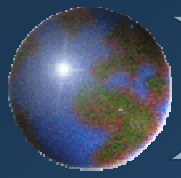


TCEQ, Austin, TX
1st May, 2008

UNIVERSITY of HOUSTON
IMAQS

Improvement of meteorological inputs for TexAQS-II air quality simulations

Fong Ngan, Daewon W. Byun, XiangShang Li and DaeGyun Lee

Institute for Multidimensional Air Quality Studies

Department of Earth and Atmosphere Sciences

University of Houston

Motivation and Objective

AQF was successfully for the planning and implementation of various measurements but some systematic problems were found;

- Over-prediction of northerly wind caused by inaccurate synoptic input.
- Sometimes, too strong southerly caused by sea breeze development.
- Discrepancies in max & min temperature for certain days.
- Precipitation & clouds not simulated well occasionally.

"Challenge is how to overcome serious biases in synoptic flows from NMM while downscaling"

The objective of this study is to generate better meteorological inputs than the AQF results to support the chemistry modeling.

MUltiscale Nest-down Data Assimilation System (MUNDAS):

Utilize existing objective analysis and nudging tools in the MM5 system
Incorporate extensive OBS available in the simulated domain for the retrospective simulation of the TexAQS-II period.

Introduction

With MUNDAS, we intend to

Generate better initial and boundary conditions using the objective analysis with observations

Use the recursive nudging procedure to maximize the correcting capabilities of FDDA.

Step I: Set up data assimilation procedure using 30 – 31 August, 2006 case

➔ multi-scale grid nudging, update assimilation cycle, initialization period,

Step II: Improve simulations for 14 – 21 August 2006

➔ understand model performances affected by the choice of science options (cumulus schemes and adding CONUS domain in 36-km resolution).

Step III: Create retrospective MM5 output for the TexAQS-II intensive period (14 August – 5 October, 2006)

MUltiscale Nest-down Data Assimilation System (MUNDAS)

AQF: grid nudging with ETA in D36 & D12, no nudging in D04.
Simulations of TexAQS 2000: grid nudging with EDAS in D36 & D12, OBS nudging with profiler/sounding in D04.

LITTLE_R (objective analysis)

Use Cressman successive correction methods to modify first guess fields (NCEP analyses or coarse domain nest-down) by ingesting observations.

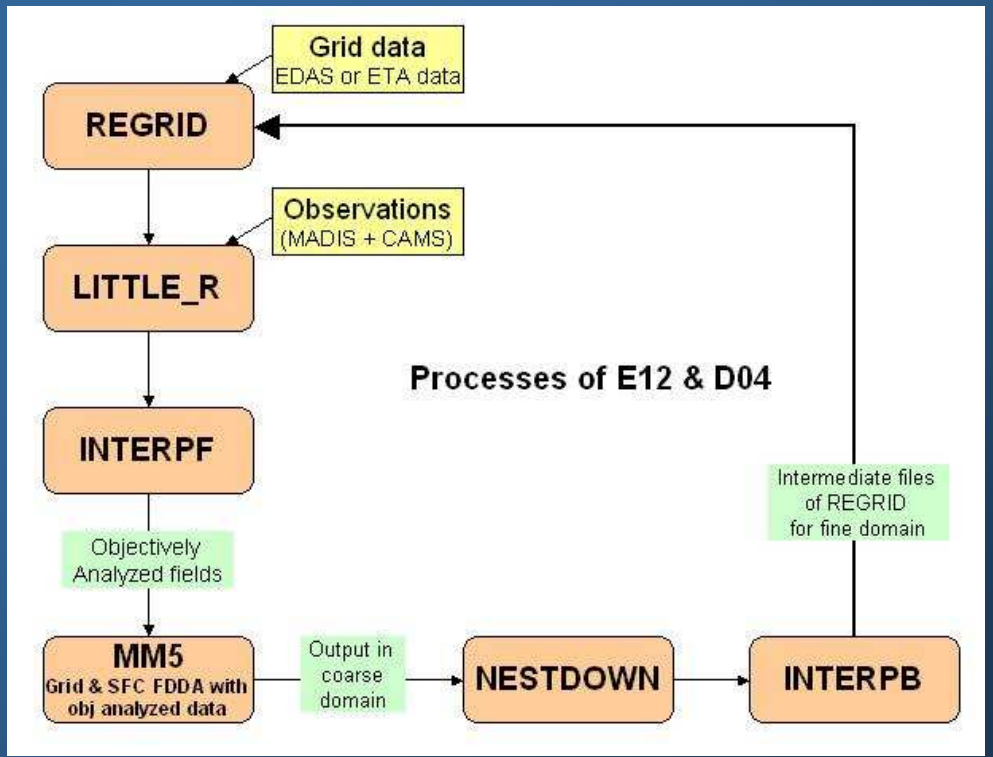
Generate updated IC/BC for MM5 and analyzed fields (3D & surface) for grid nudging.

Nudging

Adjust model state based on the difference between model and observed value continuously that help on minimize error's growth during the simulation.

Use grid (analysis) nudging both 3D and surface with objectively analyzed fields from LITTLE_R.

CAMS: surface met., only in TX large cities
MADIS: surface – METARS & Buoy etc.
upper level – NPN,
aircraft sounding & radiosonde



LITTLE_R

Cressman scheme

- one of successive correction methods
- First-guess field is corrected iteratively with OBS according to distance weighting of each OBS.

$$\varphi_g^m = \varphi_g^{m-1} + \frac{\sum_{i=1}^{N} W_i D_i^{m-1}}{\sum_{i=1}^{N} W_i}$$

First-guess field

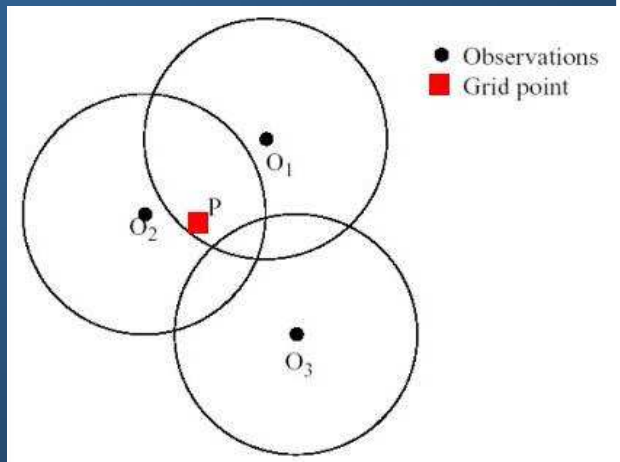
Difference between OBS & first-guess field

$$D_i^{m-1} = \varphi_{io} - \varphi_{ia}^{m-1}$$

Weighting factor for station

$$W_i = \frac{R^2 - d_i^{\,2}}{R^2 + d_i^{\,2}} \quad if \quad d_i < R$$

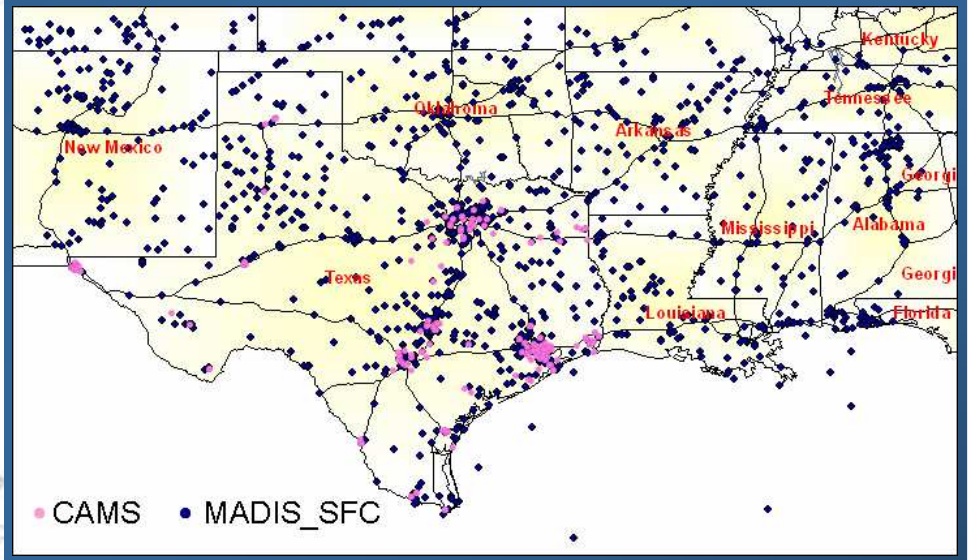
$$= 0 \quad if \quad d_i \geq R$$



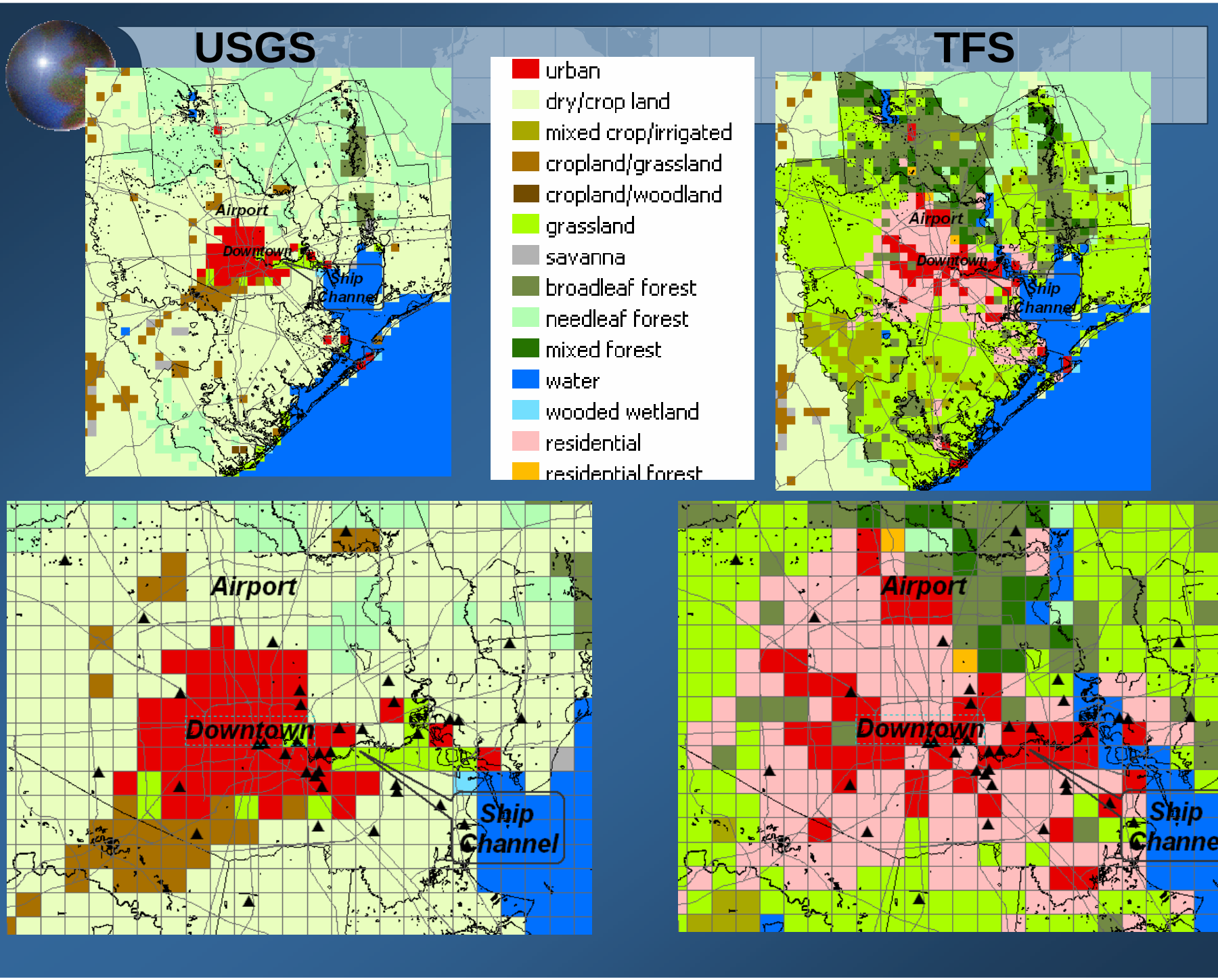
Observations O_1 and O_2 influence grid point P, O_3 does not.

