

# The Influence of Aerosols on Plant Growth

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# How Might Aerosols Influence Plants?

- **Directly changing the quantity and quality of photosynthetically active radiation (PAR) reaching the surface**
- **Modifying climate**
  - **Temperature**
  - **Precipitation**
  - **Indirectly modifying surface PAR**
- **Damaging plants by acidic deposition**
- **Increasing growth by deposition of nutrients**

# Possible Consequences?

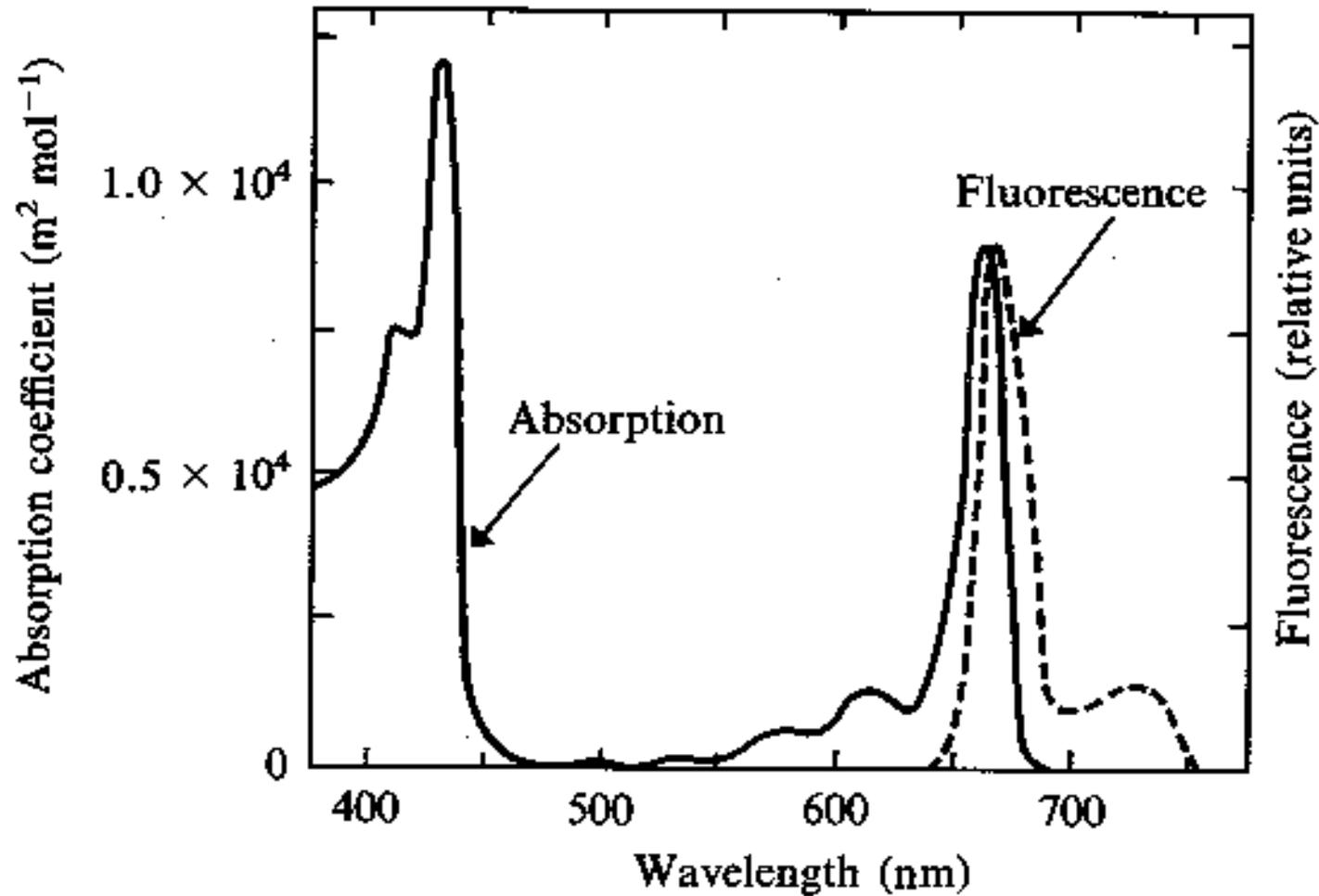
- **Decrease in Crop Production**
- **Modification of Carbon Cycle**

