Real time simultaneous prediction of air quality and weather at NOAA/FSL

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Structure of talk

- What model
- Houston 2000: Field experiment and regional and urban scale simultaneous forecasting of weather and air quality
- New England 2001/2002 : regional and local scales
- Future model: WRF/chem

Cornerstone of "online" model: MM5

- Nonhydrostatic multiscale model, many physics options
  - May be used from regional scales down to cloud scales
  - Allows research and real-time forecasting on regional as well as urban scales
- 2-way interactive grid nesting
  - Useful for targeted nesting (plumes, release of dangerous substances, complex topography, replacement of physical parameterizations,….)
- Runs on many different computer architectures
- In addition to MM5: new approaches to physical parameterizations
  - Ensemble techniques for convective parameterization

"Online" chemistry package

- Advective transport by 3-d positive definite 3rd order advection routine (or Eureka or Walczek advection)
- Subgrid-scale transport by turbulence, as well as deep and shallow convection
- Dry deposition, wet deposition by convective parameterization
- Biogenic emissions, photolysis
- Chemical mechanism from RADM2 (interaction of species with each other)

"ONLINE" application: Simultaneous integration of chemistry and meteorology!

Possible applications of current modeling system

- Prediction and simulation of weather, or regional or local climate
- Coupled weather prediction/dispersion model to simulate release and transport of constituents
- Coupled weather/dispersion/air quality model with full interaction of chemical species

Real-time setup during Houston 2000

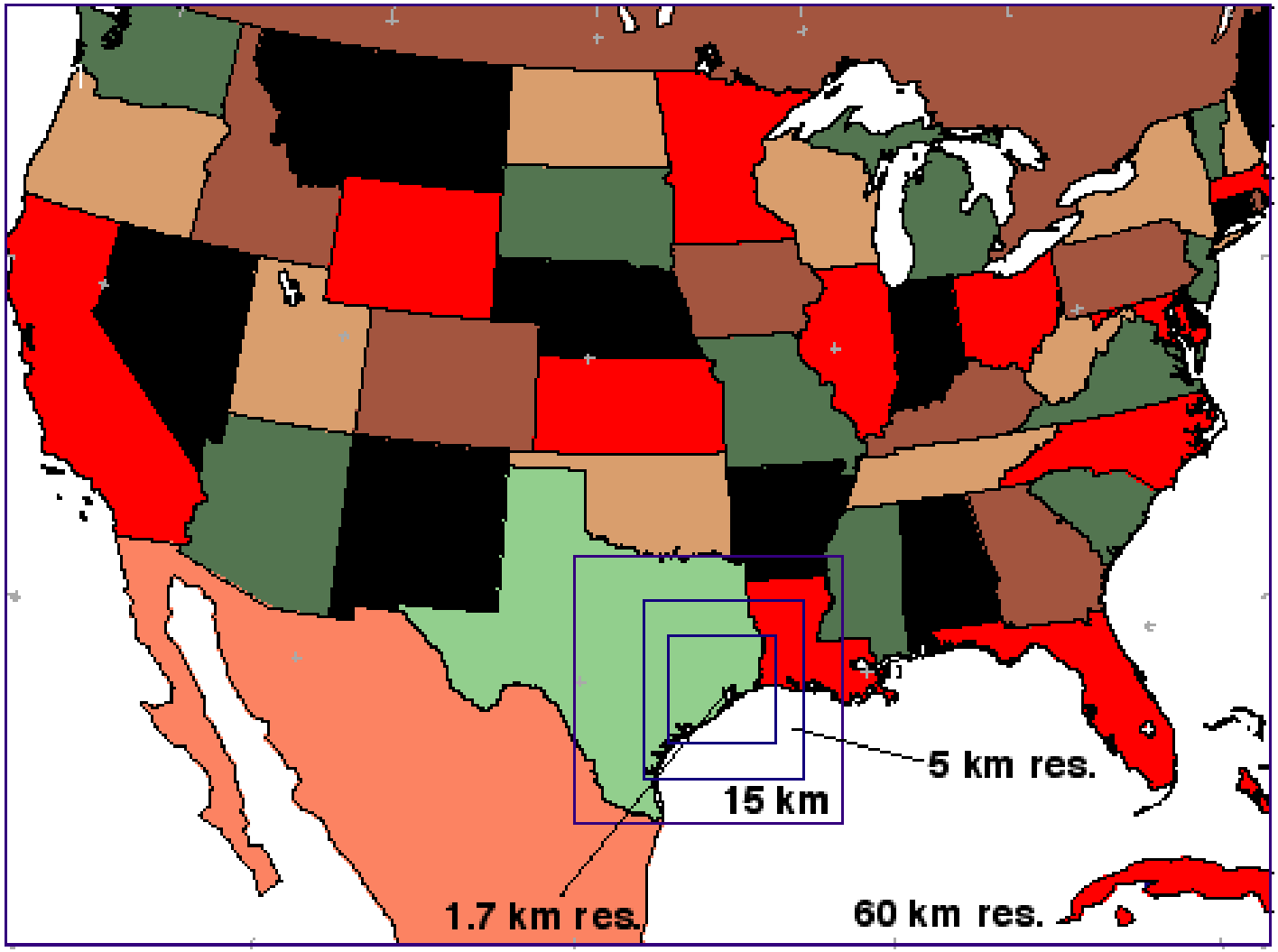
- Model was run in real-time twice a day during field experiment from August through September 15 2000
- Four different resolutions: 60 km, 15km, 5km, and 1.7km
- Forecast length was 36 hours, 12 – 24 hours for higest resolution nest (12 hours for morning forecast)
- Model results were sent to operational center for field experiment in Houston
- Ratio of wall clock/forecast time for highest resolution nest was 1:10 using 36 processors of FSL's supercomputer (massively parallel Compaq)

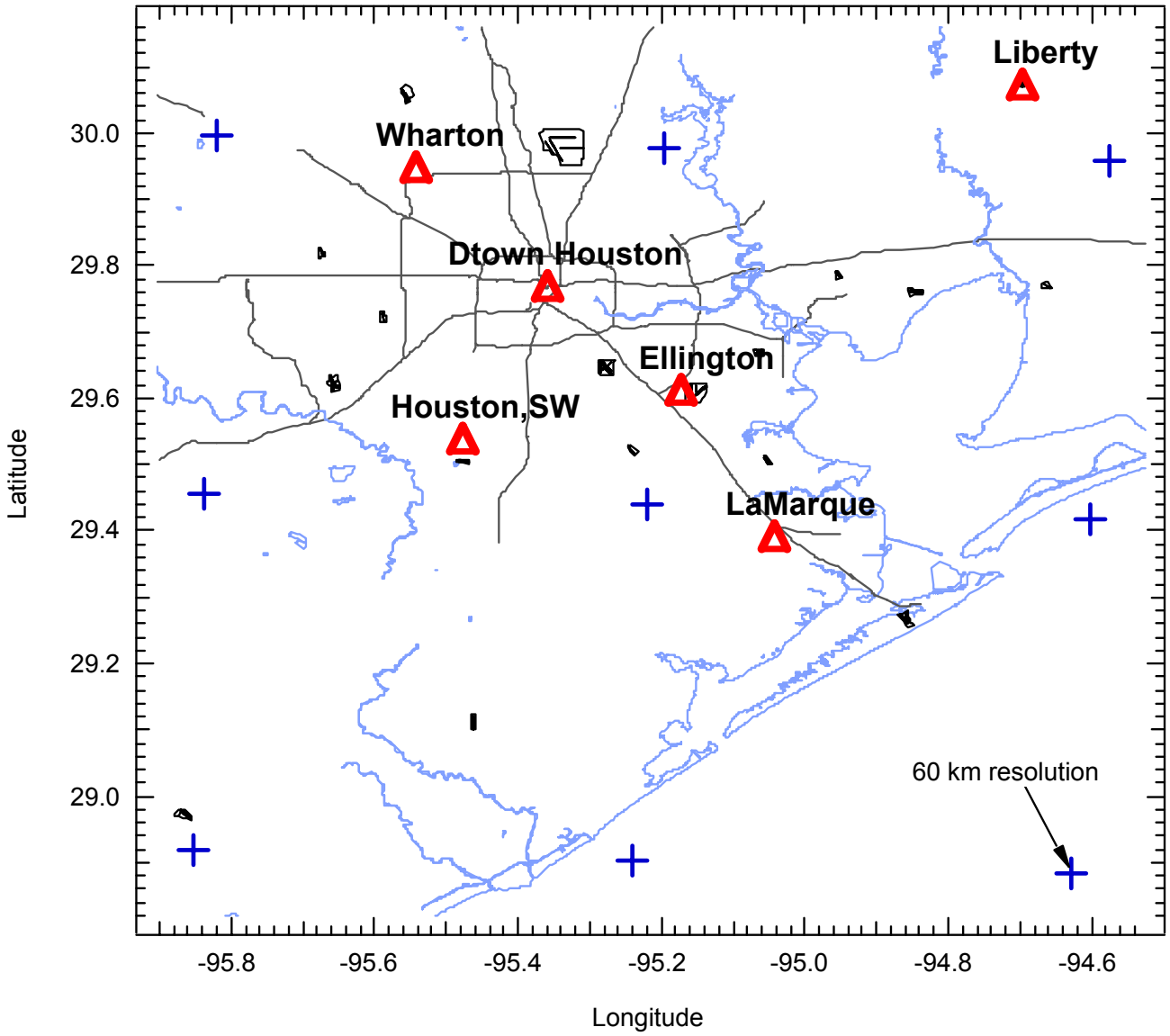
Initial and Boundary conditions

- Meteorology from RUC and ETA model
- Chemistry initial conditions from 12-hour forecasts

All nested domains: Input from coarser domain (initial and boundary conditions from chemistry and meteorology)

