

Establishing a seamless transition from Aqua-MODIS to NPP-VIIRS as the calibration reference in providing geostationary visible imager calibration

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Background

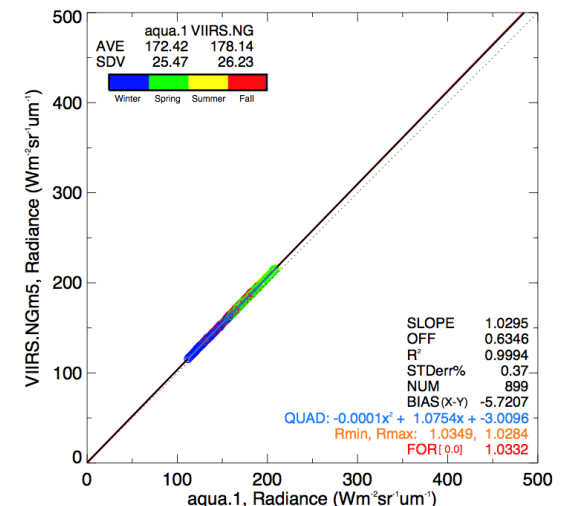
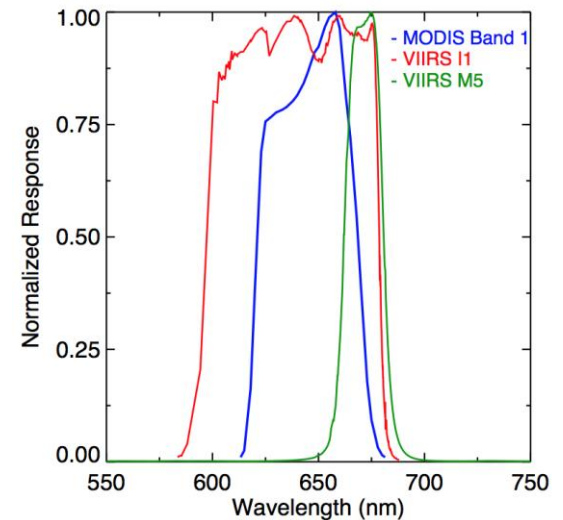
- The Clouds and the Earth's Radiant Energy System (CERES) project incorporates 3-hourly GEO-derived fluxes to fill the gap between the CERES measurements from Aqua and Terra.
- Currently, the GEO visible channels are vicariously calibrated using the Aqua-MODIS band 1 (0.65 μ m) as reference.
- With the launch of CERES FM-5 onboard Suomi-NPP, CERES will shortly transition from using Aqua-MODIS to NPP-VIIRS as its reference for calibrating the GEO imagers.
- This study presents radiometric inter-comparison between Aqua-MODIS band 1 and matching VIIRS M5 and I1 channels using SNO, desert, and DCC approaches.
- Biases exist between VIIRS and MODIS bands due to spectral mismatches and possible calibration differences.
- Biases due to spectral mismatches can be quantified using the hyperspectral signature of the observed target.

Datasets for this study

- Aqua-MODIS
 - Collection-6, Level-1B, Band 1 (0.65 μm), 1 KM pixel-level data
- For VIIRS, the NPP VIIRS AS3100 dataset generated by the NASA Land Product Evaluation and Analysis Tool Elements (PEATE) is used.
- Aqua-MODIS and VIIRS data are both obtained from NASA Langley Atmospheric Data Center (ASDC)

Spectral differences

- VIIRS M₅ and MODIS band 1 have little overlap.
- Some spectral differences exist between VIIRS I₁ and MODIS band 1 too.
- Corrections for spectral band differences are performed by computing a spectral band adjustment factor (SBAF) using SCIAMACHY data as described by *Doelling et. al* [1].
- The technique involves convolution of target-specific reflected solar spectra measured by SCIAMACHY with the sensor SRFs to compute pseudo imager radiances.
- The VIIRS pseudo-radiances are regressed against the MODIS pseudo-radiances to compute the SBAF (slope of regression).
- The Aqua-MODIS radiances are then multiplied by the SBAF to arrive at a spectrally corrected MODIS radiance.

