# PROJECT OVERVIEW: NATIONAL URBAN DATABASE AND ACCESS PORTAL TOOLS (NUDAPT)

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## 1. INTRODUCTION

Based on the need for advanced treatments of high resolution urban morphological features in meteorological, dispersion, air quality and human exposure modeling systems for future urban applications, a new project was launched called the National Urban Database and Access Portal Tool (NUDAPT). The initial NUDAPT prototype is a project sponsored by the United States Environmental Protection Agency (USEPA) and involves active collaborations and contributions from many groups from federal and state agencies, and from private and academic institutions. NUDAPT will produce gridded outputs of urban parameters capable of driving current (Dupont et al., 2004, Otte et al, 2004, Chen et al., 2006, 2007a, b, Park et al., 2007, Taha et al., 2007a, b, Ching et al., 2004) and future advanced urban meteorological (Martilli, 2007, Martilli and Schmitz, 2007) and air quality models. Additionally, ancillary data will be included such as gridded population, energy usage and traffic (Burian et al., 2007b) so as to encourage and facilitate linkages to air quality and human exposure models. Portal technology is incorporated to enable NUDAPT to be a "Community" based system, an important core-design feature. This web-based technology will facilitate data retrievals and handling based on data federation concepts. Houston Texas will serve as NUDAPT's initial prototype; it will feature advanced urban canopy implementations of the Mesoscale Meteorological model, Version 5 (MM5) as well as the Weather Research and Forceast (WRF) models; thus serving to demonstrate the NUDAPT features, including scope of the data and processing methodologies for eventual extension to all other cities.

## 2. APPROACH

In this paper, we describe a prototype operational template of this database. In principle, the Prototype will eventually provide a nation-wide resource for the model user community engaged in developing and applying advanced atmospheric transport and dispersion and air quality models. The value of using high resolution urban data in meteorological and air quality simulations has been demonstrated from sensitivity studies, Dupont, et al., (2004); Ching et al., (2004); Chen et al., (2006) and other application studies including urban heat island (UHI) modification studies based on mesoscale modeling system that incorporate urban canopy parameters, Taha (2007a,b). NUDAPT supports assessment studies needed to inform decision makers on health risk from exposure to poor air quality. Further, it addresses homeland security issues regarding the transport and dispersion of toxic releases.

We have selected Houston, the fourth largest city in the USA, as the initial prototype for demonstrating the NUDAPT 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 available from major intensive field studies. Houston has active emissions management programs to address its poor air quality and associated health effects. The NUDAPT prototype will include: (1) primary data sets such as (three-dimensional building and geo-morphological data, roads and their linkages;(b) activity data including census data, traffic, and industrial outputs, (c) land surface characteristics data; (2) derived daughter products including model specific UCPs, diurnal gridded population data, gridded anthropogenic energy inputs (Sailor et al., 2007), and gridded traffic emissions; and (3) selected illustrative examples of model outputs and analyses to demonstrate a range of applications. This initial prototype will feature advanced urban implementations; in MM5 (Ching et al, 2004) and WRF (Chen et al., 2006) and other modeling systems.

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## 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, the urbanized version of MM5, makes use of UCPs introduced to account for building and vegetation influences on the drag, the partitioning of the surface energy budget components, and the generation of turbulence of the flow in the surface boundary layer. The set of UCPs listed in Table 1 (8 of which vary with height) used in the Dupont modeling system (Dupont et al., 2004) has been calculated for each grid in the modeling domain (Burian et al., 2004, 2007b). The data to derive this set of UCPs were primarily from an airborne based LiDAR system that collects data for the Digital Elevation Model (DEM) and Digital Terrain Model (DTM). Differencing the digital elevation and terrain signals provides the building and tree information, an example of which is shown in Fig. 1a. High altitude aircraft and municipal property data provide information to complement the LiDAR database. Such data and the derived UCPs (example shown in Figure 1b) are incorporated into the Houston Prototype.

