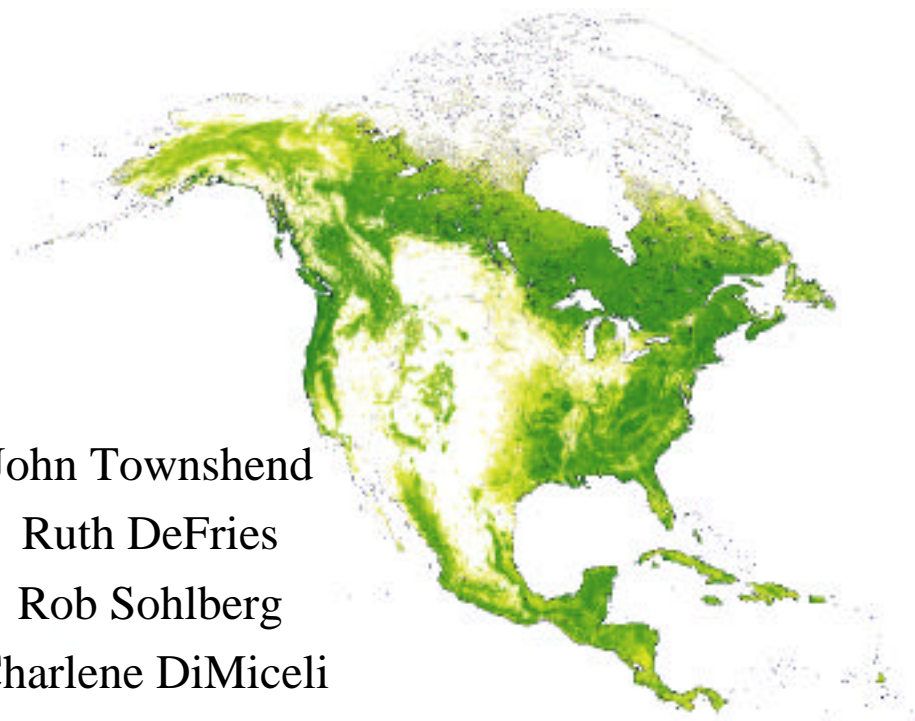# MOD44 Status:
Vegetative Cover Conversion
Vegetation Continuous Fields

John Townshend

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Rob Sohlberg

Charlene DiMiceli

Matt Hansen

Mark Carroll

Jill Eastman

Bethany Seimiks

MOD44 Product Suite

- **Products derived from 16-day interim product (running in MODAPS)**
  - Optimized for resolution and clear view
  - Re-mapped and mosaiced, delivered in binary format
    - *USVI with regional subsets*
    - *Special areas of interest in South America and Canada*
    - *Available via Global Land Cover Facility (ESIP)*

- **Vegetative Cover Conversion (to run in MODAPS)**
  - Monthly 250m global alarm product for land cover change events.
    - *Flooding, Burning, Deforestation, Agricultural Expansion, and Urbanization.*
  - Produced every 32 days with results for previous 3 month and one year period.

- **Vegetation Continuous Fields (SCF Production)**
  - Annual 500m product which provides sub-pixel estimates of forest cover, leaf type, and phenology.
    - *% Tree Cover, % Herbaceous, % Bare*
    - *% Needle Leaf / Broad Leaf, % Evergreen / Deciduous*
  - Allows user to aggregate to suit their specific needs.

MOD44 Implementation Requirements

- **Intermediate Composite Product complete**
  - Geolocation very good
  - Work-around to weak 250m cloud mask
  - L2G issues related to maximizing spatial resolution

- **Vegetative Cover Conversion**
  - Continuous year of data needed from which to construct LUTs
    - Each of four global zones, five methods, twelve months
  - Will prepare from the limited sample produced in Collection 3

- **Vegetation Continuous Fields**
 - Continuous year of 500m 8-day Surface Reflectance

Vegetation Continuous Fields

- Provides per-pixel estimates of vegetation cover and characteristics

- Based on monthly composites derived from 8-day 500m Surface Reflectance

- Produced annually

- Can be used to monitor changes in tree cover on a global basis

Example of continuous field algorithm

This example uses minimum annual red and infrared reflectances and derived NDVI as independent variables. The tree partitions the feature space and assigns mean node tree cover values, which are then refined using a stepwise regression and median-mean adjustments.
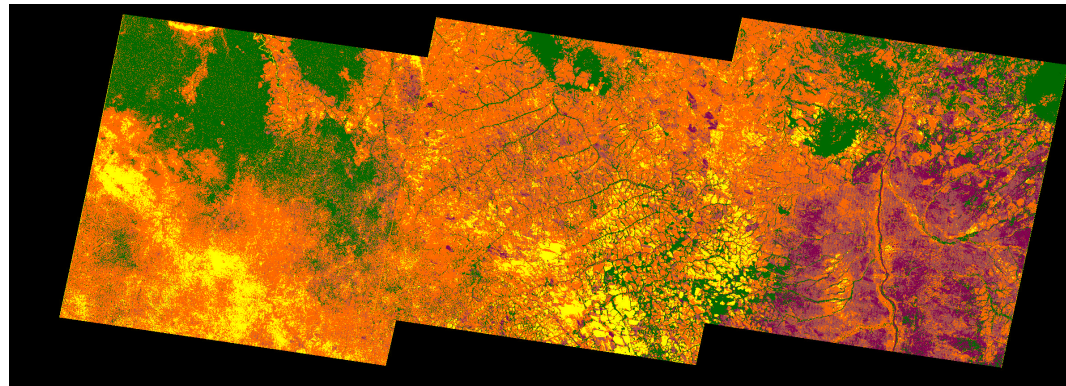
training data

% tree cover

100%

0%
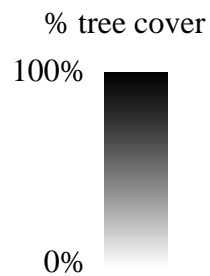
Training site for MODIS continuous field product, an example site from southern Democratic Republic of the Congo

High-resolution
data sets
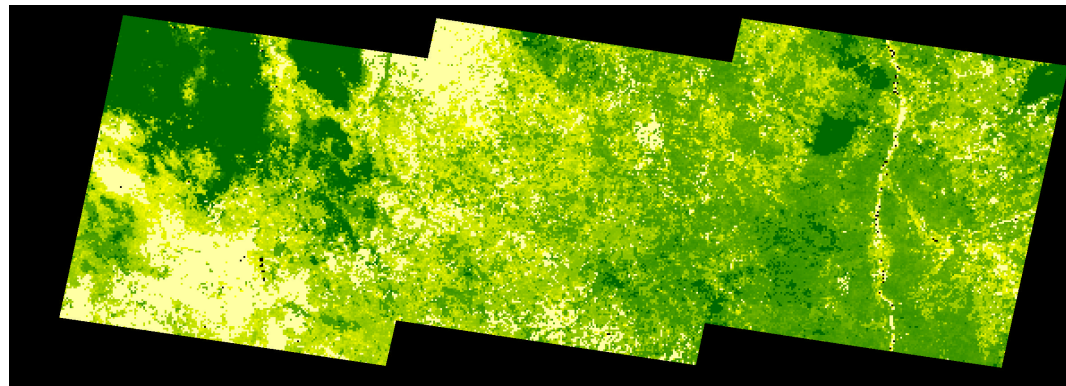
infrared, red, green composite

Classified into
tree cover strata

green=forest-80% tree cover
dark maroon=dense woodland-60%
light maroon=open woodland-40%
orange=savanna-25%
yellow=grassland-0%

Aggregated to
coarse resolution
continuous tree
cover training

% tree cover from
dark green=>80%
to light yellow=<10%

North America
500 meter MODIS
continuous field
of tree cover

North America
500 meter MODIS
continuous field
of leaf type

VCF Validation

- Field campaigns conducted in Africa and U.S.
- Africa results in press (RSE)
- Uses a combination of ground-based laser canopy closure measurements with high resolution imagery (IKONOS and Landsat)
- Are discussing joint activities with federal Forest Inventory Assessment group

# Validation of MODIS continuous fields of tree cover

New approach to test current method and calibrate future mapping efforts

- Use IKONOS data to depict tree crown cover.
- Aggregate IKONOS to 30 meter ETM+ cells and create 30 meter continuous fields using multi-temporal ETM+ imagery.
- Aggregate ETM+ results to MODIS resolutions for cal/val.
- Field measurements used for validation as well as canopy to crown cover conversions.
- Ancillary map sources and statistical databases used for evaluations
- Initial site in Western Province, Zambia.
- Twelve sites currently being developed for lower 48 United States,
- Additional sites in Africa planned, Congo humid forest/savanna interface site visit next month.
- Are discussing joint activities with federal Forest Inventory Assessment group.

