Trajectory Analysis of High Sulfur Dioxide Episodes at the Chester, NJ Monitor

July 30, 2010

Bureau of Technical Services
Division of Air Quality
New Jersey Dept. of Environmental Protection
Purpose of This Trajectory Analysis

The final rule for the new 1-hour primary National Ambient Air Quality Standard (NAAQS) for sulfur dioxide (SO₂) was promulgated on June 2, 2010 (75 Fed. Reg. 39,633 (July 12, 2010)) and became effective August 23, 2010. This report, attached to New Jersey’s supplemental 126 petition, summarizes the New Jersey Department of Environmental Protection’s (NJDEP) trajectory analysis examining whether SO₂ emissions from the Pennsylvania Portland Power Plant are the cause of elevated 1-hour concentrations being measured at a NJDEP SO₂ monitor in Chester, New Jersey. Forward and backward in time air trajectories were examined determine if emissions from the Portland Power Plant could have caused two multi-hour high SO₂ episodes that occurred at the Chester ambient air monitor in 2008 and 2009.

If a source is capable of causing high SO₂ concentrations that sometimes exceed the 1-hour SO₂ NAAQS at a monitor 21 miles away, it is logical to conclude that much higher 1-hour sulfur dioxide concentrations are occurring nearer to the source. The contribution of SO₂ emissions from the Portland Power Plant to 1-hour SO₂ concentrations closer to the source are documented in the NJDEP Bureau of Technical Services reports: AERMOD Modeling Analysis of the 1-Hour Sulfur Dioxide Impacts Due to Emissions from the Portland Generating Station (July 30, 2010) and CALPUFF Predictions of the 1-hour Sulfur Dioxide Impacts due to Emissions from the Portland Generating Station (August 25, 2010). These documents are also exhibits in NJDEP’s supplemental 126 Petition.

NJDEP Chester Ambient Air Monitor

The NJDEP Chester monitor is located in Chester, New Jersey, approximately 21 miles (34 km) east-southeast of the Portland Power Plant. Its location represents the halfway point between the Portland Power Plant and the City of Newark, New Jersey. Review of the SO₂ data collected in 2008 and 2009 revealed a three-hour episode of high concentrations beginning at 10 pm Eastern Daylight Time (EDT) on July 17, 2008. The 1-hour SO₂ concentrations measured during these three hours are the highest three measured 1-hour concentrations at the Chester monitor during 2008-2009. As can be seen in Table 1, the concentrations measured during the first two hours of the episode exceeded the new 1-hour SO₂ NAAQS.

Table 1. Hourly Measured Sulfur Dioxide Concentrations at the NJDEP Chester Monitor - Hour 22 July 17, 2010 to Hour 00 July 18, 2010

<table>
<thead>
<tr>
<th>Hour (EDT)</th>
<th>SO₂ (ppm)</th>
<th>SO₂ (µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>77</td>
<td>201</td>
</tr>
<tr>
<td>23</td>
<td>85</td>
<td>222</td>
</tr>
<tr>
<td>00</td>
<td>53</td>
<td>139</td>
</tr>
</tbody>
</table>

1-Hour SO₂ NAAQS: 75 µg/m³

a. Exceedances of the 1-hour SO₂ NAAQS in bold.

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NJDEP compared the SO₂ values measured in this episode to the 1-hour concentrations measured at the other 12 NJDEP SO₂ monitors located in the state. The measurements of July 17, 2008, hours 22-23, were the 1st and 2nd highest 1-hour SO₂ concentrations monitored in the entire NJDEP SO₂ monitoring network in 2008. In addition, the July 17, 2008, hour 00 concentration, was the 4th highest 1-hour concentrations measured in the entire NJDEP SO₂ monitoring network in 2008. The rapid rise of SO₂ values measured at the beginning of this episode and the rapid drop at the end of the episode is shown in Figure 1.

An additional multi-hour high SO₂ episode that occurred in December 2009 was also evaluated. The SO₂ concentrations monitored from hours 01-04 Eastern Standard Time (1:00 am to 4:59 am EST) on December 7, 2009 are listed in Table 2. Though the measured 1-hour SO₂ concentrations in this episode are less than the July 17, 2008 episode, they do represent 4 of the 12 highest 1 hour SO₂ concentrations recorded at the Chester monitor in 2008 – 2009. Figure 2 shows a more gradual rise and fall of SO₂ values measured during this episode as compared to the July 17-18, 2008 episode.