Geospatial databases similar to that used in Houston that consist of detailed building and other urban morphological structures imagery information at pixel resolution of order 1 m are being acquired for 133 urban centers in the USA. 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 to help respond to chemical, biological and nuclear (CBN) incidences in the 133 urban centers. These data (together with the National Map Project of the US Geological Survey) provide the foundation for a national scale database. Of course, even higher resolution descriptions of building data exist. In principle, the NUDAPT can incorporate such data if it can be made available.

Currently, a second generation National Building Statistics Database (NBSD2) consisting of sets of UCPs similar to the set shown in Table 1 (but without vegetation parameterizations have been created using the Urban Morphological Analyses Processor, UMAP, Burian et.al., (2007a). These gridded fields are created at 250m and 1 km grid sizes for urban areas shown in Figure 2. These datasets are available in NUDAPT courtesy of S.Burian and M. Brown.

### *3.2 Relevant Ancillary data*

Gridded UCP and land use data sets obtained from NUDAPT are expected to improve meteorological fields for air quality, homeland security, and planning purposes. NUDAPT will also include links to other sources of relevant data including various activities and land-use data such as roads and their linkages, and activity data including census data, traffic, industrial outputs, and land surface characteristics data from which gridded products useful for models will be derived. In addition, NUDAPT will include gridded population data for the USA, e.g., day-night populations (see Figure 3), indoor-outdoor populations, sensitive population groups and population mobility matrix. These data are made available to NUDAPT courtesy of T. McPherson and M. Brown. These data is useful to exposure and consequence management assessments. Such data are being generated for the prototype at latitude-longitude (lat-long) coordinates with a spatial resolution of 250 m (McPherson, et al., 2003a,b, 2004, 2006). Additionally, gridded anthropogenic heating rates (also at 250m grid size) are available in NUDAPT courtesy of David Sailor. These data replace crude assumptions used in previous urban meteorological modeling studies. Details are provided in Sailor et al., (2004, 2006), an example of this product is shown in Figure 4.

### *3.3. NUDAPT Design concept*

NUDAPT is structured as a two level web-enabled database that provides ready access to the various datasets, both primary or source data and processed data to users. The first level of the framework is the primary data and includes the high resolution building data. Access to this level is limited; it can be granted for those interested in creating new or modified UCP datasets. The second level provides 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. 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 allows for 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 can facilitate researcher efforts to improve 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. Once researchers utilize these UCPs in their modeling, more knowledge integration will occur through enhanced model evaluations leading to improved models.

Datasets will either reside on the NUDAPT portal server or, where available, for public download elsewhere. The portal will provide a link to facilitate the appropriate download. Because the site is expected to act as a data repository rather than an active transaction-heavy database, there does not appear to be a need to utilize database software to manage the datasets in question. Instead the datasets will exist as stand-alone files in the file system. The initial Prototype will use the ArcGIS 9.2 server that provides the desired functionality needed to handle both vector and raster data formats.

## 4. DISCUSSION AND SUMMARY

Initial sensitivity studies of air quality (and other) applications using outputs of advanced meteorological models that incorporate data such as those available from NUDAPT are being performed. Figure 5 contrasts the mixed layer simulations from MM5 with and without UCP. The urban area of Houston is categorized with one urban land use category in the standard version of MM5. Figure 6 illustrates the sensitivity of Community Multiscale Air Quality (CMAQ) model to MM5 versions with and without detailed urban canopy feature. In this instance, significant differences are seen, serving as a motivation for advancements in urban modeling.

The development of NUDAPT represents a promising resource to address many of the emerging problems in urban areas. NUDAPT provides 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, which are closely directed to urban gridded modeling applications, will need to consider various map projections that are used in typical meteorological and air quality modeling applications. Due to the various grid sizes and map projects of applications that will potentially be used by various modelers, provisions are made in NUDAPT to include or contain methodologies for re-projecting and re-gridding these daughter products.

The Portal also includes a site (called Quickplace) designed to facilitate collaborations between NUDAPT current and future Collaborators. Rooms are set up in the name of a individual and all Collaborator's. Once registered, collaborators can engage in various model development and application studies, generation of new parameters etc.

