Solutions Network Formulation Report

Using NASA Techniques to Atmospherically Correct AWiFS Data for Carbon Sequestration Studies

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1. Candidate Solution Constituents

a. Title: Using NASA Techniques to Atmospherically Correct AWiFS Data for Carbon Sequestration Studies

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c. Identified Partners: U.S. Department of Agriculture Forest Service

d. Specific DST/DSS: NASA CASA–CQUEST (Carnegie-Ames-Stanford Approach–Carbon Query and Evaluation Support Tools)

e. Alignment with National Application: Carbon Management and Air Quality

f. NASA Research Results – Table 1:

Missions	Sensors/Models	Data Product
GSFC/SSC	Atmospheric Correction Techniques	Surface Reflectance
GSFC/JPL	Atmospheric Water Vapor and Aerosol Sensors	Atmospheric Profiles

g. Benefit to Society: Continuing the ability to quantify carbon sequestration and to investigate effects of land cover change on atmospheric carbon levels, improving land use management decisions.

2. Abstract

Carbon dioxide is a greenhouse gas emitted in a number of ways, including the burning of fossil fuels and the conversion of forest to agriculture. Research has begun to quantify the ability of vegetative land cover and oceans to absorb and store carbon dioxide. The USDA (U.S. Department of Agriculture) Forest Service is currently evaluating a DSS (decision support system) developed by researchers at the NASA Ames Research Center called CASA-CQUEST (Carnegie-Ames-Stanford Approach—Carbon Query and Evaluation Support Tools). CASA-CQUEST is capable of estimating levels of carbon sequestration based on different land cover types and of predicting the effects of land use change on atmospheric carbon amounts to assist land use management decisions.

The CASA-CQUEST DSS currently uses land cover data acquired from MODIS (the Moderate Resolution Imaging Spectroradiometer), and the CASA-CQUEST project team is involved in several projects that use moderate-resolution land cover data derived from Landsat surface reflectance. Landsat offers higher spatial resolution than MODIS, allowing for increased ability to detect land use changes and forest disturbance. However, because of the rate at which changes occur and the fact that disturbances can be hidden by regrowth, updated land cover classifications may be required before the launch of the Landsat Data Continuity Mission, and consistent classifications will be needed after that time. This candidate solution investigates the potential of using NASA atmospheric correction techniques to produce science-quality surface reflectance data from the Indian Remote Sensing Advanced Wide-Field Sensor on the RESOURCESAT-1 mission to produce land cover classification maps for the CASA-CQUEST DSS. The NASA atmospheric correction techniques require atmospheric data that can be obtained from a number of current and future NASA sensors, including the Atmospheric Infrared Sounder, the

Visible/Infrared Imager/Radiometer Suite, and the Advanced Technology Microwave Sounder. A consistent, continued source of science-grade, atmospherically corrected, moderate-resolution data may benefit this DSS, which is directly related to the Carbon Management National Application.

3. Detailed Description of Candidate Solution

a. Purpose/Scope

This report examines the ability to use NASA techniques and data to produce science-quality surface reflectance from commercially available IRS (Indian Remote Sensing) P6 AWiFS (Advance Wide-Field Sensor) data to improve quantification of carbon sequestration in the NASA CASA–CQUEST DSS to the benefit of the USDA Forest Service. Carbon dioxide in the atmosphere has increased by more than 30 percent since the start of the industrial revolution, compared to an estimated 20 percent or less fluctuation from the mean over the previous 400,000 years (Sarmiento and Wofsy, 1999). Carbon dioxide is released from a number of sources; most notably from the burning of fossil fuels, but also from forest disturbances, such as the conversion of forest to agriculture. It is estimated that over the last 10–20 years, approximately half of the carbon dioxide emitted from the burning of fossil fuels has been absorbed by the land and oceans (Sarmiento and Wofsy, 1999). However, this sequestration of carbon is not well understood (Wofsy and Harriss, 2002). The U.S. Carbon Cycle Science Program was developed as an interagency partnership with the goal of understanding not only atmospheric concentrations of carbon dioxide from past and future emissions but also what has happened to past emissions through carbon sequestration (CCS, 2006). Additionally, several federal agencies are responsible for carbon management in forest and agricultural lands.

