June 29, 2005
WRF/MM5 Users' Workshop

Simulation of Meteorological Conditions of the Houston-Galveston Area with WRF for the TexAQS 2000 Episode

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Introduction

- WRF is a next-generation mesoscale meteorological model and is expected to be used to simulate the meteorological fields for air quality modeling.

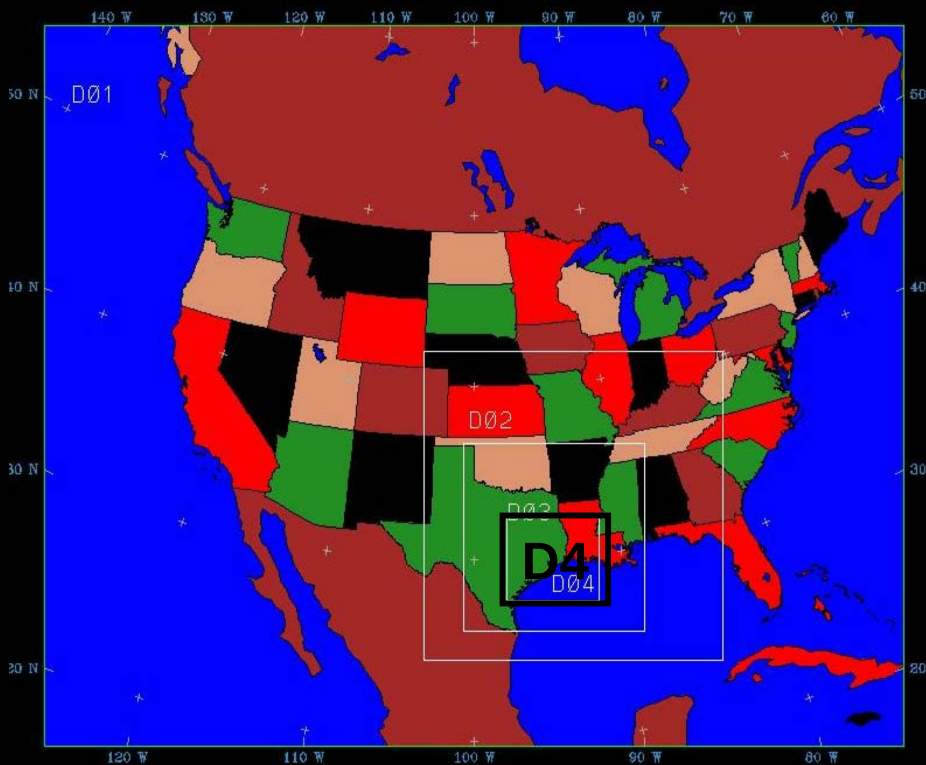
- The weather parameters such as surface wind and air temperature play a key role determining air quality in a region.

- The meteorological conditions must be accurately simulated to correctly model Houston air quality.

In this study, we test if WRF can simulate met. conditions for Houston/Galveston area during TexAQS 2000.

Nesting simulation

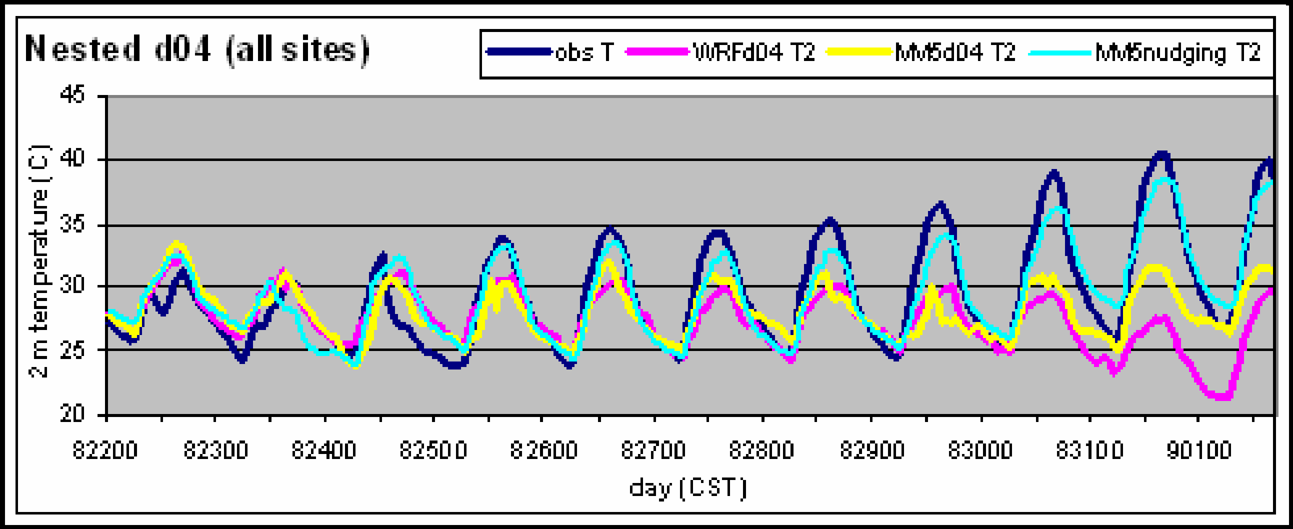
Model version: WRF v2.0.3.1 & MM5 v3.6.7
Time period: 2000/8/22 00UTC ~ 9/2 00UTC
IC/BC: From 40 km Eta reanalysis data (AWIP)
Resolution: 108km, 36km, 12km and 4 km
Nudging: NO
Nesting: 2-way nesting for 1st & 2nd domain, 1-way nesting for the others



	MM5	WRF
Microphysics	**Simple ice (Dudhia)**	
Radiation	**RRTM**	**RRTM (longwave)** **Dudhia (shortwave)**
LSM	**Noah LSM**	
PBL	**MRF**	
CU scheme	**Grell-Devenyi** **None for 4km domain**	

Nesting simulation

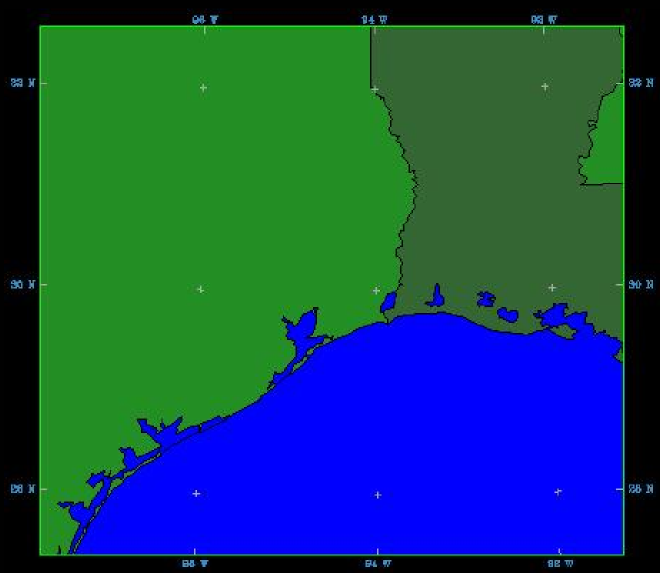
Time Series of D4 (4 km domain): 2 m Temperature



- The IC/BC inputs were generated by ETA reanalysis data
- But WRF & MM5 without nudging fail to simulate observed changes in temperature.
- Through the boundary input alone, synoptic signals were not able to propagate from coarse into fine domain.
- Without FDDA, models show very flat diurnal variations (effects of local dynamics controlled by sunrise and sunset).

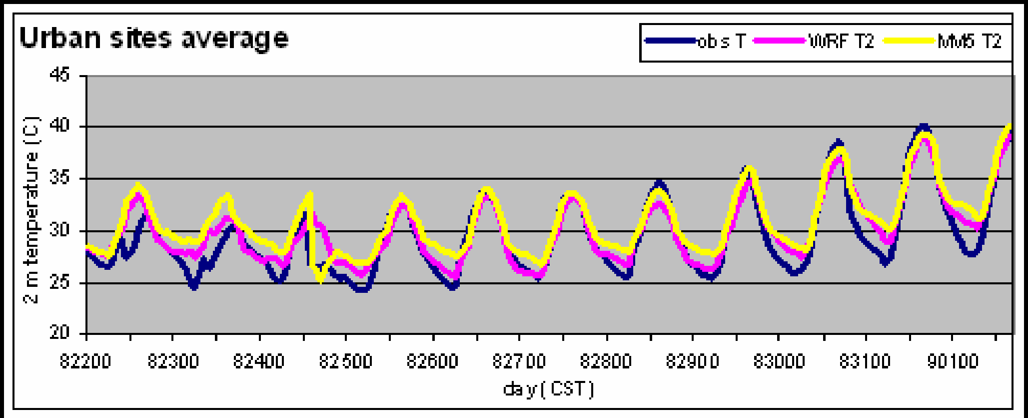
Single domain simulation

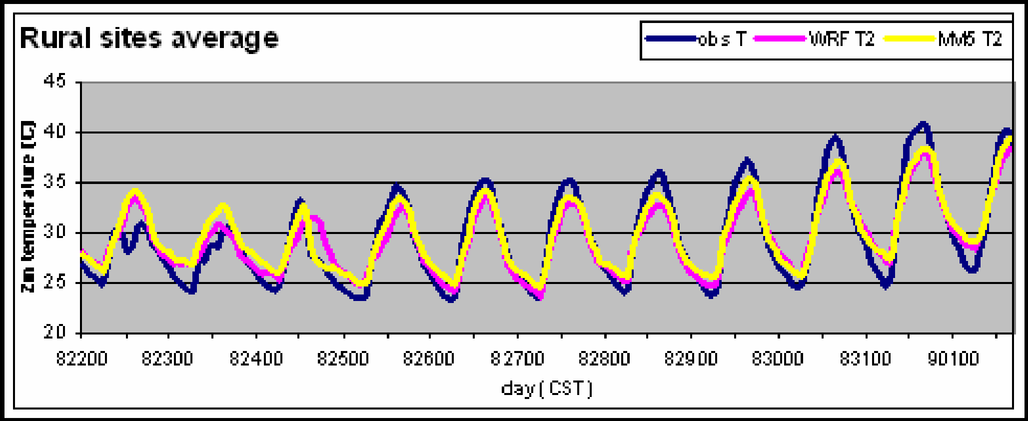
- Lack of the “grid-nudging tool” with WRF is the main cause of failure.
  - ➔ **Use single domain for the simulation**



Model version:	WRF v2.0.3.1 & MM5 v3.6.7
Time period:	2000/8/22 00UTC ~ 9/2 00UTC
IC/BC:	From 40 km Eta reanalysis data (AWIP)
Physics:	Same as before
Grid size:	161*146*43 layers
Resolution:	4 km
Nudging:	NO

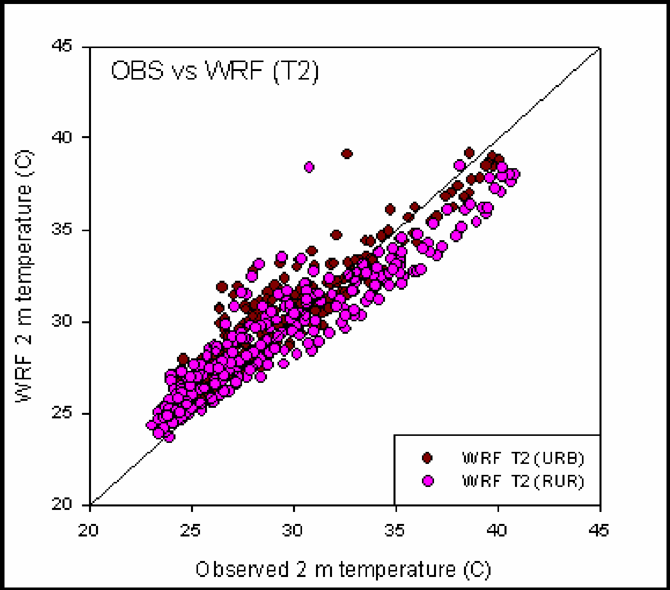
2 m temperature

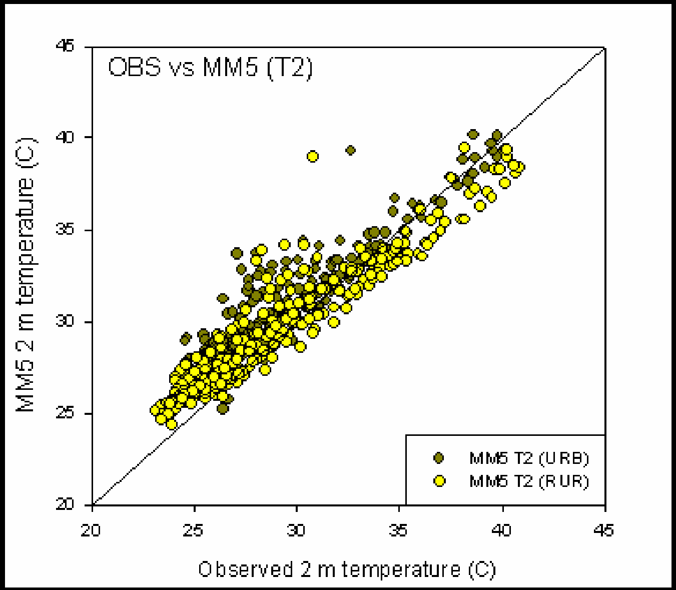




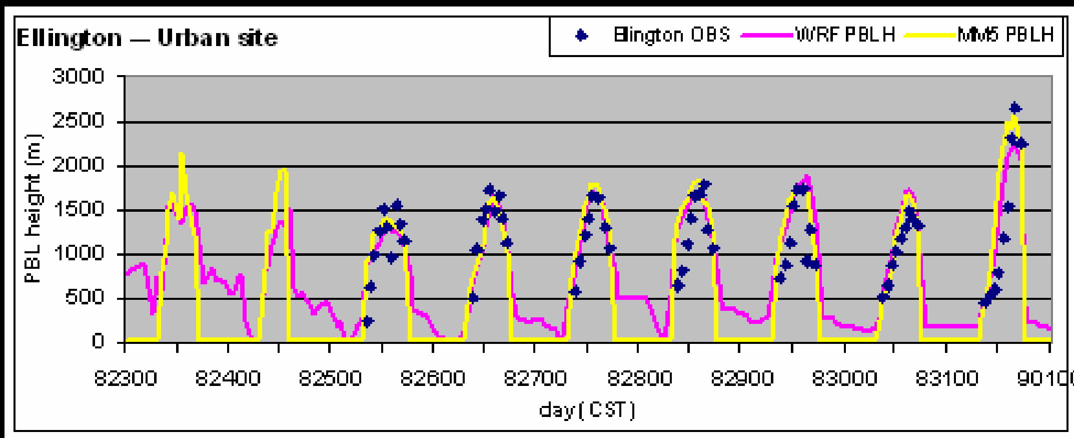
- Urban sites:
  WRF improves min temp. but still too high
- Rural site:
  Min temp. and max temp. are mildly underestimated
- Well correlated with obs.

