VIIRS to MODIS Scaling Factors Designed to Mitigate Retrieval Discontinuities between Records

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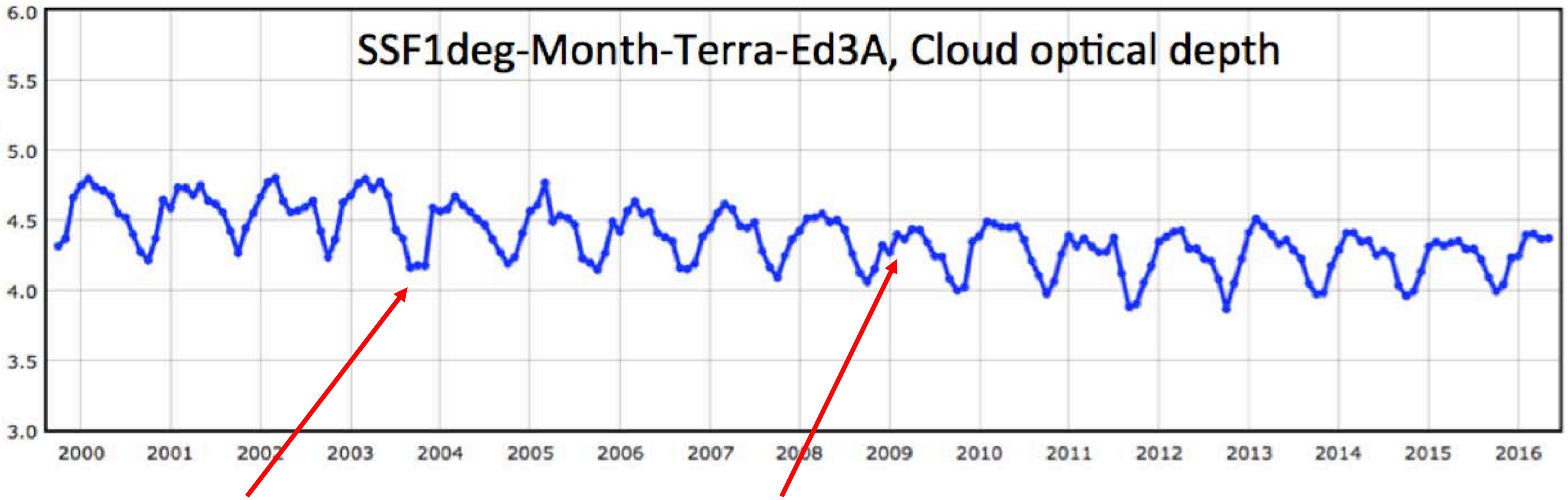
Motivation

- The CERES EBAF product is a climate quality dataset that monitors the Earth's reflected solar and emitted IR flux, that is used to validate climate models.
- The CERES TOA fluxes rely not only on the CERES instrument calibration but on the consistent temporal quality of cloud, aerosol, and atmospheric profile inputs to aid in converting the CERES observed instantaneous radiances into fluxes
  - Any change in the input version may cause a discontinuity in the CERES EBAF flux record.
  - These artificial discontinuities may be interpreted climate signals by users
- The CERES cloud properties are based on MODIS and VIIRS imager retrievals.
  - In order to avoid discontinuities between successive MODIS and VIIRS imager cloud properties, the MODIS and VIIRS imager must be radiometrically scaled.
  - Avoiding discontinuities between migrating from the various MODIS calibrations, such as C5 and C6.1

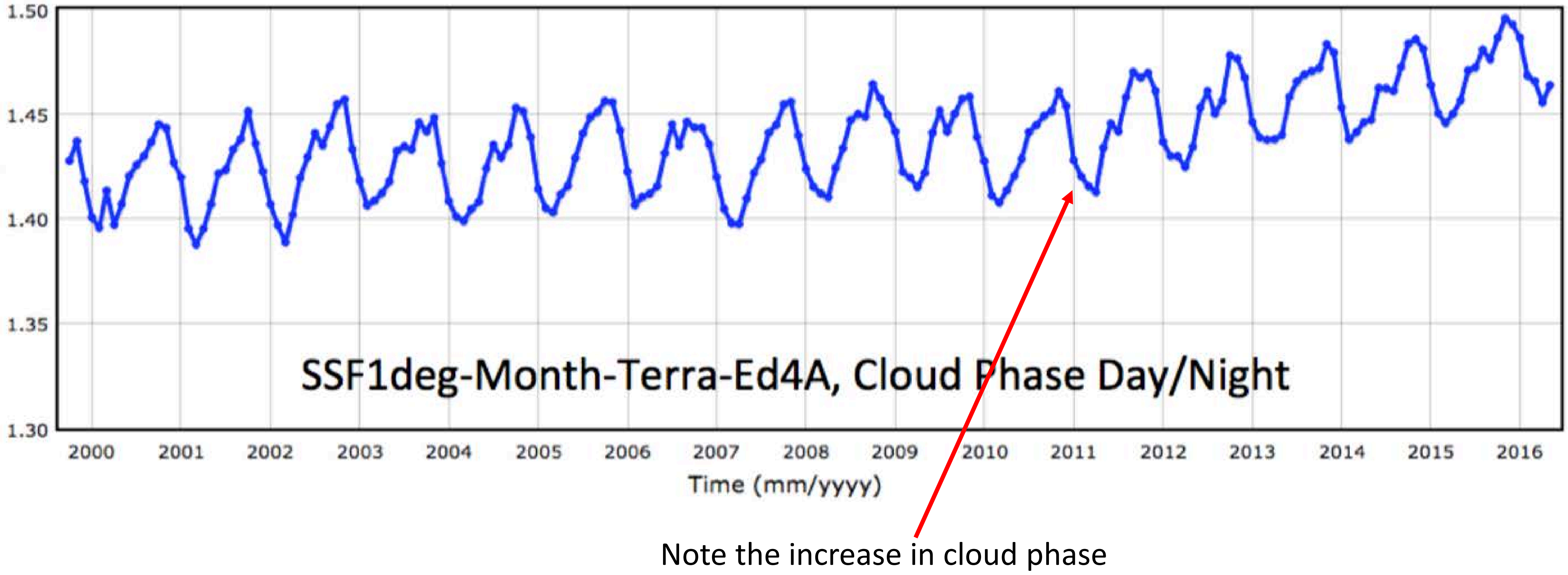
Terra-MODIS C5 B1 (0.65µm) cloud optical Depth



Solar diffuser door in open position (1.0%) Readjusting the C5 calibration to the solar diffuser (-1.5%)

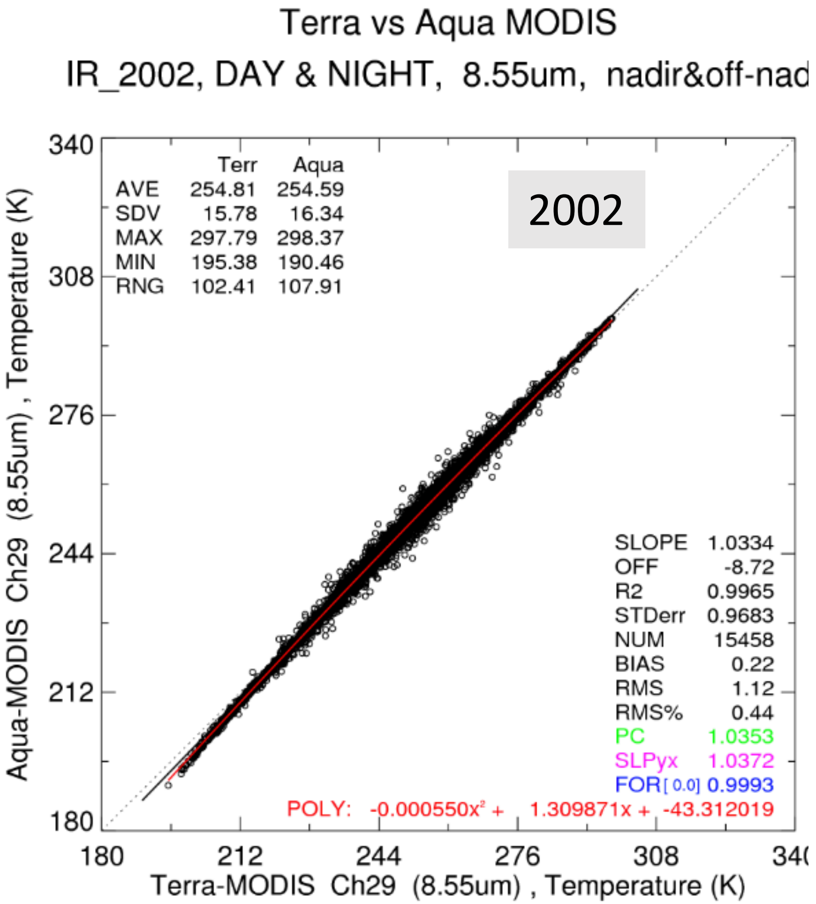
There is a slight dependency on the CERES SW radiance to flux conversion, since the ADM was based on the first 5-years of data utilizes cloud optical depth to select the appropriate ADM factor

