GIS assisted emission inventory development of variable grid emission database for Mississippi region

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Abstract

The present paper discusses methodology and highlights the results of the model for preparing variable grid emission inventory database using existing macro level emission database for inputting into pollution/chemistry – climate models. The fundamental goal behind the work is to prepare variable grid air pollution seasonal emission database for using in Community Multiscale Air Quality Model (CMAQ) system and development of microscale / mesoscale coupling of air pollution dispersion for Mississippi Gulfport area. A Geographical Information System (GIS) based methodology for distributing the emissions from macro scale inventory to finely gridded emission values (microscale), considering local micro-level details, emission sources, activity data and season of the year using relational data structure is described. For the model description, model performance a case study of Mississippi region is presented. The USEPA AP42 emission factors database is taken as the source for the development of emission inventory in conjunction with GIS database for landuse / land cover, point data sources. Various stochastic geo-statistical interpolation techniques were tested for spatial mapping under GIS environment. The model is used compute non biogenic emissions at non-sampled location and it is anticipated that in future the model will incorporate the satellite derived vegetation indices, Leaf are index database for development of comprehensive emission inventory for both biogenic and non biogenic emissions.

Introduction:

The atmospheric processes exhibit a multi-scale character. The forecasting of primary and secondary pollutant transport and dispersion is required for efficient air quality assessment in order to apply effective air quality management strategies. Because of their importance and complexity, scale interaction processes significantly affect model predictability and are one of the main sources of uncertainty in mesoscale modeling. Currently an integrated model system for air pollution applications is being developed for Mississippi Gulfport area.

The goal in this effort is to construct a multiscale dispersion forecasting capability tailored for application in the Gulf Coast region. The model system includes several meteorological and air pollution models capable of operating for different applications at different spatial scales – ranging from mesoscale to urban background scales to urban street scale. The model development is based on several air quality and meteorological models with a spatial resolution of 36 km x 36 km over the coarse grid and 4 km x 4 km on a sub-domain centered at Mississippi Gulfport. One of the major requirements of the model development, besides meteorological fields, is surface emissions database of the study regions i.e development, operation; validation is only possible if high resolution emission data are available. The paper highlights the studies carried out to develop variable grid emission inventory database for Mississippi Gulfport area, the main motivation behind the work is that highly resolved meteorological data and emission inventory improves the modeling results and enhances our understanding of the multiscale air pollutant dispersion

Domain and data:

The study region comprises the Mississippi Gulf Coast and its adjoining areas (Figure 1). Emission inventory database is developed with grid resolutions of 36, 12 and 4 km. Outer domain is taken to cover the South-central US and the surrounding Atlantic Ocean to capture the dynamics that might influence the circulation in Mississippi while inner finer grid (4 km) covers the Mississippi Gulf Coast off Louisiana above the Gulf of Mexico. The coarse domain has the size of 54x40 grid points while the finer domain has 187x 118 grid points. Data along with relevant spatial data i.e base maps, coordinates, county, local boundaries has been collected. The data for the analysis are obtained from Mississippi state GIS clearinghouse MARIS and also from FEMA for household density, house type data.

Methodology:

i) Preparation of thematic layers::

Different thematic layers are used to interact and to determine the locations of industries, areas and also for editing factors. These thematic layers will also be used to for computing emissions and extracting inventories. Different thematic layers prepared include i) EPA facility map ii) Industrial iii) counties, iv) population v) transportation layers vi) area boundaries. They are used to determine the surrogates as well as to identity the sources and to visually represent data. Figure 2 shows the different infrastructural maps prepared for the study.