Model Configuration

Surface observations in E12



	Physics options
Initialization	Edas, also ETA when EDAS is not available
Landuse	USGS 24 (12km), TFS LULC (4km)
Microphysics	Simple Ice
Radiation Scheme	RRTM
PBL scheme	UH-modified MRF
LSM scheme	UH-modified NOAH


USGS
TFS
urban
dry/crop land
mixed crop/irrigated
cropland/grassland
cropland/woodland
grassland
savanna
broadleaf forest
needleaf forest
mixed forest
water
wooded wetland
residential
residential forest
Airport
Downtown
Ship Channel
Airport
Downtown
Ship Channel
Airport
Downtown
Ship Channel
Airport
Downtown
Ship Channel

STEP I: 8/31 – 9/1 (54 hours)

Episode overview:

High ozone episode – ozone reached 147 ppb at C410 (Houston Westhollow)

Sunny day, high temperature 90F, N/NE wind in the morning, SE in the afternoon

AQF failed to predict ozone peak since too strong northerly and delay of bay breeze onset were simulated in MM5.

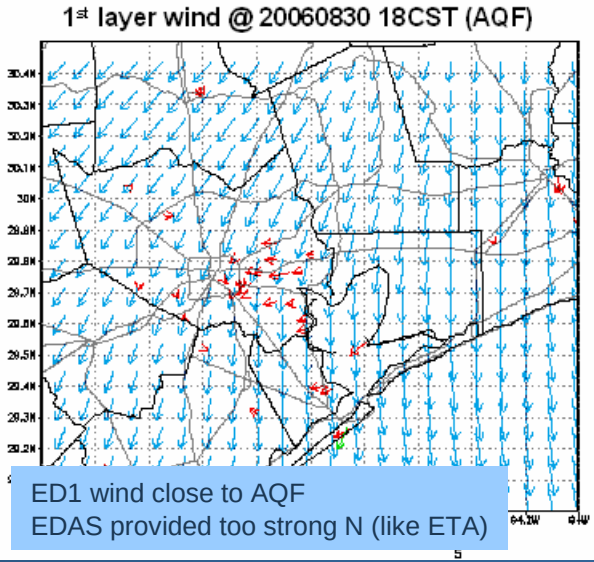
Run	Domain	Data for initialisation	Data for objective analysis and FDDA	Grid Nudging for U/V/T/Q	Update Cycle	Notes
AQF	D36	ETA forecasting	No	Upper FDDA	3 hr	default AQF settings
	E12	D36 nestdown		Upper FDDA		
	E04	E12 nestdown		No		
ED1	D36	EDAS	No	Upper FDDA	3 hr	default AQF settings but using EDAS data for D36 initialization
	E12	D36 nestdown		Upper FDDA		
	E04	E12 nestdown		No		
RD4	E04	EDAS	RDAS	Upper FDDA	3 hr	use RDAS in e04 initialization
MNS1	D12	EDAS	MADIS+CAMS	Upper & surface FDDA	1 hr	use RDAS in e12 initialization, nestdown for e04
	D04	D12 nestdown				

* In data for objective analysis, RDAS means objectively analyzed grid data constructed by ETA forecasting data and observations collected by UH-RDAS.

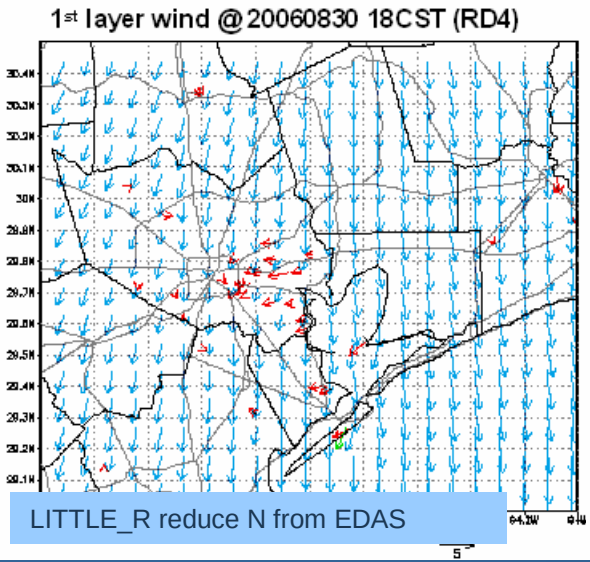
OBS collected by UH-RDAS were downloaded in near real-time, there are missing data.

STEP I: 8/30 – 31 (54 hours)

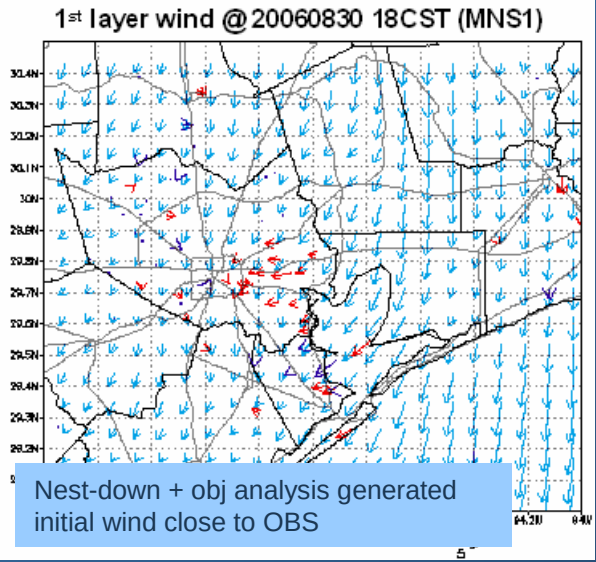
Initial time step (from obj analysis)



ED1 wind close to AQF
EDAS provided too strong N (like ETA)

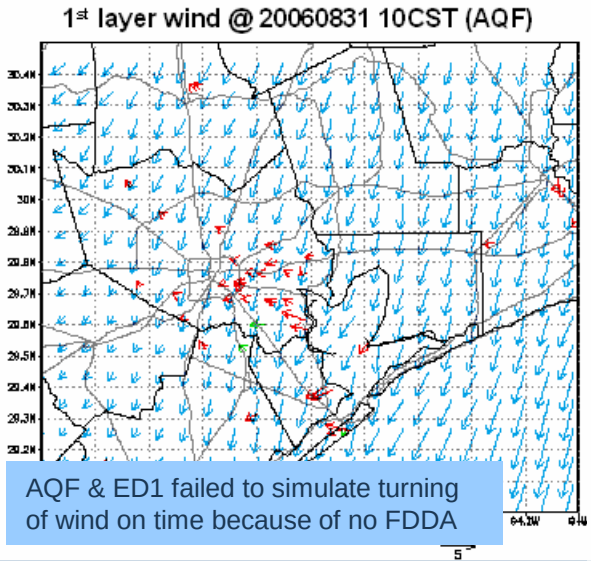


LITTLE_R reduce N from EDAS

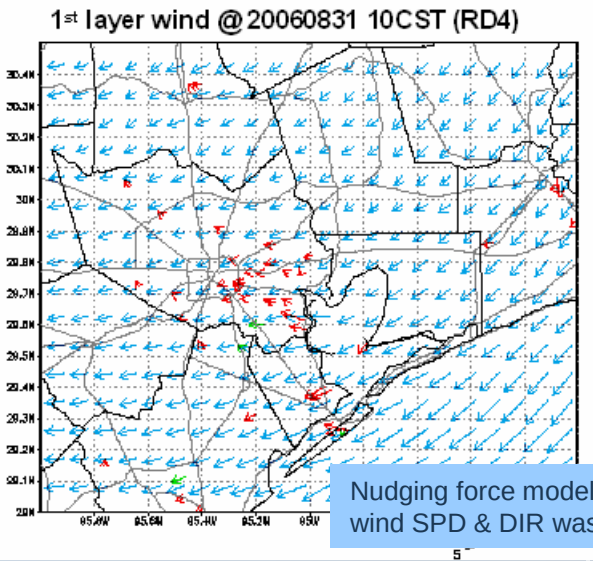


Nest-down + obj analysis generated initial wind close to OBS

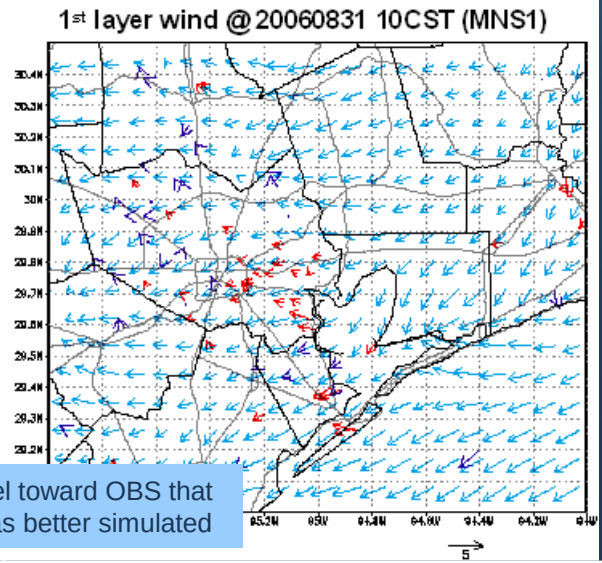
Late morning (the 16th hour)



AQF & ED1 failed to simulate turning of wind on time because of no FDDA



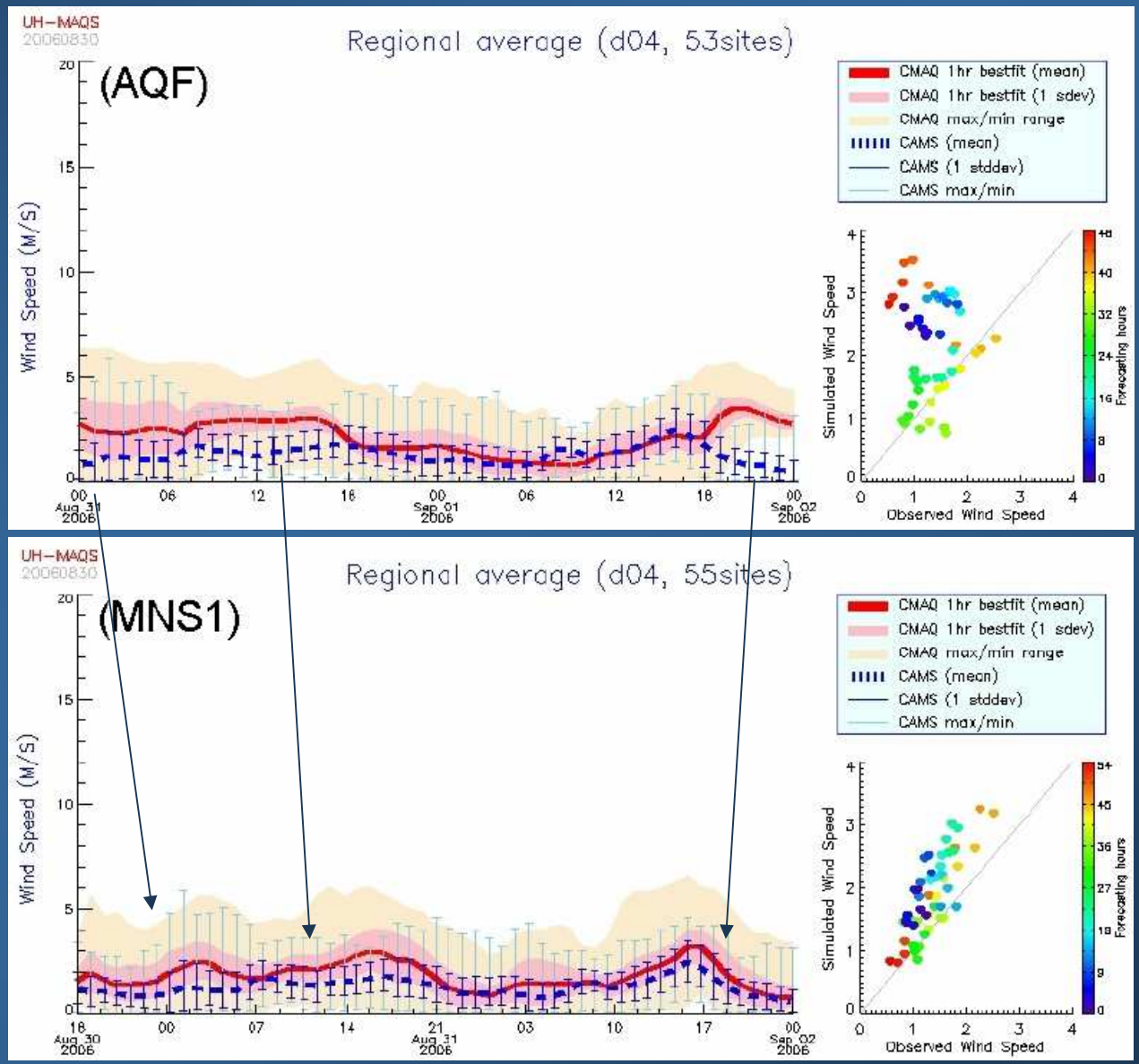
Nudging force model toward OBS that wind SPD & DIR was better simulated



Phase I: 8/31 – 9/1 (54 hours)

In MNS1, High wind speed at the beginning of simulation was reduced.

