THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

A Modeling Framework for Improved Characterization of Near-Road Air Quality at Fine Scales for Nationwide Exposure Assessment

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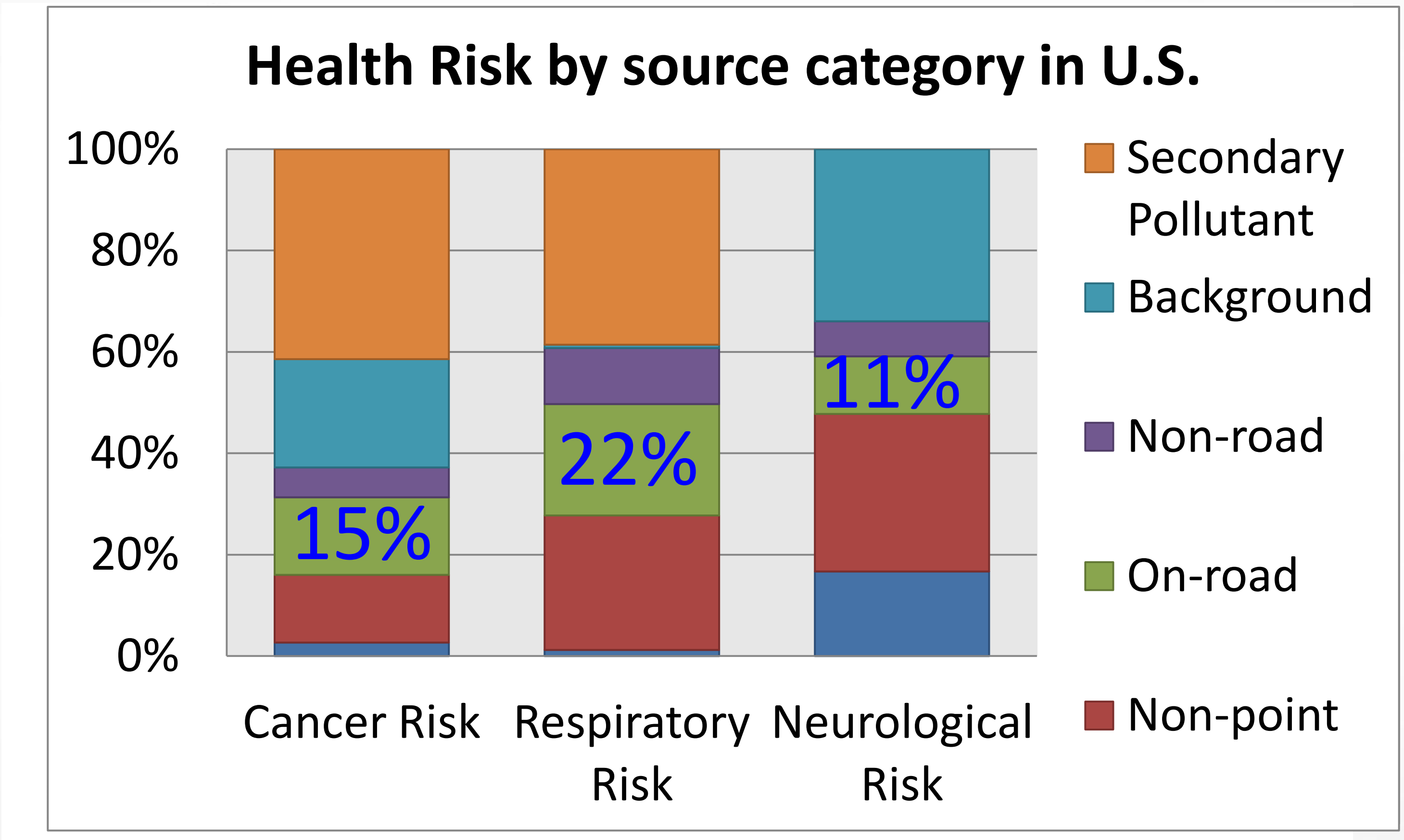
Introduction

- The importance of on-road emission source



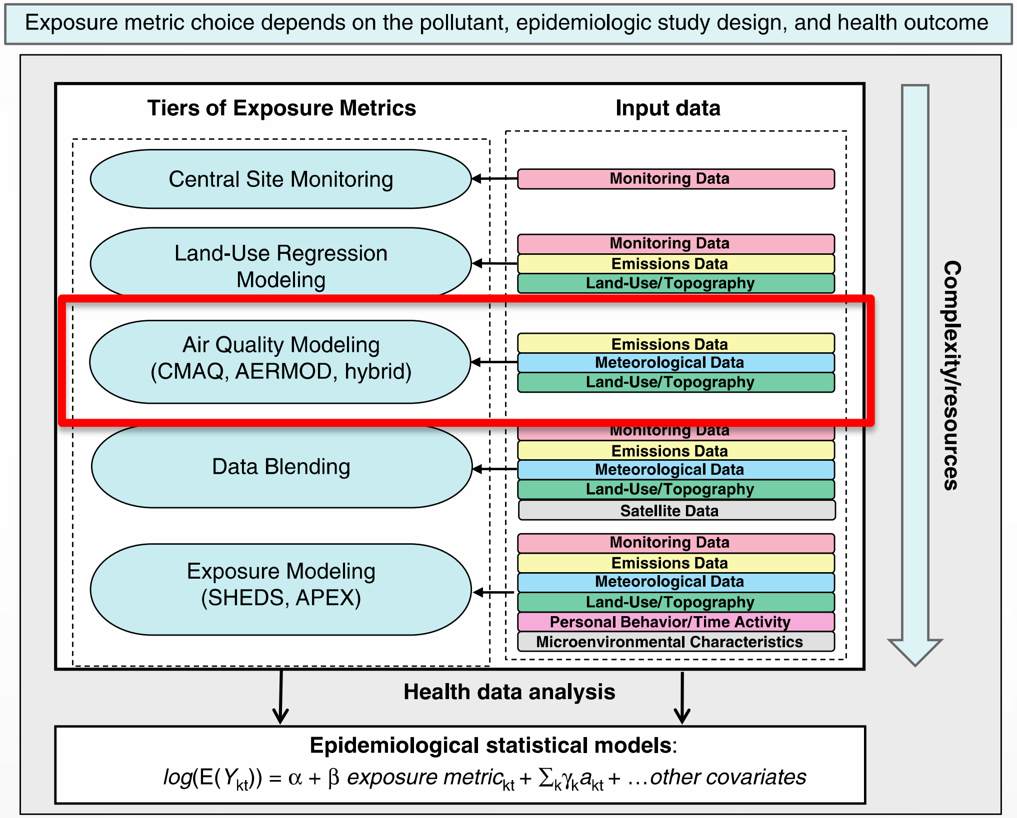
Source: EPA National-Scale Air Toxicity Assessment (NATA) 2005

