EOS Validation Investigation Annual Report

Title: Validation and Correction for the Terra MODIS Spatial Response
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Summary

The following accomplishments are reported this year: (1) collection of several pairs of coincident MODIS, ETM+ and ASTER images for MTF analysis, (2) initial on-orbit MTF analysis using coincident imagery, (3) collection of several sets of on-obit SRCA datasets and (4) presentation of three conference papers at SPIE symposia and submission of a manuscript for publication in a special MODLAND issue of Remote Sensing of Environment.

Significant results from our project during the past year are:

- Initial MODIS MTF analysis using ETM+ and MODIS of the Maricopa Agricultural Center (MAC), a MODLAND core site, indicates that the on-orbit cross-track MTF is similar to the pre-launch MTF, but the on-orbit in-track MTF may be less than the pre-launch MTF.
- An MTF correction filter has been derived using nominal MODIS specifications and laboratory data and applied to MODIS imagery of MAC for evaluation of MTF correction on NDVI and EVI.

In order to further characterize the MODIS MTF on-orbit, we plan the following tasks in the remaining contract period:

- Completion of on-orbit MTF analysis using ground targets and image comparison to ASTER and Landsat-7 ETM+
- Thorough comparison of pre-launch and on-orbit MTF results
- Characterization of MTF stability via on-orbit SRCA and lunar scan data
- Validation of the MTF correction filter for the NDVI and EVI products

Together, these activities will achieve our primary research goal, validation and correction of the MODIS spatial response. Copies of this report and our other publications are available at *http://www.ece.arizona.edu/~dial/modis*.

1.0 Progress

Progress in our characterization of the Terra MODIS MTF consists of advances in each of the following topical areas.

• Development of an MTF system model and MTF correction filter for bands 1 and 2 from pre-launch data

In order to build a MTF system model, we have been using laboratory data to deduce the optical system parameters. Using the model, we have characterized the pre-launch MTF system response for bands 1 and 2, as shown in Figure 1 (only the band 1 MTF is shown; the band 2 MTF is similar). The model results in a high frequency boost correction filter, as shown in Figure 2. Figure 3 shows a MODIS image before and after the MTF correction. The difference image before/after MTF correction (Figure 3) reveals the high frequency enhancement achieved, i.e. an edge sharpening. It is expected that this sharpening of boundaries will yield more accurate NDVI and EVI estimates, although there will be a trade-off with increased noise.

• Analysis to measure the on-orbit MODIS MTF using coincident ETM+ over the Maricopa Agricultural Center, AZ, and ASTER over Mono Lake, CA.

The on-orbit imagery is used in a two-image MTF estimation technique to characterize the on-orbit MTF for MODIS bands 1 and 2. Three datasets coincident with MODIS acquisitions have been analyzed to-date, Landsat-7 ETM+ imagery of Maricopa Agricultural Center, Arizona, on September 26, 2000 and May 24, 2001, and ASTER imagery of Mono Lake, California, on September 29, 2000. The on-orbit MTFs obtained are consistent with pre-launch validation MTF measurements in the cross-track direction, but are less than pre-launch MTFs in the in-track direction. Analysis of additional scenes is underway to compare to these initial results.

As part of the on-orbit MTF analysis, we have successfully registered a ASTER 1B image to a MODIS level 1B image for the 250m bands using geolocation data. The ASTER coordinate reference system must be changed from a geocentric to a geodetic reference frame. Using the registered ASTER images, we can simulate MODIS imagery using a spatial response model and estimate, under ideal conditions, the effect of factors such as aliasing (image undersampling) on the measured MTF.

Our progress in image registration was greatly helped by visits by Jim Storey of Raytheon STX, to the U. Arizona during August 14-18, 2000 and May 7-11, 2001. He assisted us with ETM+ and ASTER registration to MODIS and with MTF analysis techniques. The registration technique enables us to register images via geolocation data, without the use of control points.

