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

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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 photochemisty in urban areas
- Effects of built environments disproportionately important for AQ because of high emissions in these areas

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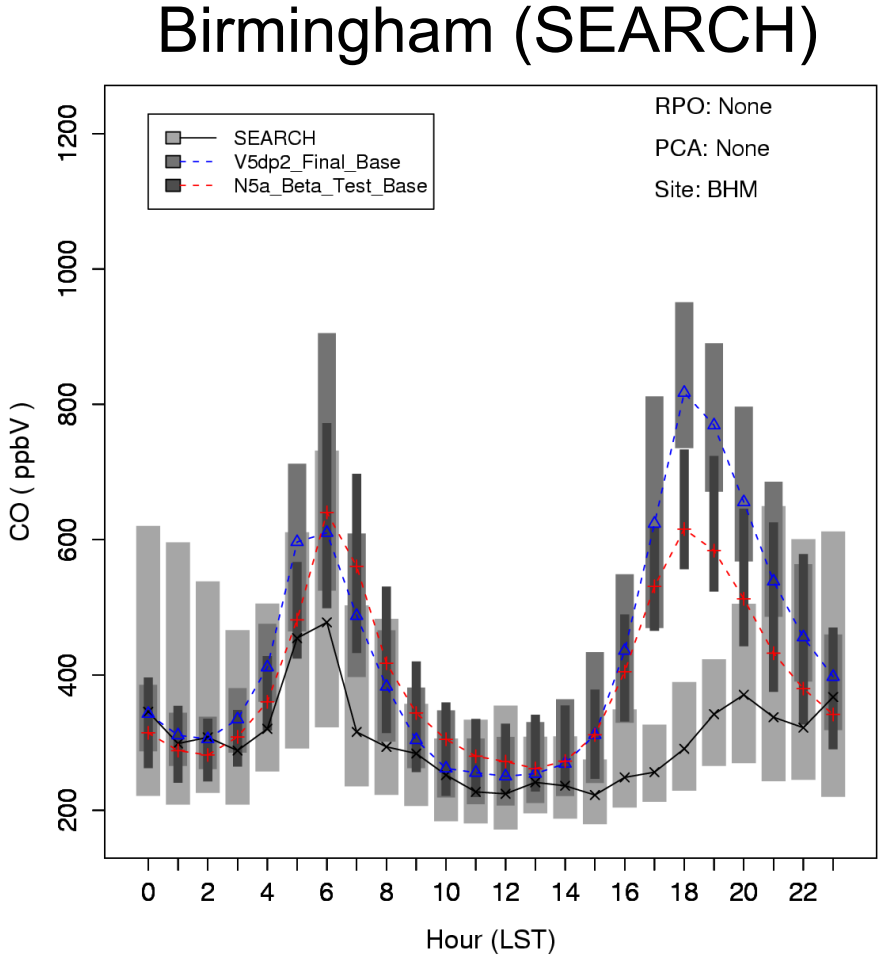
Problem

- 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

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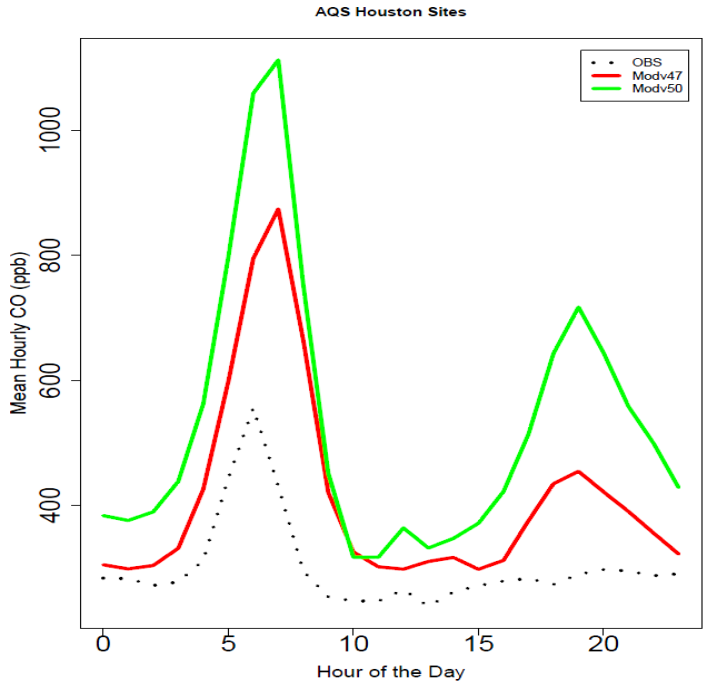
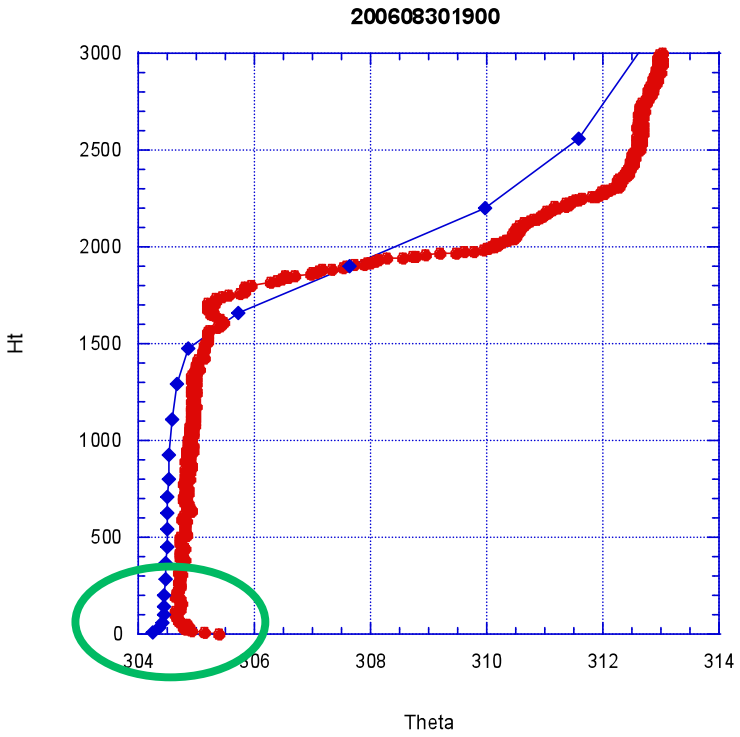
4 km modeling for Houston – August 2006



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

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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.

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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

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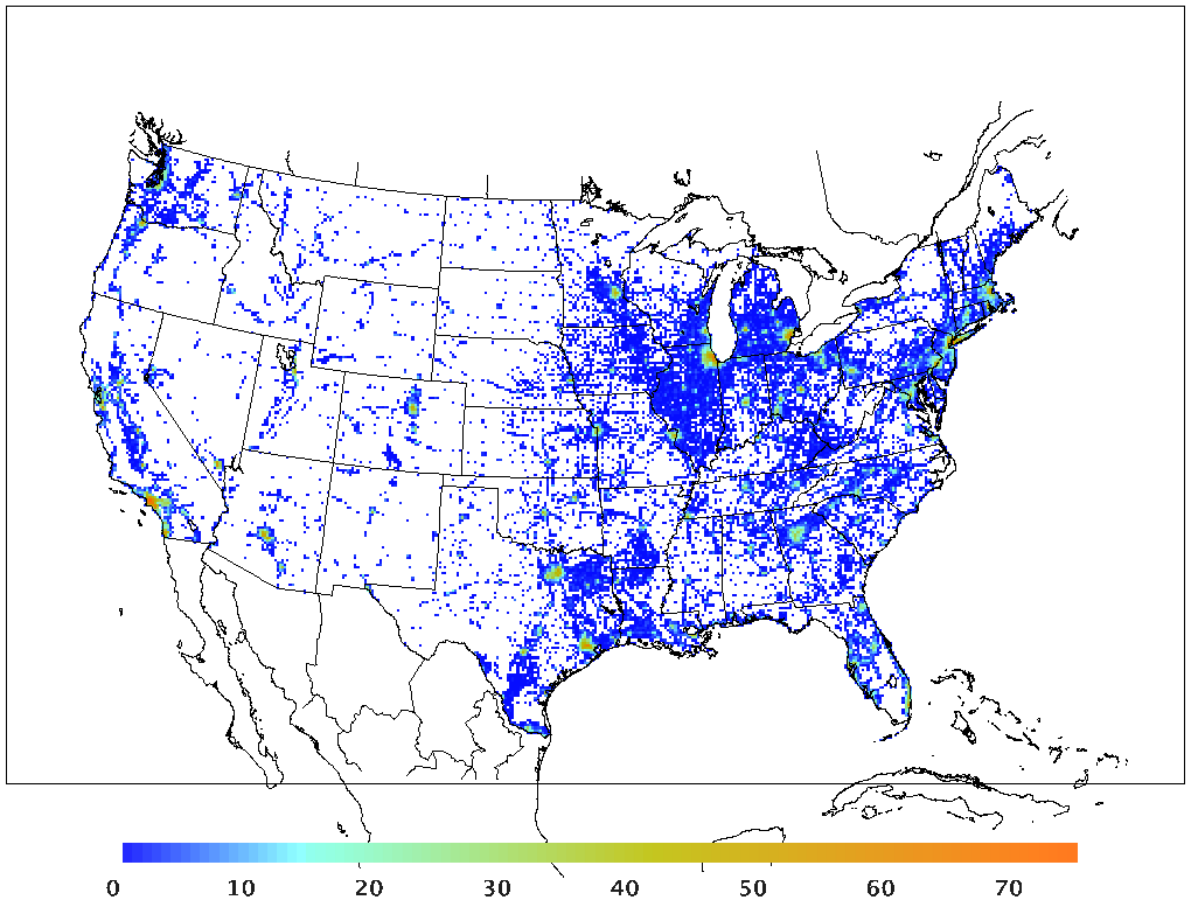
Impervious Fraction (%) for 12 km Grid



