Policy Relevant Background (PRB) ozone simulations for the US using a multi-scale regional climate modeling system
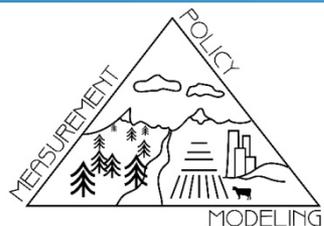
Research Collaborators

- **WSU**: Serena Chung, Rodrigo Gonzalez Abraham, and Brian Lamb
- **CARB**: Jeremy Avise
- **UW**: Cliff Mass, Eric Salathé, and Yongxin Zhang (now at NCAR)
- **NCAR**: Tiffany Duhl, Alex Guenther, and Christine Wiedinmyer
- **USDA Forest Service**: Sim Larkin, Don McKenzie, Natasha Stavros, and Tara Strand
- **EPA:** Dan Loughlin and Chris Nolte
- **Argonne National Lab**: David Streets

Background ozone: A shrinking window for air quality management
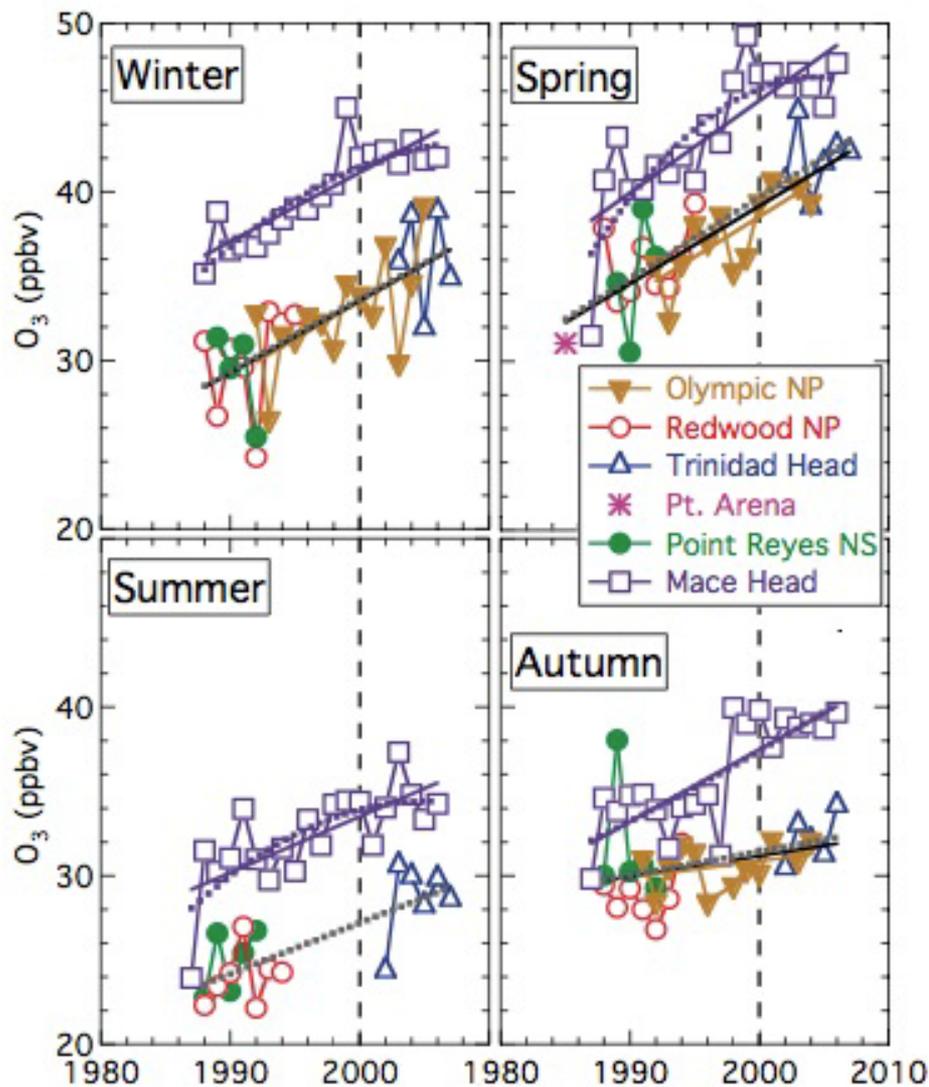
Increasing O3 background levels and A decreasing O3 air quality standard imply A smaller window for control strategies

Increasing O_3 in the marine boundary layer (US west coast): Parrish et al., 2009 (ACP)

Policy Relevant Background (PRB)

