Using Global and Regional Models to Represent Background Ozone Entering Texas





AQRP Project 12-011

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Background

- Ozone production, transport, and fate are highly dynamic
  - Multitudes of anthropogenic and natural sources
  - Many spatial and temporal scales
- EPA requires photochemical modeling to demonstrate attainment of the national ozone standard
  - As local emissions are reduced, uncontrollable "background" ozone becomes more significant
  - The background must be more accurately characterized
- In response, regulatory modeling domains are getting bigger
  - Regional models now cover the US and include worldwide contributions estimated by global models
  - Model "downscaling" via boundary conditions (BCs)

Background

- TCEQ uses the CAMx regional photochemical model for research and regulatory photochemical modeling
- Two popular global models have been routinely coupled to CAMx:
  - GEOS-Chem (Bey et al., 2001), Harvard University
  - MOZART-4 (Emmons et al., 2010), NCAR and others
  - Both employ parameterizations to treat stratospheric ozone
- A newer global model has gained attention lately
  - AM3 (Donner et al., 2011), Princeton University, NOAA GFDL
  - Fully coupled stratospheric-tropospheric chemistry and dynamics (Lin et al., 2012; Naik et al., 2013)

Objectives

- Develop boundary condition inputs for CAMx using GEOS-Chem, MOZART, and AM3
  - Use a CAMx modeling database for 2008
- Analyze ozone sensitivity in and around Texas to choice of global model
  - Quantitatively compare performance throughout the southern US against available rural ozone measurements
  - Assess ability to provide reasonable boundary conditions for regional downscaling

Approach
Global Modeling

- MOZART-4
  - Acquired from NCAR
  - 2008 6-hr global fields, 2.8° lat/lon, 28 vertical levels up 40 km
  - GEOS-5 global meteorological analyses
  - Data were mapped to CAMx/CB05 BCs using MOZART2CAMx interface program

Approach
Global Modeling

- GEOS-Chem v9-01-02
  - Run by ENVIRON
  - 2008 6-hr global fields, 2×2.5° lat/lon, 47 vertical levels up to 80 km
  - GEOS-5 global meteorological analyses
  - Doubled 2006 Asia NOx inventory (Zhang et al., 2009)
  - Data were mapped to CAMx/CB05 BCs using the GEOS2CAMx interface program

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Approach
Global Modeling

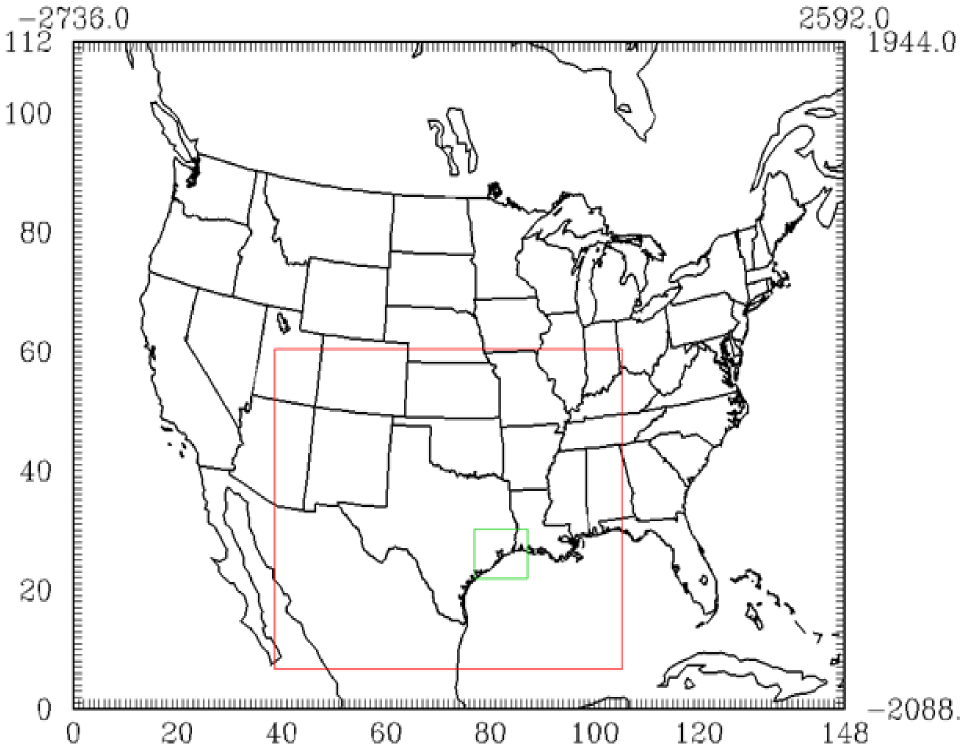
- AM3
  - Run by Princeton
  - 2008 6-hr global fields, ~200x200 km, 48 vertical levels up to 86 km
  - Nudged to NCEP/NCAR reanalysis meteorological analyses
  - RCP8.5 emissions (high scenario from 5th IPCC), 2005-2010 interpolated to 2008
  - Data processed to standard 2° lat/lon grid
  - ENVIRION and Princeton developed a new interface tool to map data to CAMx/CB05 BCs

