

Study Effects of Meteorological Inputs on Photochemistry Using MM5 & CMAQ: Application to the Houston's High Ozone Problem

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Background

- Houston's high ozone concentrations are caused by emissions from
 - *anthropogenic (e.g. Ship Channel industries & traffic) & biogenic sources.*
- Meteorology also contributes to Houston's high O₃ concentration.
 - *land-air surface interactions, turbulent mixing, dry deposition processes, wind transport*
 - *Turbulent mixing layer height affects the vertical mixing of O₃ precursors, such as NO_x and VOCs.*
 - *if mixing layer is shallow and light wind conditions, the dispersion of air pollutants is limited and the O₃ concentrations could build up.*
- Houston is located near the Gulf of Mexico and Galveston Bay
 - *land-sea breeze flow (Nielsen-Gammon, 2002).*

Land Use and Land Cover data (LULC)

- MM5 uses USGS-25 category land use data

- Houston is represented as a *complete impervious surface*

- In reality, Houston is realizing substantial cooling

- With this data, we can

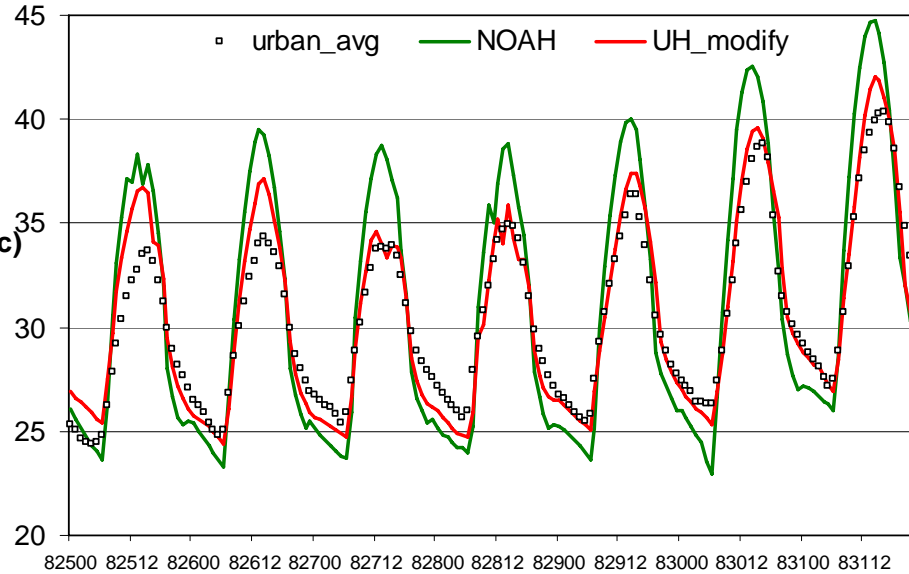
- temperatures throughout the

- downtown area

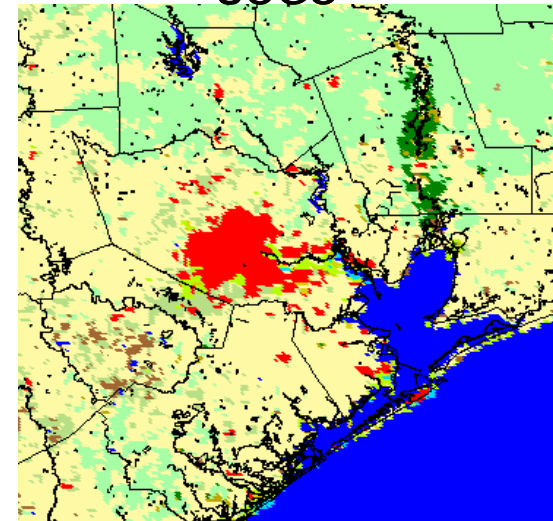
- To correct the

- the canopy water*

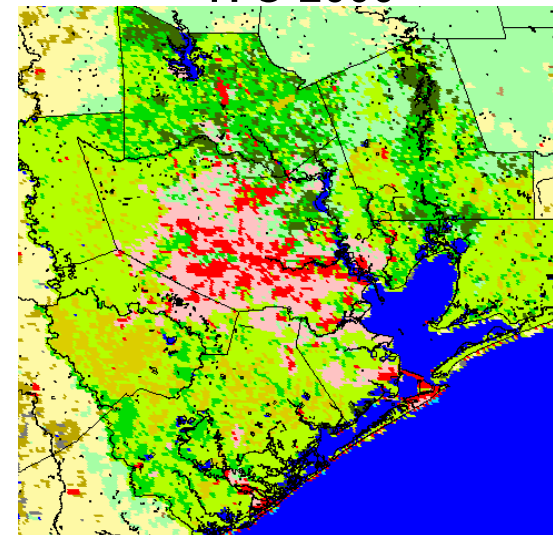
- processes in the



USGS



TFS-2000



GEM, 2003

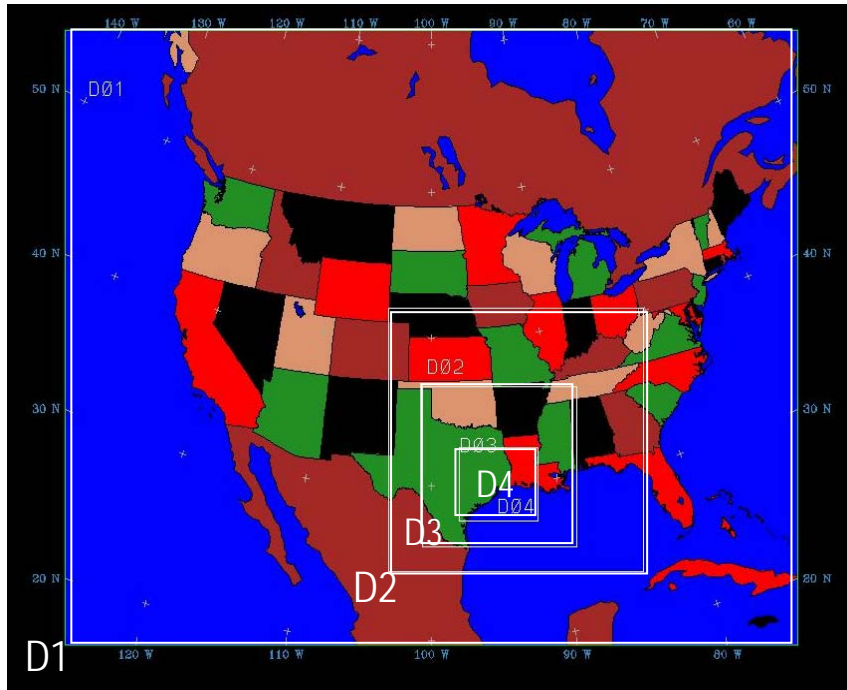
- A new LULC dataset was developed from **LANDSAT** satellite images taken in September 2000 (*GEM, 2003*) for the HGB counties provided by Texas Forest Service (TFS).

- We expect that with this dataset, the artificial addition of the canopy water will not be necessary for the MM5 simulations.

Objective

- The primary goal is to utilize the high-resolution LULC dataset for the meteorological modeling.
- The secondary goal is to demonstrate the effects of different meteorological inputs (*MM5-USGS vs. MM5-TFS*) on the air quality simulation (CMAQ) for Houston's high O₃ episodes.