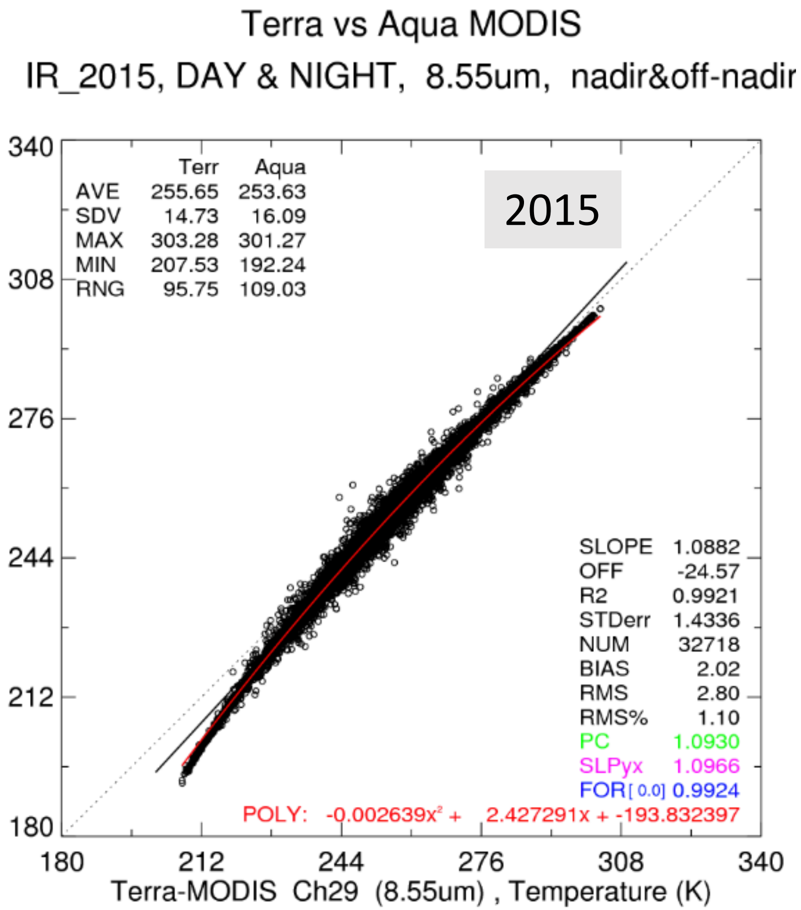
Terra-MODIS C5 B29 8.6μm BT

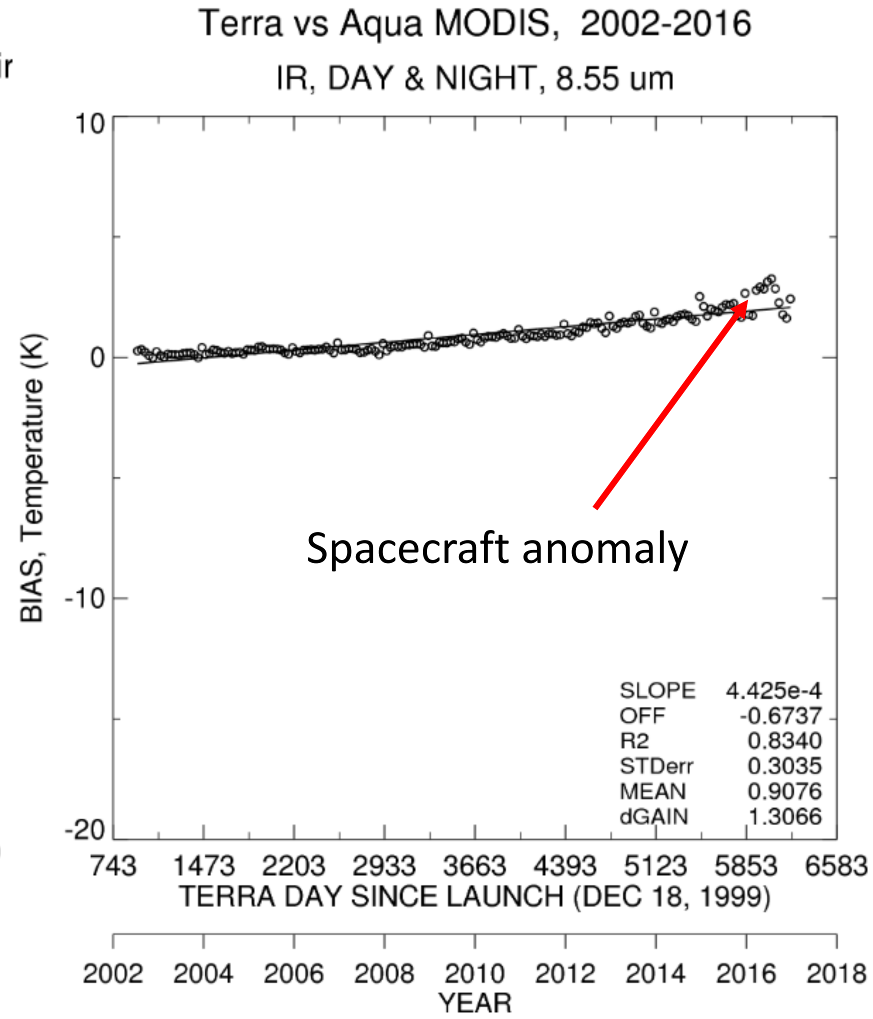


A CERES 20-km footprint with a phase=1 is entirely a liquid cloud, phase=2 is an ice cloud
The 8.6μm is used to determine whether a cloud is liquid or ice

Terra-MODIS C5 B29 8.6µm BT





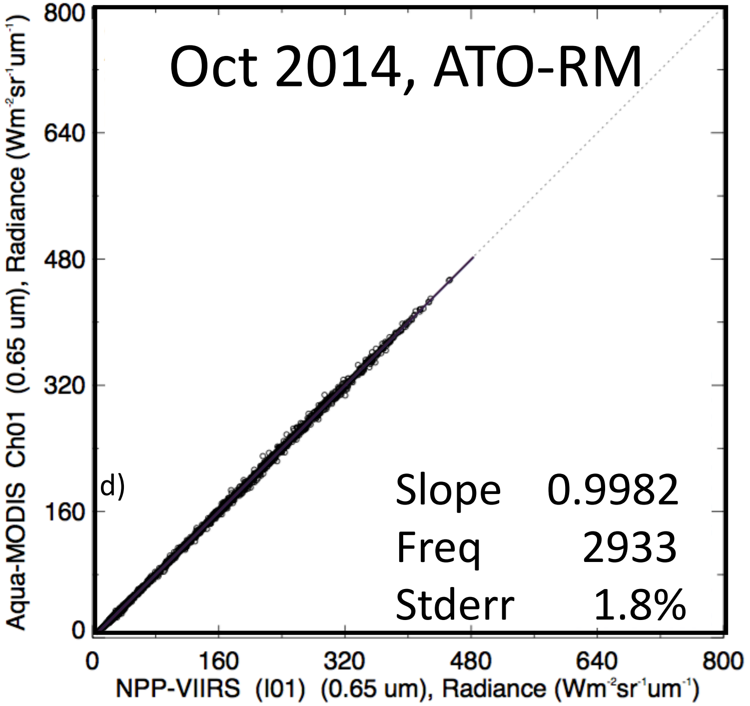


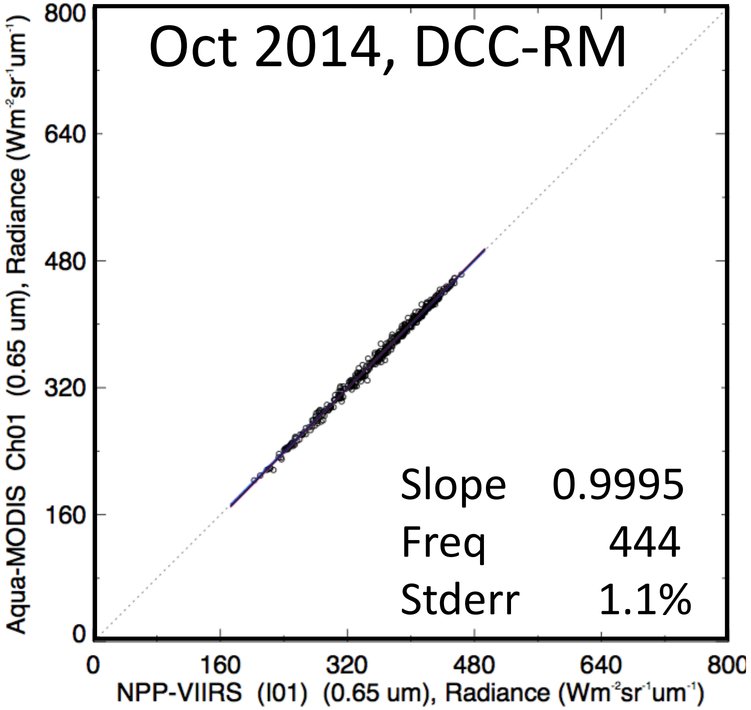
MODIS and VIIRS ray-matching techniques

- All-sky Tropical Ocean Ray-Matching (ATO-RM)
  - Grid pixel level radiances into 0.5° by 0.5° latitude by longitude regions over oceans
- Deep Convective Cloud Ray-Matching (DCC-RM)
  - Take advantage of the brightest, at TOA, flat visible spectra, and near Lambertian target
  - Identify pixels with an 11µm BT <220K in the MODIS image
  - Locate DCC 30-km diameter cells where all pixels have a BT<220K and average the MODIS pixel-level visible radiances
- Linearly regress monthly the MODIS and VIIRS radiance pairs
  - Angle and time match the MODIS and VIIRS instantaneous radiance pairs
  - Account for the solar zenith angle and spectral band difference

