Project Title: Validation and Correction for the MODIS Spatial Response

NASA Grant #: NAG5−6339

Period: October 1, 1997 - May 31, 1999

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This document summarizes 20 months of research by the Digital Image Analysis Laboratory (DIAL) group, as a MODIS Validation Affiliate, evaluating the MODIS PFM spatial response. Our accomplishments during this period include (1) a comprehensive analysis of pre−August 1998 spatial measurements on the MODIS PFM focal planes, (2) development of a data visualization software tool (3) establishment of a DIAL/MODIS website for publishing our results, (4) collection of spectrometer reflectance data at one of our primary test sites (the All−American Canal near Yuma), and (5) collaborations and interactions with MODIS teams (MCST, SDST and the Atmosphere, Land, and Oceans Discipline Groups). Future activities will include an internship (Frank Rojas) with the Land Science Team Support Group, SRCA along−scan direction MTF analysis, data acquisition field trips, and MTF simulations using MASTER and other remote sensing systems. These activities contribute to our primary research goal, validation of the MODIS PSF and MTF.

Acronyms and Definitions

- AAC — All American Canal
- ALPC−17 — Test Procedure 152762, In−Flight Calibrators Performance Characterization. Uses SRCA in spatial mode as the source. The FP is scanned with a 12 x 5 km recticle.
- AOI−14 — Test Procedure PL3095−N06052, Optical Bench Assembly (2nd build results)
- ARE — Accumulated Radial Energy. The RE is added as a function of distance from detector of interest.
- Channel — One detector in a spectral band.
- ESF — Edge Spread Function
- EE — Ensquared Energy −− See RE
- FPV — Focal Plane Viewer, visualization software for spatial datasets.
- FP — Focal Plane
- FWHM — Full Width at Half Maximum. Measurement of response curve at 50%.
- IFOV — Instantaneous Field of View
- LWIR — Longwave Infrared
- MASTER — MODIS Aster airborne simulator
- MCST — MODIS Characterization Science Team
- MFI−03 — Test Procedure 152767, Alignment of OBA to Scan Mirror.
- MFI03_q — Test Procedure 152767, Alignment of OBA to Scan Mirror using SIS lamps (VIS, NIR)
- MFI03_k — Test Procedure 152767, Alignment of OBA to Scan Mirror using elevated blackbody (S/MWIR,LWIR)
- MTF — Modulation Transfer Function
- NESF — Normalized Edge Spread Function
- NIR — Near Infrared Focal Plane
- OBA — Optical Bench Assembly
- Offset — Scan and track focal plane offsets
- PC02 — Proto−Flight Spatial Performance, Test Analysis Report PL3095−N06234. Summarizes the final system level data acquisition based on the Aft Optics Assembly and OBA measurements.
- PSF — Point Spread Function
- PSR — Point Spread Response tests. FP scanned with a 1 x 1 km recticle.
- RE — Radial Energy. Summing the DN values in square perimeters.
- S/MWIR — Shortwave Midwave Infrared Focal Plane
- Scan Offset — Scan direction offset
- SDST — Science Data Support Team
- SIS — International System Standards
- SRCA — Spectro−Radiometric Calibration Assembly
- Track Offset — Track direction offset
- USF — University of South Florida
- VIS — Visible Focal Plane

1.0 Accomplishments

1.1 Comprehensive Analysis of Spatial Test Data

This is a summary of our analysis of spatial FP measurements, which is detailed in the document "Analysis of spatial response using pre−August 1998 MFI−03, AOI−14, PSR, and ALPC−17 test results − MODIS Proto−Flight Model V1.0"[1]. The main objective is to analyze and summarize the tests in one comprehensive volume. Our four major contributions are (1) collection and correlation of all FP spatial measurements, (2) ensquared energy analysis, (3) Edge Spread Function analysis, and (4) SRCA spatial response analysis.

