The MODIS Land Cover/Land Cover Dynamics Product: Status and Validation

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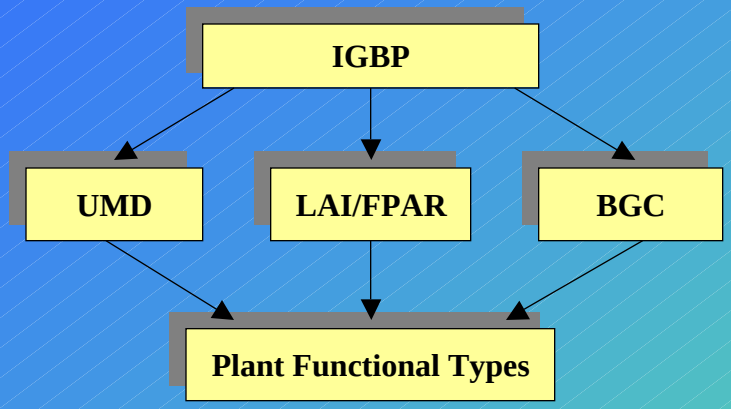
MOD12Q1: What Is It?



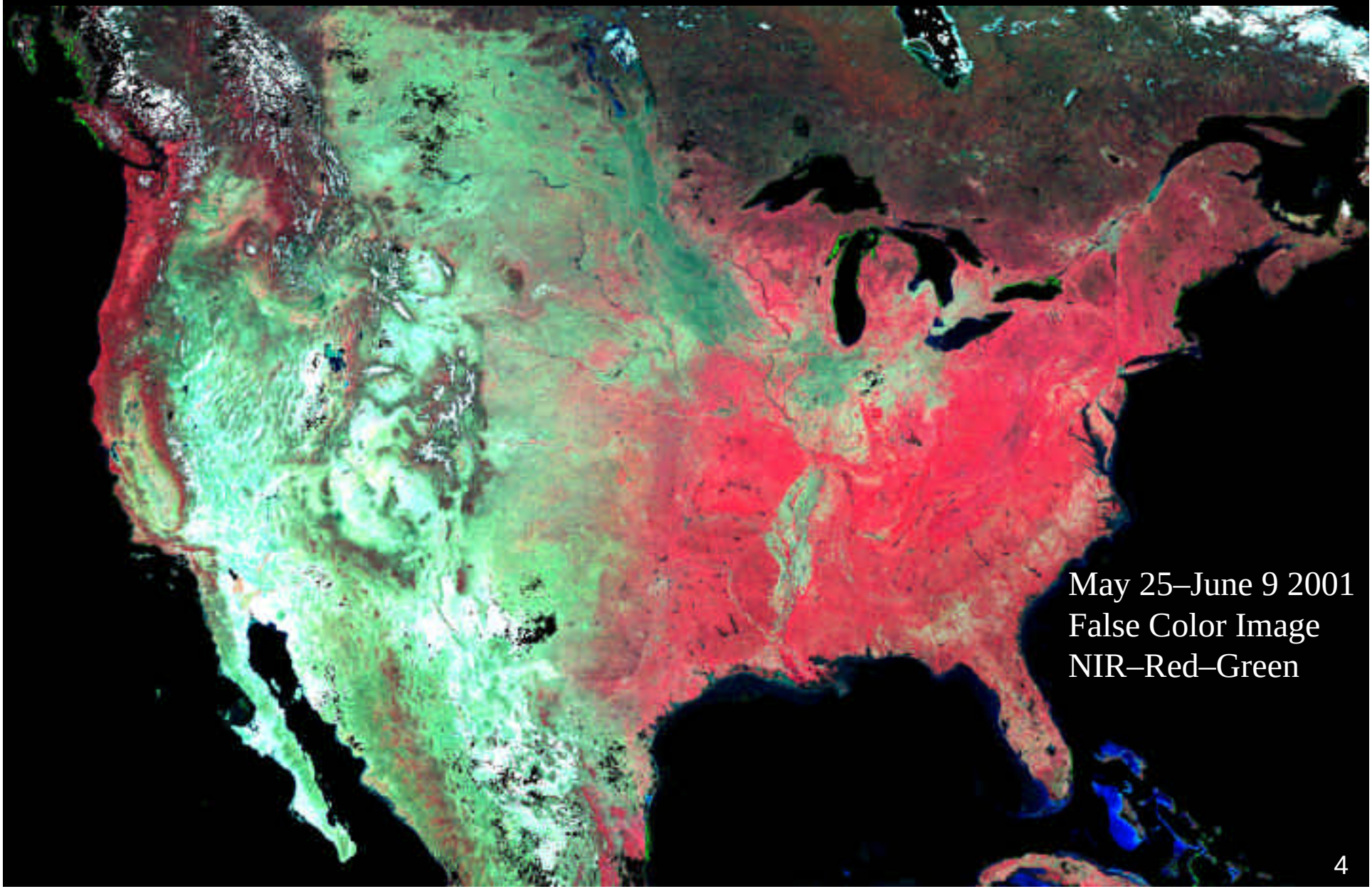
- *Plant Functional Types (Future)*
  - Plant functional types to be used with the community land model (NCAR, Bonan)
  - Exact classes TBD

- *IGBP:International Geosphere-Biosphere Project labels*
  - 17 classes of vegetation life-form
- *UMD: University of Maryland land cover class labels*
  - 14 classes without mosaic classes
- *LAI/FPAR: Classes for LAI/FPAR Production*
  - 6 labels including broadleaf and cereal crops
- *BGC: Biome BGC Model Classes*
  - 6 labels: leaf type, leaf longevity, plant persistence

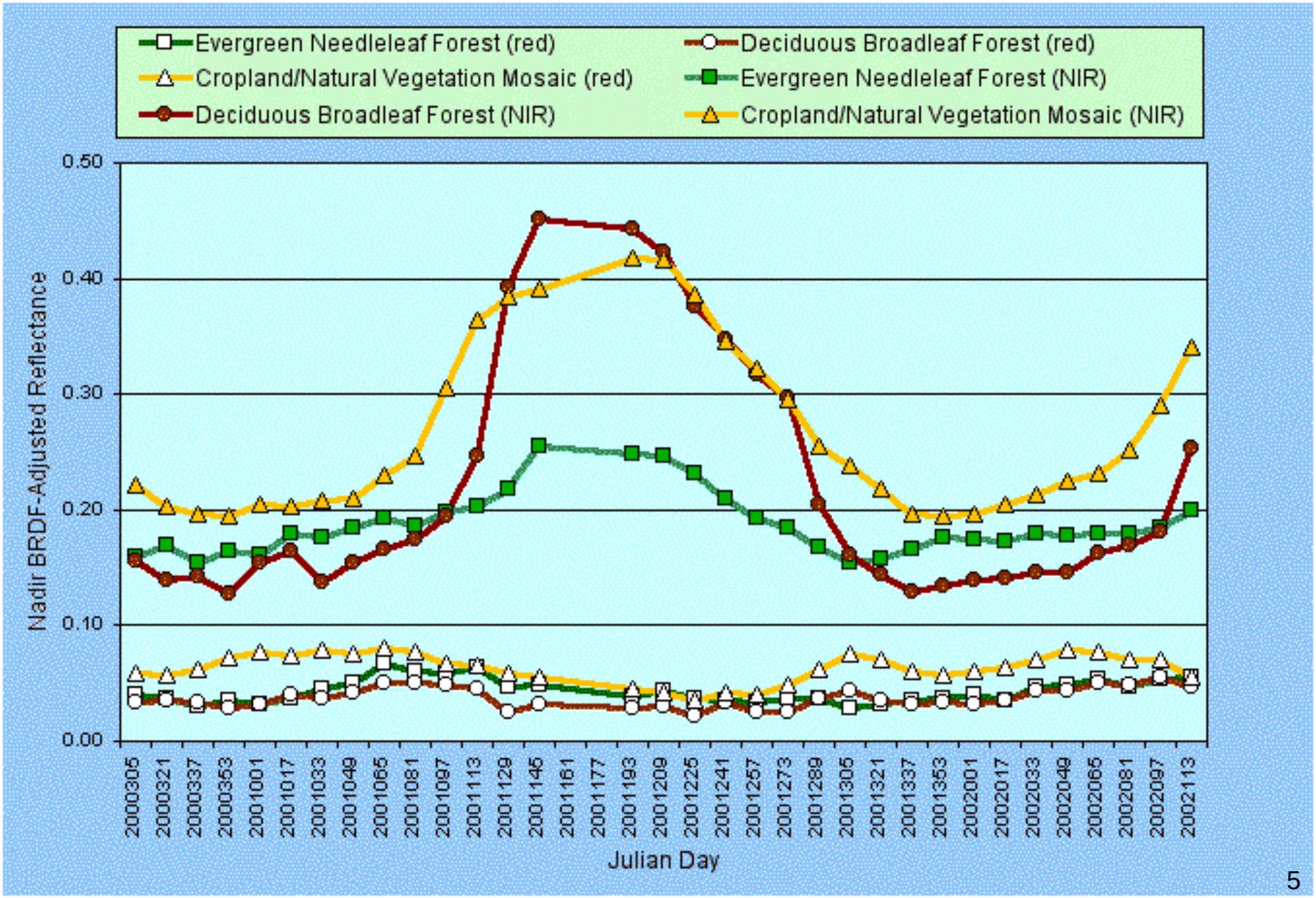
MOD12Q1: Where Does it Come From?

