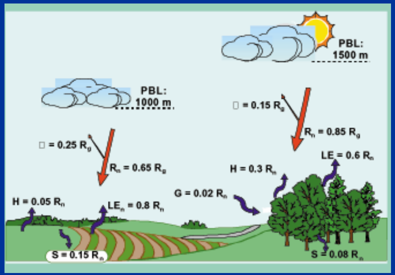
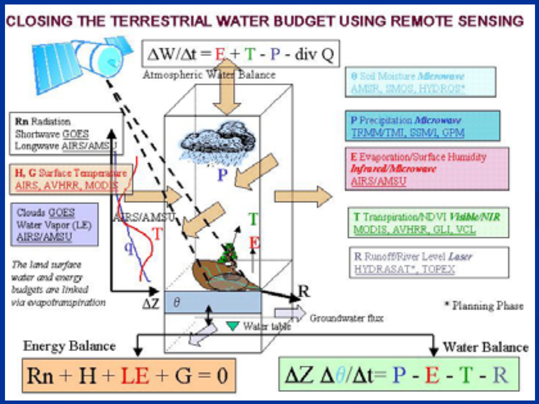
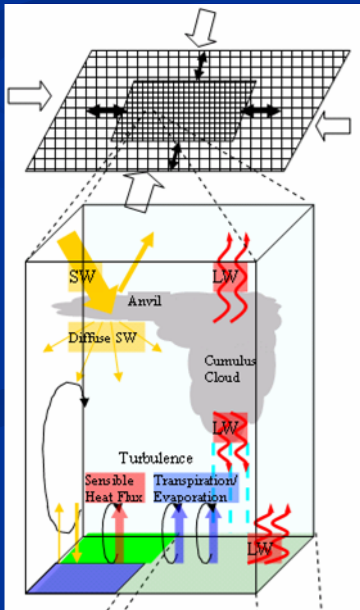
Integrated Regional Climate Study with a Focus on the Land-Use Land-Cover Change and Associated Changes in Hydrological Cycles in the Southeastern United States

NASA Land-Cover and Land-Use Change Science Team Meeting
UMUC Inn and Conference Center
October 10 – 12, 2006







Collaborative, interdisciplinary project

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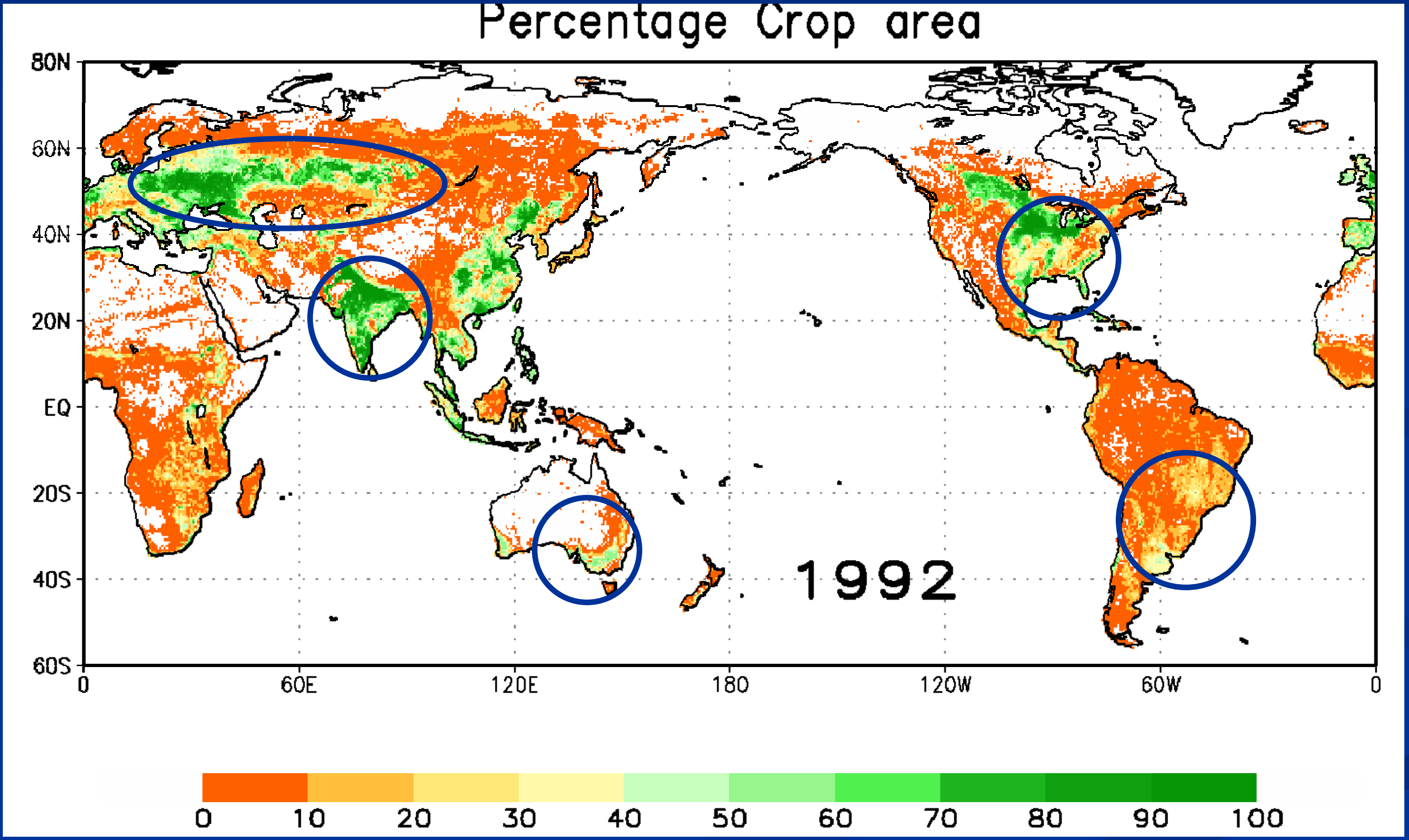
Science question