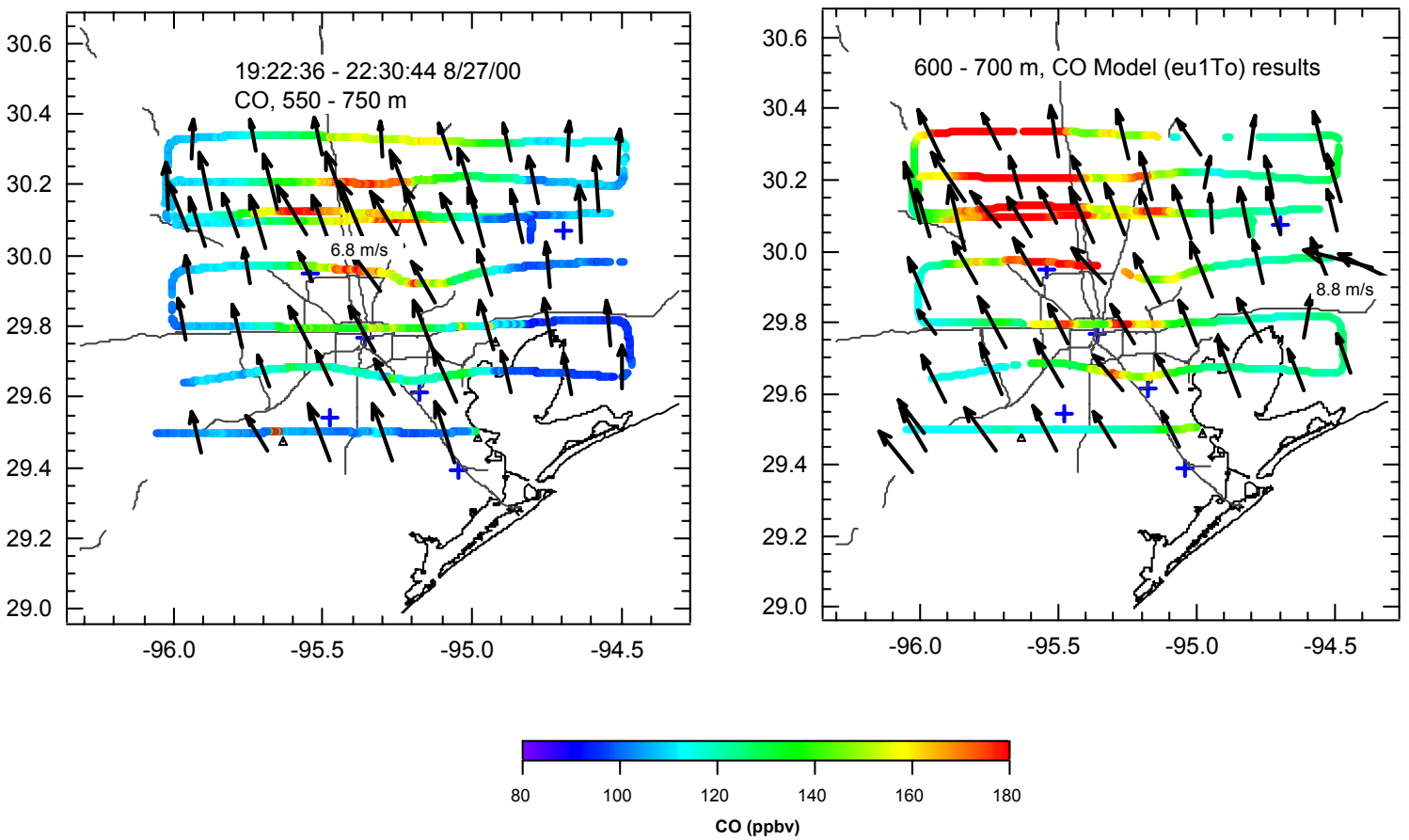
Forecast Model, 4 Nested Domains

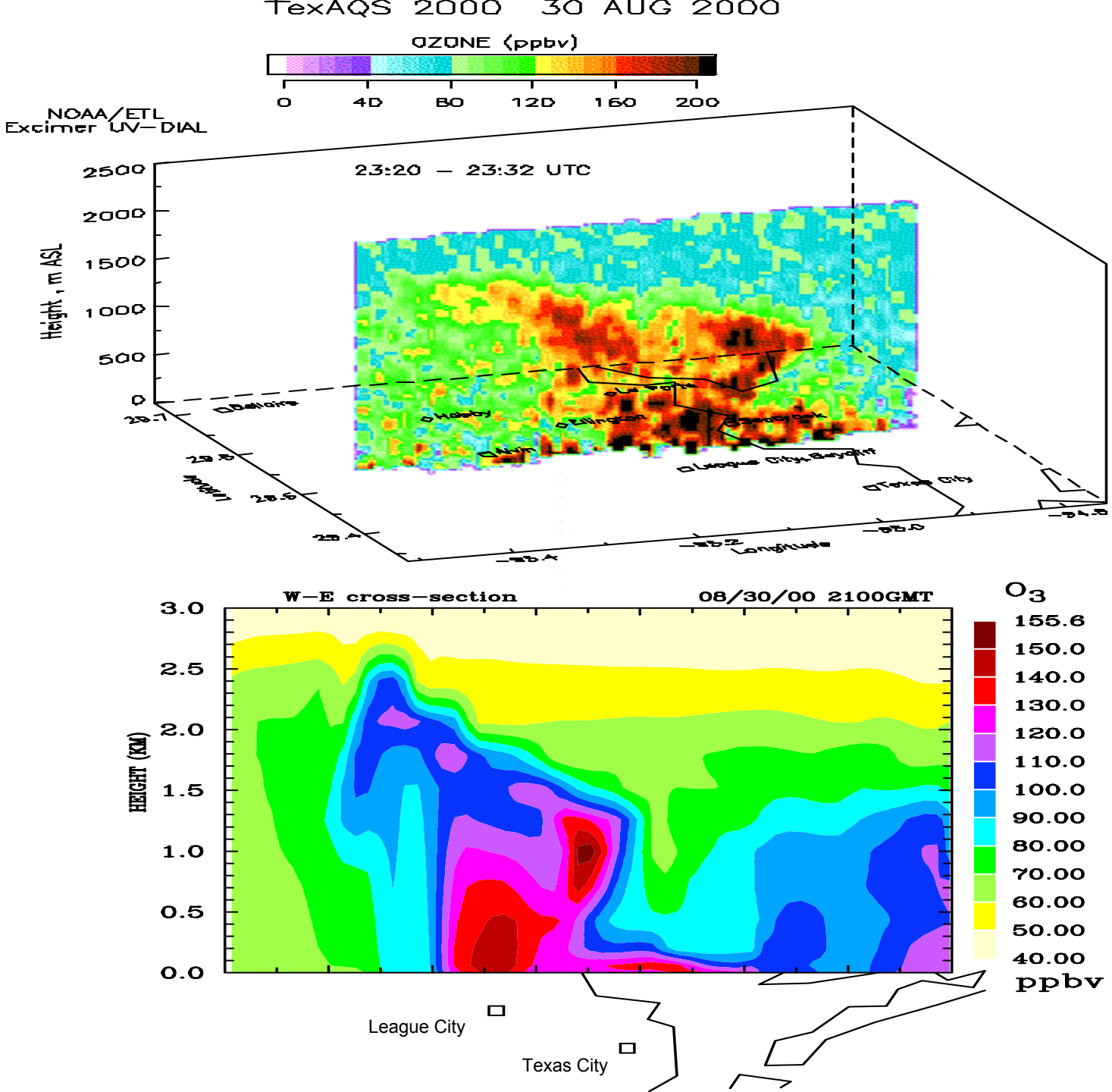



Liberty
Wharton
Dtown Houston
Ellington
Houston,SW
LaMarque
60 km resolution
30.0
29.8
29.6
29.4
29.2
29.0
Latitude
-95.8
-95.6
-95.4
-95.2
-95.0
-94.8
-94.6
Longitude

First: will show good results (after modifications have been made)

Next: Lessons that needed to be learned


19:22:36 - 22:30:44 8/27/00
CO, 550 - 750 m
6.8 m/s
600 - 700 m, CO Model (eu1To) results
8.8 m/s
30.6
30.4
30.2
30.0
29.8
29.6
29.4
29.2
29.0
-96.0
-95.5
-95.0
-94.5
80
100
120
140
160
180
CO (ppbv)


TexAQS 2000 30 AUG 2000
OZONE (ppbv)
0
40
80
120
160
200
NOAA/ETL
Excimer UV-DIAL
23:20 - 23:32 UTC
Height , m ASL
2500
2000
1500
1000
500
0
Hobby
Ellington
Clear Lake
League City
Texas City
Latitude
Longitude
W-E cross-section
08/30/00 2100GMT
HEIGHT (KM)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
O3
155.6
150.0
140.0
130.0
120.0
110.0
100.0
90.00
80.00
70.00
60.00
50.00
40.00
ppbv
League City
Texas City

= Max

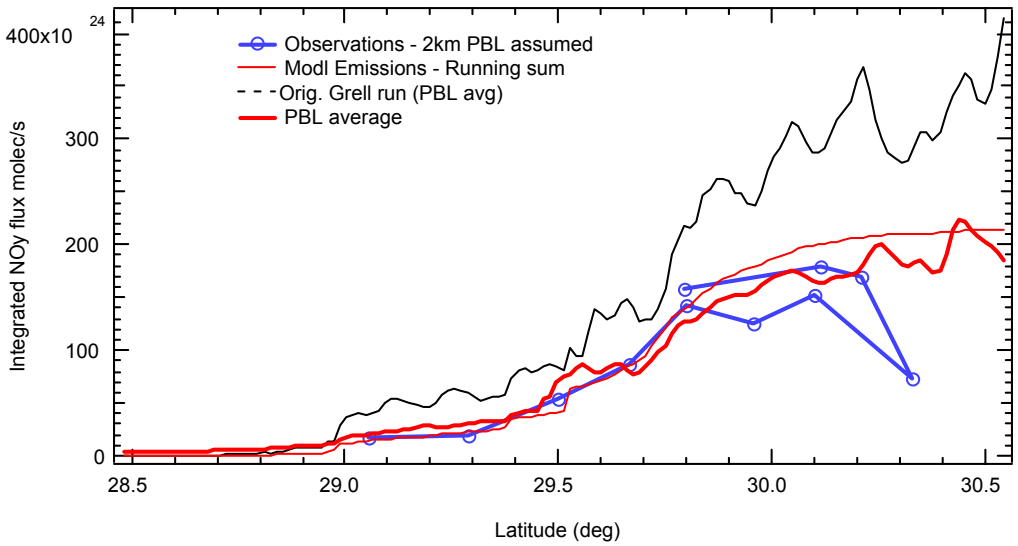
In real-time?

