

# Biogeophysical Effects of Biofuel Cultivation



**Andrew Jones, Margaret Torn, Samuel Levis, William Collins**

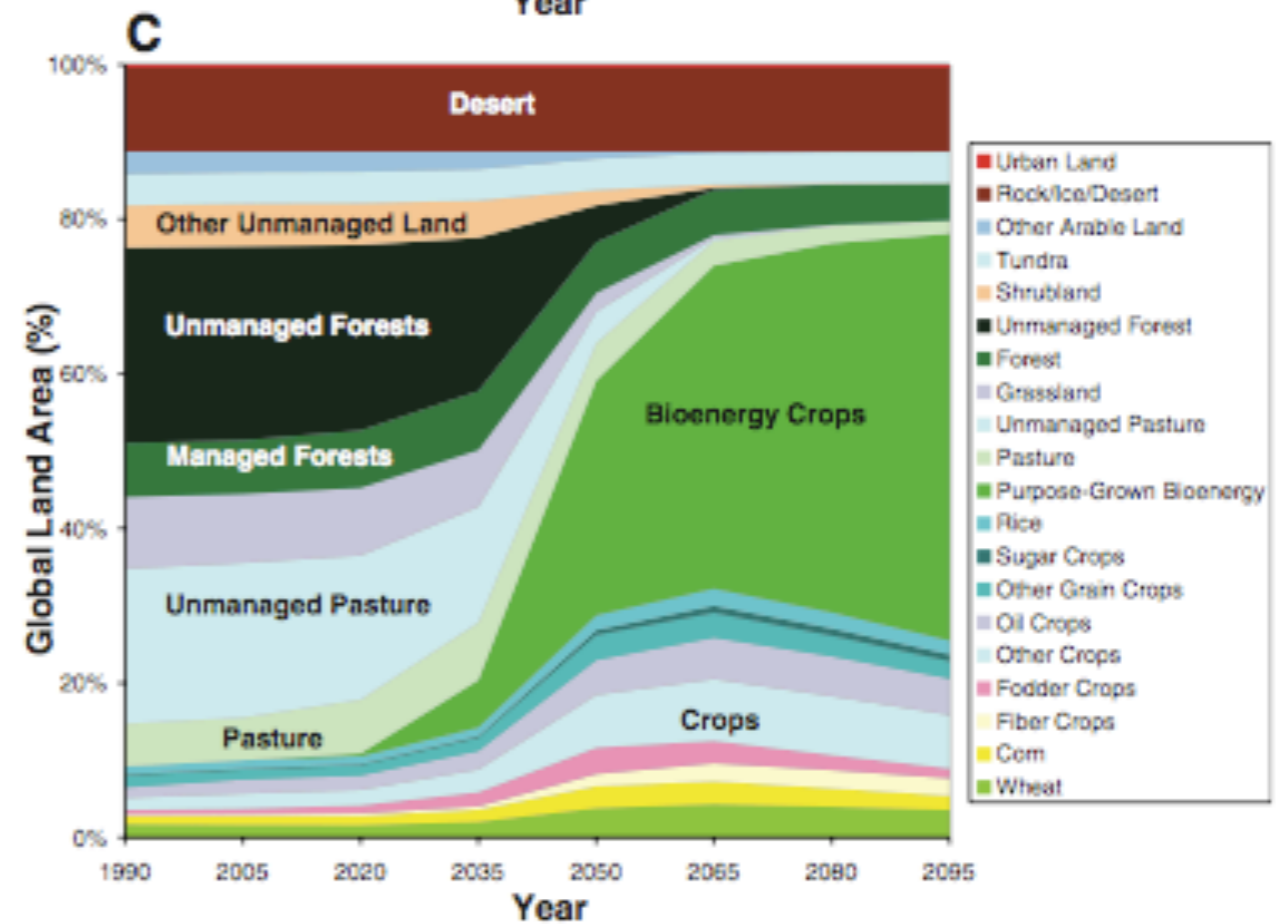
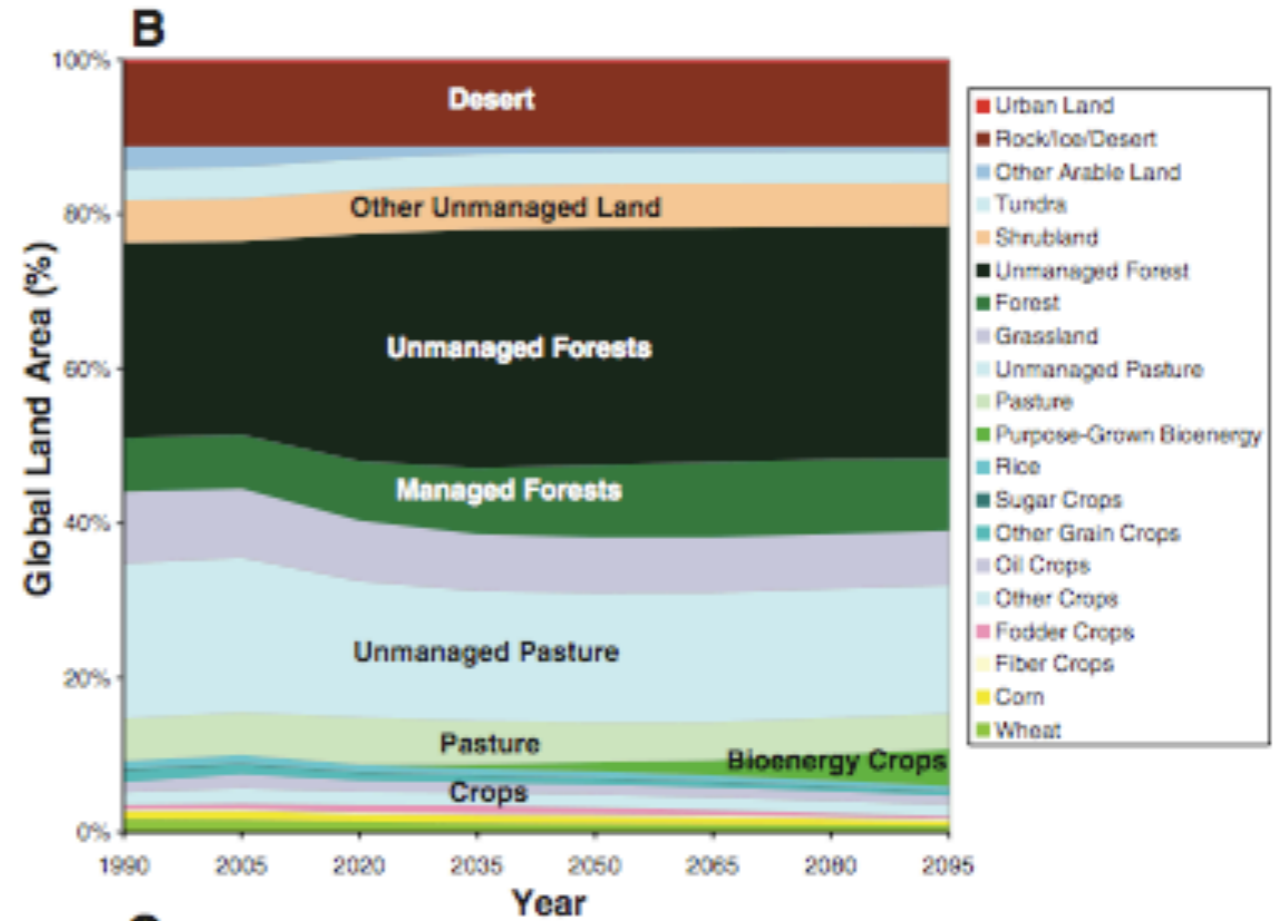
University of California, Berkeley - Lawrence Berkeley Lab - National Center for Atmospheric Research

**CESM Land Model Working Group Mtg, Mar 16, 2011**

# Implications of Limiting CO<sub>2</sub> Concentrations for Land Use and Energy

Marshall Wise, Katherine Calvin, Allison Thomson, Leon Clarke, Benjamin Bond-Lamberty, Ronald Sands,\* Steven J. Smith, Anthony Janetos, James Edmonds†

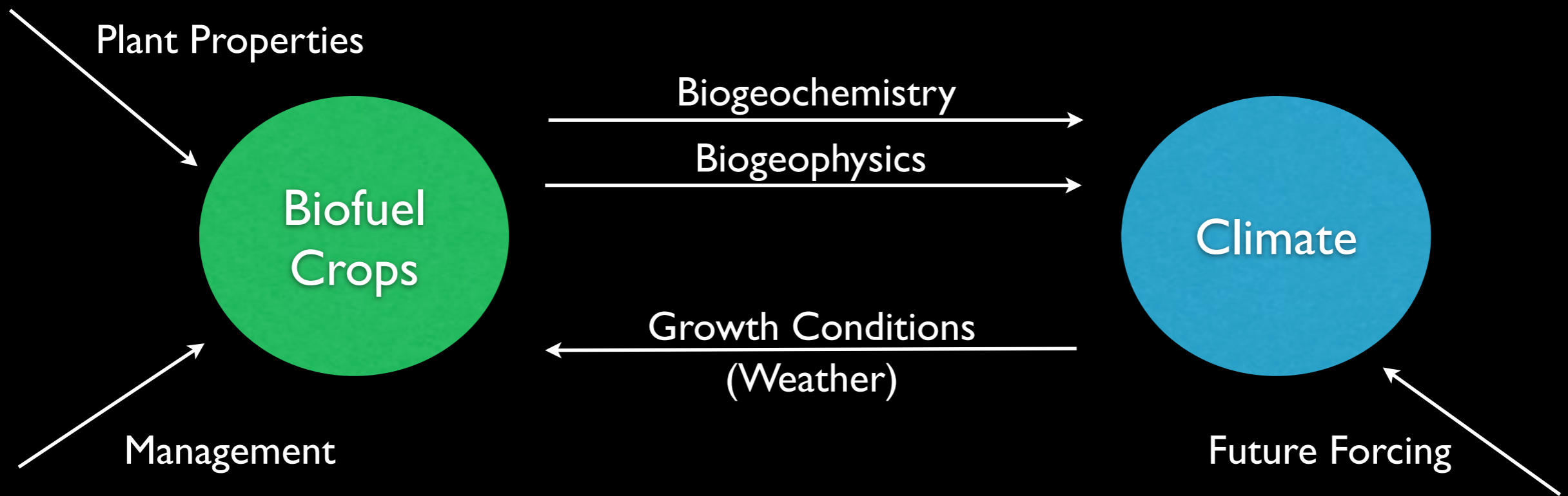
www.sciencemag.org SCIENCE VOL 324 29 MAY 2009



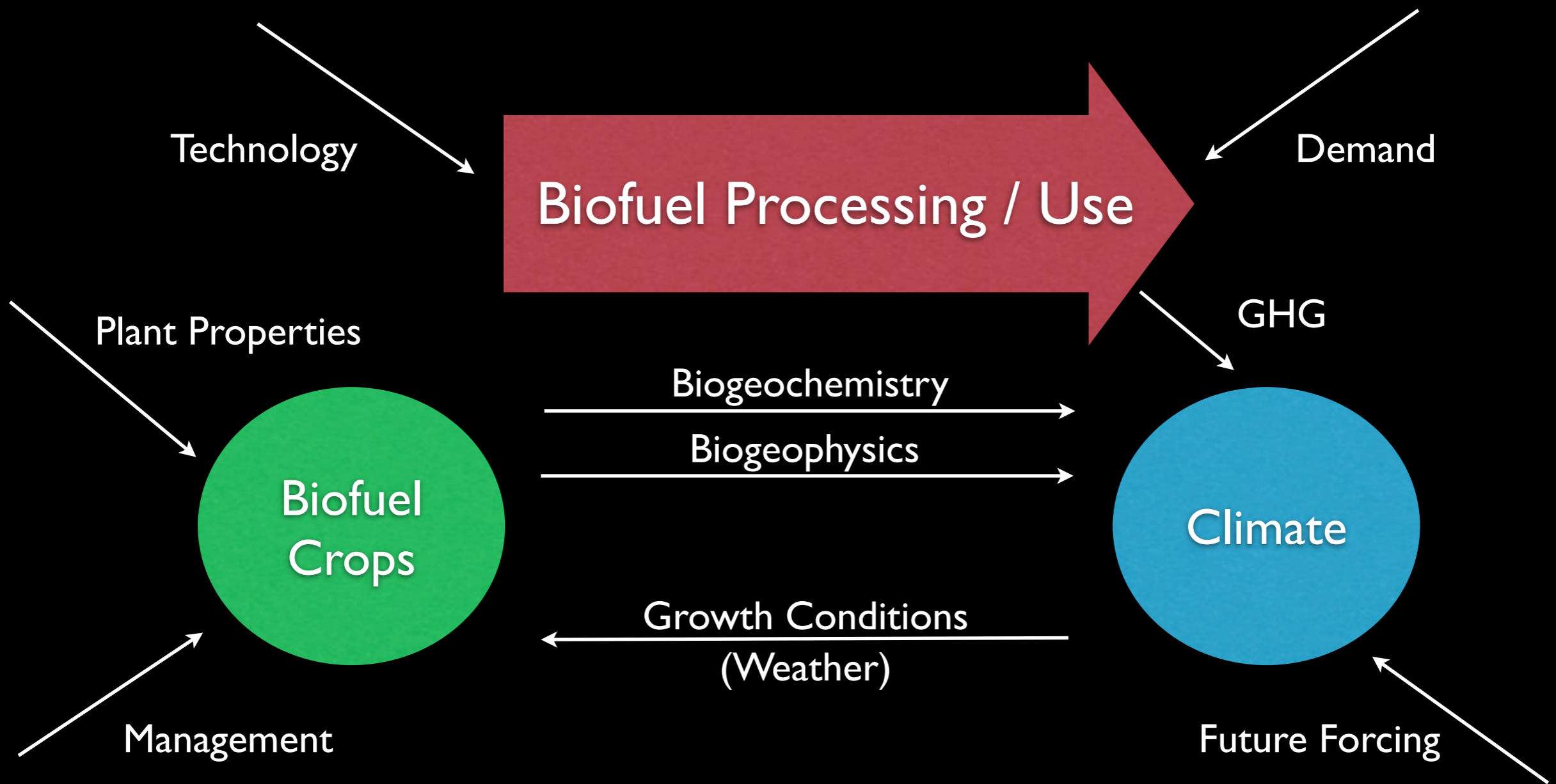
# This is not your ordinary grass (or crop)



