The Influence of the Chesapeake Bay Breeze on Maryland Air Quality

MARAMA Data Analysis Workshop
Laura Landry
January 20, 2011
Outline

- Introduction
- Investigation of the interaction between Maryland’s air quality and the bay breeze
  - Methodology
  - Overall results
- Case Study: August 18, 2009
- Future work

Source: AIRNow
Introduction
A Bay Breeze’s Influence

- Forms due to a large temperature difference between land and bay waters
  - Creates a boundary, much like a small scale cold front
  - Ozone pollution easily accumulates along this boundary
# 2009 Ozone Season

## Air Monitoring Sites

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<thead>
<tr>
<th>Date</th>
<th>Aldino</th>
<th>Davidsonville</th>
<th>Edgewood</th>
<th>Essex</th>
<th>Baltimore</th>
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<th>Padonia</th>
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<th>So. Maryland</th>
<th>Fair Hill</th>
<th>Millington</th>
<th>Hagerstown</th>
<th>Piney Run</th>
<th>Frequency of sites with an exceedance (ppb)</th>
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**Number of exceedance days:**

| Year | 2009 | 11 | 2 | 0 | 9 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 3 | 0 | 0 | 0 | 0 |

56% of 2009 Edgewood exceedance days also observed a bay breeze.
Days of analysis were selected based on...

- 75 ppb ozone NAAQS
- Baltimore NAA exceedance days in June-August from 2004-2009*

High ozone days were analyzed for event types

- Criteria were developed using Miller and Keim (2003)
- Event types: bay breeze, marginal, and non-bay breeze

Identified the “Maximum Ozone Gradient” for each day

- Difference between ozone at a monitoring site along the bay’s coast and ozone at a site further inland
- Used AIRNow-Tech Navigator
  - GIS-based tool that plots current and archived pollution and meteorological data on to customizable map

* No 2006 exceedance days were included in this study due to irregular wind data at the Edgewood site in June-August 2006.
The Fort Meade monitor was discontinued in December 2004.
Based on 83 events

- 24 bay breeze (29%)
- 15 marginal (18%)
- 44 non-bay breeze (53%)

Bay breeze events

- Showed much higher Max. Ozone Gradients
- Hour of onset: 12 PM EDT (16 UTC)
- Hour of dissipation: 7 PM (23 UTC)
Case Study: August 18, 2009
August 18th

- High pressure system over Mid-Atlantic and Southeast
- Clear skies
- Light and variable surface winds
- High temperatures in upper 80’s to lower 90’s (°F)
A nocturnal low level jet (NLLJ) formed

- Fast moving stream of air
- Shown in vertical profile measurements of wind speed and direction
- Known to transport ozone into Maryland
Ozonesonde

- Balloon carrying instruments that measure:
  - Ozone
  - Temperature
  - Wind speed and direction
  - GPS coordinates and height

- Measured 100 ppb at approximately 1 km in the afternoon, 2:40 PM EDT

Source: Howard University
Surface Ozone Measurements

- Daily maximum 8-hour ozone average
  - Highest at Edgewood with 83 ppb
  - All other sites were 31-71 ppb
  - Maximum ozone gradient was 60 ppb
    - Ozone gradient = Coastal site’s ozone – Inland site’s ozone
Hourly Ozone Concentrations

August 18, 2009

Edgewood peaked at 119 ppb

Decrease at Edgewood at 3 PM from the bay breeze’s shift inland

Essex began decline around the same time

Short-lived, increase at Padonia at 4 PM

Major drop in ozone by nearly all sites at 5 PM due to thunderstorms
Ozone and Wind Analysis

10 AM (EDT)

Estimated bay breeze

Direction wind is coming from

Onshore flow

Edgewood

Source: AIRNow-Tech
High values started at Edgewood
Ozone and Wind Analysis

1 PM (EDT)

Edgewood jumped ~20 ppb from 12 – 1 PM

Source: AIRNow-Tech
Ozone and Wind Analysis

2 PM (EDT)

...then ~20 ppb again by 2 PM

Ozone gradient:

- 119 (Edgewood) – 59 (Aldino) = 60 ppb
- 90 (Essex) – 53 (Padonia) = 37 ppb
Ozone and Wind Analysis

3 PM (EDT)

Edgewood began its decline while surrounding sites started to rise.

Source: AIRNow-Tech
Ozone and Wind Analysis

5 PM (EDT)

Source: AIRNow-Tech
Ozone and Wind Analysis

6 PM (EDT)

Back to Green (Good) air quality - thunderstorms moved eastward through MD

Source: AIRNow-Tech
Next you will see the bay breeze in an animation of radar imagery.

Pay close attention to the white dashed lines:
- It will indicate where the boundary will briefly appear.
Bay Breeze in the Radar

Boundary moved inland by 3 PM
Bay breeze close to Edgewood

NEXRAD LEVEL-II
KDOX - DOVER AFB, DE
08/18/2009 15:54:33 GMT
LAT: 38/49/32 N
LON: 75/26/23 W
ELEV: 49 FT
VCP: 32

REFLECTIVITY
ELEV ANGLE: 0.57

Legend: dBZ (Category)

<table>
<thead>
<tr>
<th>dBZ</th>
<th>Category</th>
<th>Count</th>
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End to the Episode

- Strong thunderstorms swept through the state from the west
- The following day brought cloudier skies
  - Afternoon thunderstorms moved in earlier than they had on August 18th
Future Work

