The Second Texas Air Quality Study: Atmospheric Measurement and Modeling to Study Photochemical Processes and Emissions Uncertainties

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TexAQS 2000 has found that

- Houston's bad air quality is mainly due to very large amount of volatile organic carbons from the regional petrochemical industries, NOx emissions from traffics and power plant.

- The severity of the ozone air quality problem is closely associated with the recirculation flows resulting from the interaction of synoptic weather system and local land-sea breeze

- Large uncertainties in the highly reactive olefin emissions is the key stumbling issues developing efficient emission control measures

- TCEQ "imputed" olefin emissions to develop State Implementation Plan

TaxAQS-II in 2005/2006 (2006 August – September, intensive period)

-- from Rapid Science Synthesis Report (Cowling et al., 2007)

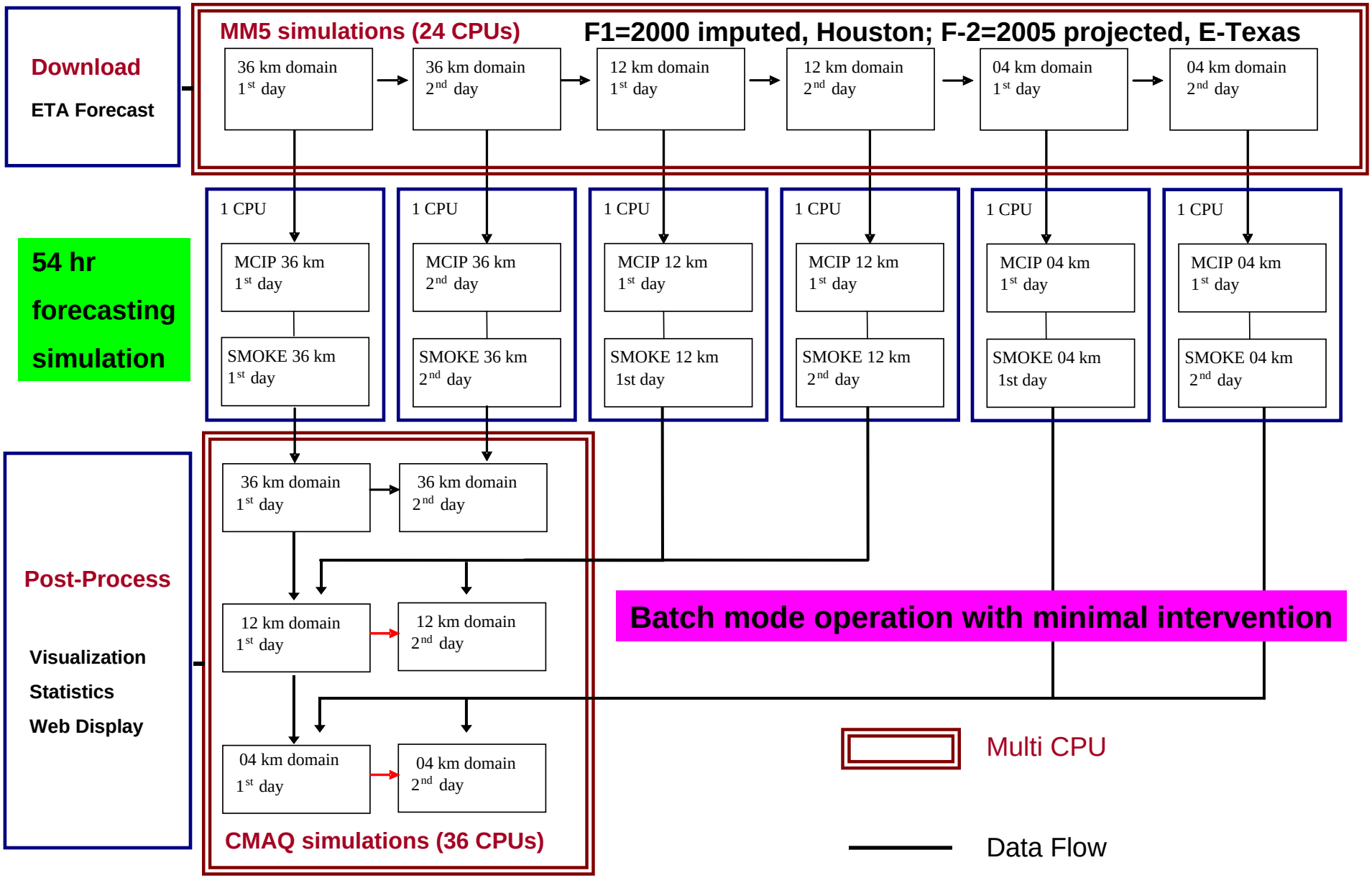
- To assess if the emissions control measures implemented since 2000 were effective and if there are any changes in the significant sources of ozone and aerosol pollution in eastern Texas

- Further investigate photochemical and meteorological processes involved in the production, transport, and accumulation of these pollutants

- To provide assessment of the adequacy of emissions inventories for both biogenic and anthropogenic sources of ozone and aerosol precursor chemicals

- To assess the skill of current air quality modeling and forecasting systems.

Air Quality Foreacsting for TexAQS-II



What configurations were used for ETAQ-F 2006?

- ETAQ-F 2006 F1 & F2

Meteorology (F1 & F2 used UH MM5)

* high-resolution Satellite observation based LULC data
* improved MRF for stable PBL and transition times (under development)
* cloud; both the subgrid scale explicit scheme at 4-km

Emissions (F1 = 2000 SIP TEI vs. F2 = 2005* projected)
+ 2000 Imputed alkene emissions from Houston Ship Channel

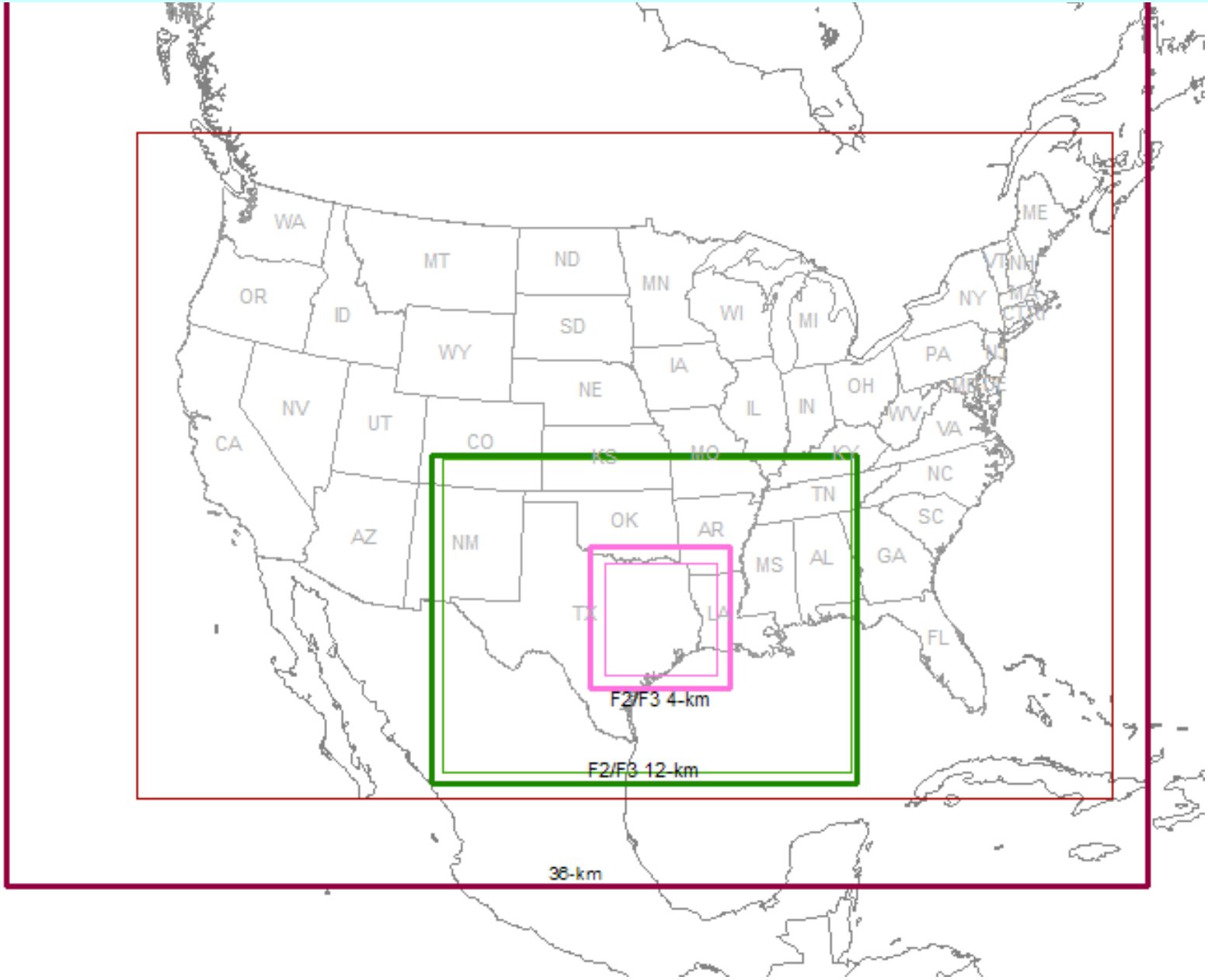
* 2005 TEI (projected from 2000 (imputed emission) & 2007)
* 2000 HRVOC (instead of 2005 projected)
* Mobile projected for 2003

→ See slides later…..

CMAQ (F1 = HGB 4-km vs. F2 = Extended 4-km (HGB + DFW)

* CB4 for forecasting and SAPRC99 for evaluation

Modeling Domains – F2, TexAQS-II



Improvement of Meteorological Modeling for Air Quality Assessment

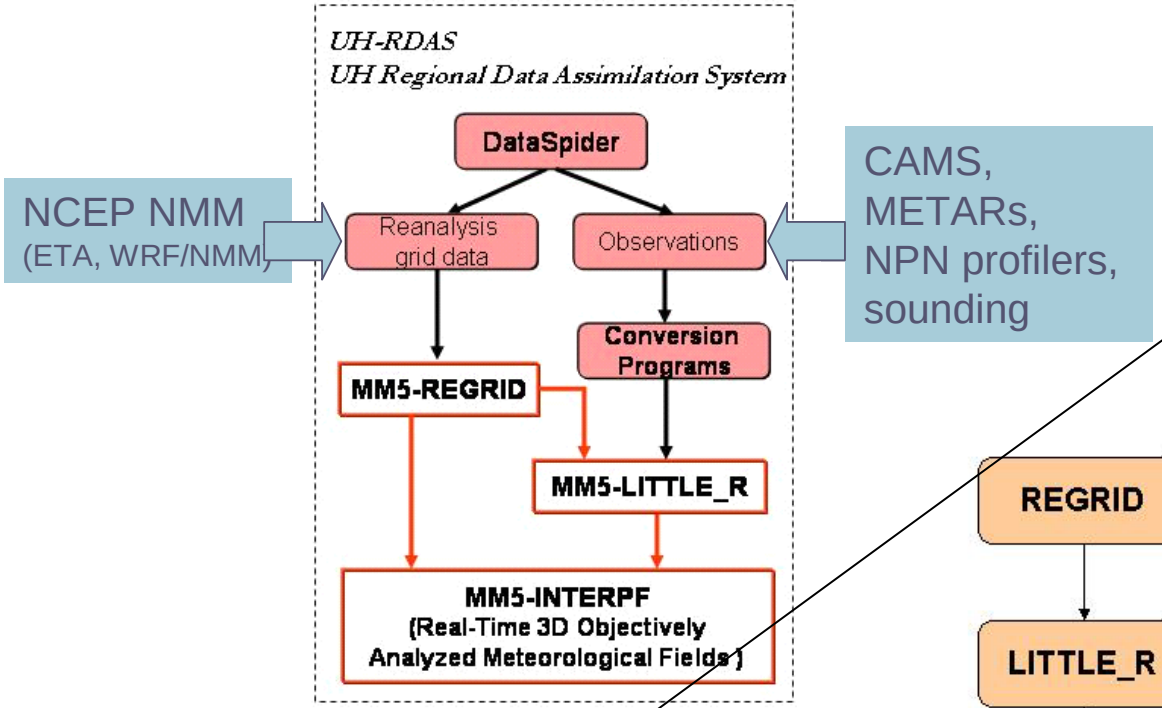
AQF was successfully used for the planning and implementation of TexAQS-II experiment, but we found systematic problems