Laser instrument reports whether the canopy immediately above is open or closed and the distance from the ground to the first leaf.
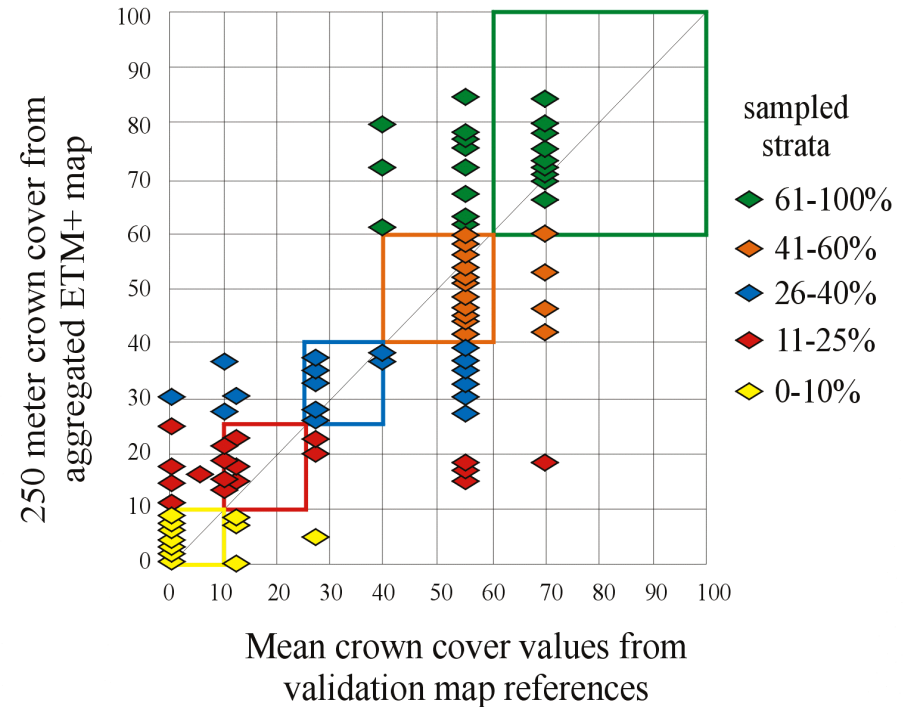
IKONOS to ETM+ to MODIS
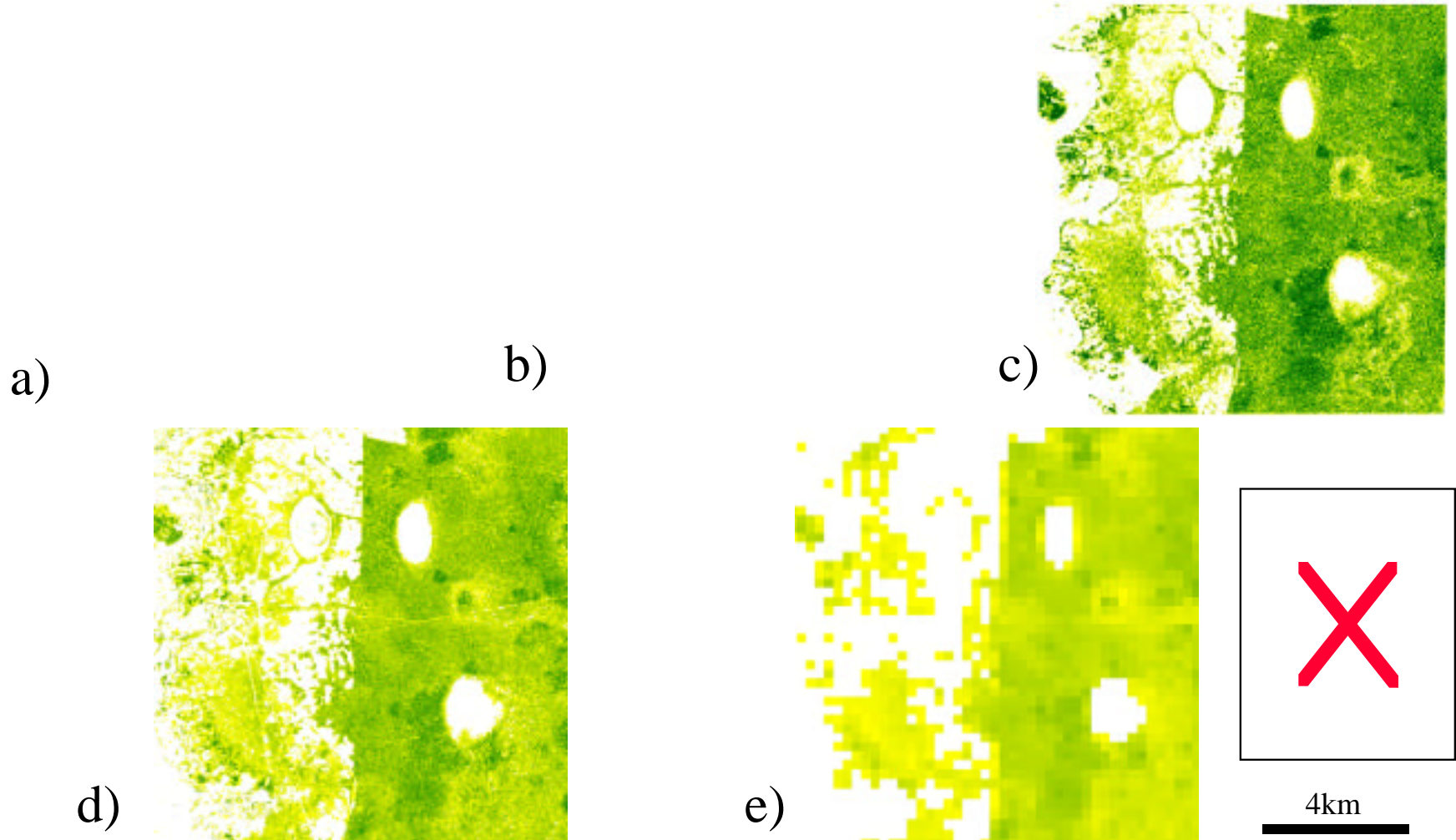
a) 4 m IKONOS 4-3-2 combination, 11km by 11km, b) crown cover interpretation,
c) aggregated continuous crown cover training at 30 meter resolution, d) TM canopy
cover from IKONOS training, result scaled using field measurements, e) result
aggregated to 250 meter for MODIS validation use

Comparison of ETM+ 30 meter tree cover estimates to field measured validation sites
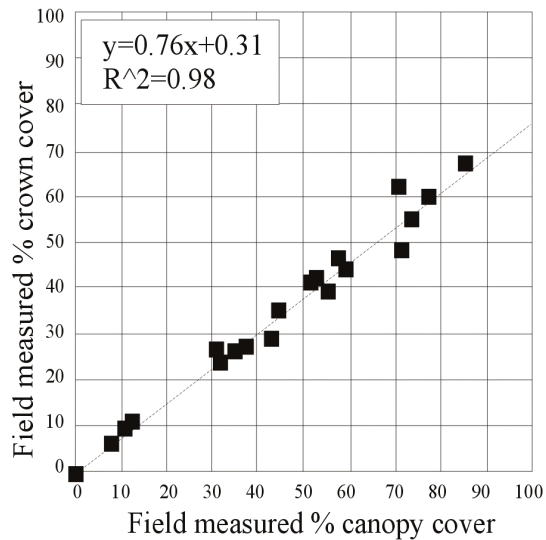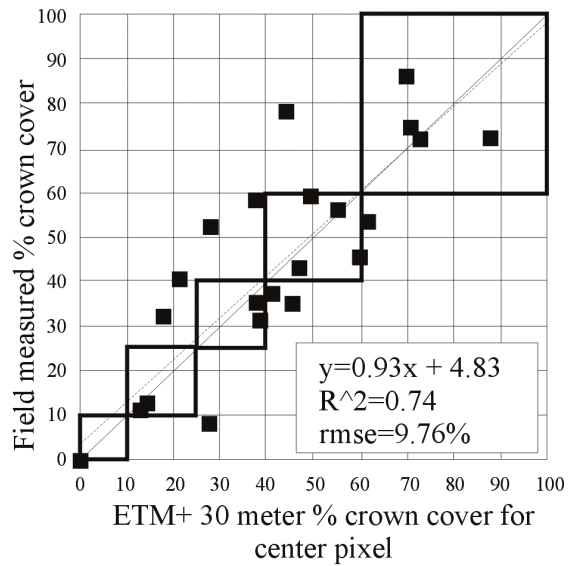
Comparison of "Landscapes and Grasslands of Western Province, Zambia" mean class crown cover values with 250 meter aggregated ETM+ map


