

**An Improved Ammonia Inventory for  
the WRAP Domain**

**ENVIRON International Corporation**

**and**

**University of California, Riverside**

**WRAP Emission Forum Meeting**

**July 15, 2004**

## **Introduction**

- Objectives
- Methods and Data Sources
- GIS-based Model Development
- Summary

## Objectives

- Improved 2002 NH<sub>3</sub> emission inventory for WRAP
- Consider major source categories
- Improved temporal/spatial allocation
- Incorporate environmental factors
- Develop GIS-based modeling system

## Methods and Data Sources

- Source categories
- Emission Factors
- Activity Data
- Temporal Allocation
- Spatial Allocation
- Environmental Data

## Source Categories

- Livestock
  - dairy & beef cows, poultry, swine, sheep, horses
- Fertilizer Usage
- Native Soils
  - urban, barren, forest, shrub/grassland, wetlands
- Domestic
  - Respiration, perspiration, infant diapers, cats, dogs

## Emission Factors

- Livestock
  - Batty, et al.
  - Chinkin, et al.
  - CMU NH3 Model
  - Others – Doorn, et al.; Keener, et al.; Pinder et al.; EEA

# Livestock Emission Factors (kg/head-year)

	Battye et al (2003) Recommended	Battye et al (2003) Handbook	Chinkin et al (2003) Recommended	Doorn et al., (2002) Measured	Keener et al. (2001)	Pfnder et al (2003)	European Environment Agency (2002)
Dairy Cow	28	20-70	<b>25</b>			13.1-55	28.5
Beef Cow	10.2	9-18	<b>9</b>				14.3
Poultry	0.28, 0.37	0.1-0.4	<b>0.1</b>		0.16, 0.52		0.28, 0.37
Swine	11.4	9.5-13.5	<b>7</b>	7			6.39, 16.43
Horses	<b>8</b>		12.2				8
Sheep	<b>1.34</b>		3.4				1.34

## Emission Factors

- Fertilizer Application
  - Battye, et al.
  - Chinkin, et al.
  - EEA
  - Potter, et al.
- Emission factors adjusted for soil pH (Potter, et al. 2001)
  - $EF_{adj} = EF * (0.3125pH - 1.01)$
  - Normalized for 4% at pH=6.5



## Effect of Soil pH on Fertilizer Emissions

Effect of Soil pH on Fertilizer NH3 Emissions (tpy)				
Region	County	NH3 w/o pH Effects	NH3 w/ pH Effects	% Diff
<b>Imperial Valley</b>				
	Imperial	2535	3698	45.90%
	Riverside	1162	1498	28.86%
	San Bernadino	32	34	5.70%
<b>Region Total</b>		<b>3729</b>	<b>5230</b>	<b>40.24%</b>
<b>Central Coast</b>				
	Monterey	1514	1659	9.53%
	San Luis Obispo	49	57	17.14%
	Santa Barbara	638	702	10.06%
<b>Region Total</b>		<b>2201</b>	<b>2417</b>	<b>9.85%</b>
<b>San Joaquin Valley</b>				
	Fresno	4287	5606	30.78%
	Kern	5847	6684	14.31%
	Kings	1922	2765	43.87%
	Madera	750	935	24.65%
	Merced	1430	1822	27.38%
	San Joaquin	1379	1499	8.70%
	Stanislaus	1854	2090	12.68%
	Tulare	1640	2055	25.31%
<b>Region Total</b>		<b>19109</b>	<b>23456</b>	<b>22.74%</b>
<b>Sacramento Valley</b>				
	Butte	3043	3385	11.23%
	Colusa	717	846	17.92%
	Glenn	529	576	9.05%
	Sacramento	242	246	1.42%
	Solano	519	573	10.58%
	Sutter	985	1127	14.38%
	Yolo	1076	1190	10.58%
<b>Region Total</b>		<b>7111</b>	<b>7943</b>	<b>11.70%</b>

# Fertilizer Emission Factors (% N)

	Battye et al., 1994	EEA, 2002 Group I	EEA, 2002 Group II	EEA, 2002 Group III	Potter et al., 2001
Anhydrous Ammonia	1	4	4	4	2.4
Aqua ammonia	1				2.4
Nitrogen solutions	2.5	8	8	8	2.4
Urea	15	20	15	15	2.4
Ammonium nitrate	2.1	3	2	1	2.4
Ammonium sulfate	8	15	10	5	2.4
Calcium ammonium nitrate		3	2	1	2.4
Ammonium thiosulfate	2.5				2.4
Other straight nitrogen	4				2.4
Ammonium phosphates	4.8	5	5	5	2.4
N-P-Ka		3	2	1	2.4
Potassium nitrate					2.4

