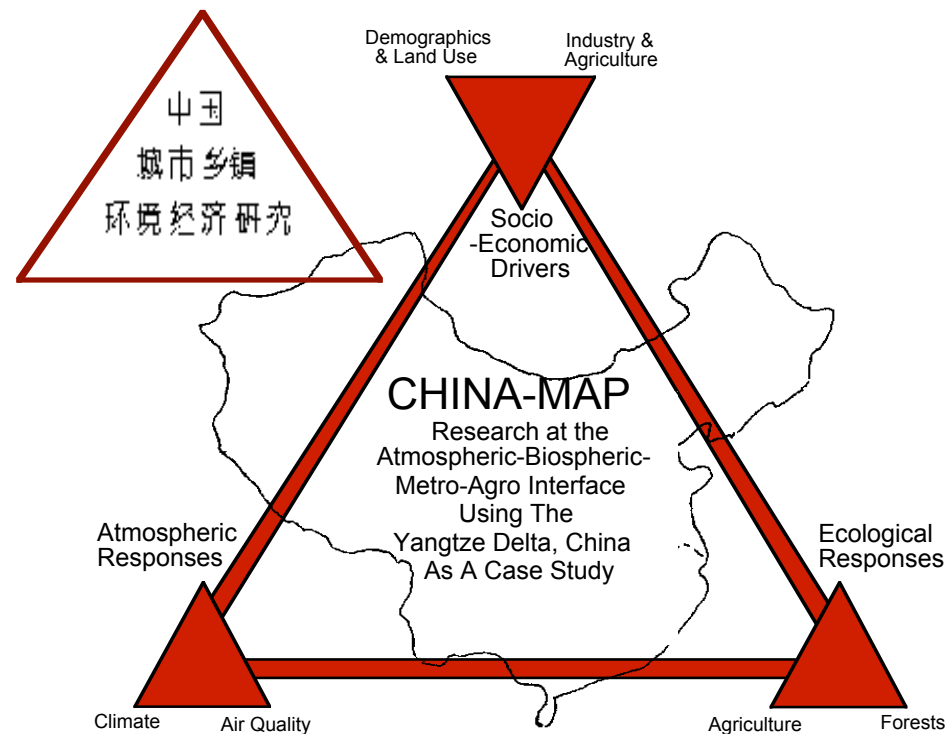


A Case Study of Atmospheric Aerosols and Their Terrestrial Impacts Over China

W.L. Chameides
Georgia Tech

Aspen Global Change Institute
August, 2000



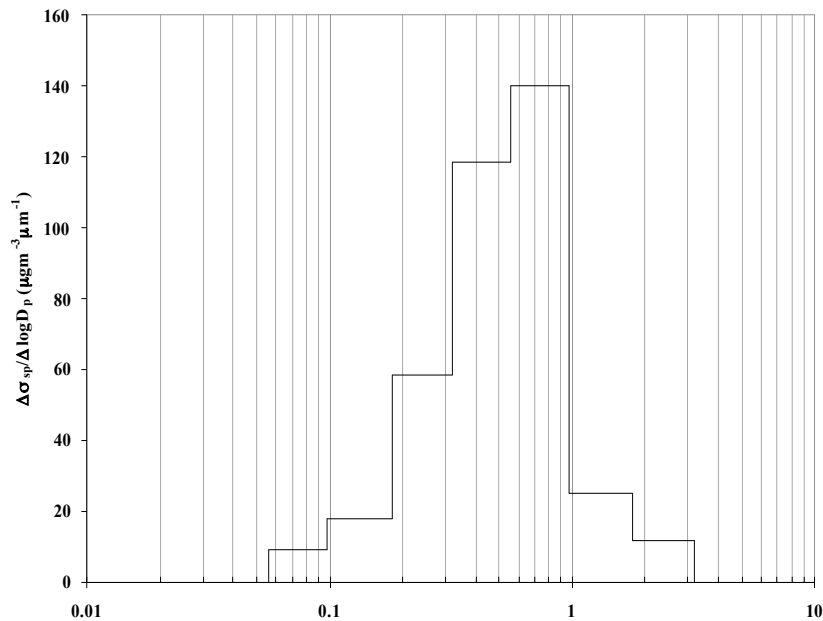
Take – Home's



- Is regional air quality affecting climate?
 - Of course: regional haze ...
 - **Aerosol impact on climate is one outcome of regional air pollution.**
- Could air quality interactions with climate affect projections of climate change?
 - Aerosols affect solar radiation at earth's surface and thus can influence photosynthesis ...
 - **One outcome may be a change in C-storage by terrestrial ecosystems.**
 - Aerosols affect boundary layer dynamics...
 - **Change in relative humidity can in turn affect aerosol radiative properties.**
 - **Positive/negative feedback?**

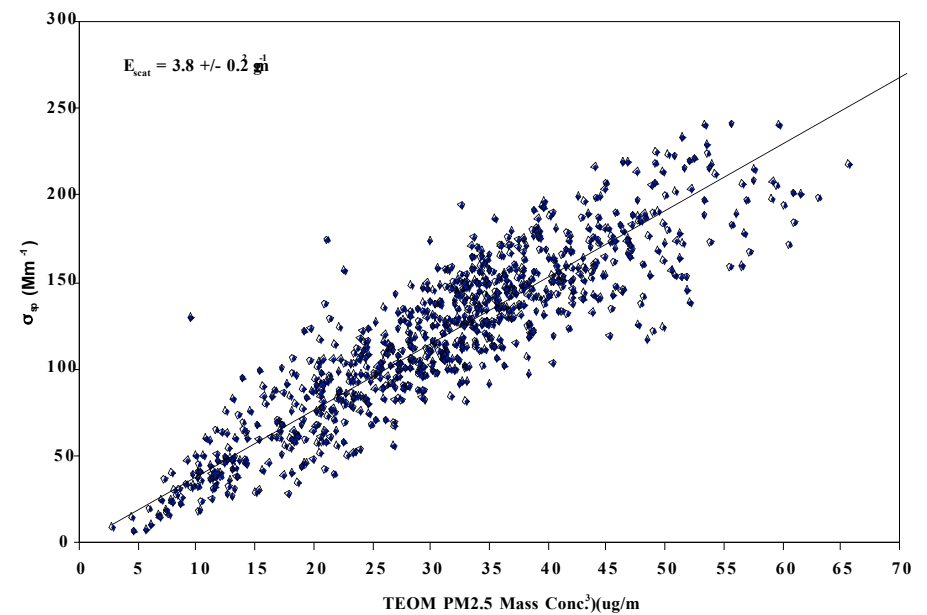
Aside: Aerosols, PM_{2.5}, and Light Scattering

Estimated Light Scattering Coefficient (550 nm)
vs. D_p During Atlanta SuperSite Study



- Aerosols having diameters $> 2.5 \mu\text{m}$ do not contribute to light scattering

Light Scattering Coefficient vs. PM_{2.5} during
During Atlanta Supersite Study



- PM_{2.5} mass is responsible for light scattering

The China-MAP Science Team

USA

USA Study Director:

W. L. Chameides*¹

Co-Investigators:

C. S. Kiang*¹

S. C. Liu*¹

Chao Luo*^{1,9}

Yan Huang*¹

J. St. John*¹

R. D. Saylor*¹

A. Steiner*¹

Hongbin Yu¹

G. Carmichael*²

S. Guttikunda*²

F. Giorgi*^{3,4}

Xunqiang Bi³

Yun Qian³

Jianhua Qian⁴

L. Mearns*⁴

D. Streets*⁵

S. Waldhoff*⁵

Mian Chin⁶

D. Blake⁷

M. Bergin¹

K. Baumann¹

H. Levy II⁸

P. Kasibhatla⁹

D. Cohan¹

* *Funded by NASA EOS/IWG*

China

China Study Director:

Zhou Xiuji¹⁰

Co-Investigators:

Chen Longxun¹⁰

Li xingsheng¹⁰

Li Weiliang¹⁰

Mao Jietai¹¹

Tang Xiaoyan¹¹

Tian Guoliang¹²

Qin Yu¹¹

Wang Chunyi¹⁰

Wang Rusong¹²

Zhang Yuanhang¹²

1 Georgia Institute of Technology

2 University of Iowa

3 Abdus Salam International Centre for Theoretical Physics

4 National Center for Atmospheric Research

5 Argonne National Laboratory

6 NASA

7 University of California at Irvine

8 Geophysical Fluid Dynamics Laboratory

9 Duke University

10 Chinese Academy of Meteorological Sciences

11 Peking University

12 Chinese Academy of Sciences

13 University of Tokyo

14 Osaka Prefectural University

15 Yamanashi University

16 Kyoto University

Japan

Japan Study Director:

H. Akimoto¹³

Co-Investigators:

H. Bandow¹⁴

N. Katanani¹⁵

H. Ueda¹⁶

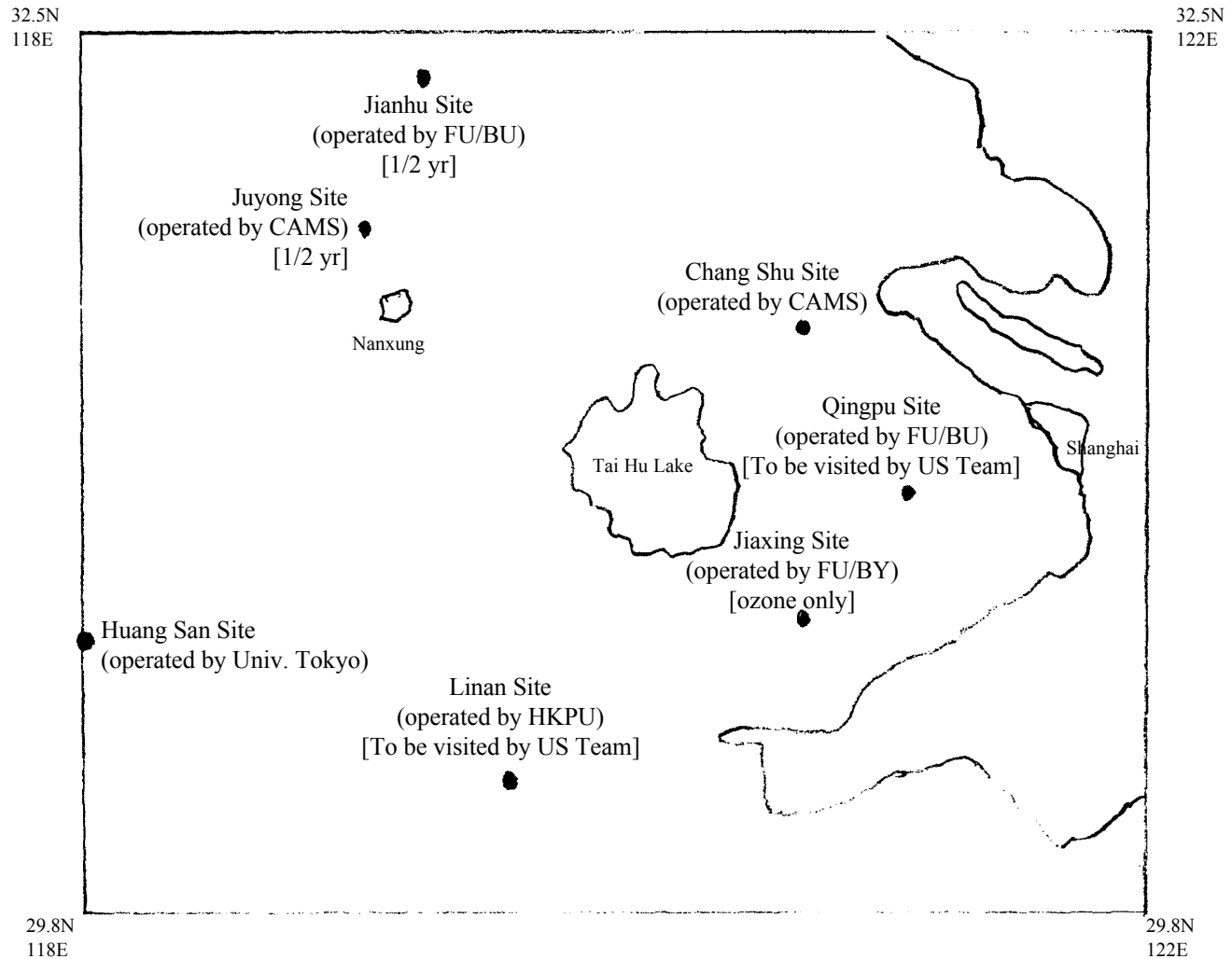
Haze in China: Early December, 1998



Haze in China: Early December, 1998



1999/2000 12-Month Yangtze Delta Field Experiment



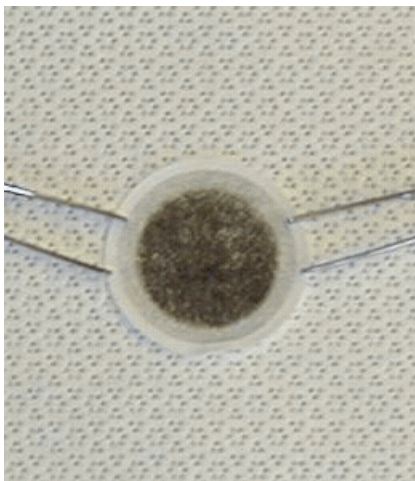
Linan Site Operated By HKPU



Qingpu Site Operated By Fudan and
Beijing Universities



Summary of Fine Particles Measurements; Yangtze, November, 1999

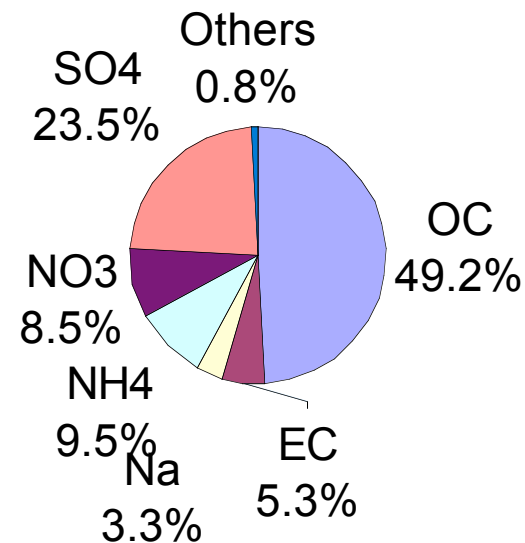


Average Observations

$[PM_{2.5}] = 102 \text{ ug/m}^3$

$[AOD] = 0.6$

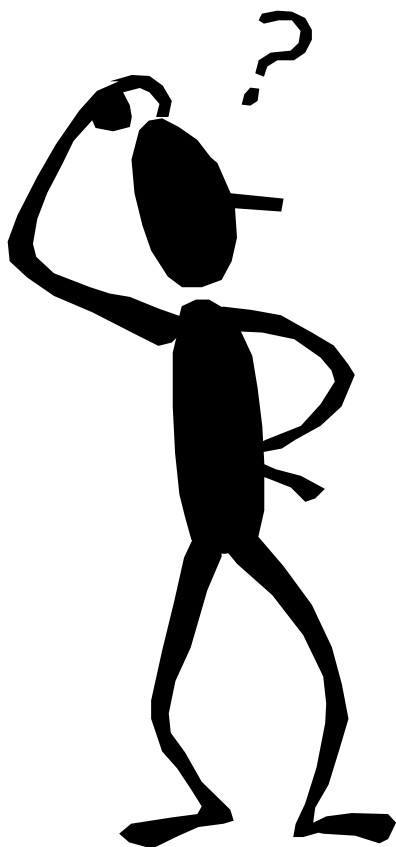
$[w] = 0.9$





What are the PM sources?

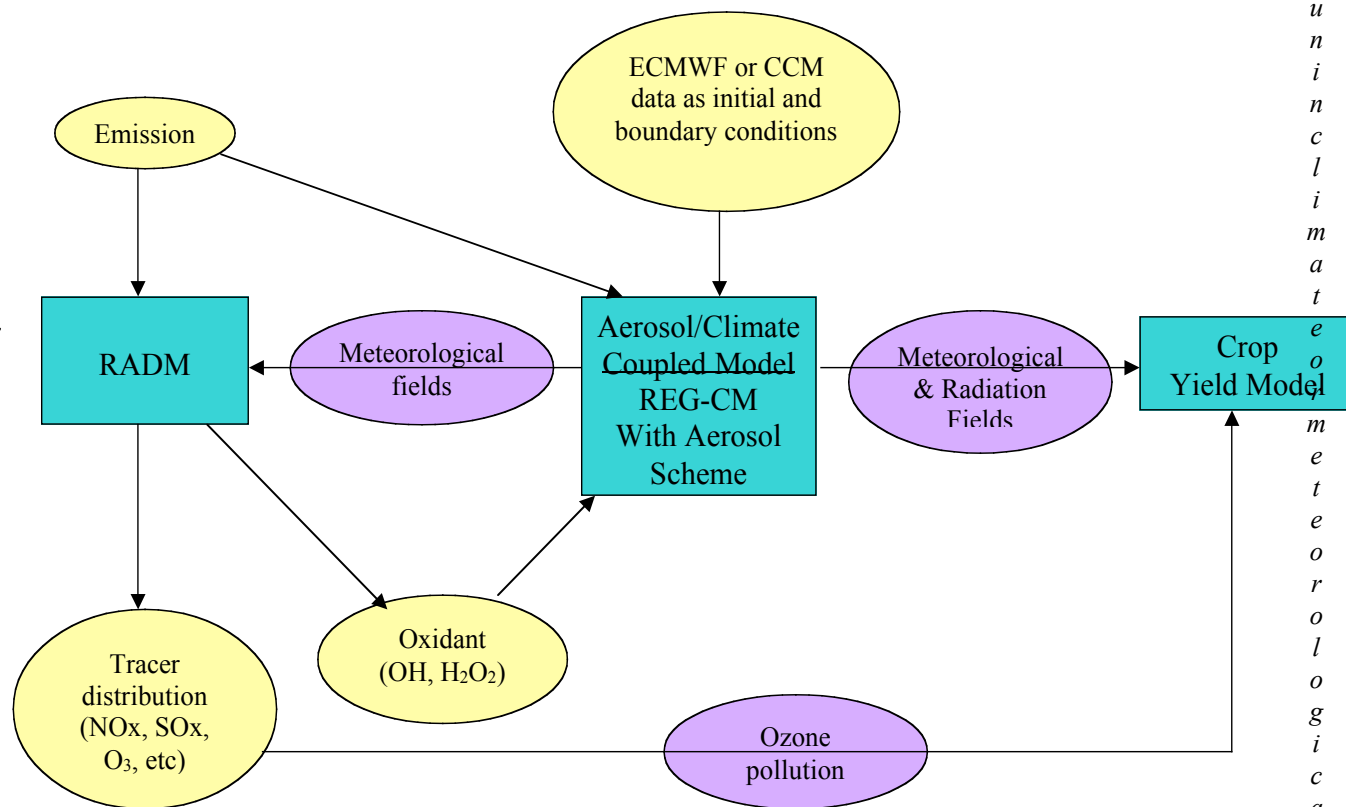
What are the PM effects?



What are the PM sources?

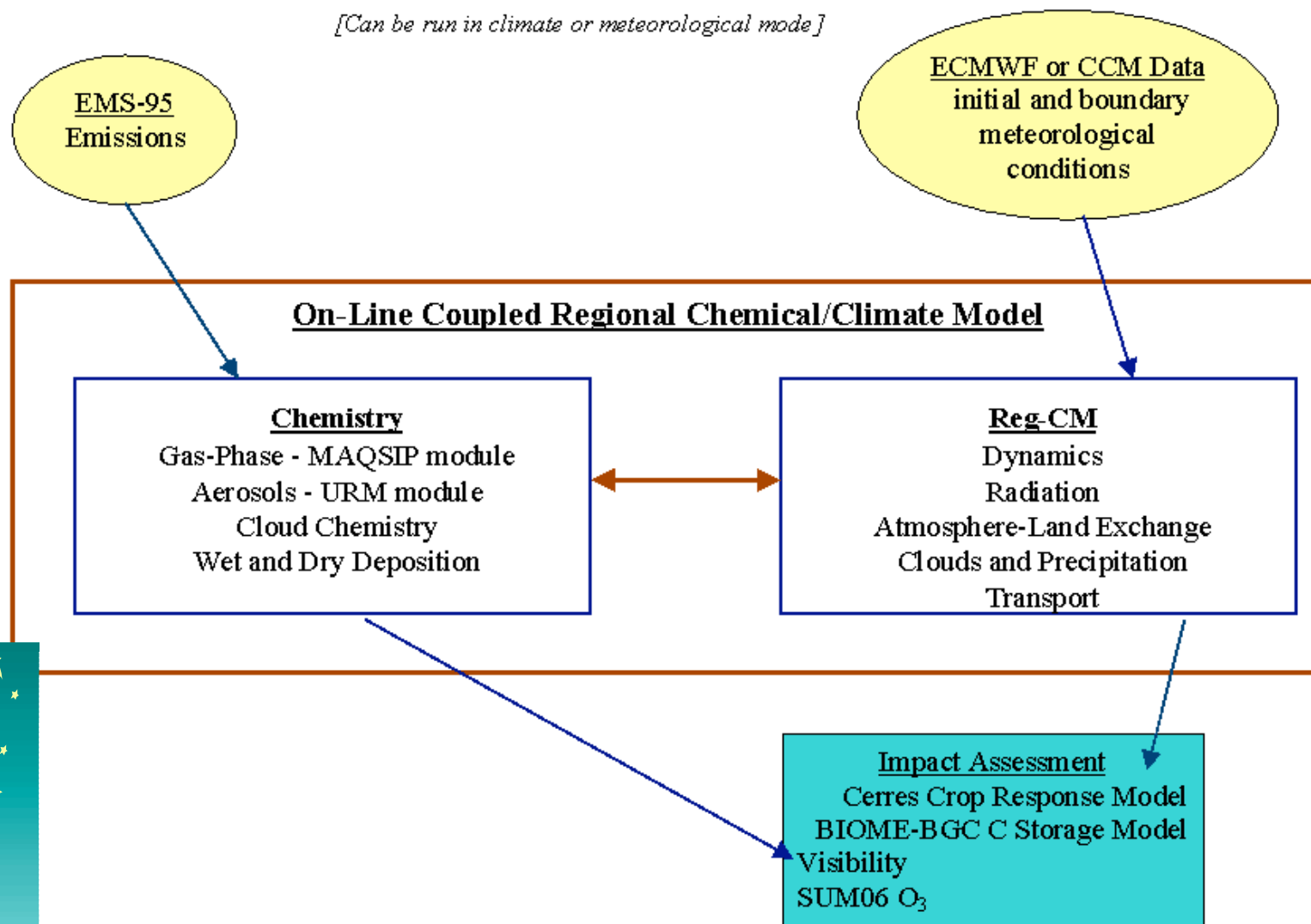
What are the PM effects?

