Developing MODIS-to-VIIRS Spectral Transformations for the VIIRS Proxy Data

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Abstract

Pre-launch proxy data for the Visible-Infrared Imager-Radiometer Suite (VIIRS) are being developed from MODIS data to support system and algorithm testing for the NPOESS Preparatory Project (NPP) satellite. The effort represents a collaboration of the SSPR, its subcontractors, George Mason University (GMU), and NASA's NPP Project Science Office.

The SSPR's initial VIIRS proxy data set uses a simple band-for-band match-up between MODIS and VIIRS, based on a nearest spectral band approach. Although this approach is fine for pre-launch functionality testing of data flows, testing of Environmental Data Record (EDR) algorithm performance requires higher spectral fidelity.

We developed spectral transformation equations that convert MODIS top-of-atmosphere brightness temperatures (MODIS Level 1B, MOD02) into proxy VIIRS values for the VIIRS mid-infrared and thermal infrared bands. Our approach includes analysis of MODTRAN simulations over different surface and atmospheric conditions to determine optimal equation functional forms. Coefficients are determined using AIRS datasets. These equations are being provided to the SSPR contractor, the NASA Science Data Segment, the NASA NPP Science Team, and the science community (Fig. 1).

VIIRS Proxy Data Collaborations

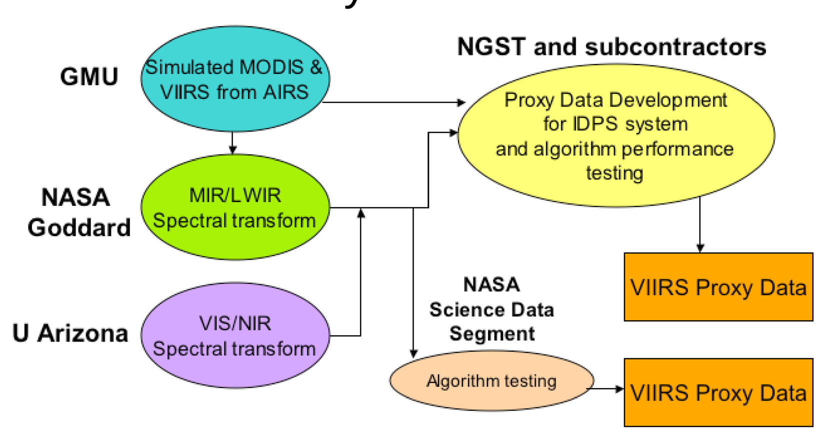

Figure 1. VIIRS Proxy Data Collaborations: George Mason Univ (GMU) is simulating MODIS and VIIRS data from AIRS, which are used in this study for MIR/LWIR spectral transformations. Univ. of Arizona is developing visible/NIR spectral transformations. The spectral transformations will be made available to both the SSPR contractor for proxy data development and to the NASA Science Data Segment for algorithm testing.

Spectral Transformation Development

Development of the spectral transform equations involves a two-step approach:

1) the MODTRAN radiative transfer model is used to develop the functional form of the equation, and

2) a database of simulated MODIS and VIIRS data based on AIRS data is used to determine the equation coefficients for the MODIS-to-VIIRS equation.

