Using Hyper-Spectral SCIAMACHY Radiances to Uniformly Calibrate Contemporary Geostationary Visible Sensors

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Inter-calibration and Validation of Operational Sensors -- Oral Session

Outline

- Motivation/Objective
- Background
  - SCIAMACHY/MODIS/MET-9
  - Inter-calibration techniques
- Spectral Band Adjustment Factors (SBAF)
- Direct calibration transfer using SCIAMACHY
- Before/After SBAF results
- Conclusions

Introduction

- Motivation
  - Geostationary satellites (GEOsat) sensors do not have on-board radiometric calibration sources for visible channels
  - Need exists to develop absolute inter-calibration techniques capable of use with GEOsat sensors
  - Cross-calibration is plagued by the differences in the sensor spectral response functions (SRFs)

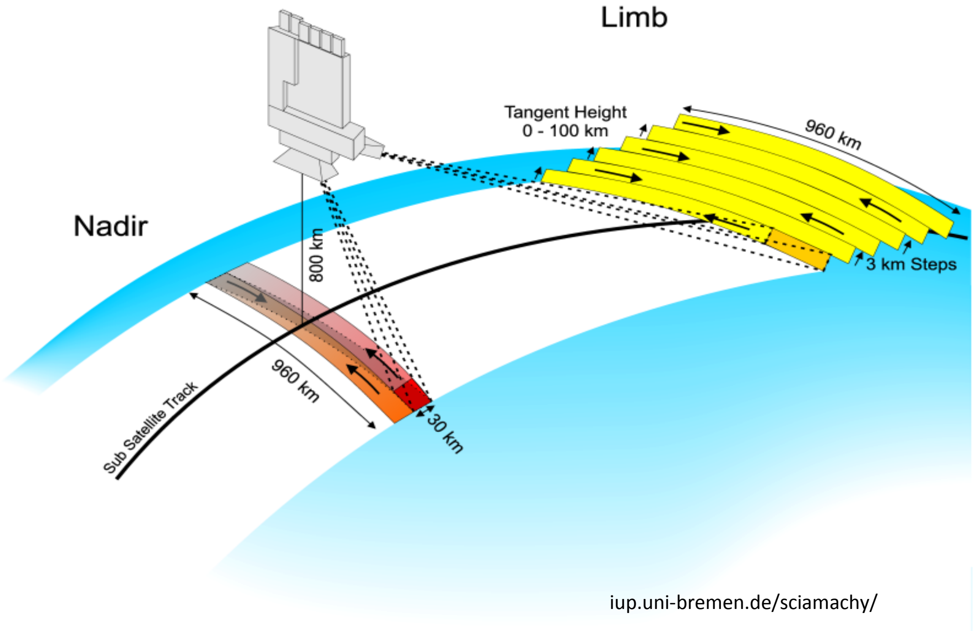
- Objective
  - Develop inter-calibration-target-dependent Spectral Band Adjustment Factors (SBAFs) using SCIAMACHY hyper-spectral visible radiances
  - Validate for accuracy using SCIAMACHY and GEOsat direct comparisons

Background

- Global Space-Based Inter-Calibration System (GSICS)
  - Goal is to monitor/improve data quality from operational environmental satellites
  - Use IASI Hyper-spectral instruments to account for IR SRF differences
  - Aqua-MODIS is reference for GEO visible channels

- Key instruments used in this research
  - MODerate resolution Imaging Spectroradiometer (MODIS)
    - Collection 6, L1B, 1-km (subset to 2-km)
  - Meteosat-9 (Met-9)
    - 3-km
  - SCanning Imaging Absorption spectroMeter for Atmospheric CartograpHY (SCIAMACHY or SCIA)
    - Level-1b, Version-7.03

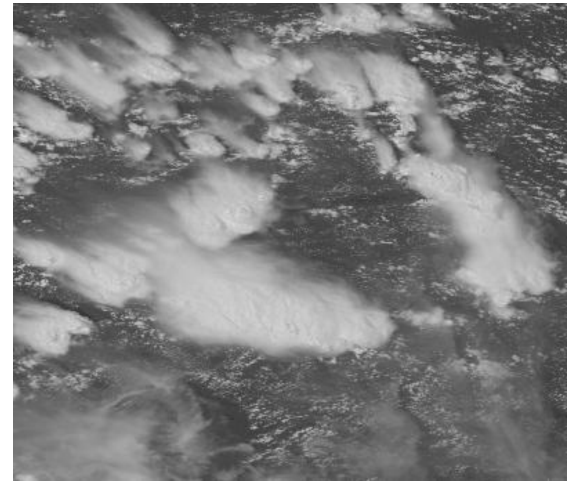
Background- SCIAMACHY Specifications



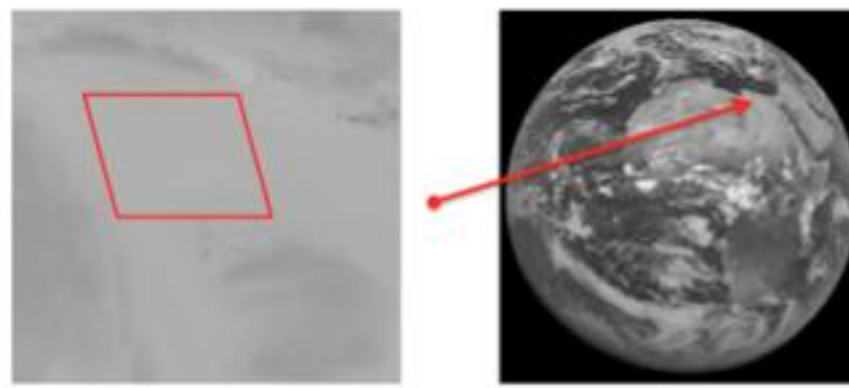
- Onboard ESA Environmental Satellite (Envisat)
- Launched on 1 March 2002
- 10:00 AM LST sun-synchronous orbit
- 35-day repeat cycle
- Shared scan duty between nadir and limb measurements
- Four 30-km along-track by 240-km across-track nadir-like footprints
    - Two nadir-like footprints on either side of ground track within a 30° view angle
    - Total nadir scan width of 960 km

Background- InterCalibration Methods

- MODIS-with-Met-9 ray-matching
  - Transfer calibration using co-incident, co-angled, and co-located ocean regions
- Deep Convective Clouds (DCC)
  - Treated as invariant targets
  - DCC model referenced to Aqua-MODIS
- Libyan Desert
  - Invariant target
  - Employs a kernel-based bidirectional reflectance distribution function (BRDF) model referenced to Aqua-MODIS
- **SBAF necessary to account for spectral differences in all three methods**



