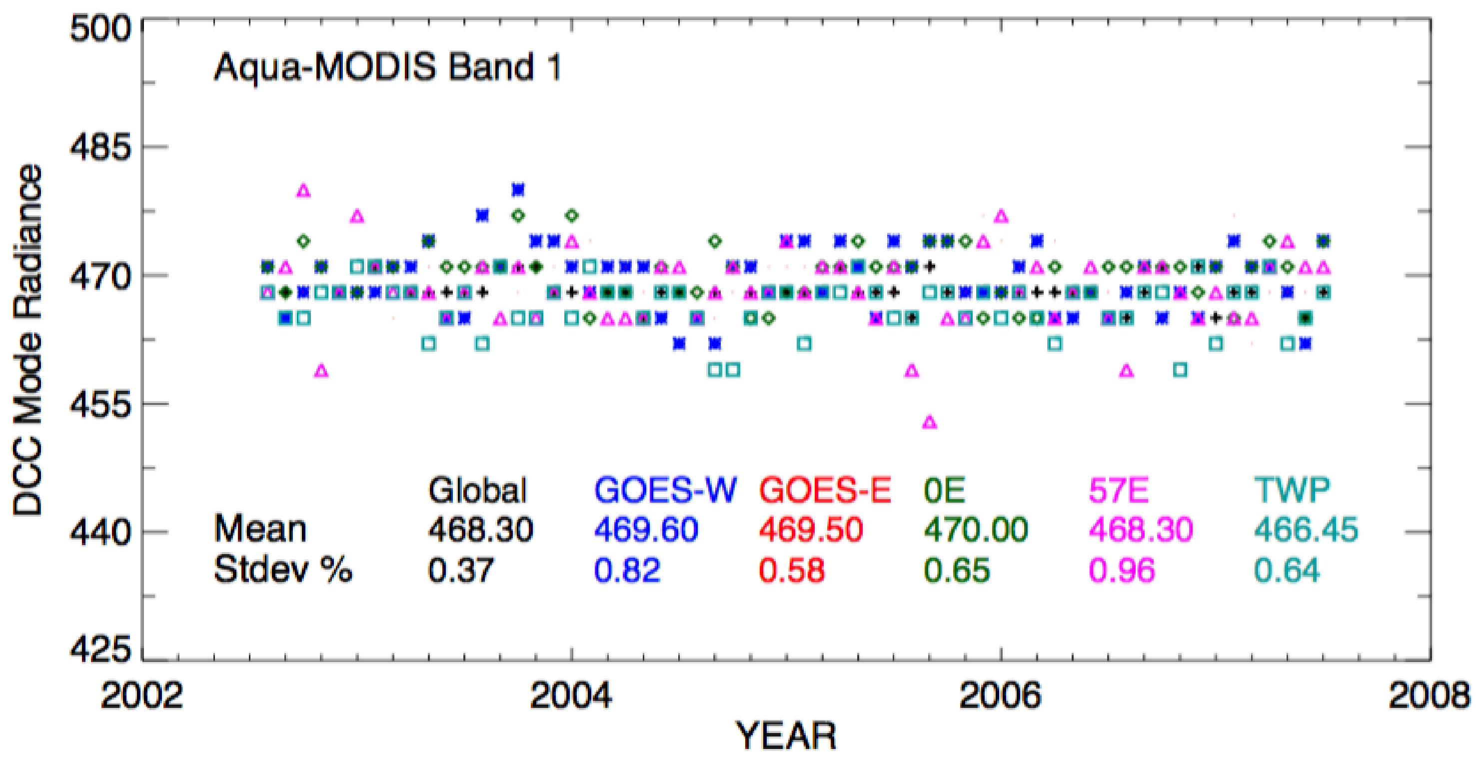
Meteosat-9 DCC





- For Met-9 the DCC corrected radiances have the largest seasonal cycle of all the GEO domains
- For Met-9 the PDF-mode or PDF-mean nearly provide the same stability and trend standard error

DCC transfer of reference calibration

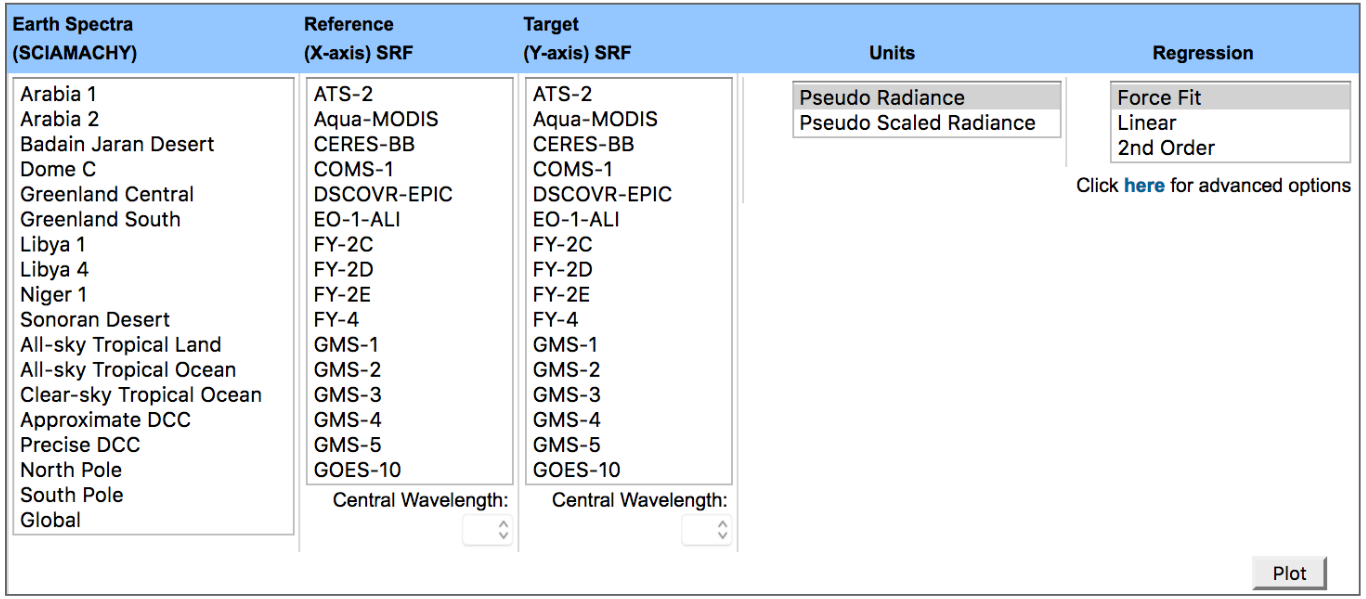


- Apply the same DCC algorithm to MODIS and compute the DCC-mode radiance for each GEO domain
- Assume that both GEO and MODIS capture the same DCC at nearly the same time and location, do not need to be angle matched
- Account for MODIS and GEO spectral band differences using a SBAF to the MODIS reference calibration

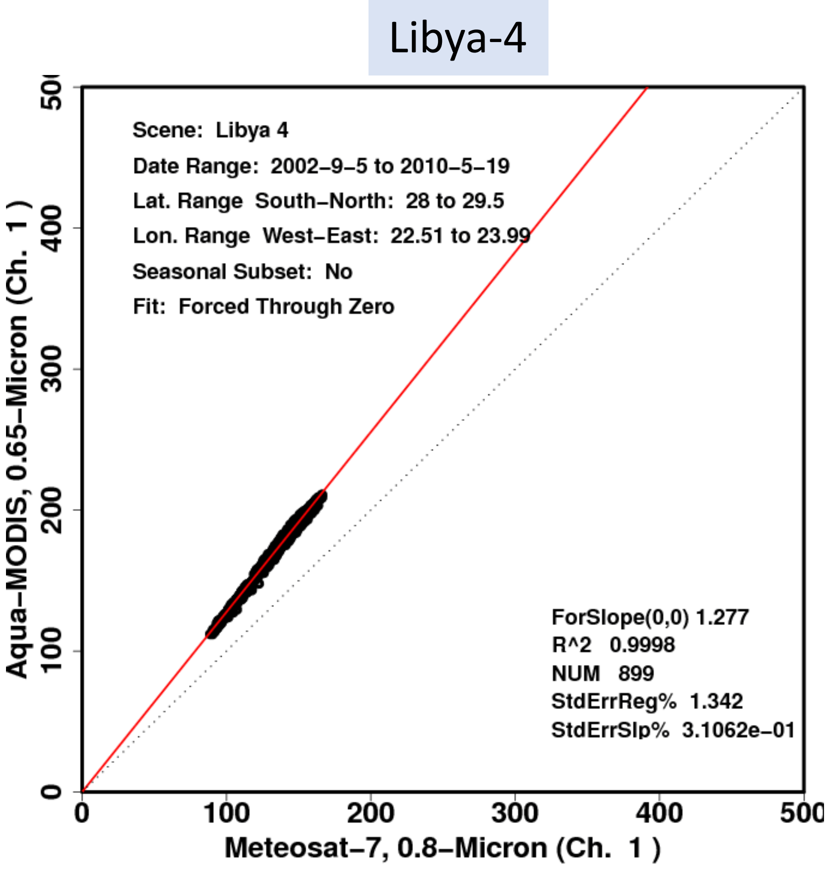
Spectral Band Adjustment Factors (SBAF)

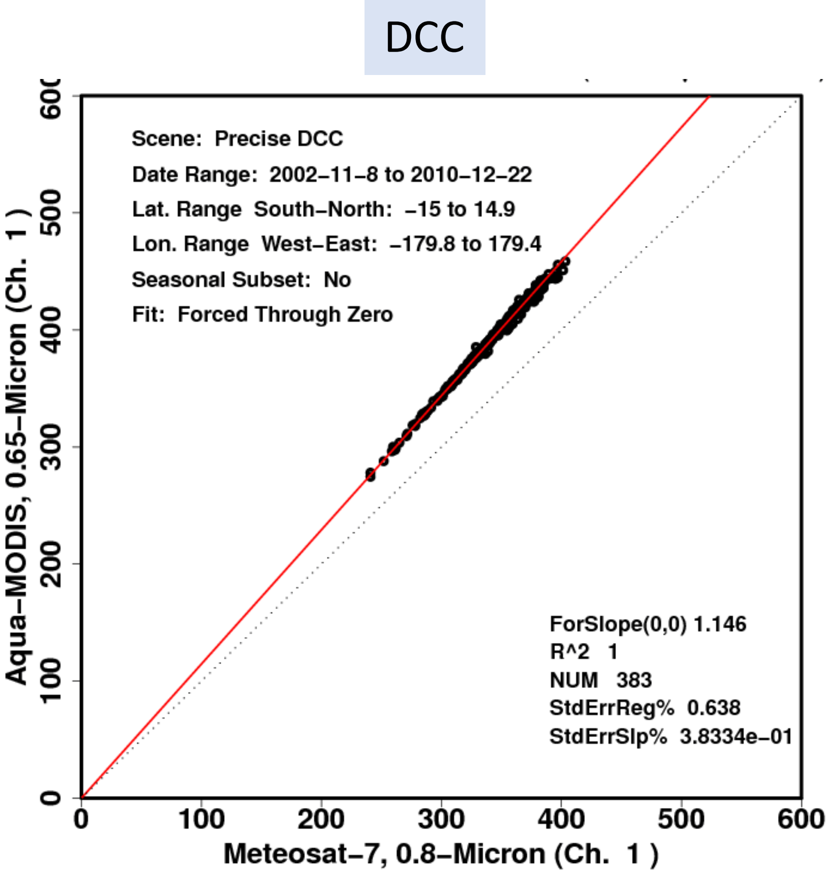
- SBAF mitigate the non-overlapping part of the spectral band induced sensor observed radiance differences
  - SBAF is a function of surface type, atmospheric and cloud conditions or scene types
- Use SCIAMACHY footprint hyper-spectral radiances convolved with the spectral response function pseudo radiance pairs to derive SBAF

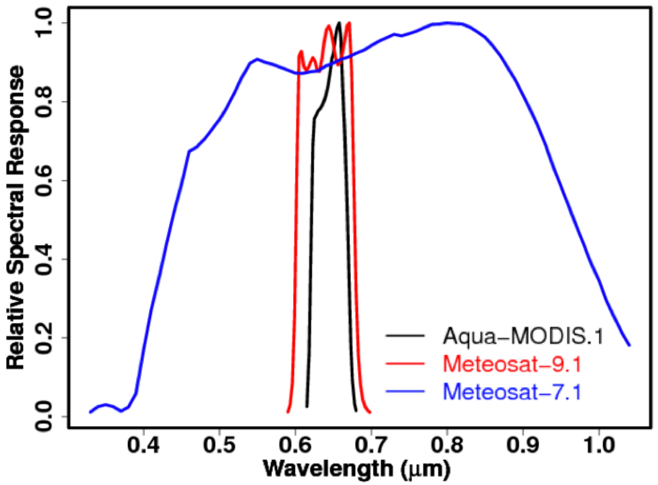
NASA Inter-consistency proposal sponsored SBAF web site https://satcorps.larc.nasa.gov/cgi-bin/site/showdoc?mnemonic=SBAF