We prepared emissions on 100km×100km and 25km×25km, 4kmX4km and 2kmX2km grid for the emission estimation, then assigned administrative unit emissions to each grids. The process was started from the 1st level administrative unit emissions, and then further transformed to the 2nd level administrative units. This information was then spatially allocated to 100km×100km grids, 25×25km grids, 4kmX4km and finally to 2kmx2km resolutions.

ii) Preparation of attribute information:

Attribute information data are used to compute activity in emission estimation. Each feature whether industries, populated areas or road transport network are correctly proportioned attributes based on the level of the information i.e .within each feature class group there may be one or more separate GIS layers (or subtypes) that represent the individual layers within each feature class (e.g., the Roads attribute feature class can contain multiple subtypes, one for a centreline road network and a second for an link-based road network) or level of population in each counties. The attribute values themselves can be edited allowing users to tweak values such as a feature’s population, number of lanes on a road, etc.

iii) Pollutant coding

Pollutants are coded using a text based short description so as to make them associate with specific Emission Factors with certain Source Characterization Codes. In the current scope of the work sulfur dioxide, oxides of nitrogen, carbon monoxide, particulate matter total area computed. In future it is anticipated that more pollutant groups namely VOCs, Ammonia, biogenic source groups will be added.

iv) Source classification coding:

Source Sector codes are mapped to relate SCCs and to use them for reporting and querying purposes. Source Classification Codes are used to identify the type of emissions being computed for a particular Emission Estimate and are the primary means of classifying and allocating emissions within the GIS.

v) Pollution calculation:

Figure 1 shows the GIS based methodology for computing emissions in the study area. Two different approaches were used for building the emission inventory - one is bottom-up and the other is top-down. The top-down approach was used for significant emission sources like Large Point Sources (LPSs), and the bottom-up approach was used for less significant sources like area and line sources. The basic methodology to estimate administrative level emission of a species can be represented as following formula:

$$\text{Emission} = \text{Activity level} \times \text{Emission factor} \times (1 - \text{Removal Efficiency})$$

Each country/species have different sectors and emission amounts by administrative unit. The emission sectors included are industry, residential, commercial, agricultural, transport, construction, and service. This method is capable of calculating emissions using GIS-based methodology for different activity areas namely land use and population, roads, rail, industry, power plants etc. Creating Emission Inventories is a tedious and time-consuming task. Energy consumption rates and other essential data are available for the county levels, which are calculated to local Microscale features based on surrogates such as population and Landuse, density of industrial sources (Fuel consumption rates)(NIF) etc.

A systematic work has been carried out to use GIS software program to compute, view and import and export Emission Inventories. Key inputs required to facilitate this process include: GIS-based activity data and associated emission factors (including scaling factors, control factors, and activity formulae), emission sources, Landuse and GIS spatial functionalities. Emission inventory parameters namely source classification codes, source sector cross-reference tables, pollutants are used to interlink different tables and to compute emissions. Emission Inventory is made up of a series of emissions data calculated using emission estimation equation using a unique Source Classification Codes (SCC) and AP42 emission factors. Using relational structure Emission Factors, SCCs, Pollutants and Activities, emission rates are computed through the study region.

vi) Interpolation scheme:

Interpolation has been used to convert the mapped point data into a continuous field for visual interpretation. Natural neighbor local interpolation method has been used to calculate the emissions.

Results:

Emission estimation is carried out in GIS using statistical functions, currently no GUI is developed for computing the emissions, and in future automated emission level computation will be incorporated. Once Emission inventory is prepared it is exported using dbf format from the tables, can be viewed as a series of maps and also as different charts, which are available in GIS. Figure 3 shows the emission inventory from different sources in the Mississippi region obtained from EPA. Figure 4 shows the GIS output maps generated using the method described. It is observed that calculation of the functionalities using GIS for normal operations is memory intensive requiring computational power of greater than 1 GB RAM.

Conclusion:

Work is being carried out to identify emission sources and emission levels using mesoscale to Microscale approach. Multiscale modeling for emissions using in-depth data inputs namely street configurations, fuel consumption rates, emission factors, and detailed population and housing types and other fugitive sources are being implemented for the finer grid for Microscale modeling. It is proposed to carried out to identify emission sources and emission levels using mesoscale to Microscale approach. Multiscale modeling for emissions using in-depth data inputs namely street configurations, fuel consumption rates, emission factors, and detailed population and housing types and other fugitive sources are being implemented for the finer grid for Microscale modeling.

