Accounting for Land Use Changes in Projecting Future-Year Emissions Scenarios

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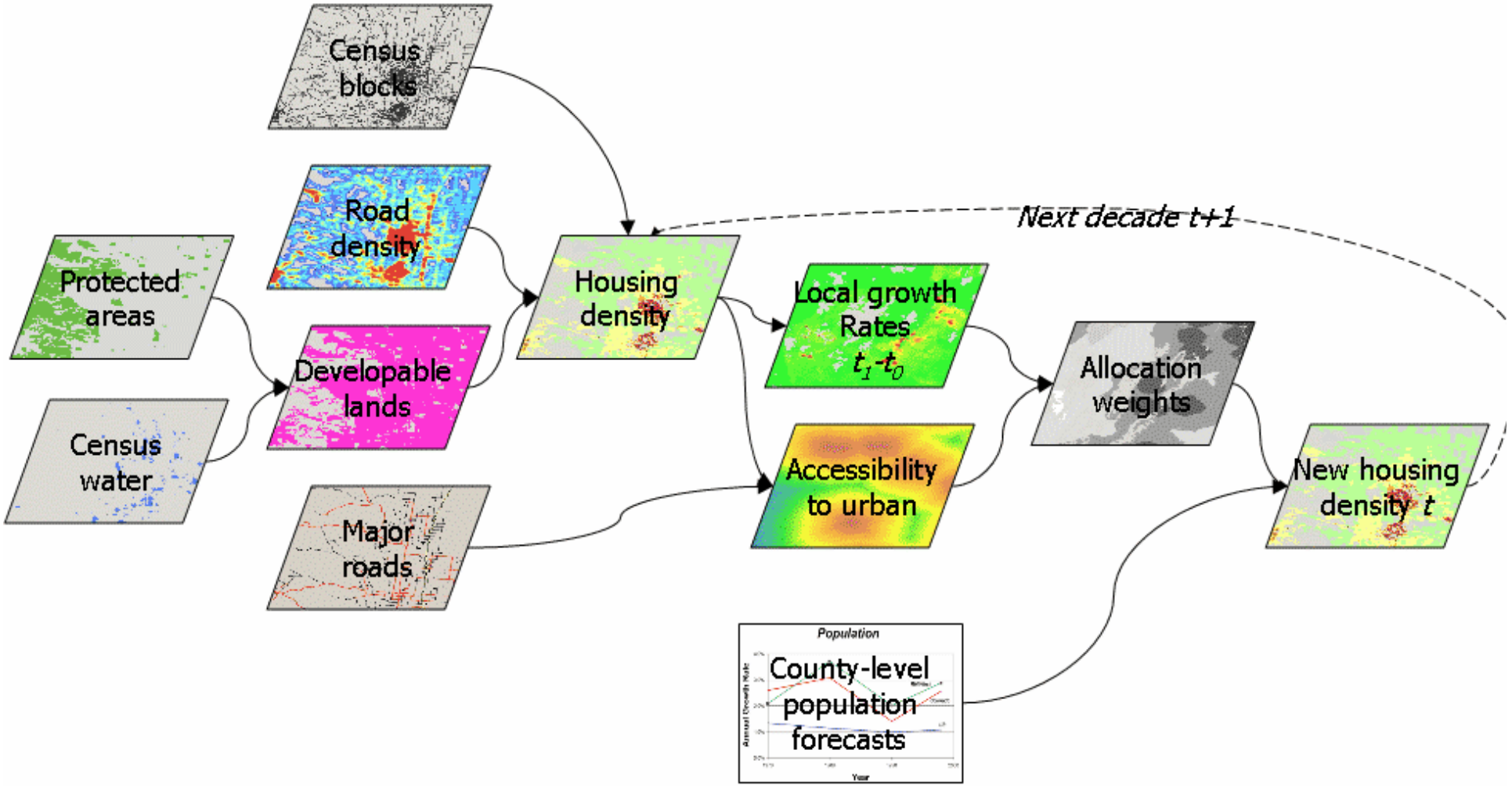
Goals of the Study

- In the real world, land use and emissions amounts change as new land is developed
- But, current modeling techniques do not update the location of emissions sources (or often emissions levels) when modeling future years
- The goals of this study are to:
  - Define procedures by which the spatial allocation of emissions in future years can be made more realistic
  - Assess the impact that updating the spatial allocation of emissions would have on future year air quality model results

Obtaining Realistic Growth/Development Estimates

- To better allocate emissions in future years, we need to know where growth in population and housing will occur
- The Spatially Explicit Regional Growth Model (SERGoM) can estimate future year housing density nationwide in 100m x 100m pixels across multiple decades
- SERGoM inputs include future year population forecasts, road networks, and information about developable land

SERGoM Provides Housing Density Estimates for 2010, 2020, 2030, …



Using SERGoM Data in Air Quality Modeling

- Future year emissions can be spatially allocated using SERGoM housing density outputs
- Sub-county level population estimates can be created based on housing density and estimated future year county population
- New urban and rural boundaries can be computed based on population density
- New spatial surrogates for allocating emissions in 2030 can be developed based on the revised population and urban/rural boundary data

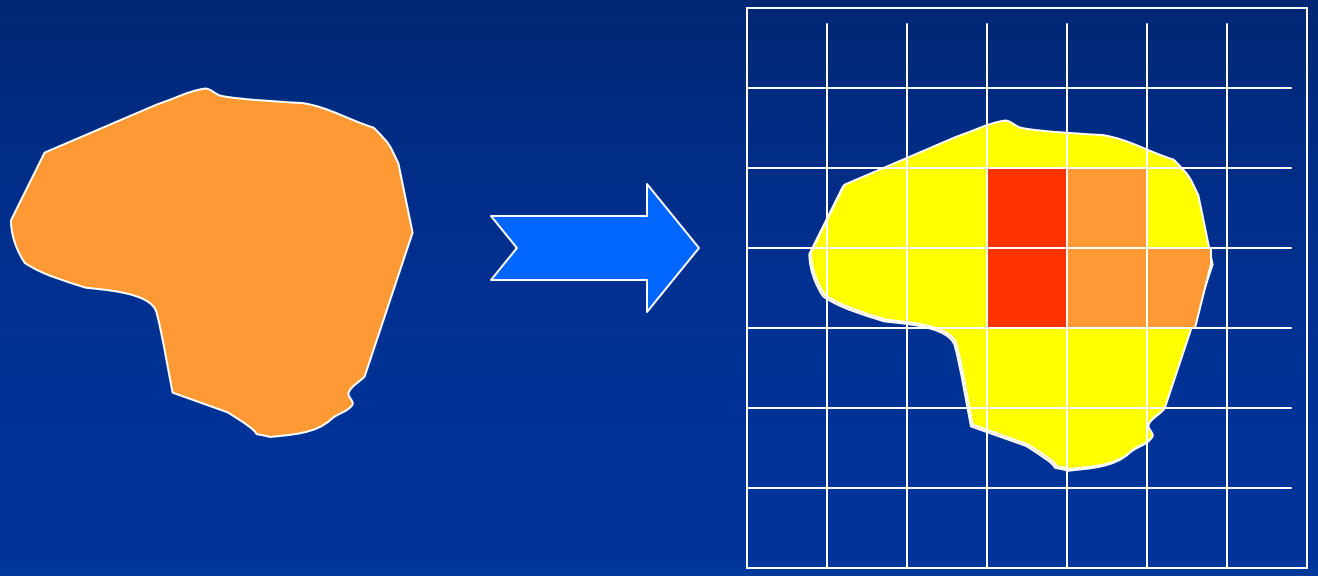
Spatial Allocation of Emissions

- For modeling, emissions must be spatially allocated into air quality model grid cells
- Spatial allocation methods vary by source type:
  - Point sources: by x and y point locations
  - Area/Nonpoint/Nonroad mobile sources: by spatial surrogates
  - Onroad Mobile sources: by spatial surrogates or road links
  - Biogenic sources: based on land use data