# Very Basic Chemistry of Photosynthesis



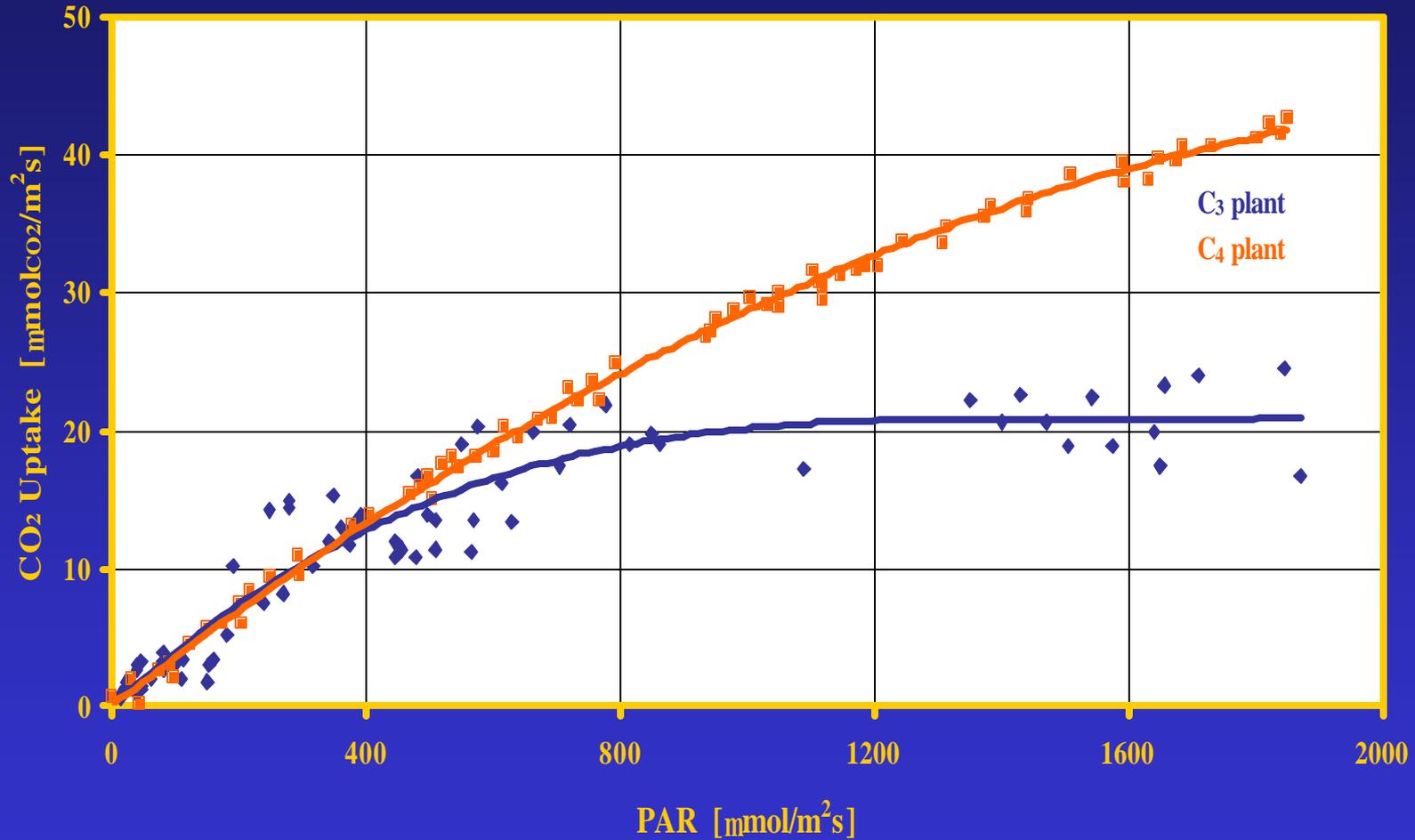
\* Also need nutrients such as N, P

# Absorption of Solar Energy by Plants

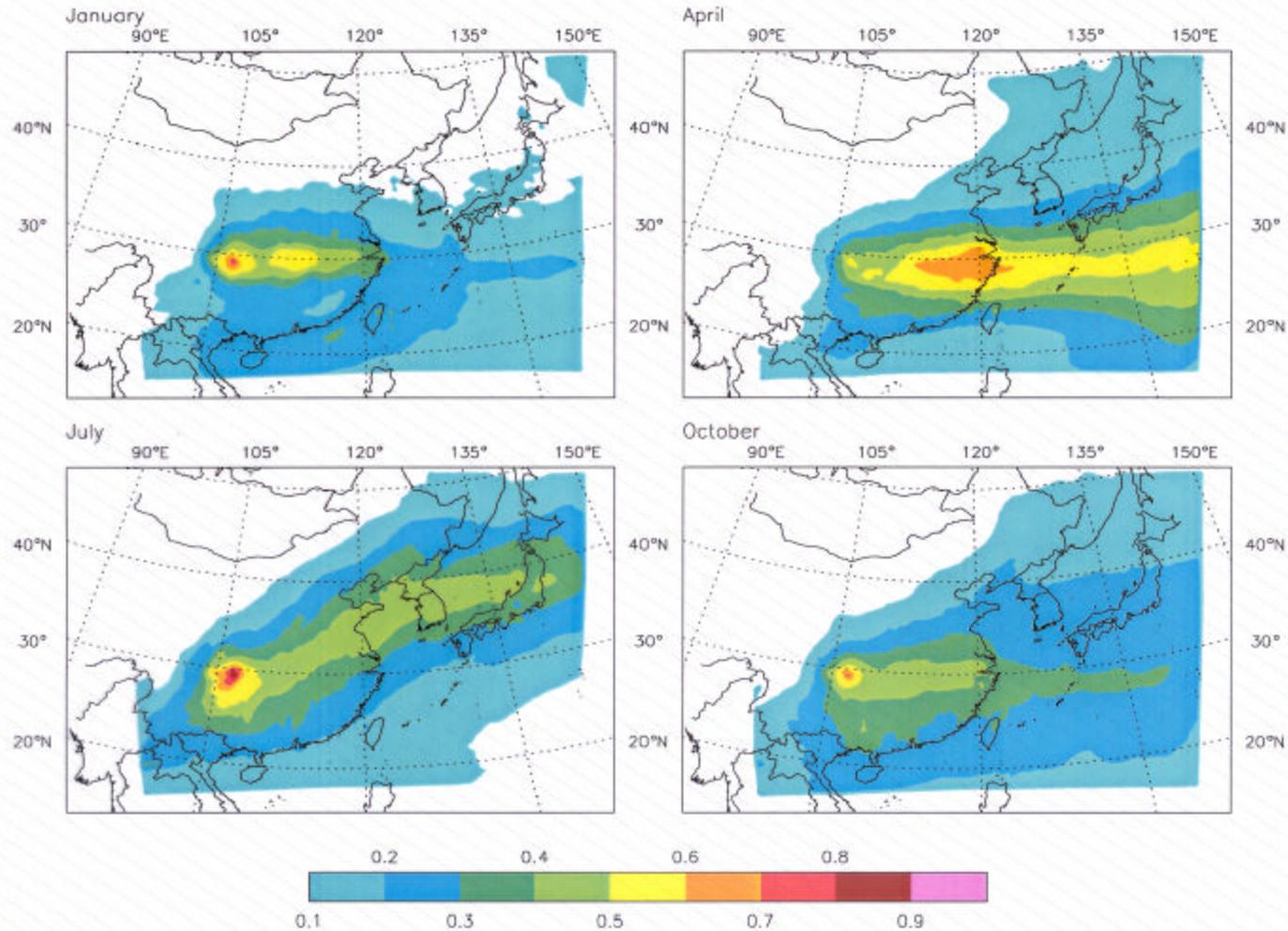


Noble, 1999

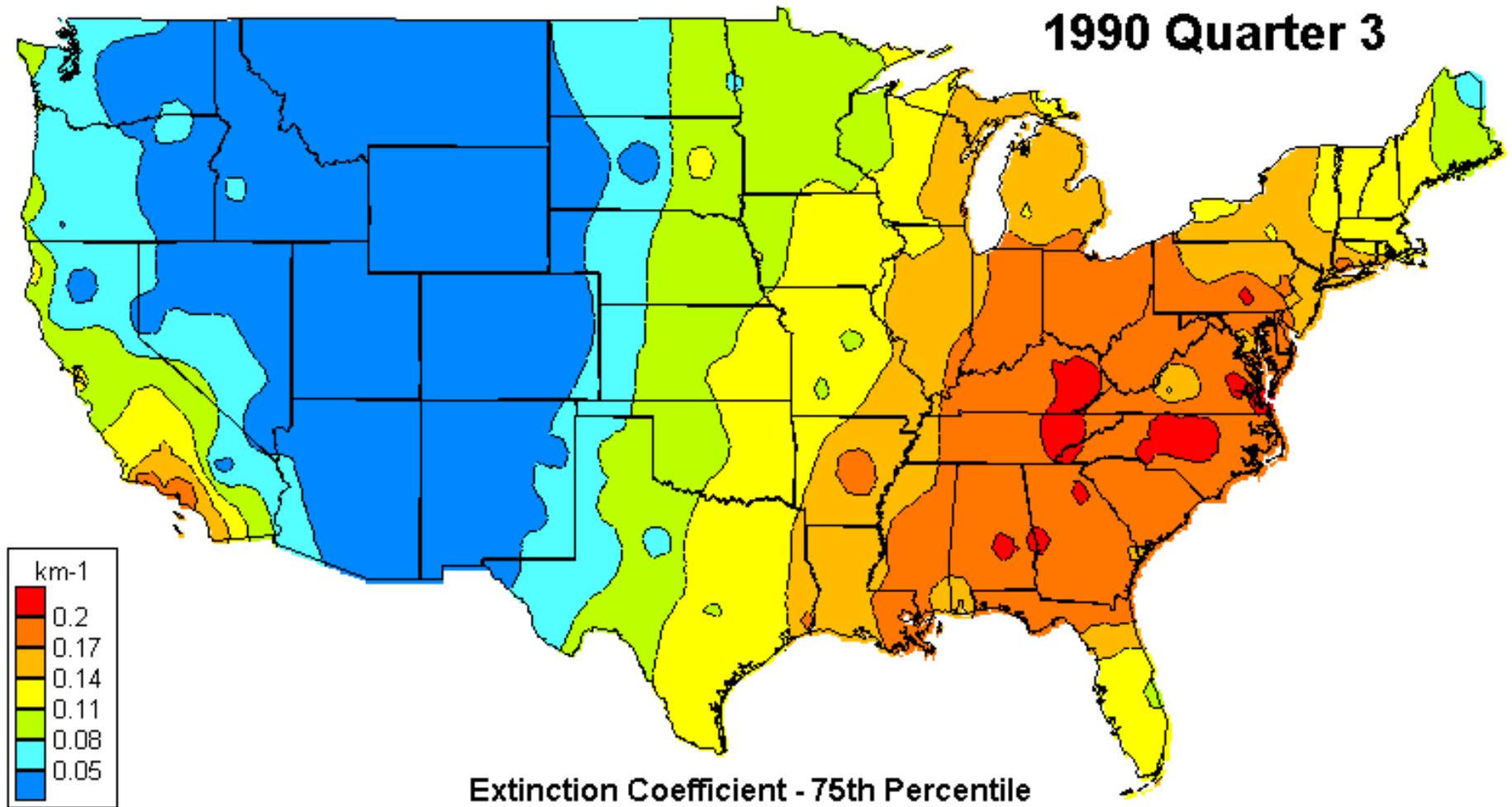
# CO<sub>2</sub> Uptake vs. PAR



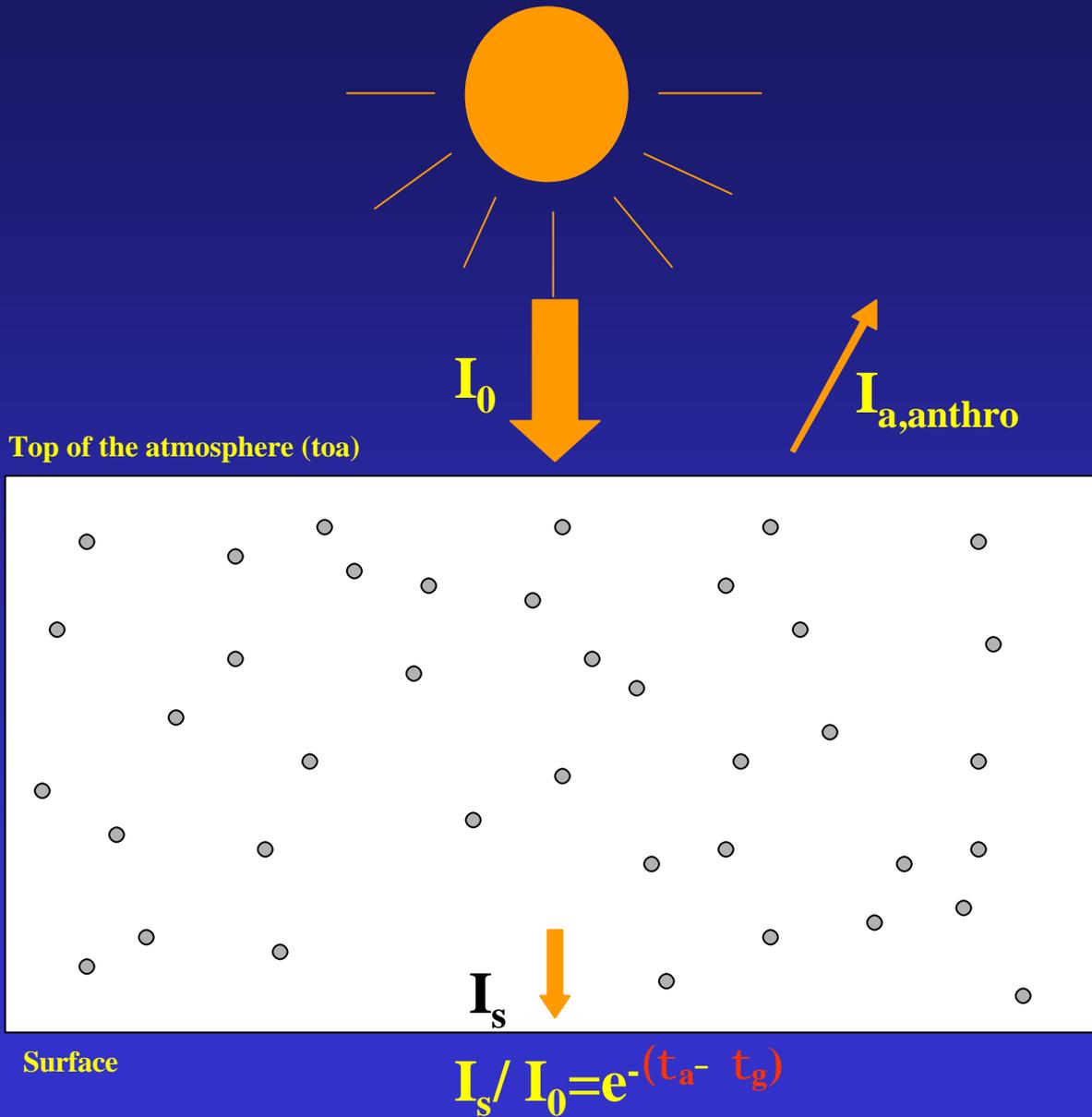
# Regional Nature of Aerosols in China



# Aerosol Spatial Distribution in the U.S.



# INFLUENCE OF AEROSOLS ON SHORTWAVE RADIATION DURING CLEAR-SKY CONDITIONS: KEY PARAMETERS



$$DF_{toa} = I_{a,anthro} - I_{a,back} = f(t_a, w_0, b)$$

where:

