Utilization of Satellite Measurements at Various Stages of Atmospheric Modeling to Improve Air Quality Simulations

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Objectives

- Present examples of utilizing satellite data for improvi ng "inputs" for air quality modeling
  - Meteorological modeling: use satellite derived high-resoluti on land use/land cover data for improving surface exchange processes in MM5 (better dynamics input)
  - Emissions modeling: use of the satellite-derived high resolu tion vegetation data and compare biogenic emissions estima tes (more accurate emissions input)
  - Air quality modeling: data assimilation of total ozone colum n in regional modeling (improved lateral & top BCs)

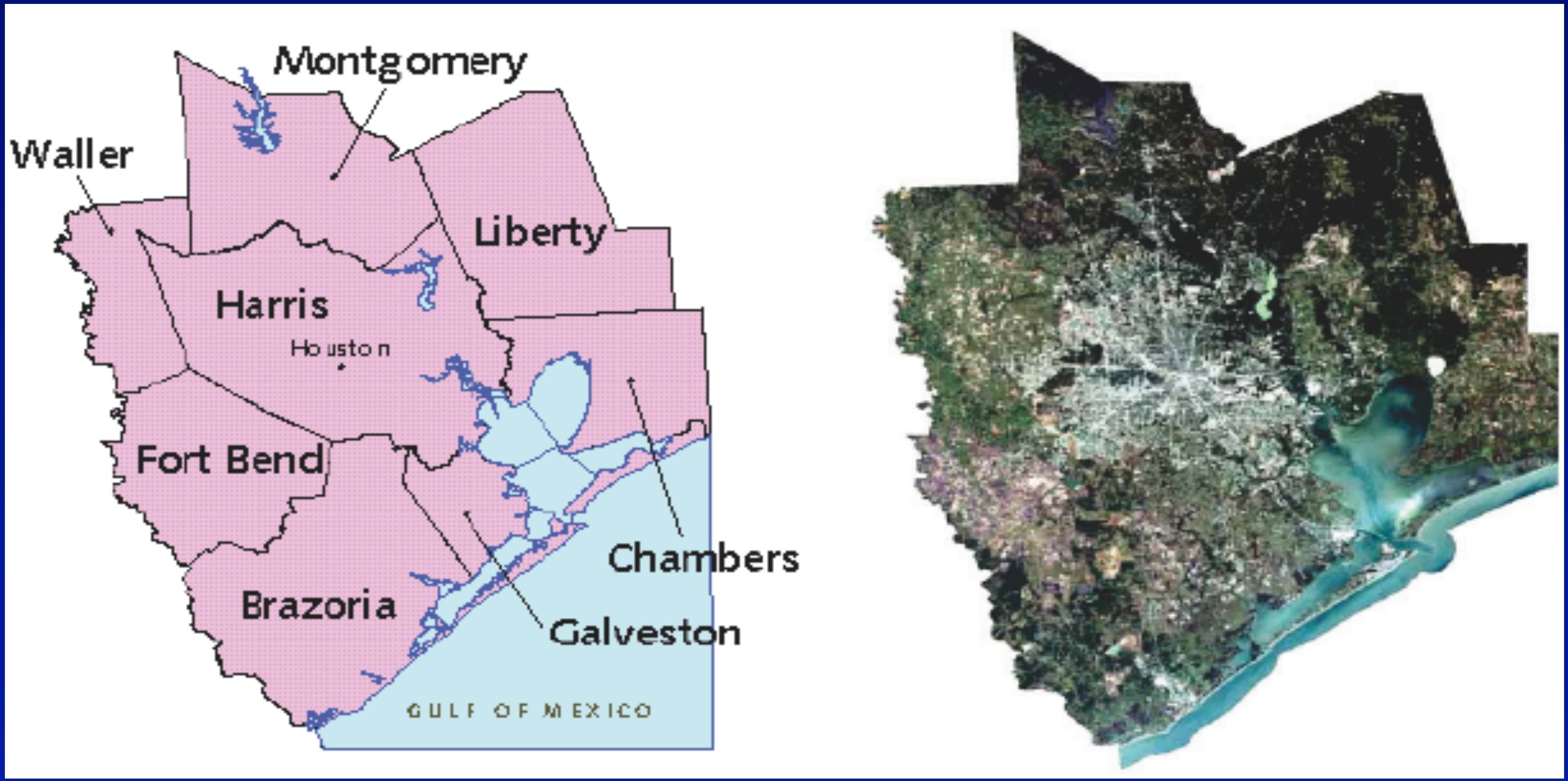
Methods

- Conduct meteorological, emissions, and air quality sensitivity modeling by …
  - Processing the satellite-derived Land Use/Land Cover data for b ase and future years for meteorological and biogenic emissions.
  - Simulating meteorological conditions using a modified MM5 wit h comprehensive NOAH land surface model.
  - Estimating biogenic emissions with leaf biomass for new satellit e-derived LULC classes.
  - Link satellite-derived ozone data from global chemistry model (RAQMS) for regional air quality modeling

TFS 2000 LULC data

- Texas Forest Service (TFS), with the support of Texas Commission on Environmental Quality (TCEQ), has compiled a new high-resolut ion land use and land cover (LULC) dataset for the eight counties in the HGA to characterize regional changes in vegetation and tree spe cies.
- The updated map of LULC was produced using LANDSAT satellite imagery and ancillary datasets for the base year 2000.
- A supervised classification process that uses an image processing so ftware was employed to define the 8 land cover (LC) classes and 15 land use (LU) classes (GEM, 2003)

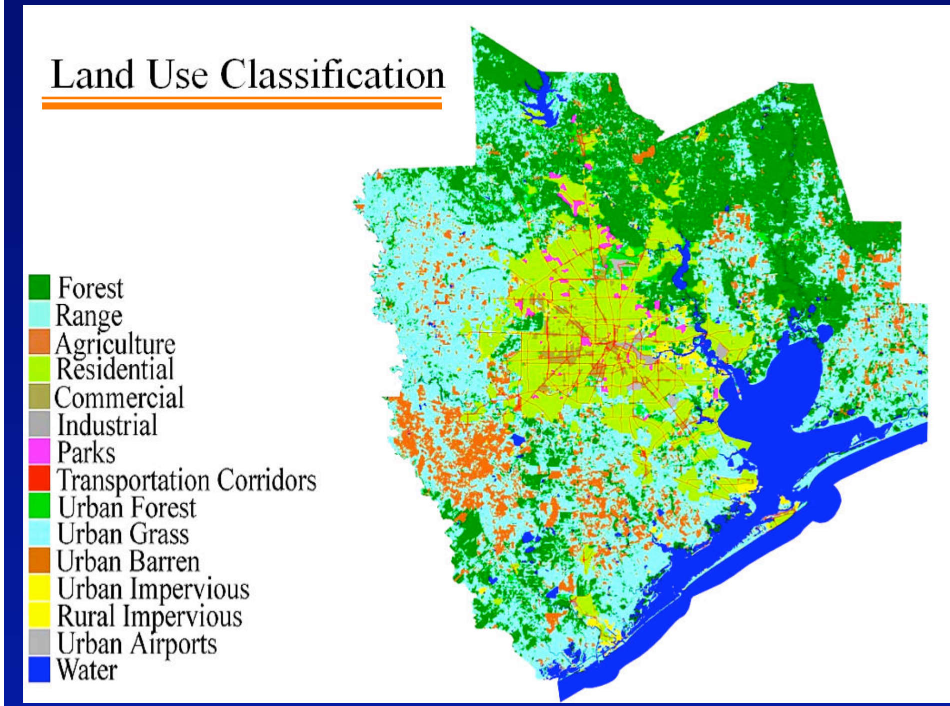
TFS 2000 LULC data

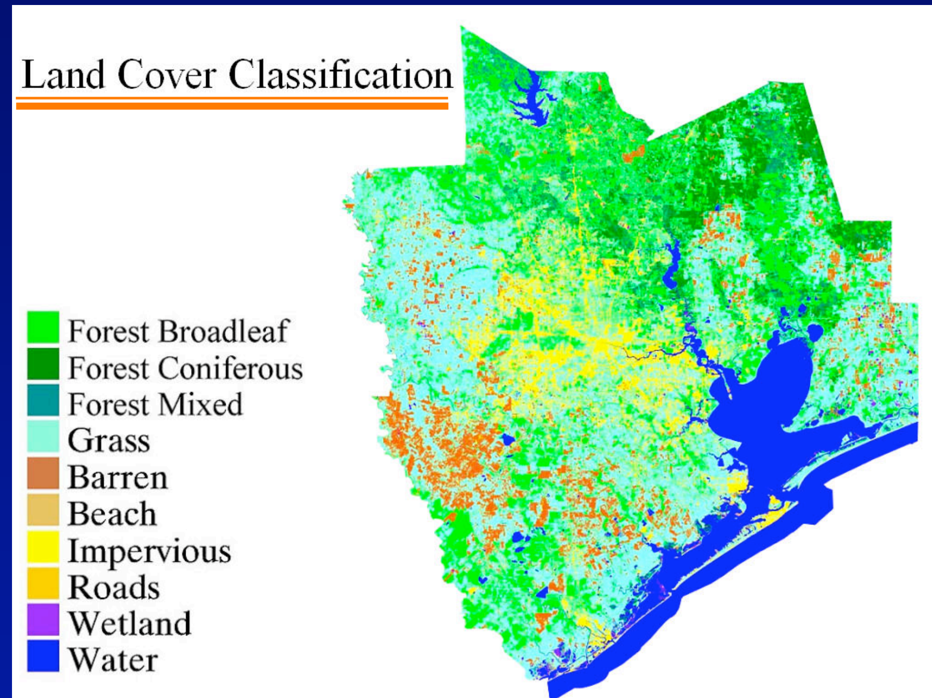


A high-resolution (~30 m) land cover and land use dataset from LANDSAT multi-spectral pictures taken in September 2000 for the purpose of managing the urban forest in HGA. (GEM, 2003)

