6.9 MICROSCALE ASPECTS OF NUDAPT

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1. INTRODUCTION

Within the NUDAPT Project, a niche for micro-scale morphology for modelers has been established. The scope of this National Data Base now includes meso-scale and micro-scale domains and their three sub-divisions of motion (alpha, beta, and gamma) such as those proposed by Orlanski (1975) some years ago. Within this scheme, the micro-gamma scale can be equated to the CFD scale. The micro-alpha and micro-beta scales are the scales being addressed in this paper. Global and country-scale aspects also are prominent within NUDAPT.

2. DISCUSSION

It was previously reported that the characteristics, properties, and format of digitized surface feature morphology for micro-scale usage (Cionco, 2006) differ from the coarse grid size and limited morphology types of the meso-scale as well as the ultra-high resolution of the CFD one-for-one dimensions/footprint and the disregard for morphology other than just buildings. Meso-scale modelers rely upon Land Use/Land Cover data sets from USGS with the usual 1km resolution. More recently Burian and his colleagues (2004a, 2004b and Priv. Comm.) and Ching and his colleagues (2002) have developed a methodology to digitize finer meso-scale data sets with a 250m resolution. The CFD modelers derive their data sets from highly exact LIDAR fly-over measurements further analyzed and documented by NGA (formerly NIMA) in collaboration with DTRA. Clearly, the micro-alpha/beta modeler needs more information than the other modelers.

Presently, micro-scale modelers have a long list of urban morphology features to work with such as 16 Urban Terrain Zone types, five building properties and characteristics, and some 18 non-building morphology types. The non-building morphology types include trees, shrubs, crops, grass, bare soil, water, marsh, and various types of impervious surfaces. Impervious surfaces include highways, roads, streets, parking lots, and gathering spaces. Data cell resolution of these types of micro-scale morphology has been implemented for 50m and 100m grid cells for more than a dozen urban (9) and rural (4) areas. Examples of micro-scale morphology data characteristics and properties as well as comparable data sets for limited areas within the Houston, TX urban area are presented.

3. MICROSCALE PROPERTIES AND CHARACTERISTICS

Ellefsen (1996, 2001a and b), Cionco and Ellefsen (1998), and Ellefsen and Cionco (2002) have presented both the Urban Terrain Zone Scheme and a more inclusive list of non-building morphology features derived from their methodology.

3.a. Urban Terrain Zone (UTZ) categories

The Urban Terrain Zone classification system contains 16 categories (see the list in Table 1). UTZs are divided into three major types: Attached buildings, Closely-spaced buildings, and Widely-spaced buildings. The categories are further subdivided into more specific building types that may also convey usage. A 17th category (D07) is possible when unusual structures such as statues, monuments etc. occur within the domain.

Table 1. Urban Terrain Zone categories* derived by Ellefsen

A1 Attached buildings, high-rise offices, hotels (old city core)
A2 Attached buildings, apartments (near old city core)
A3 Attached buildings, abutted-wall houses, near core
A4 Attached buildings, industrial/storage buildings, flush with street
A5 Attached buildings, commercial, flush with street

Dc1 Detached, closely-spaced high-rise office buildings, hotels
Dc2 Detached, closely-spaced apartment buildings
Dc3 Detached, closely-spaced houses (near core and suburbia)
Dc4 Detached, closely-spaced industrial/storage buildings, along railroad or docks
Dc5 Detached, closely-spaced commercial buildings along arterials
Do1 Detached, widely-spaced modern shopping centers w/parking lots
Do2 Detached, widely-spaced planned apartment unit w/open spaces
Do3 Detached, widely-spaced houses, usually on large lots
Do4 Detached, widely-spaced industrial/storage buildings
Do5 Detached, widely-spaced commercial buildings
D06 Detached, widely-spaced administrative/cultural buildings
D07 Detached, open set complex, unusual structures, monuments etc

