Effects of Future Emissions and a Changed Climate on Urban Air Quality

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EPA RD 83337101-0

EPA Workshop: Impacts of Climate Change on Air Quality in the Pacific Southwest
San Francisco, California
Oct. 11, 2007

Effects of Future Anth. Emissions on Natural Emissions and Air Quality

Climate-Dependent Natural Emissions Treated

Lightning NO, NO_2, HONO, HNO_3, N_2O, CO, HO_2, H_2O_2

Sea spray Na, Ca, Mg, K, Cl, S, Br, N

Ocean bacteria

Phytoplankton DMS

Soil dust

Vegetation isoprene, monoterpenes, NMVOC

Soil NO_x

Pollen

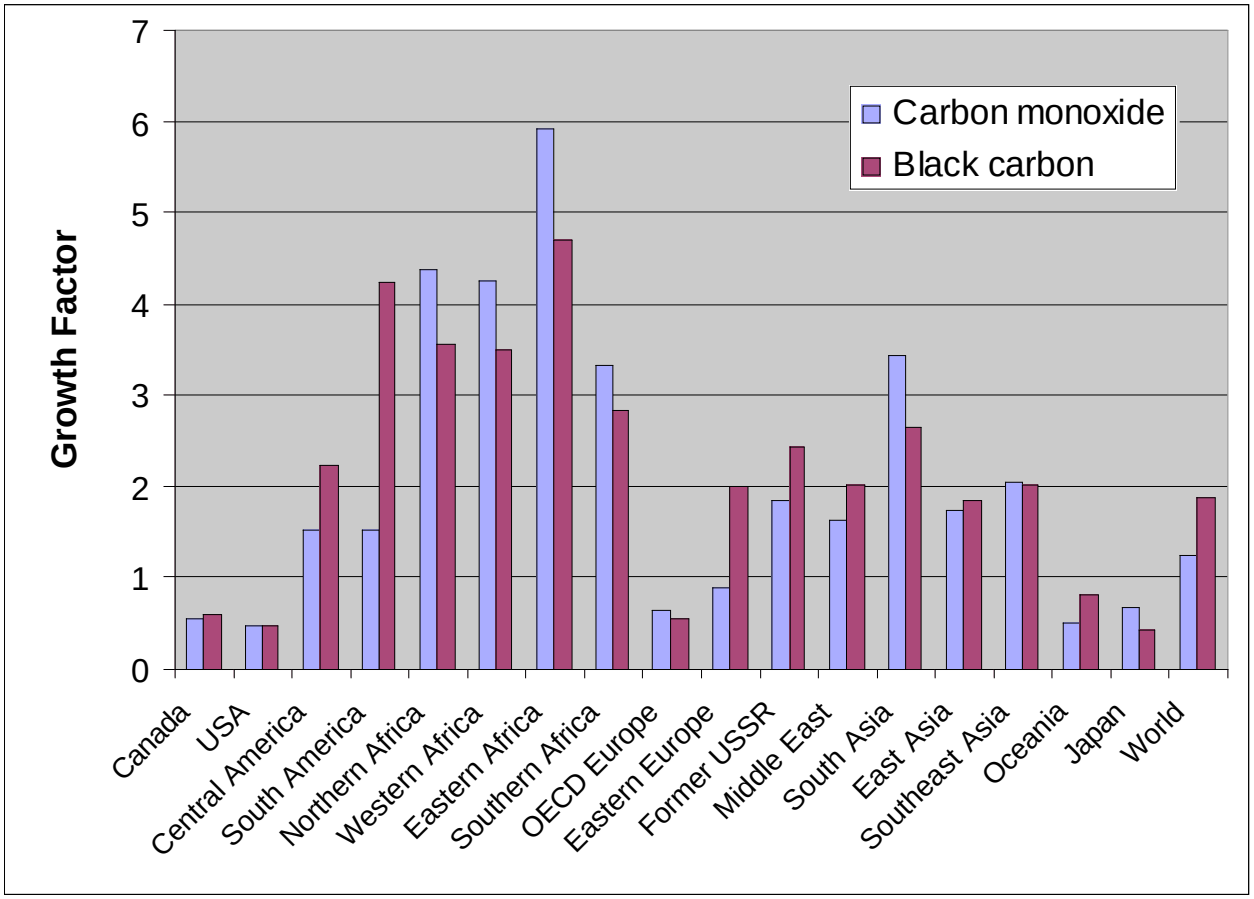
Spores

Land bacteria

Natural fire and volcanic gas and particle emissions

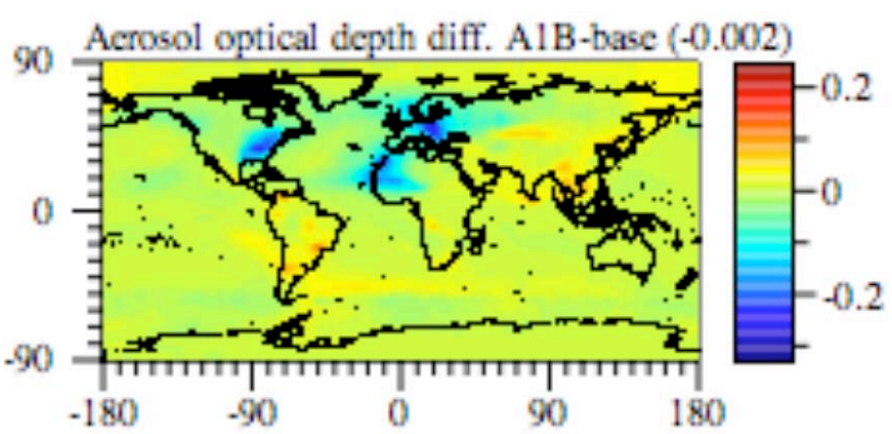
Photosynthesis, cellular respiration, soil respiration CO_2

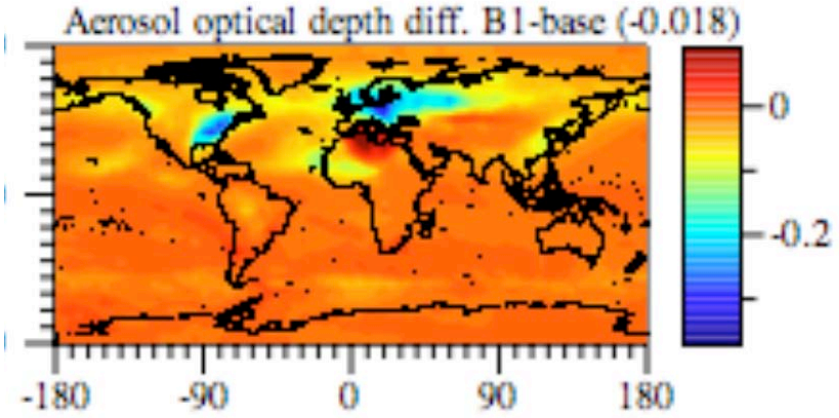
2030 A1B CO/BC Growth Factors (B1 also derived)