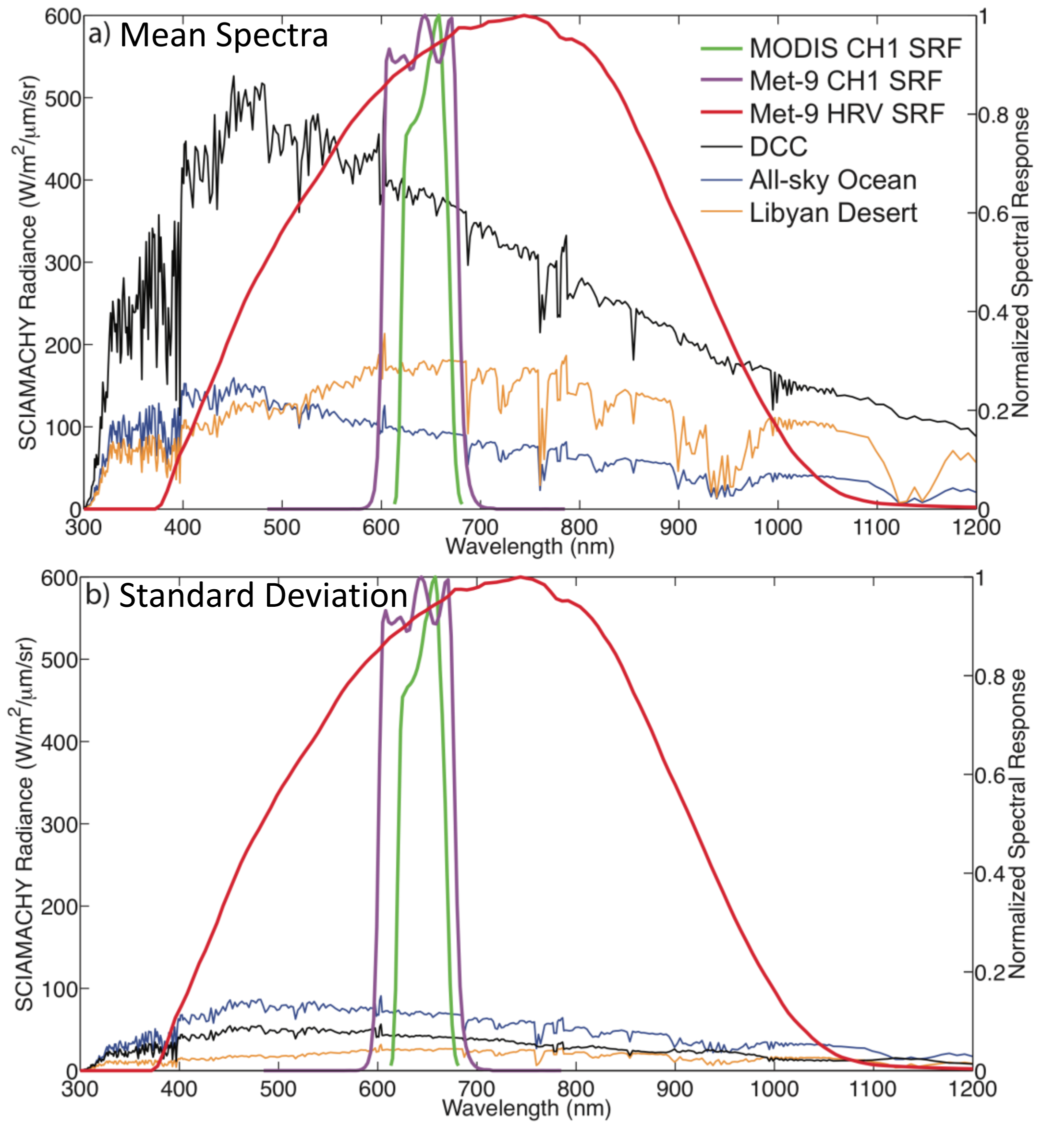
DCC



Libyan Desert

SCIA Scene Spectra/Sensor SRF

- Visible-channel spectral corrections are dependent on target and reference SRFs
  - MODIS: 0.65-µm (CH1)
  - Met-9: CH1 and High Resolution Visible (HRV)
- Scene-specific corrections for independent inter-calibration techniques (ie. Separate correction for DCC, Desert, and Ray-matching)

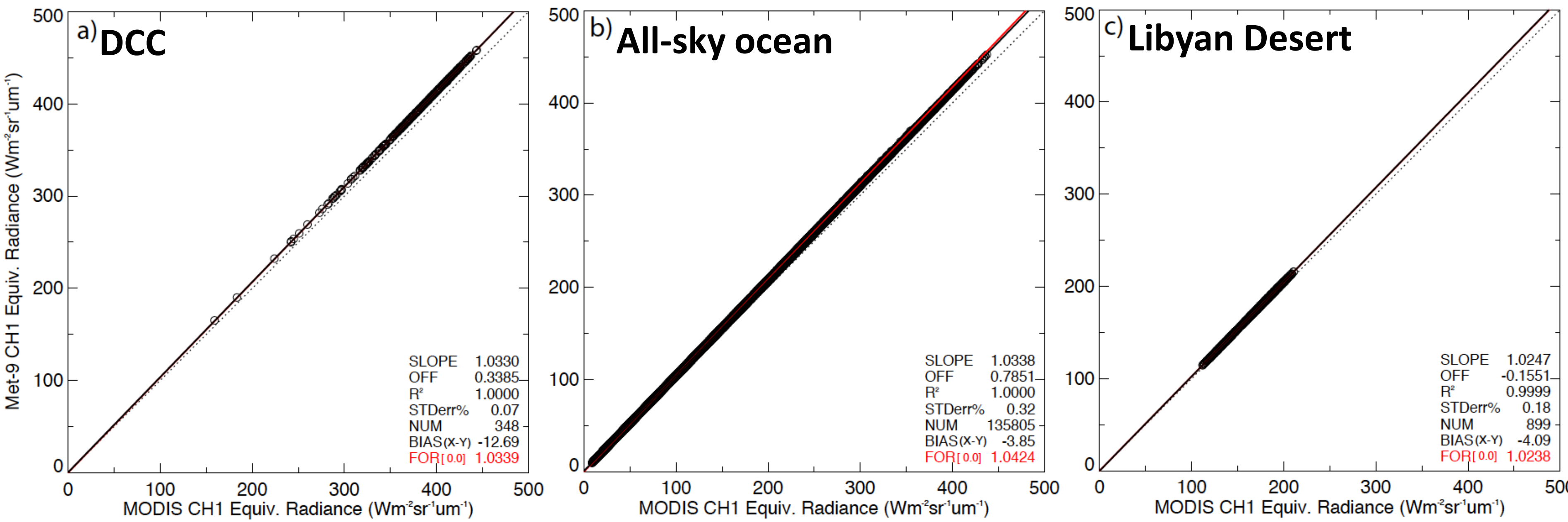


Spectral Band Adjustment Factors

- Spectra from each SCIAMACHY scene-appropriate footprint are convolved with imager SRFs to compute imager equivalent radiances
- Regression of the two convolved SCIAMACHY radiances constitutes a Spectral Band Adjustment Factor (SBAF)
  - Applied to the reference sensor (MODIS) radiance (L_{ref}) to arrive at the predicted target sensor (Met-9) radiance (L_{tar})

