EPIC VIS-NIR calibration using MODIS, MISR and VIIRS

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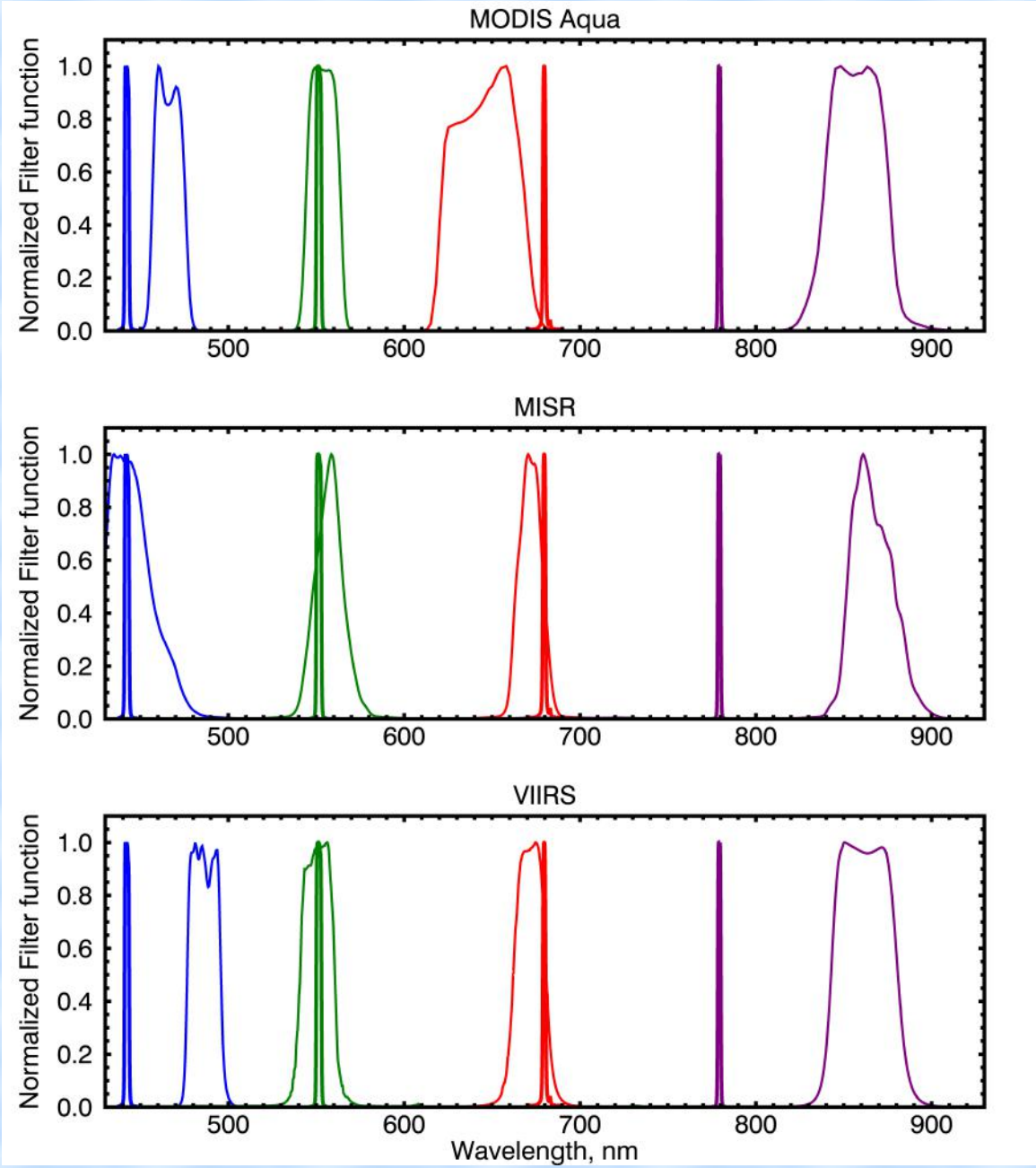


- 4 non-absorbing EPIC visible and NIR channels (443nm,551nm,680nm,780 nm)
- Four spectral radiometers:

MODIS Aqua and Terra

(Ch3, Ch4, Ch1 Ch2)

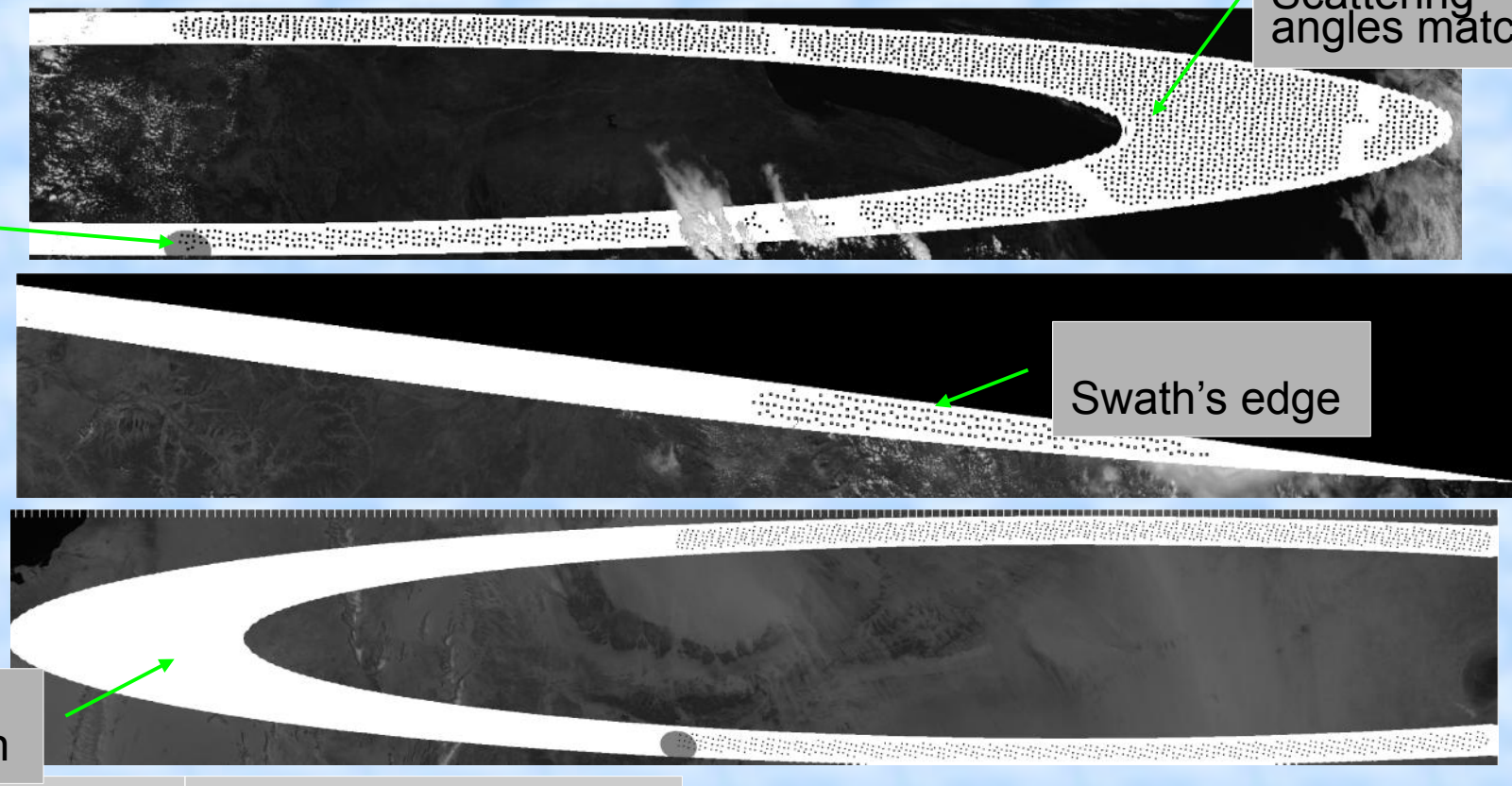
MISR (BGR and NIR)