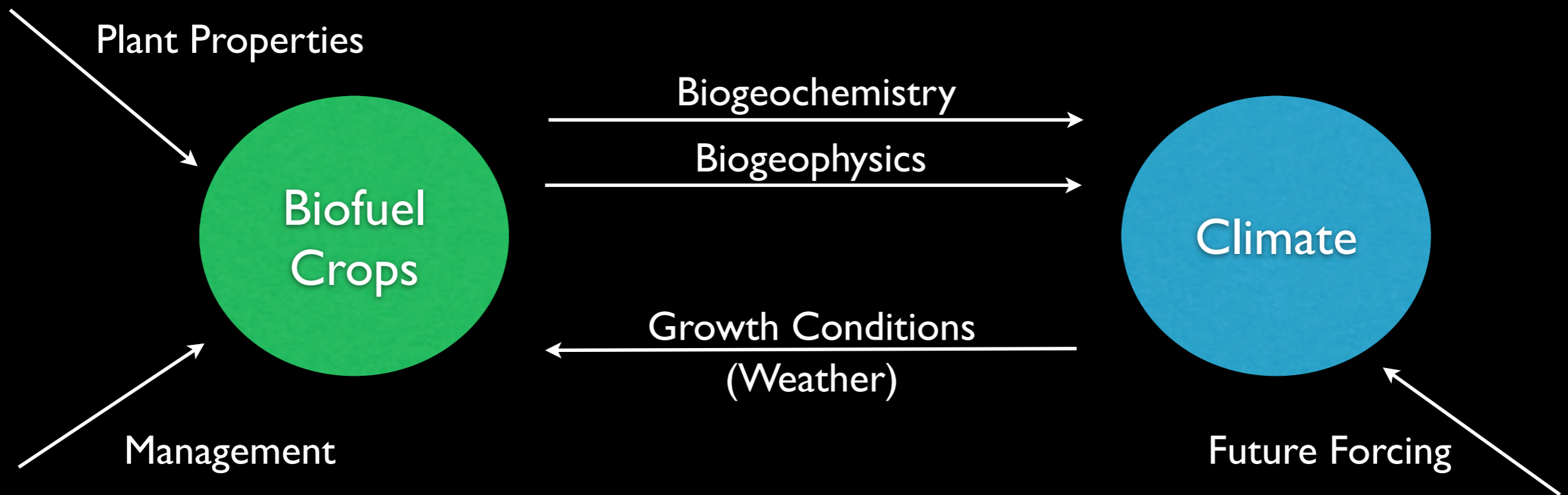
# Biofuel - Climate Interactions



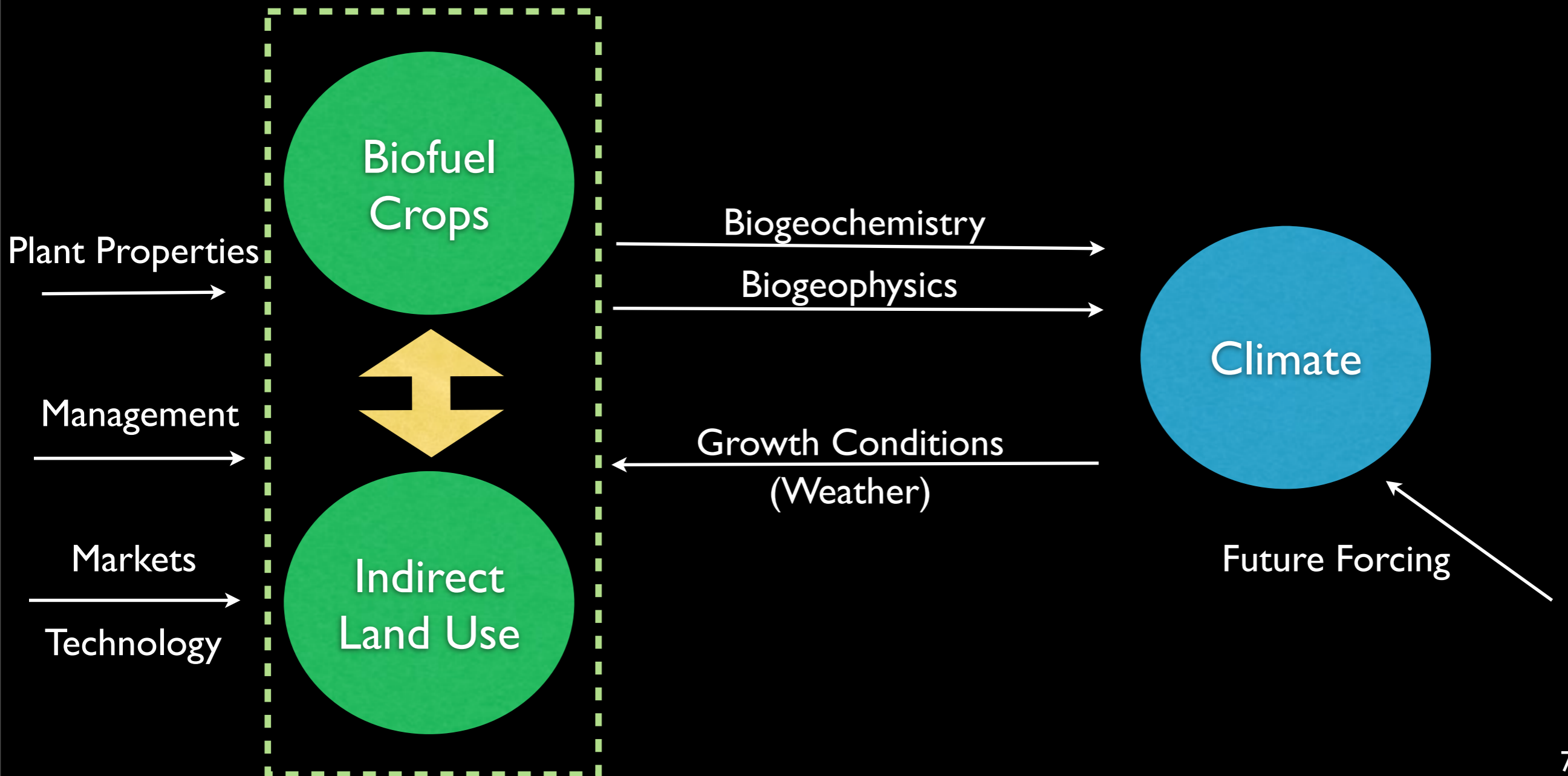
# Biofuel - Climate Interactions



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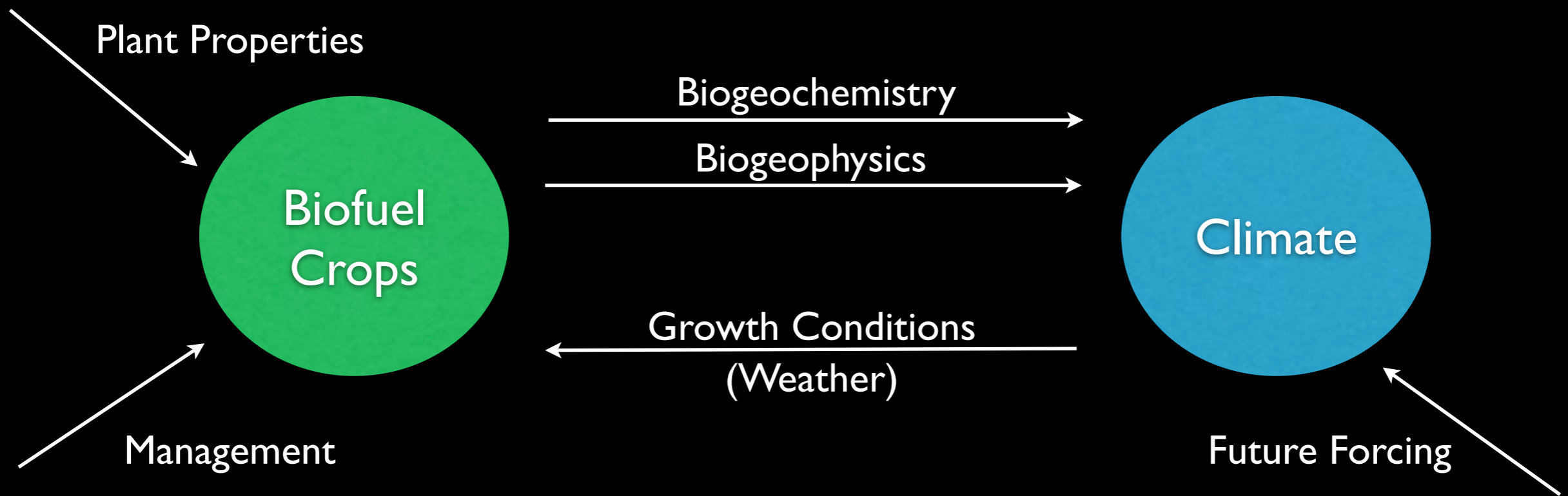


# Guiding Questions

- *What are the climate implications of biofuel crop cultivation across regional and global scales?*
- *When and where do they represent a climate stabilizing versus destabilizing endeavor?*
- *What factors (e.g. plant properties, management options) control the climate interactions of crops in general?*
- *Are biofuel crops likely to differ from traditional crops in terms of these critical factors?*
- *Are there important differences among biofuel crops?*
- *Is the supply of biofuel feedstocks robust to changing climatic conditions?*
- *How can we effectively characterize both regional scale and global scale climate effects of crop cultivation?*



# Biofuel - Climate Interactions



# Approach

- Develop plant functional types for the Community Land Model (CLM)
  - Initial focus on C4 grass crops
  - New model structures and processes
  - Systematic Global Sensitivity Analysis
  - Data Assimilation
- Coupled Global Land-Atmosphere Experiments

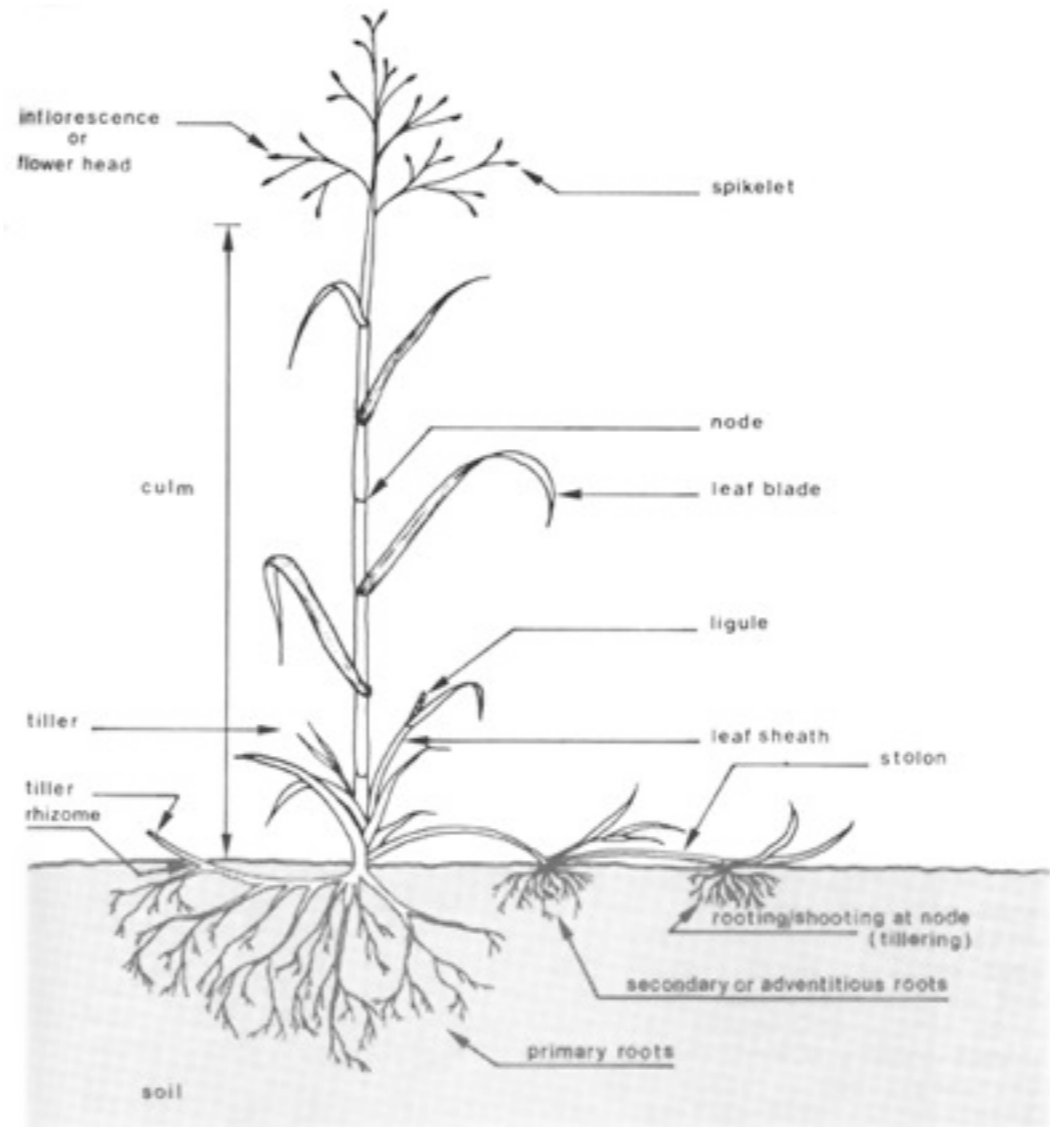


# Model Development

# Morphology



Generic CLM Grass



More Realistic Grass

# Phenology

- Spring Emergence
- Vegetative Growth
- Stem Elongation
- Grain Fill
- Senescence and Litterfall
- Harvest

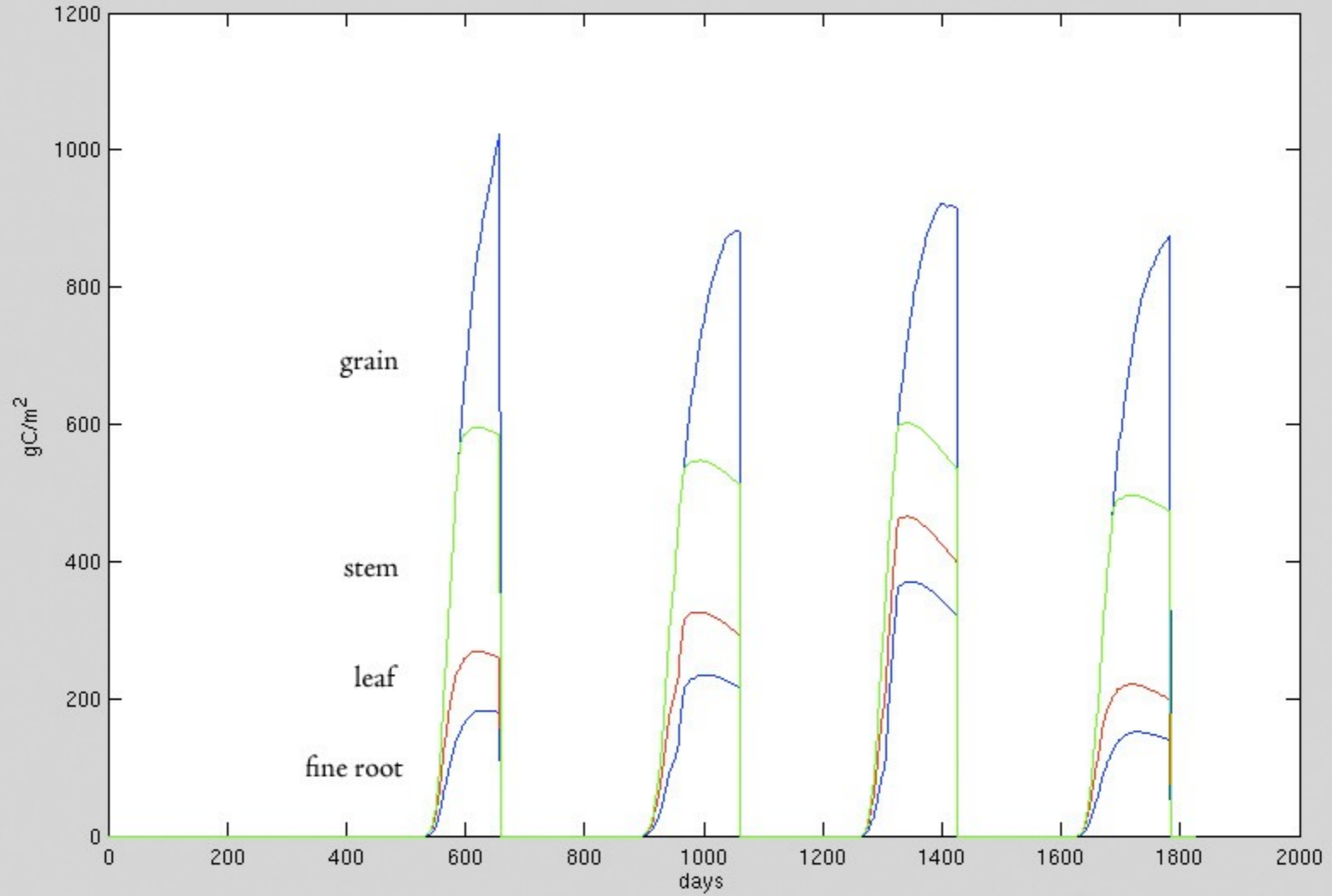


# Management

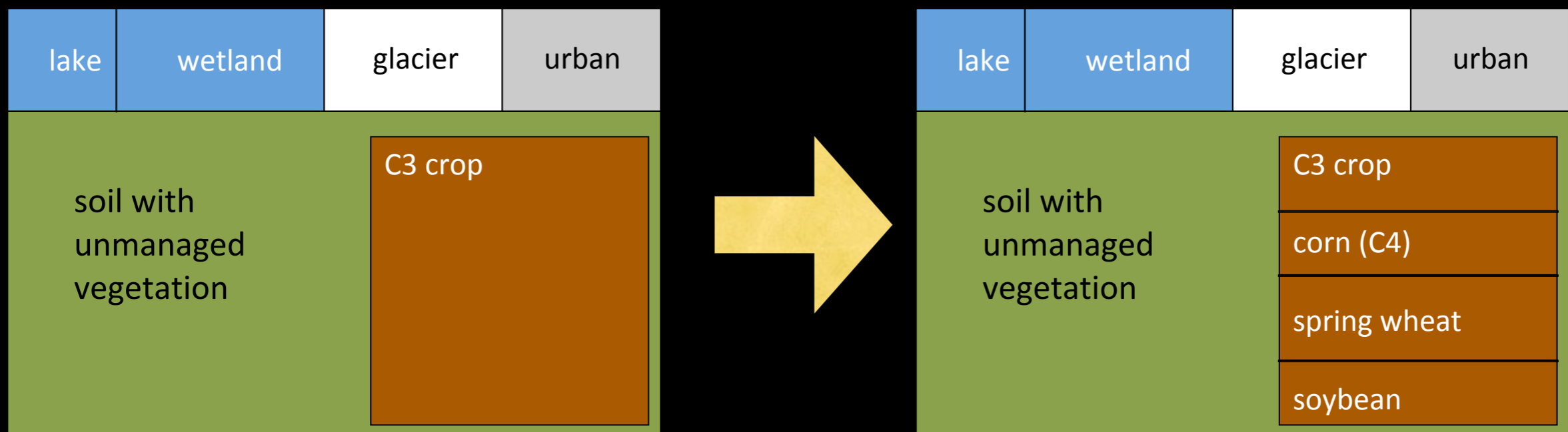
- Fertilization
- Irrigation
- Tillage
- Crop Rotation