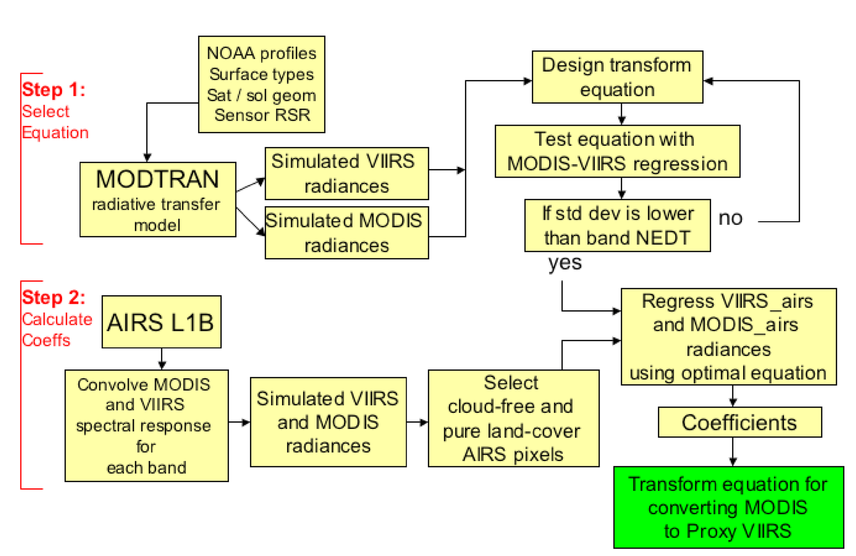

Figure 2. Flow diagram of transformation equation development

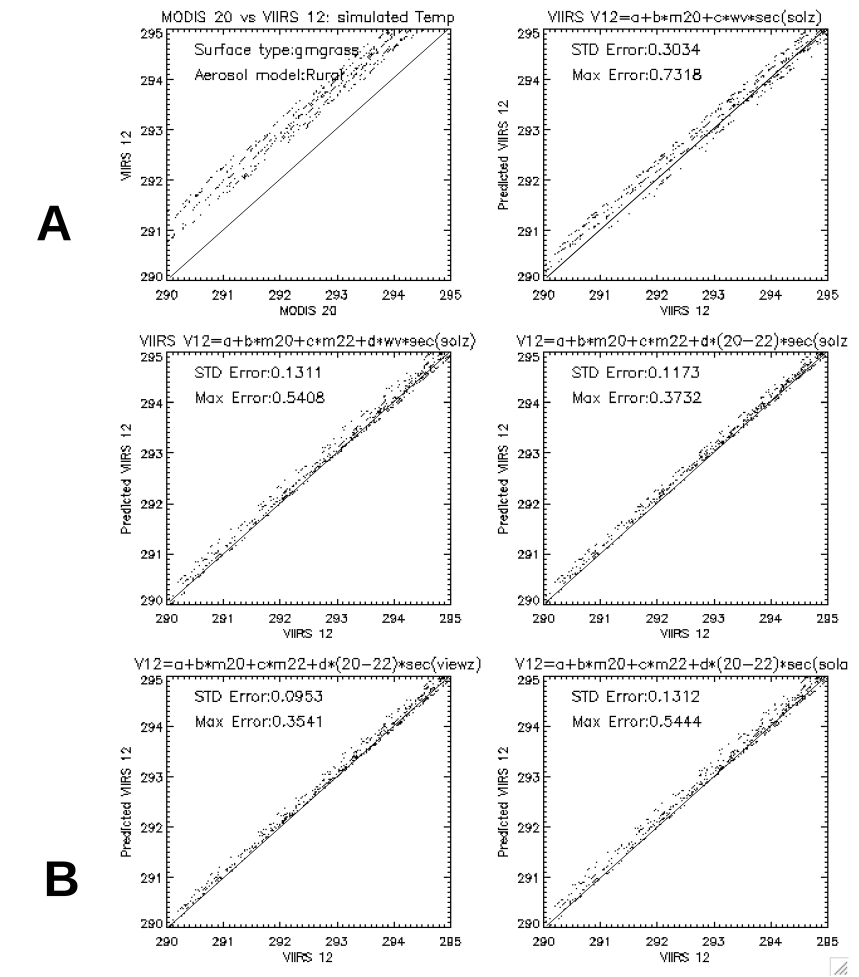

Figure 3. Example of spectral transformation equation development using MODIS and VIIRS data simulated with MODTRAN. Shown here are equations for converting MODIS data to VIIRS band M12. Graph (A) depicts the spectral nearest band approach. The remaining graphs depict variations of multiple linear regressions with different band combinations, geometries, and/or other factors such as water vapor to predict VIIRS brightness temperatures. Graph (B) shows the best equation (of these 5) for reducing the bias and variability in Graph (A).

