Environmental Factors
Carbon Dioxide

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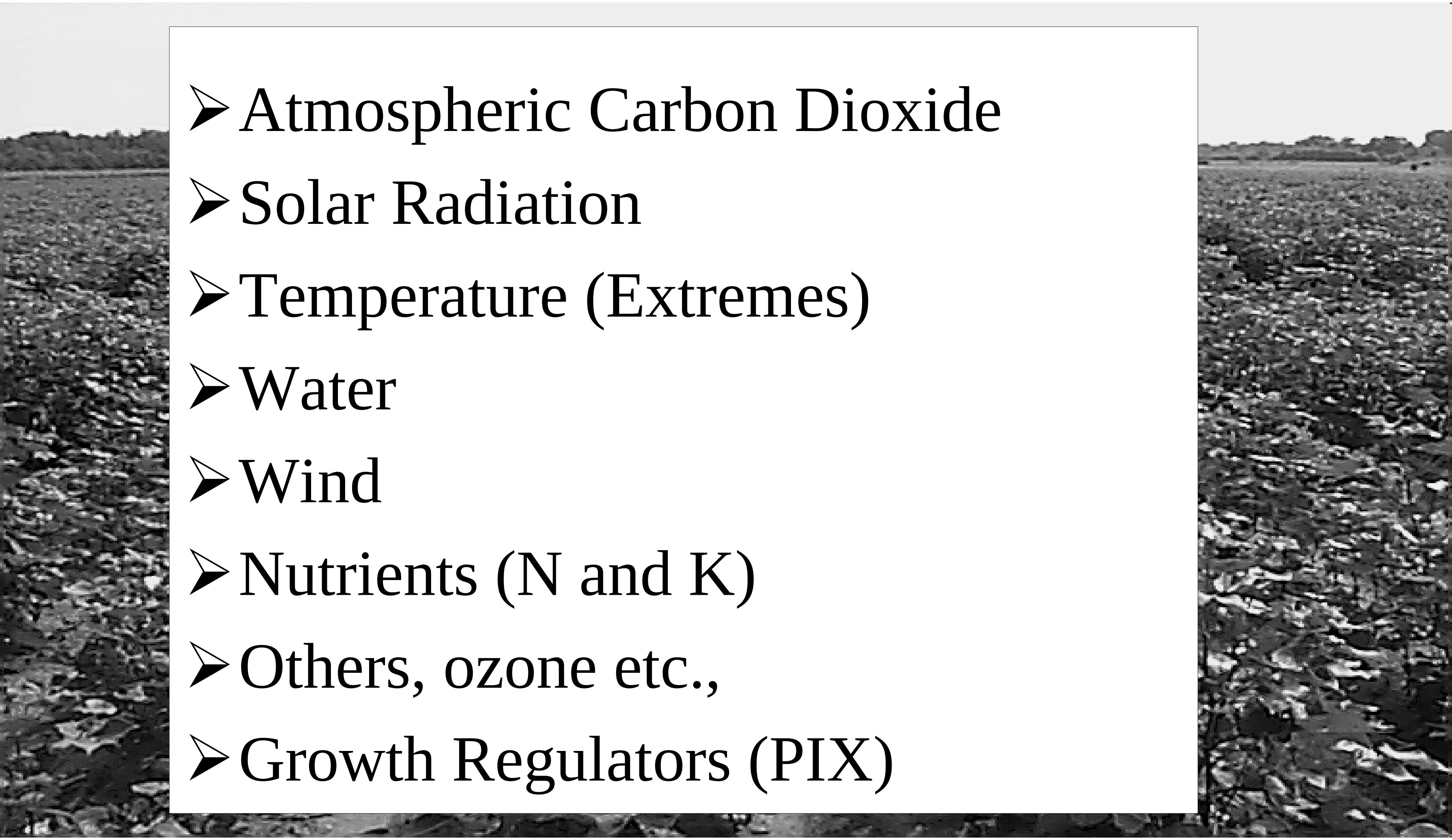
Environmental and Cultural Factors Limiting Potential Yields



- Atmospheric Carbon Dioxide
- Solar Radiation
- Temperature (Extremes)
- Water
- Wind
- Nutrients (N and K)
- Others, ozone etc.,
- Growth Regulators (PIX)

Atmospheric Carbon Dioxide - Objectives

The objectives of this lecture are:

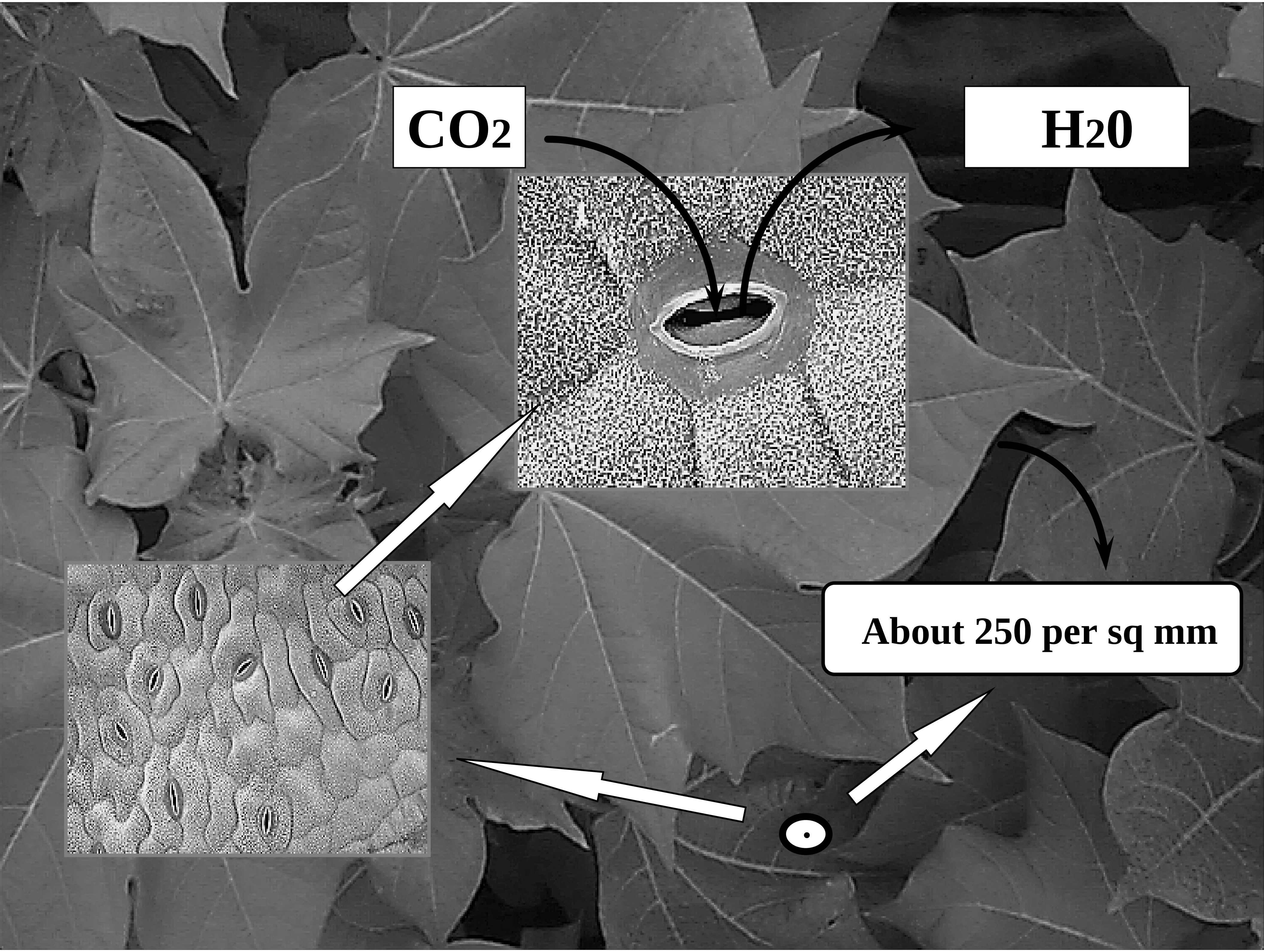
- To learn global, regional and local spatial and temporal trends in atmospheric CO_2.
- To lean diurnal trends in atmospheric CO_2.
- Contributing factors for fluxes/changes in global CO_2 concentration
- The importance of atmospheric CO_2 and its role/effects on plants and ecosystems in general.

Why are we concerned with CO2?

- Atmospheric CO_2 is essential for life on earth.
- Plants grow through photosynthesis, a process that uses the energy from sunlight to combine carbon dioxide (CO_2) from the air with water to make carbohydrates plus oxygen.

$$6\ CO_2 + 6\ H_2O \xrightarrow{\text{Light, Plant, Water, Nutrients}} C_6H_{12}O_6 + 6\ O_2$$