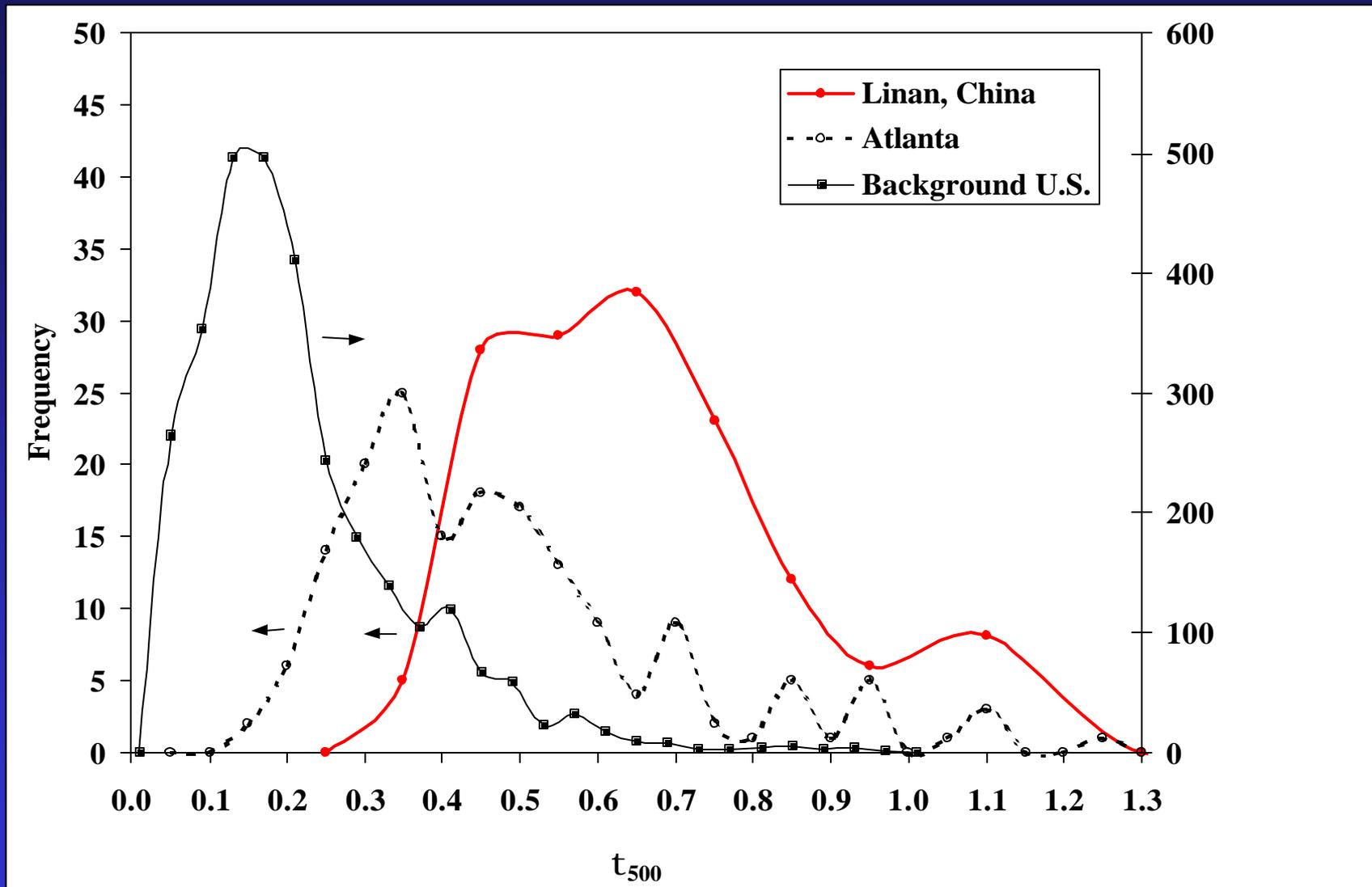
$t_a$  = Aerosol Optical Depth

$w_0$  = Single Scattering

Albedo ( $S_{sp}/S_{extp}$ )

$b$  = Upscatter Fraction

# Aerosol Optical Depth at a Few Locations

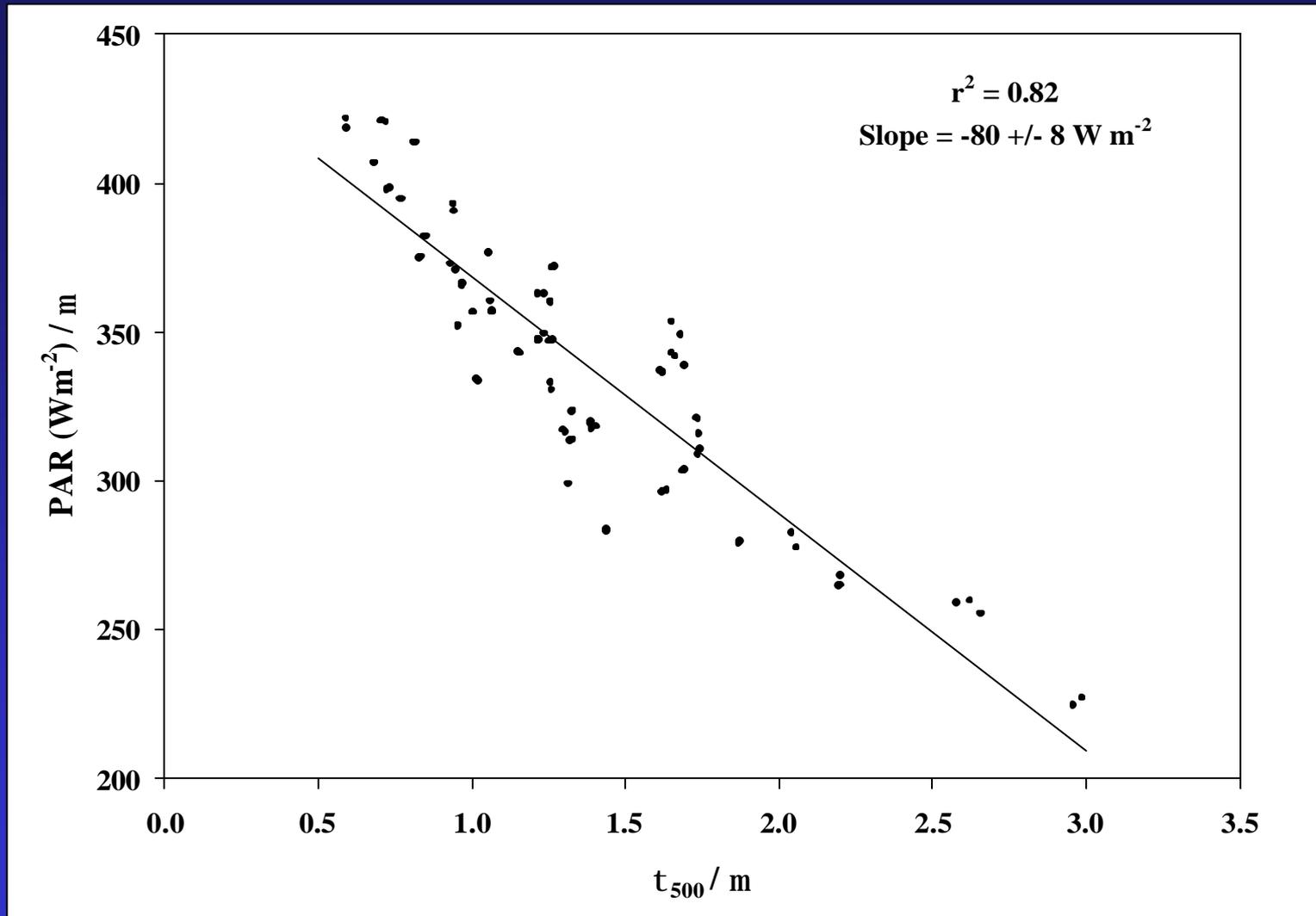


- $\tau_{500} \sim$  factor of 2-3 greater than polluted region of U.S.