Grid nudging with objectively analyzed fields helped reducing wind SPD bias and keeping the variations shown in the observed wind SPD



Step II: 8/14 – 8/21 (8 days)

Episode overview:

8/14, 15 – H centered at the Gulf, SW wind

8/16, 17, 18 – 3 high ozone days, frontal system in North TX (SW/W) on 16 ➔ frontal passage (N/NE) on 17 ➔ no strong synoptic controlled but high O3 background on 18

8/19 – rainy day, thunderstorm developed at the south & moved across the city

8/20, 21 – no strong weather pattern, light & variable wind

MNS1 was applied on 8-day period

- Unrealistic development of thunderstorms with too strong outflow
- Statistics of MNS1 was better than AQF but general flow patterns did not "look" as good as AQF

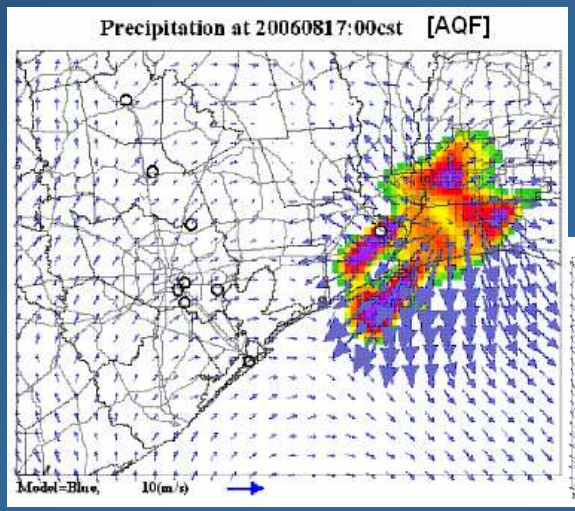
Run	Domain	Data for initialisation	Grid Nudging for U/V	Grid Nudging for T/Q*	Update Cycle	Notes
T1	D04	MNS1's E12 nestdown	No	No	1 hr	MNS1's physics
T2	E12	EDAS	Upper & surface FDDA	Upper air FDDA	1 hr	No T/Q nudging in D04
	D04	E12 nestdown	Upper & surface FDDA	No		
T5	E12	EDAS	Upper & surface FDDA	Upper air FDDA	1 hr	Nudge Upper air T/Q in D04
	D04	E12 nestdown	Upper & surface FDDA	Upper air FDDA		
T8	D04	MNS1's E12 nestdown	Upper & surface FDDA	Upper air FDDA	1 hr	Using KF scheme for cumulus parameterization
T11	D36	EDAS	Upper air FDDA	Upper air FDDA	3 hr	Similar to T2 but adding D36 simulation using EDAS data for initialization
	E12	D36 nestdown	Upper & surface FDDA	Upper air FDDA	3 hr	
	D04	E12 nestdown	Upper & surface FDDA	No	1 hr	

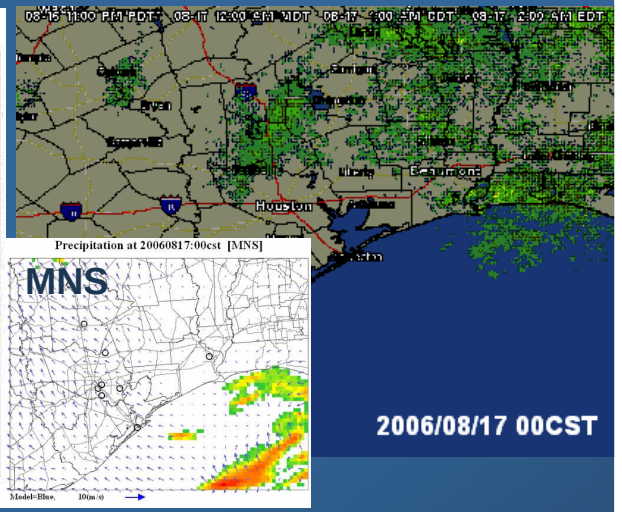
Thunderstorms

Nudging tilts the profile of T & RH
➔Trigger or prevent thunderstorms
➔Induce or reduce unwanted rain events

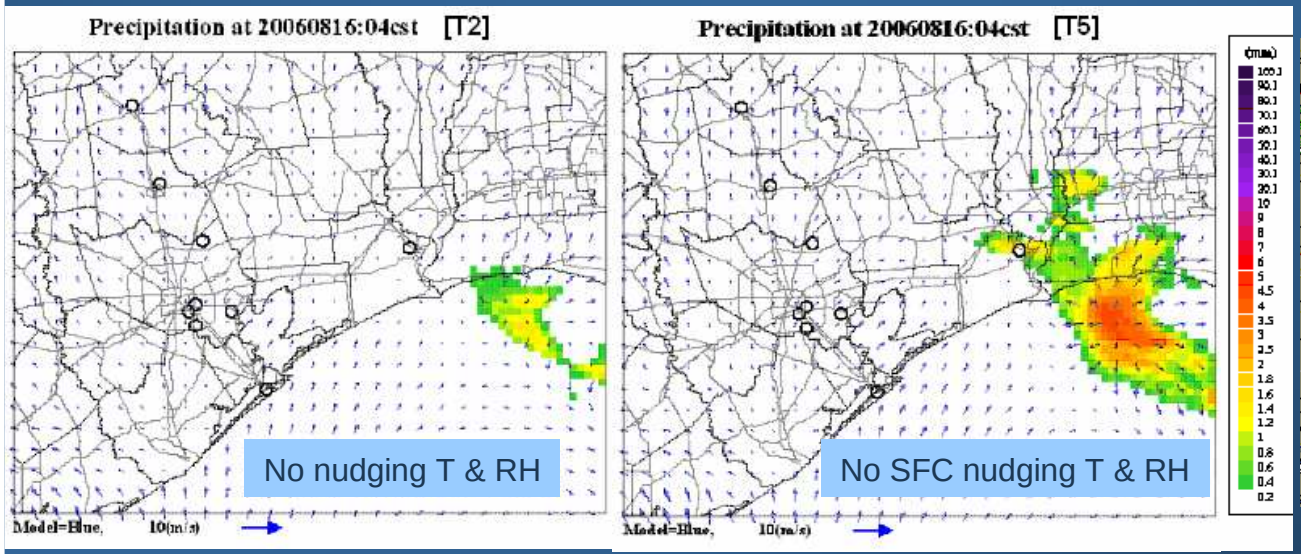
Gust wind associated with thunderstorm distorted the regional wind field.

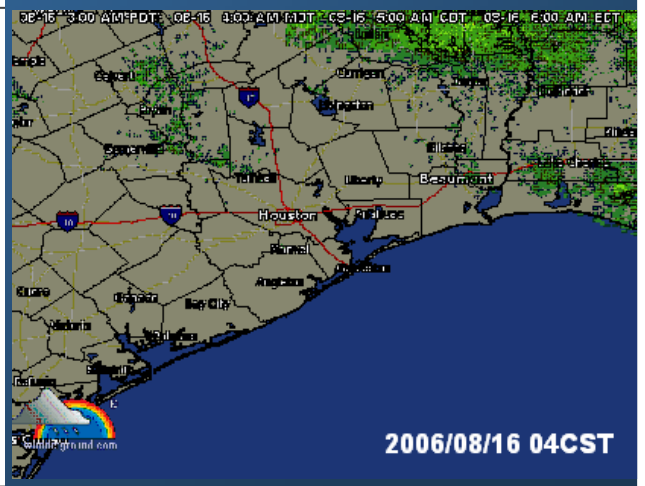
4-km resolution:
• Explicit approaches cannot represent cloud development at grid < 4km
• Sub-grid cloud parameterization have not been successful at this fine scale
(KF scheme has similar performance as Grell scheme)





To prevent unrealistic thunderstorm, nudging of T & RH was turned off at SFC & upper level.





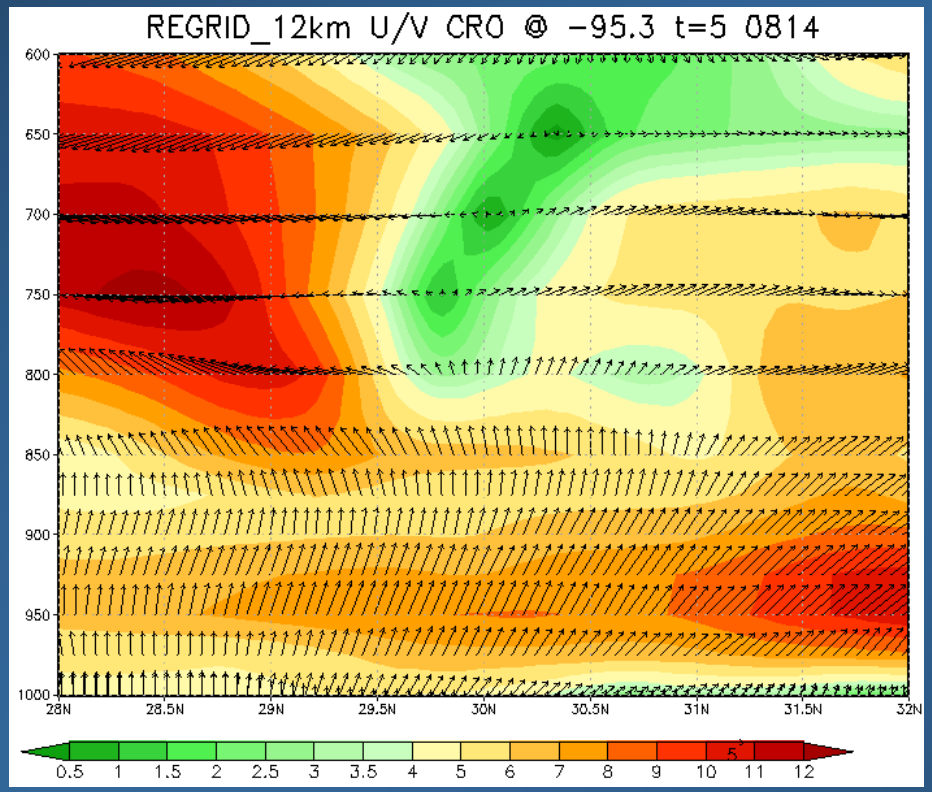
Effects of boundary Condition

General flow patterns in T2 (14 -15 August) are not as good as AQF (losing "synoptic signals"}.