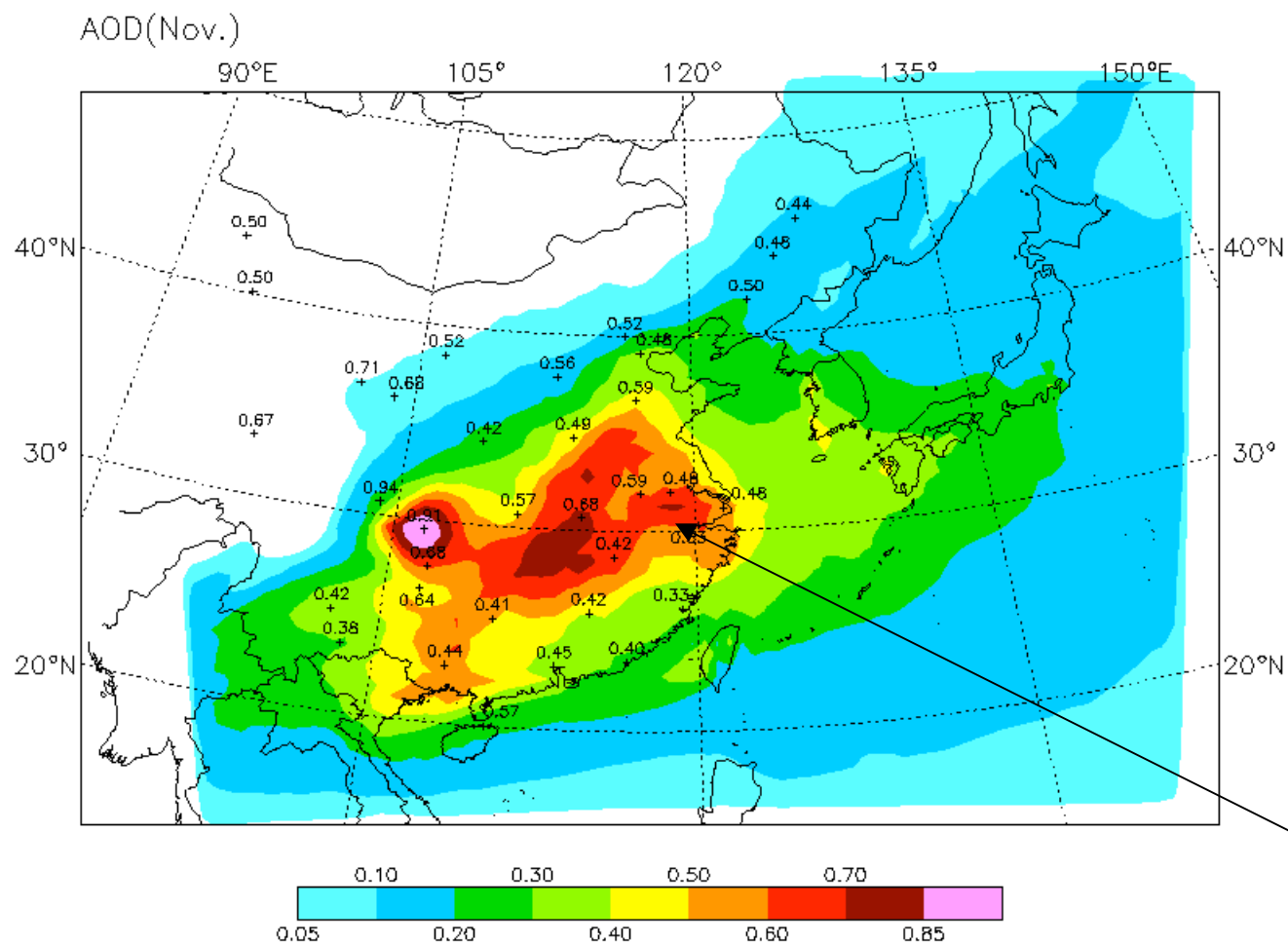
Prototype CHINA-MAP MODELING SYSTEM



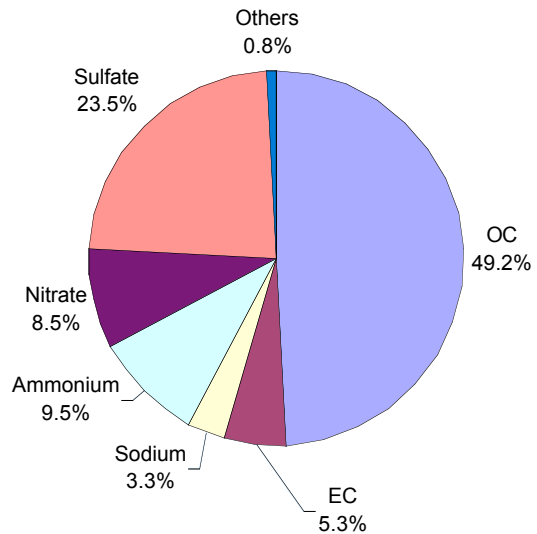
Reg-Chem-CM

[Can be run in climate or meteorological mode]

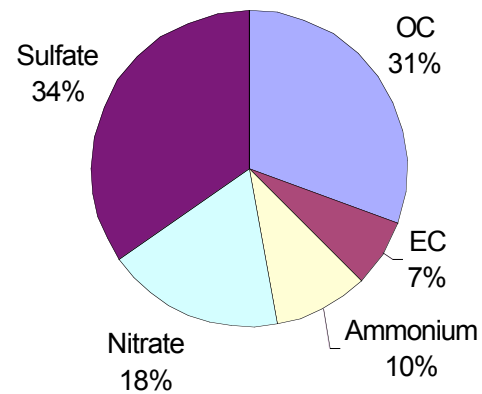




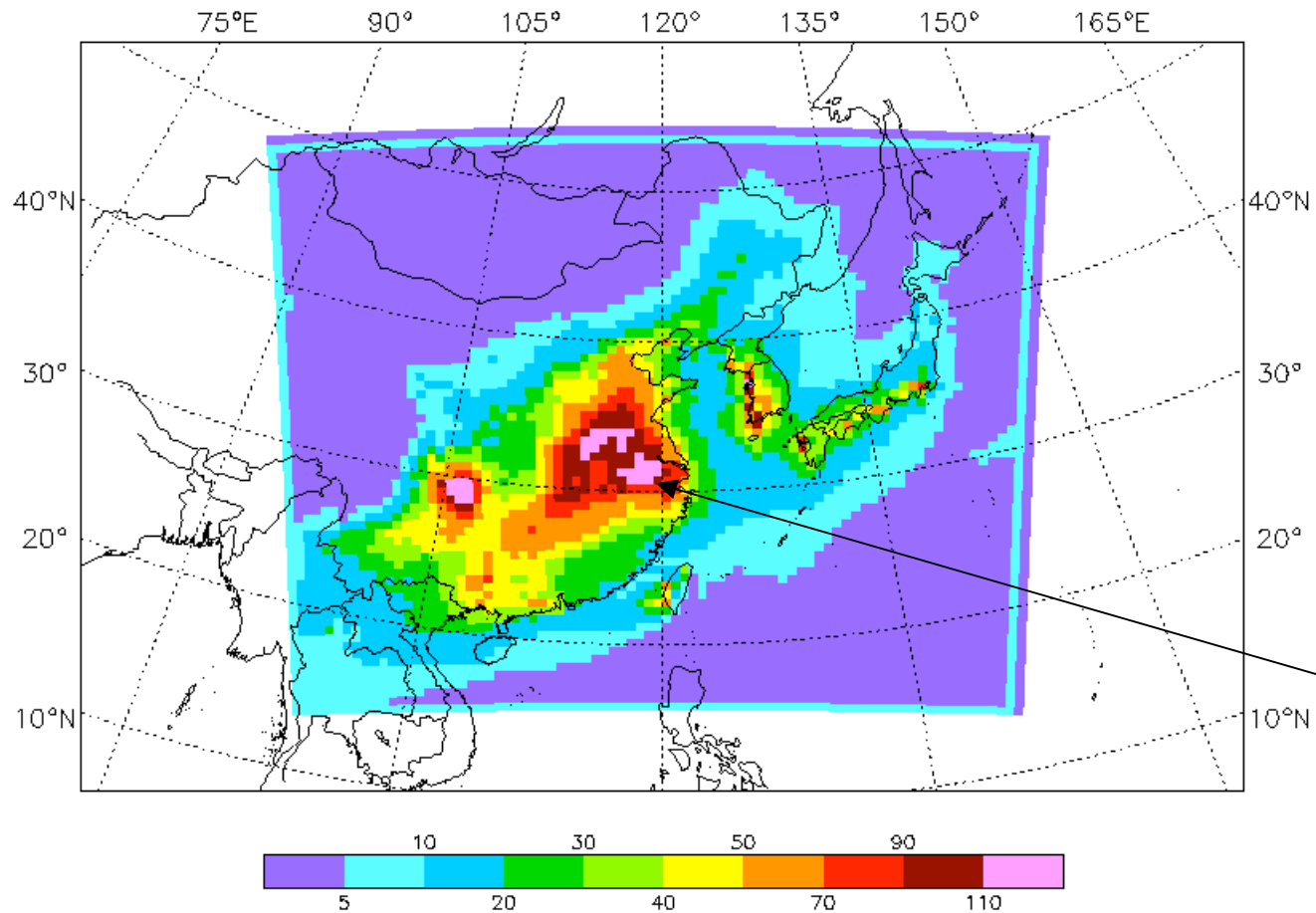
**Observed PM_{2.5} Composition
(Linan) (PM_{2.5} ~ 100 ug/m³)**



**Model-calculated PM Composition
(Linan) (PM ~ 75 ug/m³)**



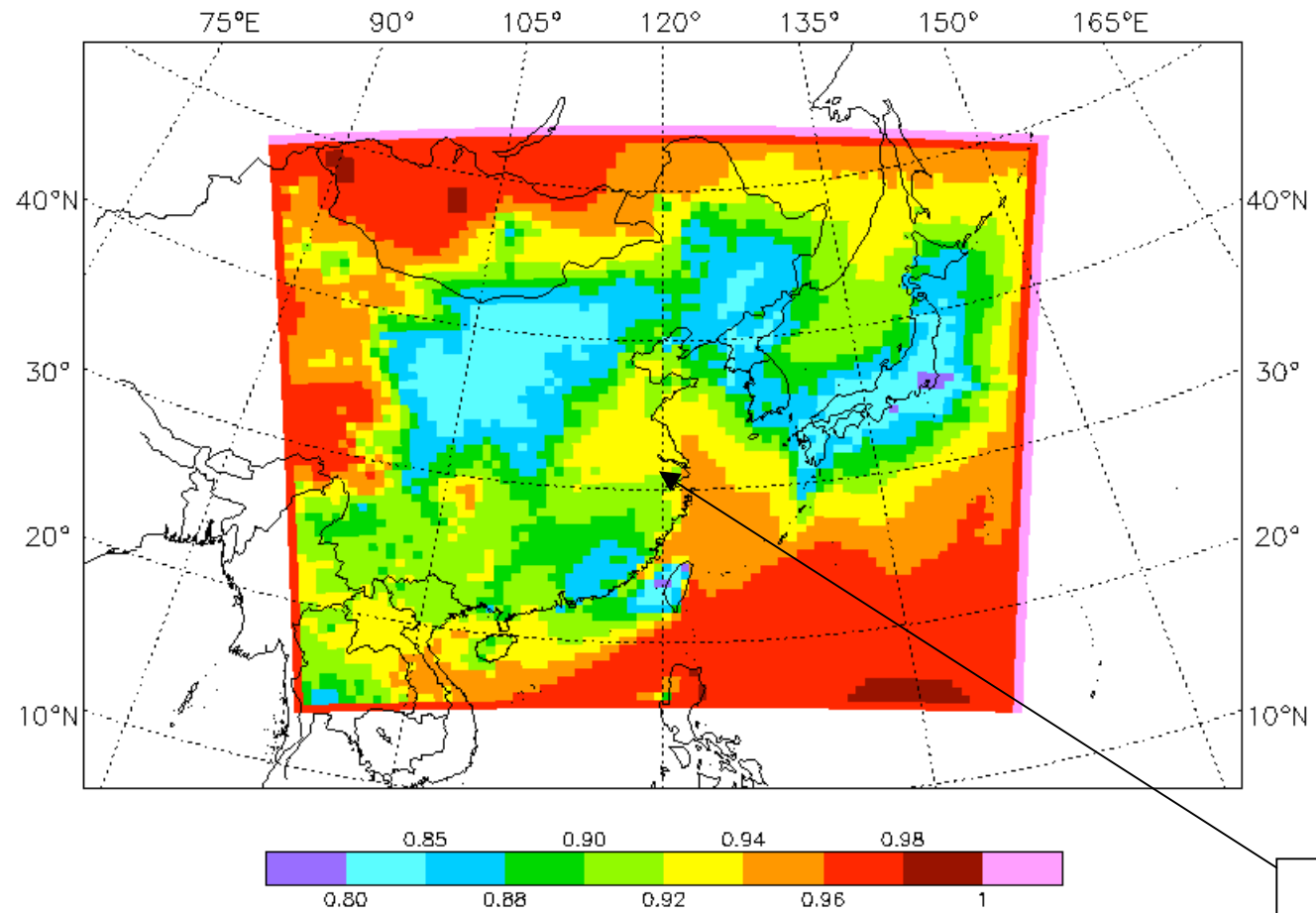
Total surface aerosol con. ($\mu\text{g}/\text{m}^3$, Nov.)