Configuration of MM5 for TexAQS2000 episode



Simulation time: Aug. 22~Sep.02, 2000

| Domain | # of X | # of Y | Z |
|-----------|--------|--------|----|
| 1 (108km) | 53 | 43 | 43 |
| 2 (36km) | 55 | 55 | 43 |
| 3 (12km) | 100 | 100 | 43 |
| 4 (4km) | 151 | 136 | 43 |

- Grell cumulus at 108, 36, 12 km; no cumulus scheme at 4km
- Analysis nudging for d1, d2, d3
- Obs nudging (wind vector) in d4
- MRF PBL Parameterization
- RRTM radiation scheme

➤ Using NOAH LSM :

➔ advantage: has more complex physical processes, vegetation transpiration and moisture diffusion processes

➤ The physical setup up are same between two MM5 simulations, EXCEPT

---- *MM5-USGS*: adding anthropogenic water source to reflect the evapotranspiration process inside Houston urban city

---- *MM5-TFS*: since TFS_LULC represents Houston central city with urban, residential and grass land use type, no need to add anthropogenic water source

MCIP/Emission/CMAQ setup

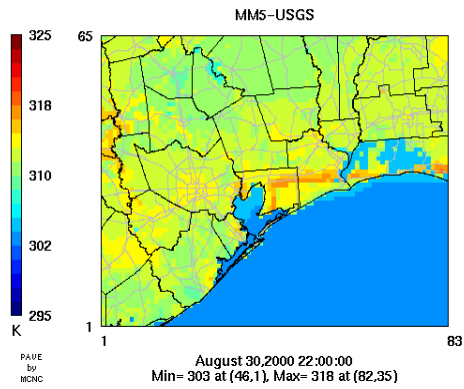
- MCIP v2.3 (released on Aug., 2004)
- *Anthropogenic emissions* in the CAMx-ready format provided by TCEQ were used in this study. The emissions including highly reactive volatile organic compounds for imputation were processed through the EPS2 (Emissions Preprocessing System Version 2) system.
- Prior input to CMAQ, the emissions inputs were converted into the CMAQ-ready format, applying the plume-rise with MM5-MCIP outputs
- GloBEIS3 is used for *Biogenic emissions*.
- Emission input are the same for CMAQ simulation **for the purpose of confining the meteorological effect.**

The emission data is prepared by Dr. Soontae Kim

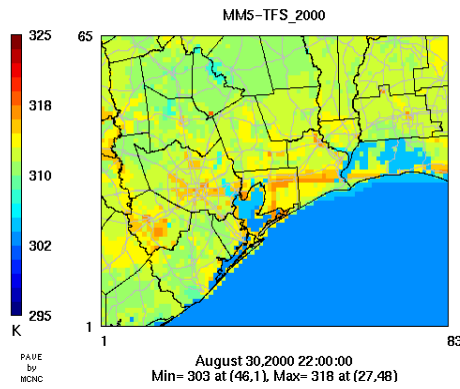
- CMAQ version 4.3 was used for air quality modeling.
(CB4 chemical mechanism)

Result of MM5 Simulation

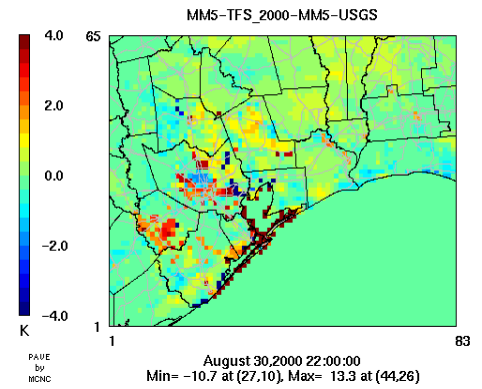
TEMPG



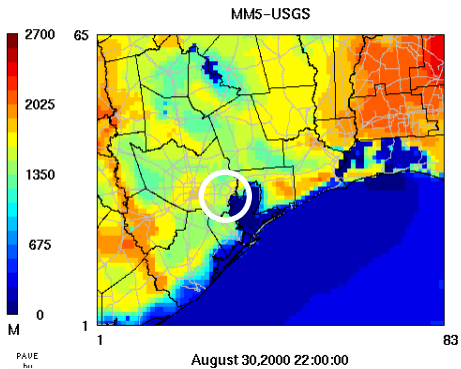
TEMPG



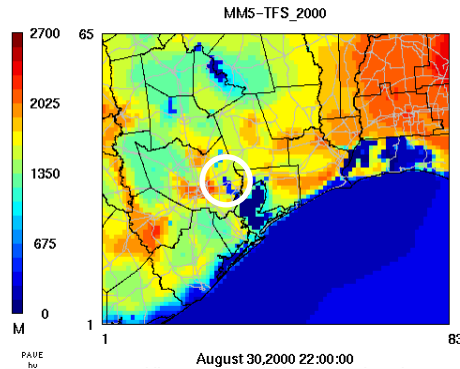
Difference:



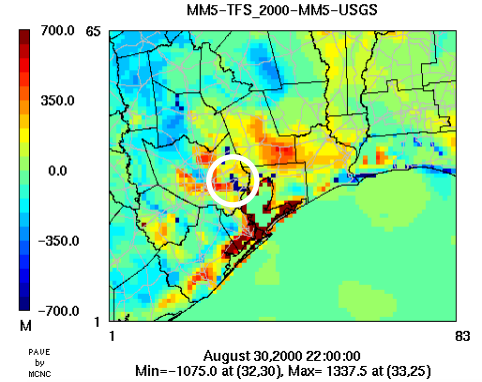
PBL



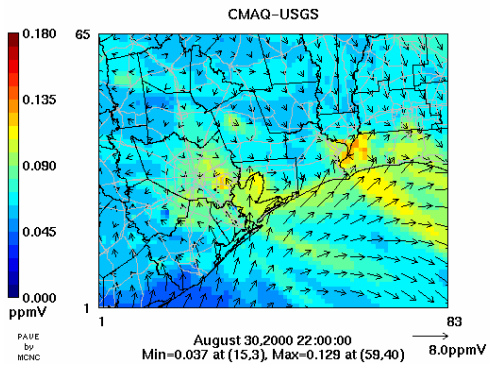
PBL



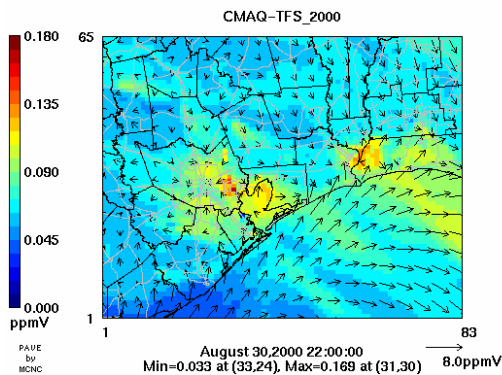
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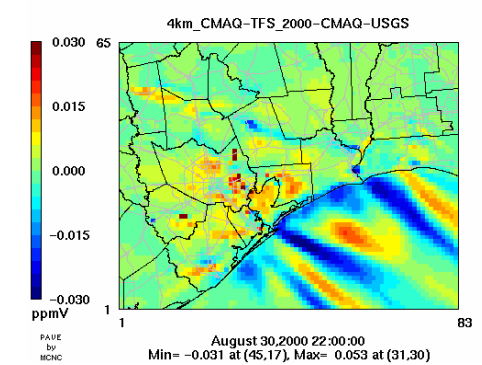
O3_L1



