New land cover and land cover change products using MODIS data

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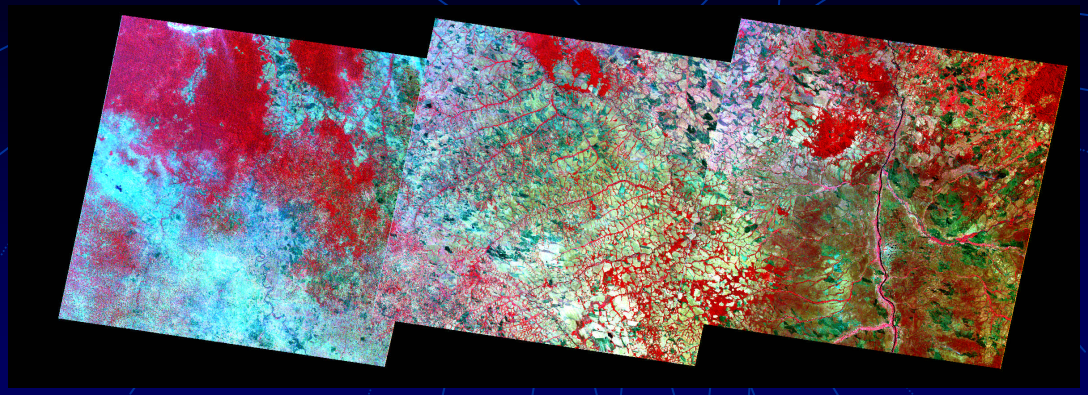
MOD44 Product Suite

- **Vegetative Cover Conversion**
  - 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**
  - 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.
- **Products derived from interim products**
  - 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)*

Vegetation Continuous Fields

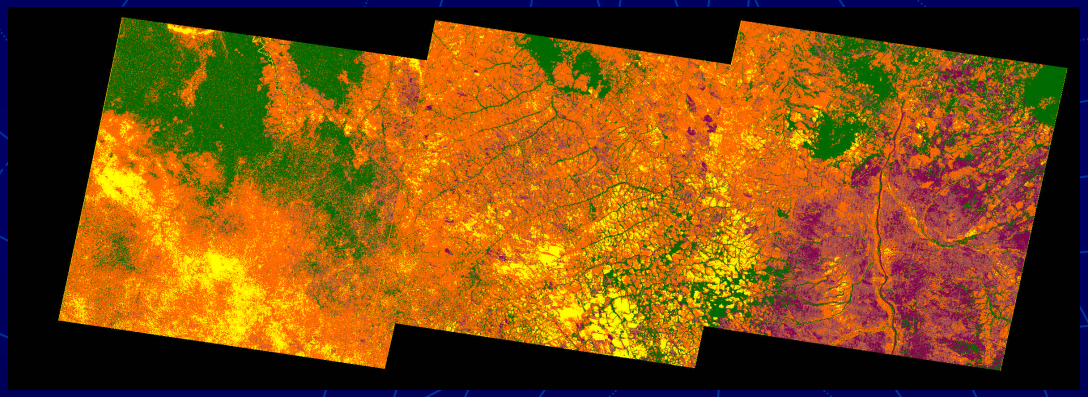
Training site for MODIS continuous field product, an example site from southern Democratic Republic of the Congo

High-resolution data sets



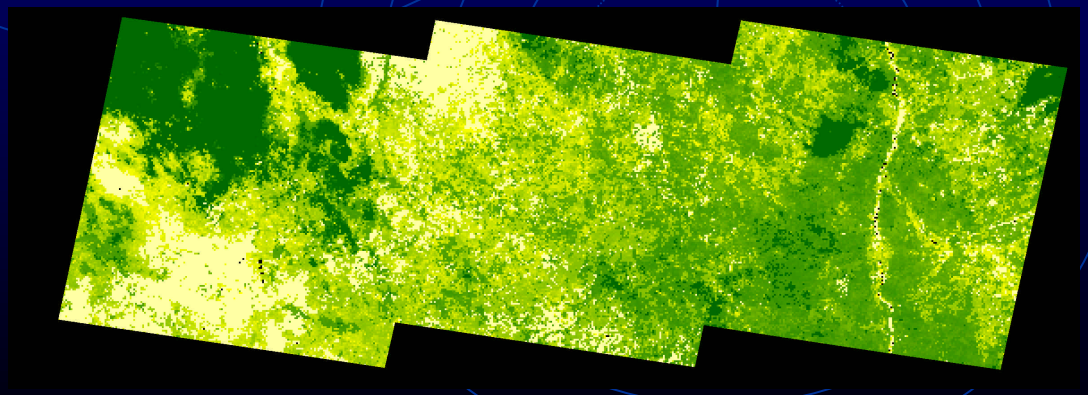
infrared, red, green composite

Classified into tree cover strata



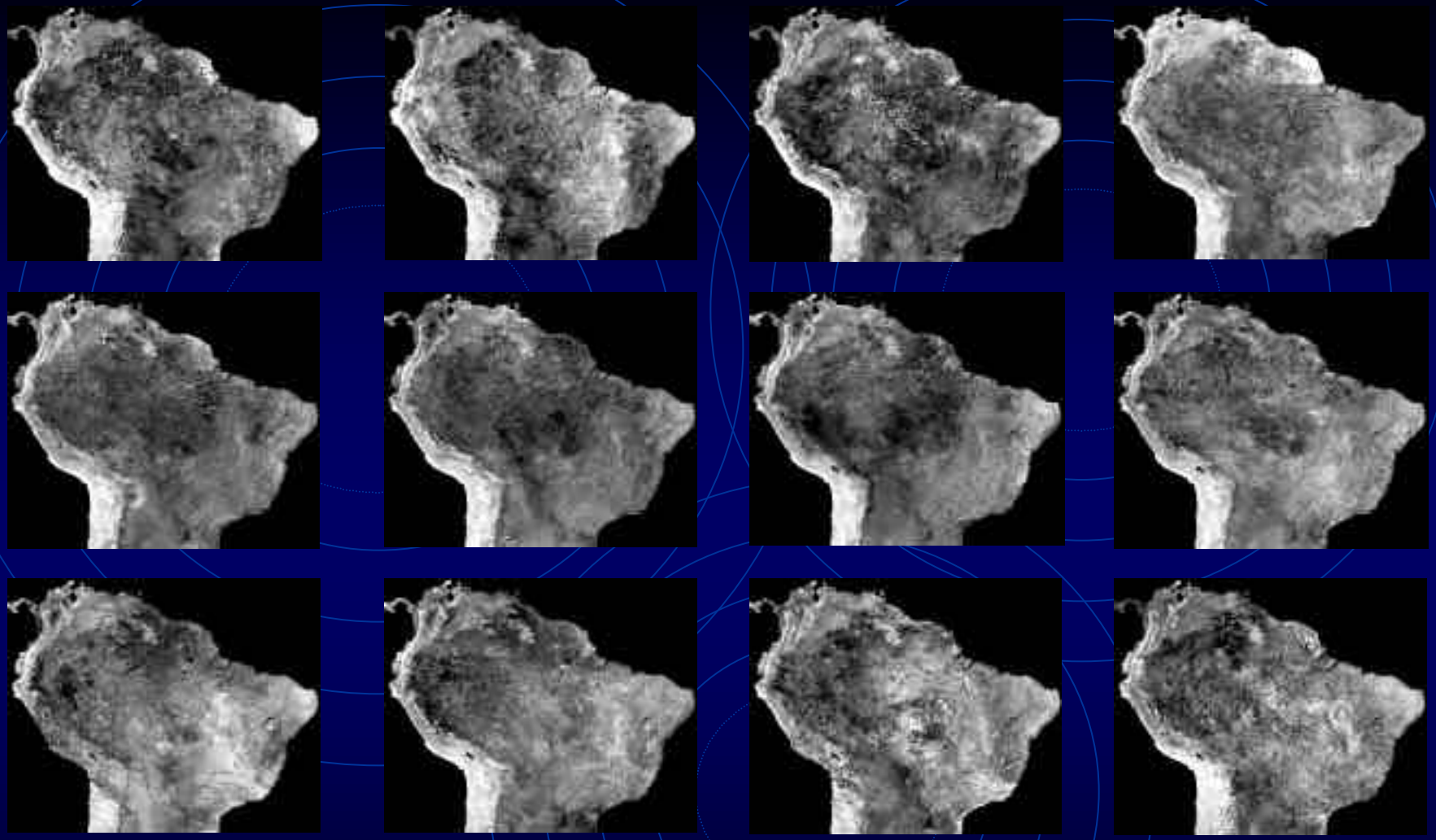
green=forest-80% tree cover
dark maroon=dense woodland-60%
light maroon=open woodland-40%
orange=savanna-25%
yellow=grassland-0%

Aggregated to coarse resolution continuous tree cover training

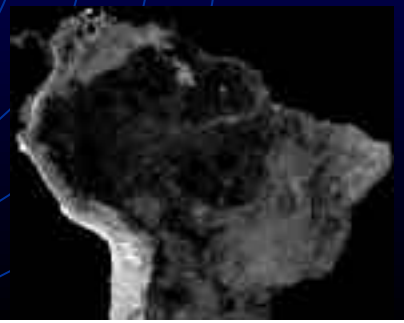


% tree cover from
dark green=>80%
to light yellow=<10%

Annual metrics for characterizing land cover

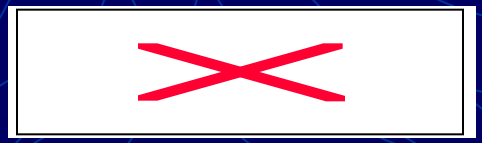


Red reflectance of monthly maximum NDVI for northern South America, January to December, with minimum annual value to the right →



Algorithm for automatic generation of global tree cover estimates

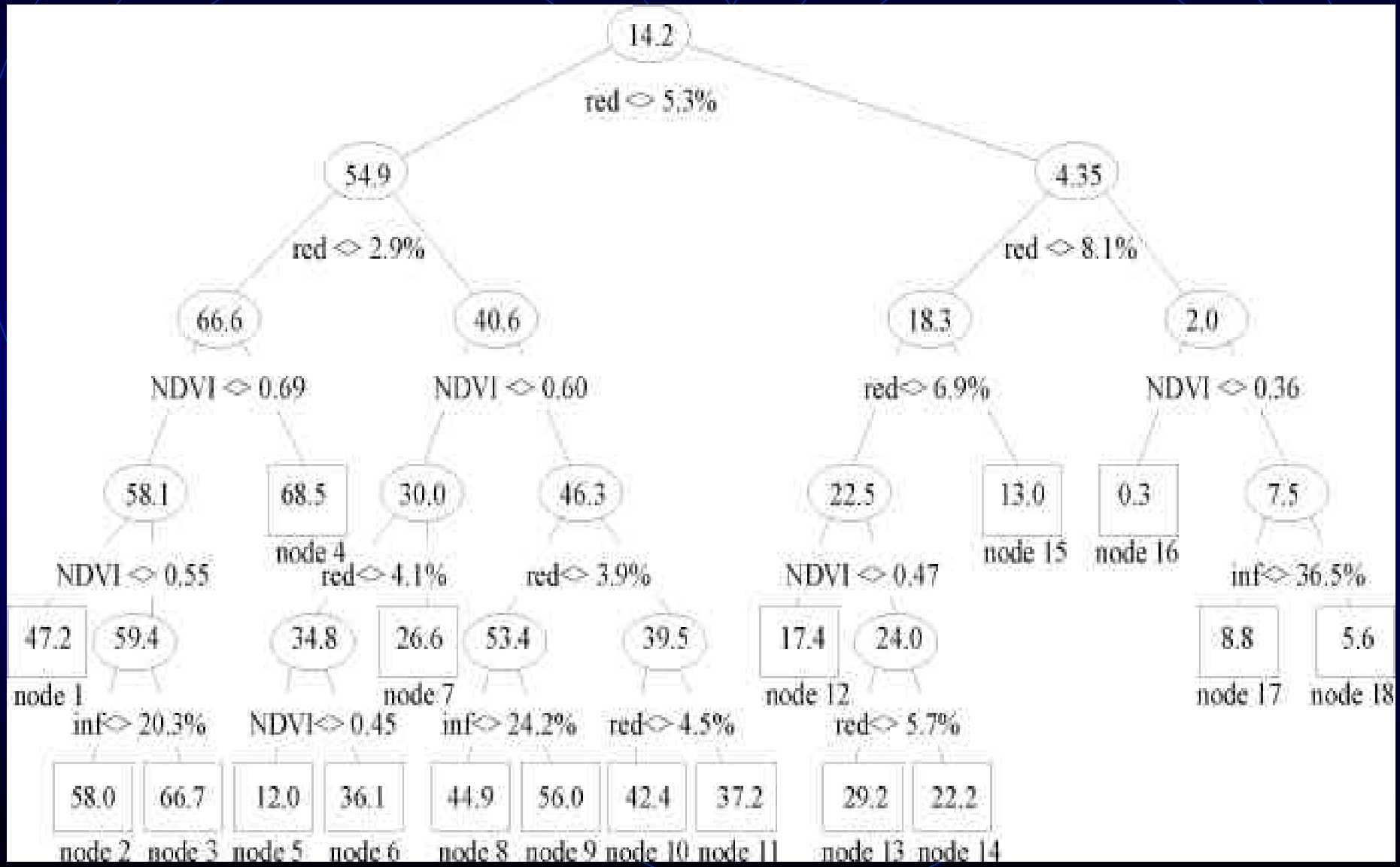
- Regression tree
  - For a given node *i*, all *j* cases of *y* and the mean value of those cases, *u*
- Solution of best split



