Eastern Texas Air Quality Forecasting System for Texas AQS-II

The goal is to provide best forecasting support with improved model inputs and physics

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Institute for Multi-dimensional Air Quality Studies (IM APS)
University of Houston
Outline

- Meteorological modeling
- Processing emissions inventories
- Result of 2005 Air Quality Forecasting for HGA
- Preparation for 2006 Air Quality Forecasting
- Result of 2006 June Air Quality Forecasting for HGA
Air Quality Modeling

CMAQ Linked with Meteorology & Emission Inputs

Chemistry - Transport model
- Chemistry
- Advection
- Diffusion & deposition
- Clouds
- Plume-in-Grid
- Aerosols

Interface Processors
- MM5
- Emissions models
- Environmental Data

Users
- Science Findings
- Policy Related Information

TEI PS (SMOKE, EPS3, GloBEIS, BEI S3, MOBILE6)
UH (Univ. of Houston)
AQF (Air Quality Forecasting) Systems

Spatial Resolution
- 36 km: U.S. Continent
- 04 km: Houston and Galveston Area (05) & Dallas-Fort Worth area (06)

Operation Period and Duration (May 2005 ~ Current)
- Spin-up: 6 hrs
  (0th day 18 CST – 0th day 23 CST)
- Forecasting: 48 hrs
  (1st day 00 CST – 2nd day 23 CST)

Two Different Air Quality Forecasting Systems
- Forecasting 1 (F-1): 2005/2006 MM5 modified by UH + Emission + CMAQ v4.4
- Forecasting 2 (F-2): 2005 Default MM5 + Emission + CMAQ v4.4
  2006 Extended MM5, Projected Emissions, CMAQ 4.4
UH AQF systems (F-1 & F-2)

Download
ETA Forecast

MM5 simulations (24 CPUs)
- F1=UH mode; F-2=MM5 default

CMAQ simulations (36 CPUs)
- Post-Process
  - Visualization
  - Statistics
  - Web Display

Multi CPU
- Single CPU
- Data Flow
# Comparison of MM5 options used for the forecasting

Meteorological Operations with UH mod MM5 vs. Default MM5

<table>
<thead>
<tr>
<th>F-1 with</th>
<th>F-2 with</th>
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<tr>
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<td>48-CPU Xeon Beowulf Cluster</td>
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<td>w/ ETA Forecasting</td>
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<td>Landuse Type</td>
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<td>USGS24 (36 &amp; 12 km)</td>
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<td>Modified NOAH LSM</td>
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<td>PBL Scheme</td>
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<td>Radiation Scheme</td>
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<td>Cloud Radiation (~ Aug. 05)</td>
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<td>RRTM (Since Sep. ~)</td>
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2000 TEI + 2000 HRVOC imputed
### Model Vertical Layer Structure

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<th>Layer Top (AGL m)</th>
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Texas Forest Service (TFS) 2000 LULC Data from Global Environmental Management (GEM) for the Houston and the surrounding eight county areas (GEM, 2003).

Data source: 30 meter resolution 2000 LANDSAT satellite imagery, digital aerial photography, aerial LIDAR data, USGS elevation data and vector based GIS data.

(Prepared by Stephen Stetson, processed by Dr. Soontae Kim)
### MM5/Noah Land Surface Model LULC Data

<table>
<thead>
<tr>
<th>LANDSAT</th>
<th>Corresponding USGS 25-category</th>
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<tr>
<td>1 'bare_flds_barren'</td>
<td>Barren or Sparsely Vegetated' (19)</td>
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<tr>
<td>2 forest_broadleaf</td>
<td>Deciduous Broadleaf Forest' (11)</td>
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<tr>
<td>3 'forest_coniferou'</td>
<td>Evergreen Needleleaf Forest' (14)</td>
</tr>
<tr>
<td>4 'forest_mixed'</td>
<td>Mixed Forest' (15)</td>
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<tr>
<td>5 'grass_range'</td>
<td>Grassland' (7)</td>
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<tr>
<td>6 impervious</td>
<td>Urban and Built-Up Land' (1)</td>
</tr>
<tr>
<td>8 water'</td>
<td>Water Bodies' (16)</td>
</tr>
<tr>
<td>9 residential</td>
<td>residential' (newly defined)</td>
</tr>
<tr>
<td>10 residential forests</td>
<td>residential forests (newly defined)</td>
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</table>

