Implementation and Evaluation of a Single – Layer Urban Canopy Model in WRF/Noah

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Outline:

- **Objectives**
- **Numerical Experiments and Results**
  - WRF-Noah model with high resolution land-use
  - WRF-Noah-UCM with high resolution land-use
- **Summary**

Urban Landuse Modeling for Weather Research and Forecast (WRF)

- **Objectives**
  - To evaluate coupled WRF/Noah LSM /Urban Canopy Model (UCM) model's capability over different urban regions
  - To give an overview of urban parameters required by UCM
  - To provide more accurate weather forecasts (near surface and PBL structures) for urban regions

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WRF Model Experiments

- **First approach: Simple urban treatment in WRF/Noah**
  - Large roughness length
  - Low surface albedo
  - Large thermal capacity and thermal conductivity
- **Second approach: using a single layer urban-canopy model (UCM, based on Kusaka et al, 2001)**
  - User defined canyon orientations
  - Shadowing from buildings and reflection of short and long wave radiations in the canyon
  - Wind profile in the canopy layer
  - Multi-layer heat transfer equation for roof, wall, and road
  - Very thin bucket model for hydrological processes.
- **Numerical Experiments and Observations**
  - 24 hours simulation starting at 12 UTC 25 Aug 2000 with each model run, and the sensitivity experiments
  - 4 domains nested runs (27km, 9km, 3km and 1km)
  - Observational data from TexAQS 2000 field experiment

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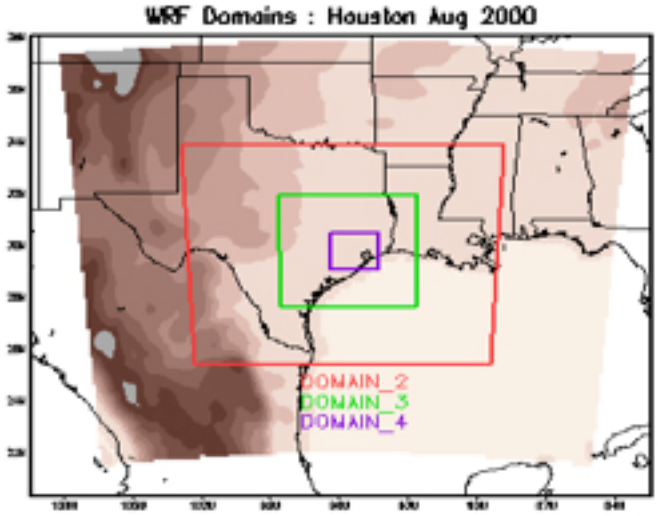
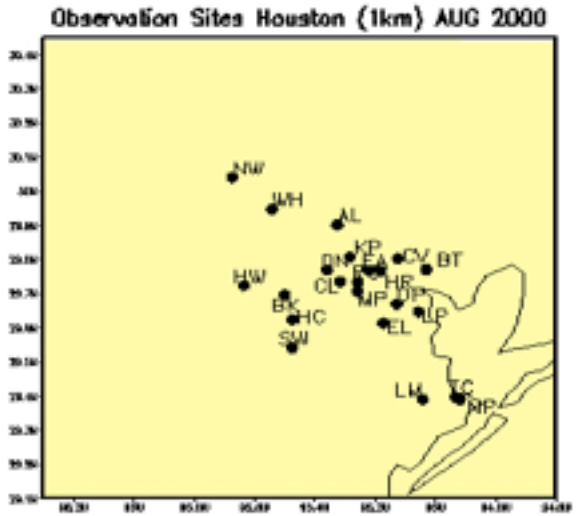
WRF/UCM Configuration for Houston Case

- **WRF 4 nested Domains**
  - 85X68 (domain1, at 27km)
  - 145X106 (domain2, at 9km)
  - 190X160 (domain3, at 3km)
  - 199X154 (domain4, at 1km)

- **WRFV2.1.2/UCM Simulation:**
  - 24-hr simulation starting 12 UTC 25 Aug 2000. A severe air-pollution case during TexAQS 2000
  - Using 3-hourly EDAS for initial and lateral boundary condition.