- ***MODIS Data***
  - **16-day Nadir BRDF-Adjusted Reflectances (NBARs) assembled over one year of observations**
  - **7 spectral bands, 0.4–2.4 μm, similar to Landsat**
  - **16-day Enhanced Vegetation Index (EVI)**
- ***Training Data***
  - **>1,500 training sites delineated from high resolution satellite imagery (largely Landsat)**
- ***Classifier***
  - **Uses decision tree classifier with boosting**

MODIS Nadir BRDF-Adjusted Reflectance



NBAR Time Trajectories



Advanced Technology Classifiers

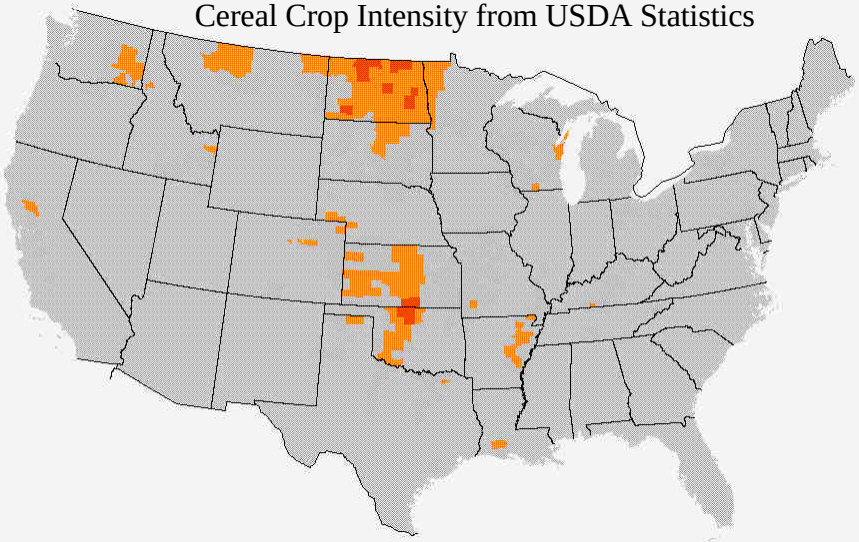
- ***Supervised Mode***
  - **Use of supervised mode with training sites**
  - **Allows rapid reclassifications for tuning**
- ***Decision Trees*—**C4.5 Univariate Decision Tree
  - **Fast algorithm**
  - **Uses boosting to create multiple trees and improve accuracy, estimate confidence**
- ***Neural Networks*—**Fuzzy ARTMAP
  - **Uses Adaptive Resonance Theory in building network**
  - **Presently not in use. Too slow; does not handle missing data well.**

Postclassification Processing

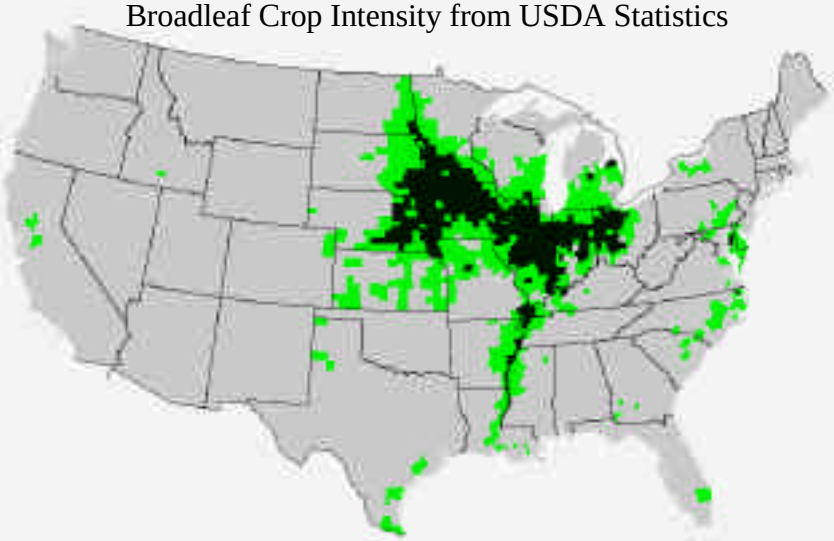
- ***Application of Prior Probabilities***
  - **Use of priors to remove training site count biases (sample equalization)**
  - **Application of global and moving-window priors from earlier products**
    - **Increases accuracies, reduces speckle**
  - **Use of external maps of prior probabilities to resolve confusions**
    - **Agriculture/natural vegetation confusion in some regions**
    - **Use of city lights DMSP data to enhance urban class accuracy (to come)**
- ***Filling of Cloud-Covered Pixels from Earlier Maps***
  - **Use of at-launch (EDC DISCover v. 2) or provisional product when there are not sufficient values to classify a pixel with confidence**

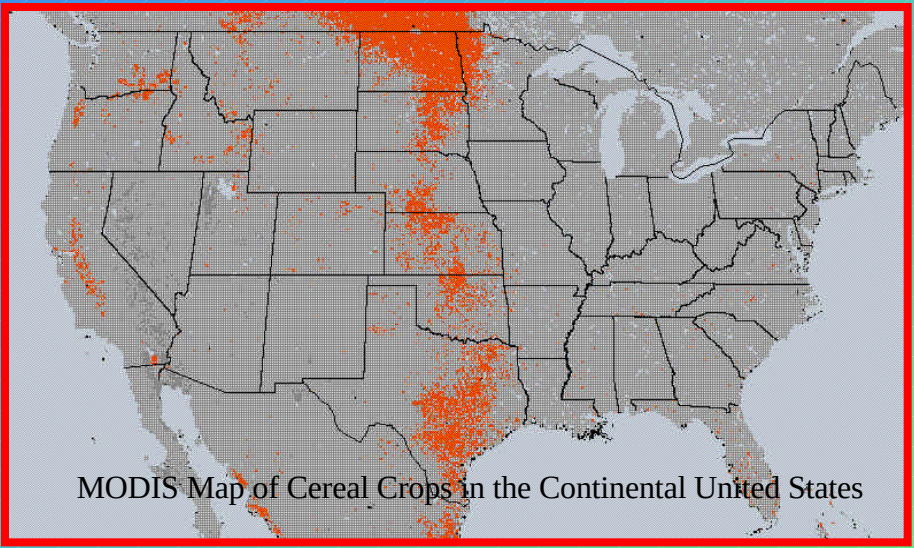
Using Priors to Classify Cereal and Broadleaf Crops

