Energy Crops and their Implications on Surface Energy and Water Balance

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Acknowledgements

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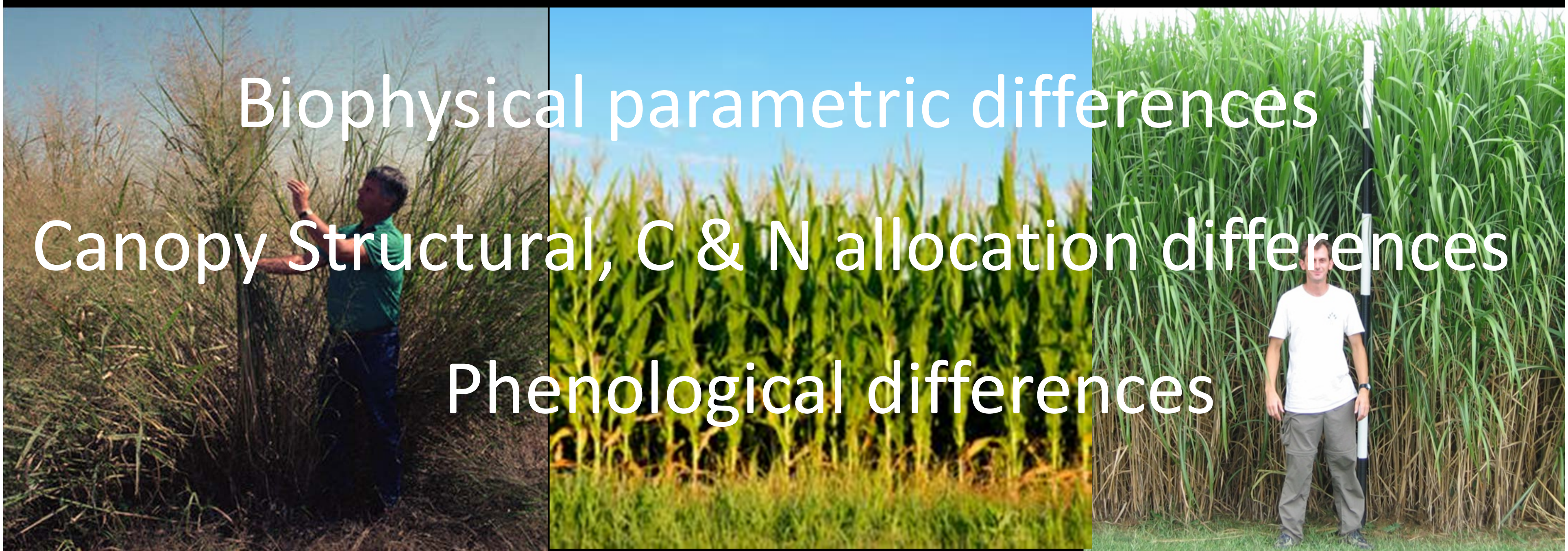
Current Bioenergy Crops considered in the US

Switchgrass Corn Miscanthus

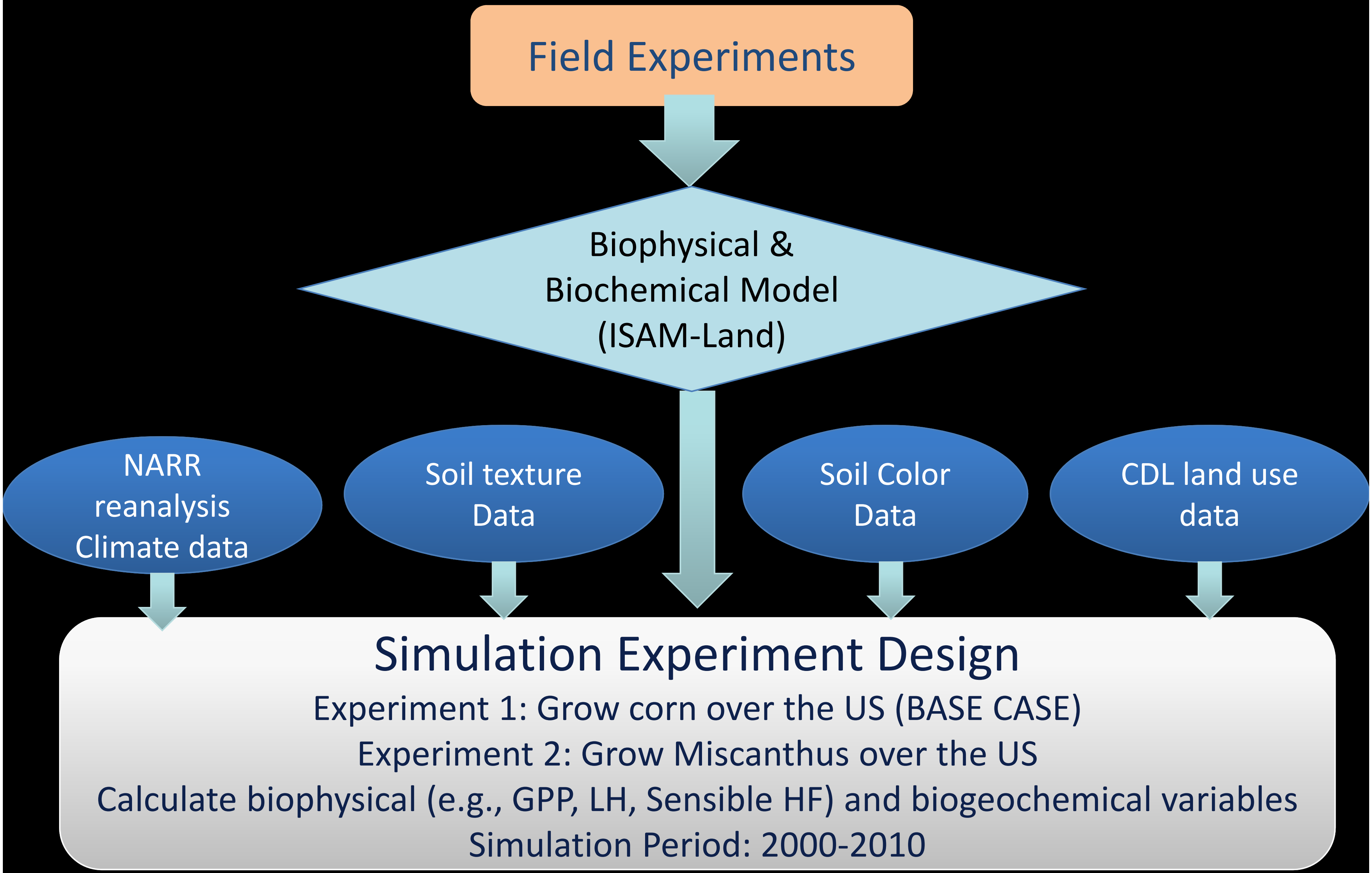


Variation in water and thermal energy consumption

Objectives

- Examine potential productivity and their spatial variability of main bioenergy crops
- Assess the impact of different bioenergy crops on energy and water balance
  - Temporal and spatial patterns of
    - Evapotranspiration
    - Radiation (albedo effect)