SBAF MODIS and Met-7







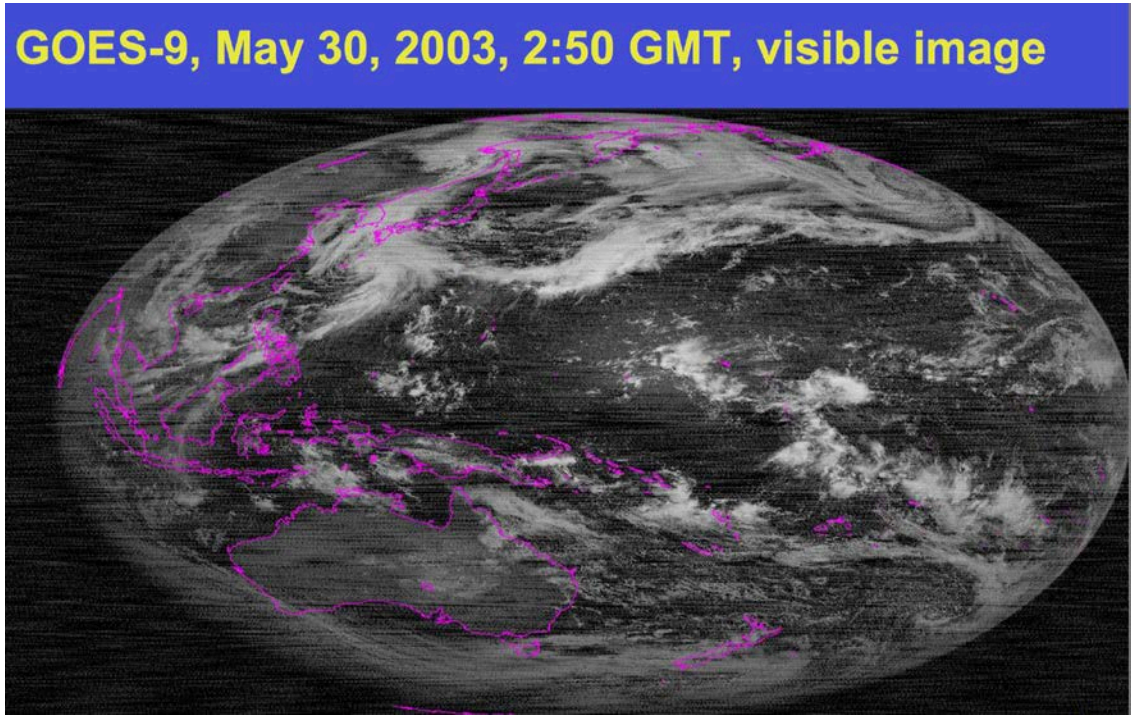
Scene Type	SBAF
Clear-sky ocean	1.097
Bright cloud	1.136
Libya-4 (annual)	1.277
DCC	1.146
Equal reflectance	1.142

Libya-4	SBAF	σ (%)
Winter	1.257	1.21
Spring	1.262	0.94
Summer	1.285	0.81
Fall	1.288	0.96
Annual	1.277	1.34

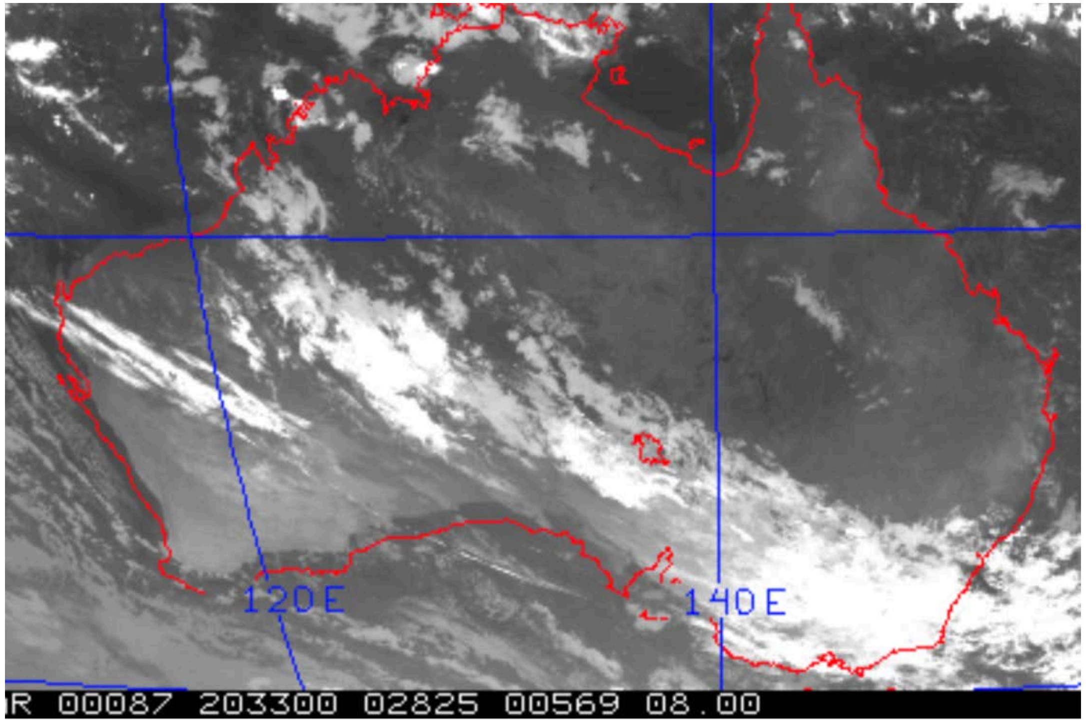
- There is a 11% SBAF induced radiance difference between DCC and Libya-4
- DCC SBAF and equal reflectance are similar, since DCC are spectrally flat
- Libya-4 seasonal SBAFs reduce the SBAF uncertainty
- A 2.5% Libya-4 SBAF difference between Fall and Winter seasons

Image Quality and Navigation

GMS-5, 11 µm, March 27, 2000



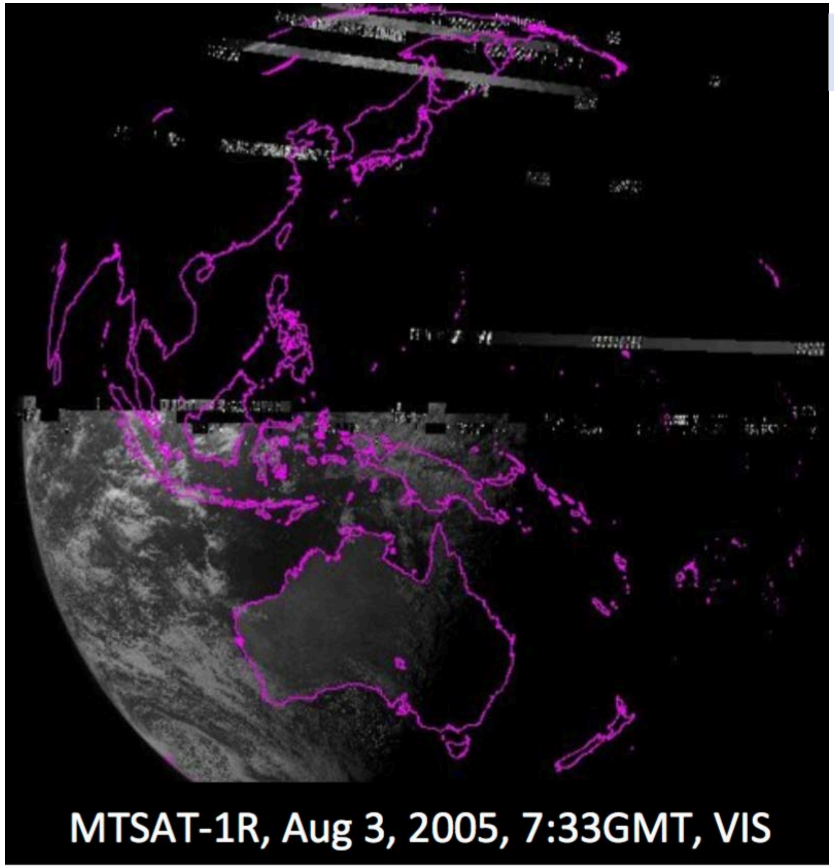
This GOES-9 GMT hour is unusable for science