Table 2. Hourly Measured Sulfur Dioxide Concentrations at the NJDEP Chester Monitor - Hour 01 to Hour 04 December 7, 2010

<table>
<thead>
<tr>
<th>Hour (EST)</th>
<th>SO₂ (ppb)</th>
<th>SO₂ (μg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>30</td>
<td>78</td>
</tr>
<tr>
<td>02</td>
<td>33</td>
<td>86</td>
</tr>
<tr>
<td>03</td>
<td>30</td>
<td>78</td>
</tr>
<tr>
<td>04</td>
<td>28</td>
<td>73</td>
</tr>
<tr>
<td>1-Hour SO₂ NAAQS</td>
<td>75</td>
<td>196</td>
</tr>
</tbody>
</table>

Sources of Sulfur Dioxide Emissions in the Vicinity of the Portland Power Plant and the Chester Monitor

There are two large source of SO₂ emissions located to the west of the Chester monitor, Portland Power Plant Units 1 and 2 and the Martins Creek Power Plant Units 3 and 4. The other SO₂ sources in the region are either much smaller and/or more distant from the Chester monitor than the Portland Power Plant and the Martins Creek Power Plant.

In New Jersey, the facilities in Warren, Sussex, Morris and Hunterdon Counties in New Jersey that emitted more than 1 ton/yr of SO₂ in 2009 are listed in Table 3. The emissions from the sources listed in the table are far below the roughly 31,000 tons/year of SO₂ Portland Power Plant has emitted in recent years. The largest, Warren County District Landfill located approximately 16 miles from the Chester monitor, emits 25.9 tons/yr, 0.08 percent of the Portland Power Plant’s total emissions. In addition, the two facilities in Morris County are located to the east of the Chester Monitor, the opposite direction of the Portland Power Plant.
Table 3. 2009 Sulfur Dioxide Emissions from Facilities in Warren, Sussex, Morris, and Hunterdon Counties in New Jersey

<table>
<thead>
<tr>
<th>FACILITY NAME</th>
<th>COUNTY</th>
<th>MUNICIPALITY</th>
<th>SO₂ (TPY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warren County District Landfill</td>
<td>Warren</td>
<td>Oxford</td>
<td>25.9</td>
</tr>
<tr>
<td>Atlantic States Cast Iron Pipe</td>
<td>Warren</td>
<td>Phillipsburg</td>
<td>4.7</td>
</tr>
<tr>
<td>Mars Chocolate NA LLC</td>
<td>Warren</td>
<td>Hackettstown</td>
<td>4.3</td>
</tr>
<tr>
<td>Warren County Landfill Energy, LLC</td>
<td>Warren</td>
<td>Oxford</td>
<td>3.6</td>
</tr>
<tr>
<td>Mallinckrodt Baker Inc.</td>
<td>Warren</td>
<td>Phillipsburg</td>
<td>1.2</td>
</tr>
<tr>
<td>Sussex County Municipal Utilities Auth.</td>
<td>Sussex</td>
<td>Lafayette</td>
<td>2.1</td>
</tr>
<tr>
<td>Hamms Landfill Energy Recovery Project</td>
<td>Sussex</td>
<td>Lafayette</td>
<td>1.1</td>
</tr>
<tr>
<td>Novartis Pharmaceuticals Corporation</td>
<td>Morris</td>
<td>East Hanover</td>
<td>4.2</td>
</tr>
<tr>
<td>Morristown Memorial Hospital</td>
<td>Morris</td>
<td>Morristown</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Besides the Portland and Martins Creek Power Plants, the other sources in Northampton County, PA that emitted more than 20 tons/yr of SO₂ in 2008 are listed in Table 4. 2008 is the latest actual emissions data available in the PADEP eFACTS data base. As can be seen in Table 4, these sources are more distant and emit much less than the Portland Power Plant. The Green Knight/Plainfield Landfill Gas, which emits only 0.15 percent of Portland’s annual emissions, is located 12 miles west of the Portland Power Plant. The other four sources in the table are all located to the west-southwest of the Chester monitor at an angle 30 degrees south of the direction of Portland Power Plant from the Chester monitor. In Figure 3, the four facilities are along a 14 mile east-west line located approximately 4 miles north, and centered on, Bethlehem PA