Land surface parameters in the LSM where roughness length ($Z_o$) is in m, minimal stomatal resistance ($R_{cmin}$) is in s m$^{-1}$, $R_{gl}$ is the visible solar flux, and $H_s$ is a parameter for calculating vapor pressure.

<table>
<thead>
<tr>
<th>Land Use Type</th>
<th>Albedo</th>
<th>$Z_o$ (cm)</th>
<th>Emissivity</th>
<th>$R_{cmin}$</th>
<th>$R_{gl}$</th>
<th>$H_s$</th>
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<td>1) Urban</td>
<td>0.18</td>
<td>50</td>
<td>0.88</td>
<td>200</td>
<td>999</td>
<td>999</td>
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<td>12</td>
<td>0.985</td>
<td>40</td>
<td>100</td>
<td>36.35</td>
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<tr>
<td>3) Mixed Forest</td>
<td>0.13</td>
<td>50</td>
<td>0.94</td>
<td>125</td>
<td>30</td>
<td>47.35</td>
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<tr>
<td>4) Residential</td>
<td>0.18</td>
<td>30</td>
<td>0.94</td>
<td>40</td>
<td>100</td>
<td>36.35</td>
</tr>
<tr>
<td>5) Residential Forest</td>
<td>0.13</td>
<td>40</td>
<td>0.95</td>
<td>125</td>
<td>30</td>
<td>47.35</td>
</tr>
</tbody>
</table>
LULC differences on simulated PBL height

**USGS**

- **PBL ht**
  - 2405.56 - 2666.69
  - 2204.71 - 2405.55
  - 2025.82 - 2204.70
  - 1885.37 - 2025.81
  - 1771.94 - 1885.36
  - 1664.70 - 1771.93
  - 1566.94 - 1664.69
  - 1449.37 - 1566.93
  - 1332.92 - 1449.36
  - 1116.62 - 1332.91
  - 755.91 - 1116.61
  - 464.90 - 755.90
  - 289.14 - 464.89
  - 205.87 - 289.13
  - 153.46 - 205.86
  - 74.09 - 153.45

**TFS**

- **PBL ht**

- **Ship Channel**
Wind Profiler

Aug.25 LM_Profiler WS(m/s)

Aug.25 LM USGS WS(m/s)

Aug.25 LM TFS WS(m/s)
Surface site: Channelview

USGS: urban

TFS: residential

- TEMP

Temperature: Channelview (C15/A115)

- WS

Wind Speed: Channelview (C15/A115)

- WD

Wind Direction: Channelview (C15/A115)
Surface site: La Porte

**USGS:** dry/crop land  
**TFS:** urban

- **TEMP**
- **WS**
- **WD**

Graphs showing temperature (TEMP), wind speed (WS), and wind direction (WD) over the period from 8/25 to 8/31.
1600 CST Aug. 30th, 2000

Sea Breeze

Horizontal Wind

Circulation vector & Vertical wind speed (contour)
Emissions processing for ETAQ

Point
- Texas EI preparation
  - Format conversion
    - AMS/AFS → IDA
  - Internal database
    - Surrogates
    - Split factors
    - Temporal profiles

Mobile
- Internal database
  - Surrogates
  - Split factors
  - Temporal profiles

Area

Biogenic
- Normalized emissions

GloBEIS3

Met. adjustment

BEIS3

SMOKE processing
- Spatial allocation
  - 36km, 12km & 4km
- Temporal allocation
  - Hourly emissions
- Chemical speciation
  - CB4, SAPRC99 & RADM2
- Plume rise

