Air Quality Forecasting for East Texas, Houston and Dallas Fort Worth Area

Goal is to improve base model inputs and physics

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University of Houston
UH (Univ. of Houston)
AQF (Air Quality Forecasting) Systems

Spatial Resolution

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Area Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>36 km</td>
<td>U.S. Continent</td>
</tr>
<tr>
<td>04 km</td>
<td>Houston and Galveston Area (05) &amp; Dallas-Fort Worth area (06)</td>
</tr>
</tbody>
</table>

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 A (F-A): MM5 modified by UH + Emission + CMAQ v4.4
- Forecasting B (F-B): Texas A&M (TAMU) MM5 + Emission + CMAQ v4.4
UH AQF system (F-A)

### MM5 simulations (24 CPUs)
- 36 km domain 1st day
- 36 km domain 2nd day
- 12 km domain 1st day
- 12 km domain 2nd day
- 04 km domain 1st day
- 04 km domain 2nd day

### CMAQ simulations (36 CPUs)
- 36 km domain 1st day
- 36 km domain 2nd day
- 12 km domain 1st day
- 12 km domain 2nd day
- 04 km domain 1st day
- 04 km domain 2nd day

### Data Flow
- Multi CPU
- Single CPU
- Data Flow

Download
- ETA Forecast

Post-Process
- Visualization
- Statistics
- Web Display
### UH MM5 Domain (2006)

<table>
<thead>
<tr>
<th></th>
<th>36 km</th>
<th>12 km</th>
<th>04 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>UH MM5 2006</td>
<td>(157,127,43)</td>
<td>(175,136,43)</td>
<td>Houston (151,136,43)</td>
</tr>
<tr>
<td>U.S. Continent</td>
<td>(175,136,43)</td>
<td>Texas/Other St.</td>
<td>Dallas* (141,136,43)</td>
</tr>
</tbody>
</table>

(* Dallas domain just in preparation*)

12 km domain (D02) is the same as TAMU’s one
And,

SST observations from satellite being implemented by modifying pre-processor

To figure out the over-cloudiness problem,

- Sub-grid cloud (Grell Cumulus) for 04 km resolution run being tested
- KF2 scheme being tested

<table>
<thead>
<tr>
<th>Physical Option</th>
<th>36 km</th>
<th>12 km</th>
<th>04 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid Nudging (Model, ETA Forecast)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explicit Moisture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cumulus</td>
<td>Grell**</td>
<td>Grell**</td>
<td>Grell**</td>
</tr>
<tr>
<td>Shallow Convection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiation</td>
<td>RRTM</td>
<td>RRTM</td>
<td>RRTM</td>
</tr>
<tr>
<td>PBL</td>
<td>MRF*</td>
<td>MRF*</td>
<td>MRF*</td>
</tr>
<tr>
<td>LSM</td>
<td>NOAH*</td>
<td>NOAH*</td>
<td>NOAH*</td>
</tr>
<tr>
<td>LULC</td>
<td>USGS</td>
<td>USGS</td>
<td>TFS†</td>
</tr>
<tr>
<td>VEG*.tbl</td>
<td>Original</td>
<td>Original</td>
<td>Modified†</td>
</tr>
<tr>
<td>LAND*.tbl</td>
<td>Original</td>
<td>Original</td>
<td>TFS2TER†</td>
</tr>
</tbody>
</table>

(* UH modification and development/ ** Kain-Fritsch scheme on being tested)
Comparison of MRF and ETA PBL at 4-km simulation

PBL mixing

• ETA TKE scheme (Janjic, 1994)
  --- based on local vertical mixing to diagnose PBL height (Janjic, 1990, 1994)

• MRF PBL scheme
  --- based on Troen-Mahrt representation for countergradient term and K profile in the well mixed PBL (Hong and Pan, 1996)

• In general PBL growth is slower with local and TKE schemes (because of the slower diffusion and the predicted TKE does not allow for a deeper CBL)
Comparison of MRF and ETA PBL at 4-km simulation

**PBL**

**ETA**

**August 25, 2000 20:00:00**

Min: 34 (85.64), Max: 125 (77.48)