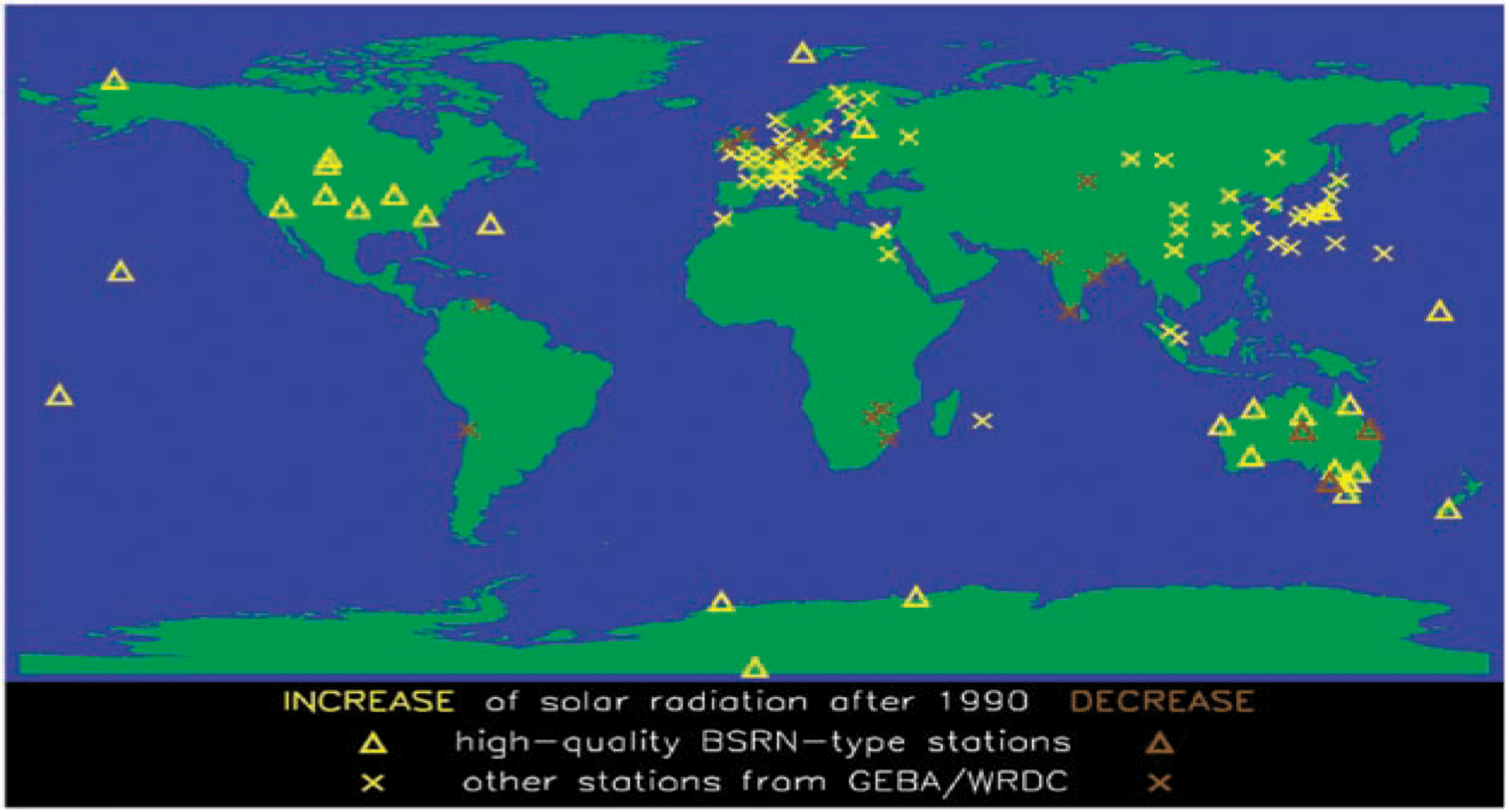
How does the change in radiative forcing associated with LULCC and aerosols/cloud radiative-precipitation processes affect the terrestrial biogeochemical and hydrological cycles, and the surface energy budget?

Example of changes in land-use land-cover: globally increase in crop area



Problem:
Surface radiative forcing from aerosols across the Globe

- **Worldwide reduction in land-surface radiation of ~ 3-6 W m^{-2} over the last several decades (1960 to 1990).**



Aerosols constitute a major forcing over places such as Indian region and may have similar impact over the U.S. SE region.

and 45 sites over Japan are displayed as aggregated regional means. The majority of the sites show an increase in surface solar radiation after 1990.

(Wild et al. 2005, Science)

Project Objective

- **Examine variability** in surface latent heat flux and precipitation and hence the regional hydrological cycle
    - **Forcings**: LCLUC, and cloud-precipitation and terrestrial ecosystem processes
  - Examine the individual, as well as the combined effect
  - Investigate the feedbacks under drought and non-drought conditions
    - **Approach**: detailed process **models**, **in-situ** and **remote-sensed data** and products

Focus of this presentation….

summarize last year results, and ongoing work …

Task 1. Calibration and evaluation of biogeochemical process in the CSU-ULM Model

- How are regional biogeochemical and water cycles responding to the variation of radiative forcing and LULC?

Task 3. Sensitivity experiments

- How do local changes in LULC scale-up to affect the regional climate and hydrological cycle?
- How does the presence of drought and non-drought conditions affect the terrestrial ecosystem process?

Task 4. Retrieval algorithm for surface latent heat flux and CO_2 flux mapping from Multi TRMM products

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Task 1. Calibration and evaluation of biogeochemical process in the CSU-ULM Model

- **How are regional biogeochemical and water cycles responding to the variation of radiative forcing and LULC?**
- **How soil moisture anomalies regulate the impact of the radiative forcing at a plant and regional scales?**

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Continental-Scale Multi-Objective Calibration and Assessment of CSU ULM

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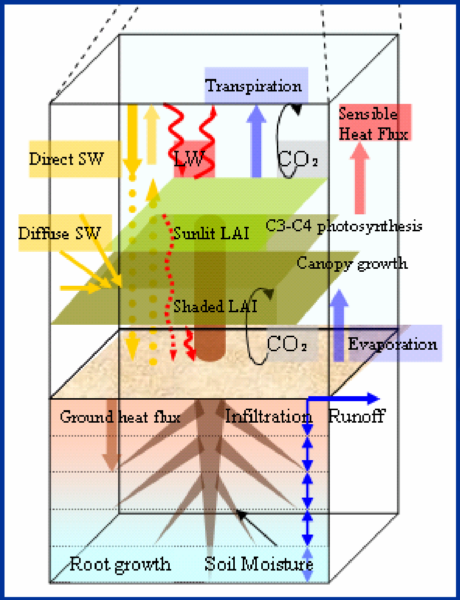
OBJECTIVE

- Establish the first continental-scale multi-objective calibration and assessment of the Colorado State University Unified Land Model (CSU ULM) over the conterminous U.S.