TFS 2000 LULC data

Stetson (2003)





A supervised classification process using image processing software was employed to defi ne the classes described below:

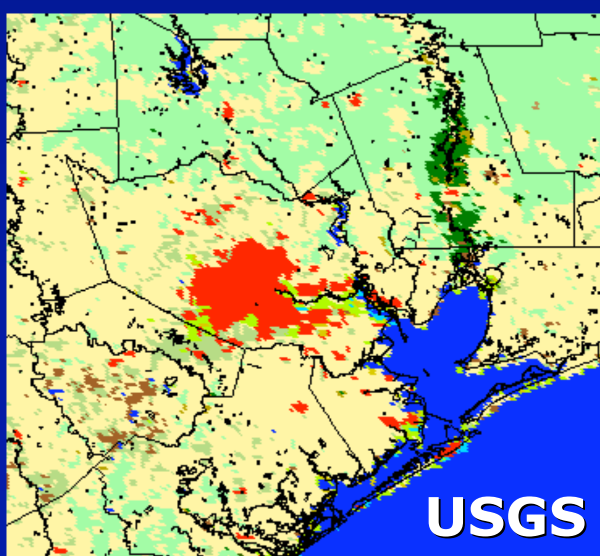
Land Use: forest, range, agriculture, urban/developed

Land Cover: forest composition (coniferous, broadleaf, mixed), grass,
wet land, water, barren (e.g., beach, bare soil),
impervious (roads, parking lots, buildings)

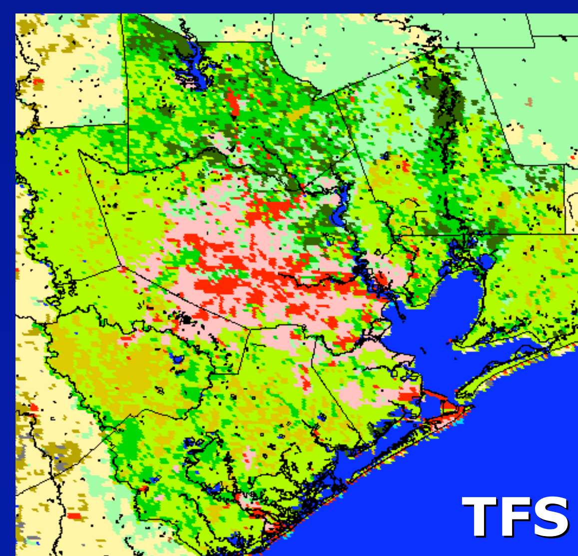
Improve Meteorological Simulations

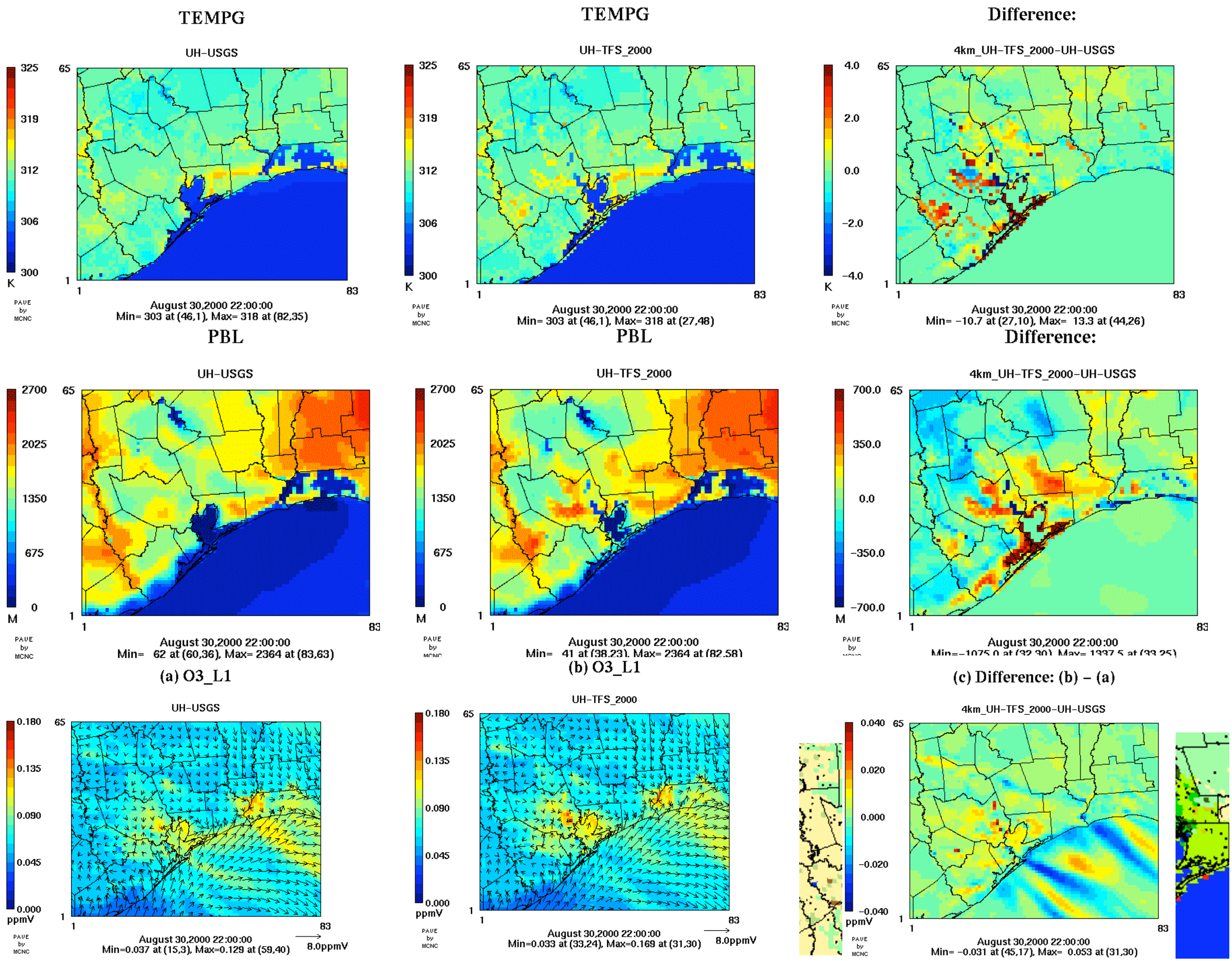
- To better represent surface-air exchange of momentum, moisture, and heat, w e need to have high quality LULC data
- High quality LULC data improves surface energy balance and thus better cha racterization of PBL mixing and dynamics.
- MM5 with the modified NOAH land surface model (Cheng et al., 2003) was used to improve meteorological input. (cf. Direct assimilation of satellite ob served ground temperature – McNider, UAH)

Original LULC in MM5 system

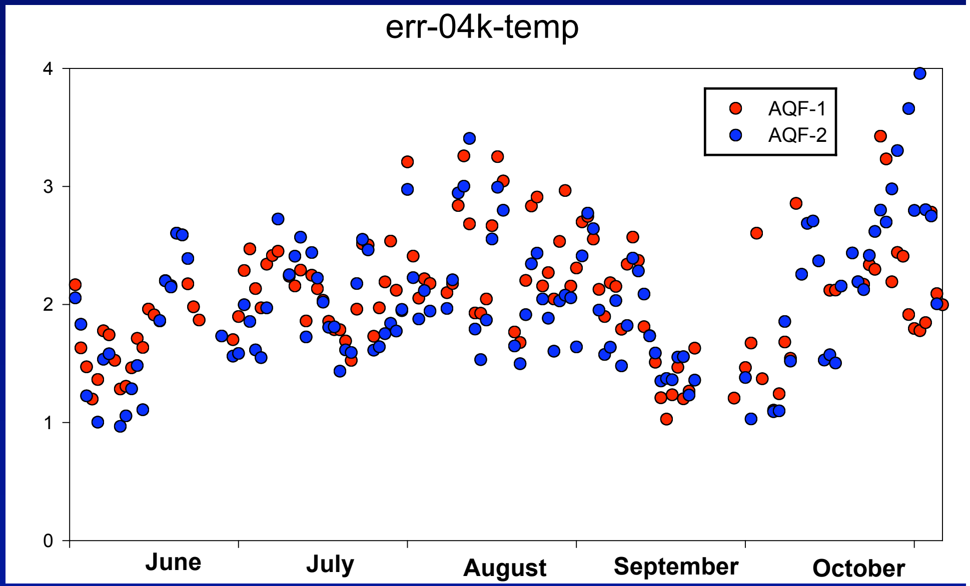


Improved 8-county LULC




TEMPG
UH-USGS
August 30,2000 22:00:00
Min= 303 at (46,1), Max= 318 at (82,35)
TEMPG
UH-TFS_2000
August 30,2000 22:00:00
Min= 303 at (46,1), Max= 318 at (27,48)
Difference:
4km_UH-TFS_2000-UH-USGS
August 30,2000 22:00:00
Min= -10.7 at (27,10), Max= 13.3 at (44,26)
PBL
UH-USGS
August 30,2000 22:00:00
Min= 62 at (60,36), Max= 2364 at (83,63)
PBL
UH-TFS_2000
August 30,2000 22:00:00
Min= 41 at (38,23), Max= 2364 at (82,58)
Difference:
4km_UH-TFS_2000-UH-USGS
August 30,2000 22:00:00
(a) O3_L1
UH-USGS
August 30,2000 22:00:00
Min=0.037 at (15,3), Max=0.129 at (59,40)
8.0ppmV
(b) O3_L1
UH-TFS_2000
August 30,2000 22:00:00
Min=0.033 at (33,24), Max=0.169 at (31,30)
8.0ppmV
(c) Difference: (b) – (a)
4km_UH-TFS_2000-UH-USGS
August 30,2000 22:00:00
Min= -0.031 at (45,17), Max= 0.053 at (31,30)