→ To pass through synoptic influence to finer scales, run MM5 starting from D36 (CONUS)

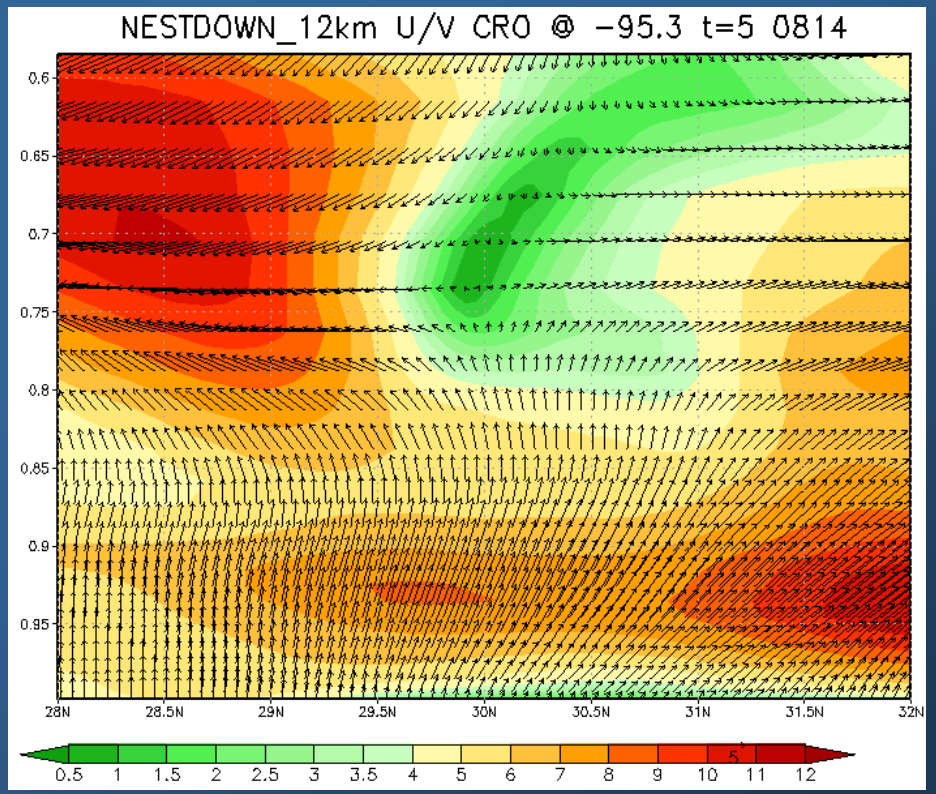
Input for T2 E12 – from EDAS/ETA

U/V cross section @ -95.3 (Houston downtown)
06 CST 14 August 2006



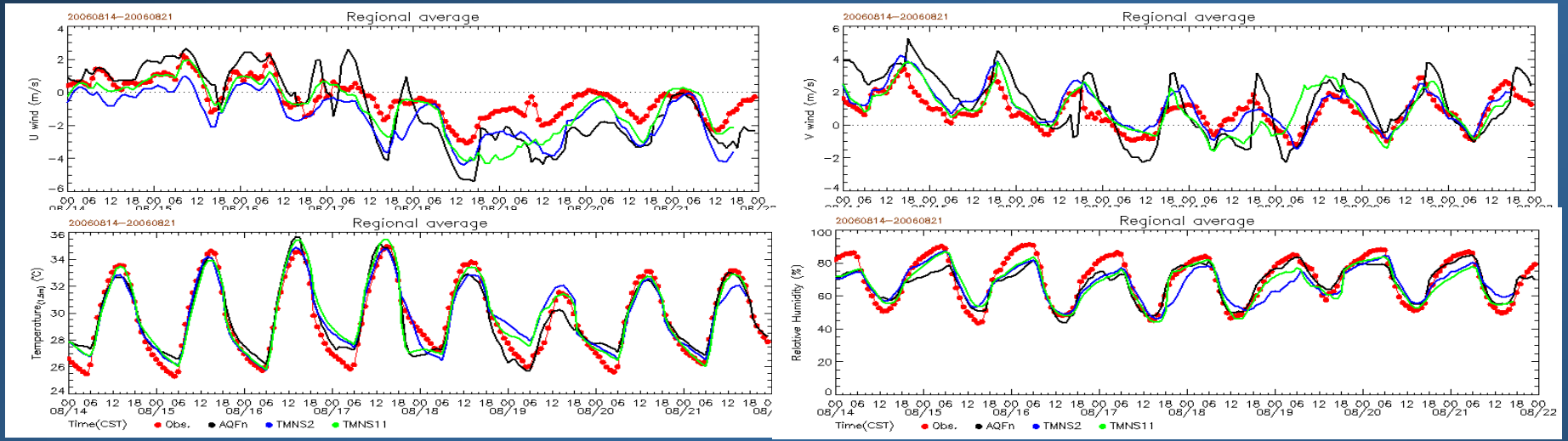
Input for T11 E12 – from D36 nest-down

U/V cross section @ -95.3 (Houston downtown)
06 CST 14 August 2006

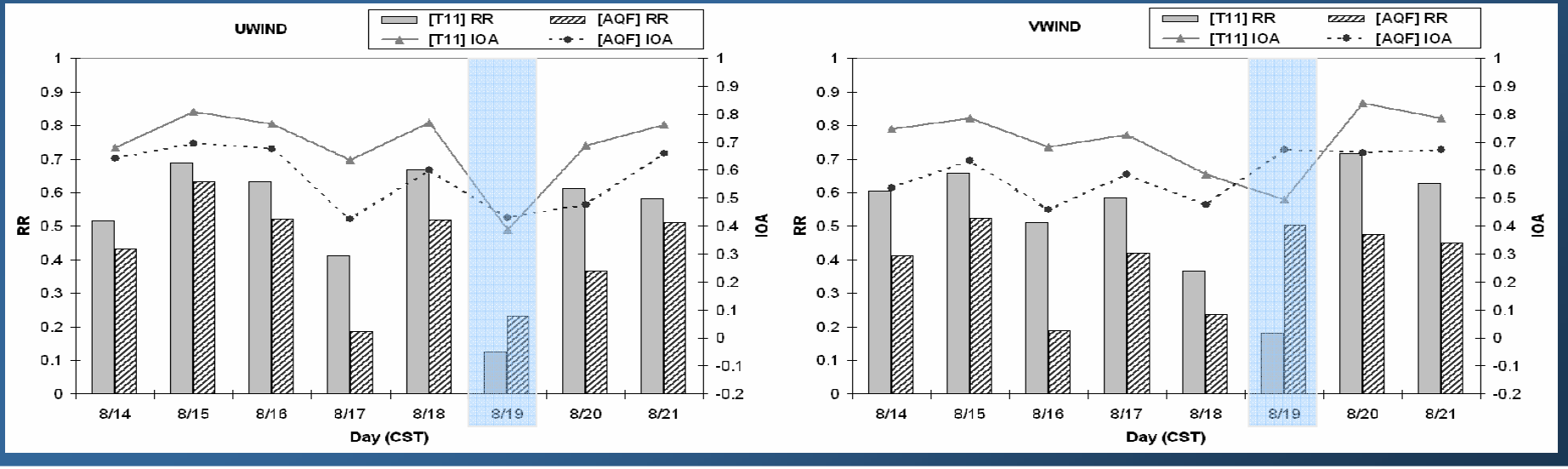


Statistics summary of Step II

Running MM5 starting from D36 (CONUS) domain, better synoptic conditions were passed into finer domain.



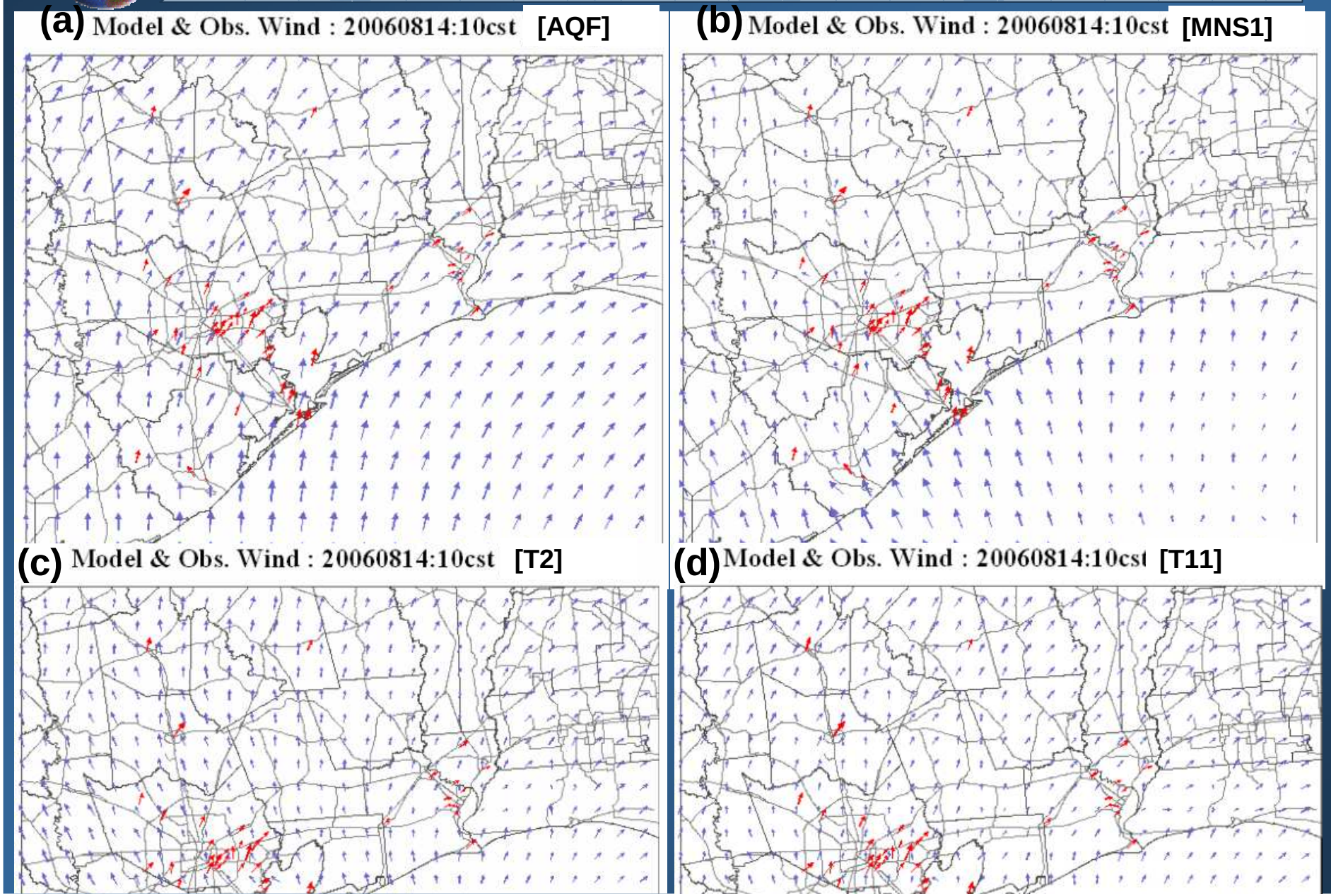
T11 gave better statistics than other runs. 8/19 was a rainy day



