Philadelphia Air Toxics Study

EPA Regional/State/Local Modelers Workshop
New Orleans, LA
May 16-18, 2005

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Purposes of Study

- Primary:
  - Refine 1996 NATA risk estimates
  - Estimate present & future day risk
- Secondary:
  - Develop regional capabilities
  - Examine importance of using link data
  - Examine importance of secondary impacts via CAMQ
  - Examine culpability (primary & secondary) for effective control strategy development
  - Develop a template to transfer to other urban areas in the Region
  - Examine regional scale modeling approach that utilizes near-field modeling to include the effects of sub-grid scale variability

Outline

- Refining 1996 NATA
- Estimating present day risk (2001 results)
  - Primary impacts from ISCST
  - Secondary impacts from CMAQ
- Comparisons
  - CMAQ to ISC
  - NATA 1999
  - Grid modeling (w/sub-grid scale variability)
  - 2001 monitored data at one site
- Conclusions
- Next Steps

Refining ’96 NATA (completed)

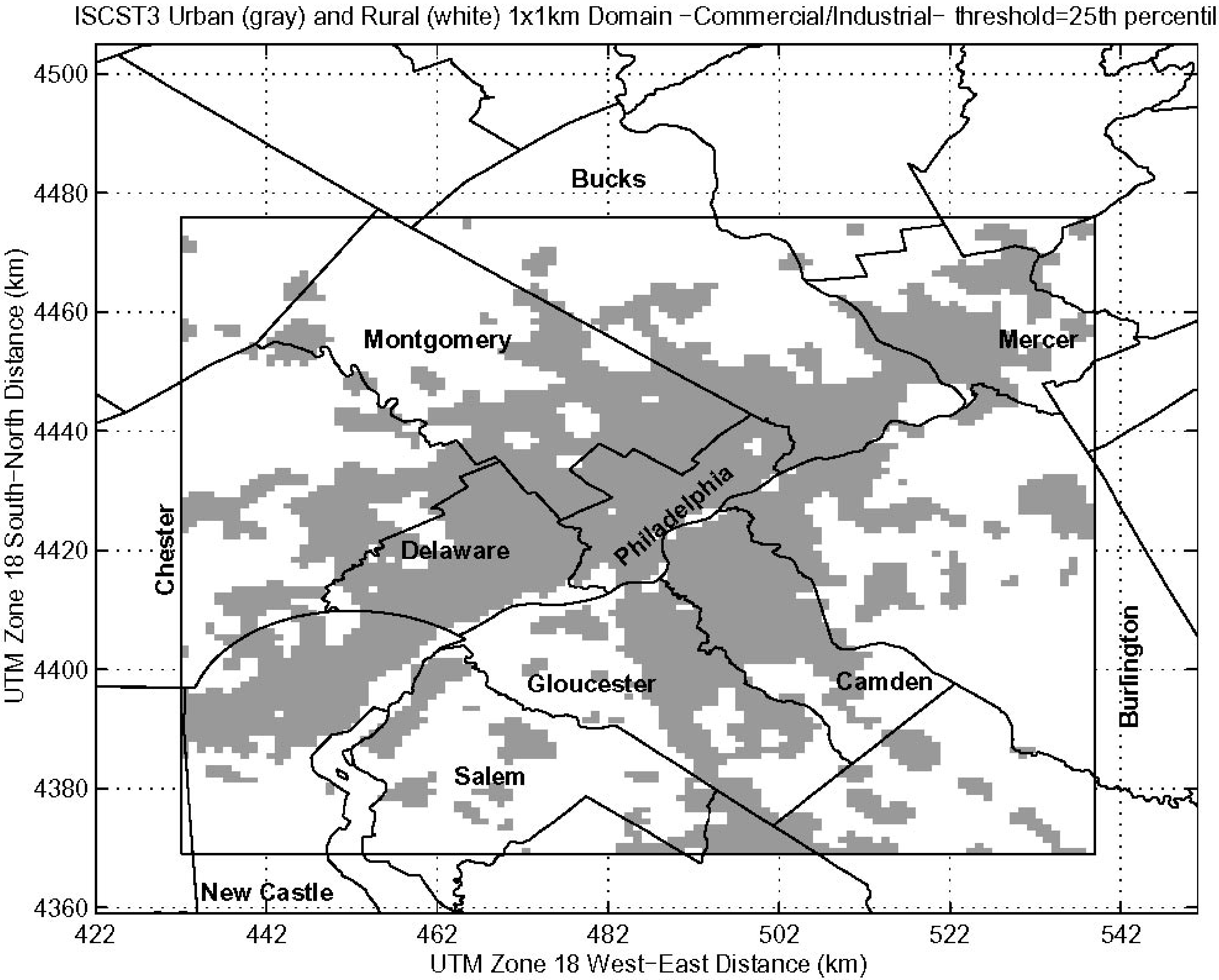
Nine pollutants examined (based on NATA)

Primary & Secondary
- Formaldehyde
- Acetaldehyde
- Acrolein

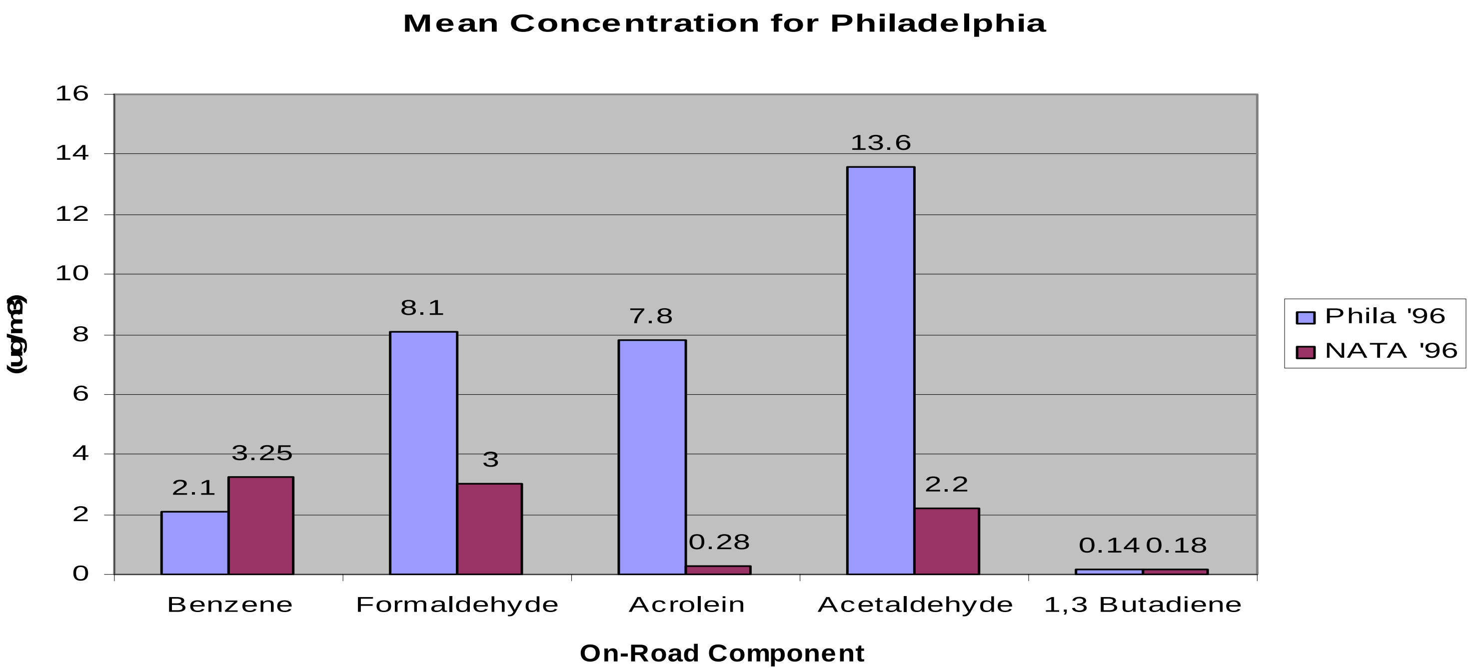
Primary Only
- 1,3 butadiene
- Benzene
- Chromium
- Ethylene Dichloride
- POM
- Diesel PM

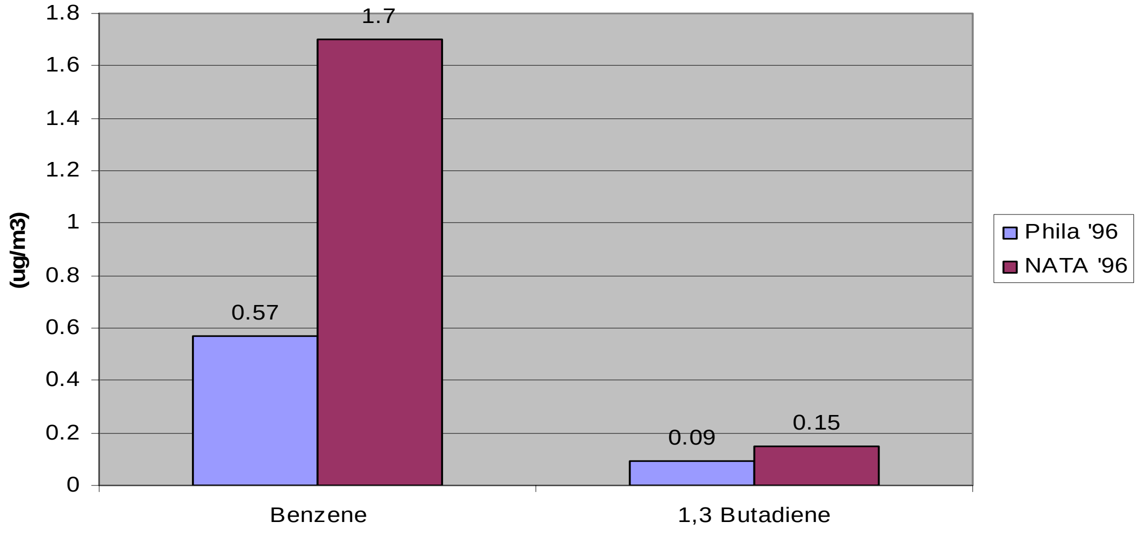
- Refined 1996 NEI Inventory: Link based mobile emissions plus 1km resolved gridded emissions
- 1990 population centroids and 3 - 500m fine grids
- Primary emissions: ISCST3 + measured background
- Secondary component: 10 cities study
- Exposure & Risk: HAPEM

Emissions Modeling Grid & Urban/Rural Land Use

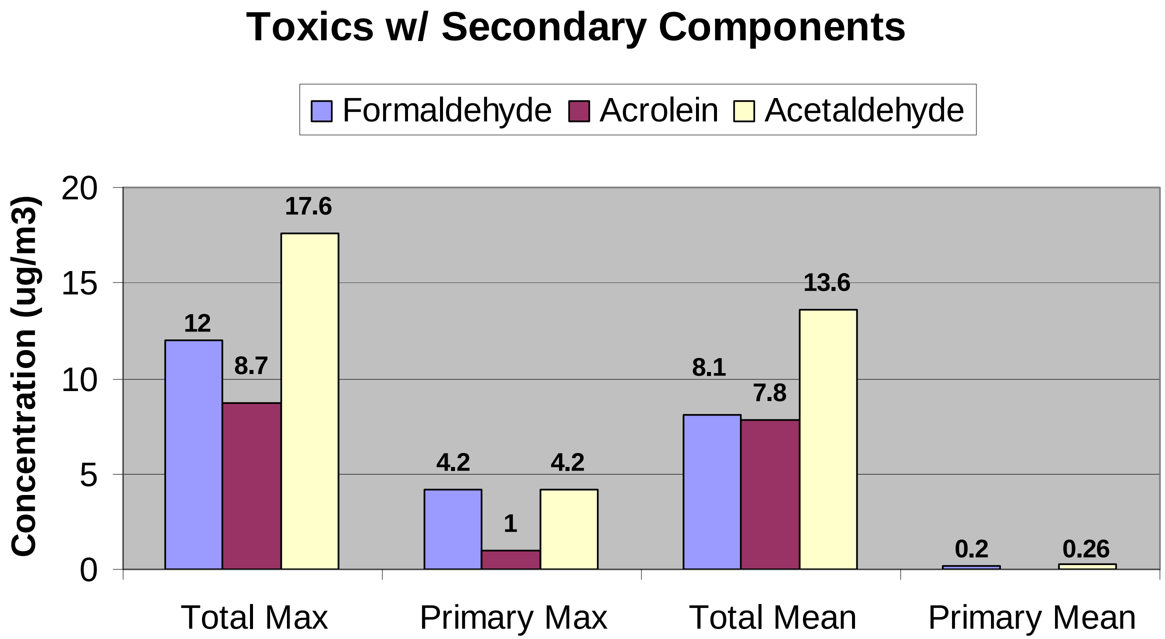


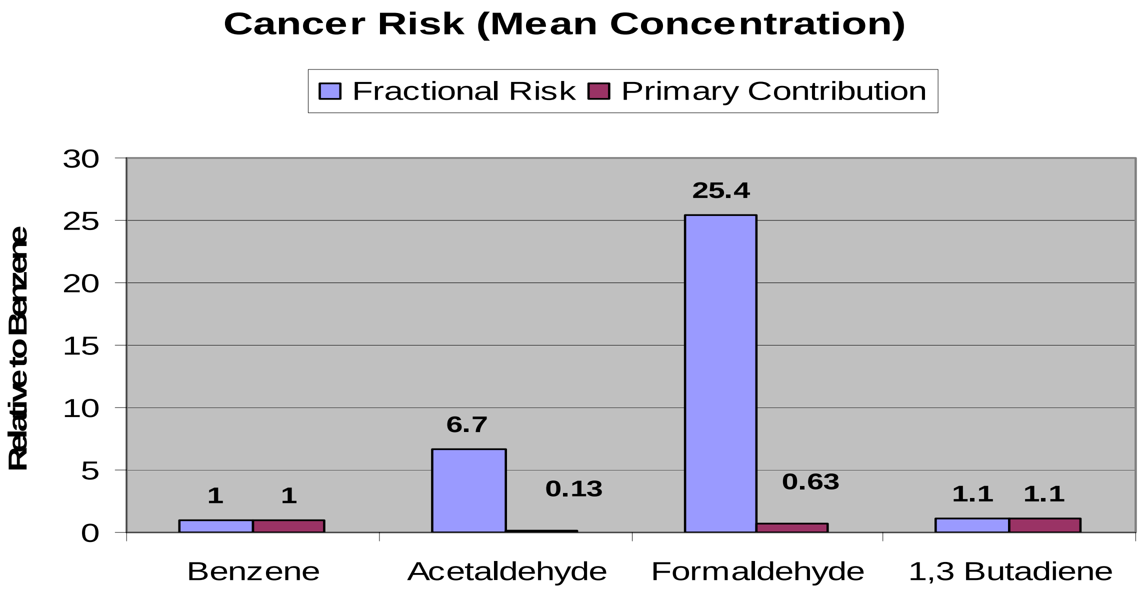
Philadelphia Air Toxics Study: **Comparison w/ NATA**





