Visible Infrared Imaging Radiometer Suite

VIIRS and MODIS Intercomparison Results

Sirish Uprety and Changyong Cao

With contributions from
Slawomir Blonski, Frank Padula,
Xi Shao and Yan Bai

Outline

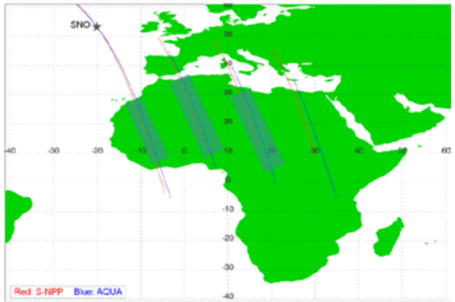
- Background
- S-NPP VIIRS and AQUA MODIS bands
  - Matching bands
  - Spectral bias over ocean and desert
- On-orbit intercomparison results
  - Radiometric bias over ocean and desert using SNO-x
  - Off-nadir comparison
- Summary

Objective

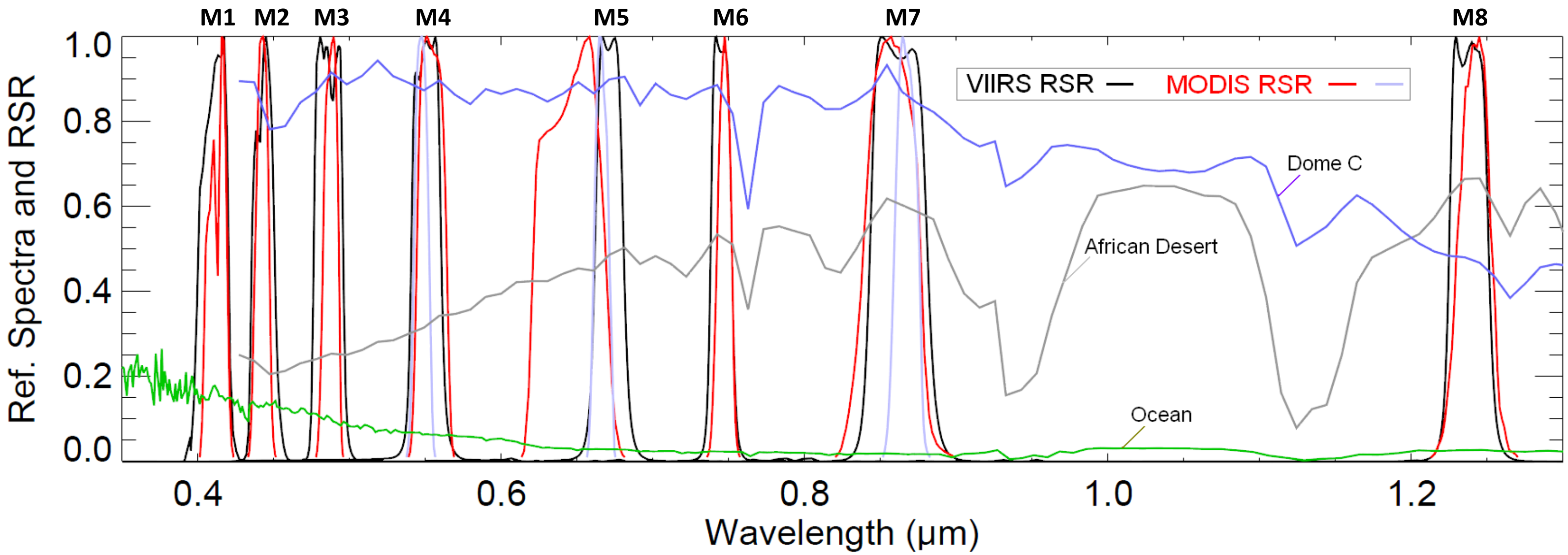
- To valuate the radiometric stability and accuracy of VIIRS RSB.

Background

- Degradation of satellite instruments over time is a common phenomena.
- Stability/characterization of sensors are critical to provide radiometrically accurate and consistent data products.
- VIIRS and MODIS sensors are compared at overlapping regions of extended SNO orbits over ocean and North African deserts to assess radiometric bias.
- The major uncertainties can be due to,
  - cloud movement, residual cloud contamination and cloud shadow
  - sun glint over ocean surface
  - BRDF and atmospheric absorption variability
  - spectral differences
  - co-location errors
  - very low signal strength for some channels over ocean (M5, M6 and M7: Radiance < ~20 w/m2-sr-µm)