Temperature



Temp MM5 w/ Better LULC (AQF1) R : 0.6679, err : 2.0202
w/ original LUL (AQF2) R: 0.6562, err : 2.0415

Correlation coefficient (R),

$$r = \frac{\sum_{i=1}^{N}(M_i - \overline{M})(O_i - \overline{O})}{\left[\sum_{i=1}^{N}(M_i - \overline{M})^2 \sum_{i=1}^{N}(O_i - \overline{O})^2\right]^{1/2}}$$

Gross Mean Absolute Error (G_ERR)

$$E_{AG} = \frac{1}{N}\sum_{i=1}^{N}\left|M_i - O_i\right|$$

Summary of Forecasting Simulatio
ns
June – October, 2005

Wind Speed

WS w/ better LULC R: 0.2272, err : 1.6862
w/ original LULC R : 0.1865, err : 1.7459

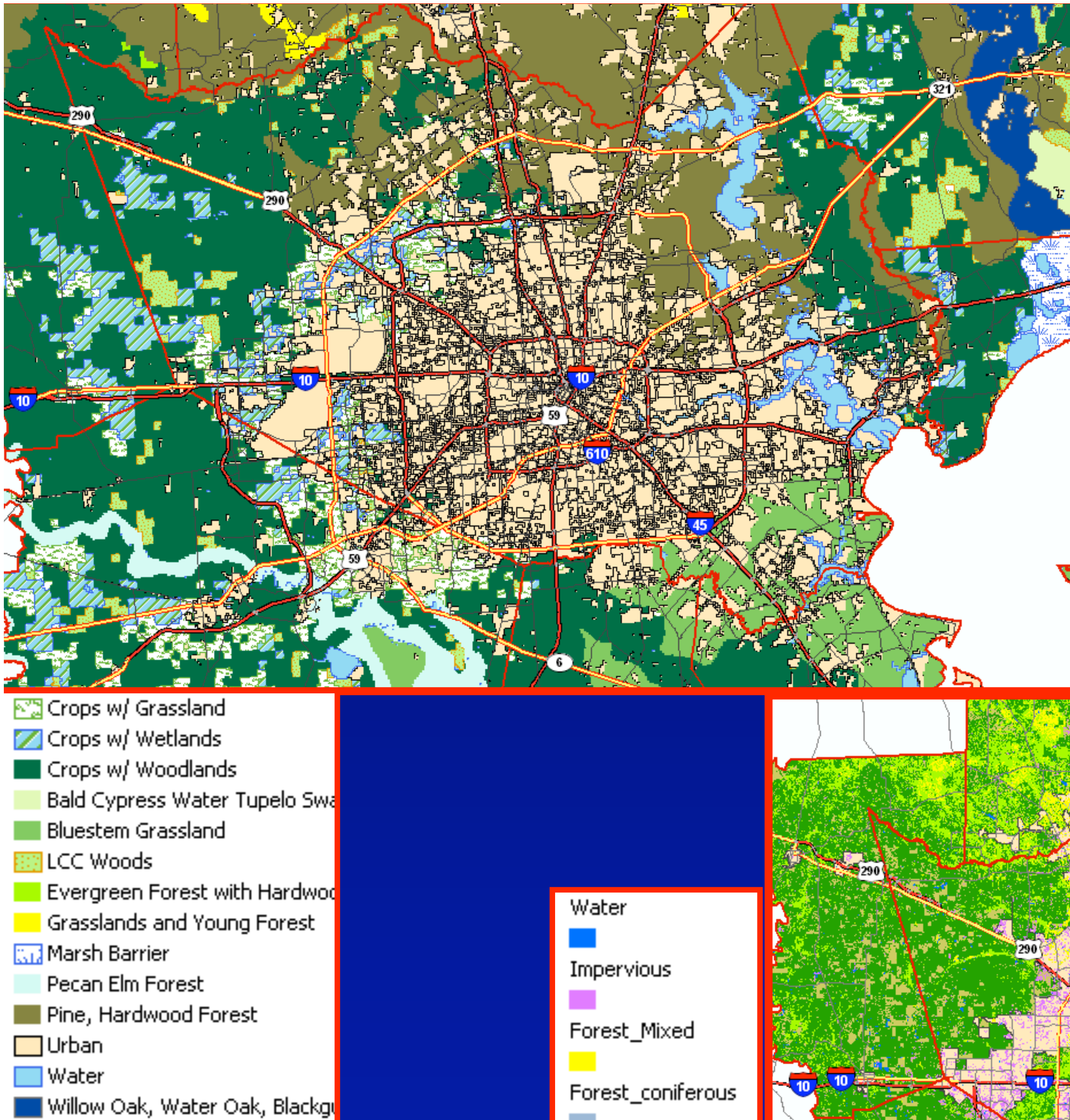
Ozone

Error point : Daily sum of absolute oz
one conc. differences between obs.
& model

Use of satellite-derived
high-resolution LULC in MM
5
improves ozone forecasting!

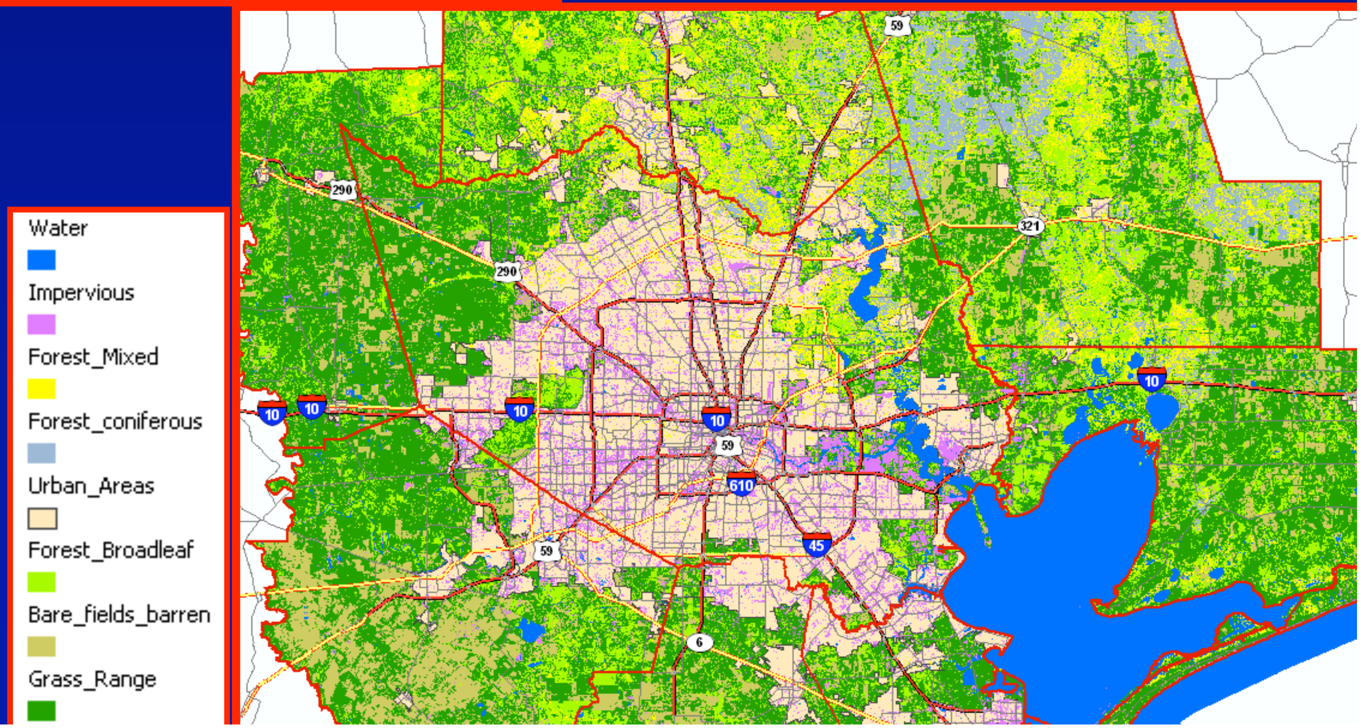
Biogenic emissions

- The GloBEIS version 3.1 (http://www.globeis.com/) (Guenther et al., 1998; Yarwood, 1999 & 2002) was used.
- The internal database was revised to couple with the TFS LULC data and leaf mass density (LMD) data prepared for HGA.
- Meteorology inputs for GloBEIS3
  - Used the same TCEQ’s photo synthetically active radiation (PASR) estimated from GOES satellite data
  - Used the canopy temperature from MM5 simulations with T FS LULC.



