Modeling subgrid scale variability in pollutant concentration due to heterogeneous urban emission

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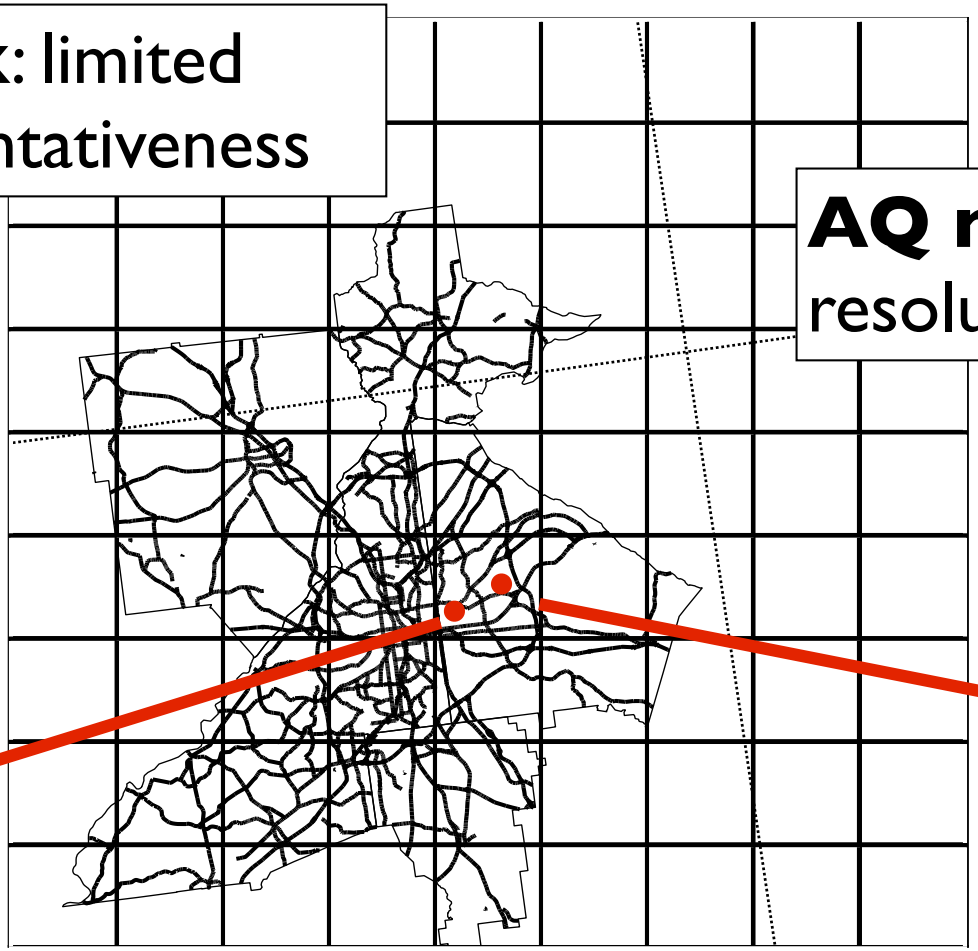
Specificities of the modeling approach

- **Urban** air-quality: anthropogenically driven
- **Exposure** estimates: 1km and below
- **Health impact**: assess correlation with health outcomes

AQ network: limited spatial representativeness

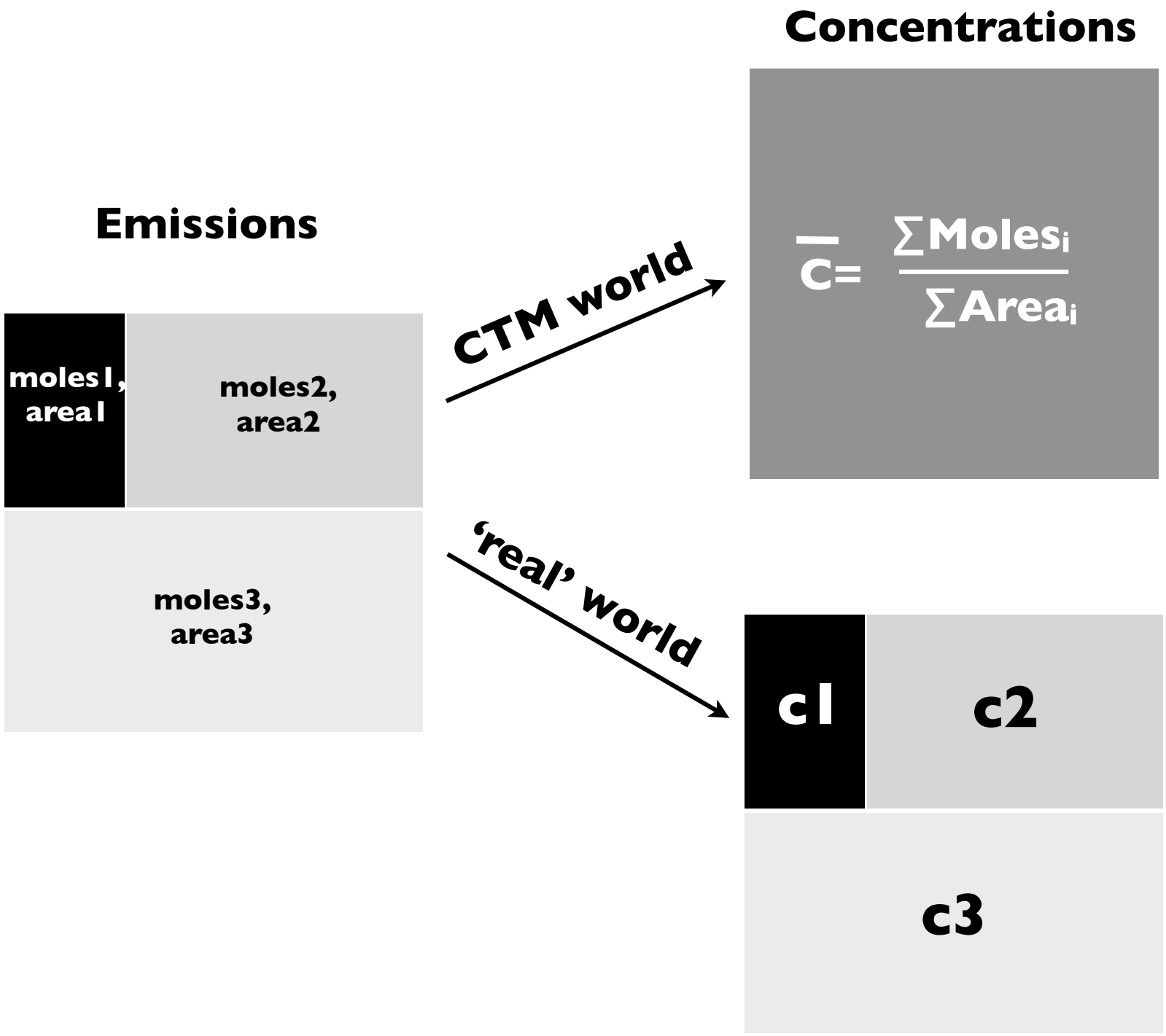
AQ models: resolution limits

Residential



Busy road

Conceptually



The model

- Force the CTM with local emission terms $\boxed{E_i = \overline{E} + E'}$

$$\overline{E} = \sum_{i=1}^{N} a_i * E_i$$

with a_i some parameter of the subgrid distribution, such as landuse

- Advection, diffusion, chemical transformations etc. act on the 'perturbation'
- CTM model 'local' concentrations $\overline{c}_i$ along with $\overline{C} = \sum_{i=1}^{N} a_i * C_i$

local emission

$$\frac{\partial c_i}{\partial t} + \overline{U}_j \frac{\partial c_i}{\partial x_j} = -\frac{\partial(\overline{u'_j c'})}{\partial x_j} + \mathbf{E_i} + P(\overline{c}_i) + L(\overline{c}_i) \cdot \overline{c}_i - \frac{(c_i - \overline{c})}{Tmix}$$

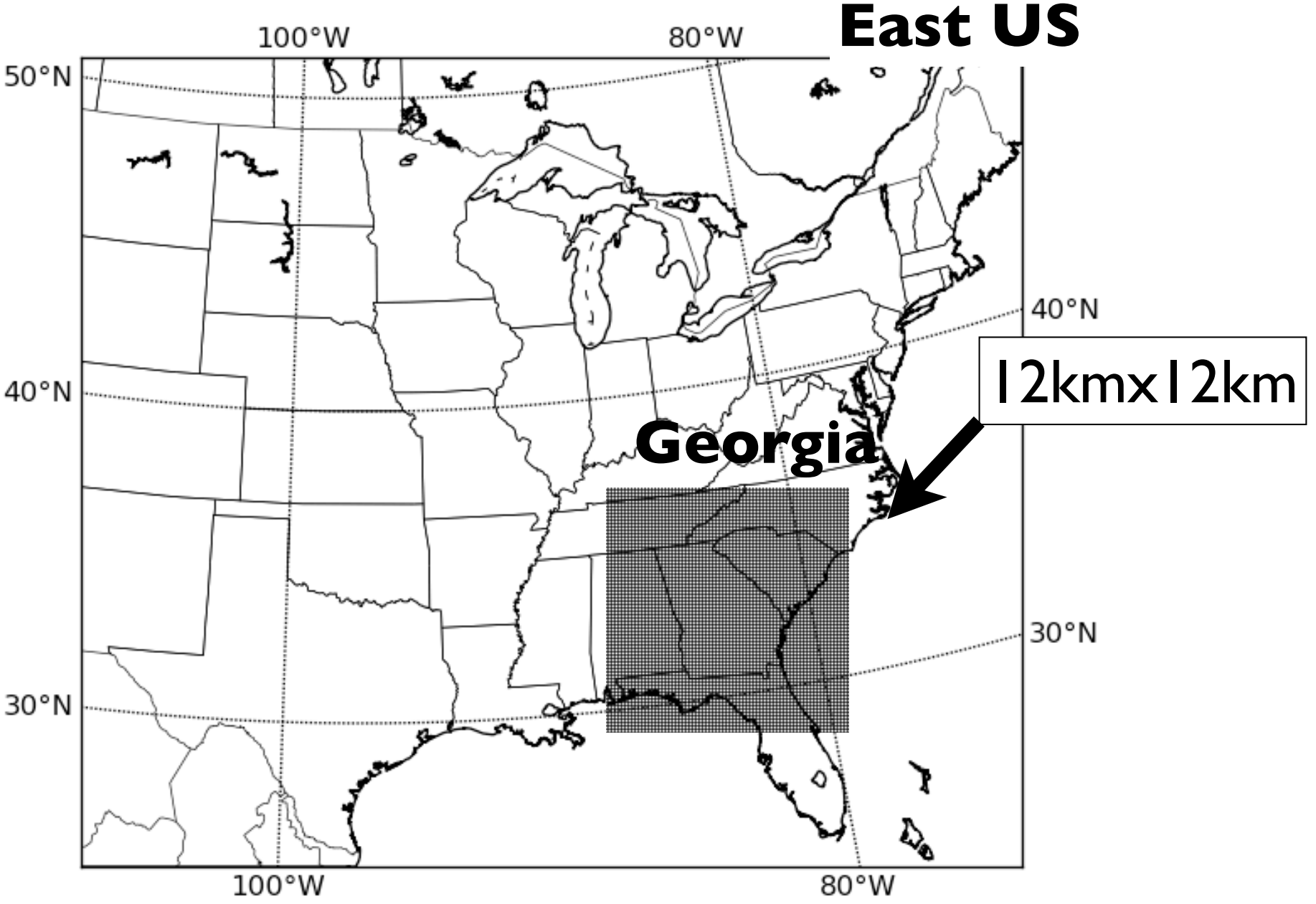
local concentration

subgrid mixing (implicit)