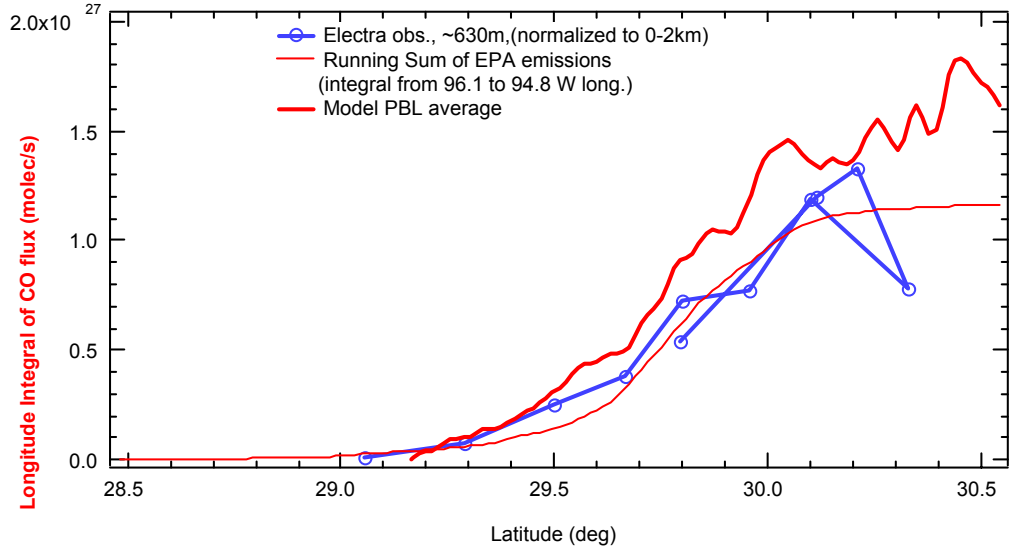
Emissions: supposedly the best we could get (EPA + TNRCC)

Emissions of NOx (kmole/hr) and emission ratios for 4 sub-regions, derived from NCAR Electra observations, or provided by TNRCC.

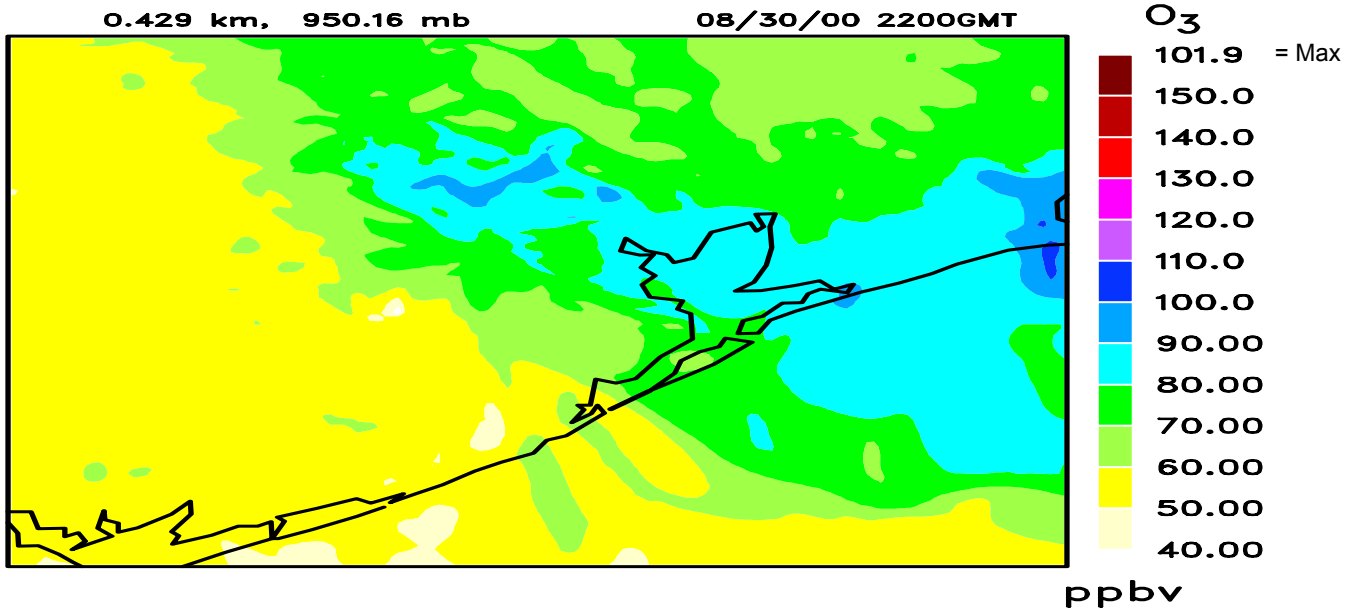
Region	Observed NOx emis.	Observed C_2H_4/ NOx	TNRCC C_2H_4/ NOx	Observed C_3H_6/ NOx	TNRCC C_3H_6/ NOx
Texas City	50.	0.50	0.01	0.20	0.006
Sweeney	15.	3.00	0.04	2.00	0.028
Chocolate Bayou	15.	1.33	0.04	4.00	0.061
Freeport -B	30.	0.67	0.03	1.00	0.012

Would have not gotten this one without intensive field experiment and strong collaboration between modelers/observationalists

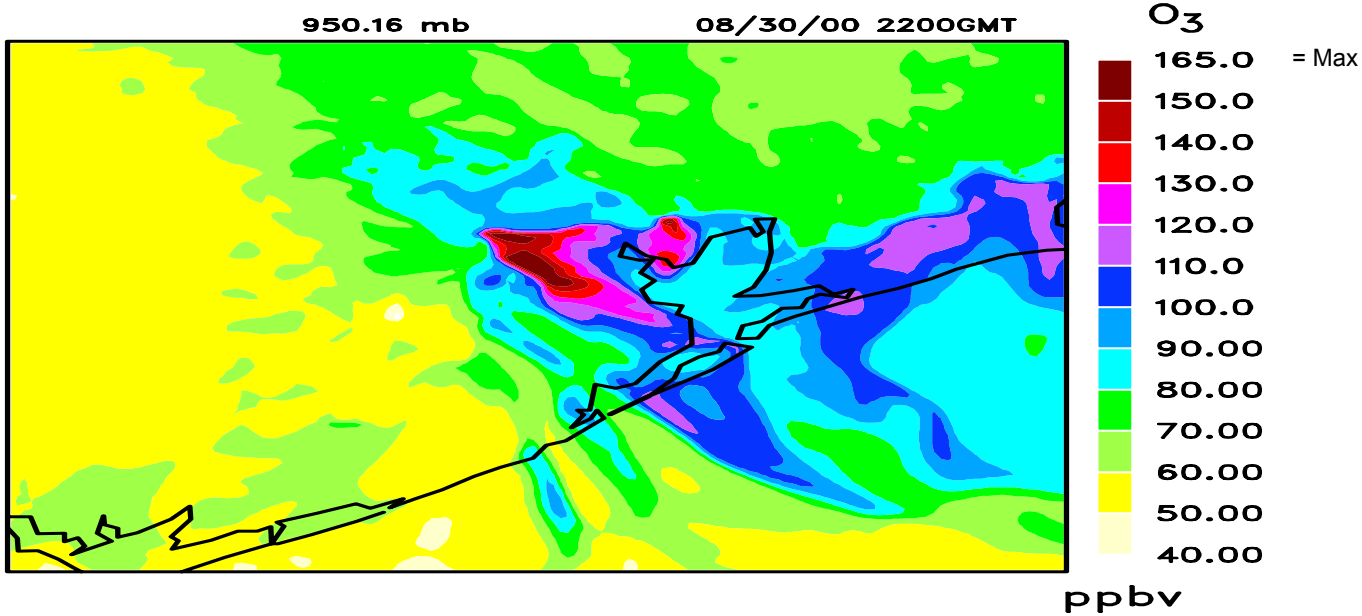

400x10 24
Integrated NOy flux molec/s
Observations - 2km PBL assumed
Modl Emissions - Running sum
Orig. Grell run (PBL avg)
PBL average
0
100
200
300
28.5
29.0
29.5
30.0
30.5
Latitude (deg)


2.0x10 27
Longitude Integral of CO flux (molec/s)
Electra obs., ~630m,(normalized to 0-2km)
Running Sum of EPA emissions
(integral from 96.1 to 94.8 W long.)
Model PBL average
0.0
0.5
1.0
1.5
28.5
29.0
29.5
30.0
30.5
Latitude (deg)