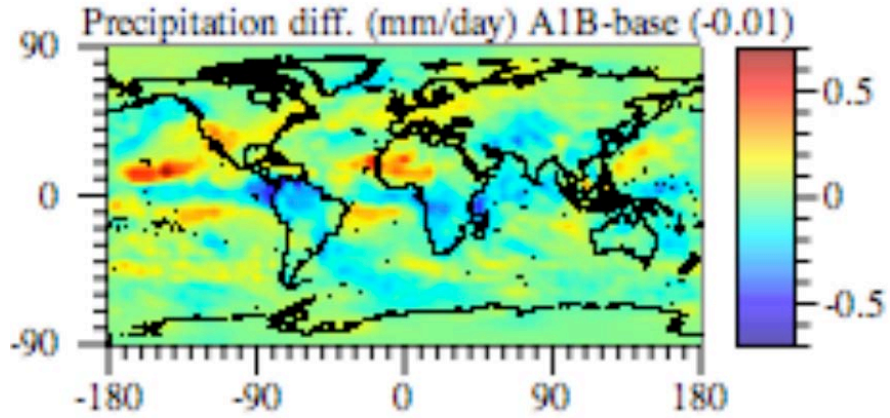


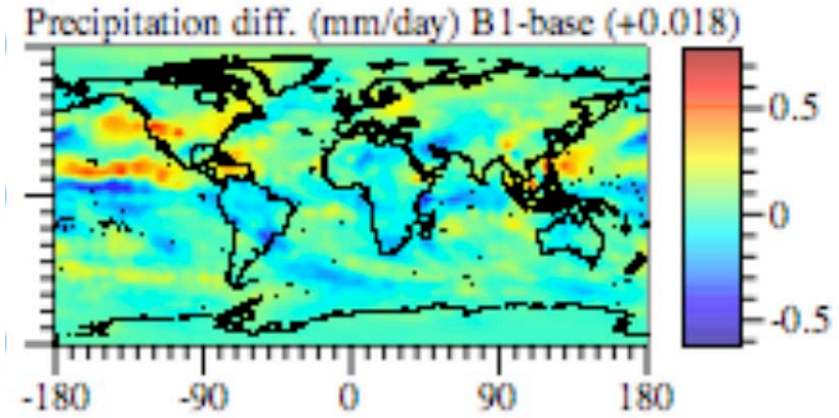
D.G. Streets

Differences 2002-2030 Under A1B and B1 Scenarios









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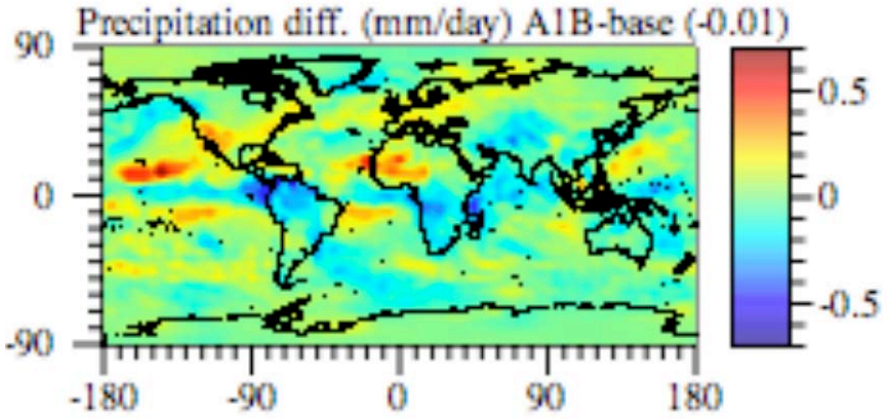