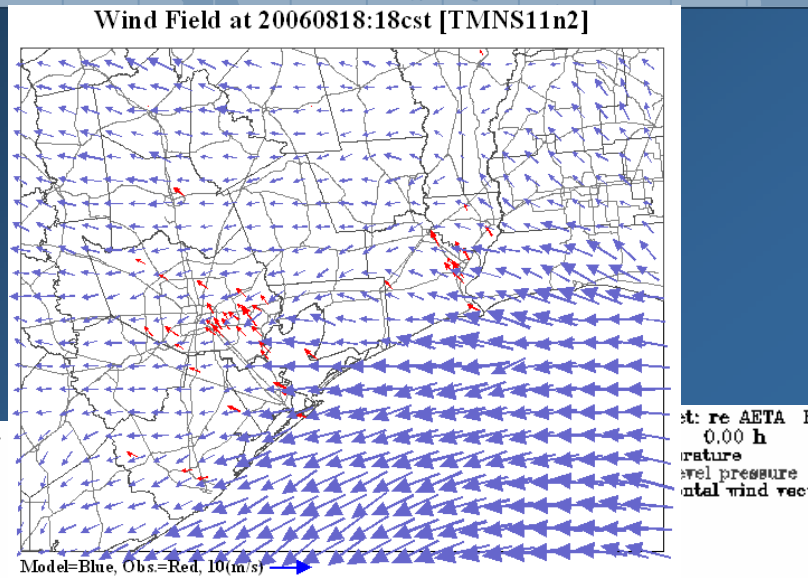
Statistics of AQF & MNS1

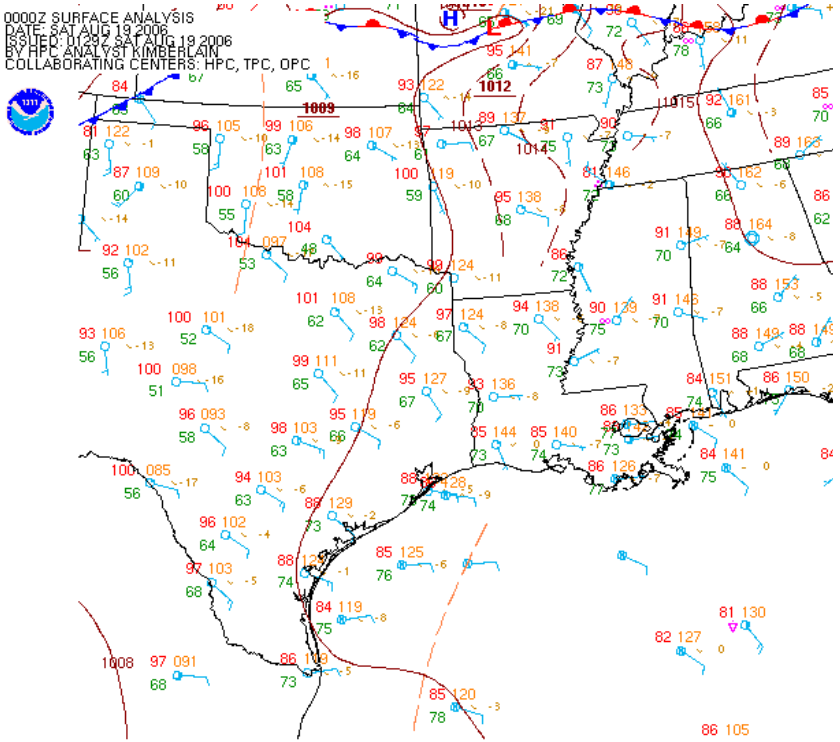
VAR_NAME	Date	Case	nDATA	MB	ME	FA2	IOA	R
UWIND	20060814	AQF	1267	0.44	0.84	42.46	0.59	0.39
		MNS	1267	-0.59	0.94	33.94	0.67	0.51
	20060815	AQF	1260	0.69	1.01	50.48	0.74	0.63
		MNS	1260	-0.76	1.09	40.40	0.75	0.67
	20060816	AQF	1267	0.93	1.38	40.65	0.65	0.48
		MNS	1267	-0.91	1.12	41.52	0.80	0.76
	20060817	AQF	1255	-0.25	1.98	18.81	0.49	0.33
		MNS	1255	-1.37	1.44	23.27	0.59	0.62
	20060818	AQF	1223	-1.59	1.79	42.85	0.66	0.73
		MNS	1223	-1.32	1.41	49.14	0.74	0.80
	20060819	AQF	1207	-2.05	2.16	30.32	0.45	0.31
		MNS	1207	-1.43	1.51	36.45	0.62	0.63
	20060820	AQF	1148	-1.66	1.72	24.39	0.50	0.44
		MNS	1148	-1.36	1.44	26.57	0.62	0.65
	20060821	AQF	1246	-0.88	1.22	39.09	0.68	0.58
		MNS	1246	-1.34	1.47	33.15	0.66	0.71
VWIND	20060814	AQF	1267	1.69	1.82	49.49	0.51	0.40
		MNS	1267	0.96	1.20	61.17	0.73	0.67
	20060815	AQF	1260	1.29	1.56	34.76	0.61	0.51
		MNS	1260	0.98	1.21	42.78	0.73	0.67
	20060816	AQF	1267	0.43	1.45	25.89	0.48	0.21
		MNS	1267	0.69	0.94	41.52	0.77	0.70
	20060817	AQF	1255	-0.13	1.67	25.90	0.61	0.46
		MNS	1255	0.48	0.87	35.22	0.79	0.67
	20060818	AQF	1223	-0.68	1.57	16.27	0.50	0.28
		MNS	1223	0.18	0.80	40.15	0.74	0.57
	20060819	AQF	1207	0.47	1.43	39.93	0.72	0.60
		MNS	1207	0.20	0.81	51.04	0.88	0.80
	20060820	AQF	1148	0.76	1.37	33.19	0.66	0.49
		MNS	1148	0.48	0.85	47.04	0.85	0.77
	20060821	AQF	1246	-0.15	1.22	33.07	0.70	0.50
		MNS	1246	0.36	0.78	58.99	0.87	0.79

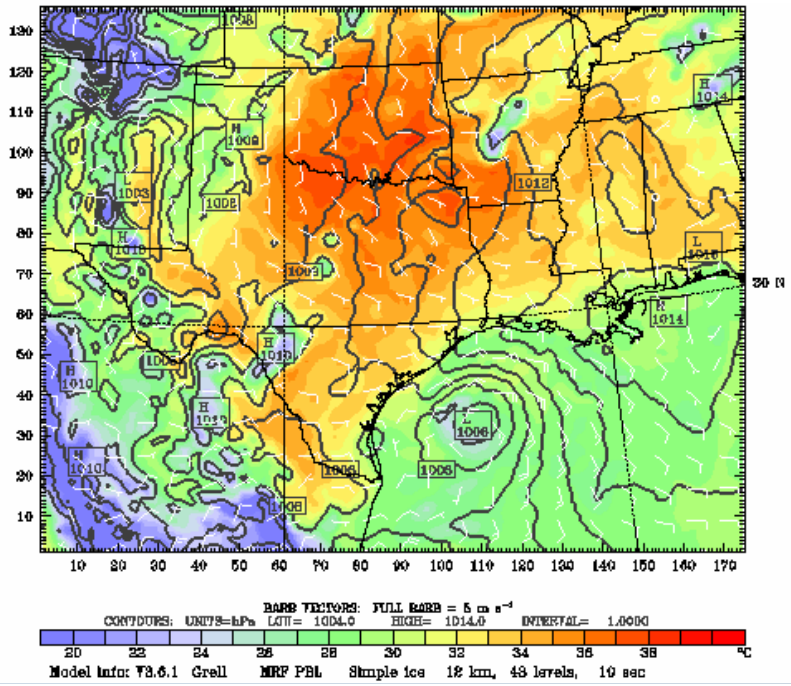
Step II: boundary condition

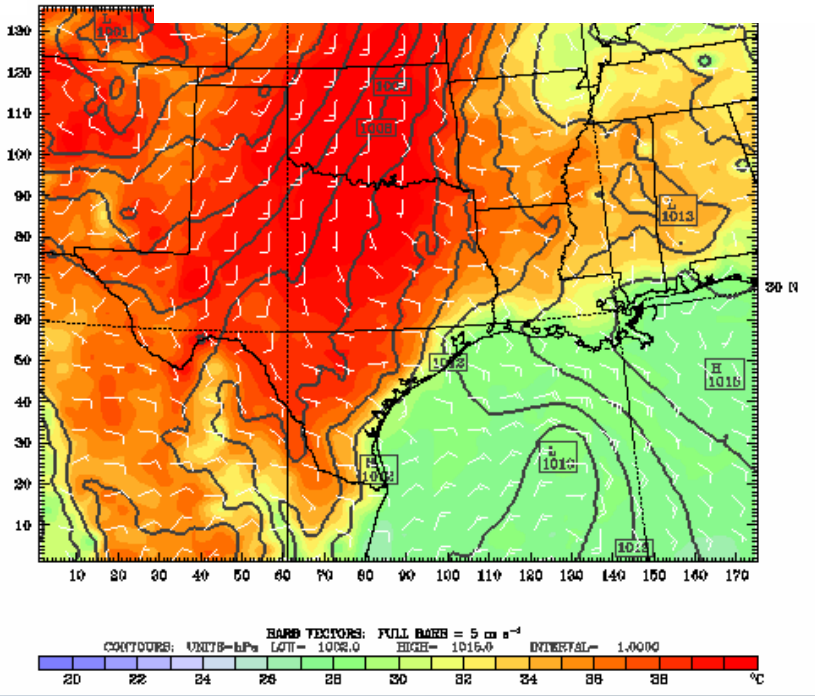


8/19 00 UTC, too strong L



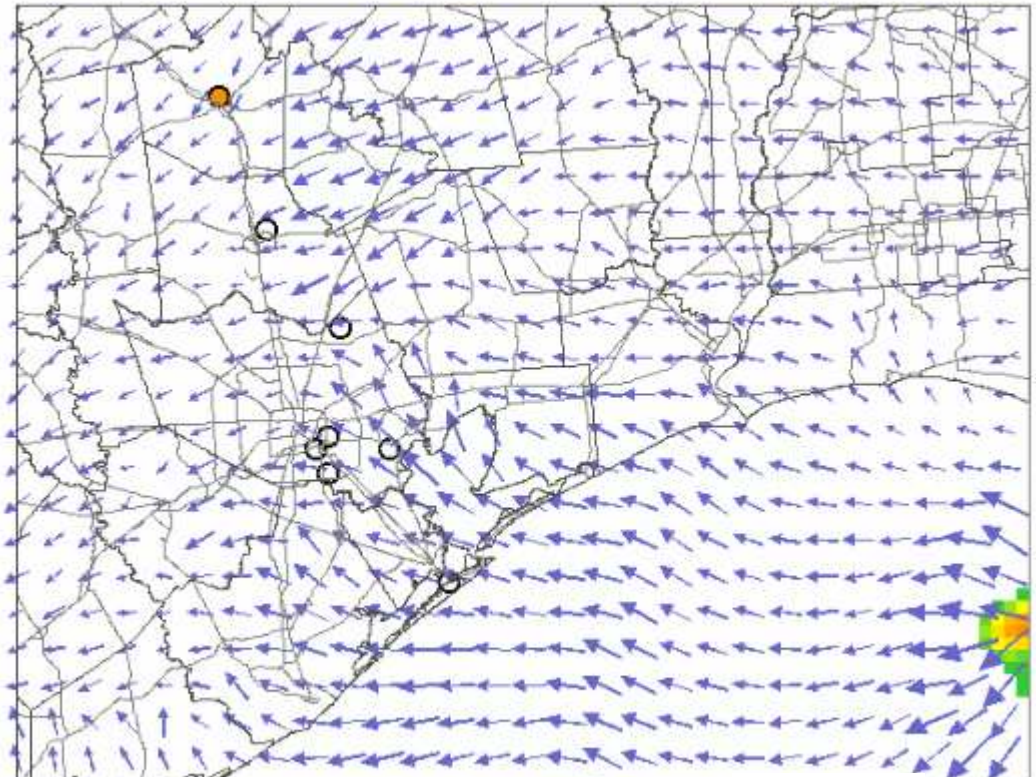




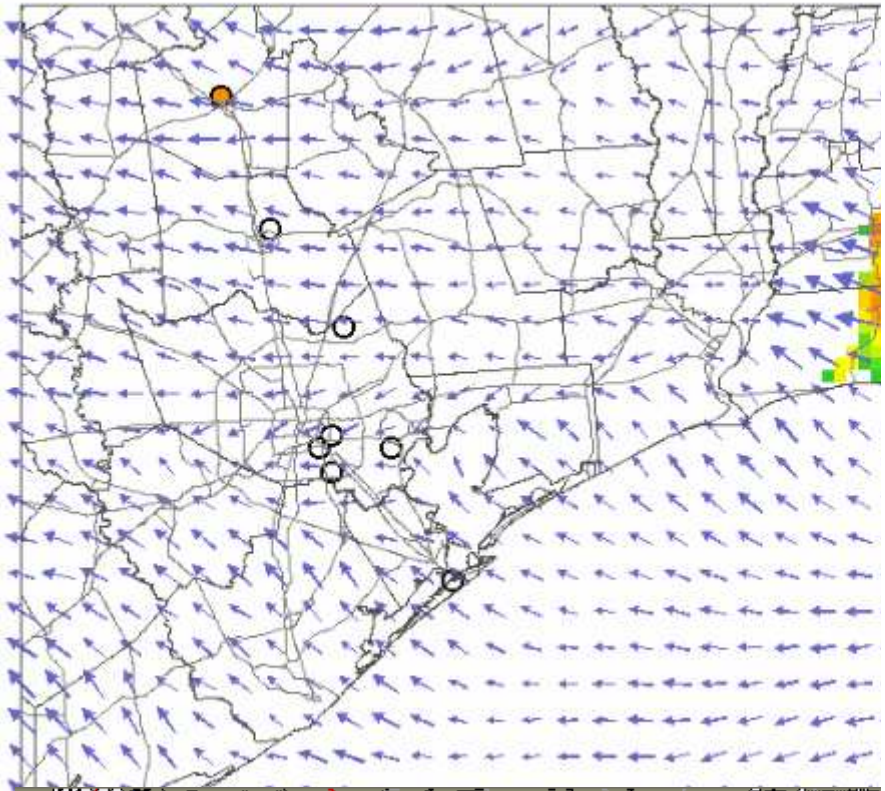


Phase II: 8/14 – 8/21 (7 days)