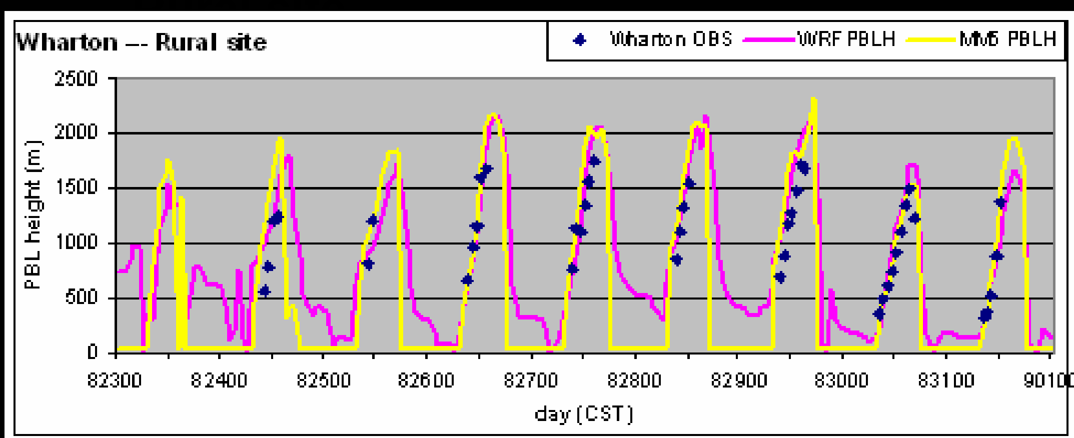
Scattered diagram of 2 m temperature





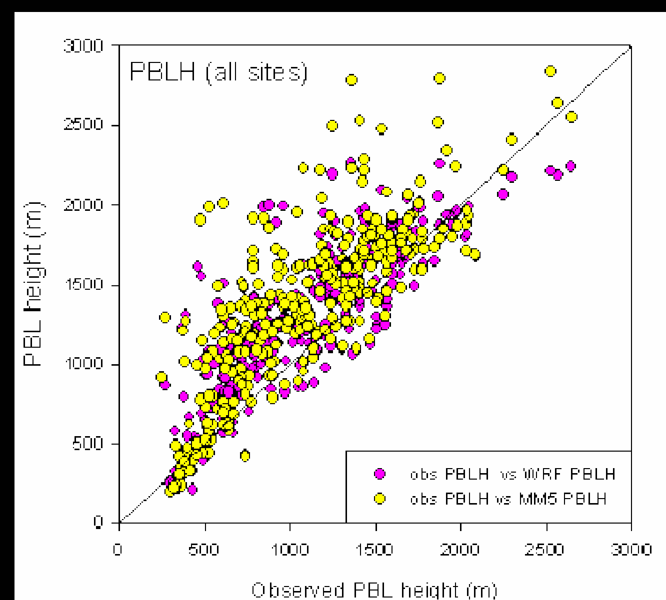
PBL Height





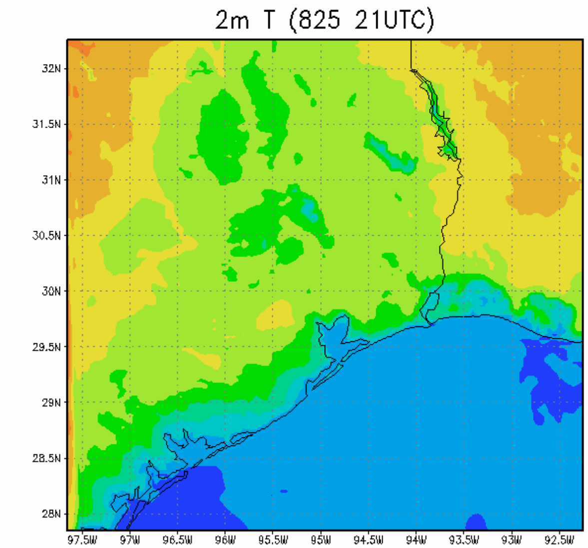
- During daytime models are able to capture PBLH
- At nighttime MM5 dose not report PBL heights (~33m) WRF reports estimated values But, there is no nighttime OBS to compare the results

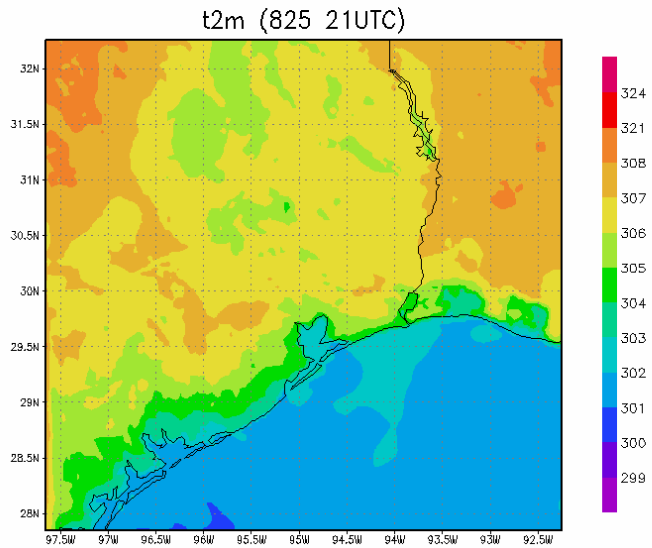
- Scattered diagram (5 profiler sites): WRF simulated the PBL height better than MM5

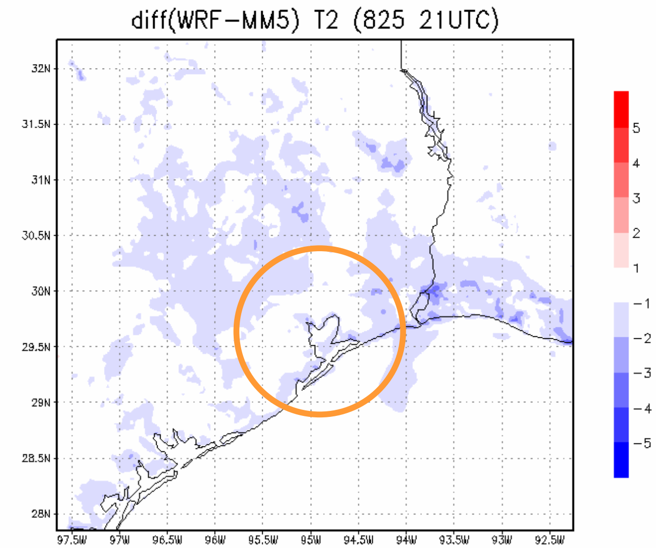


2m Temperature (21UTC = 15CST)

WRF | MM5 | WRF – MM5

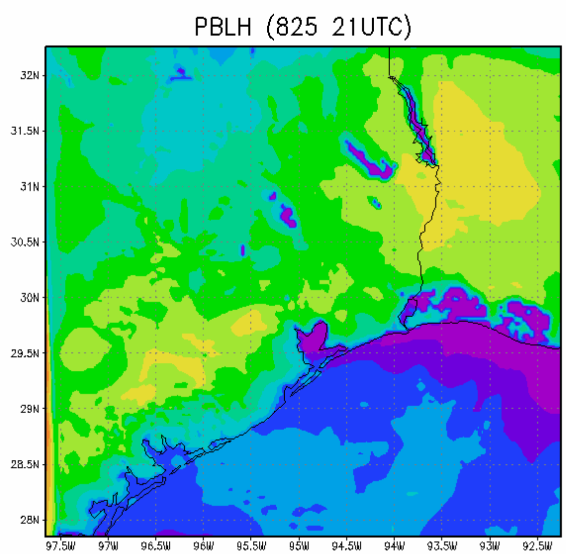


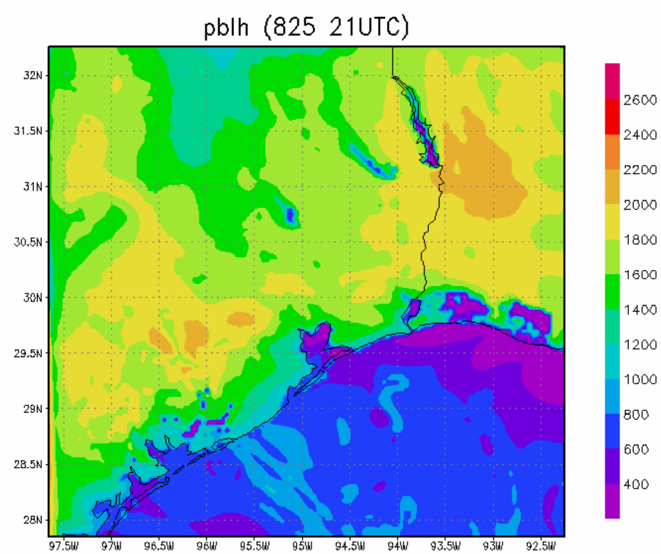


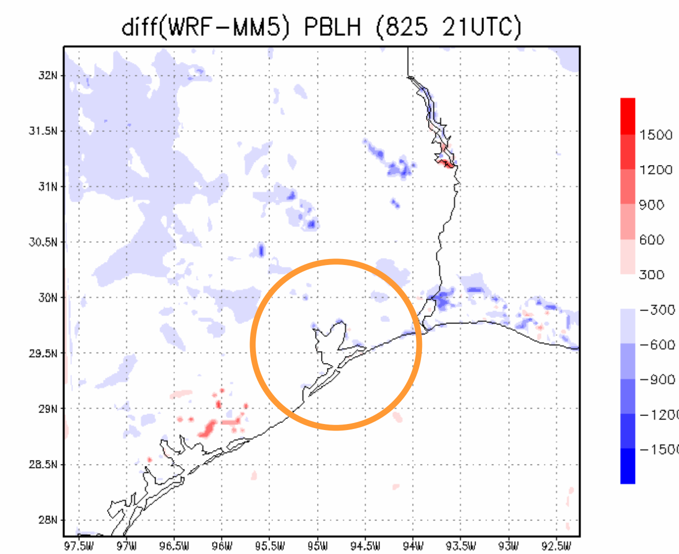


PBL Height (21UTC = 15CST)

