Quality Indicators for Societal Benefit QI4SB

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Workshop on Facilitating Implementation of QA4EO
CEOS/WGCV
01 October, 2009
Antalya, Turkey

Outline

- QA of GEOSS data products for end-users
- Quality Assurance for Societal Benefit
- Quality Indicators for Societal Benefit, QI4SB
- QA Approach for MODIS Land & Atmosphere Products
  - Best practice examples
- Error Budgets / Uncertainty Inventories
- Measured Uncertainties
  - Sensor data vs Ground truth
- Sources of Product Uncertainties
- Recommend QI4SB “Error Budget” effort
  - sample set of products
- Summary of Recommendations

Quality Assurance (QA) & Quality Indicators (QI) for GEOSS End Users

- QA of GEOSS data products for end-users requires
  - Reference Standards and a set of Best Practices for the Evaluation & Documentation of
    - Sensor Cal/Val processes, uncertainties, and biases
    - Product algorithm uncertainties
    - Product artifacting issues

- A good QA strategy provides for
  - Quality measures or Quality indicators (QIs) that specifically consider the intended performance
    - "It is for the final user of the information to determine if this information, with its associated QI, is suitable for their requirements" QA4EO-GEN-DQK-006
  - Allows end-users to have faith in the data's veracity over an extended period of time

Quality Assurance for Societal Benefit

- QA4EO key objective: Assign a QI to the output of every step in an EO information product processing chain
- GEO concerned with establishing confidence in specific data products that supports all of GEOSS's nine societal benefit areas.
  - Disasters
  - Health
  - Energy
  - Climate
  - Agriculture
  - Ecosystems
  - Biodiversity
  - Water
  - Weather

MODIS Global Burned Area Product

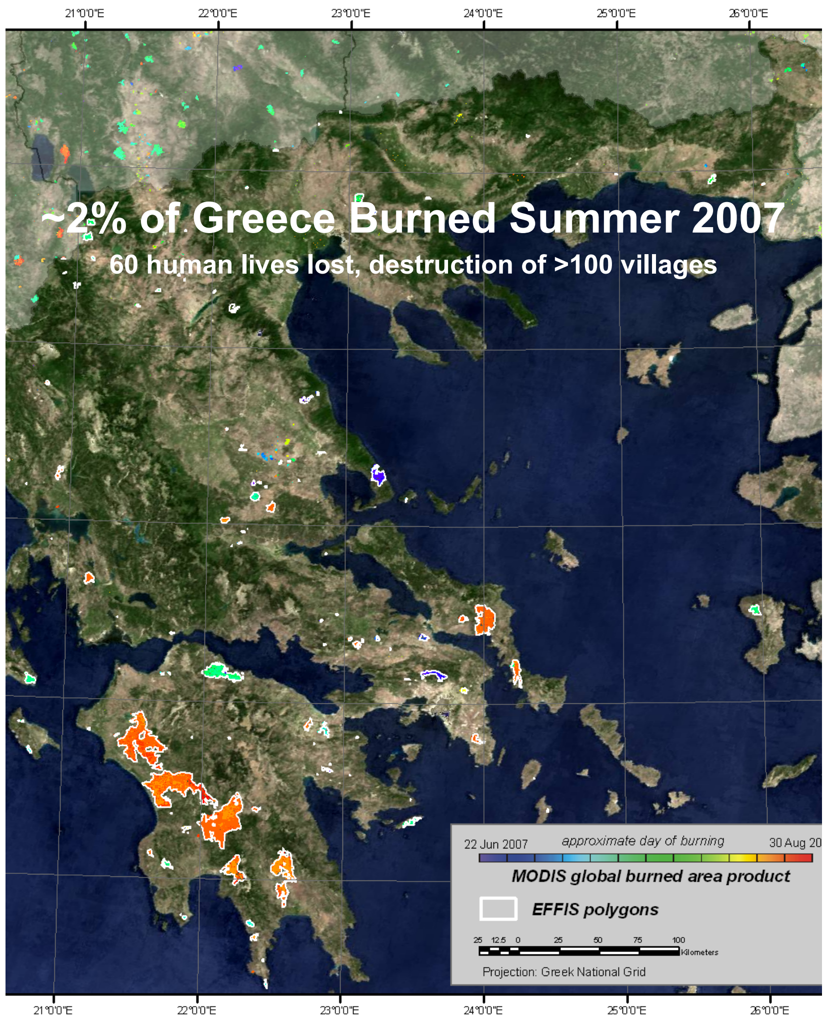
MODIS Land (MODLand) Products: Nine Years and Counting presented at IGARSS09 Cape Town
Chris Justice, David Roy and the rest of the MODIS Land Science Team

Extracting societal benefit from satellite measurements requires the development of a strong linkage between the measurements and the decision makers who will use such measurements.