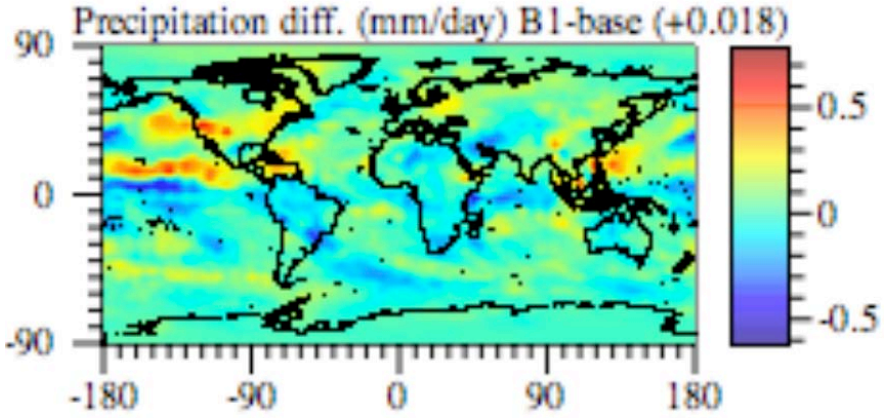

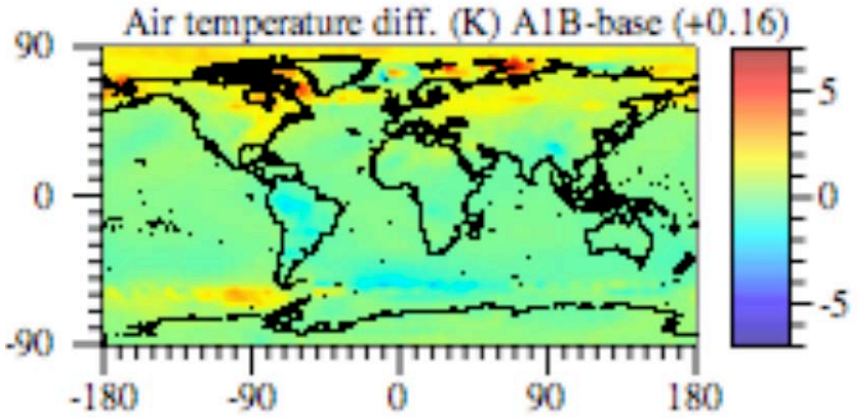

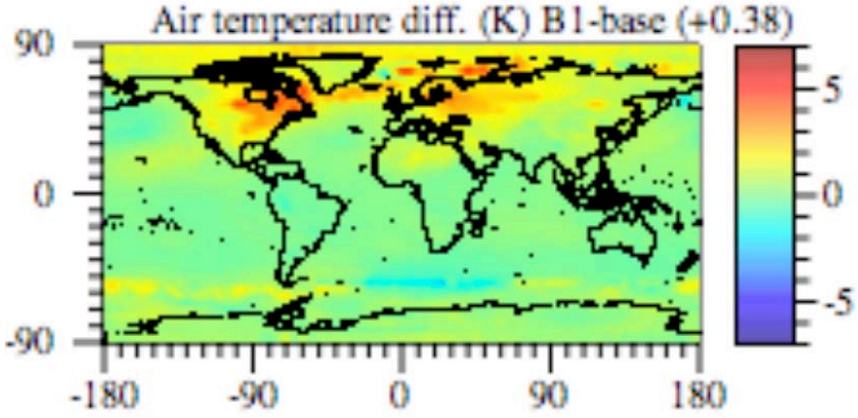

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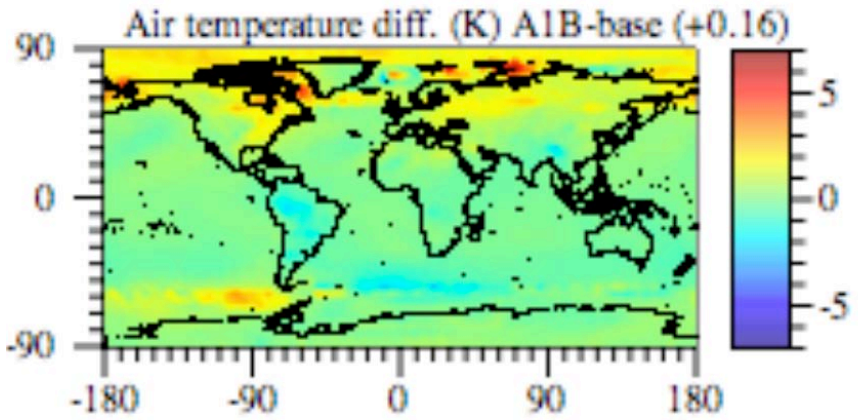
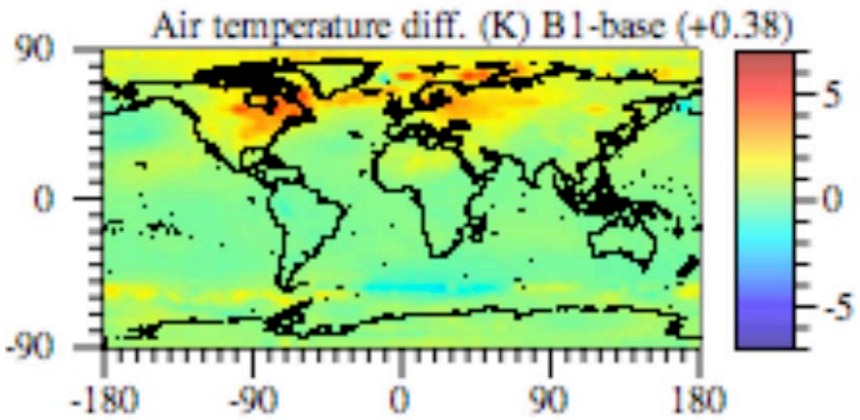
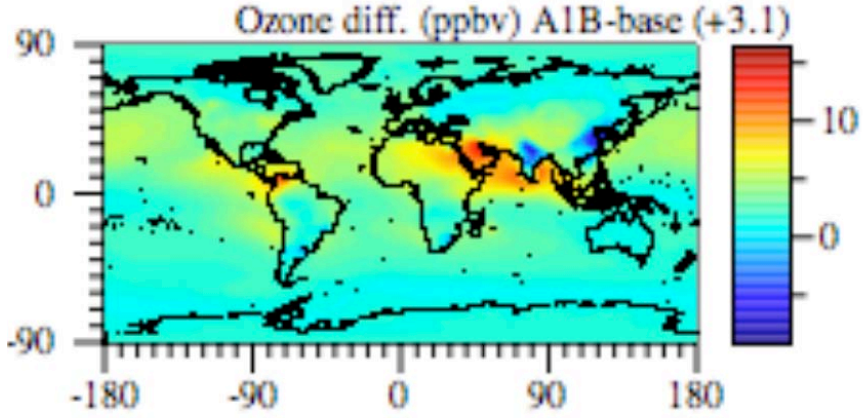
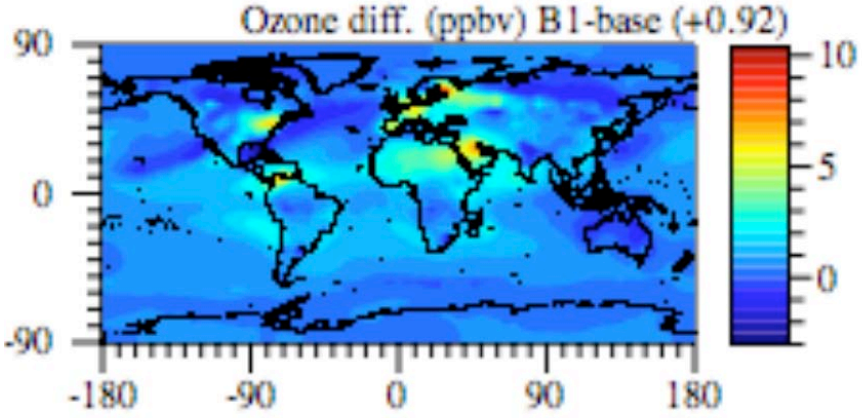








Massachusetts et al. v. EPA

Supreme Court Ruling April 2, 2007: CO_2 can be regulated

"(b) The harms associated with climate change are serious and well recognized. The Government's own objective assessment of the relevant science and a strong consensus among qualified experts indicate that global warming threatens, *inter alia*, a precipitate rise in sea levels, severe and irreversible changes to natural ecosystems, a significant reduction in winter snowpack with direct and important economic consequences, and increases in the spread of disease and the ferocity of weather events."

However, the ruling does not require the regulation of CO_2 and no study so far has demonstrated, by cause and effect, that CO_2 itself harms health through air pollution (many studies have linked warmer temperatures to ozone, but none has isolated CO_2's effect or calculated health impacts of ozone or $PM_{2.5}$).

