Development and Application of PM2.5 Interpollutant Trading Ratios to Account for PM2.5 Secondary Formation in Georgia

James Boylan and Byeong-Uk Kim
Georgia EPD – Air Protection Branch

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Introduction

- Facilities applying for PSD air permits are required to model the impact of direct PM2.5 emissions (≥10 TPY) using AERMOD.
  - In addition, these facilities must account for the impact of secondary PM2.5 formation from precursor emissions (NOx and/or SO2 ≥ 40 TPY).
- AERMOD does not contain chemistry or aerosol formation modules
  - The secondary formation of PM2.5 cannot be modeled directly in AERMOD.

Interpollutant Trading Ratios

- Sources applying for permits in areas designated nonattainment for PM2.5 can offset emissions increases of direct PM2.5 emissions with reductions of PM2.5 precursors in accordance with interpollutant trading ratios (also called “PM2.5 offset ratios”) contained in the approved SIP for the applicable nonattainment area.
  - For example, an existing source can increases PM2.5 emissions by <u>X</u> tons in exchange for reducing SO2 emissions by <u>Y</u> tons.

Equivalent Direct PM2.5 Emissions

- PM2.5 offset trading ratios can be used to account for secondary formation of PM2.5 in AERMOD.
- Convert SO2 and NOx emissions into “equivalent” direct PM2.5 emissions.
  - **100**:1 ➔100 TPY SO2 = 1 TPY direct PM2.5
  - **10**:1 ➔100 TPY SO2 = 10 TPY direct PM2.5
  - **1**:1 ➔100 TPY SO2 = 100 TPY direct PM2.5
  - **0.5**:1 ➔100 TPY SO2 = 200 TPY direct PM2.5
    - This is ~100% conversion of SO_2 to $(NH_4)_2SO_4$
- <u>Lower</u> PM2.5 offset ratios will produce <u>more</u> secondary PM2.5.

Secondary Formation in AERMOD

- Option 1: Add SO_2 and NO_x "equivalent" direct PM2.5 emissions to the actual direct PM2.5 emissions and run AERMOD
  - Allows for ratios that vary temporally
- Option 2: Calculate a percent increase in direct PM2.5 emissions due to the addition of SO_2 and NO_x "equivalent" direct PM2.5 emissions and scale the AERMOD output for actual direct PM2.5 emissions
  - Allows for ratios that vary spatially

EPA Memo – July 21, 2011

The general framework for developing PM2.5 offset ratios would include the following steps:

1) Define the geographic area(s).
2) Conduct a series of sensitivity runs with appropriate air quality models to develop a database of modeled PM2.5 concentration changes associated with reductions of direct PM2.5 emissions and PM2.5 precursor emissions.
3) Calculate the interpollutant offset ratios for PM2.5.
4) Conduct quality assurance of the resulting ratios.

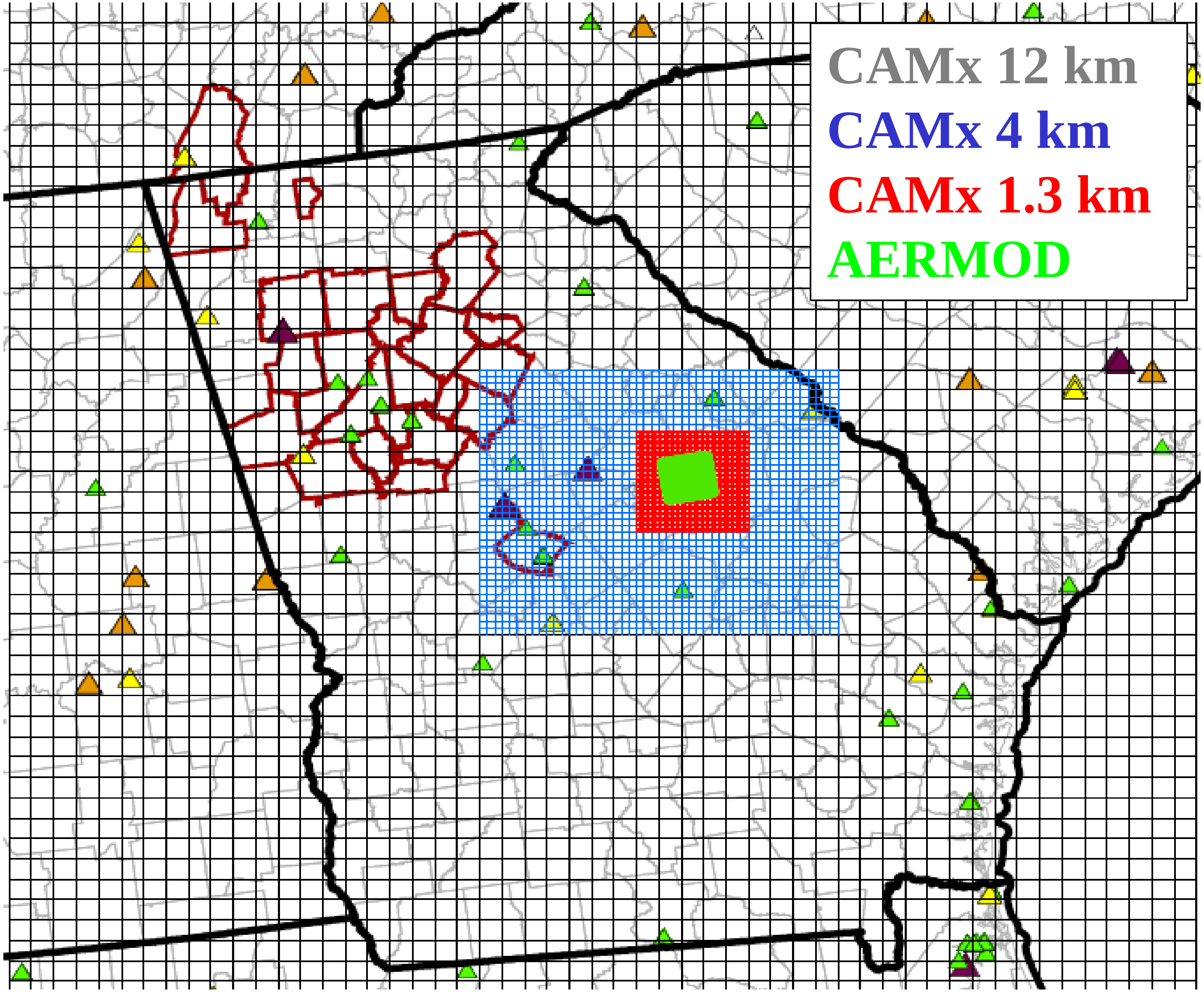
Case Study: Georgia

- Plant Washington
  - 850 MW Coal Fired Power Plant located in Washington County, GA
- GA EPD used CAMx photochemical modeling to account for secondary PM2.5 impacts and ozone impacts from the proposed facility.
- Final permit issued on April 8, 2010

Model Setup

- MM5 for Meteorology
  - VISTAS 2002
- SMOKE for Emissions
  - VISTAS 2009 used in Georgia PM2.5 SIP
  - Added power plant emissions (Plant Washington)
    - 4200 TPY SO2, 1817 TPY NOx, 6 TPY EC
    - Stack height = 137.16 meters
- CAMx with Flexi-nesting
  - 12-km/4-km/1.333-km
- Three sensitivity runs to calculate baseline PM2.5 offset ratios
  - Zero-out stack emissions: (1) SO2, (2) NOx, (3) EC

CAMx Modeling Domains



Modeled PM2.5 Offset Ratios

- Normalized Sensitivity (S)
  - $S_{SO2} = (\Delta PM2.5_{SO2}/\Delta TPY_{SO2})$
  - $S_{NOx} = (\Delta PM2.5_{NOx}/\Delta TPY_{NOx})$
  - $S_{PM2.5} = (\Delta PM2.5_{PM2.5}/\Delta TPY_{PM2.5})$
- PM2.5 Offset Ratios (R)
  - $R_{SO2} = S_{PM2.5}/S_{SO2}$
  - $R_{NOx} = S_{PM2.5}/S_{NOx}$

Sensitivity Runs

- Sensitivity runs were performed to evaluate how PM2.5 offset ratios varied by:
  - Distance from the source
  - Season of the year
  - Stack height
  - Grid resolution
  - Location in the state

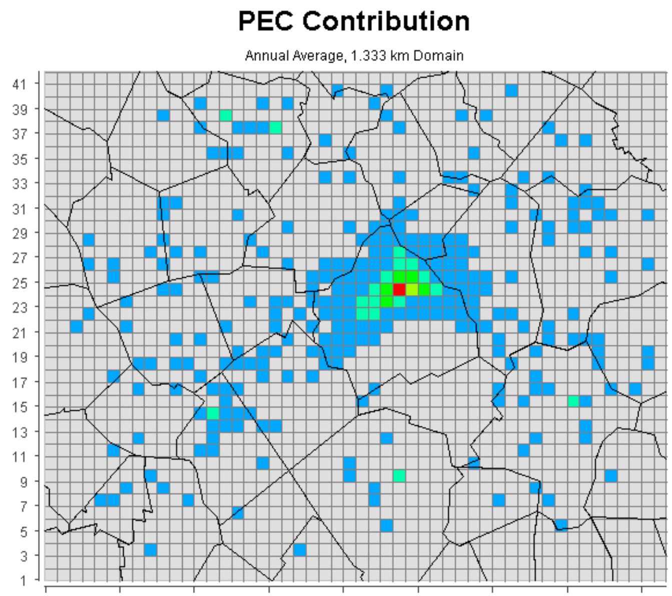
Trading Ratio vs. Distance

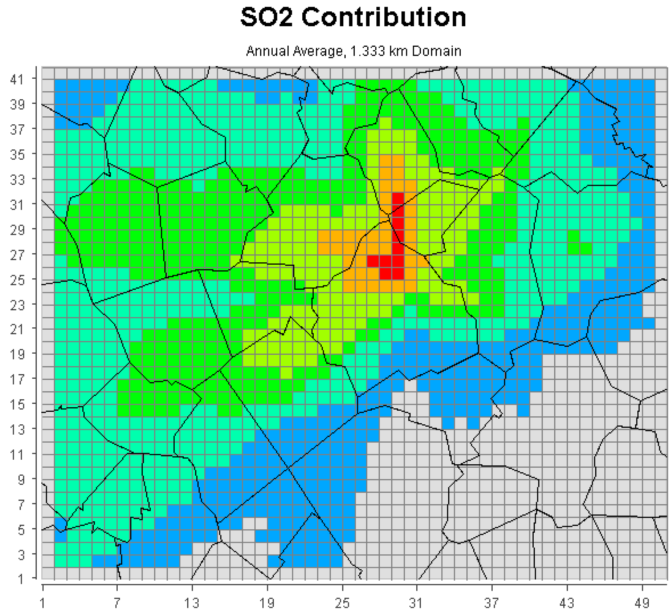
- **OPTION 1:** Average S_{SO2}, S_{NOx}, and $S_{PM2.5}$ for all grid cells at a given distance, <u>then</u> calculate the average trading ratios (R_{SO2} and R_{NOx})
- **OPTION 2:** Calculate trading ratios (R_{SO2} and R_{NOx}) for each individual grid cell, <u>then</u> average for all grid cells at a given distance
  - A single cell with small $\Delta PM2.5_{SO2}$ or small $\Delta PM2.5_{NOx}$ can bias the results
- **GA EPD picked <u>OPTION 1</u>**

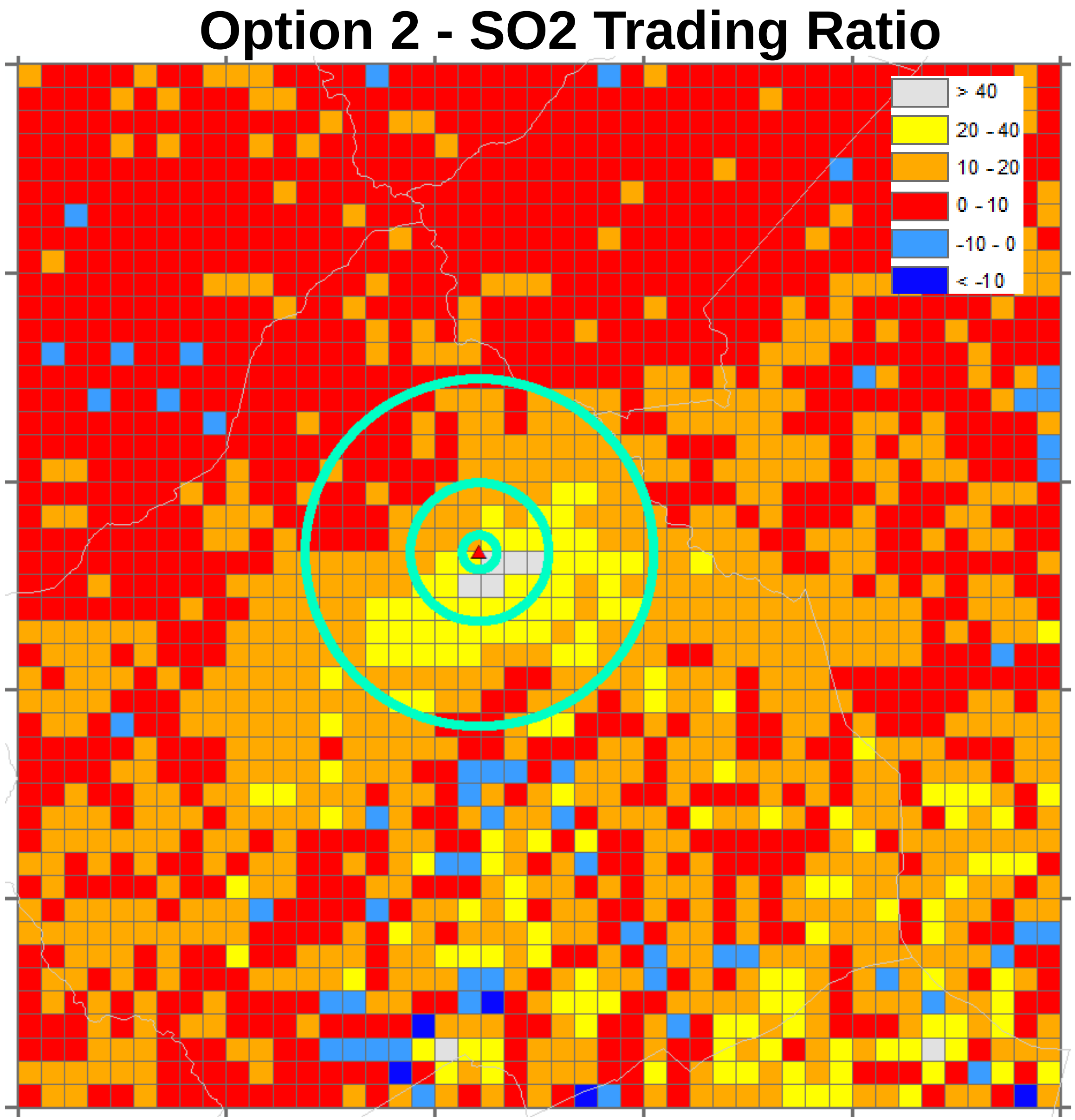
Binned Offset Ratios

- For each precursor (SO2 and NOx) and each season (spring, summer, fall, winter), average S_{SO2}, S_{NOx}, and $S_{PM2.5}$ for all grid cells at a given distance, <u>then</u> calculate the average trading ratios (R_{SO2} and R_{NOx}) for that distance
- Place trading ratios into bins and use the lowest ratio in the bin
  - <1 km, 1-4 km, 4-10 km, >10 km

