

The Differential Global and Regional Climate and Air Pollution Effects of Fossil-Fuel Versus Biofuel Soot

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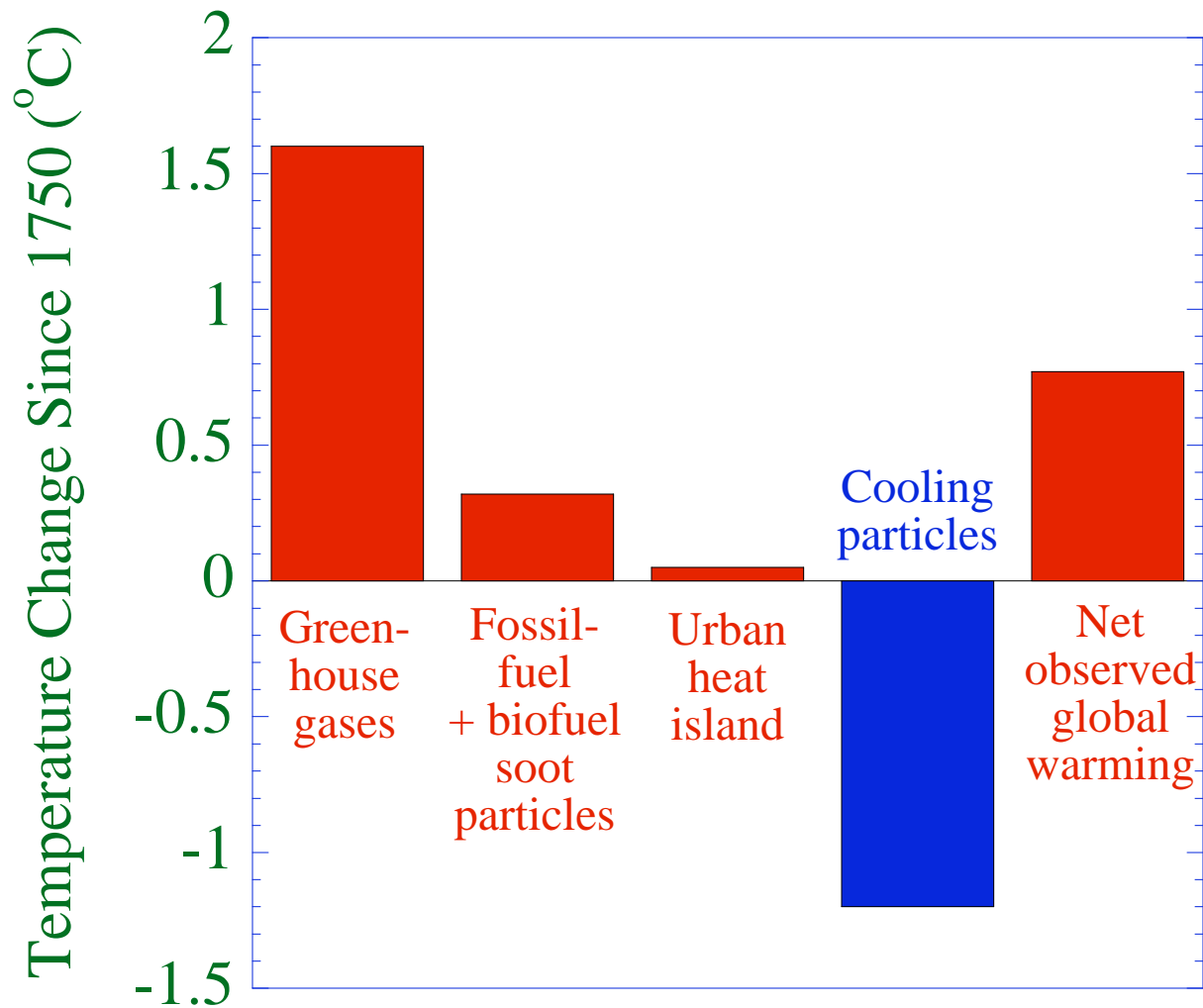
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Causes of Global Warming



GATOR-GCMOM Model

Gas processes

- Emissions
- Photochemistry
- Gas-to-particle conversion
- Cloud removal

Aerosol processes

- Emissions
- Nucleation/condensation
- Gas dissolution
- Aqueous chemistry
- Crystallization
- Aerosol-aerosol coagulation
- Aerosol-cloud coagulation
- Dry deposition
- Sedimentation
- Rainout/washout

Meteorological processes

- Pressure, winds, temp., TKE

Cloud processes

- Subgrid clouds, size-resolved physics
- Liquid/ice growth on aerosol particles
- Liquid drop freezing/breakup
- Hydrometeor-hydrometeor coagulation
- Hydrometeor-aerosol coagulation
- Precipitation, aer./gas rainout/washout
- Below-cloud evaporation/melting
- Lightning from collision bounceoffs

Radiative transfer

- UV/visible/near-IR/thermal-IR
- Gas/aerosol/cloud scat./absorption
- Predicted snow, ice, water albedos

Surface processes

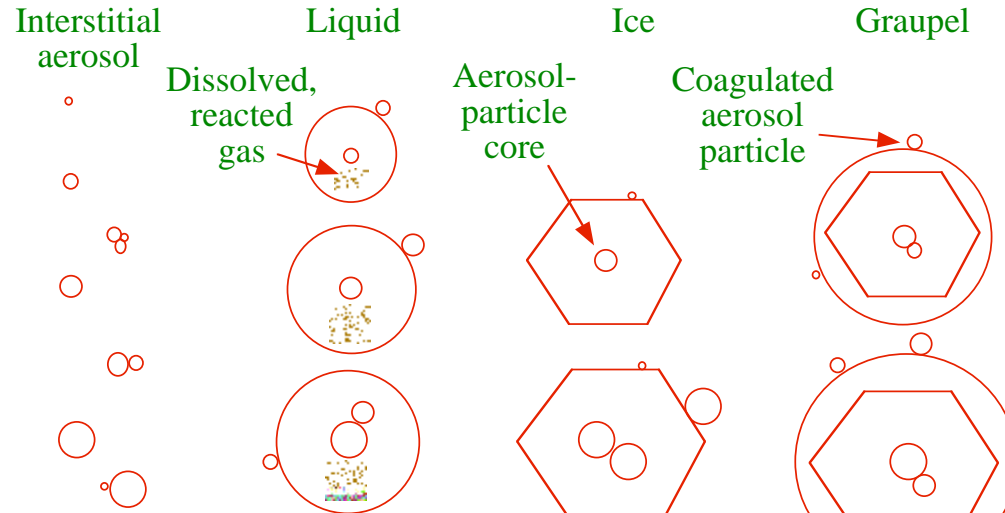
- Soil, water, snow, sea ice, vegetation, road, roof temperatures/moisture
- Ocean 2-D dynam., 3-D diffus/chem.
- Ocean-atmosphere exchange

Cloud Microphysical and Chemical Processes

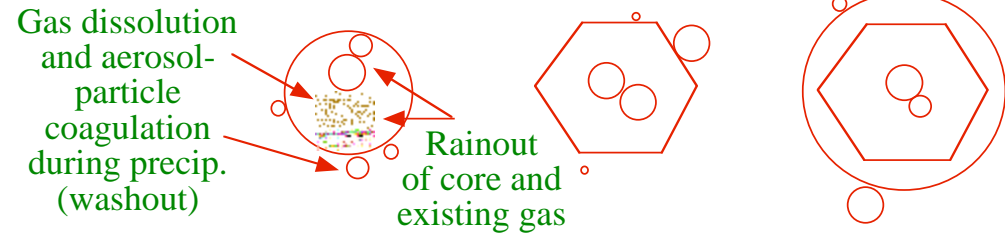
Condensation/deposition of water vapor onto aerosol particles

Coagulation: Aerosol-aerosol Aerosol-liquid Aerosol-ice Aerosol-graupel
 Liquid-liquid Liquid-ice Liquid-graupel Ice-ice
 Ice-graupel Graupel-graupel