Source: EPA National Emission Inventory, 2013

Source: Rowangould, *Transport Research Part D*, 2013

Scientists want to

- Characterize the relationship between on-road air pollutant and health



Ozkaynak et. al. *JESEE* 2013

Objective

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- Provide fine-scale on-road traffic-related air quality fields to support exposure assessment study nationwide (8.2 million census blocks)
  - A concentration map with detailed spatio-temporal characterization.
- Develop approach to speed up the modeling process without sacrificing too much accuracy
- Evaluate the approach at Cumberland County, Maine in 2010 and the North Carolina Piedmont from 2009 to 2011

Methodology

on-road

- Step 1: RLINE with Annual Average Daily Traffic (AADT) and STability ARray (RLINE-AADT-STAR)
- Step 2: Spatio-Temporal Ordinary Kriging (STOK)

background

- Step 3: Hybrid for total concentration

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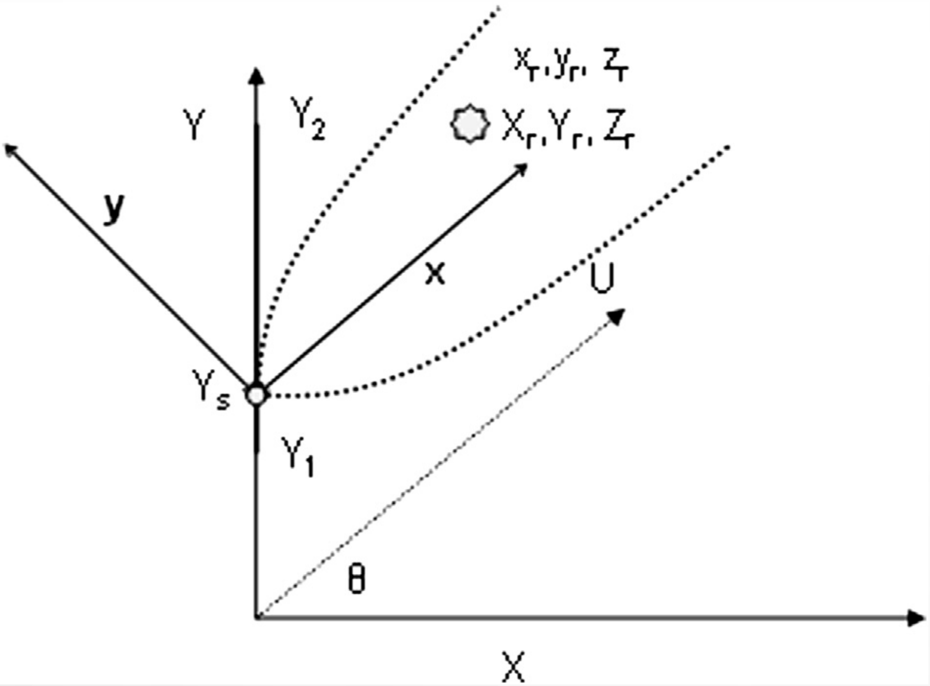
RLINE

- RLINE (Research LINE source model)
  - Dispersion model for treating on-road emissions as line sources
  - Source-receptor model



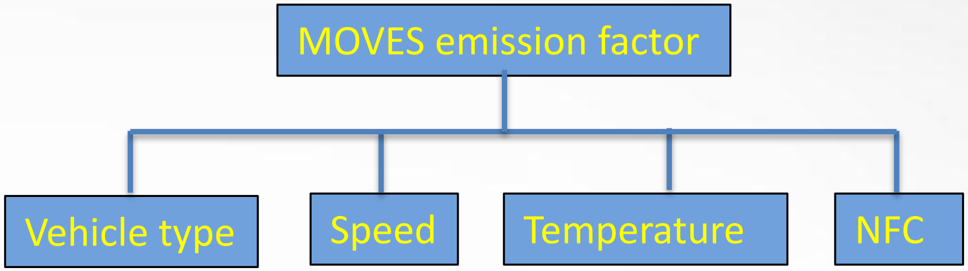
$$dC_{pl} = \frac{q\,dY_s}{U_e}\left[\mathrm{VERT}\cdot\mathrm{HORZ}_{pl}\right]$$

$$\mathrm{VERT} = \frac{1}{\sqrt{2\pi}\sigma_z}\cdot\left[\exp\left(-\frac{1}{2}\left(\frac{z_s - z_r}{\sigma_z}\right)^2\right) + \exp\left(-\frac{1}{2}\left(\frac{z_s + z_r}{\sigma_z}\right)^2\right)\right]$$

$$\mathrm{HORZ}_{pl} = \frac{1}{\sqrt{2\pi}\sigma_y}\exp\left(-\frac{1}{2}\left(\frac{y_r - y_s}{\sigma_y}\right)^2\right)$$