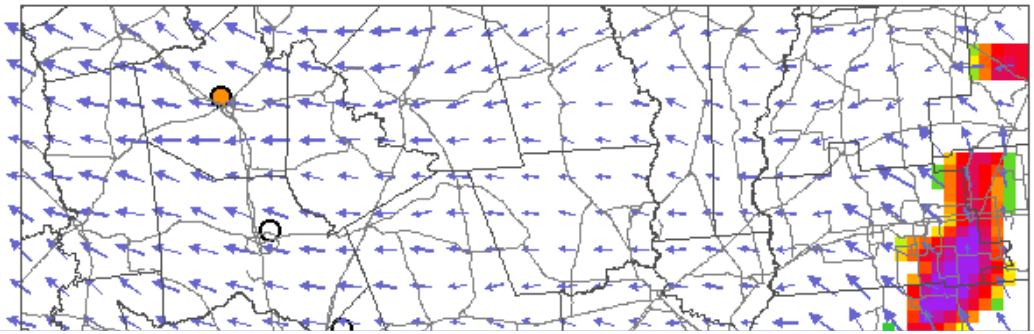
(a) Precipitation at 20060817:17cst [AQF]



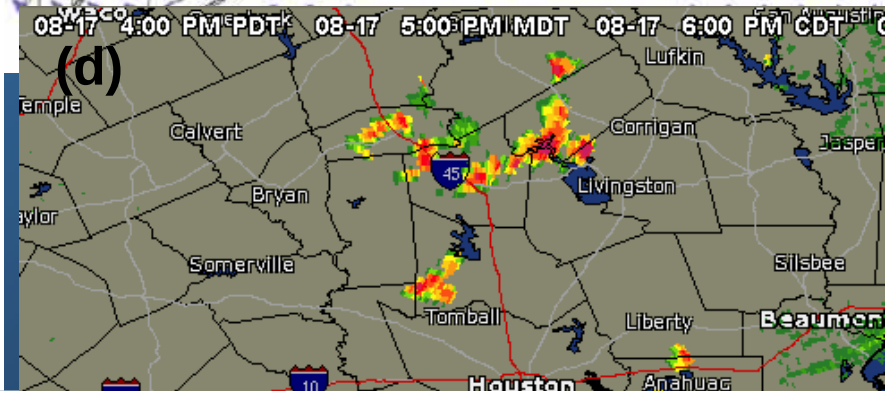
(b) Precipitation at 20060817:17cst [T5]



(c) Precipitation at 20060817:17cst [T8]

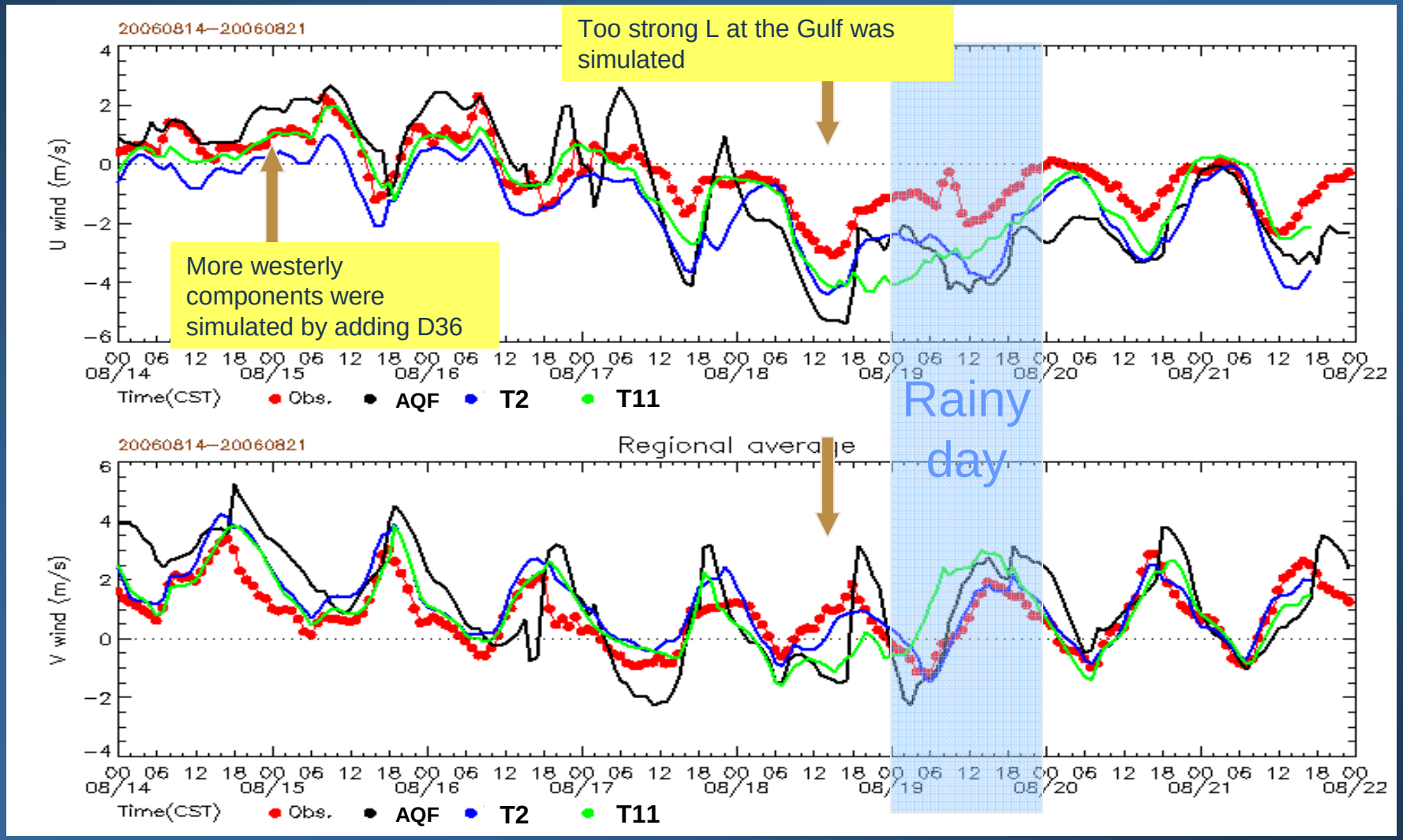


(d)

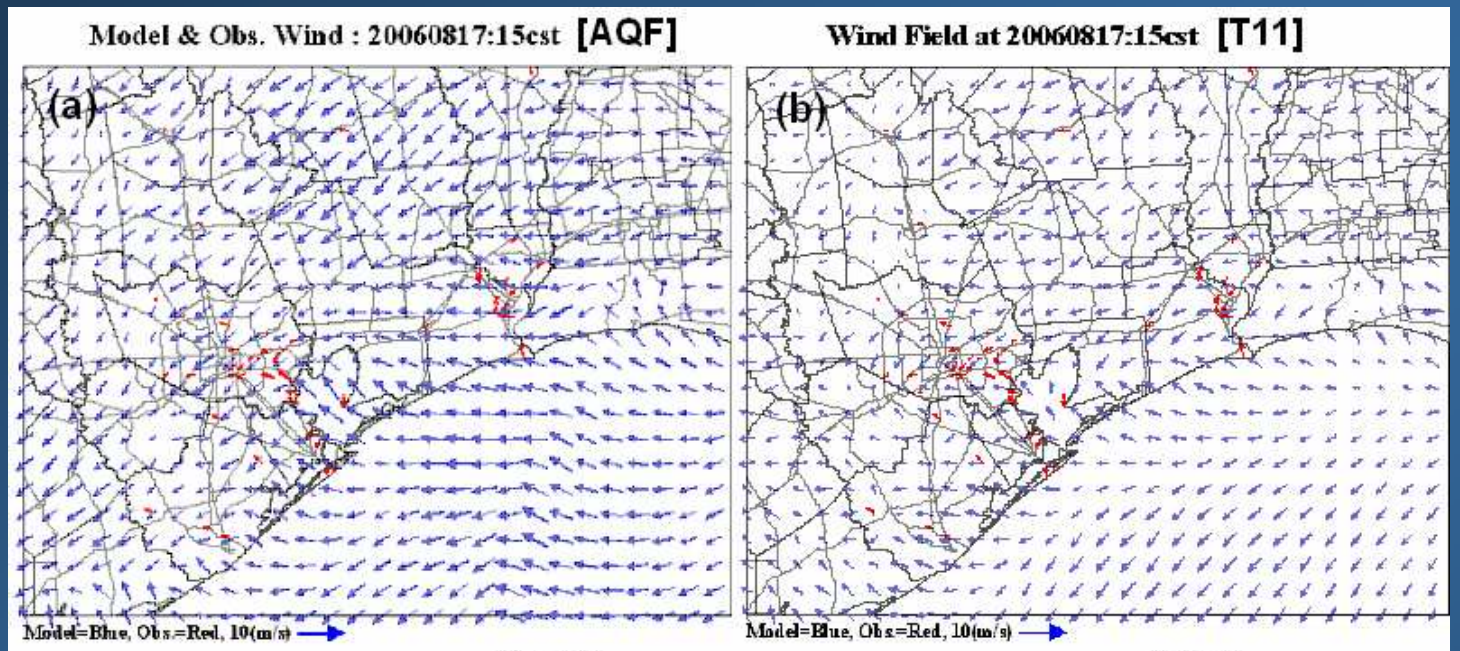


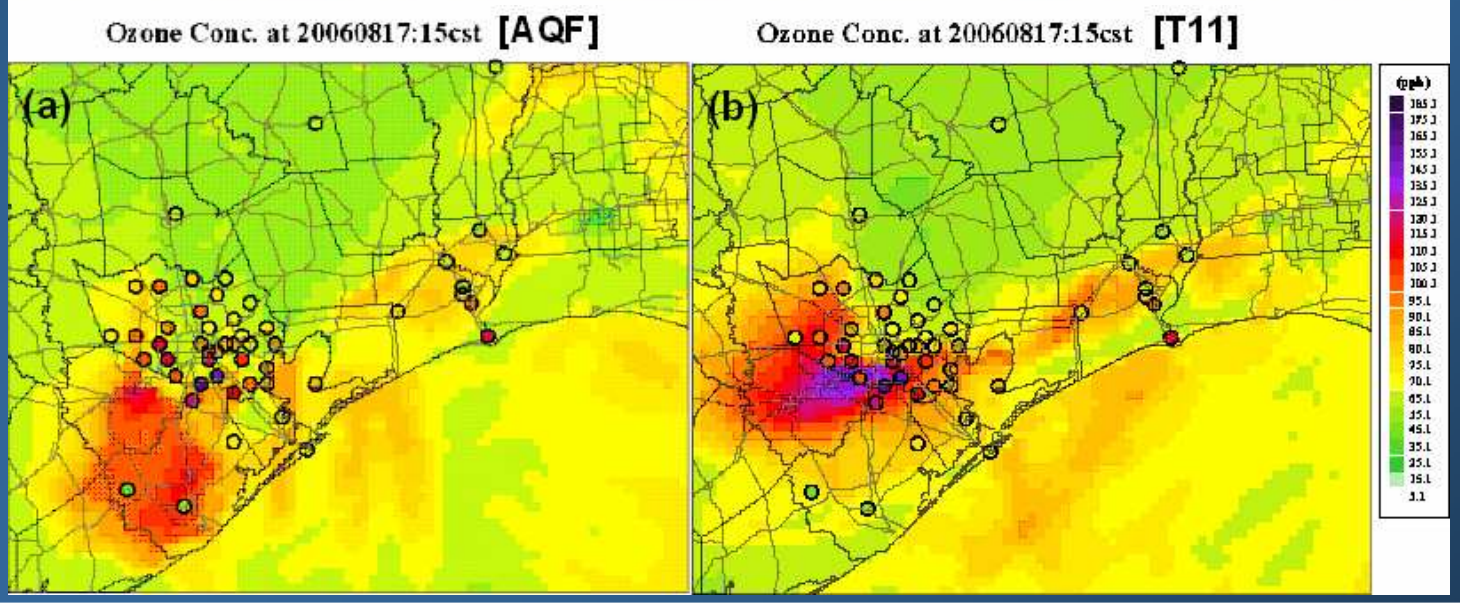
Time series of U/V wind (regional average)

T11 simulates U and V wind better than other runs.



