New insights into Houston air quality from the
Houston Network of Environmental Towers (H-NET)

Barry Lefer, James Flynn, Christine Haman
Department of Earth and Atmospheric Sciences
University of Houston
“Recent advances in our understanding of Texas Air Quality:
A tribute to Daewon Byun”

April 19, 2011
09:00 – 05:00
University of Houston – Hilton
Tale of Two Cities

Source: TCEQ, CARB
Houston Ozone Trends

Houston Ozone Exceedances 1997-2009

Source: TCEQ
Where is ozone a problem? 2004-2006

Counties with Monitors Violating the 1997 8-Hour Ozone Standard of 0.08 parts per million (ppm)
(based on 2004-2006 Air Quality Data)
Where is ozone a problem? 2004-2006

Counties with Monitors Violating the 2008 8-Hour Ozone Standard of 0.075 parts per million (ppm)

(based on 2004-2006 Air Quality Data)
Where is ozone be a problem in the U.S.?

2006-2008 AIRNOW Data, 3 yr average of 4th Highest 8-hr Ave O₃

[Map of the U.S. showing the distribution of ozone levels across different states, with color coding for various concentration ranges.]
Early Morning Hydroxyl Radical (OH) Source

\[ \text{HONO}(g) + \text{hv} \rightarrow \dot{\text{OH}}(g) + \dot{\text{NO}}(g) \]
\[ \lambda < 400 \text{ nm} \]

Nitrous acid \hspace{1cm} \text{Hydroxyl radical} \hspace{1cm} \text{Nitric oxide}
**Mid-Morning Hydroxyl Radical (OH) Source**

\[
\text{HCHO}(g) + \text{hv} \rightarrow \text{HCO}(g) + \dot{\text{H}}(g) \quad \lambda < 334 \text{ nm}
\]

Formaldehyde \hspace{2cm} Formyl \hspace{2cm} Atomic hydrogen

\[
\dot{\text{H}}(g) + \text{O}_2(g) \rightarrow \text{HO}_2(g)
\]

Atomic hydrogen \hspace{1cm} Molecular oxygen \hspace{1cm} Hydroperoxy radical

\[
\text{HCO}(g) + \text{O}_2(g) \rightarrow \text{CO}(g) + \text{HO}_2(g)
\]

Formyl radical \hspace{1cm} Molecular oxygen \hspace{1cm} Carbon monoxide \hspace{1cm} Hydroperoxy radical

\[
\dot{\text{NO}}(g) + \text{HO}_2(g) \rightarrow \dot{\text{NO}}_2(g) + \dot{\text{OH}}(g)
\]

Nitric oxide \hspace{1cm} Hydroperoxy radical \hspace{1cm} Nitrogen dioxide \hspace{1cm} Hydroxyl radical
Five Additional AQ Monitoring Sites
UH Coastal Research Center
Latitude: 29.3879, Longitude: -95.0414
UH Coastal Research Center
UH Sugar Land
UH Sugar Land
Moody Tower
Moody Tower
Moody Tower View

http://129.7.48.166
Moody Tower
UH - West Liberty
UH - West Liberty
UH – Jones Forest
UH – Jones Forest
UH – Jones Forest
Five Additional AQ Monitoring Sites

Houston Network of Environmental Towers (H-NET) collect chemistry and meteorological measurements for air quality model applications in Houston Galveston Area. This website provides real-time update of collected data, as well as historical data.

Currently, five sites have been set up in:

- UH - Main Campus (current condition)
- Jones State Forest (current condition)
- West Liberty Airport (current condition)
- UH - Sugar Land (current condition)
- UH - Coastal Center (current condition)

More about this project.
Current Conditions at UH - Sugar Land

Date/Time: 2011-02-22 11:10 PM

Temperature: 18.6°C (65.5°F)
Relative Humidity: 89%
Wind: 132° at 4.2 mph (1.88 m/s)
Barometer: 1013 hpa (29.94 in)
Precipitation (24 hr): 0.00 in (0.00 mm)

Ozone: 24 ppbv
CO: 93 ppbv

Last 24 hour Highs/Lows

High Temp: 25.1°C at 03:10 PM
Low Temp: 15.8°C at 06:59 AM

High Relative Humidity: 96.0% at 05:30 AM
Low Relative Humidity: 55.8% at 04:49 PM

High Pressure: 1015.4 hPa at 11:07 AM
Low Pressure: 1010.7 hPa at 11:10 PM

Temperature Graph
Relative Humidity Graph
Pressure Graph
Wind Direction
Wind Speed