Snyder et. al. 2013

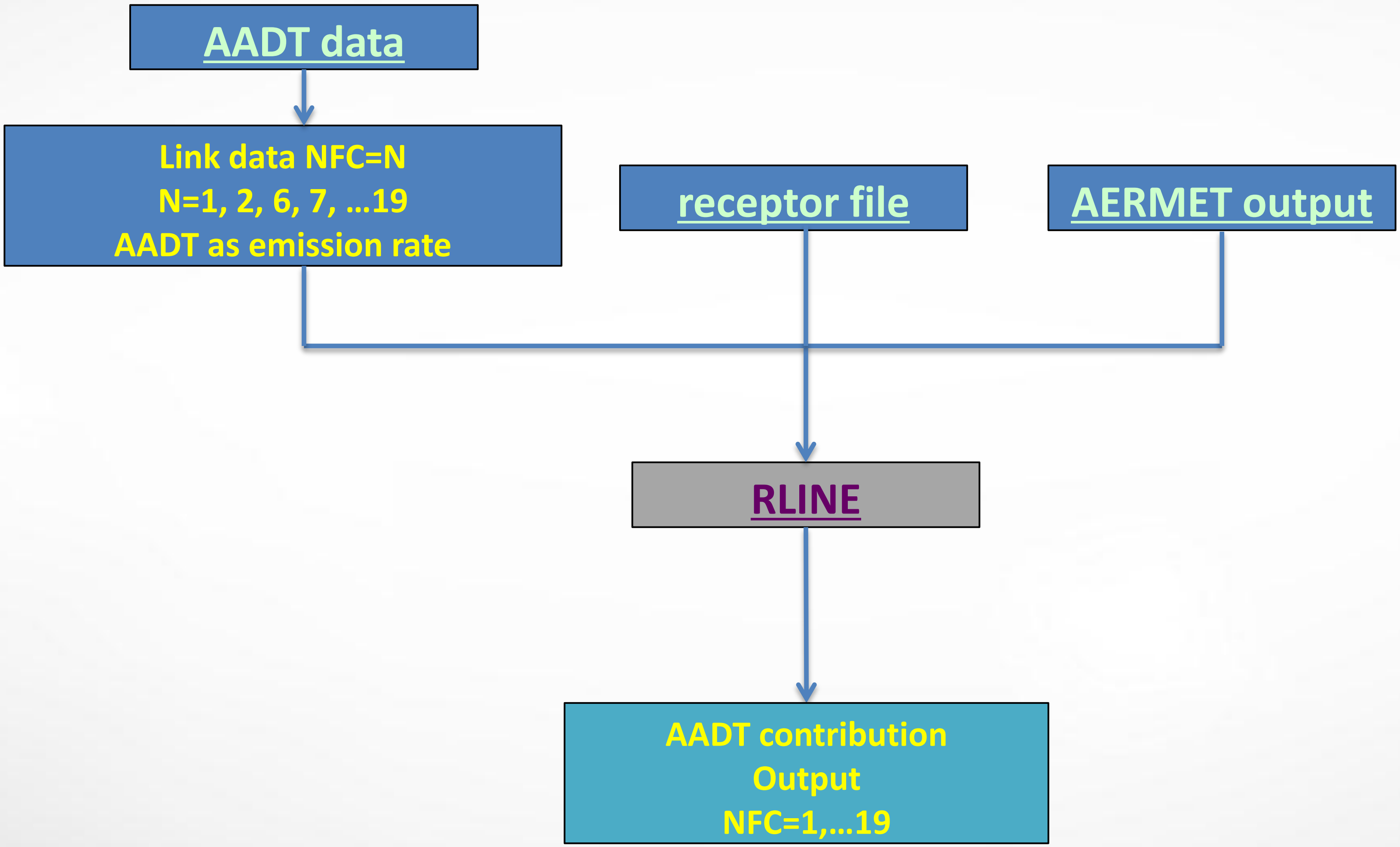
Develop emission inputs



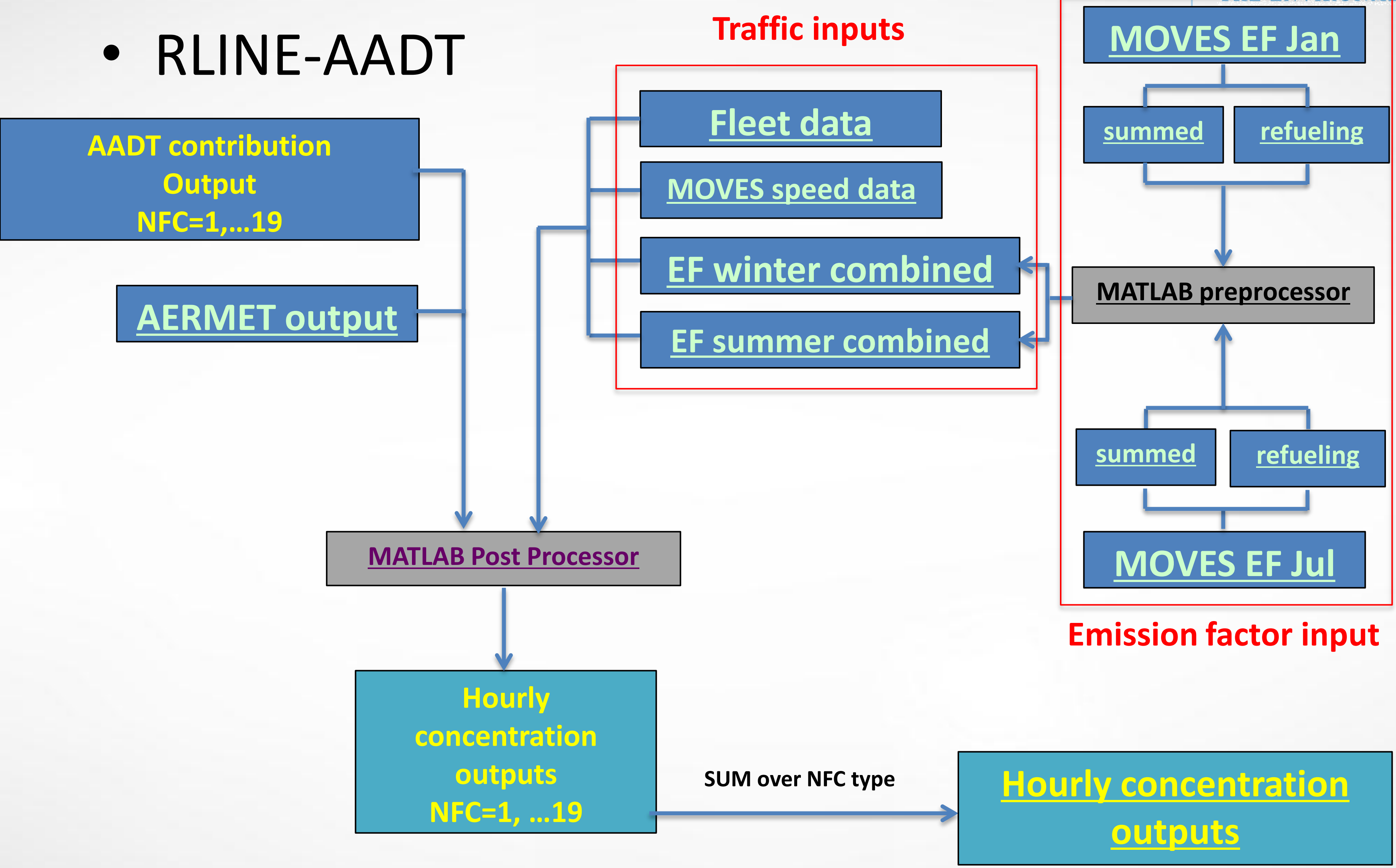
- **Speed**
  - MOVES input data
- **Vehicle Type**
  - 8 types:
    - LDGV, LDGT 1, LDGT 2, HDGV, LDDV, LDDT, HDDV, MC
    - Table VM-4 from the FHWA Statistics Series convert with EPA Emission Inventory Improvement Program
- ***Road Type**
  - 12 national function class (NFC) types:
    - Rural Interstate, Rural Principal Arterial, Rural Minor Arterial, Rural Major Collector, Rural Minor Collector, Rural Local, Urban Interstate, Urban Freeway, Urban Principal Arterial, Urban Minor Arterial, Urban Collector, Urban Local
- ***Traffic Count**
  - Annual Average Daily Traffic (AADT)
- **Temperature**
  - Temperature bins in Summer and Winter
  - Map with AERMET output from 824 National Weather Service (NWS) sites in the U.S.