*** Note that not all UTZ categories occur in all cities and some flexibility is required to accommodate special and unusual features. The specific nature of these UTZs can be helpful for on-the-ground operations in very local situations. Groups such as the first responder (HAZMAT incidents etc.), the Field Army and others will be better informed as to what type of urban structure they must address and control. It is also worth noting that even at the one-hectare (100m x 100m cells) resolution, some generalization of urban features must be made. Inventories with a resolution of a quarter hectare (50 x 50 meters) would be a more suitable scale for the actual size of most urban features, but large city inventories would entail high labor costs. Efforts should be made to automate the**

extraction and digitization of future micro-scale level morphological features.

3.b. Full list of properties and characteristics

Many more non-building morphology features were developed to complement the UTZs to describe fully all features within an urban domain. The non-building types are composed of seven generic types of vegetation, impervious surfaces, bare soil surface, water surface, and marshland. Each type is also described by its footprint in percent of a cell area, and its height in meters. Additional information about buildings not included in the UTZs are footprint (density), height in meters, orientation in 10's of degrees, pitch of roof (flat or pitched), and roof reflectivity (bright or dark). Special features such as bridges, statues, monuments etc. require additional entries as they occur within an urban domain. Table 2 lists all of the micro-scale morphology types and characteristics presently in use.

From the point of view and intended use of this morphology, some 20+ properties and characteristics have been developed to provide reasonable quantitative sets of information for a micro-scale high-resolution wind model.

Table 2. Physical attributes for urban and rural morphology categories.

Building type (using 17 Urban Terrain Zone categories noted in Table 1)
Building density (% of cover per cell, either 100m x 100m or 50m x 50m)
Building height, in meters (as 3m per story)
Building orientation (to the nearest 15 degrees)
Roof pitch (flat or pitched)
Roof reflectivity (bright or dark)
Impervious surface reflectivity (bright or dark)
Impervious surface (percent of ground covered within a cell)
Bare ground (percent of cover within a cell
Cropland (percent of cover within a cell)
Grassland (percent of cover within a cell)
Marsh (percent of cover within a cell)
Water (percent of cover within a cell)
Coniferous trees (percent of ground covered by tree canopy within a cell)
Coniferous trees, height in meters (to the nearest 5 meters)
Broadleaf evergreen trees (percent within a cell)
Broadleaf evergreen trees, height in meters (to the nearest 5 meters)
Broadleaf deciduous trees (percent within a cell)
Broadleaf deciduous trees, height in meters (to the nearest 5 meters)
Mixed trees (percent within a cell)
Mixed trees, height in meters (to the nearest 5 meters)
Shrubs (percent within a cell)

Shrubs, height in meters (generalized as two meters)
Special non-building features (such as desert vegetation/cactus, etc)

Note that properties, such as those listed below, have operational applications (pitched roof and building orientation) as well as higher order meteorological considerations (albedo, solar incident angles etc):

- Building orientation (to the nearest 15 degrees)
- Roof pitch (flat or pitched)
- Roof reflectivity (bright or dark)
- Impervious surface reflectivity (bright or dark)

4. HOUSTON AREA EXAMPLES

Two areas within the Houston urban domain were selected for digitization at the micro-scale resolution. One area is located about City Hall and the other area is centered on the University of Houston campus.

4.a. City Hall site

The image of the City Hall area, from Google Earth, is given in Figure 1.

250 meter square City Hall site. UTM coordinates (SW corner) 270900/3294400

Figure 1: The morphology of the City Hall area obtained from Google Earth with UTM coordinate grid markings.

Morphology feature types and their nominal heights are digitized in a method described by Ellefsen (1996, 2001a and b) and Cionco and Ellefsen (1998) and Ellefsen and Cionco (2002) and given below as the dominant feature within a 50m x 50m cell in Table 3. A great degree of non-uniformity of feature heights and types exists within the City Hall area.