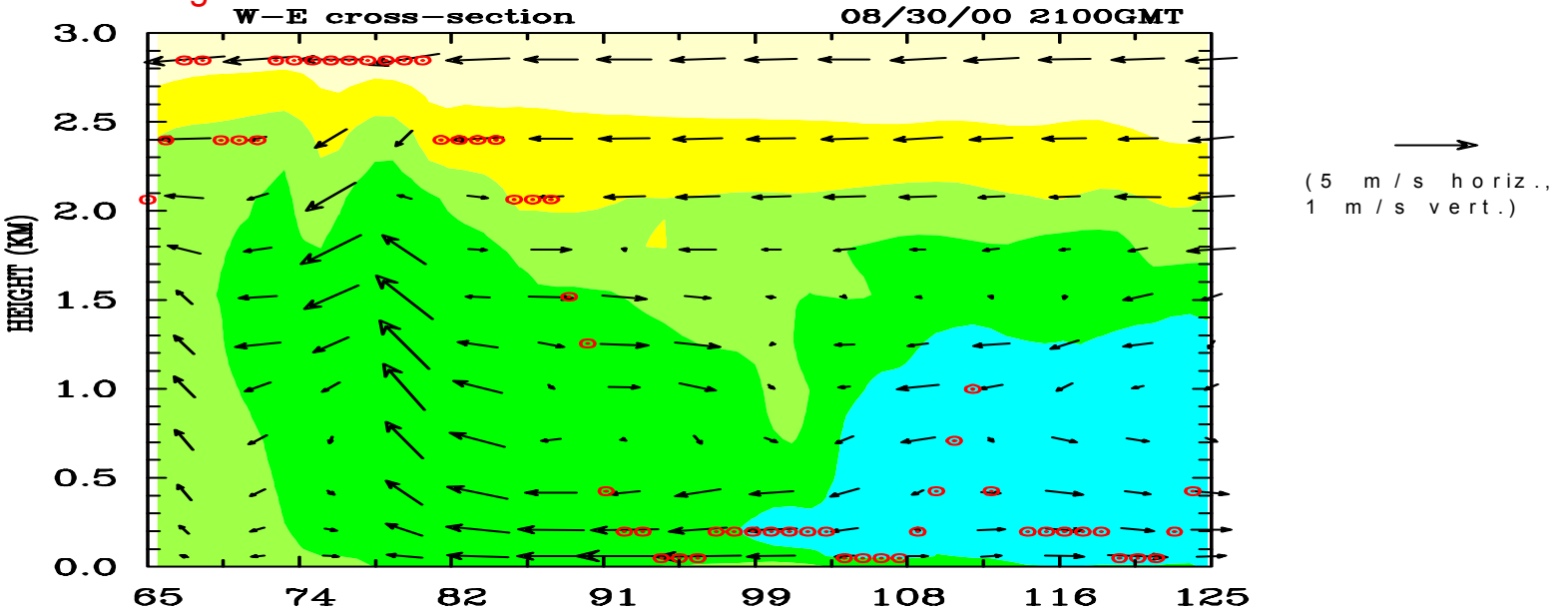
Original Emissions



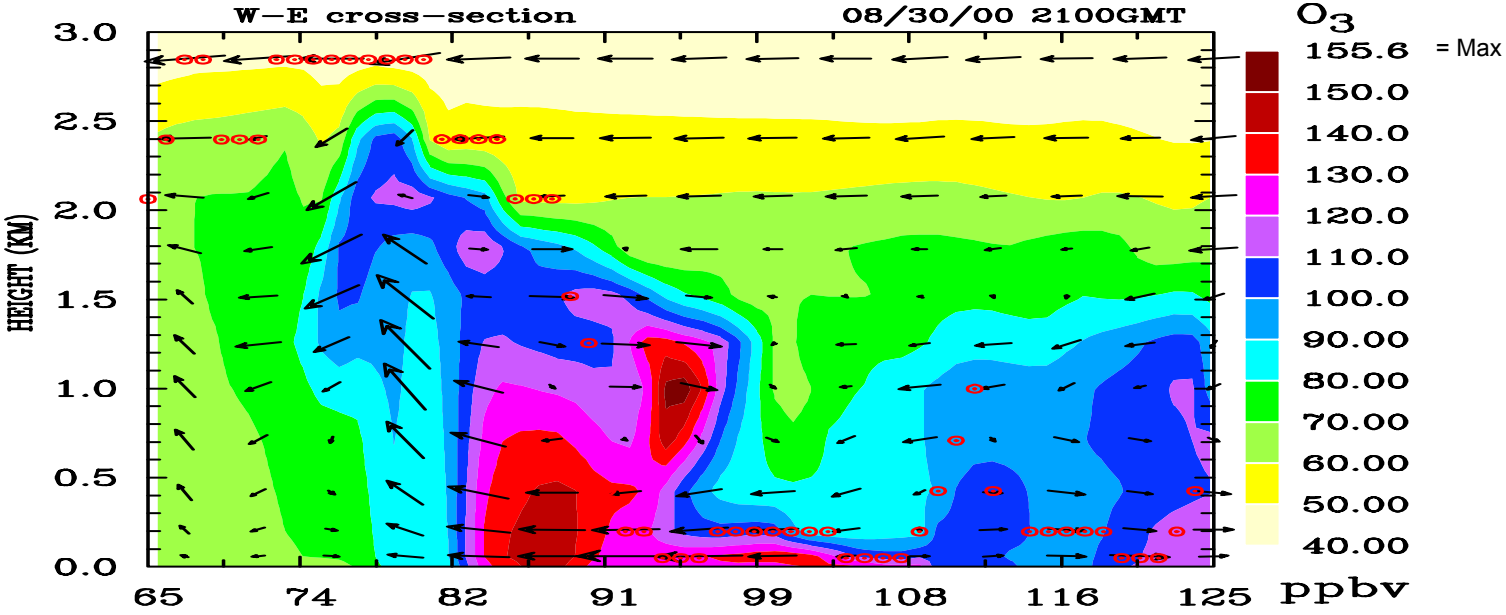
Increased Olefin Emissions



Original Emissions



Increased Olefin Emissions



Real-time setup during Summer 2002

- Model was run in real-time twice a day from June through September 22
- Forecast length was 60 hours (12 hr FDDA + 48 hr forecast
- 27 km horizontal resolution over central and eastern US (2970x3600 km)
- Model results were displayed on the Web
- Ratio of wall clock/forecast time was 1:30 using 36 processors of FSL's supercomputer

Real-time setup during Summer 2002

- For July and August: 3 level nested set-up over northeastern US, centered over New Hampshire (27 km (D1), 9 km (D2), 3 km (D3) horizontal resolution)
  - Continuous data set for D1 and D2, and D3 for retro-runs (“test bed”)
  - Special “events” data sets for D3 and D4 (domain with 1km resolution)

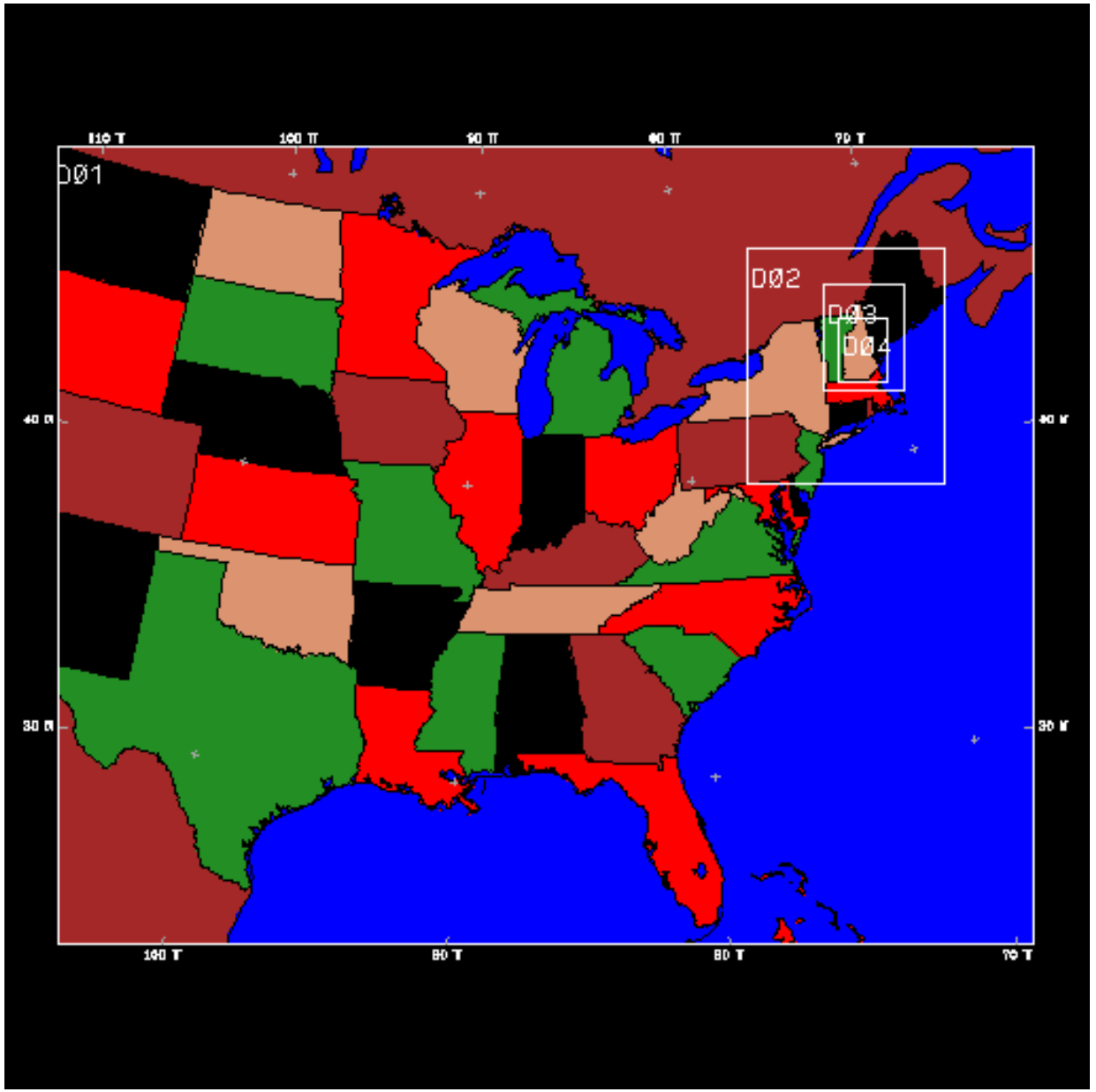
Domain setup

D1 – 27KM

D2 – 9KM

D3 – 3KM

D4 – 1KM



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Use of data for evaluation and verification

