

US EPA ARCHIVE DOCUMENT

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

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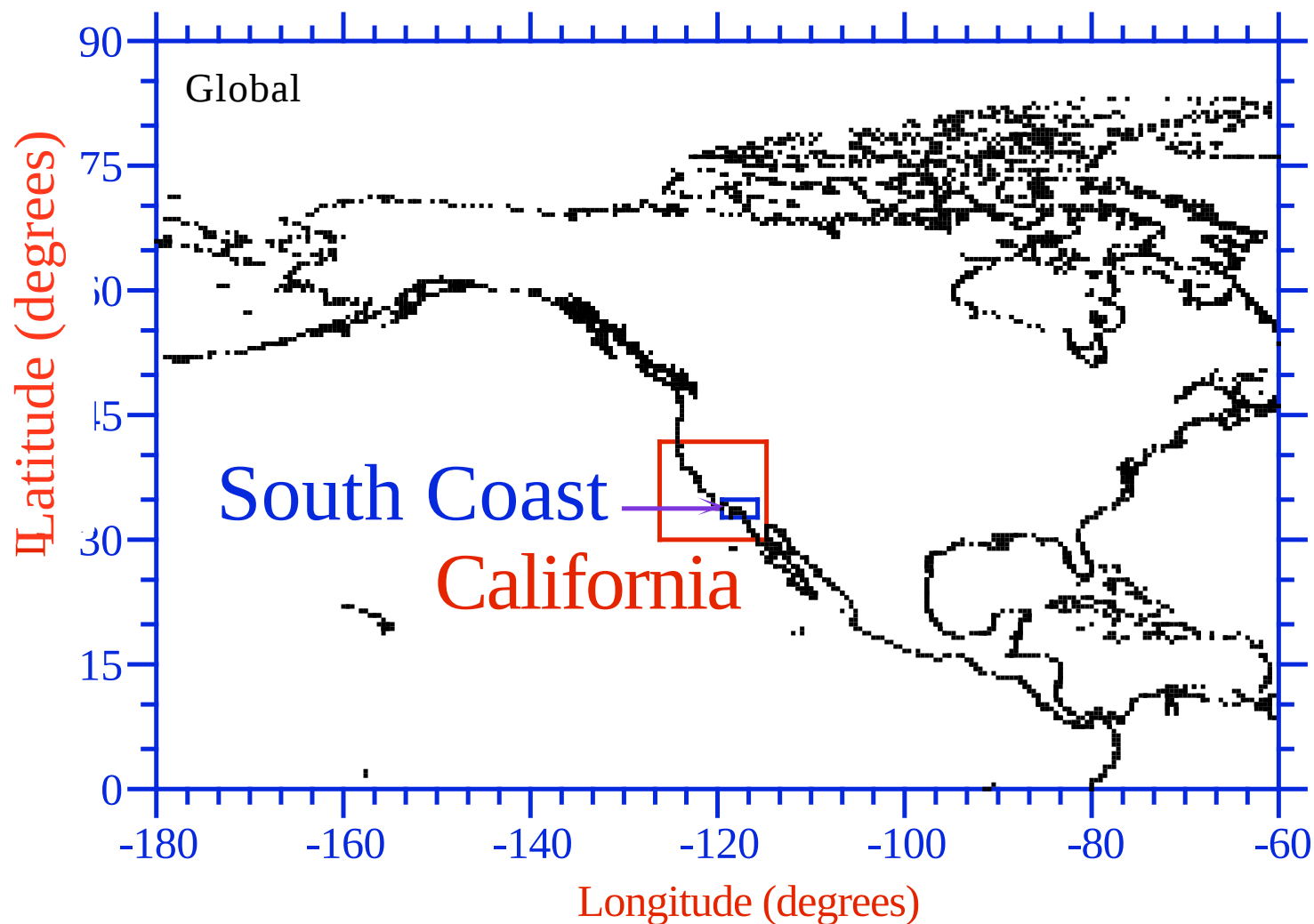
Environmental Protection Agency

Research Triangle Park, NC

Feb. 21, 2007

GATOR-GCMOM

Global-through-urban nesting of
meteorology/gases/aerosols starting 1999-2001



GATOR-GCMOM

Gas processes

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

Aerosol processes

- Emission
- 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

- Time-dependent 3-D size-res. clouds
- 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

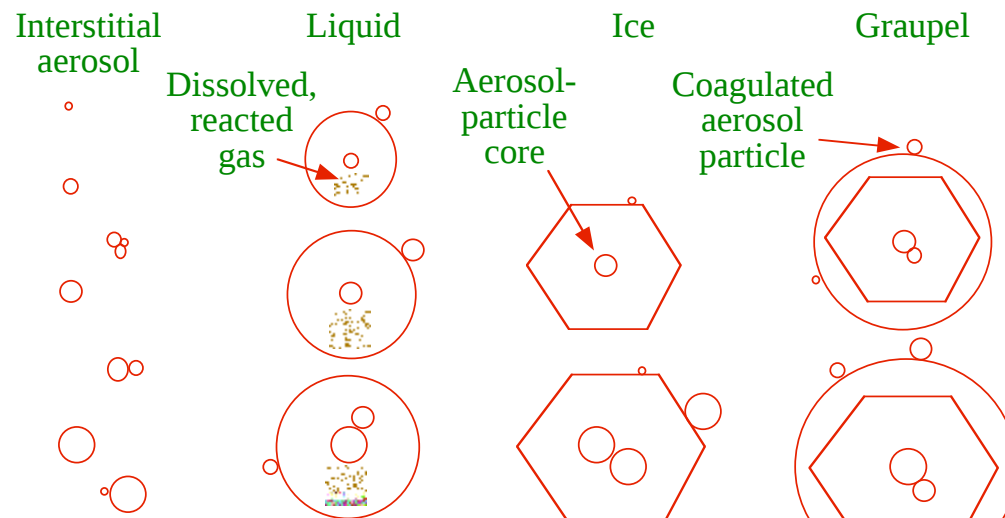
- Soil, water, snow, sea ice, vegetation, road, roof temperatures/moisture
- Ocean 2-D dynam., 3-D diffus/chem.
- Ocean-atmosphere exchange

Cloud Microphysical and Chemical Processes

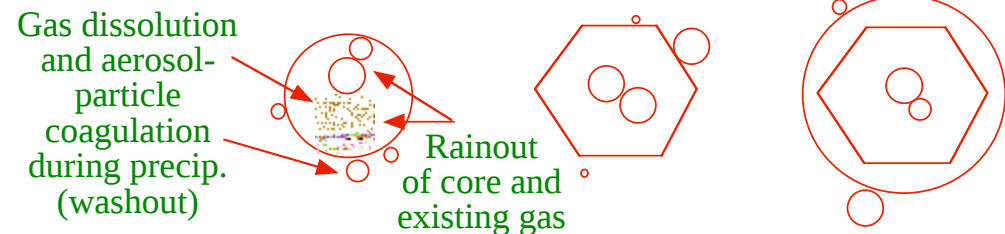
Condensation/deposition of water vapor onto aerosol particles