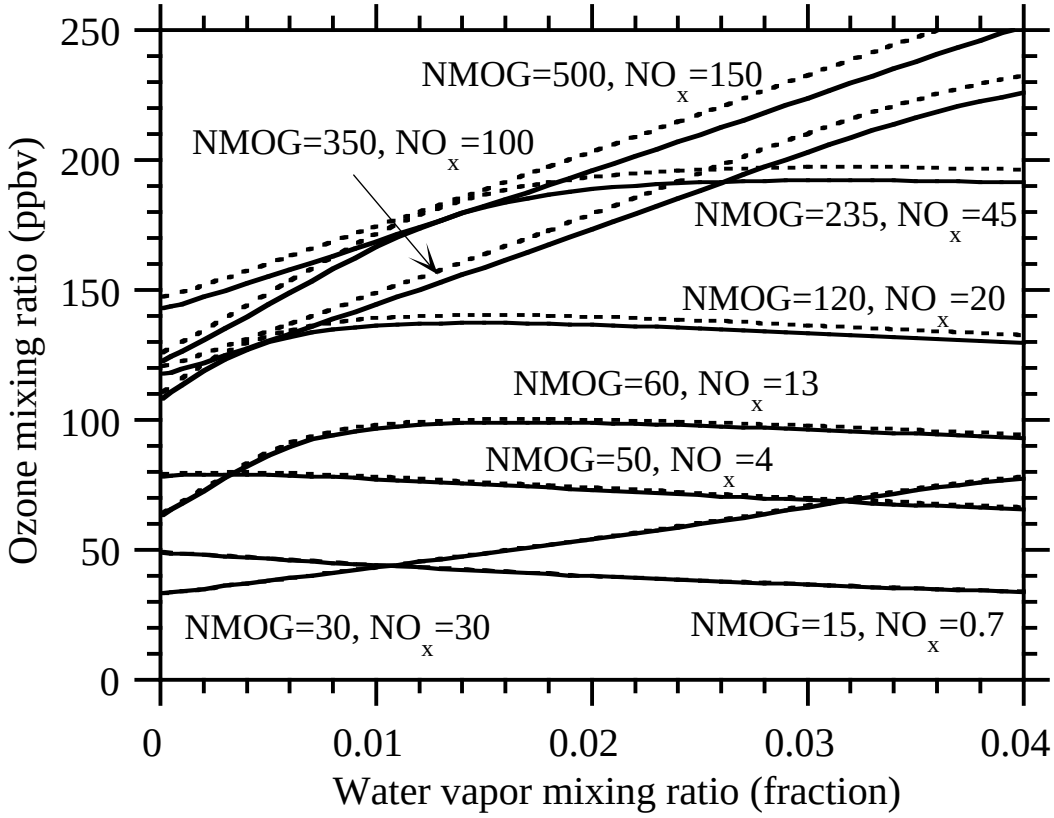
How Causal Link Between CO_2 and Health was Determined

1. An exact numerical solutions to photochemistry in a box model was used to establish the relationships between (a) water vapor and ozone and (b) temperature and ozone.

2. 3-D Nested global-regional simulations over the U.S. were used to show by cause-and-effect whether CO_2 alone increases air temperatures, whether the temperatures increase water vapor and atmospheric stability, and how all three parameters affect ozone, particulate matter, and carcinogens.

3. Population and health-statistics data were combined with the concentration changes to determine the net effect of CO_2 on air pollution mortality, hospitalization, asthma, and cancer.

Increases in H_2O and T Both Increase O_3 with Increasing O_3



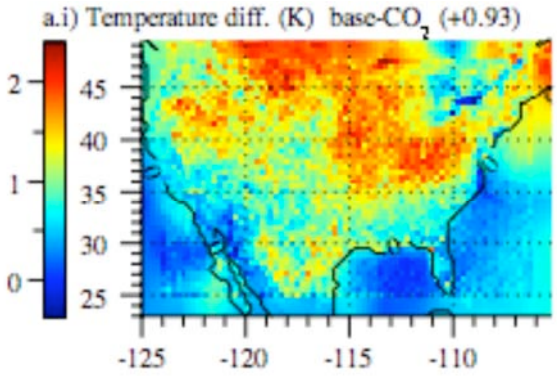
With increasing water vapor,

Hi NO_x: $NO+HO_2 \rightarrow NO_2+OH$ fast, increasing NO_2:NO, O_3

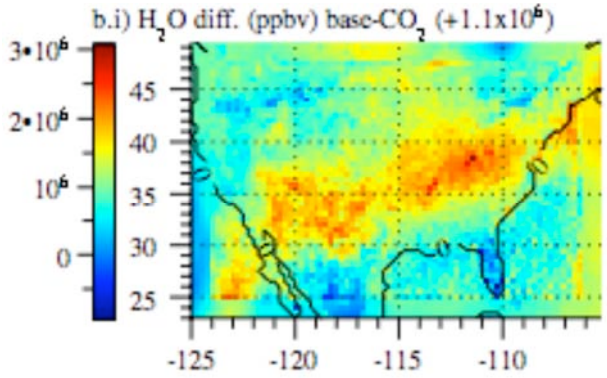
Lo NO_x: $2HO_2 - H_2O \rightarrow H_2O_2$ fast; NO_2 lost to orgnit, decr. NO_2:NO, O_3

