Addressing Texas’ Unique Ozone Challenges through Modeling and Research

Jim Smith, Senior Photochemical Modeler
Air Quality Division
Texas Commission on Environmental Quality

Presented to ENV-Vision
May 11, 2016
What’s Special About Texas?

Texas, 1718
What’s Special About Texas?

- **Geography:**
  - Larger in size than France
  - Lush piney woods to desert mountains, subtropical beaches to windswept high plains

- **Demography:**
  - Second-most populous state; four of 11 largest cities in the U.S.\(^1\)
  - Fastest-growing metro area in 2015 (Austin-Round Rock)\(^2\)

- **Economy:**
  - GDP larger than Australia, South Korea, or Spain\(^3\)
  - Oil production nearly equal to Iran or Iraq\(^4\)
  - Nation’s leading exporter (in dollars)\(^5\)

---

\(^1\)2014, U.S. Census Bureau  
\(^2\)2015, Forbes  
\(^3\)2014, U.S. Bureau of Economic Analysis, World Bank  
\(^4\)2014, Texas Railroad Commission, U.S. Energy Information Administration  
\(^5\)2013, U.S. Department of Commerce
What’s Special About Texas?
What’s Special About Texas?

- **Emission sources:**
  - Oil and gas exploration & production
  - Petroleum refining and petrochemical production
  - Biogenic isoprene and terpenes from oak and pine forests
  - Mobile sources traversing vast urban areas
  - Fossil-fueled electric generation (but leads the nation in wind generation)

- **Meteorology:**
  - Precipitation increases from 8 to 60 inches/year from West to East Texas, but -
  - It’s **all hot** in the summer
  - Highest ozone usually occurs during stagnant winds or flow reversal conditions
Land-Sea-Bay Breeze Interaction
August 20, 2012

12:00 – Land Breeze Dominant
Land-Sea-Bay Breeze Interaction
August 20, 2012

13:00 – Sea and Bay Breezes active
Texas Ozone
Texas Ozone

Texas Design Value Trends, 1991-2015

- Houston-Galveston-Brazoria
- Dallas-Fort Worth
- Beaumont-Port Arthur
- Corpus Christi
- El Paso
- Northeast Texas
- San Antonio
- Austin-Round Rock
- Waco

- 1998 Ozone NAAQS
- 2008 Ozone NAAQS
- 2015 Ozone NAAQS
TCEQ 2012 Modeling Platform
TCEQ 2012 Modeling Platform

- New modeling platform for potential ozone State Implementation Plan (SIP) development and use by local air quality planning groups and researchers
  - Full ozone season: May through September
  - Fine 4-kilometer grid covers all Texas air quality planning areas except El Paso
  - Weather Research and Forecasting (WRF) meteorology
  - Comprehensive Air Quality Model with extensions (CAMx); also running the Community Model for Air Quality (CMAQ)
  - Carbon-Bond 6 rel. 2 with halogen chemistry (CB6r2h)
  - MEGAN2.10 using 2012 Leaf Area Index with the latest emission factors and 2015 Plant Functional Type data
TCEQ 2012 Modeling Platform

Highest Maximum Daily Average Eight-hour (MDA8) Ozone Concentration by Area, 2012

May 1 - Sep. 30
Because it was the hottest and driest year in 117 years of record-keeping!
TCEQ 2012 Modeling Platform

**WRF Domains**
- 36, 12, 4 km
- 42 Layers

**CAMx Domains**
- 36, 12, 4 km
- 29 Layers
TCEQ 2012 Modeling Platform

Model Performance

Model Performance Statistics of Eight-Hour Ozone Concentrations in Texas 4 kilometer Domain

Mean Bias (MB) of Site Daily Maximum (2×2-cell bi-linear interpolated values)

Model Performance Statistics of Eight-Hour Ozone Concentrations in Texas 4 kilometer Domain

Root Mean Squared Error (RMSE) of Site Daily Maximum (2×2-cell bi-linear interpolated values)
TCEQ 2012 Modeling Platform

O3 Hourly Concentration (2x2 bi-linear interpolated value)
HSMA, 482010062, C406, Houston Monroe, C406, 9726 1/2 Monroe, Houston, Harris Co., TX

O3 Hourly Concentration (2x2 bi-linear interpolated value)
GALV, 481671034, C1034, Galveston 99th St, C1034/A320/X183, 99th St., Galveston, Galveston Co., TX

Air Quality Division • Addressing Texas' Unique Ozone Challenges • JHS • May 11, 2016 • Page 19
Texas Field Studies
Major Air Quality Field Studies

- 1993 Coastal Oxidant Assessment for Southeast Texas (COAST) study:
  - Focused on Houston and Beaumont areas
  - Coordinated with the Gulf of Mexico Air Quality Study (GMAQS)
  - Three aircraft (including two from GMAQS)
  - Enhanced surface and aloft monitoring for ozone, nitrogen oxides (NO$_X$), volatile organic compounds (VOC), and meteorology
  - Bottom-up emissions for anthropogenic and biogenic sources
  - Result: Major improvements in conceptual understanding of ozone in coastal Texas, greatly improved modeling capabilities, but still under-predicted the highest ozone peaks
Major Air Quality Field Studies