• Acquisition of on-orbit SRCA spatial mode data with assistance from MCST

The spatial mode SRCA data are intended to measure on-orbit band-to-band registration, but may also be used for stability monitoring of the cross-track MODIS MTF relative to SRCA pre-launch data. The data acquired to-date are listed in Table 1. SRCA data are acquired at a 200m sampling rate (an example is in Figure 4). Once the data are averaged, the sampling rate increases to 50m via a phasing scheme. The resulting Edge Spread Function (ESF) is shown in Figure 5. Then, a derivative operation is performed and the Fourier transform taken to produce an MTF, as shown in Figure 5. A limitation of the SRCA is that it provides only cross-track (in-scan) MTF data.

2.0 Objectives and Planned Activities

Since the previous report, the analysis of the pre-launch MODIS test data has been completed. We are now focusing on the on-orbit MTF measurement and correction, along with its possible effect on science products. Both ASTER and ETM+ are being used due to the nearly coincident temporal acquisition of the sensors and MODIS. The following are the current goals and activities:

- MTF analysis using ASTER and MODIS over Mono Lake, CA, and Lake Tahoe, NV. If the results are not adequate using these targets, then other high contrast scenes will be used.
- MTF analysis using Landsat 7 ETM+ and MODIS over Sevillita, NM and Maricopa, AZ.
- MTF cross-track on-orbit stability characterization using SRCA
- Evaluation of MTF correction on NDVI and EVI.

Our validation campaign will adhere to the schedule in Table 2. There is intentional overlap in the schedule. We are in the midst of estimating the MTF using ASTER as a reference. Once we have confidence in the results, we will continue with the MTF stability monitoring using the SRCA data and evaluating MODIS MTF using ETM+ for the other matching spectral bands.

2.1 ASTER/MODIS MTF analysis

We have developed MTF measurement procedures using ASTER and MODIS imagery. The benefit of this sensor pair is that the image acquisition is within minutes between the two sensors. This means that atmospheric conditions are essentially the same for both images. The MODIS level 1B/ASTER 1B pairs acquired to-date are listed in Table 3 and an example of Mono Lake is shown in Figure 6.

2.2 ETM+/MODIS MTF analysis

We have initial results from analysis of coincident ETM+ and MODIS over Maricopa, AZ, and are in the process of obtaining results using Sevillita, NM, acquisitions The MODIS level 1B/ETM+ 1G pairs acquired to-date are listed in

Table 2.

2.3 Characterization of cross-track MTF using SRCA

As shown in Table 1, we have acquired four of five available sets of SRCA data to-date. This extended temporal coverage facilitates monitoring of the MTF using a single, controlled source. Even though the data are acquired only in one direction (cross-track), they are valuable for monitoring MODIS MTF stability.

2.4 MTF correction for NDVI and EVI improvement

Using the correction filter determined from pre-launch data, we are in the process of evaluating the enhancement on the NDVI and EVI science products. In this case, ETM+ is being used to calculate the reference NDVI and EVI. We will assess the MODIS MTF-

corrected NDVI and EVI along transects across fields of the Maricopa Agricultural Center (Figure 3). The MODIS NDVI and EVI, before and after the MTF correction, will be compared to the ETM+ NDVI and EVI to evaluate any improvement or degradation.

3.0 Publications and Thesis

Rojas, F., R. A. Schowengerdt, F. Keita, S. F. Biggar, "Modulation Transfer Analysis of the Moderate Resolution Imaging Spectroradiometer (MODIS)," Proc. SPIE Conference on Earth Observing Systems, Vol. 4483, San Diego, August 1-3, 2001.

Rojas, Francisco, R. Schowengerdt, A. Braga and S. Biggar, "Spatial Analysis of the MODIS PFM Channel Alignment and Far Field Response using Pre-resistor Fix Data," Proc. SPIE Conference on Earth Observing Systems Vol. 4135, San Diego, July 31-August 4, 2000, p60-70.

Braga, Alexandre, F. Rojas, R. Schowengerdt and S. Biggar, "Calibration of the MODIS PFM SRCA for On-orbit, Cross-track MTF Measurement," Proc. SPIE Conference on Earth Observing Systems, Vol. 4135, San Diego, July 31-August 4, 2000, p71-79

MS thesis:

Braga, A., “Modulation Transfer Function Derivation for Spatial Calibration of NASA's Moderate Resolution Imaging Spectroradiometer (MODIS),” MS thesis in Electrical and Computer Engineering, December 2000, University of Arizona, Tucson.

