Remote Sensing based US National Crop Vegetation Condition Monitoring System - VegScape

Zhengwei Yang[1,2]
[1]Research and Development Division
USDA National Agricultural Statistics Service
[2]Center for Spatial Information System Science
George Mason University
Zhengwei_yang@nass.usda.gov

Project Goals

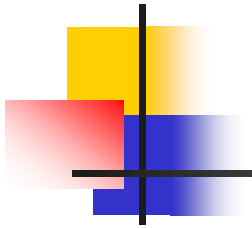
- Improve the science, objectivity, robustness and defensibility of nationwide crop vegetation condition monitoring operation at NASS
- Develop an operational National Crop Condition Monitoring System (NCCMS) - VegScape
- Produce crop vegetation condition data products that are complementary to existing NASS crop condition products.
- Enhance data accessibility, interoperability, online analytics, and dissemination.
- =>Meet user's requirements.

National Crop Condition Monitoring System (NCCMS) Background

- NASS uses AVHRR NDVI for vegetation condition monitoring;
- Subjective observation, ad-hoc point survey for crop condition and soil moisture
- Publishes weekly report based on survey

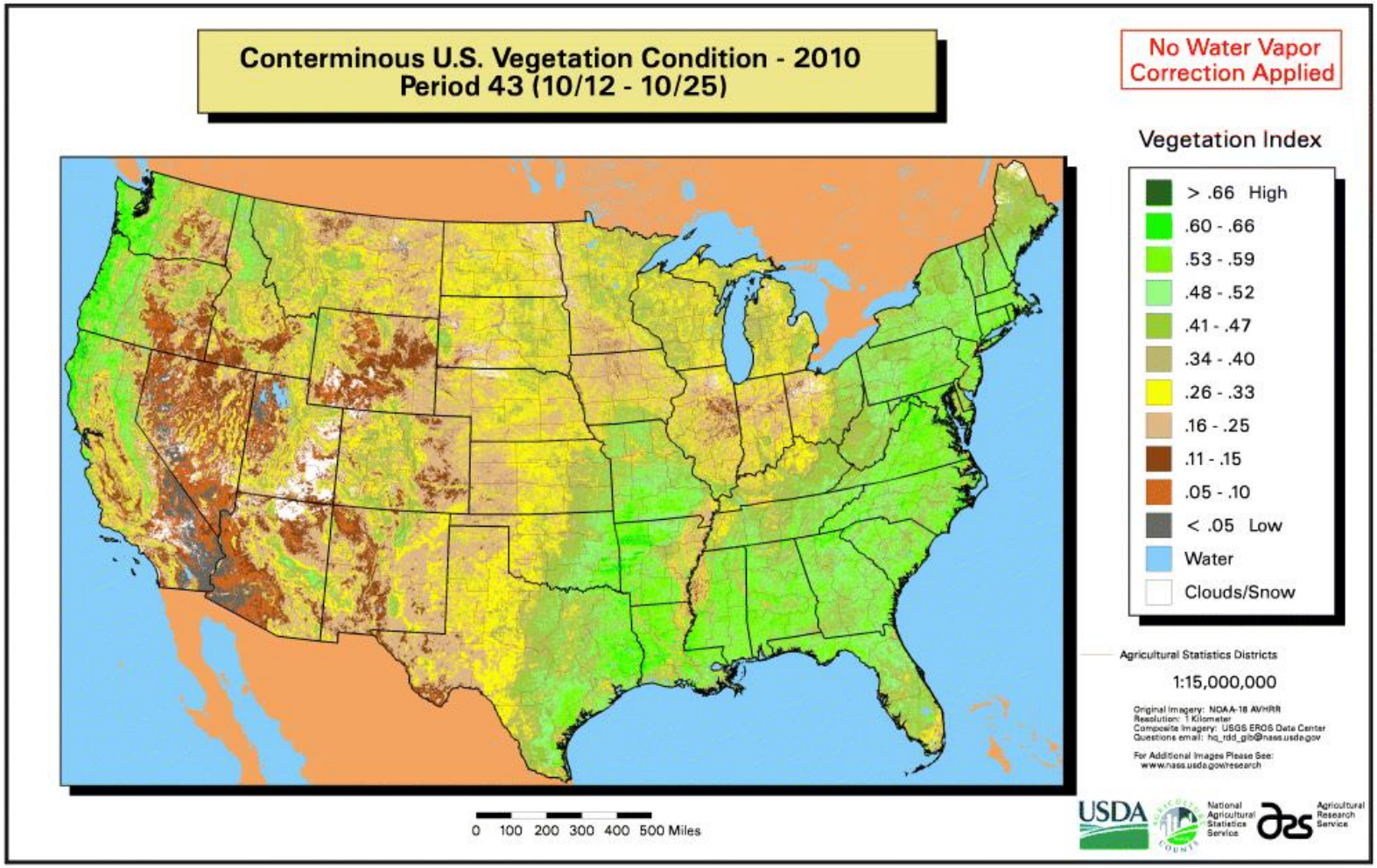
Why Do We Need A New Crop Vegetation Condition System?

- AVHRR sensor
  - AVHRR 17 – Dead;
  - AVHRR 18 – Aging, and not consistent with AVHRR 17.
  - Low spatial resolution (1km)
  - Low temporal resolution (biweekly)
- NASS weekly publishes NDVI low resolution static map; NASS needs:
  - better spatial and temporal resolutions;
  - data processing and web publishing automation;
  - better visualization and data dissemination;
  - vegetation condition analytics & assessment.

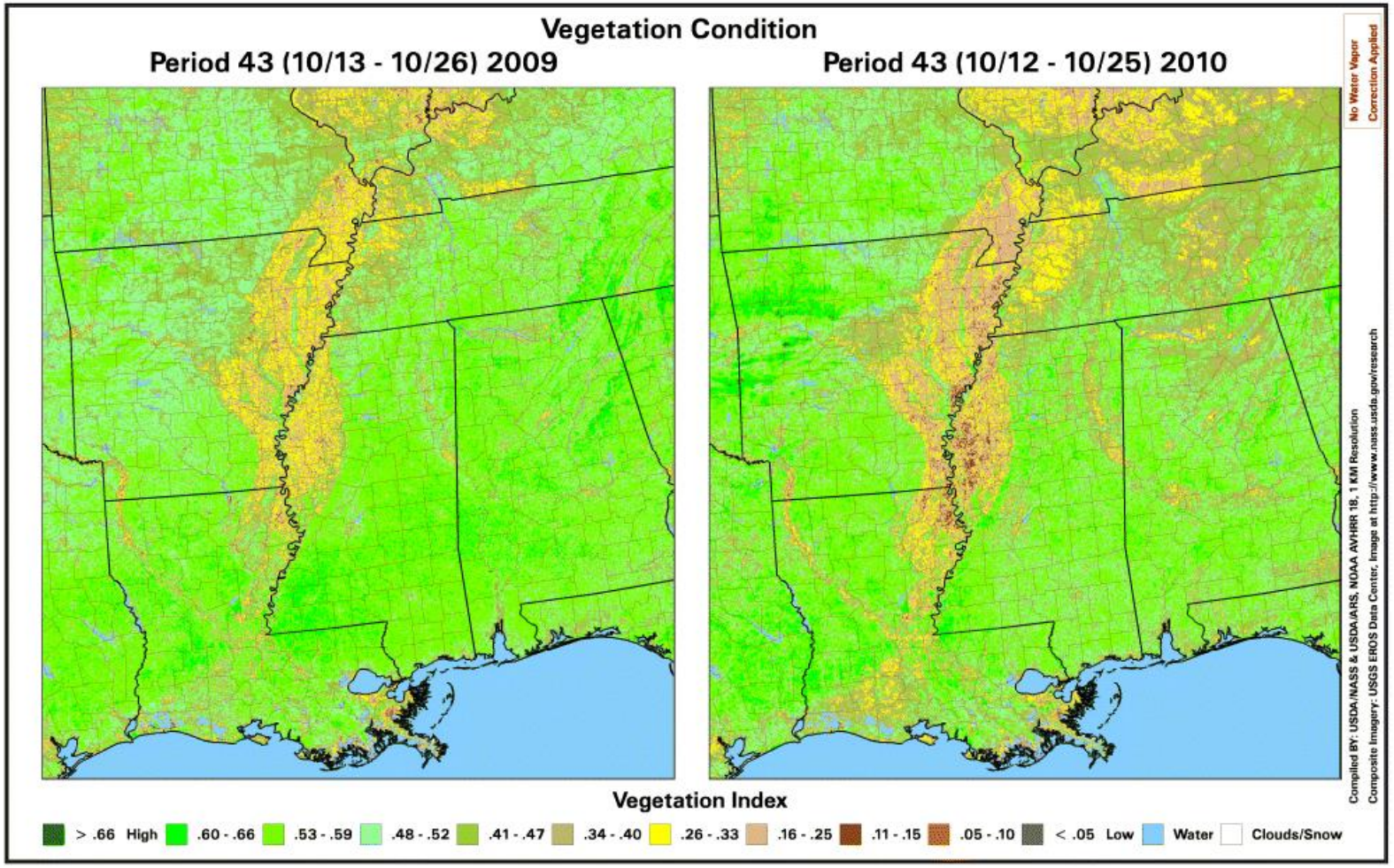


OLD VEGETATION MONITORING

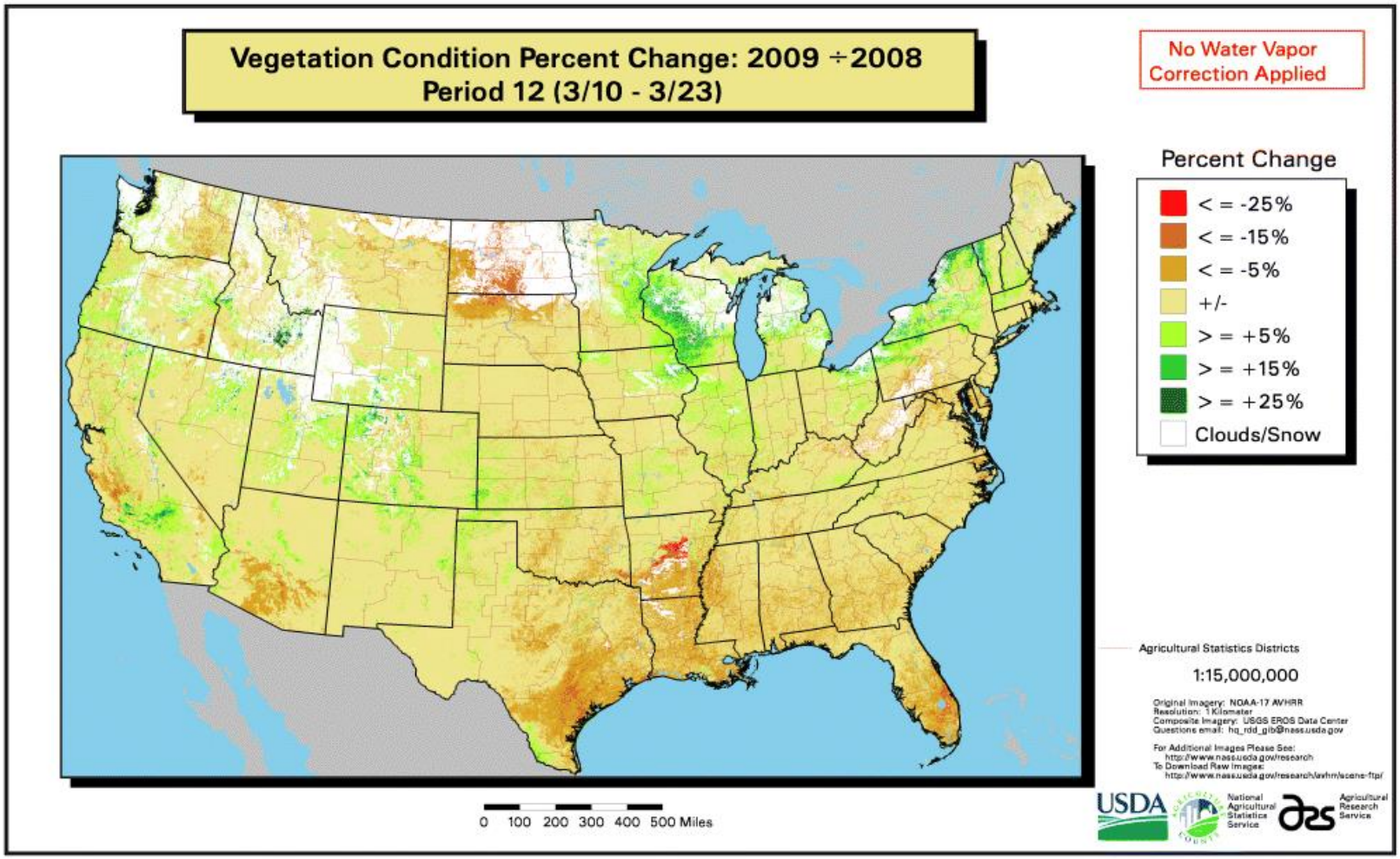
Static Crop Condition Image (NDVI)



