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Development of the Processing Framework and calibration for Ocean observations with EOS/MODIS

Introduction

This final report provides a summary of the major activities undertaken during the 13-year period of January 1990-January 2004 in support of NASA's EOS/MODIS missions aboard the TERRA and AQUA spacecraft.

Full details of the progress and problems in each three- and six-month period are discussed in the reports submitted to the MODIS Administrative Support Team, and are available at http://modis.gsfc.nasa.gov/sci_team/reports/oceans.html. Included in this report are highlights of the major results, a complete list of publications and presentations, lessons learned, and recommendations for the future.

Objectives:

The main objectives of this contract were two-fold. The first was the generation of *in situ* and inter-sensor matchup databases (MDB) for both visible and IR ocean products which would serve as the foundation for further development of the then existing (circa 1989) ocean algorithms by the MODIS Oceans team (MOT) and to quantify the error budgets and uncertainties in future ocean products. The development and maintenance of these databases were of supreme importance during analysis activities to characterize and calibrate the MODIS sensors. The second objective was the integration of selected candidate L2 and L3 algorithms into a coherent processing framework package that would be delivered to NASA for operational processing within the EOS/MODIS processing facility.

While the ultimate objective was delivery of EOS/MODIS ocean product code, a review of the activities during each year of this contract show that the Miami group was tasked to support several of NASA Ocean color and SST missions. In the early 1990's the Miami group developed and delivered to NASA's SeaWiFS project the at-launch algorithm codes for the SeaWIFS sensor that are today still the foundation of the current SeaWiFS processing. The Miami group was also tasked with both the development of the Pathfinder SST algorithm codes and the processing of Pathfinder fields that are today processed at the Miami SCF and delivered to the JPL PO.DAAC for archiving and public distribution. It is the synergy, lessons learned, and cross fertilization of ideas across these multiple missions that was and continues to be vital to development and success of the MODIS Codes.

To accomplish all of these objectives required dramatic improvements and capital investment in computer resources in regard to computational efficiency, data storage, and network infrastructure, to enable the analysis and processing of large amounts of satellite data. It is important to remember that at the time this contract was awarded the information "super highway" did not exist and access to the "world wide web" was limited. During the early stages of this project, the University of Miami/RSMAS was at the forefront of pioneering approaches for the transfer of large volumes of satellite data that would become necessary after the launch of Terra. Three primary networks, Ethernet, FDDI, and ATM were being used to move 100 GB input and 20 GB output. RSMAS enlisted the help of Oregon State University and the Naval Research Laboratory as nodes on this experimental Wide Area Network. This included the early adoption of ATM using DEC Gigaswitch and Fore ASX-100 switches. Heterogeneous computers, DEC 2100 & Alpha 3000 and SGI servers, were used as test bed for processing data, and SONY optical juke boxes and DEC TL 820 tape library for near line storage. These developments were reported in the computer press in an article by Linda Nicastro in Network Computing, May 1995, which included a two page foldout diagram. Today the RSMAS satellite scientific computing facility consists of >40 workstations, an SGI Origin 2000 16 processor machine, 11 4-processor Compaq Alpha ES-40 machines, 16 linux machines, 60TB of disk array, 1 TB of WORM jukebox capacity, 160 TB of tape jukebox capacity, and a layered network based on Gigabit Ethernet and Fiber channel, and 622 mbit/sec Internet-2 connectivity initially developed with the assistance of NSF and now maintained by the University, and a DOMSAT receiving facility for NOAA satellites.

The Remote Sensing Laboratory at RSMAS also holds significant archives of satellite data relevant to this contract, including over two decades of Level 0 global AVHRR measurements and all MODIS Level 1A global, 1km, oceanic data taken since the launches of *Terra* and *Aqua*. In addition, we have a full archive of match-ups between AVHRR and MODIS and quality controlled *in situ* measurements from moored and drifting buoys, and ship-borne M-AERIs over the life of these missions. The M-AERI data now comprise more than 1600 days of measurements that cover a full range of environmental conditions and represent the best calibrated *in situ* skin temperature measurements available.

Project summary

The work under this contract was centered on five major themes that are applicable to both the infrared and ocean color bands and were directed to both the Aqua and Terra MODIS sensors:

- *Match-up Data base and Validation –*

  Development and delivery of match-up databases and continued extraction of contemporaneous, co-located satellite and *in situ* buoy bulk temperature and M-AERI radiometric skin temperature match-up data base to support computation of empirical SST retrieval equation coefficients and collocated inter-sensor match-ups (MODIS, AVHRR, AMSR, ATSR) to validate SST.

  A complementary match-up database was also generated from MOBY *in situ* and SeaWiFS water leaving radiances measurements and the equivalent

MODIS visible band observations, for use in ocean color calibration and validation. These databases were pivotal for analysis and calibration of all sensors.

- *Calibration–*

  Development of correction factors to remove sensor artifacts and improved calibration coefficients to enable retrieval of accurate atmospherically corrected radiances. This activity was repeated at least monthly for the current MODIS sensors due to updates in the L1b calibration tables or because the atmospheric correction algorithm had evolved. During the contract we worked closely with the MODIS Instrument calibration team (MCST) and any insight gained during ocean band calibration was fed back to MCST in weekly meetings. Heritage sensors were also revisited many times over during this 13-year period as our understanding of both the sensors and algorithms improved.

- *Algorithm enhancement and Software Integration –*

  Integration and testing of team members' derived product algorithms in to the L2 atmospheric correction and product generation codes, address EOS Project and MODIS Algorithm Processing System (MODAPS) requirements and delivery of integrated code, processing tables and calibration coefficients to MODAPS for operational processing.

- *Quality Assurance* -

  Examined forward stream and reprocessed fields to determine whether product quality was maintained, worked with team members to develop corrections as required and facilitate the software integration. Monitoring of the quality of products produced by the MODAPS processing system through tools developed for both MODIS Oceans Quality assurances web page and the internal MOT RSMAS "MIRACLE" web site. Quality assurance activities also included posting and maintenance of documentation to the Oceans web page, as well as responding to users questions and problem reports.

- *Science Computing Facility –*

  The Miami SCF provided the test bed calculations to verify algorithm updates and on-going calibration updates. Testing included individual granule to global field processing in support of QA and included computation of global time series for team members to demonstrate effects of algorithm or calibration improvements.

Due to the 11 year period of performance of this contract and the breath of the activities, spanning development of more than 5 sensors and 3 missions it is difficult to summarize all the accomplishments. After reviewing each of the yearly progress reports from 1990-2003 a brief synopsis by contract year of the activities, significant developments, and deliverables was assembled and is presented in Appendix A.

Lessons learned

Competition for resources-

Even a quick glance at the activities accomplished each year; shows a continually increasing demand and competition between resources over the life of this contract, with a dramatic jump in late 1999 with the launch of the first MODIS sensor. Understanding how to better manage the competition between disciplines and processing streams for both human and computer resources will be important to the continued success of MODIS and future missions such as NPP and NPOESS.

The calibration of the visible and near-IR bands for ocean color is fundamentally more demanding requiring higher accuracy than that required for terrestrial or atmospheric bands. The retrieved normalized water leaving radiance (nLw) represents less than 10% of the total top of the atmosphere radiance (Lt) measured by the sensor for the blue part of the spectrum, 5% for the green and on the order of 1% for the red. The atmospheric correction process must remove approximately 90% of the signal in Lt to retrieve the water leaving radiance, although the exact percentage removed varies (with e.g. wavelength, aerosol content and concentration, in water properties, viewing geometry). This atmospheric signal is composed of Rayleigh and aerosol radiance components. At 443nm the Rayleigh signal represents about 70% of the atmospheric correction and is very sensitive to polarization characteristics of the sensor, while aerosol radiance comprises the remaining 20% and is globally dynamic in both concentration and scattering/absorption properties. MCST estimates that the accuracy of their on-orbit Lt is limited to the order of 2-3%, accurate ocean color retrievals require top of the atmosphere total radiances calibrated to an order of magnitude higher accuracy, 0.25%.