4.0 Tables and Figures

Table 1. On-orbit SRCA spatial mode data identified to-date.

Data source	Date	Acquired
SRCA	09/13/2001	Yes
SRCA	07/11/2001	Yes
SRCA	05/10/2001	No
SRCA	01/08/2001	Yes
SRCA	11/03/2000	Yes

Table 2. Proposed schedule for 2001-2002

Schedule	Activity	Task
May 2001 – Nov 2001	MTF on-orbit analysis	Finalize MTF results for Mono Lake and Tahoe using ASTER and MODIS
Oct 2001 – Jan 2002	MTF stability monitoring	MTF using SRCA spatial mode data
Oct 2001- Jun 2002	MTF correction assessment on MODIS science products	Via NDVI and EVI on selected high contrast targets.
Jan 2002 –Jun 2002	MTF on-orbit analysis	Using ETM+ and MODIS

Table 3. MODIS, ETM+ and ASTER datasets acquired to-date

Site	Date	MODIS	ETM+	ASTER
Sevillita Lava Field, NM	09/30/00	Y	Y	N
	07/28/00	Y	Y	N
	06/10/00	Y	Y	N
	05/09/00	Y	Y	Y
Mono Lake, CA	09/29/00	Y	N	Y
Lake Tahoe,NV	11/07/00	Y	N	Y
Maricopa, AZ	05/24/01	Y	Y	N
	04/22/01	Y	Y	N
	09/26/00	Y	Y	N

Figure 1. Modeled MODIS MTF (band 1) and pre-flight IAC test data (cross-track and in-track)