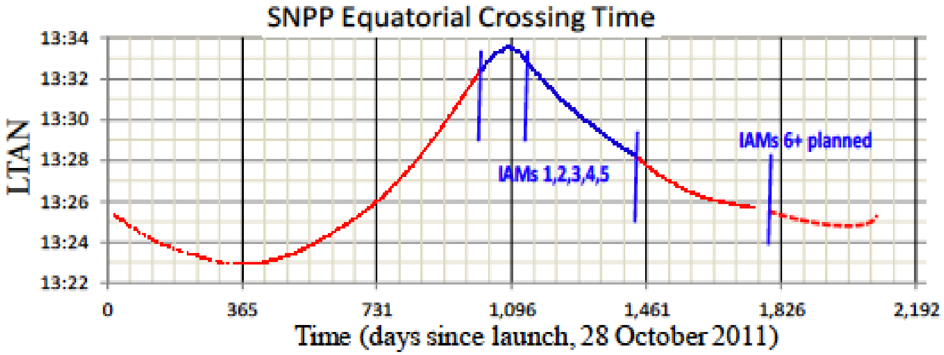
- Earth invariant targets or Pseudo Invariant Calibration Sites (PICS)
  - Deserts (Libya-4)
  - Tropical ensemble Deep Convective Clouds (DCC-IT)
  - Polar ice (Dome-C)

MODIS and VIIRS ATO-RM and DCC-RM

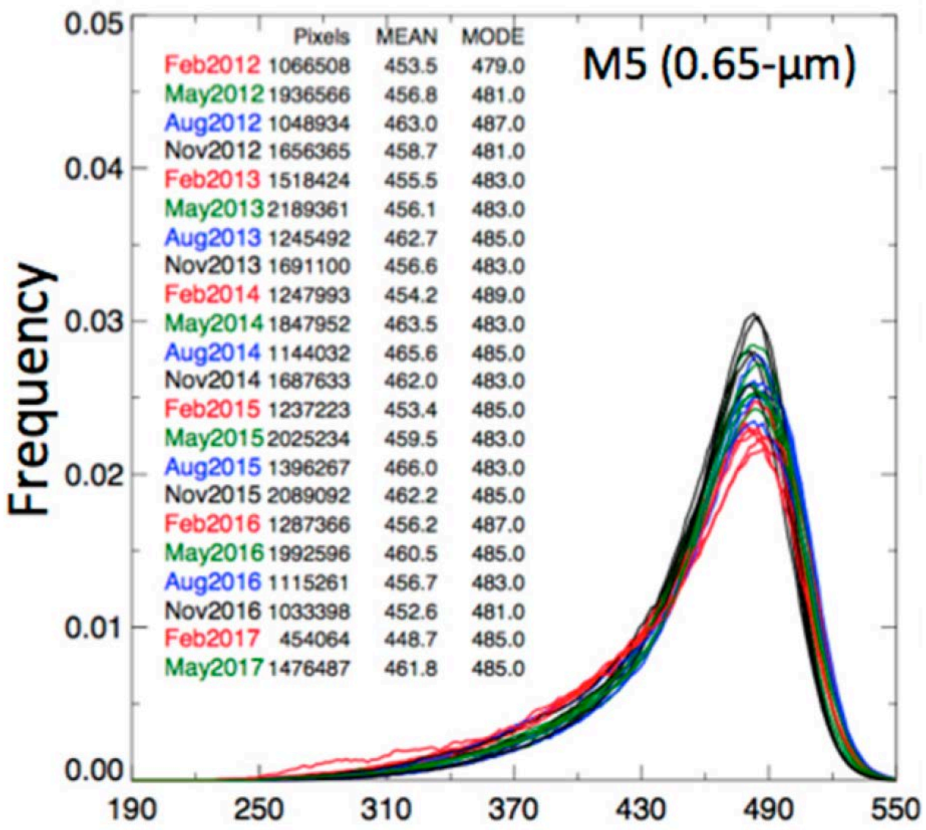




- For this month the time difference is ~2 minutes and the monthly standard error is ~2%
- When the time difference is ~11 minutes in October 2012, the standard error is ~7%

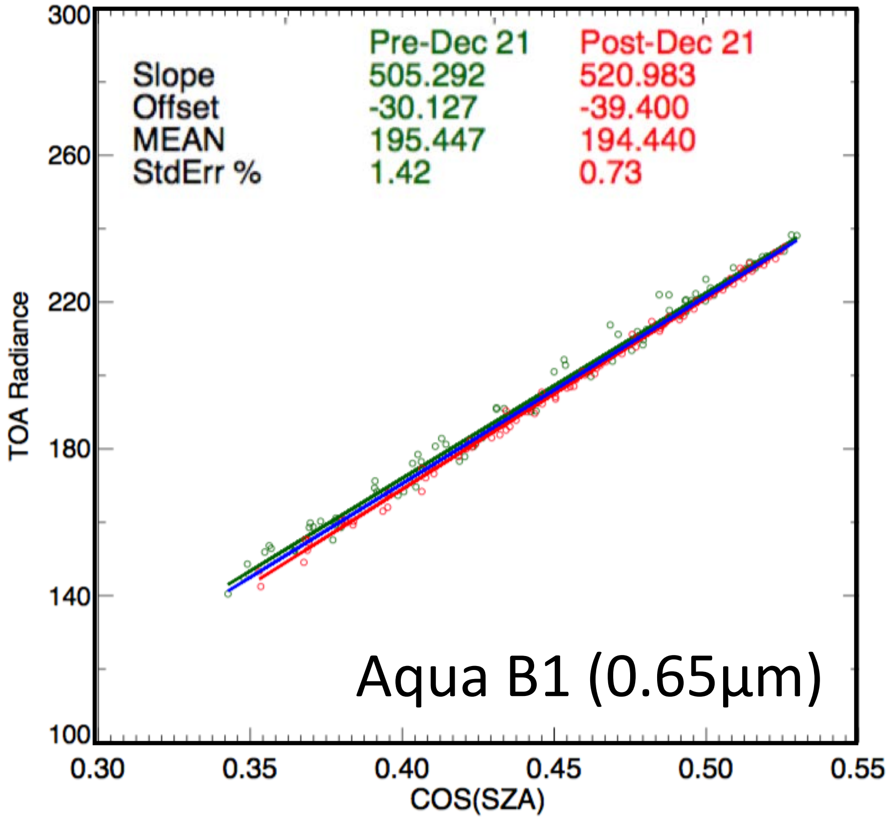


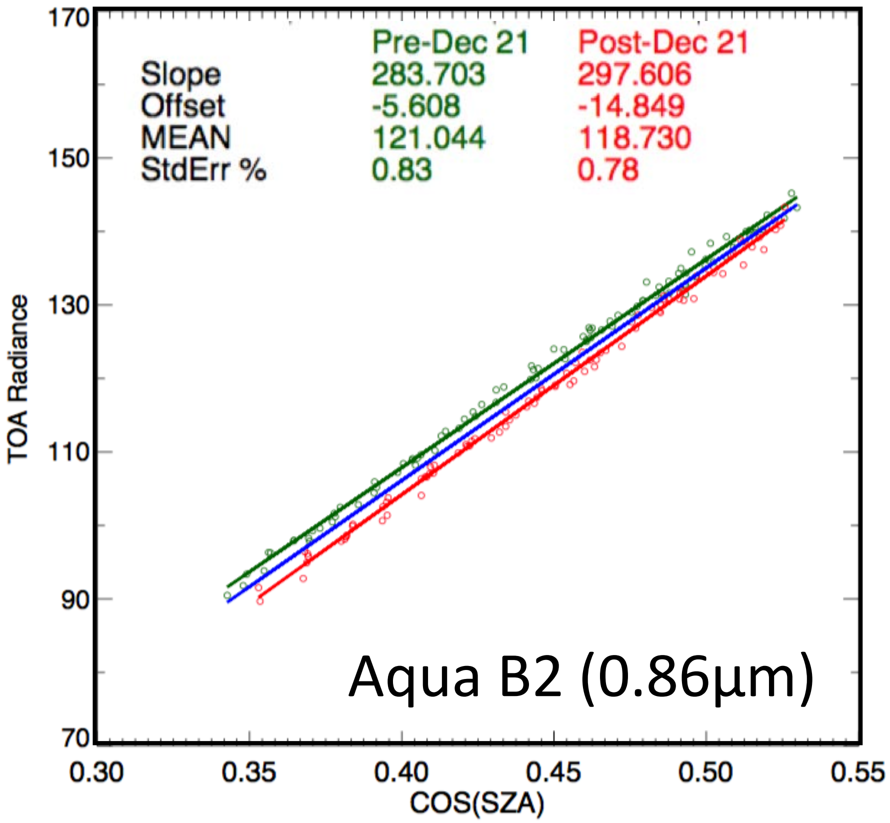
VIS/NIR DCC PICS



- DCC is a statistical approach that assumes that the collective tropical DCC reflectance is invariant, since DCC behave as solar diffusers for view < 40° and solar < 40° angles.
- DCC tops are located at the tropopause above most of the water vapor absorption and are the brightest Earth Targets
- DCC pixels are identified as having a BT<205K
- The surrounding 8 pixels σ_{VIS}<3% and σ_{IR}<1K
- Apply a near Lambertian DCC BRDF
- ¨The DCC pixels are compiled into a monthly probability density functions (PDFs) and the PDF mode DCC (peak) radiance is tracked over time. For wavelengths>1µm use the mean statistic

