Modeling Background Ozone: A Comparison between global, hemispheric and regional models
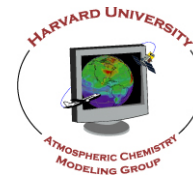
Barron H. Henderson[1], Christopher Emery[2], Lin Zhang[3], Rohit Mathur[4] and Joseph P. Pinto[4]

[1]Environmental Engineering Sciences, University of Florida

[2]ENVIRON International Corporation, Novato, CA

[3]Atmospheric Chemistry Modeling Group, Harvard University

[4]Office of Research and Development, US EPA

What is Background Ozone?

Historically - Policy Relevant Background is ozone concentrations that would exist in the absence of anthropogenic emissions of ozone precursors in the U.S., Canada and Mexico (North American Background)
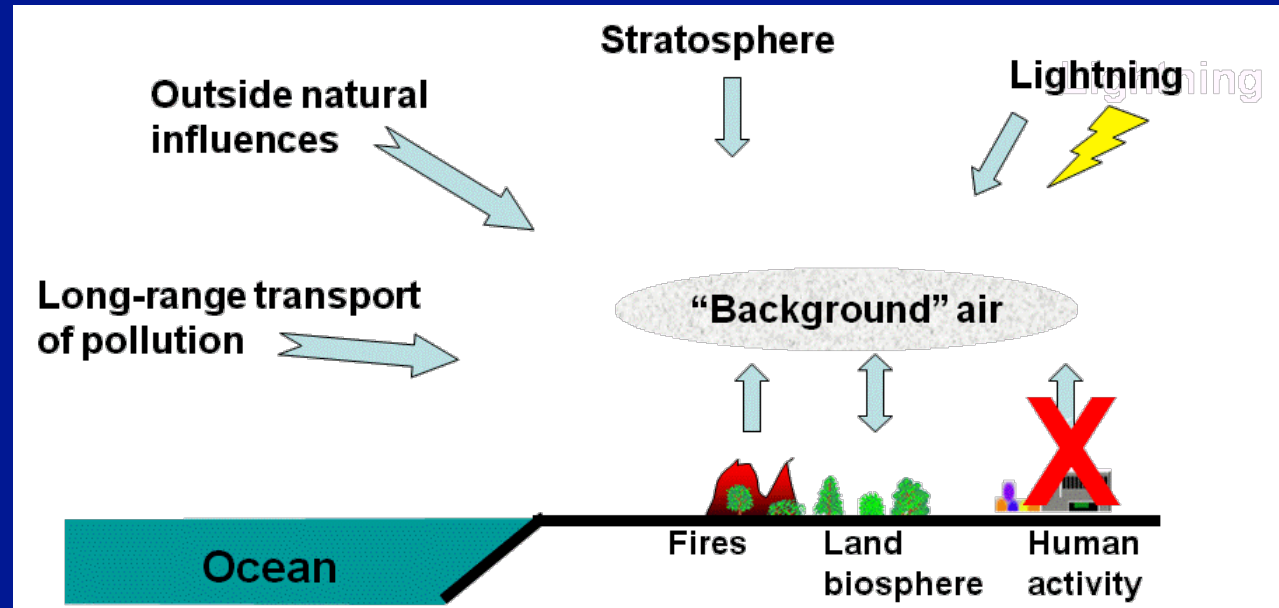

Fig. 3-7

Background O$_3$ is not directly observable → Must be estimated with models

Definitions
"Ozone concentrations that would exist in the absence of anthropogenic emissions of ozone precursors in _____"

- "all people" - Natural Background
- "the U.S. only" - U.S. Background
- "the U.S., Canada and Mexico" - North American Background (historically PRB)

Simulations used here

	CQ*	GC[†]	CX[‡]
Model	Hemispheric CMAQ	GEOS-Chem	CAMx
Resolution	108km x 108km	$1/2° \times 1/3°$	12km x 12km
Meteorology	WRF	GEOS5	WRF
Chemistry	Carbon Bond '05[§]	Version 8-02-03[‖]	Carbon Bond '05
Boundaries	N/A	GC 2x2.5°	GC 2x2.5°
Biogenic	BEIS	MEGAN	BEIS
Lightning	N/A	LTDIS scaled with Pickering 1997 profile	Scaled with Koo et al. profile
Wildfires	N/A	GFED monthly average	SmartFire daily estimate

*Simulations in development
[†]Zhang et al. JGR 2011
[‡]Emery et al. AE 2012
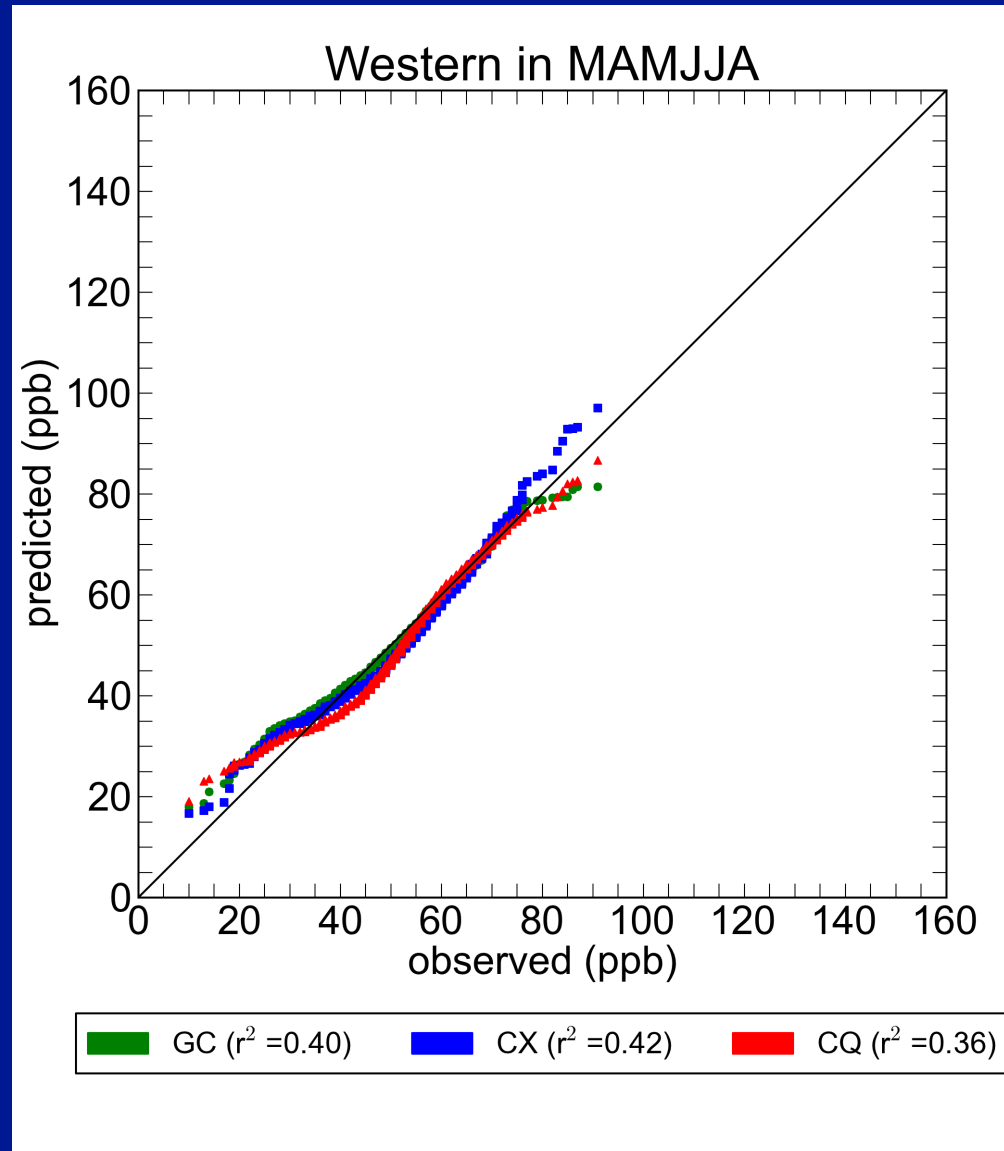[§]Nitrates updated to account for isoprene nitrates
[‖]Updates in chemistry will decrease NOx loss to isoprene nitrates