CMAQ

University of Houston Texas Emissions Processing System (TEIPS)

- **TEI 2000 Base5b**
  - TexAQS 2000 episode used for State Implementation Plan
  - The day of Week
    - Aug. 25\(^{th}\) → Friday, Aug. 26\(^{th}\) → Saturday, Aug. 27\(^{th}\) → Sunday, Aug. 30\(^{th}\) → Monday ~ Thursday
  - CB4, SAPRC99, and RADM2
  - Area & Non-road: 2000 Emissions Inventory

- **NEI99 (Final version 3)**
  - CONUS 36-km domain
  - Particulate matters and precursors (NH3, SO2)

- **Processor: SMOKE version 2.1**
  - Internal database: TCEQ’s (for spatial and temporal allocation)
    Default & TCEQ’s for chemical speciation
Gridded mobile NO emissions

Note: it changes with time
Non-road NOx Emissions

NOx emissions from non-road mobile sources take 11% of total NOx emissions.

Gridded Area & Non-road NO Emissions

Onshore and offshore emissions
Point Sources: TEI00

- EGU
- NEG U
- Additional VOC for imputation
- Elevated ship emissions
- Offshore point

Map showing various point sources with different markers.
NEI Point VOC emissions
TEI Point VOC emissions
Additional VOC emissions for TEI imputation
Gridded & speciated ETH emissions at a resolution of 4 km for CB4 mechanism

VOC emissions
Biogenic Emissions

- **Processors**
  - NEI: BEIS version 3.12
  - TEI: GloBEIS version 3.1

- **LULC data**
  - NEI: BELD3
  - TEI: TCEQ LULC for biogenic emissions

- **PAR**
  - NEI: Calculated with RGRND from MM5-MCIP
  - TEI: Derived from GOES satellite data

- **Temp**
  - NEI: 10-m temperature from MM5-MCIP
  - TEI: temperature field based on observations
Normalized isoprene emissions

BELD3

TCEQ

ISOP (kgC/hr)
- 0.0
- 0.1 - 50.0
- 50.1 - 100.0
- 100.1 - 150.0
- 150.1 - 300.0
Based on TCEQ’s ‘Base4a pt_n2o2’ emissions on Aug. 30, 2000
Daily Peak Ozone (Jun.-Sep., 2005)

Each models comparison, June 2005

Each models comparison, July 2005

Each models comparison, August 2005

Each models comparison, September 2005

** Be careful of the possibility that the location where Max. Ozone concentration happened could be different with each other

Changed radiation scheme in Sept. -> improved forecasts

** 2005 forecasting evaluation
After hurricanes, many unexplained peaks observed – possible extra emissions due to shutdown/start up and other upset emissions from industrial facilities.

** Be careful of the possibility that the location where Max. Ozone concentration happened could be different with each other.
2007 emissions inventory were projected from 2000 EI with growth and control factors from TCEQ.

For HG NOx emissions for 2005, a factor of 1.747 was applied on 2007 EI based on the 2005/2007 MECT (Mass Emission Cap and Trade) allowances.
UH AQF system uses additional VOC emissions at the 2007 level.
The emissions amounts for each county, vehicle type, hour and species were determined for 2005 based on those for 2000 and 2007.

Then, the factor was applied on 2007 MOBILE6 emissions to have 2005 emissions.
What Configuration to Use for ETAQ-F 2006?