Dome-C PICS

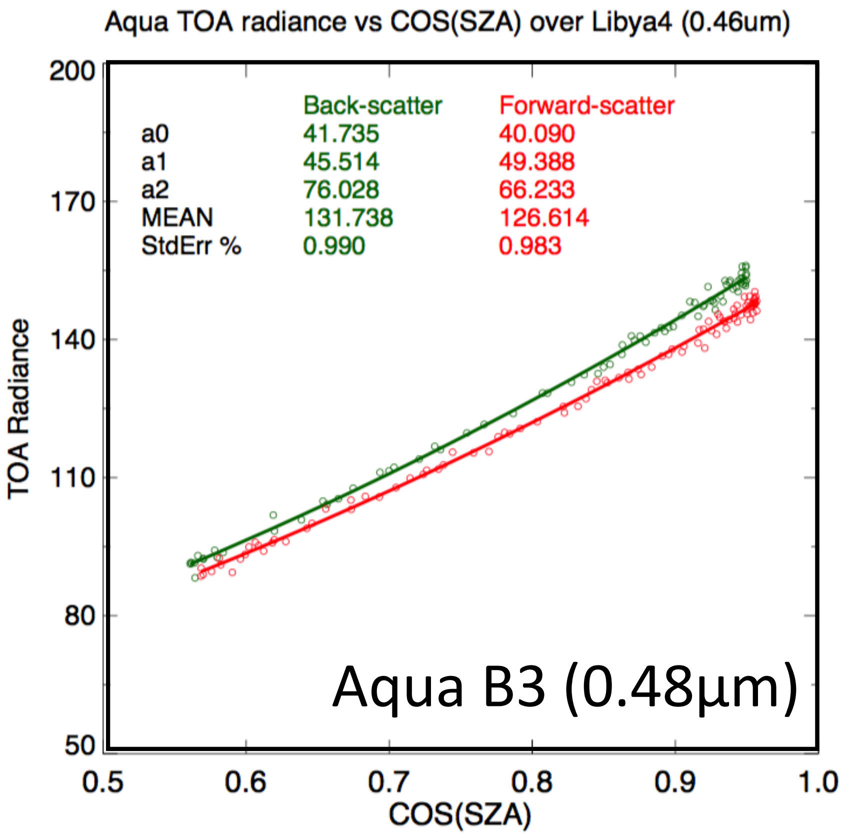


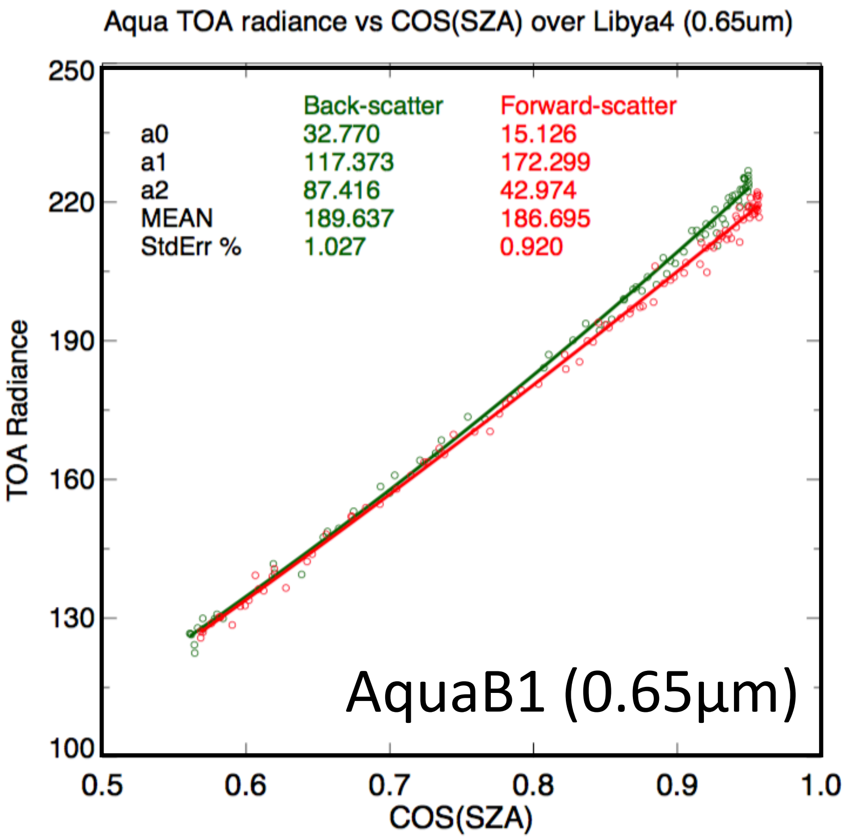


- Aqua MODIS VZA<10°, 50-km ROI radiances are regressed against the cos(SZA) for the first 5-year of operation
- To compare the VIIRS radiance with MODIS, the predicted MODIS radiance is based on the VIIRS cos(SZA) and SBAF

- It was found that the snow surface is brighter before solstice and darker afterwards. The difference increases with wavelength. This is because the snow particles are increasing in size as they melt.

Libya-4 PICS

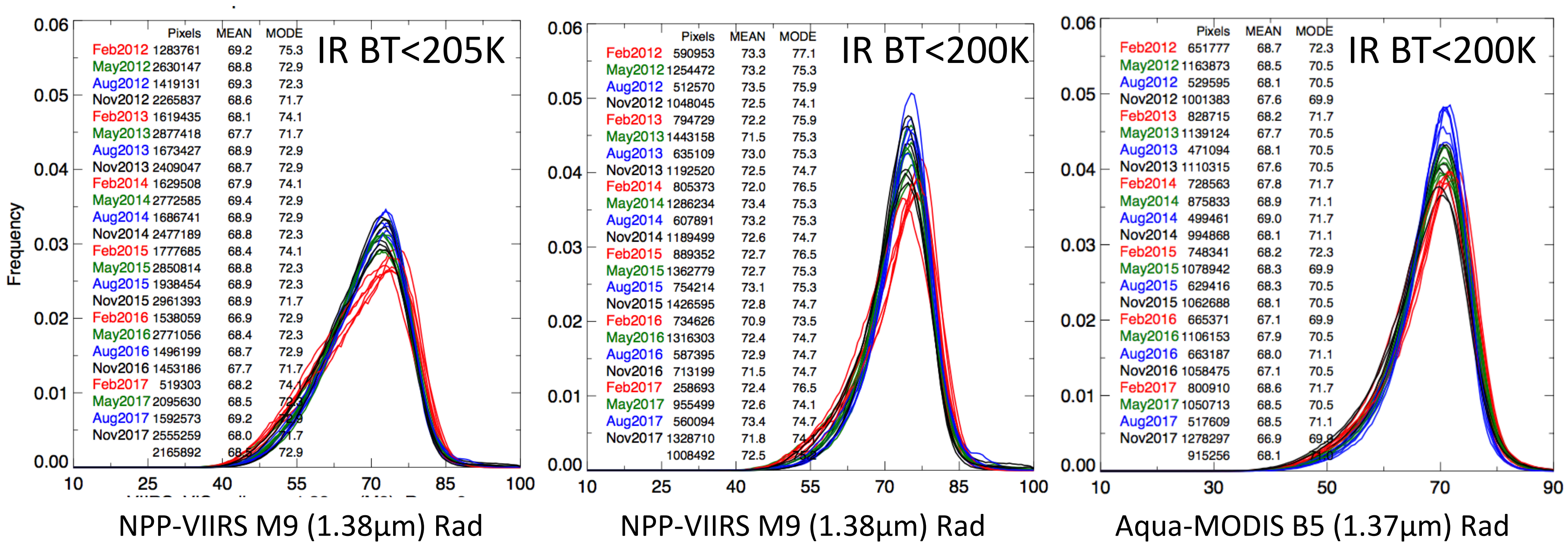




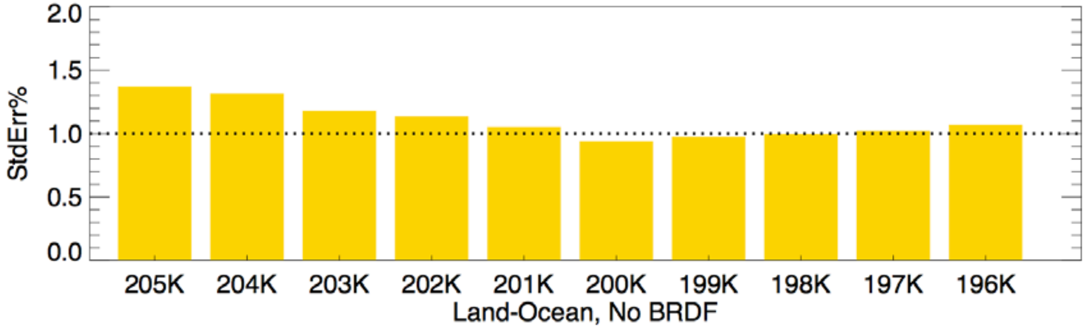
- Aqua MODIS VZA<10°, 50-km ROI radiances are regressed against the cos(SZA) for the first 5-year of operation
- To compare the VIIRS radiance with MODIS, the predicted MODIS radiance is based on the VIIRS cos(SZA) and SBAF

- It was found that the backscatter and forward scatter radiances for VZA<10° vary differently with cos(SZA) and is dependent on the Rayleigh scattering contribution
- The Libya-4 desert is very reflected in the SWIR bands, except for the 1.38µm, which is in a very strong water vapor absorption band. Only the near tropopause ice clouds can be seen in this band.