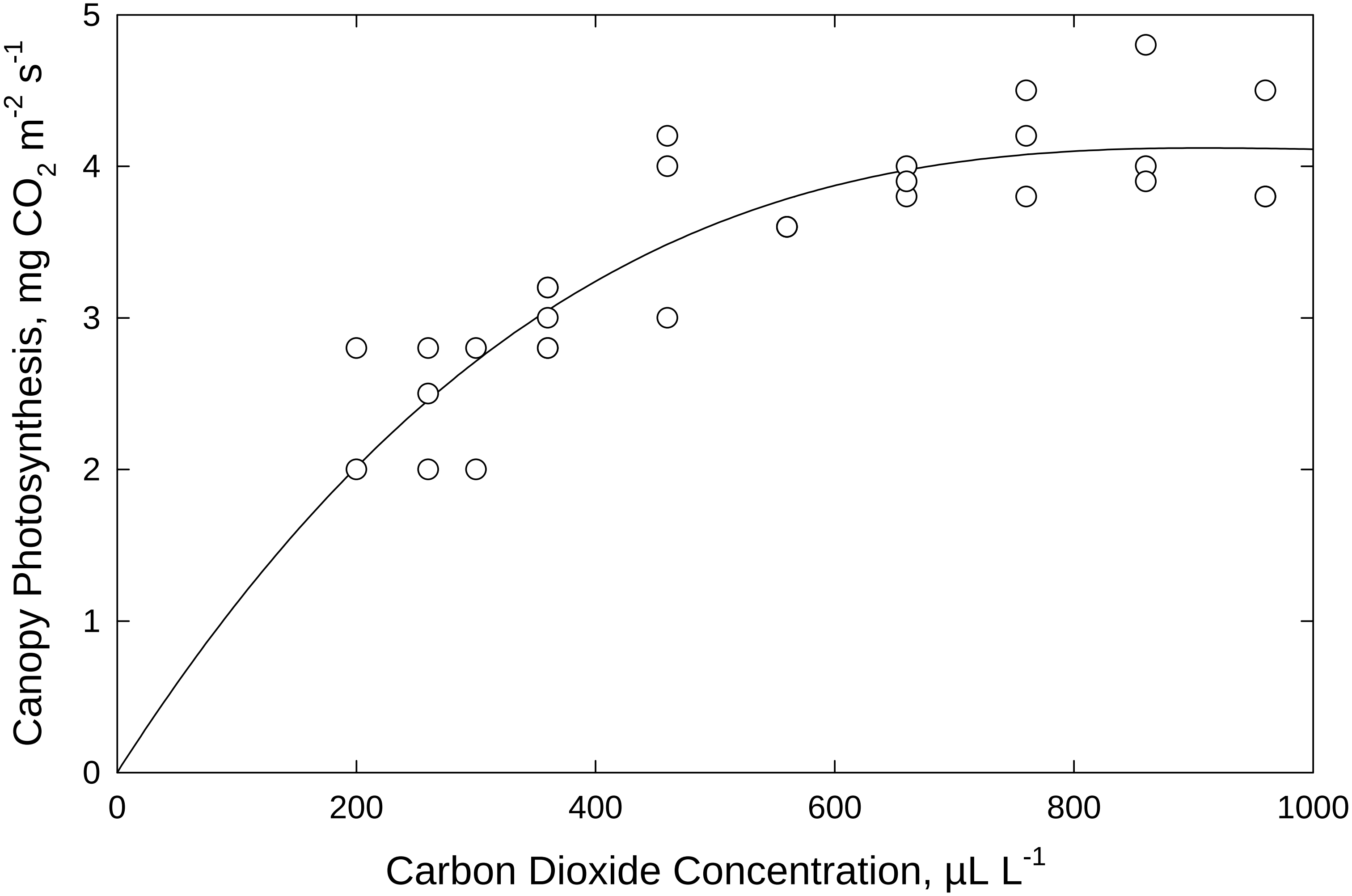
- The carbohydrates formed through photosynthesis feed not only the plants, but also almost all other organisms on earth, including those that eat the plants and those that eat the animals that eat the plants.
- Now, as the atmospheric CO_2 is rising, we are seeing almost parallel decreases in atmospheric oxygen.
- The oxygen concentration is so much higher than that of CO_2 that the decrease in oxygen from fossil fuel combustion is not a problem, but it demonstrates the connections between these two critically important atmospheric constituents.



CO_2
H_20
About 250 per sq mm

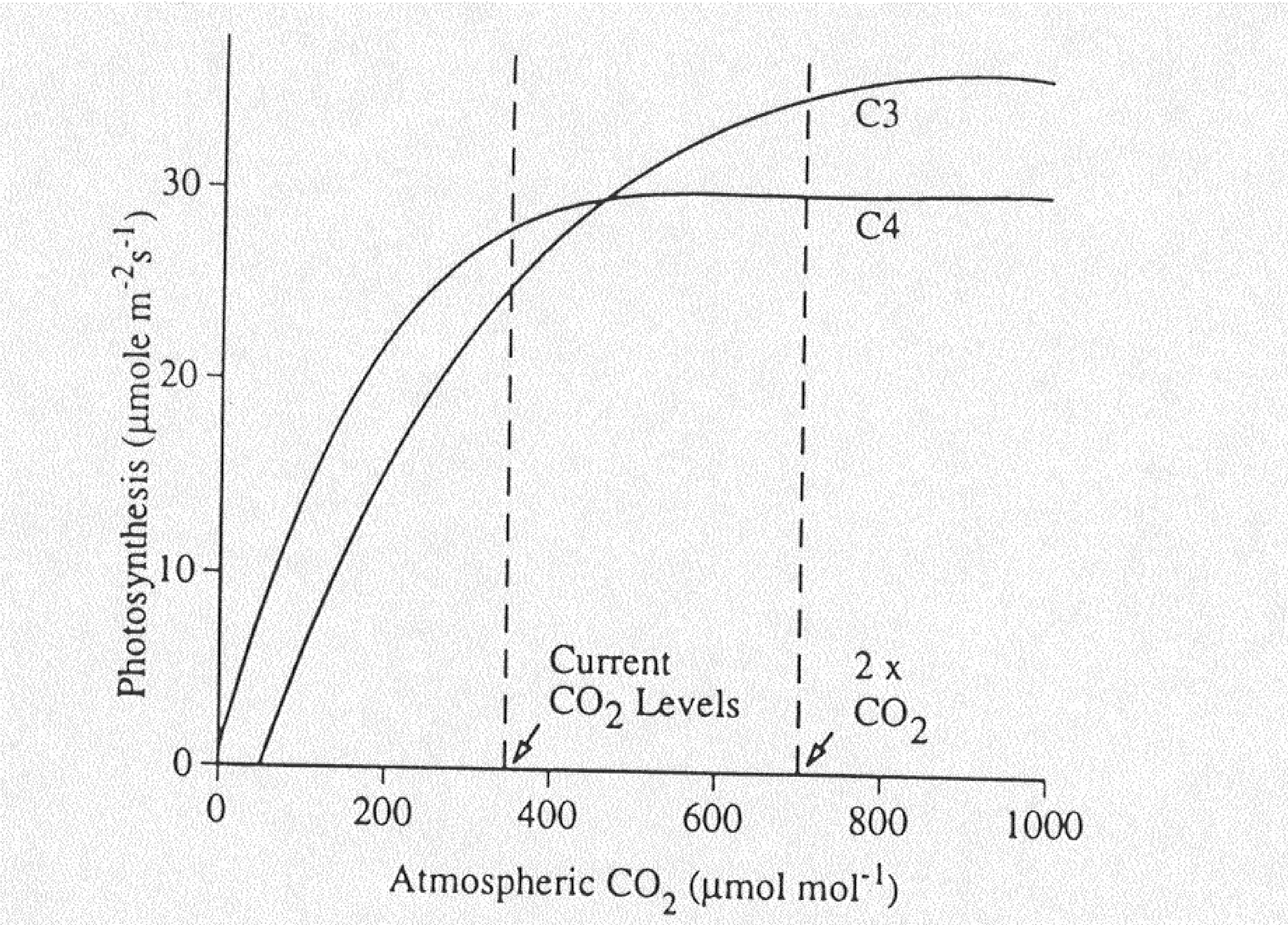
Crop Responses to Atmospheric Carbon Dioxide

Cotton Canopy Photosynthesis response to CO_2

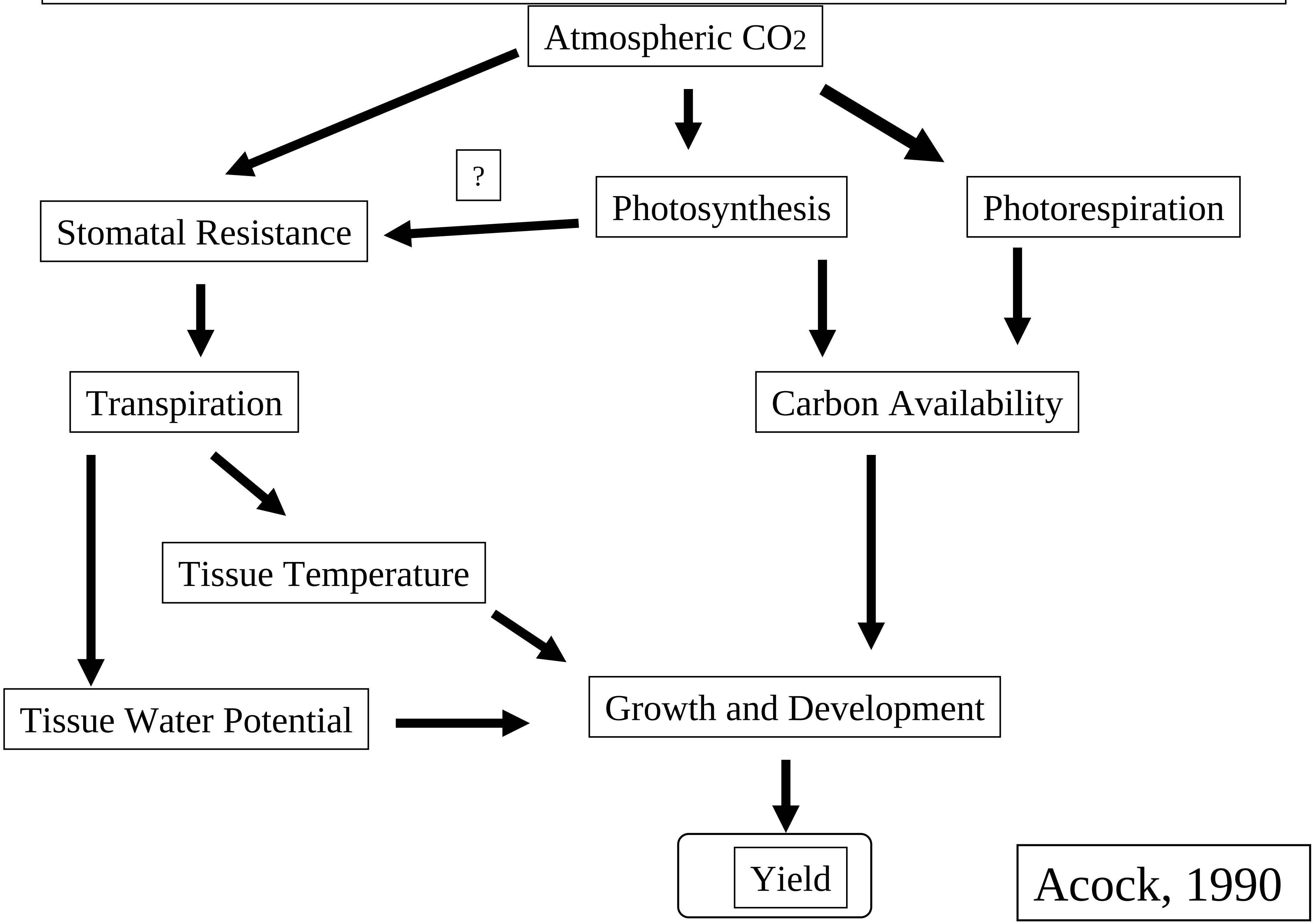


Crop Responses to Atmospheric Carbon Dioxide

Photosynthesis response to CO_2 _ Species variability



A Hierarchy of Plant Responses to CO_2 – C_3 Plants



Plant Adaptations to Atmospheric Carbon Dioxide

Direct effect of increased CO_2 on crop photosynthesis might lead to higher global food production

- ✓ Weeds: Plants are NOT unique and UNIFORM in stimulation of their photosynthesis by elevated CO_2.
- ✓ Losses to Pests: Several recent studies show that insects eat more high-CO_2 grown material, because of decreased protein levels.
- ✓ Climate: The connection between CO_2 and climate is increasingly well understood, with vast majority of evidence indicating that continued build up of these radiative gases causes gradual warming, and other changes in climate.