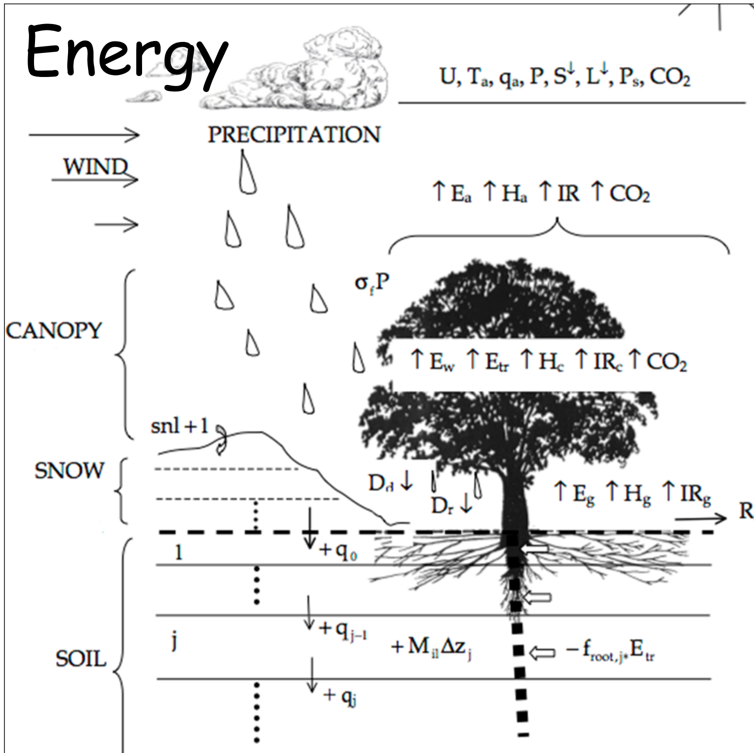
Research Approach

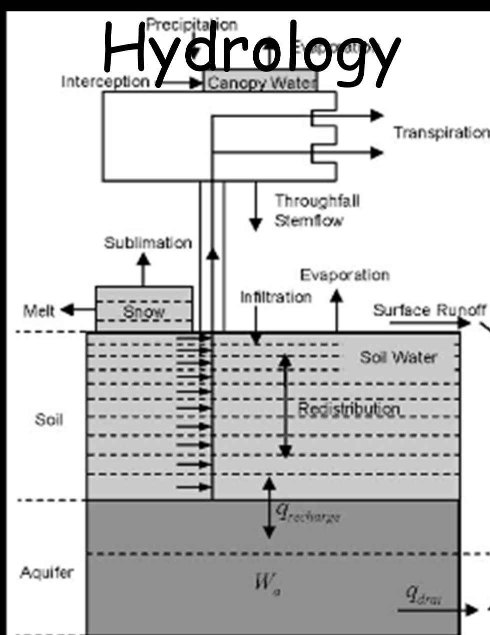


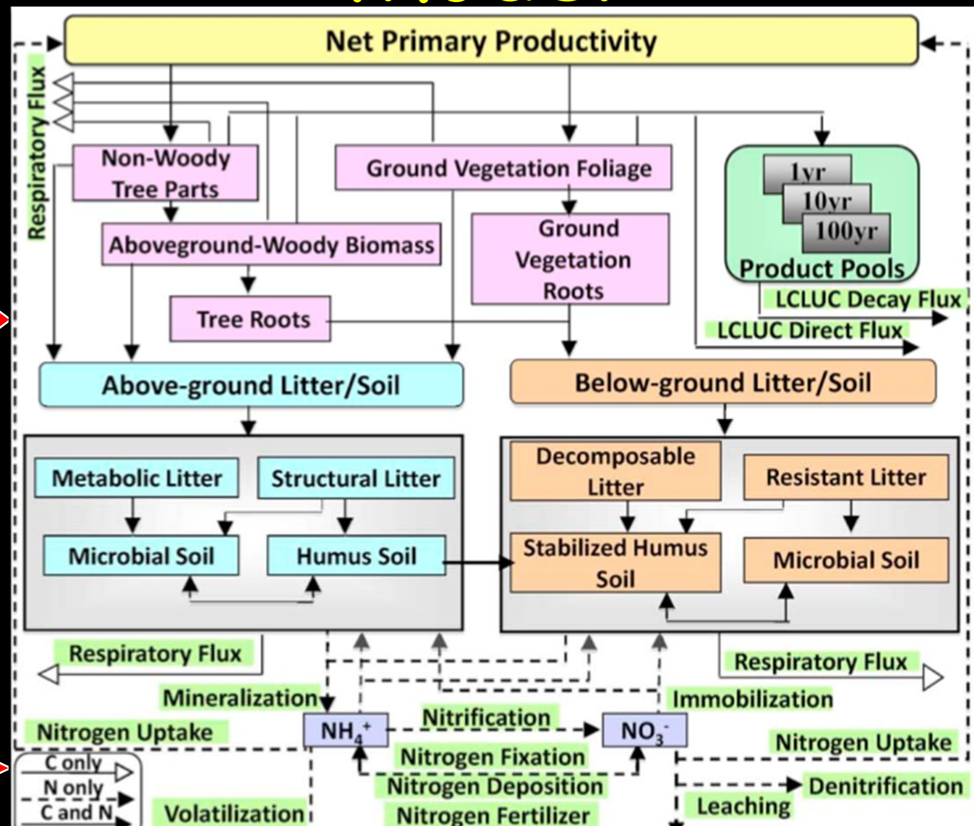
ISAM Land Model

- Biophysical
  - Photosynthesis and Energy processes
    - Canopy temperature, photosynthesis and stomatal conductance based on two-big-leaf (sunlit and shaded) scheme
    - Heat and momentum exchange fluxes between canopy and atmosphere calculated as a function of atmospheric stability, canopy height and stomatal conductance.
  - Soil/snow hydrology process
    - Layered soil water redistribution calculation related to specific root depth of species.
- Biogeochemistry
  - Carbon-Nitrogen cycling in soils and vegetation

