Appendix E-2b

Regional Haze Modeling for Southeastern VISTAS II Regional Haze Analysis Project 2011el CAMx Version 6.32 and 6.40 Comparison Report

Benchmark Run #3

August 17, 2020

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Regional Haze Modeling for Southeastern VISTAS II Regional Haze Analysis Project 2011el CAMx Version 6.32 and 6.40 Comparison Report

Task 6 Benchmark Report #2
Covering Benchmark Run #3

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Under Contract No. V-2018-03-01

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Abbreviations/Acronym List

Alpine	Alpine Geophysics, LLC
CAMx	Comprehensive Air quality Model with eXtensions
dv	Deciview
ERG	Eastern Research Group, Inc.
EPA	Environmental Protection Agency
FCRS	Crustal fraction of PM
FLM	Federal Land Manager
FPRM	Fine other primary (diameter $\leq 2.5\mu m$)
FR	Federal Register
IMPROVE	Interagency Monitoring of Protected Visual Environments
$\mu g/m^3$	microgram per cubic meter
NAAQS	National Ambient Air Quality Standard
NA	Sodium
OAQPS	Office of Air Quality Planning and Standards
O_3	Ozone
OC	Organic carbon
OM	Organic matter
OSAT	Ozone Source Apportionment Technology
PCL	Primary chlorine
PEC	Primary elemental carbon
PM	Particulate matter
$PM_{2.5}$	Fine particle; primary particulate matter less than or equal to 2.5 microns in aerodynamic diameter
PNH4	Particulate ammonium
PNO3	Particulate nitrate
POA	Primary Organic Aerosol
ppb	Parts per billion
PSAT	Particulate Source Apportionment Technology
PSO4	Particulate sulfate
R^2	Pearson correlation coefficient squared
RADM-AQ	Regional Acid Deposition Model – aqueous chemistry
RHR	Regional Haze Rule
SESARM	Southeastern States Air Resource Managers, Inc.
SIP	State Implementation Plan
SO_2	Sulfur dioxide
SOA	Secondary organic aerosol
SOAP	Secondary organic aerosol partitioning
U.S.	United States
VISTAS	Visibility Improvement – State and Tribal Association of the Southeast

1.0 INTRODUCTION

1.1 Overview

Southeastern States Air Resource Managers, Inc. (SESARM) has been designated by the United States (U.S.) Environmental Protection Agency (EPA) as the entity responsible for coordinating regional haze evaluations for the ten Southeastern states of Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia. The Eastern Band of Cherokee Indians and the Knox County, Tennessee local air pollution control agency are also participating agencies. These parties are collaborating through the Regional Planning Organization known as Visibility Improvement - State and Tribal Association of the Southeast (VISTAS) in the technical analyses and planning activities associated with visibility and related regional air quality issues. VISTAS analyses will support the VISTAS states in their responsibility to develop, adopt, and implement their State Implementation Plans (SIPs) for regional haze.

The state and local air pollution control agencies in the Southeast are mandated to protect human health and the environment from the impacts of air pollutants. They are responsible for air quality planning and management efforts including the evaluation, development, adoption, and implementation of strategies controlling and managing all criteria air pollutants including fine particles and ozone as well as regional haze. This project will focus on regional haze and regional haze precursor emissions. Control of regional haze precursor emissions will have the additional benefit of reducing criteria pollutants as well.

The 1999 Regional Haze Rule (RHR) identified 18 Class I Federal areas (national parks greater than 6,000 acres and wilderness areas greater than 5,000 acres) in the VISTAS region. The 1999 RHR required states to define long-term strategies to improve visibility in Federal Class I national parks and wilderness areas. States were required to establish baseline visibility conditions for the period 2000-2004, natural visibility conditions in the absence of anthropogenic influences, and an expected rate of progress to reduce emissions and incrementally improve visibility to natural conditions by 2064. The original RHR required states to improve visibility on the 20% most impaired days and protect visibility on the 20% least impaired days.[1] The RHR

[1] RHR summary data is available at: http://vista.cira.colostate.edu/Improve/rhr-summary-data/

requires states to evaluate progress toward visibility improvement goals every five years and submit revised SIPs every ten years.

EPA finalized revisions to various requirements of the RHR in January 2017 (82 FR 3078) that were designed to strengthen, streamline, and clarify certain aspects of the agency's regional haze program including:

A. Strengthening the Federal Land Manager (FLM) consultation requirements to ensure that issues and concerns are brought forward early in the planning process.

B. Updating the SIP submittal deadlines for the second planning period from July 31, 2018 to July 31, 2021 to ensure that they align where applicable with other state obligations under the Clean Air Act. The end date for the second planning period remains 2028; that is, the focus of state planning will be to establish reasonable progress goals for each Class I area against which progress will be measured during the second planning period. This extension will allow states to incorporate planning for other Federal programs while conducting their regional haze planning. These other programs include: the Mercury and Air Toxics Standards, the 2010 1-hour sulfur dioxide (SO_2) National Ambient Air Quality Standards (NAAQS); the 2012 annual fine particle ($PM_{2.5}$) NAAQS; and the 2008 and 2015 ozone NAAQS.

C. Adjusting interim progress report submission deadlines so that second and subsequent progress reports will be due by: January 31, 2025; July 31, 2033; and every ten years thereafter. This means that one progress report will be required midway through each planning period.

D. Removing the requirement for progress reports to take the form of SIP revisions. States will be required to consult with FLMs and obtain public comment on their progress reports before submission to the EPA. EPA will be reviewing but not formally approving or disapproving these progress reports.

The RHR defines "clearest days" as the 20% of monitored days in a calendar year with the lowest deciview (dv) index values. "Most impaired days" are defined as the 20% of monitored days in a calendar year with the highest amounts of anthropogenic visibility impairment. The long-term strategy and the reasonable progress goals must provide for an improvement in visibility for the most impaired days since the baseline period and ensure no degradation in visibility for the clearest days since the baseline period.

1.2 2011el CAMx 6.32 and CAMx 6.40 Comparison

Recent EPA 2011el and 2028el platform simulations were performed with Comprehensive Air quality Model with eXtensions (CAMx) version 6.32. Since that time the CAMx model has been updated to include better physical treatment, and to correct any model flaws that were discovered after the release of 6.32.

Alpine Geophysics, LLC (Alpine), under subcontract with Eastern Research Group, Inc. (ERG), has executed two air quality simulations for the 2011el base year modeling platform; one run with CAMx 6.32 and one with CAMx 6.40. We note that CAMx 6.50 has now been released, however that model release was too late to be included with sufficient certainty in the VISTAS II project schedule.

This comparison is to document the differences in model estimates between 2011EL simulated with CAMx 6.32 and CAMx 6.40 as is discussed in the VISTAS II Modeling Protocol[2] in Section 6.5.2 model comparison number 3.

2.0 DIFFERENCES BETWEEN CAMX 6.32 AND 6.40 SIMULATIONS

Differences in modeled output concentrations between the CAMx 6.32 and 6.40 simulations were as a result both of changes to the CAMx model code and changes to the model inputs.

Model Differences

Many updates to the CAMx model were implemented between the 6.32 and 6.40 release. According to the CAMx 6.40 release notes, the significant changes included:

2 "Regional Haze Modeling for Southeastern VISTAS II Region Haze Analysis Project, Final Modeling Protocol." Prepared for SESARM under Contract No. V-2018-03-01. Prepared by Alpine Geophysics, LLC and Eastern Research Group, Inc. June 27, 2018.

1. Updates to the chemistry to include a condensed halogen mechanism for ocean-borne inorganic reactive iodine, hydrolysis of isoprene-derived organic nitrate and SO_2 oxidation on primary crustal fine particulate matter (PM). This update includes the changes to the Ozone and Particulate Source Apportionment Technology (OSAT/PSAT) algorithms;

2. Inclusion of in-line inorganic iodine emissions to support halogen chemical mechanisms;

3. A major revision to the secondary organic aerosol portioning (SOAP) chemistry/ partitioning algorithm;

4. Updates to the Regional Acid Deposition Model – aqueous chemistry (RADM-AQ) algorithm; and

5. A major revision to the wet deposition algorithm to identify assumptions or processes that were unintentionally or otherwise unreasonably limiting gas and PM update into precipitation. The wet deposition algorithm was simplified and improved in several ways, resulting in the increased scavenging of gases and PM.

Configurations Difference

In addition to the model version, the CAMx 6.32 and 6.40 simulations contained differences in the EPA modeling platform that had been made subsequent to the 2011el/2028el model release. In the most current 2023en simulation, EPA developed new photolysis rates and ozone column data. These updates were included in the updated modeling platform and resulting CAMx 6.40 simulation and were used in the VISTAS II 2011el simulations.

Another configuration difference is how the boundary conditions were mapped for speciation in the two versions of the model. EPA and the VISTAS CAMx 6.32 and 6.40 simulations all used the same boundary condition files. However, when CAMx was updated from 6.32 to 6.40 the species in the secondary organic aerosol (SOA) scheme changed. The SOA5, SOA6, and SOA7 were removed and SOA3 and SOA4 were redefined. Neither EPA nor this study remapped the boundary conditions to account for this change. EPA examined the regional haze summary data for all Class I areas and found the total organic carbon (OC) species (not just SOA) accounted for 1-5% of the boundary condition impairment at the Southeastern Class I areas.[3] This is a small impact on regional haze and the impact of SOA on regional haze is even smaller.

3.0 CONFIRMATION METHODOLOGY

The presented comparison of model simulations are based on hourly differences in ozone (O_3), $PM_{2.5}$, Organic Matter (OM), Particulate Nitrate (PNO3), and Particulate Sulfate (PSO4). The metric for comparison are the absolute difference (Equation 1) and percent difference (Equation 2) defined as:

(Equation 1) $$(C_{6.32} - C_{6.40})$$

(Equation 2) $$\frac{(C_{6.32} - C_{6.40})}{(C_{6.40})}$$

Where $C_{6.40}$ is the concentration at each grid cell hour for the CAMx 6.40 simulation and $C_{6.32}$ is the concentration at each grid cell hour for the CAMx 6.32 simulation.

The results are presented for the hours with the largest difference between the simulations. A table presents the hours with the top 10 positive and negative absolute differences. Spatial maps are presented for the hours with the top 10 highest positive and negative differences. To provide context for the differences, the concentration maps are also presented for each of the hours of high difference. On each spatial plot the maximum positive and negative values, along with the grid cell in which these occur, are presented at the top of the graphic. The coordinates refer to the row and columns of the cell referenced to the cell coordinates on the bottom (column) and left (row) of the graphic.

Hourly animations have also been prepared and are available on the VISTAS II project ftp site. Where appropriate, this report also reports and interprets on the animations.

[3] Brian Timin, EPA Office of Air Quality Planning and Standards (OAQPS) personal communication October 11, 2018.

CAMx Species Mapping

Updates to the CAMx model between version 6.32 and 6.40 necessitated making changes to how the individual CAMx species were aggregated to the presented species. The CAMx species mapping between the two compared versions are presented in Table 3-1.

Table 3-1. Species Mapping from CAMx into Aggregated Species

Aggregated Species	CAMx 6.32 Species	CAMx 6.40 Species
Ozone	O3	O3
$PM_{2.5}$	PSO4+PNO3+PNH4+SOA1+SOA2+SOA3+SOA4+SOA5+SOA6+SOA7+SOPA+SOPB+POA+PEC+FPRM+FCRS+NA+PCL	PSO4+PNO3+PNH4+SOA1+SOA2+SOA3+SOA4+SOPA+SOPB+POA+PEC+FPRM+FCRS+NA+PCL
Sulfate	PSO4	PSO4
Nitrate	PNO3	PNO3
Organic Matter (OM)	SOA1+SOA2+SOA3+SOA4+SOA5+SOA6+SOA7+SOPA+SOPB+POA[1]	SOA1+SOA2+SOA3+SOA4+SOPA+SOPB+POA

[1] SOAH was not included in the 6.32 comparison since it was not included as an output species in the EPA simulation.

4.0 CAMX 6.32 AND CAMX 6.40 2011EL COMPARISON

This section presents comparisons of the simulations using CAMx 6.32 and CAMx 6.40 performed on the Alpine computer system using EPA's 2011el modeling platform.

4.1 Ozone

Ozone results for the top 10 positive and negative hours are presented in tabular format in Table 4-1. The maximum positive difference is 14.48 parts per billion (ppb) falling to 10.47 ppb for the 10th high. The maximum negative difference is -13.74 ppb falling to -9.61 for the 10th high. The highest positive differences are occurring on relatively high ozone hours with concentrations ranging from 80 ppb to 113 ppb for the CAMx 6.32 simulation. The maximum negative difference days generally are on hours with more modest concentrations of 51 to 72 ppb, except for a July 18th day with a 150 ppb estimate. The maximum positive percent difference is 18.9% and the maximum negative percent difference is -18.5%.

The top ten positive impact hours are presented in Figures 4-1 through 4-10. The regions of highest positive differences, meaning that estimates with CAMx 6.32 are higher that CAMx 6.40, tend to occur over the western edge of Lake Michigan. The concentration difference summed over the entire domain show a negative concentration, meaning that estimates with CAMx 6.40 is overall producing more ozone.

The top ten negative impact hours are presented in Figures 4-11 through 4-20. On days with high negative differences the areas of maximum difference vary hour to hour with the maximum difference most often over the eastern Gulf of Mexico. On five of the top ten negative days CAMx 6.32 estimates higher ozone, and on five of the days CAMx 6.40 estimates higher ozone.

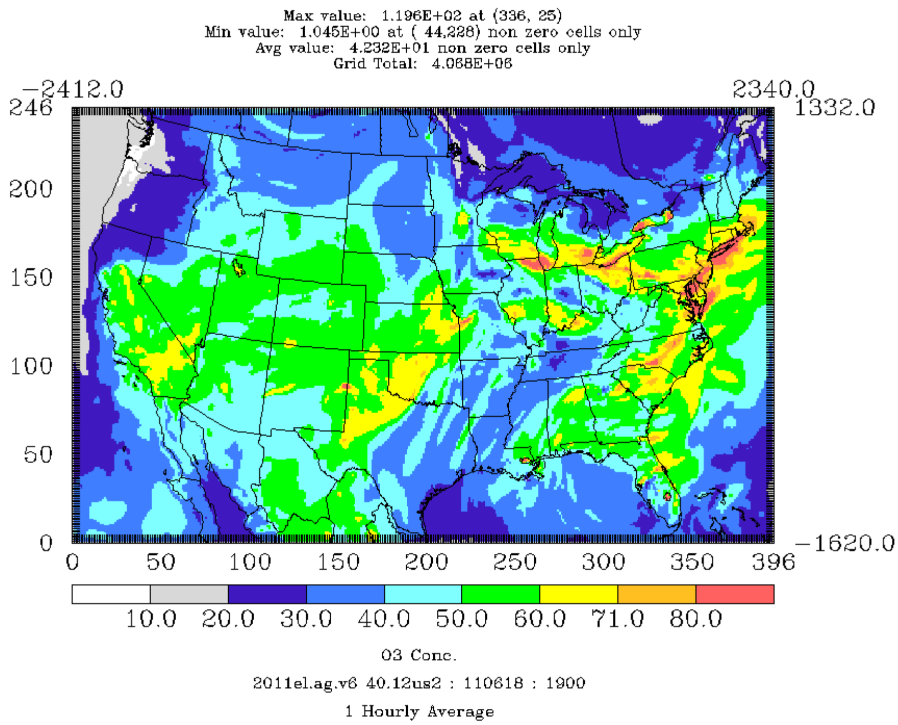
Scatterplots of the daily average ozone concentrations in local standard time at the Interagency Monitoring of Protected Visual Environments (IMPROVE) monitors across all modeled days are presented in Figure 4-21. The CAMx 6.40 results are plotted on the x-axis and the CAMx 6.32 results are plotted on the y-axis. The data has a high degree of correlation with a line of best fit with a slope of 0.9975, an intercept of 0.0592 ppb and an R^2 of 0.9995.

Examination of the animations show that in general CAMx 6.32 makes more ozone in the southern U.S. and intermountain west, and CAMx 6.40 makes more ozone in the northern U.S.

Table 4-1. Comparison of 2011el CAMx 6.32 and CAMx 6.40 Simulation of Ozone Concentrations (ppb). Hours with the top 10 maximum positive and maximum negative differences are shown.

Year	Month	Day	Hour	6.32 Conc.	6.40 Conc.	Difference (ppb)	Percent Difference	Column	Row
Maximum Positive									
2011	6	18	19	112.01	97.54	14.48	14.8%	266	159
2011	6	18	20	108.71	94.81	13.90	14.7%	266	158
2011	5	22	21	96.36	83.07	13.29	16.0%	264	170
2011	5	30	20	98.40	85.45	12.95	15.2%	263	170
2011	5	22	20	94.40	81.49	12.91	15.8%	265	169
2011	5	30	19	79.99	67.27	12.73	18.9%	263	170
2011	5	22	19	85.52	73.75	11.78	16.0%	266	166
2011	5	22	22	95.40	83.90	11.50	13.7%	264	171
2011	6	18	18	97.04	86.28	10.76	12.5%	267	159
2011	6	18	17	113.30	102.83	10.47	10.2%	374	171
Maximum Negative									
2011	4	11	17	60.41	74.16	-13.74	-18.5%	327	56
2011	4	11	18	65.23	77.66	-12.43	-16.0%	327	57
2011	4	11	16	74.52	85.97	-11.45	-13.3%	321	31
2011	7	18	15	150.15	161.50	-11.35	-7.0%	230	239
2011	5	13	21	61.51	72.62	-11.11	-15.3%	224	37
2011	5	13	20	61.36	72.25	-10.89	-15.1%	225	38
2011	4	11	19	72.21	82.25	-10.04	-12.2%	330	42
2011	4	11	20	51.39	61.28	-9.89	-16.1%	220	37
2011	4	12	0	50.55	60.29	-9.74	-16.2%	46	91
2011	4	11	21	60.86	70.47	-9.61	-13.6%	221	36

Maximum Positive Difference: June 18 at 1900 hours
CAMx 6.40



Difference (6.32 - 6.40)

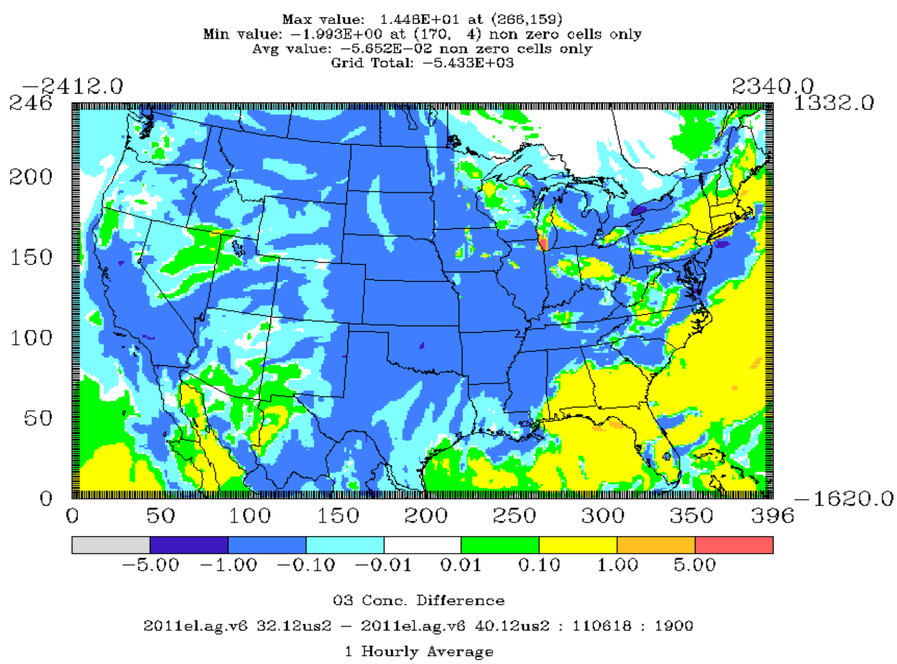
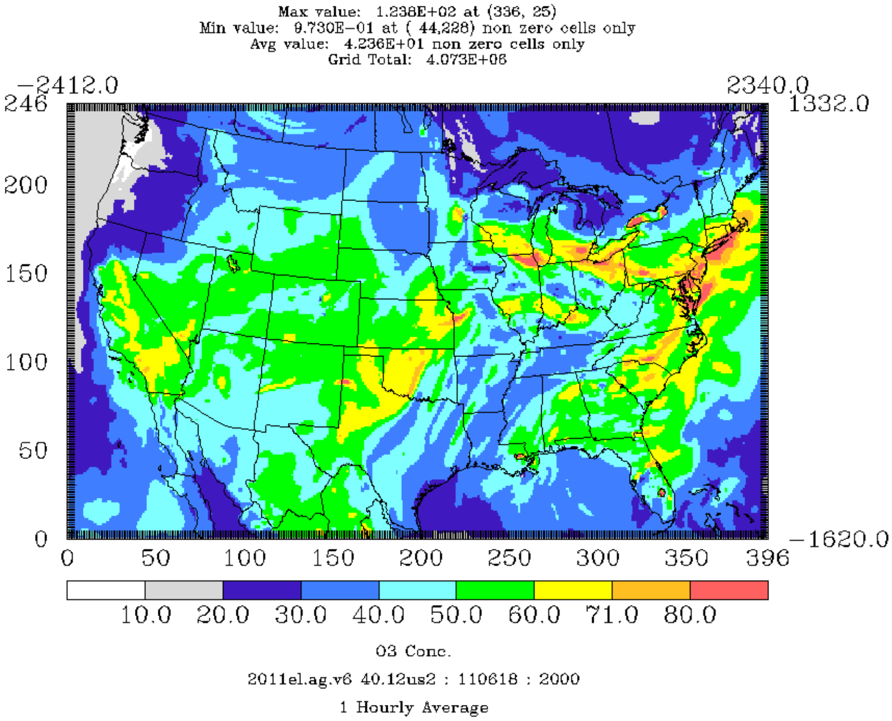


Figure 4-1: Comparison of Ozone Concentrations (ppb) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Maximum Positive Difference)

Second Highest Positive Difference: June 18 at 2000 hours
CAMx 6.40



Difference (6.32 - 6.40)

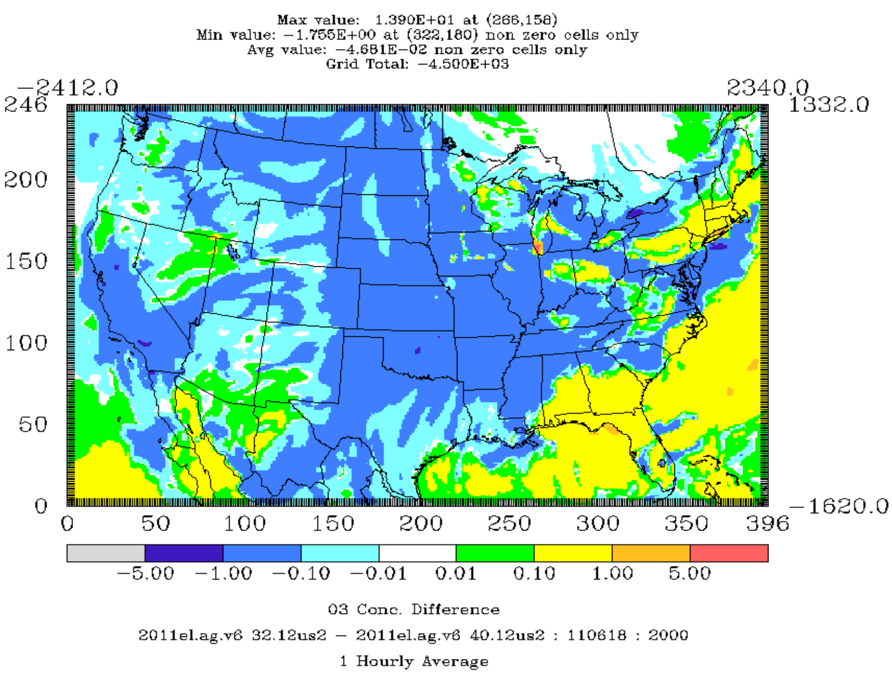


Figure 4-2: Comparison of Ozone Concentrations (ppb) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Second Highest Positive Difference)

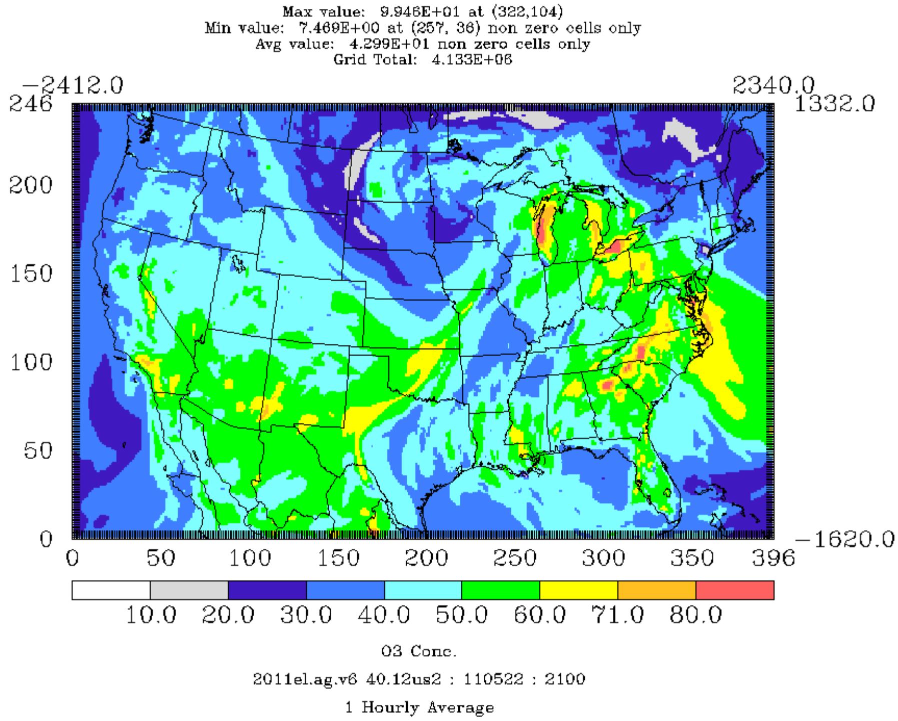
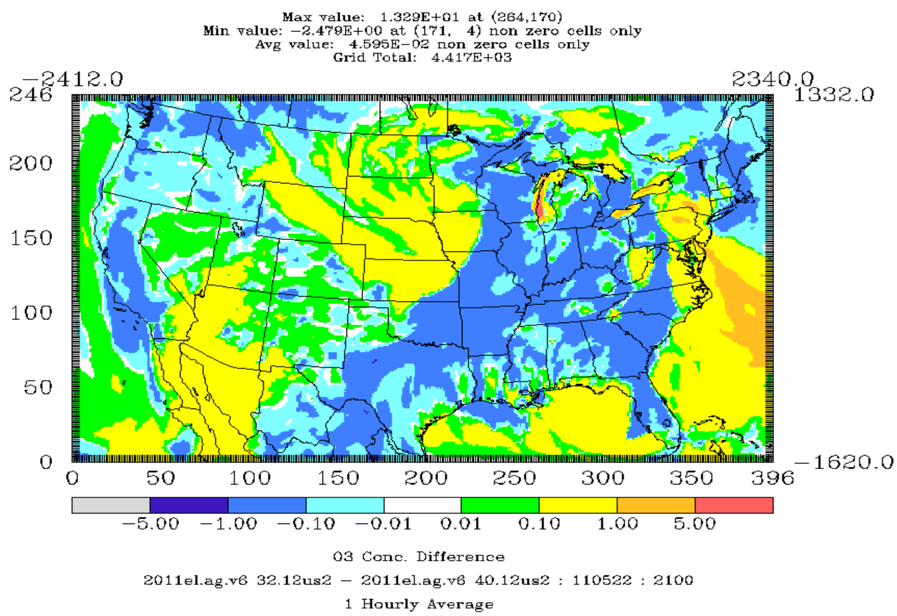
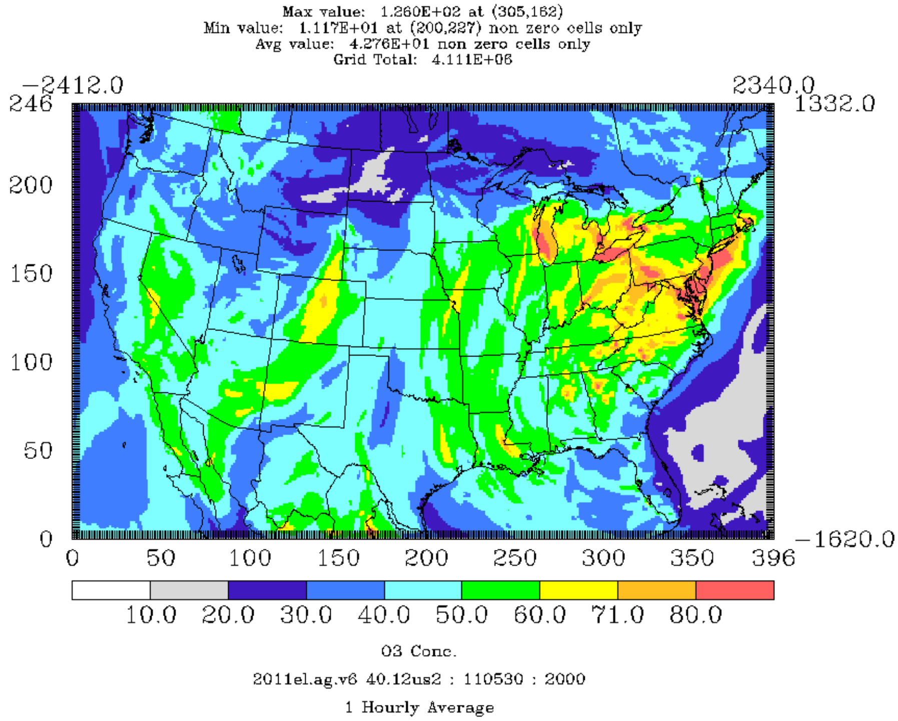
Third Highest Positive Difference: May 22 at 2100 hours
CAMx 6.40