O3_L1

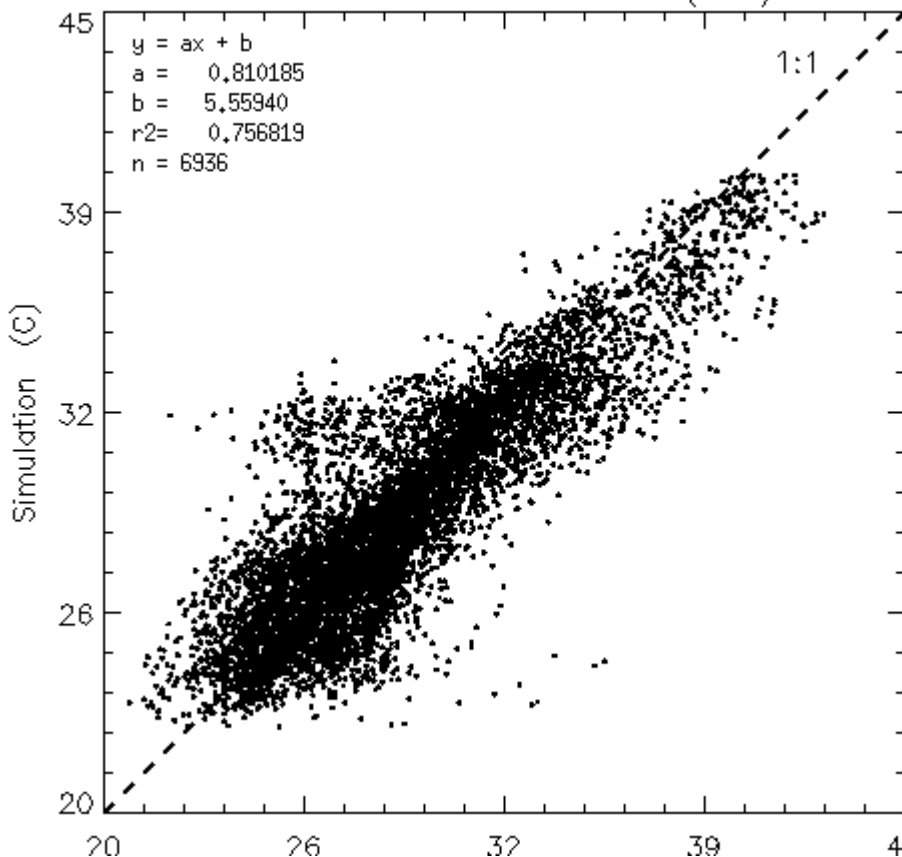


Difference

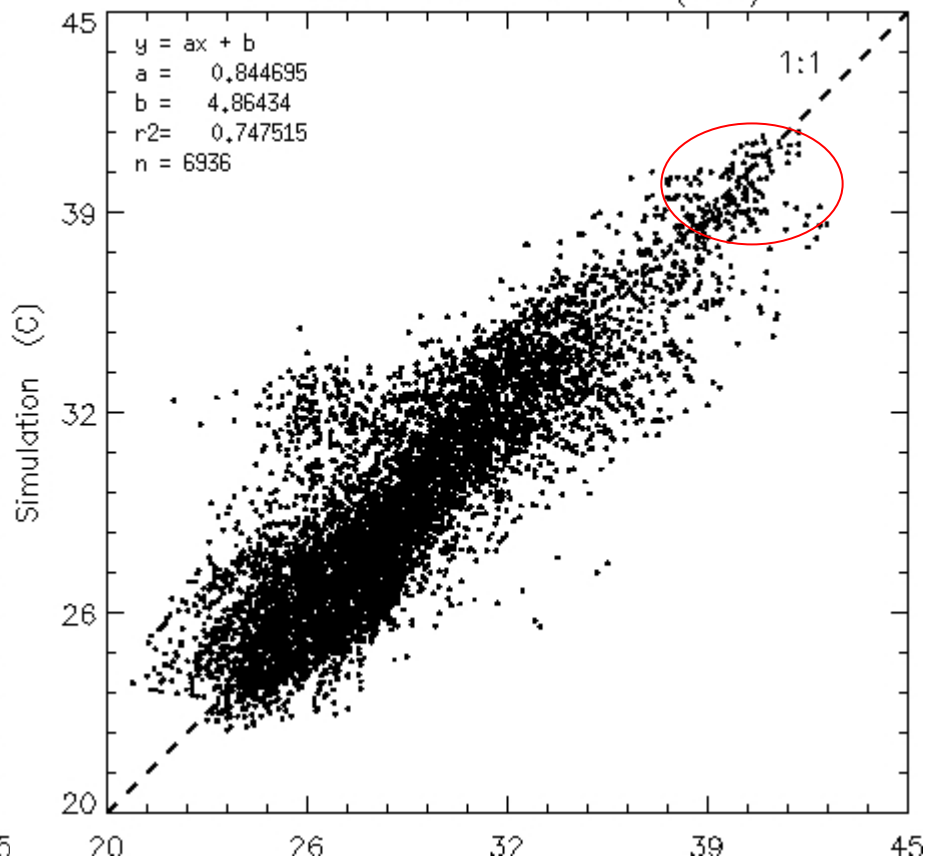


Result of UH-MM5 Simulation (LULC)

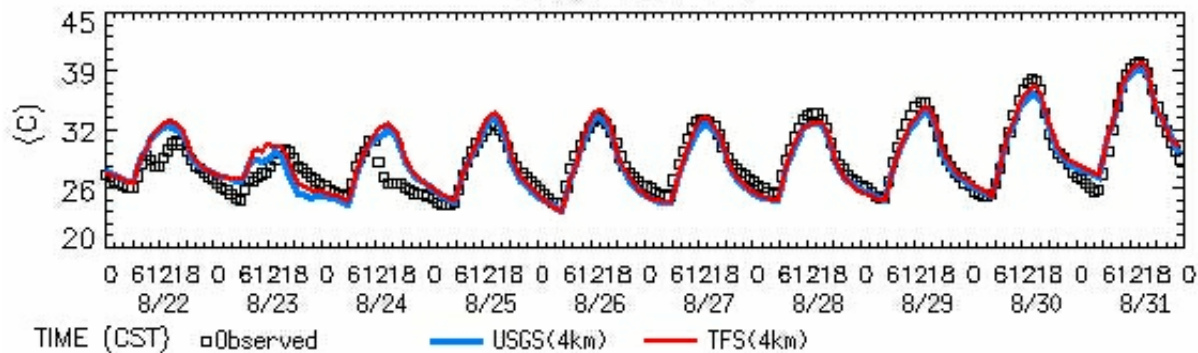
TEMP1P5: CAMS vs MET_USGS(4km)