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

For the retrospective meteorological modeling, we applied the

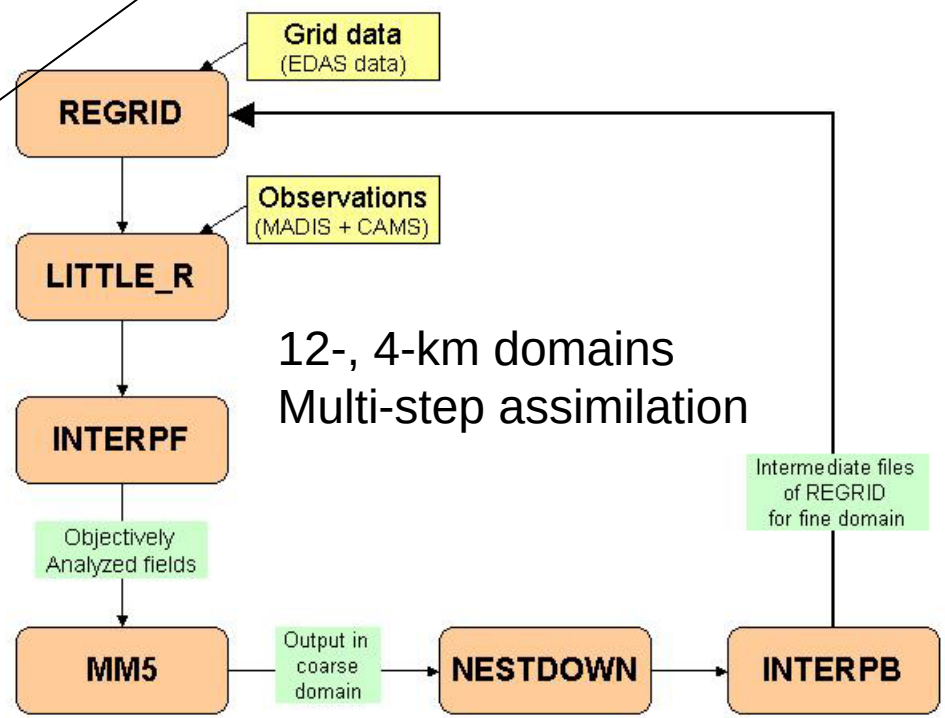
"MUltiscale Nest-down Data Assimilation System (MUNDAS)", which utilized extensive measurements and recursive application of the objective analysis/FDDA method across multiple domains with different resolutions (36-, 12-, to 4-km resolution)

Transition to Assessment Study: MM5 AQF vs. Assimilation



No time to develop a fancy scheme

Because we need the met data "now"



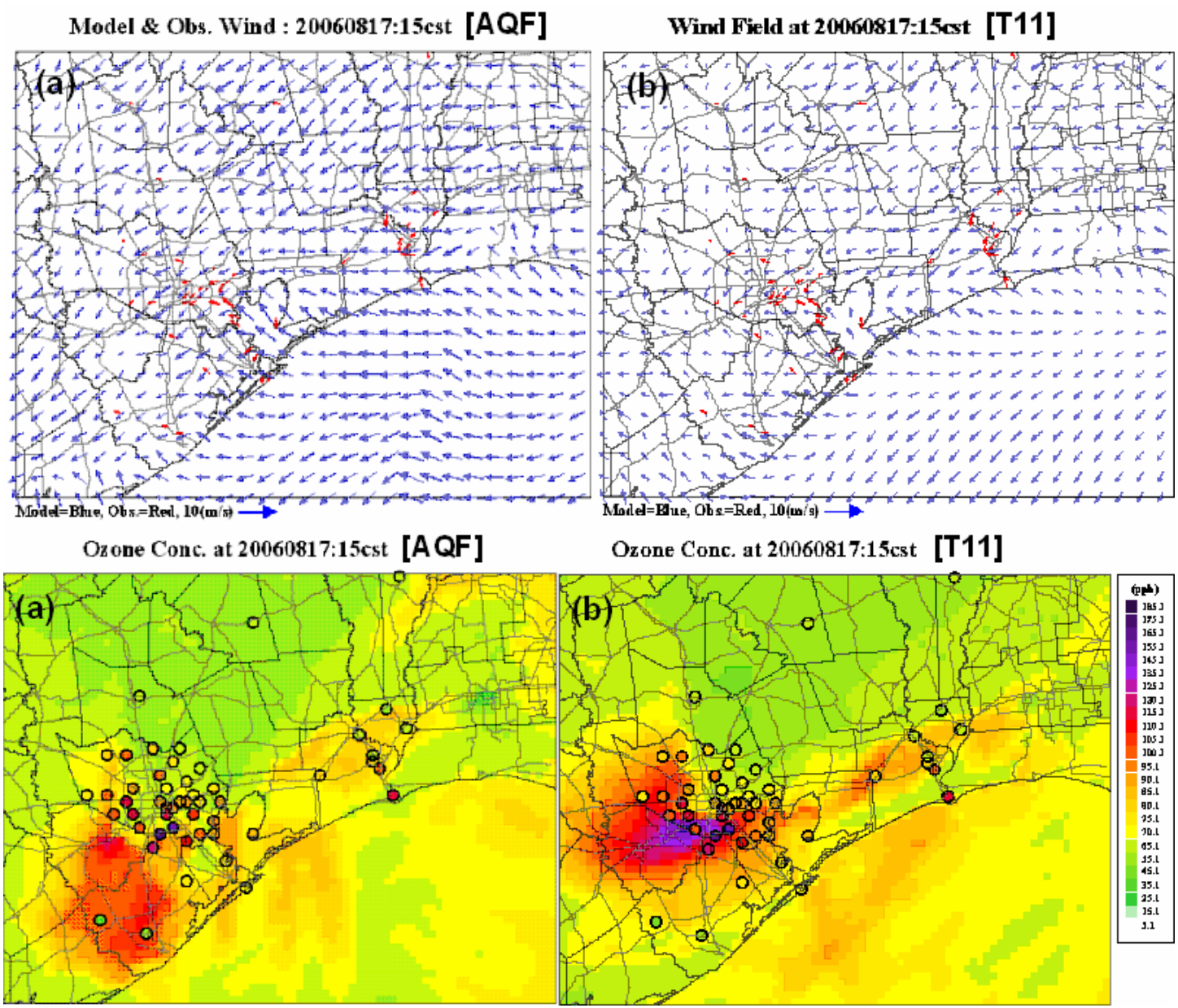
12-, 4-km domains
Multi-step assimilation

Ad-hoc tool:

Multi-stage FDDA

12- and 4- km domaina

Certain days, it improves air quality simulations greatly.



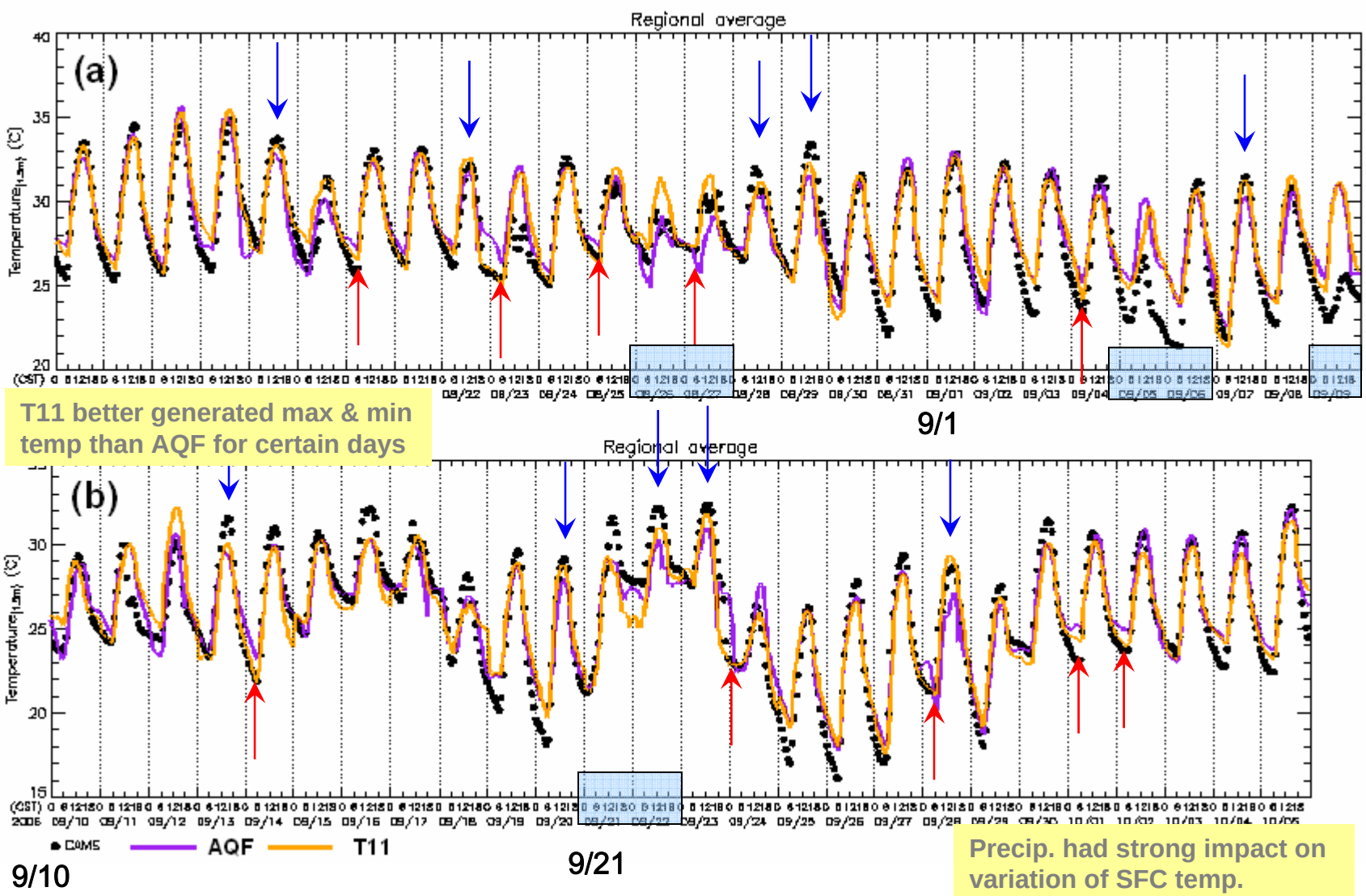
In T11, Wind was slow down that convergence ozone could be formed at the afternoon