References:

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2. United States Environmental Protection Agency (USEPA), 2001, National Emission Trends (NET) Database, via the USEPA AIRData Website.

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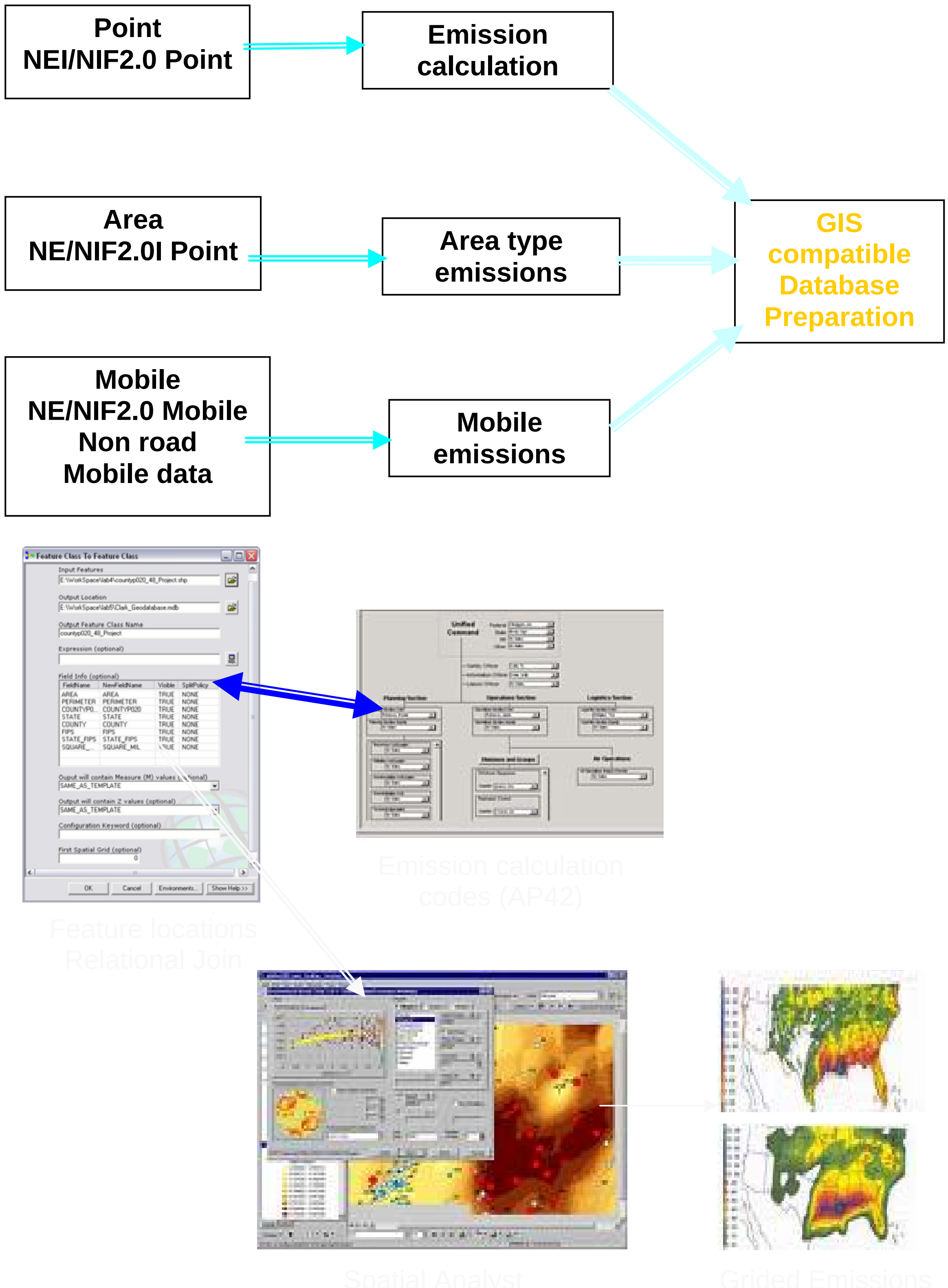