Philadelphia Air Toxics Study: Selected Results

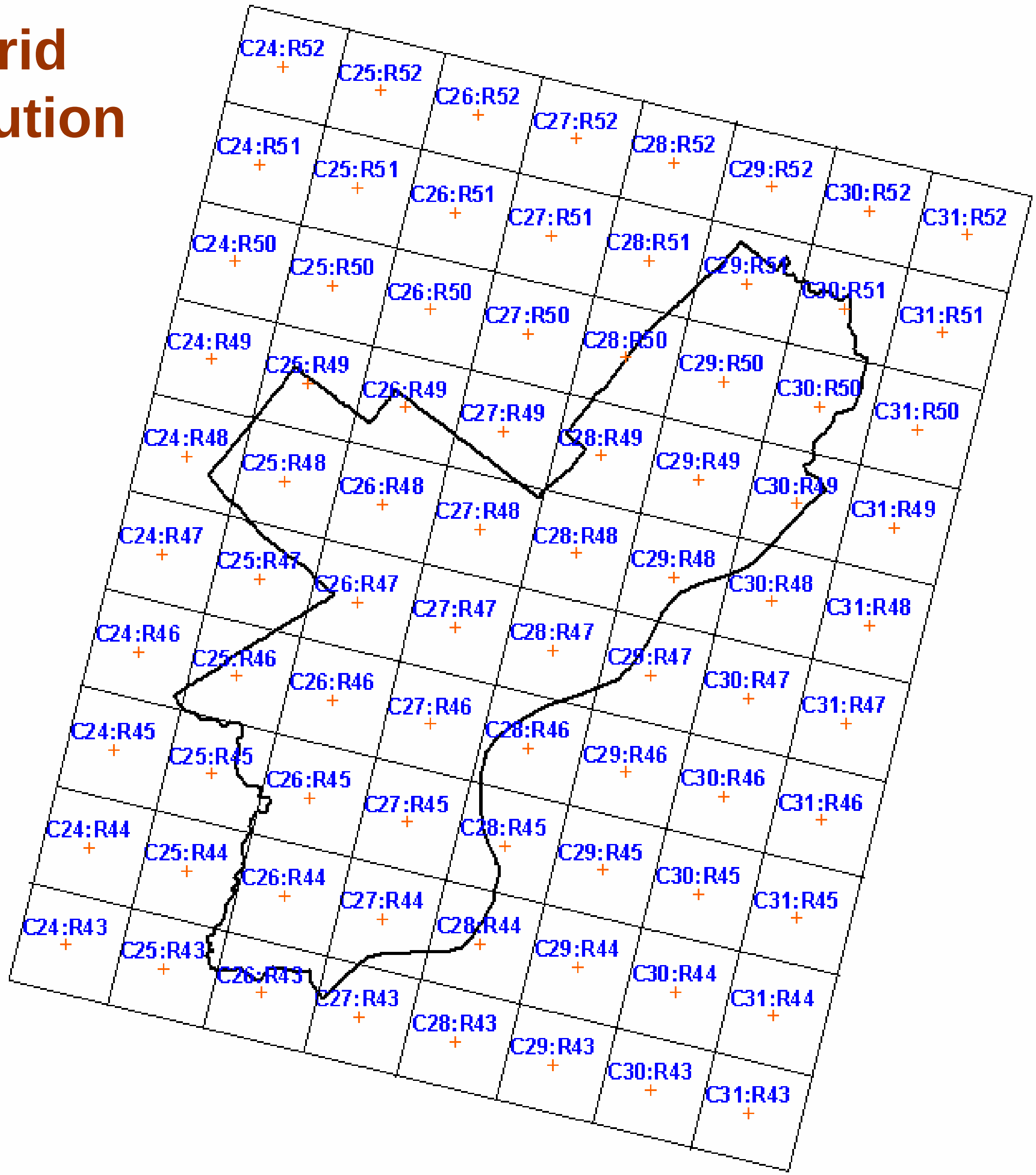




Estimate Present Day & Future Risk

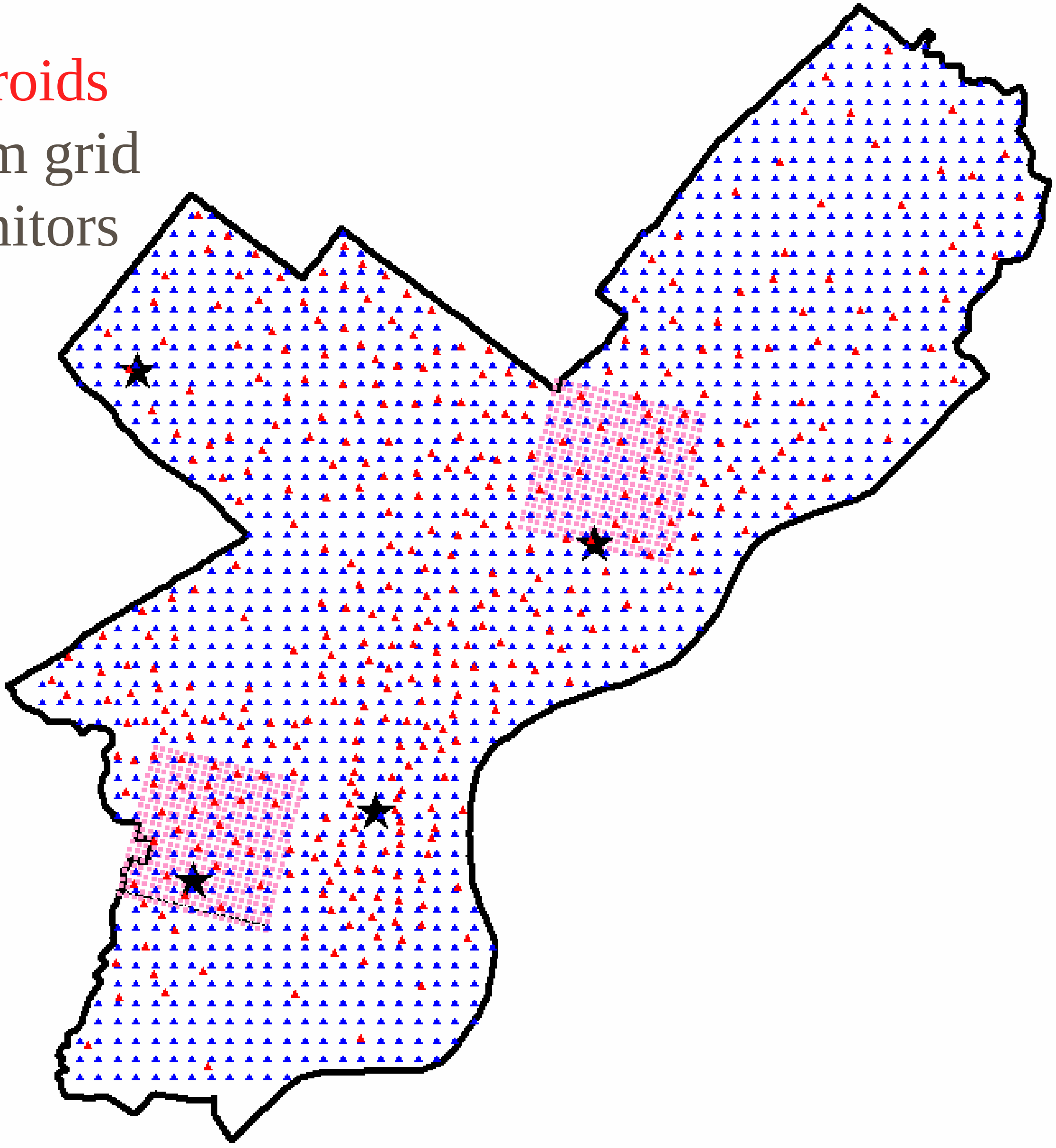
- Primary Impacts (ISCST3)
  - Hot Spot analysis: 500 m fine grid over city
- Secondary Impacts (CMAQ):
  - 36km to 12km to 4km nesting over Philadelphia
- Population Risk: 2000 population centroids / HAPEM
- Emissions Inventories:
  - Refined 1999 NEI w/ link level on-road mobile
  - 2010: Grown from refined 1999 NEI
- Meteorology
  - 1999 – for comparisons with ’99 NATA
  - 2001 – present day and future (2010) risk predictions

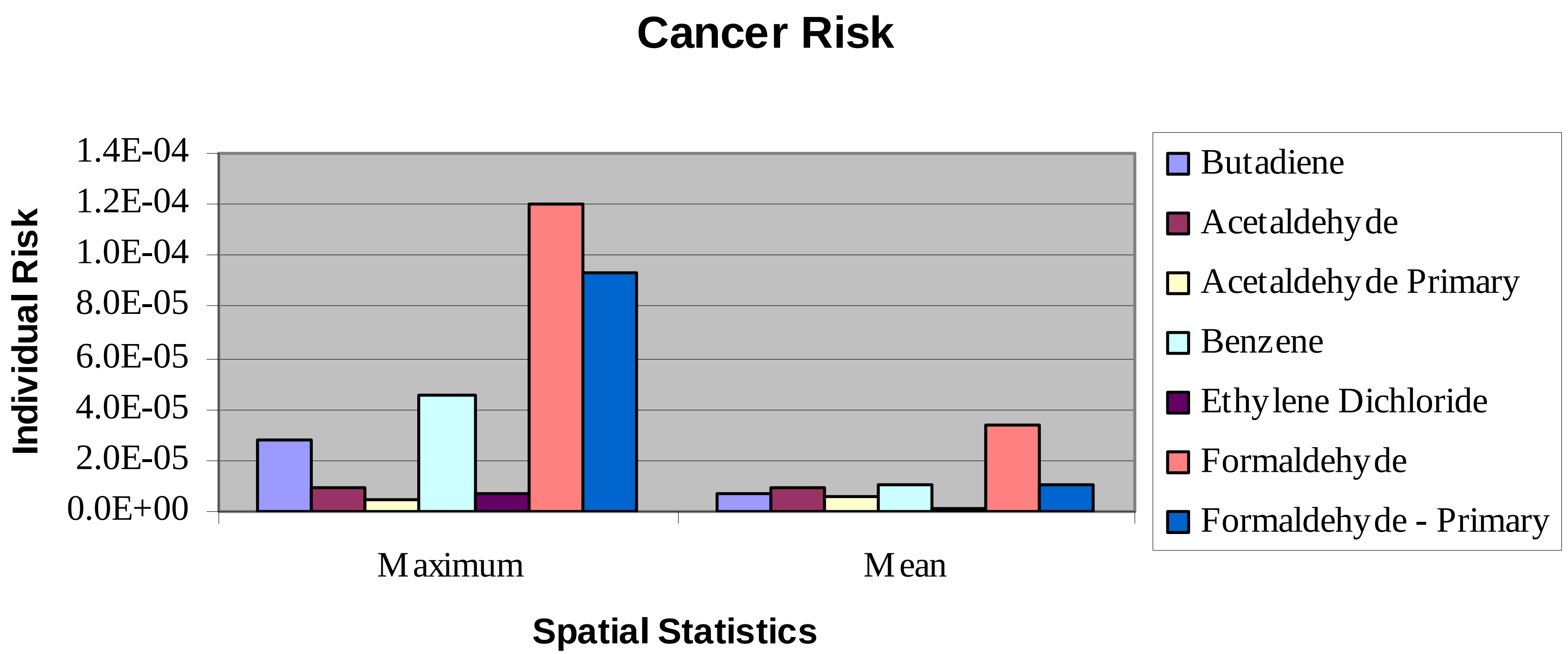
CMAQ Grid
4km Resolution

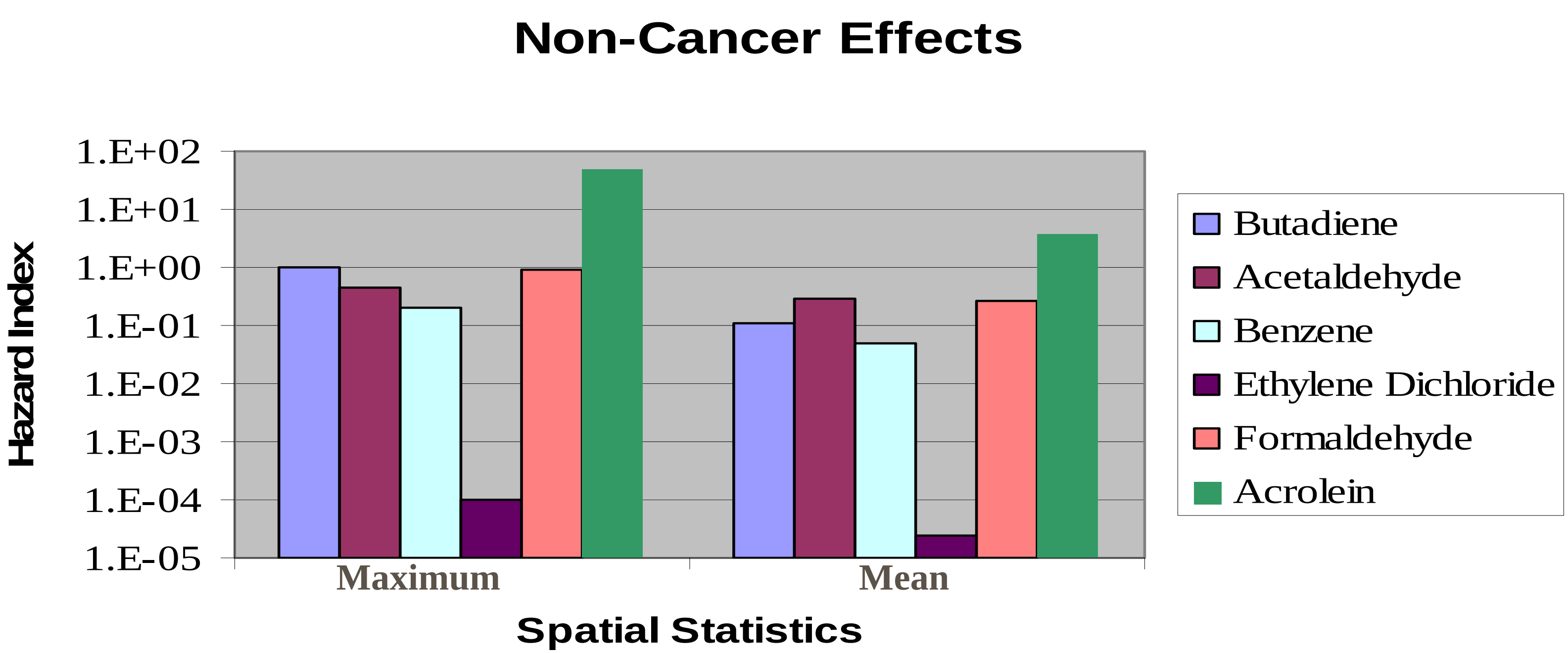


ISCST Receptors Modeled

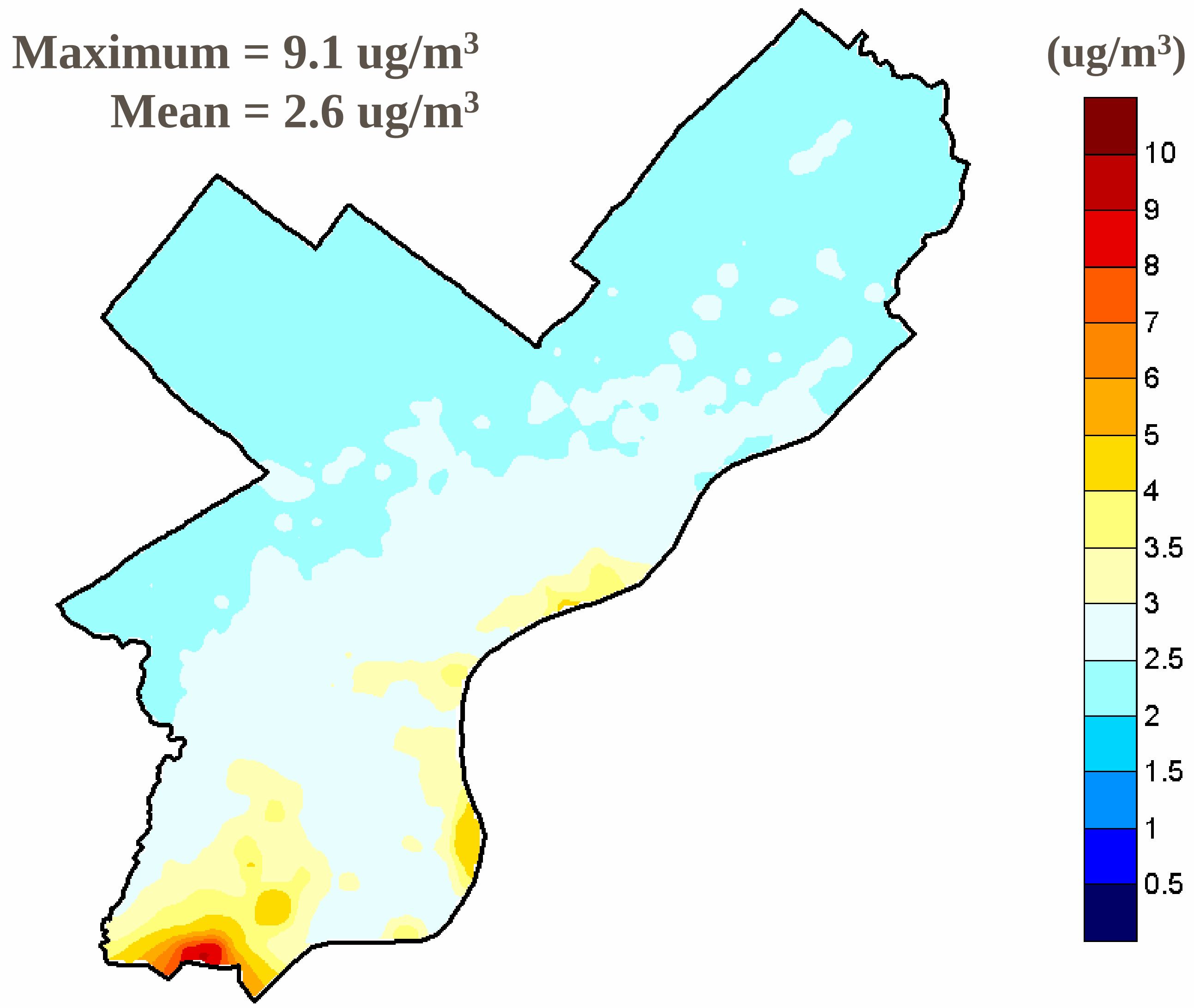
Red = Centroids
Blue = 500m grid
Stars = Monitors