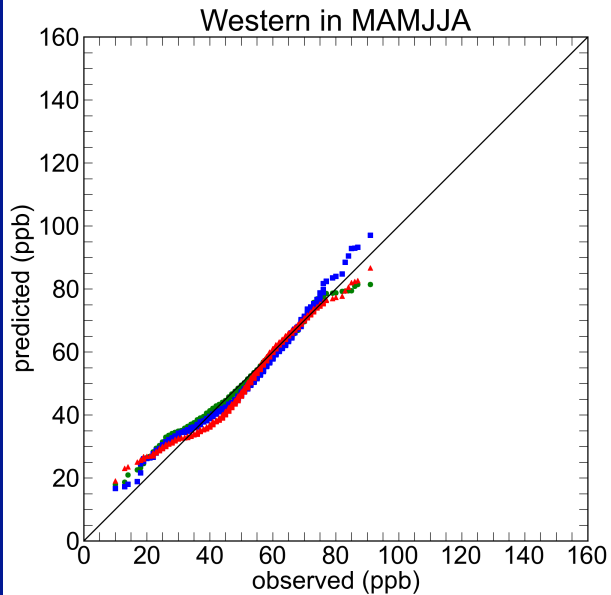# Contributions will vary in space
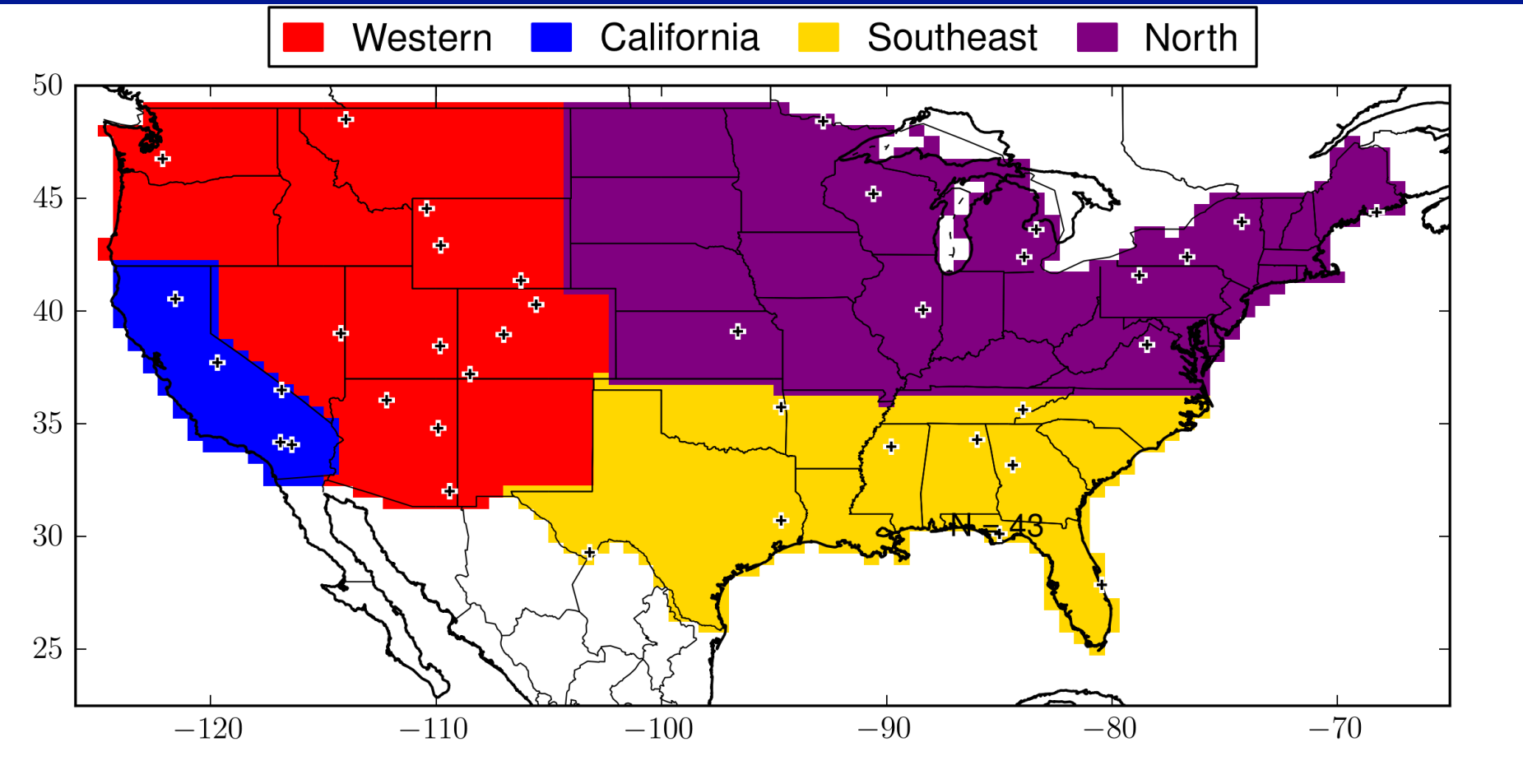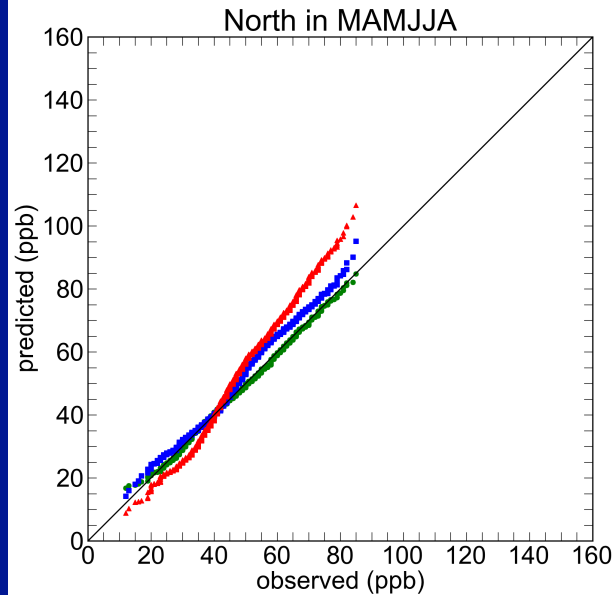