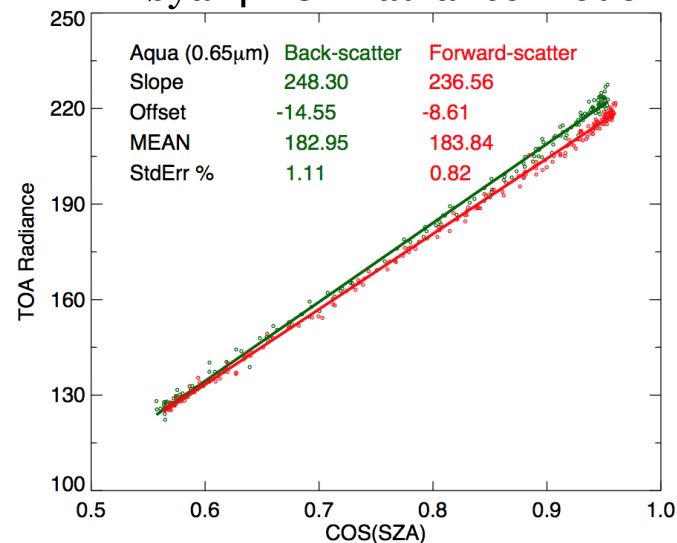


[1] Doelling, D.R.; Lukashin, C.; Minnis, P.; Scarino, B.; Morstad, D., "Spectral Reflectance Corrections for Satellite Intercalibrations Using SCIAMACHY Data," *Geoscience and Remote Sensing Letters, IEEE*, vol.9, no.1, pp.119,123, Jan. 2012

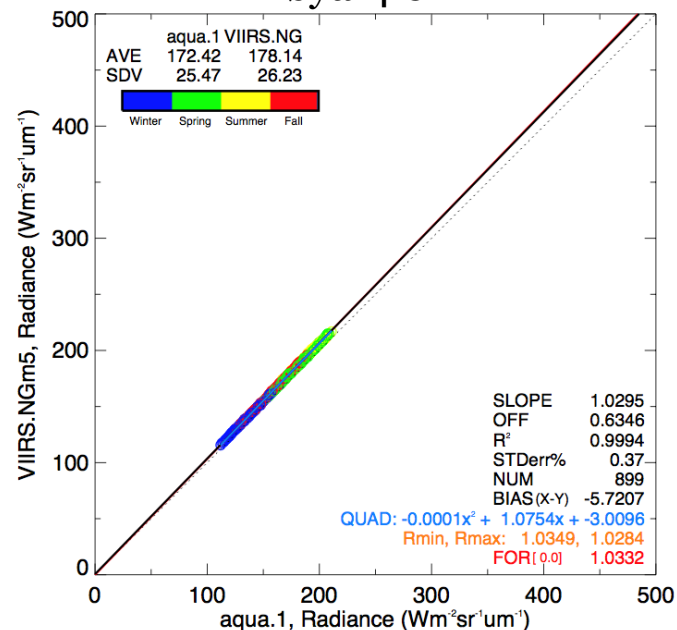
Desert approach

- Libya-4 (28.6°N, 23.4°E) desert used for inter-comparison.
- Only near-nadir observations ($VZA < 10^\circ$) from Aqua-MODIS and VIIRS are considered.
- Libya-4 TOA radiance is modeled as a function of SZA and scattering direction using 11 years of Aqua-MODIS observations.
- The model is applied to predict Aqua-MODIS TOA radiances for all given SZAs of the VIIRS observations.
- The predicted radiances are corrected for spectral differences using the Libya-4 SBAF.
- The actual VIIRS measurements are then normalized by dividing them with the corresponding predicted radiances from the MODIS-based model.