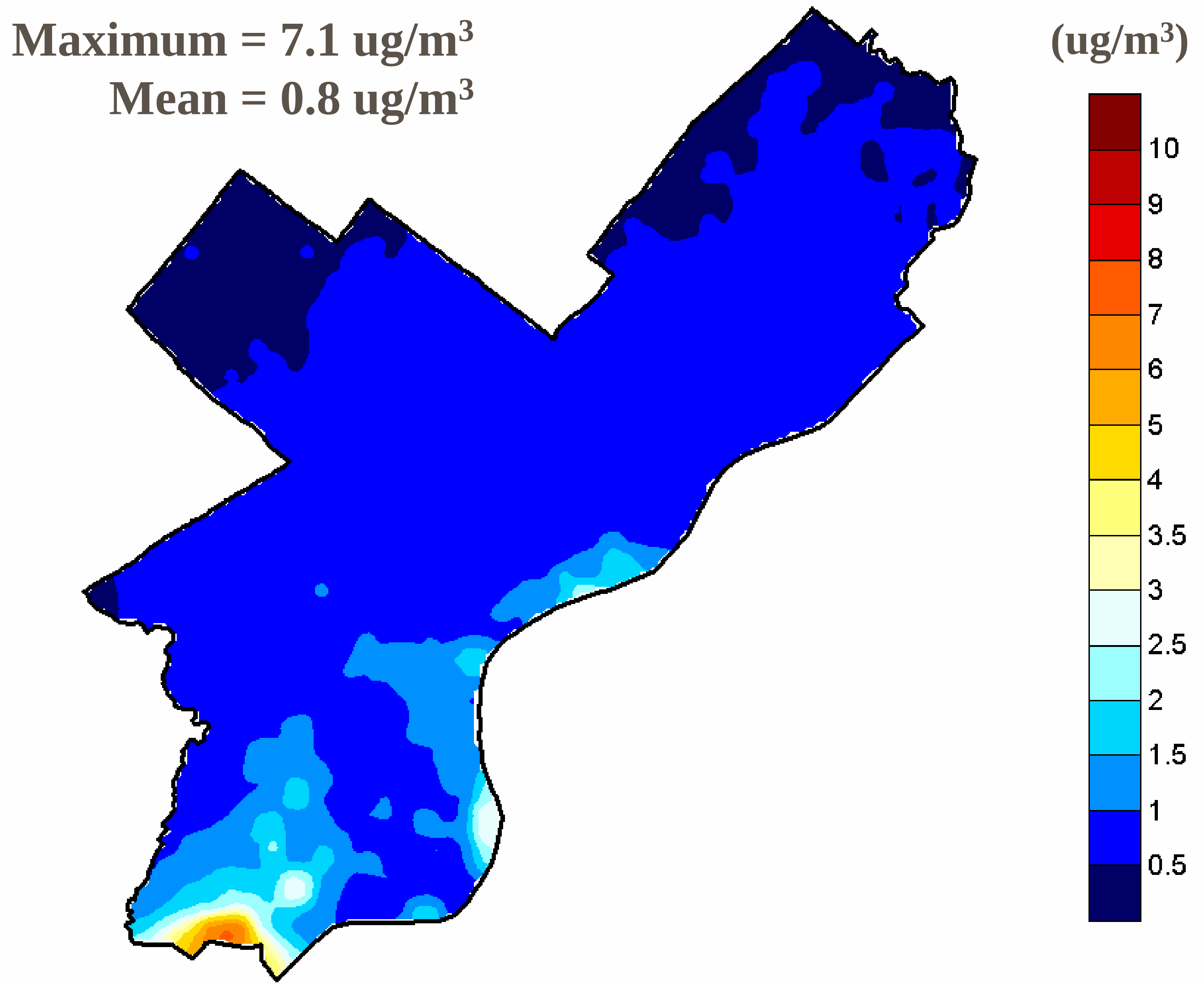

Cancer Risk
1.4E-04
1.2E-04
1.0E-04
8.0E-05
6.0E-05
4.0E-05
2.0E-05
0.0E+00
Individual Risk
Maximum
Mean
Spatial Statistics
Butadiene
Acetaldehyde
Acetaldehyde Primary
Benzene
Ethylene Dichloride
Formaldehyde
Formaldehyde - Primary


Non-Cancer Effects
1.E+02
1.E+01
1.E+00
1.E-01
1.E-02
1.E-03
1.E-04
1.E-05
Hazard Index
Maximum
Mean
Spatial Statistics
Butadiene
Acetaldehyde
Benzene
Ethylene Dichloride
Formaldehyde
Acrolein