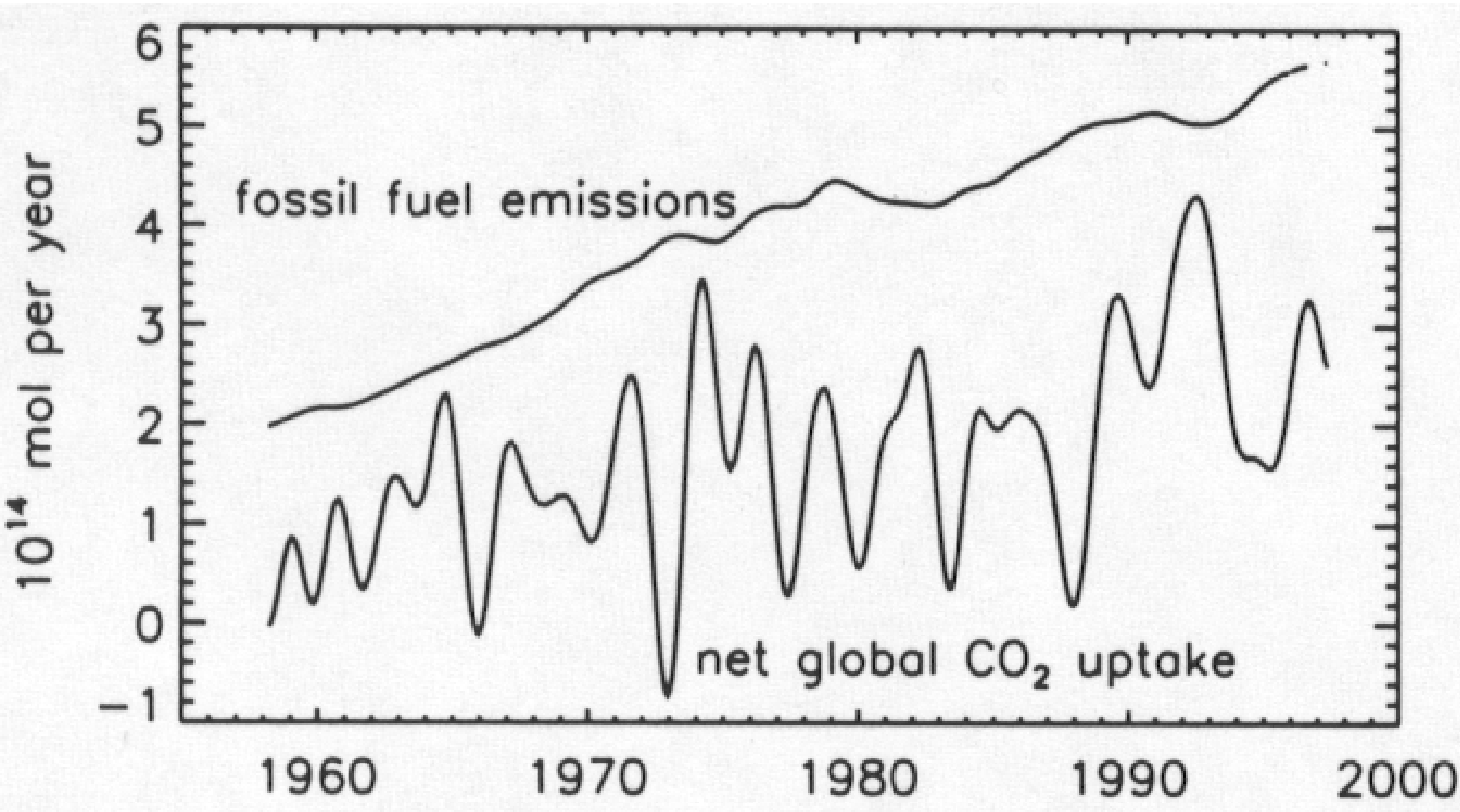
Plant Adaptations to Atmospheric Carbon Dioxide
Natural Ecosystems

In natural ecosystems, elevated CO_2 has an effect similar to that on crops; but the responses tend to be smaller or even absent. And, features like:

- ✓ Recreational value: Since responses are NOT uniform; there will be winners and losers. Evidence suggest that trees and may be introduced species are being favored in a high-CO_2 world, thus affecting the recreational and grazing value of natural ecosystems.
- ✓ Biodiversity: Rare or endemic species may be at a disadvantageous position because of their poorly adapted features.

Global Carbon Fluxes

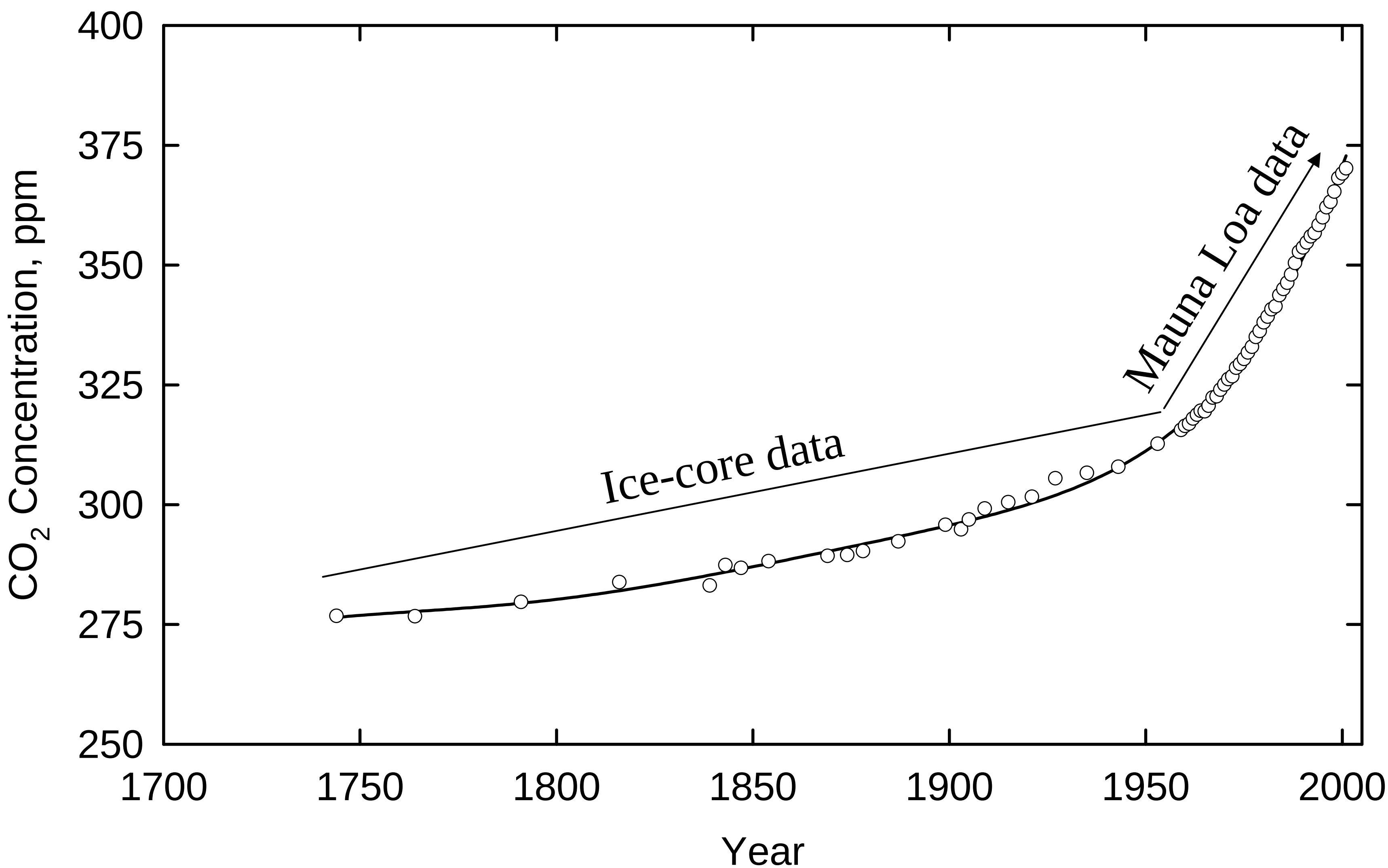
Global carbon emissions and Carbon fixation



Global Carbon Dioxide Concentrations

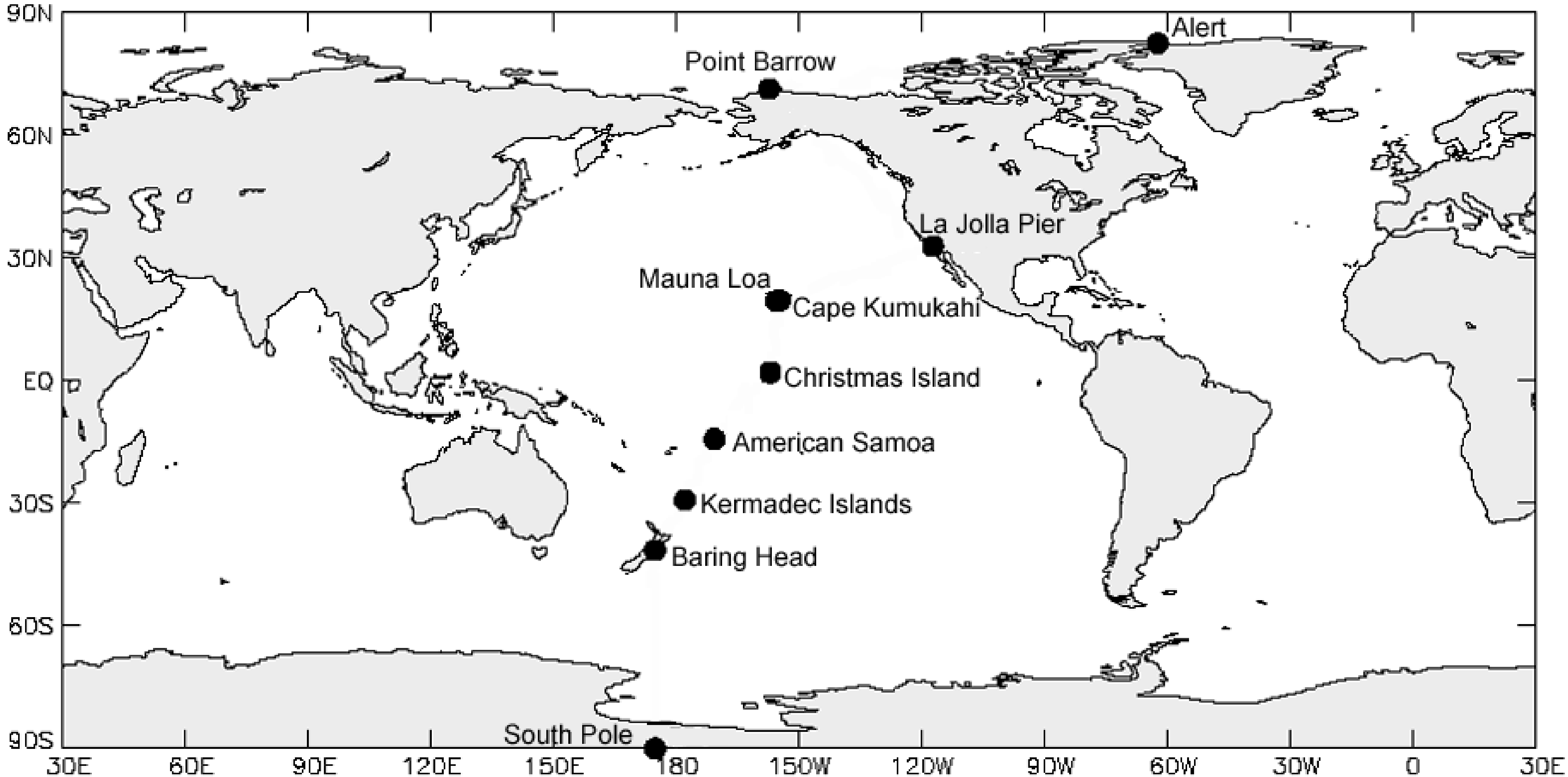
Temporal trends in CO_2 from 1750 to 2000