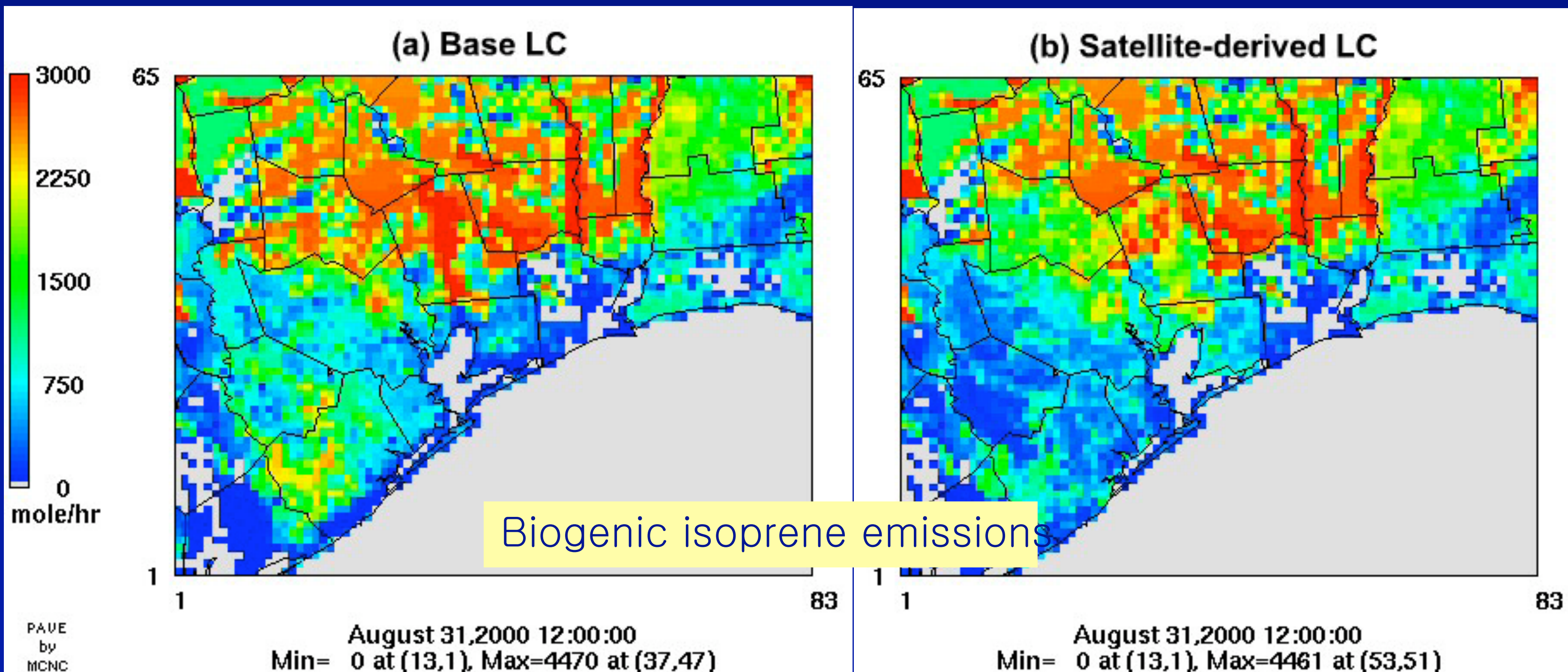
TCEQ Bio.
LU/LC (Wiedinmyer et al., 2001)

TFS LANDSAT based
Land Cover

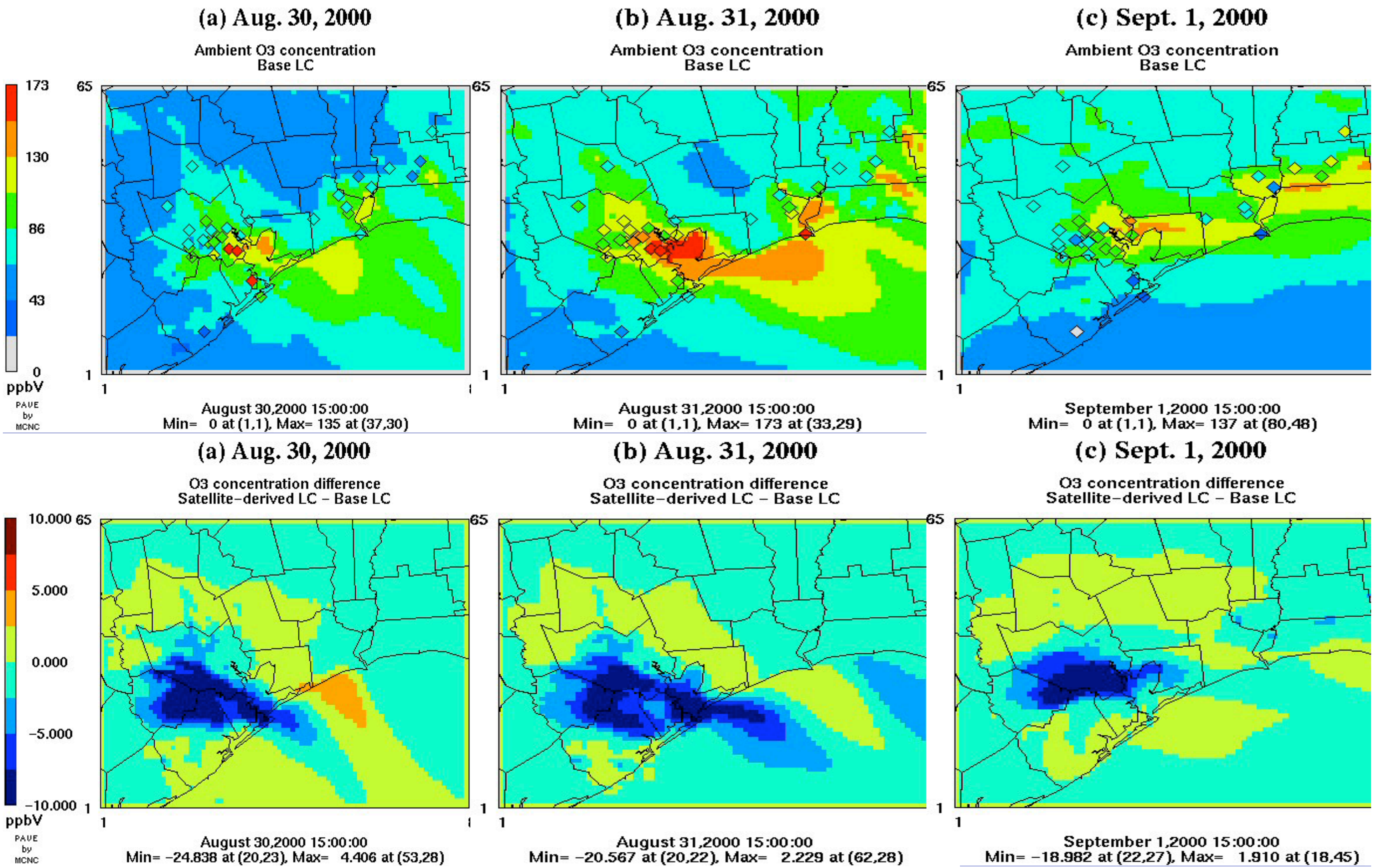


Effects of using different LU/LC data
Difference –
TCEQ-bio LU/LC vs. TFS LANDSAT LC

at least consistent with surface-air exchange spatial distribution patterns in MM5



Base case O3 & Difference between LANSAT LC & TCEQ Biogenic emissions



Chemical data assimilation of satellite observation for regional air quality modeling

- Use global scale tropospheric chemistry model with satellite data assimilated

  to improve lateral & top BCs

  Link GEOS-CHEM or RAQMS → CMAQ

- Assimilate satellite observations directly in CMAQ

Spatial/Time resolution Issue : Global and Regional CTM

Model used in this study : RAQMS and CMAQ

RAQMS (NASA Langley Research Center and University of Wisconsin)
CMAQ (U.S. EPA)

