Real-Time Green Vegetation Fraction for Land Surface and Numerical Weather Prediction Models

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Role of Vegetation in Models

• Evapotranspiration from Healthy Vegetation
  – Significant contribution of moisture transport into boundary layer, esp. in warm season
  – Important to represent vegetation density accurately in land surface models

• Horizontal and Vertical Density of Vegetation
  – Greenness Vegetation Fraction (GVF), horizontal density
  – Leaf Area Index (LAI), vertical density
  – In operational Noah Land Surface Model (LSM), LAI is prescribed while GVF varies spatially by model grid cell
Current Operational GVF Dataset

• Five-Year Monthly Global Climatology
  – Derived from AVHRR Normalized Difference Vegetation Index (NDVI) data from 1985–1991
  – 0.144° resolution, valid at mid-point of each month
  – Default dataset in Noah LSM within WRF community model and NASA Land Information System (LIS)
  – Operational at NCEP since 1997 (Ek et al. 2003)

• Cannot account for variations in GVF due to:
  – Weather/climate anomalies (e.g., drought / Temp extremes)
  – Land-use changes since the early 1990s (e.g., urban sprawl)
  – Large wildfires and prescribed burn regions
SPoRT Daily Real-Time Vegetation Product

- Continental-U.S. NDVI/GVF grid at 0.01° resolution
  - NDVI from real-time MODIS swaths, mapped to CONUS grid
  - Time-weighted NDVI composites produced from up to 6 NDVI values in the previous 20 days (negative NDVI excluded)
  - Daily composites generated since 1 June 2010
  - Calculate GVF on 0.01° grid for use in Noah LSM in WRF & LIS
  - Create distributions of $NDVI_{max}$ as function of land use class at point $i$
  - Obtain 90th percentile $NDVI_{max}$ for each land class ($NDVI_{max,i}$)
  - Obtain 5th percentile $NDVI_{max}$ for barren land use ($NDVI_{min}$)
  - Calculate GVF using the following formula:

\[
GVF_i = \frac{NDVI_i - NDVI_{min}}{NDVI_{max,i} - NDVI_{min}}
\]

- Missing data filled by GVF climatology
Examples of MODIS GVF Deviations from Climatology
Big 1-yr diff in GVF
- TX was very wet in early summer 2010
- Virtually no rain in TX/OK in 2011
- 1-yr reduction in GVF, up to 40%+
- Shows how much GVF can change from year to year

July 19, 2011
(Released Thursday, Jul. 21, 2011)
Valid 7 a.m. EST

<table>
<thead>
<tr>
<th>Drought Conditions (Percent Area)</th>
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<tbody>
<tr>
<td>None</td>
</tr>
<tr>
<td>Current</td>
</tr>
<tr>
<td>Last Week 7/12-7/18</td>
</tr>
<tr>
<td>3 Months Ago 4/19-5/15</td>
</tr>
<tr>
<td>Start of Calendar Year 1/1/2011</td>
</tr>
<tr>
<td>Start of Valuation 5/30/2010</td>
</tr>
<tr>
<td>One Year Ago 5/30/2010</td>
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</tbody>
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Intensity:
- Yellow: D0 Abnormally Dry
- Red: D3 Extreme Drought
- Orange: D4 Exceptional Drought
- Pink: D2 Severe Drought

transitioning research data to the operational weather community
Summer 2012 Drought in Midwest: 1 Sep GVF

Strong vegetation response

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"Tale of Two Marches": 2012 and 2013

THE TALE OF TWO MARCHES

MARCH 1ST-18TH, 2012

MARCH 1ST-18TH, 2013

Difference from Average Temperature (°F)

-12 0 12

DATA SOURCE: RCC-ACIS.ORG - APPLIED CLIMATE INFORMATION SYSTEM

CLIMATE CENTRAL

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“Tale of Two Marches”: Effect on GVF

SPoRT/GVF Annual Diff on 0331 (2013 – 2012)
SPoRT-MODIS GVF Incorporated into LIS & WRF

• Daily MODIS GVF used in long-term LIS-Noah spin-up simulations in place of climatology GVF
• MODIS GVF data formatted for WRF and WRF/EMS community modeling systems
  – Simple changes to “geogrid” program table files
  – Re-initialize WRF static fields each day
• SPoRT NWS WFO partners using MODIS GVF in local real-time simulations to address forecast challenges
  – Convective initiation (CI)
  – Temperature forecasts
17 July 2010 WRF Severe Weather Case Study