The downscaling approach here is **hybrid**:

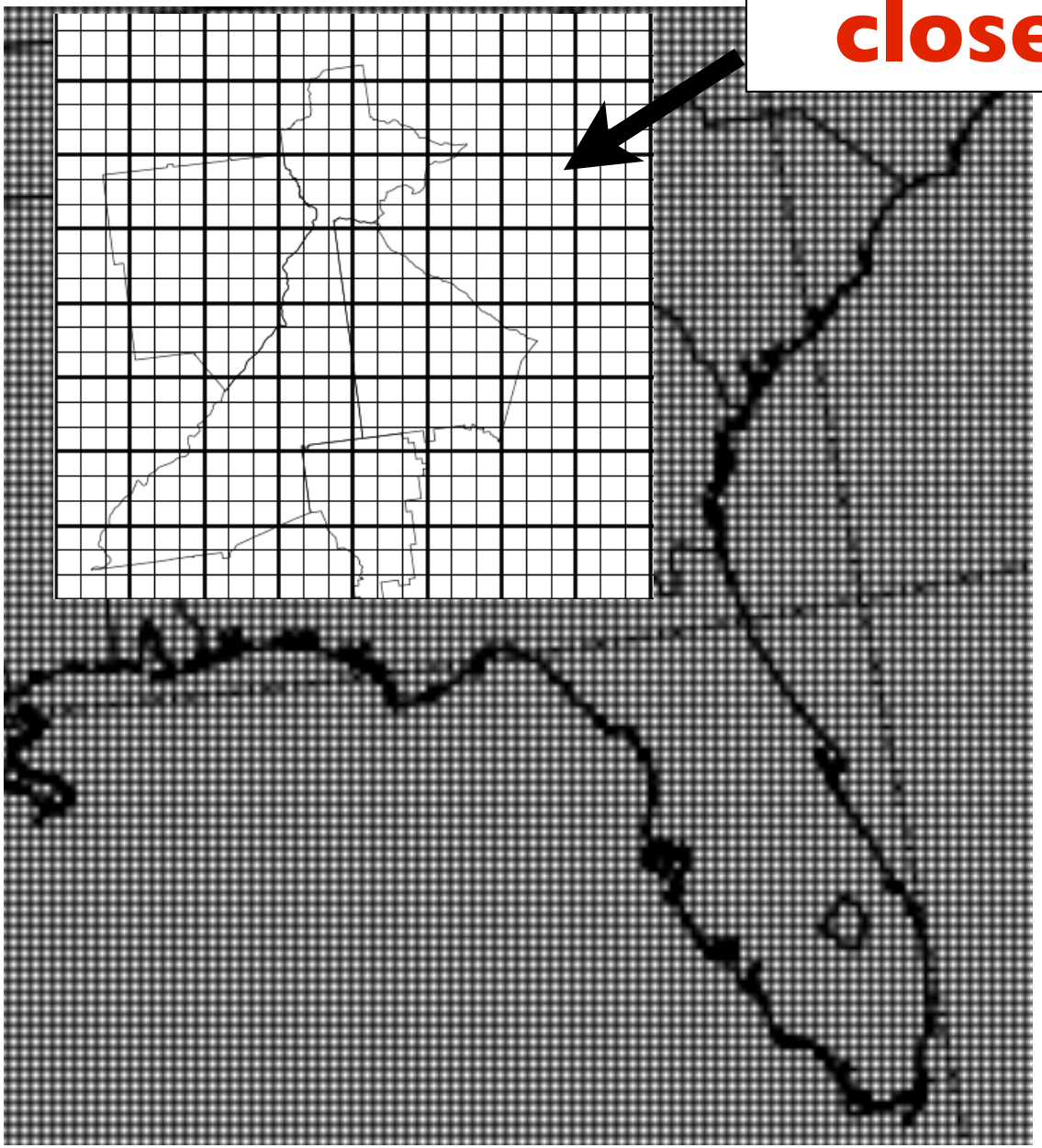
Explicit: because direct downscaling towards 1km
Statistical: because of emission allocation
Implicit: because of the subgrid mixing term (not yet implemented)

Downscaling from 12km...



...to 4 and down to 1 km

Atlanta



How close?

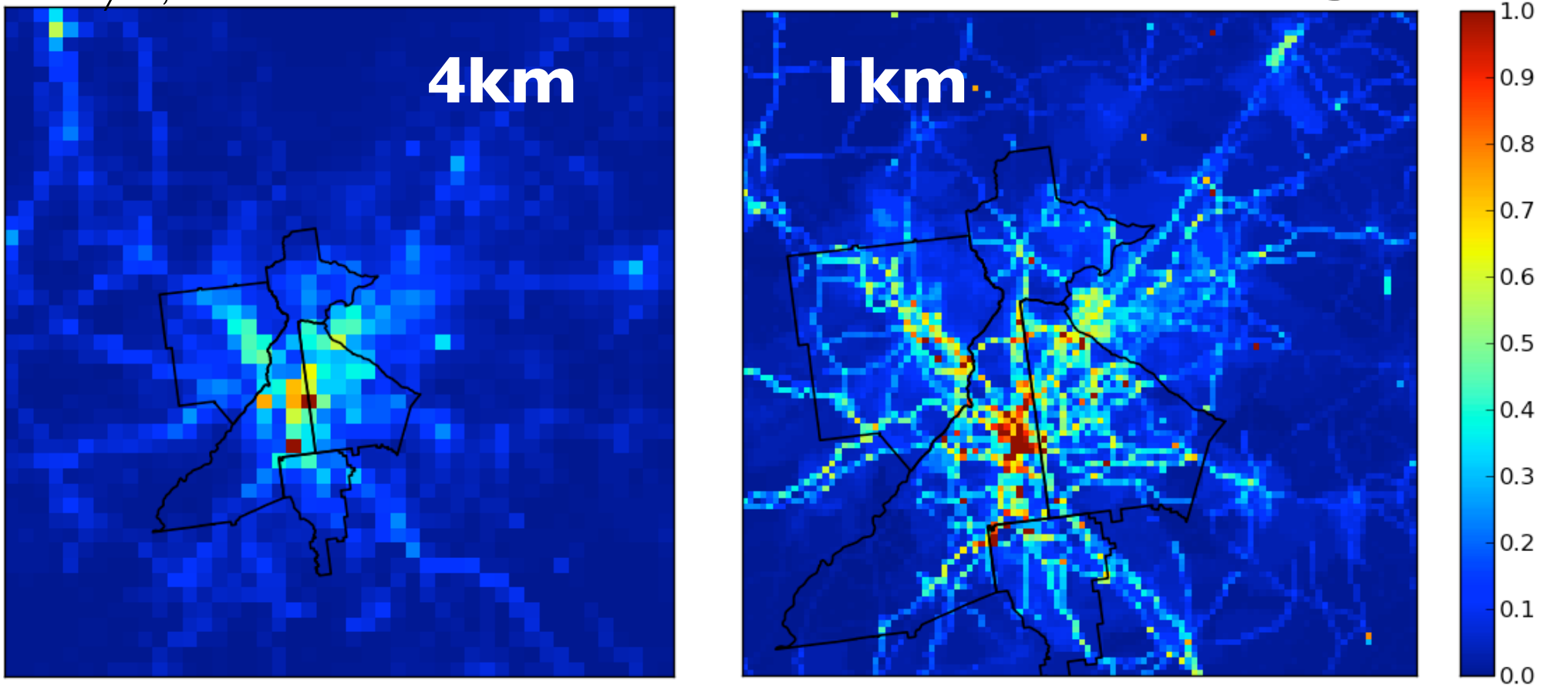
Issues raised:

- Uncertainties in the input
- Parameterization limitations
- Unknown subgrid processes
- Model evaluation issues

Typical **emission model** (SMOKE) **output** (or CTM input)

All sources included NOx emissions (8a.m. LT)

May 6, 2002



Explicit:

Statistical:

- **add** subgrid-scale information
- calculate grid **distribution**

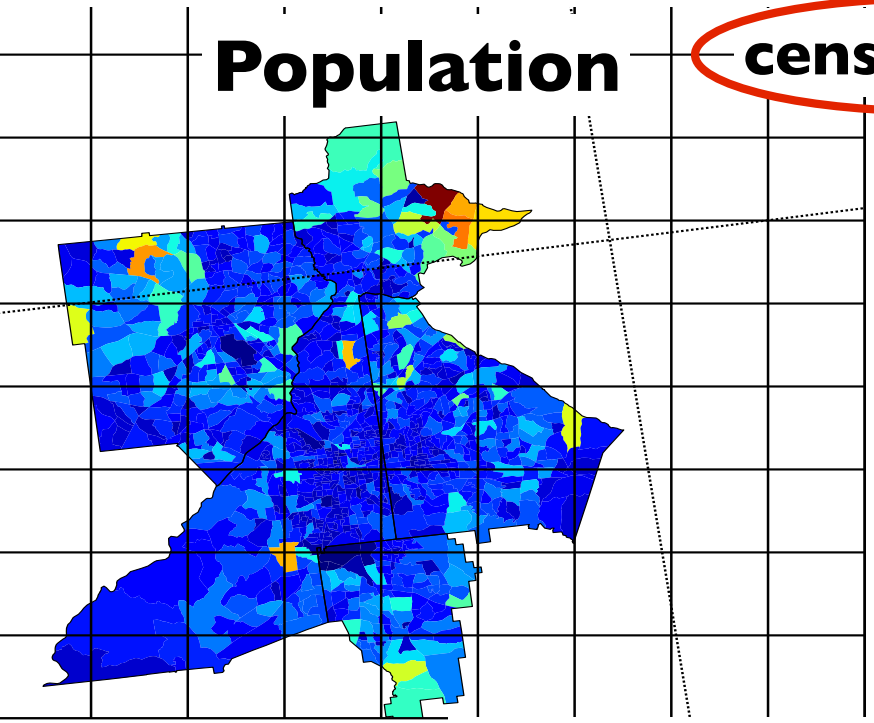
Subgrid-areas or 'micro-environments':

1. On-roads
2. Residential (heating)
3. Commercial areas
4. Industrial areas
5. Recreational areas (parks, golf courses...)