Field measured % crown cover

y=0.93x + 4.83
R^2=0.74
rmse=9.76%

ETM+ 30 meter % crown cover for center pixel

Field measured % crown cover

y=0.76x+0.31
R^2=0.98

Field measured % canopy cover

250 meter crown cover from aggregated ETM+ map

Mean crown cover values from validation map references

sampled strata

- 61-100%
- 41-60%
- 26-40%
- 11-25%
- 0-10%

GOFC strata	percent area	rmse
0-10%	35.9	4.16%
11-25%	15.6	10.60%
26-40%	16.5	14.12%
41-60%	18.8	7.16%
61-100%	13.2	12.76%
average rmse		9.8%
area weighted rmse		8.5%

Validation results per strata for the 125 randomly chosen sites

Western Province, Zambia tree cover cal/val site

ETM+ tree cover derived from
IKONOS training and aggregated
to 250 meters

MODIS tree cover estimate

United States MODIS validation sites for multi-resolution characterization of percent tree cover

% tree cover

0% 100%
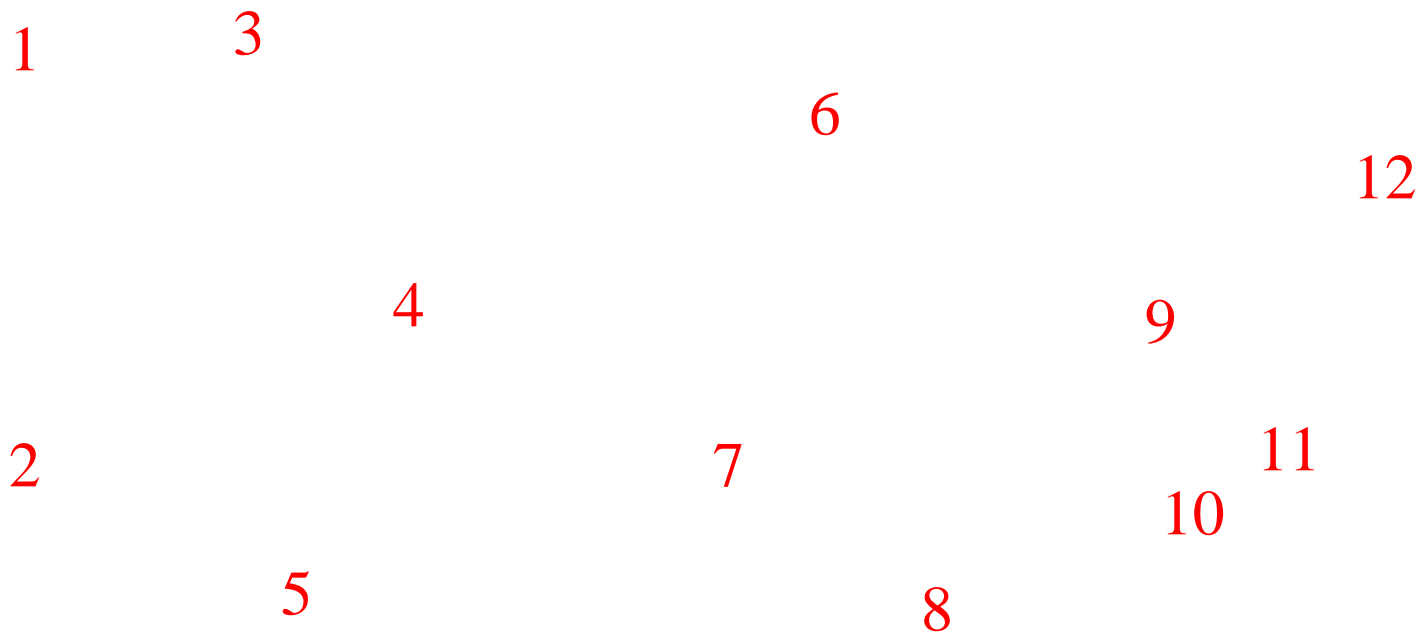
VCF 2001 Colorado Validation Campaign

Validation using existing statistical data sets—comparing USFS forest area estimates by state with continuous field estimates

Percent tree cover
threshold at which
continuous field
area estimate matches
USFS estimate

0%

100%
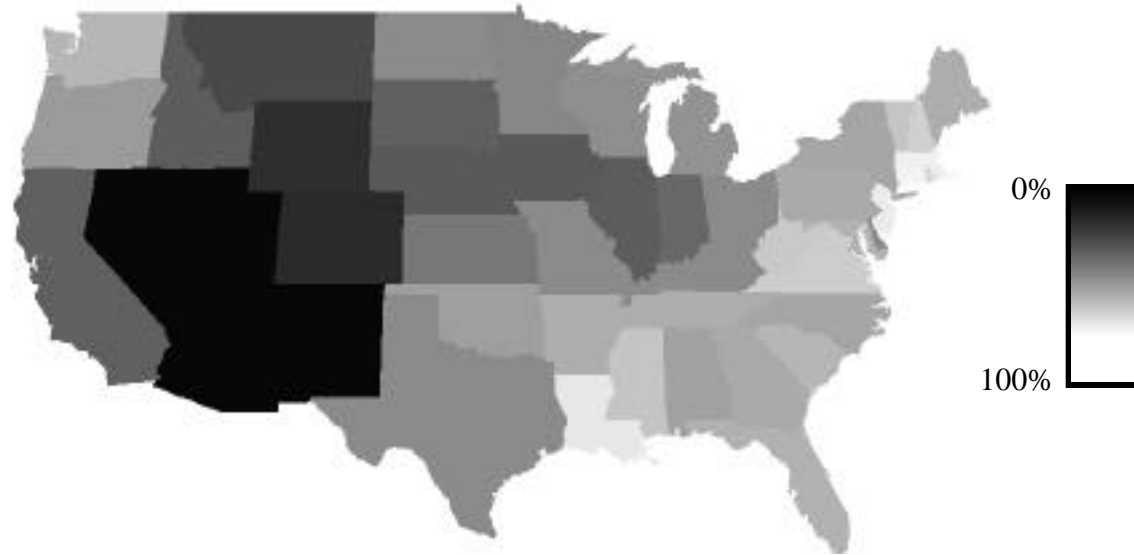
Area weighted mean
solution for matching
USFS total forest area
for lower 48 states.

Threshold = 35 %,
yielding 2.4 million square km.

Black = forest
Grey = non-forest
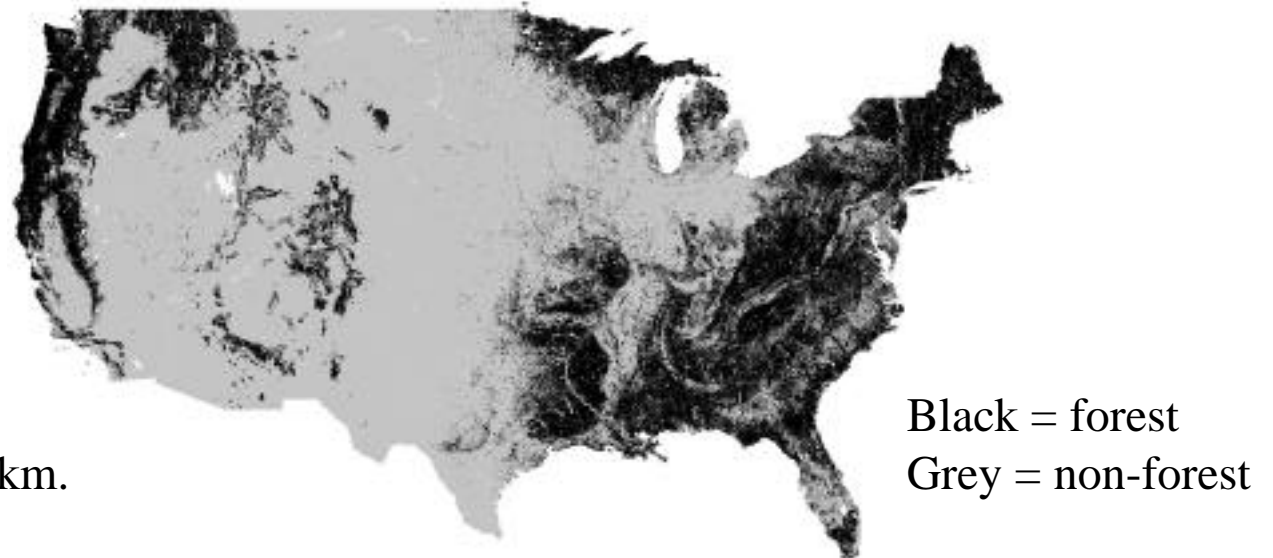
Regional differences in threshold agreement with USFS data

Production Status

- Beta version has been produced, first from Collection 1 and now from Collection 3
- Currently incorporating data from 1st reprocessing into phenologic (monthly composite) data set.
- Annual data set will be compiled by January
- Version 1 of VCF to be available in February 2002.