Surface observation sites at 1-km domain

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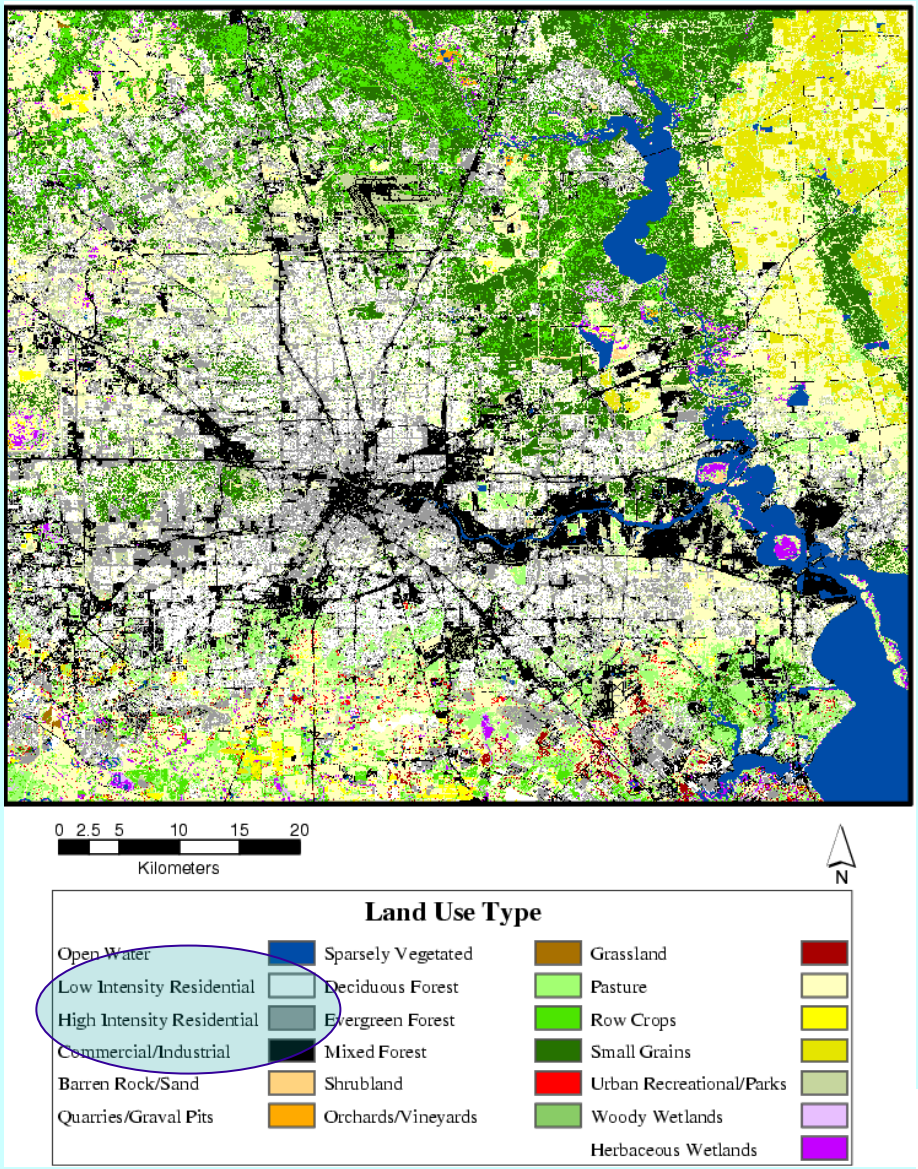
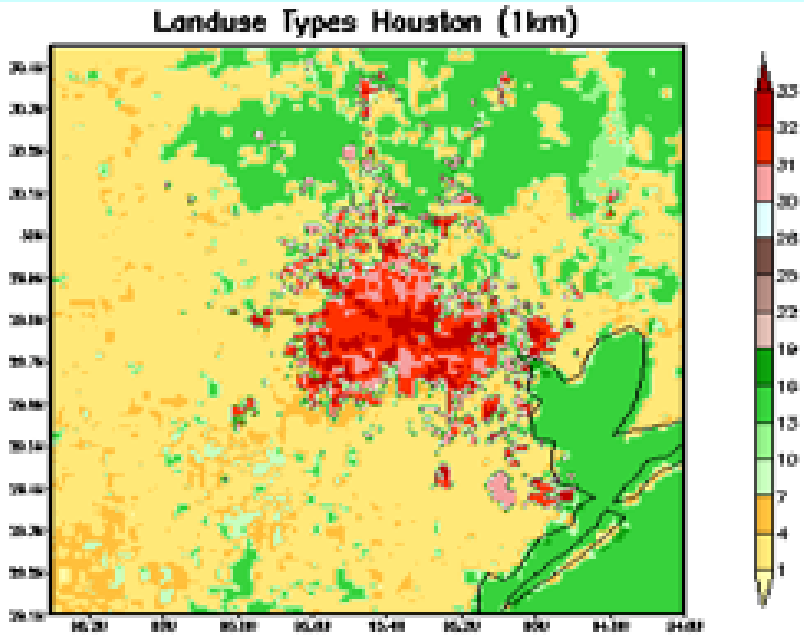
Integrate high-resolution detailed urban landuse data



30-m Landsat land-cover Houston



Aggregated to WRF 1-km domain

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Simple Bulk Scheme vs Urban Canopy Model

- **Five key parameters**
- **Surface albedo**
- **Surface emissivity**
- **Thermal conductivity/diffusivity**
- **Fractional urban coverage**
- **Soil moisture**

Fractional Urban Coverage
Urban Type
Roof level (building height)
Roof area ratio (Building coverage ratio)
Wall area ratio
Road area ratio
Volumetric heat capacity of roof
Volumetric heat capacity of wall
Volumetric heat capacity of road
Thermal conductivity of roof
Thermal conductivity of wall
Thermal conductivity of road
Sub-layer Stanton number
Roughness length
Roughness length above canyon
Roughness length above roof
Zero plane displacement height
Roof surface albedo
Wall surface albedo
Road surface albedo
Roof surface emissivity
Wall surface emissivity
Road surface emissivity
Moisture availability of roof
Moisture availability of road