Figure 1 GIS based methodology for computing emissions

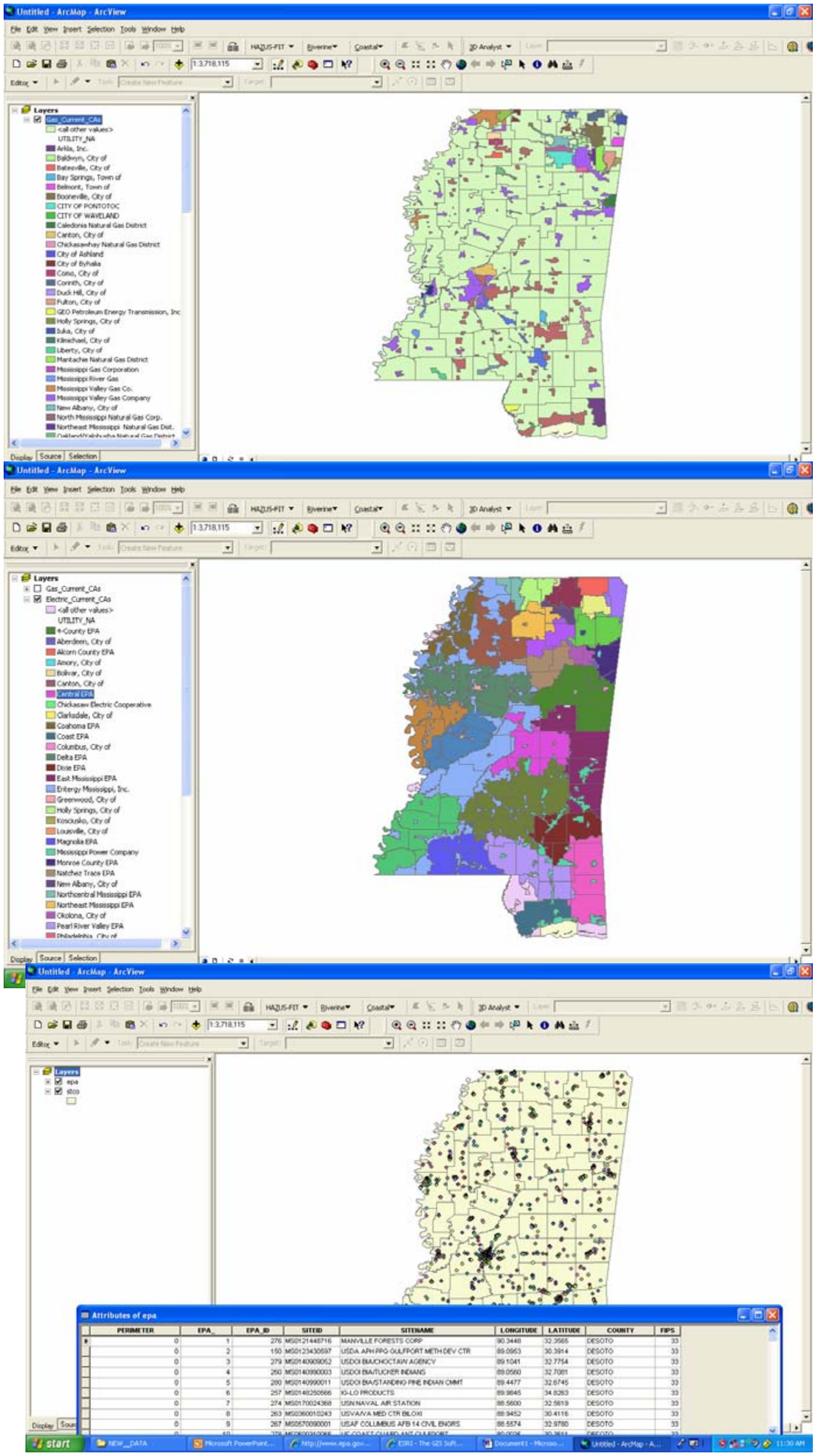

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Figure 2 Infrastructural mapping for the study area
i) Electric generating units ii) Gas based power plant locations iii) EPA FIPS codes