NPP VIIRS

(M3, M4, M5, M7)

- EPIC Ver 3 data to 2020/08

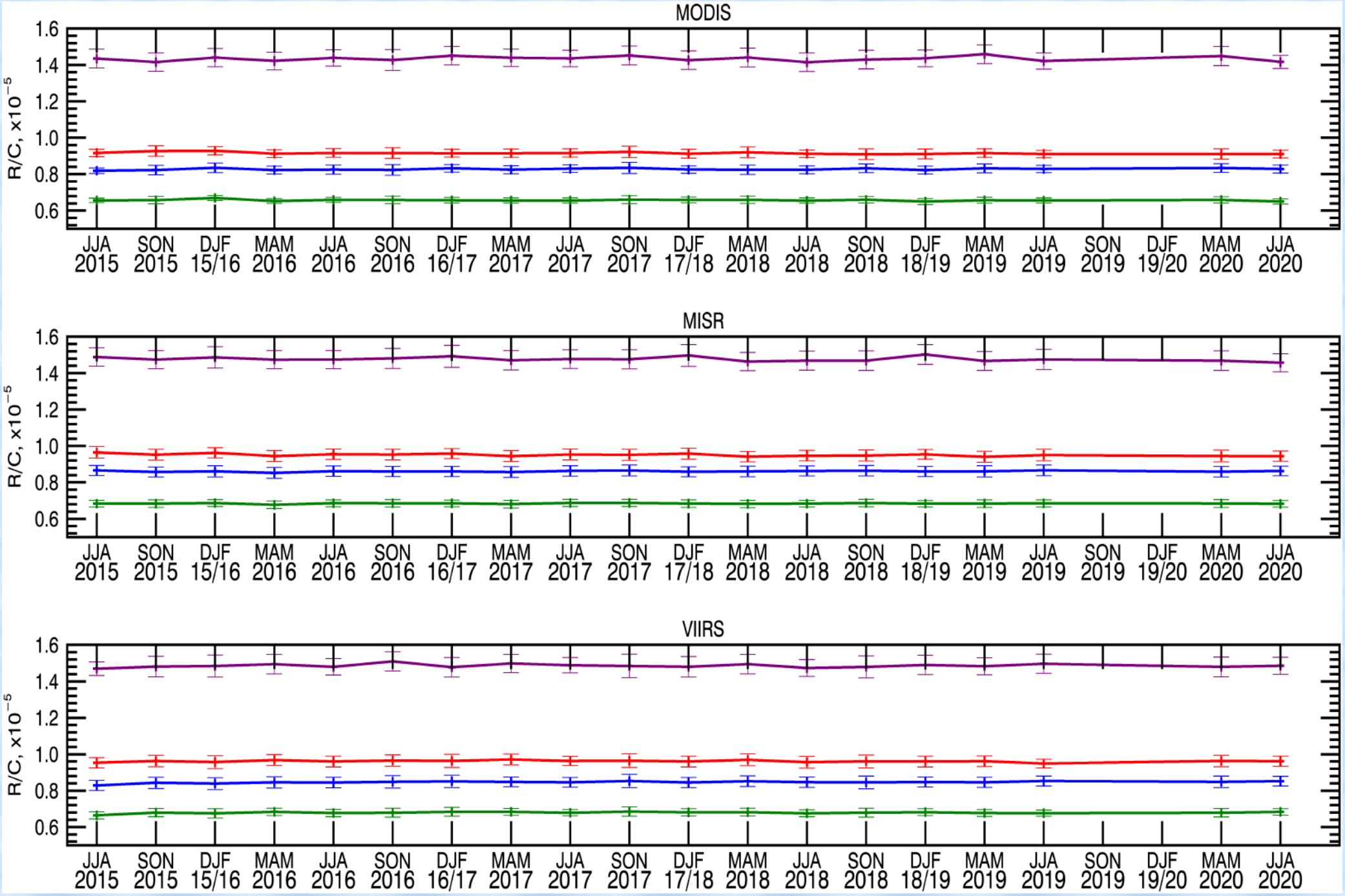
Pixel matching



Scattering angle match	<1.5° (<3.0° for MISR)
Temporal collocation	< 7min
Spatial collocation	< 25km
MODIS pixels within collocation area	Over 2/3 of the area

Solar zenith angle	< 60°
Glint removal	glint angle < 40°
Temporal filter	Remove images with R/C ratios outside 3σ

Seasonal mean reflectance/counts (R/C) ratios



Calibration gains to 2019/06

	EPIC gains ($x10^{-5}$) vs			Relative difference	
	MODIS*	MISR	VIIRS**	MODIS-VIIRS	MISR-VIIRS
443nm	0.8330	0.8686	0.8528	-2.3%	1.9%
551nm	0.6617	0.6882	0.6842	-3.3%	.6%
680nm	0.9238	0.9565	0.9658	-4.3%	1%
780nm	1.4538	1.4834	1.4887	-2.3%	.36%