**MRF**

**August 25, 2000 20:00:00**

Min: 318 (88.80), Max: 2500 (67.65)

**Difference:**

**MRF - ETA**

**August 25, 2000 20:00:00**

Min: -316.5 (88.26), Max: -244.5 (67.62)

**TEMPG**

**ETA**

**August 25, 2000 20:00:00**

Min: 301 (20.7), Max: 314 (22.92)

**MRF**

**August 25, 2000 20:00:00**

Min: 303 (46.1), Max: 312 (25.31)

**Difference:**

**MRF - ETA**

**August 25, 2000 20:00:00**

Min: -4.2 (35.21), Max: 7.0 (49.35)
Comparison of MRF and ETA PBL at 4-km simulation
Comparison of MRF and ETA PBL at 4-km simulation

**PBL(m): LB (USGS(dry/crop) -> TFS(grass))**

**PBL(m): HS (USGS(dry/crop) -> TFS(grass))**

**PBL(m): EL (USGS(dry/crop) -> TFS(res))**

![Graphs showing PBL time series for LB, HS, and EL](image-url)
Explicit vs. with Sub-grid scale cloud scheme at 4-km

Too strong thunderstorm activities with explicit scheme alone (August 23, 2000)
Explicit vs. sub-grid scale cloud scheme at 4-km

1. Improvement on the days with strong convective activity (22, 23)

2. The outburst of the local convective cell is removed with sub-grid scale cloud option.
UH MM5 Physical Options and Improvement (2006)

Animation: SST observations from satellite (GOES, Aug.-Sep., 2005)

Use SST for operational MM5 simulations (TBD)
Currently testing KF2 scheme used by TAMU to mitigate cloud problem

### KF scheme

KF scheme is a mass flux scheme similar to Grell scheme

- **Notable differences**
  - Large-scale destabilization not required to trigger convection, only +CAPE
  - Updraft and downdraft formulations more sophisticated
  - Intensity of convection based on instantaneous CAPE, (rather than time rate of change of CAPE)

### Comparing Convective Parameterization Schemes

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Convection Initiated by</th>
<th>Modifies by</th>
<th>Downdraft Processes?</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modified Kuo</td>
<td>Moisture Convergence</td>
<td>Adjustment</td>
<td>No</td>
<td>No clouds</td>
</tr>
<tr>
<td>BMJ</td>
<td>Buoyancy/Moisture</td>
<td>Adjustment</td>
<td>No</td>
<td>No clouds</td>
</tr>
<tr>
<td>Kain-Fritsch</td>
<td>Subcloud Layer Conv.</td>
<td>Mass Flux</td>
<td>Yes</td>
<td>Streamlined cloud model</td>
</tr>
<tr>
<td>Tiedtke</td>
<td>Moisture Conv./BL Turb</td>
<td>Mass Flux</td>
<td>Yes</td>
<td>Streamlined cloud model</td>
</tr>
<tr>
<td>Arakawa-Schubert</td>
<td>Destabilization Rate</td>
<td>Mass Flux</td>
<td>No</td>
<td>Models multiple cloud sizes</td>
</tr>
<tr>
<td>Grell</td>
<td>Destab. Rate/CIN</td>
<td>Mass Flux</td>
<td>Yes</td>
<td>Streamlined cloud model</td>
</tr>
</tbody>
</table>

[The COMET Program (Nov., 1998)]
## Comparison of MM5 options used for the forecasting