Calibration or atmospheric correction changes needing significant validation were in constant competition for resources with the forward stream processing. It was often difficult to manage both the forward stream and the retrospective reprocessing steams since each has dramatically different accuracy requirements and uses. The quality of the forward stream was continually in flux due to either changes in the instrument state or changes in the definition of the L1b calibration. The term "epoch" was coined by the Oceans team to identify these changes in the instrument state or calibration characterization. As each epoch was identified, both the Ocean and L1b LUT calibrations were examined and updated as necessary. Furthermore, the entire calibration time series would also require updating whenever a revision occurred in the *in situ* measurements (MOBY mooring or SeaBASS observations) or atmospheric correction algorithm.

Often there were large time and phase lags between L1b and Oceans LUT updates to correct the operational forward stream. Because the frequency of these epoch changes at times were high, 8-12 weeks during the first year, new LUTs were sometimes invalid before they could be delivered, tested, and pass configuration management prior to operational installation. Epochs occurring during the Northern Hemisphere summer months were further impacted by a lack of quality *in situ* measurements due to sun glint and cloud contamination at the Hawaii MOBY buoy site. These lags resulted in periods of very uneven data quality.

With this uneven quality of the forward stream data there was a justified need and program mandated pressure to reprocess. However, reprocessing was often being geared not to when the Ocean science code and calibration was ready, but rather to when the computer resources would be available at the MODAPS processing facility. Oceans reprocessing activities were further exacerbated by resource competition between the MODIS Land, Atmospheres, Oceans disciplines whose products were based on differing L1b versions. It was not until late 2003 that this was fully appreciated by upper management and the Oceans team was able to utilize the L1a subset and thus assure consistency between the L1b calibration LUTs and the Ocean calibration tables.

The MODIS Calibration and Sensor Team (MCST) developed special Ocean L1b LUTs that focused on the challenging 400nm bands. While these special Oceans "M" reprocessing L1b LUTs represent a giant step forward, they do not alleviate the competition for human resources needed to complete the detailed analysis of the atmospheric correction and the impact of uncertainties in the L1b calibration required for reprocessing while also monitoring and maintain reasonable forward stream quality. In the future it will be important to identify resources to track the forward stream separate from the system resources needed for retrospect reprocessing.

Main Technical and Scientific Results

The MODIS instruments produce the highest resolution global ocean color measurements currently available, as a consequence of its 12-bit digitizer precision and 1km global spatial resolution. Exploitation of these features for scientific studies requires an accurate and stable calibration of the ocean color bands.

At launch images below (Figure 1 and 2) showed severe mirror side banding, inter-detector stripes, and response vs. scan (RVS) sensor artifacts.

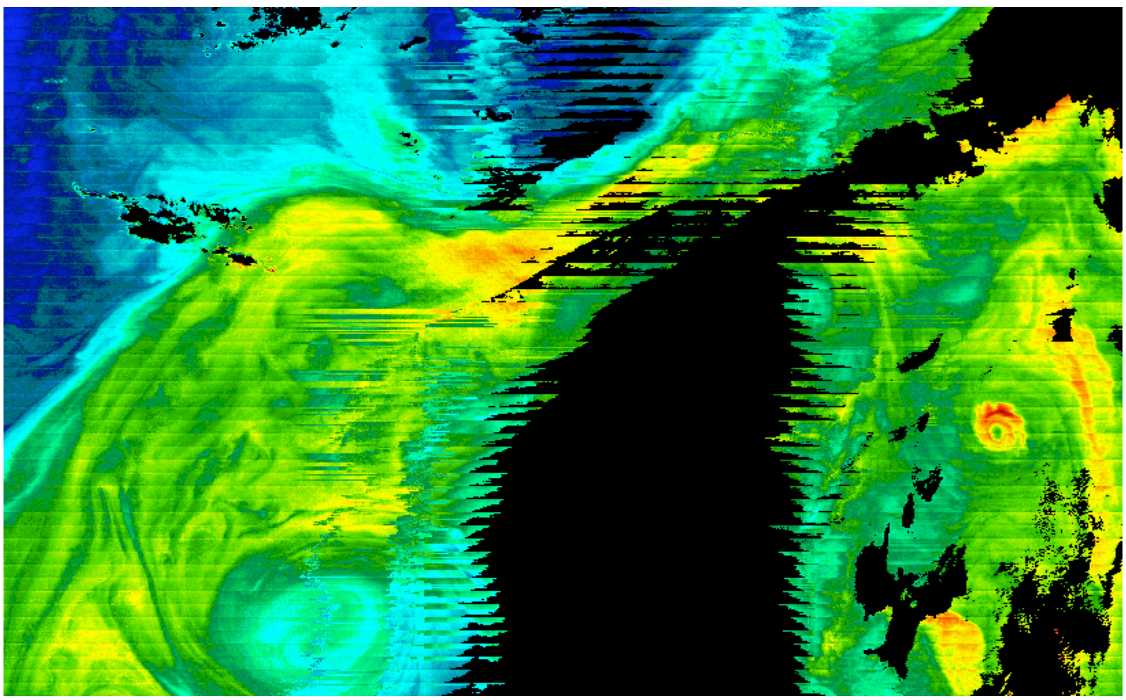

Figure 1. Example of at- launch inter detector stripping

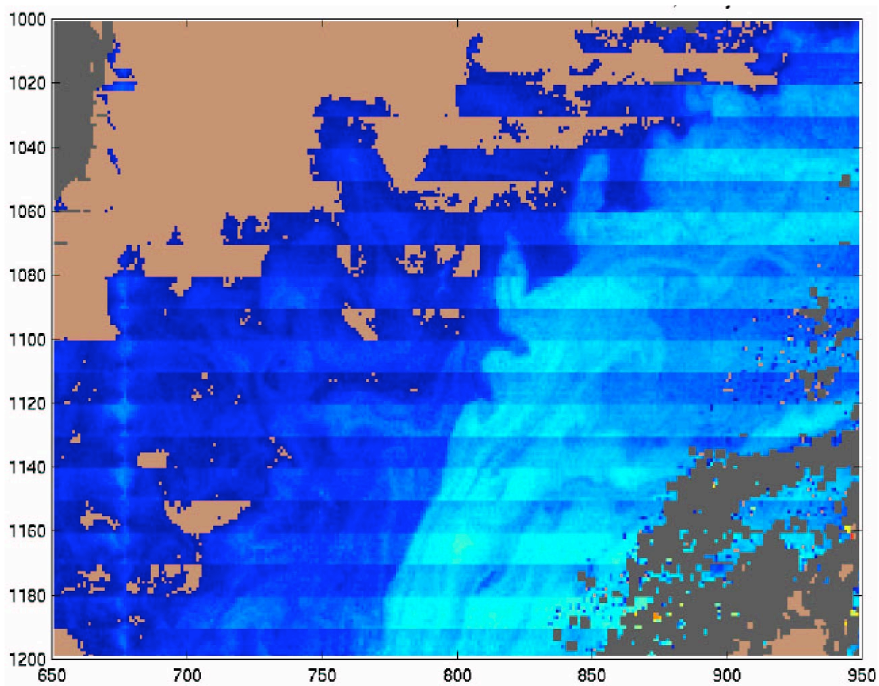

Figure 2. Example of at-launch images. Mirror side banding

In addition to these obvious visual artifacts, the MODIS TERRA sensor Level 1 m1 calibration (figure 3) and characterization also experienced numerous changes in degradation rates and electronic state on-orbit (epochs) that were difficult to understand at the time. Attempts by MCST to predict calibration temporal behavior encountered significant problems and resulted in poor quality ocean products.