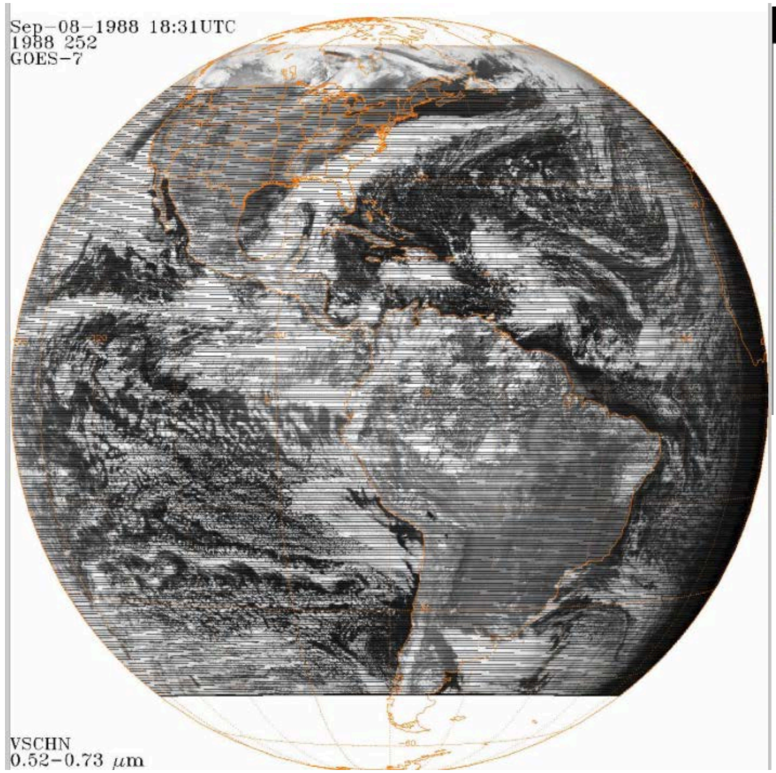
Navigation is off by 90-km

Navigation effects desert but not DCC calibration

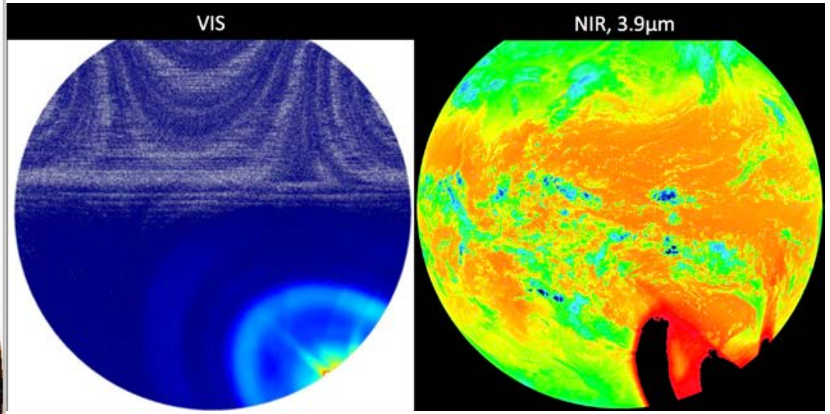
Bad Scan lines and stray light



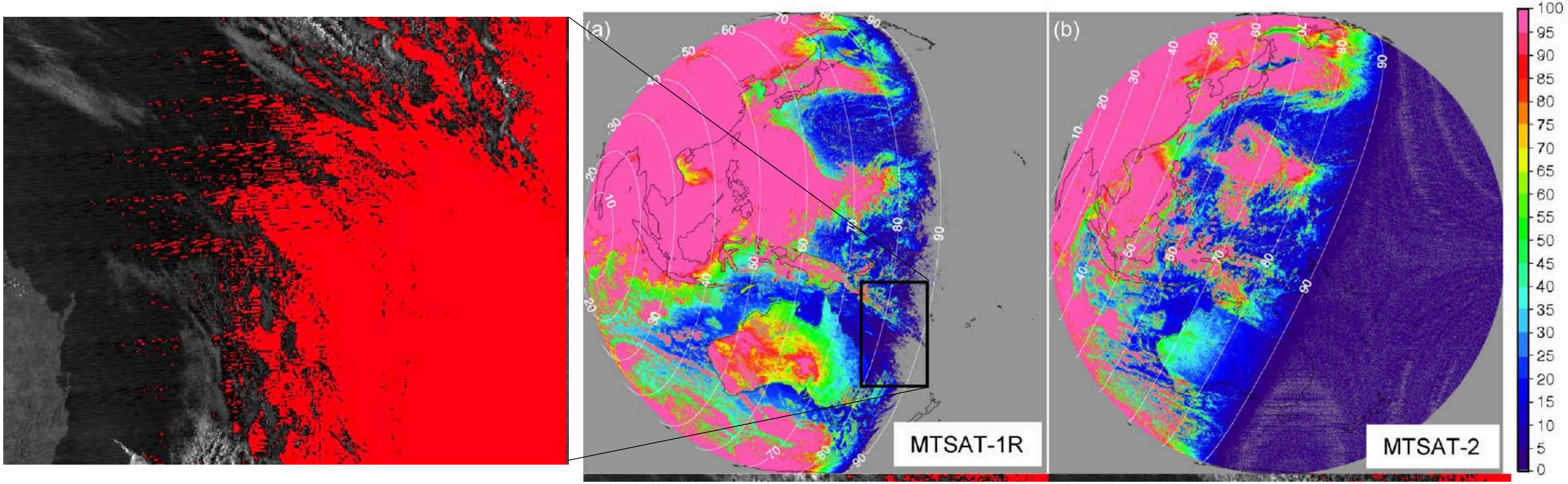
GOES-7, Sept 8, 1988, 18:31GMT, VIS



MTSAT-2, Feb. 28, 2012, 14:30 GMT

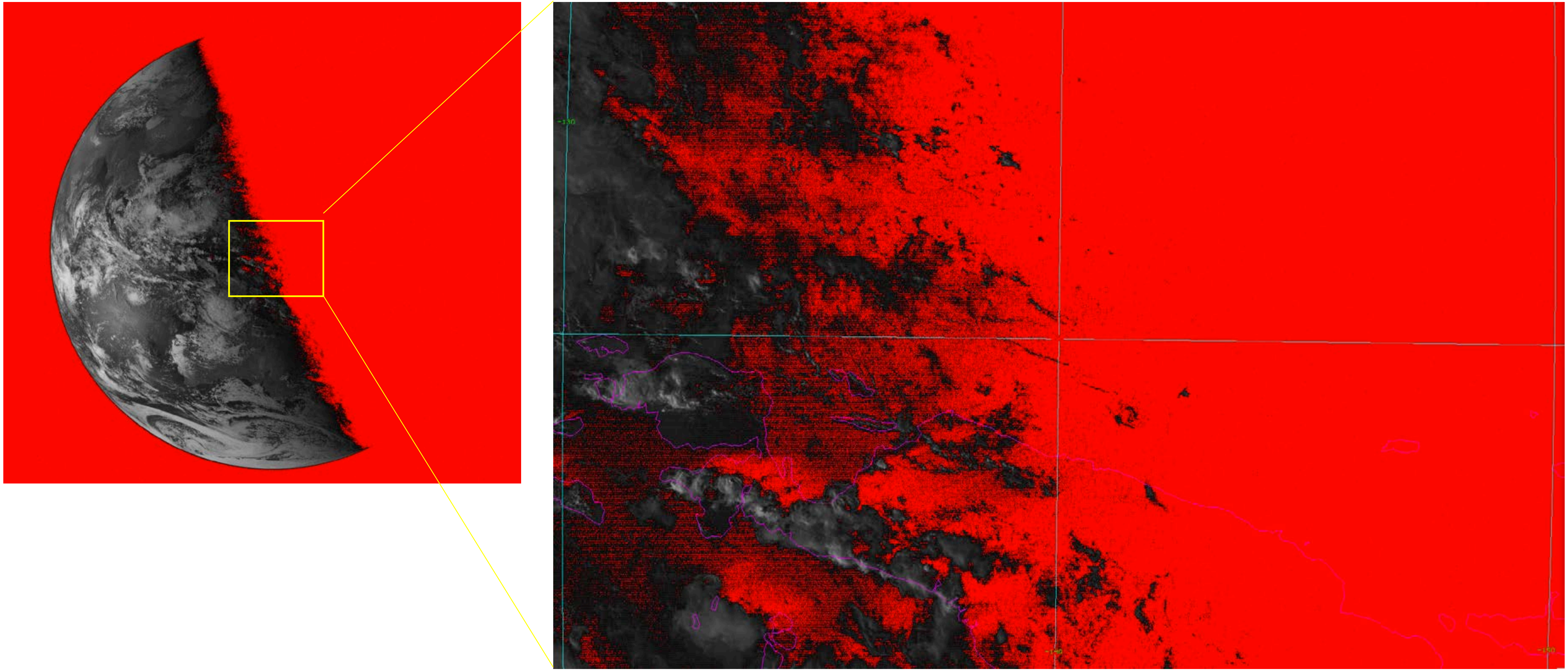


Negative space count offset

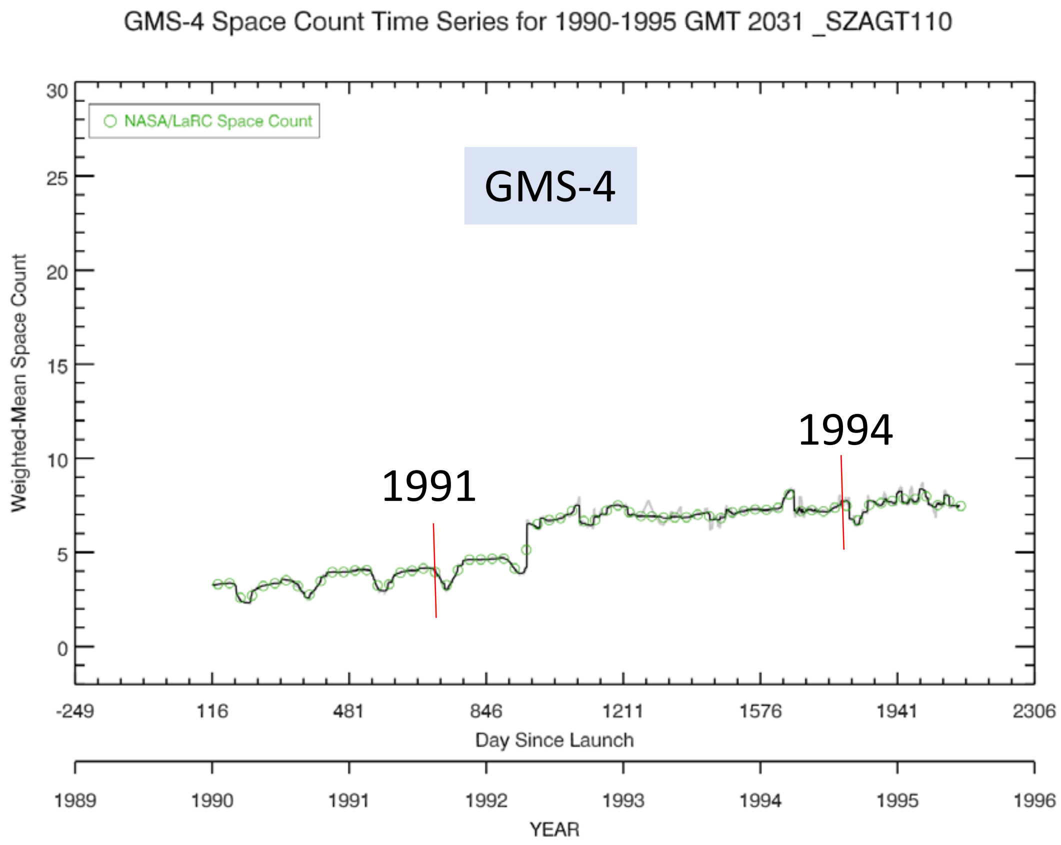


- Negative space count is a count of zero when the solar zenith angle is less than 90°
- All GEO operational centers should use space offsets that are significantly greater than 0