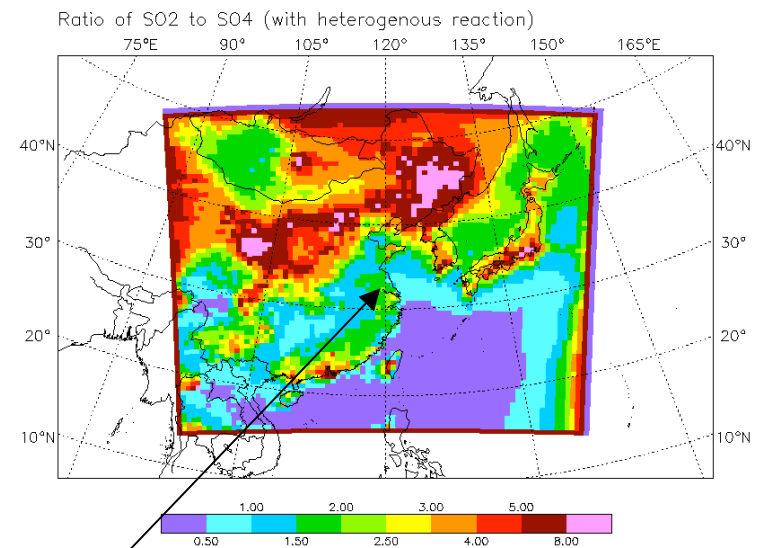
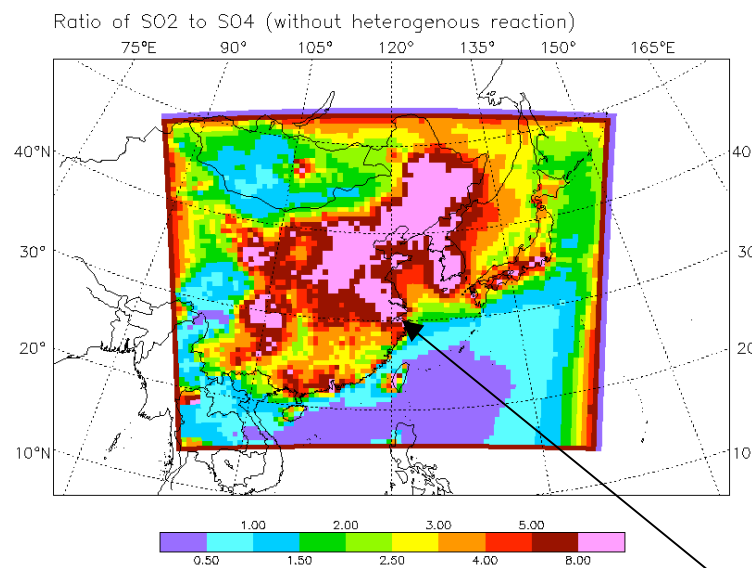
Obs:

~ 100
 $\mu\text{g}/\text{m}^3$

Single scattering albedo (surface, Nov.)

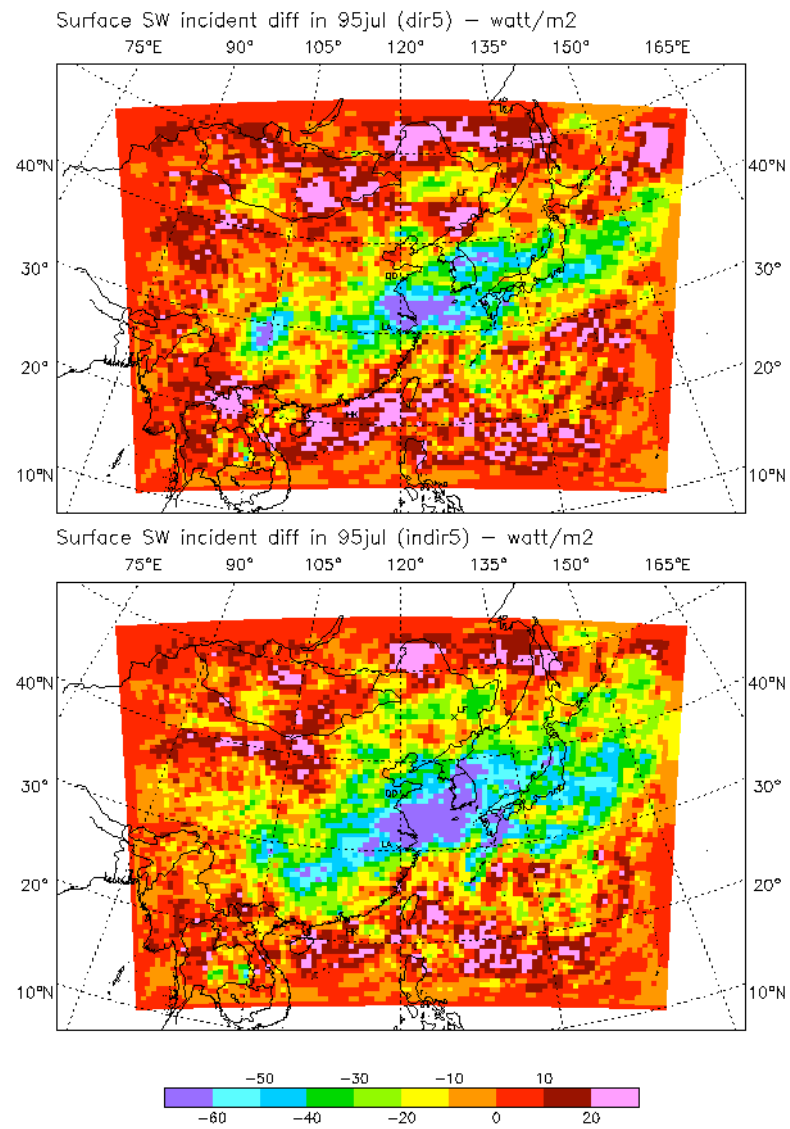


Need for an additional heterogeneous SO_2 -to- SO_4^- conversion pathway ...

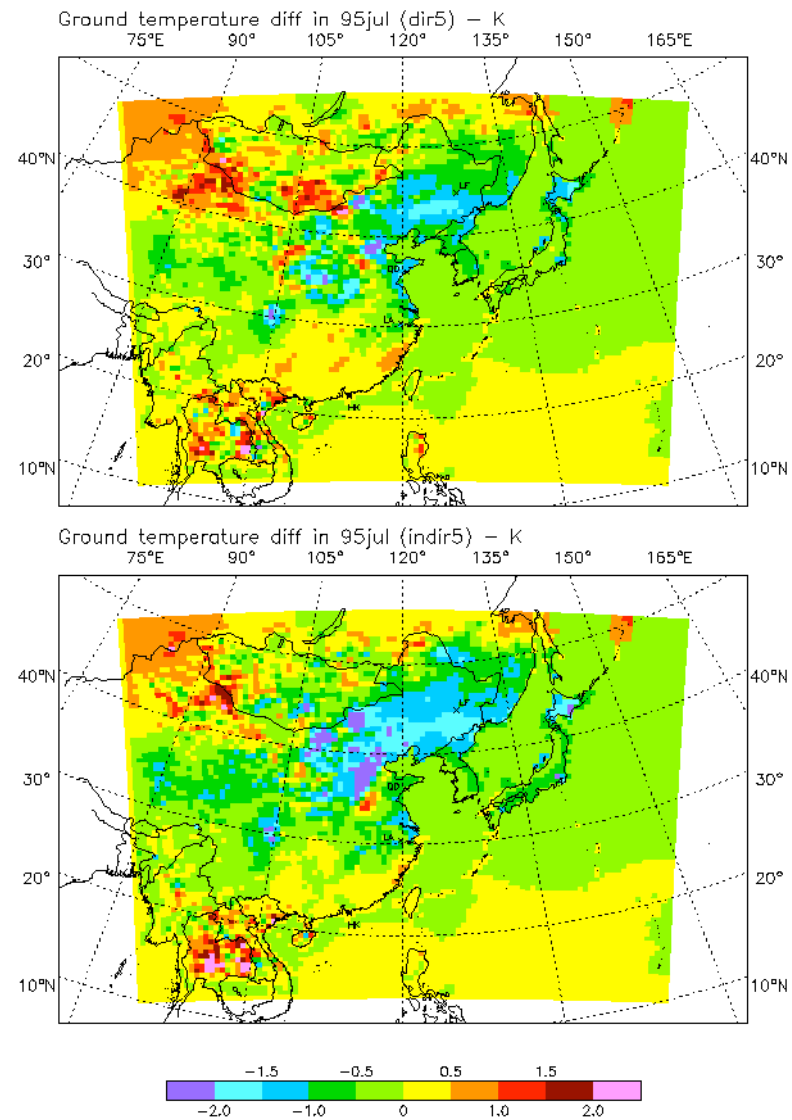


Obs:
 ~ 1 ppbv/ppbv

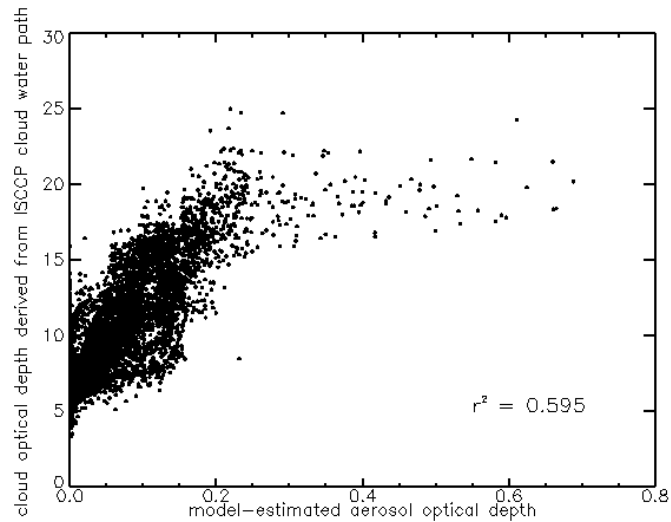
Radiative forcing exceeds 60 W/m² ...



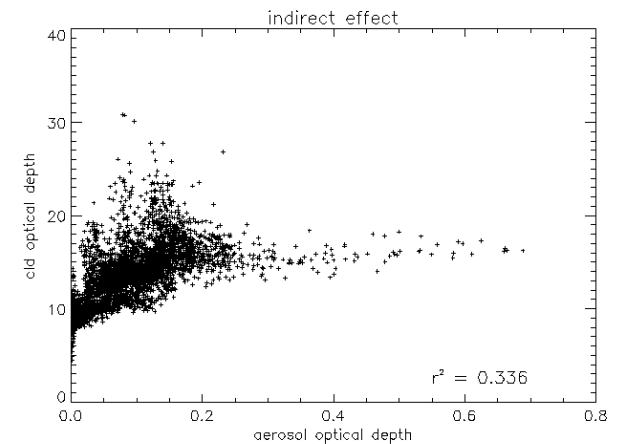
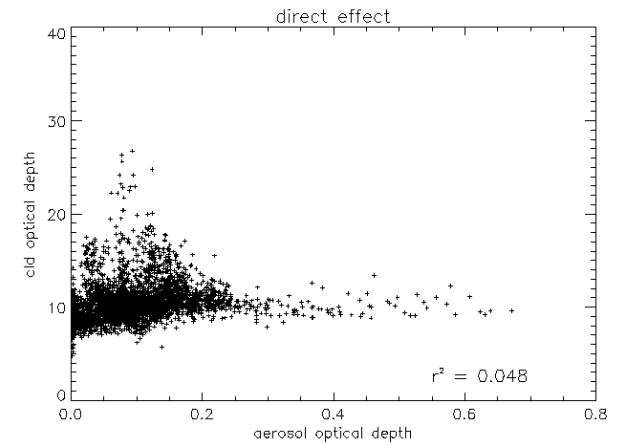
Significant aerosol-induced
temperature decreases
predicted from ‘direct effect’ in
regions of China where records
indicate downward temperature
trends ...