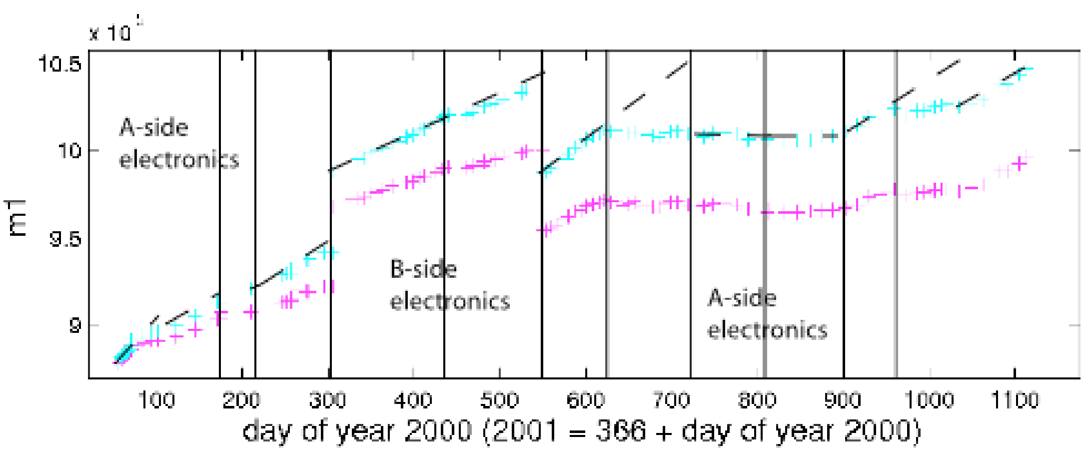

Figure 3 Band 8 412nm Time series measured solar diffuser m1's (blue mirror side 1, purple mirror side 2), and predicted m1's mirror side 1 at time of forward processing (dashed line). Vertical black lines indicate complete vicarious re-characterization and calibrations epochs of oceans bands.

A successful calibration of the Terra-MODIS Ocean color bands has been attained, but not without many challenges. While the calibration strategy for the MODIS ocean color algorithms is based on the heritage CZCS and SeaWiFS sensors, design and stability characteristics unique to MODIS have necessitated new innovations in the ocean color calibration strategy.

Calibration and Instrument artifacts

- Inter-detector imbalances across the focal plane
- Mirror-side differences
- Response-versus-scan angle imbalance
- Instrument state changes
- Instabilities in maintaining calibration both along orbit and seasonally
-

The complications that have arisen from each of these factors are reproduced in Table 1. Since the first year of the Terra mission, we have been able to empirically correct for most of the significant types of MODIS instrument errors that were first identified: detector to detector trends averaged across scan, mirror side banding, and cross-scan calibration adjustment. This group of adjustments is determined through a statistical comparison of MODIS spectral band data obtained from a time series of MODIS granules.

Types of correction:

Issue	**Effect on nLw images**	**Original variability after MCST corrections at L1B**	**Remaining variability after Miami L2 corrections**	
		% nLw Variability	% nLw Variability	Quasi-random % nLw variability
Inter-detector	Occasional striping, cross-scan variation	+/- 3% at center of scan +/- 6% at edges of scan	<1% at center of scan +/- 3% at edges of scan	3% 412 nm ** 3% 551 nm **
Cross-scan	Mis-matches between adjacent orbits	30% @ 412 nm 30% @ 551 nm	<1%	3% 412 nm ** 2% 551 nm **
Mirror-side	View Zenith Angle Dependent Banding	15% @ 412 nm 6% @ 551 nm	<1%	<1% 412 nm <1% 551 nm
Absolute calibration	Temporal variations	4% +/- 15% @ 412 nm	<1% blue bands <4% green bands	10% 412 nm 10% 551 nm

Table 1. Magnitudes of remaining nLw variability, both systematic biases and quasi-random variability in L2 products after MCST and the Miami corrections. Those quantities marked with asterisks (**) have a substantial portion of real geophysical variability included in the estimate.

The overall Level-2 accuracy at the Hawaii validation site after all corrections and calibrations factors have been applied is presented in Table 2. The statistics in Table 2 suggest that despite temporal changes in the instrument, the overall ocean color production system (including software) is performing quite well. However, the limited time and space distribution of *in-situ* matchups used to determine and evaluate the corrections and absolute calibration do not adequately capture seasonal and regional biases on larger scales.

Wavelength	**% nLw bias**	**% RMS**
412 nLw	0.0	7.0
443 nLw	-0.3	7.9
448 nLw	-1.6	6.1
531 nLw	-2.7	10.5
551 nLw	-3.7	12.3
Chlorophyll *	14	27.1

* Chlorophyll matchups from SEADAS *in situ* database not limited to Hawaii only

Table 2. Water leaving radiance accuracy over the Hawaii validation site after all corrections and calibration factors are applied. Statistics are based on 1km *in situ* matchups. Note: Established Mission accuracy requirements are 5% nLw, 35% chlorophyll, Terra meets this objective based on matchup analysis.

The MCST L1 correction captures most, but not all, of the MODIS trends. For the level of accuracy required to produce climate quality ocean color, L1 data are required to be stable and accurate at the level of 0.25 to 0.5%. This level of performance exceeds that achievable by the on board calibrators and will always require some form of vicarious calibration. Comparison of SeaWiFS and Terra-MODIS water leaving radiances and analysis of Terra-MODIS and MOBY mooring *in situ* observations show differences in the retrieved water leaving radiances from less than 5% near the MOBY site to MODIS-SeaWIFS differences at large solar zenith angles that at times approach 30%. This difference of 20-30% in water leaving radiance translates to a 2-3% error in total top of the atmosphere radiance measured by the sensor. This discrepancy is by far the largest unresolved factor remaining in the MODIS calibration effort. Climate quality retrievals for all solar zenith angles are achievable once the 412 and 443nm blue band behavior is understood. Several different factors have been hypothesized by various groups in the last 6-8 months as an explanation to the differences seen, the leading potential candidates fall into Three classes: 1) Factors active during level-1 calibration coefficient (m1) determination, and 2) Factors that impact the ability of the sensor to maintain the calibration along orbit. 3) Geophysical differences due to different overpass times and orbits.