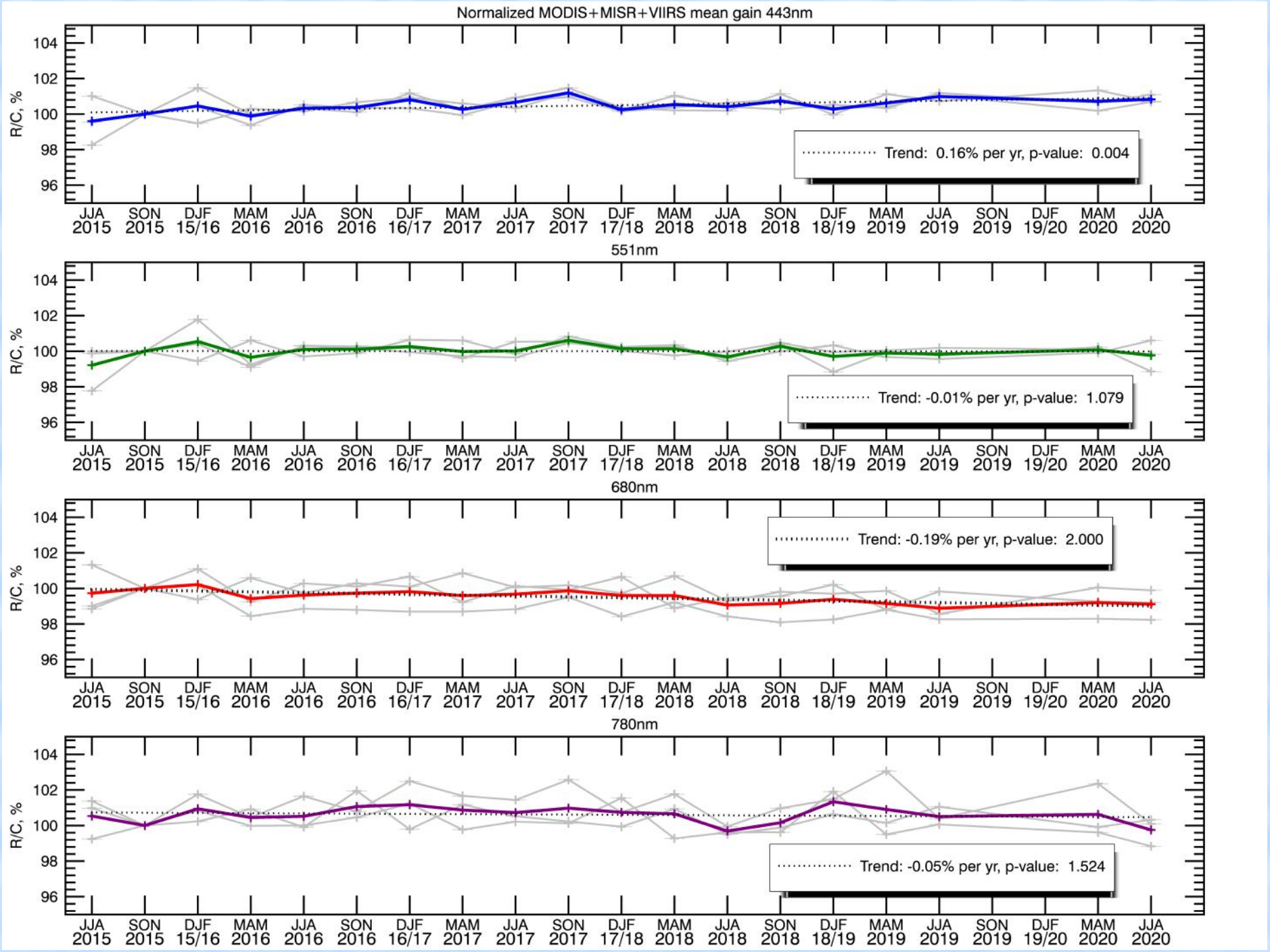
* 1.4%, 0%, 1.2%, 2.6% differences with corresponding values from
** Agree to within 0.4% with corresponding values from

Doelling, D., C. Haney, R. Bhatt, B. Scarino, A. Gopalan (2019) The Inter-Calibration of the DSCOVR EPIC Imager with Aqua-MODIS and NPP-VIIRS, Remote Sens. 2019, 11,1609; doi:10.3390/rs11131609