City Hall morphology is characterized by just four features: broadleaf deciduous trees (03) with nominal heights of 6m to 9m, impervious surfaces such as streets, parking areas, and walking areas (10) with a given height of 1dm, water surfaces (10) with a zero height, and of course, buildings (21) with heights ranging from 12m to 180m.

Table 3. Digitized dominant feature morphology for 50m cells, City Hall area

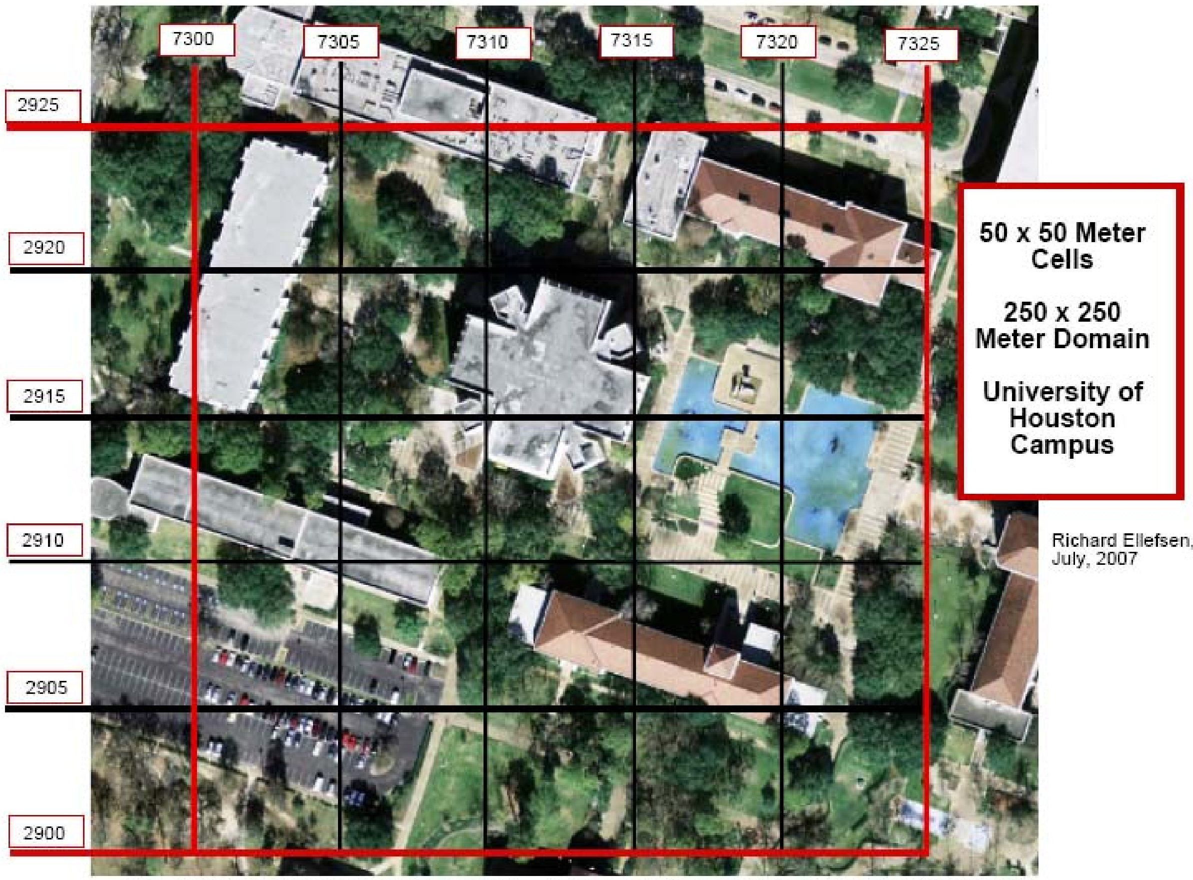
UTM COORDS	270900m	270950m	271000m	271050m	271100m
3294600m	6003	0110	0110	0110	18021
3294550m	45021	9003	6003	12021	12021
3294500m	0110	0010	9003	36021	36021
3294450m	9003	9003	180021	0110	0110
3294400m	12021	0110	180021	0110	0110