Table 4. 2008 Sulfur Dioxide Emissions from Facilities in Northampton County PA

<table>
<thead>
<tr>
<th>Facility Name</th>
<th>Municipality</th>
<th>Distance from Chester Monitor</th>
<th>SO₂ (TPY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hercules Cement Co.</td>
<td>Stockertown</td>
<td>30 mi</td>
<td>1,822</td>
</tr>
<tr>
<td>Keystone Portland Cement</td>
<td>East Allen Township</td>
<td>36 mi</td>
<td>1,200</td>
</tr>
<tr>
<td>ESSROC</td>
<td>Nazareth</td>
<td>33 mi</td>
<td>1,038</td>
</tr>
<tr>
<td>Northampton Generating Station</td>
<td>Northampton</td>
<td>44 mi</td>
<td>541</td>
</tr>
<tr>
<td>Green Knight/Plainfield Landfill Gas</td>
<td>Plainfield Township</td>
<td>33 mi</td>
<td>46</td>
</tr>
</tbody>
</table>

Sulfur Dioxide Emissions from Portland and Martins Creek Power Plants Before and During the Episodes

Hourly emissions of SO₂ from Portland Power Plant Units 1 and 2 and the Martins Creek Power Plant Units 3 and 4 are available from the EPA Clean Air Markets web site (http://www.epa.gov/airmarkets/emissions/).
Episode I

The hourly SO$_2$ emissions from the Portland Power Plant Units 1 and 2 and the Martins Creek Power Plant Units 3 and 4 starting at Hour 16 (3 pm) on July 17, 2008 through midnight July 17, 2008 are listed in Table 5. As can be seen, the hourly emissions from Portland Units 1 and 2 were significant during this time period. The values are roughly 85 percent of each unit’s maximum allowable emission rate (Unit 1 = 5,820 lbs/hr, Unit 2 = 8,900 lbs/hr). During the same time period, the emissions from Martins Creek Units 3 and 4 were negligible.

Table 5. Hourly Sulfur Dioxide Emissions on July 17, 2008 $^a$$^a$

<table>
<thead>
<tr>
<th>Hour (EDT)</th>
<th>Portland Unit 1 (lbs/hr)</th>
<th>Portland Unit 2 (lbs/hr)</th>
<th>Martins Creek Units 3 &amp; 4 (lbs/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>5,024</td>
<td>7,574</td>
<td>35</td>
</tr>
<tr>
<td>16</td>
<td>5,041</td>
<td>7,536</td>
<td>42</td>
</tr>
<tr>
<td>17</td>
<td>5,051</td>
<td>7,436</td>
<td>33</td>
</tr>
<tr>
<td>18</td>
<td>5,013</td>
<td>7,569</td>
<td>21</td>
</tr>
<tr>
<td>19</td>
<td>5,003</td>
<td>7,556</td>
<td>16</td>
</tr>
<tr>
<td>20</td>
<td>4,969</td>
<td>7,580</td>
<td>16</td>
</tr>
<tr>
<td>21</td>
<td>4,913</td>
<td>7,532</td>
<td>9</td>
</tr>
<tr>
<td>22</td>
<td>4,986</td>
<td>7,548</td>
<td>0</td>
</tr>
<tr>
<td>23</td>
<td>4,475</td>
<td>6,792</td>
<td>0</td>
</tr>
</tbody>
</table>

$^a$ From EPA Clean Air Markets web site.

Episode II

As can be seen in Table 6, the hourly SO$_2$ emissions from the Portland Power Plant Units 1 and 2 during Episode II are lower emissions than Episode I. The values during this episode are approximately 55 percent of each unit’s allowable emission rate. Martins Creek Units 3 and 4 were not in operation during the episode and emitted no SO$_2$ emissions.