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



Natural Emissions Treated

Lightning NO, N₂O

Sea spray constituents

Ocean bacteria

DMS from phytoplankton

Soil dust

Biogenic gases from vegetation (isoprene, monoterpenes, NMVOC)

NO_x from soils

Pollen

Spores

Land bacteria

Natural fire gas and particle emissions

Volcanic emissions

Lightning NO, N₂O Emissions

$$\frac{dQ_{b,m}}{dt} = \left[\sum_{J=1}^{N_H} \sum_{j=1}^{N_C} \sum_{I=J}^{N_H} \sum_{i=j}^{N_C} B_{Ii,Jj} \frac{(v_{Ii} n_{Ii,t} n_{Jj,t-h} + v_{Jj} n_{Ii,t-h} n_{Jj,t})}{v_{Ii} + v_{Jj}} \Delta Q_{Ii,Jj} \right]_m$$

Charge separation per unit volume of air in model layer

N_H = number of hydrometeor distributions

N_C = number of size bins in each hydrometeor distribution

n = number concentration of hydrometeor particles

v = single-particle volume

B = bounceoff kernel

ΔQ = charge separation per bounceoff

Pollen, Spore, Bacteria Emissions

$$E_{po,i} = E_{po,max} R_{TKE} R_{h,po} R_{m,po} R_{n,i,po} \sum_{j=1}^{N_s} L_{T,j} f_{v,j}$$

$$E_{sp,i} = E_{sp,max} R_{TKE} R_{RH} R_{m,sp} R_{n,i,sp} \sum_{j=1}^{N_s} L_{T,j} f_{v,j}$$

$$E_{lb,i} = E_{lb,max} R_{TKE} R_{m,lb} R_{n,i,lb} \sum_{j=1}^{N_s} f_{v,j}$$

R_{TKE} = TKE-dependent emission factor

R_{RH} = RH-dependent emission factor

R_h = hour of day-dependent emission factor

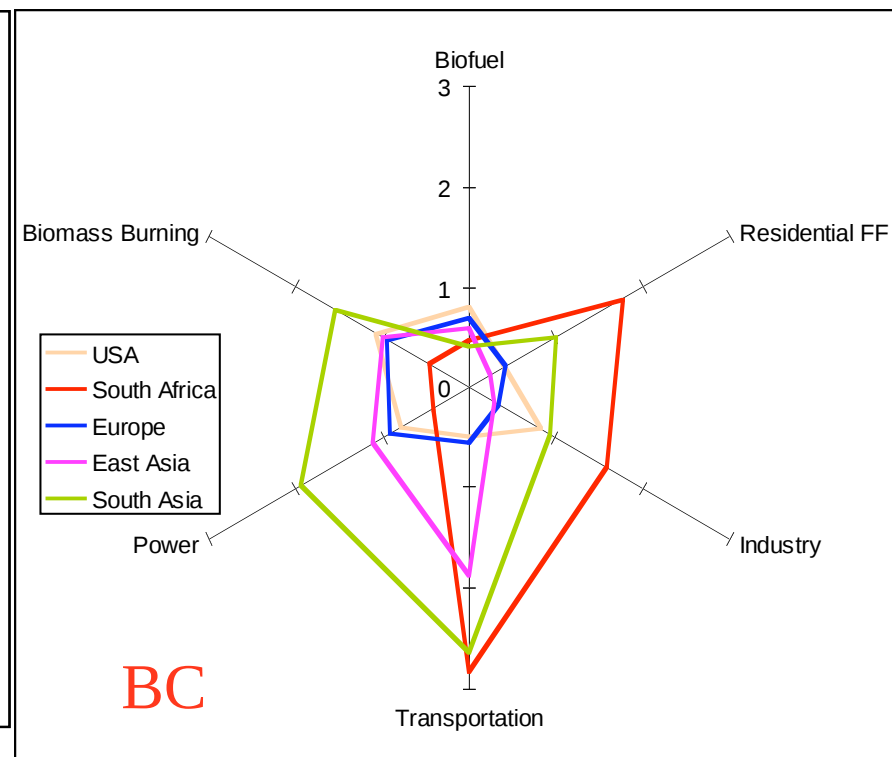
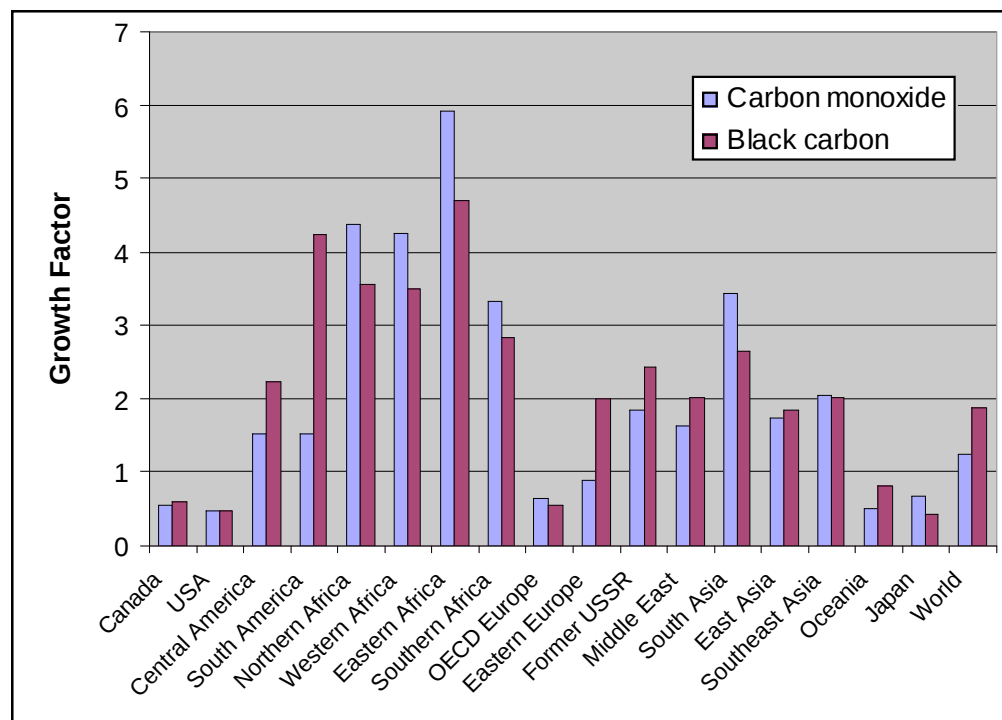
R_m = month-dependent emission factor

