RAPID PROTOTYPING CAPABILITY FOR EARTH-SUN SYSTEM SCIENCES

FINAL REPORT

Submitted by:

Institute for Technology Development (ITD) and SSC Information Technology Services Contractor Team

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Summary

In 2006 Mississippi State University (MSU) proposed and was awarded a Rapid Prototyping Capability (RPC) project titled “Rapid Prototyping Capability for Earth-Sun System Sciences” through the Mississippi Research Consortium (MRC). The Institute for Technology Development (ITD), Science Systems and Applications, Inc (SSAI), and Computer Science Corporation (CSC) each have a presence at the NASA Stennis Space Center (SSC) and teamed together to support MSU in this RPC project.

This “Stennis Team” partnership provided an array of products and services. The data acquisition activities included downloading or purchasing Moderate Resolution Imaging Spectroradiometer (MODIS) and Advanced Wide Field Sensor (AWiFS) data products for data simulation, crop type classification and yield estimation. In addition, it involved acquiring Landsat data products over Mobile Bay for sediment mapping.

Application code for the creation of simulated data from currently available sensor data was developed and delivered. The algorithm development for this application code included the refinement of the Application Research Toolbox (ART) and the Time Series Product Tool (TSPT). ART was used to simulate Visible Infrared Imager Radiometer Suite (VIIRS) data from the MODIS data. TSPT generated Normalized Difference Vegetation Index (NDVI) time series products for the Pampas region of Argentina. TSPT also used a temporal interpolation algorithm to replace “bad” NDVI values with estimated “good” NDVI values. The bad NDVI values were due to cloud cover, shadows or other anomalies. The processing resulted in cloud-free NDVI time series products. The NDVI time series products were generated from the simulated VIIRS and MODIS data. ART was also used to simulate MODIS and VIIRS data products from AWiFS data.

AWiFS, MODIS and simulated VIIRS data products were delivered to MSU. In addition, the operational versions of the ART and TSPT were delivered to MSU along with guidance on how to install these products in the MSU processing environment. Landsat data products over Mobile Bay were also delivered to MSU.

Analyses using the MODIS, VIIRS and AWiFS data products were performed for crop type classification. The Stennis Team supported MSU at several outreach activities to disseminate the results of the MSU RPC project and to promote the SSC national applications. Outreach activities included participation at conferences and the development of publications.

Project Activity

The overall MSU management for the RPC project was provided by Dr. Robert Moorhead. Additional guidance for specific activities within the project was provided by Dr. Chuck O’Hara and Dr. Jenny Du. The Stennis Team attended periodic review meetings as well as submitted technical reports and monthly status reports throughout the project.
**Data acquisition activities**

Both the Terra and Aqua satellites have a MODIS sensor on board. The Terra satellite was launched in December, 1999, while the Aqua satellite was launched in May, 2002. The Terra satellite descends across the equator at 10:30am local time, while the Aqua satellite ascends across the equator at 1:30pm local time. Therefore the MODIS sensors on the two satellites provide morning and afternoon data products. These data products can be fused to compensate for missing data due to cloud cover and other data anomalies.

Data products from both the Aqua and the Terra MODIS sensors were collected over the Pampas region of Argentina from 08/25/2004 through 07/15/2007. Both daily and composite MODIS products were acquired. The data products include:

- At-Sensor reflectance data (MOD02 (Terra), MYD02 (Aqua) products)
- Surface reflectance data (MOD09 (Terra), MYD09 (Aqua) products)
- Land surface temperature/emissivity data (MOD11 (Terra), MYD11 (Aqua) products)
- 16-day vegetation indices (MOD13 (Terra), MYD13 (Aqua) products)
- 8-day leaf area index/FPAR (MOD15 (Terra), MYD15 (Aqua) products)

The MOD02/MYD02 at-sensor reflectance data products are sometimes referred to as planetary reflectance products. Although there is some processing performed to create these products, there has not been any atmospheric correction performed. Algorithms that remove atmospheric and other effects are used to transform the planetary reflectance data into the surface reflectance products (MOD09/MDY09). Many earth observation projects use surface reflectance products because they have already been corrected for these atmospheric effects.