simulated carbon allocation by maize over 4 years



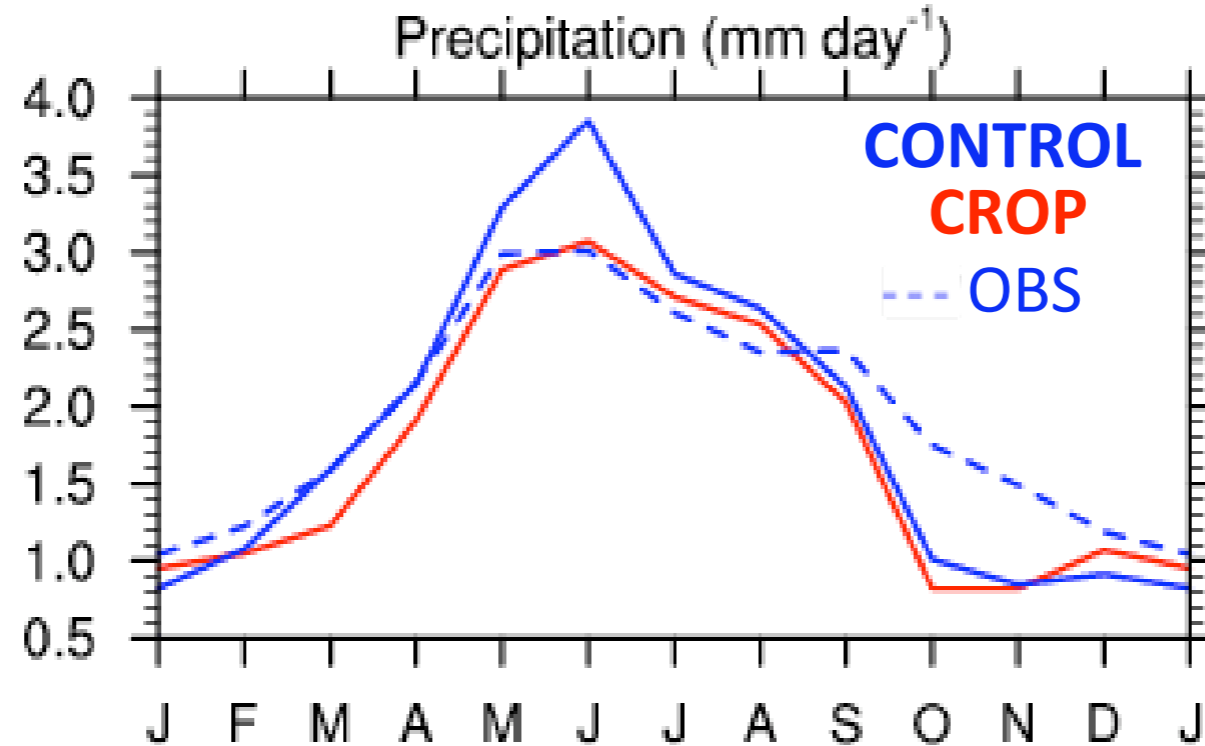
# Changes to the CLM Grid Cell Structure