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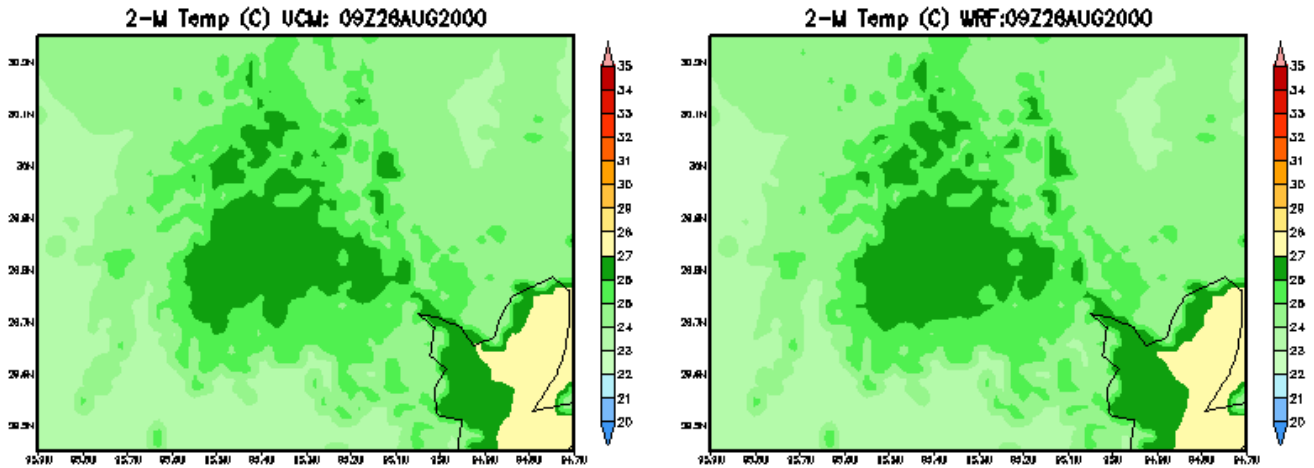
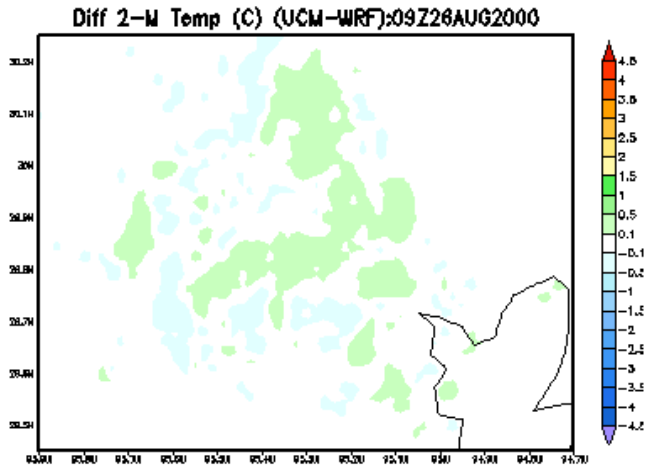
Simple Bulk Scheme vs Urban Canopy Model

2-M Temperature at 09Z (0300 LST) 26 Aug 2000





Generally higher nocturnal temp with UCM

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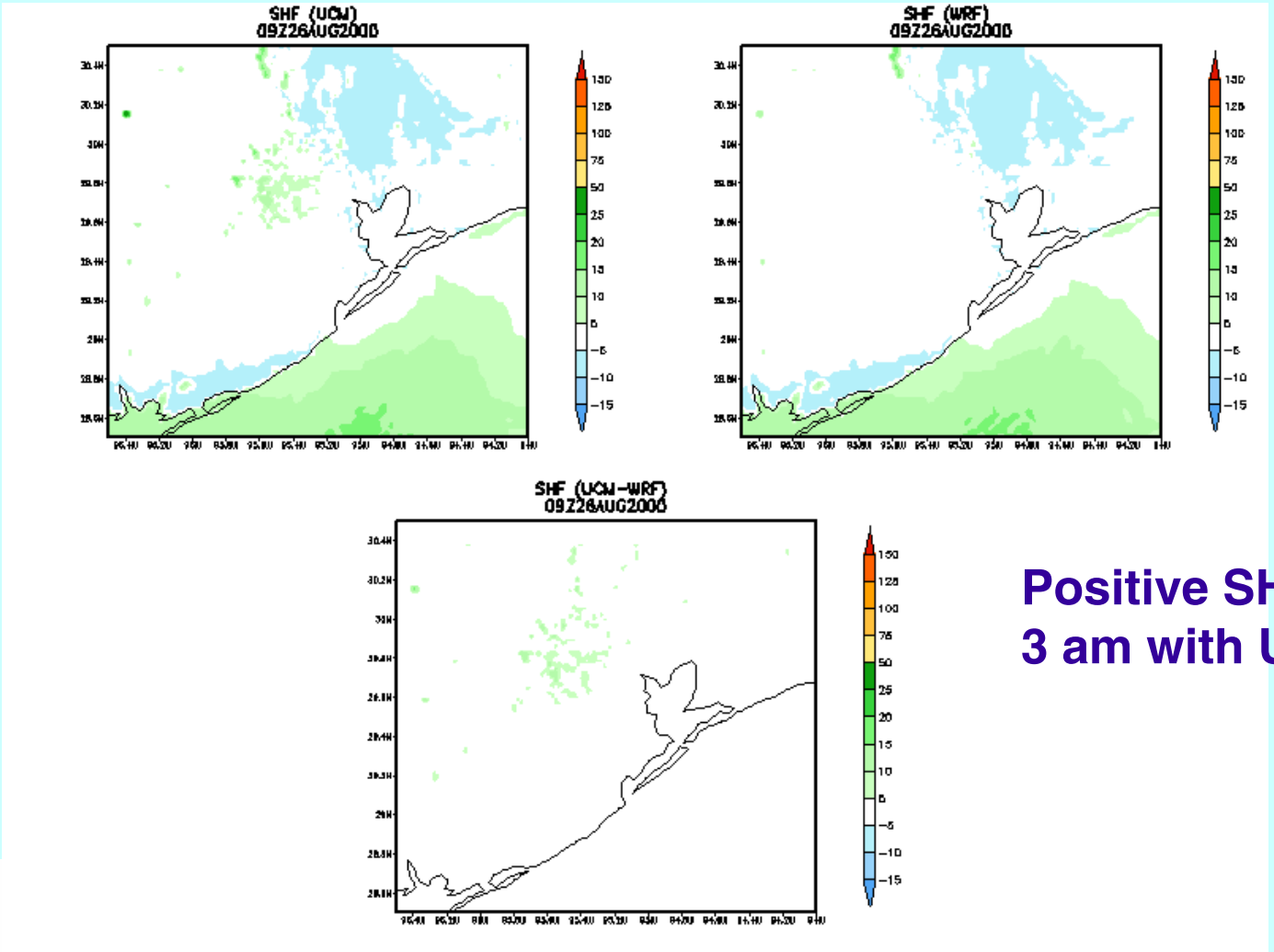
Simple Bulk Scheme vs Urban Canopy Model

