

**5th CRC On-Road Vehicle  
Emissions Workshop**

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**DEVELOPING NEW ENGINE START EMISSIONS MODULES**

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Motor vehicle emission rates are elevated during the first few minutes of vehicle operation. The magnitude of the elevation is a function of: duration and magnitude of commanded enrichment, engine temperature and combustion efficiency, and catalyst temperature. Once combustion stabilizes, commanded enrichment ceases, and the catalytic converters reaches "light-off" temperatures (not necessarily in that order), emission rates decrease drastically.

The next generation motor vehicle emissions model being developed by Georgia Tech for metropolitan Atlanta is a modal emissions model within a geographic information system (GIS). The basis for the engine starts module is the spatial allocation of engine starts and important variables that affect emissions rates. The modeling framework employs engine start zones associated with land use characteristics and network links associated with modeled roadway classifications.

In the first phase of model development, the emission rates associated with engine start activity were estimated as emissions "puffs" and spatially allocated to engine start zones. The gram per start emission rates were based upon modified default values developed from existing modeling methods and a re-analysis of the Federal Test Procedure (FTP) database. The final phase of model development is a probabilistic approach which models gram/start emission rates as a function of vehicle characteristics, environmental parameters, vehicle activity prior to soak, soak time, influence of driver behavior, and modal activity undertaken after the engine is started (including idle, cruise, acceleration and road grade effects). The final model will allocate the majority of the engine start emissions to the engine start zone, and a portion to network links proximal to the engine start zone as a function of vehicle activity distributions.

# **Developing New Engine Start Emissions Modules**

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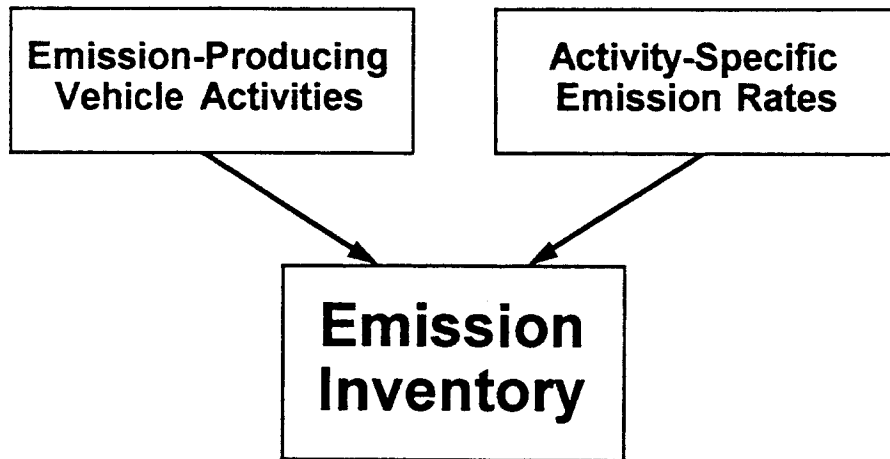
## **Introduction**

**Lay a Framework for Discussion:**

**(Why are new engine start algorithms needed?)**

**Outline the Basis of the GIS-Based Modal Emissions  
Model Being Developed at Georgia Tech**

**Present the Phased Implementation Plan for Engine  
Start Emissions Modeling (plus data requirements)**



Guenzler, 1993

## Emission-Producing Vehicle Activities and Emissions Produced

- Vehicle Miles Traveled → Running Exhaust  
Running Evaporative
- Cold Engine Starts → Elevated Running Exhaust
- Warm Engine Starts → Elevated Running Exhaust
- Hot Soaks → Evaporative
- Engine Idling → Running Exhaust  
Elevated Evaporative
- Exposure to Temp Cycles → Evaporative
- Vehicle Refueling → Evaporative
- Modal Behavior → Elevated Running Exhaust