Ice-core data and Mauna Loa (HI) measurements



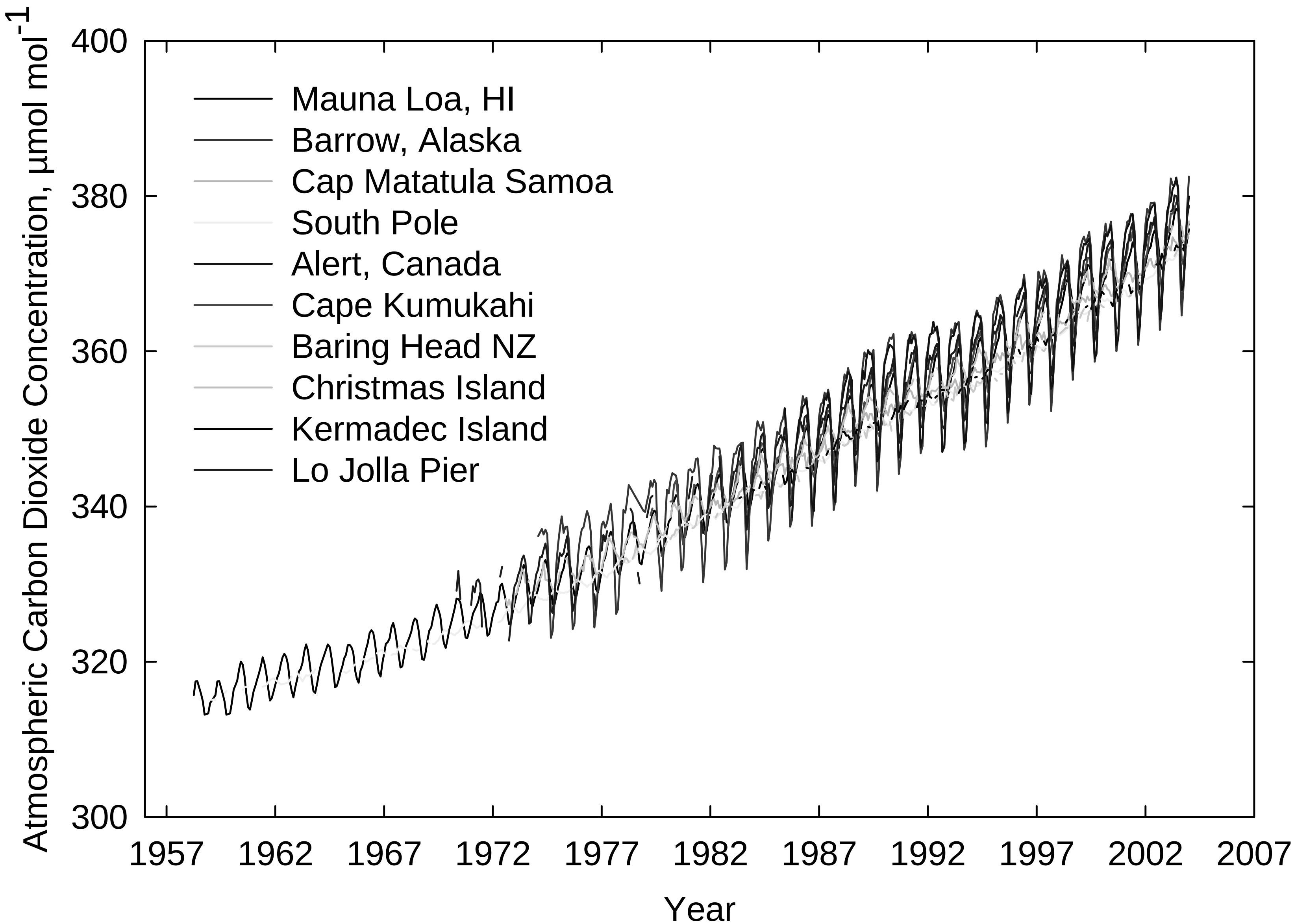
Atmospheric Carbon Dioxide Concentration

Pole to pole measurement sites



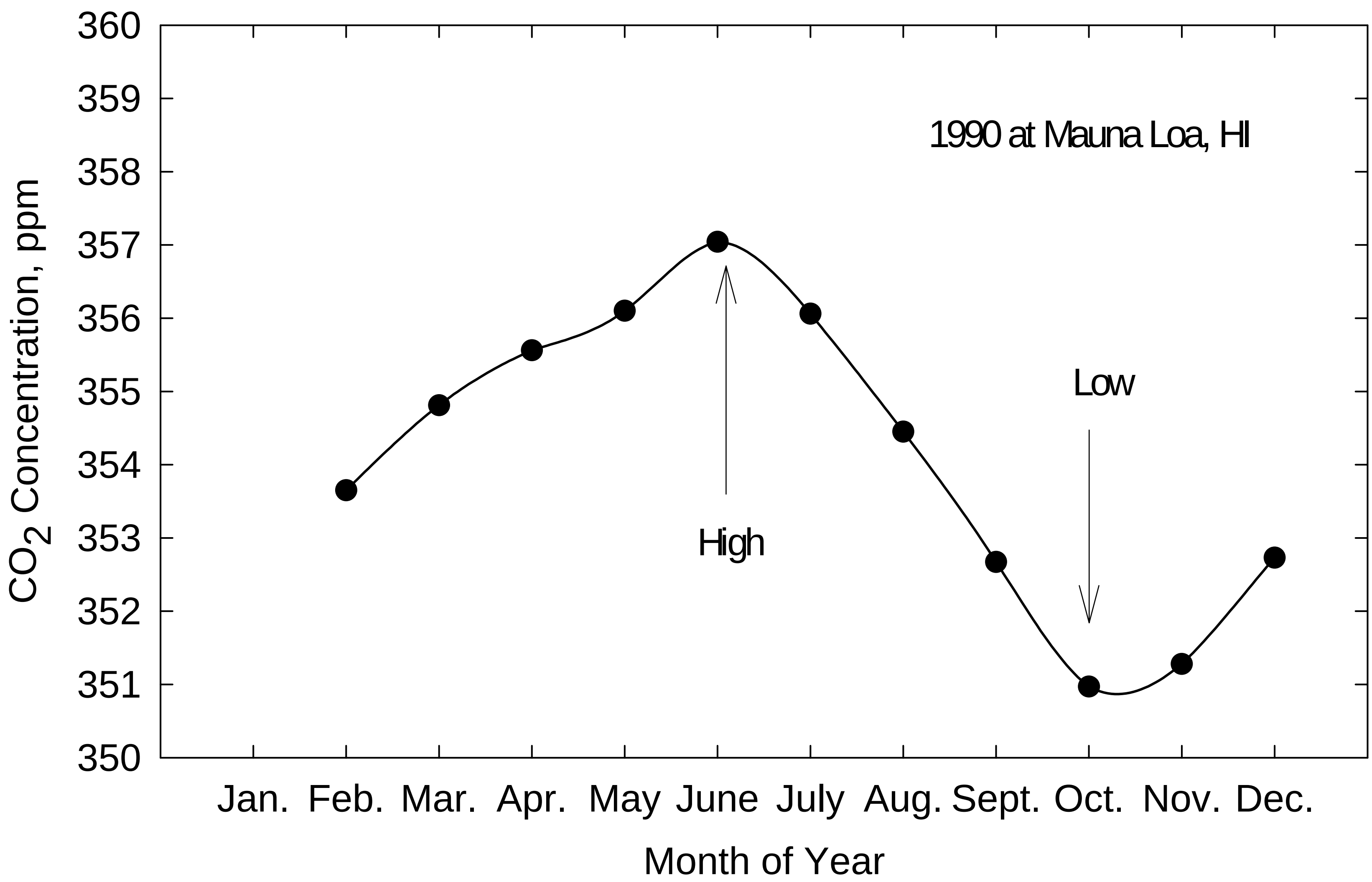
Atmospheric Carbon Dioxide Concentration