ISAM-Land-Surface Model





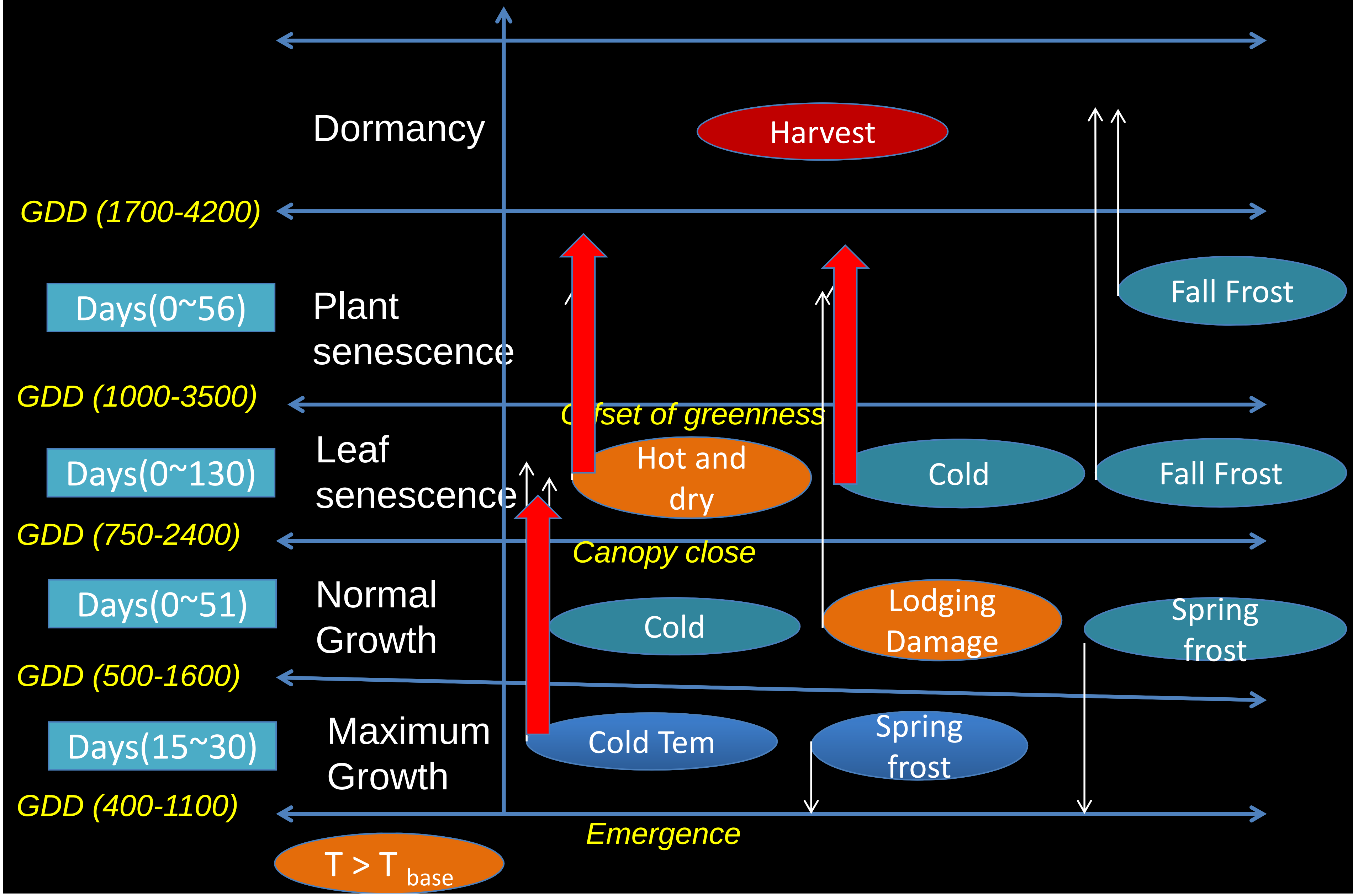


Carbon and Nitrogen Cycling

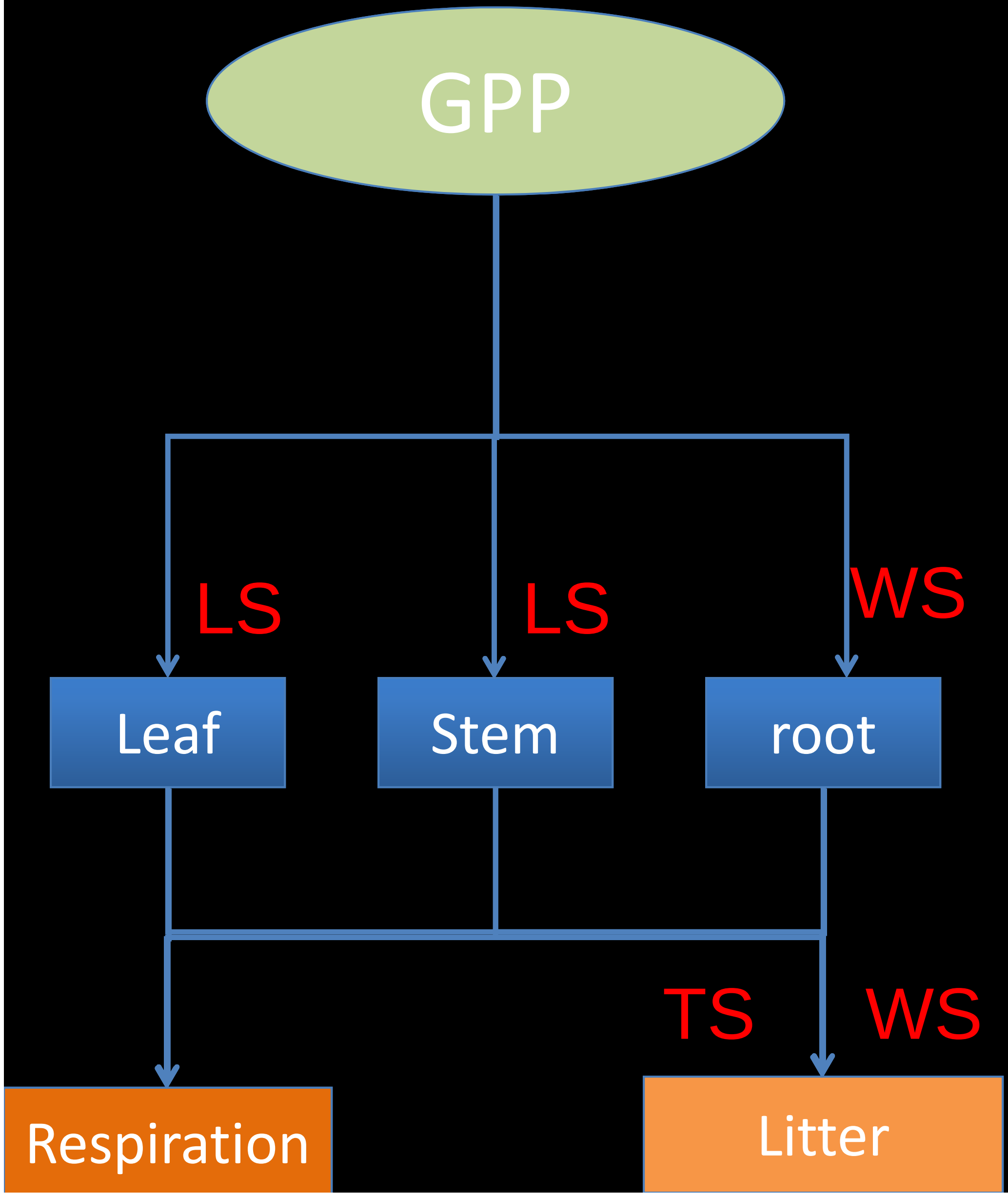
Calculate fluxes of carbon, nitrogen, energy, water, and the dynamical processes that alter these fluxes

- 18 Biome types 0.5 x 0.5 degree resolution
- 30 minutes temporal scale
- Season-to-interannual variability (penology)

Perennial Grasses Phenology



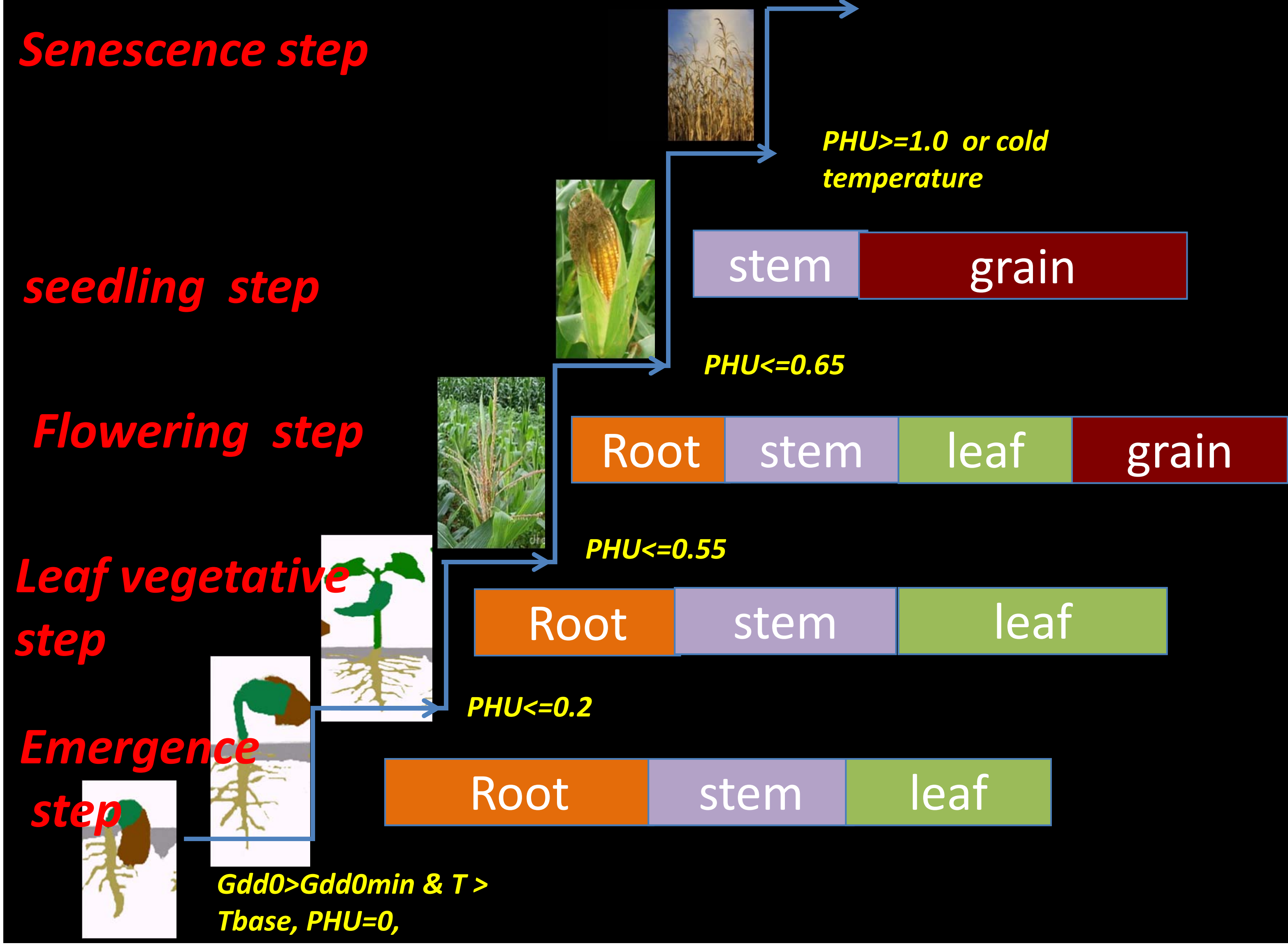
Dynamic Carbon Allocation for Perennial Grasses



- Soil water stress (WS) - Advantageous allocation to roots
- Light stress (LS) - Advantageous allocation to leaves and stem
- Water stress (WS) and Temperature stress (TS) - Advantageous leaf loss to litter