$$L_{ref} \times SBAF_{tar/ref} = L_{tar}$$

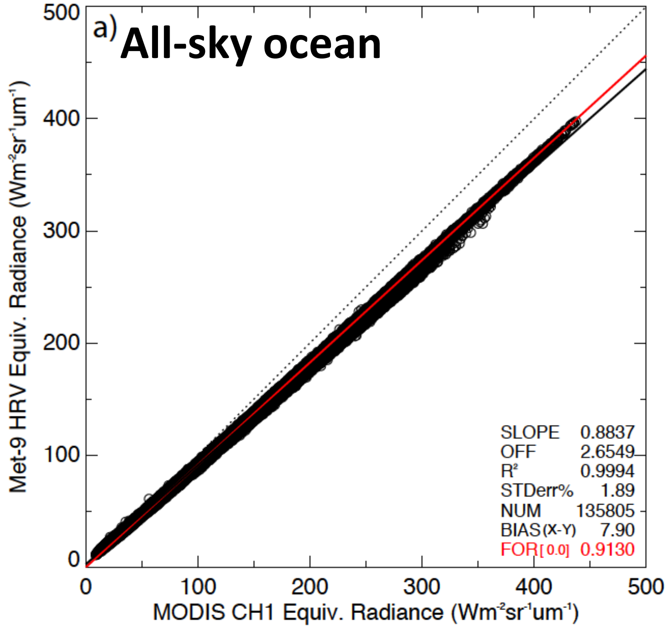
Narrowband-to-Narrowband SBAFs



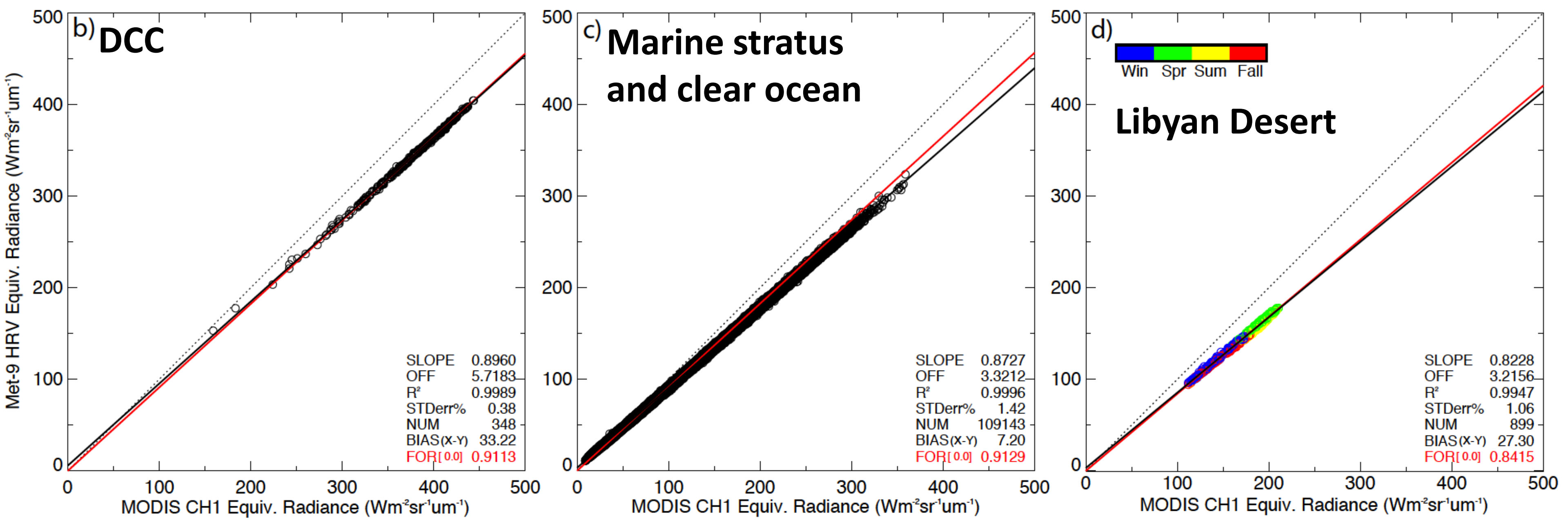
Regressions well-behaved for narrowband-to-narrowband case

Corrections are small but not insignificant

Narrowband-to-Broadband SBAFs



Specific scene selection critical for obtaining representative Spectral Band Adjustment Factors when calibrating narrowband to broadband