Conclusions and recommendations for the future to address outstanding calibration issues:

Generation of stable L1 LUT and L2 corrections sufficient to produce climate quality ocean color fields is an extremely challenging but achievable task. Results using the latest experimental “smoothed” L1b LUT from MCST incorporating improved estimates of the SD degradation and the latest oceans codes, presented to the outside calibration review panel held at Goddard in early February 2004, at the close of this contract (Mueller et. al. 2004), demonstrated that MODIS Terra and Aqua are relatively stable, slowly varying instruments once retrospective, smoothed L1b calibration coefficients are available to be used in the production of L1b granules. Furthermore, MODIS Aqua and Terra exhibit similar on orbit trends (e.g. RVS), although Terra has additional mirror side 1 to 2 trends not yet seen in Aqua. The detailed time series characterization of TERRA MODIS will be pivotal in the future understanding of AQUA MODIS as the sensor ages on orbit. Comparisons of the first 1.5 years on orbit of both sensors show they are exhibiting similar trends both in time and as a function of solar zenith angle. The lessons learned with TERRA to date should be applied to AQUA and include the following recommendations:

i. Orderly update of L1b LUT’s to include smoothed, de-trended calibration coefficients (m1). The current LUT’s are based on measured SD measurements and contain noise that can be reduced when SDSM and SD measurements are smoothed with time. Uncertainties in m1 calculation contribute a significant percentage of nLw uncertainty, on the order of 10%. This is a large contribution to the forward or near real-time processing. It is suggested that rapid updates to L1 LUT to replace measured m1 with filtered m1 be instituted.

ii. Increased SD degradation due to the prolonged open TERRA SD door in 2003 are not reflected in the standard operational Level-1 LUT, it is recommended that MCST incorporate these revised degradation rates operationally.

iii. Identify and correct for ‘excess light’ at low solar zenith angle scans, this will impact RVS and calibration adjustments. In the latest calibration it was assumed that stray light in the form of sun glint and MOBY self-shadowing is present in the June-August periods and these matchups were therefore removed from MODIS characterization. This eliminated some but not all of the excess radiance, other sources likely remain and will need to be further explored.

iv. Identify and correct for blue band hemispheric trends likely the result of polarization issues. Solar zenith angle polarization, mirror side difference and MODIS-SeaWiFS difference increase significantly when the solar zenith angle > ~45 deg.

v. Identify methods to track changes in polarization sensitivity which are likely changing on orbit, this impacts mirror side balance, RVS and calibration.

vi. Track relative performance and balance of the three calibration sources to better monitor MODIS scanner performance versus trends in calibration sources. Relative degradation of and temporal trends in the TERRA MODIS calibration sources, e.g lunar, SRCA, SD, are not completely characterized. This contributes 1-2% error in blue band Lt over Terra mission, (10-20% nLw) and impacts RVS and possibly m1 corrections. In addition any imbalance between the three calibration sources are currently interpreted as a scanner RVS problem.

vii. The current sun glint correction is based on vector Cox-Munk slope distribution forced by model winds. The correction depends on fidelity of wind field and ignores any time history of wind-wave-current interaction. Use of a 'measured' rather than modeled sun glint distribution would minimize these limitations. The glint correction is important as glint can impact 60% of the scan.

viii. Additional polarizations studies are needed. Howard Gordon developed polarization corrections with instrument polarization sensitivity provided by pre-launch measurements. Temporal change in relative scan mirror side-to-side performance and RVS (mirror response vs scan angle) suggest that further work is required in this area.

ix. Further work is needed to better understand the use of Morel et. al. 2002 BRDF correction, in particular to understand and verify the magnitude of the Rgoth correction at high scan angles. Recent work with Ken Voss suggests that the theoretical Rgoth factor may be too large at large viewing angles.

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MODAT. Index of the on-line documents maintained by RSMAS MODAT personnel in conjunction with the MODIS Adaptive processing center,(MODAPS), MCST instrument calibration team, data ordering centers (EDG, DAAC), and direct broadcast communities can be found on the MODIS Oceans web page. http://modis-ocean.gsfc.nasa.gov/qual.html/doclinks.html

Workshops and courses science community outreach:

Documents and course materials listed below are available for download from the MODIS Oceans web site http://modis-ocean.gsfc.nasa.gov/refs.html

Remote Sensing of the Earth's Environment from Terra, a Workshop at the International Summer School on Atmospheric and Oceanic Science, L'Aquila, Italy, August 25-30, 2002.

MODIS Overview, Atmospheric Correction, and Calibration,Chlorophyll (empirical algorithm),Primary Productivity (P1) and SST –lectures by R. Evans

MODIS: Fluorescence, Primary Productivity, Calcite, and Some Applications (PowerPoint presentation), lectures V. Banzon,

Second Workshop for Earth Science Satellite Remote Sensing, George Mason University, Fairfax, VA, October 15-22, 2002

MODIS Ocean Products Workshop, University of New Hampshire, Durham, NH, February 3-4, 2003.

Water-leaving Radiances and the Atmospheric Correction , R. Evans.
Filenames, Structures and Useful Metadata , K. Kilpatrick.

MODIS Ocean Products Workshop, Oregon State University, Corvallis, OR, September 4-5, 2003

Water-leaving Radiances and the Atmospheric Correction , R. Evans.
Sea Surface Temperature , R. Evans.
Filenames, Structures and Useful Metadata , K. Kilpatrick.
Hands-on computer tutorial – T. Moore, K. Kilpatrick, J. Norsiak

Awards

- NASA Group Achievement Award, Moderate Resolution Imaging Spectroradiometer (MODIS) Support Team. August 2001.
- NASA Outstanding Teamwork Award – NASA Earth Observing System Aqua satellite, June 2003.
- NASA Group Achievement Award, Aqua Mission Team. August 2003.

Budget summary:

The original contractor cost estimate was 22.2 million dollars over 10 years (~2million per year). The final actual expenditures were 14 million, 40% under original estimates. A breakdown of the actual direct costs show that 37% was spent on salary, 43% on capital expenditures, and 10% for hardware maintenance and third party software licensing agreements, and 2% on expendable supplies.

6. REPORTING CATEGORY	Actual expenditures * VALUE	Original contract estimate VALUE
LABOR HOURS	102	215
LABOR COSTS	3887	6782
FRINGE BENEFITS	973	2638
MATERIALS & SUPPLIES	307	1209
TRAVEL	133	135
COMMUNICATIONS	63	79
MAINTENANCE Computer hardware and software agreements	461	165
COMPUTER TIME	25	1076
PUBLICATIONS	8	69
CONSULTING	7	0
CAPITOL EQUIPMENT	4482	2805
DIRECT COSTS	10345	14958
INDIRECT COSTS	3518	7292
TOTAL COSTS	13863	22250

*cost units of $1,000

Appendix A.

<u>List of major tasks completed by year</u>

1992- Year 1

Processing frame work:

1. Begin evaluation of future processing environments
2. Added SGI, SUN, DEC, and VAX operating system support to DSP per NASA HQ request.
3. Define machine and processing environments for MODIS and SeaWiFS
4. Preliminary testing based on AVHRR and CZCS codes
5. Retrospective examination of CZCS calibration tecniques
6. Begin development of processing methodology for SeaWiFS sensor. Exploration of client/server processing environments
7. Substitution of improved SeaWifs modules for CZCS modules

Matchup databases:

8. Identification of moored and drifting *in situ* data sources
9. Development of Time of Closest Approach (TCAP) software to automate identification of orbits and pixels extractions for co-located matchups.
10. Identify and evaluate programs relating spacecraft orbital models and geolocation of matchups.
11. Evaluate existing Algorithm capabilities used for CZCS and NOAA AVHRR Sensors using V1.0 matchups databases to determine research focus areas where algorithm improvements can be made.

1993 – Year 2

Processing framework:

1. Define SeaWiFS level 1 specifications
2. Develop improved data-day definition methodology for global files
3. Develop space and time binning methods based on quality level assignments
4. Development of the RSMAS gridding scheme, a modification of the ISSCP grid known as the intergerized sinusoid grid (ISEAG).
5. Conversion of CZCS level1 data into a Seawifs L1 format for testing of integrated modules for pre-launch SeaWifs.
6. Delivery of integrated SeaWiFS V1code under a VDC processing environment.
7. MODIS ATBD v1 delivered based on heritage CZCS, SEAWiFS, and AVHRR algorithm evaluations.
8. Begin work on developing High speed networks between Universities.