Sensible heat flux at 0300 LST 26 Aug



Positive SHF at 3 am with UCM

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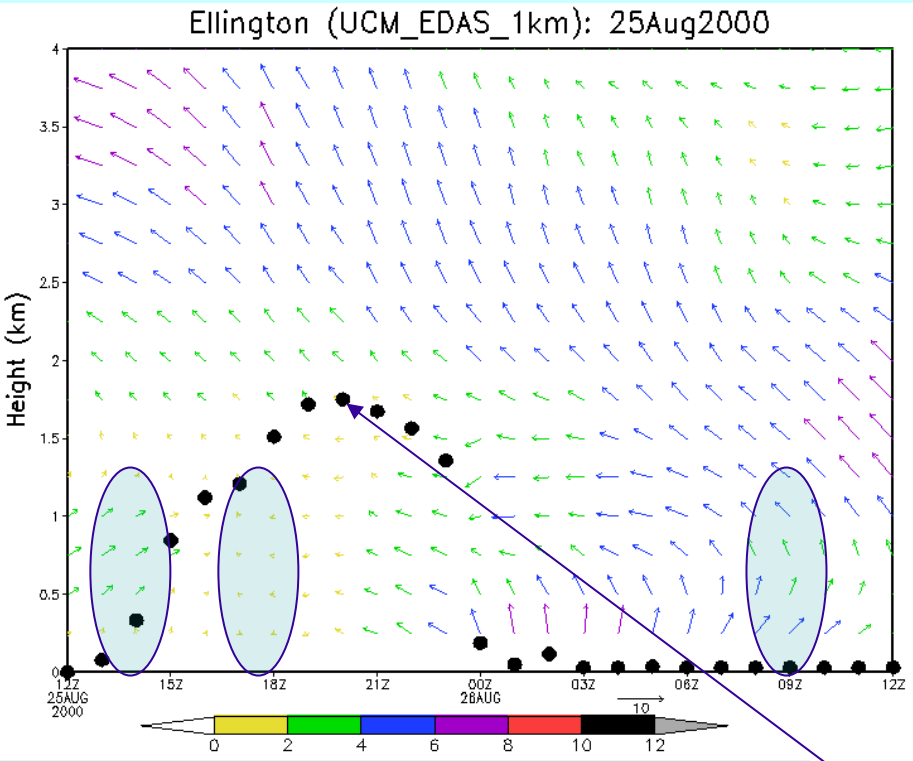
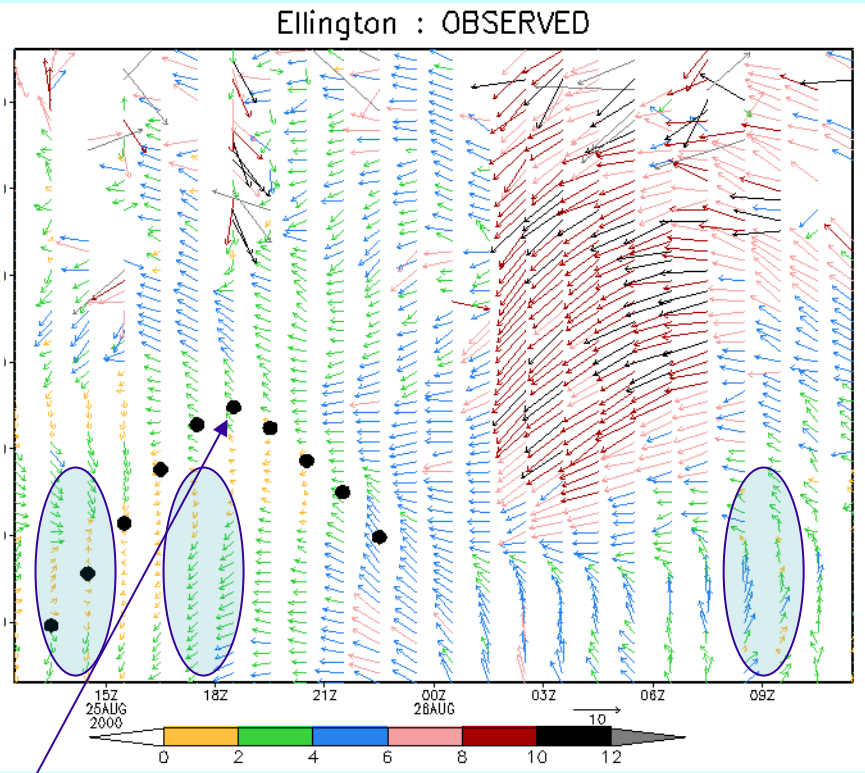
Wind Profiler at Ellington 25 Aug 2000





