NASA LaRC Spectral Band Adjustment Factor (SBAF) Online Calculation Tool Update

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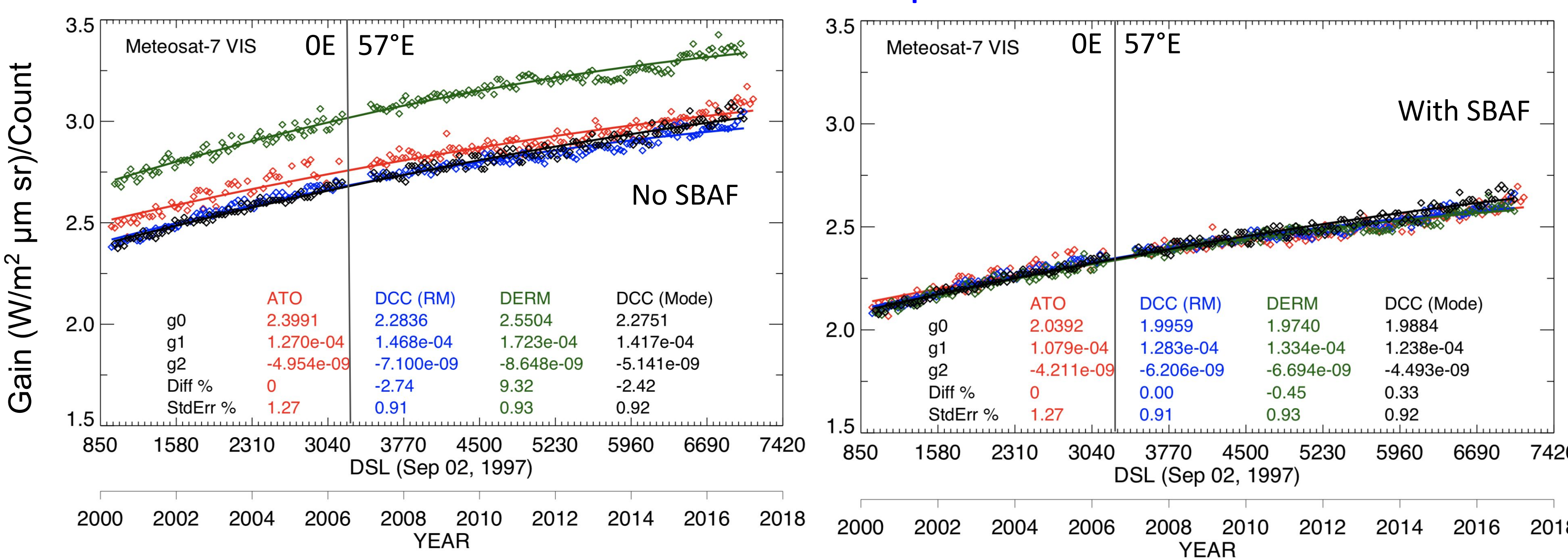
Outline

- Spectral Band Adjustment Factor (SBAF) Review
  - importance, theory, and applications
- NASA Langley SBAF and Spectral Plotting Tools
  - Key features and new developments
  - Double Spectral Filtering Highlight
- Spectral Filtering Use-case
- Extreme use case of SBAF tool
  - OSIRIS-REx to EPIC inter-calibration
- Summary

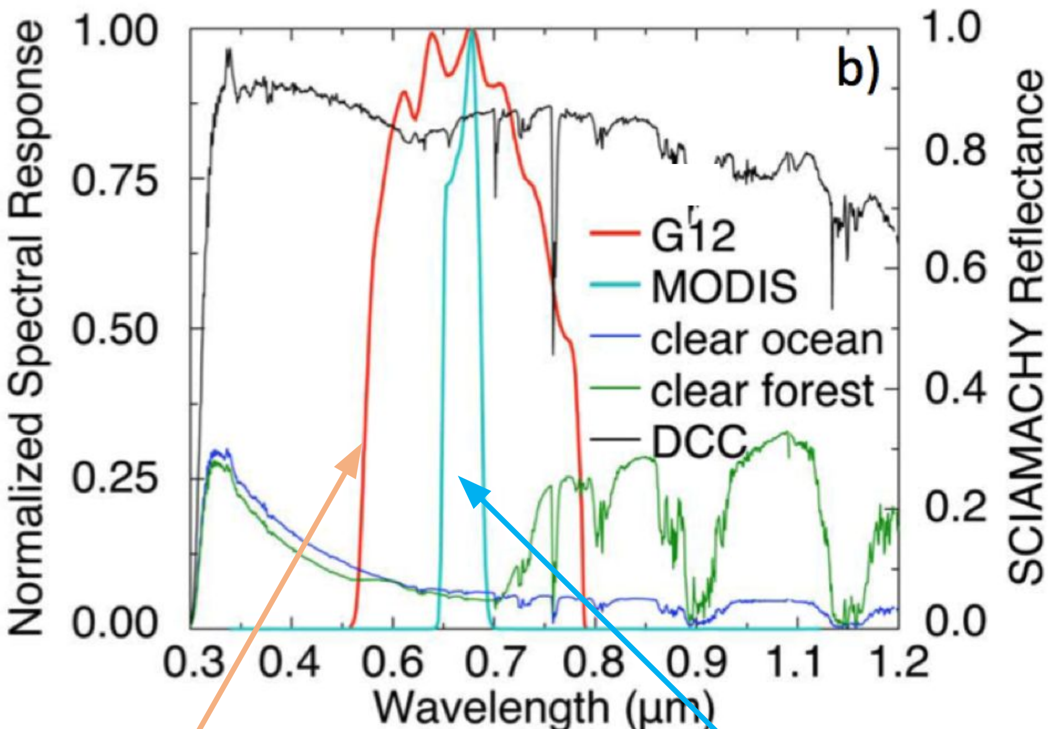
SBAF review: Why SBAF is important?

- Inter-calibration practices utilize different Earth scene types
- Reference and target sensors exhibit spectral differences
- Inter-calibration bias has two components: *absolute radiometric bias* and *spectrally induced bias*
- Accurate SBAF is required to quantify absolute radiometric bias

Meteosat-7 VIS calibration referenced to Aqua-MODIS C6.1 Band 1



SBAF calculation



Every Earth scene has a unique spectral signature

$$L_{p,tar} = \frac{\sum_{n}^{nbins} L_{s,n} \times RSR_{tar,n} \times (\lambda_n - \lambda_{n-1})}{\sum_{n}^{nbins} RSR_{tar,n} \times (\lambda_n - \lambda_{n-1})}$$

$$L_{p,ref} = \frac{\sum_{n}^{nbins} L_{s,n} \times RSR_{ref,n} \times (\lambda_n - \lambda_{n-1})}{\sum_{n}^{nbins} RSR_{ref,n} \times (\lambda_n - \lambda_{n-1})}$$

Derive reference- and target-sensor *pseudo* radiance/reflectance (L_p) via hyperspectral convolution over each RSR to account for band difference/out-of-band absorption

NASA LaRC SBAF tool features

- Based on actual hyperspectral satellite measurements taken from TOA
  - SCIAMACHY, Hyperion, GOME-2
- Over 30 predefined Earth scene selection (deserts, polar ice, DCC, all-sky tropical ocean, etc)
- Data subsetting control options
    - Unit : radiance and reflectance
    - Fit (SBAF) type : forced-fit, linear, 2^{nd} and 3^{rd} order regression
    - Angle allowance
    - Precipitable water allowance
    - Outlier cutoff
    - Fit/plot limits
    - Domain/time/season
- Double spectral filtering (new)

Special thanks to ESA, EUMETSAT, USGS, and NASA teams for help in obtaining, reading, and correcting their hypersectral data.

NASA LaRC Calibration Webpage

GSICS Global Space-based Inter-Calibration System

Product, Services and Technic... ×

https://gsics.wmo.int/en/product-services-and-technical-information

WMO GSICS Global Space-based Inter-Calibration System

Global Space-based Inter-Calibration System

An international collaboration to monitor, improve and

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- GSICS Product Catalogue
- GSICS Coordination Centre
- GSICS WIKI
- Dataserver EUMETSAT
- Dataserver NOAA
- Dataserver CMA

GSICS Processing and Research Centres (GPRCs)

- GPRC NOAA/NESDIS
- GPRC CMA/NSMC
- GPRC EUMETSAT
- GPRC JMA
- GPRC KMA
- GPRC Roshydromet
- GPRC ISRO

Other links

- NASA/Langley/Calibration
- WMO Space Programme
- CGMS

Basic Documents

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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NASA Fact

The Dryden Flight Research Center (DFRC) is NASA's center for aeronautical flight research and atmospheric flight operations. DFRC is chartered to research, develop, verify, and transfer advanced aeronautics, space and related technologies. It also serves as a backup landing site for the Space Shuttle and a facility to test and validate design concepts and systems used in development and operation of the Orbiters.

+ More NASA facts...