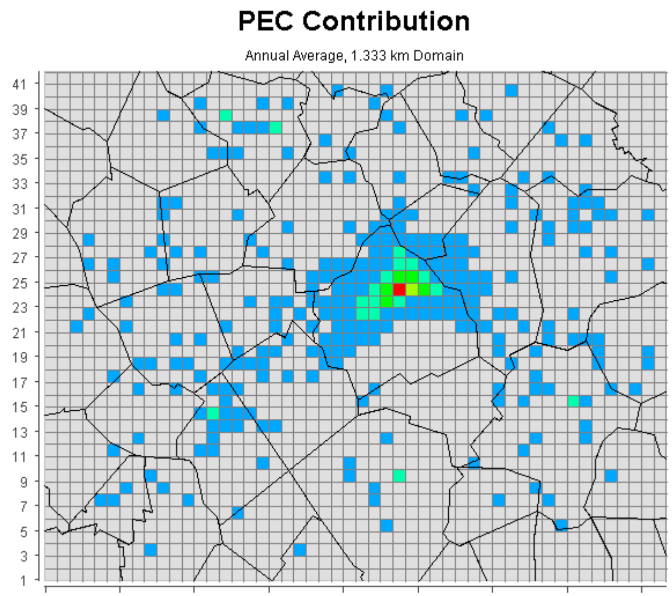
Δ PM2.5 – Annual EC and SO2

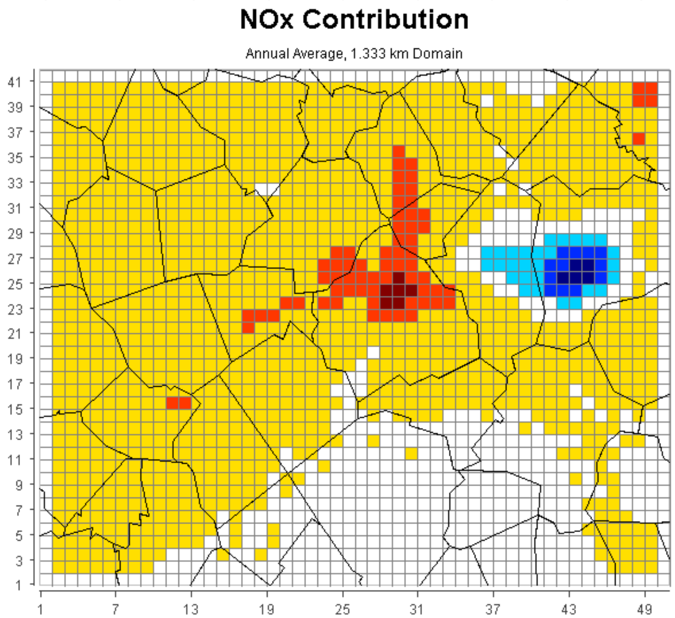


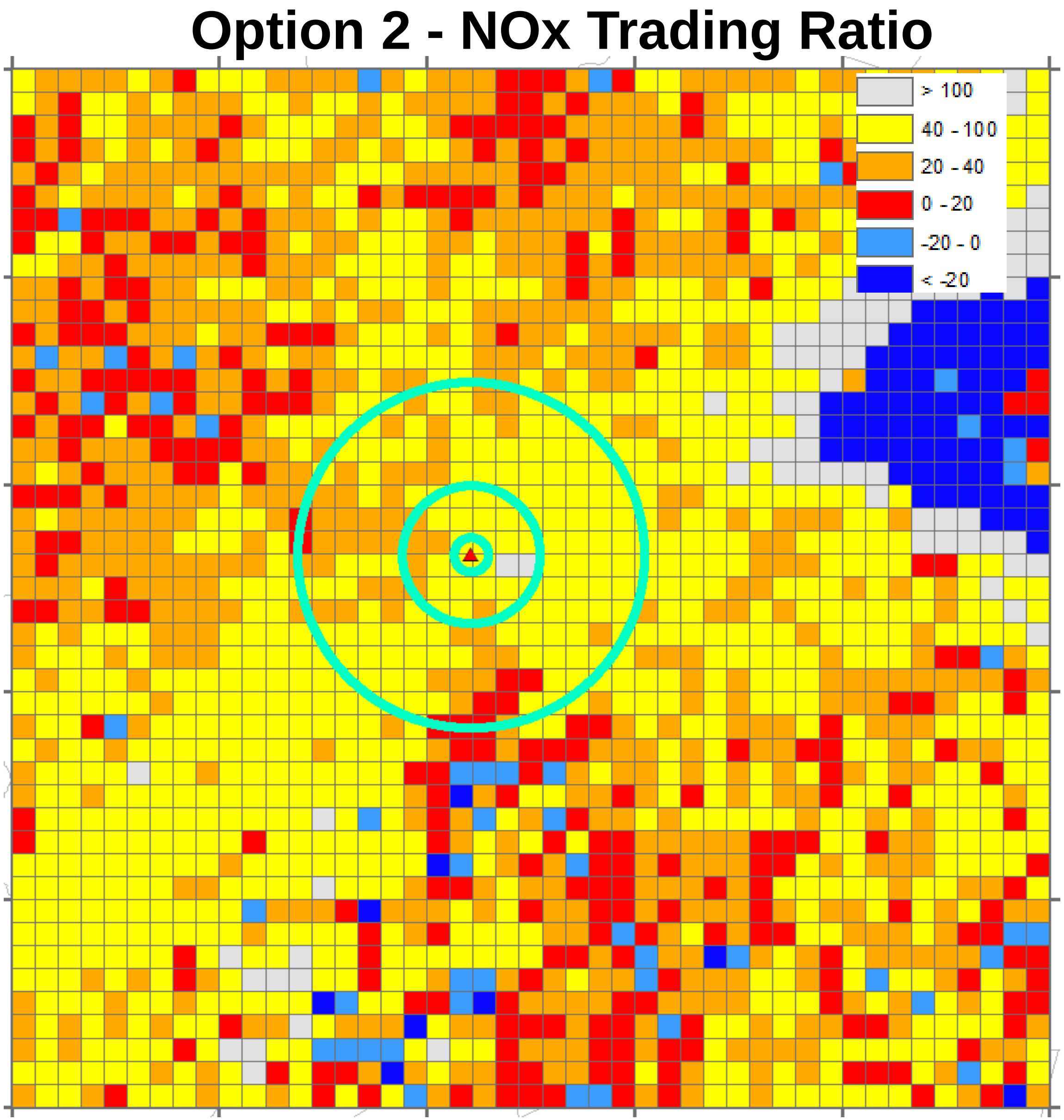




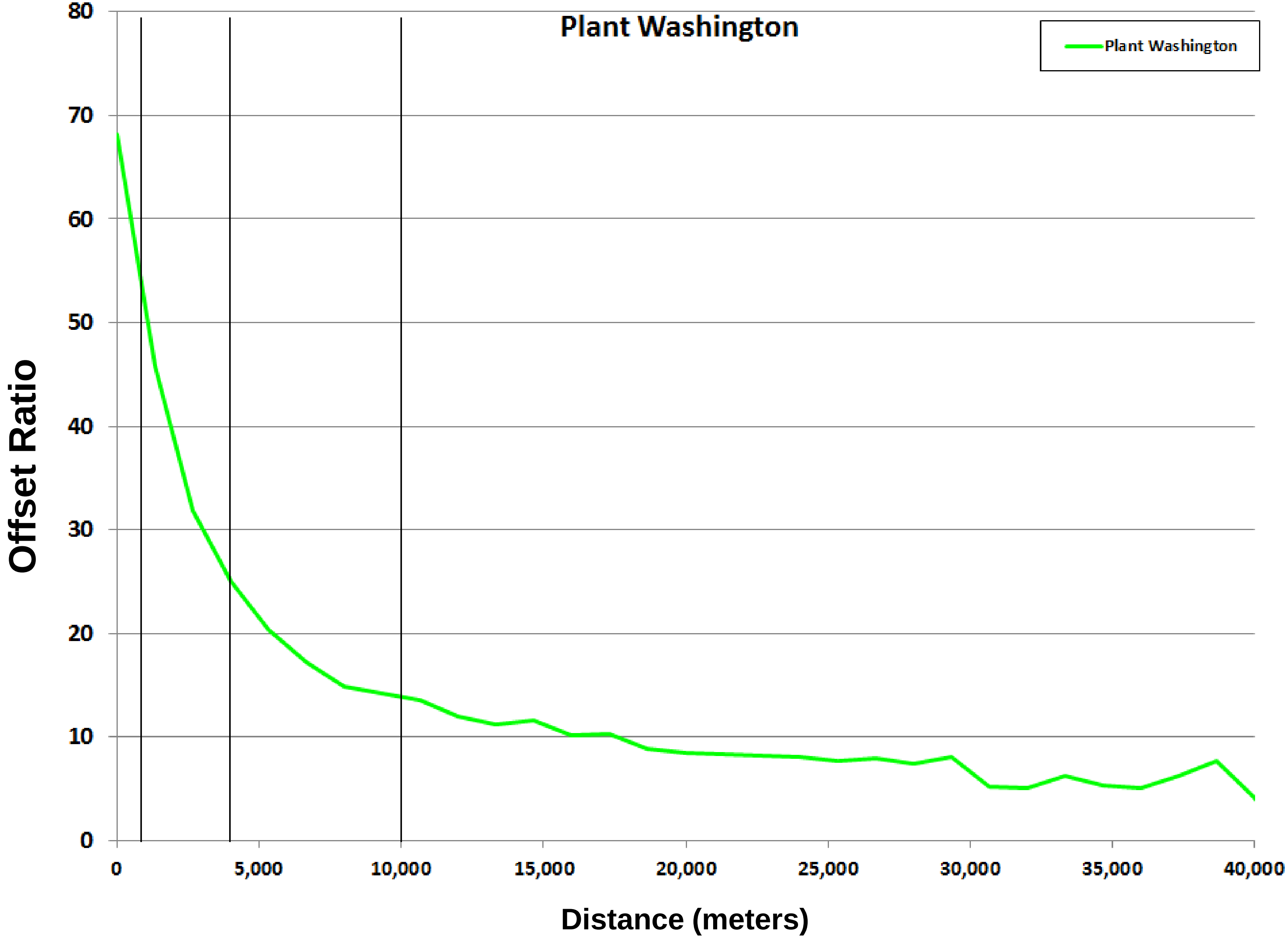
Δ PM2.5 – Annual EC and NOx



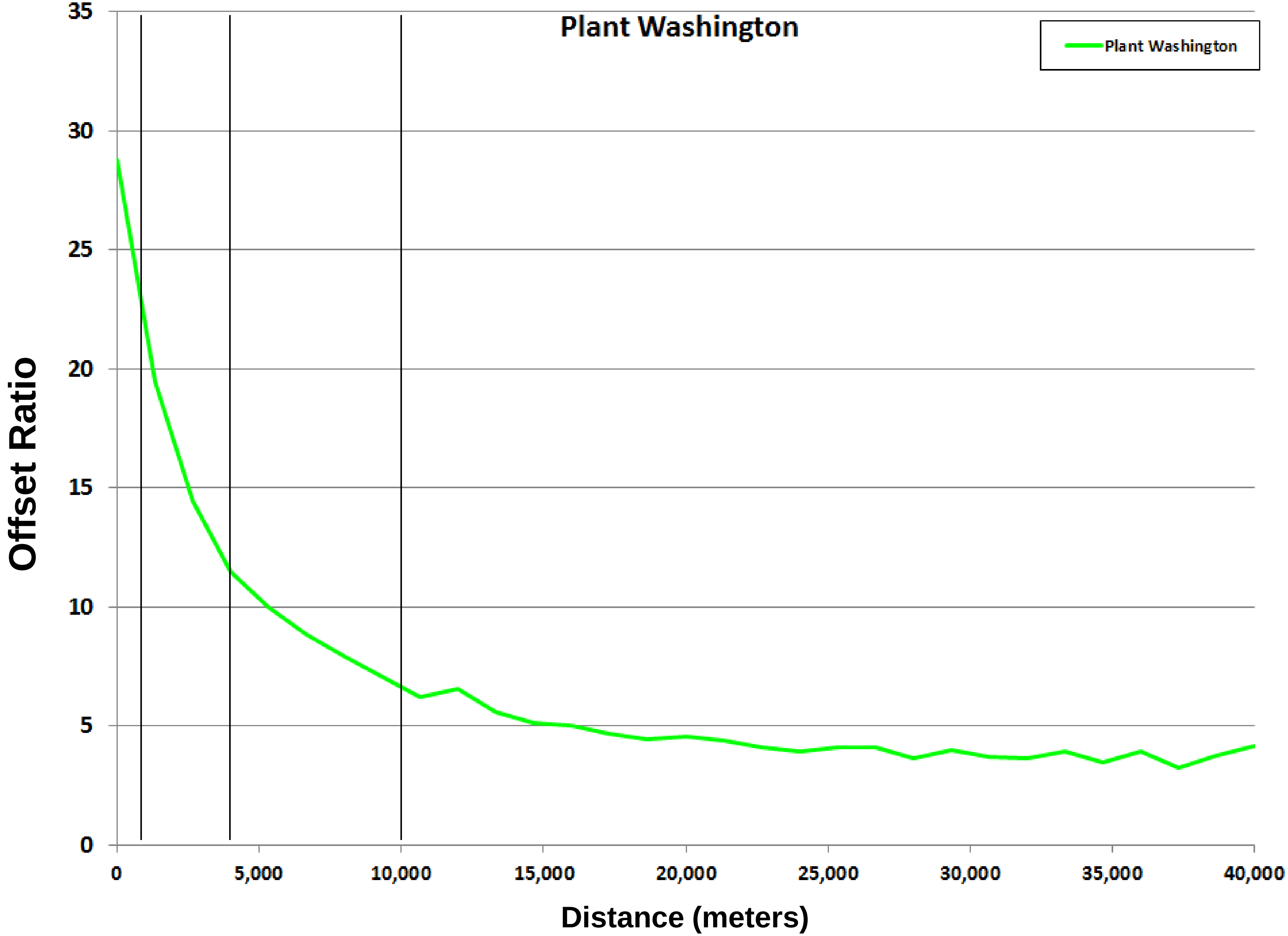




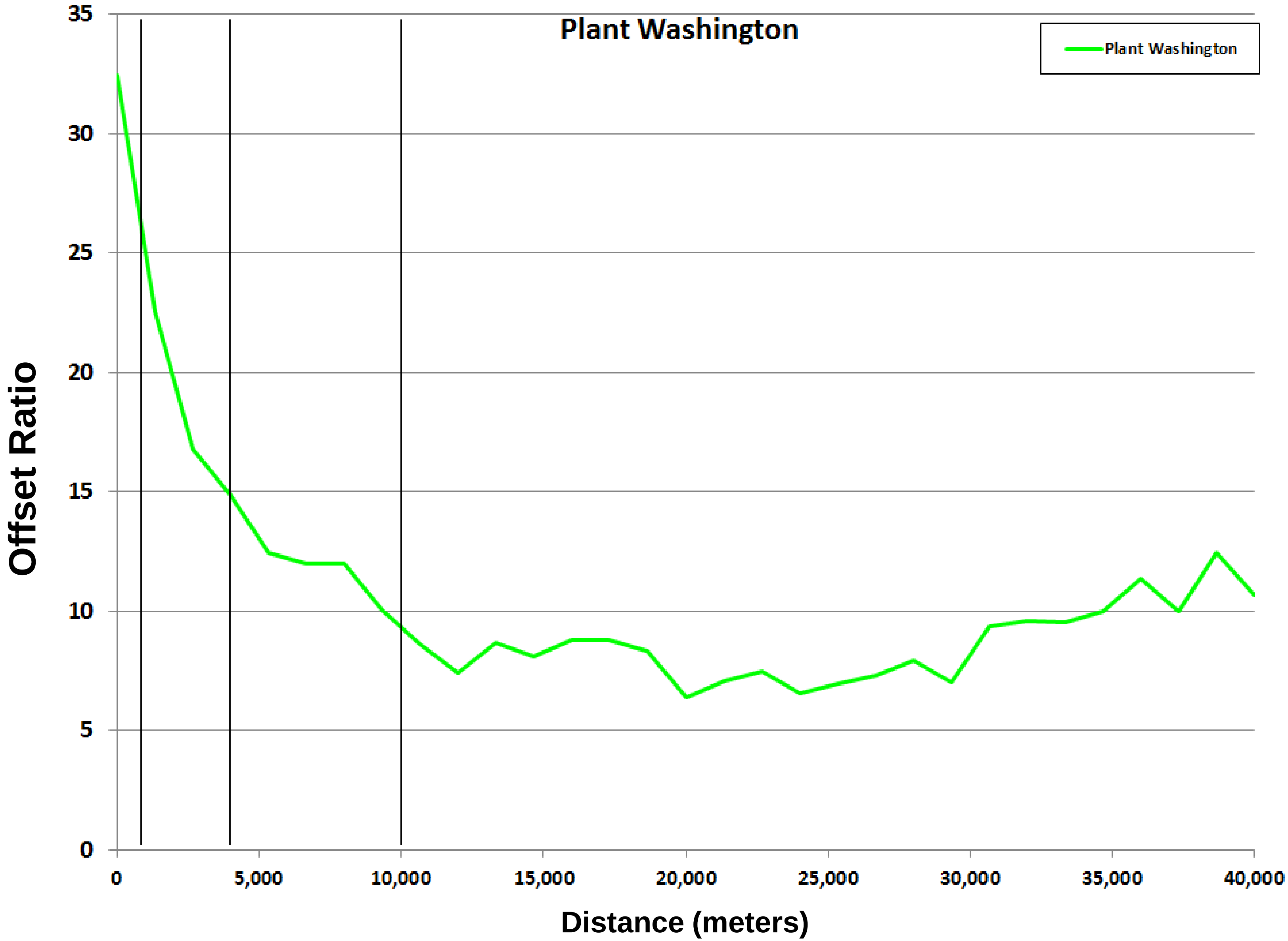
Spring SO_2 Offset Ratios



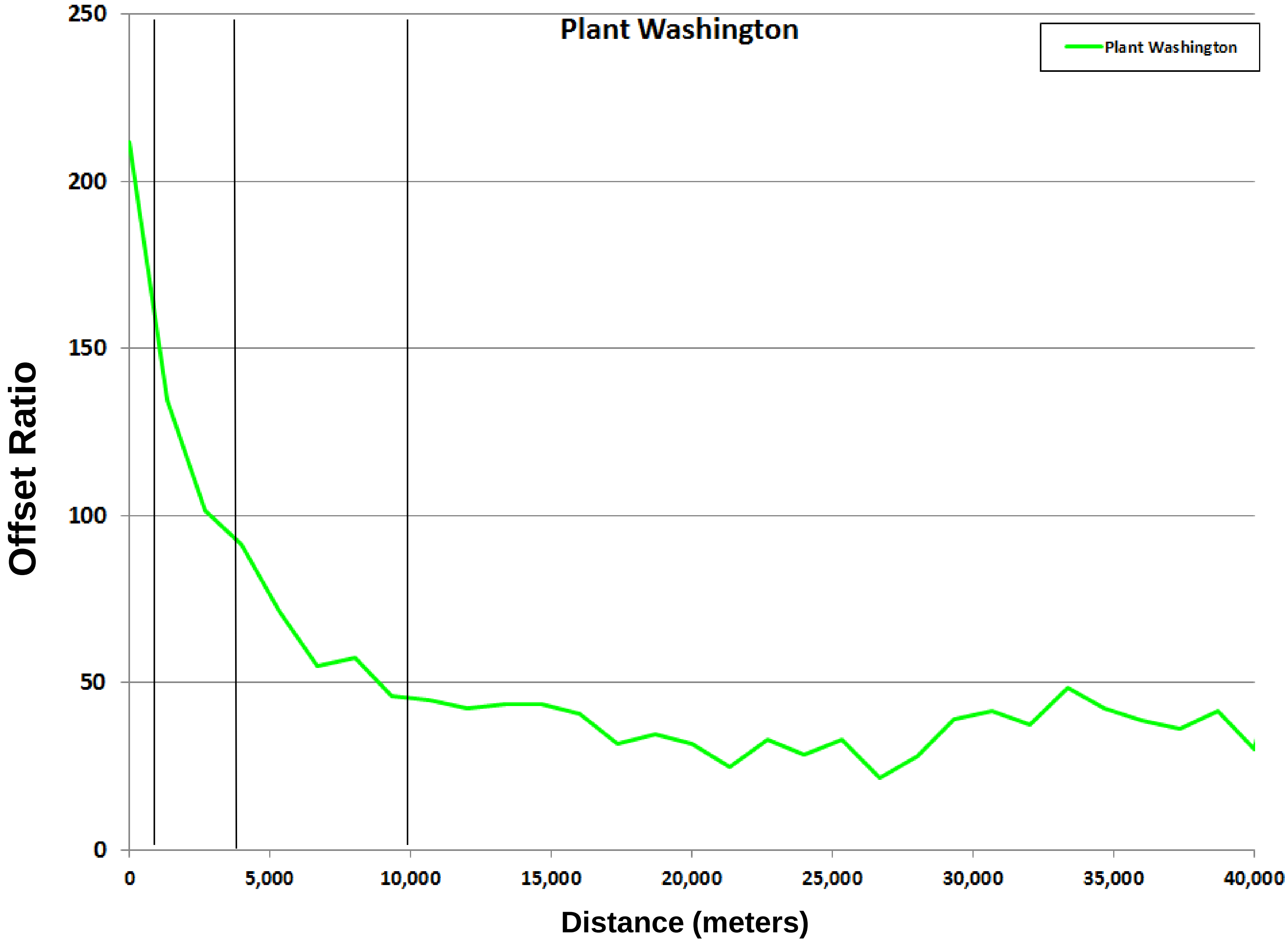
Summer SO_2 Offset Ratios



Fall SO_2 Offset Ratios

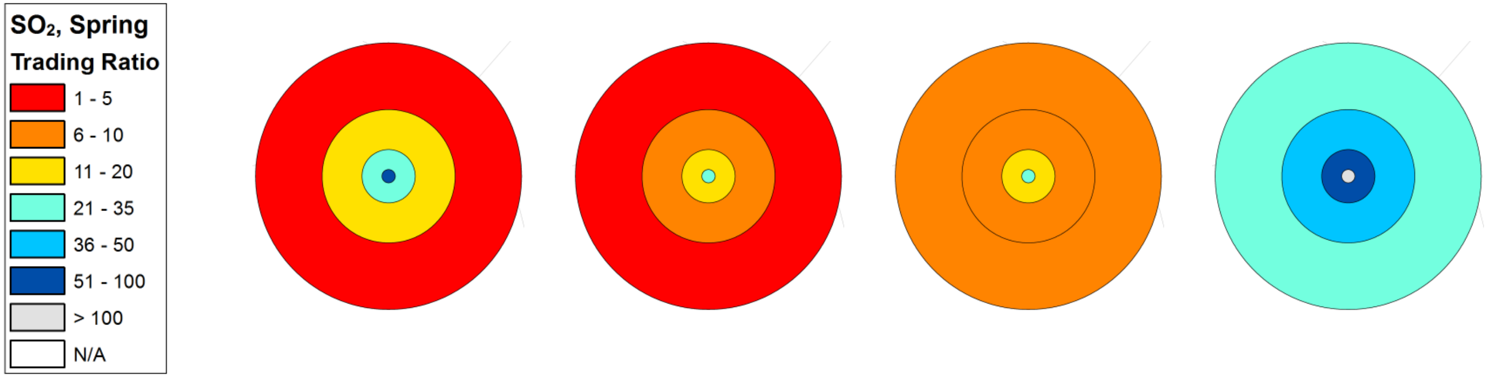


Winter SO_2 Offset Ratios



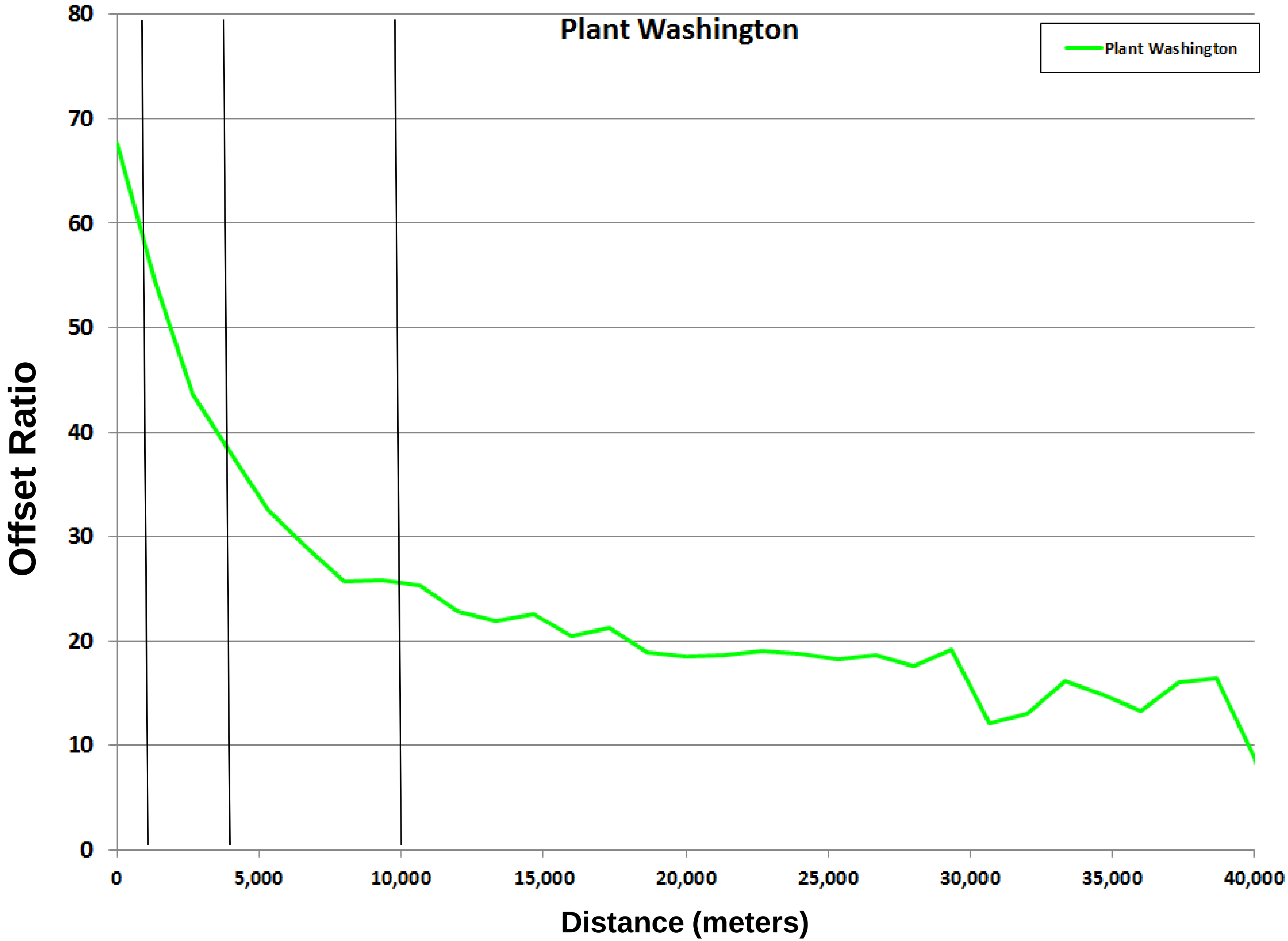
Binned SO2 Offset Ratios

Distance	Spring	Summer	Fall	Winter
< 1 km	51:1	22:1	25:1	154:1
1 – 4 km	25:1	11:1	15:1	91:1
4 – 10 km	13:1	7:1	9:1	45:1
> 10 km	5:1	4:1	7:1	25:1