Libya-4 TOA radiance model



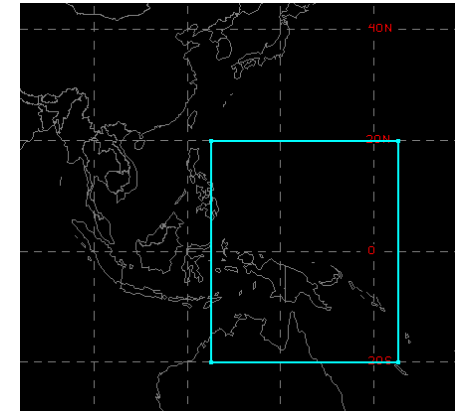
Libya-4 SBAF



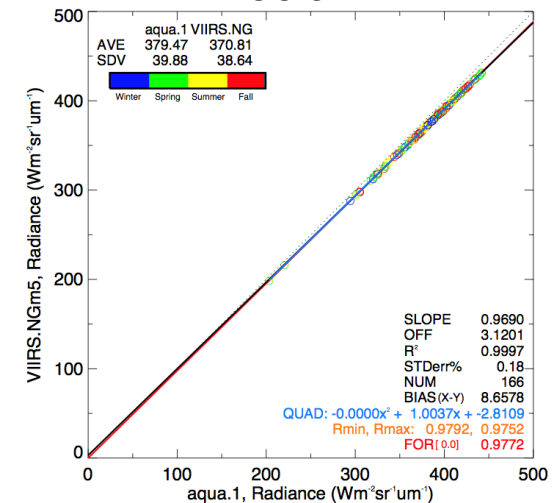
DCC calibration approach

- Deep convective clouds are an ideal visible calibration target because
 - they are the brightest terrestrial invariant targets
 - the impact of water vapor absorption and aerosols in TOA reflectance measurements is minimal
 - they are viewed by all satellites
- This study follows the approach of the GSICS DCC ATBD
- A fixed DCC domain extending from 120°E to 160°E longitude, and 20°N to 20°S latitude is used over the Tropical Western Pacific (TWP)
- DCC pixel selection criteria: $BT_{11\mu m} < 205.0^\circ K$, $SZA < 40^\circ$, $VZA < 40^\circ$, $10^\circ < AZA < 170^\circ$, $\sigma(BT_{11\mu m}) < 1.0^\circ K$, and $\sigma(VIS) < 3\%$
- The anisotropic correction of each DCC pixel is performed using the angular distribution model by Hu et al [2].
- Spectral bias is removed using SCIAMACHY data.

DCC domain



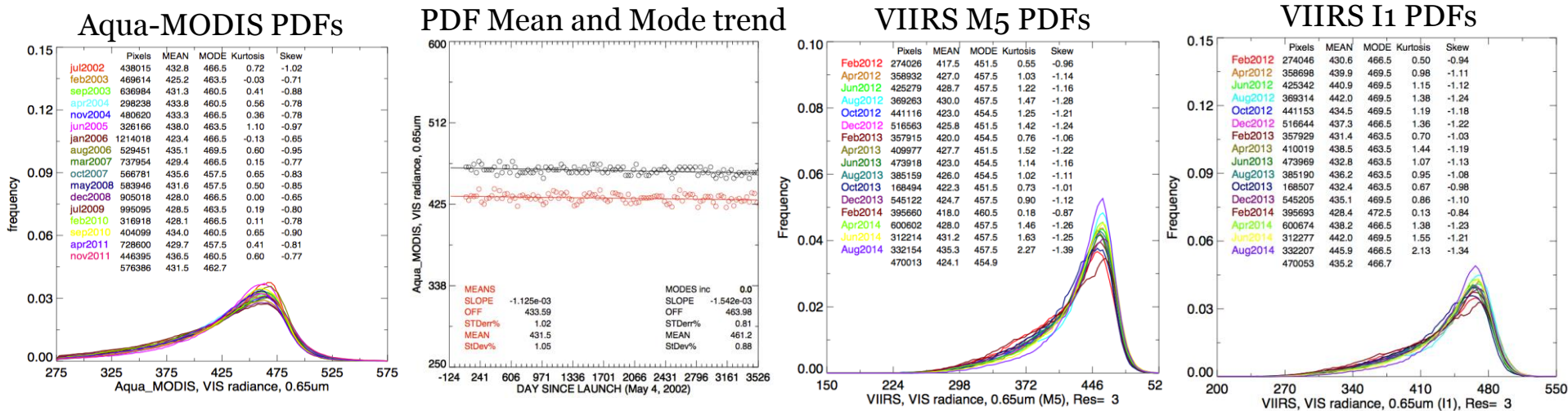
DCC SBAF



[2] Hu, Y., B. Wielicki, P. Yang, P. Stackhouse, B. Lin, and D. Young, "Application of deep convective cloud albedo observations to satellite-based study of terrestrial atmosphere: monitoring stability of space-borne measurements and assessing absorption anomaly," *IEEE Trans. Geosci. Remote Sens.* 42(11), 2594-2599, (2004).

DCC calibration approach (contd.)