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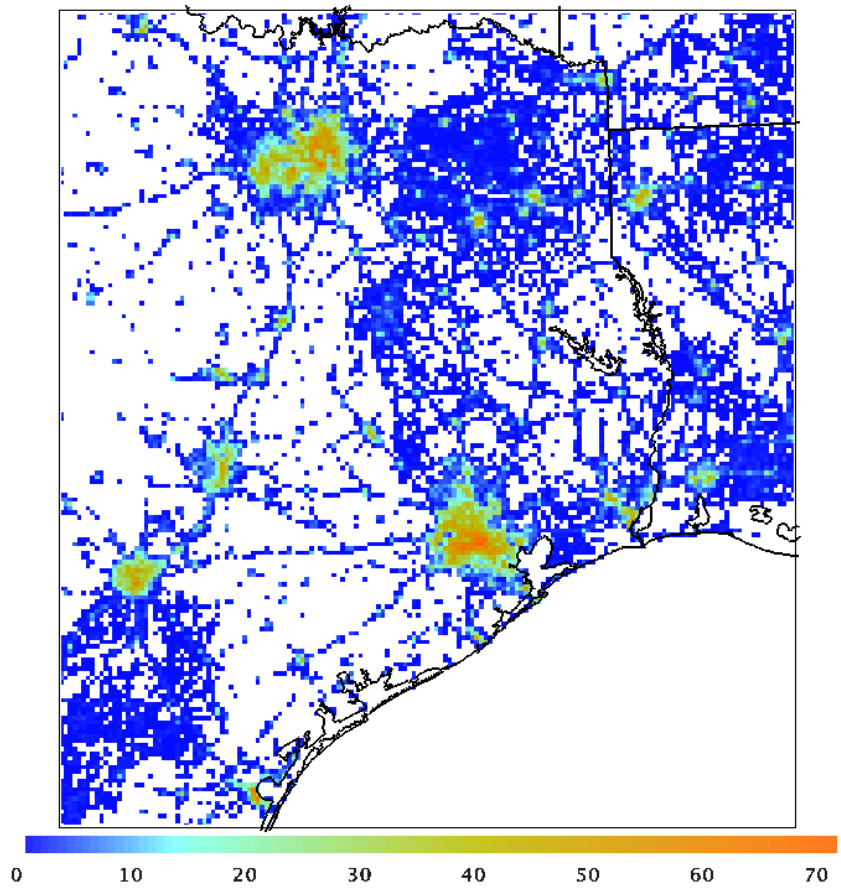
Impervious Fraction (%) for 4km Grid



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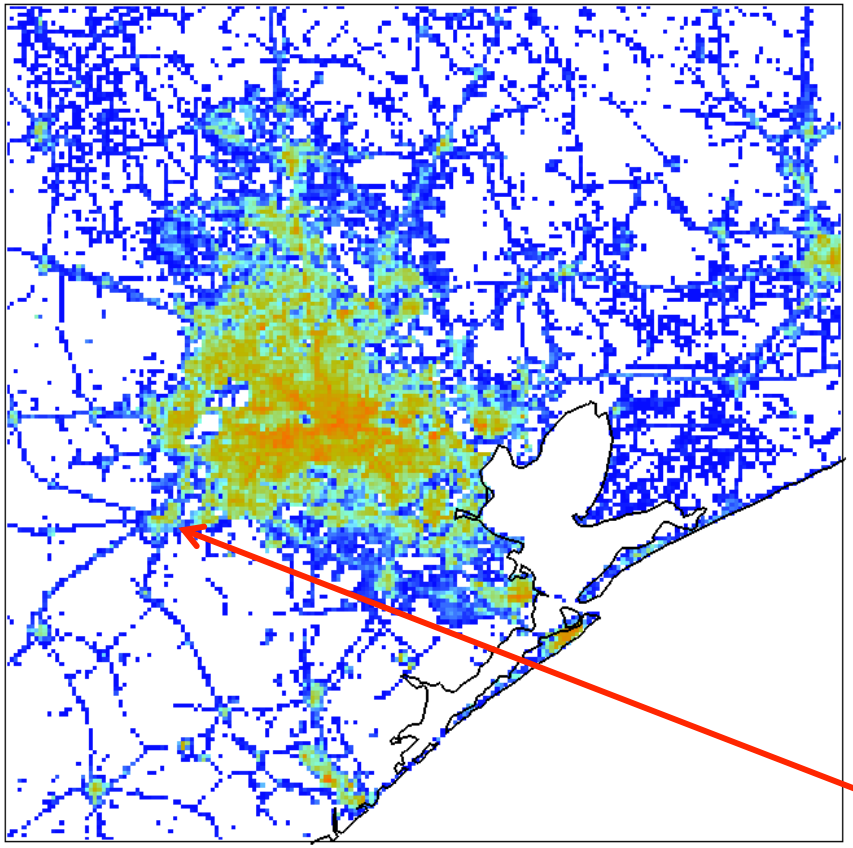
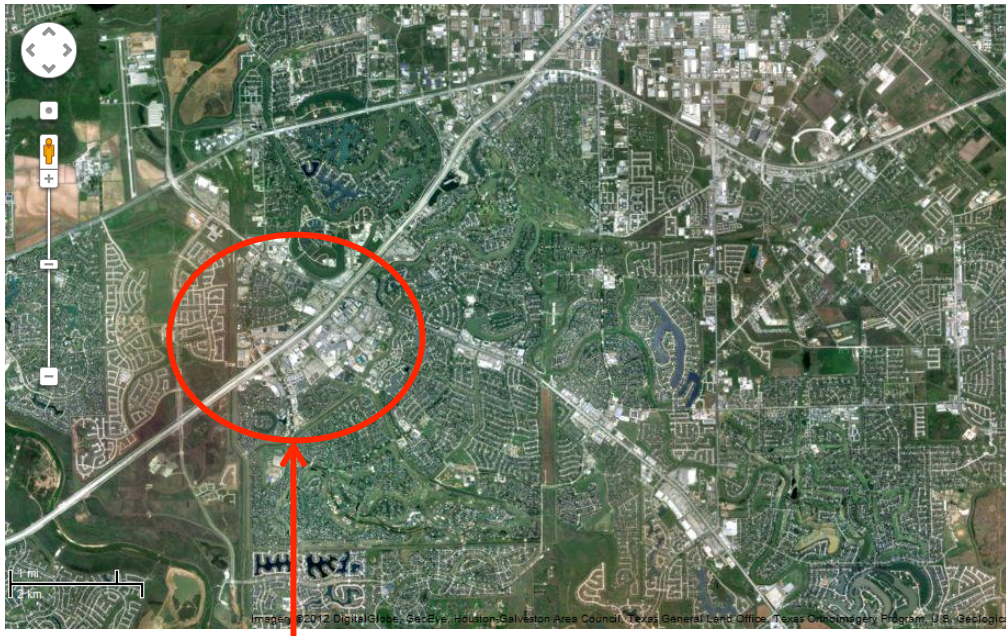
Impervious Fraction (%) for 1 km Grid