Spatial Surrogates

County-Total Emissions

Gridded Emissions



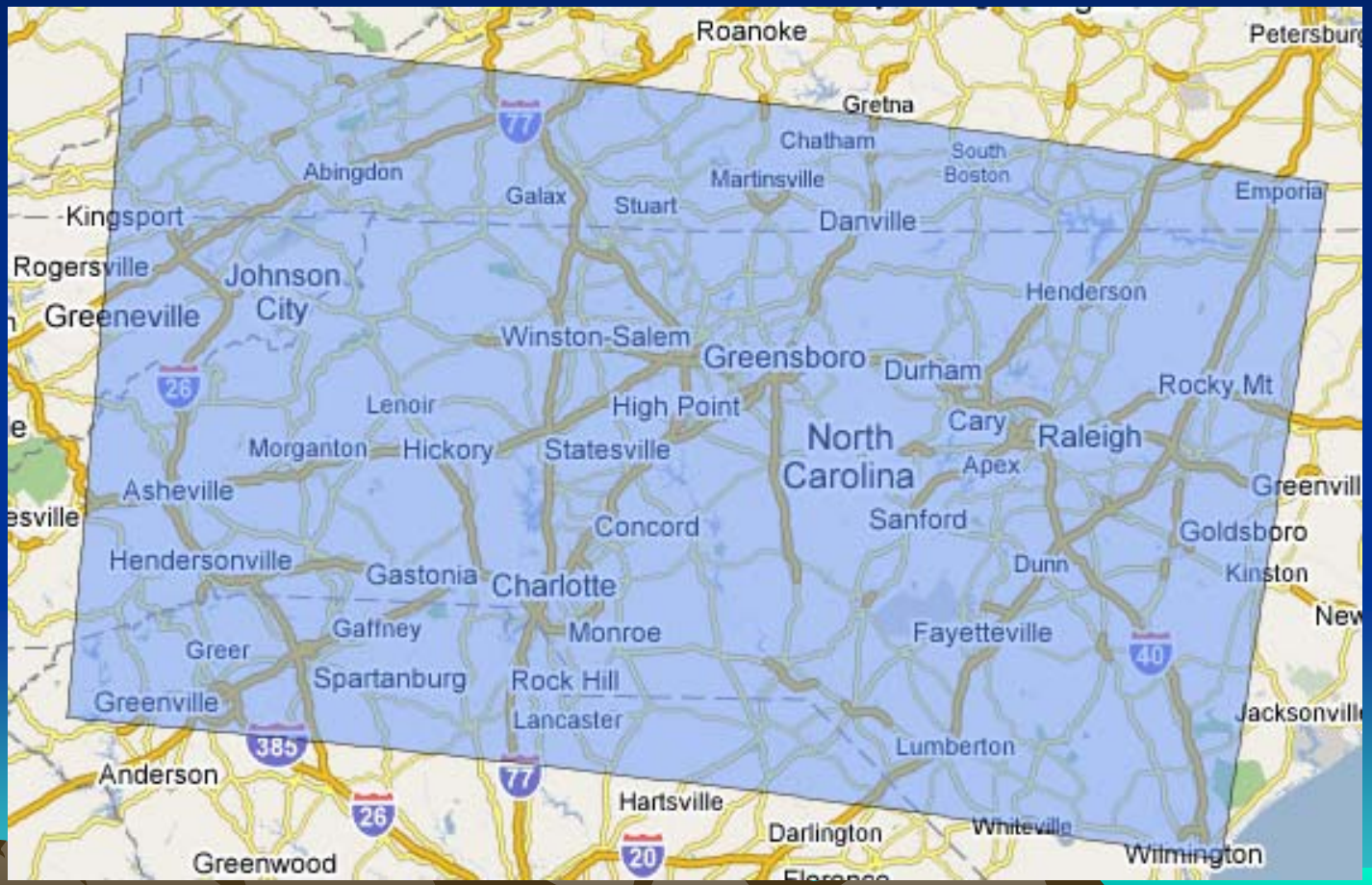
- Spatial Surrogates are fractions that add up to 1 for each county
- Emissions(grid cell) = srg(Cty, grid cell) * emissions(Cty)

EPA's Use of Spatial Surrogates

- Currently 65 spatial surrogates are used in EPA modeling
  - e.g., Population, Urban Population, Housing, Urban Primary Road Miles, Rural Secondary Road Miles
- They can be generated using the Surrogate Tool
- Based on data found in about 2 dozen Shapefiles
- Generated specific to each modeling grid

Study Area

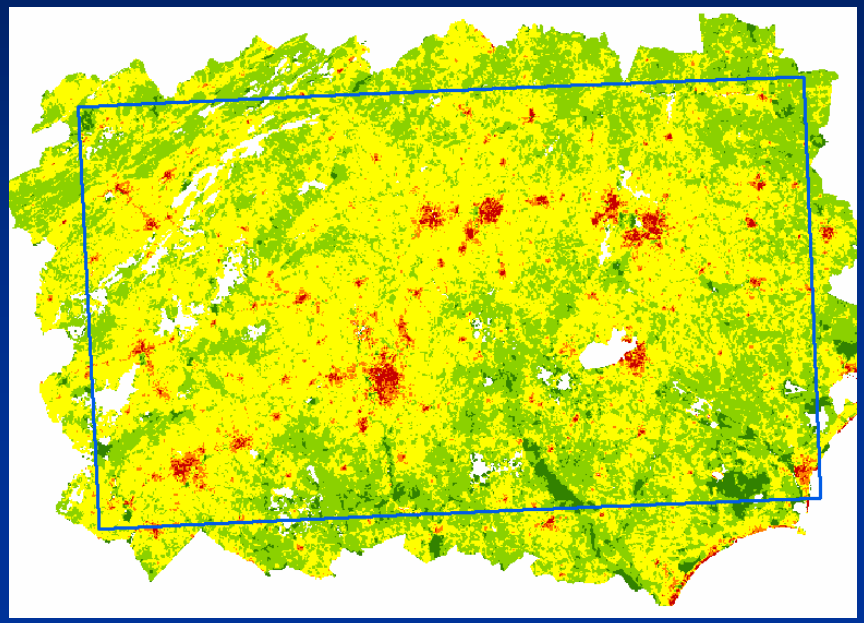
A 4km x 4km study domain previously used for modeling by the NC Department of Environment and Natural Resources (NCDENR) was selected

