# NATIONAL URBAN DATABASE AND ACCESS PORTAL TOOL (NUDAPT): FACILITATING ADVANCEMENTS IN URBAN METEOROLOGY AND CLIMATE MODELING WITH COMMUNITY-BASED URBAN DATABASES

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## 1. INTRODUCTION

Current data and modeling tools are limited in their capabilities to perform accurate air quality assessments in the urban areas that contain our highest and most vulnerable population densities; this lack is especially problematic because many such areas are experiencing large growth rates. In response, a new project called National Urban Database with Access Portal Tool (NUDAPT) has been launched. This pilot program addresses various recommendations from a survey conducted by the American Meteorological Society (AMS) Board of Urban Environment, recommendations from the Office of the Federal Coordinator for Meteorology's (OFCM) Urban Environment Workshop (2005), and the need for improved information to support hot-spot assessments of the National Air Toxics Assessment (NATA). NUDAPT, sponsored by the U.S. EPA, involves collaborations and contributions from Federal and state agencies as well as from private and academic institutions. NUDAPT is designed to fill a critical gap: it will provide the refined and specialized information needed to fulfill the accuracy requirements for urban modeling applications. This project builds on several foundations:

- The emergence of new science and model advancements related to urban meteorology.
- New databases containing a wealth of data, such as high-resolution building data; land use data; "daughter products" parameters and/or variables that are derivable from the primary data, such as urban canopy parameters (UCPs); and ancillary data products (e.g., gridded, diurnally varying population data).
- The feasibility of disseminating the data on demand from a centralized database using web-based data access tools.

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## 2. APPROACH

We describe here a prototype that will result in an operational template that, when extended, will provide a nationwide capability serving a broad user community that is engaged in developing and driving powerful, advanced atmospheric transport/dispersion and air quality modeling tools.† This project will provide a strategic implementation to the modeling and decision support communities, both of which require appropriate modeling tools to support the assessments and applications needed to help reduce health risk from exposure to poor air quality. Further, it will address homeland security issues relative to the transport and dispersion of deadly toxic agent releases.

When fully implemented, NUDAPT will produce gridded outputs of urban parameterizations that can then be used to drive advanced urban meteorological and air quality models (Dupont et al., 2004; Otte et al., 2004; Chen et al., 2006; Ching et al., 2004). NUDAPT takes advantage of advances in modeling and parameterizations to improve urban simulations, given the availability of new high-resolution data of urban morphological features. Portal technology is being used to develop NUDAPT as a "community-based" system. The portal will facilitate data retrievals and handling based on data federation concepts, which provide a means for integrating diverse data into an application. Houston, the fourth largest city in the United States, will serve as the test bed to demonstrate NUDAPT's features. A set of lidar-derived building data for Houston is available for unrestricted use (Figure 1), as are several derived products, and sets of air quality data resulting from major

†Already, the value of using high-resolution urban data in meteorological and air quality simulations has been demonstrated in sensitivity studies based on mesoscale modeling systems that incorporate urban canopy parameters (Dupont et al., 2004; Ching et al., 2004; Chen et al., 2006).

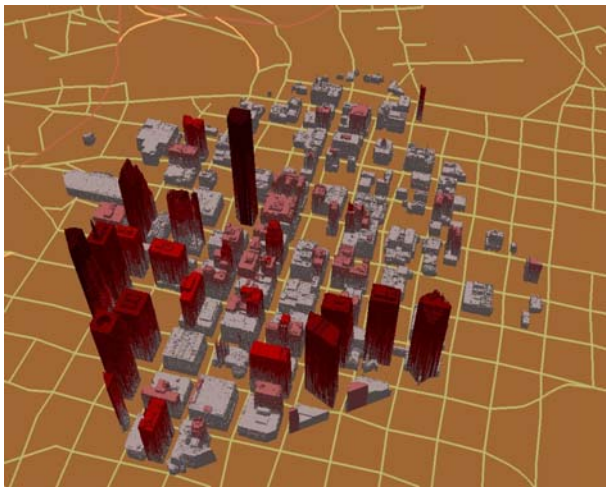

Fig. 1: Three-dimensional digital elevation data derived from an airborne lidar platform for a 1X1-km section of downtown Houston.

intensive field studies. Houston has active emissions management programs to address its substandard air quality and associated health effects. The NUDAPT prototype will include

(1) Primary data sets, such as three-dimensional building and geomorphological data; roads and their linkages; activity data, including census data, traffic, and industrial outputs; land-surface characteristics data

(2) Derived daughter products, including model-specific UCPs, diurnal gridded population data, gridded anthropogenic energy inputs, gridded traffic emissions

(3) Selected illustrative examples of model outputs and analyses to demonstrate a range of possible applications

The initial prototype will feature advanced urban implementations in MM5, WRF, and other modeling systems. (Chen et al., 2006; Ching et al., 2004).