This linkage must be sustained throughout the life cycle of the mission.

-- Decadal Survey Report (2007)

U.S. National Academy of Sciences



Original analysis Boschetti et al.

Quality Indicators for Societal Benefit QI4SB implementation proposal

- Goal: Develop a set of Quality Indicators linking initial scientific instrument measurements to the products delivered to societal benefit end-users

- Quality Indicators to be based on the uncertainties of key processing steps; including the errors associated with product modeling
- Combined QIs are to be compared by end-users to their uncertainty requirements
  - **Lower quality data sets may be acceptable for some applications where product uncertainty (or error) tolerances are large**
  - **High quality sensor-calibration data are needed when scientists must estimate small changes in important geo-physical variables**
    - **(e.g. SST time series need to be accurately measured to 0.1 deg over a decade)**

A QI4SB best practice example

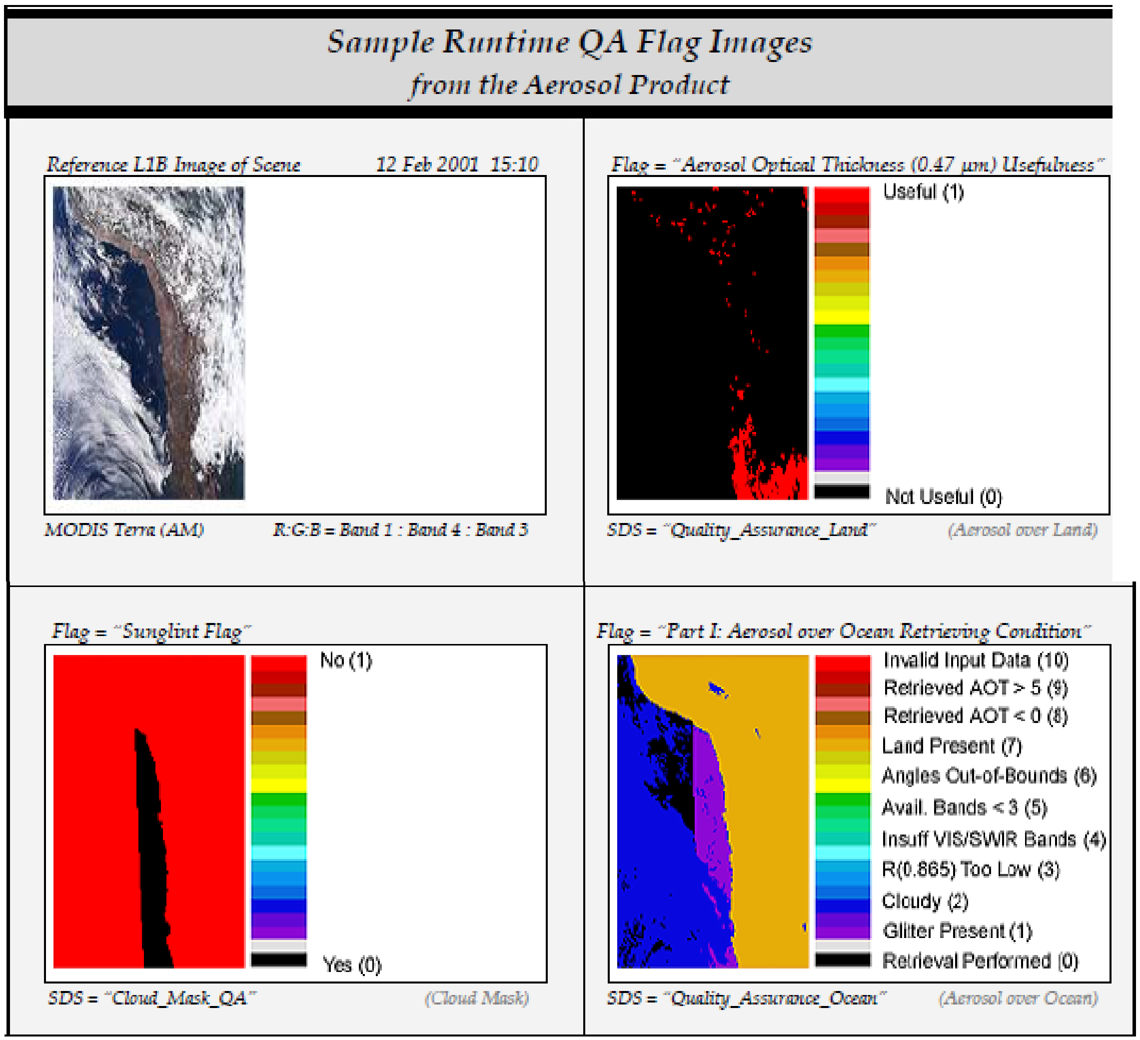
"The MODIS Land Product QA Approach"