PBL depth

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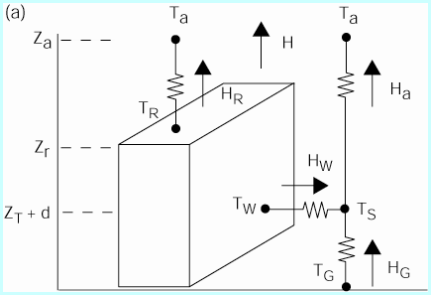
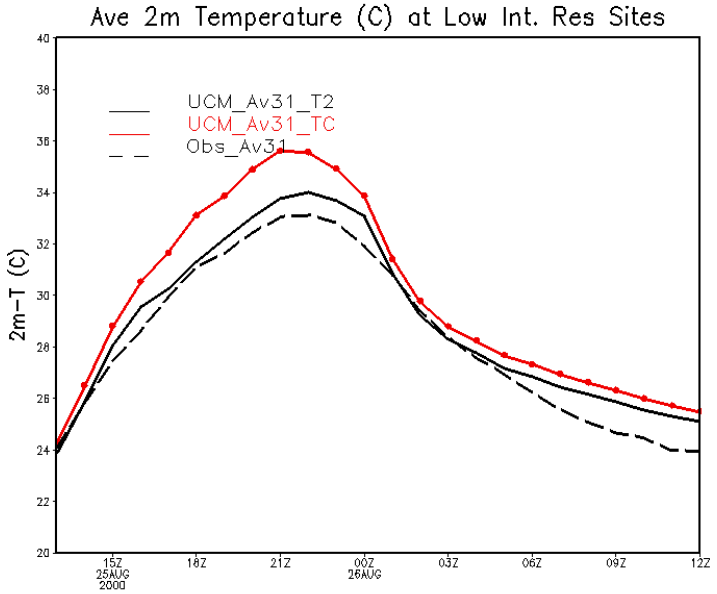
Which diagnostic variable is more representative?

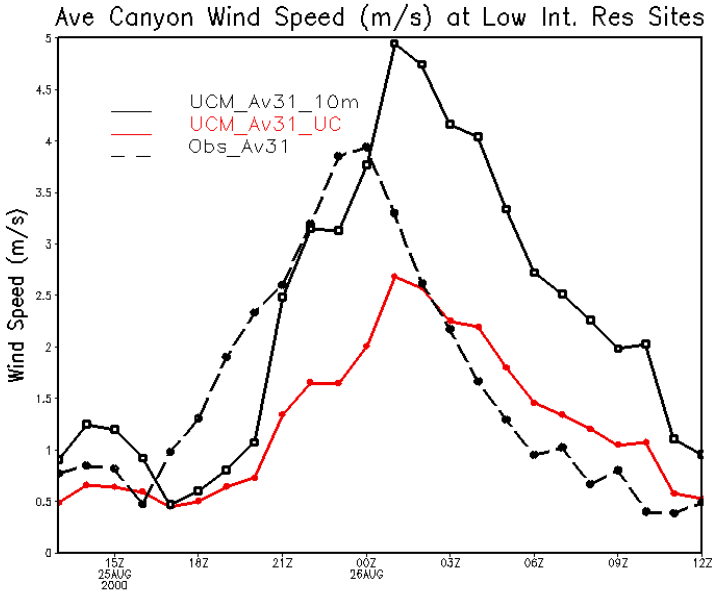


Traditional 2-m T and 10-m Wind

Temperature and wind in urban canyon

Observations (e.g., surface fluxes) are obtained in the urban roughness sublayer





Solid Red: T in the canyon
Dash Black: Observed
Solid Black: 2-m T

Solid Red: Wind speed in the canyon
Dash Black: Observed
Solid Black: 10-m wind speed