Satellite Calibration Page

Calibration Coefficients

- AVHRR Calibration Coefficients
- GEO Calibration Coefficients
  - Pre-CERES_1.0 Link
  - Pre-CERES_2.0 Link
  - CERES-Ed4
  - CERES-Updated-Realtime

Imager Scaling Factors

- Terra to Aqua MODIS Scaling Factors (VIS/NIR/SWIR)
- Terra to Aqua MODIS Scaling Factors (IR)
- Terra MODIS C6 to C5 Scaling Factors
- Aqua MODIS C6 to C5 Scaling Factors
- Terra MODIS C6 to C6.1 Scaling Factors
- Aqua MODIS C6 to C6.1 Scaling Factors
- NPP VIIRS V001 to V03110 Scaling Factors
- Terra MODIS C6.1 to C5 Scaling Factors
- Aqua MODIS C6.1 to C5 Scaling Factors

Imager Stability Plots

- Terra and Aqua MODIS Stability Plots

Spectral Band Adjustment Factors (SBAF)

- SCIAMACHY
- HYPERION
- GOME-2
- IASI
- AIRS

Spectral Plotting Tools

- SCIAMACHY
- HYPERION
- GOME-2

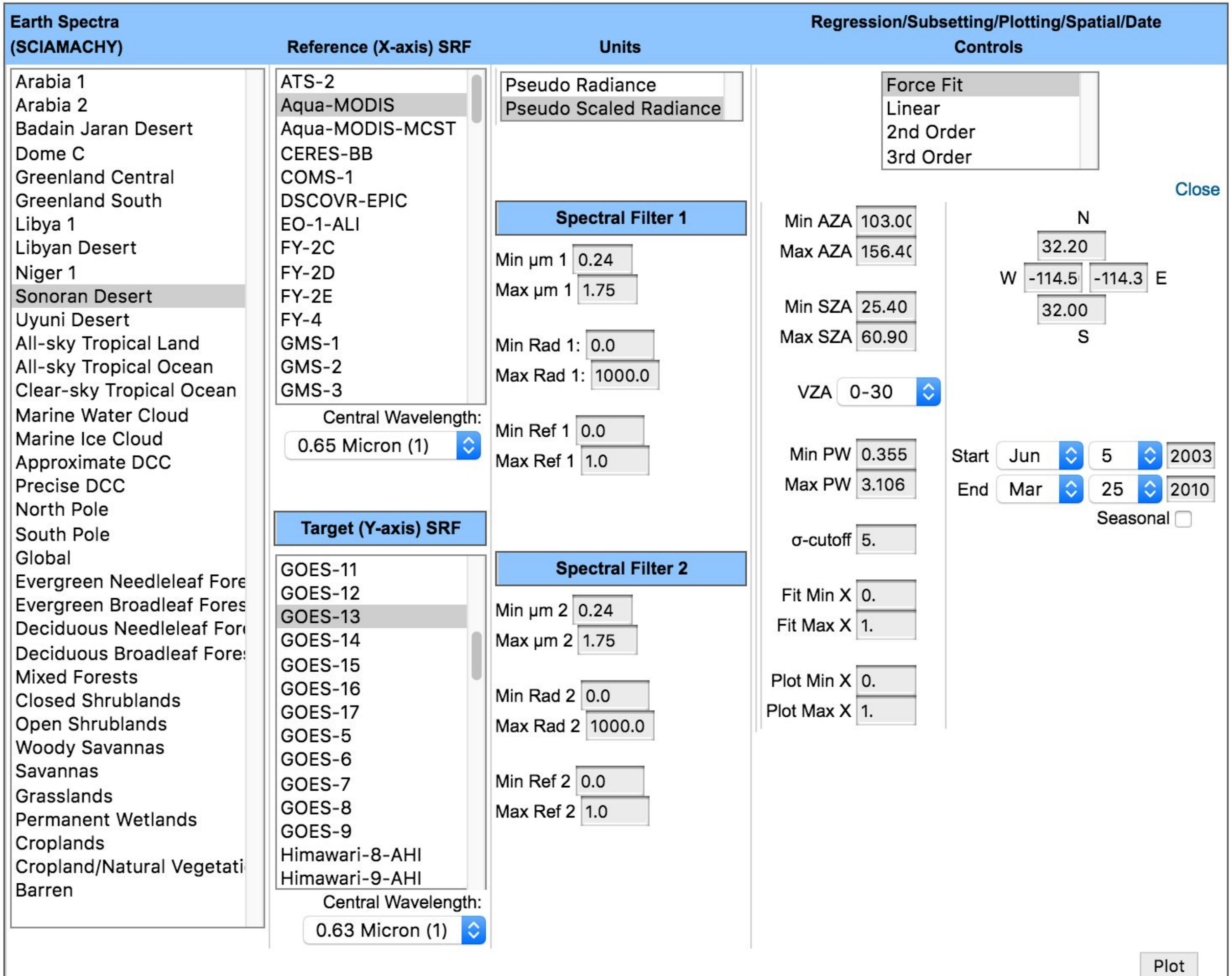
Tools

- Satellite Spectral Response Function (SRF) comparison tool
- Satellite Visible Band Solar Constant Comparison Tool
- IR Brightness Temperature Correction Coefficients for Conversion from Radiances

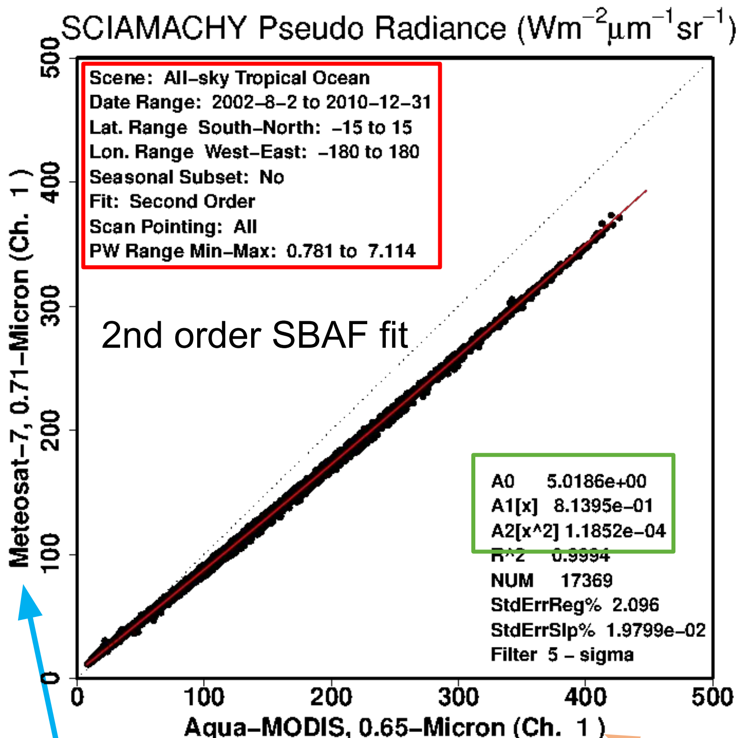
Publications

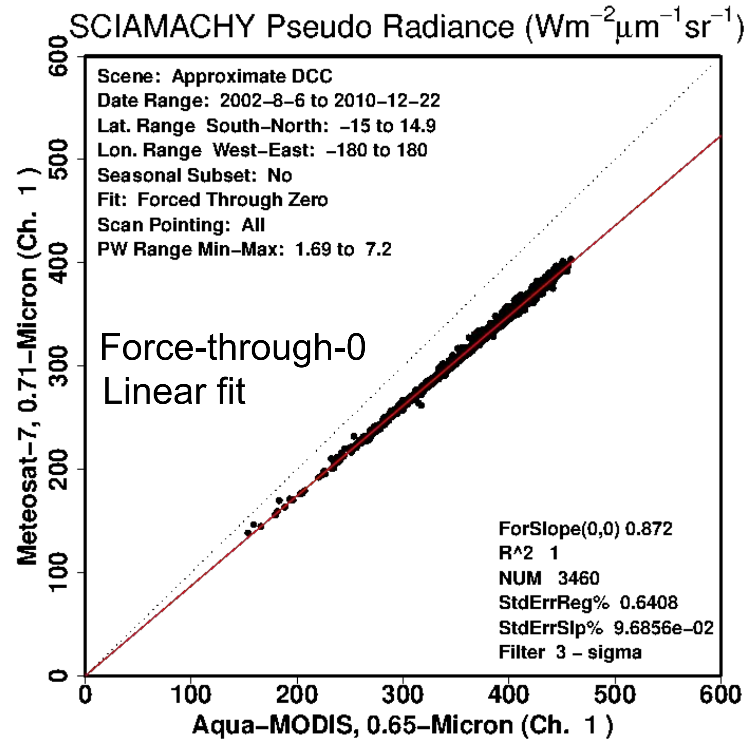
NASA URL: https://cloudsway2.larc.nasa.gov/cgi-bin/site/showdoc?mnemonic=SAT_CALIB_USER

SCIAMACHY SBAF Calculation tool input



SBAF calculation example





$$L_{p,tar} = \frac{\sum_{n}^{nbins} L_{s,n} \times RSR_{tar,n} \times (\lambda_n - \lambda_{n-1})}{\sum_{n}^{nbins} RSR_{tar,n} \times (\lambda_n - \lambda_{n-1})}$$

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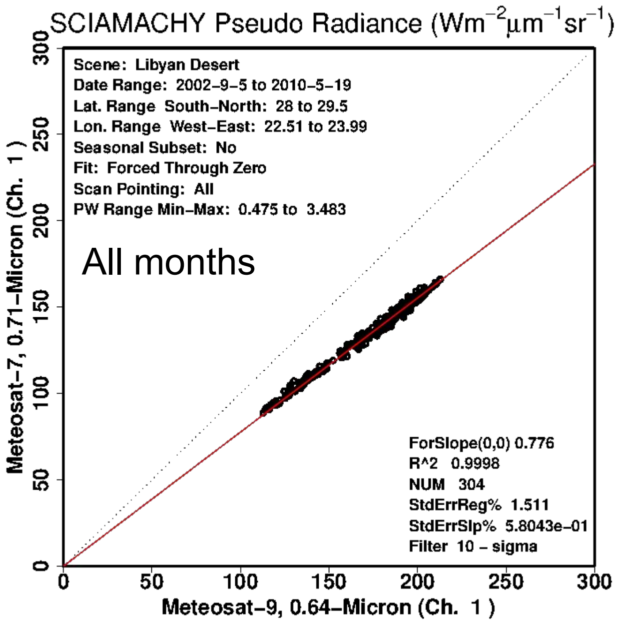
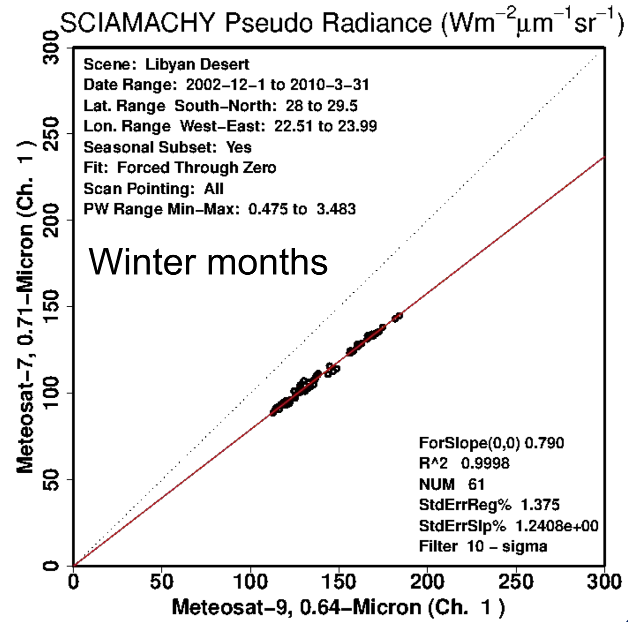
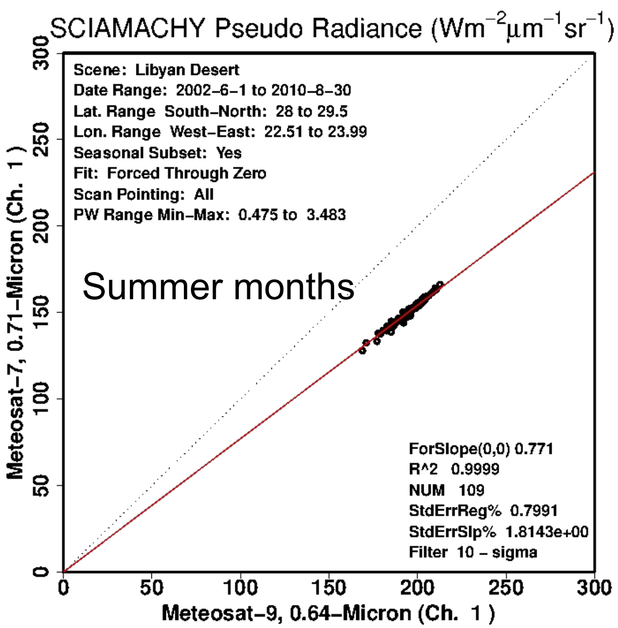
Regression coefficient(s) define the SBAF