R_n = size-dependent emission factor

N_s = number of soil types in each grid cell

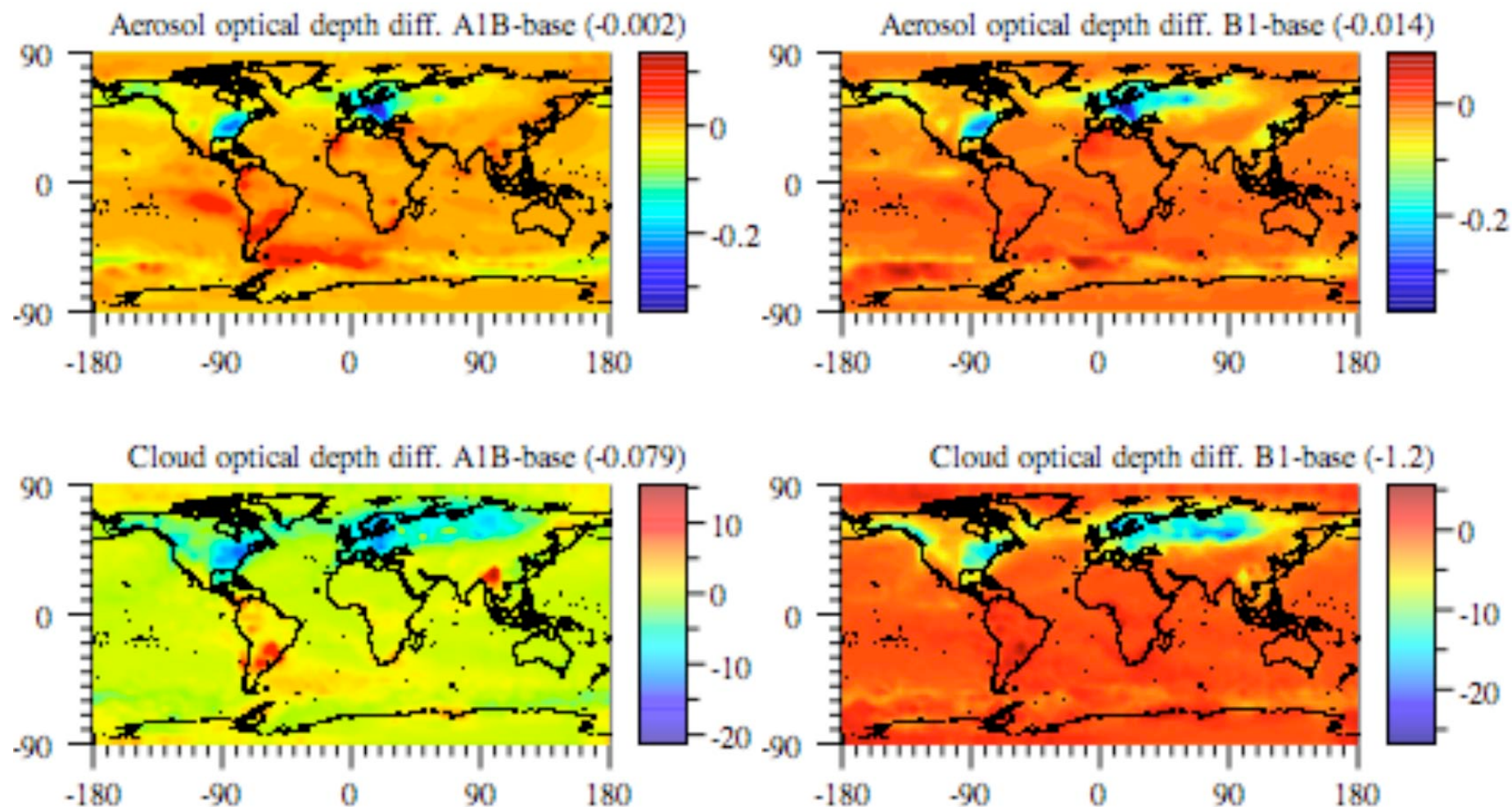
L_T, f_v = one-sided leaf-area index, vegetation fraction