- ETL: meteorological data for verification with profiler data and surface obs
- AL: three-dimensional data set for verification with chemistry/met data, and forecasting aid for Ron Brown (NOAA's vessel)
- ARL: Surface chemistry for verification

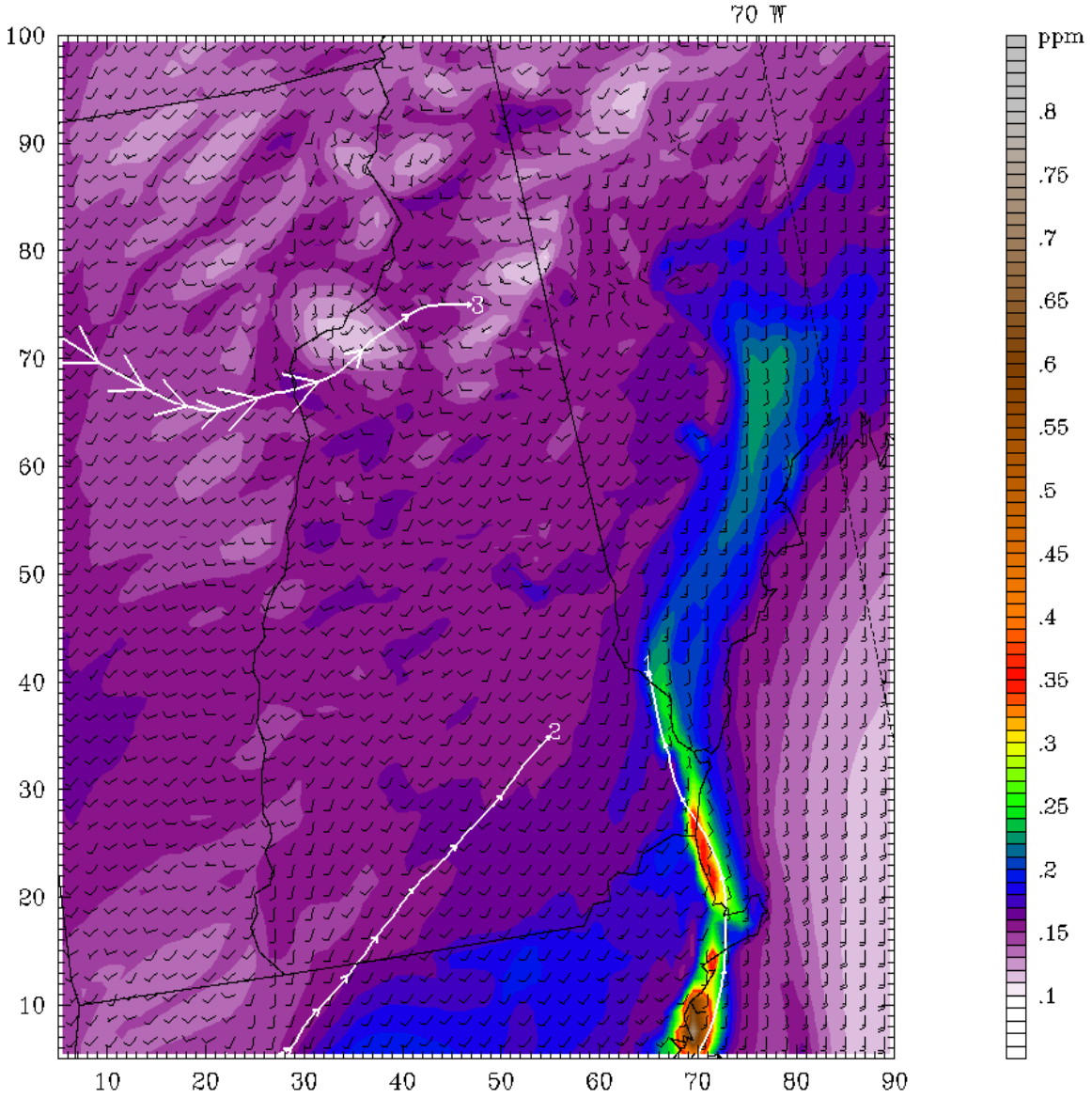
Chemical initial and boundary conditions for model runs

- 12-hour FDDA (nudging) simulations were used in fully coupled mode to assimilate anthropogenic emissions data. Meteorology was strongly nudged towards 3-hourly RUC analysis from T-12 to T-0 (ETA as back-up)
- This was done continuously every 12 hours
- Anthropogenic emissions data from EPA Net-96 (Stu McKeen, AL)
- For nested domains: 12hr forecasts were used for initial conditions, coarse domain chemistry for lateral boundaries

Meteorological initial and boundary conditions for model runs

- Any NCEP model is possible for meteorological initialization
- RUC20 for initial conditions (ETA as back-up) was used (including soil moisture initialization)
- ETA for boundary conditions

CO Concentration at level 1 DX = 3KM Init: 0000 UTC Mon 23 Jul 01
Fcst: 20.00 Valid: 2000 UTC Mon 23 Jul 01 (1400 MDT Mon 23 Jul 01)



CO concentration near surface

Backward Trajectories

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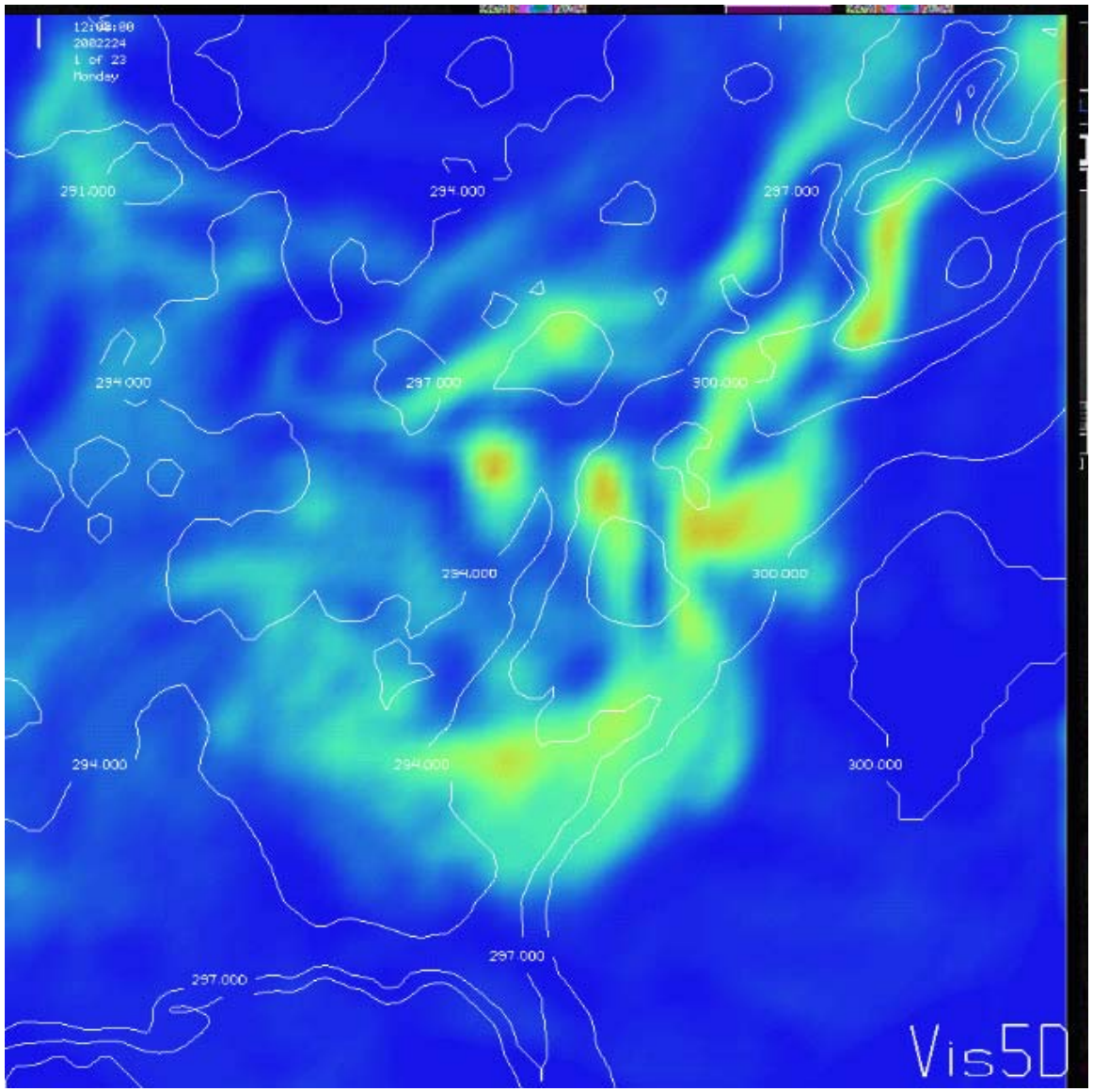
Model info: V3.3.0 No Cumulus Reisner 1 3 km, 29 levels, 1 sec