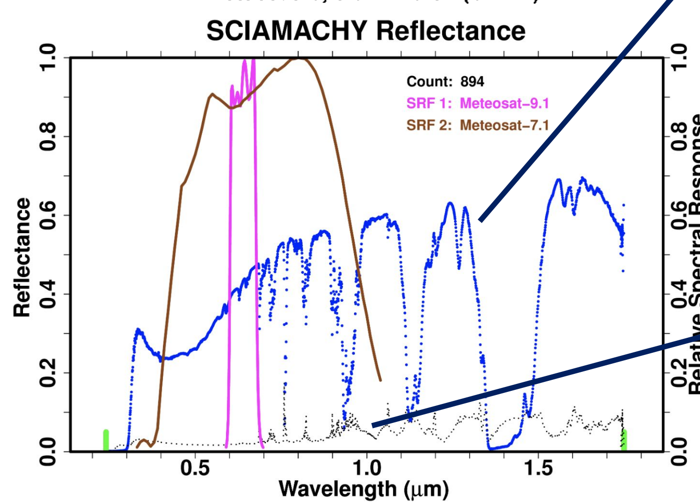
$$L_{Meteosat\text{-}7\text{-}equivalent} = A2 \times L_{Actual,MODIS}^{2} + A1 \times L_{Actual,MODIS} + A0$$

Seasonal SBAF







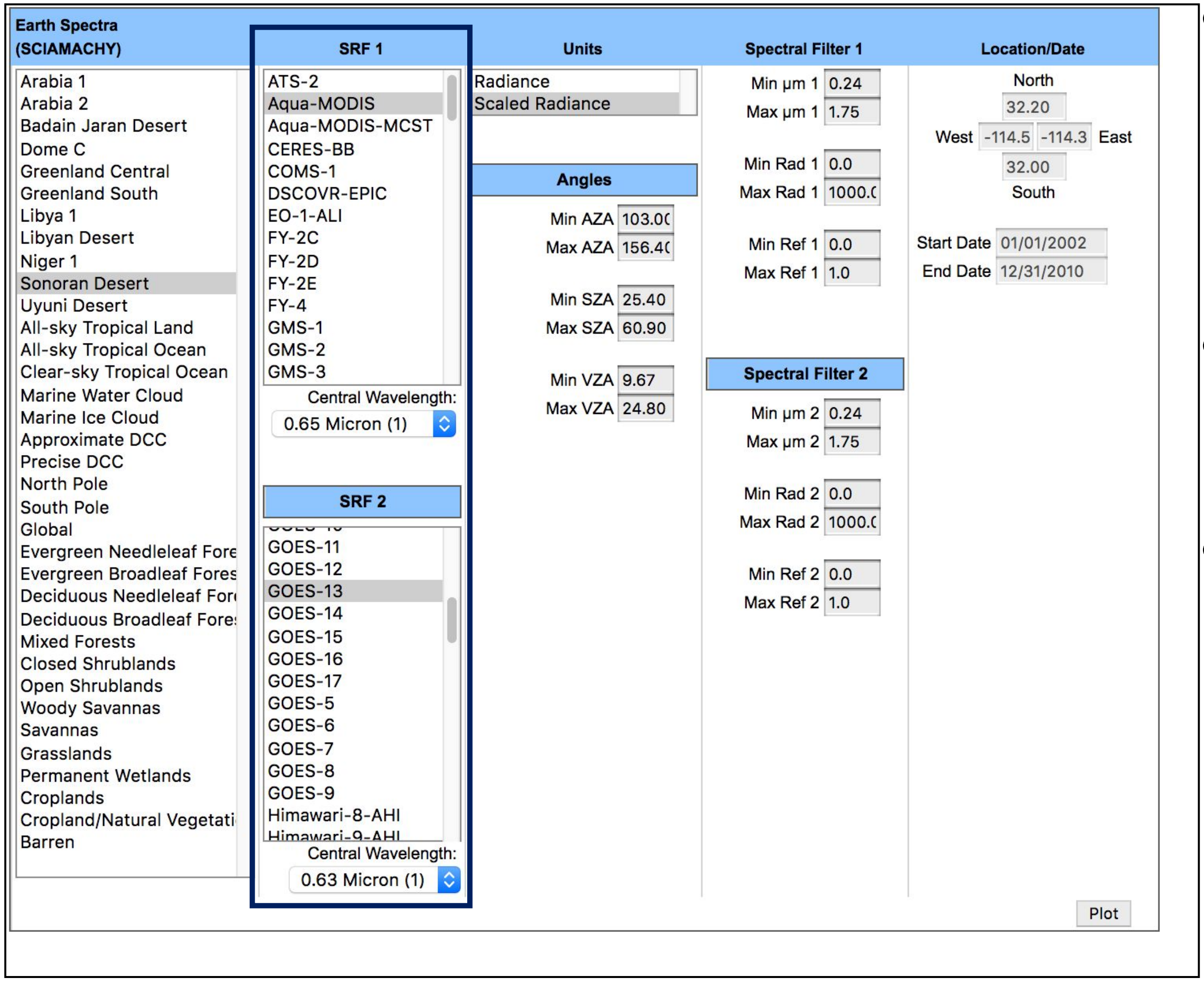


Libyan Desert Mean reflectance spectra

Standard deviation

- Spectral signature can vary over the same PICS with seasons
- Met-9/Met-7 SBAF over Libyan Desert can vary by **~2.5%**
- Seasonal SBAF can reduce uncertainty by excluding days that fall outside the specified month/day limit

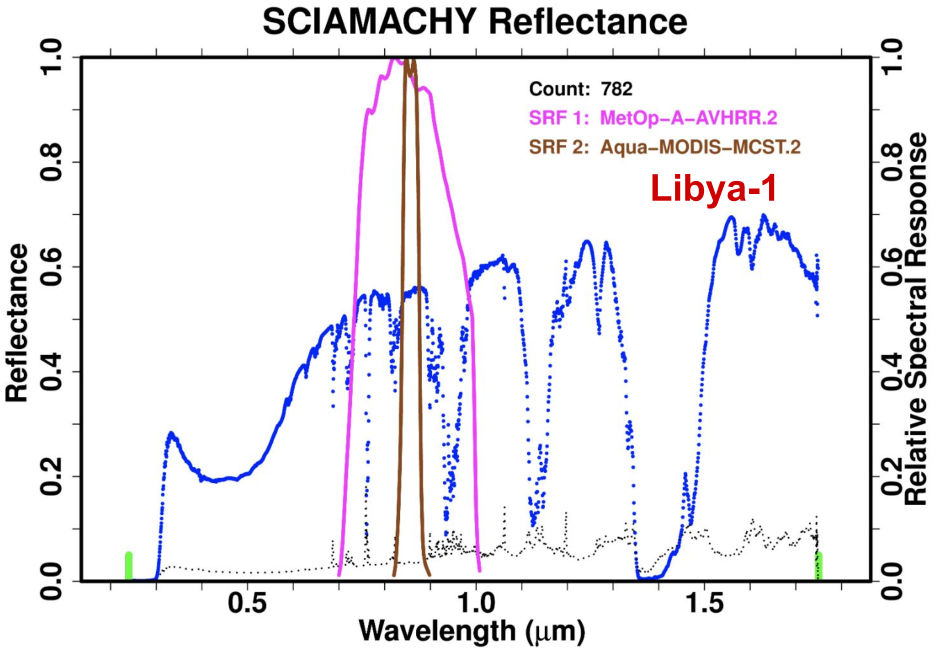
SCIAMACHY Spectra Plotting tool



SCIAMACHY Spectra Tool Input

- Plot the average SCIAMACHY **Earth-reflected Spectra** for a chosen scene/PICS and unit type
- Overlay and convolve with chosen **spectral response functions** (SRFs)
- Yields SCIAMACHY-average SRF-defined **pseudo radiance/reflectance**