In (1), FP measurements are analyzed using data from MFI−03_k, MFI−03_q, and AOI−14 test procedures. They are collected using three sets of measurements for each channel. By having three measurements of each FP at different levels of assembly, we can verify non−responding channels and band alignment offsets (Figure 1). In this figure we see that several of the channels did not respond, in particular band 27 (channel 10), band 34 (channel 4), band 36 (channels 8 and 9), and band 32 (channel 1). Also Bands 30 and 32 show a track offset of about 20% and Band 29 an offset of 15%. A summary of the FP registration is in Table 3.

In (2), the PSR data is used to derive RE graphs, which describe the amount of energy in each band that channel 5 receives from the surrounding area. The RE plots in Figure 2 show the signal contribution in bands 33 and 34 as a function of radial distance with the origin in channel 5. The ARE plots are the accumulated sum of RE. The ARE values show that 90% of the signal energy is contained within 2 km of channel 5. They also show signal spikes at 11 and 9 km away from channel 5 in bands 33 and 34, respectively (Figure 2).

In (3), the ESF is calculated for each band (Figure 3). They will be used to derive scan direction MTFs.

Finally, the SRCA spatial mode data were analyzed to compare the mirror side responses (Figure 4). Several statistics are derived for each band to characterize the difference in response between the mirror sides. The analysis facilitates visualization at critical areas in the response graph. These areas are critical because they fall inside the FWHM region, which is used to derive centroid and IFOV data. Figure 4 shows how the errors in band 8 are significant at the FWHM region.

1.2 Focal Plane Viewer (FPV)

FPV is a software application developed to display centroid, IFOV, and PSR measurements. Its display allows the user to view MFI03_q, MFI03_k, AOI−14 and PSR results simultaneously. FPV uses IFOV and Centroid measurements to plot each channel. The capabilities of the program are demonstrated in Figure 7, which show the PSR for bands 8, 9, and 10 with the VIS FP located below the PSR grids. Striping features (probable crosstalk between bands) are observed next to bands 4, 11, and 12. This program is available through the DIAL/MODIS website, and it has been provided to MCST and SDST.

1.3 Project Website

The DIAL/MODIS website is located at http://www.ece.arizona.edu/~dial/modis and our anonymous ftp site is at modis.ece.arizona.edu:/pub/outpoing/MODIS. They are the repository for DIAL's progress and research objectives. Copies of our reports and analysis tools may be downloaded through the website or the ftp site.

1.4 Field Trip

In May 1998, we obtained spectral measurements at one of our target sites for MTF analysis, the All American Canal (AAC) near Yuma, Arizona. Figures 5 and 6 show the spectral reflectance of the canal and the

1 Available through anonymous *ftp modis.ece.arizona.edu:/pub/outgoing/MODIS/lpaper.pdf*

surrounding sand. The measurements set the expected ground truth values for the MTF analysis. More field measurements will be taken to monitor the seasonal and yearly variations. The DIAL participants for this particular trip were Drs. Schowengerdt and Biggar, and Frank Rojas. More data from this site is available from our website.

2.0 Interactions with other MODIS teams

In April 1998, Dr. Schowengerdt visited the ocean groups at USF and U. Miami. The purpose was to evaluate their need for MODIS spatial response data and plans for such measurements. Carder's group at USF, in particular, is planning to use the sharp sea floor drop at the "Tongue of the Ocean" (25°30'N, 78°10'W) to estimate the atmospheric adjacency effect on MODIS. This target may equally serve as part of our on−orbit PSF measurement program. Dr. Schowengerdt also attended the meetings and field trips in Table 1. Futhermore, we have established a collaborative relationship with the MODIS Land Science Support Team through Robert Wolfe.

3.0 Objectives and planned activities

We have three major objectives during the next year of our project: (1) to model the MODIS MTF and compare to on−orbit image−based measurements, (2) to acquire simultaneous ground measurements with overhead instrument coverage, and (3) to actively continue interaction with other MODIS teams. See Table 2 for a listing of our planned activities.

Francisco Rojas will have an internship with the MODIS Land Science Support Team and attend a three week High Performance Computing Workshop sponsored by the University Space Research Association during Summer 1999. We will use these activities to learn about MODIS processing requirements and investigate parallel processing techniques for MODIS MTF correction. Scan direction MTF analysis will be initiated this summer for completion this fall. We will continue our field campaigns on the AAC and Lake Tahoe during the early data acquisition period after the Terra launch. We hope to use Landsat 7 and MASTER as a surrogate MODIS, until the successful launch of MODIS PFM.