2030 A1B CO/BC Growth Factors

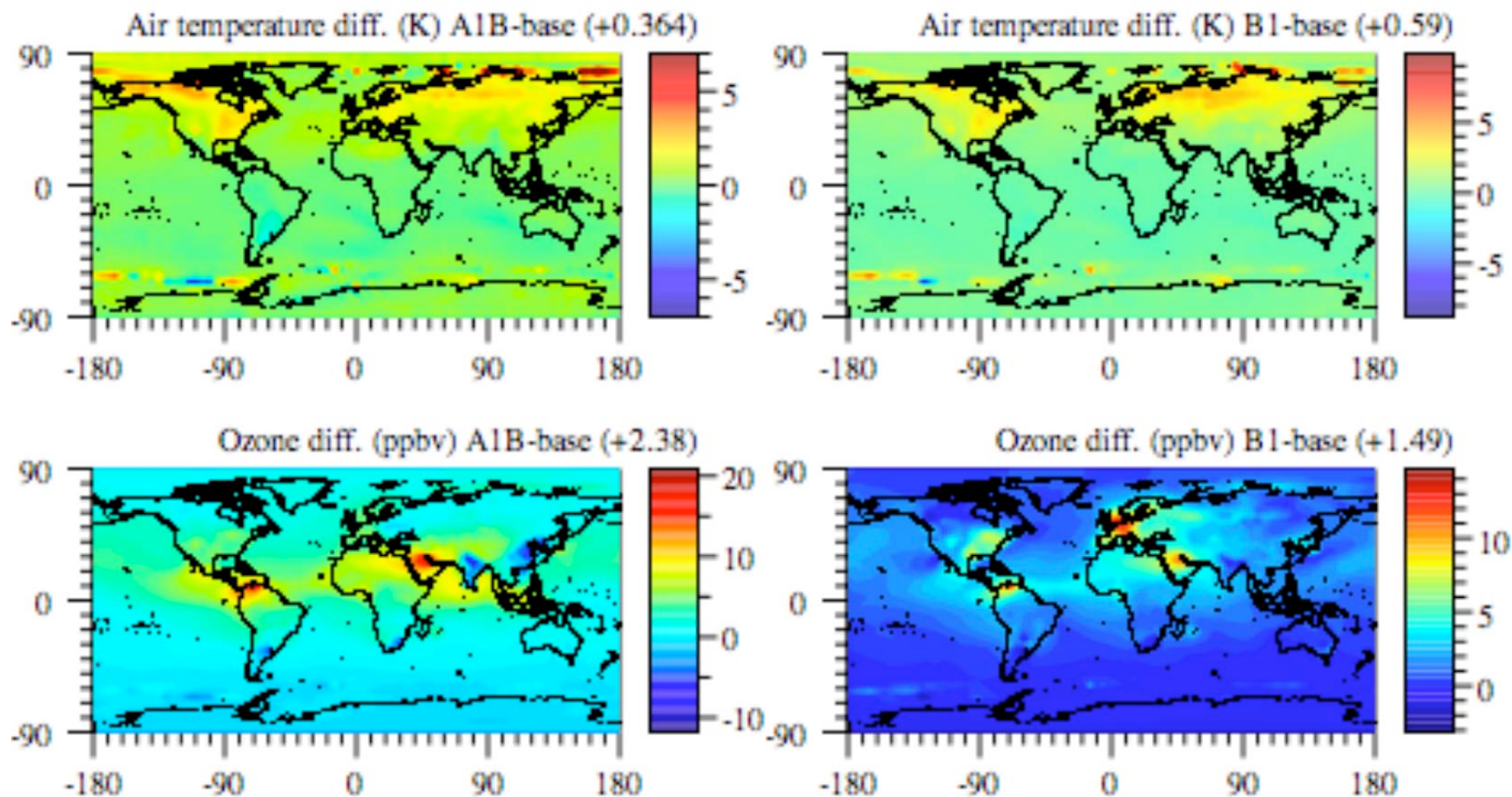


D.G. Streets

Differences 2002-2030 Under A1B and B1 Scenarios

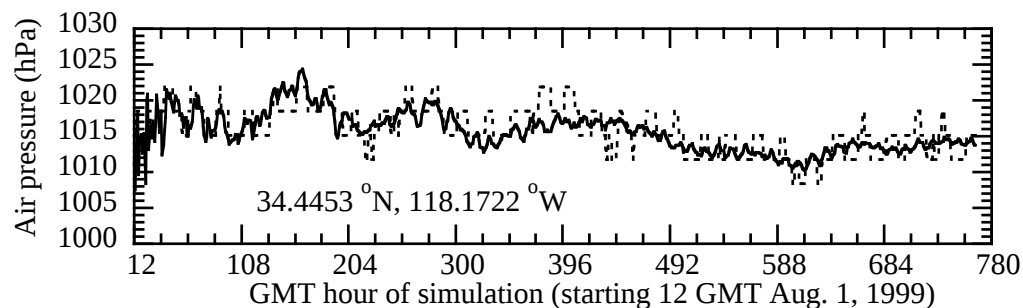


Differences 2002-2030 Under A1B and B1 Scenarios

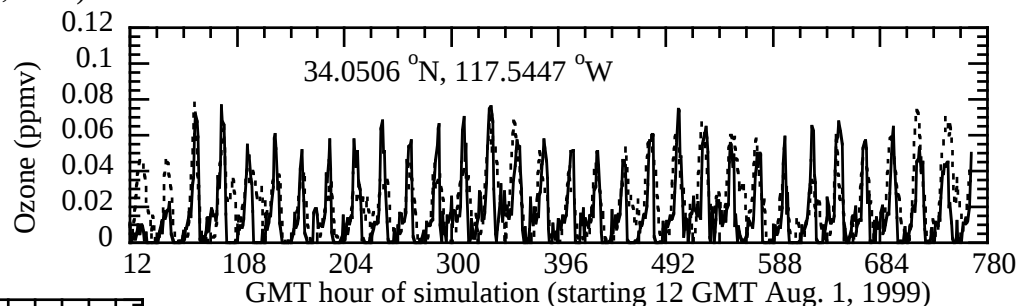


30-Day Weather Predictions vs. Data

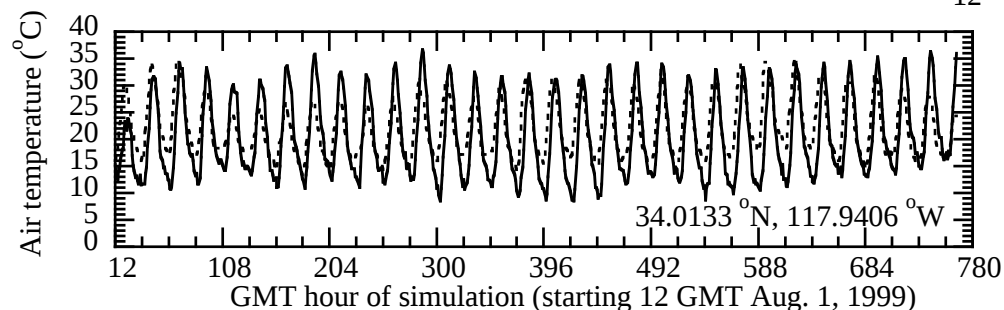
Results with no model spinup or data assimilation



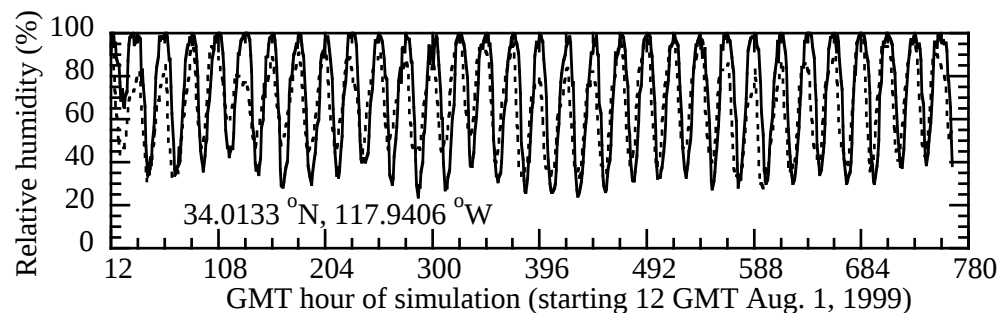
Pressure



Ozone



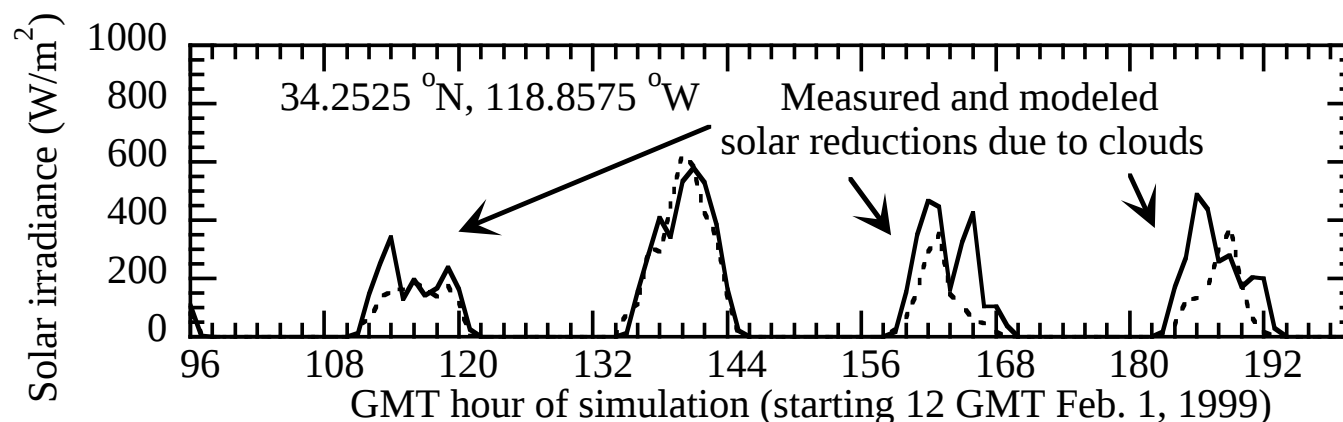
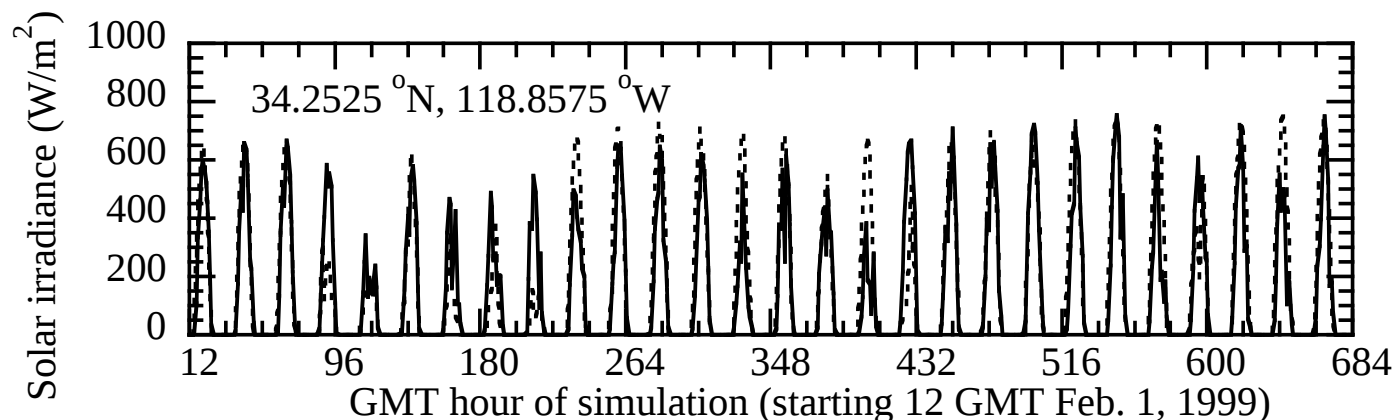
Temperature