* from Freight Analysis Framework (FAF3), Federal HighWay Administration (FHWA)

Run RLINE with AADT as inputs



- RLINE-AADT



$$[Concentration] = \Sigma_{i=vehicle(1)}^{i=vehicle(8)}[AADT\ contribution]_i \times [emission\ factor]_i$$

$$[Emission\ rate] = \Sigma_{i=vehicle(1)}^{i=vehicle(8)}[AADT]_i \times [emission\ factor]_i$$

STability ARray (STAR)

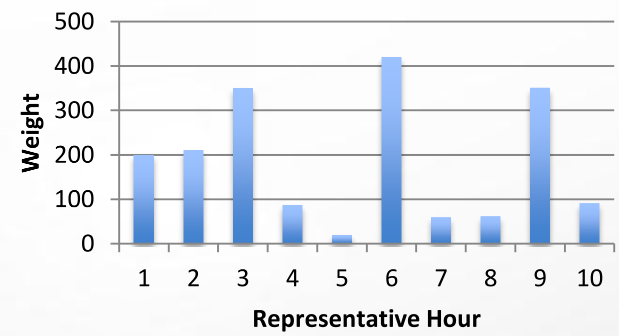
- RLINE—meteorology
  - STability ARray (STAR) Approach
    - Use representative hours instead of actual hourly meteorological data
    - Scale model output to annual average concentration using weights

1 year: 8760 hours

Monin-Obukhov length: 5 categories
Unstable, Slightly Unstable, Neutral, Slightly Stable, Stable

Wind Direction: 4 categories
North, East, South, West

Wind Speed: 5 categories
0~1, 1~2, 2~4, 4~7, >7



1 year: 100 hours

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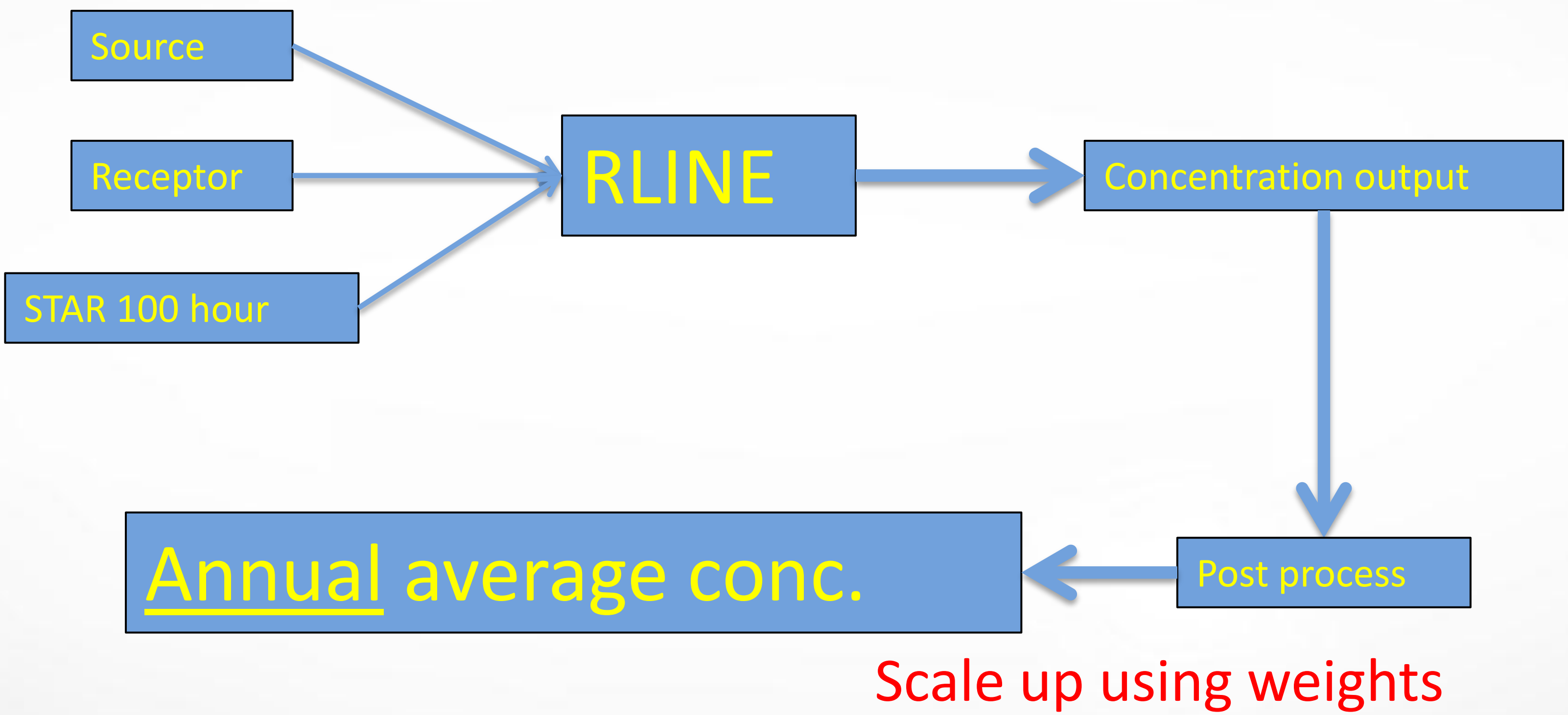
RLINE-STAR