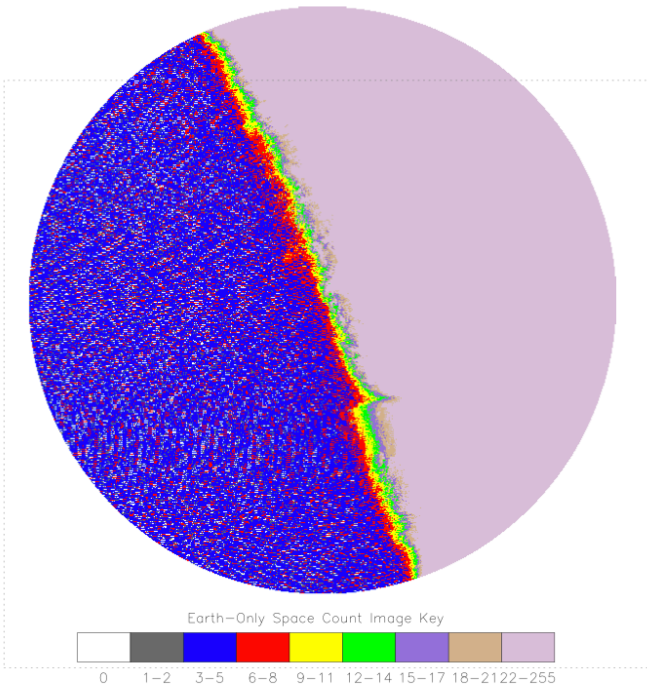
GMS-5 space count



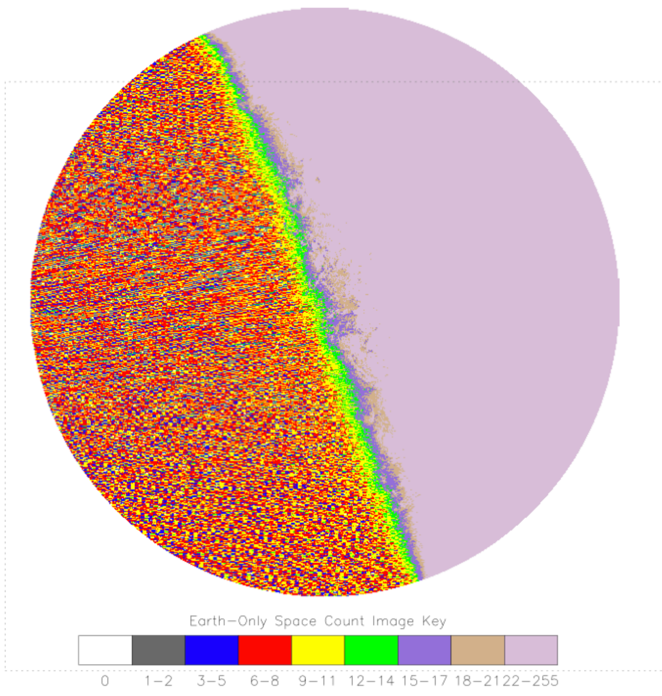
Space count changes over time



GMS-4, 1991, July 7, 20:30 GMT



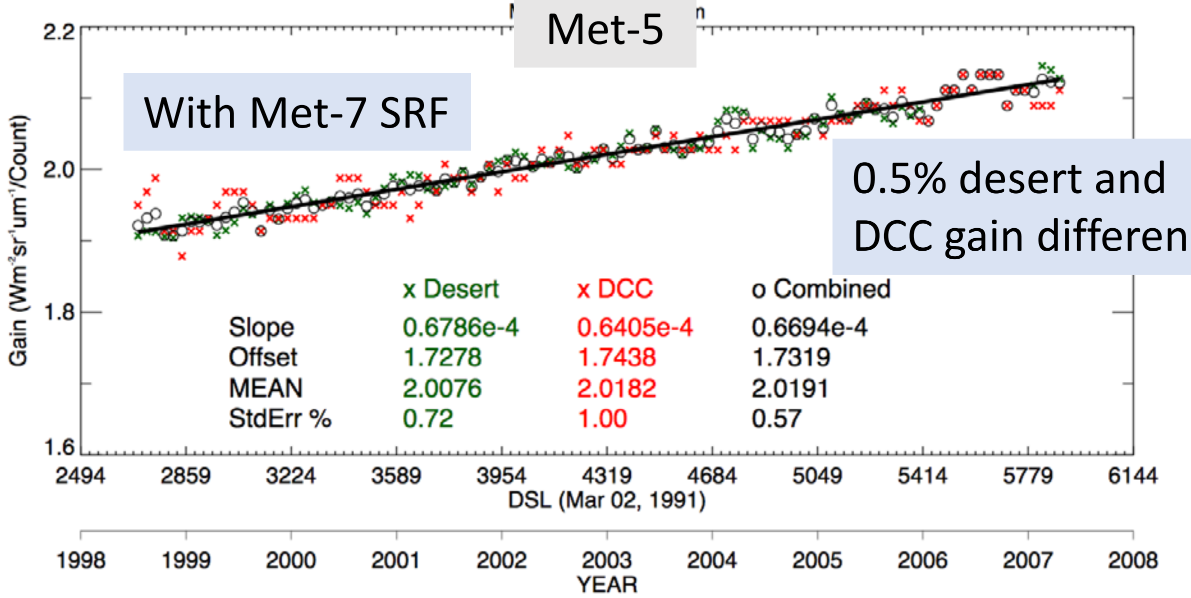
GMS-4, 1994, July 7, 20:30 GMT



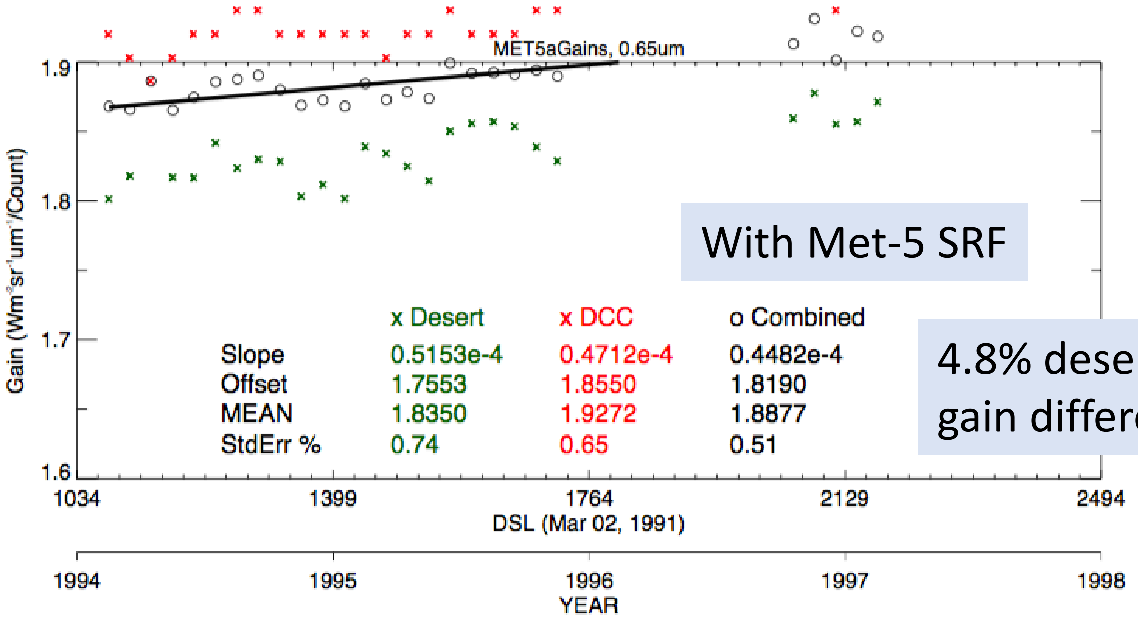
Met-5 with differing SRFs

Met-5

With Met-7 SRF

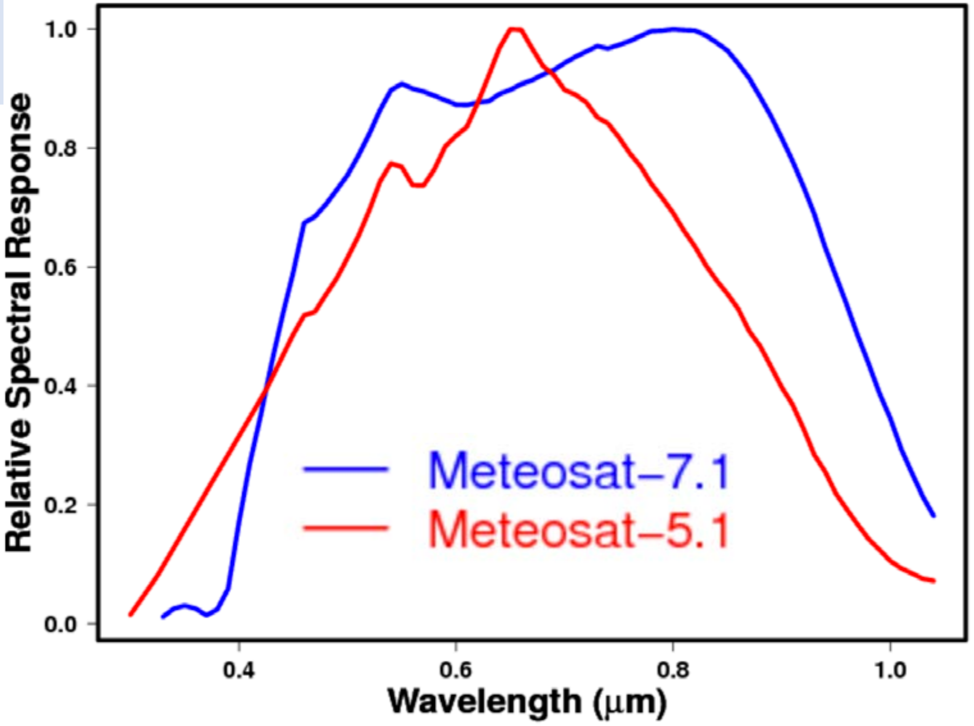


0.5% desert and DCC gain difference

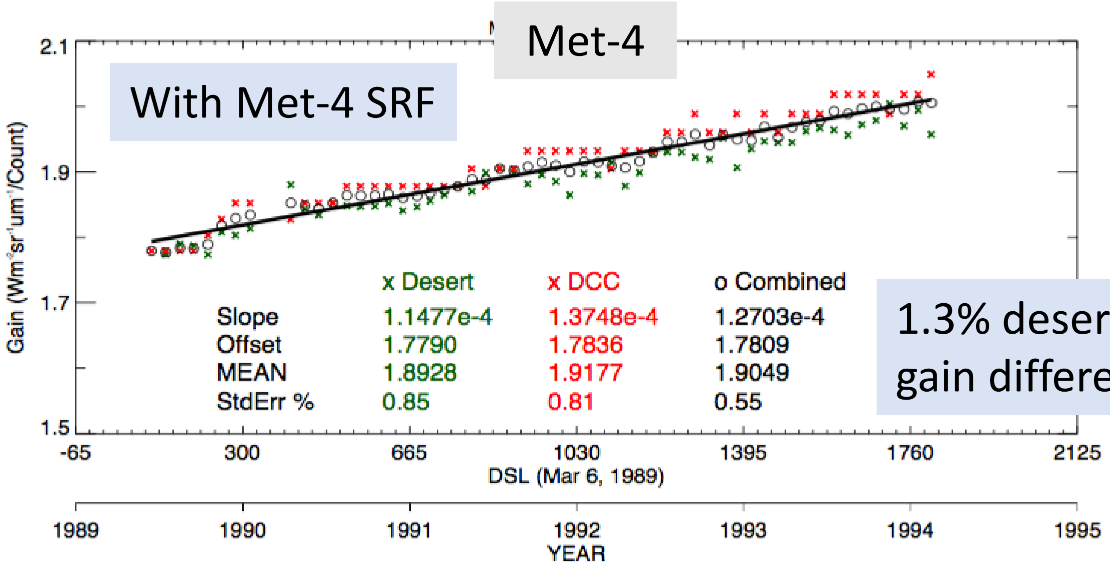


With Met-5 SRF

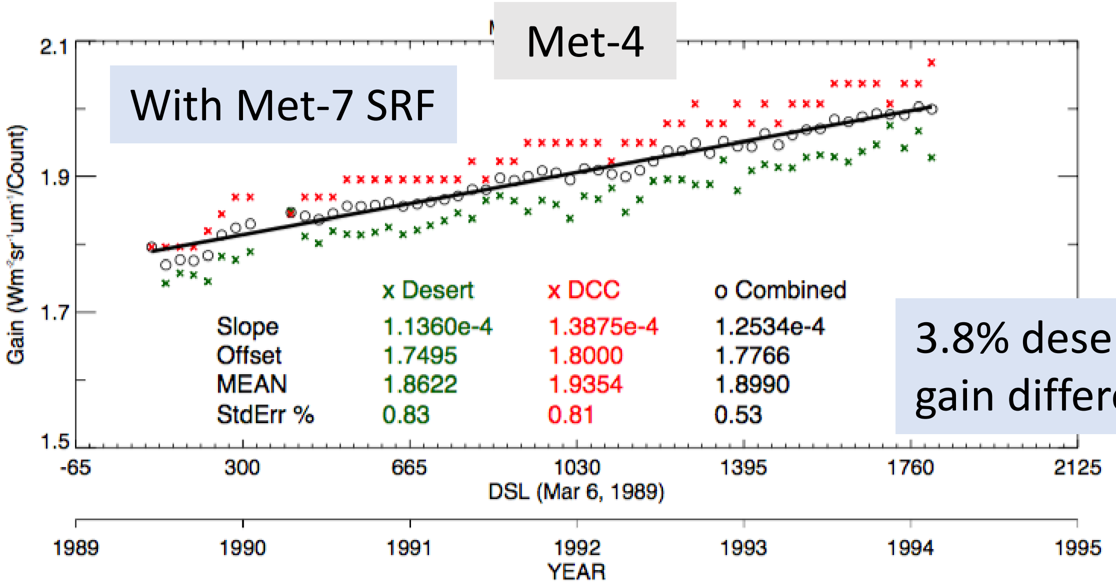
4.8% desert and DCC gain difference



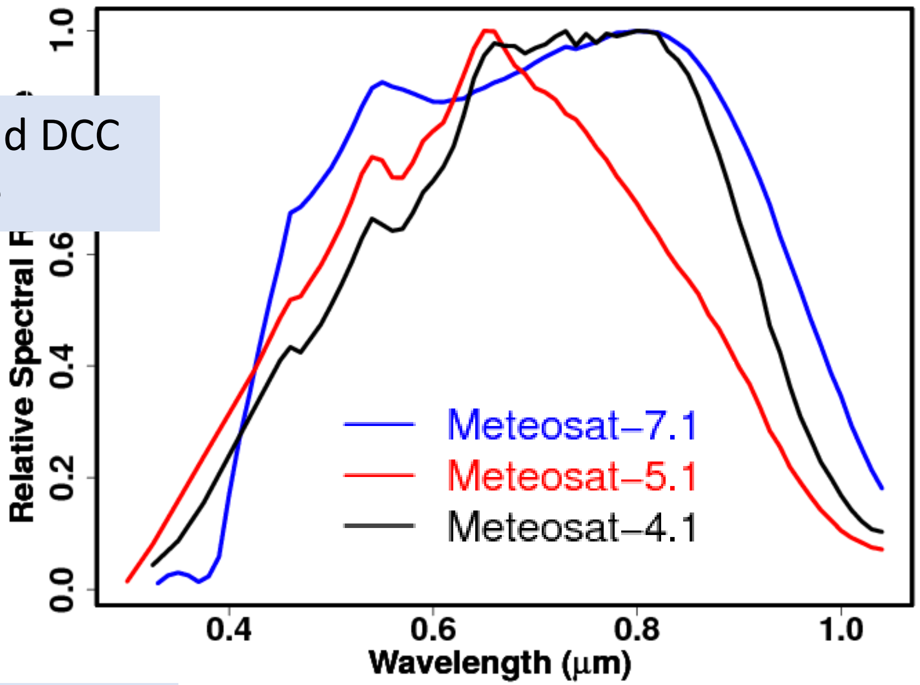
Met-4 with differing SRFs



1.3% desert and DCC gain difference

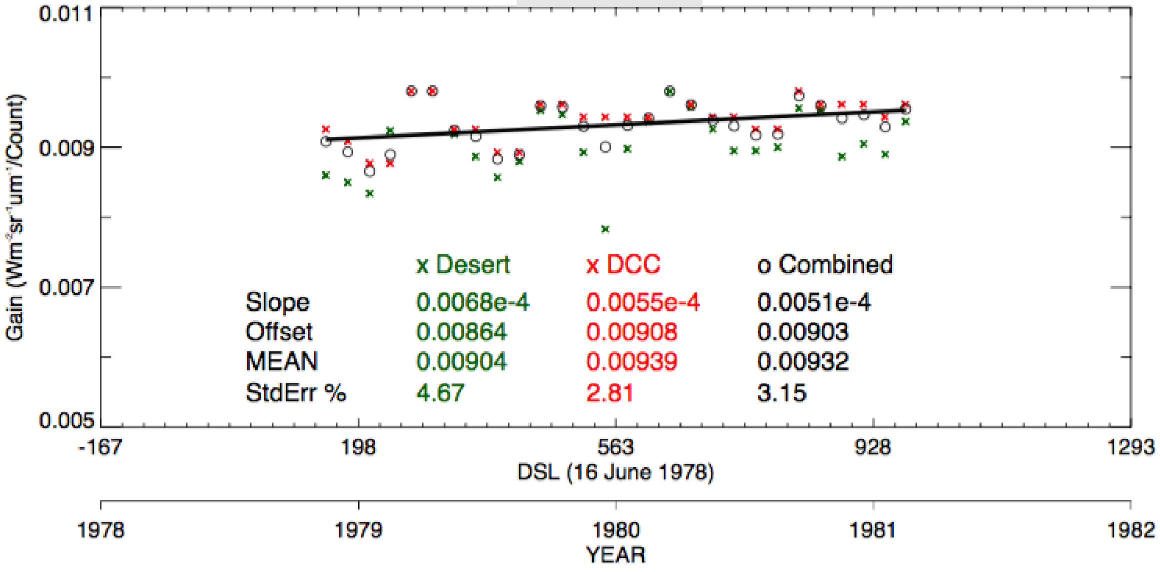


3.8% desert and DCC gain difference



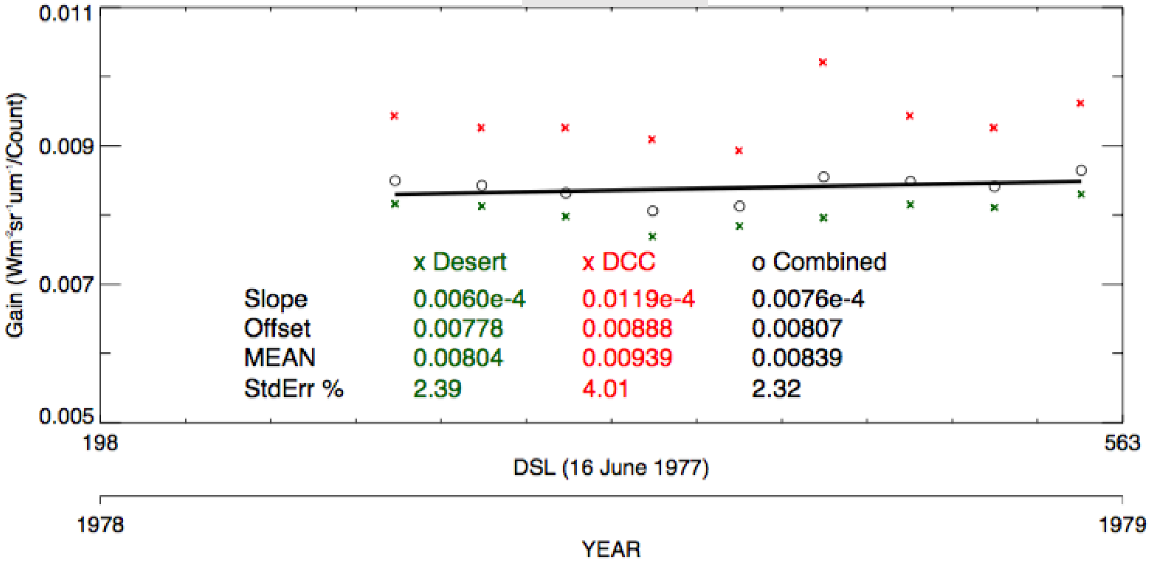
Spectral response mismatch, GOES-2 and 3 have no associated SRF. Use GOES-5 SRF