Step II: CMAQ results



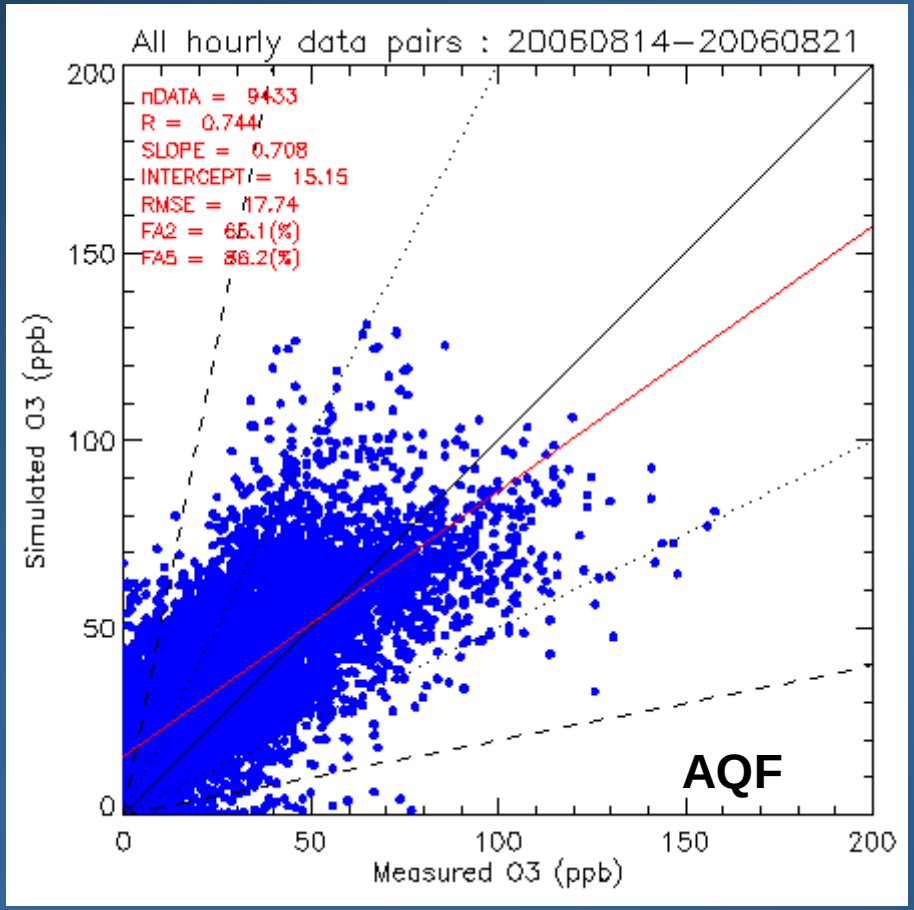


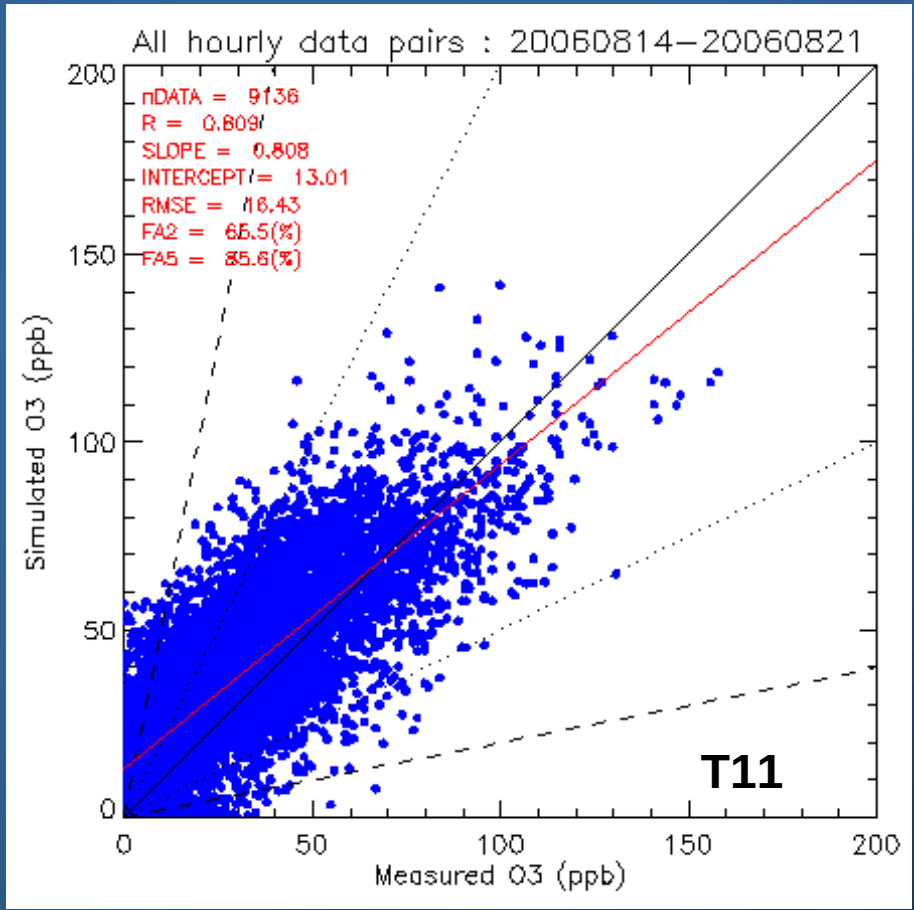
In T11, Wind was slow down that convergence ozone could be formed at the afternoon

With T11 met., O3 was able to build up & location of peak stayed south of downtown.

Step II: CMAQ results

Scattered diagram of Ozone (8-day simulation)
Less over-prediction and under-prediction in T11

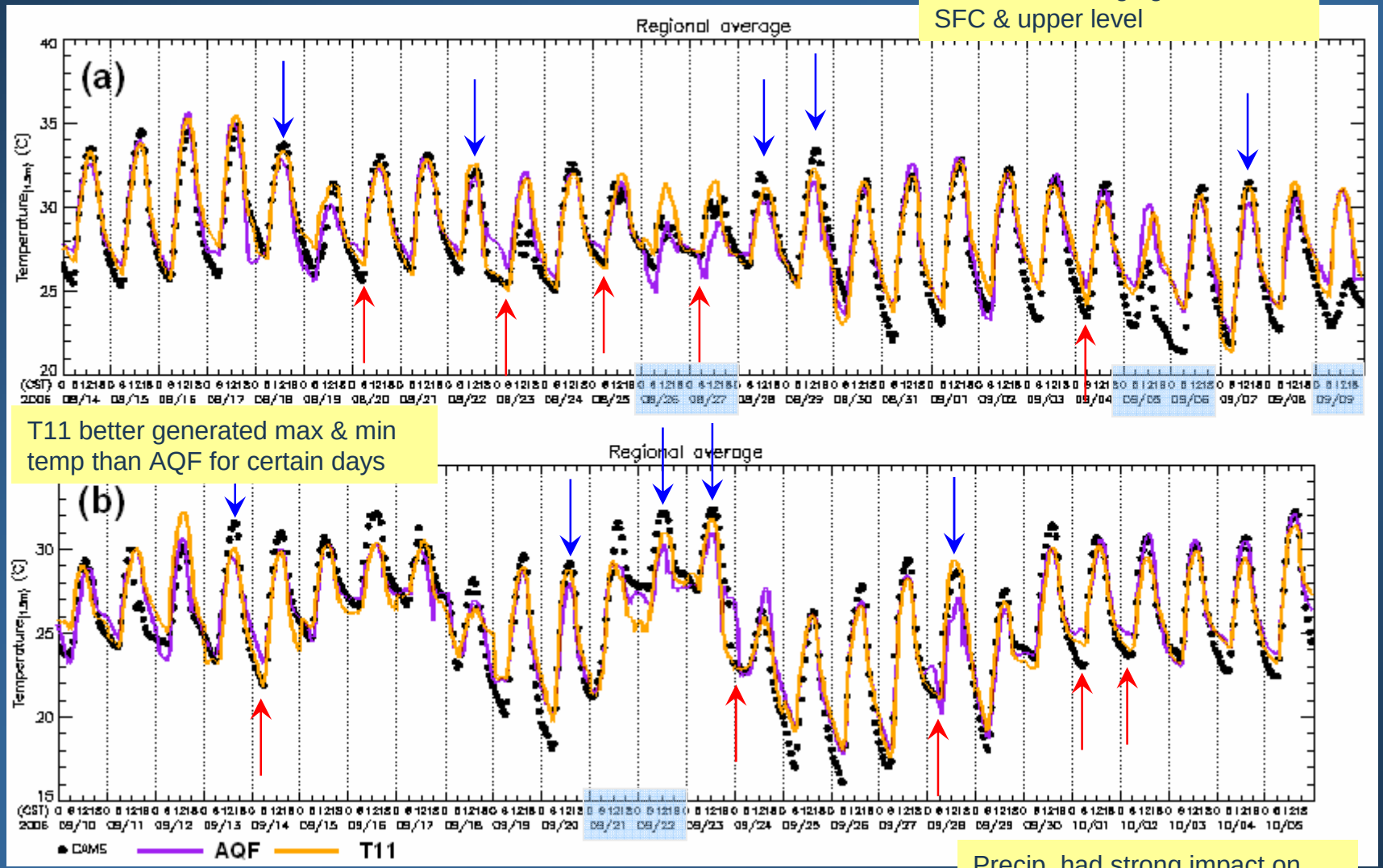




Step III: 8/14 – 10/5 (54 days)