The AWiFS sensor flies on the RESOURCESAT-1 (IRS-P6) satellite. IRS-P6 was launched by the Indian Space Research Organization (ISRO) in October, 2003. The AWiFS data has a spatial resolution of 56 meters with 4 bands covering the following spectral regions:

- green (0.52 – 0.59 microns)
- red (0.62 – 0.68 microns)
- near-infrared (0.77 – 0.86 microns)
- shortwave-infrared (1.55 – 1.70 microns)

Six specific dates of AWiFS imagery over the Pampas region of Argentina and one scene over Illinois were acquired. The dates and path/row designators of these images are:

- 11/13/2006 - p319r102
- 12/26/2006 - p318r103
- 01/14/2007 - p317r103
- 02/02/2007 - p316r100
- 02/17/2007 - p319r103
- 03/13/2007 - p319r102
- 05/28/2008 – p275r039
The Stennis Team supported some data collection for a regional sediment mapping project led by Dr. Jenny Du. Landsat data from the Landsat-7 sensor was collected for the project. The Landsat Program has provided a series of earth-observing missions that span over four decades.

Landsat-7 was launched in April, 1999 with the Enhanced Thematic Mapper Plus (ETM+) instrument. The satellite has a 16 day repeat coverage time. The spectral and spatial resolutions of the ETM+ data bands are:

- blue (0.45 – 0.52 microns): 30 meter
- green (0.52 – 0.60 microns): 30 meter
- red (0.63 – 0.69 microns) : 30 meter
- near-infrared (.76 – 0.90 microns) : 30 meter
- shortwave-infrared (1.55 – 1.75 microns): 30 meter
- thermal (10.40 – 12.50 microns) : 60 meter
- middle-infrared (2.08 – 2.35 microns) : 30 meter

The ETM+ on Landsat-7 was plagued by a scan-line corrector mirror malfunction in 2004. A series of adjustments were made to provide Landsat-7 data collected with the scan-line corrector in “SLC-off” mode.

Landsat data archives for Mobile, Alabama were searched. A series of thumbnails were generated and provided to Dr. Du, who recommended two scenes for acquisition. The scenes that were acquired are from dates:

- 1/20/2008
- 3/24/2008

The ETM+ bands 1 through 5 and 7 were atmospherically corrected to surface reflectance using the dark pixel subtraction method. Clear water pixels were identified using a histogram of the near-infrared band. These pixels were found in the other bands and averaged to determine the value of the dark pixel, which was assumed to be the contribution of atmospheric path radiance to total top-of-atmosphere radiance and was subtracted from each band before delivery.

**Algorithm development and product generation activities**

Researchers have used the global, daily repeated MODIS data for a variety of terrestrial research. The MODIS red and near infrared bands are collected at a 250 meter spatial resolution. Therefore NDVI products generated from the red and near infrared bands also have a 250 meter spatial resolution. There are no plans to replace the currently operational MODIS sensors. Instead, a new National Polar-Orbiting Operational Environmental Satellite System (NPOESS) will contain the VIIRS sensor which will provide spectral radiometric measurements for atmospheric, oceanic, and terrestrial science disciplines. The VIIRS instrument will replace three sensors: the Defense Meteorological Satellite Program (DMSP) Operational Line-scanning system (OLS) sensor, the NOAA Polar-orbiting Operational Environmental Satellite (POES) Advanced Very High Resolution Radiometer (AVHRR) sensor, and the NASA Earth Observing
System (EOS Terra and Aqua) MODIS sensors. The VIIRS red and near infrared spectral bands will have a 375 meter spatial resolution. Therefore, a major focus of the RPC project is to simulate the 375 meter VIIRS data from the 250 meter MODIS data to provide products that can be used to test the ability of VIIRS to continue the legacy of projects that have been supported by the MODIS sensor.

The Stennis Team refined and used the ART and the TSPT to rapidly prototype data streams and simulate VIIRS data products from MODIS and AWIFS data. These data sets were used by MSU in agricultural yield prediction research. They were also used by the Stennis Team to investigate crop type identification.

The ART is an integrated set of algorithms and models developed in MATLAB® that allows users to perform a suite of simulations and statistical studies on remote sensing systems. Specifically, the ART provides the capability to generate simulated multispectral image products at various scales from multispectral and/or hyperspectral image products that have higher spatial resolution. The ART utilizes acquired (“real”) datasets, along with sensor specifications and metadata, to create simulated datasets, which can be in either radiance or reflectance units of measure.

