Updated GIS Data for Use in WRAP Regional Modeling

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ABSTRACT

The Western Regional Partnership (WRAP) is a collaborative effort of tribal governments, state governments and various federal agencies to implement the recommendations of the Grand Canyon Visibility Transport Commission (GCVTC) and to develop the technical and policy tools needed by western states and tribes to comply with the U.S. Environmental Protections Agency's (EPA) regional haze rule (RHR). WRAP activities are conducted by a network of committees and forums composed of WRAP members and stakeholders who represent a wide range of viewpoints.

The air quality and emission inventory development efforts of the WRAP require a variety of Geographic Information System (GIS) databases. Specific uses of these data include the following:

- air quality analysis and support of source attribution/apportionment activities;
- improvement of near-field activity data and analysis of emissions strengths; and
- creation of temporally consistent regional estimates of biogenics, ammonia, and windblown dust emissions, as well as a consistent baseline for area source activity data and planning, via the use of uniform landuse and demographic data.

Current GIS data used in these modeling efforts are generally based on information from the early 1990s and include various limitations with respect to the attributes represented. The WRAP funded a project to identify, evaluate and assemble updated GIS databases for use in the WRAP's emissions and air quality modeling efforts. This paper describes and summarizes the updated GIS databases developed during the project. Examples are presented illustrating the impacts associated with utilizing these updated databases in some emission inventory development models currently employed by the WRAP.

INTRODUCTION

Background

A variety of GIS data are necessary in regional air quality model development and evaluation. These include data required to characterize various features of the land (vegetation, landuse/landcover, soils, etc.), transportation networks (roads, railways, shipping lanes, airports, and marine ports), and socioeconomic data (population, housing statistics). In the development of emission inventories, spatial surrogates are required for allocating regional or county-level emissions to modeling grid cells for air quality modeling. Spatial surrogates generally depend on the type of activity that produces the emissions for each source category and can be developed using a variety of GIS databases. In addition, for biogenic, windblown dust and ammonia emissions, the GIS data form the basis for the emissions factors as well as the "activity" data for developing emissions estimates.

GIS data is also used in air quality modeling and analysis, specifically land use data for the estimation of deposition. The evaluation of emission inventories and air quality modeling results can be

aided by the analysis of GIS data. Spatial relationships between source regions and underlying geography and demographics may reveal various patterns that can help in the evaluation of modeling results, model performance and emission inventory quality assurance and evaluation. For those emissions sources inherently related to the land characteristics (biogenics, ammonia, windblown dust), GIS data is required and can be used in the determination and assessment of appropriate control strategies and implementation.

Thus, the development and availability of GIS data that is accurate, detailed and representative of the time period for which air quality and emissions modeling is conducted and/or analyzed is of paramount importance. Many recent regional emission inventories and air quality modeling databases have been developed using data that are outdated by several years, and in some cases, even decades. Relatively few GIS databases of this nature with the required attributes are available within the public domain due in part to the need for the data to caver broad geographic areas. The current study seeks to address the need for, and develop, these detailed and up-to-date databases.

Objective and Approach

The objective of this study is to develop updated, current year (2000-04) GIS databases for use in air quality and emission inventory development efforts. Specific uses of these data may include the following:

- air quality analysis and support of source attribution/apportionment activities;
- improvement of near-field activity data and analysis of emissions strengths;
- creation of temporally consistent regional estimates of biogenics, ammonia, and windblown dust emissions, as well as a consistent baseline for area source activity data and planning, via the use of uniform landuse and demographic data; and
- development of appropriate GIS data layers for Canada and Mexico.

The project was completed through a series of steps involving the identification, collection, evaluation and application of updated GIS data layers. Specifically, the following tasks were performed:

1) **Identification of Relevant GIS Data and Sources:** Updated and recent GIS data and sources were identified and documented in a Technical Memorandum (Mansell, et al., 2005)[1].

2) **GIS Data Evaluation:** GIS data sources identified under the first task were evaluated. The specific GIS data layers evaluated and the evaluation criteria were documented in another Technical Memorandum (Mansell and Hoats, 2005a)[2].

3) **Processing and Development of Final GIS Database:** The GIS data layers evaluated and recommended for modeling use under the second task were assembled and processed. A description of these GIS data layers and formats were documented in a Technical Memorandum (Mansell and Hoats, 2005b)[3].

4) **Recommendations and Reporting:** An evaluation of the impacts of using the updated GIS data layers in a number of emission inventory development applications was performed. Summary documentation is available in the Final Report (Mansell and Hoats, 2005c)[4].

GIS DATA IDENTIFICATON AND EVALUATION

Identification of GIS Data and Data Sources

Updated and recent GIS data and sources were identified based on a number of considerations, primarily the GIS data requirements of the various regional emissions and air quality modeling tools used by WRAP. Data collection efforts were focused on data representing broad geographical regions and recent years (i.e., post-1993, preferably in the 2000-2004 time period). The attributes available in the databases were also a prime consideration.

Data sources were identified primarily through Internet searches of known federal, state and local agencies. General types of GIS data collected and evaluated included geographic and administrative boundaries; landuse/landcover characteristics, including soil characteristics and vegetation density; transportation networks; and population and housing statistics.

In addition to on-line data searches, a "Request for Information" was sent out to appropriate state representatives within the WRAP region requesting any available datasets and/or contacts that could provide relevant sources of information. These representatives were identified by the WRAP Project Manager, who also took the responsibility of distributing the request. All responses received were incorporated into tabulated data source catalog for the project. The GIS data catalog was further updated and revised during the course of the project. The final complete version of the GIS data catalog is available as Appendix A of the Final Report (Mansell and Hoats, 2005c)[4]. The work performed as part of this task is summarized in a Technical Memorandum prepared for the project (Mansell et al., 2005a)[1].

GIS Data Evaluation

Based on recommendations from the original cataloguing of sources, a subset of the numerous GIS databases and sources were identified for further review and evaluation. These data included the general categories of administrative boundaries (state, county, tribal and federal lands), landuse/landcover and surface characteristics (LULC, soil characteristics, vegetation cover, human impacts, etc.), transportation network and demographic and socioeconomic data. In addition, various environmental data and other miscellaneous GIS databases were reviewed. As many of the websites from which several of the reviewed databases were obtained are in a continual state of flux, a number of the more robust GIS data portals were included in the evaluation. The datasets evaluated under this task are briefly summarized below. A more detailed description of these data was presented in a Technical Memorandum prepared for the project (Mansell and Hoats, 2005a)[2].

Evaluation Criteria

The criteria used in the GIS data evaluation include the following attributes of the data:

- Vintage, spatial resolution and extent, data quality and cost
- Specific characteristics of the data
- Required data processing resources
- Expected impact with respect to emission inventory development
- Intended uses of the data

Clearly, a number of trade-offs were required with respect to evaluation of the data characteristics listed above. These relate to the need to balance the advantages of updating and improving upon a specific dataset versus the resources required for data processing. In addition, the expected benefits which derive from these updated data were considered with respect to the subsequent improvements associated with their intended use among the various modeling tools used in the emission and air quality related analyses. Emphasis was placed on those databases and geographic regions expected to exhibit the most pronounced changes or impacts associated with their intended uses. In addition, the data evaluation efforts are focused on national and regional scale databases.