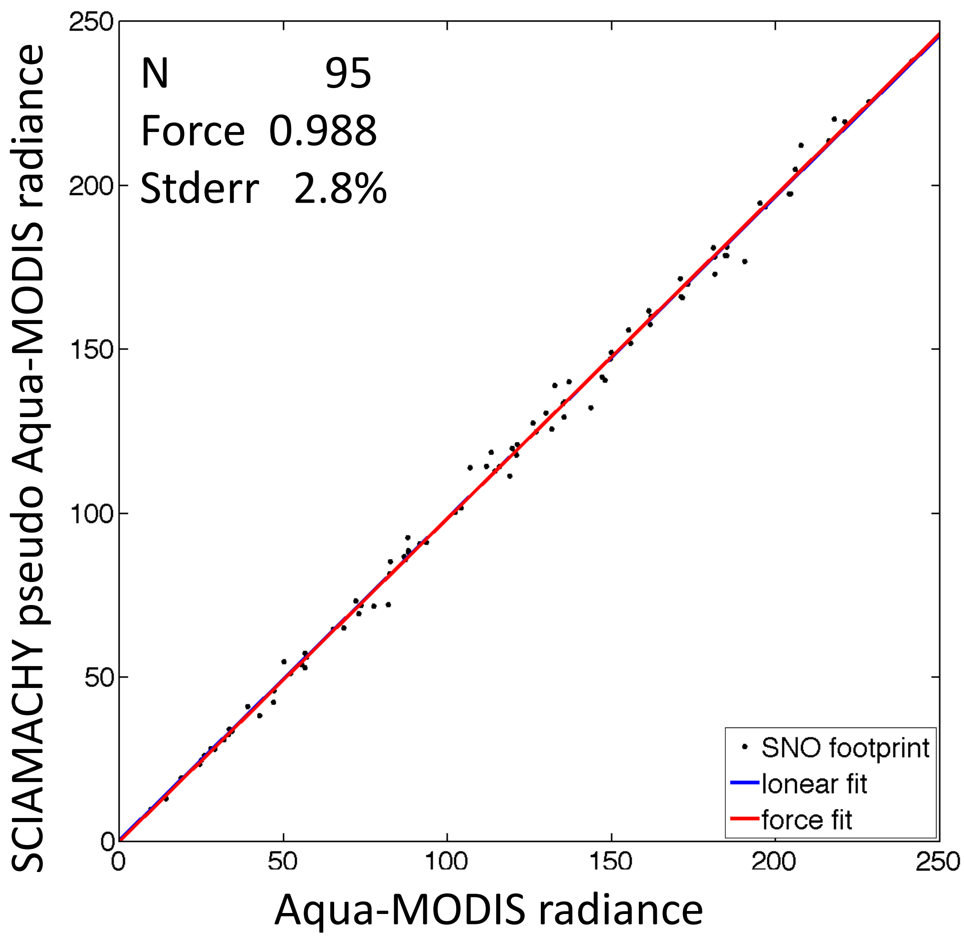


Direct SCIAMACHY Calibration Transfer

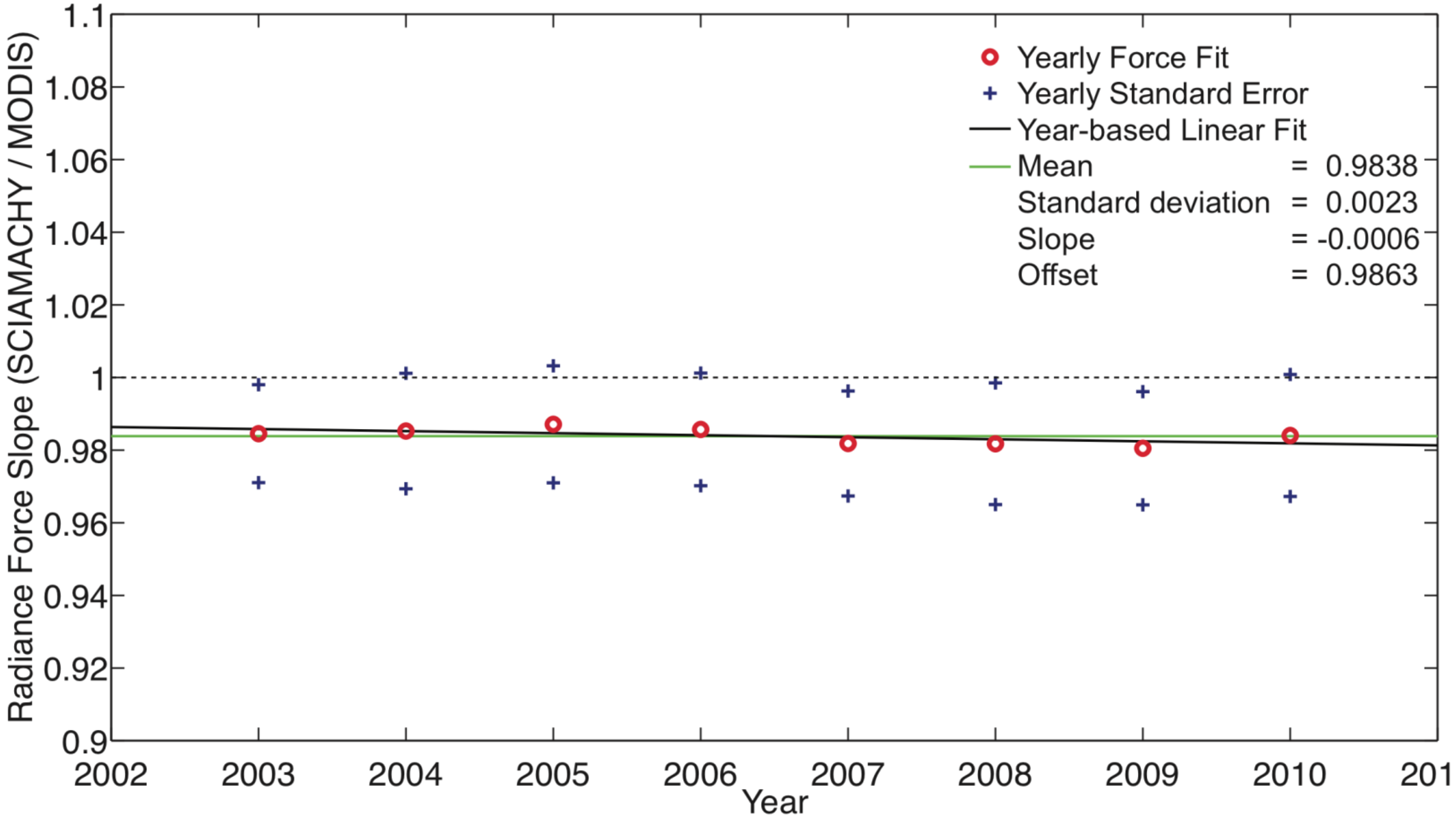
- Inter-calibrate SCIAMACHY and Aqua-MODIS 0.65µm channel using Near-SNOs
  - Determine SCIAMACHY stability compared against Aqua-MODIS
  - Determine relative calibration difference
- Inter-calibrate GEO with SCIAMACHY using ray-matching
- Can be used to validate the SBAF corrections for the other inter-calibration methods

SCIAMACHY Aqua-MODIS 0.65µm, Jul 2010

- coincident within 15 minutes
- ~1300 1-km sub-sampled MODIS pixels are averaged into a 30x240km SCIAMACHY footprint
- limited to <70° SZA



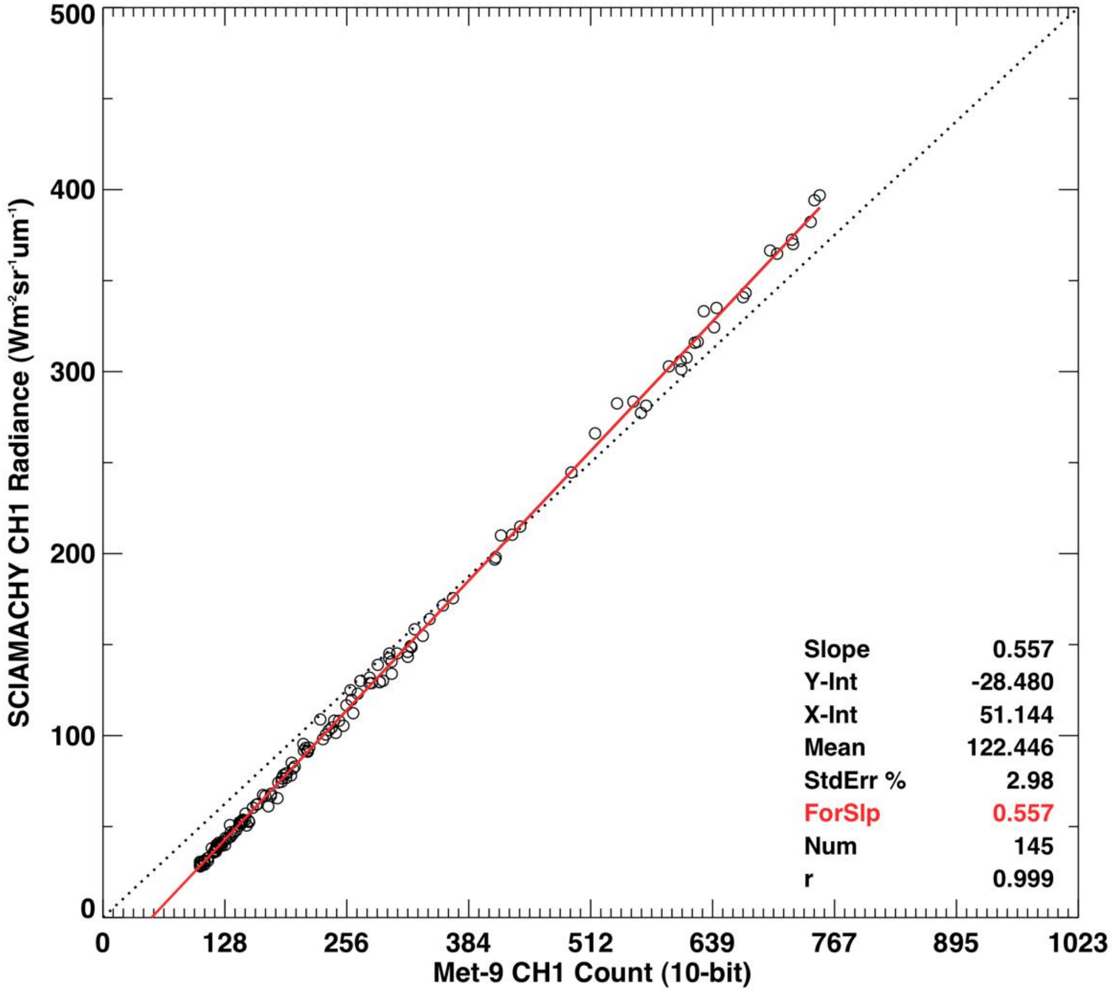
Nearly Simultaneous Nadir Overpass Comparisons with Aqua-MODIS