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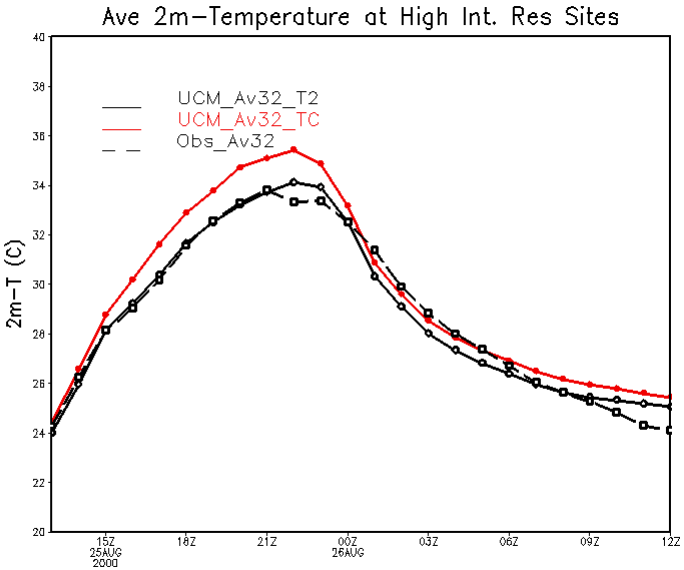
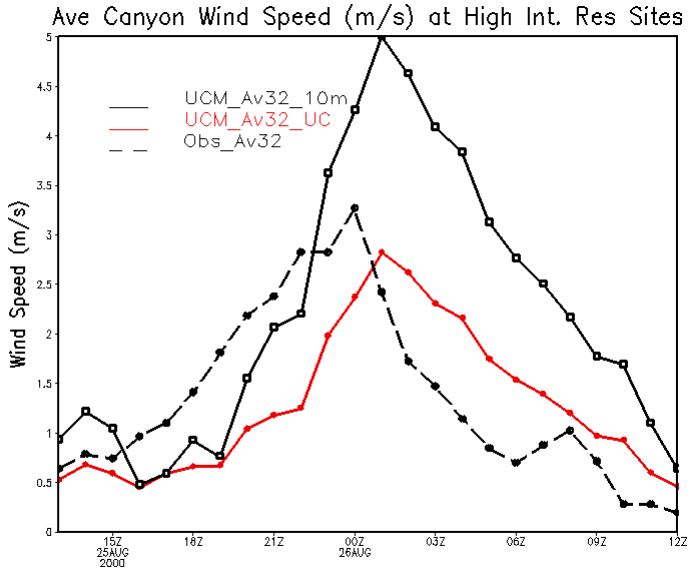
Wind Speed and Temp (Average of High Intensity Res Sites using EDAS)





Solid Red: UCM_TC
Dash Black: Observed
Solid Black: UCM_T2

Solid Red: UCM_UC
Dash Black: Observed
Solid Black: UCM_10m

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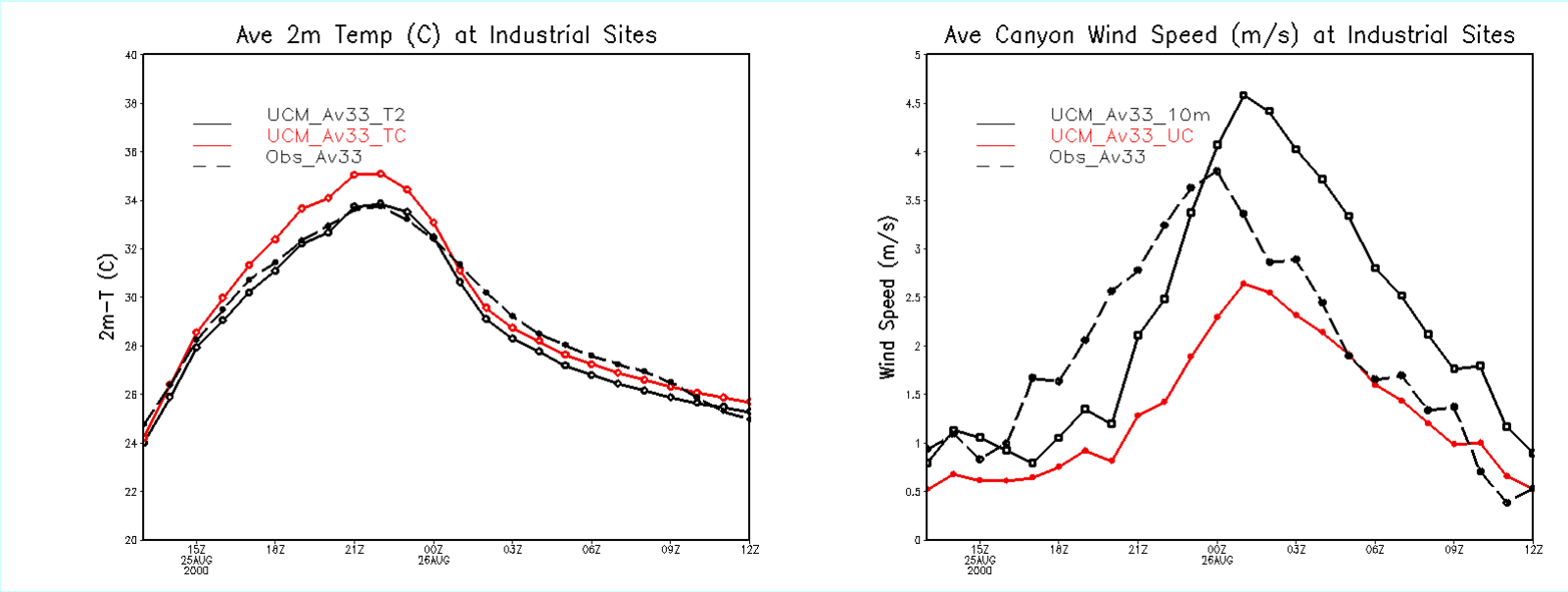
Wind Speed and Temp (Average of Industrial Sites using EDAS)