Source: Arora and Boer (2005)

Annual Crop Phenology and Carbon Allocation



Thermal Schedule Dominated

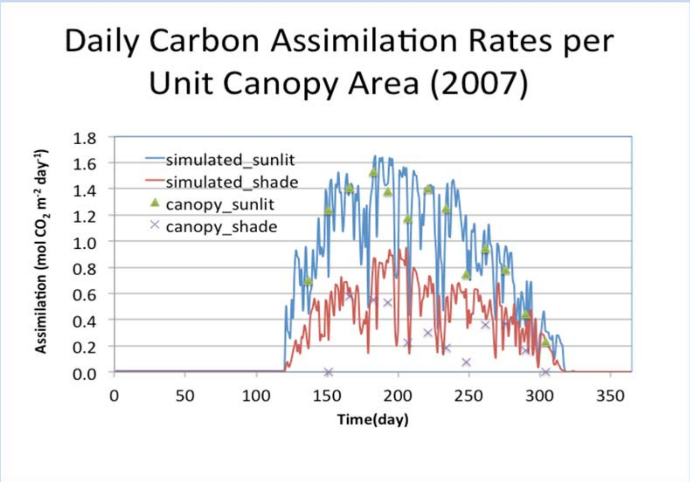
Heat unit index PHU= gdd/gddmax

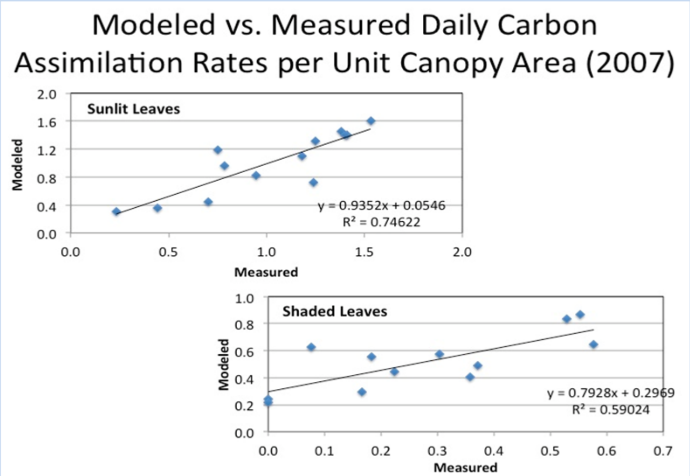
gdd-growing degree days based on base temperature(degree C)

gddmax-potential maximum growing degree days for mature (degree C)

Model Calibration-GPP

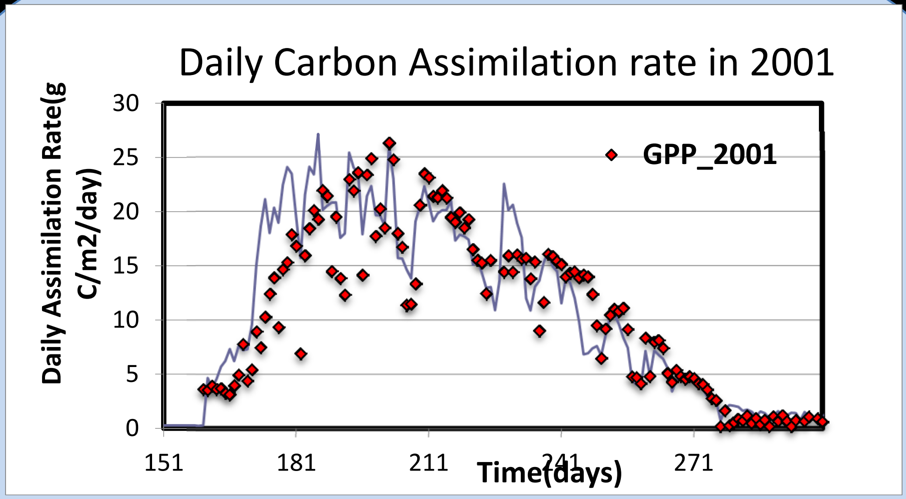
Miscanthus-Urbana Site

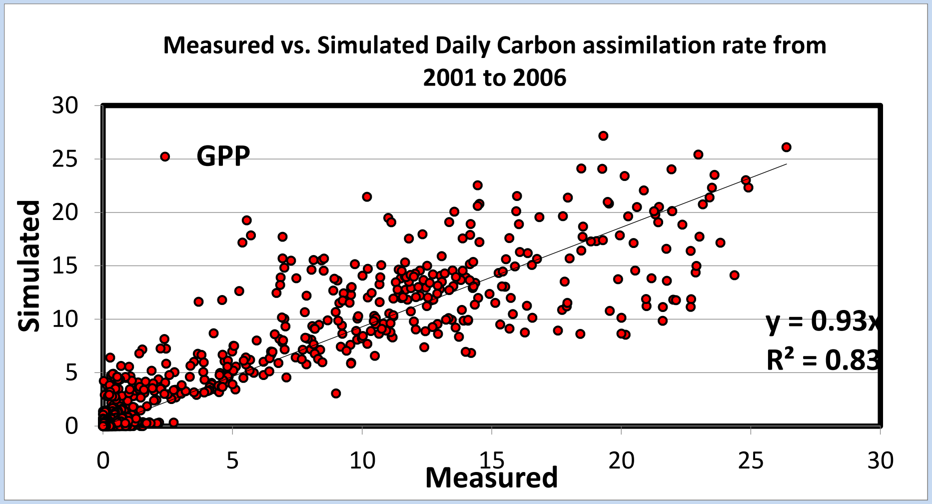




Field data and validated parameter sources:
Dohleman and Long (2009)
Dohleman et al. (2009)
Bonan et al. (2011)

Corn-Mead Ameriflux Site



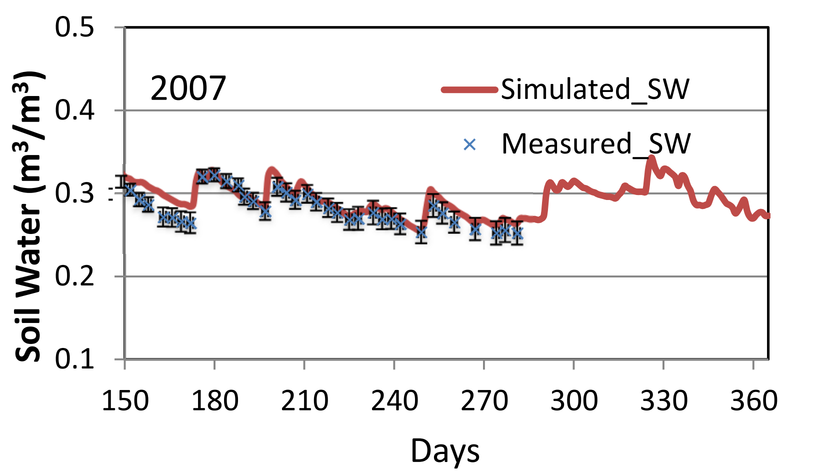


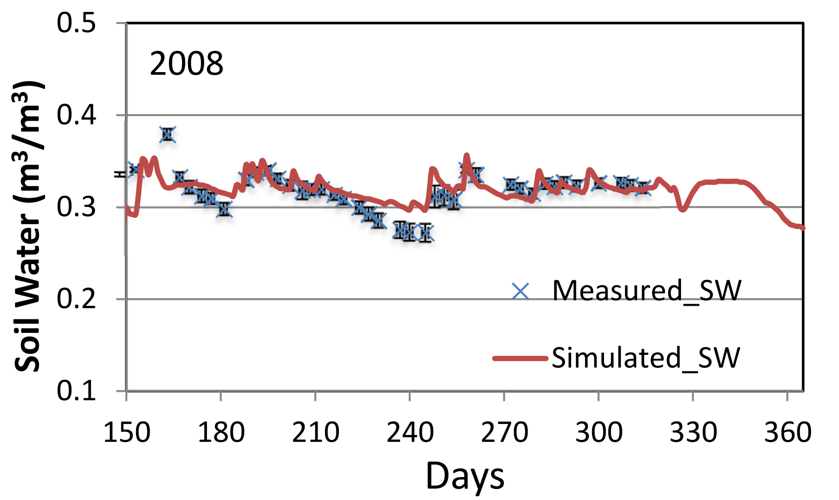
Field data and validated parameter sources:
Verma et al, 2005