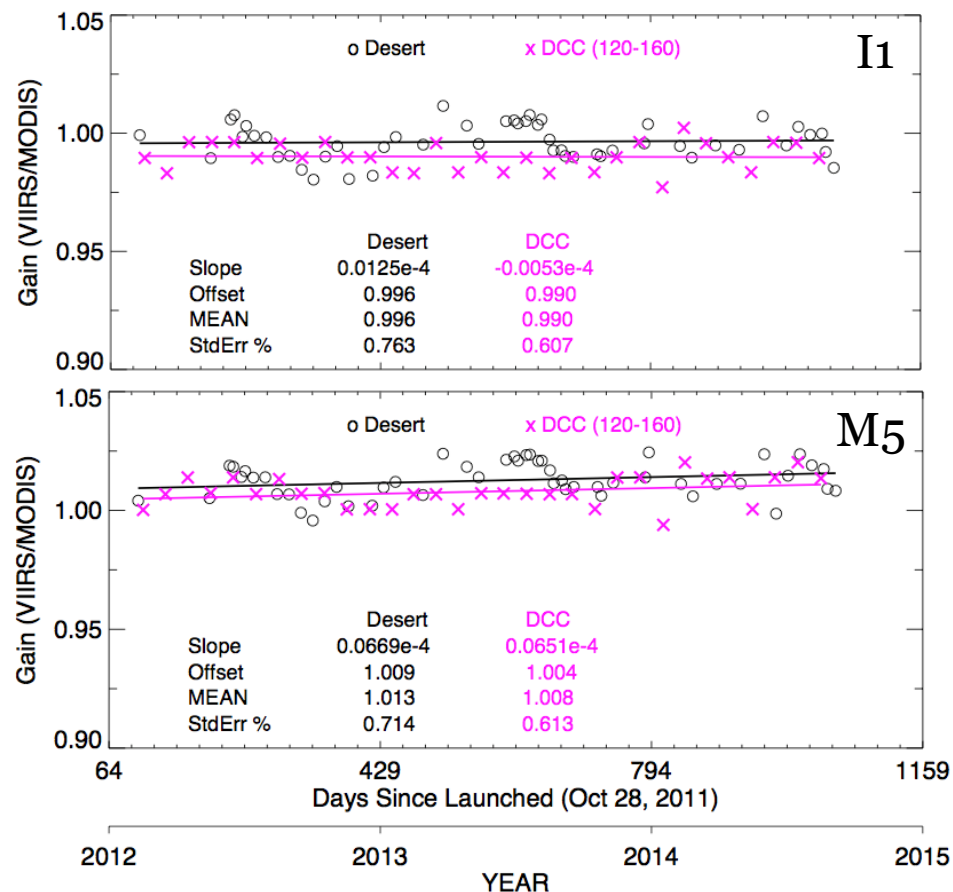
- DCC pixel radiances are compiled into monthly probability distribution functions (PDFs).
- The statistical mode and mean is computed for each monthly PDF.
- An expected TOA DCC radiance over the TWP domain is computed from the mean of 10 years of Aqua-MODIS Band 1 DCC monthly PDF modes.
- VIIRS DCC monthly PDF mode radiances are normalized by dividing them with the 10-year mean MODIS DCC mode radiances.



- The normalized VIIRS DCC and Desert responses are trended over time to estimate any bias due to difference in absolute calibration of VIIRS and MODIS.