RAQMS : Global CTM

Meteorology : U. of Wisconsin
Chemical Mech. : NASA LaRC

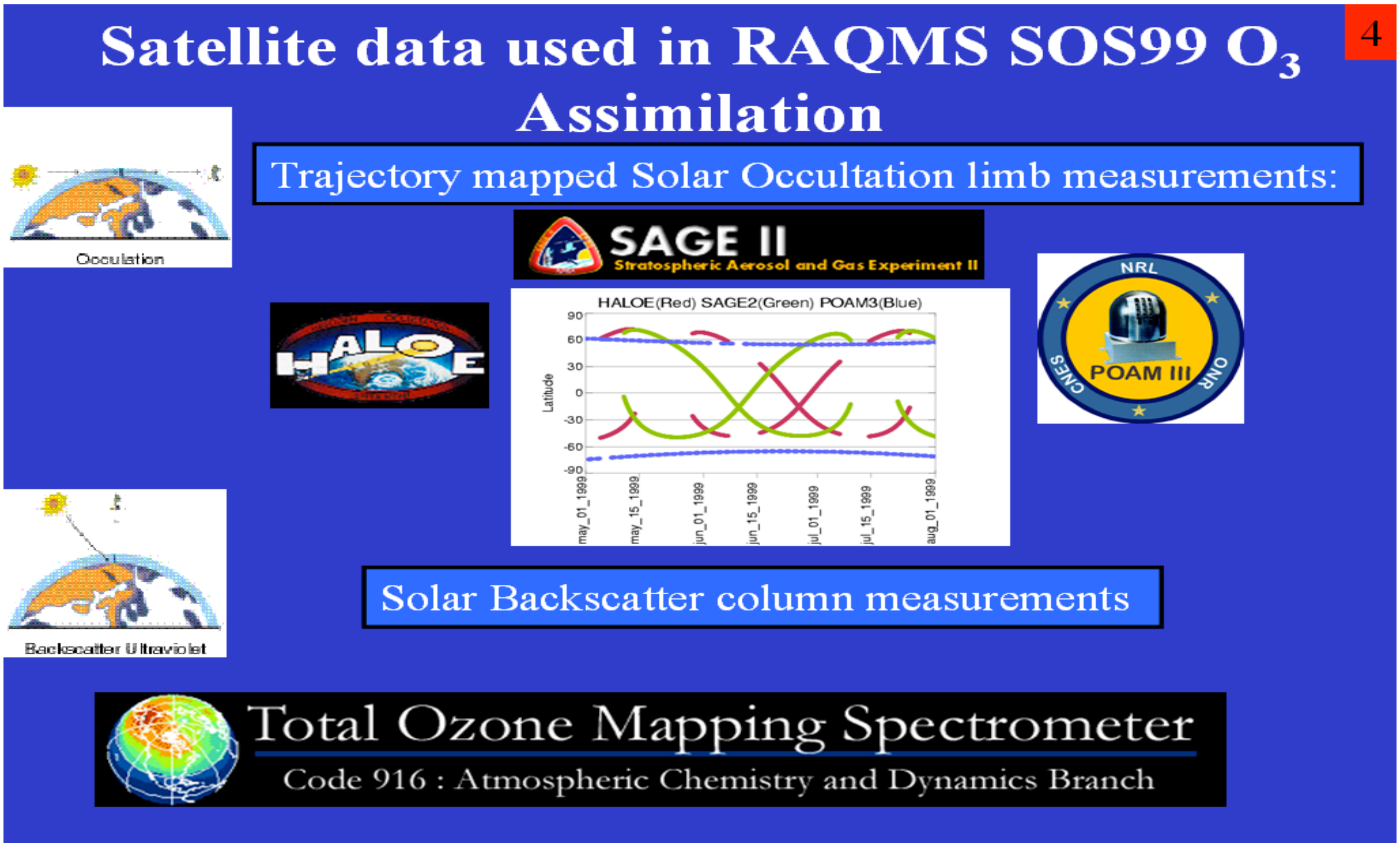
CMAQ :Regional CTM

Meteorology : MM5, WRF/EM, ETA
Chemical Mech. : CB4, SAPRC, RADM

RAQMS Satellite Data Assimilation

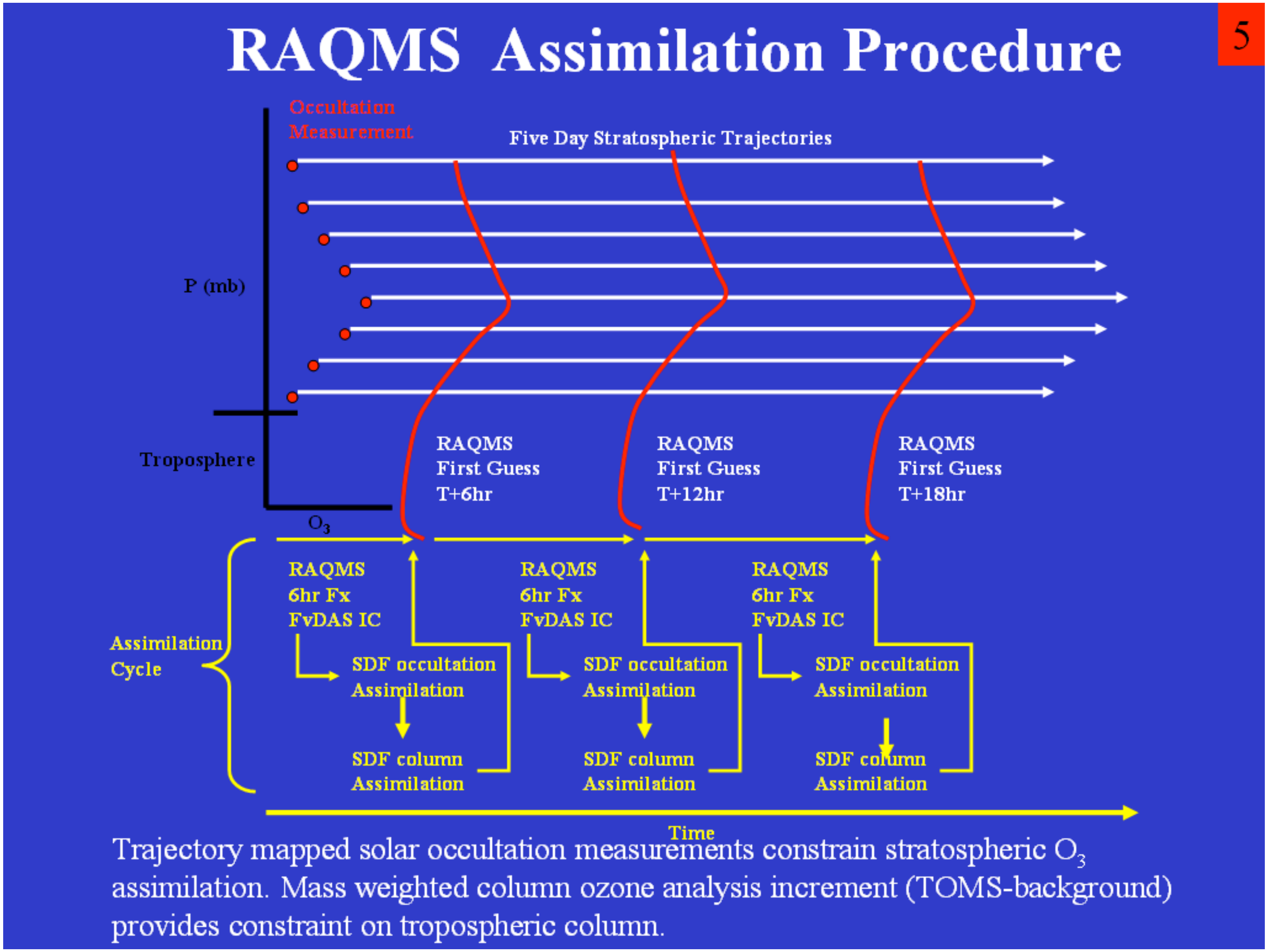
[Pierce et. al., 2004, NCEP Talk]

RAQMS uses the Statistical Digital Filter (SFD) [Stobie, 2000] (an Optimal Interpolation approach) and online chemical predictions, to evaluate the feasibility of assimilating trajectory mapped solar occultation and TOMS total column measurements.



RAMQMS Satellite Data Assimilation

[Pierce et. al., 2004, NCEP Talk]



CMAQ Satellite Data Assimilation – example

EPA

–MM5 run
–CMAQ v4.3 control run

NASA/UW

–RAQMS run
–Satellite data (GOES)
–SDF package

UH : Development of CMAQ Process

1. Linking tool between RAQMS/CMAQ
2. Modification of CMAQ for Satellite Data Assimilation

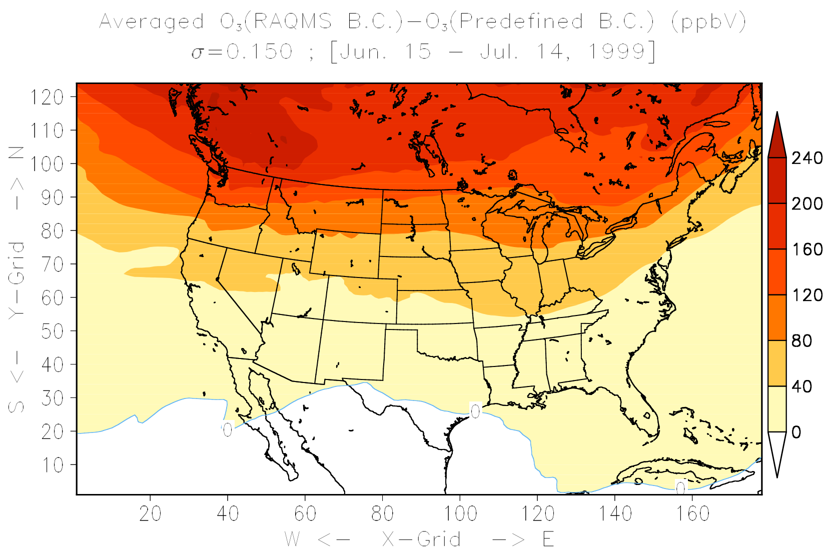
Evaluation : Southern Oxidant Study (SOS-99) Obs.

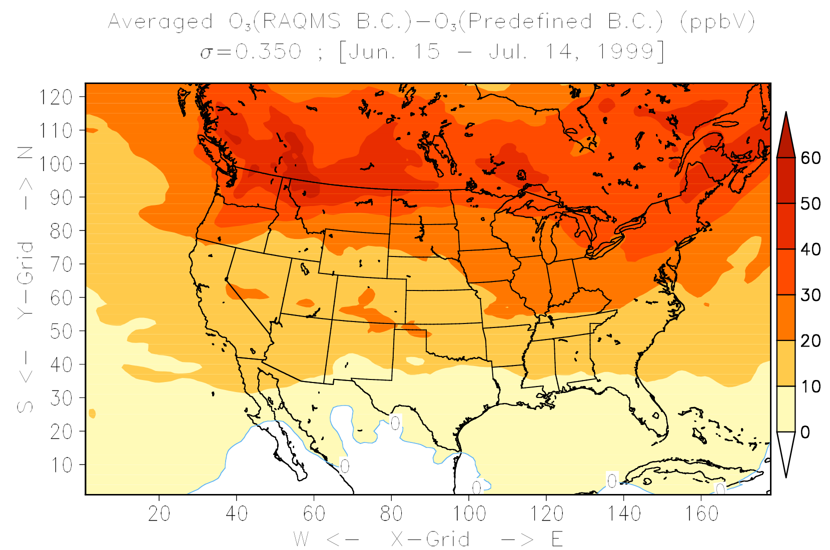
Evaluation

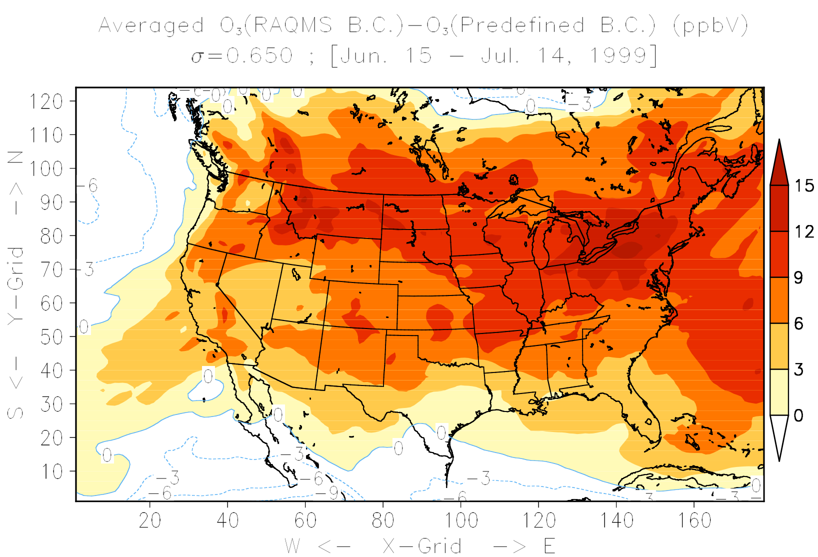
– CMAQ/Profile Results
– CMAQ/RAQMS Results