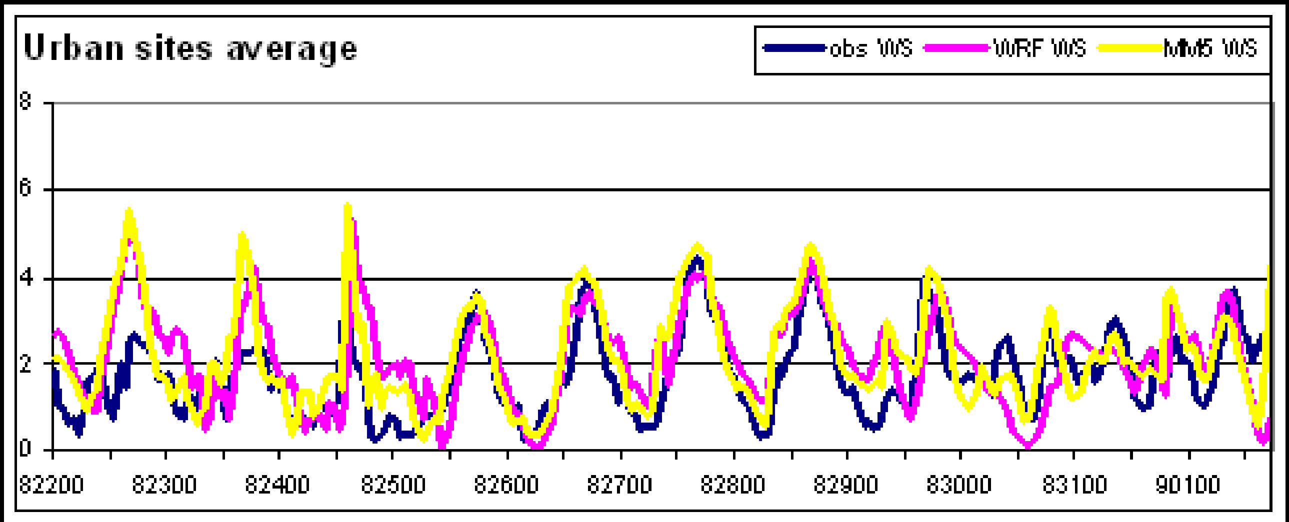
WRF | MM5 | WRF – MM5

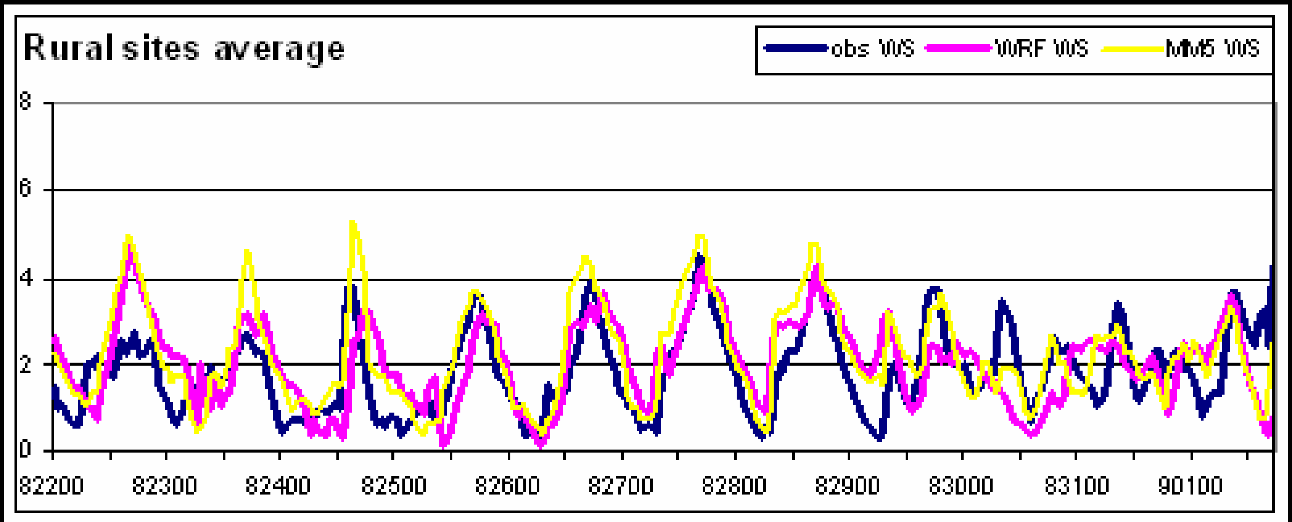






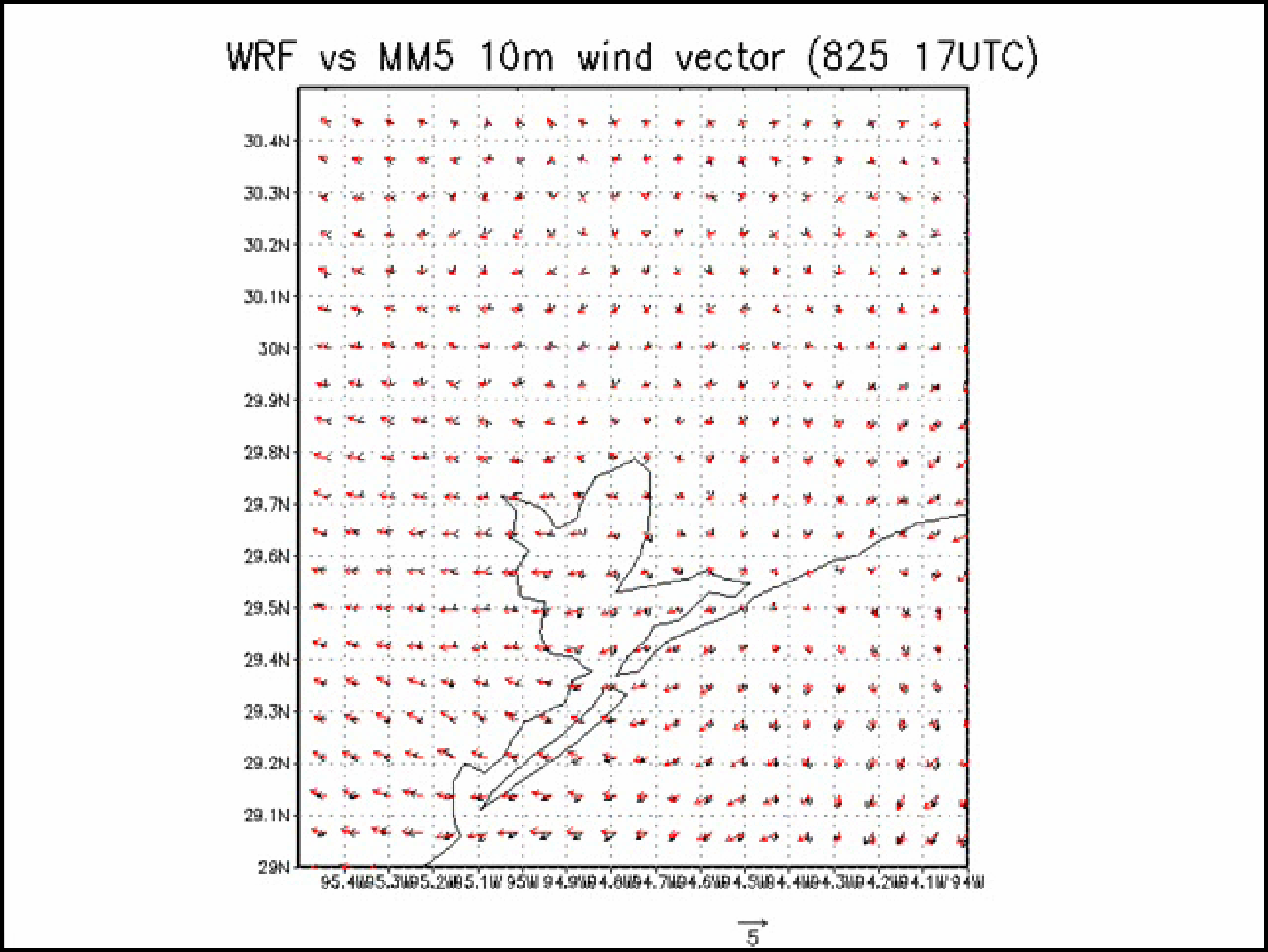
10 m Wind Speed





- model performance characteristics at urban and rural sites are similar.
- somewhat noisy
- doing well on 26 ~ 29, Aug.
- needs improvement

10 m Wind Vector (from 17 to 22 UTC)



Black arrows: WRF result
Red arrows: MM5 result

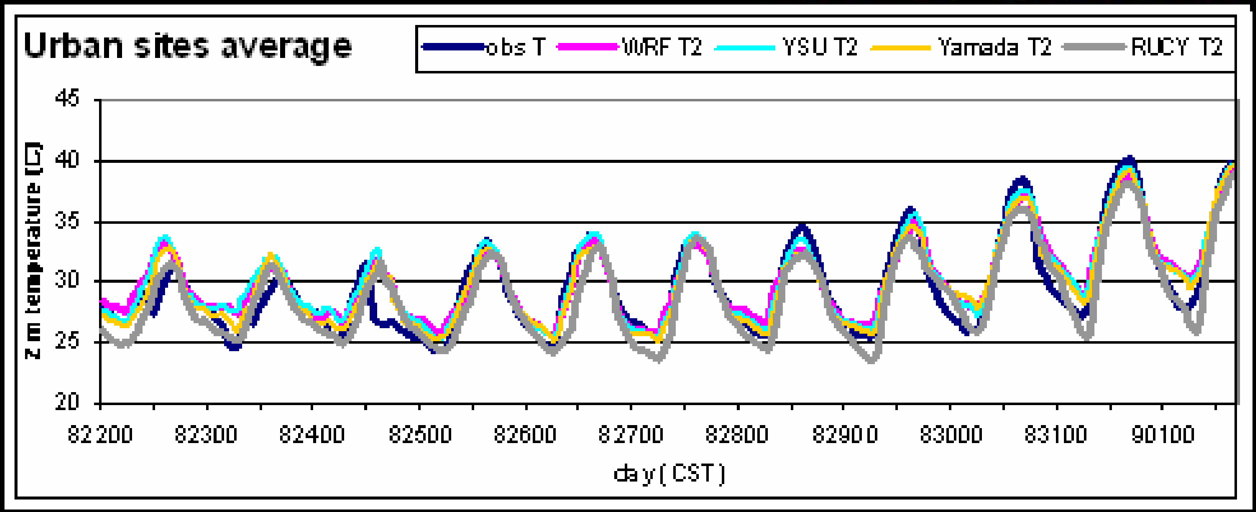
Sea breeze developed at the late afternoon.
The development of sea breeze in WRF was later than MM5

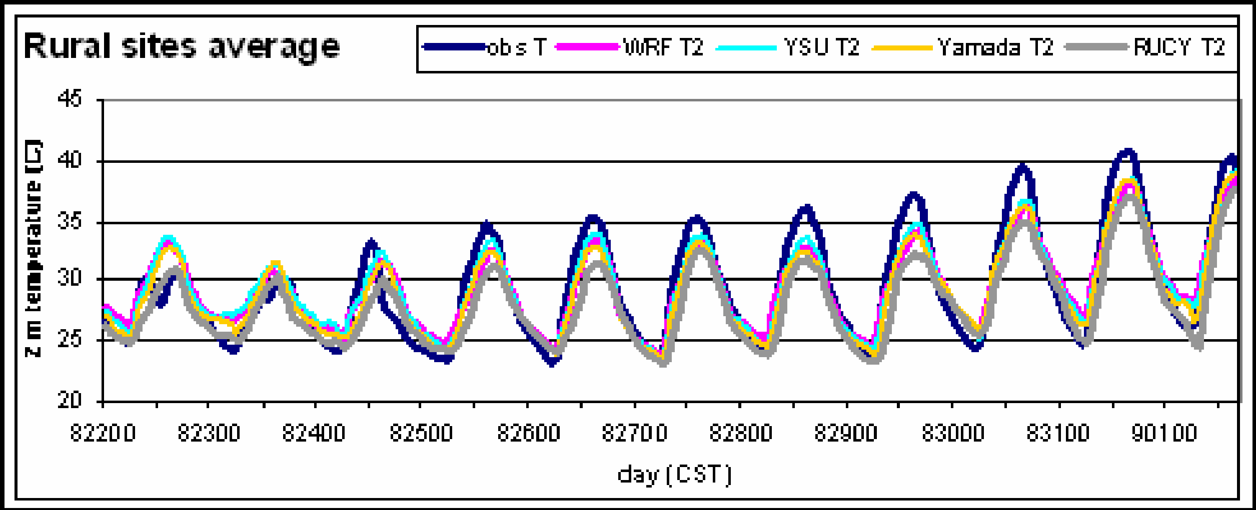
Sensitivity Tests

- PBL scheme: YSU scheme, Mellor-Yamada-Janjic TKE scheme and MRF scheme
- Land-surface: Noah LSM and RUC LSM

	WRF	YSU	Yamada	RUCY
Microphysics	Simple ice (Dudhia)			
Radiation	RRTM (longwave) Dudhia (shortwave)			
LSM	Noah LSM			RUC LSM
PBL	MRF	YSU	Yamada	Yamada
CU scheme	None			