Matchup databases:

9. Re-evaluation of AVHRR IR calibration techniques and development of a new non-linear calibration approach.

10. Evaluation of candidate algorithms for Pathfinder SST based analysis of the SST matchup database. The goal was to find the algorithm with least amount of bias and low rms. All algorithms were found lacking based on comparisons of limited *in situ* measurements, and limited satellite qualities.
11. Expanded the number of fields in the matchups database from 45 to 195. This included the addition of more channels, surrounding pixels in a 3x3 box, calibrator e.g. Black body information, and ancillary data such as the Reynolds SST climatology, water column depth, water vapor, wind speed, air temperature to facilitate error analysis.
12. Using the expanded algorithm explore uncertainties and sources of error in the candidate algorithms; e.g. satellite and solar zenith angle effects, water vapor, wind speed, air-sea temperature differences, sensor calibration changes, regional and latitudinal dependences.
13. Develop improved SST algorithm based in the non-linear nlsst algorithm with two sets of coefficients for low and high water vapor regime.

1994 Year 5

Processing framework:

1. Continued updates and incorporate new development to SeaWifs V2 code
2. Begin Operational processing of V1 Pathfinder SST products at RSMAS. Products delivered to JPL for distribution to the community.
3. Design and costing of improved computer networks and resource needed to meet the data transfer and processing loads in preparation for MODIS at the RSMAS scientific computing facility (SCF).

Matchup databases:

4. Continued expansion of the number of records in the matchup databases.
5. Began Radiative Transfer (RT) modeling of SST coefficients based on radiosonde data and MODIS spectral response. Analysis of RT coefficients versus empirical coefficients using SST matchups databases.
6. Analysis of pathfinder V1 SST fields against buoys, Reynolds climatologies, NOAA MCST operational products, and other ancillary fields.
7. Explore techniques to improve cloudy pixel identification based on binary decision trees and inclusion of additional ancillary information from other channels.
8. Explore latest statistical techniques for coefficient estimation based on robust regressions.
9. Explore use of monthly coefficients using time weighting functions during empirical coefficient estimation to reduce seasonal and latitudinal trends.
10. Begin near real-time acquisition of *in situ* SST measurements from the GTS system in conjunction with Doug May at the Navy research lab.

1995 – Year 3

Processing framework:

1. Discussions begin with the AdHocWGP to define data requirements, processing environment and hardware for MODIS. Includes cost and processing model development with potential vendors.
2. MODIS V1 L2 ocean code delivered to NASA December 1995 based on progress made for SeaWiFS code.
3. Integrate and test improved data day and space binning code developed in 1993 into both the MODIS and SeaWifs, and Pathfinder Level-3 code.
4. Begin definition and development of MODIS file formats, ECS metadata, PGE scripts, makefiles.
5. Delivered SeaWifs code updates with 4.2 and 4.4 I/O specifications. The relationship with the seaWifs project was that Miami maintained the core atmospheric correction and ocean color algorithm code while the SeaWIFS project was responsible for I/O routines and testing. Any changes in I/O routines often required minor changes in the core algorithm. Thus there was an iterative pass back between SeaWiFS project I/O coding group and the Miami algorithm developers.

1996 – Year 4

Processing framework:

1. ATM high speed network and additional computer resources become fully operational at RSMAS SCF.
2. Detailed documentation and prologues added to all MODIS ocean modules and subroutines, including new code, and heritage code.
3. Begin development of MODIS V2 atmospheric correction codes with the addition of white caps, diffuse transmission, and additional aerosol models.
4. Reprocessing of entire AVHRR mission using V3.0 pathfinder algorithm to produce a 10-year consistent time series across multiple AVHRR sensors N-9 thru N-11.
5. New space seawifs binner, problem corrections. Seawifs begins to rewrite the code from scratch. Detailed discussions on-going to assist.

Matchup databases:

6. Automate collection and quality control of *in situ* satellite matchups
7. Transition to near real-time operational matchup and quality assessment of pathfinder SST based on the NRL GTS data.
8. Continue routine expansion of the records in the machups database and coefficient estimation for current sensors.
9. The first Maeri instrument becomes operational and cruise measurements begin to be added to the matchup database. This represents a exciting improvement to the SST matchups database as the Maeri represents the first truly calibrated *in situ* measurement that can be directly linked to NIST calibration sources and will allow detailed exploration of the satellite skin to buoy bulk temperature differences

1997- Year 5

Processing Framework:

1. SeaWiFS launched September 1997 and directly benefited from the 6 years of prior development under the MODIS contracts.
2. Participated in SeaWiFS initialization cruises and developed *in situ* satellite calibration routines "caleps" for the SeaWiFS project.
3. Begin finalization of MODIS V2 at-launch algorithms developed based on the latest developments from both SeaWiFS and Pathfinder AVHRR.
4. Pathfinder V4 reprocessing release with improved cloud identification, expanded quality level assignment, and well defined and characterized uncertainty estimate. The AVHRR mission was reprocessed at the Miami SCF and delivered to JPL for distribution, along with the expanded matchup databases for each sensor.
5. Begin to develop operational interim (today one would call this forward stream processing) Pathfinder SST product generation based on preliminary coefficients.
6. Annual reprocessing of previous years AVHRR data, based on retrospective analysis of calibration information, revised algorithm coefficients and quality control results from the matchup database. This annual archive data is delivered to the JPL and replaces the interim near realtime product and is suitable of longterm climate studies.
7. Continued expansion of computer resources in preparation of MODIS volumes and loads.
8. Continued updates to SeaWifs for v5.0 I/O changes. Coordinate with the SeaWiFS project to maintain compatibility with the MODIS algorithms so that they could re-write into seadas environment.

Matchup database:

9. Continued collection of matchups databases and coefficient estimation
10. Continue analysis of matchup databases for quality control
11. Exploration of general additive models (GAMs) for coefficient estimation.
12. Case studies of N-7 (limited network of buoys deployed mostly coastal US) and N-14 (large network of distributed world wide) matchups to understand the impact of geographic distributions of *in situ* buoys on coefficient estimation and uncertainty.
13. Began visible band matchups with MOBY buoy and SeaWiFS

1998-Year 6

Processing framework:

1. V2 versions of PGE09 (ocean color), PGE10 (SST), PGE20 (L3 interim daily) were submitted to SDST on for acceptance testing. This delivery contained bug fixes, additional and improved diagnostic messages, and support for processing SeaWiFS data converted to MODIS format. Final versions of the L3 PGES (PGE20, PGE49, PGE50, PGE53, PGE54) were submitted to SDST on for acceptance testing. Also included with this delivery were programs and procedures developed to automate testing of L3 processing.