  - Where *s* is parent node, *t* is left split, u is right split
- Stepwise regression applied to each node

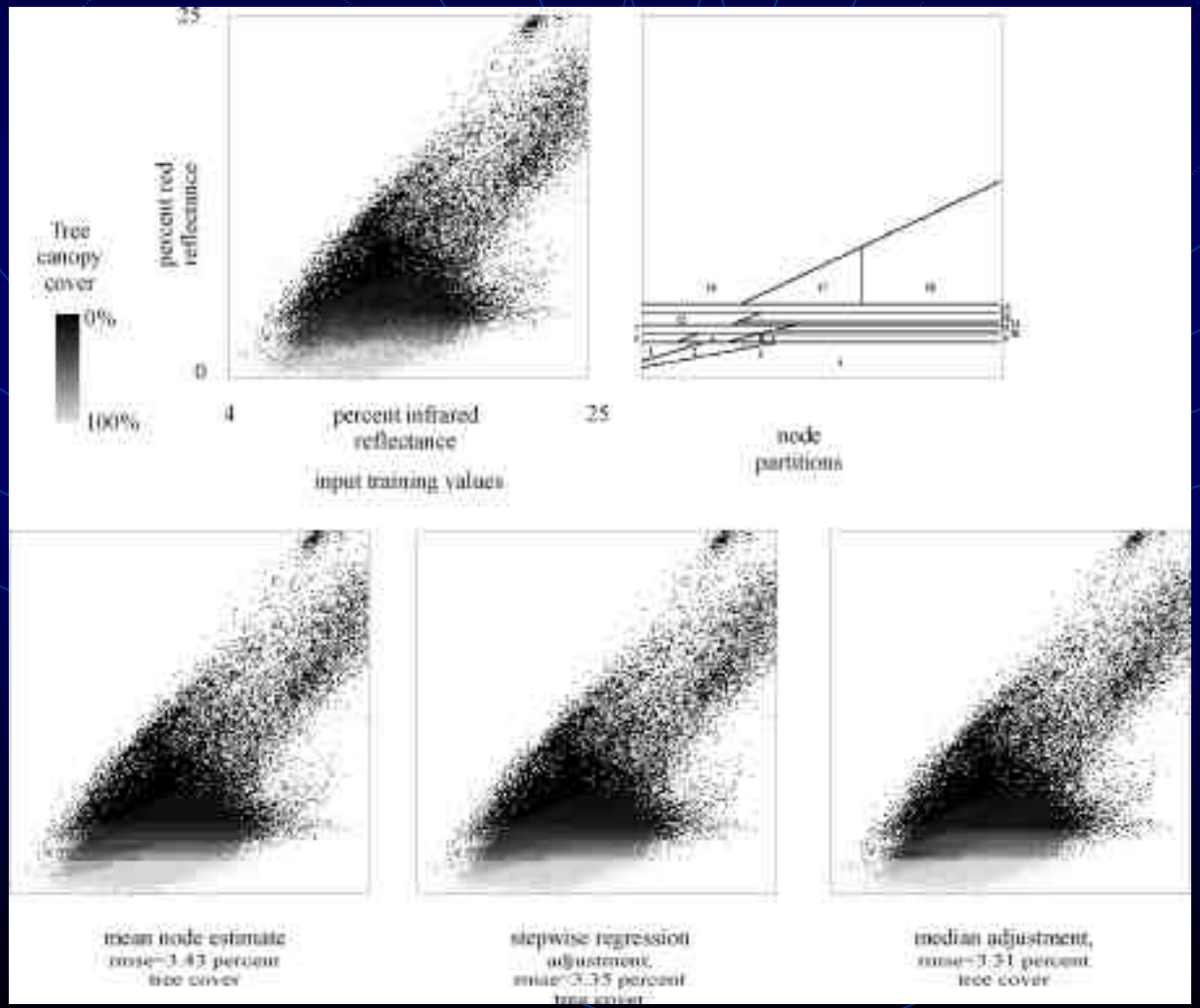
- Bias adjustment for skewed distributions

Example tree object for 1999 AVHRR data, minimum annual red and nir reflectances and derived NDVI

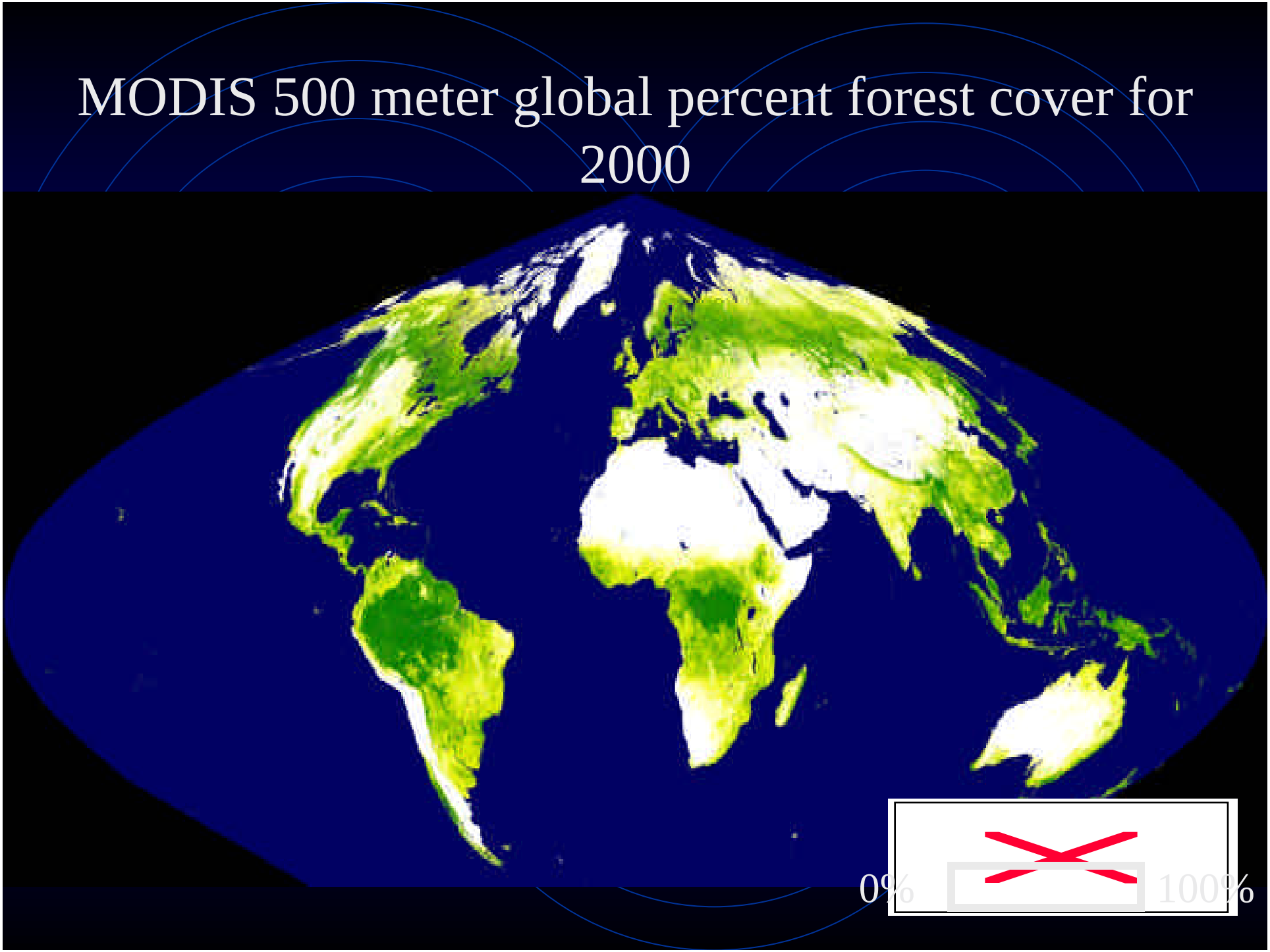


Example of continuous field algorithm

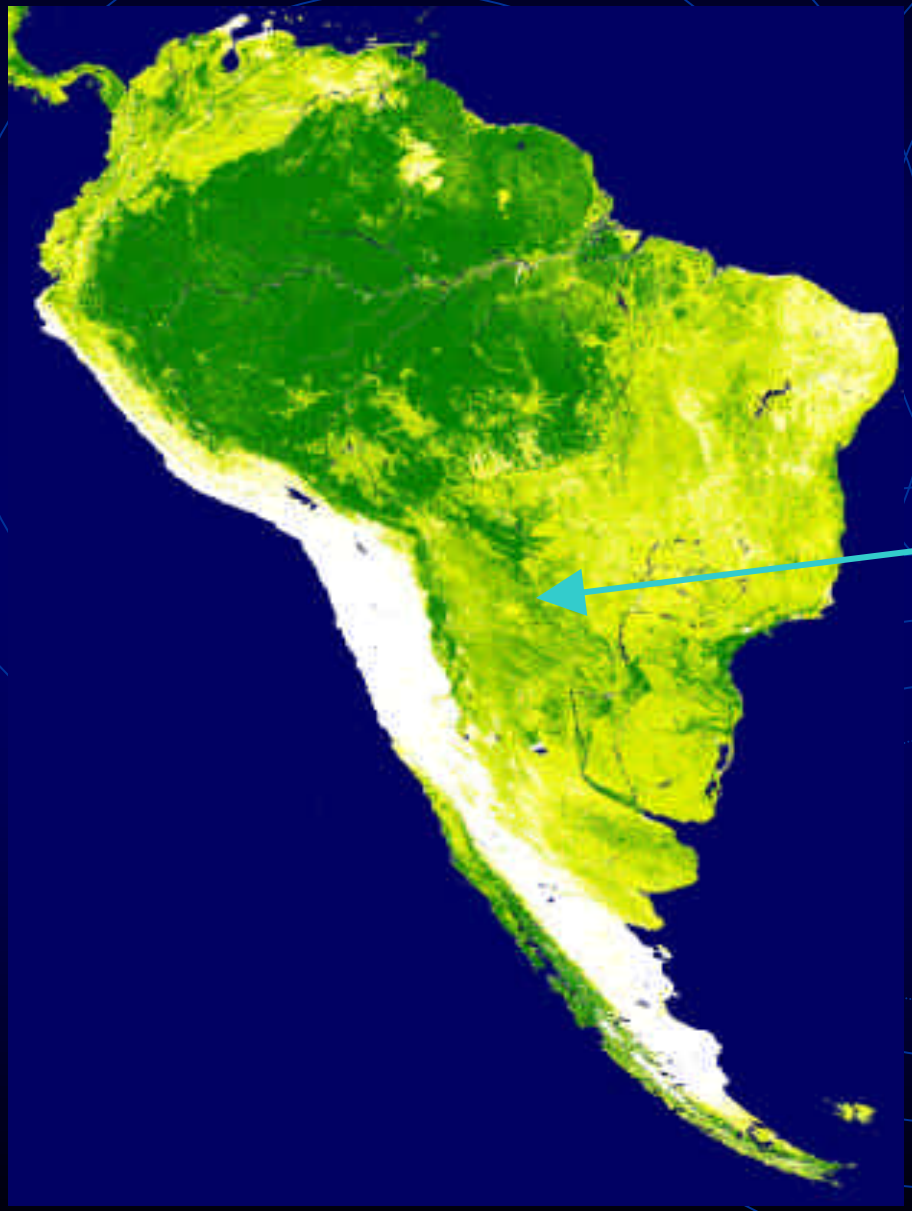
This example uses 1999 8km data, with minimum annual red and infrared reflectances and derived NDVI as independent variables. The tree partitions the feature space and assigns mean node tree cover values, which are then refined using a stepwise regression and median-mean adjustments.