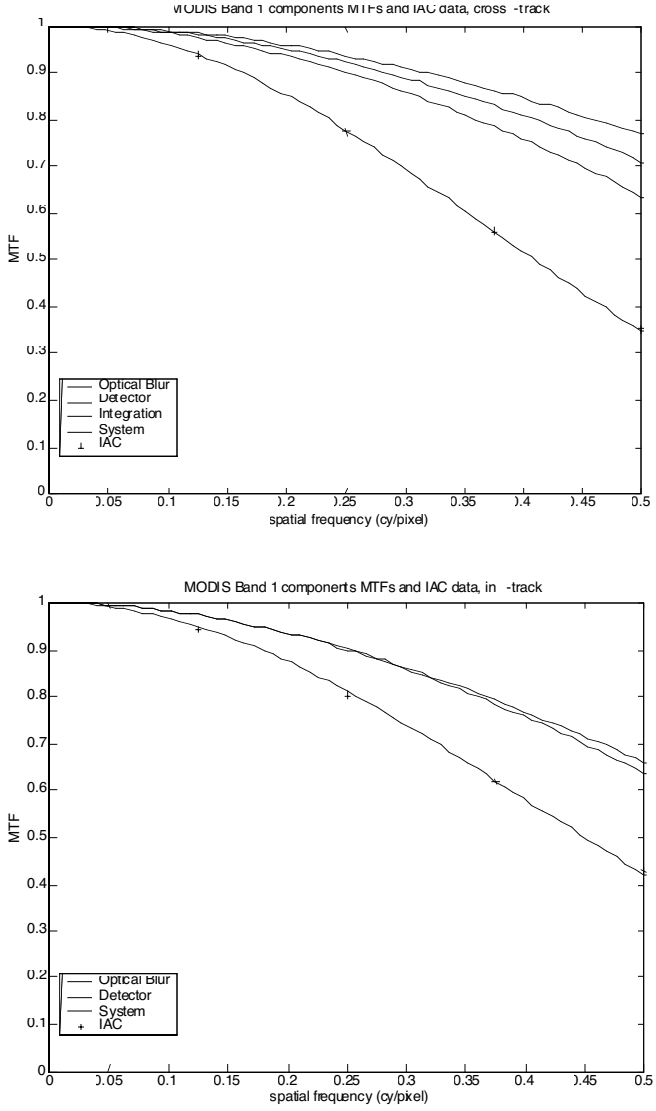

Figure 2. Along-track and cross-track MTF correction function for band 1

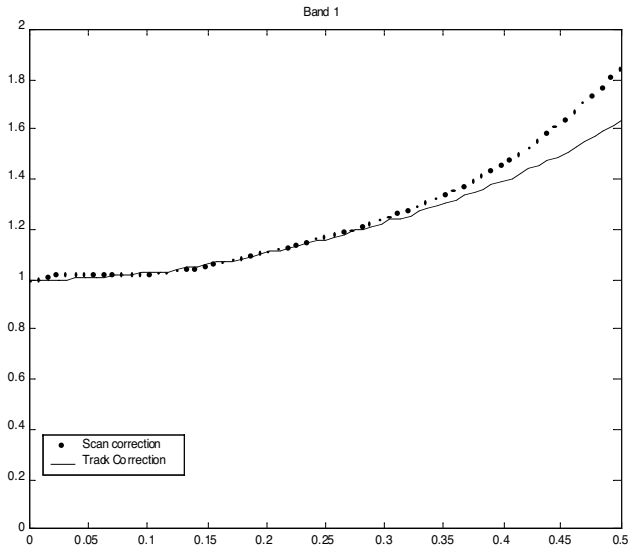

Figure 3. Modis band 1Maricopa 09/29/2000 (top left), corresponding MTF-corrected image (top right) and their difference (bottom).