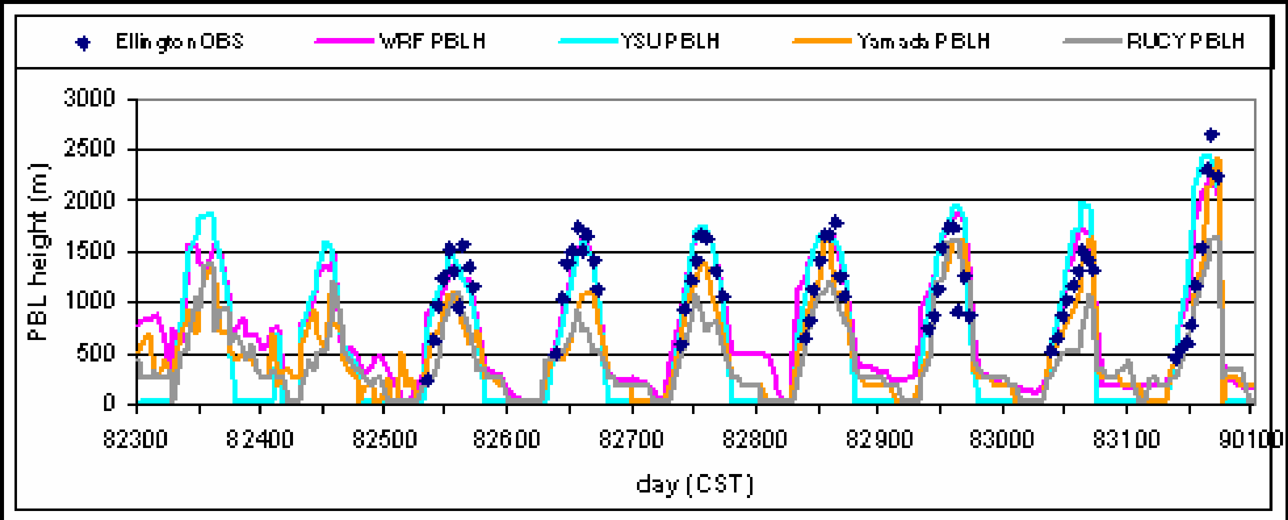
Sensitivity tests --- 2m temperature

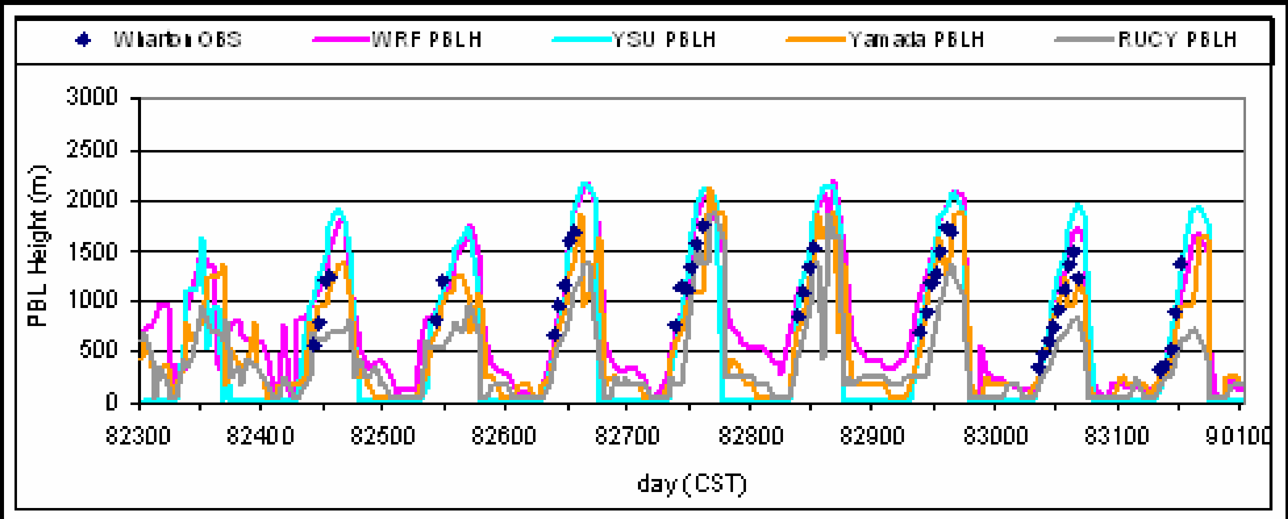


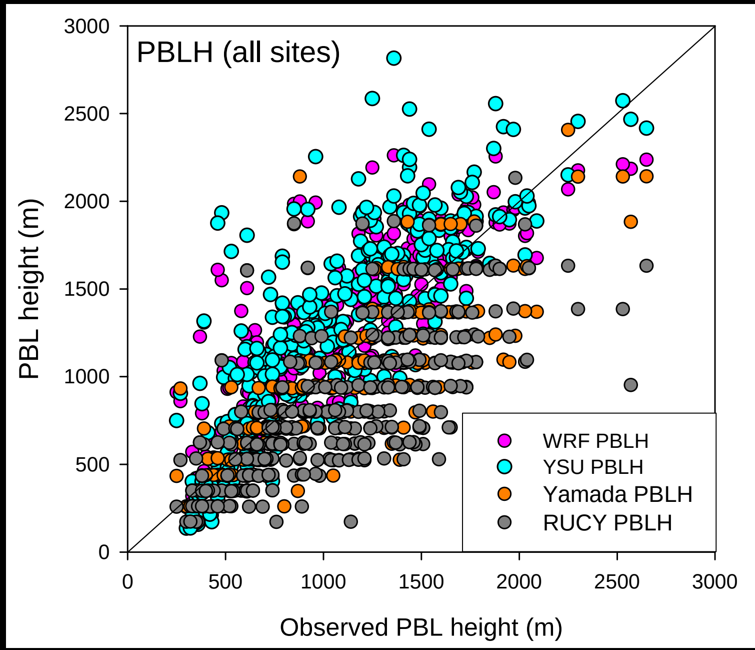


- Results of WRF, YSU and Yamada runs are almost the same.
- 2-m Temp. by RUCY run is underestimated more than those by others; but it overestimated min temp for urban sites.

Sensitivity tests --- PBLH







- YSU PBL scheme does not report PBLH at nighttime. (~17m)
- RUCY run underestimated PBLH much more (gray dots) while YSU run overestimated PBLH more (blue dots)

Summary

- WRF is not ready for nesting simulation without FDDA.

  No synoptic phenomena can propagate to the fine domains through BC alone.

- Single domain simulation of WRF:

  Simulated 2 m temperature is highly correlated with the OBS.

  Mildly underestimated min and max temp.

  Development of PBL can be captured but overestimated

  Nighttime measurements can help to evaluate results

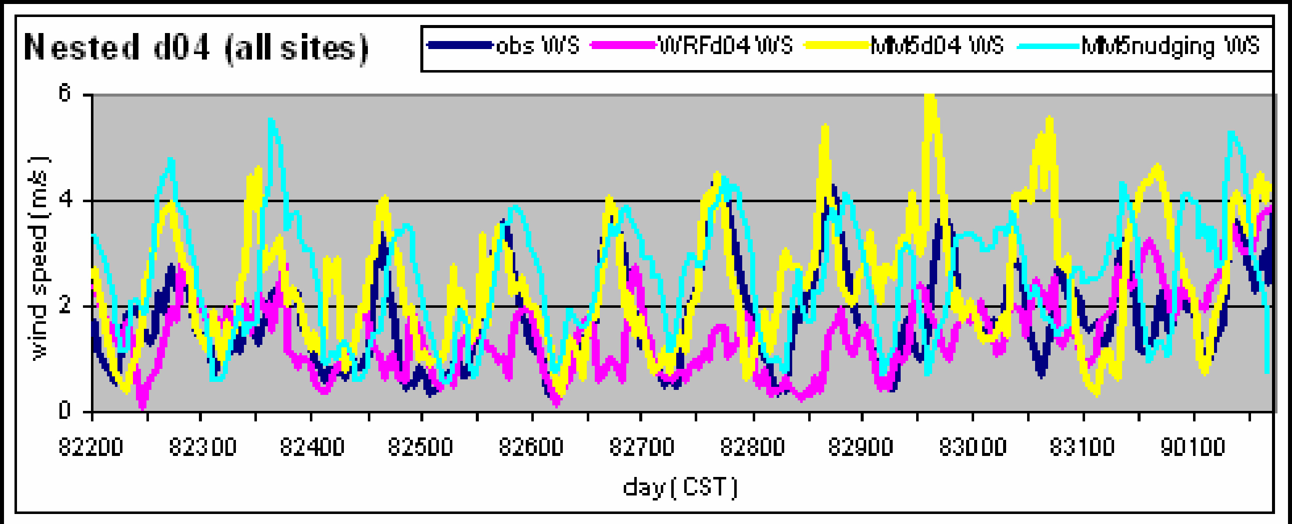
  10 m wind speed results varied during the simulation period

Future Work

- MCIP3 with WRF and MM5 output for generating met. inputs for air quality model, CMAQ.

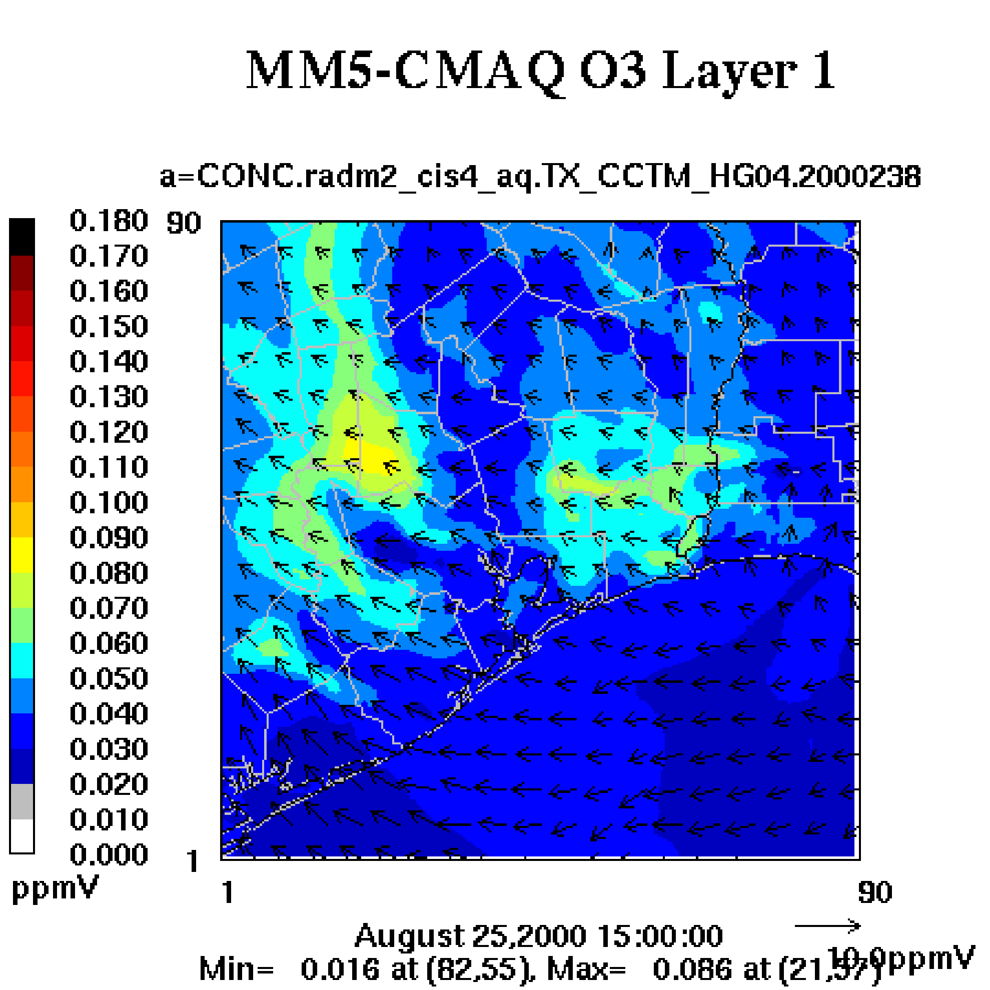
- Evaluate WRF-CMAQ and MM5-CMAQ to figure out the best way for linking WRF and CMAQ while maintaining the dynamic consistency in the off-line air quality modeling.

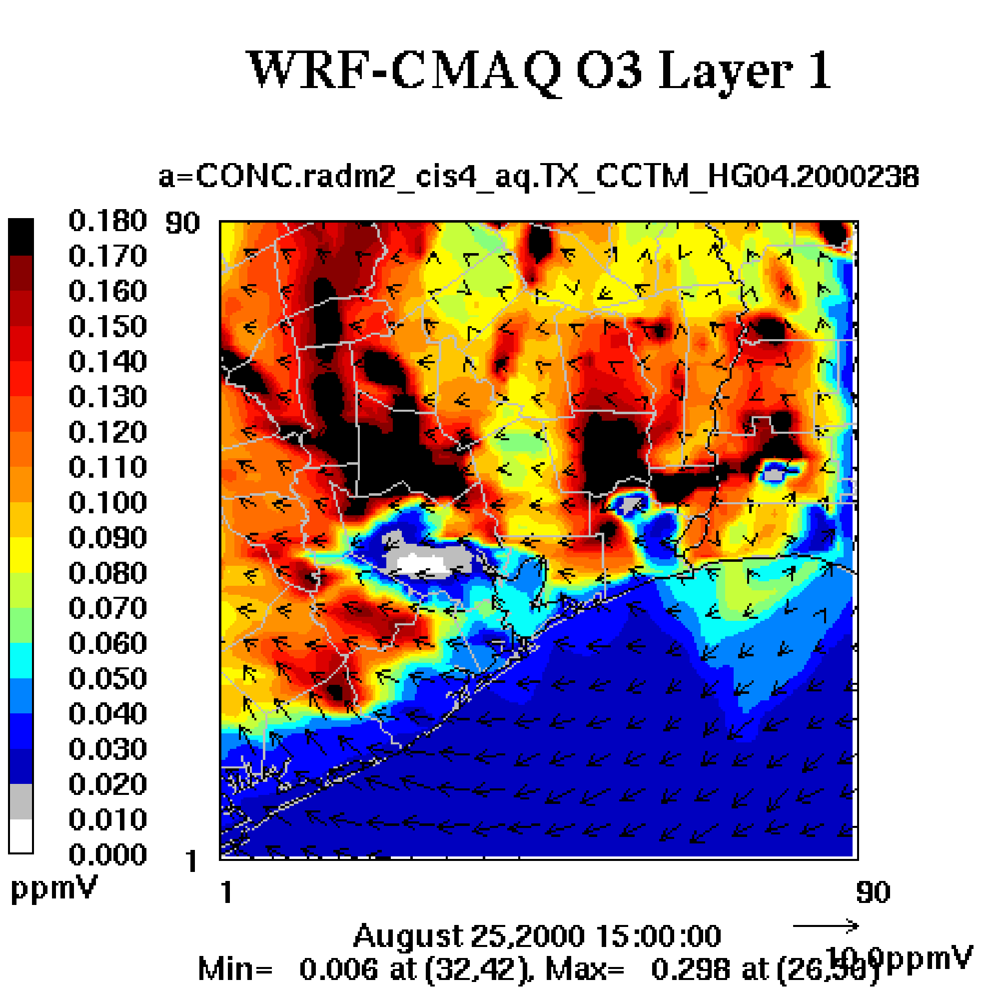
Time Series of D4 (4 km domain): 10 m wind speed