Causal Effect of CO_2 on Mortality

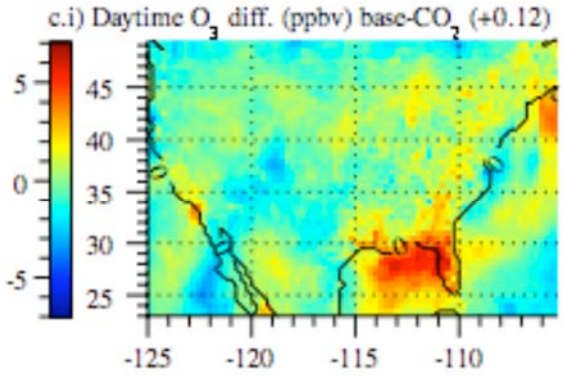
Global-regional nested simulations:
CO_2 alone increases T, H_2O, O_3, $PM_{2.5}$



Δ Temperature



Δ Water vapor

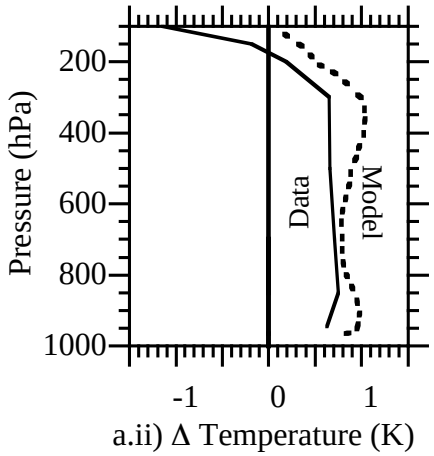


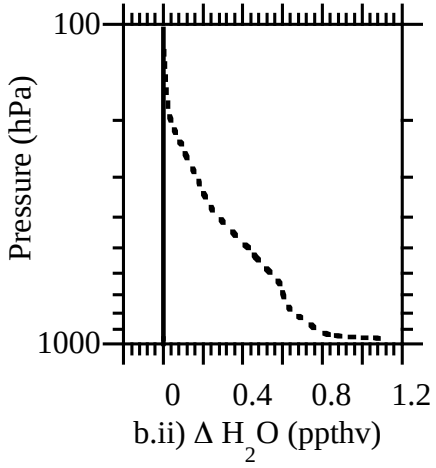
Δ Ozone

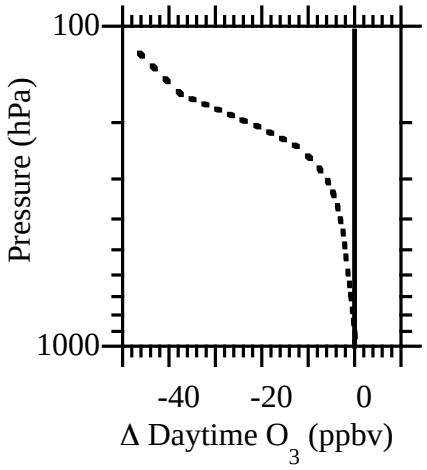
U.S. Δ Total deaths/yr per 1K +1000 (350-1800)
40% due to ozone; 60% due to $PM_{2.5}$

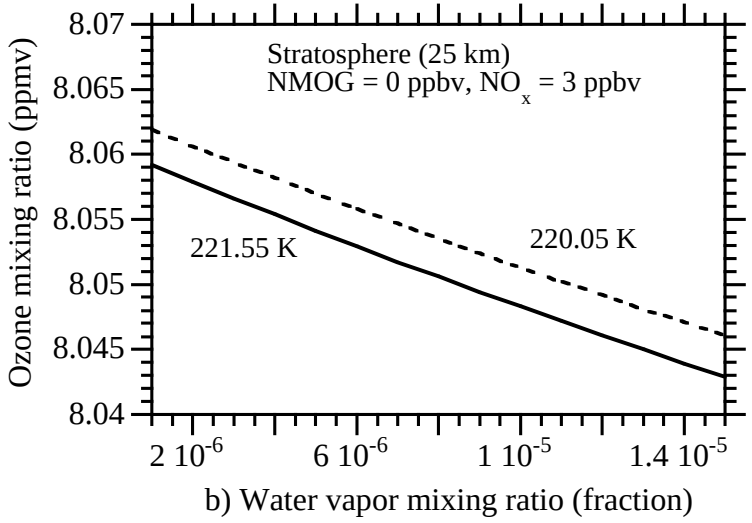
World Δ Total deaths/yr per 1K +21,600 (7400-39,000)