MM5/chem

dx=3km

July 23, 0100 UTC

to July 24, 1200 UTC

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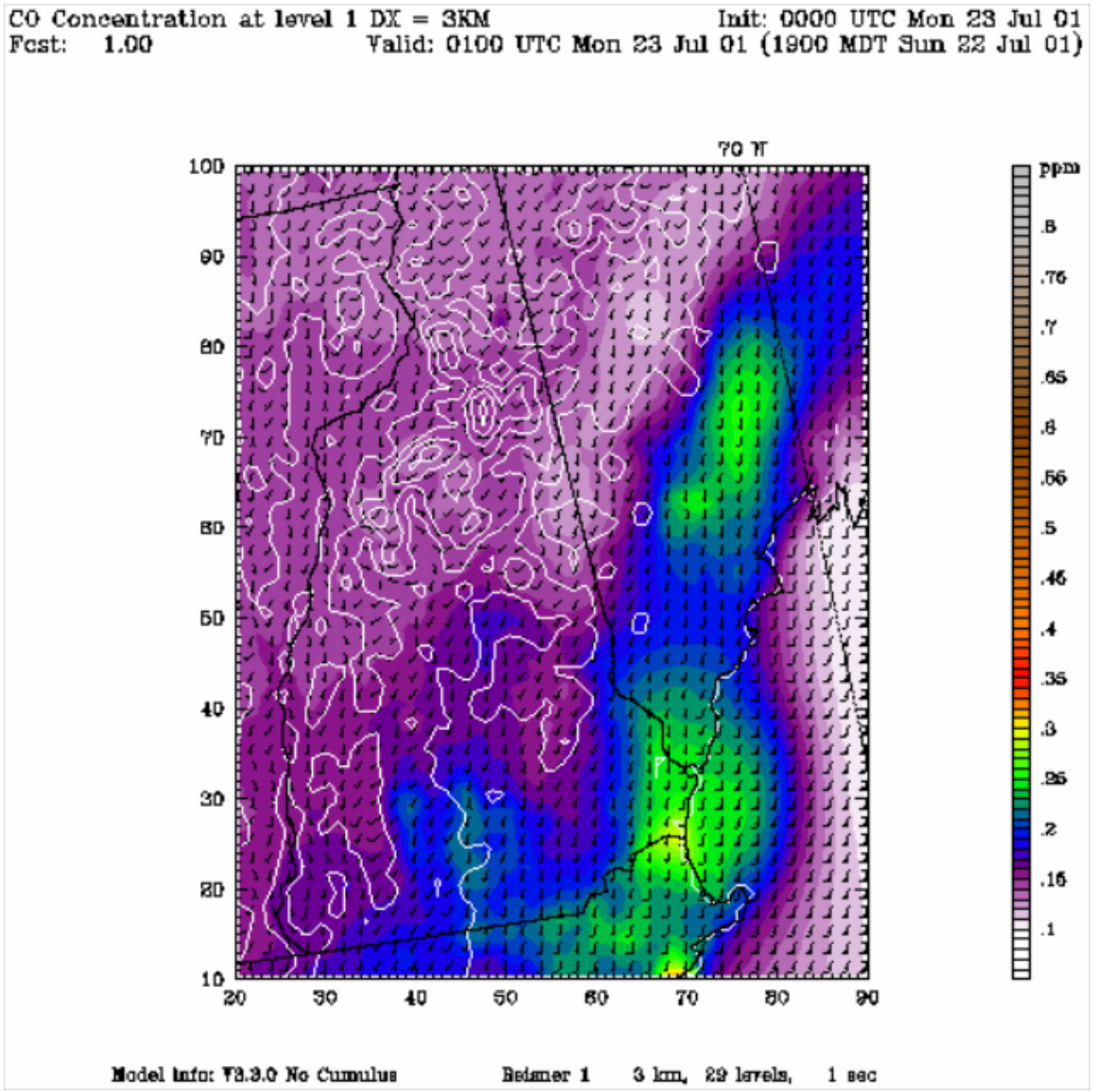

CO

MM5/chem

dx=3km

July 23, 0100 UTC

to July 24, 1200 UTC

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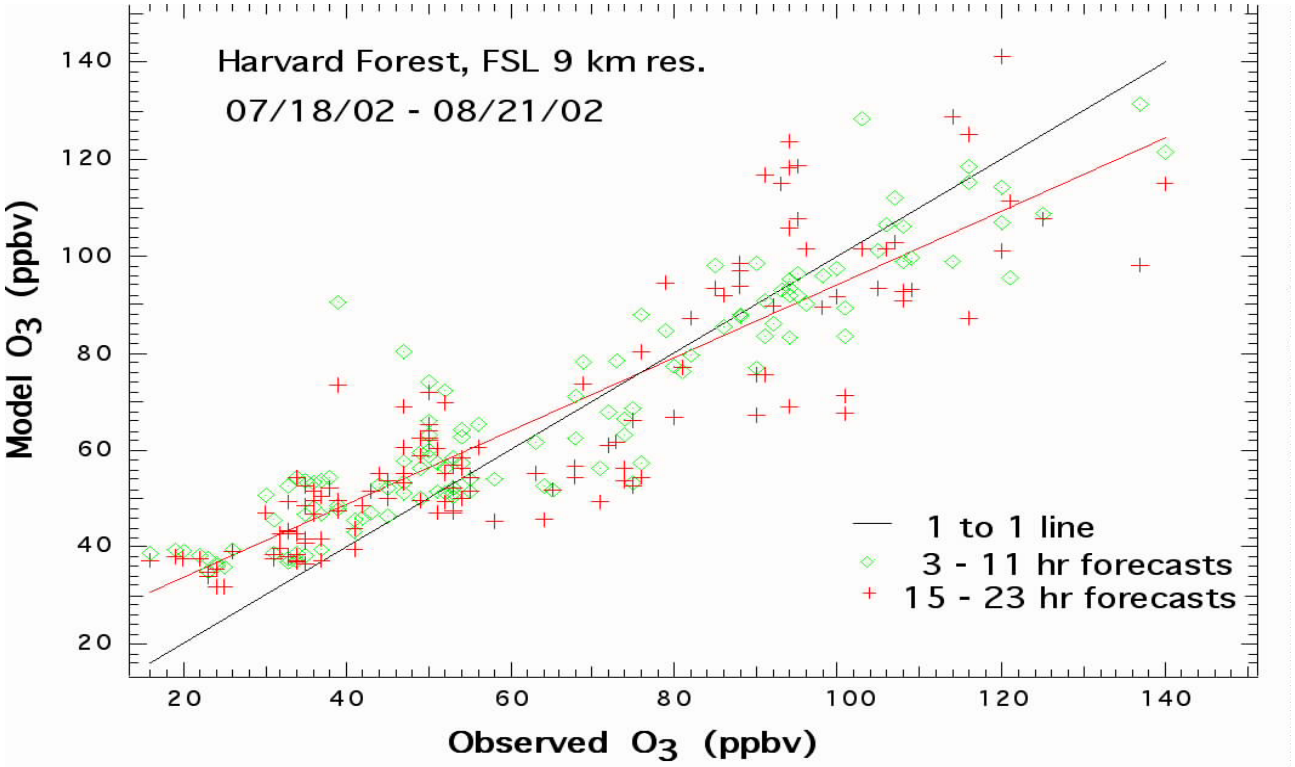
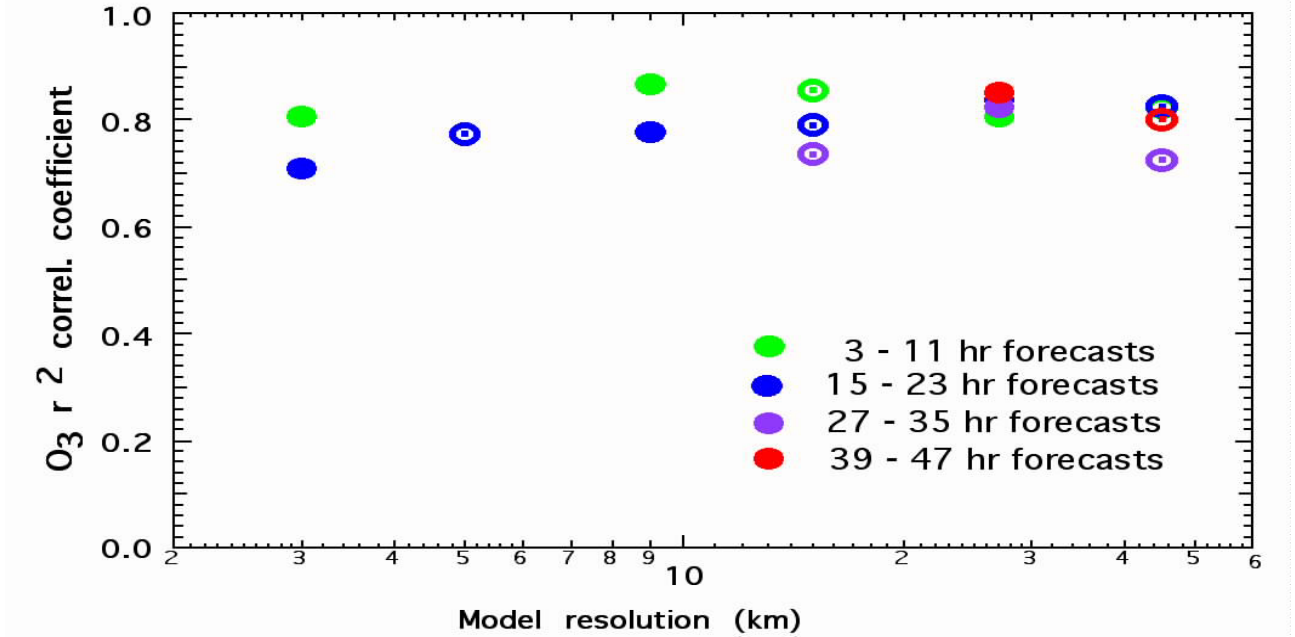
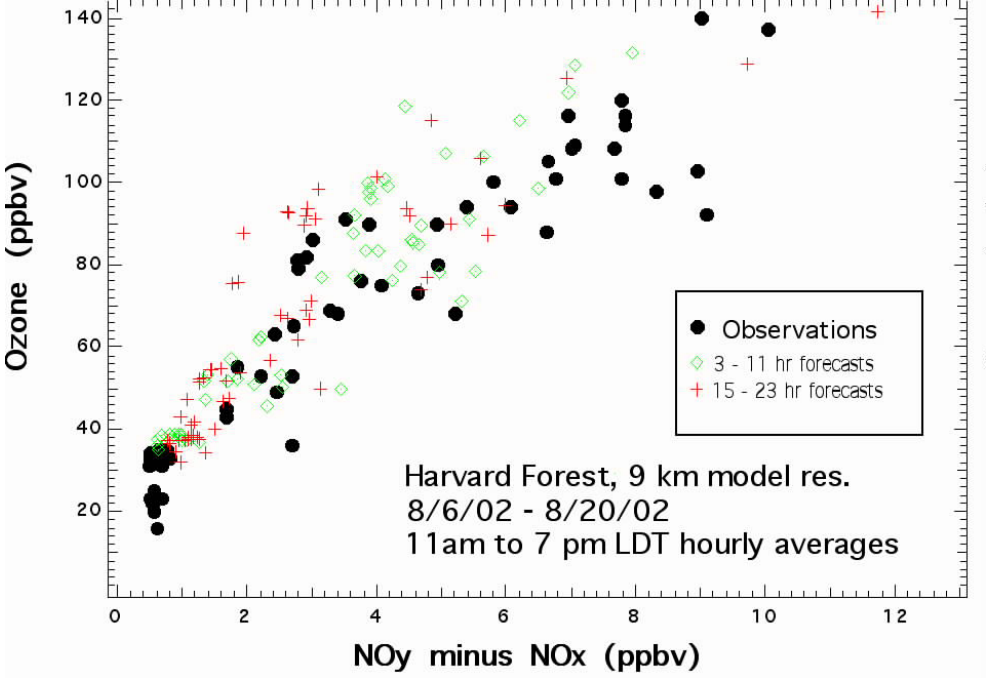
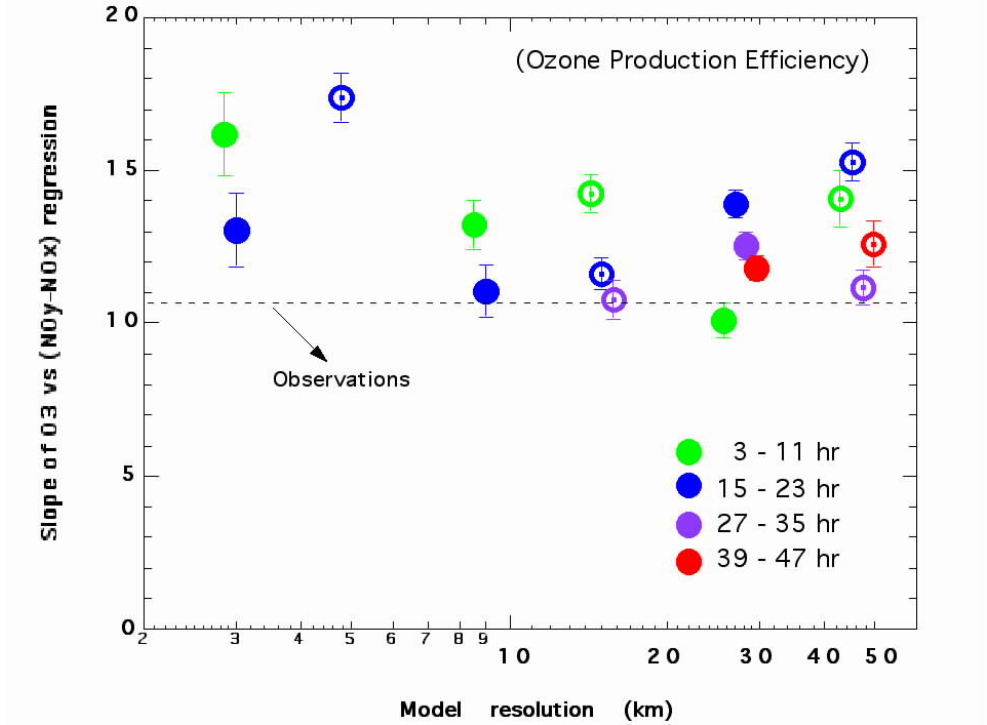
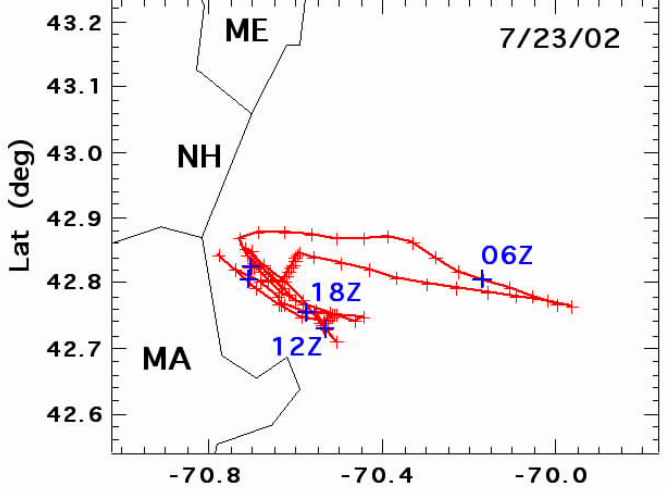