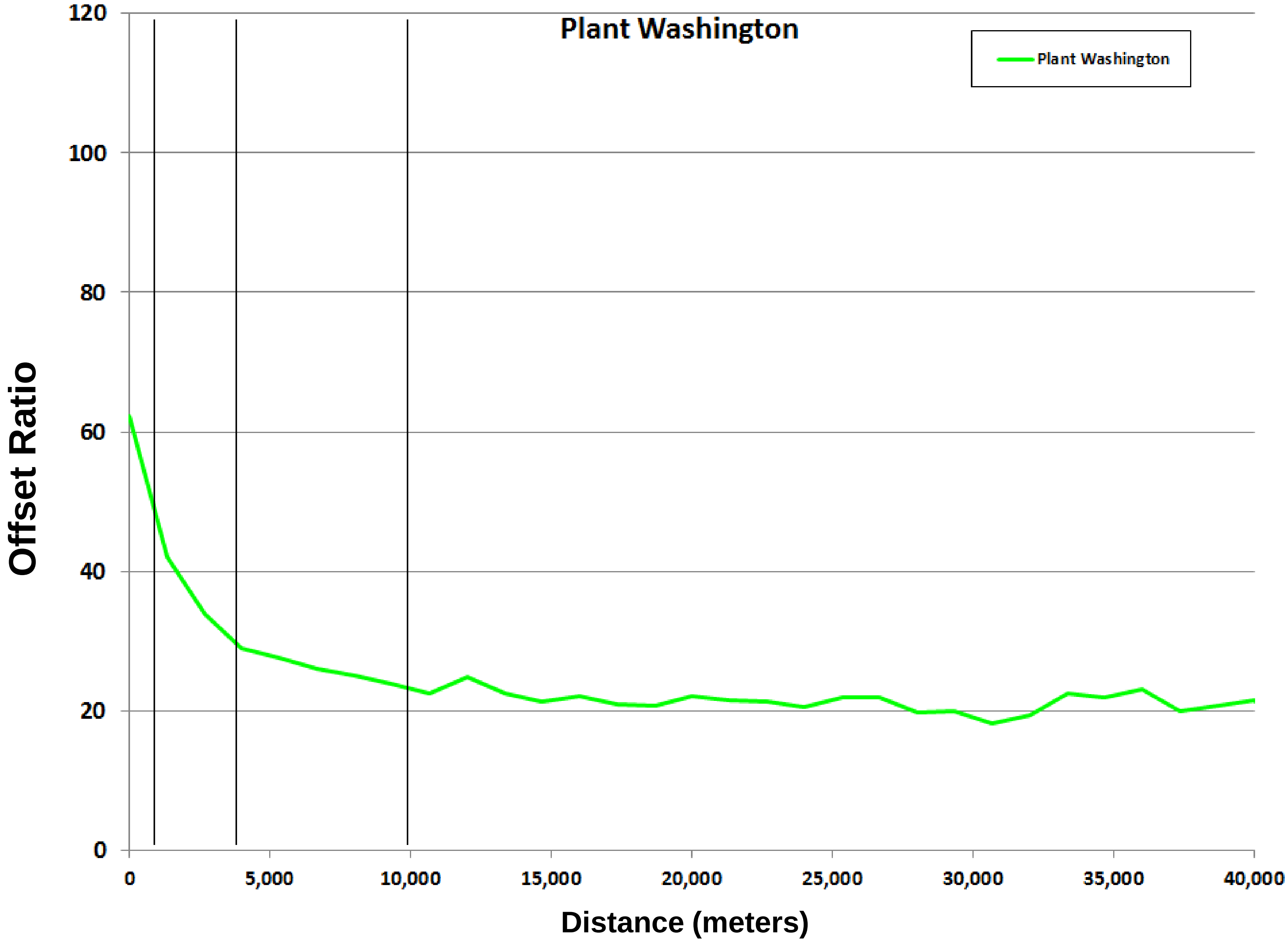


"Donut" plots are binned by distance and offset ratio

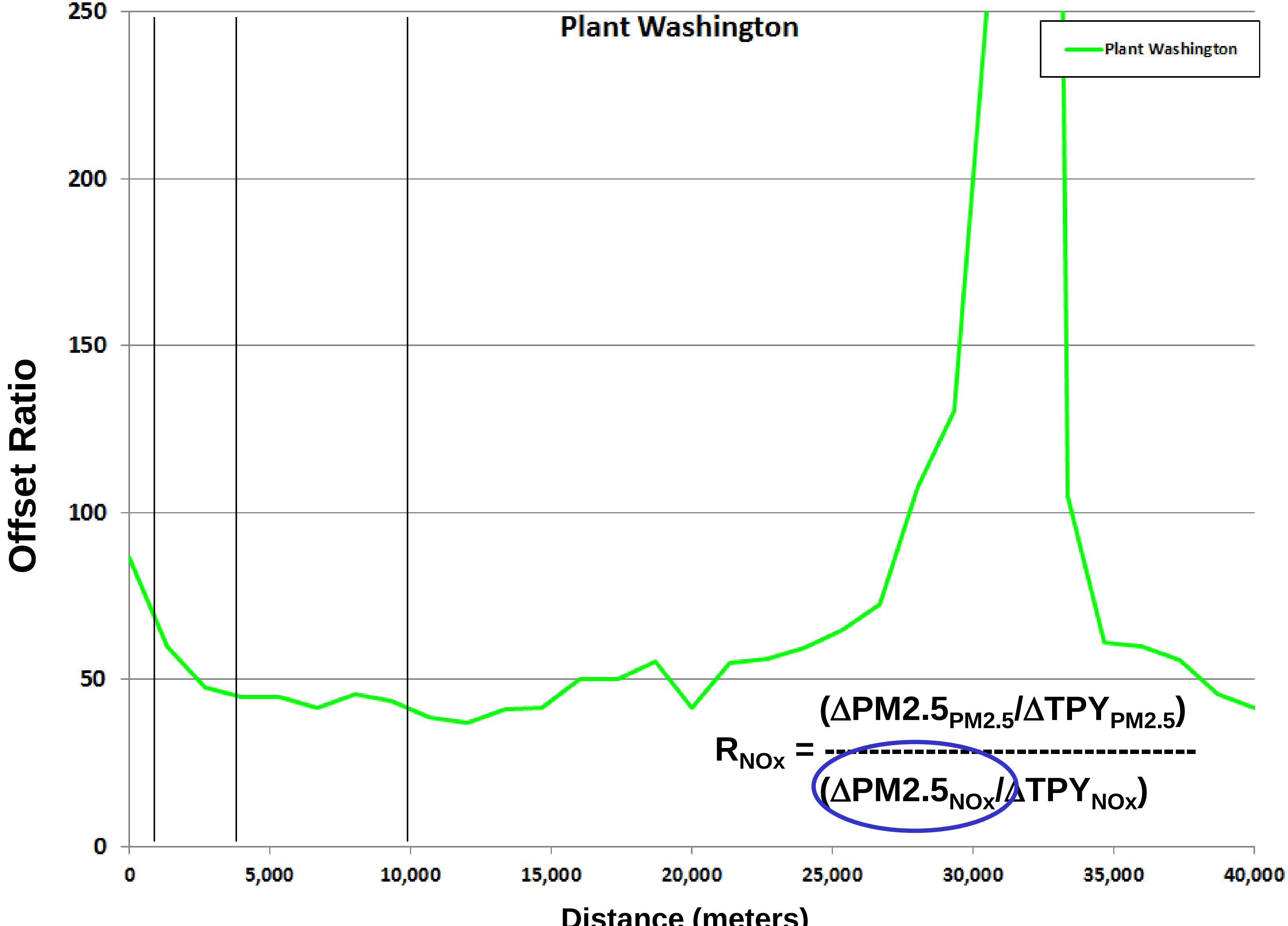
Spring NOx Offset Ratios



Summer NOx Offset Ratios

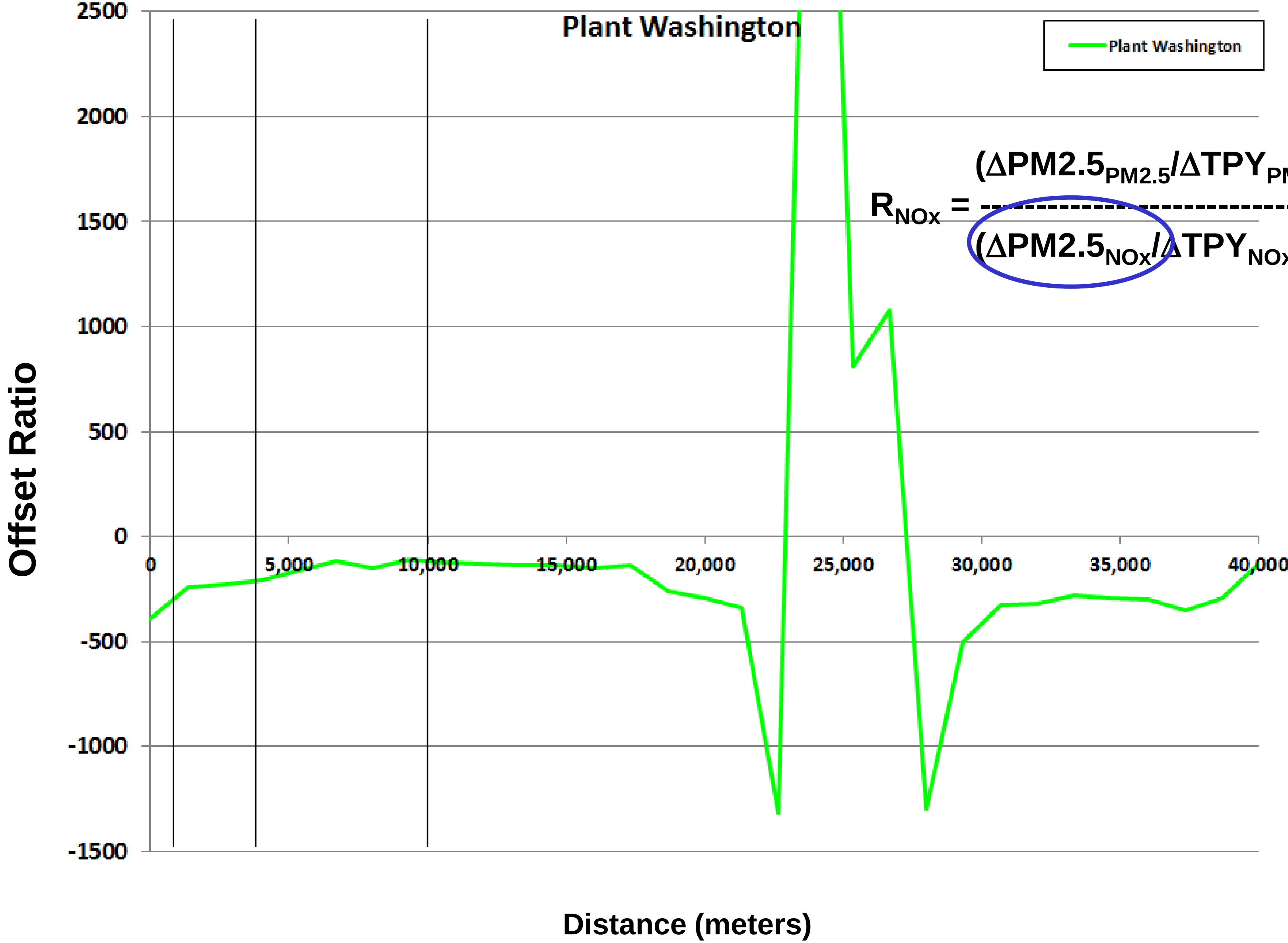


Fall NOx Offset Ratios



$$R_{NOx} = \frac{(\Delta PM2.5_{PM2.5}/\Delta TPY_{PM2.5})}{(\Delta PM2.5_{NOx}/\Delta TPY_{NOx})}$$

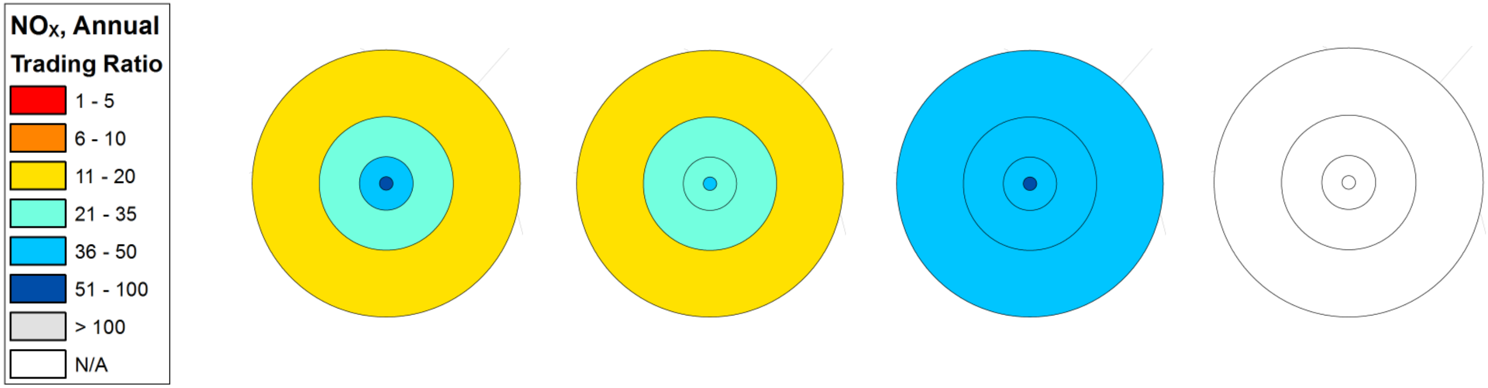
Winter NOx Offset Ratios



$$R_{NOx} = \frac{(\Delta PM2.5_{PM2.5}/\Delta TPY_{PM2.5})}{(\Delta PM2.5_{NOx}/\Delta TPY_{NOx})}$$

Binned NOx Offset Ratios

Distance	Spring	Summer	Fall	Winter
< 1 km	58:1	47:1	67:1	N/A
1 – 4 km	38:1	29:1	45:1	N/A
4 – 10 km	26:1	23:1	41:1	N/A
> 10 km	15:1	20:1	37:1	N/A



Impact of Stack Height

- Stack height has a small impact on the SO_2 offset ratios.
- Stack height has a bigger impact on NO_x offset ratios.
- Shorter stacks have higher offset ratios (less $PM_{2.5}$ formation), so using the lower offset ratios is conservative.
- Taller stacks will be limited by GEP Stack Height Regulations, so we will not need to adjust the ratios.

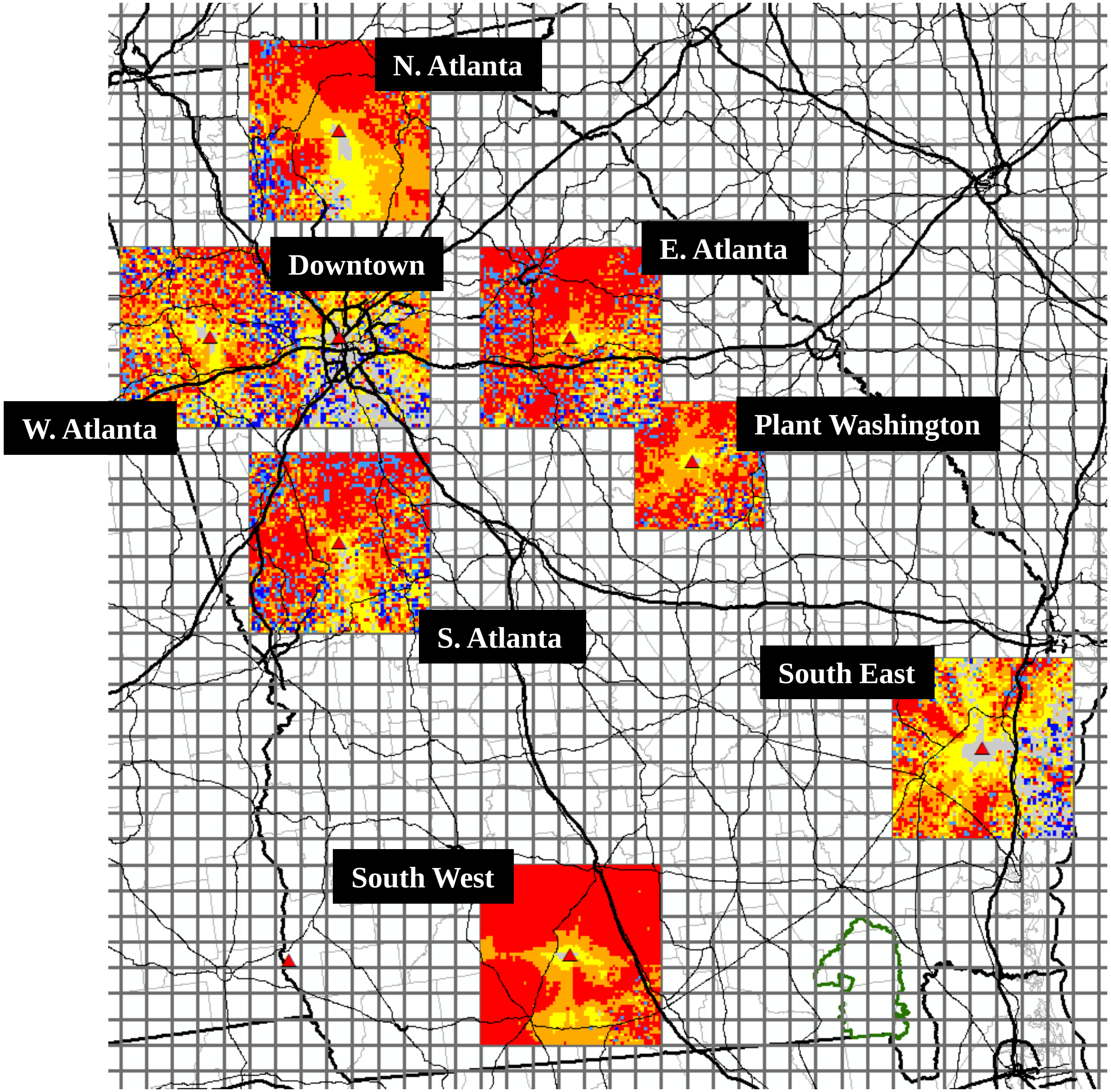
Impacts of Grid Resolution

- Larger grid resolutions (e.g., 12 km) produce more conservative SO_2 and NO_x offset ratios (lower ratios) compared to smaller grid resolutions (e.g., 1.3 km) <u>near</u> the source.
- Larger grid resolutions produce similar SO_2 and NO_x offset ratios compared to smaller grid resolutions <u>far</u> from the source.
- Creating SO_2 and NO_x offset ratios using larger grid cells is a conservative approach.

