Long Term Monitoring of Vegetation Greenness from Satellites

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The Beautiful Season
Motivation

The following two statistics are sufficient to justify monitoring our planet -

- 47% increase in global population (4.45 billion in 1980 to 6.53 billion in 2006)

- 12% increase in atmospheric carbon dioxide concentration (340 ppmv in 1980 to over 380 ppmv in 2006)
What Have We Learned?

Some examples,

[1] Greening of the Northern Latitudes
[2] Climate driven increases in NPP
[3] Seasonality in Amazon rainforests

Jackson Pollock (1912-1956)
Autumn Rhythm (Number 30) (1950)
Analyses of satellite greenness index data sets indicate a significant greening of the northern latitudes since the early 1980s. This greening trend shows a strong correlation with the pronounced warming of surface temperatures observed in these regions, and the spatio-temporal pattern of greening coincides with the major modes of global climate variability, namely, the El Nino Southern Oscillation and the Arctic Oscillation.
Recent results indicate that global changes in climate have eased several critical climatic constraints to plant growth, such that net primary production increased 6% (3.4 petagrams of carbon over 18 years) globally. The largest increase was in tropical ecosystems. Amazon rain forests accounted for 42% of the global increase in net primary production, owing mainly to decreased cloud cover and the resulting increase in solar radiation.
Recent analysis of five years of MODIS LAI data suggest seasonal swings in green leaf area of about 25% in a majority of the Amazon rainforests. That is, leaf area equivalent to nearly 28% the size of South America appears and disappears each year in the Amazon. This seasonal cycle is timed to the seasonality of solar radiation in a manner that is suggestive of anticipatory and opportunistic patterns of net leaf flushing during the light rich dry season and net leaf abscission during the cloudy wet season.
MODIS: The MODerate resolution Imaging Spectroradiometer is an instrument on board NASA’s Terra and Aqua platforms for remote sensing of the Earth’s atmosphere, oceans and land surface.

LAI: one sided green leaf area per unit ground area in broadleaf canopies, and half the total needle surface area per unit ground area in coniferous canopies.

FPAR: fraction of photosynthetically active radiation (0.4-0.7 µm) absorbed by the vegetation.
MODIS LAI and FPAR Products

Terra LAI/FPAR (MOD15A2 product):
- Collection 3-- Coverage: November 2000 – December 2002 [1 km and 8 day]
- Collection 4-- Coverage: March 2000 –present [1 km and 8 day]
- Collection 5-- Began June 30th, 2006 [1 km and 8 day]

Aqua LAI/FPAR (MYD15A2 product):
- Collection 3-- Coverage: July 2003- December 2003 [1 km and 8 day]
- Collection 4-- Coverage: July 2002- present [1 km and 8 day]
- Collection 5-- Began June 30th, 2006 [1 km and 8 day]

Terra and Aqua MODIS Combined Products in Collection 5 [1 km, 4 and 8 day]
The Standard MODIS Products are available from the EDC DAAC

Boston University LAI/FPAR (MOD15_BU):
- 1- and 4- km monthly best quality composites of Collection 4 MOD15A2 product
- Available from LAI/FPAR PI website, http://cybele.bu.edu
MODIS LAI and FPAR Production

1. Development of the at-launch algorithm
2. Prototyping of the algorithm
3. Algorithm refinement

I. Input uncertainty constraint
II. Global algorithm performance
MODIS LAI and FPAR Algorithm

Best quality retrievals are obtained with the Main RT-based algorithm. In case of high LAI (>5) surface reflectances have low sensitivity to LAI (saturation domain). Only retrievals by main algorithm (with or without saturation) are recommended for application studies.

In case of main algorithm failure, the back-up algorithm (LAI/FPAR-NDVI empirical relationships) is employed. Such retrievals have generally low reliability and are not recommended for application studies, including validation.
Main algorithm retrievals increased from 55 percent in Collection 3 to 67 percent in Collection 4 as a result of algorithm refinements. The impact can be seen even in globally averaged LAI values.
From Product Assessment & Validation to Algorithm Refinement

• **Steps**
  – Analyze the products
  – Identify anomalies
  – Trace the cause of anomalies
  – Refine the operational algorithm

• **Sources of uncertainties**
  – Landcover data (KONZ, Alpilles)
  – Surface reflectance (AGRO, KONZ)
  – Model (HARV)

• **For example, Collection 3 anomalies include**
  – Summer product LAI higher than *in situ* LAI in herbaceous vegetation
  – Too few main algorithm retrievals during summer
  – Seasonality differences between main and backup algorithms
Global Validation Sites

- Grasses/Cereal Crops
- Shrubs
- Savannas
- Needleleaf Forests
- Broadleaf Crops
- Broadleaf Forests
Validation Procedure

- Field sampling representative of LAI spatial distribution and dynamic range within each major land cover type at a validation site.

- Development of a transfer function between field measured LAI and high resolution satellite data to generate a reference LAI map over an extended area.

- Comparison of MODIS LAI with the aggregated reference LAI map at patch scale in view of geo-location and pixel shift uncertainties.
Validation Example

- **Site:** Ruokolahti, Finland
- **Measurements Dates:** June 14-21, 2000
- **Land Cover Type:** Coniferous forests
- **Results:** Comparison of aggregated high-resolution LAI map and corresponding MODIS LAI retrievals suggests satisfactory behavior of the MODIS LAI algorithm although variation in MODIS LAI product is higher than expected. Collection 4 MODIS LAI match field measurements within 0.5LAI (meet specifications)
Validation Results

\[ y = 1.12x + 0.12 \]
\[ R^2 = 0.87 \]
\[ RMSE = 0.66 \text{ LAI} \]
Collection 5 MODIS LAI & FPAR Products

- LAI/FPAR algorithm was optimized to improve consistency of RT-simulated and MODIS surface reflectances
  -- LUTs for all biomes were recalculated based on new Stochastic RT model
  -- Special focus of refinements was on woody vegetation. 6-biome LC was replaced with 8-biome LC and separate LUTs were developed to account for variability spectral signatures of evergreen and deciduous subclasses of broadleaf and needle leaf forests.
  -- Terra and Aqua combined 8- and 4-day products were prepared for production

- Extensive refinements have been implemented for MODIS surface reflectances product (bug fixes, conservative cloud mask, improvements of geolocation accuracy, aerosol retrievals only over non-cloudy pixels, inclusion of polarization effect).

- Due to significant amount of changes science testing and production of Collection 5 was delayed (Started on June 20th 2006).
Lessons Learned

• User needs should drive the program.

• Scientists should be involved intimately - from instrument design, algorithm development, implementation, data system design and data processing.

• Plan on processing the data in real time, at least for the critical products.

• Plan on multiple re-processings - this should be based on feedback from validation.

• Make data available freely through the web.

• Data should be accompanied by quality information and documentation.

• The goal should be to serve the user!
Some Thoughts on Collaborative Work

• India has the satellite data

• There is knowledge out there to extract useful information from this data

• Let us build a system that put outs critical information to serves India’s needs

• Examples
  – real time hazards monitoring (fire, droughts, floods, etc.)
  – crop and forest productivity monitoring
  – land cover change and land use change monitoring
  – help meet India’s commitments to International treaties