A Consistent EPIC Visible Channel Calibration using VIIRS and MODIS as a Reference

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Introduction

- EPIC onboard the DSCOVR satellite at L1 lacks onboard calibration
- Filter wheels radiometrically calibrated against the moon to monitor stability
- EPIC's constant view of the sunlit-disk of Earth provides unique opportunity for inter-calibration of EPIC channels using well-calibrated instruments on low Earth orbit (LEO) satellites
- Inter-calibration is performed by ray-matching with MODIS on Aqua satellite and VIIRS on NPP-Suomi
- EPIC bands 1-4 are in the ultraviolet wavelengths and have no MODIS/VIIRS channel counterparts, and therefore are not considered here

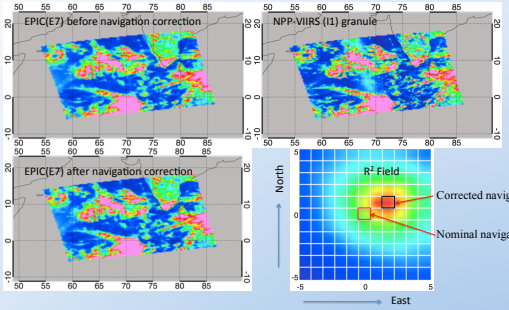
Data

- EPIC L1B, bands 5-10
  - -- Version 02 is used for most of this study
  - -- Version 01 is briefly used for navigation analysis
- Aqua-MODIS Collection 6 L1B
  - -- Nominal 1-km resolution subsampled to 2-km
- NPP-VIIRS Land PEATE L1B version 001
  - -- M-bands at 750-m resolution
  - -- I-bands nominally at 350-m but subsampled to 750-m

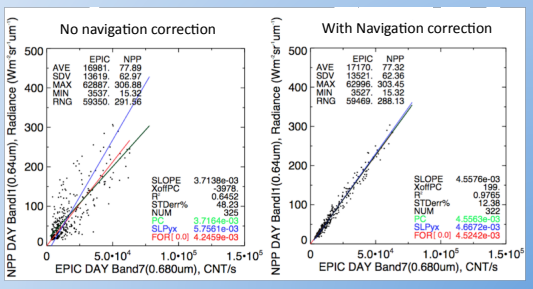
EPIC		MODIS		VIIRS	
Band ID	λ (nm)	Band ID	λ (nm)	Band ID	λ (nm)
E5	443	B1	645	M3	488
E6	551	B2	865	M4	555
E7	680	B3	470	M5	672
E8	688	B4	555	I1	640
E9	764			M7	865
E10	780				

Table listing the different band and wavelengths used among the different instruments in this analysis

EPIC Navigation Correction using MODIS or VIIRS Imagers

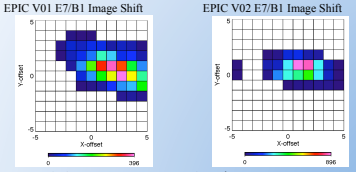


- Spatially average the EPIC (E7) and VIIRS (I1) imager pixels into 0.25° x 0.25° latitude by longitude grid for images within 15 minutes
- Linearly regress the corresponding grid location and compute R^2
- Shift the EPIC grid ±5 gridded regions in both the latitude and longitude directions to find the highest R^2



MODIS/VIIRS-based navigation correction improves the navigation dramatically

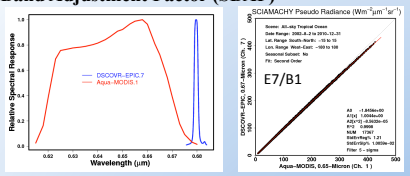
Version 01 to 02: Navigation Improvement



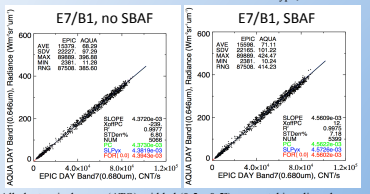
Total EPIC image shifts from navigation correction for E7/B1 matching up through June 2016, using EPIC version 01 (LEFT) and version 02 (RIGHT)

- Image shift analysis indicates that navigation could still be improved, although in V02 it does appear more consistent than in V01
  - The most common shift seems to be +1 East and +1 North, with +2E/+1N also in high frequency
  - All other channel channel pairings show similar shift frequency
  - Shifts using both MODIS and VIIRS show similar results

Spectral Band Adjustment Factor (SBAF)



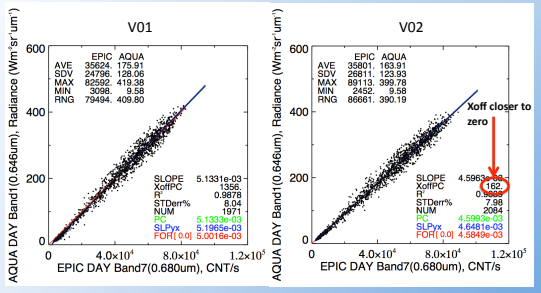
- Spectral band differences must be taken into account when inter-calibrating EPIC with MODIS/VIIRS bands
- Use SCIAMACHY hyper-spectral footprint convolved with spectral response function pseudo radiance pairs and apply a 2nd order fit to estimate the SBAF over the all-sky ocean domain
- The 2nd order fit allows the SBAF to be a function of scene type, dark radiances will differ from bright radiances