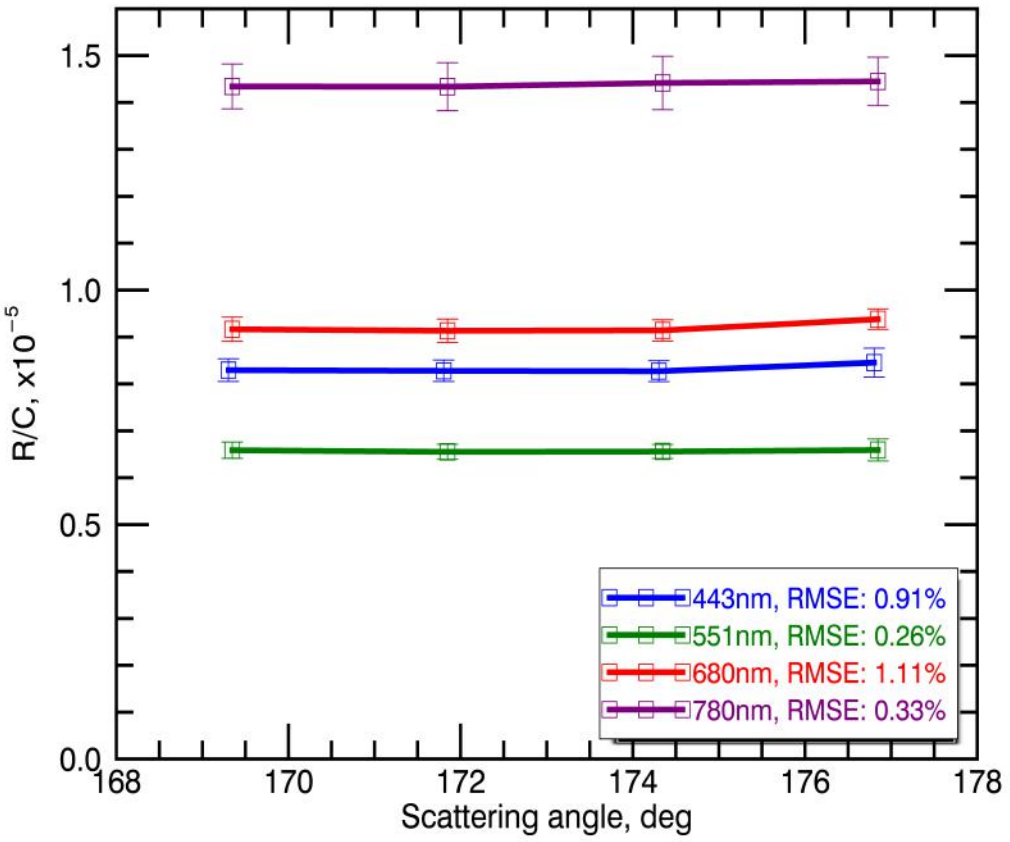
Calibration gain trends

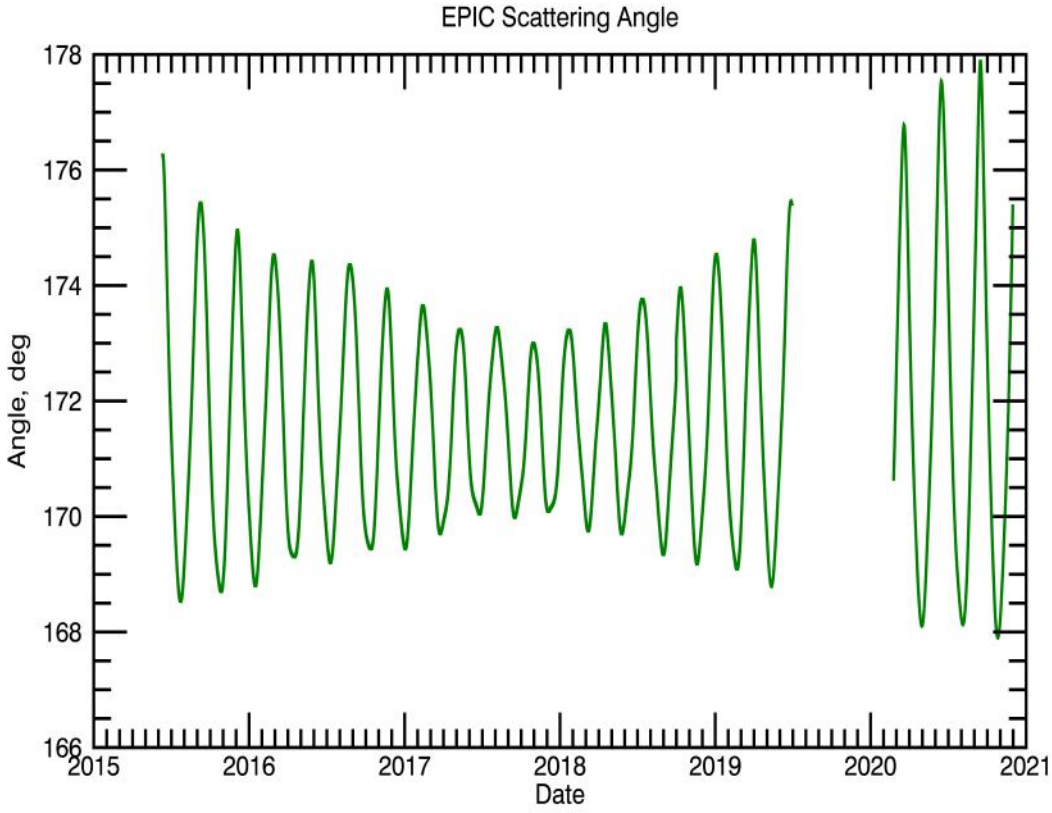
	Epic channel	Absolute linear trend per year	Relative linear trend per year	Significance	Relative RMSE
MODIS	443nm	1.19E-08	0.14%	NO (p=0.12)	0.52
	551nm	-9.99E-09	-0.15%	NO (p=1.86)	0.59
	680nm	2.22E-08	-0.24%	NO (p=1.99)	0.45
	780nm	4.09E-09	0.03%	NO (p=0.85)	0.88
MISR	443nm	5.96E-09	0.07%	NO (p=0.3)	0.39
	551nm	4.16E-10	0.01%	NO (p=0.92)	0.34
	680nm	-2.69E-08	-0.28%	NO (p=1.99)	0.56
	780nm	-3.00E-08	-0.20%	NO (p=1.89)	0.72
VIIRS	443nm	2.31E-08	0.27%	YES (p=.006)	0.52
	551nm	8.83E-09	0.13%	NO (p=0.24)	0.64
	680nm	-3.93E-09	-0.04%	NO (p=1.34)	0.54
	780nm	2.48E-09	0.02%	NO (p=0.88)	0.64

