Improved Treatment of Boundary Layers in Urban Areas for Air Quality Modeling.

Jonathan Pleim and Robert Gilliam
USEPA
Motivation

• Urban/suburban areas are generally warmer and more turbulent than surroundings
• Less stable boundary layers at night and during morning and evening transitions mix surface emissions more quickly
• Rate of morning PBL growth and entrainment from residual layers are critical for photochemistry in urban areas
• Effects of built environments disproportionately important for AQ because of high emissions in these areas
Problem

- Without realistic treatment of UHI:
  - PBL too stable during morning and evening transitions and overnight
  - Overprediction of ground emitted primary species (e.g. CO, NOx, Primary PM)

July 2006 – CMAQ 12 km CO
4 km modeling for Houston – August 2006

CMAQ v4.7 and 5.0 overpredict CO especially during morning and evening rush hours

WRF Potential temperature (blue) in Houston at 7 PM shows premature surface inversion
Potential Solutions

• Meteorological models and parameterizations for urban areas vary greatly in complexity and data requirements.
• Currently WRF has several urban parameterizations: Bulk, single-layer, and multi-level BEP-BEM NUDAPT all tied to the NOAH LSM
• Need for a simple scheme considers the effects of development at the local (1-4 km) and regional (12 km) grid scales that works with the PX LSM that we use for WRF-CMAQ.
A New Bulk Approach for PX LSM

- Leverage very high resolution National Land Cover Database (NLCD) with multi-level urban classifications
  - PX LSM considers subgrid LU fractions
- Utilize NLCD-based Impervious surface data directly in land-surface model to scale surface heat capacity
- Increase surface roughness for urban LU classes to better represent developed areas
- Decrease albedo in urbanized areas to account for sky-view and radiation trapping effects
- Reduce deep soil temperature nudging strength
Impervious Fraction (%) for 12 km Grid
Impervious Fraction (%) for 4km Grid
Impervious Fraction (%) for 1 km Grid

Shopping malls in Sugarland
Skin Temperature on Aug 24,2006 at 10Z

Base – NLCD 2006

Impervious 2
Evaluation Using Tethersonde Profiles

*Tethersondes were launched on selected evening and nights in September through November at U of Houston*

Profiles from 2 model runs:

**NoImp** --- no impervious, NLCD 2006

**Imp2** -- Impervious, increased roughness, decreased albedo and weaker deep soil temp nudging

*Tethersonde data* provided by Bernhard Rappenglueck (UH)
September 7, 23LT (4Z)
September 7, Midnight LT (5Z)
September 8, 2LT (7Z)

Graph showing the following data:

- **wrf_9-8_noimpout**
  - Theta-noimp
  - Theta-imp2
  - Tethersonde

Graph showing the following data:

- **wrf_9-8_noimpout**
  - WS-noimp
  - WS-imp2
  - Tethersonde

**Office of Research and Development**
Atmospheric Modeling & Analysis Division, National Exposure Research Laboratory
September 8, 3LT (8Z)
September 8, 4LT (9Z)
September 8, 6LT (11Z)

wrf_9-8_noimpout

wrf_9-8_noimpout
September 8, 8LT (13Z)
Effects of urban scheme on AQ modeling

Average CO over AQS sites in Houston for 5 days

These preliminary experiments show modest reduction of CO overprediction
Conclusions

• New bulk urban scheme for the PX-LSM shows much improved PBL structure in evening, overnight, and morning compared to Houston tethersonde measurements

• Designed to take advantage of hi-resolution NLCD LU data and impervious surface area.

• The capability of the PX LSM to include subgrid LU fractions and any amount of impervious surface allows effects of development in all areas

• This is particularly important for AQ modeling since emissions occur mostly from highways, residential, and urban areas
Next steps

• Add anthropogenic heating based on population and housing unit density
• Add NLCD canopy fraction data for accurate accounting of tree cover in all areas including urban.
• Comprehensive evaluation of meteorology and AQ at all scales