Gas dissolution, aqueous chemistry, hom.-het. freezing, contact freezing



Shrinkage, precipitation, rainout, and washout



Cloud evaporation --> interstitial aerosol plus evaporated cores



Size Distributions Treated

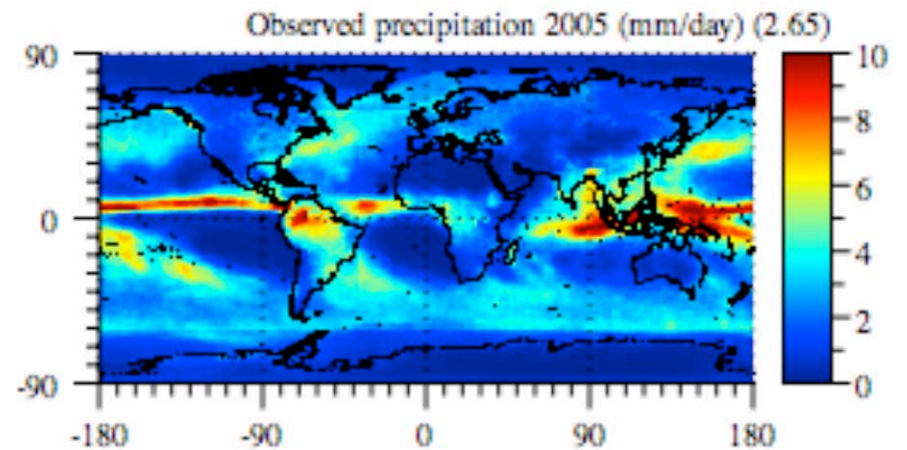
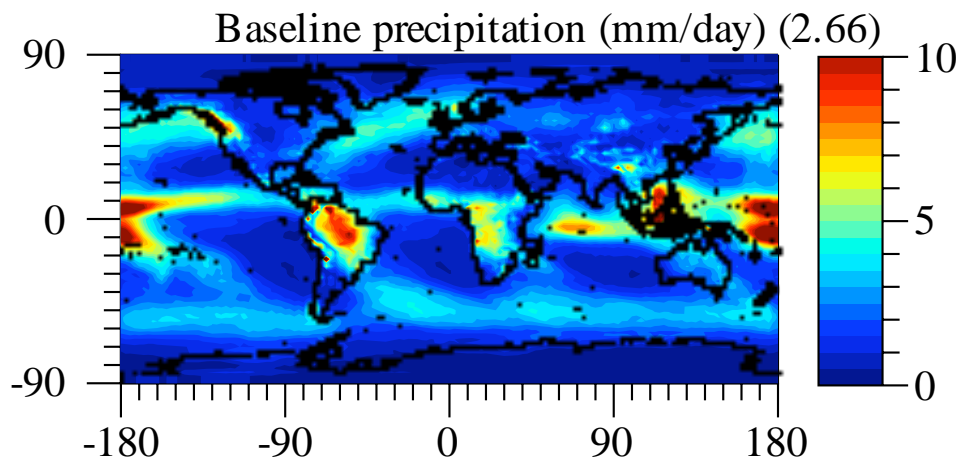
FF Soot	Intern.-mix	Liq.	Ice	Graupel
Number	Number	Number	Number	Number
BC	BC	BC	BC	BC
POM	POM	POM	POM	POM
SOM	SOM	SOM	SOM	SOM
H ₂ O-h	H ₂ O-h	H ₂ O-h	H ₂ O-h	H ₂ O-h
H ⁺	H ⁺	H ⁺	H ⁺	H ⁺
H ₂ SO ₄	H ₂ SO ₄	H ₂ SO ₄	H ₂ SO ₄	H ₂ SO ₄
HSO ₄ ⁻	HSO ₄ ⁻	HSO ₄ ⁻	HSO ₄ ⁻	HSO ₄ ⁻
NH ₄ ⁺	NH ₄ ⁺	NH ₄ ⁺	NH ₄ ⁺	NH ₄ ⁺
NO ₃ ⁻	NO ₃ ⁻	NO ₃ ⁻	NO ₃ ⁻	NO ₃ ⁻
Cl ⁻	Cl ⁻	Cl ⁻	Cl ⁻	Cl ⁻
NH ₄ NO ₃	NH ₄ NO ₃	NH ₄ NO ₃	NH ₄ NO ₃	NH ₄ NO ₃
(NH ₄) ₂ SO ₄	(NH ₄) ₂ SO ₄	(NH ₄) ₂ SO ₄	(NH ₄) ₂ SO ₄	(NH ₄) ₂ SO ₄
	Na ⁺	Na ⁺	Na ⁺	Na ⁺
	Soildust	Soildust	Soildust	Soildust
	Pollen/spore	Pollen/spore	Pollen/spore	Pollen/spore
		H ₂ O(l)	H ₂ O(ice)	H ₂ O(ice)

Fossil- and Bio-fuel Emissions (Tg/yr)

	Fossil-Fuel	Biofuel
BC	3.2	1.6
POC	2.4	6.5
S(VI)	0.03	0.3
Na ⁺		0.023
K ⁺ as Na ⁺		0.14
Ca ²⁺ as Na ⁺		0.18
Mg ²⁺ as Na ⁺		0.08
NH ₄ ⁺		0.018
NO ₃ ⁻		0.16
Cl ⁻		0.30
H ₂ O-hydrated	calculated	calculated
H ⁺	calculated	calculated
		+ 43 gases

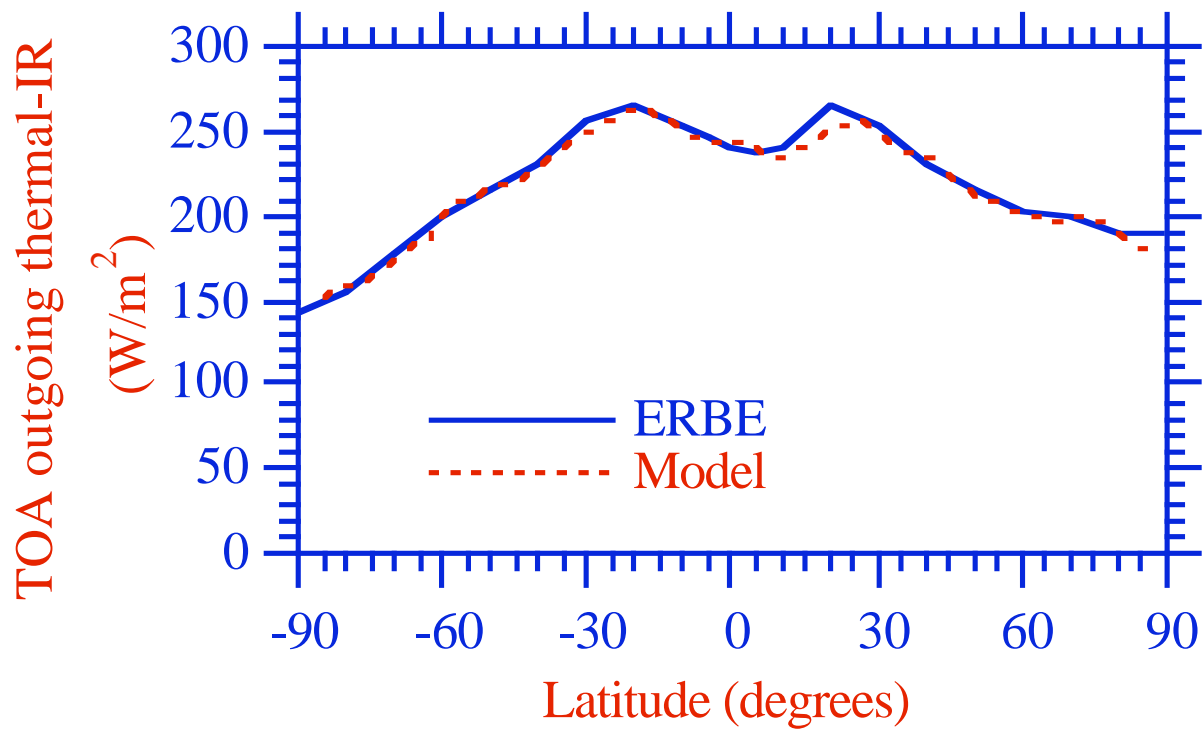
BC/POC from Bond et al. (2004); other emis factors Andreae, Ferek

Modeled vs. Measured Annual Precipitation



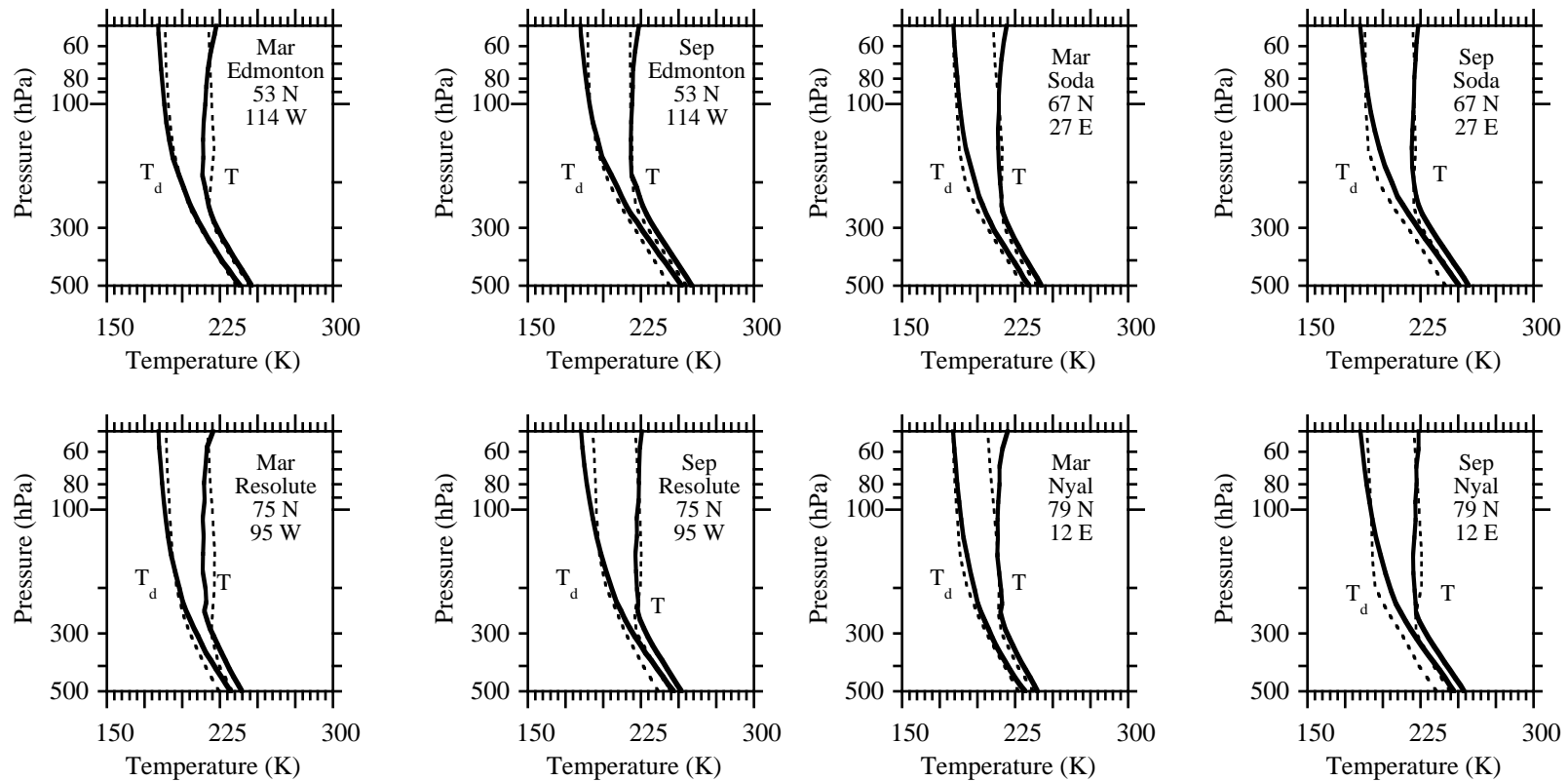
Data from Huffman et al.