By simulating data for existing multispectral sensor systems, the simulated data products can be used for verification and validation of the ART methodology. By simulating data for proposed sensor systems, the simulated products can be used to conduct various trade studies and statistical analyses to ensure that the proposed sensor system will meet scientific, academic, and commercial communities’ requirements. The ART simulations have been validated through comparisons with Landsat, Hyperion, the Advance Land Imager (ALI), and high spatial resolution airborne imaging systems. Visual and quantitative assessments show excellent agreement between existing multispectral sensor systems and simulated datasets of those multispectral sensor systems created with ART.

The process of creating a simulated multispectral data product from a multispectral or hyperspectral image begins with the application of a spectral band synthesis. If the input image data does not have data in the spectral range of the targeted sensor’s spectral range, spectral band synthesis may not be possible. Spectrally degraded, band-to-band misregistration artifacts can be added to simulate sensor artifacts introduced during data collection.

Next, the spatial degradation or spatial synthesis algorithm is applied to convert the multispectral and/or hyperspectral image to the ground sample distance (GSD) and point spread function (PSF) of the targeted sensor. Spatial simulation is the emulation of a multispectral wide band sensor with a low resolution GSD using data from a higher resolution GSD sensor. Spatial simulation processing converts the input image’s GSD through aggregation and resampling to that of the targeted sensor as well as performing an estimate for the PSF. Noise is added to the simulated image by applying a physics-based noise model that accounts for detector and quantum noise as well as systematic artifacts. An appropriate digitization model is then used to quantize the resultant image to the desired radiometric precision. The process flow for ART is shown in Figure 1.
Figure 1. ART process flow using high spatial resolution hyperspectral or multispectral imagery to generate various coarser datasets.

The TSPT has been developed to create enhanced NDVI time series products from input data, which can be either MODIS or simulated VIIRS data. It provides functionality for “bad NDVI values” to be identified and masked. It can also be used to fuse the NDVI products from the Aqua and Terra MODIS sensors. These fused data sets may still have bad NDVI values due to clouds, shadows or other artifacts. Finally, TSPT has the ability to use an interpolation and median or Savitzky-Golay filtering with temporally adjacent data to estimate good NDVI values that will replace the remaining NDVI values that have been masked as bad values. The resulting transformed data set contains fused cloud-free data. The process flow for TSPT is shown in Figure 2.

The TSPT can display the images either in a file coordinates system (row, column), a geographic coordinate system (latitude, longitude) or a projected coordinate system. TSPT can display various MODIS data products in time series form. These time series displays can be sequenced one image after the other and saved as a video, which can be viewed to visualize change in landscape over time.
TSPT can ingest MODIS data over a time range to create both time series of cloud-free MODIS data and time series of cloud-free VIIRS data simulated by ART. These time series products can produce phenology curves by plotting one pixel’s value throughout the time series of NDVI products. Time series plots, image videos, and quality assurance (QA) reports can be created. These QA reports use the Hierarchical Data Format (HDF) metadata that include statistics on bad pixels, on pixels adversely affected by clouds, and on pixels flagged as less than ideal.

Geographic information system (GIS) shape file information, such as roads, state boundaries, and crop field boundaries, can be included in the image displays. If the dataset selected is in the native sinusoid projection, TSPT can reproject the dataset to a geographic coordinate system or a standard projection system. The display function of TSPT can also be controlled to zoom-in or zoom-out to show specific subsets of the entire image area.

The resulting NDVI time series have shown to compare favorably with standard MODIS global composited products and could be the basis of new VIIRS products. Although the TSPT was developed for vegetation indices, this tool could also be useful for rapid prototyping of other
products. By expanding the functionality of the TSPT to other sensor data, early analysis of time series products could be enhanced.

During the development of the RPC project, the previous versions of ART and TSPT were considerably enhanced. In addition to enhancing the functionality of ART as was discussed above, the RPC project development also integrated algorithms from the MODIS Reprojection Tool (MRT) and MRT-Swath directly into the ART. This allowed for reprojection from the MODIS native sinusoidal projection to the UTM projection, thereby allowing the output data products to be transformed to projection systems more common for analysis than the sinusoidal projection.

The TSPT was upgraded to allow for the creation of layerstacks of hypertemporal NDVI data products that could then be used for phenological studies and be used to provide temporal vegetation information for crop classification and yield prediction studies. The filtering and interpolation schemes allowed for pixels dominated by clouds or shadows to be estimated. This functionality provides for data filling activity that can recreate the expected NDVI values for pixels from the NDVI values in their temporal neighborhood. This also provided intrinsic noise reduction and refined NDVI data sets over time even if there are cloud coverage issues within different sections of the imagery throughout the local time period.