Approach
CAMx Modeling

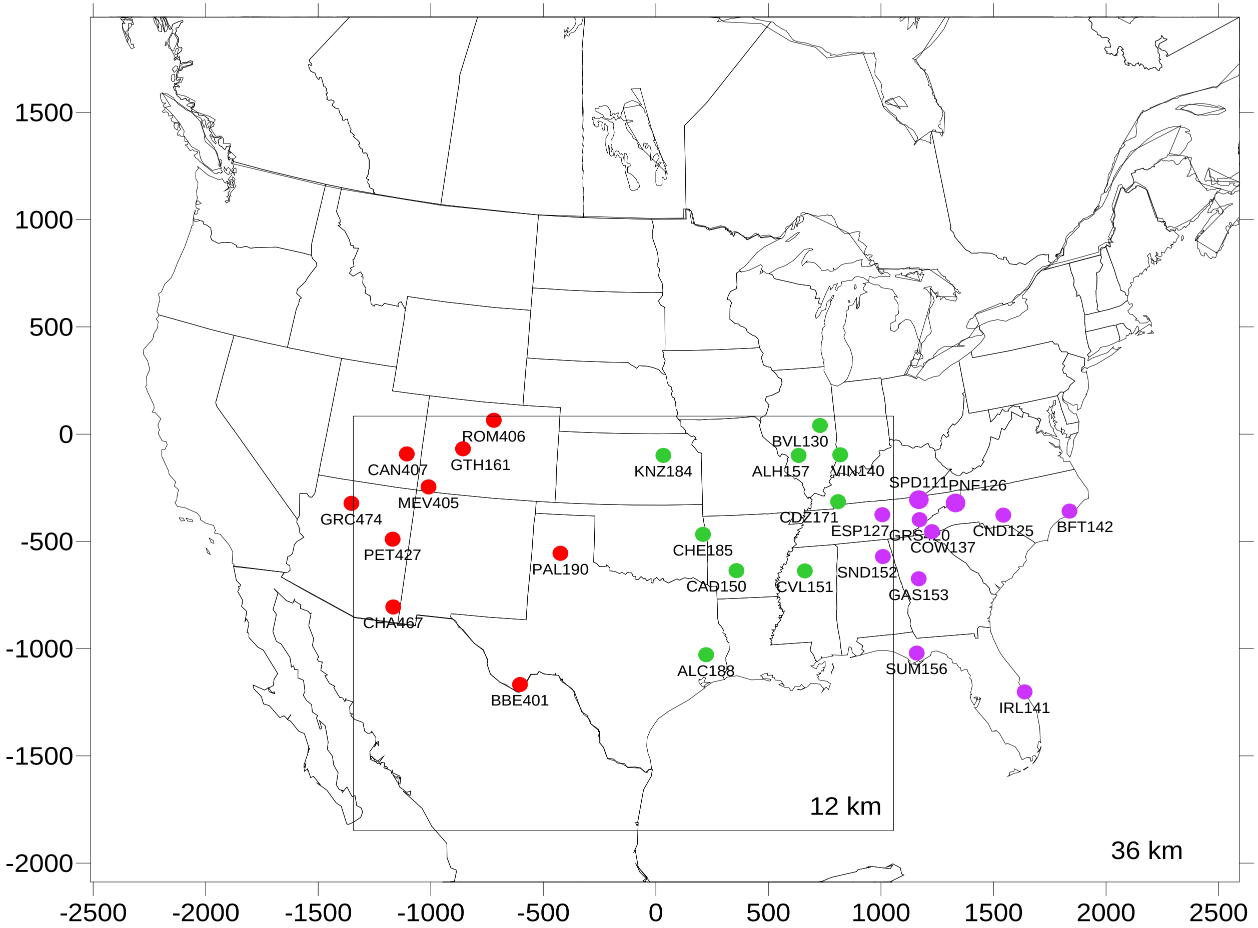
- April-October 2008 regional modeling database
  - Developed independently by Alpine Geophysics
  - Used for several concurrent AQRP modeling projects
  - Includes both ozone (CB05) and particulate matter
  - CAMx run with BCs from each global model
  - CAMx sensitivity test with invariant BCs to provide a simple reference frame
    - Ozone = 30 ppb
    - NOx = 0.1 ppb
    - NOz = 1 ppb (HNO_3, HONO, N_2O_5)
    - CO = 100 ppb
    - VOC = 5 ppbC

Approach
CAMx Modeling

Model Component	Description
Modeling Period	April 1 - October 18, 2008
Modeling Domain	36/12 km resolution (4 km not used)
Vertical Structure	30 Vertical Layers
Meteorological Model	WRF
Chemical Mechanism	CB05
Deposition	Zhang
Emissions	
Biogenics	GloBEIS
On Road Mobile	MOVES
Off Road Mobile	EPA NEI
Shipping	EPA NEI
Area Source	EPA NEI
Point Source	TCEQ
Wildfire	BlueSky/EPA SMARTFIRE 2