Finally, we need assistance in obtaining any available PSF or MTF measurements and/or design data from SBRS to complete our end−to−end model. The measurements needed are for the optical and electronic filter components, as outlined in our proposal.

4.0 Acknowledgements

Dr. Bruce Guenther and Dr. Jerry Godden for conversations about the different datasets.
Dr. Farida Adimi from MCST for giving us the MFI−03, AOI−14, and the ALPC−17 data.
Robert Wolfe from the Land Support Science Team for proving the opportunity for the internship.
Tim Zilkowski from SWALES Inc. for providing the PSR data.
MODARCH support group for database maintenance.

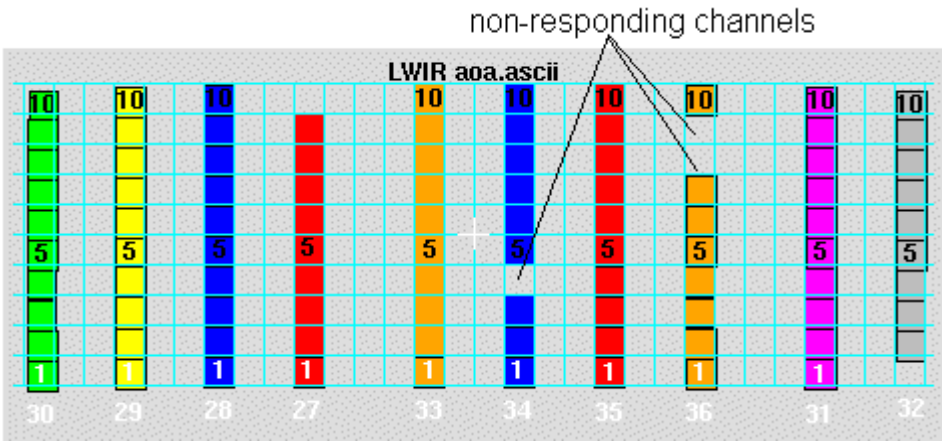

Figure 1. AOI−14 LWIR FP results. The FP is on a 1 km grid. The origin is indicated by the white crosshairs.

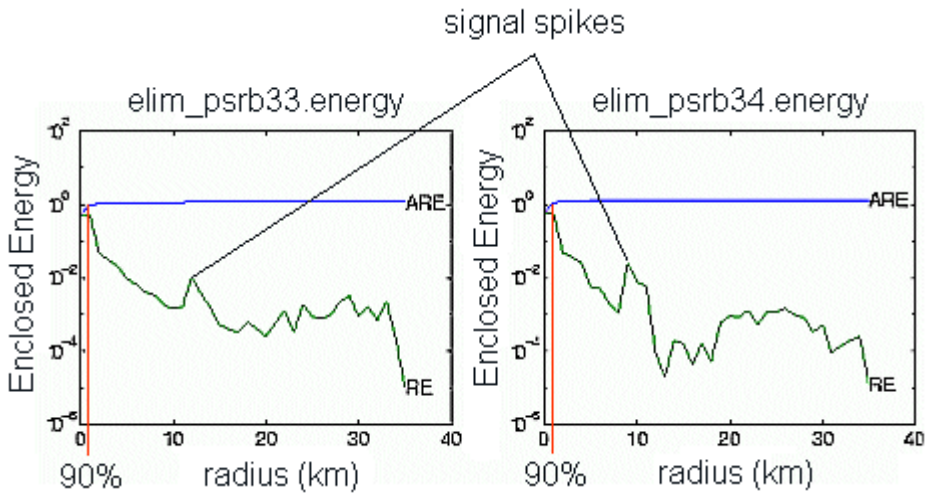

Figure 2. The RE and the ARE curves are plotted for bands 33 (left) and 34 (right). 90% of the energy in channel 5 is contained within 2 km as indicated in the graph.