- PRB is defined as US ozone in the absence of US, Canada, & Mexico anthropogenic emissions
  - Includes biogenic vegetation and soil emissions
  - Can include wildfires, lightning NOx and stratospheric O3
  - Includes long range transport of pollutants from Asia
- PRB is based on simulations of global and regional ozone
  - Uncertainty estimates require an ensemble of model simulations
- PRB is required as a foundation for development of effective control strategies
  - PRB varies in time and space
  - PRB should be based on a representative mean
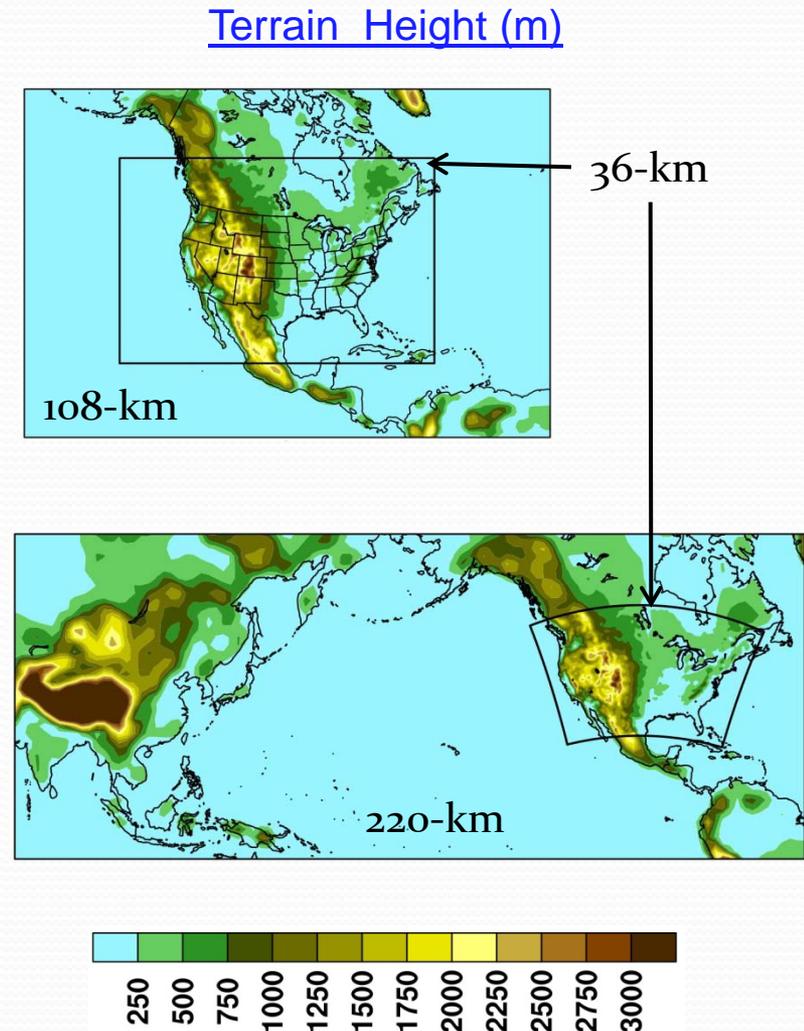 - PRB simulations should account for the effects of global change on PRB in the future

Assessment of Global Change and US Air Quality

Meteorological Downscaling

- ECHAM5 A1B climate driver
- WRFv2.2 simulations
  - ➤ 220-km grids for partial hemispheric domain
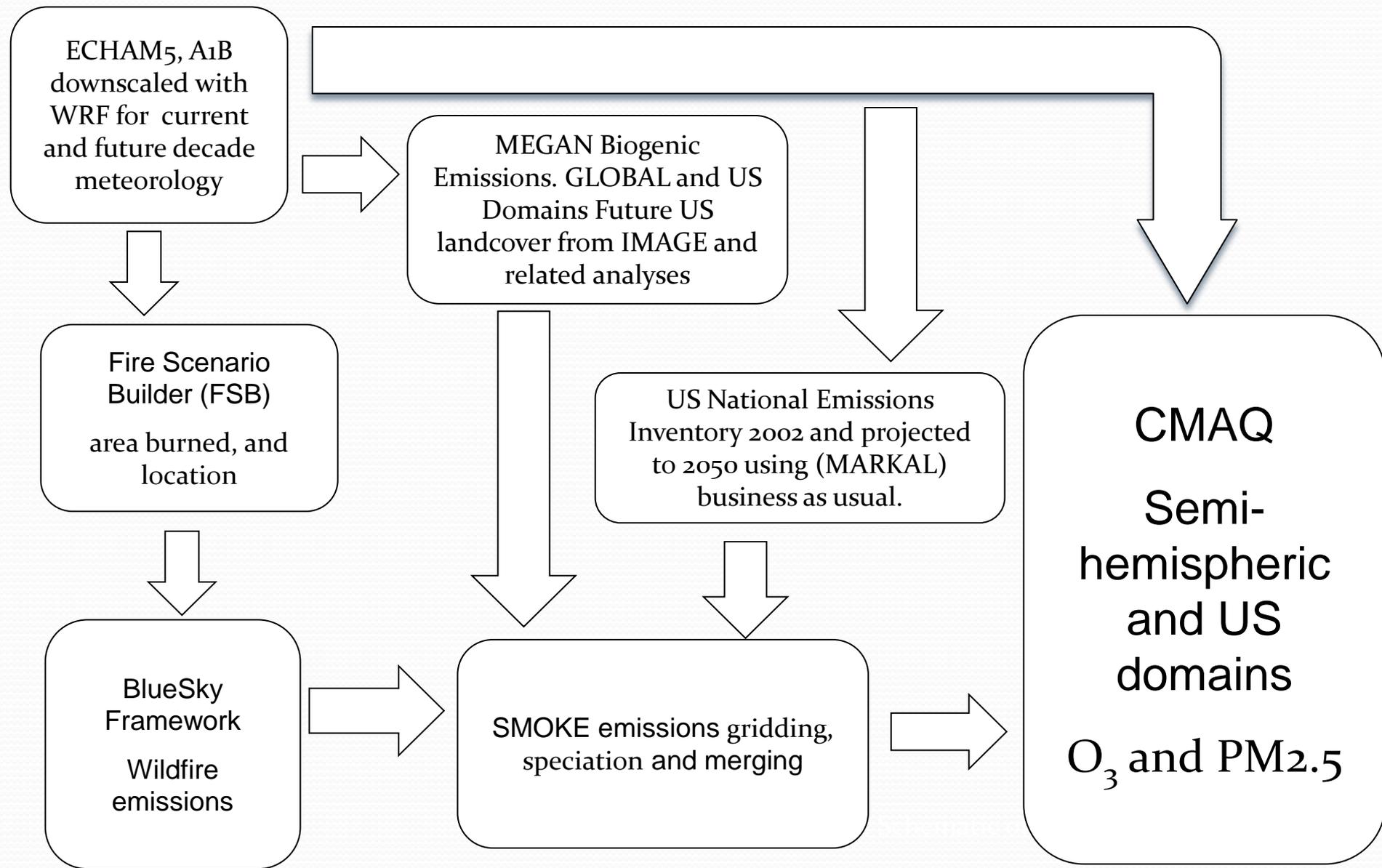 - ➤ nested domains with 108-km & 36-km grids for the US