Evidence of the ‘Indirect Effect’?

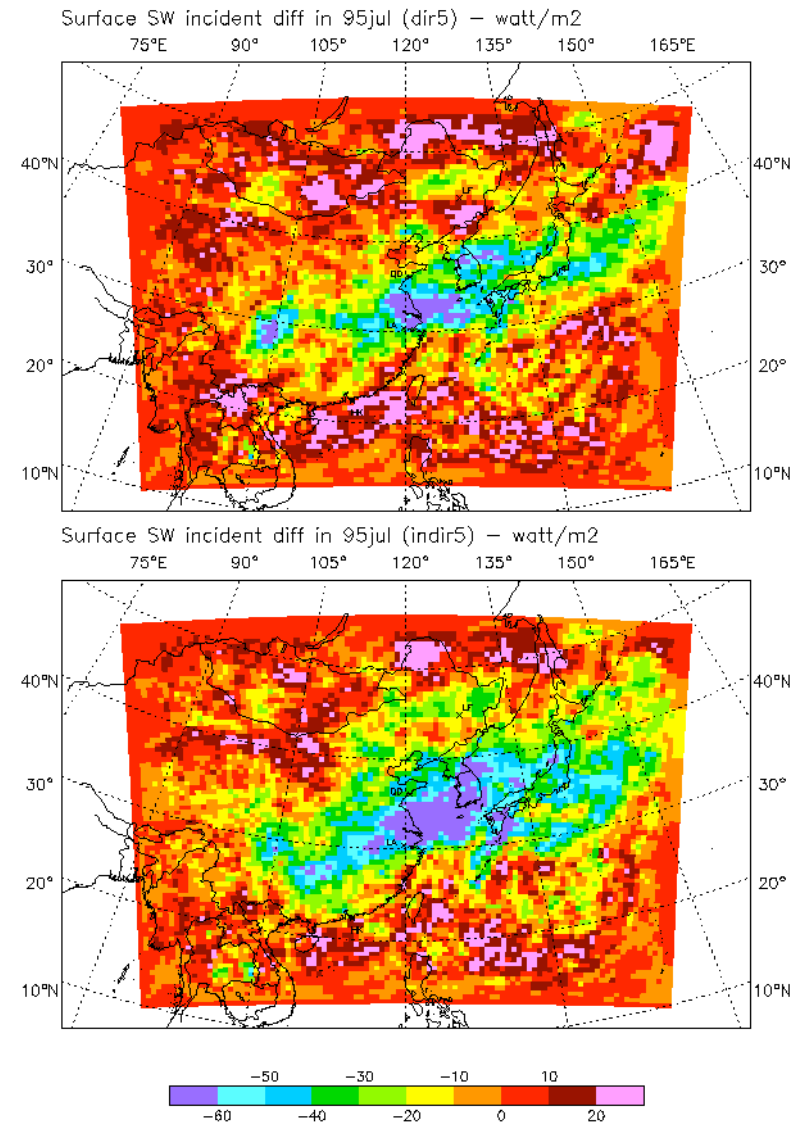
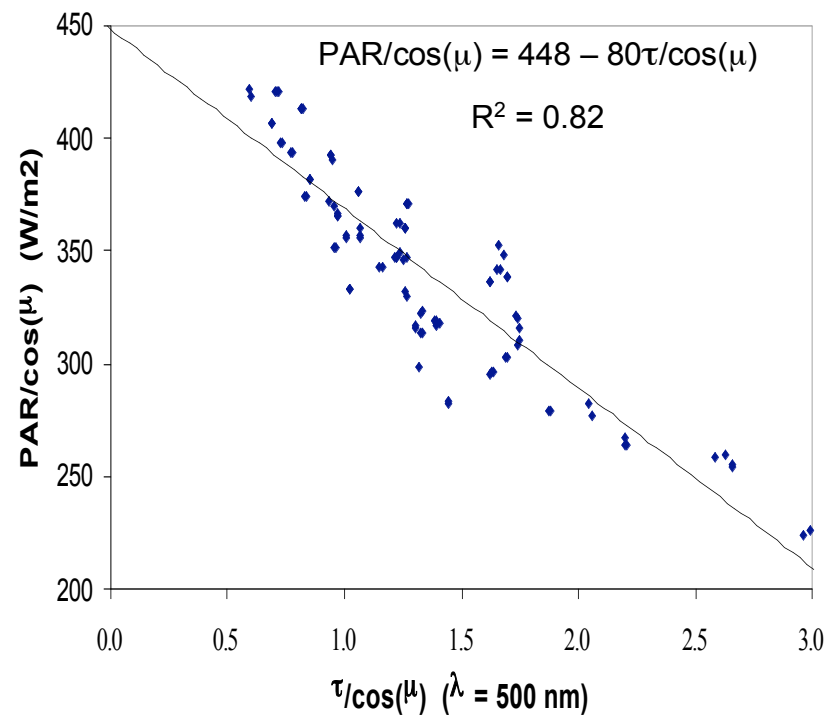


ISCCP COD vs. Model AOD

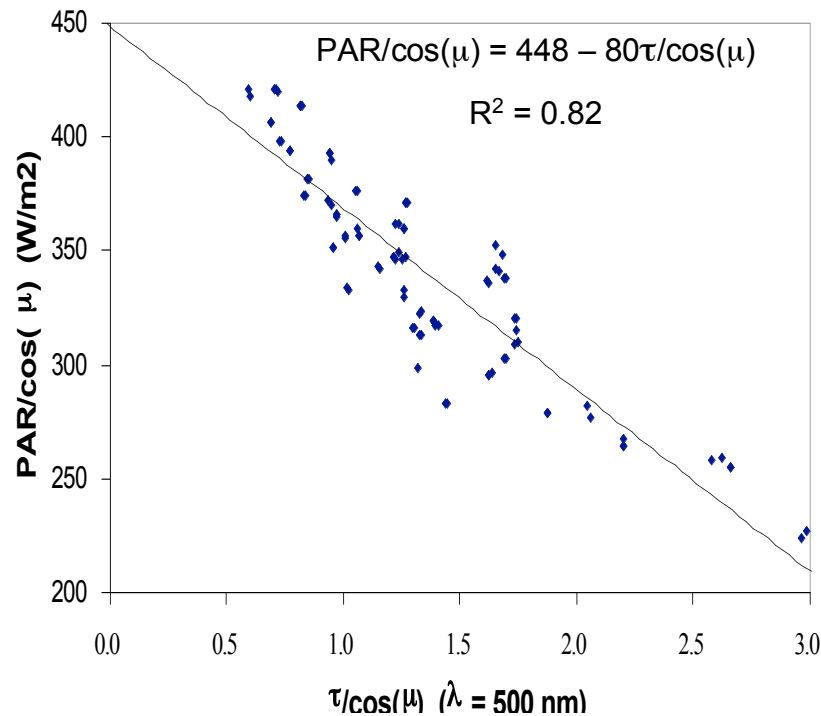


Model COD vs. Model AOD
with and without indirect effect

Is perturbation to *physical climate* only environmental consequence of aerosol loadings?



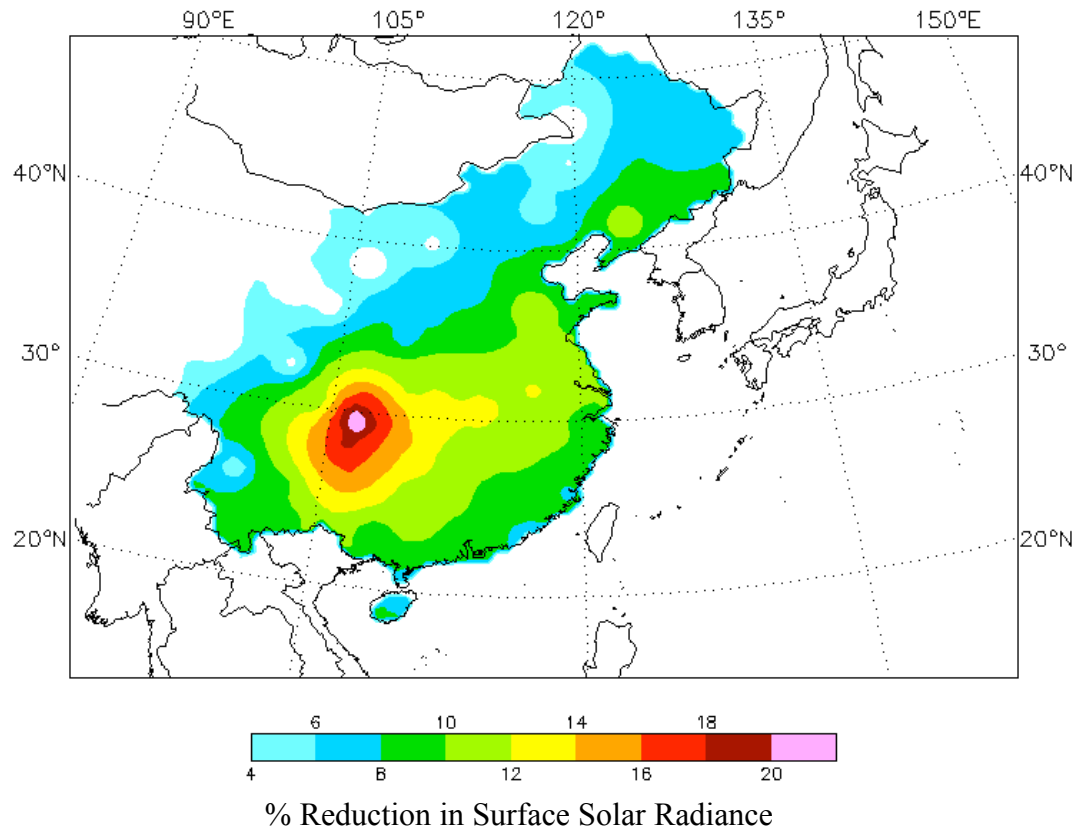
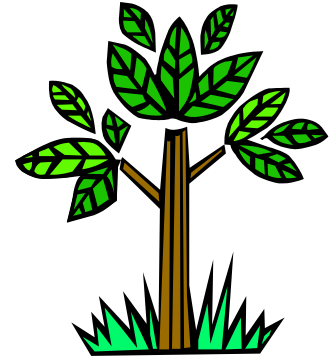
PM and PAR in China



- Simple ‘Rule of Thumb’
 - $\text{PAR} \sim 450\cos(\mu) - 80\tau$
- For each 0.1 increment in τ , PAR reduced by ~ 8 W/m²
- In Eastern China
 - $\tau \sim 0.2 - 0.9$
 - So $\Delta\text{PAR} \sim 15 - 70$ W/m²
- $\text{PAR} \sim 250 - 500$ W/m²
 - So $\Delta\text{PAR}/\text{PAR} \sim 5 - 30\%$