Currently, a database for Houston Texas is serving as the focus city of the NUDAPT prototype. Eventually, the goal for NUDAPT is to be extended to all major urban areas within the United States.

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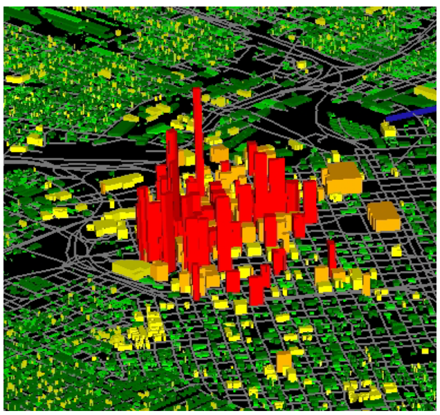
**Table 1: Gridded UCPs from lidar-derived building and vegetation data for urbanized MM5 model.**

| Canopy UCPs: | Building UCPs: | Vegetation, 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 |



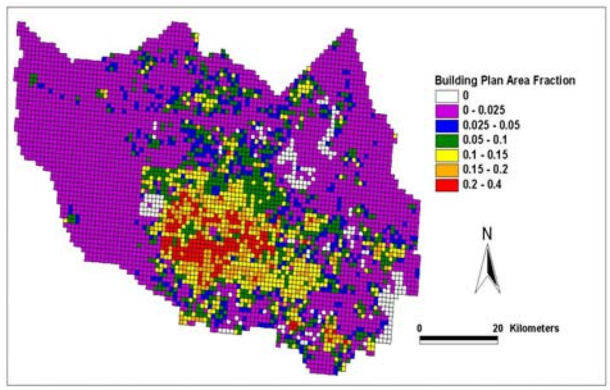



Fig. 1(a) Left: Three dimensional building data derived from airborne lidar platform for 1x1 km section of downtown Houston. (b) Right: Building plan area density, an example of a UCP for Harris County (Houston Metropolitan area) (cf Table 1)

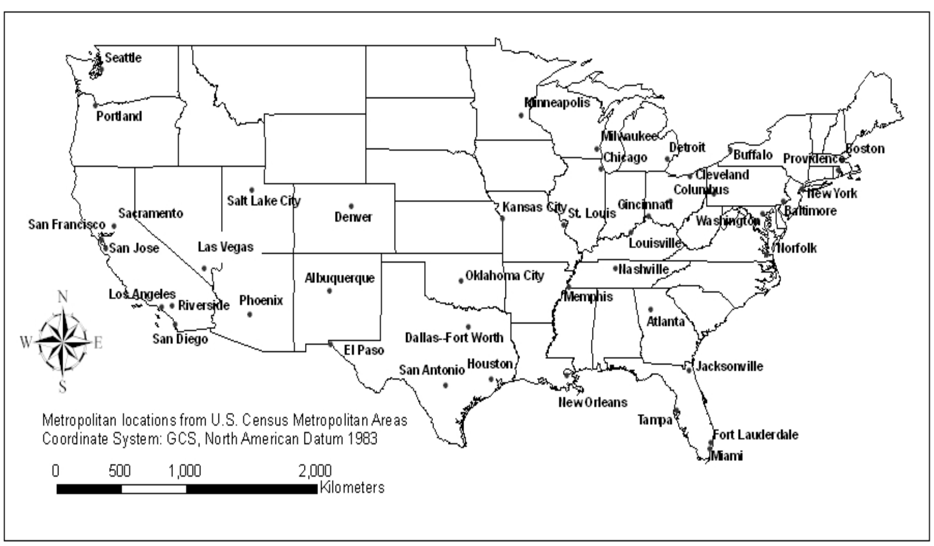



Figure 2 (a) National Building Statistics Database ((Version 2.0) (47 + Cities))