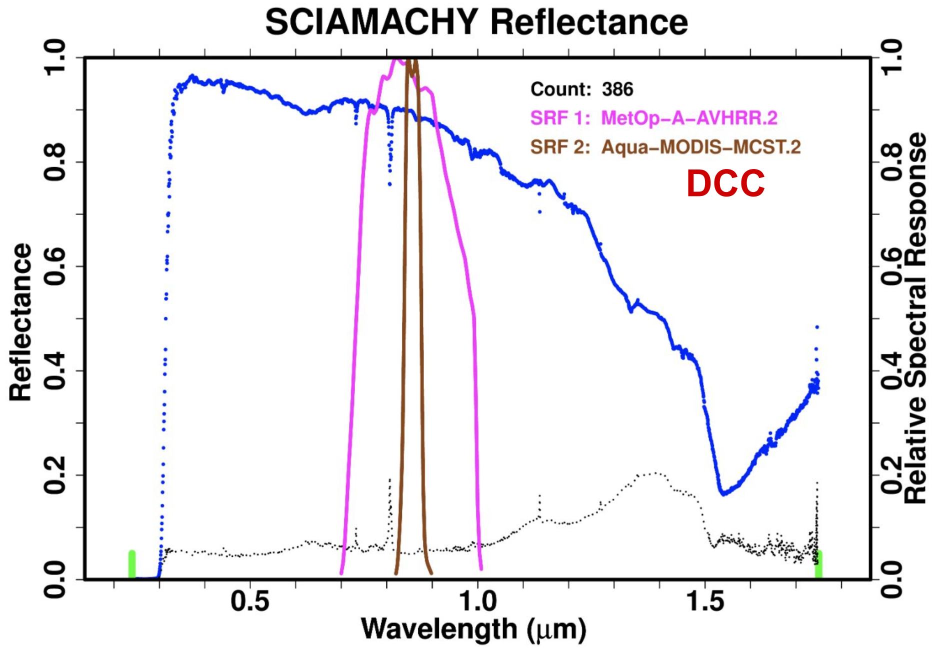
SCIAMACHY Spectra Plotting Tool Output



Libya 1

	Name	Pseudo_Radiance	Pseudo_Reflectance
SRF 1	MetOp-A-AVHRR.2	124.81	0.4653
SRF 2	Aqua-MODIS-MCST.2	140.73	0.5477

Note: Pseudo_Radiance Units: Watts per (meter^2-steradian-micron)



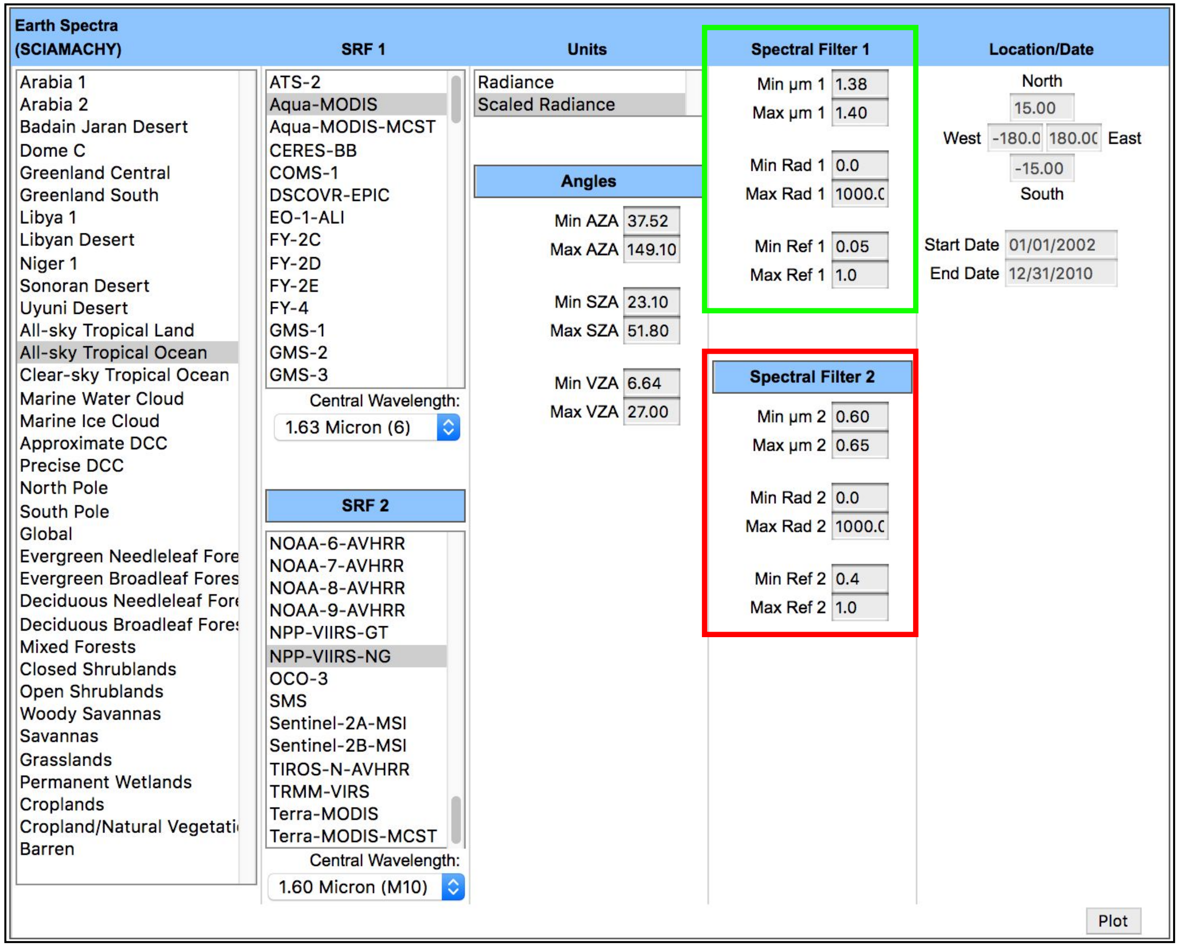
Precise DCC

	Name	Pseudo_Radiance	Pseudo_Reflectance
SRF 1	MetOp-A-AVHRR.2	249.16	0.8821
SRF 2	Aqua-MODIS-MCST.2	246.49	0.8917

Note: Pseudo_Radiance Units: Watts per (meter^2-steradian-micron)

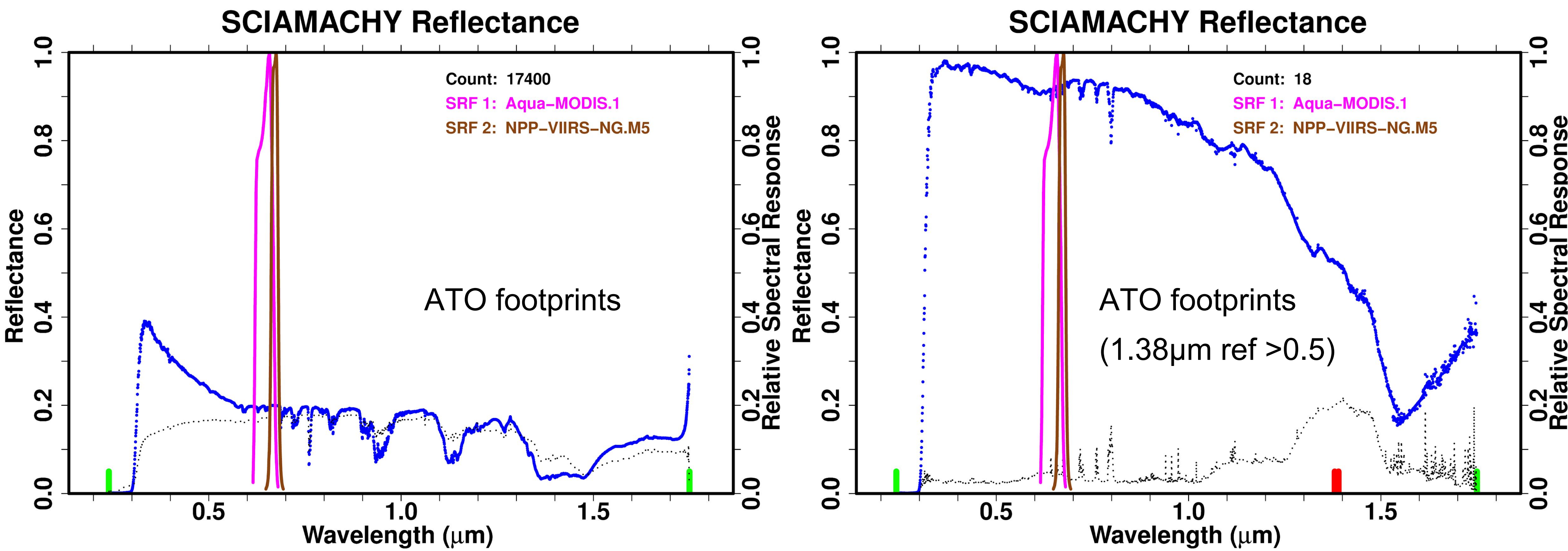
- Raw SCIAMACHY Earth-reflected spectra (**blue dotted line**)
- Table shows mean **pseudo radiance and reflectance** values based on chosen SRFs
- **Black dotted line** indicates standard deviation of footprints

Spectral Filtering: Spectra Plotting tool



- Spectral filter allows exclusion of hyperspectral footprints that do not meet specified criteria
- Indicate the min/max allowable radiance or reflectance (or both) permitted within the chosen wavelength range
- Remove outliers, ensure pristineness, find narrow subset of broad dataset
- Use two spectral filters for better control of scene specification

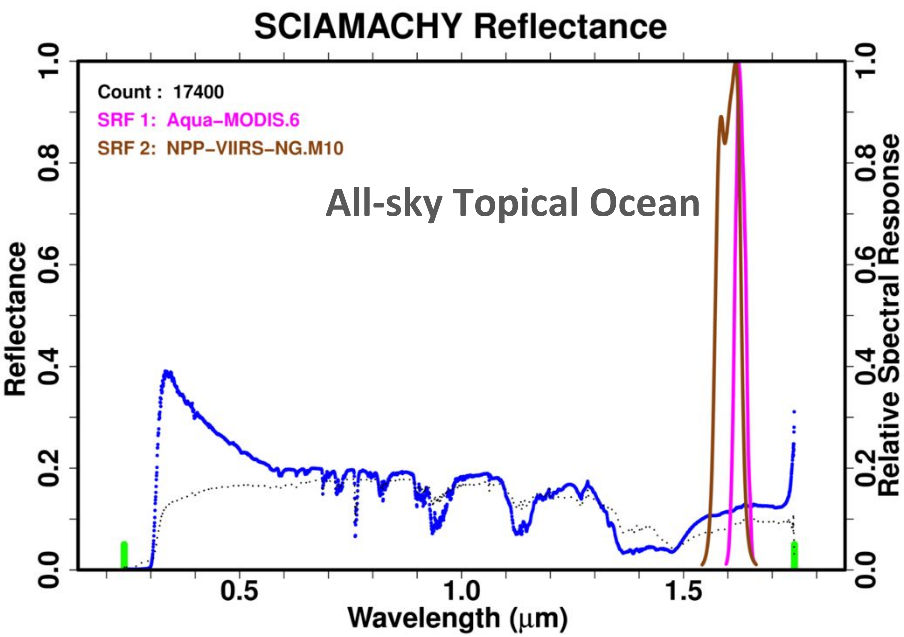
Single Spectral Filtering Example



Extraction of DCC conditions from Raw SCIAMACHY **all-sky tropical ocean (ATO)** footprints