Shopping malls in Sugarland

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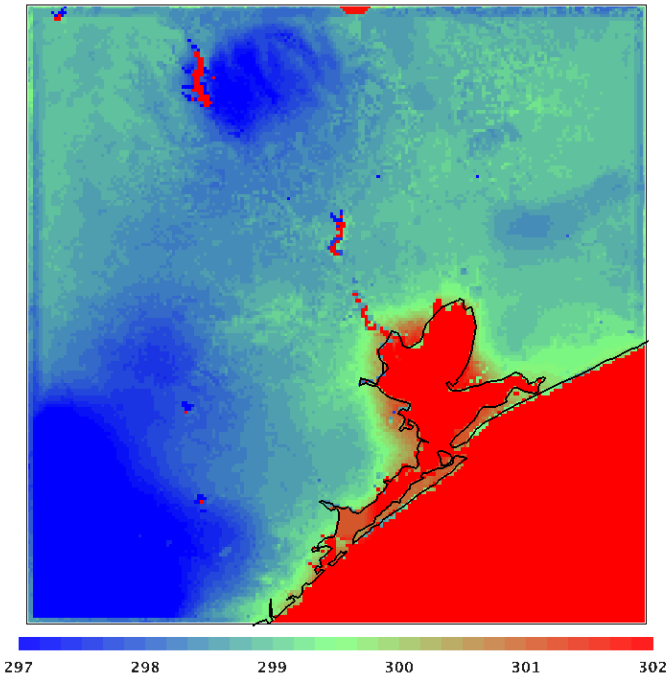
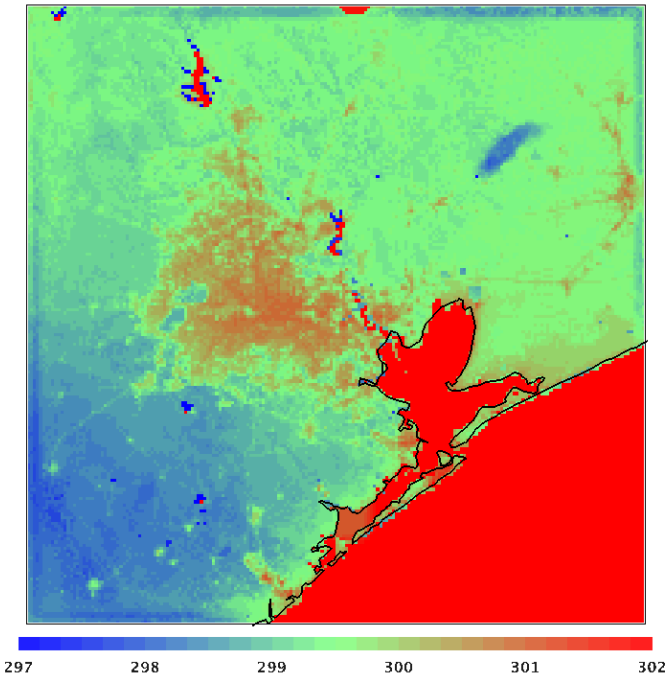
Skin Temperature on Aug 24,2006 at 10Z

Base – NLCD 2006



Impervious 2



Evaluation Using Tethersonde Profiles

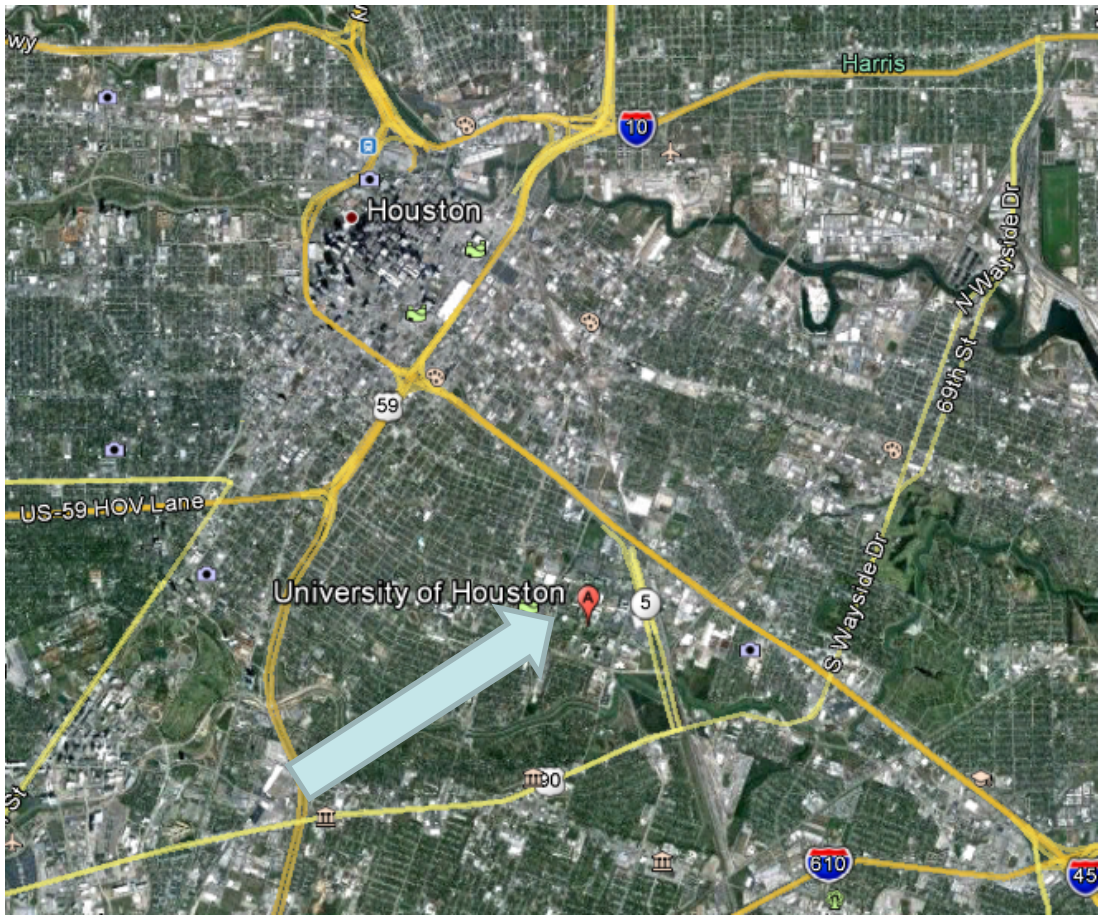
Tethersondes were launched on selected evening and nights in September through November at U of Houston

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)