<table>
<thead>
<tr>
<th></th>
<th>UH MM5 (v3.6.0)</th>
<th>TAMU MM5 (v3.6.0)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F-A</td>
<td>F-B</td>
</tr>
<tr>
<td><strong>Platform</strong></td>
<td>Beowulf Cluster</td>
<td>Beowulf Cluster</td>
</tr>
<tr>
<td><strong>Initialization</strong></td>
<td>w/ ETA Forecasting</td>
<td>w/ ETA Forecasting</td>
</tr>
<tr>
<td><strong>Landuse Type</strong></td>
<td>USGS24 (36 &amp; 12 km)</td>
<td>USGS24 (36 &amp; 12 km)</td>
</tr>
<tr>
<td></td>
<td>TFS LULC (4 km)</td>
<td></td>
</tr>
<tr>
<td><strong>Model Start</strong></td>
<td>00 UTC</td>
<td>00 UTC</td>
</tr>
<tr>
<td><strong>(Duration)</strong></td>
<td>(54 hrs)</td>
<td>(54 hrs)</td>
</tr>
<tr>
<td><strong>Land SFC Model</strong></td>
<td>Modified NOAH LSM</td>
<td>Force-Restore (Slab) Model</td>
</tr>
<tr>
<td><strong>PBL Scheme</strong></td>
<td>Modified MRF</td>
<td>Mellow-Yamada/Eta</td>
</tr>
<tr>
<td><strong>Radiation Scheme</strong></td>
<td>Cloud Radiation (~ Aug. 05)</td>
<td>Cloud Radiation</td>
</tr>
<tr>
<td></td>
<td>RRTM (Since Sep. ~)</td>
<td></td>
</tr>
</tbody>
</table>
Emissions processing with SMOKE

Point

Mobile

Area

Biogenic

Texas EI preparation

Format conversion
• AMS/AFS → IDA

Internal database
• Surrogates
• Split factors
• Temporal profiles

SMOKE processing

Spatial allocation
• 36km, 12km & 4km

Temporal allocation
• hourly emissions

Chemical speciation
• CB4, SAPRC99 & RADM2

Plume rise

CMAQ

Normalized emissions

GloBEIS3

BEIS3

Met. adjustment

University of Houston Texas Emissions Processing System (TEIPS)
Biogenic Emissions

- LULC data
  - CONUS 36k: BELD3
  - ETX 12 km & HGBP 04km: TCEQ’s LULC

- Processors
  - CONUS 36k: BEIS version 3.12
  - ETX 12 km & HGBP 04km: GloBEIS version 3.1 + BEIS version 3.12 (Revised)

- Step 1: Using GloBEIS 3.1
  - Normalized emissions (30 °C, 1000 µmol m⁻² s⁻¹)
  - Split factors for a chemical mechanism selected

- Step 2: Using BEIS 3.12
  - Temperature & PASR adjustment
Anthropogenic Emissions

- **TEI 2000 Base5b**
  - TexAQS 2000
  - The day of Week
    - Aug. 25th → Friday, Aug. 26th → Saturday, Aug. 27th → Sunday, Aug. 30th → Monday ~ Thursday
  - CB4, SAPRC99, and RADM2
  - Mobile: projected for year 2005
  - Point: projected emissions for 2007, except HG NOx for 2005
  - Area & Non-road: 2007 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
Texas EGU NOx emissions

- 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.
VOC emissions for imputation

✓ UH AQF system uses additional VOC emissions at the 2007 level.
MOBILE6 Links for 2000 and 2007

HGB Links for MOBILE6 emissions

![Map of HGB Links for MOBILE6 emissions showing changes from 2000 to 2007.](image)
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.
4-km and 12-km resolution extended AQF domains (TBD)

- TAMU 4-km MM5
- Extended 4-km CMAQ
  For HGA & DFW
  (F-B only)
- Extended 12-km CMAQ
- F-A only
Compare different CMAQ/SMOKE options used for the forecasting

<table>
<thead>
<tr>
<th></th>
<th>F-A</th>
<th>F-B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain</td>
<td>36-, 12-, and 4-km (HGA)</td>
<td>4-km (East Texas – HGA &amp; DFW)</td>
</tr>
<tr>
<td>CMAQ</td>
<td>v4.4</td>
<td>v4.4</td>
</tr>
<tr>
<td>SMOKE</td>
<td>V2.1 (except layer fraction w/ v1.4)</td>
<td>V2.1 (except layer fraction w/ v1.4)</td>
</tr>
<tr>
<td>Mechanism</td>
<td>CB4</td>
<td>CB4</td>
</tr>
<tr>
<td>Emission</td>
<td>Texas Emission Inventory (TCEQ) + NEI99</td>
<td>Texas Emission Inventory (TCEQ) + NEI99</td>
</tr>
<tr>
<td>Boundary Condition</td>
<td>Downscaling Linkage From GEOS-Chem</td>
<td>F-A 12-km simulation</td>
</tr>
</tbody>
</table>