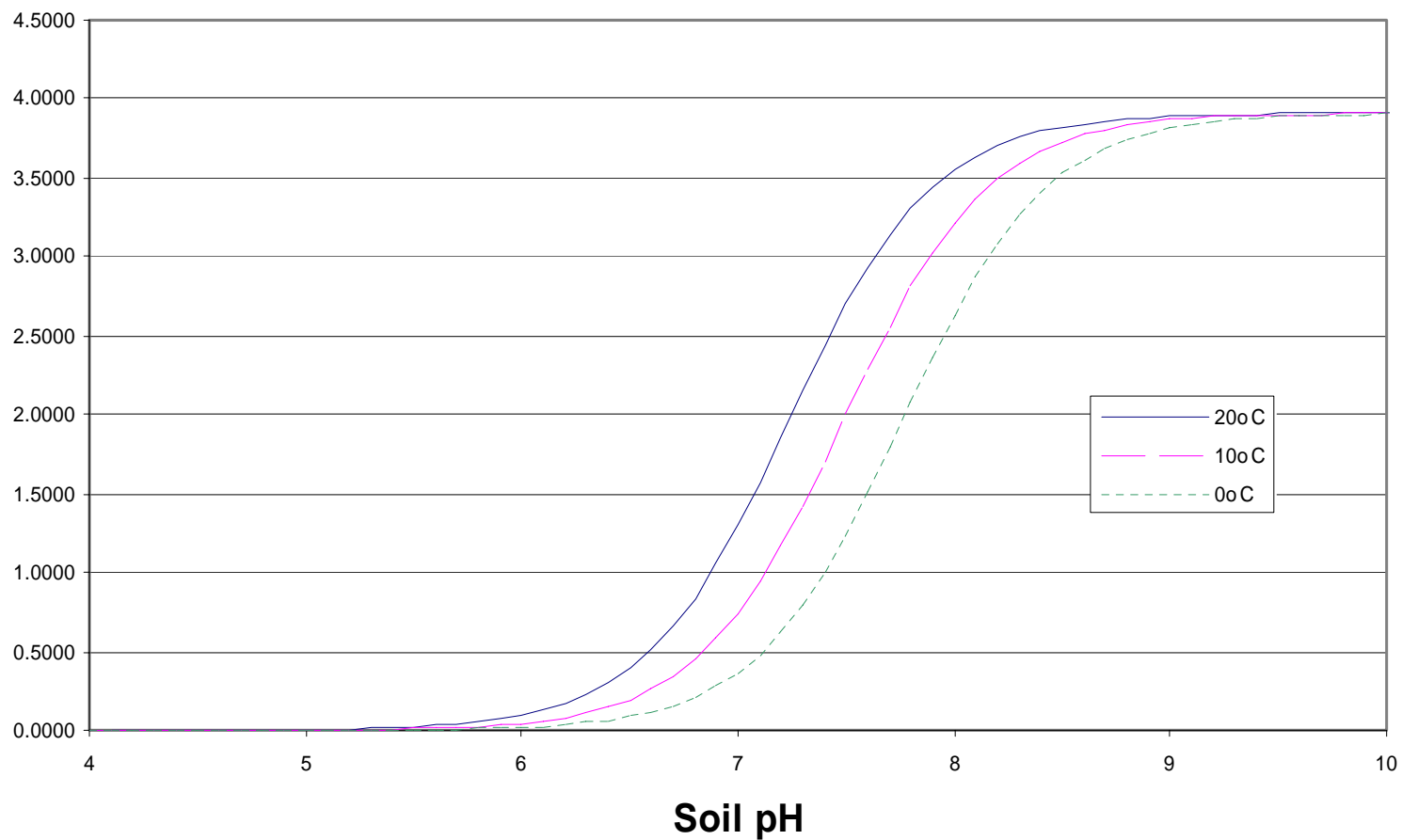
## Emission Factors

- Natural soils – source or sink
- Soil emission factors adjusted to account for soil conditions (Potter, et al., 2003)
- $EF_{adj} = EF * (1-M) \{ 1/[1+10^{(0.09+2730/T-c*pH)}] \}$ 
  - M = soil moisture
  - T = soil temp (K)
  - C = constant determines sensitivity to pH (=1.3)