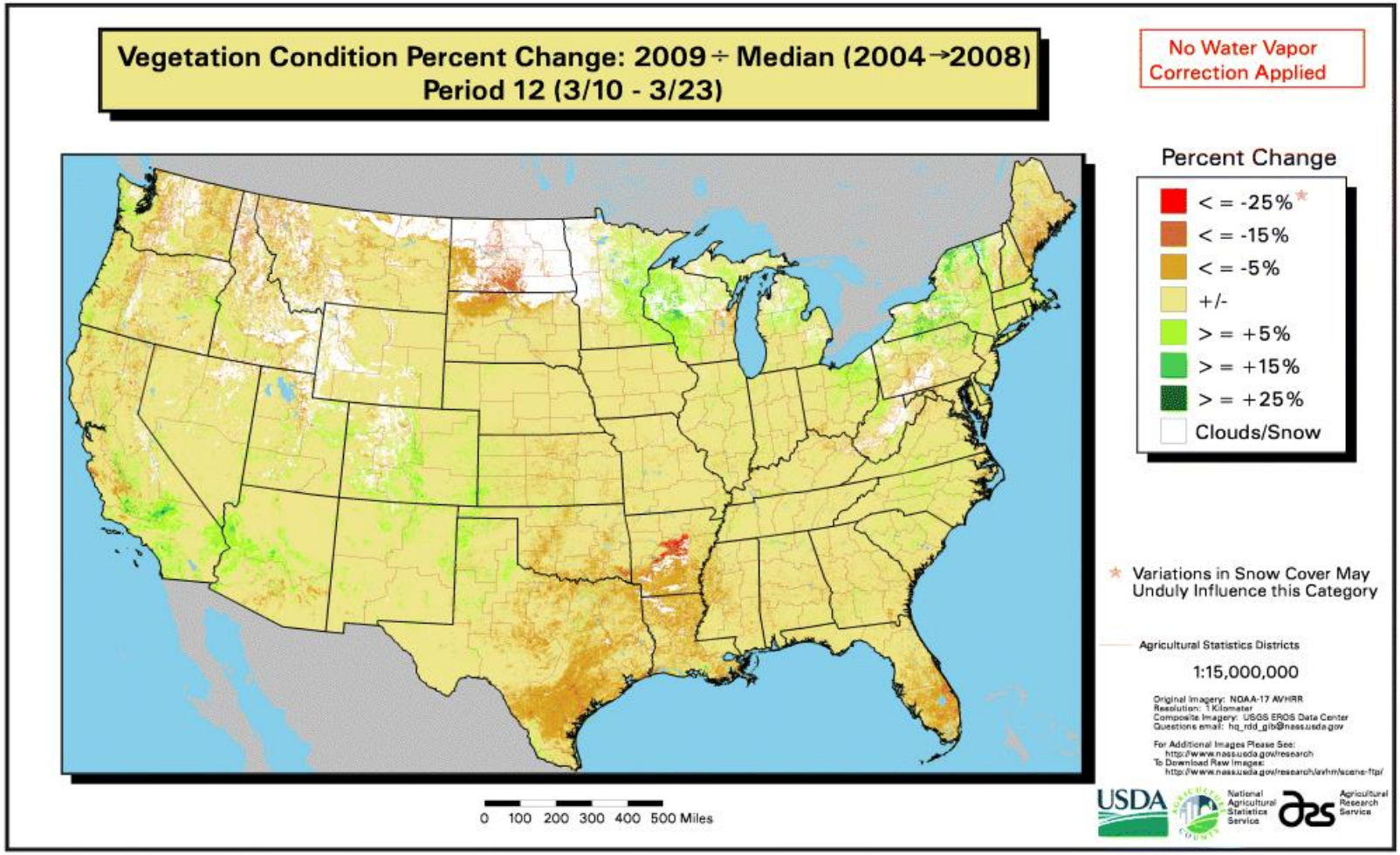
Yearly Comparison (Ratio to Previous Year)

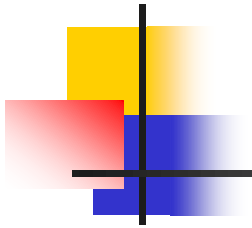


Ratio Comparison to Previous Year in Percent



Percent Change Ratio to Median





VegScape Design & Implementation

Data Sources for Crop Condition

- USDA NASS CDL & historical crop progress data
- USDA FSA CLU & 578 Administrative data
- NASA MODIS products
  - Surface reflectance – NDVI & other ;
  - Leaf Area Index (LAI), Fraction of Photosynthetically Active Radiation (fPAR), and Land Surface Temperature (LST), etc.
- Other NASA remote sensing data
  - Preciptation - Tropical Rainfall Measuring Mission (TRMM) & others
  - Soil moisture - 25-km global soil moisture derived from Aqua AMSR-E
- NOAA weather data

User's Major System Requirements

- Interactive vegetation condition mapping.
- Pixel level granularity.
- On-the-fly data processing and presentation.
- Online analytics within user defined region.
- Geospatial query capability.
- Crop specific vegetation condition information.
- Equal accession and dissemination via spatially enabled Web-based system to facilitate equal information access.

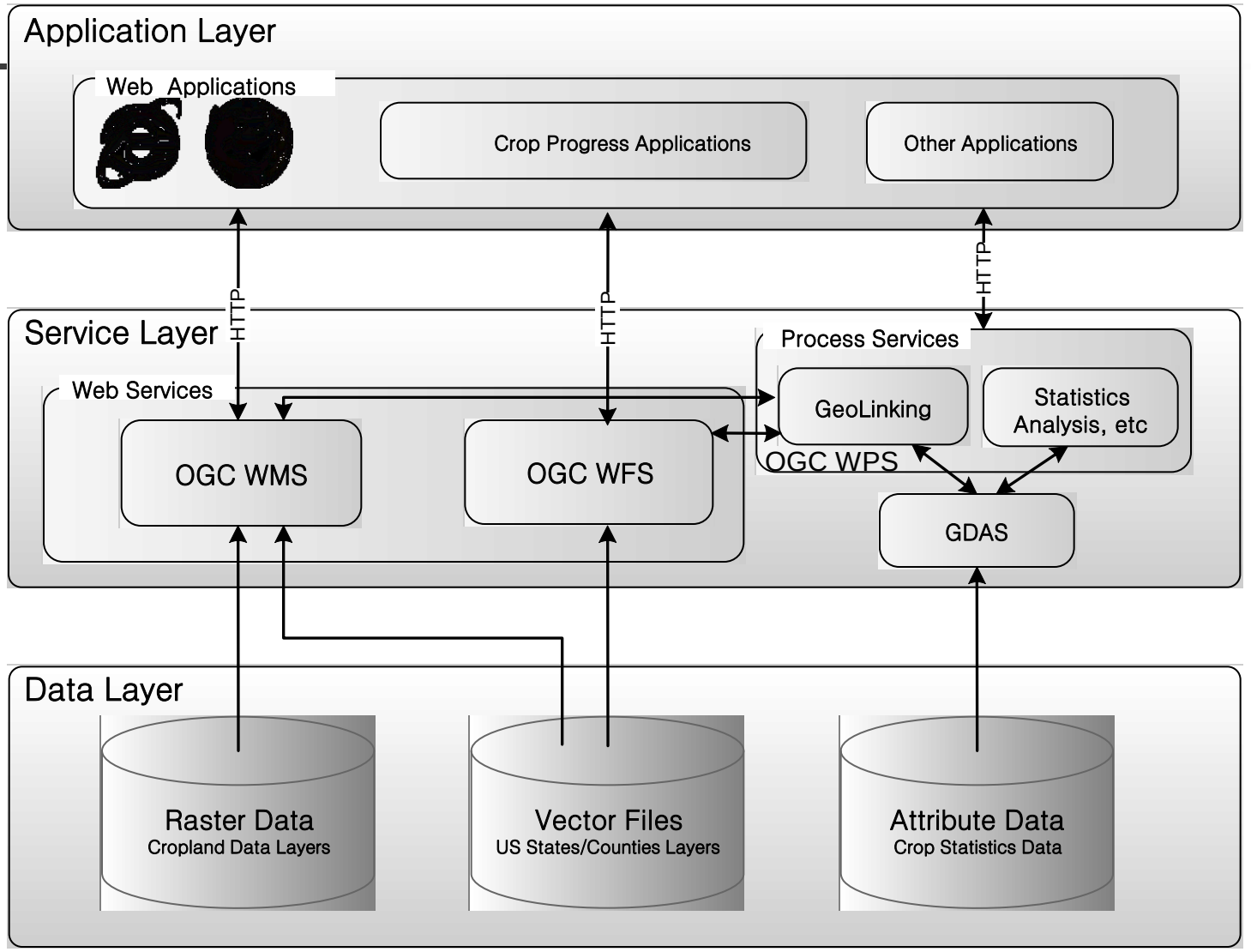
New Vegetation Condition Monitoring System - VegScape

- Different sensor - MODIS
  - Daily repeat => weekly composite
  - 250 meter spatial resolution;
  - Rich cloud pixel information and better preprocessing;
- GIS technology provides
  - Web-based interactive mapping
  - Various online capabilities: online navigation, zooming, panning, downloading, or on-the –fly processing, online statistics, data profiling, etc.
- VegScape provides
  - Data retrieving and processing automation
  - Web publishing and dissemination automation
  - Irregular, ad-hoc data retrieving and processing for emergency assessment or reporting
  - Objective historical data comparison for vegetation condition assessment
  - Various vegetation condition metrics;
  - Crop land focused, or even crop specific monitoring;
- VegScape reuses the same geo-information technology as CropScape

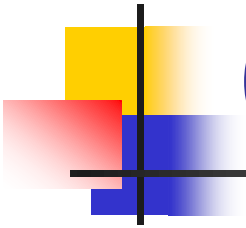
Considerations of Architecture Design and Technology

- Web Based Service Oriented Architecture
- OGC standard compliant web services:
  - Web Feature Service (WFS), Web Map Service (WMS), Web Processing Service (WPS), Sensor Observation Service (SOS), etc.
- Service Integration
  - Support of workflows: Business Process Execution Language (BPEL), BPEL execution engine
  - Re-use services published in WPS
- Re-use functions/algorithms already developed

Service-Oriented Architecture (SOA)



Service-Oriented Architecture (SOA)



- Integrates data through interoperable services into decision support information (reports, tables, views, charts, maps etc.)
  - Open Architecture
  - Interoperable at organizational levels
  - Comprehensive Standard API
  - Accessible through HTTP
  - Scalable, Robust, and Reusable

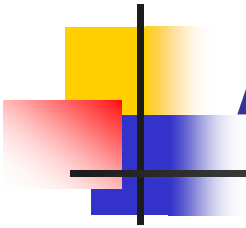
Service Layer - OGC Compliant

- Implement all web services to fulfill various tasks such as data retrieving, visualization, query and dissemination
- Web Feature Service (WFS) server
  - Serves vector files, attribute data
- Web Map Service (WMS) server
  - Handles the map data rendering and manipulation
- Web Processing Service (WPS)
  - Implements various application functionalities such as downloading, on-line analytics, data visualization, etc.
- GeoLinking Service (GLS)
  - Merges geo-linked data based on linking attributes
- Geolinked Data Access Service (GDAS)
  - Implements online access to the vast number of data collections

For each operation defined in these services, **HTTP GET/KVP (Key-value pair) and **HTTP POST/XML** are supported

Data Layer

- Vector data files
  - US state, county, ASD or other boundaries
  - Statistical maps
  - Road, water body
- Attribute Data
  - Various associated feature data, e.g. names
- Other Raster data
  - Satellite images in GeoTIFF
  - Crop Mask



Application Layer

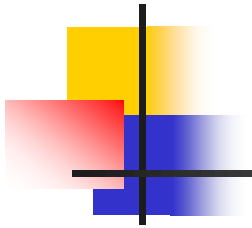
- Browsers – IE, Firefox, Google Earth, etc.
- Interactive map:
  - Geo navigation;
  - Attribute querying;
  - Geospatial querying;
  - On-line analytics;
  - Statistics visualization;
  - …

Server Side (Service Layer)

- Web Server: Apache 2.2 (or WebSphere, IIS, etc.)
- Application Server: Tomcat 6.016
- MapServer
  - An Open Source geographic data rendering engine written in C
  - A platform for publishing spatial data and interactive mapping applications to the web
  - Open source software originally developed in the mid-1990's at the University of Minnesota
  - Runs on all major platforms (*Windows*, *Linux*, *Mac OS X*);
  - Support for popular scripting and development environments - PHP, Python, Perl, Ruby, Java, and .NET
  - Support OGC standards - WMS (client/server), non-transactional WFS (client/server), WMC(Web Map Context), WCS, Filter Encoding, SLD(Styled Layer Descriptor), GML, SOS(Sensor Observation Service), OM (Observation & Measurements Standard), etc.
  - A multitude of raster and vector data formats -TIFF/GeoTIFF, EPPL7, *ESRI shapfiles*, *PostGIS*, *ESRI ArcSDE*, *MySQL* *etc.*
  - Support on-the-fly map projections

Client Side (Web Map Application)

- OpenLayers
  - Easily puts a dynamic map in any web page
  - Display map tiles and markers loaded from any source
  - Display map data in most modern web browsers
  - No server-side dependencies
  - Free open source originated from MetaCarta
  - Pure JavaScript library (JavaScript API)
  - OGC Web Mapping Service (WMS) and Web Feature Service (WFS) protocols implemented
  - Released under a BSD-style License
  - Information: http://openlayers.org/



Data Processing

Vegetation Condition Indices

$$NDVI = (IR\text{-}R)/(IR+R)$$

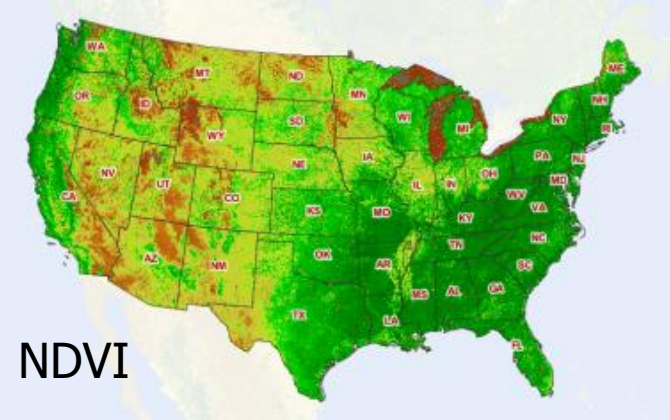
$$MVCI = \frac{NDVI(x,y) - NDVI_m(x,y)}{NDVI_m(x,y)} \times 100$$