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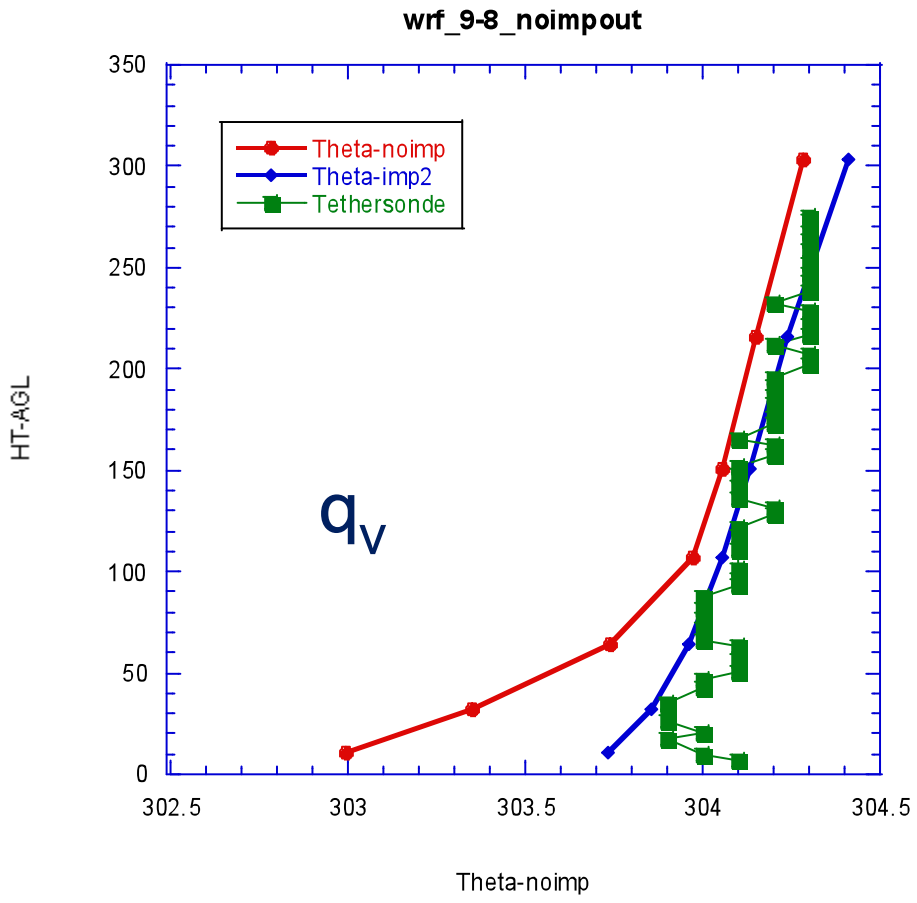
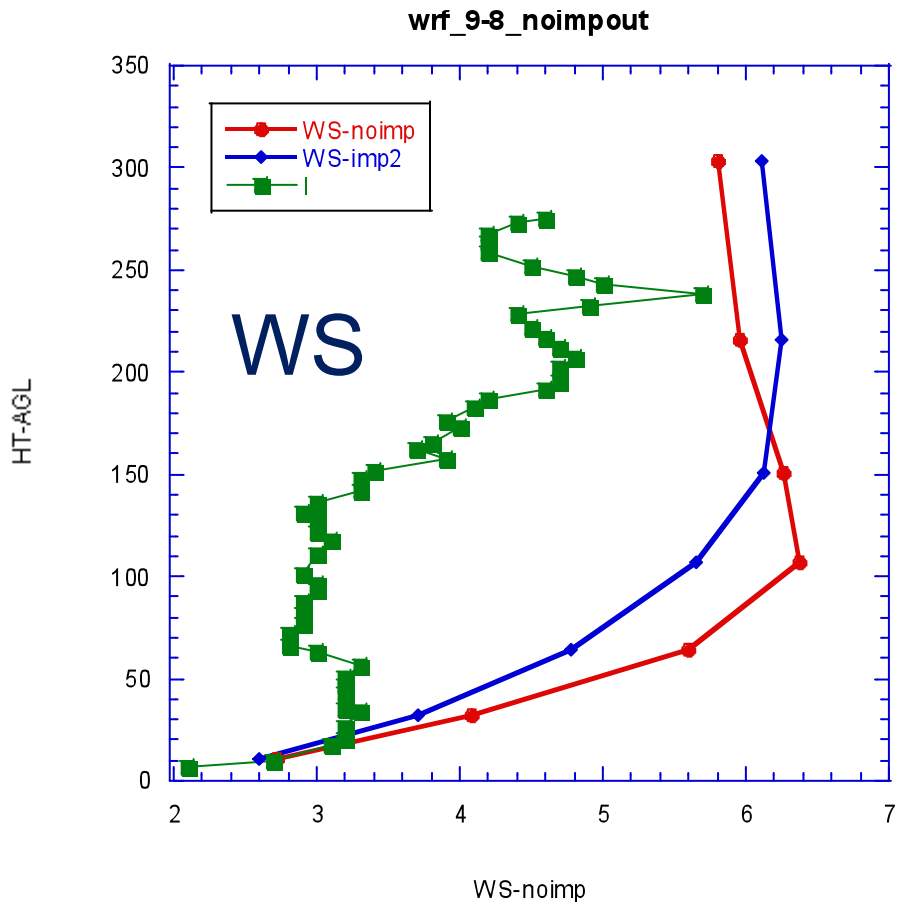
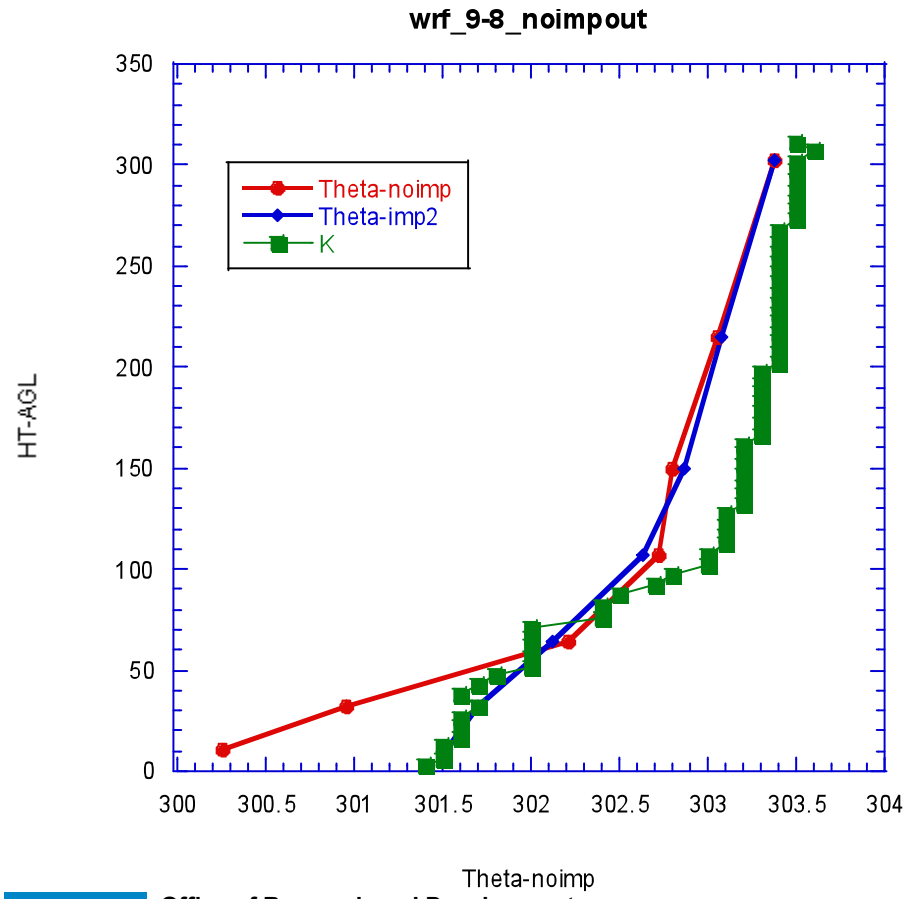
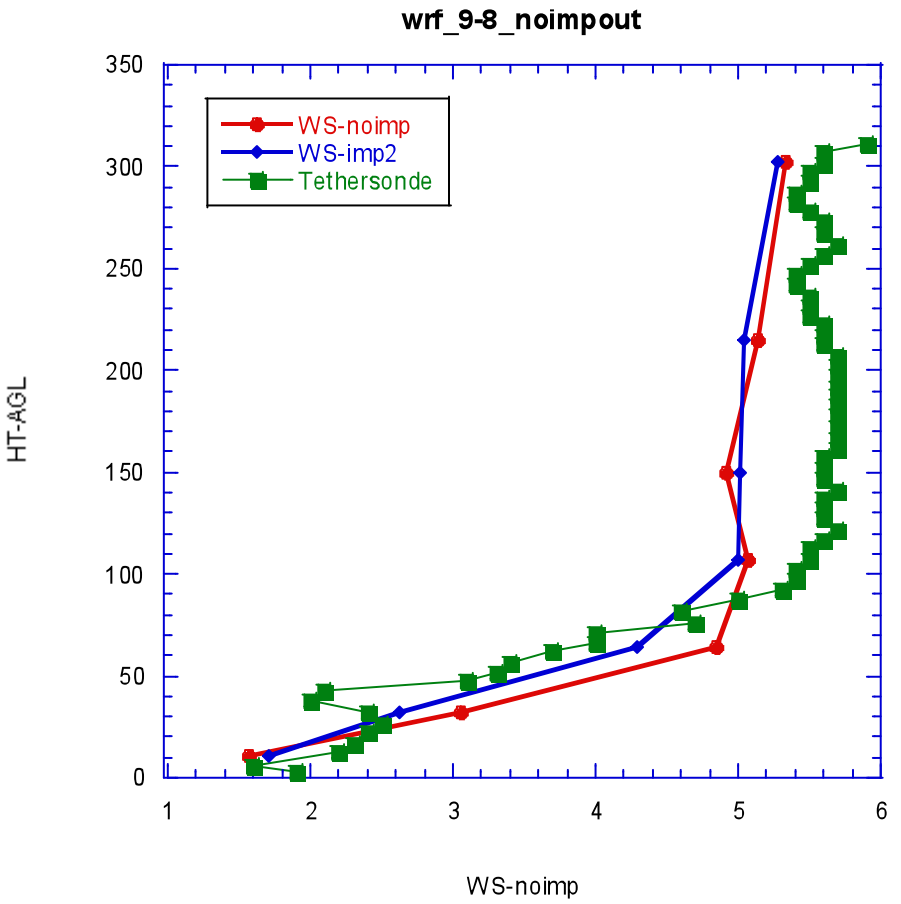
September 7, 20 LT (1Z)





September 7, 23LT (4Z)