Model Calibration-Hydrology

Miscanthus-Urbana Site

Modeled vs. Measured Soil Water Content (0-90 cm)

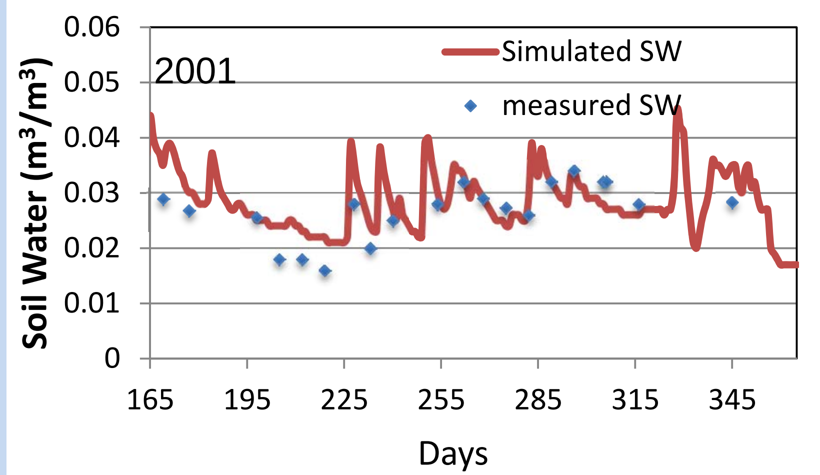


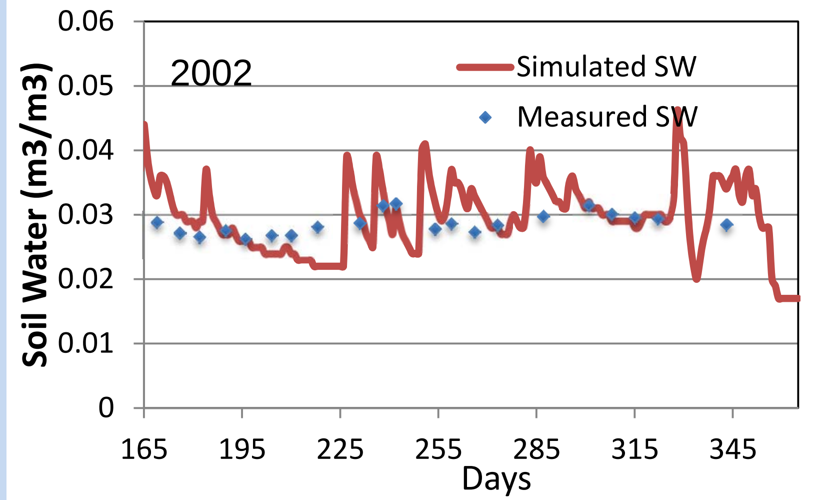


Observed data sources: McIsaac et al (2010)

Corn-Mead Ameriflux Site

Modeled vs. Measured Soil Water Content (0-100 cm)



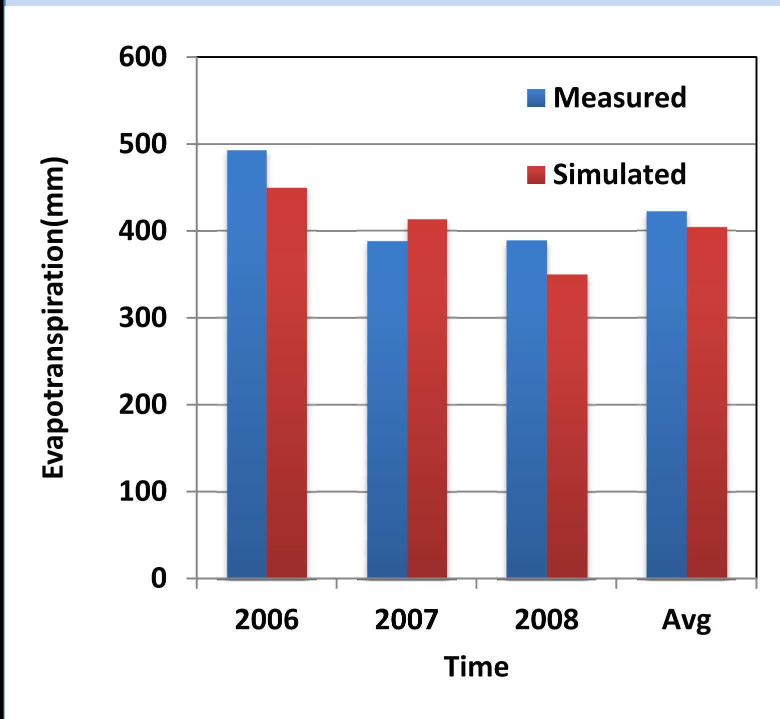


Observed data sources: Verma et al, 2005

Model Calibration-Heat Fluxes

Miscanthus Urbana Site

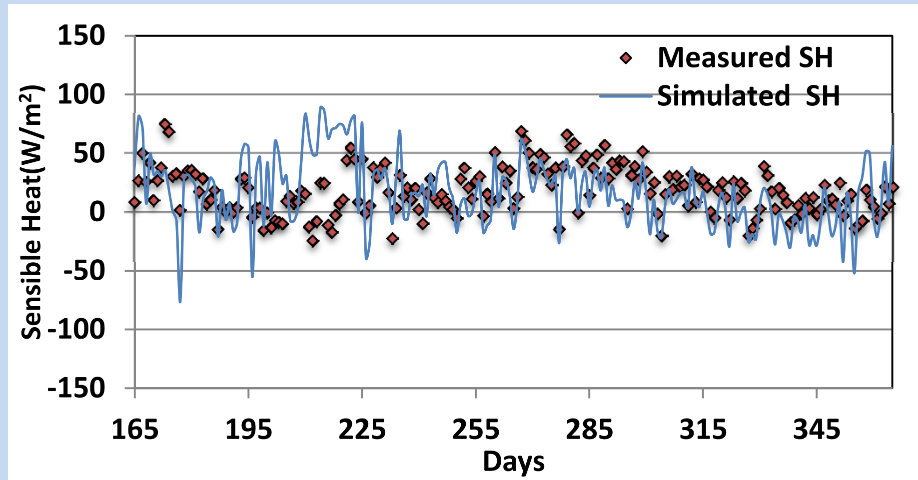
Evapotranspiration during growing season(mm/year)



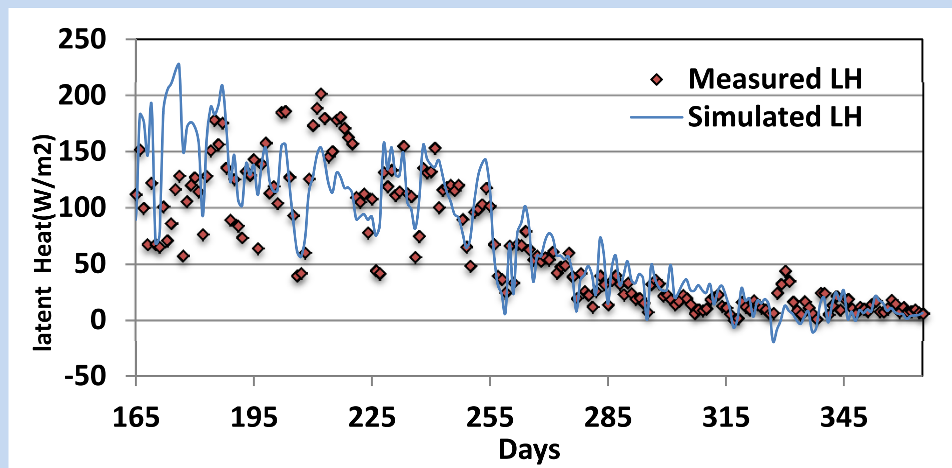
Observed data sources: McIsaac et al (2010)