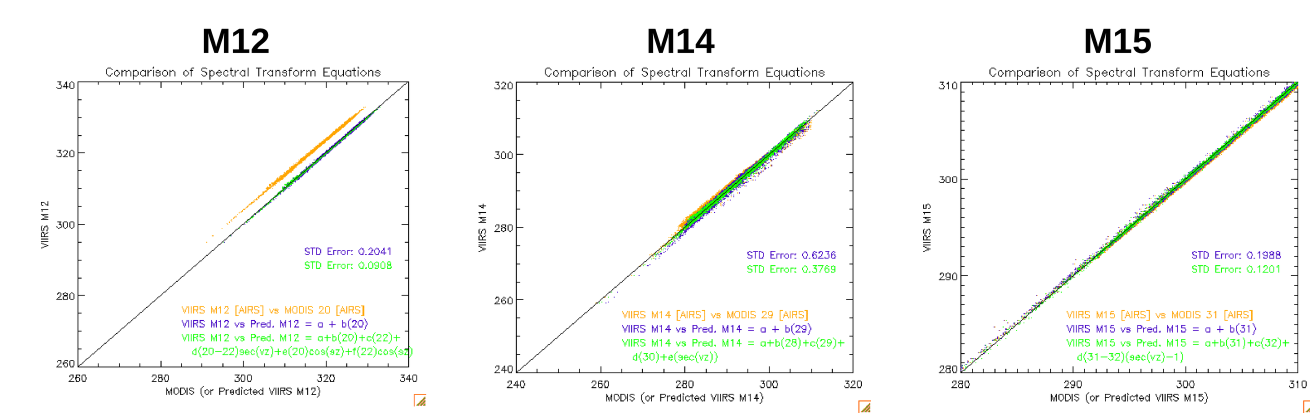

Figure 4. Comparison of different spectral transformations for different VIIRS bands using AIRS data. Orange indicates the spectral nearest neighbor choice: MODIS band X matched with VIIRS band Y simulated from a single AIRS scene (arid surface type). Purple indicates a simple linear regression using a single AIRS-derived MODIS band to predict a VIIRS band. Green indicates a multiple linear regression, often with multiple MODIS bands, to predict a VIIRS band. While the purple equation reduces the bias between a MODIS band a VIIRS band, the green equation reduces bias and variability.

Results

Equation Functional Forms

Land:

3.7 um day: VIIRS M12 = a + b*20 + c*22 + d*(20-22)*(sec(viewz)-1) + e*20*cos(solz) + f*22*cos(solz)
3.7 um night: VIIRS M12 = a + b*20 + c*22 + d*(20-22)*(sec(viewz)-1)
4.0 um day: VIIRS M13 = a + b*22 + c*23 + d*(22-23)*(sec(viewz)-1) + e*22*cos(solz) + f*23*cos(solz)
4.0 um night: VIIRS M13 = a + b*22 + c*23 + d*(22-23)*(sec(viewz)-1)
8.5 um: VIIRS M14 = a + b*29 + c*sec(viewz)
11.0 um: VIIRS M15 = a + b*31 + c*32 + d*(31-32)*(sec(viewz)-1)
12.0 um: VIIRS M16 = a + b*31 + c*32 + d*(31-32)*(sec(viewz)-1)

Ocean:

3.7 um day: VIIRS M12 = a + b*20 + c*22 + d*(20-22)*(sec(viewz)-1) + e*20*cos(solz) + f*22*cos(solz)
3.7 um night: VIIRS M12 = a + b*20 + c*22 + d*(20-22)*(sec(viewz)-1)
4.0 um day: VIIRS M13 = a + b*22 + c*23 + d*(22-23)*(sec(viewz)-1) + e*22*cos(solz) + f*23*cos(solz)
4.0 um night: VIIRS M13 = a + b*22 + c*23 + d*(22-23)*(sec(viewz)-1)
11.0 um: VIIRS M15 = a + b*31 + c*32 + d*sec(viewz)
12.0 um: VIIRS M16 = a + b*31 + c*32 + d*sec(viewz)

where "20" denotes MODIS band 20, "viewz" denotes MODIS view zenith angle, etc.

Equation Coefficients

a, b, c, d, e, f (above) are calculated from MODIS and VIIRS data simulated from AIRS (from GMU)

- One day of AIRS data: Jan 25, 2003
- Cloud-free pixels determined using AIRS cloud fraction
- Pure land-cover pixels determined using MODIS land cover (17 IGBP classes)
- Results in 119 equations for land (17 classes, day/night, 5 bands), and 6 equations for ocean

Equation accuracy is a trade-off between number of pixels (N) and the regression equation's standard error. Standard error should be low (less than the band noise or NEDT), while N should be high and globally distributed. N is determined by selecting the cloud fraction and land cover purity (%) that maximizes N while minimizing standard error.

Surface Type	VIIRS band (um)	Max Cloud Fraction	Min Land Cover Purity (%)	N	Std Err	NEDT
Grassland	M12 (3.7)	0.1	95	964	0.092	0.396
	M13 (4.0)	0.1	95	964	0.165	0.107
	M14 (8.5)	0.1	95	964	0.023	0.091
	M15 (11.0)	0.1	95	964	0.102	0.071
	M16 (12.0)	0.1	95	964	0.150	0.070
Deciduous Needle Forest	M12 (3.7)	0.4	70	1052	0.103	0.396
	M13 (4.0)	0.4	70	1052	0.050	0.107
	M14 (8.5)	0.4	70	1052	0.007	0.091
	M15 (11.0)	0.4	70	1052	0.066	0.071
	M16 (12.0)	0.4	70	1052	0.053	0.070
Ocean	M12 (3.7)	0.05	N/A	17436	0.057	0.396
	M13 (4.0)	0.05	N/A	17436	0.032	0.107
	M15 (11.0)	0.05	N/A	65767	0.069	0.071
	M16 (12.0)	0.05	N/A	65767	0.086	0.070

Equation accuracy is good, i.e. standard error is below or near band NEDT, except for band M16 over Grassland, where standard error is > 2xNEDT. For M12 and M13 (MIR), results are for the daytime equations.