Modeled vs. Measured Thermal-IR



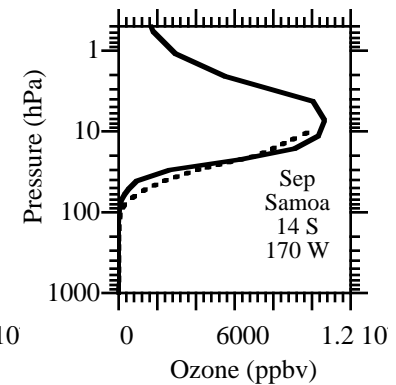
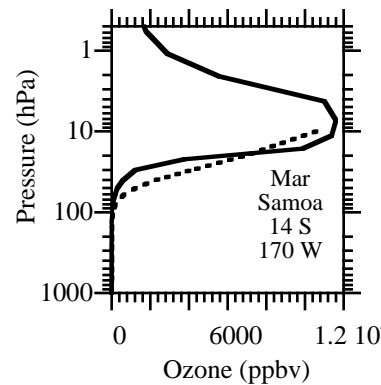
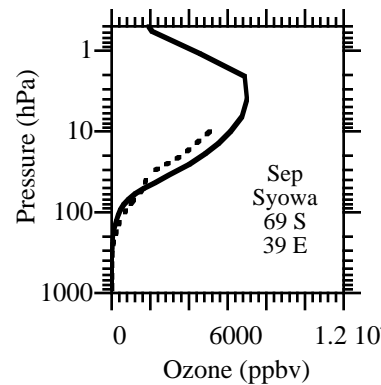
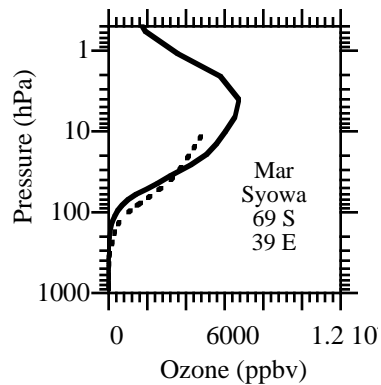
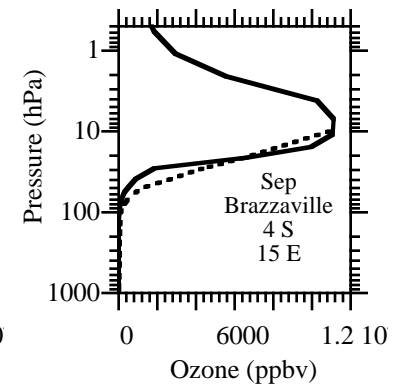
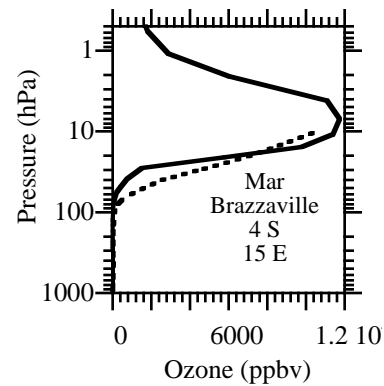
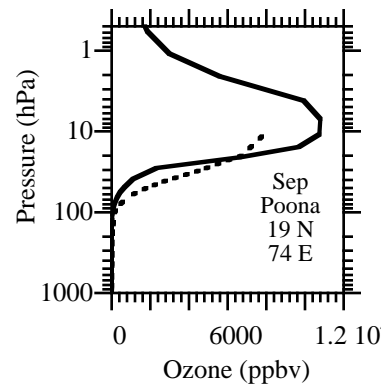
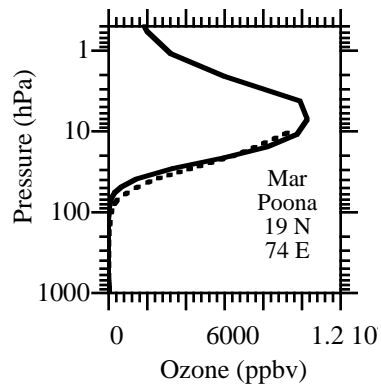
Data from Kiehl et al., 1998

Modeled vs. Measured Paired in Space Monthly T and T_d



Data from FSL (2008)

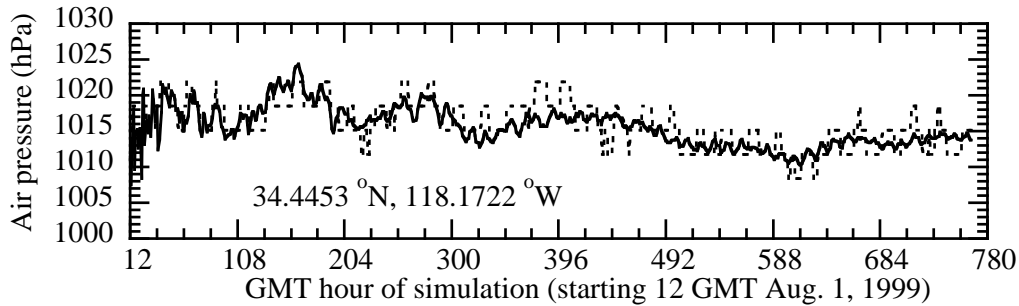
Modeled vs. Measured Paired in Space Monthly Climatological Ozone



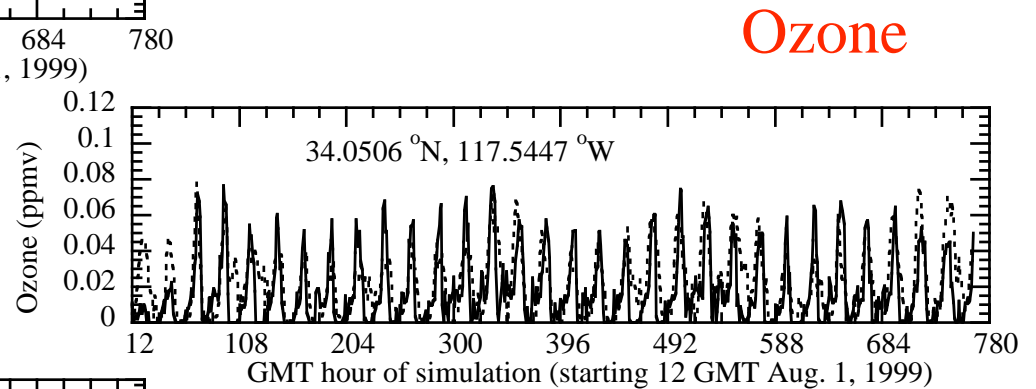
Data from Logan et al. (1999)

30-Day Weather Predictions vs. Data

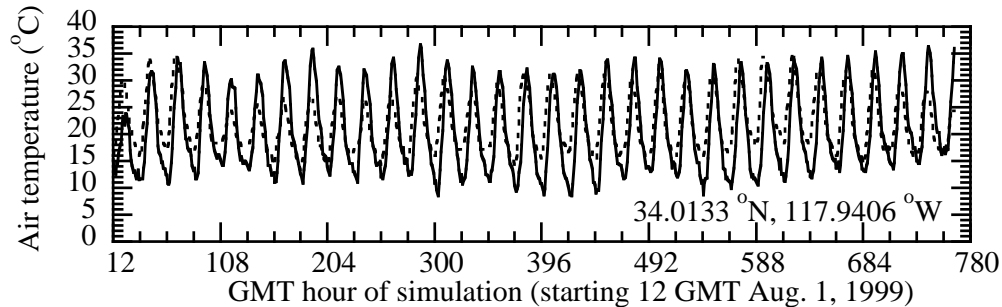
Results with no model spinup or data assimilation