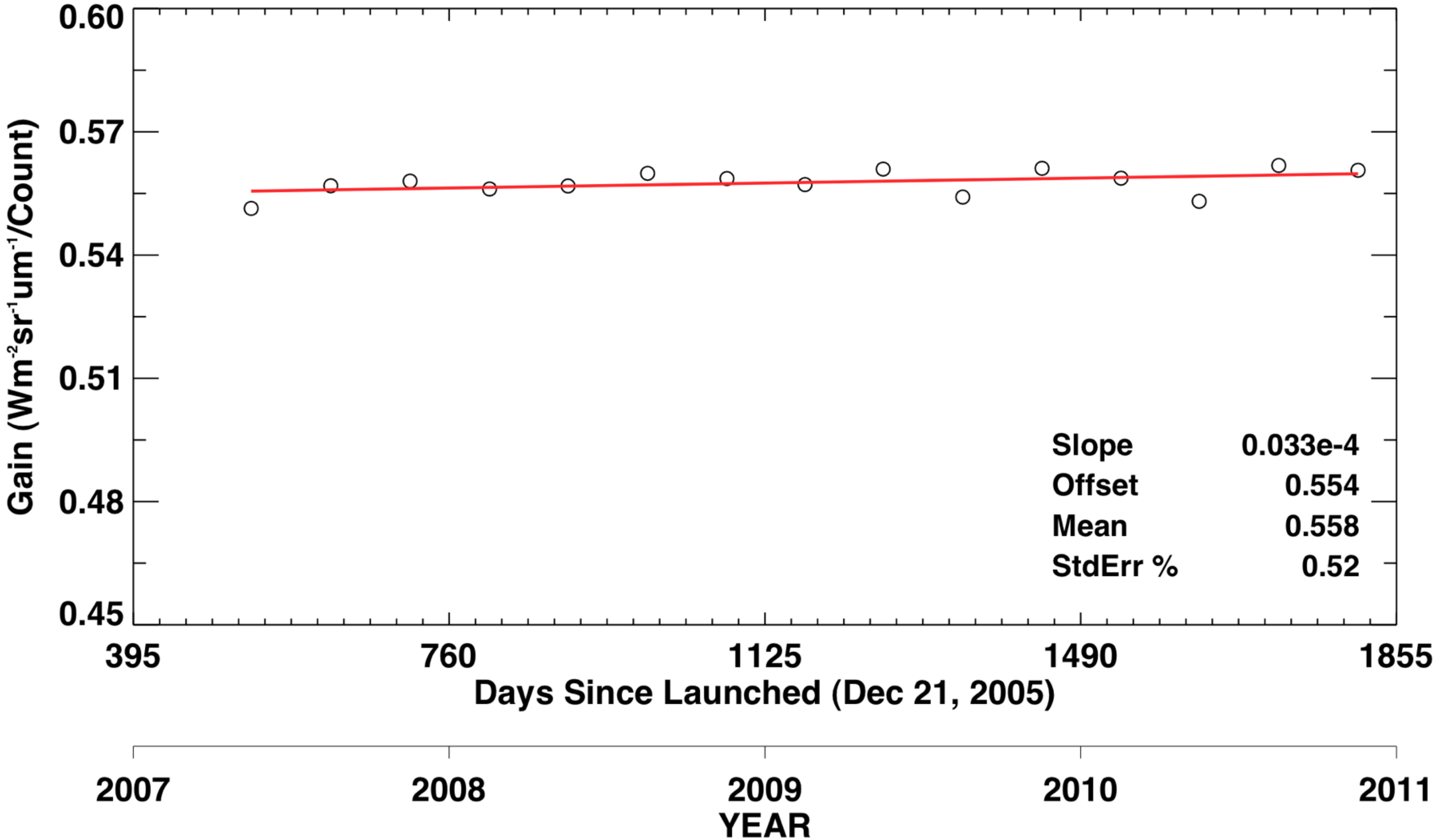
SCIAMACHY Radiance is stable to within -0.6% per decade compared to Aqua-MODIS

SCIAMACHY-with-Met-9 Ray-Matching

- Average Met-9 10-bit count computed within SCIA footprint bounds
  - 4-km pixels
  - Count ∝ radiance
  - Match within 15 min
- Three-monthly gains found by regressing SCIA convolved radiances with Met-9 average counts
  - Regression forced through the Met-9 space count
  - SCIA radiances scaled to Aqua-MODIS using NSNO comparisons
- Figure: Jan – Mar 2008 SCIA-with-Met-9 CH1 gain = 0.557