Table 6. Hourly Sulfur Dioxide Emissions on December 6 and 7, 2009 $^a$$^a$

<table>
<thead>
<tr>
<th>Hour (EST)</th>
<th>Portland Unit 1 (lbs/hr)</th>
<th>Portland Unit 2 (lbs/hr)</th>
<th>Martins Creek Units 3 &amp; 4 (lbs/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec. 6 - 18</td>
<td>3,503</td>
<td>5,326</td>
<td>0</td>
</tr>
<tr>
<td>19</td>
<td>3,554</td>
<td>5,818</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>3,493</td>
<td>5,819</td>
<td>0</td>
</tr>
<tr>
<td>21</td>
<td>3,352</td>
<td>5,611</td>
<td>0</td>
</tr>
<tr>
<td>22</td>
<td>2,830</td>
<td>4,612</td>
<td>0</td>
</tr>
<tr>
<td>23</td>
<td>2,856</td>
<td>4,535</td>
<td>0</td>
</tr>
<tr>
<td>Dec. 7 - 00</td>
<td>3,192</td>
<td>4,617</td>
<td>0</td>
</tr>
<tr>
<td>01</td>
<td>3,305</td>
<td>4,653</td>
<td>0</td>
</tr>
<tr>
<td>02</td>
<td>3,423</td>
<td>4,532</td>
<td>0</td>
</tr>
</tbody>
</table>

$^a$ From EPA Clean Air Markets web site.
**HYSPLIT Model**

The trajectory analysis was conducted with the NOAA Air Resources Laboratory’s (ARL) HYSPLIT Trajectory Model. Access to the interactive trajectory model is available at: [http://ready.arl.noaa.gov/](http://ready.arl.noaa.gov/). Below is a description of the HYSPLIT model from the web site:

The Air Resources Laboratory’s HYbrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model is a complete system for computing both simple air parcel trajectories and complex dispersion and deposition simulations. The model calculation method is a hybrid between the Lagrangian approach, which uses a moving frame of reference as the air parcels move from their initial location, and the Eulerian approach, which uses a fixed three-dimensional grid as a frame of reference. In the model, advection and diffusion calculations are made in a Lagrangian framework following the transport of the air parcel, while pollutant concentrations are calculated on a fixed grid. Through a joint effort between NOAA and Australia’s Bureau of Meteorology, the model uses advection algorithms, updated stability and dispersion equations, a graphical user interface, and the option to include modules for chemical transformations. HYSPLIT can be run interactively on ARL’s READY (Real-time Environmental Applications and Display sYstem) web site, or it can be installed on a PC and run using a graphical user interface.

The model is designed to support a wide range of simulations related to the atmospheric transport and dispersion of pollutants and hazardous materials, as well as the deposition of these materials (such as mercury) to the Earth’s surface. Some of the applications include tracking and forecasting the release of radioactive material, volcanic ash, wildfire smoke, and pollutants from various stationary and mobile emission sources. Operationally, the model is used by NOAA’s National Weather Service through the National Centers for Environmental Prediction and at local weather forecast offices.

**Air Trajectory Analysis**

Several forecast meteorological data sets are available at the web site to use with the HYSPLIT Trajectory Model. Because of its denser grid spacing, the NAM (Eta) 12 km forecast meteorological data was selected for use in this analysis. The following start location coordinates were input into HYSPLIT to estimate the forward and backward air trajectories:

**Chester Monitor:**
- latitude = 40 deg, 47 min., 15 sec. north (40.7876 N)
- longitude = 74 deg, 40 min., 35 sec. west (74.6763 W)

**Portland Power Plant:**
- latitude = 40 deg, 54 min., 35 sec. north (40.909797 N)
- longitude = 74 deg, 40 min., 35 sec. west (75.07875 W)
All times referenced in the trajectory analysis below are based on local time EDT or EST, not Greenwich Mean Time (GMT) or Coordinated Universal Time (UTC). EDT is - 4 hours different than GMT or UTC. EST is - 5 hours different than GMT or UTC.

**Episode I**

Trajectories were calculated at two heights above ground level. One trajectory represents a parcel of air located 221 meters above ground. This is the approximation of the height of the plume emitted from the Portland Power Plant stacks (121 meter stack height and a 100 meter plume rise). The other trajectory is for a parcel of air 10 meters above ground (the lowest height allowed by the HYSPLIT Trajectory Model). This level is used to represent the height of the Chester monitor. The trajectory analysis shows that the SO₂ emitted from the Portland Power Plant stacks will initially start near the 221 meter level above ground (i.e., plume height). As the plume is advected downwind, some of the SO₂ contained in the plume will disperse vertically downward and eventually reach ground-level. Therefore, the path of SO₂ emitted from the Portland Power Plant stacks traveling horizontally and vertically to the Chester monitor is best represented by a combination of the 221 meter and 10 meter trajectories.