Guenzler, 1993

## **Factors Affecting Emission Rates**

**Vehicle Parameters**  
**Fuel Parameters**  
**Environmental Factors**  
**Vehicle Operating Conditions**

## **Modeling Approaches for Elevated Emission Rates**

### **Puff Method:**

**Emission-producing activity considered a discrete event, producing an emissions "puff"**

### **Incremental Rate Method:**

**Emission rate for the parent activity (running exhaust emissions) incrementally increased under specific conditions**

## **Problems with Existing Cold and Hot Start Emission Estimates**

**Single Cycle (FTP) Testing**

**Problematic Statistical Methods**

**Commanded Enrichment and Catalyst Light-Off Issues**

**Modal and Super-Emitter Effects not Incorporated**

## **Engine Start Emissions**

**Duration and Magnitude of Commanded Enrichment**

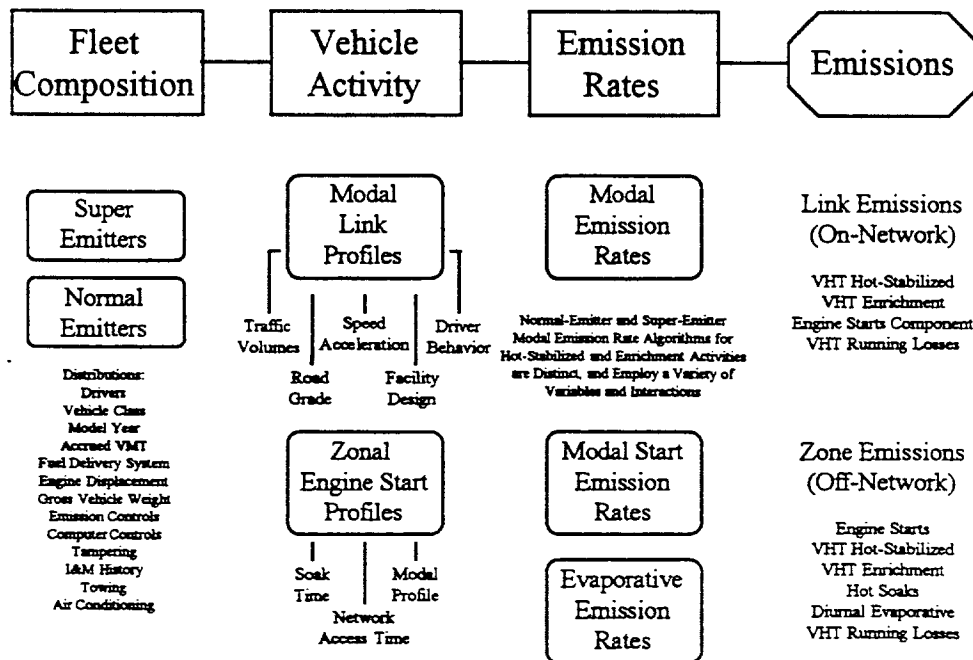
**Engine Temperature and Combustion Efficiency**

**Catalyst Temperature (light-off)**

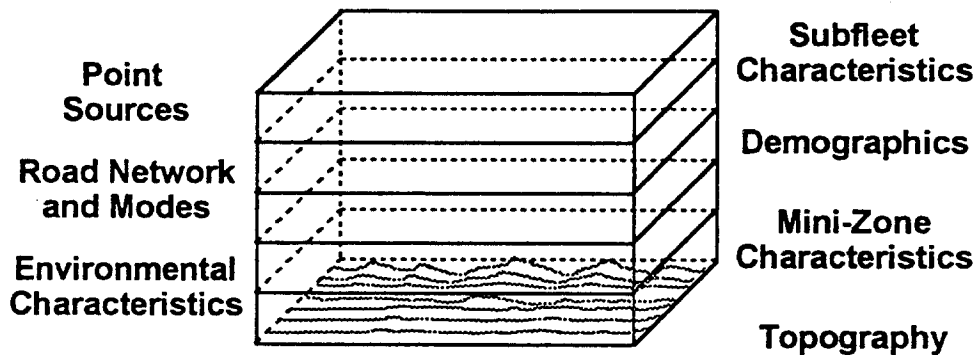
# Modeling Issues to be Addressed in Developing New Modal Models

- Employ a Representative Sample Fleet
- Test Representative Operating Modes
- Define and Control Influential Variables
- Investigate Interactions
- Over-sample Infrequent Critical Events
- Improve Spatial and Temporal Allocation of Emissions
- Compare Laboratory and On-Road Data
- Explicitly Address Uncertainty