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

Phase III: 8/14 – 10/5 (54 days)

No T & RH nudging at both SFC & upper level

Regional average of observed and model 1.5 m temperature



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

9/1

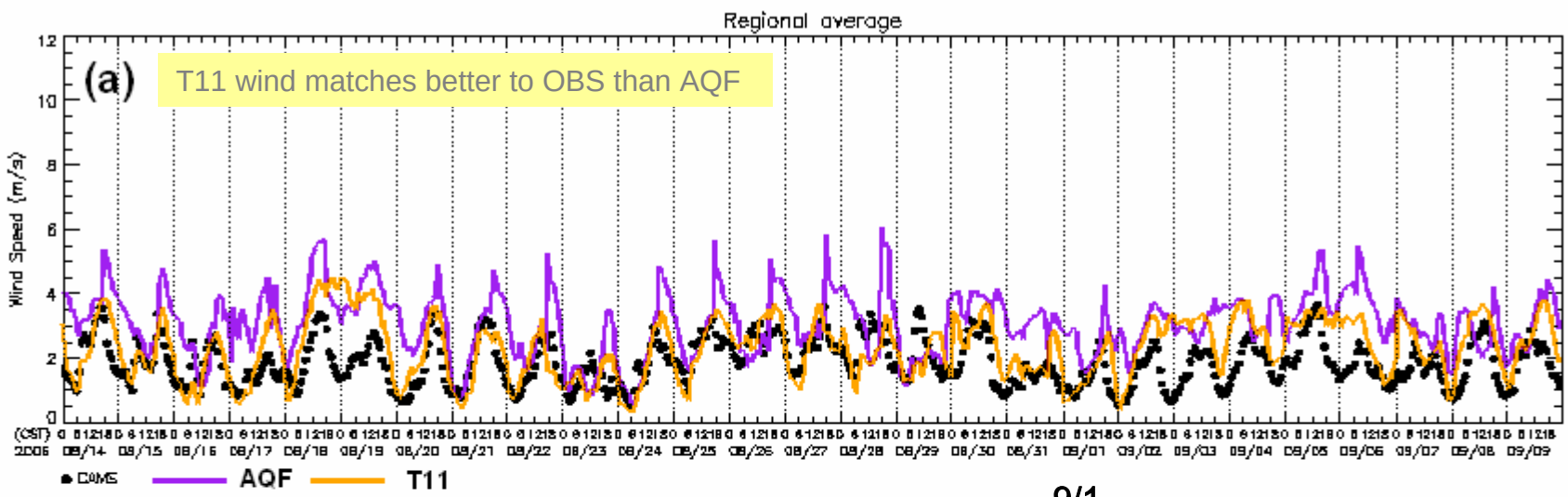
9/10

9/21

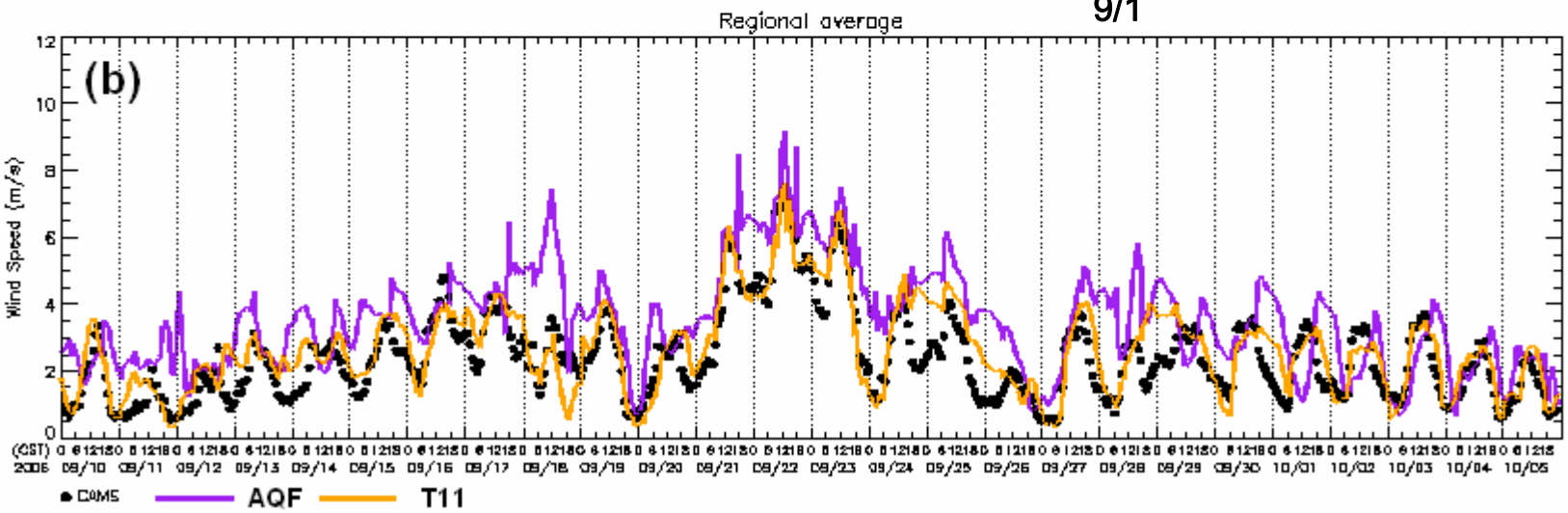
Precip. had strong impact on variation of SFC temp.

Phase III: 8/14 – 10/5 (54 days)

Regional average of observed and model 1st wind speed



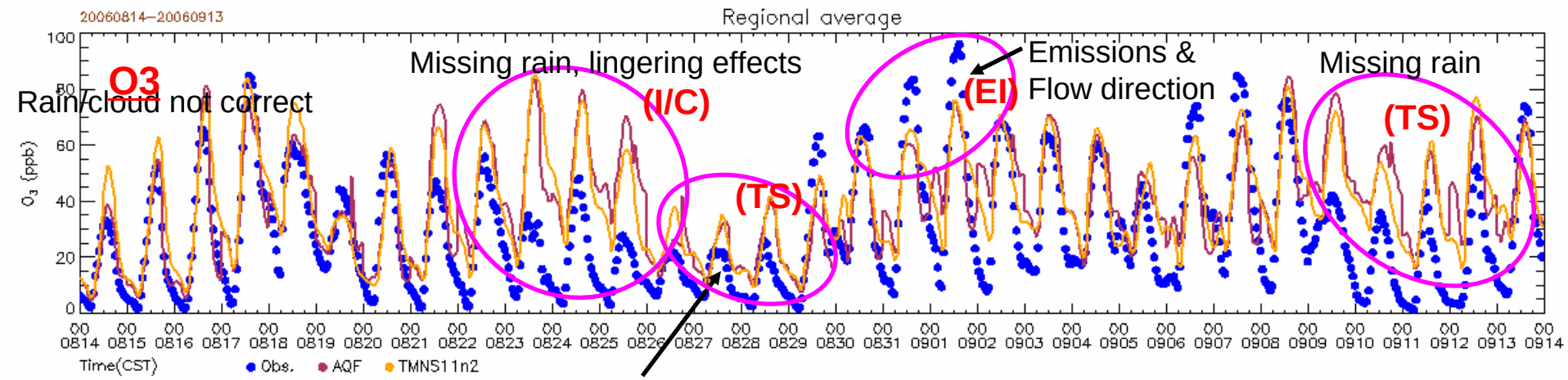
9/1

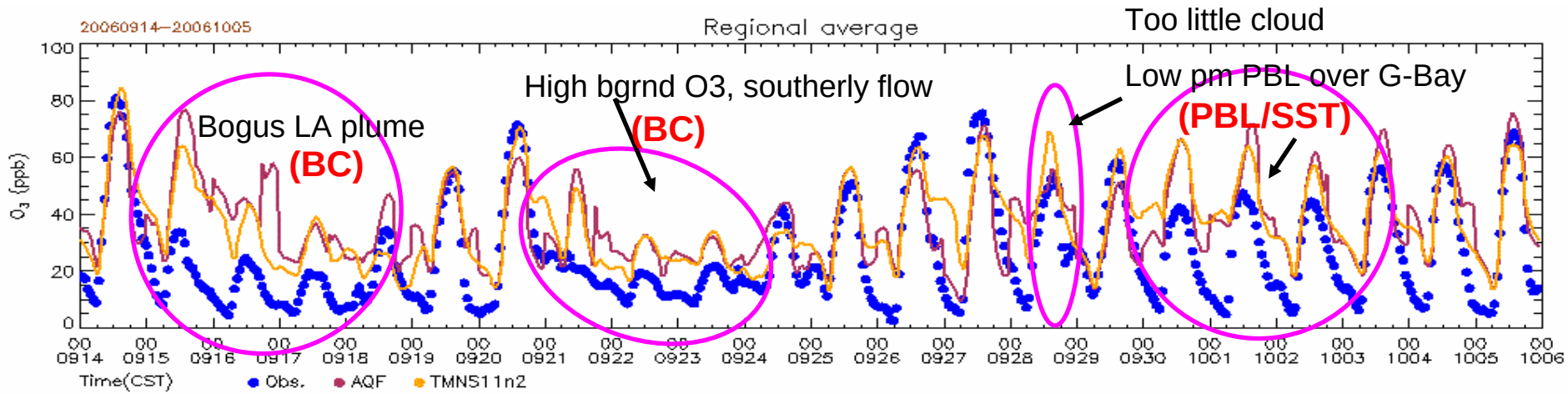


9/10

9/21

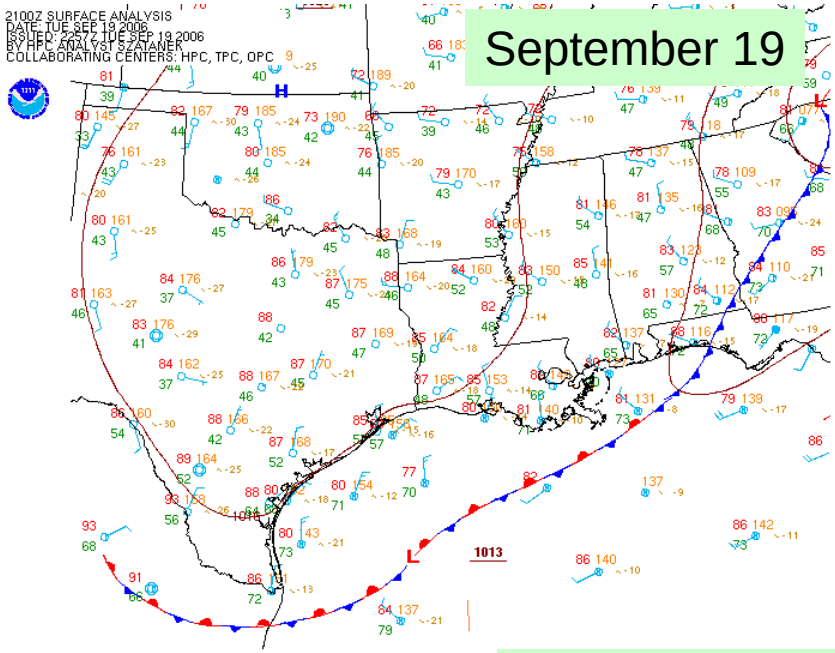
Reduce O3 model biases by improving meteorology through data assimilation