Summary of GIS Data Portals Evaluated

The following GIS data portals were identified as part of the project. A brief description of the types of data available from each is provided in Table 1. A more detailed discussion can be found in Mansell and Hoats, 2005a[2].

Table 1. GIS Data Portals.

Portal Name and Web Address	Description
National Atlas of the United States *(http://www.nationalatlas.gov/)*	The National Atlas allows users to generate maps of the US interactively. The maps can depict a variety of information including spatial features and demographic data. Accurate and reliable data sources are derived from more than 20 Federal agencies and organizations coordinated by the USGS.
USGS GISDATA Map Studio *(http://gisdata.usgs.gov/)*	This is a site hosted at the National Center for Earth Resources Observation and Science (EROS) by the USGS and allows users to access public web map services, and interfaces developed at the center.
US EPA Emission Surrogate Database *(ftp.epa.gov/pub/EmisInventory/emiss_shp2003)*	In 2003, the US EPA developed numerous GIS data layers and spatial surrogate datasets for emissions development applications. The data were derived from various sources and includes data for the entire US and parts of Canada and Mexico. All data layers are available as ArcView shapefiles in a Lambert Conformal projection corresponding to the Inter-RPO National Modeling domain. Data sources and attributes associated with the GIS databases are described in the available documentation.
National Spatial Data Infrastructure Geospatial One-Stop *(http://www.geodata.gov/gos)*	The geodata.gov portal, also known as the Geospatial One-Stop, serves as a public gateway for improving access to geospatial information and data under the Geospatial One-Stop e-government initiative. The portal, sponsored by the Federal Office of Management and Budget (OMB), is designed to facilitate communication and sharing of geographic data and resources to enhance government efficiency and improve citizen services. This portal provides easier, faster and less expensive access to a wealth of geospatial data and information.
The National Map (USGS) *(http://nationalmap.gov/)*	The National Map is a consistent framework for geographic knowledge. It provides public access to high-quality, geospatial data and information from multiple partners to help support decision making by resource managers and the public. The National Map is the product of a consortium of Federal, State, and local partners who provide geospatial data to enhance the public's ability to access, integrate, and apply geospatial data at global, national, and local scales.
Geography Network *(http://www.geographynetwork.com/)*	The Geography Network is a global network of geographic information users and providers. It provides the infrastructure needed to support the sharing of geographic information among data providers, service providers, and users around the world. Through the Geography Network, you can access many types of geographic content including dynamic maps, downloadable data, and more advanced Web services.
Geospatial Data Depot *(http://data.geocomm.com/)*	The GeoCommunity's Geospatial Data Depot is a leading online provider of geographic products and services to the GIS community. Its mission is to support and promote the GIS industry by providing software, data, news, job postings and other services to GIS/CAD professionals via the Internet. The GeoCommunity is a GIS portal site that offers a virtual marketplace for buyers, sellers, advertisers, students and government officials to exchange information.

Summary of GIS Data Layers Evaluated

Brief descriptions of the GIS data layers identified during the project, including the associated attributes, are provided below. Where noted, more detailed discussions of the development and

processing of these data are provided in the various project documents (Mansell and Hoats, 2005a; 2005b; 2005c: Mansell, et al., 2005)[1,2,3,4].

Administrative Boundaries

State/County/Tribal Boundaries

State Boundaries of the United States map layers were downloaded from the nationalatlas.gov website, the official online version of the National Atlas of the United States hosted by the U.S. Department of the Interior and coordinated by the U.S. Geological Survey (USGS). This layer includes boundaries for the 50 States and for 3 State equivalents: the District of Columbia, the Commonwealth of Puerto Rico, and the U.S. Virgin Islands. State names, two-letter State abbreviations, and the Federal Information Processing Standards (FIPS) codes for each State are provided.

The County Boundaries for the United States, 2001 map layer is the most recent source of County boundaries from nationalatlas.gov. This Shapefile features boundaries for counties and county equivalents for the United States, Puerto Rico, and the U.S. Virgin Islands. Descriptive information includes county and State names and the FIPS codes for each county.

The Indian Lands of the United States map layer from nationalatlas.gov shows lands administered by the Bureau of Indian Affairs. Indian lands are defined as areas with boundaries established by treaty, statute, and/or executive or court order, recognized by the Federal Government as territory in which American Indian tribes have primary governmental authority. Federally administered lands within a reservation, which may or may not be considered part of the reservation, are included for continuity.

Class I Areas

Federally designated Class I Areas, defined under the Clean Air Act, include national parks greater than 6,000 acres, wilderness areas and national memorial parks greater than 5,000 acres, and international parks that existed in 1977. The U.S. National Park Service provides map layers defining the boundaries of most of these areas in ArcView Shapefile format at http://www2.nature.nps.gov/air/maps/classILoc.cfm.

Federal Lands

The National Atlas of the United States provides a Federal Lands of the United States map layer, which shows lands owned or administered by the Federal Government, including the Bureau of Land Management (BLM), the Bureau of Reclamation (BOR), the U.S. Department of Agriculture Forest Service (FS), the Department of Defense (DOD), the U.S. Fish and Wildlife Service (FWS), the National Park Service (NPS), the Tennessee Valley Authority (TVA), and other agencies. This layer was created by extracting Federal land features from the October 2003 National Atlas map layer: Federal Lands and Indian Reservations of the United States, and was then updated from additional sources. The current vector dataset can be downloaded in compressed ArcView Shapefile format from http://www.nationalatlas.gov. Included in this aggregation of Federal lands are national parks, national wildlife refuges, military reservations, and federal wilderness areas, among others.

Census

Statistical boundaries, such as census tracts, block groups and blocks are available via the U.S. Census TIGER/Line Files. Similar data are also available in US population and housing statistics data files developed by EPA for emission inventory development.

Landuse/Landcover (LULC) and Surface Characteristics

Landuse/landcover (LULC) and surface characteristics data (soil characteristics, vegetative cover, etc.) are used for a variety of spatial allocation and emission inventory development purposes. A brief description of recent LULC data sets identified and evaluated during the project is presented below. Recently identified soil characteristics and vegetative cover databases are also presented.

USGS National Land Cover Data (NLCD-92)

Currently the WRAP RMC uses the National Land Cover Data to develop spatial surrogates for emission development in addition to providing the basis for the development of windblown dust and ammonia emission estimates. The National Land Cover Data (NLCD) was developed as part of a cooperative project between the U.S. Geological Survey and the U.S. Environmental Protection Agency to produce a consistent land cover data layer for the entire conterminous U.S. based on 30-meter Landsat thematic mapper (TM) data. The NLCD was developed from TM data acquired from the Multi-Resolution Land Characterization (MRLC) Consortium, a partnership of federal agencies that produce or use land cover data. The partners include USGS (National Mapping, Biological Resources, and Water Resources Divisions), the USEPA, the U.S. Forest Service and the National Oceanic and Atmospheric Administration. A description of the land cover classification scheme using 21 separate categories can be found at www.mrlc.gov/index.asp.