GOES-3



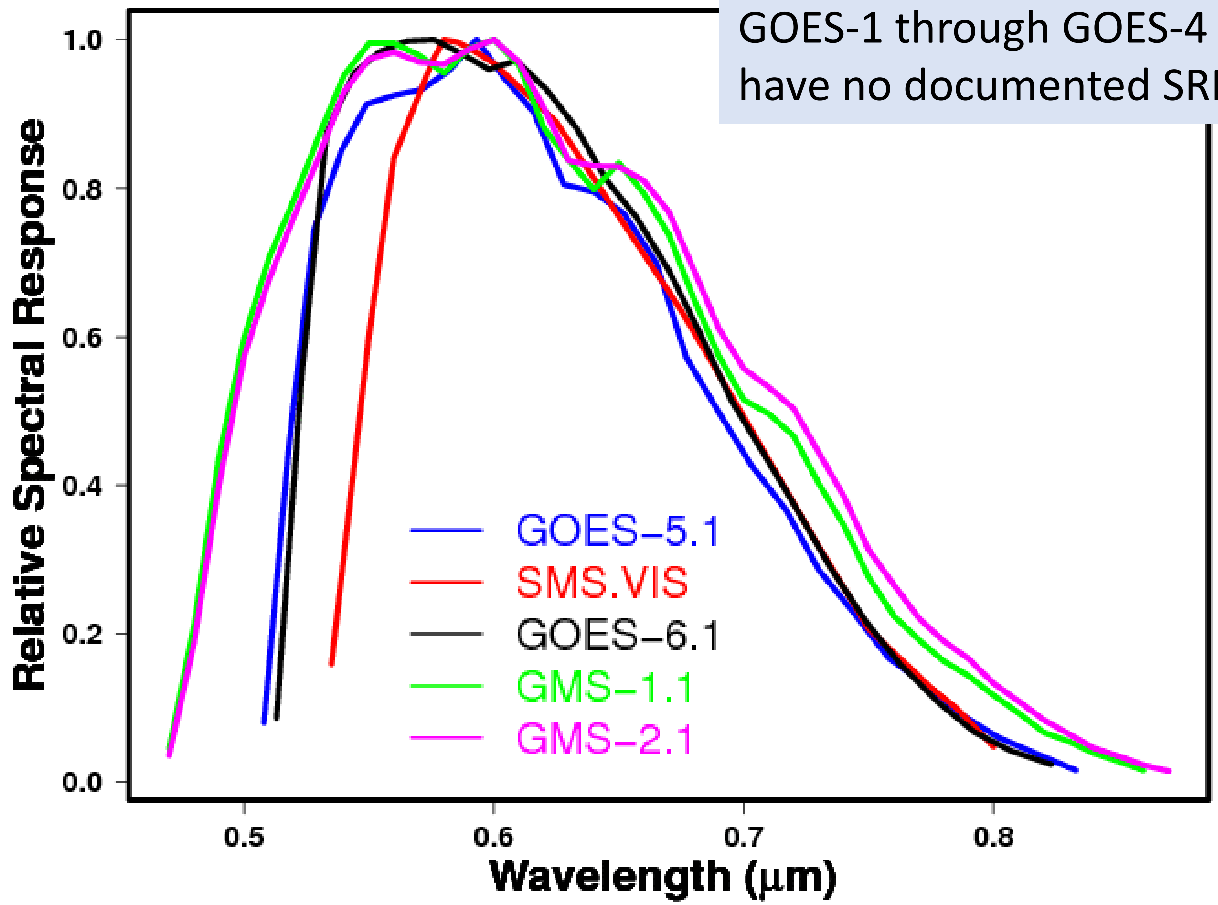
3.1% gain difference between desert and DCC

GOES-2



14.4% gain difference between desert and DCC

Usually similar builds have the same SRF

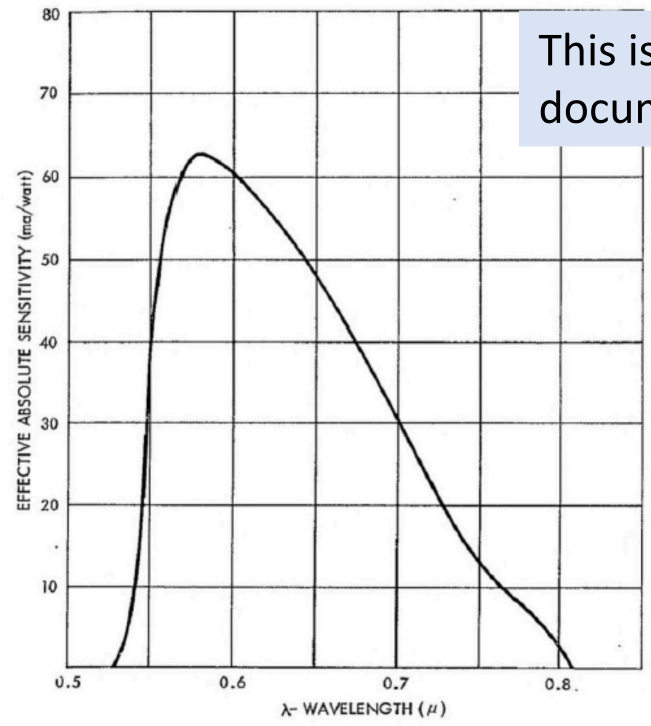


GOES-1 through GOES-4 have no documented SRFs

SMS Visible Spectral Response

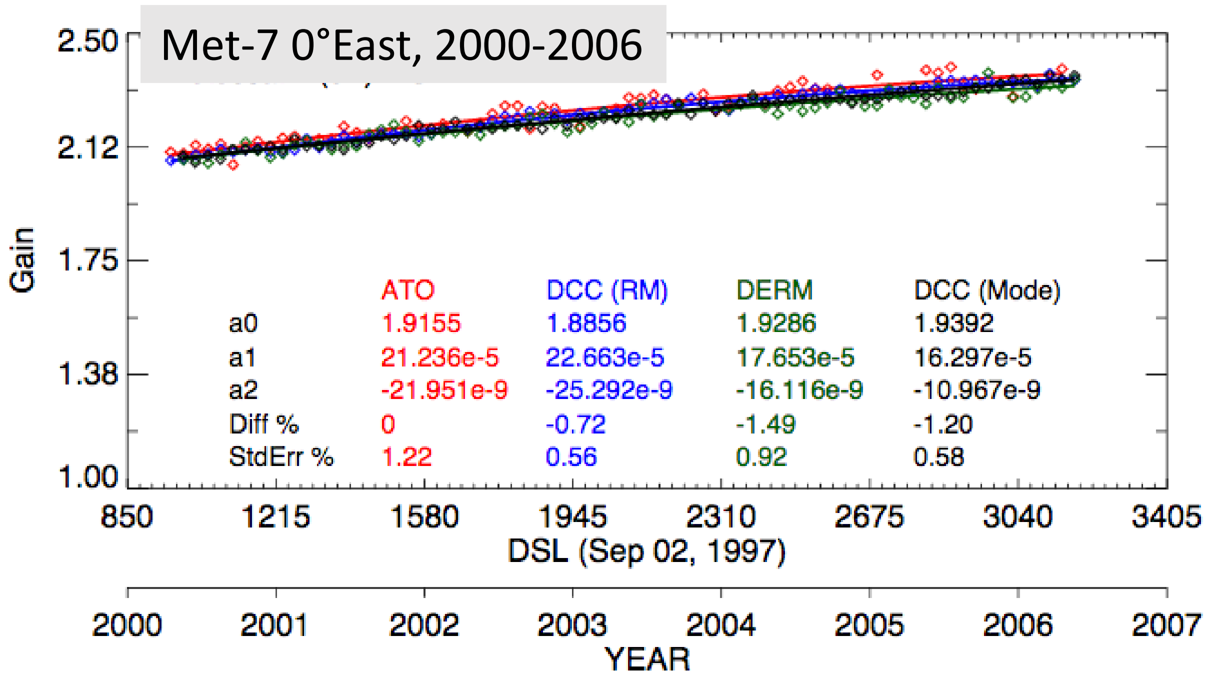
VISSR information is available here
https://archive.org/stream/NASA_NTRS_Archive_19700025072#page/n71/mode/2up

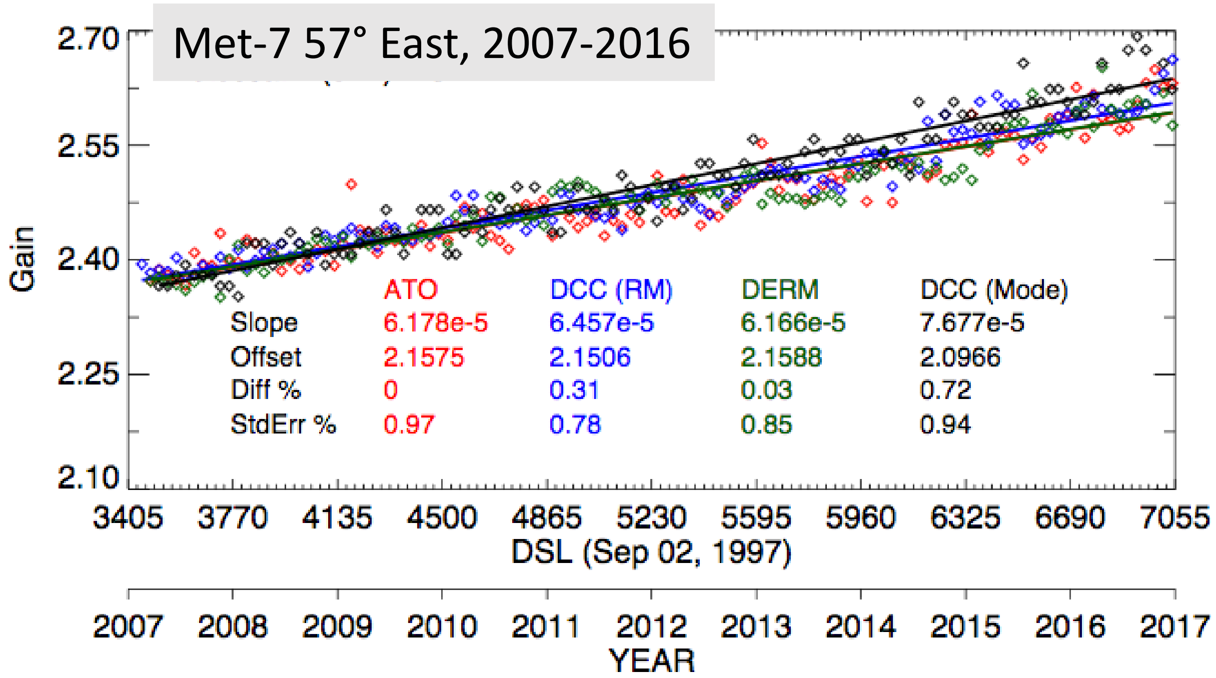
The screenshot from page 72 of spectral response is:



This is the only documented SMS SRF

Met-7 SRF degradation

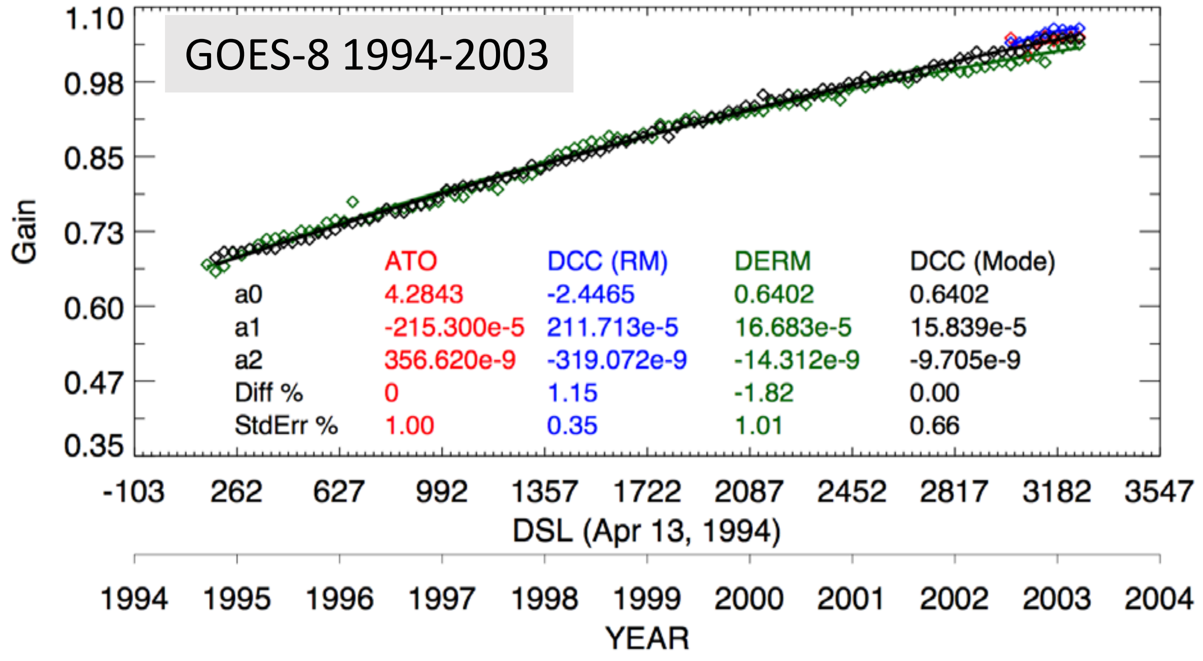


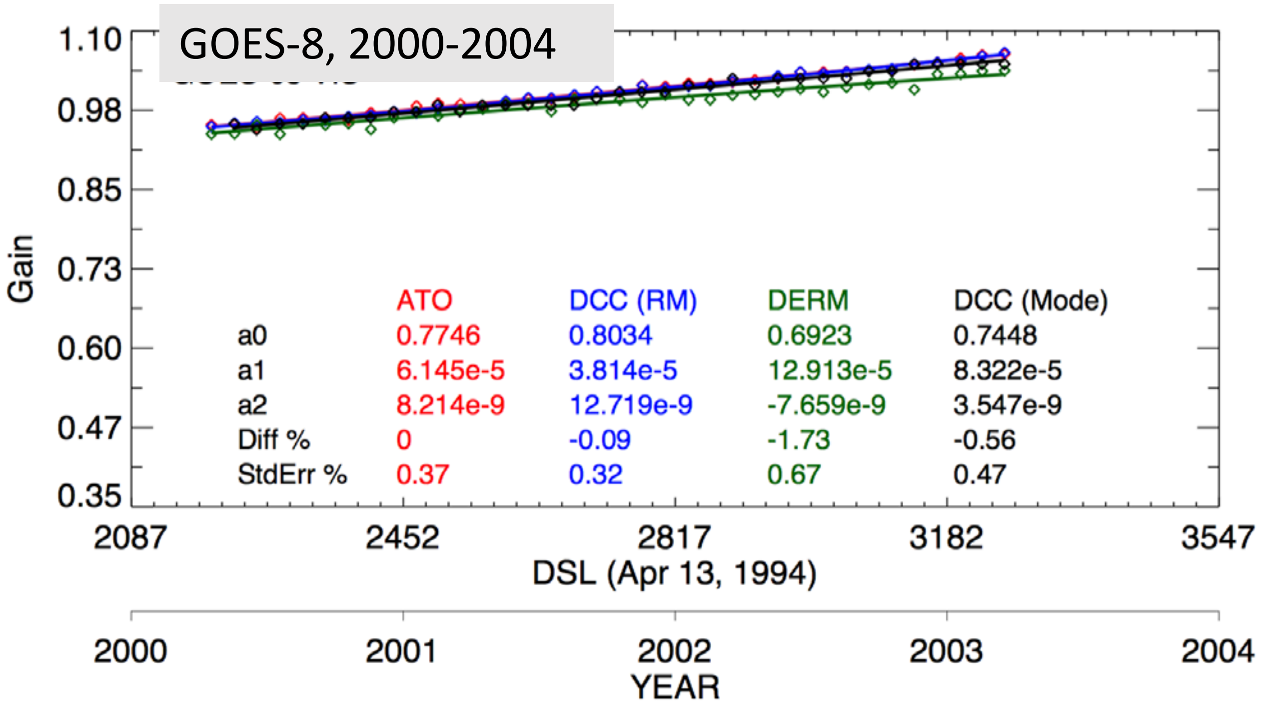


- Desert is spectrally red, whereas DCC are spectrally flat
- DCC reflectance would decrease more with spectral response degradation than deserts
- DCC would have a greater gain than deserts

Decoster et al. 2013, also documented spectral degradation
Yves Govaerts working on SRF degradation over time

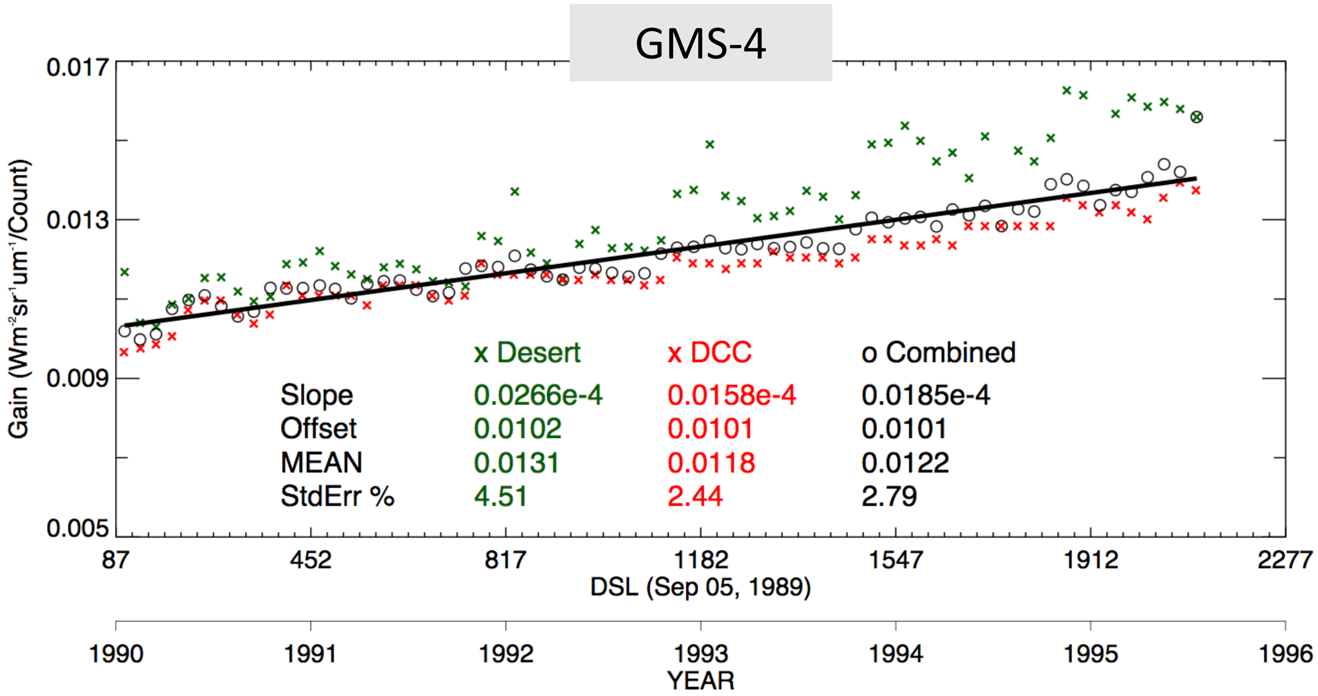
Short Wavelength Spectral Response Degradation





- GOES-8 DCC has a greater gain than deserts, consistent with Met-7

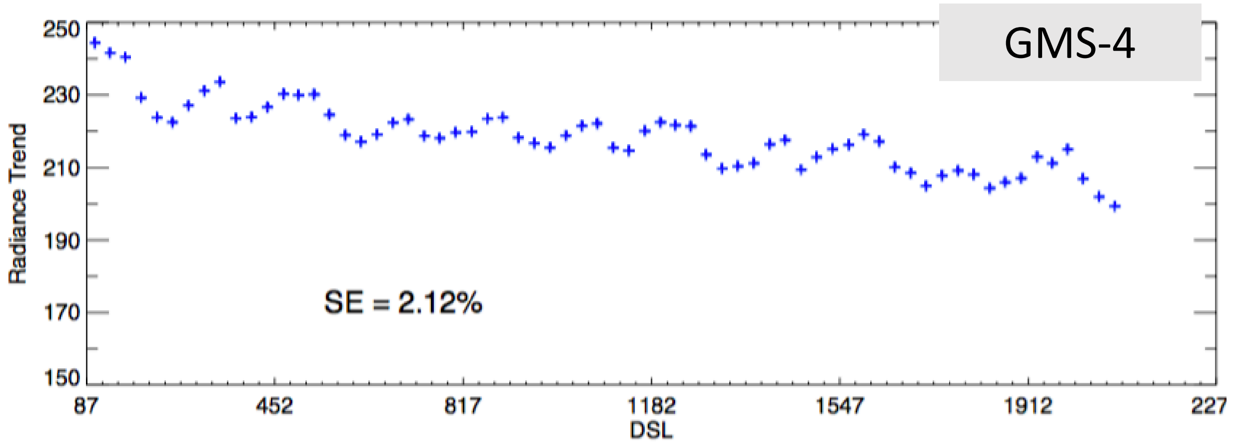
GMS-4 method inconsistency

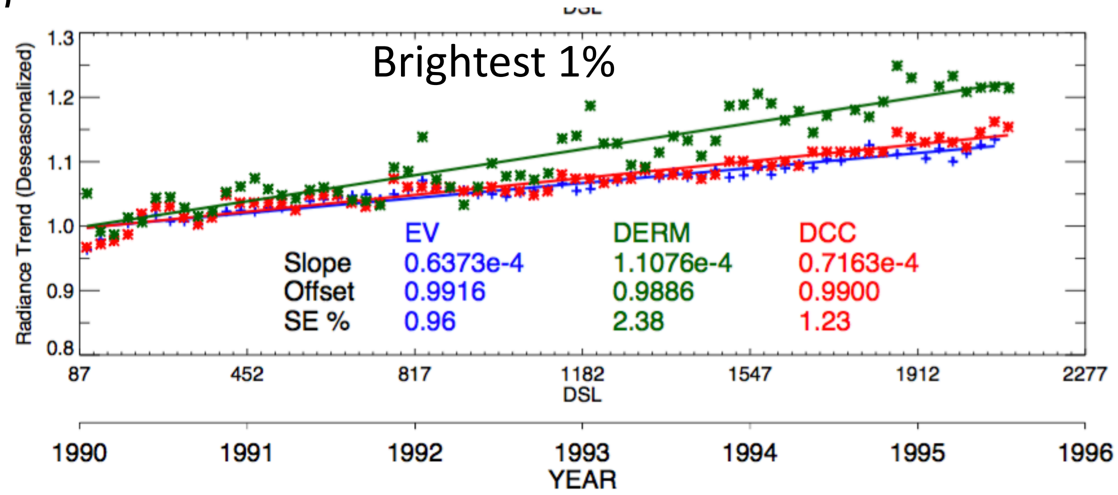


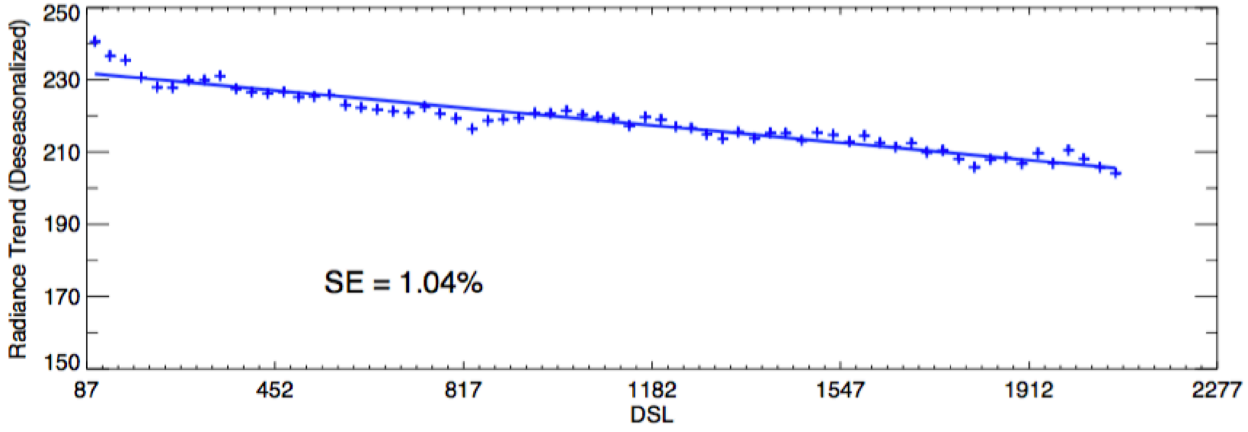
- Unlike Met-7 and GOES-8, GMS-4 has DCC gains degrading less than deserts
- Maybe not spectral, check methods