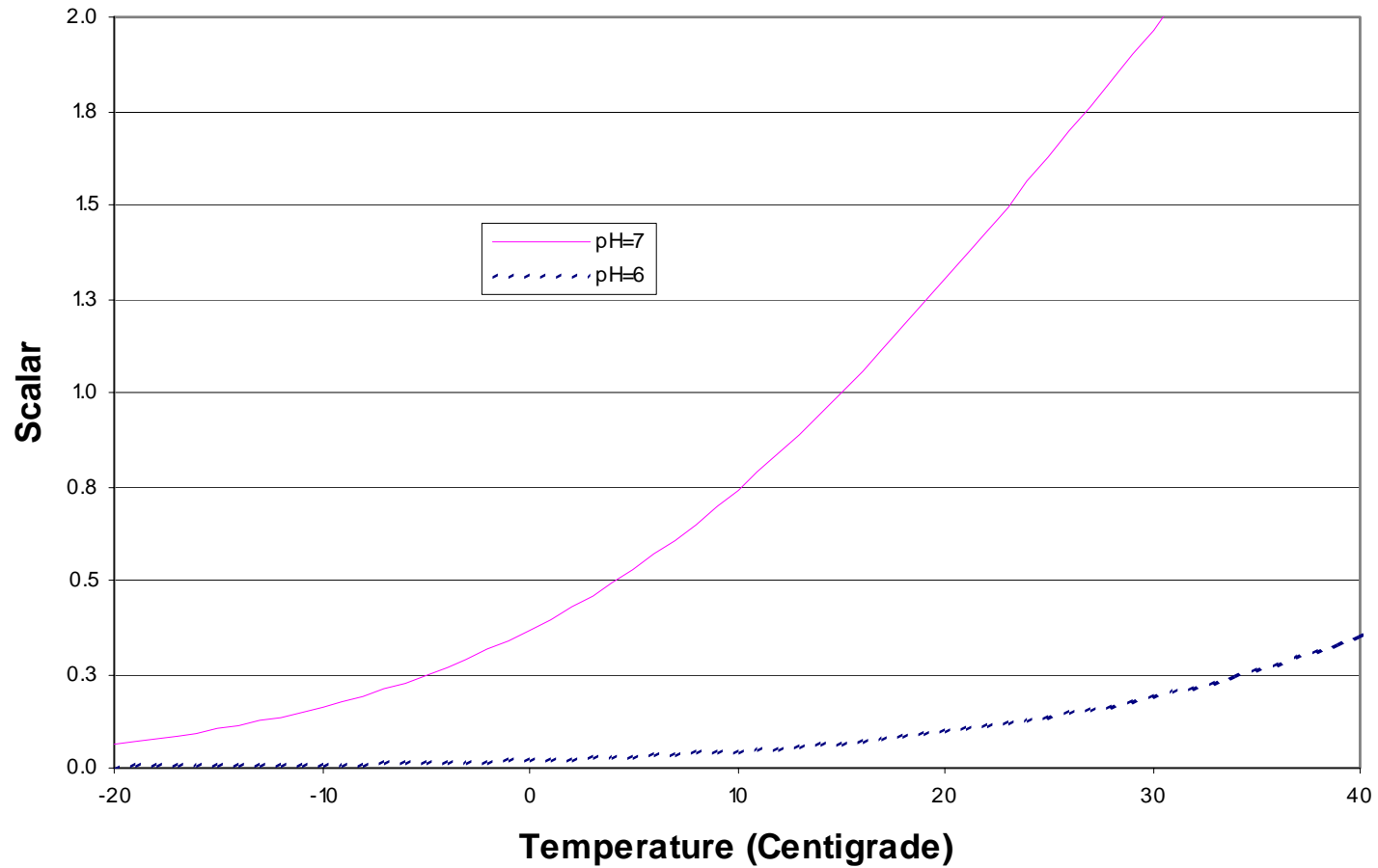
# Native Soils Emission Factors (kg/km<sup>2</sup>-yr)

Description	Emission Factor	Source
Urban	10	Batty, et al. (2003)
Barren	10	
Forest	174 - Deciduous 54 - Evergreen 114 - Mixed	Chinkin, et al. (2003)
Shrub/Grassland	400	
Fallow	205	
Wetlands	400	

## Soil Emission Factor Adjustments



## Soil Emission Factor Adjustments



# Domestic Emission Factors

(Chitjian et al, 2000)

Source	Emission Factors	Units
Cats	0.348	lb N/cat/yr
Dogs	2.17	lb N/dog/yr
Human Respiration	0.55	lb/person/yr
Human Perspiration	0.0035	lb/person/yr
Cloth Diapers	6.9	lb/infant/yr
Disposable Diapers	0.36	lb/infant/yr

## **Activity Data**

- Livestock headcounts – National Ag Services Statistics (NASS, 2003)
- Fertilized usage – Assoc. of American Plant Food Control Officers (AAPFCO, 2003); USDA; NASS
- Native soils – Land cover acreage (NLCD)
- Domestic – 2000 US Census; Pet per capita ratios from Dickson et al., 1991



## Temporal Allocation

- Livestock
  - Monthly profiles recommended by Chinkin et al. (2003)
  - Diurnal profiles based on Russell & Cass (1986)

