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

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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

Vegetation Condition Percent Change: 2009 ÷ 2008
Period 12 (3/10 - 3/23)
Percent Change Ratio to Median

Vegetation Condition Percent Change: $2009 \div \text{Median (2004 - 2008)}$
Period 12 (3/10 - 3/23)

Percent Change

- \(< = -25\%^*\)
- \(< = -15\%\)
- \(< = -5\%\)
- \(\pm\)
- \(> = +5\%\)
- \(> = +15\%\)
- \(> = +25\%\)
- Clouds/Snow

*Variations in Snow Cover May Unduly Influence this Category

Agricultural Statistics Districts
1:15,000,000

Original Image: NOAA-17 AVHRR
Reduction Method: Geometric
Composite Image: USGS EROS Data Center
Support email: nc_hrl_gib@nasa.gov
For Additional Images Please Visit:
http://www.sci.gsfc.nasa.gov/AVHRR/climref/AVHRR.html
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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
  - Precipitation - 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)

Application Layer
- Web Applications
- Crop Progress Applications
- Other Applications

Service Layer
- OGC WMS
- OGC WFS
- GeoLinking
- Process Services
- GDAS

Data Layer
- Raster Data
  - Cropland Data Layers
- Vector Files
  - US States/Counties Layers
- Attribute Data
  - Crop Statistics Data
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

\[
NDVI = \frac{(IR-R)}{(IR+R)}
\]

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

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

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

\[
VCI = \frac{NDVI(x, y) - NDVI_{\text{min}}(x, y)}{NDVI_{\text{max}}(x, y) - NDVI_{\text{min}}(x, y)} \times 100\%
\]
NDVI and RVCI

NDVI

RVCI
MVCI vs RMVCI

MVCI

RMVCI
VCI Result
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

Example process: Iowa, May 2010

MVC Compositing

May 11-17 Weekly composite
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 – Tool Bar
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
2011 Flood Missouri Bootheel
NDVI Ratio to Median
(Median of 10 years NDVI)

Cropland Data Layer
AOI Statistics - Ratio to Median VCI

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**


- **GetLegendGraphic**

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
  - Precipitation - 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?

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