Monitoring and modeling the US crop production under climate change

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UNL SIF Workshop, Sep 26, 2017
Study domain in red box. The background shows the averaged corn production from 2006-2010, and the numbers indicate the percentage (%) of the state production to the national total corn production.

Sun-induced chlorophyll fluorescence (SIF) as a proxy of photosynthesis.

Credit: NASA
Integrating field work, satellite, and supercomputing for monitoring and modeling crop production at continental scales.
Blue Waters is a petascale supercomputer at the National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana-Champaign. On August 8, 2007, the National Science Board approved a resolution which authorized the National Science Foundation to fund "the acquisition and deployment of the world's most powerful leadership-class supercomputer." The NSF awarded $208 million for the Blue Waters project.
Current Research Directions in our lab

(1) Multi-sensor integration for crop yield monitoring
   • Various satellite data

(2) Long-term sensing network for agricultural ecosystems
   • Ground-based SIF, camera network

(3) High-resolution satellite fusion and field-level mapping

(4) Modeling crop responses to drought and heat stress
Multi-sensor integration for crop yield monitoring

A New Era of Earth Observation from **Satellite:**
Vegetation Properties

what people and satellite see
what people really care about

(Guan et al., RSE, 2012; Guan et al., Ecosphere, 2013; Guan et al., IEEE, 2014; Guan et al., JGR, 2014; Guan et al., GCB, 2016; He et al., RSE, 2016; Guan et al., RSE, 2017)
Multi-sensor integration for crop yield monitoring

A New Era of Earth Observation from Satellite:
Vegetation Properties

Take home message:
All the satellite data share some common information.

However, when excluding this common information, many data contain their unique information that tremendously improve our understanding of vegetation growth.

(Guan et al., RSE, 2012; Guan et al., Ecosphere, 2013; Guan et al., IEEE, 2014; Guan et al., JGR, 2014; Guan et al., GCB, 2016; He et al., RSE, 2016; Guan et al., RSE, 2017)
Innovative use of fluorescence information

What is **Solar-induced chlorophyll fluorescence (SIF)**?

SIF is only possible to retrieve from space in recent years.
A new framework of using remote sensing SIF for crop monitoring

(Guan et al., “Improving the monitoring of crop productivity using spaceborne solar-induced fluorescence”, Global Change Biology, 2016)
(Guan et al., “Improving the monitoring of crop productivity using spaceborne solar-induced fluorescence”, Global Change Biology, 2016)
Long-term measurements of solar-induced fluorescence (SIF) – Guofang Miao

FluoSpec2 designed by Dr. Xi Yang

(Guan et al., NASA New Investigator, 2016) (Frankenberg, Guan et al., NASA Carbon Sciences, 2016)

<table>
<thead>
<tr>
<th>Site</th>
<th>Management</th>
<th>Growing season (May-Oct)</th>
<th>Expected crop calendar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>total rainfall (mm/y)</td>
<td>daily mean temperature (°C)</td>
</tr>
<tr>
<td>Champaign1</td>
<td>Rain-fed</td>
<td>834</td>
<td>25.6</td>
</tr>
<tr>
<td>Champaign2</td>
<td>Rain-fed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mead Ne3</td>
<td>Rain-fed</td>
<td>598</td>
<td>19.1</td>
</tr>
<tr>
<td>Mead Ne2</td>
<td>Irrigated</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2016 field deployment

<table>
<thead>
<tr>
<th></th>
<th>Fiber height (h)</th>
<th>Footprint (diameter (d = (h-h_c)\tan(12.5)\times2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean</td>
<td>3.6 m</td>
<td>1.1 m (if (h-h_c = 2.5) m)</td>
</tr>
<tr>
<td>Maize</td>
<td>4.8 m</td>
<td>0.9 m (if (h-h_c = 2.0) m)</td>
</tr>
</tbody>
</table>

Irradiance

2 spectrometers per site:
- OceanOptics QEPRO: 730-780 nm (0.04-0.07 nm)
- OceanOptics HR2000+: 400-900 nm (0.42-0.47 nm)
Ground-based SIF

GPP = APAR × LUE
SIF = APAR × SIF_y
Miao, Guan et al. (In review) Sun-induced fluorescence, photosynthesis, and light-use efficiency of a soybean field.