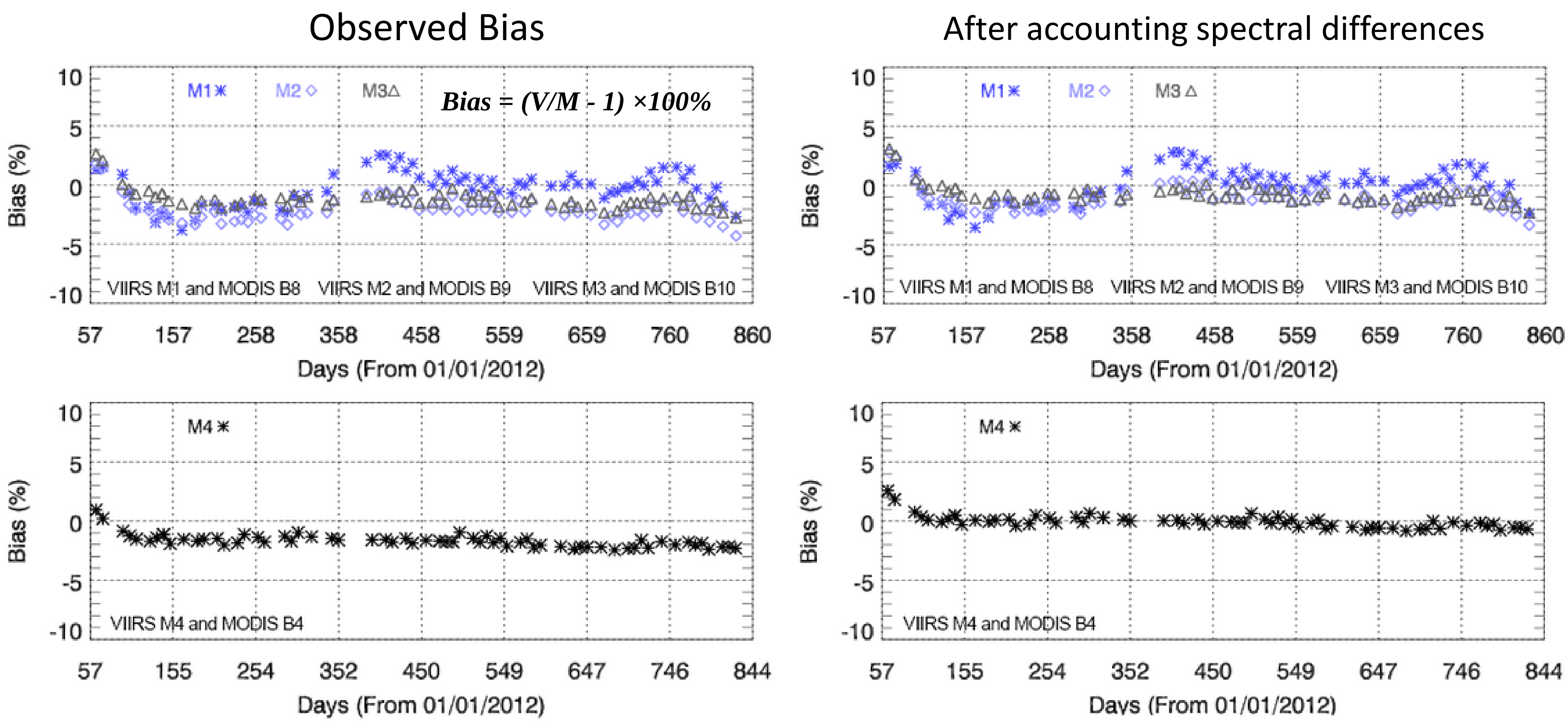
VIIRS and MODIS Matching Bands and Spectral Bias



VIIRS	Desert Bias (V-M)×100%/M		Ocean Bias (V-M)×100%/M	
	Hyperion	MODTRAN	AVIRIS	MODTRAN
M-1	-	-0.26%	-1.10%	-1.40%
M-2	-0.94% ± 0.03%	0.01%	0.52%	0.70%
M-3	-0.47% ± 0.07 %	0.00%	-0.45%	0.36%
M-4	-1.63% ± 0.17%	-1.04%	0.79%	-1.17%
M-5	7.8% ± 0.06%	9.72%	0.92%	0.45%
M-6	-		1.41%	0.40%
M-7	1.56% ± 0.16%	1.22%	2.76%	0.87%
M-8	0.18% ± 0.18%	-0.39%	-	-

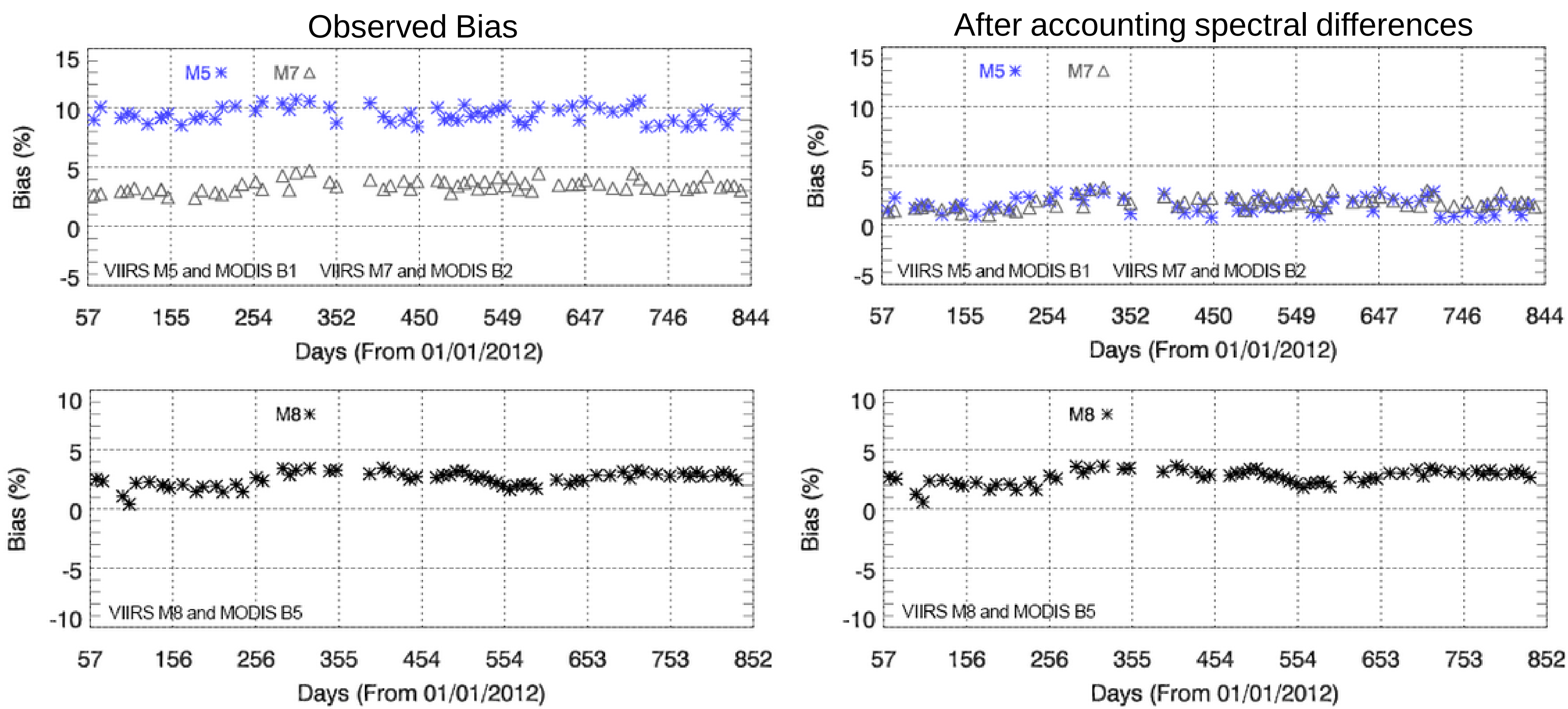
VIIRS		MODIS		Compared at
Band	Wavelength (μm)	Band	Wavelength (μm)	
M1	0.402 - 0.422	8	0.405 - 0.420	Desert and Ocean
M2	0.436 - 0.454	9	0.438 - 0.448	Desert and Ocean
M3	0.478 - 0.498	10	0.483 - 0.493	Desert and Ocean
M4	0.545 - 0.565	4	0.545 - 0.565	Desert
		12	0.546 - 0.556	Ocean
M5	0.662 - 0.682	1	0.620 - 0.670	Desert
		13	0.662 - 0.672	Ocean
M6	0.739 - 0.754	15	0.743 - 0.753	Ocean
M7	0.846 - 0.885	2	0.841 - 0.876	Desert
		16	0.862 - 0.877	Ocean
M8	1.230 - 1.250	5	1.230 - 1.250	Desert and Dome C