Ref: D. Roy, et al Remote Sensing of Environment, Vol. 83, pp. 62-76, 2002

- QA is an integral part of NASA's MODIS Land data products.
- Correct interpretation of information for the user requires
  - Ability to discriminate between product and modeling uncertainties and real changes in the Earth processes.
- Goal of MODLAND QA
  - Evaluate and document scientific quality of the data products as pertains to their intended performance.
- Users review QA results prior to selecting MODLAND products
  - Ensure that the products have been generated with low levels of uncertainty and artifacting so that the requested products meet the specific needs of the users
- Users urged to inspect the QA metadata (including artifact info) to decide on a product's utility

QA Flags, MODIS Aerosol product

Ref:P. Hubanks, "MODIS Atmospheric QA Plan for Collection 005", April 07



Note: Images were created by "bitflag_visualizer", available at http://modis-atmos.gsfc.nasa.gov/tools_bitflag_visualizer.html.

Note:
Flags differ in various sub-regions of the image

QA flags and Quality Confidence Measures

MODIS Aerosol product

MODIS Atmosphere QA plan 13

Scientific Data Set (SDS): "Quality_Assurance_Ocean"
*Description: **Product quality and retrieval processing flags over Ocean***
*Length: **5 bytes (40 bits)***

Flag Name	Number of Bits	Bit Values	Bit Value Definitions
Aerosol Parameters (Best Soln.) Usefulness Flag	1	0	Not useful
		1	Useful
Aerosol Parameters (Best Soln.) Confidence Flag	3	0	No Confidence (or Fill)
		1	Marginal
		2	Good
		3	Very Good
Aerosol Parameters (Avg. Soln.) Usefulness Flag	1	0	Not useful
		1	Useful
Aerosol Parameters (Avg. Soln.) Confidence Flag	3	0	No Confidence (or Fill)
		1	Marginal
		2	Good
		3	Very Good
processing path flags			
Part I: Aerosol over Ocean Retrieving Condition when inversion is NOT performed. *Note: τ (550 nm) fill value will be output on conditions 1 through 10.*	4	0	Retrieval is performed
		1	Glitter is present
		2	Cloudy
		3	*R* (0.865 μm) too low for retrieving optical thickness
		4	Total number of available VIS / SWIR wavelength bands (from 550 to 1240 nm) is insufficient
		5	Total number of available wavelengths < 3
		6	Angles Out-of-Bounds
		7	Land present in 10 x 10 km box
		8	τ (550 nm) < -0.01; algorithm found negative values of optical thickness (there is a problem)
		9	τ (550 nm) > 5.0; out of bounds in lookup table
		10	All Channels do not have valid data

[Quality Confidence Measures]

Accuracy Statement for Land Product

Ref: Jeffrey Morisette, GEO/CEOS Cal/Val Workshop, NIST, May 2008

MODIS land team

validation

Home | Core Sites | Val Status | Campaigns | Documentation

Status for: BRDF/Albedo (M*D43)

General Accuracy Statement

Validation at stage 1 has been achieved for the surface reflectance product (MCD43). The accuracy of the high quality MODIS operational albedos is well less than 5% albedo at the validation sites studied thus far and even those albedo values with low quality flags have been found to be within 10% of field data.