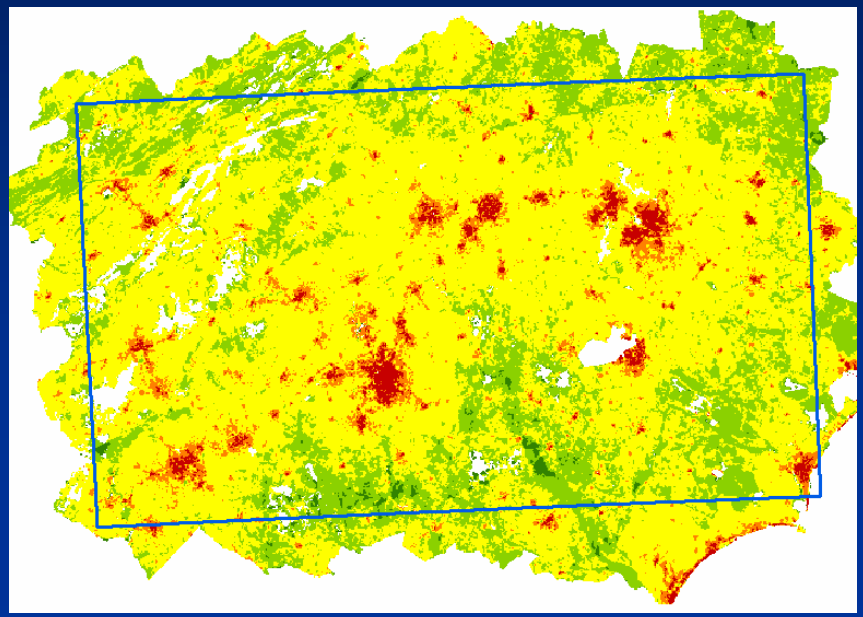


Data Used in Our Processing

- Projected county-level population data that was used as input to run SERGoM.
  - Not the same as 2000 census population data, but less than 1% different (except that 12 counties and cities in VA had missing values)
- SERGoM Housing density output for the year 2000 and 2030 was provided by David Theobald at Colorado State University (ArcGIS grid format)
- Surrogate input Shapefiles posted on EPA's Emission Modeling Clearinghouse web site.

SERGoM Housing Density Data 2000 and 2030





- Undeveloped Private
- Rural
- Exurban
- Suburban
- Urban

Surrogate Shapefile Generation

- SERGoM housing density data were clipped, converted to polygons from raster, reprojected to the map projection of the grids, and overlaid with the county Shapefile to generate:
  - Population = county population * housing units / county total housing units
  - Urban areas = areas with population density >= 1000 people per square mile
  - EPA 2000 roads were reclassified into urban and rural using the newly computed urban and rural areas, but no road network changes were included

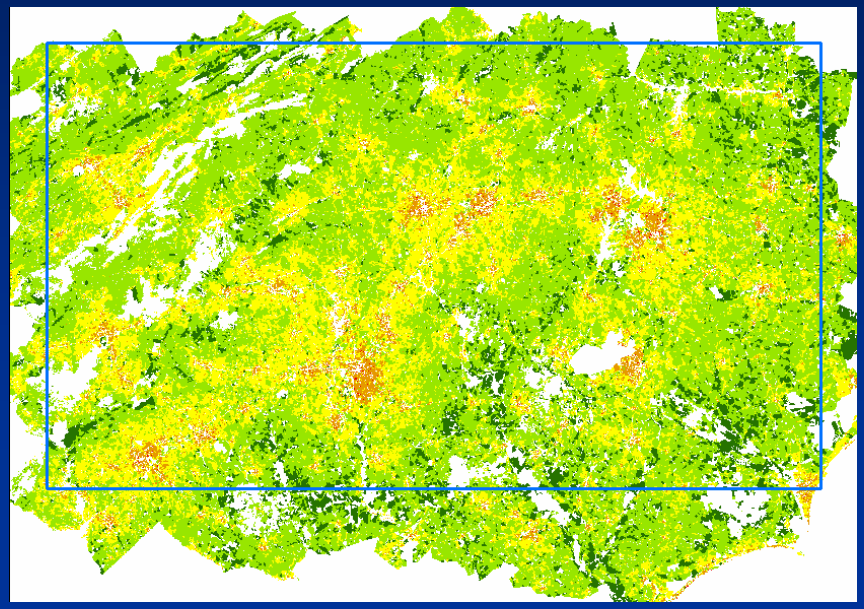
Adjusted Surrogates

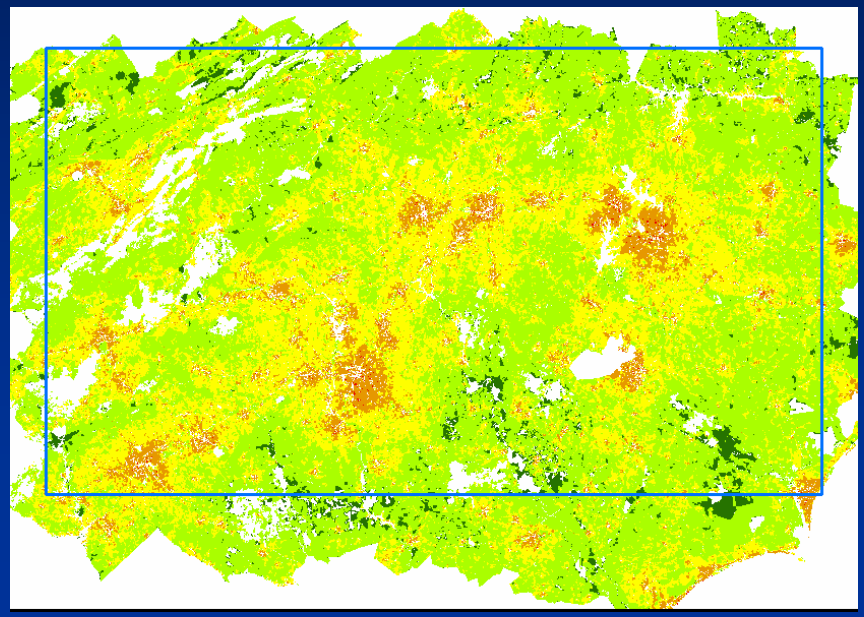
Eleven spatial surrogates were generated using the Surrogate Tool on 4km, 12km, and 36km grids

(http://www.epa.gov/ttn/chief/emch/spatial/spatialsurrogate.htm)