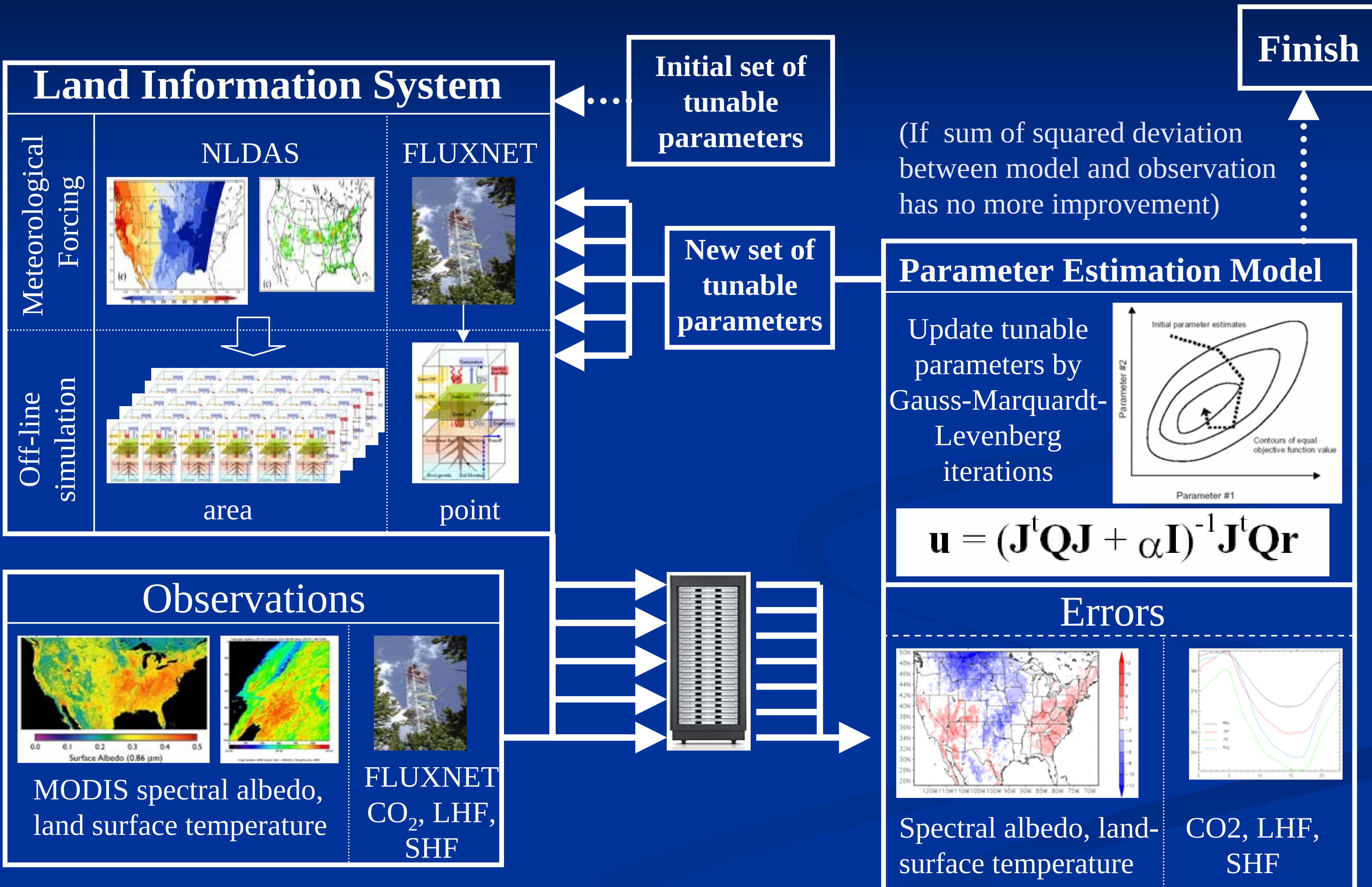
- This **calibration** framework uses CSU ULM within the NASA GSFC's Land Information System (LIS) coupled with the Parameter Estimation model (PEST). Comparisons are made with MODIS albedo, LST, and turbulent heat fluxes in Fluxnet sites.

- CSU ULM includes features from
  - CLM 2.0 (Oleson et al. 2004)
  - GEMTM (Chen and Coughenour 1994)
  - LEAF2 (Walko et al. 2000)

- UMD-type 13-class LULC

See poster (Matsui et al.: Continental-Scale Calibration of Surface Albedo in CSU Unified Land Surface Model Using Remote Sensing Data and Parameter Estimation Model) for more details.

Land Model Calibration System



Part I: Albedo

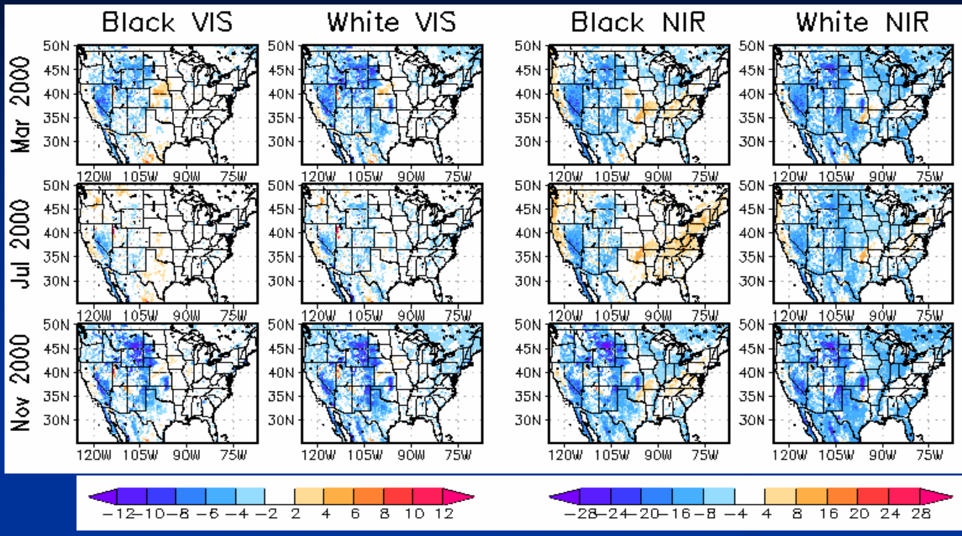
- Leaf and soil optical properties

- Improved the model representation (reduce 80% the sum of square deviation) of surface albedo over the entire domain in comparison with the operational MODIS snow-free albedo.