Harvard Forest, FSL 9 km res.
07/18/02 - 08/21/02
Model O3 (ppbv)
Observed O3 (ppbv)
1 to 1 line
3 - 11 hr forecasts
15 - 23 hr forecasts
20
40
60
80
100
120
140

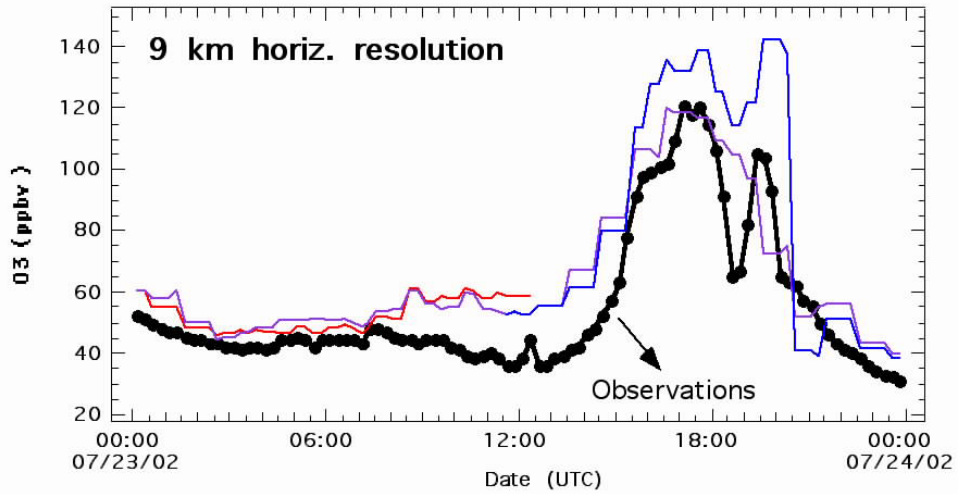

O3 r 2 correl. coefficient
Model resolution (km)
3 - 11 hr forecasts
15 - 23 hr forecasts
27 - 35 hr forecasts
39 - 47 hr forecasts
0.0
0.2
0.4
0.6
0.8
1.0
10

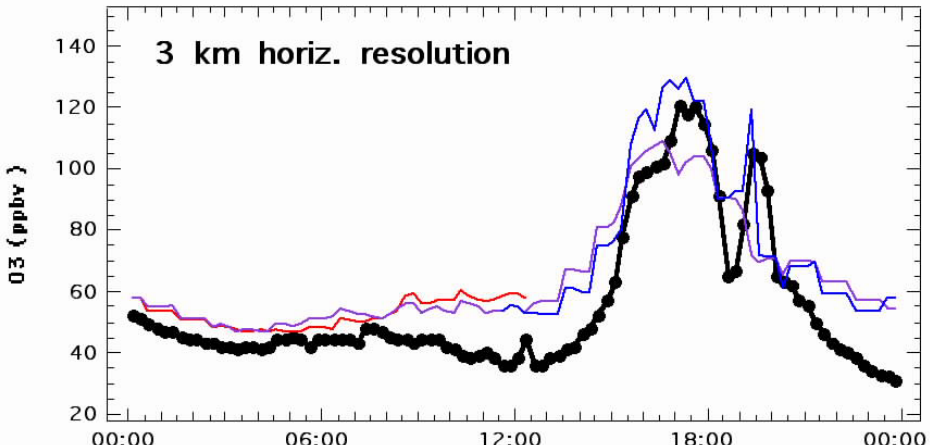

Ozone (ppbv)
NOy minus NOx (ppbv)
Observations
3 - 11 hr forecasts
15 - 23 hr forecasts
Harvard Forest, 9 km model res.
8/6/02 - 8/20/02
11am to 7 pm LDT hourly averages


(Ozone Production Efficiency)
Slope of O3 vs (NOy-NOx) regression
Observations
3 - 11 hr
15 - 23 hr
27 - 35 hr
39 - 47 hr
Model resolution (km)



R.V. Ron Brown
Ship Track
Down-wind of
Boston Plume





Current and future activities

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Next Cornerstone: WRF

- Weather Research and Forecast model: the next generation
  - Originally WRF was collaborative project between NCAR, FSL, and NCEP. Many other groups have now joined in the development effort
- NOAA's goal: leadership role in WRF/chem development
- Prototype version of this model now
  - Minimum requirement: same chemical modules as in MM5/chem

Weather Research and Forecast (WRF) model, what's new?