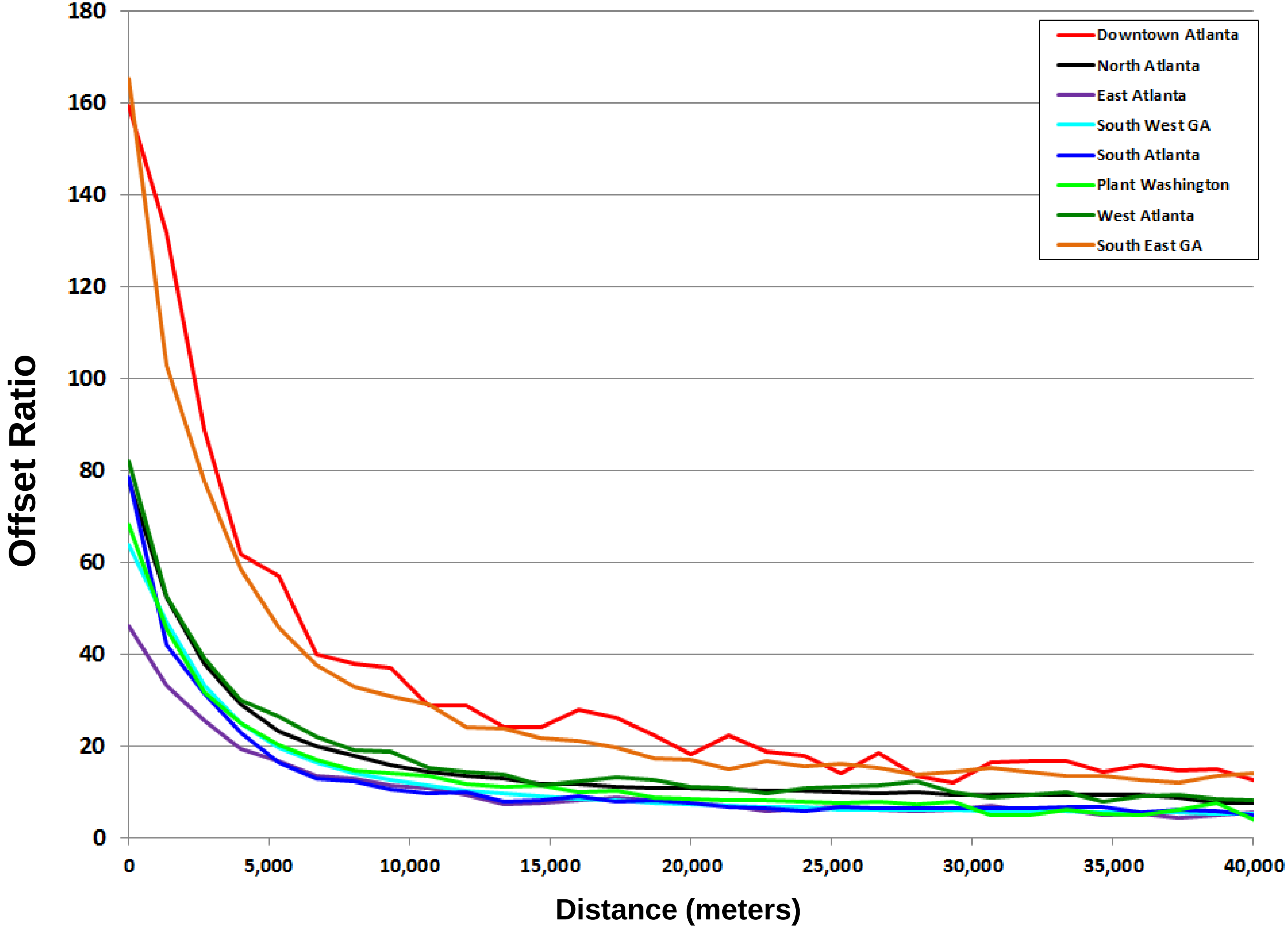
Impact of Location

- Developed PM2.5 offset ratios for eight different locations in Georgia
- Need to assign specific PM2.5 offset ratios to each county in Georgia based on distance from the eight locations.