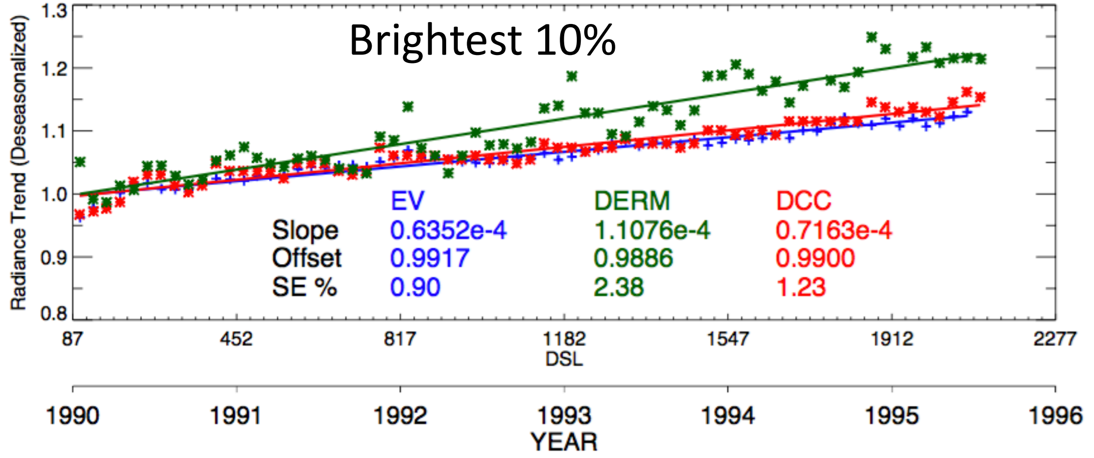
Compare brightest 1% pixel with DCC calibration

Brightest 1 %pixels of the GMS-4 full disc at 3 GMT (local noon)



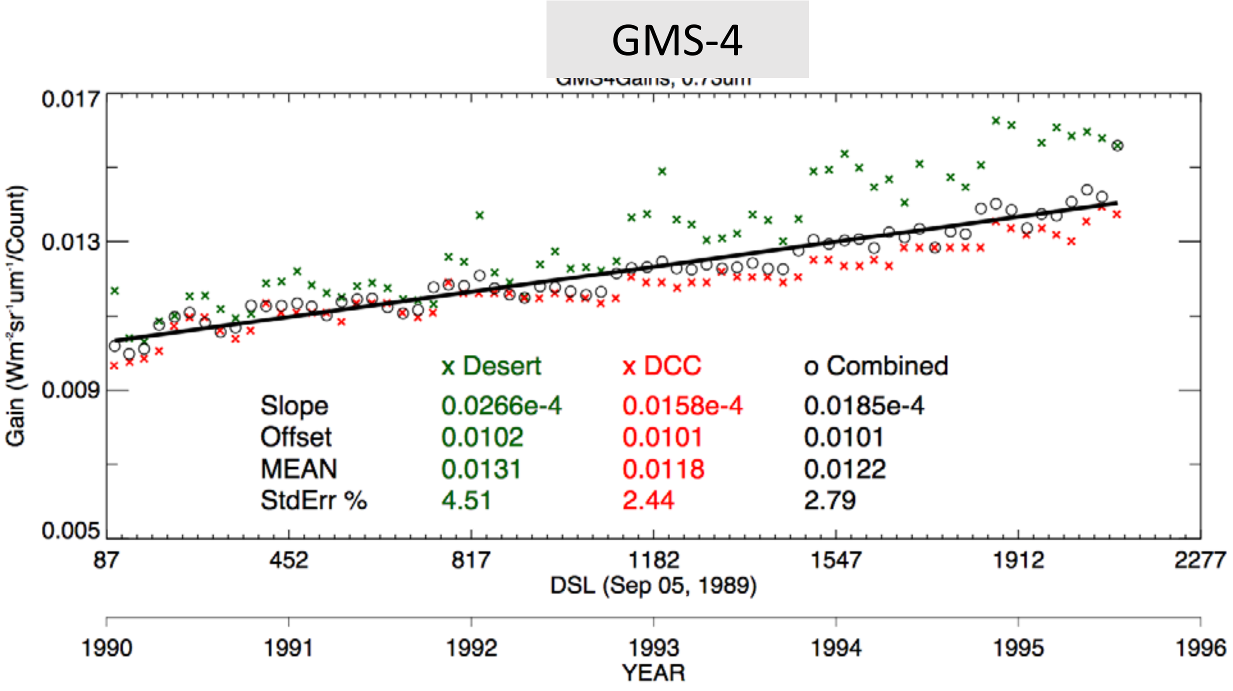


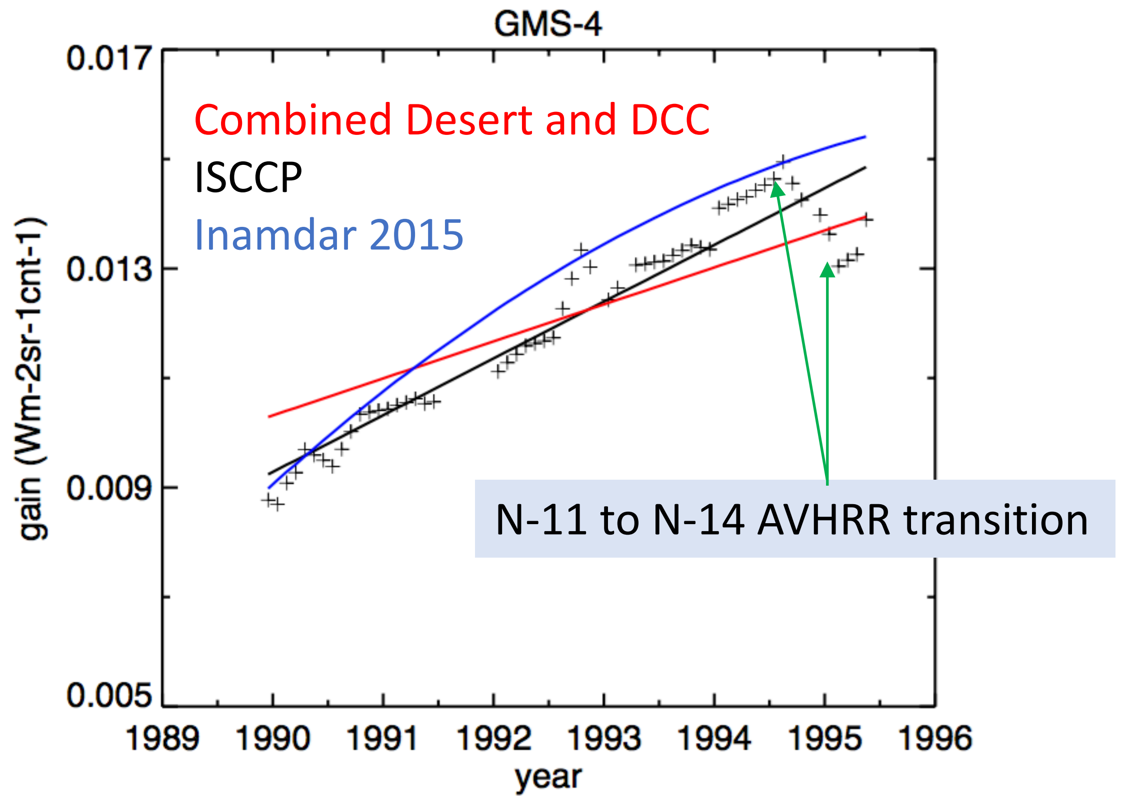




Brightest 1% and 10% gains are consistent with DCC gains, DCC calibration is working

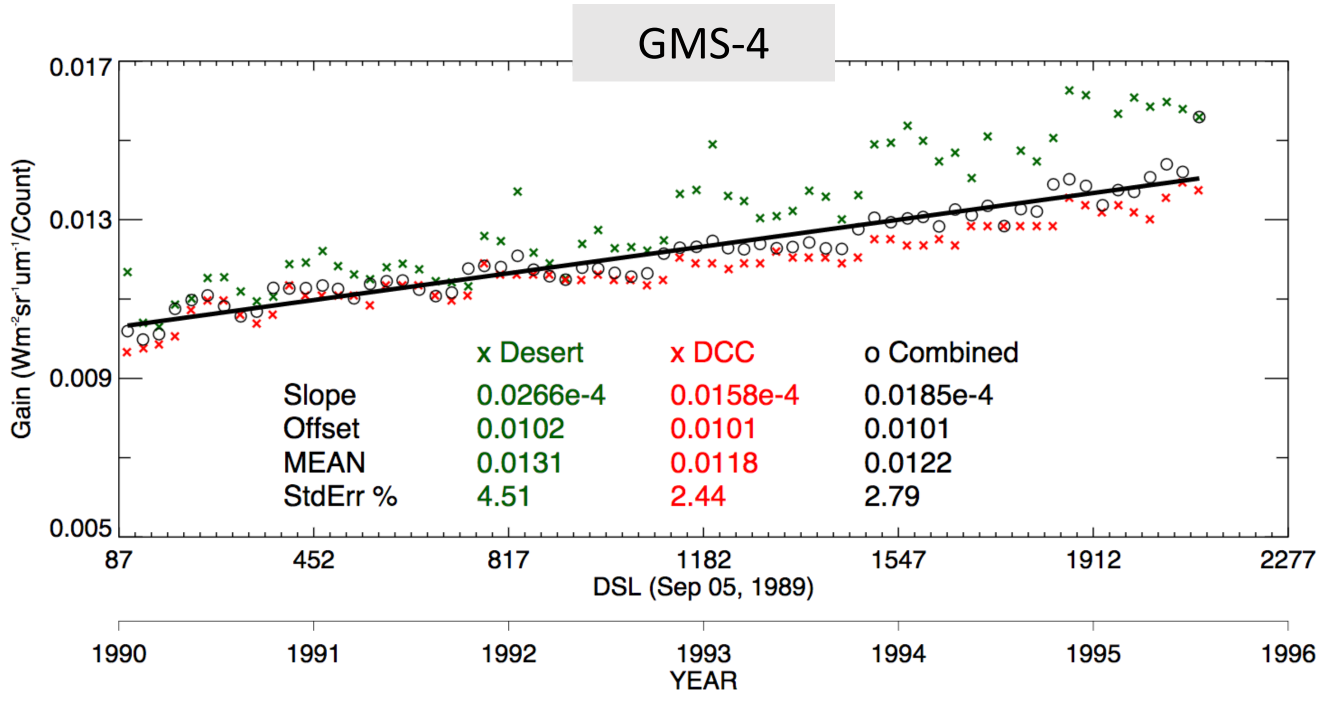
ISCCP calibration comparison

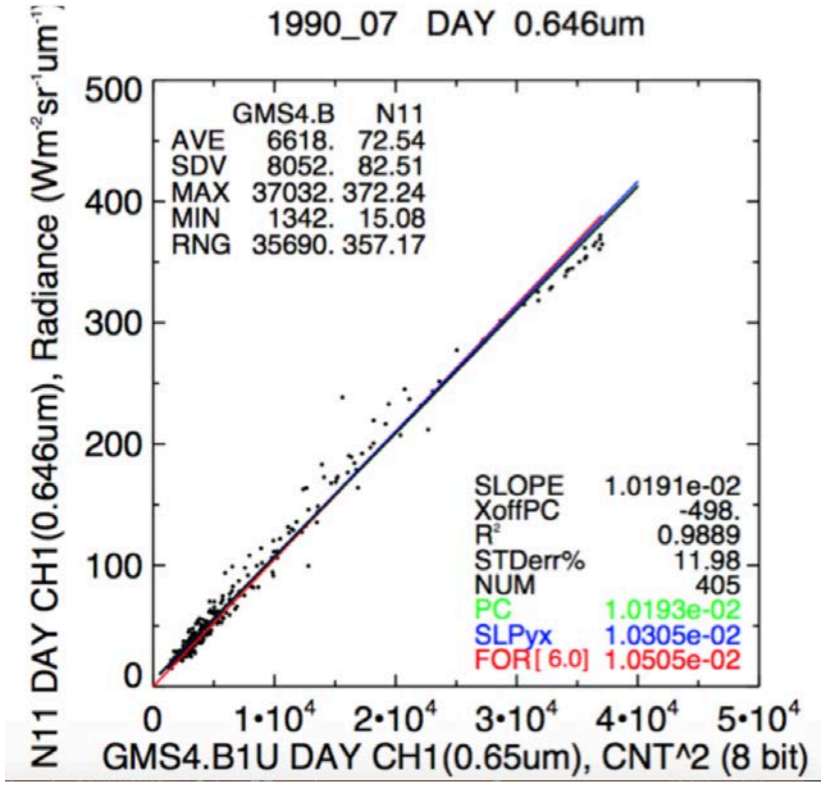




ISCCP is using clear-sky land targets and is similar to CERES desert gains
Inamdar is using GMS-4 AVHRR inter-calibration