- Urban areas can be resolved much better by the SPoRT GVF.
- Higher GVF s prevail from NE to ND due to wet Spring
Higher SPoRT GVF s in the western portion of the focus area correctly led to lower forecast 2-m temperatures.
Higher GVF values led to higher 2-m dewpoints
Net result was an increase in CAPE up to 1000 J kg$^{-1}$
17 July 2010, WRF Fcst 1-h precip: 27/33 h

- Both model runs close on placement with initial development and movement
- Some intensity variations

- cntrl run moves convection southward through Iowa too quickly
- sportgvf run correctly re-develops convection along IA/NE border and has slower evolution in Iowa
NOAA/NESDIS VIIRS GVF Product

Future real-time product; generated daily
- Global coverage at 4-km resolution (10000 x 5000); netcdf4
- Updated daily with previous week of VIIRS swath data
  - Surface reflectance composites based on view-angle adjustments
  - Max value from previous 7 days retained for each daily composite
  - GVF computed from Enhanced Vegetation Index (EVI); 3 channels (NIR, red, blue)

NESDIS/VIIRS formulation:

\[
EVI = 2.5 \frac{NIR - \text{red}}{NIR + 6 \cdot \text{red} - 7.5 \cdot \text{blue} + 1}
\]

\[
GVF = \frac{EVI - EVI_{\text{min}}}{EVI_{\text{max}} - EVI_{\text{min}}} ; \text{ where}
\]

\[
EVI_{\text{min}} = 5^{th} \text{ percentile of global EVI values}
\]

\[
EVI_{\text{max}} = 95^{th} \text{ percentile of global EVI values}
\]

SPoRT/MODIS current formulation:

\[
NDVI = \frac{NIR - \text{red}}{NIR + \text{red}}
\]

\[
GVF = \frac{NDVI - NDVI_{\text{min}}}{NDVI_{\text{max}} - NDVI_{\text{min}}} ; \text{ where}
\]

\[
NDVI_{\text{min}} = 5^{th} \text{ percentile of NDVI values for a given land-use type}
\]

\[
NDVI_{\text{max}} = 90^{th} \text{ percentile of NDVI values for a given land-use type}
\]
NESDIS VIIRS GVF in WRF over Eastern Africa

Good correspondence between GVF climo (left columns) and VIIRS GVF (right columns)

VIIRS GVF provides much more detail in complex terrain of east Africa

Simulated sfc CAPE shows sensitivity to different input GVF (as expected)

[Red = lower VIIRS GVF than climo $\rightarrow$ lower CAPE]

[Blue = higher VIIRS GVF than climo $\rightarrow$ higher CAPE]
Summary and Future Work

- SPoRT developed CONUS ~1-km MODIS GVF dataset (1 June 2010 to date)
- Daily MODIS GVF used in local modeling applications by select NWS forecast offices
- Real-time vegetation data have potential to improve model performance in warm season
- Future work with NESDIS VIIRS GVF
  - Transition to 4-km NOAA/NESDIS global VIIRS GVF product
  - Code development already completed by SPoRT for both NASA LIS and WRF modeling frameworks
Backup Slides
GVF Comparison: 17 July 2010

- Improved resolution
  - Ability to resolve vegetation variation in complex terrain
- Greener in Western U.S.
  - Nearly 20-40% over High Plains
  - High Plains rainfall well above average in previous 3 months

data to the operational weather community
17 July 2010: Verification Stats

- **BIAS**
  - 2-m Temperature
  - 2-m Dewpoint

- **ERROR STANDARD DEVIATION**
  - 2-m Temperature
  - 2-m Dewpoint

**Verification Stats: Critical Success Index**

- CSI for 1 mm/1-h Precip: MDW region
  - NCEP-CI
  - SPoRT-CI

**Transitioning research data to the operational weather community**
22 May 2011: Joplin, MO tornado day

SPC Storm Reports for 05/22/11
Map updated at 1211Z on 06/01/11

- TORNADO REPORTS: (75)
- HIGH WIND REPORTS/WIND... (350/5)
- HAIL REPORTS/HAIL... (409/50)
- TOTAL REPORTS: (643)

PRELIMINARY DATA ONLY.

transitioning research data to the operational weather community
22 May 2011, WRF fcst 1-h precip: 23/27 h

- More intense 1-h rain rates in sportgvf run just prior to tornadic event
- Both runs have too much false alarm in AR

- After event, sportgvf run better handles squall line evolution into Arkansas
- Reduced false alarm in central Arkansas