[Side bar: The data word and it parts are decoded as feature height in decimeters in the first part of the data word followed by morphology type as the last two digits. The locations of these features are preserved within the input data file based upon their UTM coordinates. The existing set of morphology types that micro-scale models can accommodate is composed of 10 non-building types (vegetation, soil, water and impervious surfaces etc) and a generic building type]

4.b. University of Houston site

The satellite image, from Google Earth, is given in Figure 2

Feature heights tend to vary less on the University campus than for City Hall area, but feature types are still non-uniform in coverage. The University of Houston campus-area morphology is characterized by five recordable features: broadleaf deciduous trees (03) with nominal heights of 6m to 9m, grass areas with 20cm heights, impervious surfaces such as streets, parking areas, and walking area (10) with a given height of 1dm, water surfaces (10) with a zero height, and buildings (21) with heights ranging from 6m to 9m.



250 meter University of Houston site. UTM coordinates (SW corner) 273000/3290000

Figure 2. The morphology of the University campus area is shown. Image source: Google Earth with superimposed UTM coordinates for 50 meter cells.

Table 4. Digitized dominant feature morphology for 50m cells, U of Houston area

UTM COORDS	273000m	273050m	273100m	273150m	273200m
3290200m	6021	9003	9003	9021	9021
3290150m	6021	9003	9021	0110	9003
3290100m	9003	9003	9021	0010	0010
3290050m	0110	0110	9021	9021	6003
3290000m	0110	0110	0207	6003	0207

5. ANALYSES

Using the remarkable Google Earth images and the morphology definitions and categories given above, examples of micro-scale dominant feature data sets for the City Hall and U of Houston areas were digitized for micro-scale applications. Color-coded maps are presented in Figures 3 and 4 to exhibit the variability of surface feature morphology that can be used as input data (in digital format) for micro-scale wind and diffusion models. Tables 3 and 4 are the digitized data used to prepare the figures that follow.

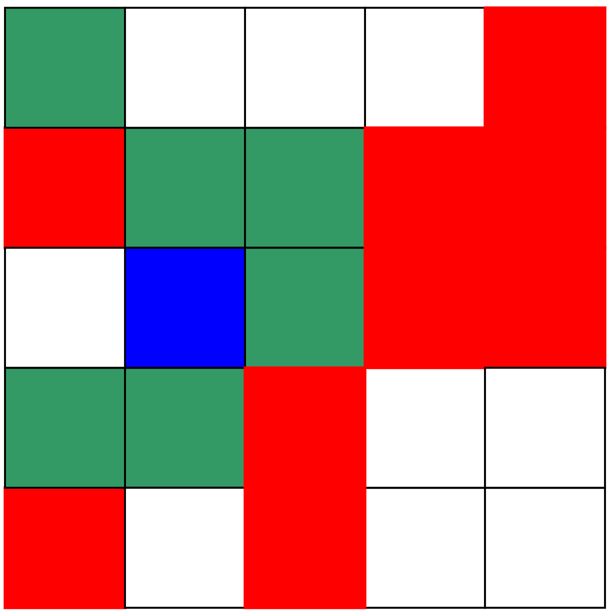


Figure 3. Map of dominant features within 50m x 50m cells for the City Hall area of 250m x 250m.