RH

Model vs. Measured Solar Radiation

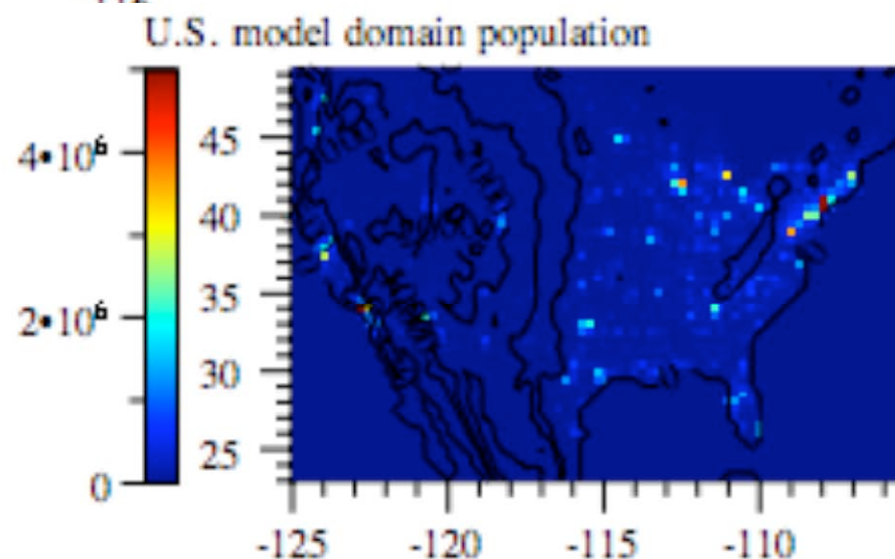
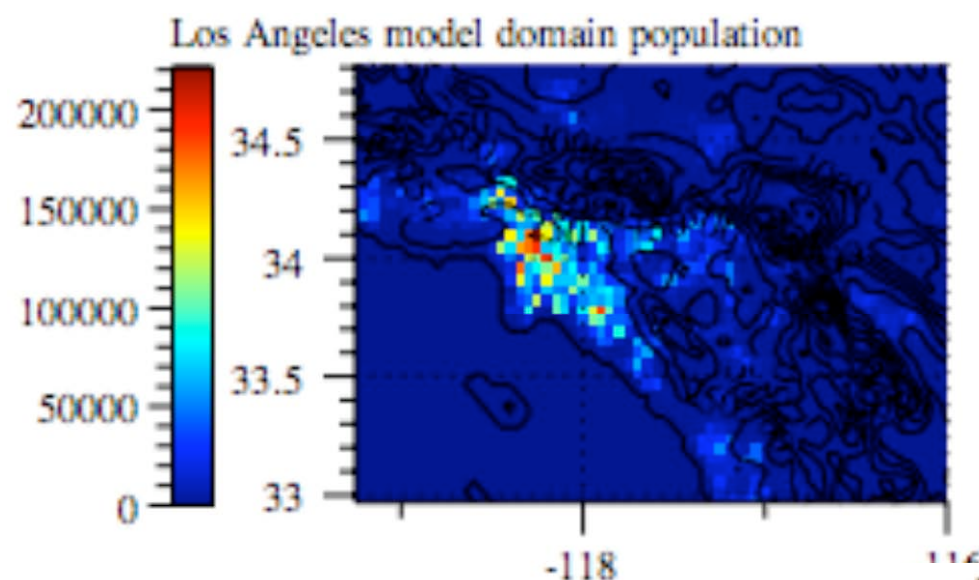
Model predicted the location and magnitude of cloud reduction of sunlight for four days in a row



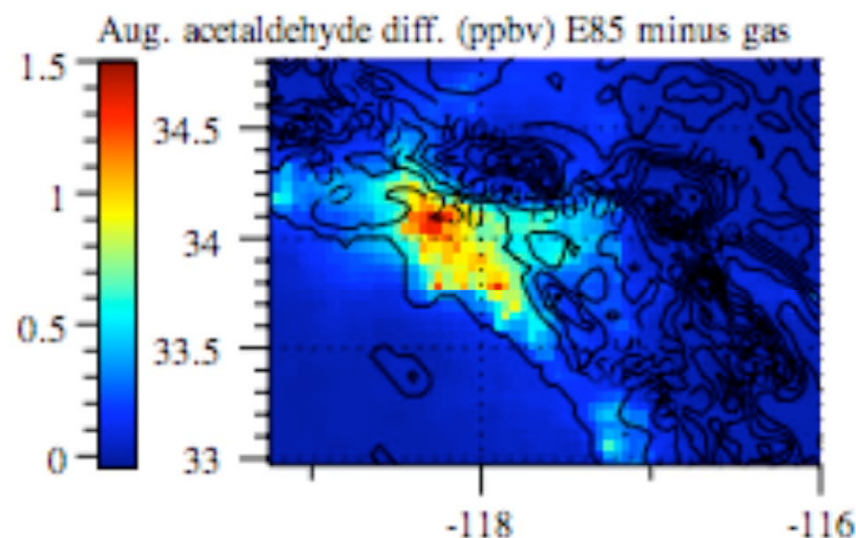
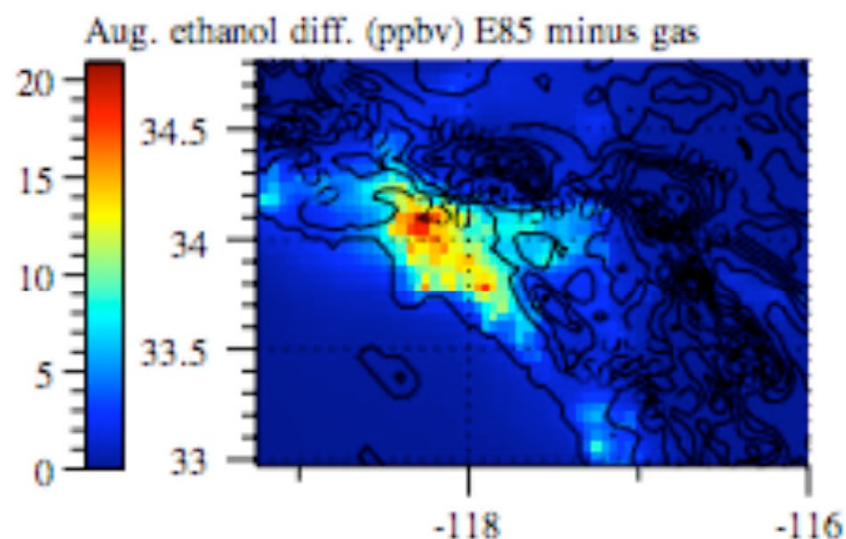
Emission Differences E85:Gas From Field/Laboratory Data