Cereal Crop Intensity from USDA Statistics

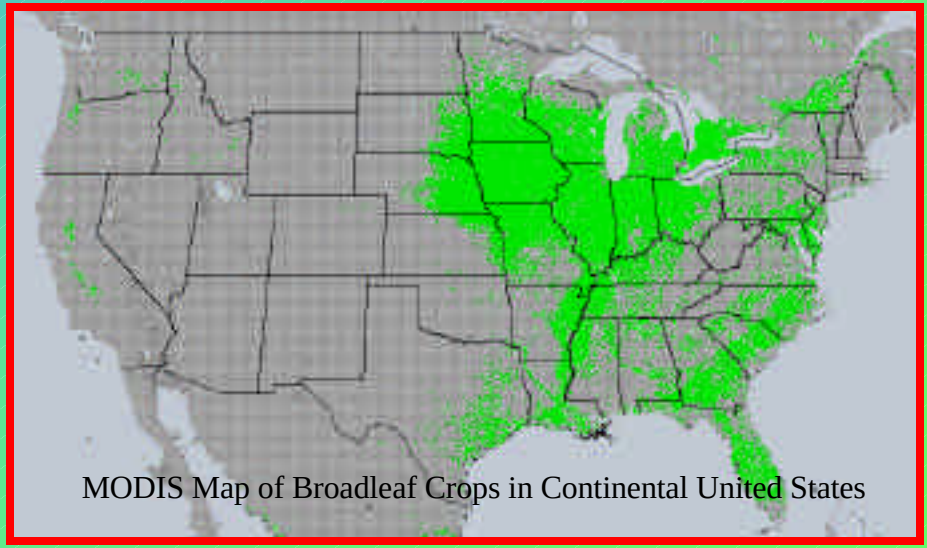


Broadleaf Crop Intensity from USDA Statistics



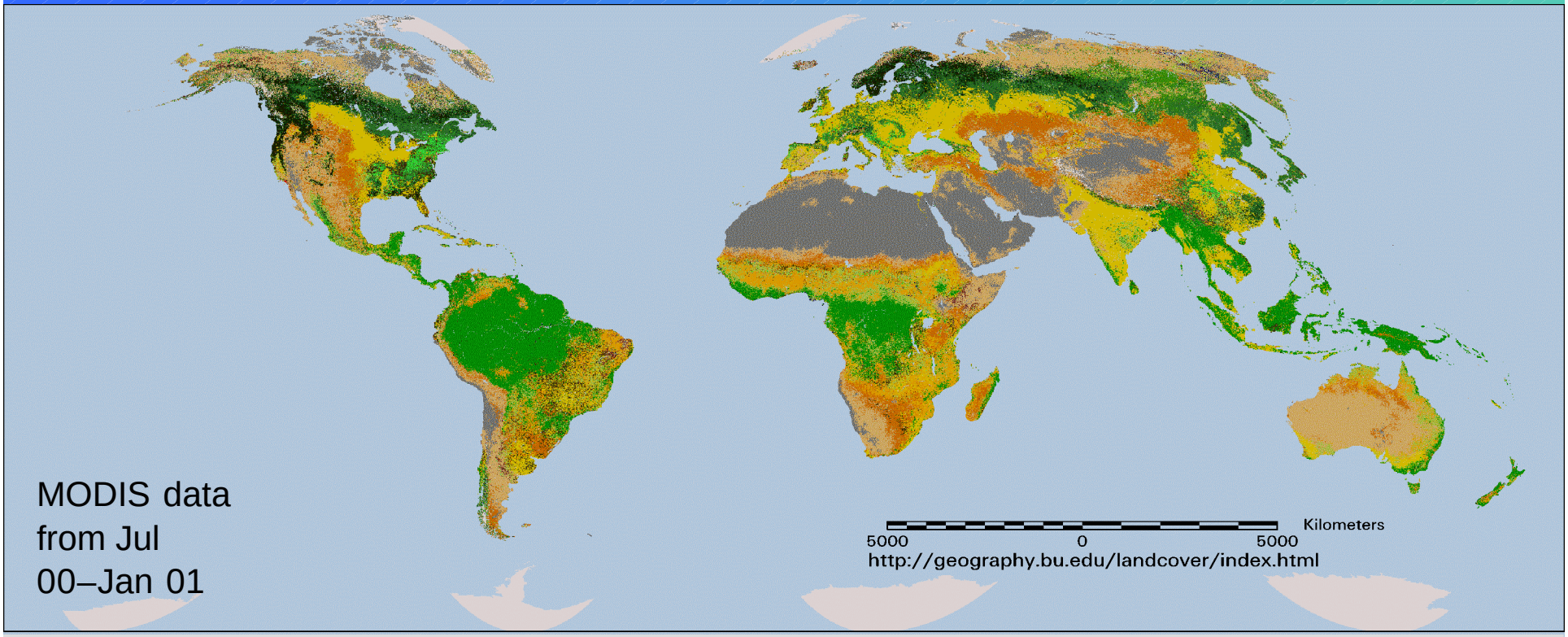


MODIS Map of Cereal Crops in the Continental United States



MODIS Map of Broadleaf Crops in Continental United States

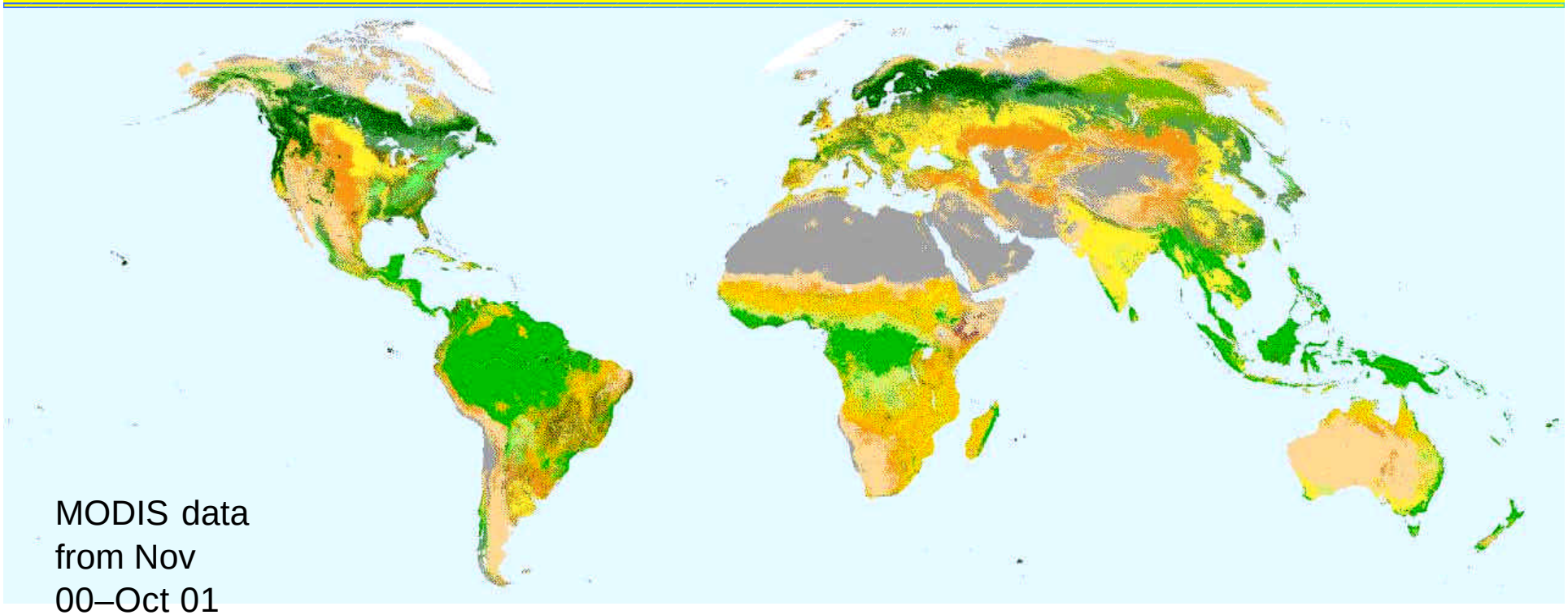
Provisional Land Cover Product June 01



TERRA/MODIS MOD12Q1 2001001 IGBP Land Cover Classes

- 0 Water
- 1 Evergreen Needleleaf Forest
- 2 Evergreen Broadleaf Forest
- 3 Deciduous Needleleaf Forest
- 4 Deciduous Broadleaf Forest
- 5 Mixed Forests
- 6 Closed Shrublands
- 7 Open Shrublands
- 8 Woody Savannas
- 9 Savannas
- 10 Grasslands
- 11 Permanent Wetlands
- 12 Croplands
- 13 Urban and Built-Up
- 14 Cropland/Natural Vegetation Mosaic
- 15 Snow and Ice
- 16 Barren or Sparsely Vegetated

Consistent Year Land Cover Product June 02—IGBP

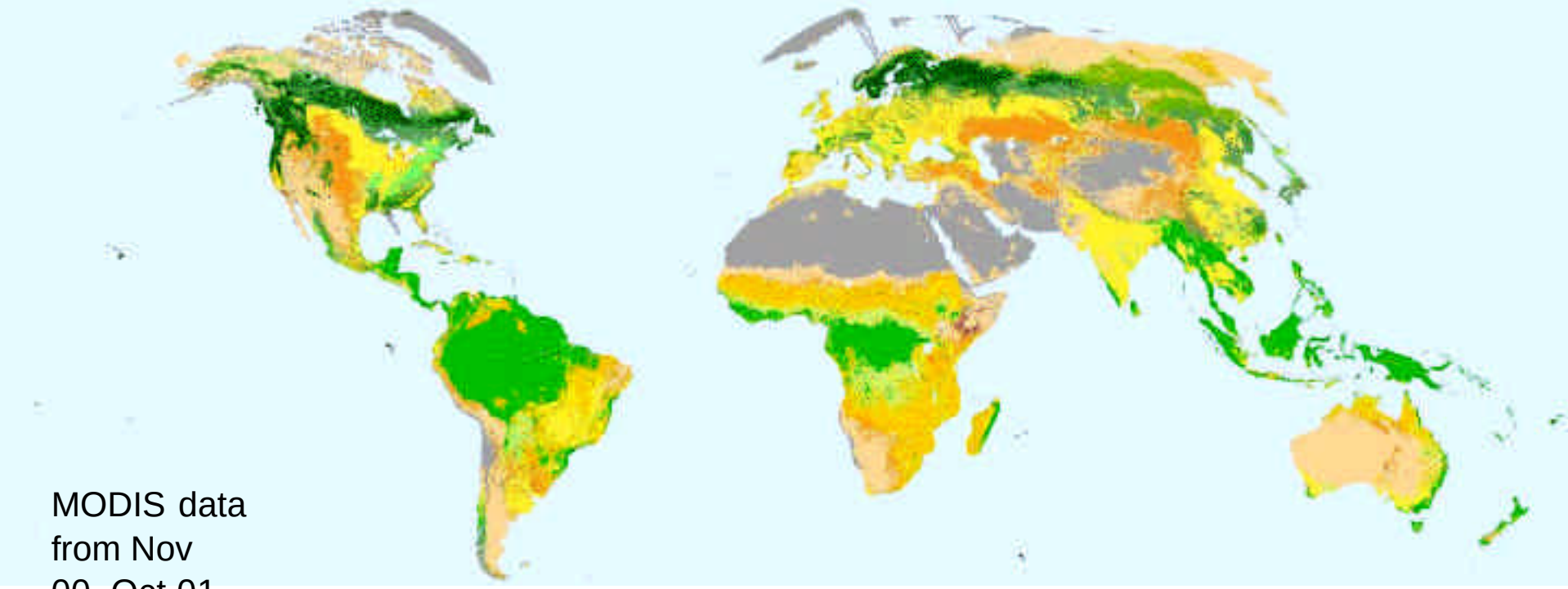


MODIS data from Nov 00–Oct 01

IGBP Land Cover Classes

0 Water	6 Closed Shrublands	12 Croplands
1 Evergreen Needleleaf Forest	7 Open Shrublands	13 Urban and Built-Up
2 Evergreen Broadleaf Forest	8 Woody Savannas	14 Cropland/Natural Vegetation Mosaic
3 Deciduous Needleleaf Forest	9 Savannas	15 Snow and Ice
4 Deciduous Broadleaf Forest	10 Grasslands	16 Barren or Sparsely Vegetated
5 Mixed Forests	11 Permanent Wetlands	254 Unclassified