b. Identified Partners

One of the main responsibilities of the USDA Forest Service is the management of public lands in national forests and grasslands, including carbon management and decision making regarding land use. Under the authorization of a 2002 revision to the 1992 Energy Policy Act Section 1605(b), the Forest Service assisted the Department of Energy in the revision of guidelines for voluntary greenhouse gas estimation and reporting (Buford, 2005). The Forest Service determined low-cost, high-accuracy methods of estimation for forestry to assist carbon managers, such as look-up tables, models, and measurements (Buford, 2005). As a result, the Forest Service is evaluating a DSS developed by the CASA project team at the NASA Ames Research Center called CQUEST, which estimates the amount of carbon sequestration that results from different types of ecosystems (NASA, 2006). This DSS allows users to estimate the amount of carbon stored based on current land cover and to make decisions by investigating the effects of land use changes. Outputs of the CASA-CQUEST include a national carbon sequestration inventory, simulation of future scenarios, and assessment of past and future climate variability (NASA, 2006).

The CASA–CQUEST DSS currently uses data from several sources and contains a baseline carbon prediction map on an 8-km grid. The DSS also uses climate and soil information as well as land cover data from MODIS. The CASA Project team has used data from the USDA Forest Inventory and Analysis program to validate and improve predictions from the CASA–CQUEST DSS. Additional projects associated with the CASA–CQUEST DSS have investigated the effect of forest disturbance using Landsat-derived land cover maps in collaboration with the USDA Forest Service Pacific Northwest Research Station.

c. NASA Earth-science Research Results

Surface reflectance is an essential data product for use in estimates of land carbon sequestration from remote sensing platforms. Gases and aerosols in the atmosphere change the amount of radiation measured by the satellite, so atmospheric correction will improve the accuracy of a land cover classification, especially when used with imagery acquired on multiple dates (Song et al., 2001).

Accurate classification is essential for defining the spatial extents of different types of land cover that may be absorbing carbon, and thus is an important part of carbon sequestration studies (DeFries et al., 2000).

Satellite-measured top-of-atmosphere radiance data can be converted to surface reflectance using a number of different atmospheric correction methods. Pagnutti et al. (2005) developed an accurate method of atmospheric correction to produce science-quality surface reflectance from commercially available data. This method utilizes the MODTRAN (Moderate resolution atmospheric Transmittance) radiative transfer code to model the atmosphere between the ground and the satellite sensor, although other radiative transfer codes, such as 6S (Second Simulation of the Satellite Signal in the Solar Spectrum), can be used. Pagnutti et al. (2005) demonstrated using water vapor and aerosol information available from the MODIS sensor as inputs to MODTRAN. However, atmospheric information obtained from AIRS (Atmospheric Infrared Sounder) on the Aqua mission and from GPS (Global Positioning System) Radio Occultation satellites using GPS receivers developed by the NASA Jet Propulsion Laboratory has already been used successfully in MODTRAN (Pagnutti et al., 2006). Additionally, with the upcoming launch of NPOESS (National Polar-orbiting Operational Environmental Satellite System), this atmospheric information may be obtained from VIIRS (Visible/Infrared Imager/Radiometer Suite) and ATMS (Advanced Technology Microwave Sounder) in the future. Although this method was developed for atmospheric correction of high-resolution imagery, the method is ideal for correcting large-swath, moderate-resolution imagery because it uses satellite data as a source for atmospheric information.