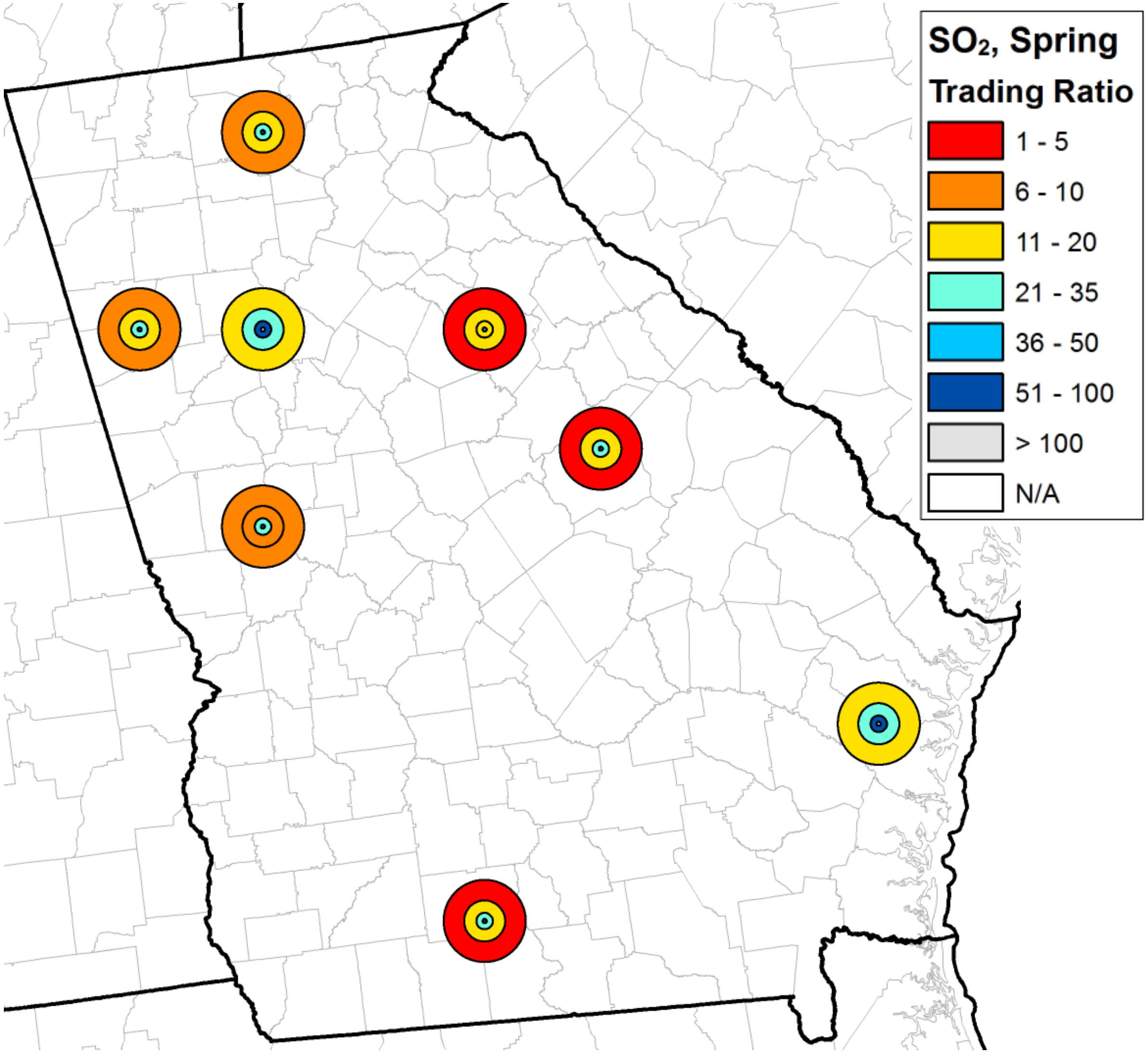
Modeling Domains



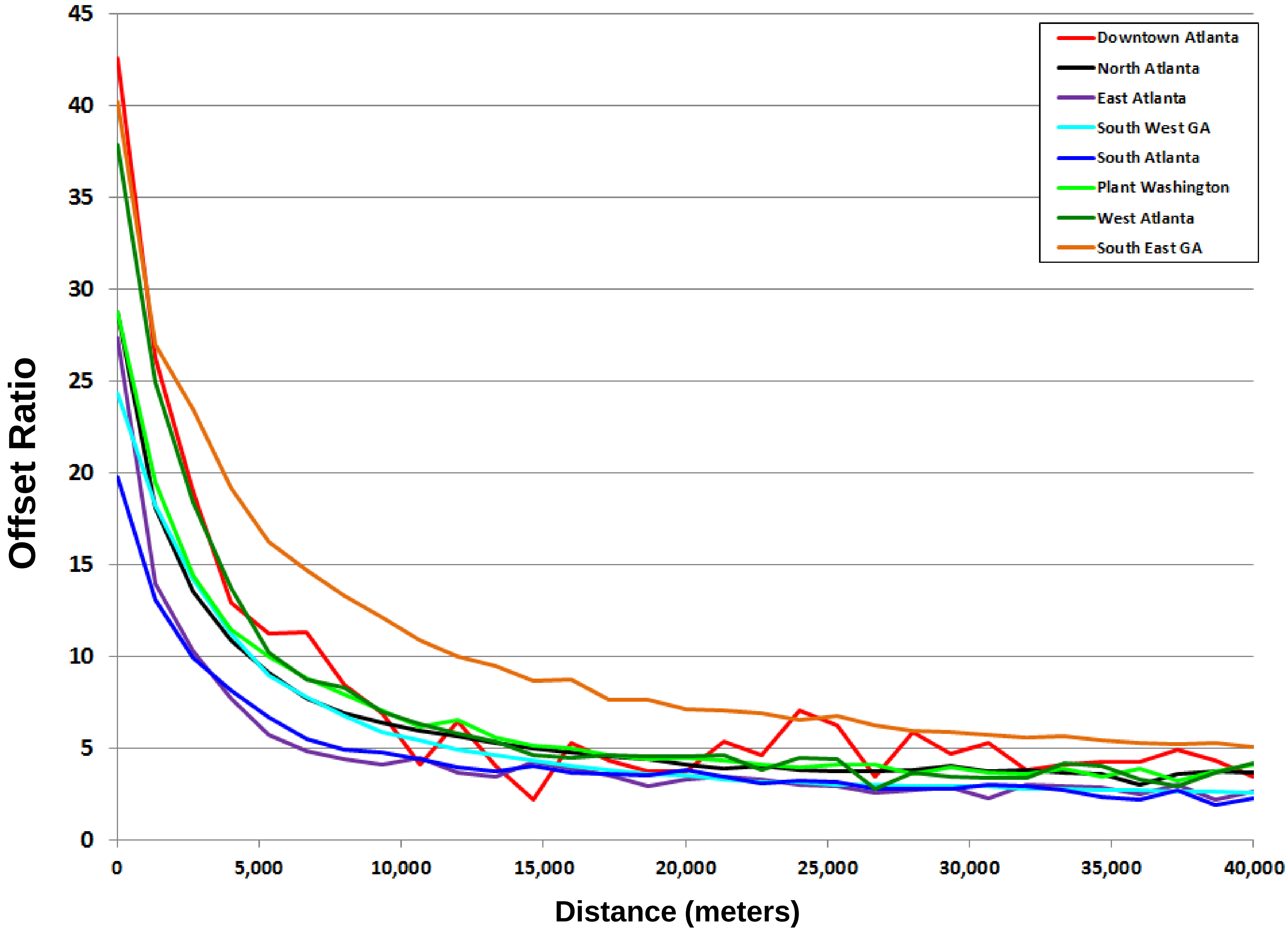
Spring SO_2 Offset Ratios



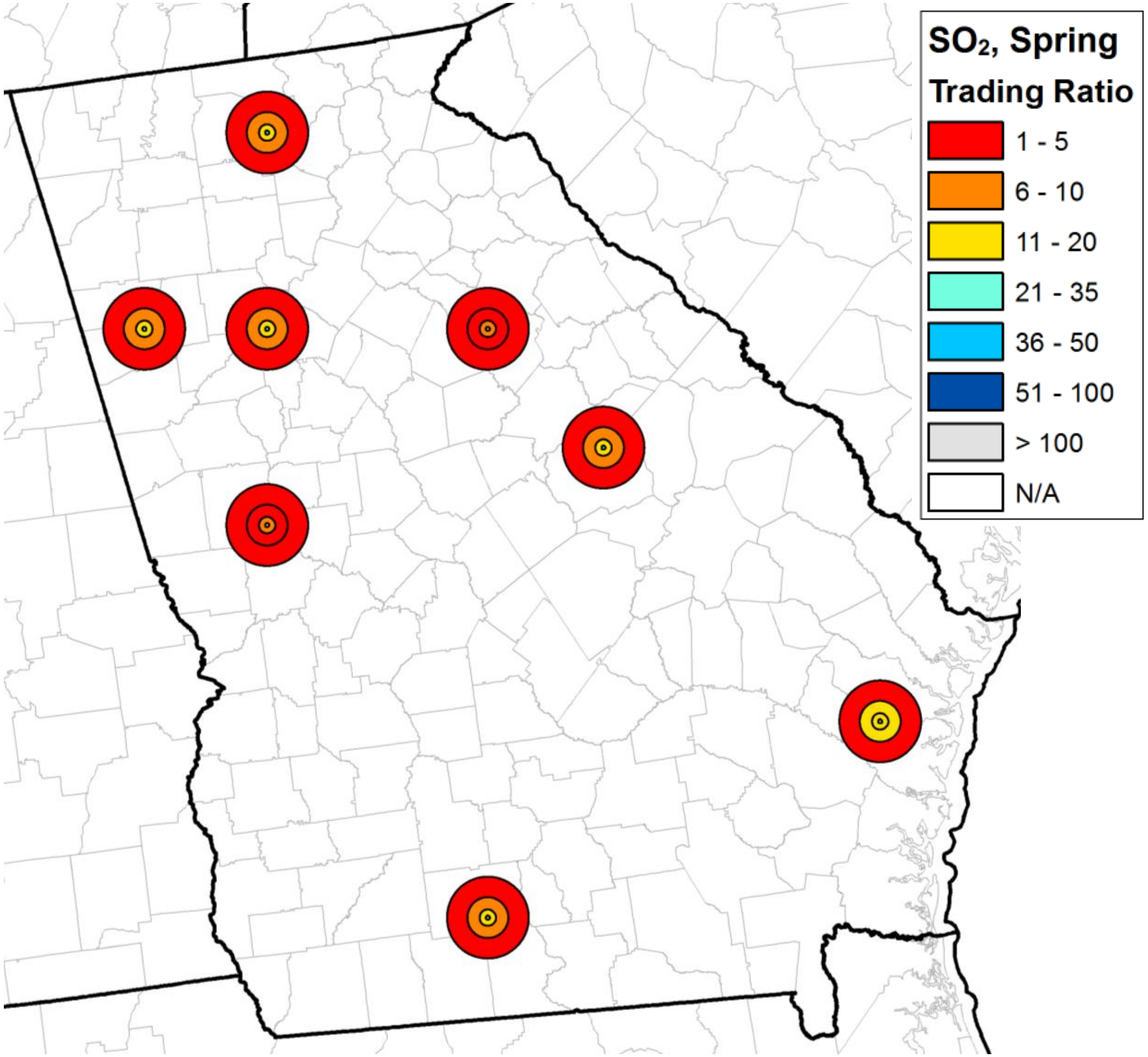
Spring SO_2 Ratios



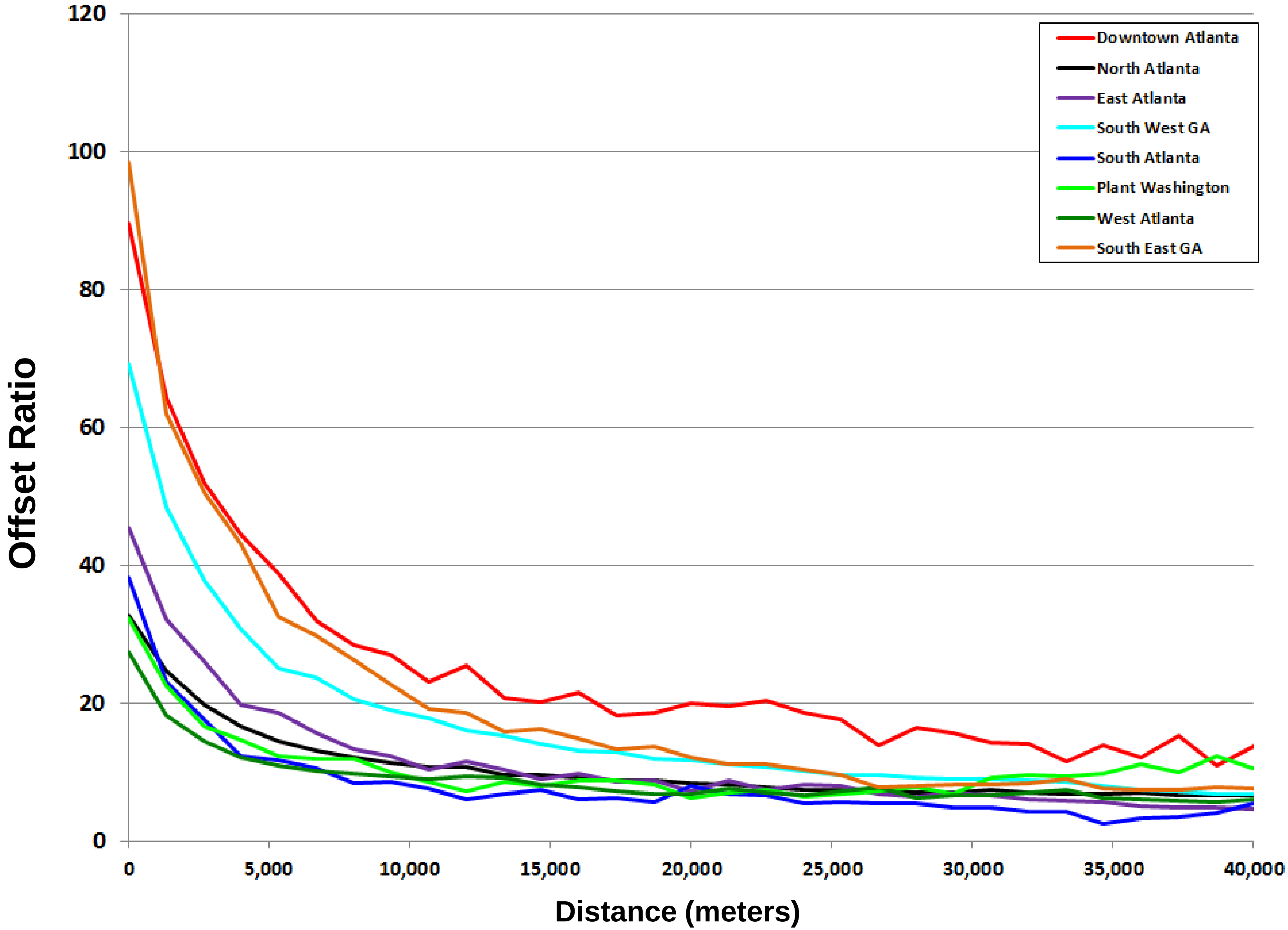
Summer SO_2 Offset Ratios



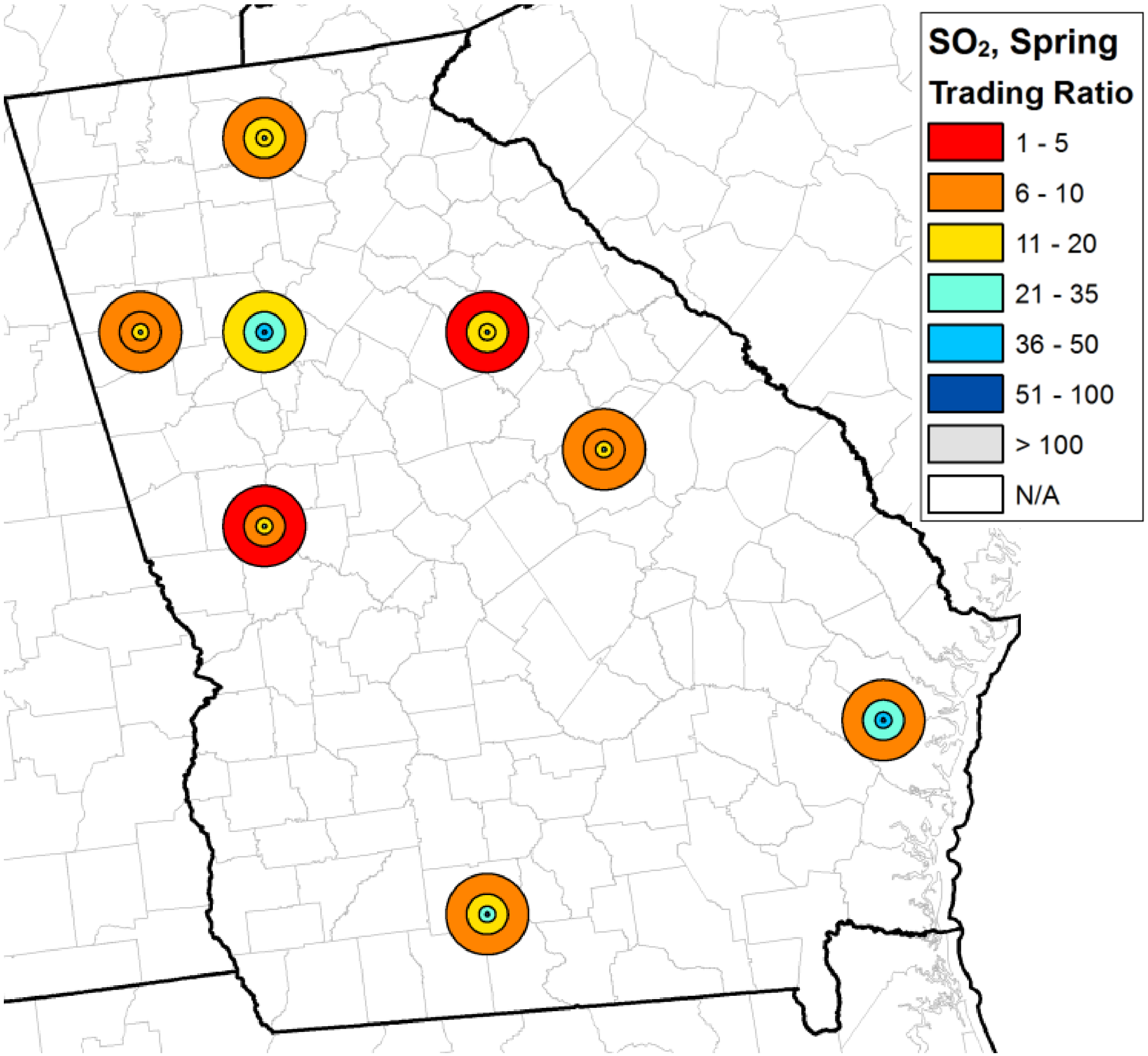
Summer SO_2 Ratios



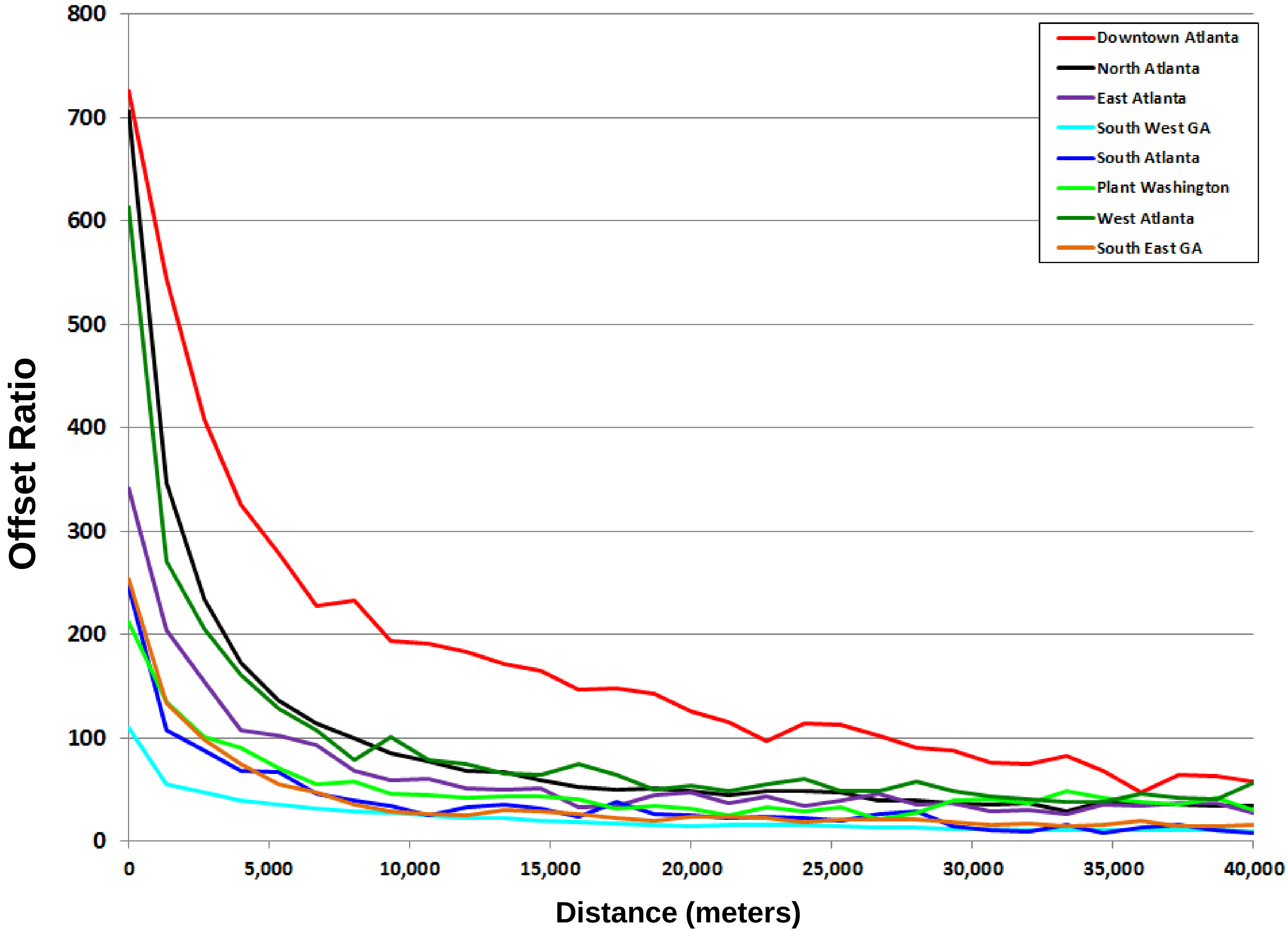
Fall SO_2 Offset Ratios



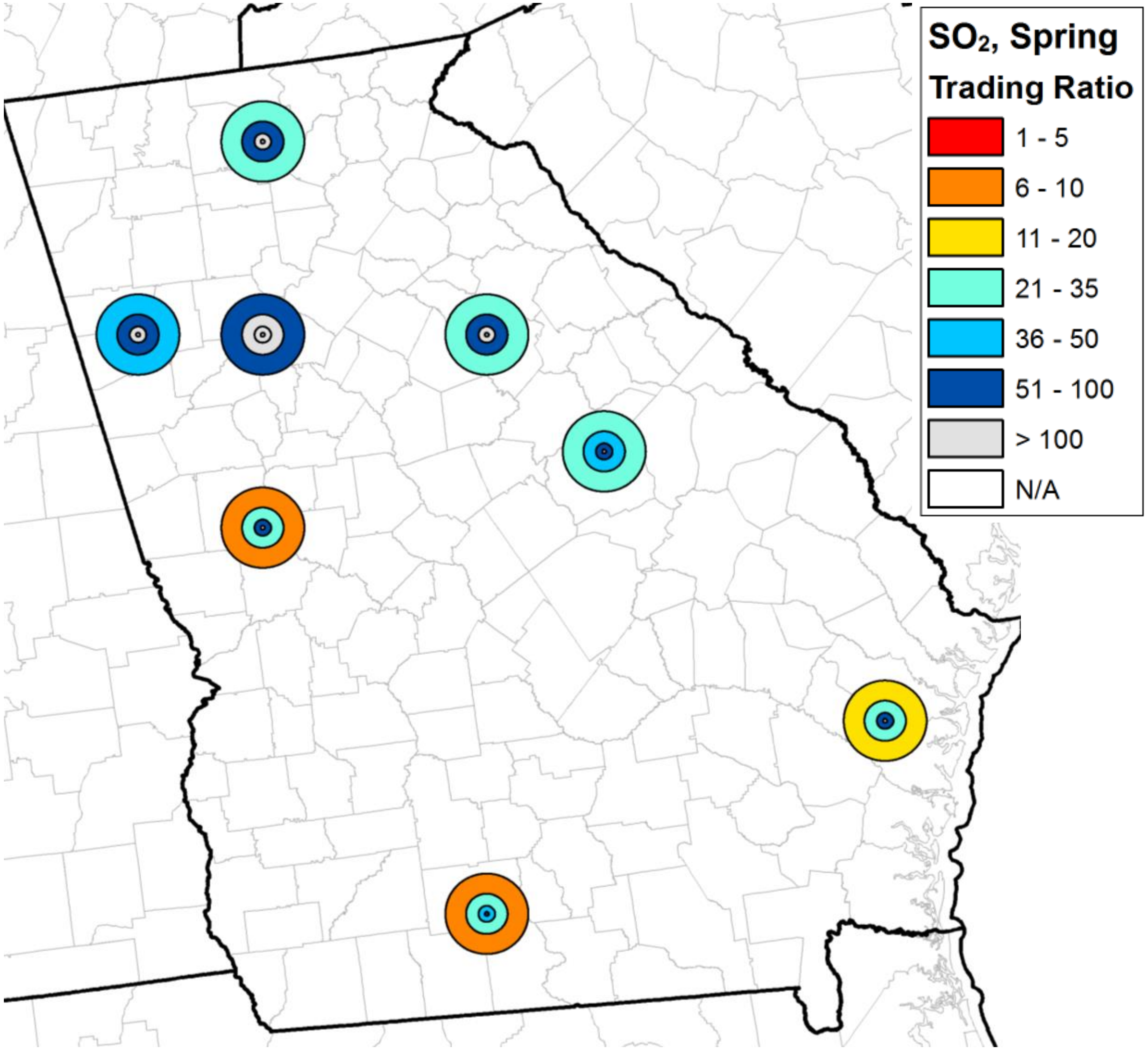
Fall SO_2 Ratios



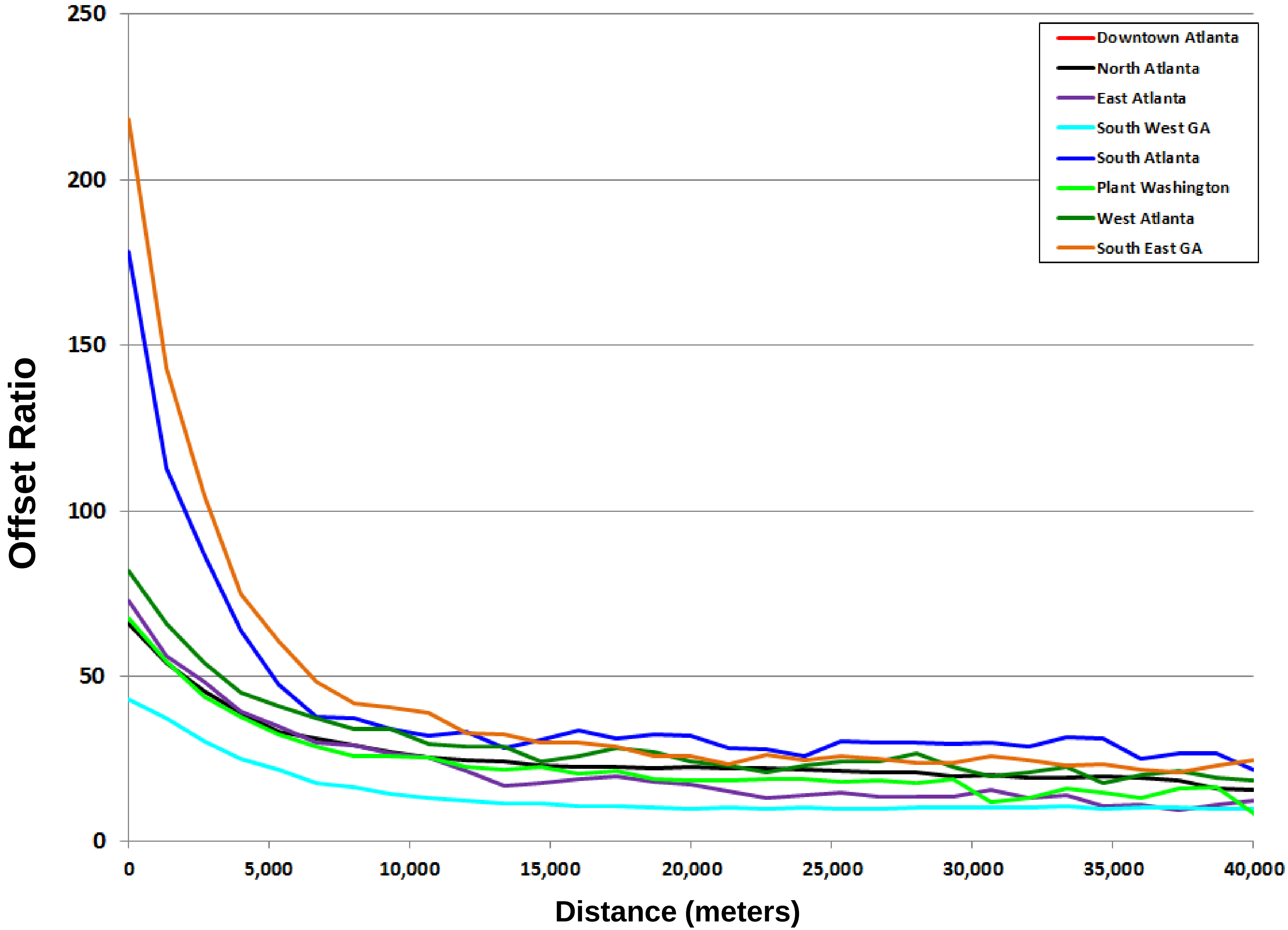
Winter SO_2 Offset Ratios



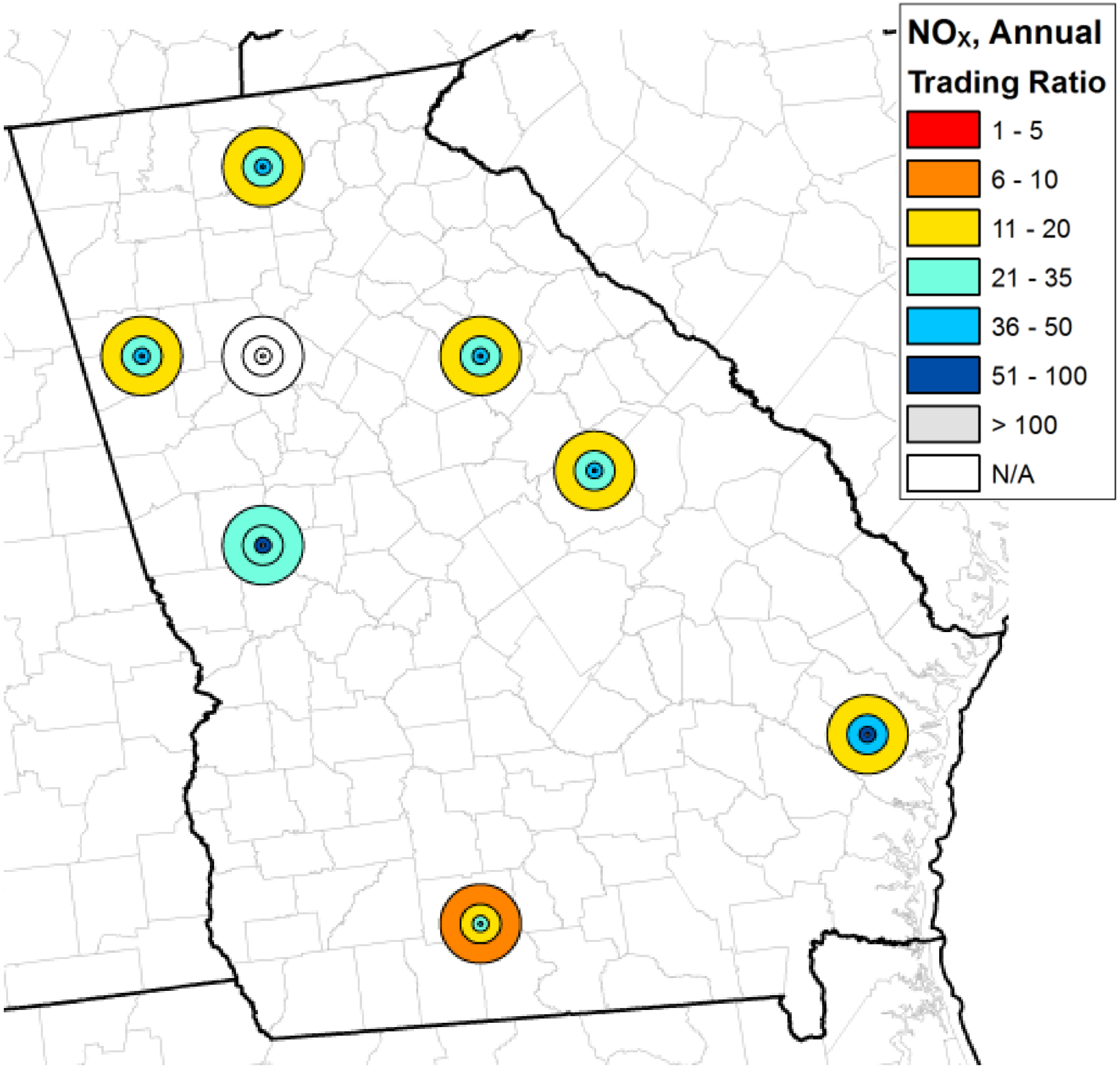
Winter SO_2 Ratios



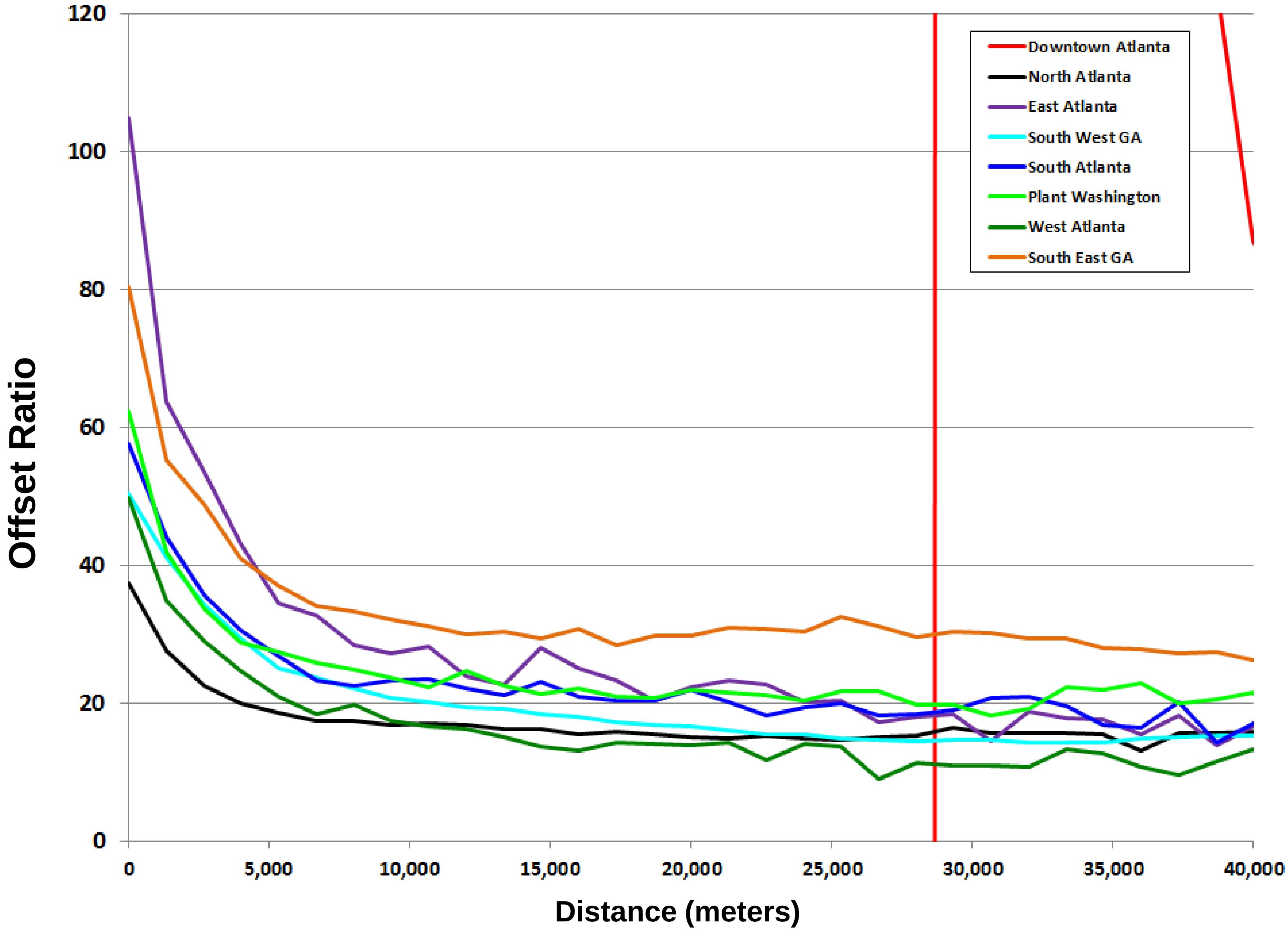
Spring NOx Offset Ratios



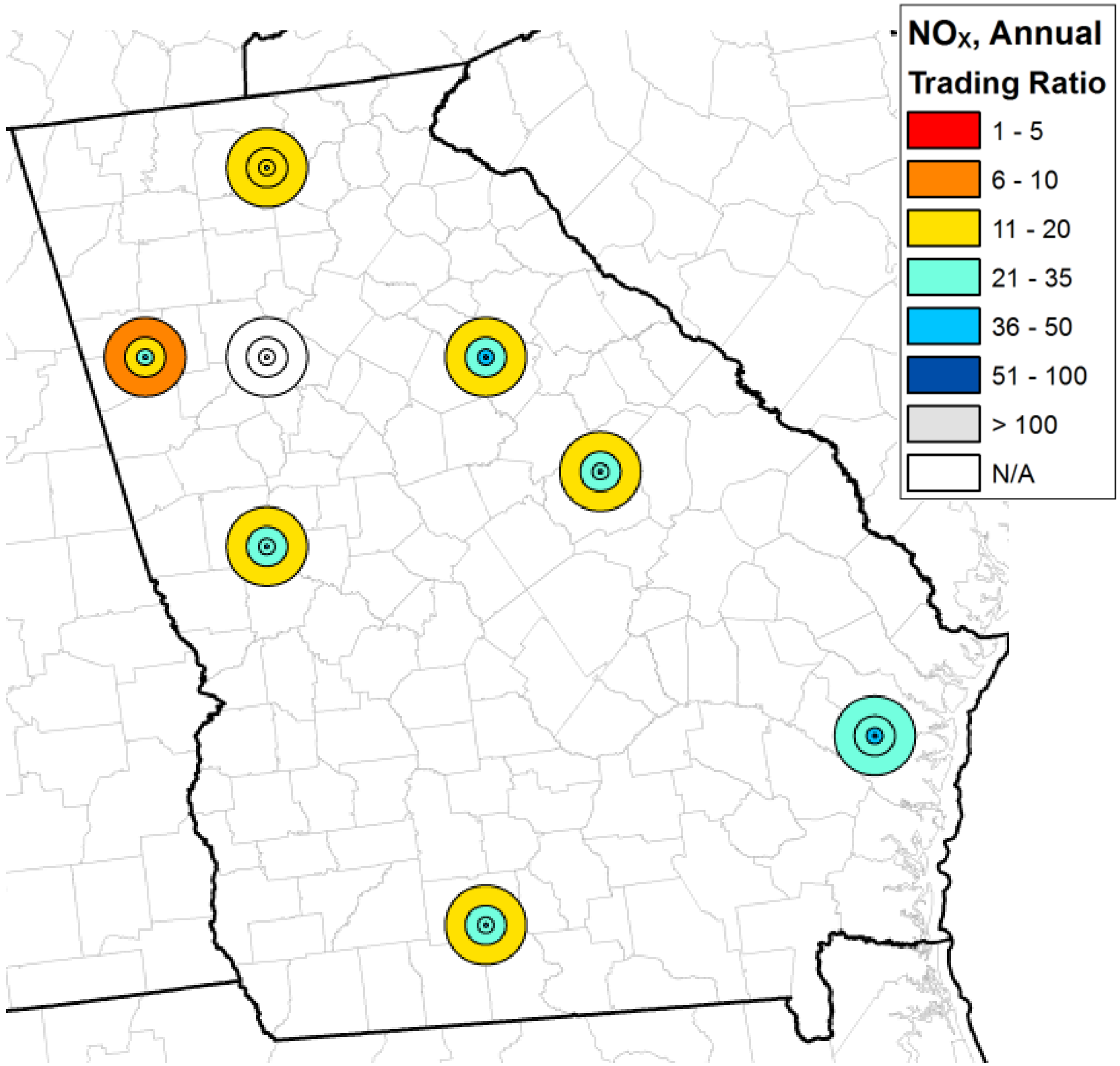
Spring NOx Ratios