Vegetative Cover Conversion
REQUIREMENTS FOR RUNNING ALGORITHM

- Sub-pixel geolocation accuracy
- Cloud-free, near-nadir data set
  - Has required extensive work with L2G data structure
  - Poor quality of 250m cloud mask required alternate approaches
- Compositing method is a challenge
  - Every compositing scheme has drawbacks and when identifying subtle, small-scale changes an optimized composite is critical
- Look-up tables for spectral methods
  - Depicts the movement in spectral space resulting from land cover change
  - Phenology must be removed (a LUT for each month)
  - Regional bias must be removed (a LUT for each of four latitudinal zones)
  - Consistent, continuous year of data must be processed and staged to derive LUTs
- Integration of results
  - Conservative alarm product is desired

Vegetative Cover Conversion
CURRENT WORK

- Evaluating improved composites and preparing to deliver next version of code

- Updating MODIS-based lookup tables
  - Requires annual data for each of 4 zones in each of 12 months
  - Will delivery ca. 1 month after continuous year is received

- Engaged in validation and activities with several units of USDA Forest Service (Remote Sensing Applications Center and Forest Inventory Assessment)

PROGRESS ON COMPOSITING ISSUES

Early composite showing problems that have been linked to clouds and aerosols.

Improved version of this where some of the artifacts have been removed.

Current iteration where both cloud contamination and aerosol contamination have been improved by using the QA flags in L2G.

* Compositing: screen out missing values, high aerosols, flagged clouds, constrain view angle to <50 deg., then max NDVI (if no value increase view angle).
* Further work is in test to better utilize additional layers in L2G.
* All images are 250m resolution showing the US-Canada border with bands assigned 1-2-1 R-G-B respectively.

Visual Depiction of LUTs for Change Vector Characterization
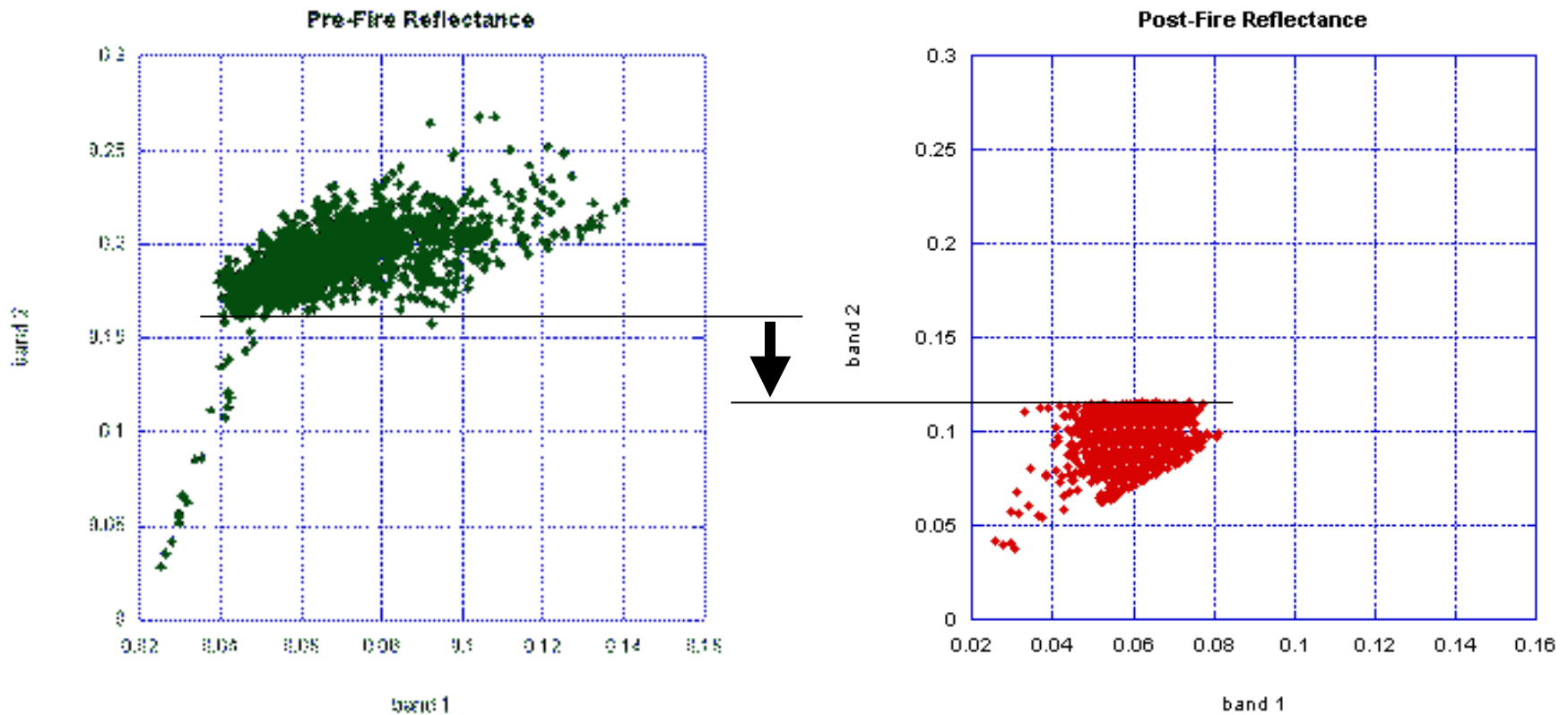
Individual LUT for Each Month for Four Latitudinal Zones
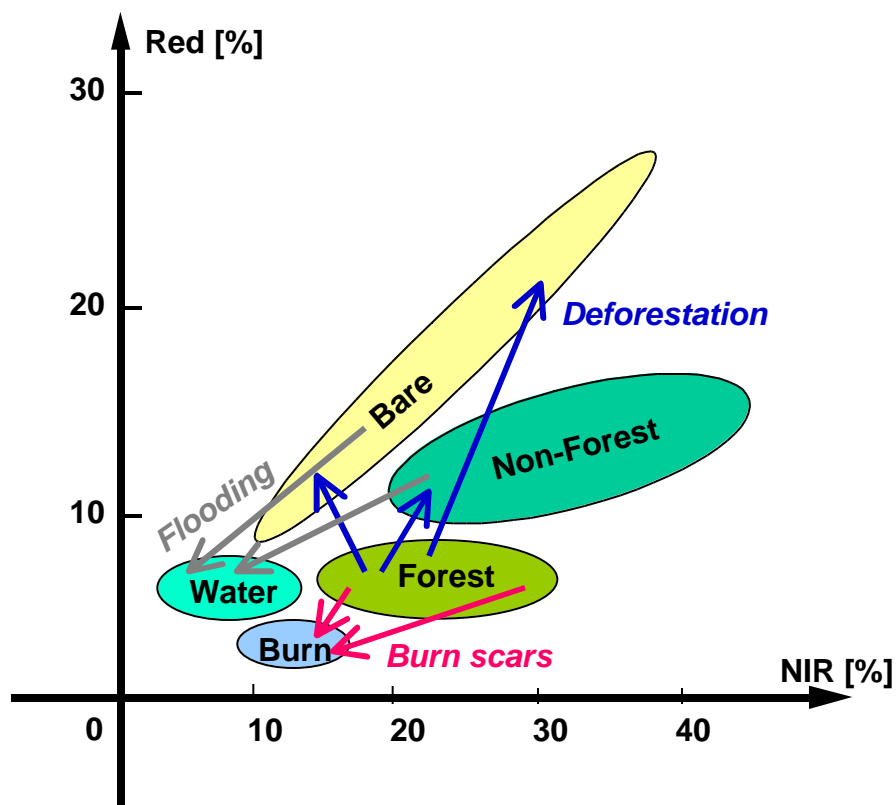
Example for a growing season month
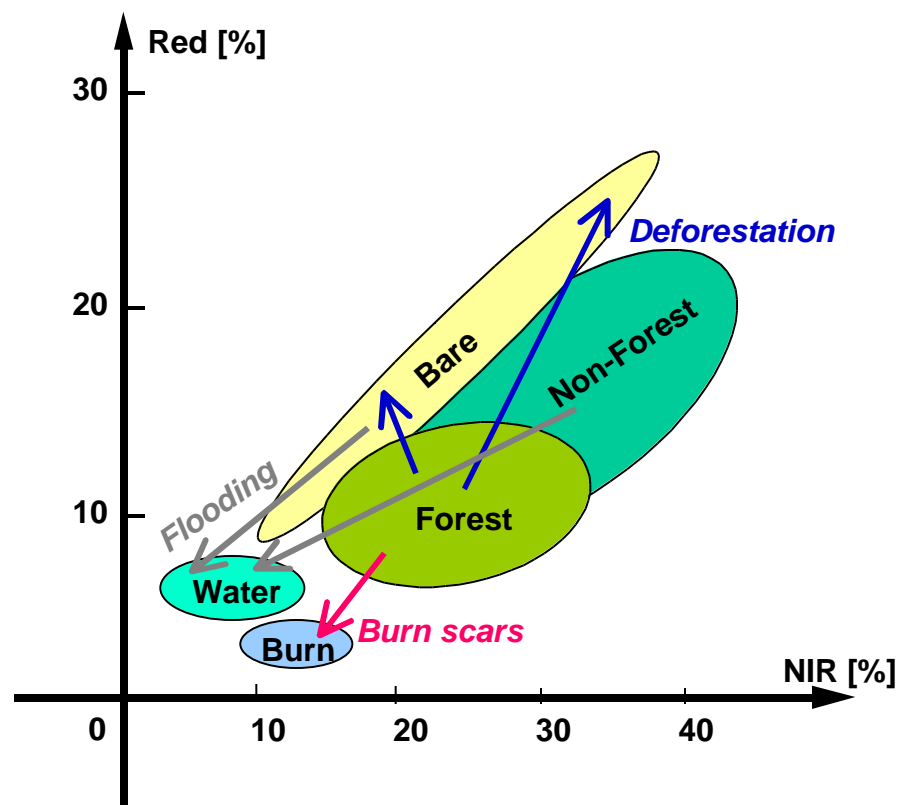
Example for a senescent month