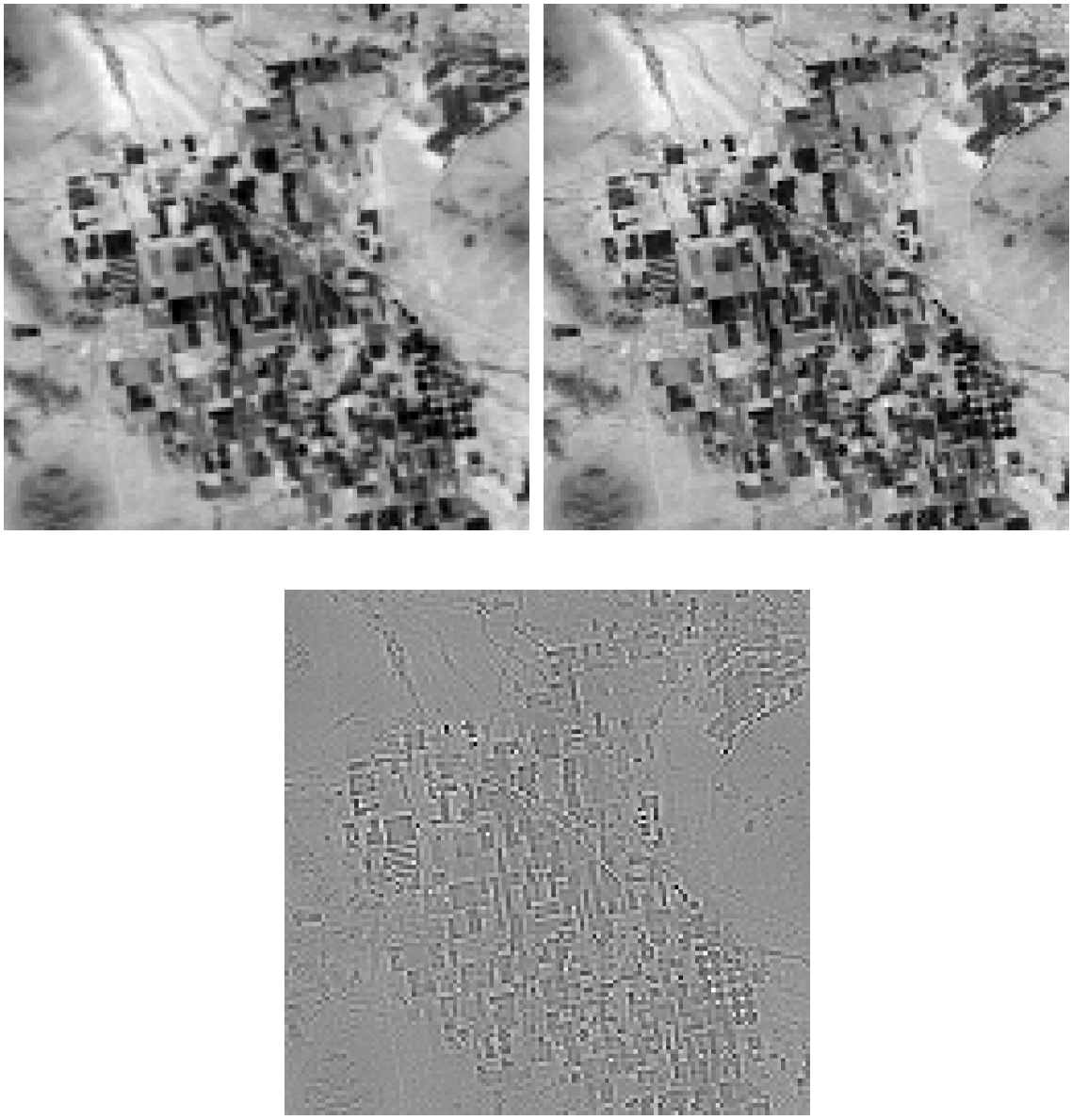

Figure 4. A MODIS granule containing the SRCA data of spatial mode calibration acquisition.

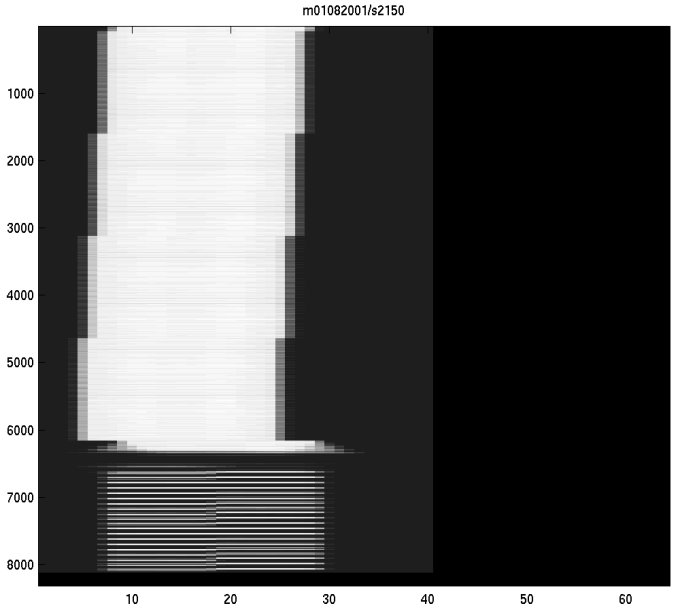

Figure 5. The Edge Spread Function (ESF) from the SRCA spatial mode calibration data (left) and the Fourier transform of the derivative of the ESF (right). The data are phase interleaved and averaged.

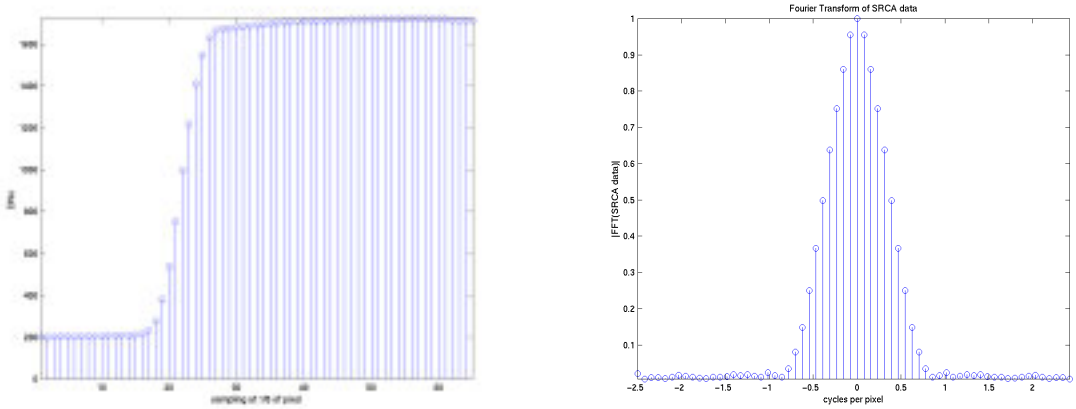

Figure 6. Example registered ETM+ band 3 (left) and MODIS band 1 (right) imagery for Mono Lake, CA, on September 29, 2000.