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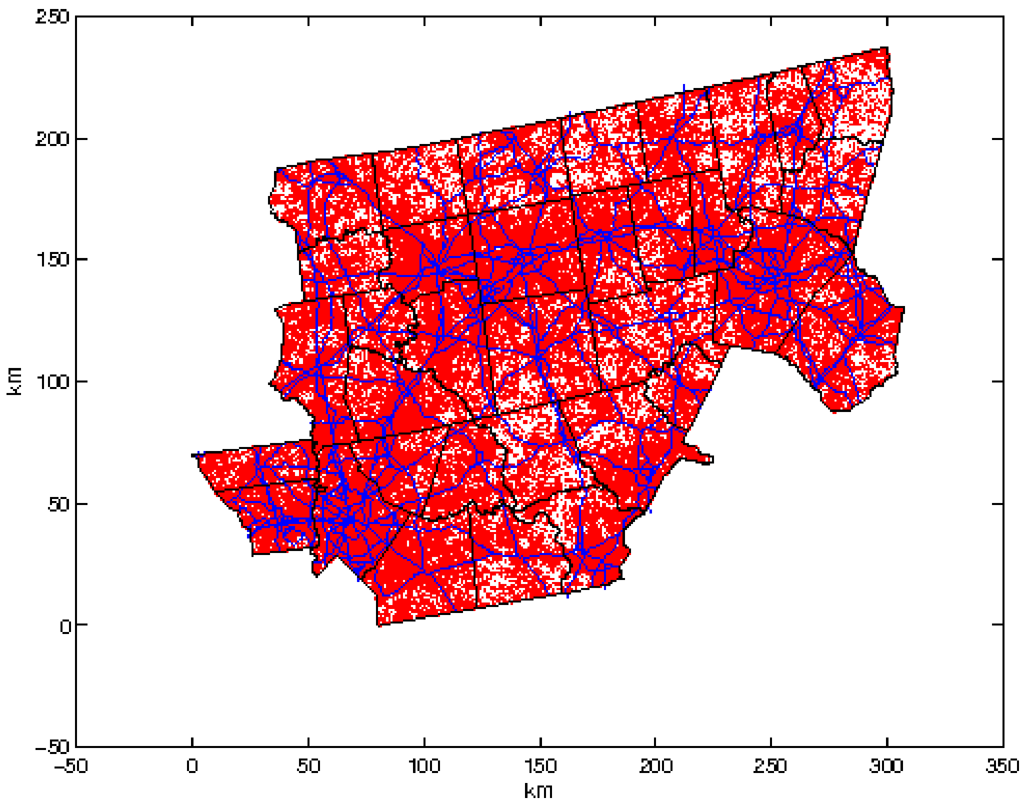
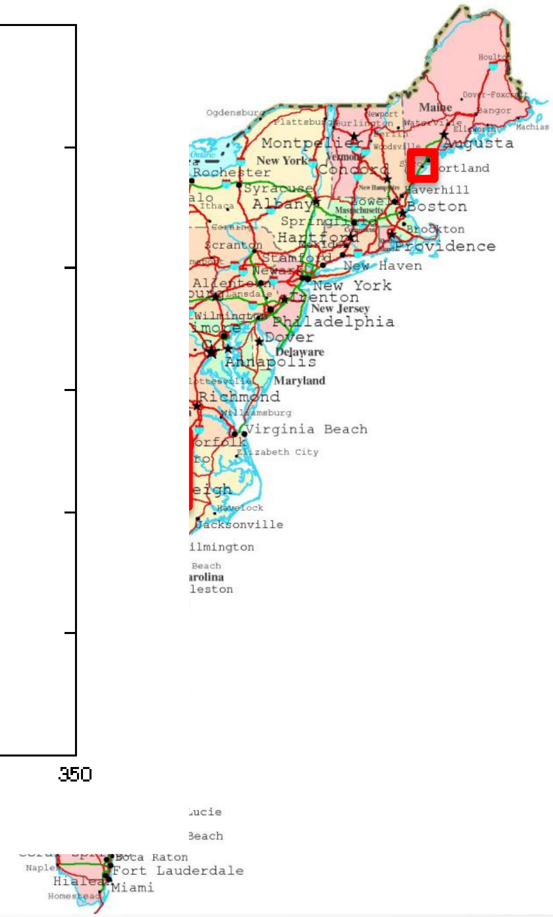
Step 2 & 3

- Step 2: Estimate Background concentrations from other sources
  - Spatio-Temporal Ordinary Kriging (STOK)
  - Use AQS observations as inputs to estimate field of background concentrations at census block resolution
  - If AQS observations available, use STOK
    - Hourly: $PM_{2.5}$, NOx, CO
    - Daily: Acetaldehyde, Benzene, Formaldehyde, $PM_{2.5}$ OC, $PM_{2.5}$ EC, $PM_{2.5}$ SO4
  - Else, use estimates from NATA-2008
    - Annual: 1,3-Butadiene, Acrolein

- Step 3: Estimate total concentrations (Hybrid)
  - Add onroad estimates to background concentrations at each census block centroid
  - Spatio-Temporal variability provided in background concentration
  - Spatial variability provided in onroad estimates