- DCC are the most reflective targets at 1.38μm wavelength
- Based on MODIS and VIIRS observations, DCC reflectance is ~0.5 at 1.38 μm band
- Limiting the ATO reflectance at 1.38μm to >0.5 results in a DCC spectra

Double Spectral Filtering Example



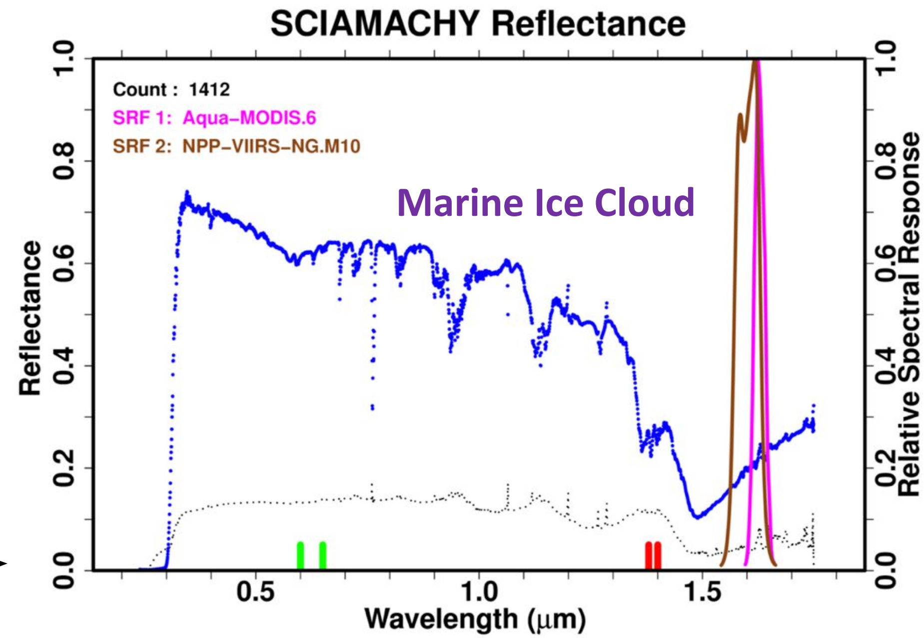
All-sky Tropical Ocean

	Name	Pseudo_Radiance	Pseudo_Reflectance
SRF 1	Aqua-MODIS.6	7.448	0.1234
SRF 2	NPP-VIIRS-NG.M10	7.333	0.1153

Note: Pseudo_Radiance Units: Watts per (meter^2-steradian-micron)

	SF_Range	SF_Radiance	SF_Reflectance
Spectral Filter 1	0.24 - 1.75	41.86	0.155
Spectral Filter 2	0.24 - 1.75	41.86	0.155

Note: SF_Radiance Units: Watts per (meter^2-steradian-micron)
Note: SF_Range Units: micron



All-sky Tropical Ocean

	Name	Pseudo_Radiance	Pseudo_Reflectance
SRF 1	Aqua-MODIS.6	13.278	0.2201
SRF 2	NPP-VIIRS-NG.M10	12.539	0.1971

Note: Pseudo_Radiance Units: Watts per (meter^2-steradian-micron)

	SF_Range	SF_Radiance	SF_Reflectance
Spectral Filter 1	1.38 - 1.4	24.141	0.2554
Spectral Filter 2	0.6 - 0.65	278.280	0.6213

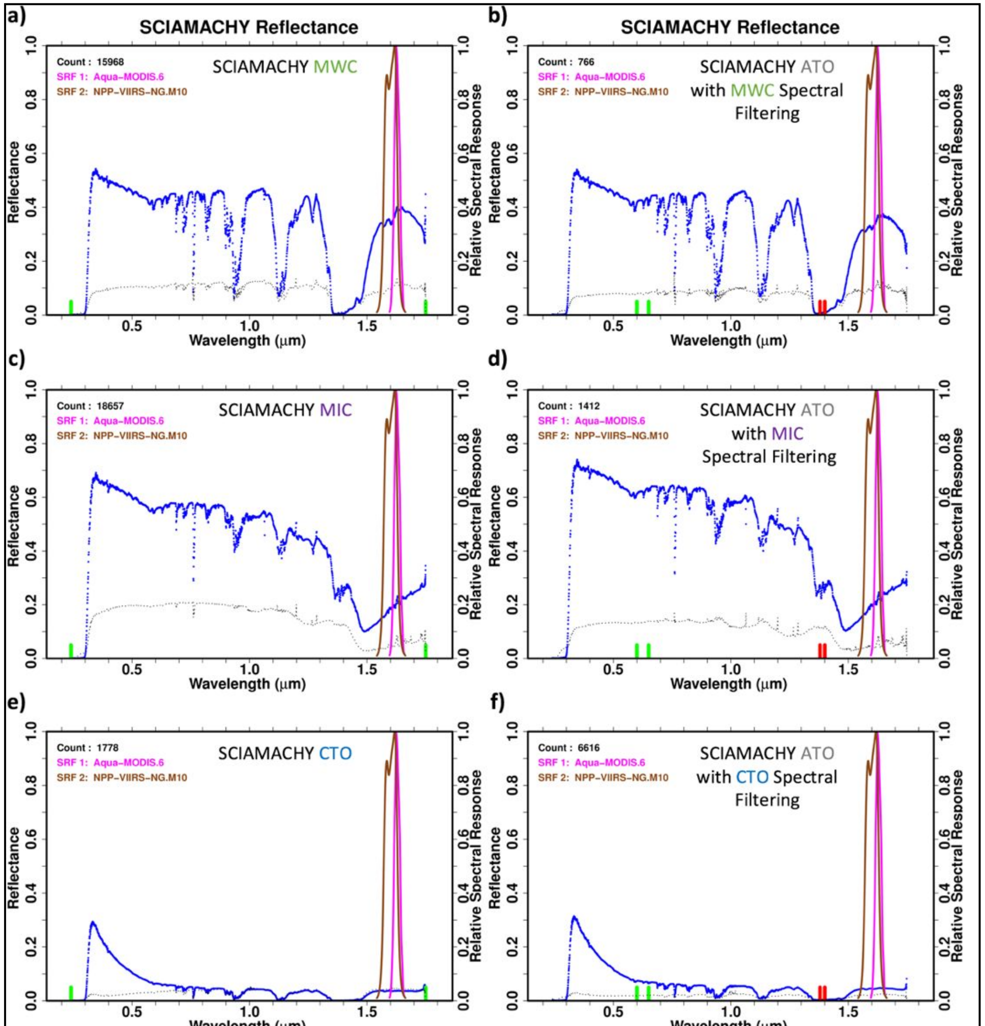
Note: SF_Radiance Units: Watts per (meter^2-steradian-micron)
Note: SF_Range Units: micron

- Raw SCIAMACHY **all-sky tropical ocean (ATO)** Earth-reflected spectra filtered to look like **marine ice clouds (MIC)**
- Average radiance/reflectance within **each spectral filter range** also available
- Useful in scene selection for bands in which composition cannot be easily **distinguished** by radiance or reflectance thresholds
  - e.g., **1.6 µm**