# Linan, China



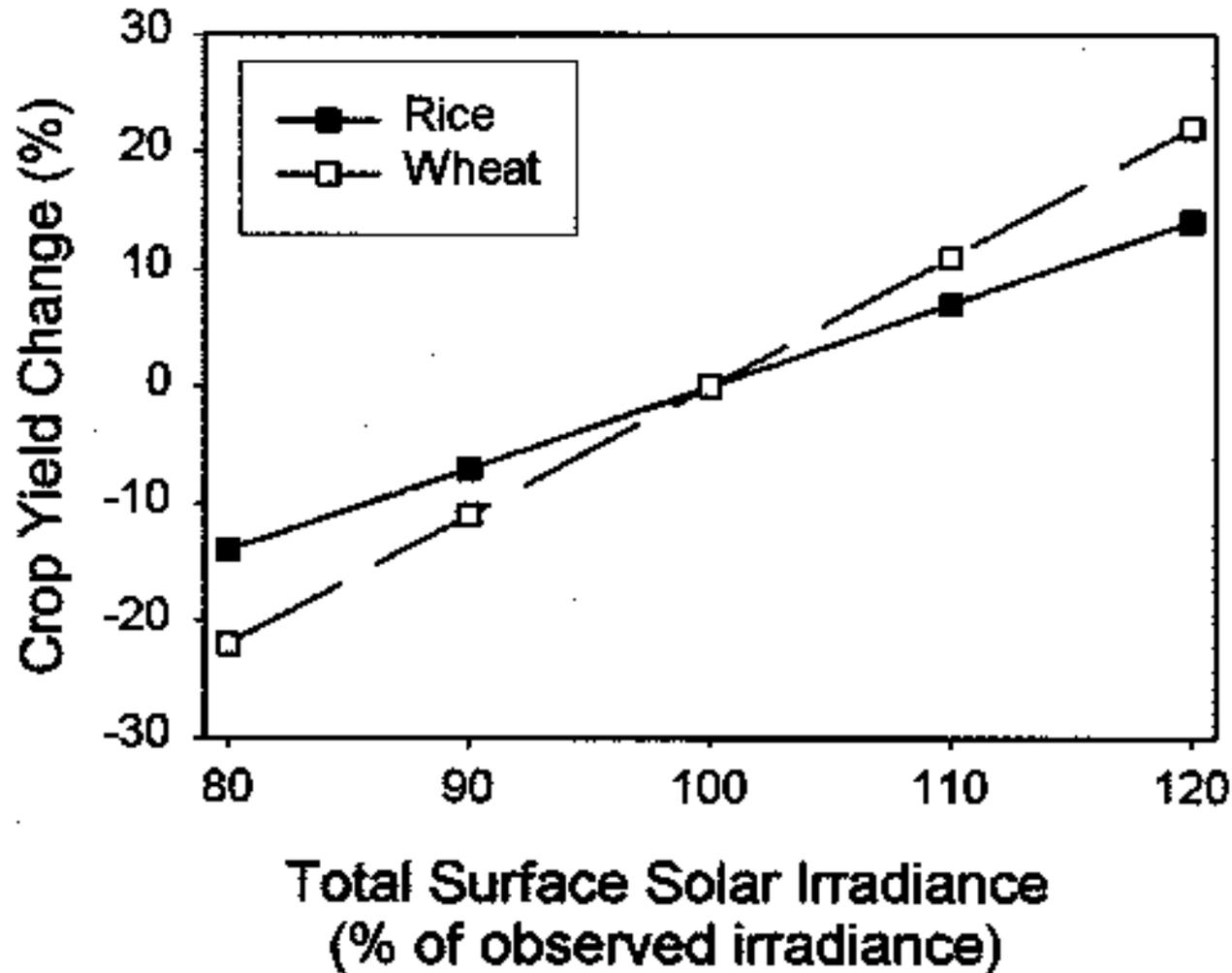
# Relationship Between Aerosol Optical Depth and PAR During Clear-Sky Conditions



- Aerosols can decrease PAR by ~ 20 - 30% during clear conditions in China
- Estimated 24-hr average DF<sub>TOA</sub> is ~ -11 W m<sup>-2</sup>

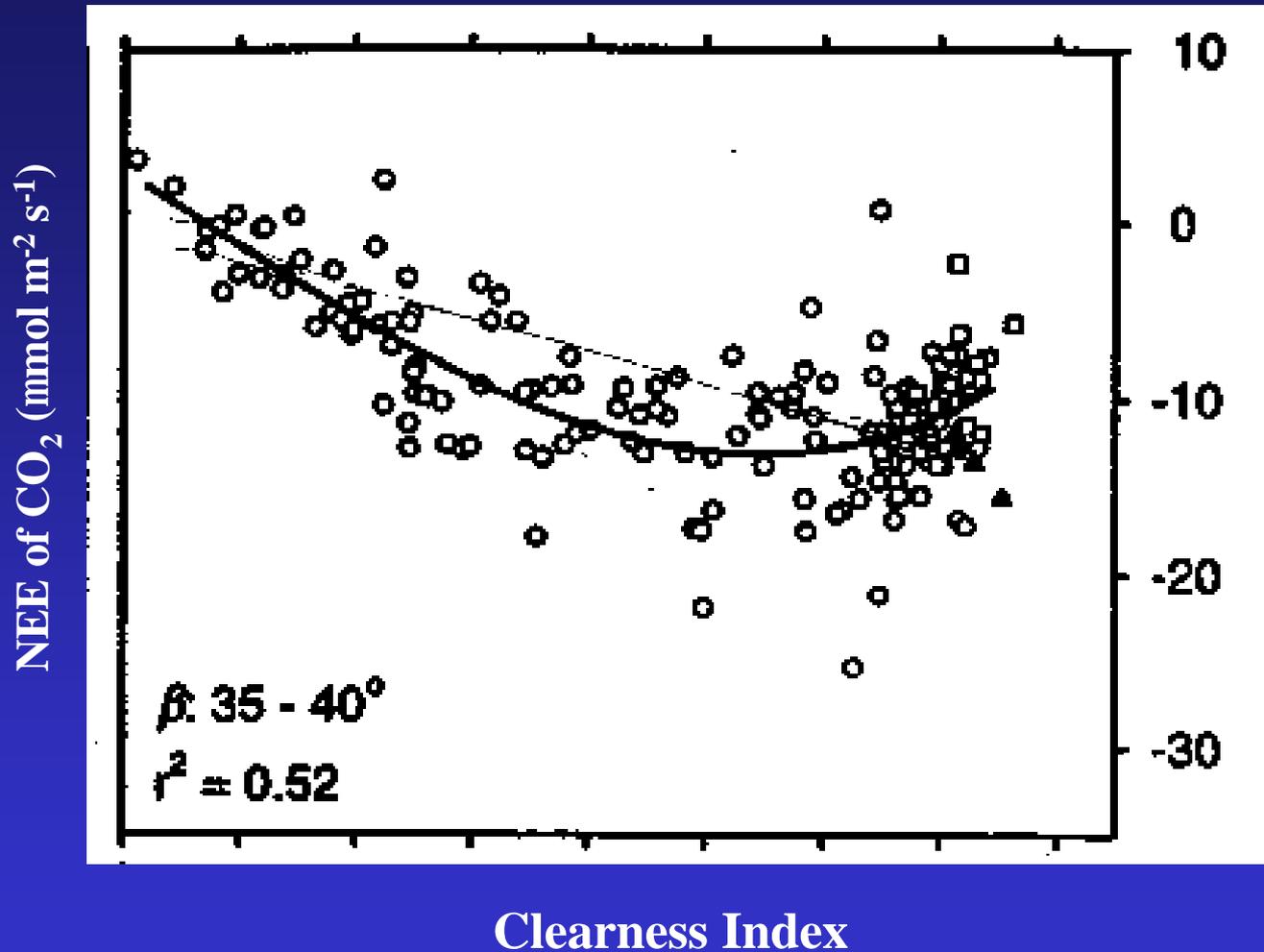
# Sensitivity of Crop Model Rice and Wheat Yield to Surface Irradiance