USGS National Land Cover Data (NLCD-2001)

The MRLC is currently in the process of updated the NLCD for the year 2001. Although the LULC classification is not greatly improved from the 1992 database, the real advantage of this dataset is the temporal period of the data. Because the NLCD 2001 project is still ongoing, only a limited portion of the country has been completed to date. Completion of the update process is expected in 2006.

NALC 2000

The North America Land Cover (NALC) for the year 2000 (Latifovic, et al. 2002)[5] was developed jointly by the Natural Resources Canada - Canada Centre for Remote Sensing and the USGS EROS Data Center as part of the larger Global Land Cover 2000 project implemented by the Global Vegetation Monitoring Unit, Joint Research Center (JRC) of the European Commission. The data are available as GIS raster datasets for each continent, in a geodetic coordinate system and can be obtained from the project website at http://www.gvm.sai.jrc.it/glc2000/ProductGLC2000.htm. Comparisons of the NALC 2000 and NLCD 1992 databases and their corresponding classification schemes were presented the documentation for the project.

Gap Analysis Program (GAP)

The purpose of the Gap Analysis Program (GAP) is to provide regional assessments of the conservation status of native vertebrate species and natural land cover types and to facilitate the application of this information to land management activities. The National GAP URL is http://www.gap.uidaho.edu/. The GAP is conducted as state-level projects. Although each state is being developed separately, detailed vegetation species covers are being developed based on predetermined classifications. As part of the project, these data layers were processed and merged into regional and national data layers. The processing steps and development of consistent classification schemes are described in detail in the project documentation.

Although GAP datasets can be useful, the lack of detailed classifications for some land use categories result in certain limitations regarding their applicability as a source of data for development of gridding surrogates for emission inventories.

USGS Urban Change

Recognizing that the shape and extent of urban areas change over time, the USGS has created refined LULC layers for 1990 and 2000. Starting with the historical Land Use and Land Cover (LULC) data from the 1970s, USGS overlaid census block group information to make the refinements. Areas were reassigned a new land use code of "New residential" if (1) the original LULC code was not urban or built-up, (2) the original LULC code was not water, and (3) the population density was at least 1,000 people per square mile in the year of the census block group layer. A more detailed discussion of the procedures classification schemes used can be found in Mansell and Hoats, 2005a[2].

USGS Land Cover Characteristics (LCC)

The USGS North America Land Cover Characteristics (LCC) database is part of an on-going global vegetation database development. These data are on a 1-km by 1-km grid for the entire North American continent and are presented in four different classification systems and two coordinate system projections. The most detailed classification scheme includes 205 categories for the entire continent of North America. The data can be obtained from the ftp site at ftp://edcftp.cr.usgs.gov. Quality assurance of the database is in varying stages and lacks accompanying ground-truthing.

In addition to the detailed 205-category classification scheme, the data are available in a number of simpler composite classification schemes, which may be more appropriate for use in developing area source category surrogate indicators. While the USGS Land Use/Land Cover classification scheme does distinguish the basic land cover categories for surrogate development, certain relevant categories are not represented.

National Elevation Dataset (NED)

The National Elevation Dataset (NED) is a raster product assembled by the U.S. Geological Survey (USGS). This data is designed to provide national elevation data in a seamless form with a consistent datum, elevation unit, and projection. Data corrections are made in the NED assembly process to minimize (but not eliminate) artifacts, perform edge matching, and fill sliver areas of missing data. At a resolution of one arc-second (approx. 30 meters), NED data are available for the conterminous United States, Hawaii, and Puerto Rico. NED data for Alaska has a resolution of two arc-seconds.

The data can be downloaded in ArcGRID, BIL, GridFloat or TIFF format for free from the USGS Seamless Data Distribution site (http://seamless.usgs.gov), although there is a maximum area (thirty degree square) for free download. Larger areas must be purchased on CD at a fixed price. NED datasets at 1/3 arc-second (~10 meters), as well as 1/9 arc-second (~3 meters) are currently under development, with coverage progress shown on the Seamless Data Distribution map viewer. As higher-resolution or higher-quality data become available, the NED 1 Arc Second data is periodically updated to incorporate best-available coverage. As USGS's 7.5-minute and 15-minute digital elevation products near completion for the conterminous United States and Alaska, NED data will soon be derived from these sources at a minimum.

Soils Data

The characteristics, or type, of soil is one of the parameters of primary importance for the estimation of emissions from wind erosion. Soil pH is also an important parameter in the estimation of

ammonia emission for fertilizer application, livestock emissions and natural soil ammonia emissions. The State Soil Geographic Database (STATSGO) can be used to specify the soil types from which emissions from wind erosion can be developed. The STATSGO database was developed by the Natural Resources Conservation Service of the US Department of Agricultural (USDA) and provides detailed information concerning the taxonomy of the soils, including soil texture class, percentage of sand, silt and clay, and the available water capacity of the soil. Processed soils databases were obtained from the Earth System Science Center (ESSC) at Penn State University via anonymous ftp at http://www.essc.psu.edu/soil_info/. The datasets archived by the ESSC at Penn State include GIS coverages of relevant soil characteristics for the conterminous U.S. Available attributes include soil texture and pH, soil erodibility factors and soil moisture, among others. Data were derived primarily from information collected during the 1990s. The data are available in a number of coordinate projections and can be downloaded in Arc export (e00) and raster formats. Many of the available datasets are also provided on a number of standard Mesoscale Modeling (MM5) domains at various gridded resolutions.

Fractional Vegetative Cover

In addition to soil characteristics, the ESSC archives numerous other data sets related to the Earth sciences. Of these, the fractional vegetative cover was evaluated for use in emission development and spatial allocation, particularly as related to the windblown dust emission model. The dataset contains estimates of the fractional vegetation cover for biweekly periods during 2002 for the 48 conterminous United States and adjoining parts of Canada and Mexico. Datasets are also available for 2003 and 2004.

Transportation Networks

The spatial allocation of mobile sources, both on-road and non-road, typically requires the specification of roadway type and location. In addition the estimation of mobile source emissions may require the knowledge of additional parameters related to transportation networks, including link-based transportation network data and specification of traffic analysis zones (TAZs). A variety of data sources for these parameters may be found through national and state transportation agencies as well as local metropolitan planning organizations. A brief discussion of some of these data sources is provided below.