	X-Offset	
Band Pairing	Without SBAF	SBAF
E5/B3	3439	1632
E6/B4	541	468
E7/B1	-239	12
E8/B1	-258	27
E9/B1	-510	47
E10/B1	-861	-289

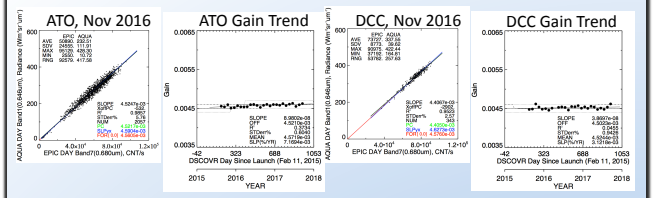
- All-sky tropical ocean (ATO) gridded (0.5 x 0.5°) ray-matching, linearly regresses the E7/B1 radiance pairs over tropical oceans
- The SBAF correction brings the offset of the linear regression closer to zero
- SBAFs are available on the NASA LaRC SBAF Webtool (https://satcorps.larc.nasa.gov/SBAF)

Version 01 to 02: Stray-light Improvement



- Stray-light correction implimented in V02 has improved the regression by reducing the radiance of the clear-sky points and moving them closer to the zero offset

Comparison of ATO and DCC Ray-matched Calibration



- All-sky tropical ocean (ATO) gridded (0.5° x 0.5°) ray-matching, linearly regressed E7/B1 radiance pairs over tropical oceans
- Deep convective cloud (DCC) (0.25° x 0.25°) ray-matching, linearly regressed E7/B1 radiance pairs that have BT < 220K
- The DCC and ATO have their own unique SBAFs

MODIS	DCC			ATO			Gain
EPIC/ MODIS	Mean Gain	σ (%)	Trend %/yr	Mean Gain	σ (%)	Trend %/yr	DCC/ ATO (%)
E5/B3	5.126e-3	0.8	+0.006	5.128e-3	0.4	+0.008	-0.04
E6/B4	3.947e-3	0.9	+0.005	3.965e-3	0.5	+0.007	-0.5
E7/B1	4.524e-3	0.9	+0.003	4.572e-3	0.6	+0.007	-1.0
*E8/B1	1.083e-3	1.1	+0.007	1.125e-2	2.5	+0.009	-3.7
*E9/B1	1.067e-3	1.9	+0.007	1.082e-2	4.5	+0.014	-1.4
E10/B1	5.245e-3	1.2	+0.003	5.280e-3	1.0	+0.006	-0.7

VIIRS	DCC			ATO			Gain
EPIC/ VIIRS	Mean Gain	σ (%)	Trend %/yr	Mean Gain	σ (%)	Trend %/yr	DCC/ ATO (%)
E5/M3	5.284e-3	0.8	+0.007	5.264e-3	0.5	+0.006	+0.4
E6/M4	4.108e-3	0.9	+0.006	4.104e-3	0.5	+0.007	+0.1
E7/I1	4.607e-3	1.0	+0.004	4.615e-3	0.7	+0.005	-0.2
E7/M5	4.667e-3	1.0	+0.003	4.684e-3	0.7	+0.004	-0.4
*E8/I1	1.082e-2	1.2	+0.004	1.126e-2	2.3	+0.004	-3.9
*E8/M5	1.095e-2	1.2	+0.003	1.143e-2	2.4	+0.003	-4.2
*E9/I1	1.042e-2	2.2	+0.003	1.089e-2	3.8	+0.008	-4.3
*E9/M5	1.056e-2	2.2	+0.002	1.107e-2	4.0	+0.007	-4.6
*E9/M7	1.034e-2	2.2	+0.002	1.071e-2	4.2	+0.005	-3.5
E10/I1	5.332e-3	1.1	+0.002	5.325e-3	1.1	+0.005	+0.1
E10/M5	5.404e-3	1.1	+0.002	5.404e-3	1.0	+0.005	0.0
E10/M7	5.338e-3	1.1	+0.002	5.342e-3	0.9	+0.003	-0.1

* Visible absorption bands

- The DCC and ATO temporal trends for all non-absorption band pairings are very similar, with their mean gains within 1%
- Gains derived from MODIS and from VIIRS will be slightly different due to differences in absolute calibration
- All bands appear to be very stable, with the largest degredation only being 0.014%/year.
- The absorption in bands E8 and E9 make them more difficult to calibrate, and therefore further study is required for confidence in the results for those bands

Conclusions

- EPIC Version 02 shows navigation improvement over version 01, but still could be further improved
- SBAF accounts for spectral differences and brings the x-offsets closer to zero
- The stray-light improvements in V02 also bring the x-offsets closer to zero
- ATO an DCC temporal trends for non-absorption band pairings are within 1% of each other
- All bands appear to be very stable, which is expected since the distance between Earth and DSCOVR is so vast

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