Slide modified from S. Levis

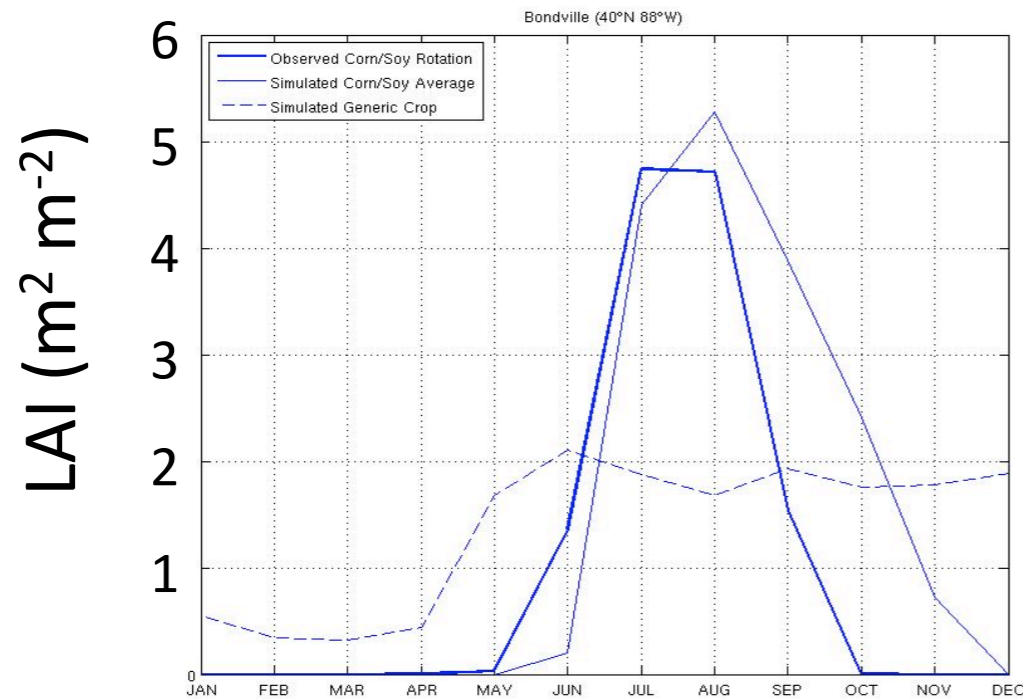


# Central U.S. (30-50°N 105-90°W)

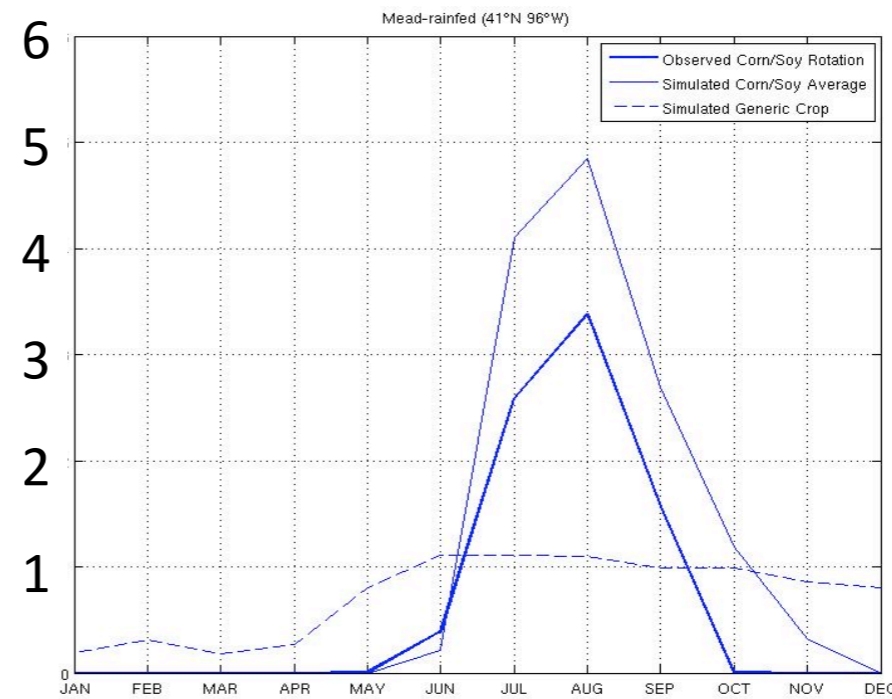


## AMERIFLUX sites:

### Bondville IL



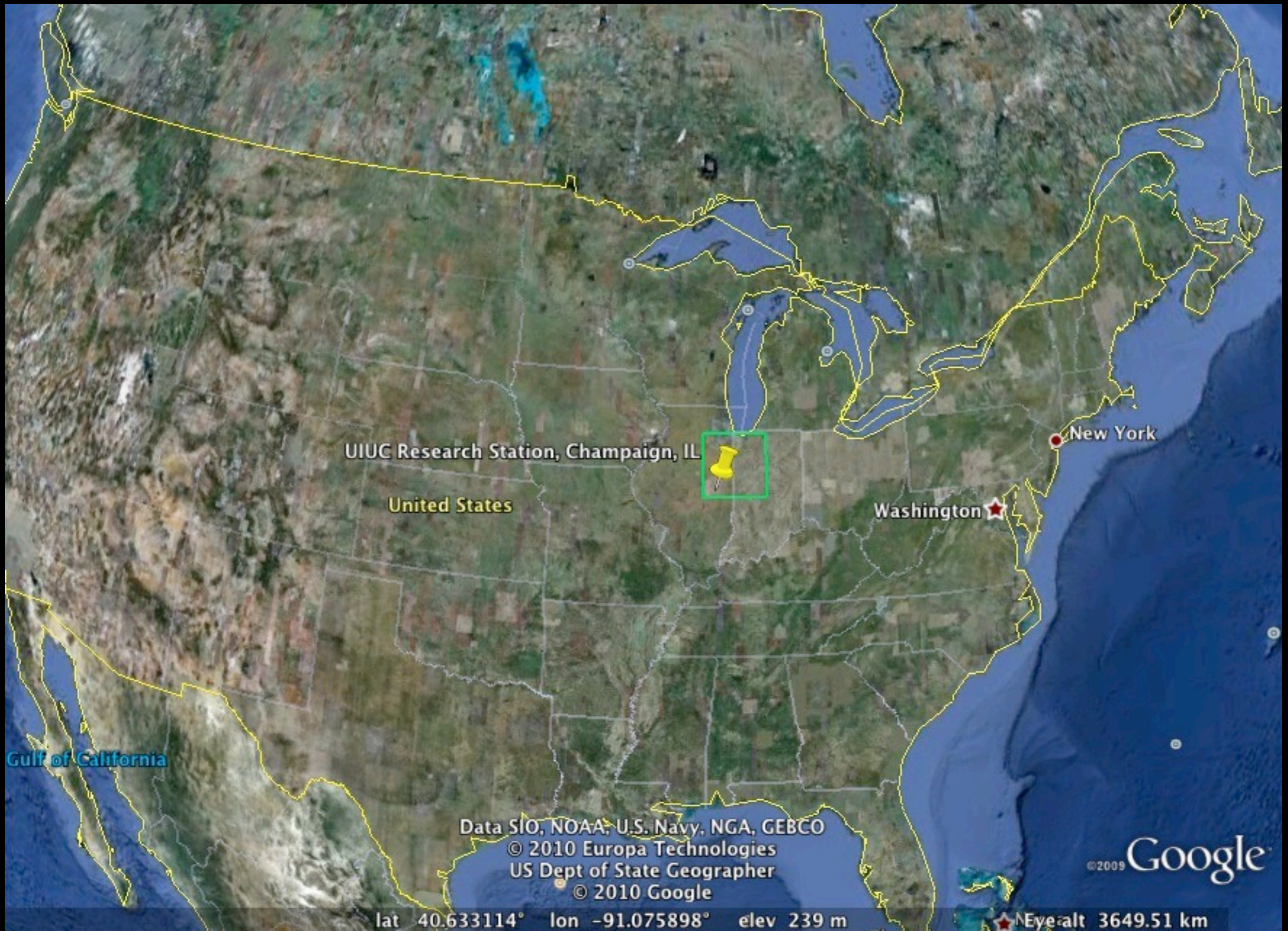
### Mead NE



Slide modified from S. Levis

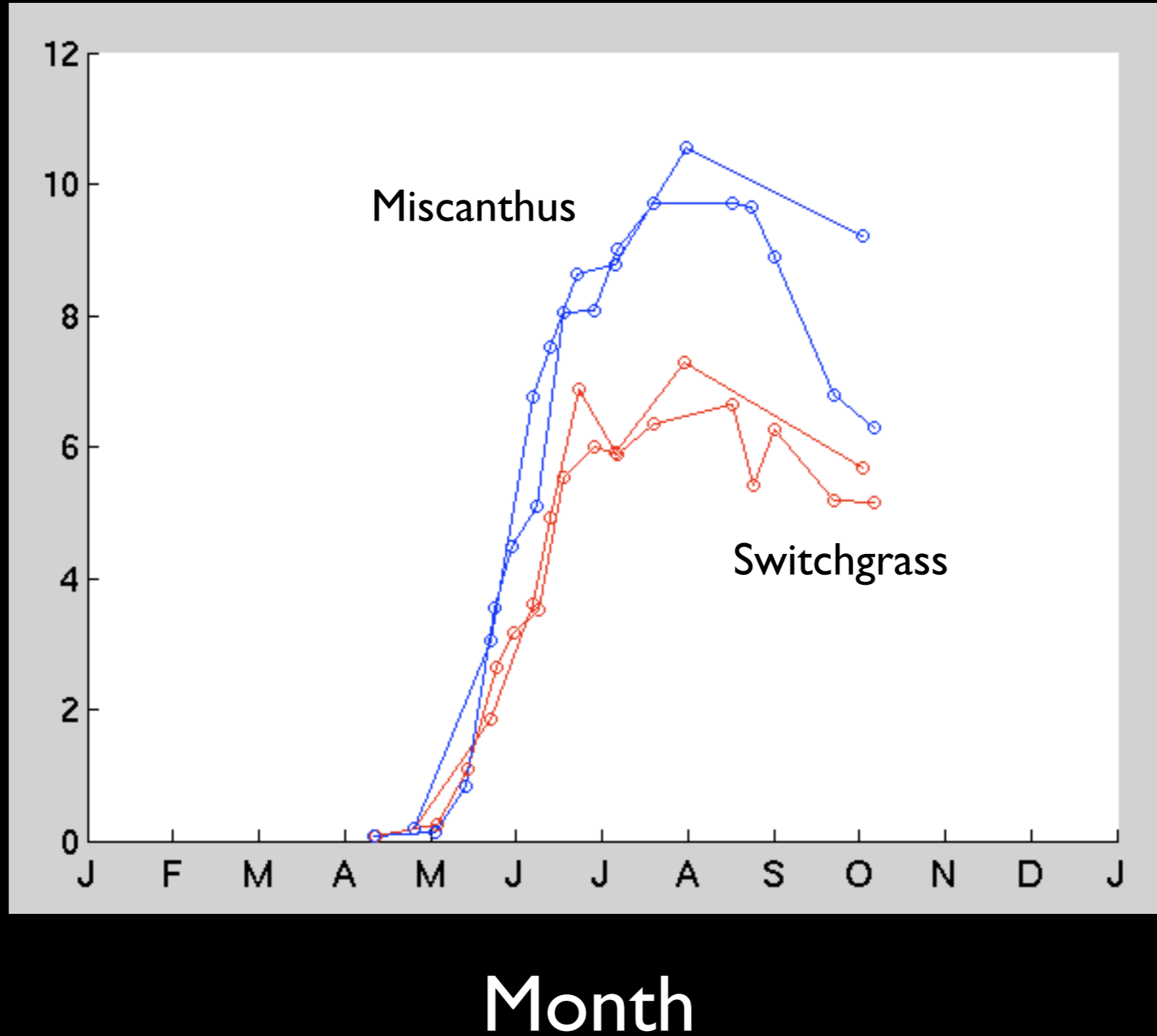
# Site-Level Parameterization





# Observations - Leaf Area Index

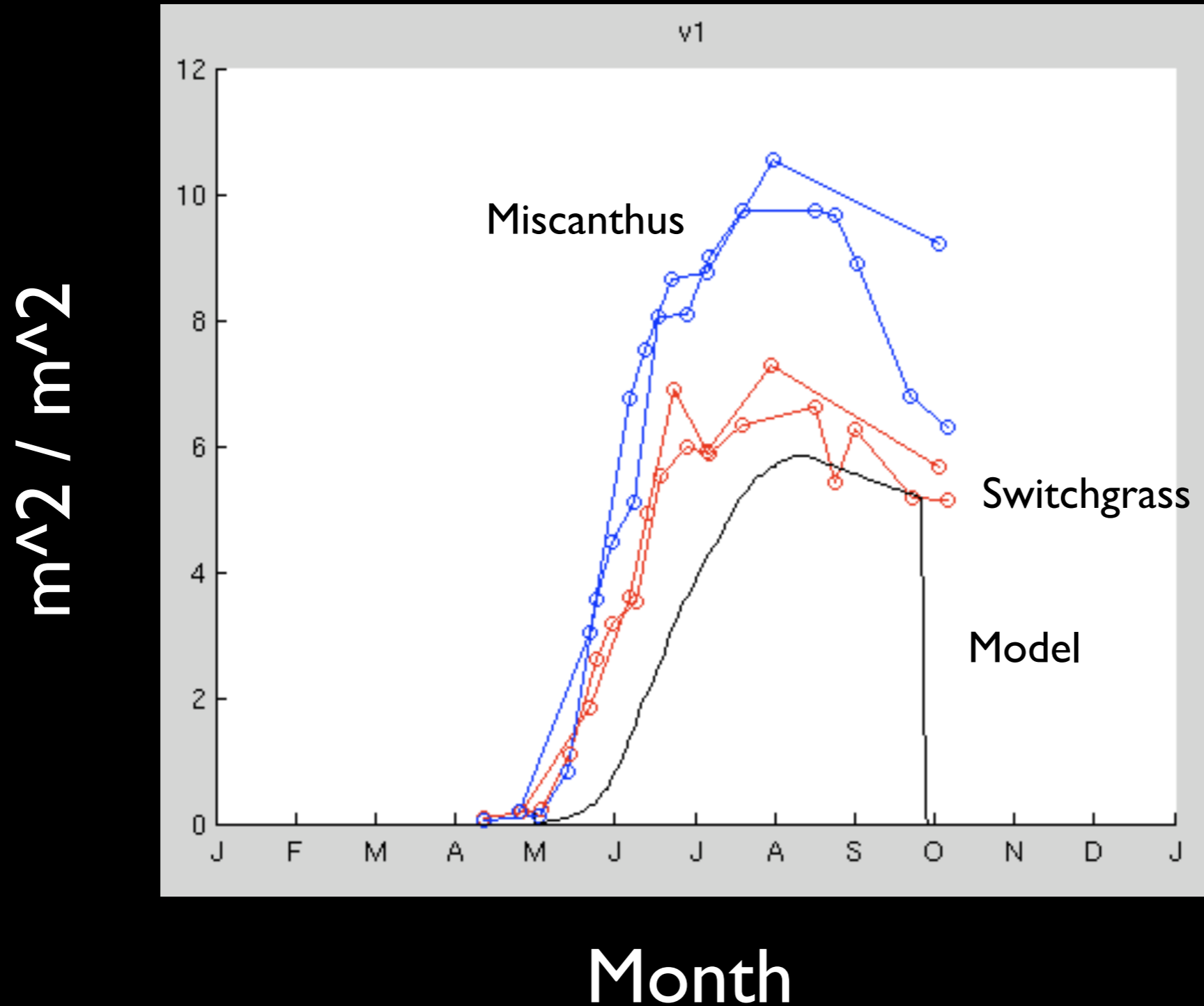
$m^2 / m^2$



# Parameter Selection

- 72 Parameters + 8 Hidden Constants
  - 21 are inconsequential
  - 17 from DiVittorio switchgrass lit review
    - CN ratios, SLA, leaf longevity, stomatal sensitivity
  - 17 from c4 Grass PFT
    - optical properties, roughness, photosynthesis, root depths
  - 16 from Corn PFT
    - phenology and carbon allocation
  - 9 “Tuned”

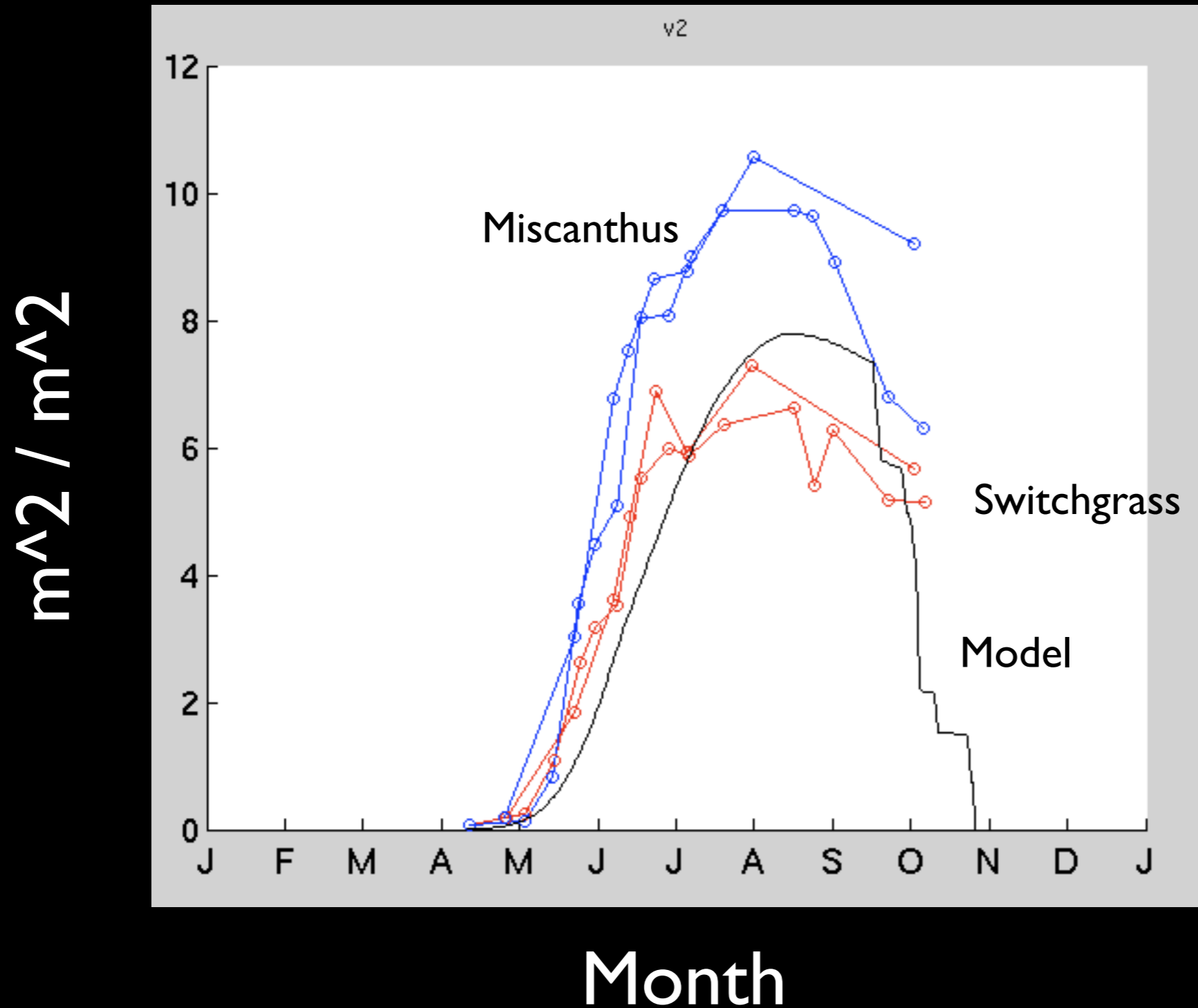
# Model vs. Observations - Leaf Area Index



## Changes

- Extended Season
- Extended Veg Phase

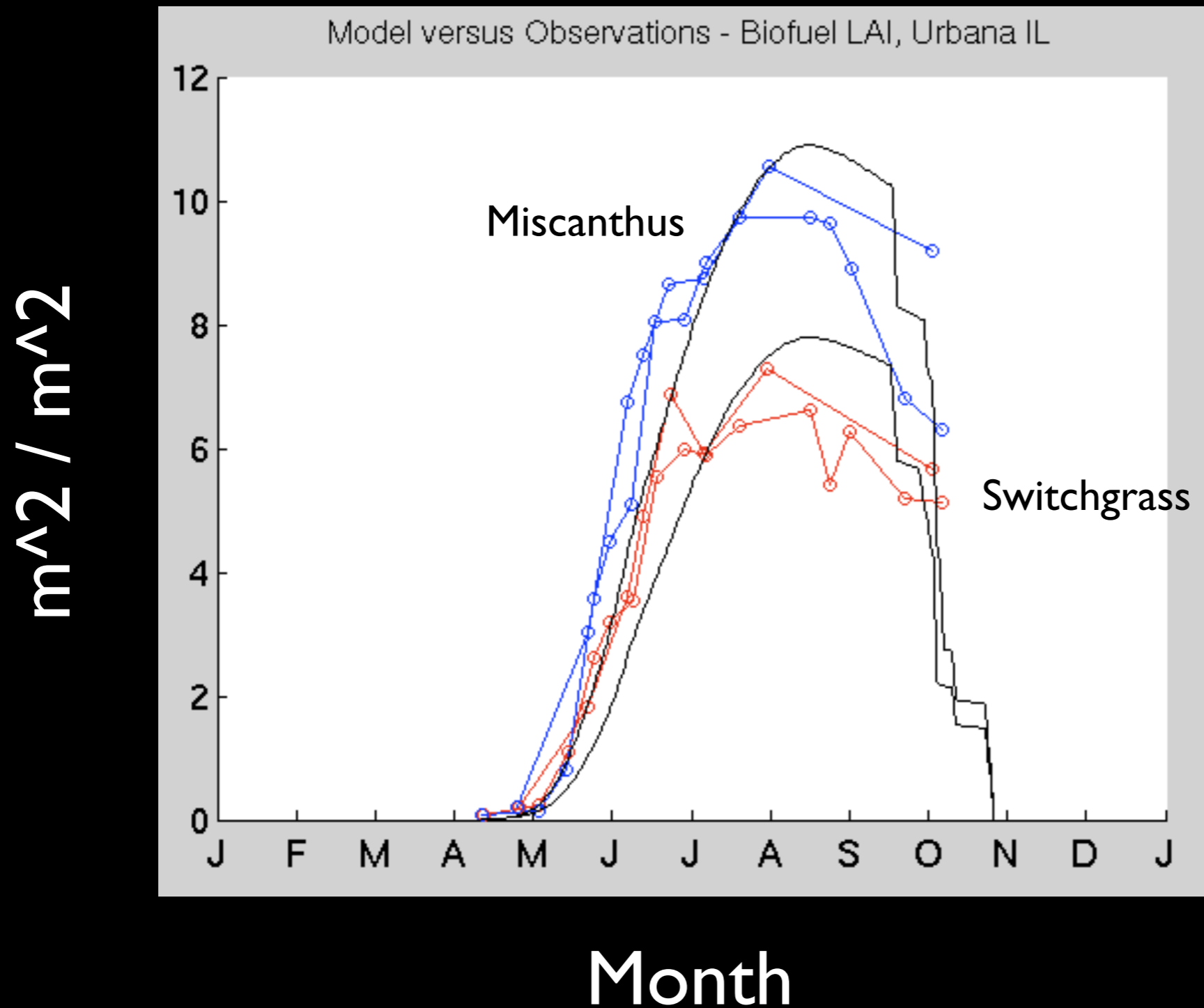
# Model vs. Observations - Leaf Area Index



## Changes

- Earlier “Planting”
- Further Extended Season
- Extended Veg Phase

# Model vs. Observations - Leaf Area Index

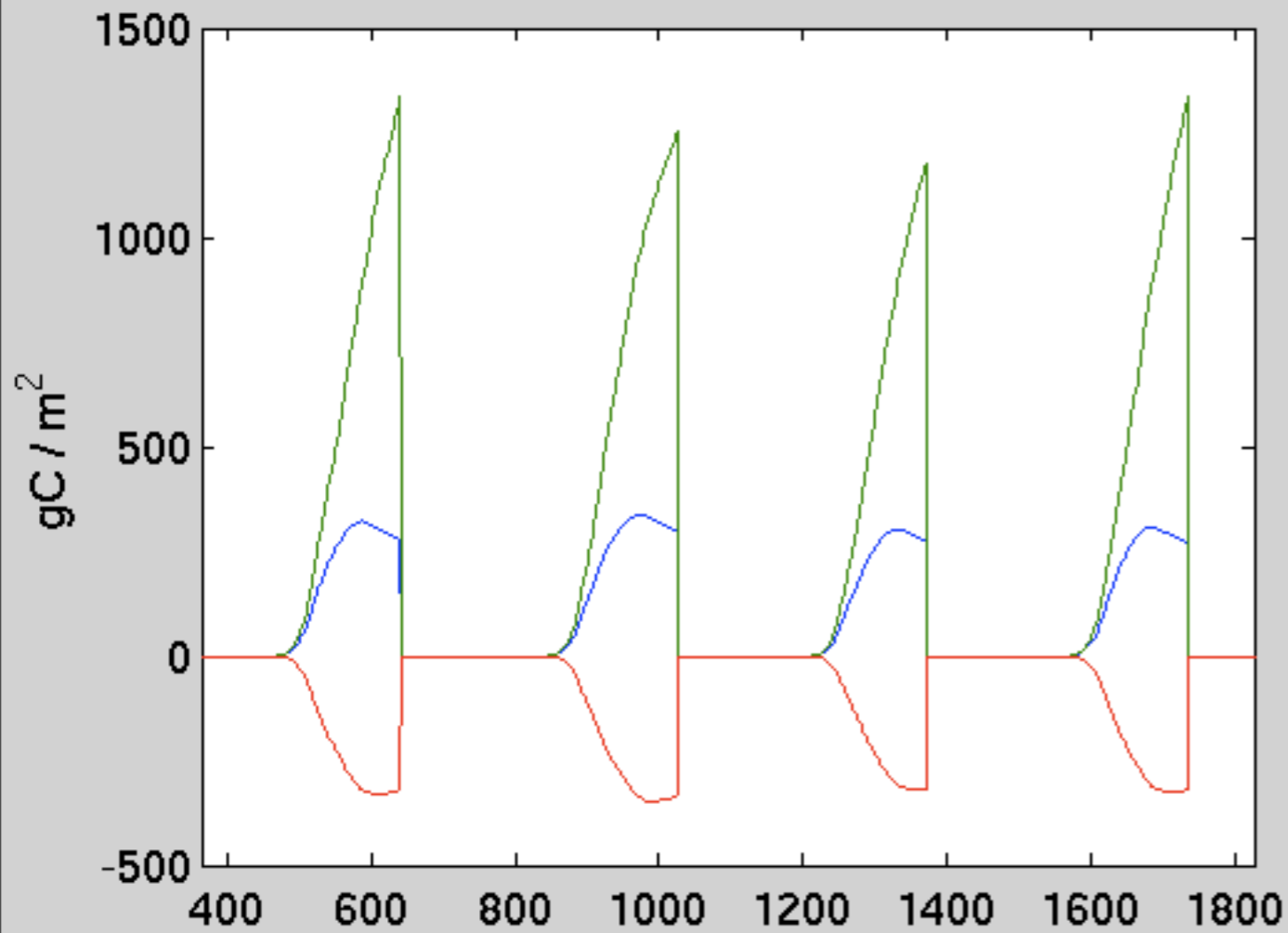


## Changes

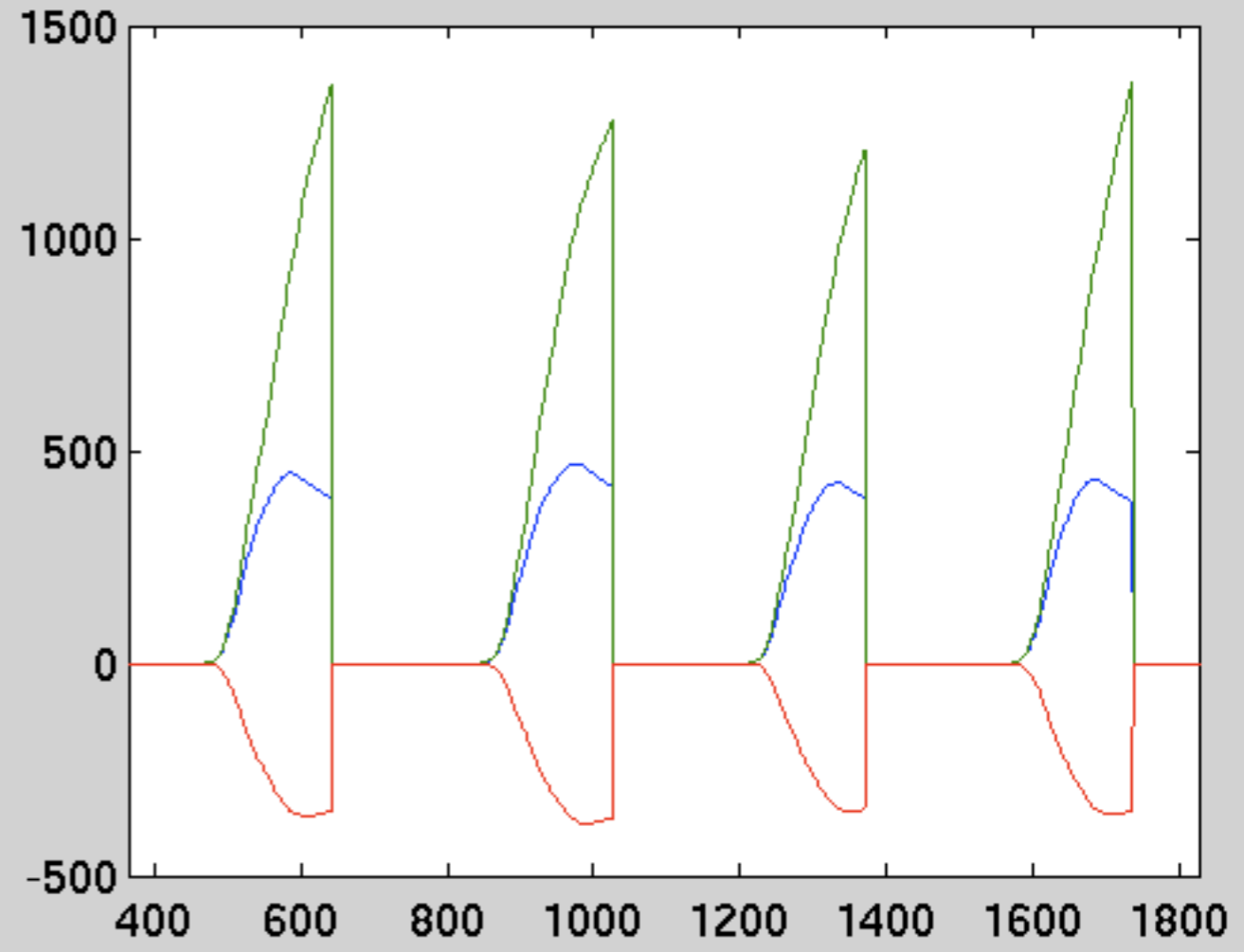
- Inc Leaf - Allocation
- Earlier “Planting”
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Switchgrass Carbon Allocation