Forest Fire Example:
Movement of pixels within Red-NIR space
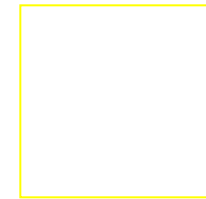(MODIS reflectances from Blue Complex fire)

The reflectance delta associated with a change event can be quite subtle, in this case a reduction of 5% reflectance in MODIS band 2.

Blue Complex Fire
California, August 2001

Pre-fire image

10 km

Post-fire image

Acres Burned

MODIS VCC	25,761
USFS Incident Report	34,400

VCC measurement of burned area is typically less than the USFS because it is able to discriminate unburned areas within the fire perimeter.
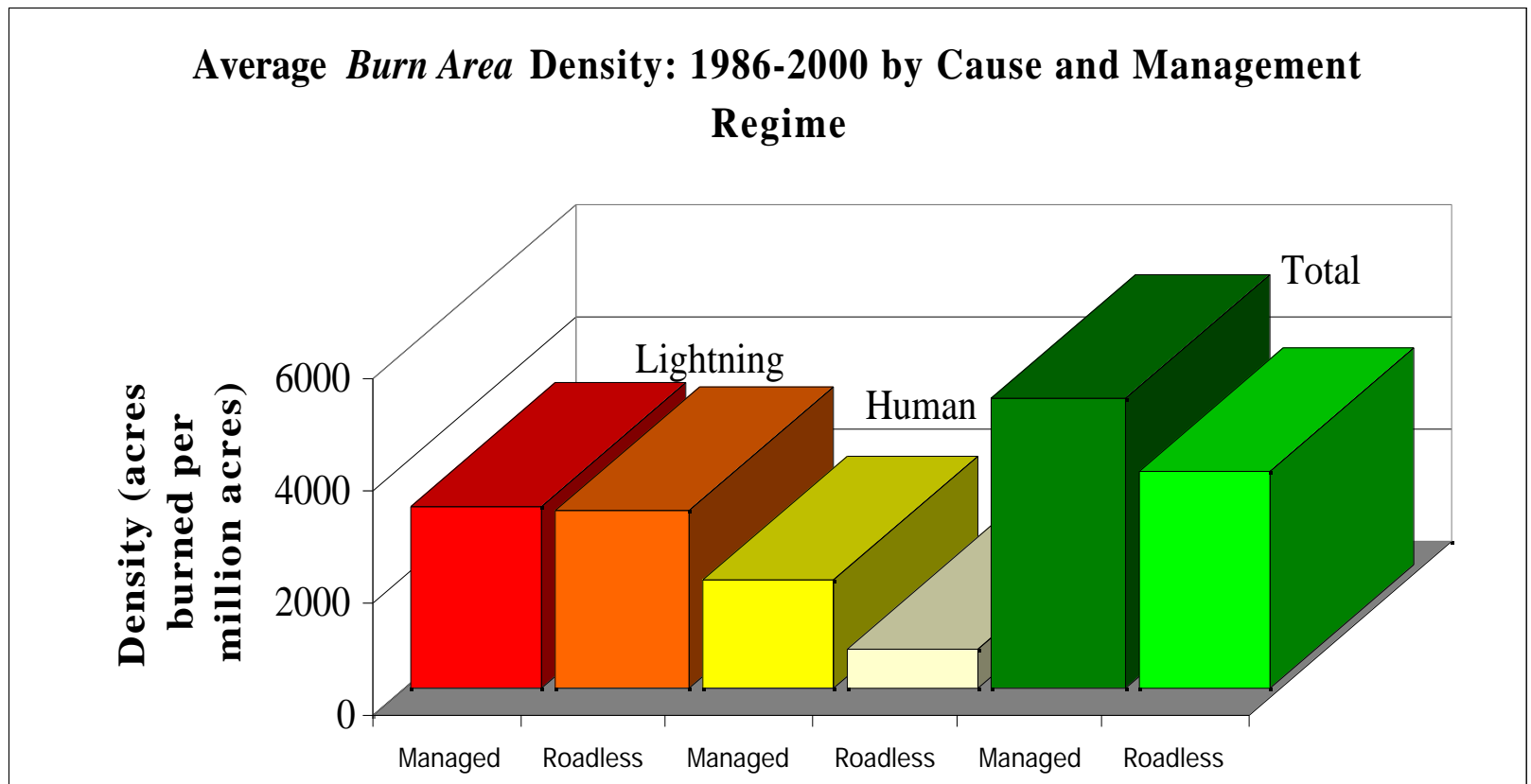
In this bitmap red indicates that change has occurred, in this case due to fire.