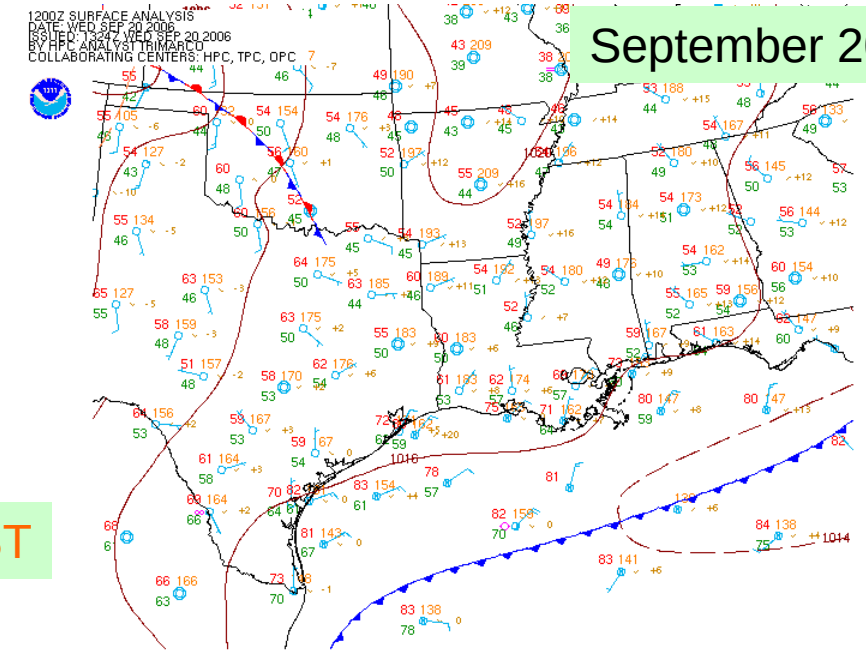




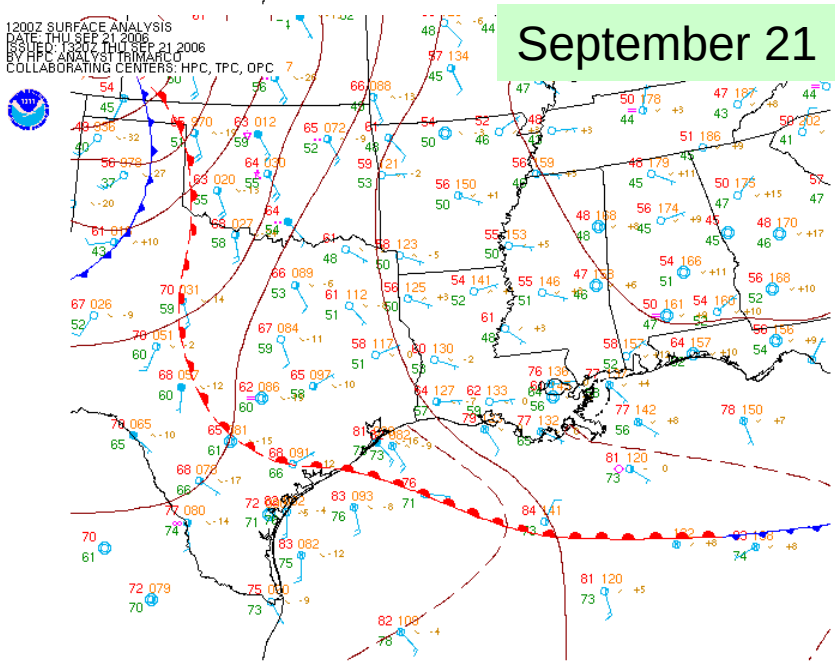
O3 averaged over the CAMS sites in the HGB domain
for Aug. 16-Sept. 14, 2006 (upper) and Sept. 15 – Oct. 6, 2006 period (lower).

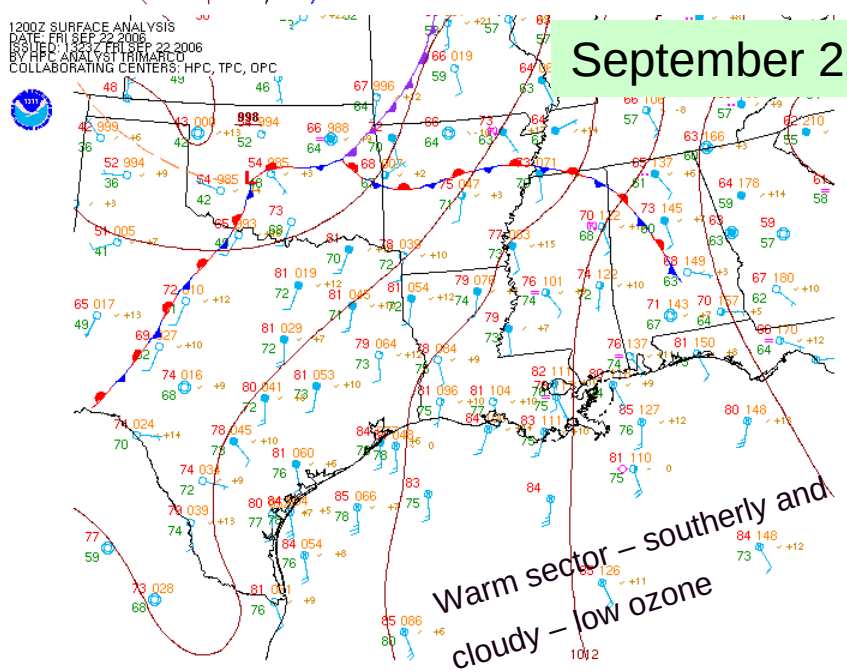
September 19 – 26, 2006

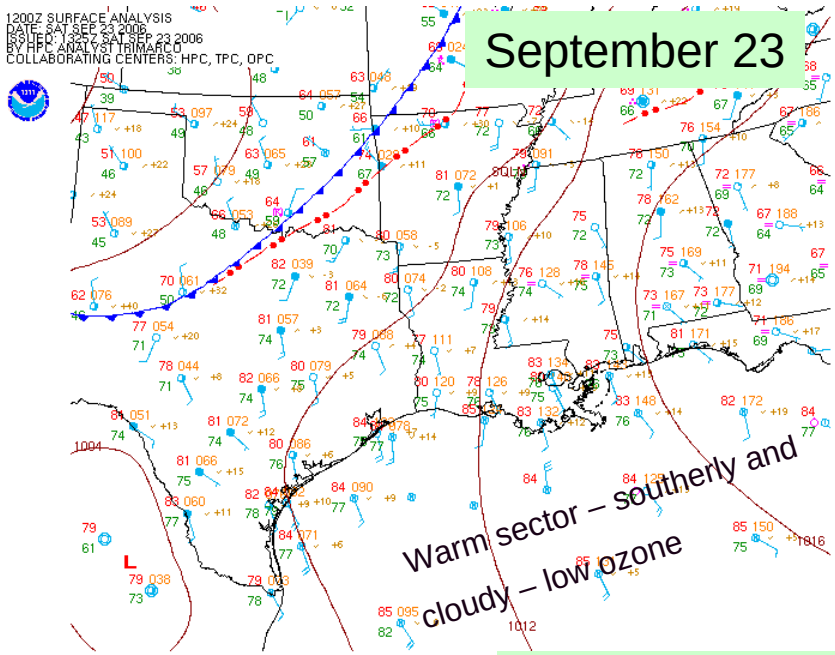




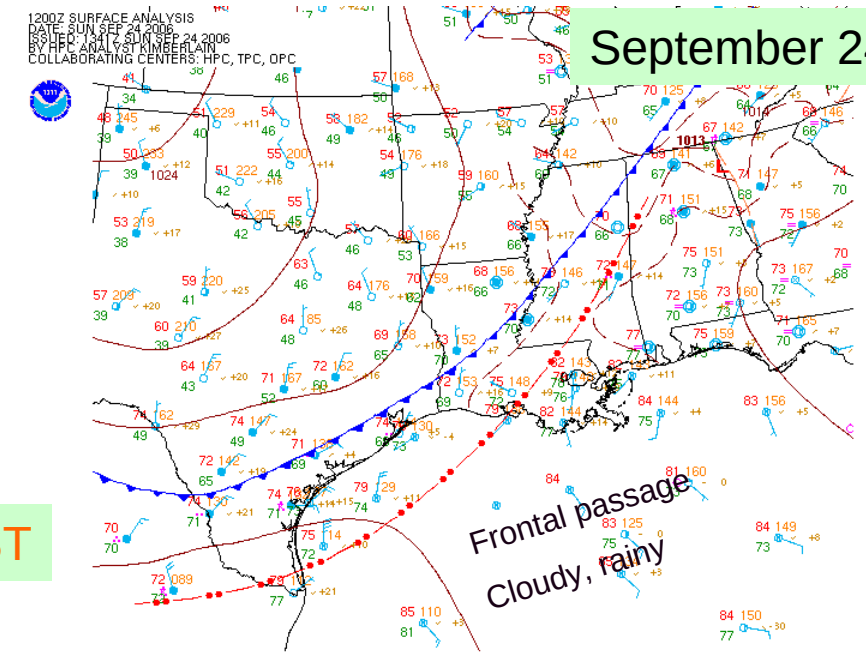
06 CST

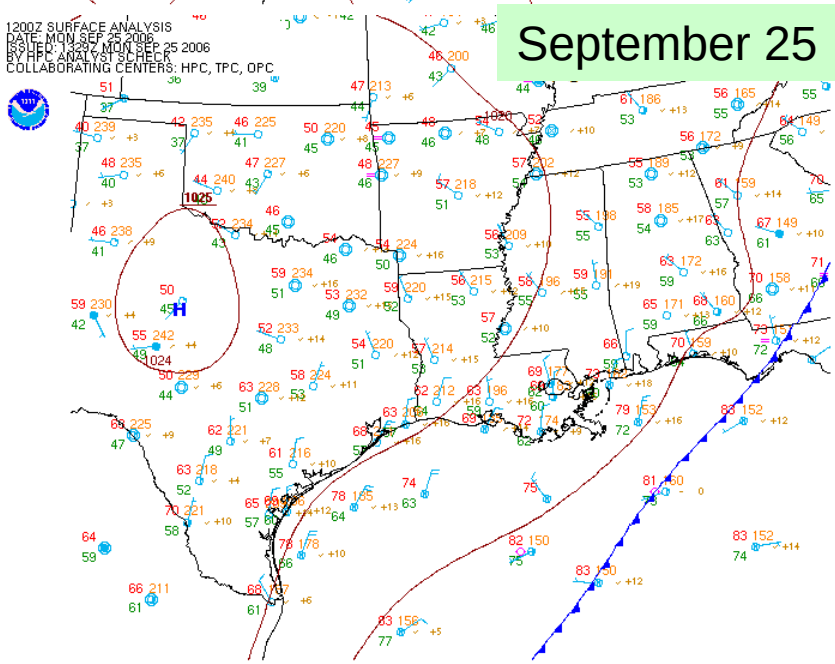


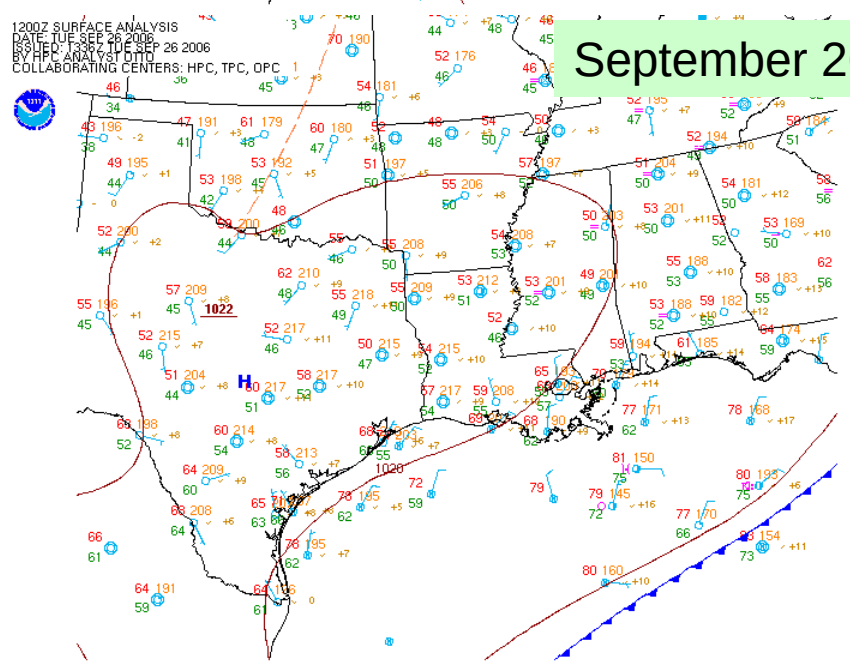



1200Z SURFACE ANALYSIS
DATE: SAT SEP 23 2006
ISSUED: 1235Z SAT SEP 23 2006
BY HPC ANALYST TRIMARCO
COLLABORATING CENTERS: HPC, TPC, OPC
September 23
Warm sector – southerly and
cloudy – low ozone