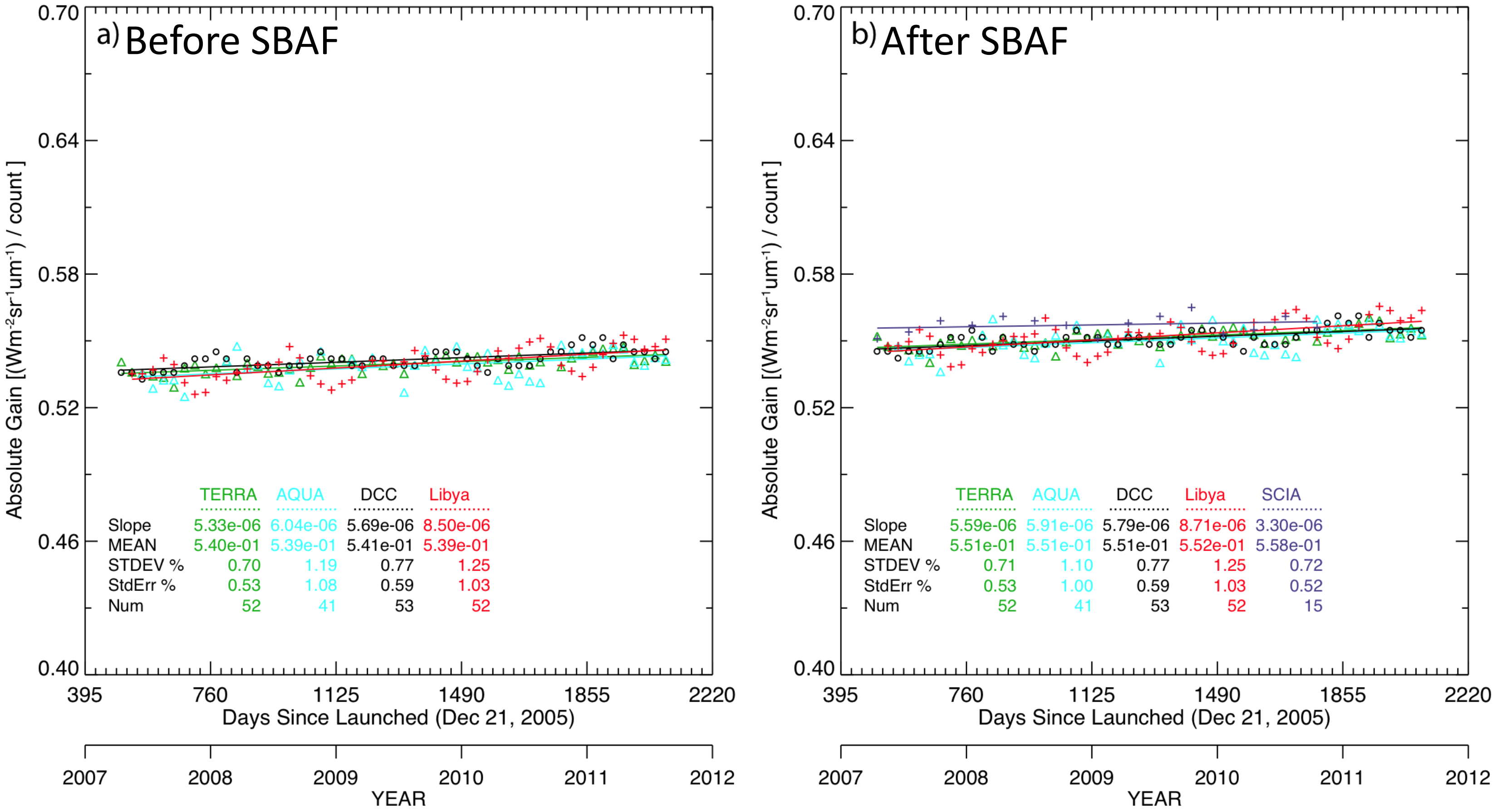


SCIAMACHY-with-Met-9 Ray-Matching



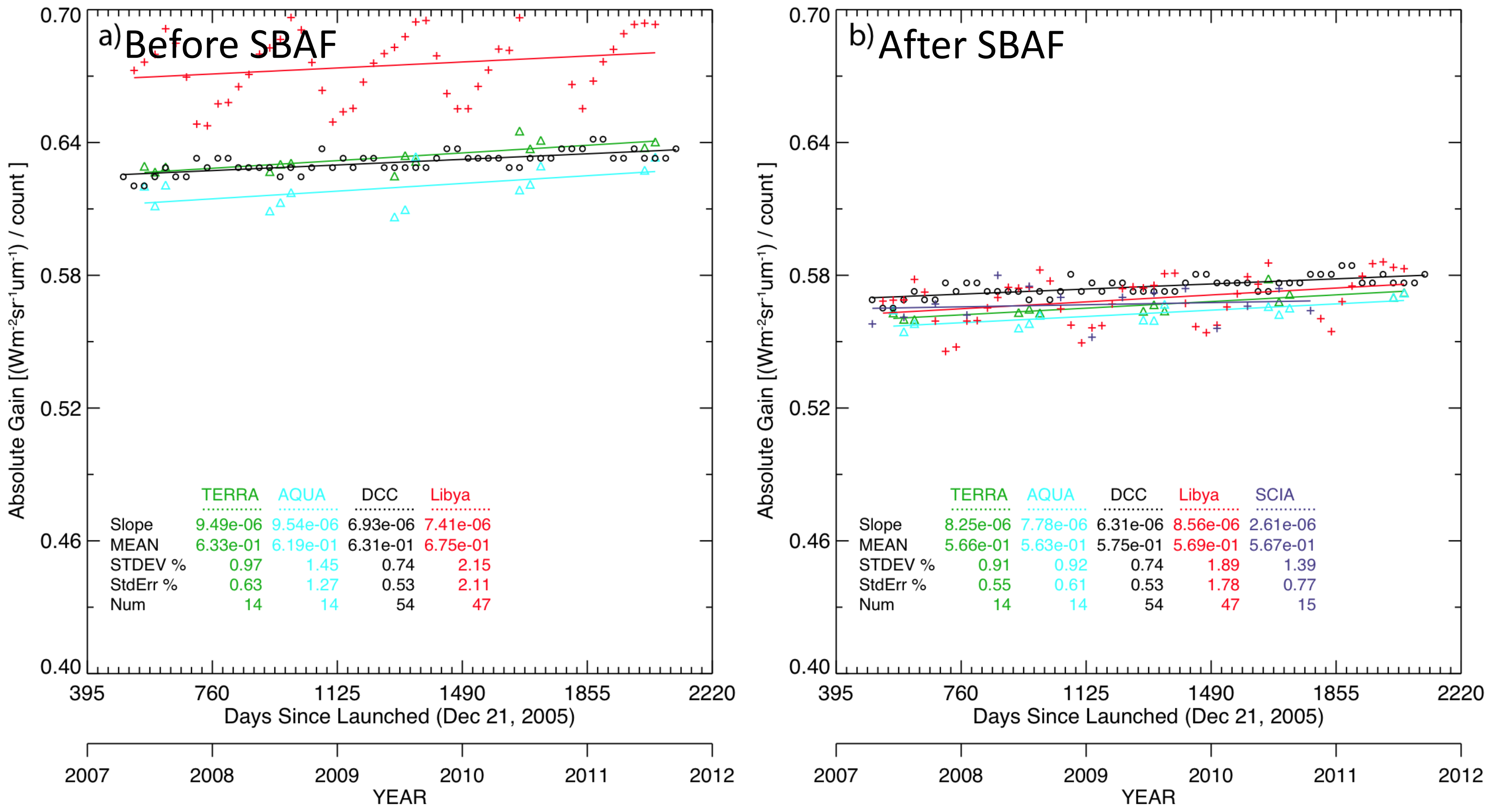
Standard error of 0.52% means absolute calibration coefficients are well-represented by the linear trend

Before and After: Narrow-to-Narrow



- Before the SBAF is applied, the maximum mean difference in gain between the three methods for Met-9 CH1 **0.4%**
- After the SBAF is applied, the difference reduces to within **0.2%**
- The mean difference in CH1 gains from before to after application of the SBAF is +2.0%
- SCIAMACHY-to-Met-9 CH1 gain is within **1.3%** of other methods after SBAF is applied

Before and After: Narrow-to-Broad

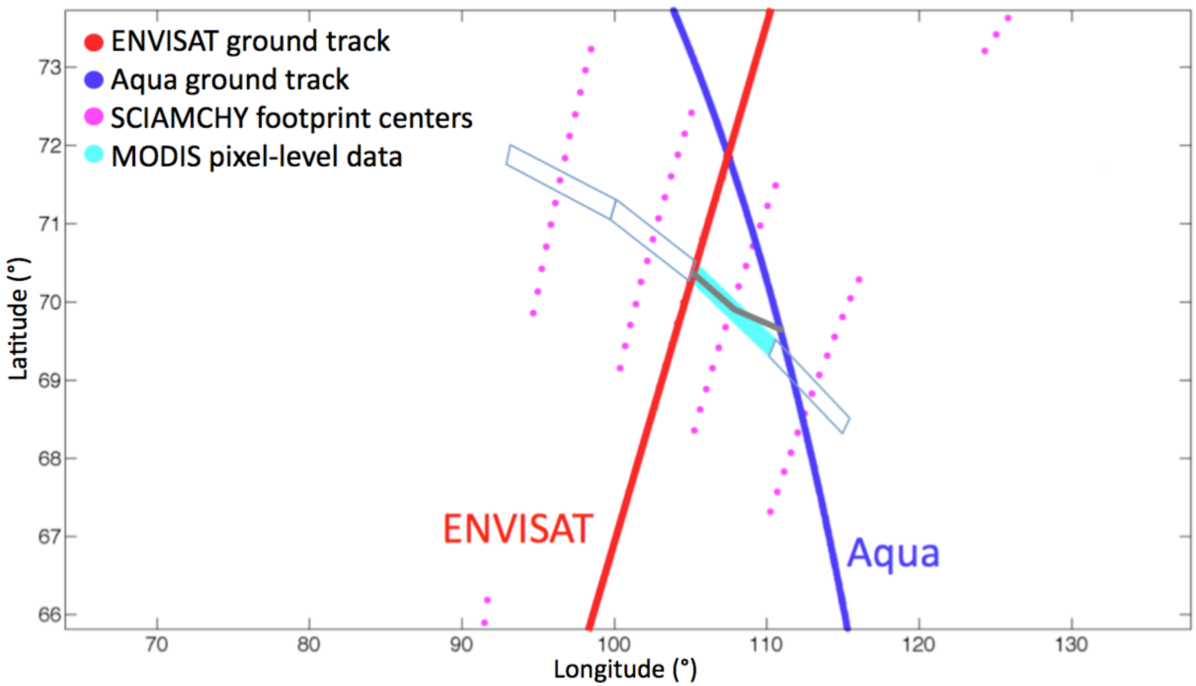


- Before the SBAF is applied, the maximum mean difference in gain between the three methods for Met-9 HRV **8.3%**
- After the SBAF is applied, the difference reduces to within **1.0%**; reduced spread
- The mean difference in HRV gains from before to after application of the SBAF is -11.3%
- SCIAMACHY-to-Met-9 HRV gain is within **0.2%** of other methods after SBAF is applied