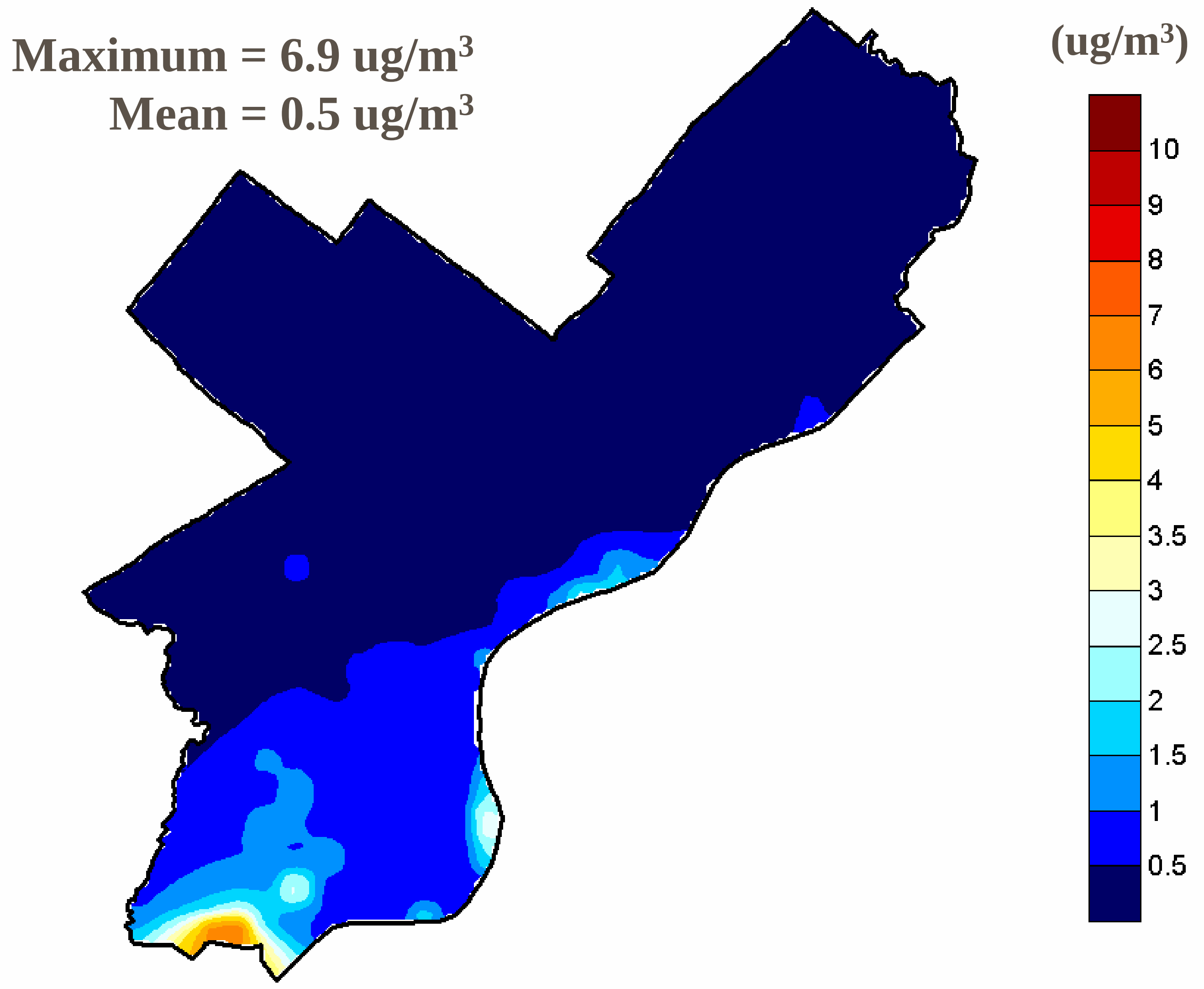
Formaldehyde: Primary + Secondary



Formaldehyde: Primary Only

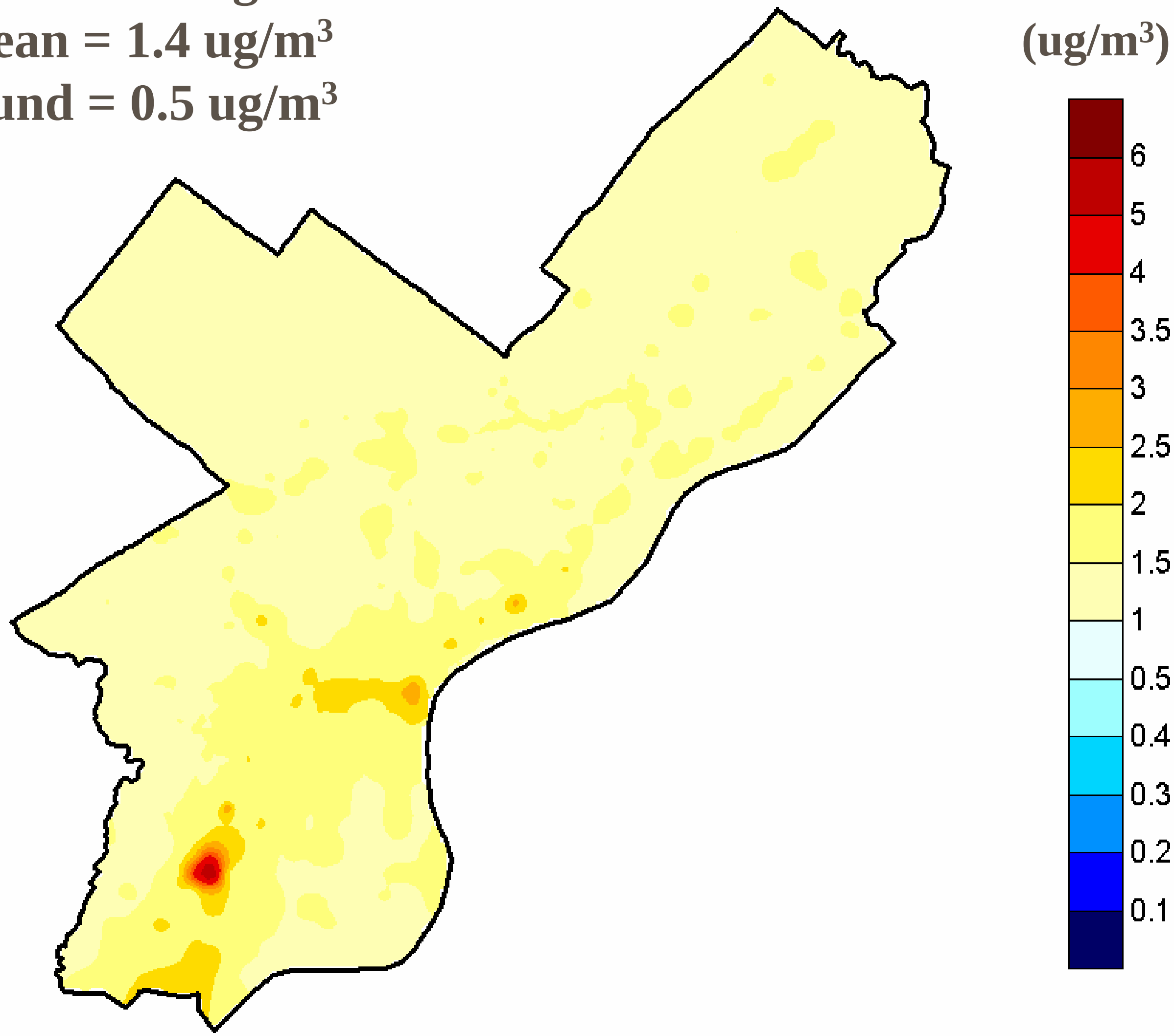


Formaldehyde: Non-Road



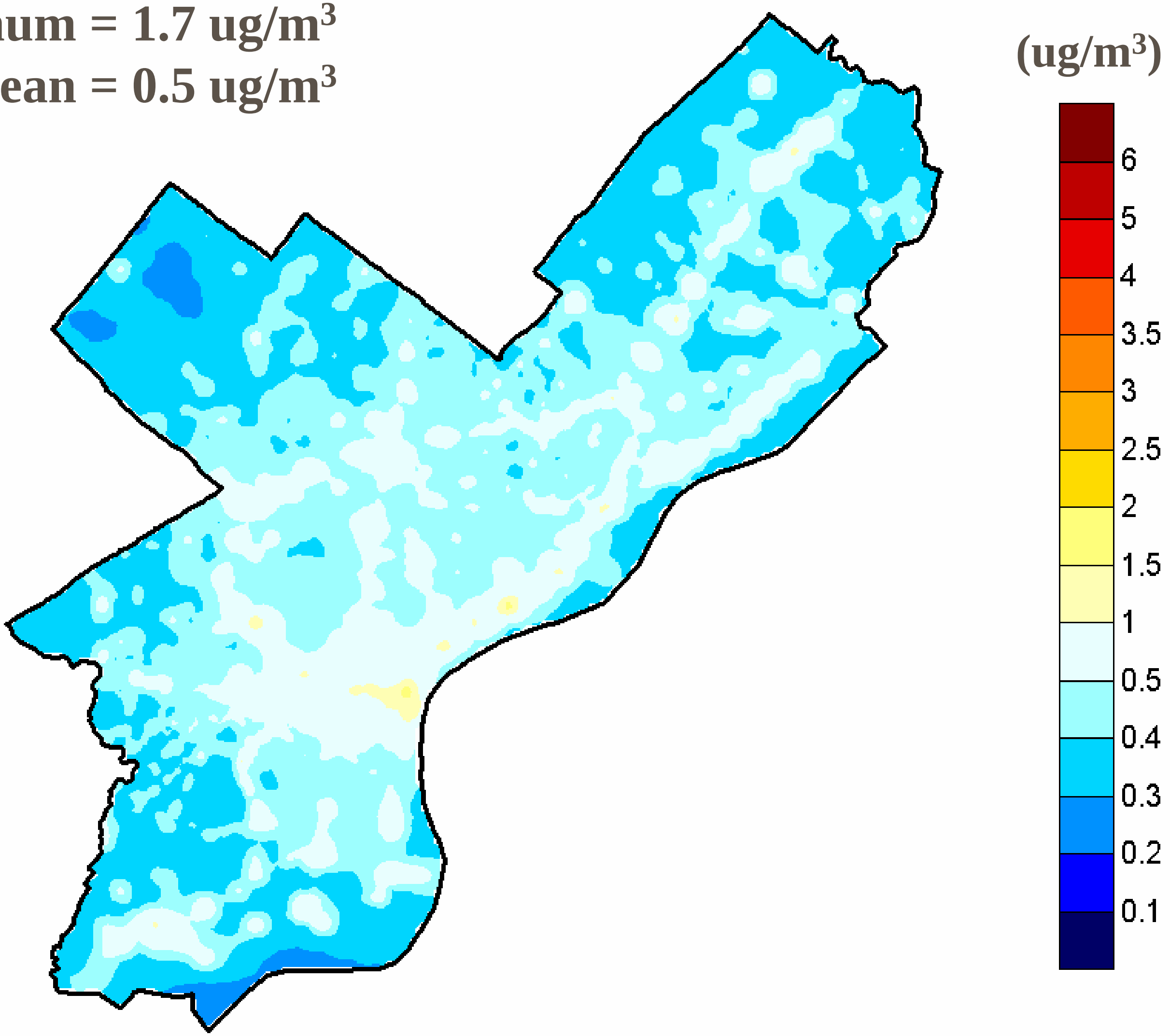
Benzene: Total including Background

Maximum = 6.0 ug/m^3
Mean = 1.4 ug/m^3
Background = 0.5 ug/m^3

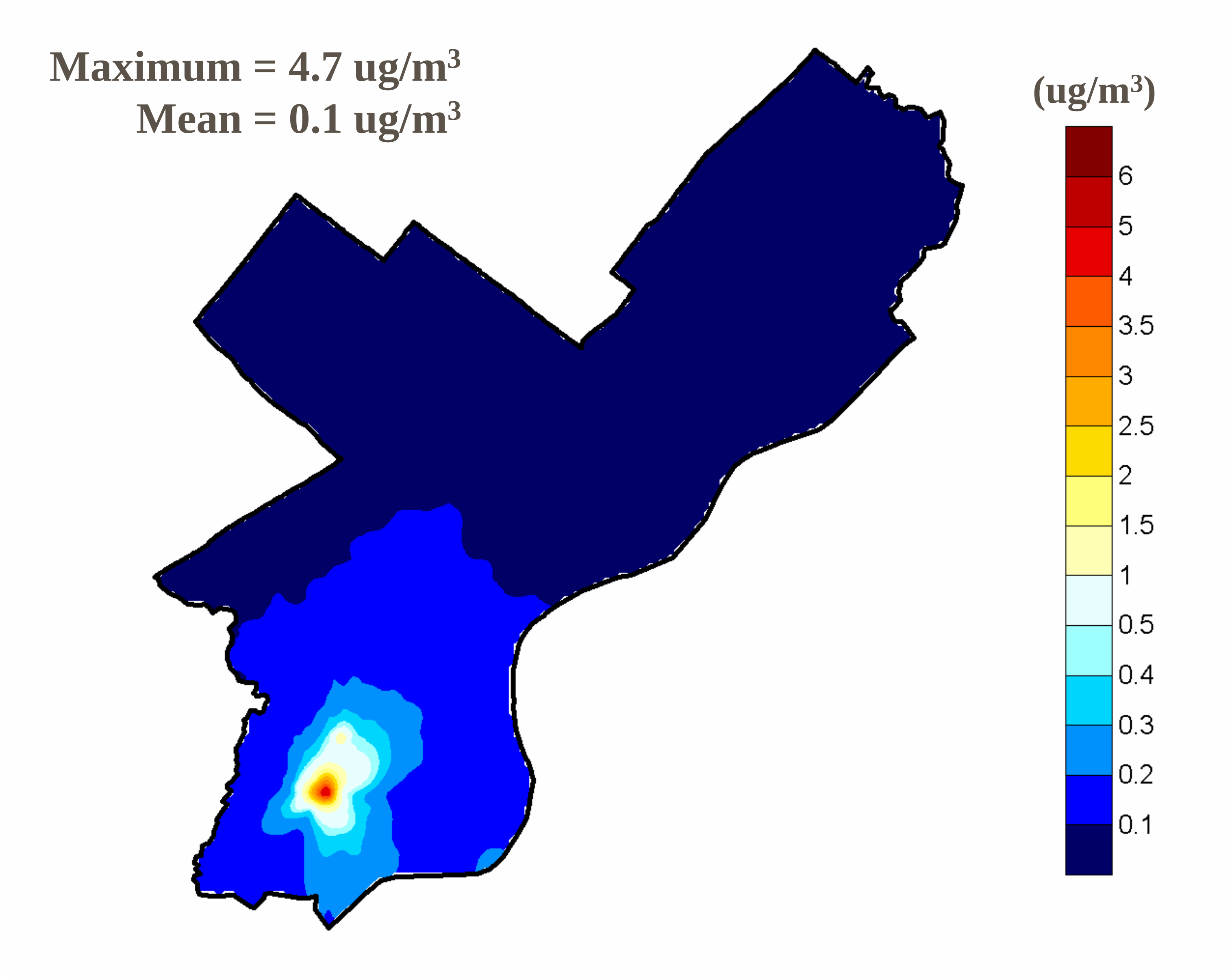


Benzene: On-Road

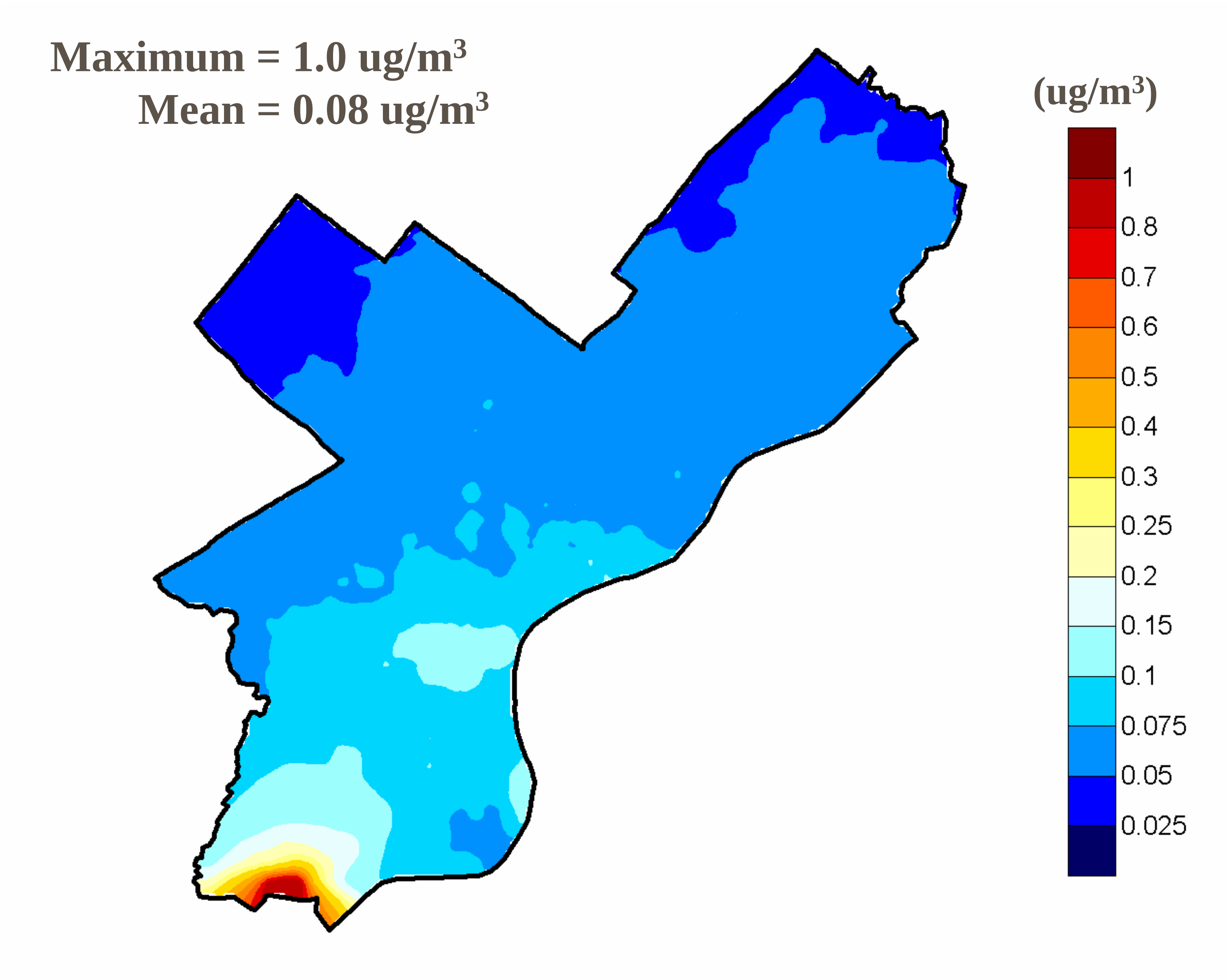
Maximum = 1.7 ug/m³
Mean = 0.5 ug/m³



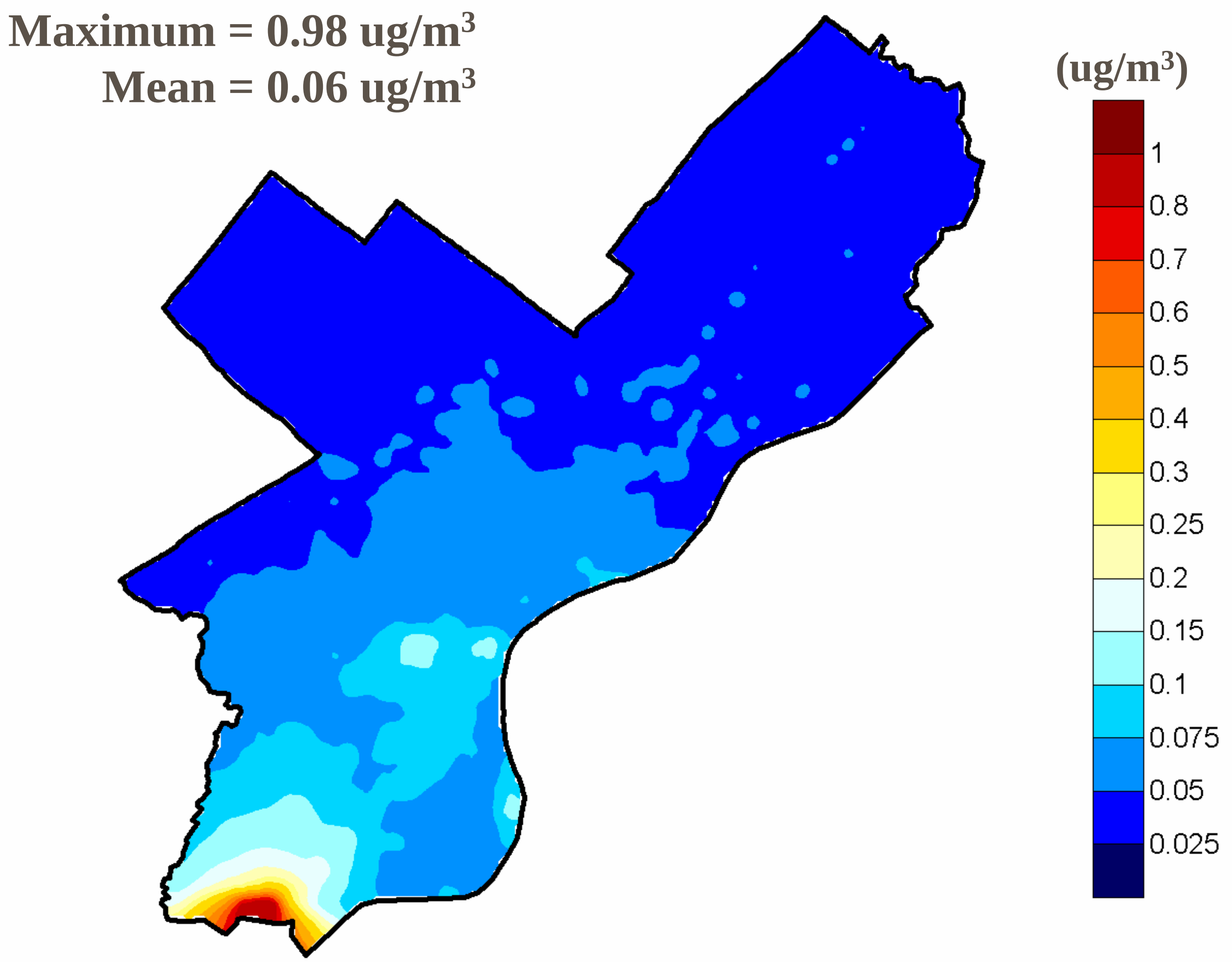
Benzene: Major Point



Acrolein: Primary + Secondary

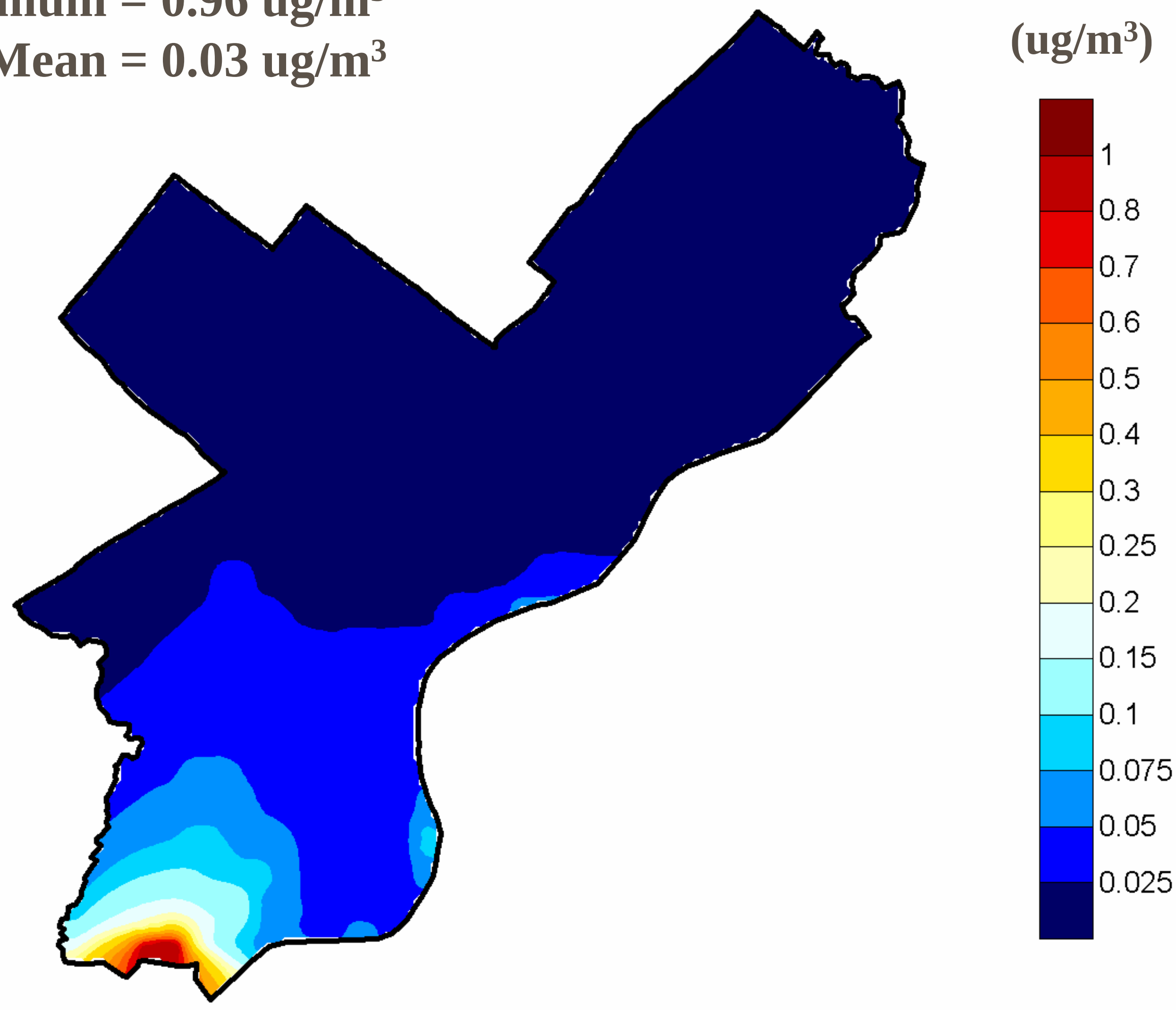


Acrolein: Primary Only



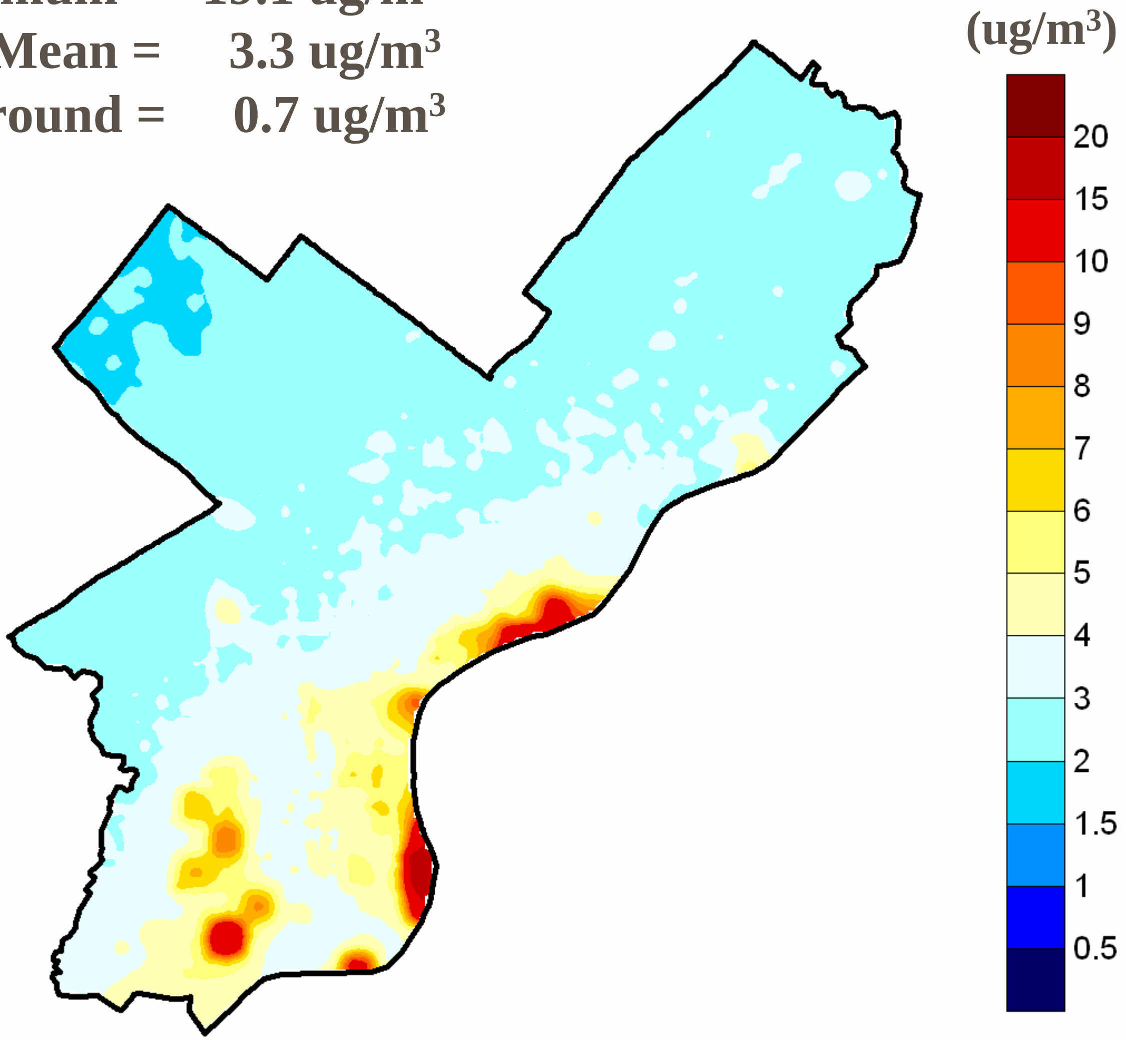
Acrolein: Non-Road Only

Maximum = 0.96 ug/m^3
Mean = 0.03 ug/m^3



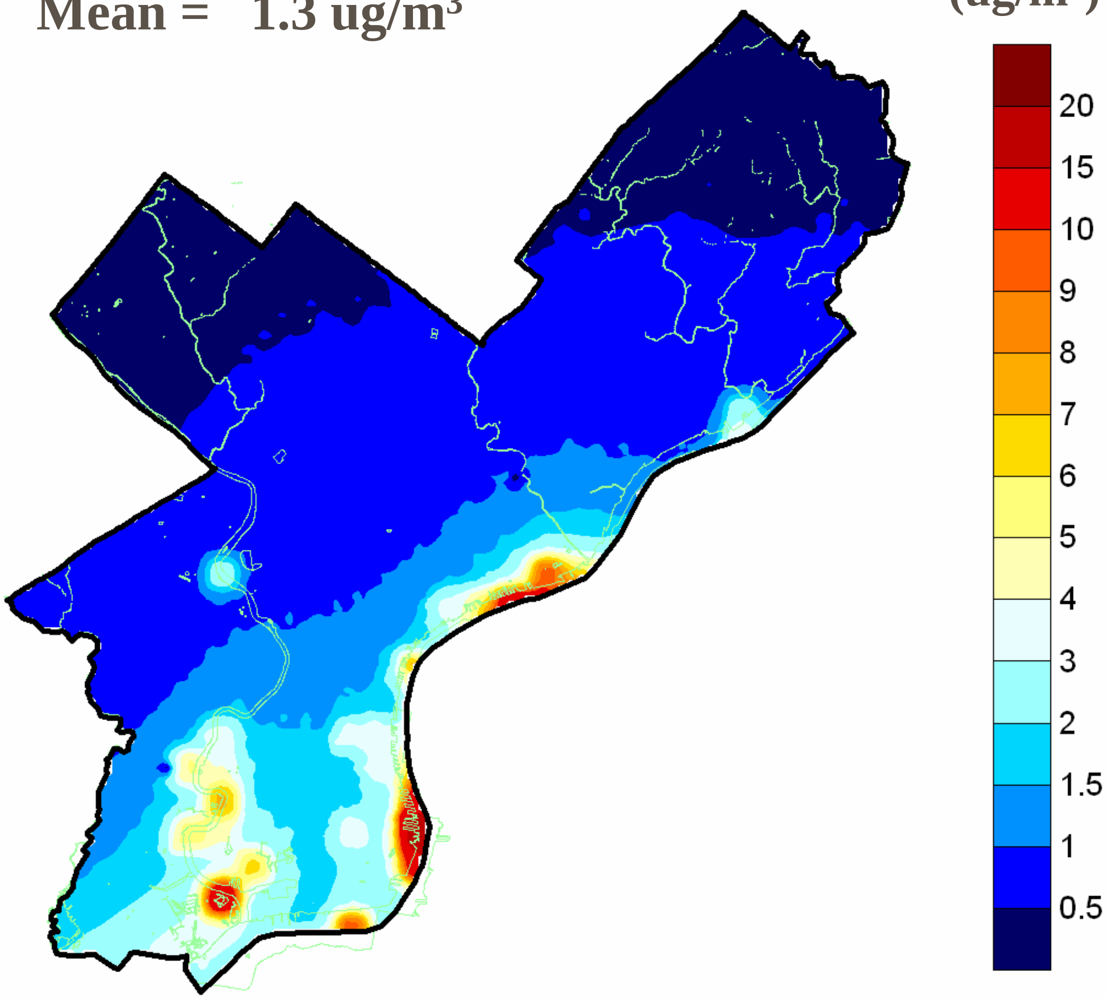
Diesel PM: Total Including Background

Maximum = 19.1 ug/m^3
Mean = 3.3 ug/m^3
Background = 0.7 ug/m^3



Diesel PM: Marine Component

Maximum = 17.2 ug/m^3
Mean = 1.3 ug/m^3



Conclusions – 2001 Runs

- Formaldehyde, benzene & acetaldehyde appear to present the greatest cancer risk (excluding diesel particles)
- The photochemically formed fractions are very significant especially for Formaldehyde – need a **one atmosphere** approach