Normalized MODIS+MISR+VIIRS trend



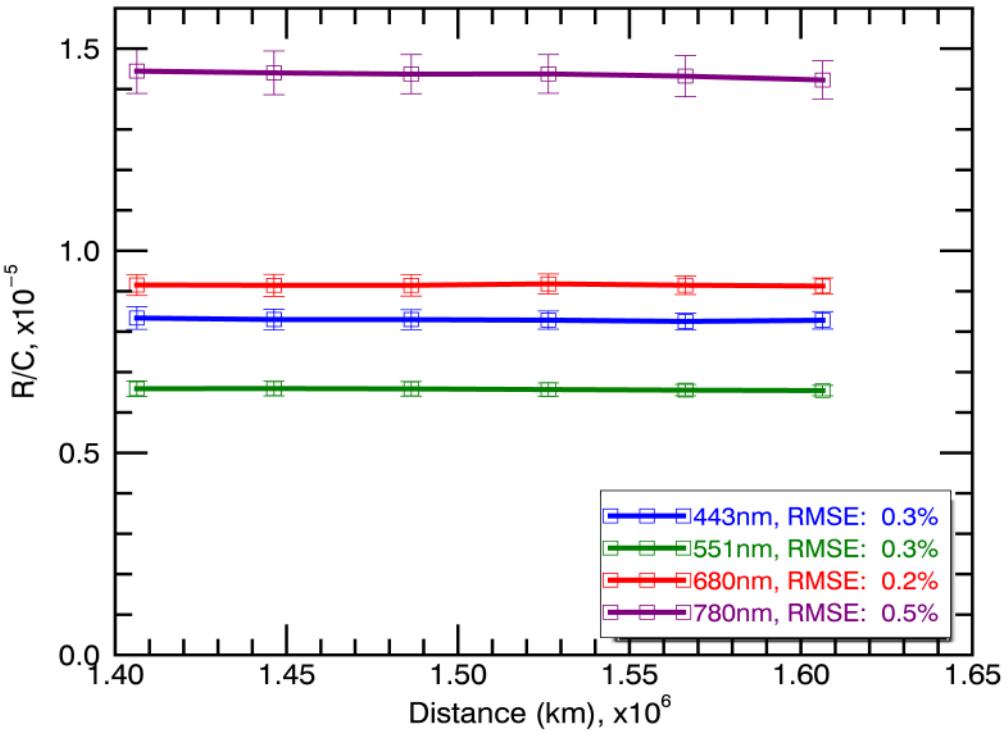
Scattering Angle Dependence

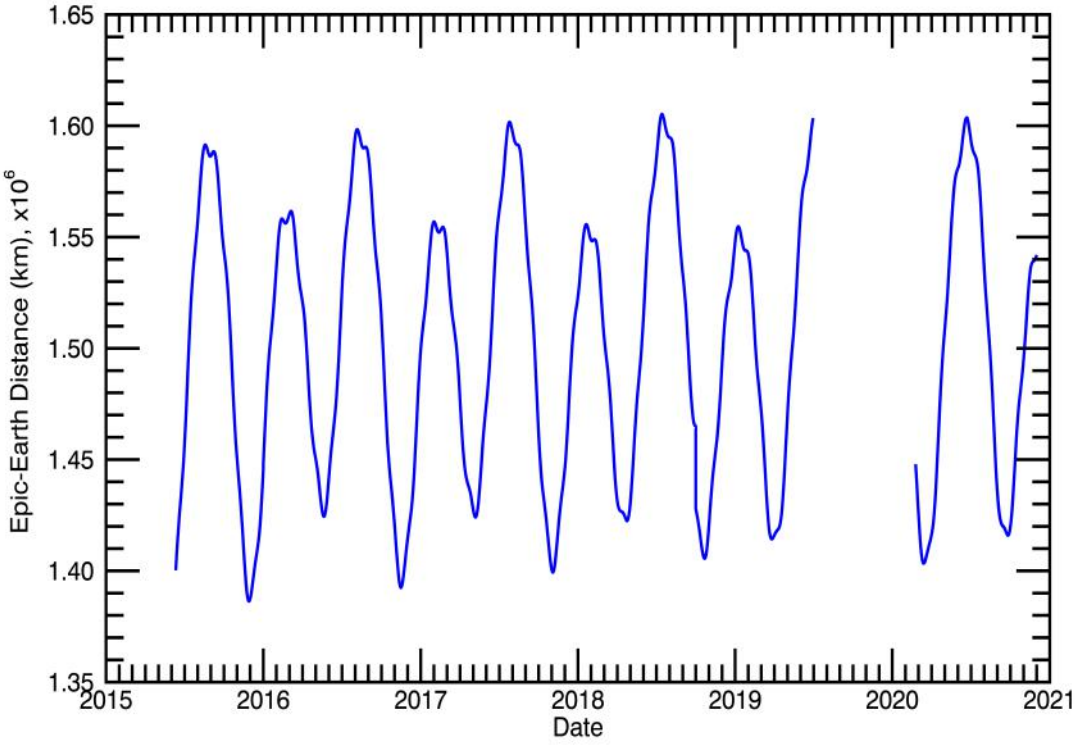




Analysis of the entire EPIC detrended dataset shows no significant dependence on EPIC scattering angle.