Consistent Year Land Cover Product June 02—UMd

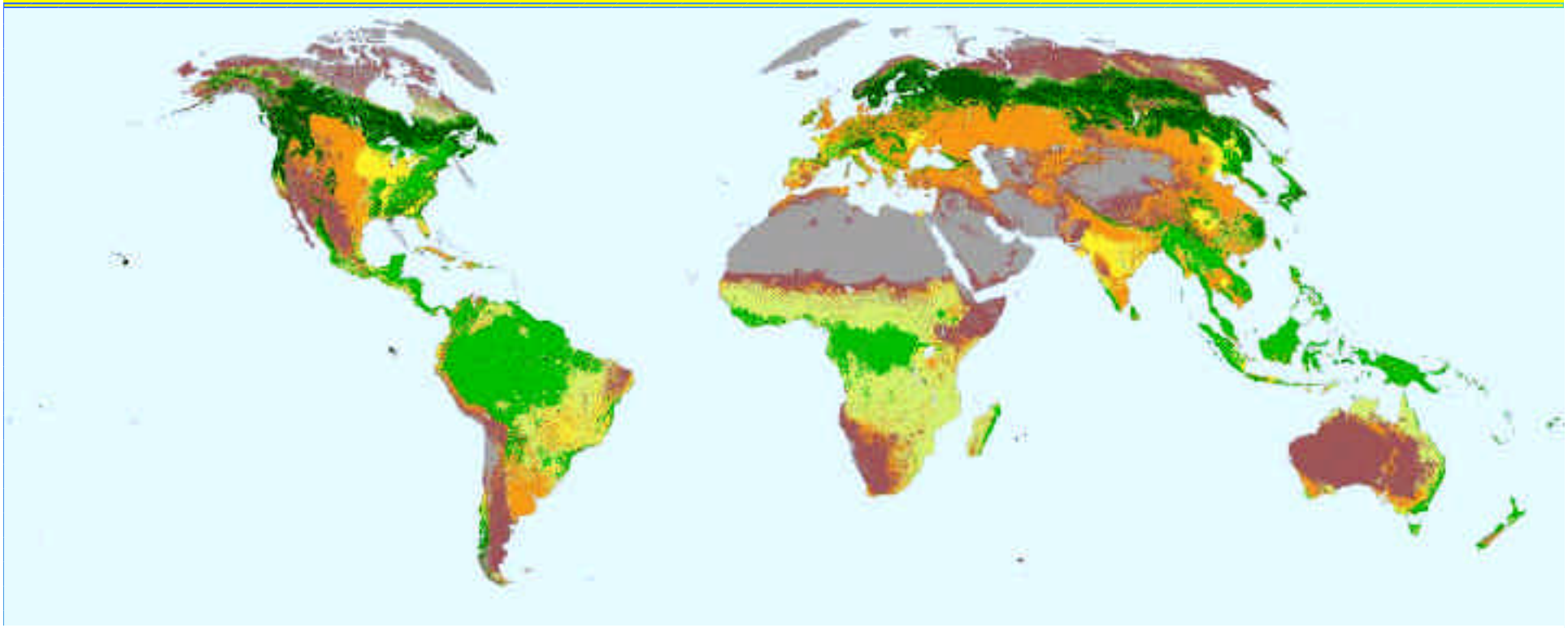


MODIS data from Nov 00–Oct 01

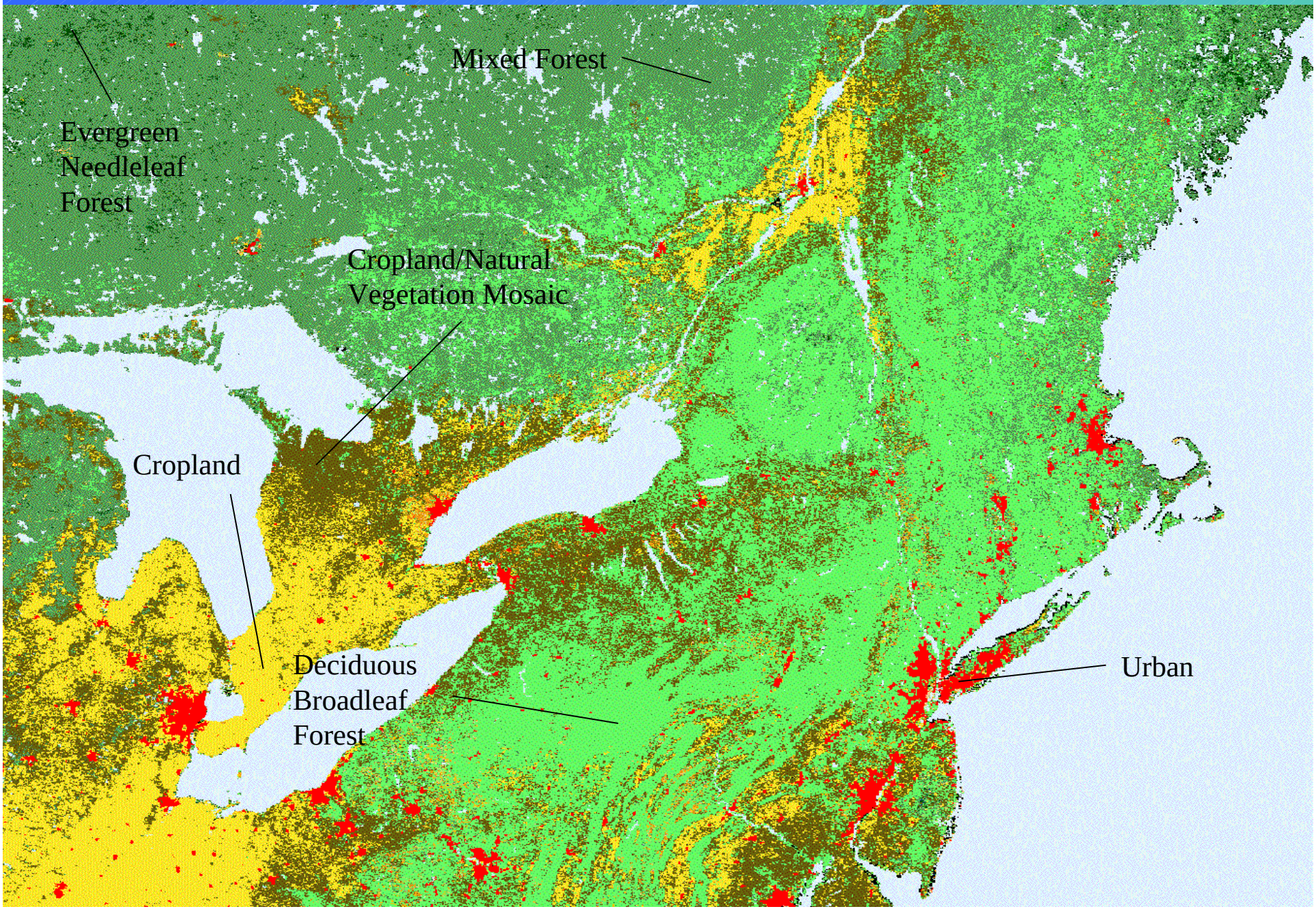
UMD Land Cover Classes

0 Water	5 Mixed Forests	10 Grasslands
1 Evergreen Needleleaf Forest	6 Closed Shrublands	12 Croplands
2 Evergreen Broadleaf Forest	7 Open Shrublands	13 Urban and Built-Up
3 Deciduous Needleleaf Forest	8 Woody Savannas	16 Barren or Sparsely Vegetated
4 Deciduous Broadleaf Forest	9 Savannas	254 Unclassified

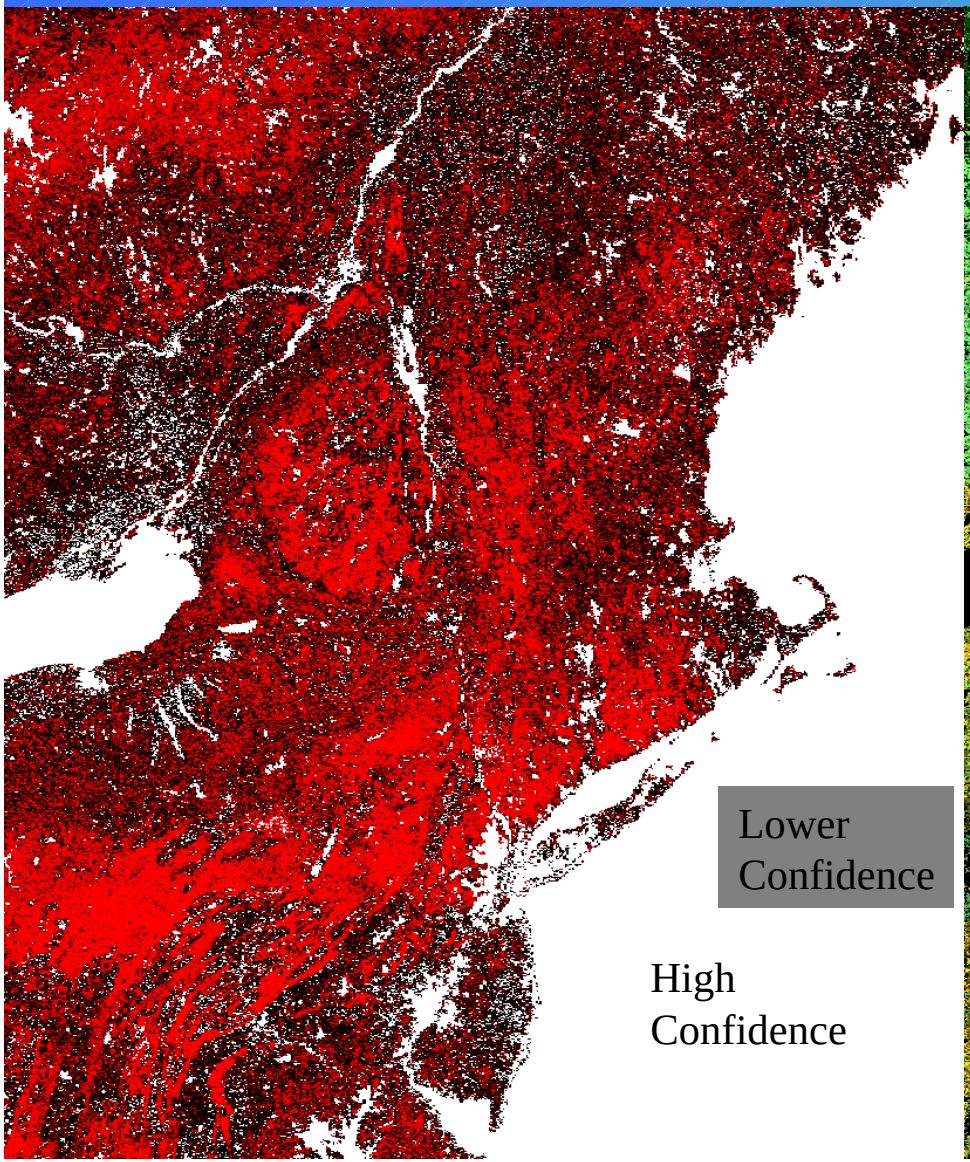
Consistent Year Land Cover Product June 02—LAI/FPAR Biomes



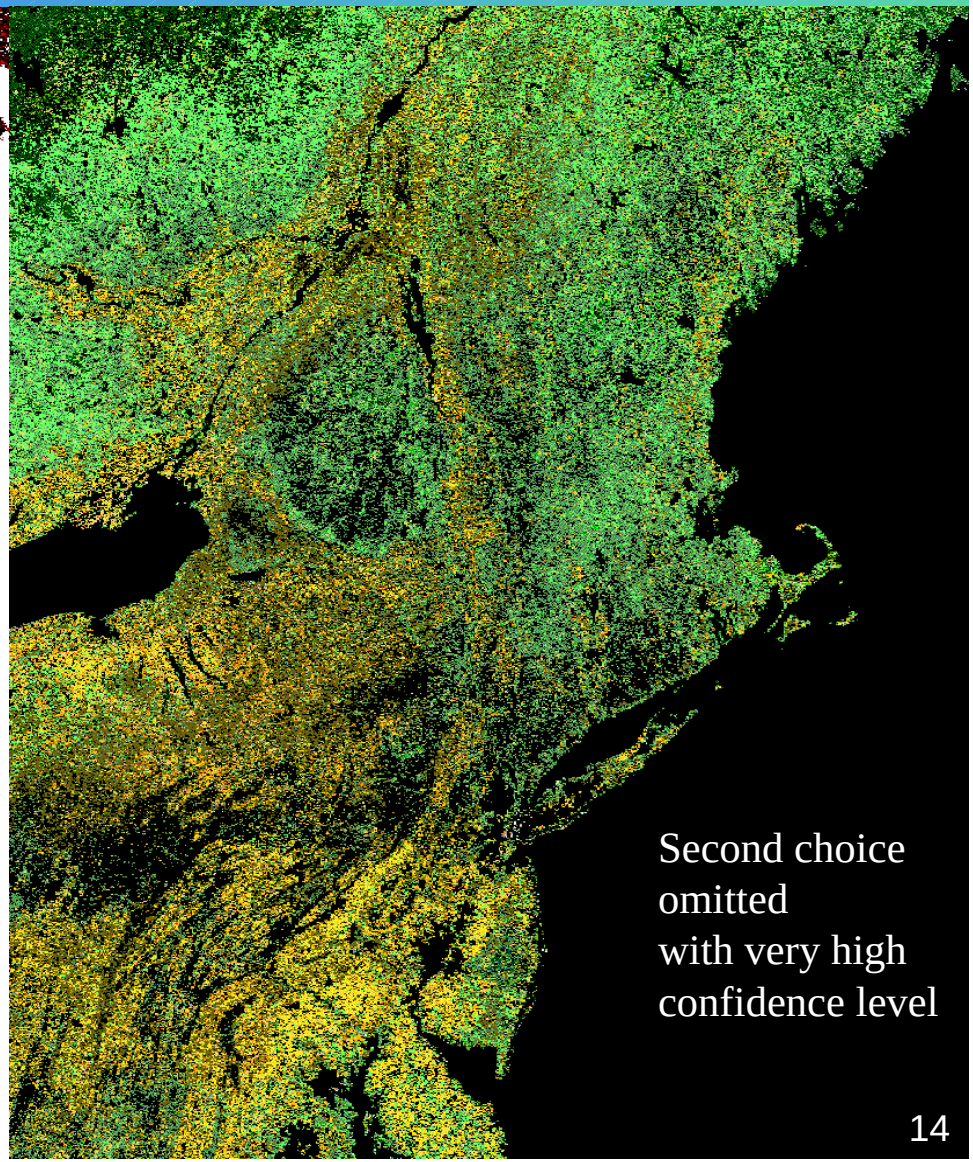
Consistent Year Land Cover Product, Nov 00–Oct 01