Chemical Modeling

- CMAQ v4.7 with 220-km grids for partial hemispheric domain
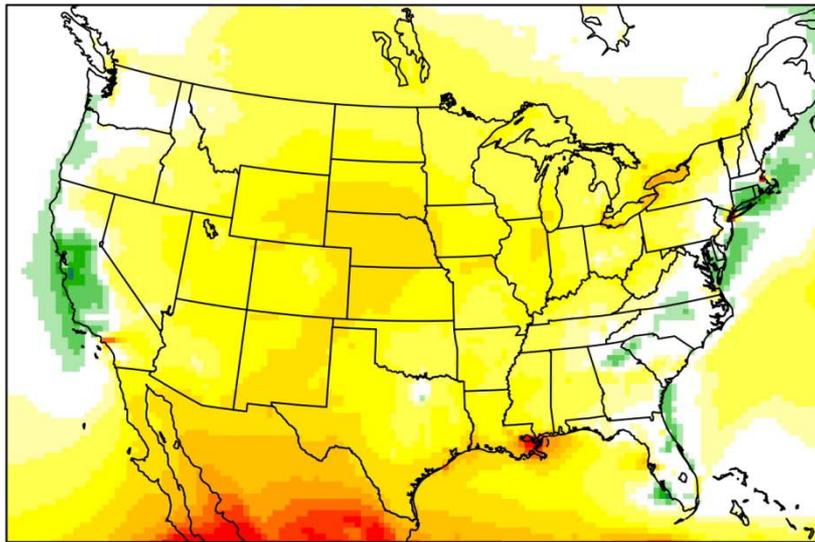- CMAQ v4.7 with 36-km grids for the US domain

Terrain Height (m)

36-km

108-km

220-km

250 500 750 1000 1250 1500 1750 2000 2250 2500 2750 3000

Current and Future Decade US Simulations
5 representative summers in each decade (1995-2004, 2045-2054)

ECHAM5, A1B downscaled with WRF for current and future decade meteorology

MEGAN Biogenic Emissions. GLOBAL and US Domains Future US landcover from IMAGE and related analyses

Fire Scenario Builder (FSB)

area burned, and location

US National Emissions Inventory 2002 and projected to 2050 using (MARKAL) business as usual.

CMAQ

Semi-hemispheric and US domains

O_3 and PM2.5

BlueSky Framework

Wildfire emissions

SMOKE emissions gridding, speciation and merging

Future vs Current Summertime Air Quality

Δ Daily Maximum 8-Hour O_3
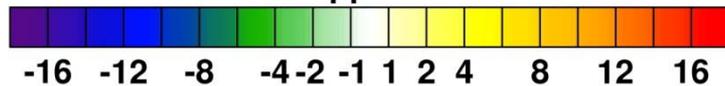
Δ Hourly $PM_{2.5}$