VIIRS Bias Over Desert using SNO-x



- Large negative bias during early 2012 is due to the update of SDSM transmission screen data.
- M1 to M3 bias is getting larger in recent months (from early 2014).
  - ➢ Possibly due to the recent change in F-factor trend seen after February 2014.
- M1 shows positive bump in bias during early 2013 which repeats in early 2014 as well!
- M4 is the most stable band with a small decreasing trend in bias of ~1% after May 2013.

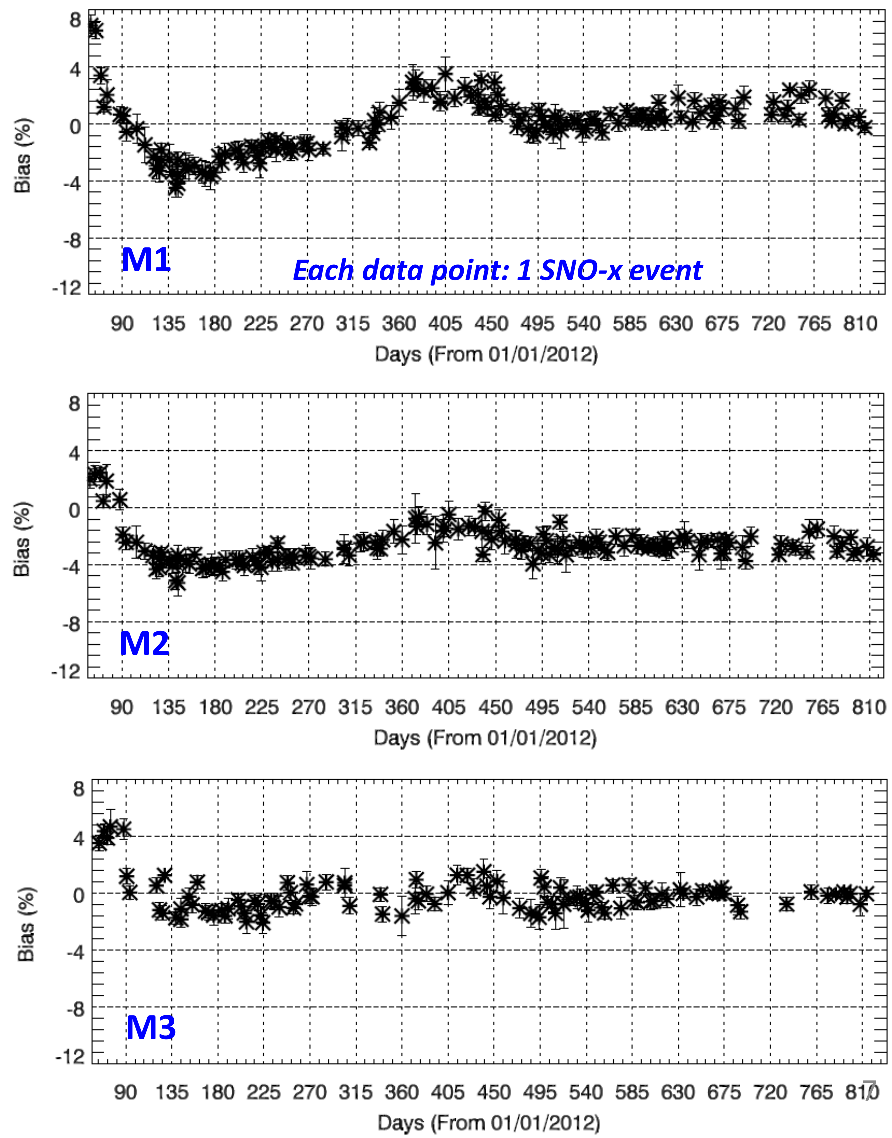
VIIRS Bias over Desert (M5 to M8)



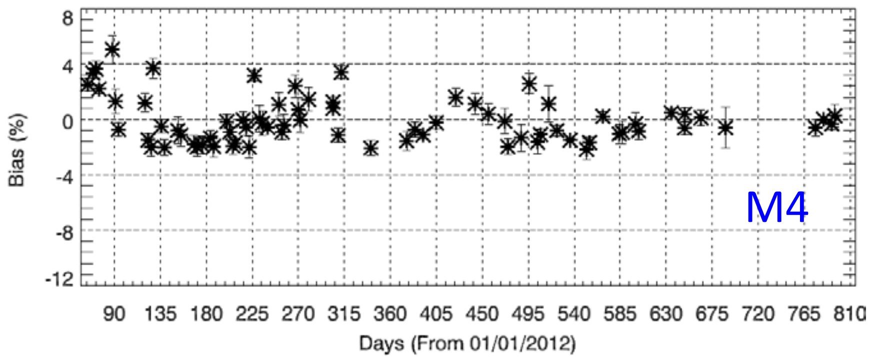
- Large bias exists for M5 (0.65 µm) mainly due to spectral differences of MODIS and VIIRS.
- After accounting spectral differences, bias is significantly decreased to around 2% for both M5 and M7.
- M8 bias is nearly 3%. Note that the bias was smaller during few months after launch.