Further work on albedo validation is planned. A summary of these plans can be found in the May-June 2004 issue of the Earth Observer.

Product status updated: October 2004 (modified January 2007)
Product version: Collection 4

Supporting Studies:

Title: Validation of the MODIS Bidirectional Reflectance Distribution Function and Albedo Retrievals Using Combined Observations From the Aqua and Terra Platforms
Author: Jonathan G. Salomon, Crystal B. Schaaf, Alan H. Strahler, Feng Gao, Yufang Jin
Source: IEEE Transactions on Geoscience and Remote Sensing, Vol. 44, No. 6, June 2006 1555
View Summary Results From This Document

Title: Comparison of MODIS broadband albedo over an agricultural site with ground measurements and values derived from Earth observation data at a range of spatial scales
Author: M. Disney, P. Lewis, G. Thackrah, T. Quaife, M. Barnsley
Source: Int. J. Remote Sensing, 10 December, 2004, vol. 25, no. 23, pp. 5297-5317

Done

Error Budgets
or "Uncertainty Inventories"
A basis for establishing Quality Indicators

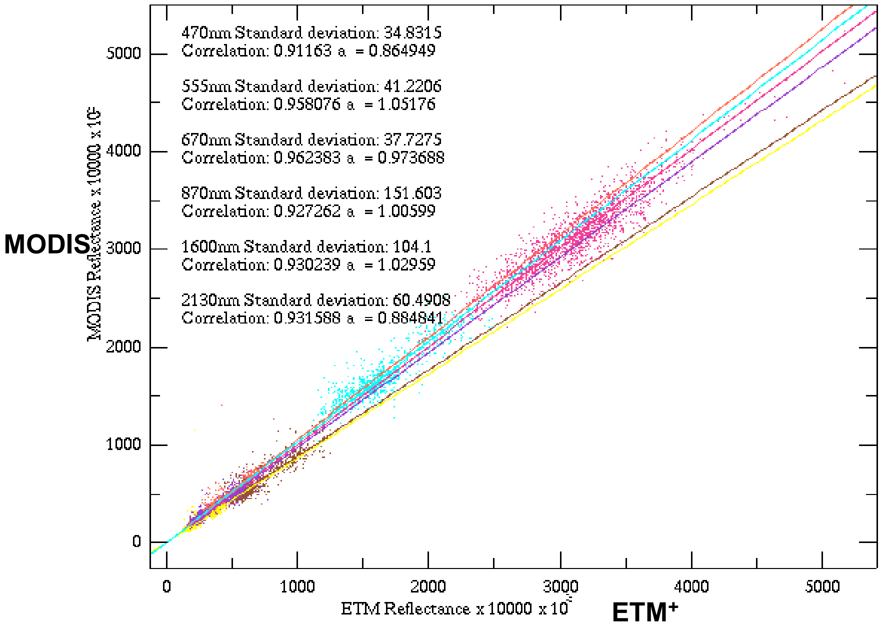
- Error Budgets:
  - Provide a means for tracking source of errors
  - Establishes a quantitative basis for constructing product Quality Indicators and/or QA metadata.
- A comprehensive error budget quantifies the impact of:
  - Calibration Uncertainty, Product Modeling, and Noise Sources
- An example is the Error Budget for the MODIS Land Surface Temperature product