Regional average of observed and model 1.5 m temperature

NO T & RH nudging at both SFC & upper level

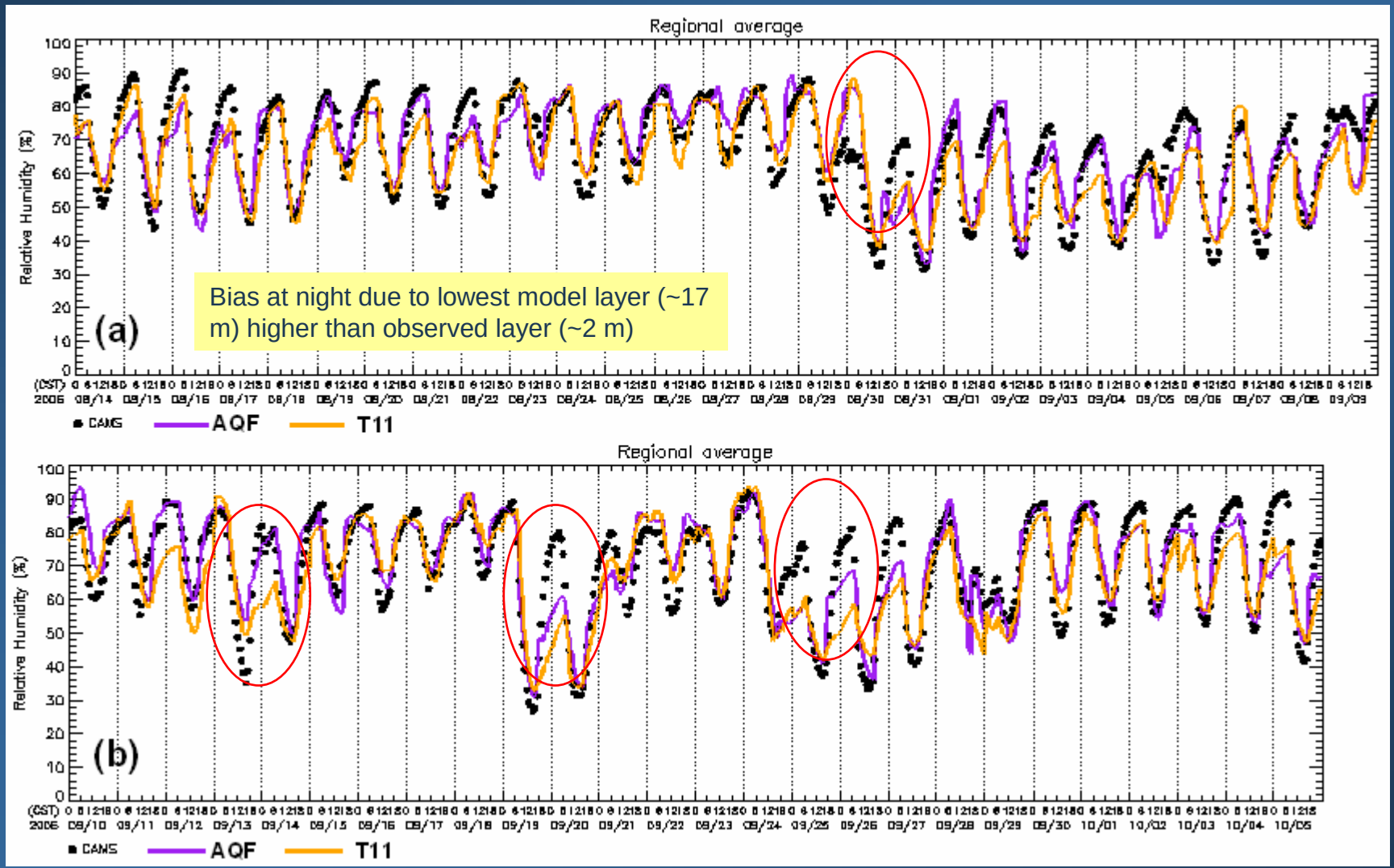


T11 better generated max & min temp than AQF for certain days

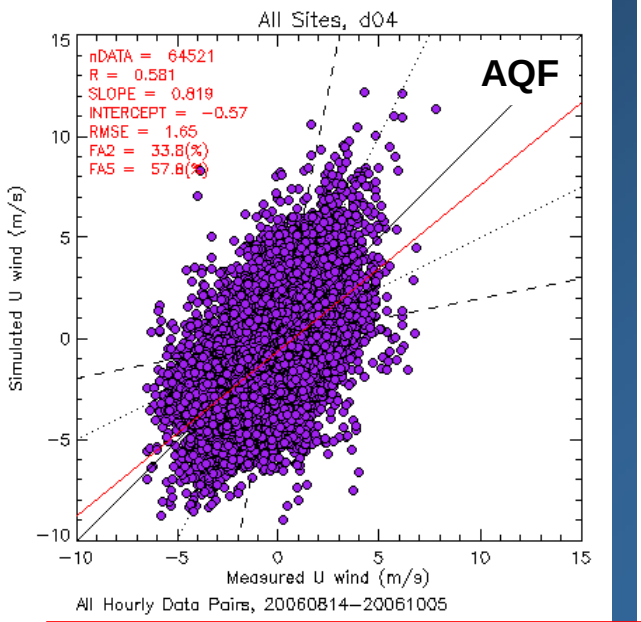
Precip. had strong impact on variation of SFC temp.

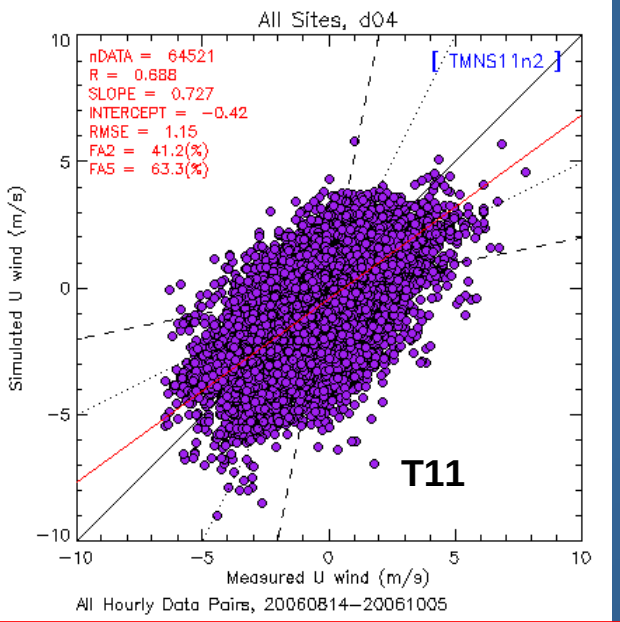
Step III: 8/14 – 10/5 (54 days)

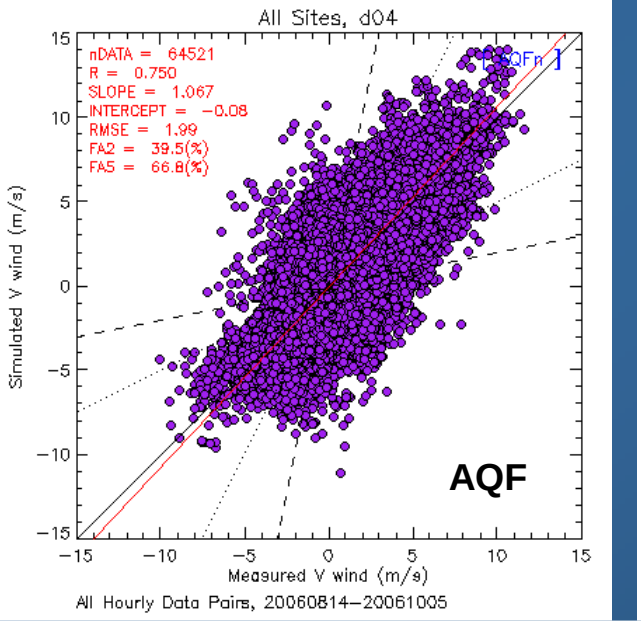
Regional average of observed and model relative humidity (RH)

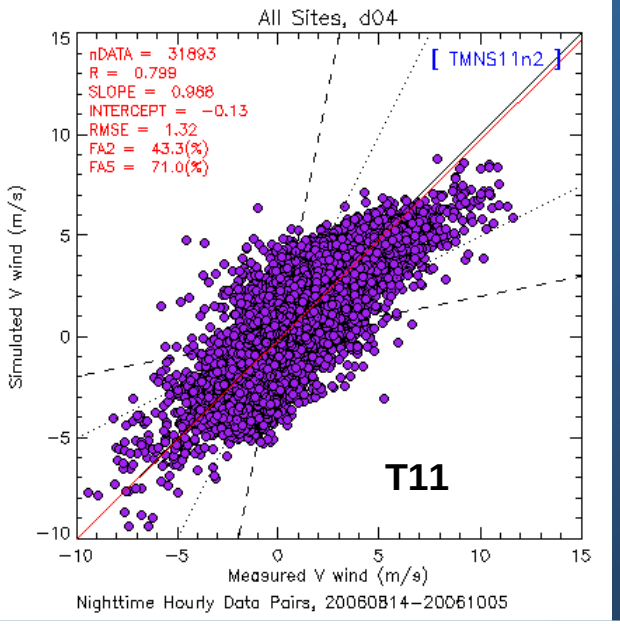


Scattered plots of U/V (54 days)





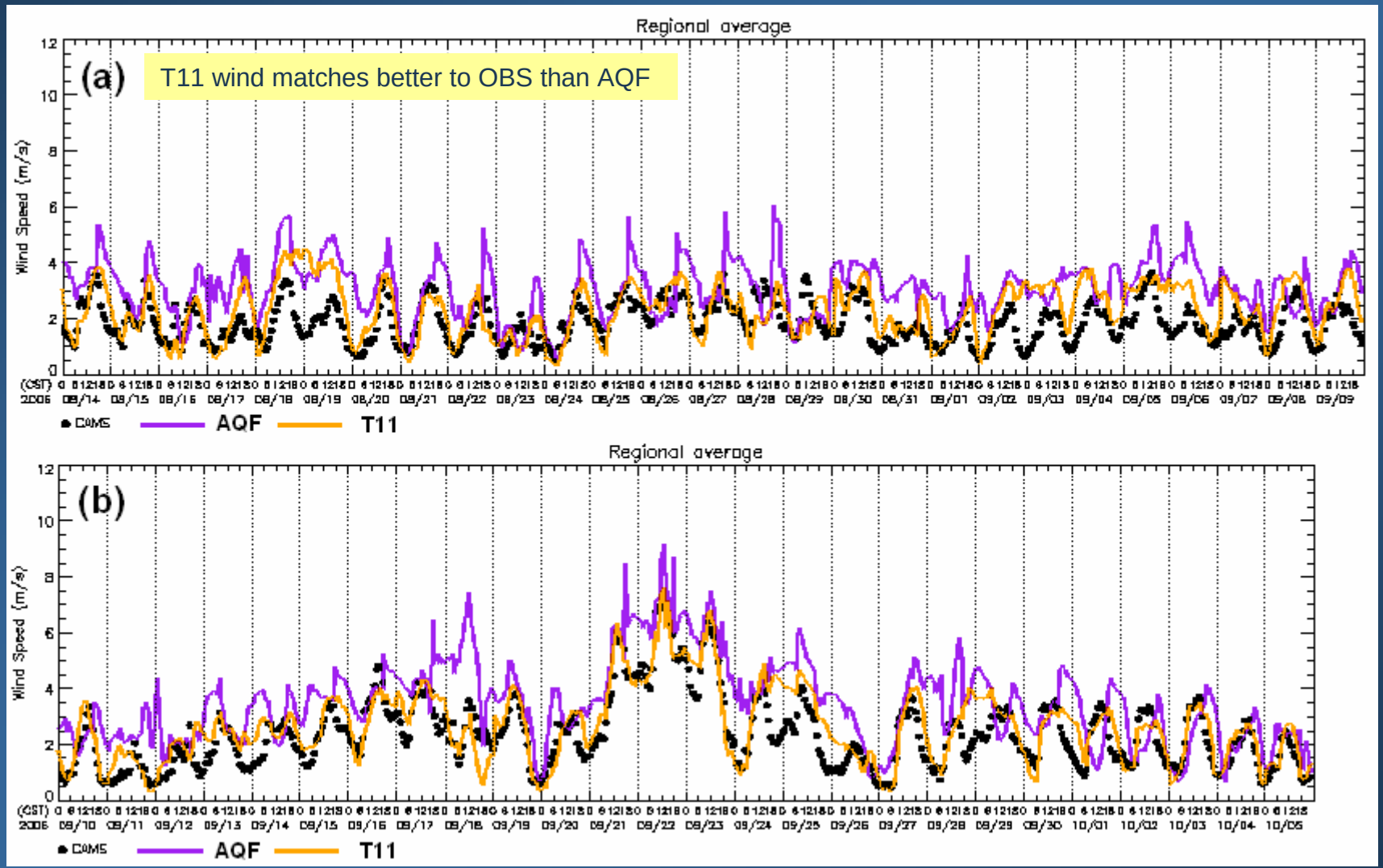




T11 reduced high bias of U/V wind & better simulated the winds in calm condition

Step III: 8/14 – 10/5 (54 days)

Regional average of observed and model 1st wind speed



Conclusion

- MUltiscale Nest-down Data Assimilation System (MUNDAS) was developed using existing obj analysis and nudging tools in MM5 and incorporating extensive met. OBS.

- Wind – reduce the over-prediction of northerly wind coming from the coarse domain, the delay of wind turning in the afternoon and too strong wind speed induced by sea breeze.

  Temperature – better predict max & min temp.

  Thunderstorm & strong outflow – less active than AQF

- With assimilated met. inputs, locations & magnitudes of O3 are better simulated.

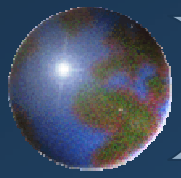
- Failure of simulating precip. & clouds still can be seen.

Future Works

- Include extra wind profiler data & radiosonde available during TexAQS-II into assimilation system

  Test other analyses dataset like GFS and NARR for providing better large-scale met. flow patterns.

  Assimilate clouds by using satellite data for minimize the errors of clouds & precip. simulations.



~ The End ~