Chameides et al., 1999

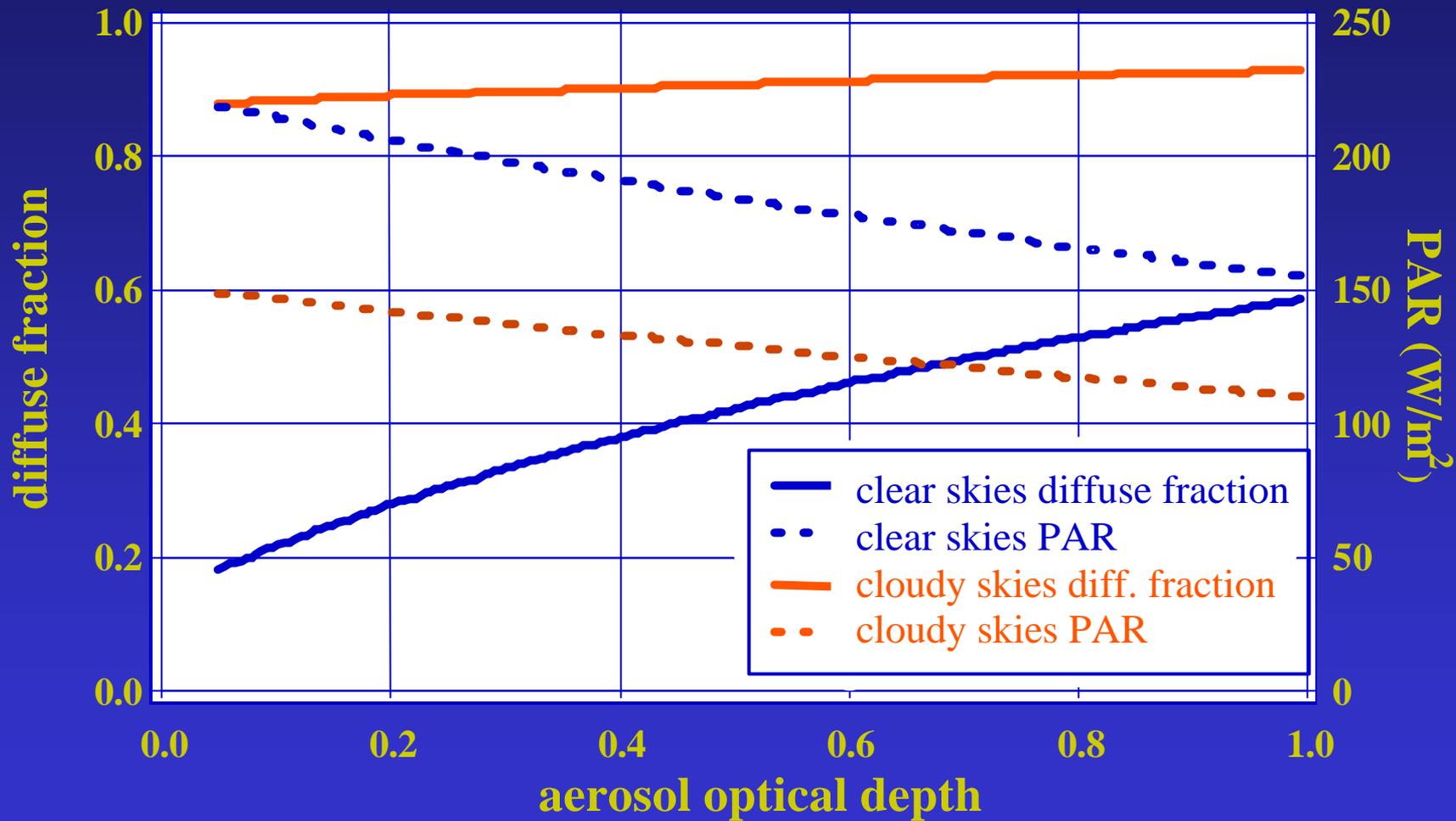


- Crop Growth = f (PAR, nutrients, water, T, RH)

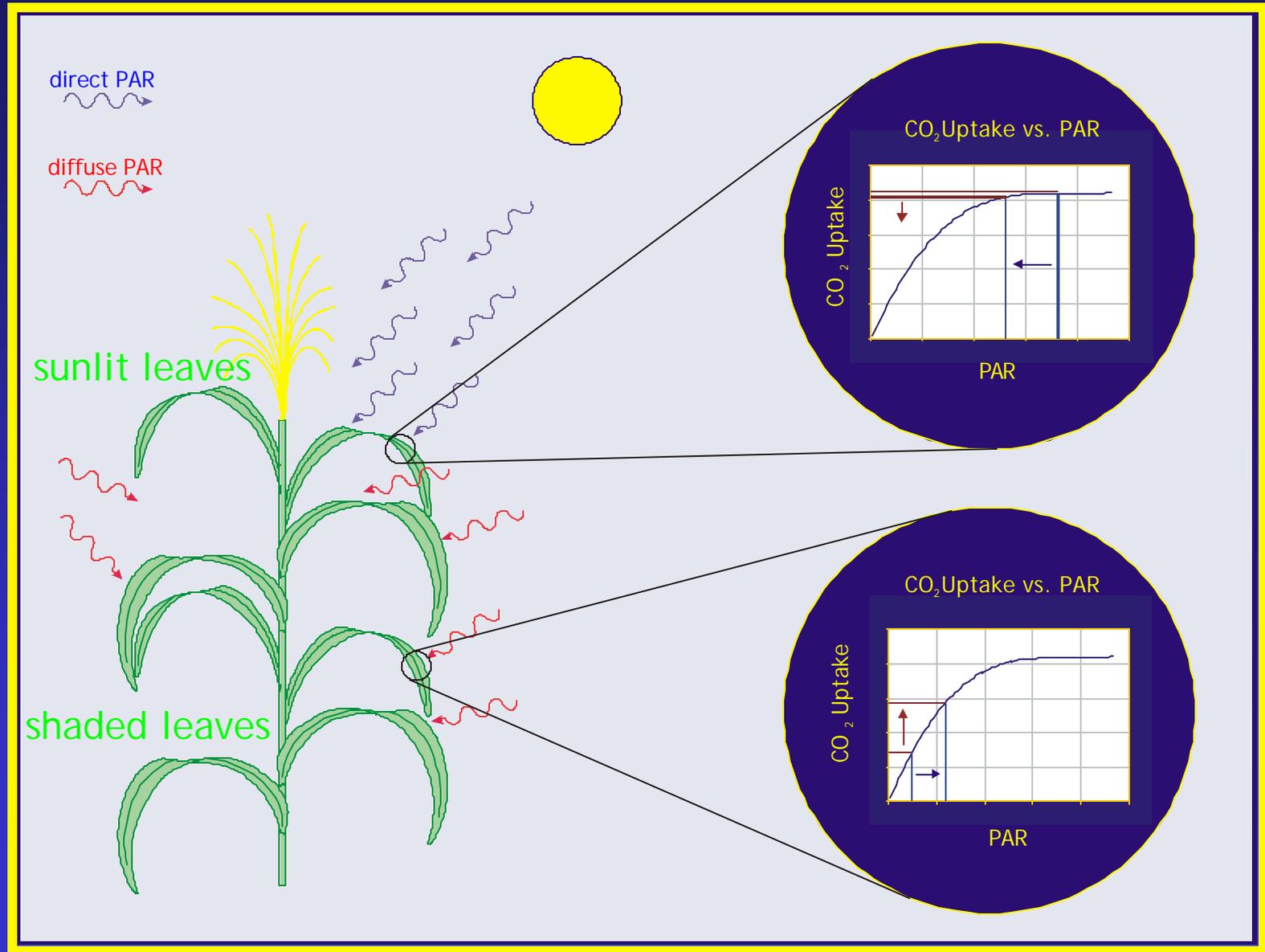
# Can the Quality of Solar Radiation Reaching the Surface Influence Plant Growth?



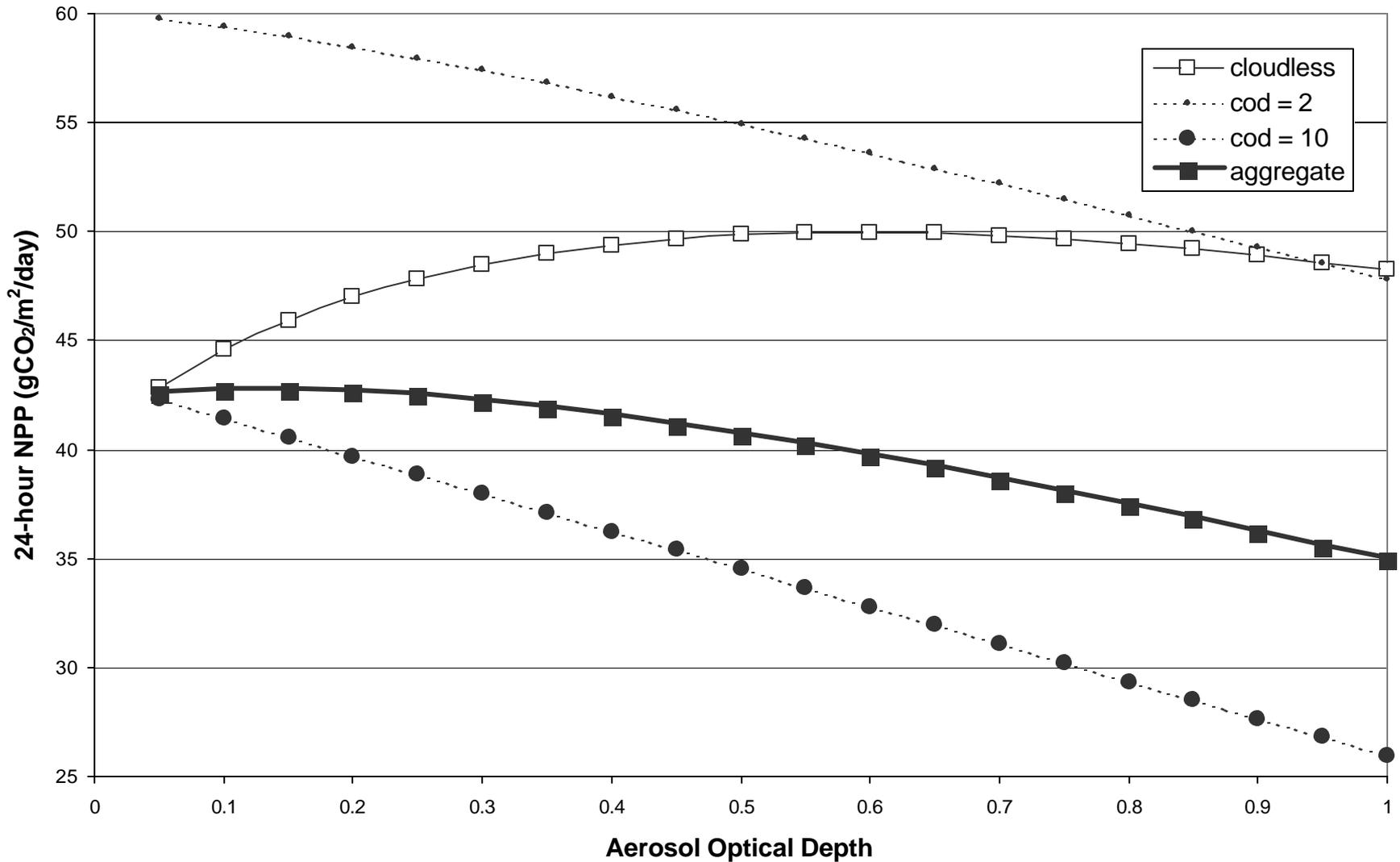
# Relationship Between Aerosols and Diffuse PAR