Last 24 Hour Ozone (Sugar Land)

LAST 24 Hours Graphs
# 2010 Peak 8-hr Ozone Events

## 2010 Sorted by Maximum Value

<table>
<thead>
<tr>
<th>Location</th>
<th>Region</th>
<th>CAMS</th>
<th>AQS</th>
<th>Date</th>
<th>Time</th>
<th>Value</th>
<th>POC</th>
</tr>
</thead>
<tbody>
<tr>
<td>UH Moody Tower C695</td>
<td>12</td>
<td>695</td>
<td>48_201_0695</td>
<td>August 11 2010</td>
<td>11:00</td>
<td>102</td>
<td>1 N</td>
</tr>
<tr>
<td>Houston Aldine C8/AF108/X150</td>
<td>12</td>
<td>8</td>
<td>48_201_0024</td>
<td>May 3 2010</td>
<td>11:00</td>
<td>97</td>
<td>2</td>
</tr>
<tr>
<td>Northwest Harris Co. C26/A110/X154</td>
<td>12</td>
<td>26</td>
<td>48_201_0029</td>
<td>May 3 2010</td>
<td>10:00</td>
<td>96</td>
<td>2</td>
</tr>
<tr>
<td>UH WG Jones Forest C698</td>
<td>12</td>
<td>698</td>
<td>48_339_0698</td>
<td>September 14 2010</td>
<td>10:00</td>
<td>96</td>
<td>1 N</td>
</tr>
<tr>
<td>Sheldon C551</td>
<td>12</td>
<td>551</td>
<td>48_201_0551</td>
<td>October 16 2010</td>
<td>10:00</td>
<td>95</td>
<td>1</td>
</tr>
<tr>
<td>Seabrook Friendship Park C45</td>
<td>12</td>
<td>45</td>
<td>48_201_1050</td>
<td>May 4 2010</td>
<td>10:00</td>
<td>95</td>
<td>1</td>
</tr>
<tr>
<td>Manvel Croix Park C84</td>
<td>12</td>
<td>84</td>
<td>48_039_1004</td>
<td>May 28 2010</td>
<td>10:00</td>
<td>94</td>
<td>1</td>
</tr>
<tr>
<td>Northwest Harris Co. C26/A110/X154</td>
<td>12</td>
<td>26</td>
<td>48_201_0029</td>
<td>September 15 2010</td>
<td>11:00</td>
<td>94</td>
<td>2</td>
</tr>
<tr>
<td>Crosby Library C553</td>
<td>12</td>
<td>553</td>
<td>48_201_0553</td>
<td>October 8 2010</td>
<td>11:00</td>
<td>94</td>
<td>1 N</td>
</tr>
<tr>
<td>Meyer Park C561</td>
<td>12</td>
<td>561</td>
<td>48_201_0561</td>
<td>May 3 2010</td>
<td>10:00</td>
<td>94</td>
<td>1</td>
</tr>
<tr>
<td>UH Moody Tower C695</td>
<td>12</td>
<td>695</td>
<td>48_201_0695</td>
<td>May 26 2010</td>
<td>10:00</td>
<td>94</td>
<td>1 N</td>
</tr>
<tr>
<td>UH WG Jones Forest C698</td>
<td>12</td>
<td>698</td>
<td>48_339_0698</td>
<td>April 28 2010</td>
<td>11:00</td>
<td>94</td>
<td>1 N</td>
</tr>
<tr>
<td>Eagle Mountain Lake C75</td>
<td>4</td>
<td>75</td>
<td>48_439_0075</td>
<td>June 4 2010</td>
<td>12:00</td>
<td>94</td>
<td>1</td>
</tr>
<tr>
<td>Park Place C416</td>
<td>12</td>
<td>416</td>
<td>48_201_0416</td>
<td>August 11 2010</td>
<td>10:00</td>
<td>93</td>
<td>1</td>
</tr>
<tr>
<td>Mercer Arboretum C557</td>
<td>12</td>
<td>557</td>
<td>48_201_0557</td>
<td>May 3 2010</td>
<td>10:00</td>
<td>93</td>
<td>1 N</td>
</tr>
<tr>
<td>Mercer Arboretum C557</td>
<td>12</td>
<td>557</td>
<td>48_201_0557</td>
<td>September 14 2010</td>
<td>10:00</td>
<td>93</td>
<td>1 N</td>
</tr>
<tr>
<td>Clear Lake High School C572</td>
<td>12</td>
<td>572</td>
<td>48_201_0572</td>
<td>October 16 2010</td>
<td>10:00</td>
<td>93</td>
<td>1 N</td>
</tr>
<tr>
<td>Seabrook Friendship Park C45</td>
<td>12</td>
<td>45</td>
<td>48_201_1050</td>
<td>October 8 2010</td>
<td>09:00</td>
<td>93</td>
<td>1</td>
</tr>
<tr>
<td>UH WG Jones Forest C698</td>
<td>12</td>
<td>698</td>
<td>48_339_0698</td>
<td>April 21 2010</td>
<td>11:00</td>
<td>93</td>
<td>1 N</td>
</tr>
<tr>
<td>Keller C17</td>
<td>4</td>
<td>17</td>
<td>48_439_2003</td>
<td>June 4 2010</td>
<td>11:00</td>
<td>93</td>
<td>2</td>
</tr>
<tr>
<td>Manvel Croix Park C84</td>
<td>12</td>
<td>84</td>
<td>48_039_1004</td>
<td>October 7 2010</td>
<td>11:00</td>
<td>92</td>
<td>1</td>
</tr>
</tbody>
</table>
## 2010 Peak 1-hr Ozone Events