Difference (6.32 - 6.40)


Figure 4-3: Comparison of Ozone Concentrations (ppb) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Third Highest Positive Difference)

Fourth Highest Positive Difference: May 30 at 2000 hours

CAMx 6.40



Difference (6.32 - 6.40)

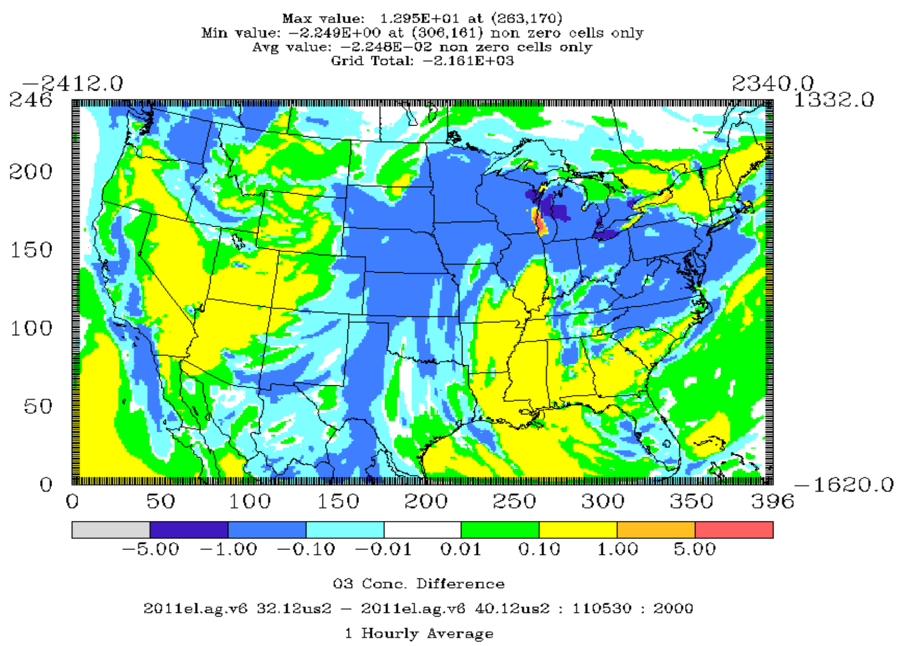
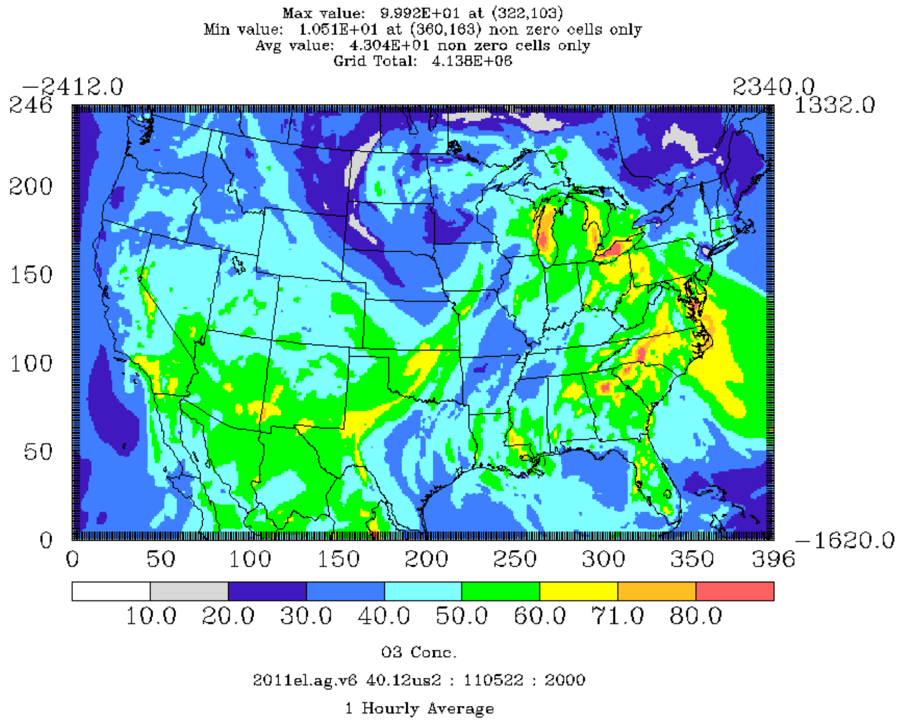


Figure 4-4: Comparison of Ozone Concentrations (ppb) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Fourth Highest Positive Difference)

Fifth Highest Positive Difference: May 22 at 2000 hours

CAMx 6.40



Difference (6.32 - 6.40)

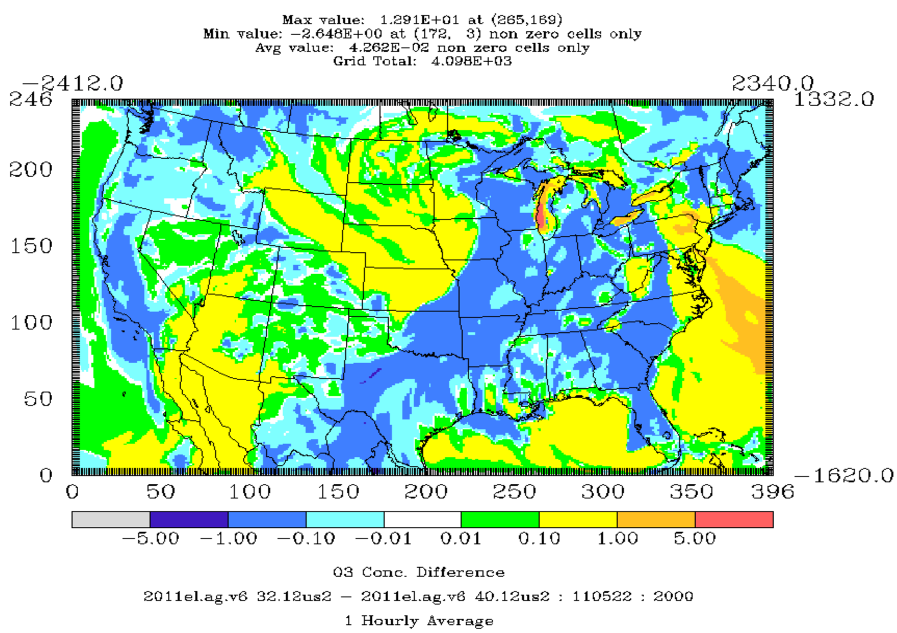
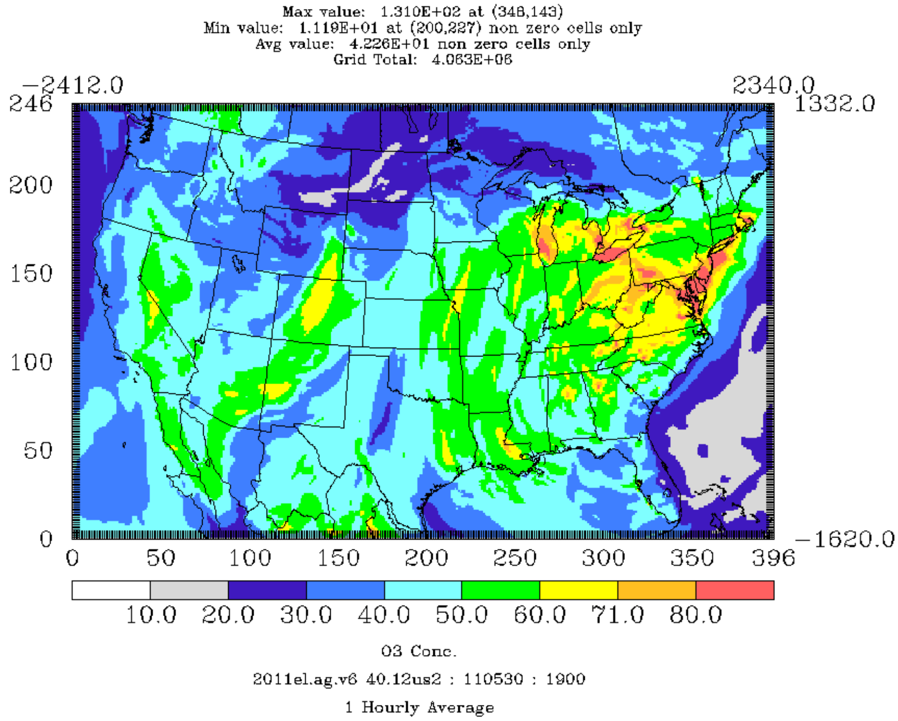


Figure 4-5: Comparison of Ozone Concentrations (ppb) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Fifth Highest Positive Difference)

Sixth Highest Positive Difference: May 30 at 1900 hours

CAMx 6.40



Difference (6.32 - 6.40)

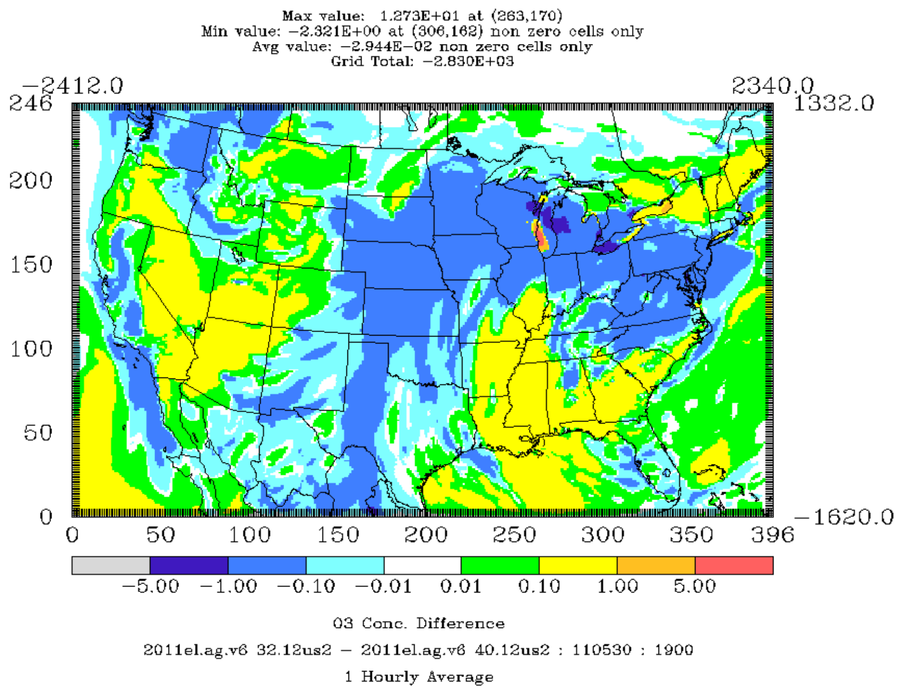
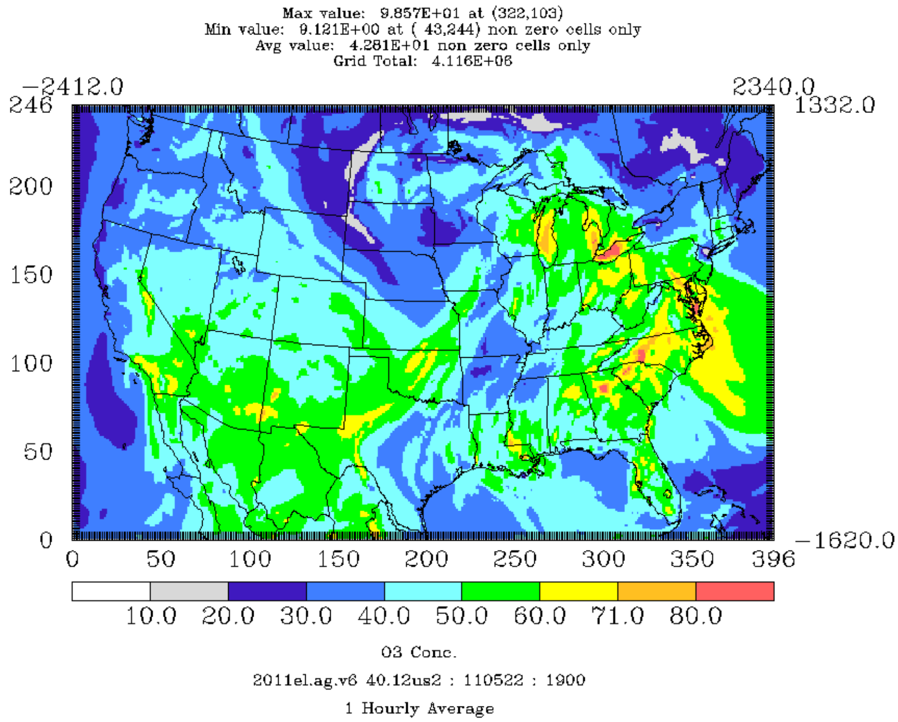


Figure 4-6: Comparison of Ozone Concentrations (ppb) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Sixth Highest Positive Difference)

Seventh Highest Positive Difference: May 22 at 1900 hours

CAMx 6.40



Difference (6.32 - 6.40)

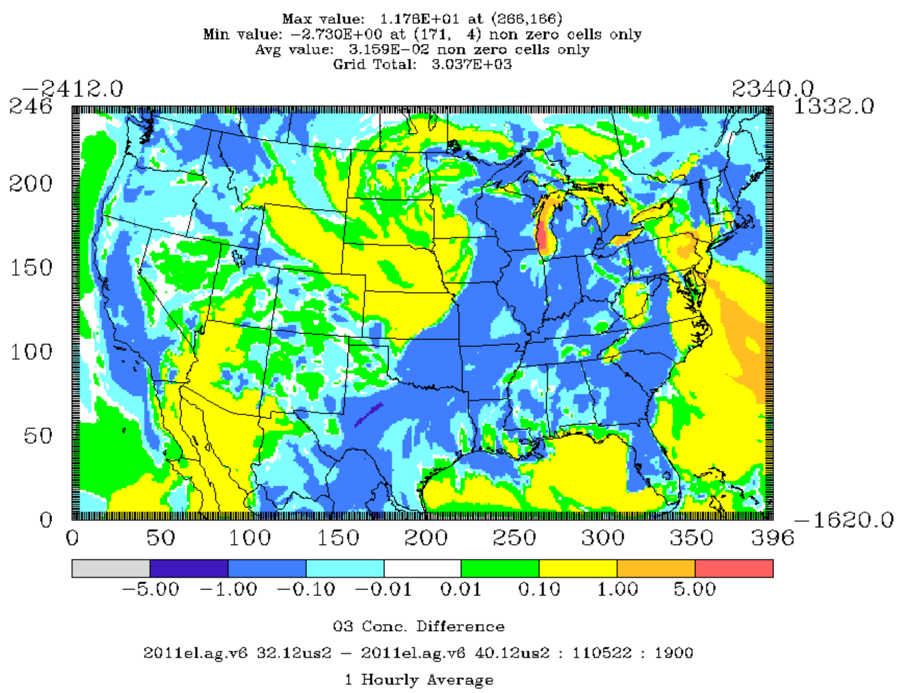
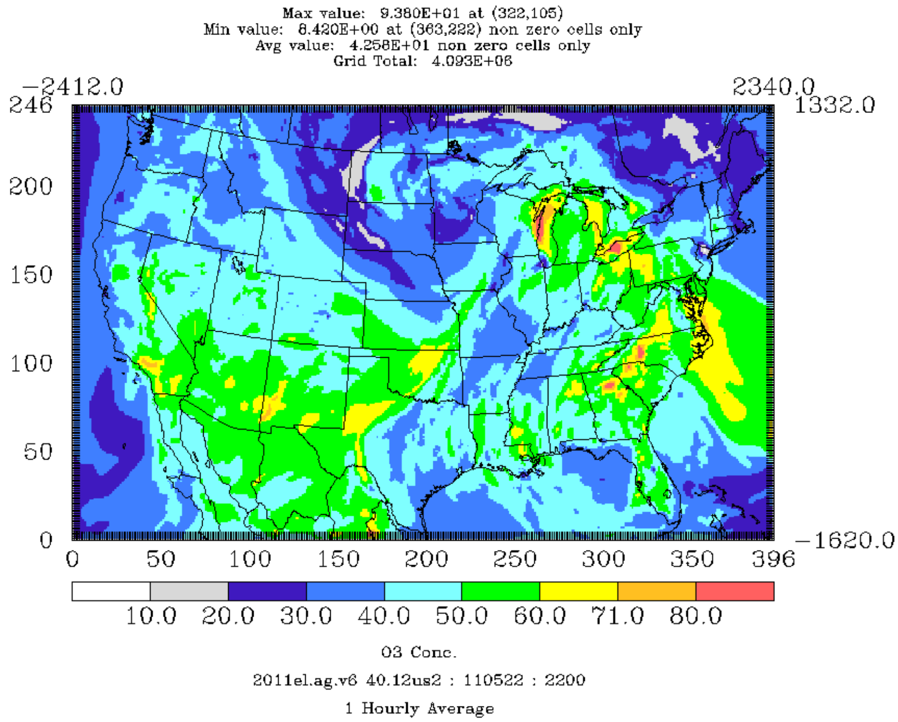


Figure 4-7: Comparison of Ozone Concentrations (ppb) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Seventh Highest Positive Difference)

Eighth Highest Positive Difference: May 22 at 2200 hours
CAMx 6.40



Difference (6.32 - 6.40)

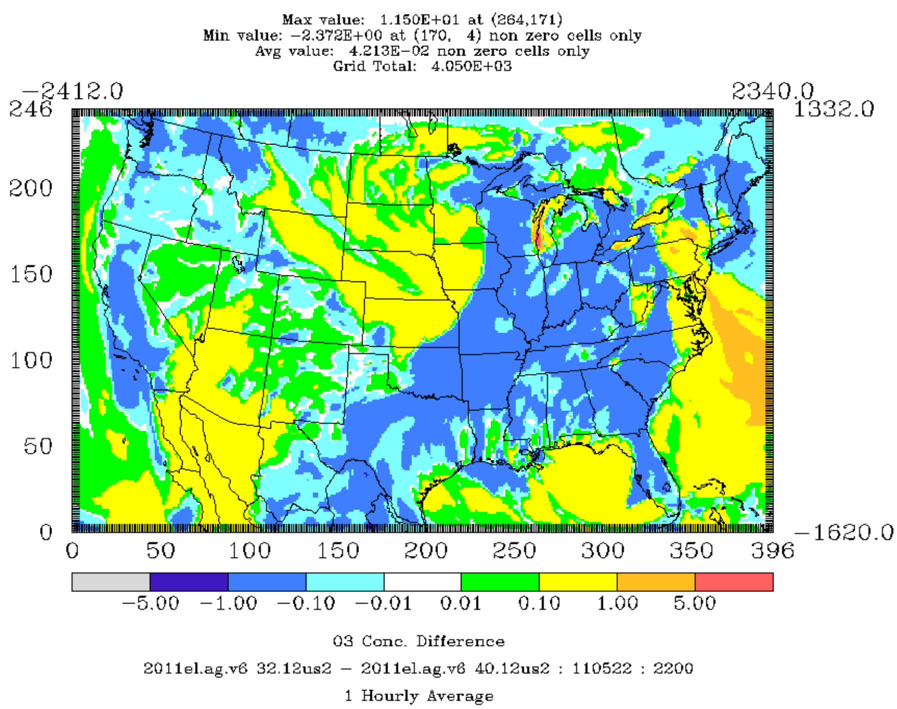
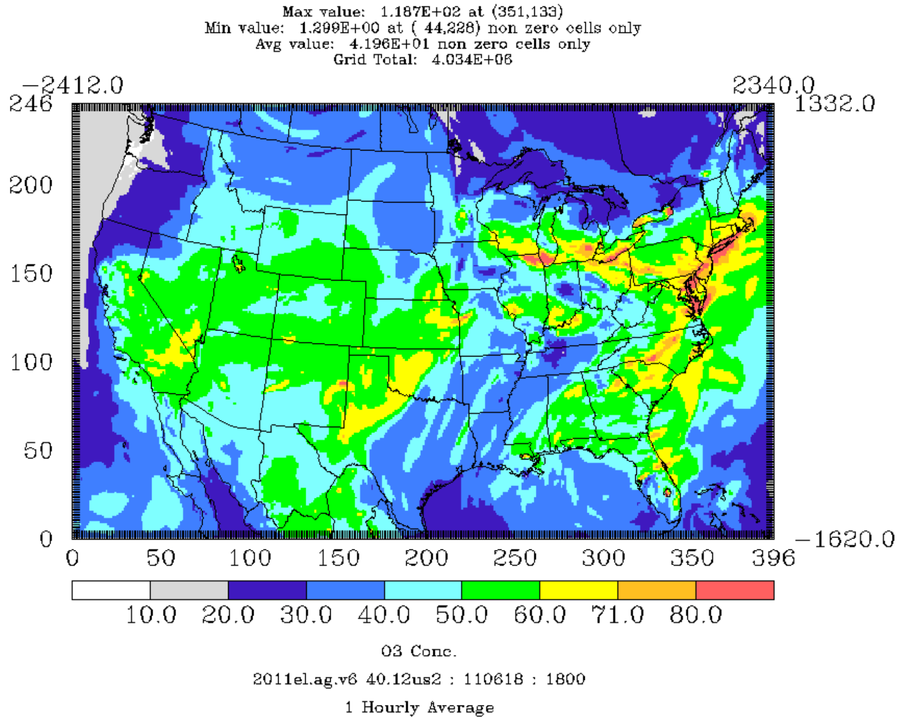


Figure 4-8: Comparison of Ozone Concentrations (ppb) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Eighth Highest Positive Difference)

Ninth Highest Positive Difference: June 18 at 1800 hours

CAMx 6.40



Difference (6.32 - 6.40)

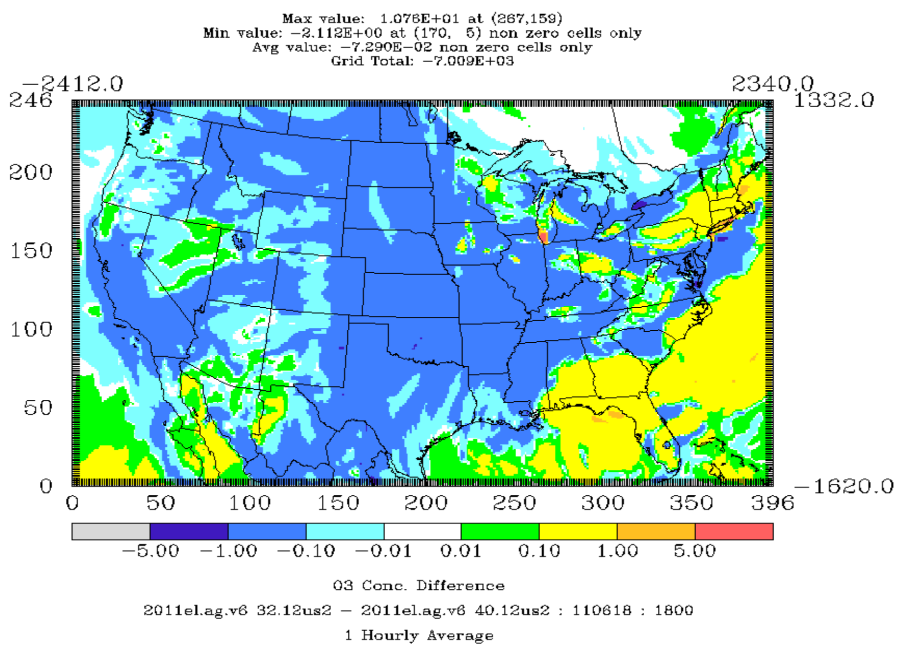
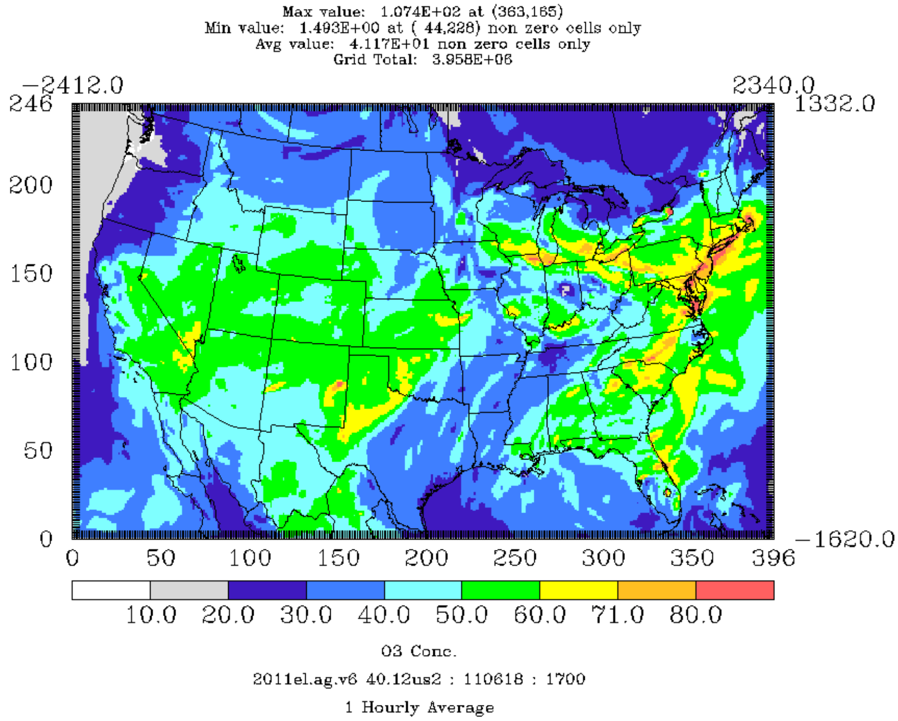


Figure 4-9: Comparison of Ozone Concentrations (ppb) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Ninth Highest Positive Difference)

Tenth Highest Positive Difference: June 18 at 1700 hours

CAMx 6.40



Difference (6.32 - 6.40)

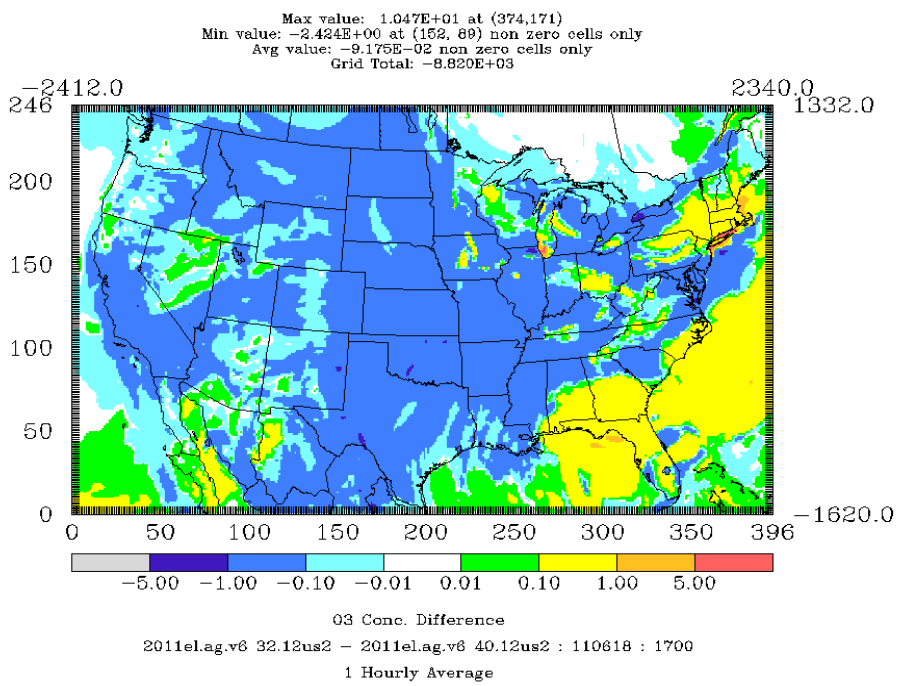
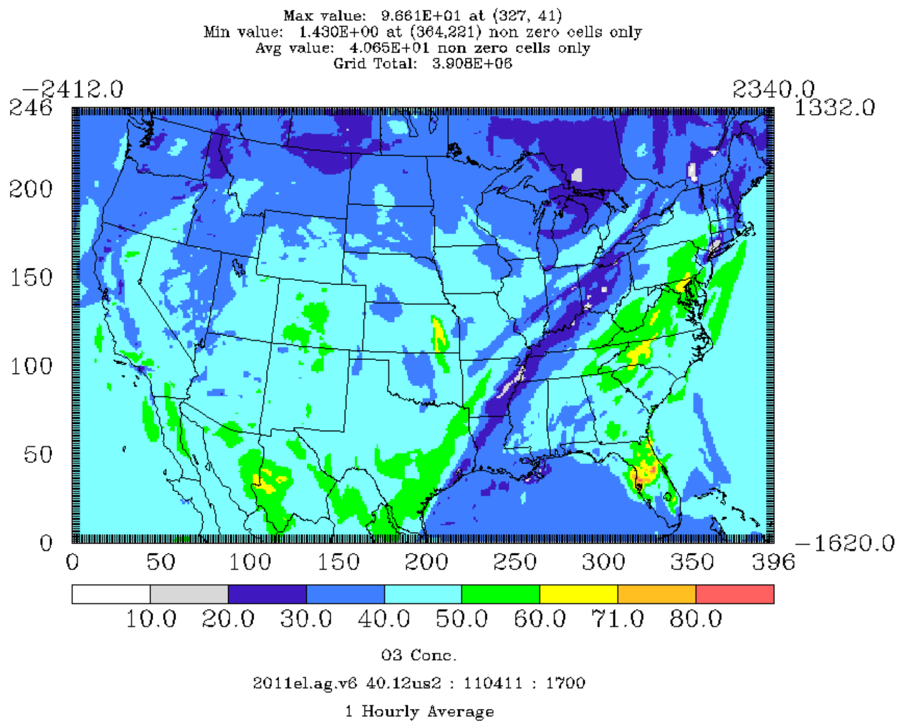