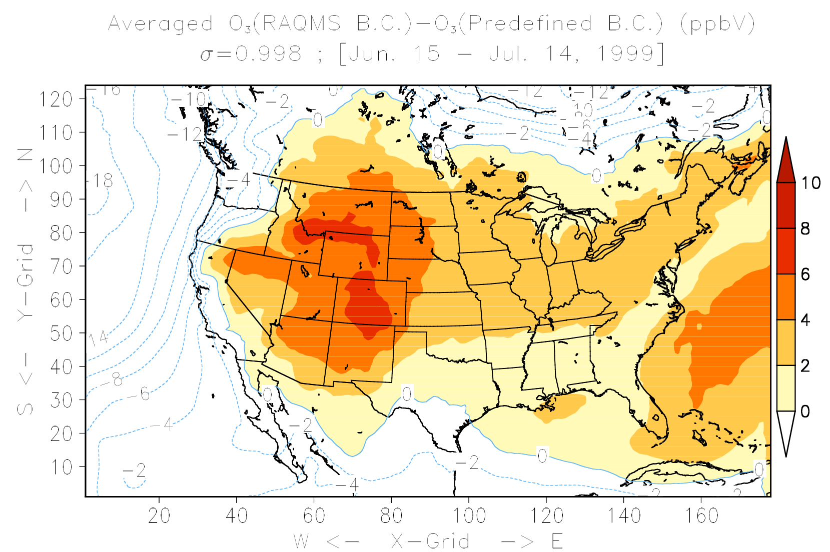
by using SFC and O_3 radiosonde obs.
(SOS -- June 15-July 14, 1999)

Results : Difference of Spatial distribution at each level



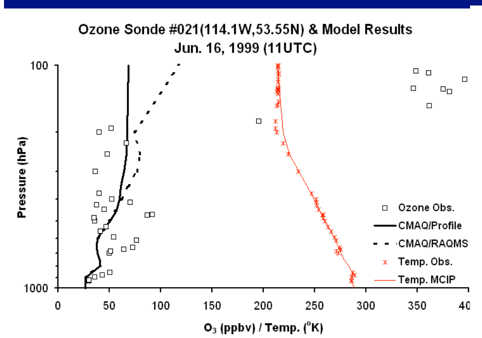


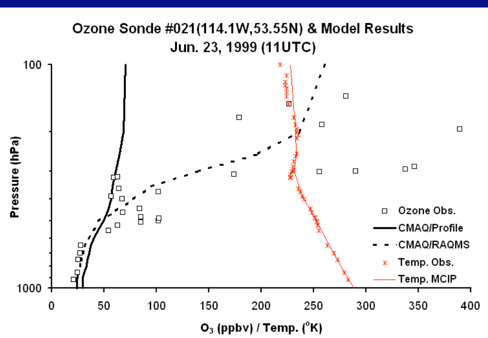


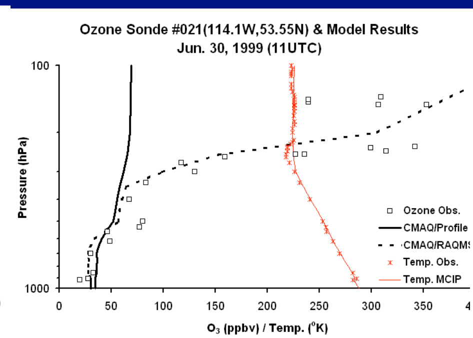


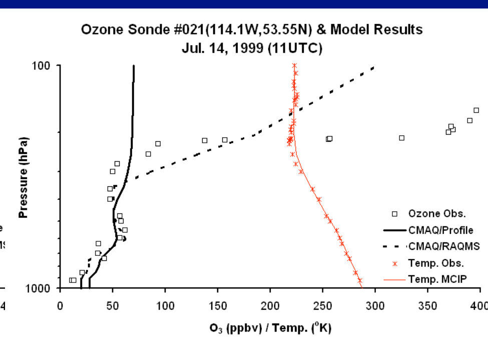
Results : Evaluation for Vertical Sounding

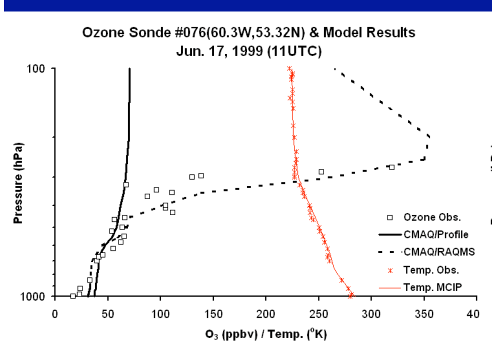
SITE #	Location	Nation	LAT.	LON.	ALT.
STN021	EDMONTON/STONY PLAIN	CAN	53.55	-114.10	766.00
STN076	GOOSE BAY	CAN	53.30	-60.36	40.00
STN077	CHURCHILL	CAN	58.75	-94.07	35.00
STN107	WALLOPS ISLAND	USA	37.90	-75.48	13.00