## 3. FEATURES OF NUDAPT

### *3.1 Morphology Databases and Urban Canopy Parameters*

An important feature of NUDAPT is the provision to incorporate urban structure data, and their derivative urban parameters, that can be used by mesoscale meteorology models. For example, in the urbanized version of MM5, the urban canopy parameterization follows definitions of urban canopy parameters that determine how building and vegetation influence the drag, the turbulent generation, and the energetics of the flow near the surface. The UCPs listed in Table 1 (eight of which vary with height), which are used in the Dupont modeling system (Dupont et al., 2004), have been calculated for each grid in the modeling domain (Burian et al., 2004). The data used to derive this set of UCPs came primarily from an airborne-based lidar system that collects data for the Digital Elevation Model (DEM) and the Digital Terrain Model (DTM). Differencing the digital elevation and terrain signals provides the building and tree information (Figure 1 is an example). High-altitude aircraft and municipal property data provide information to complement the lidar database. Such data and the derived UCPs are being incorporated into the Houston prototype.

Geospatial databases (similar to those used for Houston) that consist of detailed imagery information on buildings and other urban morphological structures at resolutions on the order 1 m are being acquired for 133 urban centers in the U.S. This is in response to the Homeland Security Infrastructure Program (HSIP); the Nunn-Lugar-Dominici Act (Defense Against Weapons of Mass Destruction Act of 1996) established a project by which DOD was tasked with helping to respond to chemical, biological, or nuclear/radiological (CBN) incidents in the 133 urban centers. These data (together with the National Map Project of the U.S. Geological Survey) provide the foundation for HSIP on a national scale.

### *3.2 Relevant Ancillary Data*

Data obtained from NUDAPT will serve to improve meteorological fields for air quality, homeland security, and planning purposes. NUDAPT will include a wide variety of activities and land-use data, such as roads and their linkages, and activity data such as census data, traffic, and industrial outputs, as well as land surface characteristics data. In addition, it will include gridded population data for the U.S., such as day-night populations, indoor-outdoor populations, sensitive population groups, and population mobility matrix. Some of these data, such as the indoor-outdoor populations, are not regionally or seasonally dependent; such data are being generated for the prototype at latitude-longitude (lat-lon) coordinates with a spatial resolution of 250 m. Other derived daughter products include model-specific urban canopy parameters, gridded anthropogenic energy inputs, and gridded traffic emissions.

### *3.3 NUDAPT Design Concept*

NUDAPT will have a two-level framework, in the form of a web-enabled database, that gives users ready access to the various datasets, both primary (source) data and processed data. The first level will provide unrestricted access; users can query the database for relevant data, retrieve data in a form that can be readily assimilated into models such as MM5, and submit model results for further analysis. Access to the second level will be restricted; it is intended for use by those interested in creating new or modified UCP datasets. New datasets derived from lidar data, UCPs, and other data such as modeling results can then be resubmitted back to NUDAPT for community use. The database is federated, i.e., the database will act as a repository for multiple, heterogeneous datasets that all adhere to a consistent format and metadata specification. This framework facilitates analysis by the scientific community by providing an efficient means of sharing observed and modeled data. The community provides the means for detailed analysis and knowledge integration. The data-sharing concept in NUDAPT has the potential to translate into improved models of the urban environment. For example, a researcher wishes to compare their model results with another simulation that used a different set of UCPs. This is easily accomplished by a query to the database, retrieval of the model run of interest, and analysis accomplished at the user end. As more researchers utilize these UCPs in their simulation modeling, more knowledge integration will occur through enhanced model evaluations, leading to improved models. Figure 2 is a schematic description of NUDAPT.