Figure 4-10: Comparison of Ozone Concentrations (ppb) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Tenth Highest Positive Difference)

Maximum Negative Difference: April 11 at 1700 hours

CAMx 6.40



Difference (6.32 - 6.40)

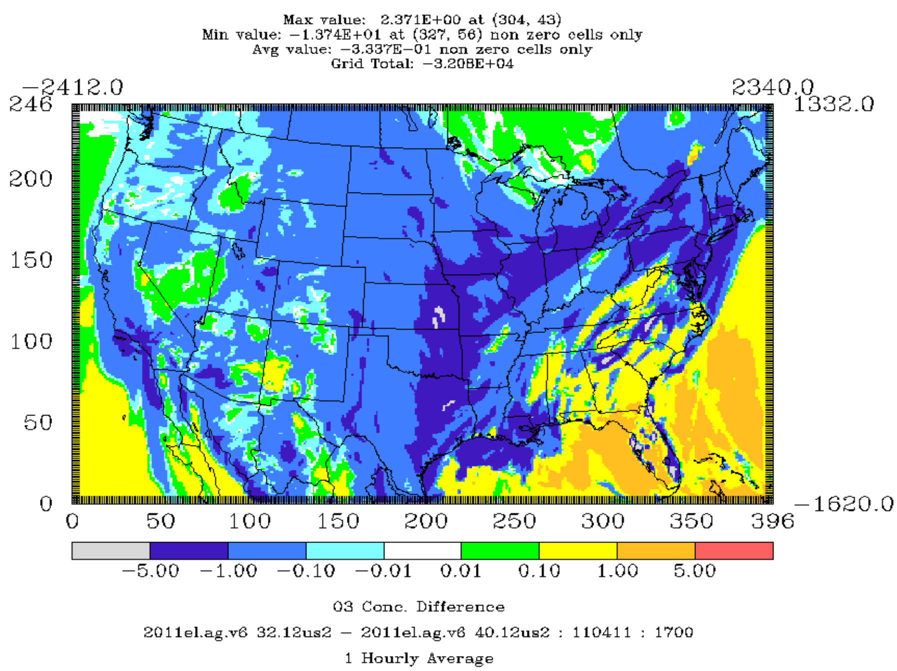
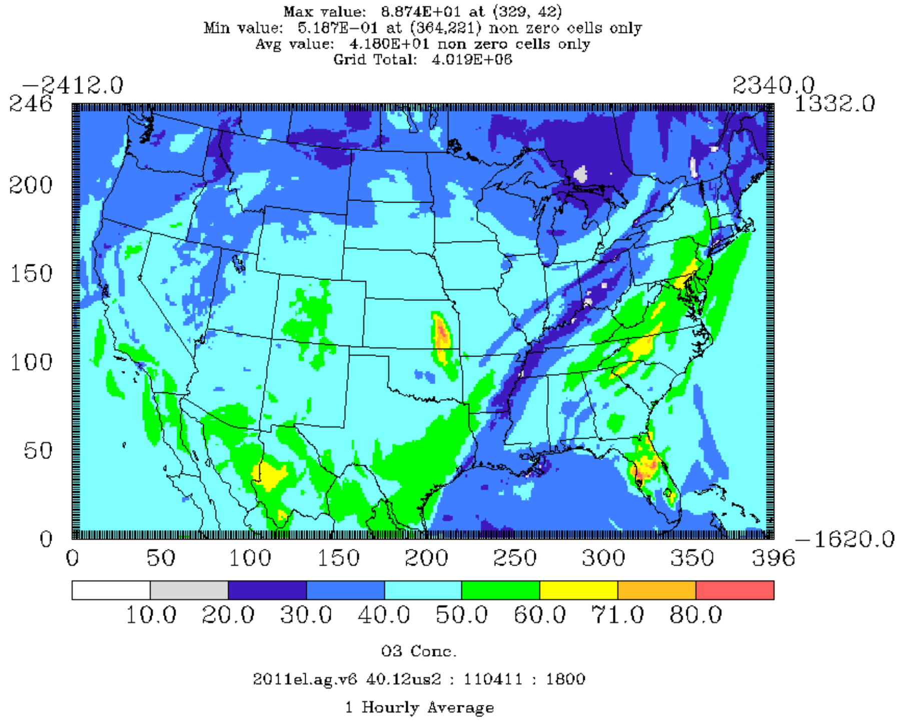


Figure 4-11: Comparison of Ozone Concentrations (ppb) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Maximum Negative Difference)

Second Highest Negative Difference: April 11 at 1800 hours

CAMx 6.40



Difference (6.32 - 6.40)

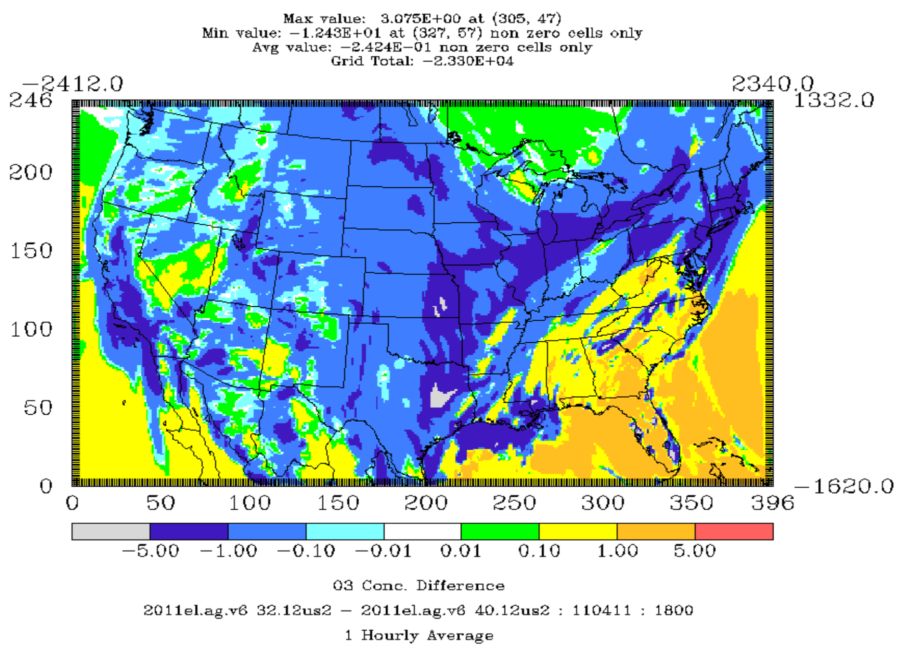
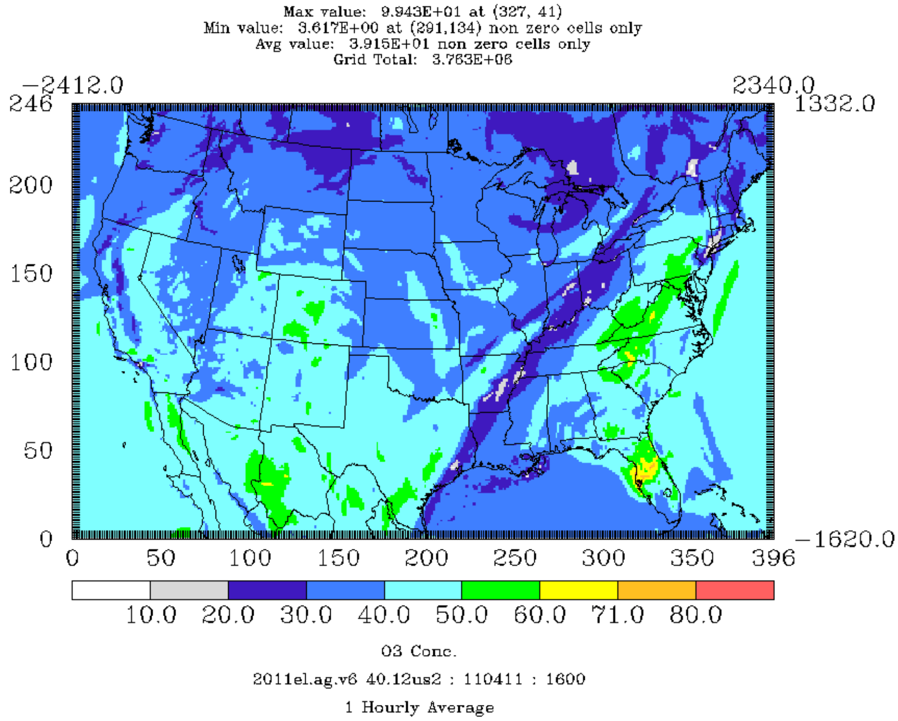


Figure 4-12: Comparison of Ozone Concentrations (ppb) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Second Highest Negative Difference)

Third Highest Negative Difference: April 11 at 1600 hours

CAMx 6.40



Difference (6.32 - 6.40)

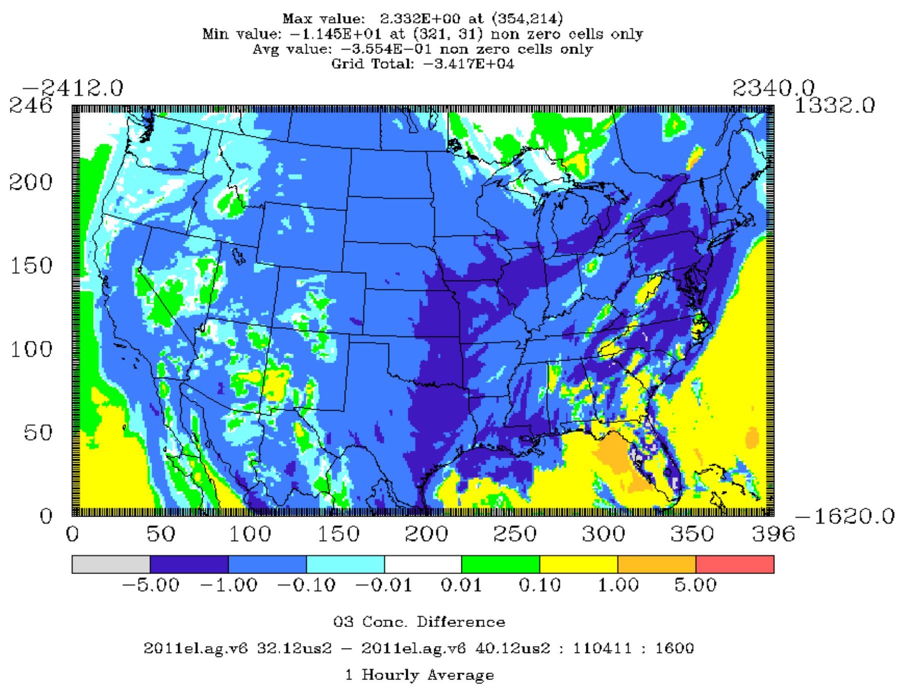
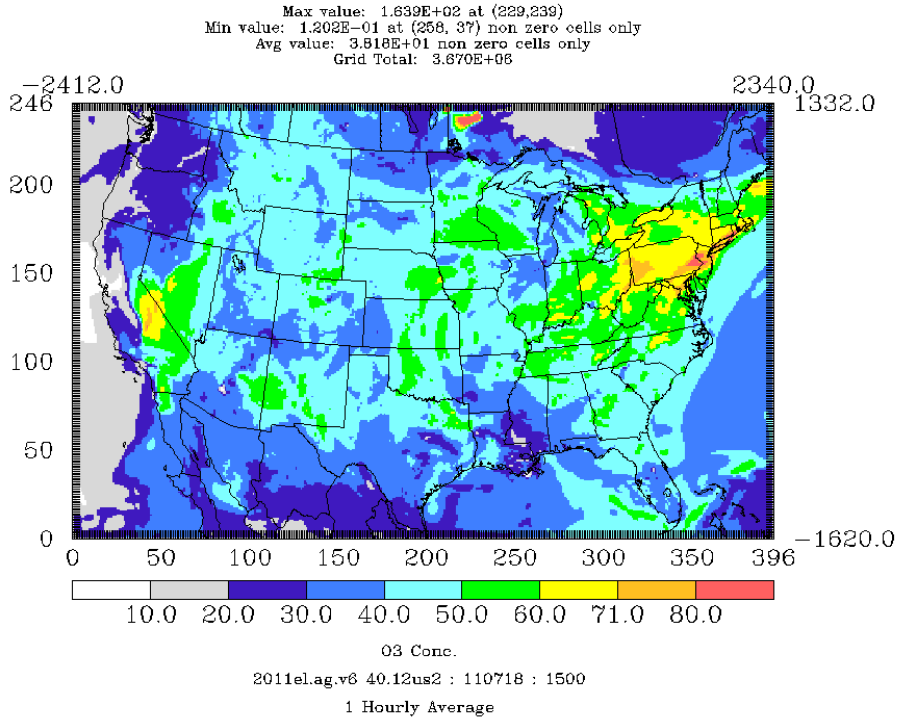


Figure 4-13: Comparison of Ozone Concentrations (ppb) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Third Highest Negative Difference)

Fourth Highest Negative Difference: July 18 at 1500 hours

CAMx 6.40



Difference (6.32 - 6.40)

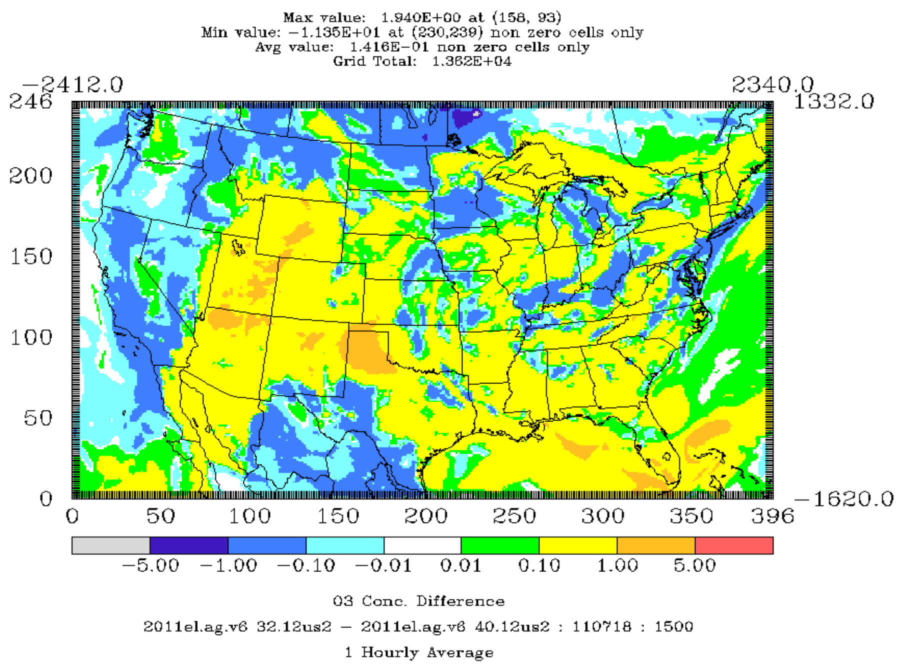
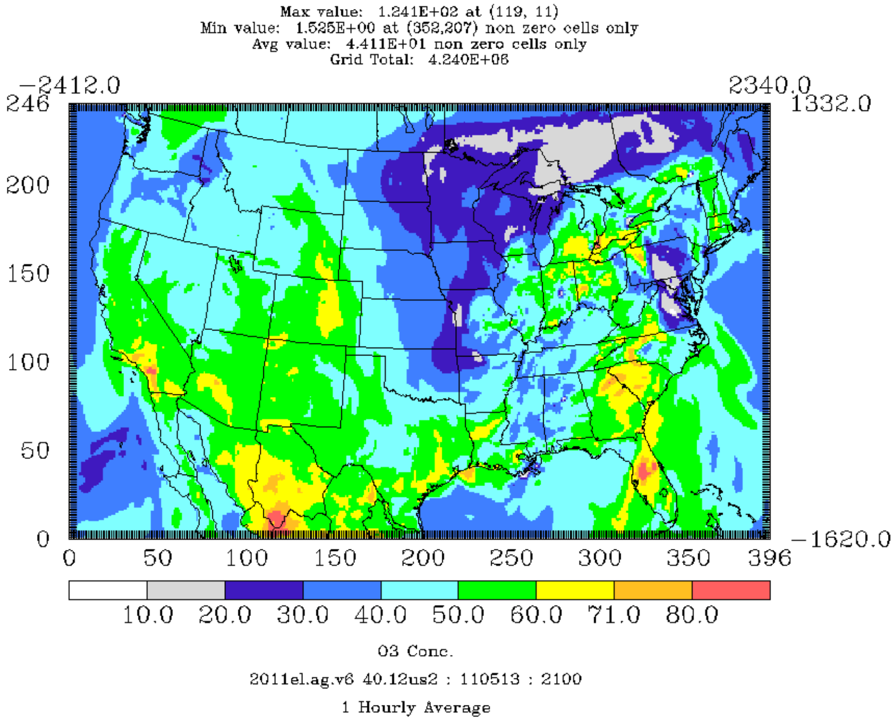


Figure 4-14: Comparison of Ozone Concentrations (ppb) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Fourth Highest Negative Difference)

Fifth Highest Negative Difference: May 13 at 2100 hours
CAMx 6.40



Difference (6.32 - 6.40)

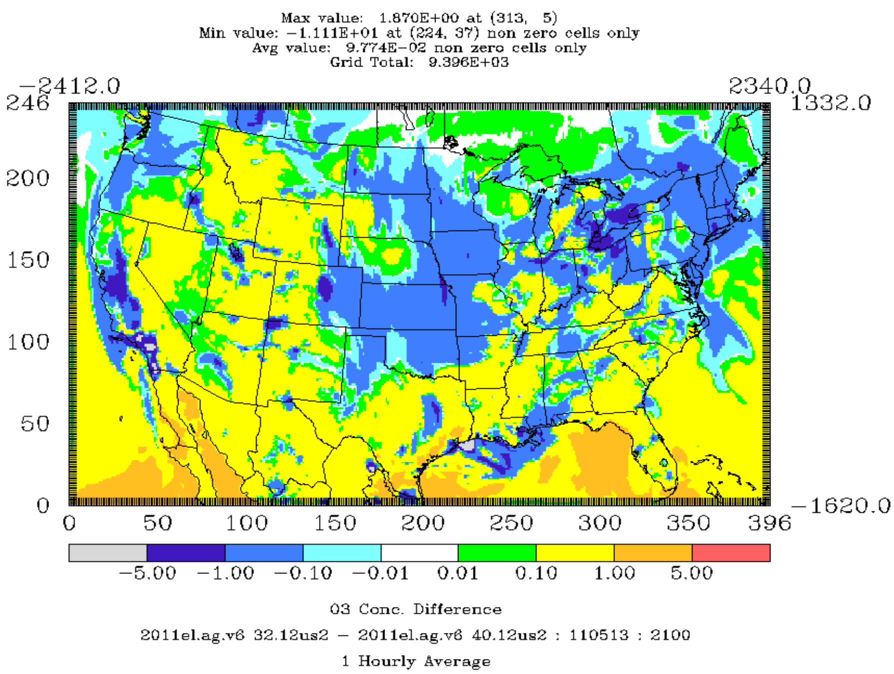
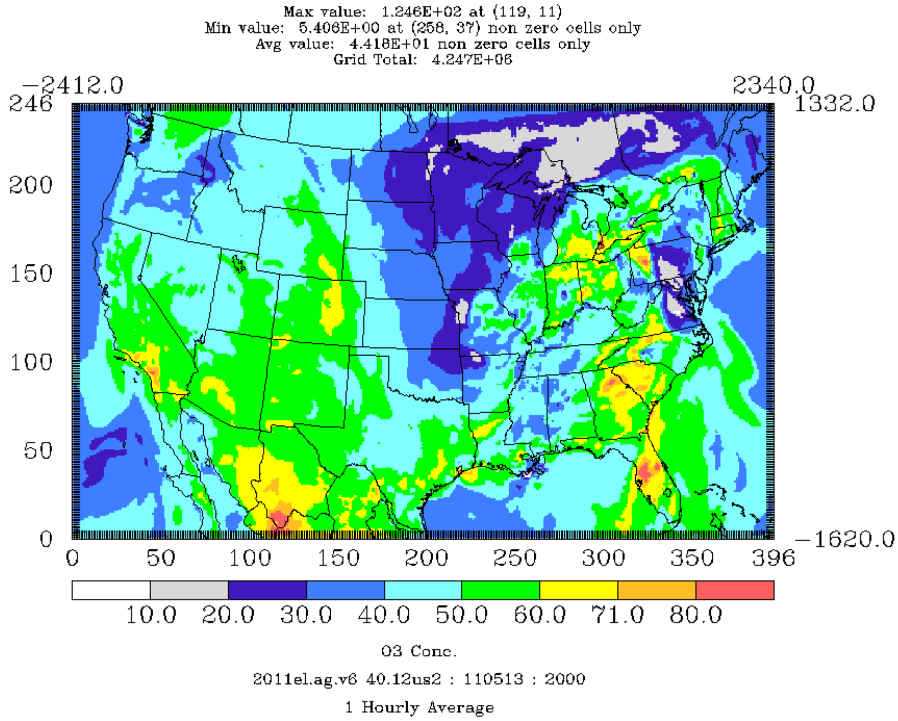


Figure 4-15: Comparison of Ozone Concentrations (ppb) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Fifth Highest Negative Difference)

Sixth Highest Negative Difference: May 13 at 2000 hours

CAMx 6.40



Difference (6.32 - 6.40)

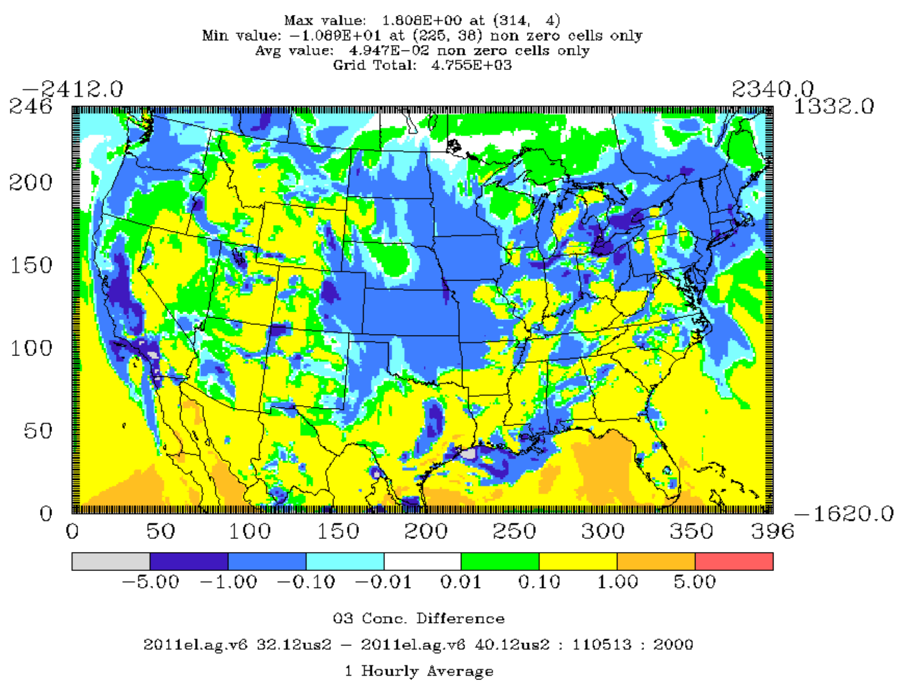
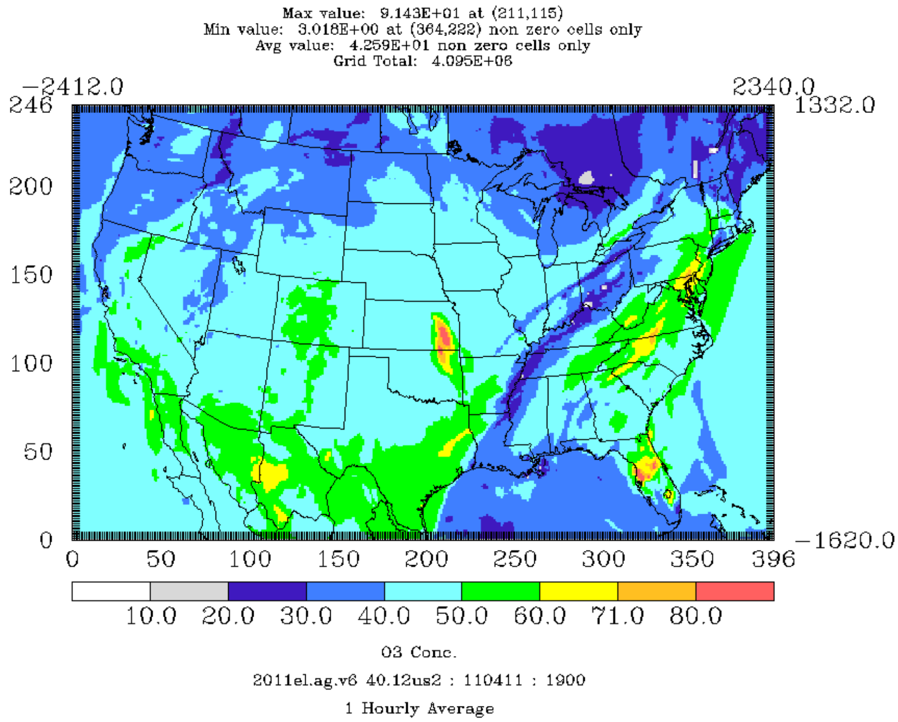


Figure 4-16: Comparison of Ozone Concentrations (ppb) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Sixth Highest Negative Difference)

Seventh Highest Negative Difference: April 11 at 1900 hours

CAMx 6.40



Difference (6.32 - 6.40)

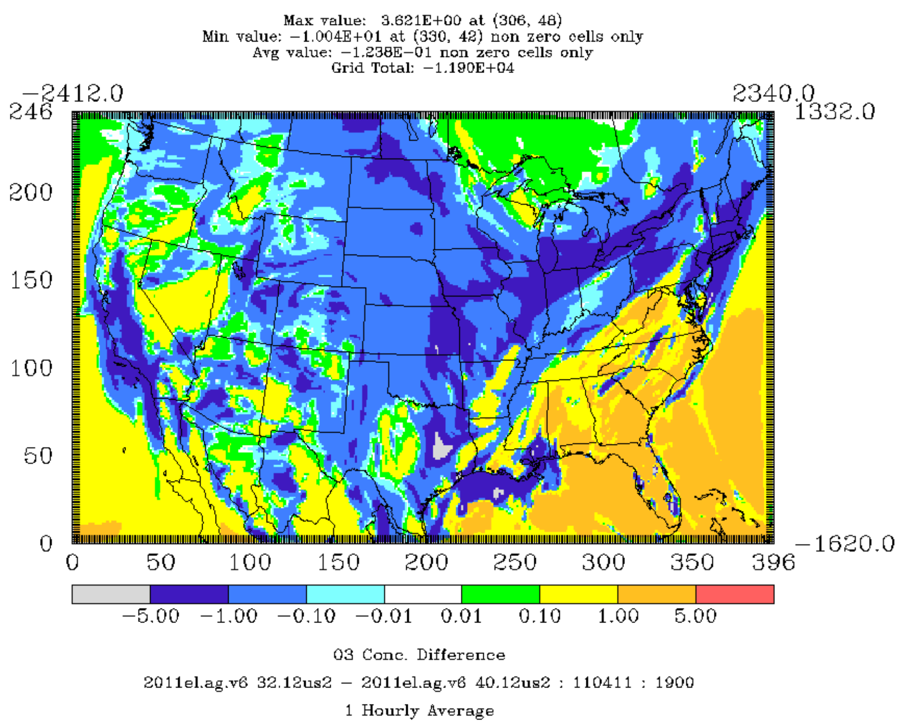


Figure 4-17: Comparison of Ozone Concentrations (ppb) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Seventh Highest Negative Difference)