d. Proposed Configuration’s Measurements and Models

The CASA-CQUEST DSS currently contains land cover data from the MODIS sensor at 1-km resolution. Land cover data available at a higher spatial resolution could improve estimates of the effects of land-use change produced by the DSS. One such source of data is the LEDAPS (Landsat Ecosystem Disturbance Adaptive Processing System) project at Goddard Space Flight Center, which used decadal Landsat imagery covering three time periods from 1975 to 2000 to map North American forest disturbance for use in carbon modeling (Wolfe et al., 2004). Also, the Mid-Decadal Global Land Survey is a new project with the goal of extending the LEDAPS results globally using data acquired in the 2005-2006 timeframe (Masek and Covington, 2006). However, Landsat-5 is predicted to run out of fuel by 2009 and Landsat-7, which is producing only marginally useful data, is predicted to run out of fuel by 2011 (Chander et al., 2006), while the LDCM (Landsat Data Continuity Mission) is not planned for launch until 2012 (Gutman, 2006). Additionally, Goward et al. (2005) states that major forest disturbances can be obscured by regrowth within 2-3 years; this may necessitate an update to the land cover maps during a time in which useful Landsat data cannot be obtained. Thus, an alternate data source would be beneficial for the production of consistent, continuous updated forest disturbance maps for use in the CQUEST DSS.

AWiFS, onboard the RESOURCESAT-1 IRS-P6 mission, is a 56-m GSD (ground sample distance) sensor with 4 bands (green, red, near-infrared, and short-wave infrared), which are similar to 4 of the Landsat bands. AWiFS consists of 2 cameras, each tilted 11.94 degrees from nadir, which combined produce a swath of 740-km and a revisit time of approximately 5 days (NRSA, 2003). AWiFS data is commercially available in GeoTIFF format through GeoEye (GeoEye, 2006). Improved calibration coefficients are available to convert AWiFS digital numbers to radiance units (Pagnutti, 2006). RESOURCESAT-1, which was launched in October 2003, has a design life of 5 years.

Research is ongoing to determine if data from the RESOURCESAT-1 IRS-P6 AWiFS sensor may be compatible with the Landsat data record (Chander et al., 2006; Pagnutti, 2006). Although RESOURCESAT-1 has only a 5-year design life, the mission could easily continue operation past 2008. Additionally, a follow-on mission, RESOURCESAT-2, is already planned for launch in the 2008-2009 timeframe (ISRO, 2006). The AWiFS onboard the RESOURCESAT-2 mission will have an improved GSD of 25-m and a 600-km swath, and will cover the same spectral region as its predecessor (Puckorius, 2006). With its improved spatial resolution, the next-generation AWiFS should be even more compatible with the Landsat data record than the current AWiFS.

The ability to produce accurate classifications with land cover maps generated from atmospherically corrected AWiFS data using NASA data and techniques could be verified by directly comparing them to classifications generated from Landsat and MODIS data. The next-generation AWiFS is in a position to fill the data gap between Landsats-5 and 7 and the LDCM, especially if the two RESOURCESAT missions overlap to allow comparison of the two versions of AWiFS, and to continue to produce consistent and comparable moderate-resolution land cover maps beyond the launch of LDCM. The introduction of land cover maps derived from AWiFS data would have minimal impacts on the CASA-CQUEST DSS because it is already capable of using data from sensors with varying spatial resolution, and the atmospherically corrected data can be produced by NASA in a format compatible with the DSS. However, the resulting benefit of such an introduction is a consistent and continued source of higher spatial resolution land cover data than is currently available, which would improve the estimates of carbon sequestration levels produced by the DSS. This improvement could increase the ability of the USDA Forest Service to make informed decisions regarding land use.

4. Programmatic and Societal Benefits

A continuous source of consistent, moderate-resolution, land-cover data could increase detection of forest disturbance and other land cover changes that have a direct impact on carbon sequestration. Incorporating this data into the CASA-CQUEST DSS could improve its ability to estimate amounts of stored carbon in different land cover types and to investigate the effects of land cover change. This DSS directly applies to the Carbon Management National Application but also pertains to Air Quality. Societal benefits include improved estimates of carbon levels for reporting and for decisions regarding land use management.

5. References

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