F-A: UH/MM5        F-B: TAMU/MM5
Last Year high Ozone

[June 15, 2005]

F1 (CMAQ with UH-mod MRF MM5)

F2 (CMAQ with original M M5)
High Ozone Case
[August 22, 2005]

F1 (CMAQ with UH-mod MRF MM5)
F2 (CMAQ with original M M5)

Observed

F1
O3 Layer 1

F2
O3 Layer 1

a=CONC.cb4-ae3.2005234

August 22, 2005 17:00:00
Min= 0.021 at (29,48), Max= 0.122 at (19,27)
10.0ppmv

Min= 0.026 at (18,49), Max= 0.077 at (55,27)
10.0ppmv
High Ozone Case
[August 23, 2005]
- F1 (CMAQ with UH-mod MRF MM5)
- F2 (CMAQ with original MM5)

**Observed**

**F1**
- O3 Layer 1
- a=CONC.cb4-aes.2005235

**F2**
- O3 Layer 1
- a=CONC.cb4-aes.2005235
Daily Peak Ozone (Jun.-Sep., 2005)

**June, 2005**

- Each models comparison, June 2005

**July, 2005**

- Each models comparison, July 2005

**August, 2005**

- Each models comparison, August 2005

**September, 2005**

- Each models comparison, September 2005

**Hurricane Rita**

**Katrina**

---

**Changed radiation scheme in Sept. -> improved forecasts**

**Be careful of the possibility that the location where Max. Ozone concentration happened could be different with each other**
Observation peaks – possible extra emissions due to startup and other operation of certain industry facilities.

** Be careful of the possibility that the location where Max. Ozone concentration happened could be different with each other.
Summary: Two AQF systems for TexAQS-II

- UH-MM5/CMAQ (36-km CONUS, 12-km East Texas, and 4-km HGA domains)  
  **Target Operation Date:** May 2006

- TAMU-MM5 CMAQ (4-km extended 4-km for DFW and HGA)  
  **Target:** June 2006

MM5 Physics options tested to provide best simulations

1. Better LULC data
2. Subgrid scale cloud at 4-km to reduce cloudiness
3. Improved MRF scheme with NOAA LSM
4. Tested longwave radiation schemes
5. SST to be added

Improved Anthropogenic Emissions: TEI 2000 Base5b for day of week of TexAQS 2000

1. CB4, SAPRC99, and RADM2
2. Mobile: projected for year 2005
3. Point: projected emissions for 2007, except HG NOx for 2005
4. Area & Non-road: 2007 Emissions Inventory

Biogenic Emissions: BELD3 (36-km) and TCEQ LULC (12- and 4-km)

1. CONUS 36-km: BEIS V 3.12, E. Texas 12-km & HGBP A 4-km (GloBEISV3.1)_BEIS3.12 (rev.)
2. Fire emissions to be added
Internal Website to Access the East Texas Air Quality Forecasting Results

http://imaqs.uh.edu/
 ETAQ
East Texas Air Quality

Winnie Hamilton
Shanti Ningthoujam

Baylor College of Medicine (BCM),
Houston, TX

BCM Subcontract to UH-IMAQS:
Interactive Web Access
GIS Maps

Geographical Information System (GIS) maps at the 4-km resolution are available for Harris County for May and June 2005. Current 24-hour average concentrations of CMAQ-modeled levels of carbon monoxide, nitrogen dioxide, ozone, sulfur dioxide, and particulate matter; 24-hour observed pollutant values at area monitors; TRI facilities; superfund sites; annual median income; and percentage minority. Please choose either the HTML Viewer or the Java Viewer. The HTML Viewer is easier to use and does not require software to be installed. The Java Viewer requires that a Java applet be installed on your machine, but offers more advanced interactivity.