Nocturnal Boundary Layer Evolution in Houston During TexAQSII

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Craig B. Clements - San José State University

January 21, 2008
AMS Annual Meeting
September 7-8 Nocturnal Inversion Heights
20:26 – 07:00 CDT

05:00-07:00 avg height = 224 m

22:00-04:38 avg height = 125 m
September 7-8, 2006
Wind Speed and Direction
20:26 – 07:00 CDT

Methods
- Winds averaged in 50-m layers
- Tethersonde and radiosonde data represented

Results
- General clockwise circulation overnight
  - Sea breeze to land breeze
- In early morning, winds shift quickly from S to N
  - Wind shift occurs at different times depending on layer
September 14-15 Nocturnal Inversion Heights
21:13 – 07:00 Local Time

21:13-07:00 avg height = 128 m
September 14-15, 2006
Wind Speed and Direction
21:13 – 07:00 CDT

Results
- Winds southeasterly during entire overnight period
- Synoptic flow overwhelmed local winds
- Higher wind speeds vs. Sept 7-8
Conclusions

• Houston land-sea breeze circulations
  – Seen on some nights in dataset
  – More evident aloft vs. near surface

• Land breeze development may influence
  – Nocturnal inversion height
  – Vertical temperature profile

• Synoptic winds can dominate local winds
Ship-based lidar measurements of nocturnal mean winds, mixing height and boundary layer dynamics and correlation to Houston ozone measurements during TexAQS II


NOAA/ESRL/CSD, also with CIRES, University of Colorado
Jet and Turbulence Profiles

Horizontal mean wind speed

Deep LLJ

velocity variance, $\sigma_v^2$

Stronger BL turbulence reaches higher

Horizontal mean wind speed

Weak/Shallow LLJ

velocity variance, $\sigma_v^2$

Weaker BL turbulence intensity and max height
Connecting nocturnal winds to daytime ozone levels

Peak ship based ozone measurement of the day vs. $A_{jet}^{-1}$ the previous night, where

$$A_{jet} = V_{max} * H_{max}$$

$V_{max} = \text{max speed of jet}$

$H_{max} = \text{height of max speed of jet}$.

Deeper/faster nocturnal LLJs correlate to lower ozone values the following day.

- Currently studying the affect the LLJ has on those levels.
Conclusions

- The DSLJJ reduces nocturnal ozone/Ox concentration levels via the following mechanisms:
  - Transport of “unpolluted” marine air into the Houston area.
  - Generation of mechanical turbulence that mixes the surface air with the relatively clean air aloft.
  - Transport of surface emitted pollutants that enter the jet layer.

- Deeper/stronger jets clean out a larger/deeper volume for less “residual” ozone/Ox available the next day.

- Surface winds don’t tell the whole story.

- Inverse of the jet “area parameter” is a good indicator of peak ozone the following day.

Acknowledgements: NOAA’s Air Quality Program & the Texas Commission on Environmental Quality
Aerosol and Trace Gas Measurements at Deer Park and Bayland Park in the 2006 Houston Triangle Experiment

M. L. Alexander¹, X.Y. Yu², J. Ortega¹, M. Newburn¹, T. Jobson⁴, R. Zaveri², J. Neece⁵, D. Worsnop³, J. Jayne³, T. Onasch³, M. Canagaratna³ and C. Berkowitz²

1. William R. Wiley Environmental Molecular Sciences Laboratory, Pacific Northwest National Laboratory, 3335 Q Street, Richland, WA 99352
2. Atmospheric Science & Global Change Division, Pacific Northwest National Laboratory, 3200 Q Ave., Richland, WA 99352
3. Aerodyne Research Inc. (ARI), 45 Manning Road, Billerica, MA 01821
4. Department of Civil and Environmental Engineering, Washington State University, Pullman, WA 99164-2910
5. Air Quality Planning Division, Texas Commission on Environmental Quality, CP O. Box 13087, Austin, TX 78711-3087
PTR-MS from Deer Park - Overview

Deer Park - Isoprene/Biogenics

Deer Park - Alkane/Alkene

Deer Park - Oxygenated Species

Deer Park - Aromatics
Analysis of Primary vs. Secondary Fraction of Formaldehyde in the Houston Area during TexAQS-II

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⁵ Texas Commission on Environmental Quality, Austin
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Correlations

- "Ship Channel" data higher scatter, also during nighttime during nighttime (other sources than traffic may contribute)
Airborne Measurements

Morning flight on 8/31/06
Airborne Measurements
Airborne Measurements

Flare Flight; 3 cross sections – about 1000 ft a.g.l.
Correlations

**Other Correlations (“nighttime”):**

<table>
<thead>
<tr>
<th>Location</th>
<th>Correlation</th>
<th>R²</th>
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</thead>
<tbody>
<tr>
<td>Moody Tower (“Urban”)</td>
<td>0.0069</td>
<td>0.61</td>
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<tr>
<td>Moody Tower (“Ship Channel”)</td>
<td>0.0064</td>
<td>0.20</td>
</tr>
<tr>
<td>HRM3</td>
<td>0.0024</td>
<td>0.10</td>
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<tr>
<td>Lynchburg Ferry</td>
<td>0.0054</td>
<td>0.11</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>HCHO&lt;&gt;CO</th>
<th>HCHO&lt;&gt;NO₂</th>
<th>HCHO&lt;&gt;SO₂</th>
<th>HCHO&lt;&gt;Ethylene</th>
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<tbody>
<tr>
<td>Moody Tower (“Urban”)</td>
<td>0.060</td>
<td>0.058</td>
<td>0.46</td>
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<tr>
<td>Moody Tower (“Ship Channel”)</td>
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<td>HRM3</td>
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<td>0.802</td>
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<tr>
<td>Lynchburg Ferry</td>
<td>0.184</td>
<td>0.797</td>
<td>0.21</td>
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</tbody>
</table>