Add subgrid scale information

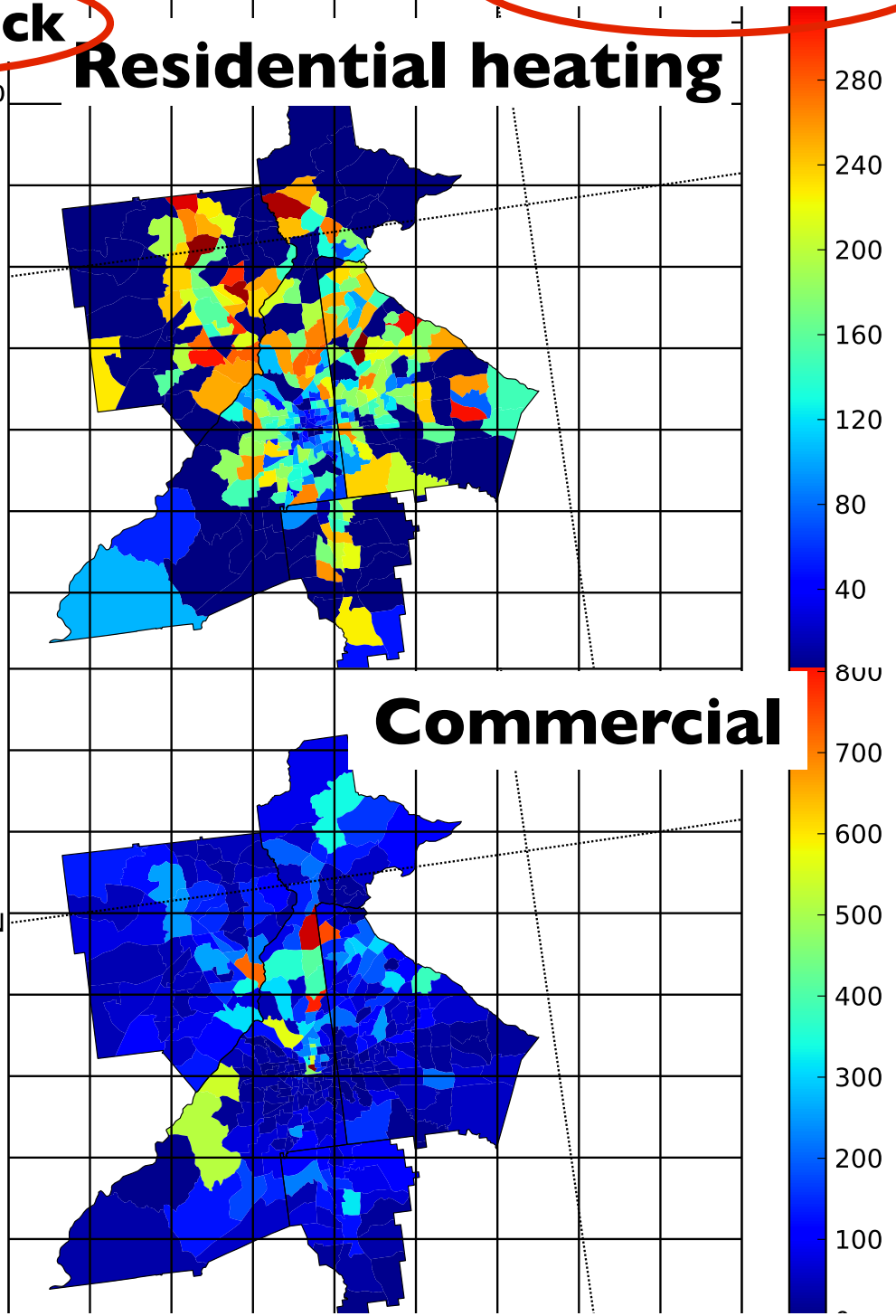
Population

census block

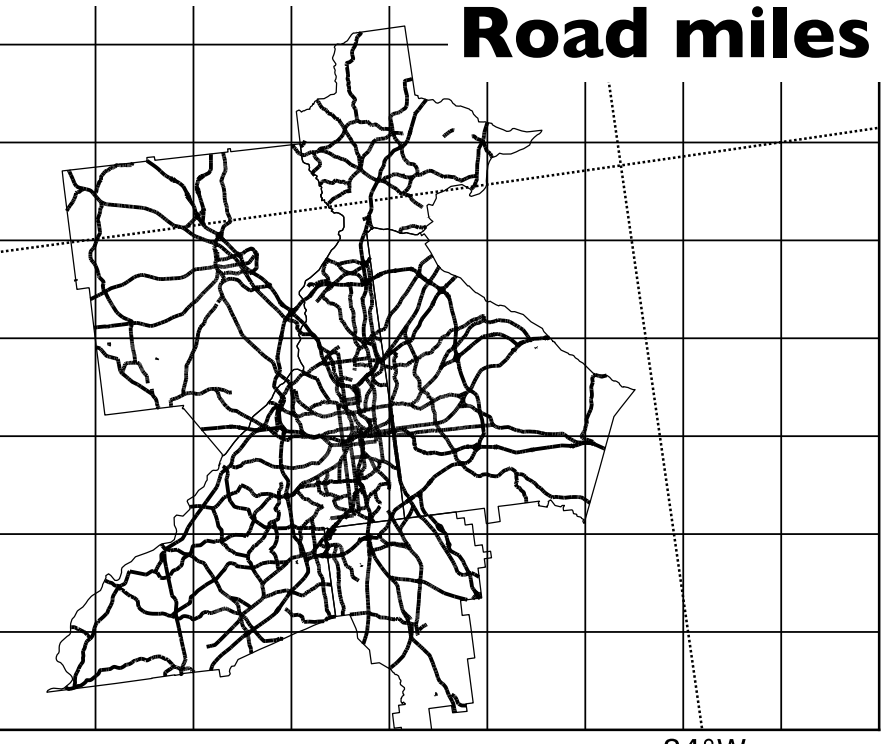


Residential heating

m^2/census tract

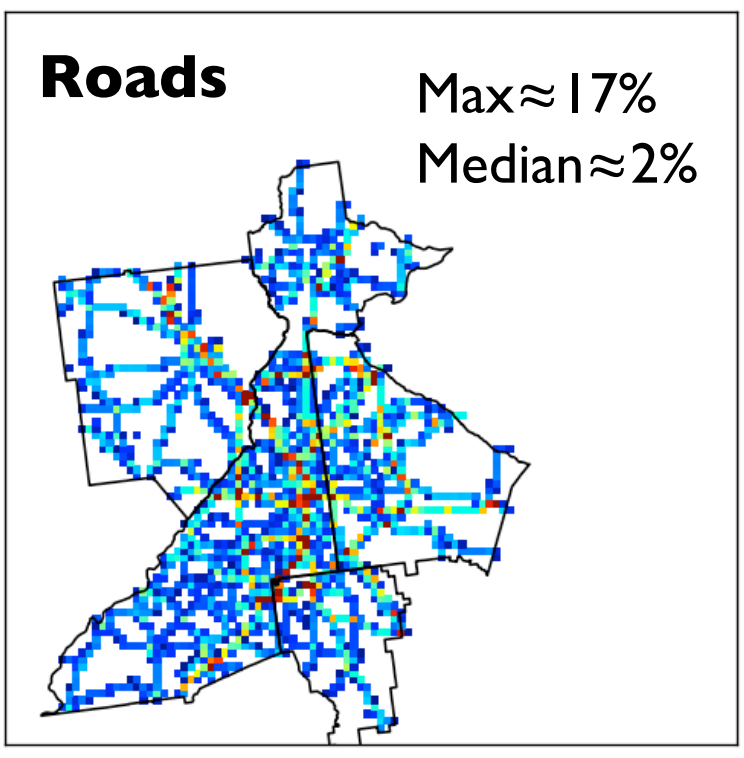


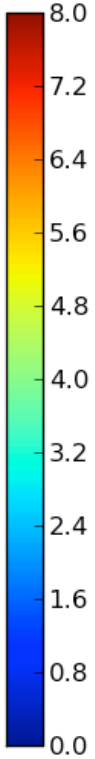
Road miles

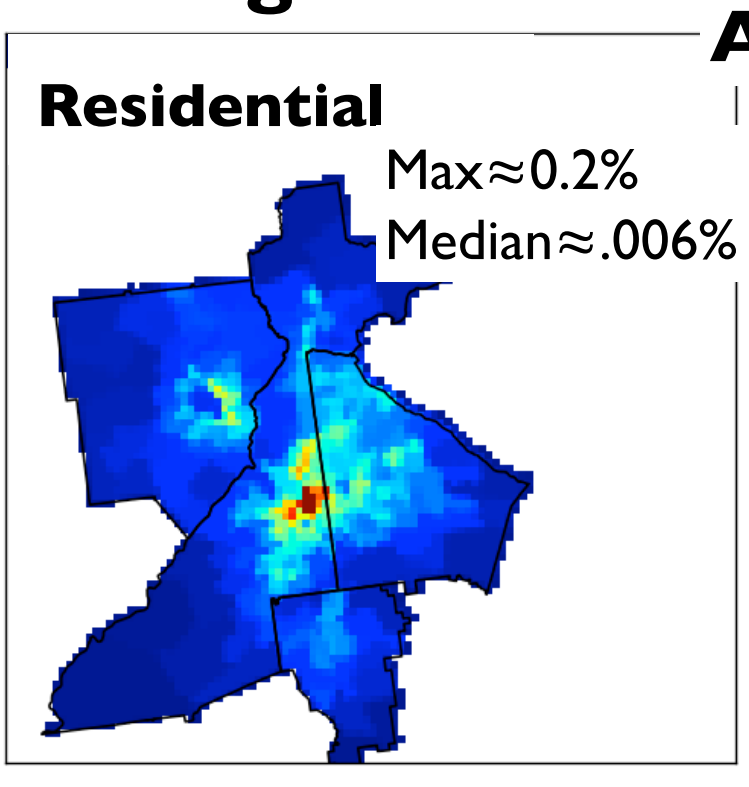


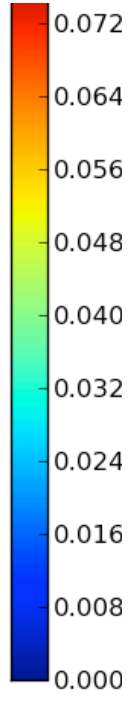
Commercial

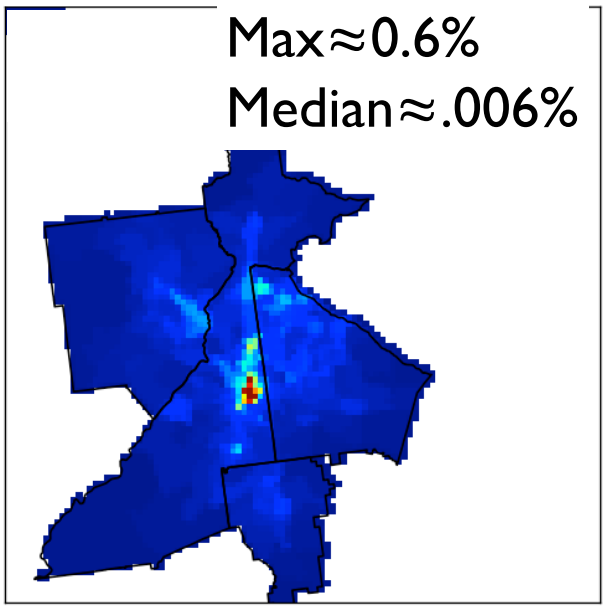