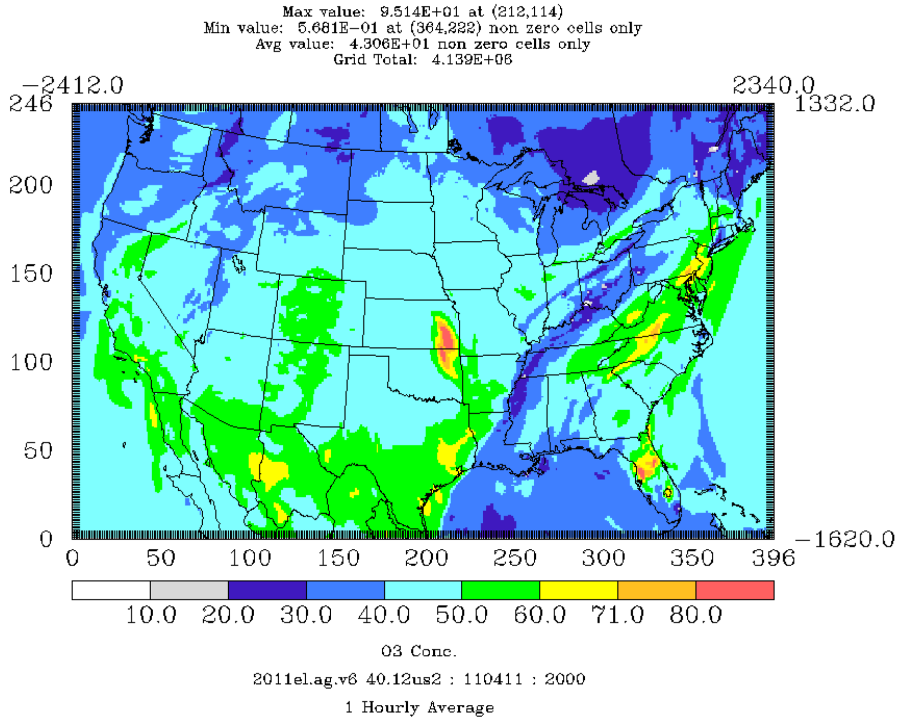
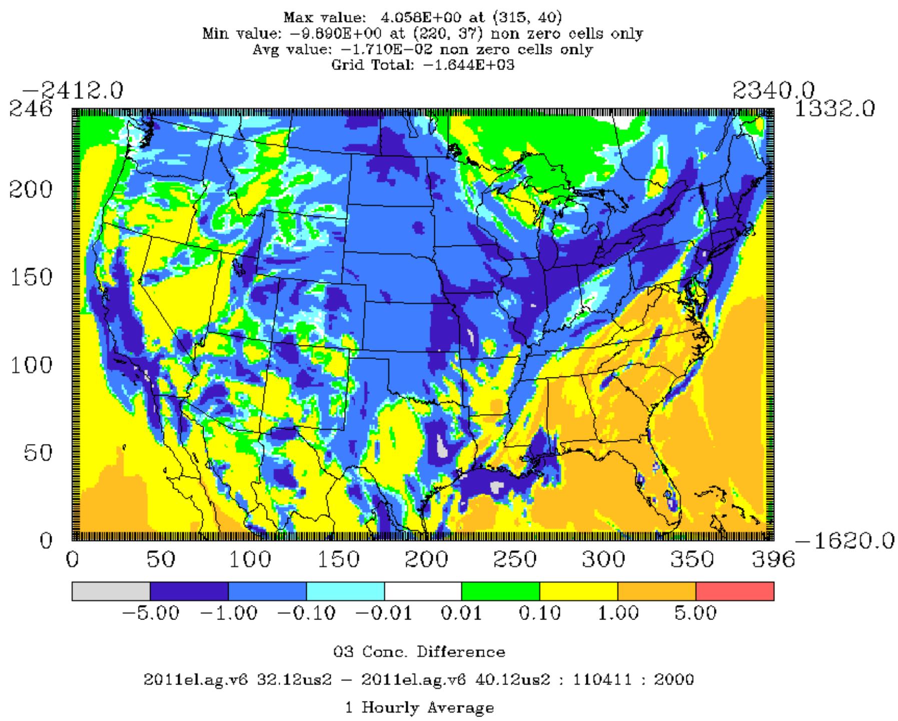
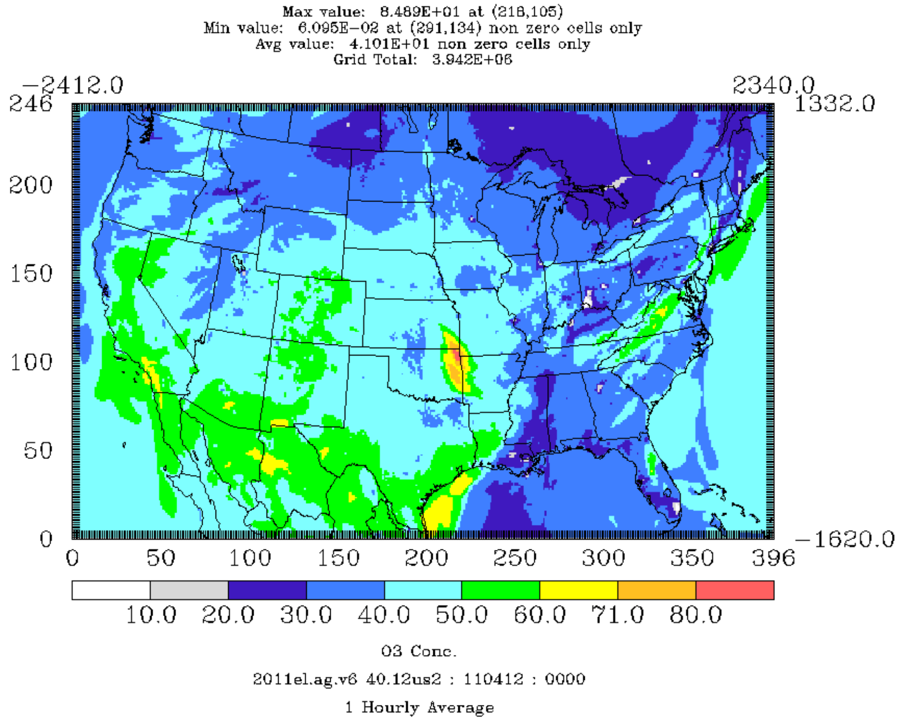
Eighth Highest Negative Difference: April 11 at 2000 hours
CAMx 6.40

Difference (6.32 - 6.40)


Figure 4-18: Comparison of Ozone Concentrations (ppb) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Eighth Highest Negative Difference

Ninth Highest Negative Difference: April 12 at 0000 hours

CAMx 6.40



Difference (6.32 - 6.40)

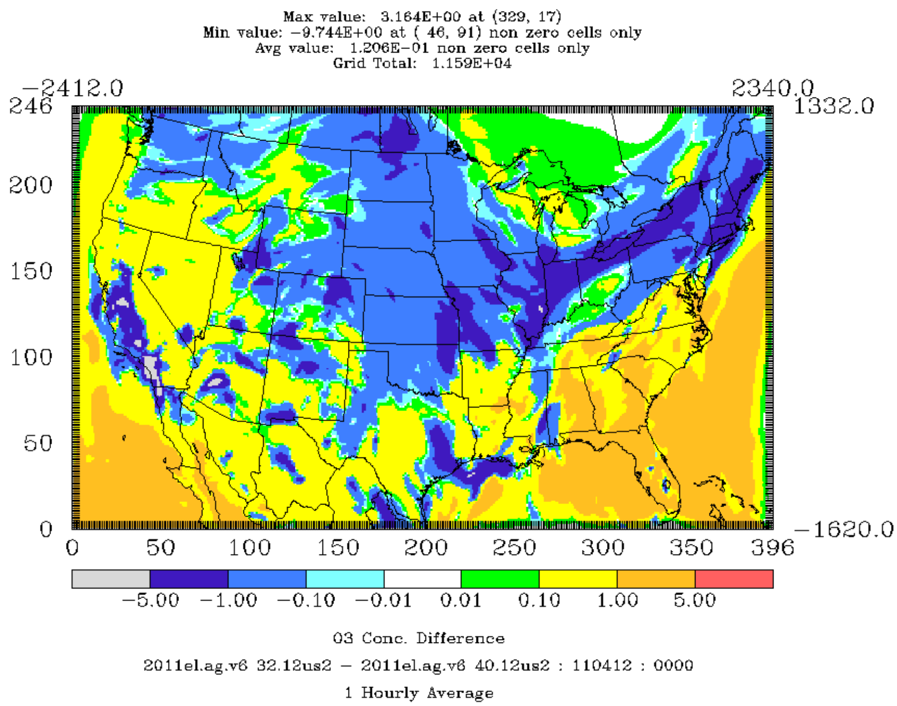
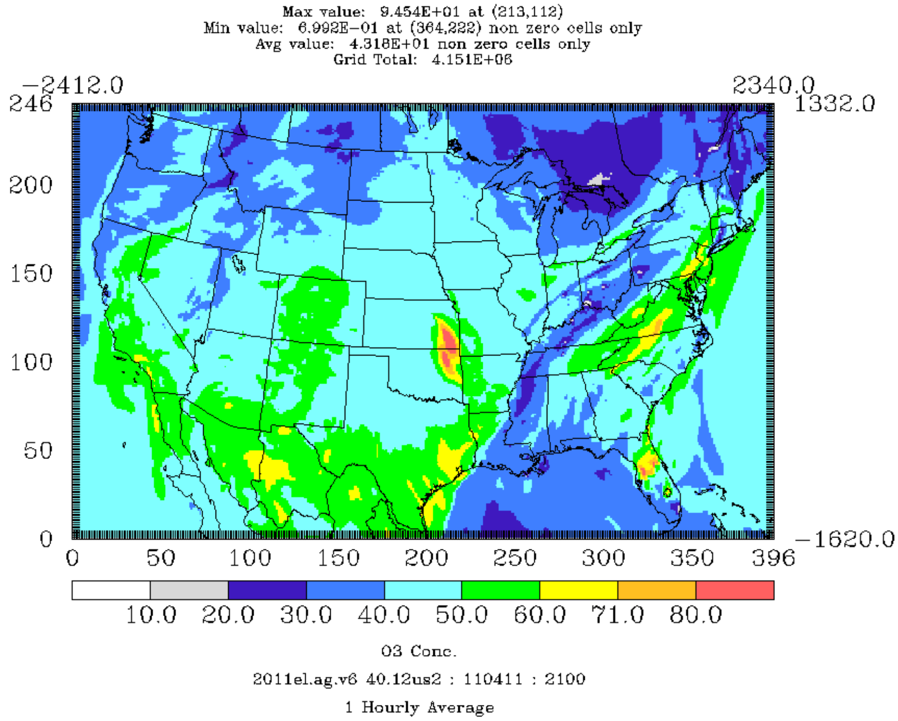


Figure 4-19: Comparison of Ozone Concentrations (ppb) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Ninth Highest Negative Difference)

Tenth Highest Negative Difference: April 11 at 2100 hours

CAMx 6.40



Difference (6.32 - 6.40)

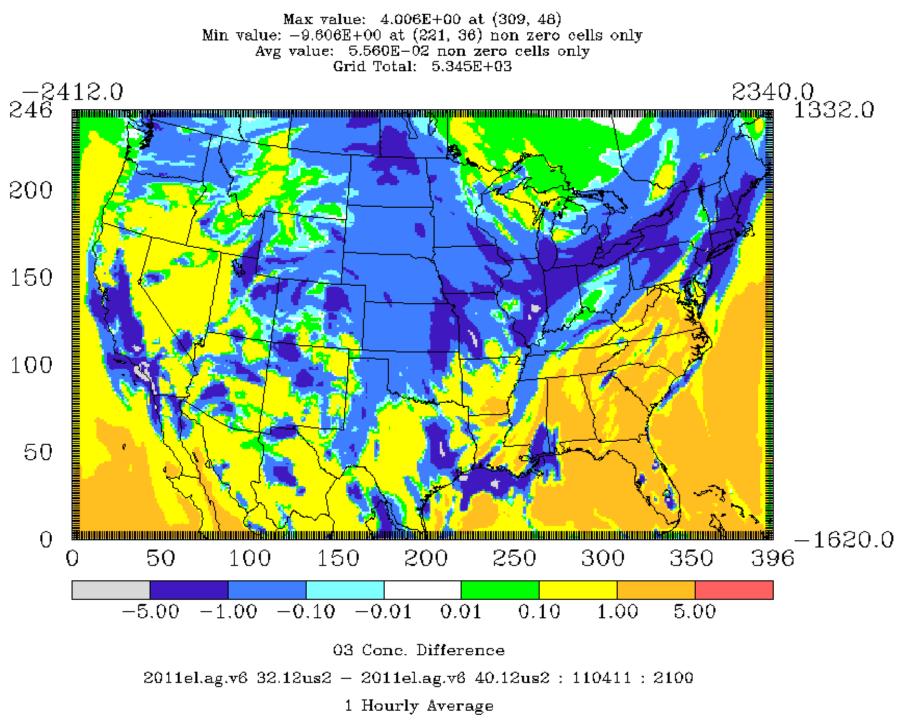


Figure 4-20: Comparison of Ozone Concentrations (ppb) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Tenth Highest Negative Difference)

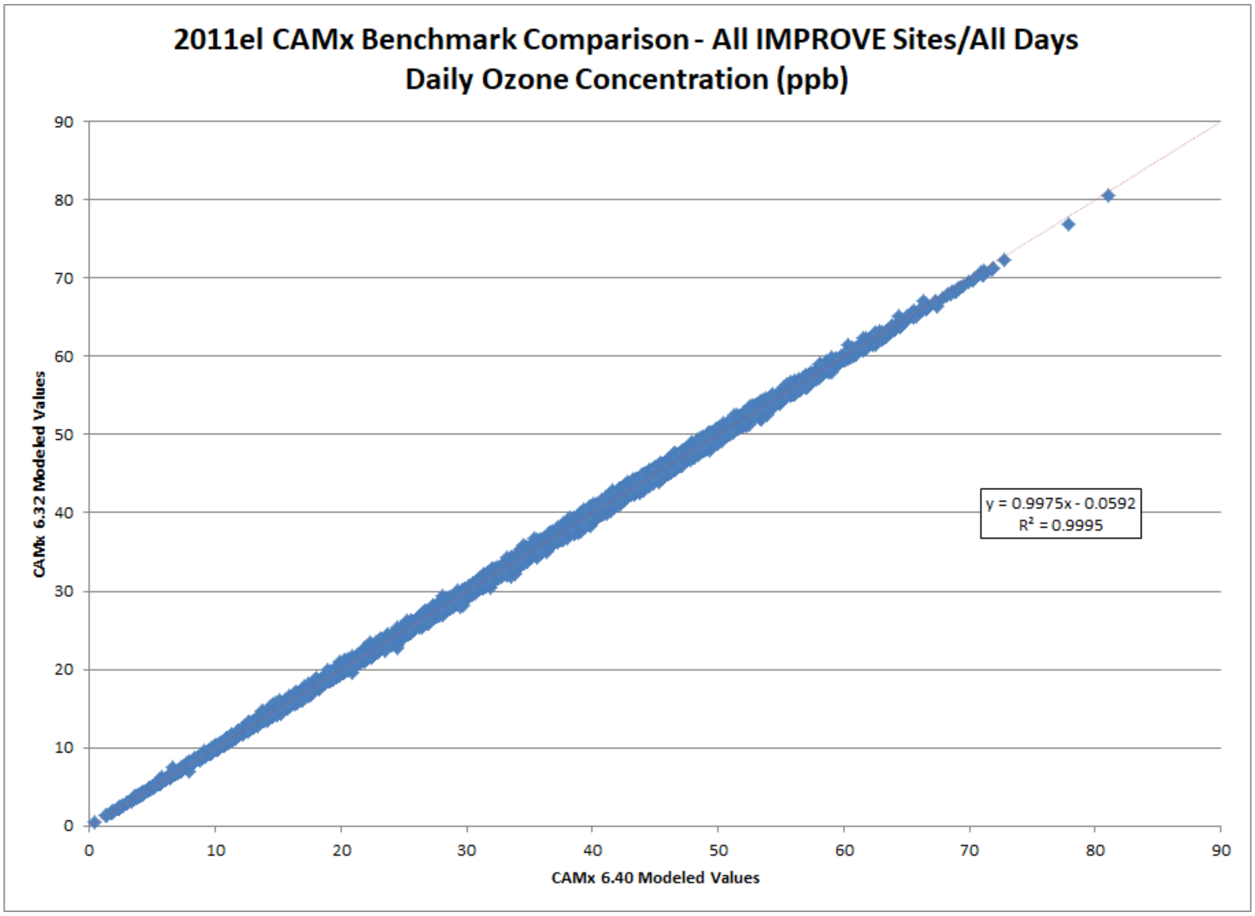


Figure 4-21: Scatterplot Comparing 24-hour Average Predicted Ozone Concentrations (ppb) for All Days at all IMPROVE Monitor Locations for CAMx 6.32 and CAMx 6.40 2011el Simulations Performed by VISTAS (Alpine).

4.2 $PM_{2.5}$

$PM_{2.5}$ results for the top 10 positive and negative hours are presented in tabular format in Table 4-2. The maximum positive difference is 64.76 micrograms per cubic meter (μg/m^3) falling to 52.61 μg/m^3 for the 10th high. The maximum negative difference is -35.09 μg/m^3 falling to -18.42 μg/m^3 for the 10th high. The maximum positive percent difference from these days is 1445% and negative percent difference of -59%. On the day of the maximum positive difference (September 24 at 0400) the maximum difference in $PM_{2.5}$ concentration was 64. μg/m^3 ppb. At this hour the difference in the sulfate, nitrate, and OM concentrations were 10.26 μg/m^{3,} 28.08 μg/m^3, 9.28 μg/m^3, respectively with the difference dominated by the differences in the nitrate estimates.

The top 10 positive difference hours are presented in Figures 4-22 through 4-31. The hours of the maximum positive difference are tending to occur in two periods on August 26 and September 24. The CAMx 6.40 results are significantly lower that CAMx 6.32 throughout the majority of the domain. On August 26 the region of the maximum difference is offshore of Florida, Georgia, and South Carolina. This appears to be Hurricane Irene that was active during this time

The top 10 negative impact hours are presented in Figures 4-32 through 4-41. While the majority of the domain shows positive difference (CAMx 6.32 with higher concentrations), there are scattered regions where CAMx 6.40 is higher.

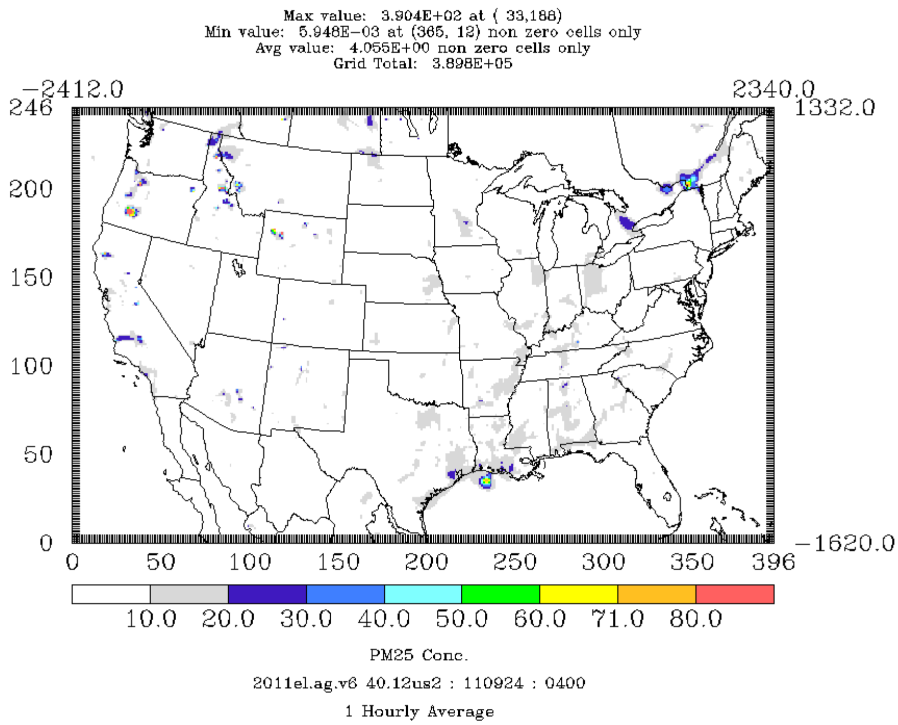
Scatterplots of the daily average $PM_{2.5}$ concentrations in local standard time at the IMPROVE monitors are presented in Figures 4-42 and 4-43. The CAMx 6.40 results are plotted on the x-axis and the CAMx 6.32 results are plotted on the y-axis. The data has a high degree of correlation with a line of best fit with a slope of 1.0083, an intercept of 0.4966 μg/m^{3}and an R^2 of 0.9875. The agreement between the models is higher at higher concentrations. At lower concentrations the CAMx 6.32 results are higher than the CAMx 6.40 results.

Examination of the animations clearly shows the Hurricane Irene entering the domain on August 24th and moving up the eastern seaboard through August 28th.

Table 4-2. Comparison of 2011el CAMx 6.32 and CAMx 6.40 Simulation of $PM_{2.5}$ Concentrations (µg/m³). Hours with the top 10 maximum positive and maximum negative differences are shown.

Year	Month	Day	Hour	6.32 Conc.	6.40 Conc.	Difference (µg/m³)	Percent Difference	Column	Row
Maximum Positive									
2011	9	24	4	69.24	4.48	64.76	1445.0%	342	201
2011	9	24	3	72.57	10.31	62.27	604.0%	343	201
2011	8	26	14	71.90	11.64	60.27	517.9%	358	62
2011	9	24	5	63.70	5.32	58.37	1096.3%	342	200
2011	8	26	12	73.55	15.55	58.00	373.0%	359	58
2011	8	26	13	74.13	17.34	56.79	327.5%	359	60
2011	8	26	15	67.82	12.01	55.81	464.5%	357	64
2011	8	26	17	68.07	13.57	54.49	401.5%	357	69
2011	8	26	16	85.96	32.42	53.54	165.2%	357	68
2011	8	26	20	64.19	11.58	52.61	454.3%	355	75
Maximum Negative									
2011	7	20	14	4,665.24	4,700.33	-35.09	-0.7%	231	244
2011	7	20	12	6,908.06	6,937.38	-29.32	-0.4%	231	244
2011	7	20	13	5,435.89	5,464.69	-28.79	-0.5%	231	244
2011	7	20	11	8,766.18	8,789.09	-22.92	-0.3%	231	243
2011	7	20	15	5,136.34	5,157.34	-21.00	-0.4%	230	243
2011	7	20	18	1,471.59	1,492.23	-20.64	-1.4%	227	244
2011	7	3	21	12.76	31.44	-18.68	-59.4%	269	156
2011	8	19	5	80.11	98.72	-18.61	-18.9%	216	52
2011	7	3	22	13.37	31.92	-18.54	-58.1%	269	156
2011	7	20	19	1,215.64	1,234.06	-18.42	-1.5%	226	244

Maximum Positive Difference: September 24 at 400 hours
CAMx 6.40



Difference (6.32 - 6.40)

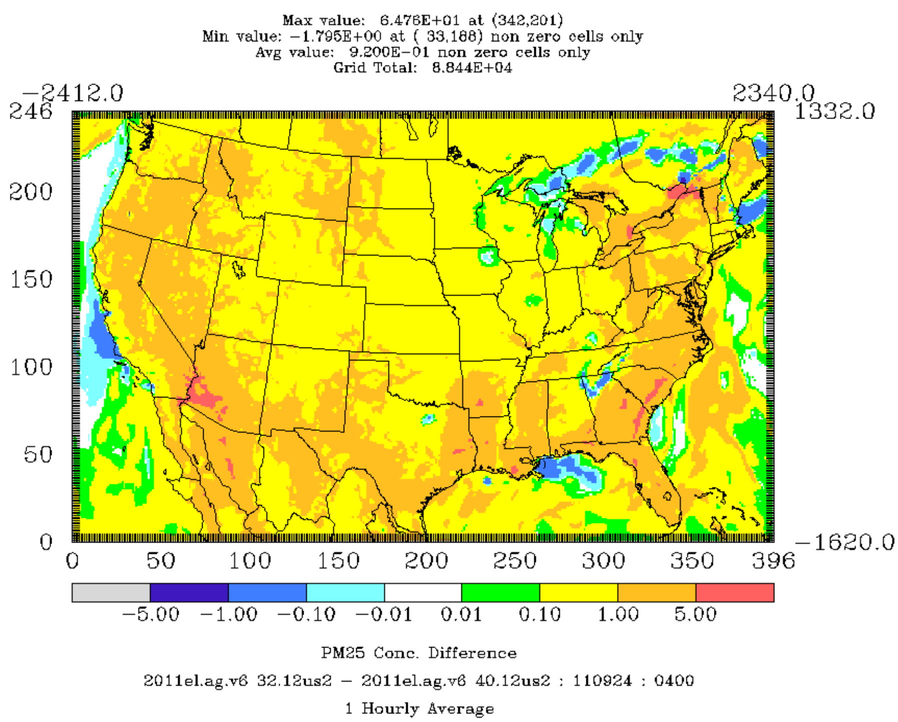
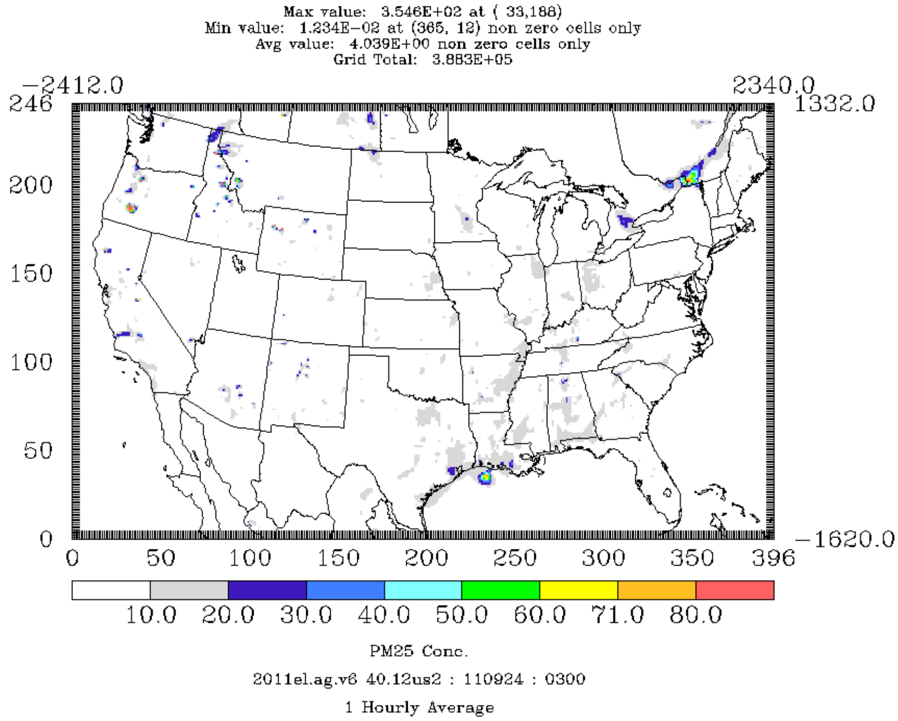


Figure 4-22: Comparison of $PM_{2.5}$ Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Maximum Positive Difference)

Second Highest Positive Difference: September 24 at 300 hours

CAMx 6.40



Difference (6.32 - 6.40)

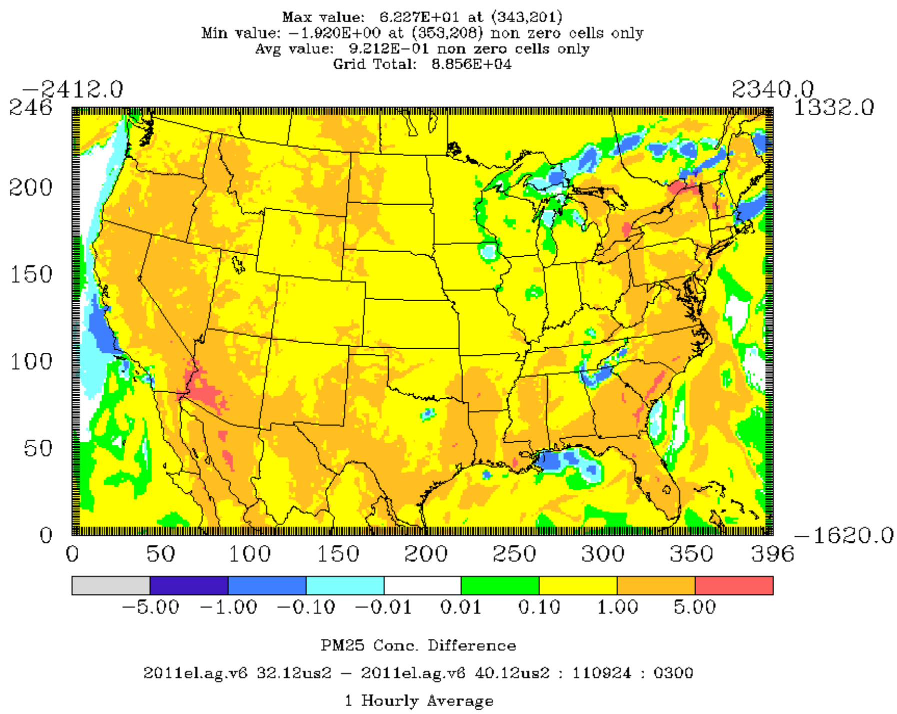
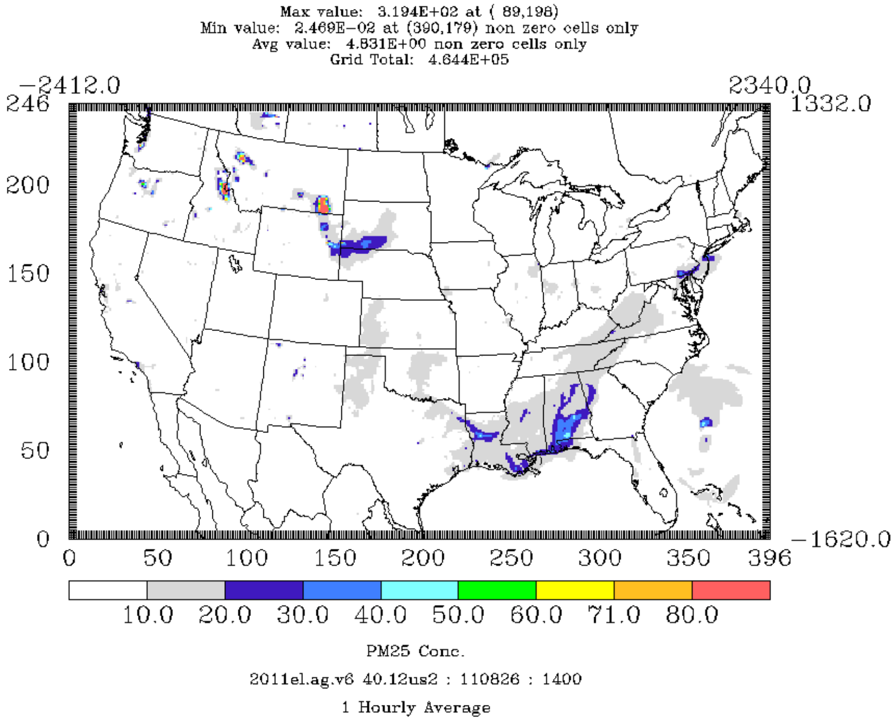