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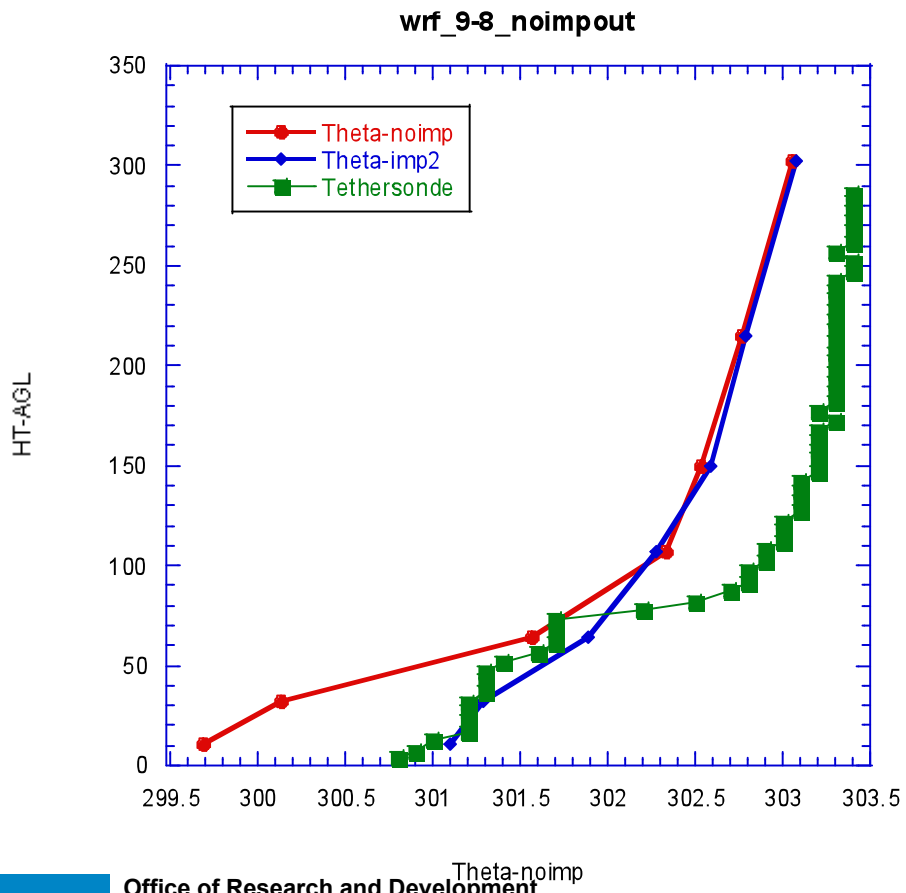
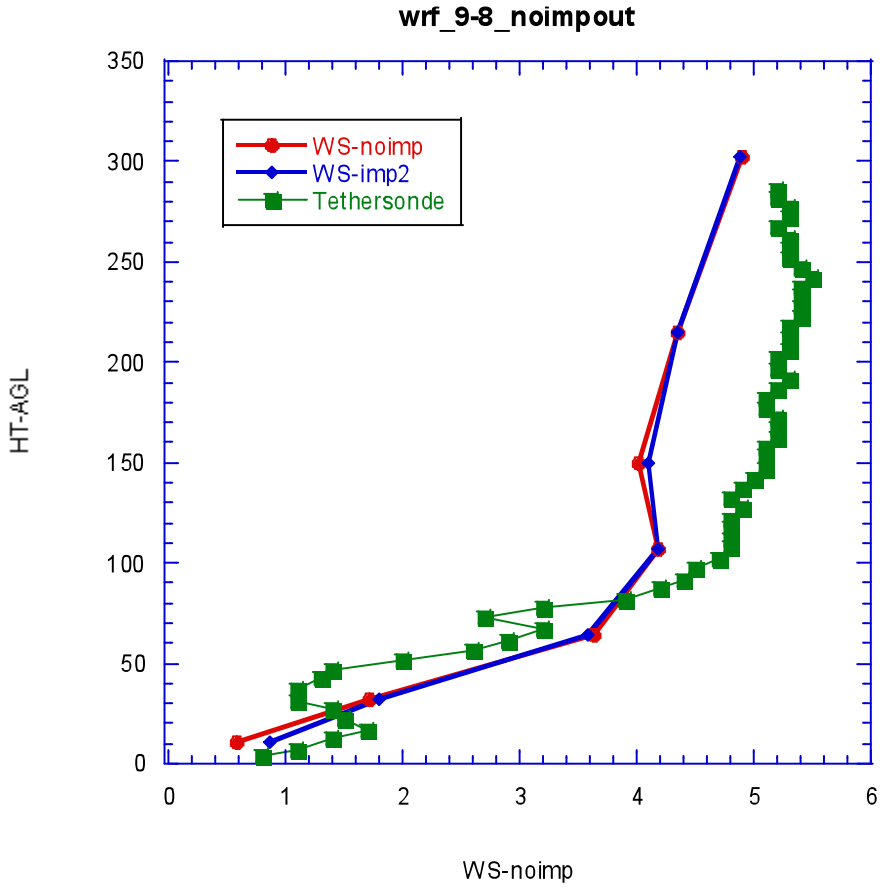
September 7, Midnight LT (5Z)





