Creating a Washington DC Urban Morphology for use in RAMS/TEB

Major Timothy E. Nobis, CIRA/Colorado State University
DoD Center for Geosciences/Atmospheric Research Annual Review, April 17-19, 2007, Fort Collins, CO

Introduction and Motivation

In military and civilian operations today, output from mesoscale weather models are critical input to a number of follow-on decision applications which are extremely sensitive to atmospheric boundary layer values. Examples include air quality and dispersion modeling systems (e.g. Pentagon Shield, Warner et al., 2007) and the Air Force's Target Acquisition Weapons Software (TAWS).

Mesoscale models are starting to incorporate urban boundary layer schemes to improve performance in urban areas; however, these models need urban morphologies to operate properly. This work reports on my effort to create an urban morphology as part of coupling a mesoscale weather model (the Regional Atmospheric Modeling System, RAMS) to an urban parameterization scheme (Town Energy Balance model, TEB; Masson 2000).

Background

- The TEB model combines a user provided morphology database, meteorological forcing from the parent model, and urban canyon geometry theory to calculate surface radiation and roughness effects in urban areas.
- TEB expects the 'morphology' variables listed in table 1.
- RAMS/TEB simulations were conducted over Washington DC for dates in 1984.
- No existing morphology for Washington DC from this time could be found.
- Creating a detailed morphology (instead of a simple city wide approximation) would allow testing of RAMS/TEB sensitivity to morphology details.

Avg Building Height	Thickness of each layer
Fraction Area of Bld vs. Roads	Thermal Conductivity of each Layer
Building Aspect Ratio	Heat Capacity of each Layer
Dynamic Roughness	Internal Building Temperature
Albedo's for Roads, Roofs, and Walls	Sensible Heat from Traffic and Industry
Emissivities for Roads, Roofs, and Walls	Latent Heat from Traffic and Industry
# of Layers for Roads, Roofs, and Walls	

Table 1: Morphology (or non-meteorological) values required for the TEB urban parameterization scheme. Values in red are those derived as part of this morphology exercise, and thus were different for each grid cell. The remaining ones were estimated from literature and did not vary by grid cell

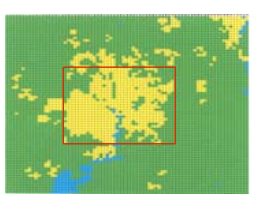

Figure 1: Standard RAMS 1km Landuse data plotted for 75km area around Washington DC. Green is vegetation, blue is water, yellow is urban. The red square indicates the 36X34km area selected for the urban morphology database. In all 1224 1km grid cells were databased.

Methodology: Creating the Morphology

The Washington DC morphology was calculated over a 36X34km area (Fig 1.) at a resolution of1km. To construct the morphology, three primary resources were used: A series of USGS 1:24,000 maps, a series of high altitude photographs, and the book "Above Washington" (Cameron, 2000). The data in each of these references dated mostly from 1978-1984 giving a morphology that matched well with the dates of the RAMS/TEB Simulations.

Basic Process: Fig 2 shows a nominal example of the process used. The USGS maps had a 1km grid on them that formed the grid cell layout. An overlay of 16 smaller grids was placed over each 1km square in both the USGS map and high altitude photo. Land use (including both morphology and vegetation) was then estimated for each 1/16th and entered into a spreadsheet for aggregation. Cameron's book was used to provide finer detail where available.

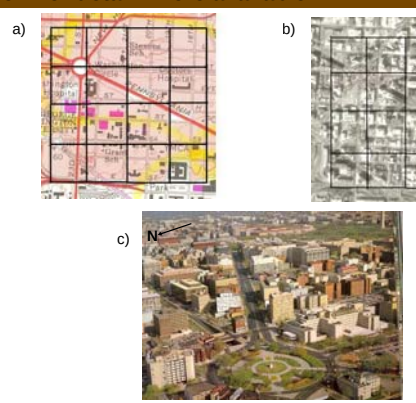

Figure 2: Examples of a) USGS map, b) High Altitude Photo, and c) Photo from "Above Washington" (note north orientation) for one 1km grid cell. In this example, 14/16ths were identified as 'downtown' with avg height of 21m (7-stories), 70% roofs/30% roads, aspect ratio of 1, and roughness of 2.1m (h/10). The remaining 2/16ths were categorized as vegetation, 70% grass, 30 % trees.