Figure 4-23: Comparison of $PM_{2.5}$ Concentrations ($\mu g/m^3$) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Second Highest Positive Difference)

Third Highest Positive Difference: August 26 at 1400 hours
CAMx 6.40



Difference (6.32 - 6.40)

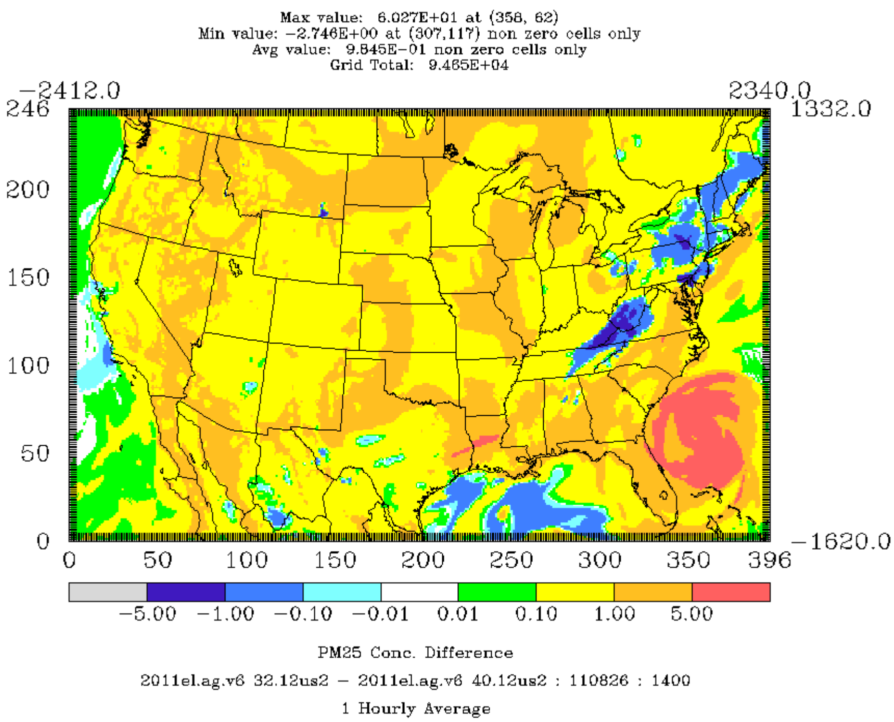
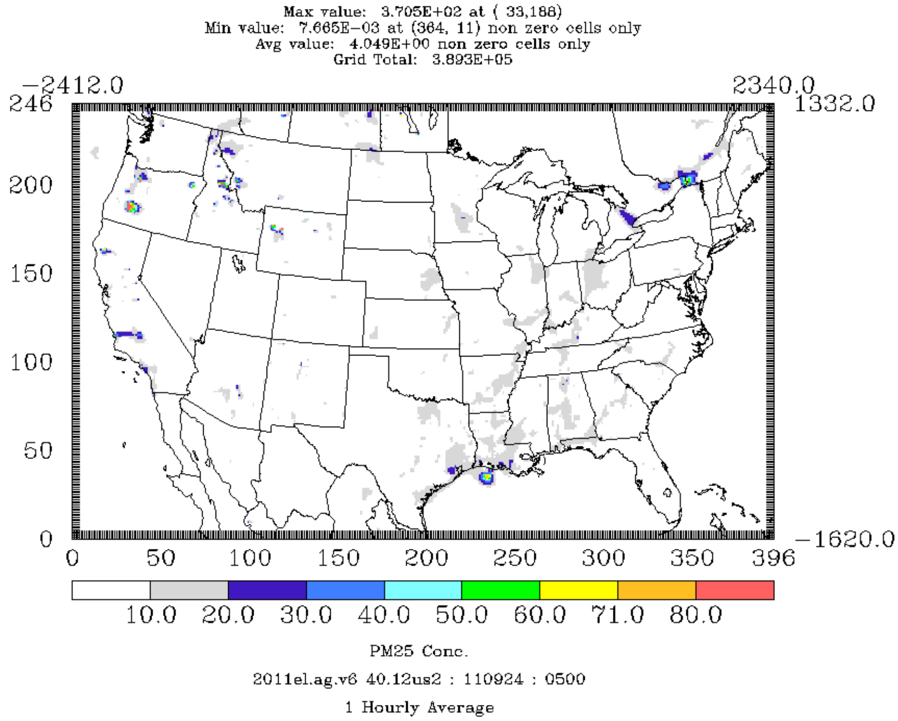


Figure 4-24: Comparison of $PM_{2.5}$ Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Third Highest Positive Difference)

Fourth Highest Positive Difference: September 24 at 500 hours

CAMx 6.40



Difference (6.32 - 6.40)

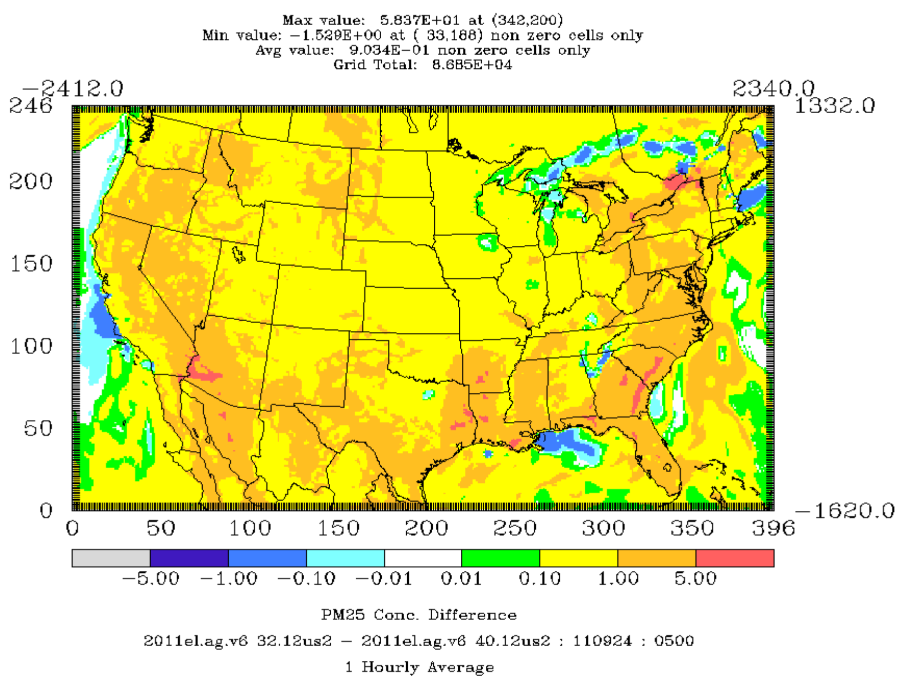
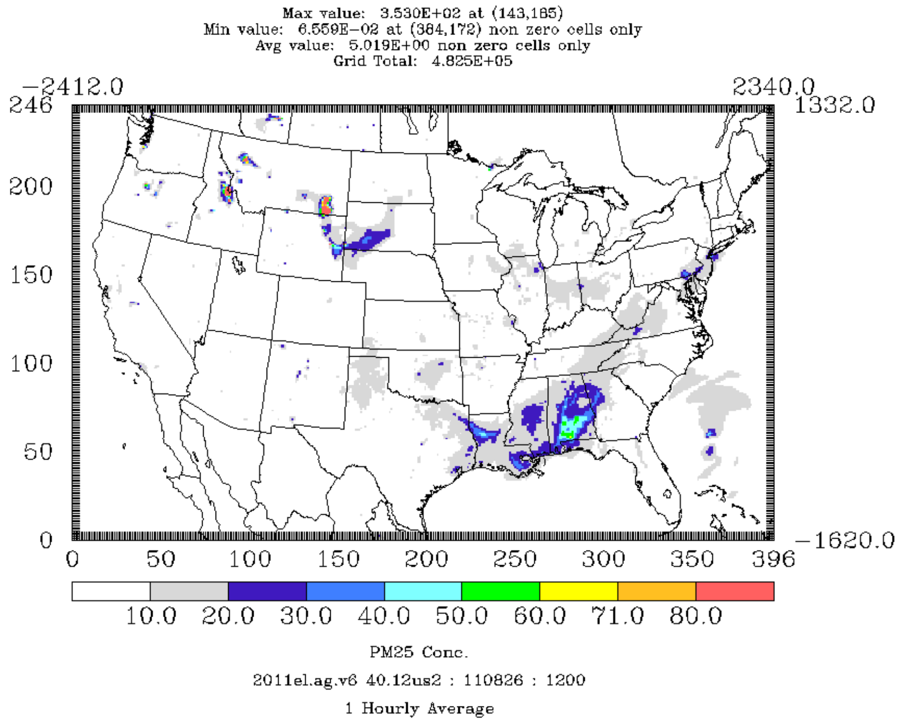


Figure 4-25: Comparison of $PM_{2.5}$ Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Fourth Highest Positive Difference)

Fifth Highest Positive Difference: August 26 at 1200 hours

CAMx 6.40



Difference (6.32 - 6.40)

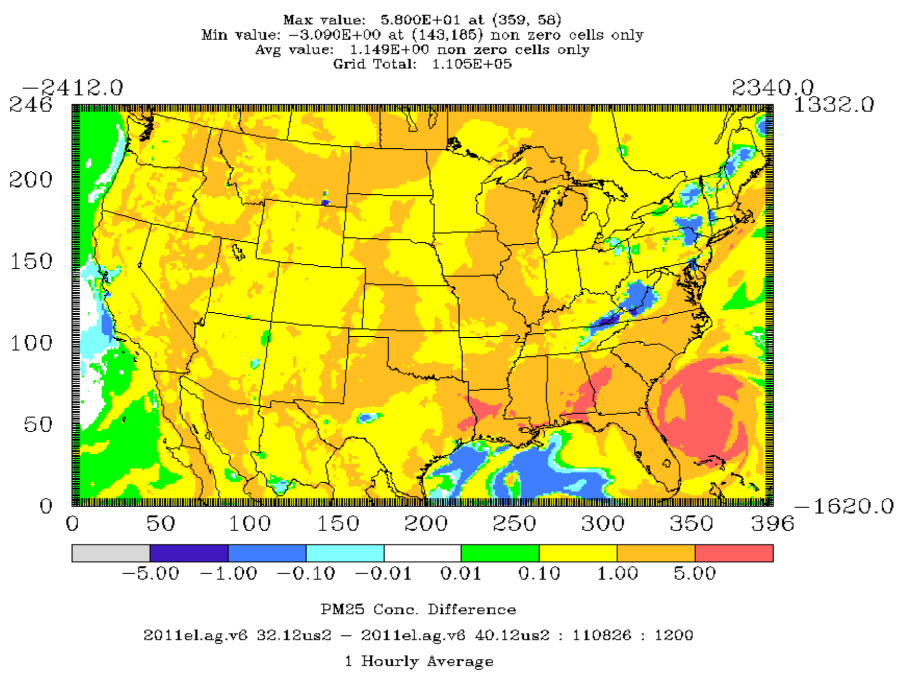
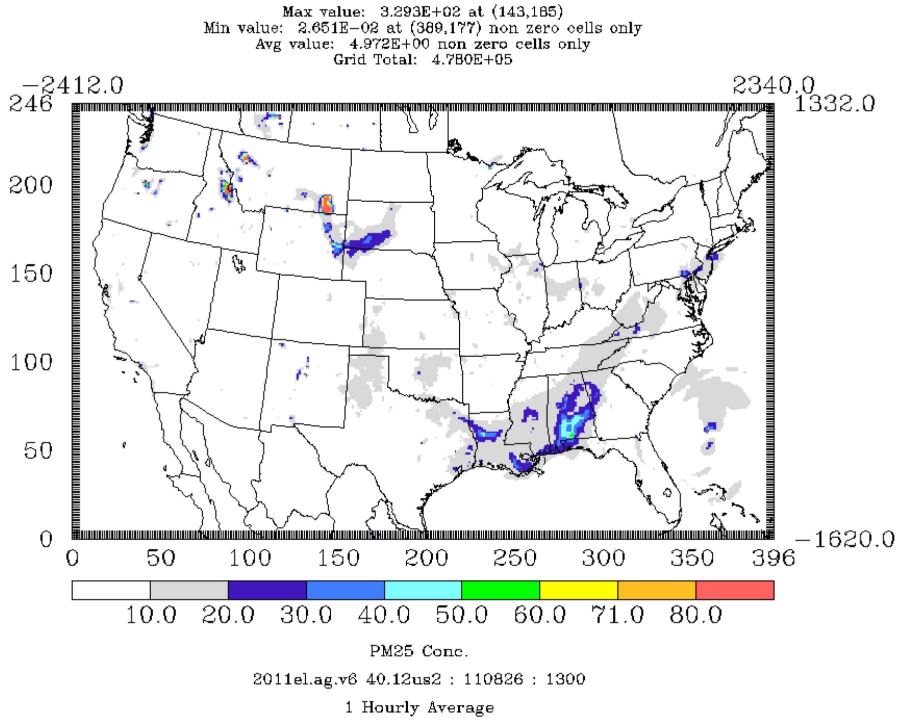


Figure 4-26: Comparison of $PM_{2.5}$ Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Fifth Highest Positive Difference)

Sixth Highest Positive Difference: August 26 at 1300 hours

CAMx 6.40



Difference (6.32 - 6.40)

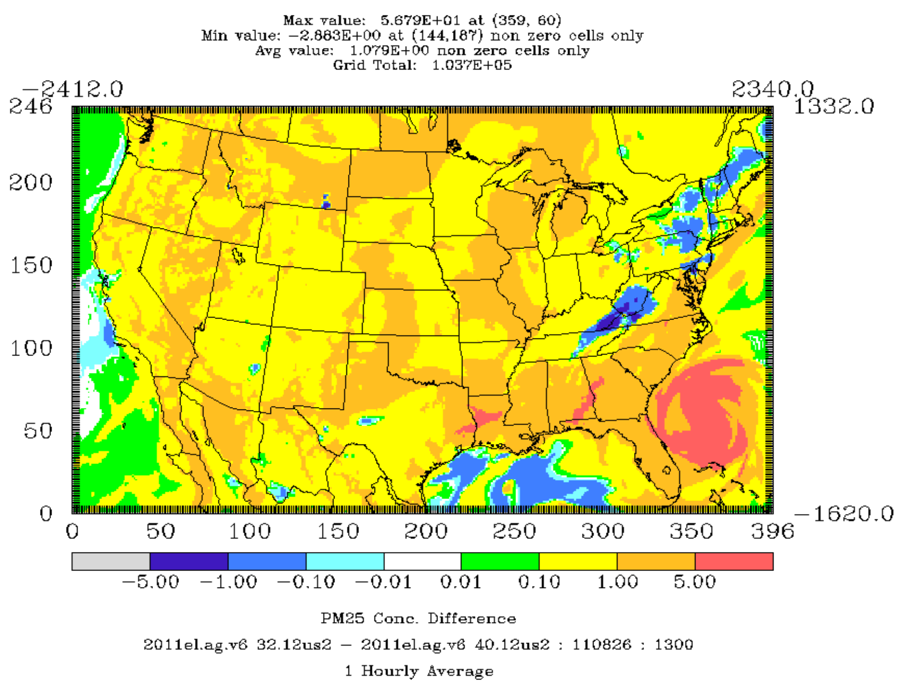
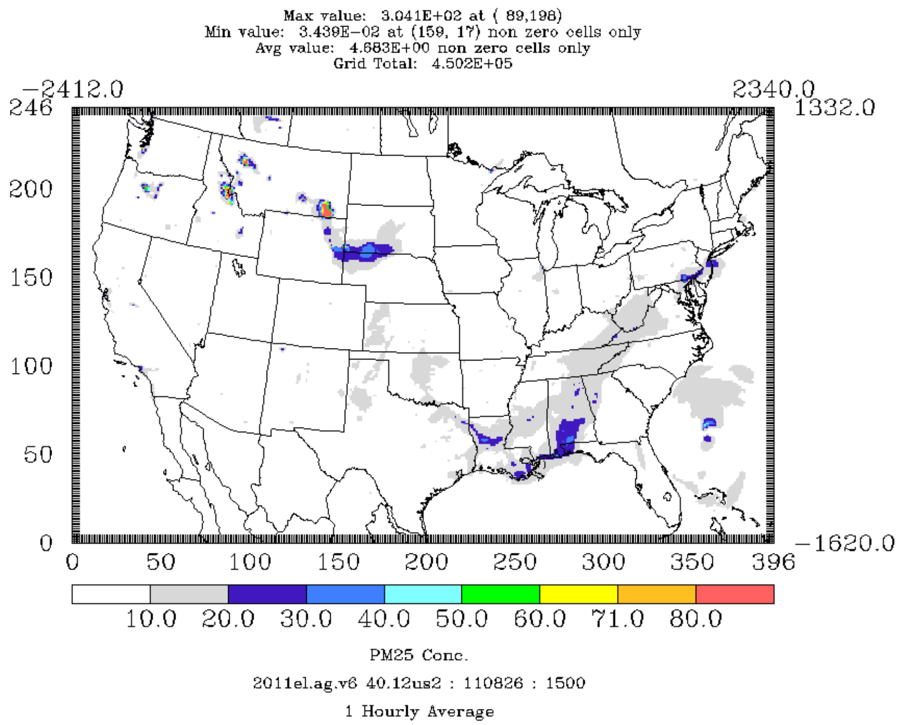


Figure 4-27: Comparison of $PM_{2.5}$ Concentrations (μg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Sixth Highest Positive Difference)

Seventh Highest Positive Difference: August 26 at 1500 hours

CAMx 6.40



Difference (6.32 - 6.40)

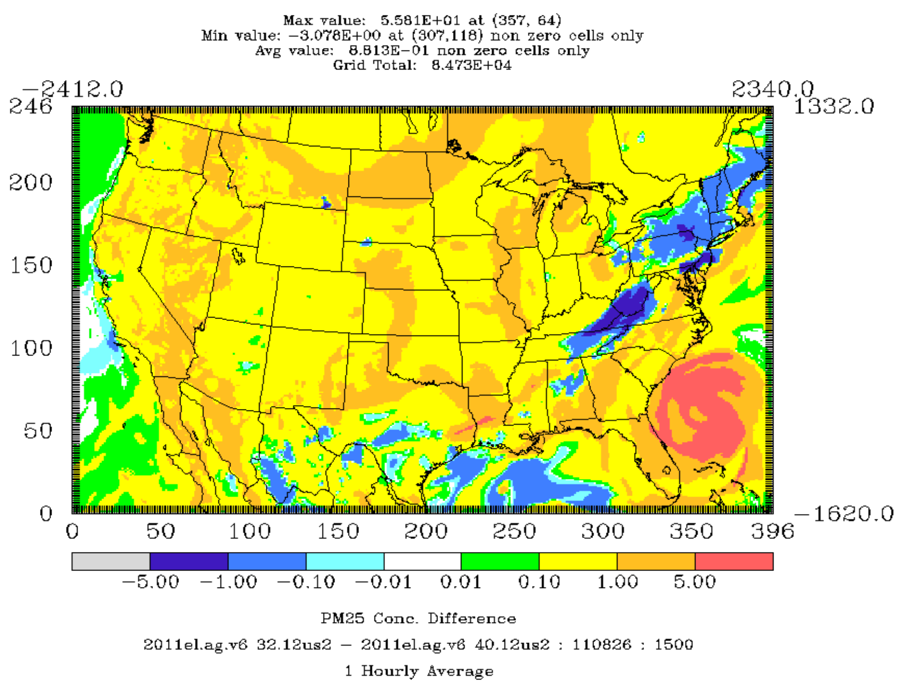
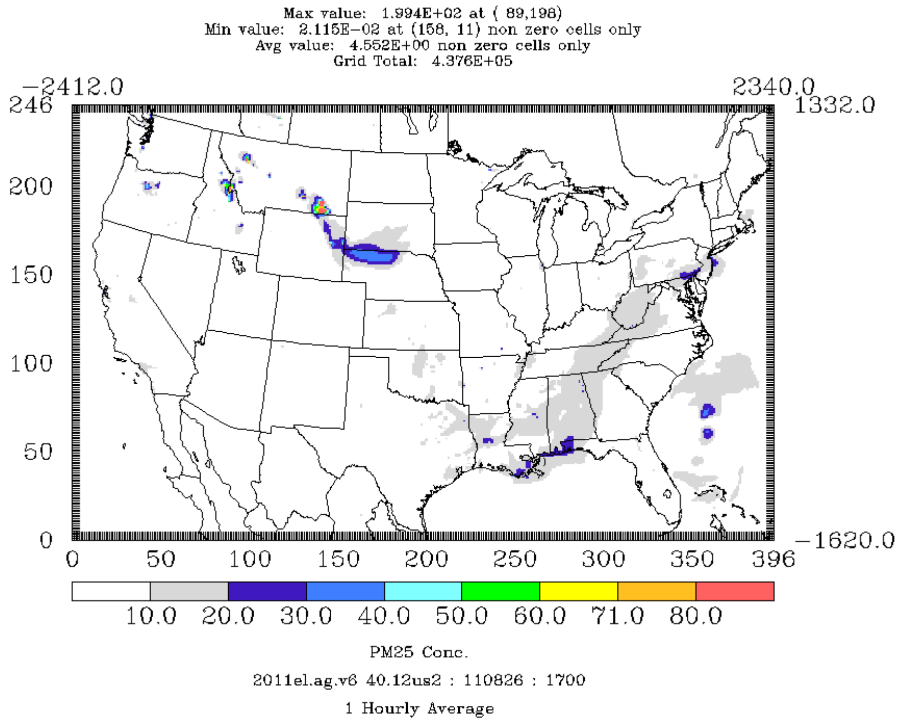


Figure 4-28: Comparison of $PM_{2.5}$ Concentrations (μg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Seventh Highest Positive Difference)

Eighth Highest Positive Difference: August 26 at 1700 hours
CAMx 6.40



Difference (6.32 - 6.40)

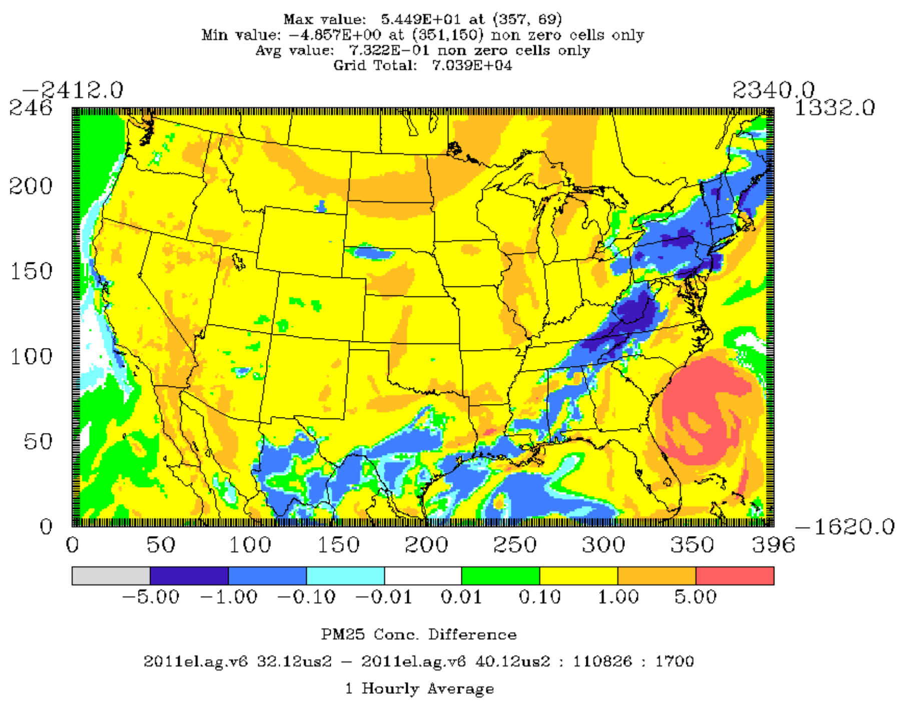
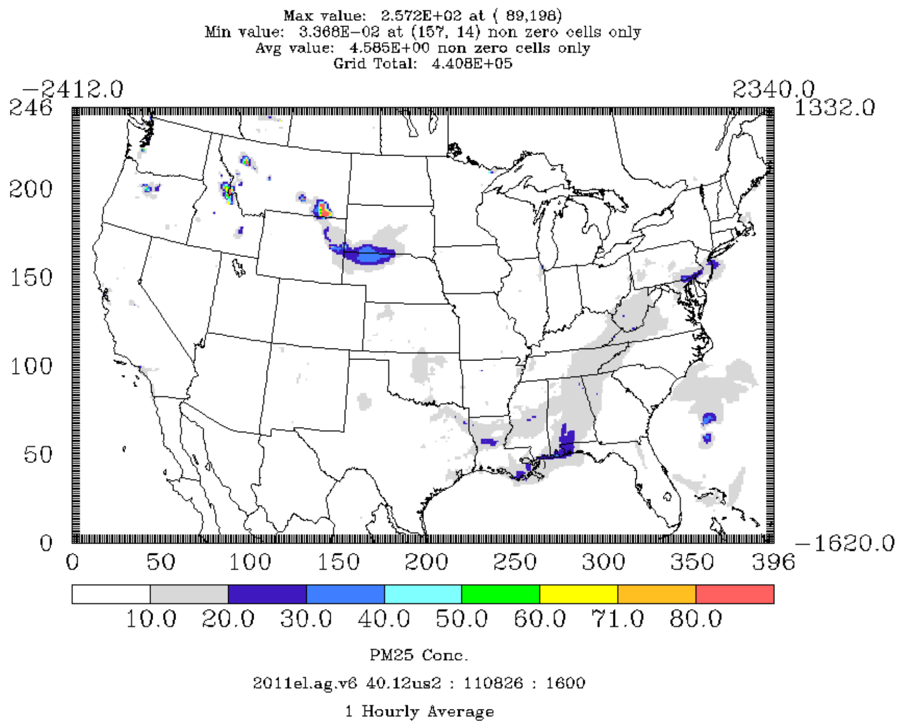


Figure 4-29: Comparison of $PM_{2.5}$ Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Eighth Highest Positive Difference)

Ninth Highest Positive Difference: August 26 at 1600 hours

CAMx 6.40



Difference (6.32 - 6.40)