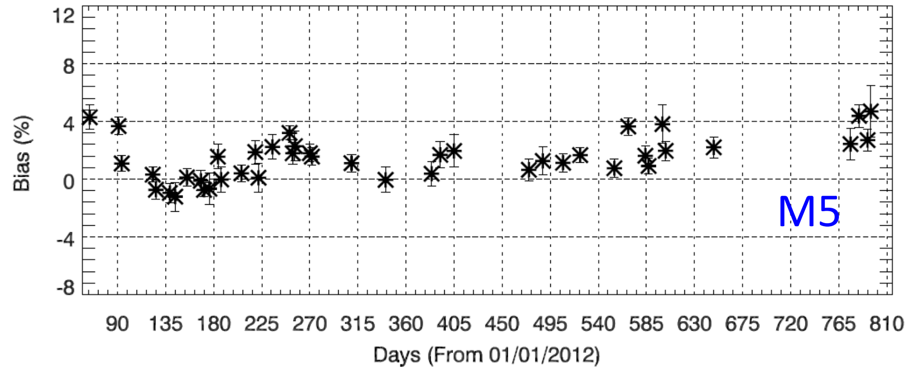
Observed Radiometric Bias over Ocean

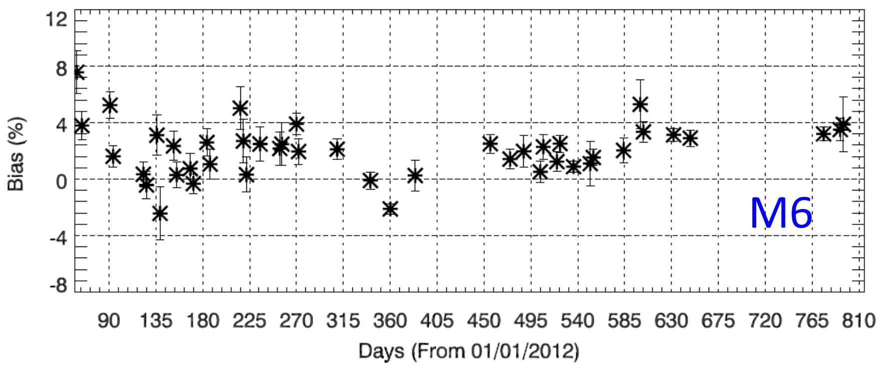
- Bias trends over desert and ocean are consistent during early 2012 showing large dip.
- M1 and M2 shows larger bias during early 2013 similar to what was seen over the desert.
- After early 2013, M1 is slightly increasing whereas M2 and M3 in general flat bias trend.
- The time difference of about 10 to 15 minutes makes bias estimation process more complicated due to movement of clouds by adding uncertainty.

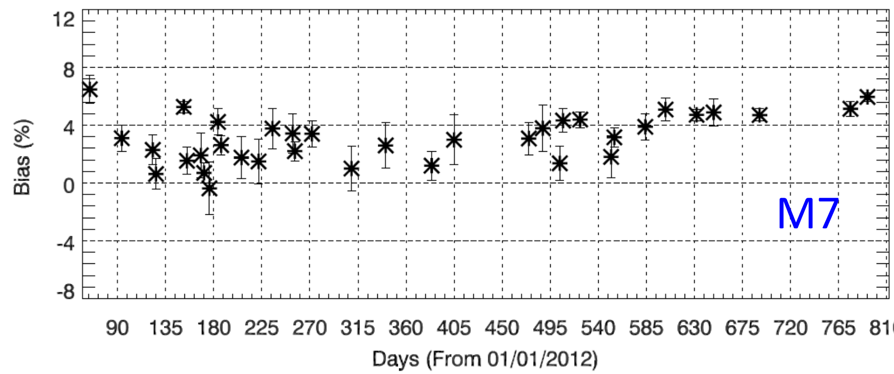


Observed Radiometric Bias over Ocean









- Number of valid ROIs are much smaller for M4 through M7 as compared to M1 through M3.
- Very small signal strength (< 5% reflectance) for bands M5 through M7 makes the bias trends noisier.
- Most strict cloud mask used along with spatial uniformity of 0.9% to filter out invalid bias data.
- M6 and M7 bias are larger after July 2013. However, there are few data points to conclude this trend.
- Very few bias data points exists during winter months.

Bias Time Series Summary

- VIIRS VNIR bands (M1-M7) indicate the observed radiometric bias **at nadir** to be within 2% ± 1% relative to MODIS for most or the bands.
- Bands M1 to M3 suggests increasing bias since early 2014.
- Some bands (M5, M6 and M7) show much larger variability and few bias data points mainly due to their small signal strength over ocean. This increases the uncertainty in bias estimation to greater than 1%.
- M7 bias over ocean indicates an increase after mid 2013 to nearly 4% but there are few points to verify and this needs further investigation.
- SNO-x technique will be used to regularly monitor VIIRS radiometric performance.