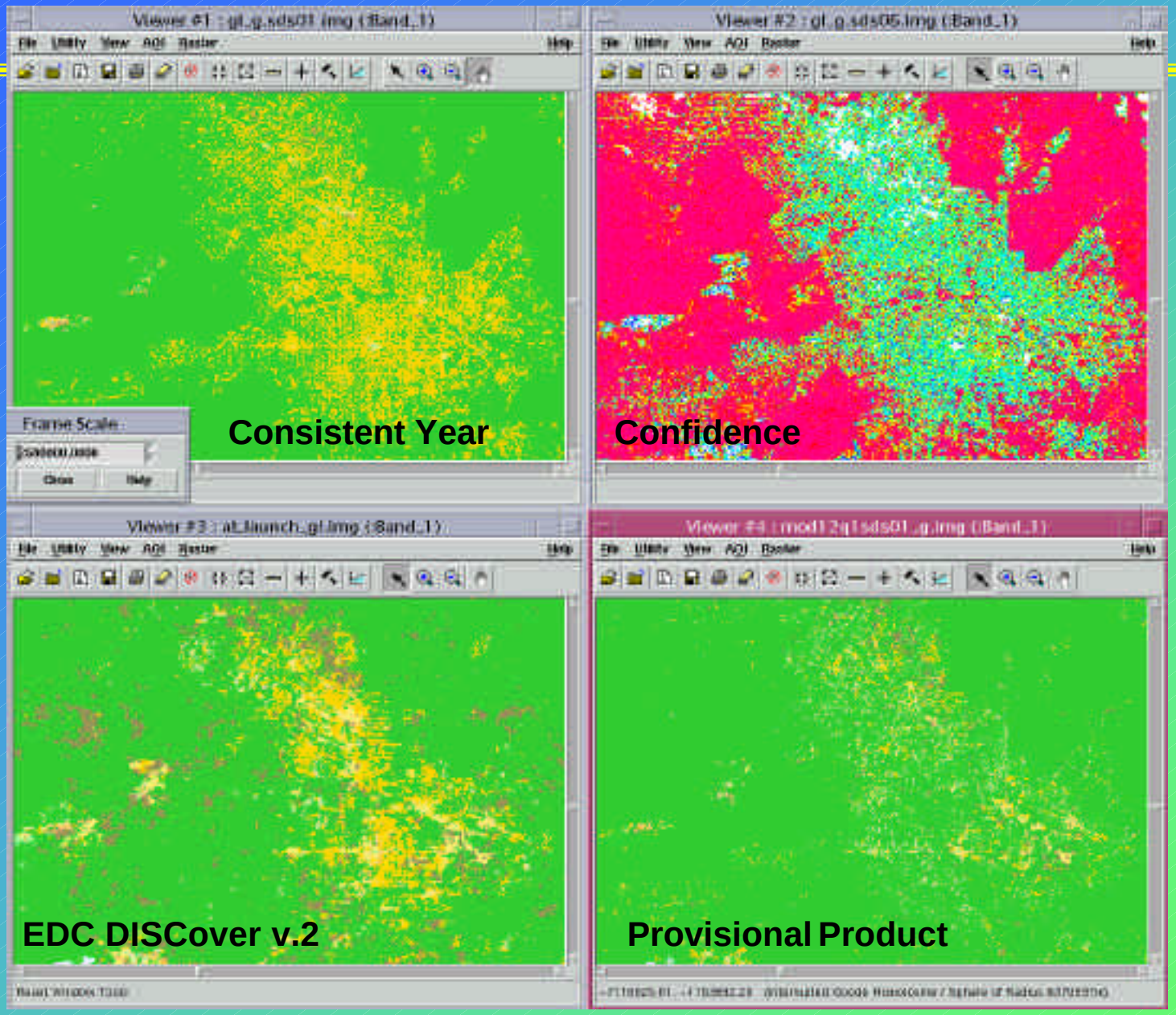
Classification Confidence Map



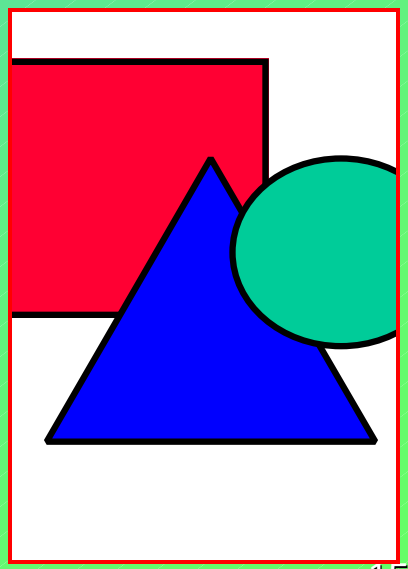
Second Most-Likely Class



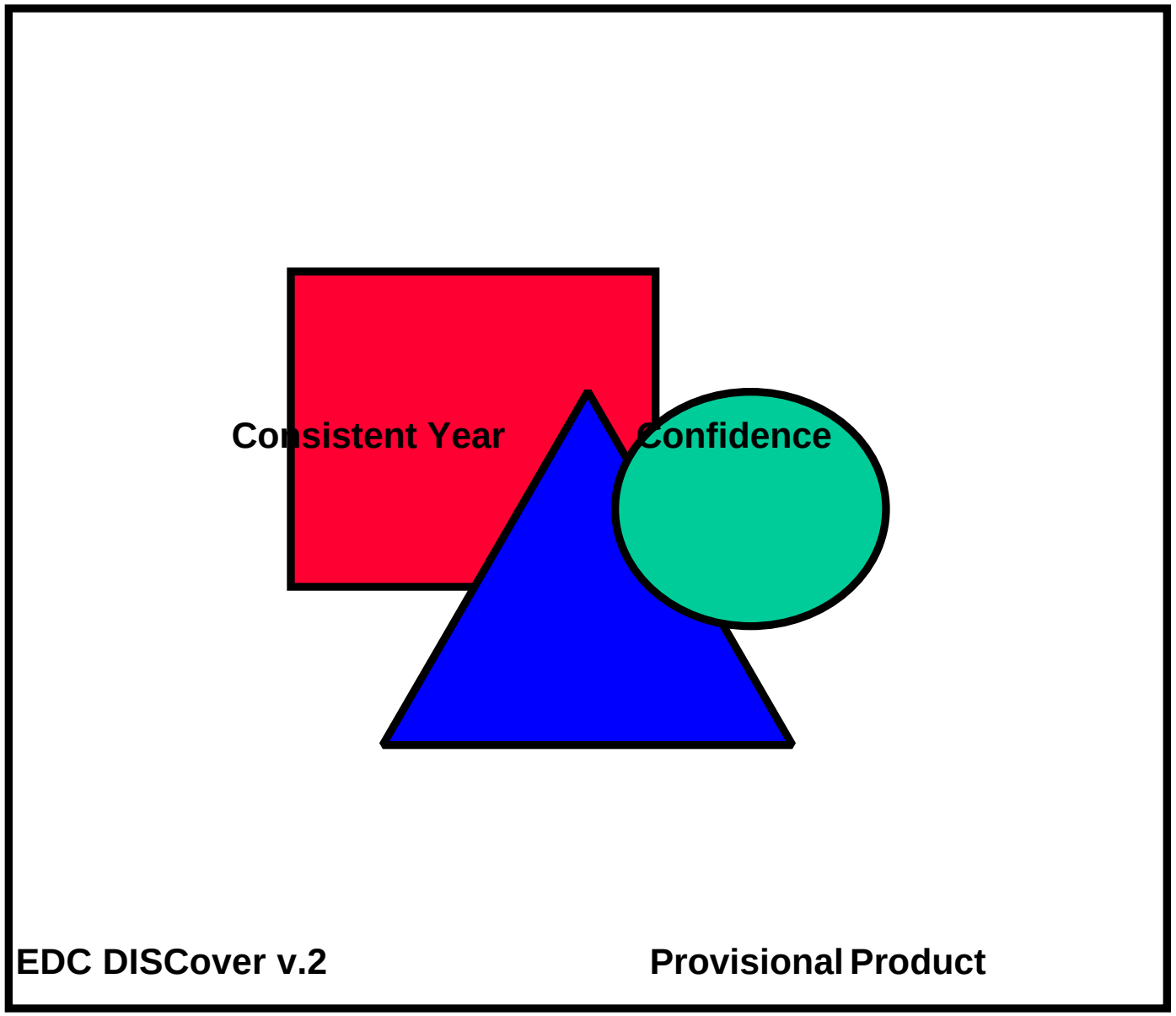
Rondonia Comparison



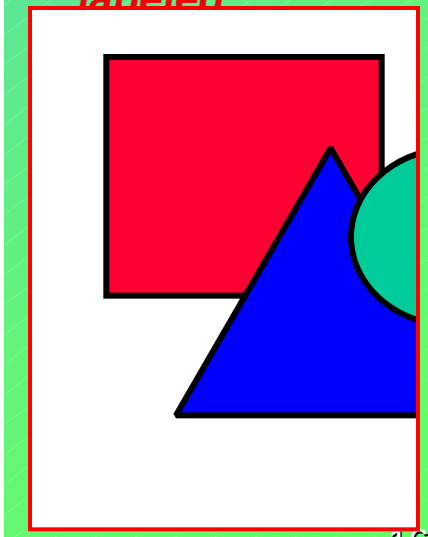
- *Note better delineation of land cover pattern*