DCC IR BT threshold Cirrus Channel (1.38μm)

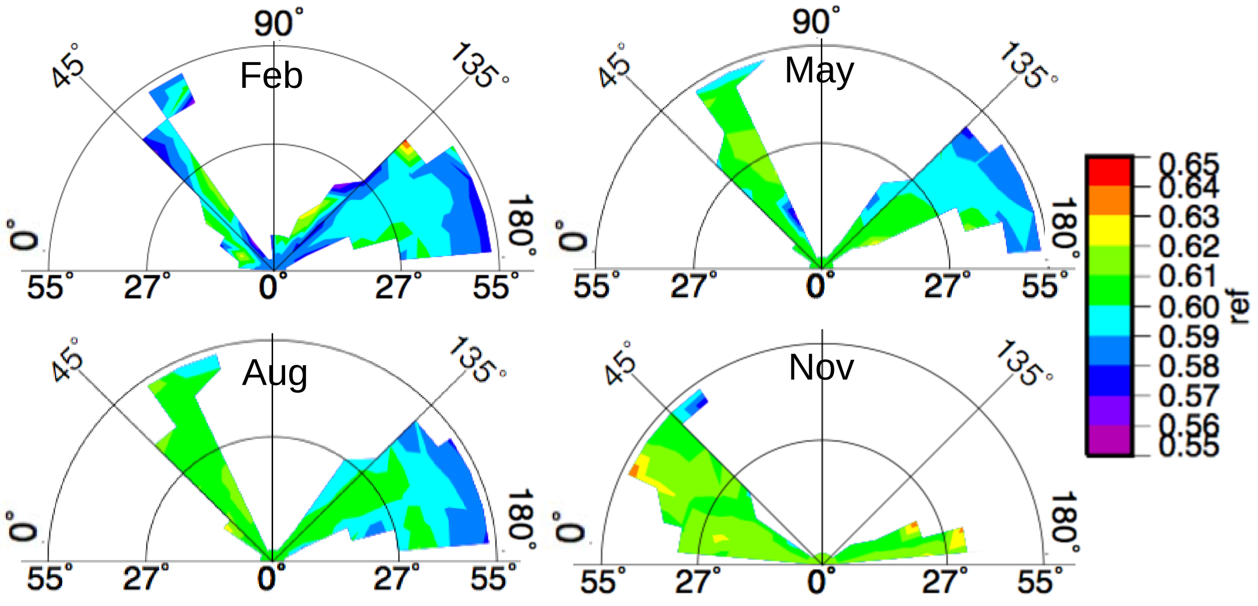


- The 1.38μm channel is located in a strong water vapor absorption band
- Only bright ice clouds near the tropopause can be observed from the satellite sensor
- Lowering the IR BT threshold sharpens the PDF and reduces the monthly temporal variability



Monthly DCC BRDFs, M9 (1.38µm)

- The DCC BRDF SWIR band reflectances and angular sampling vary monthly, due to the geographical location of DCC and associated microphysics, which varies seasonally.
- However, the inter-annual variation is much smaller than the seasonal variation
- The VIS/NIR bands have more uniform monthly BRDFs



- The monthly BRDF DCC reflectance is very effective in removing the seasonal DCC reflectivity
- The monthly BRDF DCC models can be derived from MODIS and applied to VIIRS for similar bands
- This eliminates the need for 2 more years of record in order to deseasonalize

Bias = 100% x (VIIRS-MODIS)/VIIRS

Band pair	Radiance bias (%)					
	Dome-C	Libya-4	DCC-IT	ATO-RM	DCC-RM	range
B3/M3 (0.48μm)	+1.8	+2.5	+1.4	+0.8	+2.1	1.7%
B4/M4 (0.55μm)	+2.7	+2.8	+2.1	+2.8	+3.0	0.9%
B1/M5 (0.65μm)	+1.1	+1.4	+1.1	+1.6	+2.0	0.9%
B1/I1 (0.65μm)	+0.0	+0.2	-0.4	+0.3	+0.6	1.0%
B2/M7 (0.86μm)	+0.3	+1.0		+0.5		0.5%
B5/M8 (1.24μm)		-1.4	-1.4	-1.2	-0.7	0.7%
B26/M9 (1.38μm)			+2.8	+2.8	+3.8	1.0%
B6/M10 (1.6μm)		+2.3	0.0	+1.2	+0.6	2.3%
B6/I3 (1.6μm)		+4.8	+1.9	+2.8	+2.2	2.9%

Radiance : MODIS MCST and VIIRS MODTRAN (IDPS) spectra for converting to radiance