Performance Evaluation Sites



CAST NET Ozone Monitors Used for the AQRP Evaluation

- Southwest
- South-central
- Southeast

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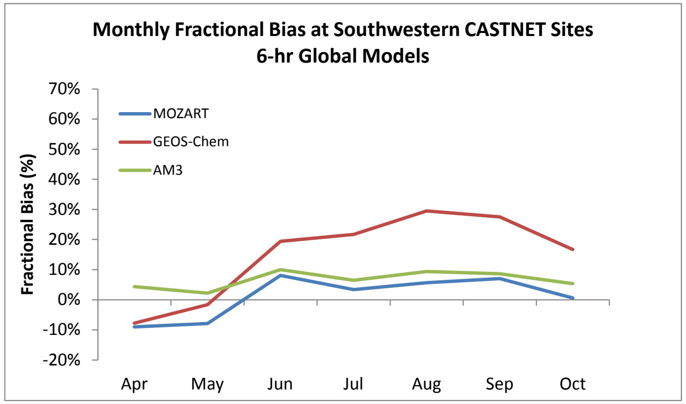
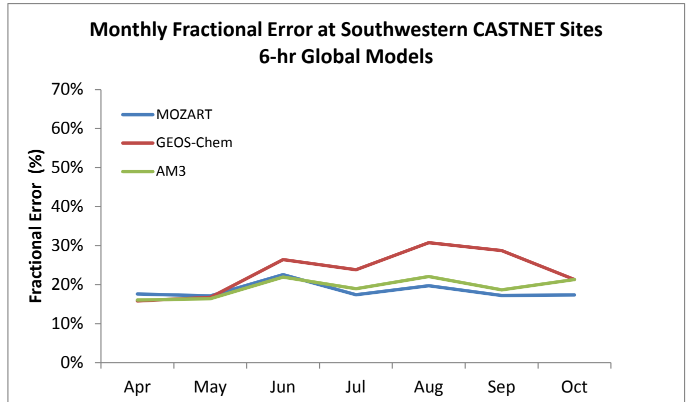
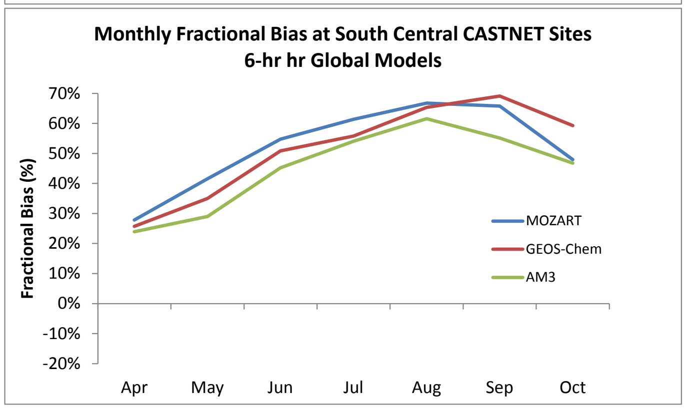
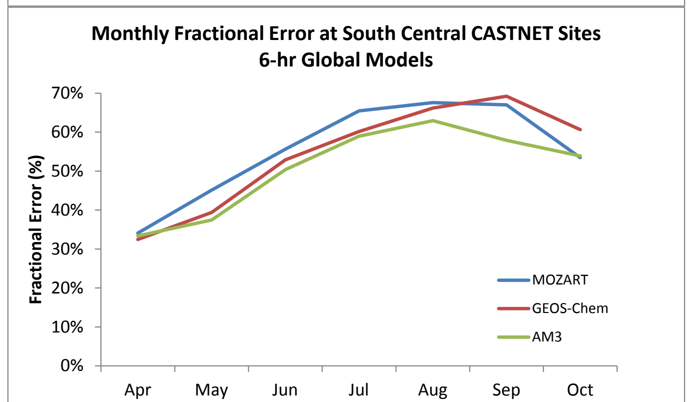
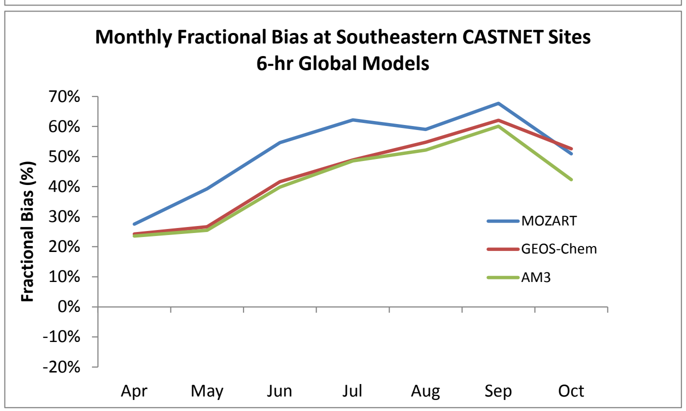
Monthly Global Model 6-hr Ozone Statistics

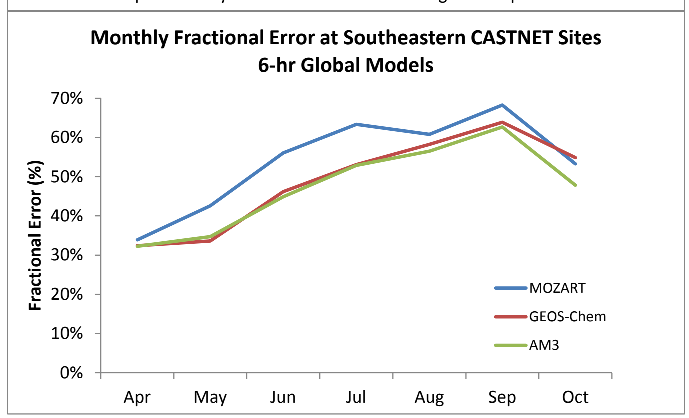












Summary – Global Model Statistics

- Similar performance among all global models
  - Very large global model over prediction bias in SC and SE US during warm season (May – Oct)
    - Coarse resolution → increases ozone production efficiency, reduces ozone chemical sinks
    - Too much ozone over Gulf, convective influences?
  - All 3 global models performed better in the SW US
    - MOZART and AM3 performed well year-round
    - GEOS-Chem too high during warm season (lightning NOx)
    - AM3 performed best in spring (stratospheric-tropospheric exchange)