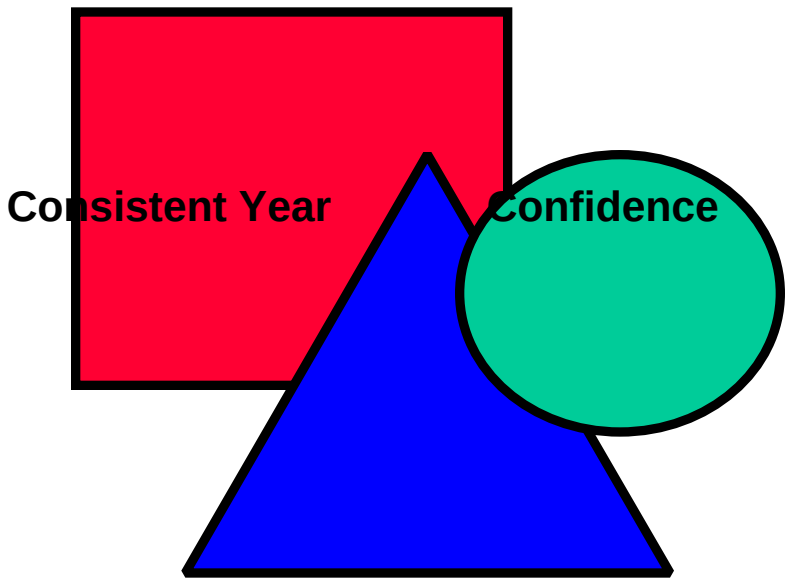
Central Africa Comparison



- *Note more accurate depiction of open shrubland–savanna–woody savanna transition*
- *DISCover patches of crop/nat veg properly labeled*



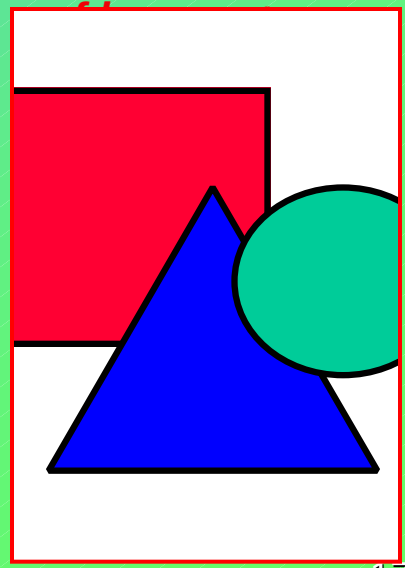
Siberia Comparison



EDC DISCover v.2

Provisional Product

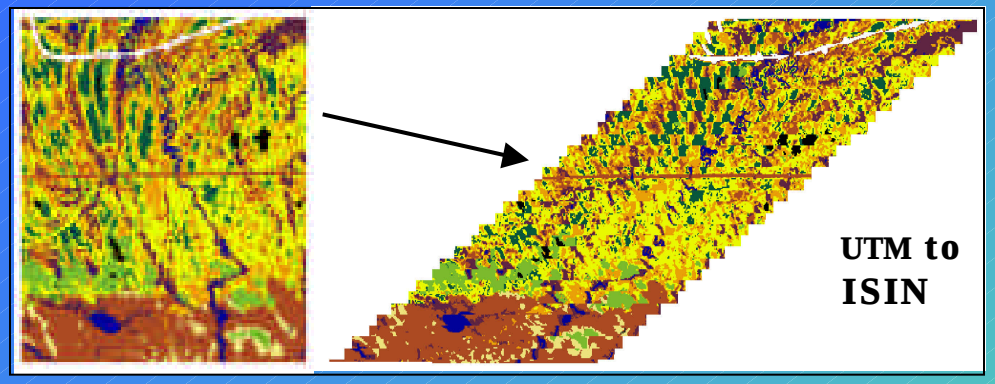
- *Loss of tile/swath boundaries from provisional to consistent year products*
- *Better transition from decid ndlf to open shrubland, wetland; loss*



Land Cover Validation

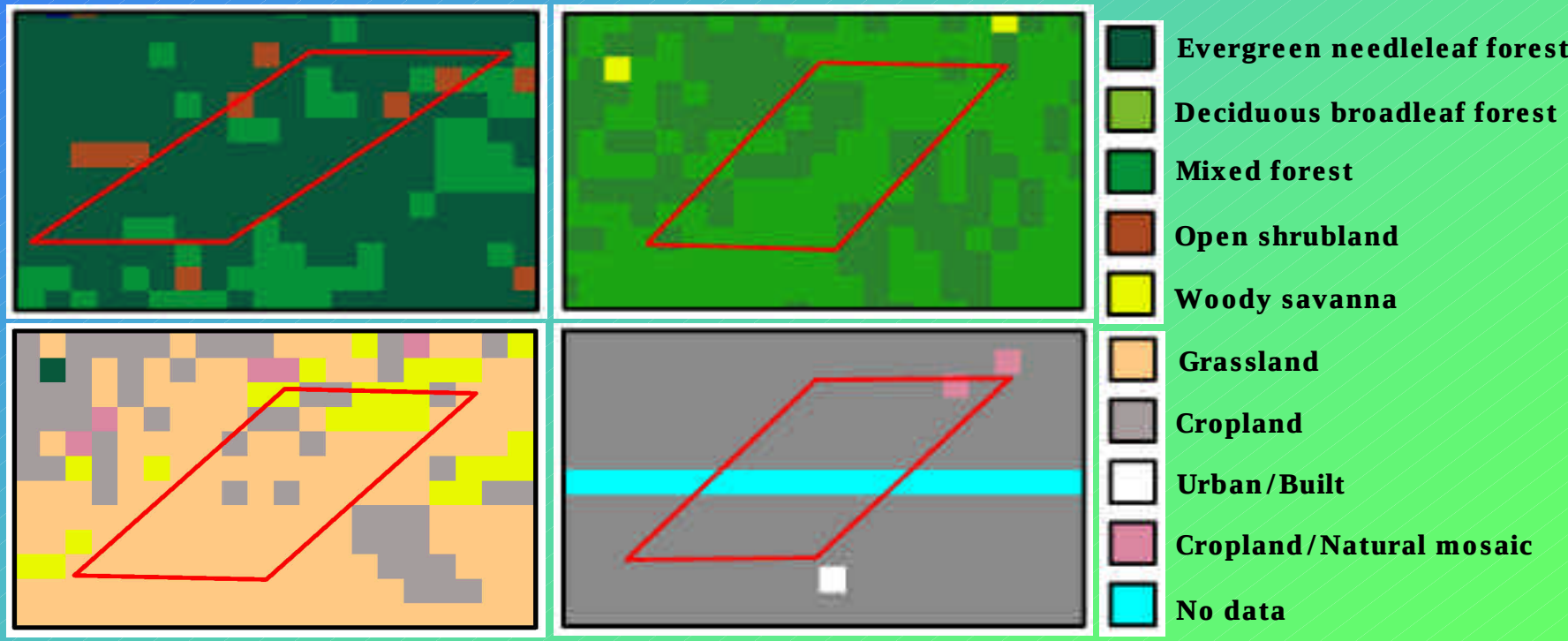
- ***Validation Plan Utilizes Multiple Approaches***
- ***Level 1: Comparisons with existing data sources***
  - **Examples**
    - **Global AVHRR land cover datasets: DISCover, UMd**
    - **Humid Tropics: Landsat Pathfinder**
    - **Forest Cover: FAO Forest Resources Assessment**
    - **Western Europe: CORINE**
    - **United States: USGS/EPA MLRC**
    - **United States: California Timber Maps (McIver and Woodcock)**
    - **MODIS and Bigfoot test site comparisons**

IGBP Land Cover, 2000–01, V003



Clockwise from upper left:

NOBS
HARV
AGRO
KONZ



Courtesy Warren Cohen, OSU

Validation Levels, Cont.

- ***Level 2: Quantitative studies of output and training data***
  - **Per-pixel confidence statistics**
    - **Aggregated by land cover type and region**
    - **Describe the accuracy of the classification process**
  - **Test site cross-comparisons**
    - **Confusion matrices globally and by region**
    - **Provides estimates of errors of omission and commission**
- ***Level 3: Sample-based statistical studies***
  - **Random stratified sampling according to proper statistical principles**
  - **Costly, but needed for making proper accuracy statements**

Confidence Values by Land Cover Type (Preliminary)

IGBP Class		Confidence
1	Evergreen Needleleaf	68.3
2	Evergreen Broadleaf	89.3
3	Deciduous Needleleaf	66.7
4	Deciduous Broadleaf	65.9
5	Mixed Forest	65.4
6	Closed Shrubland	60.0
7	Open Shrubland	75.3
8	Woody Savanna	64.0
9	Savanna	67.8
10	Grasslands	70.6
11	Permanent Wetlands	52.3
12	Cropland	76.4
14	Cropland/Nat. Veg'n.	60.7
15	Snow and Ice	87.2
16	Barren	90.0
	Overall Confidence	**76.3**

Includes adjustment for prior probabilities. Urban and Built-Up (13), Water (17) classes omitted. Pixels filled from prior data omitted. Based on preliminary data, subject to change.

Confidence Values by Continental Region (Preliminary)

Region	*Confidence, percent*
Africa	**79.4**
Australia/Pacific	**83.2**
Eurasia	**76.8**
North America	**71.9**
South America	**78.5**
Overall Confidence	***76.3***

Includes adjustment for prior probabilities. Urban and Built-Up (13), Water(17) classes omitted. Pixels filled from prior data omitted. Based on preliminary data, subject to change.