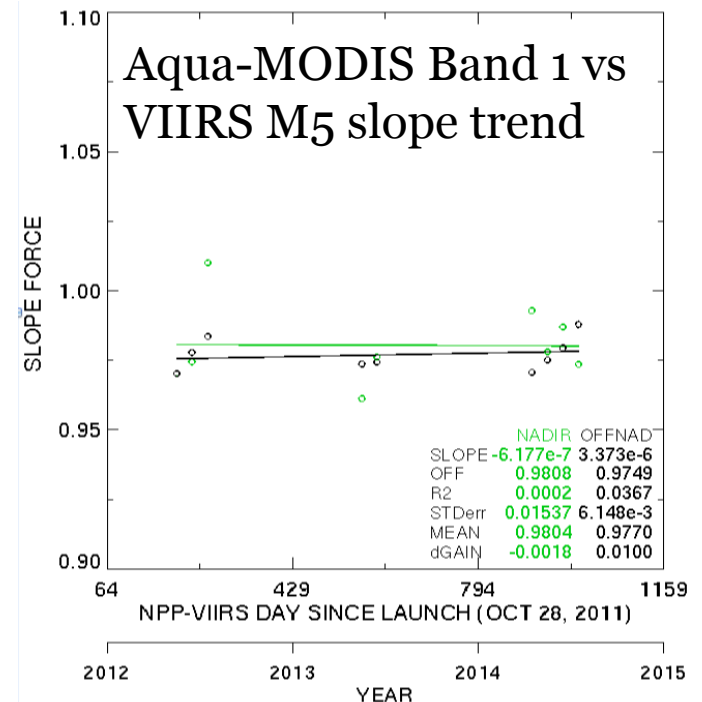
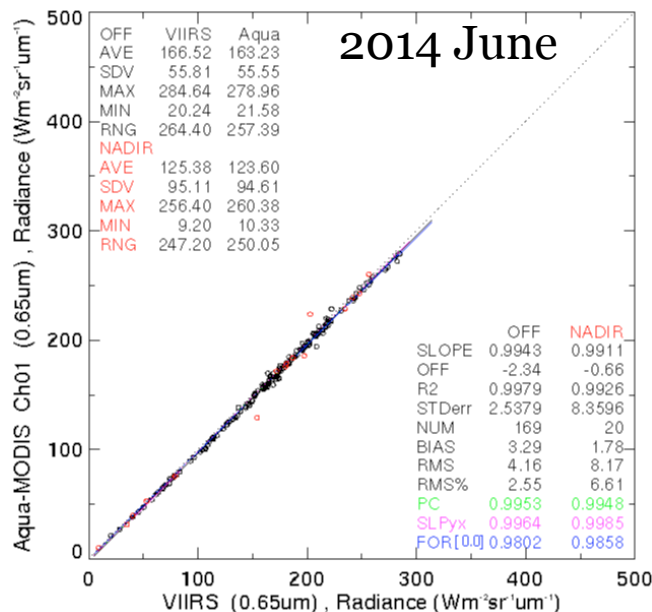
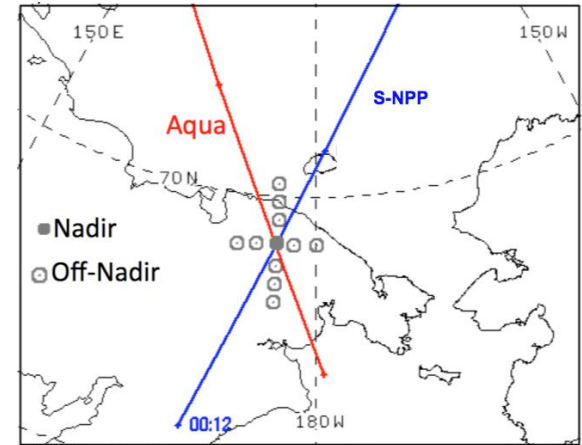
DCC and desert results

- VIIRS M5 and I1 bands calibration is stable.
- VIIRS I1 and MODIS band 1 responses agree within 1% (MODIS is brighter) for both DCC and desert.
- VIIRS M5 shows a radiometric bias of 1.3% (VIIRS is brighter) for desert, and 0.8% for DCC.