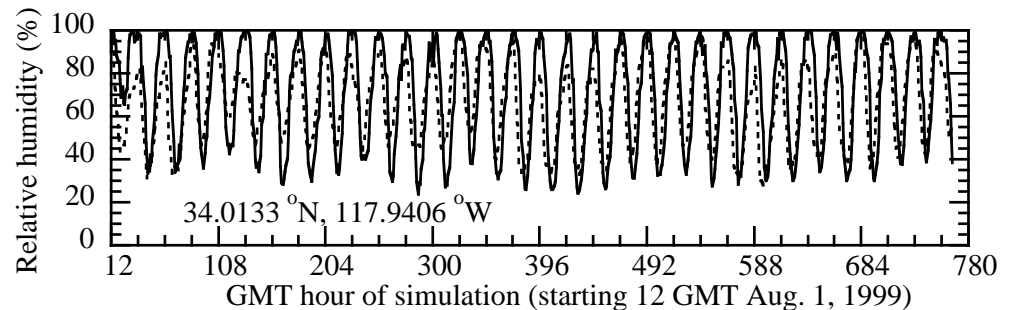
Pressure



Ozone



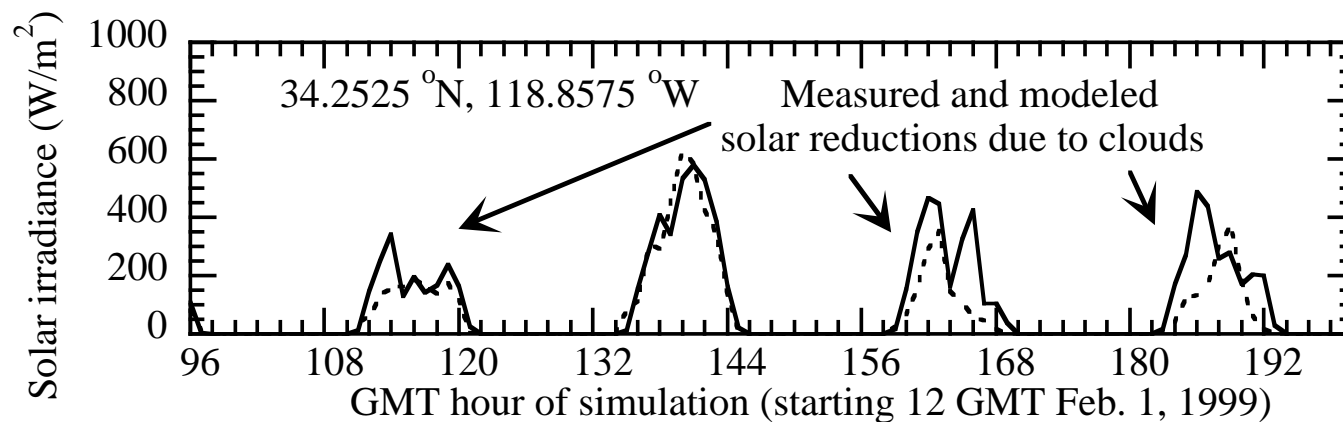
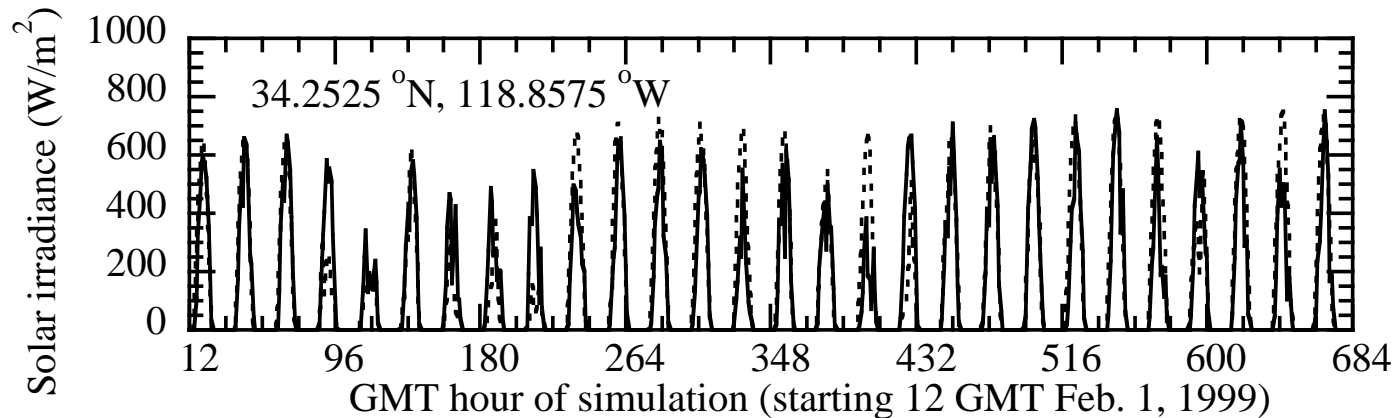
Temperature



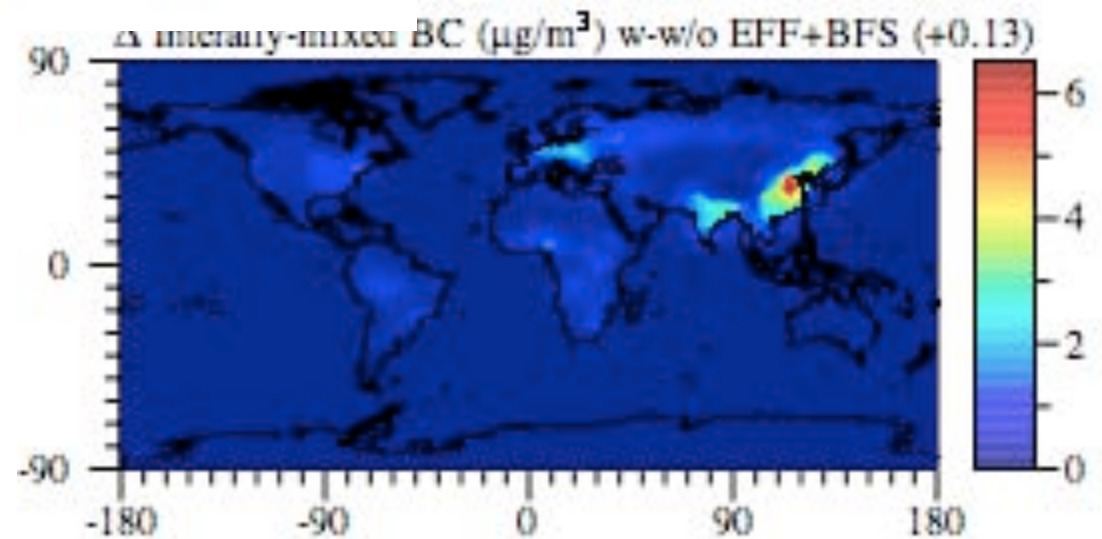
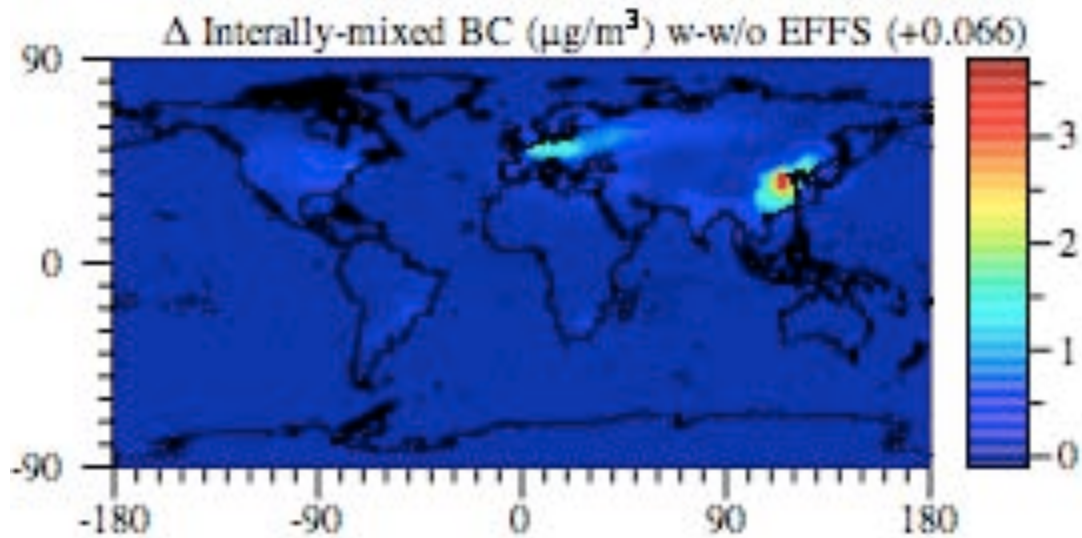
RH