- **2000 Texas Air Quality Study (TexAQS 2000)**
  - Focused on Houston area
  - Over 200 participants from government (EPA, NOAA, DOE), universities (UT, others), and private industry
  - Five aircraft, five major surface chemistry sites
  - Tunnel study
  - Real time measurements of ozone, CO, NO, NO$_2$, SO$_2$, peroxides, PAN, MPAN, nitric acid, formaldehyde, ammonia, selected hydrocarbons (including isoprene), aerosol size distributions
  - Results: Observed very high ozone production efficiencies tied to highly reactive VOCs (HRVOC); TCEQ established HRVOC Cap and Trade program (HECT)

Note: For TCEQ regulatory purposes, HRVOC is defined as these specific light olefins: Ethylene, Propylene, 1,3 Butadiene, and Isomers of Butene
Major Air Quality Field Studies

• 2006 Texas Air Quality Study (TexAQS II)
  - Focused on Eastern Texas
  - Twenty-eight universities, over a dozen government agencies, several corporations and research consortia
  - Four aircraft and one research vessel (R.V. Ron Brown)
  - Ten additional fixed radar profiler sites plus one on the ship
  - Ozone sondes launched from ship and shore
  - Remote sensing: Differential Optical Absorption Spectroscopy (DOAS), Solar Occultation Flux (SOF)
  - Real-time measurements of ozone, CO, NO, NO$_2$, SO$_2$, speciated hydrocarbons, peroxides, PANs nitric acid, carbonyls, radicals, and more
  - Special inventory of HRVOC sources
Major Air Quality Field Studies

- **TexAQS II Results:**
  - Improved understanding of:
    - Ozone transport
    - Halogen and nitrate chemistry
    - Deposition
    - Emissions from biogenic sources, ships, vehicles, and industry
    - Aerosol composition
    - Meteorology and its relation to ozone formation
  - Provided modeling episodes used by TCEQ and air quality planning areas for eight years
  - Model Performance Evaluation (MPE) in three dimensions and for locations and species not routinely observed
  - TexAQS II measurements supported model performance evaluation using process analysis – showed that the model accurately captured VOC-"NO\_X" sensitivities in Houston.
Three-dimensional Model Performance Evaluation (TexAQS II)
Major Air Quality Field Studies

- 2013 Deriving Information on Surface Conditions from COnumn and VERtically Resolved Observations Relevant to Air Quality (DISCOVER-AQ)
  - Focused on Houston area
  - NASA program; Collaborators include EPA, NOAA, TCEQ, 13 universities, Aerodyne Corp.
  - Two aircraft P-3B in situ sampling; King Air TOPAZ
  - Tethersonde, ozone sondes, radar profiler, aerosol lidar, trace gas monitoring at Smith Point
  - Mobile SOF, DOAS, and in-situ sampling
  - Results:
    - Sampling of an extreme ozone event (September 25)
    - Vertical profiles of many trace gases
    - MPE for future ozone modeling at TCEQ?
Texas Research Programs
Research Programs in Texas

- **TCEQ-Managed Projects**
  - 30+ projects/year
  - Includes routine inventory update, inventory improvement tasks, and a variety of applied research projects

- **Selected Highlights:**
  - 2010 TCEQ Flare Study, flare operator training course
  - Halogen Chemistry
    - Add halogen chemistry to CAMx
    - Coastal measurement of halogen compounds using DOAS
    - Boundary Conditions from GEOS-Chem with halogen chemistry
  - Assimilation of satellite-observed cloud cover into WRF
  - Mobile monitoring in Eagle Ford Shale area
Properly operated flares can achieve over 99% Destruction and Removal Efficiency (DRE) but over-assisted flare DRE declines rapidly.
Halogen Chemistry

- Hourly Concentration: O3
- MDA8 Ozone Bias

June 7-9, 2012 14:00 back trajectories, 50m agl at Galveston
June 10-15, 2012 14:00 back trajectories, 50m agl at Galveston
June 22-26, 2012 14:00 back trajectories, 50m agl at Galveston
Research Programs in Texas

• Air Quality Research Program (AQRP)
  – Funded by the State of Texas using TERP funds, around $11,000,000 since 2010
  – Managed by the University of Texas
  – Independent research, coordinated with TCEQ needs
  – Approximately 50 projects funded to date

• AQRP Support for DISCOVER AQ Texas:
  – Infrastructure for ground sites
  – Mobile in-situ and remote sensing-based trace gas and PM measurements and subsequent analyses
  – Boundary-layer meteorology characterization
  – Airborne formaldehyde analysis
  – Ozone and aerosol formation studies
  – More
Research Programs in Texas

- Other Selected AQRP Research Highlights:
  - Expanded 2010 TCEQ Flare Study
  - Dallas-Fort Worth field study (4 coordinated projects)
  - Analysis of ozone production from light alkenes using hydroxynitrate reaction products
  - Cloud-in-grid modeling in CAMx
  - Impact of large circulation patterns on ozone concentrations in Texas
  - Constraining NO\textsubscript{X} emissions using satellite observations
  - Dry deposition to built environmental surfaces
  - Soil moisture effects on biogenic emissions
  - Improved land cover and emission factors for estimating biogenic emissions
Research Programs in Texas