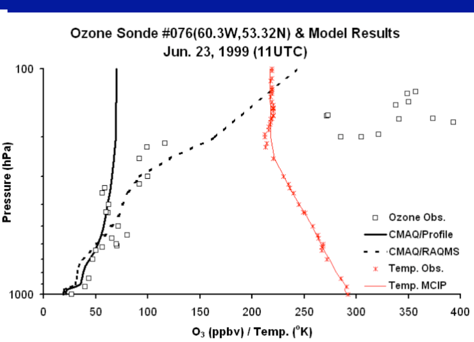


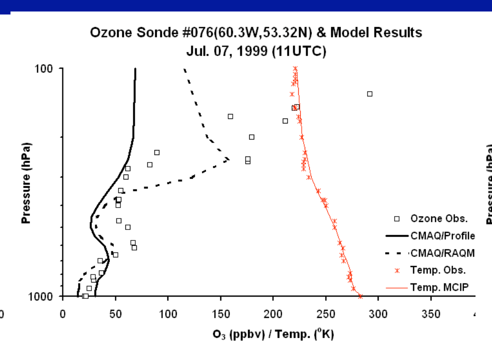


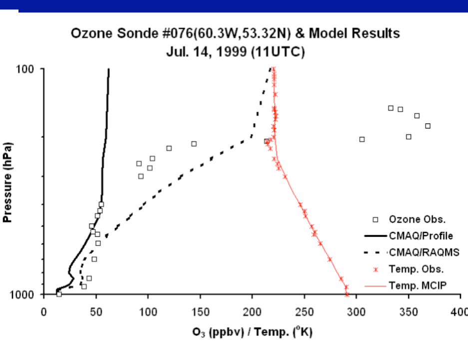


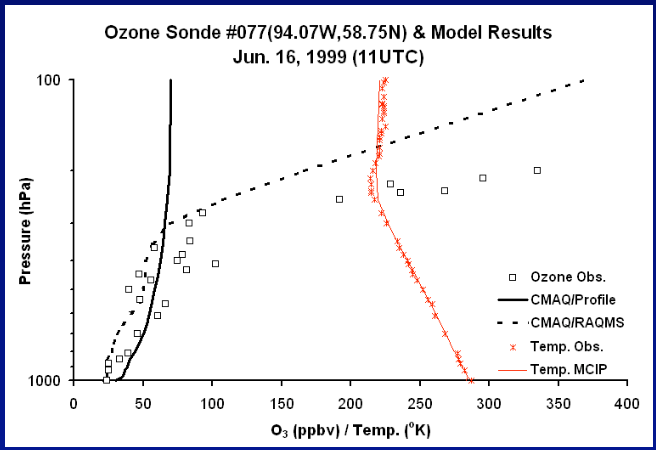


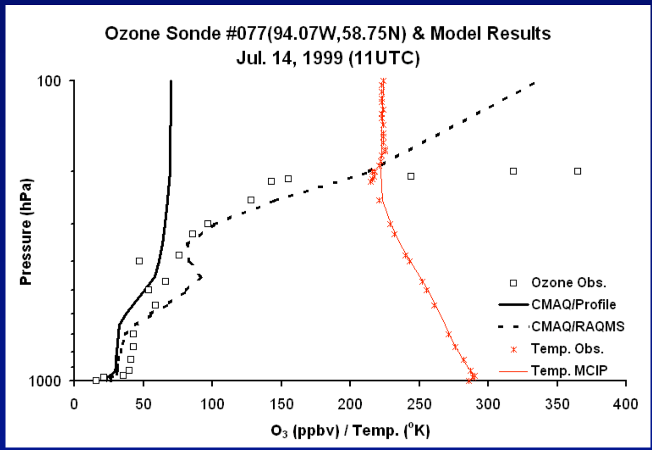


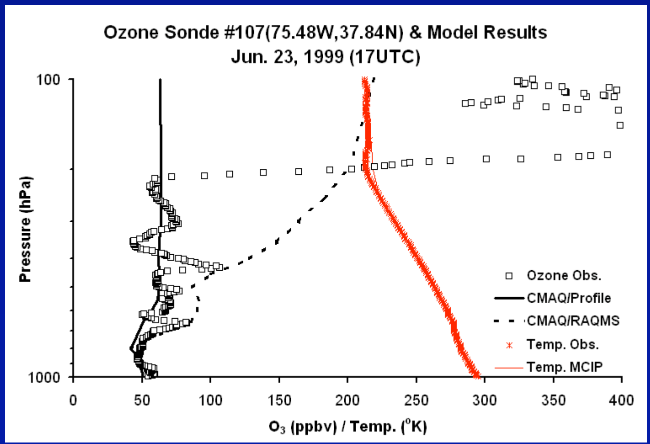


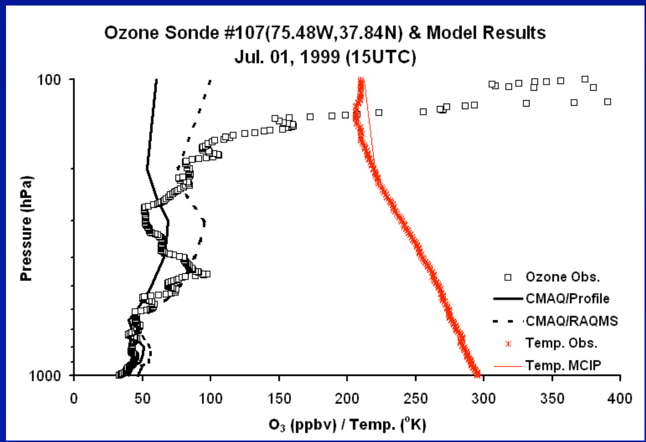




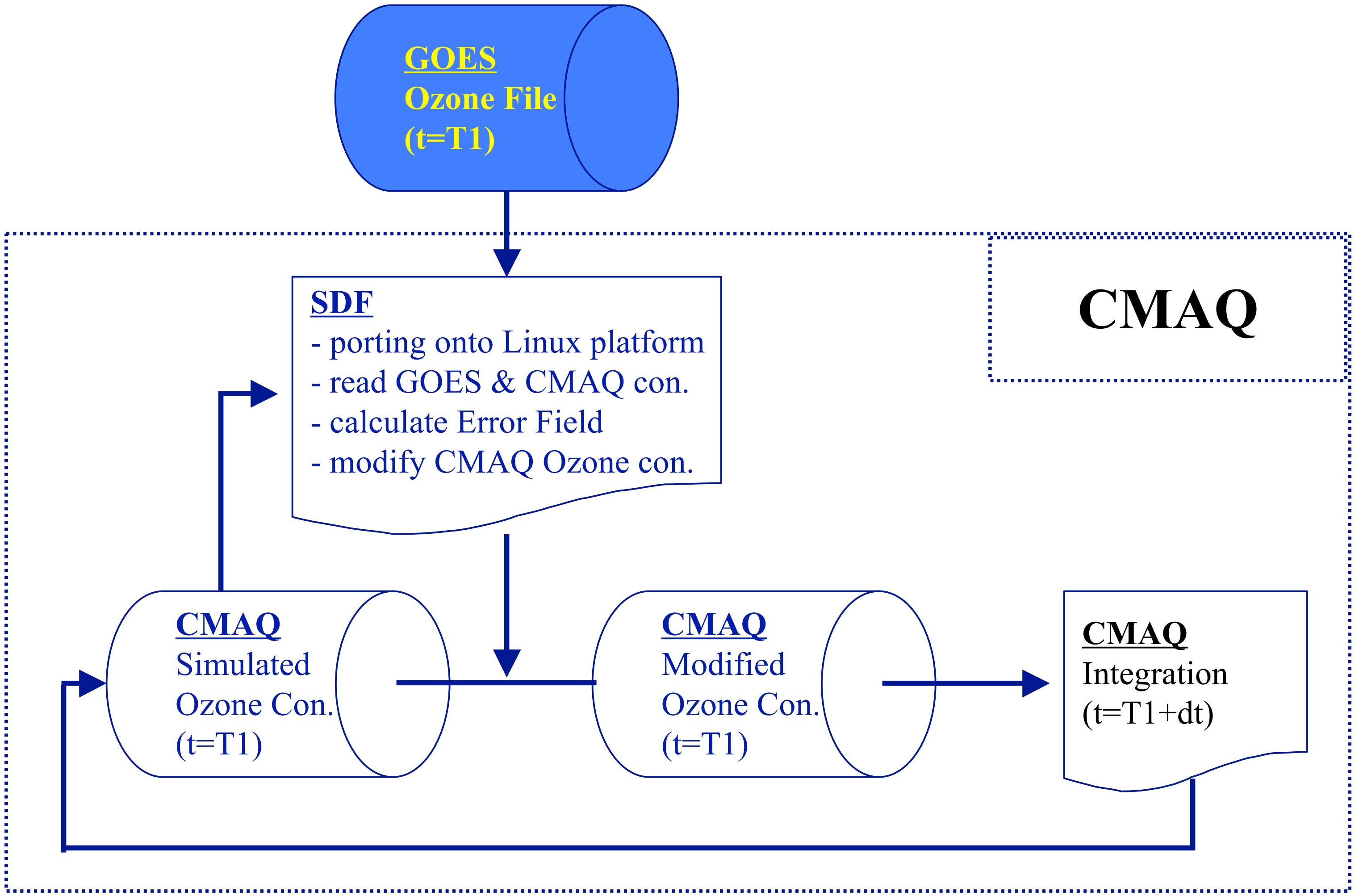

Ozone Sonde #077(94.07W,58.75N) & Model Results
Jun. 16, 1999 (11UTC)
Pressure (hPa)
O_3 (ppbv) / Temp. (^oK)
Ozone Obs.
CMAQ/Profile
CMAQ/RAQMS
Temp. Obs.
Temp. MCIP


Ozone Sonde #077(94.07W,58.75N) & Model Results
Jul. 14, 1999 (11UTC)
Pressure (hPa)
O_3 (ppbv) / Temp. (^oK)
Ozone Obs.
CMAQ/Profile
CMAQ/RAQMS
Temp. Obs.
Temp. MCIP

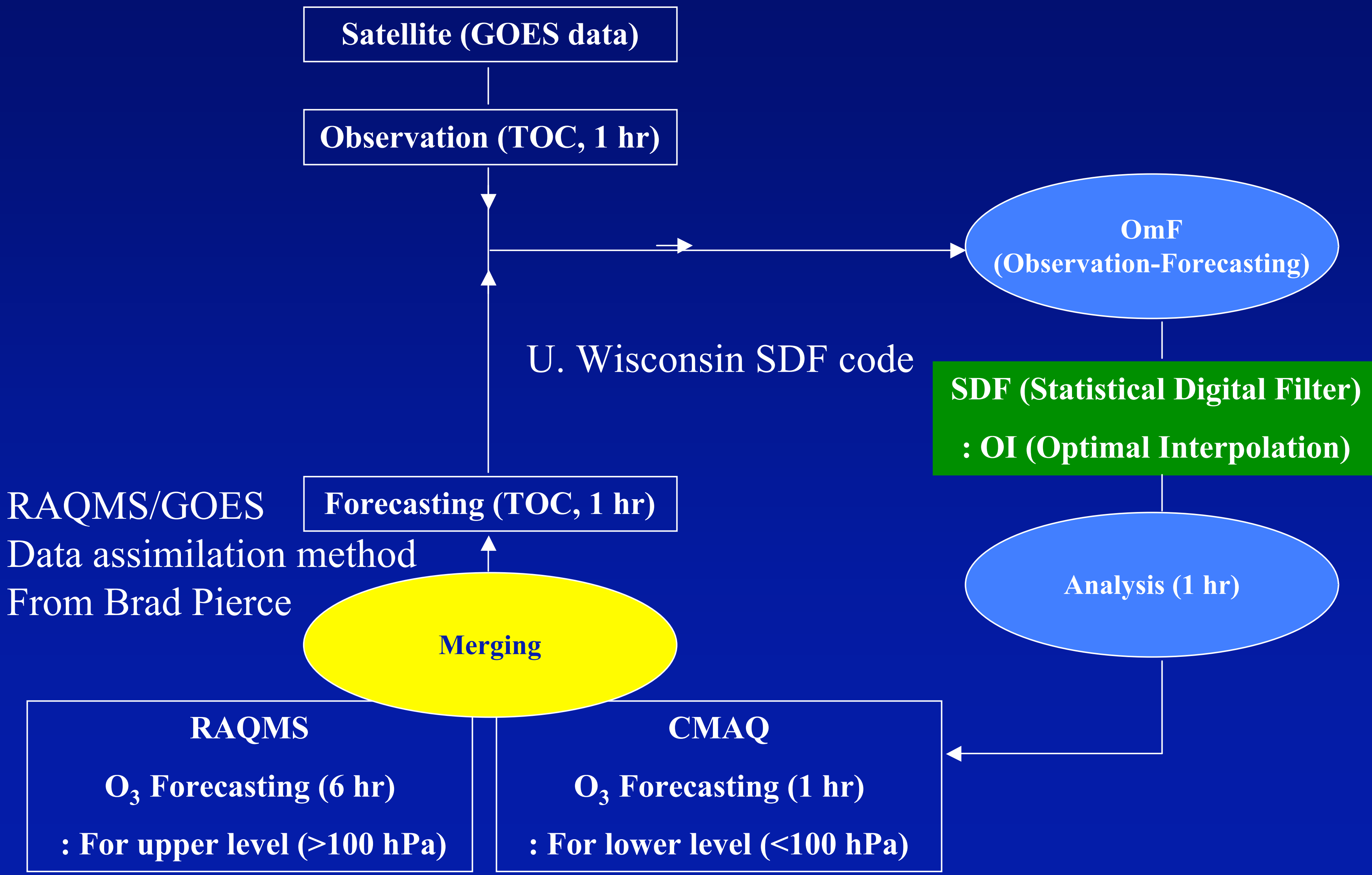

Ozone Sonde #107(75.48W,37.84N) & Model Results
Jun. 23, 1999 (17UTC)
Pressure (hPa)
O_3 (ppbv) / Temp. (^oK)
Ozone Obs.
CMAQ/Profile
CMAQ/RAQMS
Temp. Obs.
Temp. MCIP