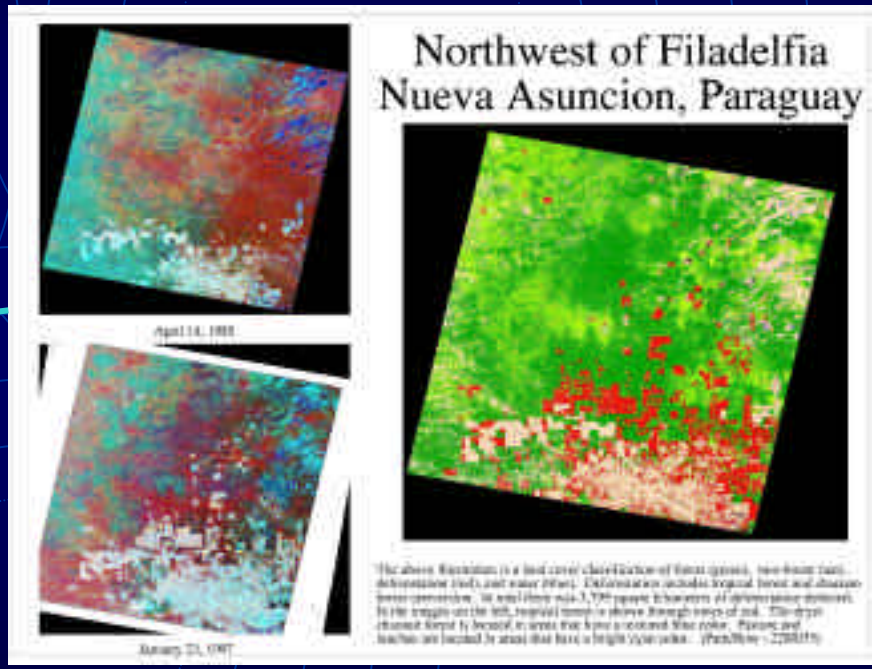


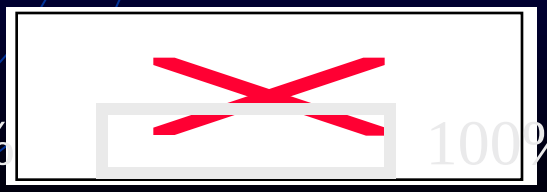
MODIS 500 meter global percent forest cover for 2000

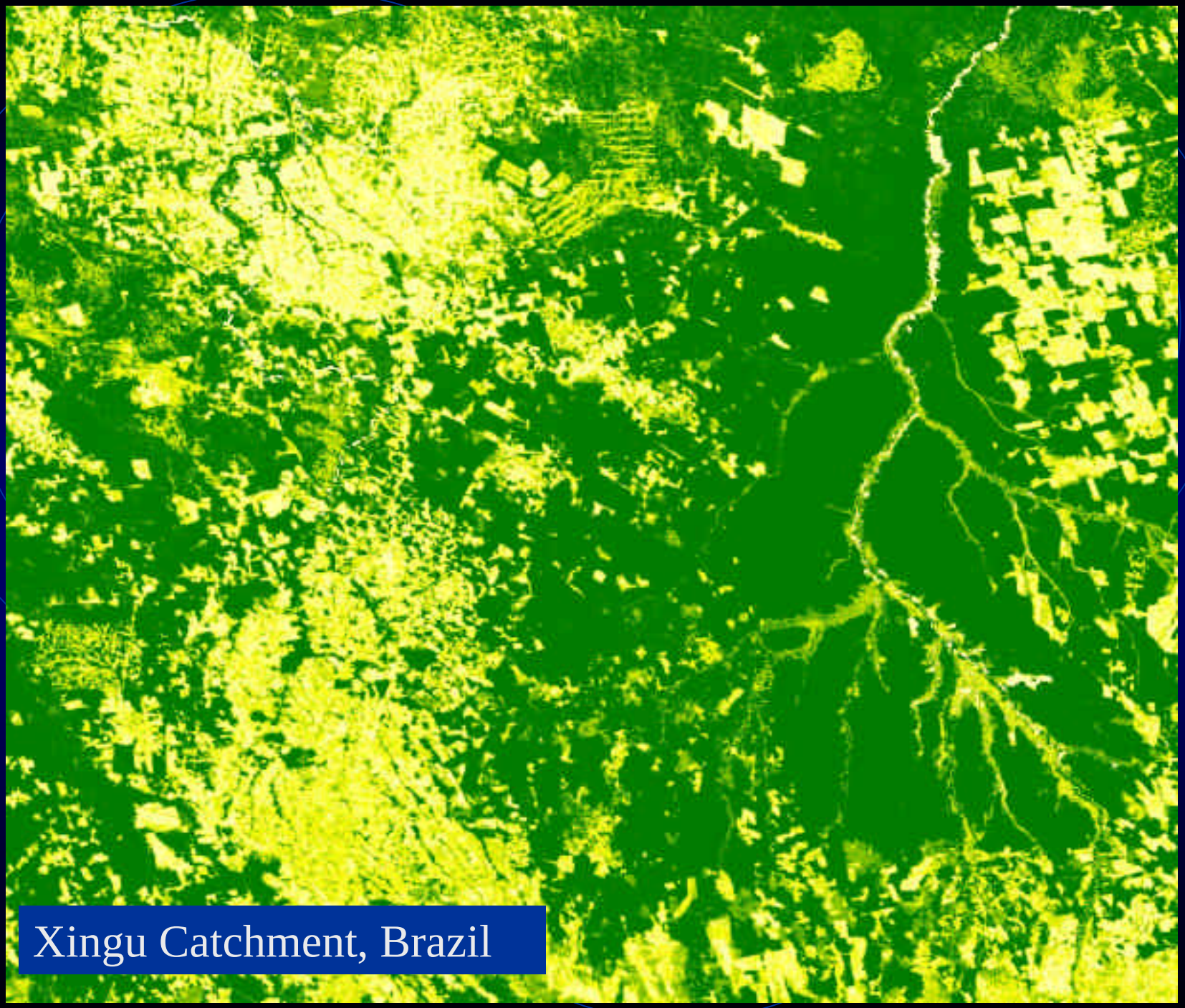


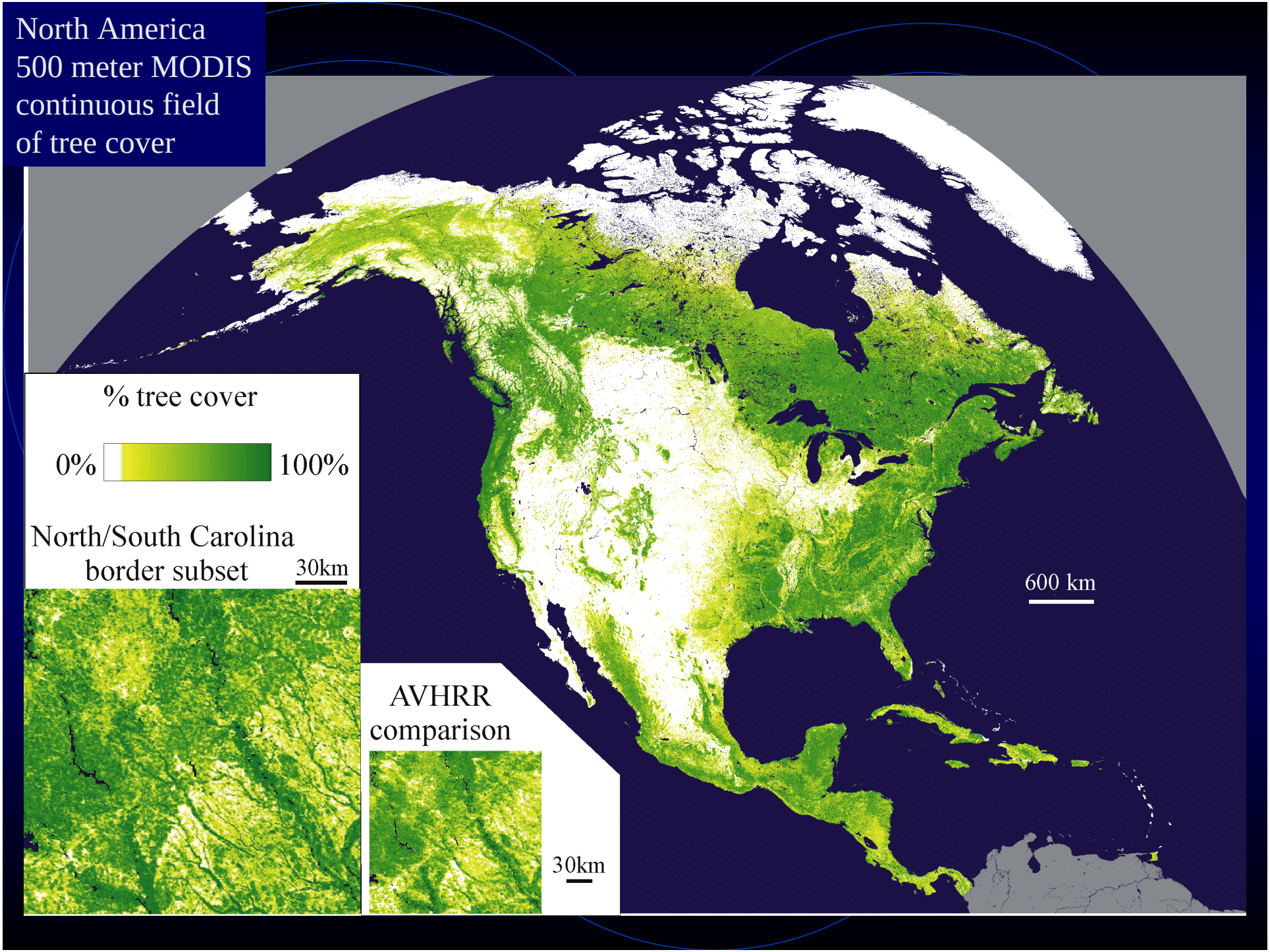
South America subset of MODIS 500 meter tree cover map