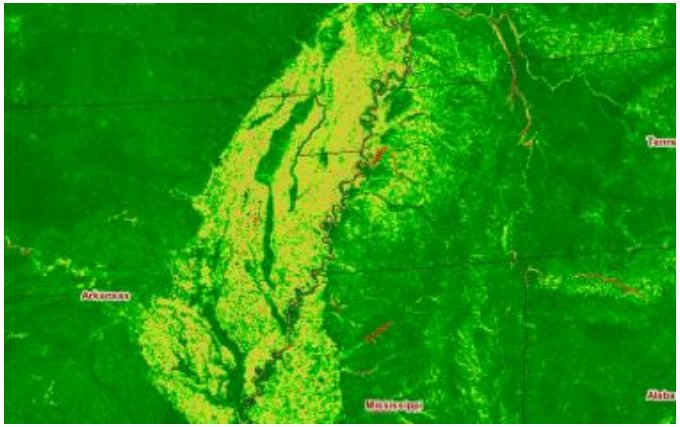
$$RMVCI = \frac{NDVI_i(x,y) - NDVI_{med}(x,y)}{NDVI_{med}(x,y)} \times 100\%$$

$$RVCI = \frac{NDVI_i(x,y) - NDVI_{i-1}(x,y)}{NDVI_{i-1}(x,y)} \times 100\%$$

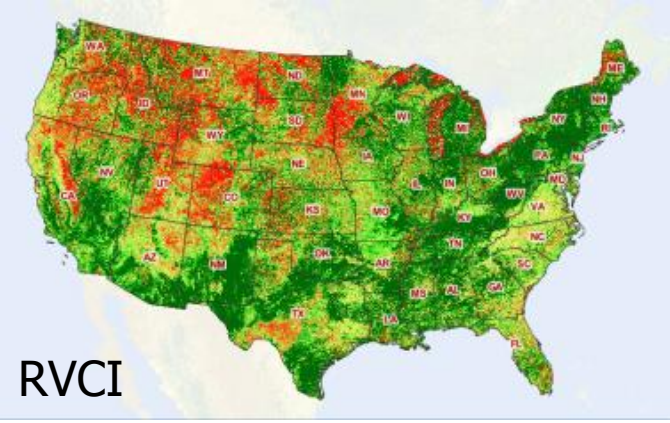
$$VCI = \frac{NDVI(x,y) - NDVI_{min}(x,y)}{NDVI_{max}(x,y) - NDVI_{min}(x,y)} \times 100\%$$

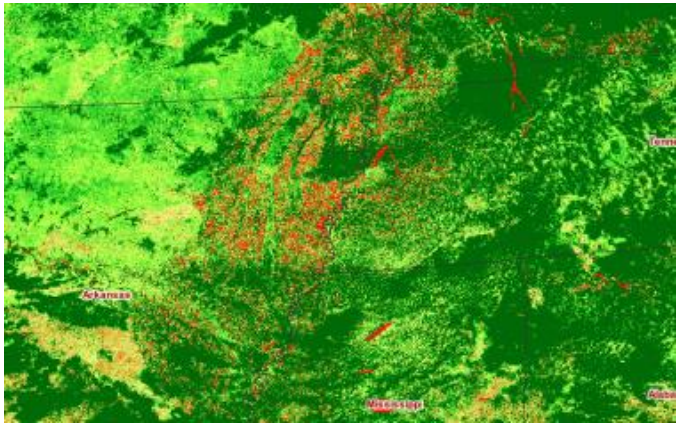
NDVI and RVCI





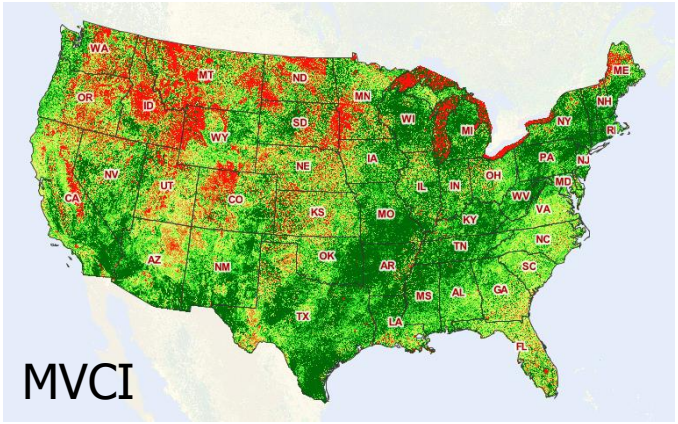
> .88 High
.84 - .87
.78 - .83
.76 - .77
.63 - .75
.55 - .62
.44 - .54
.27 - .43
.09 - .26
.03 - .08
< .03 Low

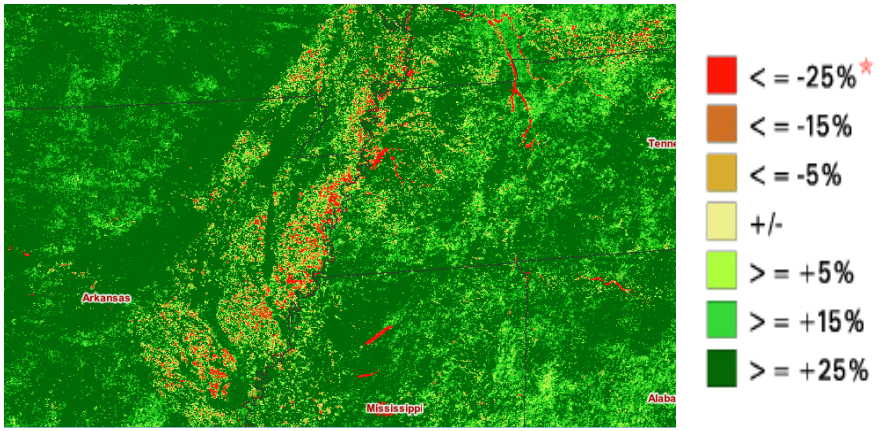


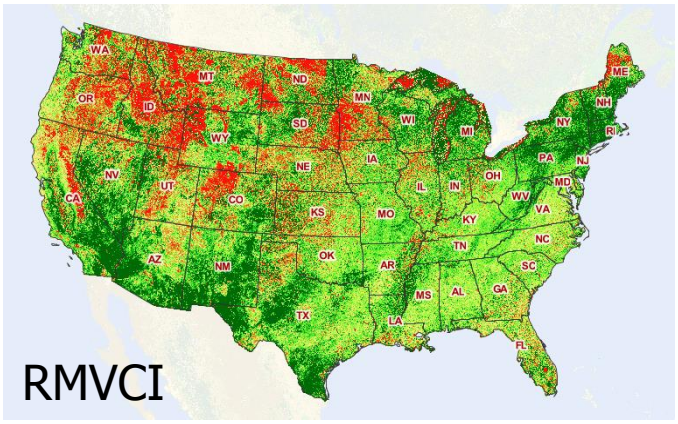


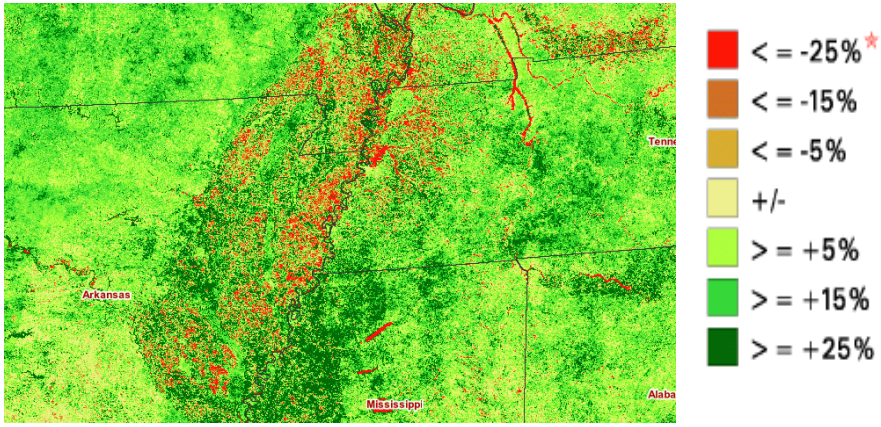
< = -25%*
< = -15%
< = -5%
+/-
> = +5%
> = +15%
> = +25%

MVCI vs RMVCI

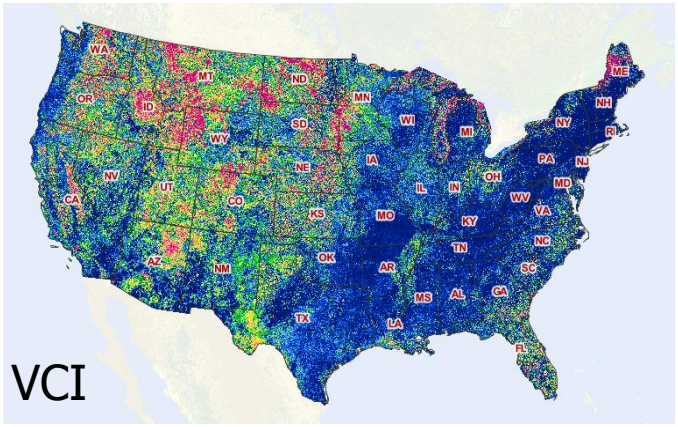


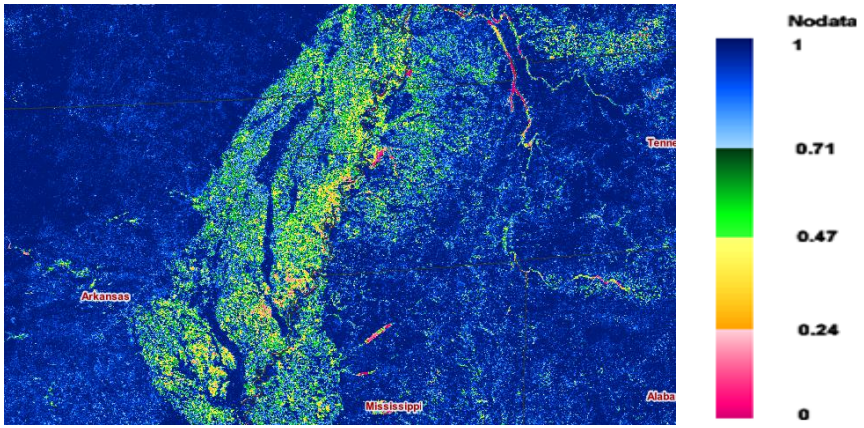




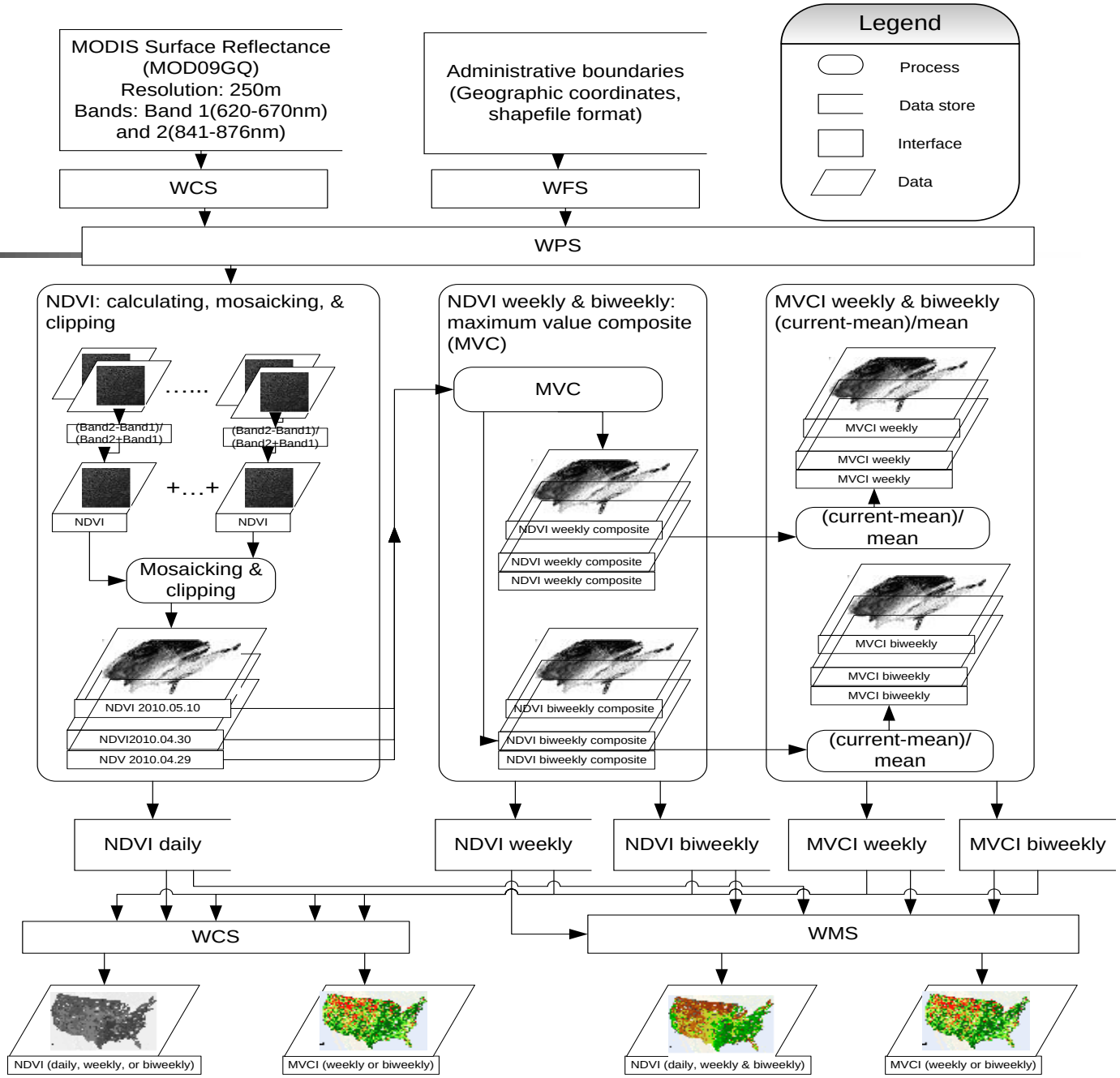


VCI Result


WA
OR
CA
ID
NV
MT
WY
UT
AZ
CO
NM
ND
SD
NE
KS
OK
TX
MN
IA
MO
AR
LA
WI
IL
MS
MI
IN
KY
TN
AL
OH
WV
GA
FL
SC
NC
VA
PA
NY
MD
NJ
NH
ME
RI
VCI


Arkansas
Mississippi
Nodata
1
0.71
0.47
0.24
0

Data processing

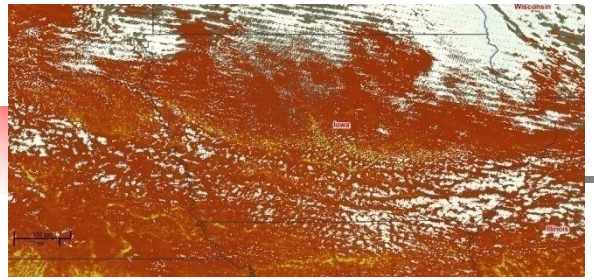


Data processing flow for vegetation index calculation.