Ozone Sonde #107(75.48W,37.84N) & Model Results
Jul. 01, 1999 (15UTC)
Pressure (hPa)
O_3 (ppbv) / Temp. (^oK)
Ozone Obs.
CMAQ/Profile
CMAQ/RAQMS
Temp. Obs.
Temp. MCIP

CMAQ/SDF with GOES Ozone

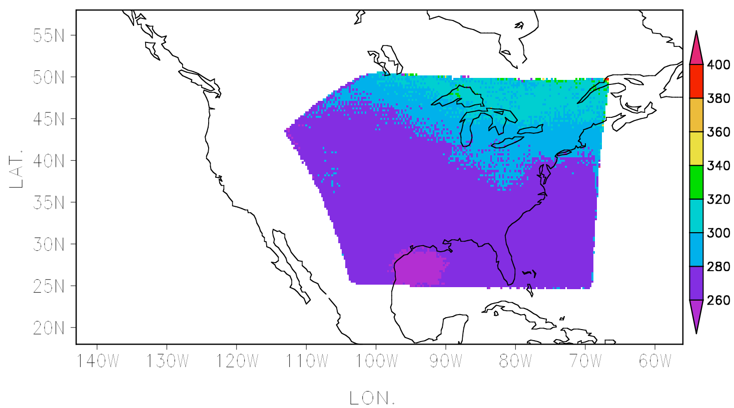


Assimilation of satellite column ozone data for regional air quality modeling: CMAQ/SDF



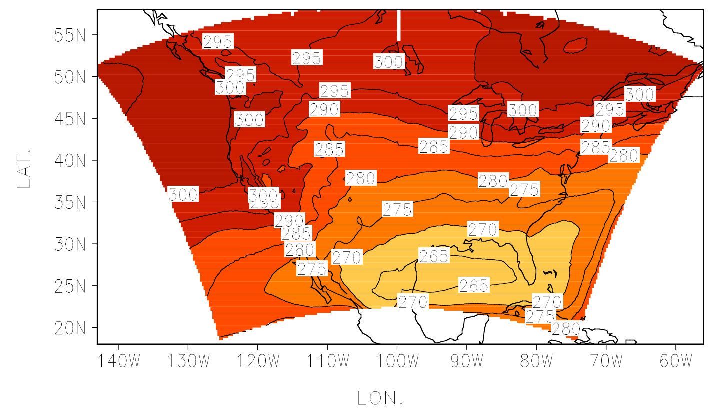
Observation (TOC, 1 hr)

Averaged Obervation (GOES data) of Total O_3 Column (DU)
[Jun. 15 – Jul. 14, 1999]

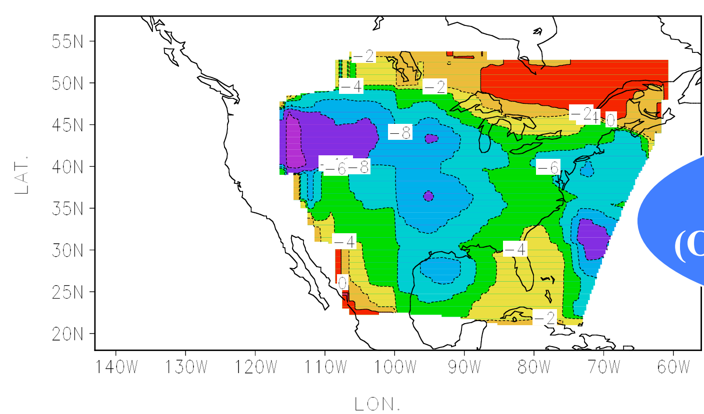


First guess (TOC, 1hr)

Averaged Total O_3 Column from CMAQ and RAQMS (DU)
[Jun. 15 – Jul. 14, 1999]



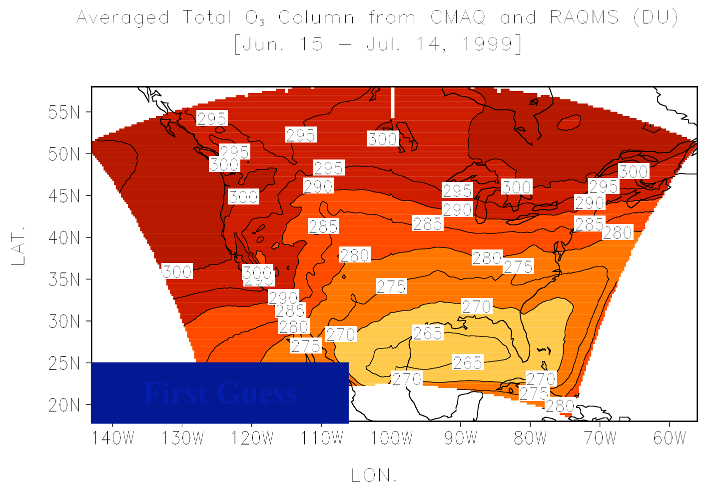
Averaged OmF(Observation–Model) of Total O_3 Column (DU)
[Jun. 15 – Jul. 14, 1999]



OmF (TOC, 1hr)
(Observation-Forecasting)

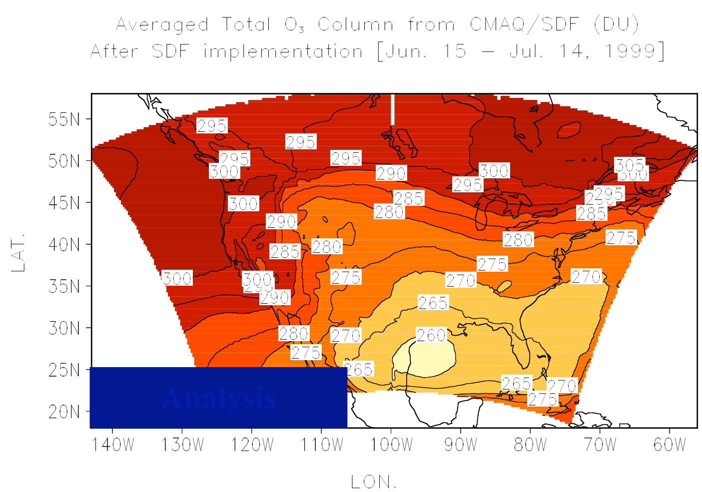
Result : [CMAQ/SDF – CMAQ/Default]

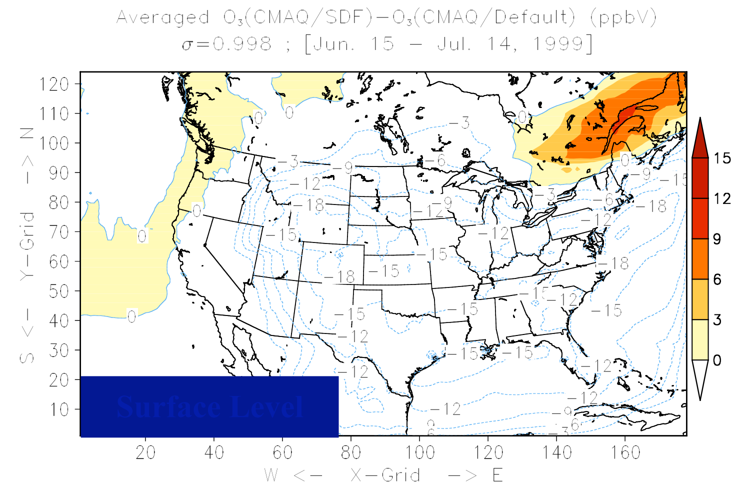
O_3 concentration (ppb)

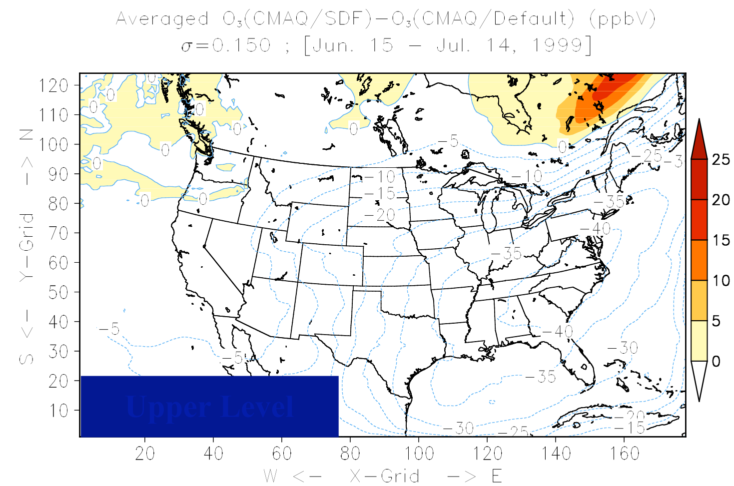


SDF (Statistical Digital Filter)

: OI (Optimal Interpolation)







On-going work

(1)Utilization of satellite-derived sea-surface temperature in MM5 modeling to improve meteorological inputs

(2)Inclusion of satellite-derived fire emissions to improve emissions inputs (NESDIS, ARL, NCAR – C. Wiedinmyer, Harvard – J. Logan & D. Jacob)

(3)CMAQ-4D VAR (in collaboration with Sandu (VT), Carmichael (U. Iowa), HARC, EPA, CalTech)

Acknowledgement

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EPA: Jim Szykman, Alice Gilliland, Ken Schere

SAIC: Fred Vukovich,

University of Wisconsin, USDA, Texas Forest Service, TCEQ, GEM