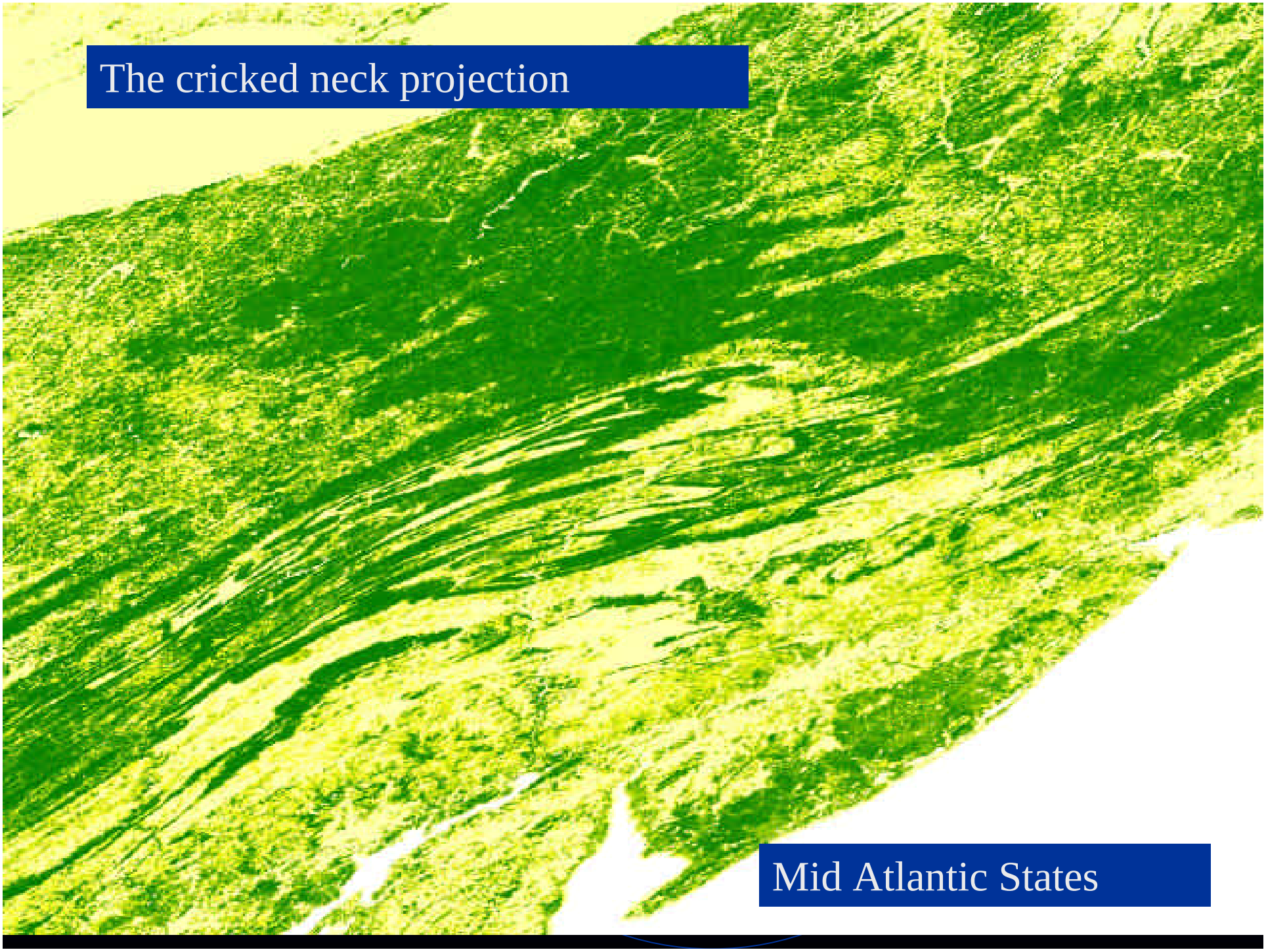





Xingu Catchment, Brazil

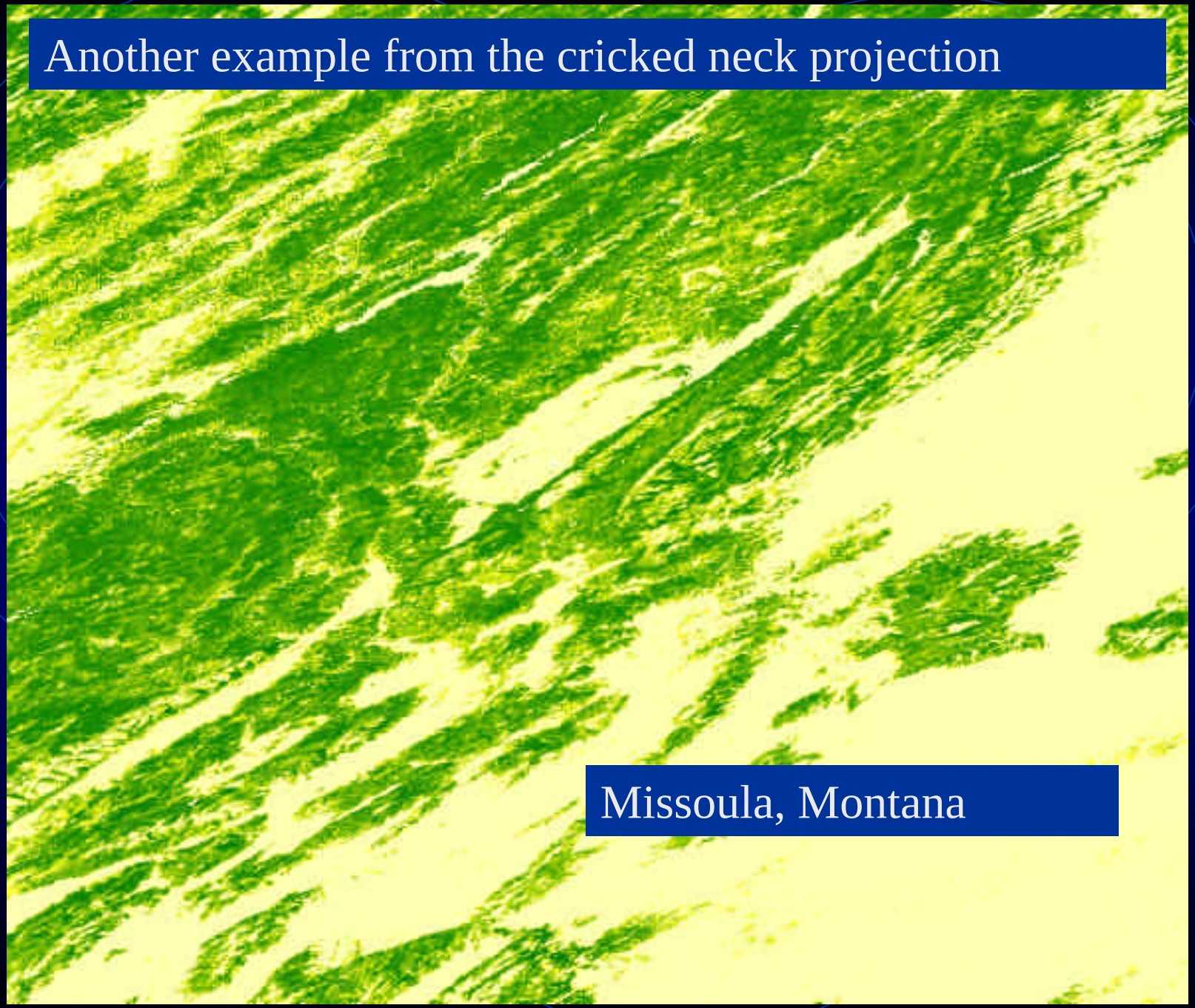

North America
500 meter MODIS
continuous field
of tree cover
% tree cover
0%
100%
North/South Carolina
border subset
30km
AVHRR
comparison
30km
600 km

The cricked neck projection

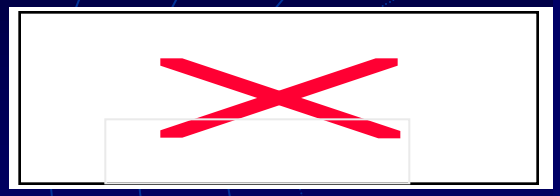


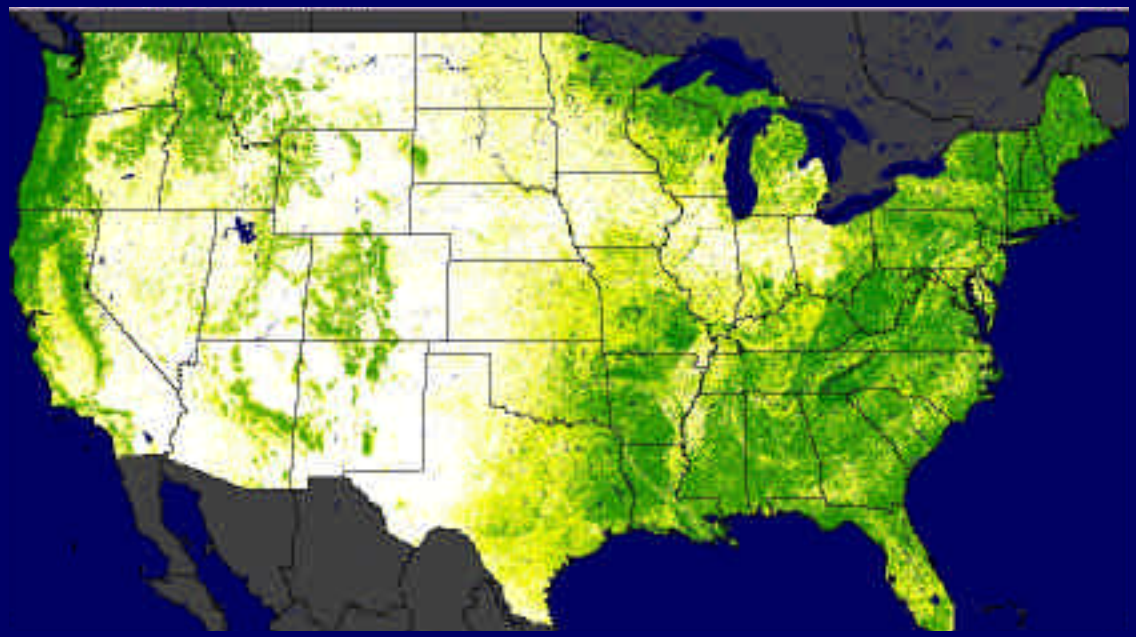
Mid Atlantic States

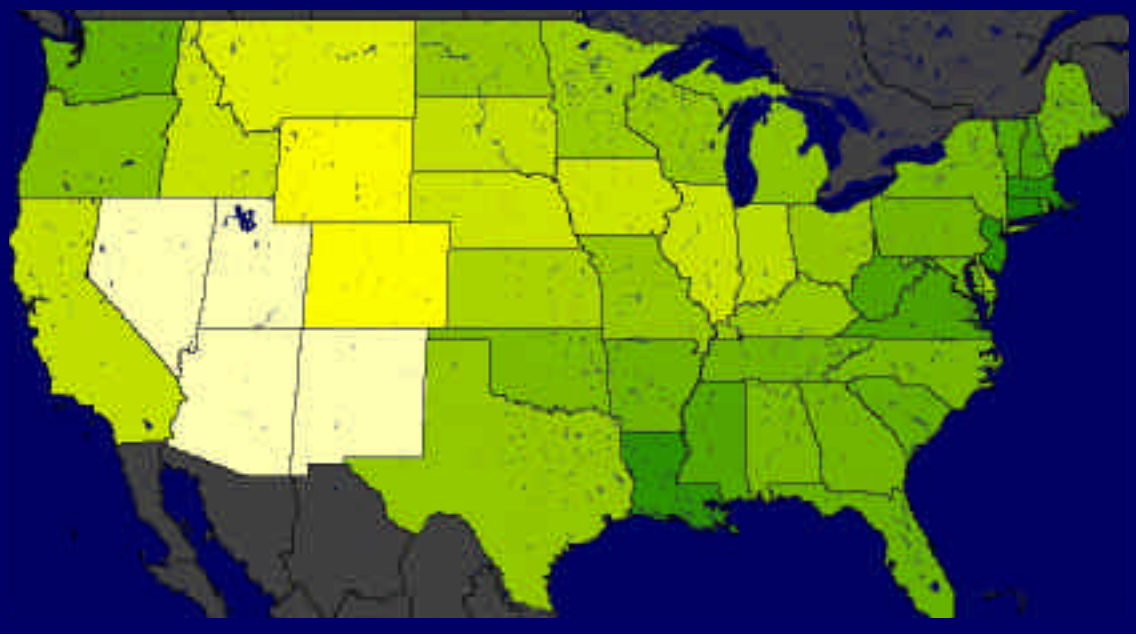
Another example from the cricked neck projection



MODIS 500 meter continuous field result for the lower 48 United States







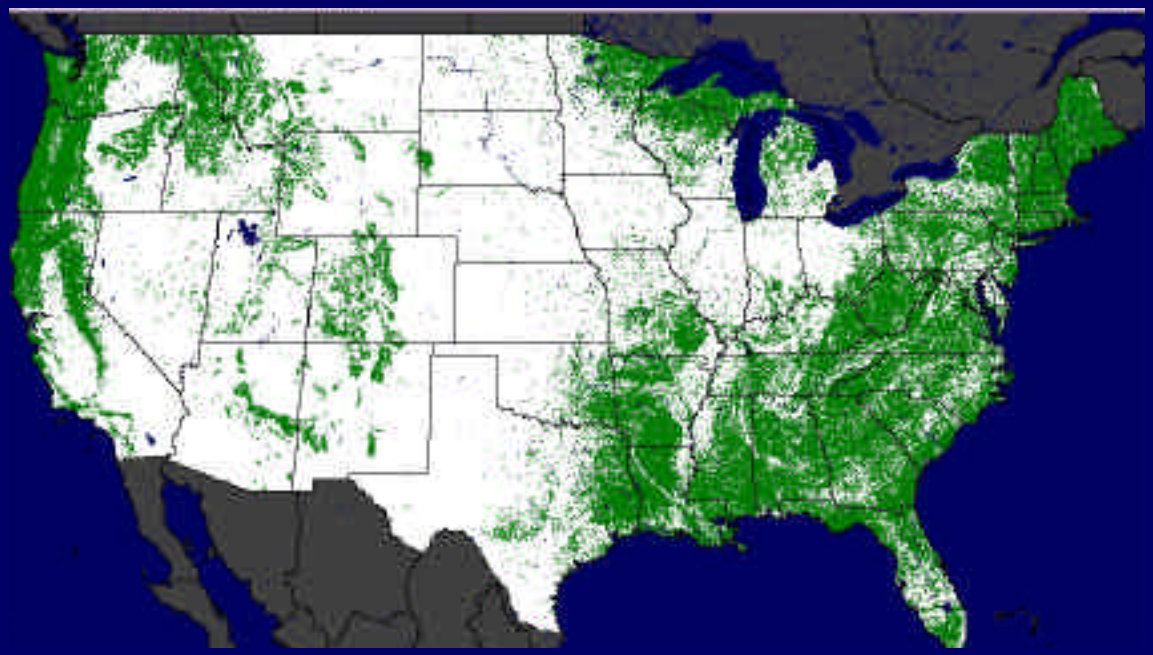
Comparing results with USFS forest area estimates by state

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

Matching the continuous field tree cover estimate for the lower 48 United States to the USFS estimate

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

Threshold = 35 %, yielding 2.4 million square km.



Calibration/validation of MODIS continuous fields of tree cover: *a 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 completed
- Twelve sites currently being developed for lower 48 United States, completion end of 2002
- Additional sites in Africa planned, Congo humid forest/savanna interface visited


Laser instrument reports whether the canopy immediately above is open or closed and the distance from the ground to the first leaf.