Temporal trends in CO_2 concentration from pole to pole



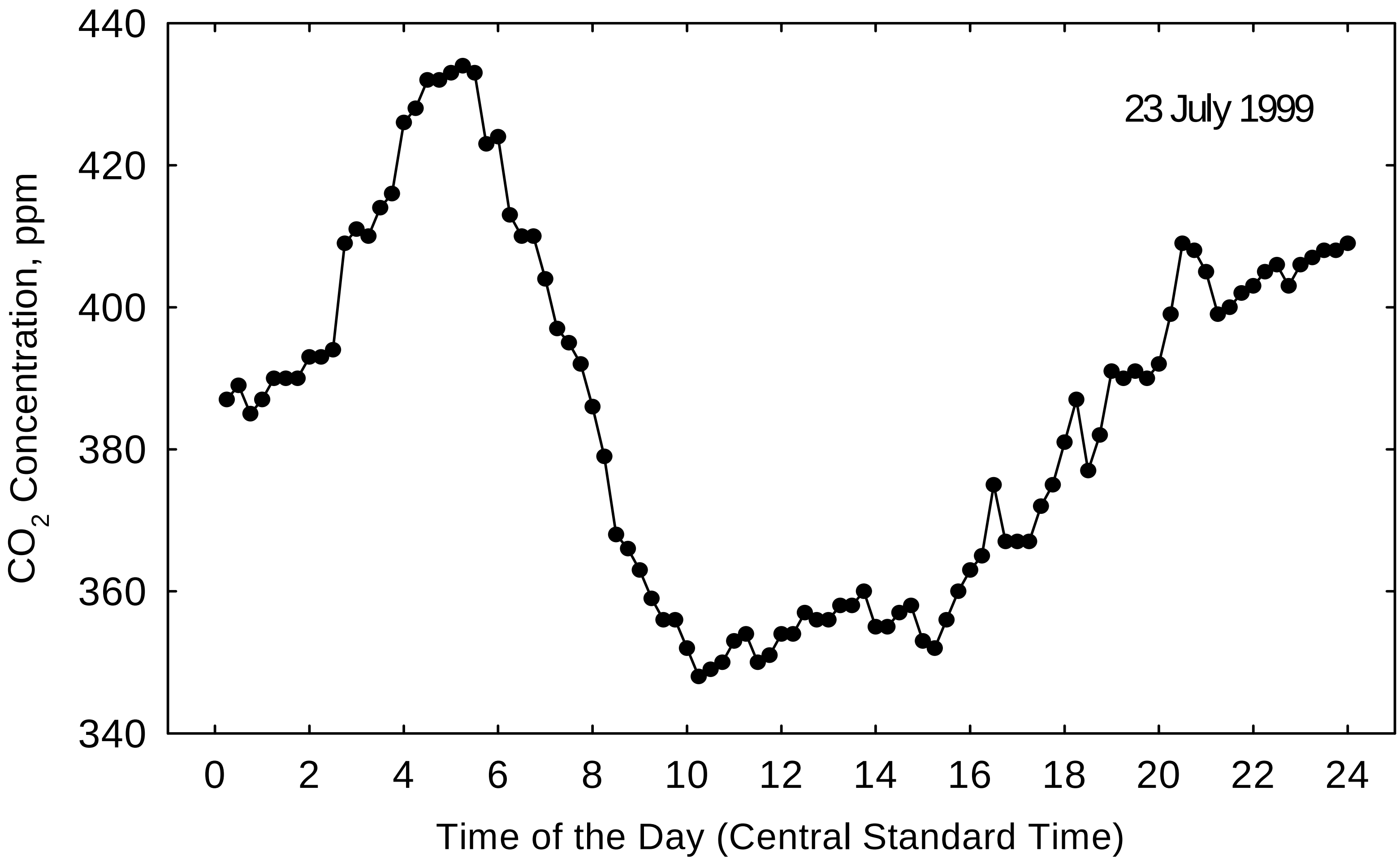
Global Carbon Dioxide Concentrations

Trends – Atmospheric Carbon Dioxide – Monthly



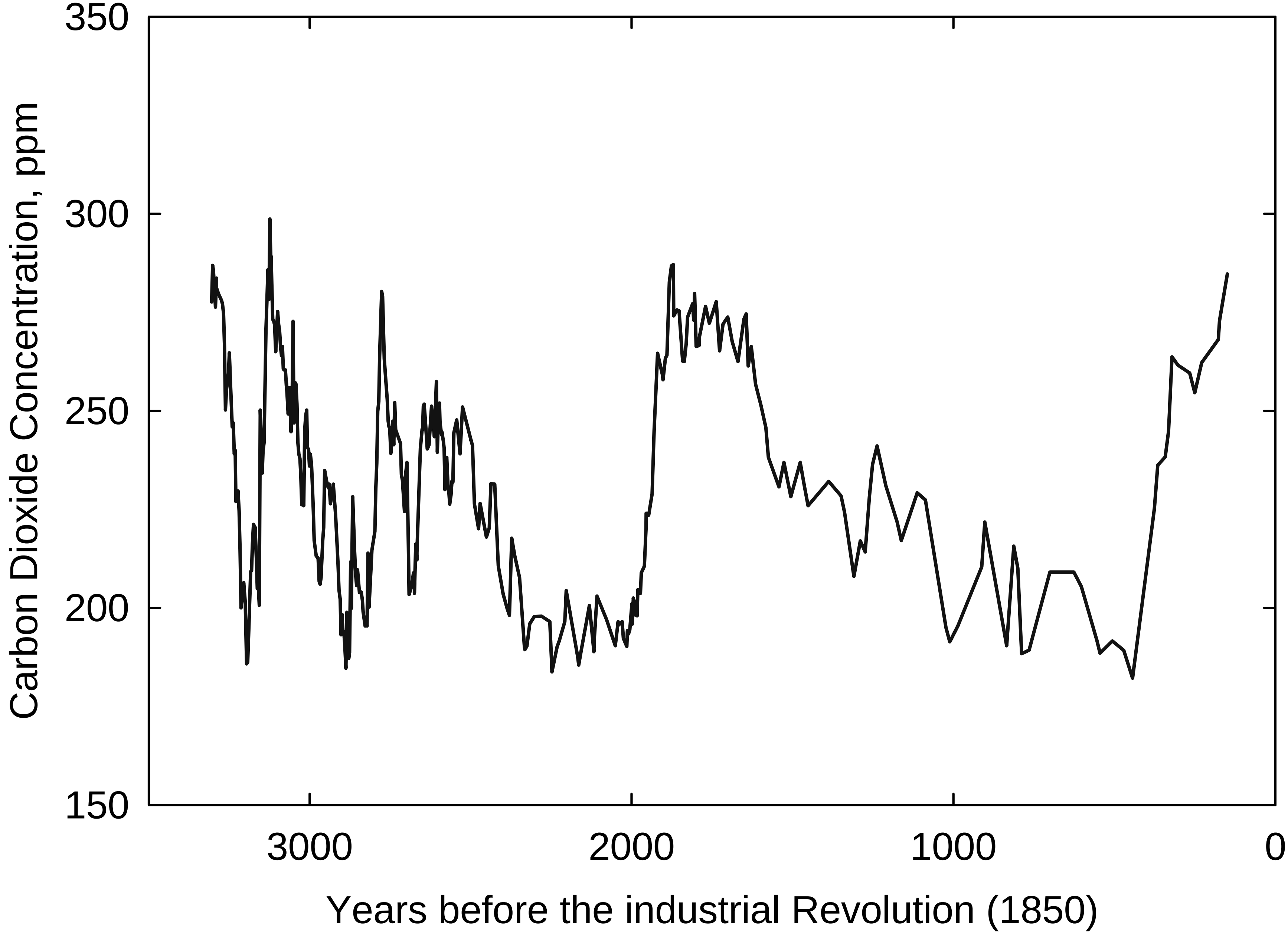
Global Carbon Dioxide Concentrations

Diurnal trends in CO_2 – Starkville, 27 July 1999



Global Carbon Dioxide Concentrations

Temporal trends in CO_2 years before the Industrial revolution (1850)



Global Circulation Models

Predictive capabilities – Data requirements

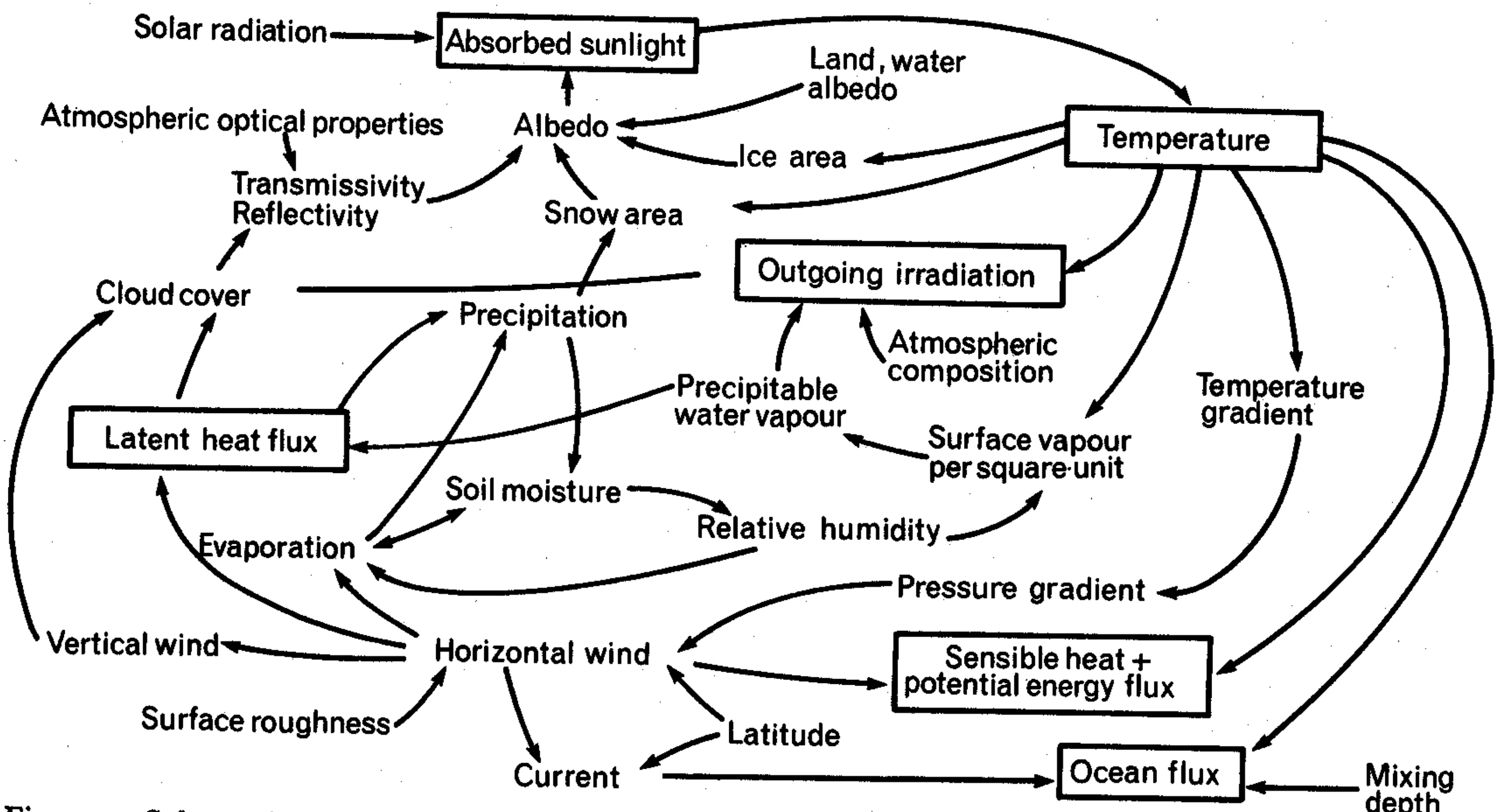
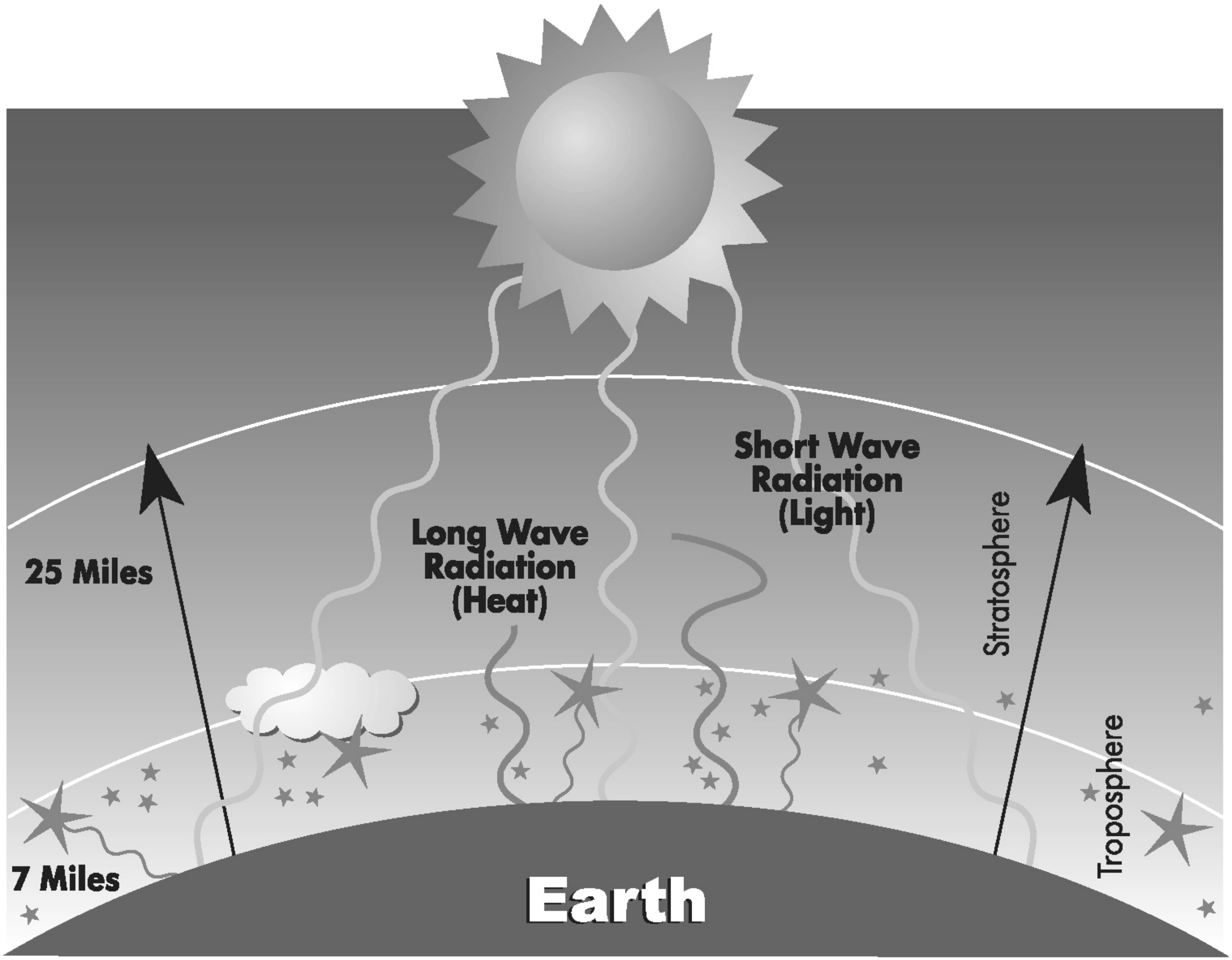