2. FloridaNET vBNS network connection to GSFC completed
3. Began testing of data flow between RSMAS and EOSDIS and MODAPS machines.
4. QA testing using SeaWiFS/MODIS products. Testing of the MODIS ocean color algorithms utilizes two types of input data sets. The first is the synthetic MODIS L1B radiance file and associated meteorological, cloud and navigation files. This set is used only to test compliance with MODIS data flow due to compatibility problems between the radiance provided in the synthetic data and what is expected by the PGE. Science testing is performed using a L1B file converted from SeaWiFS observations and transformed into MODIS radiance units. Resulting Lw outputs are then compared with the same radiance files processed through the SeaWiFS L2 program. Granules are collected for a "data day" and assembled into global files by product. Multiple data day files are then collected to provide fields for longer time periods. To date we have produced fields assembled with one, two and three days of data exercising the L2 and L3 PGEs.
5. Hosted Ocean Color group meeting in April
6. Established Q/A prodecures using test MODIS data
7. Established MOCEAN web site
8. Modified MODIS codes to run with SeaWiFS input for testing
9. Developed new PGE's to create 3-week weighted global averages
10. Dual processing streams/double spoolers/double day processors were implemented and tested. Current versions of Autosys and auto-processing command files were put into CVS. The automatic processing environment based on Autosys (production) and Networker (archiving) has been used to process AVHRR Pathfinder, SeaWiFS, and SeaWiFS/MODIS products. These products are being used to generate climatologies as well as test algorithm performance and quality assessment. Processing both real-time and retrospective fields for several projects is providing experience and reliability testing of the overall system. Some of the lessons arising from this exercise concern network stability and disk management. We are continuing to integrate the fiber channel raid disk array into the SGI and DEC environments and are working with the companies to isolate and remedy problems encountered with their respective device drivers.
11. Updated file format descriptions and documentation and prologs to reflect changes in the MODIS code.
12. Major metadata issue arose during late 1998 imposed by the redefinition of the MODIS Ocean ESDTs within the EOS processing system. The redefinition generated a number of changes to the metadata of each PGE to reflect new LocalGranuleID, Long and SHORTESDT names.
13. Pathfinder processing is being used to prototype MODIS-like product resolution. Daily SST maps are produced at 4km resolution within 800 km of the coasts using the current Pathfinder algorithm. Cloud masks are maintained separately from the data; masks can be applied at the quality level selected by the user when the images are presented at the web site.

14. Produced navigated and calibrated radiance and brightness temperatures for a sequence of NOAA-14 pass segments defined by W. Barnes for comparison with contemporaneous TRMM retrievals.
15. Reprocessed Pathfinder V4.1 GAC data were verified and released to the general scientific community. These data were made available via the NASA JPL DAAC.

Matchup database;

16. Continued collection and expansion of the SST Matchups databases
17. Continued expansion of MOBY - SeaWifs visible matchup database
18. Analysis of SeaWifs matchups to evaluate calibration strategies and algorithm performance and explored atmospheric correction performance based in the ratio of the 6XX/8XX bands compared to the 7XX/8XX as the 6/8 ratio provided better signal to noise.
19. Explore techniques to improve empirical coefficient estimation of early AVHRR's 1981-1984 when *in situ* sources are limited.
20. Efforts are underway to use aerosol products from the TOMS sensor and the AVHRR visible channels to begin to correlate SST anomaly patterns with these 'aerosol' fields. The TOMS AI field monthly climatologies were found to correlate well with Pathfinder anomalies (v. Reynolds' Optimally Interpolated SST fields) in the tropical Atlantic.

1999- Year 7

1. Updated versions of all ocean PGES were delivered to SDST in January for acceptance testing. This update included performance enhancements, integration of SDP Toolkit V5.2.3 and bug fixes for problems found during testing of earlier versions.
2. June/July deliveries incorporated the latest atmospheric corection, product algorithms, computational efficiency enhancements and general program corrections have been sent for I&T.
3. Updated versions of all ocean PGES were delivered to SDST in October. The new version included support for the collapsed level 3 ESDTs [products at level 3 are stored by resolution, and binning period in the same ESDT, so the product identifier was removed from the ESDT and the product name added to the LocalGranuleID]
4. Major metadata issues between ECS DAAC and MODAPS and Ocean code continue to be a problem, solutions result in numerous changes and redeliveries to all oceans PGE's.
5. Implement updated Toolkit and associated libraries (SDPTK5.2.5v1.00, HDF4.1r2, HDF-EOS2.5v1.00).
6. Three weeks of seawifs data (from june and july 97) were converted to Modis format and is being used to develop and test this process. These procedures will allow us to independently (from ECS or MODAPS) test the Modis code in a way that simulates a production environment. These results are being used to identify bottle-necks in the processing and improve performance.
7. During the later half of 1999 All MODIS code was ported to Digital Unix and the results verified against the SGI version of the code. This will allow the new DEC Alpha ES40 cpus (~2x the SGI R10000) to process MODIS algorithms. We also have produced new estimates of the processing times for Level-2 and level-3

Ocean Products using SeaWiFs and AVHRR data and the latest MODIS Ocean PGE's and simulated processing environments.

8. Improved processing capacity through a combination of algorithm efficiency improvements and upgraded hardware to achieve a capability to process reduced resolution (4km) MODIS observation at a rate that exceeds 10 data days/day. This capability will permit changes such as algorithm enhancements or updated calibration to be easily verified.
9. Detailed analysis of the volume and loads undertaken to ensure MODAPS will have the appropriate resources at-launch.
10. Algorithm development concentrated on developing absorbing aerosol models to complement the standard scattering aerosol models incorporated in the atmospheric correction scheme. Work in conjunction with H Gordon and C Moulin produced an absorbing aerosol model based on aerosol spectral atmospheric reflectances observed in SeaWiFS images over the eastern tropical Atlantic.
11. Network-The SOX/VBNS connection to GSFC has shown improvement since NIS routing changes in March. Testing indicates that potential data rate as high as 2000 KBs. However, the network is not consistent in supporting this rate and often drops well below 1000 KBs.
12. Set up MODIS product browse capabilities on UMiami website "miracle" in preparation for launch. This web page and browse tool will be password protected and used by the Oceans team to evaluate at launch products prior to public release.

Matchup database:

13. Continued both the IR and visible matchups databases from both seawifs and AVHRR.
14. The visible matchup database was used to test changes to our local SeaWIFS processing stream to incorporate recent developments in calibration and atmospheric model selection in collaboration with Howard Gordon at the University of Miami Physics department. These changes included new calibration values in channels 1-7 (generally on the order of a 1% lower) and the addition of a new oceanic atmospheric model. This new atmospheric model assumes only a single mode of large particles associated with breaking waves. The current maritime atmospheric models contain two modes, big and small particles. We implemented the above changes in our processing stream and extracted the satellite information for a 3x3 km box located over the MOBY Hawaii location to examine the impact of these changes on the accuracy of the atmospheric correction and nLw retrieval.
15. IR matchups database used to evaluate performance of the latest set of SST coefficients developed from RT techniques.
16. Explore various formulation for the new 4um SST algorithm
17. Prepare for MODIS IR and visible bands QA activities, including the elimination of inter-detector differences within bands, the evaluation of RVS/AOI corrections, and estimate of the mirror side differences.
18. Examine DNs to establish inherent noise level for each detector of each band.