+ = Monitor Locations – Zhang + Emery CASTNet
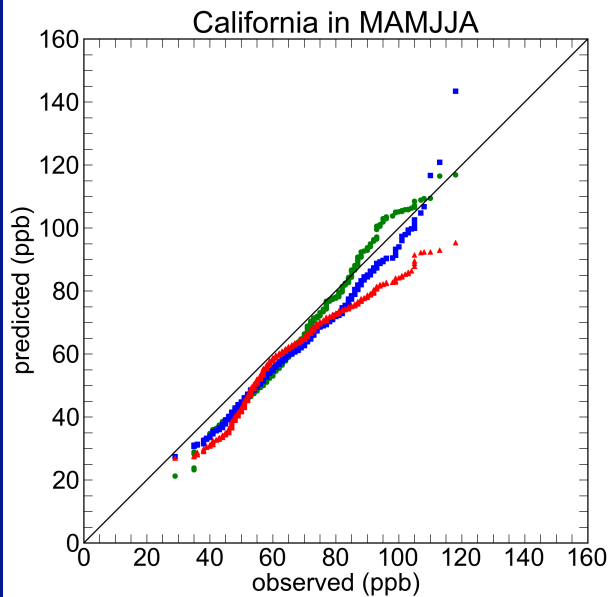
Rank Paired Evaluation Example

Western in MAMJJA

Legend: GC (r^2 =0.40)   CX (r^2 =0.42)   CQ (r^2 =0.36)

Relatively Consistent Performance

Western in MAMJJA

GC (r^2 =0.40)   CX (r^2 =0.42)   CQ (r^2 =0.36)

North in MAMJJA

GC (r^2 =0.47)   CX (r^2 =0.49)   CQ (r^2 =0.40)

California in MAMJJA

GC (r^2 =0.52)   CX (r^2 =0.50)   CQ (r^2 =0.48)

Southeast in MAMJJA
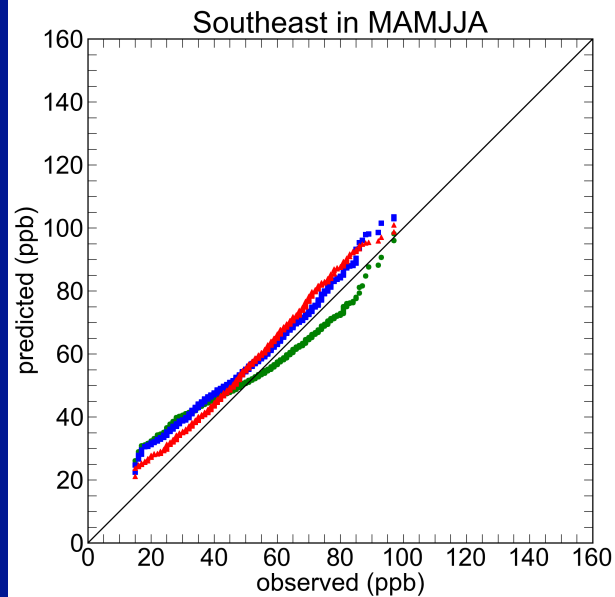
GC (r^2 =0.22)   CX (r^2 =0.47)   CQ (r^2 =0.44)

Contribution vs Factor Separation

- Stein and Alpert 1993 showed 2^n zero-out simulations separate nonlinear factors and interactions – How much ozone in the absence of emissions?

- Each model has 2 simulations
  - Base case: all emissions
  - NAB: United States, Canada, and Mexico anthropogenic emissions removed

- Do the models agree about how NAB varies as a function of total ozone?

Background varies by season

- **MAM, JJA**
  - Prevalence and extent of wildfires
  - Biogenic emissions are a function of temperature