- Texas Universities Conducting Air Quality Research:
  - University of Texas at Austin
  - University of North Texas (Denton)
  - University of Houston
  - Texas A&M University (College Station)
  - Lamar University (Beaumont)
  - St. Edwards University (Austin)
  - Rice University (Houston)
Research Programs in Texas

- Other organizations conducting or sponsoring research in Texas:
  - The Houston Advanced Research Consortium (HARC) is actively engaged in modeling and remote-sensing studies of ozone precursors and toxics.
  - The Texas Air Research Center (TARC) supports several projects each year primarily focused on Southeast Texas.
  - The 8-Hour Coalition industry group supports ozone modeling studies primarily focused on the Houston area.
  - The Sierra Club and EPA Region 6 also occasionally commission modeling studies in Texas.
• Involvement with non-TCEQ studies includes:
  – Tropospheric Ozone Pollution Project (TOPP), ongoing
  – Big Bend Regional Aerosol and Visibility Observational (BRAVO) Study, 1999
  – TexAQS II Radical Measurement Project (TRAMP), 2007
  – Study of Houston Atmospheric Radical Precursors (SHARP), 2008
Some Texas Initiatives

Texas Emissions Reduction Plan
A Program of the TCEQ
Some Texas Initiatives

• Texas Emission Reduction Plan (TERP): The TERP program, established by the Texas Legislature in 2001, provided financial incentives to eligible individuals, businesses, or local governments to reduce emissions from heavy-duty on-road vehicles and non-road equipment, marine vessels, locomotives, and certain stationary equipment.

• Inter-pollutant and inter-basin credit use: TCEQ has developed guidance for modeling inter-pollutant (i.e. VOC for NO$_x$ emission credits) and/or inter-basin (i.e. Dallas to Houston) credit use to show no net degradation to air quality.

• State and Local Air Quality Planning Program: The Texas legislature appropriates funds to support local air quality planning in areas close to nonattainment for ozone.
Some Texas Initiatives

• Supplemental Flare Operations Training for Plant Personnel: “The objective of the training is to enhance plant personnel's understanding of industrial flare operation and provide practical information about variables affecting flare performance, with the aim to maximize flare destruction and removal efficiency (DRE) of dual-purpose assisted flares consistent with state and federal regulations using existing on-site resources.”

• Remote Sensing of Emissions: Pioneered use of infrared (IR) cameras for detecting unseen hydrocarbon emissions
Thermal Infrared (IR) Camera

Over-assisted Flare

Casing-head Gas Release

Storage Tank Leak

Unlit Flare
Some Lynx
Some Lynx

- TCEQ Air Modeling Data:
  [http://www.tceq.state.tx.us/airquality/airmod/data/am_data](http://www.tceq.state.tx.us/airquality/airmod/data/am_data)
- TCEQ Research Project Reports:
  [http://www.tceq.state.tx.us/airquality/airmod/project/pj.html](http://www.tceq.state.tx.us/airquality/airmod/project/pj.html)
- Texas Emission Reduction Program (TERP):
  [http://www.tceq.state.tx.us/airquality/terp](http://www.tceq.state.tx.us/airquality/terp)
- State and Local Air Quality Planning Program:
  [https://www.tceq.texas.gov/airquality/airmod/rider8/rider8-background](https://www.tceq.texas.gov/airquality/airmod/rider8/rider8-background)
- Air Quality Research Program (AQRP):
  [http://aqrp.ceer.utexas.edu/projects.cfm](http://aqrp.ceer.utexas.edu/projects.cfm)
- Houston Advanced Research Center (HARC):
  [http://www.harcresearch.org/Projects/AirQuality/](http://www.harcresearch.org/Projects/AirQuality/)
- Texas Air Research Center (TARC):
  [https://engineering.lamar.edu/research/tarc/index.html](https://engineering.lamar.edu/research/tarc/index.html)
- Tropospheric Ozone Pollution Project
  [http://www.ruf.rice.edu/~ozone/](http://www.ruf.rice.edu/~ozone/)
Some More Lynx

- DISCOVER AQ:
- TexAQS 2000:
  http://www.esrl.noaa.gov/csd/projects/texas2k/
- TexAQS II:
  https://www.tceq.texas.gov/airquality/research/texas
- TCEQ 2010 Flare Study:
- Halogen Chemistry Presentation:
- Interactive Model Performance Evaluation using GRIMREAPr (poster)
- Big Bend Regional Aerosol and Visibility Observational (BRAVO) Study
  https://www.nps.gov/bibe/learn/nature/aq_bravo.htm
Even More Lynx

- TexAQS II Radical Measurement Project:
  [Link](http://files.harc.edu/Projects/AirQuality/Projects/H086/H086FinalReport.pdf)
- Study of Houston Atmospheric Radical Precursors (SHARP)
  [Link](http://files.harc.edu/Sites/TERC/About/Events/SAC200802/RadicalSourcesVOCEmissionsLefer.pdf)