06 CST


1200Z SURFACE ANALYSIS
DATE: SUN SEP 24 2006
ISSUED: 1347Z SUN SEP 24 2006
BY HPC ANALYST KIMBERLAIN
COLLABORATING CENTERS: HPC, TPC, OPC
September 24
Frontal passage
Cloudy, rainy

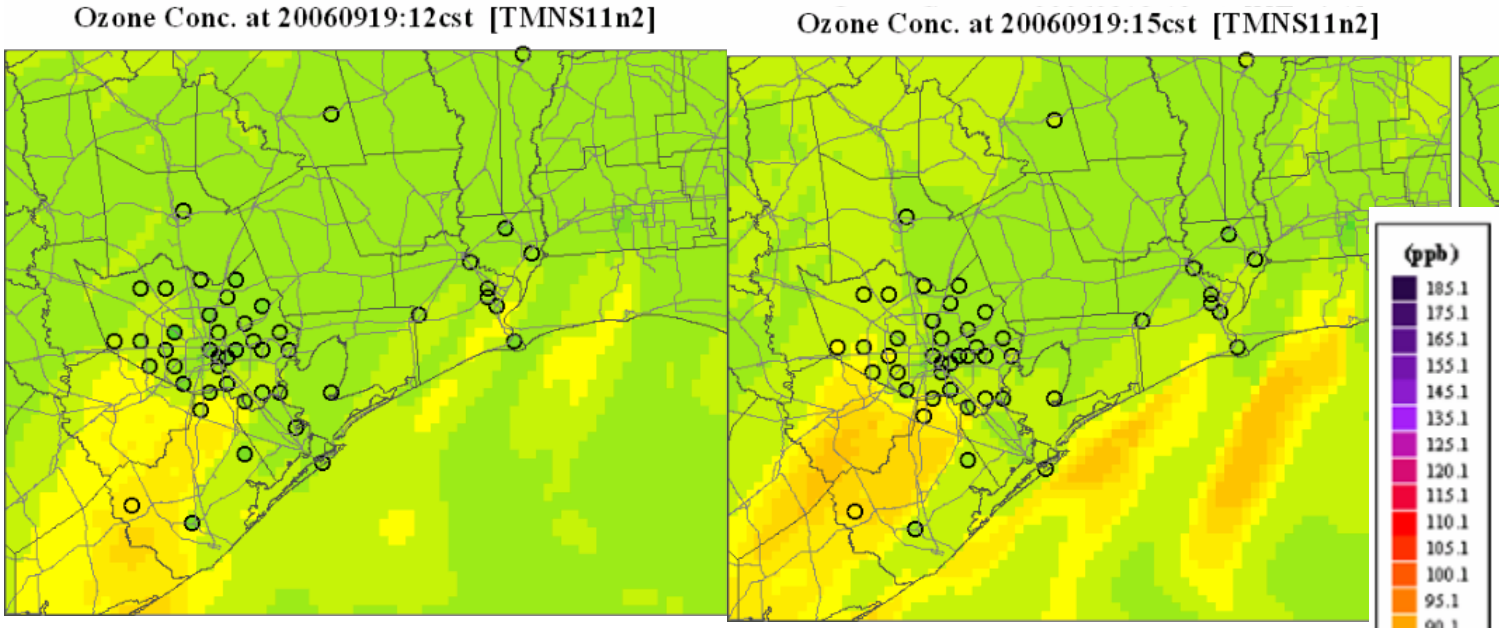

1200Z SURFACE ANALYSIS
DATE: MON SEP 25 2006
ISSUED: 1329Z MON SEP 25 2006
BY HPC ANALYST SCHECK
COLLABORATING CENTERS: HPC, TPC, OPC
September 25


1200Z SURFACE ANALYSIS
DATE: TUE SEP 26 2006
ISSUED: 1336Z TUE SEP 26 2006
BY HPC ANALYST OTTO
COLLABORATING CENTERS: HPC, TPC, OPC
September 26

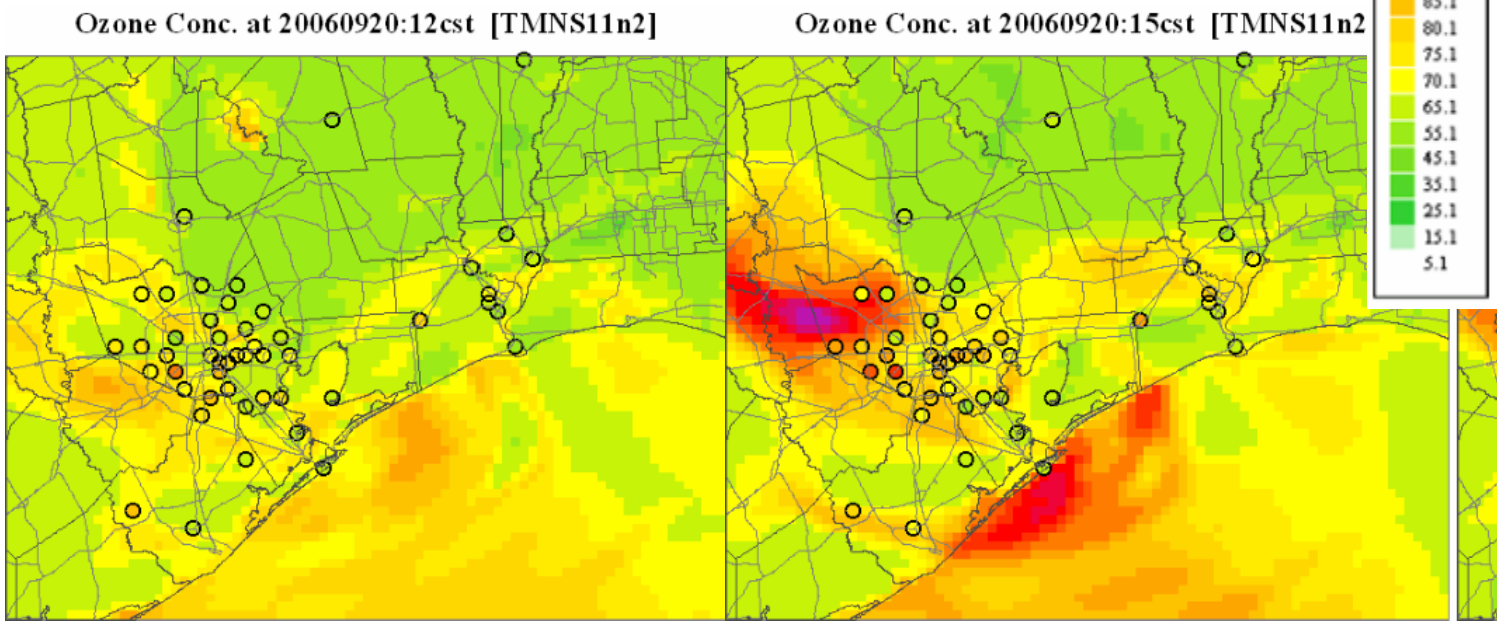
CMAQ, CB-4, F2 Projected with 2000 Imputed vs. Reduced Imputation to 2005 level