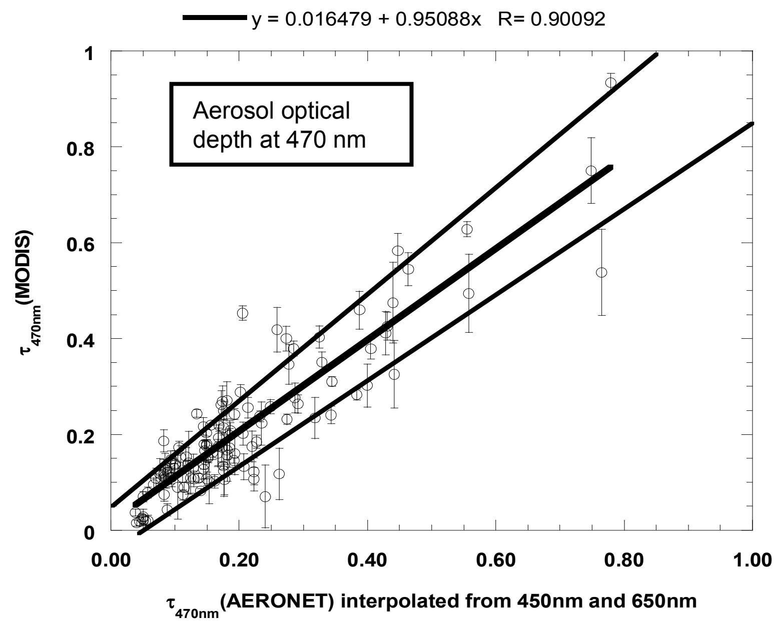
Instrument and model uncertainties	**Temperature Uncertainty, °K**
Algorithm	0.58 K
Mean emissivity error estimate, ε	0.31 K
Delta emissivity error estimate, $\Delta\varepsilon$	0.65 K
Instrument noise, NEΔT = 0.5K	0.30 K
Instrument calibration error (deg K)	0.35 K
Combined Root mean square of all uncertainties	**1.03 K**

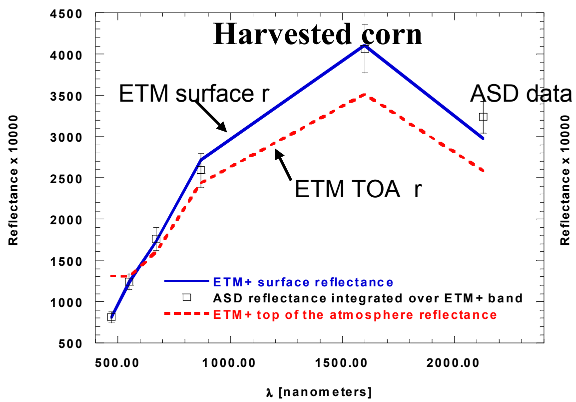
Errors based on split-window LST Algorithm
Ref: Z. Wan, MODIS Land-Surface Temperature Algorithm Theoretical Basis Document, Version 3.3, April 1999

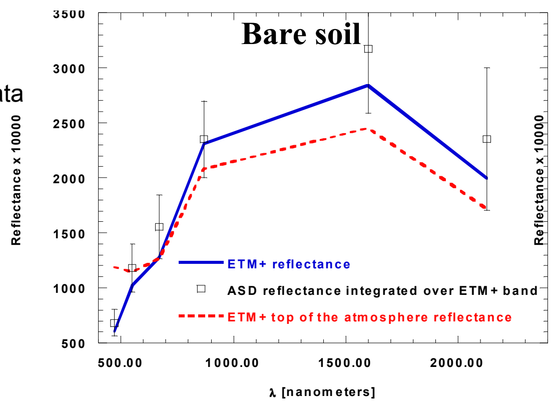
MODIS Surface Reflectance Stage 1 Validation re ETM+ /Landsat 7 data

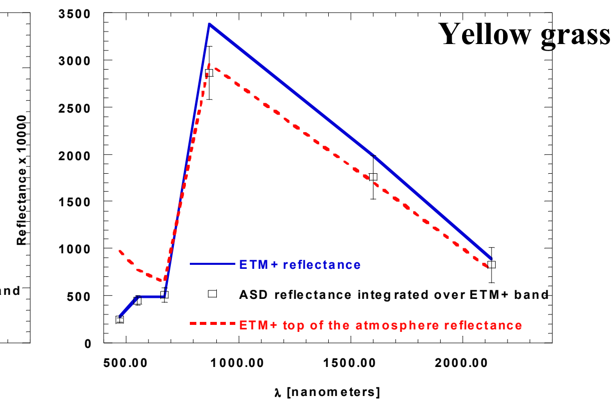
" Evaluation of NPP/VIIRS Land surface Earth data with respect to climate change objectives"
Vermote and Saleous, NPP Science Team meeting, Nov 4-6 2003