- **Ozone Lifetime**
  - Inter-continental transport enhanced in spring and winter
  - Local production more important in summer
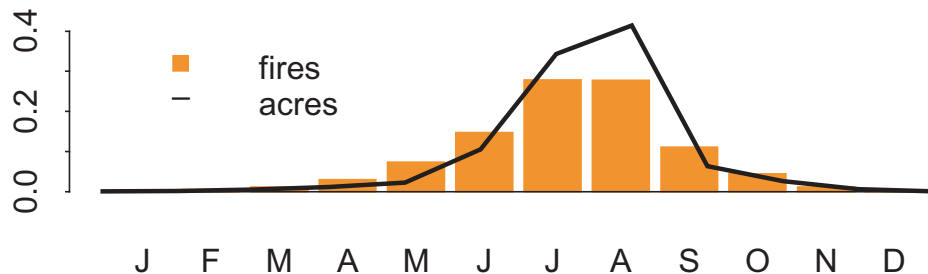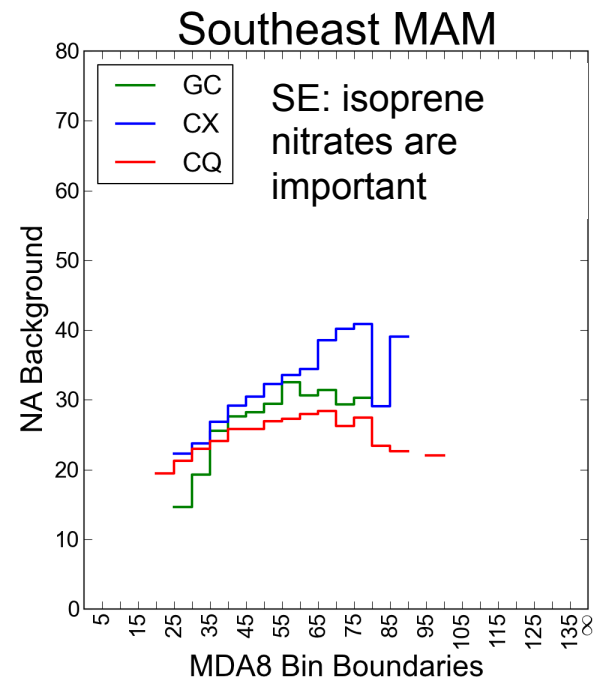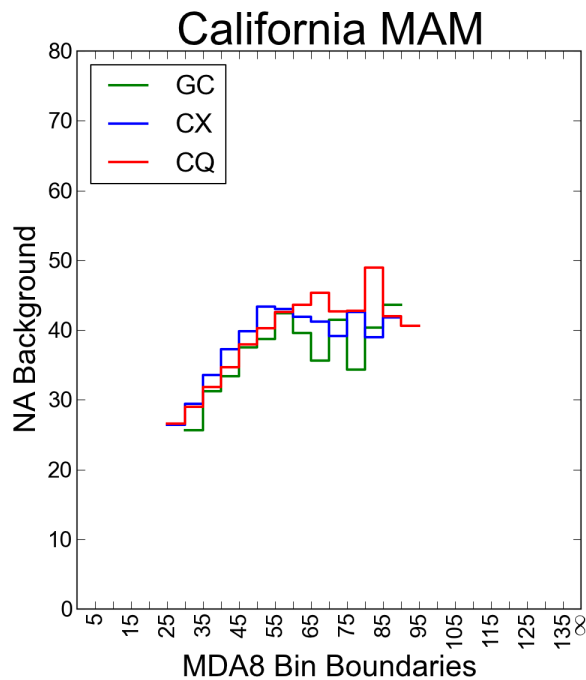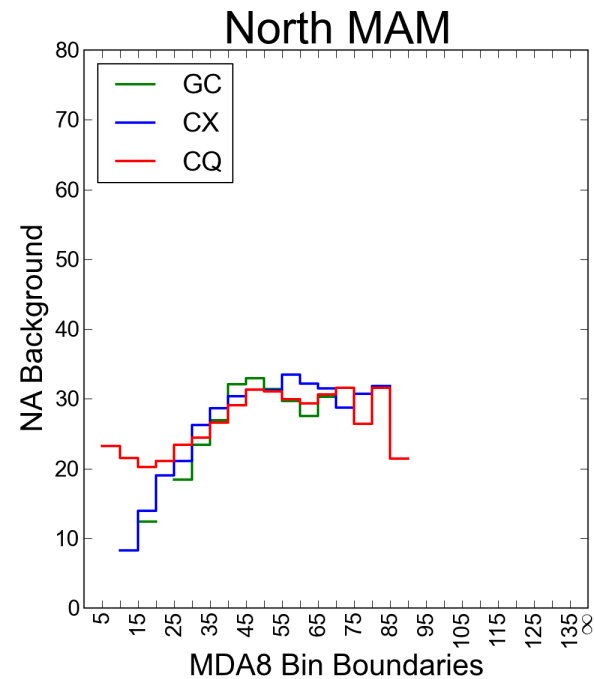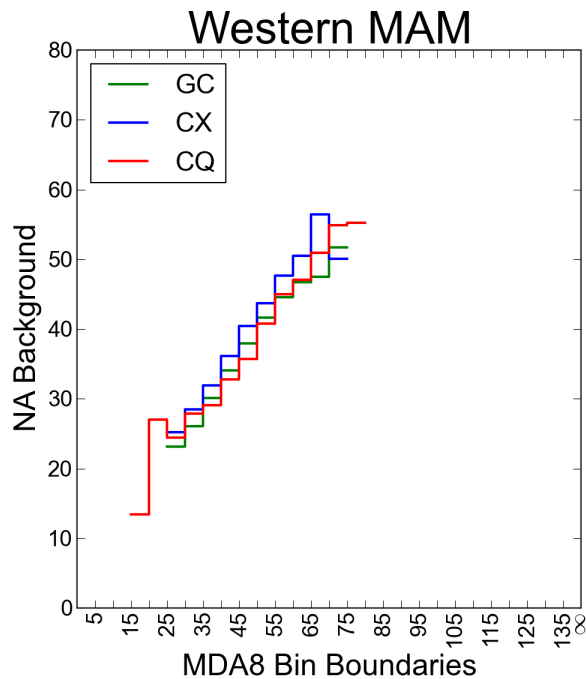
Fig. 1. Percentage of regional annual fire starts (bars) and area burned (line) by month.