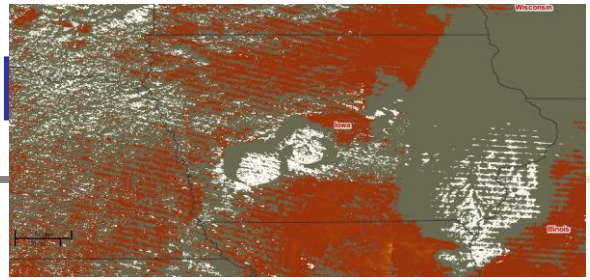
Maximum Value Composition algorithm (1/3)

- Maximum Value Composition (MVC) is one of the most popular algorithm to composite time series NDVI from daily to weekly, biweekly, or monthly
- Pro
  - Keep the upper envelope of the NDVI value
  - Reduce the effect of cloudiness, fog, or moisture to some degree
  - Simple to implement
- Con
  - Not sure which date is picked up as the final NDVI value to represent that period: cross-period comparison may be problematic, especially for crop during its growing season

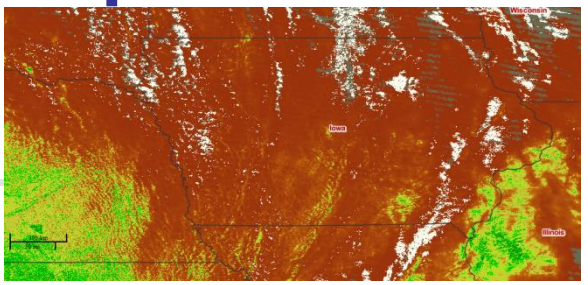
Maximum Value Composition



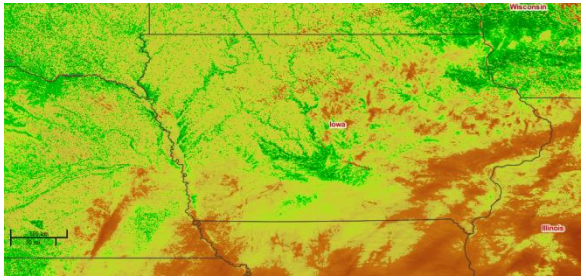
May 11



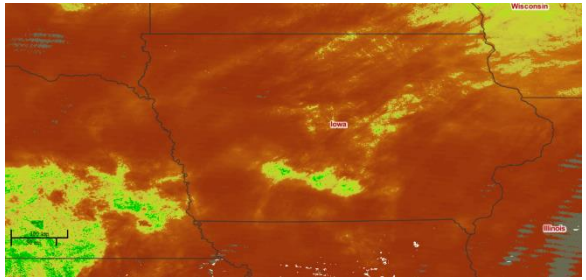
May 12



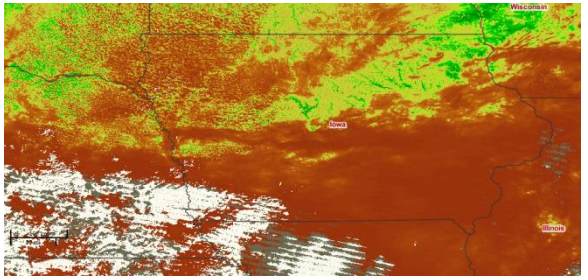
May 13



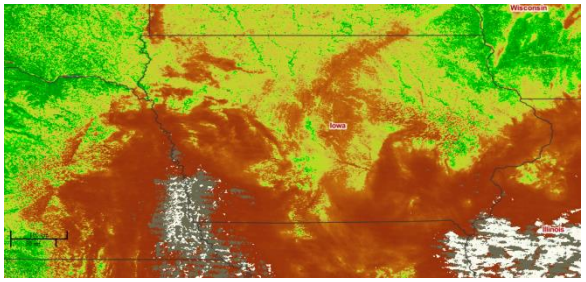
May 14



May 15

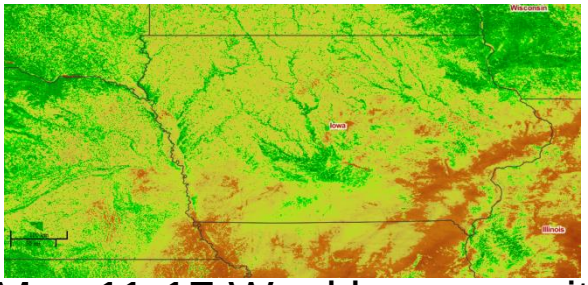


May 16



May 17

MVC Compositing

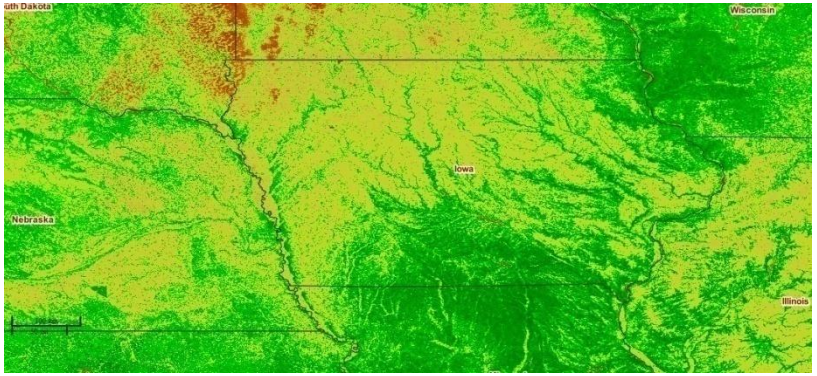


May 11-17 Weekly composite

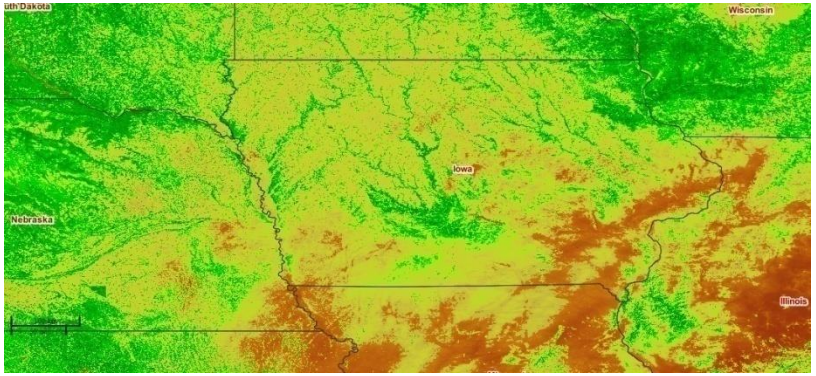
- Example process: Iowa, May 2010

Maximum Value Composition algorithm (3/3)

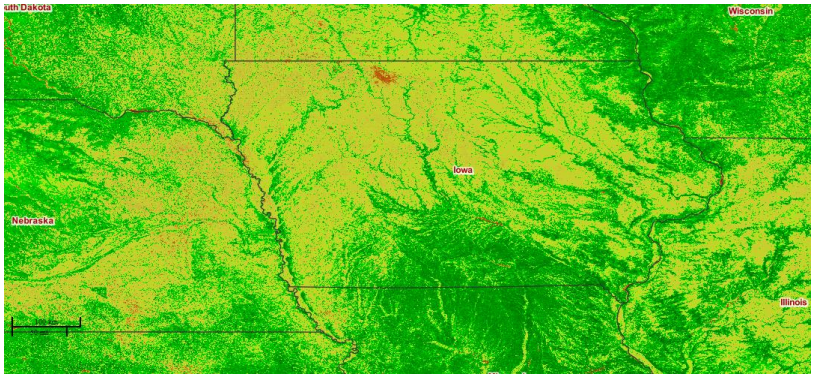
- More example MVC results for Iowa, May 2010



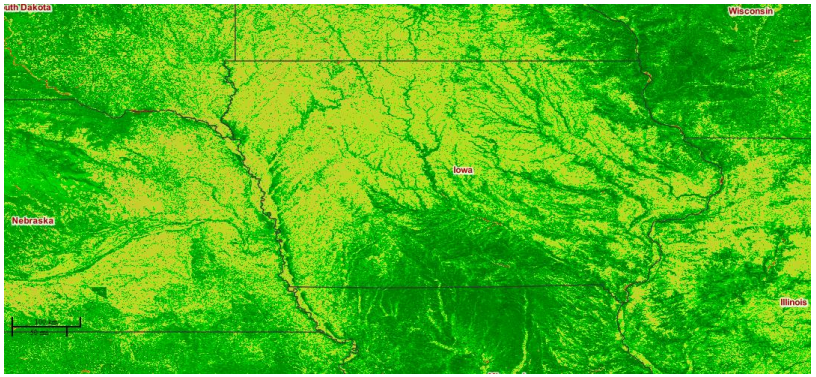
May 4-10 weekly NDVI composite



May 11-17 weekly NDVI composite



May 18-24 weekly NDVI Composite



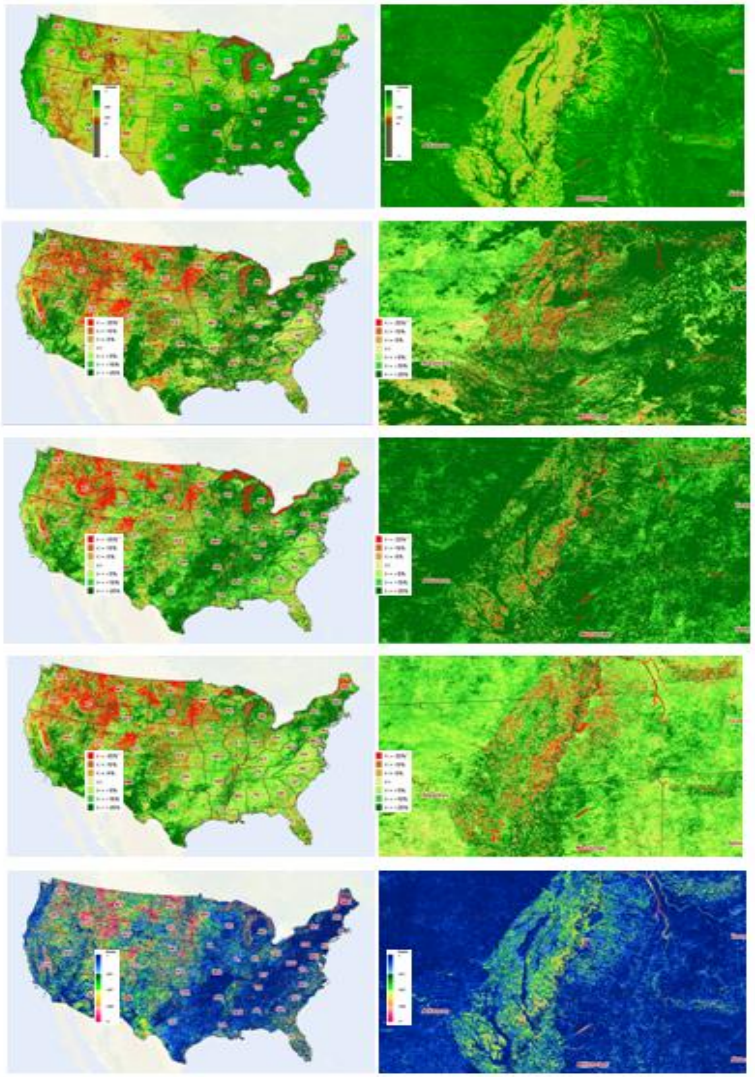
May 18-24 weekly NDVI Composite

Smoothing – moving median filtering

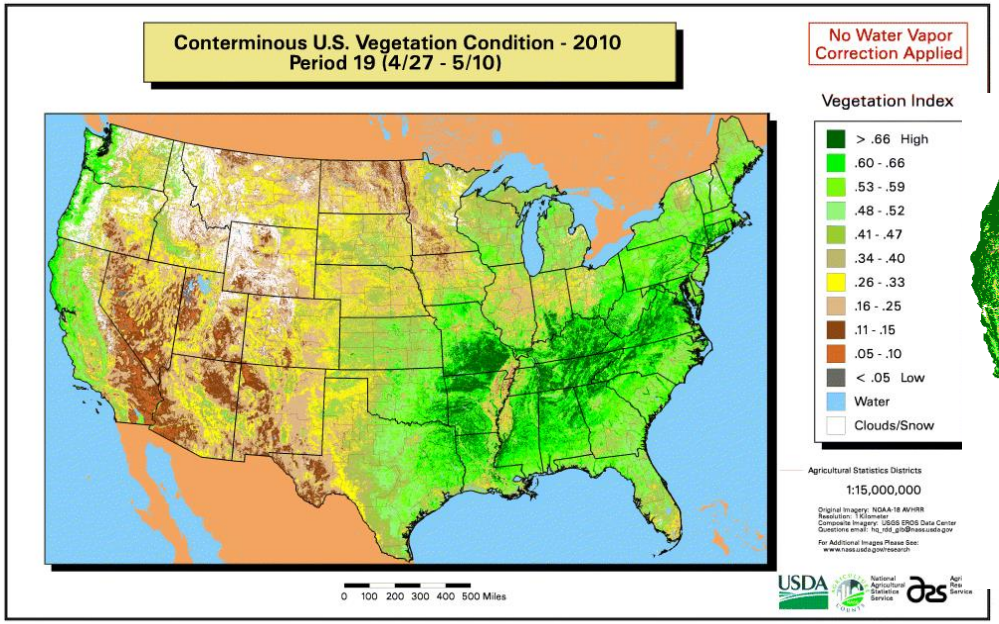
- Replace each value with the median of a period centered around the point in the time series
- Pro
  - Easy to implement
  - Partially filter out the bad values (contaminated pixels due to fog, cloudiness, or aerosols)
- Con
  - Not keep up the upper envelope
  - Not sure the value of which date is eventually used: the similar effect as MVC