Relating MODIS Vegetative Measure Uncertainties to Reflectance Calibration Uncertainties & vice versa

A. Huete et al: MOD 12 Algorithm Theoretical Basis Document, April 30, 1999

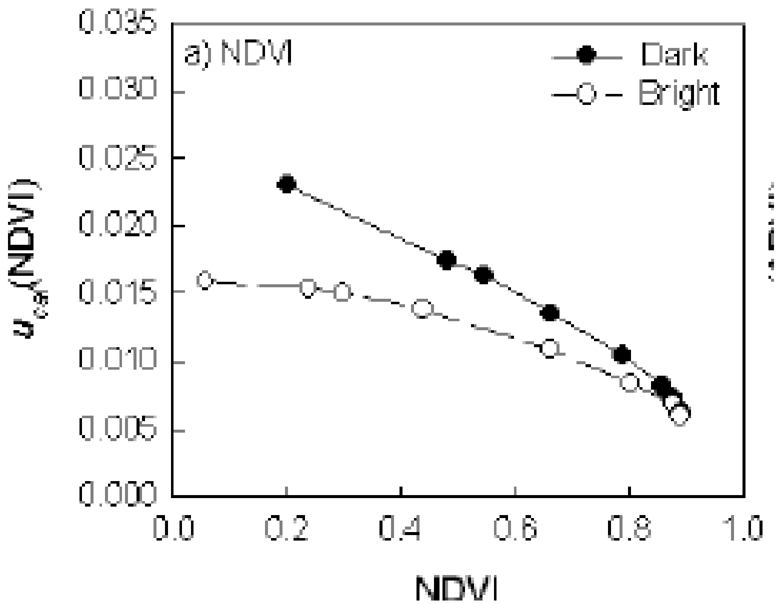


Table 8: Predicted Reflectance Calibration Uncertainties (%) Requirements for Desired Levels of VI Uncertainty

	Required Reflectance Calibration Uncertainties (%)			
u_{cal}(VI) Desired	*NDVI*	*SAVI*	*ARVI*	*EVI*
0.01	1.9%	2.1%	1.0%	1.2%
0.02	3.8%	4.2%	1.9%	2.4%
0.05	9.4%	10.5%	4.8%	5.9%
0.10	18.9%	21.1%	9.6%	11.9%

- Uncertainties of NDVI estimate due to a 2% reflectance calibration uncertainty
  - Based on Model atmosphere with 10 km visibility; for both Dark and Bright backgrounds
- If an end user requires that the level of NDVI uncertainty be no great than 0.01, then the sensor data must be well calibrated with