Model vs. Measured Solar Radiation

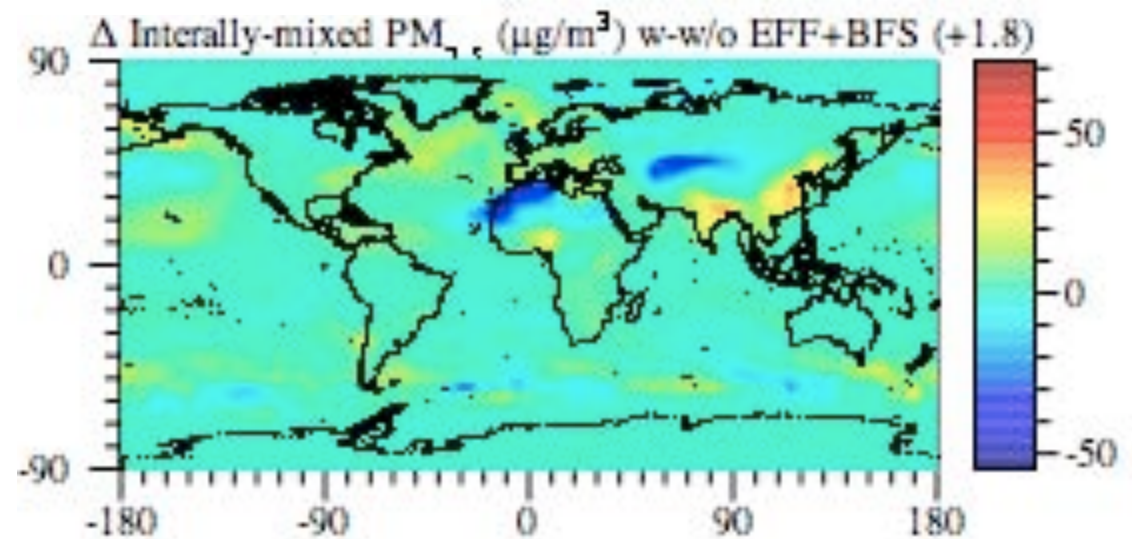
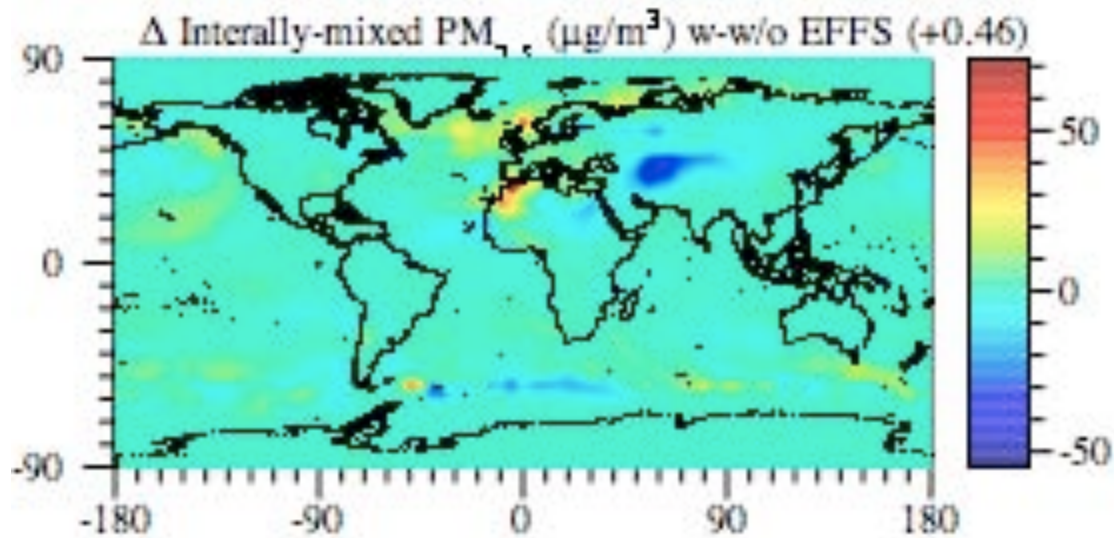
Model predicted the location and magnitude of cloud reduction of sunlight for four days in a row



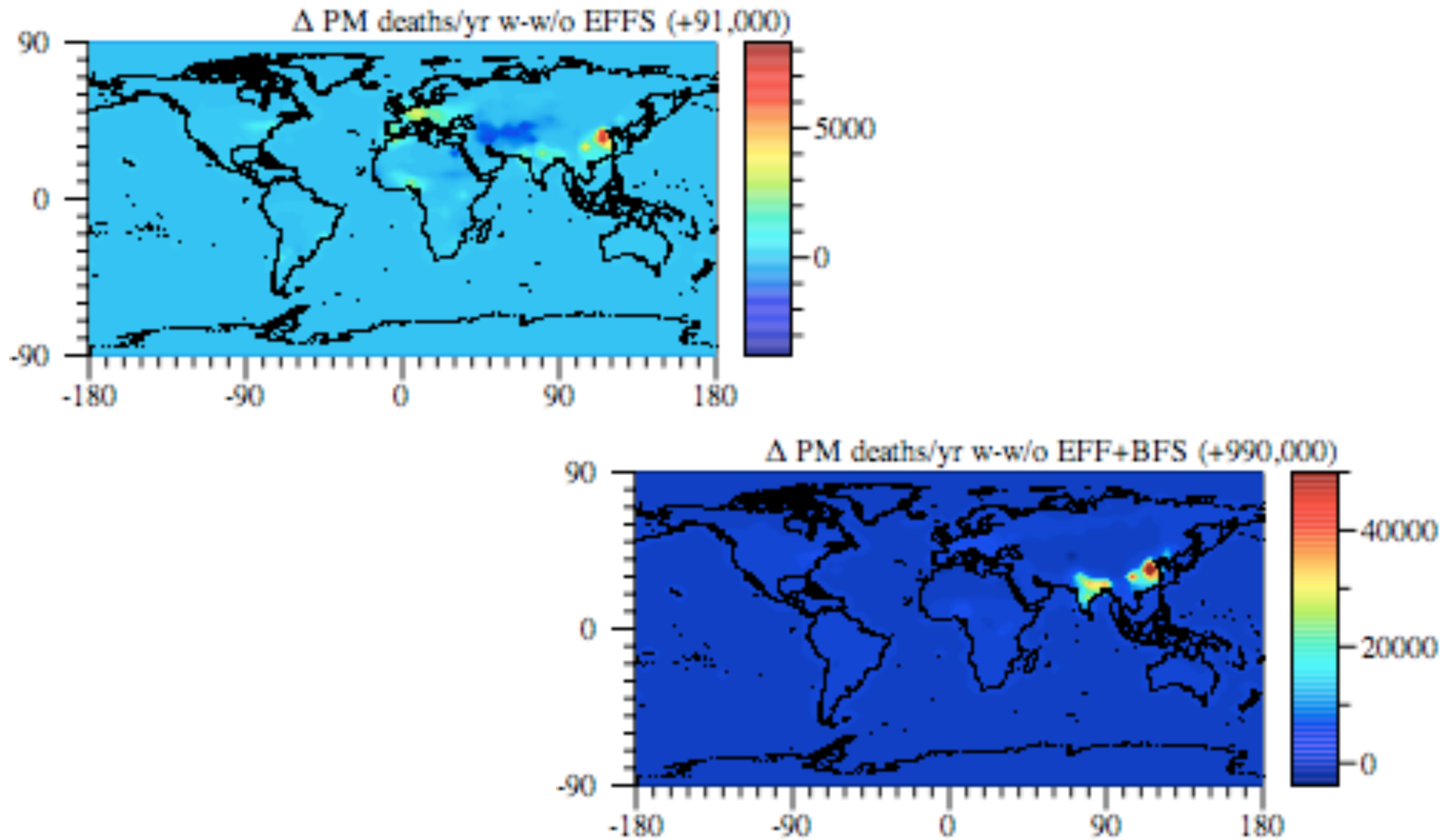
BC Changes Due to (a) FF (b) FF+ BF Soot after 6 years