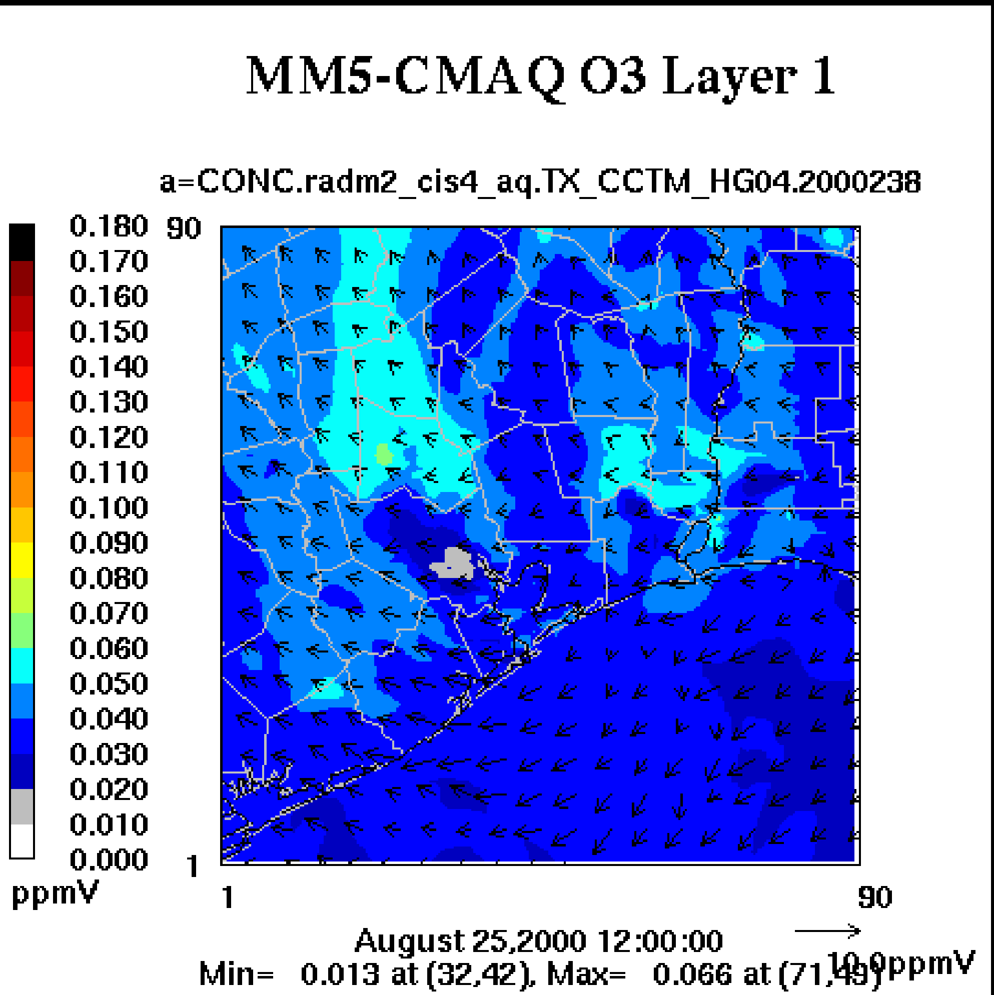


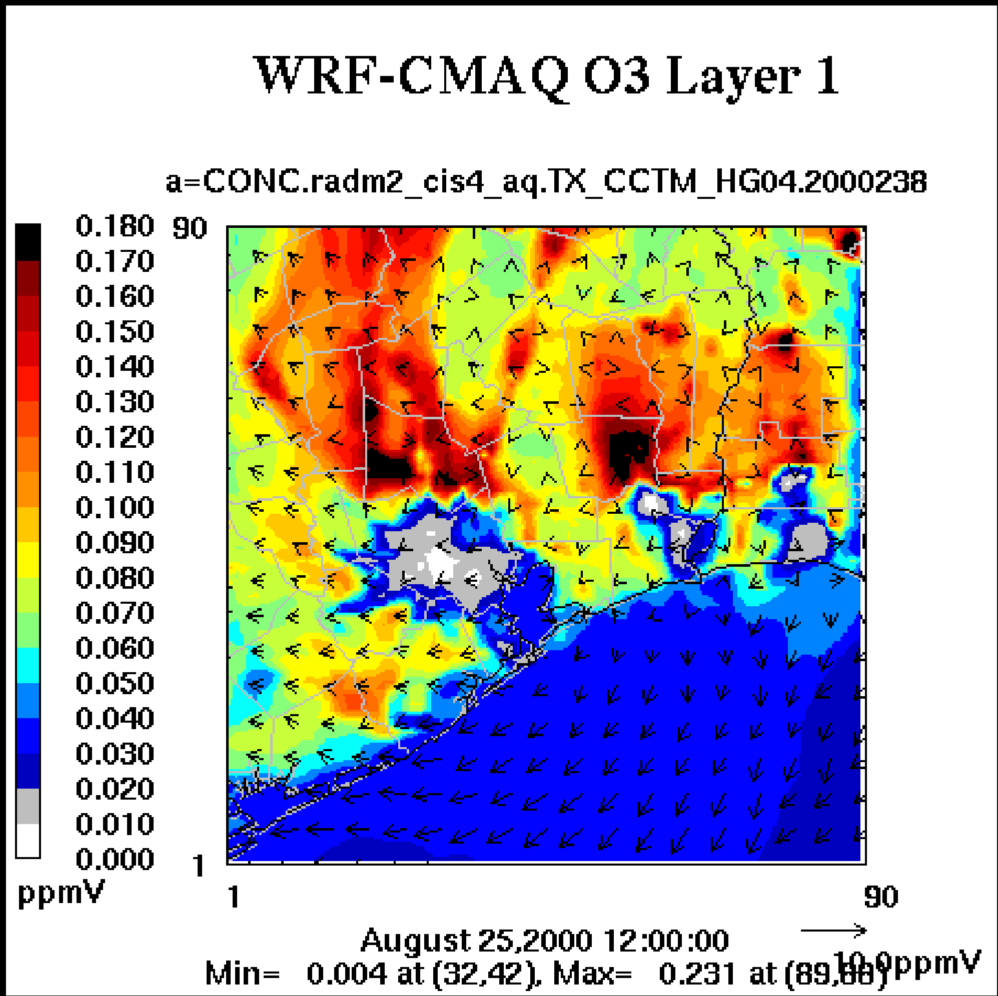
WRF-CMAQ v.s MM5-CMAQ

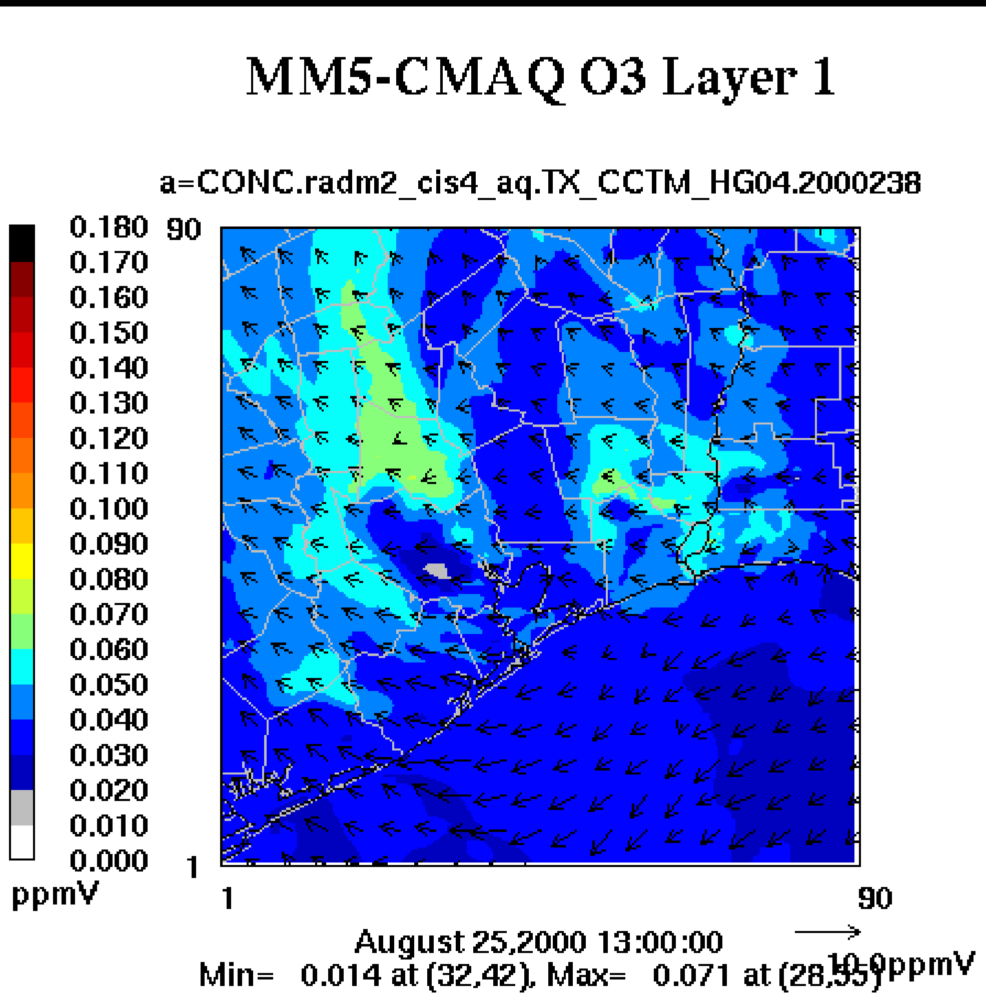
Model version: CMAQ 4.3
Grid size: 90*90*34
Resolution: 4 km
Mechanism: radm2-cis4-aq
Solver: mebi-radm2-cis4