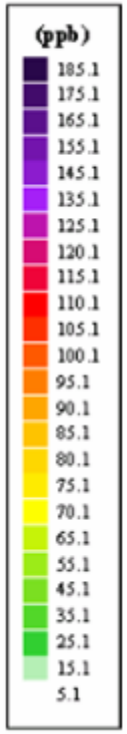
12 CST **15 CST**

September 19, 2006



September 20, 2006

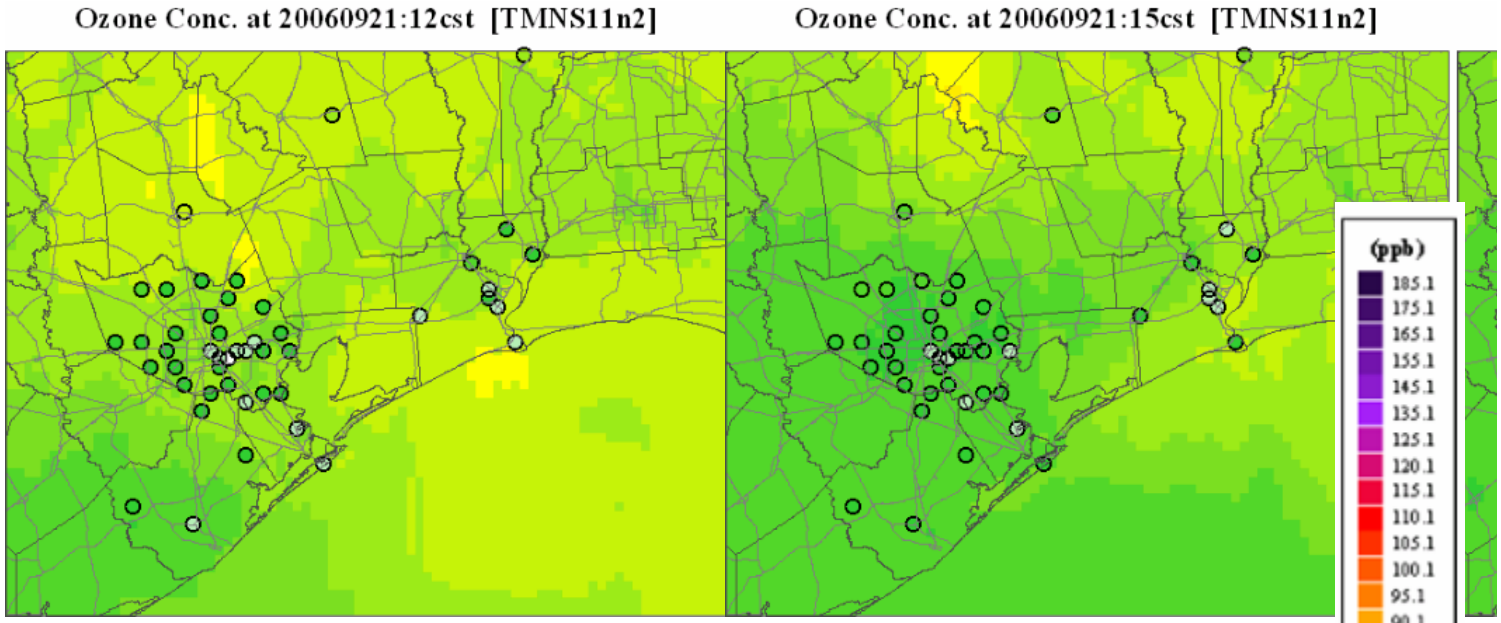




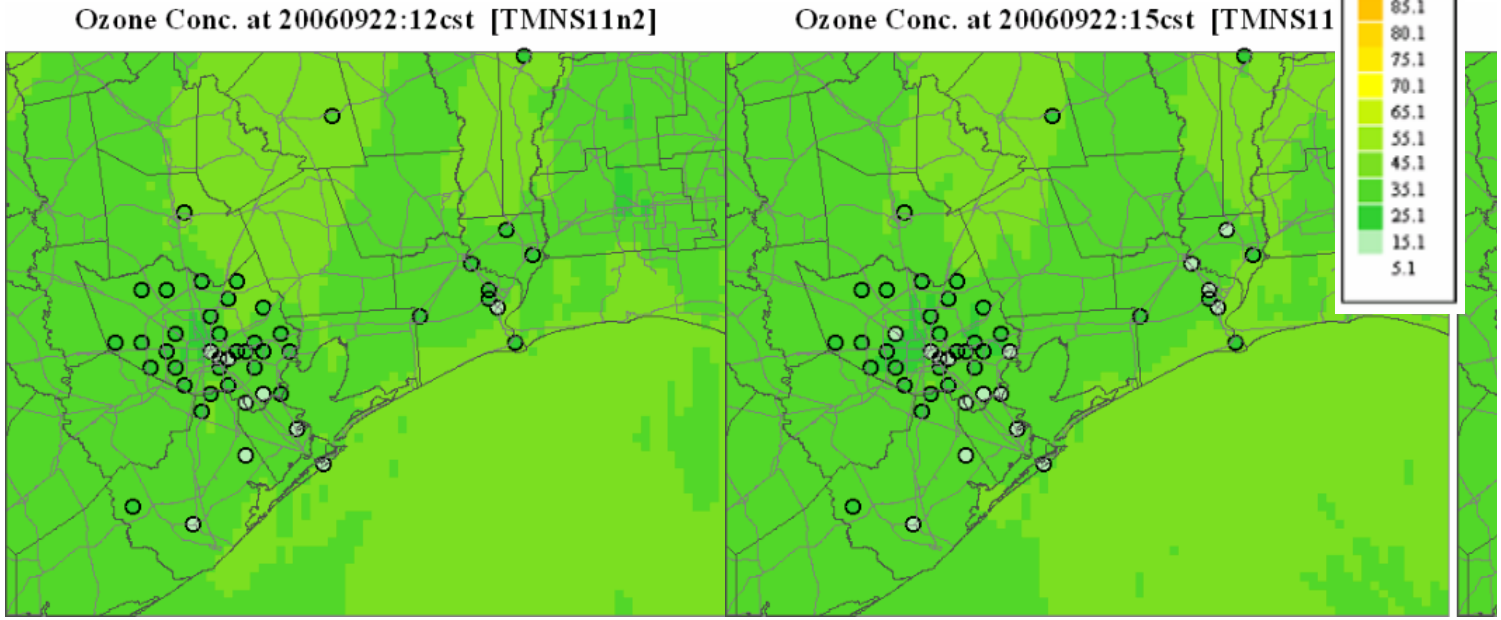
CMAQ, CB-4, F2 Projected with 2000 Imputed vs. Reduced Imputation to 2005 level

12 CST **15 CST**

September 21, 2006



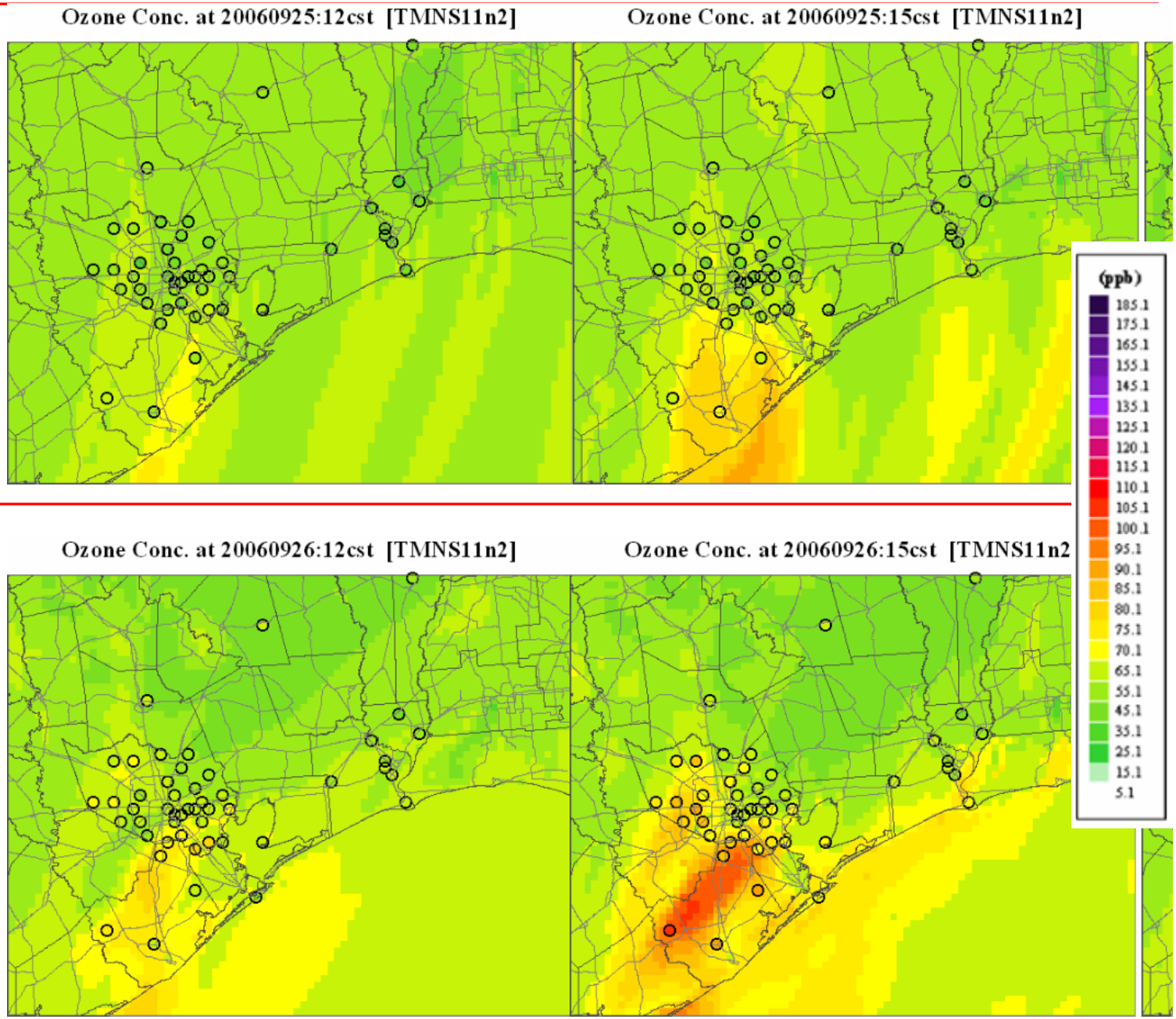
September 22, 2006



CMAQ, CB-4, F2 Projected with 2000 Imputed vs. Reduced Imputation to 2005 level

12 CST **15 CST**

September 25, 2006



September 26, 2006

Highlights of O3 simulation

•Model generally captured the daily ozone cycle well, although there were some night-time overprediction

•08/23, model overpredicted the low ozone values in the daytime due to the MM5's failure of simulating precipitation events in HGB. High bias continued to linger (08/24, 08/25) due to the daisy-chained I/Cs used

•overpredicted ozone by around 10 to15 ppb during southerly wind days (08/26-27, 09/16 –17, 09/21 – 23) when erroneous high ozone drift problem LA

•Overprediction of ozone during 9/9 – 9/12 are also attributed to both the missing precipitation and some weaker southerly flows in the MM5 simulations compared to the observations.

•Significant overprediction of regional average ozone concentrations on 9/30 – 10/01 is probably caused by the much less cloud cover simulated by MM5

Updated Emission Inventory for 2006 Summer

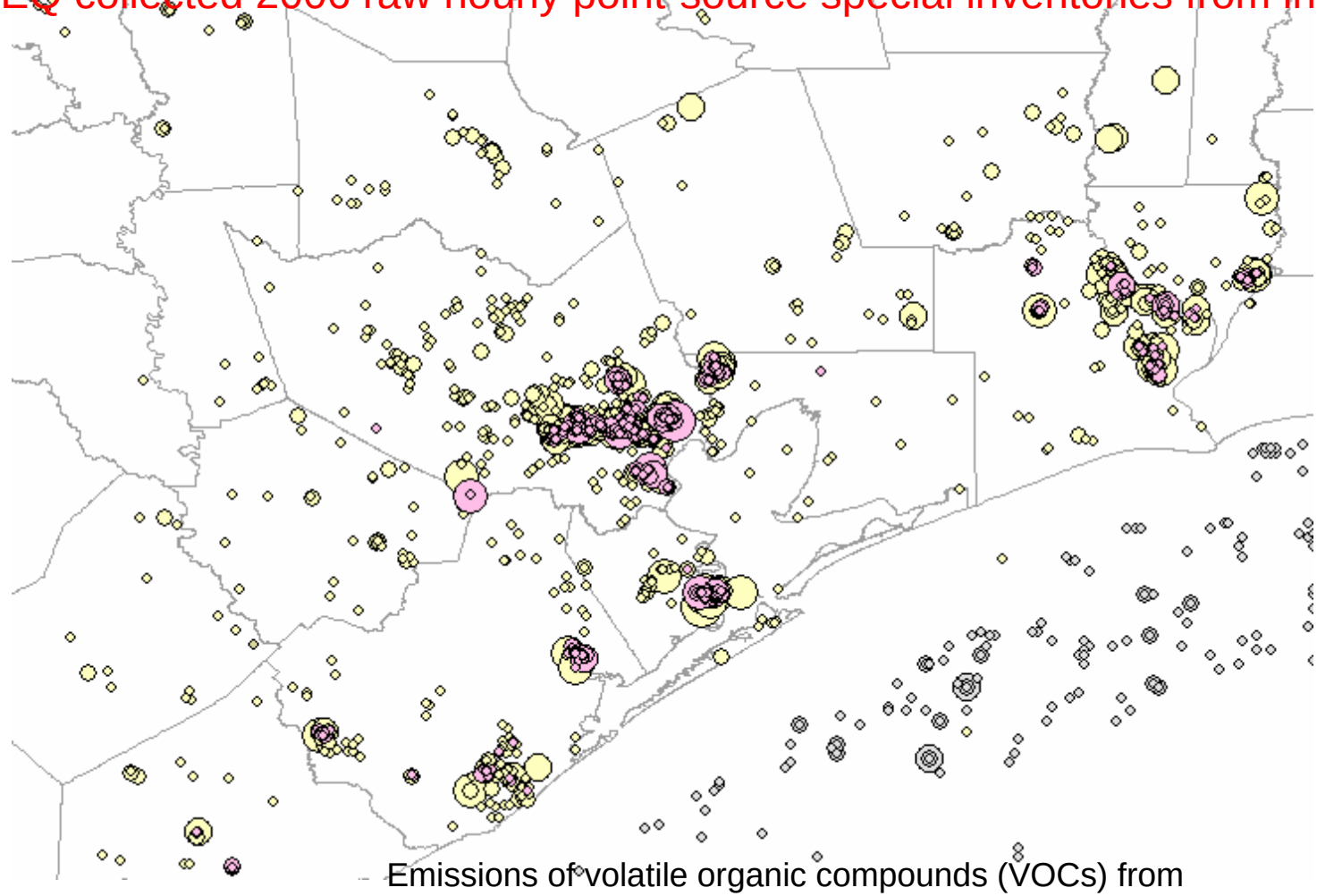
TCEQ collected 2006 raw hourly point-source special inventories from industry