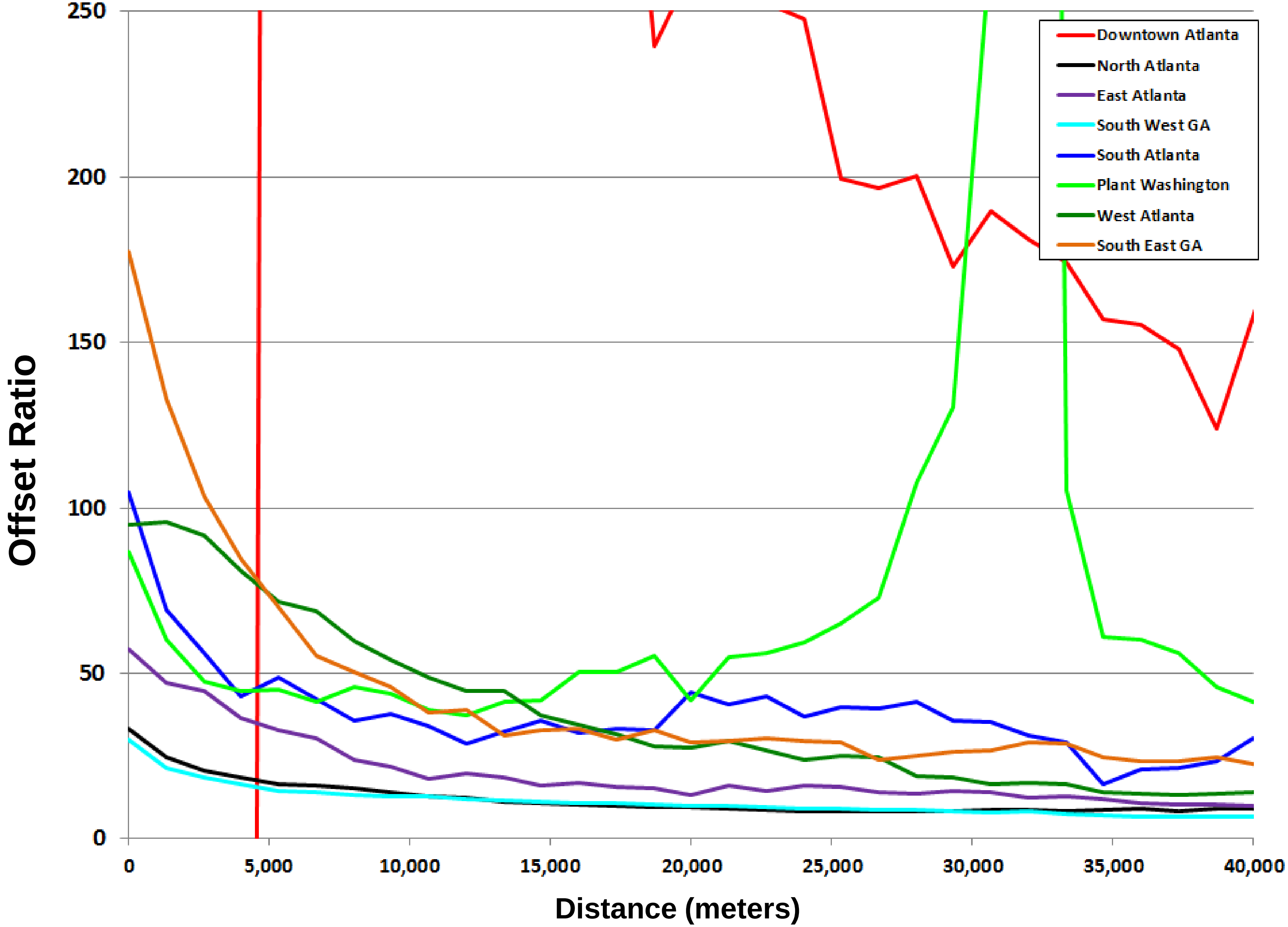
Summer NOx Offset Ratios



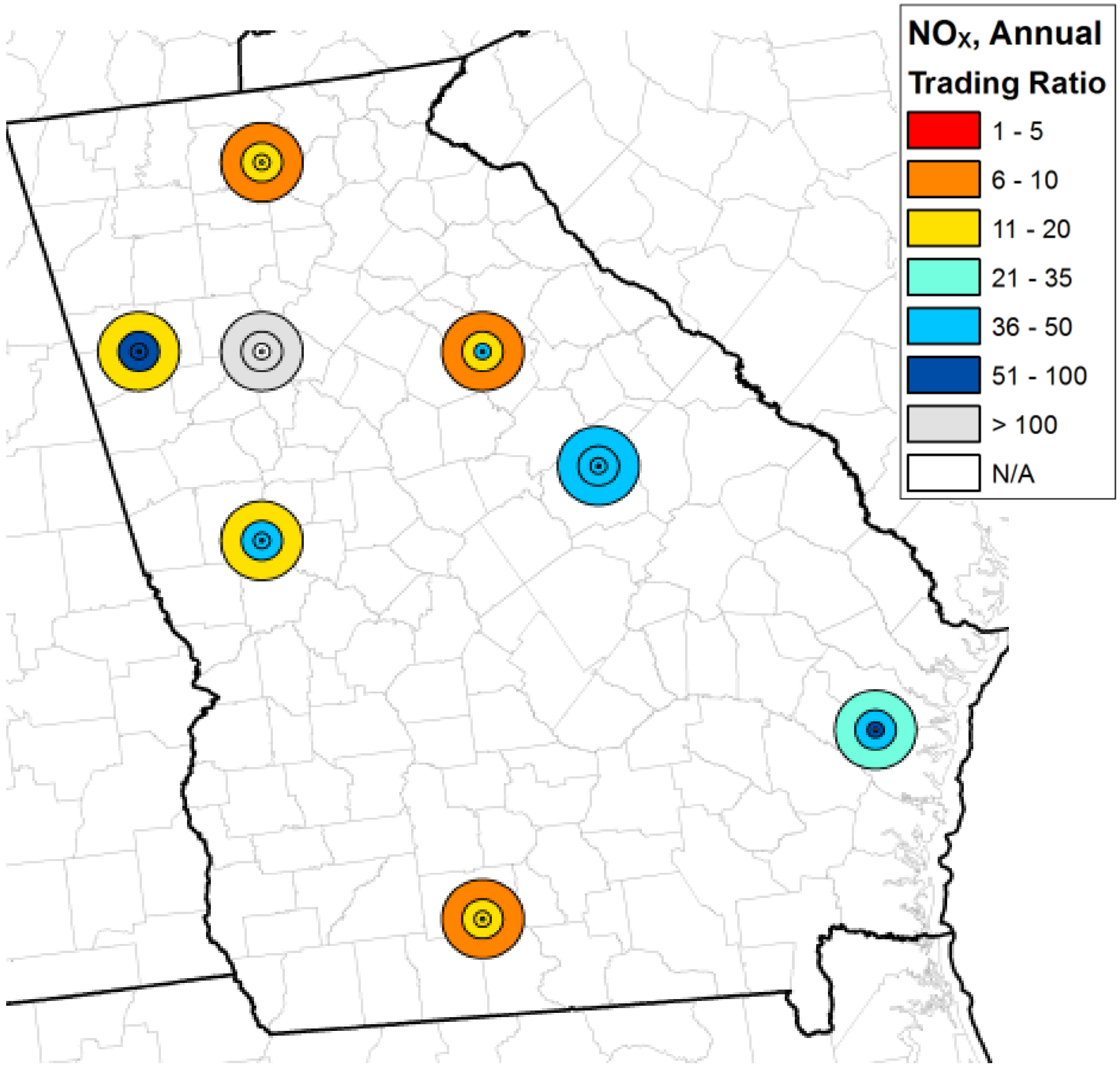
Summer NOx Ratios



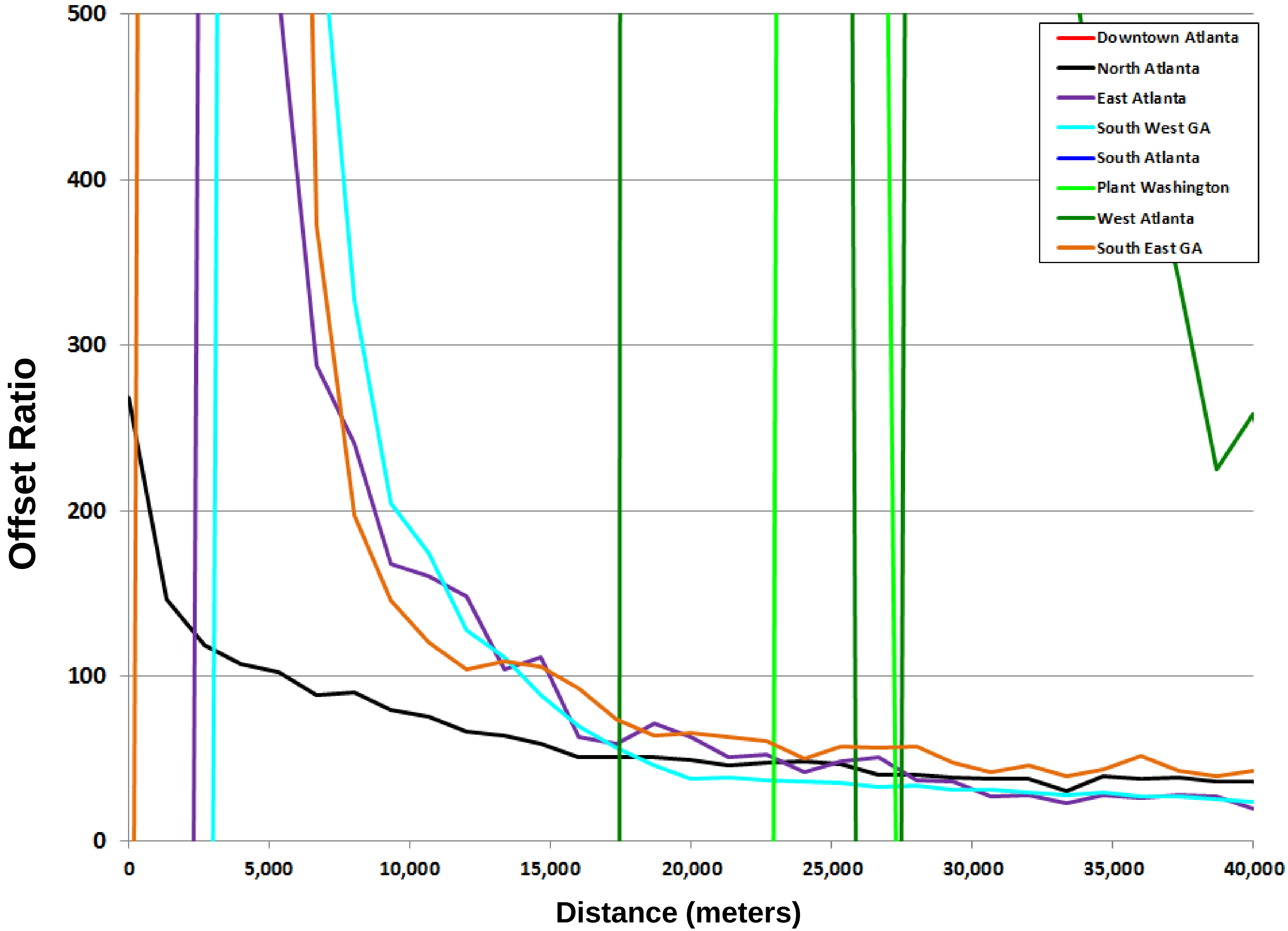
Fall NOx Offset Ratios



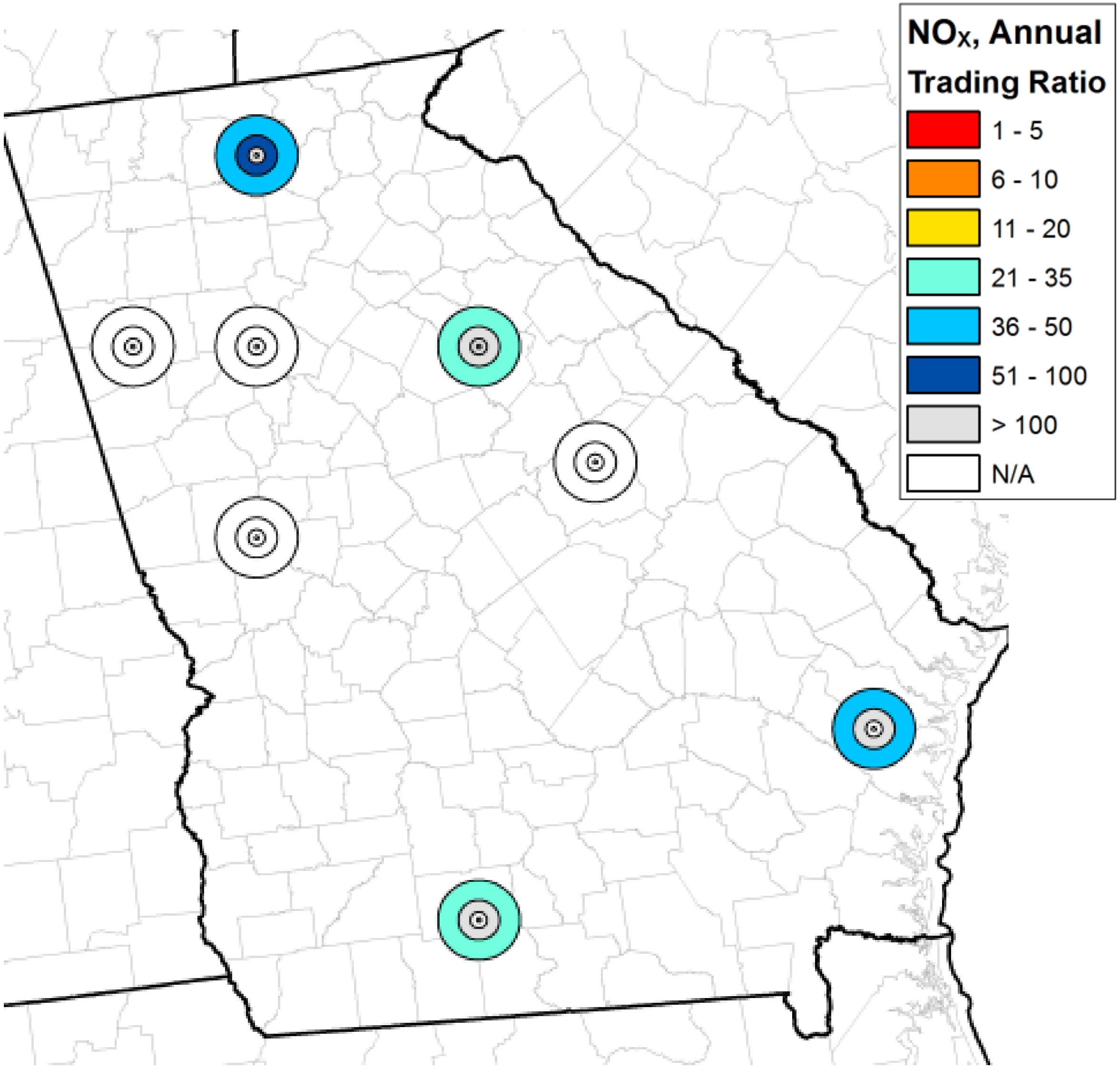
Fall NOx Ratios



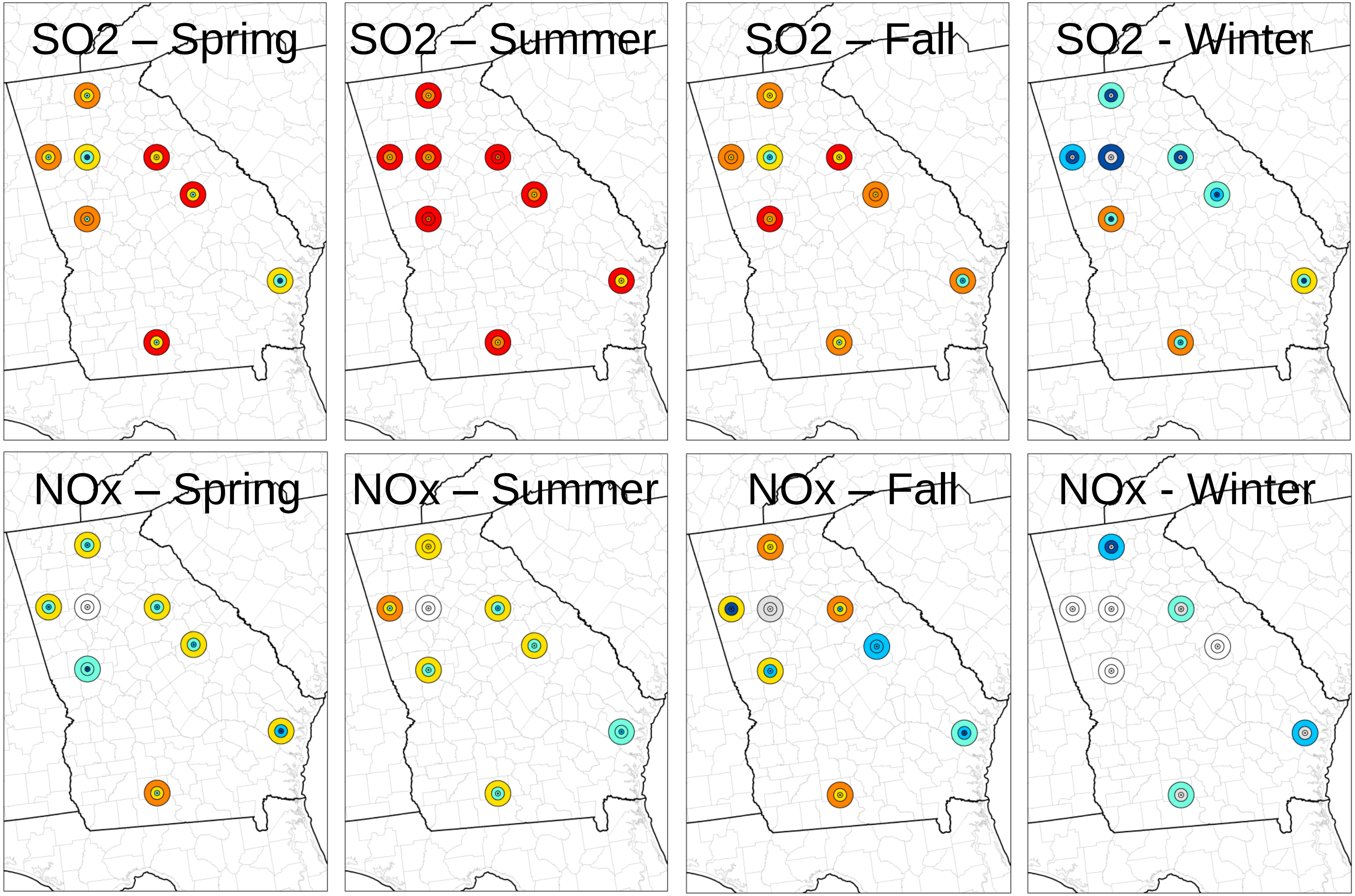
Winter NOx Offset Ratios



Winter NOx Ratios



SO_2 and NOx Offset Ratios



Example Tiered Approach

- Use tiered approach starting with the most conservative offset ratios and easiest to apply:
  - Tier 1
    - SO_2 and NO_x ratios from Q3 at d > 10 km
  - Tier 2a
    - SO_2 and NO_x ratios from Q3, vary with distance
  - Tier 2b
    - SO_2 and NO_x ratios by quarter at d > 10 km
  - Tier 3
    - SO_2 and NO_x ratios by quarter, vary with distance