$$E_i \% [2.36^{(T_i - 273)/10}] V_i A$$

$E_i$  = hourly emission rate

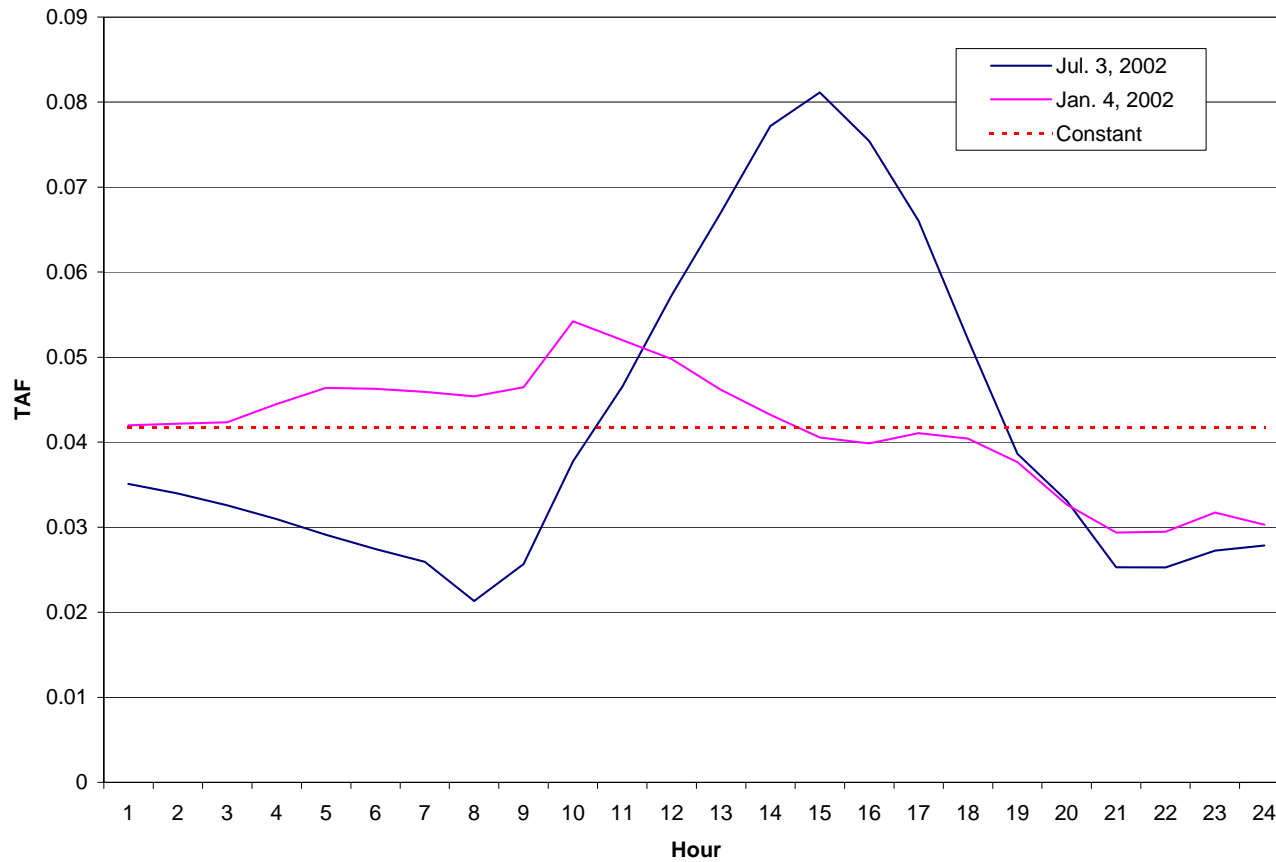
$A$  = daily total emission rate

$T_i$  = hourly ambient air temperature (K)

$V_i$  = hourly wind speed (m/s)

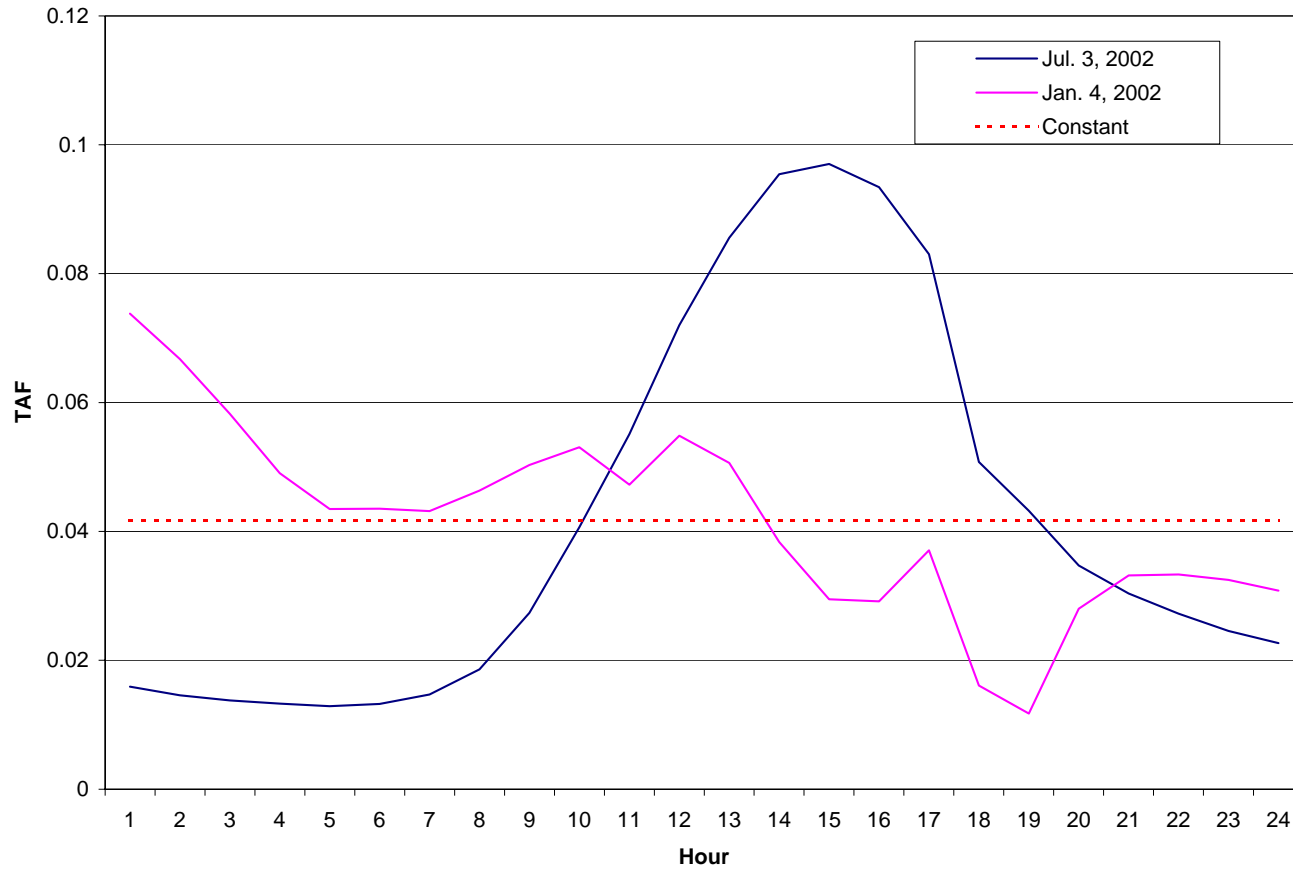
## Livestock Diurnal Profiles

Temporal Variation for Butte Co.