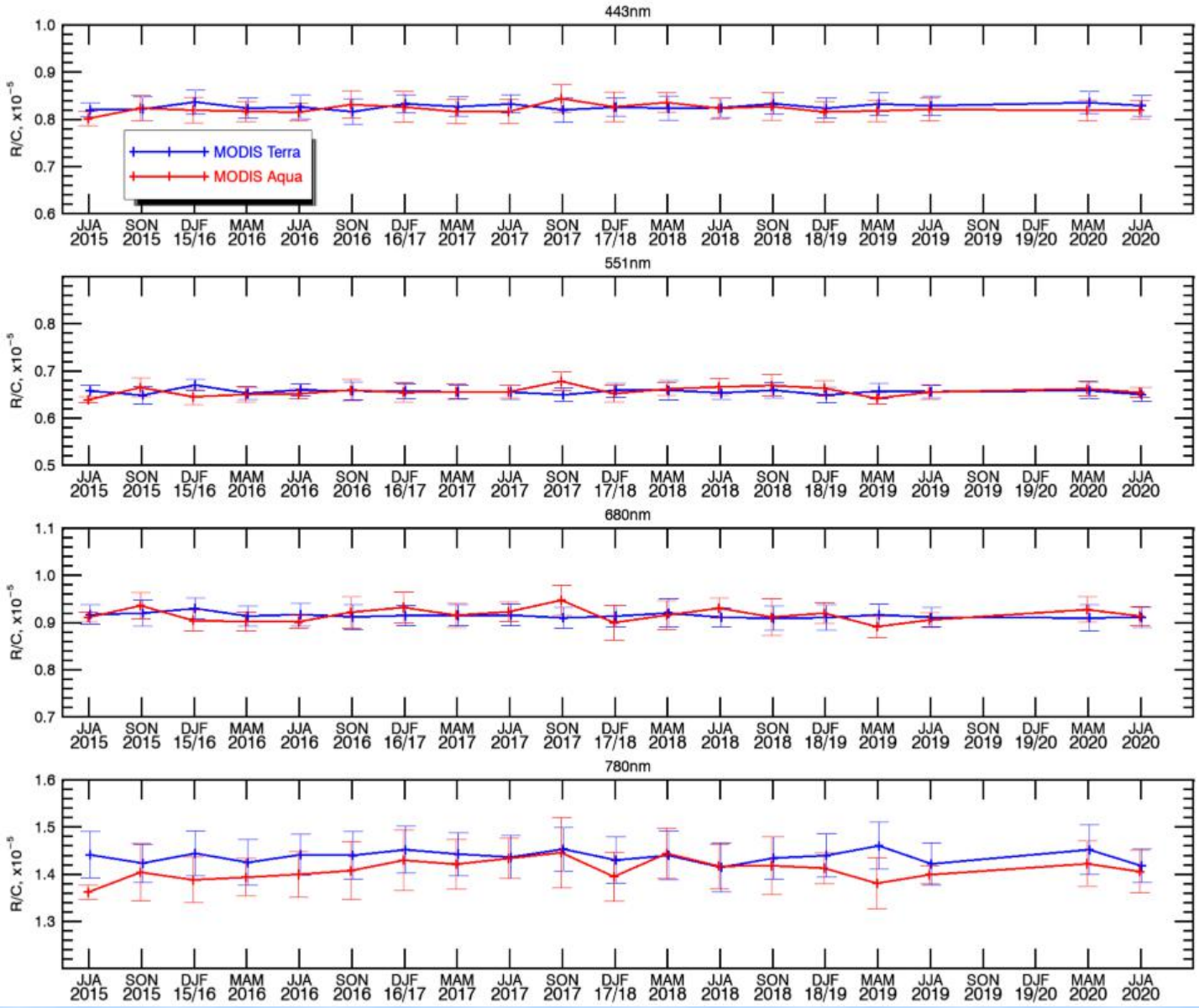
Epic-Earth Distance Dependence





Analysis of the entire EPIC detrended dataset shows no significant dependence on Earth-EPIC distance.

Aqua and Terra Comparison



EPIC Chn	Terra RMSE	Aqua RMSE
443 nm	.68%	1.06%
551 nm	.75%	1.41%
680 nm	.53%	1.51%
780 nm	.86%	1.47%

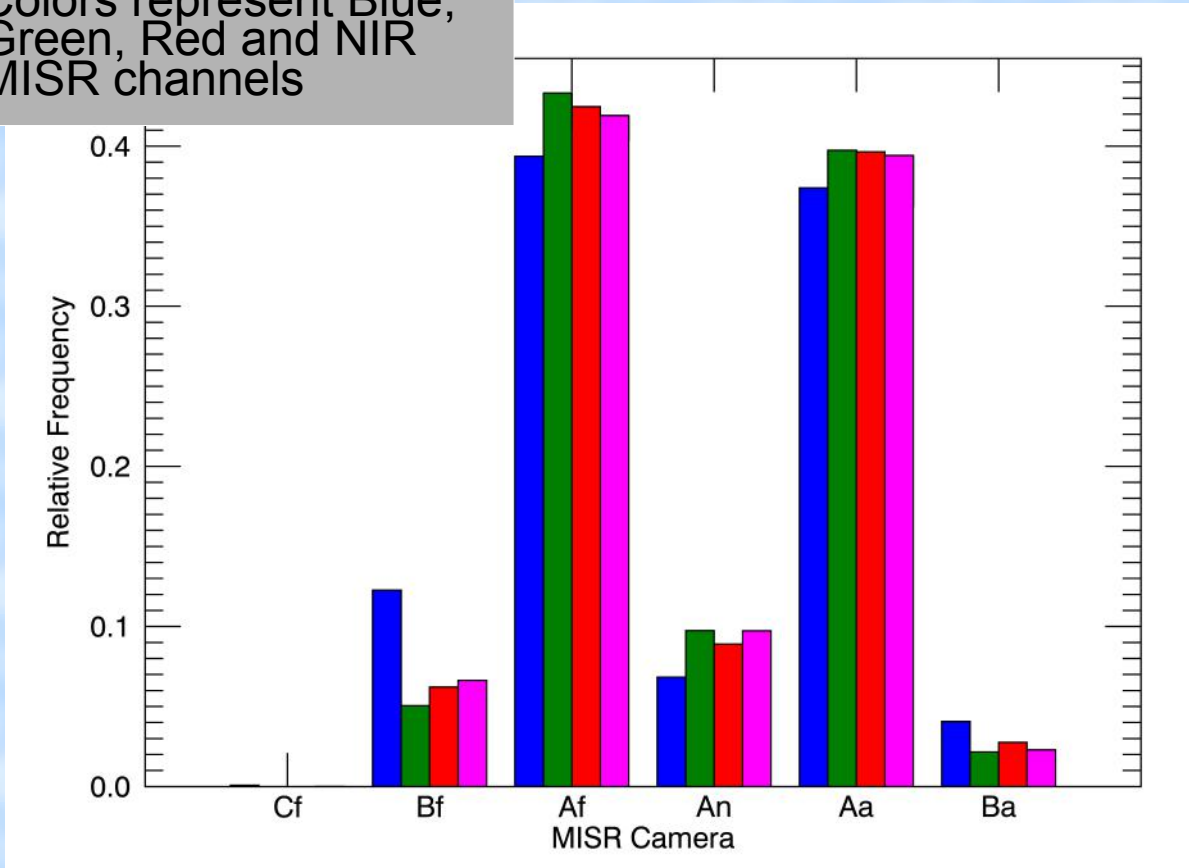
EPIC Chn	Terra-Aqua diff	KS test Signifi-cant	Relative RMSE diff
443 nm	0.61%	No (p=.05)	1.5%
551 nm	-0.13%	No (p=.25)	1.9%
680 nm	-0.19%	No (p=.25)	1.75%
780 nm	1.96%	Yes p=.0005	2.53%

- Higher RMSE for Aqua
- Statistically significant (Kolmogorov-Smirnov test) differences exist between Aqua- and Terra- derived 780nm gains
- Aqua 780nm R/C ratios may show time dependence