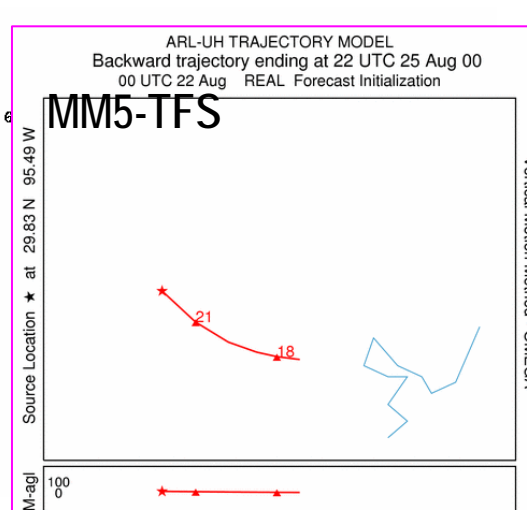
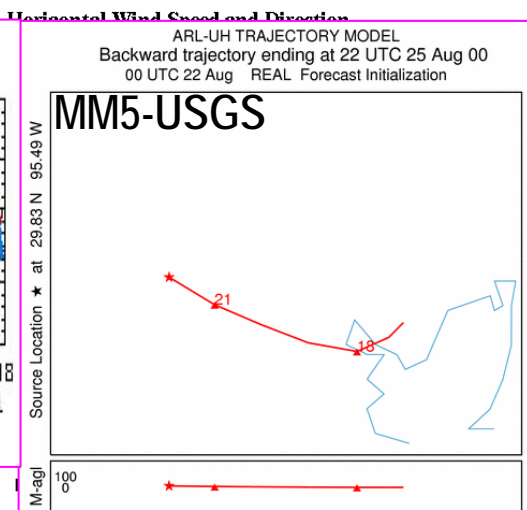
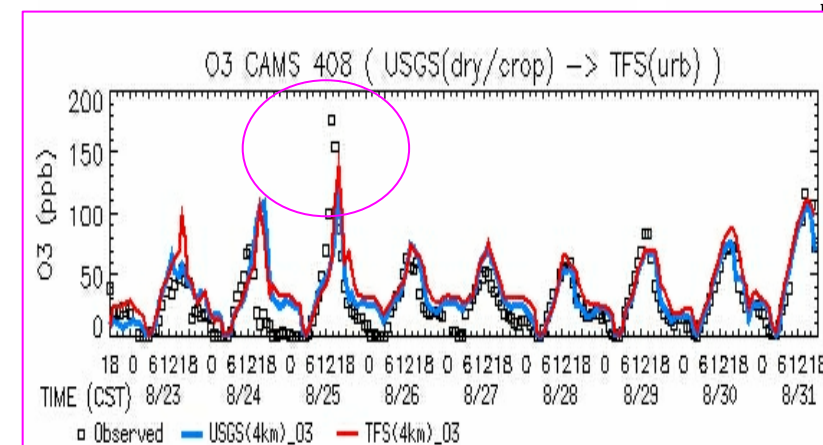
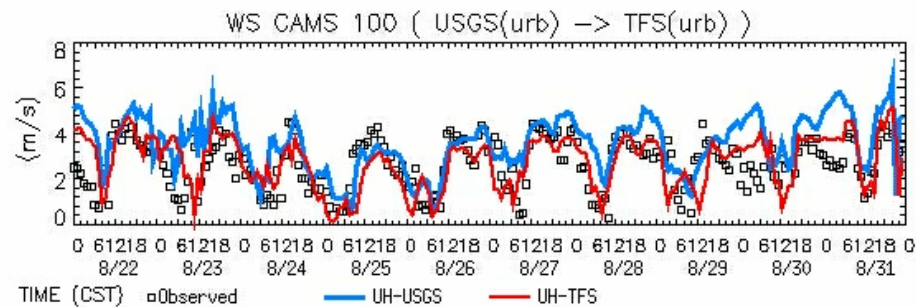
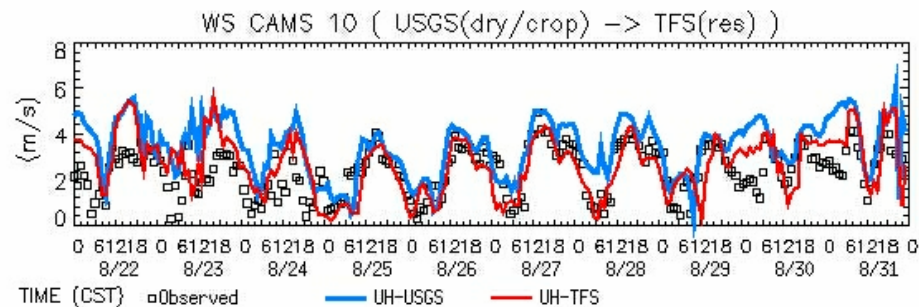
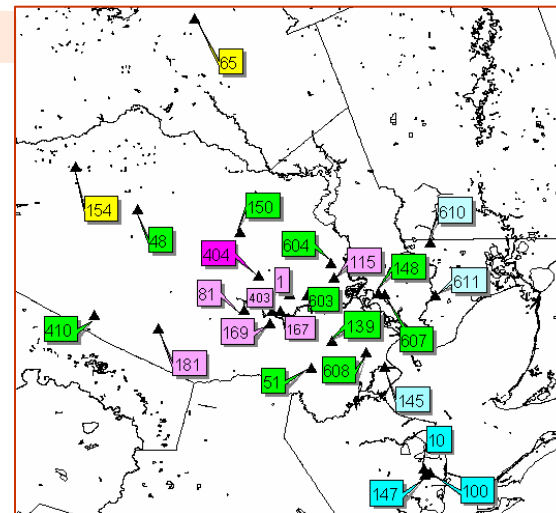
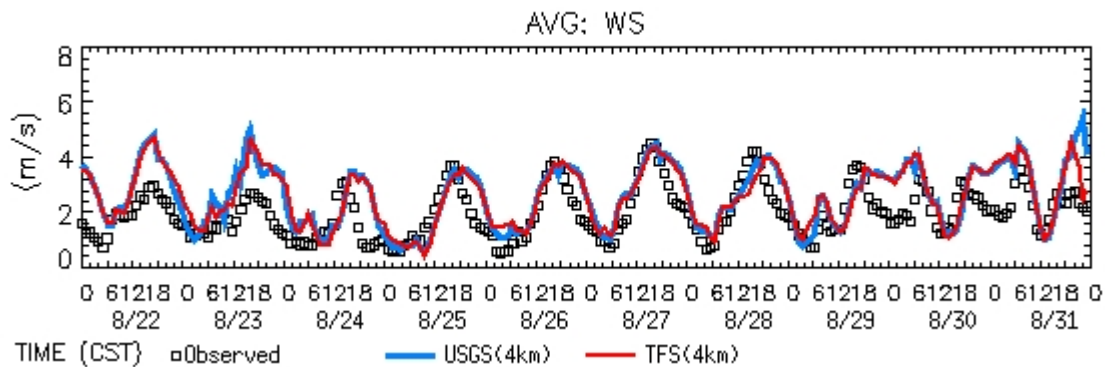
TEMP1P5: CAMS vs MET_TFS(4km)