## Livestock Diurnal Profiles

Temporal Variation for Kern Co.



## Temporal Allocation

- Fertilizers
  - Monthly variation from fertilizer usage data
  - Diurnal profiles based on Russell & Cass (1986)
- Domestic Sources
  - Temporally invariant

## Temporal Allocation

- Native Soils
  - Temporal variation based on environmental parameters
  - $EF_{adj} = EF * (1-M) \{ 1/[1+10^{(0.09+2730/T-c*pH)}] \}$ 
    - M = soil moisture
    - T = soil temp (K)
    - C = constant determines sensitivity to pH (=1.3)

## Spatial Allocation by Source Category

Source Category	Spatial Surrogate
Livestock	LULC
Fertilizer	Agricultural crop land
Soils	Land use/Land cover
Domestic	Population

## Environmental Data

- Soil pH
  - STATSGO
- Soil Moisture
  - 2002 36-km MM5 modeling results
- Temperatures, wind speeds
  - 2002 36-km MM5 modeling results

## **GIS-Based Emissions Model Development**

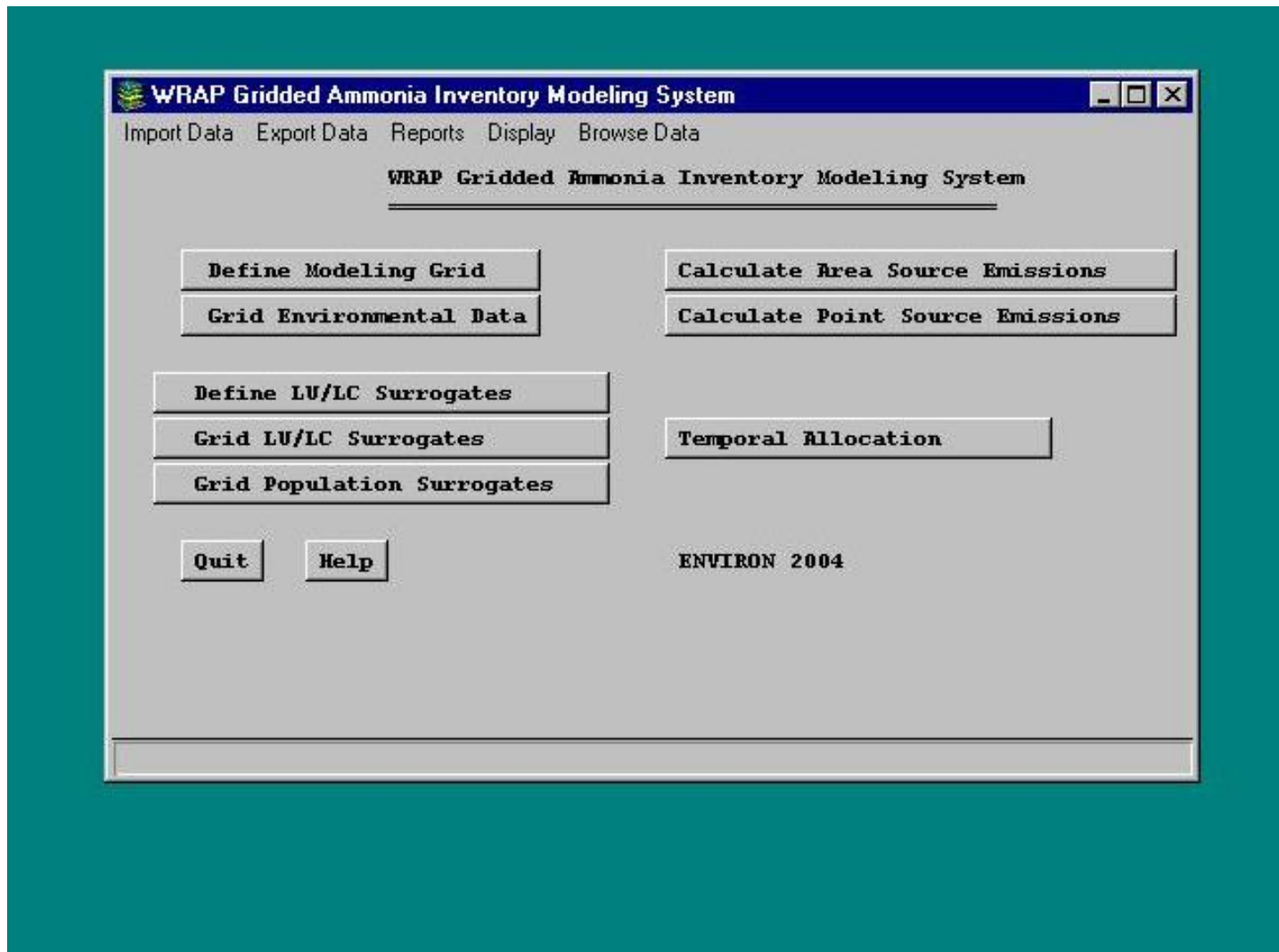
- Designed to :
  - treat relationship of ammonia emissions to environmental variables (wind speed, temperatures, soil moisture & pH)
  - incorporate high resolution spatial data (LU/LC databases; population density; geo-coded point sources)
  - incorporate detailed source classification schemes
- Based on Arc/INFO GIS
- Flexible input data sources/formats; easily modified input tabular data (activity data, EF, spatial surrogate relationships)
- Modular & efficient processing capabilities
- Intuitive user interface