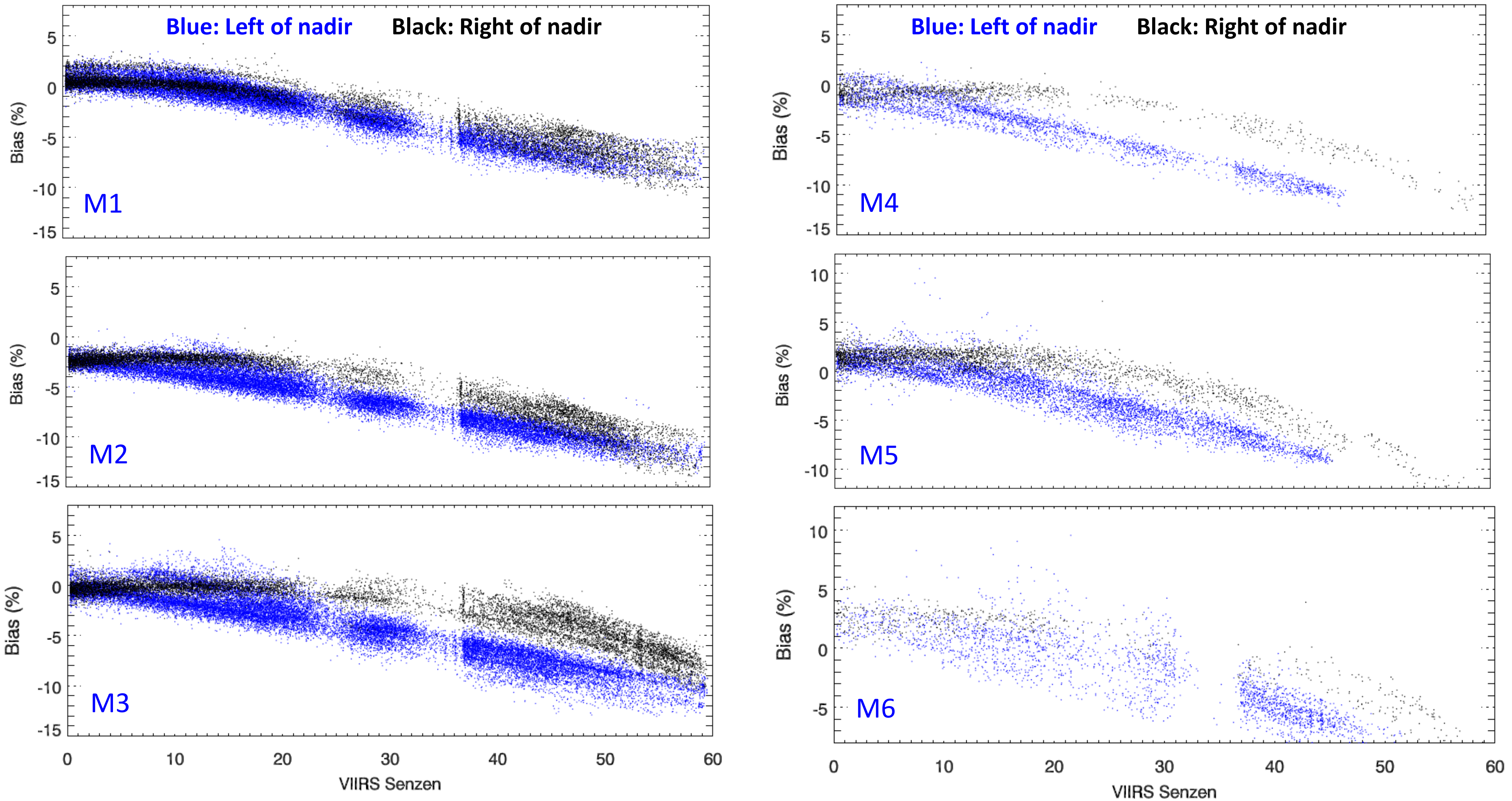
Ref:

Uprety, Sirish, Changyong Cao, Xiaoxiong Xiong, Slawomir Blonski, Aisheng Wu, Xi Shao, 2013: Radiometric Intercomparison between Suomi-NPP VIIRS and Aqua MODIS Reflective Solar Bands Using Simultaneous Nadir Overpass in the Low Latitudes. J. Atmos. Oceanic Technol., 30, 2720–2736.

VIIRS Off-nadir Bias Analysis over Ocean

- Bias estimation is extended from nadir (shown in previous slides) to scan edges over ocean.
- Implemented for SNO-x events over ocean (2013 and 2014)
- At nadir, both VIIRS and MODIS observe same ocean target with almost identical viewing geometry.
- At larger scan angles, the viewing geometry changes due to different altitude of S-NPP and AQUA satellites. This mainly changes the sensor zenith angles for the two instruments.
- The altitude differences causes 0° to 5° differences in sensor zenith for MODIS and VIIRS.
- The time differences of 10 to 15 minutes causes 1° to 2° change in solar zenith angles of the two instruments. However, the impact is very small due to the comparison in reflectance unit.

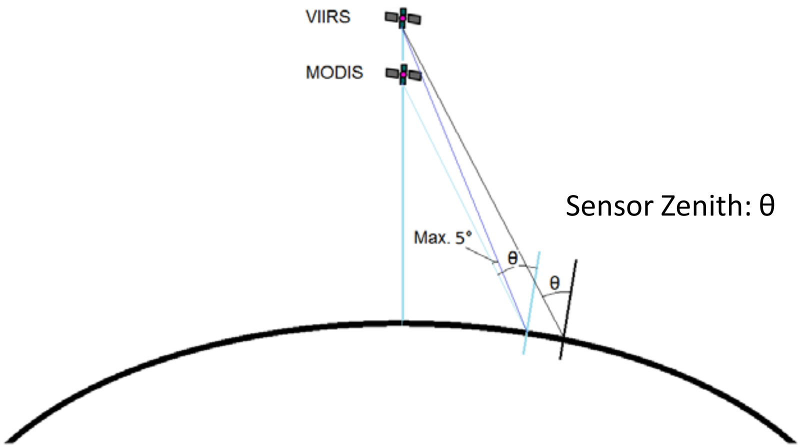
VIIRS Observed Bias

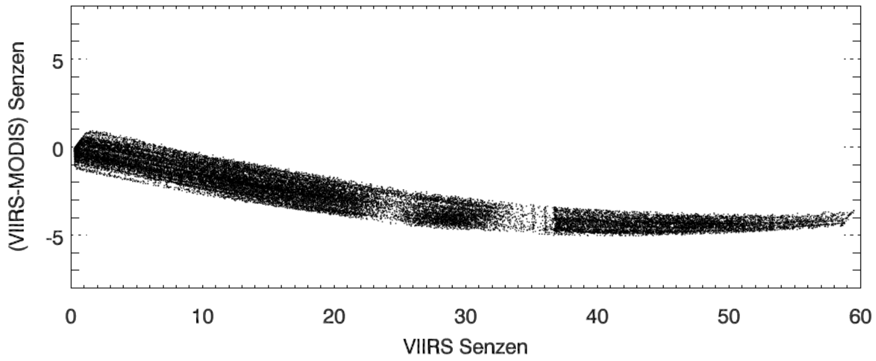


- Bias increases from within 2% to more than 10% as a function of view zenith angle for most of the bands.