Ultimately, the ART and TSPT provided a data development path for VIIRS to be simulated from both MODIS and AWiFS data. It also provided the data development path for MODIS to be simulated from AWiFS data.

**Data processing activities**

The Stennis Team activity for the project involved the refinement of ART and TSPT, which were used in research activity. The multi-year MODIS data that was collected over Argentina was processed with these tools to generate layerstacks of MODIS and simulated VIIRS hypertemporal NDVI data to use in crop type identification and yield prediction.

The initial phase of the project used ART to create fused simulated VIIRS data from both the Aqua and Terra MODIS sensors. The surface reflectance MODIS (MOD09/MYD09) product was used for this processing. The surface reflectance product is created from the planetary reflectance with algorithms designed to remove atmospheric effects in the data. These surface reflectance measurements are more appropriate for assessing conditions in crop fields than are the planetary reflectance.

The processing of the surface reflectance data using ART created two data processing pathways; one for MODIS and one for simulated VIIRS. For each of these processing pathways, the TSPT was used to create NDVI time series products from both the Aqua and Terra surface reflectance data. Then TSPT used these NDVI products to identify and mask bad pixels due to clouds, shadows or other factors. The NDVI images from the Aqua and Terra MODIS data were fused together into one NDVI data product. The fusion allowed for bad pixels from one sensor’s NDVI product to be filled by the other sensor’s NDVI value. However this did not necessarily fill in the mask of all the bad NDVI values. Once the fused NDVI product was created for the
entire data range, the final function of TSPT used good pixels in the temporally adjacent neighborhood of the bad pixels to estimate a good pixel through temporal interpolation. This estimated good NDVI value replaced the existing low-quality NDVI value. The result of replacing all the low-quality “bad NDVI values” with estimated “good NDVI values”, was the creation of a cloud-free, fused, NDVI MODIS time series data set across the date range of interest. The TSPT was used in a similar fashion to generate cloud-free simulated VIIRS NDVI time series products from the surface reflectance VIIRS products simulated from Aqua and Terra MODIS data.

These hypertemporal NDVI layerstacks were used in classification activities. Ground truth data from croplands during the 2004-2005 growing season that identified crop types across the Argentine Pampas were used in the project. The majority of the croplands had soybean, corn and second plant soybean crops. There were also other land cover types such as pasture or urban, but these secondary cover types had minimal pixels in their samples.

Six AWiFS scenes from the 2005-2006 Argentine growing season were acquired over Argentine agricultural production fields. MODIS and VIIRS data sets were simulated from these scenes. Since the six scenes were spread out over the growing season, the cloudy or bad pixels had no temporally adjacent scenes to use for filtering and data filling. Therefore, TSPT was not used to enhance the simulated data sets from the AWiFS scenes. There were residual clouds and other anomalies in the simulated data. However, the resulting images did simulate the MODIS and VIIRS data products and were used in a validation study to determine the ability for using AWiFS to simulate both MODIS and VIIRS data.

Data and product delivery activities

Several data products were delivered to Dr. O’Hara. The almost three years worth of MODIS data products that were acquired over Argentina were delivered. These data products included reflectance, data quality, vegetation indices and other ancillary information. In addition, the selected AWiFS scenes over Argentina during the 2006-2007 growing season were delivered along with the MODIS and VIIRS scenes that were simulated from these AWiFS scenes. Dr. O’Hara used these data sets as input into crop yield prediction models and temporal map algebra studies.

Dr. Du requested Landsat data over Mobile Bay. Thumbnail images of the available data were delivered. This was followed by the delivery of the Landsat image scenes and atmospherically corrected data that she selected to use in a regional sediment mapping project.