SURROGATE NAME	SURROGATE CODE
Population	100
Housing	110
Urban Population	120
Rural Population	130
Urban Primary Road Miles	200
Rural Primary Road Miles	210
Urban Secondary Road Miles	220
Rural Secondary Road Miles	230
Total Road Miles	240
Urban Primary plus Rural Primary	250
0.75 Total Roadway Miles plus 0.25 Population	255

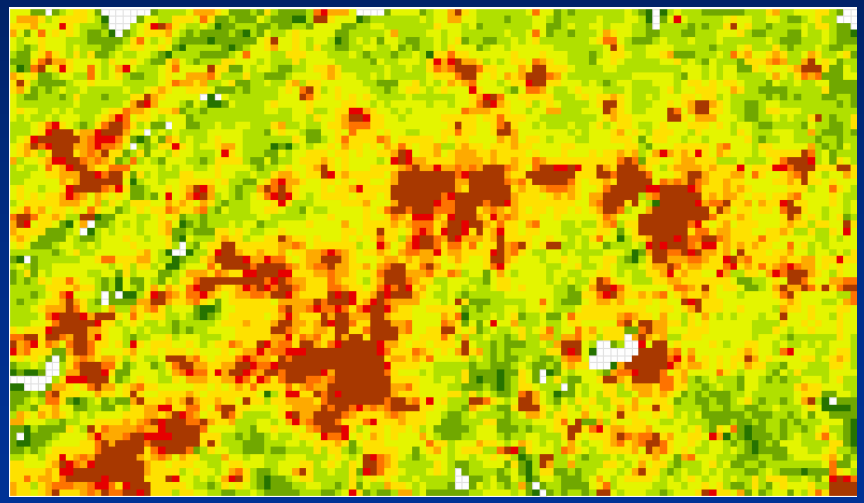
Estimated Population per Square Mile (2000 and 2030)

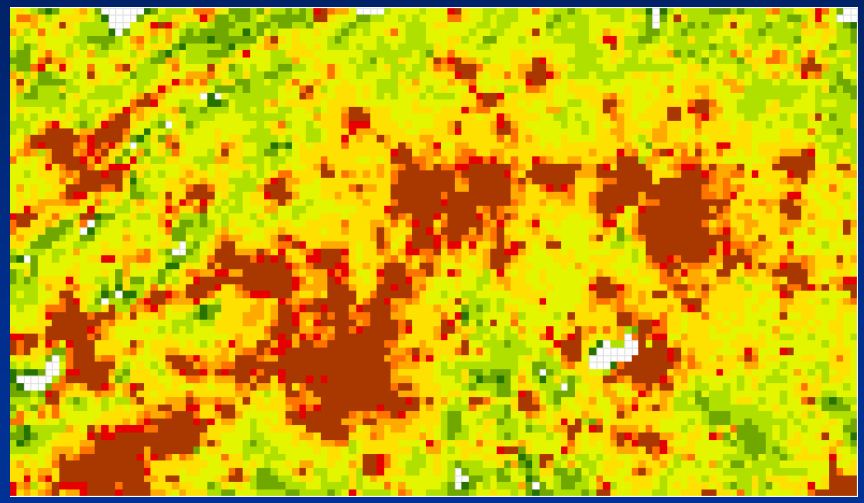




Note expansion of the urban, suburban, and exurban areas

4km Gridded Population 2000 and 2030



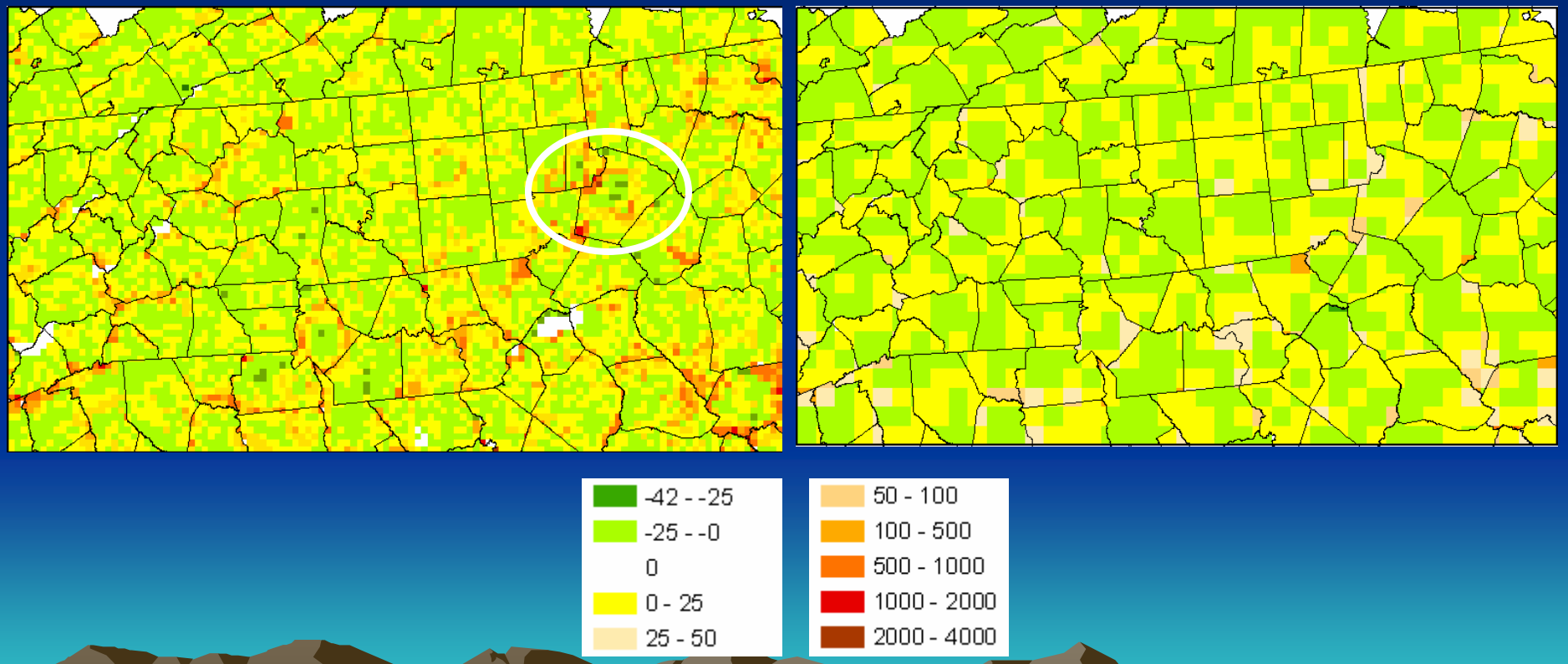


0	501 - 1000
1 - 10	1001 - 1500
11 - 100	1501 - 2000
101 - 250	2001 - 2500
251 - 500	2501 - 35875