Corn-Mead Ameriflux Site

Sensible Heat in 2001



Latent Heat in 2001



Observed data sources: Verma et al, 2005

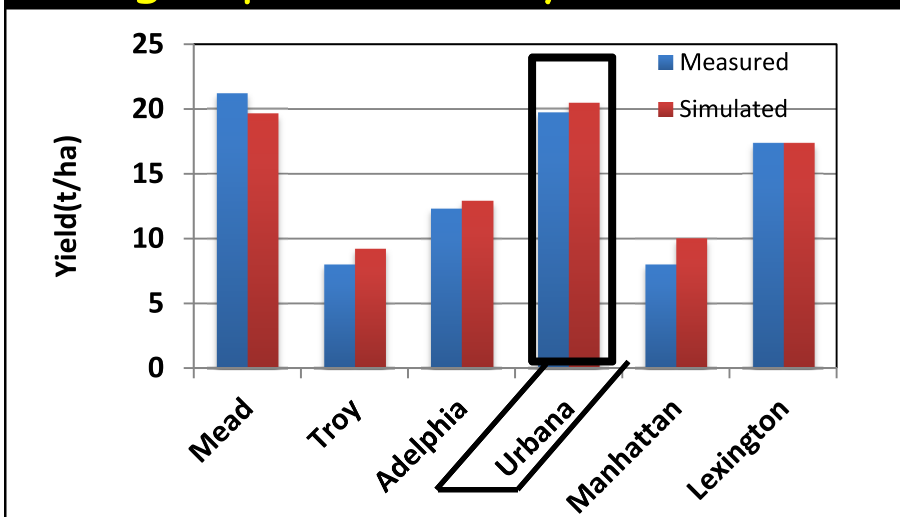
Model Validation

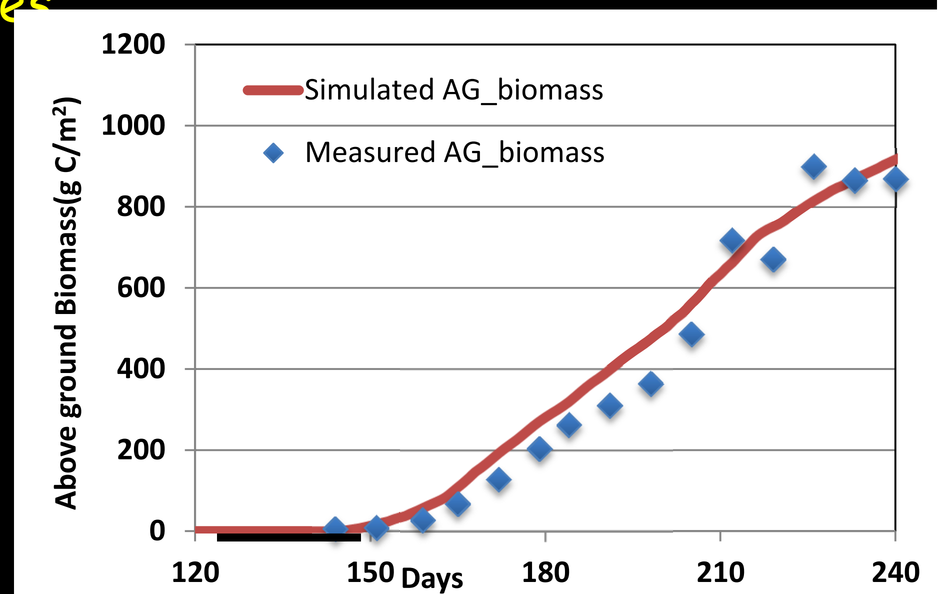
Distribution of validated sites

Corn-Bondville Sites

Daily accumulated aboveground biomass in 2001

Mean Miscanthus Harvested Yield(t/ha) during experimented years for each sites

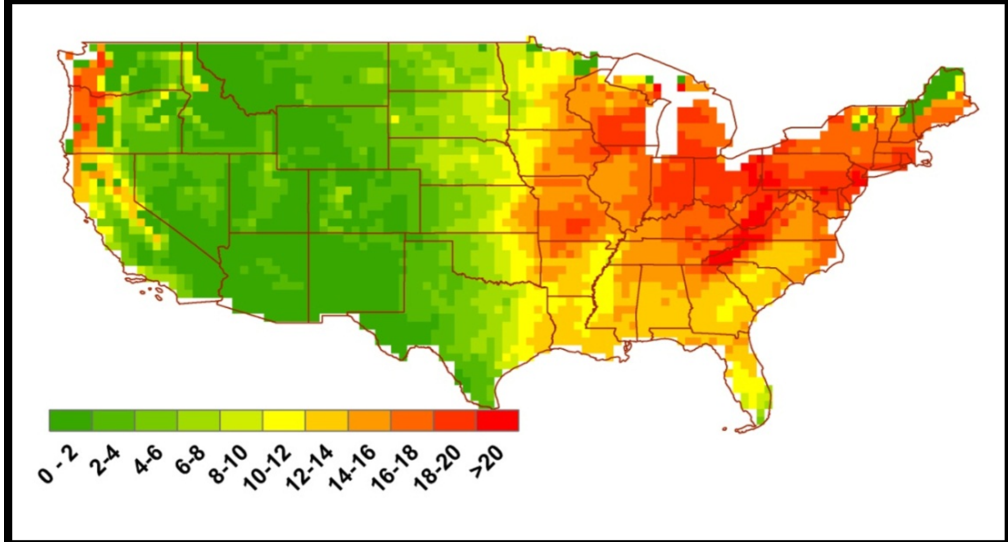




Source of Data:

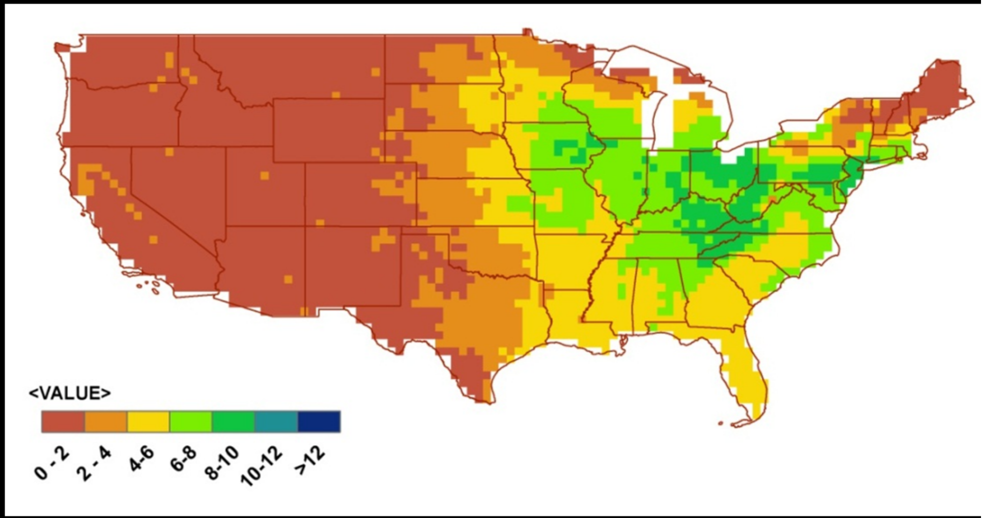
Maughan et al., 2011
Dohleman and Long (2009) ; Propheteret al., 2010
American Fluxes: bondville sites