Cross Validation with Training Sites

- ***Cross-Validation Procedure***
  - **Hide 10 percent of training sites, classify with remaining 90 percent; repeat ten times for ten unique sets of all sites**
  - **Provides “confusion matrix” based on unseen pixels where whole training site is unseen**
  - **Not a stratified random sample, but a reasonable indication of within-class accuracy**

Confusion Matrix (Preliminary)

Global Test Site Confusion Matrix—Consistent Year Product, After Priors

Site Class	Class Name	Classification Outcome															
		1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	Total
1	Evergreen Needleleaf	1460	42	18	11	266	7	9	17	23	10	15	21	2	0	0	1901
2	Evergreen Broadleaf	31	4889	0	14	14	11	18	79	23	17	4	38	10	0	1	5149
3	Deciduous Needleleaf	87	0	104	25	118	0	0	4	0	0	0	10	0	0	0	348
4	Deciduous Broadleaf	22	56	16	384	278	0	3	11	1	3	0	47	82	0	0	903
5	Mixed Forest	405	63	94	148	1355	3	1	27	7	8	40	41	17	0	0	2209
6	Closed Shrubland	34	35	2	12	5	140	124	29	15	30	2	158	19	0	8	613
7	Open Shrubland	10	12	3	9	1	41	1002	33	45	203	0	210	6	0	213	1788
8	Woody Savanna	62	133	0	16	110	11	104	577	141	71	0	221	22	0	3	1471
9	Savanna	10	53	1	0	21	18	48	93	440	43	1	252	79	0	16	1075
10	Grasslands	2	16	0	2	20	4	179	6	101	632	0	249	13	0	363	1587
11	Pmnt Wtlnd	63	24	0	5	28	23	1	2	36	2	89	1	7	0	0	281
12	Cropland	6	75	2	7	16	8	61	42	132	133	2	5168	183	0	18	5853
14	Cropland/Natural Vegn	2	133	0	48	28	2	8	16	66	8	1	320	832	0	7	1471
15	Snow+ice	1	0	0	0	0	1	2	0	0	0	5	1	0	1297	5	1312
16	Barren	0	2	1	0	0	1	162	4	5	126	3	56	5	14	3537	3916
	Total	2195	5533	241	681	2260	270	1722	940	1035	1286	162	6793	1277	1311	4171	29877

Accuracies—Consistent Year Product (Preliminary)

Based on Global Test Site Confusion Matrix

Dataset	Training Site Accuracy
Before priors	78.6 %
After priors	71.0 %
After priors, first two classes	84.0 %

Overall Accuracies

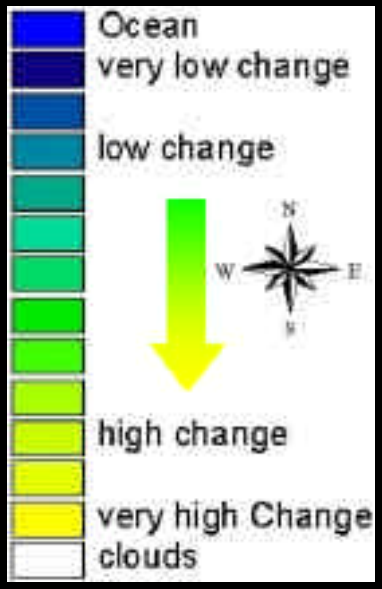
- *Proper accuracy statements require proper statistical sampling*
- *AVHRR state of the art has been 60–70 percent, depending on class and region*
- *MODIS accuracies are falling in 70–80 percent range*
- *Most "mistakes" are between similar classes*
- *Land cover change should* ***NOT*** *be inferred from comparing successive land cover maps*

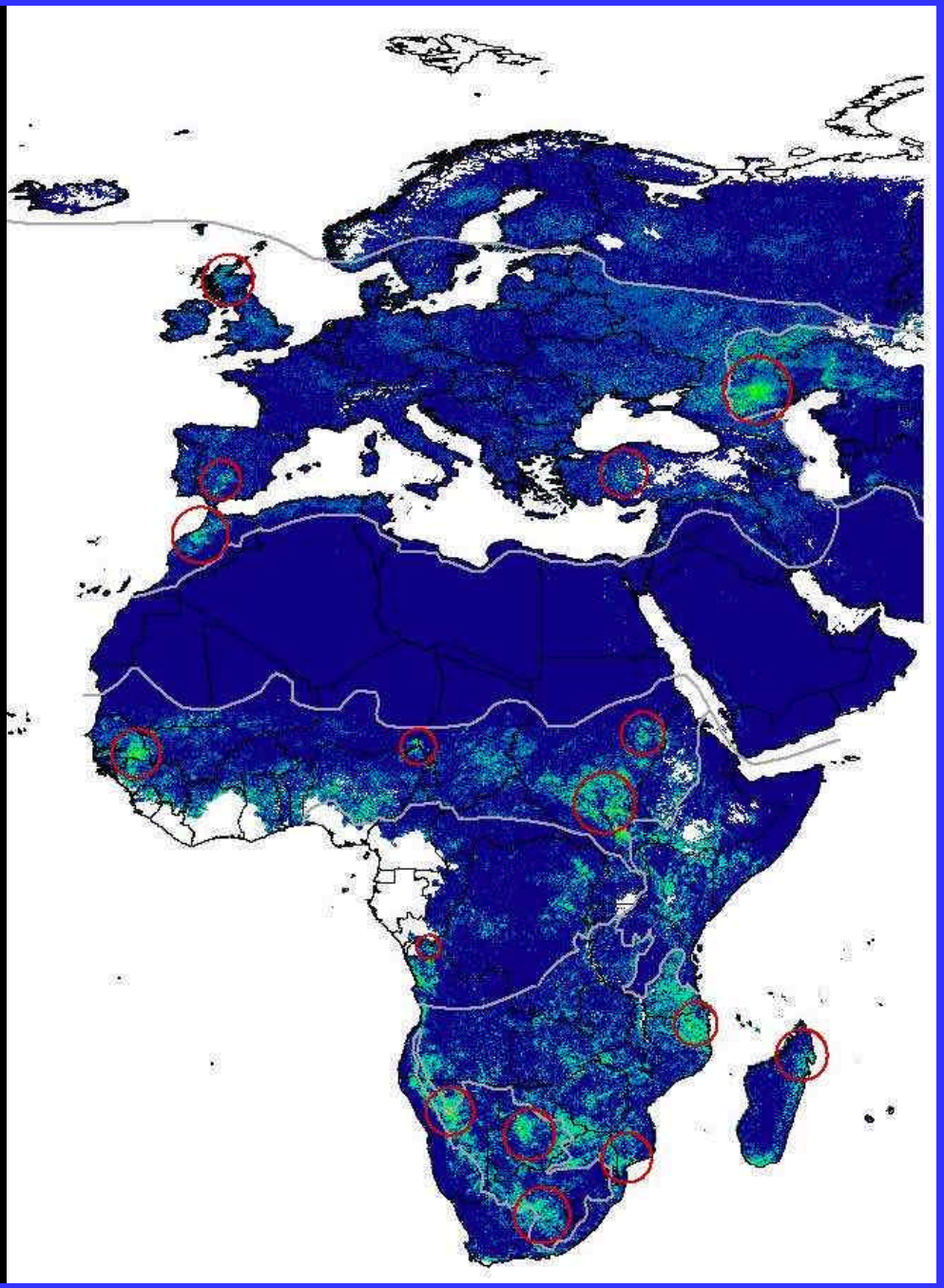
Land Cover Dynamics

- ***Primary Objectives:***
  - **Quantify interannual change**
    - **Uses change vectors comparing successive years**
    - **Identifies regions of short-term climate variation**
    - **Under development with Eric Lambin, Frederic Lupo at UCL, Belgium**
  - **Quantify phenology**
    - **Greenup, maturity, senescence, dormancy**
    - **Values of VI, EVI at greenup and peak, plus annual integrated values**
    - **Uses logistic functions fit to time trajectories of EVI**

Land-cover change map of Europe and Africa from SPOT VEGETATION:

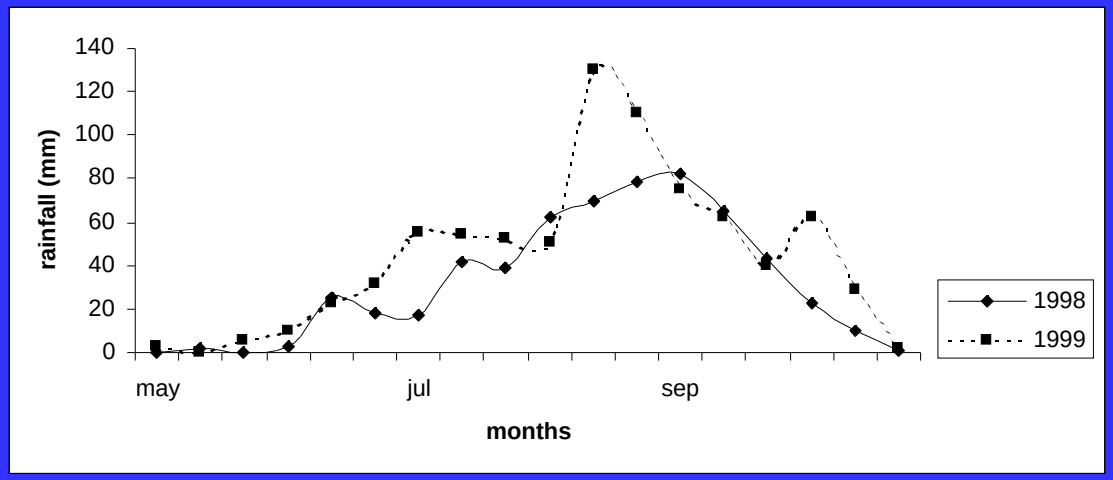
Impact of natural disasters from May 1998 to April 2000

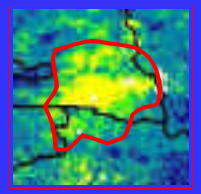




Monitoring land-cover changes in West Africa with Spot VEGETATION: Impact of natural disasters in 1998-1999