- Climate, biogenic, land-use & Asian emission effects generally increase O_3, while US emission reduction somewhat offset these increases.
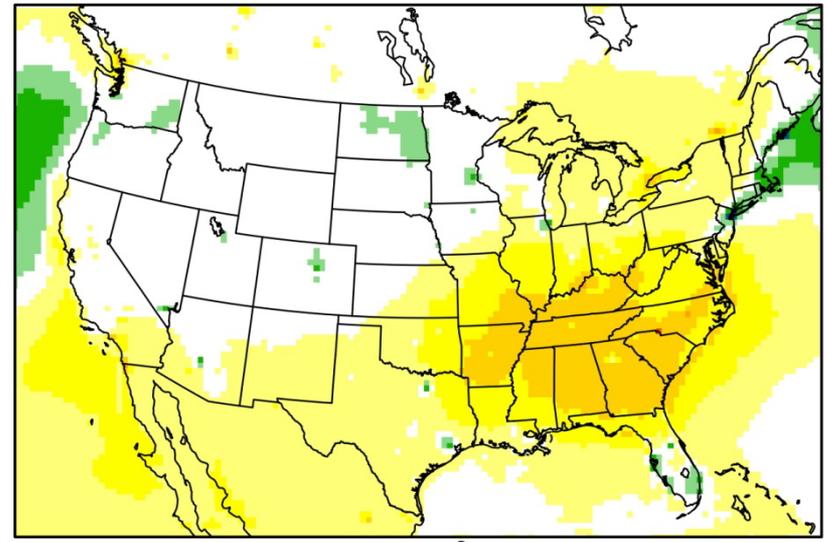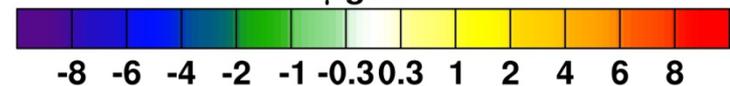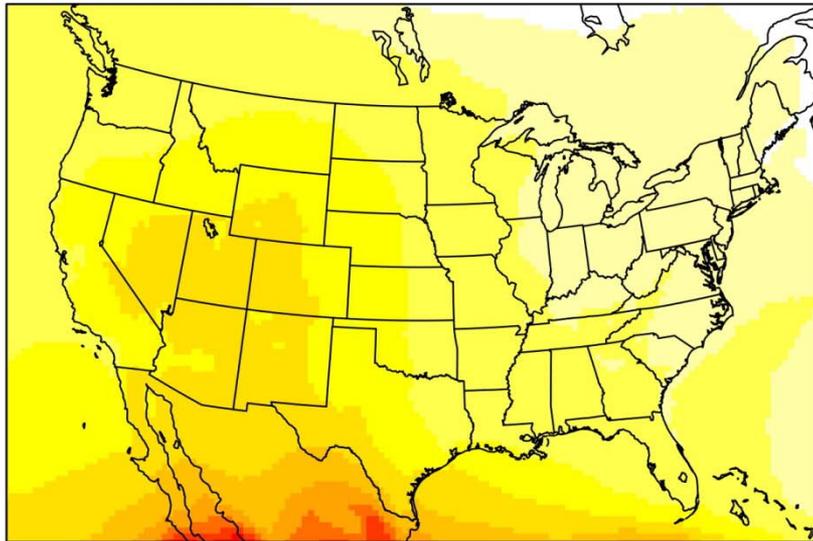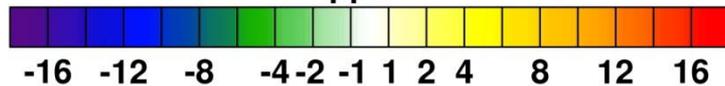
- Dominant effect is increased SOA in the Southeast due to increased biogenic emissions, especially mono- & sesqui-terpene emissions

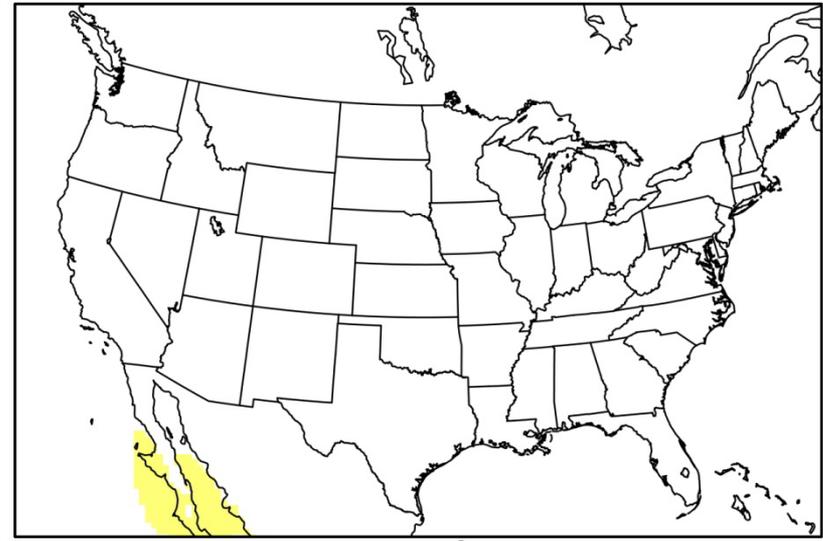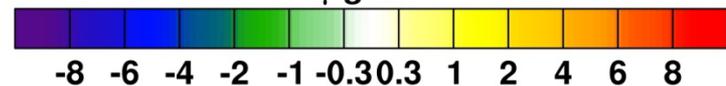# Effect of Future Asian Anthropogenic Emissions (all other factors held at current decade conditions)