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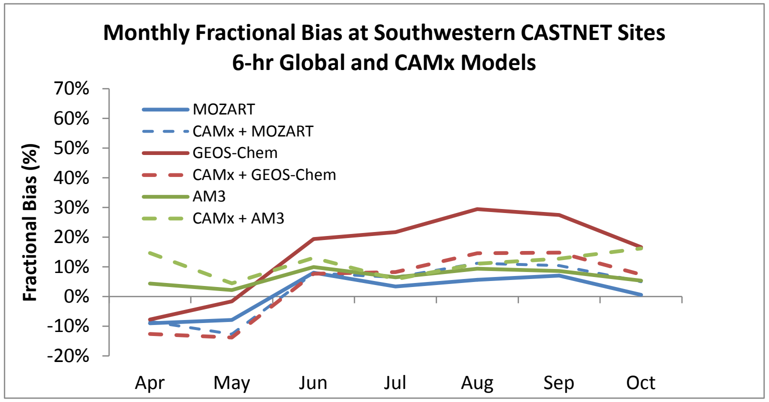
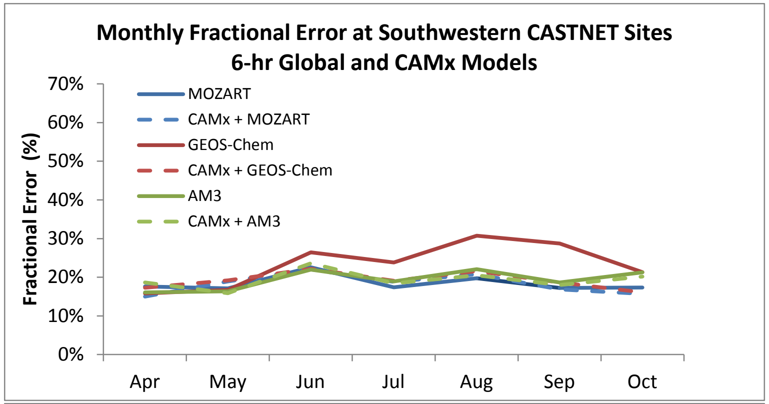
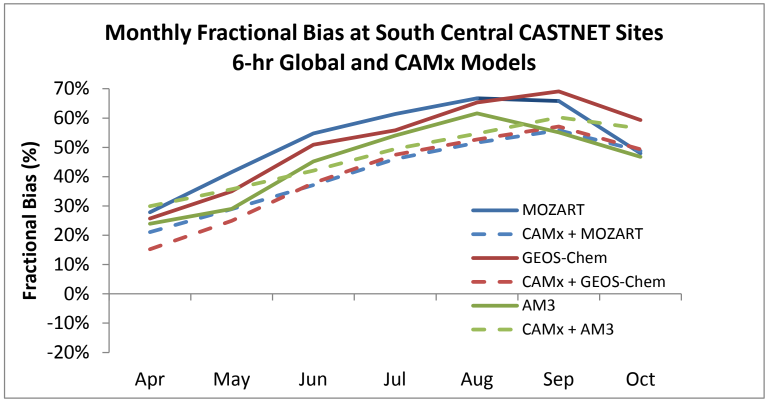
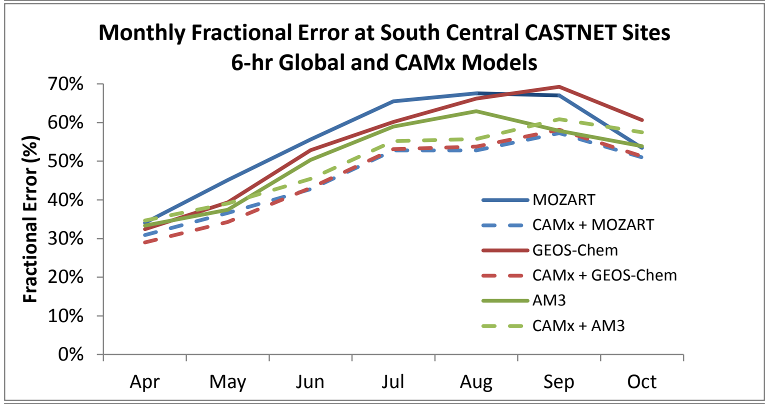
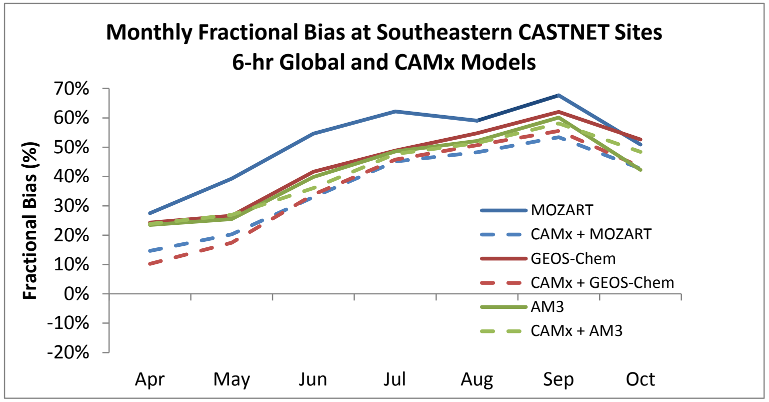
Monthly Global/CAMx 6-hr Ozone Statistics