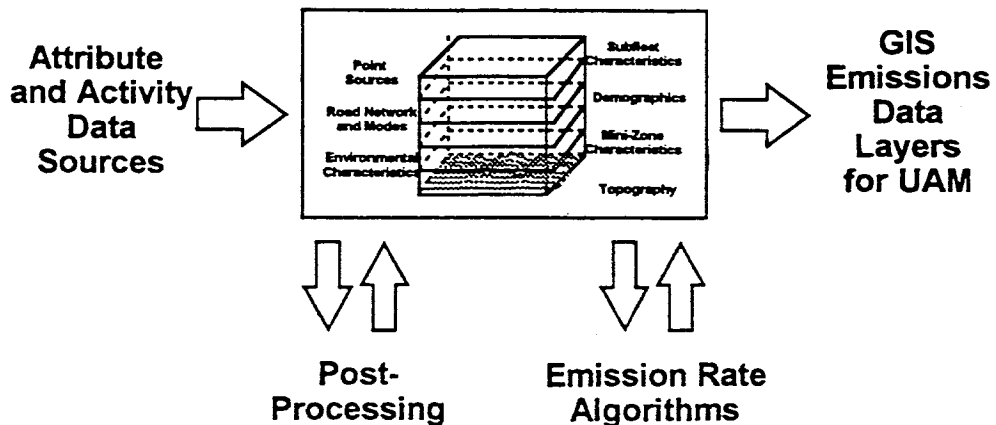
## GIS-Based Modal Model



### GIS Framework Points, Lines and Polygons Spatial Attribute Coverages



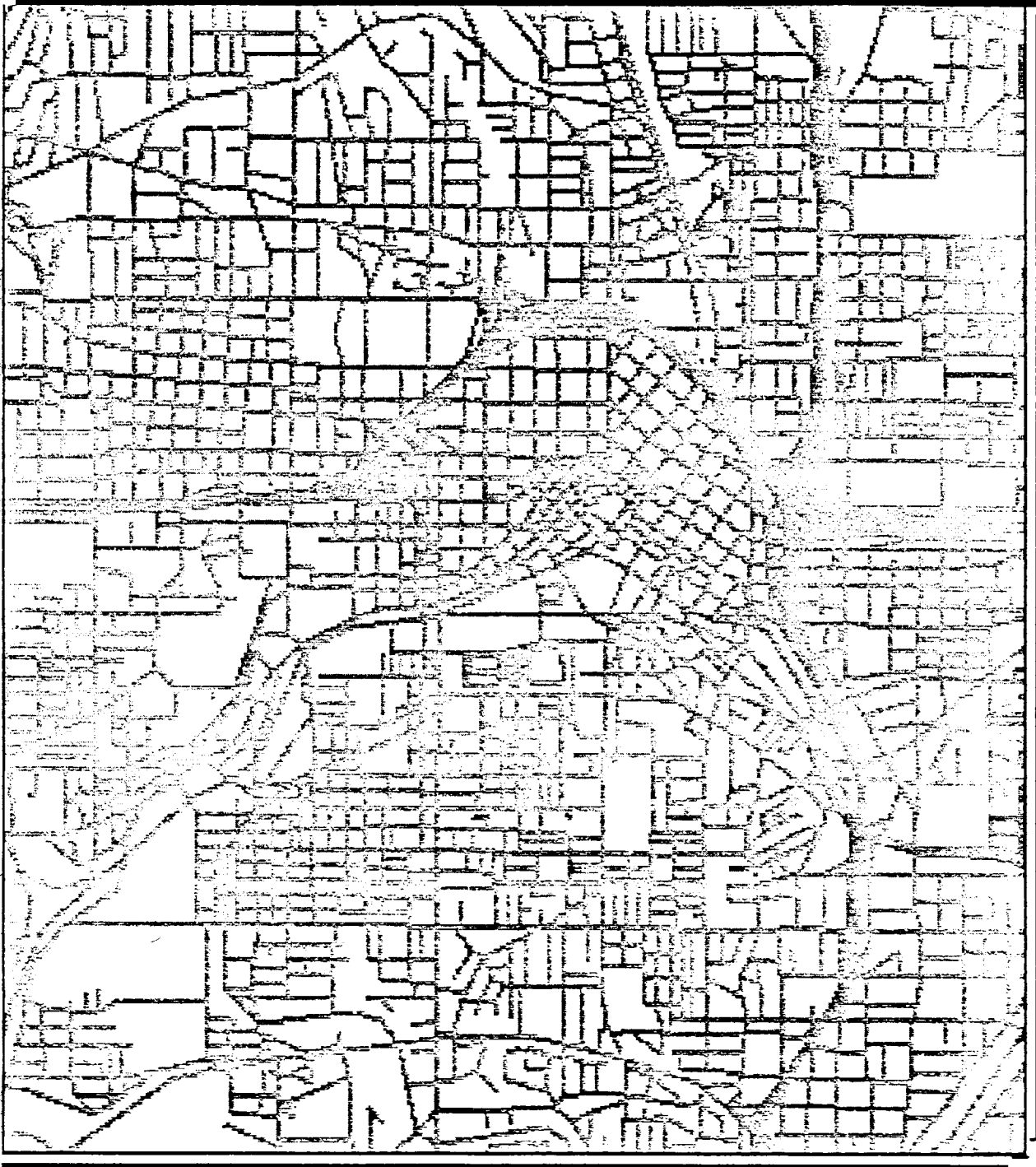
### GIS Framework Emission Layer Creation