	Percent change
Oxides of nitrogen	-30 (-59 to +33)
Carbon monoxide	+5 (-33 to +320)
Total organic gas	+22 (+38 to +95)
Methane	+43 (+43 to +340)
Nonmethane organic gas	+43 (0 to +63)
Formaldehyde	+60 (+7 to +240)
Acetaldehyde	+2000 (+1250 to +4340)
1,3-butadiene	-10 (0 to -13)
Benzene	-79 (-62 to -85)
PM number	0 (+100)
PM mass	0 (+31)

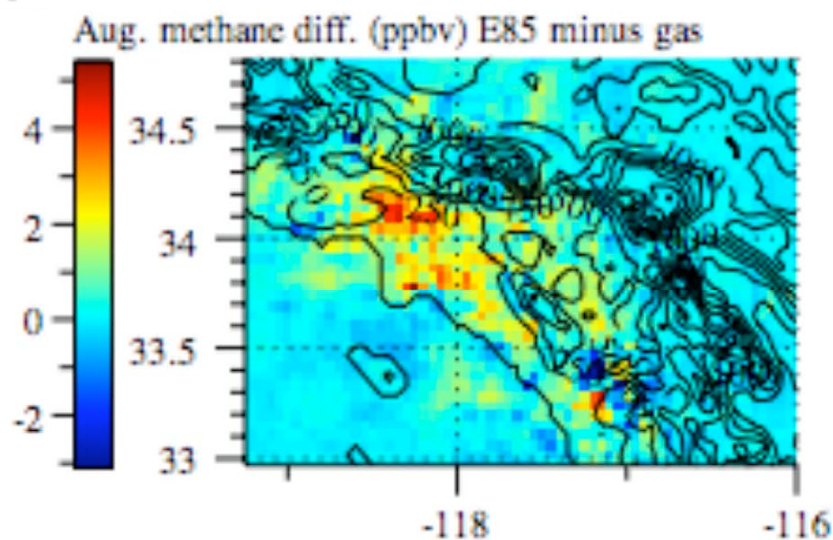
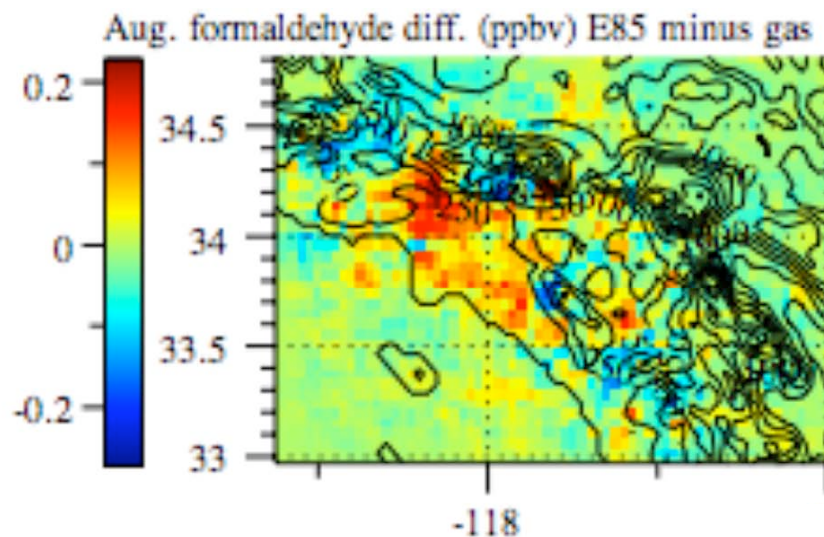
Los Angeles / U.S. Population Distributions



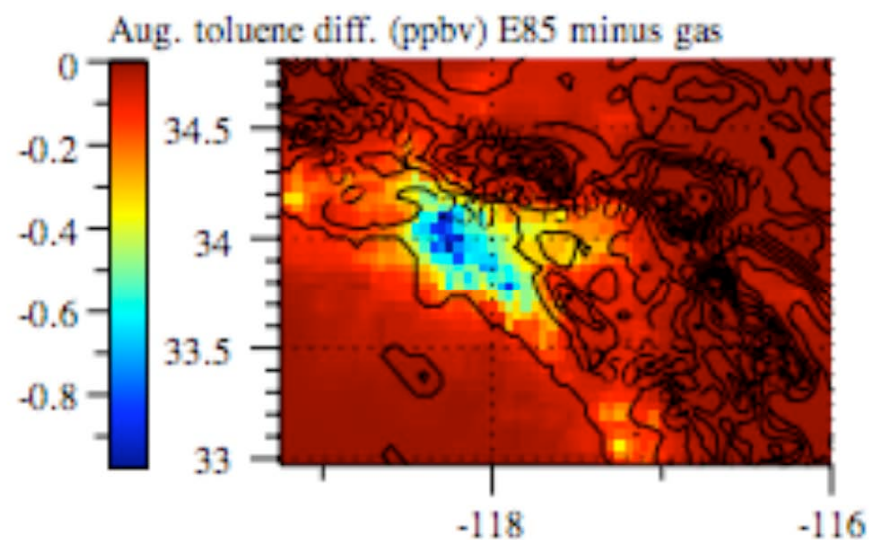
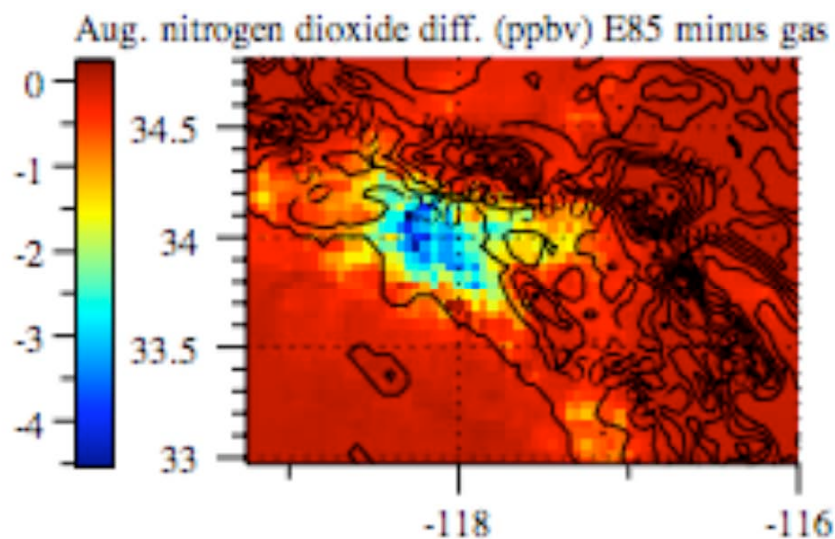
Effect in 2020 of E85 vs. Gasoline on Ethanol and Acetaldehyde