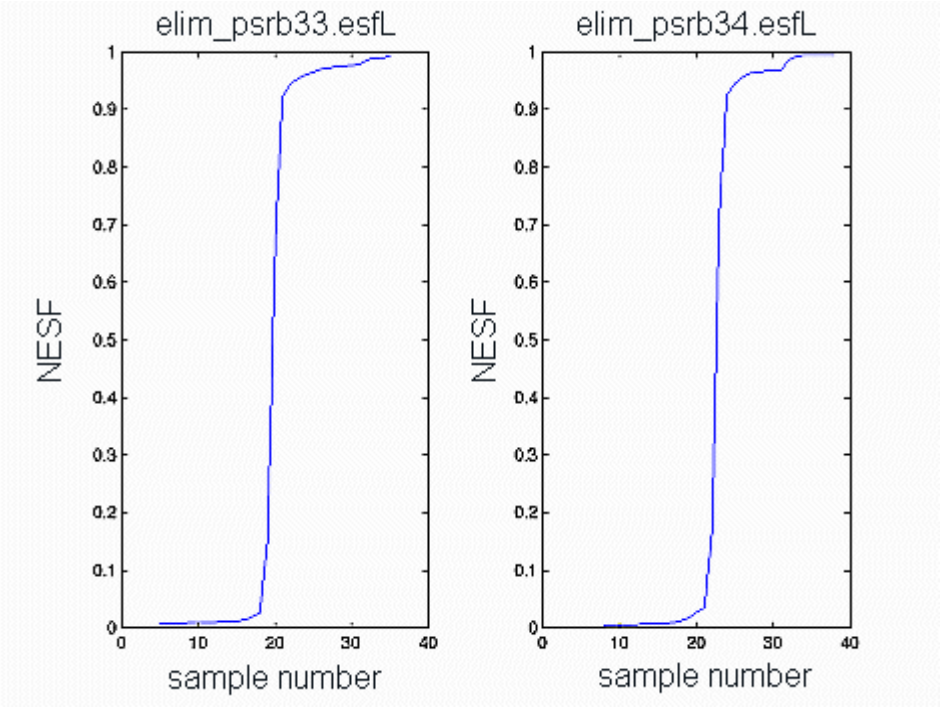

Figure 3. Normalized ESFs (NESF) for bands 33 (left) and 34 (right).

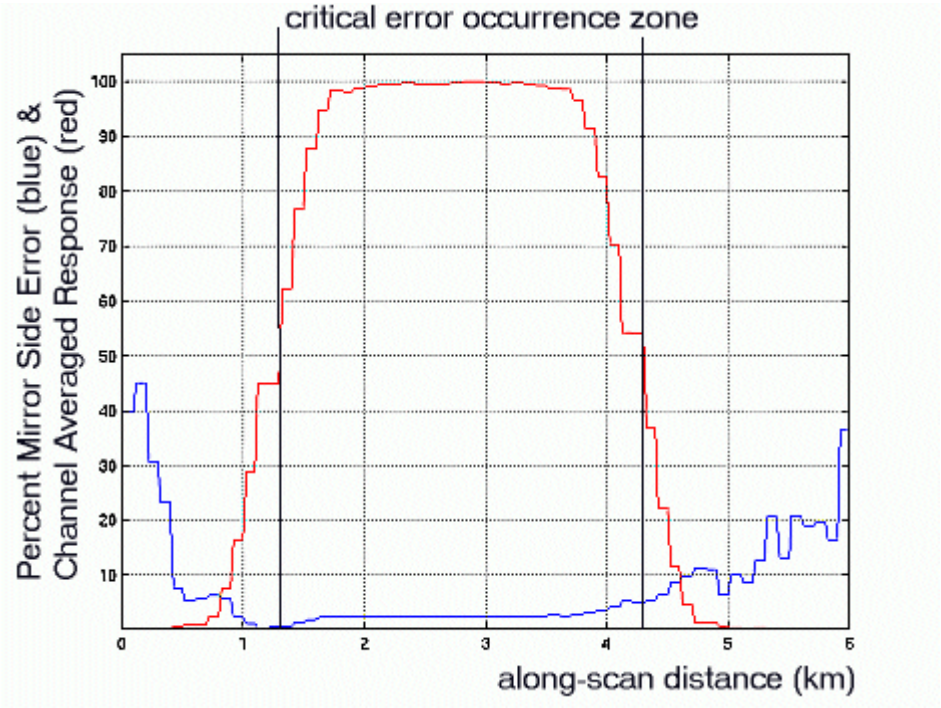

Figure 4. Channel Averaged Response from SRCA data for band 8.