Road networks in Portland, Maine
Census blocks in the NC Piedmont

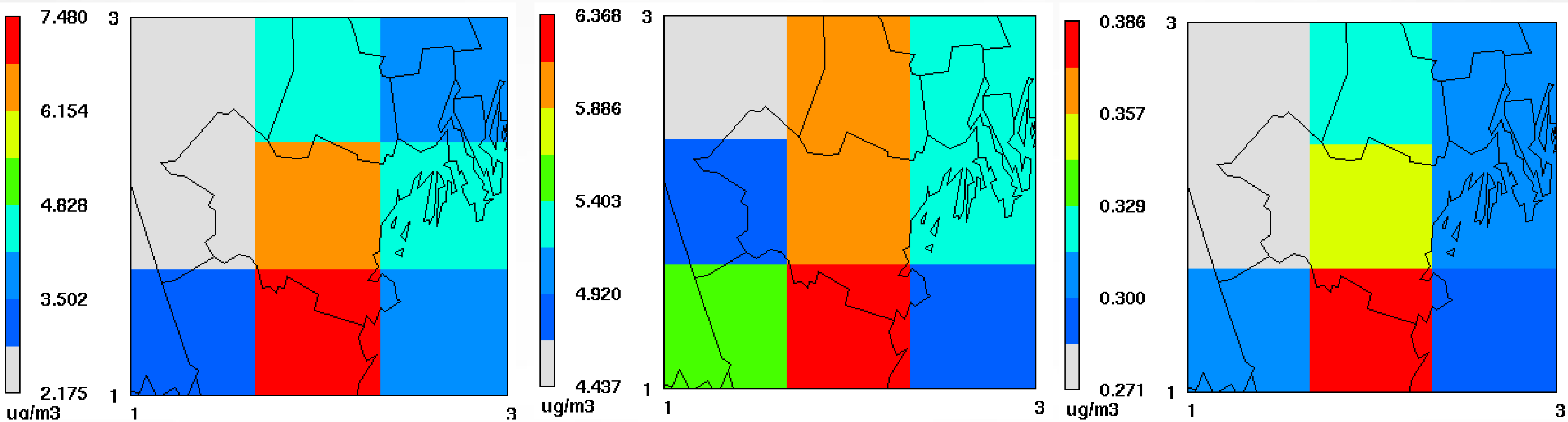




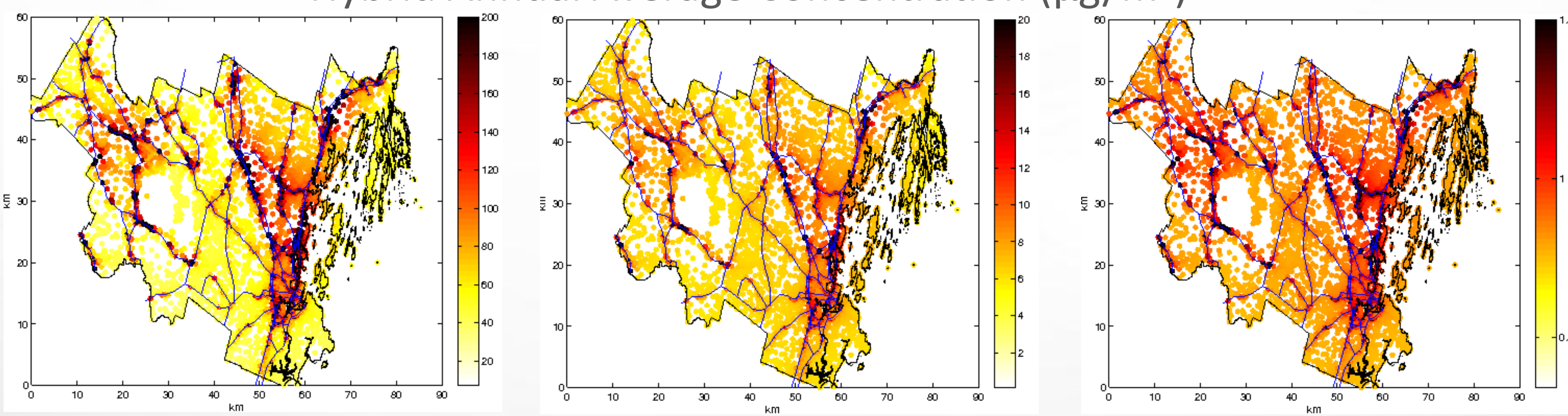
Results (Portland)

- NOx
- $PM_{2.5}$
- BENZENE

CMAQ Annual Average Concentration (μg/m³)



Hybrid Annual Average Concentration (μg/m³)