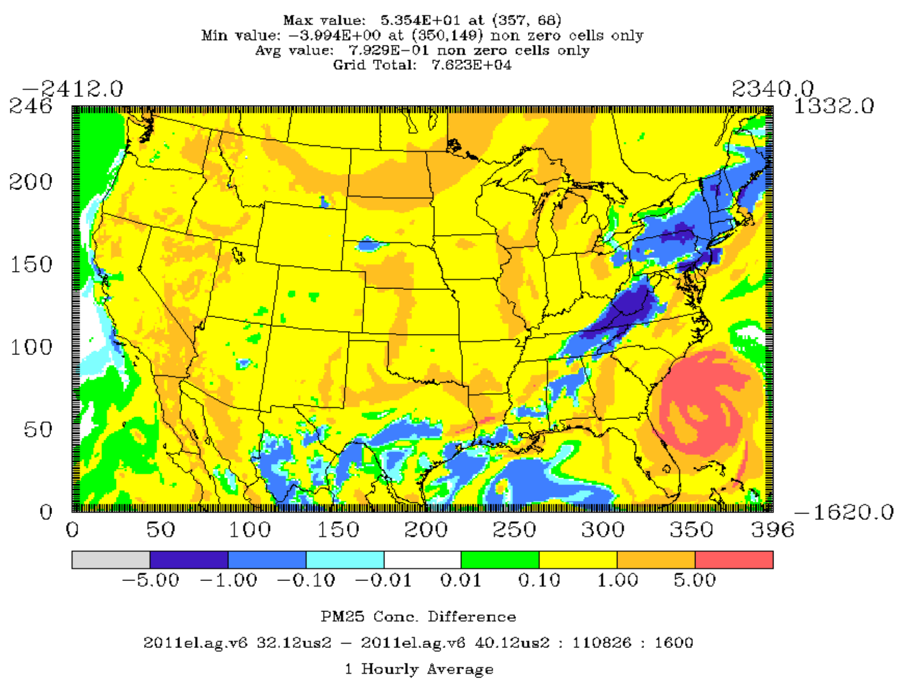
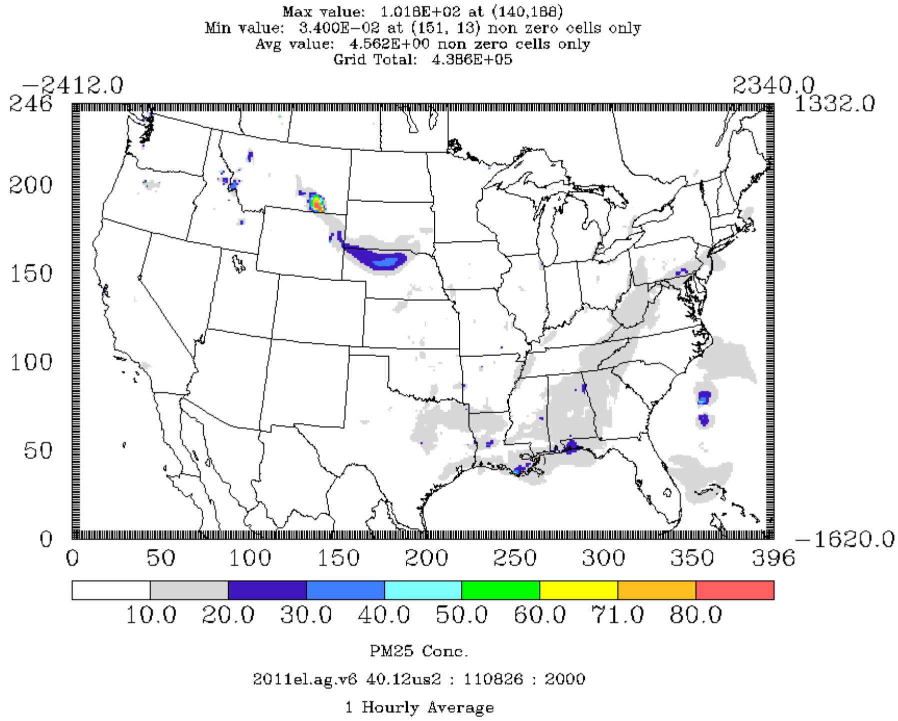


Figure 4-30: Comparison of $PM_{2.5}$ Concentrations (μg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Ninth Highest Positive Difference)

Tenth Highest Positive Difference: August 26 at 2000 hours

CAMx 6.40



Difference (6.32 - 6.40)

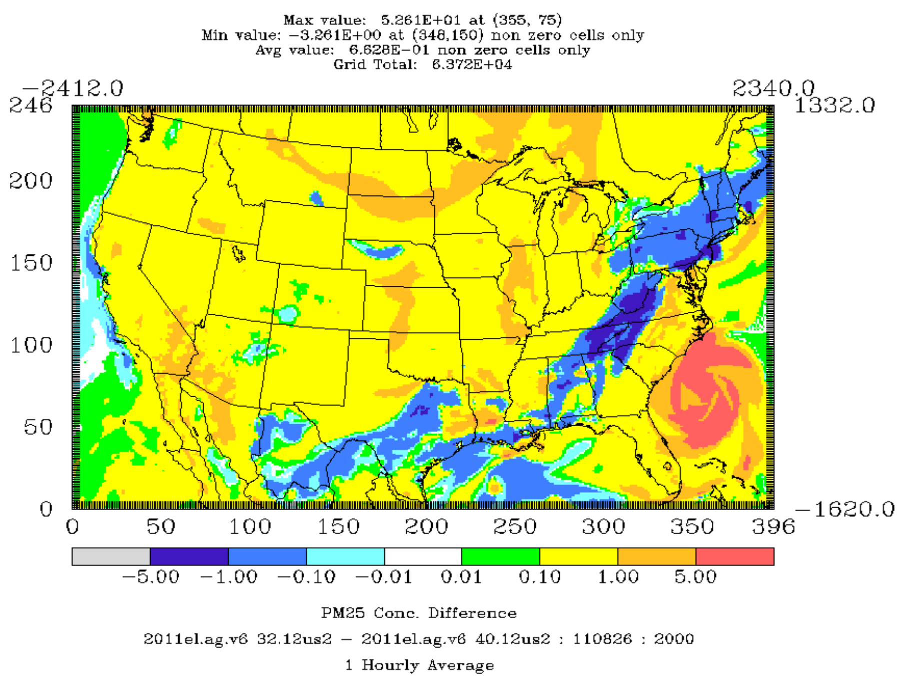
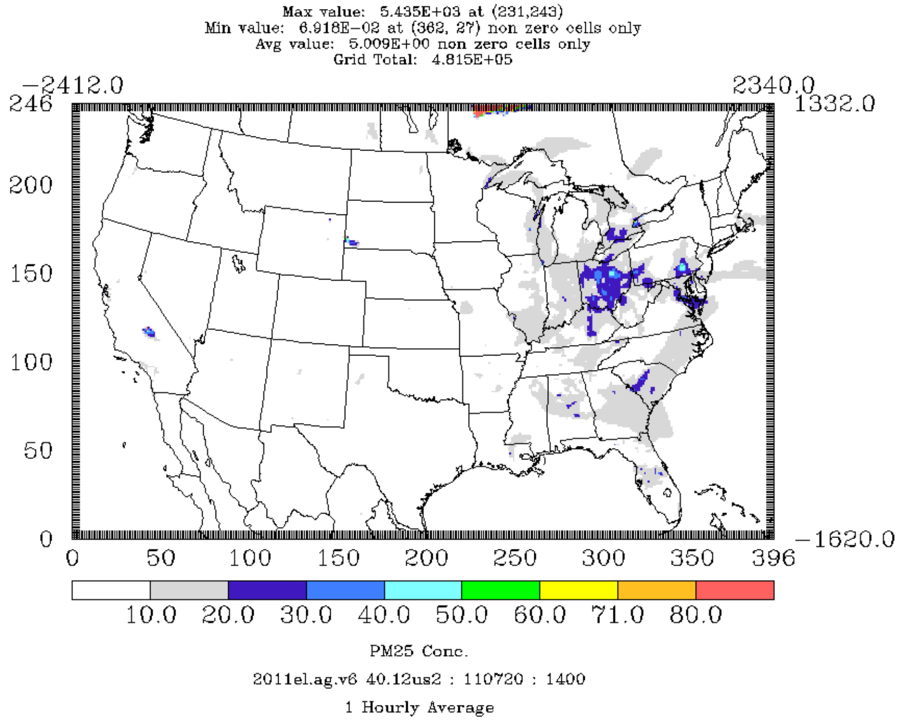


Figure 4-31: Comparison of $PM_{2.5}$ Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Tenth Highest Positive Difference)

Maximum Negative Difference: July 20 at 1400 hours

CAMx 6.40



Difference (6.32 - 6.40)

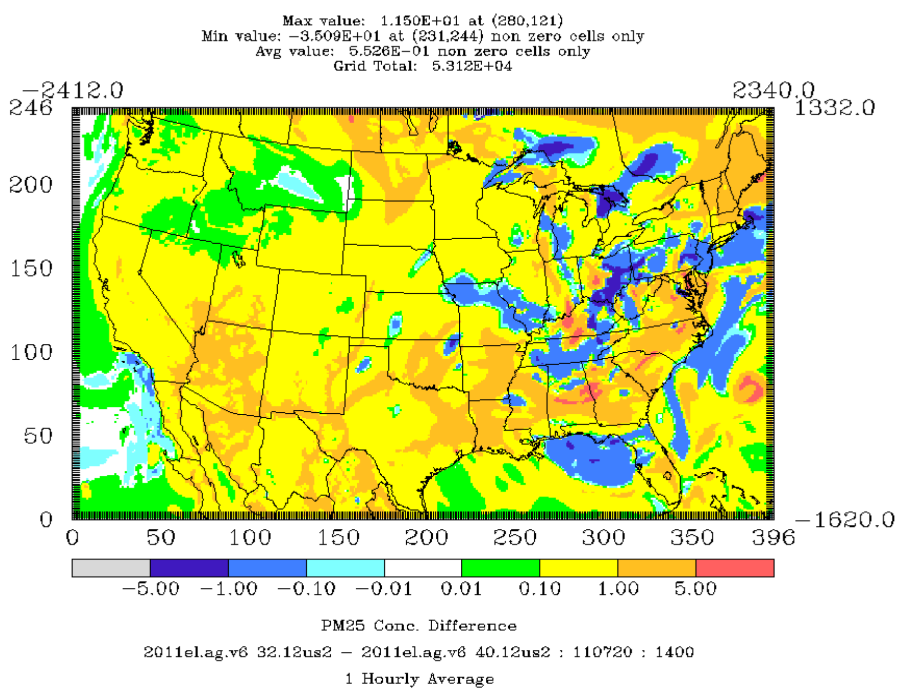
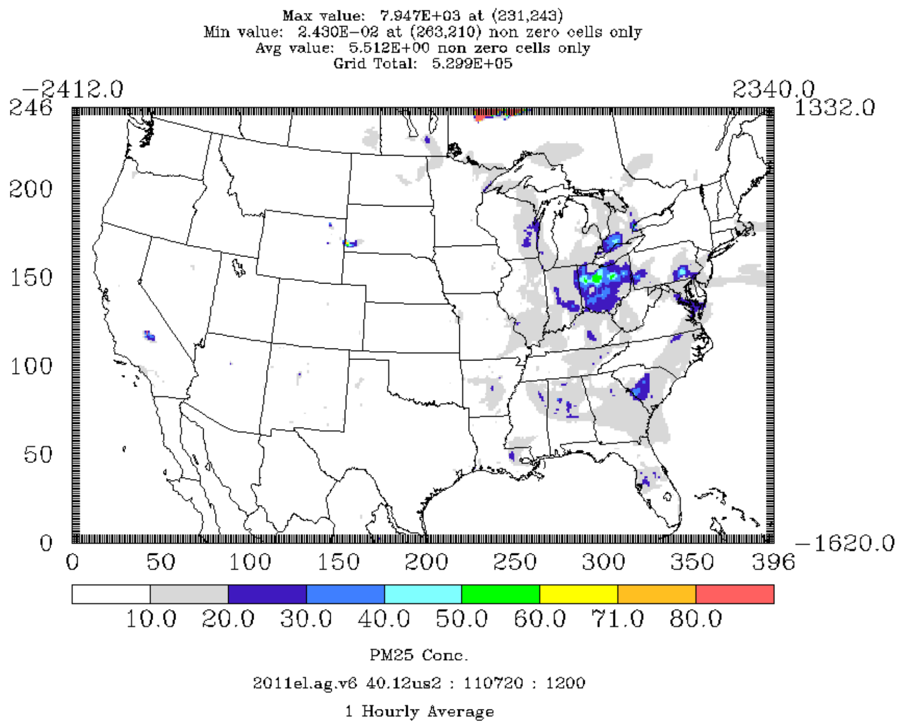


Figure 4-32: Comparison of $PM_{2.5}$ Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Maximum Negative Difference)

Second Highest Negative Difference: July 20 at 1200 hours

CAMx 6.40



Difference (6.32 - 6.40)

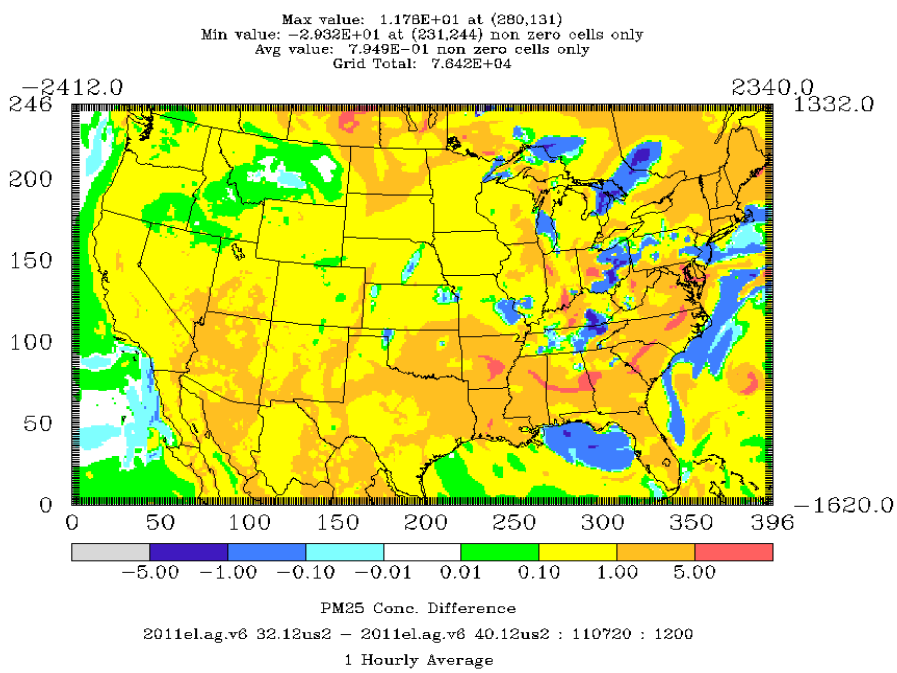
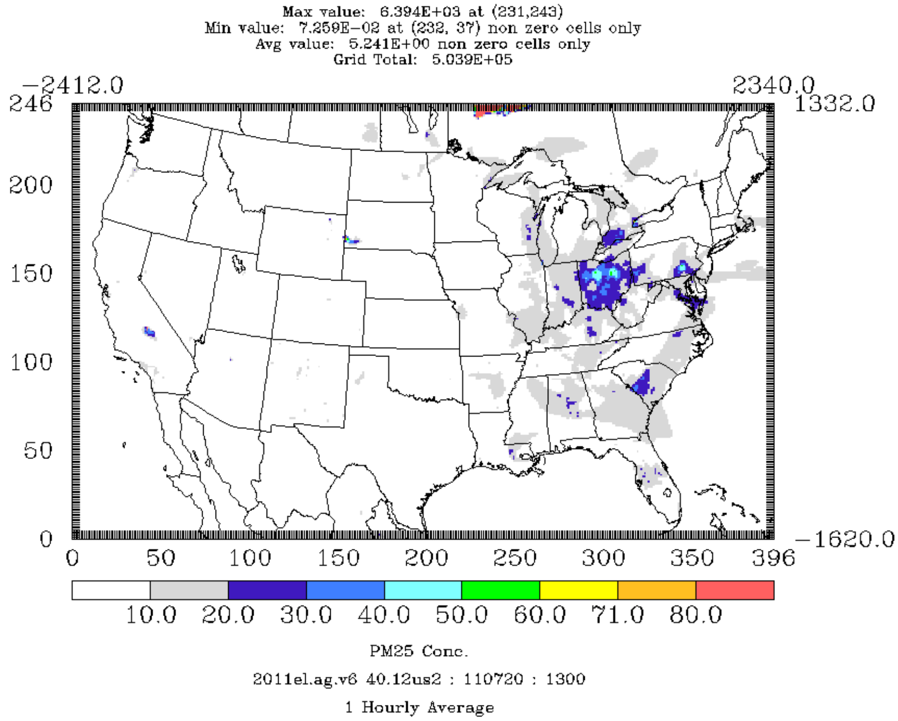


Figure 4-33: Comparison of $PM_{2.5}$ Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Second Highest Negative Difference)

Third Highest Negative Difference: July 20 at 1300 hours
CAMx 6.40



Difference (6.32 - 6.40)

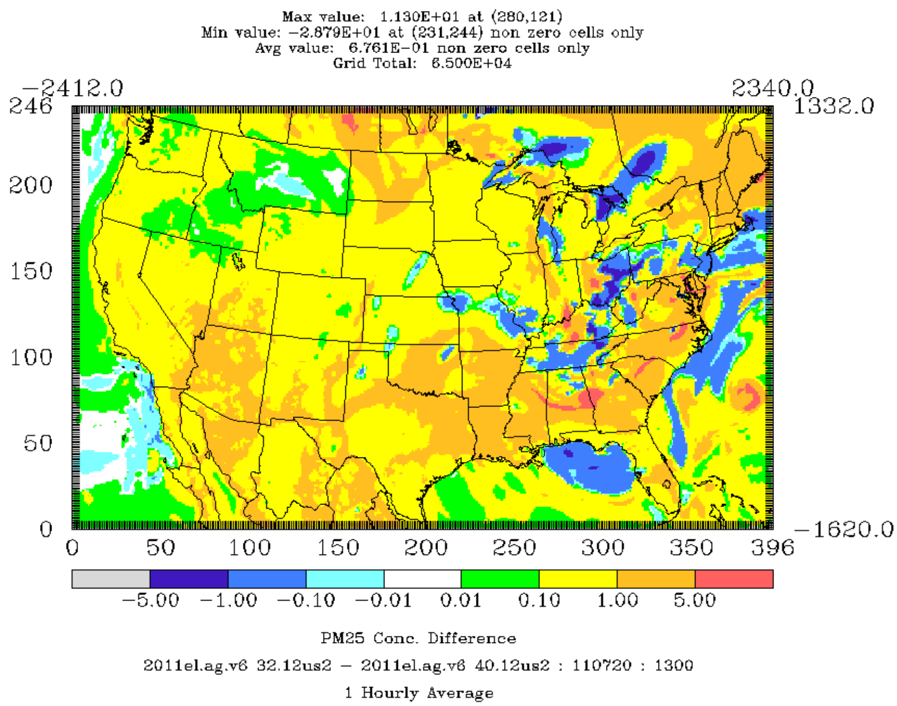
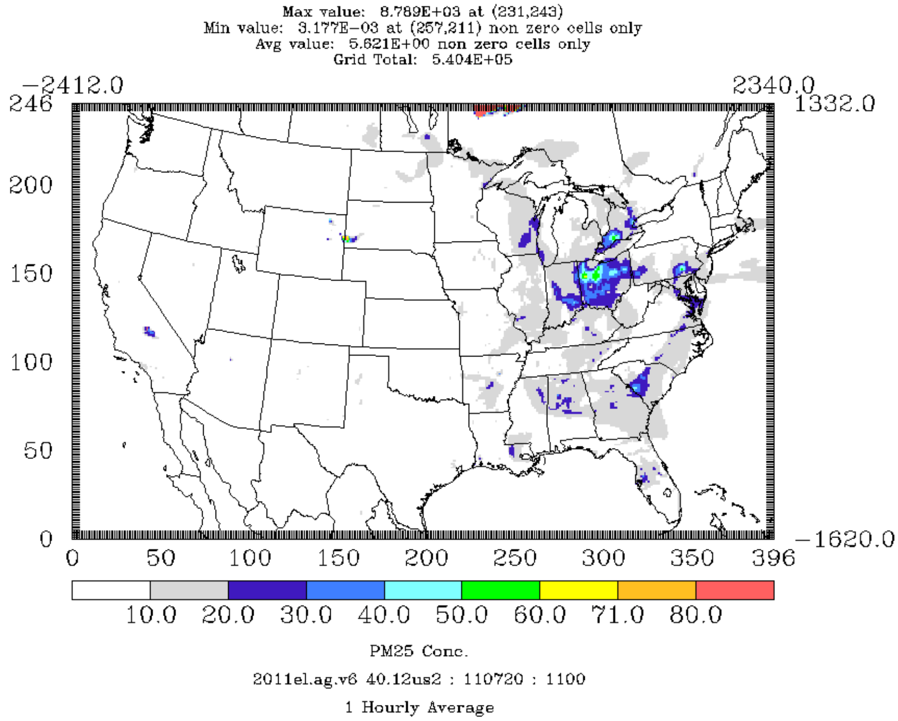


Figure 4-34: Comparison of $PM_{2.5}$ Concentrations (μg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Third Highest Negative Difference)

Fourth Highest Negative Difference: July 20 at 1100 hours
CAMx 6.40



Difference (6.32 - 6.40)

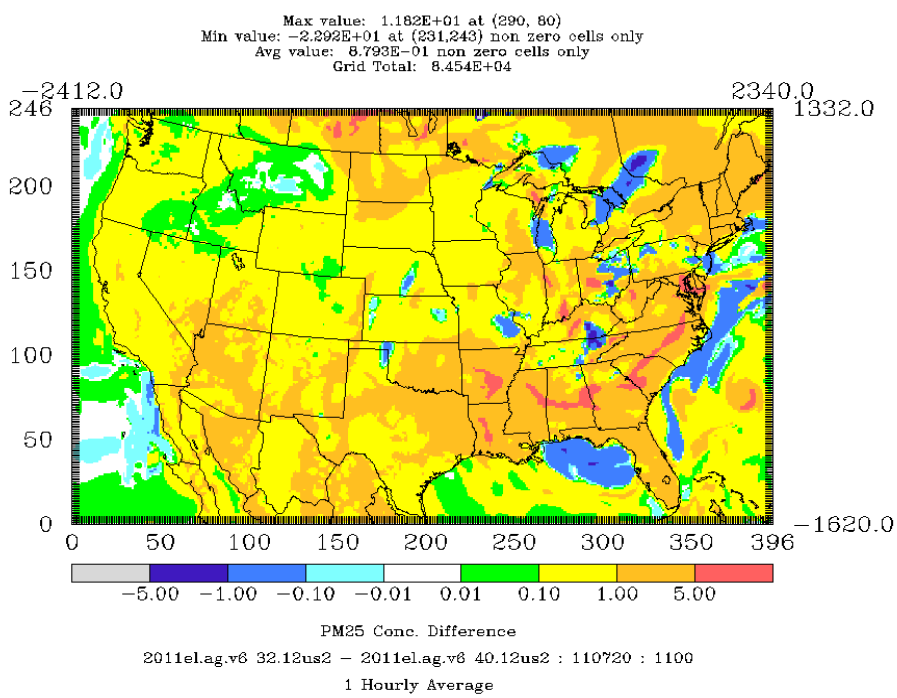
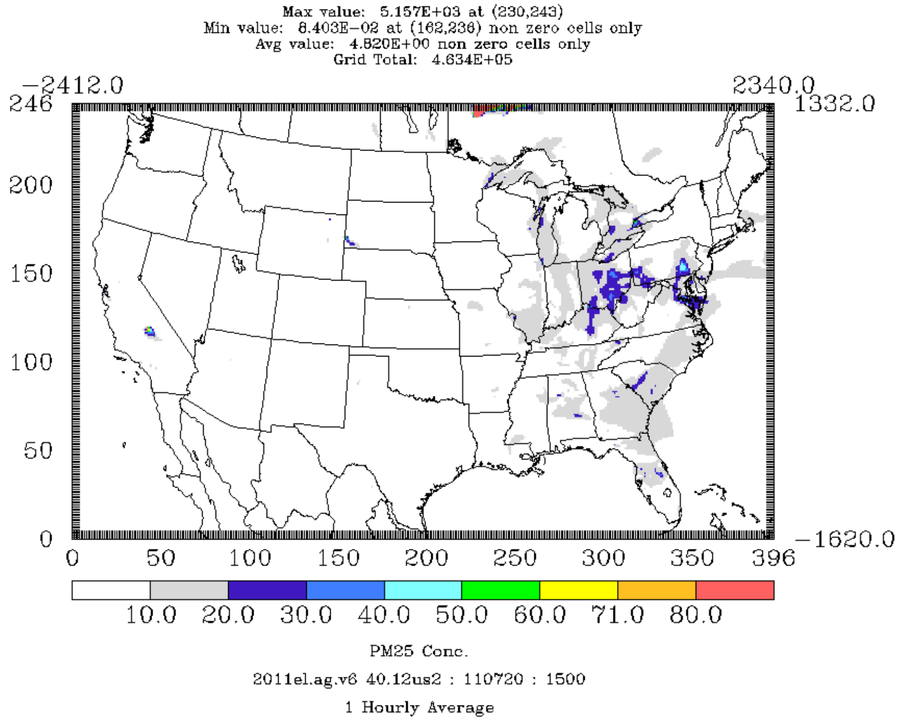


Figure 4-35: Comparison of $PM_{2.5}$ Concentrations (µg/m³) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Fourth Highest Negative Difference)

Fifth Highest Negative Difference: July 20 at 1500 hours
CAMx 6.40
Difference (6.32 - 6.40)



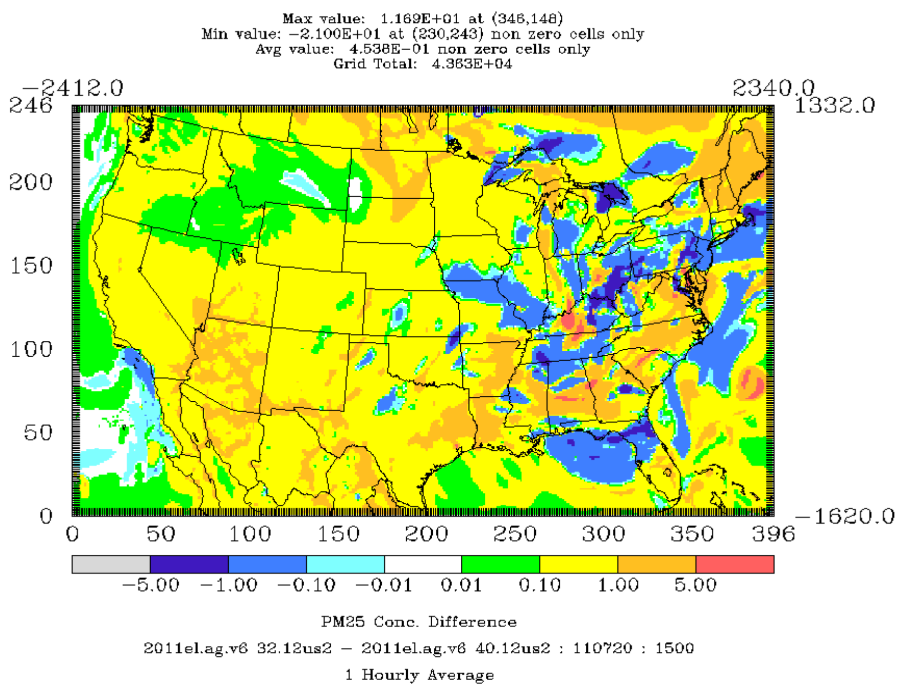
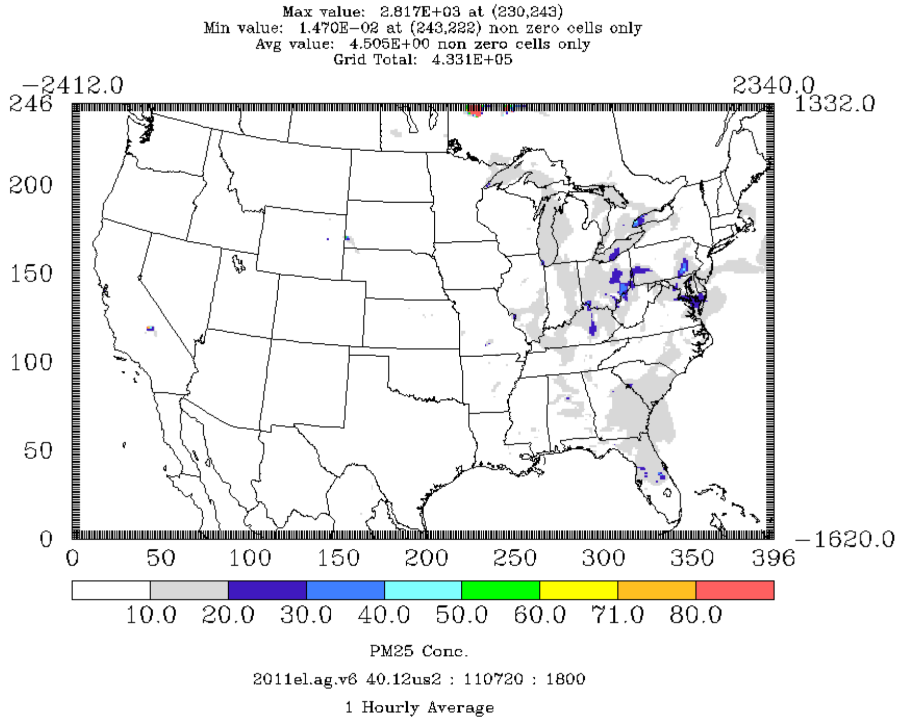


Figure 4-36: Comparison of $PM_{2.5}$ Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Fifth Highest Negative Difference)

Sixth Highest Negative Difference: July 20 at 1800 hours
CAMx 6.40



Difference (6.32 - 6.40)