Emissions inventories used for the base AQF and
the “best-effort model-ready” (BEMR) Texas Emission Inputs

	Base AQF	BEMR
Area & Non-road	Base5b 2000	Base5b 2007 (TCEQ)
On-road	Linked-based and HPMS MOBILE6 projected for 2003	Linked-based and HPMS MOBILE6 projected for 2005
Point	Base5b regular emissions projected for 2005 & additional VOC for 2000 imputation	2006 Texas point-source special inventory (TPSI2006)
Biogenic	TCEQ's 2000 LULC and MM5 meteorology	TCEQ's 2006 biogenic emissions
Supplementary	NEI99	NEI2002

Updated Emission Inventory for 2006 Summer

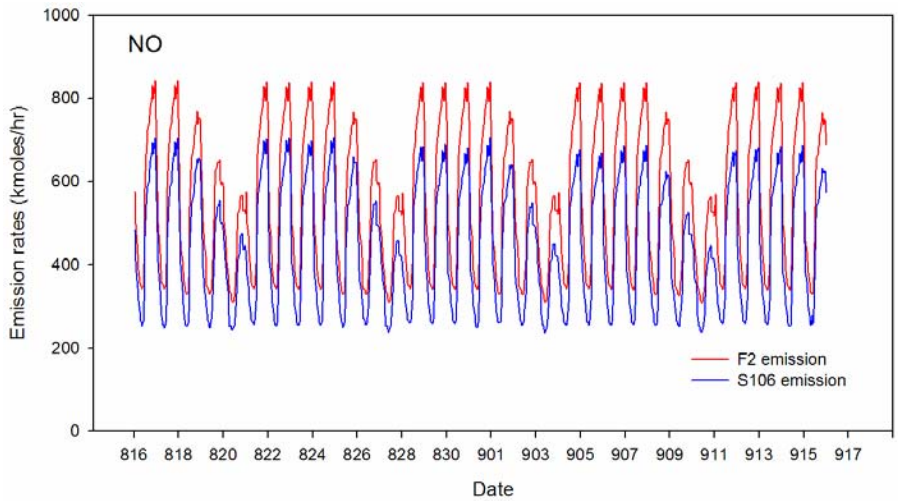
TCEQ collected 2006 raw hourly point-source special inventories from industry

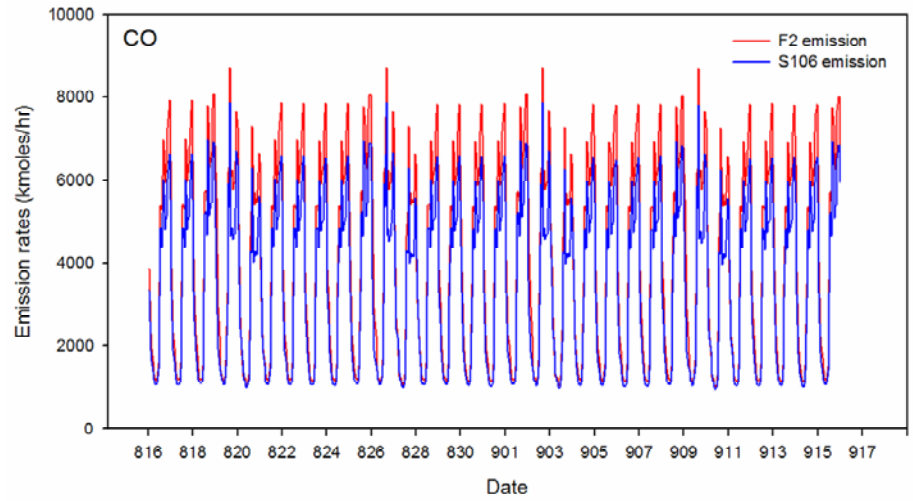


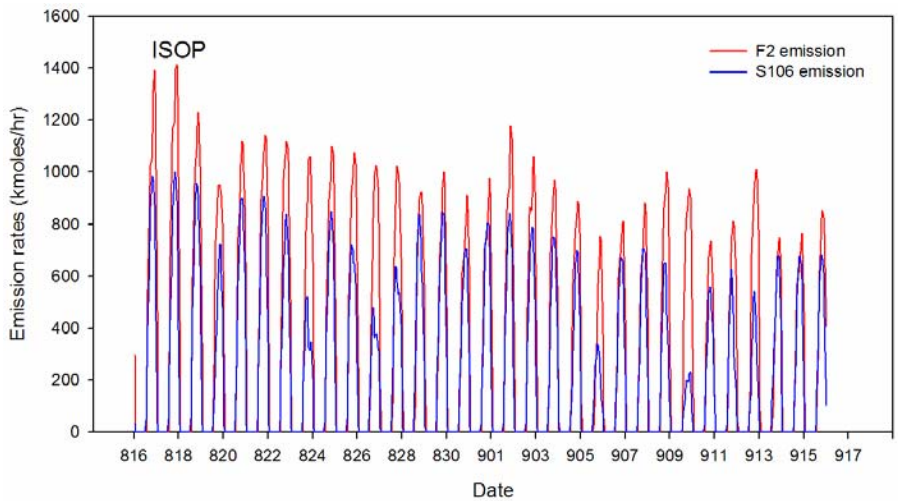
Emissions of volatile organic compounds (VOCs) from the Houston-Galveston-Brazoria (HGB) point sources. Pink and yellow circles represent TPSI2006 and VOC and Texas ozone-season day (OSD) emissions, respectively.

Updated Emission Inventory for 2006 Summer

TPSI 2006 vs. AQF2 (NO, CO and Isoprene)



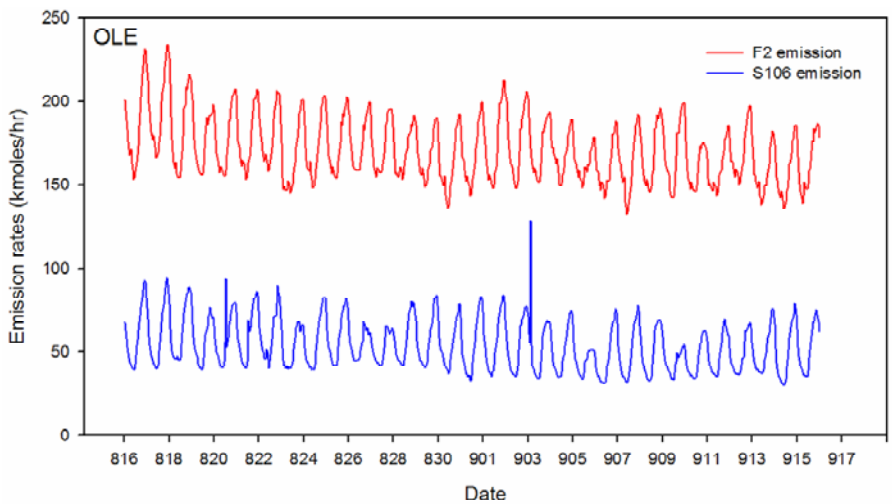


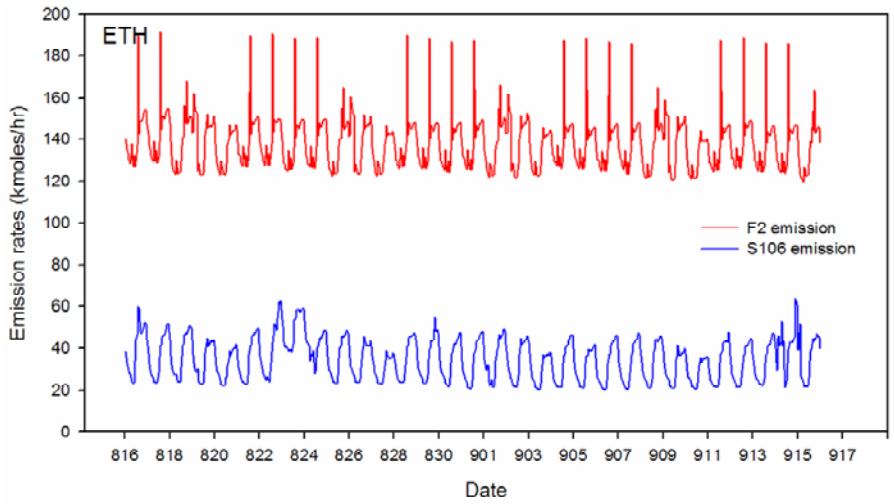


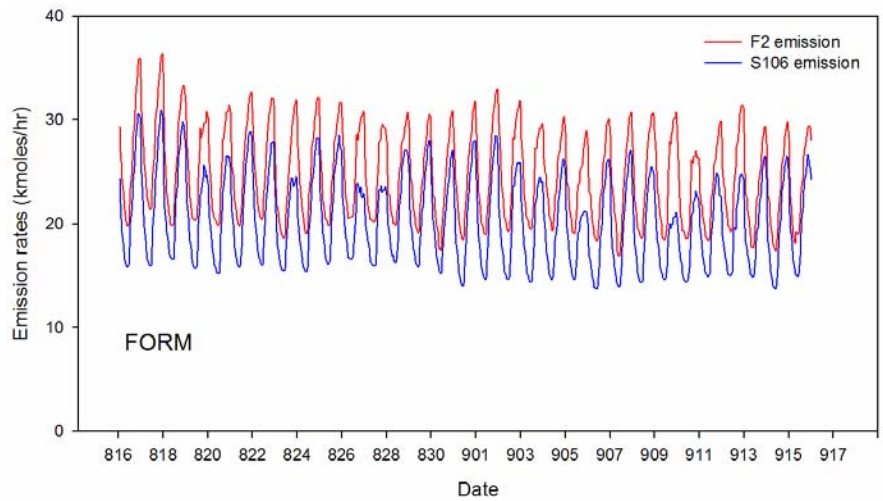
Biogenic emissions between 2000 vs. 2006 inventories (from TCEQ)