- Benzene background is as large as its on-road & non-road components
- Acrolein is the only pollutant examined who's impact is above a hazard index = 1.0
- Secondary acrolein impacts are much less significant than originally thought (about 25%) w/ similar contributions from on-road and non-road components.
- Major impacts from Diesel PM due to marine activity
- The Philadelphia airport stands out as a significant non-road source for many toxics

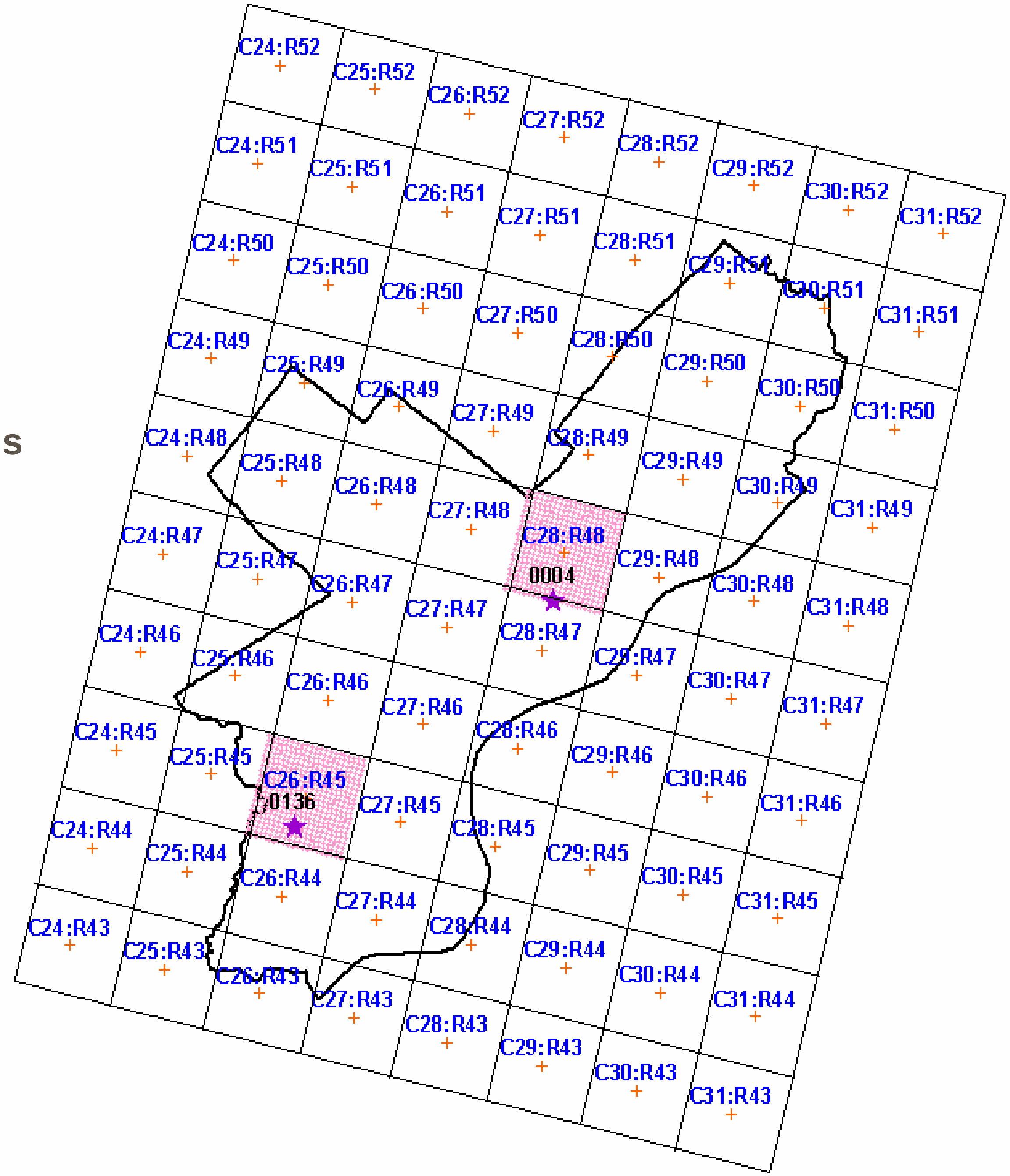
COMPARISONS

- CMAQ to ISC primary only
- NATA 1999 to ISCST 1999
- Grid modeling (w/sub-grid scale variability) to ISC + background / CMAQ secondaries
- Observations: 2001 data at one site

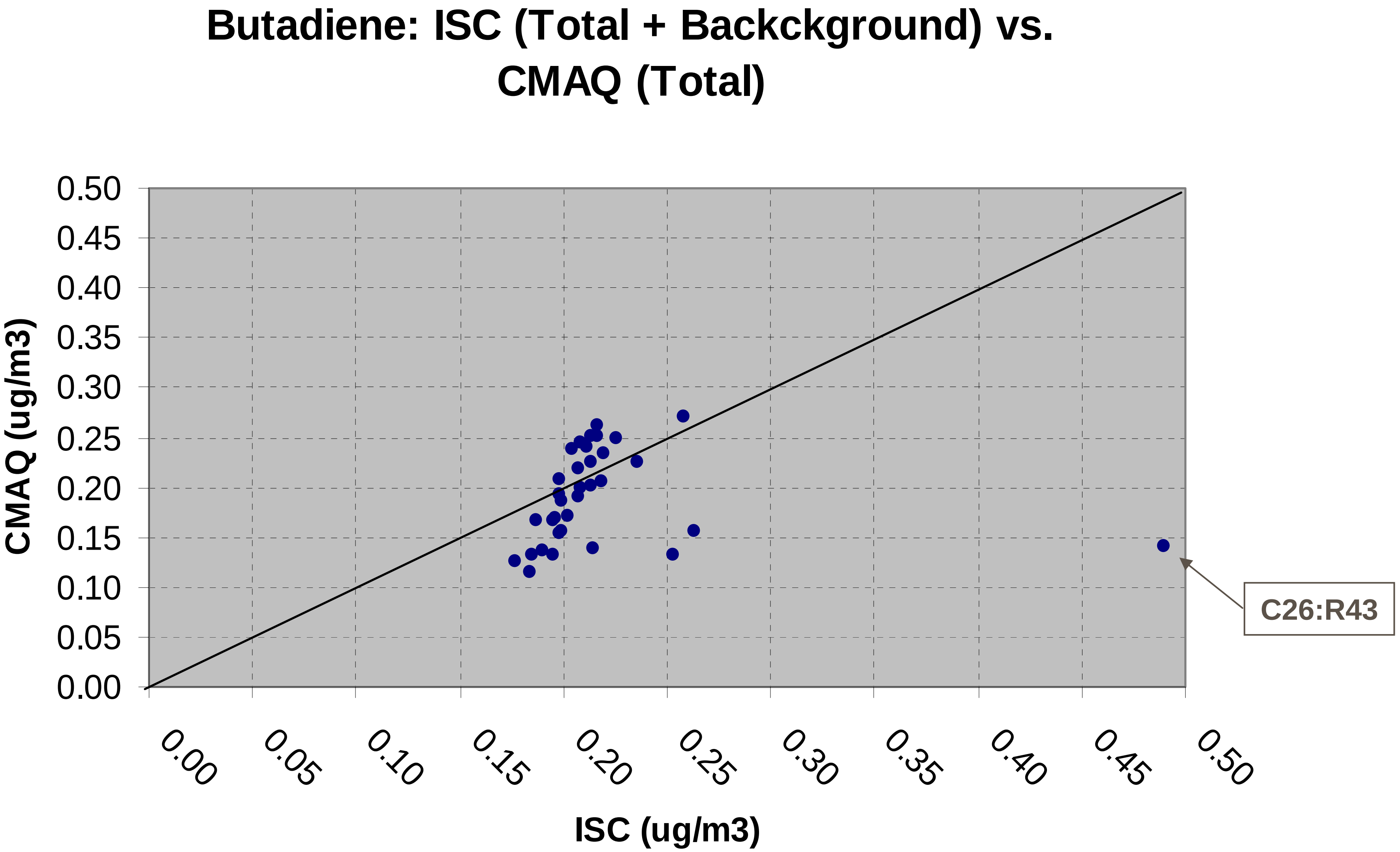
3-D 200m ISC Grid
In Two CMAQ Cells
Level 1: Ground
Level 2: 15m
Level 3: 30m

Total of 1323 receptors
In each of the 2 cells

Star = Monitor Locations



Each Philadelphia CMAQ Grid Cell Concentration
vs.
The Average of All ISC Concentrations in the Cell



Each Philadelphia CMAQ Grid Cell Concentration
vs.
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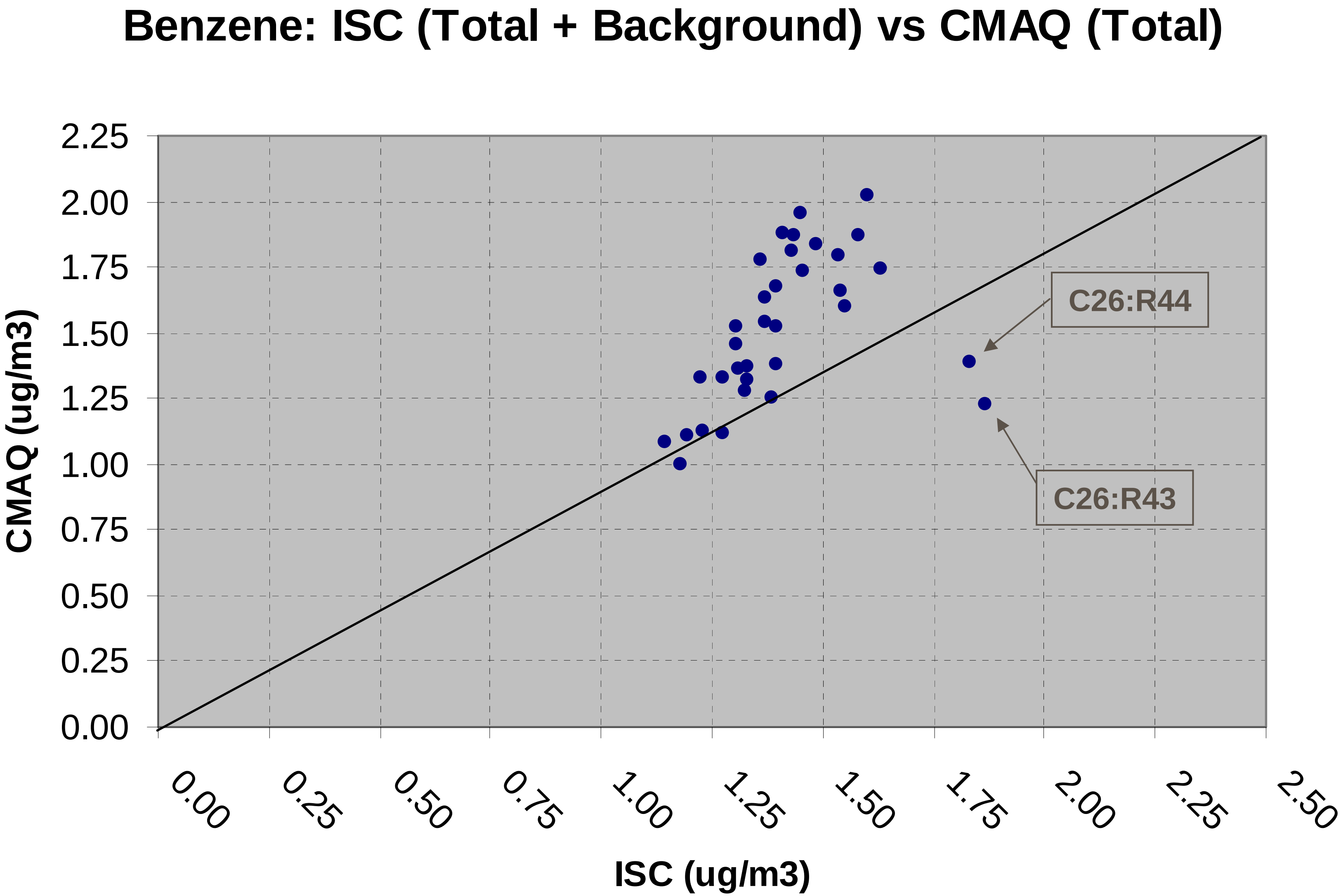