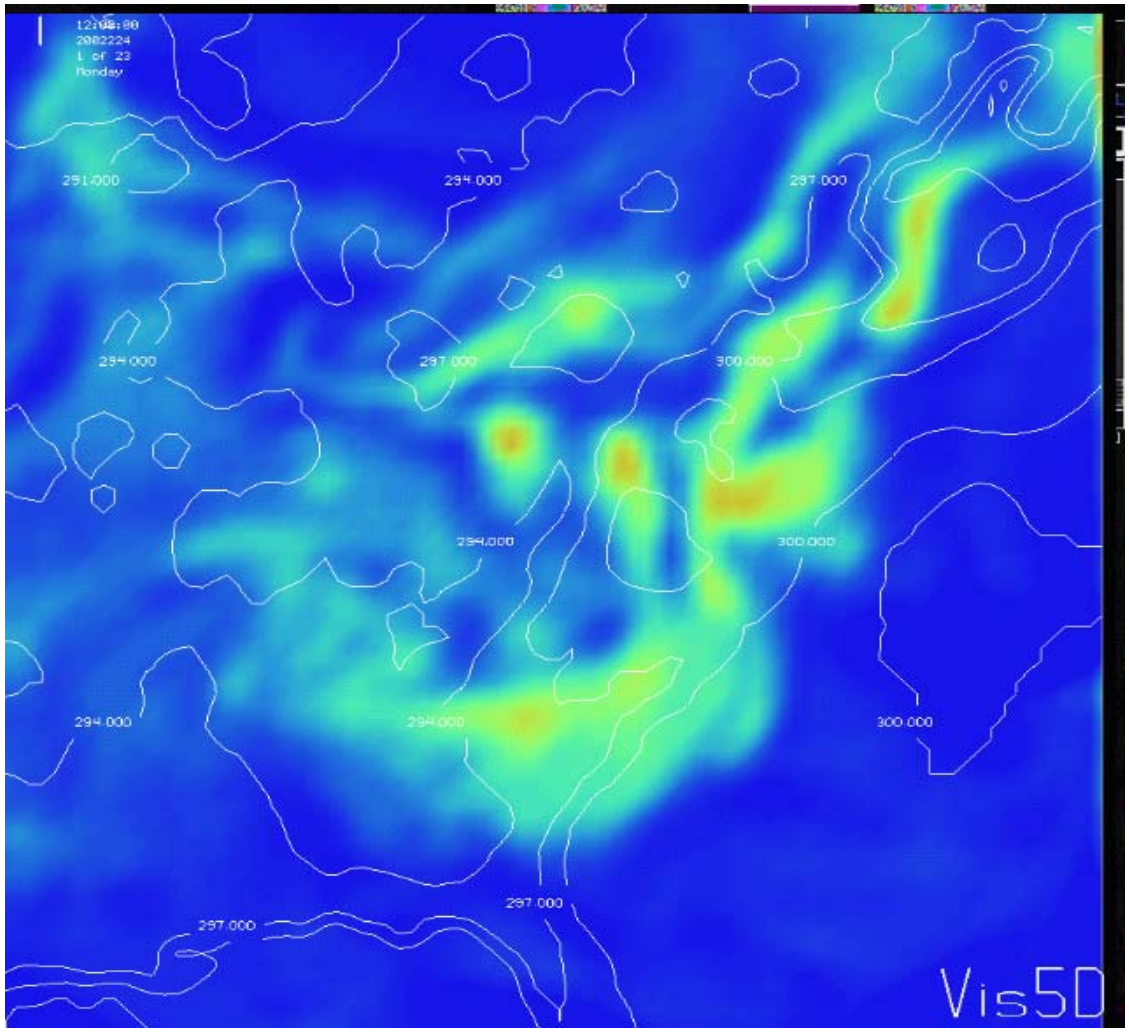
- Flux form, fully conservative
- Ready to use distributed memory as well as shared memory machines (or both at same time)
- Highly accurate and robust numerics (not YET positive definite)
- Already several dynamic cores (mass and height coordinate, NCEP's NMM to follow)

“Online” chemistry package for

- WRF grid-scale transport
- Subgrid-scale transport by turbulence
- Subgrid-scale transport by convection
- Dry deposition (Wesley),
- Biogenic emissions (Guenther et al.)
- Chemical mechanism from RADM2
- Photolysis (Madronich)
- Wet deposition

What is and what is not

- Subgrid-scale transport by turbulence
- Subgrid-scale transport by convection
- Dry deposition (Wesley)
- Biogenic emissions (Guenther et al.)
- Chemical mechanism from RADM2
- Photolysis (Madronich)
- Wet deposition


1 of 23
Monday
291.000
294.000
297.000
294.000
297.000
300.000
294.000
300.000
294.000
294.000
300.000
297.000
297.000
Vis5D

Near future:

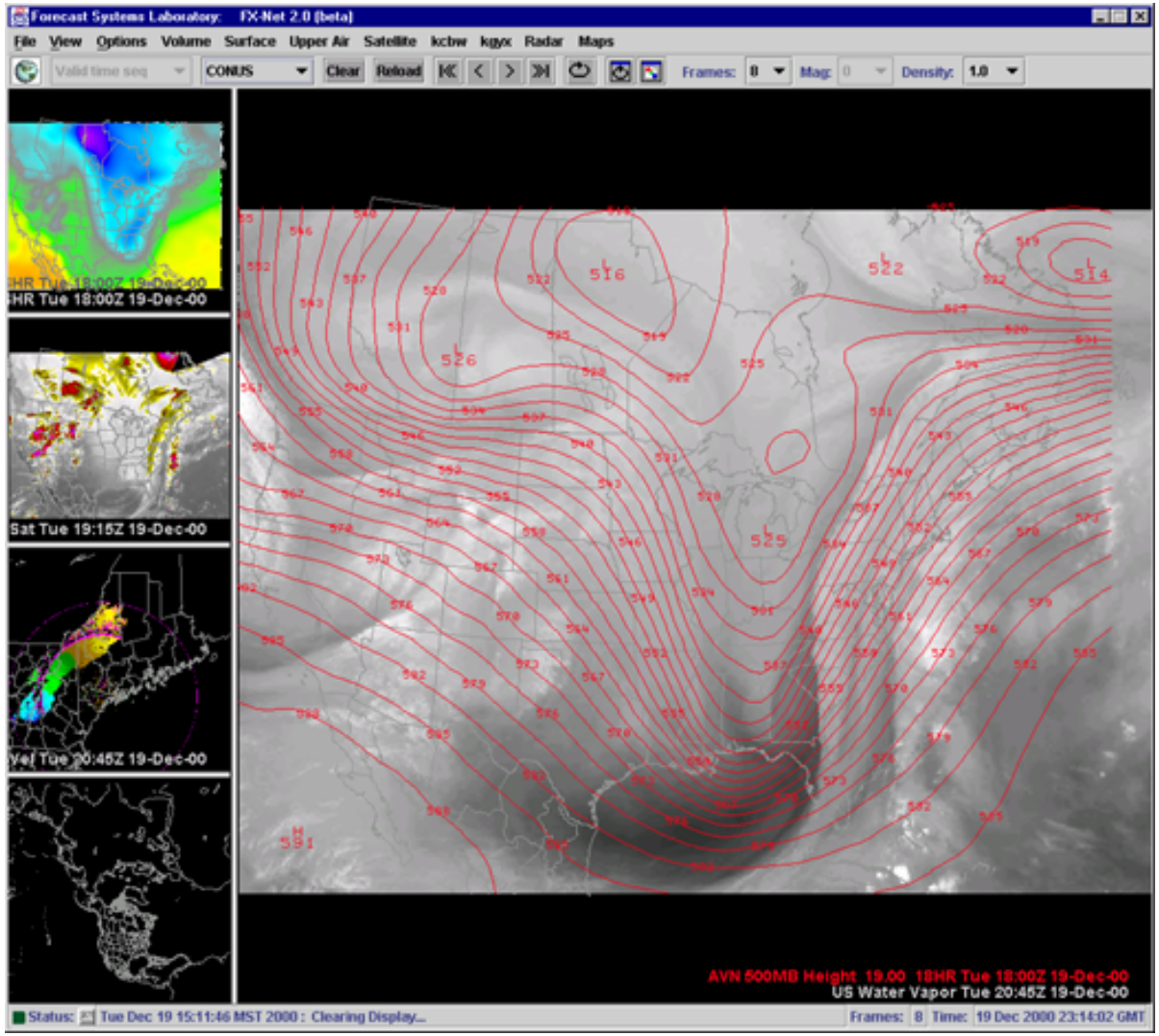
- Clean up the really UGLY stuff (IO)
- Clean up lateral boundary conditions (especially for 1-way nests)
- Test with retro-runs (Summer 2001 and Summer 2002)

Who has voiced interest so far into taking part in further development in the **NEAR** future

- MCNC (John McHenry, Carly Coats, Implementation of SMOKE emissions module as well as aerosol module)
- NCAR (Peter Hess, Christine Wiedenmeyer, sleek chemical mechanism, better photolysis, improved biogenic emissions, smoke from fires in real-time)
- ARL/RTP/EPA (Jon Pleim and others, deposition, biogenic emissions, sleek chemical mechanism)
- University of Houston (Daewon Byun, advection, offline versus online)
- AFWA (turbulence, fdda, biogenic emissions/luse/LSM coupling)
- DRI (Bill Stockwell, sleek chemical mechanism)

Many other groups have already voiced interest for the not so near future

FX-Net User Interface



Imitates the AWIPS User Interface

Functionality:

- Load
- Animation
- Overlay/Toggle
- Zoom
- Swap

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