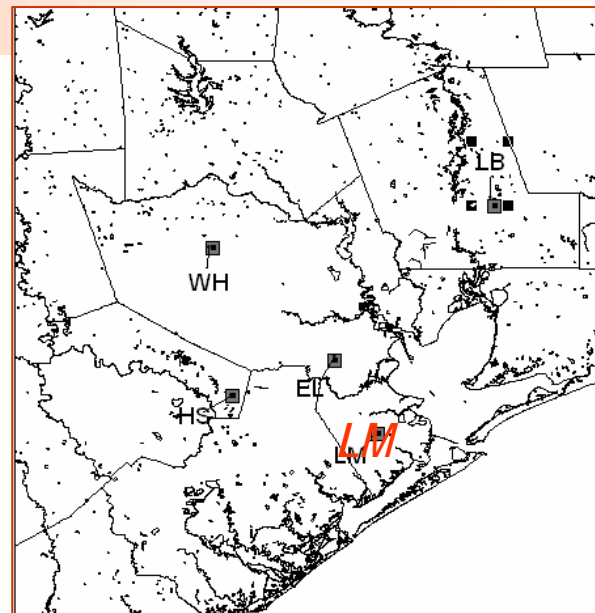
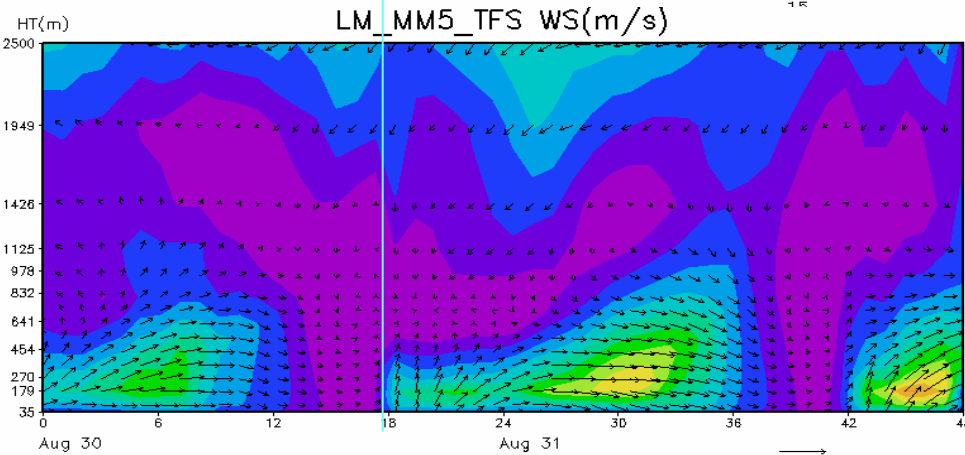
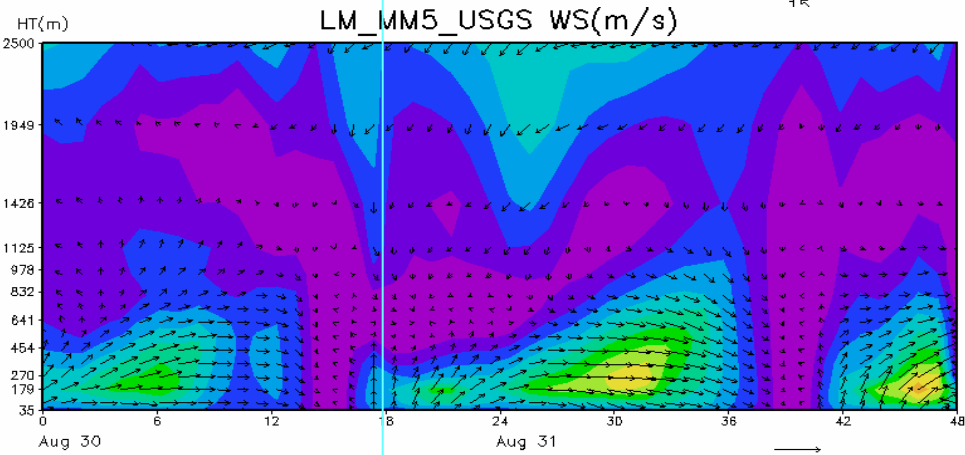
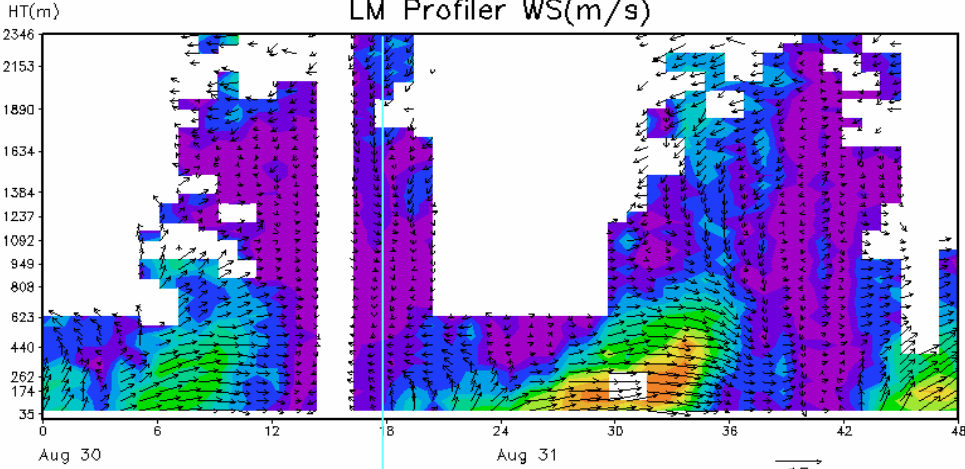