Δ Daily Maximum 8-Hour O_3

Δ Hourly $PM_{2.5}$

- Relatively uniform increase of 2 to 4 ppb across the West to the Midwest
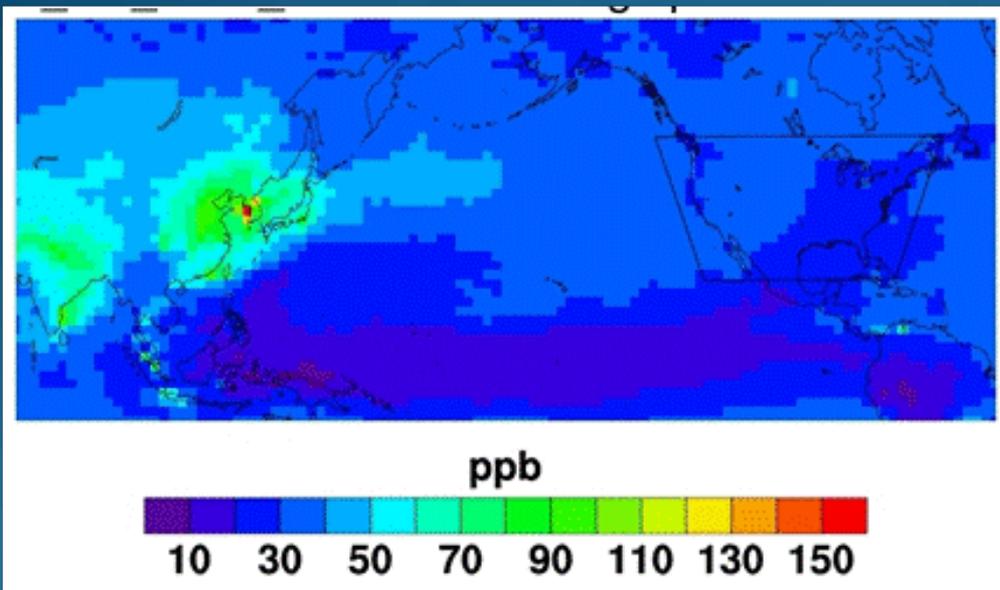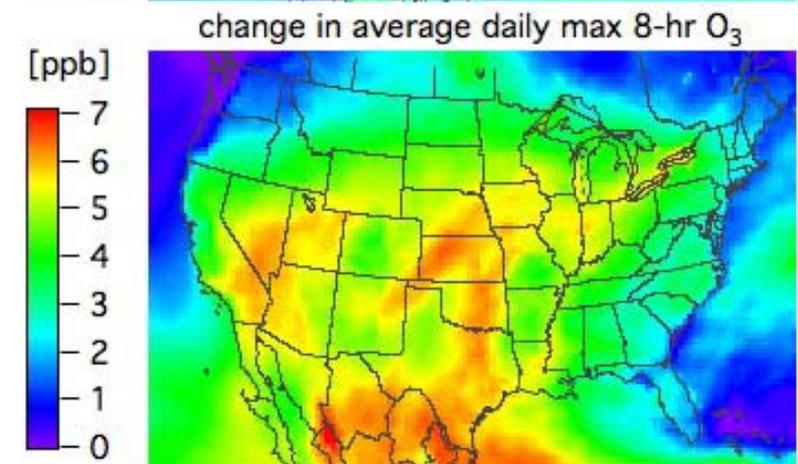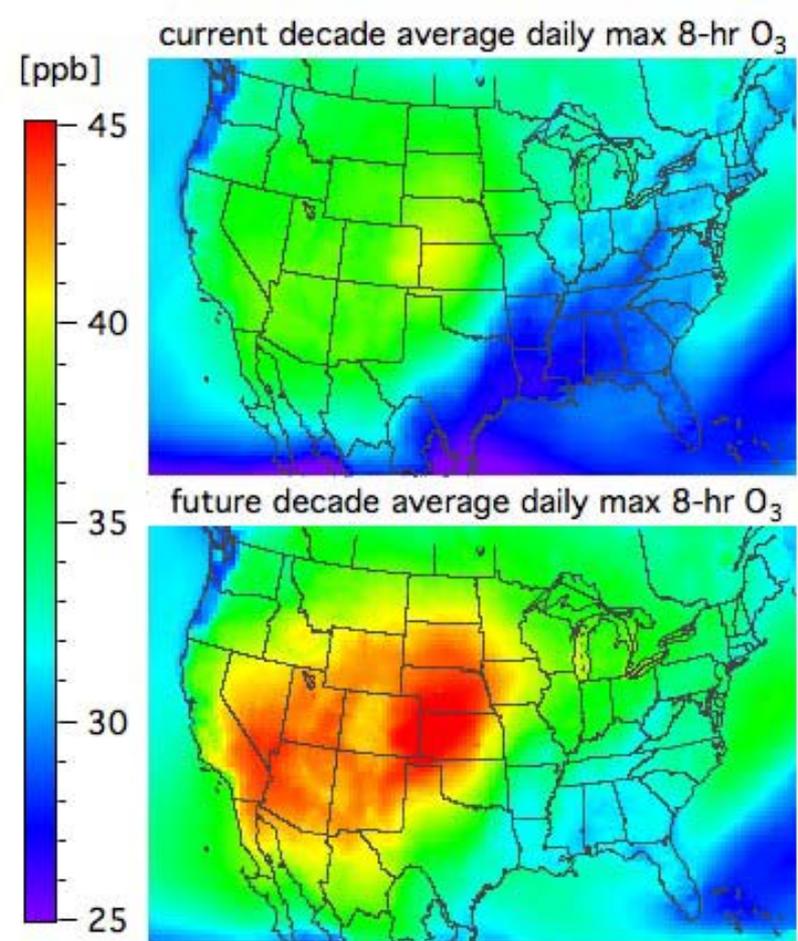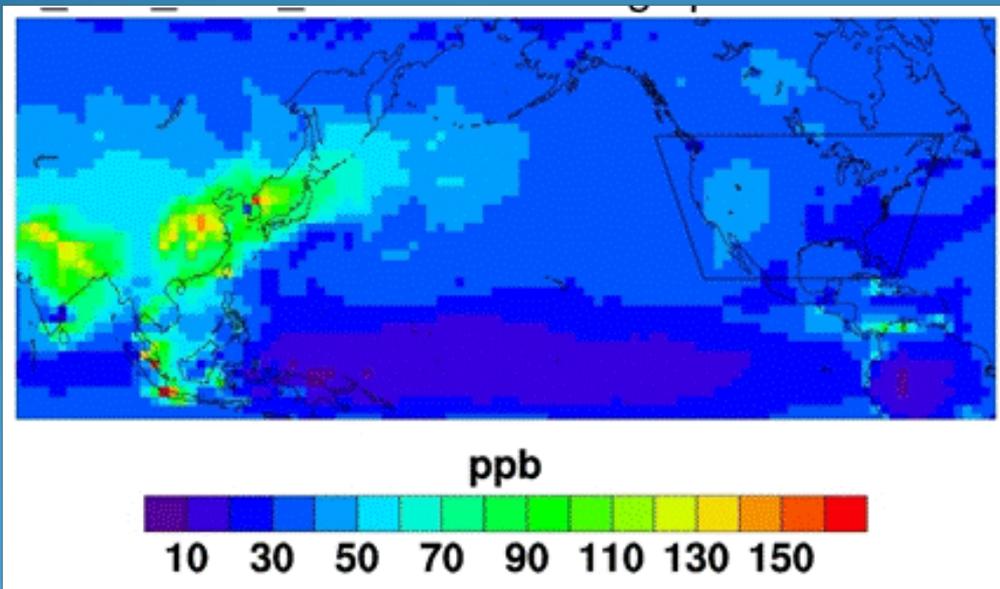- Gradient is consistent with west to east transport