# Can the Quality of Solar Radiation Reaching the Surface Influence Plant Growth?

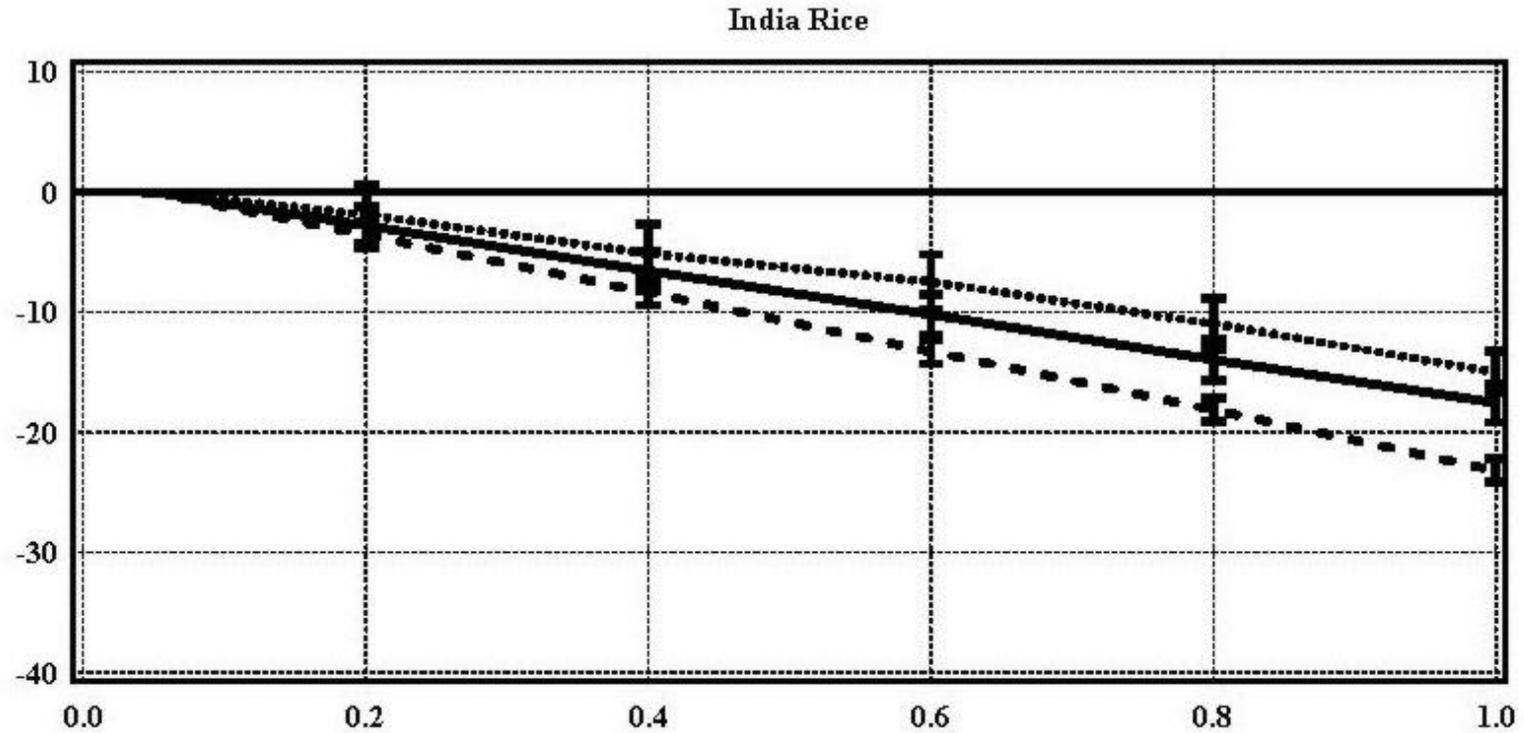


# Model Estimation of the Influence of Diffuse Radiation on NPP ?



# The Estimated Influence of Aerosols on Crop Production Over a Growing Season: India Rice

percent change in yield



AOD

# Influence of Water Stress on Grain Yield During 1998

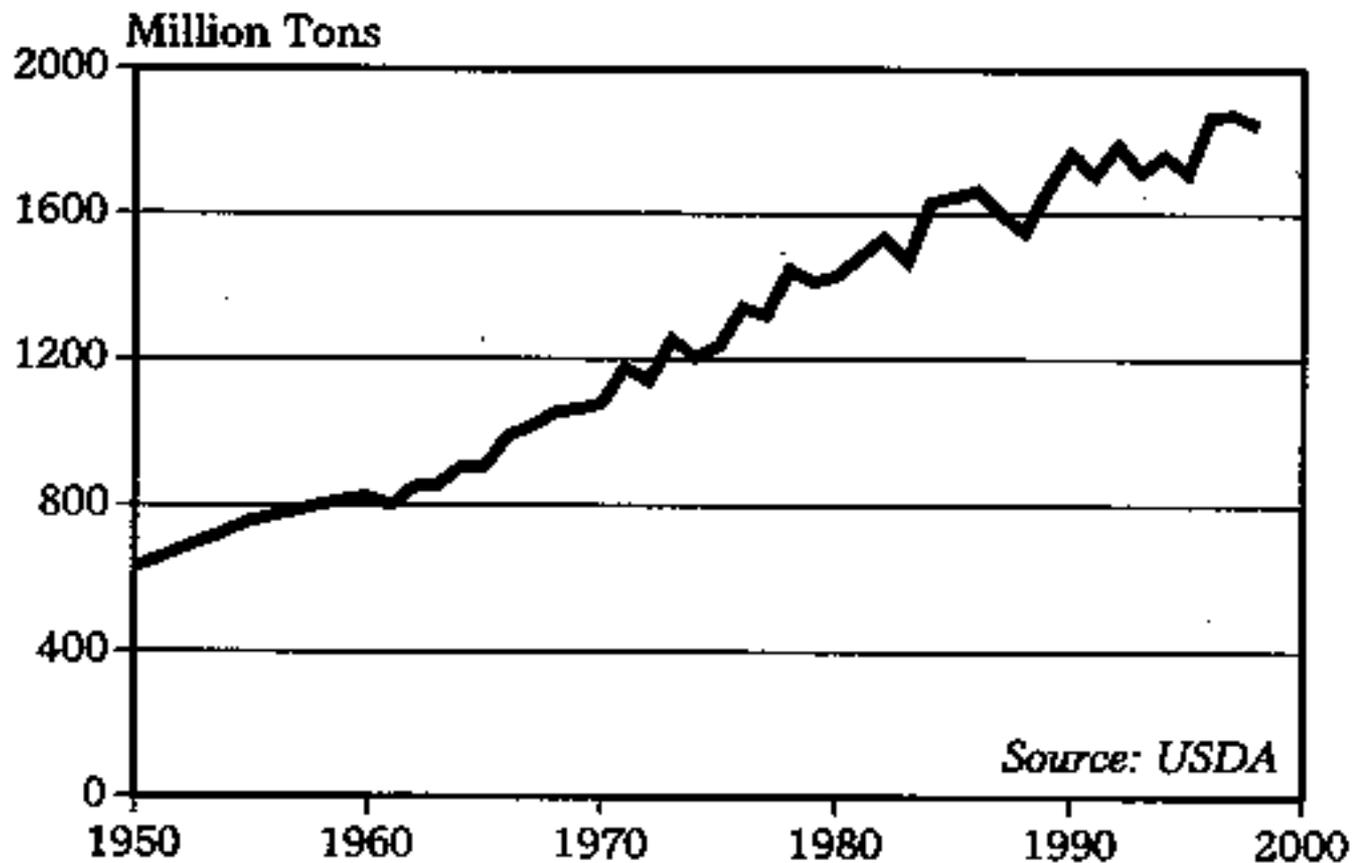


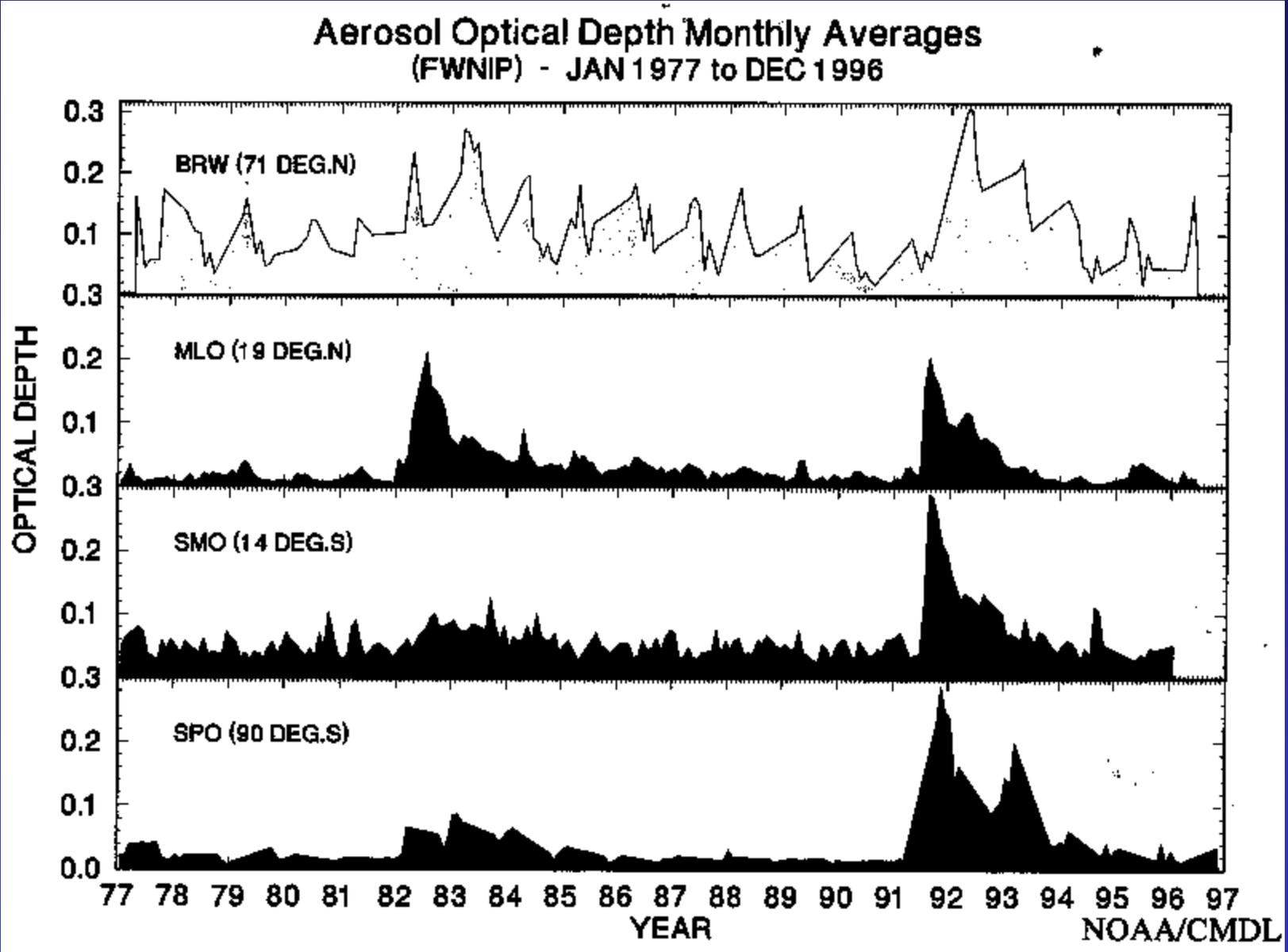
Figure 1: World Grain Production, 1950-98

- Russian wheat yield down ~40% due to drought
- World grain yield down ~4%

# **Cost of 10% Reduction in Rice Yield in China and India (Economics Slide)**

- **In 1999/2000 India and China combined produced ~333 million metric tons of rice**
- **At a price of \$200 / ton a 10% reduction in this value costs about \$7 billion**
- **The FY2000 budget for NSF was \$3.6 billion**

# The influence of Mt. Pinatubo on Global Aerosol Optical Depth

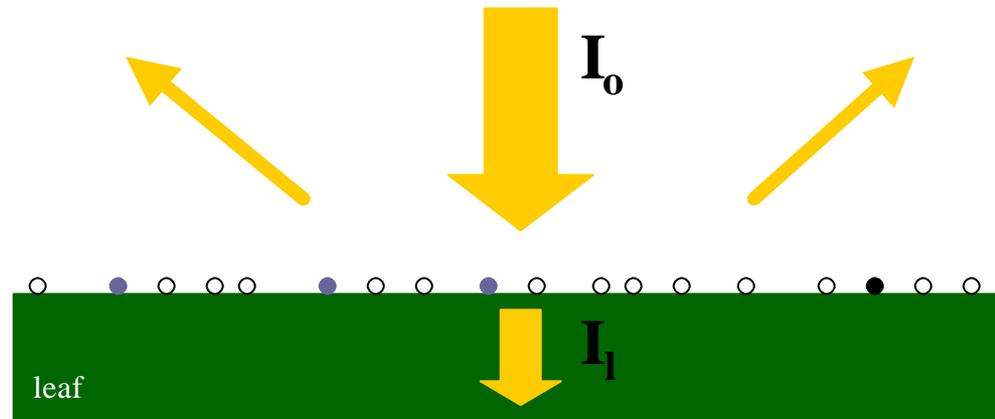


E. Dutton, pers. comm.