Grid distributions: 1km grid ratios

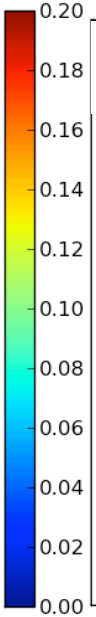


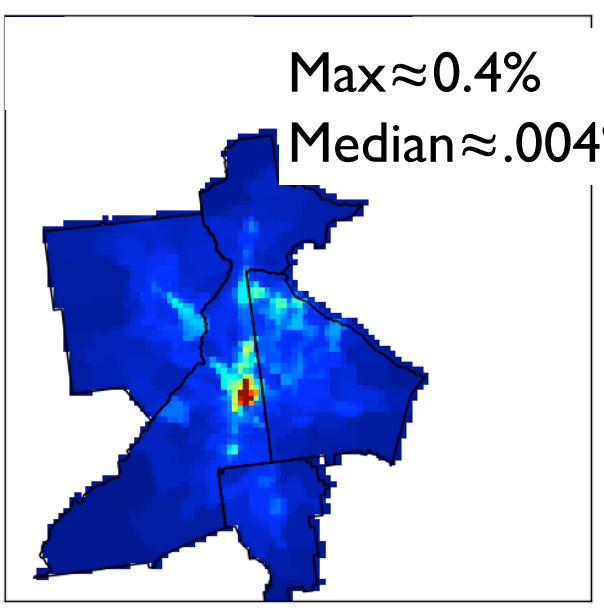


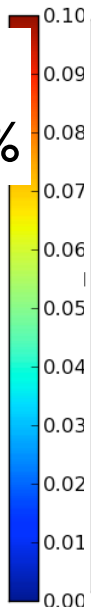


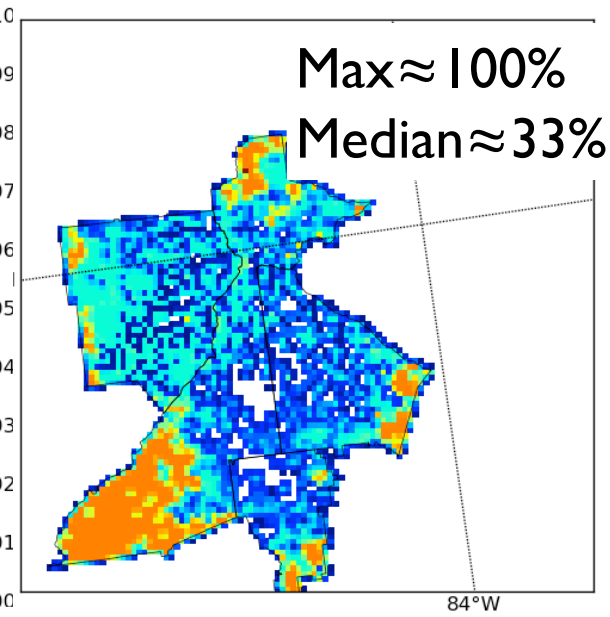


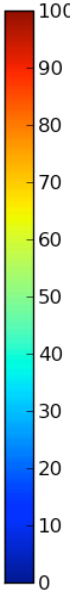






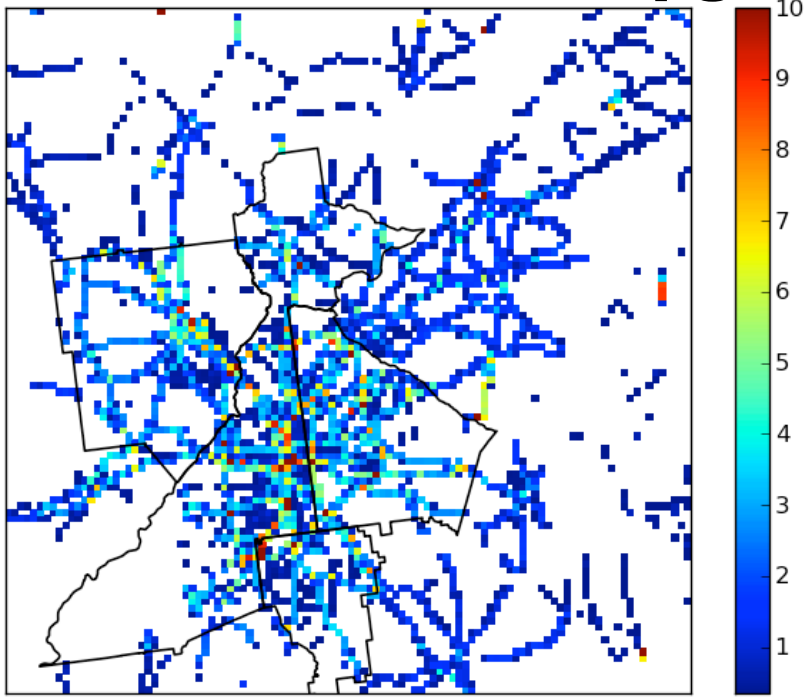




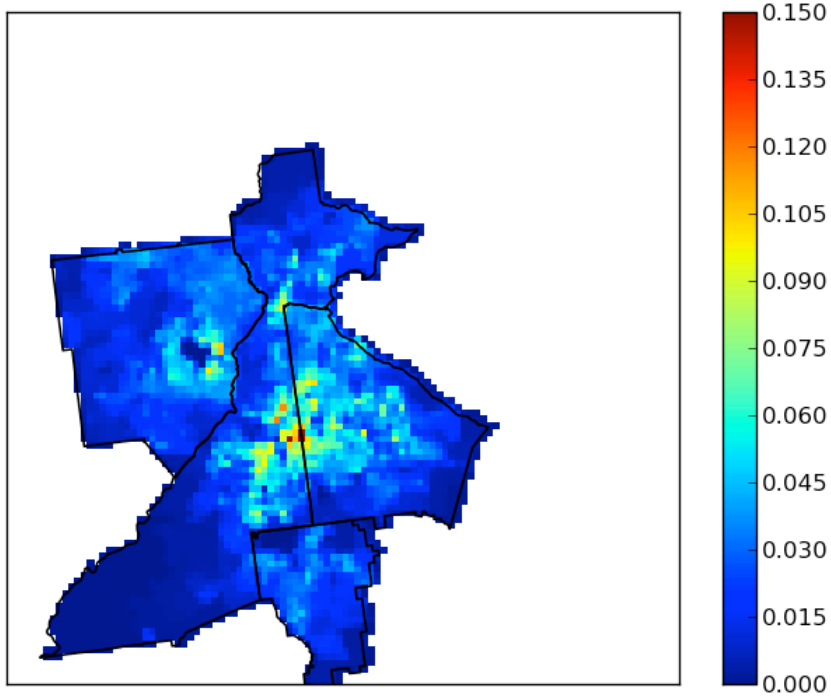


Source-specific emissions (NOx at noon)

