Automatic Identification Systems (AIS) Data Use in Marine Vessel Emission Estimation

Roger Chang, Heather Perez, Richard Billings
Eastern Research Group

18th Annual International Emissions Inventory Conference
April 15, 2009
Outline

• Texas State Waters Inventory Context
• AIS Background
• AIS Dataset
• Data Processing Methods
• Results
• Limitations
• Final Discussion of AIS Data Applicability in Inventory Efforts
Inventory Effort: Texas State Waters

- Texas has over 600 miles of tidewater coastline
- Needs for more accurate emission inventories
- Commercial Marine Vessel (CMV) emissions pose unique challenges
- Excludes Houston/Galveston Area
- Automatic Identification Systems (AIS) data for use in activity estimation
- Strengths and limitations of AIS data
AIS - Background

- AIS = Automatic Identification System
- Electronically transmits data to Vessel Traffic Service (VTS) stations and other ships
  - Vessel Identification
  - Position
  - Speed
  - Course
- Uses GPS, ship sensors and VHF radio
AIS Data Transmittal

Every 2 to 10 seconds (underway) and every 3 minutes (at anchor):

- Maritime Mobile Service Identity
- Status (anchor/underway/not under command)
- Rate of turn
- Speed
- Latitude and Longitude
- True Heading
- Time Stamp, Coordinated Universal Time (UTC)
AIS Data Transmittal

Every 6 minutes, underway or at anchor:

- International Maritime Organization’s (IMO) ship identification number
- Vessel Name
- Ship Type/Cargo
- Ship Dimensions
- Destination
- Estimated time of arrival (ETA) at destination – UTC
AIS Data – Coverage

• Required by IMO in 2000 for the following:
  • All international vessels $\geq 300$ gross tons
  • All passenger ships

• Required by U.S. Coast Guard in 2005 for all CMV transiting U.S. inland waterways and ports

• Over 40,000 ships worldwide
AIS Data Utilization

- AIS data obtained from AIRSIS, Inc.
- Area of Interest (AOI) included all of Texas state waters, including inland waterways and 9 nautical miles from coastline
- Houston-Galveston (HGA) nonattainment area excluded
- Over 132 points of interest (POI) with vessel monitoring stations
AIS Data Set

• Base year 2007
• 2,912 matchable vessels
• Trips identified with a unique “Transit ID”
  • 82,355 transits
• Each transit had $\geq 1$ “Event IDs” indicating an origin, waypoint, or destination
  • 545,141 events
• Origins/Destinations outside of the AOI were marked as “At Sea”
Methods - Summary

- Addressed erroneous AIS data using GIS
- Linked AIS data to Vessel Characteristics
- Gap-filled missing characteristics data
- Calculated horsepower-hours of operation
- Assigned emission factors from the Swedish EPA
- Estimated emissions
Methods – Linking AIS

• AIS data linked to vessel characteristic data sets
  • Lloyd’s Register of Ships
  • American Bureau of Shipping
  • Bureau Veritas
• Linked by IMO, MMSI, vessel name, and vessel type
• Data gaps filled using averaged data by vessel type
# Methods – Linking AIS

<table>
<thead>
<tr>
<th>Description</th>
<th>Vessel Count</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Vessels in AIS</td>
<td>3,398</td>
<td>100%</td>
</tr>
<tr>
<td>With IMO</td>
<td>2,657</td>
<td>78%</td>
</tr>
<tr>
<td>Matched using IMO</td>
<td>1,913</td>
<td>56%</td>
</tr>
<tr>
<td>Matched using MMSI or Name and Type</td>
<td>1,006</td>
<td>30%</td>
</tr>
<tr>
<td><strong>Total Matched</strong></td>
<td><strong>2,919</strong></td>
<td><strong>86%</strong></td>
</tr>
</tbody>
</table>
Methods – Hp-Hrs

• Hp-Hrs = HP * Number of engines * Hours of operation

• Inaccurate AIS time stamps
  • Hp-Hrs = HP * Number of engines * (Distance / Speed)

• 12% had the same origination and destination
  • Assist tugs, pilot boats, patrol boats: all time in state waters
  • Larger vessels ≤ 12 hours: intra-ports shift in state waters
  • Larger vessels > 12 hours: port to state/federal boundary and back
Methods – Calculating Emissions

- 2007 emissions for criteria and various HAPs
- \( AE = AH \times CF_1 \times LF \times EF \times CF_2 \)

where:

- \( AE = \) Annual Emissions
- \( AH = \) Annual Activity (hp-hr)
- \( CF_1 = \) Conversion factor (0.741 kW/Hp)
- \( LF = \) Load factor: 80% cruising/maneuvering 10% (hoteling)
- \( EF = \) Swedish emission factor (g/kw-Hr)
- \( CF_2 = \) Conversion factor (1.10231 E-6 ton/g)
## Results – All Vessels

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Annual (tons)</th>
<th>OSD (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Monoxide</td>
<td>13,391.10</td>
<td>36.69</td>
</tr>
<tr>
<td>Volatile Organic Compounds</td>
<td>3,114.15</td>
<td>8.53</td>
</tr>
<tr>
<td>Nitrogen Oxides</td>
<td>162,621.94</td>
<td>445.54</td>
</tr>
<tr>
<td>Sulfur Oxides</td>
<td>92,425.76</td>
<td>253.22</td>
</tr>
<tr>
<td>Primary PM$_{10}$ (Includes Filterables + Condensables)</td>
<td>7,874.50</td>
<td>21.57</td>
</tr>
<tr>
<td>Primary PM$_{2.5}$ (Includes Filterables + Condensables)</td>
<td>7,874.50</td>
<td>21.57</td>
</tr>
</tbody>
</table>
## Results – Tugs Comparison

Data and Comparison from Independent Reviewer

<table>
<thead>
<tr>
<th>Area</th>
<th>U.S. ACE WCUS 2006 Vessel Movements</th>
<th>AIS Vessel Movement 2007*</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sabine-Neches</td>
<td>~ 33,000</td>
<td>~ 33,000</td>
<td>AIS similar to WCUS</td>
</tr>
<tr>
<td>Corpus Christi</td>
<td>~ 6,000</td>
<td>12,809</td>
<td>AIS overreports</td>
</tr>
<tr>
<td>Brownsville</td>
<td>~ 1,100</td>
<td>(No POIs)</td>
<td>AIS underreports</td>
</tr>
<tr>
<td>Victoria</td>
<td>~ 2,400</td>
<td>1,677</td>
<td>AIS underreports **</td>
</tr>
</tbody>
</table>

* Includes Blank/Unknown assumed to be tugs

** Lower AIS movement may be indicative of decline of economic activity (Alcoa and Dow facilities closures)
Limitations

- Placement of POIs
- Vessels $\geq 300$ Gross Tons
- Data Gaps
  - Missing records. Vessels leaving a port, not going past POIs, and appearing in another port
  - Vessels that seem to travel over land.
  - Poor vessel type data (probably includes tugs)
Discussion

• Automatic and electronic nature of AIS improves reporting consistency and minimizes data entry errors.

• Accurate to Tug Comparison with WCUS in biggest port area.

• More POIs will possibly improve AIS data

• Use of other datasets (e.g., U.S. ACE) to refine AIS data
Acknowledgements

• Theodore L. Kosub
• Sam Wells
• AIRSIS, Inc.
  • Dave Tyler
  • Brian Crawford
  • Kevin Crawford