Validation work

- Adding sites to test and characterize errors found in first global maps
- Twelve sites in the United States, one in the Democratic Republic of the Congo
- Flat depiction in the Kalahari due to three possible causes
  - Poorly labeled low-end tree cover training
  - Inadequate global signal (works locally)
  - Local difficulty associated with tree cover on bright sands

Testing composited metrics versus 1b data in reproducing validation data from Zambia

500 meter validation data set created using IKONOS And ETM+ imagery

Result using 4 cloud-free Level 1b 500 meter swaths –

RMSE=7.04

Result using global composited metrics used in continuous field of tree cover product-

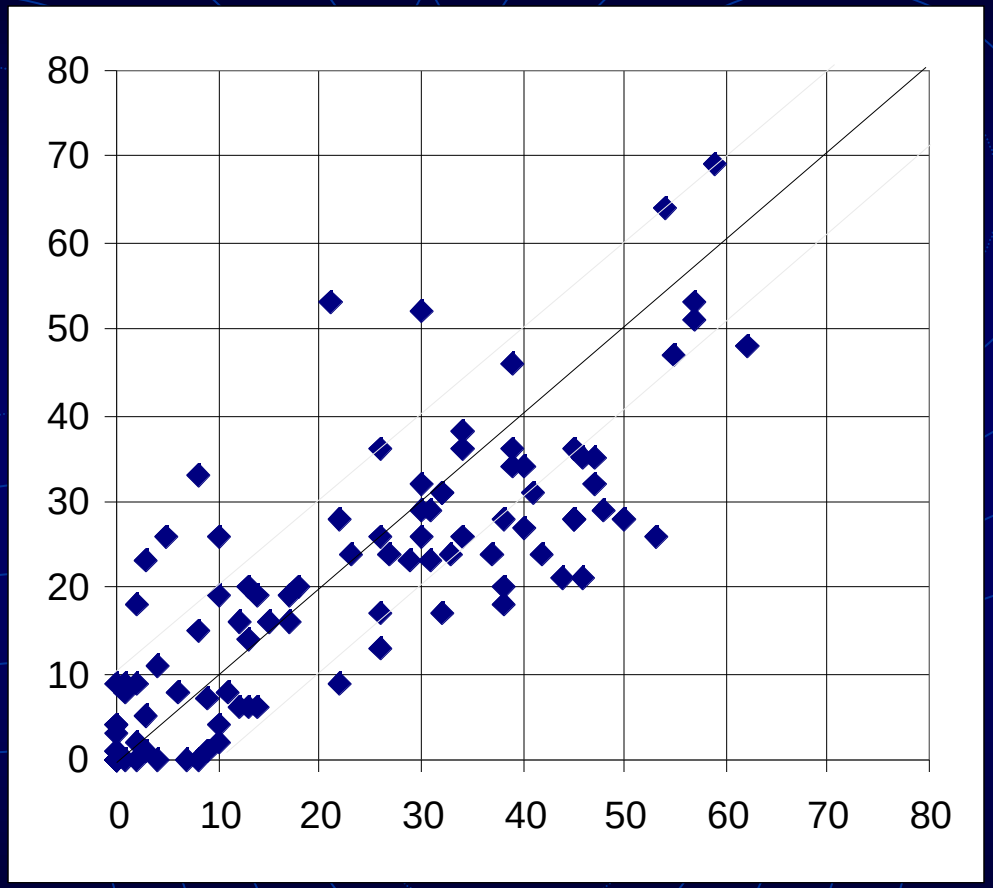
RMSE=7.79

Comparing v0.1 global percent tree cover product to validation site in Zambia

RMSE=11.21

Flatter depiction of Kalahari woodlands on sands and slight underestimation of denser cryptosepalum woodlands in north

Plot of validation dataset versus global subset for Zambia



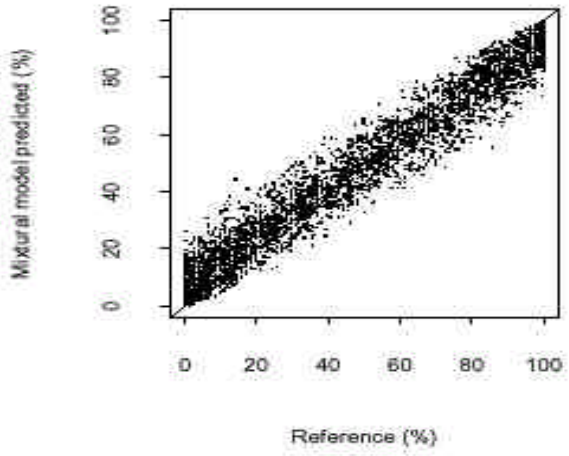
100 site random sample yields

R2 = 0.663

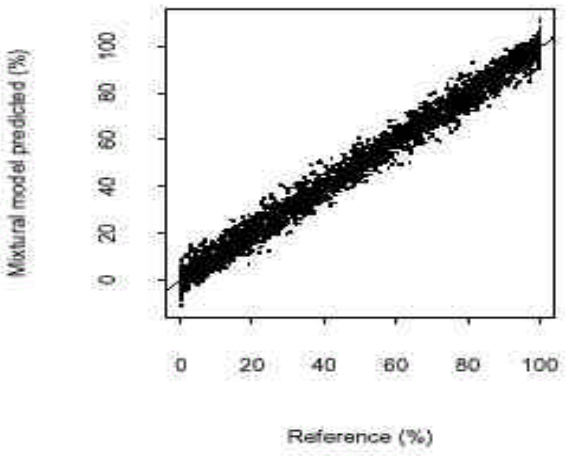
Flat depiction of low to mid-range cover evident

Choosing the right resolution – predicted proportions vs. actual proportions

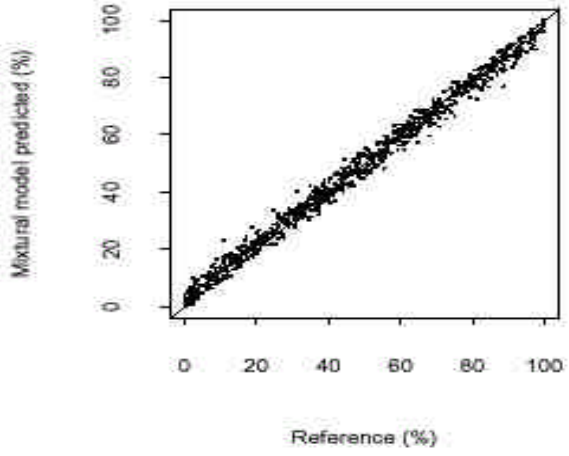
250m simulated



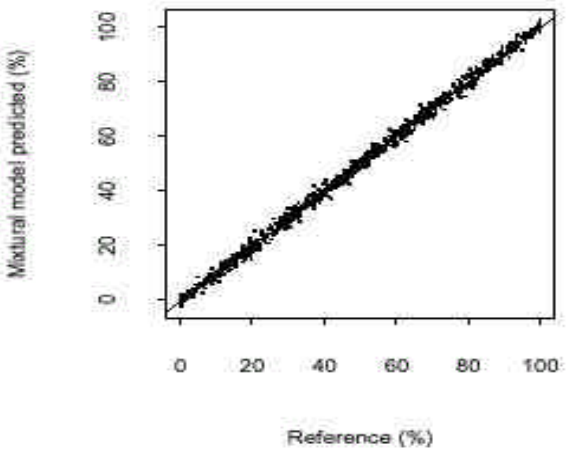
Deconvolved



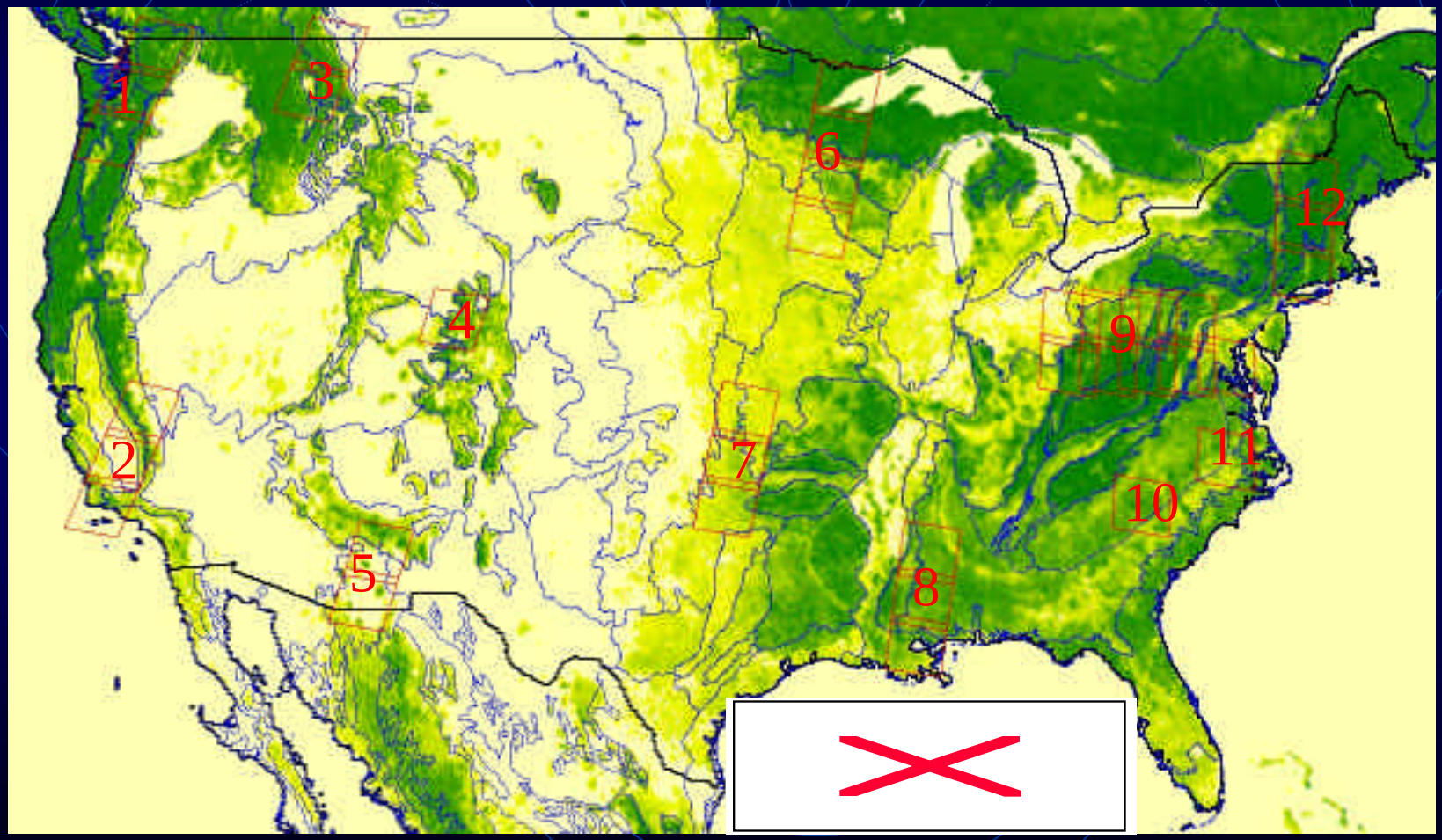
Aggregated



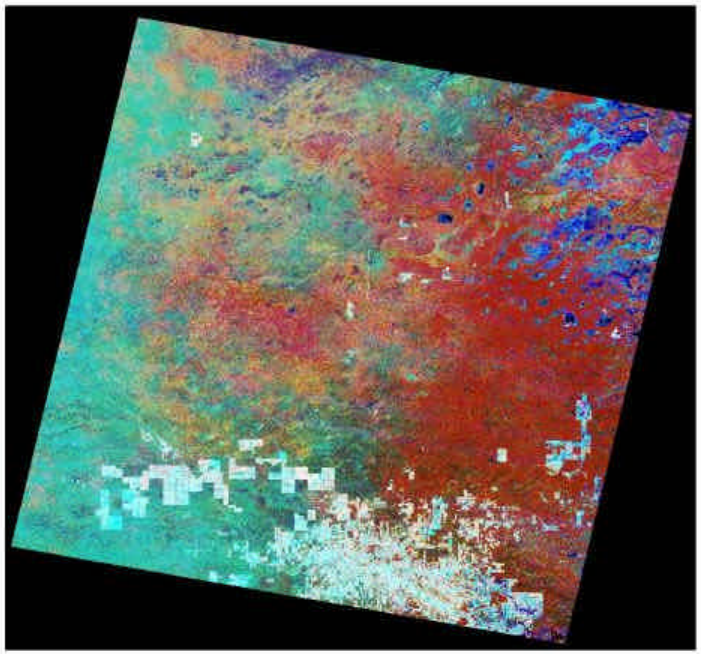
Deconvolved and Aggregated



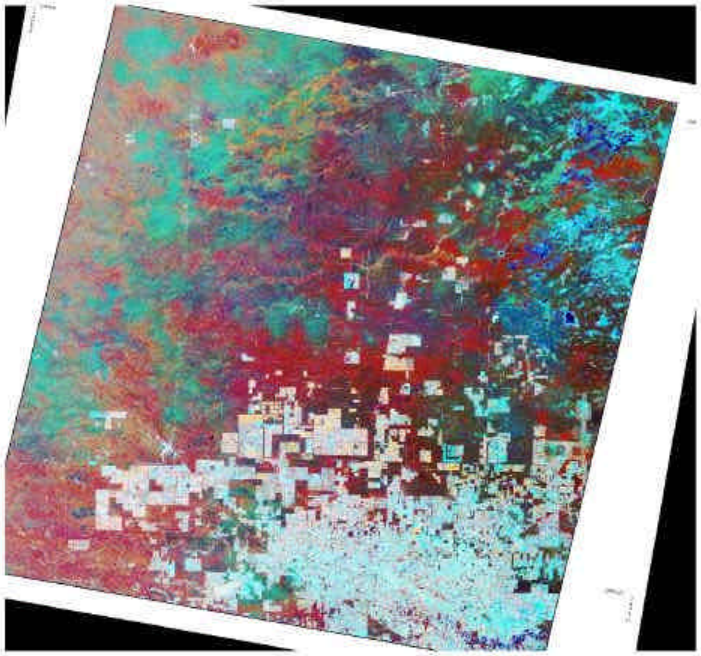
United States MODIS validation sites for multi-resolution characterization of percent tree cover