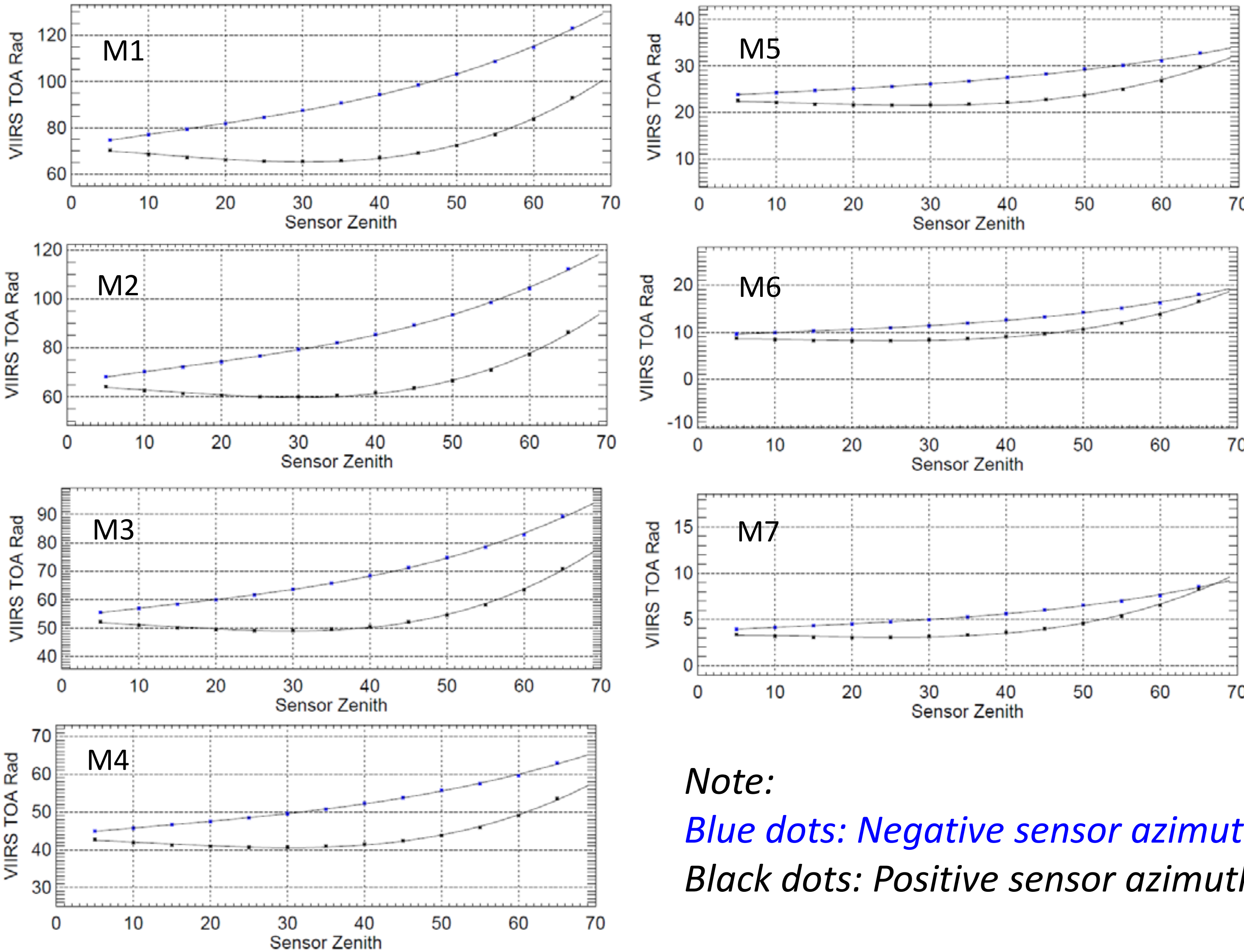
Sensor Zenith Difference

- Altitude difference between VIIRS and MODIS results in sensor zenith difference for collocated ROIs.
- Senzen difference: 0° at nadir to ~5° at large sensor zenith.
- The impact could be corrected to some extent by using radiative transfer models such as MODTRAN, 6S.