Validating the Approach

The approach was validated by creating proxy AVHRR data from a MODIS scene and comparing it with real AVHRR data from a coincident AVHRR scene. Since VIIRS and AVHRR have very similar spectral band passes, success with AVHRR suggests the VIIRS estimates will be reasonable.

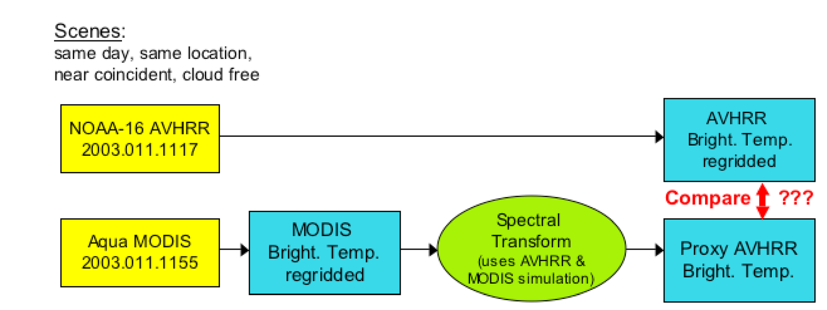

Figure 5. Flow diagram of validation activity

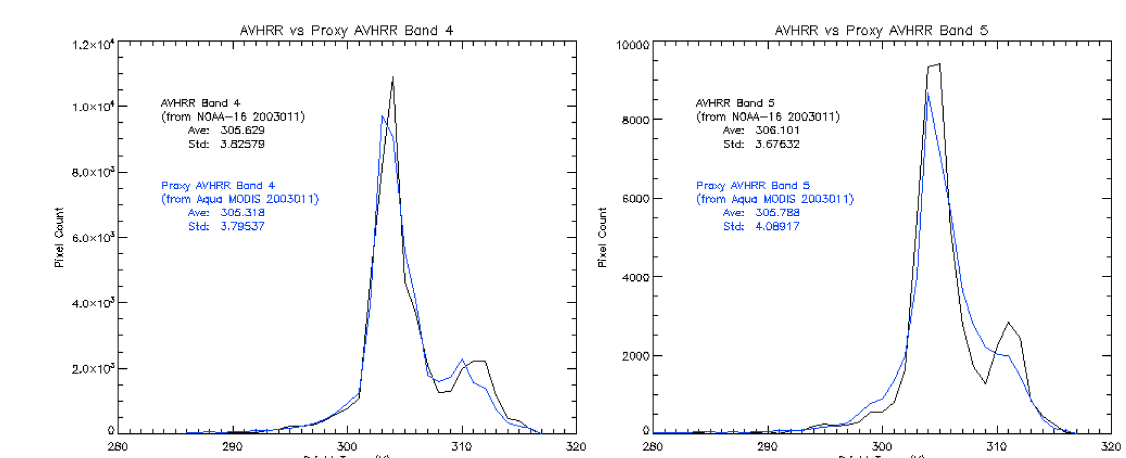

Figure 6. Histograms of proxy AVHRR (from MODIS) **in blue** and real AVHRR **in black** from coincident MODIS and AVHRR scenes. The scenes are 50 minutes apart, cover the same land area, contain minimal cloud cover, represent similar view zenith angles, and were regridded to the same 0.01 degree grid. Perfect overlap is not expected given the time difference between AVHRR and MODIS sampling.

Conclusions

- High-fidelity VIIRS proxy data can be developed with spectral transformations that incorporate multiple terms based on multiple MODIS bands, solar zenith angle, and satellite zenith angle.
- These equations reduce the bias and variability that are apparent when using the nearest spectral band approach.
- Since AVHRR and VIIRS band passes are similar, successful validation results suggest that proxy VIIRS data may be suitably realistic.
- The improved VIIRS proxy data will be useful for testing the VIIRS EDR algorithms.
- **Next steps** are to transform a large set of MODIS scenes to VIIRS proxy for community use. These will be available through the NPP Science Data Segment at NASA.