Scene Specification by Spectral Filter

CERES MODIS Cloud Properties

Spectral Filtering

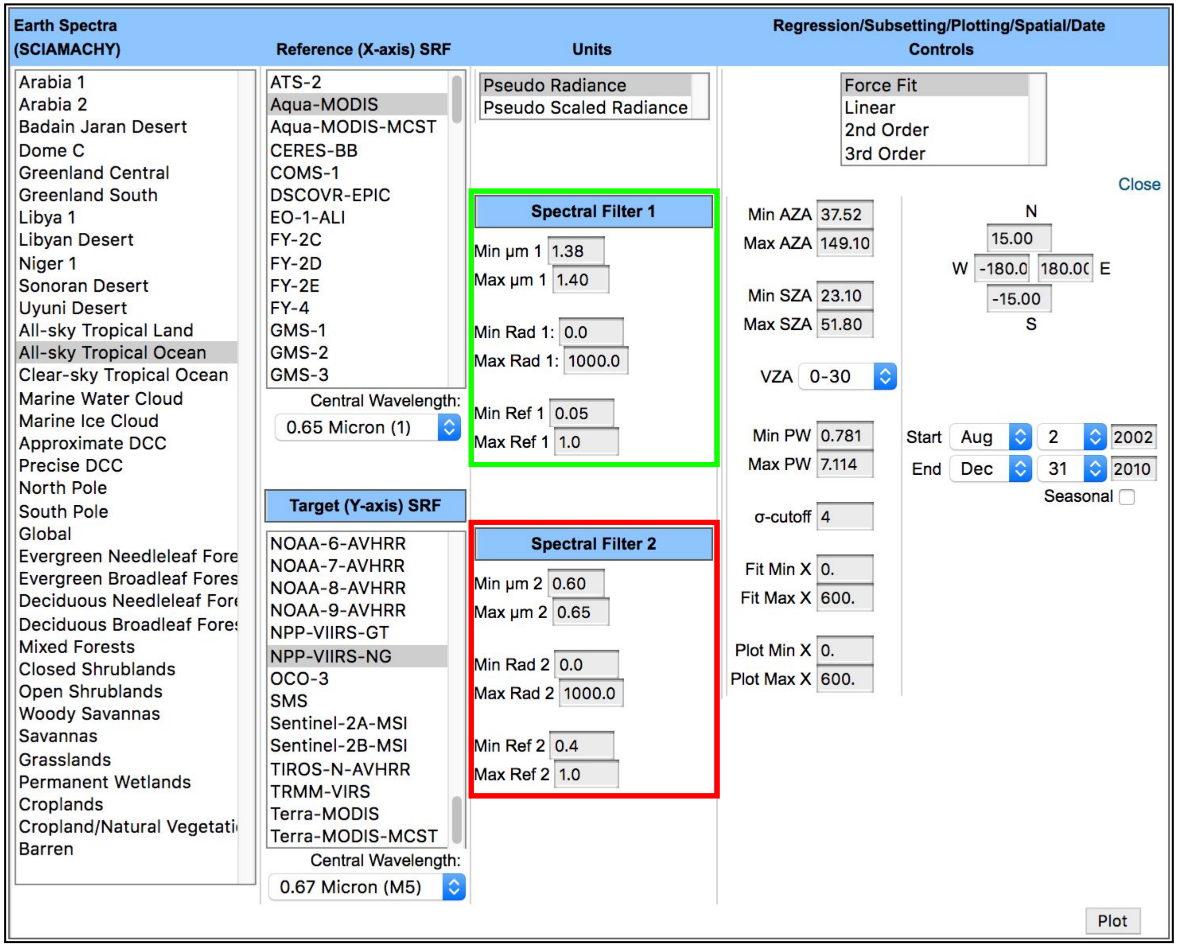


- Left (a, c, e): SCIAMACHY spectra over CERES-identified **marine water clouds (MWC)**, **MIC**, and **clear-sky tropical ocean (CTO)**
- Right (b, d, f): **MWC**, **MIC**, and **CTO** scenes duplicated from spectral filtering of **ATO**

	Spectral Filter 1			Spectral Filter 2		
	Range (μm)	Min Ref.	Max Ref.	Range (μm)	Min Ref.	Max Ref.
MWC	1.38-1.40	0.00	0.05	0.60-0.65	0.30	1.00
MIC	1.38-1.40	0.05	1.00	0.60-0.65	0.40	1.00
CTO	1.38-1.40	0.00	0.05	0.60-0.65	0.00	0.11

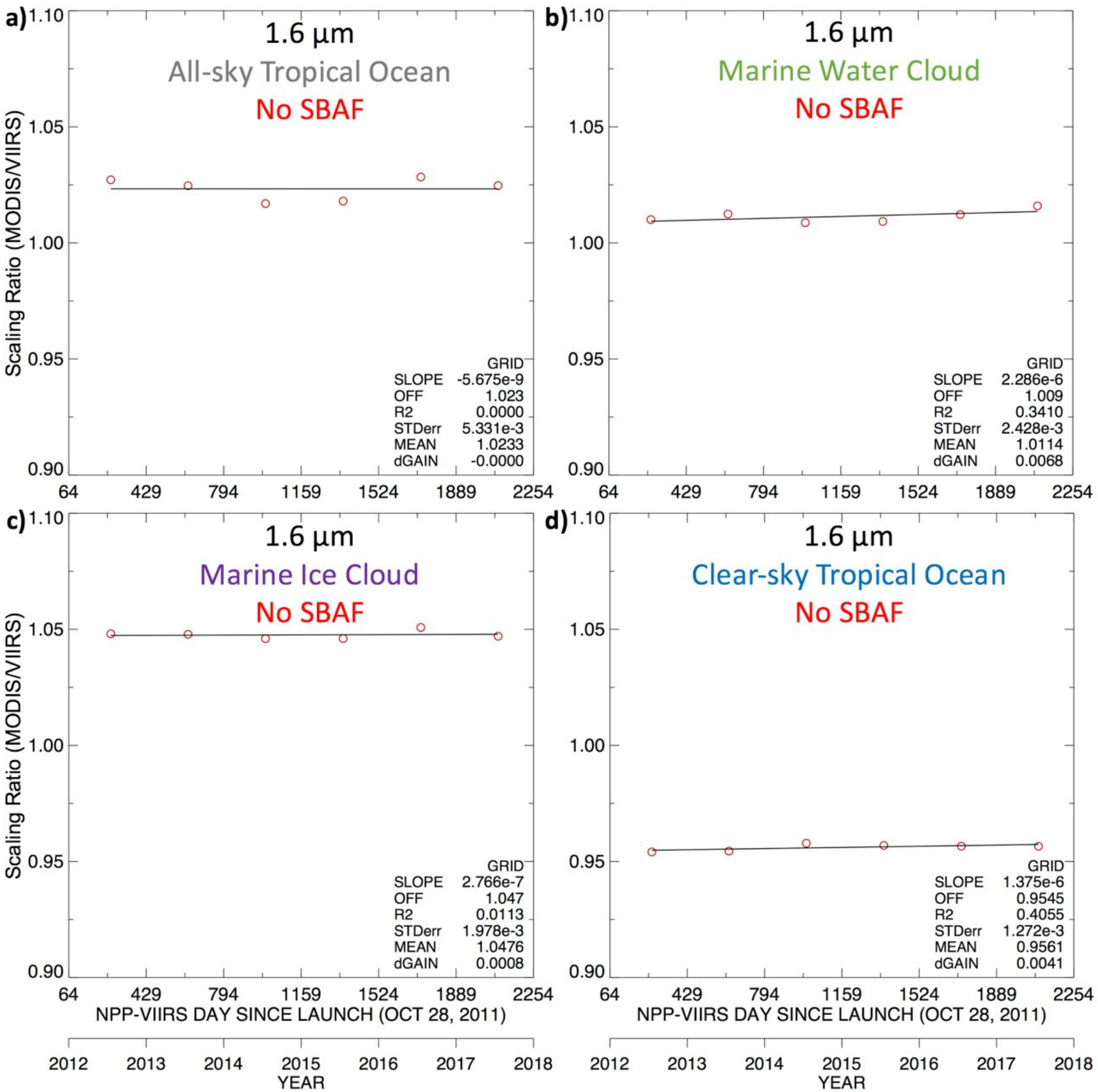
Wavelength ranges and min/max reflectance values used for spectral Filters 1 and 2 to come up with the MWC-, MIC-, and CTO-equivalent scenes using **ATO** Earth-reflected spectra

SBAF Calculation by Spectral Filter



- Employ same spectral filters in the SBAF tool
- SBAF regression plots include only hyperspectral footprints that satisfy both filters
- Use filters with calibration data (e.g., MODIS channels) to isolate desired scenes
- Same spectral filter for calibration data and SBAF should help ensure the SBAF is applicable to the target scene

Aqua-MODIS B6 /VIIRS M10 (1.6-µm) SCALING RATIO: NO SBAF

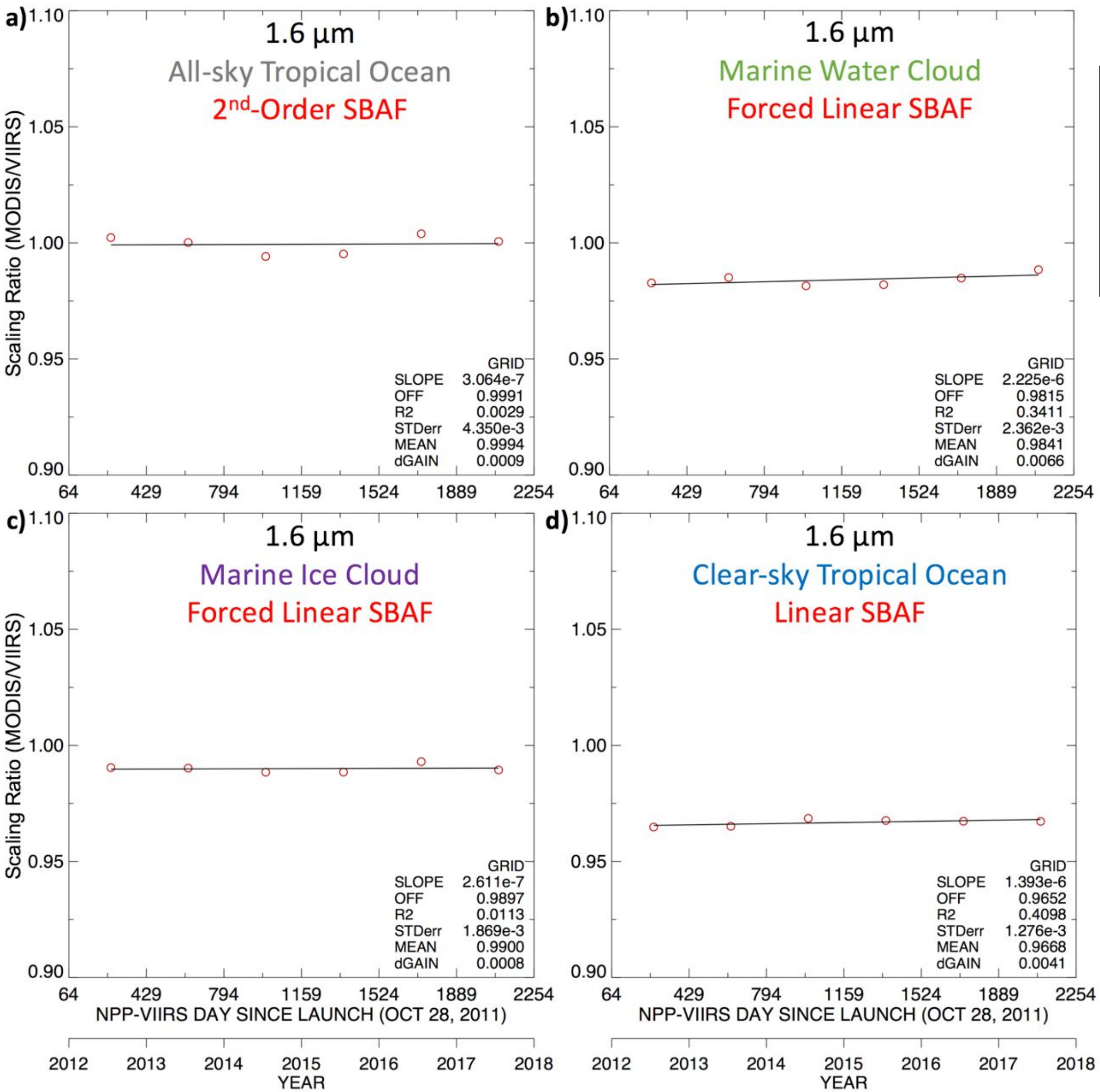


Mean Scaling Ratio

1.6 µm	ATO	MWC	MIC	CTO
No SBAF	1.0233	1.0114	1.0476	0.9561

- Average Aqua-MODIS and NPP-VIIRS SNO scaling ratio (MODIS/VIIRS) varies greatly depending on scene type
- Can we at least better-characterize the “all-sky” subset through spectral filtering and spectrally filtered SBAFs?
- If SBAFs were perfect, then the scaling ratio would be the same regardless of scene type