Solid Red: UCM_TC
Dash Black: Observed
Solid Black: UCM_T2

Solid Red: UCM_UC
Dash Black: Observed
Solid Black: UCM_10m

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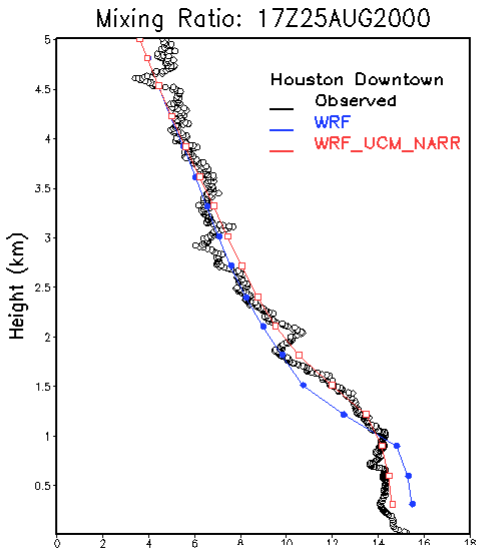
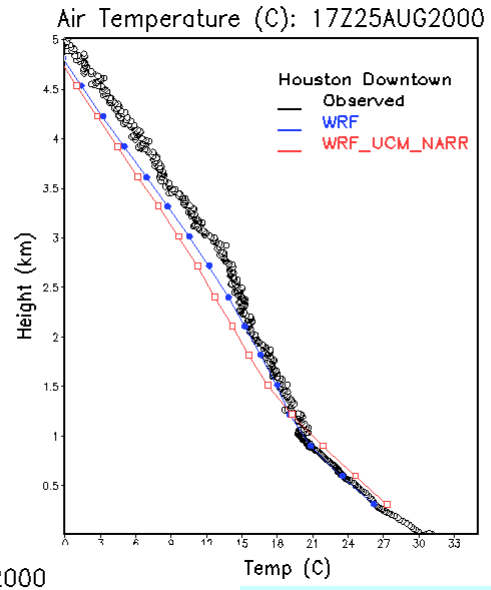
Verification with Sounding

Downtown Houston, 1700 UTC 25 Aug 2000

Mixing Ratio

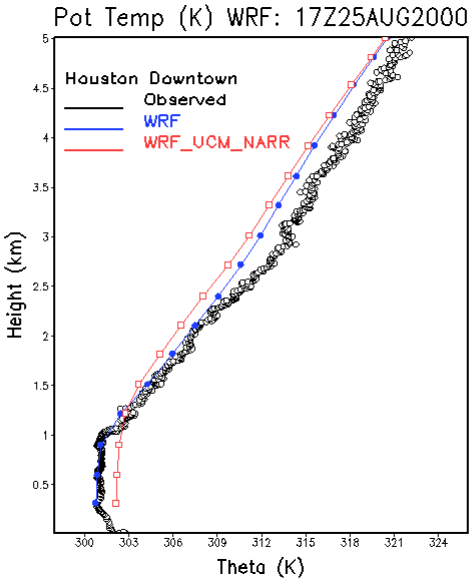


WRF
WRF/UCM
Observation



Temperature

Potential temperature



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Results from Sensitivity Experiments

- **Numerical Experiments:**
  - Replacing all urban with grassland (Grassland)
  - Replacing all urban with high intensity residential (UCM_32)
  - CTL (Original UCM Run)

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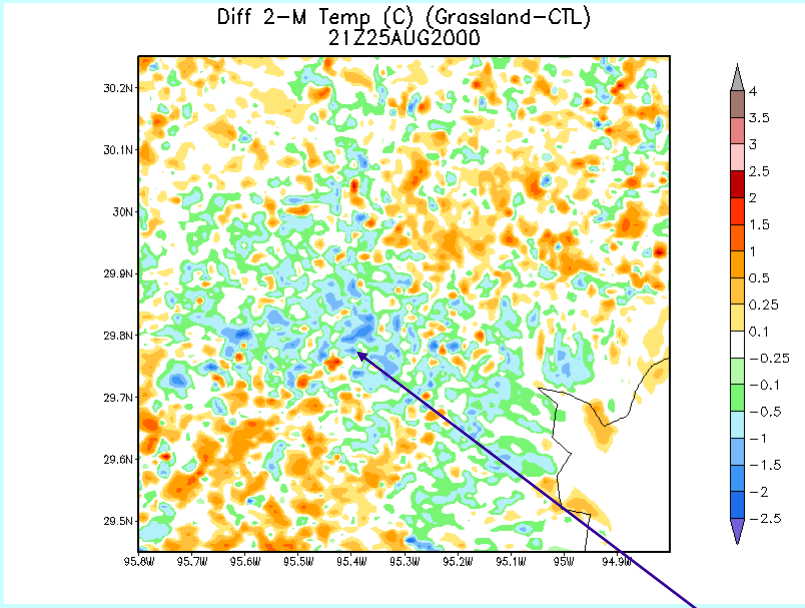
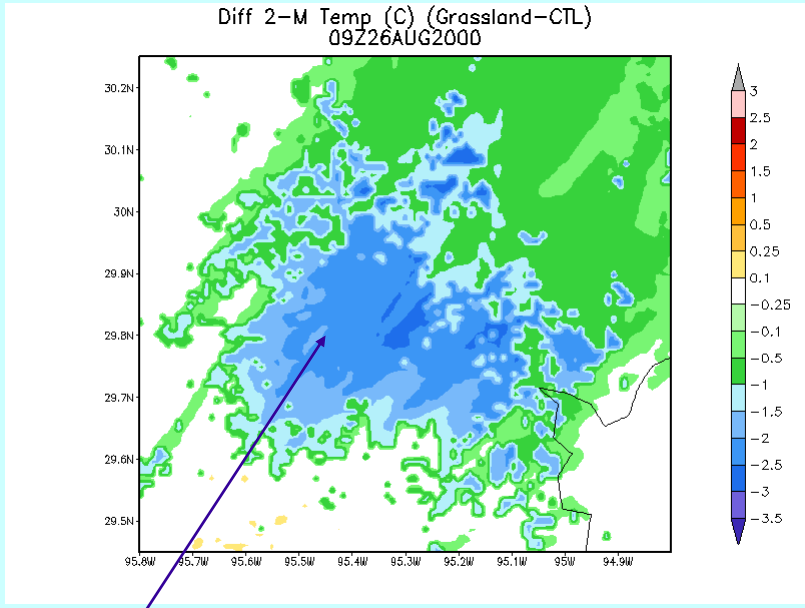
Difference 2m Temperature (Grassland-CTL) Domain4