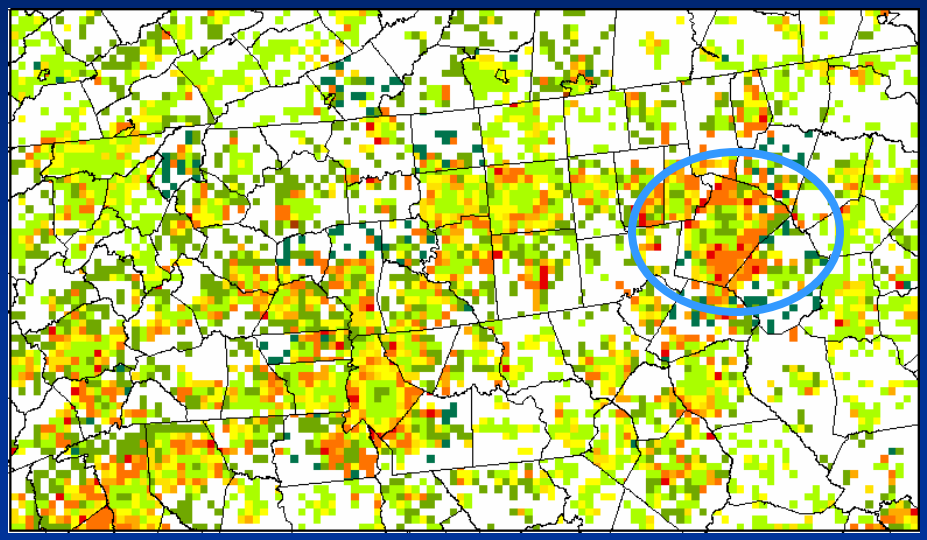
Resulting Changes in Surrogates

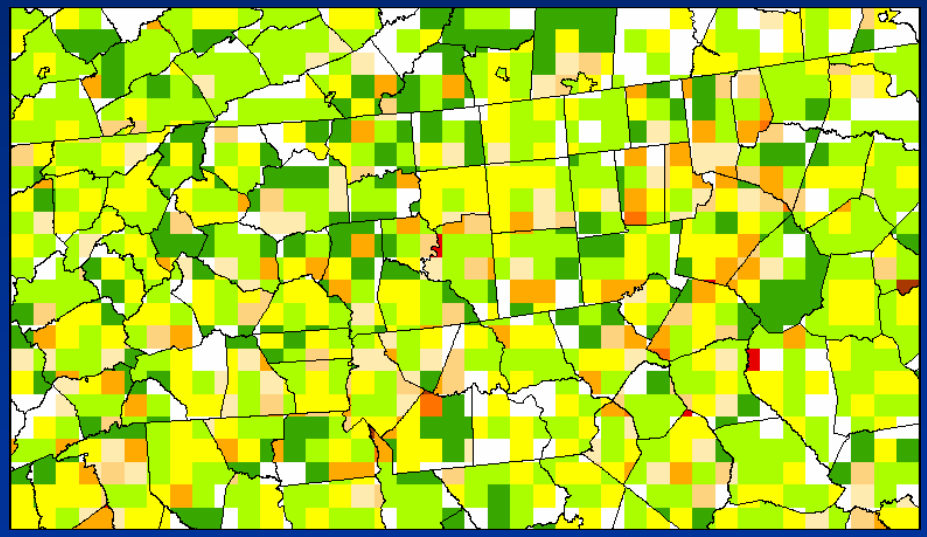
- Population surrogate differences from 2000 to 2030 are larger on 4km grid than 12km grid
  - 4km grid: -100% to 124216% vs. 12km grid -42% to 4000%
- Urban population showed spikier differences
  - 4km grid: -100% to 441453% vs. 12km grid: -42% to 2738%
- For both grid scales the percent of change in most areas go between -25 to 25 percent, but changes are more muted in coarser grid
- Within a county, when one area gets higher, another area has to get lower (because the sum of surrogates within a county must be 1)