Many datasets will reside on the NUDAPT portal server. Where data are available for public download elsewhere, the portal will provide a link to facilitate the download. Because the site is expected to act as a data repository rather than an active, transaction-heavy database, it does not appear that database software will be needed to manage the datasets in question. Instead, they will exist as stand-alone files in the file system.

The portal design allows for web-based data extraction and conversion in both raster and vector formats. ESRI's relatively new ArcGIS Server provides a single engine capable of all the desired functionalities that are needed to handle both data formats. ArcObjects Java appears to be the preferable language; this will allow the application to be easily ported to a high-performance Linux environment if the server-side processing demand becomes severe.

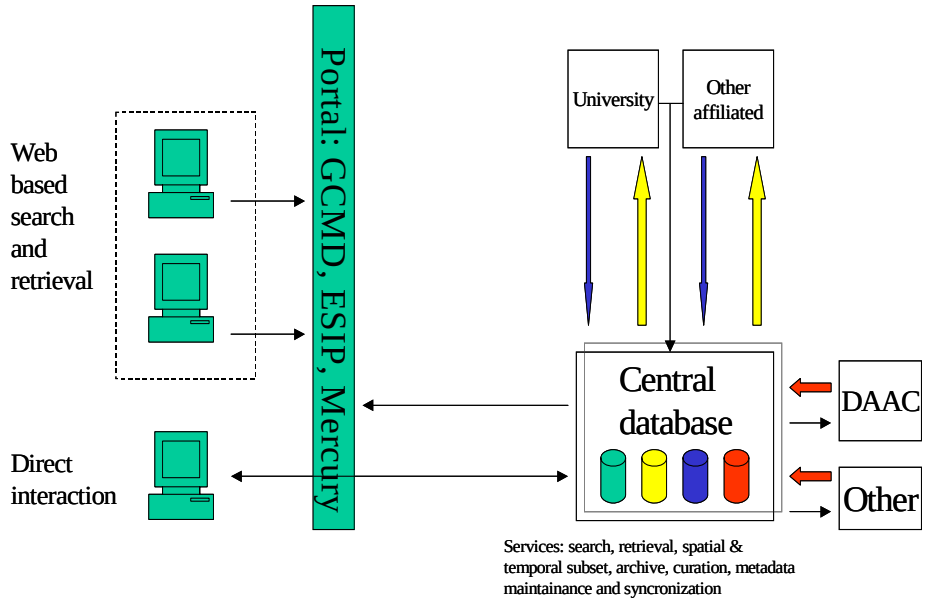


Fig. 2. Notional database architecture. There are two level of access. In Level 1 (black arrows), the public has access to metadata and processed data (e.g., gridded urban morphological parameters) for use in modeling. Level 2 (yellow and blue arrows) allows Principal Investigators full access to upload and download source data. Width of arrows illustrates bandwidth requirements.

## 4. SUMMARY AND DISCUSSION

The development of NUDAPT will provide a needed resource that will stimulate research and modeling to address many of the emerging problems in urban areas, such as pollution impacts on population and accidental release of hazards. NUDAPT will provide a platform for accessing

and developing data and for sharing information with the user community. Primary data in NUDAPT will include physical and morphological data prepared and collected under various conventional and unconventional systems. The preparation of NUDAPT daughter products that are closely directed to urban gridded modeling applications will need to consider the various map projections that are used in typical meteorological and air quality modeling applications. Due to the multiple scales of the applications that could be used in various studies, it is important to develop a methodology for projecting and regridding the data to conserve the features of the transferred data. Although NUDAPT is being developed as a prototype for the Houston area., the goal is to extend NUDAPT for use in all major urban areas in the United States.

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Table 1: Gridded UCPs from lidar-derived building and vegetation data for the urbanized MM5 model.

| Canopy UCPs | Building UCPs | Vegetation and Other UCPs |
|---|---|---|
| Mean canopy height | Mean building height | Mean vegetation height |
| Canopy plan area density | Standard deviation of building height | Vegetation plan area density |
| Canopy top area density | Building height histograms | Vegetation top area density |
| Canopy frontal area density | Building wall-to-plan-area ratio | Vegetation frontal area density |
| Roughness length | Building height-to-width ratio | Mean orientation of streets |
| Displacement height | Building plan area density | Plan area fraction surface covers |
| Sky view factor | Building rooftop area density | Percent directly connected impervious area |
| | Building frontal area density | Building material fraction |