Assessing Summertime Urban Energy Consumption in a Semiarid Environment: WRF(BEP+BEM)

F. Salamanca¹, M. Georgescu¹,², A. Mahalov¹, M. Moustaoui¹, M. Wang¹, and B. M. Svoma²

¹School of Mathematical and Statistical Sciences, Global Institute of Sustainability
²School of Geographical Sciences and Urban Planning

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• Introduction
Introduction

• *Why is important to assess Urban Energy Consumption?*

- Evaluation of energy demand is necessary in light of global projections of urban expansion.

- Of particular concern are rapidly expanding urban areas in warm environments where AC energy demands are significant.
Introduction

• How can we estimate Urban Energy Consumption?

Observations: Total load values from power company

Meteorology (cooling/heating consumption)

Human behavior consumption
Introduction

• How can we estimate Urban Energy Consumption?

✓ Cooling/Heating energy requirements can be predicted with the WRF model in conjunction with building energy parameterizations.
Introduction

• *How can we estimate Urban Energy Consumption?*

Observations:
- Total load values from power company
- Human behavior consumption
- Meteorology (cooling/heating consumption)

WRF (BEP+BEM) simulations
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• Application area
Application Area

- We focus on the rapidly expanding Phoenix Metropolitan Area (PMA).
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The expanding built environment is expected to raise summertime temperatures considerably.
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- The expanding built environment is expected to raise summertime temperatures considerably.
- Air Conditioning cooling requirements are excessive in summer.
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• Simulations
The WRF (V3.4.1) simulations were performed with four two-way nested domains with a grid spacing of 27, 9, 3, and 1 km respectively. The number of vertical sigma pressure levels was 40 (14 levels in the lowest 1.5 km).

The simulations were conducted with the NCEP Final Analyses data (number ds083.2) covering a 10-day EWD period from 00 LT July 10 to 23 LT July 19, 2009.

The US Geological Survey 30m 2006 National Land Cover Data set was used to represent modern-day LULC within the Noah-LSM for the urban domain. Three different urban classes describes the morphology of the city: COI, HIR and LIR.

The building energy parameterization (BEP+BEM) was applied to the fraction of grid cells with built cover.
Simulations

2m-Air Temperature (°C)

Urban Stations
$RMSE = 1.698 \, ^0C$
$MAE = 1.343 \, ^0C$

Rural Stations
$RMSE = 1.700 \, ^0C$
$MAE = 1.305 \, ^0C$
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• Splitting the Energy Consumption
Splitting the Energy Consumption

- Observed total load values obtained from an electric utility company were split into two parts, one linked to meteorology (AC consumption), and another to human behavior consumption (HBC).
- To estimate the HBC two approaches were considered for March and November based on the assumption that heating/cooling energy consumption for these months was small (ensemble of minimum consumption days denoted as M1, M2, N1, and N2).
Splitting the Energy Consumption

- Observed total load values obtained from an electric utility company were split into two parts, one linked to meteorology (AC consumption), and another to human behavior consumption (HBC).

- To estimate the HBC, two approaches were considered for March and November based on the assumption that heating/cooling energy consumption for these months was small (ensemble of minimum consumption days denoted as M1, M2, N1, and N2).
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• Results
During evening hours the 65% of the total electric consumption is due to the use of the AC systems. AC systems accounted for $\sim 53\%$ averaged across the diurnal cycle.

The time scale of the hourly loads was normalized to minimize monthly variation.
Parking structures, home garages, etc are represented as air conditioned buildings when these spaces are not really cooled.

Assuming 65% of indoor volume is cooled for the PMA, WRF(BEP+BEM)-simulated results are in excellent agreement with observational data.
Non-dimensional AC consumption profiles

Diurnal evolution of observed and simulated AC consumption as a fraction of total AC consumption.

The general shape of model-simulated non-dimensional AC consumption profiles was apparent for different Extreme Heat Events in July.
2D-Diurnal Mean AC Electric Consumption

10-day EWD period in July 2009 (LT 01)

AC energy consumption (MW)
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• Conclusions
Conclusions

- The hourly ratio of AC to total electric consumption accounted for 53% of diurnally averaged total electric demand, ranging from 35% during early morning to 65% during evening hours.

- WRF(BEP+BEM)-simulated non-dimensional AC consumption profiles compared favorably to diurnal observations in terms of both amplitude and timing.

- Assuming 65% of indoor volume is cooled for the PMA, WRF(BEP+BEM)-simulated results are in excellent agreement with observational data.

- The presented methodology establishes a new energy consumption-modeling framework that can be applied to any urban environment where the use of the AC systems is prevalent across the entire metropolitan area.
Simulations

2m-Air Temperature (°C)

10-day EWD period in July 2009 (LT 15)

Daytime Urban Cooling

10-day EWD period in July 2009 (LT 23)

Nighttime Urban Heat Island
Simulations

10m-Wind Speed (m/s) 10m-Wind Direction (°)

Urban Stations

a) Urban Stations

b) Rural Stations

Time series from July 10 LT (00:00) to July 19 LT (23:00)

Observed
Simulated
Splitting the Energy Consumption

- For the first method we select the day with the minimum total load (EC1) and the day with the minimum hourly load range (EC2) (methods N1 and M1):

\[ HBC_i = \frac{EC1_i + EC2_i}{2} \text{ for all } i = 1, \ldots, 24 \]

- For the second method, the minimum hourly load was selected for each hour of the day considering the entire month (methods N2 and M2):

\[ HBC_i = \min_j(EC_{ij}) \text{ for all } i = 1, \ldots, 24; \]
\[ j = 1, \ldots, 30 \text{ (November), } 31 \text{ (March)} \]