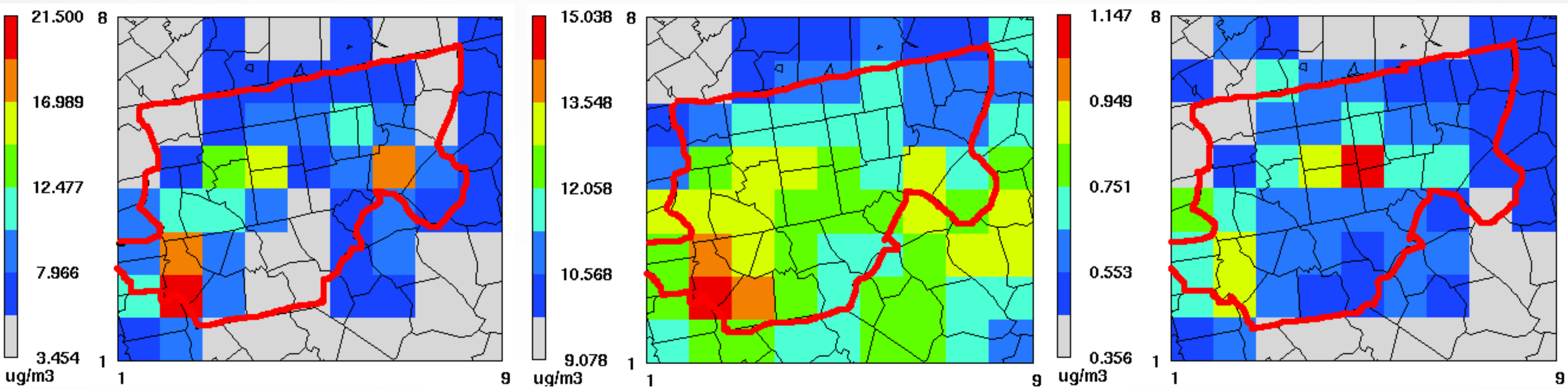


The hybrid method shows much more detailed spatial variability

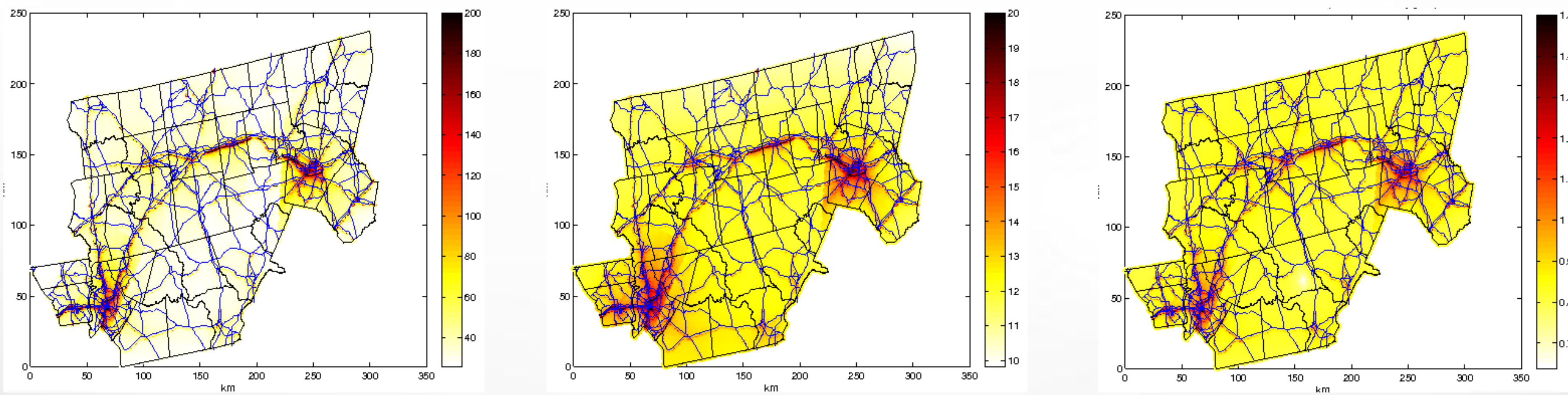
Results (NC)

- NOx
- $PM_{2.5}$
- BENZENE

CMAQ Annual Average Concentration (ppbV)



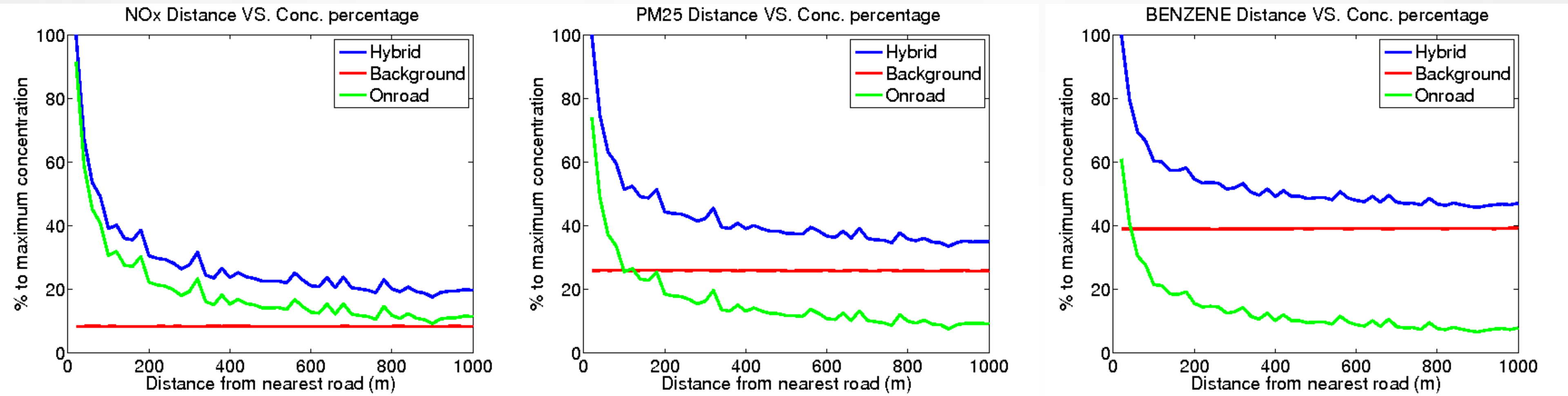
Hybrid Annual Average Concentration ($\mu g/m^3$)



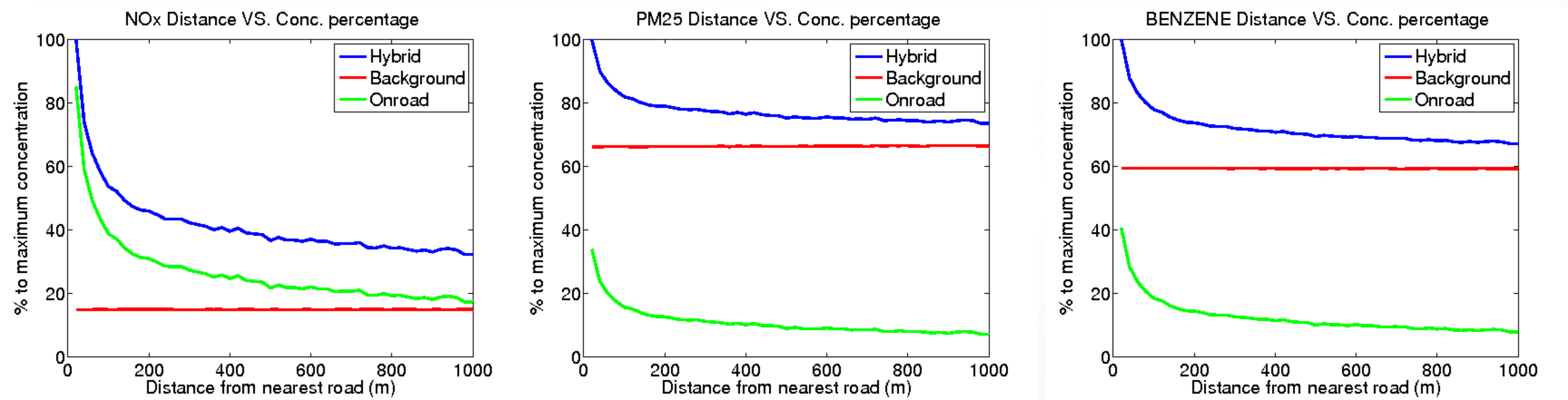
The hybrid method shows much more detailed spatial variability