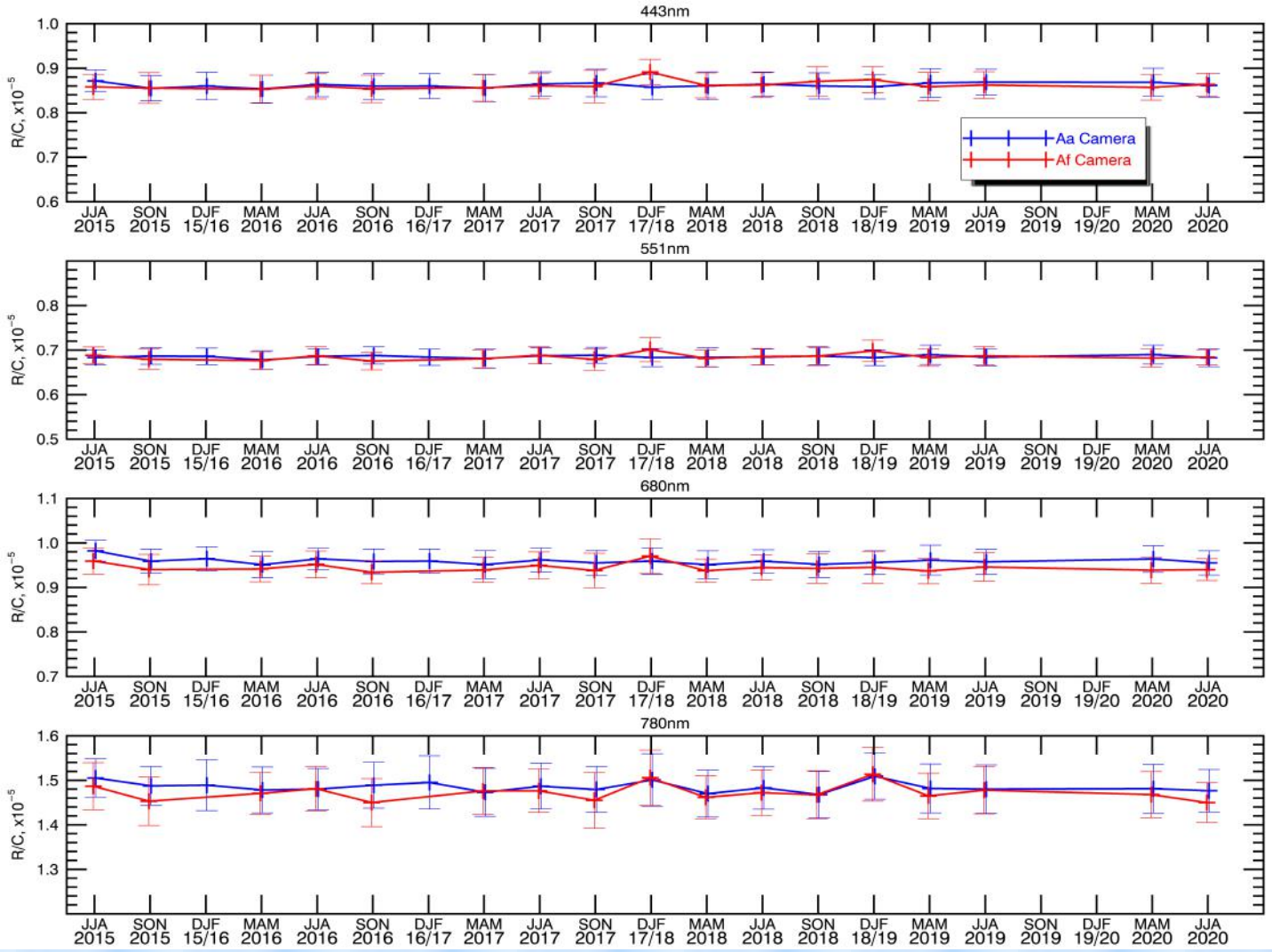
MISR Cameras comparison I

- MISR has a nadir, 4 forward and 4 aftward cameras
- Over 80% of EPIC matches are viewed through the two cameras closest to nadir (Af and Aa)
- We can compare the calibration gains derived separately for the two cameras

Colors represent Blue, Green, Red and NIR MISR channels



MISR Cameras comparison II



EPIC Chn	Aa-Af Cam diff	Signifi-cant?	Relative RMS diff
443 nm	0.03%	No (p=.5)	1%
551 nm	-0.02%	No (p=.3)	1%
680 nm	-1.53%	Yes (p=0)	1.7%
780 nm	-0.85%	Yes p=.004	1.4%

EPIC calibration gains based on MISR forward and aftward cameras show differences on the order of 1.5% which are statistically significant in red and NIR channels

Modeling EPIC Reflectances

EPIC and MODIS view a collocated scene at the same scattering angle but view and azimuth angles may differ.

How does the differences in viewing geometry affect EPIC calibration coefficients?

Are there systematic differences due to viewing geometry between MODIS Aqua (morning satellite) and MODIS Terra (afternoon satellite) and between MISR cameras?

We calculated a reflectance look-up table for water clouds of various brightness.

We then calculate what EPIC and MODIS would see had they flown over such clouds.

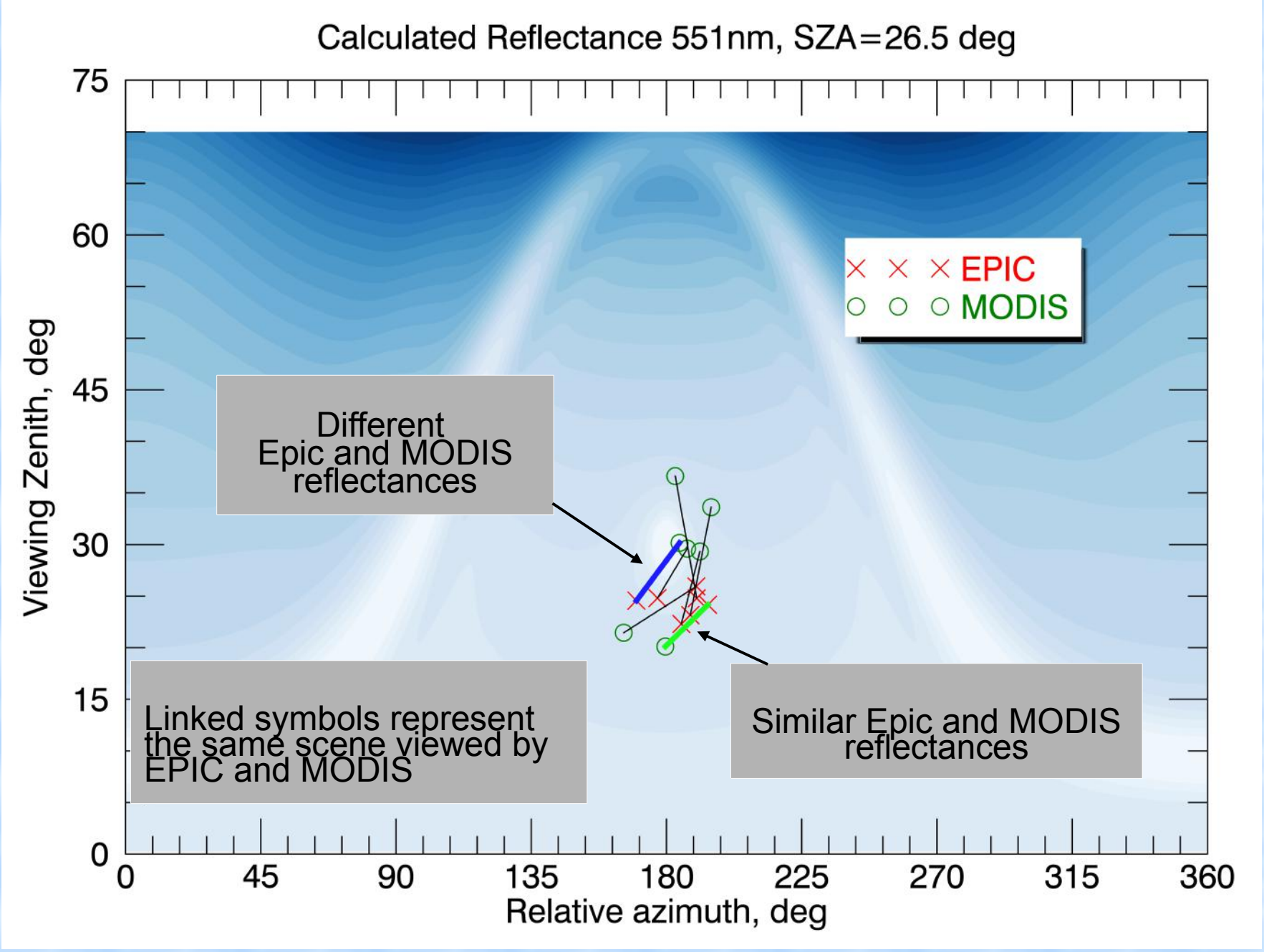
Specifically we use measured MODIS reflectance and viewing geometry (for the actual pixels used for calibration) to look up a matching cloudy scene.