Aqua-MODIS B6 /VIIRS M10 (1.6-µm) SCALING RATIO: With SBAF

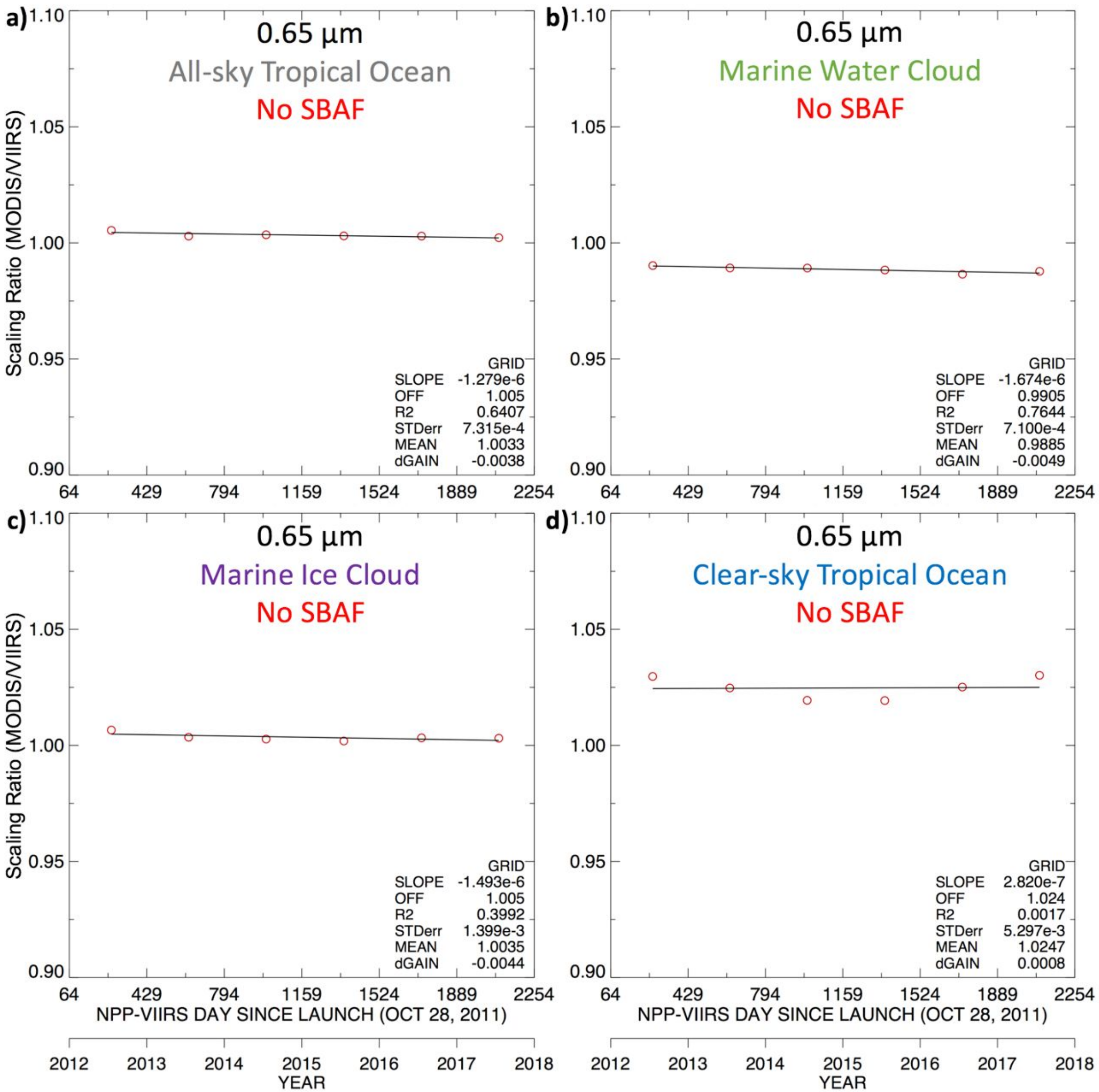


Mean Scaling Ratio

1.6 µm	ATO	MWC	MIC	CTO
No SBAF	1.0233	1.0114	1.0476	0.9561
With SBAF	0.9994	0.9841	0.9900	0.9668

- Spectrally filtered SBAFs help bring **MWC-** and **MIC**-based scaling ratios closer
- The **MIC** and **MWC** ratios show the same radiance values, but the 2nd-order **ATO** SBAF does not effectively characterize both scenes
- For **CTO**, the radiances are dark and cloud contamination would induce strong bias
- SCIAMACHY uses very large footprints and thus it is difficult to reliably find **CTO** adequate enough for this channel

MODIS B1/VIIRS M5 (0.65-µm) SCALING RATIO: NO SBAF

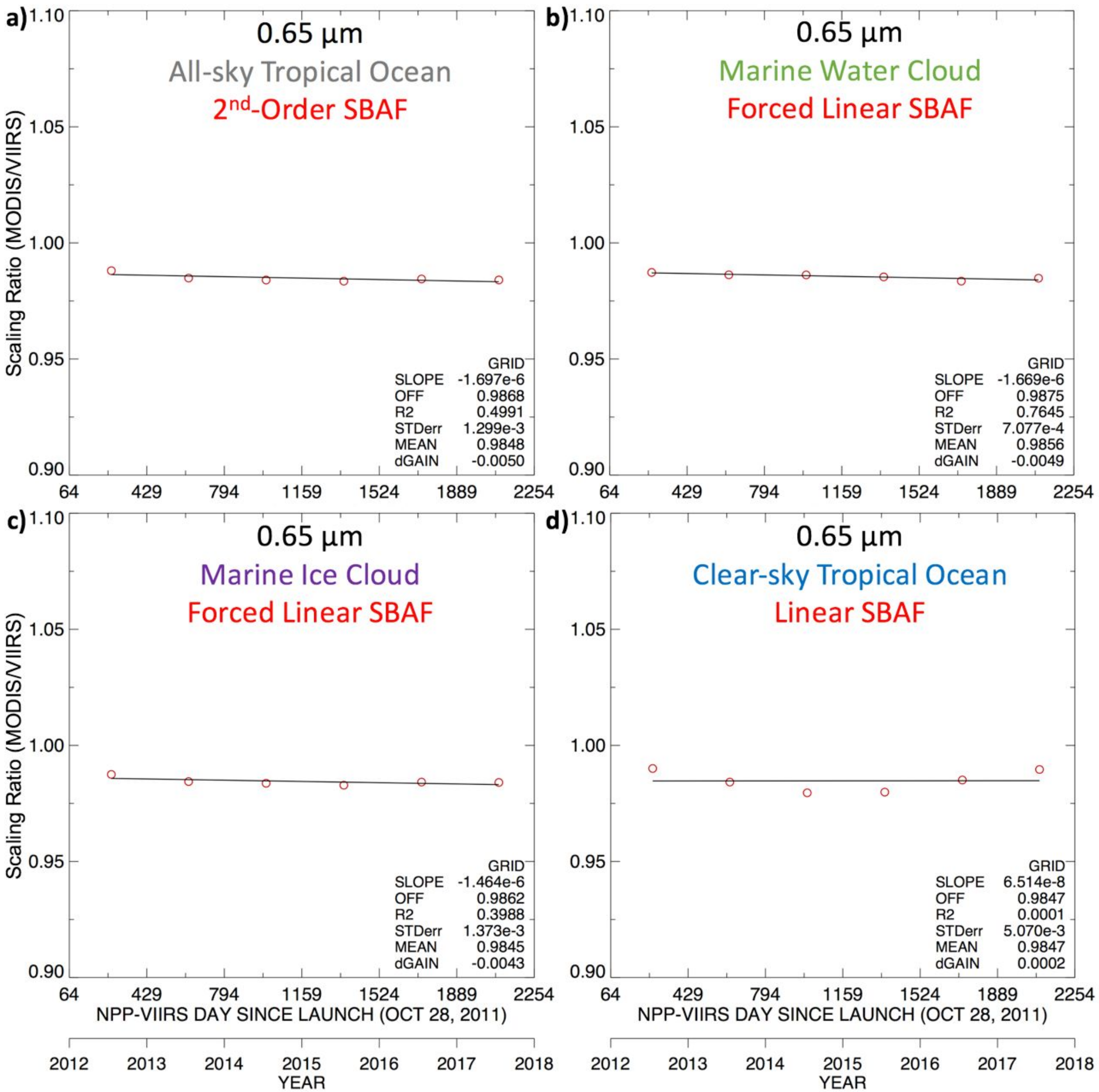


Mean Scaling Ratio

0.65 µm	ATO	MWC	MIC	CTO
No SBAF	1.0033	0.9885	1.0035	1.0247

- For 0.65-µm channel, pre-SBAF maximum scaling discrepancy is 3.7%
- Mean ratio standard deviation is 1.5%

