Simulating Visible/Infrared Imager/Radiometer Suite Normalized Difference Vegetation Index Data Using Hyperion and MODIS

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Abstract

The success of MODIS (Moderate Resolution Imaging Spectroradiometer) in creating unprecedented, timely, high-quality data for vegetation and other studies has created great anticipation for data from VIIRS (the Visible/Infrared Imager/Radiometer Suite). VIIRS will be carried onboard the joint NASA/Department of Defense/National Oceanic and Atmospheric Administration NPP (NPOESS (National Polar-orbiting Operational Environmental Satellite System) Preparatory Project). Because the VIIRS instruments will have lower spatial resolution than the current MODIS instruments at nadir—400 m versus 250 m—for the channels used to generate Normalized Difference Vegetation Index data, scientists need the answer to this question: how will the change in resolution affect vegetation studies?

By using simulated VIIRS measurements, this question may be answered to a great degree before the VIIRS instruments are deployed in space. Using simulated VIIRS products, the U.S. Department of Agriculture and other operational agencies can then modify their decision support systems appropriately in preparation of receipt of actual VIIRS data. One pathway to achieving VIIRS simulations and validations is the ART (Application Research Toolbox), an integrated set of algorithms and models developed in MATLAB® that enables users to perform a suite of simulations and statistical trade studies on remote sensing systems. Specifically, the ART provides the capability to generate simulated multispectral image products, at various scales, from high spatial hyperspectral and/or multispectral image products. The ART uses acquired (i.e. "real") or synthetic datasets, along with sensor specifications, to create simulated datasets. Existing data products (such as those from MODIS) can be generated to validate the simulation process.

In this study, VIIRS simulations were performed using Hyperion and MODIS datasets. The hyperspectral and hyperspatial properties of Hyperion data were used to produce simulated MODIS and VIIRS products. Hyperion-derived MODIS data were compared with near-coincident MODIS collects to validate spatial synthesis, which provided a basis to ascertain the accuracy of converting from MODIS to VIIRS. MODIS-derived VIIRS data is needed for global coverage and for the generation of time series for regional and global investigations. These types of simulations have errors associated with aliasing for some scene types. This study helps quantify these errors and identify common cases where high–quality, MODIS-derived VIIRS data can be effectively simulated.

Problem

Vegetation monitoring applications that have begun to depend on daily MODIS data must convert VIIRS, but significant differences exist between the two instruments.

MODIS:
Whiskbroom imaging radiometer
Bands: 36 from 0.4 to 14.5 µm
Spatial Resolution: 250 m; 500 m; 1,000 m
Swath: 2,330 km
Repeat Time: Global coverage in 1-2 days
Design Life: 6 years

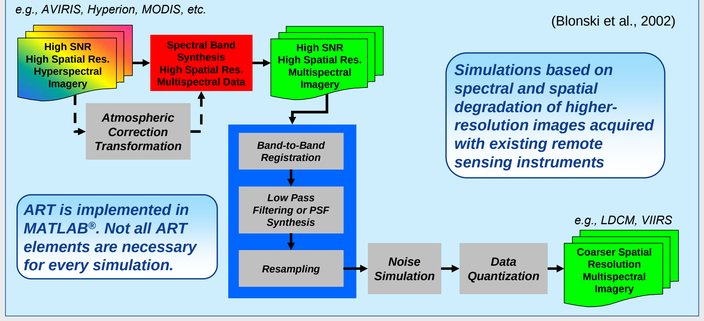
VIIRS:
Whiskbroom imaging radiometer
Bands: 22 between 0.3 µm and 14 µm
Spatial Resolution: 400 m and 800 m
Swath: ~3,000 km
Repeat Time: 1 day
Design Life: 7 years

(NASA SSC, 2006)

Capability: The Application Research Toolbox

e.g., AVIRIS, Hyperion, MODIS, etc.

(Blonski et al., 2002)



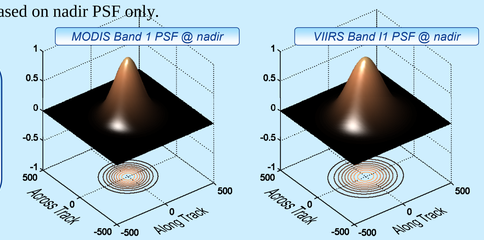
Simulations based on spectral and spatial degradation of higher-resolution images acquired with existing remote sensing instruments

ART is implemented in MATLAB®. Not all ART elements are necessary for every simulation.

Simulation Approach for VIIRS

- To satisfy the needs of data experiments requiring simulated VIIRS vegetation indices for high temporal frequency regional applications, multitemporal VIIRS red and near-infrared data from must be simulated from MODIS red and near-infrared bands. The initial simulation approach is limited to differences in spatial characteristics between the imaging systems, so PSF (point spread function synthesis and pixel degradation are applied.
- Initial simulation is based on nadir PSF only.