Each Philadelphia CMAQ Grid Cell Concentration
vs.
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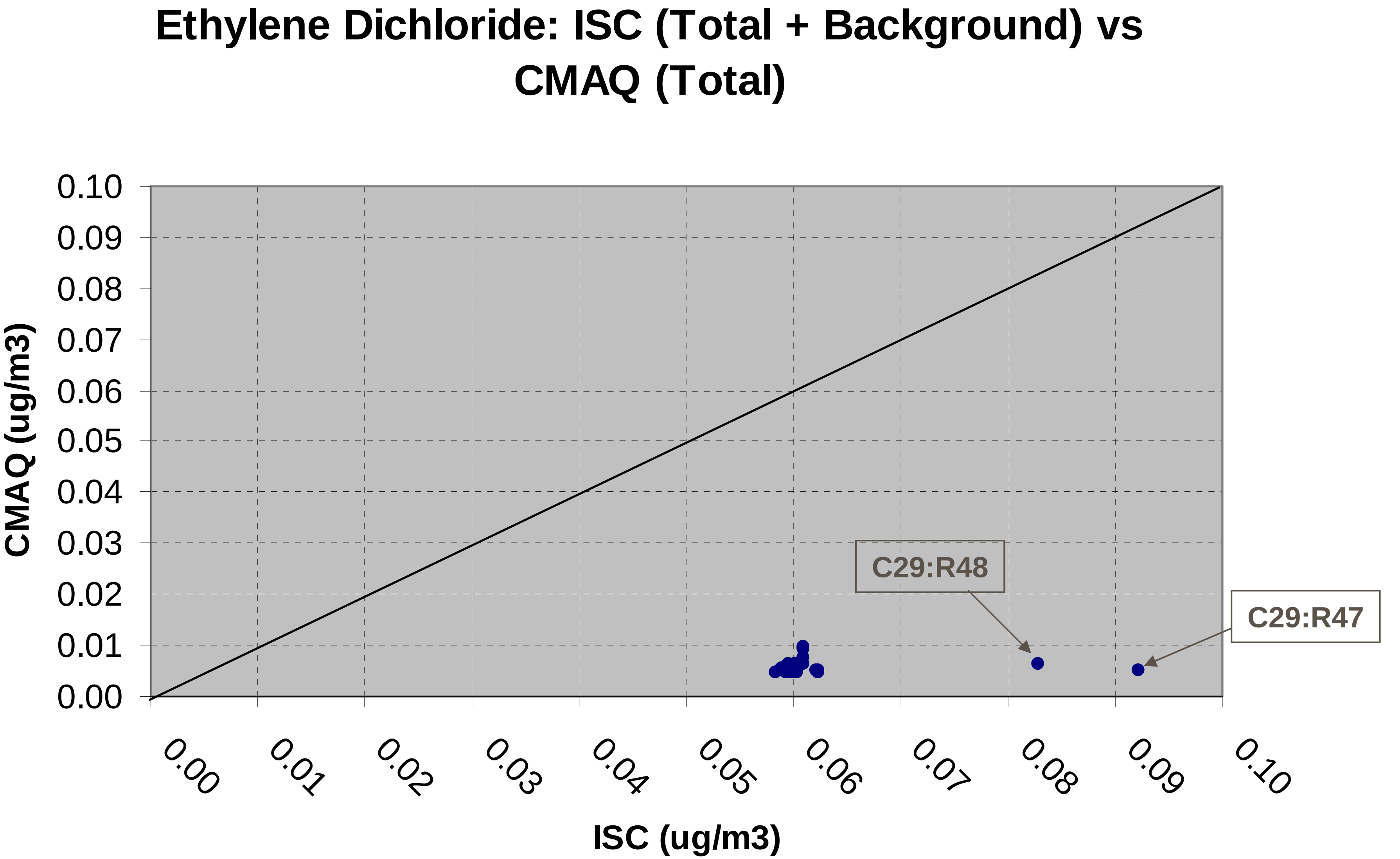
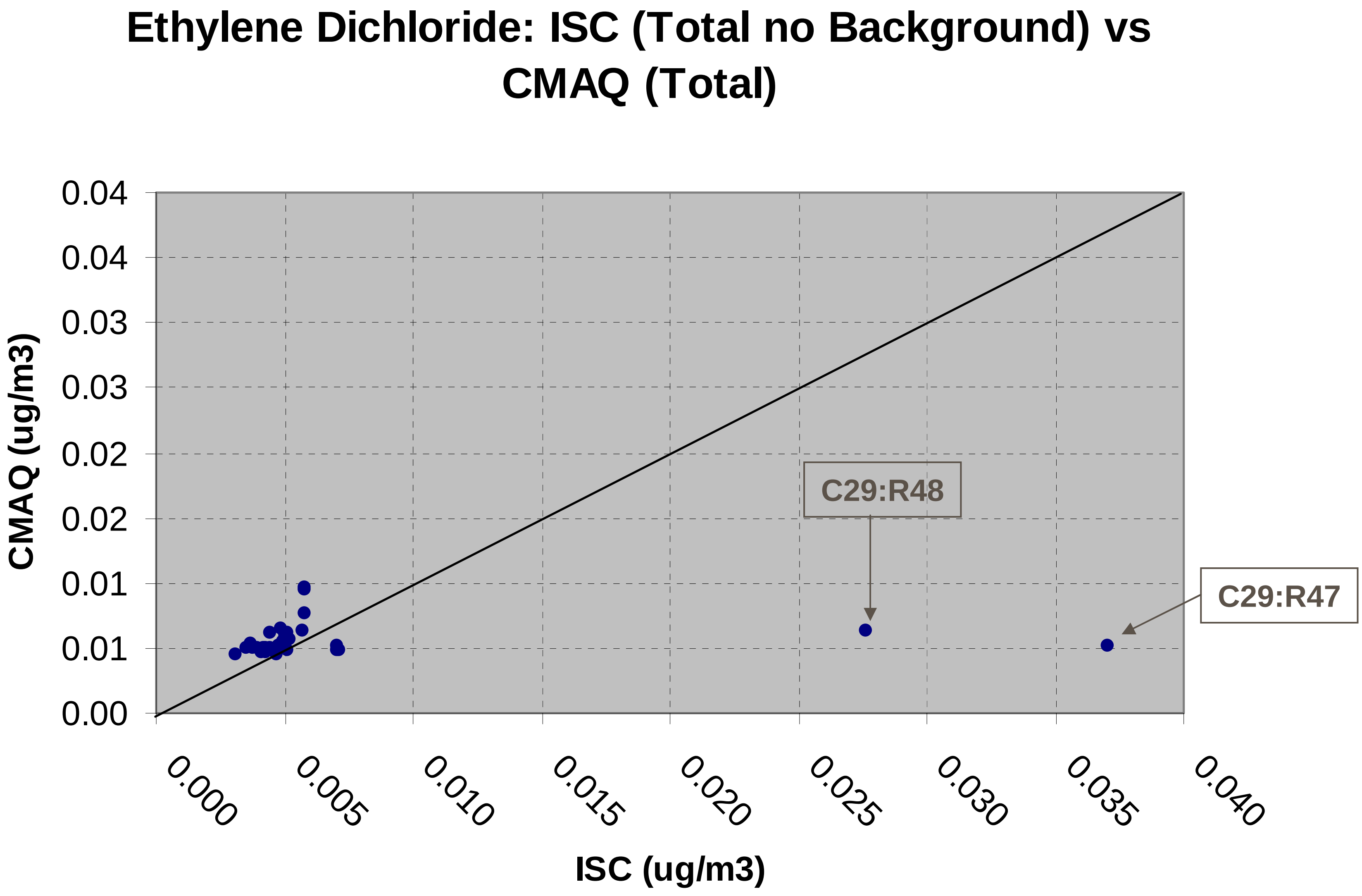


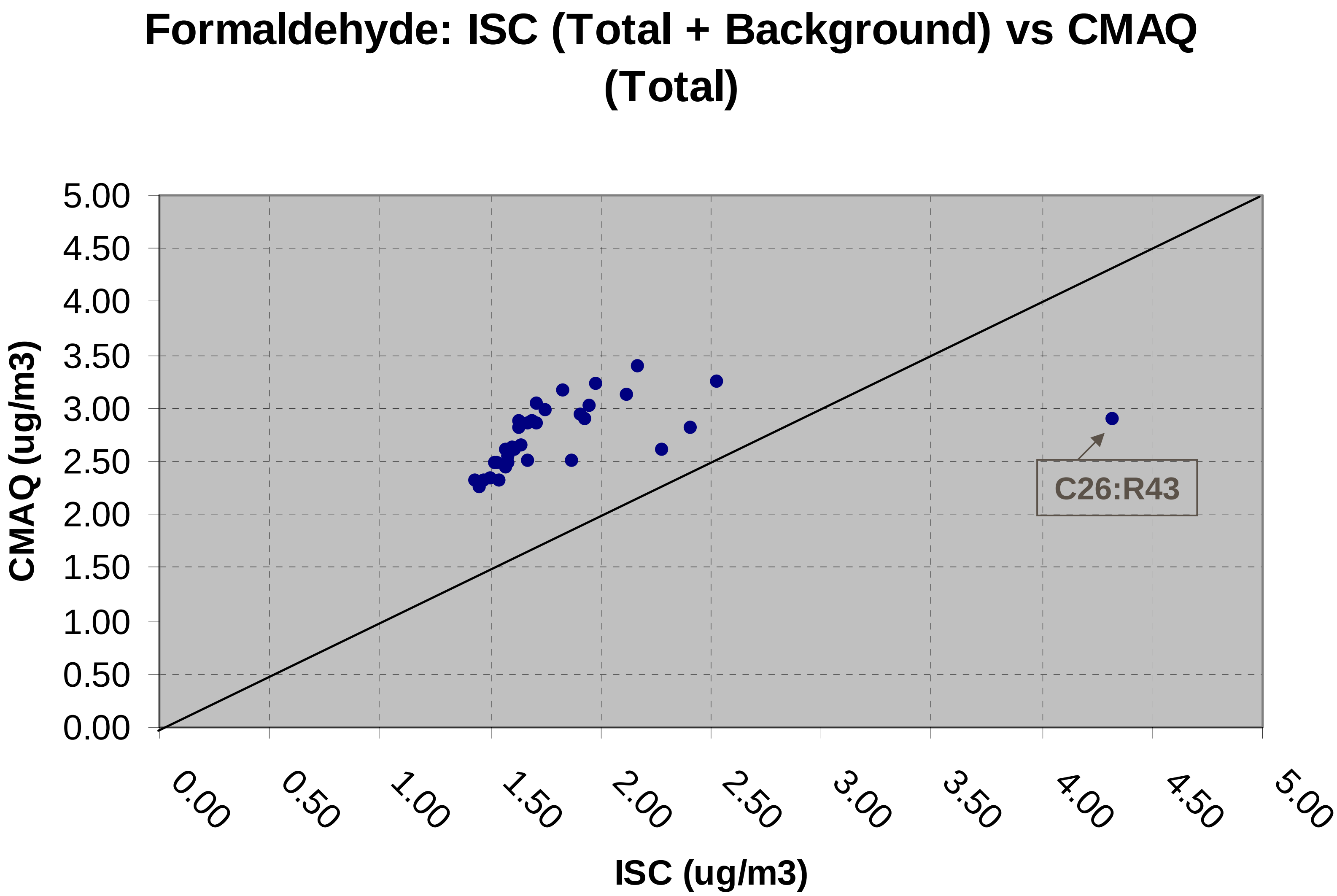
Each Philadelphia CMAQ Grid Cell Concentration
vs.
The Average of All ISC Concentrations in the Cell



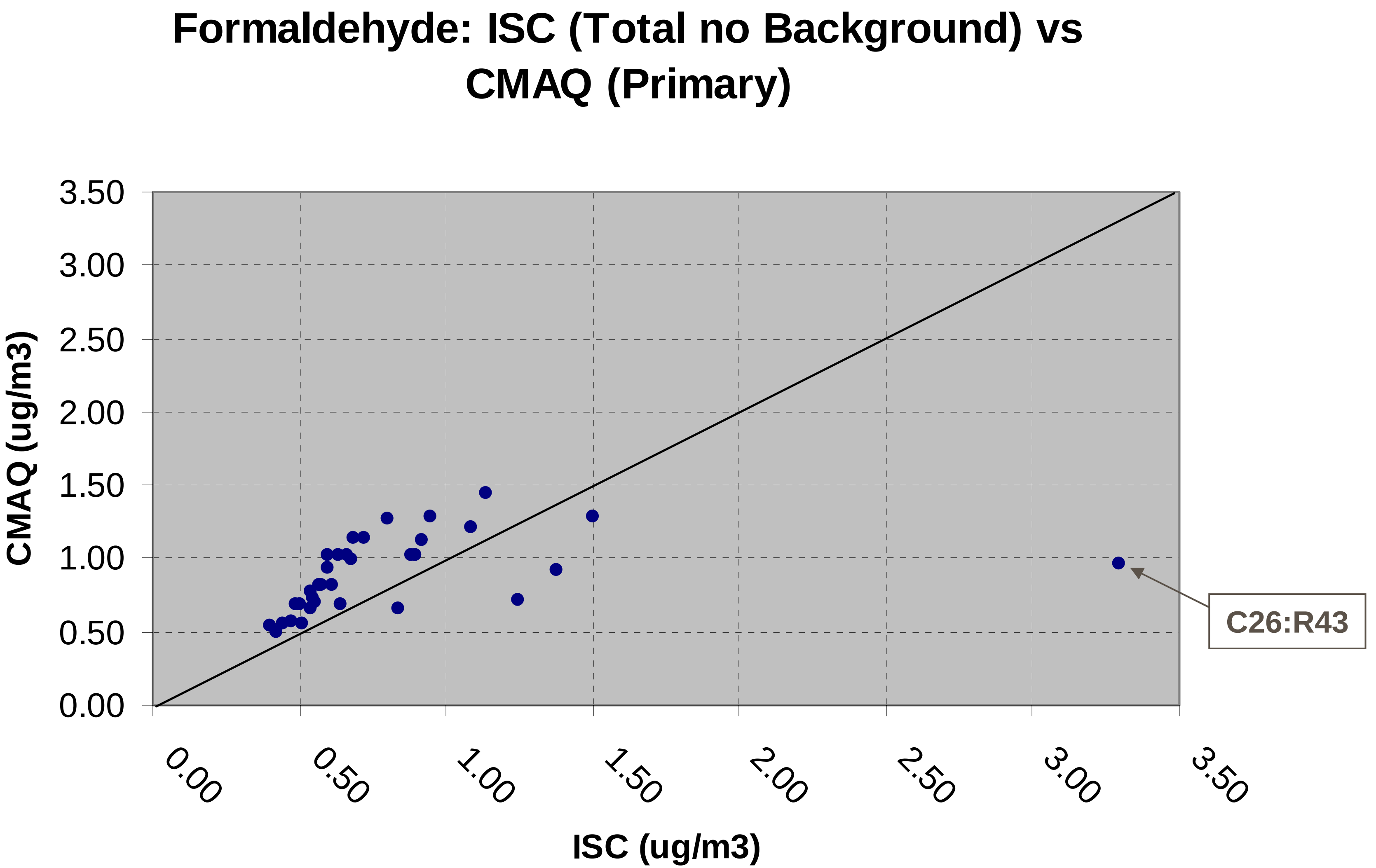
Each Philadelphia CMAQ Grid Cell Concentration

vs.

The Average of All ISC Concentrations in the Cell



Each Philadelphia CMAQ Grid Cell Concentration
vs.
The Average of All ISC Concentrations in the Cell



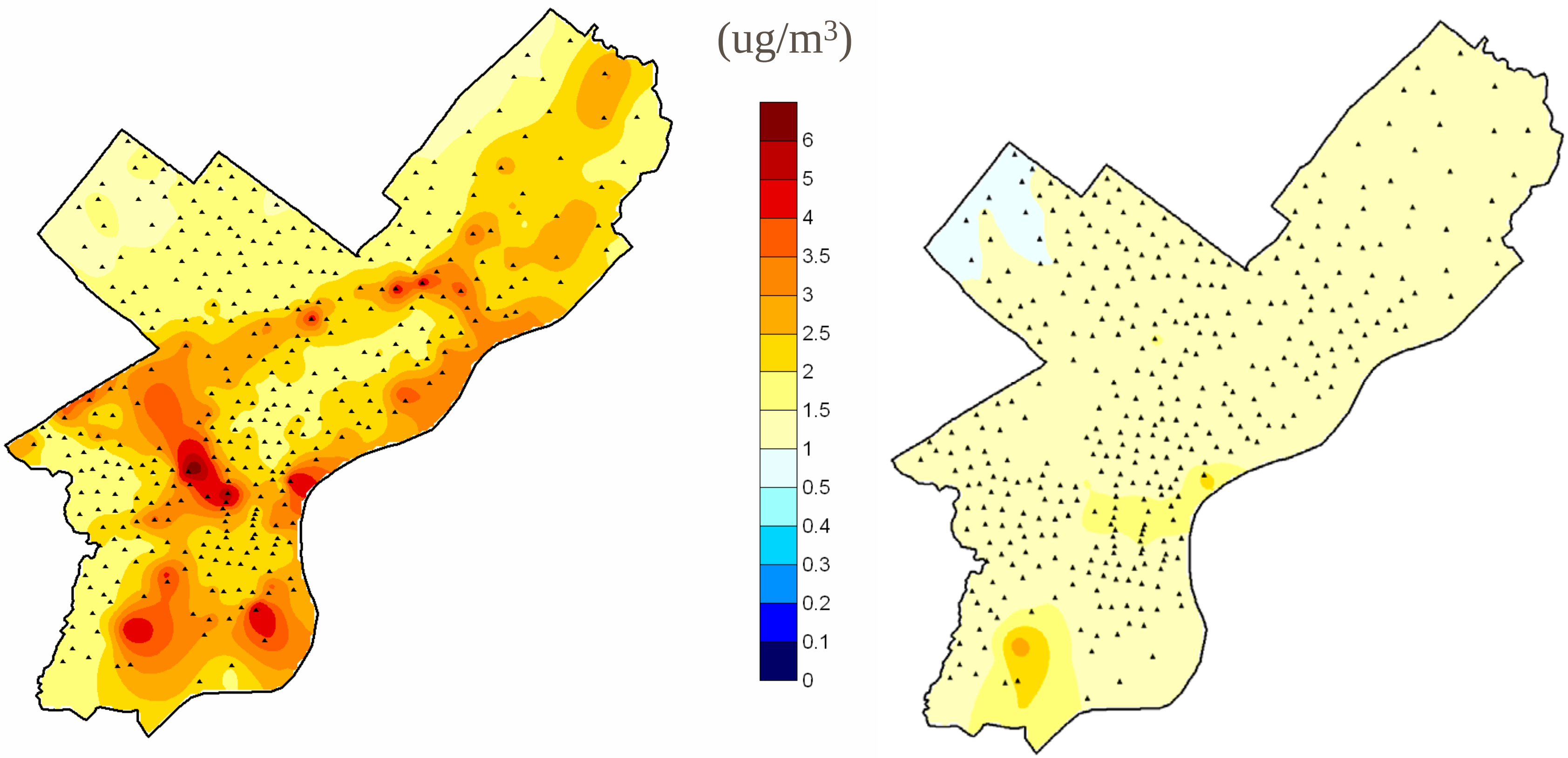
Comparison: NATA to ISCST

- For comparison purposes:
  - Secondary formation not considered
  - Centroids only
  - 1999 meteorology
- Pollutants:
  - Benzene
  - Formaldehyde
  - Diesel PM
- Total Impacts
- On-Road Impacts