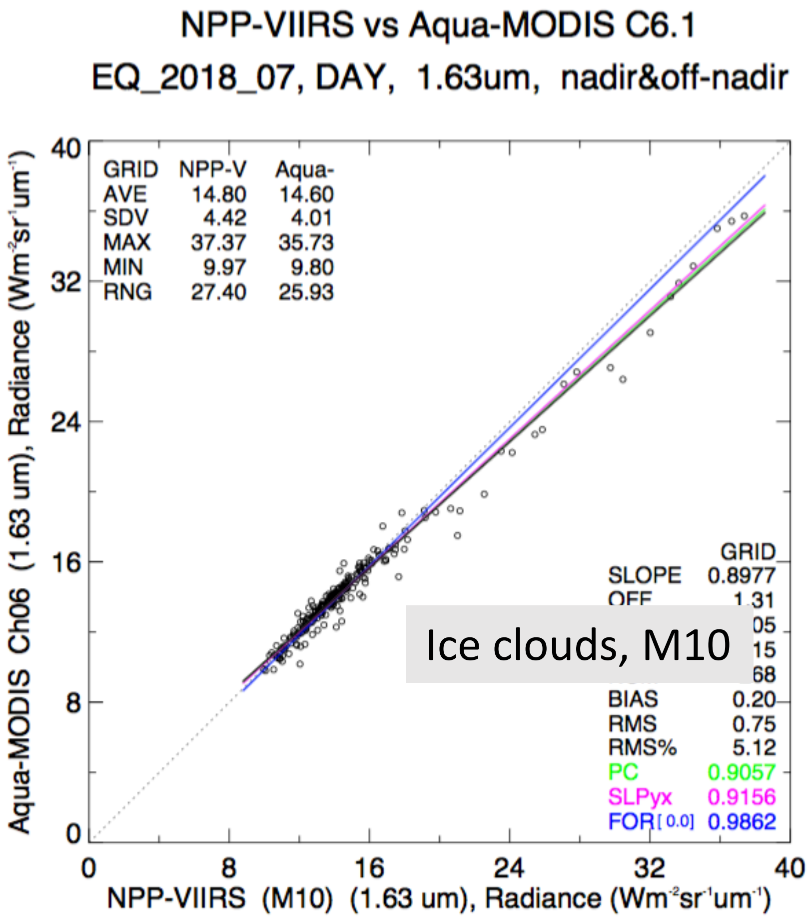
Mostly consistent within 1%

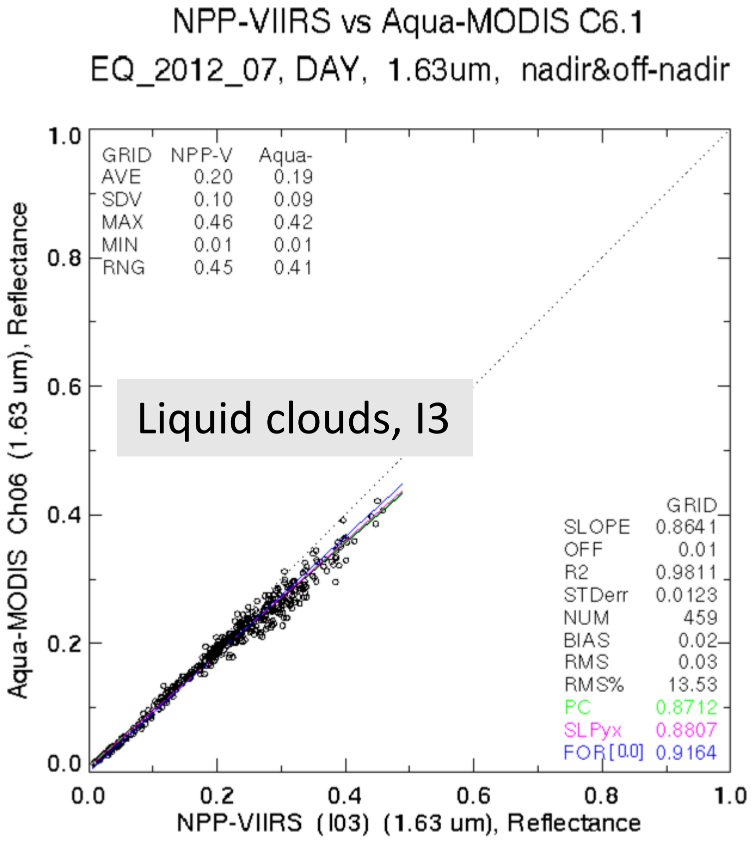
Bias = 100% x (VIIRS-MODIS)/VIIRS

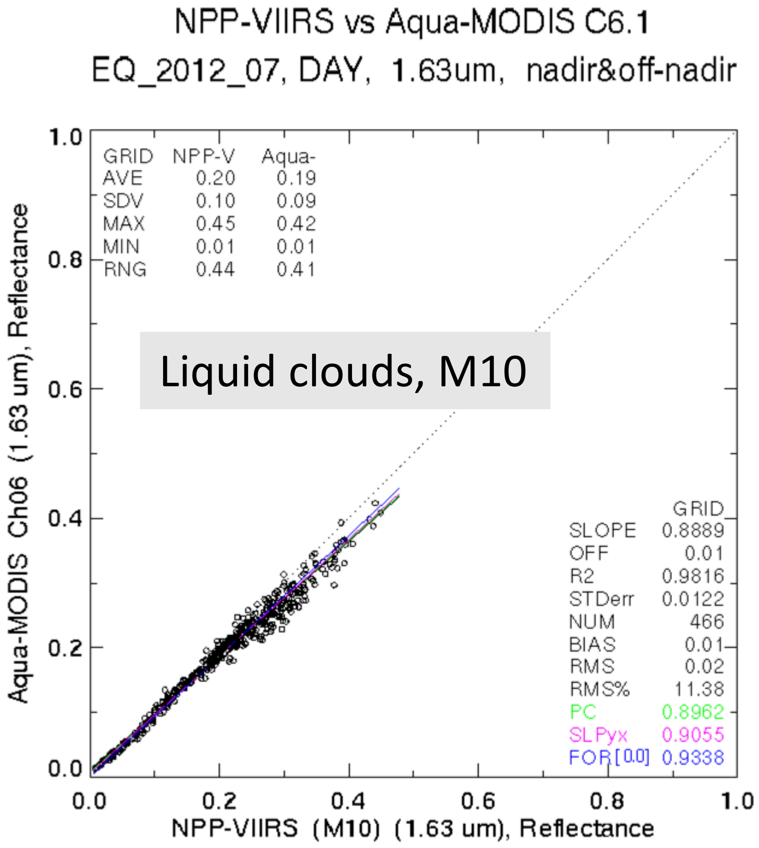
Band pair	Reflectance bias (%)					
	Dome-C	Libya-4	DCC-IT	ATO-RM	DCC-RM	range
B3/M3 (0.48µm)	+2.7	+3.4	+2.2	+1.8	+2.9	1.6%
B4/M4 (0.55µm)	+2.3	+2.5	+1.8	+2.5	+2.8	1.0%
B1/M5 (0.65µm)	+1.8	+2.1	+1.8	+2.2	+2.7	0.9%
B1/I1 (0.65µm)	+0.7	+1.0	+0.3	+1.1	+1.3	1.0%
B2/M7 (0.86µm)	+2.1	+2.7		+2.1		0.6%
B5/M8 (1.24µm)		+3.3	+2.9	+3.4	+3.7	0.8%
B26/M9 (1.38µm)			+5.2	+5.2	+5.9	0.7%
B6/M10 (1.6µm)		+3.9	+1.1	+3.2	+1.8	2.8%
B6/I3 (1.6µm)		+5.8	+2.9	+4.7	+3.5	2.9%

Mostly consistent within 1%

Comparison of MODIS and VIIRS 1.61µm



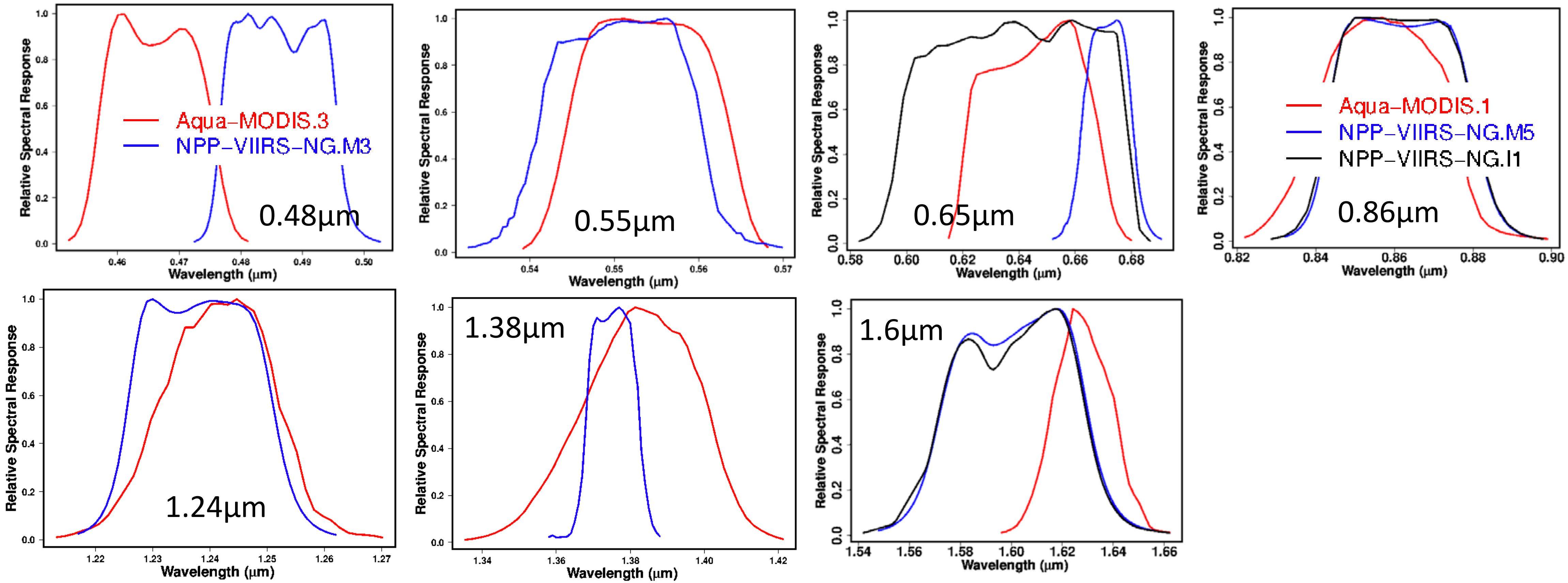




Backup Slides

MODIS and VIIRS spectral response function (SRF)

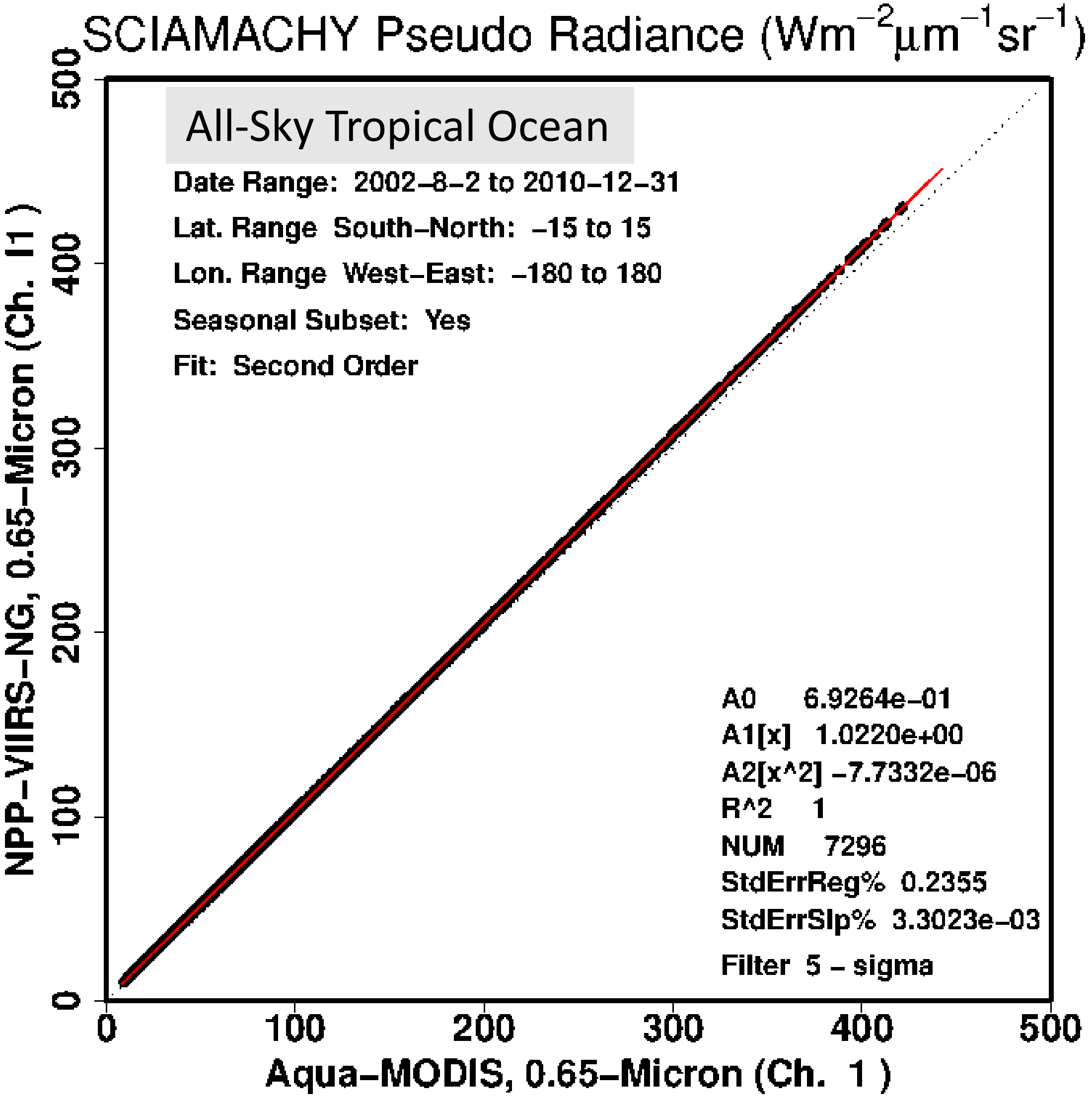
https://satcorps.larc.nasa.gov/cgi-bin/site/showdoc?docid=194&c=home2



- The MODIS and VIIRS 0.55µm, 0.86µm, 1.24µm have similar SRF
- The 0.48µm, 0.65µm, 1.38µm and 1.6µm SRF differ