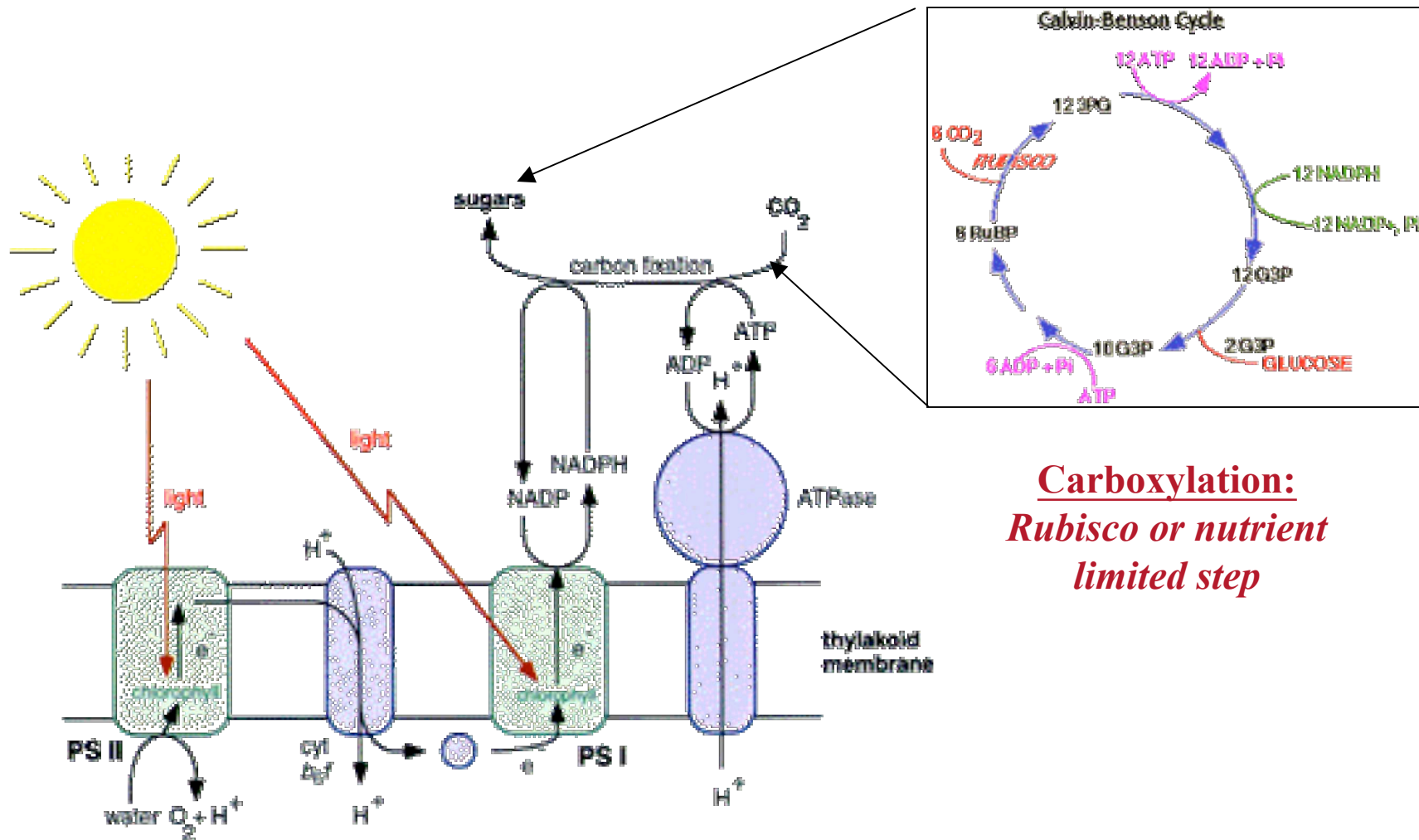
Regional Haze and Photosynthesis

- We estimate that aerosols are reducing surface solar irradiance by $\sim 5\text{-}30\%$
- Does that have any effect on photosynthesis?
 - Crop yields
 - C storage in forests



Brief Primer on Photosynthesis

-- 2-Step Process --

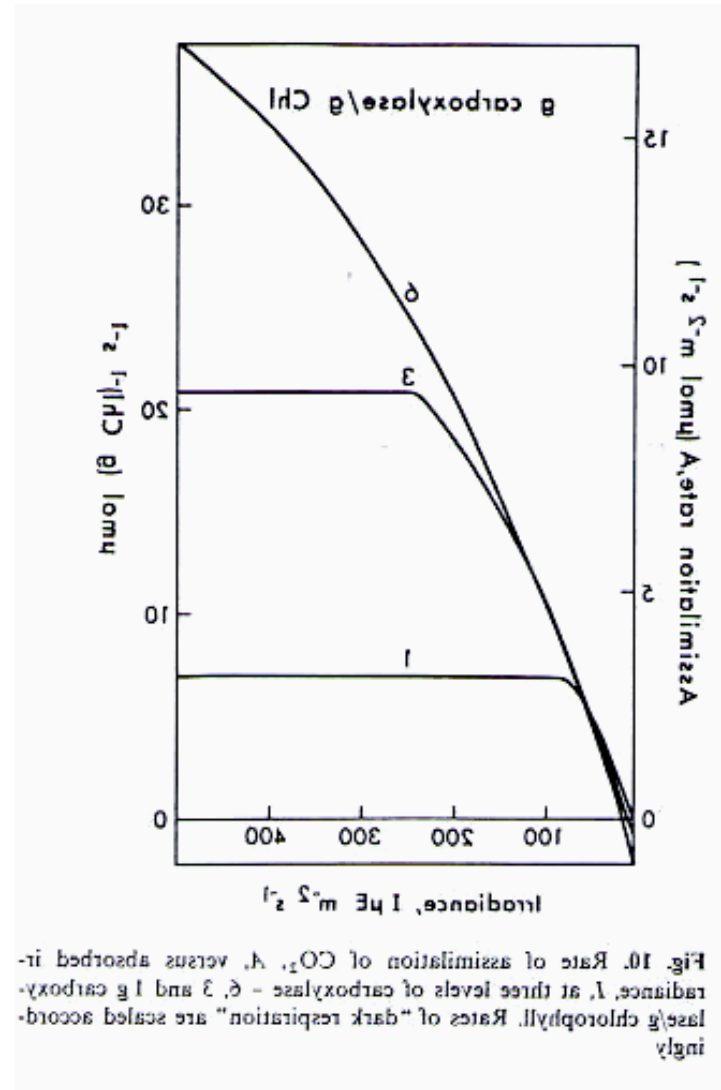


Carboxylation:
*Rubisco or nutrient
limited step*

Phosphorylation: *Light limited step*

Regional Haze and Photosynthesis

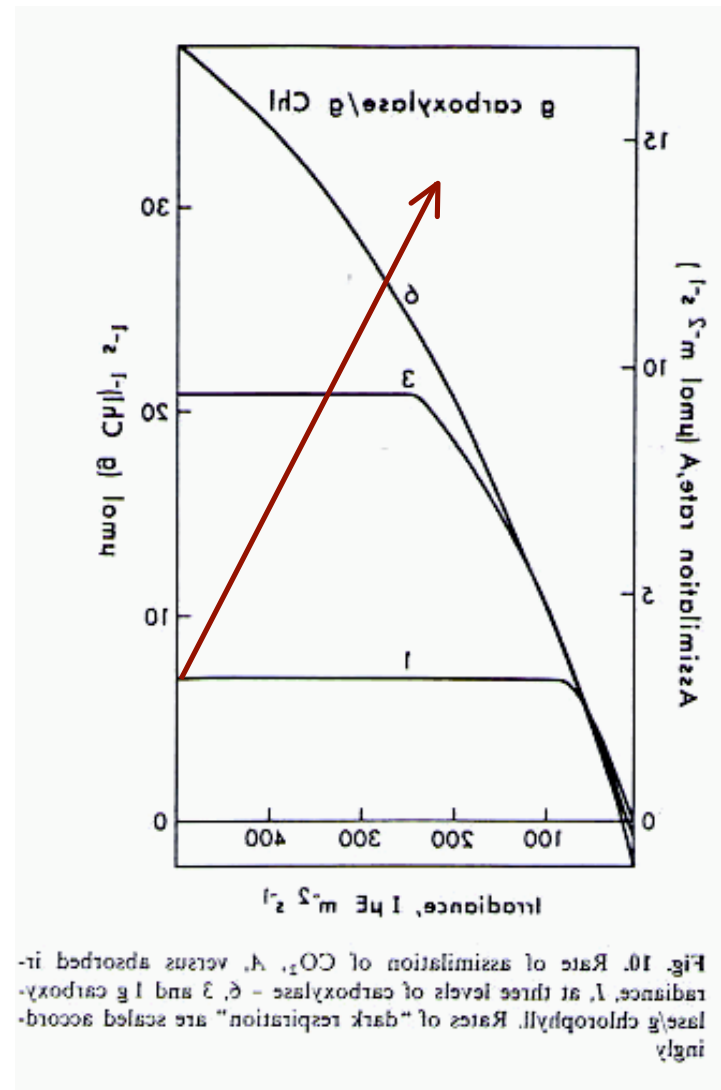
Effect of aerosols depends upon whether photosynthetic rates are in *light-limited* regime.



Regional Haze and Photosynthesis

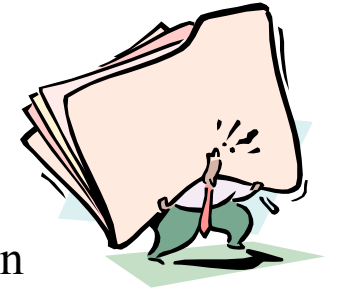
Effect of aerosols depends upon whether photosynthetic rates are in *light-limited* regime.

- If there are adequate nutrients (e.g., N), plant will simply increase *carboxylase* or *rubisco* activity as light intensity increases to optimize productivity.
- Under these conditions, increase in aerosols should decrease productivity...

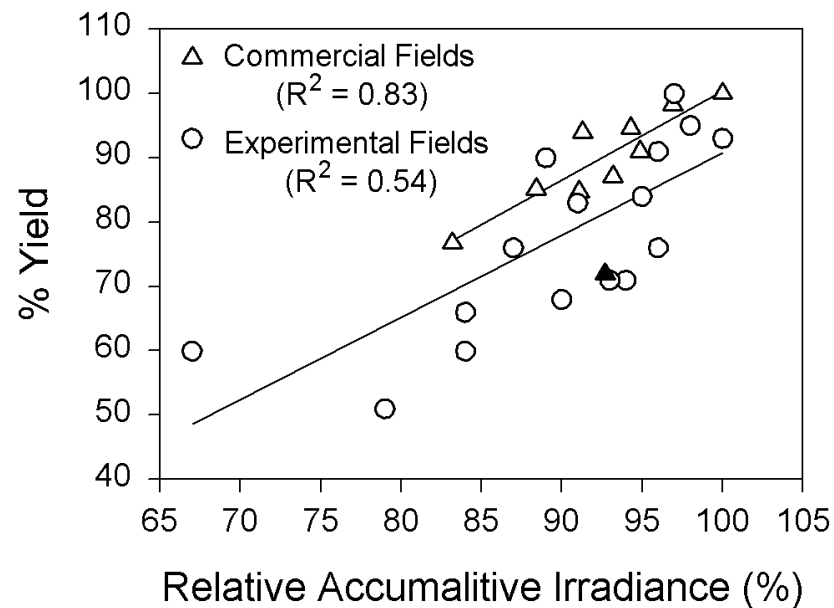


Regional Haze and Photosynthesis:

The Simple Picture

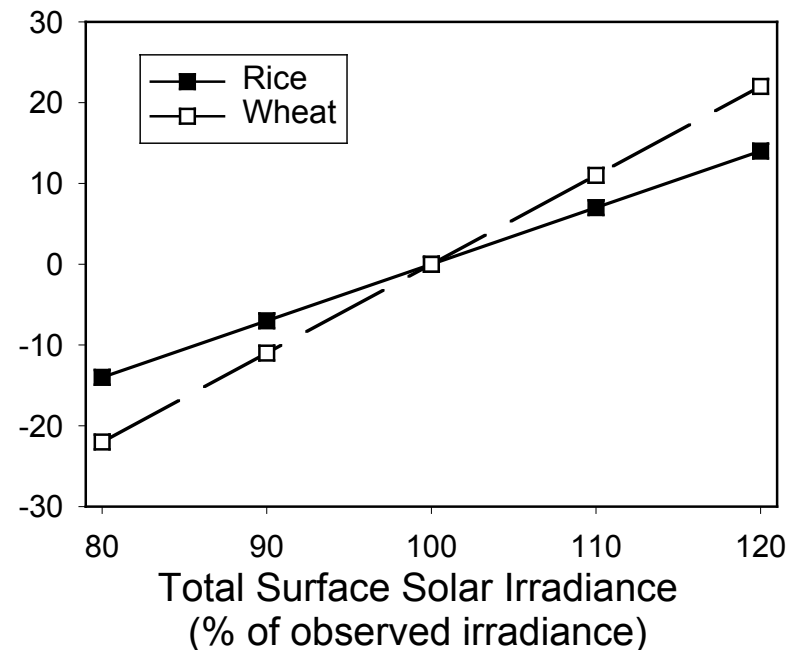


- In fact, agricultural field data generally show that for each 1% reduction in irradiance, there is ~ 1% reduction in crop yields
- Crop response models for rice and wheat tuned to conditions appropriate for agricultural fields in China indicate a similar effect.