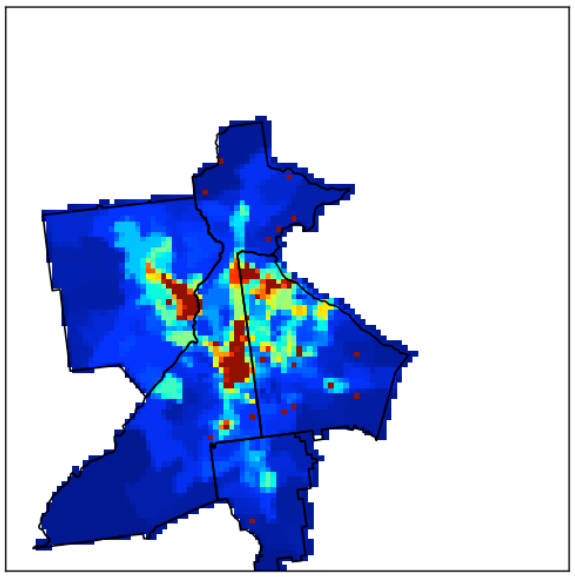
Roads



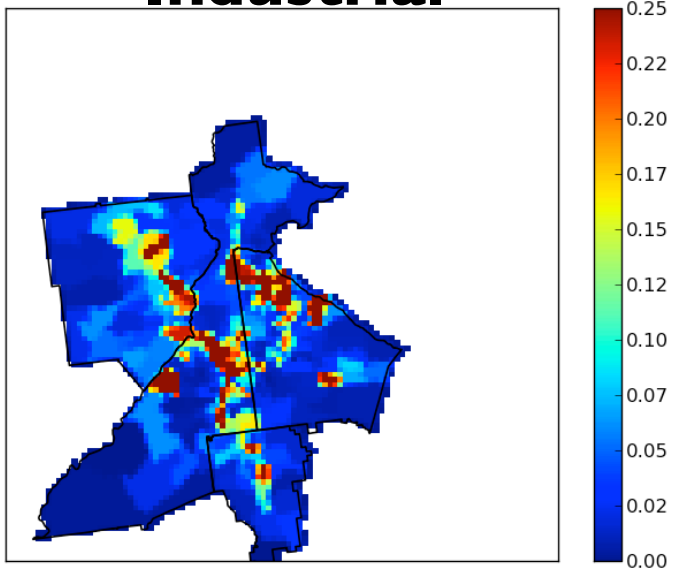
Residential



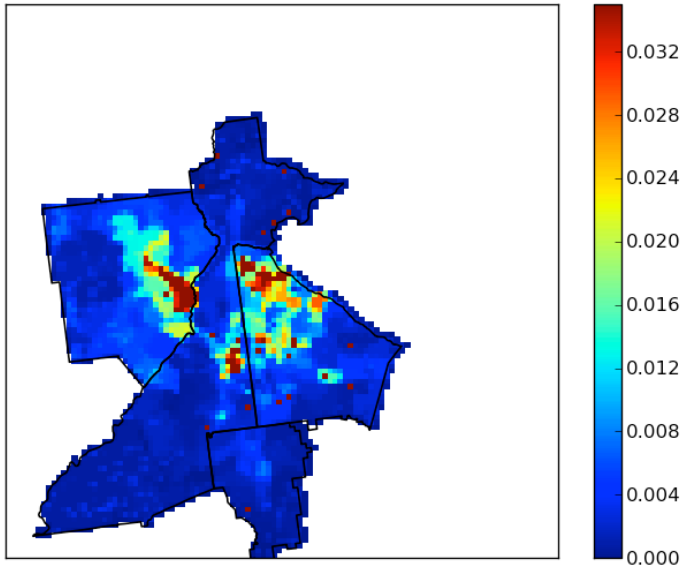
Commercial



Industrial

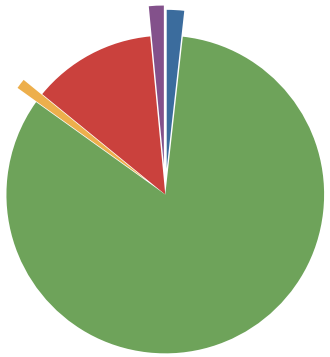


Recreational



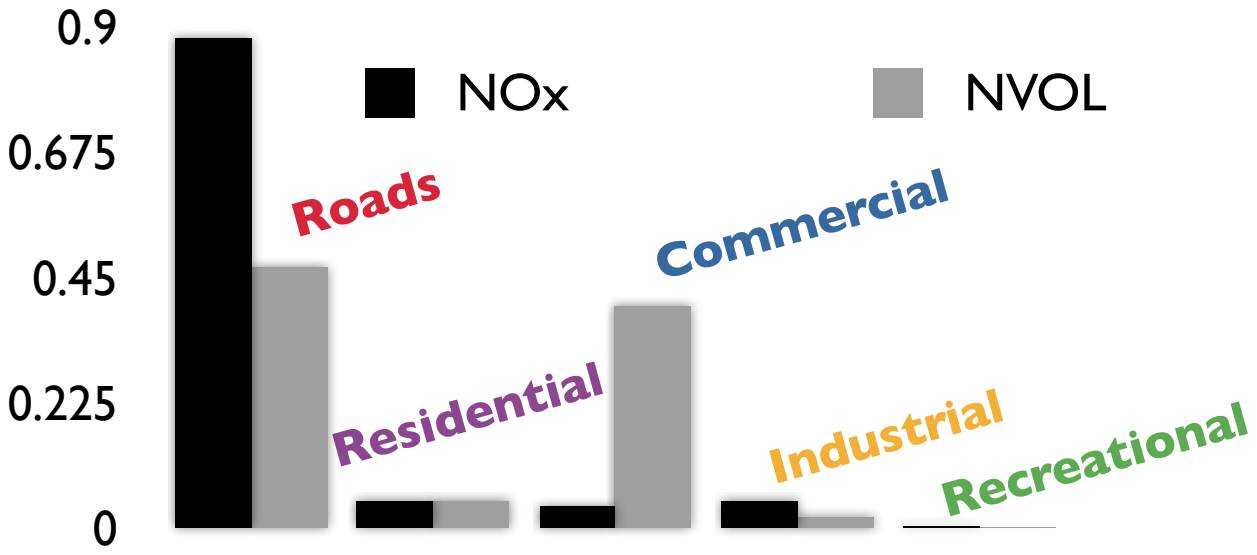
1km grid area ratios %

- **Roads: median at** 2% with uniform distribution
- **Residential:** narrow but relatively uniform
- **Commercial** and **Industrial:** narrow and rare
- **Recreational:** may be 0 or 100%



Source-specific Emissions at noon

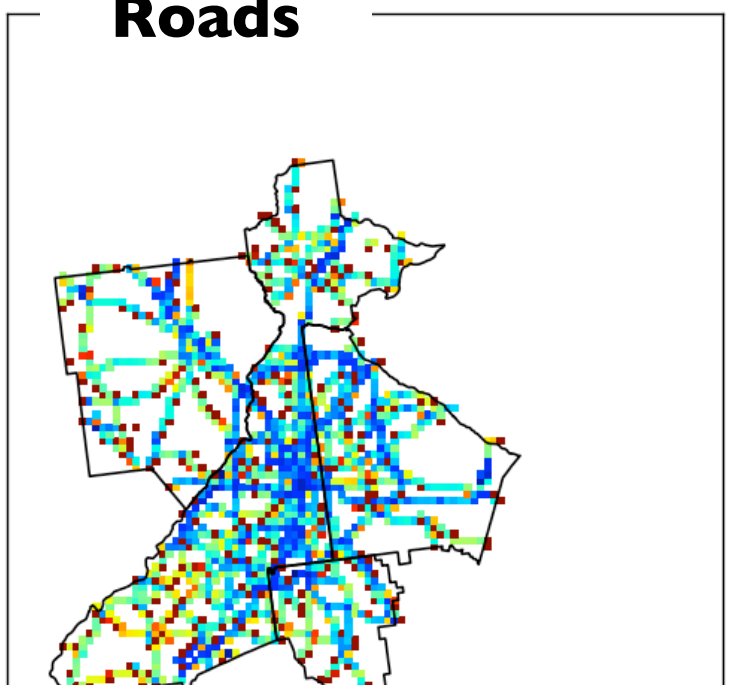
Sector-specific vs. all sectors

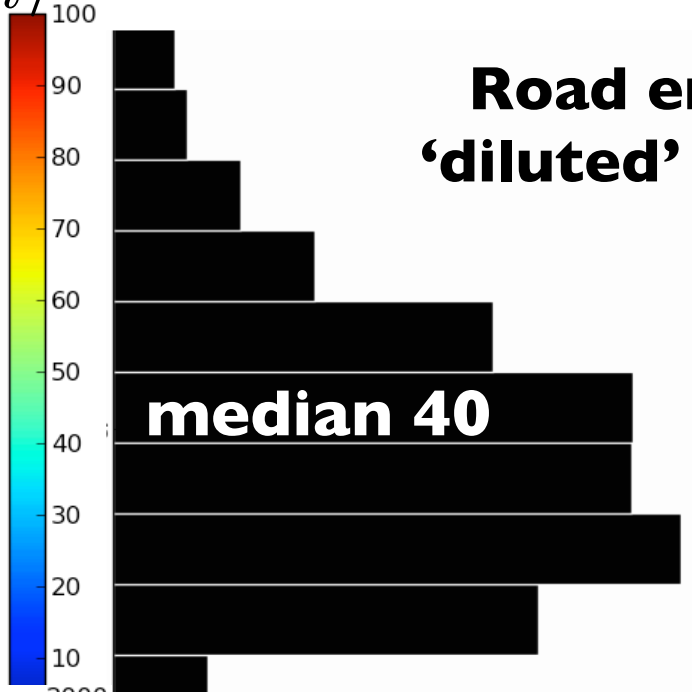


- **Subgrid emissions** $E_i = N_i/A_i$ subject to speciation & temporal
- **Forcing terms** $E_i/\overline{E}$ express local deviations from averaged flux