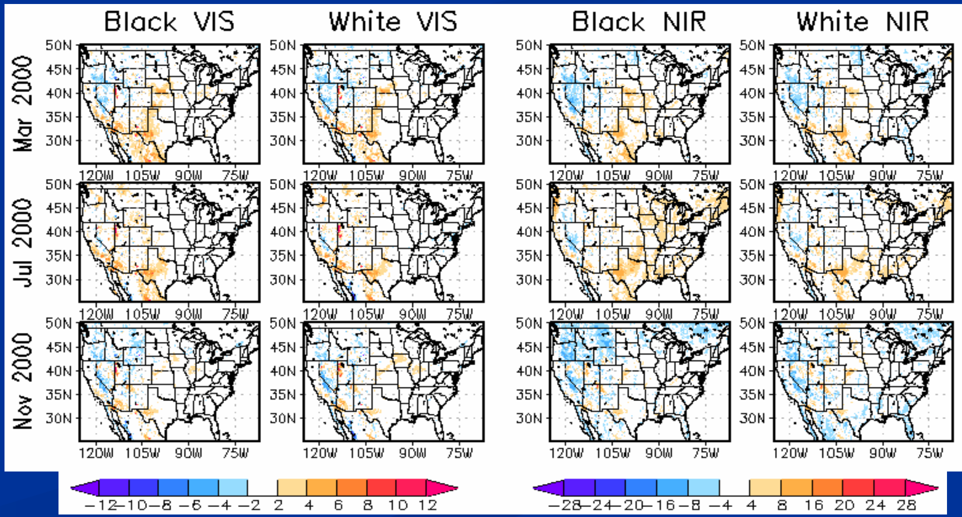
- Continental-scale calibration suggested a functional error in the model.

- Calibrated albedo affected the summer-time surface energy budget simulated by offline ULM.

Initial Experiment



Second Calibration



Spatial map of pre and post-calibration differences (MODIS – ULM) in spectral surface black and white albedo (×100). Note VIS and NIR albedo use different scales.

Part II: Land Surface Temperature and Turbulent Heat Flux

Ongoing work….

- Coupling the Fu-Liou Radiative Transfer Model and
- Satellite-model assimilated aerosol optical depth (AOD) with off-line CSU-ULM simulation.

Mechanical Response of Surface Carbon and Turbulent Heat Flux to the Aerosol Direct Effect over Eastern U.S., Using Non- and Well-Calibrated Sun-Shade Canopy Model . Matsui et al. In preparation

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The Link Between Aerosols and Land-Surface Processes

- Aerosols can change the radiative forcing:

  Total solar radiation = (**Diffuse + Direct**) solar radiation

- For increased **cloud cover** or increased **aerosol loading**, **diffuse component** increases => changes the **Diffuse to Direct Radiation Ratio** (DDR)

- We have shown using field measurements that an increase in aerosols will impact the terrestrial water and carbon cycle through transpiration and photosynthesis changes (Niyogi et al. 2004, GRL)

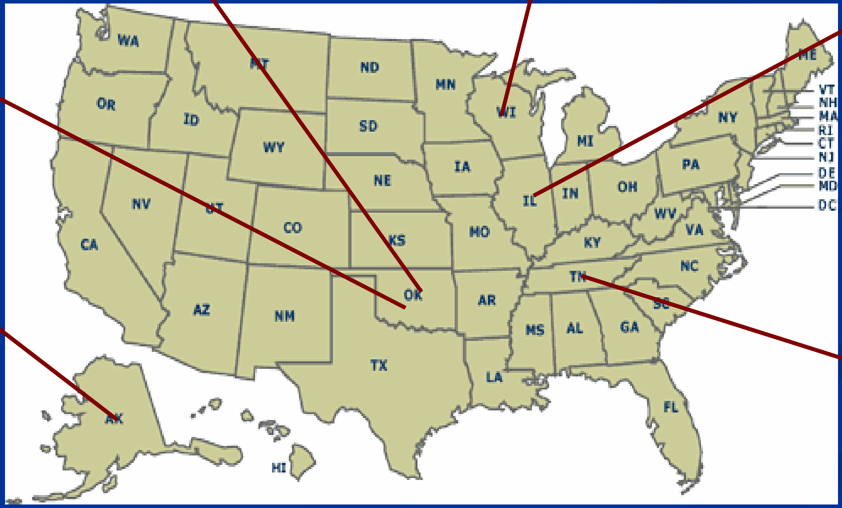
Six sites available that have information on the required variables for the study: aerosol optical depth (AOD), diffuse radiation, and CO_2 and latent heat fluxes.

Shidler, OK
(Grassland 98,99)

Willow Creek, WI
Lost Creek, WI
(Mixed Forest,00-01)

Ponca, OK
(Wheat 98,99)

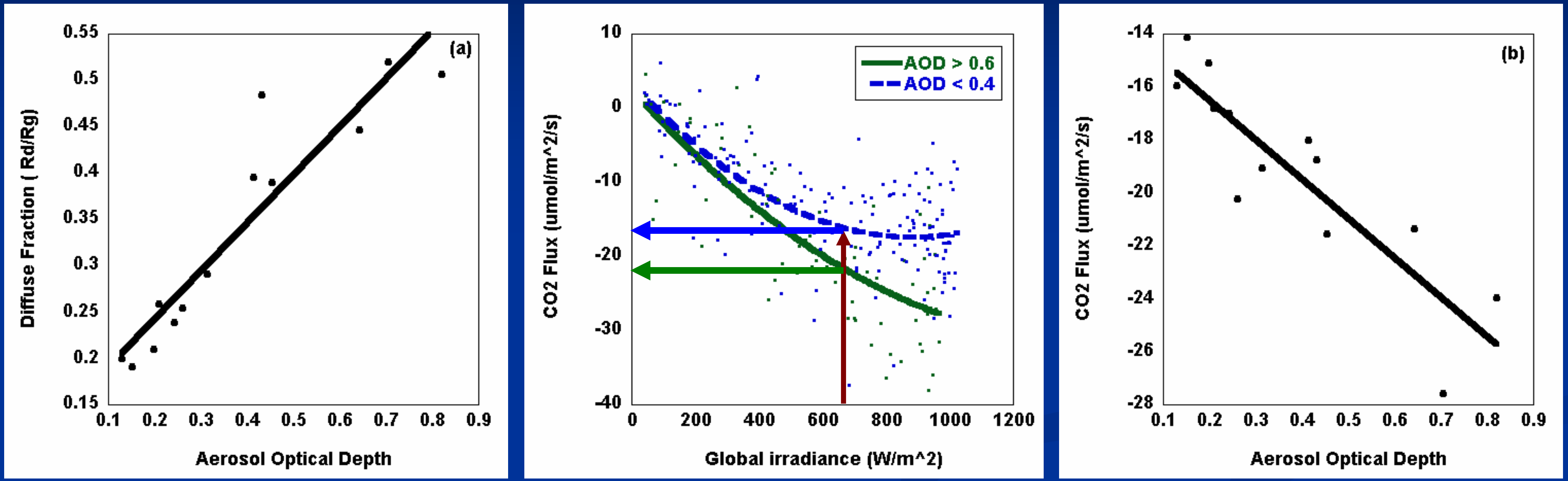
Bondville, IL
(Agriculture, C3/C4, 98-02)



Barrow, AK
(Grassland 99)

Walker Branch, TN
(Mixed Forest 2000)