2000- Year 8

Processing frame work:
MODIS TERRA launches

1. Early at-launch images demonstrated severe striping and discontinuities in both the along and cross scan direction.
2. Sensor characterization and use of revised calibration tables produces a dramatically improved image but granule to granule, and orbit to orbit inconsistencies remain.
3. Artifacts L2 currently identified included:
   Inter-detector discrepancies
      Response versus scan angle (RVS)
      Mirror side differences
      Angle of incidence (AOI)
      Digitizer noise in IR and 765nm and 865nm bands
      Channel cross-talk; electrical and optical have been identified in the L1b product
      Polarization and sun glint corrections
4. Impact of known artifacts on level 3 global images violates a fundamental assumption of the current time and space binning rules and algorithms used to create global level 3 products. Implemented highly restrictive binning rules of "mask" out poor quality data.
5. Instrument changes electronic states several times (A to B side electronic changes)further complicating our understanding and production of consistent time series to properly analyze sensor artifacts.
6. Intensive work in conjunction with MCST to understand these artifacts
7. Several revised algorithms from team members currently in test mode included:
   a. Gordon-Balch a new 3 banded Coccolithophore
   b. Gordon-Abbott- new FLH based on the new 3-banded Coccolith algorithm are being refined and evaluated by Gordon, Balch, and Abbott for possible future operational use.
   c. Major revisions to the Ken Carder's 3 band Chlorophyll algorithm (Carder V2) were incorporated into the provisional code. The revised chlor_a3 improved the handling of the nitrogen deficit term of the algorithm and produces superior results compared to the Beta V1 version.
   d. Campbell -The SeaWIFS OC3M algorithm was integrated into the provisional code and replaces the OC2V2 algorithm present in the Beta code for the seaWIFS chlor_a2 product. Based on comparisons to SeaWIFS data by Janet Campbell, the OC3M algorithm produced MODIS retrievals more similar to operational SeaWiFS OC4V4 same day retrievals.
   e. Hoge- A new test algorithm for absorption of Phycoerythrin (Hoge V3) was also integrated and includes 2 new test products total backscatter and concentration of dissolved organic matter. These new products are under test evaluation.
8. The Miracle web site http://miracle.rsmas.miami.edu upgraded with several

new viewing tools. Products can be viewed at the 36 and 4km global map level and regional selection boxes allow direct visualization of the high resolution level 2 products for the geographically selected region. Data can be masked by selecting various quality levels and or common or product specific flags from a menu prior to generation of the image on screen.

9. Provided content and pages for the MODIS OCEAN QA web site these web documents include:
    a) Disclaimer and known problems web site
    b) General disclaimers and product status
    c) Listing of known problems under investigation
    d) Listing by product of QA_science flag and flag as DAAC QA metadata update tool not operational
    e) Trouble ticket web page tracks status of end user reported problems received at the GDAAC
    f) general product information and sample IDL codes for reading
    g) pixel quality levels, common flags, and product specific flags.
10. QA Monitoring of MODAPS production
11. Routing archiving of MODIS level 1 subset data at Miami and comparisons of the Miami archive and the DAAC archive indicate that granules are being dropped and traced to PGE71 problems at the DAAC.
12. Begin Tracking of MCST level-1 lookup tables.
13. The Miami SCF has been participating in weekly telcons with MCST in regard to MOD02 calibration tables. The Miami SCF monitors the delivery and installation into operations of all changes to PGE02 LUT's. The Miami SCF identified that the wrong PGE LUT V3.0.0 had been delivered to GDAAC I&T and installed into operations. Miami receives advanced tables directly from MCST for testing prior to delivery to STIG. Miami also receives an automatic push from STIG when new LUT's are received for integration into operations. Miami compared the two LUT tables and found that they did not match. MCST and STIG were notified of the discrepancy. MCST confirmed the error in the delivery and the correct tables were redelivered by MCSST to STIG.
14. Weekly telecons with MCST, PI processing group (PIP) and Oceans TEAM . Intermittent telecoms with cross sensor and cross discipline QA representative. Continued interactions with MODIS ocean PI's to coordinate algorithm and QA updates.

Matchup and calibration:

15. *In situ* databases for all sensors continue to be expanded
16. Mitigate the impact of known but poorly understood artifacts in derived products through the use of additional calibration coefficients developed from comparisons to SeaWiFs and AVHRR equivalent products, (i.e. force agreement)
17. Time series analysis with matchups from *in situ* buoy and cruise data, AVHRR and SeaWiFS sensors continue.
18. First MOCE MODIS initialization cruise does not occur until December 2000,

almost a year after launch. Providing the first full suite of *in situ* calibration data.

19. SST coefficients (c1, c2, c3) for the at-launch Beta SST and SST4 algorithms, were estimated by radiative transfer modeling. For reasons that are currently unclear, this modeling approach produced poor results and very large biases (~4C) as a function of scan angle (SST4) and (~2C) over the 0-30C temperature range for SST, when compared to Pathfinder SST. Coefficients for the Provisional algorithm were therefore developed using a regression analysis of brightness temperature and Pathfinder SST at selected locations and MODIS viewing geometry. The regressive approach to coefficient estimation has dramatically improved both the SST and SST4 products. Generally the Provisional SST4-SST MODIS product difference is <0.8ºC. We continue to investigate why the radiative transfer method did not produce reasonable results.

2001-Year 9

Processing framework:

1. Numerous code changes are made as a result of calibration activities and changes in the ECS, MODAPS processing system
2. Work has begun on making available to the general public real-time level-2 Oceans direct broadcast data for the East coast U.S. We have set up a mechanism to receive via ftp the 2.5min level 1b from the Goddard receiving station and modified our ocean programs to except the direct broadcast format for input into the standard Oceans level-2 code.
3. Continued participation in weekly teleconferences with MCST, PIP and Oceans and intermittent teleconferences and meetings with MODIS QAWG and interactions with MODIS Ocean PI's to coordinate algorithm and quality level and flag definition updates. With the announcement that the MODIS 11-12um SST product is validated we worked closely with the PR office to create still and animated SST images and associated text.
4. Continue upgrading the RSMAS SCF in terms of disk and tape storage in anticipation of the launch of AQUA which will double the data loads at the Miami SCF.

Matchup database and calibration:

5. In September we became aware that there was a time-dependent trend in normalized water-leaving radiances (nLw) of ocean color PGE's version V3.3 and earlier. This trend was caused by a discrepancy between Level 1B and Level 2 correction procedures.
6. The correction for Earth-Sun distance, required for the reflectance calibration, was applied twice, once to generate the m1 coefficient at MCST, and once again during Level 2 ocean color production. This discrepancy was initially masked by the ocean normalization process and was repeated for different instrument calibration epochs (A side vs. B side electronics, mirror sidedness episodes, formatter problems, etc.).
7. Only when a consistent operationally processed time series from MODAPS became available in late summer was the obvious trend present. Once this problem was identified from the time series analysis we immediately

corrected the problem and re-calibrated the visible channels and delivered V3.4 of the oceans code to correct this problem.

8. During October and November the RSMAS SCF purchased additional disk storage capacity to enable local processing of selected days to facilitate rapid creation of global time series for calibration and analysis in a timely manner.
9. Ocean color products as derived from radiances measured by MODIS have since undergone exhaustive corrections and calibrations at the University of Miami SCF since the instrument was activated aboard the Terra satellite. Six epoch time discrepancies since launch were identified where the instrument characterization changes. The corrections have been developed and applied both at the engineering and algorithm levels.
10. Reprocessing of MODIS ocean color data is expected to begin in June, 2002 (Collection IV processing) and will be based on the calibration and corrections factors presented here.
11. Given the slow progress towards removing instrument artifacts from the L1b (RVS, mirror side difference, polarization - changes seen in time, long term and orbit) we began the new approaches, detailed in the semi-annual reports to limit the instrument effects in the data set to permit evaluation of derived products.
12. The performance of the correction and calibration procedures continued to be evaluated from *in situ* matchups. The *in situ* visible channel data currently includes a preliminary stray light correction determined by NIST for the MOS profiling instrument applied to both MOBY buoy instruments. *In situ* data is included from only the top arm of the buoy measured at the time of the 2000hr overpass.
13. Detailed MODIS SeaWiFS time series comparisons continued; preliminary agreement appears good. However, additional comparisons will be needed to evaluate systematic differences between the two sensors.
14. While the bulk of our activities have focused on the ocean color products during this time frame the MODIS SST 11-12um product was declared validated. Time series analysis and comparisons with both MAERI and buoy matchups were in reasonable agreement.
15. The validated Sea Surface Temperature (11 micrometer) data have well defined uncertainties and are suitable for longer term and systematic scientific studies and publication. However, improvements in the SST data are ongoing, and there will be later improved versions. The entire time series of Collection 3, i.e. November 2000 to the present, is considered validated.
16. Problems still remain with the 4um SST algorithm and we continue to analyze matchups, time series, and coefficient estimation procedures and radiative transfer models to better understand the issue with these channels.
17. Continue to extend in time matchup database for SST and visible channel data