Results for NOx: local emission forcing

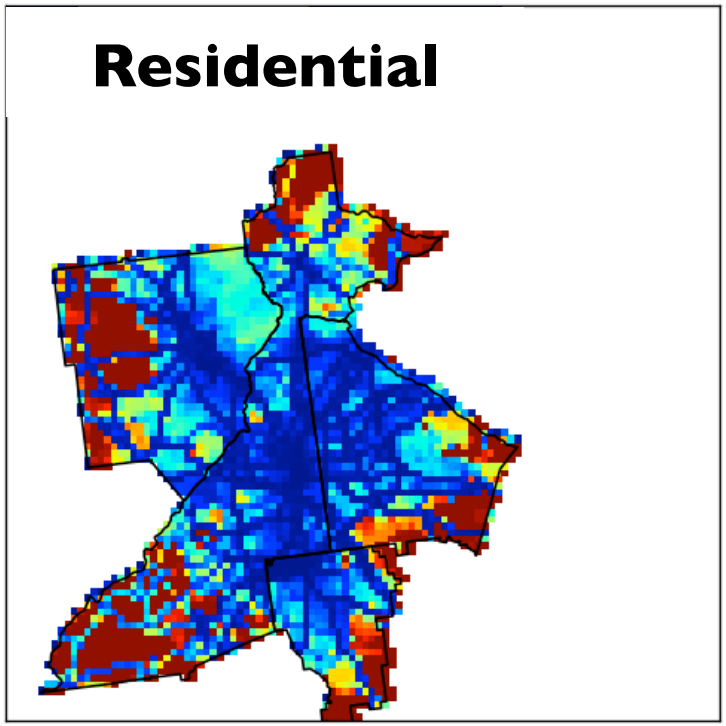
$E_i / \overline{E}$

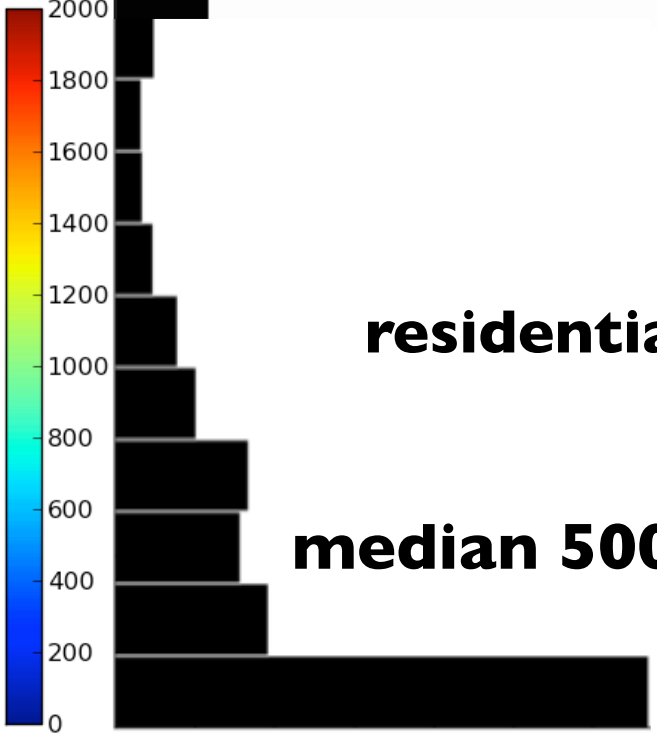




Road emissions are 'diluted' by a factor of 40

median 40



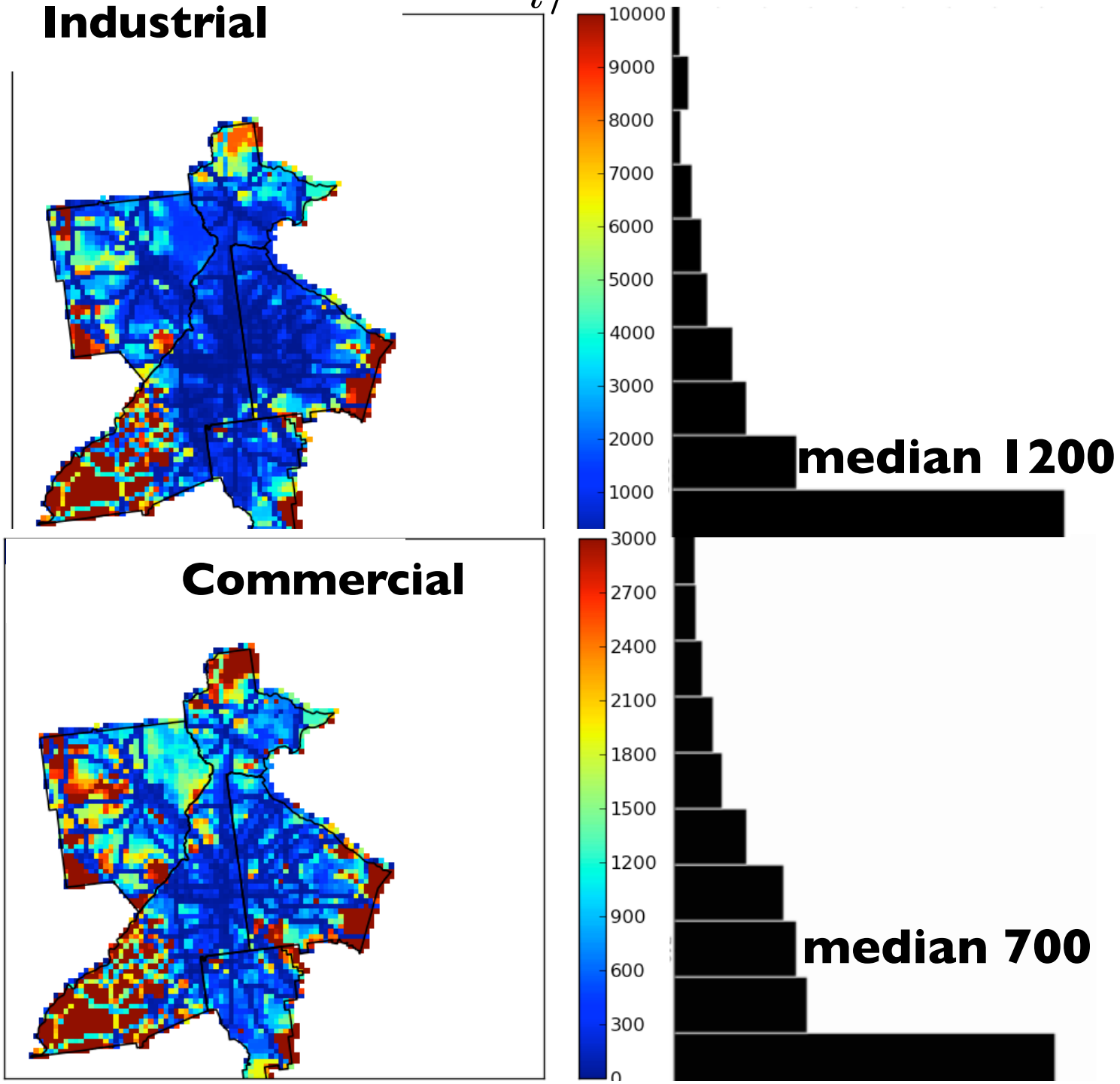


residential by a factor of 500

median 500

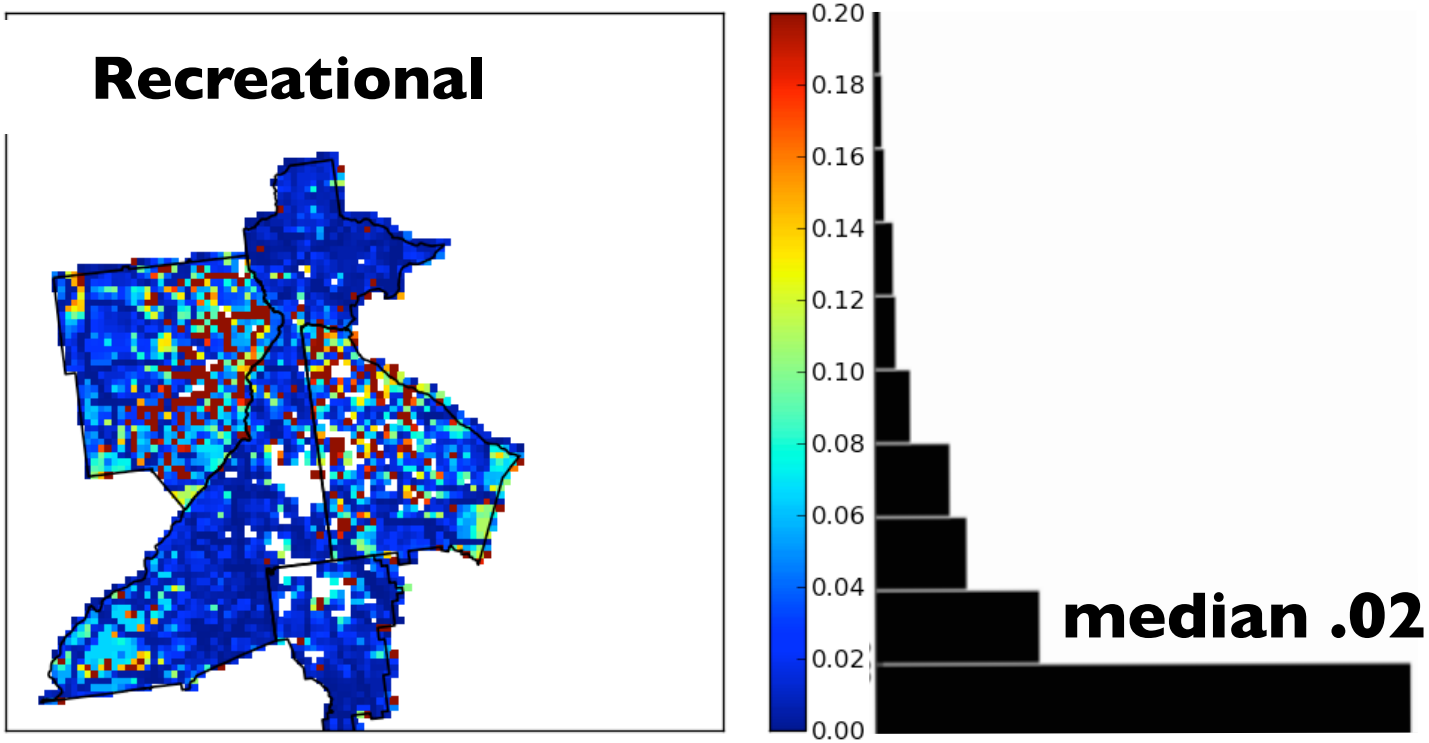
Results for NOx: local emission forcing

$E_i / \overline{E}$



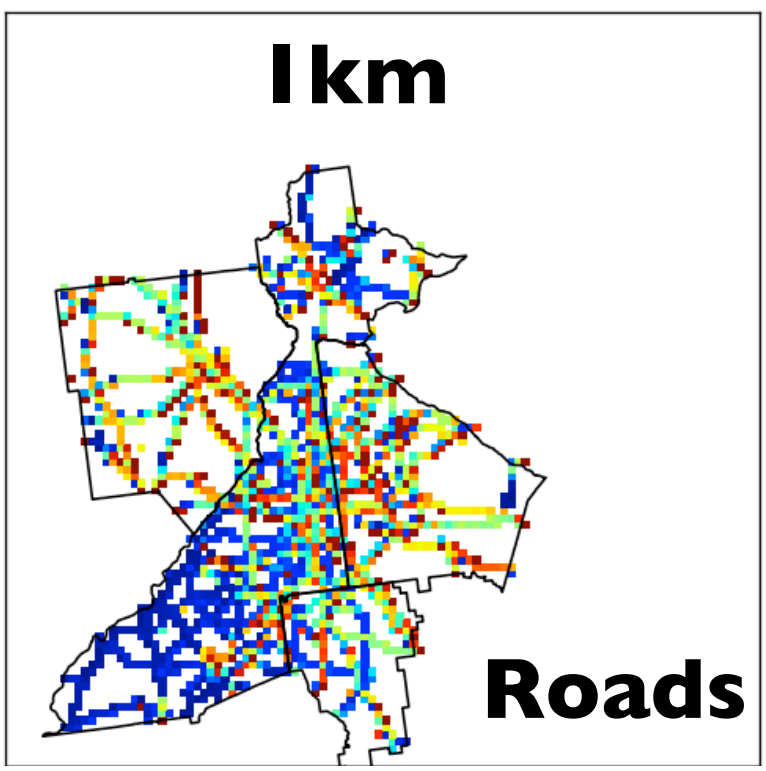
Results for NOx: local emission forcing

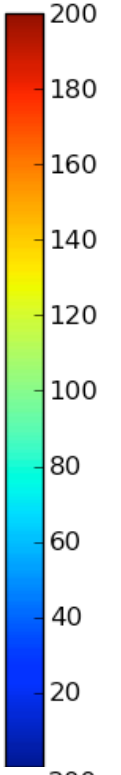
$$E_i / \overline{E}$$

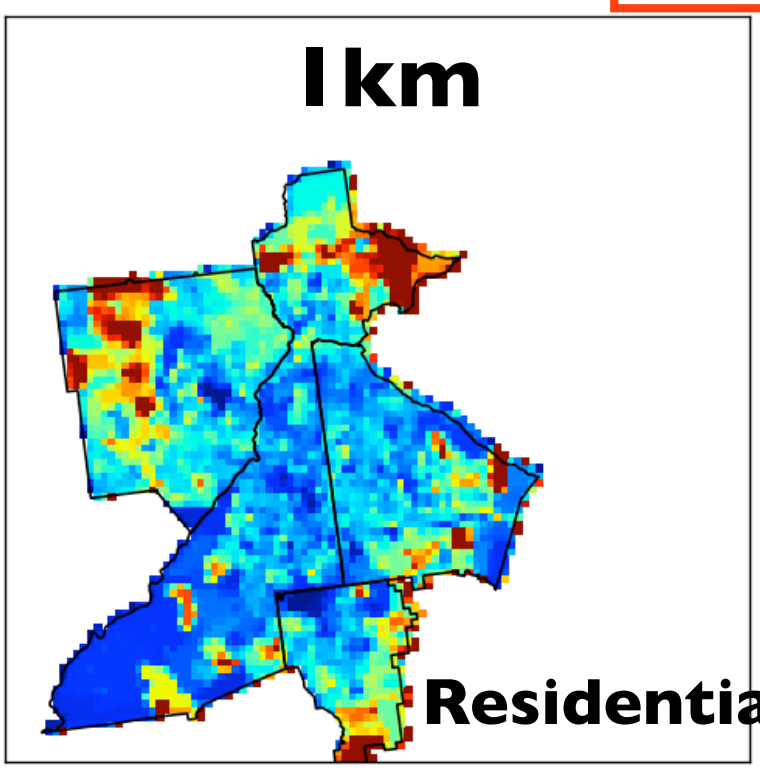