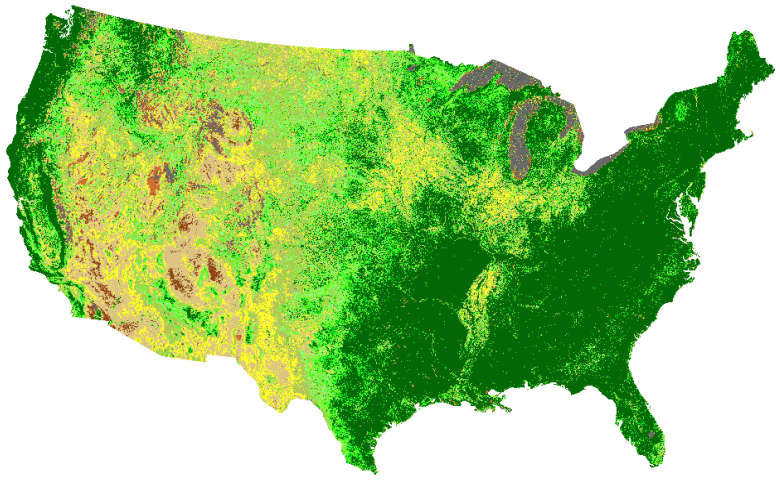
Evaluating different indices for assessing crop condition

- Indices: from top to bottom shown the index NDVI, RVCI, MVCI, RMVCI, VCI for first week weekly composite of May 2010; the left column illustrated vegetation condition indices of US conterminous states and the right column displayed the corresponding zoomed-in Mississippi delta area
- The observations from the zoomed-in Mississippi delta area, as shown in right column of the figure, indicate that the NDVI ratio to the previous year RVCI shows the biggest vegetation dynamics and sensitivity to the vegetation condition change as expected
- The proposed vegetation condition index MVCI shows the best vegetation condition with respect to ten years of historical average while the RMVCI shows overall relatively poor vegetation condition with respect to the historical median.



Radiometric Difference between AVHRR and MODIS





AVHRR NDVI

MODIS NDVI

MODIS NDVI after Calibrated with AVHRR

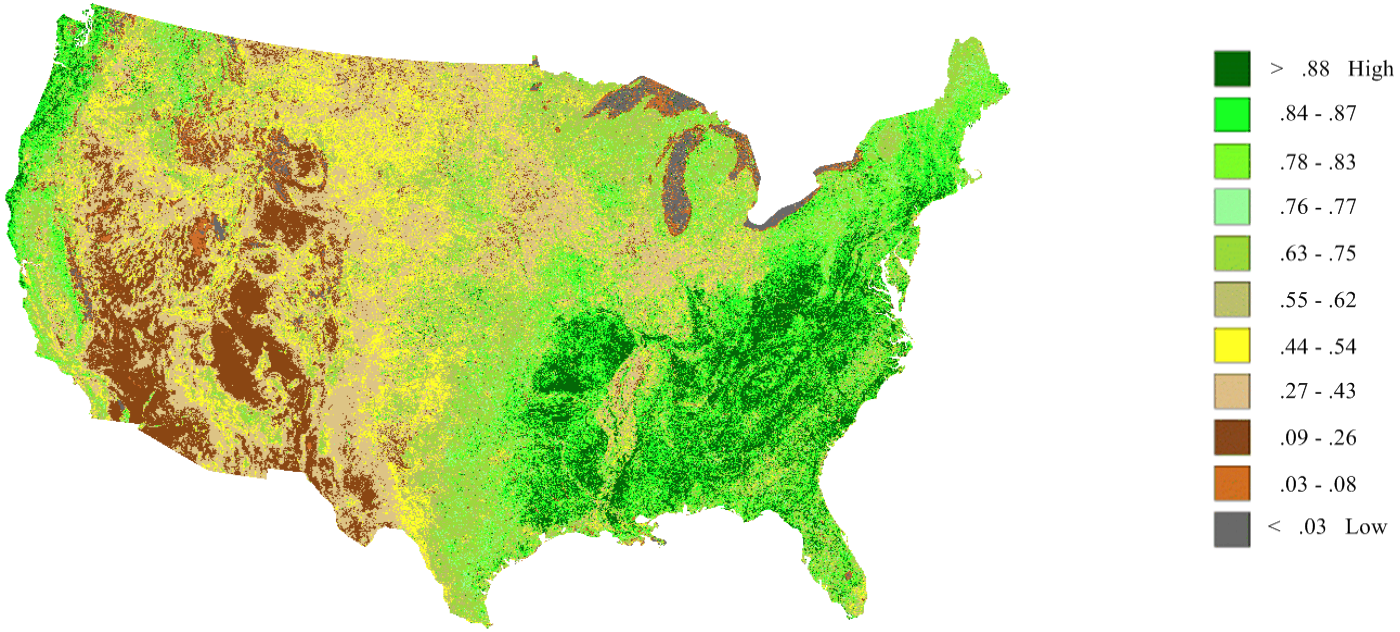
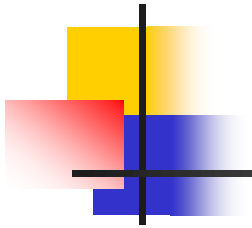
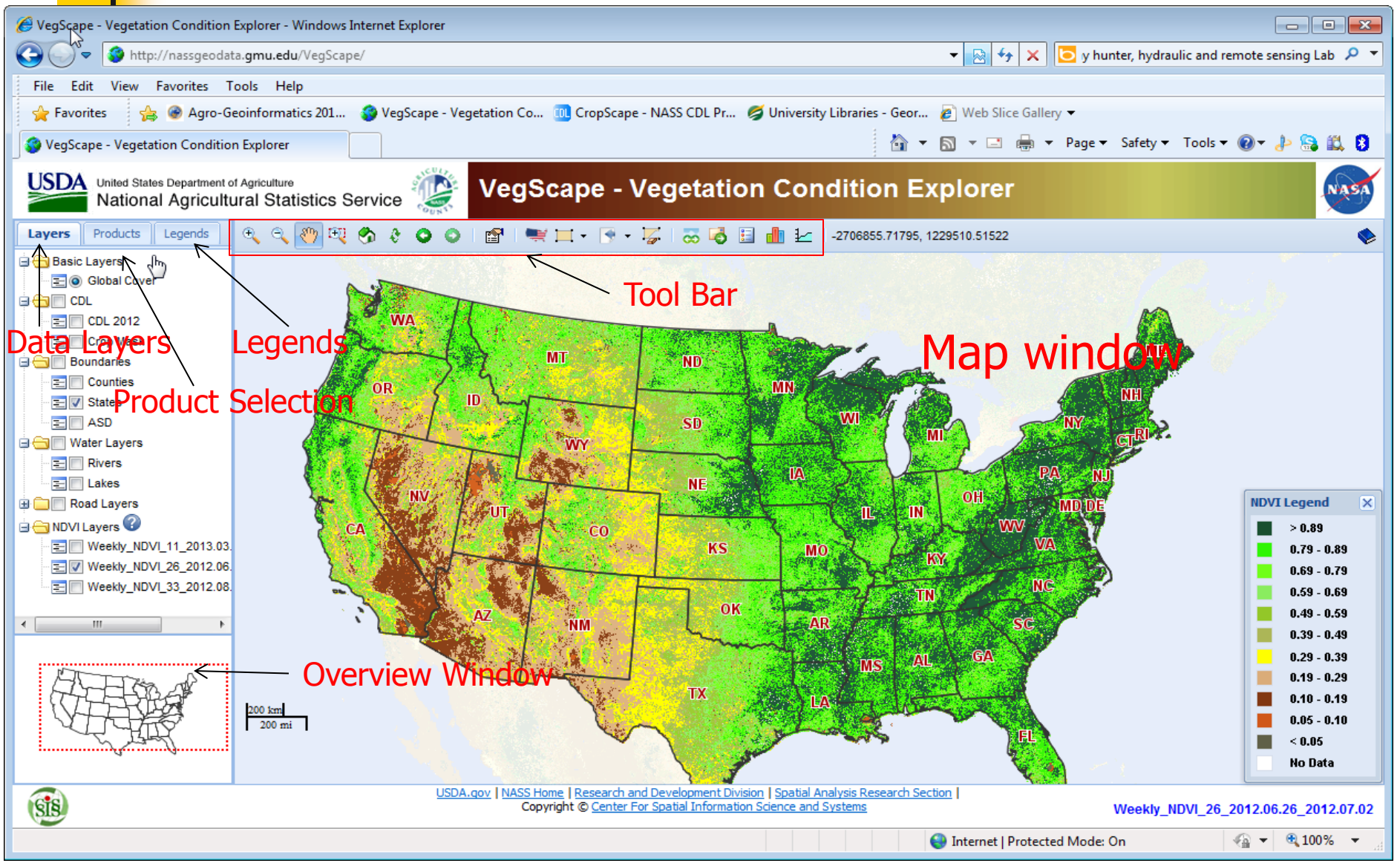


Figure 2. Indirect radiometric difference between AVHRR and MODIS sensors; (a) current NASS biweekly NDVI composite thematic map from AVHRR; (b) biweekly NDVI composite thematic map from MODIS with the same legend; (C) biweekly NDVI composite thematic map from MODIS with NDVI value calibration with AVHRR (displayed with different legend).