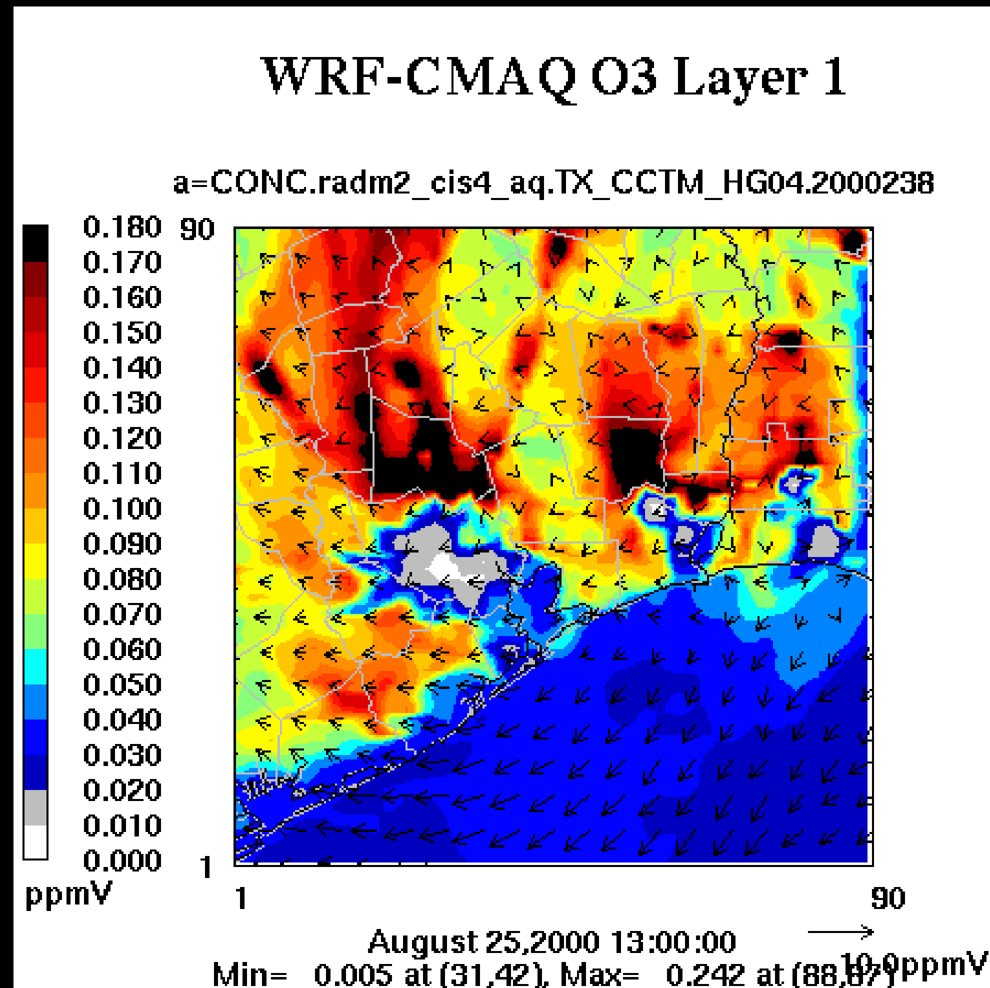


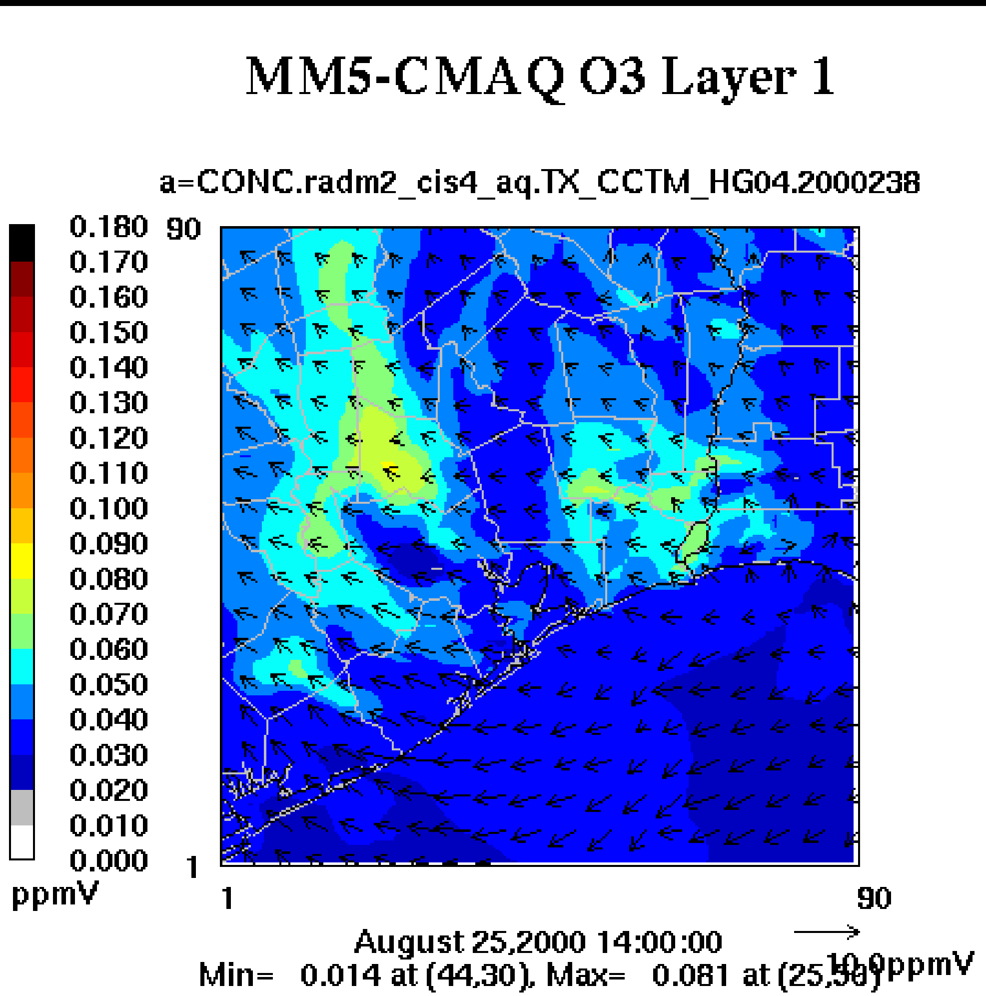


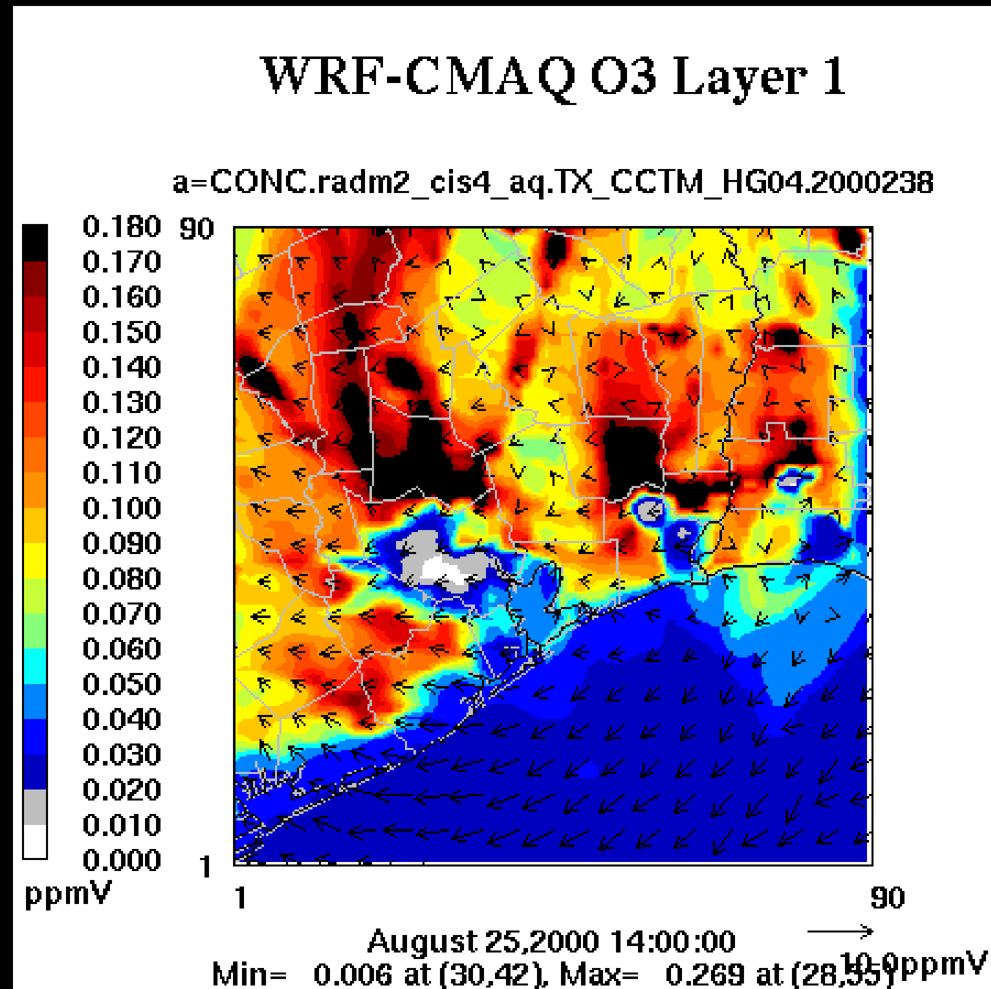

MM5-CMAQ O3 Layer 1
a=CONC.radm2_cis4_aq.TX_CCTM_HG04.2000238
0.180
0.170
0.160
0.150
0.140
0.130
0.120
0.110
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
ppmV
90
1
1
90
August 25,2000 12:00:00
Min= 0.013 at (32,42), Max= 0.066 at (71,49)
10.0ppmV


WRF-CMAQ O3 Layer 1
a=CONC.radm2_cis4_aq.TX_CCTM_HG04.2000238
0.180
0.170
0.160
0.150
0.140
0.130
0.120
0.110
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
ppmV
90
1
1
90
August 25,2000 12:00:00
Min= 0.004 at (32,42), Max= 0.231 at (89,88)
10.0ppmV


MM5-CMAQ O3 Layer 1
a=CONC.radm2_cis4_aq.TX_CCTM_HG04.2000238
0.180
0.170
0.160
0.150
0.140
0.130
0.120
0.110
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
ppmV
90
1
1
90
August 25,2000 13:00:00
Min= 0.014 at (32,42), Max= 0.071 at (28,55)
10.0ppmV


WRF-CMAQ O3 Layer 1
a=CONC.radm2_cis4_aq.TX_CCTM_HG04.2000238
0.180
0.170
0.160
0.150
0.140
0.130
0.120
0.110
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
ppmV
90
1
1
90
August 25,2000 13:00:00
Min= 0.005 at (31,42), Max= 0.242 at (88,87)
10.0ppmV


MM5-CMAQ O3 Layer 1
a=CONC.radm2_cis4_aq.TX_CCTM_HG04.2000238
0.180
0.170
0.160
0.150
0.140
0.130
0.120
0.110
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
ppmV
90
1
1
90
August 25,2000 14:00:00
10.0ppmV
Min= 0.014 at (44,30), Max= 0.081 at (25,50)


WRF-CMAQ O3 Layer 1
a=CONC.radm2_cis4_aq.TX_CCTM_HG04.2000238
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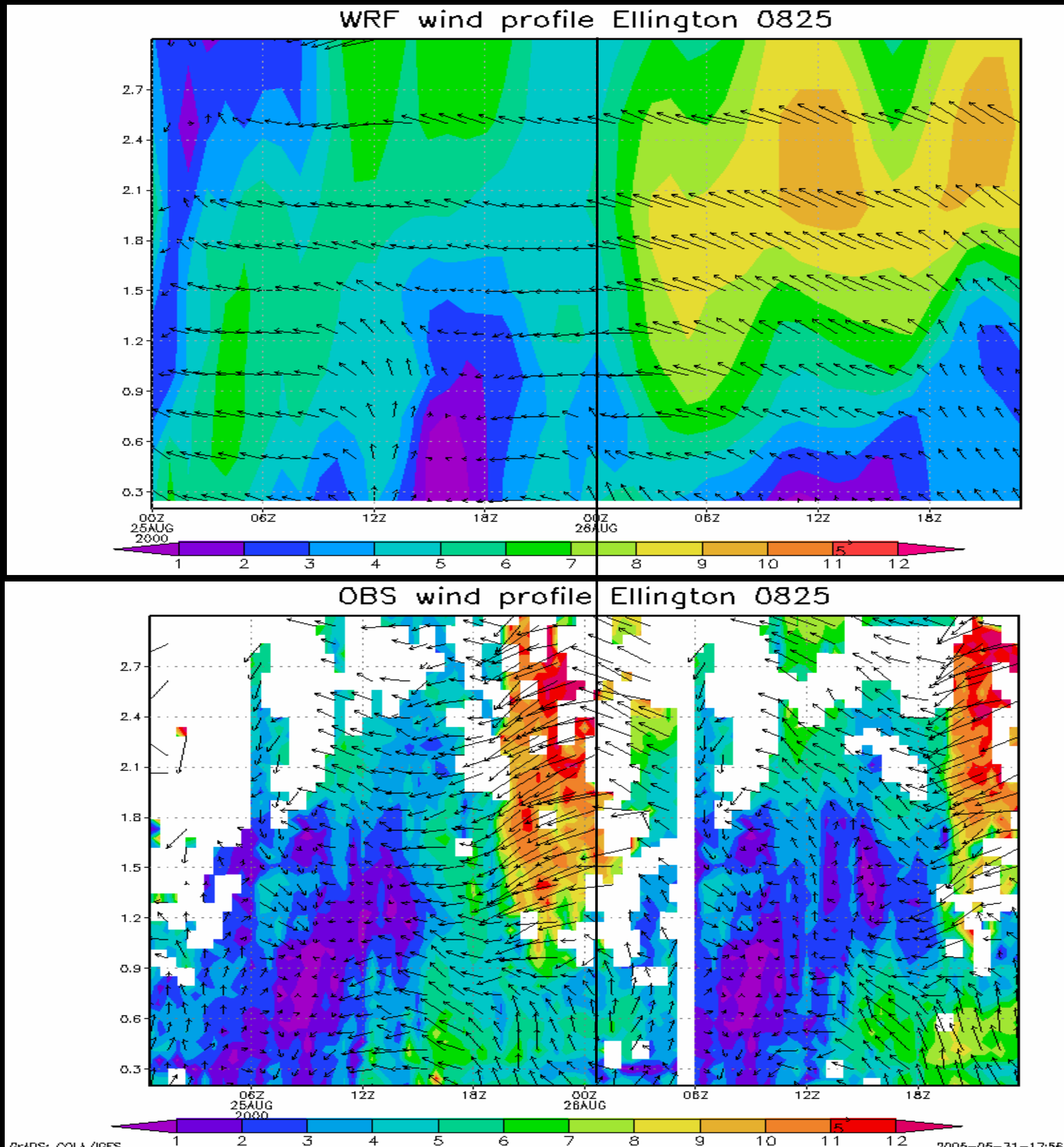
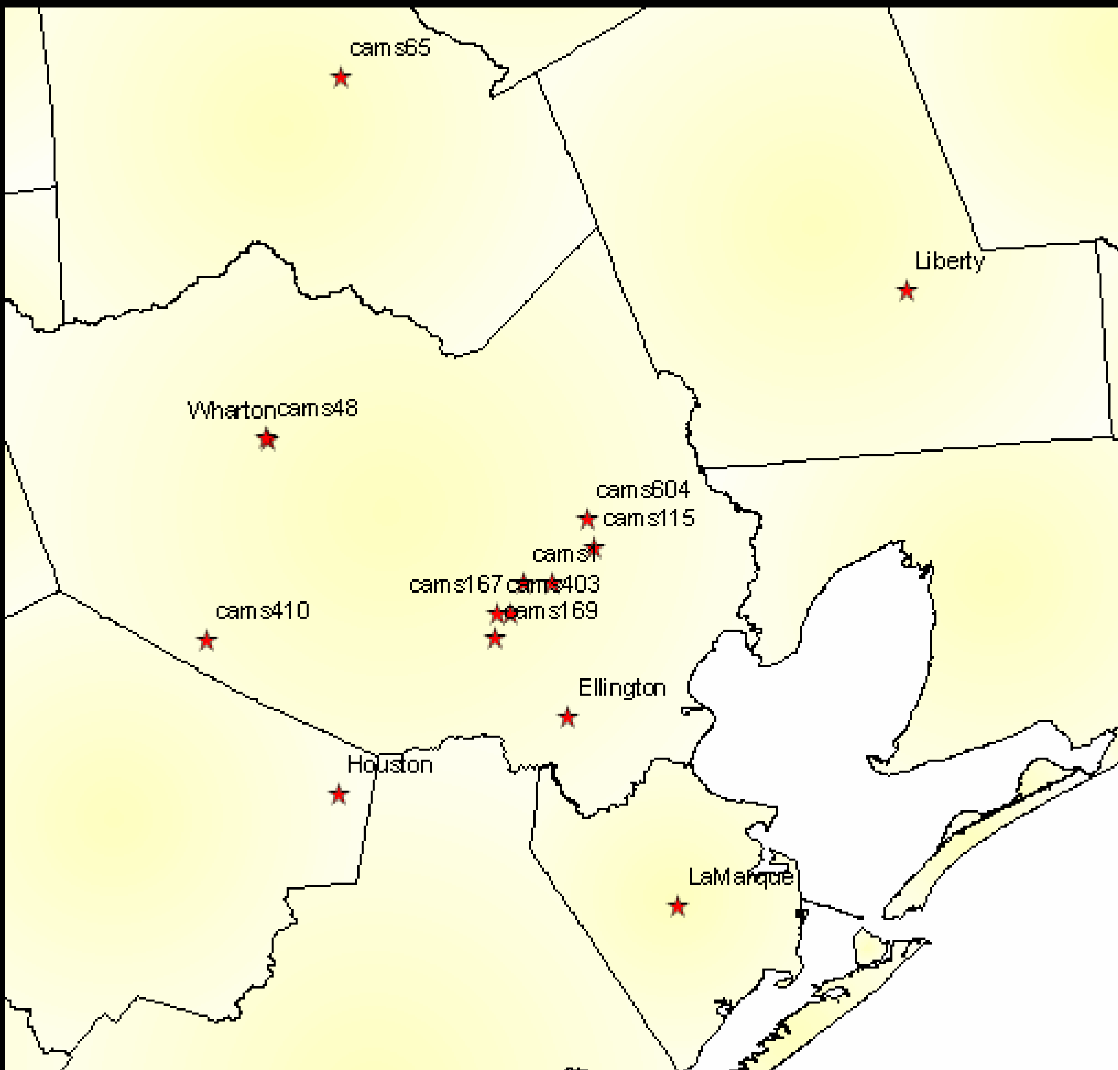
0.170
0.160
0.150
0.140
0.130
0.120
0.110
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
ppmV
90
1
1
90
August 25,2000 14:00:00
10.0ppmV
Min= 0.006 at (30,42), Max= 0.269 at (28,55)