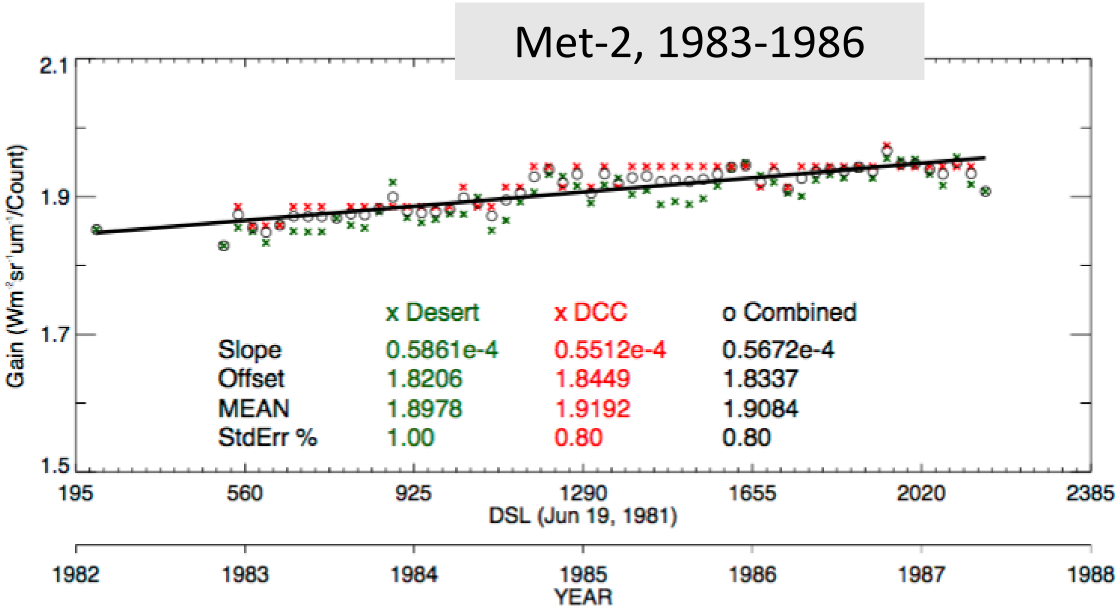
Non-linear sensor response

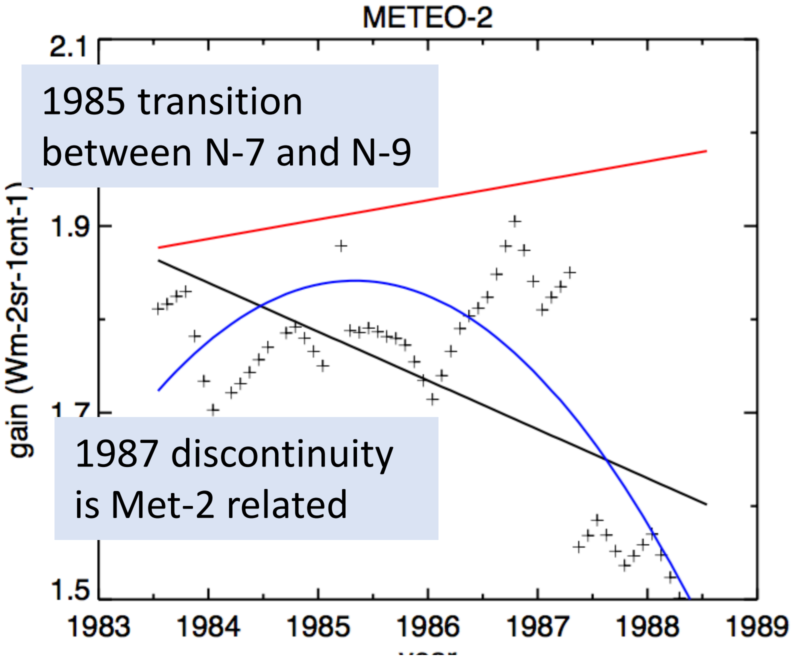


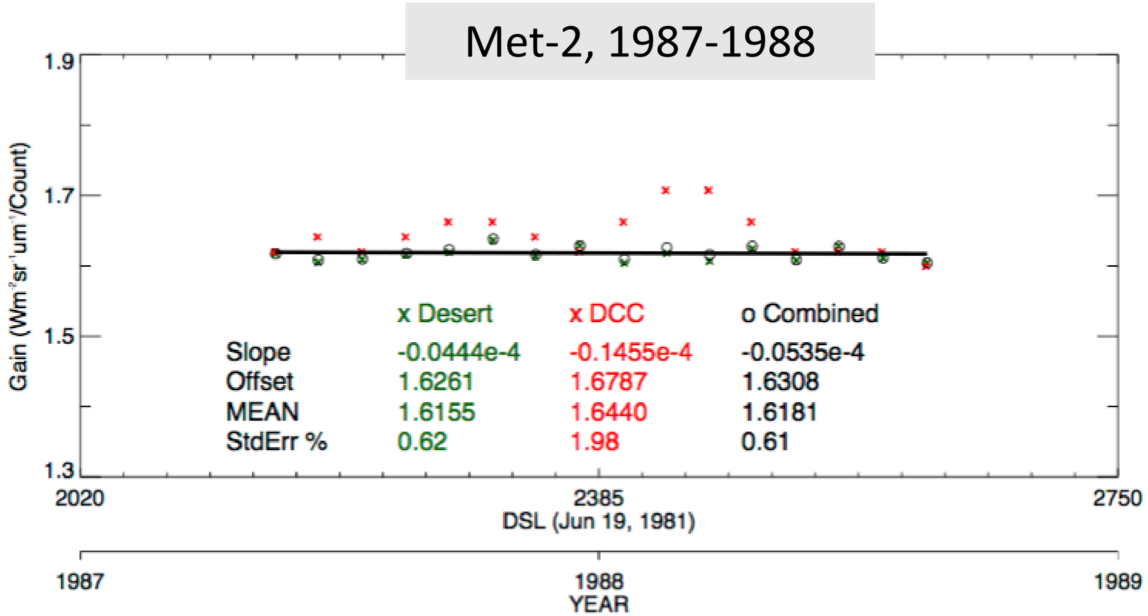


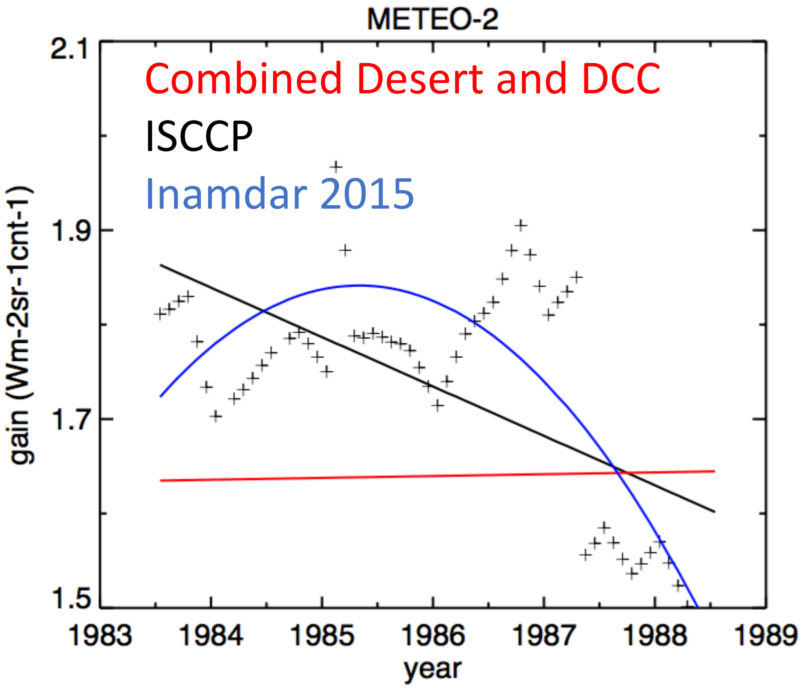
- Perform NOAA-11 and GMS-4 ray-matched radiance pair inter-calibration
- Seems that the inter-calibration reveals a non-linear response

There was a calibration gain shift in early 1987 for Met-2



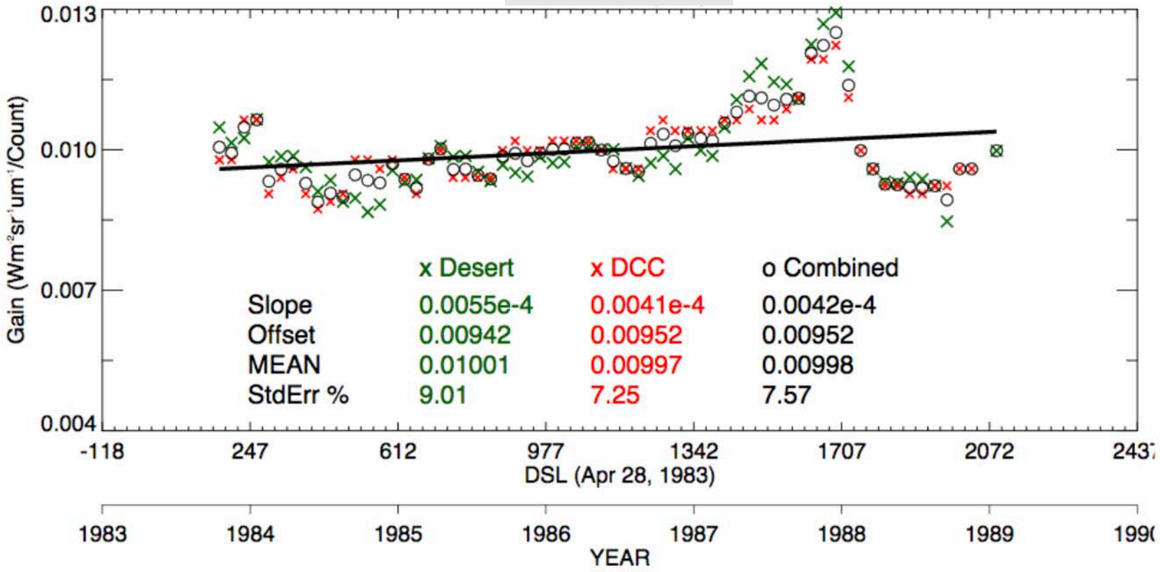




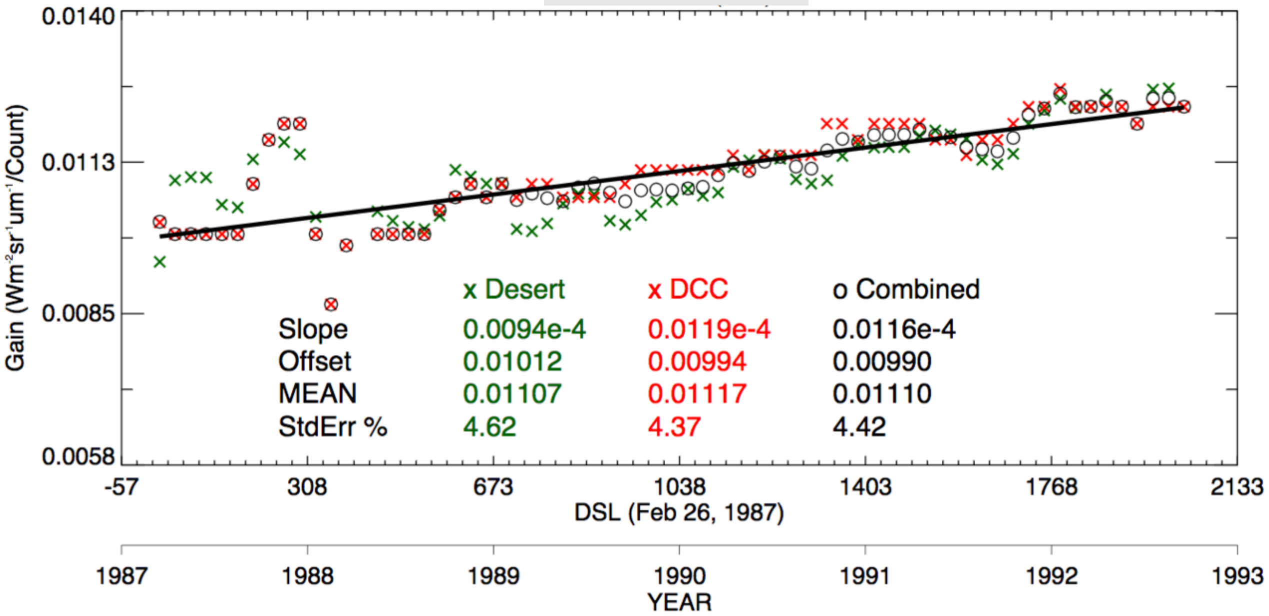


Unresolved calibration drifts

GOES-6



GOES-7



Conclusions

- Calibration methods provide both stability monitoring and to transfer the reference calibration
- Need at least two calibration method
- Inconsistent results indicate
  - Space offset issues
  - Calibration shifts, due to ground segment, etc
  - Spectral response function degradation in space
  - Spectral response function improper characterization
  - Non-linear sensor response
  - Some are still unresolved
- Did not examine response versus scan angle, polarization, and stray-light, etc.