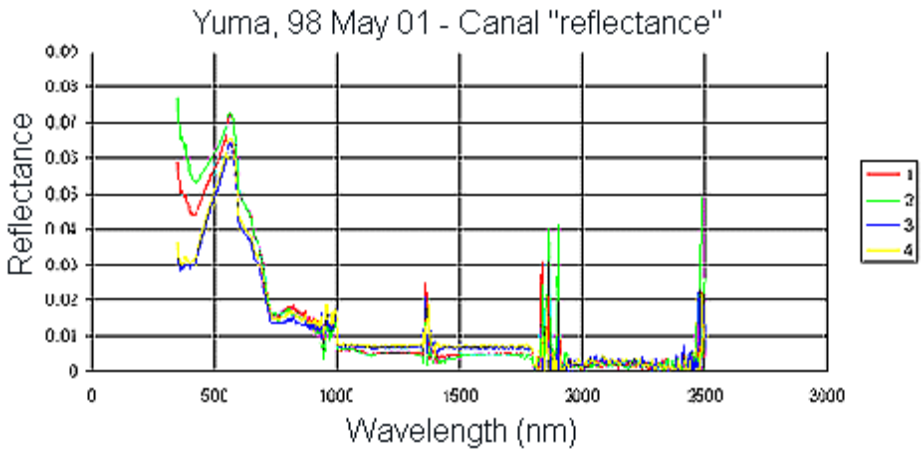

Figure 5. All American Canal Water reflectance.

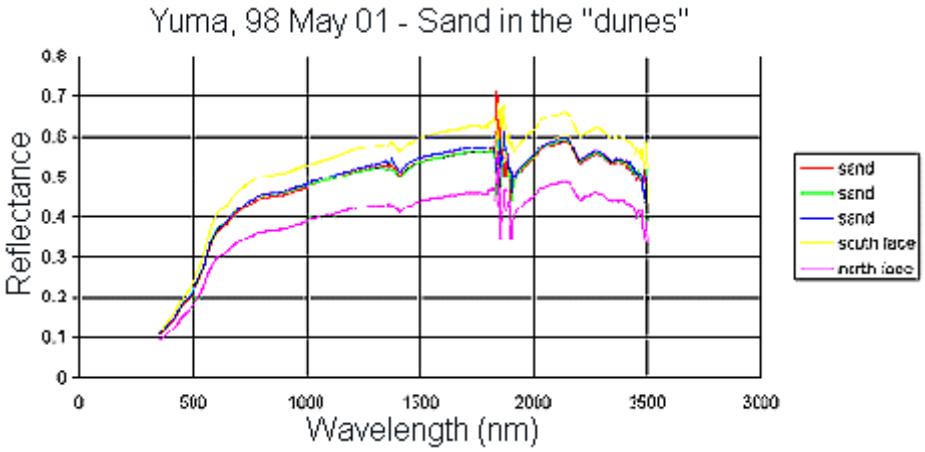

Figure 6. All American Canal sand dune reflectance.