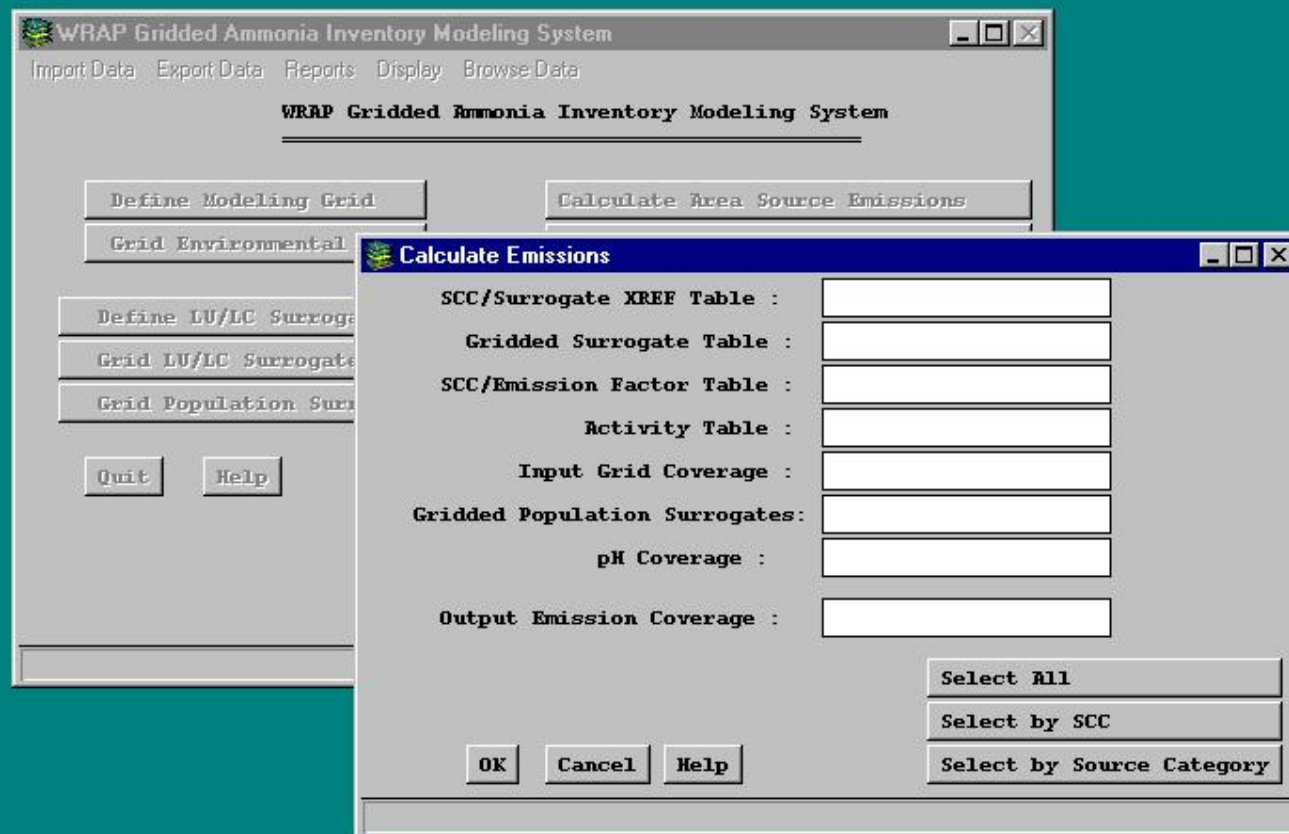
## Geospatial Data

- Land Use/Land Cover (LULC)
  - NLCD LU/LC coverages -- GIS raster data; high spatial resolution (30 m); 21 LU/LC classifications for land use
- Soil pH
  - STATSGO - PSU
- Population
  - 2000 US Census data assembled by EPA

## Main Menu



## GIS-based NH3 Emissions Model Emission Calculation Menu



My Computer

Network Neighborhood

Inbox

Recycle Bin

My Briefcase

log

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WRAP Gridded Ammonia Inventory Mode