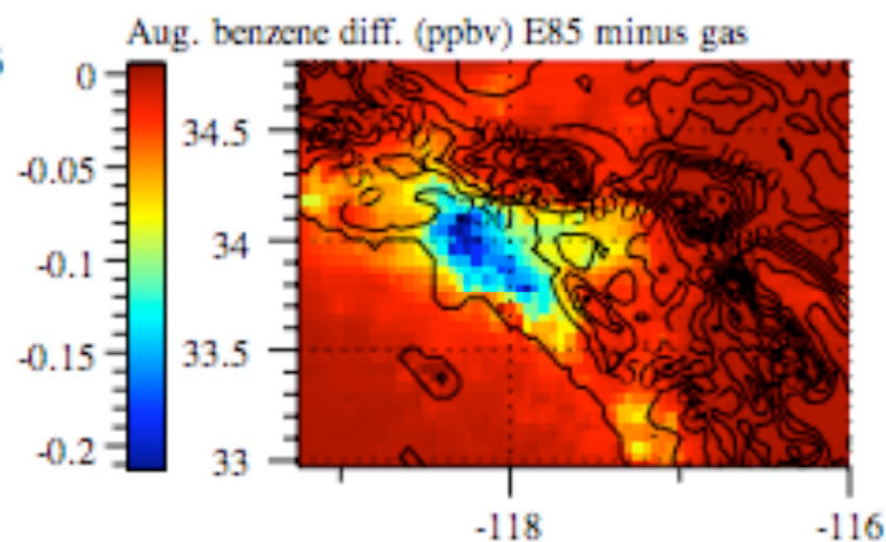
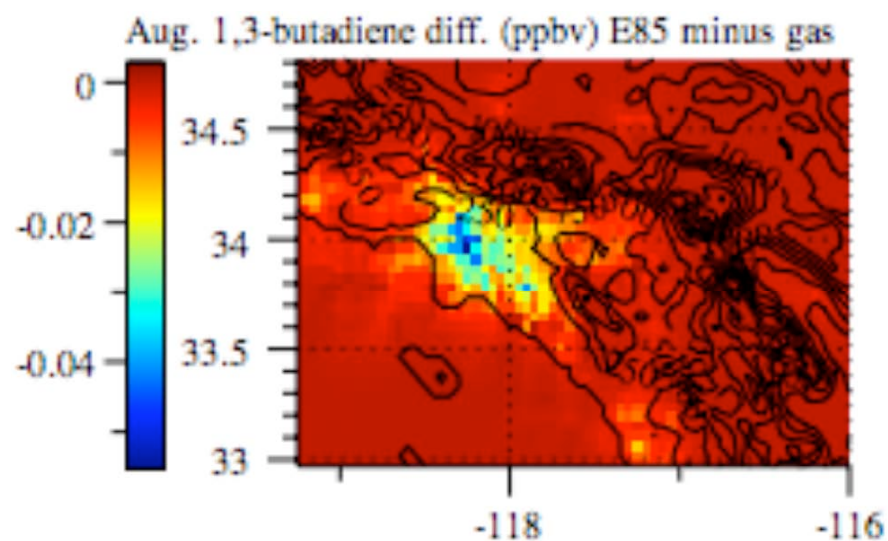
Effect in 2020 of E85 vs. Gasoline on Formaldehyde and Methane



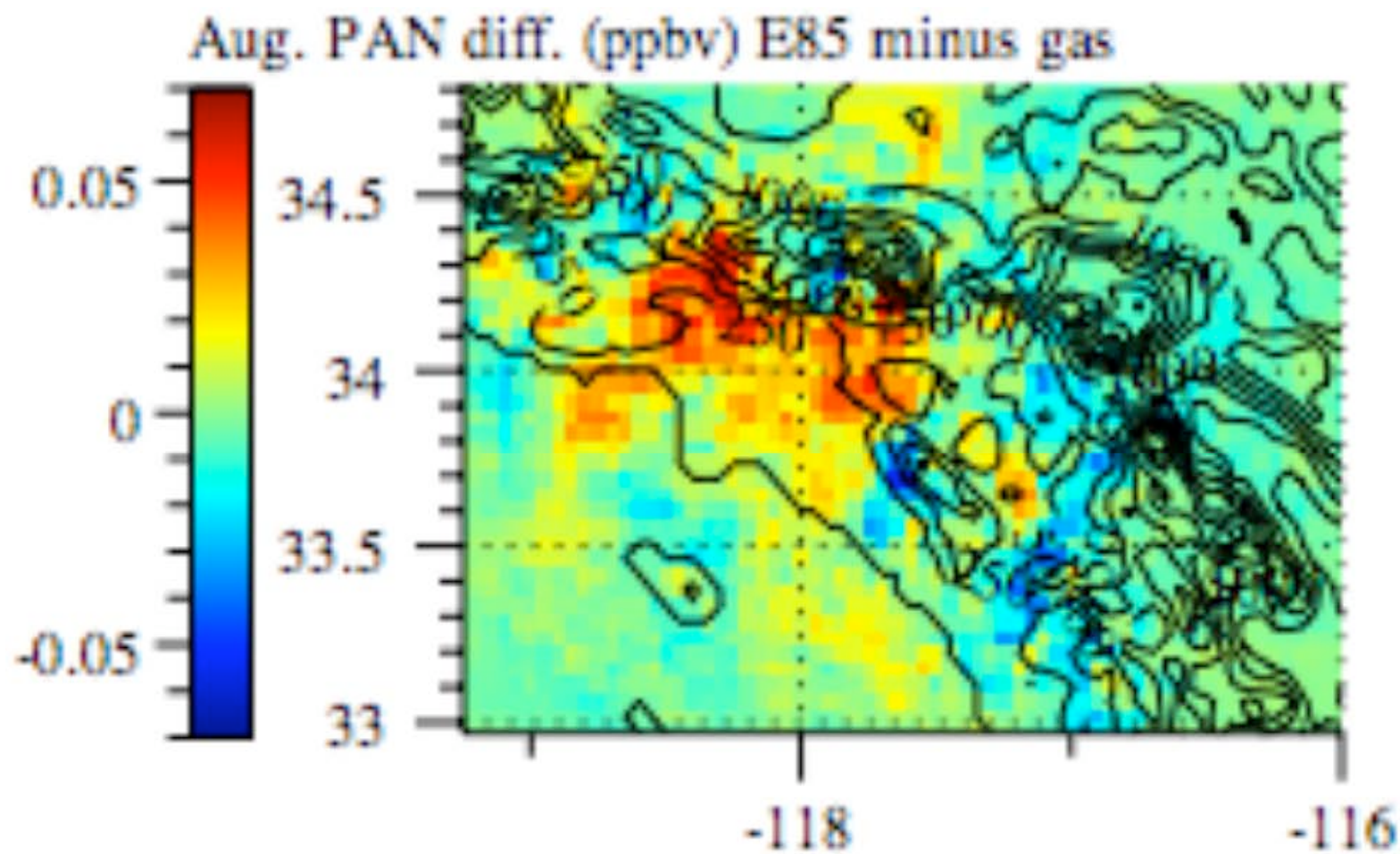
Effect in 2020 of E85 vs. Gasoline on Nitrogen Dioxide and Toluene