- Insignificant impact on $PM_{2.5}$ because PM precursors have relatively short atmospheric lifetimes.

Future vs Current PRB

Current

Future

current decade average daily max 8-hr O₃

future decade average daily max 8-hr O₃

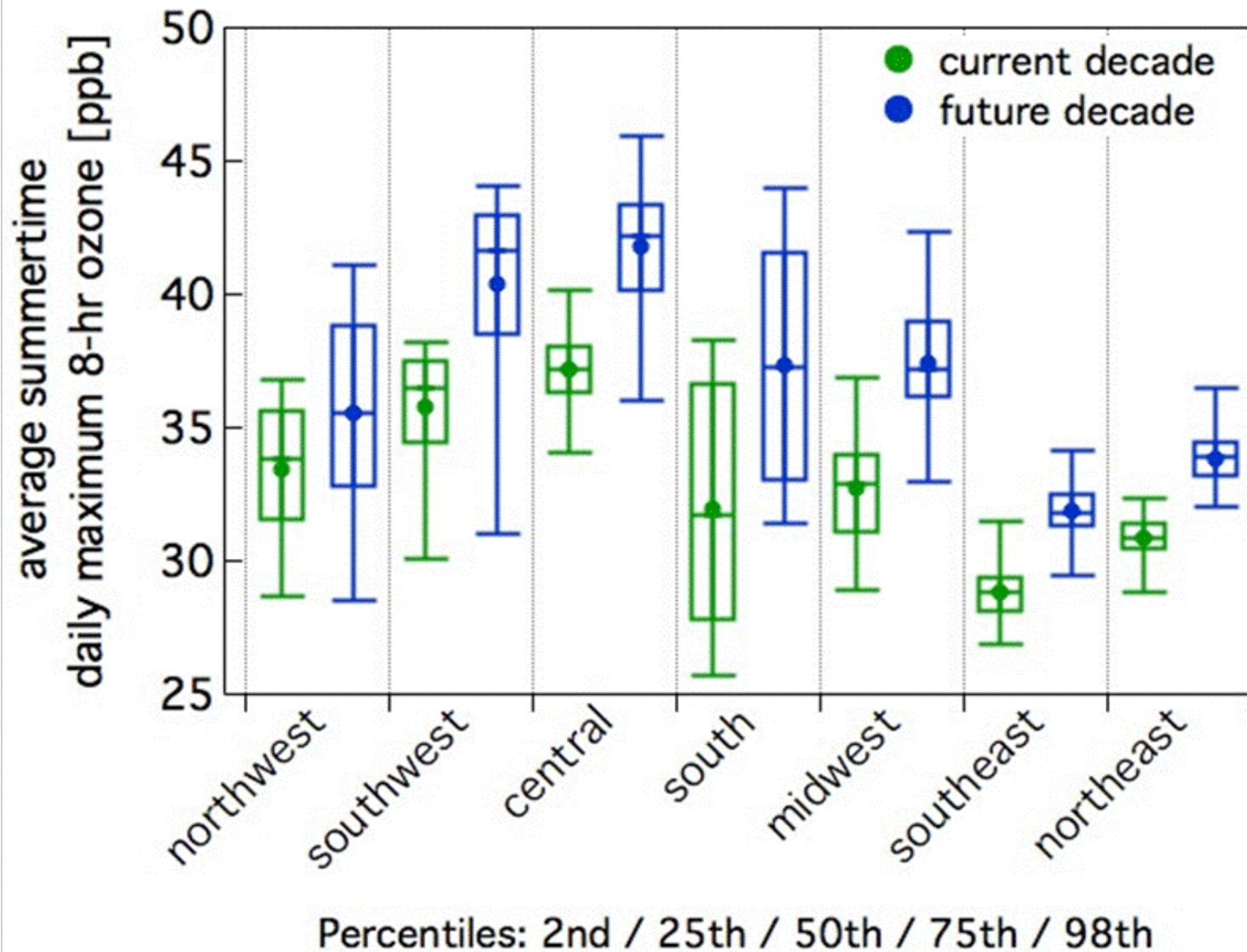change in average daily max 8-hr O₃
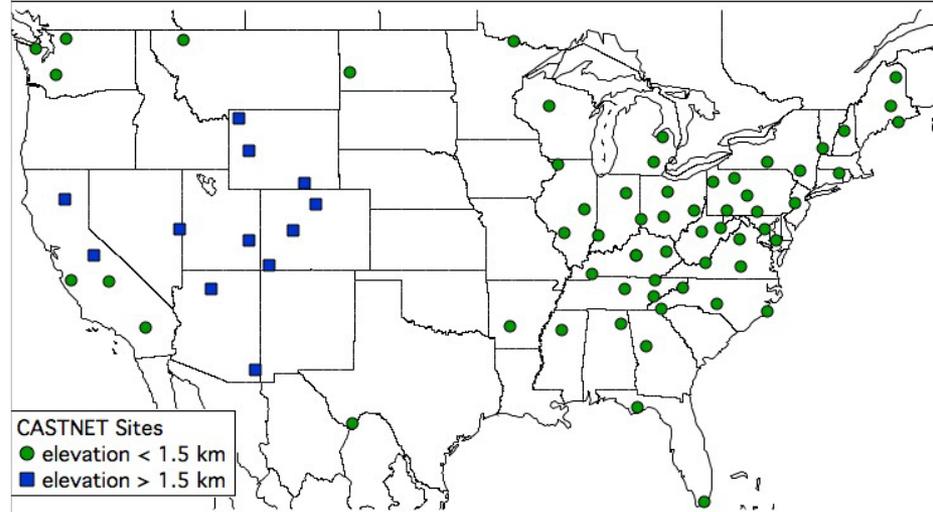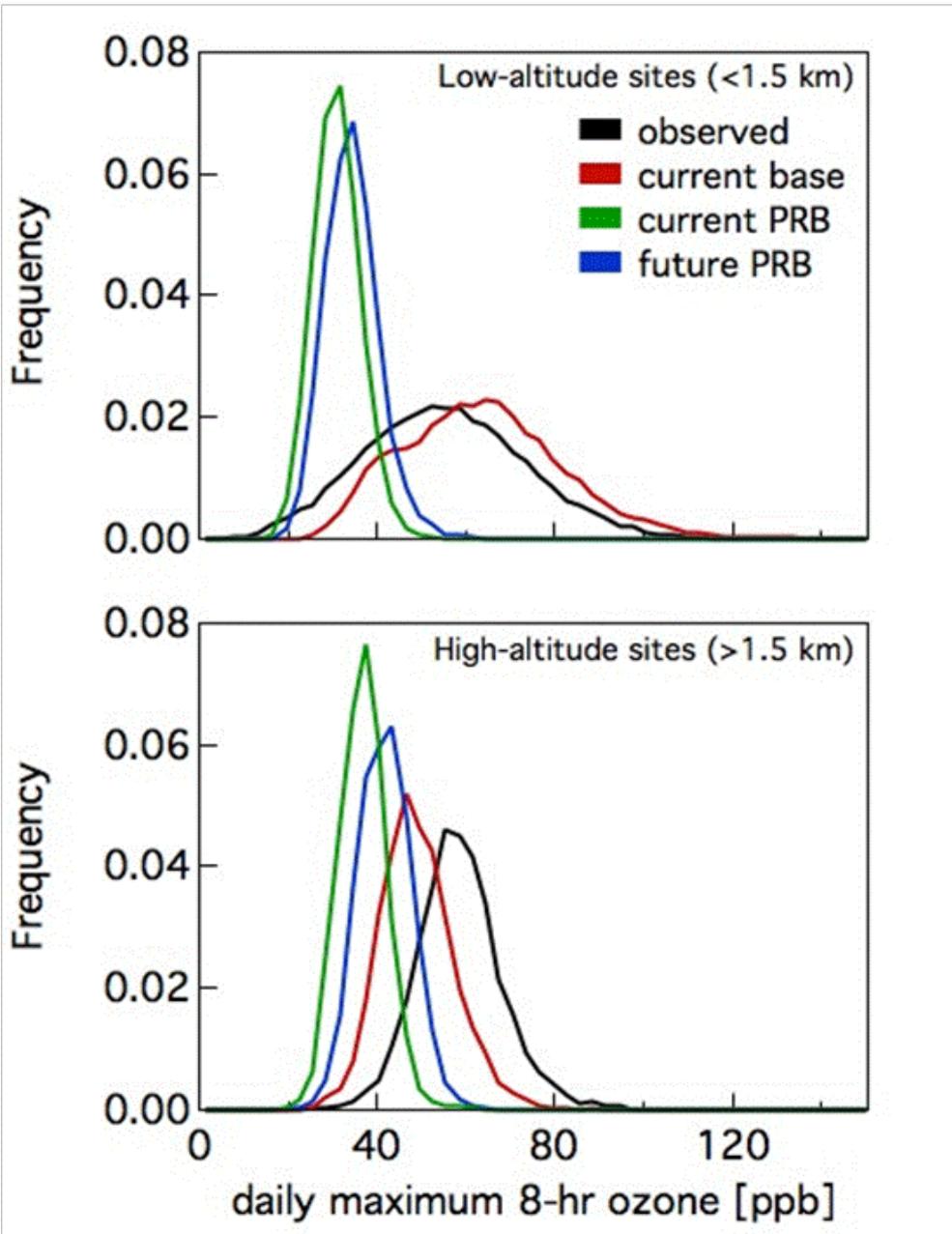
Base Case Climate Realization and Observations