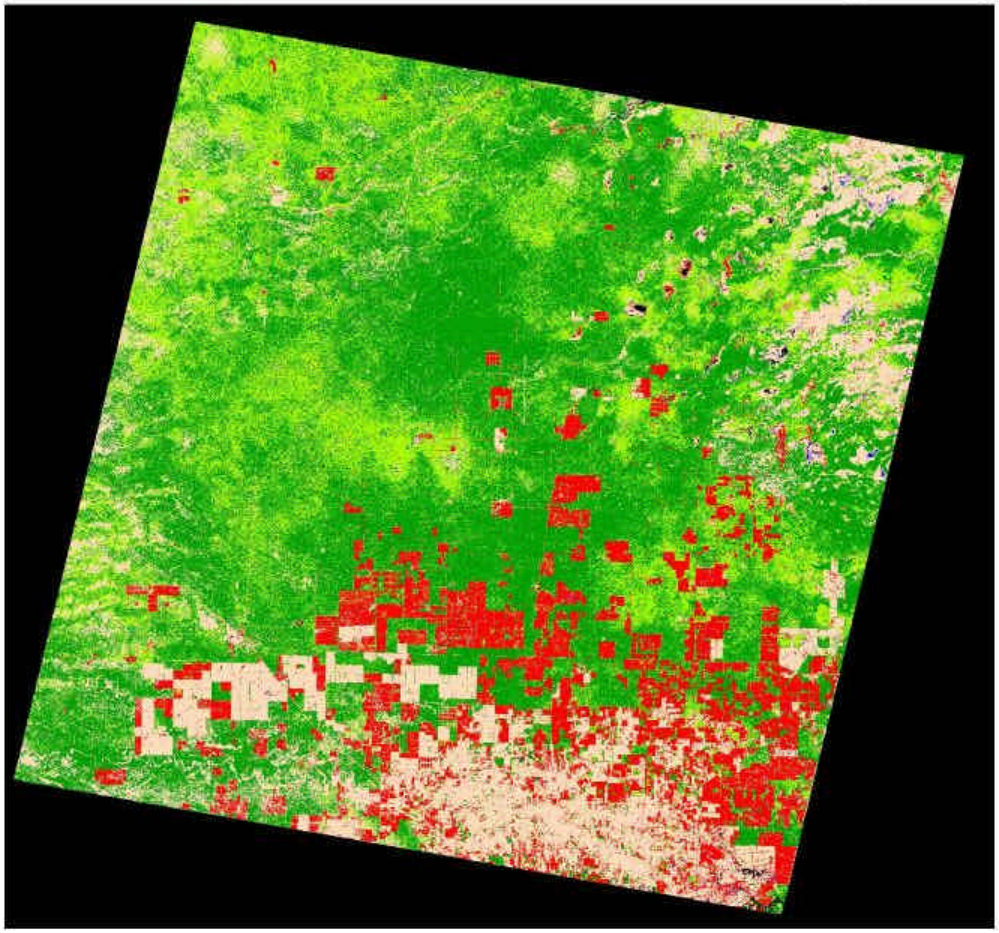
Northwest of Filadelfia
Nueva Asuncion, Paraguay



April 14, 1985



January 23, 1997



The above illustration is a land cover classification of forest (green), non-forest (tan), deforestation (red), and water (blue). Deforestation includes tropical forest and chacoan forest conversion. In total there was 3,799 square kilometers of deforestation detected. In the images on the left, tropical forest is shown through tones of red. The dryer chacoan forest is located in areas that have a textured blue color. Pasture and ranches are located in areas that have a bright cyan color. (Path/Row - 228/075)

Continuous Fields Conclusions

- MODIS data offer increased spatial detail and are appropriate for monitoring change
- Must minimize deleterious effects of compositing
- 1km thermal band is needed to capture certain tree covers (drought deciduous forest and woodlands)
- Preliminary tree cover results show general agreement with USFS data
- IKONOS offers improved way to drive the algorithm with proportional estimates tied directly to the variable of interest (tree crown cover)
- Release of Version 1.0 tree cover by 15 August (through GLCF and delivered through MODAPS)
- Other layers to follow this summer

Vegetation Cover Conversion

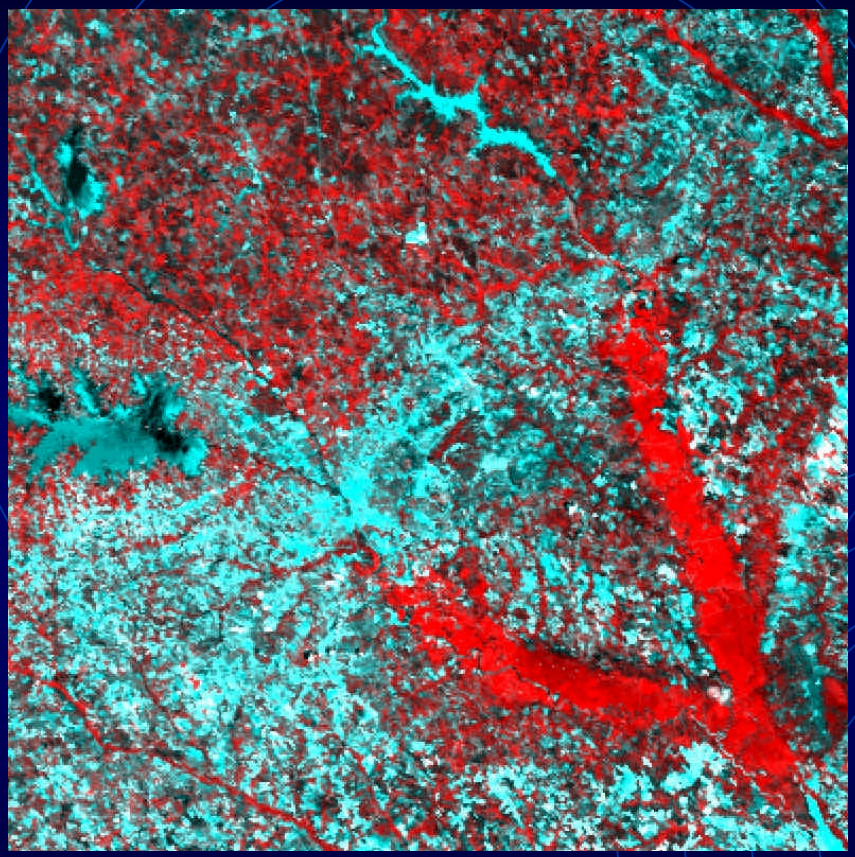
250m Data Slow in Coming

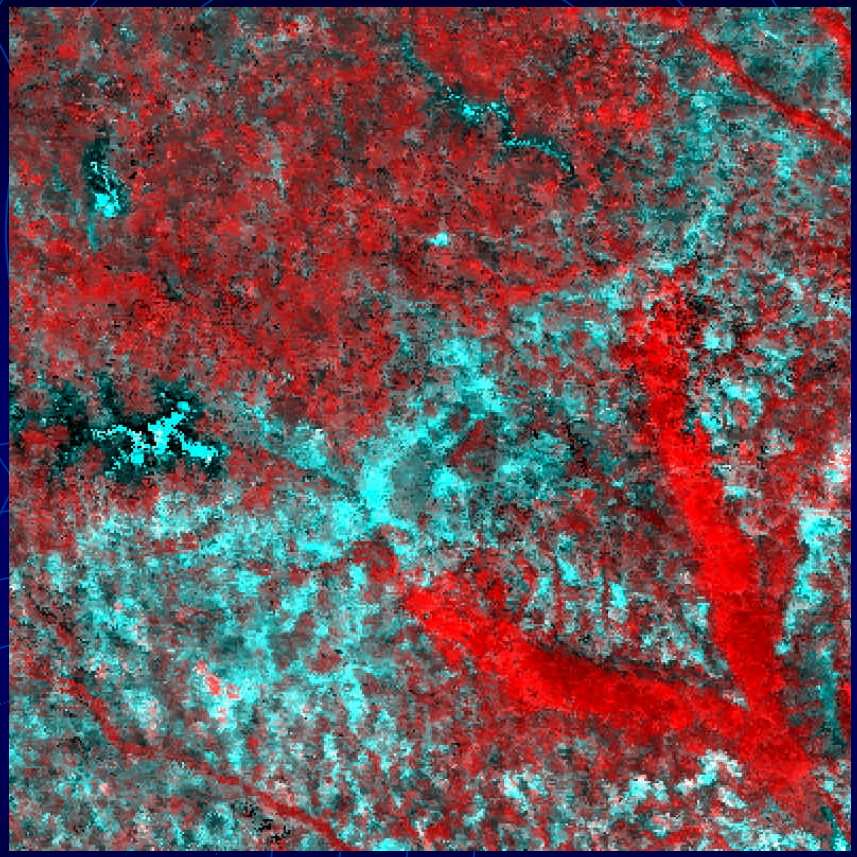
- In immediate post-launch period, PIs had to process outside ECS on limited resources and were thus limited to 5% sample over US
- Collection 3 began production of 10% sample in main production system
- Volume of L2G had to be reduced to allow for archive
- As of April 2002, production has reached 112 of 326 tiles containing land; as of July 2002 100% global processing.
- In Collection 4 (all of record, to begin in October) all 250m data will be produced and archived globally
- This will provide inputs for annual to annual VCC

Name of method	Criteria used	Implementation
Red-NIR space partitioning	Based on partitioning of red-NIR space between cover types at a given time of year and latitude. Identification of whether pixel value changes from sub-space of one cover type to a second.	Implemented using LUTs depicting cover type for a given pair of red and NIR reflectance values for each month and latitudinal zone at times 1 and 2.
Red-NIR space change vector	Using the Red-NIR space, based on the angle and magnitude of the vector defined by the pixel value at time 1 to that at time 2.	Implemented using LUTs depicting the angle and magnitude couplets associated with all possible land cover changes for each pair of months and latitudinal zone.
Modified delta space thresholding	Uses space defined by differences in pixel values for time 1 and 2 for the red and NIR values of each pixel (no change occurs at the origin). Type of conversion defined by angle and distance from origin and the initial state of the pixel.	Implemented using LUTs defining the initial cover type at time 1 and the sector of the delta space in which the pixel lies at time 2 for each latititudinal zone.
Texture	Uses coefficient of variation of the NDVI within a 3x3 kernel at times 1 and 2. Conversion flagged when change exceeds a threshold.	Implemented using LUTs defining threshold value for change between each pair of cover types for each month, latitudinal zone, and initial state of the pixel.
Linear feature	Compute the mean of the absolute difference of the pixel value for each neighbor pixel in a 3x3 kernel. A threshold determines whether a linear feature is present.	Implemented using rule identifying whether linear feature exists in time 2 when absent in time 1.
Integrated measure of change		Voting method: conversion confirmed where 3 out of 5 methods flag conversion.

Degradation of information content from compositing

example from Columbia, South Carolina





25 km

250 meter infrared and red image of level 1b data from June 10, 2000

250 meter infrared and red image of NDVI composite from available Summer level 2g data

Compositing Procedure

*What we start with:

I) MOD 09A1 8day surface reflectance composite

i) rule based minimum blue composite

ii) details can be obtained at Surface Reflectance website

iii) http://modis-land.gsfc.nasa.gov/mod09/

*What we decided to do:

I) composite based on a 32 day time step

II) allowed use of 4 8-day composites

i) more opportunity to get rid of clouds

ii) covered phenologic time step that was advantageous

III) early attempts were made to use min. blue and max NDVI

neither produced acceptable results

Compositing Procedures cont.

IV) analysis of the spectral signatures in the MOD09A1 performed
V) spectral signal of the visible bands yields best results
VI) final algorithm description

1) Set all values in the output file to 0.