<table>
<thead>
<tr>
<th>Location</th>
<th>Region</th>
<th>CAMS</th>
<th>AQS</th>
<th>Date</th>
<th>Time</th>
<th>Value</th>
<th>POC</th>
<th>Hours Exceeded</th>
</tr>
</thead>
<tbody>
<tr>
<td>UH WG Jones Forest C698</td>
<td>12</td>
<td>698</td>
<td>48_339_0698</td>
<td>August 2 2010</td>
<td>16:00</td>
<td>149</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>UH Moody Tower C695</td>
<td>12</td>
<td>695</td>
<td>48_201_0695</td>
<td>August 11 2010</td>
<td>13:00</td>
<td>142</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Texas City 34th St. C620</td>
<td>12</td>
<td>620</td>
<td>48_167_0056</td>
<td>October 8 2010</td>
<td>12:00</td>
<td>138</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>HRM-3 Haden Road C603/A114</td>
<td>12</td>
<td>603</td>
<td>48_201_0803</td>
<td>July 16 2010</td>
<td>14:00</td>
<td>135</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Wallisville Road C617</td>
<td>12</td>
<td>617</td>
<td>48_201_0617</td>
<td>May 18 2010</td>
<td>13:00</td>
<td>133</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Crosby Library C553</td>
<td>12</td>
<td>553</td>
<td>48_201_0553</td>
<td>October 8 2010</td>
<td>16:00</td>
<td>131</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mercer Arboretum C557</td>
<td>12</td>
<td>557</td>
<td>48_201_0557</td>
<td>August 2 2010</td>
<td>14:00</td>
<td>131</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>UH Moody Tower C695</td>
<td>12</td>
<td>695</td>
<td>48_201_0695</td>
<td>July 24 2010</td>
<td>13:00</td>
<td>131</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Atascocita C560</td>
<td>12</td>
<td>560</td>
<td>48_201_0560</td>
<td>August 2 2010</td>
<td>13:00</td>
<td>130</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Lynchburg Ferry C1015/A165</td>
<td>12</td>
<td>1015</td>
<td>48_201_1015</td>
<td>July 16 2010</td>
<td>14:00</td>
<td>130</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>UH Moody Tower C695</td>
<td>12</td>
<td>695</td>
<td>48_201_0695</td>
<td>August 10 2010</td>
<td>14:00</td>
<td>129</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Houston East C1/G316</td>
<td>12</td>
<td>1</td>
<td>48_201_1034</td>
<td>July 16 2010</td>
<td>16:00</td>
<td>129</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Houston Aldine C8/AF108/X150</td>
<td>12</td>
<td>8</td>
<td>48_201_0024</td>
<td>August 3 2010</td>
<td>14:00</td>
<td>127</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Channelview C15/AH115</td>
<td>12</td>
<td>15</td>
<td>48_201_0026</td>
<td>August 1 2010</td>
<td>15:00</td>
<td>126</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Park Place C416</td>
<td>12</td>
<td>416</td>
<td>48_201_0416</td>
<td>August 11 2010</td>
<td>13:00</td>
<td>126</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Baytown Wetlands Center C552</td>
<td>12</td>
<td>552</td>
<td>48_201_0552</td>
<td>August 1 2010</td>
<td>14:00</td>
<td>126</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Houston East C1/G316</td>
<td>12</td>
<td>1</td>
<td>48_201_1034</td>
<td>August 3 2010</td>
<td>13:00</td>
<td>125</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