**In flare:**
- HCHO/CO ~ 5-7 times higher than in background
- HCHO/CO ~ 3 times higher than traffic induced
- HCHO/CO ratios
- Ethylene values relative moderate

*closest TCEO site taken
Conclusions

- “Background” HCHO values range between 2.9 (Moody Tower) - 6.6 ppbv (Lynchburg site). Maximum values are between 31.5-52.4 ppbv

- Best correlation of HCHO with CO. Primary emissions of HCHO estimated to be up to 0.7% of the CO emissions.

- Diurnal HCHO variations indicate “Ship Channel” impact.

- Indications that flare emissions may be up to 2-5% of flare CO emissions.

- CMAQ simulates well HCHO at Moody Tower; results indicate:
  - during daytime photochemical production dominates
  - nighttime HCHO formation, most likely through olefin- O₃ reactions
  - non-negligible HCHO emissions
The role of background versus locally contributed ozone during the TexAQS2 field campaign

James Tobin and John Nielsen-Gammon
Department of Atmospheric Sciences
Texas A&M University
# Background Ozone

- **Mean statistics by background station**

<table>
<thead>
<tr>
<th>STATION</th>
<th>PEAK</th>
<th>BKGD</th>
<th>N</th>
<th>SPD</th>
<th>DIR</th>
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<tbody>
<tr>
<td>039-1003</td>
<td>62.30</td>
<td>25.03</td>
<td>256</td>
<td>3.43</td>
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<tr>
<td>039-1016</td>
<td>61.22</td>
<td>30.32</td>
<td>305</td>
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<tr>
<td>167-0014</td>
<td>62.82</td>
<td>32.19</td>
<td>242</td>
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<tr>
<td>201-0029</td>
<td>62.16</td>
<td>38.76</td>
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<tr>
<td>201-0066</td>
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</tr>
<tr>
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<td>55.73</td>
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<tr>
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<td>49.24</td>
<td>42</td>
<td>3.73</td>
<td>51.24</td>
</tr>
</tbody>
</table>

Cleanest background associated with SSE flow detected in Brazoria County.

Dirtiest background associated with NE flow detected in Montgomery County.
Conclusions (2 of 3)

- Onshore winds, leading to background ozone observed in Harris, Brazoria, and Galveston counties, typically favor lower background and peak ozone values.
- Northeast winds, leading to background ozone observed in Conroe, typically favors higher background and peak ozone values.
Evaluation of Meander-Like Wind Variance in High-Resolution WRF Model Simulations of the Stable Nocturnal Boundary Layer

Nelson Seaman¹, Brian Gaudet¹, Aijun Deng, Scott Richardson¹, David Stauffer¹, John Wyngaard¹, and Larry Mahrt²

Penn State University¹ & Oregon State University²
WRF Horizontal Grid Configuration

- WRF-ARW is configured with 5 nested-grid domains:

<table>
<thead>
<tr>
<th>Domain No.</th>
<th>Horiz. Res. (km)</th>
<th>No. of Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>36.0</td>
<td>141 x 91</td>
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<tr>
<td>2</td>
<td>12.0</td>
<td>130 x 127</td>
</tr>
<tr>
<td>3</td>
<td>4.0</td>
<td>193 x 169</td>
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<tr>
<td>4</td>
<td>1.333</td>
<td>121 x 121</td>
</tr>
<tr>
<td>5</td>
<td>0.444</td>
<td>151 x 151</td>
</tr>
</tbody>
</table>

- All inner grids use one-way nested grid interfaces.
444-m Innermost WRF Domain
(DTED-1 Terrain Database, ~90 m Resolution)

Terrain (m) shown on color bar at right;
(R = Rock Springs, S = State College, B = Bellefonte)

Field Site (ellipse):
Extensive PSU-owned agricultural land at Rock Springs, PA

- Sub-kilometer resolution is necessary to resolve fine-scale terrain important for shallow SBL flows.
- Small box shows sub-domain for diagnostics.
- Gold line indicates location of cross section.
WRF Vertical Grid Configuration

- WRF is configured with 41 layers; model top is at 50 hPa.
- Lowest five layers are 2 m thick, gradually increasing upwards.
- 10 layers below 50 m AGL.
Fluctuation of near-surface winds in WRF near Rock Springs, PA, due to transient gravity waves and cold-air drainage, yields **meandering plume trajectories**.

Parcels ascending to 30-40 m are advected almost straight northeastward.

Parcels remaining below 20 m follow meandering paths to the northeast.