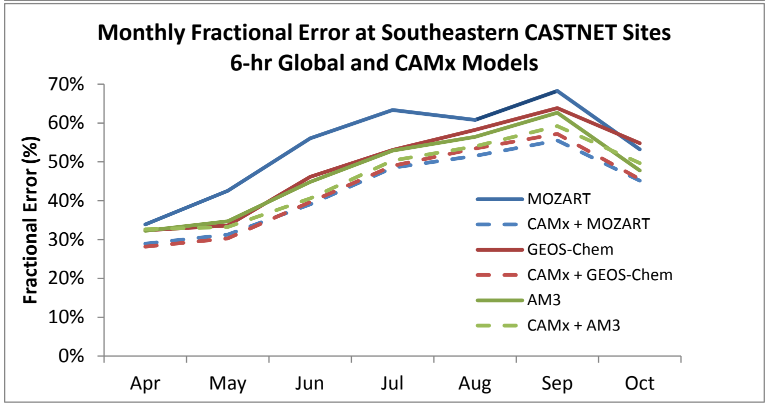






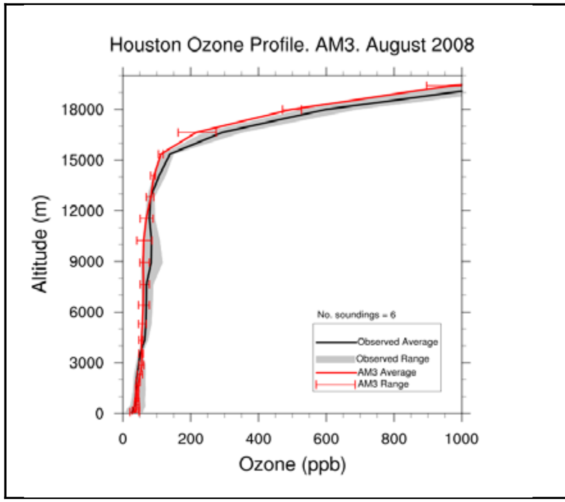


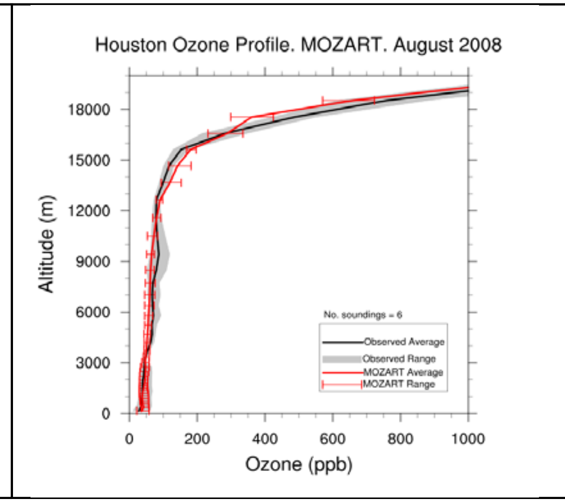


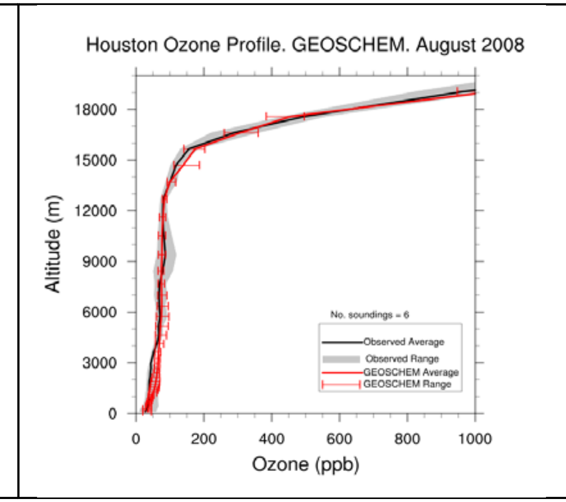


Model Performance Aloft
August-Average Houston Ozone Profiles

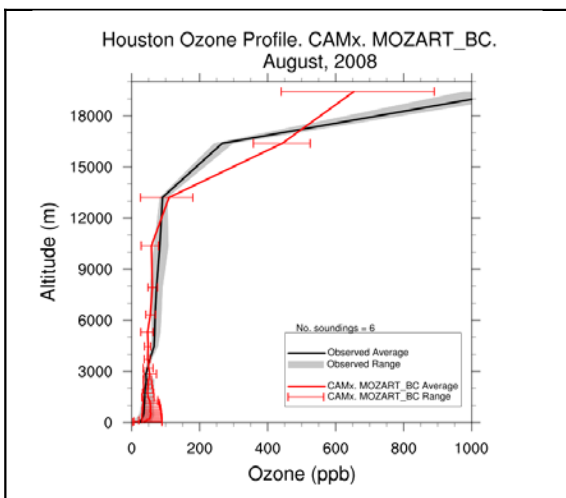
Global Models

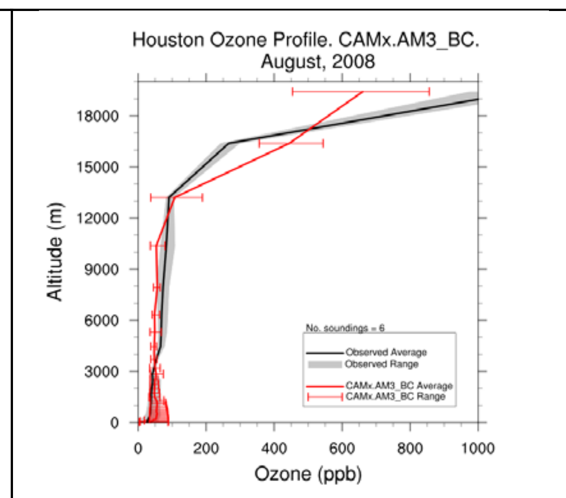


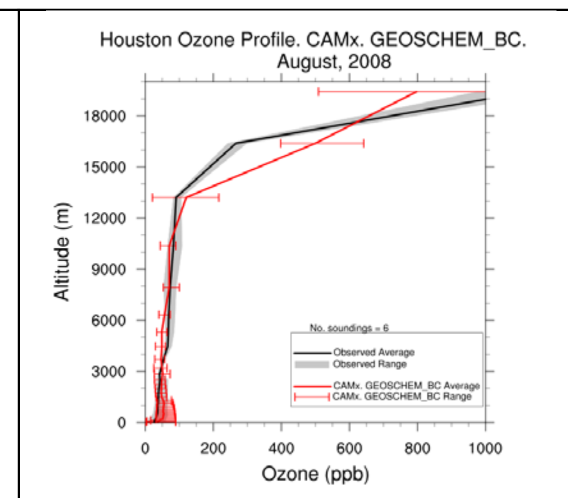




CAMx

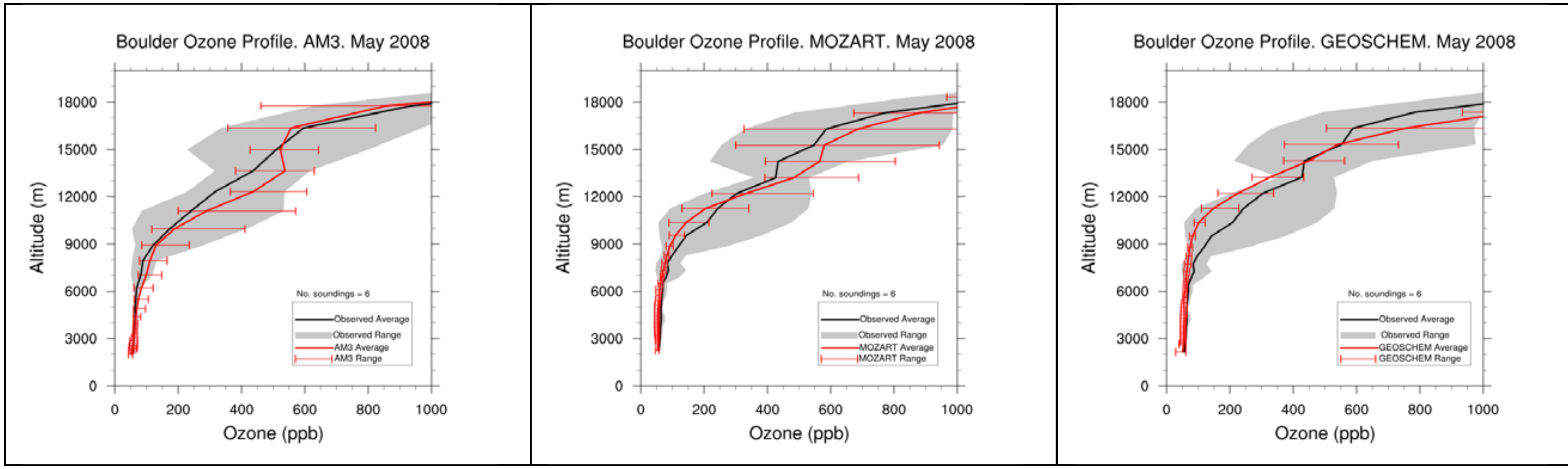




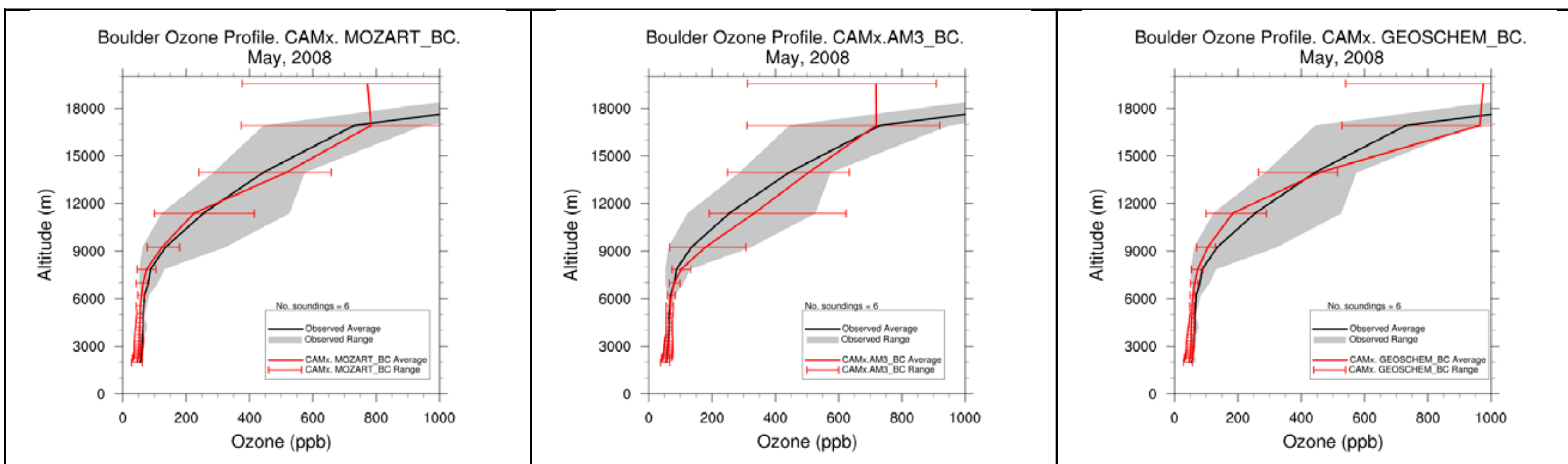


Model Performance Aloft
May-Average Boulder Ozone profiles

Global Models



CAMx



Summary – CAMx Model Statistics

- CAMx warm-season bias in SC and SE US better than global models by 10-20%
  - Fairly insensitive response to the choice of boundary conditions
  - 6-hr bias/error metrics influenced by over predictions of low ozone at night
    - Bias for MDA8 reduced ~20%
- Simple time/space-constant BCs led to only minor improvements
  - Suggests local causes in the CAMx modeling
  - No clearly superior source of boundary conditions