VCC Results used to Validate Relationship Between
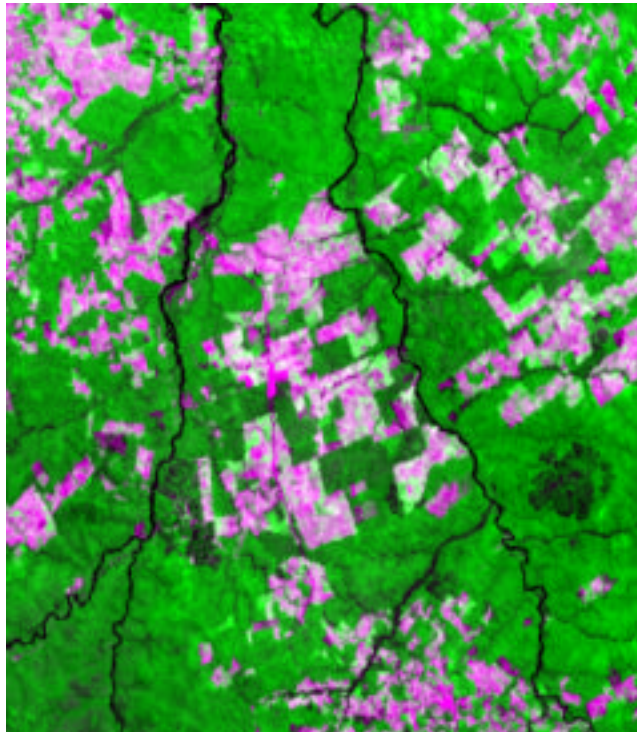# Fire Start Locations and Burned Polygons
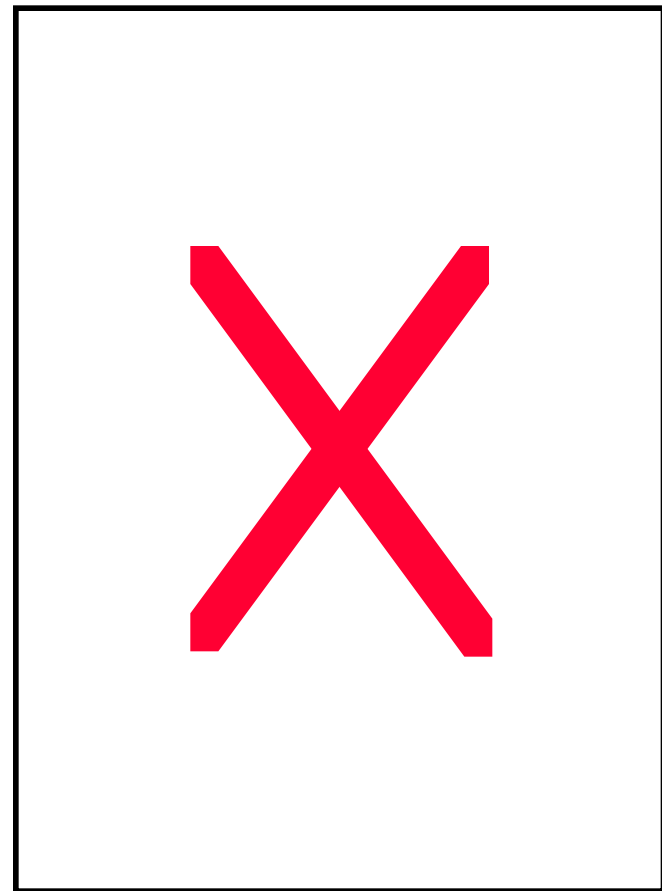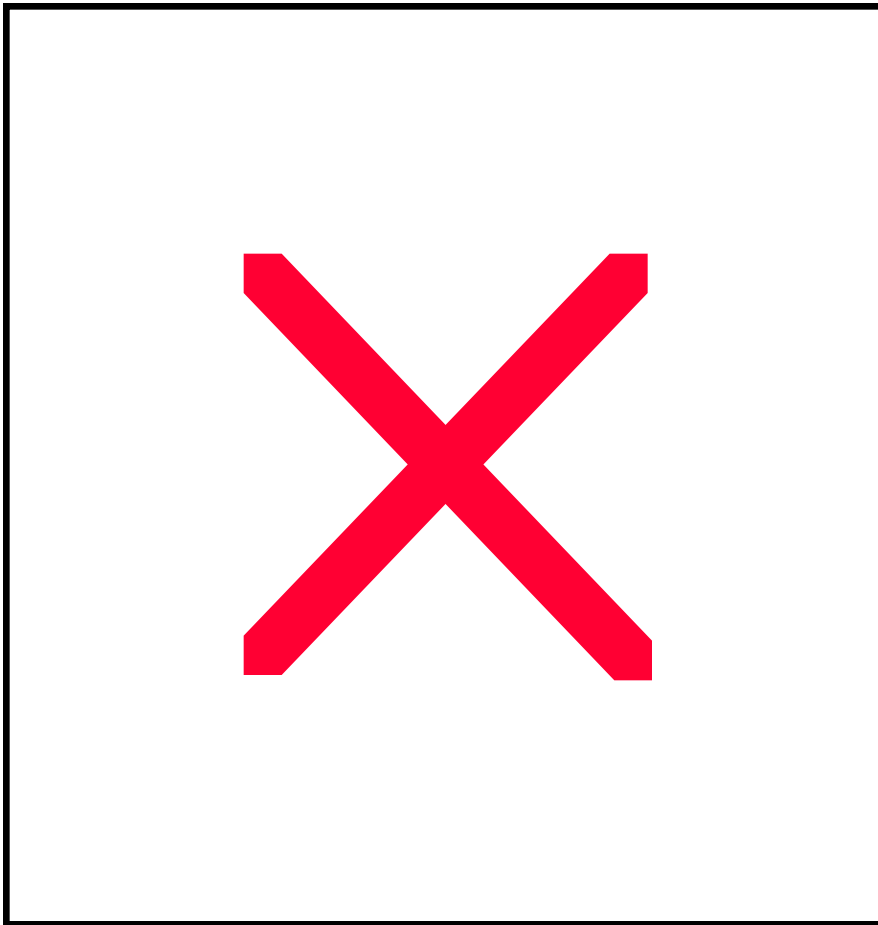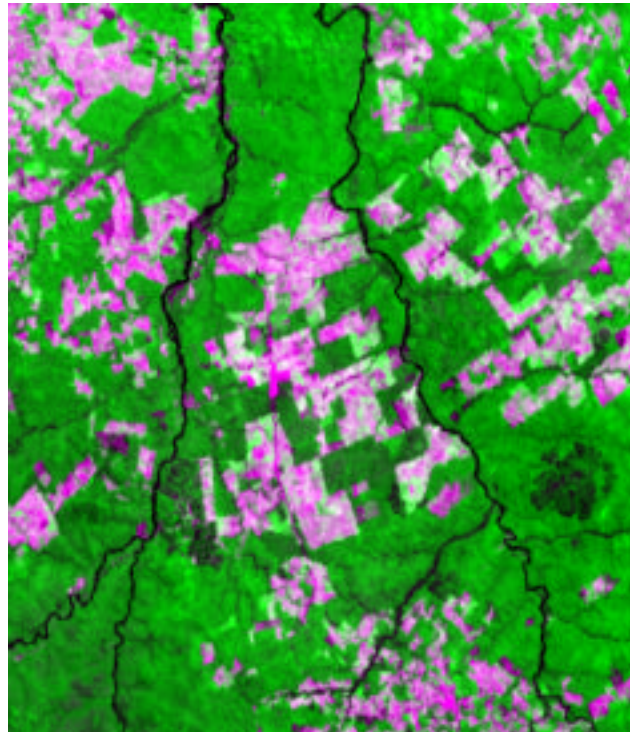
Average (1986-2000) Burned Area Results

Average _Burn Area_ Density: 1986-2000 by Cause and Management Regime

Deforestation in Brazil

| June 23, 2000 | September 22, 2000 | VCC Result |

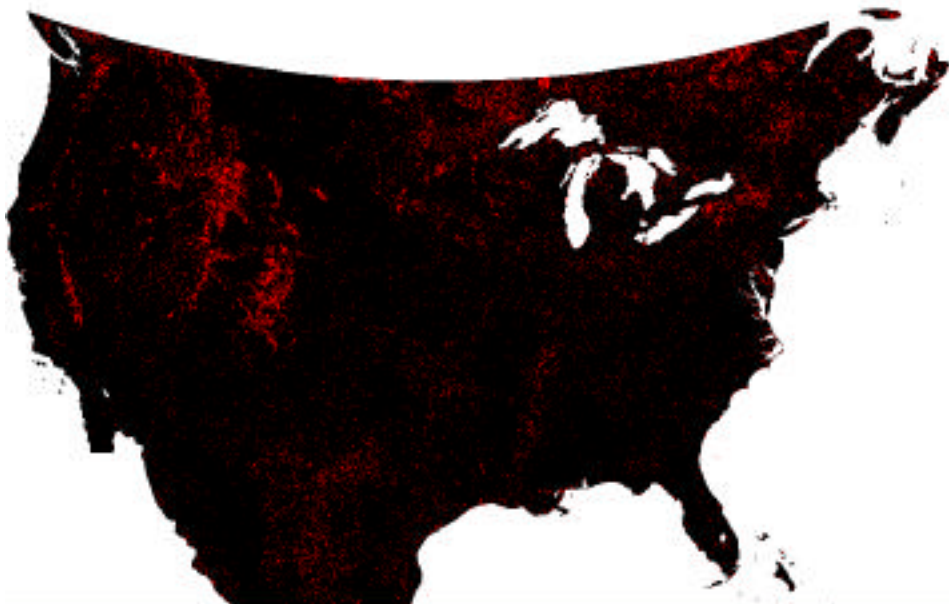In this bitmap red indicates that change has occurred, in this case due to deforestation.

The images above, from Western Brazil, cover an area of 1000 square kilometers. VCC identified that 1% of the land area shown experienced deforestation in 90 days.

# Continental-scale results are promising, but LUT improvements are needed.

At left is a VCC result for the conterminous U.S. for the 3 month period covering Mar.22 - Jul. 28, 2001.

At bottom left is the VCC result in red over a maximum NDVI composite for the period Mar.22 – Apr.6.

At right is a full resolution (250m) image of the Idaho/Montana border region. This shows where VCC incorrectly detected a change due to snow melt, and a region of checker-board logging.

Plus issues of cloud over water.