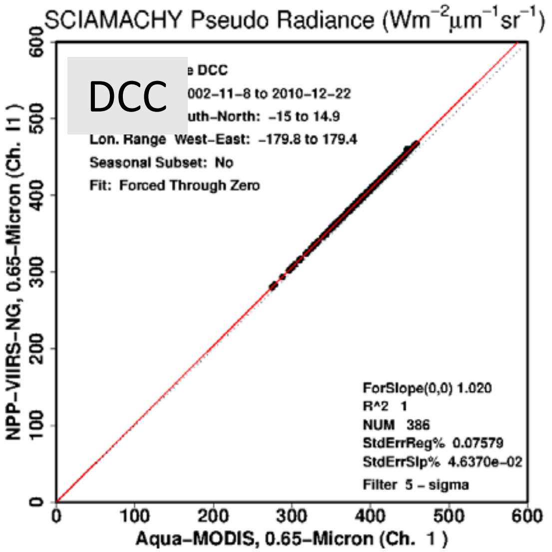
Spectral band adjustment factors (SBAF)

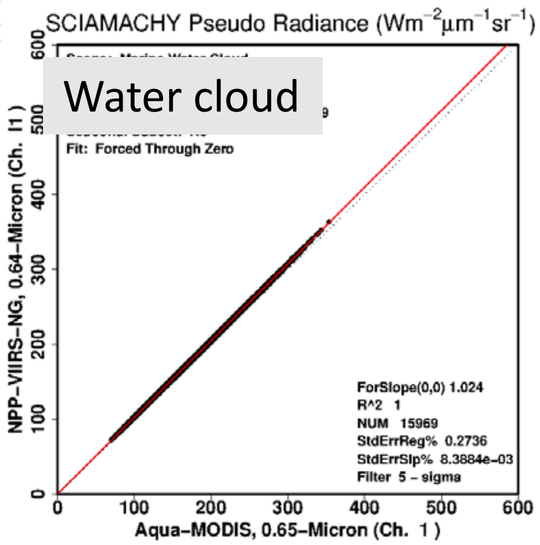
https://satcorps.larc.nasa.gov/cgi-bin/site/showdoc?docid=194&c=home2

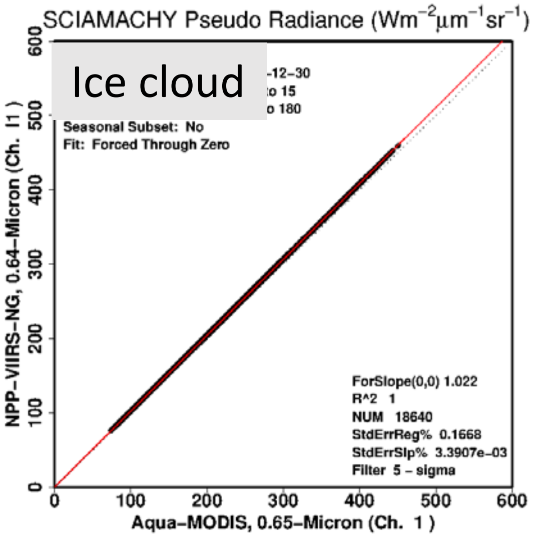


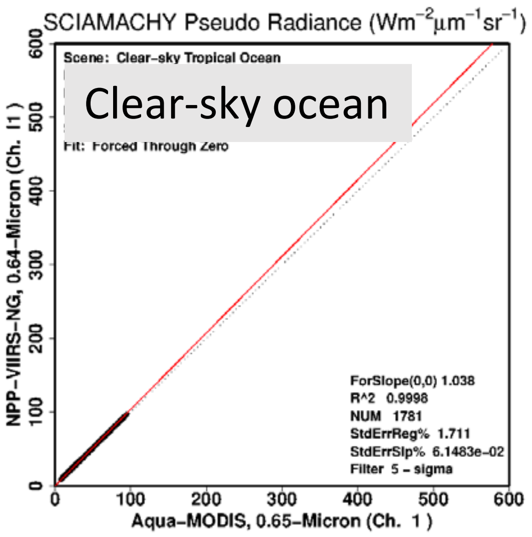
- Convolve the ENVISAT (10AM) SCIAMACHY spectral radiances using the Aqua-MODIS B1 and VIIRS I1 spectral response functions over the given scene conditions
- For all all-sky tropical ocean conditions the scene conditions are dependent on the radiance. Use 2nd order fit to determine SBAF as a function of radiance
- The SCIAMACHY-SBAF represents the average conditions of the inter-calibration domain. Use the tool surface type and angular selections to represent the inter-calibration conditions.

MODIS B1 and VIIRS I1 (0.65µm) SBAFs









- Validate using single scene (DCC, ice cloud, water cloud and clear-ocean) to validate the ATO 2nd order fit

SBAF	Linear regression	ATO 2nd order fit @ rad ()
DCC	1.020	1.022 (400)
Ice cloud	1.022	1.022 (300)
Water cloud	1.024	1.023 (250)
Clear-Ocean	1.038	1.035 (50)

- Even for SRFs that are very similar the scene conditions must be properly accounted for in the SBAF

MODIS and VIIRS solar spectra and solar constant

https://satcorps.larc.nasa.gov/cgi-bin/site/showdoc?mnemonic=SOLAR-CONSTANT-COMPARISONS

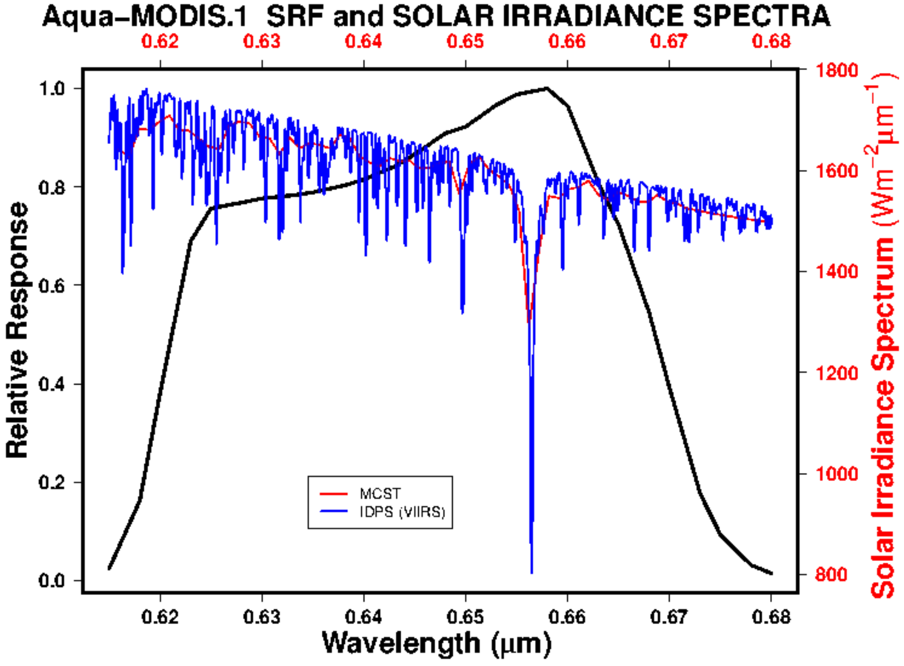
Solar Constant Comparison

Band Solar Constant Comparisons

SRF	Solar Spectra (1)	Solar Spectra (2)	Solar Spectra (3)	Solar Spectra (4)
ATS-2	Thuillier-2003	None	None	None
Aqua-MODIS	SORCE	Thuillier-2003	Thuillier-2003	Thuillier-2003
CERES-BB	MCST	SORCE	SORCE	SORCE
COMS-1	Wherli-YYYY	MCST	MCST	MCST
DSCOVR-EPIC	Kurucz-YYYY	Wherli-YYYY	Wherli-YYYY	Wherli-YYYY
EO-1-ALI	Thekaekara	Kurucz-YYYY	Kurucz-YYYY	Kurucz-YYYY
FY-2C	IDPS (VIIRS)	Thekaekara	Thekaekara	Thekaekara
FY-2D	SCIAMACHY	IDPS (VIIRS)	IDPS (VIIRS)	IDPS (VIIRS)

Central Wavelength: 0.65 Micron (1) Plot

Plot of /prod/website/temp/SOLAR_CONST/Aqua-MODIS.1_web-invoke-14290.gif below



Spectral Response File: Aqua-MODIS.1						
Solar Spectrum Reference	Band Center (micron)	Eqv. Width (microns)	Flux (W m-2)	IRRADIANCE (W m-2 um-1)	RADIANCE (W m-2 um-1 sr-1)	Solar Constant (Mean Sun-Earth Distance)
MCST (MODIS)	0.64586	0.04248	67.96754	1600.12512	509.33563	1380.4011
IDPS (VIIRS)	0.64586	0.04249	67.76243	1594.93616	507.68393	1367.9952

Both MODIS and VIIRS RSB calibration is reflectance based

MODIS uses for 0.4 to 0.8µm Thuillier et al 1998,
0.8 to 1.1µm Neckel and Labs, 1984
1.1 to 2.3µm Smith Gottlieb 1974