Georgia Tech

Road Network







Georgia Tech

Census Tracts

ATLANTA\_AREA\_MOBILE\_EMISSIONS  
 SECOND GENERATION MOBILE EMISSION PROJECT  
 HC MODULE

-----Base Map Display-----  
 Road Network ) Census Tracts ) 1 km Grid )  
 Clear ) Interstates )

-----Thematic Display (variables)-----

ENGINE START EMISSIONS:  
 AM HC Starts (g)  
 PM HC Starts (g)

HOT STABILIZED EMISSIONS:  
 AM HC Hot Stabilized (g)

GRID CELL:  
 AM Starts ) PM Starts )  
 AM Hot Stabilized ) PM Hot Stabilized )  
 AM Enrichment ) PM Enrichment )  
 AM PK/hr Total ) PM PK/hr Total )  
 TOTAL AM + PM GRAMS )

Pan/Zoom  x,y: 3,54331,1,57480  
 dx,dy: 3,54331,1,57480

ARC PLOT  
 dist: 3.87750

## Phase I Emission Puff Default

**Engine start emissions estimated as "puffs" and spatially allocated to engine start zones. Hot and cold start approach continues.**

**Activity Data - Reconcile various static sources of activity data (e.g., census block) and existing synthetic equations.**

**Emission Rate Data - Modified default values developed from existing methods and a re-analysis of the Federal Test Procedure (FTP) database.**

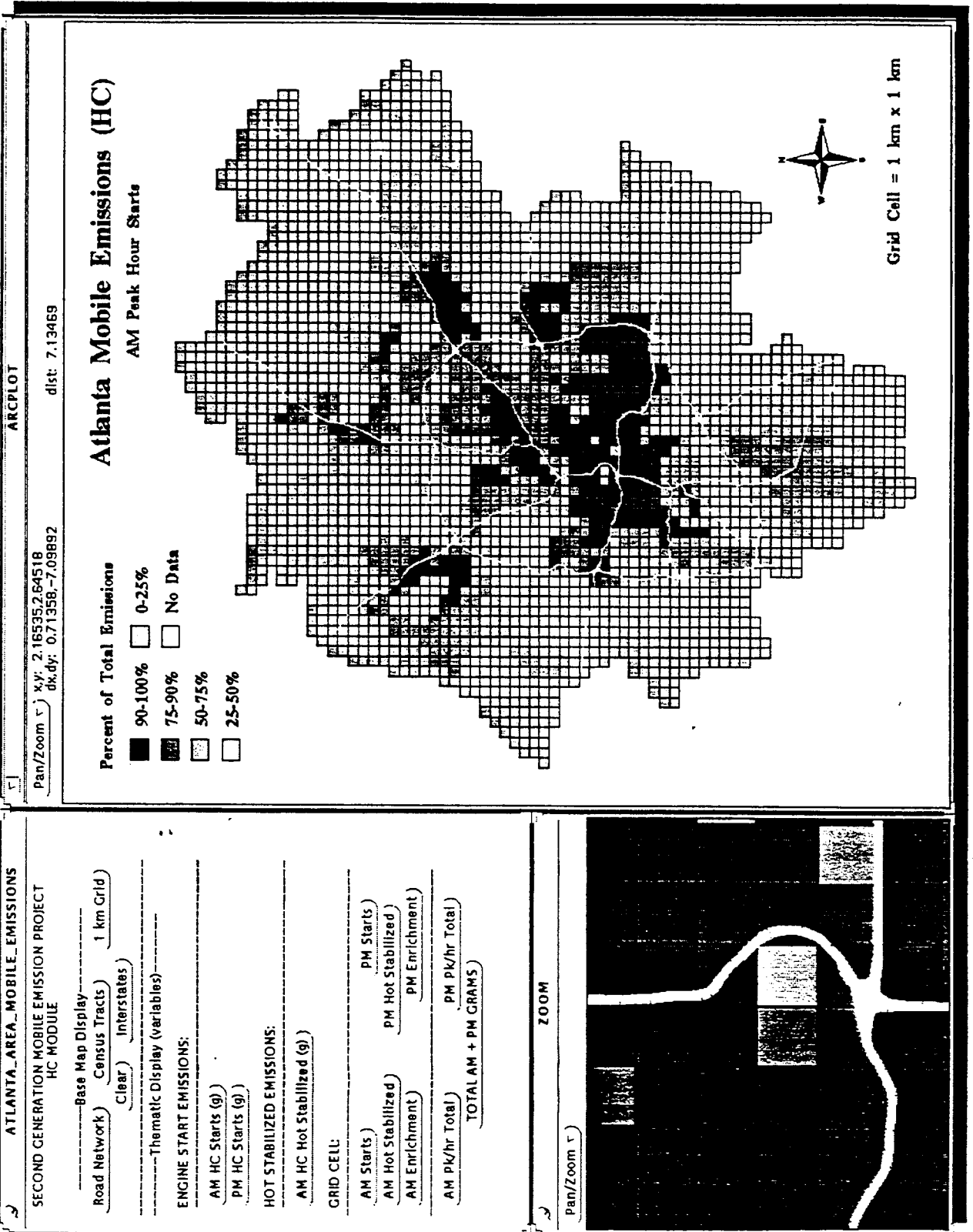
## Sources of Engine Start Activity (Trip Generation) Data