Aerosols affect terrestrial CO_2 fluxes…

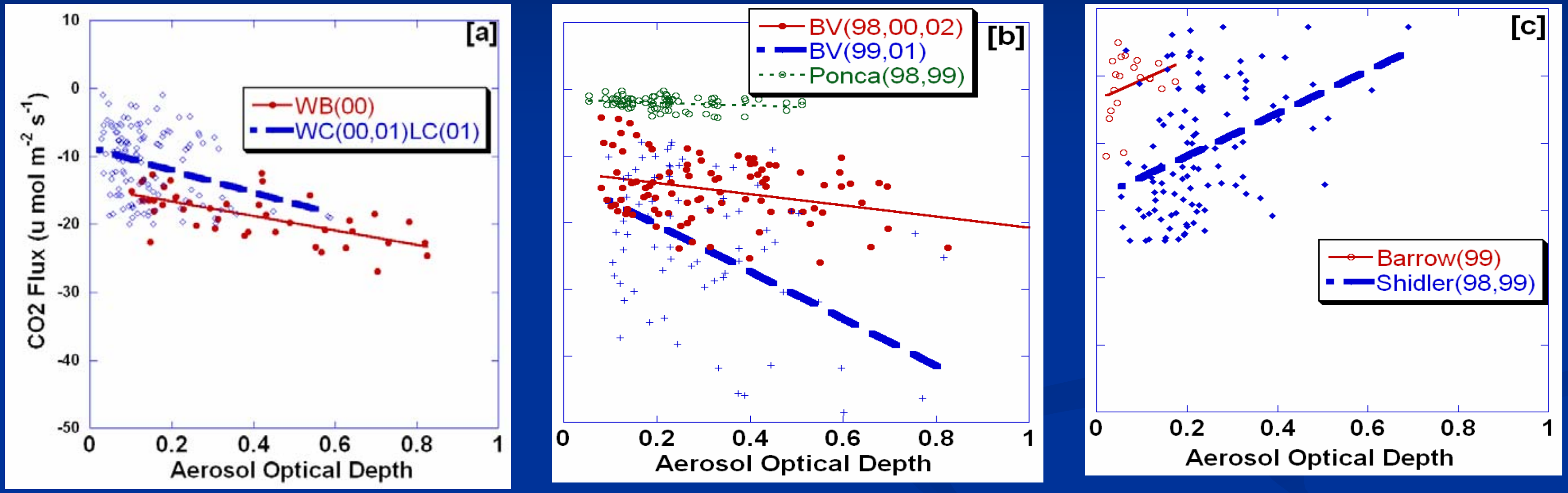


Increase in AOD (no cloud conditions) causes **increase** in DDR (diffuse fraction).

CO_2 flux (photosynthesis) is **larger** for **higher** AOD conditions.

Aerosol loading appears to cause changes in the net ecosystem CO_2 exchange

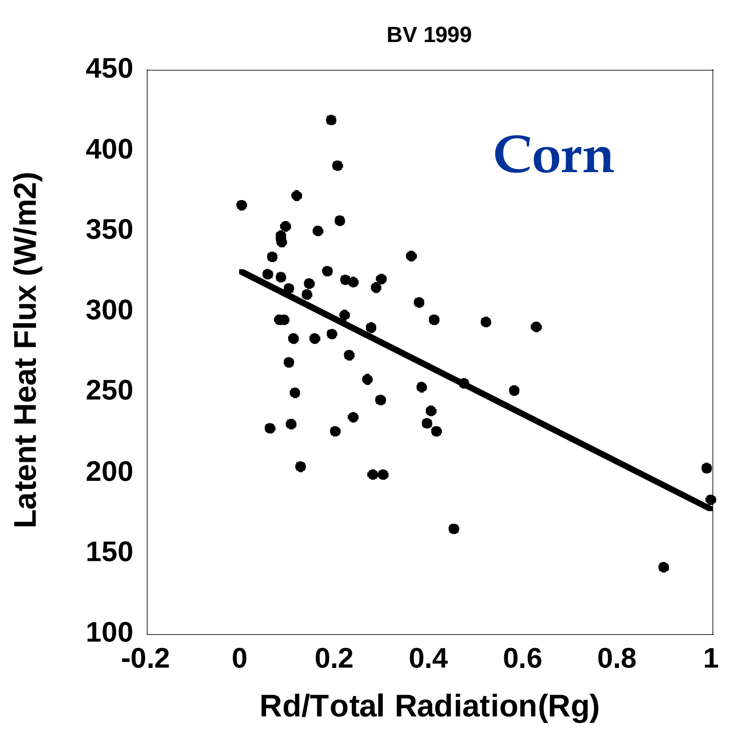
Aerosol-land surface impact seem to be generally valid for different landscapes….

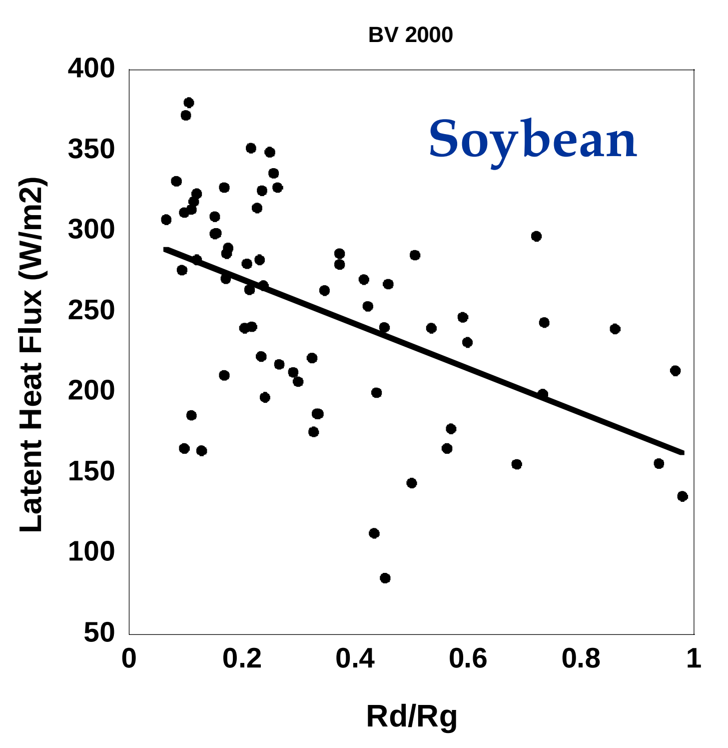


Forests Croplands Grasslands

For Forests and Croplands, aerosol loading has a **positive effect** on CO_2 flux, and a **negative** (source) effect for Grasslands.