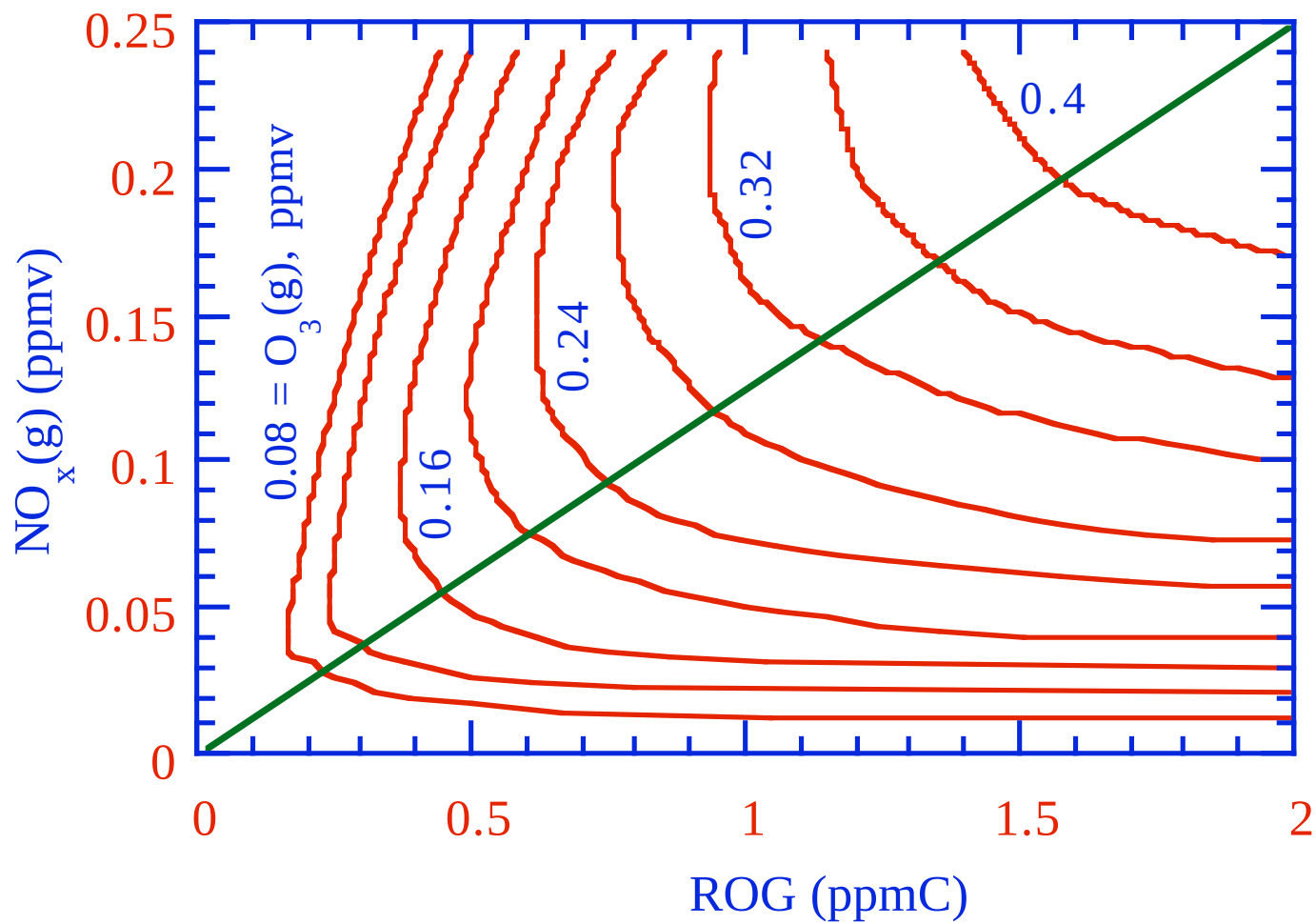
Effect in 2020 of E85 vs. Gasoline on 1,3-Butadiene and Benzene



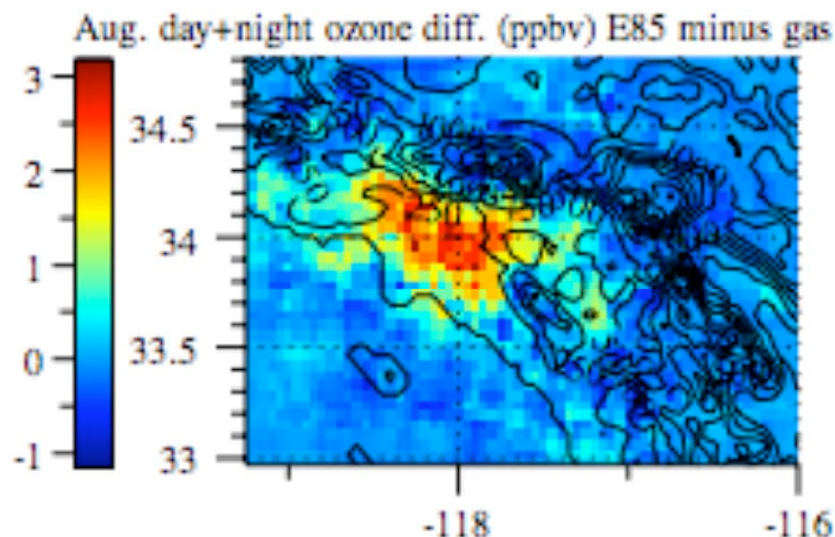
Effect in 2020 of E85 vs. Gasoline on PAN



Ozone isopleth



Effect in 2020 of E85 vs. Gasoline on Ozone and Health



Δ Pop-weighted ozone ≥ 35 ppbv E85 minus gas:	+1.33 ppbv
Δ Ozone deaths/yr:	+120 (+9%)
Δ Ozone hospitalizations/yr respiratory illness:	+650
Δ Ozone-emergency-room visits/yr for asthma:	+770
Δ Cancer/yr USEPA CUREs - for carcinogens:	+0.3
Δ Cancer/yr OEHHA CUREs - for carcinogens:	-3.5

Work for Project

Develop 50-year emission factors for A1B and B1 scenarios.

Develop 50-year emission factors for E85, plug-in-hybrid, wind-hydrogen fuel cell scenarios.

Simulate climate and emission changes and their feedback to air quality in Los Angeles, the Central Valley, and Atlanta over 50-year period.

Quantify the effects of climate change on natural emissions in the same scenarios.