6S simulations of VIIRS TOA Radiance

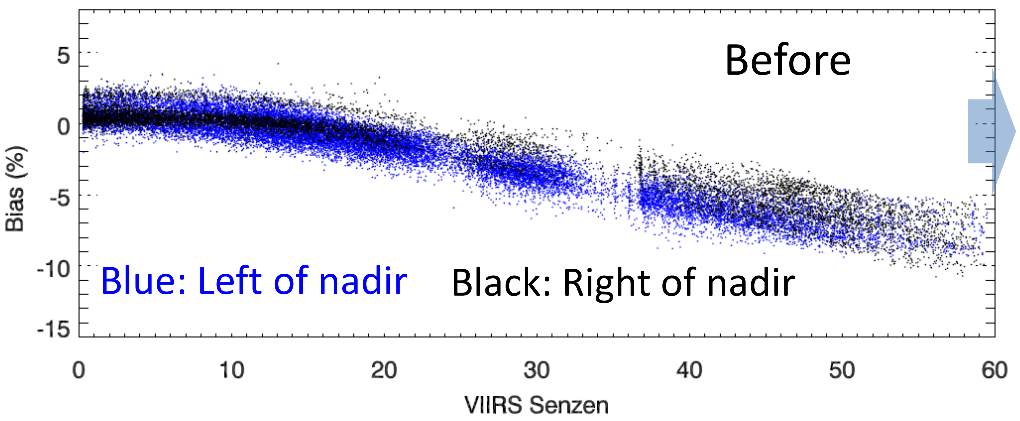


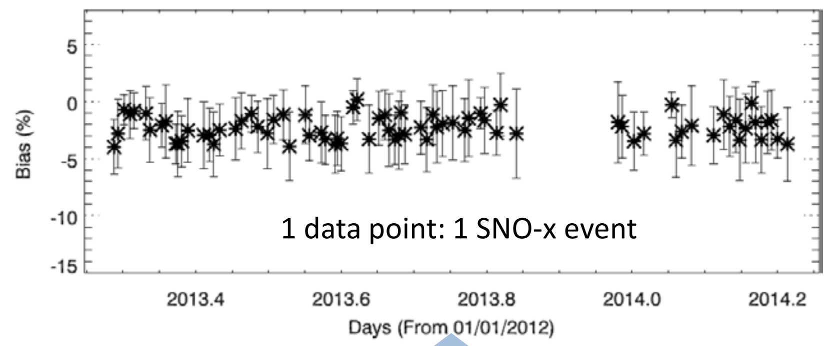
Note:

Blue dots: Negative sensor azimuth

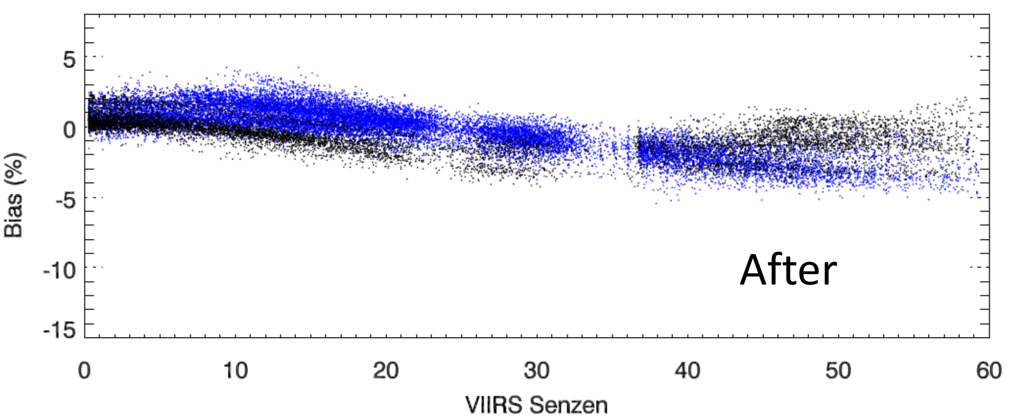
Black dots: Positive sensor azimuth

M1 Off-nadir Bias Analysis





Large 1-sigma bar: Bias varying from nearly 2% to -10% (nadir to the edges)



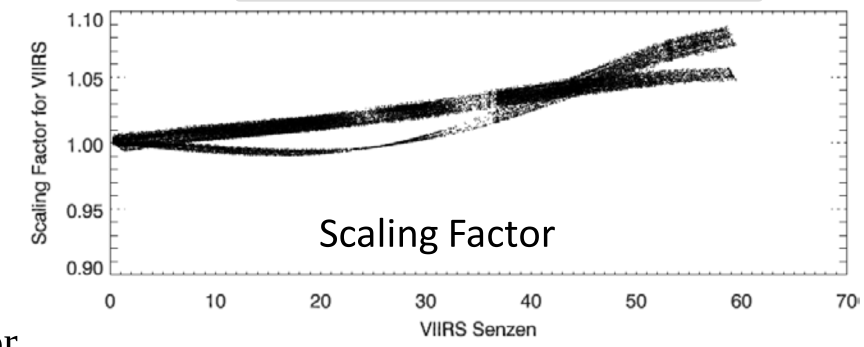
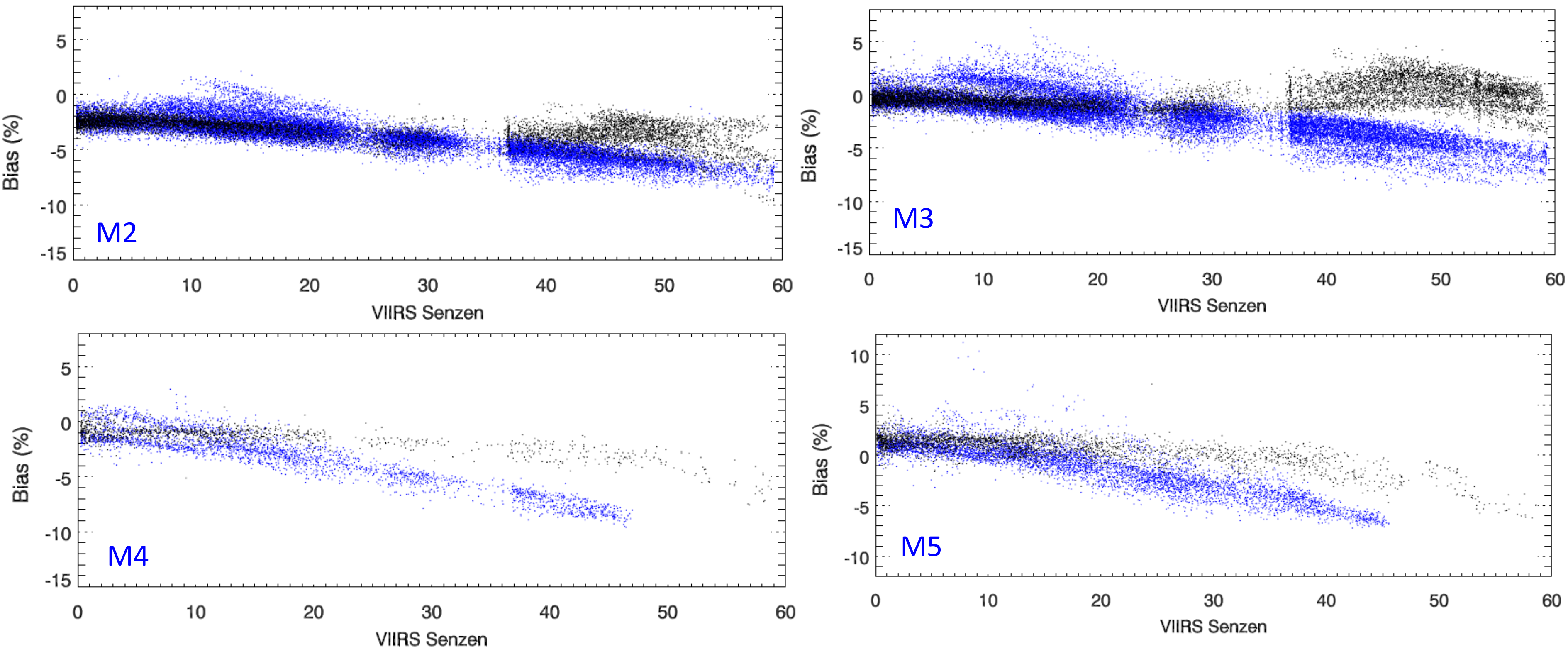