Modeled Average Yield (t/ha)
for the Period 2001-2010

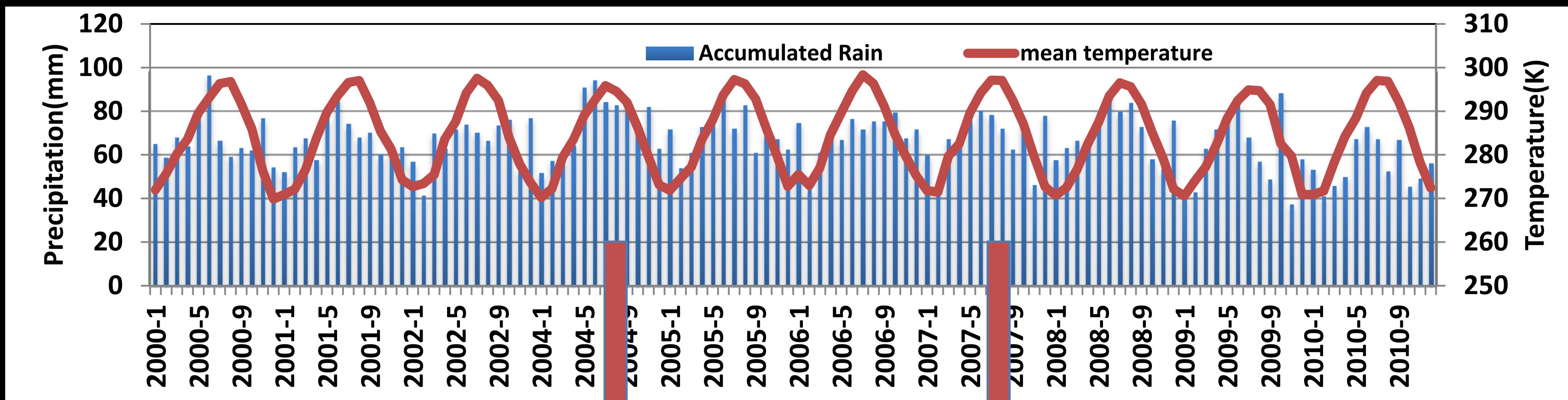


Mean Miscanthus yield

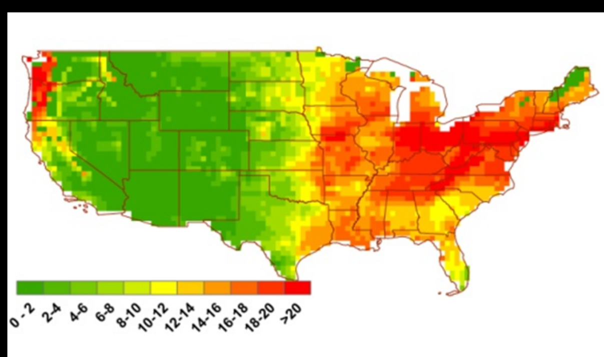
Mean Corn Grain Yield



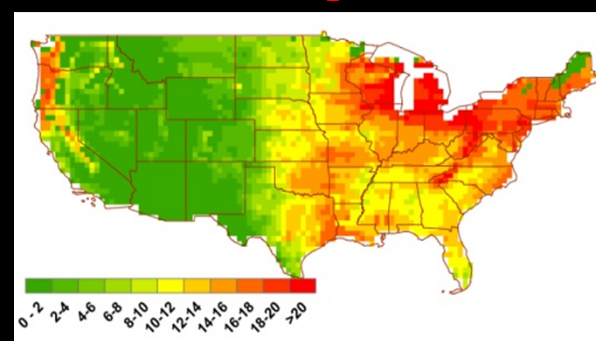
Monthly climate data (precipitation and temperature) and its impact on Miscanthus yield



2004 Wet Year

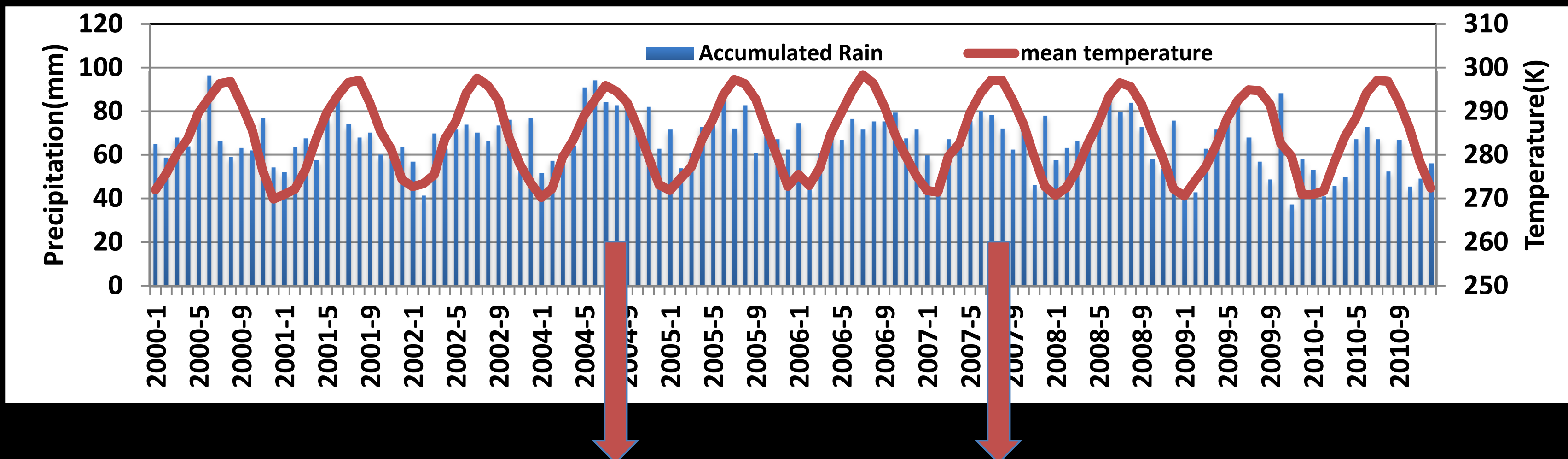


2007 Drought Year

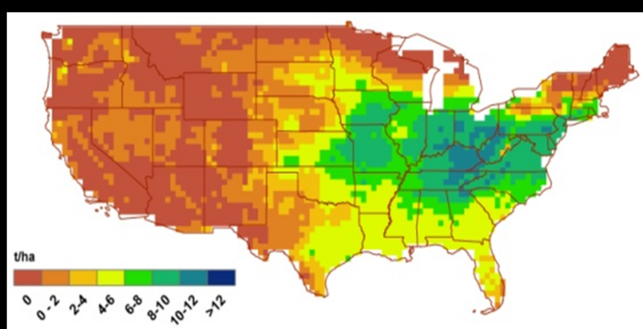


Miscanthus Yield

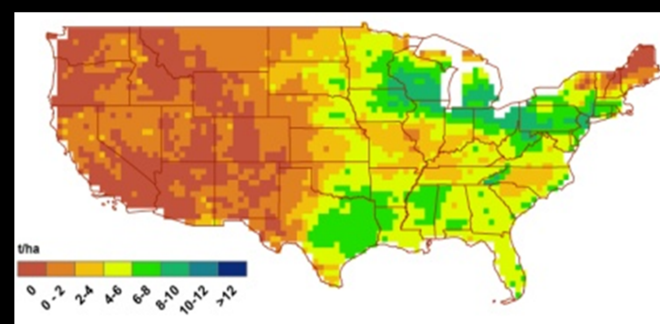
Monthly climate data (precipitation and temperature) and its impact on Corn yield



