Module 7:

Natural Source Emissions

Natural Source Definition

- Nonanthropogenic sources (not human caused)
  - Biogenic sources
    - Vegetation
    - Soil microbes
  - Geogenic sources
    - Volcanoes
    - Oil and gas seeps
  - Weather related
    - Lightning
    - Wildfires
Pollutants Emitted by Natural Sources

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Biogenic</th>
<th>Geogenic</th>
<th>Weather</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vegetation</td>
<td>Soil</td>
<td>Volcanoes</td>
</tr>
<tr>
<td>VOC</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>NO₃</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>SO₄</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>PM</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

Factors Influencing Natural Source Emissions

- Diurnal and seasonal variations
- Spatial variations
- Species resolution
Biogenic Emissions
- Emissions from Plants and Soils -

Important Reactive VOCs Emitted by Biogenic Sources

- Terpenes
  - Isoprene
  - 2-methyl-3-buten-2-ol (MBO)
  - Monoterpenes
- Alkenes
- Aldehydes
- Alcohols
- Ketones
Specific Factors Influencing Biogenic Emissions

- Type of plant
- Leaf area index (LAI)
- Leaf biomass
- Ambient temperature
- Photosynthetically active radiation (PAR)
- Others (humidity, wind speed, drought)

Estimating Biogenic Source Emissions

- Computer models
  - Biogenic Emission Inventory System (BEIS)
  - Global Biosphere Emissions and Interactions System (GloBEIS)
- Land use/land cover types data
- Required meteorological data
- 1990 Global Emissions Inventory Activity (GEIA)
  - http://www.geiacenter.org
Biogenic Emissions Computer Models

<table>
<thead>
<tr>
<th>Model</th>
<th>Sponsor</th>
<th>Website to Download</th>
<th>Programming Language</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC-BEIS2.2</td>
<td>U.S. EPA</td>
<td><a href="http://www.epa.gov/asmdner1/">www.epa.gov/asmdner1/</a></td>
<td>DOS Fortran</td>
</tr>
<tr>
<td>BEIS2.3</td>
<td>U.S. EPA</td>
<td>biogen.html</td>
<td>C++/JAVA</td>
</tr>
</tbody>
</table>

BEIS Characteristics

- Originally developed in 1991 by U.S. EPA
- Updates provide improved emission factors for different types of vegetation BEIS2.3
- Updates allow program to be run on a personal computer (PC-BEIS2.3)
- Current version BEIS3 developed to run with Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system
GloBEIS Characteristics

- Essentially updates BEIS2
  - Integrates recent research
  - Allows more user inputs
  - Generates output for multiple lat/long pairs over multiple days

- System requirements:
  - CPU of Pentium III or higher
  - 64 Mb of RAM
  - 300 Mb of hard disk
  - Microsoft Access2000

Land Use / Land Cover Data

- Land use/land cover data are typically digital satellite images which have been coded for different vegetation types.

- There are several agencies that maintain Southern African LU/LC data sets
  - Global Land Cover Facility – University of Maryland (http:glcf.umiacs.umd.edu/data/guide/)
  - ARTEMIS: Africa Real Time Monitoring Information System-UN Food and Agricultural Organization (http://metart.fao.org)
  - SAFARI 2000 – Oakridge National Laboratory (http://metart.fao.org)
  - Daily Global Area Coverage – EU Joint Research Centre, Space Applications Institute (http://www.sai.jrc.it)
Required Meteorological Data

- Though most models can handle a variety of meteorological data elements, there really are only two that are needed to run the models:
  - Hourly ambient temperature
  - Hourly cloud coverage data

Such data are typically available from the South Africa Weather Service

Geogenic Emissions
Volcano Emissions

- Volcanoes emit SO₂, hydrochloric and hydrofluoric acids, CO₂, dust and ash
- Emissions usually quantified using remote measurements by airborne and ground based instruments and by satellite observations

Mount Kenya
Mount Kenya is an extinct volcano in central Kenya. At 5,199 m (17,057 ft) tall, it is the second tallest mountain in Africa.