Figure. M1 bias before and after correcting for senzor zenith differences using 6S simulation

- Bias is much improved after correction for M1.
- The two bias trends are still distinguishable.

After Correcting for Sensor Zenith



- Sensor zenith correction improves to some extent.
- Large bias (>5%) still exists @ higher scan angles.
- The two bias trends are still distinct.

Off-nadir Bias Summary

- Observed radiometric bias suggest increasing trend with increasing scan angle.
- Two bias trends exist, one for each side of the sensor nadir track (+ve and –ve sensor azimuth).
- After correcting sensor zenith differences, the bias trend is improved, however, there is still large bias (more than 5%) for most of the bands.
- What are the possible causes?
  - Model: 6S model simulation might not represent the exact observation scenario including the atmospheric variability.
  - Polarization impact at large scan angles for MODIS and VIIRS?
  - How well is RVS characterized for MODIS and VIIRS? Is the uncertainty similar on both cross-track sides?
  - calibration uncertainties of MODIS and VIIRS @ large scan angles?
  - BRDF impact?

Questions?

Backup

SNO-x Inter-comparison Methodology

1. Identify low latitude SNO events
2. collect VIIRS SDR (~750m) and MODIS L1b (1km) data for SNO-x orbits

Note: MODIS collection 6 data is used

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Map VIIRS into MODIS lat/lon grid

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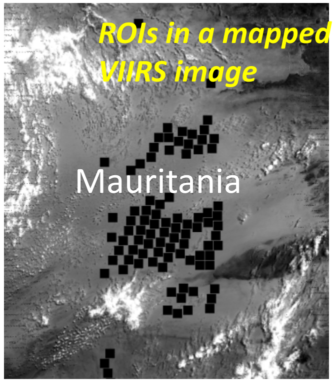

<u>ROI selection</u>
- spatial uniformity < 2% (Desert), < 1% (Ocean)
- sensor zenith: <10^{o} (Desert), <6^{o} (Ocean)
- strict cloud mask criteria for ocean
- ROI size: VIIRS and MODIS: 25km × 25km

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- Extract TOA reflectance mean for each ROI and compute
  Bias=(VIIRS – MODIS)*100%/MODIS
- Compute bias mean by using all ROIs for each SNO event
- Construct and analyze the bias time series

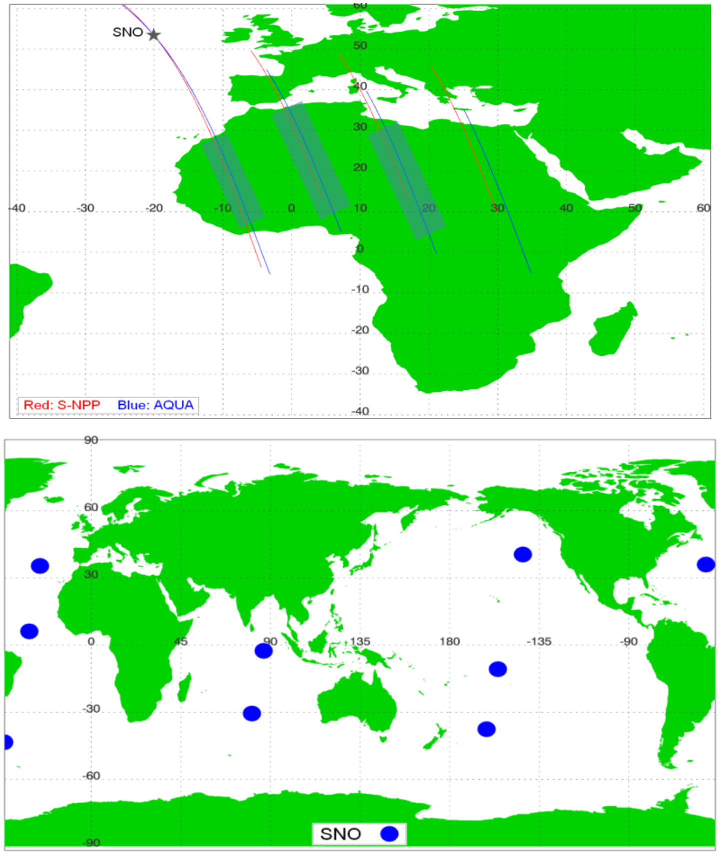

Figure: Orbits showing Low latitude SNO events
i) Extended SNOs to desert ii) SNOs over ocean

- SNO time difference of more than 8 minutes causes the movement of clouds and its shadows.
- Latitude limits: ±40°