Reduced Upper-Trop/Lower Strat O_3 due to Higher H_2O, Lower T there From CO_2



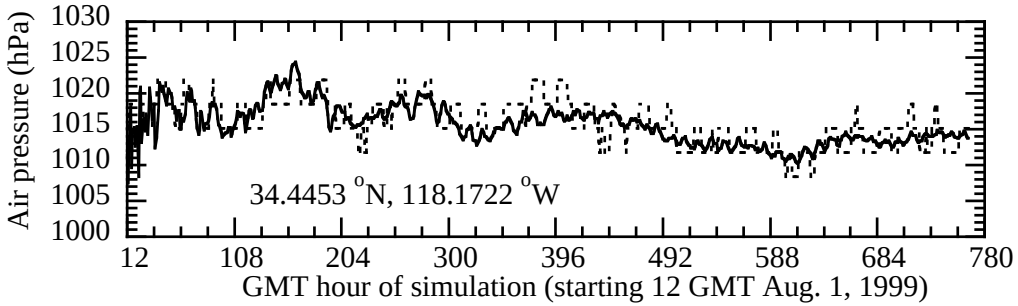






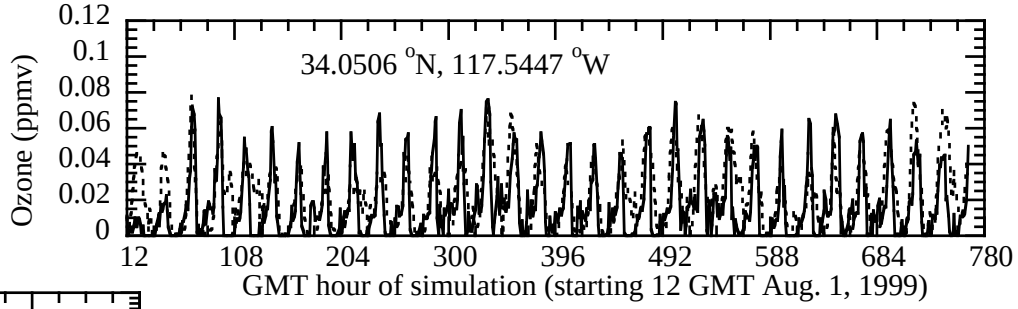
30-Day Weather Predictions vs. Data

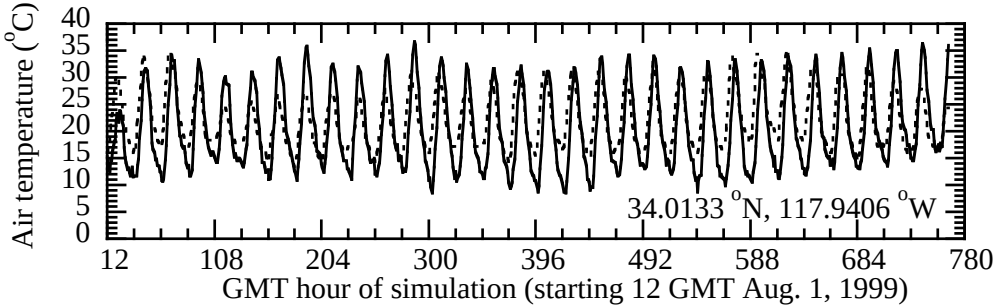
Results with no model spinup or data assimilation