Westerling et al., BAMS, 2003
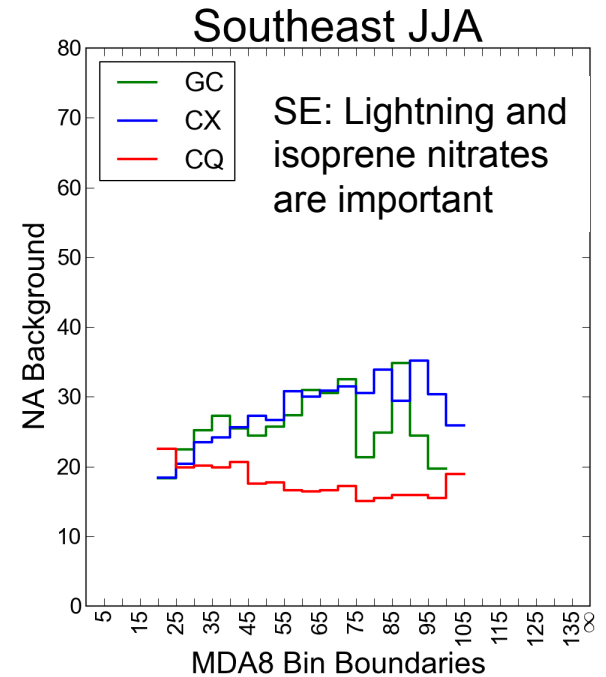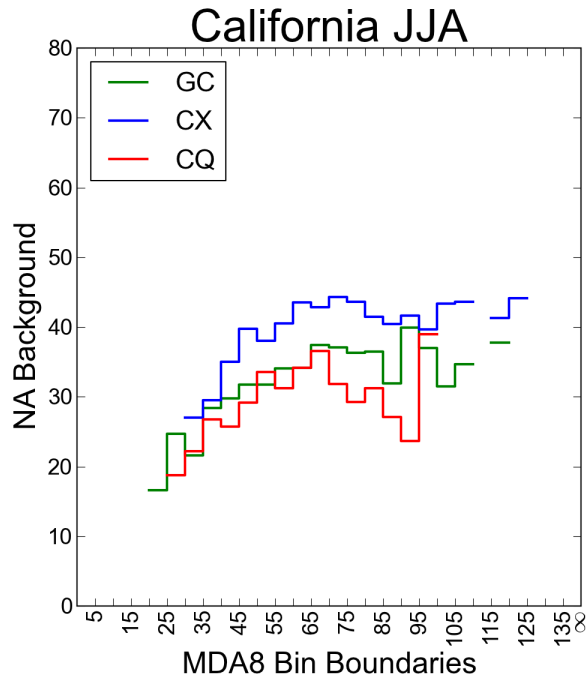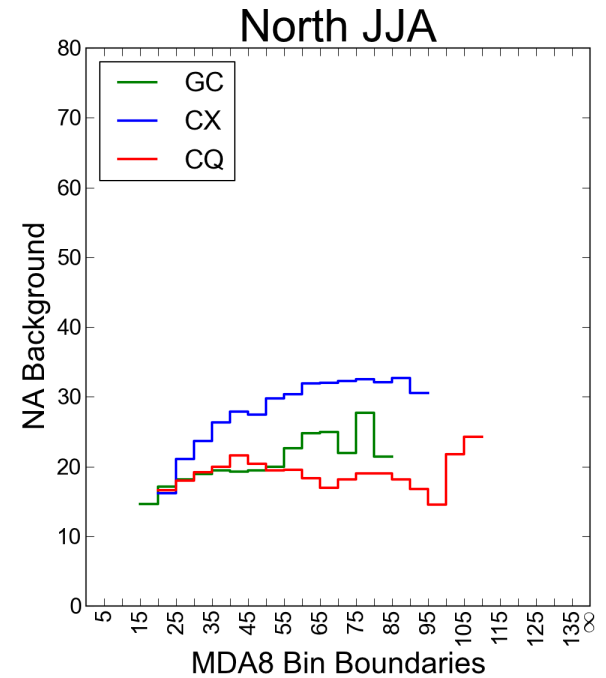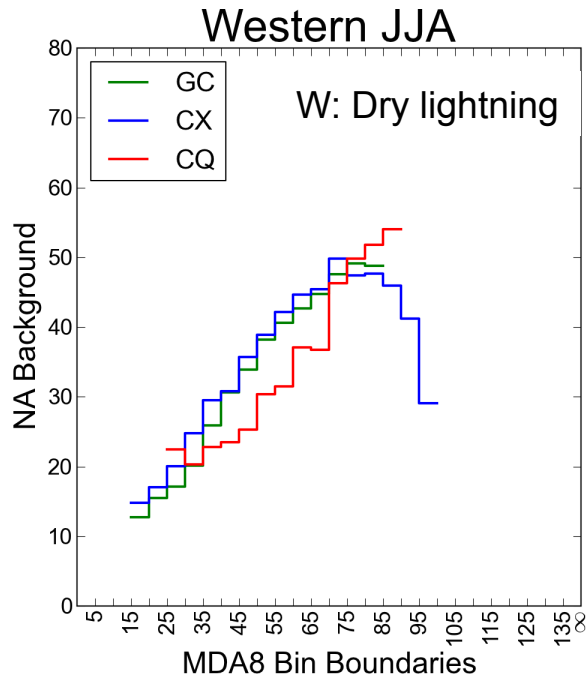
Ozone Lifetime (Liu and Trainer 1988)
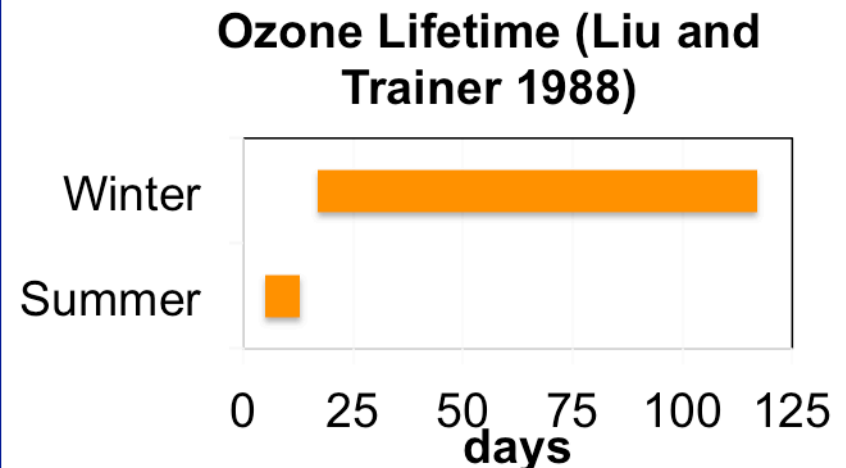
Background Contribution Example
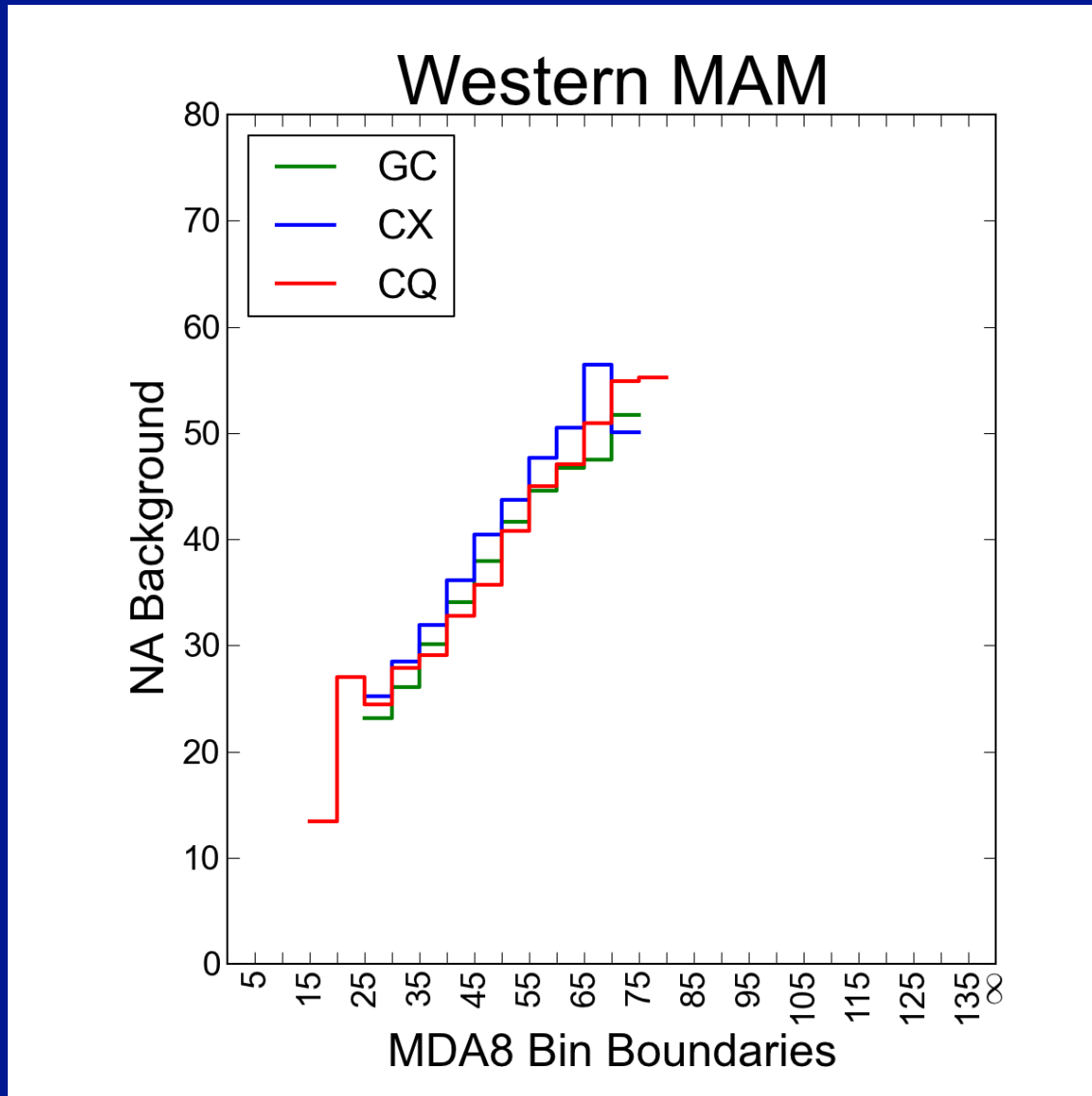
Relatively Consistent Spring Contribution