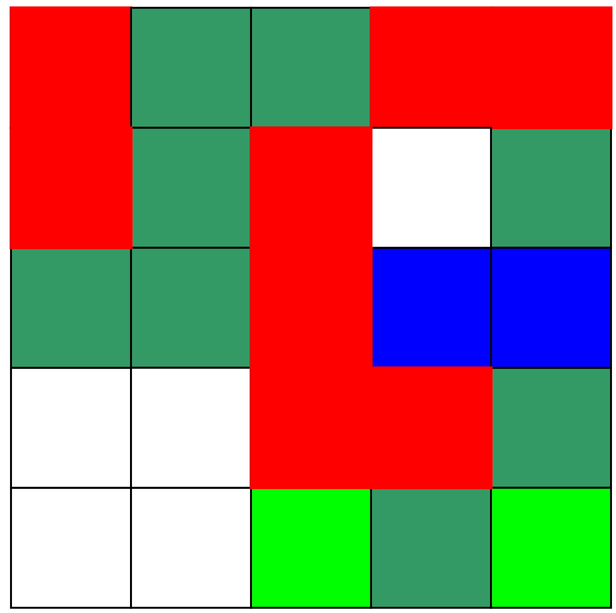


Figure 4. Map of dominant features within 50m x 50m cells for the U. of Houston area of 250m x 250m.

Color codes for the dominant morphology types in the above figures are: red for buildings, green for trees, light green for grass, blue for water surfaces and white for impervious surfaces. The relative footprints of each morphology type within the 250 meter squared areas of each map are:

	City Hall	U. of Houston
Buildings	36%	32%
Trees	24%	32%
Grass	0%	8%
Water sfc.	4%	8%
Impervious sfc.	36%	20%

The differences are easily explainable due to the planned land-use of each site.

Coupling the above information with the surface feature heights, a micro-scale wind models will generate a wind field of some complexity. And the resultant micro-scale wind field will be different than either a meso-scale or CFD model wind field due to the completeness and fine resolution of the micro-scale morphology lower boundary condition. In that the micro-scale wind field is not the subject of this paper, the reader can locate comparative wind fields in papers published in previous AMS Proceedings.

6. SUMMARY

The requirements for digitized surface feature morphology are unique to each scale of motion: meso-beta and gamma, micro-alpha and beta, and CFD micro-scale gamma. The intended use of these data also governs the completeness and precision of these input data. This discussion focused specifically on micro-alpha and beta scale interactions and resolutions. Clearly, the additional information provided on the micro-scale is important to the application for high resolution analyses.

Both the university campus example and the City Hall area have large areas covered by trees, grass, shrubs, and impervious walkways, as would be expected considering that both are planned land-uses where public buildings are intentionally given extensive landscaped areas. The Urban Terrain Zone (UTZ) classification for both is Do6 (Detached, widely spaced administrative/cultural buildings). The vegetation factor changes from lesser to more importance from one site to other.

There is a great degree of non-uniformity of feature heights and types within the City Hall area. Feature heights tend to vary less on the university campus, but feature types are still non-uniform in coverage. In terms of surface roughness alone, the heights of City Hall area features vary from 10cm to a nominal 180m, whereas the campus area has much smaller structures ranging from 10cm to 9m.

Although not shown, 250-meter cells just to the east of the City Hall site would provide measurements of very tall buildings, recorded by the 50 meter cells in which all or part of a building is located. Also, non built-upon areas, such as parking lots, would also be inventoried in their proper locations.

Each of the example areas for Houston exhibits a limited number of morphological features rather than the entire range listed in Tables 1 and 2. All classes might be encountered when an entire city is inventoried. Just as the remarkable images from Google Earth show us, our input data sets must also contain all of the existing surface features in a structural manner, that is to say, its morphology.
There are many potential users of this level of refined morphology data. Organizations and agencies that focus on micro-scale modeling and

analyses include US Department of Agriculture, US Forest Service (USDA), Urban Forest Centers, US Army small area field operations, city planners of new urban development, energy and nuclear facilities, HAZMAT responders, and more generally speaking, Homeland Security entities. Efforts should be made to automate the extraction and digitization methods described herein so that future micro-scale morphological data sets can be as readily available to modelers as are those data sets on the meso-scale and CFD scale.

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