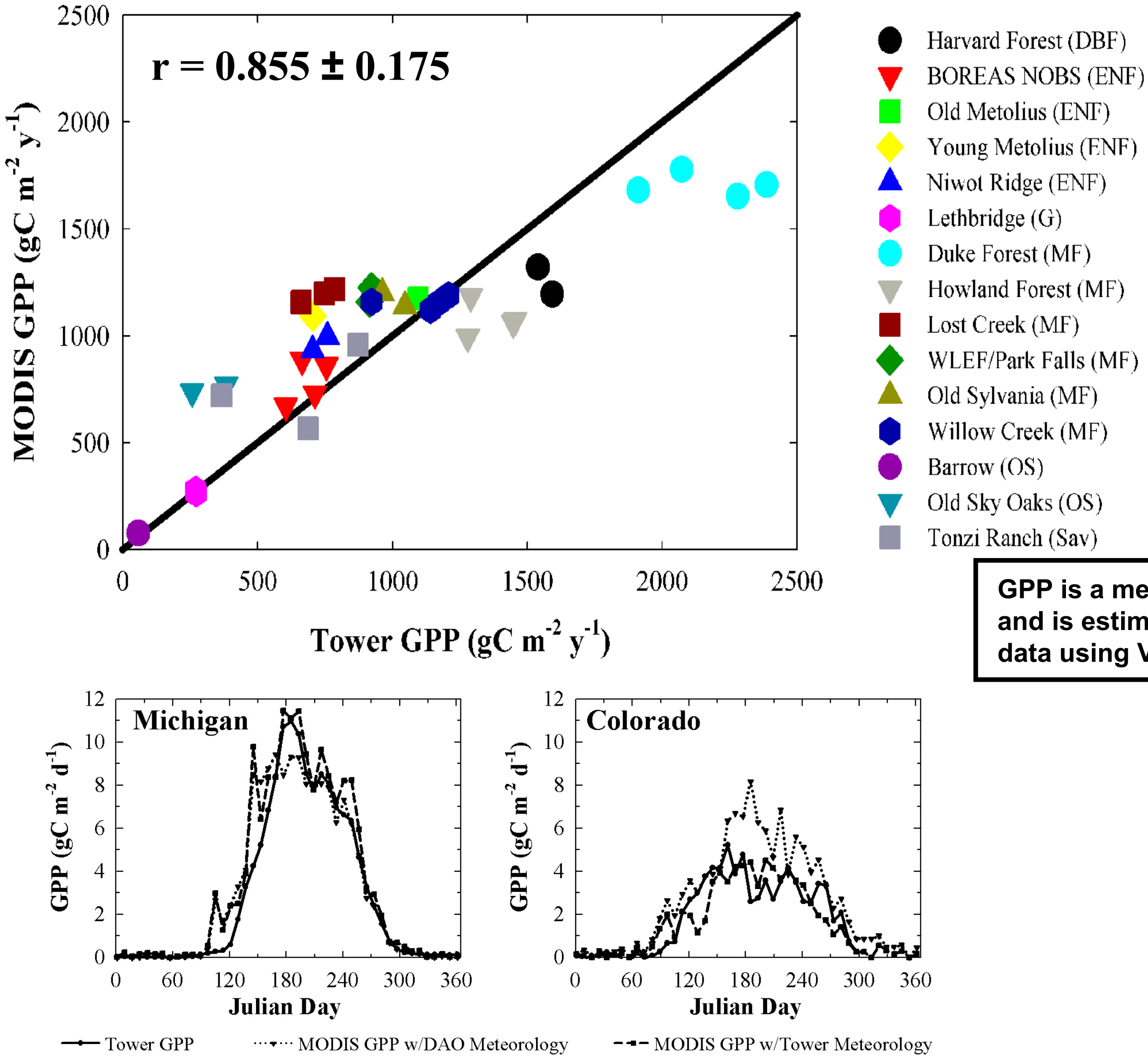
  reflectance uncertainty ≤ 1.9%.
- However if the requirement on NDVI uncertainty can be as much as 0.10, then the sensor data need not be tightly calibrated;

  now reflectance uncertainty ≤ 18.9%

Accuracy of Annual Gross Primary Production (GPP) Data
Validation of MODIS vs Tower measured GPP

"Evaluation of Remote Sensing Based Terrestrial Productivity From MODIS Using Regional Tower Eddy Flux Network Observations"

F.A. Heinsch, et al, TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 44, NO. 7, JULY 2006