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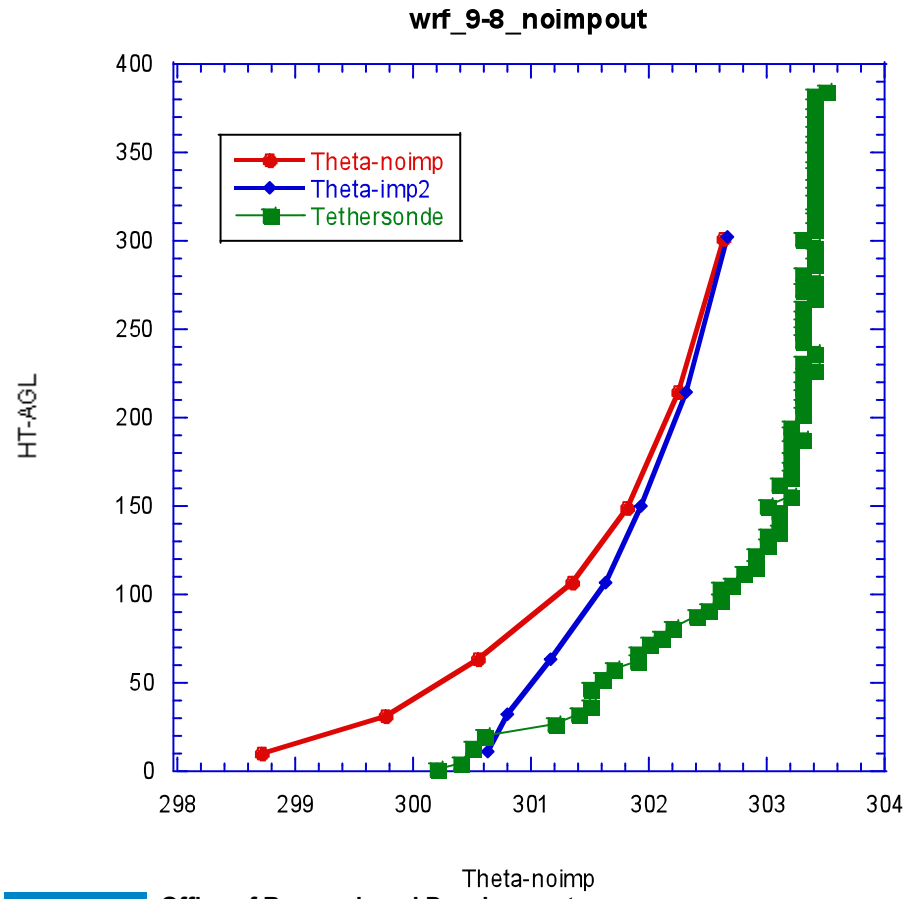
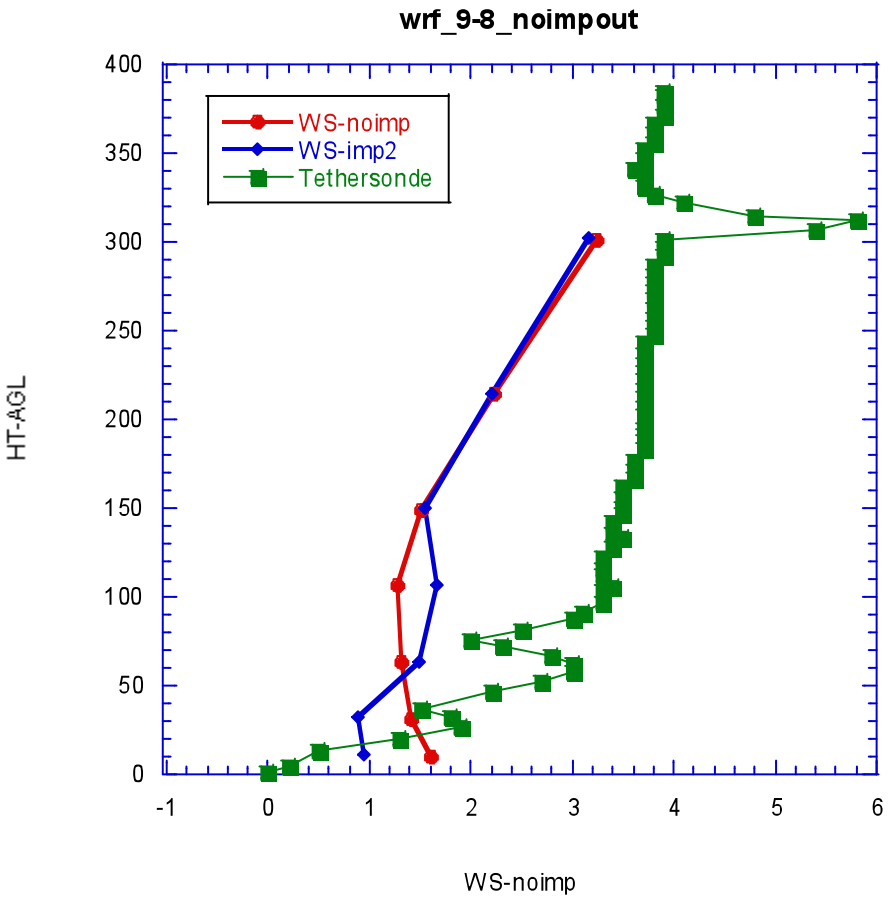
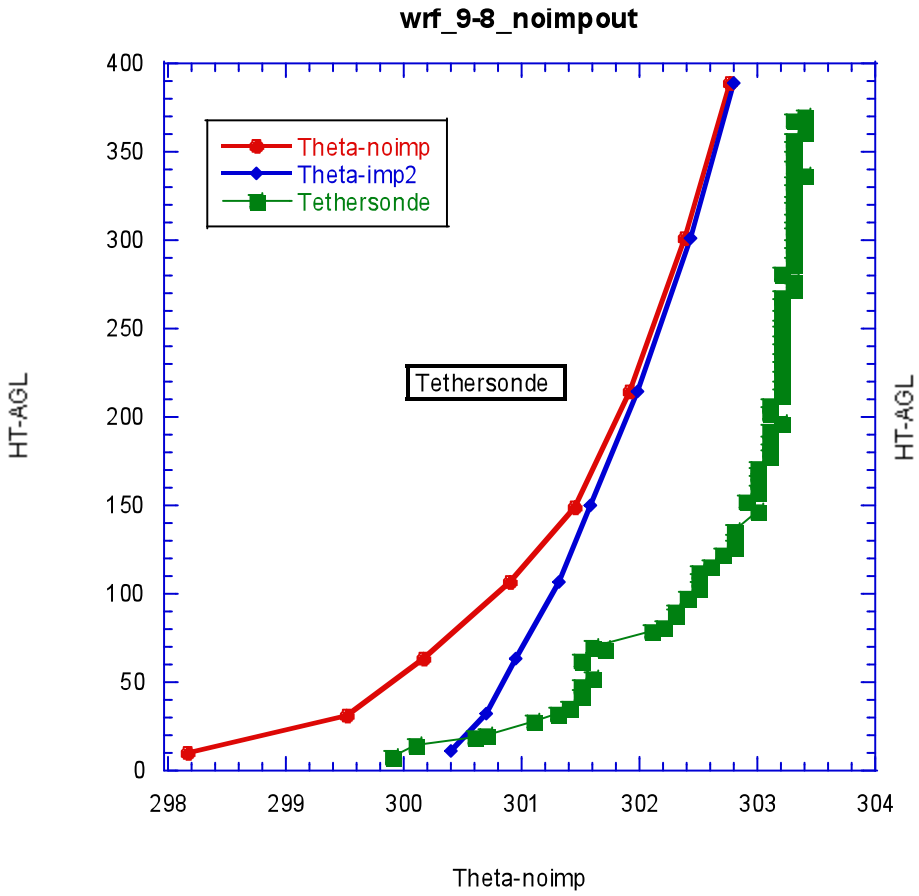
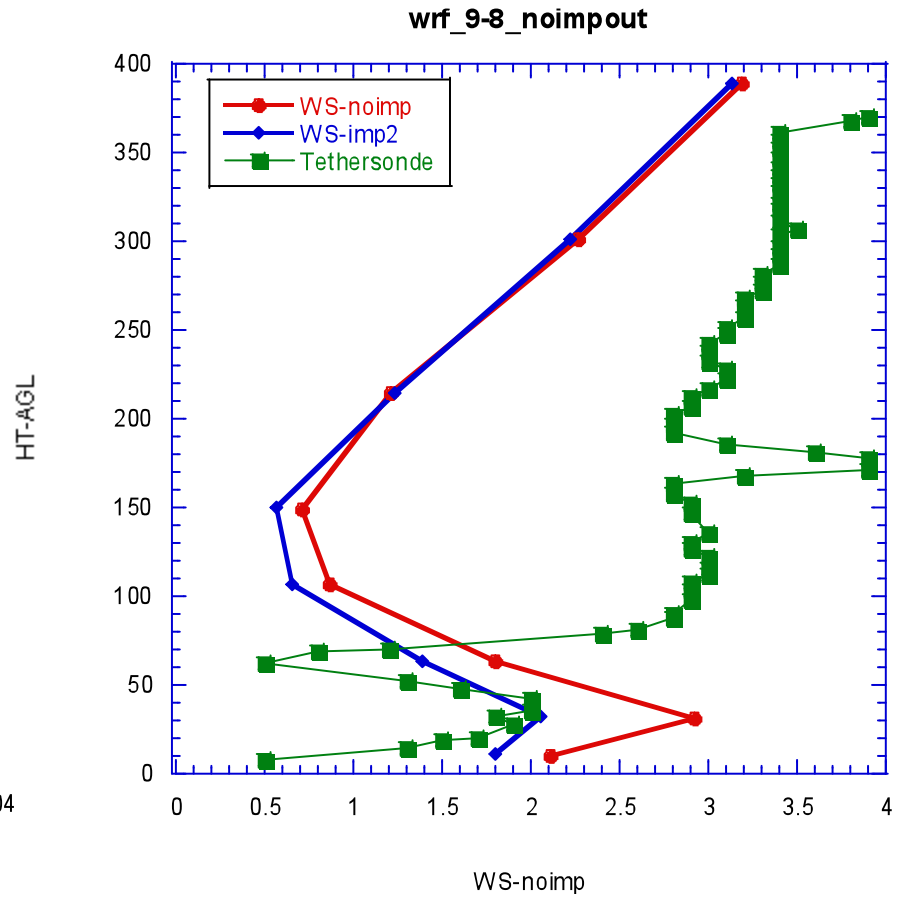
September 8, 2LT (7Z)