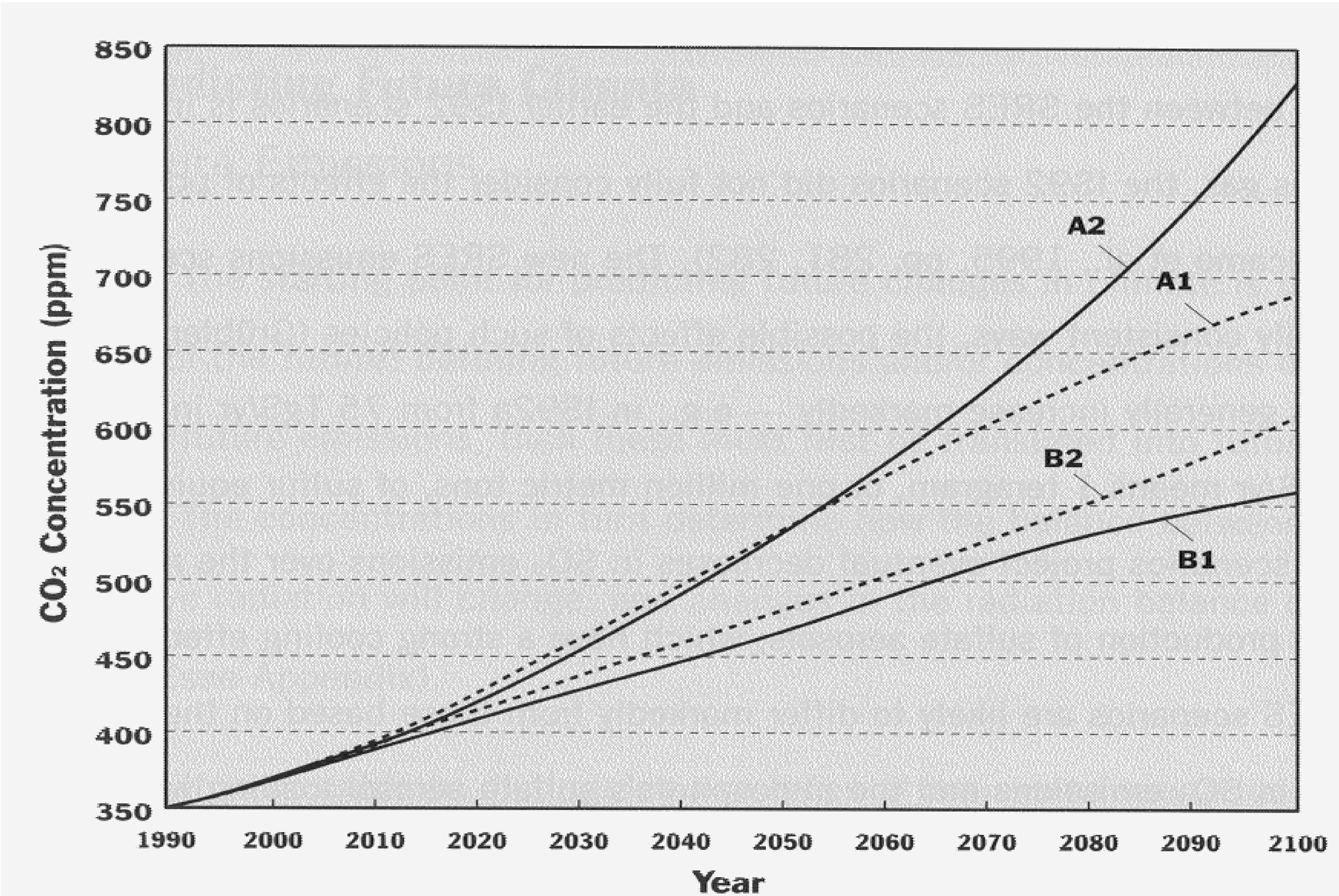
Fig. 14.5. Schematic illustration of many of the potential climatic feedback interactions that need to be considered in a climatic model.[27]

Greenhouse Gases and Climate Change



Global Carbon Dioxide Concentrations

Projected trends



Future trends in global carbon dioxide concentration and associated climate change, if no interventions are made

Climate variable	**2025**	**2050**	**2100**
Carbon dioxide concentration	405-460 ppm	445-640 ppm	540-970 ppm
Global mean temperature change from the year 1990	0.4-1.1 ^{o}C	0.8-2.6 ^{o}C	1.4-5.8 ^{o}C
Global mean sea-level rise from the year 1990	3-14 cm	5-32 cm	9-88 cm

Predicted Annual Temperature Increase in GCMs for Doubled CO_2 Scenario

(Adams et al., 1990)

Region	GISS	GFDL
	°C	
Southeast	3.5	4.9
Delta	5.3	4.4
Northern Plains	4.7	5.9
Southern Plains	4.4	4.5
Mountain	4.9	5.3
Pacific	4.7	4.7

Our biosphere is changing

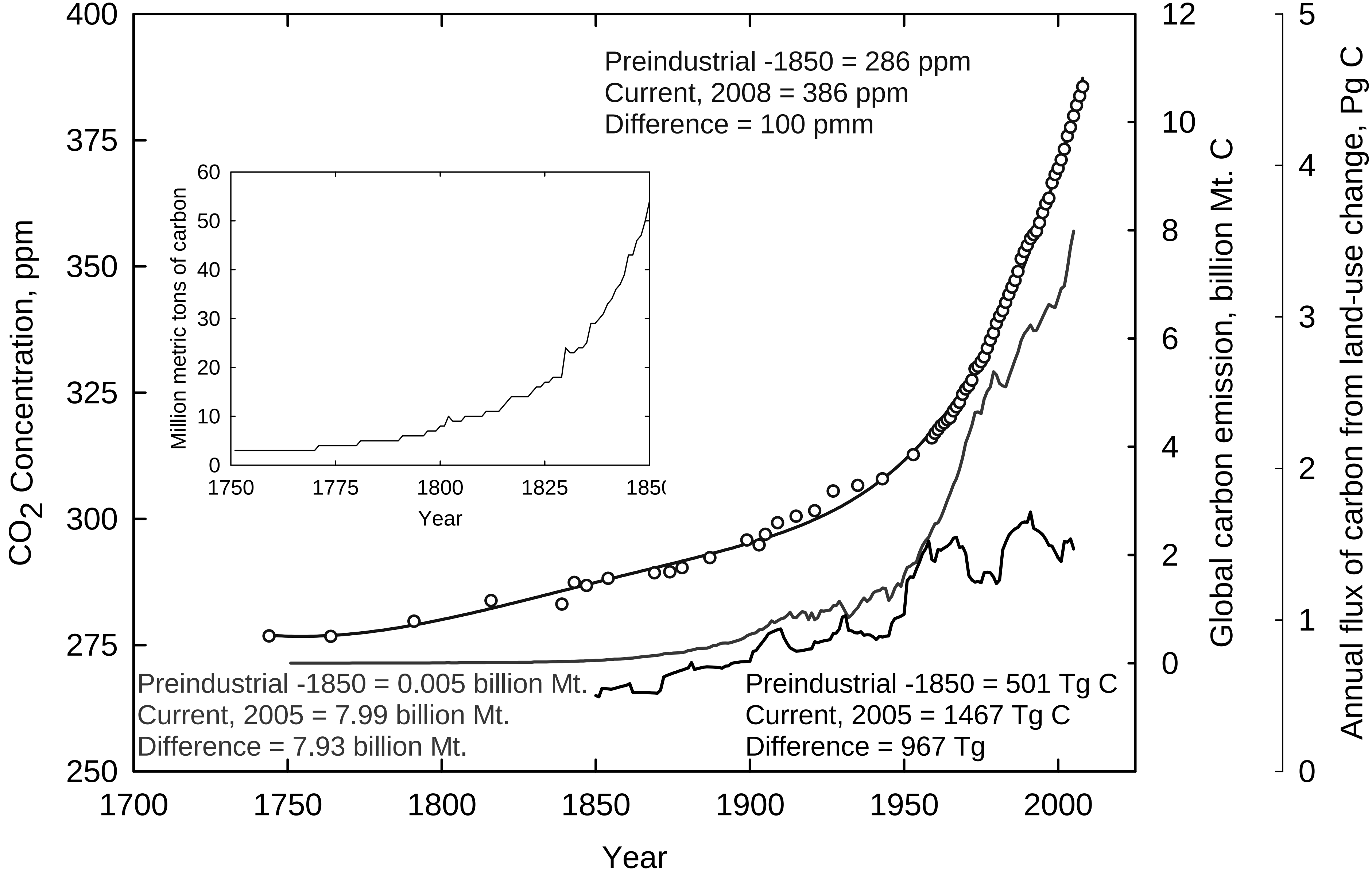
(CNN)