2) Read the Solar Zenith angle flag

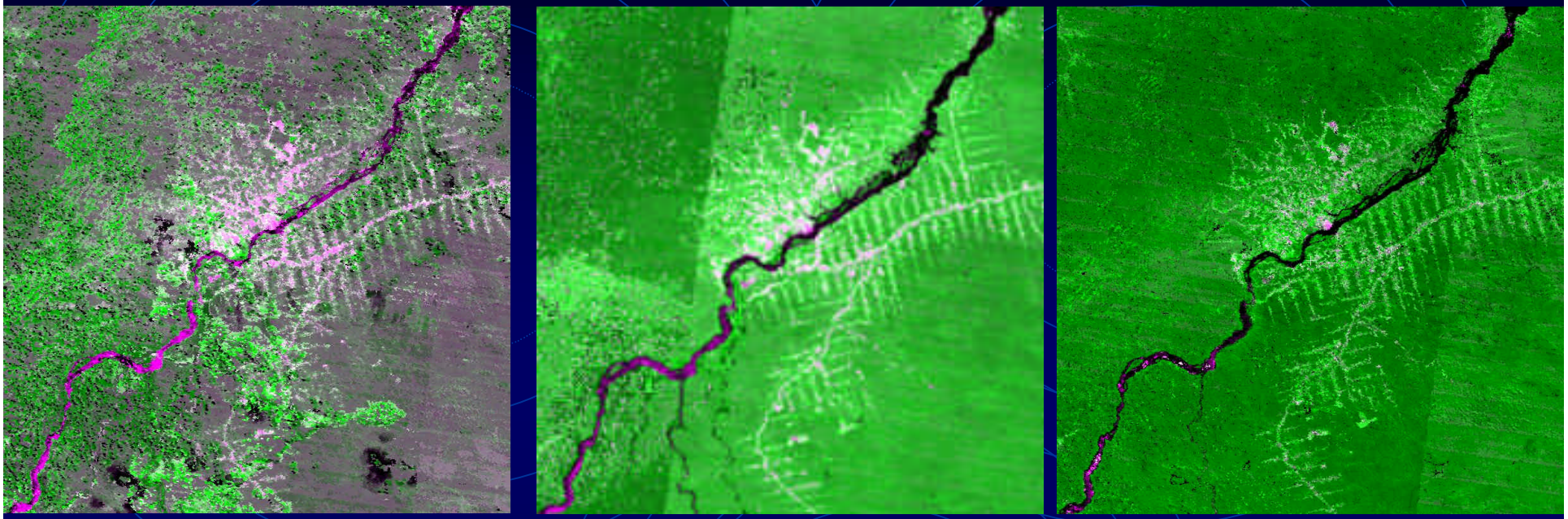
a) disregard any pixels with solar zenith angle greater than 85 deg
b) retain any pixels with solar zenith angle less than 85 deg

3) Select the second darkest albedo as determined from the three visible bands. (MODIS bands 1,3,4)

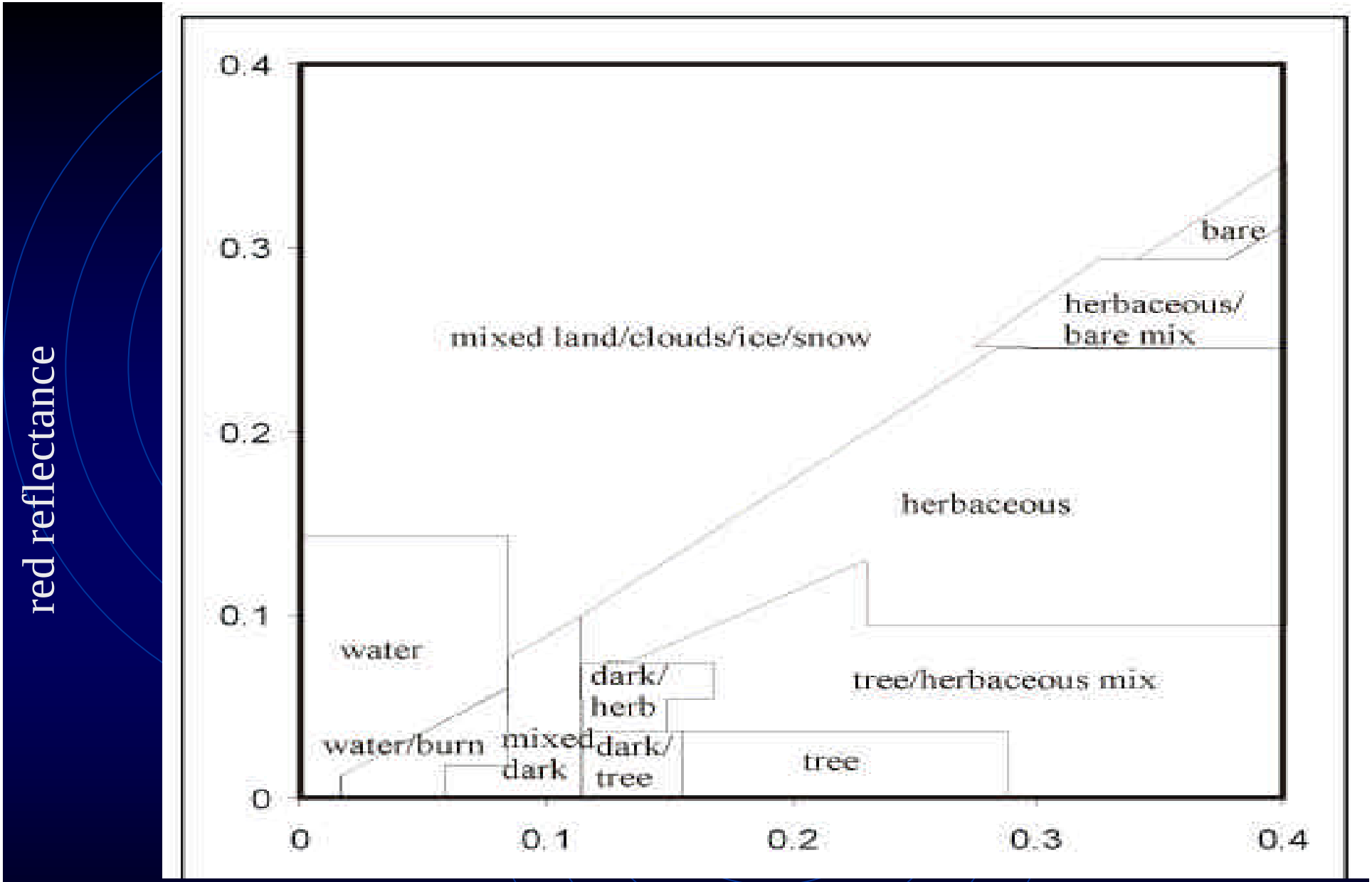
if only one or no values are below a threshold take the darkest albedo

Comparison of Composites

MOD13Q1 MOD09Q1 MOD44CQ



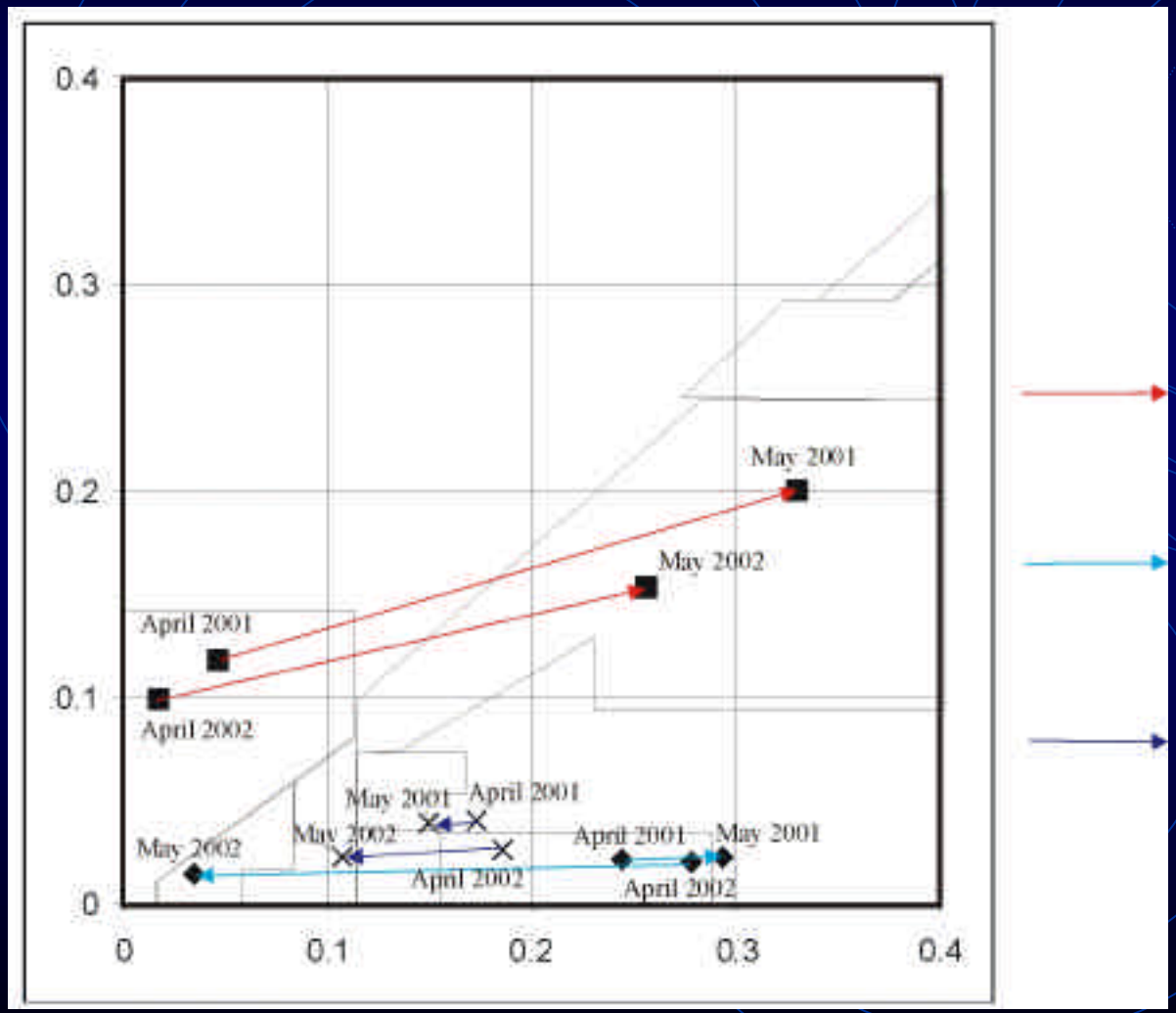
The data shown above are three different composites made from L2G data. The MOD09Q1 product is only an 8-day composite, while the other two are 16 day composites. The time period covered is day of year 2001209 through 2001224. The MOD44CQ product feeds the UMD Vegetative Cover Conversion product and exhibits the results of extensive testing of compositing methods.



Simplified May North America look-up table

Trajectory examples using prior and current year data

(awaiting full year of 250 meter data for North America, currently have only 4 16 day periods)



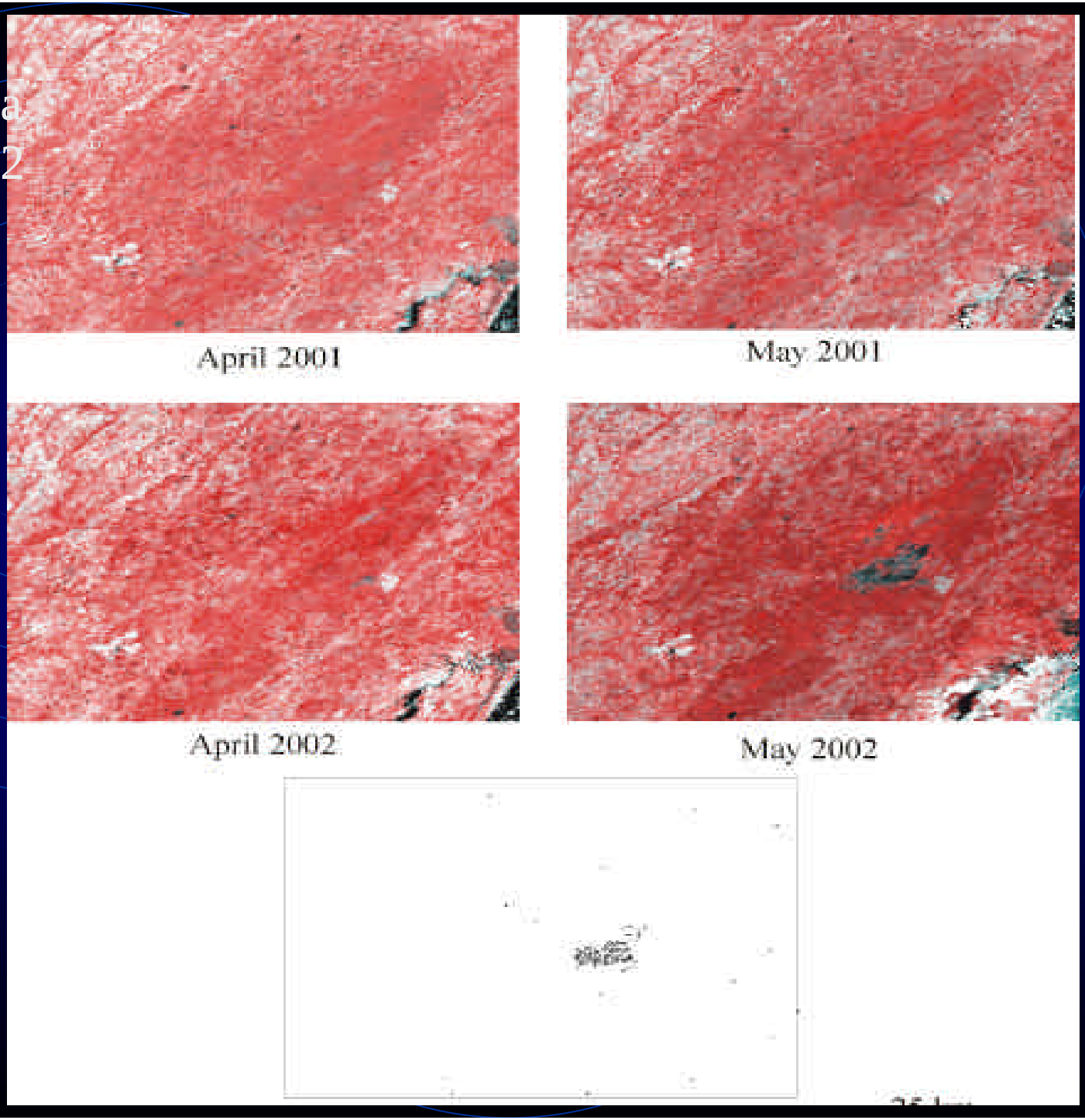
Annual drying of retention basin in central valley of California