US Census TIGER/Line Files

One of the most common and widely used sources of GIS data for transportation related information is the U.S. Census Redistricting TIGER/Line Files. The TIGER/Line files are a digital database of geographic features, such as roads, railroads, rivers, lakes, political boundaries, and census statistical boundaries covering the entire United States. The database contains information about these features such as their location in latitude and longitude, the name, the type of feature, address ranges for most streets, the geographic relationship to other features, and other related information. They are the public product created from the Census Bureau's TIGER (Topologically Integrated Geographic Encoding and Referencing) database of geographic information. TIGER/Line 2000 include files for all counties and statistically equivalent entities in the United States. The data layers are stored in geographic coordinates expressed as decimal degrees and are provided in the North American Datum of 1983 (NAD83). The data layers are available in industry-standard shapefile format so they are easily accessible with GIS software products. Additional information on the Census TIGER Data can be found in the TIGER/Line Files Technical Documentation, the TIGER/Line Files Metadata, or from the U.S. Census Web Site at http://www.census.gov/.

Descriptions of the available features from the TIGER/Line files, as well as their use in the development of emission inventory gridding surrogates by the EPA, can be found in Mansell and Hoats, 2005a[2].

2004 TIGER Line File Updates

Since the development of the TIGER/Line-based datasets by the EPA in 2003, the US Census has embarked on an accuracy improvement project to increase the accuracy of the geo-coded line features in the 2000 Census TIGER files (Johnson and Kunz, 2005)[6]. The original TIGER line files have a nominal accuracy of approximately 20 meters, which for most purposes is quite sufficient. However, the on-going update project strives to increase this accuracy to approximately 7.5 meters. The expected completion date for the project is 2007.

Population/Socioeconomic Data

Population and socioeconomic data is important for both the development of emission estimates as well as the spatial allocation of those emissions. In this section, a selection of these data are presented and discussed.

2000 US Census Data

As noted above, the US EPA developed a number of GIS data layers for use in emission inventory development. Included in these data are shapefile of 2000 US population and housing statistics. The data are linked to the US Census blocks and include the entire country.

2000 Global Population

The Gridded Population of the World (GPW), Version 3.0 (v3) Beta consists of estimates of human population for the years 1990, 1995, and 2000 by 2.5 arc-minute grid cells. The 4 products available are population counts (raw counts), population densities (per square km), land area (actual area net of ice and water), and population-weighted mean administrative unit area. All these formats are all available in three GIS-compatible data formats at the global, continent Antarctica not included), and country levels. GPW v3 is produced by the Columbia University Center for International Earth Science Information Network (CIESIN) in collaboration with Centro Internacional de Agricultura Tropical (CIAT). The data can be downloaded in raster data format from http://beta.sedac.ciesin.columbia.edu/gpw/index.jsp#.

Environmental Data

Although not strictly GIS data, a variety of environmental data and databases are available through various web sites. The types of data include meteorology, agricultural and economic statistics, ambient observational data, and other datasets useful for air quality and emissions inventory development and analysis. As part of this project, these data were not rigorously evaluated, although a number of sources were identified. A brief listing of representative data sources for environmental data is provided below.

- US EPA
- National Weather Service (NWS)
- Penn State University Earth System Science Center (ESSC)
- National Agricultural Statistics Service (NASS)
- Visibility Information Exchange Web System (VIEWS)
- Center for Air Pollution Impact & Trend Analysis (CAPITA)
- Institute for Tribal Environmental Professionals (ITEP)
- Other WRAP Project website (e.g., DRI's Causes of Haze Assessment project web site)

Geospatial Data for Canada and Mexico

As part of the GIS data update, data sources and data layers for Canada and Mexico were also evaluated. Landuse/landcover characteristics data are available for these regions from the North American Land Cover 2000 database, described above. Soil characteristics data is also available from a variety of sources. Similarly, population data can be derived from the year 2000 global population database discussed above.

Administrative boundaries for Canada and Mexico are available from a variety of sources including Natural Resources Canada, the Center for International Earth Science Information Network (CIESIN), the Global Change Master Directory (NASA) and the GeoData Depot.

Transportation network data can be downloaded from the GeoData Depot, which also includes additional GIS data layers such as administrative boundaries, land use and hydrography. For this project, roadways and railways for Canada and Mexico were obtained from the GeoData Depot. One shortcoming of these transportation layers is the lack of detail concerning the type, or class, of roads, as is available for the US from the TIGER/Line files.

ANALYSIS OF UPDATED GIS DATA

Revised Analyses Using Updated GIS Data

One of the primary goals of the project was to develop updated, current GIS data layers for use by the WRAP. To evaluate the impacts of using these updated GIS data layers with various WRAP models and analysis tools, a select set of GIS data were incorporated into the analyses and revised. The impacts of these updated data were then reviewed. Given the limited time and resources for the project, only two model applications were chosen for revisions: the landuse-based GIS NH_3 emission inventory model and the WRAP Windblown Dust emission model. For each of these applications the North America Land Use 2000 data was used to replace the current LULC data used in the applications. In addition, where appropriate, updated population and transportation networks were utilized.

The results of these revisions to the WRAP analyses and modeling tools are presented and discussed in this section.

<u>Landuse-Based NH_3 Emissions Inventory Model</u>

The landuse-based GIS NH_3 emission model was developed by WRAP to estimate ammonia emissions from major source categories including fertilizer application, livestock, natural soils, domestic sources and wild animals. The development of the model and results for 2002 are documented in Mansell, 2005[7]. The model relies on GIS layers for landuse/landcover and population density, among other parameters. The current version of the model and inventory make use of the 1992 NLCD GIS data layers.

For this project the model was run for the WRAP states using the North America Land Cover 2000 data layers. Only fertilizer application, livestock native soils were considered because the remaining source categories (except for wild animals) would not be affected by a change in LULC data. Table 2 presents the available LULC categories in the 1992 NLCD. Table 3 provides the relationships between the LULC data and the gridding surrogates. Similar information is presented in Tables 4 and 5 for the NALC 2000 landuse data.

Based on these revisions, the results will only reflect differences in the spatial allocation to modeling grid cells for the fertilizer application and livestock ammonia emission source categories. For natural soils, however, there will be variation in both the spatial distribution as well as magnitude of the resulting emissions since the landuse provides both the spatial distribution as well as the activity associated with this source category.

Table 2. NLCD Land Cover classification codes.

Code	Description
11	Open Water
12	Perennial Ice/Snow
21	Low Intensity Residential
22	High Intensity Residential
23	Commercial/Industrial/Transportation
31	Bare Rock/Sand/Clay
32	Quarries/Strip Mines/Gravel Pits
33	Transitional
41	Deciduous Forest
42	Evergreen Forest
43	Mixed Forest
51	Shrubland
61	Orchards/Vineyards/Other
71	Grasslands/Herbaceous
81	Pasture/Hay
82	Row Crops
83	Small Grains
84	Fallow
85	Urban/Recreational Grasses
91	Woody Wetlands
92	Emergent Herbaceous Wetlands

Table 3. Surrogate assignments based on the NLCD-92 data.