Pressure

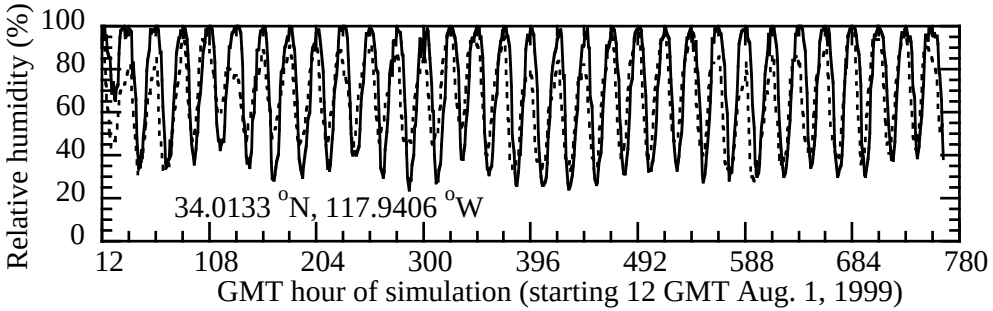
Ozone





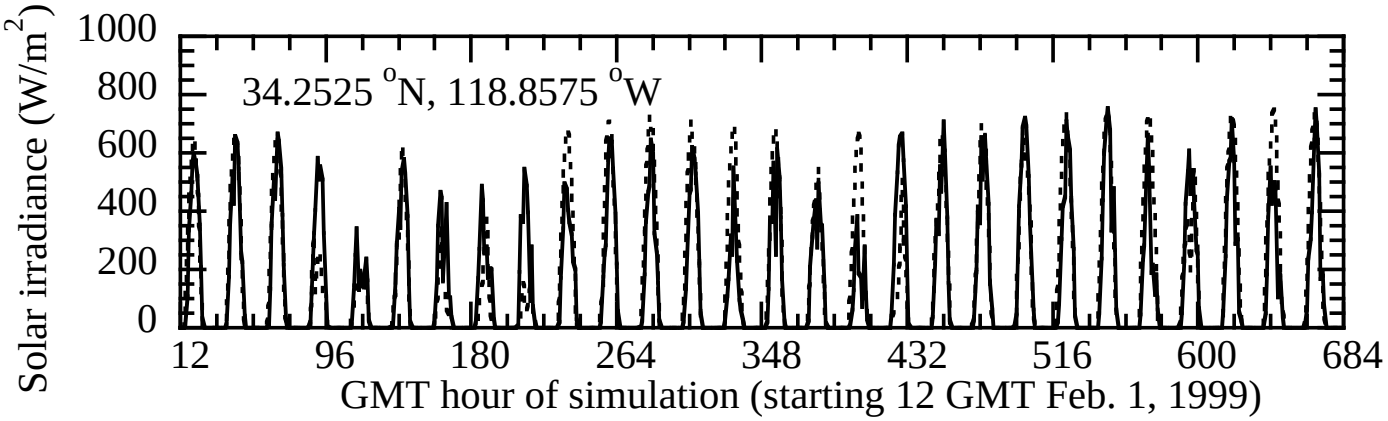
Temperature

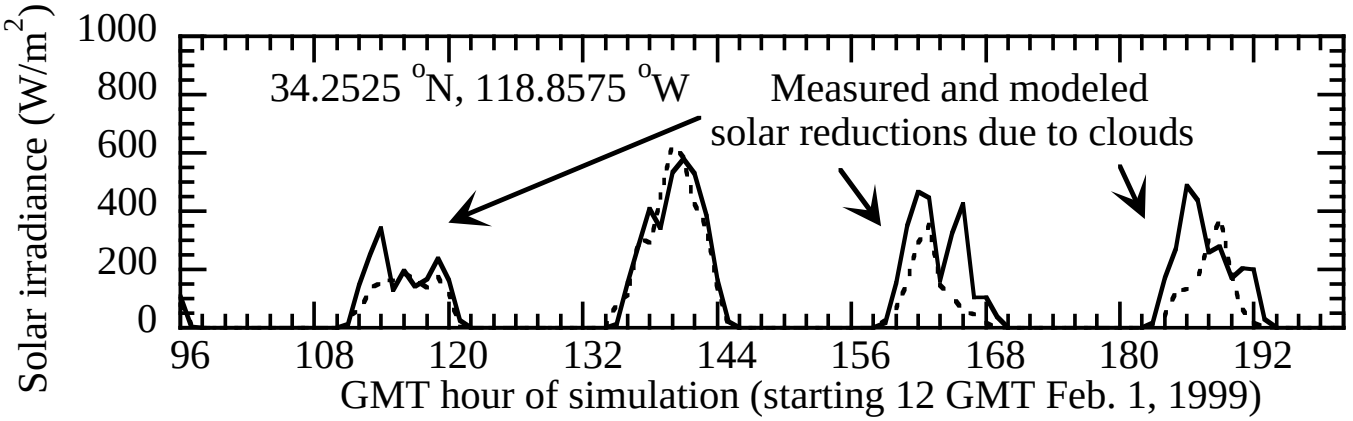
RH



Model vs. Measured Solar Radiation

Model predicted the location and magnitude of cloud reduction of sunlight for four days in a row





Summary

Increased water vapor and temperatures from higher CO_2 separately increase ozone more with higher ozone; thus, global warming may exacerbate ozone most in already-polluted areas.

CO_2 may increase U.S. annual air pollution deaths by about 1000 (350-1800) and cancers by 20-30 per 1 K rise in CO_2-induced temperatures, with 40% due to O_3 and 60% due to $PM_{2.5}$, which increases from enhanced stability. Increases in worldwide deaths could be about 21,600 (7400-39,000) more than those from enhanced storminess.

CO_2 decreases column ozone by decreasing upper tropospheric/lower stratospheric ozone. Although this increases UV, increased aerosol loadings reduce this UV at the surface.

The results provide a basis for controlling CO_2 on air-pollution health grounds.

Summary

A1B and B1 emission scenarios for 2030 were developed. Although B1 was cleaner, global warming increased more with it because A1B warming was masked by added reflective particles.

Lightning emissions decreased in both scenarios as cloud ice decreased. Photosynthesis-cellular respiration (NPP) increased in both scenarios. Seas spray, ocean bacteria, DMS, soil dust, pollen, spores, land bacteria emissions slightly decreased due to enhanced stability. Ozone increased in both scenarios.