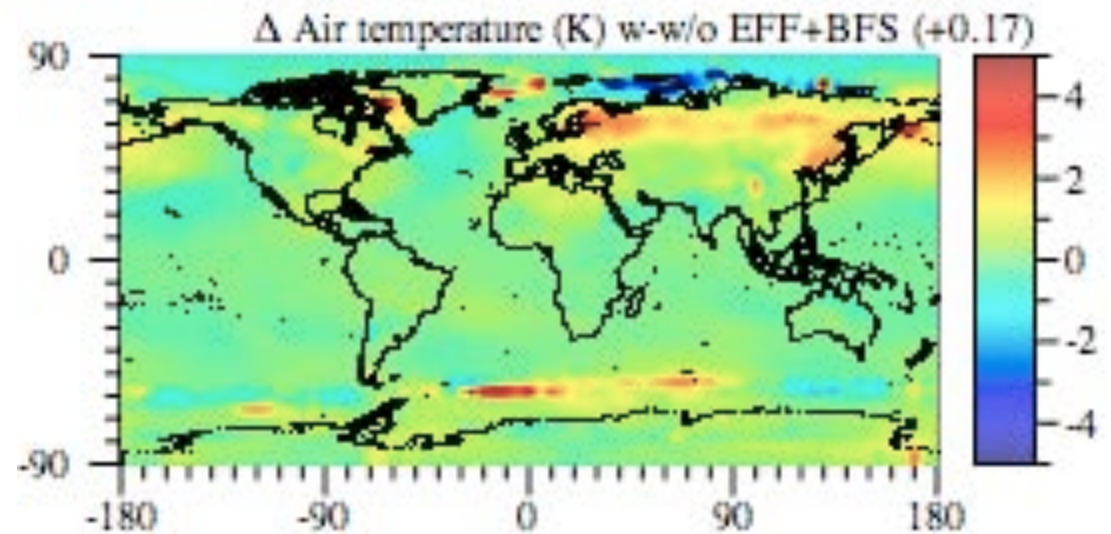
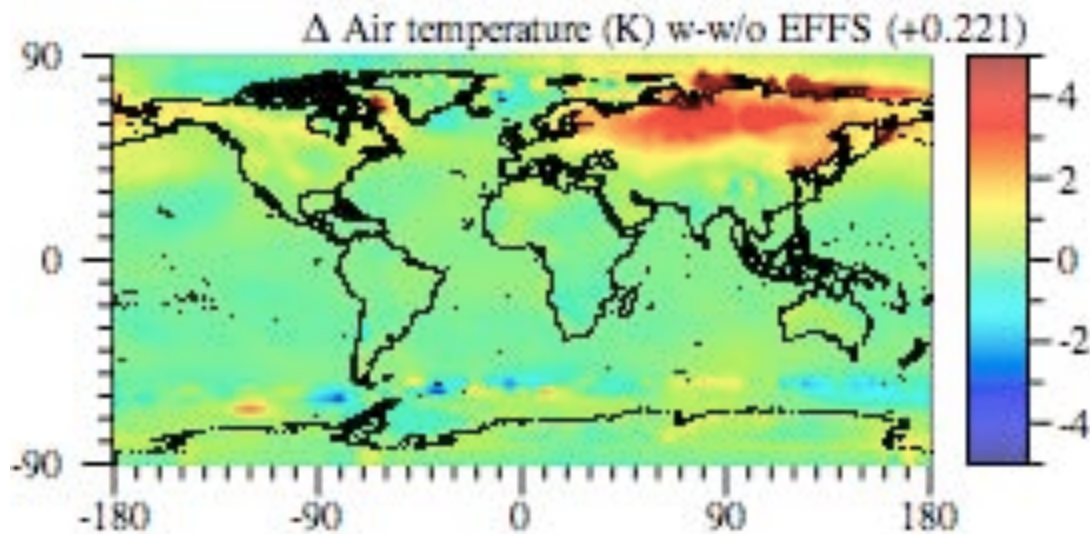
PM_{2.5} Changes Due to (a) FF (b) FF+ BF Soot after 6 years



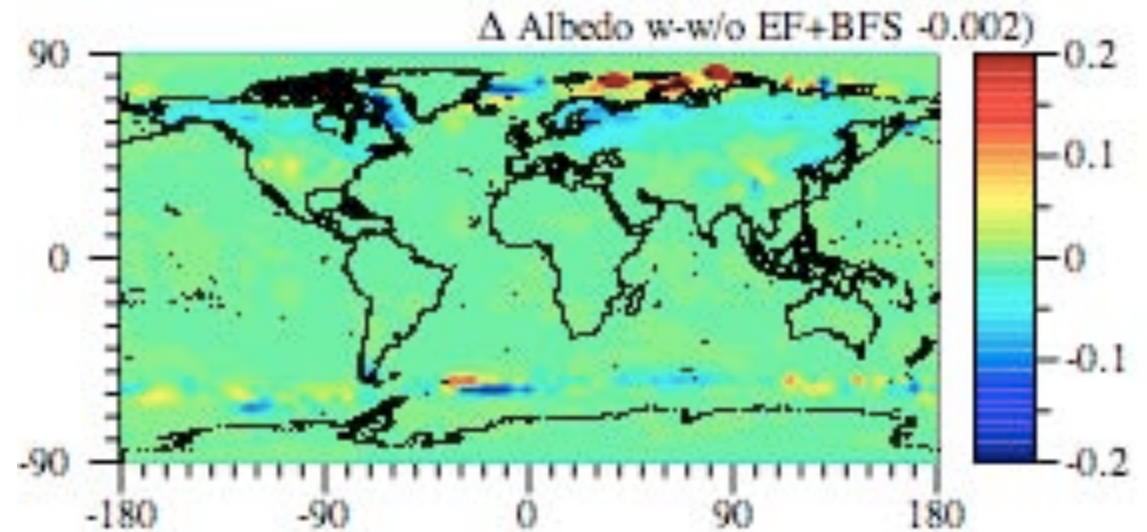
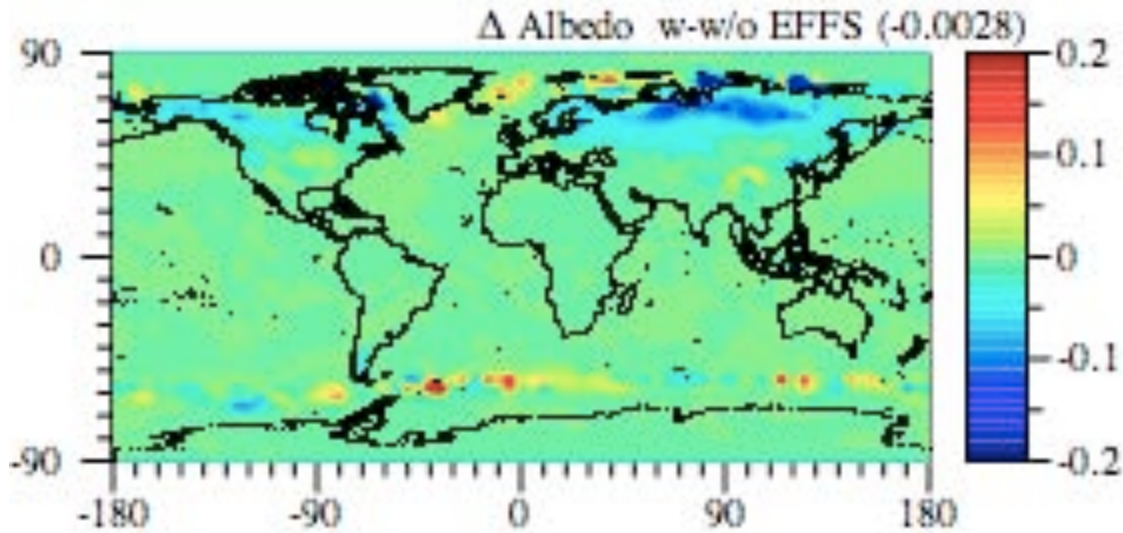
PM Deaths/yr Due to (a) FF (b) FF+ BF Soot



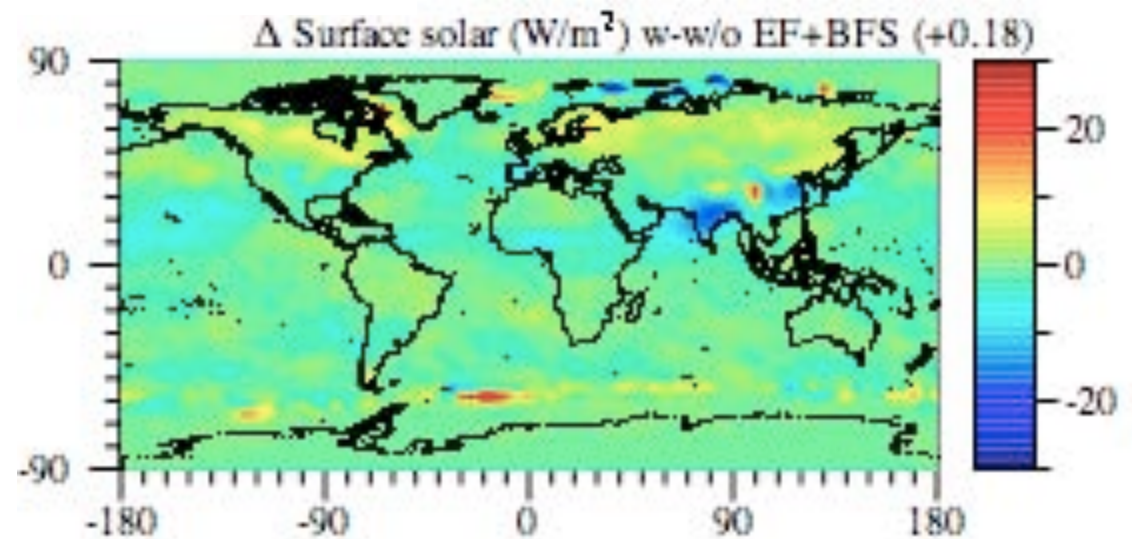
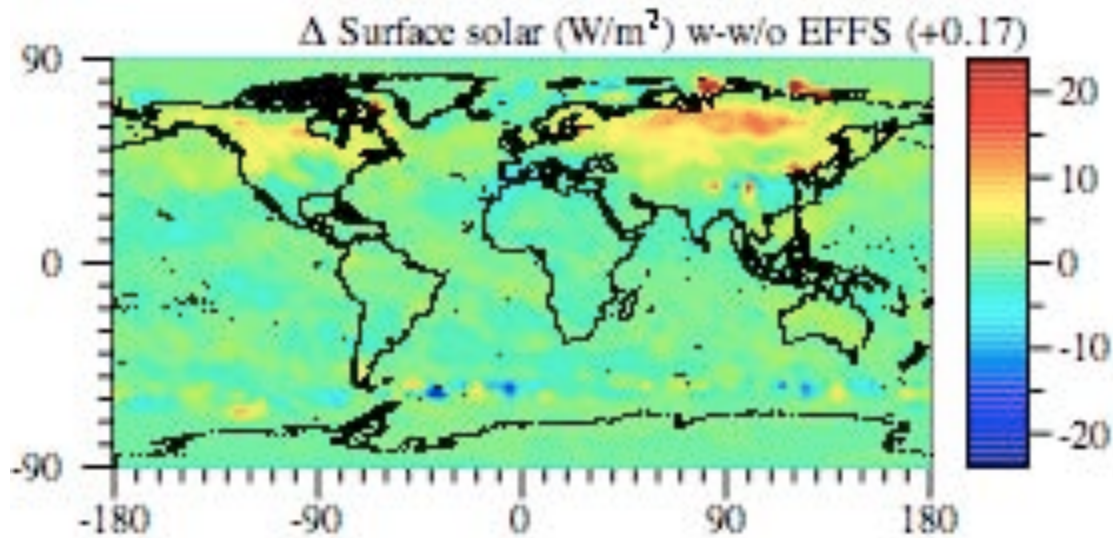
Temperature Changes Due to FF and FF+ BF Soot after 6 years