SRG_NUM	LU_CODES	Surrogate Description
1	11,12	SRG1 - water
2	21,22,23	SRG2 - urban
3	31,32,33	SRG3 - barren
4	41	SRG4 - deciduous forest
5	42	SRG5 - evergreen forest
6	43	SRG6 - mixed forest
7	51	SRG7 - shrublands
8	71	SRG8 - grasslands
9	84	SRG9 - fallow
10	85	SRG10 - urban grasses
11	91,92	SRG11 - wetlands
12	71,81	SRG12 - grasslands + pasture
13	61,81.82,83	SRG13 - agricultural
14	41,42,43,51,61,71	SRG14 - forest + shrub + grasslands
15	41,42,43,51,61,71,81,82,83,84	SRG15 - rural land

Table 4. NALC 2000 LULC classification scheme.

Code	Description
1	Tropical or Sub-tropical Broadleaved Evergreen Forest - Closed Canopy
2	Tropical or Sub-tropical Broadleaved Deciduous Forest - Closed Canopy
3	Temperate or Sub-polar Broadleaved Deciduous Forest - Closed Canopy
4	Temperate or Sub-polar Needleleaved Evergreen Forest - Closed Canopy
5	Temperate or Sub-polar Needleleaved Evergreen Forest - Open Canopy
6	Temperate or Sub-polar Needleleaved Mixed Forest - Closed Canopy
7	Temperate or Sub-polar Mixed Broadleaved or Needleleaved Forest - Closed Canopy
8	Temperate or Sub-polar Mixed Broaddleleaved or Needleleaved Forest - Open Canopy
9	Temperate or Subpolar Broadleaved Evergreen Shrubland - Closed Canopy
10	Temperate or Subpolar Broadleaved Deciduous Shrubland - Open Canopy
11	Temperate or Subpolar Needleleaved Evergreen Shrubland - Open Canopy
12	Temperate or Sub-polar Mixed Broadleaved and Needleleaved Dwarf-Shrubland - Open Canopy
13	Temperate or Subpolar Grassland
14	Temperate or Subpolar Grassland with a Sparse Tree Layer
15	Temperate or Subpolar Grassland with a Sparse Shrub Layer
16	Polar Grassland with a Sparse Shrub Layer
17	Polar Grassland with a Dwarf-Sparse Shrub Layer
18	Cropland
19	Cropland and Shrubland/woodland
20	Subpolar Needleleaved Evergreen Forest Open Canopy - lichen understory
21	Unconsolidated Material Sparse Vegetation (old burnt or other disturbance)
22	Urban and Built-up
23	Consolidated Rock Sparse Vegetation
24	Water bodies
25	Burnt area (resent burnt area)
26	Snow and Ice
27	Wetlands
28	Herbaceous Wetlands
29	Tropical or Sub-tropical Broadleaved Evergreen Forest - Open Canopy

Table 5. Surrogate assignments based on the NALC_2000 data.

SRG_NUM	LU_CODES	Surrogate Description
1	24	SRG1 - water
2	22	SRG2 - urban
3	21,23,25	SRG3 - barren
4	2,3	SRG4 - deciduous forest
5	1,4,5,20,29	SRG5 - evergreen forest
6	6,7,8	SRG6 - mixed forest
7	9,10,11,12	SRG7 - shrublands
8	13,14,15,16,17	SRG8 - grasslands
9	-	N/A
10	-	N/A
11	27,28	SRG11 - wetlands
12	13,14,15,16,17,19	SRG12 - grasslands + pasture
13	18,19	SRG13 - agricultural
14	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,20,29	SRG14 - forest + shrub + grasslands
15	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15, 16,17,18,19,20,21,25,27,28,29	SRG15 - rural land

A comparison of the resulting ammonia emissions due to incorporation of updated LULC data with the original emission estimates is provided in Figures 1 through 3. Displayed are the fertilizer application emissions on the 12km WRAP domain for April 2002 using the 1992 NLCD and the corresponding emissions using the NALC 2000 (Figure 1); annual 2002 ammonia emissions for livestock using 1992 NLCD data and NALC 2000 (Figure 2); and the annual 2002 natural soils ammonia emissions with 1992 NLCD and NALC 2000 (Figure 3). The incorporation of the NALC 2000 results in a more locally resolved spatial distribution, particularly for the livestock and fertilizer emissions. Differences due to variation in the land use characterization between the two GIS data layers are seen throughout the domain.

Figure 1. Comparison of April 2002 fertilizer ammonia emissions on the WRAP 12-km domain using 1992 NLCD and 2000 NALC data.

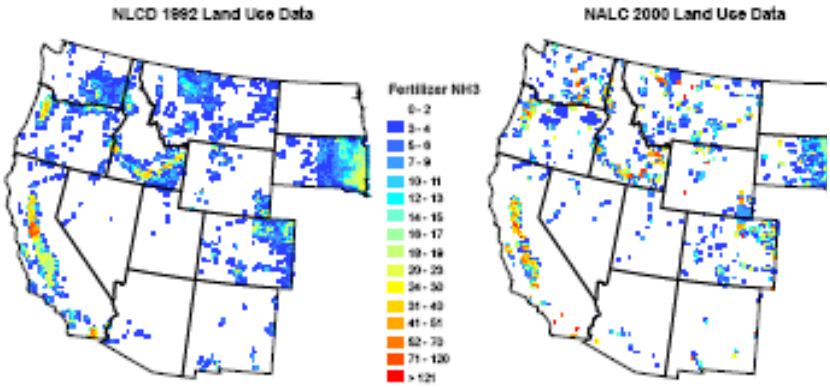


Figure 2. Comparison of annual 2002 livestock ammonia emissions on the WRAP 12-km domain using 1992 NLCD and 2000 NALC data.

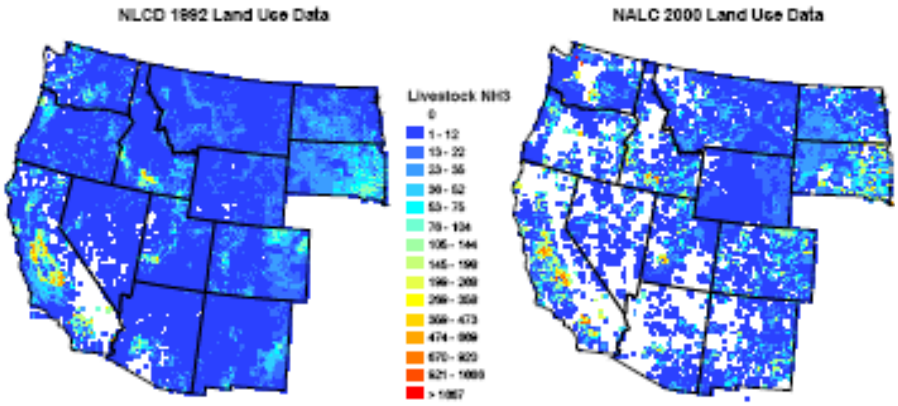
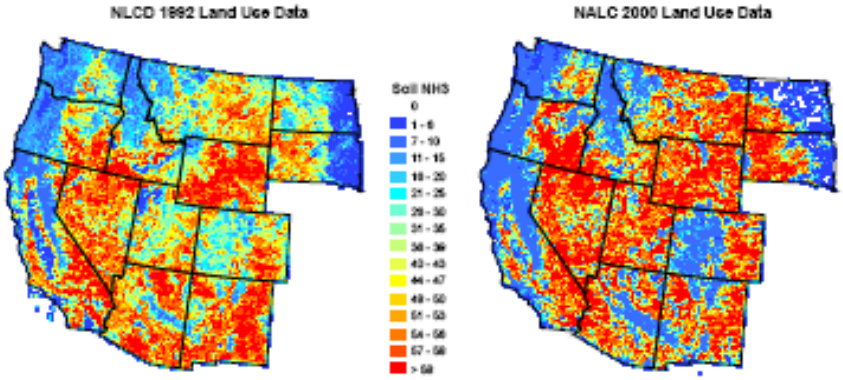