Using that scene we determine the reflectance EPIC would see.

The procedure is used to create a set of synthetic (modeled) EPIC reflectances which may be used in place of MODIS reflectances for “calibration”.

How would calibration gains change if MODIS were always in the line of sight of EPIC (perfect viewing geometry match)?

Modeling EPIC reflectances

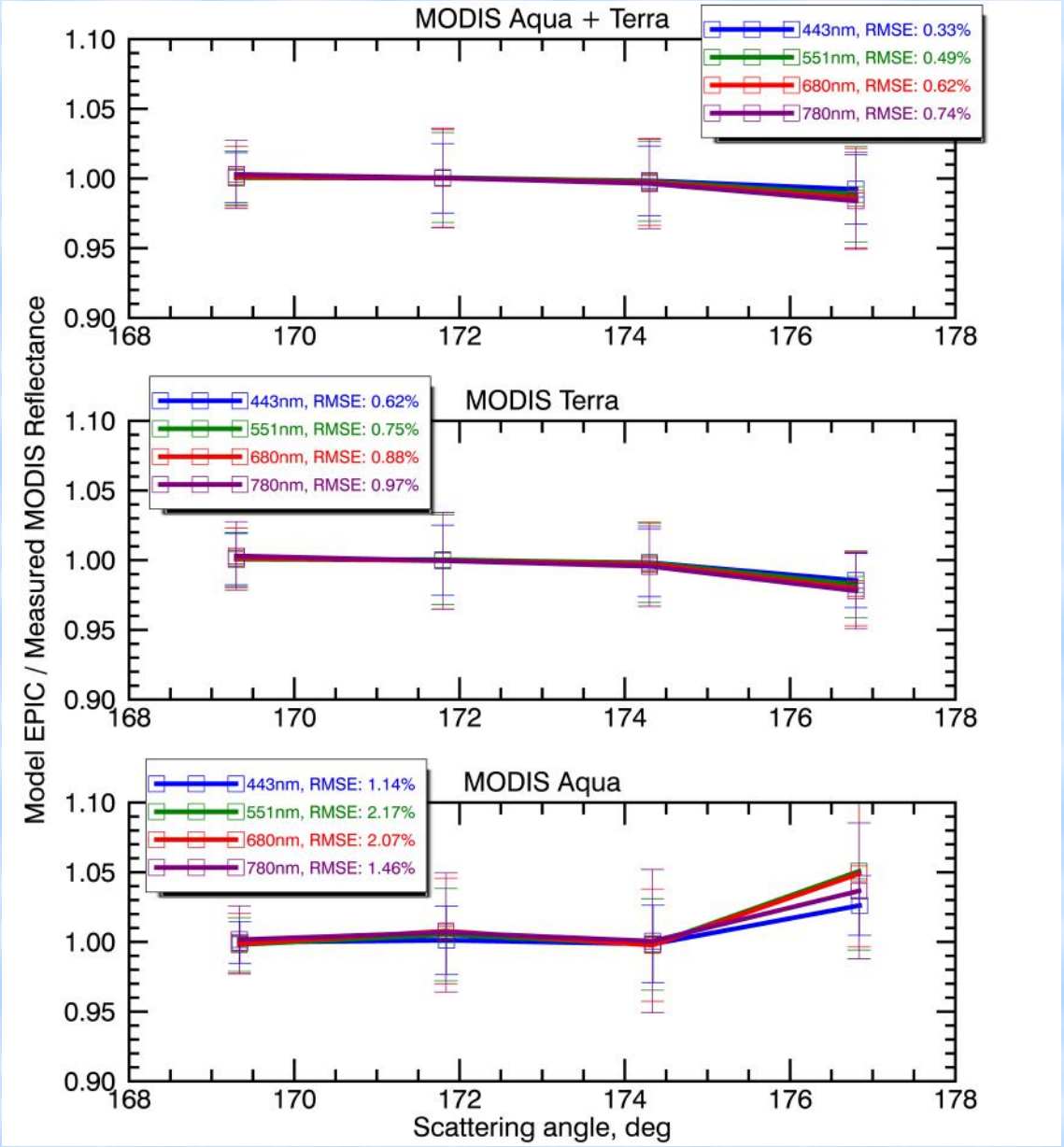


Modeling EPIC reflectances

Using combined MODIS-Aqua and MODIS-Terra is likely to reduce biases due to varying viewing geometry

Relative difference between modeled and measured gains				
	443nm	551nm	680nm	780nm
Terra	0.28%	0.1%	0.1%	0.5%
Aqua	-1.2%	-0.02%	0.4%	-2.27%
Terra+Aqua	**0.02%**	**0.09%**	**0.13%**	**0.18%**

Modeling EPIC reflectance



In this idealized case MODIS Terra and Aqua may exhibit biases for large scattering angles.

However, they point in opposite directions for MODIS Terra and MODIS Aqua and tend to cancel when the data is combined.

Future work

- Submit the results for publication
- Add NOAA-20 VIIRS

(Data from 2018 on, ~1h difference with NPP VIIRS)

- Use radiometers in geostationary orbit
- Use EPIC lunar views and LRO mosaics for absolute and/or relative spectral calibration of other EPIC chanels

Thank you!