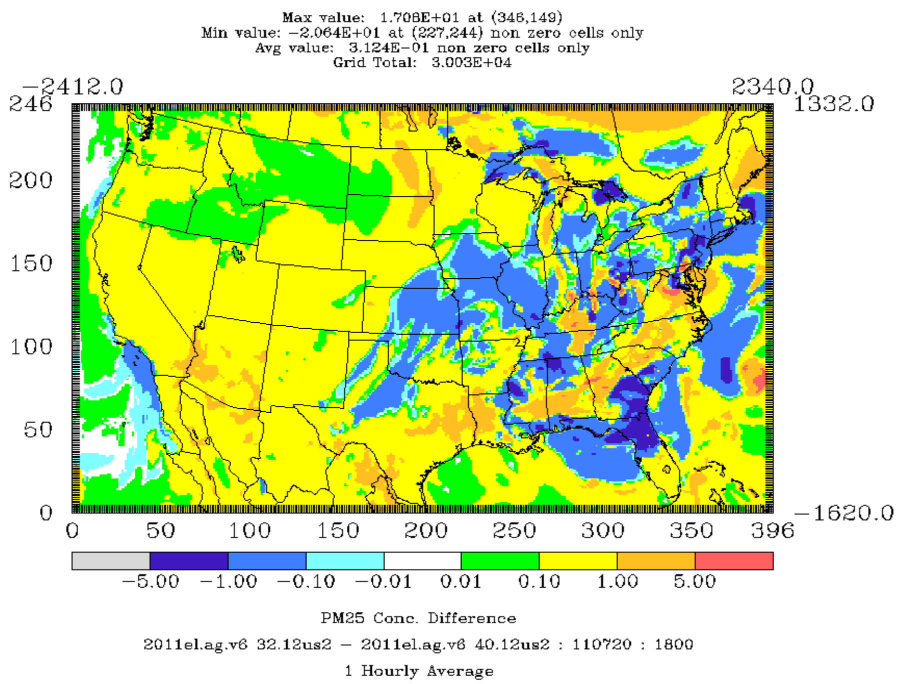
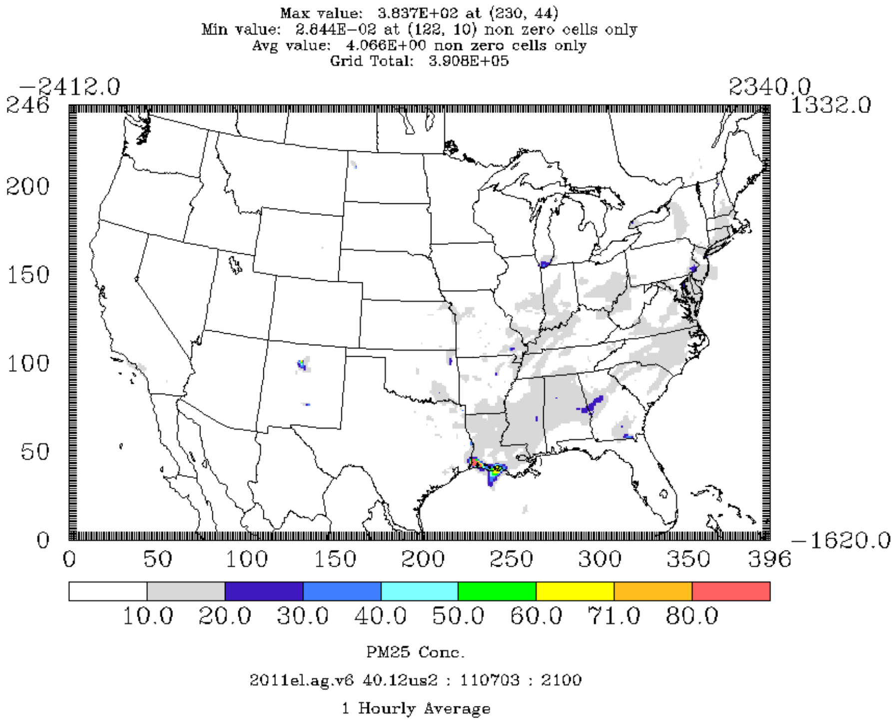


Figure 4-37: Comparison of $PM_{2.5}$ Concentrations (μg/m³) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Sixth Highest Negative Difference)

Seventh Highest Negative Difference: July 3 at 2100 hours
CAMx 6.40



Difference (6.32 - 6.40)

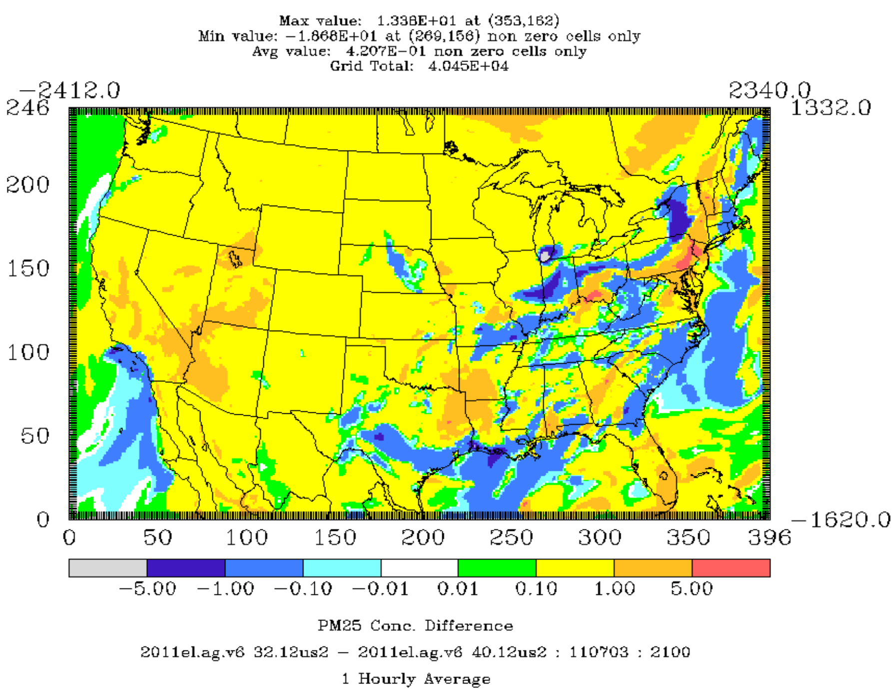
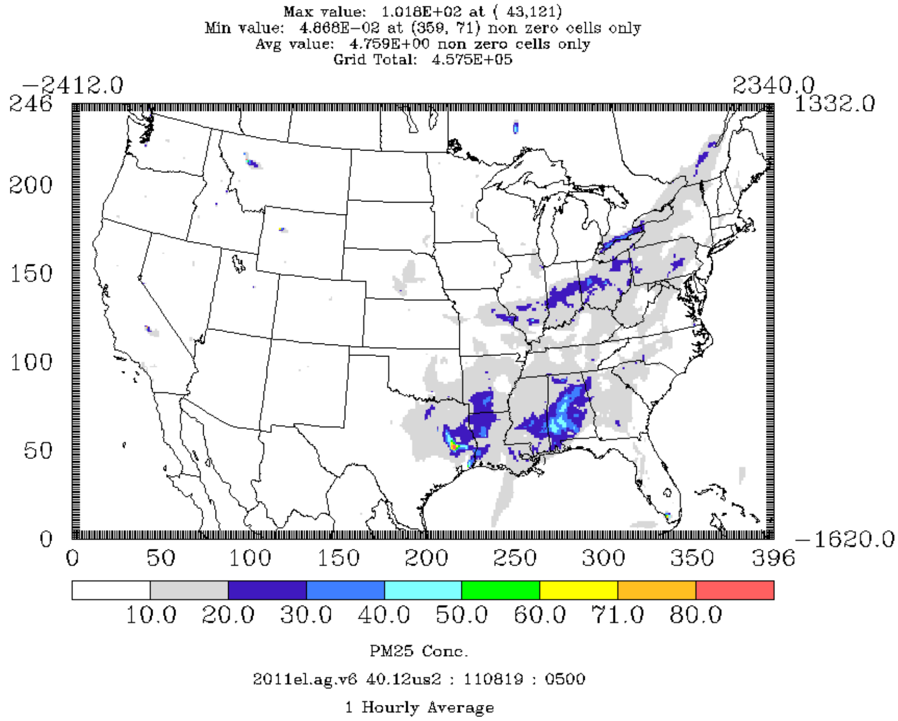


Figure 4-38: Comparison of $PM_{2.5}$ Concentrations ($\mu g/m^3$) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Seventh Highest Negative Difference)

Eighth Highest Negative Difference: August 19 at 500 hours
CAMx 6.40



Difference (6.32 - 6.40)

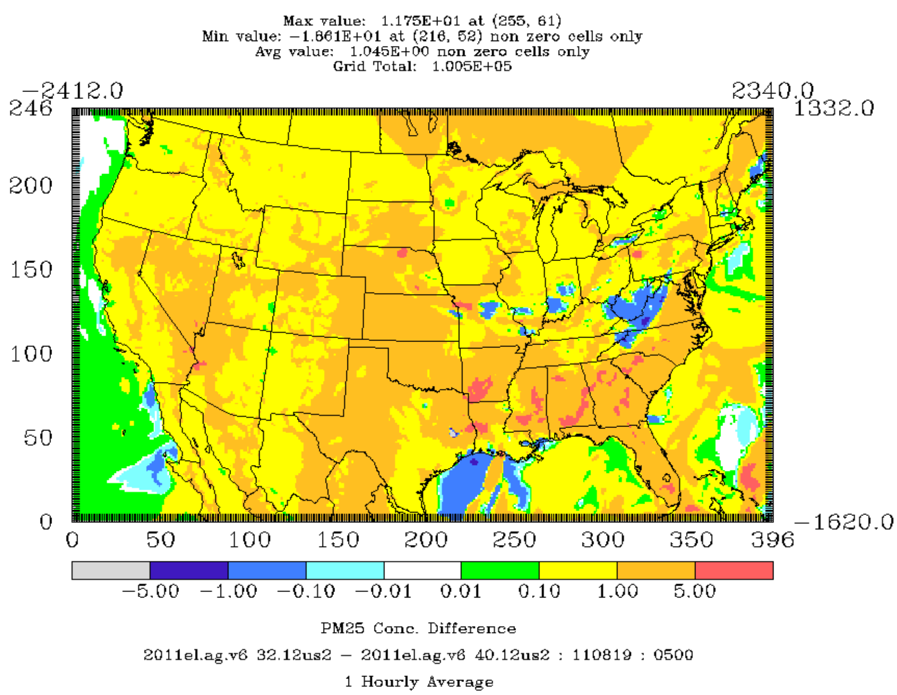
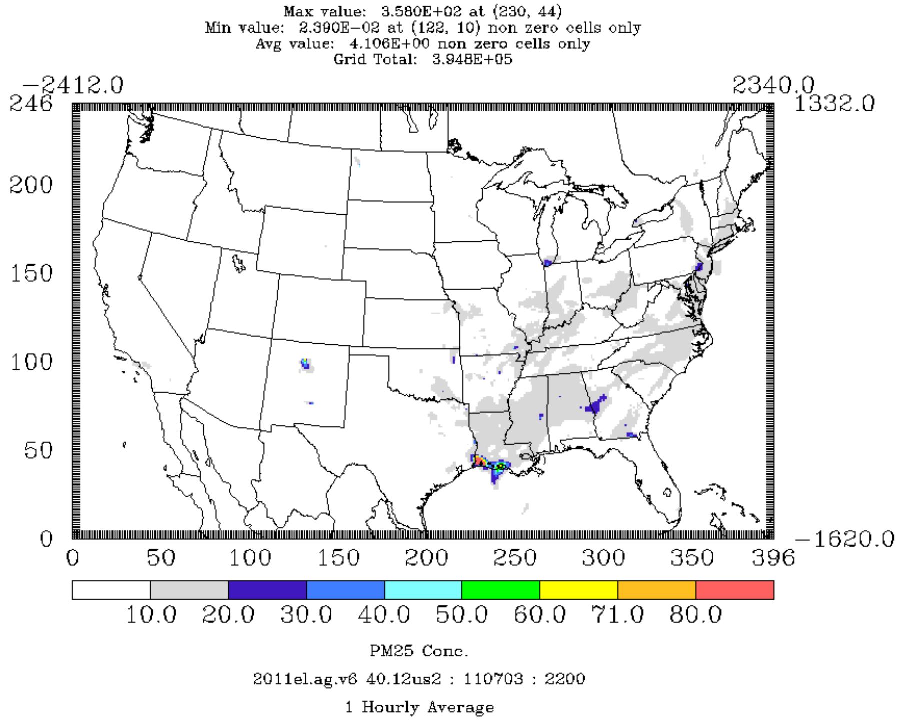


Figure 4-39: Comparison of $PM_{2.5}$ Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Eighth Highest Negative Difference)

Ninth Highest Negative Difference: July 3 at 2200 hours

CAMx 6.40



Difference (6.32 - 6.40)

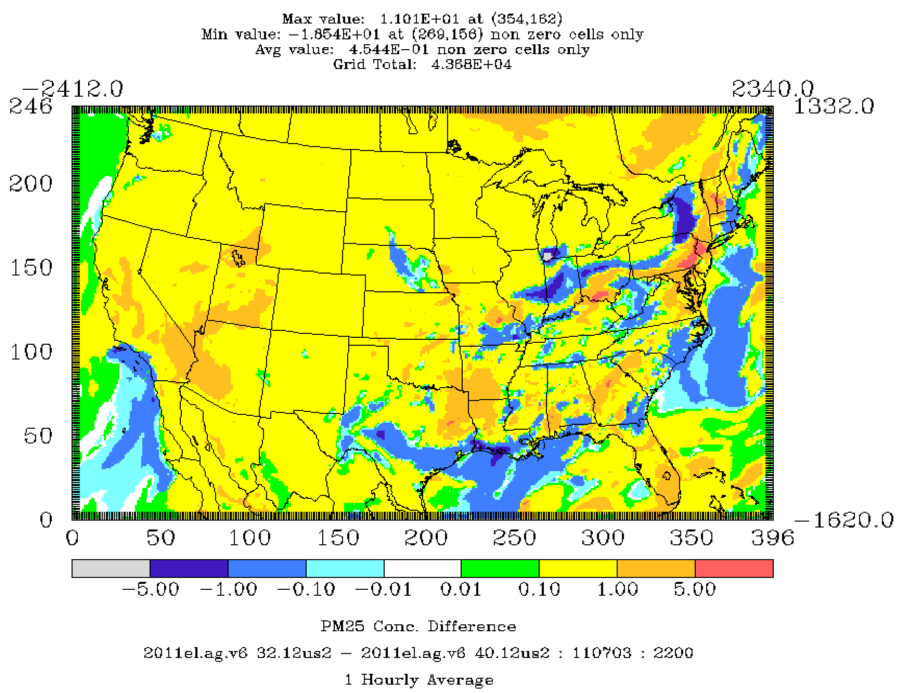
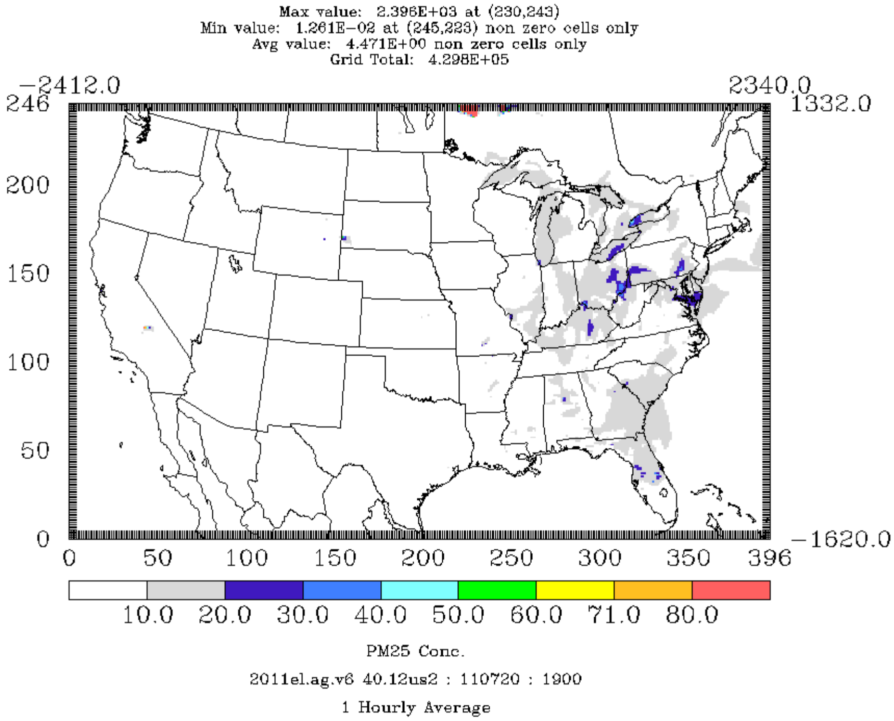


Figure 4-40: Comparison of $PM_{2.5}$ Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Ninth Highest Negative Difference)

Tenth Highest Negative Difference: July 20 at 1900 hours

CAMx 6.40



Difference (6.32 - 6.40)

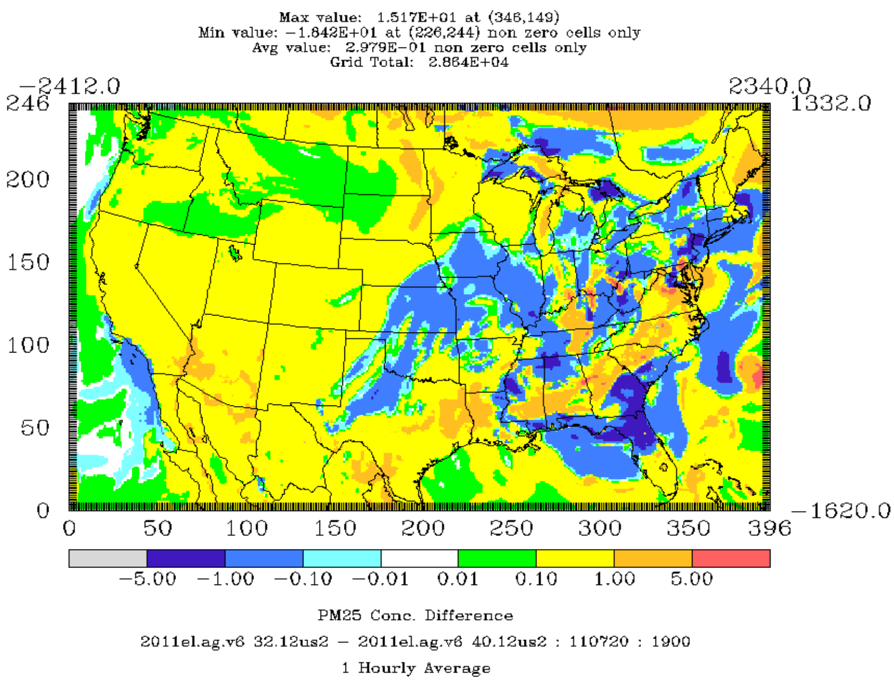


Figure 4-41: Comparison of $PM_{2.5}$ Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Tenth Highest Negative Difference)

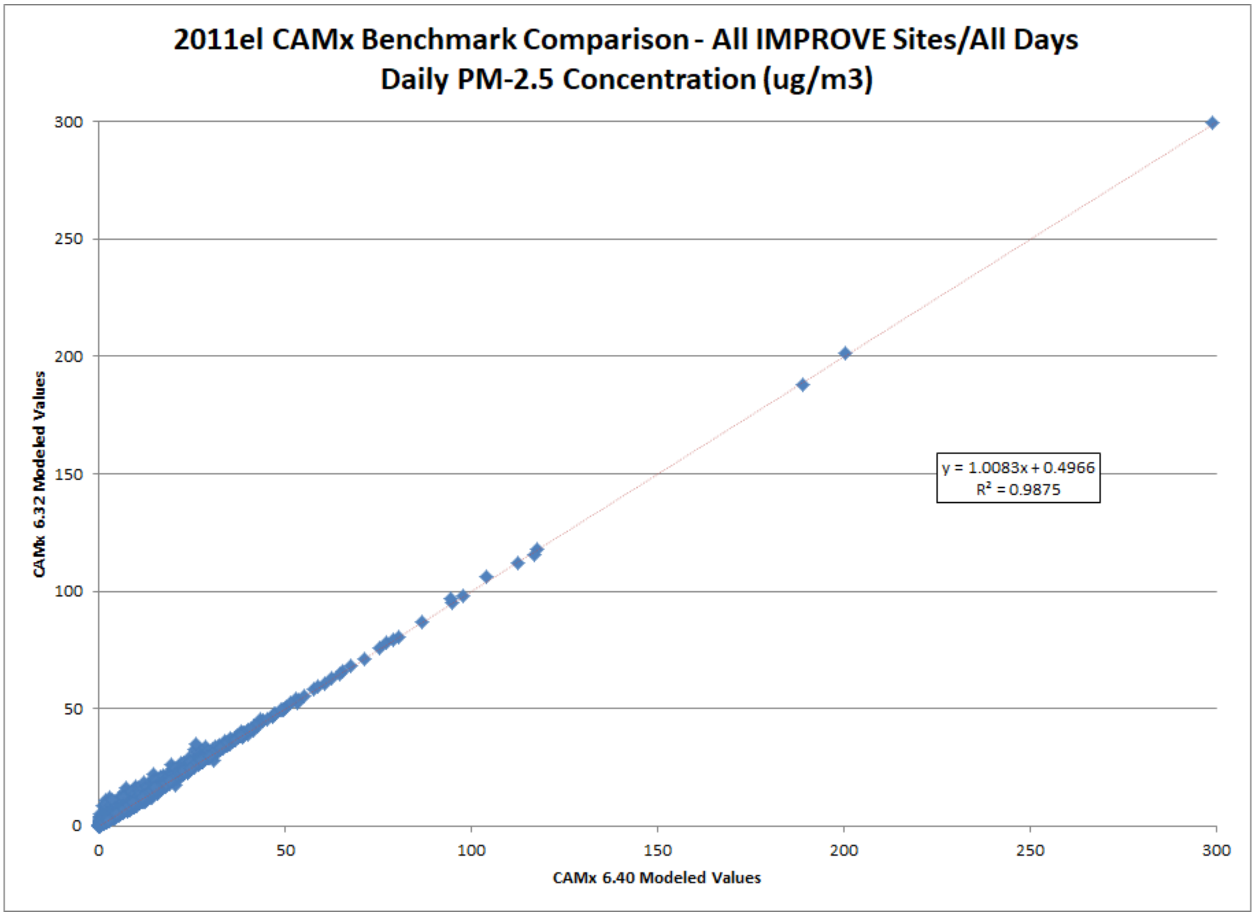


Figure 4-42: Scatterplot Comparing 24-hour Average Predicted $PM_{2.5}$ Concentrations ($\mu g/m^3$) for All Days at all IMPROVE Monitor Locations for CAMx 6.32 and CAMx 6.40 2011el Simulations Performed by VISTAS (Alpine).

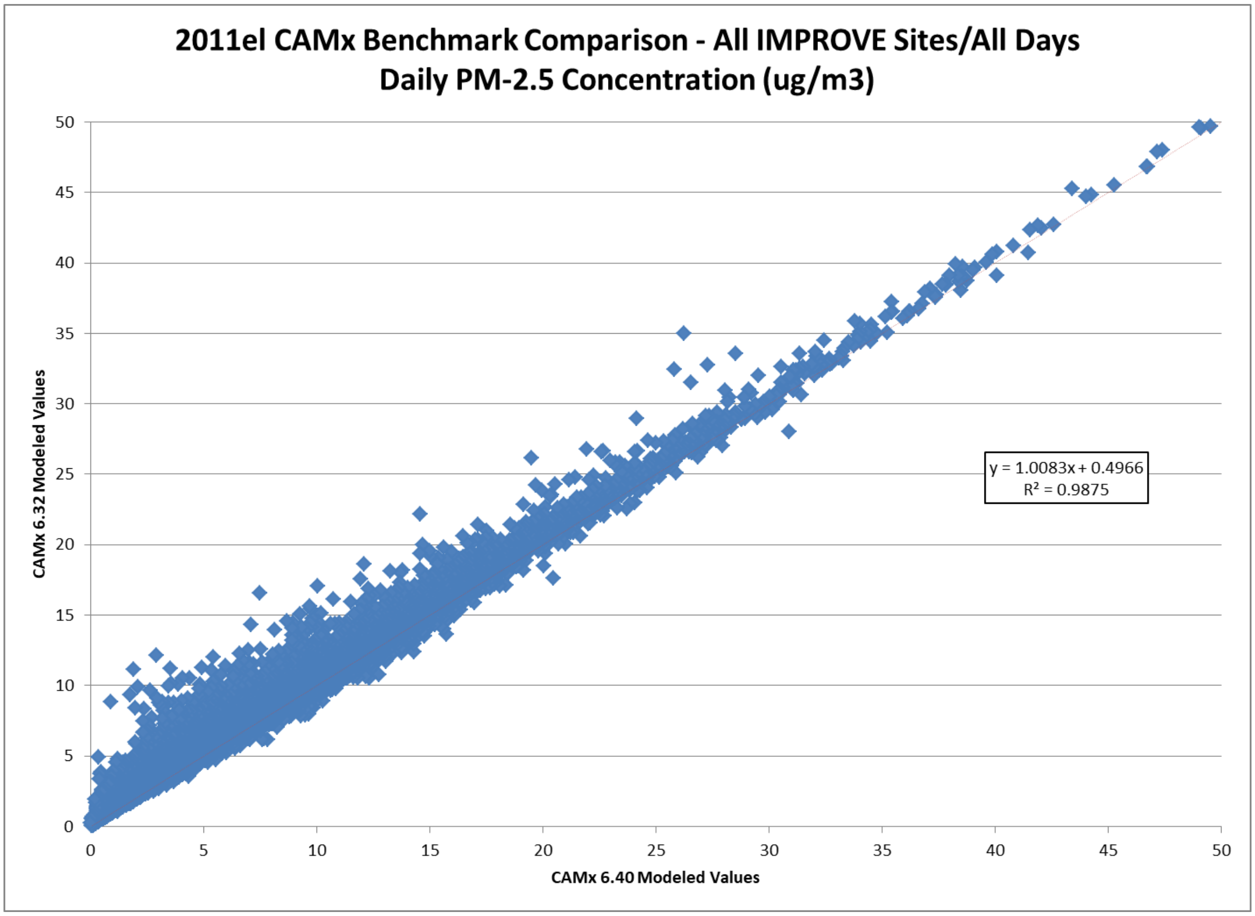


Figure 4-43: Scatterplot Comparing 24-hour Average Predicted $PM_{2.5}$ Concentrations ($\mu g/m^3$) for All Days at all IMPROVE Monitor Locations for CAMx 6.32 and CAMx 6.40 2011el Simulations Performed by VISTAS (Alpine); Modified Scale.

4.3 Sulfate

Sulfate results for the top 10 positive and negative hours are presented in tabular format in Table 4-3. The maximum positive difference is 23.32 µg/m^3 falling to 14.769 µg/m^3 for the 10th high. The maximum negative difference is -17.77 µg/m^3 falling to -5.76 µg/m^3 for the 10th high. The maximum positive percent difference from these days is 171% and negative percent difference of -26.9%.

The top 10 positive difference hours are presented in Figures 4-44 through 4-53. The regions of the maximum impact are highly variable. The maximum and several other days shows the maximum difference is located near the Chicago metro area. The second and third highest maximum and other days show impacts along the Gulf of Mexico coast.

The top 10 negative difference hours are presented in Figures 4-54 through 4-63. The maximum negative differences for all but one day are occurring on July 20 or 21 along the northern U.S. border, north of Minnesota.

Scatterplots of the daily average sulfate concentrations in local standard time at the IMPROVE monitors are presented in Figure 4-64. The CAMx 6.40 results are plotted on the x-axis and the CAMx 6.32 results are plotted on the y-axis. The data has considerably more scatter than the ozone or $PM_{2.5}$ results with a line of best fit with a slope of 1.0842, an intercept of 0.0832 µg/m^3 and an R^2 of 0.9068. The vast majority of the points are above the 1:1 line, meaning that the CAMx 6.32 modeled values are higher than the CAMx 6.40 results. This is likely a result of the changes in the wet deposition algorithms and the oxidation of SO_2 on primary crustal particles and updates to the RADM-AQ algorithm.

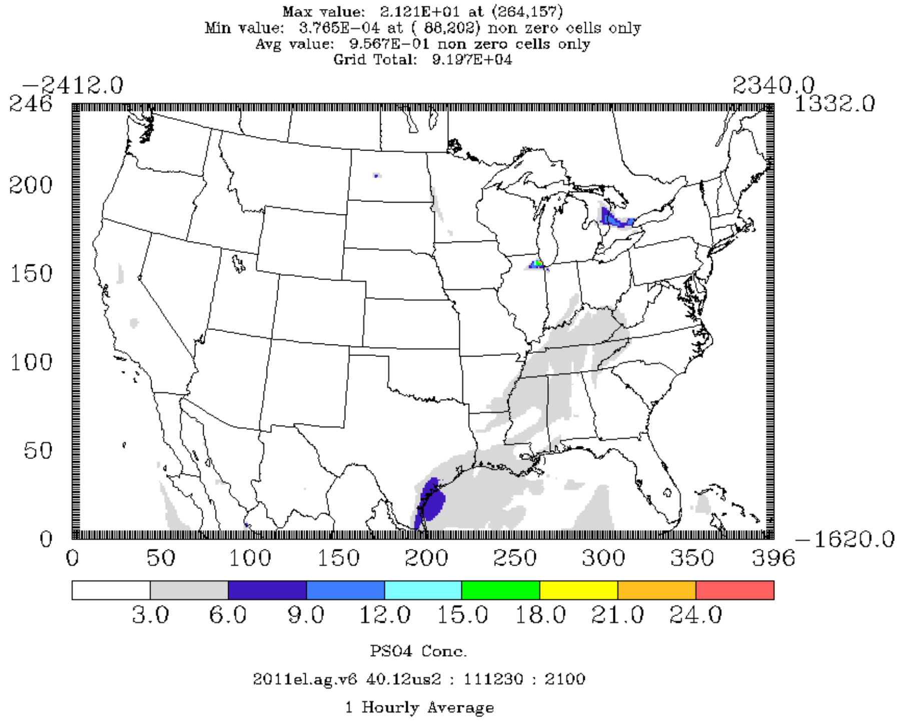
Examination of the CAMx 6.40 animations show generally lower concentrations compared to CAMx 6.32, particularly in the Southeastern U.S.

Table 4-3. Comparison of 2011el CAMx 6.32 and CAMx 6.40 Simulation of Sulfate Concentrations (µg/m³). Hours with the top 10 maximum positive and maximum negative differences are shown.