(COURTESY NREL)

(CNN)

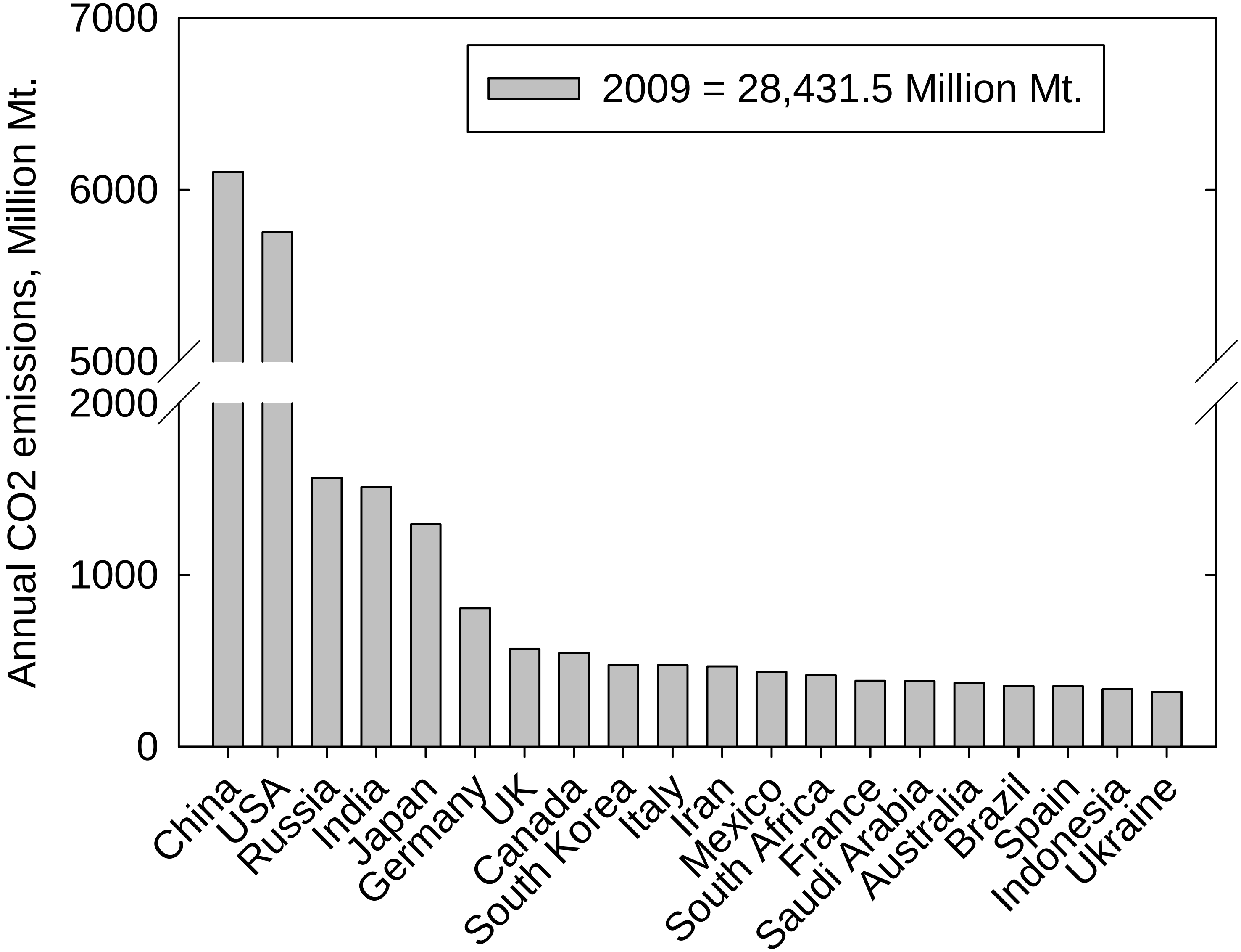
Global Carbon Emissions

Sources

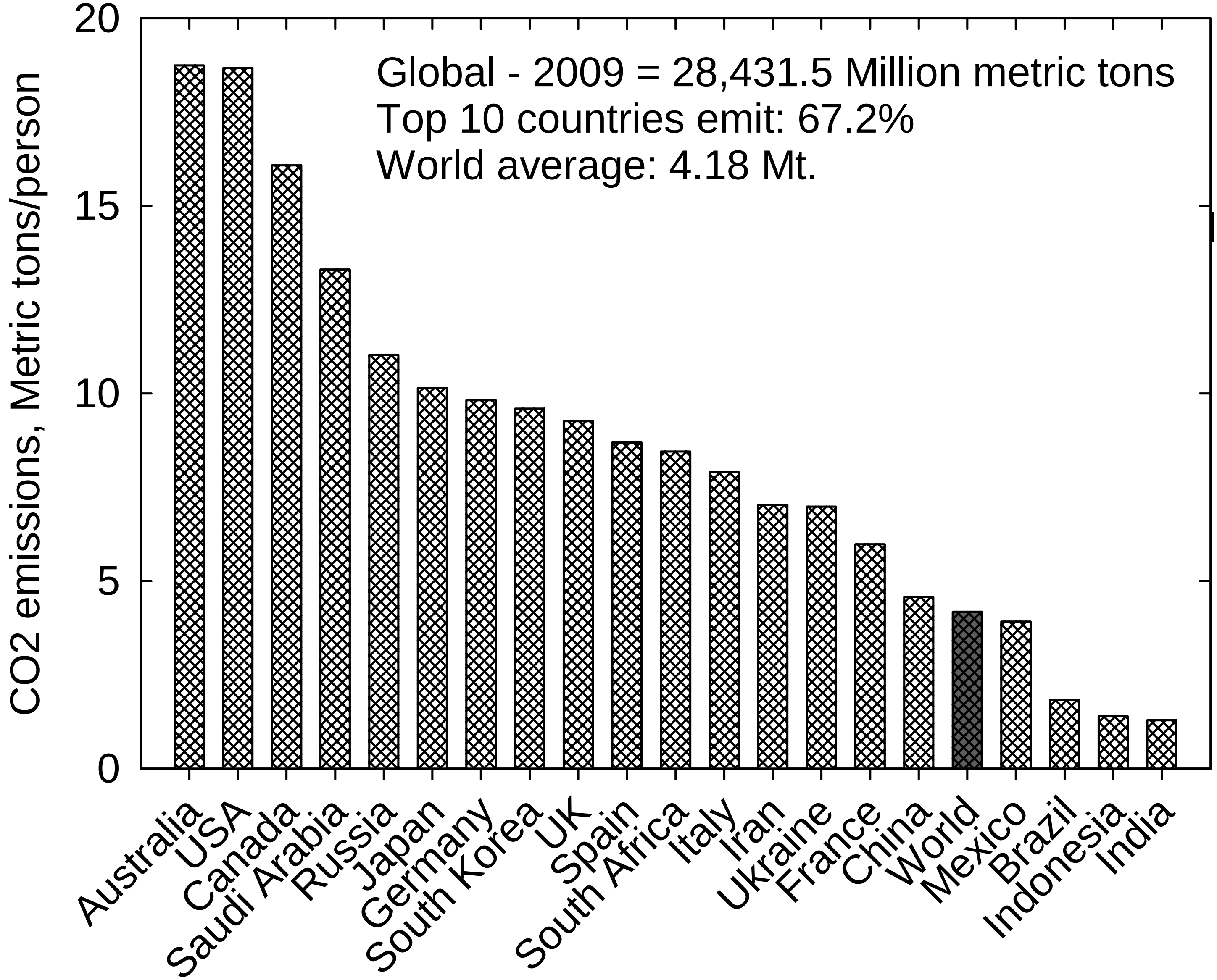


Global Carbon Emissions

Sources – Top 20 Countries



Trends, Signs and Signatures from the Earth
Carbon foot-print per person



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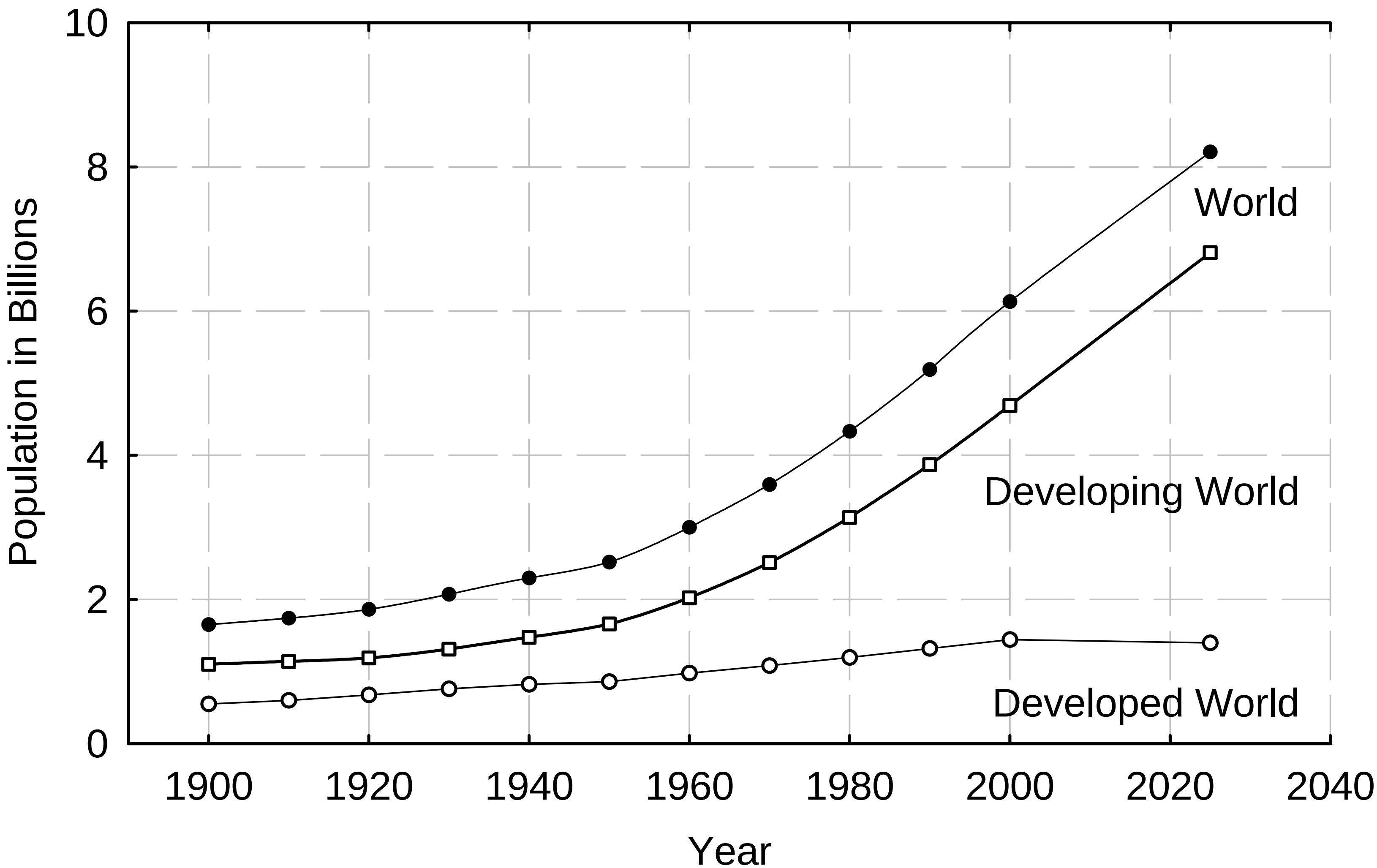
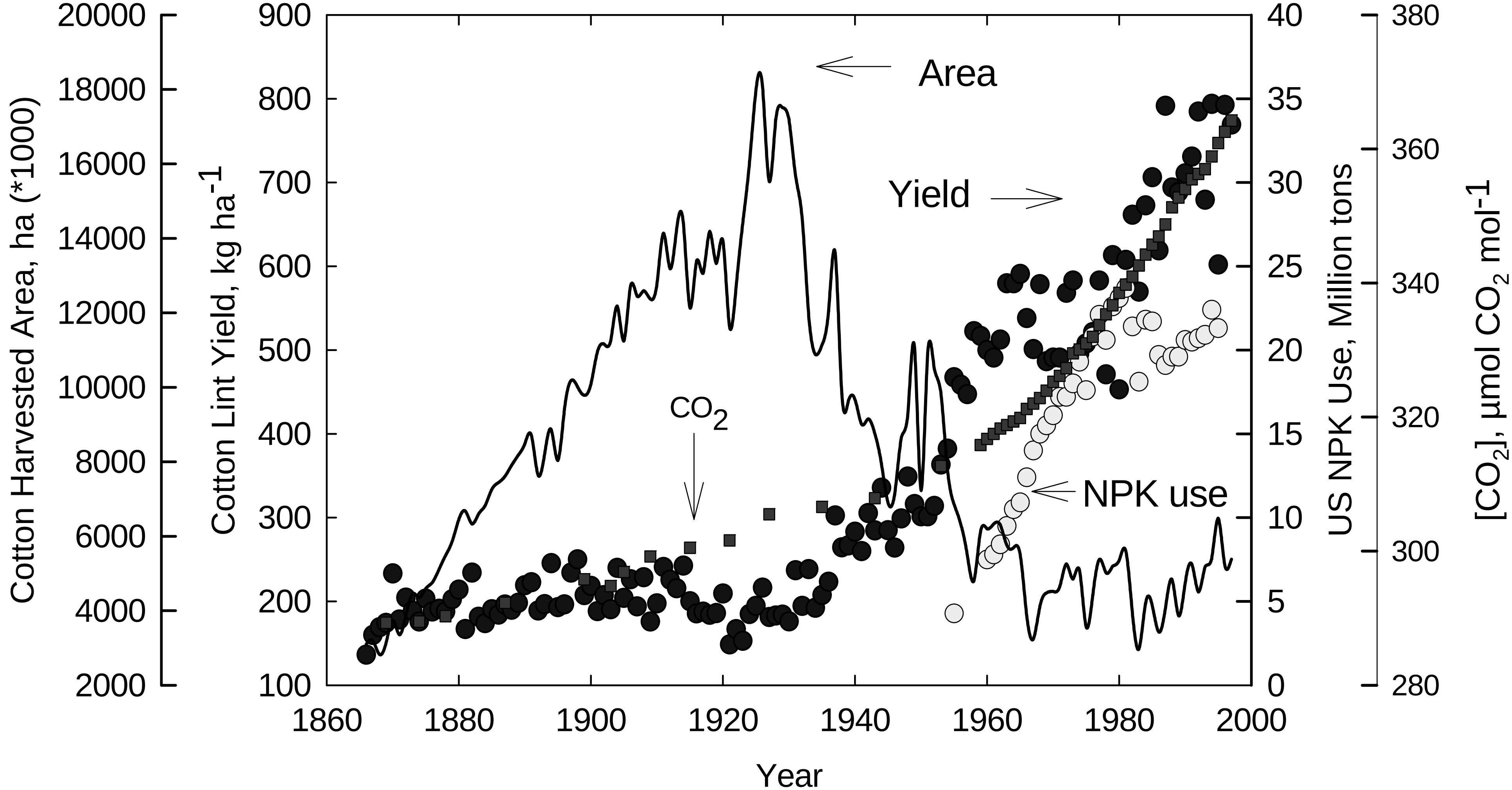
Global Population

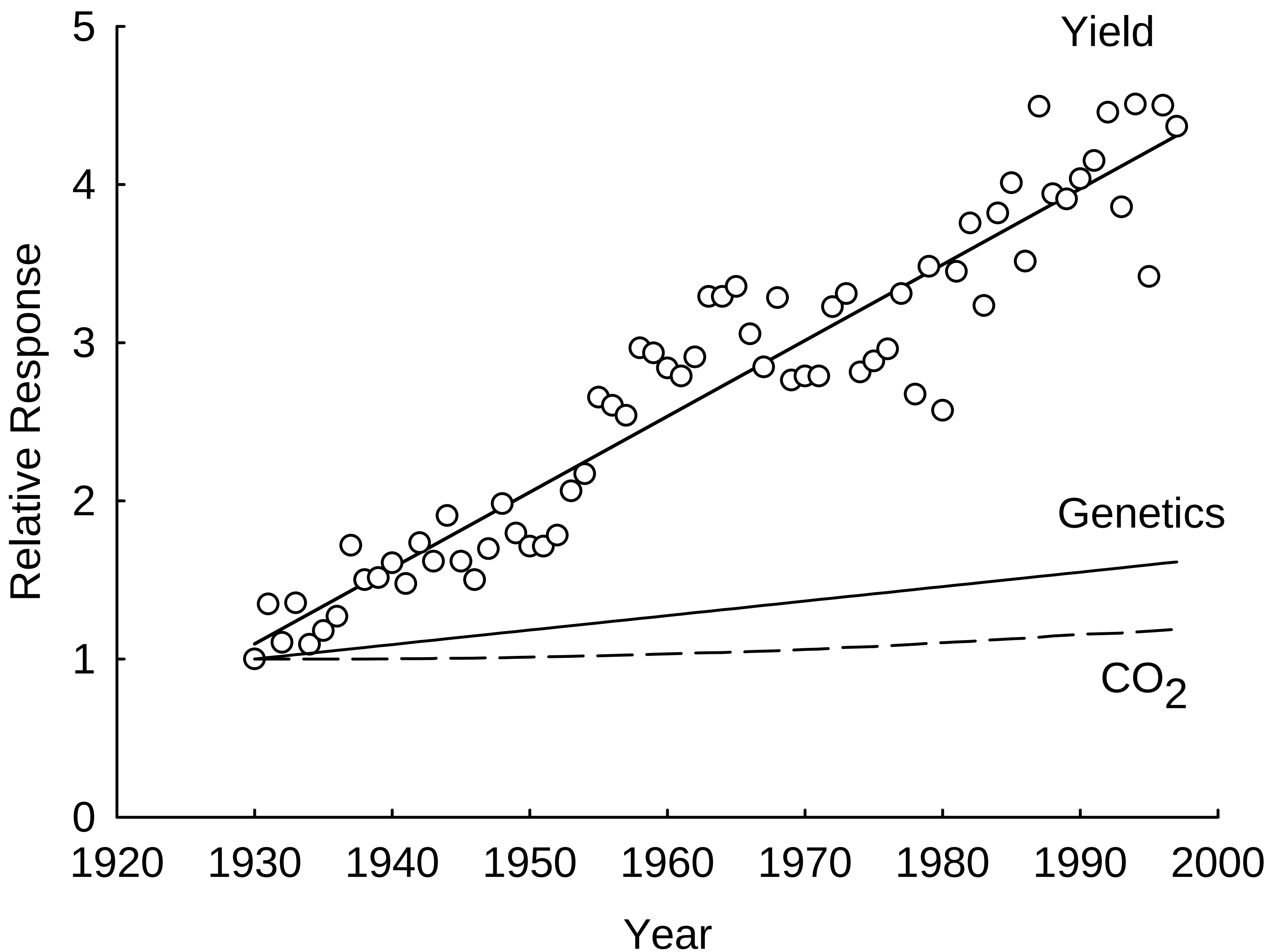
Projected trends



Climate Change and Crop Production
CO2, NPK Use, Cotton Acreage and Yields



Cotton Yield Trends
Best management practices, genetics, CO_2
Relative contributions



Summary

- ✓ Atmospheric CO_2 is a critical component of the atmosphere.
- ✓ Increases in CO_2 will have both positive and negative impacts on agriculture and natural ecosystems.
- ✓ The negative impacts expressed through climate change and global warming affect not only agriculture but also other sectors.
- ✓ Overall, increasing CO_2 is likely to have serious consequences.

Summary

- ✓ It is extremely unlikely that terrestrial uptake of CO_2 will be sufficient to prevent these climate problems.
- ✓ A major adaptive response for agriculture ecosystems will be breeding or designing new cultivars: heat-and-cold and drought resistance crop varieties that may be better adapted to new climate (short-term fixes).
- ✓ Plants in the natural ecosystems will have cope with changes in climate and adapt accordingly.
- ✓ Additional steps to limit CO_2 emission by world's nations is another possibility (long-term strategies).

Suggested Reading Material:

1. Climate Change and the Global Harvest. C. Rosenzweig and D. Hillel. 1998. Oxford University Press, pages 1-69.

2. Climate change and variability by L. O. Mearns. In: Climate Change and Global Crop Productivity, edited by K. R. Reddy and H. F. Hodges. 2000. Pages 7-35.

3. Agricultural contribution to Greenhouse gas emissions by D. C. Reicosky, J. L. Hatfield and R. L. Sass. In: Climate Change and Global Crop Productivity, edited by K. R. Reddy and H. F. Hodges. 2000. Pages 37-55.