Dr. Tomasz Haupt of MSU designed and implemented a “RPC Node” that ran application tools which were embedded into a parallel and distributed computing environment. Part of the Stennis Team involvement to the RPC project dealt with assisting in the establishment of the RPC Node. The Stennis Team contributed a version of ART and TSPT that was installed in the RPC Node. Activities for this installation included bringing the software to MSU, installing it in the MSU GRI computing system, and working through differences between the operating environment at MSU and the operating environment at SSC.
Data analysis activities

The daily hypertemporal layerstacks of cloud-free MODIS and simulated VIIRS data were used in classification studies. This work compared the crop type mapping abilities of the MODIS and simulated-VIIRS NDVI time series data using data acquired during the 2004-2005 growing season in Argentina. The Maximum Likelihood and Mahalanobis classifiers did a good job in identifying the corn, soybean and second-plant soybean crops. However, the Spectral Angle Mapper (SAM) classification method performed better with greater than 81% overall accuracies and .72 Kappa Coefficients in mapping corn, soybean, and wheat/soybean crop fields.

The granularity threshold is the point where most changes in land cover become difficult to resolve from remotely sensed imagery. Classification accuracies using the simulated VIIRS data performed reasonably similar to the accuracies using the MODIS data. Therefore the approximate 375 meter spatial resolution of the future VIIRS sensor apparently does not cross the agricultural landscape granularity threshold. This analysis was drafted into a format for publication and a suitable journal is being investigated for publication submission.

The results of the MODIS and VIIRS products simulated from AWiFS data were also analyzed. The available AWiFS data was recorded in at-sensor radiance levels. In other words, the data was planetary reflectance data. Therefore, in order to perform the validation work, it was used to simulate MODIS MOD02/MYD02 planetary reflectance data products. ART and TSPT used the MODIS planetary reflectance products to generate daily cloud-free MODIS and simulated cloud-free VIIRS data. The products derived from AWiFS data were compared to MODIS planetary reflectance products and VIIRS products simulated from MODIS planetary reflectance products.

Histograms of the real MODIS and simulated MODIS from AWiFS data sets were compared. Scatter plots of the real MODIS and simulated MODIS from AWiFS data sets were also compared. These analyses showed ART to perform very well in creating simulated MODIS data and were used to validate the ART methodology. The results were favorable and validated the use of AWiFS to simulate both MODIS and VIIRS data. This analysis was drafted into a form for publication and a suitable journal is being investigated for publication submission.

AWiFS data over sections of Illinois were used also used to evaluate AWiFS ability to enhance crop type classification capability. Ground truth data that was collected in Illinois and the acquired AWiFS imagery were used in the Classification And Regression Tree (CART) algorithm. Results show AWiFS to be a good resource both for simulating other data sets, and also in providing good classification of crop type.

Outreach Activities

Various conferences and meetings were attended to support the MSU MRC RPC project. A variety of poster sessions were given and booth participations were performed. In addition, the Stennis Team contributed in paper presentation rehearsals and critiques.
2008 IGARSS

The Stennis Team had a presence at a booth at the 2008 International Geoscience and Remote Sensing Symposium (IGARSS). The activities at this booth were to promote awareness of projects including the MSU MRC RPC Project.

2007 AGU Conference

The Stennis Team attended the American Geophysical Union (AGU) 2007 Fall Meeting in San Francisco to support the “Computational Technologies and Capabilities for Advancing Science toward Societal Benefits” sessions that were sponsored by NASA, NOAA and the MRC. The Stennis Team participated in the review for the session topic “NASA Earth Science Research Results for Improved Regional Crop Yield Prediction” that was presented by Preeti Mali.

The poster sessions the Stennis Team helped to develop and/or present were:

- Soil Moisture Estimation Using Hyperspectral SWIR Imagery (IN43B-1184)
- The NSA Earth Science Knowledge Base (ESKB) (IN43B-1186)
- A Comparison of the Hypertemporal Crop Mapping Abilities of NDVI Products Derived from both MODIS Surface Reflectance and Calibrated Geolocated Radiance Data (IN43B-1184)

2006 AGU Conference

The Stennis Team attended the American Geophysical Union (AGU) 2006 Fall Meeting in San Francisco to support the “Computational Rapid Prototyping Capabilities for Advancing Science toward Societal Benefits” sessions that were sponsored by NASA, NOAA and the MRC.