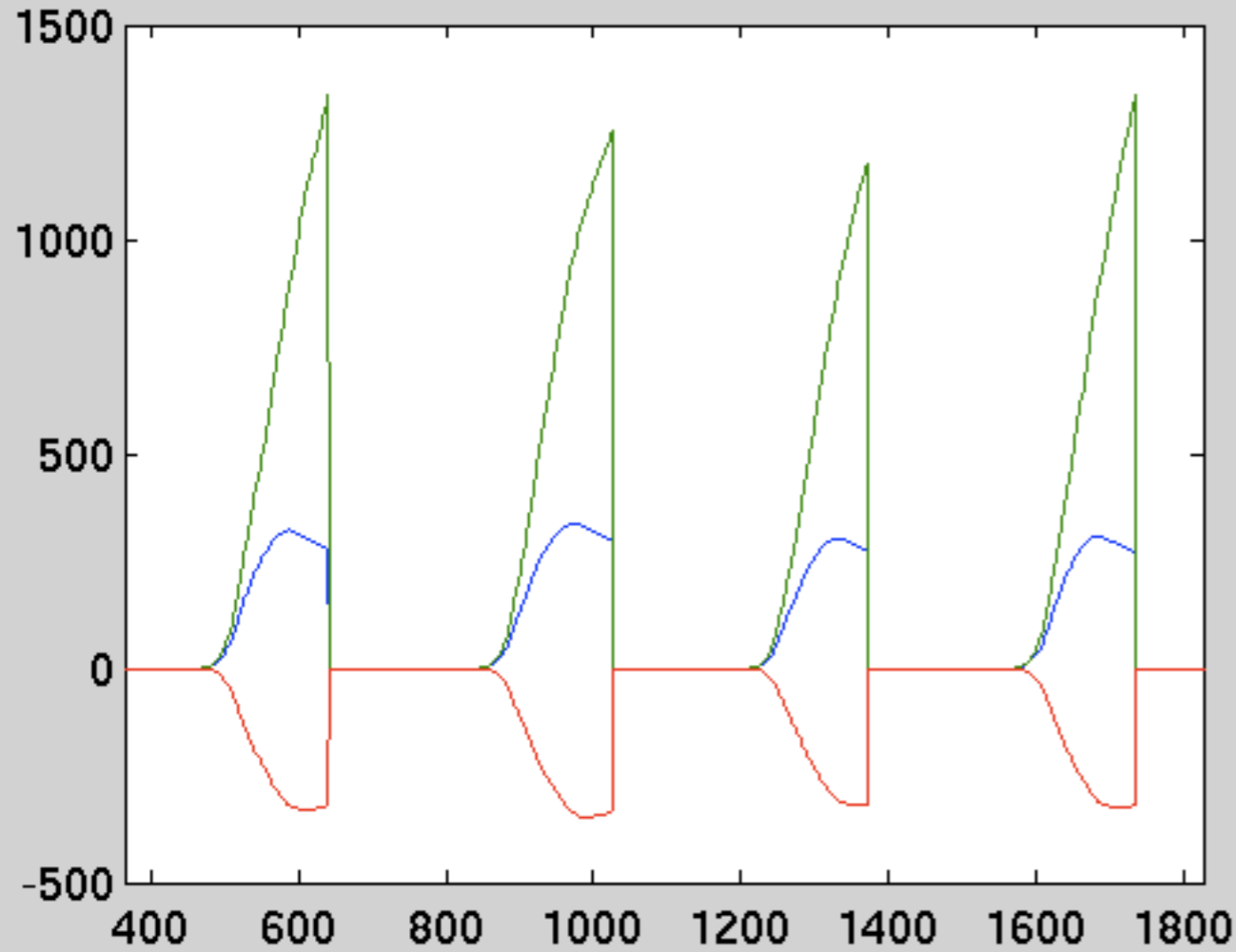


Miscanthus Carbon Allocation

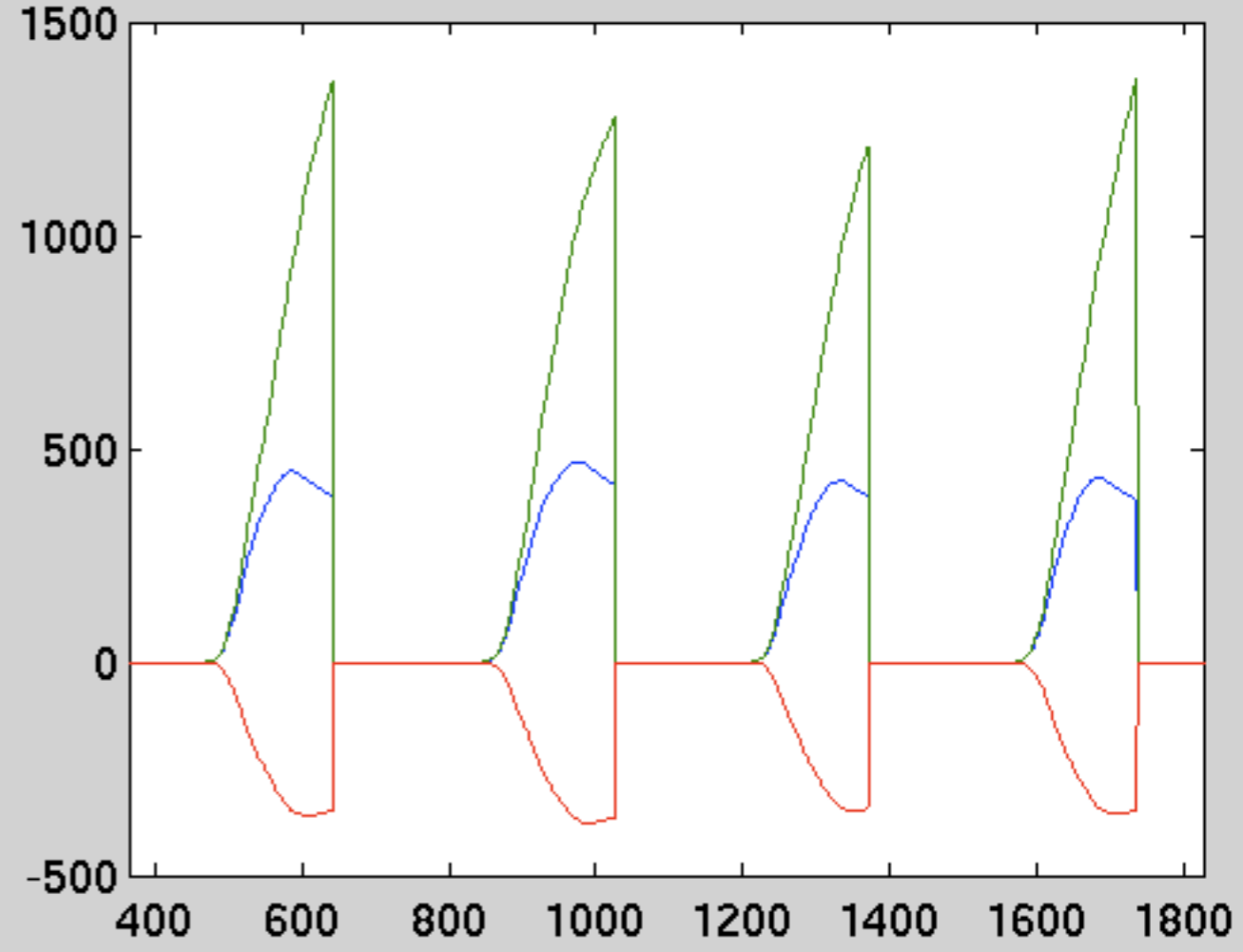


~14 tons/ha

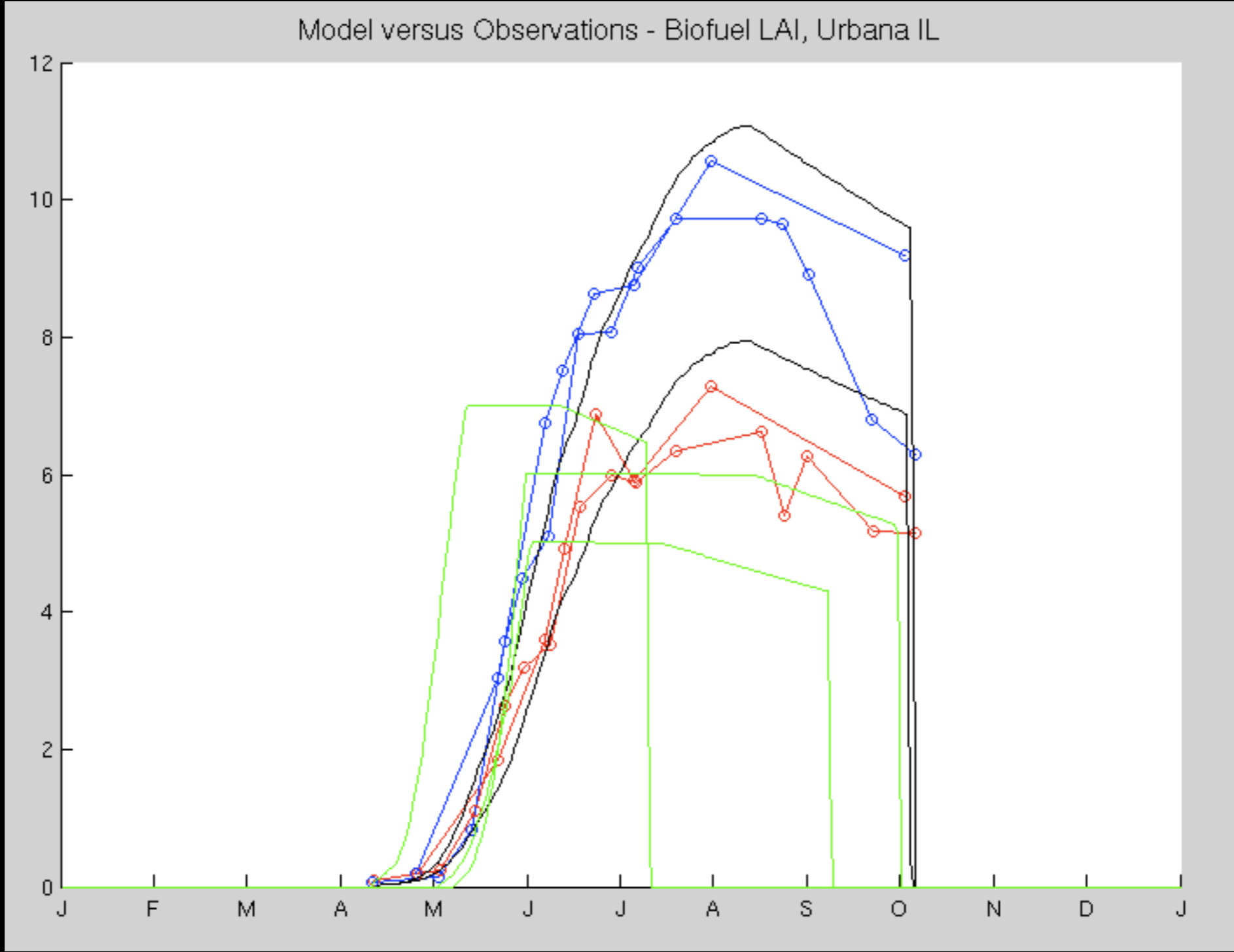
Switchgrass Carbon Allocation



Miscanthus Carbon Allocation

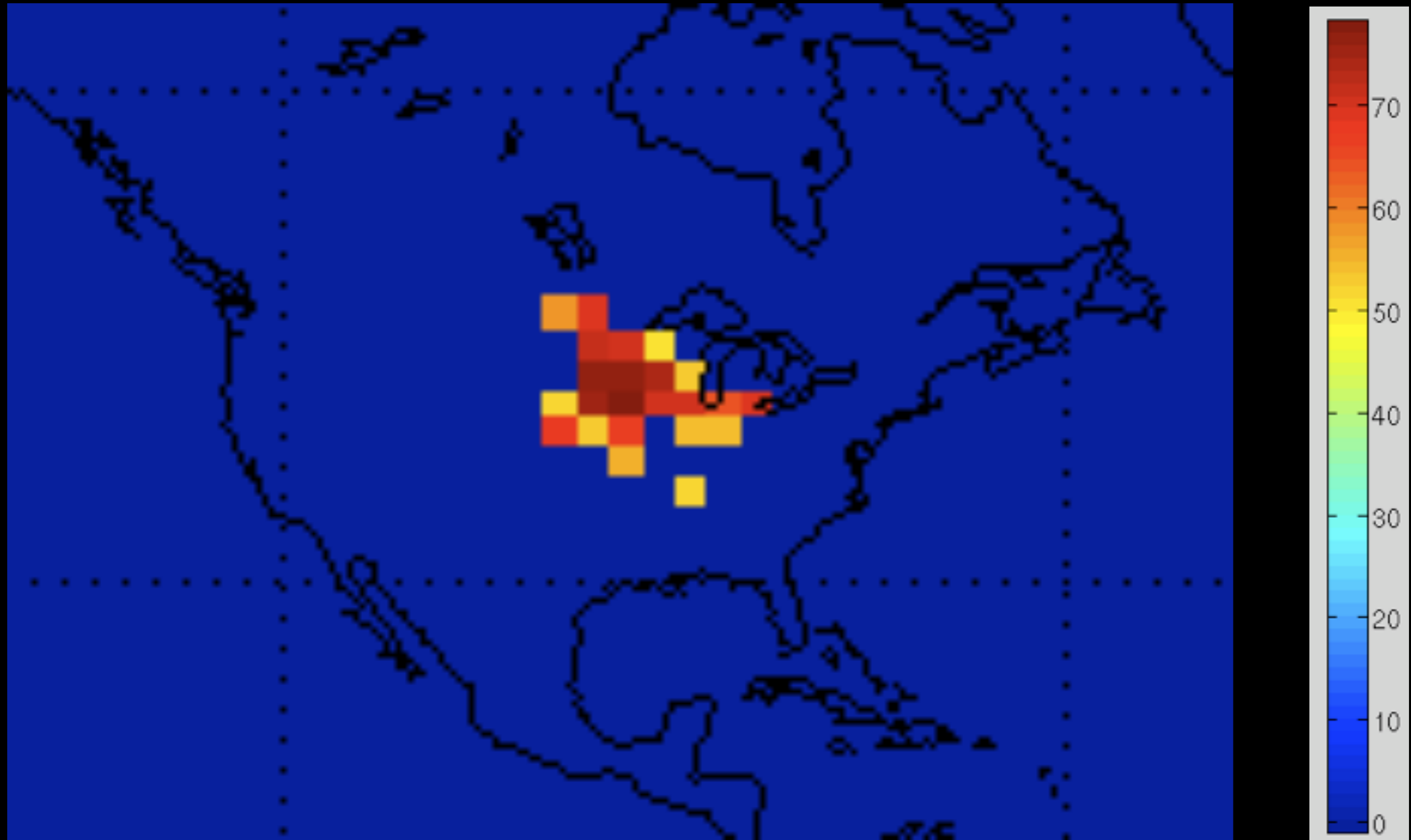


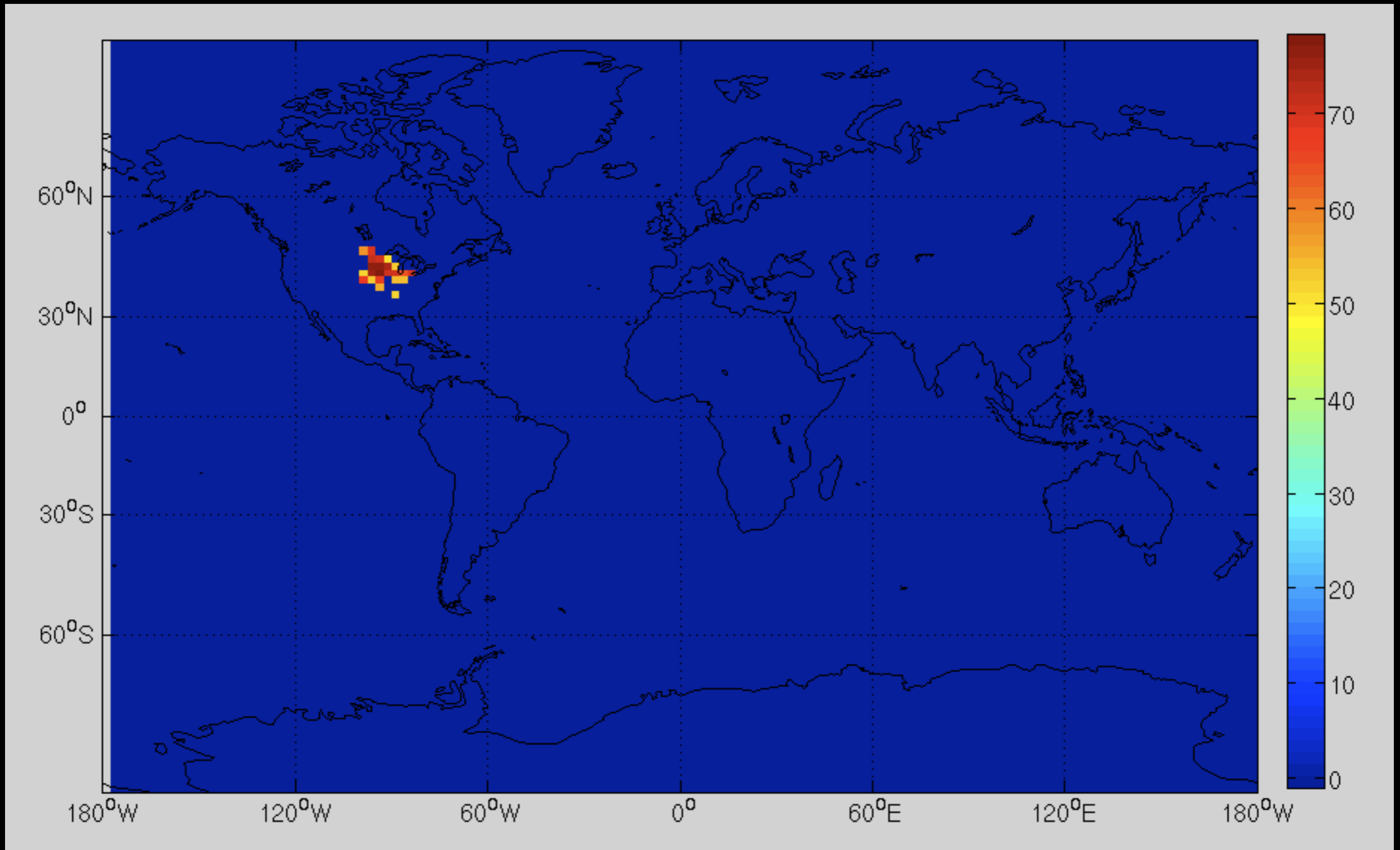
$m^2 / m^2$



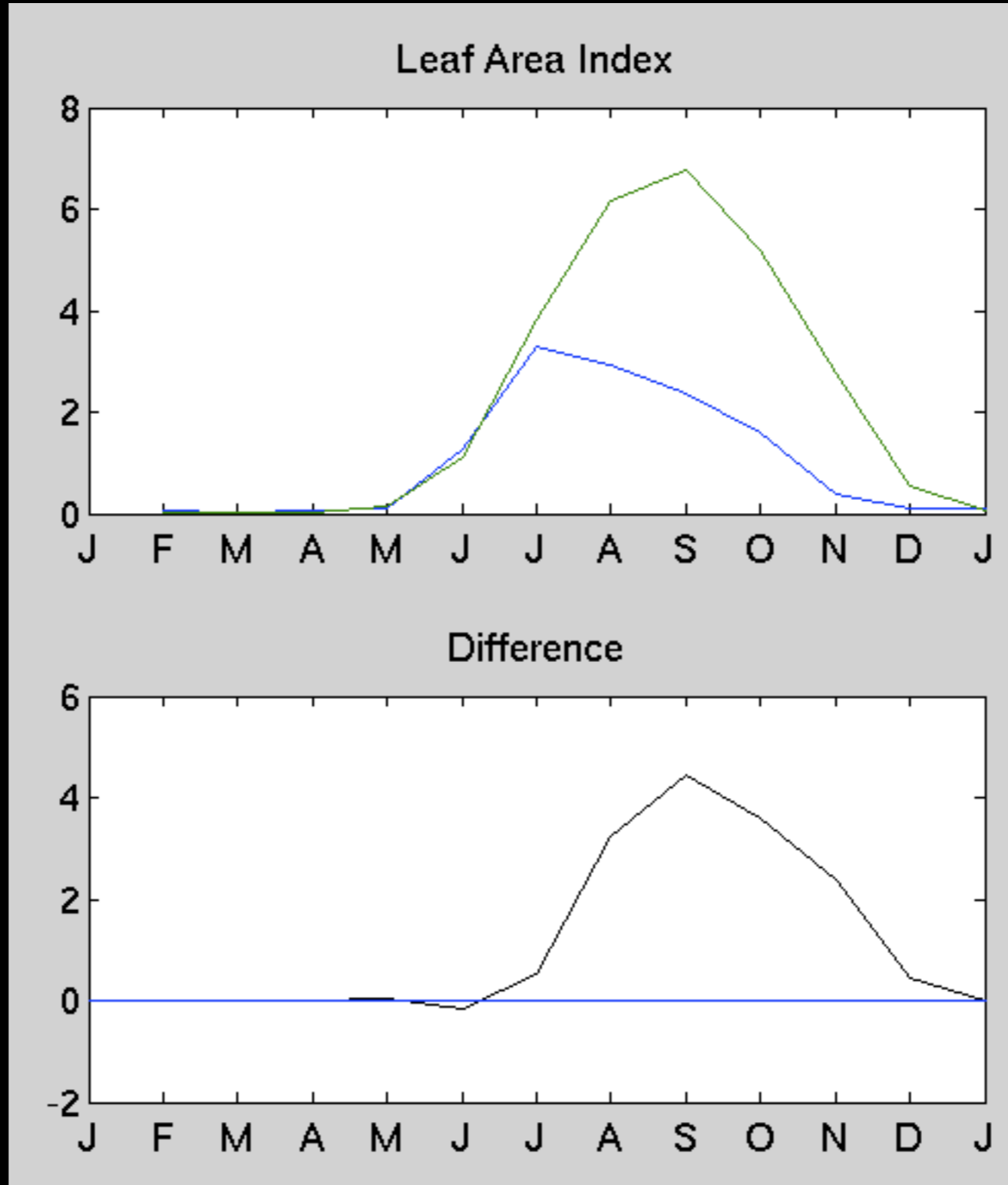
# Regional Scale Effects

# Land Area Converted to Biofuel

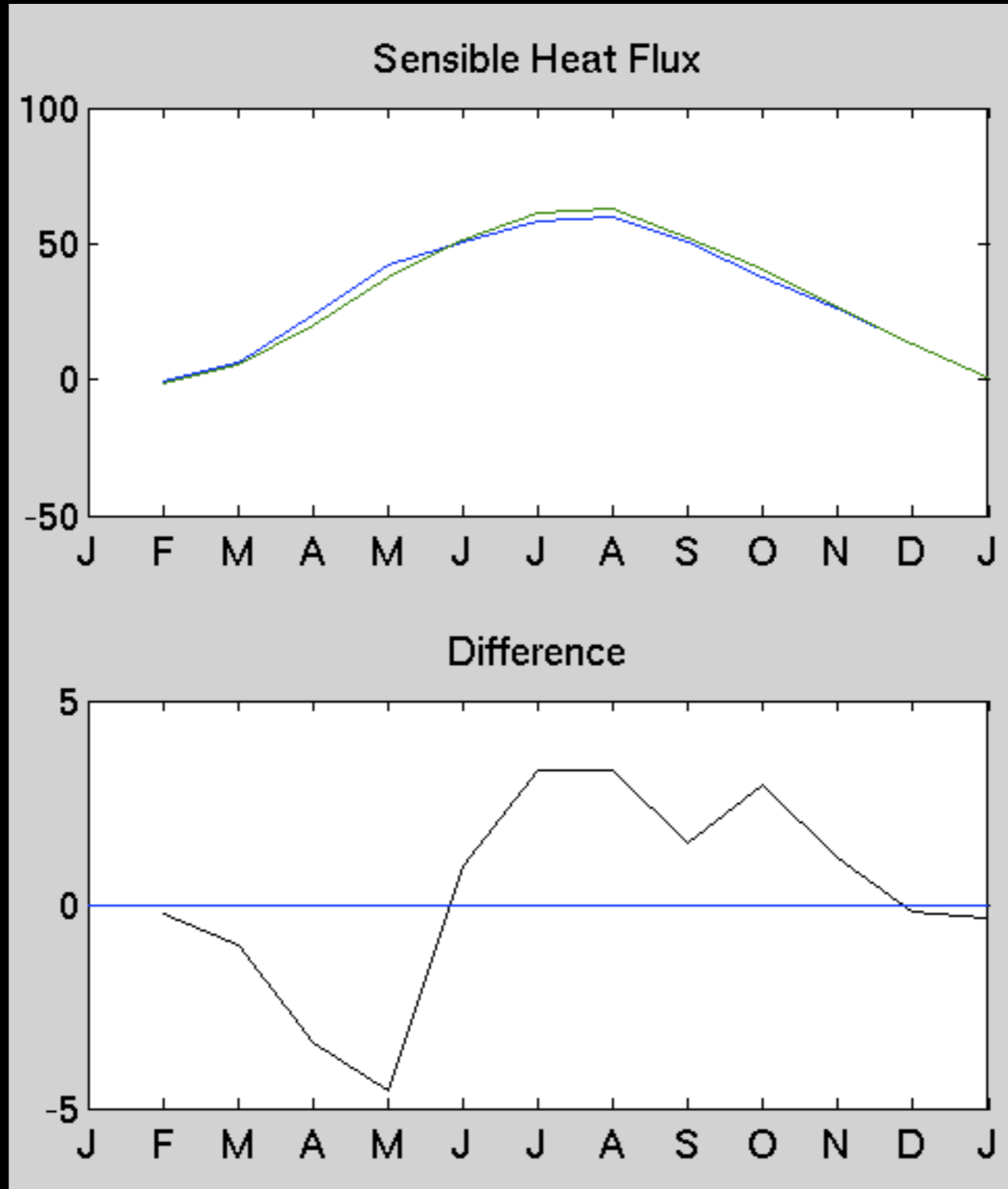




$m^2 / m^2$

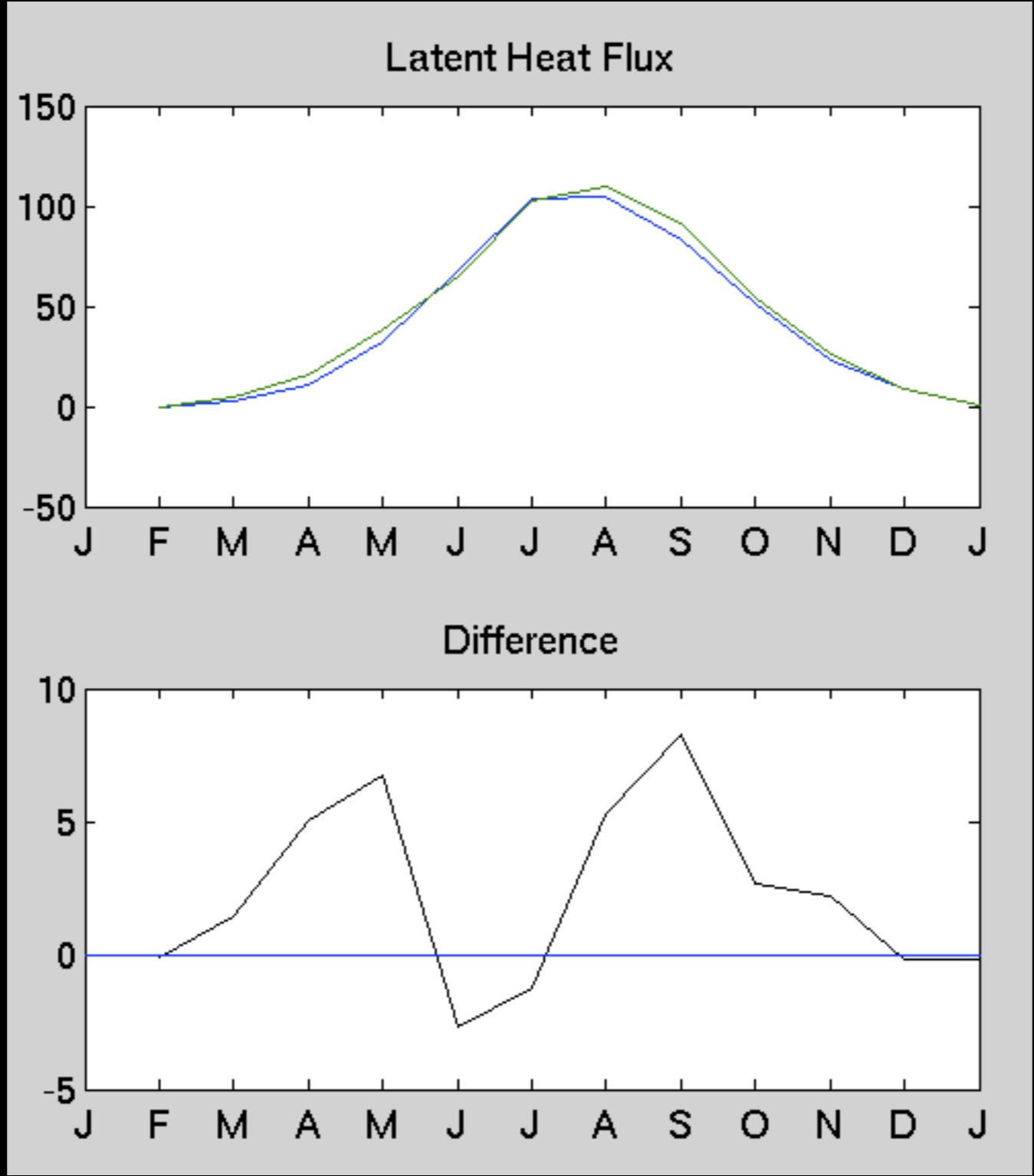


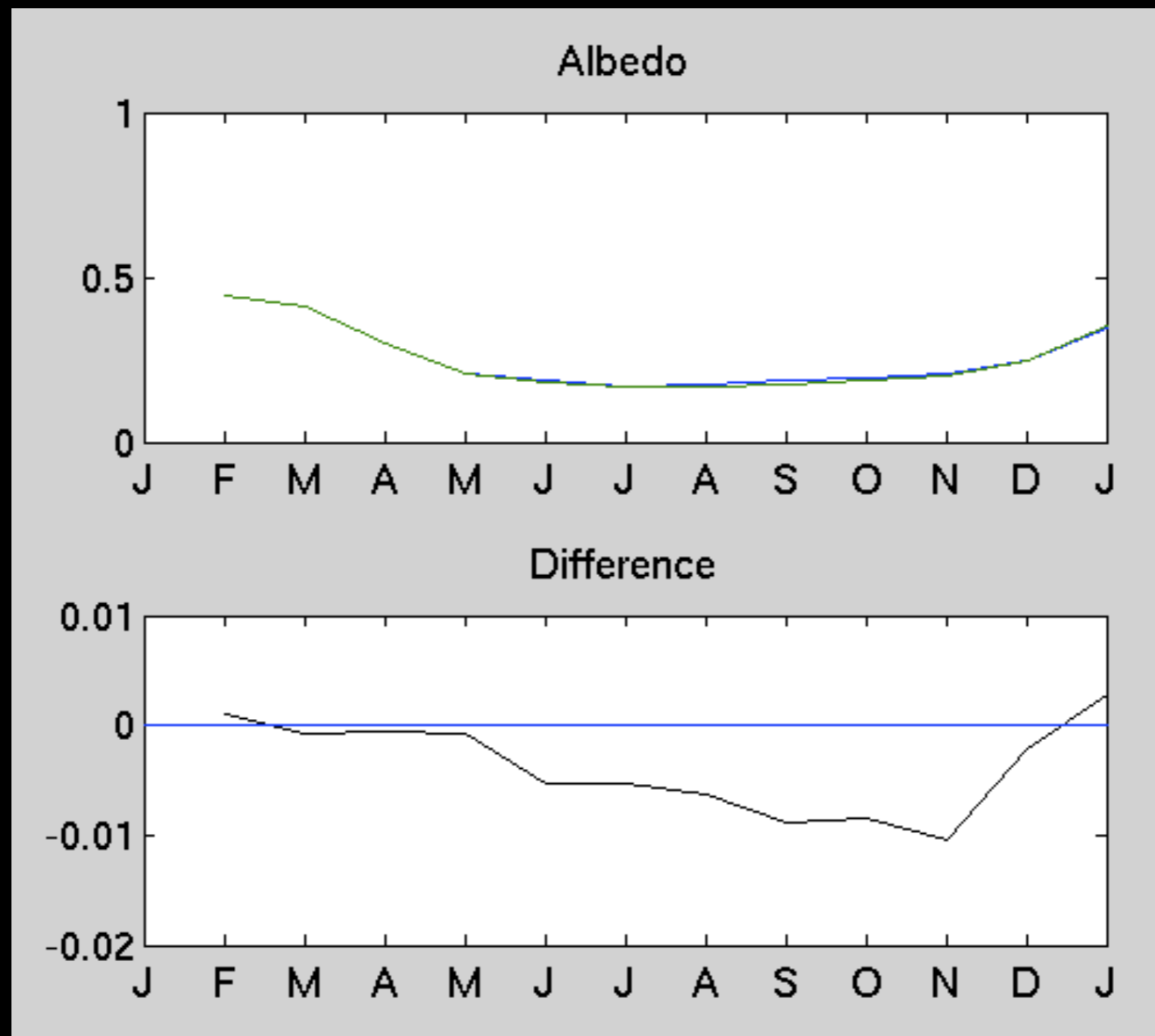
$W / m^2$



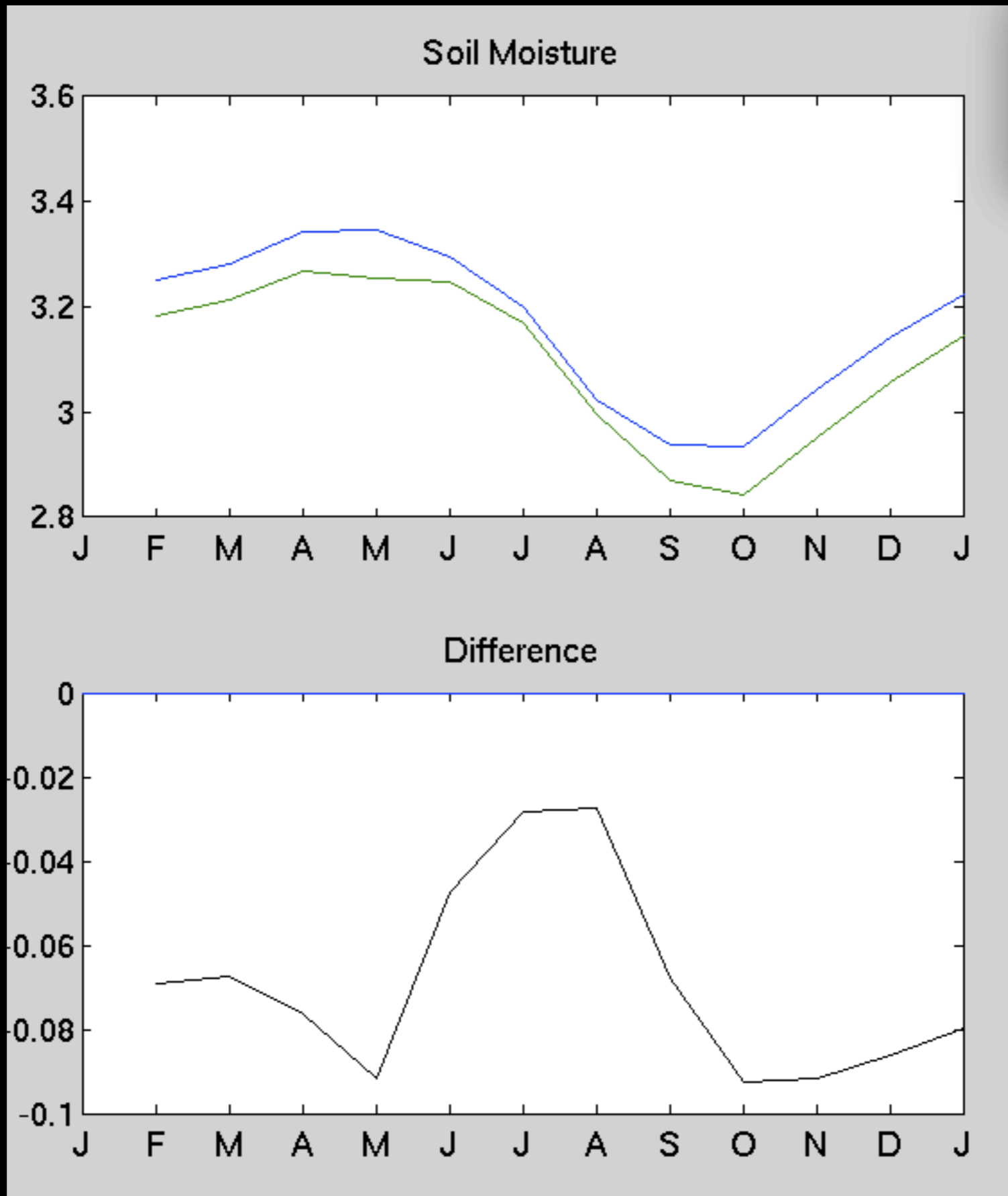


$W / m^2$





mm<sup>3</sup> / mm<sup>3</sup>



# Systematic Sensitivity Analysis



Corn



Switchgrass



Miscanthus



Sugarcane



	Corn	Switchgrass	Miscanthus	Sugarcane