# How Did Pinatubo Influence Surface Radiation and Carbon Uptake ?

- **Surface irradiance decrease of ~4%; ~10% decrease in direct irradiance; ~40% increase in diffuse irradiance**
- **Global cooling of ~0.2 deg C**
- **Significant increase in terrestrial carbon uptake (~2 Gt C), particularly in northern hemisphere**
  - **Increasing plant growth due to precipitation changes?**
  - **Decrease in soil respiration?**
  - **Increase in the diffuse radiation fraction enhancing plant growth?**

# Influence of Aerosol Dry Deposition on PAR Available to a Plant for Photosynthesis



$$EX_{PAR}(t) = \frac{\alpha V_d C_p}{\zeta \text{LAI}} \frac{\ddot{\theta}}{\theta} (E_{abs} + E_{scat} \beta) t$$

Where:

$EX_{PAR}(t)$  = Fractional reduction in incident PAR

$V_d$  = Aerosol dry deposition velocity

$C_p$  = WIA concentration

$\text{LAI}$  = Leaf area index

$E_{abs}$  = Mass absorption efficiency

$E_{scat}$  = Mass scattering efficiency

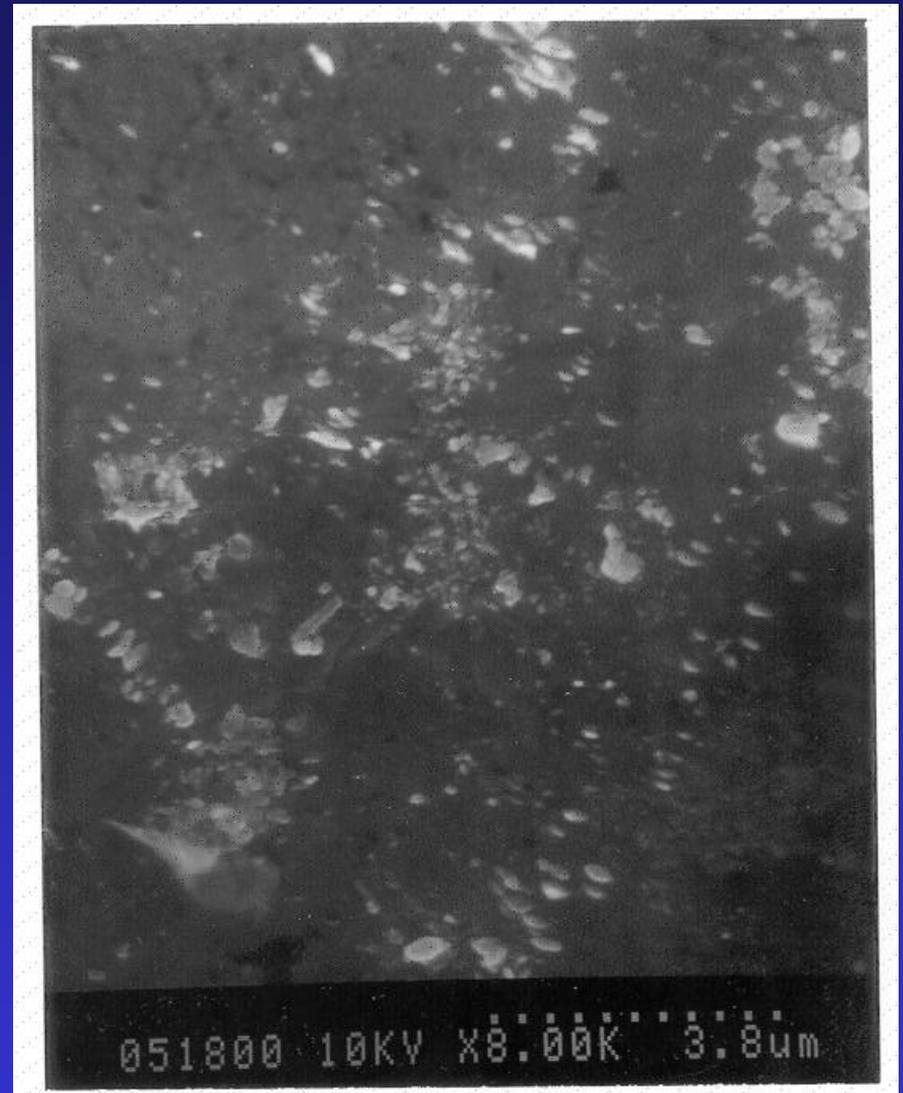
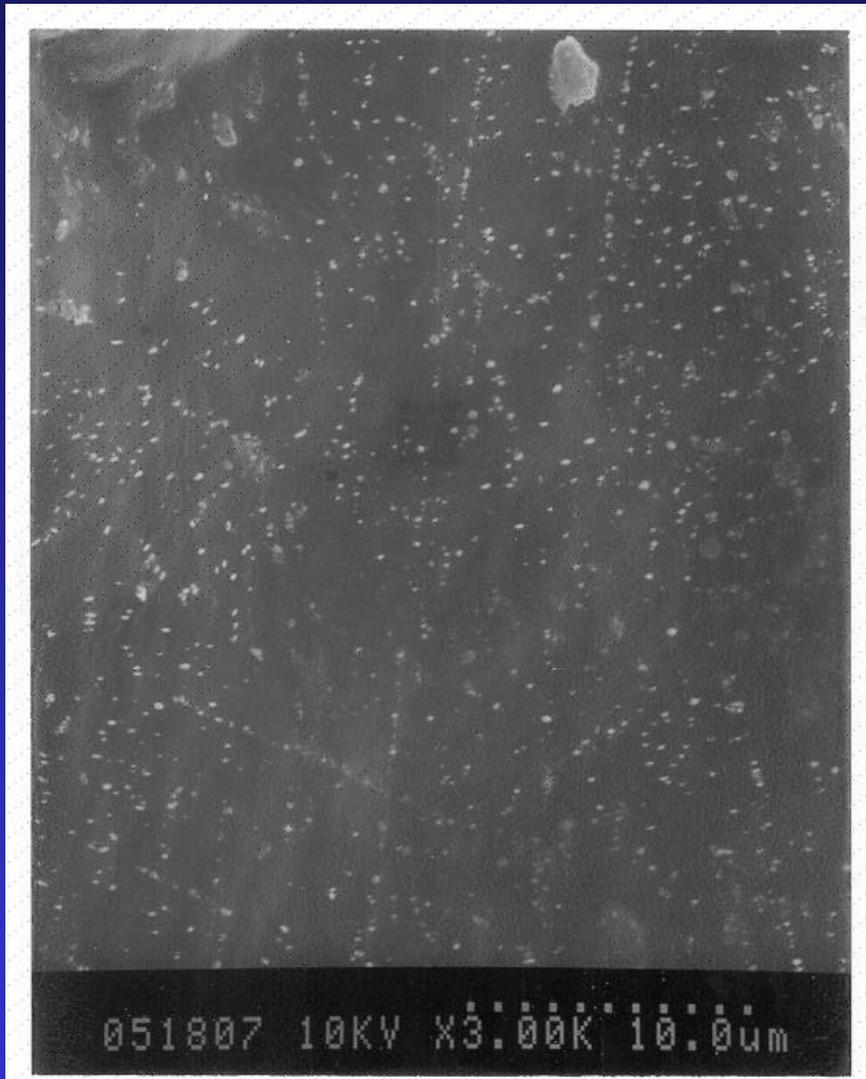
# AEROSOL PROPERTIES IN IN LINAN, CHINA DURING NOV.-DEC., 1999