For ETAQF 2005, we used TCEQ’s 2000 Base5b with imputed HRVOC

* Was quite successful
* NOx and some VOC emissions might have been too high

For ETAQF 2006,

**Meteorology**

* improved LULC
* improved MRF for stable PBL and transition times (under development)
* cloud; both the subgrid scale explicit scheme at 4-km
* satellite observed sea surface temperature (in preparation)

**Emissions**

* 2005 TEI (projected)
* 2000 HRVOC (instead of 2005 projected)
* 2000 mobile and CO with 2005 projected noroad
* satellite observed fire events (in preparation)

**CMAQ**

* with and w/o cloud attenuation
* CB4 for forecasting and SAPRC99 for evaluation
* Better regional characterization at 12-km resolution
Welcome to the Institute for Multi-dimensional Air Quality Studies. We are a diverse group of researchers from fields of geosciences, math, computer science and chemistry committed to using premier scientific tools to model the complex issues of air quality and climate change. Our modeling efforts address many critical components simultaneously including emissions inventories, meteorology, and atmospheric chemistry. We are currently developing atmospheric boundary layer measurement techniques. We work closely with national, state and local leaders to identify key scenarios to run on our modeling systems so that public policy is guided with the best science.
(1) Spatial plot

- Species name
- Plot type: daily maximum of forward 8hr moving average
- Unit
- Color scale indicates EPA AQI numbers and colors
- Value and location of CMAQ maximum
- Value and location of CMAQ minimum
- Day of CMAQ run and layer
- Target date and hour (in CST)
- CAMS site location and measured value (color within the circles also indicates the measured amount)
(2) Time series

Houston East C1/G316 (Harris)

- CAMS site name
- CAMS site ID
- County name where this CAMS site is located
- CMAQ simulation value at the CAMS site location (exact cell)
- Best-fit value of CMAQ simulation within the adjacent 3X3 cells of CAMS location
- Forward moving average of best-fit values
- CAMS measurements
- Forward moving average of CAMS measurements
- Min/max range of 3X3 CMAQ cells
- Day of CMAQ run

Graph showing time series of O₃ (ppb) with different lines and markers representing CMAQ 1hr, CMAQ 1hr (best fit in 3x3), CMAQ 8hr (best fit in 3x3), CAMS 1hr, CAMS 8hr, and 9th Ave Hr. The graph includes a legend for color and hours, with colors ranging from 0 to 48 hours.

Graph with x-axis showing dates from Jun 09 to Jun 11, 2006, and y-axis showing O₃ values from 0 to 200 ppb.
(2) Time series (regional average)

Regional average (d04, 48sites)

- Domain: 'd04' indicates Houston-Galveston-Brazoria-Beaumont-Port Arthur 04km domain
- Number of CAMS sites used
- Mean of best-fit (the closest CMAQ simulation to CAMS measurements from adjacent 3x3 CMAQ output cells)
- 1 standard deviation of best-fit
- Min/max range of 3x3 CMAQ output cells used for best-fit estimation
- Mean of CAMS measurements
- 1 standard deviation of CAMS measurements
- Min/max range of CAMS measurements
- Day of CMAQ run
- Forecasting hours in CST
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① species name  ② ‘d12’ indicates EXT 12 km domain
③ ndata : number of data used
④ mean_m : mean CMAQ simulation ⑤ mean_o : mean CAMS measurements
⑥ stddev_m : standard deviation of CMAQ simulations ⑦ stddev_o : standard deviation of CAMS measurements
⑧ slope of CMAQ/CAMS correlation
⑨ offset of CMAQ/CAMS correlation
⑩ correlation coefficient ⑪ gross mean bias ⑫ gross mean absolute error
⑬ gross root mean square error ⑭ gross standard deviation of error ⑮ index of agreement
Transient High Ozone Event 6/12/06

Hr 07-08
Hr 08-09
Hr 09-10
Hr 10-11
Hr 11-12
Hr 12-13

Baytown
Hourly Snapshot
June 29, 2006
Issues with ETAQ-F 2006?

How do the two meteorological runs compare?

* F1 meteorology
* F2 meteorology
* How to improve meteorological simulations?

How important is the emissions uncertainty?

* 2005 TEI (projected)
* 2000 HRVOC (instead of 2005 projected)
* 2000 mobile and CO with 2005 projected noroad
* satellite observed fire events (in preparation)

How important is the chemistry?

* CMAQ vs. CAMx
* CB-4 and SAPRC