Conclusions

- SCIAMACHY convolved radiances can account for sensor SRF differences
- SCIAMACHY-with-Met-9 gain within 0.2% – 1.3% of other methods after the SBAF is applied
- A unique SBAF is required for each scene type
  - After SBAF application, three inter-calibration methods within 0.2%-1.0%
  - Better than 7% improvement in narrowband-to-broadband calibration agreement, suggests SBAF is important in deriving a gain

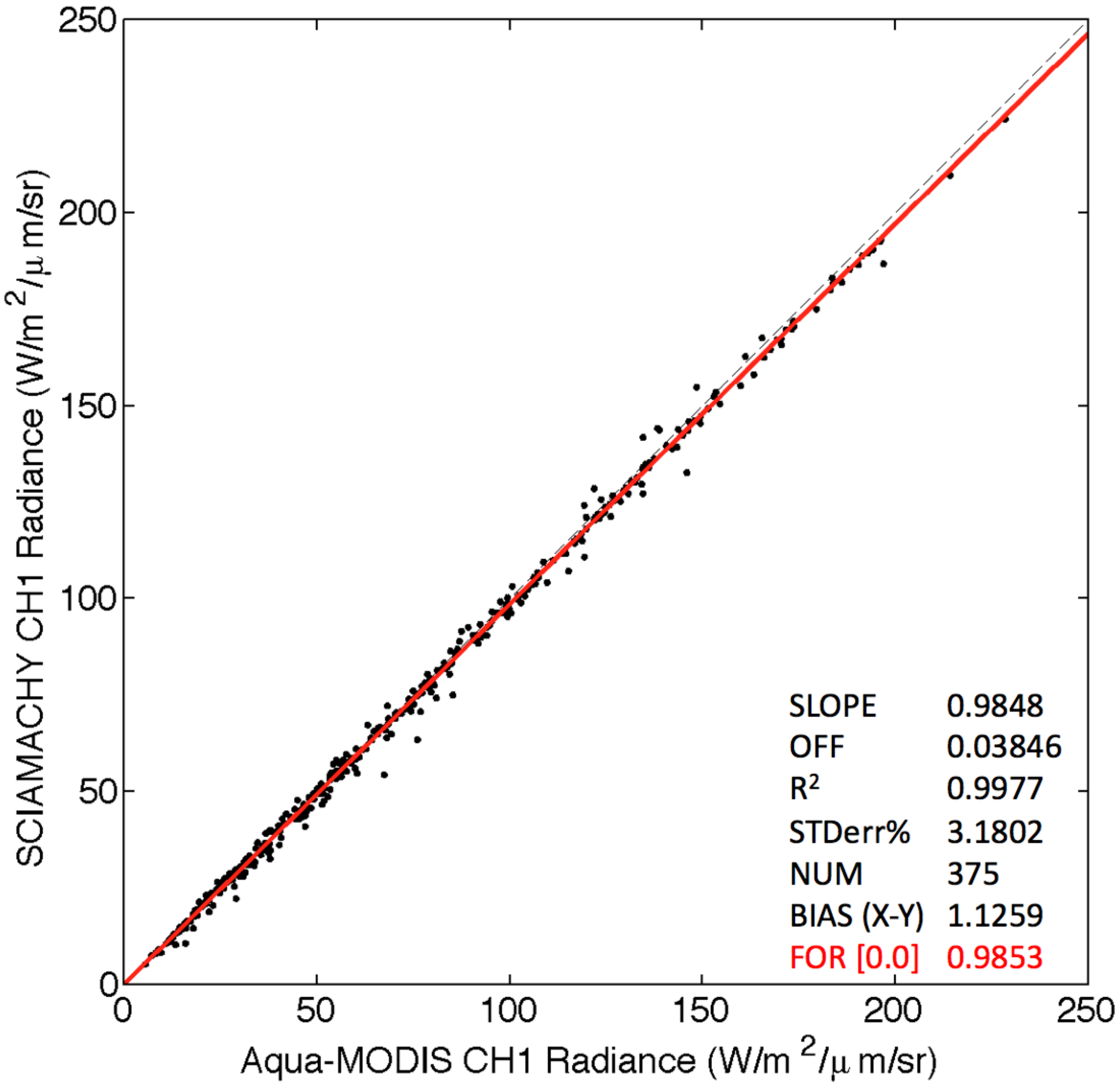
Nearly Simultaneous Nadir Overpass Comparisons with Aqua-MODIS



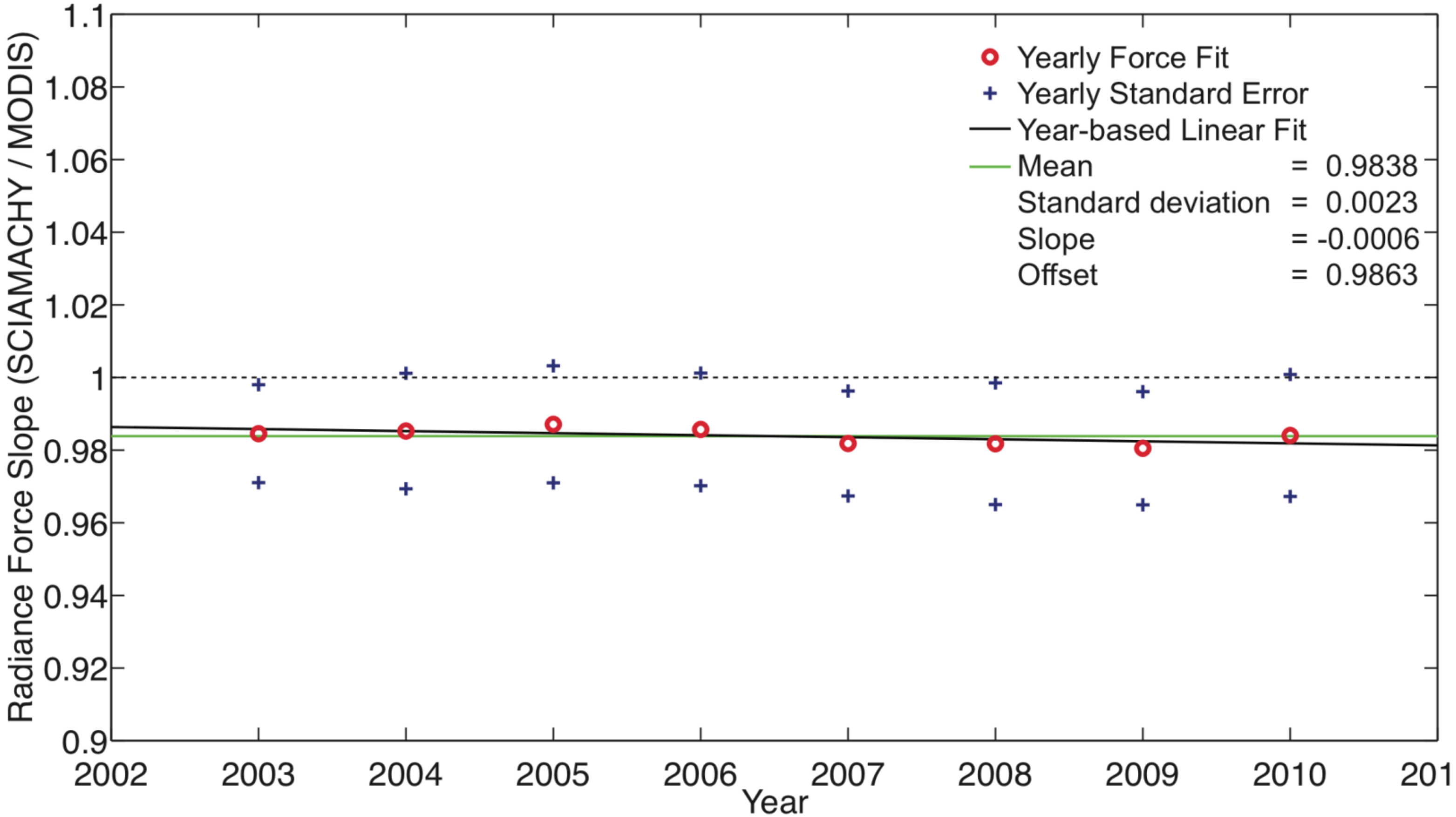
- Establish the stability of SCIAMACHY by radiometrically scaling to Aqua-MODIS
- Accomplished using nearly simultaneous nadir overpass (NSNO) comparisons near the north pole during Apr-Sep
- Aqua-MODIS is chosen following recommendations from GSICS
- About 14 NSNOs per day (dependent on scan duty cycle) at 11:45 am LST
  - Minimal view angle difference
  - Near-symmetric solar conditions (corrections for SZA differences applied)