Tier 1

SO2 Ratios

Distance	Q1	Q2	Q3	Q4
< 1 km	80:1	35:1	20:1	40:1
1 – 4 km	40:1	20:1	10:1	25:1
4 – 10 km	25:1	10:1	7:1	18:1
> 10 km	15:1	7:1	**5:1**	10:1

NOx Ratios

Distance	Q1	Q2	Q3	Q4
< 1 km	250:1	50:1	50:1	120:1
1 – 4 km	160:1	35:1	35:1	120:1
4 – 10 km	80:1	20:1	20:1	120:1
> 10 km	40:1	20:1	**20:1**	N/A

Tier 1 “equivalent” direct PM2.5 emissions from SO2 and NOx can be accounted for by scaling the standard AERMOD output files.

Tier 2a

SO2 Ratios

Distance	Q1	Q2	Q3	Q4
< 1 km	80:1	35:1	**20:1**	40:1
1 – 4 km	40:1	20:1	**10:1**	25:1
4 – 10 km	25:1	10:1	**7:1**	18:1
> 10 km	15:1	7:1	**5:1**	10:1

NOx Ratios

Distance	Q1	Q2	Q3	Q4
< 1 km	250:1	50:1	**50:1**	120:1
1 – 4 km	160:1	35:1	**35:1**	120:1
4 – 10 km	80:1	20:1	**20:1**	120:1
> 10 km	40:1	20:1	**20:1**	N/A

Tier 2a "equivalent" direct PM2.5 emissions from SO2 and NOx can be accounted for by scaling the standard AERMOD output files.

Tier 2b

SO2 Ratios

Distance	Q1	Q2	Q3	Q4
< 1 km	80:1	35:1	20:1	40:1
1 – 4 km	40:1	20:1	10:1	25:1
4 – 10 km	25:1	10:1	7:1	18:1
> 10 km	**15:1**	**7:1**	**5:1**	**10:1**

NOx Ratios

Distance	Q1	Q2	Q3	Q4
< 1 km	250:1	50:1	50:1	120:1
1 – 4 km	160:1	35:1	35:1	120:1
4 – 10 km	80:1	20:1	20:1	**120:1**
> 10 km	**40:1**	**20:1**	**20:1**	N/A

Tier 2b "equivalent" direct PM2.5 emissions from SO2 and NOx should be added to the actual direct PM2.5 emissions prior to running AERMOD.

Tier 3

SO2 Ratios

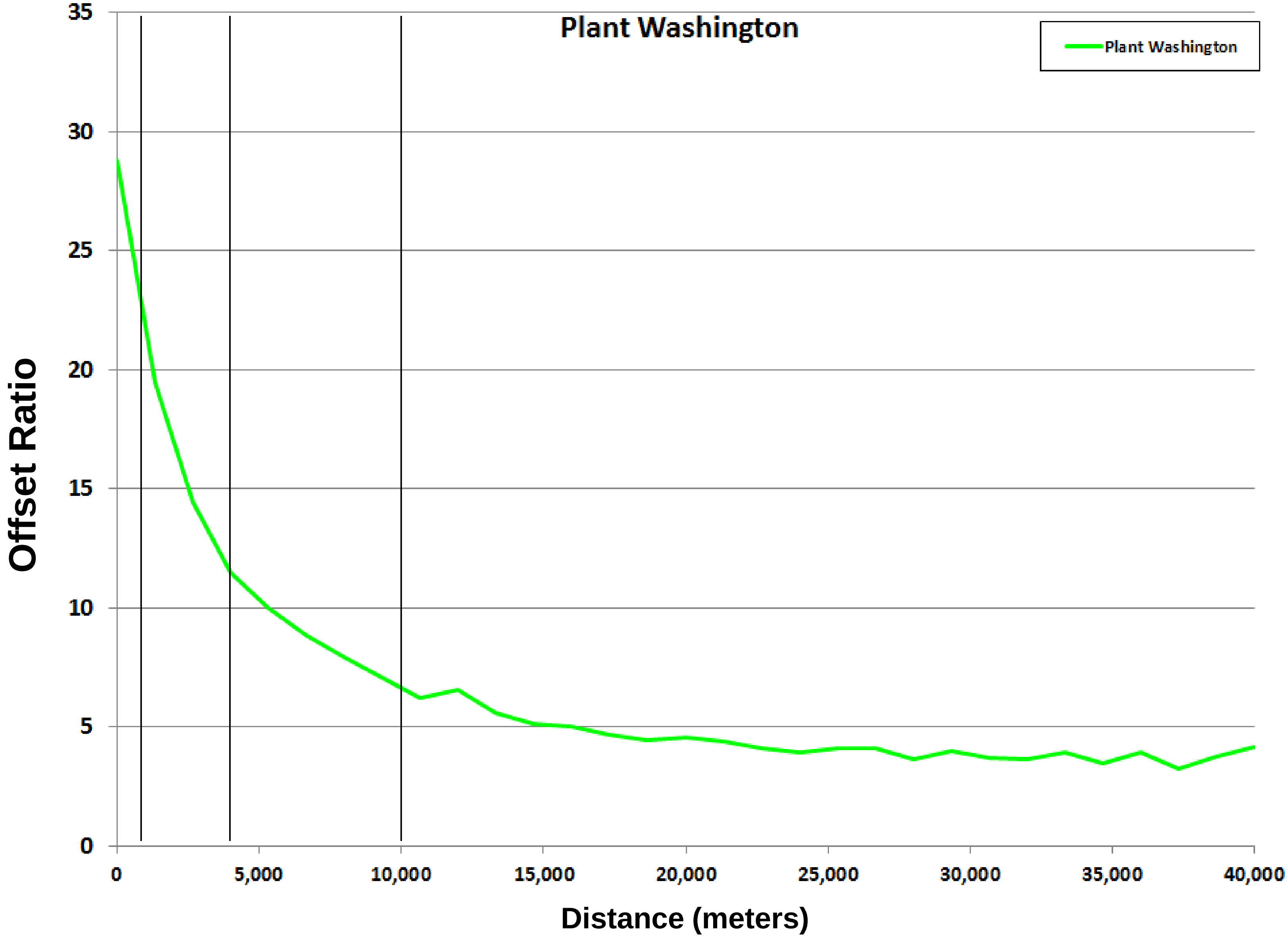
Distance	Q1	Q2	Q3	Q4
< 1 km	80:1	35:1	20:1	40:1
1 – 4 km	40:1	20:1	10:1	25:1
4 – 10 km	25:1	10:1	7:1	18:1
> 10 km	15:1	7:1	5:1	10:1

NOx Ratios

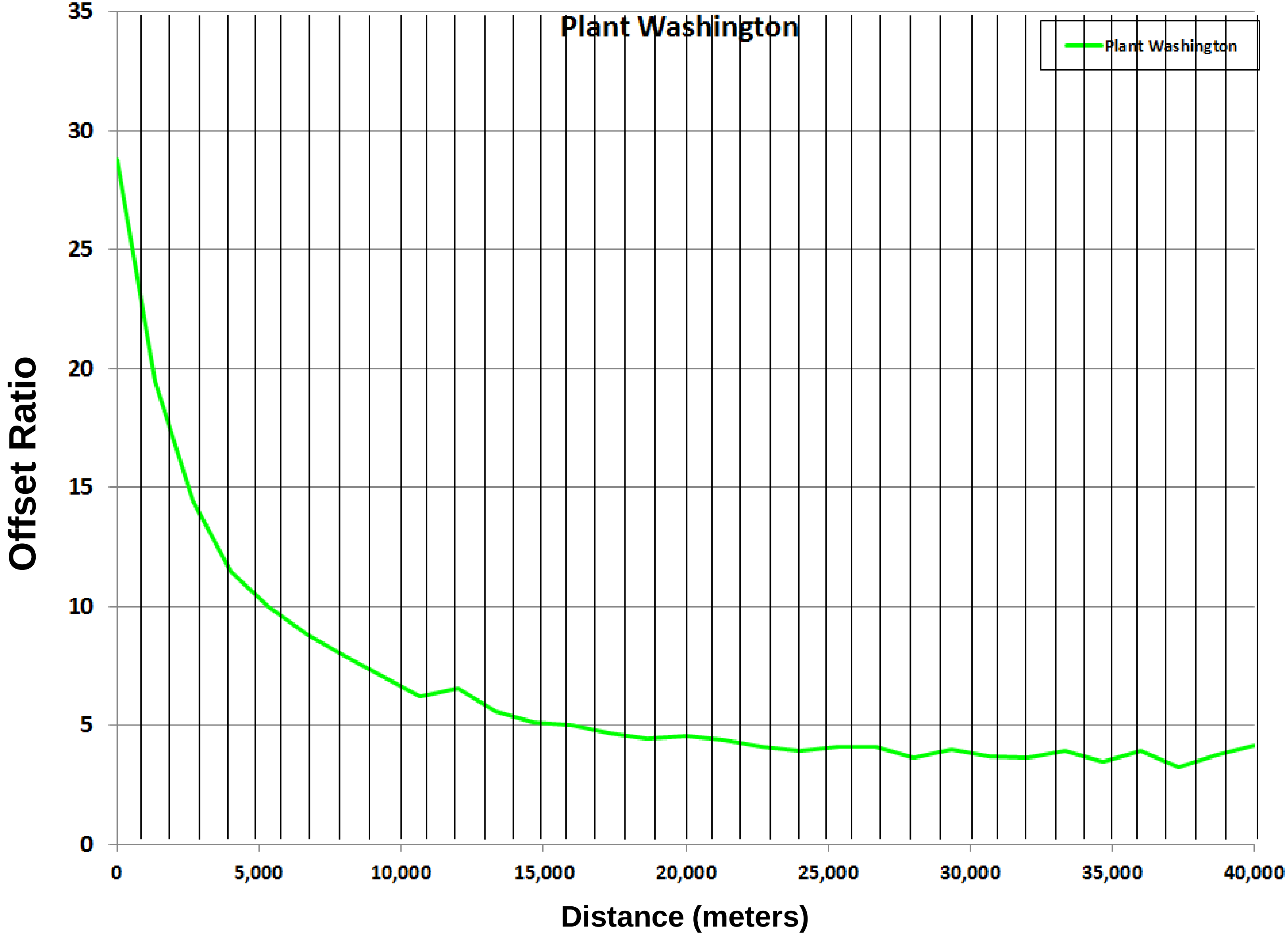
Distance	Q1	Q2	Q3	Q4
< 1 km	250:1	50:1	50:1	120:1
1 – 4 km	160:1	35:1	35:1	120:1
4 – 10 km	80:1	20:1	20:1	120:1
> 10 km	40:1	20:1	20:1	N/A

Tier 3 “equivalent” direct PM2.5 emissions from SO2 and NOx will require scaling quarterly AERMOD outputs followed by recalculation of annual and daily PM2.5 impacts.

Summer SO_2 Offset Ratios



Summer SO_2 Offset Ratios



Example PSD Application

- Direct PM2.5 emissions = 118.30 TYP
- SO2 emissions = 190.93 TPY
- NOx emissions = 340.65 TPY

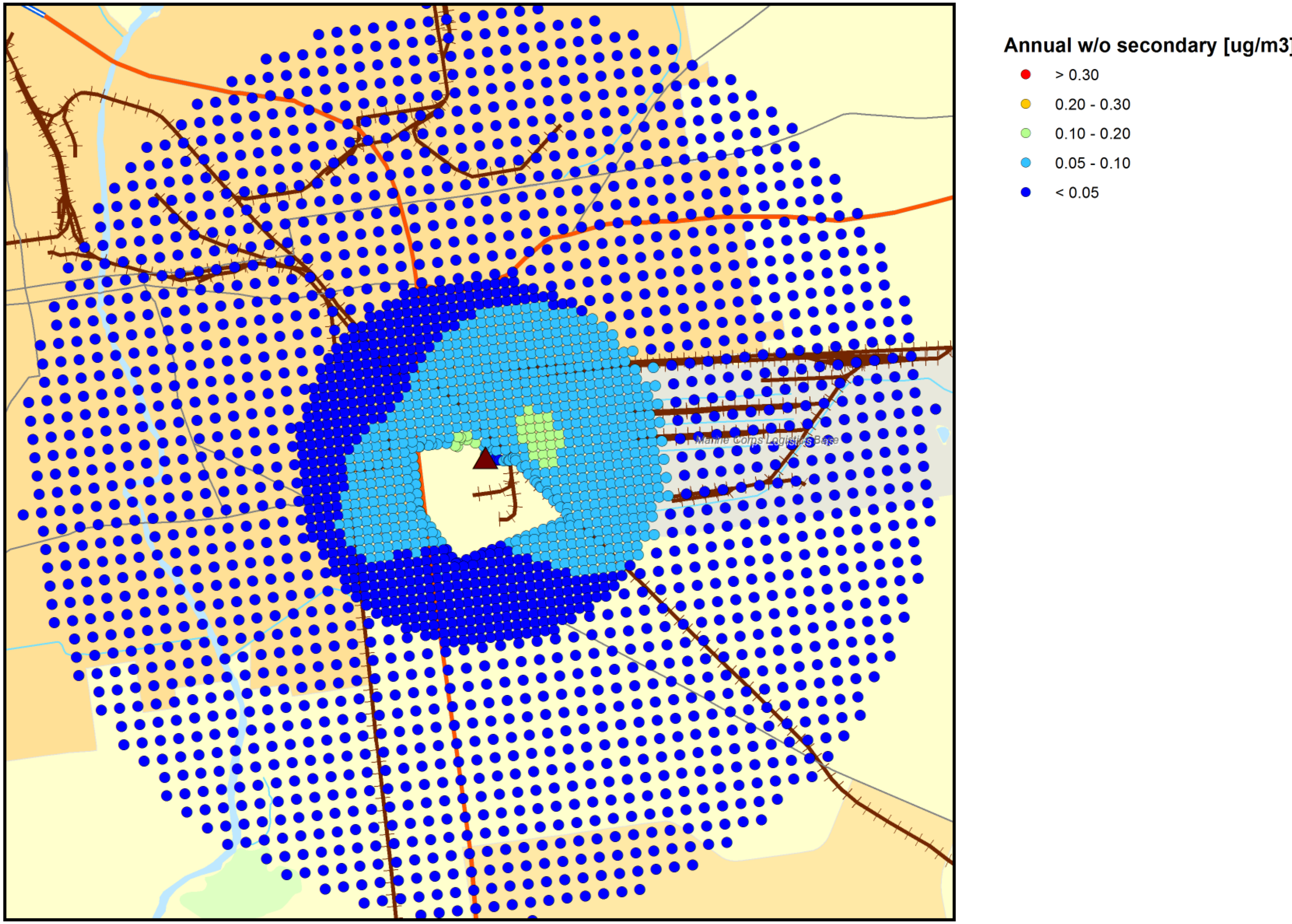
- PM2.5 Scaling Factor =

$$\frac{(\text{SO2 TPY/SO2 Ratio}) + (\text{NOx TPY/NOx Ratio}) + \text{PM2.5 TPY}}{\text{PM2.5 TPY}}$$

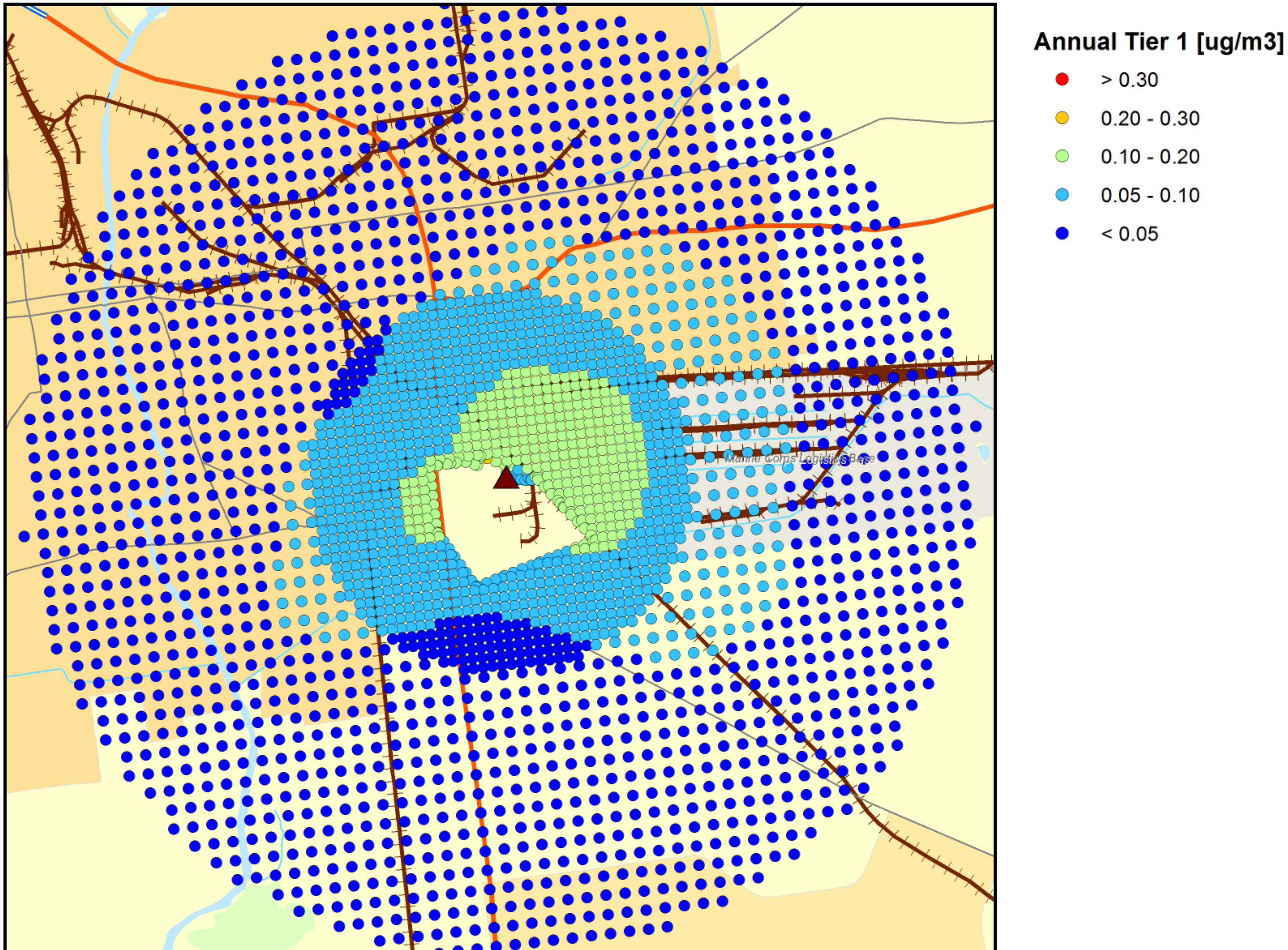
Distance	Q3 SO2 Ratio	Q3 NOx Ratio	Scaling Factor
< 1 km	20	50	1.138
1 - 4 km	10	35	1.244
4 - 10 km	7	20	1.375
> 10 km	**5**	**20**	**1.467** → **(Tier 1)**