For weather forecast models/regional climate studies latent heat flux is of interest. And aerosols impact surface latent heat fluxes…





Overall, with **increasing** aerosols the surface latent heat fluxes tend to **decrease.**

Continued investigations on aerosol – plant transpiration studies

D. Niyogi et al.

- Analysis for AOD – LHF effects extended considering interaction terms such as LAI, soil moisture

    - Experiments
    - Modeling

LI6400 CO_2/H_2O flux system

- Leaf and canopy scale measurements of CO_2 and Water Vapor Flux for plants grown under **different soil moisture conditions** at USDA Facility in Raleigh, NC

- Experiments:
  - Effect of Diffuse Radiation (Clouds and Aerosols) on plant scale response

- Modeling:
  - of the plant scale response for changes in Diffuse Radiation

- Potted soybean plants were grown in two sheds with different **diffuse radiation screens**
- CO_2/H_2O exchange measured

More diffuse

0.415

Relatively clear

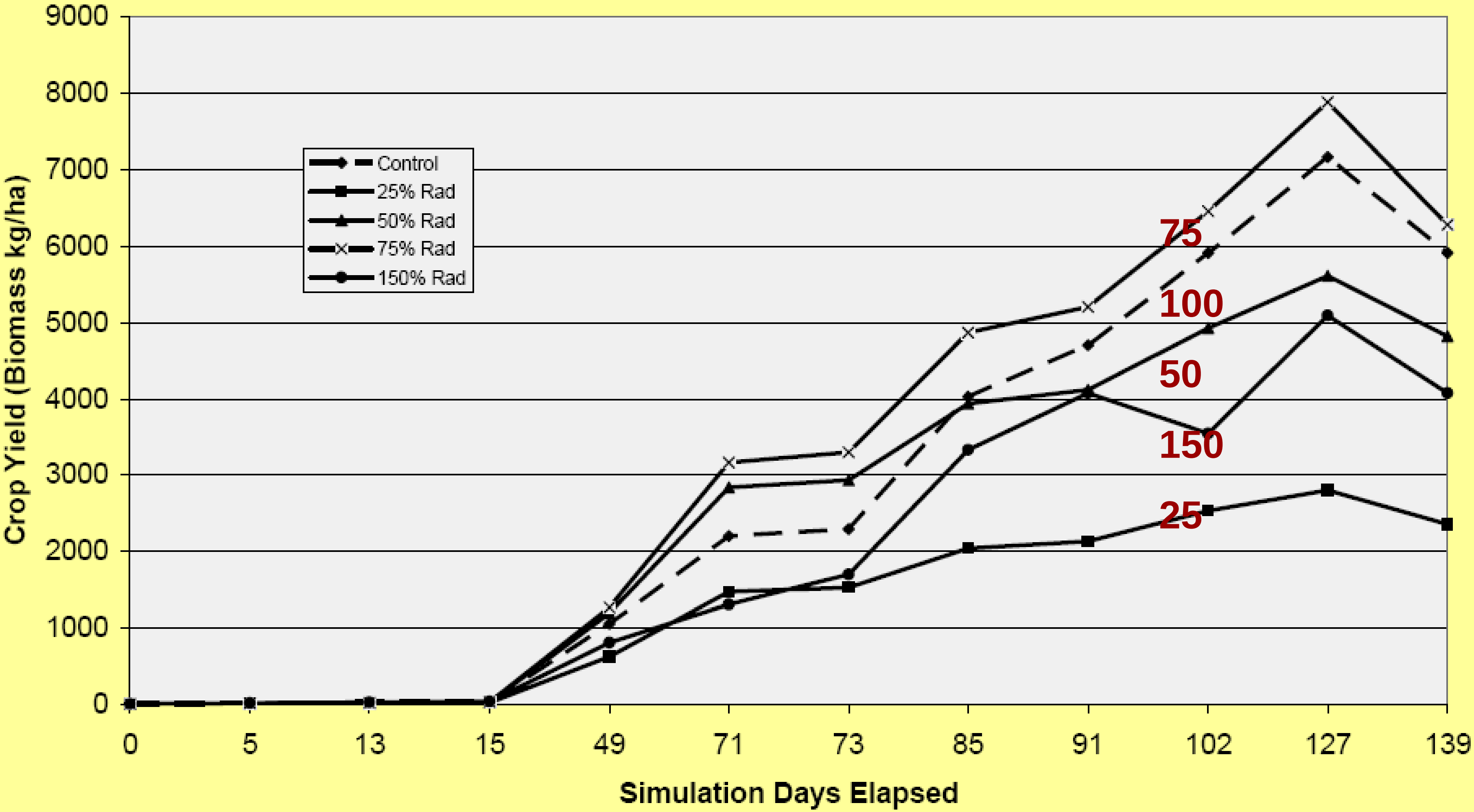
0.39

Soybean biomass responses under Clear and Diffusing materials (mean ± SE). Plants were harvested for determination of biomass at 88 days after planting. Statistics: $P \leq 0.1$ (†).