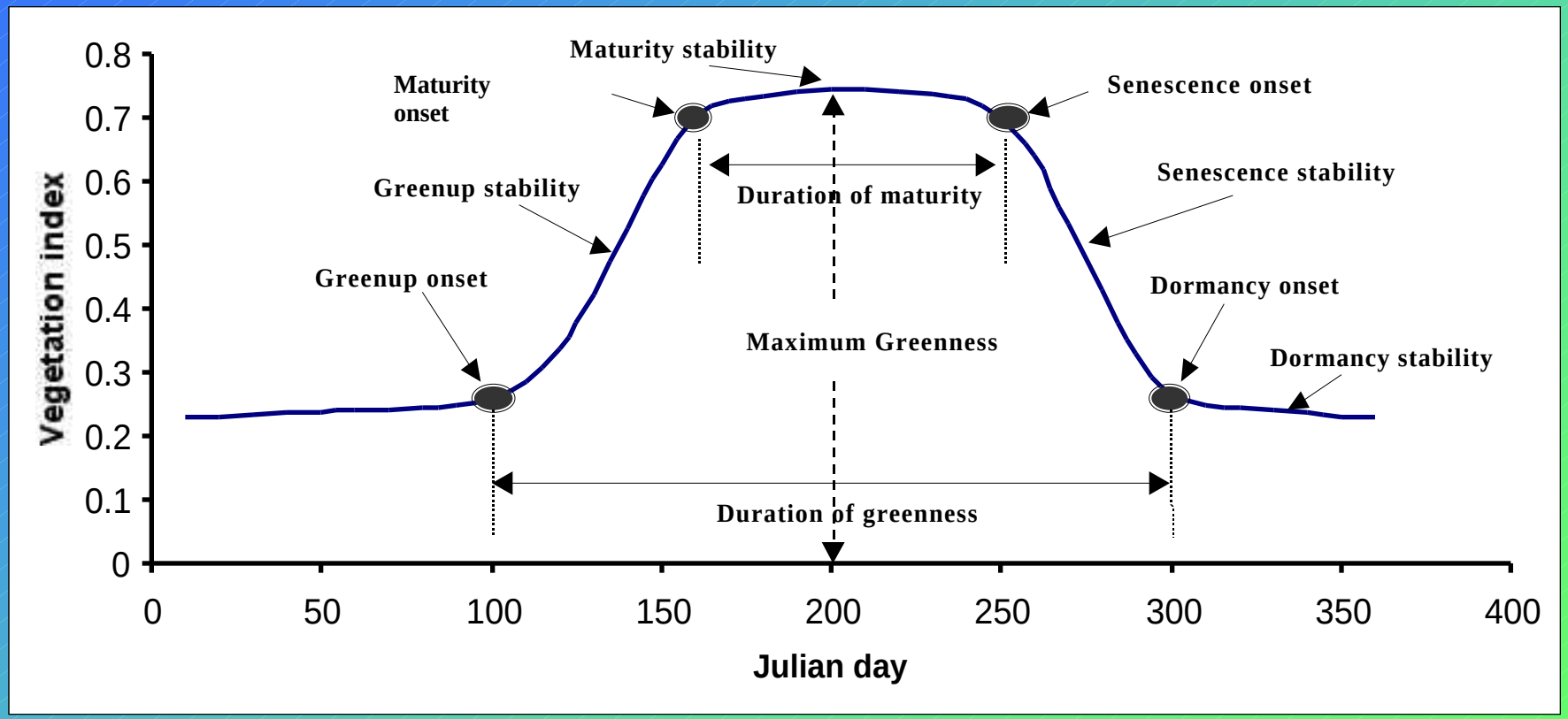
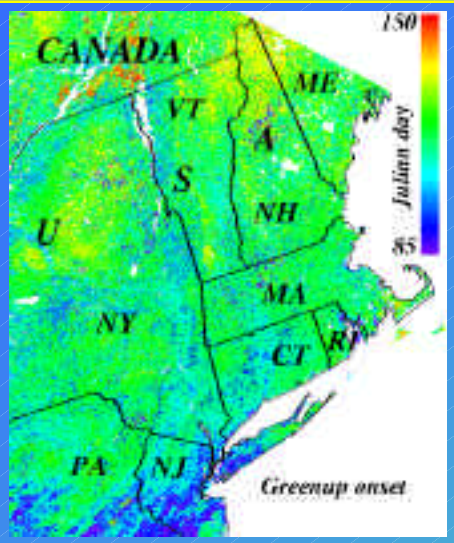
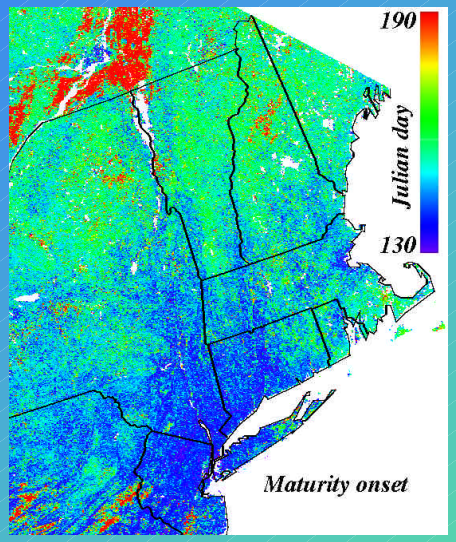
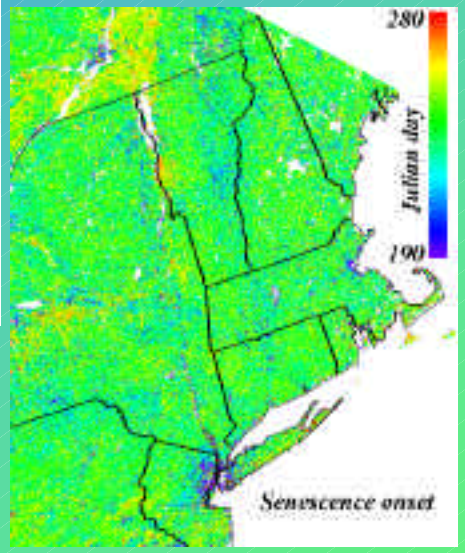
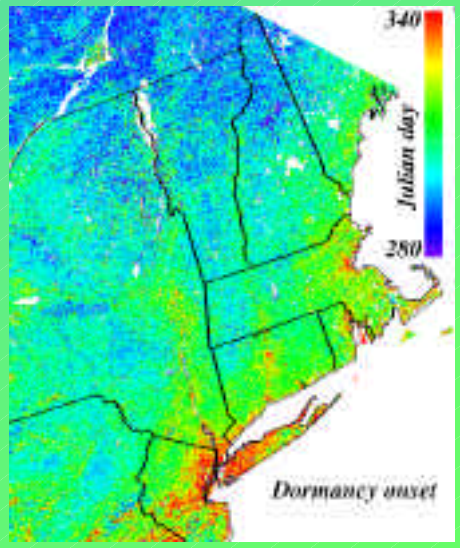
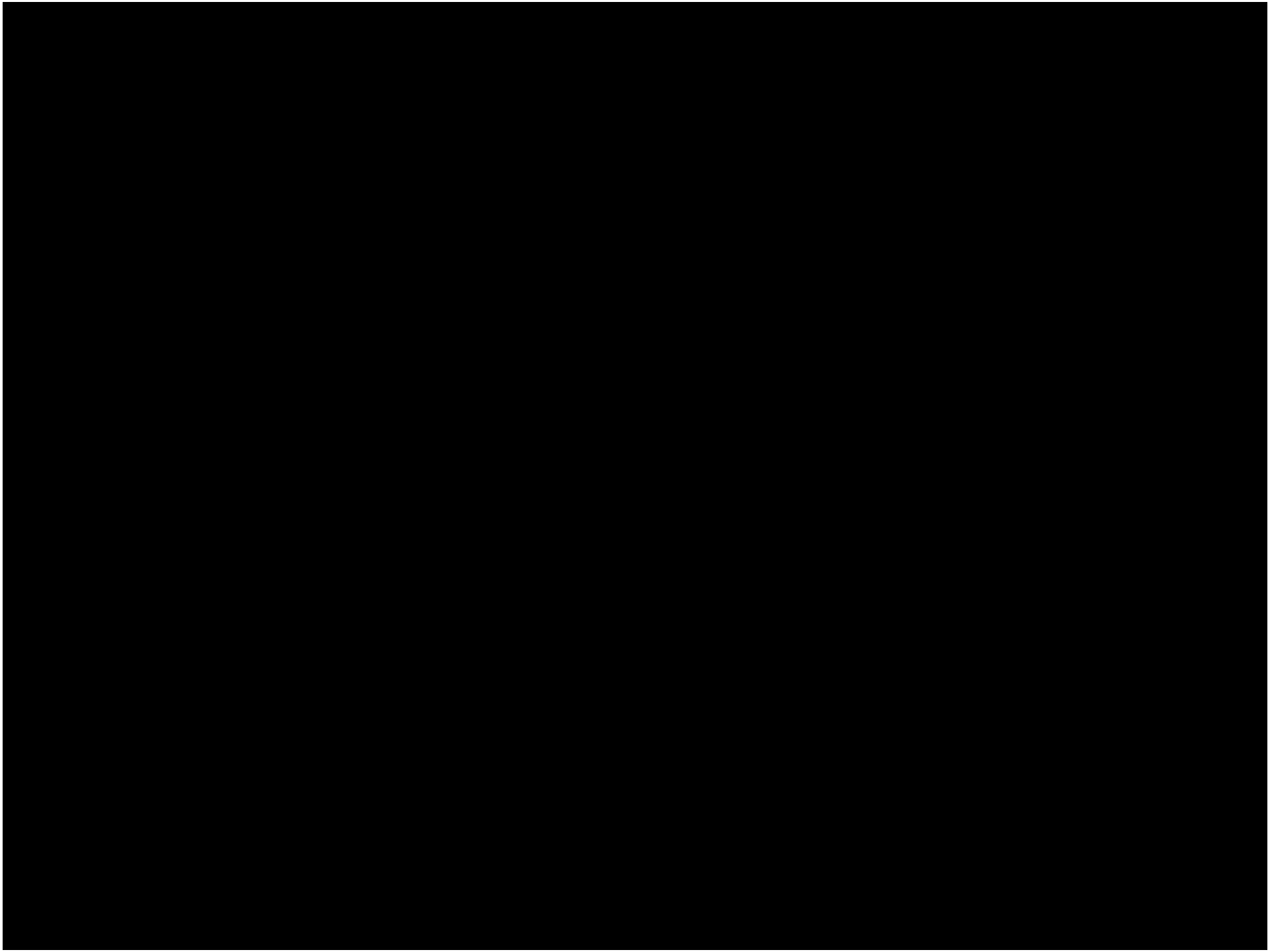
Rainfall in Senegal (13°N/ 12°W):





- low NDVI values in June, July and August 1998,
- large number of fires in June 1999.

Land Cover Dynamics: Defining Phenological Attributes



Northeast Phenology