Forest fire in northern Florida

Dark boreal woodland with mixed signal and no change

Backdrop is May lut

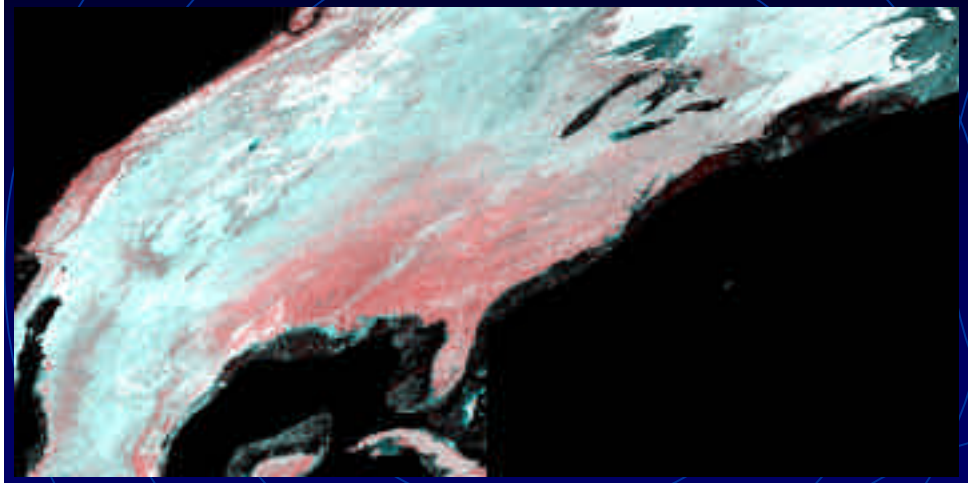
Northern Florida fire of May 2002



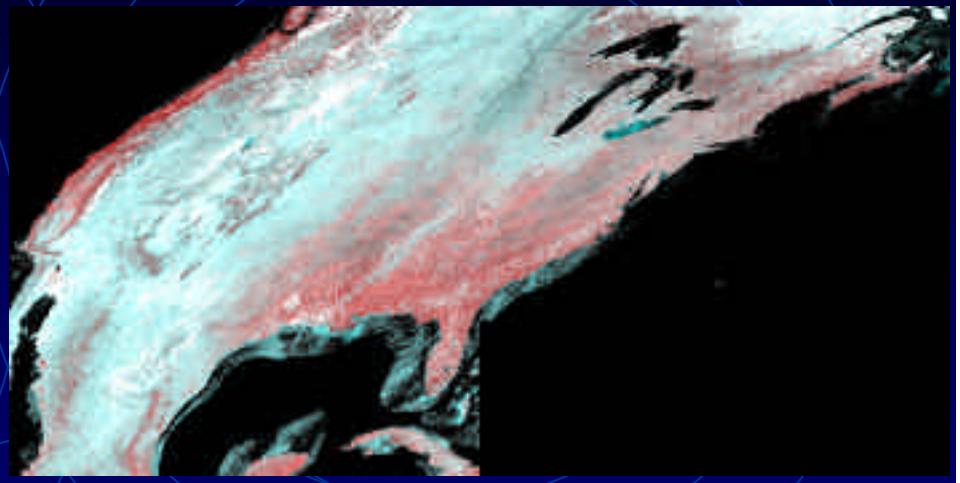
First Annual to Annual Results

From Collection 3

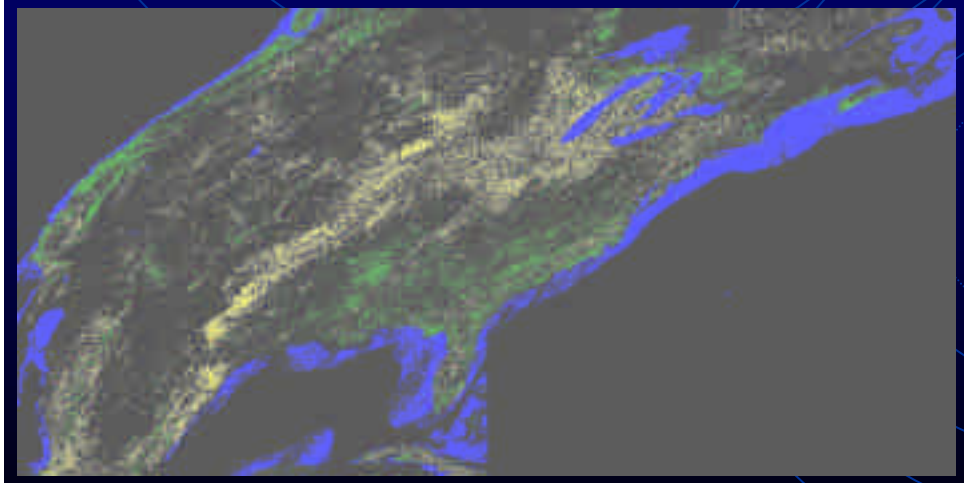
April 2001



April 2002



No Change



Change

Yellow = Herb, Blue=Water, Green=Forest

Difficult at start of season, but reasonable

Burned Area Emergency Rehabiliation

- Direct rehabilitation efforts
- Mandate for remediation plan within 6 days
- Focus efforts to:
  - protect water quality
  - prevent mass wasting
  - encourage re-growth of native species
- Three burn severity classes in standard use
- Combustion of organic soil is key
- MODIS product will be rapid 1st cut
  - Maximize use of time in the field
- RR in partnership with selected BAER teams
- Will support 4-6 BAER events in 2002

High

Moderate

Low

Cooperative Development of Advanced Products

Mapping Burn Severity With MODIS

The Devil Fire Susanville, California May 2001

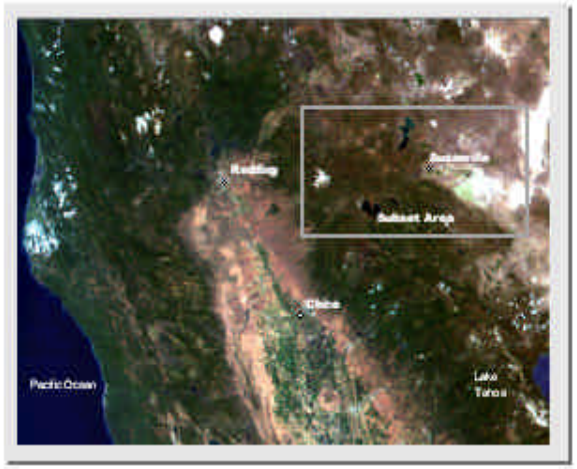
These MODIS images were obtained shortly after containment of the 4,200 acre Devil Fire on June 3, 2001.

Two models were run on the subset area using Erdas Imagine:

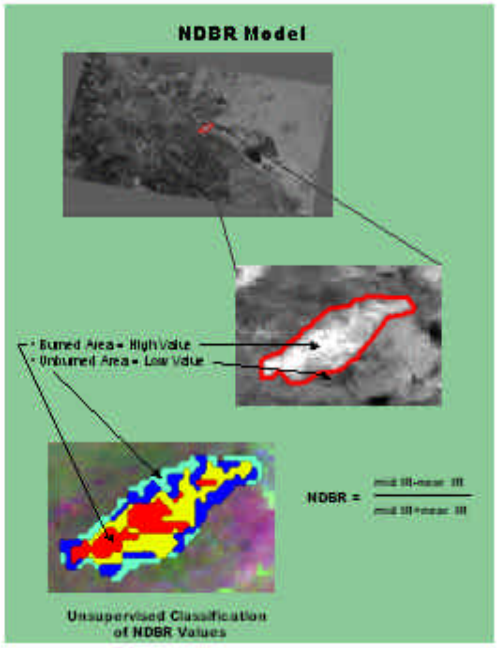
- NDVI (Normalized Difference Vegetation Index)
- NDBR (Normalized Difference Burn Ratio), developed by the USGS.

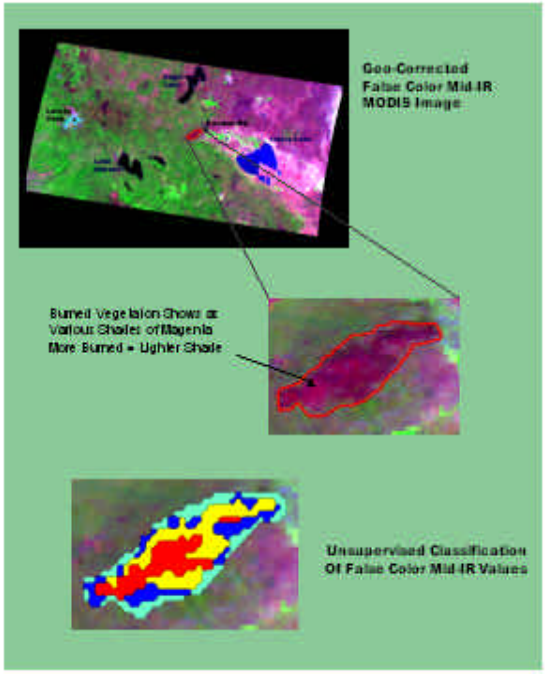
Unsupervised classifications were then performed on these 2 images as well as on the false color NIR image.

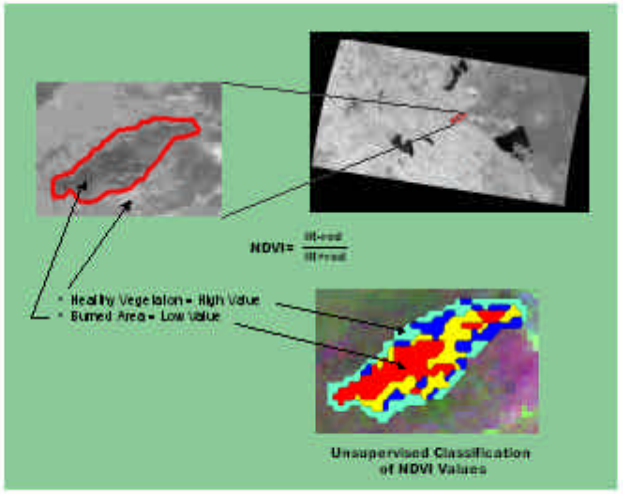
Ground truthing would be required to determine the accuracy of each technique as well as the burned severity of the perimeter area.



True Color MODIS Image of Northern California June 3, 2001







Fire field work

2002 Burn Severity Field Validation

cooperative work with USFS-RSAC

Measurements:
-Antecedant vegetation
-Soil color
-Ash color
-Completeness of combustion

Sites:
-Missionary Ridge, CO
-East Fork, UT
-Next is Southern Oregon

Vegetative Cover Conversion
THE WAY FORWARD

- Simplified, near real-time algorithm planned for Rapid Response in 2002
- Field work with USFS this 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 (at maximum, 16% of globe).
- Aqua overpass time will improve cloud-free data in tropical forest, thus increasing detected change

MOD44 Implementation Requirements

- **Intermediate Composite Product complete**
  - Geolocation very good
  - Work-around to weak 250m cloud mask
  - L2G issues related to maximizing spatial resolution
  - All compositing methods have implications for data quality
- **Vegetative Cover Conversion**
  - Continuous year of data needed from which to construct LUTs
    - Each of four global zones, five methods, twelve months
  - Prepared from the limited sample produced in Collection 3
  - Collection 4, with two years of data, will provide necessary inputs for annual to annual comparison
  - Additional development of month to month product
  - Accuracy dependent upon phenologic state of sample period

Global 500m Mosaics to be available via GLCF

- Global maximum NDVI composites
- Derived from MOD09A1
- 500m resolution
- Based on Collection 3
- Provides a time series and a global view
- http://glcf.umiacs.umd.edu