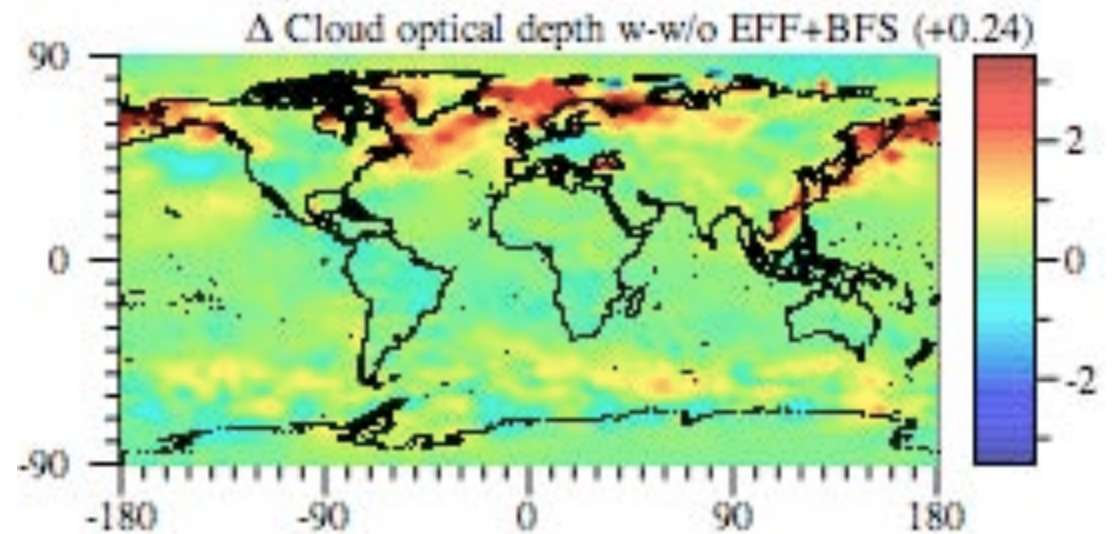
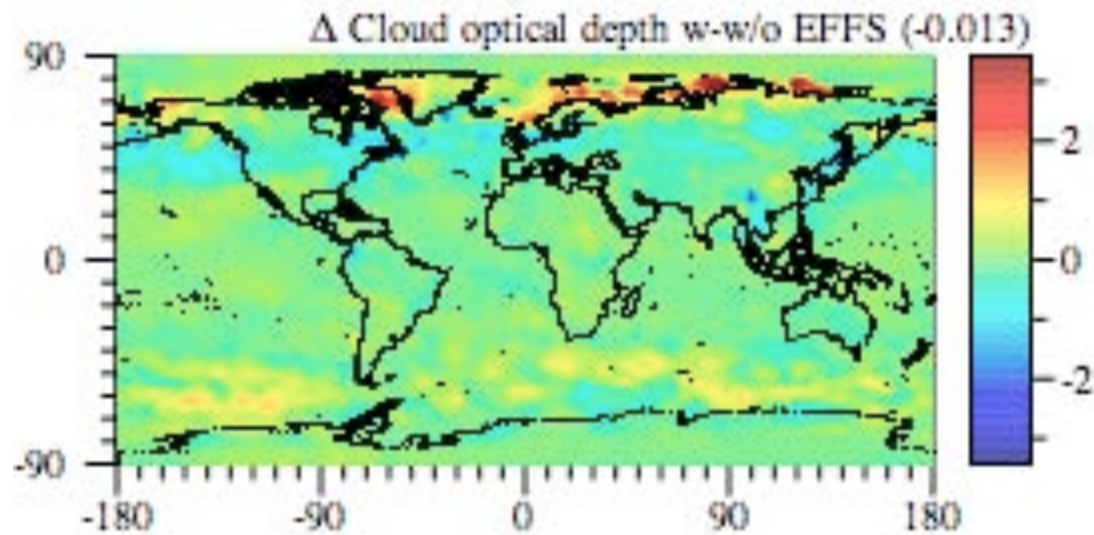
Albedo Change Due to FF and FF+ BF Soot



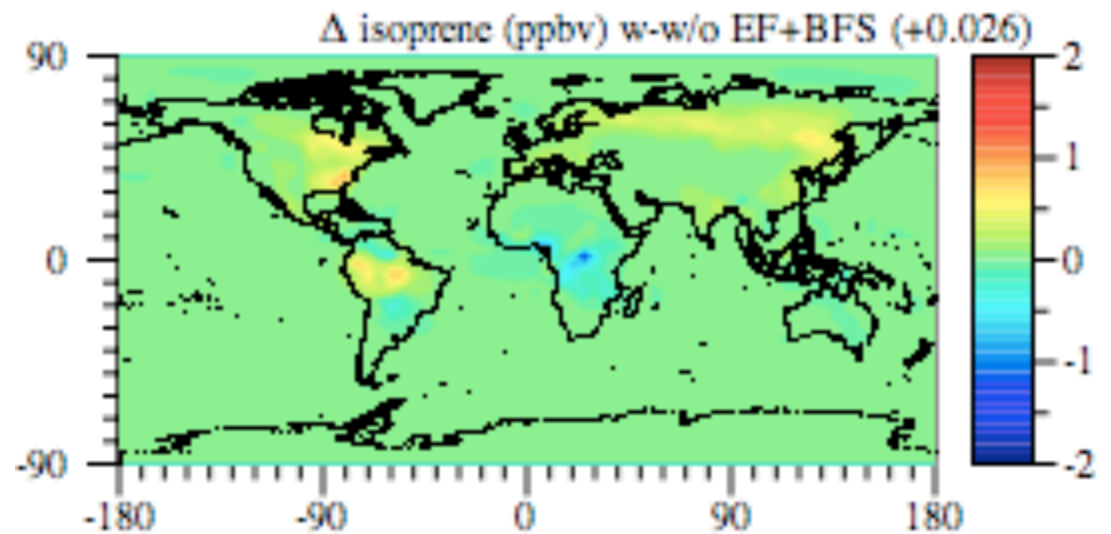
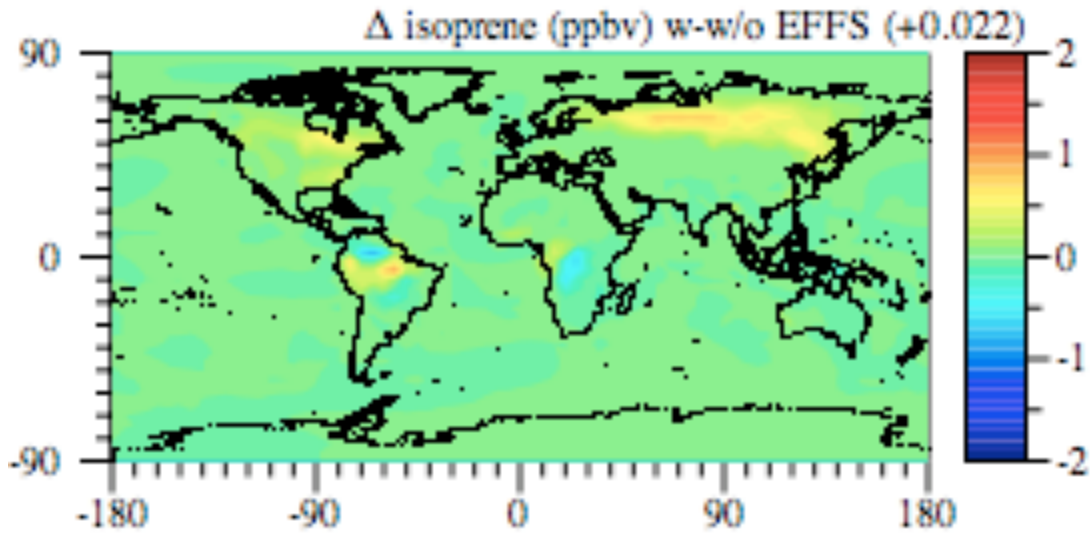
Surface Solar Changes Due to FF and FF+BF Soot