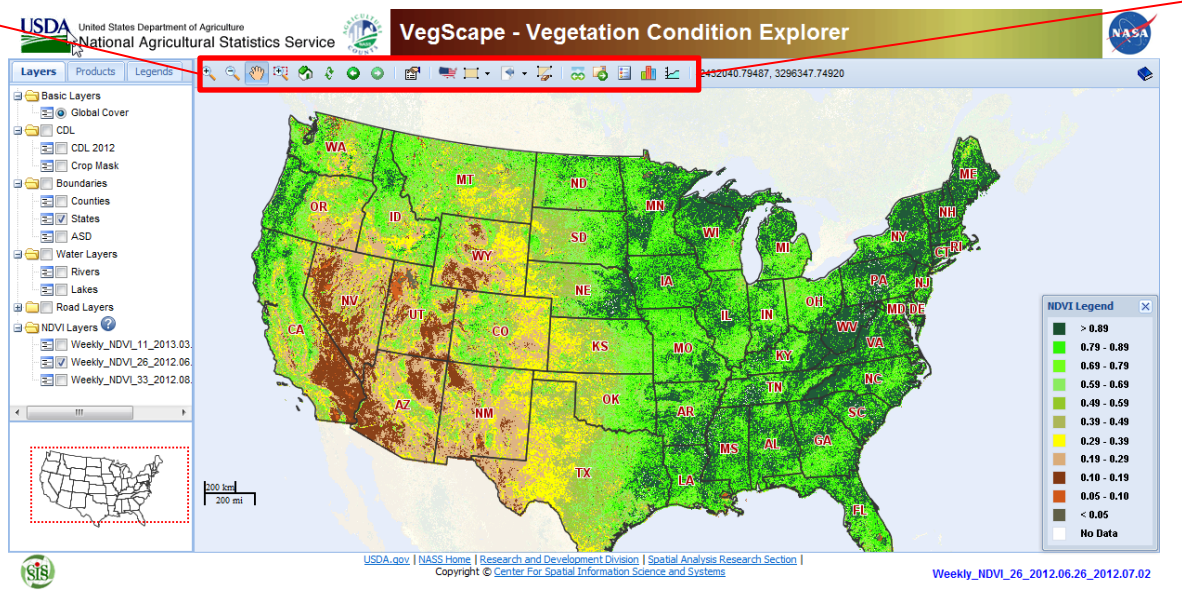
VegScape Client Interface

VegScape – Browser Client

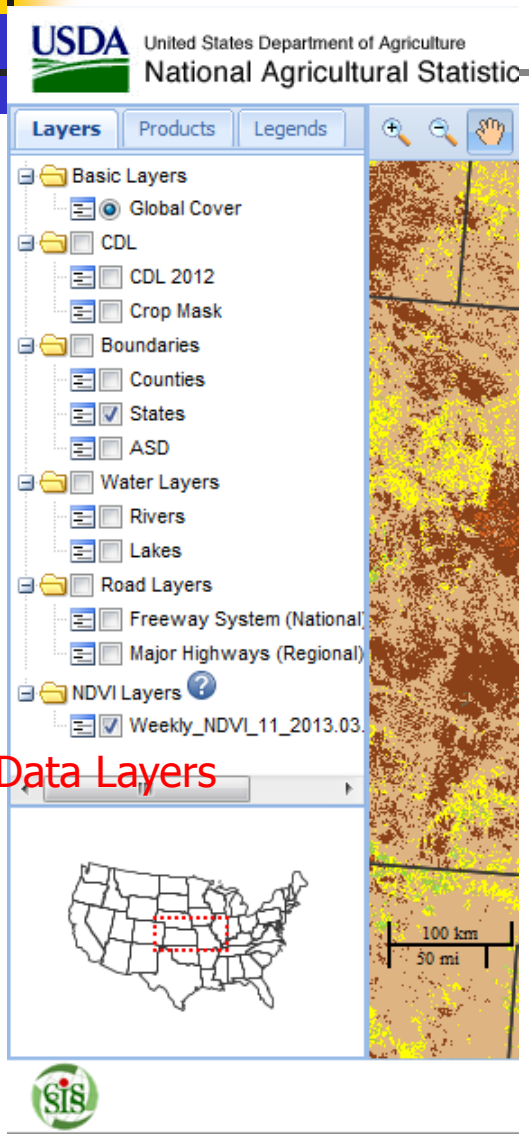


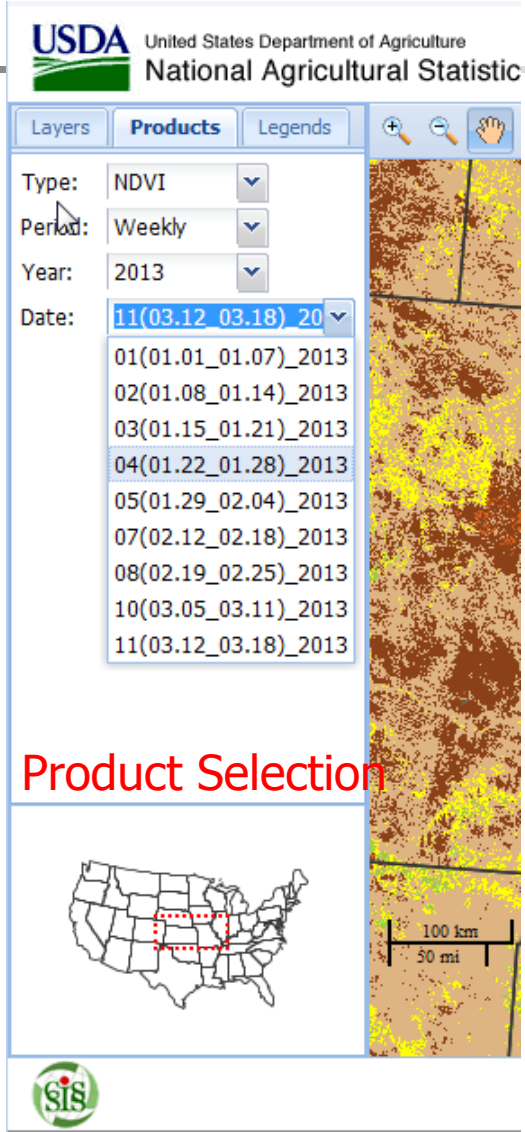
VegScape – Tool Bar

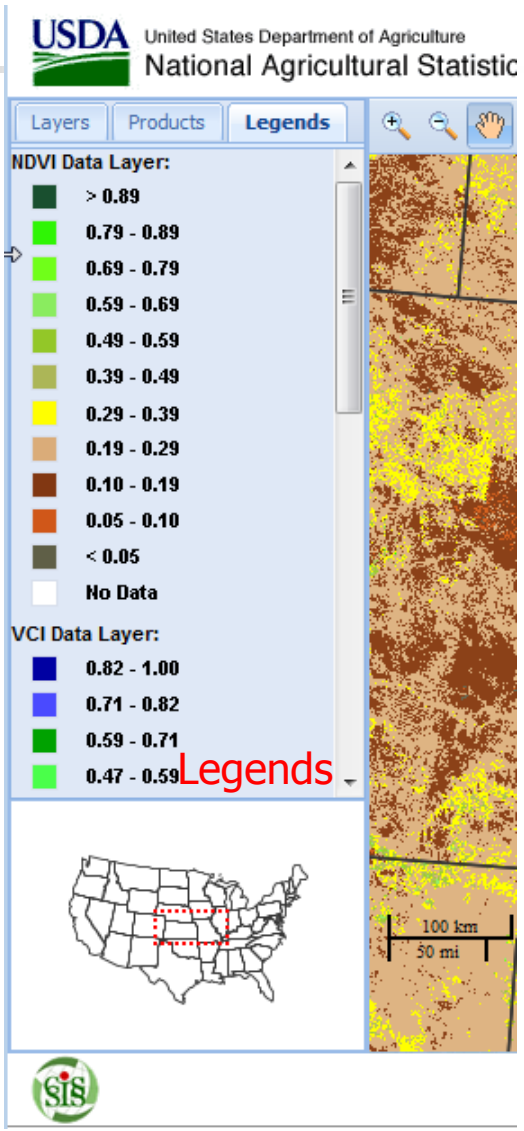
Zoom in
Zoom out
Pan
Drag zoom
Home
Refresh
Previous View
Next view
Identify pixel value
Define state/county AOI
Define rectangle AOI
Import AOI
Swipe layer
Download AOI
Clear AOI
Show/hide legend
Statistics
Profile

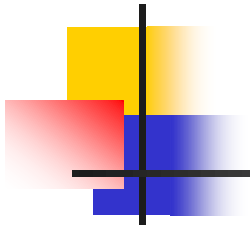


VegScape – Layers, Products and Legends



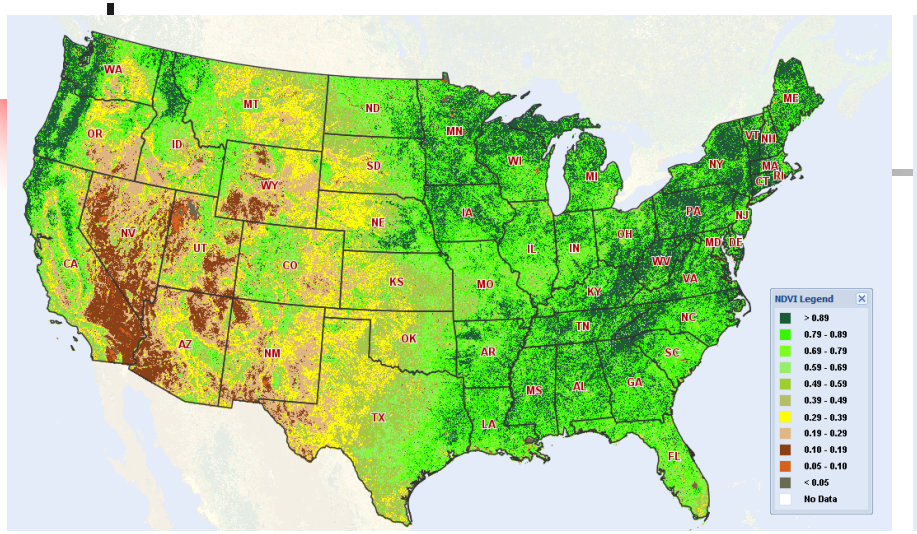




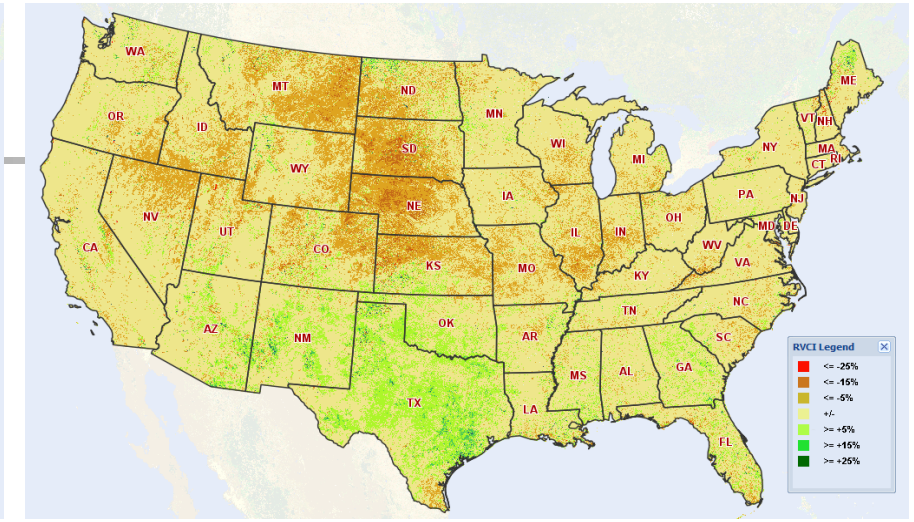


VegScape Function Highlight

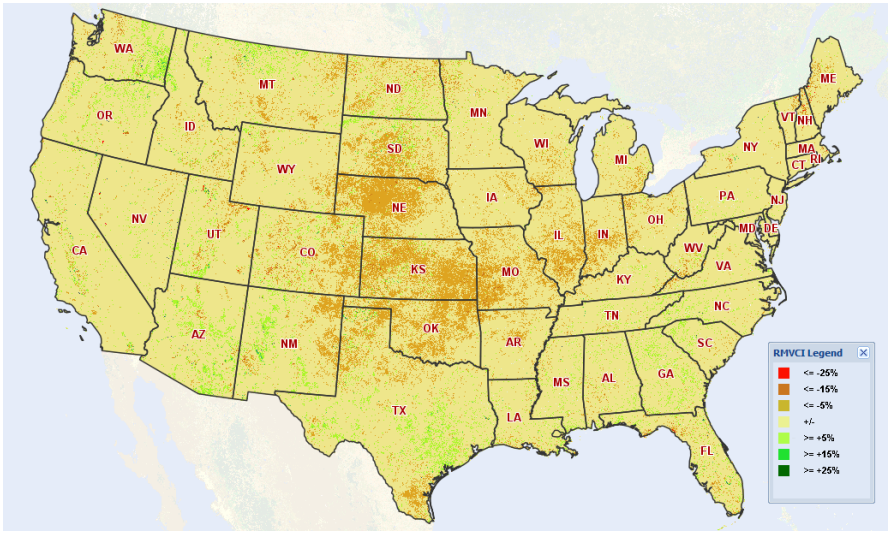
Weekly Vegetation Indices 07/24/12 – 07/30/12