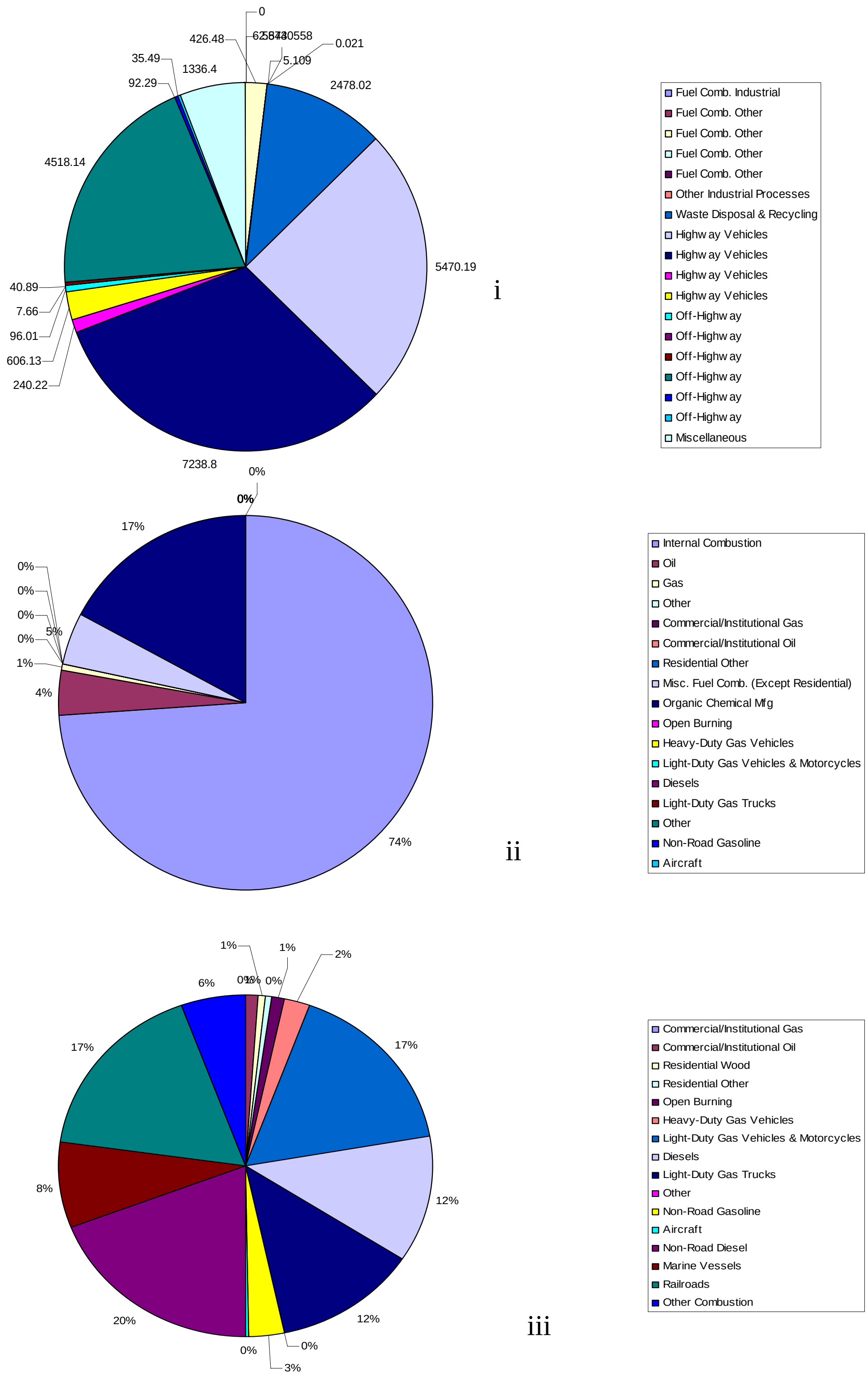

Figure 3 Category based emission inventory for the study area
i) Total area based CO emissions ii) Point based sulfur emissions iii) area based sulfur emissions