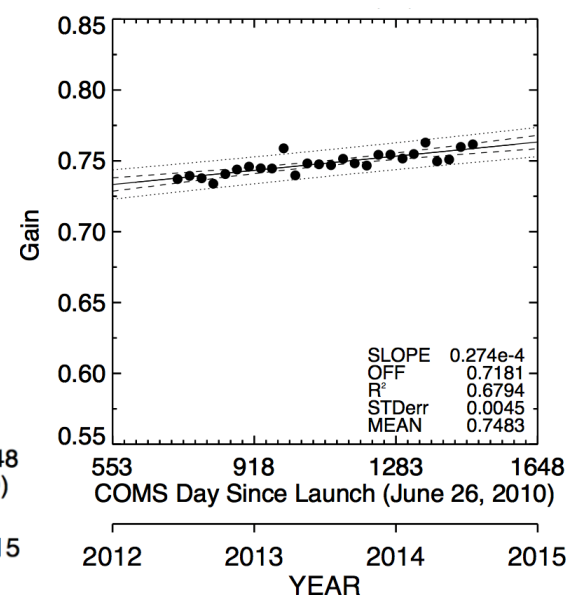
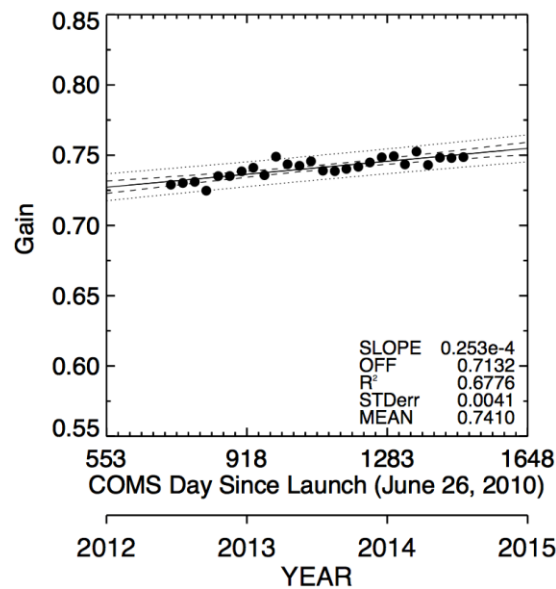
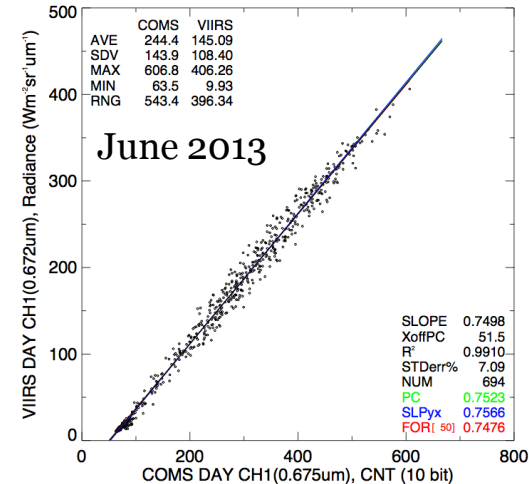
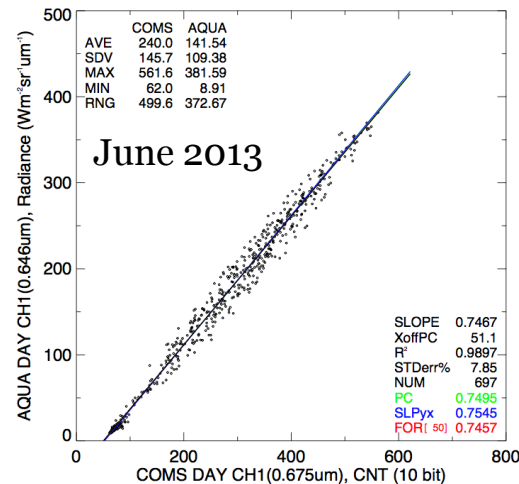
VIIRS and Aqua-MODIS SNOs

- SNO events occur between S-NPP and Aqua over the poles.
- Inter-comparisons are performed between VIIRS M5 and Aqua-MODIS Band 1 with time-difference within 15 minutes.
- May through August months over the north pole.
- VIIRS and MODIS pixels are averaged within a diameter of 50 KM to mitigate the displacement of cloud.
- Nadir and Off-nadir radiance pairs are compared separately.



GEO calibration using MODIS and VIIRS

- COMS raw counts are ray-matched to VIIRS and MODIS visible radiances over an equatorial domain extending $\pm 15^\circ$ latitude and 108°E - 148°E longitude.
- Matching criteria are:
 - $\Delta\text{time} < 15$ minutes
 - $\Delta\text{SZA} < 5^\circ$, $\Delta\text{VZA} < 10^\circ$, $\Delta\text{RAZ} < 15^\circ$
- Ray-matched COMS counts are regressed against MODIS and VIIRS radiances (after spectral corrections) on a monthly basis.
- The forced-slope gives the calibration gain of COMS.
- The mean lifetime gains computed from ray-matching with VIIRS and MODIS are consistent within 1%.



Summary

- Inter-comparison between Aqua-MODIS Band 1 and VIIRS M5 and I1 channels were presented.
 - VIIRS M5 and I1 channels data from NASA LPEATE exhibit excellent radiometric calibration stability.
 - The assessment shows the absolute calibration of VIIRS M5 and I1 channels are consistent with Aqua-MODIS Band 1 within 2% using all four techniques.
 - VIIRS M5 and I1 channels calibration quality is suitable to be used as a reference for calibrating GEOs for the CERES project, as well as for the GSICS studies in future.

Method	Difference (VIIRS-MODIS)/MODIS		Uncertainty (%)	
	I1	M5	I1	M5
SNO	NA	+2%	NA	1.7%
Desert	-0.4 %	+1.3%	1.3%	1.3%
DCC	- 1 %	+0.8%	1.1%	1.1%
GEO	NA	+0.9%	NA	2.5%