NPP-VIIRS uses MODTRAN 4.3 solar spectra

N20-VIIRS uses Thuillier 2003

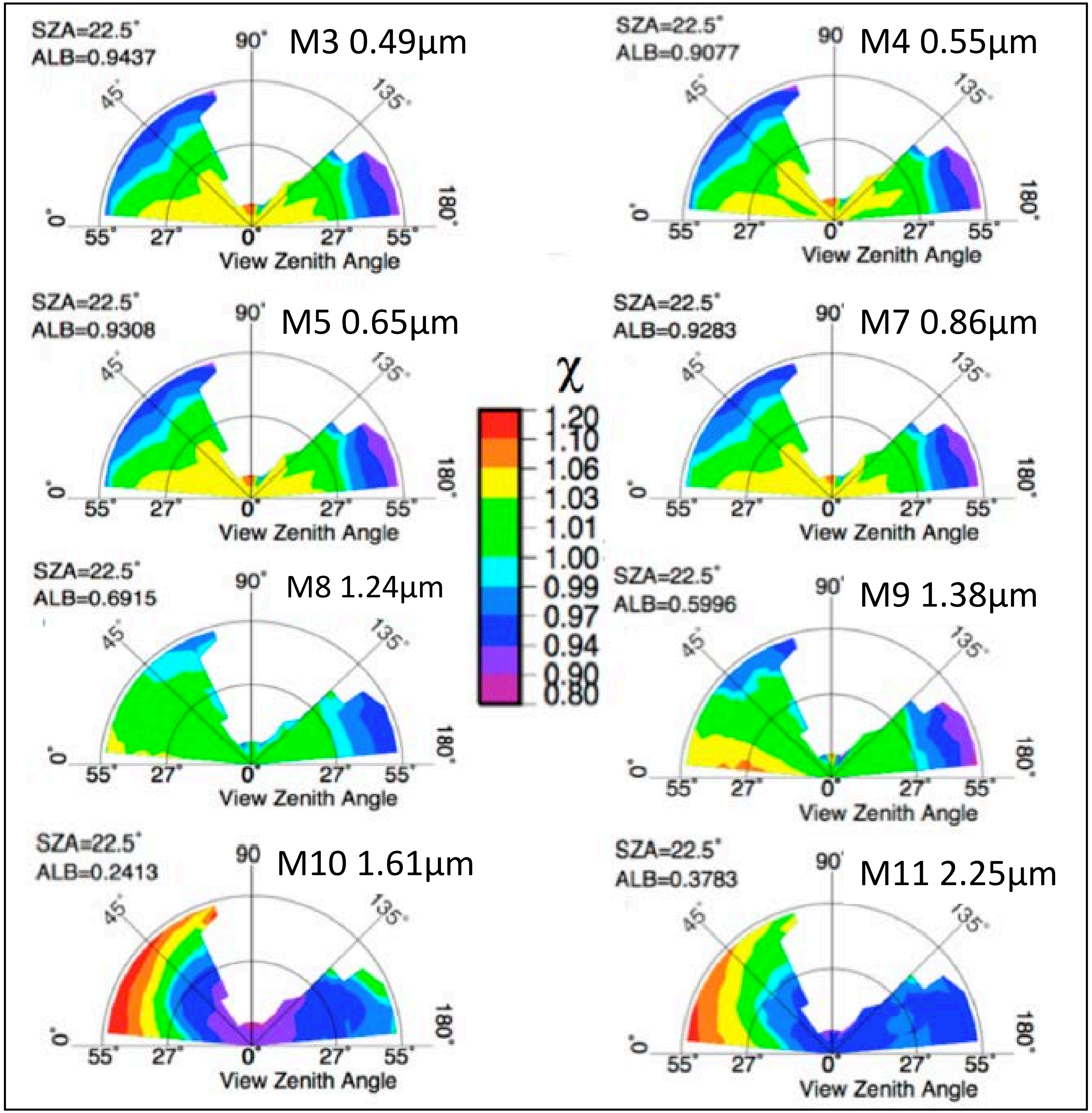
Band center µm	MODIS/ VIIRS Bands	MODIS MCST ($Wm^{-2}sr^{-1}\mu m^{-1}$)	VIIRS IDPS ($Wm^{-2}sr^{-1}\mu m^{-1}$)	Solar Constant RATIO
0.48	B3/M3	664.70	636.54	+4.4%
0.55	B4/M4	593.73	595.13	-0.2%
0.65	B1/I1	509.34	518.34	-1.7%
0.65	B1/M5	509.34	487.08	+4.1%
0.86	B2/M7	315.73	306.36	+3.1%

Inter-calibration performed using Radiances for this study

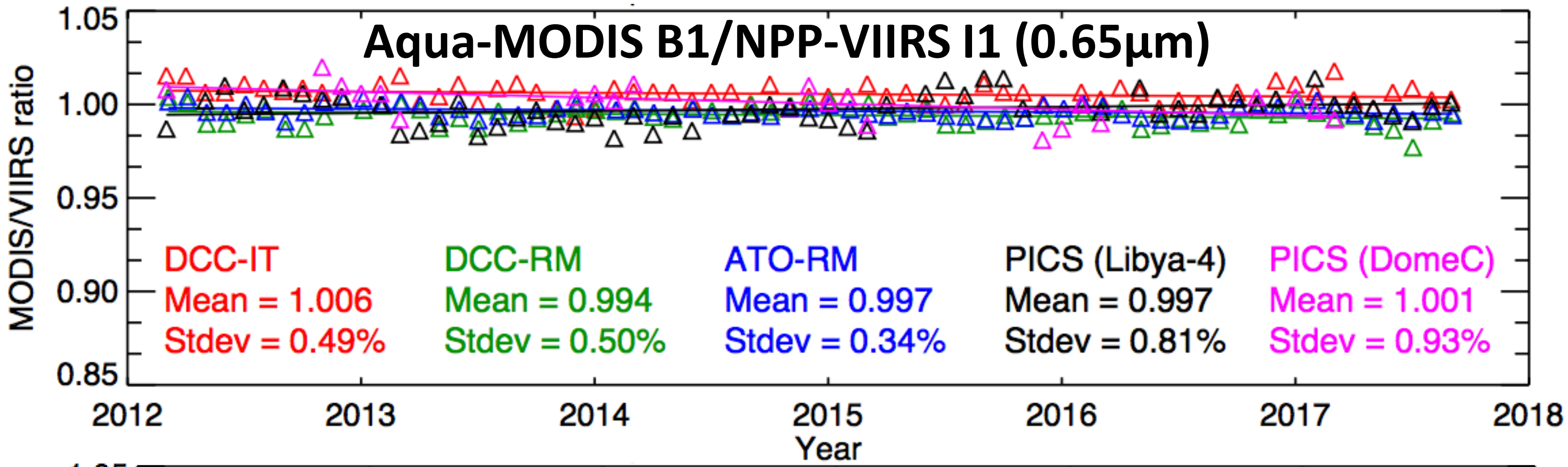
NPP-VIIRS DCC BRDFs

- For VIS/NIR bands the BRDF has a similar structure across bands and is brightest near nadir
- For the 1.24µm band the BRDF is nearly Lambertian
- For the other SWIR bands, the DCC forward scatter is greater than the backscatter and the near nadir reflectances are darker than for larger view angles

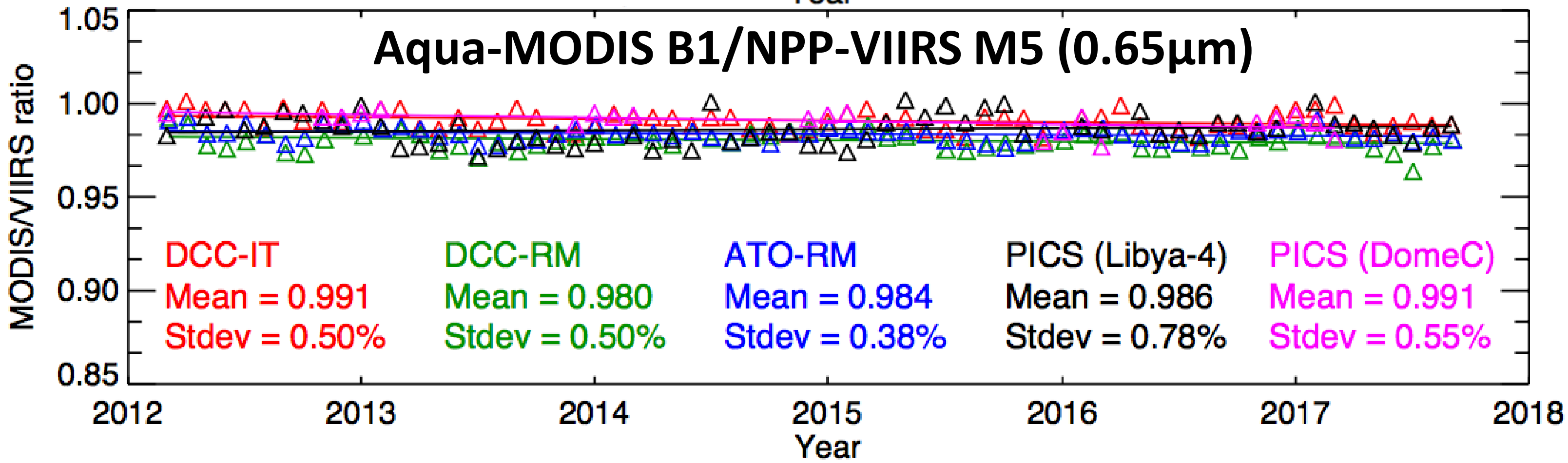
Based on 5 years of NPP-VIIRS DCC reflectances



MODIS/VIIRS 0.65µm band relative calibration



All methods within 1.2%



All methods within 1.1%

- For this wavelength the ray-matching and DCC methods provide the lowest uncertainties over time
- NPP VIIRS M5 band is brighter by ~1.5% than the I1 band. The I1 band is more consistent with Aqua B1