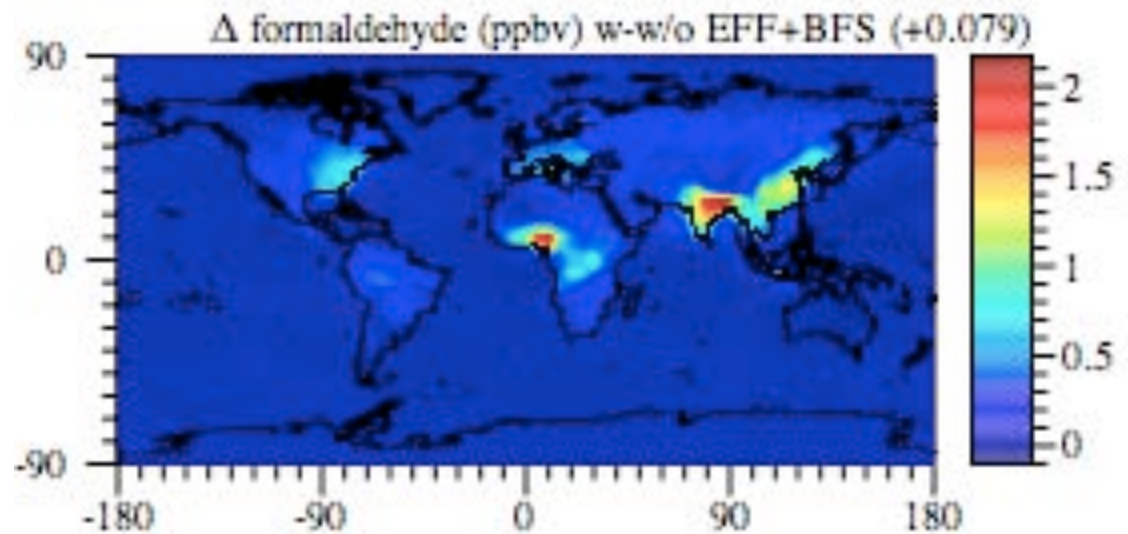
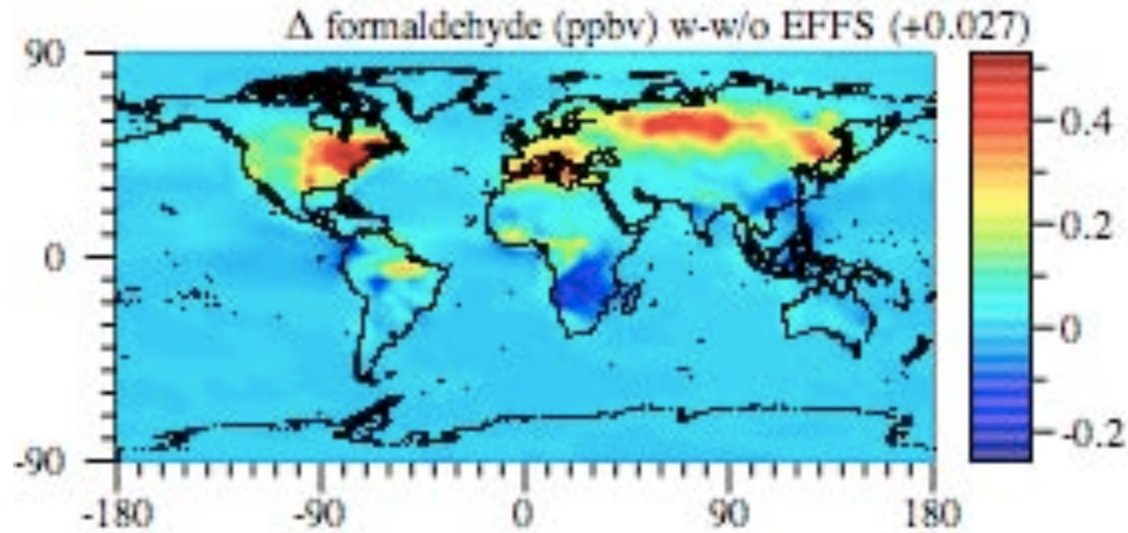
Cloud OD Changes Due to FF and FF+ BF Soot



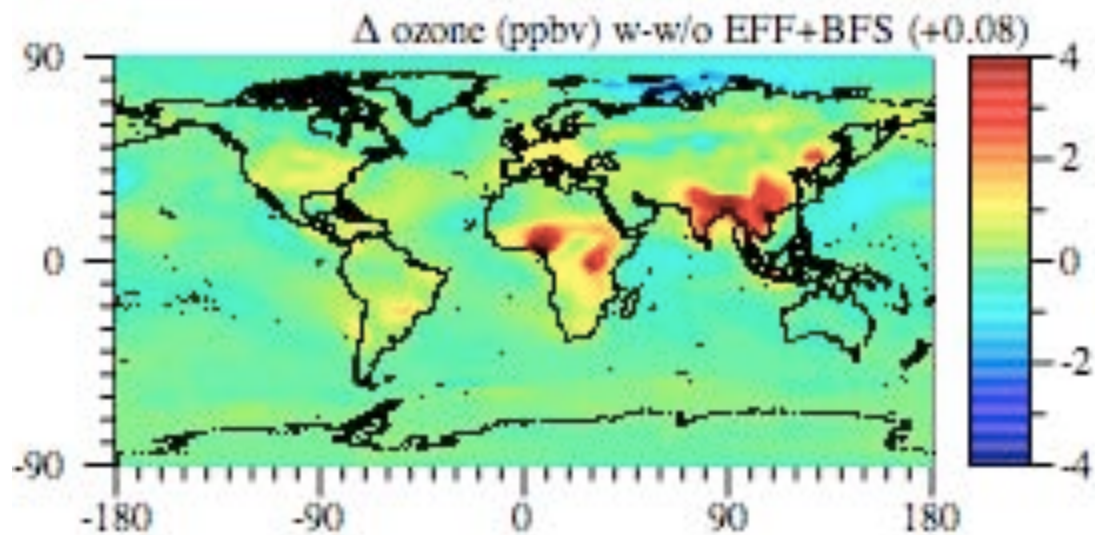
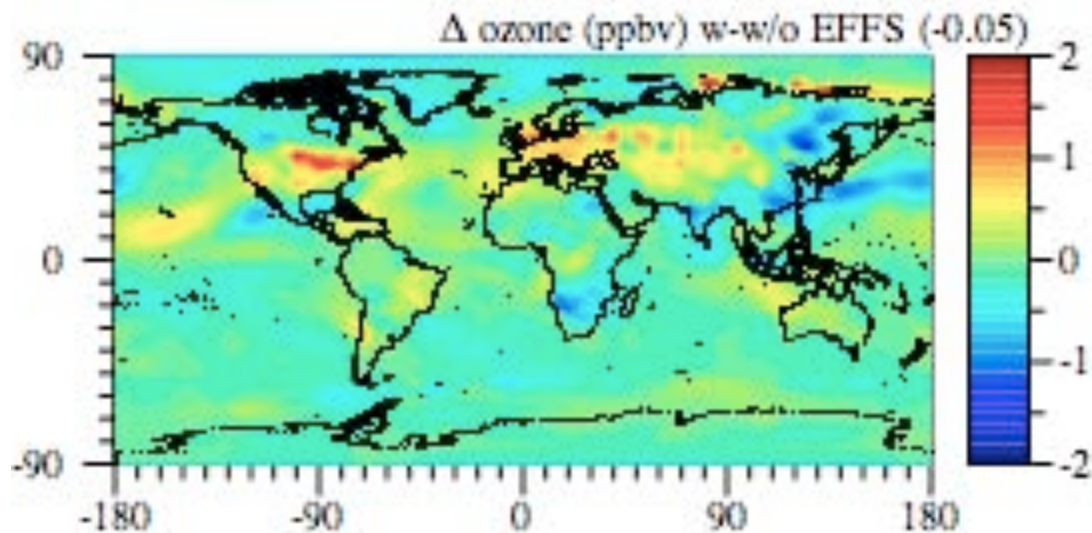
Isoprene Changes Due to FF and FF+ BF Soot



HCHO Changes Due to FF and FF+ BF Soot



Ozone Changes Due to FF and FF+ BF Soot



Summary

Simulations of the effect of controlling fossil-fuel versus biofuel soot were run. Fossil-fuel soot controls were assumed to eliminate BC, POM, and S(VI) particulate matter (e.g., through a particle trap). Biofuel soot controls (elimination of burning) were assumed to eliminate all gas and particle emissions from biofuels.

Fossil-fuel soot alone caused a warming similar to that of fossil-fuel + biofuel soot, indicating that biofuel soot may have a net neutral effect on temperatures since the cooling particle components from biofuel soot offset the warming components.

Biofuel soot, though, caused a worldwide outdoor premature death rate on the order of one million people per year, about 10 times that of fossil-fuel soot. As such, although, control of biofuel soot may reduce temperatures less than control of fossil-fuel soot, its control will reduce air pollution mortality more.