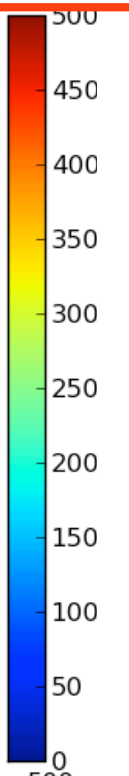
Comparison between 1 and 4 km

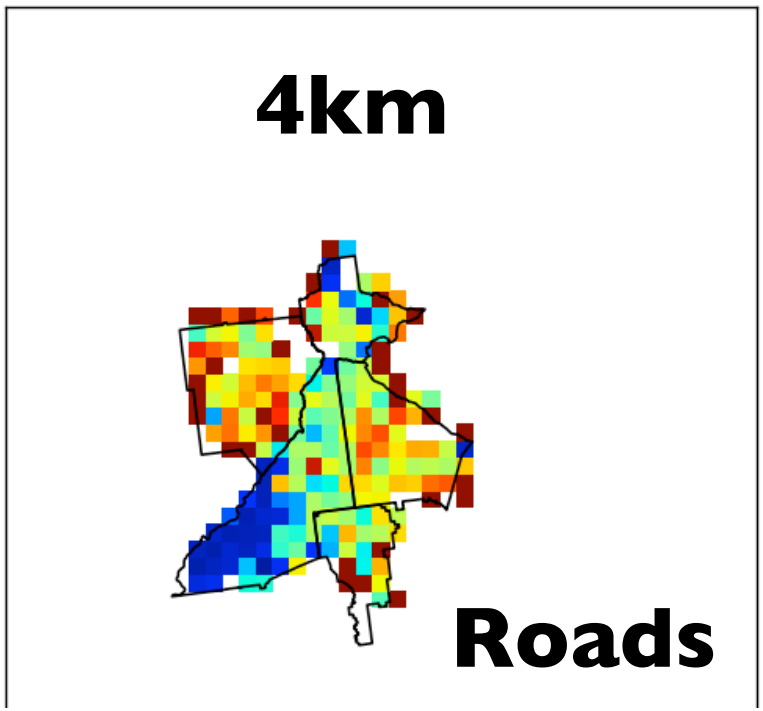
μg $s^{-1}m^{-2}$

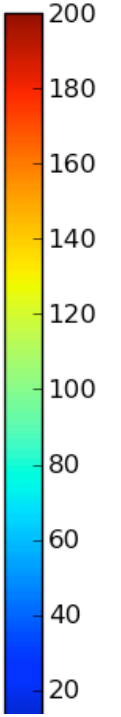


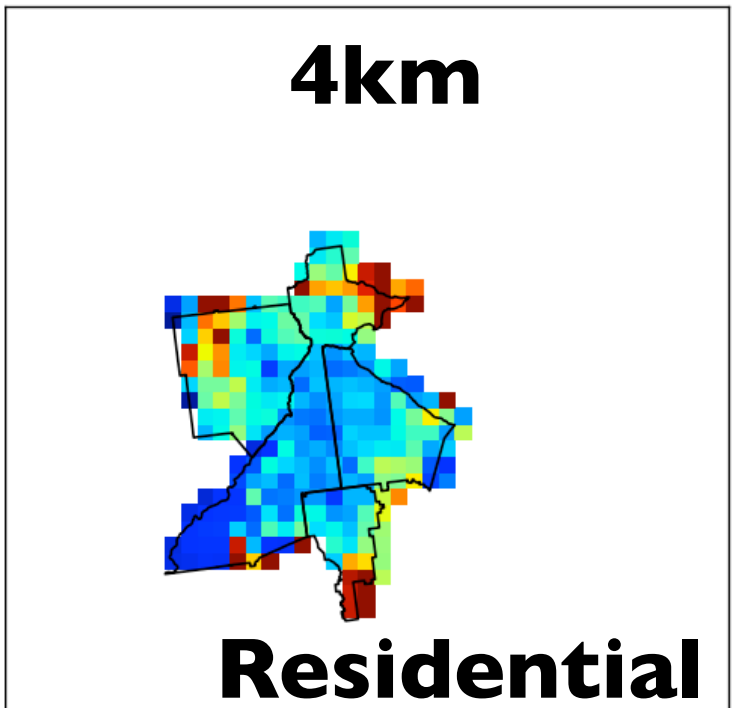


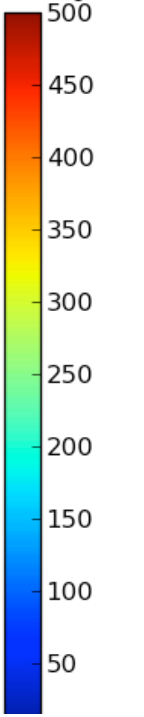








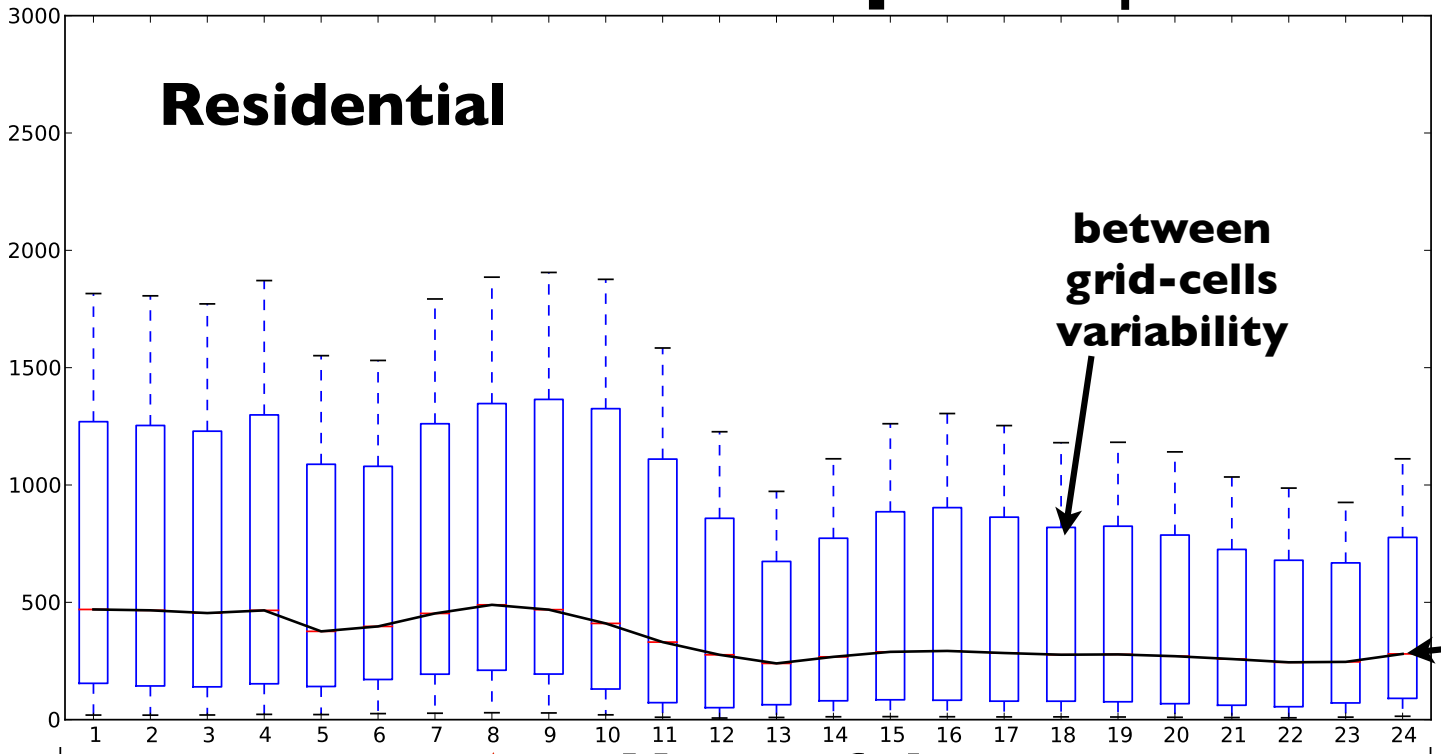




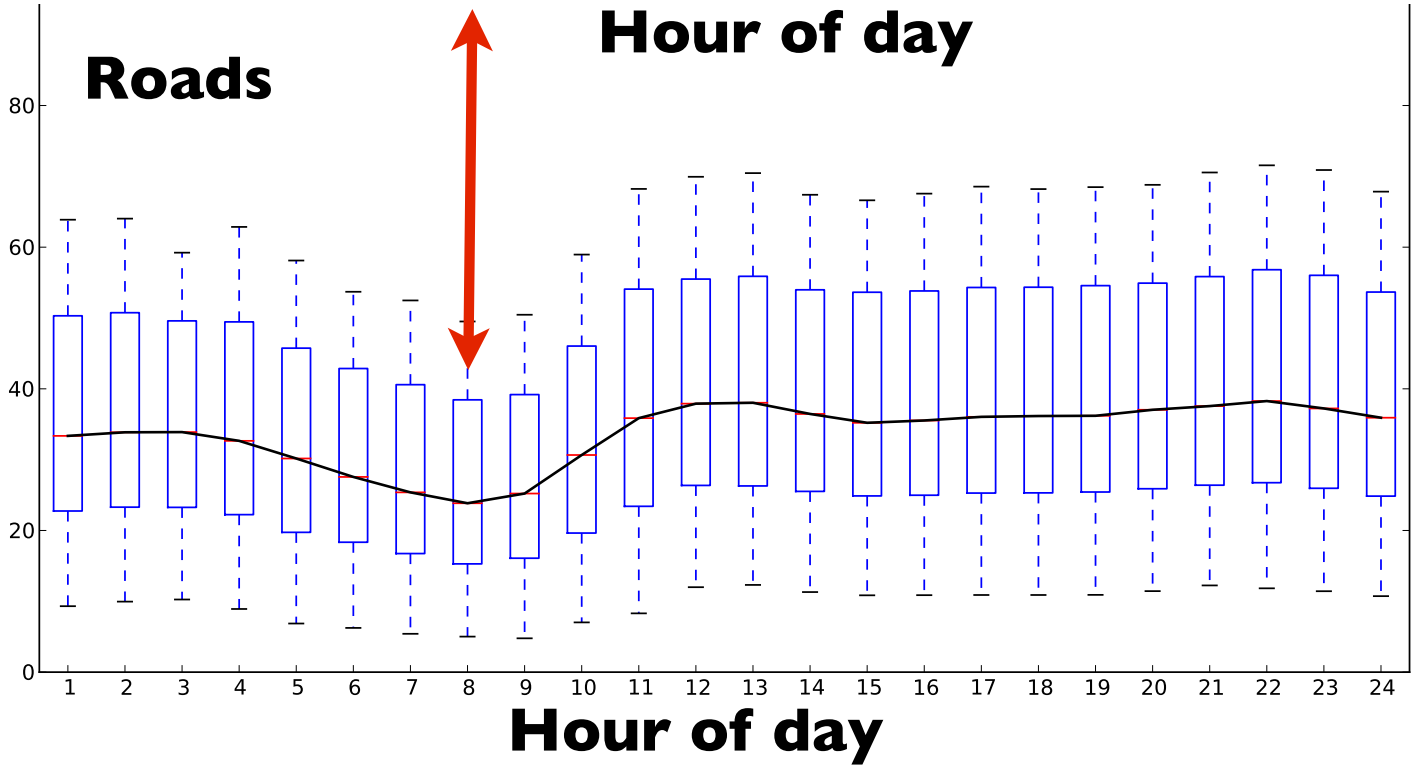
Differences in **temporal** profiles

NOx

$E_i / \overline{E}$



$E_i / \overline{E}$

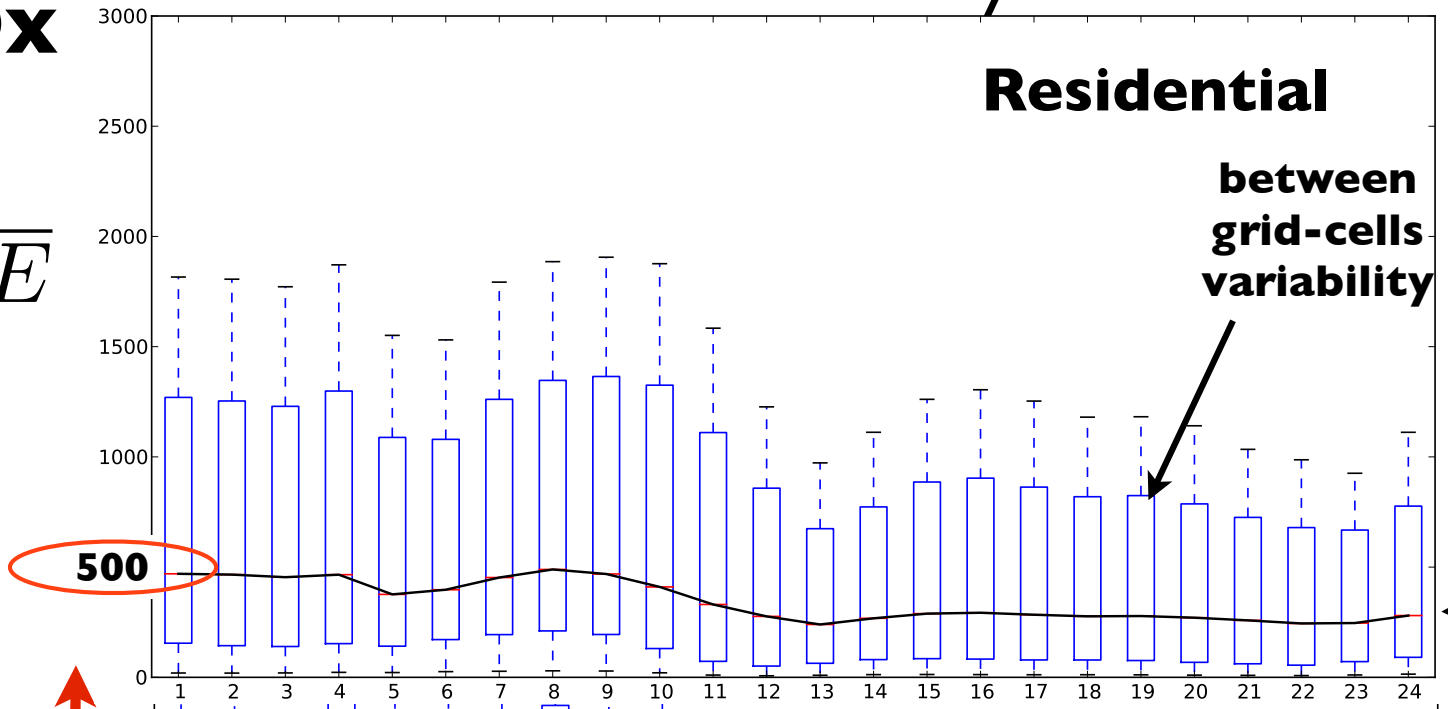


Differences **between counties**

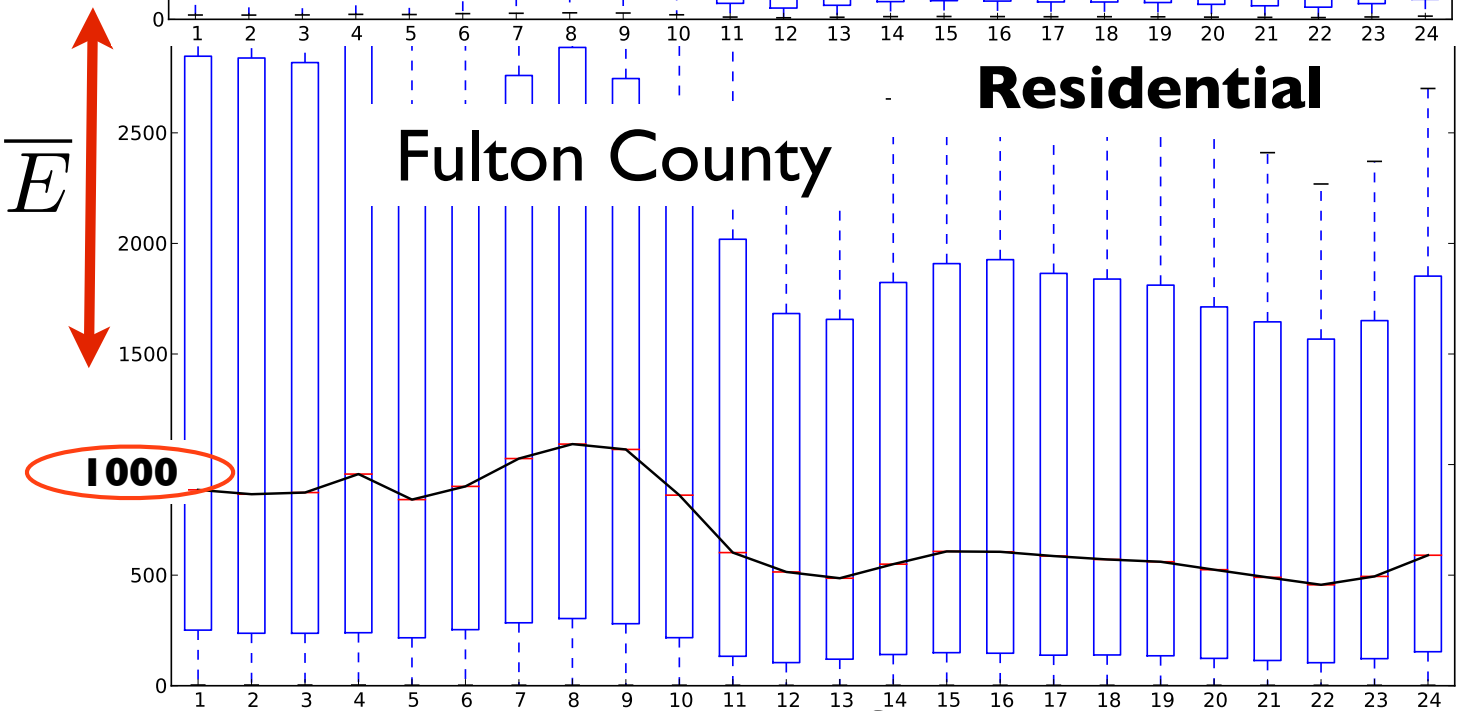
De Kalb County

NOx

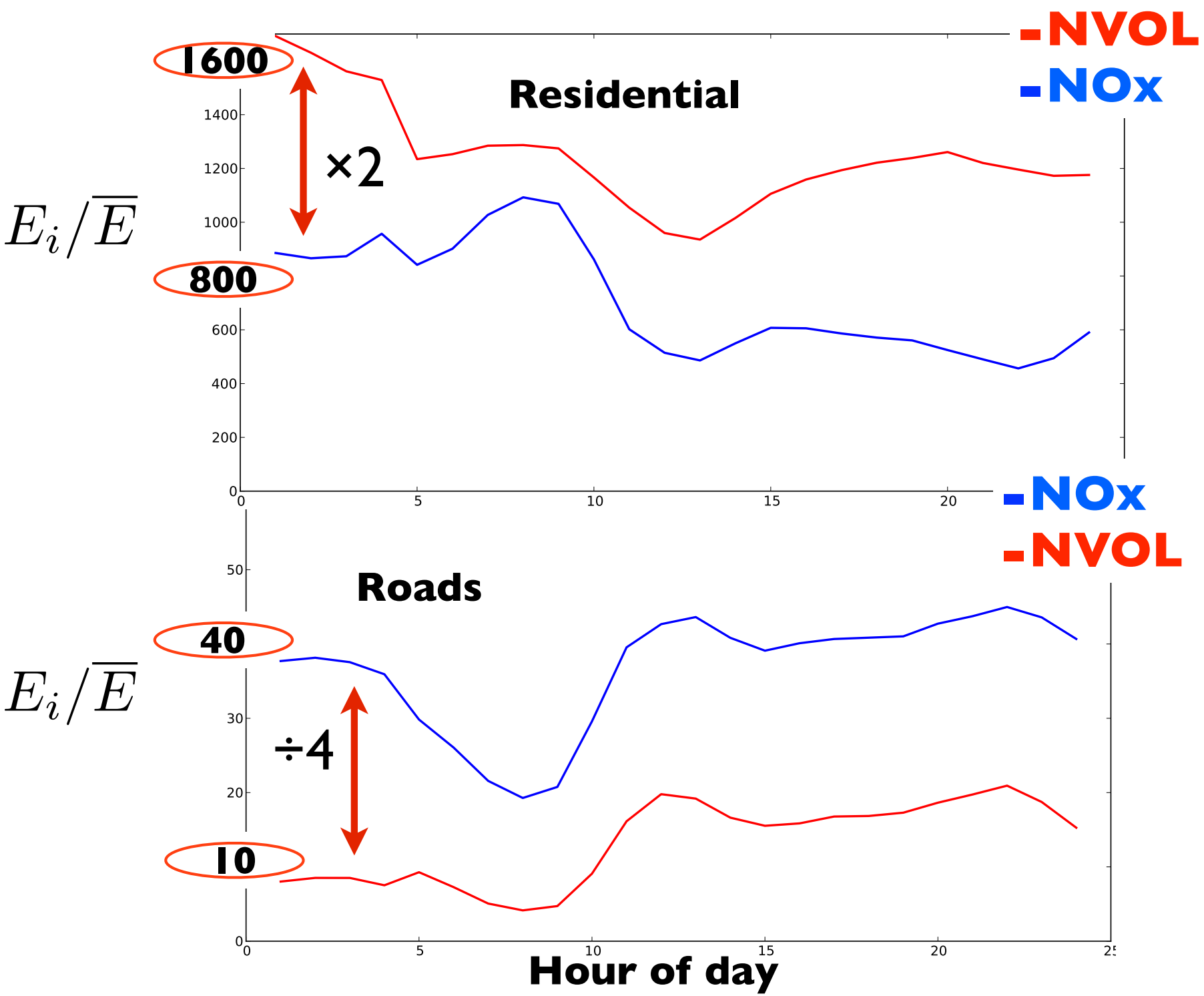
$E_i / \overline{E}$



$E_i / \overline{E}$



Differences **between pollutants**



In progress:

- Implementation into CMAQ
- Parameterization of the subgrid mixing *Tmix*
- Evaluation (available measurements, local scale model)

Medium term conclusions:

High variability in forcing terms:

- spatially between grid cells
- between counties
- temporally
- between pollutants

Attenuation of resolution effects (similar results for 1 and 4 km)

Tips:

- Low computational cost (selected grids, selected 'sectors')
- Link between local concentrations and time activity
- Concentrations 'ready to use' for exposure estimates