The poster sessions the Stennis Team helped to develop and/or present were:

- Designing and Developing a NASA Research Projects Knowledge Base and Implementing Knowledge Management and Discovery Techniques (IN33B-1337)
- Developing and Deploying a partnership Network Knowledge Base for Analysis of the Partners and Components within NASA’s Earth Science Community (IN33B-1339)
- Simulating Visible/Infrared Imager Radiometer Suite Normalized Difference Vegetation Index Data Using Hyperion and MODIS (IN33B-1340)
- Remote Sensing Time Series Product Tool (IN33B-1341)
- Evaluating the Usefulness of High-Temporal Resolution Vegetation Indices to Identify Crop Types (IN33B-1343)
- Crop Residue Coverage Estimation Using ASTER Imagery (IN33B-1344)
- Development of a Remote Sensing Program to Monitor for Resistance Development in Transgenic Crops (IN33B-1346)
- Use of Earth Observation System (EOS) Missions for Food Security Applications (IN33B-1349)
• Antarctic Iceberg Tracking Based on Time Series of Aqua AMSR-E Microwave Brightness Temperature Measurements (IN33B-1352)
• Estimating Temperature Retrieval Accuracy Associated with Thermal Band Spatial Resolution Requirements for Center Pivot Irrigation Monitoring and Management (IN33B-1353)
• Thermal Band Atmospheric Correction Using Atmospheric Profiles Derived from Global Positioning System Radio Occultation and the Atmospheric Infrared Sounder (IN33B-1354)
• Implementation of Sequential Gaussian Co simulation in Remote Sensing Based Agricultural Management Decision Making (IN33B-1355)

Publication Development

The Stennis Team’s collaboration resulted in a several documents being drafted with the intent that they be submitted for publication. These include:

1. **FAS RPC Project Final Report: Crop Mapping Abilities of Hypertemporal NDVI Imagery Derived from Simulated VIIRS Products**
2. **A Comparison of the Crop Classification Abilities of MODIS and Simulated VIIRS NDVI Time Series Data**
3. **Crop Classification for Identification of Resistance in Transgenic Maize using Geospatial Technologies**
4. **An Approach to Simulation of VIIRS Normalized Vegetation Indices using AWiFS Data Products**

The first phase of the RPC project ended in March, 2008. The paper titled, **“FAS RPC Project Final Report: Crop Mapping Abilities of Hypertemporal NDVI Imagery Derived from Simulated VIIRS Products”** discussed the state of crop type classification done through the end of March, 2008. This article was submitted to the *Agronomy Journal* which responded with some suggested changes. These changes were incorporated into the article titled, **“A Comparison of the Crop Classification Abilities of MODIS and Simulated VIIRS NDVI Time Series Data”**. The RPC project’s extension activities supported the development this enhancement of the crop type assessment article which describes the use of ART and TSPT to create NDVI time series data and use them in classification of croplands in Argentina. The paper titled, **“Crop Classification for Identification of Resistance in Transgenic Maize using Geospatial Technologies”** discusses additional crop type identification activities, specifically using the Classification and Regression Tree Algorithm. The paper titled, **“Validation of Simulated MODIS and VIIRS data using AWiFS Data”** describes the individual processing steps performed by ART including atmospheric correction, spectral simulation, spatial simulation, noise simulation, and data quantization. An example is shown that takes AWiFS data as input to create simulated MODIS and simulated VIIRS data products. The paper also performs validation work by comparing histograms and scatter plots of the simulated MODIS data product against real MODIS data products.

While these drafts are completing internal review, journals are being evaluated to determine which would be the most appropriate for their publication. After the internal review is
completed, it is intended that the articles will be submitted for publication in the selected journals.

**Reports**

The Stennis Team delivered monthly status reports throughout the project. In addition to the monthly reports and the articles developed for publication submission, a user guide for the use of the ART and TSPT was developed and delivered. This user guide explained the functionality and usage of the ART and TSPT versions that were installed in the RPC Node. This user guide is titled, “*Mississippi Research Consortium RPC Node Application Research Toolbox and the Time Series Product Tool for VIIRS Simulation User Guide*”.

**Conclusions**

The participation of the Stennis Team in the MSU MRC RPC project was focused on the development of simulation tools and the investigation of the products generated from these tools which were applied to agricultural crop type assessment. This work developed versions of the ART and TSPT that were integrated into the MSU RPC Node. A variety of MODIS data products covering almost three years were acquired and delivered to MSU. MSU researchers used the data sets and simulation tools to generate simulated VIIRS data products from the MODIS data acquired. This created a time series of simulated VIIRS and enhanced MODIS data products that were used by Dr. O’Hara for yield prediction studies. The Stennis Team also used these products to perform a variety of investigations into crop type assessment. Several publication development activities established drafts of articles that are intended to be submitted to appropriate journals.