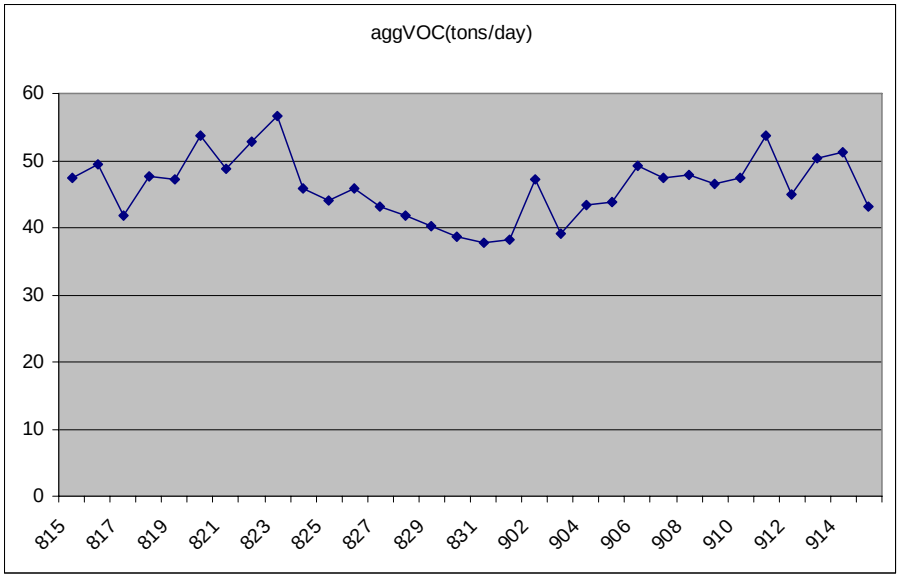
Updated Emission Inventory for 2006 Summer

TPSI 2006 vs. AQF2/imputed emissions



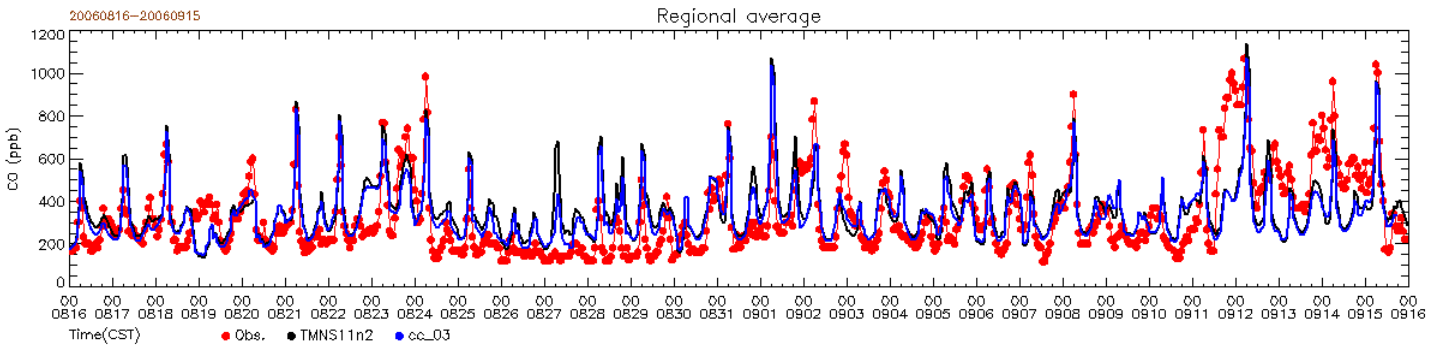




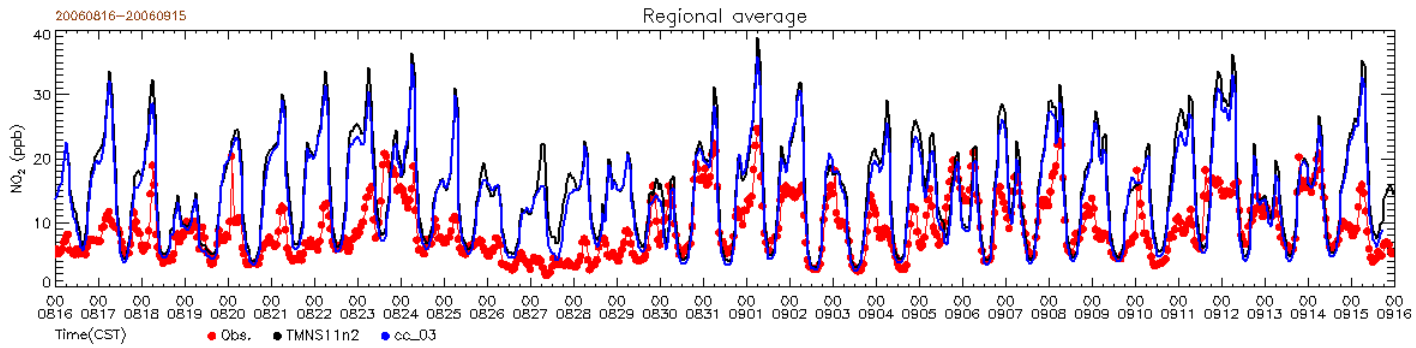


Air quality simulations with BEMR 2006 and AQF2

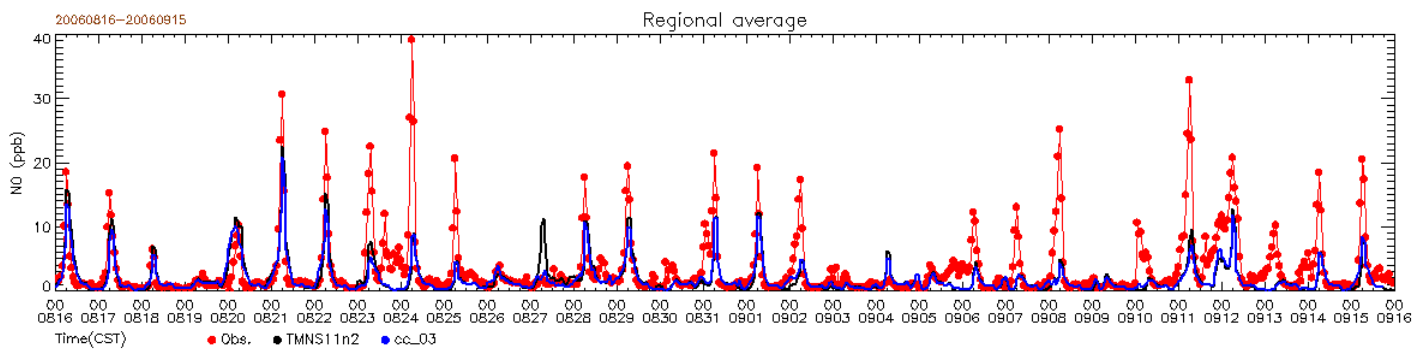
TPSI 2006 vs. AQF2/imputed emissions (regional average)



CO



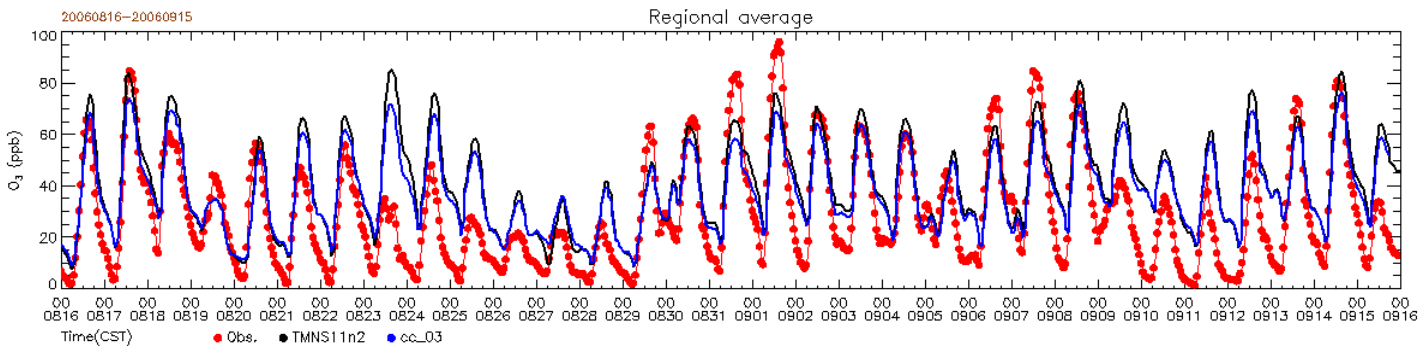
NO2



NO

Air quality simulations with BEMR 2006 and AQF2

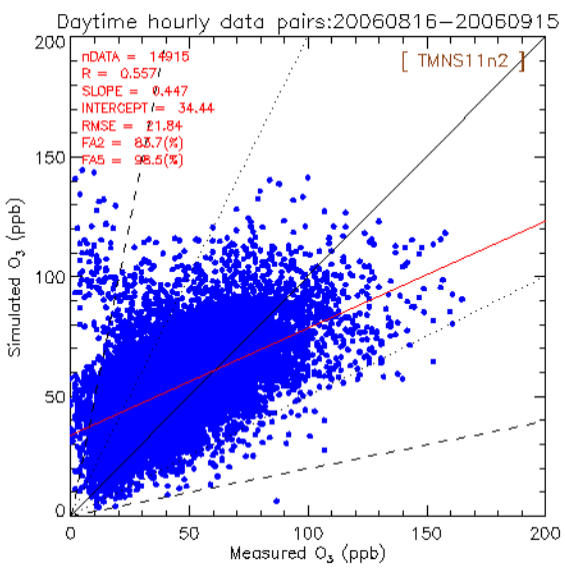
TPSI 2006 vs. AQF2/imputed emissions

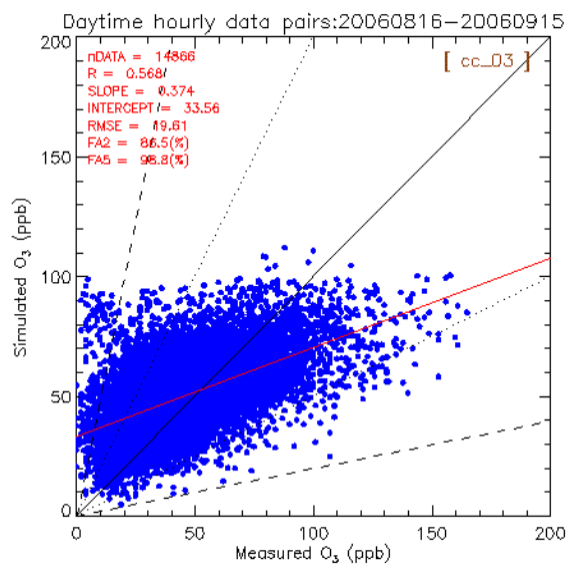


O3

Regional average do not represent different emissions impact properly for O3 !

(dominated by the boundary flux)





Comparison with for all the Individual CAMS sites:

BEMR/TPSI shows less scatter

But lacks reactivity significantly!

→Need HRVOC emissions for 2006 as well

Summary

◆ MM5/FDDA re-simulation with CAMS, MADIS, others

- **Reduction of WD & Speed biases and more realistic flow variations overall**
- **But, some unwanted flow patterns due to difficulties in T-Storm simulations**

◆ Emissions

- **AQF1 (2000 TEI) with 2000 TCEQ imputed alkene too high NOx and VOC….**
- **AQF2 (2005* projected) with 2000 TCEQ imputed alkene ~ OK**
- **BEMR/TPSI2006 – lower NOx, CO, and VOC than AQF2**

◆ CMAQ re-simulation results

- **Used of TMNS112n meteorology quite successful**

  But not always improves met & air quality simulation results

  - **Shows effects of evening mixing and wind speed bias**

- **Used of BEMR/TPSI**
  - **Less scatter**
  - **lacks some O3 reactivity…**
  - **Need substantial amount of additional HRVOC emissions over TPSI2006**
  - **Upset event simulation issues existing for certain days**

http://www.imaqs.uh.edu/

Acknowledgement: HARC, TCEQ, EPA, NOAA, NASA