Percent difference in Population Surrogate (2030-2000) 4km and 12km



Percent difference in Urban Population Surrogate (2030-2000) 4km and 12km





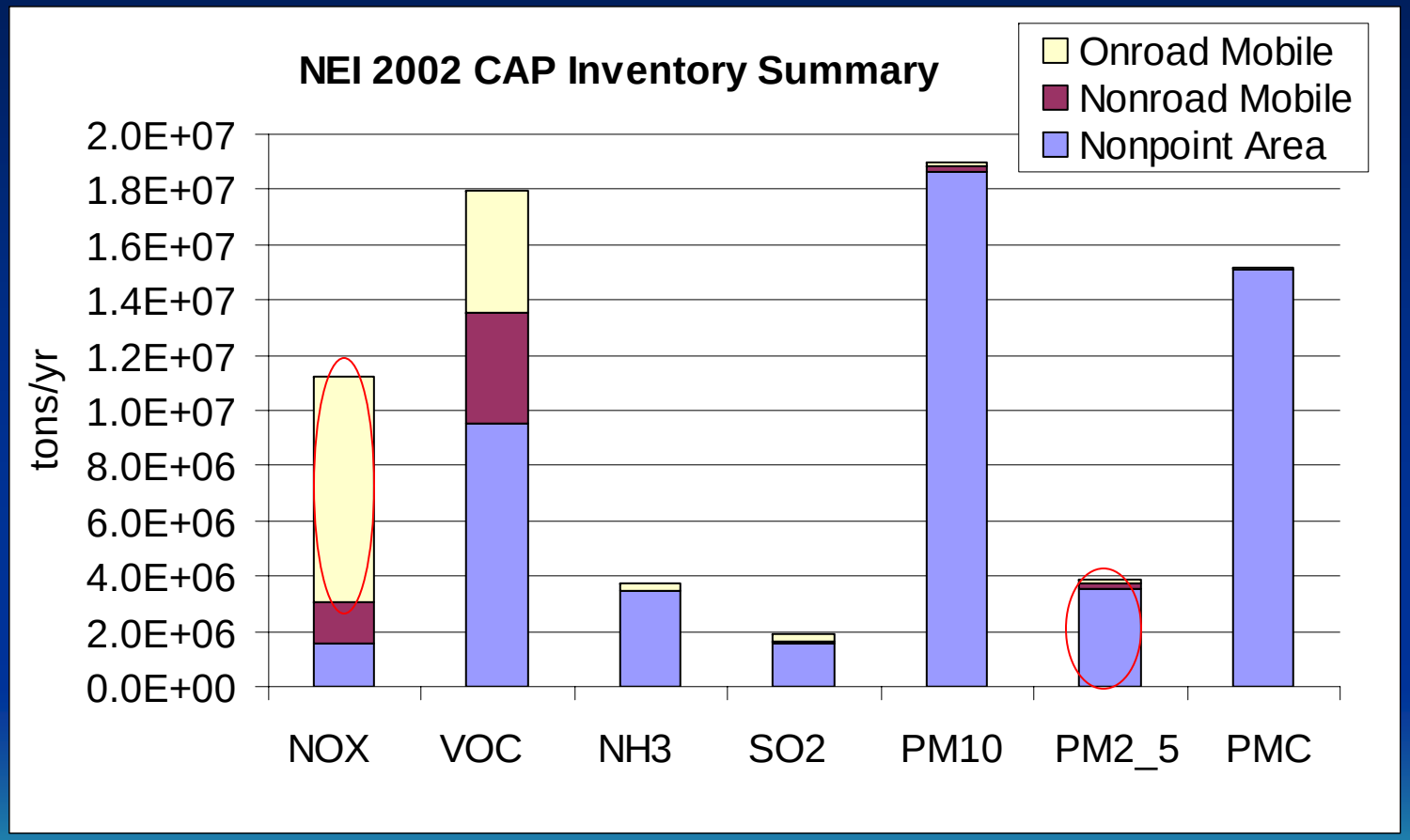
-42 - -25
-25 - -0
0
0 - 25
25 - 50

50 - 100
100 - 500
500 - 1000
1000 - 2000
2000 - 2738

Emission Processing

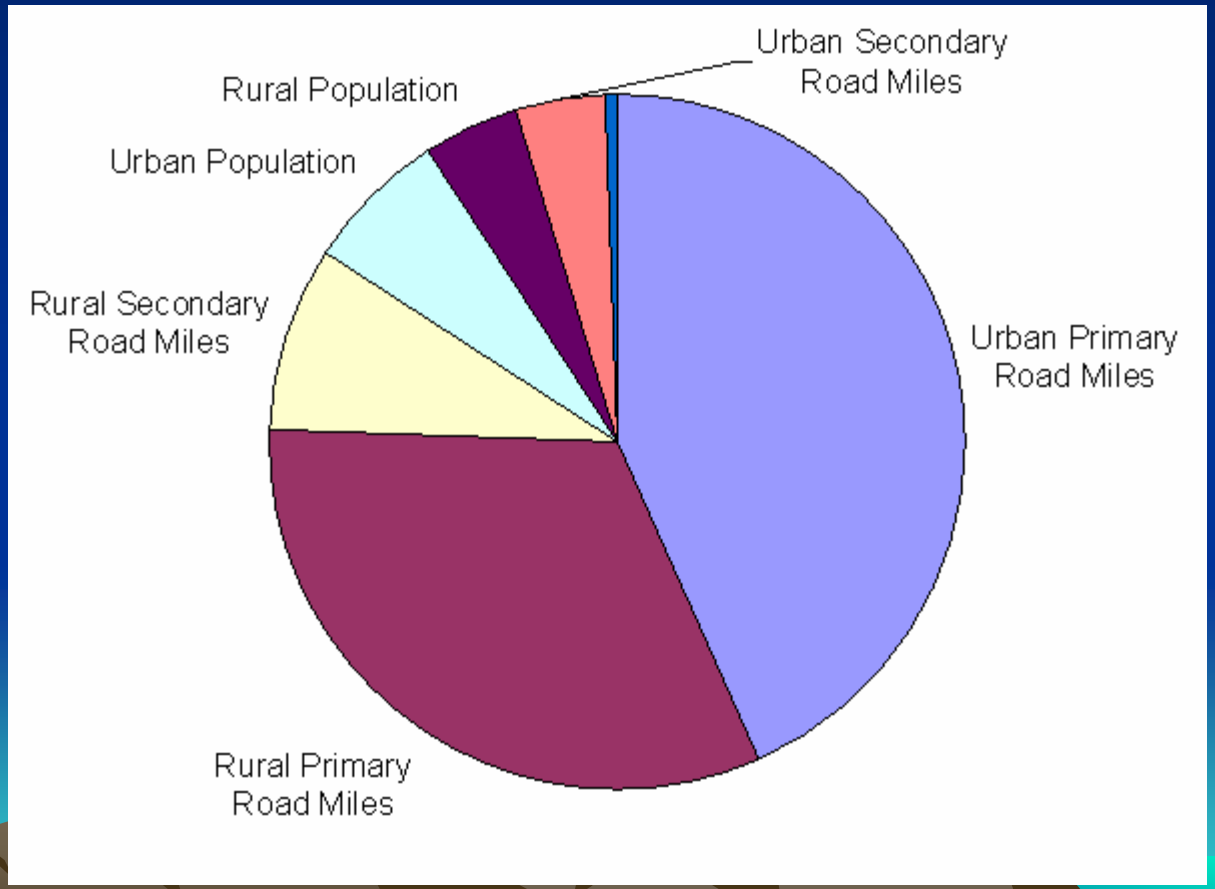
- The 2002 NEI area and mobile source inventories were processed using the adjusted surrogates for 2000 and 2030
- Reports of gridded, unspeciated, annual emissions were created for inventory sector-pollutant combinations that made up a substantial component of the inventory
- No emissions growth was included