- Formulate a bay breeze climatology for Edgewood only
  - Seems most prone to its ozone being negatively affected by the bay breeze
  - Tentative methodology
    - Edgewood ozone exceedance days
    - Use the NOAA MADIS mesonet of weather observations to aid in wind analysis
      - This dataset will aid in determining how far inland the bay breeze can move
      - More precise hour of onset/dissipation
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Acknowledgements:

Duc Nguyen and Michael Woodman

References:

- NOAA NCDC, cited 2009: NCDC NEXRAD Data Inventory Search. [www.ncdc.noaa.gov/nexradinv/]
- Plymouth State University, cited 2009: Plymouth State Weather Center. [http://vortex.plymouth.edu]
Appendix

The appendix includes the following items:

1. Event Type Criteria
2. Additional measurements from the August 18th ozonesonde
3. Poster presented at the 2010 AMS Annual Meeting and the 2010 National Air Quality Conference
Criteria were developed to identify bay breeze, marginal, and non-bay breeze events. These were an adaptation of Miller and Keim (2003) sea breeze event criteria.

### BAY BREEZE:

1. An onshore wind shift must occur at 1+ coastal sites.
   - *Coastal sites:* Edgewood, Essex
   - Average of morning to midday cloud cover must be < BKN to ensure a wind shift was not synoptically driven
2. 1+ inland sites must display parallel, antiparallel, or perpendicular wind flow to the shoreline.
   - *Inland sites:* Aldino, Padonia
3. Wind speeds associated with the bay breeze must be ≥ 3 kts. 1 hour of lighter wind speed was allowable due to the bay breeze’s light wind nature.
4. Criteria #1-3 must be sustained for ≥ 3 hrs.

### MARGINAL:

1. All bay breeze event criteria were met except the bay breeze duration, lasting < 3 hrs.

### NON-BAY BREEZE:

1. Bay breeze and marginal event criteria were not met.
Ozonesonde on August 18th

Ozonesonde at Beltsville, MD
Launched: August 18, 2009, 2:40 PM (EDT)

- Temperature (T in degC)
- Relative Humidity (RH in %)
- Wind Direction (deg)
- Wind Speed (m/s)

Graphs showing vertical profiles of temperature, relative humidity, wind direction, and wind speed with height.
The Influence of the Chesapeake Bay Breeze on Maryland Air Quality

Laura Landry, Michael Woodman, and Duc Nguyen | Maryland Department of the Environment, Baltimore, MD

OVERVIEW

Maryland has greatly improved its air quality over the past several years. However, one region within the Baltimore Nonattainment Area (BNAA) presents many challenges in meeting the 2008 8-hour average ground-level ozone National Ambient Air Quality Standard (NAAQS) of 75 ppb. The northern Chesapeake Bay region observes the highest ozone concentrations throughout the year, largely due to its location downwind of two major metropolitan areas as well as the development of the bay breeze. The formation of this micro-scale circulation has been known to create a sharp gradient of monitored ozone concentrations across its boundary. A climatological study of the Chesapeake Bay breeze is presented, specifically focusing on the northern bay region of the BNAA. The results of this study describe bay breeze frequency during the months of June-August, 2004-2009 with respect to days when ozone exceeded the standard. In addition, a comparison of ozone concentrations between inland and coastal air monitoring sites will help quantify the ozone load that can be attributed to the bay breeze.

METHODOLOGY

Criteria were developed to identify bay breeze, marginal, and non-bay breeze events. These were an adaptation of Miller and Keim (2003) sea breeze event criteria.

BAY BREEZE:
1) An onshore wind shift must occur at 1+ coastal sites.
2) 1+ inland sites must display parallel, antiparallel, or perpendicular wind flow to the shoreline.
3) Wind speeds associated with the bay breeze must be ≥ 3 kts. 1 hour of lighter wind speed was allowable due to the bay breeze's light wind nature.
4) Criteria #1-3 must be sustained for ≥ 3 hrs.

MARGINAL:
All bay breeze criteria were met except the bay breeze duration lasts < 3 hrs.

NON-BAY BREEZE:
Bay breeze and marginal criteria were not met.

RESULTS

Of the 83 cases selected from 130 BNAA exceedance days, there were 24 bay breeze events, 15 marginal events, and 44 non-bay breeze events. For bay breeze events, the average hour of onset was 1600 UTC, with the typical hour of dissipation was 2300 UTC. For marginal events, most had an hour of onset and dissipation of 1800 and 2000 UTC, respectively. The maximum ozone gradient was calculated by taking the difference in ozone concentrations from coastal sites to inland sites. These gradients showed a large spread of values, especially for marginal events. However, they do show that the bay breeze's median gradient of 37 ppb was the largest while non-bay breeze events had the lowest of 17 ppb. This means that the median gradient of bay breeze events was nearly 3X greater than the non-bay breeze.

BAY BREEZE
Onset: 1600 UTC
Dissipation: 0100 UTC
- Maximum ozone gradient of 36 ppb at 2100 UTC
- High pressure over the southeastern Mid-Atlantic region
- Stationary front W-E across the Midwest and PA
- Mostly sunny skies
- Maximum temperatures in the upper 80's (F)

MARGINAL
Onset: 1800 UTC
Dissipation: 2100 UTC
- Maximum ozone gradient of 21 ppb at 2000 UTC
- High pressure over the southern Mid-Atlantic
- Stationary front W-E across the Midwest and PA
- Mostly sunny skies
- Maximum temperatures in the low 90's (F)

NON-BAY BREEZE
Onset: -
Dissipation: -
- Maximum ozone gradient of 17 ppb at 2100 UTC
- High pressure over the Midwest and western Mid-Atlantic regions
- Synoptic wind flow from N
- Mostly sunny skies
- Maximum temperatures in the low 90's (F)