Import Data Export Data Reports Display Bro

**WRAP Gridded Ammo**

Define Modeling Grid

Grid Environmental Data

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Define LU/LC Surrogates

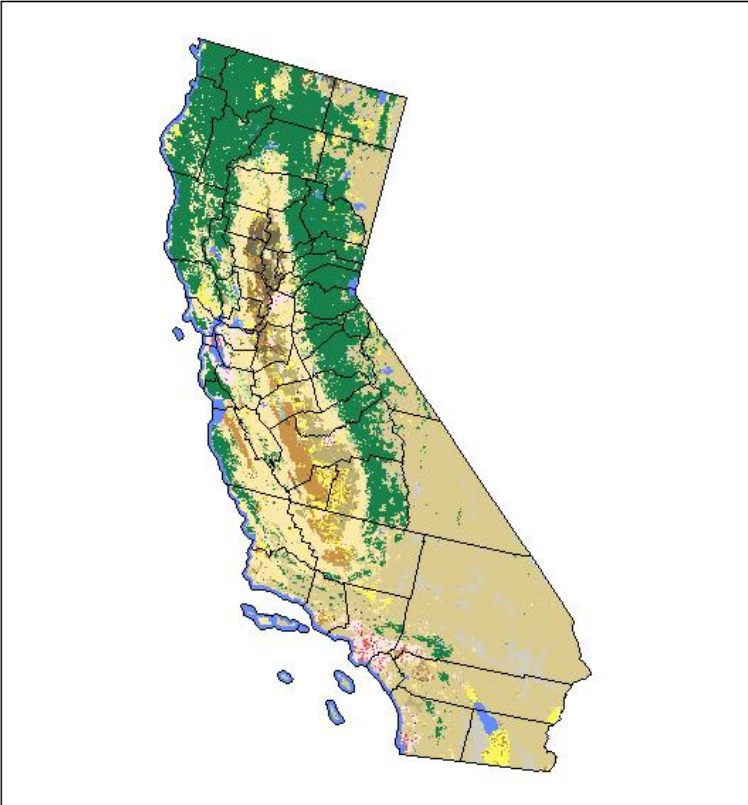
Grid LU/LC Surrogates

Grid Population Surrogates

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Quit Help

## NLCD Landuse/Landcover



X:3.23573 Y:0.17224 dx:-3.35876 dy:-0.38140 Dist 3.38034

LULC Categories

- 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
- 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