Inconsistent Summer Contribution

Simulation Overview

- Rank-paired evaluation
  - All models show relatively good performance
  - Best performance depends on region/season
- NAB contributions to total ozone
  - Consistent in Spring, the West and Southeast
  - Differences in Summer California and North
- Background contributes more to CAMx results
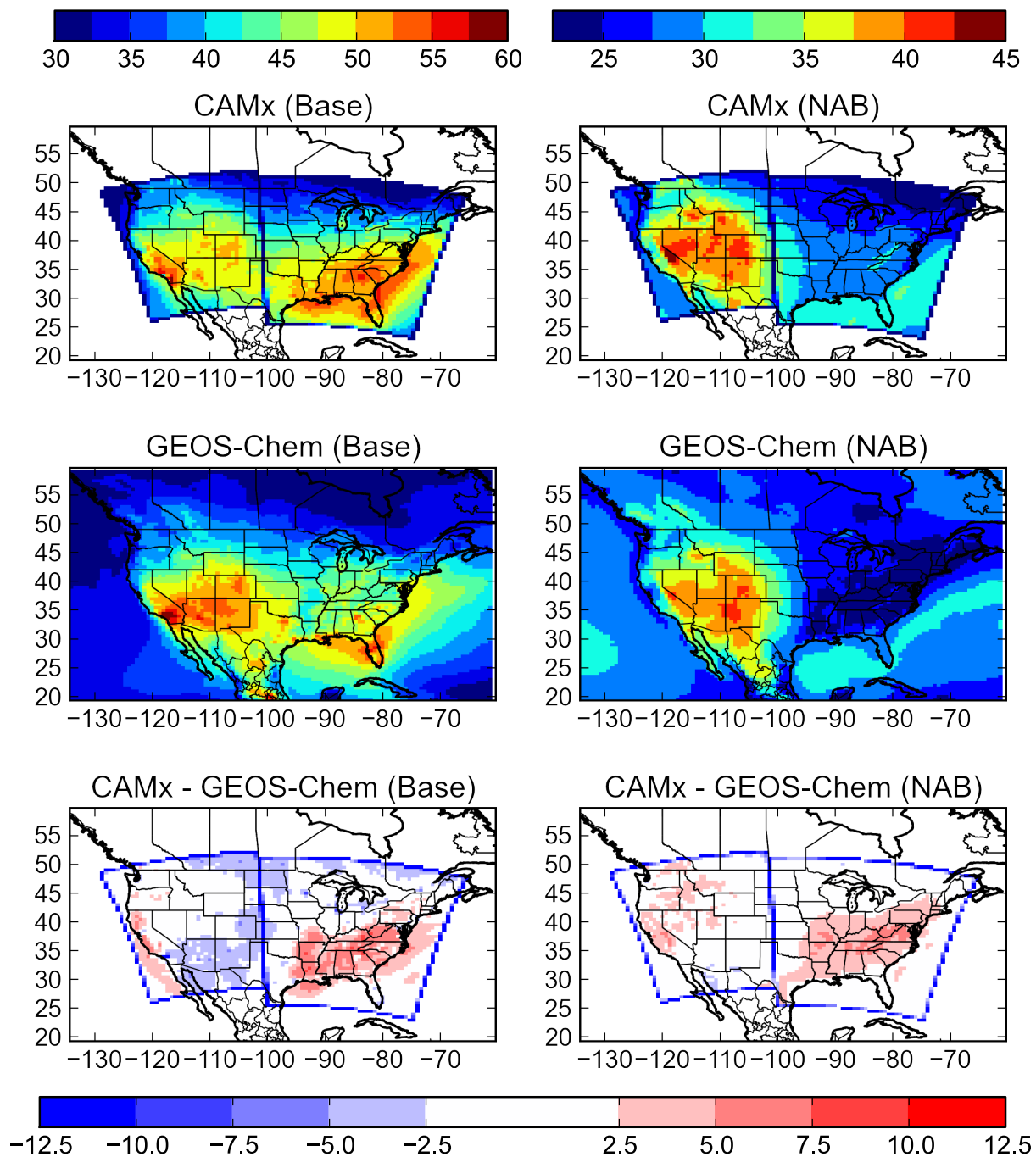- Does that correlate with observations?