Summary – CAMx Model Statistics

- CAMx performed best in SW US
- MOZART, GEOS-Chem, and related CAMx runs under estimated ozone in the spring months
  - Influenced by deep vertical transport from upper troposphere and lower stratosphere
  - Higher terrain elevation
- AM3 and related CAMx run performed better
  - But CAMx has coarse vertical resolution aloft → diffusion
  - Simple BC's clearly inferior in SW US
  - Performance aloft impacts surface ozone over the western US, including west Texas
- AM3 was a superior source of BCs for the SW US

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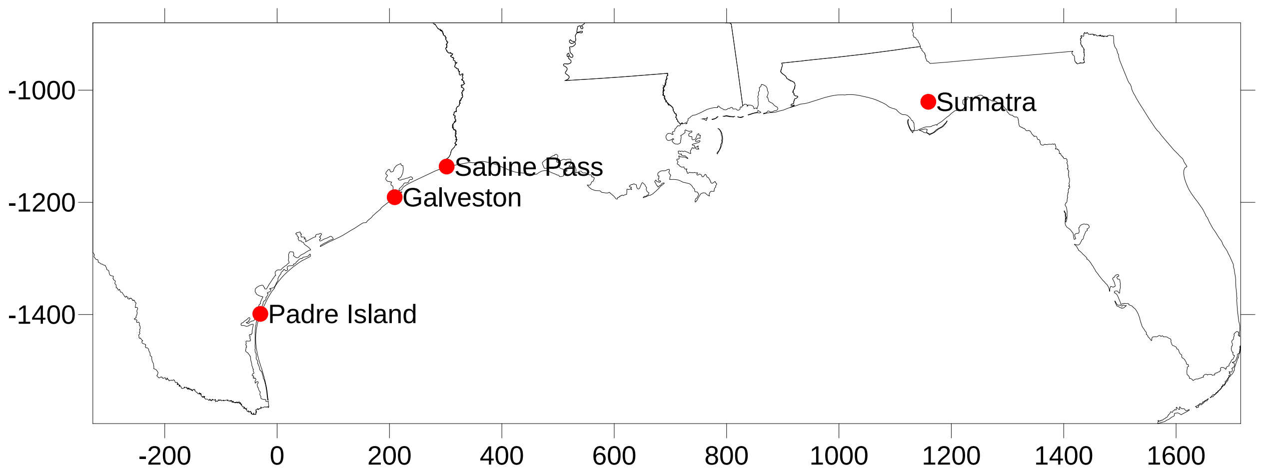
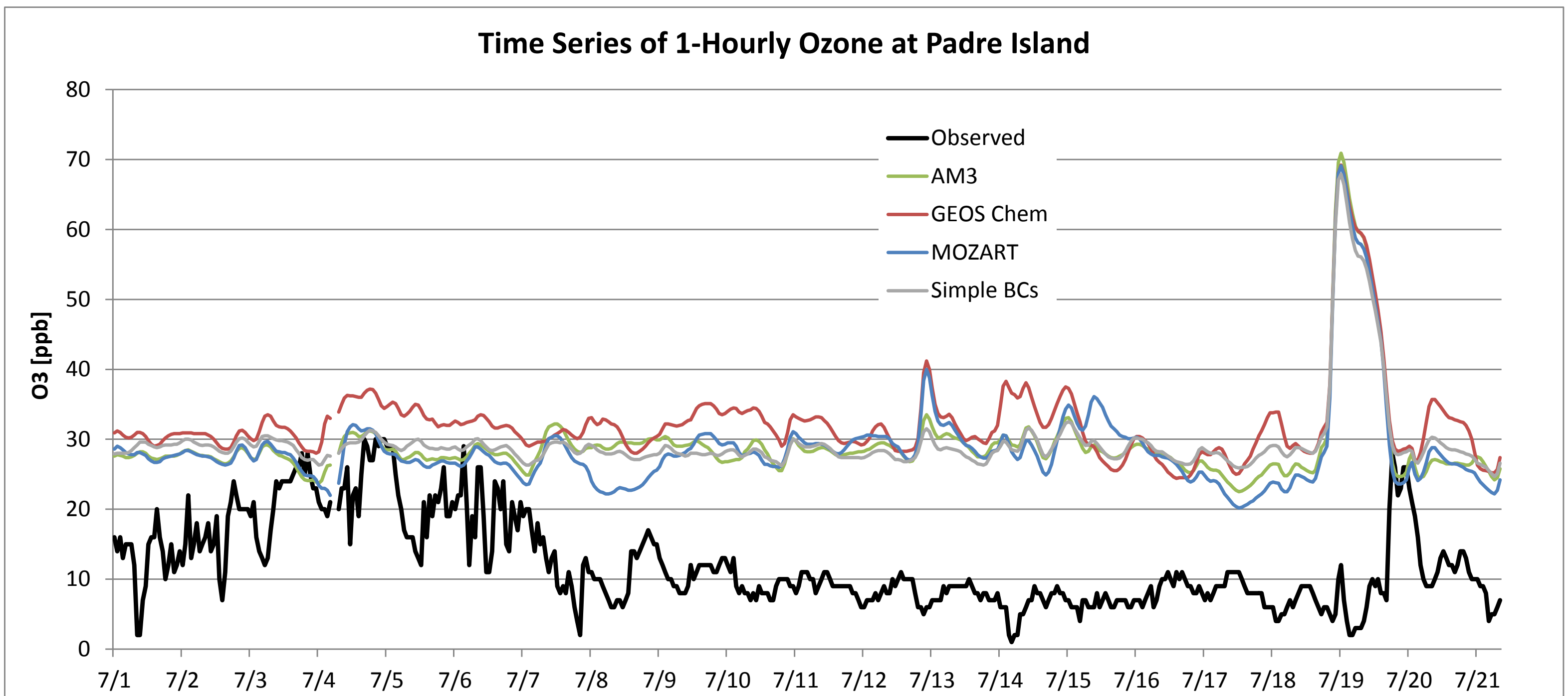
Coastal CAMx Model Performance