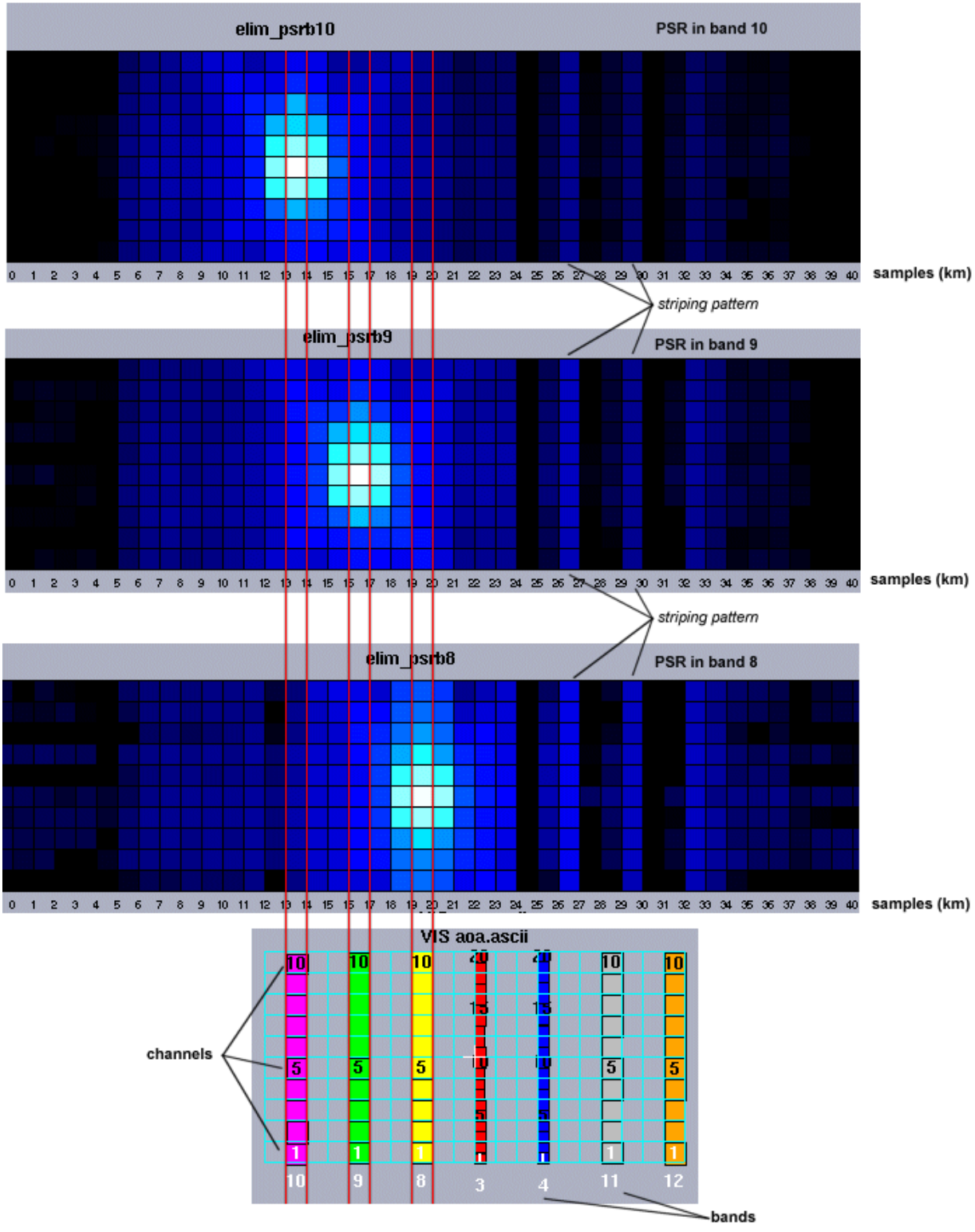

Figure 7. FPV with PSR, channel 5 illumination, for bands 10 (top), 9 (middle), and 8 (bottom). The VIS FP shows alignment. The striping patterns are aligned in the three PSR datasets from samples 25 through 32.

Table 1. List of Meetings.

Organization	***Personnel***	***Date***
U. Arizona Optical Sciences	B. Guenther/H. Montgomery/N. Che briefing	9/17/97
NASA/GSFC	MODIS Science Team Meeting	10/22/97 − 10/24/97
U. Arizona	B. Guenther/G. Godden/E. White	10/28/97
NASA/GSFC	MODLAND Meeting	12/3/97 − 12/5/97
U. South Florida	Ken Carder	4/17/98
U. Miami	O. Brown,R. Evans,H. Gordon	4/20/98
Imperial Sand Dunes (Yuma)	S. Bigger, R, Schowengerdt, F, Rojas	5/1/98
NASA/GSFC	MODIS Science Team	6/22/98 − 6/24/98
NASA/GSFC	MODIS Science Team	12/14/98 − 12/17/98

Table 2. Summary of Planned Activities.