AVG: TEMP1P5



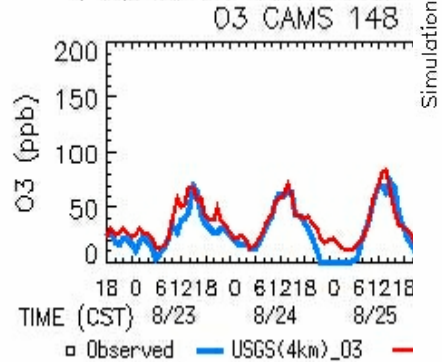
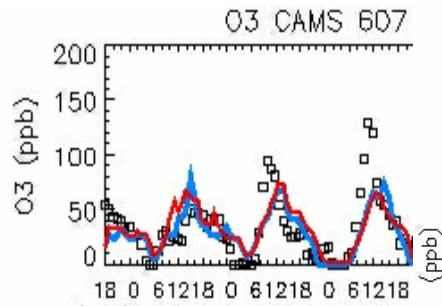
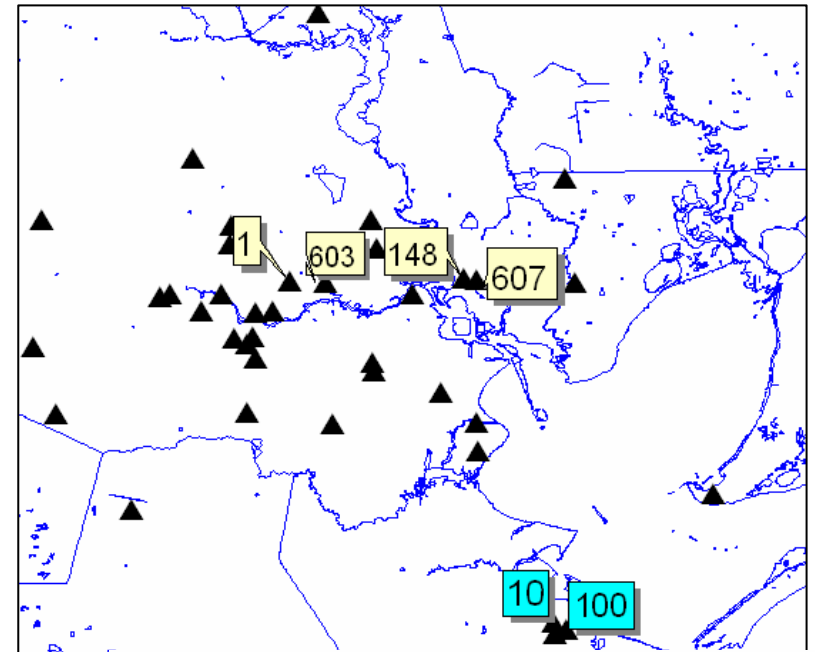
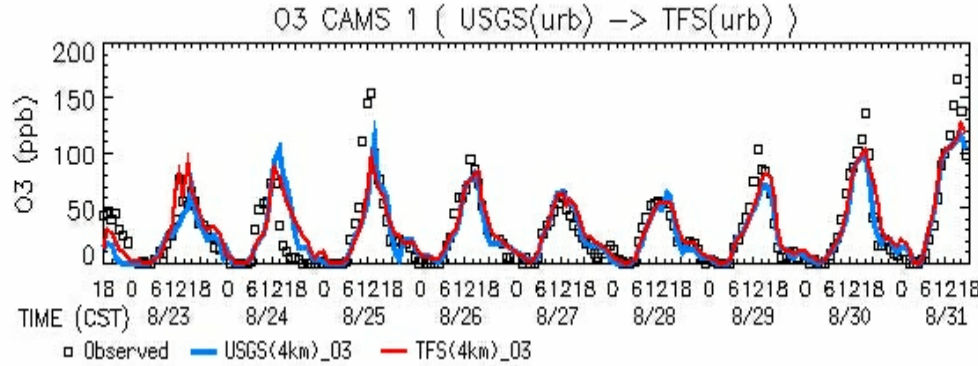
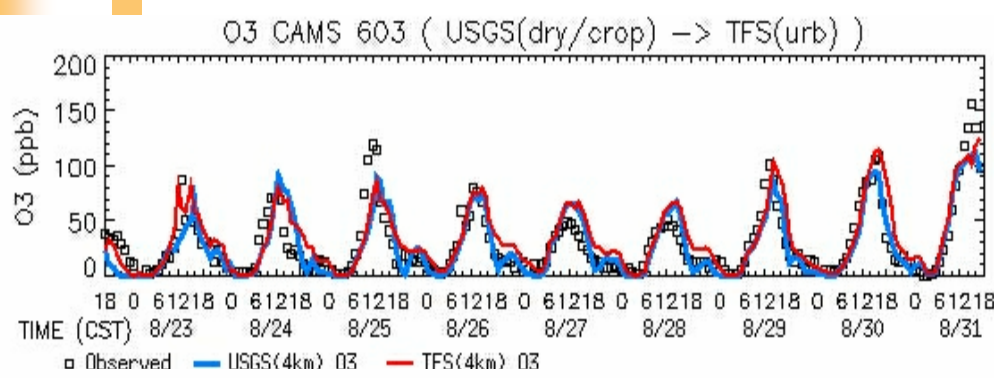
Result of MM5 Simulation