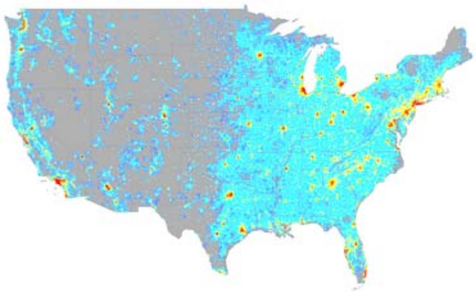


Figure 3 Gridded Day-Night Population database (Courtesy of McPherson and Brown)

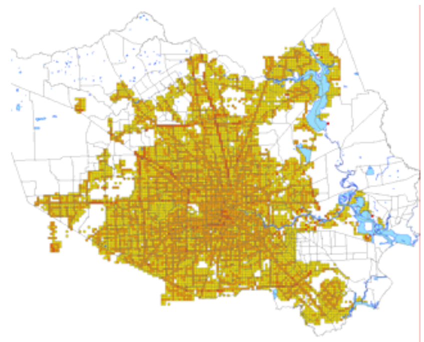


Figure 4: Anthropogenic heating: Houston August, 2000 CDT (Courtesy of David Sailor)

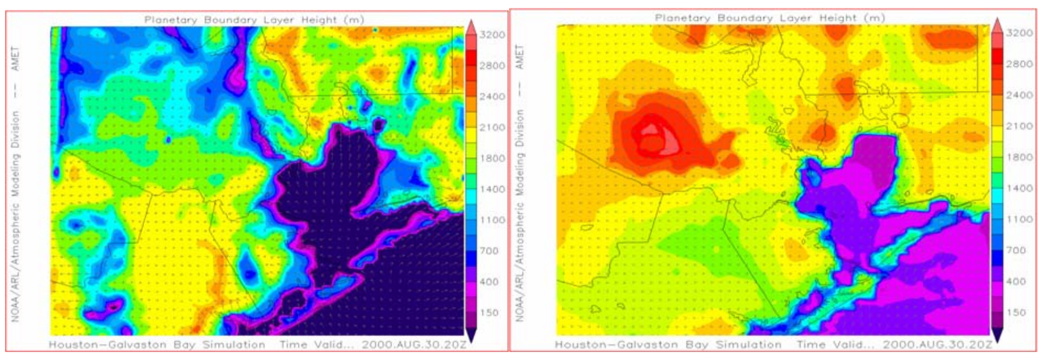



Figure 5. Simulations of mixed layer heights size for 2100 GMT, August 30, 2000. MM5 with UCP (left) and standard version of MM5 (right) at 1 km grid.

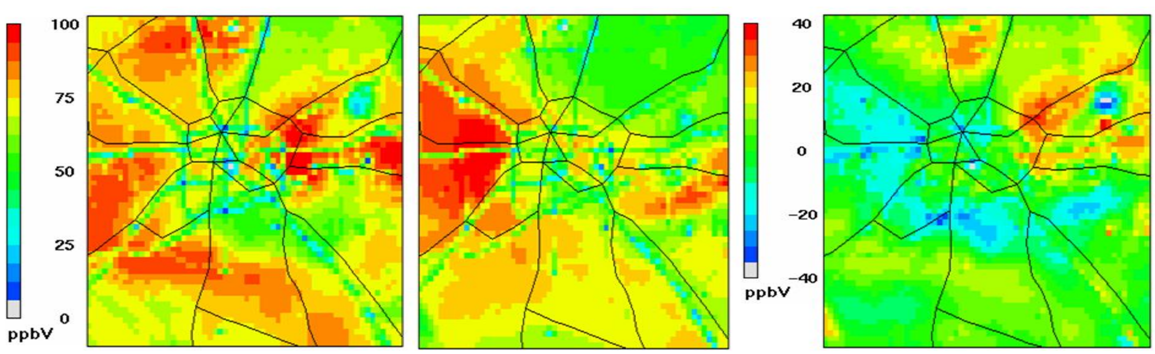



Figure 6: Simulations of surface ozone using CMAQ driven by UCP (left) and No-UCP (center) versions of MM5 (see Figure 2). Differences are shown on right panel.