2004 Wet Year

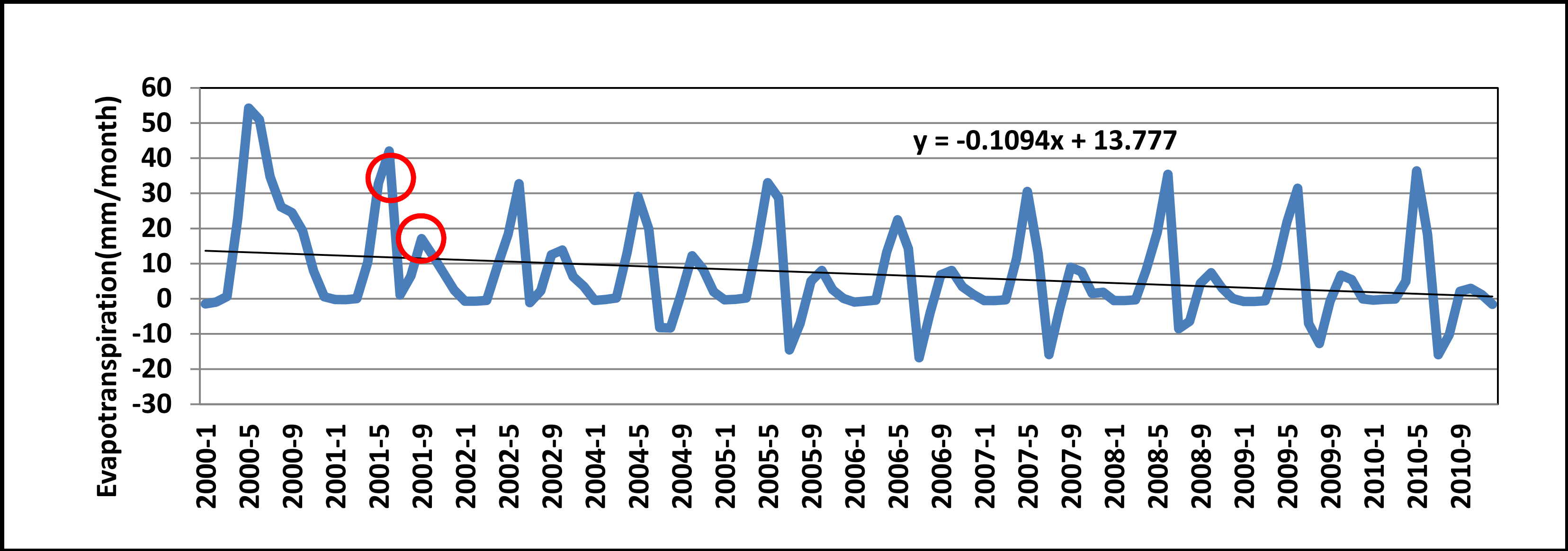


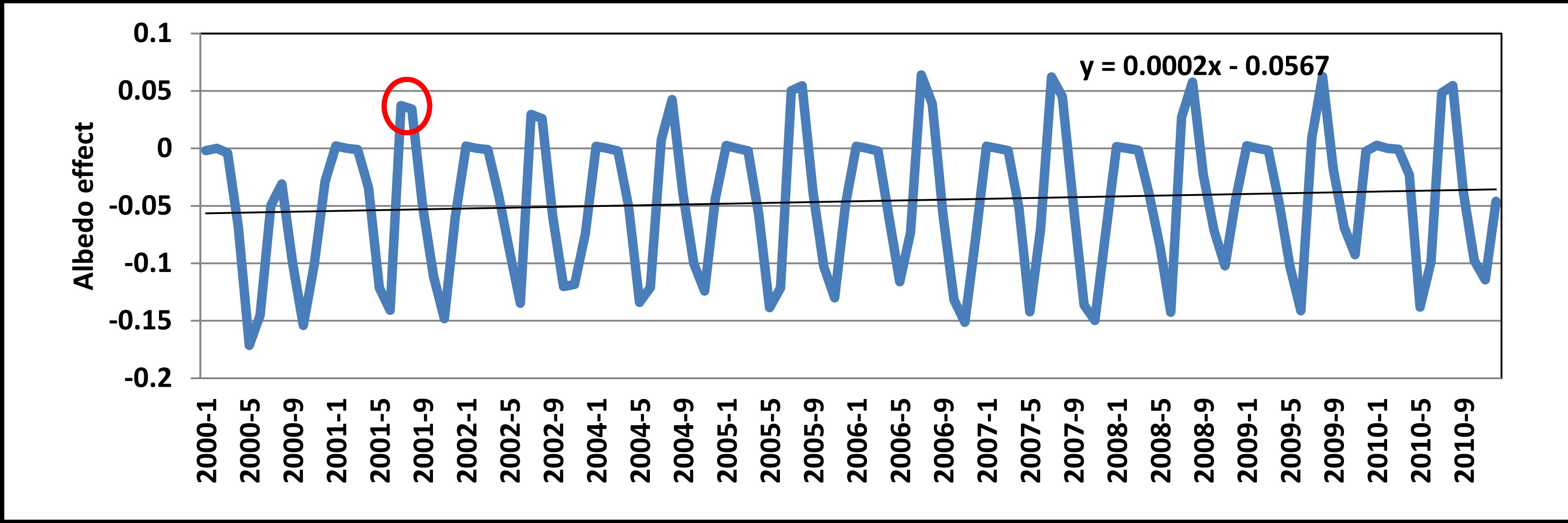
2007 Drought Year



Corn Grain Yield

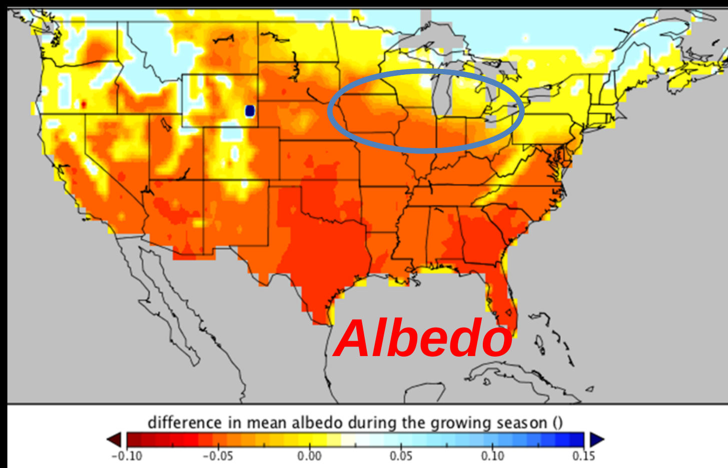
Effect of Miscanthus relative to Corn

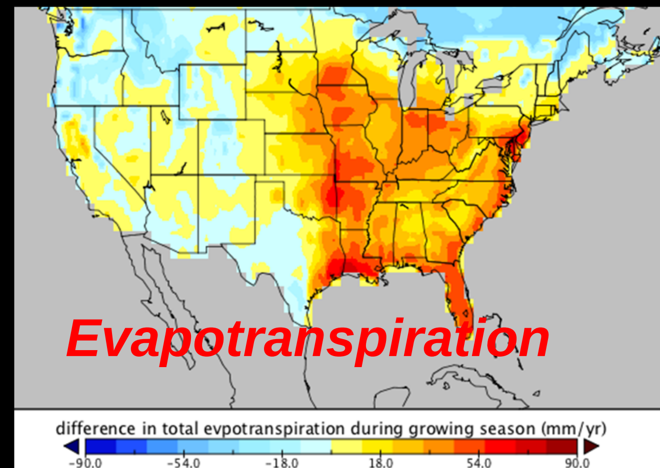




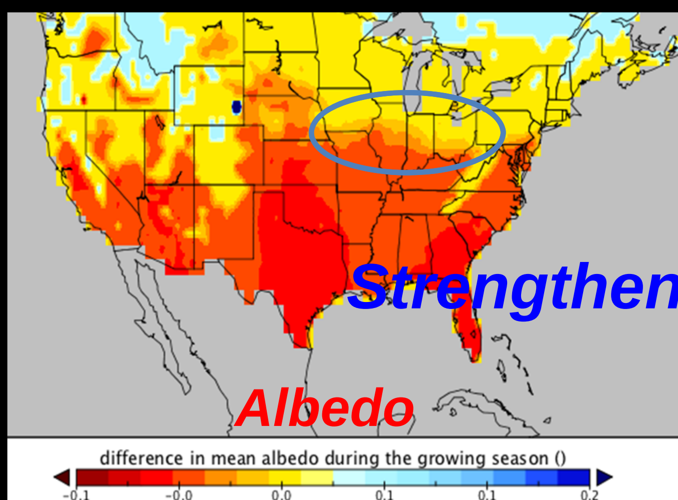
Comparison of Spatial pattern of difference in heat balance between Miscanthus and Corn in a drought and wet year

2007 Drought Year(Miscanthus-Corn)

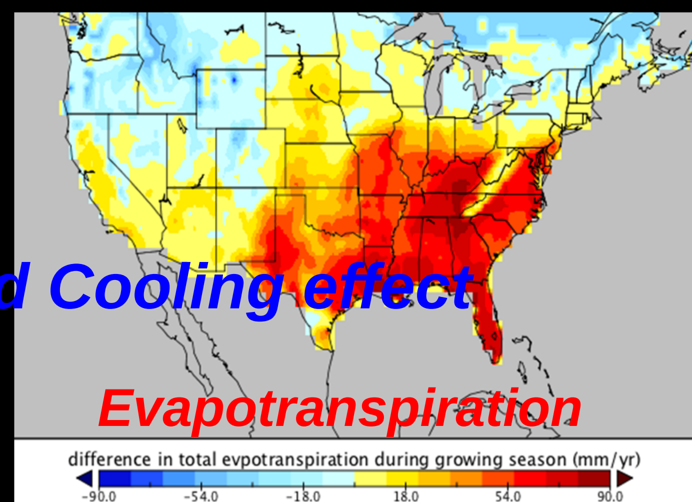




2004 Wet Year(Miscanthus-Corn)



Strengthened Cooling effect



Conclusions

- Miscanthus and Corn production has strong spatial and temporal variability over the US.
  - High productivity is in midwest-US.
  - Temporal pattern are strongly controlled by climate variability (tem and precip).
- Miscanthus has larger latent heat loss to atmosphere due to its higher evapotranspiration rate. This effect could cool the earth's surface.
  - Over the time this effect will be mitigated due to limitation of water availability.
- Compared to corn, Miscanthus has lower albedo due to higher canopy interception during the beginning and later part of growing season, but higher albedo during the peak of growing season due to its larger LAI.
- Wet climate condition could strengthen cooling effect of Miscanthus to the surface by increased albedo and evapotranspiration rate, compared to corn.

Thank You