Reasonable result
(not yet validated)

Error of Commission
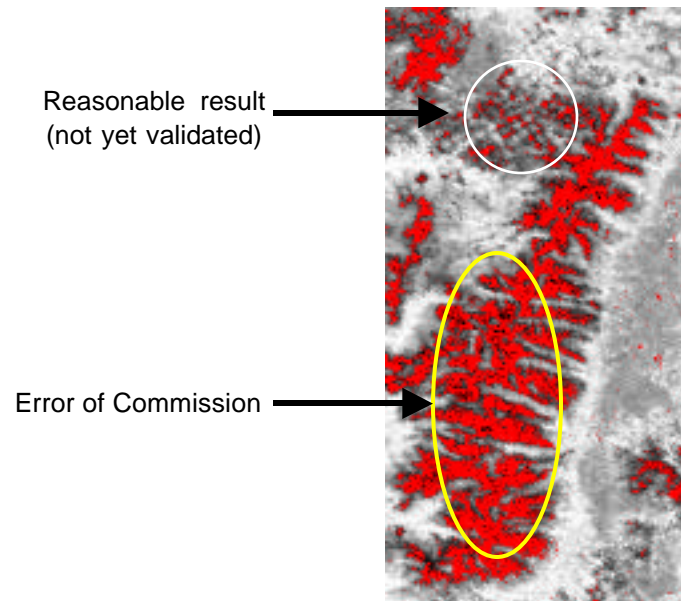
Vegetative Cover Conversion
## PRODUCT STATUS

- Using Collection 3 to finalize LUTs
- Initial release will be limited to available 250m production (geographic constraint)
- High resolution imagery used to validate results
  - IKONOS
  - Landsat 7
 - Quickbird

Vegetative Cover Conversion
THE WAY FORWARD

- Simplified, near real-time algorithm planned for Rapid Response in 2002
- Field work with USFS next summer
- Plan to update LUTs again with each re-processing
  - Important because Collection 4 will include the full global land area, whereas Collection 3 was a limited sample (16% of globe).
- Aqua overpass time will improve cloud-free data in tropical forest, thus increasing detected change

Using Continuous Fields for Change Detection

0%
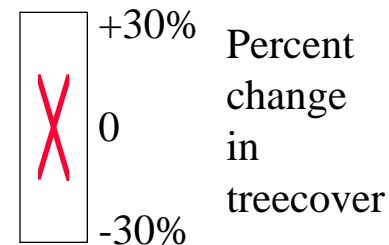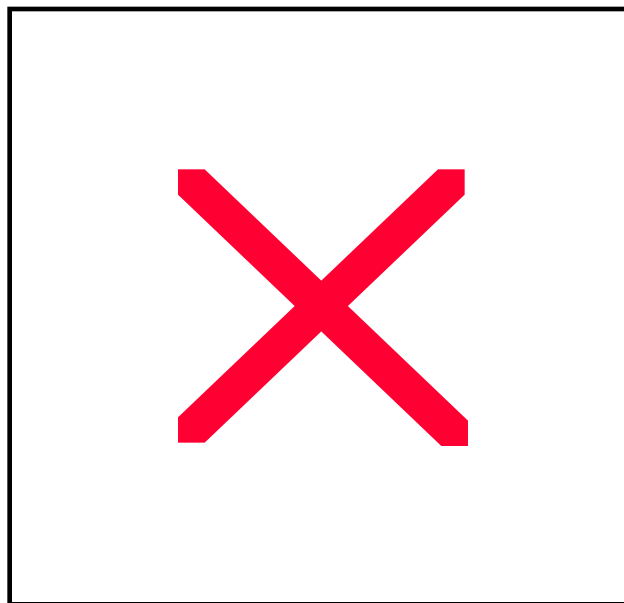
Treecover

>80%
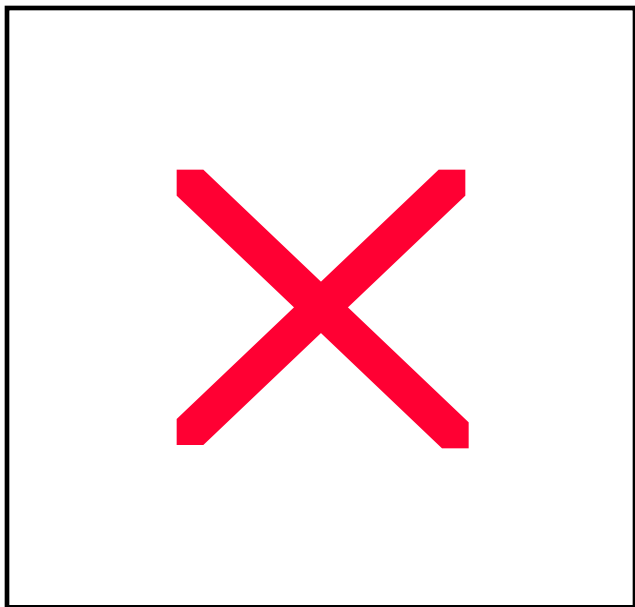
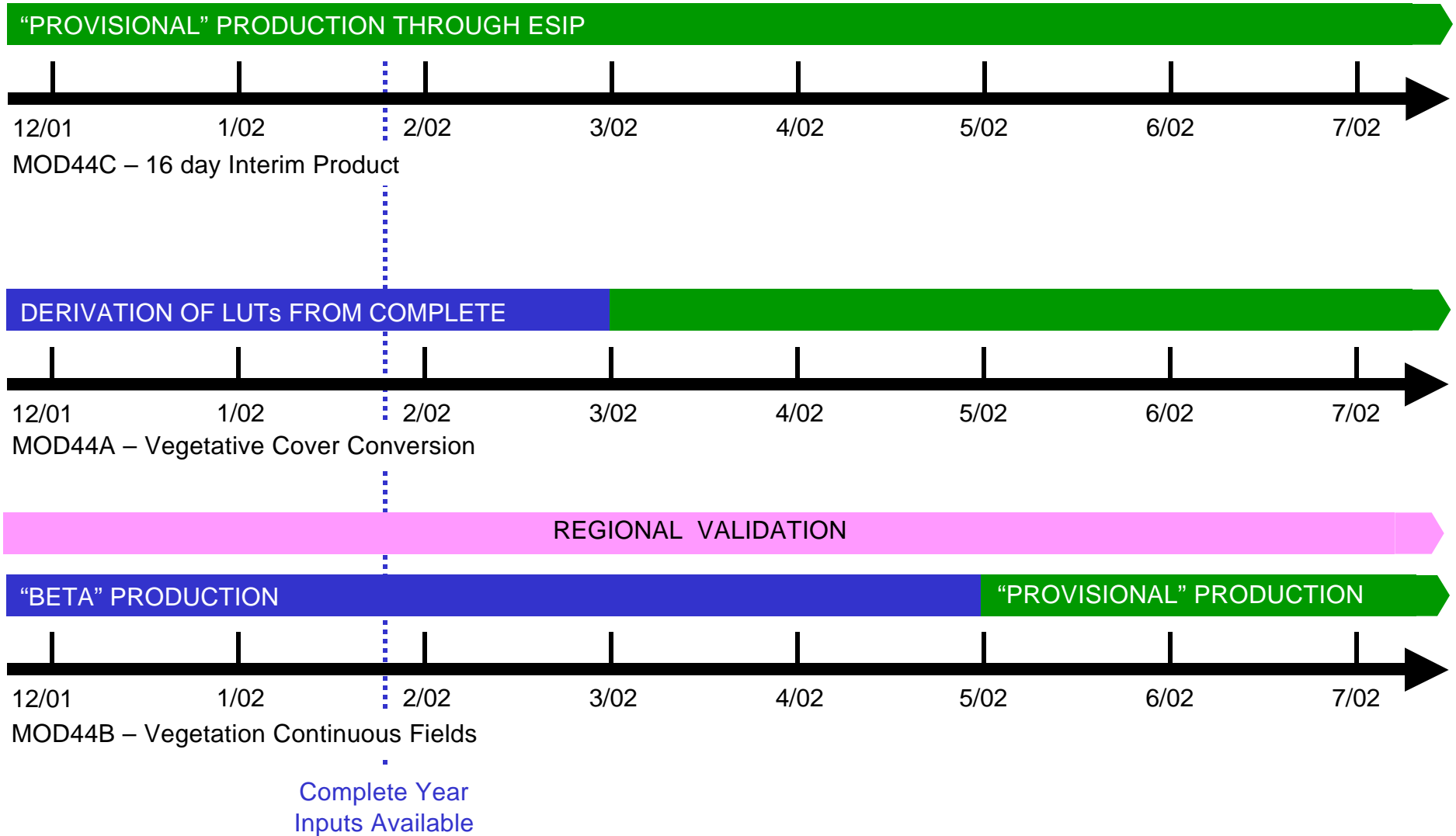Percent tree cover ~1985
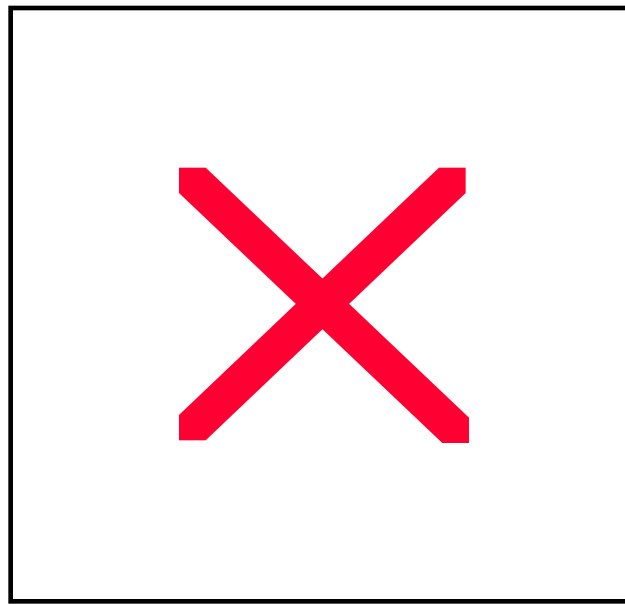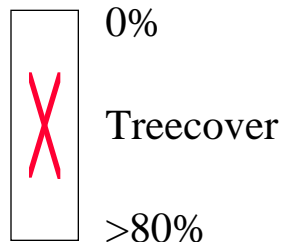
Percent treecover ~1997