**POC (Parameter Occurrence Code):** a code used to correctly separate data from multiple instruments at one site.

**N** - Data from this instrument does not meet EPA quality assurance criteria and cannot be used for regulatory purposes.
Meteorological Conditions

![Graph showing ambient temperature and wind direction over a period from April to May 2009. The graph includes data on temperature and rainfall fluctuations.]
Ozone Production Sensor

Direct measurement of ozone production in Houston and correlation with ambient NO. May 4, 2009. Measured P(O3) will be compared with modeled P(O3) to test mechanisms. Measured P(O3) also can be compared with calculated P(O3) from peroxy radicals and NO. Cazorla, M. and Brune, W.
UH Aerosol LIDAR for Boundary Layer Height Measurements

University of Houston $\log_{10}$ of negative gradient on 19.+20.05.2009 in $10^{-9}$ m$^{-1}$ sr$^{-1}$

Height in m (240 m mean, tilted by 1°)

Time on 19.+20.05.2009 (1200 s mean)
UH Aerosol LIDAR for Boundary Layer Height Measurements
Daily Peak BLH and variation in monthly bins
Summer (JJA) BLHs

![Graph showing PBL Height (m) over Date (UTC) with lines for June, July, and August.](image)
Fall (SON) BLHs
<table>
<thead>
<tr>
<th>Season</th>
<th>Number of High Ozone Days</th>
<th>Mean 8-hr Ozone (ppbv)</th>
<th>Std Dev (ppbv)</th>
<th>Max 8-hr Ozone (ppbv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring 2009</td>
<td>13</td>
<td>82.6</td>
<td>12.5</td>
<td>113.0</td>
</tr>
<tr>
<td>Fall 2009</td>
<td>8</td>
<td>79.3</td>
<td>12.2</td>
<td>106.0</td>
</tr>
<tr>
<td>Spring 2010</td>
<td>9</td>
<td>84.6</td>
<td>6.9</td>
<td>94.7</td>
</tr>
<tr>
<td>Fall 2010</td>
<td>21</td>
<td>79.1</td>
<td>8.6</td>
<td>103.8</td>
</tr>
<tr>
<td>7/1/2009</td>
<td></td>
<td></td>
<td></td>
<td>106.2</td>
</tr>
<tr>
<td>7/2/2009</td>
<td></td>
<td></td>
<td></td>
<td>87.4</td>
</tr>
<tr>
<td>11/6/2009</td>
<td></td>
<td></td>
<td></td>
<td>71.8</td>
</tr>
<tr>
<td>7/24/2010</td>
<td></td>
<td></td>
<td></td>
<td>83.2</td>
</tr>
</tbody>
</table>
Moody Tower – Monthly Wind Direction (Summer)
PBH Height and Solar Radiation

Mean PBL Height (m) vs. Mean 500 nm Radiation (W/m² nm) over Date (UTC)
Ozone Histograms (8-hr Average)
Spring and Fall Ozone Histograms (Peak 8-hr Average)

2009 vs. 2010
Spring and Fall Windspeed Histograms
Spring and Fall Windspeed Histograms
2009 vs. 2010
Spring and Fall Wind Direction Histograms
Spring and Fall Wind Direction Histograms
2009 vs. 2010
Spring and Fall Wind Direction Histograms
2009 vs. 2010
Daylight Hours (8am – 6pm)
Spring BLH Growth Rates
High vs Low Ozone Days

![Graph showing the comparison of PBL Height Growth Rates between High and Low Ozone Days over the course of the day (UTC). The graph indicates that High Ozone Days have generally higher growth rates compared to Low Ozone Days, with peaks occurring during 13:30 to 15:30 UTC.]
Spring BLH Growth Rates
High vs Low Ozone Days
Future Plans / Needs

2011 Summer:

- Dallas Ground Site
- Solar Occultation Flux – Houston & Dallas
- Dallas Aircraft Measurements
- Ozonesonde launches Oklahoma and Houston

TREX 2013 (Texas Regional transport EXPeriment)
ACKNOWLEDGEMENTS:

TCEQ

EPA

HARC

University of Houston