DATA SOURCE	RESID.	EMPLOY	SERVICE & COMM.	SPECIAL GENRTS.
Census Block Data	X			
Census Block Group	X			
Census Long Form	X	X		
ARC Land Use DB	X	X	X	X
ARC Synthetic Eq's	X	X	X	X
ARC O-D Survey	X	X	X	X
Instrumented Vehicles	X	X	X	X
Property Tax Roles	X	X	X	X
Secretary of State		X	X	
Registration DB	X		X	X
I&M Database	X			
Development Permits	X			
Employ. Devt. Dept.		X	X	
Regional Devt. Comm.	X	X	X	X
Insurance Consortium	X	X	X	X
Polk DB	X			
Dun and Bradstreet		X	X	
Phone Book DB		X	X	
Parking Receipts				X
Surveys			X	X
Space Counts			X	X
ITE Trip Gen Rates		X	X	X



Georgia Tech

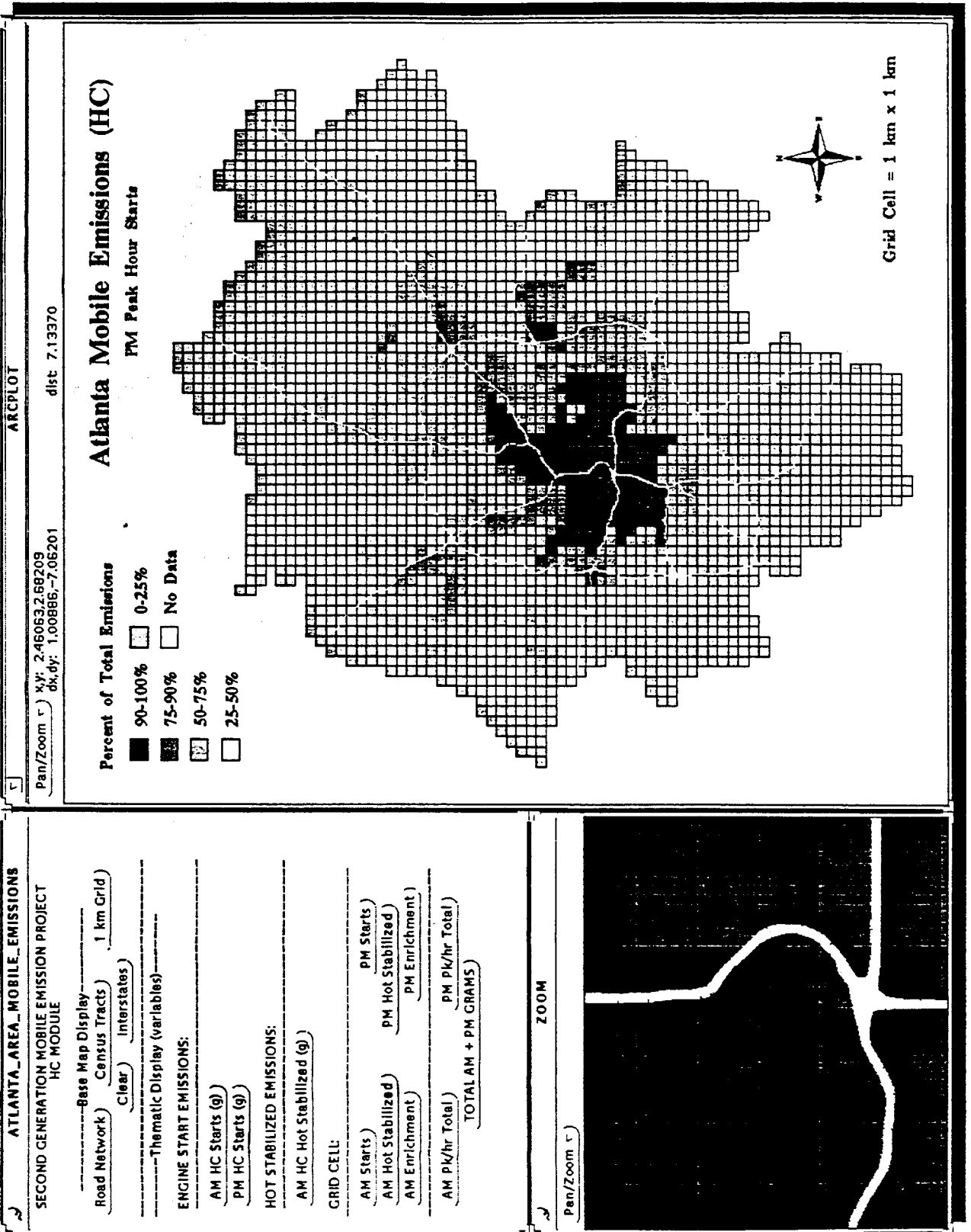
AM Peak Hr. Starts





Georgia Tech

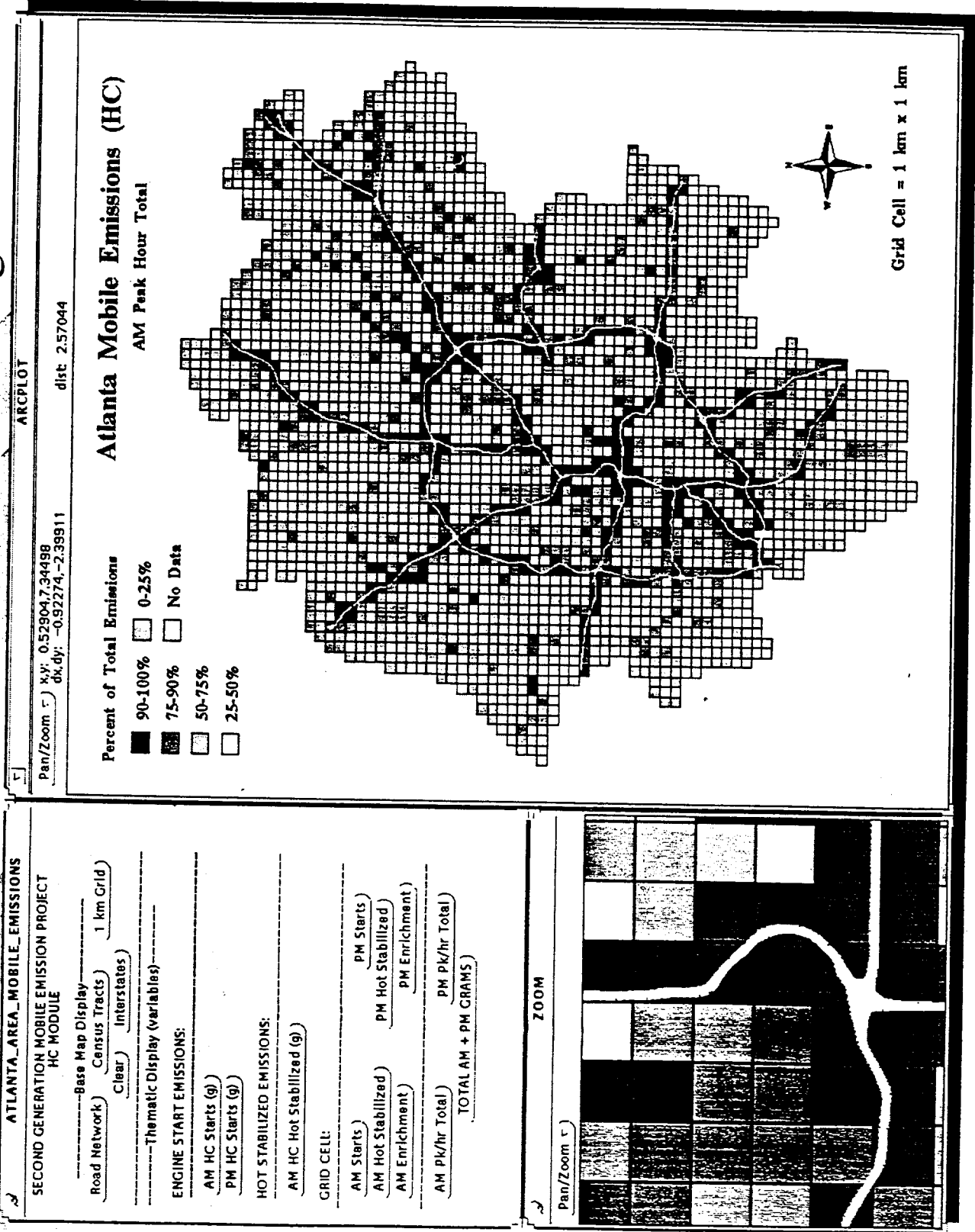
PM Peak Hr. Starts