Wind Profile 08/25 08/26



Observation Sites

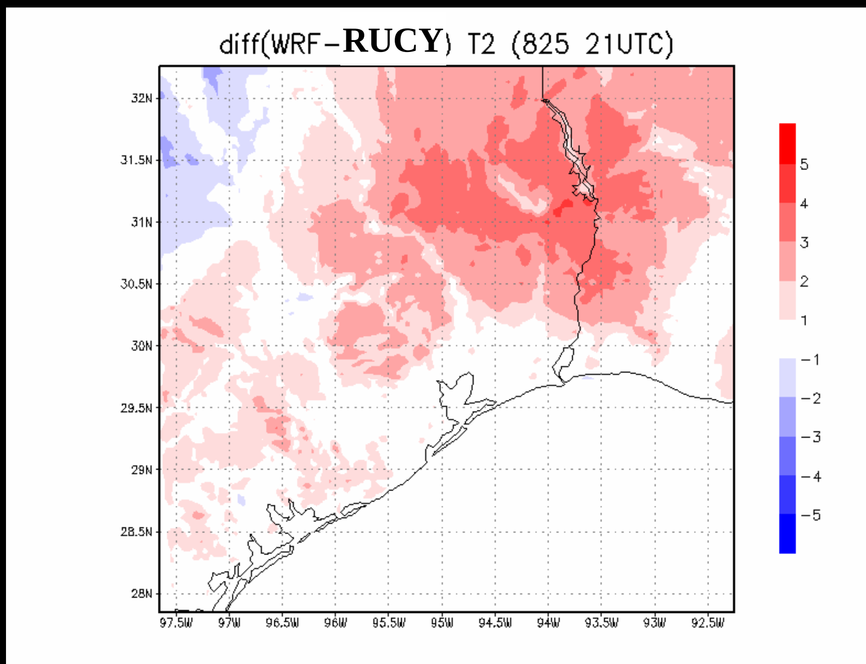


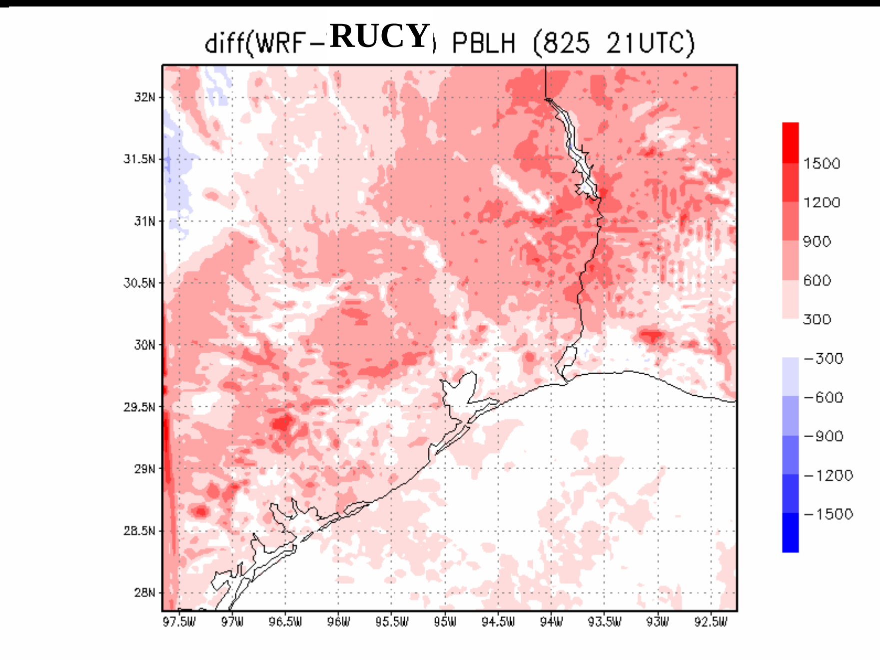
Surface OBS
urban sites ---
cams 1, 169, 115, 167, 403
rural sites ---
cams 48, 410, 603, 604, 65

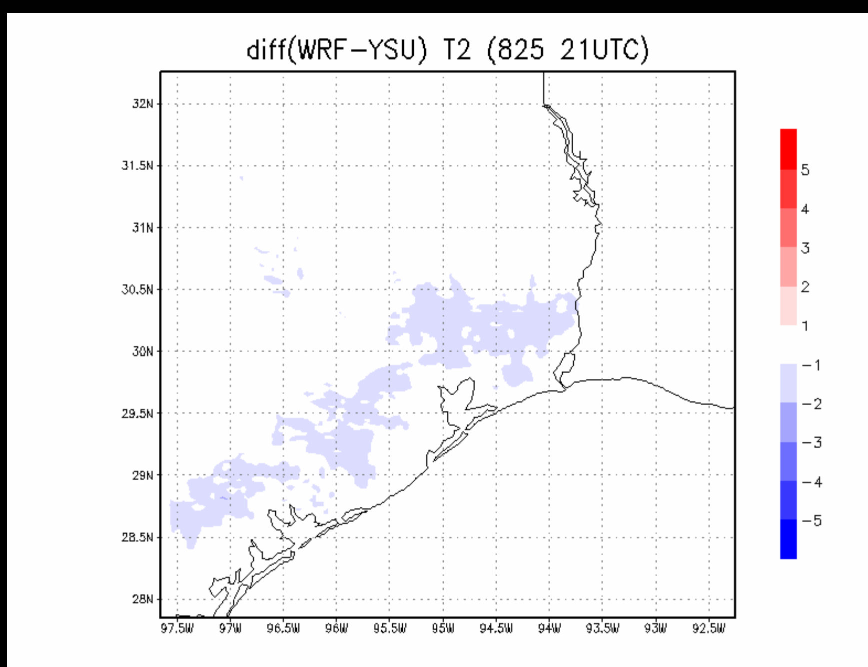
Profile OBS
Ellington, Houston SW, Liberty, LaMarque and Wharton

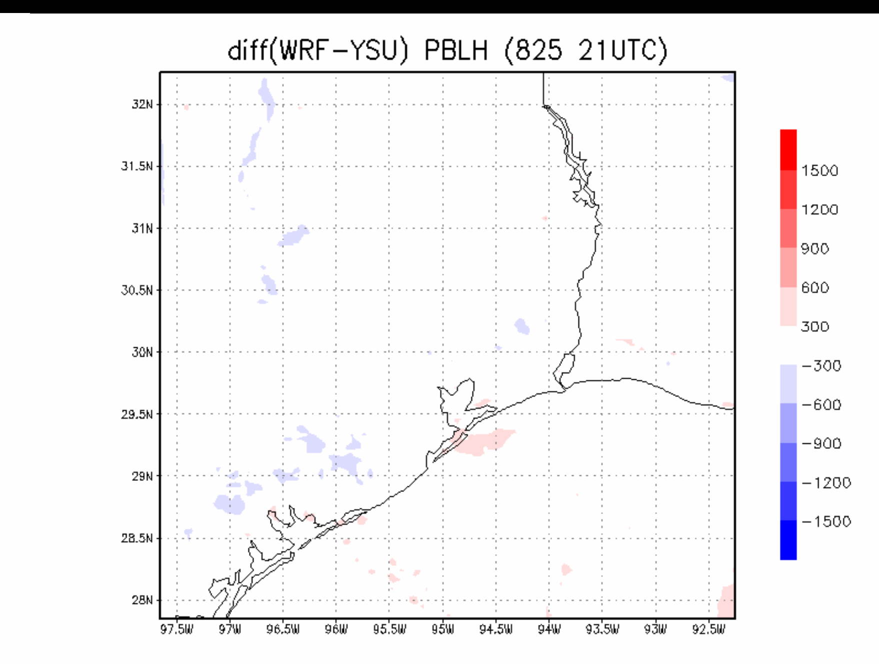
2m Temperature

PBL Height



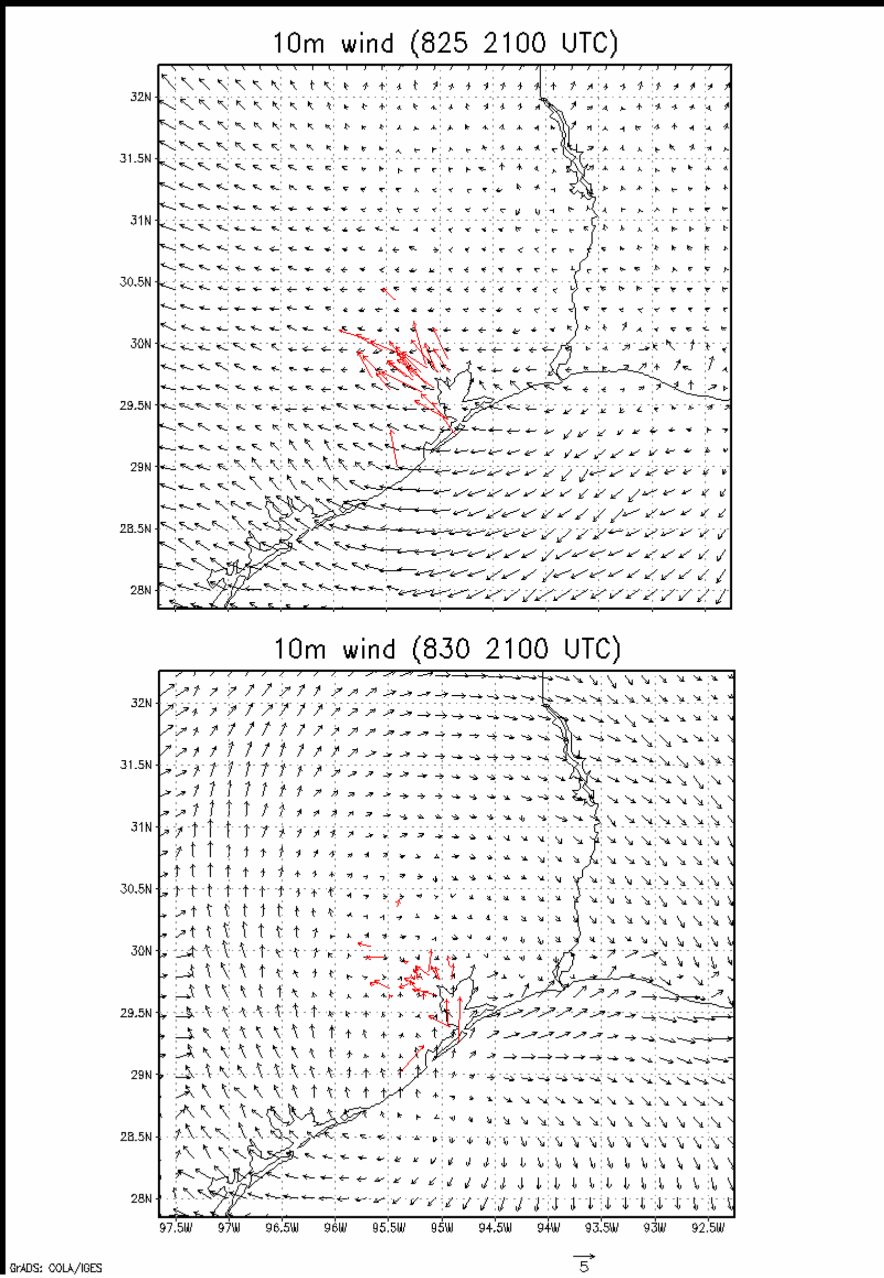




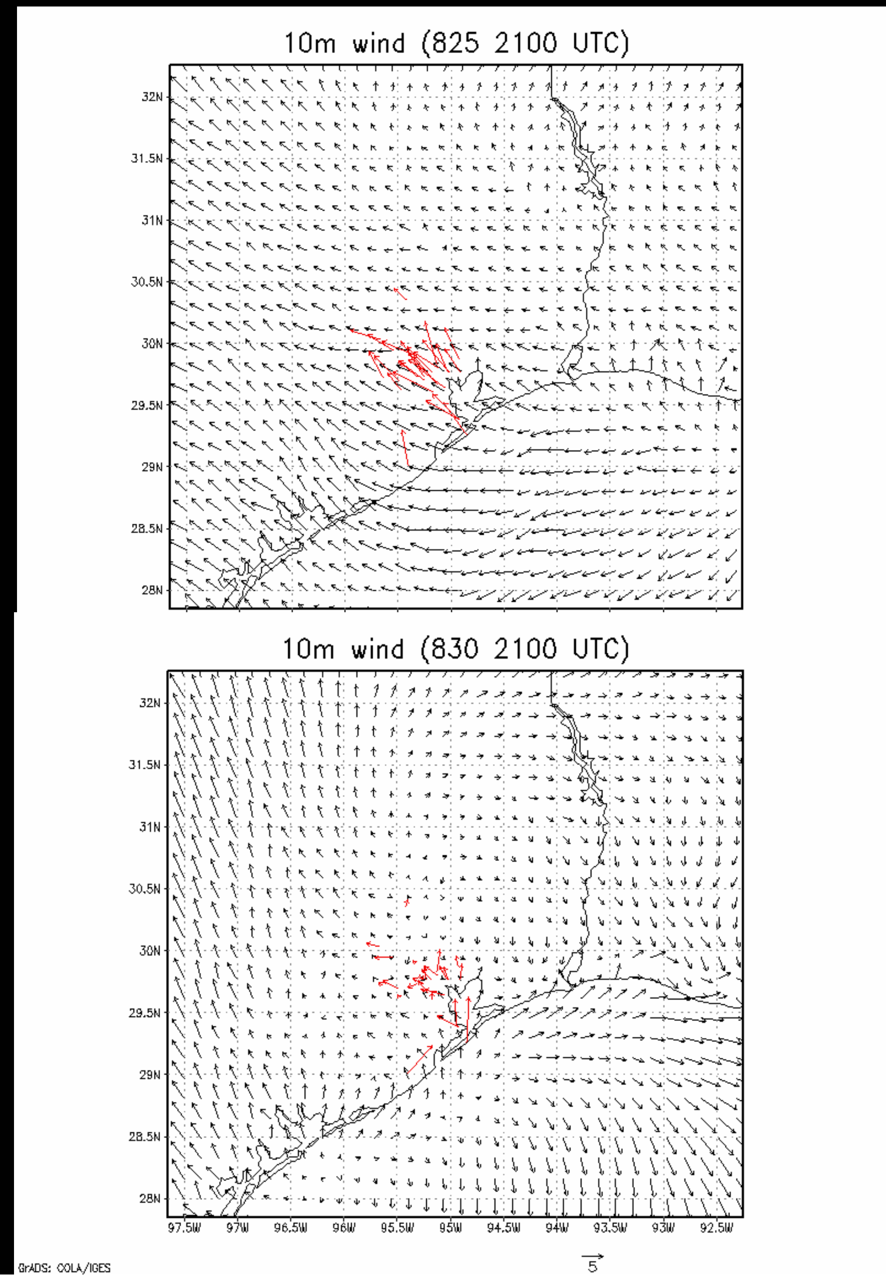


10 m Wind (21UTC = 16:00 p.m)