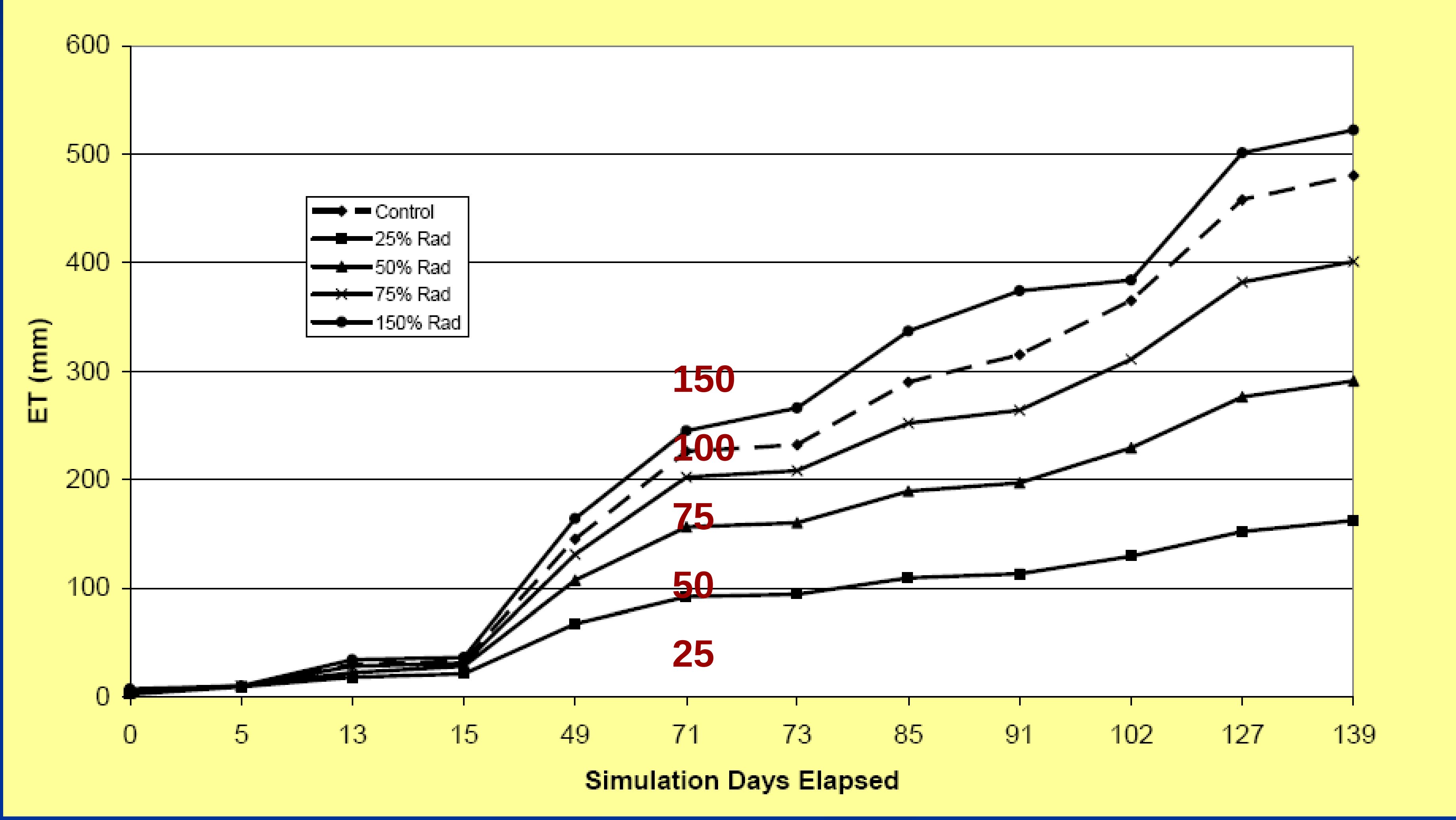
Parameter	**Clear**	**Diffusing**
Height (cm)	55.6 ± 1.4	56.1 ± 1.4
Branch number ($plant^{-1}$)	17.3 ± 1.4	18.0 ± 1.4
Stem dry mass ($g\ plant^{-1}$)	19.2 ± 1.5	19.8 ± 1.5
Leaf dry mass ($g\ plant^{-1}$)	**45.4 ± 3.0**	**52.0 ± 3.0**
Branch dry mass ($g\ plant^{-1}$) (43%)	**51.7 ± 3.9**	**63.0 ± 3.9 (+22%) †**
Pod dry mass ($g\ plant^{-1}$)	**67.3 ± 8.0**	**75.4 ± 8.0**
Root mass ($g\ plant^{-1}$)	30.1 ± 2.6	28.8 ± 2.6
Total dry mass ($g\ plant^{-1}$)	**213.7 ± 15.2**	**239.0 ± 15.2**
Stem leaf area ($m^2\ plant^{-1}$)	0.19 ± 0.01	0.20 ± 0.01
Branch leaf area ($m^2\ plant^{-1}$) (87%)	**1.21 ± 0.08**	**1.41 ± 0.1 (+16%) †**
Total leaf area ($m^2\ plant^{-1}$)	**1.40 ± 0.08**	**1.61 ± 0.1 (+15%) †**

- Interestingly, we did not find significant differences in photosynthesis rates between plants grown under the Clear and Diffusing treatments on either an upper canopy leaf or whole-plant basis.

Follow-up studies with Biospheric and detailed Crop Models (SOYGRO and CERES-Maize)



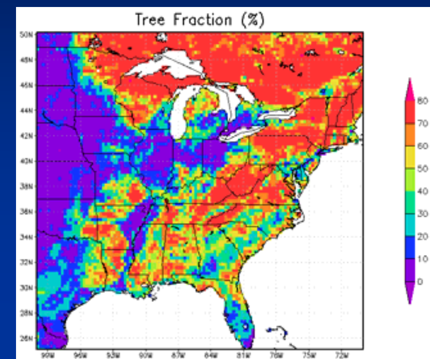
ET – Radiation response appears to be nearly linear

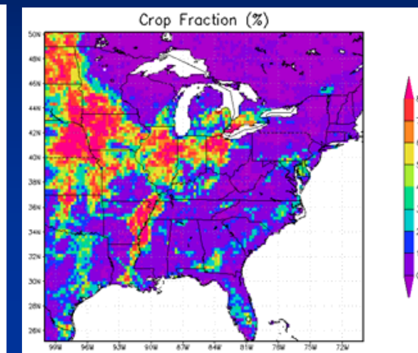


Dynamical response of aerosols on weather

T. Matsui et al.

Sensitivity experiments of **latent heat flux** and **Net Primary Production** to **diffuse radiation**

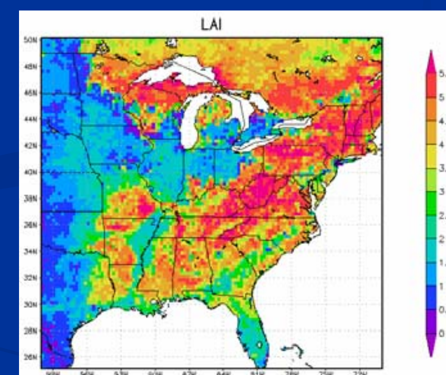




LSM: CSU Unified Land Model (ULM) including the Sun-Shade Two-Big Leaf scheme in the NASA's Land Information System.

Period: 2001, 1st Jun ~ 1st Sep

Diffuse radiation: Empirical transmittance function derived from NOAA ISIS observation.

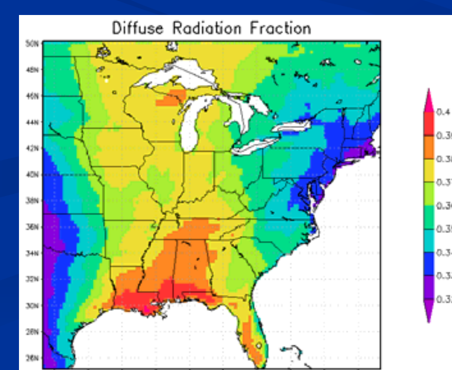


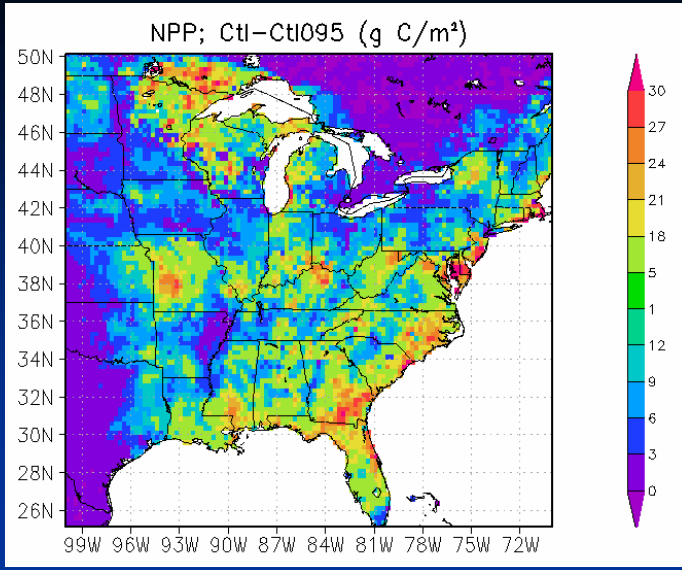
Experiments:

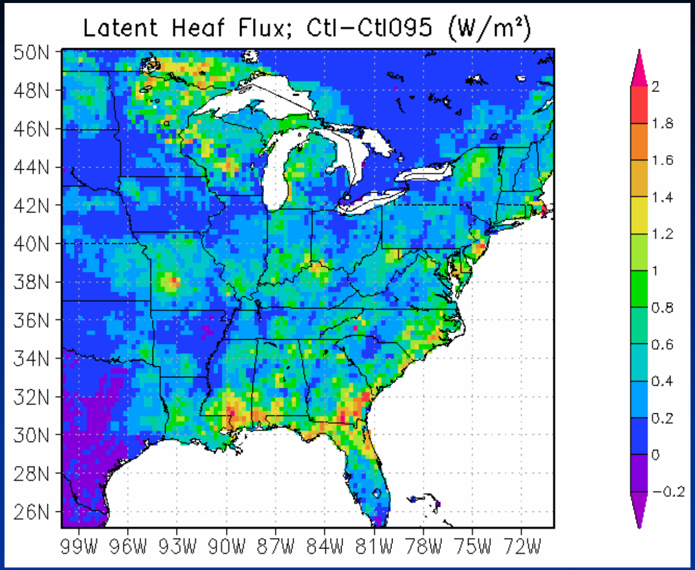
Ctl : Control

Ctl095 : 95% of diffuse radiation of *Ctl s*imulation

Ctl – Ctl095 : represent the effect of increase in diffuse radiation fraction about 5% homogeneously in domain.

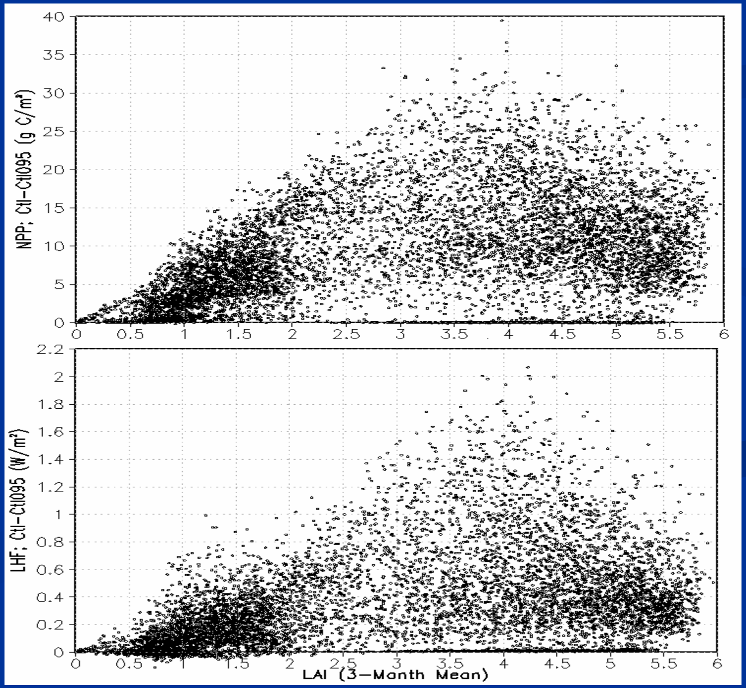






Net Primary Production (NPP) increases up to 30 gC/m^2

Latent Heat Flux (LHF) increases up to 2 W/m^2



Magnitude of increase in NPP and LHF are mostly explained by the LAI, i.e., dense vegetation is more sensitive to the changes in diffuse radiation.

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Derivation of Surface Latent Heat Flux Using TRMM VIRS and TMI

Wang et al.

Procedure

A. Derive absorbed surface solar radiation.

- Use TRMM VIRS channel 1 (visible, ~ 0.63 um) and channel 4 (infrared, ~ 10.8 um). Do space and time contrasts test (F and Student's t) for cloud detection.
- Use North American Regional Reanalysis precipitable water as ancillary data.
- Extract surface observed solar radiation data from Ameriflux, CONFRRM, and SURFRAD.
- Derive absorbed surface shortwave flux from TOA reflected flux following Li et al. 1993.

B. Find out the relationship among soil moisture, NDVI, absorbed surface SW flux.

- Derive soil moisture and soil temperature using TRMM TMI data (Bindlish et al. 2003, Rem. Sens. Environ., 85).
- Bi-weekly GIMMS NDVI-LAI product will be interpolated to provide the daily LAI.
- Build up the statistical relationship.

Additional ongoing and future work…

- ***Calibrate CSU-ULM photosynthesis and respiration rate against Ameriflux observations.***
- ***Couple ULM with an atmospheric model and do sensitivity tests.***
- ***Complete the Coupled Regional Climate Experiment.***

Papers resulting from this grant (2005-2006)

Alpert, P., D. Niyogi, R.A. Pielke Sr., J.L. Eastman, Y.K. Xue, and S. Raman, 2006: Evidence for carbon dioxide and moisture synergies from the leaf cell up to global scales: Implications to human-caused climate change. Global and Planetary Change, Special Issue, accepted

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Pielke Sr., R.A., and T. Matsui, 2005: Should light wind and windy nights have the same temperature trends at individual levels even if the boundary layer averaged heat content change is the same? Geophys. Res. Letts., 32, No. 21, L21813, 10.1029/2005GL024407.

Pielke Sr., R.A., T. Matsui, G. Leoncini, T. Nobis, U. Nair, E. Lu, J. Eastman, S. Kumar, C. Peters-Lidard, Y. Tian, and R. Walko, 2006: A new paradigm for parameterizations in numerical weather prediction and other atmospheric models. National Wea. Digest, in press.

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Pielke, R.A. Sr., J. Adegoke, A. Beltran-Przekurat, C.A. Hiemstra, J. Lin, U.S. Nair, D. Niyogi, and T.E. Nobis, 2006: An overview of regional land use and land cover impacts on rainfall. Tellus B, accepted.

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Additional papers, presentations and reports are available on the website of Pielke's Research Group at:
http://blue.atmos.colostate.edu

and at Niyogi's Research Group at:
landsurface.org