Derived Parameters: In addition to morphology elements that could be estimated directly from photos, several were derived. Albedo and emissivity were varied by estimating the relative ratio of light to dark roofs and assigning a weighted value. A similar technique was used for roads by estimating the relative ratio of asphalt vs concrete. Finally, anthropogenic terms were varied by total road area and approx density of buildings. (Details for these parameters will appear in my Dissertation.)

Residential Areas: The vast majority of the DC area consists of residential neighborhoods. A review of the photographs suggested that all of these areas could be categorized into four basic types each with it's own set of characteristics, greatly easing the burden of dealing with these areas. Fig 3 shows examples of each and table 2 details the characteristics.

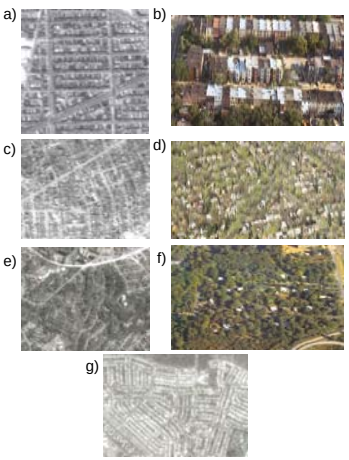

Figure 3: Photos of the four different residential neighborhoods: a) & b) 'Gridded-10', c) & d) 'Gridded-7', e) & f) 'Sub-Urban Mature' and g) 'Sub-Urban' (no color picture). Table 2 has the details.

Name	Description	Bld Height (m)	aspect ratio	Fractional area of roofs vs. roads	% Veg	% Trees	% Grass
Gridded-10	Oldest residential areas. Row houses generally 3 or 4 stories with flat roofs, Houses are densely packed with little vegetation and narrow streets	10	0.75	0.6	20%	60%	40%
Gridded-7	First sub-urban areas. Mature neighborhoods with lots of trees. Houses are generally 1-2 stories with pitched roofs. Steets are generally gridded, houses have small yards.	7	0.5	0.5	30%	50%	50%
Sub-Urban Mature	Next major wave of sub-urban building. 1-2 stories situated on larger lots with winding and wider streets. Area is old enough to have mature tree growth	7	0.3	0.4	40%	50%	50%
Sub-Urban	Newest neighborhoods, similar in structure to 'Sub-Urban Mature', but without the mature tree growth.	7	0.3	0.4	40%	15%	85%

Table 2: Description and Characteristics of the four residential categories.

Results

The aggregated result is a 1km resolution morphology database. 3 of the 1224 grid cells are shown as an example:

Lat	Long	bld h	h/l	zo	aroof	aroad	awall	eroof	eroad	ewall	Traffic SH	Traffic LE	Industry SH	Industry LE	water	vegetation
38.7916	-77.0782	.44 7.4	.31	.74	.18	.13	.25	.90	.95	.90	3.1	0.0	10.0	5.0	.000	.6
38.7918	-77.0666	.32 24.9	.30	2.49	.18	.12	.25	.90	.95	.90	3.9	0.0	10.0	5.0	.063	.556
38.7921	-77.0551	.35 10.7	.63	1.07	.15	.15	.25	.88	.94	.90	13.4	0.0	10.0	5.0	.188	.56

This database allowed me to vary the morphology in my simulations from grid-point to grid-point and conduct sensitivity experiments to address the question of the need for detailed morphology databases in mesoscale model simulations. My results suggests that a detailed morphology did not have a significant impact on Urban Heat Island simulations at grid-increments of 5km (a typical value in today's operational models). Therefore, a city wide, non-varying estimate may suffice at these resolutions.

References

Cameron, R., 2002: Above Washington. Cameron and Company, San Francisco, 159pp.

Masson, V., 2000: A Physically-Based Scheme for the Urban Energy Budget in Atmospheric Models. *Boundary-Layer Meteor.*, **94**: 357-397.

Warner, T., et al., 2007: The Pentagon Shield Field Program *Bull. Amer. Met. Soc.*, **88**: 167-176.