By comparing two time periods of VCF results one can see the change in forest cover over time.
The bitmap to right shows that there was a large amount of deforestation in south america, particularly Brazil, Bolivia and Paraguay. There was also a small amount of regrowth in Venezuela.

+30%

0

-30%

Percent change in treecover

MOD44 Timeline

Validation status based on that of surface reflectance

"PROVISIONAL" PRODUCTION THROUGH ESIP

| 12/01 | 1/02 | 2/02 | 3/02 | 4/02 | 5/02 | 6/02 | 7/02 |

MOD44C – 16 day Interim Product

DERIVATION OF LUTs FROM COMPLETE

| 12/01 | 1/02 | 2/02 | 3/02 | 4/02 | 5/02 | 6/02 | 7/02 |

MOD44A – Vegetative Cover Conversion

REGIONAL VALIDATION

"BETA" PRODUCTION   **"PROVISIONAL" PRODUCTION**

| 12/01 | 1/02 | 2/02 | 3/02 | 4/02 | 5/02 | 6/02 | 7/02 |

MOD44B – Vegetation Continuous Fields

Complete Year
Inputs Available
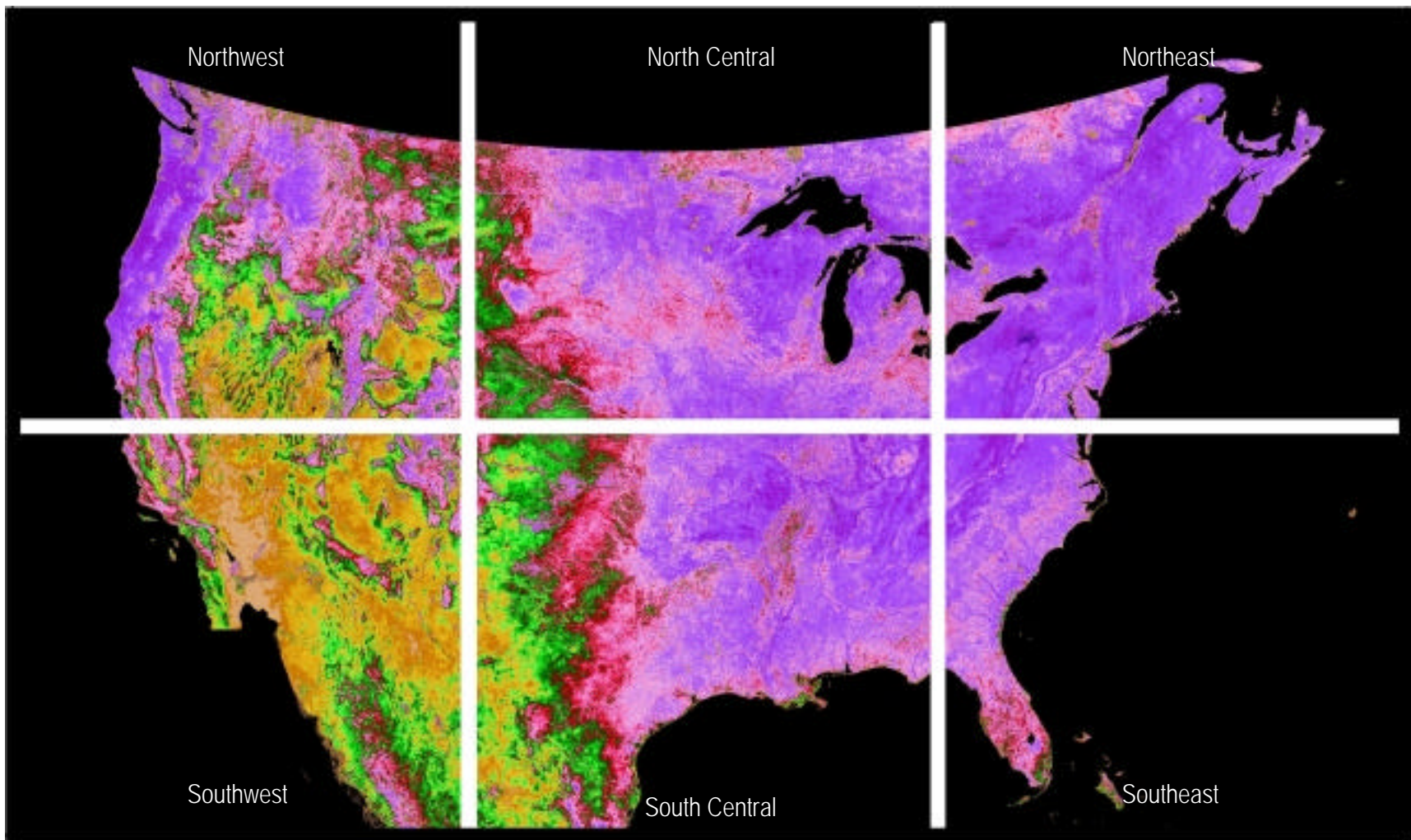
16-day NDVI composites in USGS standard Alber's projection are available for both the conterminuous U.S. and six regional subsets. 15 periods are now available from June 2000. As Collection 3 data is available, Collection 1 data are being replaced. Data are also being produced for areas of special interest in South America and Western Canada.

http://glcf.umiacs.umd.edu

MODIS 250m NDVI Mosaic of South America

This NDVI mosaic of South America is being produced to meet the needs of the LBA science community. It incorporates data from 6 MODIS tiles and is delivered in a sinusoidal projection with a local meridian (55° West). See http://glcf.umiacs.umd.edu/MODIS/special.html.

Recent MOD44 Science Code Modifications

- ## MOD44C - Intermediate product
  - New compositing method requires use of all 250m observation layers, 16 days of data and multiple SDSs from 250m, 500m and 1km data. Increased code complexity resulted from the additional pointer use and machine memory limitations.
  - New code is in final testing. No known bugs. A couple of metadata and file spec issues will be corrected before delivery.
  - Data structures are becoming unwieldy and should be revised for a future delivery.

- ## MOD44A - Vegetative Cover Conversion
  - Revised to take newest MOD44C as input.
  - Minor code changes remain to standardize lookup table format.
  - Will be ready for delivery as soon as lookup tables based on Collection 3 continuous year are finished and tested.

- ## MOD44B - Vegetation Continuous Fields
  - New compositing and reprojection tools were built for 500m VCF production.

- ## USVI
  - Production code updated to add metadata needed for reprojection.

The way forward

- Simplified, near real-time algorithm planned for Rapid response in 2002
- Field work with USFS next summer
- Plan to update LUTs again with each re-processing

Conclusions

- VCF algorithms performing well.
- VCC now being readied for distribution with more consistent products and revised LUTs.
- Utilizing Collection 3 to refine products
- Allows the user to both determine baseline vegetative cover and determine changes in same.
- Validation is ongoing and is being conducted with land management partners.

MODIS 500m Vegetation Continuous Fields

North America – Beta Version

Result Applied to Western U.S.

Fires on USFS Lands, 1986-2000