Nearly Simultaneous Nadir Overpass Comparisons with Aqua-MODIS

- MODIS CH1 2-km pixel radiances averaged within bounds of SCIA footprint
- Regressed with SCIA radiances that were convolved with the MODIS CH1 SRF



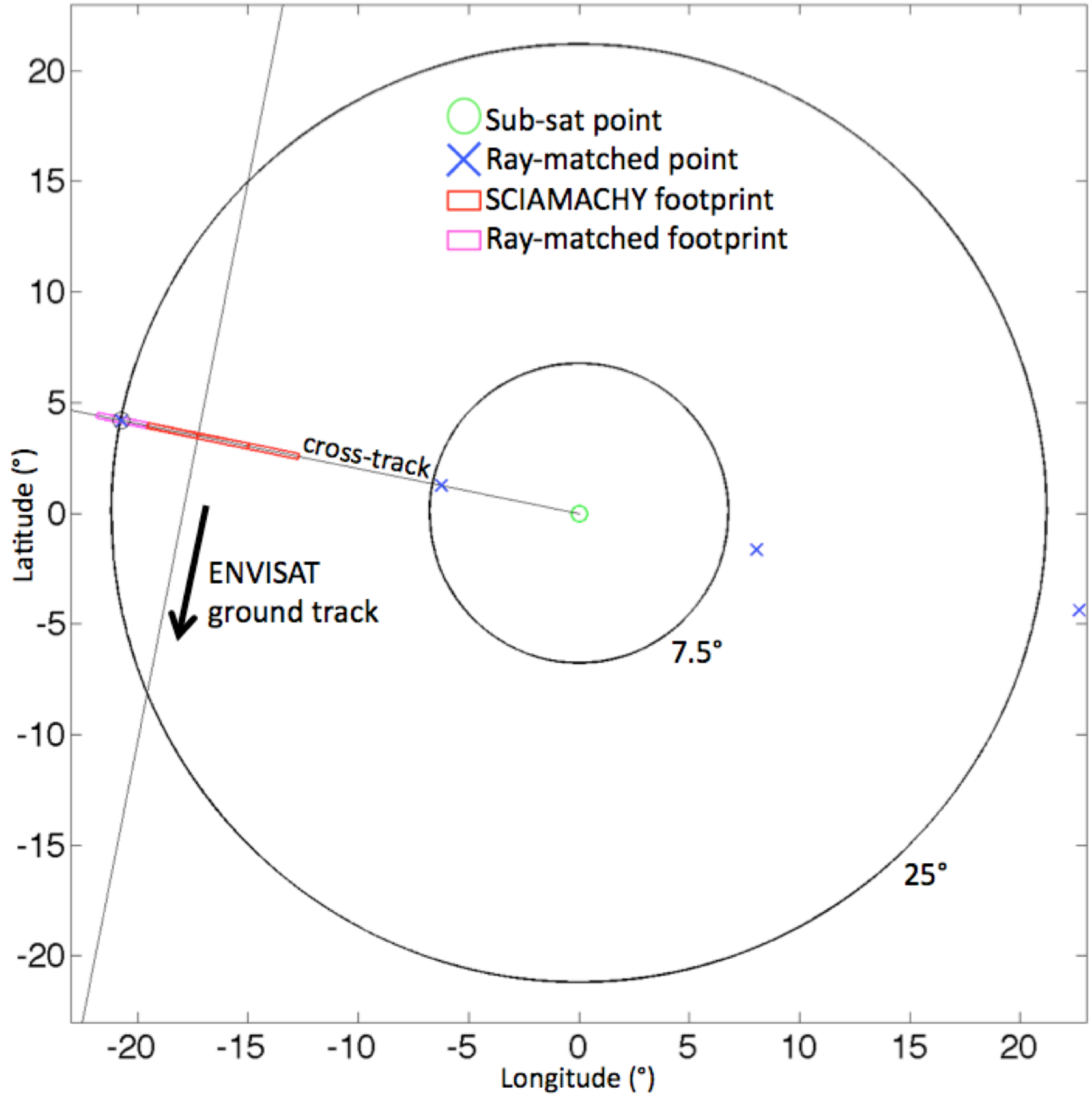
Nearly Simultaneous Nadir Overpass Comparisons with Aqua-MODIS



- Stability of SCIAMACHY assessed with timeline of yearly regressions
- Mean correction value between SCIAMACHY and Aqua-MODIS of 0.9838
- Degradation of SCIAMACHY of 0.6% per decade
- Low degradation and 0.23% standard deviation suggests that SCIAMACHY is stable

SCIAMACHY-with-Met-9 Ray-Matching

- Match VZA for Met-9 and SCIA FOV
- One ray-matched location per FOV, four SCIA FOVs
- Four ray-matched locations per GEOsat sub-satellite domain
- Match occurs when:
  - SCIA FOV is within 160 km of corresponding ray-matched location
  - Scan difference < 15 min
- Threshold of 160 km provides sufficient sampling; does not significantly increase standard error relative a tight threshold



Before and After: Summary

<u>MODIS Characterization Support Team</u>
Met-9 CH1 / Aqua CH1 SC ratio = 1.013
Met-9 HRV / Aqua CH1 SC ratio = 0.883

(+) Increase from previous Column
(-) Decrease from previous Column

	Average Gain (CH1) Before SBAF	Average Gain x SC ratio (CH1)	Average Gain (CH1) After SBAF	Average Gain (HRV) Before SBAF	Average Gain x SC ratio (HRV)	Average Gain (HRV) After SBAF
Terra-MODIS	0.540	(+1.3%) 0.547	(+0.7%) 0.551	0.633	(-11.7%) 0.559	(+1.3%) 0.566
Aqua-MODIS	0.539	(+1.3%) 0.546	(+0.9%) 0.551	0.619	(-11.6%) 0.547	(+2.9%) 0.563
DCC	0.541	(+1.3%) 0.548	(+0.5%) 0.551	0.631	(-11.7%) 0.557	(+3.2%) 0.575
Libya	0.539	(+1.3%) 0.546	(+1.1%) 0.552	0.675	(-11.7%) 0.596	(-4.5%) 0.569

Combination of surface reflectance and atmospheric absorption differences means that a single SBAF cannot account for all calibration methods

SBAFs are impactful and add value