Light Capture Efficiency				



	Corn	Switchgrass	Miscanthus	Sugarcane
Light Capture Efficiency				
Efficiency of Carbon Storage				



	Corn	Switchgrass	Miscanthus	Sugarcane
Light Capture Efficiency		++	++	
Efficiency of Carbon Storage	++		++	





	Corn	Switchgrass	Miscanthus	Sugarcane
Light Capture Efficiency				
Aboveground Carbon Storage				
Water Use Efficiency				



	Corn	Switchgrass	Miscanthus	Sugarcane
Light Capture Efficiency				
Aboveground Carbon Storage				
Water Use Efficiency				
Drought Tolerance				



	Corn	Switchgrass	Miscanthus	Sugarcane
Light Capture Efficiency				
Aboveground Carbon Storage				
Water Use Efficiency				
Drought Tolerance				
Nutrient Demand				



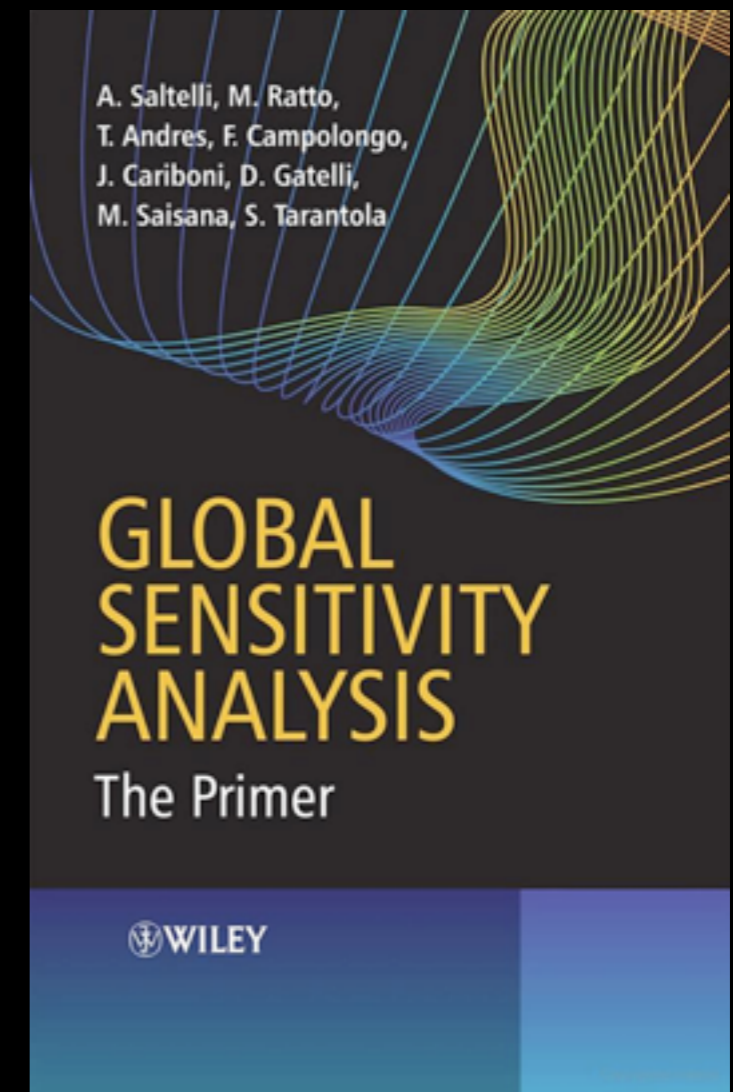
	Corn	Switchgrass	Miscanthus	Sugarcane
Light Capture Efficiency				