WRF

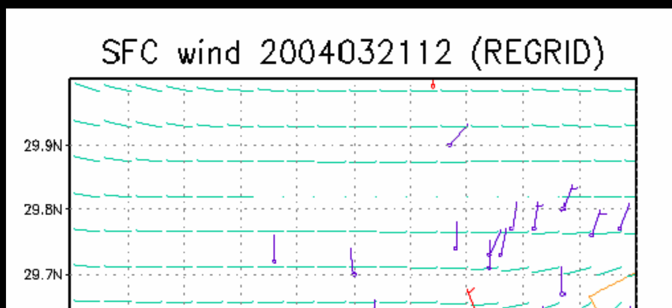


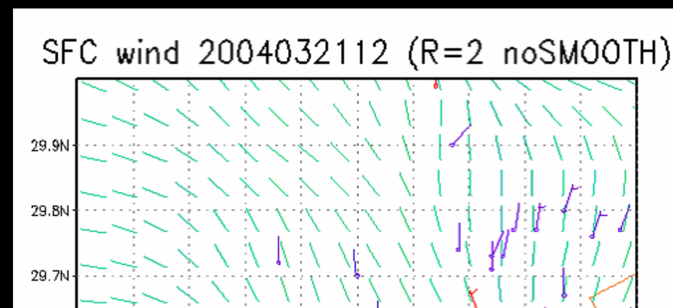
MM5



Introduction

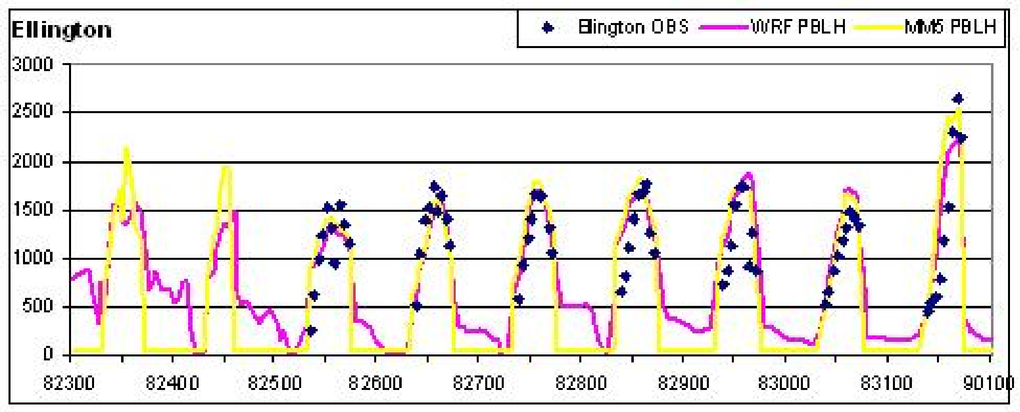
ex. Different wind fields can be obtained by different models
➔ results in different plume trajectories

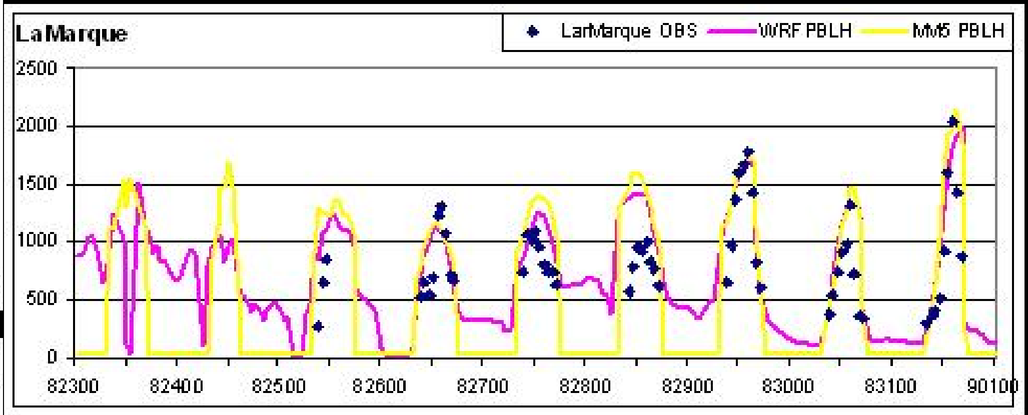


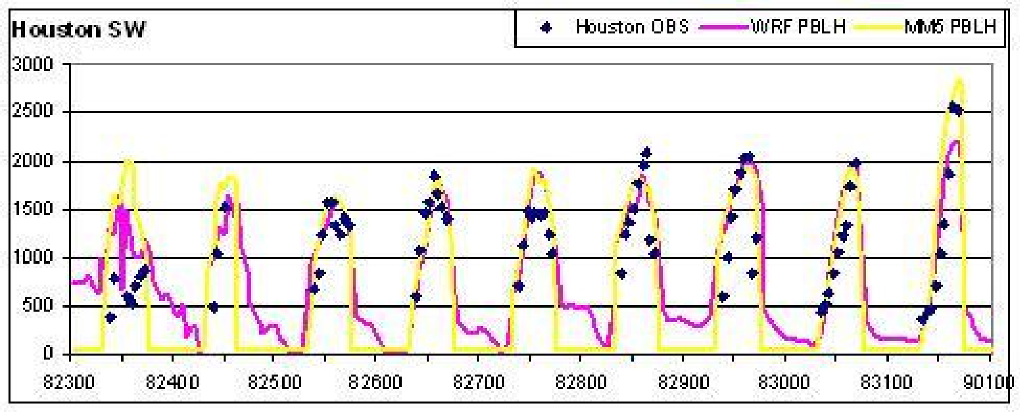


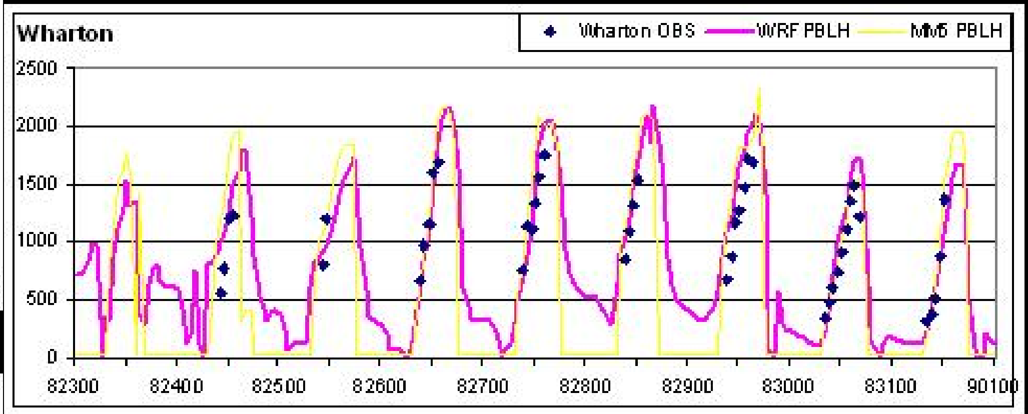
The meteorological conditions must be accurately simulated to correctly model Houston air quality.
In this study, we test if the new state-of-science weather forecasting model, WRF, can simulate met. conditions of TexAQS 2000.

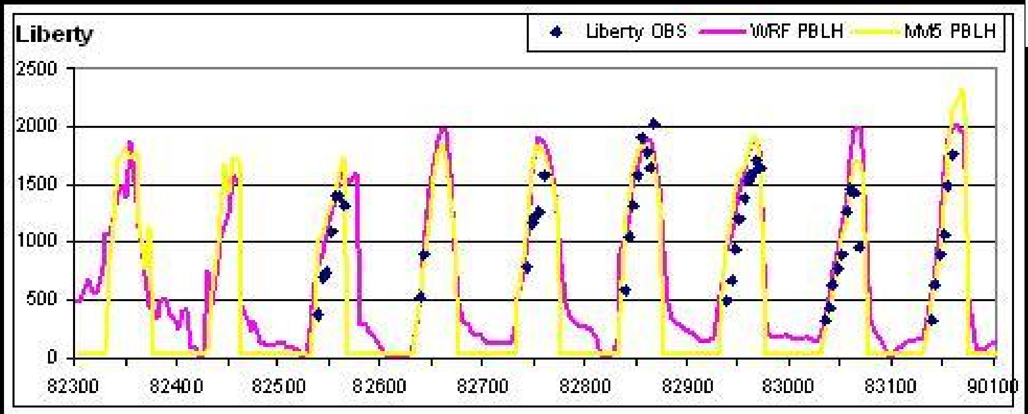
Time Series: PBL Hight







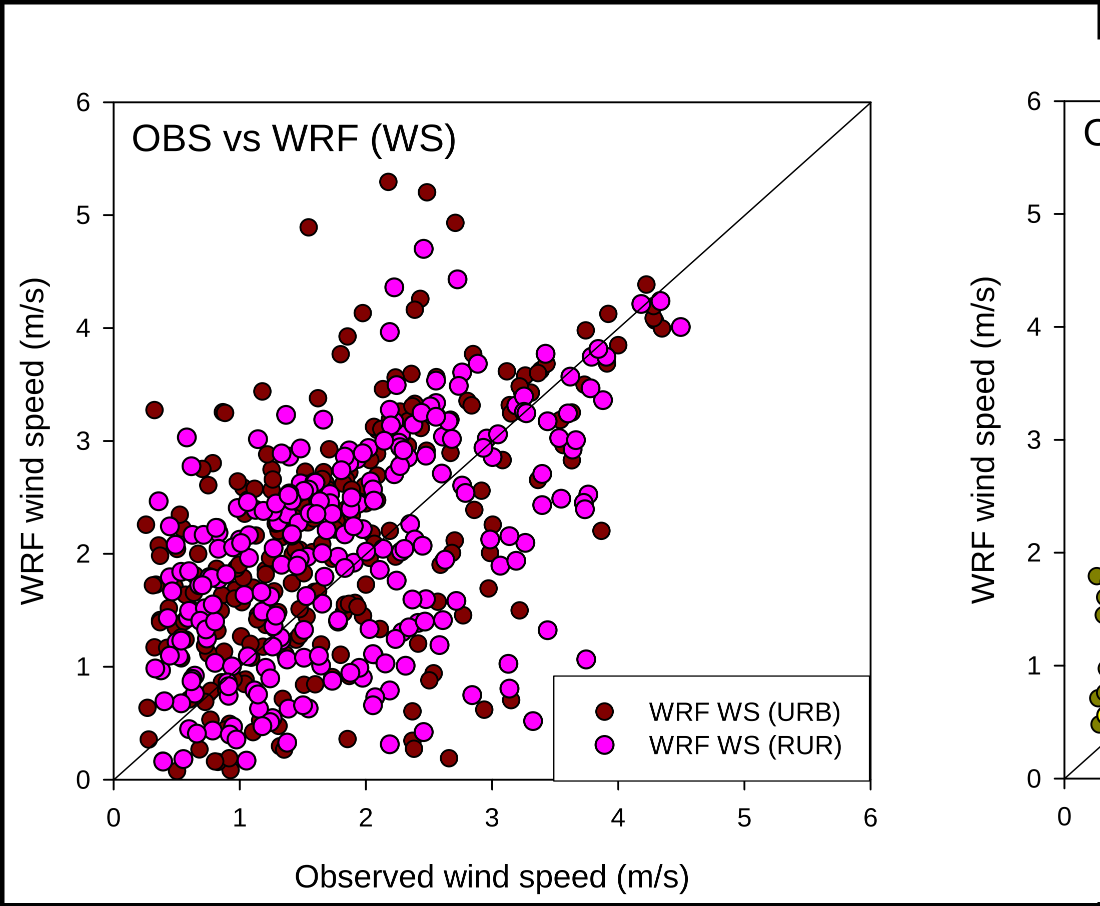


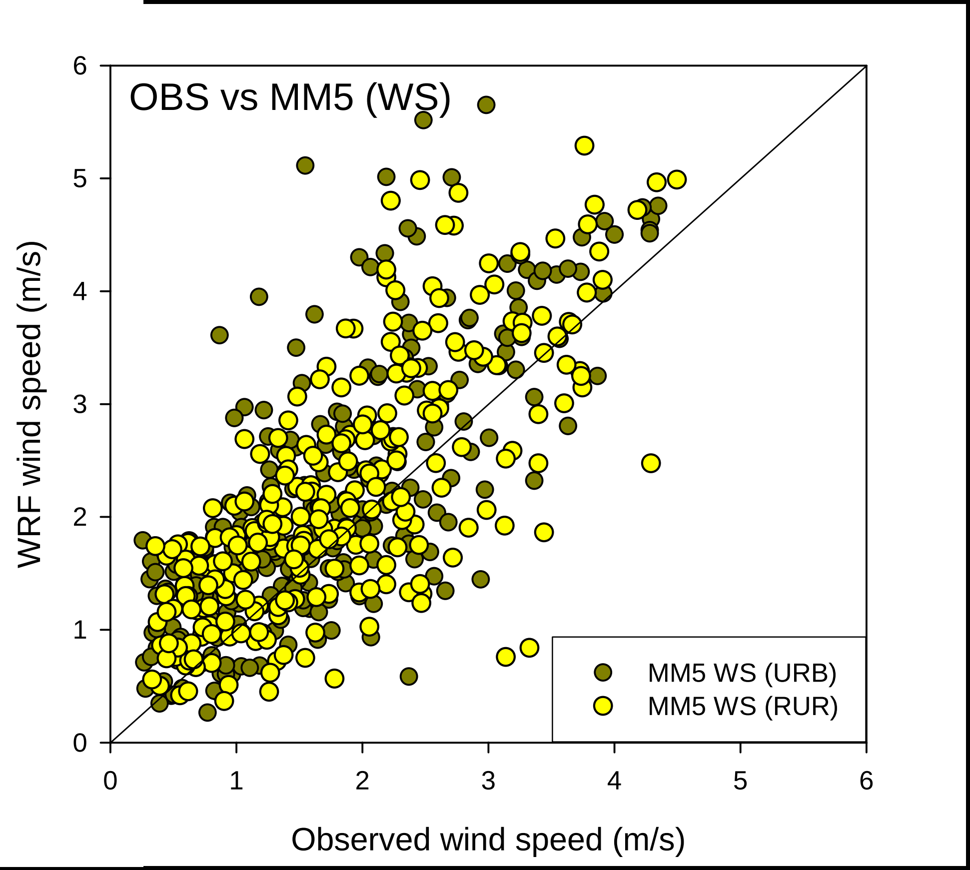


WRF PBLH drops gradually
MM5 PBLH drops rapidly

Max: MM5 > WRF

10 m Wind Speed (single domain)





Future Works

- Improve the wind field simulation with WRF thorough the application of a grid nudging tool

- Apply WRF output to air quality modeling to develop a method to effectively link WRF and an AQ model maintaining dynamic consistency

Acknowledgment:

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