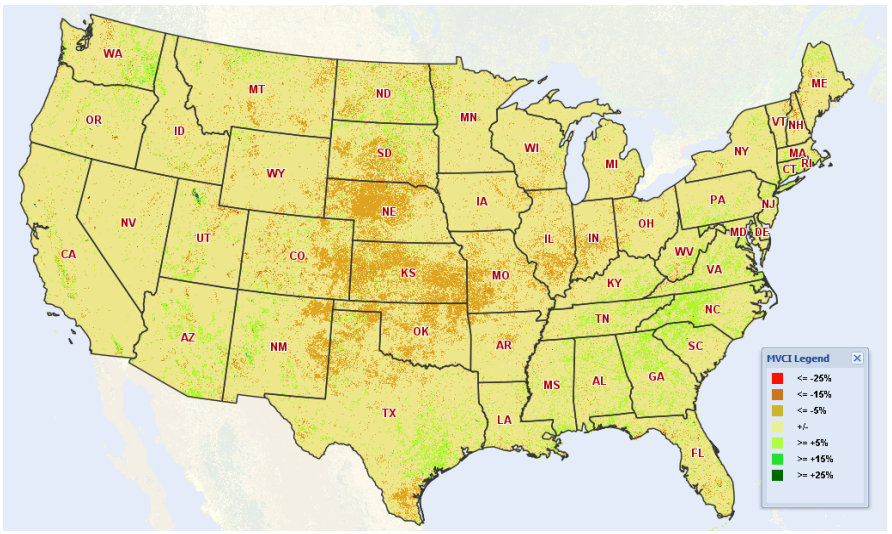
NDVI



NDVI Ratio to Previous Year



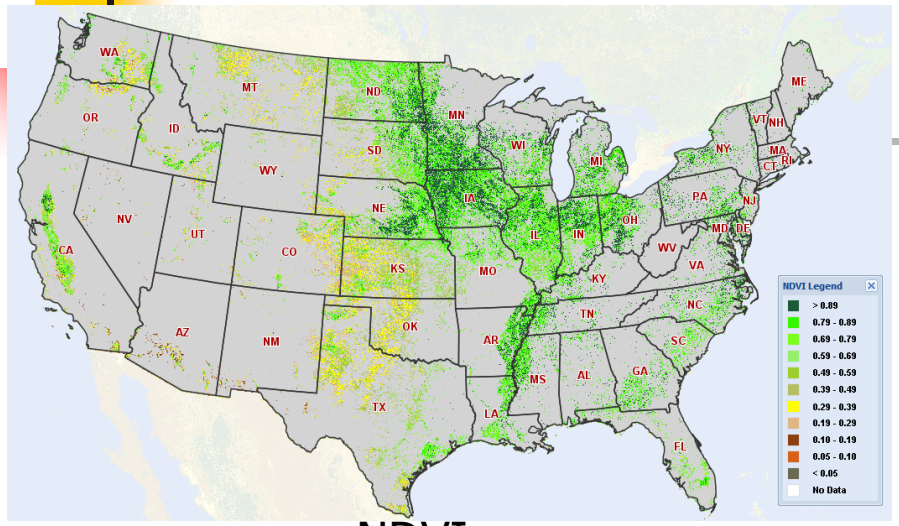
NDVI Ratio to Median



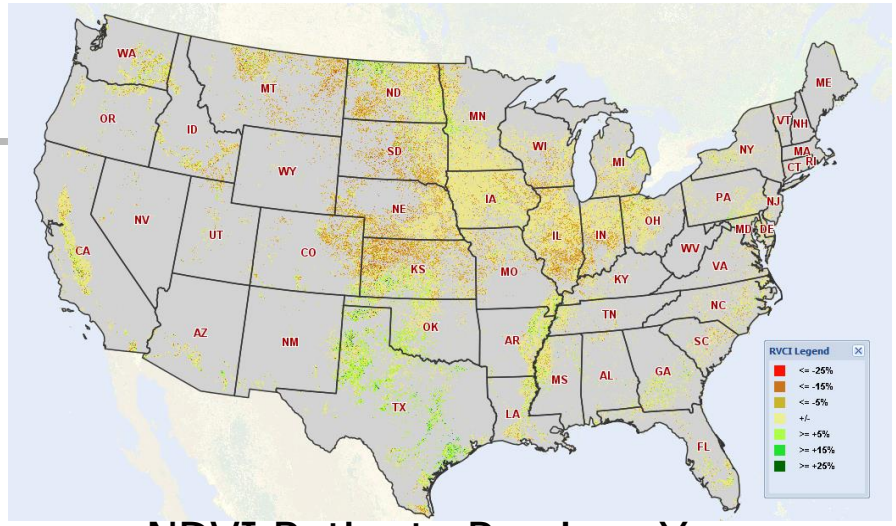
NDVI Ratio to mean

Weekly Vegetation Indices 07/24/12 – 07/30/12

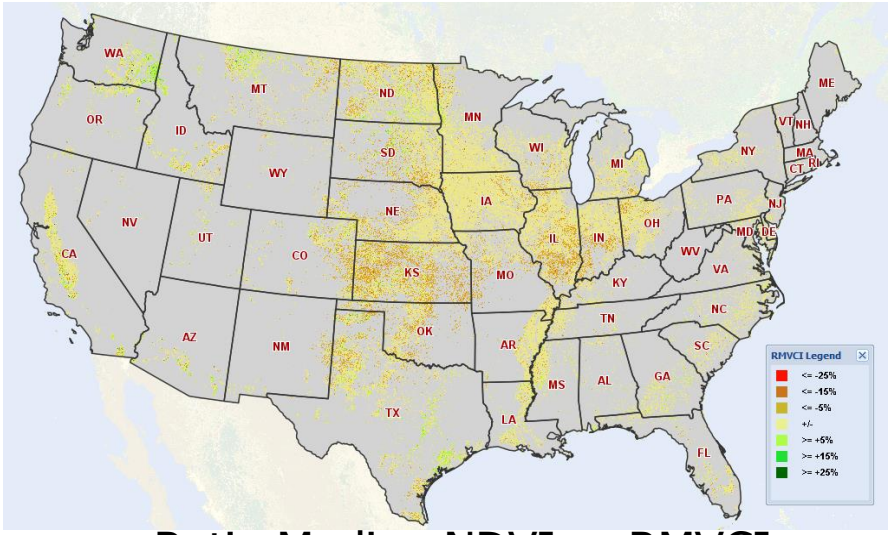
Crop Mask Applied



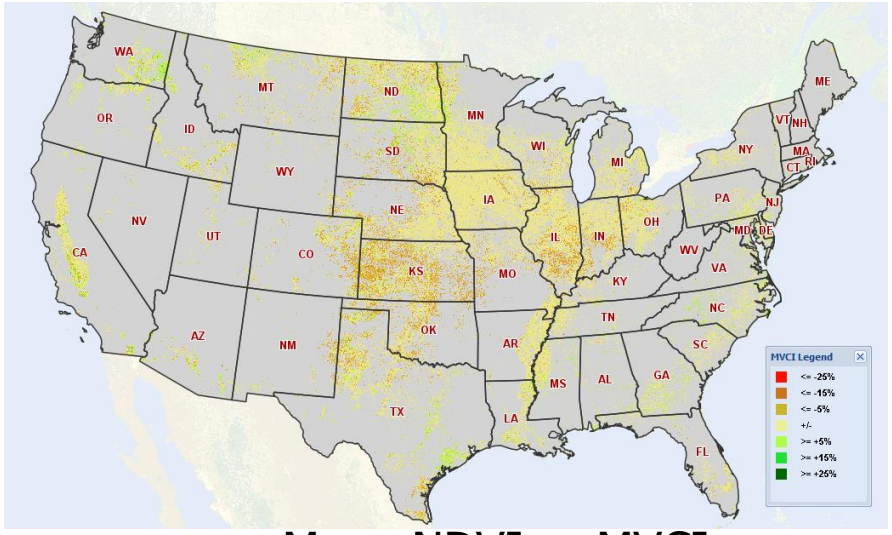
NDVI



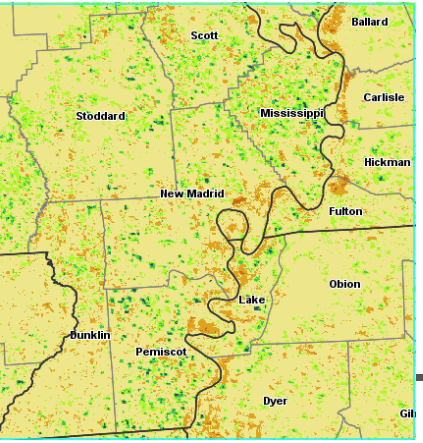
NDVI Ratio to Previous Year



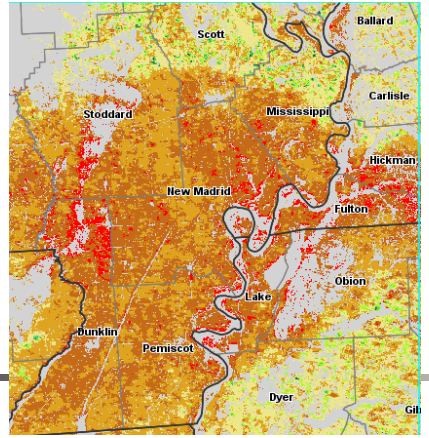
Ratio Median NDVI or RMVCI



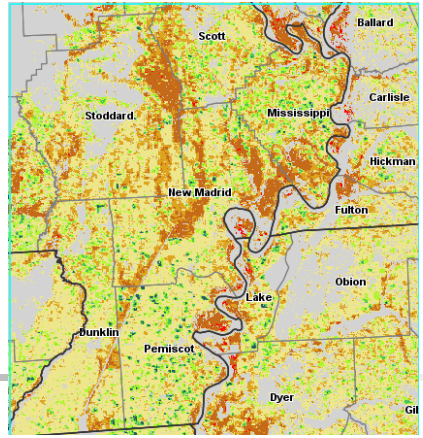
Mean NDVI or MVCI



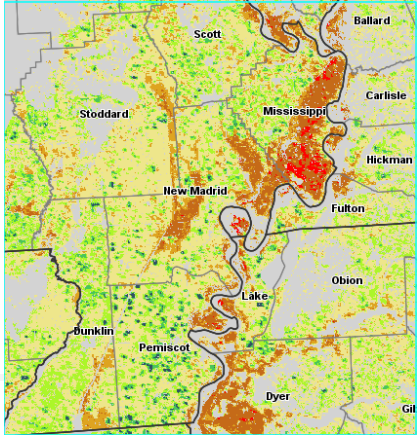
04/12-04/18/11



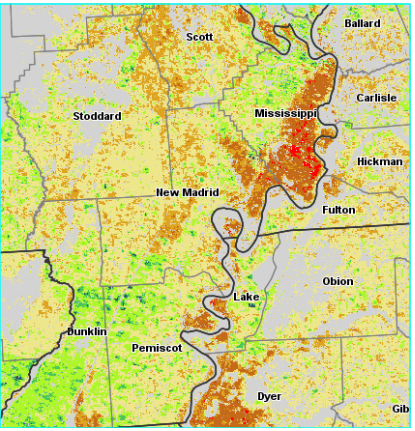
04/19-04/25/11



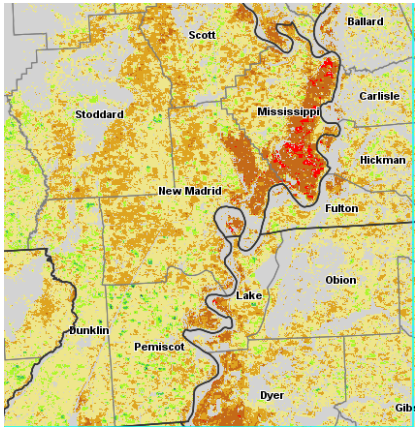
04/26-05/02/11



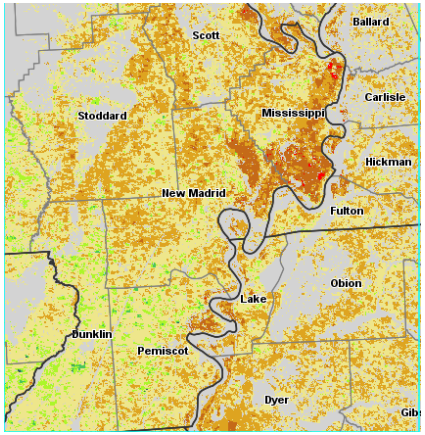
05/03-05/09/11



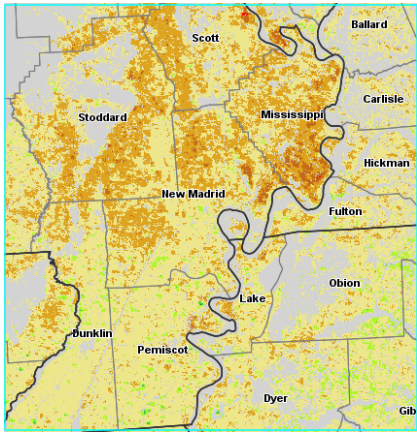
05/10-05/16/11



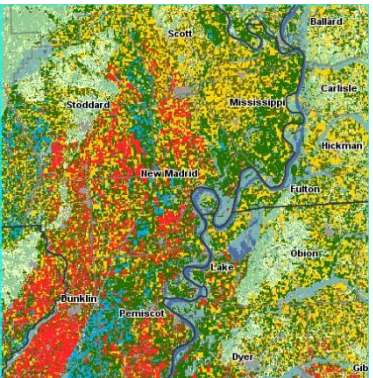
05/17-05/23/11



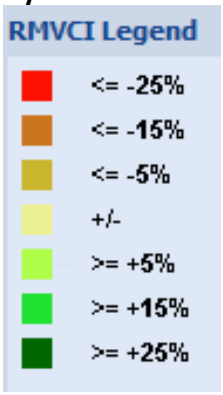
05/24-05/30/11



05/31-06/06/11

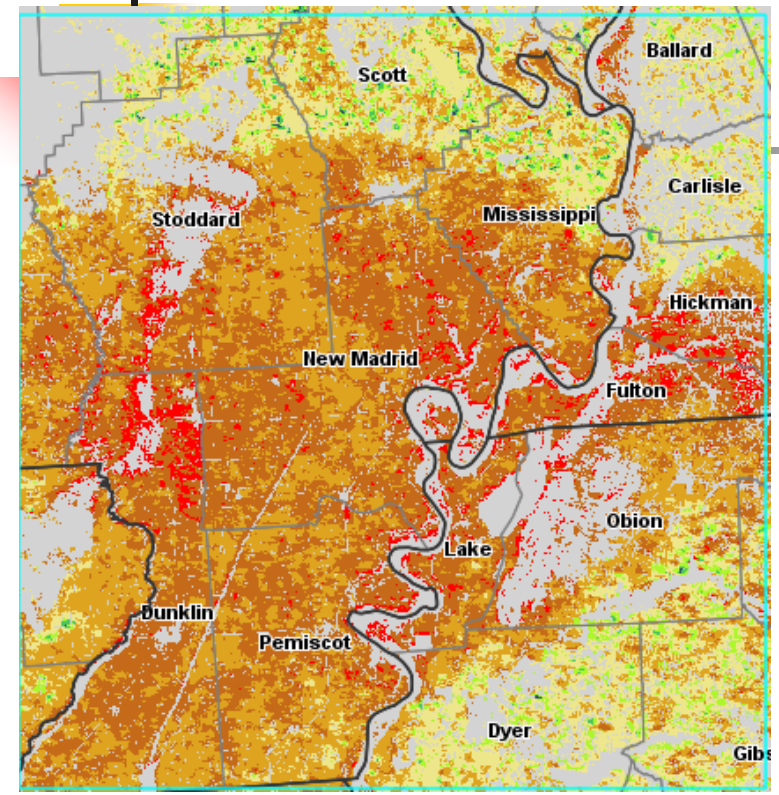


Cropland Data Layer



2011 Flood Missouri Bootheel NDVI Ratio to Median (Median of 10 years NDVI)

AOI Statistics - Ratio to Median VCI

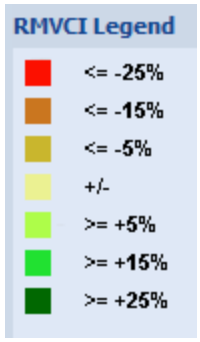


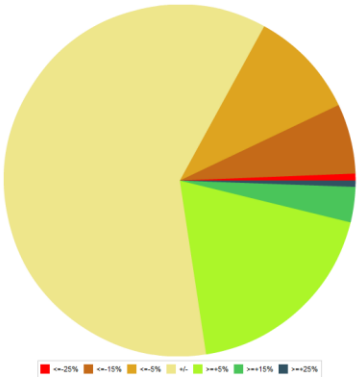
Weekly_RMNDVI_18_2011.05.03_2011.05.09 Data Layer Statistics for the Defined Area of Interest

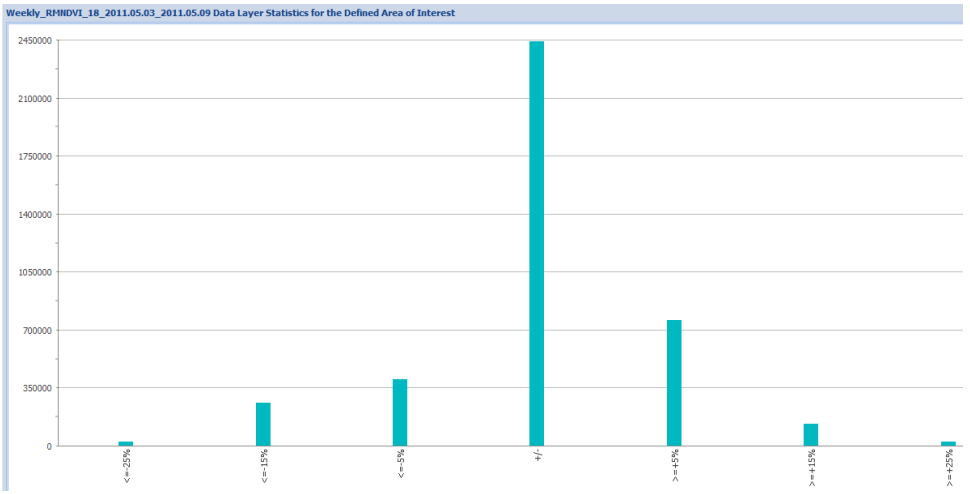
Note: Pixel and acreage counts are not official estimates.