Crop Yield (%)

Model-Calculated Yields (Nanjing)

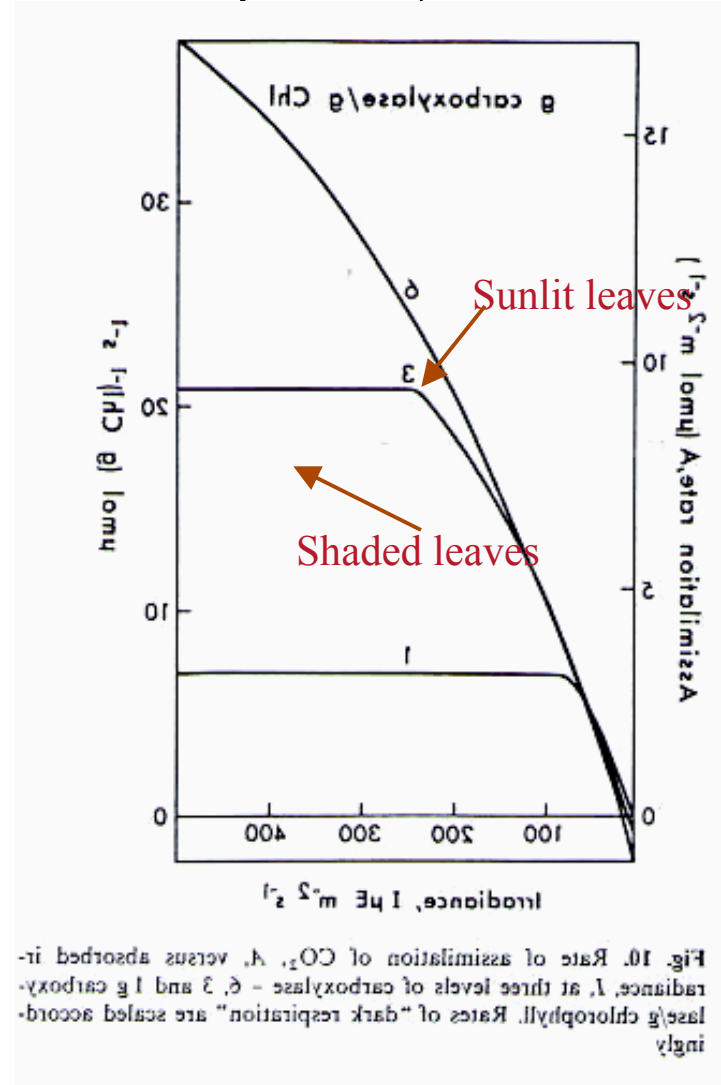


Implication: Mitigation of aerosols and regional haze in China could produce a 5-30% increase in **optimal** crop yields in China.

Regional Haze and Photosynthesis: *The More Complex Picture*

Effect of aerosols depends upon whether photosynthetic rates are in *light-limited* regime.

- In ecosystems with nutrient limitation (e.g., unmanaged ecosystems) plants can not routinely increase *carboxylase* or *rubisco* activity.
- Under these conditions, sunlit leaves are generally in the light saturated regime, while shaded leaves are not.
- Thus, an increase in aerosols could cause an increase or decrease in productivity...



Regional Haze and Photosynthesis

➤ It is possible that aerosols and regional haze cause an increase in photosynthesis (and C storage) under some conditions.



Less radiation, but more efficient use of the radiation

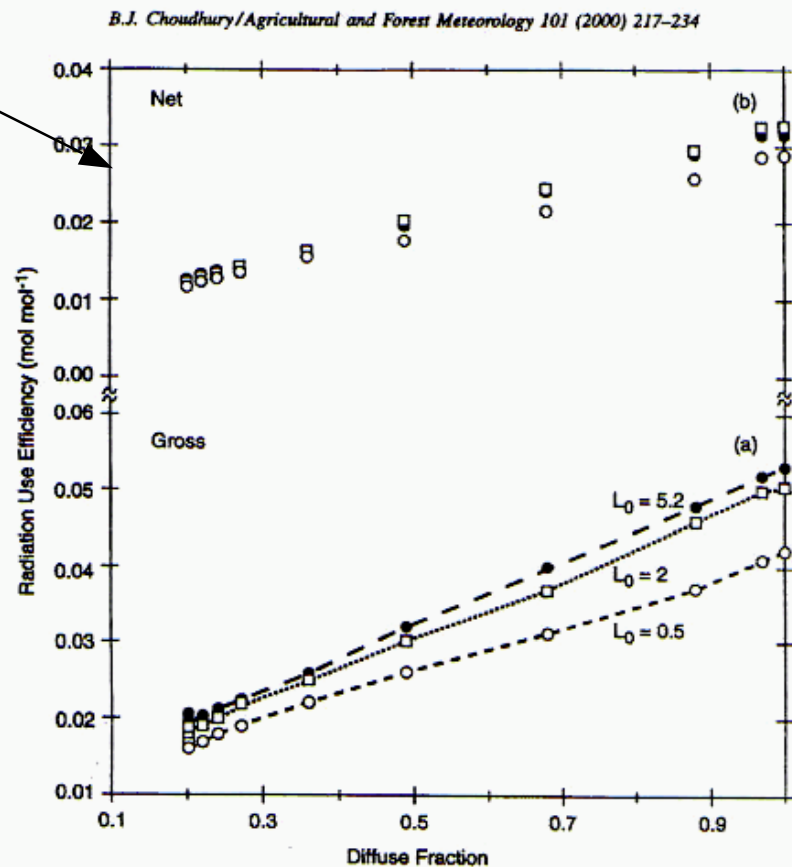
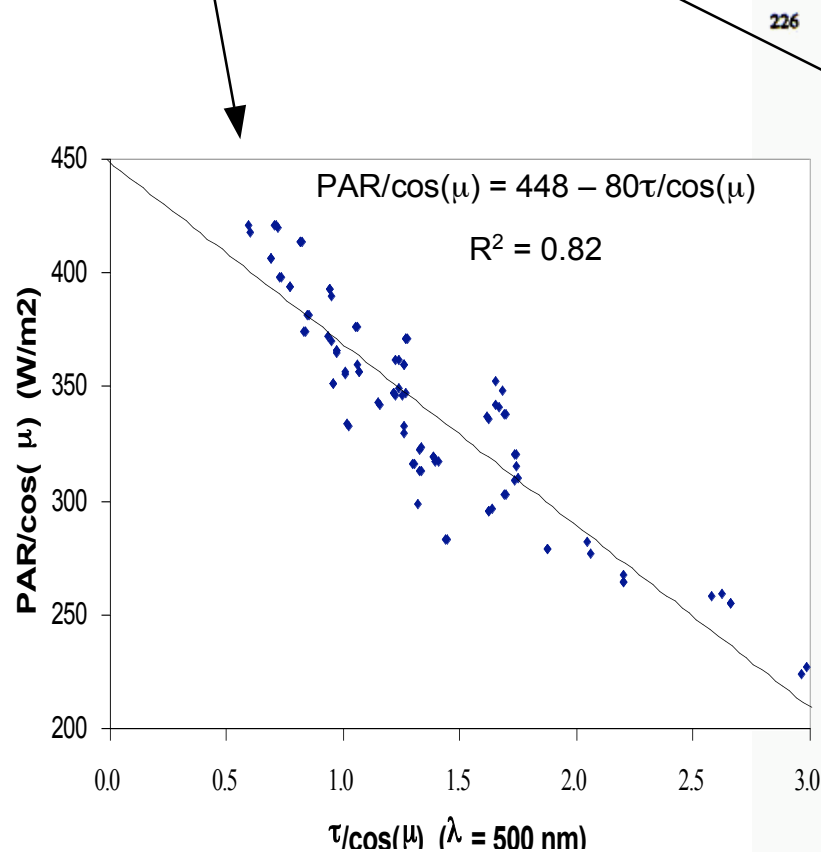
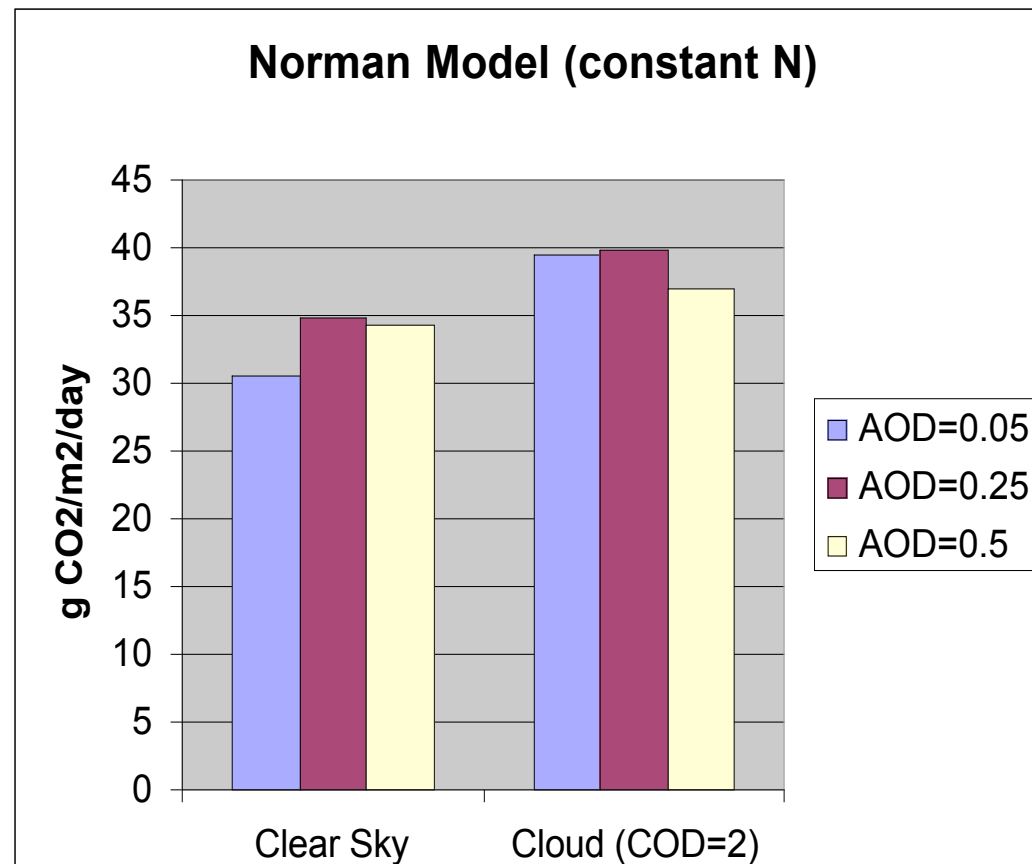


Fig. 2. Variation of the radiation use efficiency (mol CO₂ mol⁻¹ photon intercepted) for, (a) gross photosynthesis, and (b) net carbon accumulation, with the diffuse fraction of the incident irradiance for three canopies, as annotated within the figure by leaf area index (L_0).

Regional Haze and Photosynthesis

Photosynthesis models with static leaf properties predict both increases and decreases depending upon conditions...



Regional Haze and Photosynthesis

Experimental results often indicate increasing C uptake with increased diffuse radiation ...