The 221 meter and 10 meter trajectories indicated little directional wind shear in the vertical. As a result, no additional trajectory heights were deemed necessary in evaluating this episode. Wind speeds were relatively light during the episode. At the 221 meter level the wind speed was approximately 4.5 m/s (10 mph). At the lower 10 meter level the wind speed was approximately 2.7 m/s (6 mph). At these low wind speeds a 6-hour trajectory was needed to transport the plume a sufficient distance to and from the monitor.

Figure 3 shows the forward trajectories of two particles of air starting at the Portland Power Plant at hour 15 (3 pm EDT) on July 17, 2008 and traveling for 6 hours until hour 21 (9 pm EDT). Hour 21 is one hour before the beginning of the three-hour episode of high SO₂ concentrations at the Chester monitor. Both the 221 meter and 10 meter trajectories from the Portland Power Plant site are just to the north of the Chester monitoring site suggesting no impact at the monitor during hour 21 (the end of the trajectory).

Figure 4 shows the forward 6-hour trajectories of these same two levels of air starting one hour later. Beginning at the Portland Power Plant at hour 16 (4 pm EDT) on July 17, 2008, these trajectories’ end time (hour 00 on July 18, 2008) coincides with the beginning of the three-hour episode of high SO₂ concentrations at the Chester monitor. The combination of the 221 meter and 10 meter trajectories indicate that SO₂ emissions from the Portland Power Plant would be arriving in the vicinity of the Chester monitor at this time.

Figure 5 shows the forward 6-hour trajectories of these same two particles of air starting hour 17 (5 pm EDT) on July 17, 2008, one hour later than Figure 4. These trajectories’ end time (hour 01 July 18, 2008) coincides with the mid-point of the three-hour episode.
of high SO₂ concentrations at the Chester monitor. While the 221 meter and 10 meter
trajectories are located further south than the previous hours (Figures 3 and 4), they still
imply that at ground-level the SO₂ emissions from the Portland Power Plant would be
measured at the Chester monitor at this time.

The last figure for this episode, Figure 6, shows the back trajectories of two particles of
air starting at the Chester monitor at hour 22 (10 pm EDT) on July 17, 2008 and traveling
back in time for 6 hours to hour 16 (4 pm EDT). This is the same time period shown in
Figure 4. These trajectories are another indicator of where the air containing SO₂ high
concentration measured at the Chester monitor originated at the beginning of the three-
hour episode. The combination of the two trajectories clearly indicates the SO₂ measured
at the monitor beginning hour 22 came from a source in the vicinity of the Portland
Power Plant (likely the Portland Power Plant).

**Episode II**

When evaluating this 4 hour episode, trajectories at three different heights above ground
level were calculated. As before, one trajectory represented the approximate plume height
of the emissions (221 meters above ground) and one represented the height of the Chester
monitor (10 meters above ground). A third trajectory of 100 meters was also used in
order to better track the SO₂ transport at a height between the plume height and the
monitor’s height. Use of a third trajectory was warranted because of the significant
directional wind shear in the vertical that occurred during this episode.

As compared to the July 17, 2008 episode, the December 7, 2009 episode also had much
higher wind speeds at the higher levels above ground. While the lower 10 meter level
winds had a similar speed (approximately 3 m/s), the wind speeds at the higher levels
were significantly higher than the July 17 episode. At the beginning of the December 7th
episode at the 221 meter level winds were approximately 11.2 m/s (25 mph) and the 100
meter level winds were approximately 6.7 m/s (15 mph). As a result, 3-hour trajectories
were sufficient to track the plume between the Portland Power Plant and the monitor.
Also, the 100 meter and 221 meter trajectories were considered more representative of
trajectory between the Portland Power Plant and monitor because the plume will be these
wind regimes for most of the transport time. To assist in understanding plume transport
during this episode, the position of the 221 meter air parcel after each hour is indicated on
the trajectory.