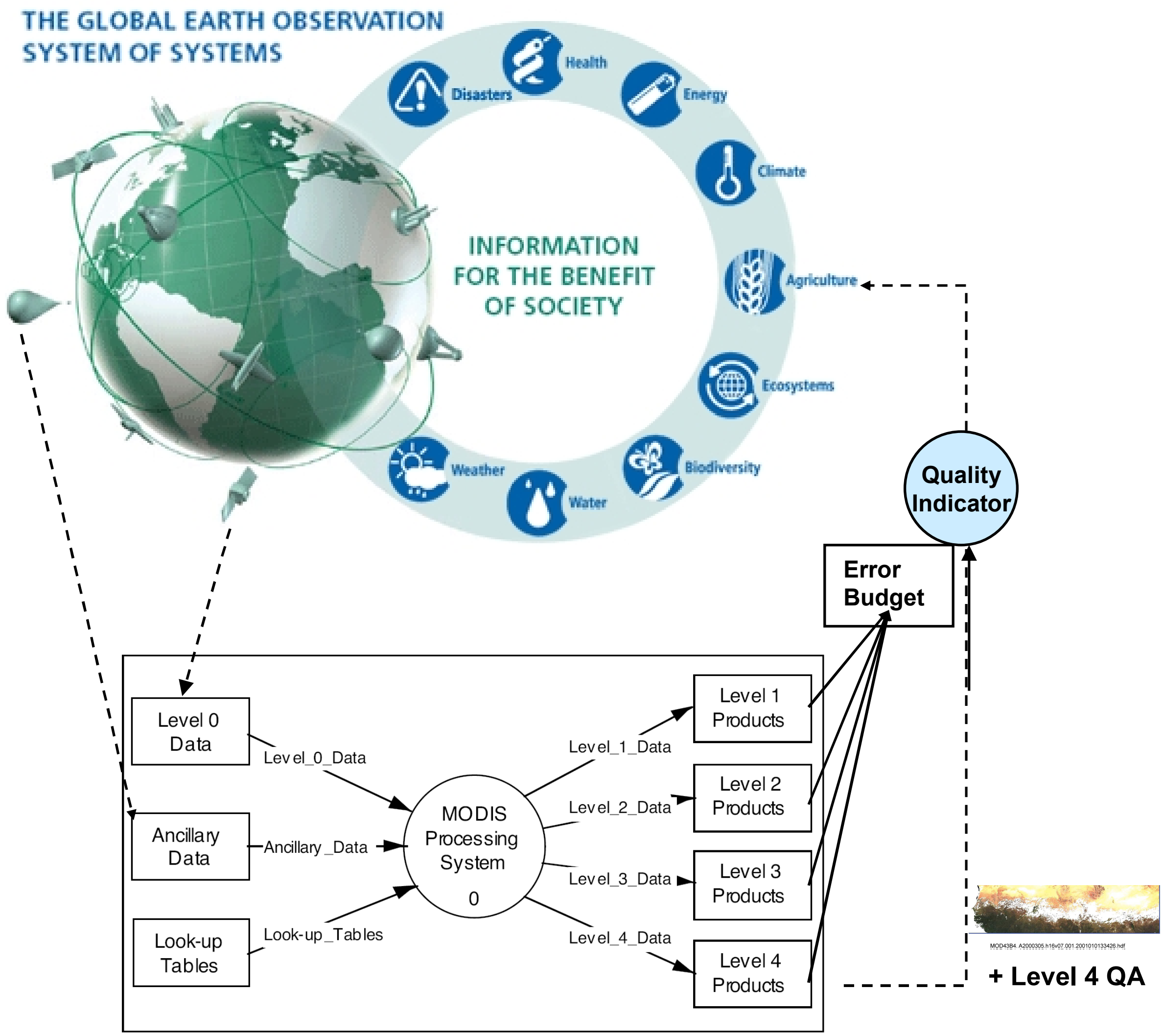
GPP is a measure of photosynthesis and is estimated from remote sensing data using Visible and NIR spectra

Sources of Product Uncertainties

Ref: D. Roy, et al Remote Sensing of Environment, Vol. 83, pp. 62-76, 2002

- Instrument uncertainties
  - Artifacting errors
- Incomplete transmission of instrument and ephemeris data to ground
- Incomplete instrument calibration knowledge
  - Particularly post-launch
- Geolocation uncertainties
  - Spatial and temporal
- Software coding errors
- Algorithms not mature enough (taking into account the major physical processes) to properly account for the sensitivity to surface, atmospheric, and remote sensing variations
- Errors introduced by the production, archiving, and distribution processes

Recommend GRSS develop "Error Budget" and QIs for a sample set of land and atmospheric products typically requested in the nine societal benefit areas



Summary of Recommendations

- **Propose a QI4SB task be undertaken by the IEEE/GRSS community to establish methods for constructing error-budget-based Quality Indicators for GEOSS end users.**
  - QIs are to be compared with specific uncertainty requirements in each of GEO's nine societal benefit areas
  - Goal: Provide quantitative measures or indicators (QIs) to better determine product acceptability by end users
- **We Propose a Pilot Project to create model QIs linked directly to a limited number of important societal benefit problems**
  - e.g. Infrared sensor specialists should work directly with experts from the fire safety community to ensure that the collected data and the proposed QIs provide information that is specifically useful for protecting property and lives under real world conditions