Figure 3. Comparison of annual 2002 natural soil ammonia emissions on the WRAP 12-km domain using 1992 NLCD and 2000 NALC data



Windbown Dust Emission Inventory Model

The WRAP Windblown Dust emission model was developed to provide estimates of PM_{10} dust emissions from wind erosion. The model relies on land use and soil characteristics in order to estimate threshold surface friction velocities and emission rates. In addition, agricultural lands are treated with additional adjustments based on crop types and farm management practices. Agricultural lands are characterized using the BELD3 database. A complete description of the development of the emission estimation methodology and the resulting emission inventory can be found in Mansell et al., 2005b[8].

The current implementation of the Windblown Dust model uses the 1992 NLCD to classify land use and land cover. A dust code parameter is used to define emission rates as a function of the LULC. The dust code is related to the LULC and is used in combination with assumed surface roughness lengths to estimate the threshold surface friction velocities. Table 6 presents the relationship between the 1992 NLCD categories and the dust code parameter. For this project, the LULC used in the model was updated with the 2000 NALC data. Table 7 presents the LULC classifications and their relationship to the dust code parameter. Table 8 presents the basic definition of the dust code in terms of general land use type. Using the 2000 NALC, the Windblown Dust model was run for April 2002 for the 36-km WRAP modeling domain. Comparisons were made between the resulting emissions inventories using each of these LULC databases. The results are presented in Figures 4 through 7.

Figure 4 presents the estimated coarse PM dust emissions using the 1992 NLCD data. The corresponding results using the 2000 NALC data is displayed in Figure 5. Notably differences include increased dust emissions outside the US while regions of reduced dust emissions in the Midwest result form the incorporation of the 2000 NALC. Corresponding displays for fine PM dust emission are presented in Figures 6 and 7. Table 9 presents a comparison of the total PM10 dust emissions in the WRAP states by landuse type using the 1992 NLCD and the 2000 NALC databases.

It should be noted that in this application, no attempt was made to improve the assignment, or assumptions, of surface roughness lengths based on the different LULC classification schemes available in the landuse databases. Possible improvements in the overall dust emission inventory may be realized if a more refined relationship between land use and surface roughness lengths were developed.

Table 6. Land use and dust code cross-walk for the 1992 NLCD data.

Code	Land Use Description	Dust Code
1	N/A	1
11	Open water	1
12	Ice/Snow	1
21	Low intensity residential	2
22	High density residential	2
23	Commercial/Ind/Trans	2
31	Bare rock/Clay/Sand	7
32	Quarries/Strip mines	7
33	Transitional	7
41	Deciduous Forest	2
42	Evergreen Forest	2
43	Mixed Forest	2
51	Shrubland	6
61	Orchards/Vineyards	5
71	Grasslands	4
81	Pasture/Hay	3
82	Prow crops	3
83	Small grains	3
84	Fallow	3
85	Urban/Rec grasses	1
91	Woody wetlands	1
92	Herbaceous wetlands	1
30	USGS Urban	2
40	USGS Dryland cropland & pasture	4
50	USGS Irrigated cropland	4
60	USGS cropland/grassland mosaic	4
70	USGS cropland/woodland mosaic	2
80	USGS grassland	4
90	USGS shrubland	6
100	USGS mixed shrub/grassland	6
110	USGS savanna	1
120	USGS deciduous forest	2
130	USGS evergreen broadleaf forest	2
140	USGS evergreen needleleaf forest	2
150	USGS mixed forest	2
160	USGS water	1
170	USGS wooded wetlands	1
180	USGS Barren	7
190	USGS wooded tundra	1
200	USGS mixed tundra	1
210	USGS ice or snow	1
220	Alfalfa	3
230	Barley	3
240	Corn	3
250	Cotton	3
260	Grass	3
270	Hay	3
280	Misc. crops	3
290	Oats	3
300	Pasture	3
310	Peanuts	3
320	Potatoes	3
330	Rice	3
340	Rye	3
350	Sorghum	3
360	Soybeans	3
370	Tobacco	3
380	Wheat	3
390	Forest (from FIA data)	2

Table 7. Land use and dust code cross-walk for the 2000 NALC data.

Code	Land Use Description	Dust Code
1	Tropical or Sub-tropical Broadleaved Evergreen Forest - Closed Canopy	2
2	Tropical or Sub-tropical Broadleaved Deciduous Forest - Closed Canopy	2
3	Temperate or Sub-polar Broadleaved Deciduous Forest - Closed Canopy	2
4	Temperate or Sub-polar Needleleaved Evergreen Forest - Closed Canopy	2
5	Temperate or Sub-polar Needleleaved Evergreen Forest - Open Canopy	2
6	Temperate or Sub-polar Needleleaved Mixed Forest - Closed Canopy	2
7	Temperate or Sub-polar Mixed Broadleaved or Needleleaved Forest - Closed Canopy	2
8	Temperate or Sub-polar Mixed Broadleaved or Needleleaved Forest - Open Canopy	2
9	Temperate or Subpolar Broadleaved Evergreen Shrubland - Closed Canopy	6
10	Temperate or Subpolar Broadleaved Deciduous Shrubland - Open Canopy	6
11	Temperate or Subpolar Needleleaved Evergreen Shrubland - Open Canopy	6
12	Temperate or Sub-polar Mixed Broadleaved and Needleleaved Dwarf-Shrubland - Open Canopy	6
13	Temperate or Subpolar Grassland	4
14	Temperate or Subpolar Grassland with a Sparse Tree Layer	4
15	Temperate or Subpolar Grassland with a Sparse Shrub Layer	4
16	Polar Grassland with a Sparse Shrub Layer	4
17	Polar Grassland with a Dwarf-Sparse Shrub Layer	4
18	Cropland	3
19	Cropland and Shrubland/woodland	6
20	Subpolar Needleleaved Evergreen Forest Open Canopy - lichen understory	2
21	Unconsolidated Material Sparse Vegetation (old burnt or other disturbance)	7
22	Urban and Built-up	1
23	Consolidated Rock Sparse Vegetation	7
24	Water bodies	1
25	Burnt area (resent burnt area)	7
26	Snow and Ice	1
27	Wetlands	1
28	Herbaceous Wetlands	1
29	Tropical or Sub-tropical Broadleaved Evergreen Forest - Open Canopy	2
300	USGS Urban	2
400	USGS Dryland cropland & pasture	4
500	USGS Irrigated cropland	4
600	USGS cropland/grassland mosaic	4
700	USGS cropland/woodland mosaic	2
800	USGS grassland	4
900	USGS shrubland	6
1000	USGS mixed shrub/grassland	6
1100	USGS savanna	1
1200	USGS deciduous forest	2
1300	USGS evergreen broadleaf forest	2
1400	USGS evergreen needleleaf forest	2
1500	USGS mixed forest	2
1600	USGS water	1
1700	USGS wooded wetlands	1
1800	USGS Barren	7
1900	USGS wooded tundra	1
2000	USGS mixed tundra	1
2100	USGS ice or snow	1
2200	Alfalfa	3
2300	Barley	3
2400	Corn	3