<table>
<thead>
<tr>
<th>Diurnal scale</th>
<th>LUE:APAR</th>
<th>SIF:APAR</th>
<th>LUE:SIF</th>
<th>Data sources</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean (sunny)</td>
<td>Negative</td>
<td>Positive</td>
<td>Negative</td>
<td>Ground</td>
<td>This study</td>
</tr>
<tr>
<td>Soybean (cloudy)</td>
<td>Negative</td>
<td>Negative</td>
<td>Weak positive</td>
<td>Ground</td>
<td>This study</td>
</tr>
<tr>
<td>Soybean (sunny)</td>
<td>Negative</td>
<td>Positive</td>
<td>Negative</td>
<td>Ground</td>
<td>This study</td>
</tr>
<tr>
<td>Temperate forest</td>
<td>Negative</td>
<td>Negative</td>
<td>Positive</td>
<td>Ground</td>
<td>Yang et al., 2015</td>
</tr>
<tr>
<td>C₃ Grassland</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
<td>Satellite</td>
<td>Verma et al., 2017</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Seasonal scale</th>
<th>LUE:APAR</th>
<th>SIF:APAR</th>
<th>LUE:SIF</th>
<th>Data sources</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean &amp; Deciduous broadleaf forest (low light)</td>
<td>Negative</td>
<td>Positive</td>
<td>Negative</td>
<td>SCOPE model</td>
<td>Zhang et al., 2016</td>
</tr>
<tr>
<td>Soybean &amp; Deciduous broadleaf forest (high light)</td>
<td>Negative</td>
<td>Negative</td>
<td>Positive</td>
<td>SCOPE model</td>
<td>Zhang et al., 2016</td>
</tr>
</tbody>
</table>

**Diurnal & Extrapolated Seasonal scales**

**Seasonal Scale**
Morning mean values (9 am - 12 pm)
2017 field deployment

- Compare GPP and SIF, LUE and SIF, as indications of the difference in maize growth across a water stress gradient.
- Assess the potential of SIF in identifying the growth stages that are mostly affected by water stress.
2018 Plan (Ground + Airborne)

(From Xi Yang)
Ag webcam network

— Hyungsuk Kim (PhD student)

Network of images (for now, 20 corn and 20 soy sites in Champaign county)

Machine learning/computer vision to identify crop phenology stage and growth condition

Use these signals to scale up to the whole Champaign county, State of Illinois, and whole Corn Belt
Camera installation

- Footprint: 5 m, Height: 3 m
- Footprint: 10 m, Height: 2 m
- Footprint: 15 m, Height: 1 m
• Southern half of Champaign County, IL
• 21 Soybean, 19 Corn sites
High-resolution satellite fusion and field-level mapping

- Yunan Luo (PhD student)

Luo, Guan, Peng. (In Review) “A generic method to fuse multiple sources of multi-spectral satellite data to generate high-resolution, daily and cloud-free data - the case for fusing MODIS and Landsat”
Regional crop yield mapper

Fig. 4. A snapshot of the preliminary results for Champaign County, IL. (a) Landsat/MODIS fused satellite images for Aug 15, 2013, shown in the true color; (b) classified crop types for 2013; (c,d) estimated crop yield of 2013 for corn and soybean, respectively; (e,f) comparison between model and observation yield for corn and soybean on the test data for the whole County, respectively.

Luo, Guan, Peng. (In Review) “A generic method to fuse multiple sources of multi-spectral satellite data to generate high-resolution, daily and cloud-free data - the case for fusing MODIS and Landsat”
Coupling CLM with APSIM for large-scale crop/biofuel yield forecasting and climate change impact study - Bin Peng (Postdoc)

Peng, Guan et al., “Improving the maize growth processes in the Community Land Model: implementation and evaluation”, accepted.
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Thanks!

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