Value	Category	Pixel Counts	Acreage
0	<=-25%	1931	25606.6
1	<=-15%	19647	260535.3
2	<=-5%	30411	403274.7
3	+/-	184180	2442377.2
4	>=+5%	57280	759579.6
5	>=+15%	9910	131414.7
6	>=+25%	1765	23405.3
Total	7	305124	4046193.4

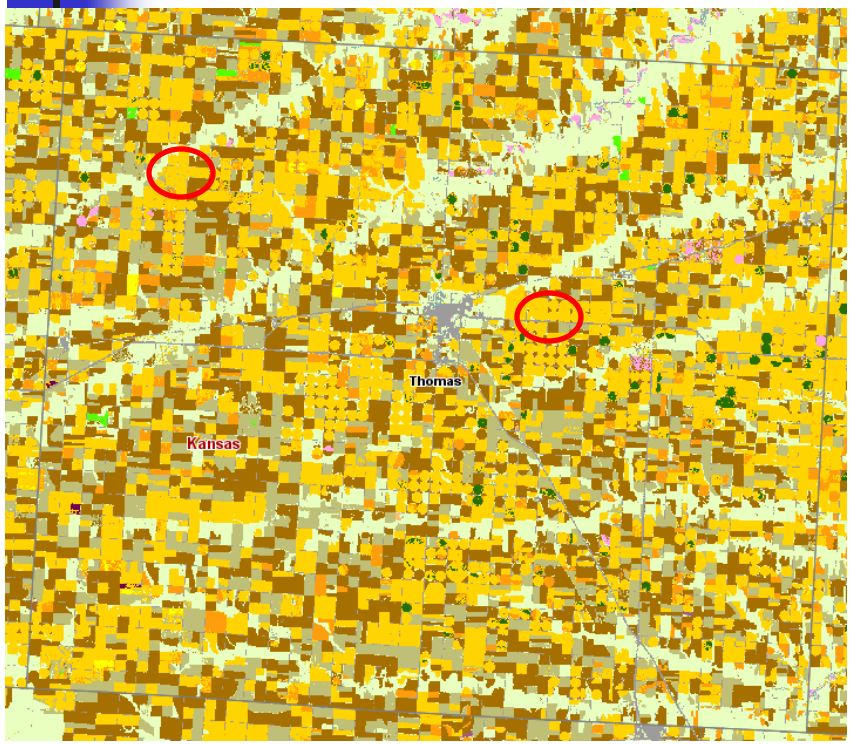
04/19-04/25/11
Quantify vegetative area condition



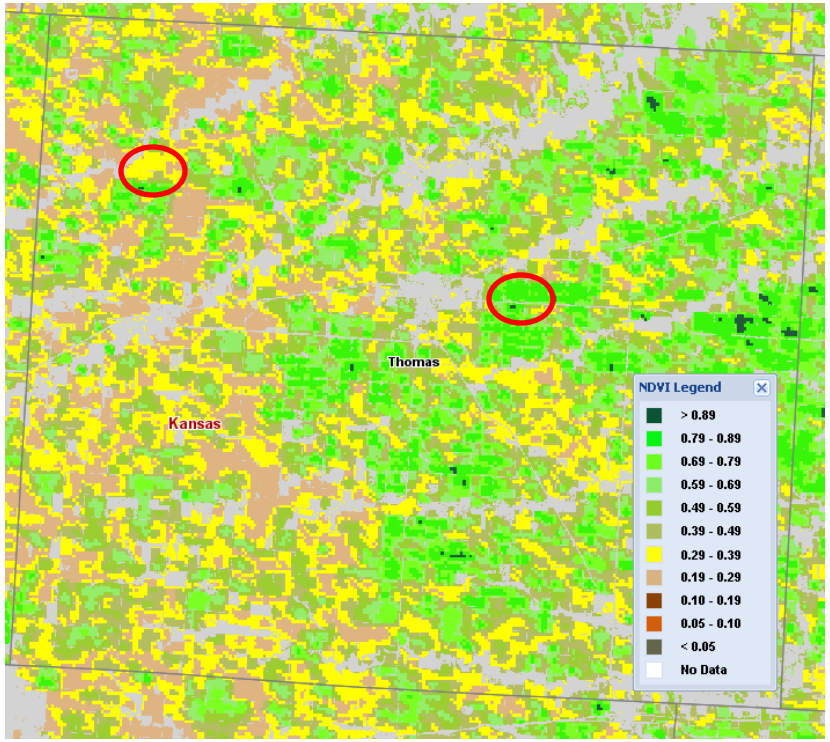




VegScape Serves 2012 CDL by Using CropScape Web Service

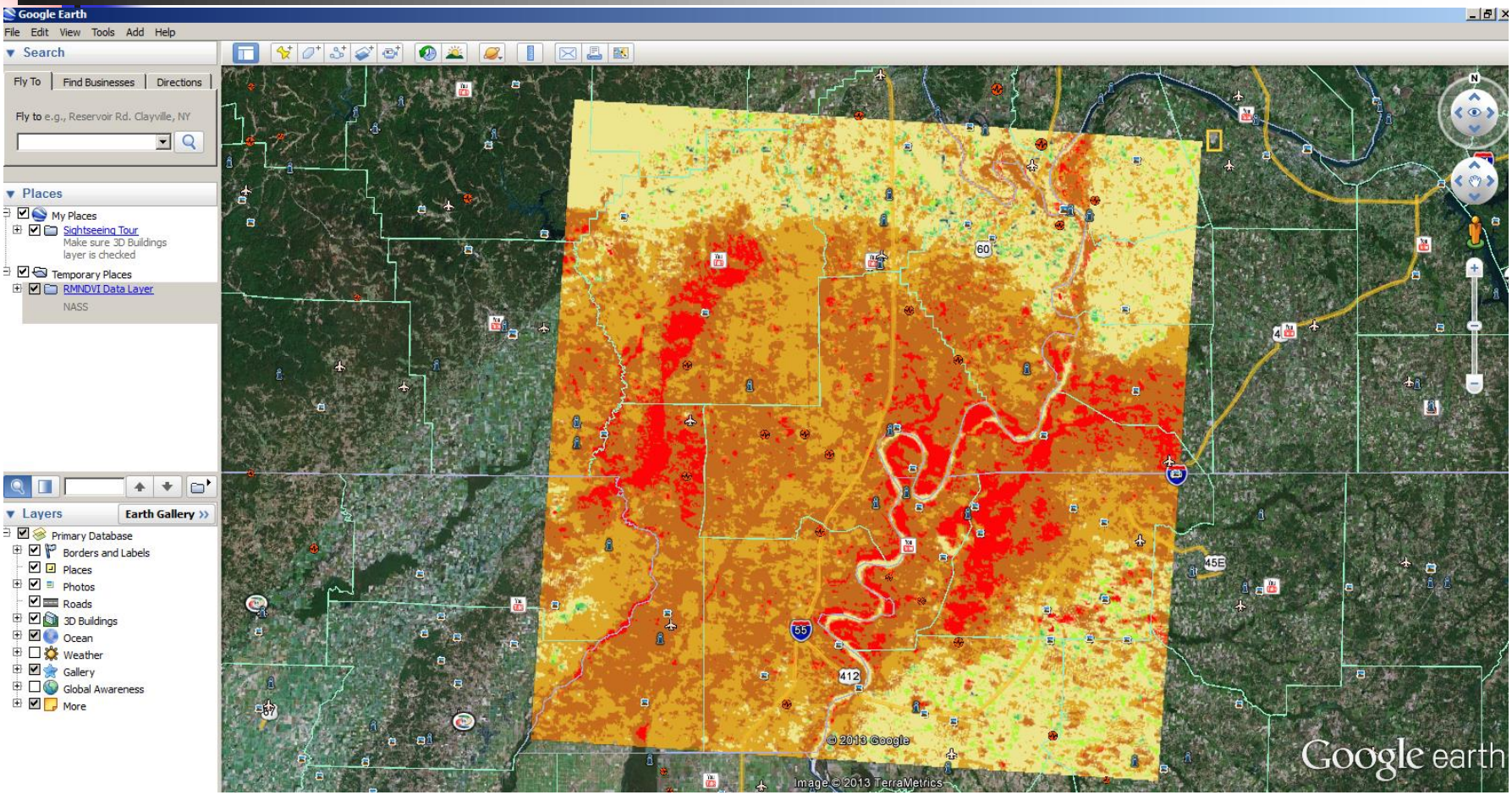


2012 Cropland Data Layer
The 2012 Cropland Data Layer (CDL) product depicts land cover



7/24/12 – 7/30/12 NDVI
Vegetative condition indicates crops under stress from the 2012 drought

Data Mashup with Google Earth



Export any selected index data directly into **Google Earth**

Web Map Service (WMS, CONUS, WEEKLY) Request Examples

- GetCapabilities

  http://129.174.131.8/cgi-bin/weekly_ndvi_2012?SERVICE=WMS&VERSION=1.1.1&REQUEST=GetCapabilities

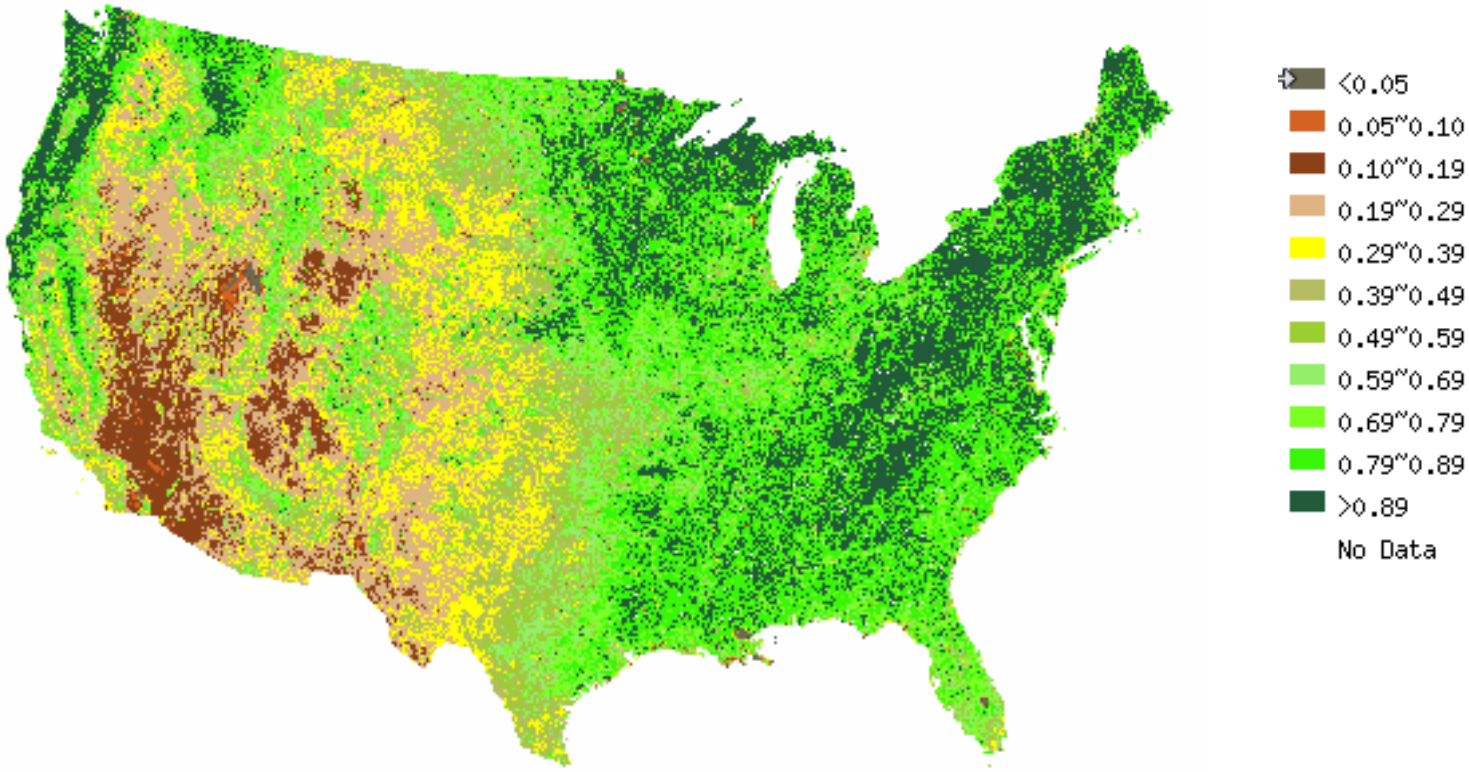
- GetMap

  http://129.174.131.8/cgi-bin/weekly_ndvi_2012?LAYERS=Weekly_NDVI_30_2012.07.24_2012.07.30&SERVICE=WMS&VERSION=1.1.1&REQUEST=GetMap&FORMAT=image/png&TRANSPARENT=true&SRS=EPSG:102004&BBOX=-3987459.135,168311.354,4472862.725,4177587.947&WIDTH=800&HEIGHT=400

- GetLegendGraphic

  http://129.174.131.8/cgi-bin/weekly_ndvi_2012?LAYER=Weekly_NDVI_30_2012.07.24_2012.07.30&SERVICE=WMS&VERSION=1.1.1&REQUEST=GetLegendgraphic&FORMAT=image/png

Results from Calling Web Service



GetMap Service Result

GetLegendGraphic Service

Conclusions

- MODIS offers high spatial/temporal resolution and data continuity for cropland vegetation condition monitoring.
- VegScape provides Irregular, ad-hoc data retrieval and processing for emergency assessment / reporting.
- Web-based interactive mapping enables online geospatial data equal access, data exploration, navigation, querying, visualization, dissemination, and greatly improved user experiences.
- Assessing crop condition and identifying the areal extent of floods, drought, major weather anomalies, and vulnerabilities of early/late season crops
- The service oriented architecture allows scalability.
- The open GIS technology is robust and has better performance.
- It greatly enhances geospatial crop vegetation condition information for decision support.

Unfinished Business:

- Further refine data processing algorithms to improve performance and quality:
  - Calibration with ground truth
  - Quantifying crop condition
  - Ground truth data collection
- Add more remote sensing crop condition data layers:
  - Leaf Area Index (LAI), Fraction of Photosynthetically Active Radiation (fPAR), and Land Surface Temperature (LST), etc.
  - Other NASA remote sensing data
  - Preciptation - Tropical Rainfall Measuring Mission (TRMM) & others
  - Soil moisture - 25-km global soil moisture derived from Aqua AMSR-E
- Further performance turning and adding more functionalities.

Questions & Comments?

NASS: zhengwei_yang@nass.usda.gov

FACT FINDERS FOR AGRICULTURE
UNITED STATES DEPARTMENT OF AGRICULTURE