2002- Year 10

1. MODIS AQUA launches- data transfer and work loads doubles
2. Numerous code changes are made and delivered as bug/patches to aqua processing. Examples include: problems with AQUA ephemeris and data-day splitting, meta-data issues.
3. MODAPS adds Linux to the operating systems to be supported s requiring numerous code changes and testing to ensure that codes are both Linux and SGI compliant and produce nearly identical results as processing will be done in both environments.

4. Provisional AQUA calibration tables delivered in late part of the year ocean color products were made available to the public beginning in late December.
5. RSMAS personnel are now monitoring delivery, testing, production and quality control of two sensors for both the forward and reprocessing streams currently in operations.
6. MCST delivered new AQUA Level-1b v4.09 LUT's during this reporting period. Each new MSCT delivery requires Oceans to completely revaluate correction and calibration tables. Preliminary analysis showed the v4.09 L1b LUT to be an improvement to previous versions. Much of the time tends and RVS problems present in the v3 LUT are reduced in this new V4 table.
7. This table was therefore put into operational forward stream production beginning on data day November 1,2002. Oceans developed new calibration (oceans V4.4) and correction factors for this version of the l1b
8. Time series analysis of the Oceans reprocessed stream (v4.3) based on Level 1b V3, and same day SeaWiFS retrievals confirmed the MCST finding that predicted v3 level1b m1 calibration coefficients began to significantly deviate from measured vales beginning around October 2002. To facilitate a consistent time series, Oceans data between September-December 2002 would benefit from a reprocessing using Level1b 4.09 and the associated new Oceans LUT. The Oceans teams would like to piggy back on the upcoming land reprocessing based on V4.09 for this data period.
9. Simple experimental binning algorithms were developed for prototype merged AQUA TERRA and other sensors. Preliminary results are very promising and demonstrate nearly complete global coverage (exclusive of persistent clouds).
10. These and other fields were exchanged with with F. Wentz and C. Gentemann, AMSR Team, and the individual fields were used to develop a prototype combined IR, Microwave SST field
11. The Miami level 2 direct broadcast web page was expanded to included data from both AQUA and Terra Sensors.
12. The miracle web site (http: miracle.rsmas.miami.edu/modis) provides a framework for sharing data and includes on-demand image generation for all types of MODIS Ocean data products to support the Oceans team activities.
13. During this reporting period enhancements to the site where made to allow access to all l1a data (both on disk and in the tape archive). MOD01SS data now may be requested and obtained by FTP push via a web based GUI interface based on time and location. Also during this period, the level 2 image generation tools and pages were improved based on user feed back and now include improved navigation and a graphical representation of the granule location to aid in the selection of level 2 granules.
14. Participated in weekly teleconferences with MCST, PIP , and Oceans science team.
15. Workshop meetings were held between Miami SCF personnel and the SeaWiFS project office in September of 2002 to discuss current status of the MODIS code and joint validation activities.

16. Meetings held in Dec 2002 between the Miami SCF personnel and the MODIS MCST group to discuss oceans current calibration findings and develop a joint strategy for rapid calibration response changes on TERRA.
17. MODIS Ocean institutional software was made publicly available on Jan 1, 2003. During this reporting period the University of Miami technology transfer and legal offices held several meetings with the GSFC legal office to resolve copyright of heritage code and indemnification issues, and third party licensing in regard to MODIS oceans software
18. Discussion continued with GDACC direct broadcast portal in regard to how to manage updates to direct broadcast code and documention.
19. Worked with MODAPS to develop MODIS cookie matchups from the standard and variable SeaWiFS validation sites. These MODIS cookies are being made available to the public from the SeaWiFS cookie page.

Matchup and calibration:

20. Since Aqua launch in June, efforts have begun to characterize and calibrate the visible bands of the Aqua-MODIS instrument. Of primary use in these efforts are the *in situ* radiances measured at the Marine Optical Buoy (MOBY) and the radiances measured by its sister instrument, Terra-MODIS.
21. Using a time series of Aqua-MODIS data over the MOBY site (Hawaii), preliminary absolute calibrations for each band were derived. Though quality single pixel MODIS v. MOBY matchups were lacking in number due mostly to persistent summer clouds, a modal analysis of MODIS data within a 5x5 box around the MOBY site provided a sufficient number of MODIS/mode v. MOBY/point comparisons. Using these comparisons, the absolute calibrations for each band were adjusted so that the remaining bias for each band relative to MOBY was removed. This provisional calibration and revised AQUA code was delivered to the DAAC for integration into operations. While this calibration is considered provisional due to the small number and short time series of available matchups, comparisons to same day TERRA retrievals (and experimental merged AQUA and TERRA products appear very promising.
22. MODIS Oceans SST group developed and delivered improved SST retrieval equations and coefficients for AQUA and Terra MODIS instruments. Both the 11-12um and 4um are declared validated for reprocessed and forward stream data. The mid IR SST4 product had been designated a provisional products in earlier versions due to the fact that comparisons to other Satellite SST products (e.g..Validated MODIS far IR and AVHRR Pathfinder SST) demonstrated a very large cold bias on the order of ~ 0.6 degrees. Furthermore, residuals indicated strong trends as a function of satellite zenith angle and latitudinal band as a function of season. The addition of a satellite zenith angle term to the SST4 algorithm and subsequent re-estimation of coefficients eliminated the previous bias and trends. The V4.5 changes enabled the SST4 product to move from Provisional to Validated status.
23. Continued time extension of both the visible and IR matchups databases and validation analysis

2003 –Year 11

Processing framework:

1. Evaluate numerous L1b LUT's for both forward and reprocessing streams. Forward stream LUT's changed to use measured M1's updated weekly. Explored several different LUT for potential use in reprocessing of the Terra mission.
2. Change oceans code to use new solar constants
3. Revised polarization table from Howard Gordon incorporated
4. Addition of Morel BRDF algorithm to atmospheric correction code
5. Improved sun glint correction with polarization term
6. Revised ocean Radcor tables as each of the above changes are introduced into the level-2 code. New approach used to develop final gain corrections based in only December winter data at the Hawaii calibration site. Blue and green bands adjusted with slightly different techniques.
7. New code delivered for both the forward and reprocessing streams
8. Numerous meetings are held with MCST, SeaWiFS project and NASA HQ on the calibration status of TERRA ocean color.

Matchups:

9. Continued time extension of both the visible and IR matchups databases and validation analysis for both AQUA and TERRA.
10. Continued time series comparisons of MODIS ocean color products to Seawifs same day and weekly retrievals to better understand how to create a climate quality record.
11. Continued comparisons of MODIS SST fields to AVHRR pathfinder and other sensors.
12. Detailed analysis of AQUA SST matchups suggests small mirror side differences and an RVS problem in band 32 exists in AQUA SST fields.