Component Correlation with Observations
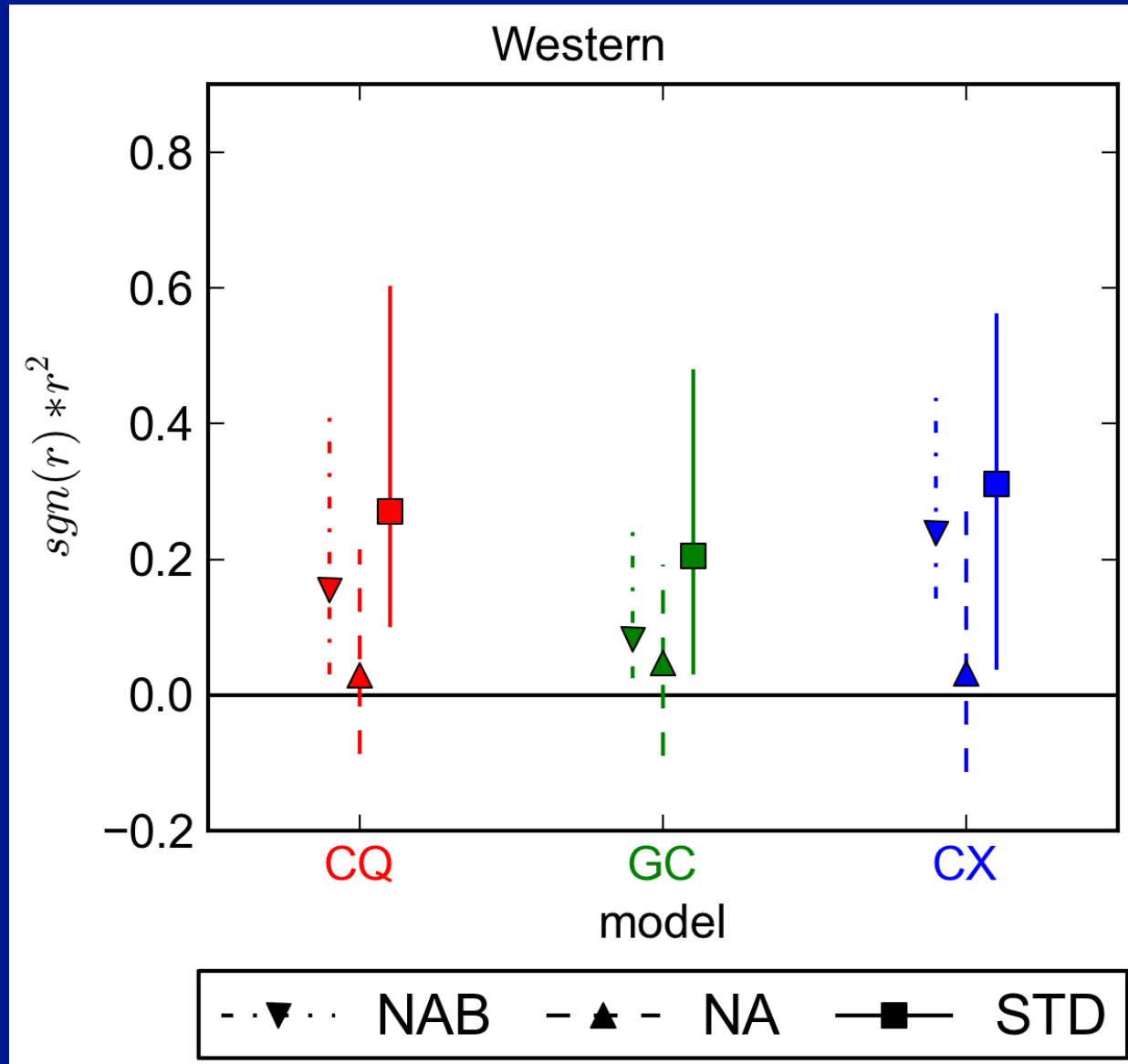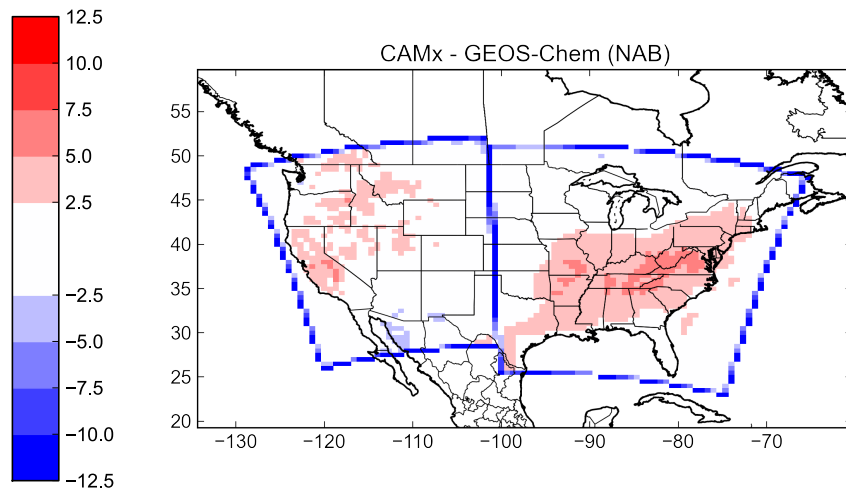
Component Correlation with Observations
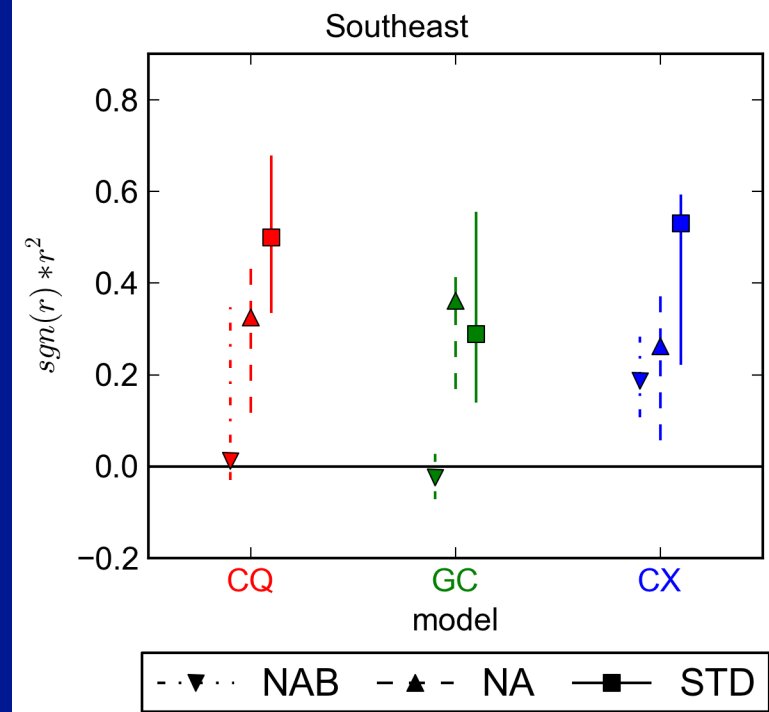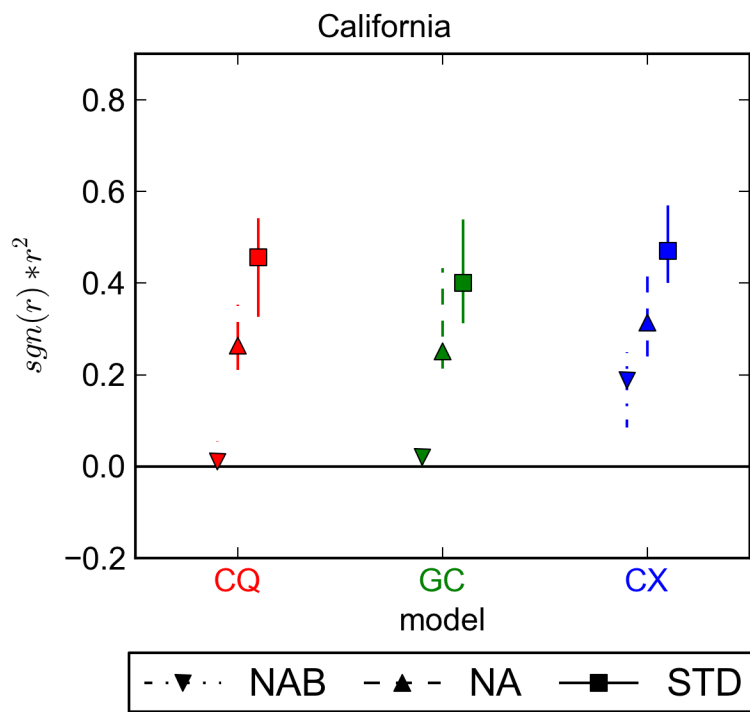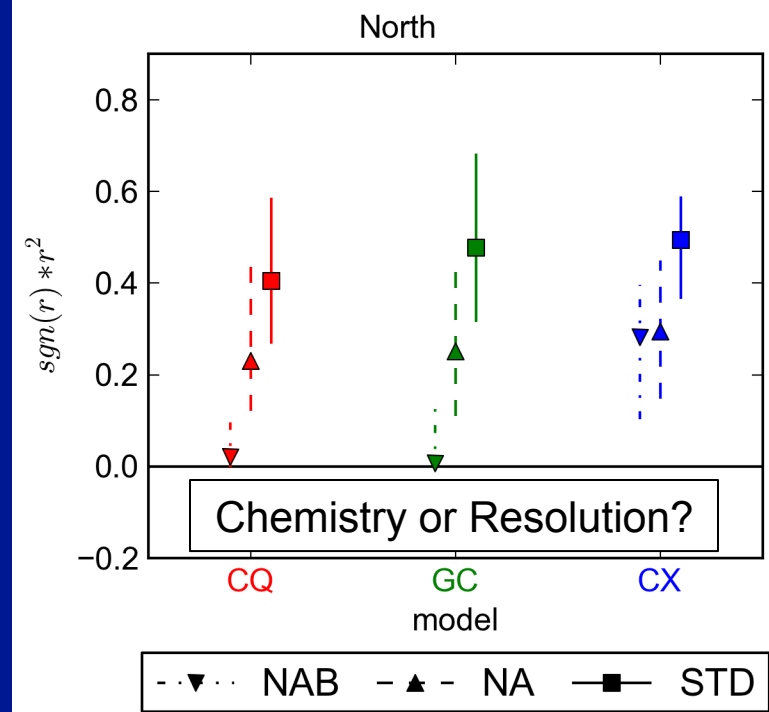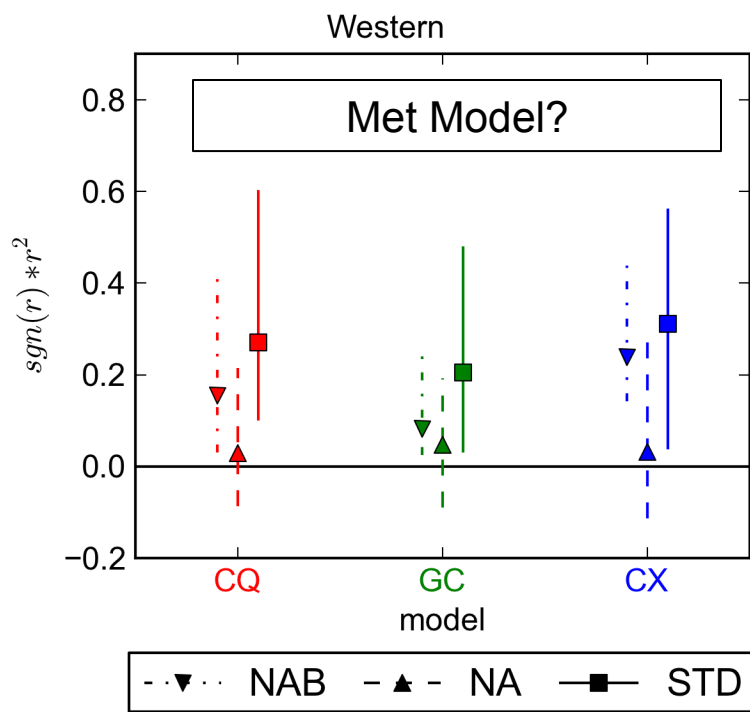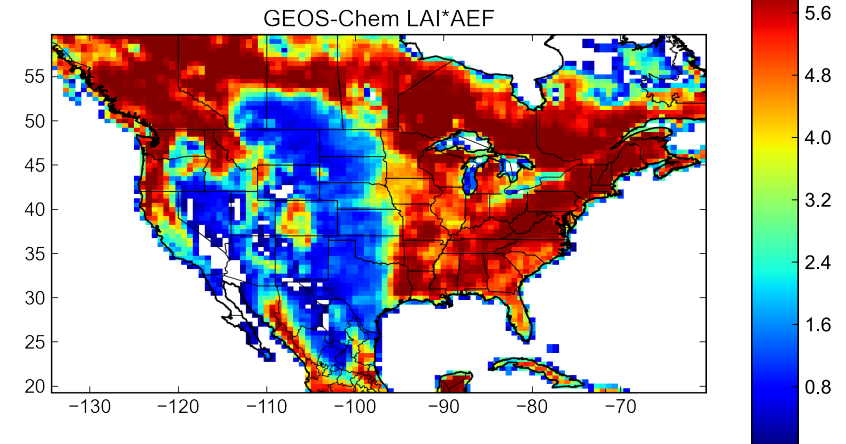
CAMx Compared to GEOS-Chem

15

Model Differences and Isoprene Emissions

CAMx – GEOS-Chem (NAB)

Leaf Area Index times emission factor

Conclusions

- Encouraging NAB/Base consistency
  - Spring with exception of Southeast
  - Western summer
- Differences in background
  - NAB better correlated with observations in CAMx
  - Appear related to isoprene emissions
- Isoprene affects:
  - VOC budget
  - NOx budget via organic nitrate formation

Future Work

- Why do models disagree about NAB correlation?
  - 3 different treatments of organic nitrates
    - Update mechanisms focused on isoprene nitrates
  - 2 emission inventories that are known to differ
    - MEGAN > BEIS (Carlton and Baker EST 2011)
- Need sensitivity studies to identify cause of the difference

Acknowledgements

- US EPA OAQPS: Farhan Akhtar, Heather Simon, Norm Possiel

- Supported in part by an appointment to the Research Participation Program at EPA/ NERL administered by the Oak Ridge Institute for Science and Education

- American Petroleum Institute for funding modeling datasets