Code	Land Use Description	Dust Code
2500	Cotton	3
2600	Grass	3
2700	Hay	3
2800	Misc. crops	3
2900	Oats	3
3000	Pasture	3
3100	Peanuts	3
3200	Potatoes	3
3300	Rice	3
3400	Rye	3
3500	Sorghum	3
3600	Soybeans	3
3700	Tobacco	3
3800	Wheat	3
3900	Forest (from FIA data)	2

Table 8. Dust definitions.

Dust Code	LULC
1	Open water
2	Urban
3	Agricultural
4	Grasslands
5	Orchards/Vineyards
6	Shrubland/Rangeland
7	Barren

Table 9. Comparison of total PM10 dust emissions for the WRAP states (tons/year).

Landuse Category	2002 NALC	1992 NLCD
Agricultural	393,306	988,264
Grasslands	308,099	411,595
Shrublands	1,950,862	820,937
Barren	79,435	143,292
Total	**2,731,702**	**2,364,089**

Figure 4. April 2002 windblown dust coarse PM emissions using 1992 NLCD data.

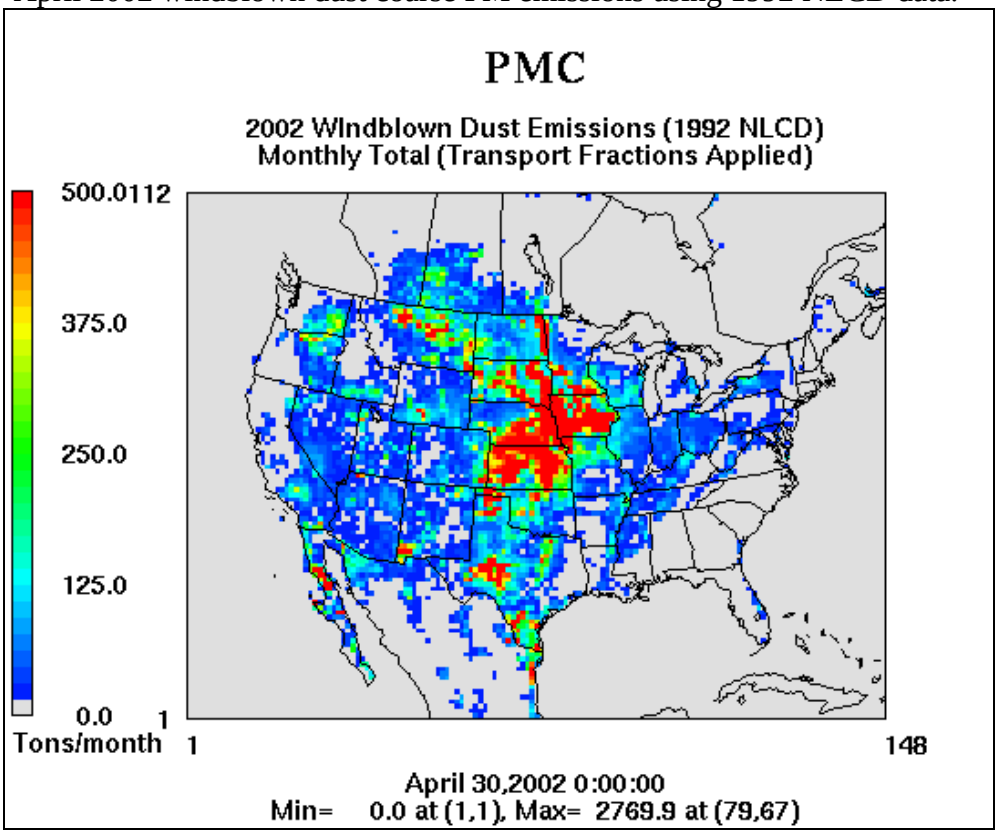


Figure 5. April 2002 windblown dust coarse PM emissions using 2000 NALC data.

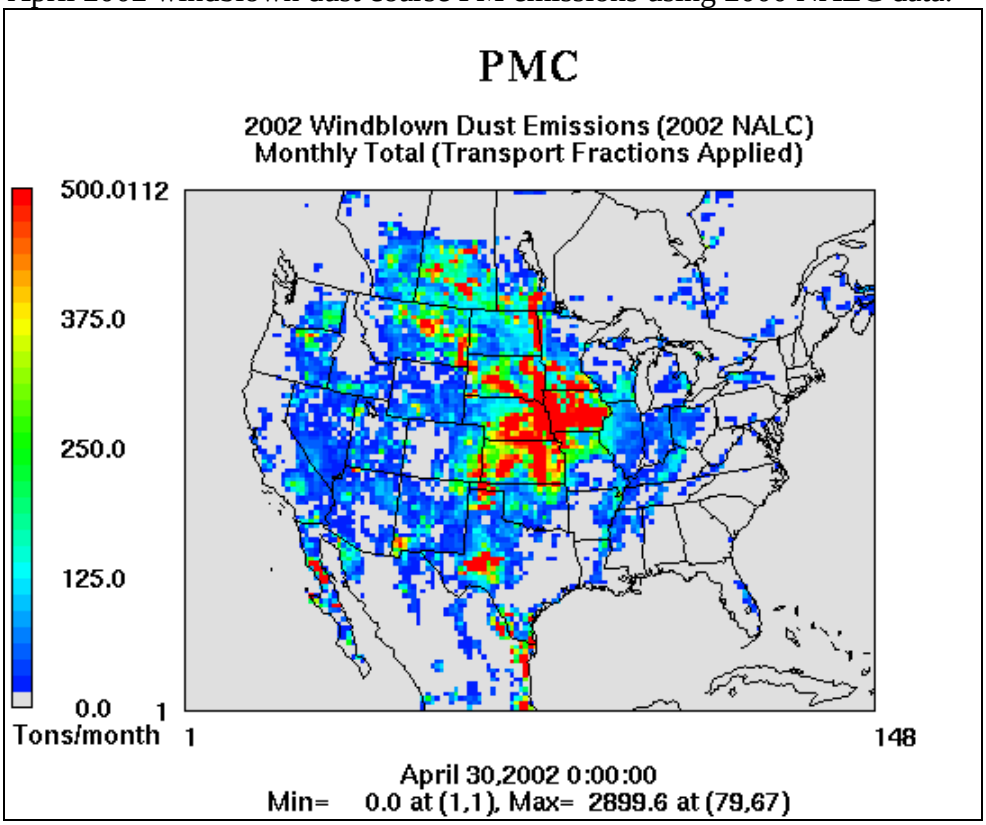


Figure 6. April 2002 windblown dust fine PM emissions using 1992 NLCD data.