Sources of Global Volcano Activity and Emissions Data

- Smithsonian Institute’s Volcanism Program and the U.S. Geological Survey’s Volcano Hazards Program
  > http://www.volcano.si.edu
- National Oceanic and Atmospheric Administration’s Satellite Services Division
  > http://www.ssd.noaa.gov/VAAC/
Ocean Vents and Seep Emissions

- Ocean vents and seeps tend to occur near large oil deposits
- Vents and seeps can be significant sources of VOCs and methane
- Emissions can be quantified using airborne and satellite observations or by implementing an underwater survey

Sources of Ocean Vents and Seeps Data


Weather Related Emission Sources

Wildfire Emissions

- Primarily particulate matter (PM$_{10}$, PM$_{2.5}$) emissions that relate to health & visibility concerns
- Other pollutants are also emitted:
  > CO
  > Carbon dioxide (CO$_2$)
  > NO$_x$
  > SO$_x$
  > VOCs
  > Air toxics
  > Methane (CH$_4$)
  > NH$_3$
Typical Wildfire Emissions Calculation

- Inputs needed for emission estimates
  - Fuel type
  - Fuel loading
    (available fuel burned, not total fuel)
  - Hectares or tons burned
  - Emission rate (kg/Mg, fuel specific)
- Typically only annual summaries will be available

Emissions = Tons Burned x Emission Rate

Wildfire PM$_{10}$ Emissions Estimation Example

<table>
<thead>
<tr>
<th></th>
<th>Fire 1</th>
<th>Fire 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Type</td>
<td>Chaparral</td>
<td>Conifer</td>
</tr>
<tr>
<td>Fuel Loading (Mg/Hectare)</td>
<td>18</td>
<td>40</td>
</tr>
<tr>
<td>Hectares</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Emission Factor (kg/Mg, prescribed)</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Emissions (Mg, PM$_{10}$)</td>
<td>1.4</td>
<td>6.4</td>
</tr>
</tbody>
</table>
Wildfire Emission Resources

- U.S. EPA AP-42 and other resources used for emission factors and fuel loadings
- Prescribed & Open Burning (AP-42)
  - [http://www.epa.gov/ttn/chief/ap42c2.html](http://www.epa.gov/ttn/chief/ap42c2.html)
- Wildfires - Statewide Methodology (ARB)
  - [http://www.arb.ca.gov/emisinv/areasrc/idex9.htm](http://www.arb.ca.gov/emisinv/areasrc/idex9.htm)
- Forest fires – Corinair (European Environmental Agency)

Lightning Emissions

- Lightning flashes cause molecular nitrogen to react to form nitric oxide (NO)
- Lightning occurs in two forms:
  - Cloud-to-cloud (CC) flashes
  - Cloud-to-ground (CG) flashes
Lightning Emissions Methodology

\[
\text{NO (kg)} = N_{\text{cg}} \times E_{\text{cg}} \times E_{\text{cg}} + [(N_{\text{cg}} \times E_{\text{cg}}) \times 10/(1+\Phi/30)^2 -1)] \times E_{\text{cc}}
\]

Where:
- \( N_{\text{cg}} \) = Number of CG flashes
- \( E_{\text{cg}} \) = CG emission factor = 33 kg NO/flash
- \( E_{\text{cg}} \) = Efficiency of CG network (dimensionless)
- \( \Phi \) = Latitude of study area (degrees)
- \( E_{\text{cc}} \) = CC emission factor = 3.3 kg NO/flash

Lightning Emissions

- Emission factors
  - CC flashes = 3.3 kg of NO/flash
  - CG flashes = 33 kg of NO/flash
Sources of Lightning Data

- Lightning Flash Detection Network
  > [http://www.lightningstorm.com](http://www.lightningstorm.com)

- Global Hydrology Climate Center (supported by NASA)
  > [http://www.ghcc.msfc.nasa.gov/ghcc_data.html](http://www.ghcc.msfc.nasa.gov/ghcc_data.html)

Summary: Natural Sources

- Natural sources can emit significant quantities of VOC, NO\textsubscript{x}, and SO\textsubscript{x}
- Classifications include biogenic, geogenic, weather related emission sources
- Models are generally used to estimate biogenic emissions
- Measurements and location-specific data are needed to estimate emissions from other categories
  > Ambient measurements
  > Satellite observations
  > Lightning activity
  > Fuel loading and acres burned by vegetation type for wildfires
Questions or Comments?

END
Module 7: Natural Sources
Emission Inventory Development