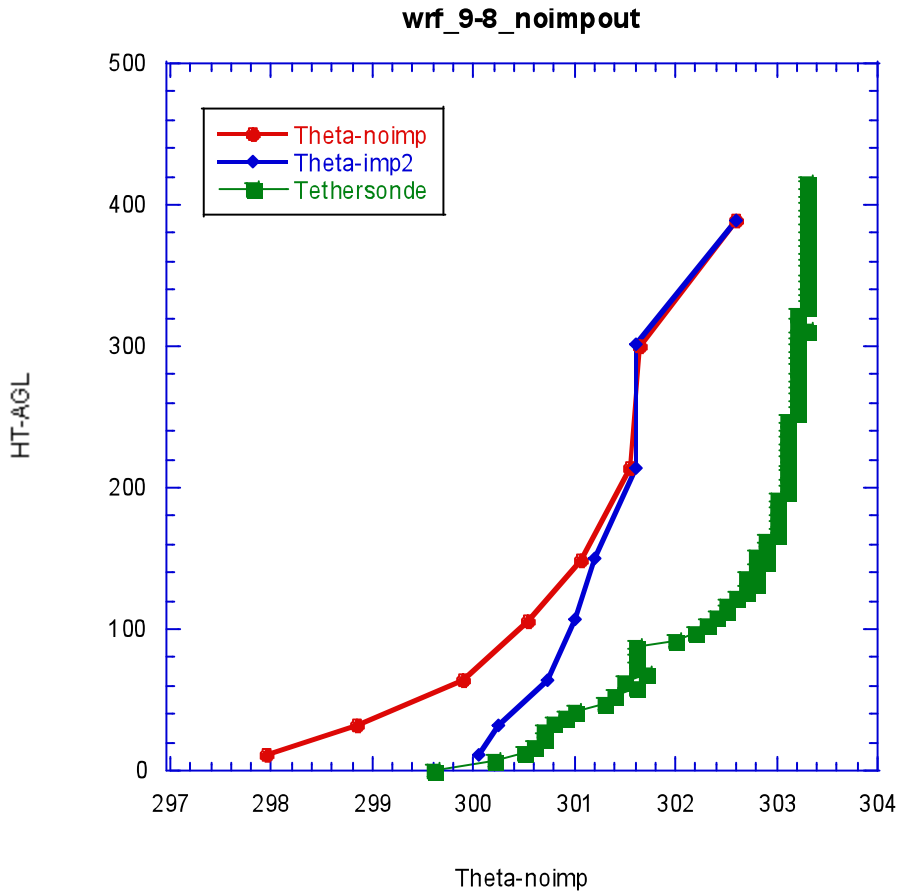


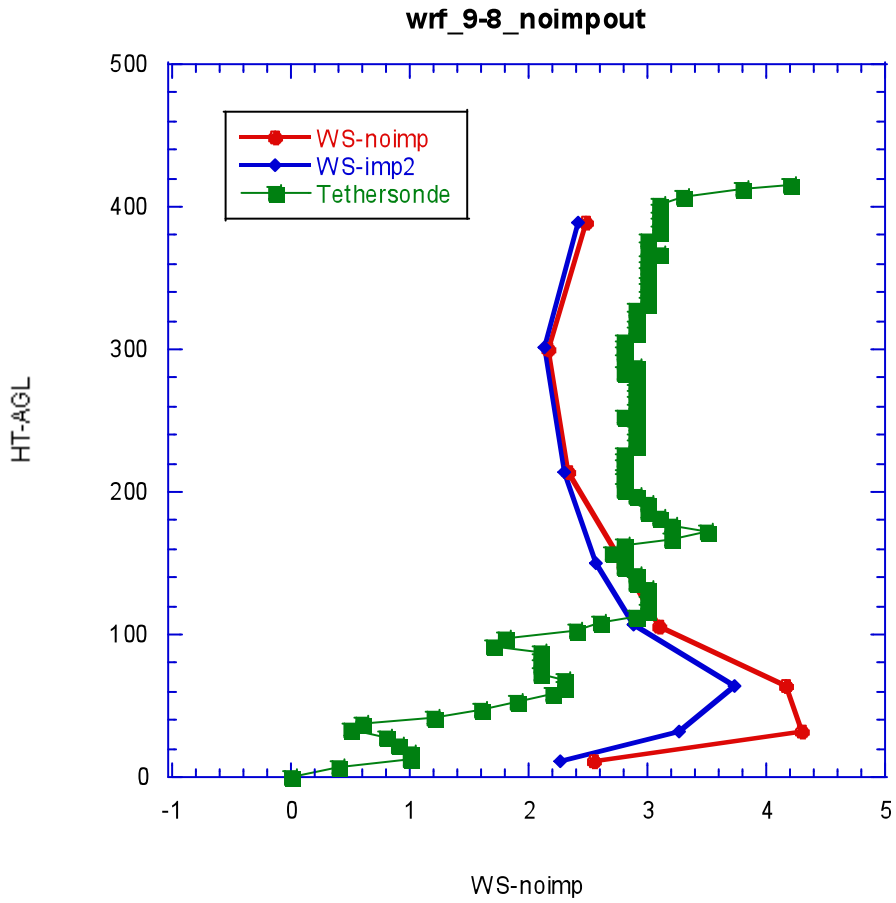
September 8, 3LT (8Z)





September 8, 4LT (9Z)