Benzene: NATA 1999 vs. ISCST 1999 w/ Link Based On-Road Emissions (Centroids Only)

NATA: Max = 6.3 ug/m^3
Mean = 2.3 ug/m^3

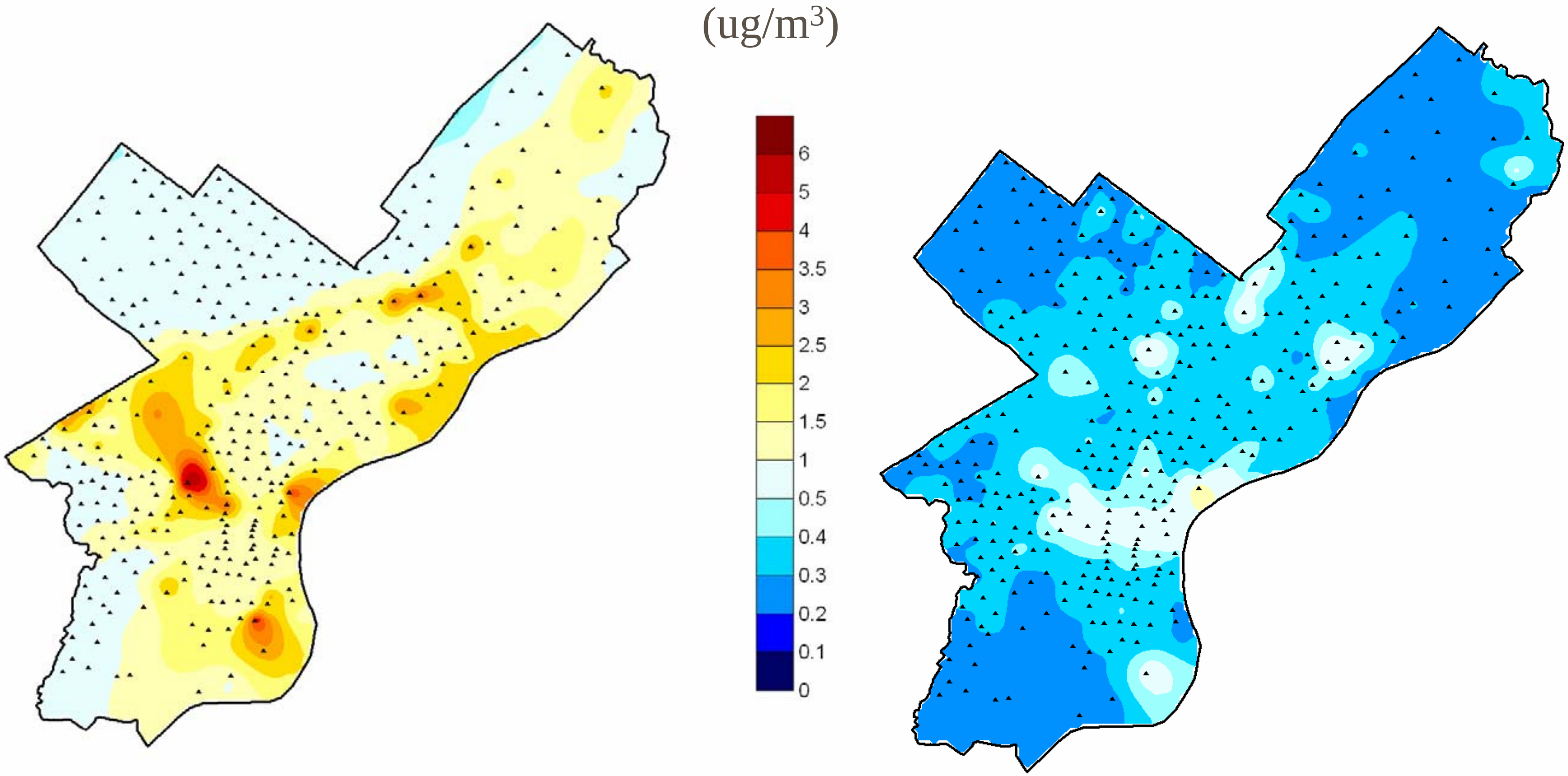
ISCST: Max = 2.8 ug/m^3
Mean = 1.9 ug/m^3



Benzene: NATA 1999 On Road vs. ISCST 1999 On Road (Centroids Only)

NATA – On Road
Total Q = 468 T/yr

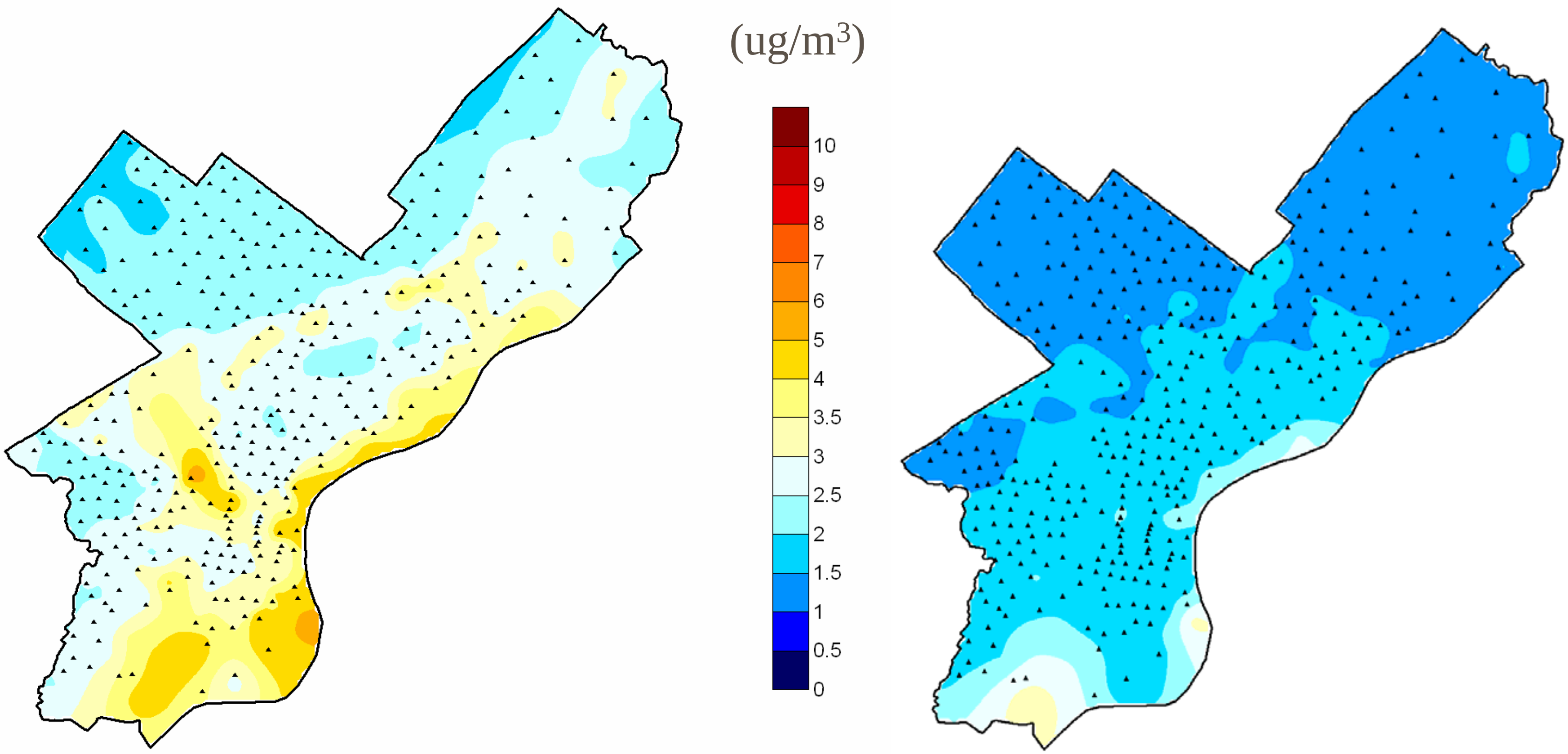
Link Based – On Road
Total Q = 170 T/yr



Formaldehyde: NATA 1999 vs. ISCST 1999 w/ Link Based On-Road Emissions (Centroids Only)

NATA: Max = 5.6 ug/m^3
Mean = 2.8 ug/m^3

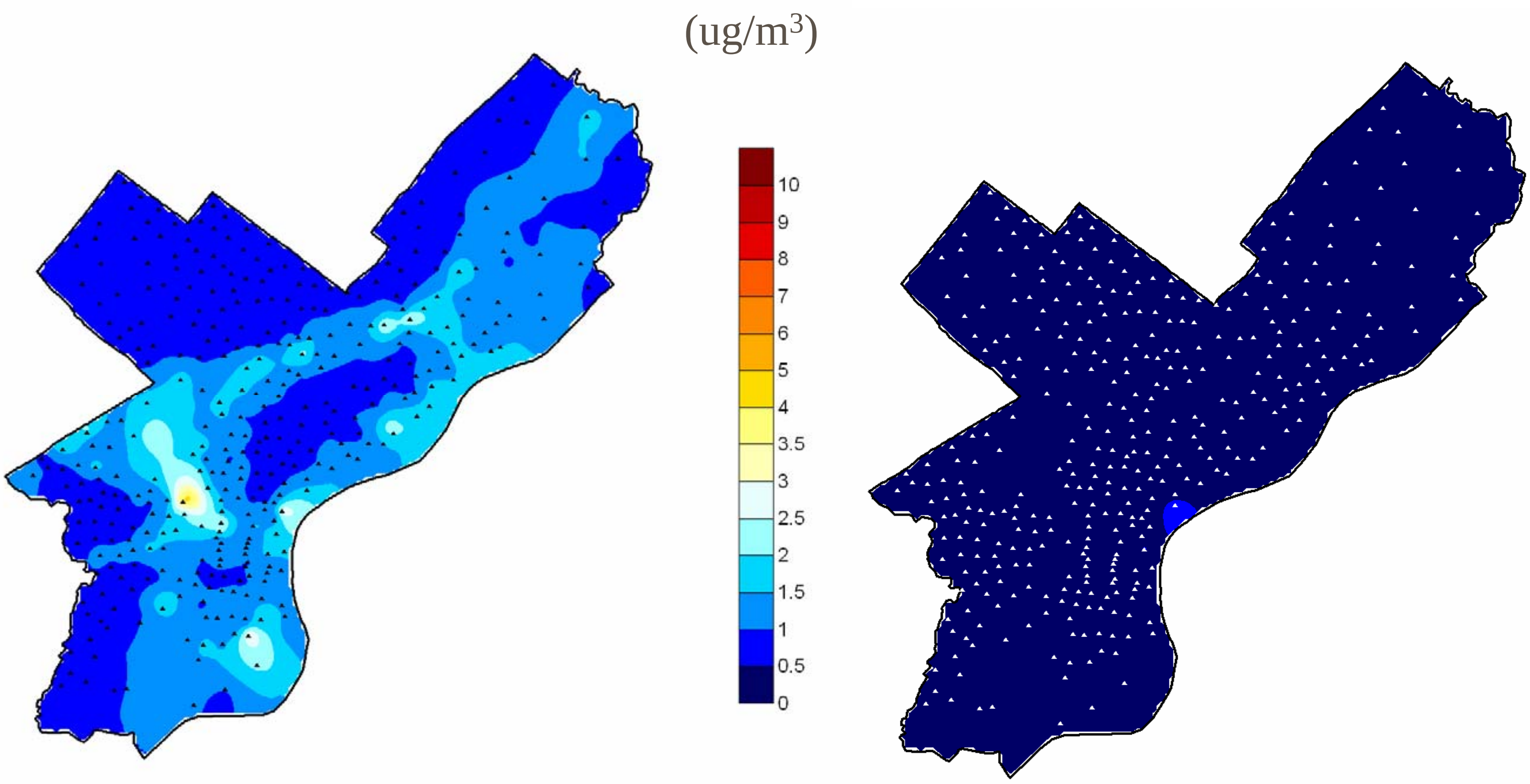
ISCST: Max = 3.4 ug/m^3
Mean = 1.6 ug/m^3



Formaldehyde: NATA 1999 On Road vs. ISCST 1999 On Road (Centroids Only)

NATA – On Road
Total Q = 305 T/yr

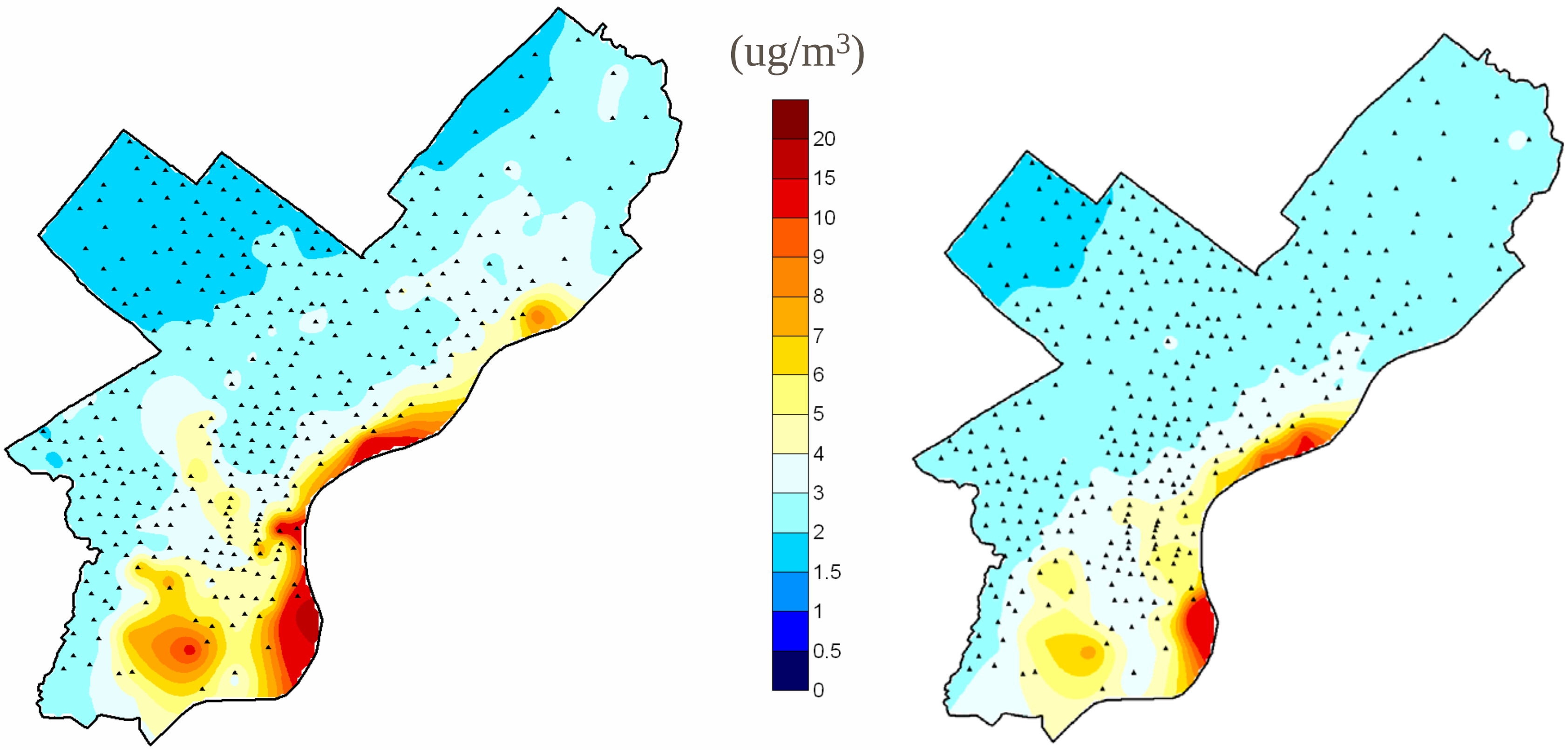
Link Based – On Road
Total Q = 102 T/yr



Diesel PM: NATA 1999 vs. ISCST 1999 w/ Link Based On-Road Emissions (Centroids Only)