Figure 7 shows the forward 3-hour trajectories of three particles of air at three different
heights above ground, starting at the Portland Power Plant at hour 22 (10 pm EST) on
December 6 and ending at hour 01 (1 am EST) on December 7. Hour 01 on December 7
is the beginning of the four-hour episode of high SO₂ concentrations at the Chester
monitor. The combination of the 221 meter and 100 meter trajectories demonstrate that
SO₂ emissions from the Portland Power Plant would be arriving in the vicinity of the
Chester monitor at this time.
Figure 8 shows the forward 3-hour trajectories of these same three particles of air starting hour 00 (midnight) on December 7, which is two hours later than the starting time of Figure 5. These trajectories’ end times (hour 04 on December 7) coincide with the midpoint of this four-hour episode’s high SO₂ concentrations at the Chester monitor. While the wind speeds have slowed down slightly, the 221 meter and 100 meter trajectories are similar to those in Figure 7 and continue to indicate an impact of the Portland Power Plant emissions on the Chester monitor.

Figures 9 and 10 show a similar time period as Figures 7 and 8, but instead of forward trajectories, the back-trajectories from the Chester monitor are shown. Figure 9 shows the back trajectories of three particles of air starting at the Chester monitor at hour 1 (1 am EST) on December 7, and traveling back in time for 3 hours to hour 22 (10 pm EST) on December 6. As mentioned earlier, hour 01 (1 am EST) on December 7 represents the beginning of the four-hour episode of high SO₂ concentrations at the Chester monitor. Figure 10 shows the back trajectories of three particles of air starting at the Chester monitor at hour 03 (3 am EST) on December 7, and traveling back in time for 3 hours to hour 00 (midnight) on December 7. Hour 03 on December 7 is in the second half of the high SO₂ episode. Both figures bring the critical 100 meter and 221 meter trajectories back to the vicinity of the Portland Power Plant.
Figure 1. Hourly Sulfur Dioxide Measurements at the Chester Monitor from 18:00 July 17 to 3:00 July 18, 2008.

Figure 2. Hourly Sulfur Dioxide Measurements at the Chester Monitor from 20:00 December 6 to 8:00 December 7, 2009.
Figure 3. July 17, 2008 Forward 6-Hour Trajectory from the Portland Power Plant (starting time of 3pm EDT)

Red Line = 10 meter above ground trajectory (approximate monitor height)
Blue Line = 221 meter above ground trajectory (approximate plume height)
Figure 4. July 17, 2008 Forward 6-Hour Trajectory from the Portland Power Plant (starting time of 4 pm EDT)

Red Line = 10 meter above ground trajectory (approximate monitor height)
Blue Line = 221 meter above ground trajectory (approximate plume height)
Figure 5. July 17, 2008 Forward 6-Hour Trajectory from the Portland Power Plant (starting time of 5 pm EST)

Red Line = 10 meter above ground trajectory (approximate monitor height)
Blue Line = 221 meter above ground trajectory (approximate plume height)
Figure 6. July 17, 2008 Backward 6-Hour Trajectory from the Chester Monitor (starting time of 10 pm EST)

Red Line = 10 meter above ground trajectory (approximate monitor height)
Blue Line = 221 meter above ground trajectory (approximate plume height)
Figure 7. December 7, 2009 Forward 3-Hour Trajectory from the Portland Power Plant (starting time of December 6, 10 pm EST)

Red Line = 10 meter above ground trajectory (approximate monitor height)
Blue Line = 100 meter above ground trajectory
Green Line = 221 meter above ground trajectory (approximate plume height)
Figure 8. December 7, 2009 Forward 3-Hour Trajectory from the Portland Power Plant (starting time of midnight December 7)

Red Line = 10 meter above ground trajectory (approximate monitor height)
Blue Line = 100 meter above ground trajectory
Green Line = 221 meter above ground trajectory (approximate plume height)
Figure 9. December 7, 2009 Backward 3-Hour Trajectory from the Portland Power Plant (starting time of December 7, 1 am EST)

Red Line = 10 meter above ground trajectory (approximate monitor height)
Blue Line = 100 meter above ground trajectory
Green Line = 221 meter above ground trajectory (approximate plume height)
Figure 10. December 7, 2009 Backward 3-Hour Trajectory from the Portland Power Plant (starting time of December 7, 3 am EST)

Red Line = 10 meter above ground trajectory (approximate monitor height)
Blue Line = 100 meter above ground trajectory
Green Line = 221 meter above ground trajectory (approximate plume height)