	Mass concentration ( $\text{mgm}^{-3}$ )		Mean % contribution to PM2.5 mass
	Mean	Std. Dev	
<b>PM2.5</b>	<b>102.4</b>	<b>52.3</b>	
<b>Organic Compounds</b>	<b>50.4</b>	<b>27.4</b>	<b>48</b>
<b>Sulfate</b>	<b>24.2</b>	<b>12.8</b>	<b>23</b>
<b>Ammonium</b>	<b>9.8</b>	<b>5.7</b>	<b>9</b>
<b>Nitrate</b>	<b>8.8</b>	<b>7.7</b>	<b>8</b>
<b>Elemental Carbon (EC)</b>	<b>5.4</b>	<b>2.0</b>	<b>5</b>
<b>Sodium</b>	<b>3.4</b>	<b>1.3</b>	<b>3</b>
<b>Other</b>	<b>3.8</b>	<b>5.3</b>	<b>4</b>
<i><b>Water Insoluble Aerosol (WIA)</b></i>	<i><b>34.0</b></i>	<i><b>14.0</b></i>	<i><b>33</b></i>
	Extinction Efficiency ( $\text{m}^2 \text{g}^{-1}$ )		
	Mean	Std. Dev.	
<i><b><math>E_{abs}</math></b></i>	<i><b>0.86</b></i>	<i><b>0.70</b></i>	
<i><b><math>E_{scat}</math></b></i>	<i><b>4.0</b></i>	<i><b>0.4</b></i>	

# Deposition of Aerosol Particles to Leafs

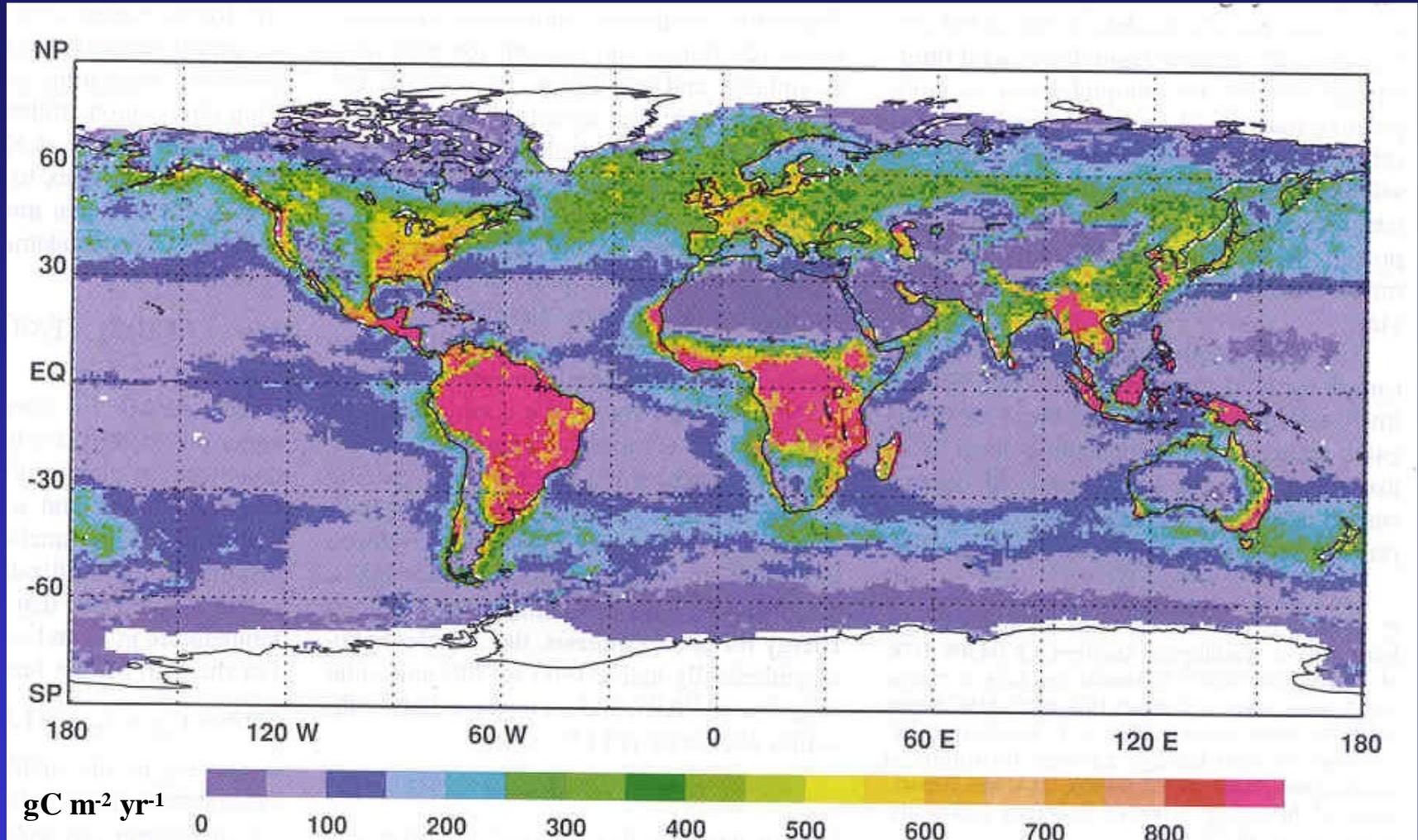


# Aerosol Particles Deposited on Leaves



- Results suggest as much as a 30% reduction in PAR available to plants over a growing season due to extinction of photons by deposited aerosol particles

# Do Aerosols Influence Net Primary Productivity (NPP)?



$$\text{NPP} = f(\text{NDVI}) * \text{PAR} * e * g(T) * h(W)$$

# Other Possible Influences of Aerosols on Plants

- **Deposition of Nitrogen to Nutrient Limited Ecosystems**
- **Acid Deposition**
- **UV Damage**
- **Transport of Nutrients to the Oceans (Fe)**
- **Climate Modification**
  - **Indirect Effect**
  - **Precipitation**
  - **Temperature**

# FUTURE EFFORTS

- **Field studies on various types of plants focusing on the relationship between variables that influence plant growth (T, precipitation, RH, nutrients) and quantity and quality of radiation**
- **Field and lab studies to look at influence of aerosol deposition on plant photosynthesis**
- **Development of new algorithms to predict NPP based on field observations**

# Research Collaborators

## Georgia Tech

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