25 Aug, 21Z (3pm LST)



26 Aug, 9Z (3am LST)



Generally Lower day/night Temp
Over originally urban region

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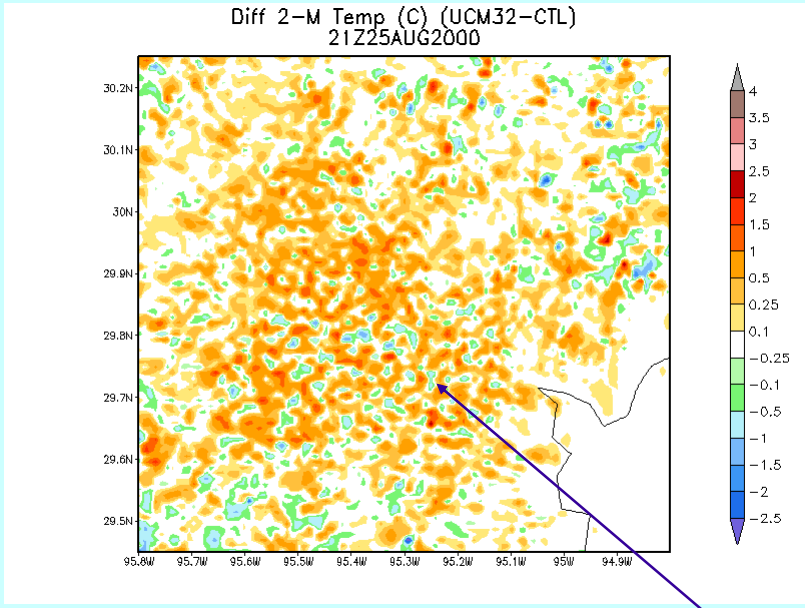
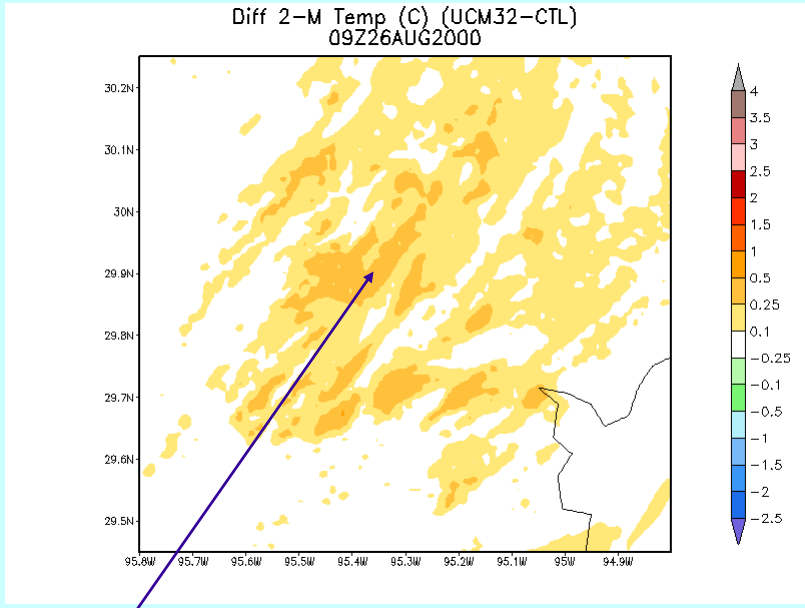
Difference 2m Temperature (UCM32-CTL) Domain4

25 Aug, 21Z, (3pm LST)



26 Aug, 9Z (3amLST)



Generally higher day/night Temp
Over originally urban region

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Conclusions

- Both simple urban treatment and UCM can capture essential UHI features. Able to simulate multi-scale interactions is critical.
- UCM, with more realistic physics, is promising
- Specifying UCM parameters is a challenge
- UCM would be released soon

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