Aboveground Carbon Storage				
Water Use Efficiency				
Drought Tolerance				
Nutrient Demand				
Leaf Reflectance				

# Systematic Sensitivity Analysis

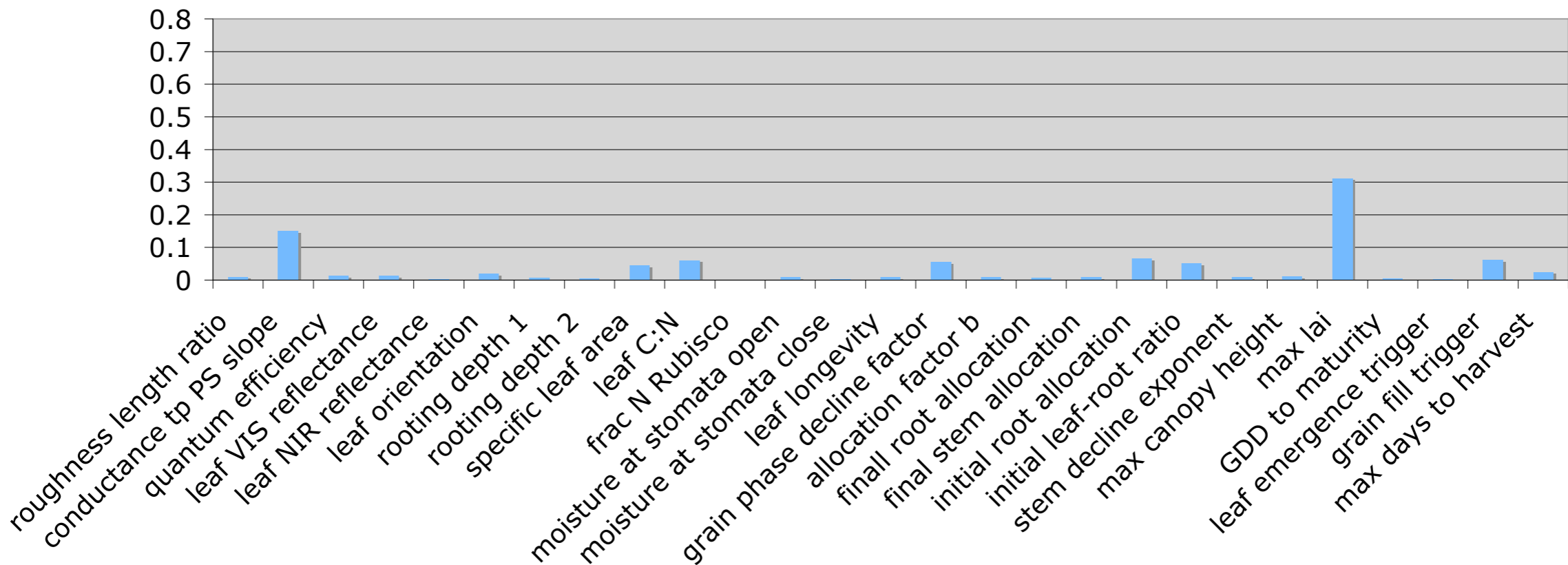
- Goal is to compute a metric representing the importance of each parameter in the variance of a model output of interest
- Sobol First Order Term
  - $S_i = V[E(Y|X_i)] / V(Y)$
- Sobol Total Effect Term
  - $ST_i = 1 - V[E(Y|X_{\sim i})] / V(Y)$

# Systematic Sensitivity Analysis

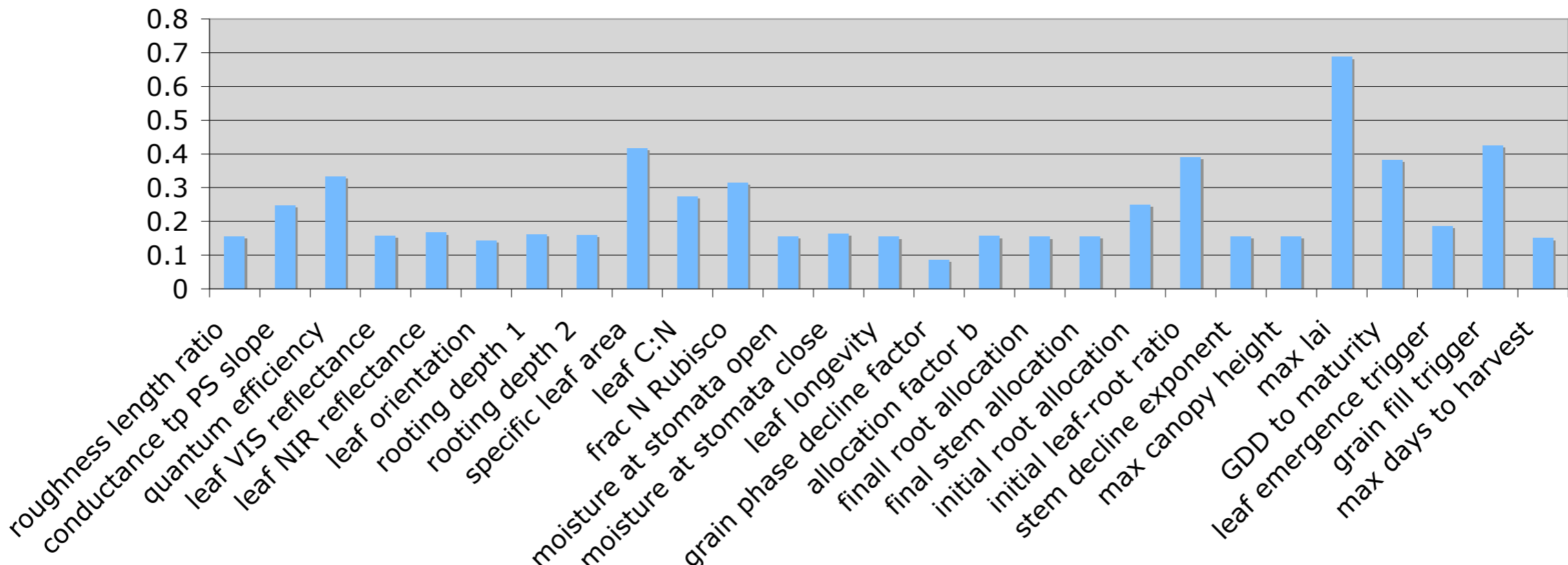
- Using approximation method of Saltelli et al.
- Several 10,000's of model runs at Mead Site
- 27 parameters
- Uniform distributions over a broad area of the parameter space



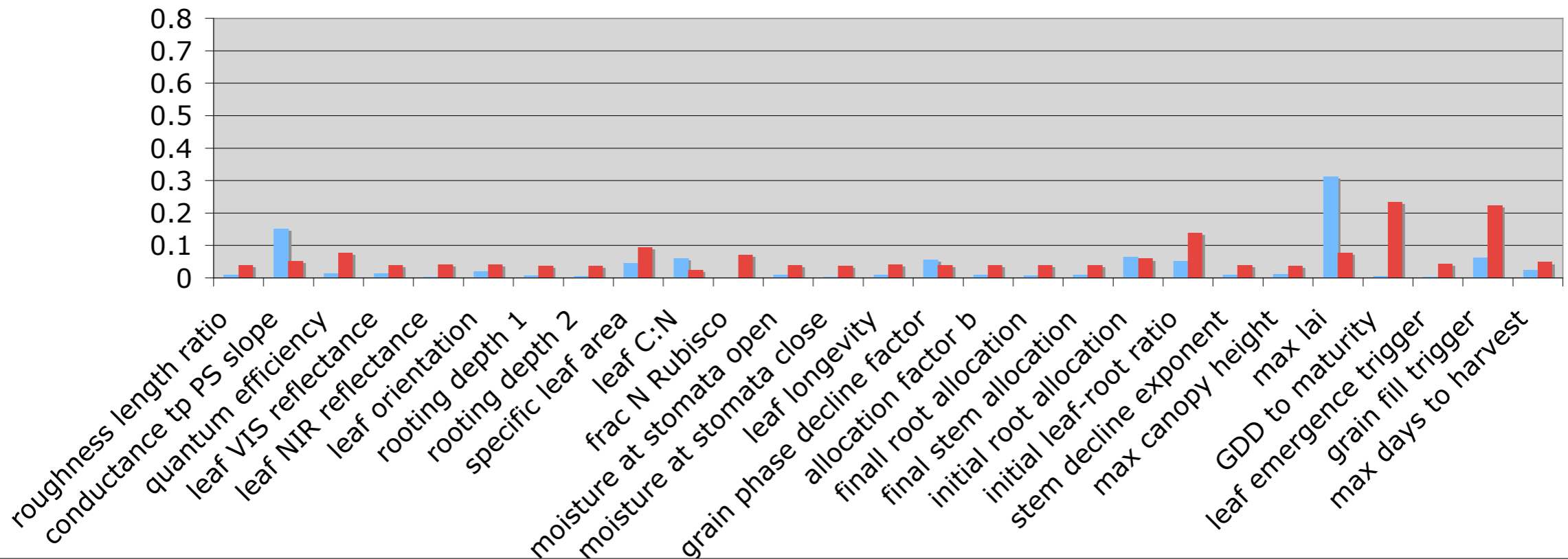
### First Order Effect (Si) of Selected Parameters on LAI Goodness-of-Fit