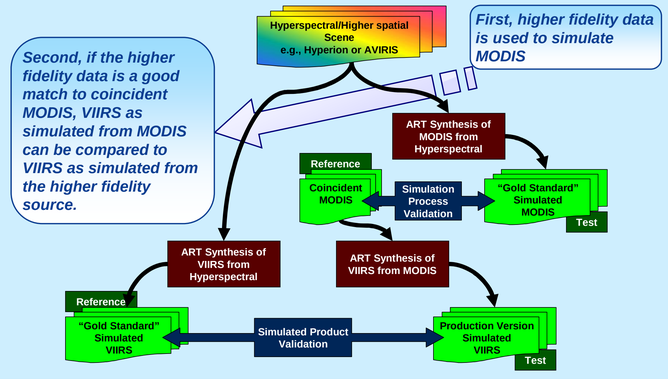
At-nadir PSFs for MODIS and VIIRS red bands are shown at right. The ART convolves the input MODIS data to the VIIRS PSF.



MODIS PSF based on on-orbit characterization by Rojas et al. (2002). VIIRS PSF based on anticipated performance as stated by Schueler et al. (2003).

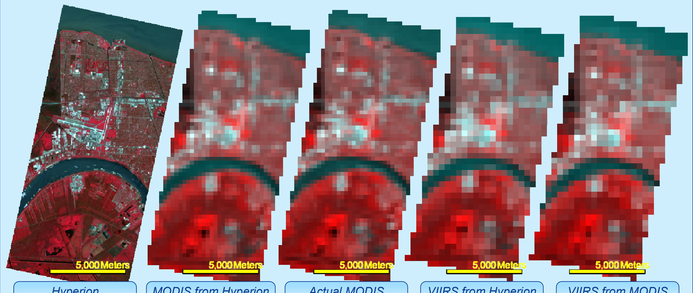
Two-Tiered Validation

Because no actual VIIRS data exists with which to test the simulation approach, it is necessary to validate with higher spatial/spectral fidelity data.



Kenner, LA – VIIRS Simulation Test

Image data acquired on September 6, 2005. The MODIS data is from the MOD02 product and was acquired at 16:50 UTC. The Hyperion data was captured at 16:28 UTC.

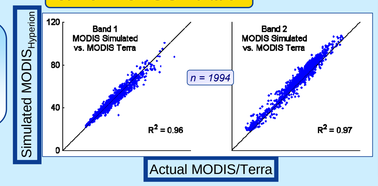


Results

- The MODIS case demonstrates expected results from higher spatial/spectral fidelity.
- The VIIRS case demonstrates that simulation of VIIRS from MODIS has its limitations. Spatially, MODIS does not meet the Nyquist criterion, so there are phasing errors in challenging scenes like this Kenner urban/rural mix.

MODIS simulated from Hyperion was highly correlated with actual MODIS

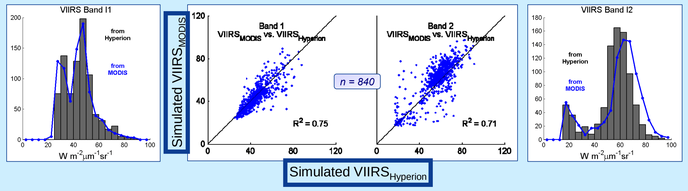
1st Tier: MODIS Simulation



The VIIRS simulation has somewhat greater scatter and lower correlation, which indicates that the simulations should be used carefully in rapidly varying scenes

All scatter plot units W m⁻² µm⁻¹ sr⁻¹

2nd Tier: VIIRS Simulation



Conclusions

- The usefulness of the ART software is borne out by the excellent correlative results in simulating MODIS from coincident Hyperion.
- The simulation of VIIRS from MODIS performed reasonably well in a challenging scene. Better results can be expected in more homogeneous scenes such as one might expect in agricultural and forest-dominated landscapes.

Next Steps

- Conduct additional validation experiments in areas of extensive large field agriculture and large managed timberlands to establish usefulness for vegetation monitoring.
- Update spatial simulation to more closely model the across-track variation of MODIS and VIIRS spatial characteristics.
- Refine metadata to more closely conform to that currently available for MODIS products.

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Related Poster & Presentation

- Prados, D., R.E. Ryan, and K.W. Ross, 2006. Remote Sensing Time Series Product Tool. *Eos Transactions AGU,* 87(52), Fall Meeting Supplement, Abstract IN33B-1341. *(poster)*
- O'Hara, C.G., R. Moorhead, D. Shaw, B. Shrestha, K.W. Ross, D. Prados, J. Russell, and R.E. Ryan, 2006. Integrated use of tools and technologies for rapidly prototyping simulated data products of future NASA observing systems for evaluation in application of national importance. *Eos Transactions AGU,* 87(52), Fall Meeting Supplement, Abstract IN32A-05. (*presentation, Session IN32A, Wednesday, Dec. 13, 11:20*)

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14. ABSTRACT

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