Near-road analysis: by Distance

- Portland



- NC



The concentrations drop dramatically after 100 meters from the road

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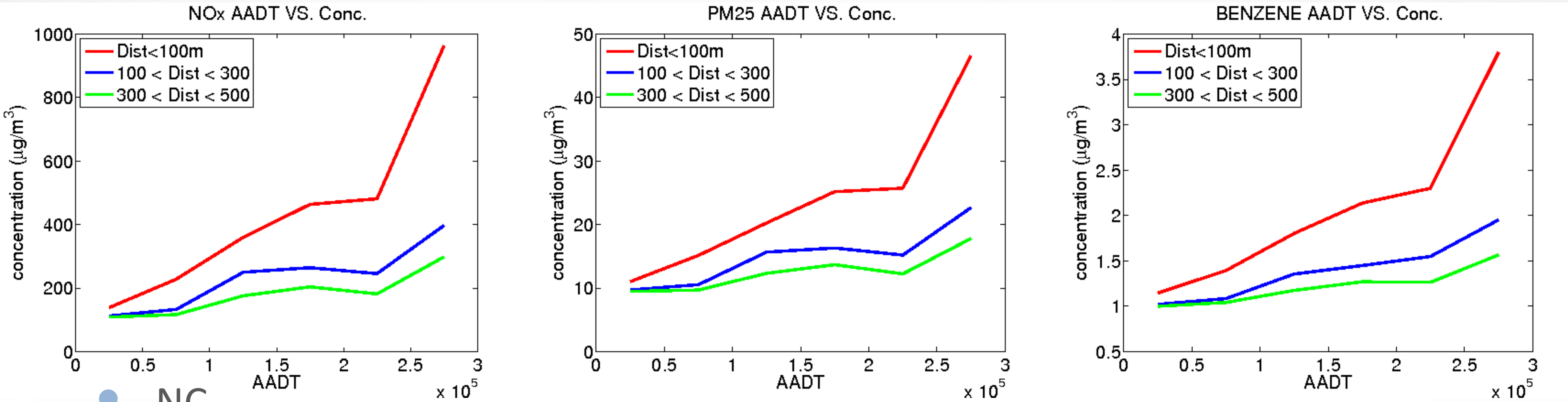
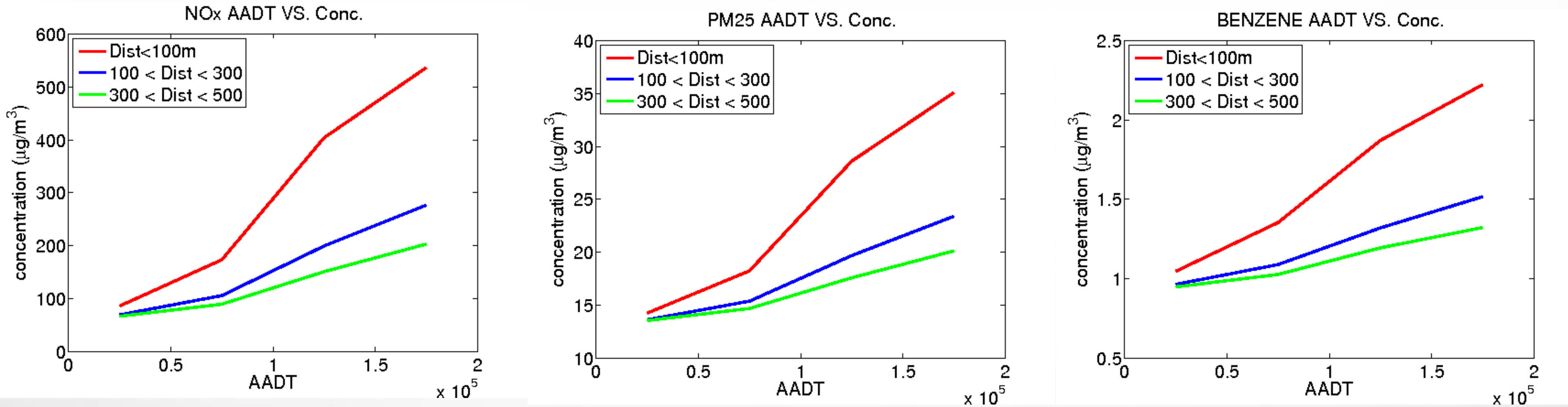
Near road analysis: by AADT

- Portland



- NC



Concentrations could be very high near roads with heavy traffic

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Summary

- Developed a modeling framework using state-of-the-art tools and databases to characterize on-road source contribution to air quality at census block resolution to support population exposure studies
- Using STAR approach greatly reduces computational burden, while estimating annual averages without losing accuracy
- $PM_{2.5}$, Acrolein, Formaldehyde and NOx concentrations in Portland and NC Piedmont exceed health based thresholds.
- QA against emission shows comparable on-road contribution for several pollutants. The contribution matches better at a finer scale
- Concentrations drop off rapidly after 100m from the roads
  - By 40-60% in Portland
  - By 20-50% in NC Piedmont
- Concentration could be high near traffic-intense roads

Future work

- Continue QA'ing the result
  - Evaluate model predictions at AQS sites
- Assess relative contribution from different vehicles and road types
- Extend methodology to apply to the whole nation
- Perform health-based risk assessment using these fine-scale outputs

Acknowledge

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