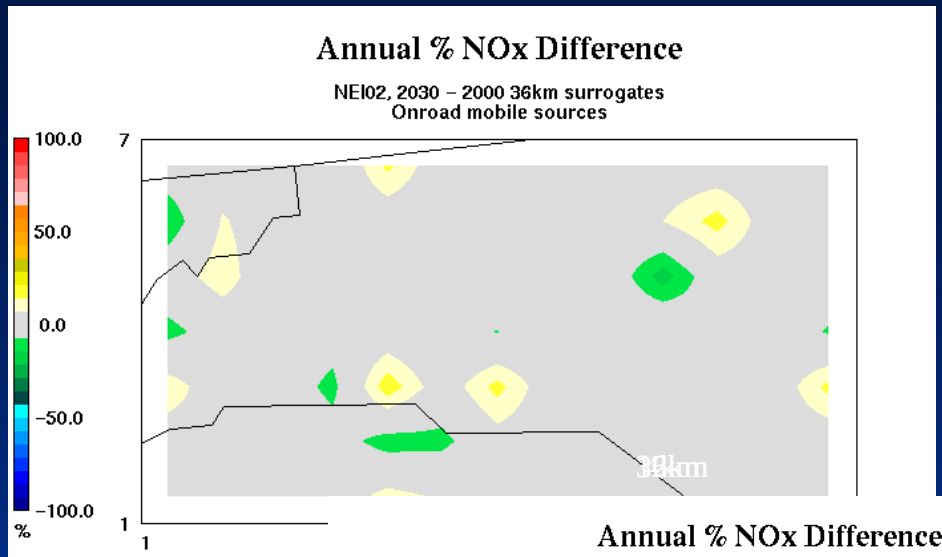
NEI 2002 Pollutant Summary

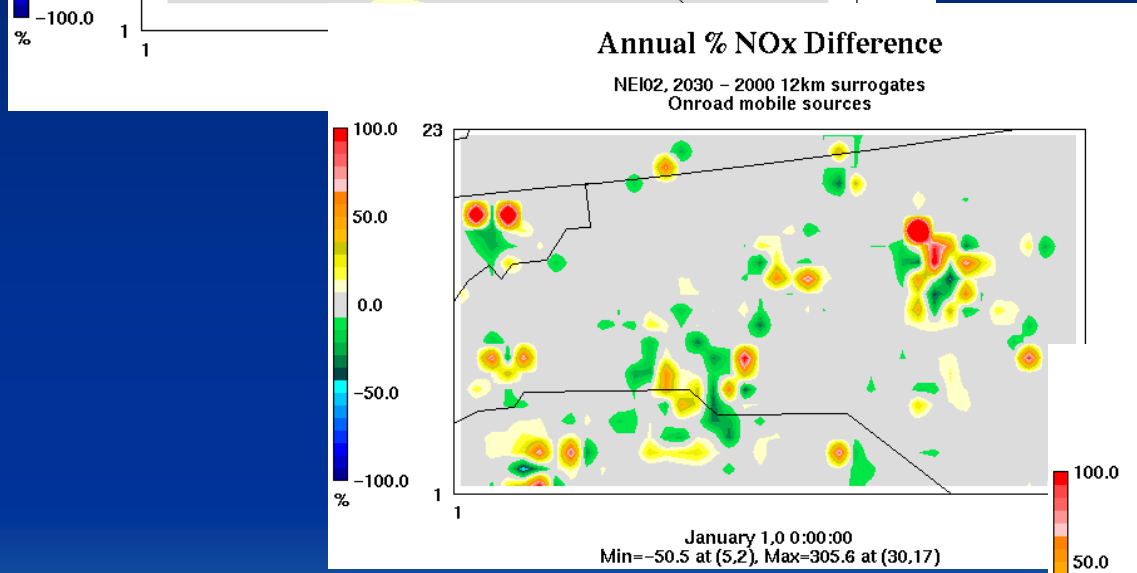


Major Surrogates Used for Onroad Mobile NOx Emissions

Emission sources are mapped to surrogates based on SCCs

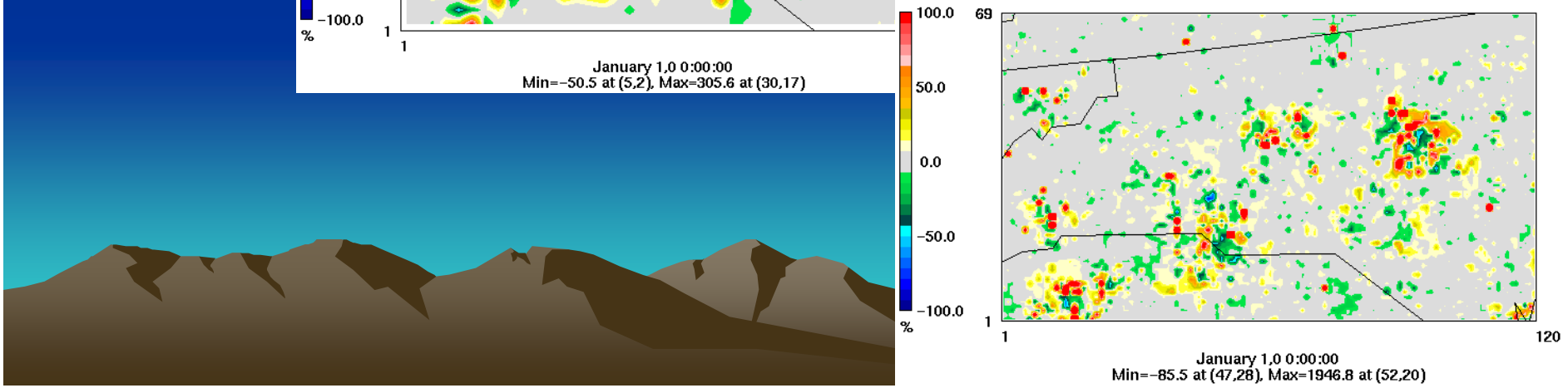




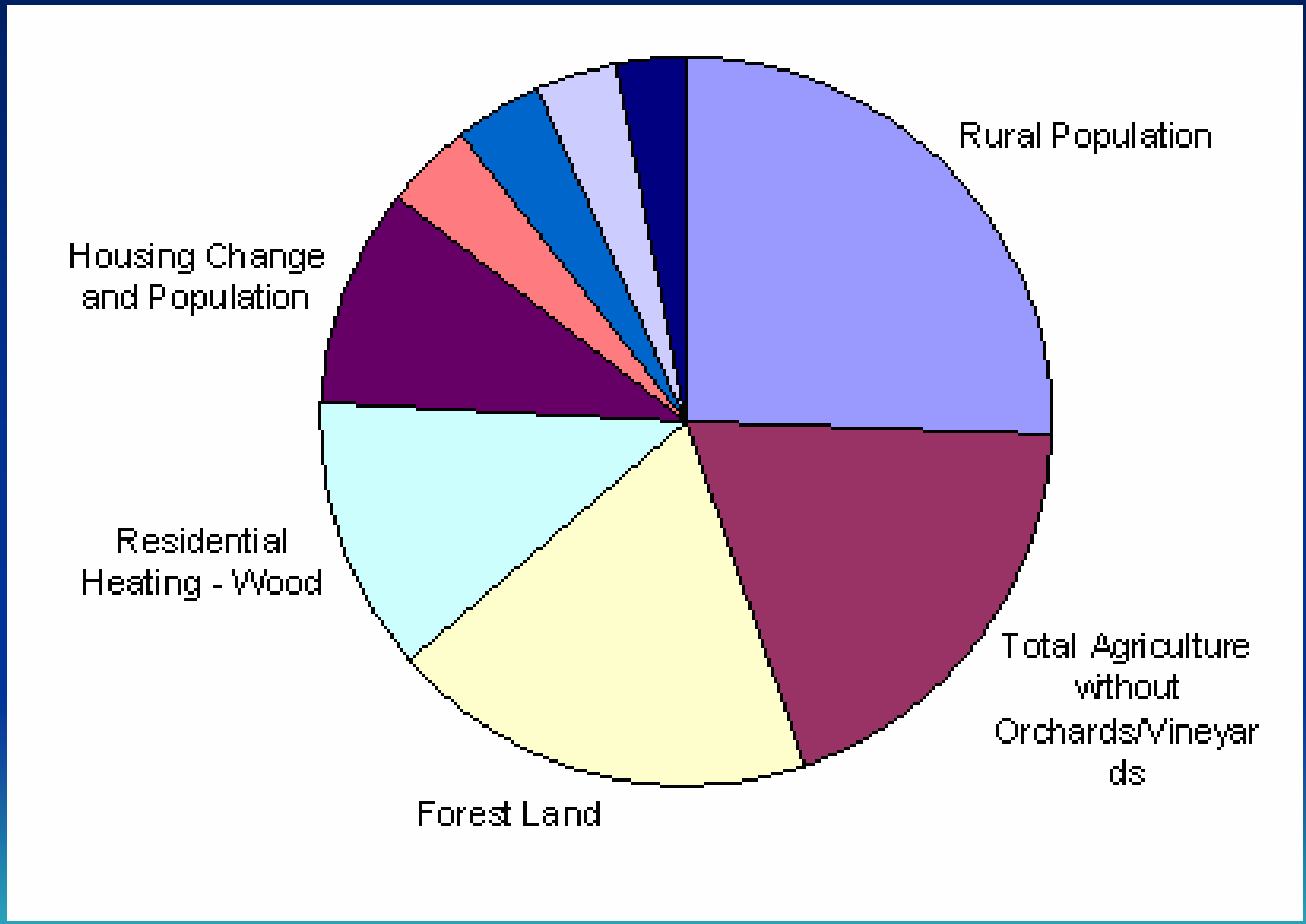


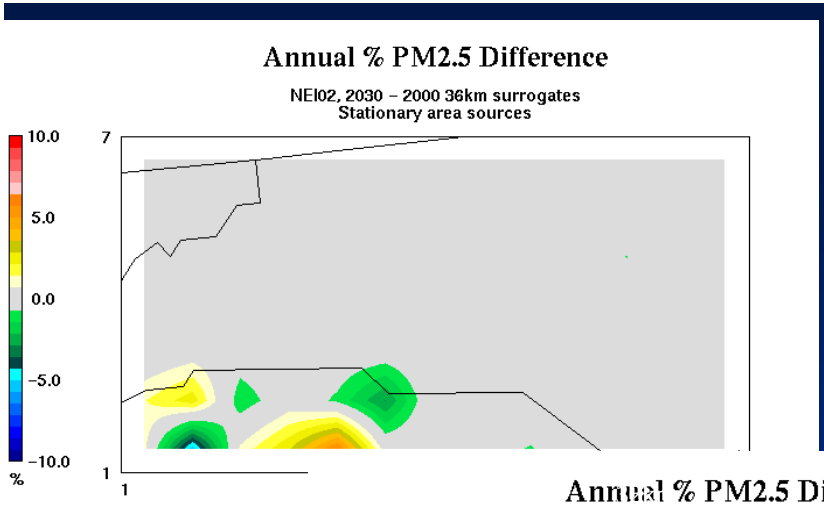
Impact of grid scale on emissions changes at 36km 12km, and 4km:

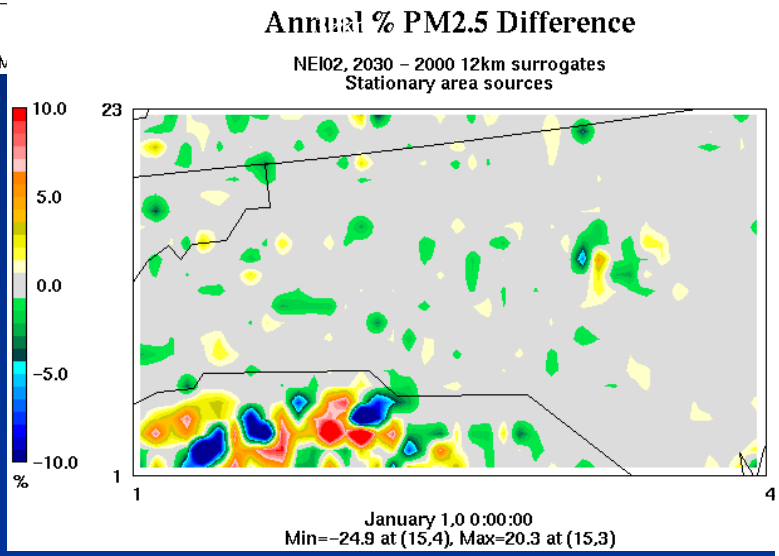
- Note that the changes are much more significant at finer grid scales
- In Raleigh area, fewer emissions are allocated to downtown



Major Surrogates Used for Stationary Area PM 2.5

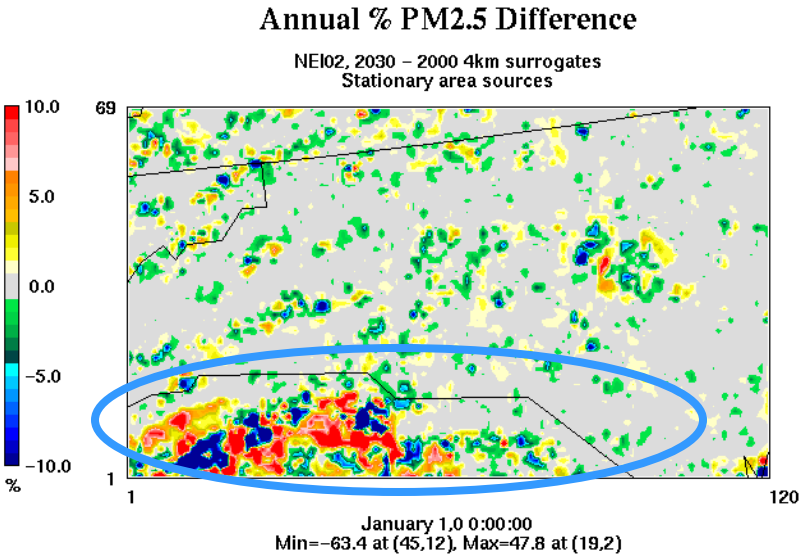






These illustrate that in South Carolina the updated surrogate Rural Population is heavily used

- Greater impacts in NC would have been seen if we had also updated the housing change and population surrogate



Map Projection Issues

- The Surrogate Tool, SMOKE, and CMAQ can only handle a spherical earth
- But housing density data were provided in the Albers Conformal Conic projection using the NAD83 geographic datum
- We found a substantial coordinate distortion (on the order of 20 kilometers) after transforming NAD83 data to Sphere and back using ArcGIS
- This can be a problem for fine resolution grids
- We suggest using the same sphere projection for all shapefiles to minimize distortion during shapefile generation
- Coordinate transformation functions using control points may be needed when distortion is large

Summary of Results

- Updating some of the surrogates with SERGoM outputs over 30 years resulted in significant changes in the surrogates and in the resulting emissions
- Changes are more noticeable at smaller grid resolutions

Limitations and Assumptions

- The accuracy of created Shapefiles largely depends on projected population and housing density data
- We assumed that population is proportional to housing units (this may not be valid in vacation hotspots with many seasonal residents)
- The definition of Urban was based solely on population (city boundaries were not considered)
- Assumed that road networks remain the same and only urban/rural classification changed
- Assumed that the amount of emissions remained constant between 2000 to 2030

Possible Future Work

- Consider adjusting additional surrogates (e.g., housing Change and population, rural land area, total agriculture)
- Consider using fewer than 66 surrogates for future year modeling (e.g. map more SCCs to housing)
  - We did not have a way to adjust the household heating surrogates, which account for a large fraction of the stationary area VOC and PM emissions
- Consider updating road networks for mobile sources and land use data for biogenic sources
- Recompute results with latest SERGoM run and population projections
- Consider adjusting actual emissions in areas of substantial population growth

Acknowledgements

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