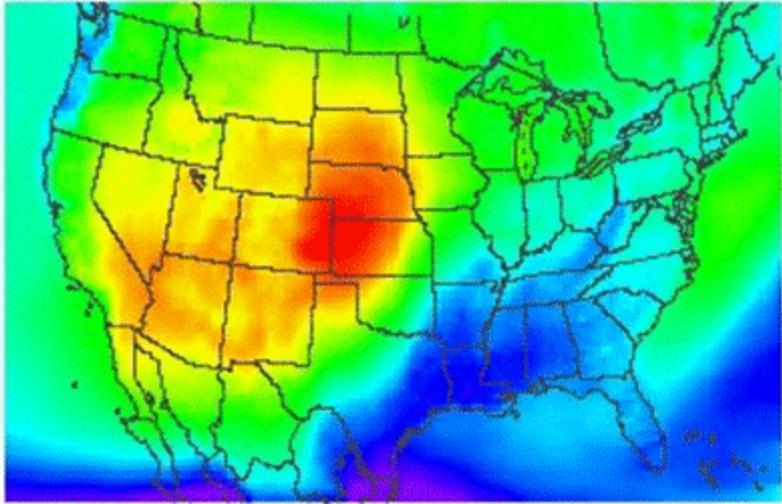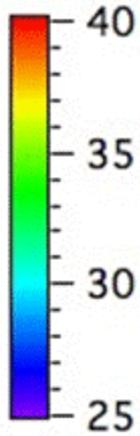- Slight high bias for low altitude (eastern) sites
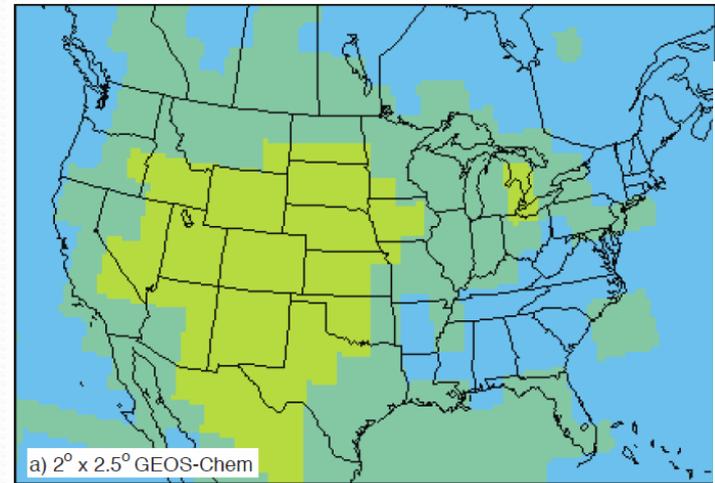- Slight low bias for high altitude (western) sites

PRB by region

Percentiles: 2nd / 25th / 50th / 75th / 98th

current decade average daily max 8-hr O₃

[ppb]

PRB Simulations from three different modeling frameworks
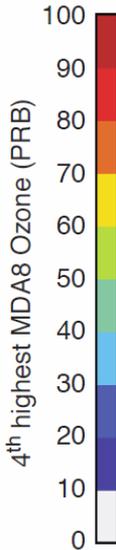
4th highest MDA8 Ozone (PRB)

a) 2° x 2.5° GEOS-Chem

d) 12 km CAMx (West - No Fire)
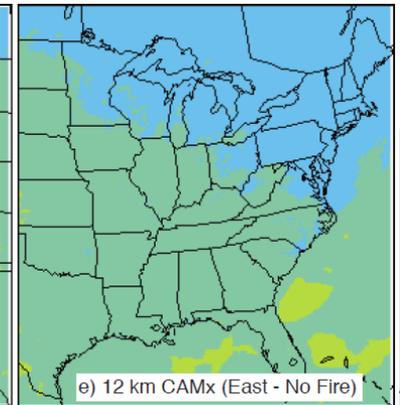
e) 12 km CAMx (East - No Fire)

McDonald-Buller et al. (ES&T 2011)

Emery et al., 2011

Summary
Policy Relevant Background O_3

- Current decade base case climate realization shows slight bias vs observations
  - Varies with low vs high altitude sites
- PRB distributions
  - 30 to 40 ppb current decade (no fires)
  - Significant variability among regions
    - Higher in the west, lower in the southeast
  - PRB tends to increase with higher model resolution
- PRB increases by 5 to 10 ppb for 2050's
- There are obvious differences among PRB from different modeling frameworks and configurations