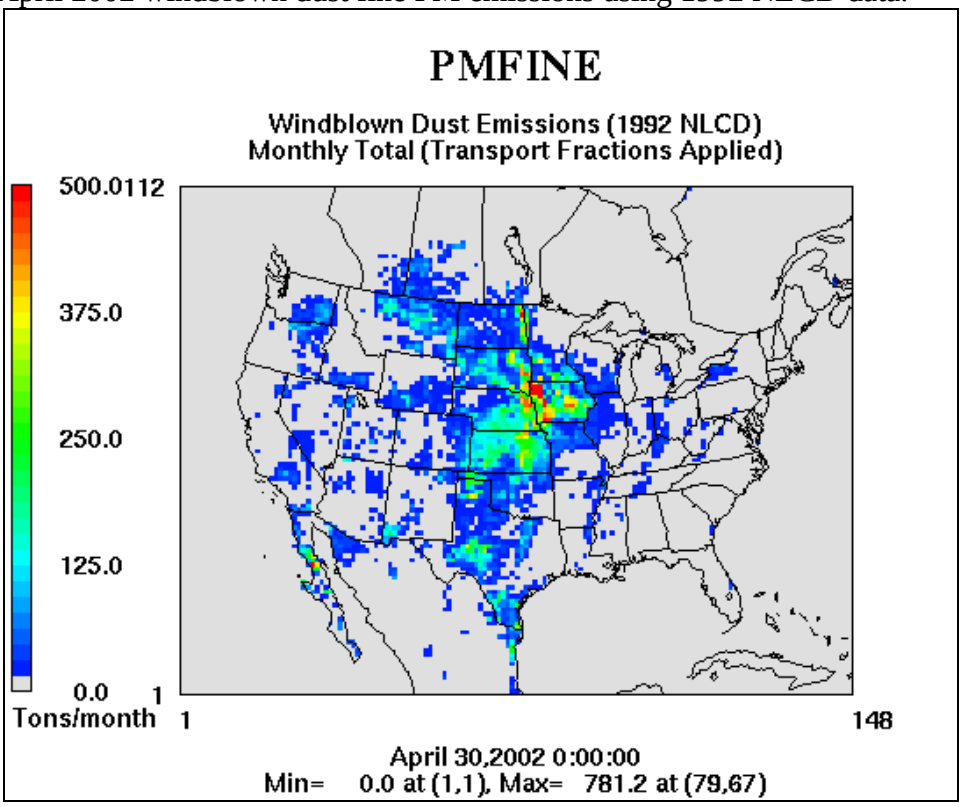
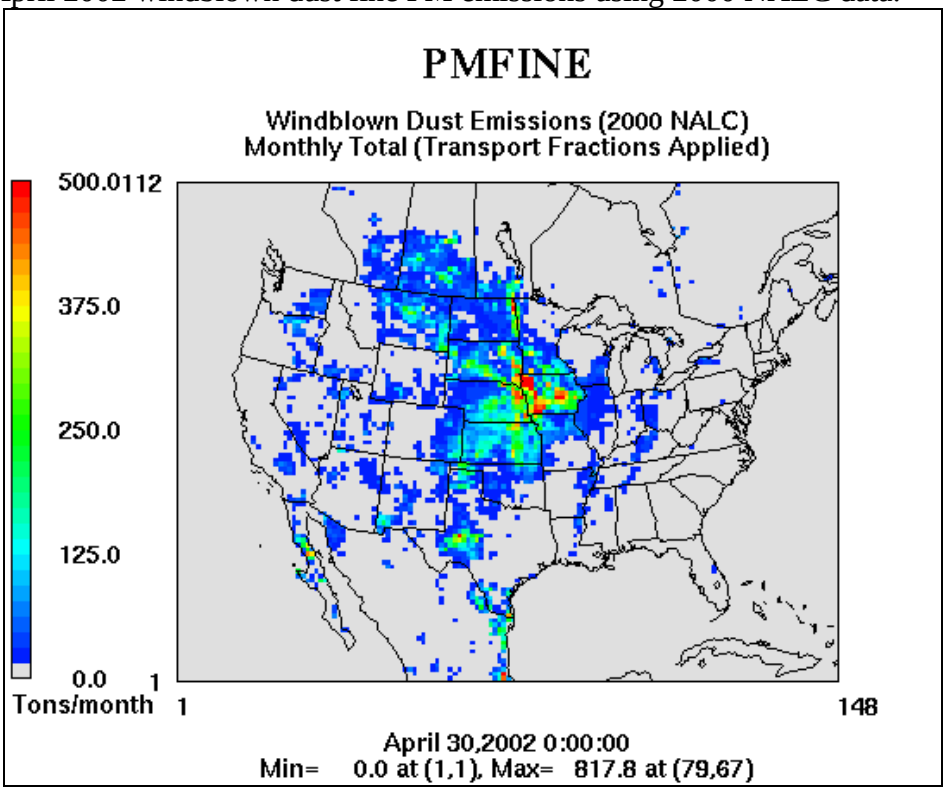


Figure 7. April 2002 windblown dust fine PM emissions using 2000 NALC data.



SUMMARY

Updated GIS data were obtained and evaluated for use in the WRAP air quality and emissions modeling efforts. Numerous sources of data were identified through web searches and specific data requests to state and local agencies throughout the WRAP states. Data sets were reviewed and evaluated based on a number of criteria, including spatial resolution and quality, data processing requirements, and expected impacts with respect to emission inventory development and air quality analyses. Results of selected applications using updated GIS data were presented. Comparisons of the results of these applications with those obtained using previous data, as currently implemented in the WRAP modeling efforts, are also provided.

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2) Mansell and Hoats, "Task 2 Summary – GIS Data Evaluation"; Technical Memorandum prepared for the Western Governors' Association by ENVIRON, 2005a. Available at http://www.wrapair.org/forums/toc/GIS.html

3) Mansell and Hoats, "Task 3 Summary – Draft GIS Data Documentation"; Technical Memorandum prepared for the Western Governors' Association by ENVIRON, 2005b. Available at http://www.wrapair.org/forums/toc/GIS.html

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KEY WORDS

GIS Data
Emissions Inventories
Regional Modeling