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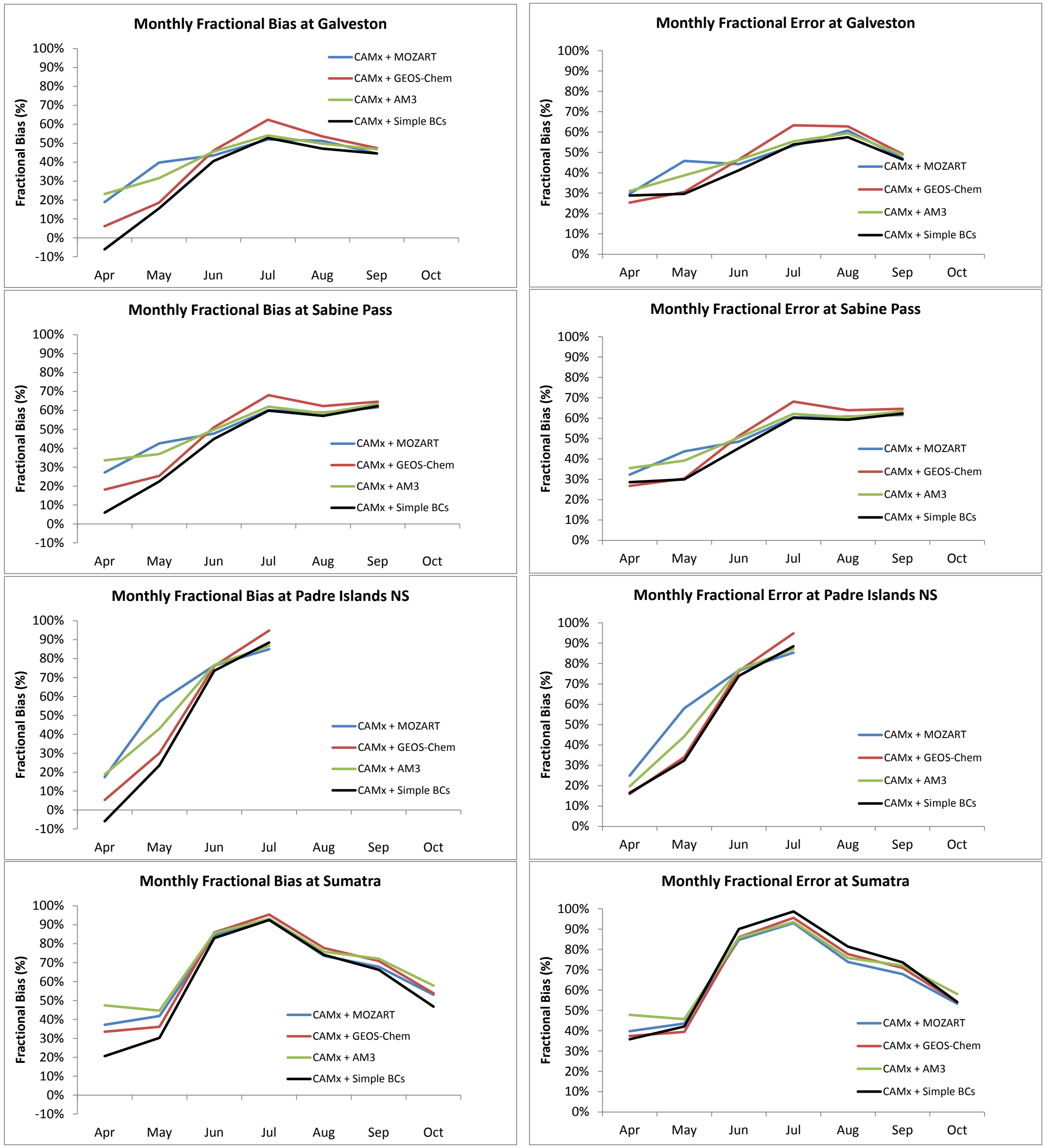
Monthly Coastal CAMx 1-hr Model Performance



Summary – Coast Site Analysis

- Ozone performance at coastal sites
  - Routinely measure very low ozone during on-shore flow
  - Often influenced by BCs
    - Minor source impacts between the boundaries and the Texas coastline
  - Over predictions of nearly 100% at two sites during mid-summer (5-10 ppb observed vs. 30 ppb modeled)
  - Practically identical results among all models
  - Missing important ozone destruction mechanism?

Acknowledgements

- Harvard University http://acmg.seas.harvard.edu/geos/ index.html
- NCAR http://www.acd.ucar.edu/gctm
- Princeton/NOAA GFDL http://www.gfdl.noaa.gov/atmospheric-model
- EPA CASTNET http://epa.gov/castnet/javaweb/ index.html
- NOAA ESRL/GMD ftp://ftp.cmdl.noaa.gov/ozwv/ozone/
- Valparaiso University http://physics.valpo.edu/ozone/ houstondata_2008_2011.htm #2008

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TCEQ has not yet reviewed the final project report and has not fully reviewed the findings presented here

Monthly CAMx MDA8 Ozone Statistics