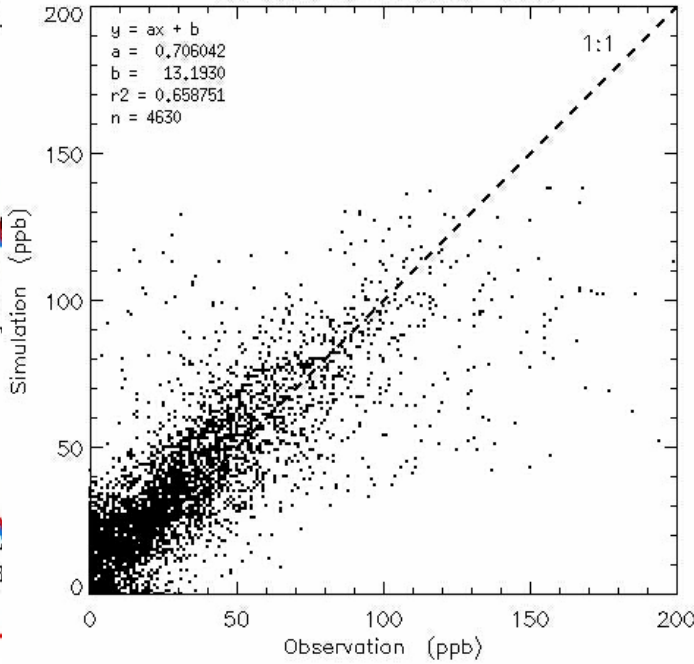


- La Marque site is influenced by the land sea breeze flow.
- On Aug. 30, the inland flow develops lately in the afternoon. MM5-TFS simulation has better agreement than MM5-USGS simulation in terms of capturing the timing of the wind transport.

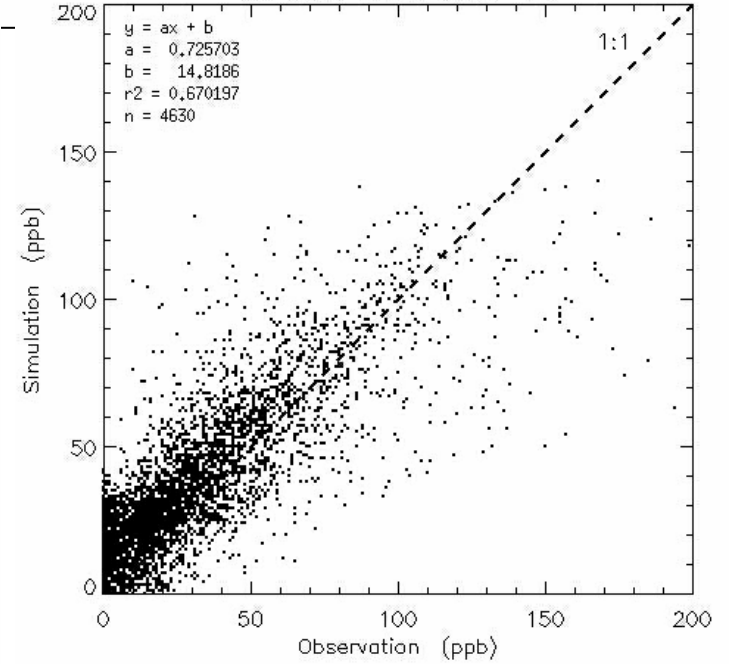
Result of CMAQ Simulation



O3: CAMS vs MET_CMAQ-USGS



O3: CAMS vs MET_CMAQ-TFS



Conclusion

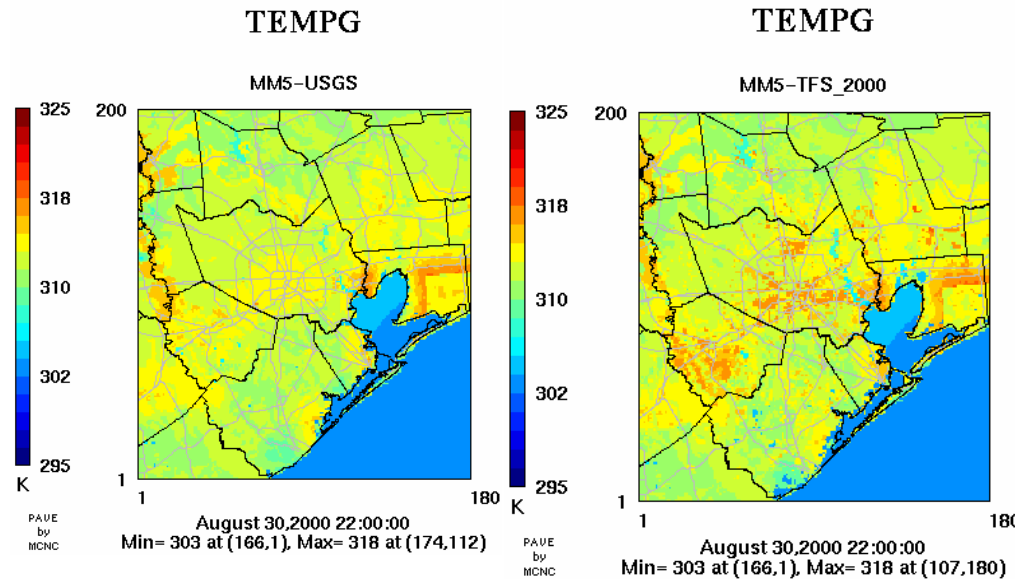
- USGS LULC dataset displays Houston city as a **large contiguous surface**
- TFS-LULC better describes the urban impervious surface areas as urban, residential and grassland land use type.
 - The meteorological simulation is improved with the more accurate and updated land use map.
- Higher ozone concentrations were observed when
 - *the PBL heights is shallower*
 - *photochemical reactivity is higher*
 - *stagnant wind condition*

Future Plan

➤ Current 4-km CMAQ simulation does not capture the observed maximum O3 concentration at ~200 ppb level.

--- The Ship Channel emission source area which has complicated surface texture and also located near the water body, the meteorological condition is difficult to simulate.

--- We are hoping with more accurate land use data, MM5 simulations at the higher resolution (*1-km*) will provide more realistic meteorological condition for CMAQ modeling.



--- therefore, maximum O3 values are expected to simulate near the Ship Channel source area.

Questions??

Thanks