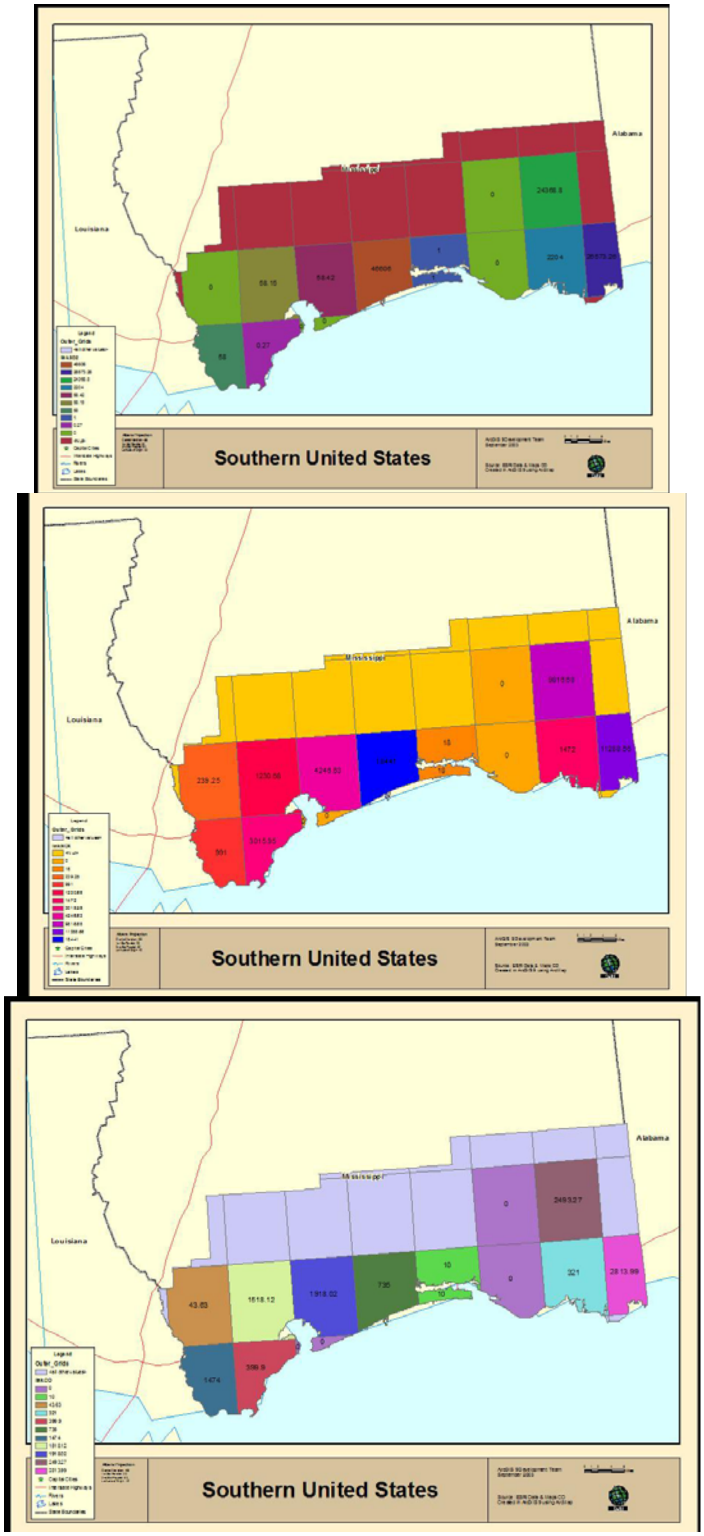

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Figure 4 Grided Emission database for the study area
i) Sulfur dioxide ii) Oxides of Nitrogen iii) Particulate matter