NATA: Max = 17.9 ug/m^3
Mean = 3.4 ug/m^3

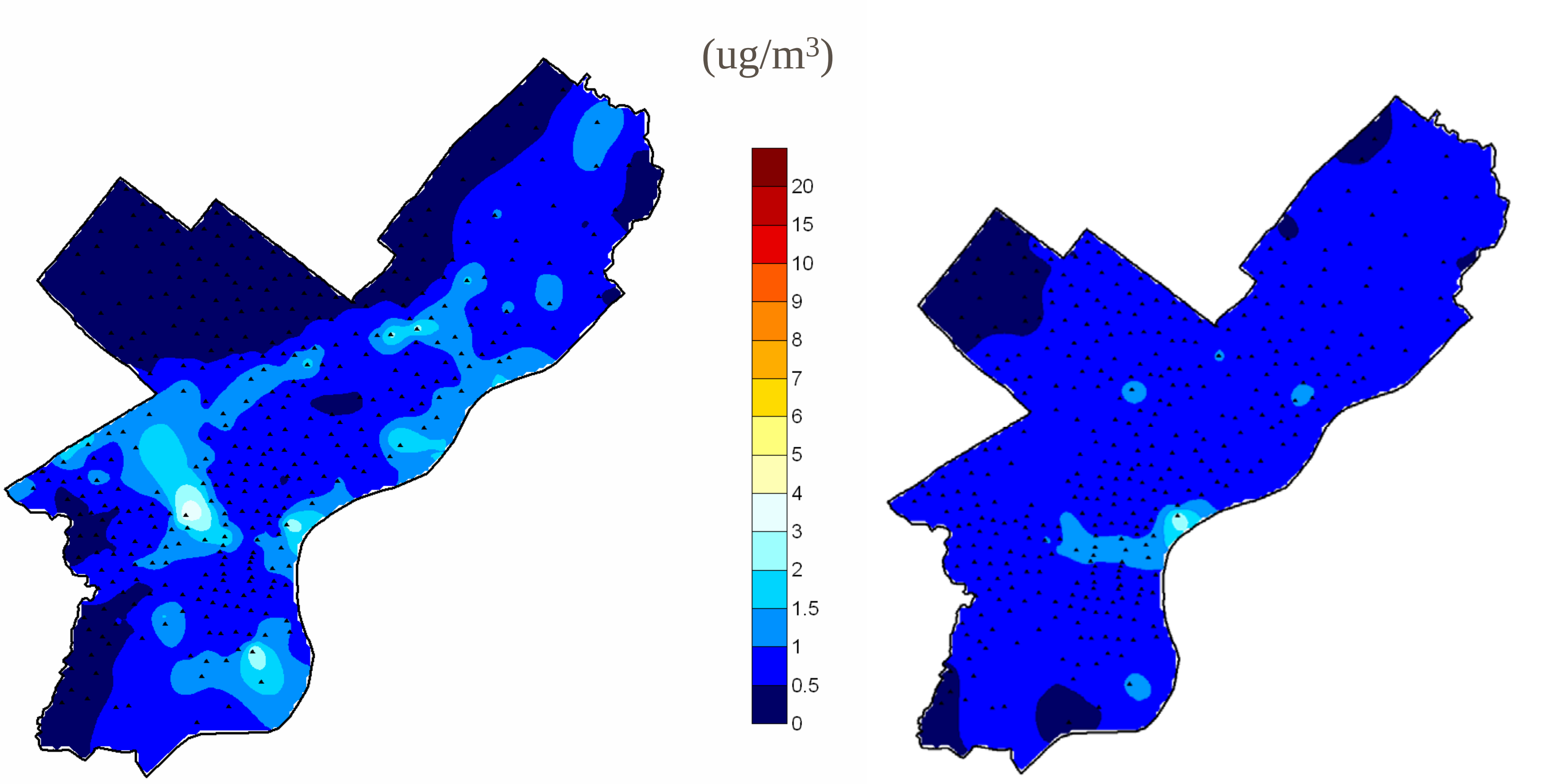
ISCST: Max = 15.0 ug/m^3
Mean = 3.1 ug/m^3



Diesel PM: NATA 1999 On Road vs. ISCST 1999 On Road (Centroids Only)

NATA – On Road
Total Q = 356 T/yr

Link Based – On Road
Total Q = 222 T/yr



Comparison: ISC vs. CMAQ (w/ sub-grid scale variability)

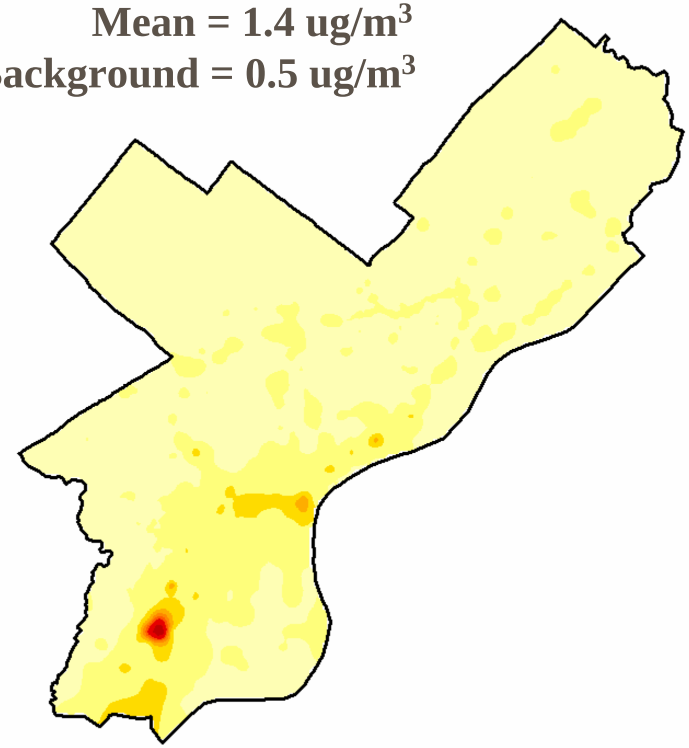
- CMAQ + ISC defined sub-grid variability:

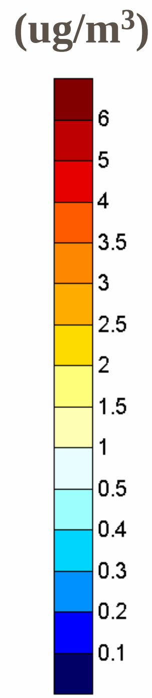
  $C_{\text{sub-Grid}} = C_{\text{CMAQ}} + C_{\text{ISC}} - [C_{\text{ISC}}]_{\text{AVG}}$
- Benzene:
  - C_{ISC} does not include background
  - Compare $C_{\text{sub-Grid}}$ with $C_{\text{ISC + Back}}$
  - $C_{\text{sub-Grid}}$ is tantamount to replacing measured background with CMAQ estimate
- Formaldehyde:
  - C_{ISC} does not include secondary component
  - Compare $C_{\text{sub-Grid}}$ with $C_{\text{ISC + CMAQ secondary}}$
  - $C_{\text{sub-Grid}}$ can be thought of as an alternative method of combining primary estimates from ISC with secondary estimates from CMAQ without having to partition CMAQ estimates into primary and secondary components.

Benzene: Sub-grid Scale Comparison

ISC + Background

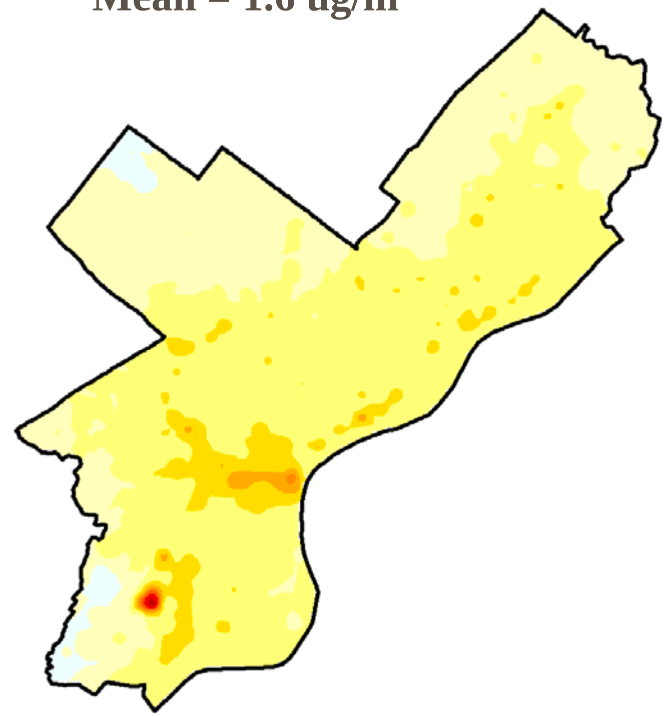
Maximum = 6.0 ug/m^3
Mean = 1.4 ug/m^3
Background = 0.5 ug/m^3





$C_{sub\text{-}Grid}$

Maximum = 5.56 ug/m^3
Mean = 1.6 ug/m^3



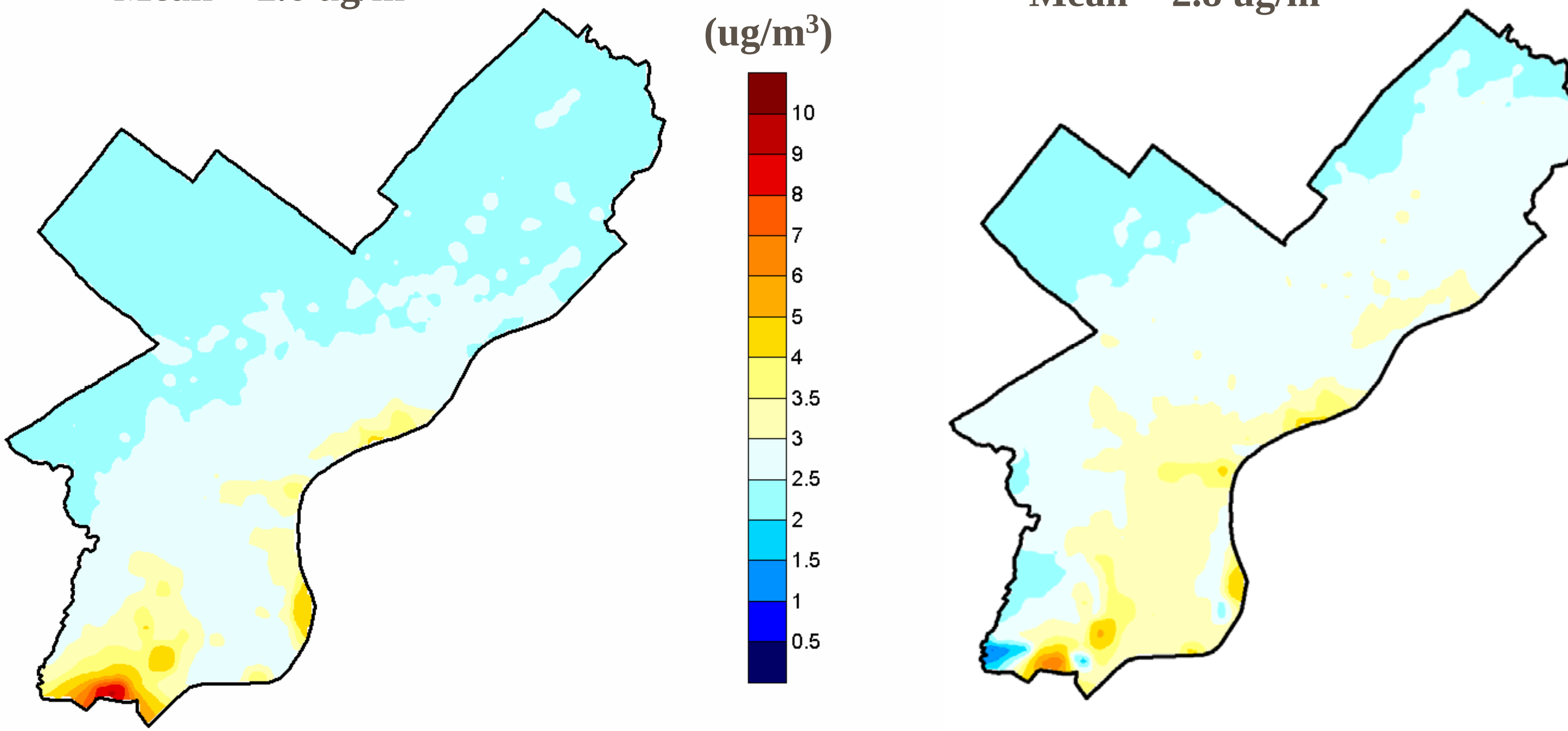
Formaldehyde: Sub-grid Scale Comparison

ISC + $CMAQ_{secondary}$

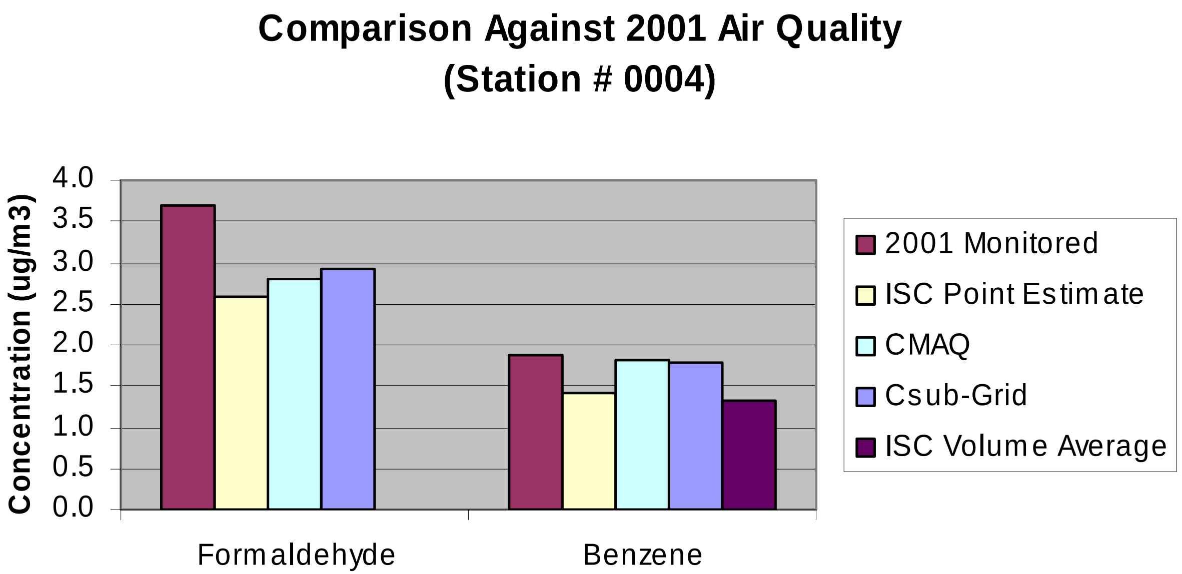
Maximum = 9.1 ug/m^3
Mean = 2.6 ug/m^3

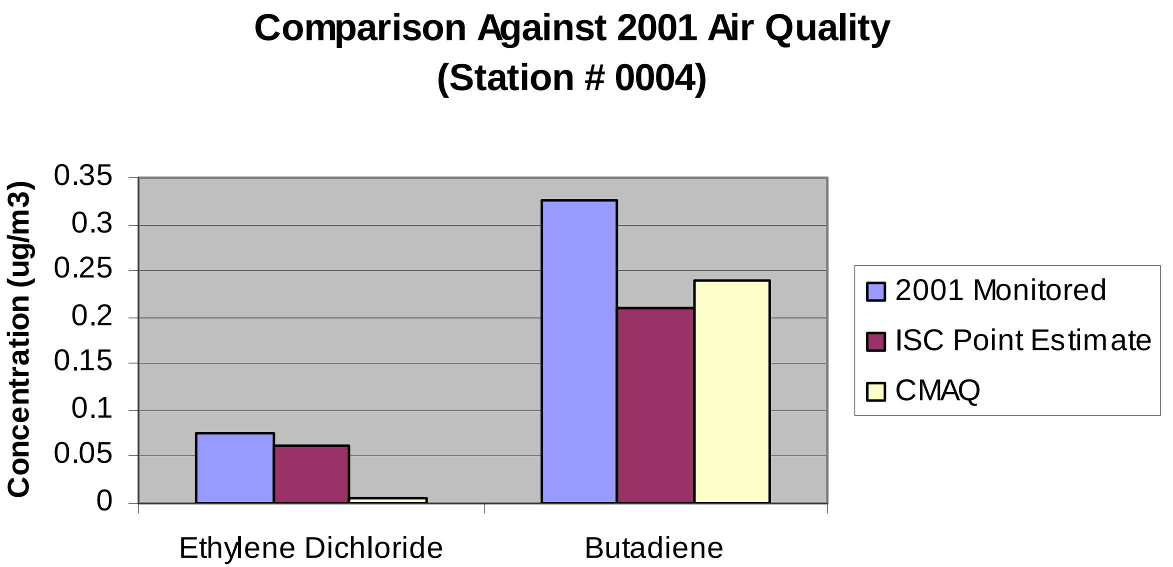
$C_{sub\text{-}Grid}$

Maximum = 6.5 ug/m^3
Mean = 2.8 ug/m^3



Model Comparisons with Monitor Data from Station # 0004





Conclusions: Comparisons

- NATA on-road impacts for all pollutants are significantly larger than our findings – REASONS:
  - **NEI VMT is 2x larger (starting from traffic demand modeling)**
  - **NEI emissions are > 2x larger**
  - **NATA (ASPEN): Within each census tract, on-road emissions are modeled as five separate point sources**
- CMAQ at 4kms compares well with ISC cell-wide averages – poorest comparisons occur in cells with greatest d**P**/dx and/or poor spatial coverage (few receptors)
- NATA compares reasonably well for all source groups except on-road
- Adding ISC defined sub-grid scale variability to CMAQ estimates, appears to produce reasonable results
- 2001 predictions compare well with monitoring site

Next Steps: Control Strategy Analysis

- Funding through a RARE
- Identify the importance of specific VOCs to each secondary pollutant
- Identify the sources that emit the important precursor VOCs
- Perform culpability analysis for primary pollutant emitters
- Develop a set of potential control scenarios
- For each control scenario estimate the ambient concentrations of the important toxic pollutants plus **Ozone and PM 2.5** (one atmosphere approach)
- Establish criteria for deciding on most effective control strategy
  - Environmental: Based on pollutant impacts and risk indicators
  - Social-Economic: e.g., control costs, ease of enforcement, etc.
- Evaluate decision options using MIRA