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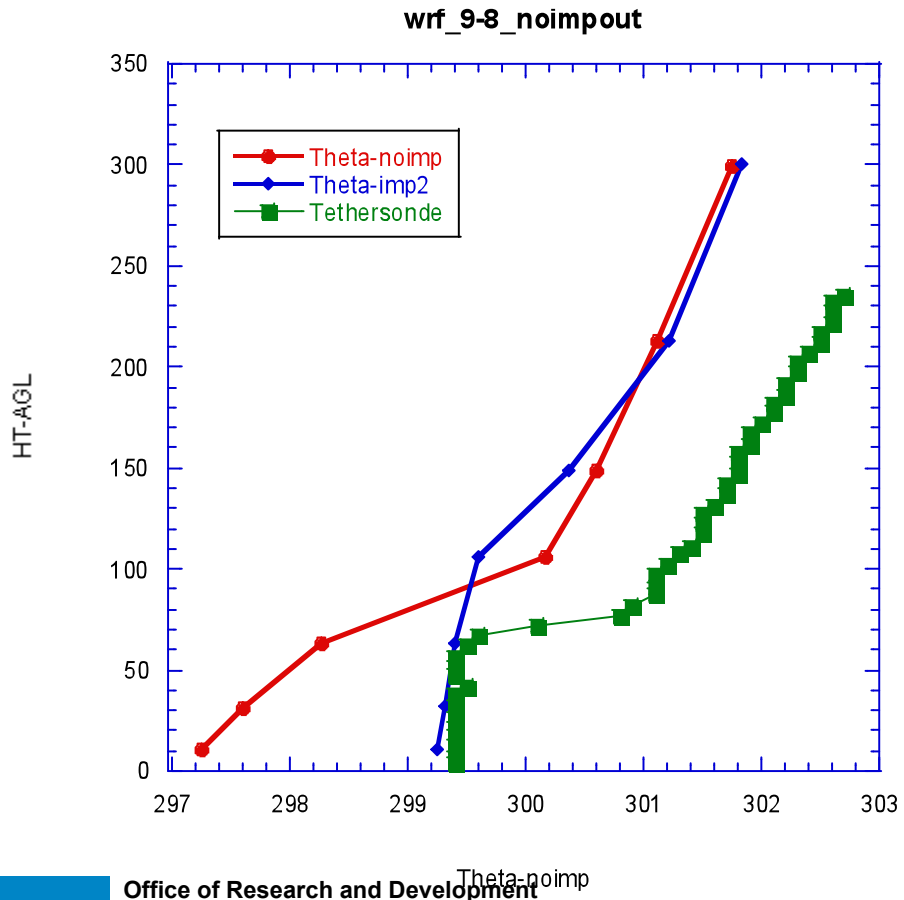
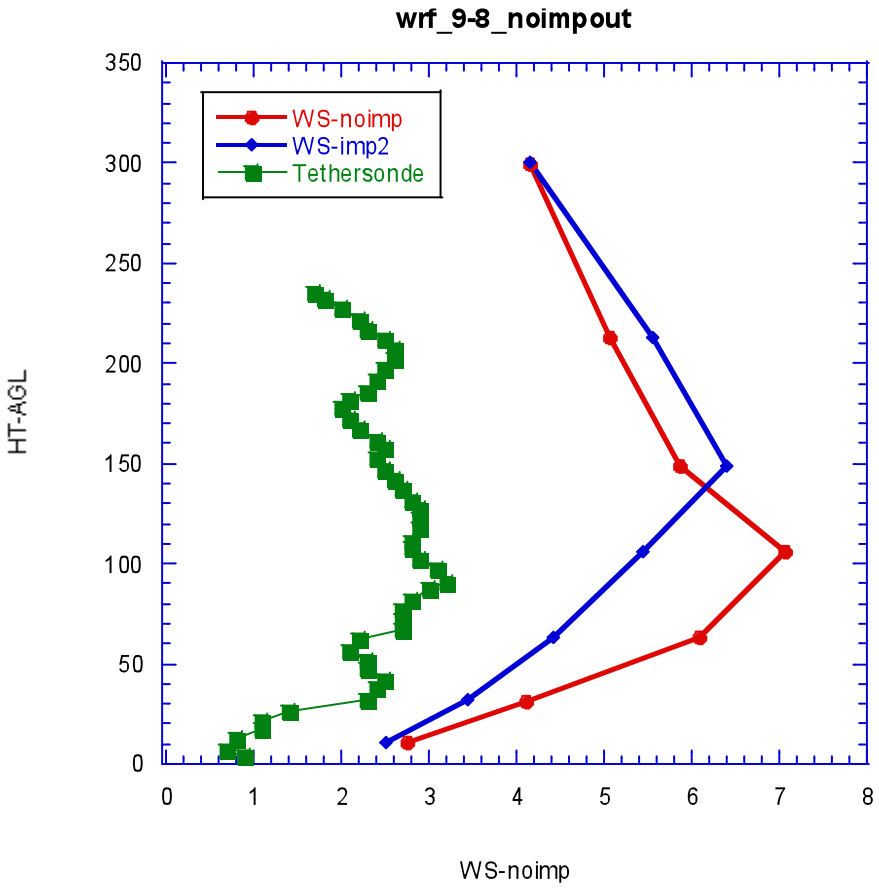
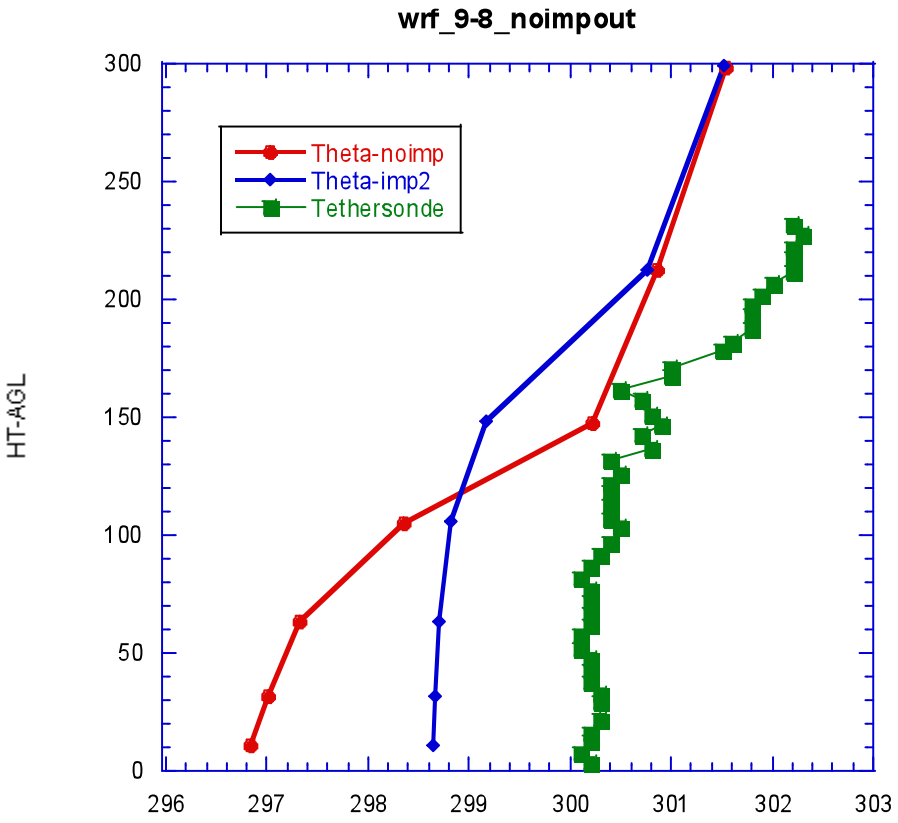
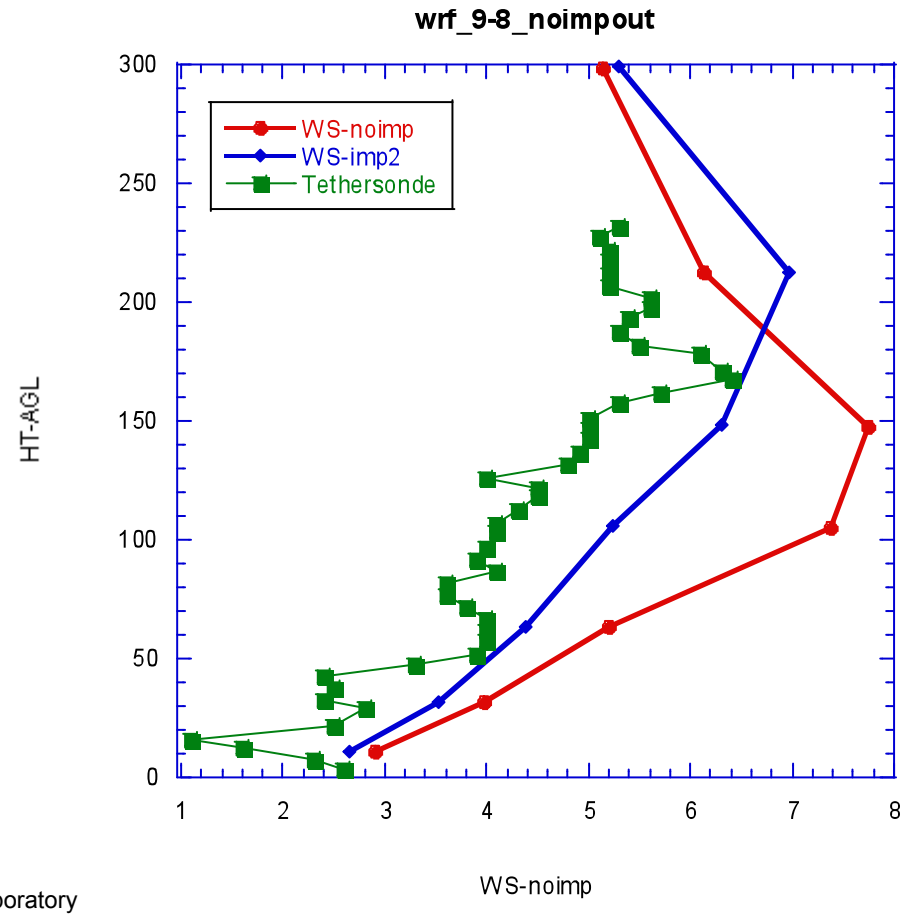
September 8, 6LT (11Z)





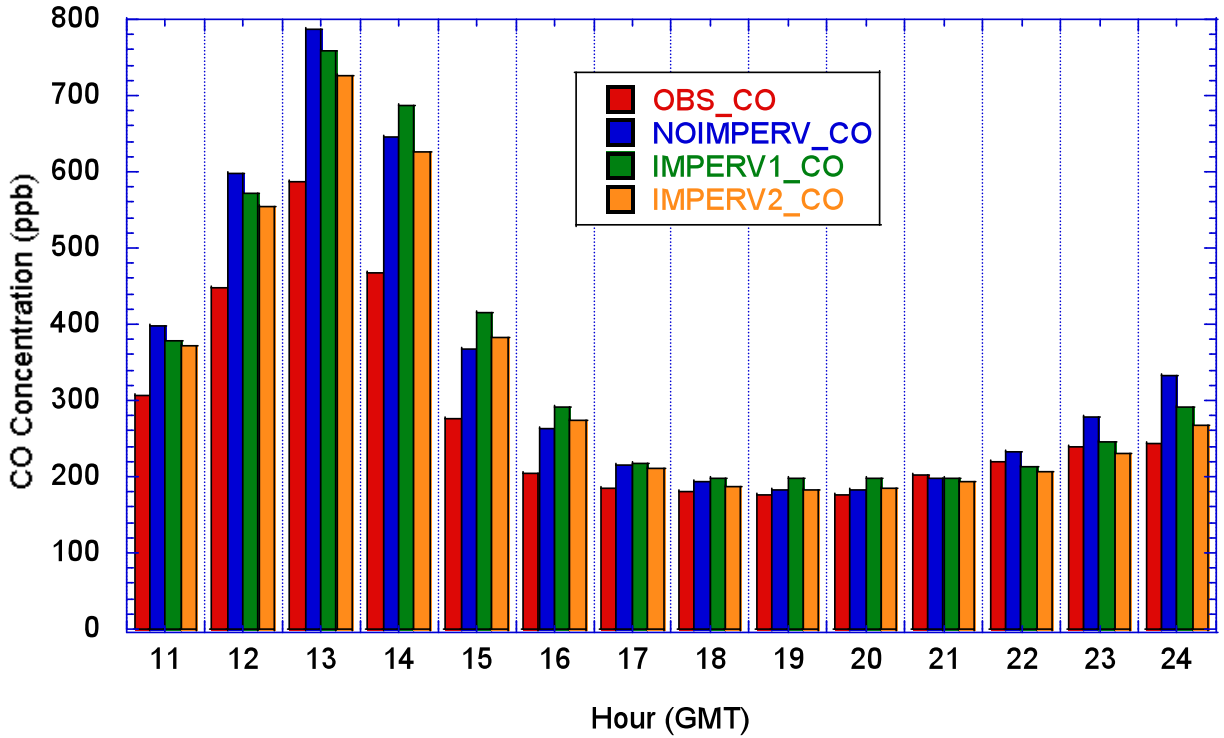
September 8, 8LT (13Z)





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

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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

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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