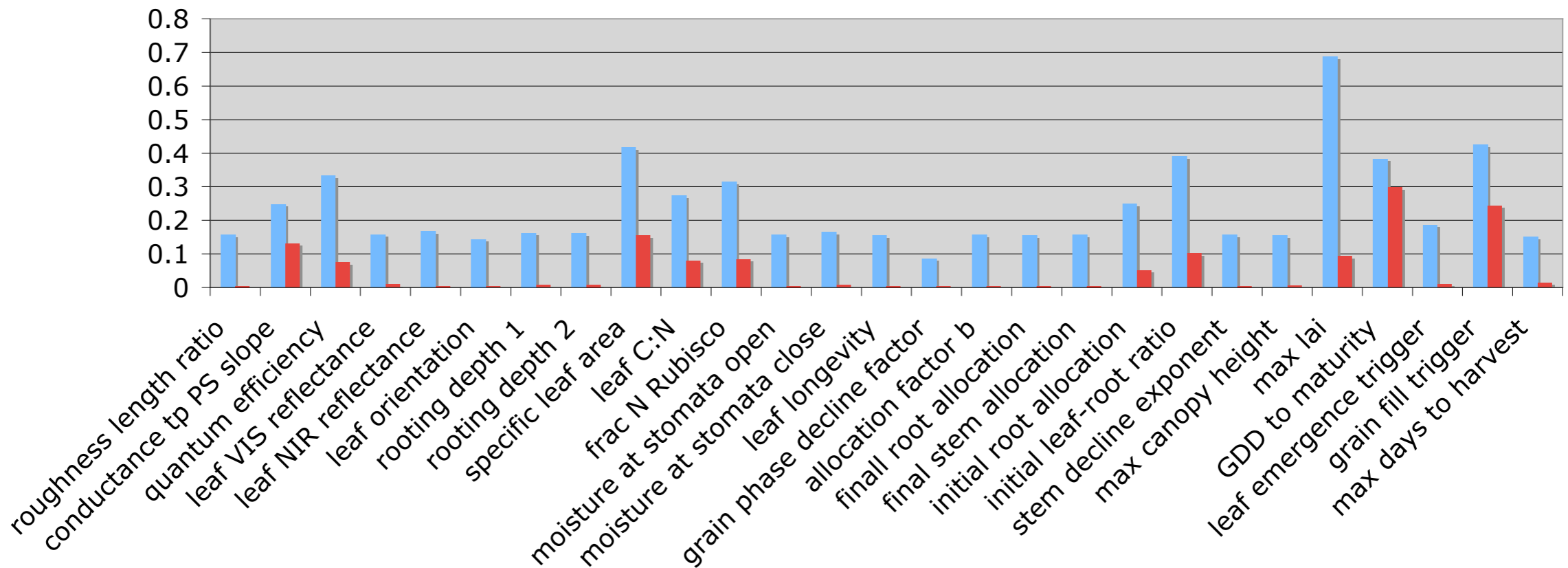
### Total Effect (STi) of Selected Parameters on LAI Goodness-of-Fit



### First Order Effect (Si) of Selected Parameters on Annual Mean LAI



### Total Effect (STi) of Selected Parameters on Annual Mean LAI





# Next Steps

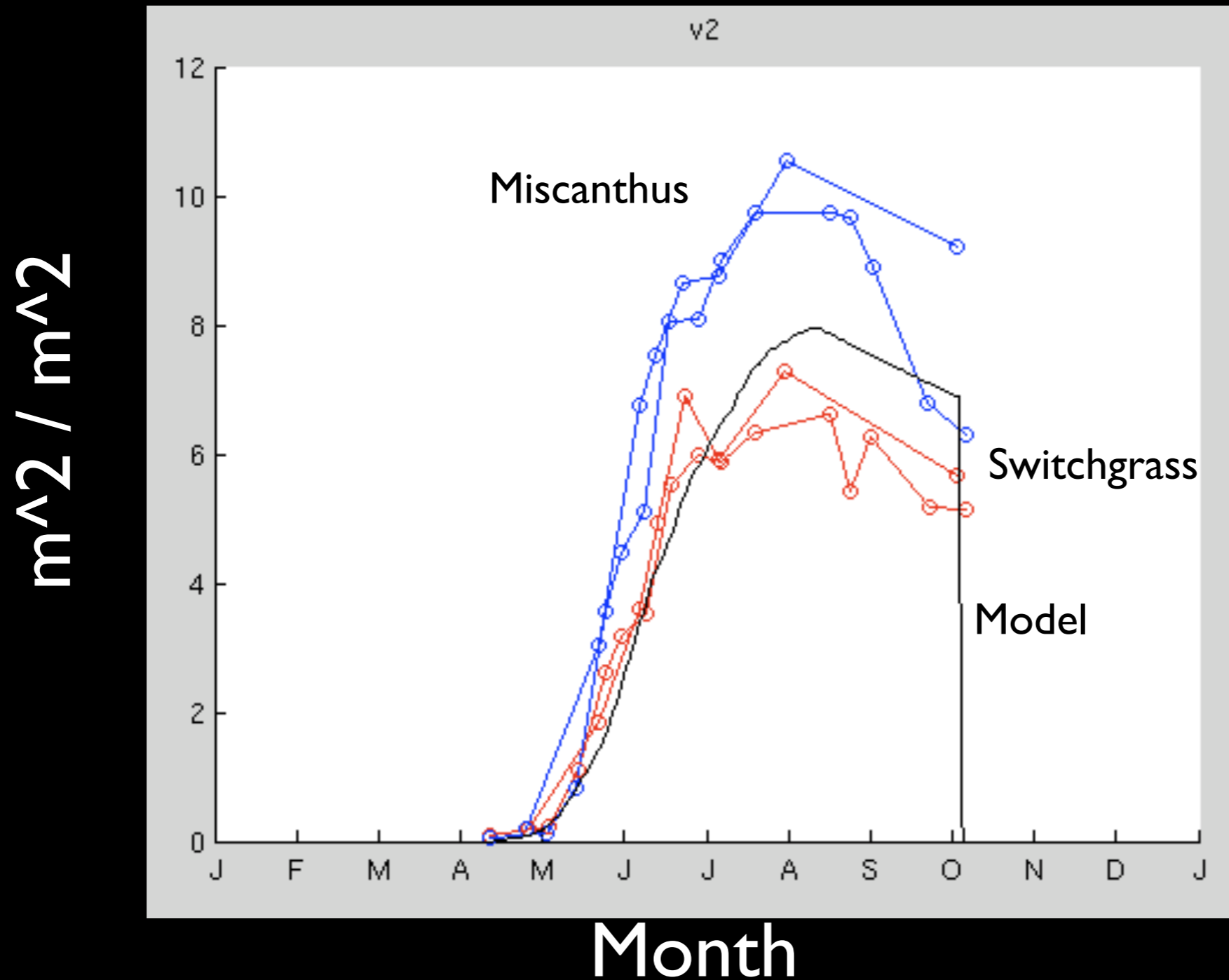
- Near Term
  - Further constrain parameters with carbon allocation data
  - Coupled biogeophysical simulations
- Longer Term
  - management
  - flux data assimilation
  - standing dead biomass
  - N retranslocation
  - sensitivity to interannual variability, geography

# Thank You

The background of the slide features a silhouette of a church steeple with a cross on top, set against a bright, golden sunset sky. The sun is low on the horizon, creating a strong glow and casting long, soft shadows. In the foreground, there is a dark, silhouetted area that appears to be a shoreline or a body of water with some trees or bushes on the right side.

- Margaret Torn
- Sam Levis
- Bill Collins
- Peter Thornton
- Bill Riley
- Zack Subin
- Mike O'Hare
- Lisa Murphy

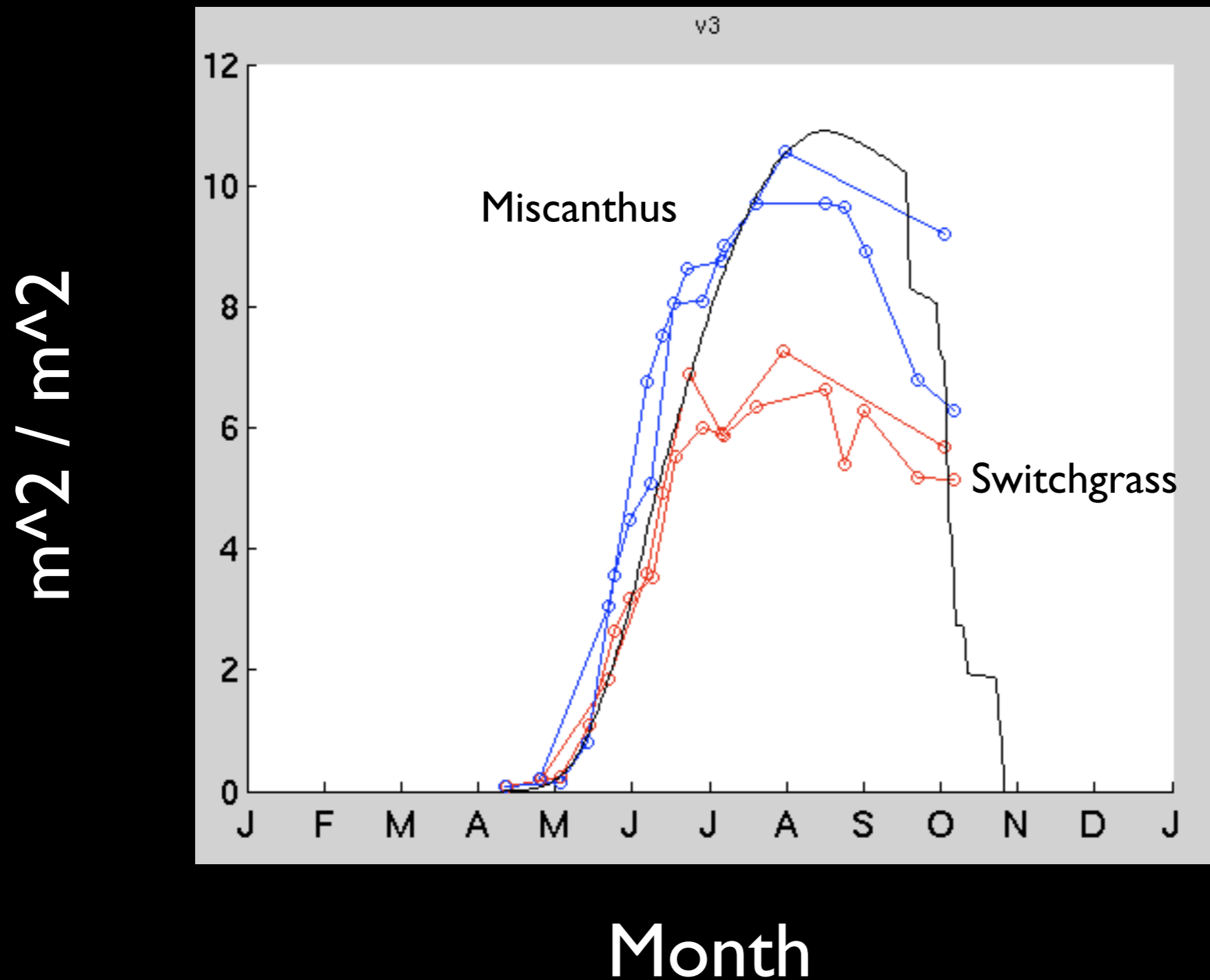
# Model vs. Observations - Leaf Area Index



## Changes

- Earlier “Planting”
- Further Extended Season
- Extended Veg Phase

# Model vs. Observations - Leaf Area Index

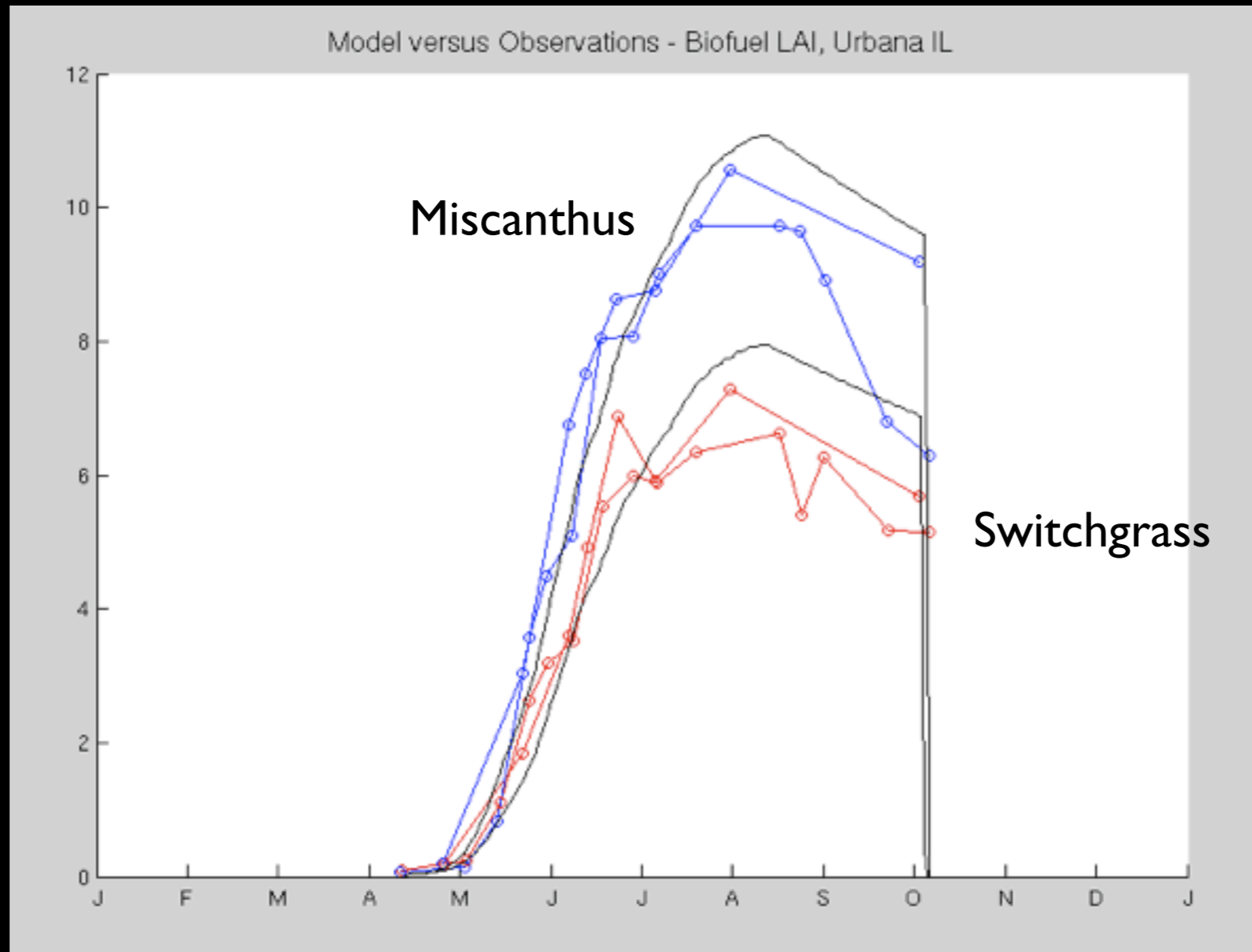


## Changes

- Inc Leaf - Allocation
- Earlier “Planting”
- Further Extended Season
- Extended Veg Phase

# Model vs. Observations - Leaf Area Index

$m^2 / m^2$



Month

## Changes

- Inc Leaf - Allocation
- Earlier “Planting”
- Further Extended Season
- Extended Veg Phase

### Evapotranspiration

### Drainage