Activities	***Objectives***	***Time Frame***
Internship at NASA Goddard with Land Support Science Team	Process Ground Control Points for 128 TM scenes, Learn about the requirements for MTF Correction Algorithms	Summer 1999
Scan Direction MTF Analysis for SRCA data	to extract the MTF from the SRCA data and use it to compare with the MTF model	Summer − Fall 1999
Acquire PSF data from SBRC	use on the MTF model development	on−going
Acquire MASTER coverage over AAC	use the images with ground data to model the overall PSF	Fall 1999
Acquire Landsat 7 coverage over AAC and Lake Tahoe	add to MASTER data for MODIS	post−launch
Simultaneous ground truth measurements with MODIS acquisition of test sites	validate the MTF	post−launch
Develop Correction PSF/MTF Algorithms	Enhance MODIS science products	Spring 2000−2001

Table 3. Summary of FP Alignment for VIS, NIR, S/MWIR, and LWIR FPs.

Band	***MFI−03 _q***	***MFI−03 _k***	***AOI−14***	***Plane***
1	offset < 15 %	N/A	offset < 15 %	NIR
2	offset < 15 %	N/A	offset < 15 %	NIR
3	offset < 10 %	N/A	offset ≈ 10 %	VIS
4	offset < 10 %	N/A	offset < 10 %	VIS
5	N/A	N/A	No Response	S/MWIR
6	N/A	N/A	offset < 10 %	S/MWIR
7	N/A	N/A	offset < 10 %	S/MWIR
8	offset < 10 %	N/A	offset ≈ 10 %	VIS
9	offset < 10 %	N/A	offset ≈ 10 %	VIS
10	offset < 10 %	N/A	offset ≈ 10 %	VIS
11	offset ≈ 10 %	N/A	offset ≈ 10 %	VIS
12	offset ≈ 10 %	N/A	offset ≈ 10 %	VIS
13	offset < 10 %	N/A	scan offset ≈ 20 %	NIR
14	offset < 10 %	N/A	scan offset ≈ 20 %	NIR
15	offset < 10 %	N/A	scan offset ≈ 20 %	NIR
16	offset < 10 %	N/A	scan offset ≈ 20 %	NIR
17	offset < 10 %	N/A	scan offset ≈ 20 %	NIR
18	offset < 10 %	N/A	scan offset ≈ 20 %	NIR
19	offset < 10 %	N/A	scan offset ≈ 20 %	NIR
20	N/A	offset < 10 %	offset < 10 %	S/MWIR
21	N/A	offset ≈ 15 %	offset ≈ 10 %	S/MWIR
22	N/A	offset < 10 %	offset ≈ 10 %	S/MWIR
23	N/A	offset < 10 %	offset ≈ 10 %	S/MWIR
24	N/A	offset < 10 %	offset < 10 %	S/MWIR
25	N/A	offset < 10 %	offset < 10 %	S/MWIR
26	N/A	offset < 10 %	offset < 10 %	S/MWIR
27	N/A	Channel 9 & 10 no response	Channel 9 responded	LWIR
28	N/A	offset ≈ 10 %	track offset ≈ 15 %	LWIR
29	N/A	offset ≈ 10 %	track offset ≈ 15 %	LWIR
30	N/A	track offset ≈ 20 %	track offset ≈ 20 %	LWIR
31	N/A	track offset ≈ 20 %	track offset ≈ 15 %	LWIR
32	N/A	Channel 1 no response	Channel 1 no response	LWIR
33	N/A	offset < 10 %	offset < 10 %	LWIR
34	N/A	Invalid data	Channel 4 no response	LWIR
35	N/A	Channel 7 offset approx 20 %	offset < 10 %	LWIR
36	N/A	Channel 8 & 9 no response	Channel 8 & 9 no response	LWIR