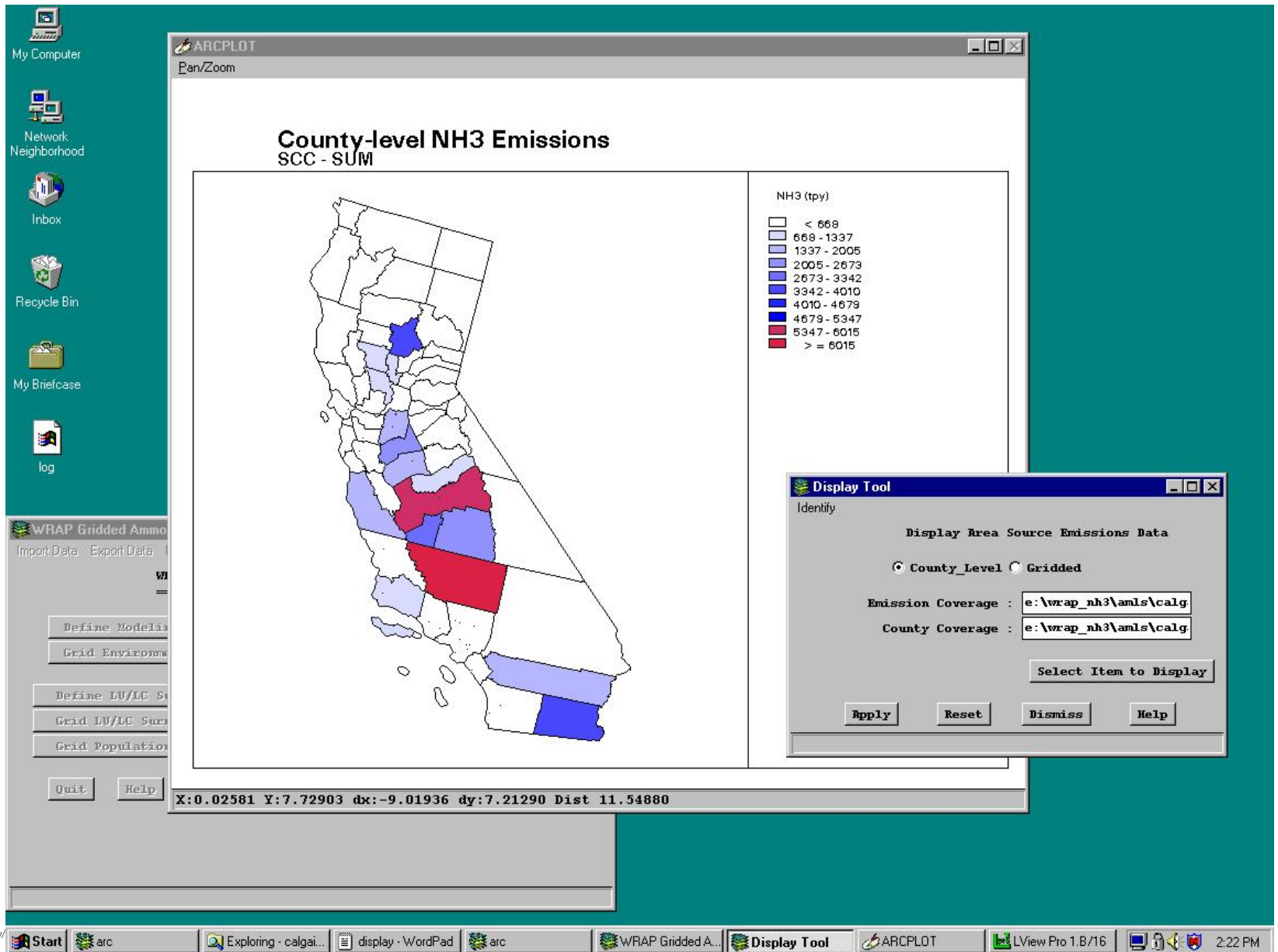
**Display Tool**

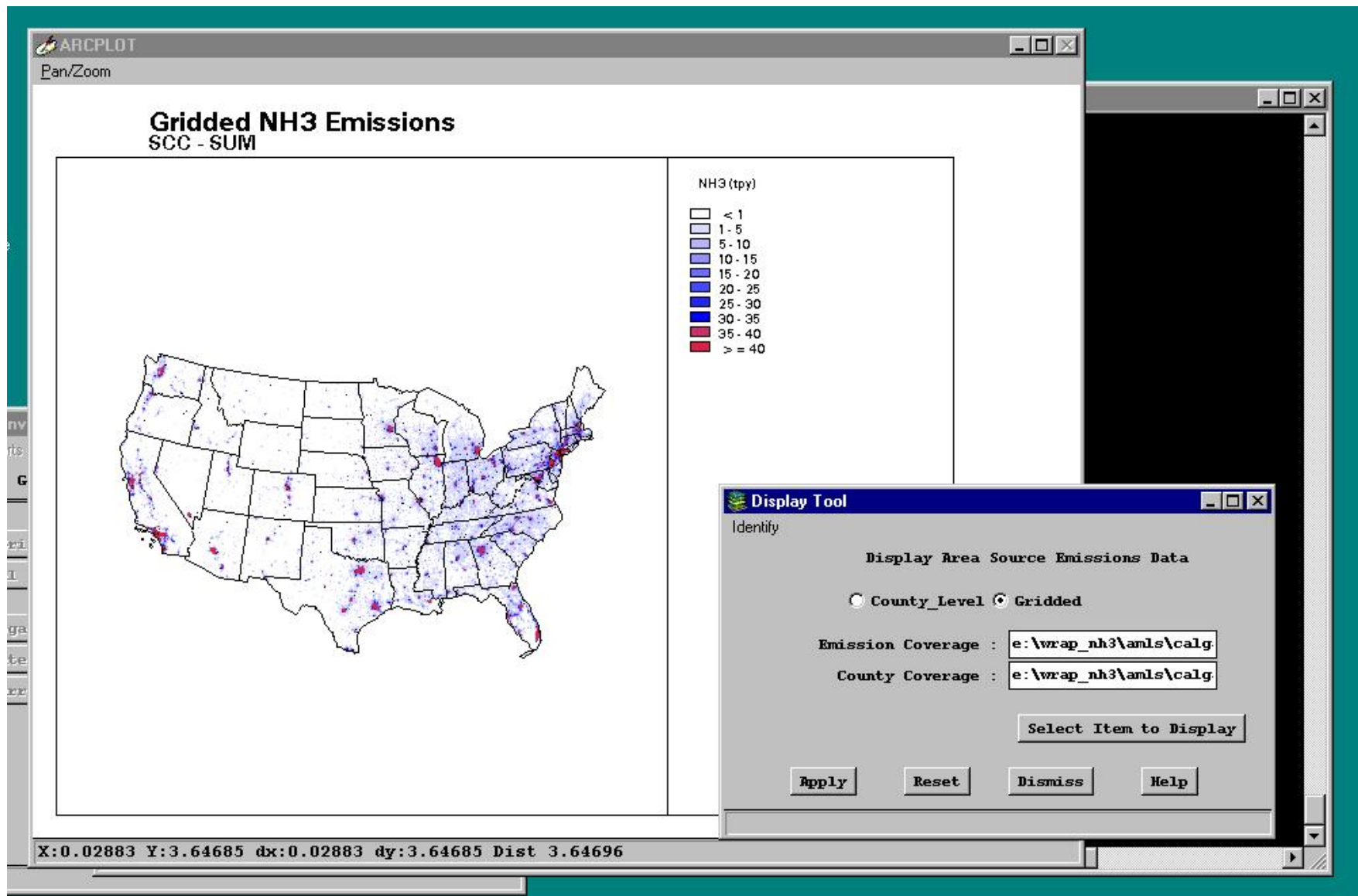
Identify

**Display LU/LC data**

LU/LC Coverage : e:\wrap\_nh3\amls\c

County Coverage : e:\wrap\_nh3\amls\c





## Summary

- 2002 NH<sub>3</sub> emission inventory for WRAP
  - Livestock, fertilizers, soils, domestic sources
- Updated emission factors, temporal allocation
- Incorporates environmental parameters
  - Temperature; soil moisture, pH; wind speed
- GIS-based NH<sub>3</sub> emissions modeling system
- Final 2002 gridded inventory completed in late July