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dx,dy: 1.00886,-7.06201  
dist 7.13370

# AM Peak Hr. Total

# Georgia Tech



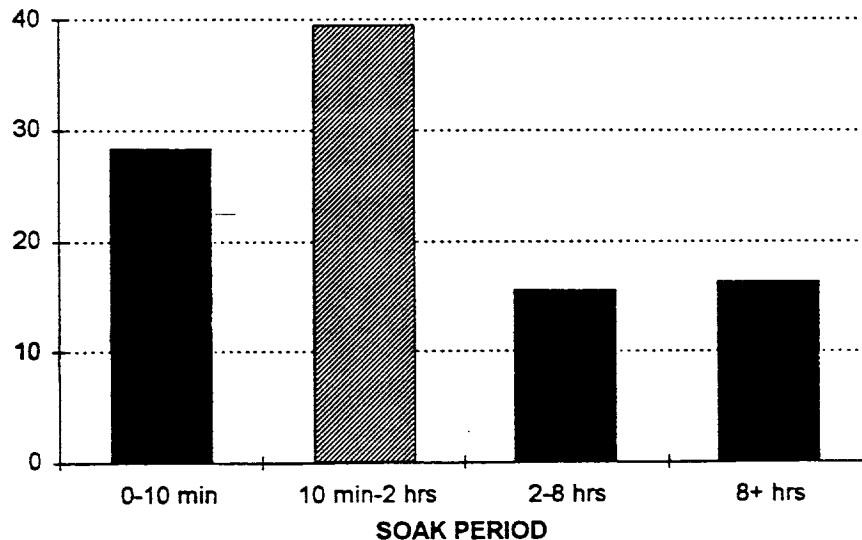
## Phase II Continuous Start Model

**Emission puff as a function of vehicle soak time (similar to CARB). Emissions allocated to the engine start zone (fraction carried onto network links using activity probability distributions).**

**Activity Data - Improved algorithms from existing and new data. Reconcile instrumented vehicle data for false starts and non-trips. Parking turnover studies for commercial/retail.**

**Emission Rate Data - Recent EPA and CARB studies. Limited existing instrumented vehicle data. New data collection.**

### *Soak Distributions: Baltimore*



## **Phase III Complex Start Model**

**Emission puffs derived as a function of vehicle characteristics, environmental parameters, vehicle activity prior to soak, soak time, influence of driver behavior, and modal activity undertaken after the engine is started.**

**Activity Data - Improved model algorithms for numbers of starts and important causal variables based upon existing and new data.**

**Emission Rate Data - Existing data, driver behavior study and data from new sources where variables are controlled.**

## **Major Research Efforts**

**Quantifying relationships between elevated emissions and a variety of causal variables.**

**Improving estimates of number of starts and variables that affect emission rates.**

**Estimating the probability functions for vehicle warm-up off and on the network.**