Subtropical field experiment for grasses using 'solarweave' as a surrogate for clouds/aerosols

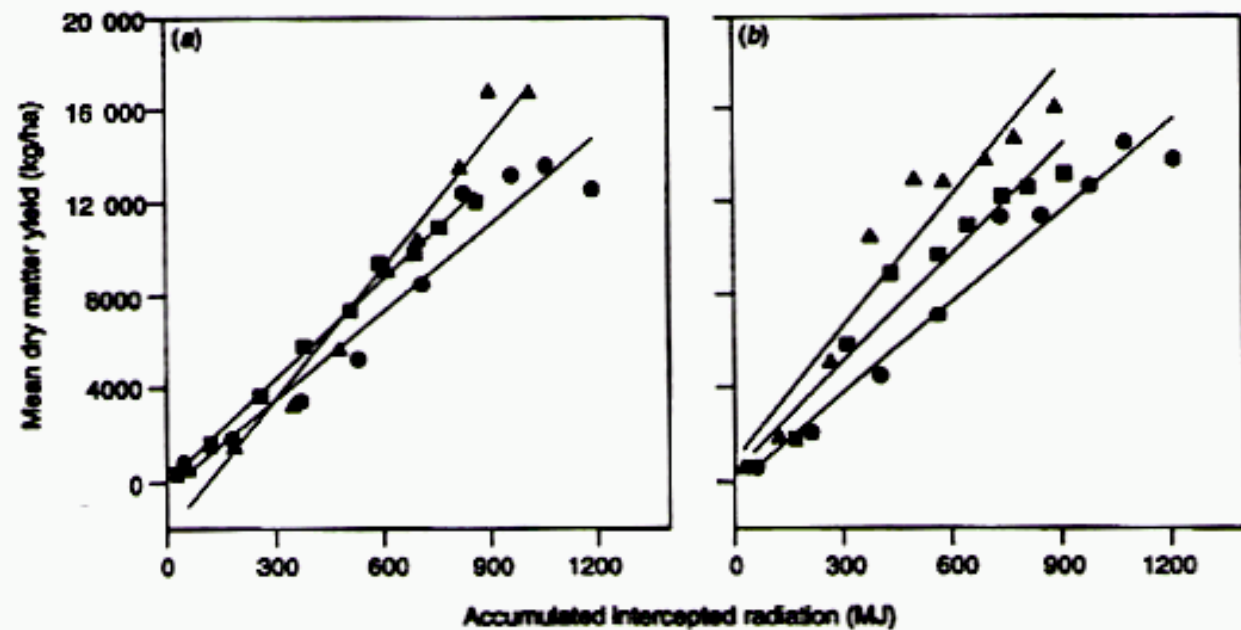
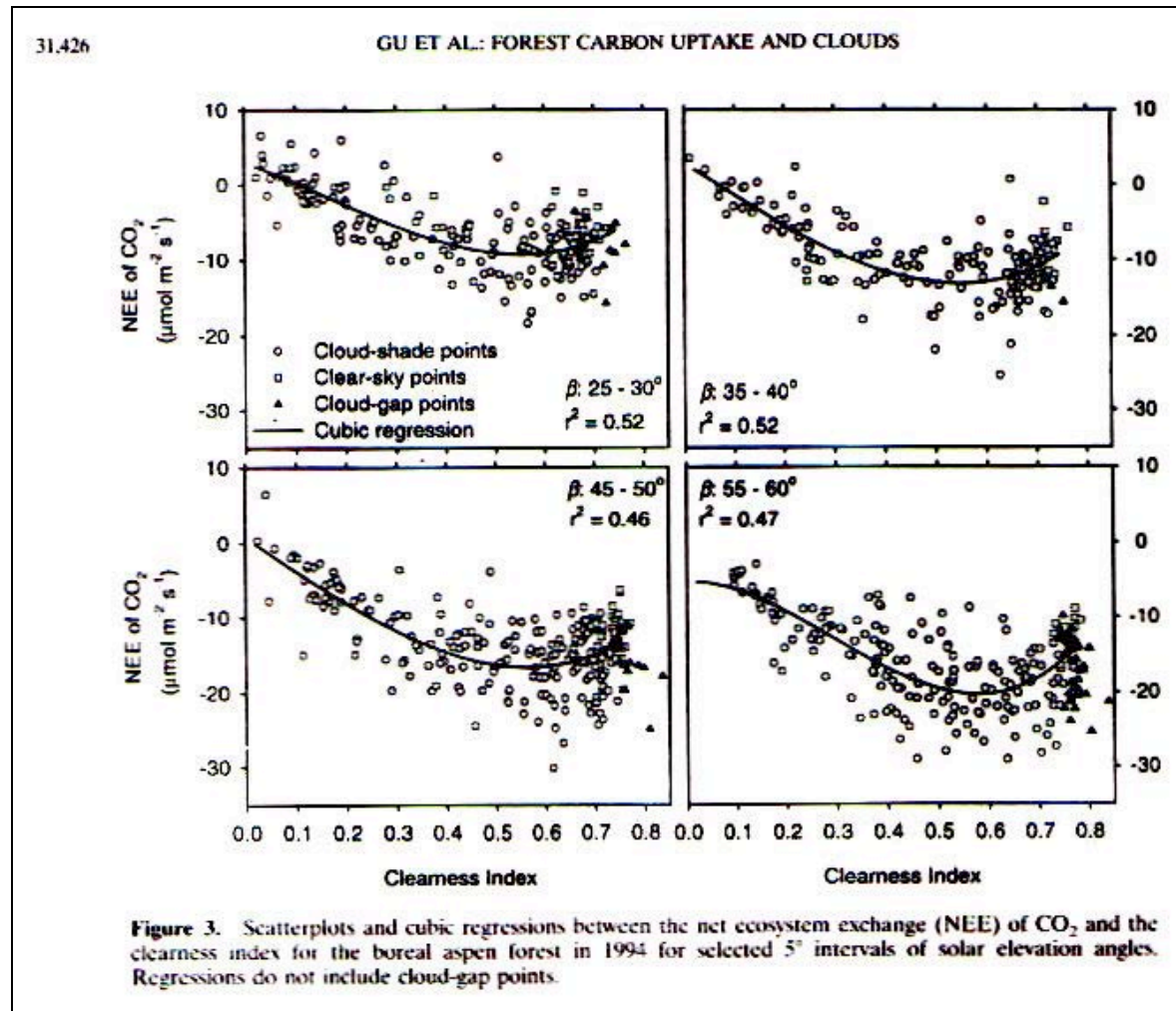


Fig. 3. Relationship between accumulated dry matter yield and accumulated intercepted shortwave radiation during the regrowth period for (a) bluegrass and (b) green panic grown in full sun [●, (a) $r^2 = 0.93$, (b) $r^2 = 0.96$] and beneath birdguard [■, (a) $r^2 = 0.99$, (b) $r^2 = 0.96$] and solarweave [▲, (a) $r^2 = 0.97$, (b) $r^2 = 0.93$].

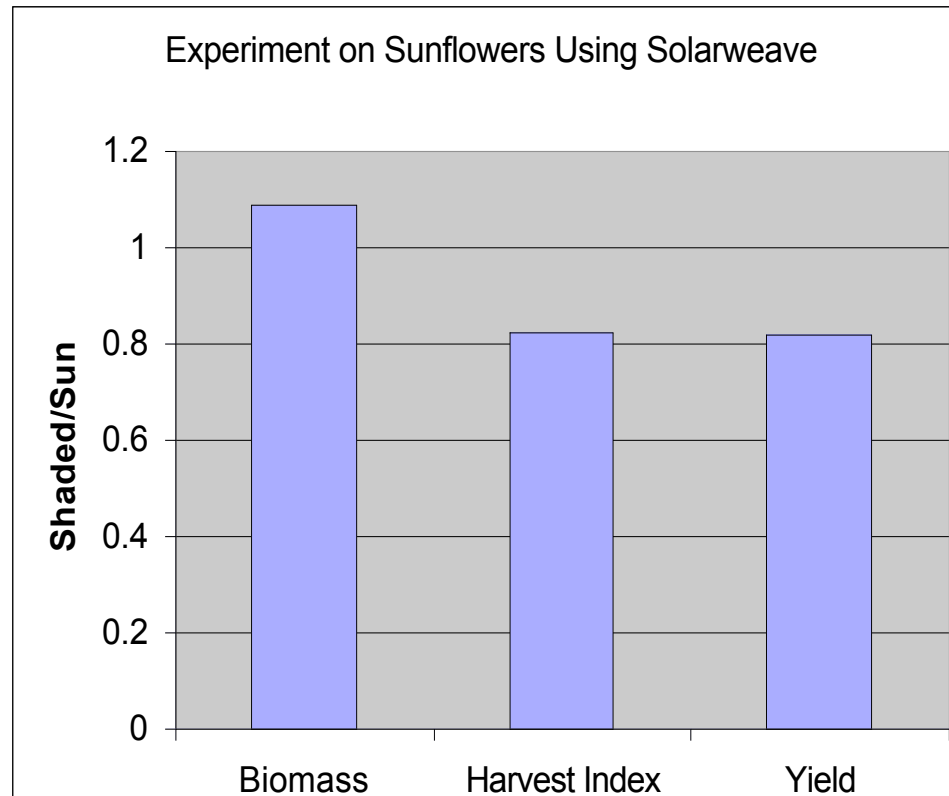
Regional Haze and Photosynthesis

Experimental results often indicate increasing C uptake with increased diffuse radiation ...**but, up to a point**



Regional Haze and Photosynthesis

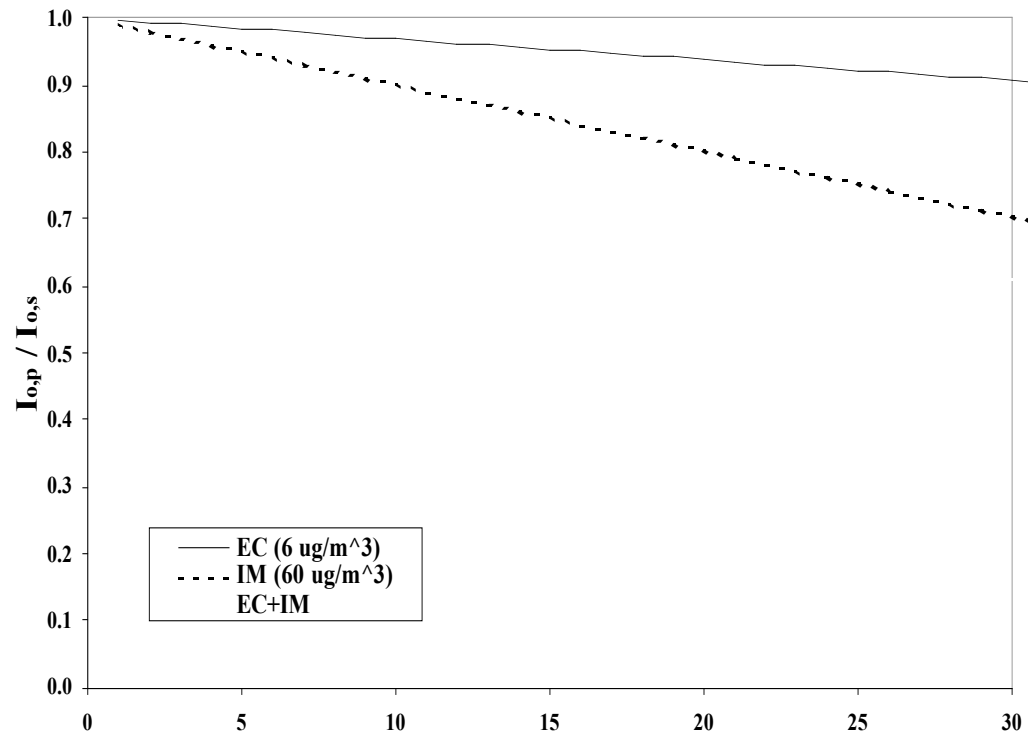
Also important to bear in mind that increases in C uptake do not necessarily translate into increased grain yield --- it depends on C allocation ...



Another Complication: Insoluble particles



SEM image of particles deposited to an SEM grid mounted on leaf in Yangtze Delta region of China over 2-week period.



Estimation of light transmission at leaf surface with time due to dry deposition of elemental carbon (EC) and insoluble mass (IM) based on measurements in the Yangtze Delta region of China

Conclusions



- Anthropogenic emissions produce large fine particle loadings over much of eastern China
 - PM $\sim 100 \text{ ug/m}^3$
 - $\sim 50\%$ is organic C
 - In summer and fall mineral aerosol is a small contribution to total scattering
 - Significant gradients on spatial scales of $\sim 100 \text{ km}$
 - Impact on terrestrial biosphere may be significant
 - Agriculture
 - Carbon storage