(Tier 2)

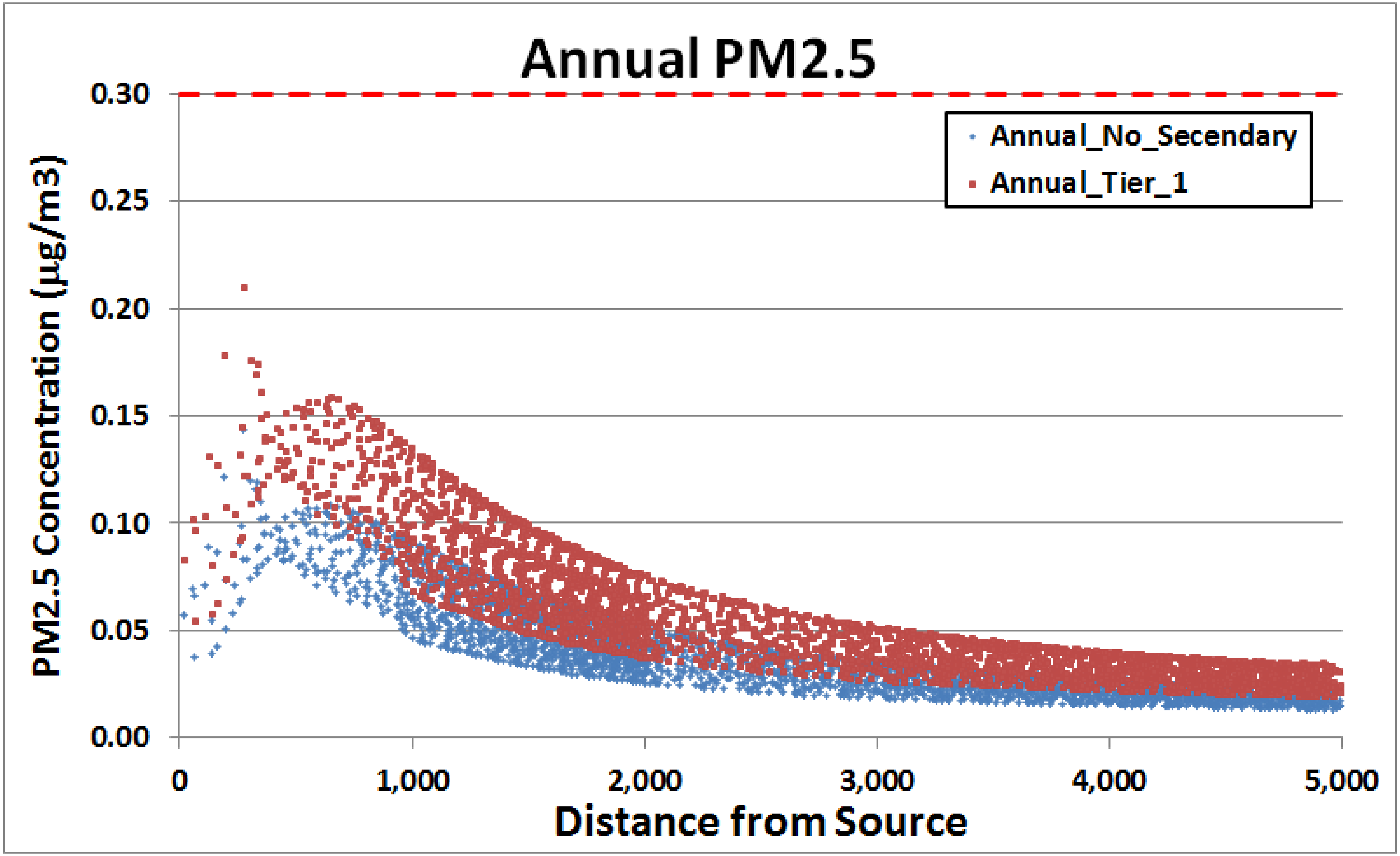
Annual PM2.5 – No Secondary



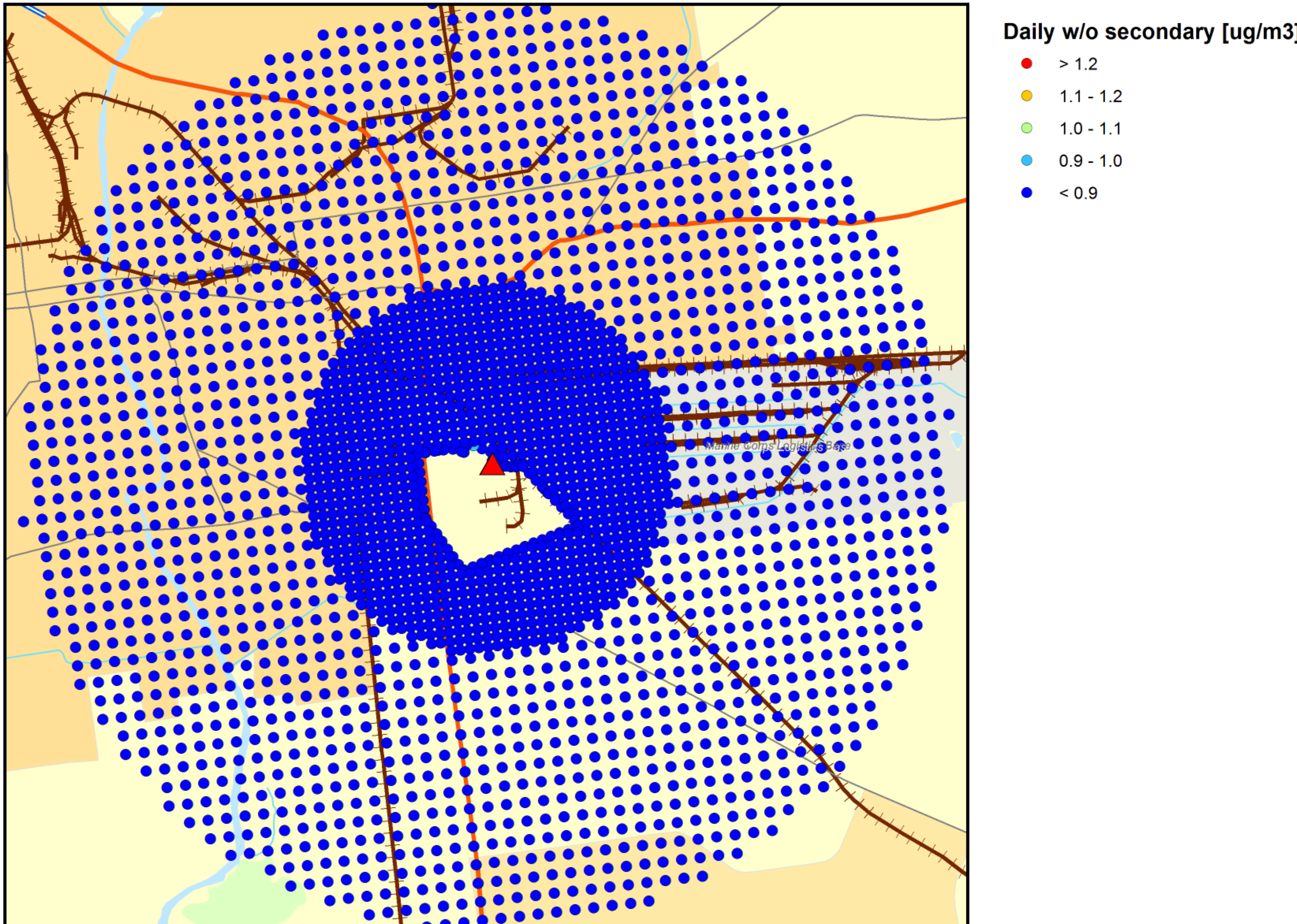
Annual PM2.5 – Tier 1



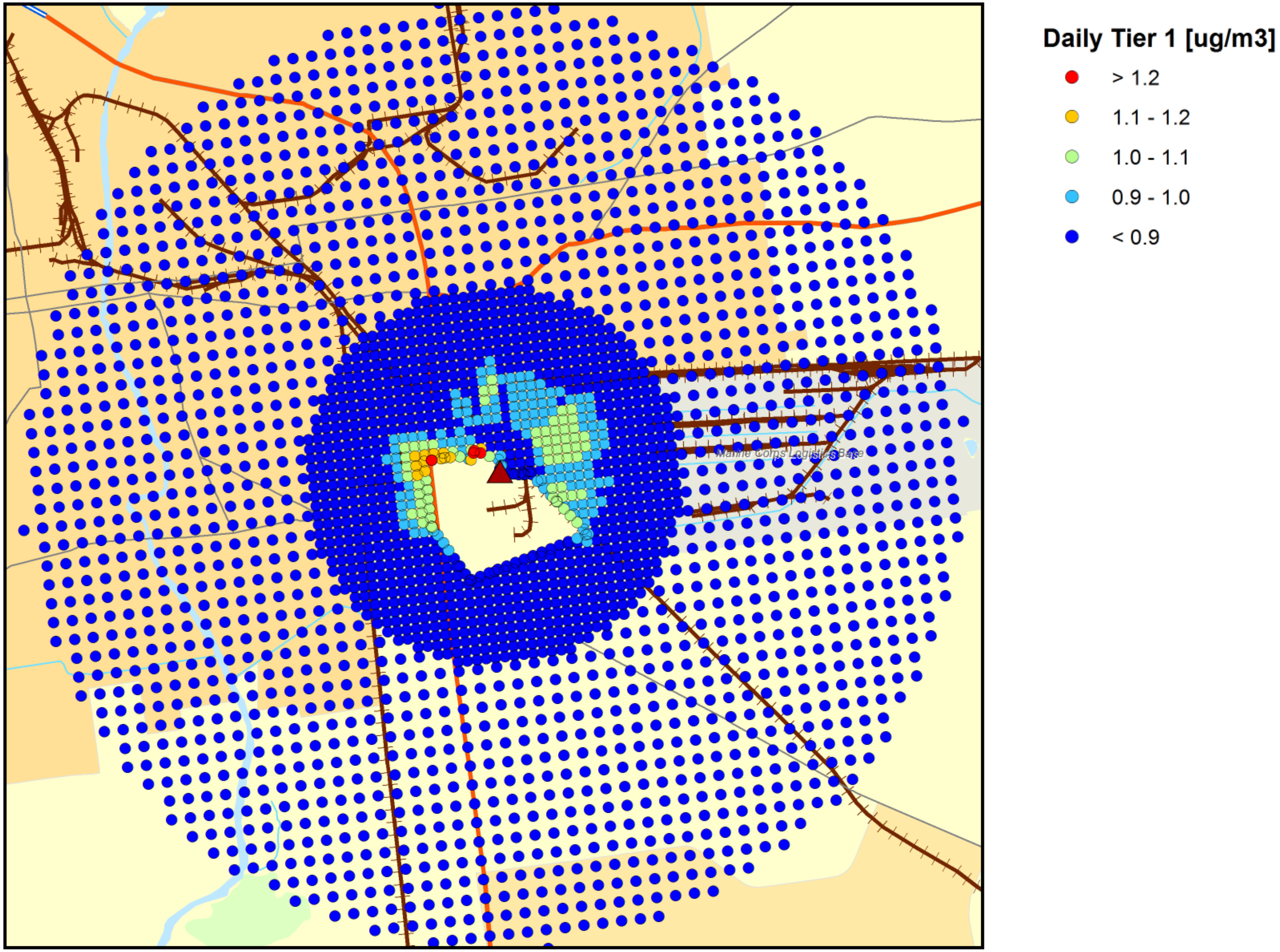
Annual PM2.5 vs. SIL



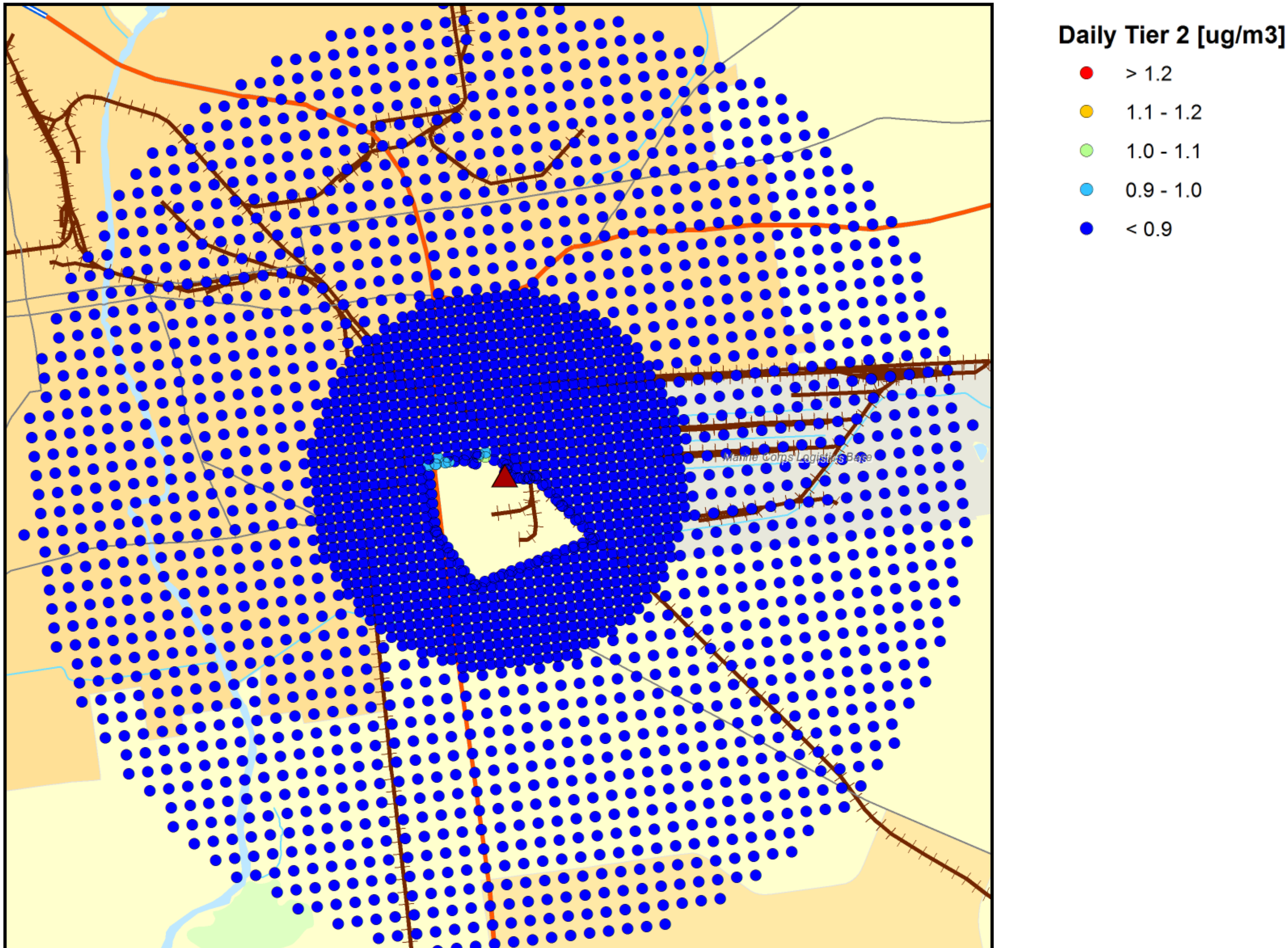
Daily PM2.5 – No Secondary



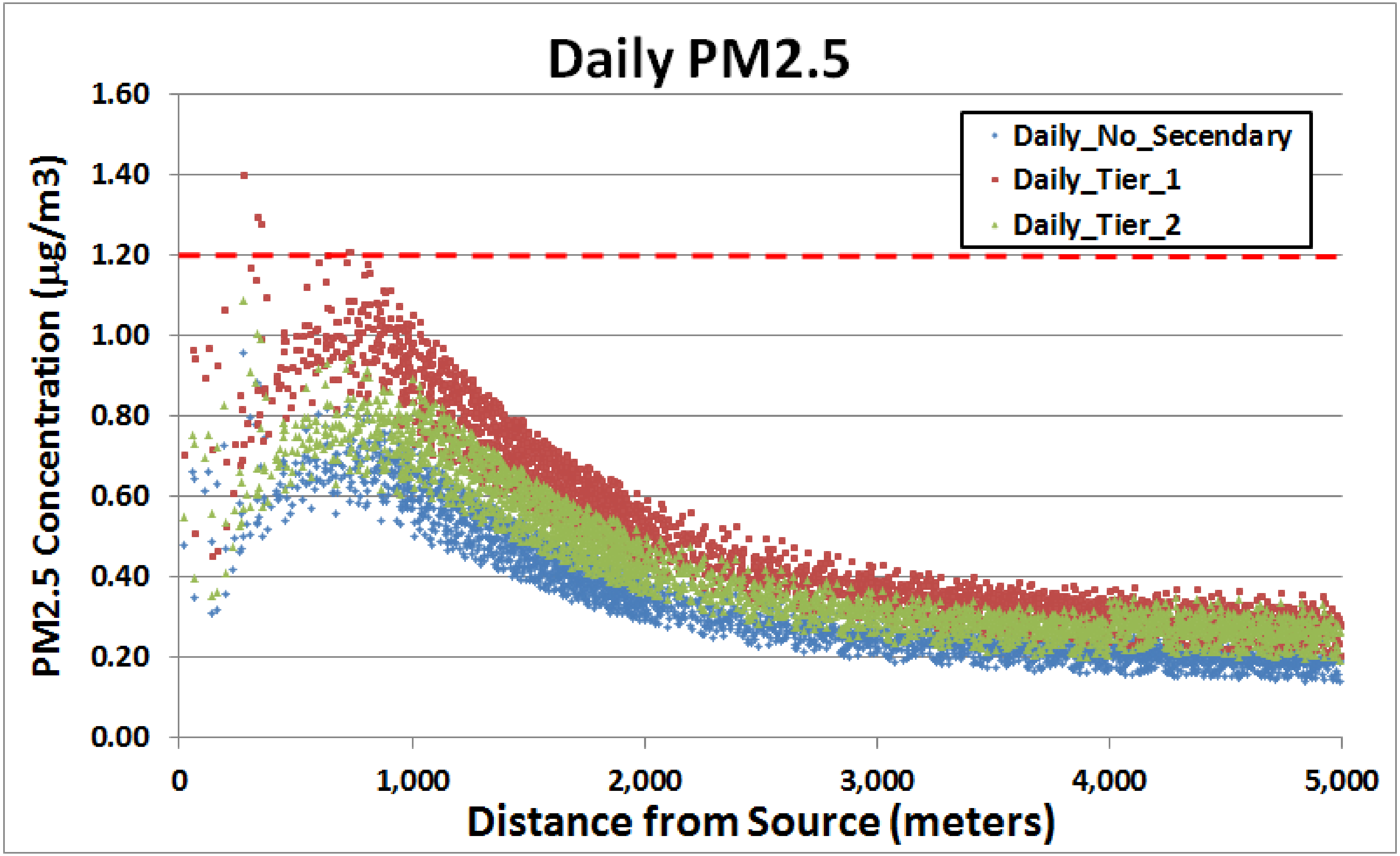
Daily PM2.5 – Tier 1



Daily PM2.5 – Tier 2



Daily PM2.5 vs. SIL



Next Steps

- Perform Tier 2b and Tier 3 calculations for example PSD application.
- Assign binned SO2 and NOx offset ratios to each county in Georgia so applicants can use them in PSD applications.
- Document approach and final results.
- Repeat the analysis with new 2011/2018 modeling platform.

Contact Information

Jim Boylan, Ph.D.
Georgia Dept. of Natural Resources
4244 International Parkway, Suite 120
Atlanta, GA 30354

James.Boylan@dnr.state.ga.us
404-362-4851