MODIS B1/VIIRS M5 (0.65-µm) SCALING RATIO: WITH SBAF

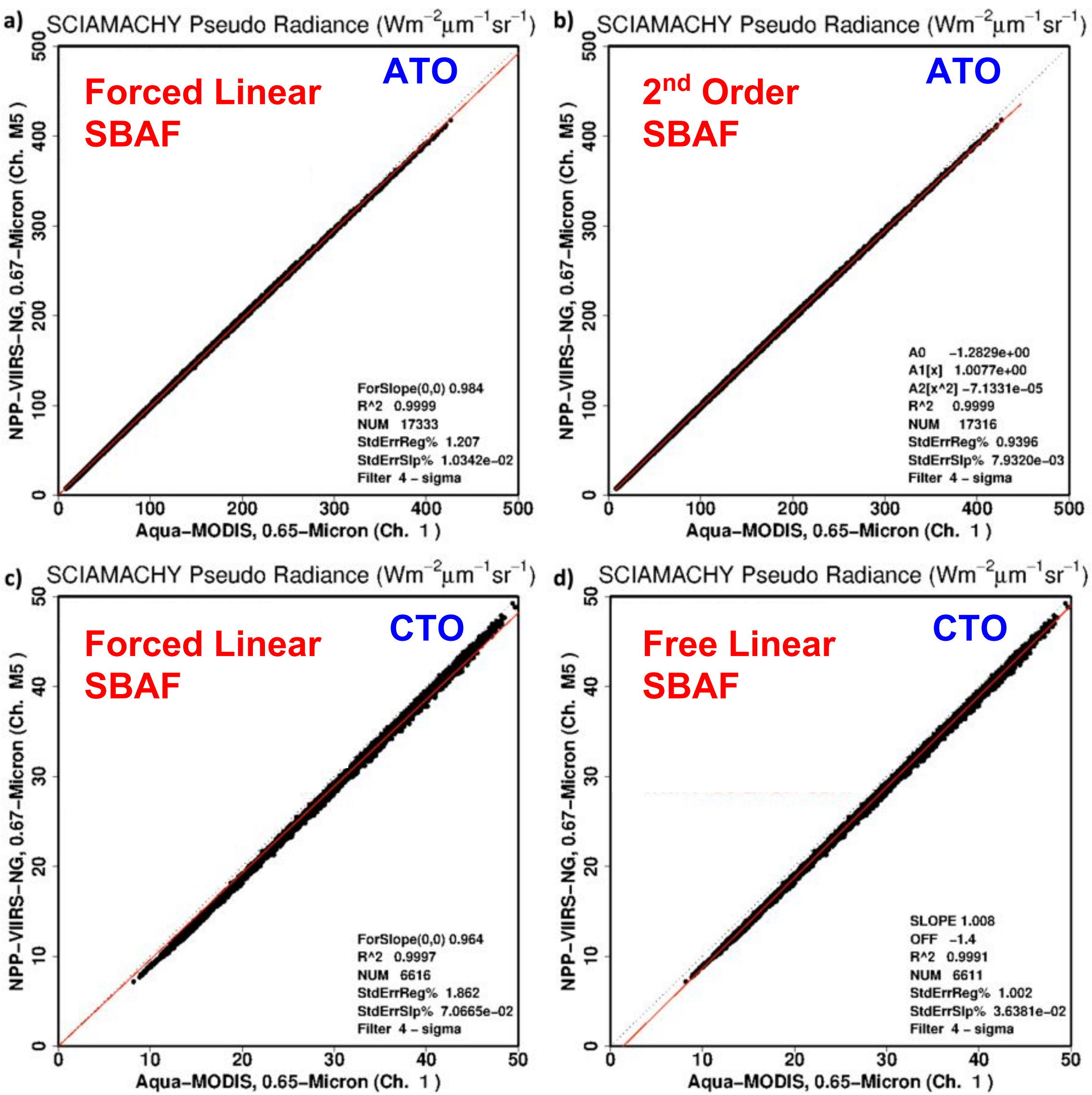


Mean Scaling Ratio

0.65 µm	ATO	MWC	MIC	CTO
No SBAF	1.0033	0.9885	1.0035	1.0247
With SBAF	0.9848	0.9856	0.9845	0.9847

- After SBAF, the maximum discrepancy is reduced to 0.1%
- Mean ratio standard deviation fell to 0.05%
- 2nd-order **ATO** SBAF yields values between **MWC** and **MIC**, which is expected if the single SBAF accurately represents both scene types

Choice of SBAF 'Degree of Polynomial'



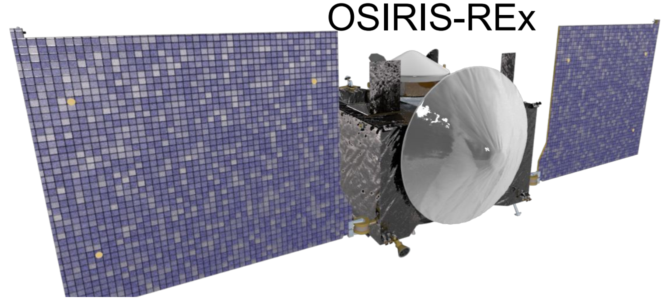
- User can select the regression type (degree of polynomial) that most effectively captures the variability of the pseudo radiance pairs
- The SBAF using linear regression forced through the origin (i.e. **Force Slope or 0th Order**) does not accurately characterize **ATO** nor **CTO** spectra
- **ATO** is better represented with a quadratic polynomial (i.e., **2nd Order**)
- **CTO** is better represented with a "free" linear regression (i.e., **Slope and Offset or 1st Order**)
- Better characterization results in **regression standard error** (STDErrReg%) improvement

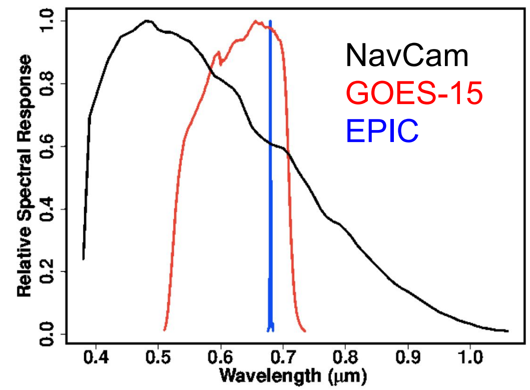
STDErrReg%	ATO	CTO
Forced linear	1.207	1.862
1st-Order	1.158	1.002
2nd-Oder	0.940	0.995

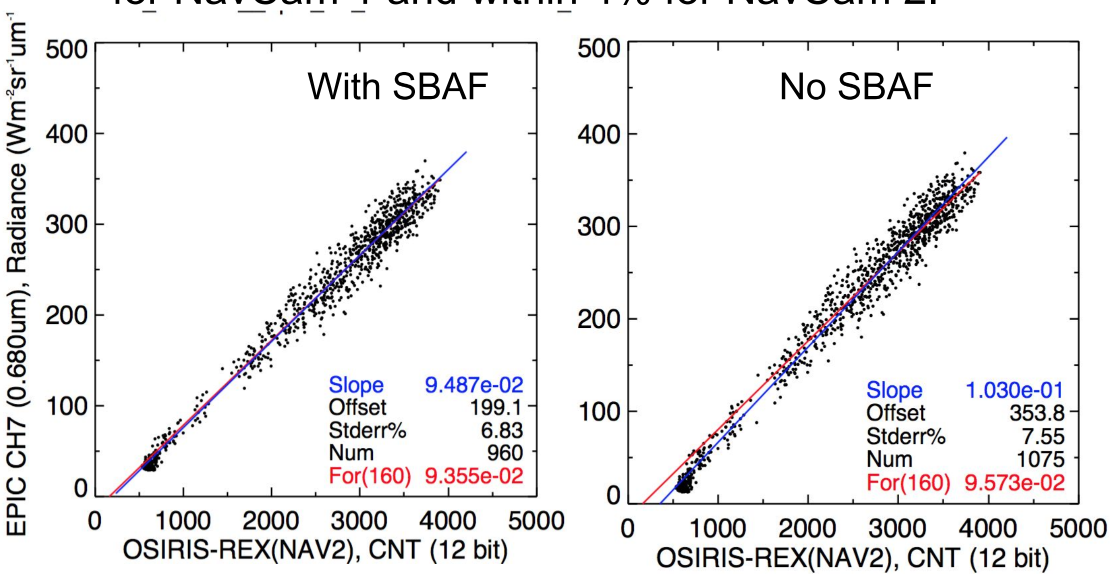
Extreme use case of SBAF

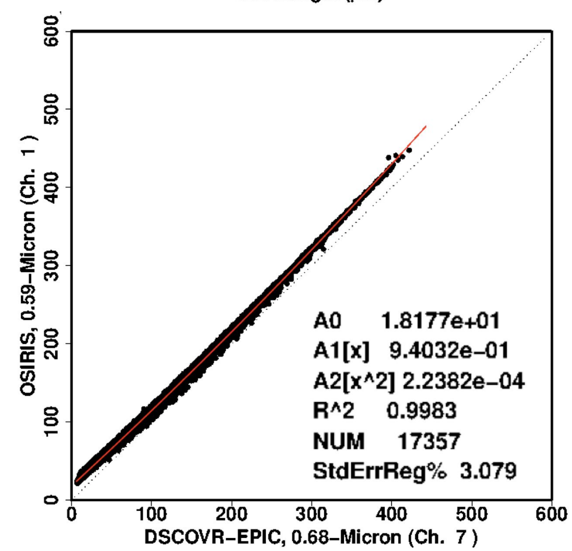
- OSIRIS-REx is a NASA asteroid study mission
- Goal is to obtain a sample from asteroid Bennu
- NASA LaRC's TISA calibration team has performed post-launch radiometric calibration of on-board NavCam imagers
- OSIRIS-REx acquired Earth viewed images during an Earth gravity assist flyby maneuver on September 22, 2017
- Ray-matched with calibrated radiances of GOES-15 and DSCOVR EPIC over ATO
- ATO and pre-launch calibrations agree within 3% for NavCam 1 and within 4% for NavCam 2.

OSIRIS-REx









Summary

- NASA LaRC's SBAF Tool enables accurately quantifying spectrally induced biases in cross-calibration of satellite sensors
- We will continue to develop and actively maintain/enhance open-access, on-demand calibration tools
  - Benefit to GSICS and the broader calibration community
- Tell us how these tools can be made more useful
  - Add new satellites SRFs to database
  - Additional subsetting options
  - Different output controls
- E.g., spectral filtering options arose from need to accurately distinguish scene conditions for a chosen channel based on energy level stratification at separate wavelengths
  - More accurate SBAF
  - More accurate radiometric inter-comparison