Year	Month	Day	Hour	6.32 Conc.	6.40 Conc.	Difference (µg/m³)	Percent Difference	Column	Row
Maximum Positive									
2011	12	30	21	44.45	21.13	23.32	110.4%	265	157
2011	5	12	11	71.22	51.23	19.99	39.0%	258	45
2011	5	8	9	43.25	23.36	19.88	85.1%	258	45
2011	12	21	14	46.03	27.37	18.66	68.2%	316	176
2011	3	16	1	29.04	10.70	18.34	171.5%	291	145
2011	5	12	12	75.61	60.06	15.55	25.9%	258	45
2011	5	9	10	42.96	27.94	15.02	53.7%	258	45
2011	12	30	22	45.61	30.69	14.92	48.6%	265	157
2011	5	12	10	56.99	42.11	14.88	35.3%	258	45
2011	5	20	3	26.13	11.37	14.76	129.8%	352	206
Maximum Negative									
2011	7	20	12	87.16	104.93	-17.77	-16.9%	231	244
2011	7	20	11	95.08	109.81	-14.72	-13.4%	231	244
2011	7	20	13	68.92	82.16	-13.24	-16.1%	231	244
2011	7	20	14	59.18	69.69	-10.51	-15.1%	231	244
2011	7	21	3	67.32	77.08	-9.76	-12.7%	230	244
2011	7	21	2	108.88	117.08	-8.19	-7.0%	230	243
2011	7	20	15	43.94	51.06	-7.11	-13.9%	231	244
2011	7	21	4	35.42	42.46	-7.05	-16.6%	230	245
2011	7	20	10	94.54	100.83	-6.29	-6.2%	231	241
2011	1	4	18	15.63	21.39	-5.76	-26.9%	170	29

Maximum Positive Difference: December 30 at 2100 hours

CAMx 6.40



Difference (6.32 - 6.40)

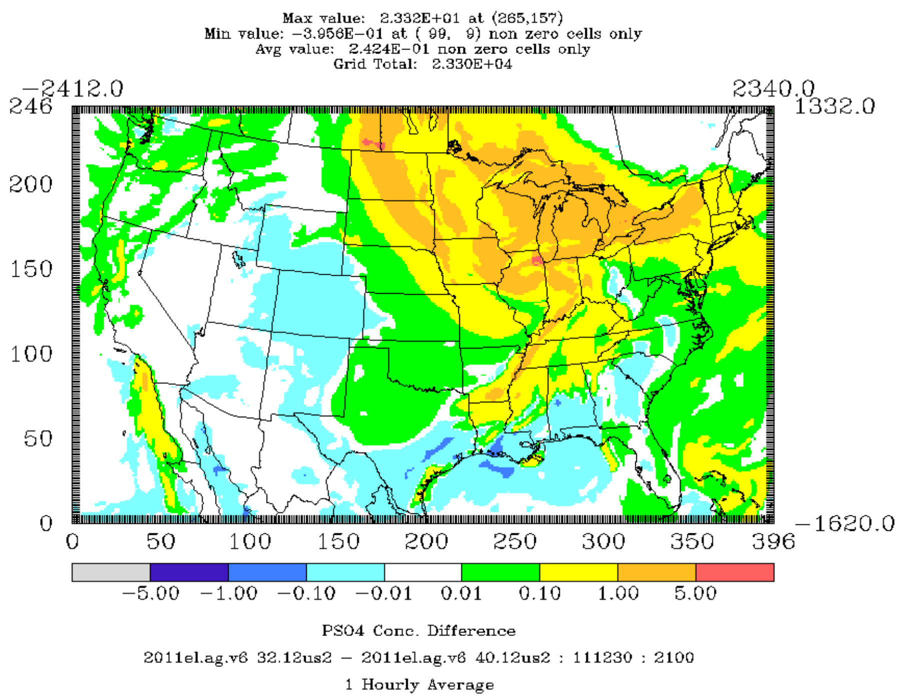
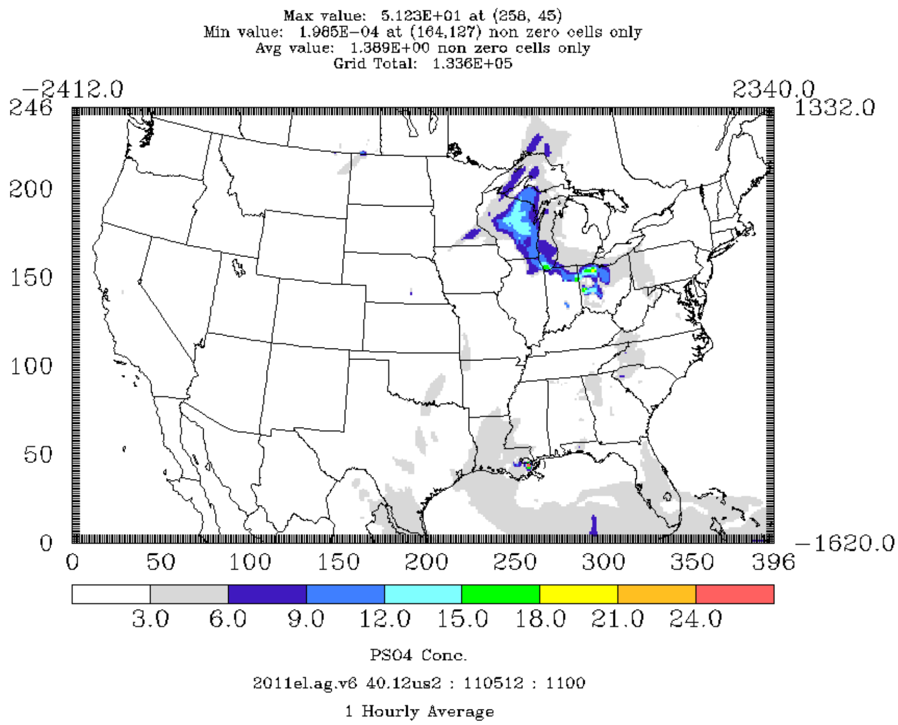


Figure 4-44: Comparison of Sulfate Concentrations (µg/m³) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Maximum Positive Difference)

Second Highest Positive Difference: May 12 at 1100 hours

CAMx 6.40



Difference (6.32 - 6.40)

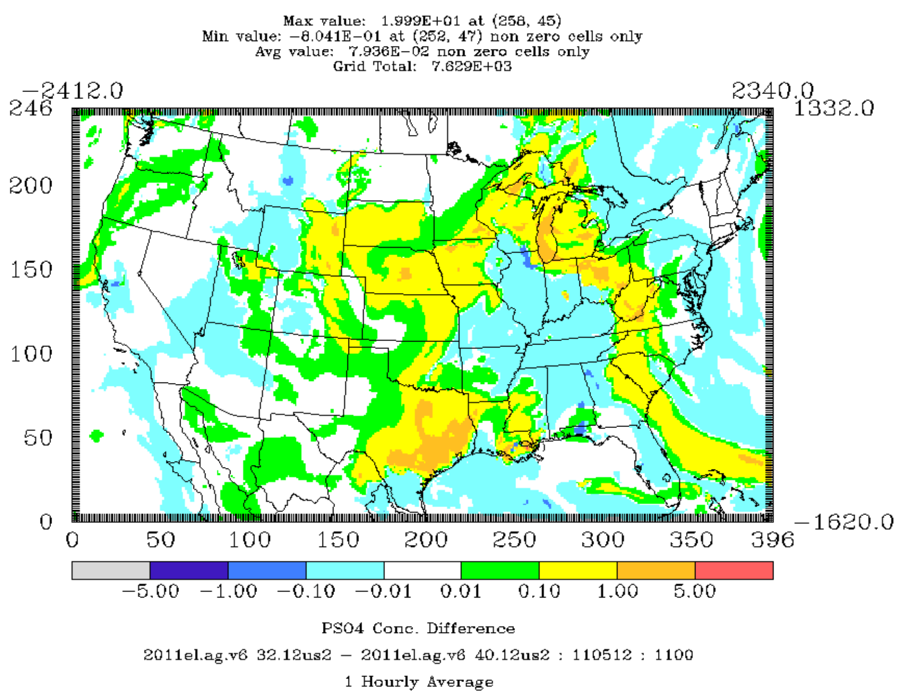
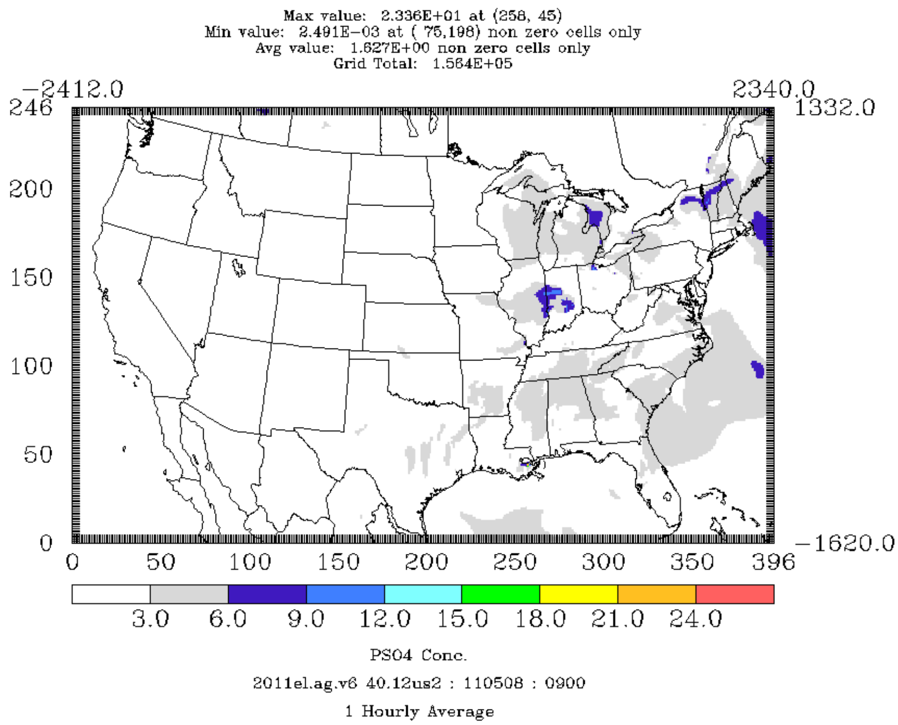


Figure 4-45: Comparison of Sulfate Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Second Highest Positive Difference)

Third Highest Positive Difference: May 8 at 900 hours

CAMx 6.40



Difference (6.32 - 6.40)

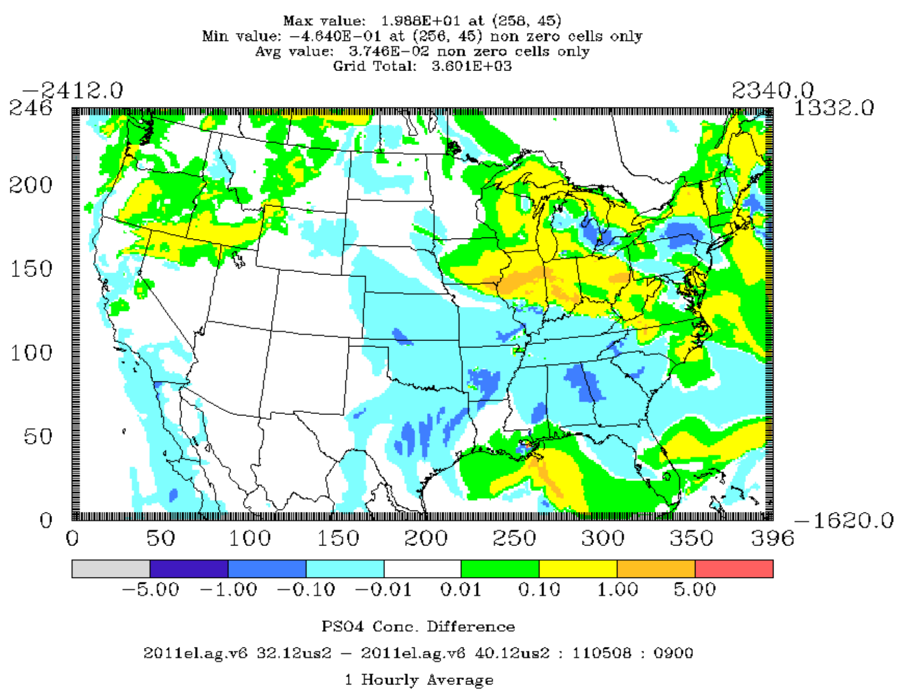
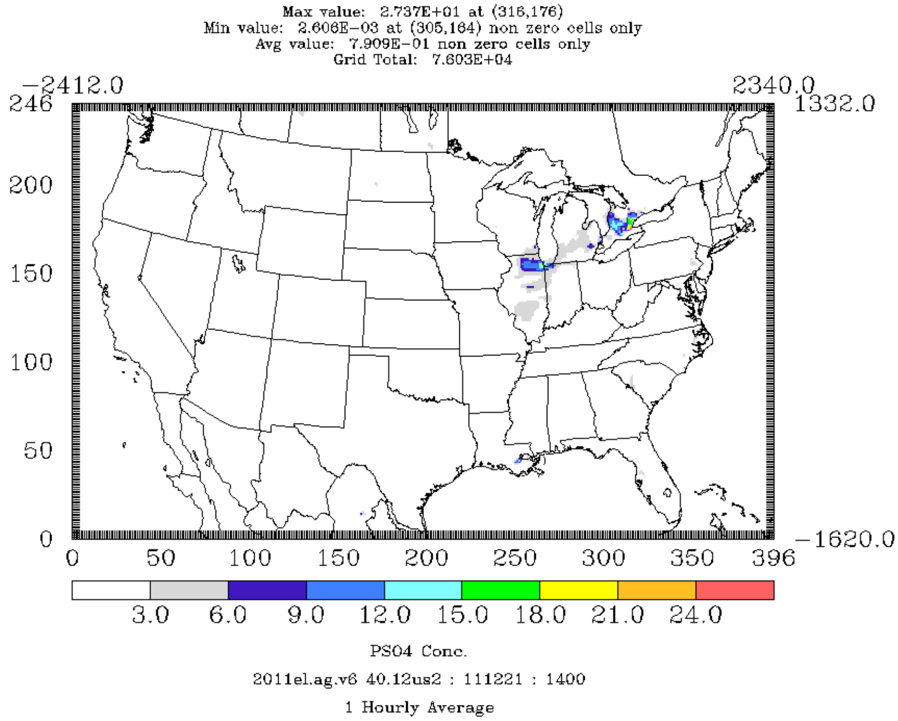


Figure 4-46: Comparison of Sulfate Concentrations (µg/m³) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Third Highest Positive Difference)

Fourth Highest Positive Difference: December 21 at 1400 hours

CAMx 6.40



Difference (6.32 - 6.40)

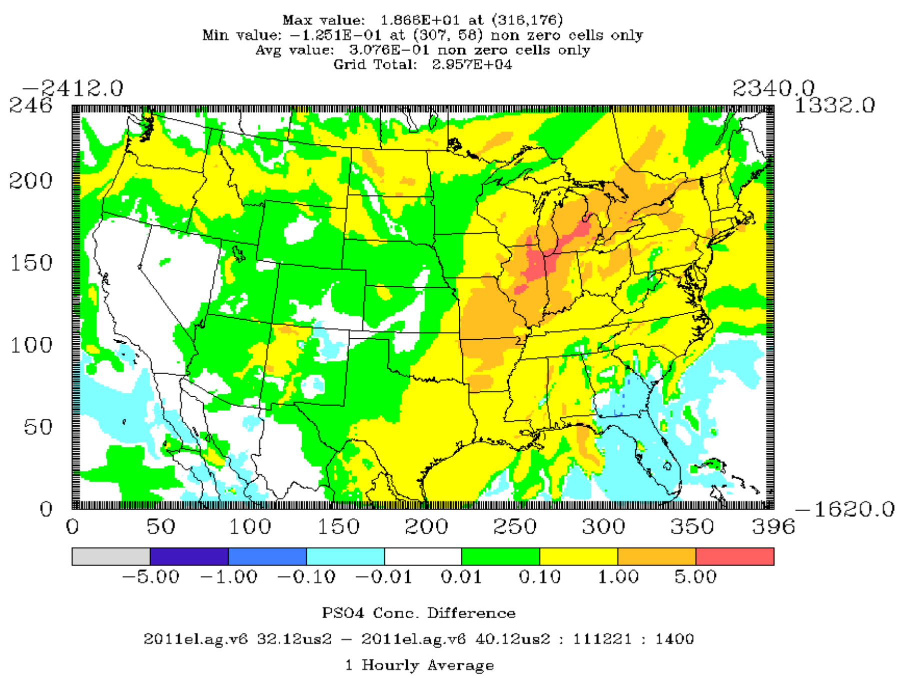
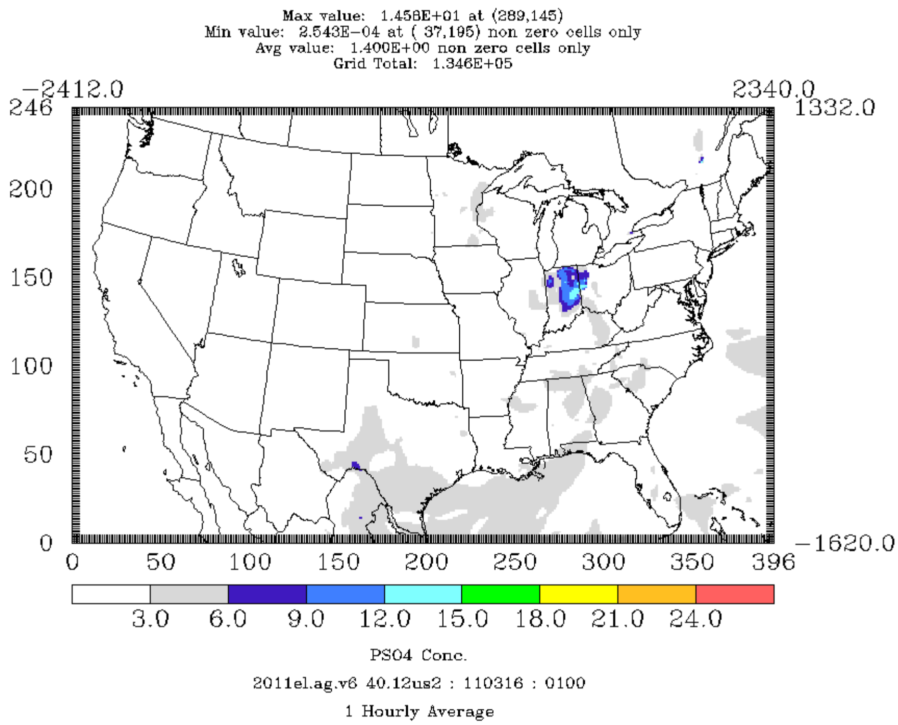


Figure 4-47: Comparison of Sulfate Concentrations (µg/m³) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Fourth Highest Positive Difference)

Fifth Highest Positive Difference: March 16 at 100 hours
CAMx 6.40



Difference (6.32 - 6.40)

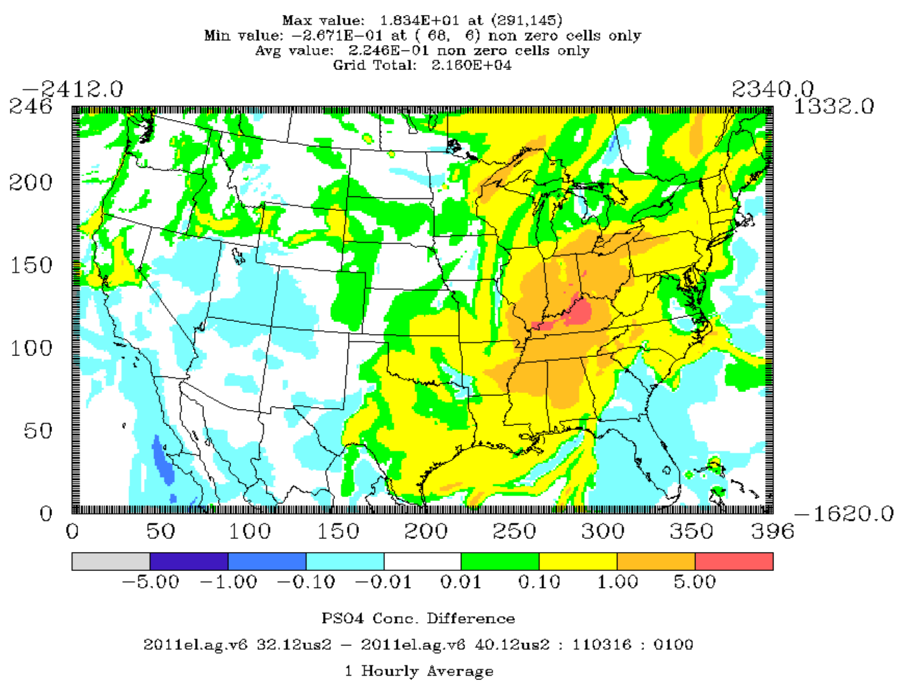
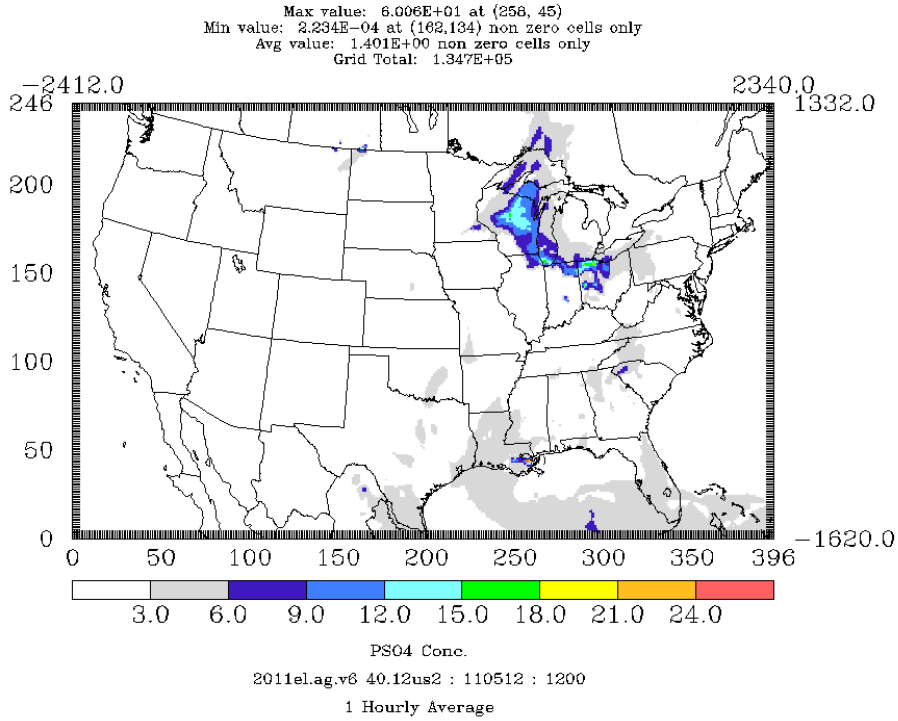


Figure 4-48: Comparison of Sulfate Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Fifth Highest Positive Difference)

Sixth Highest Positive Difference: May 12 at 1200 hours
CAMx 6.40



Difference (6.32 - 6.40)

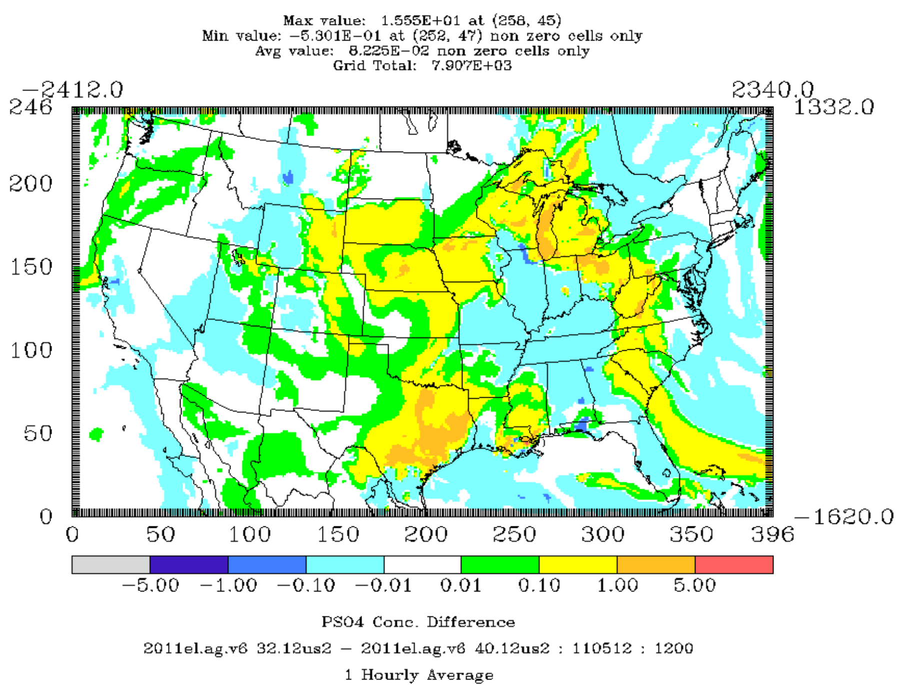
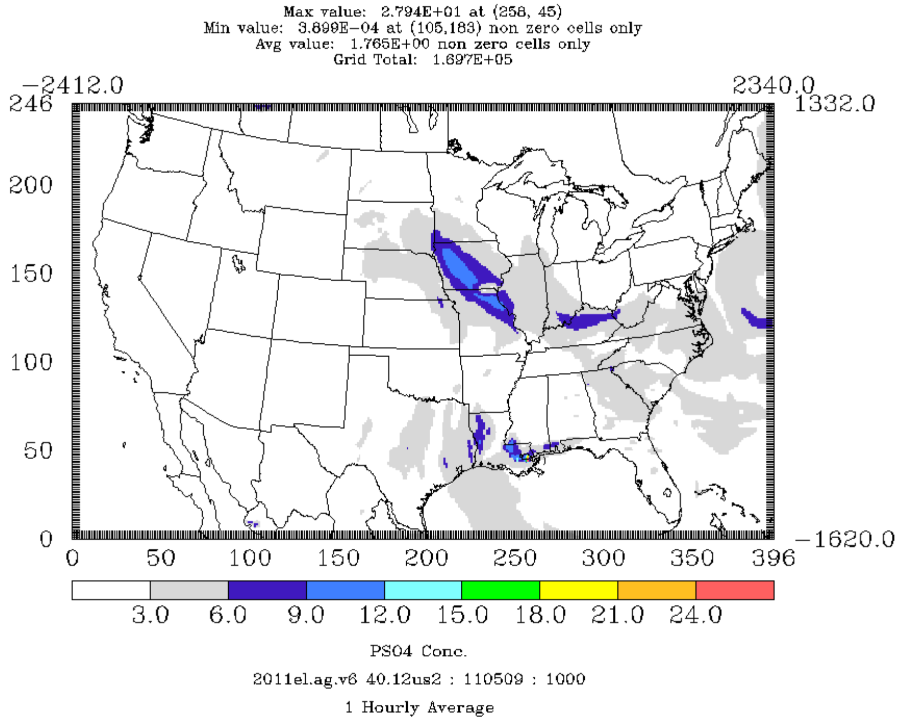


Figure 4-49: Comparison of Sulfate Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Sixth Highest Positive Difference)

Seventh Highest Positive Difference: May 9 at 1000 hours
CAMx 6.40



Difference (6.32 - 6.40)

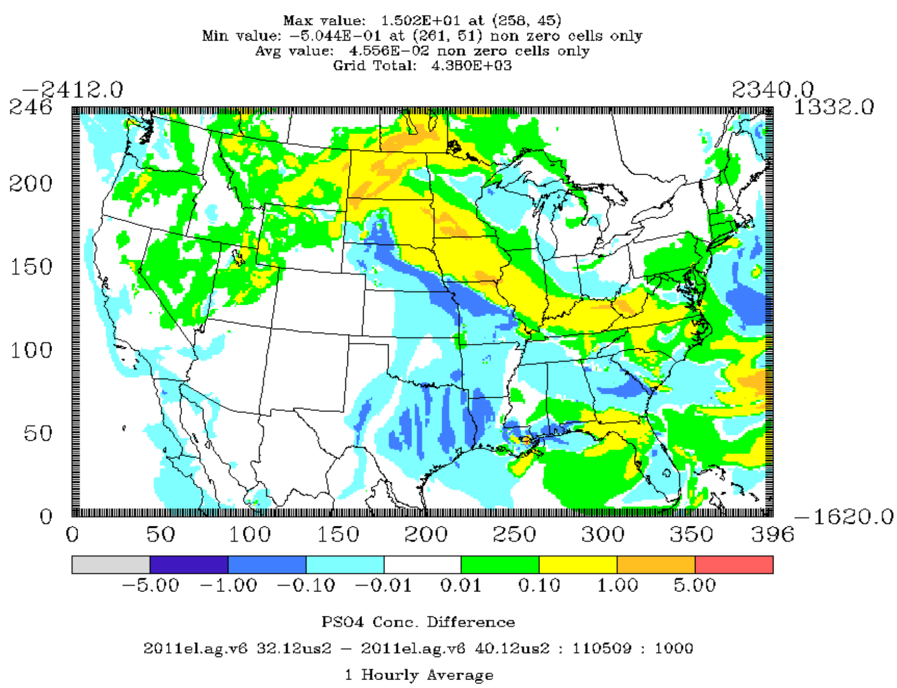
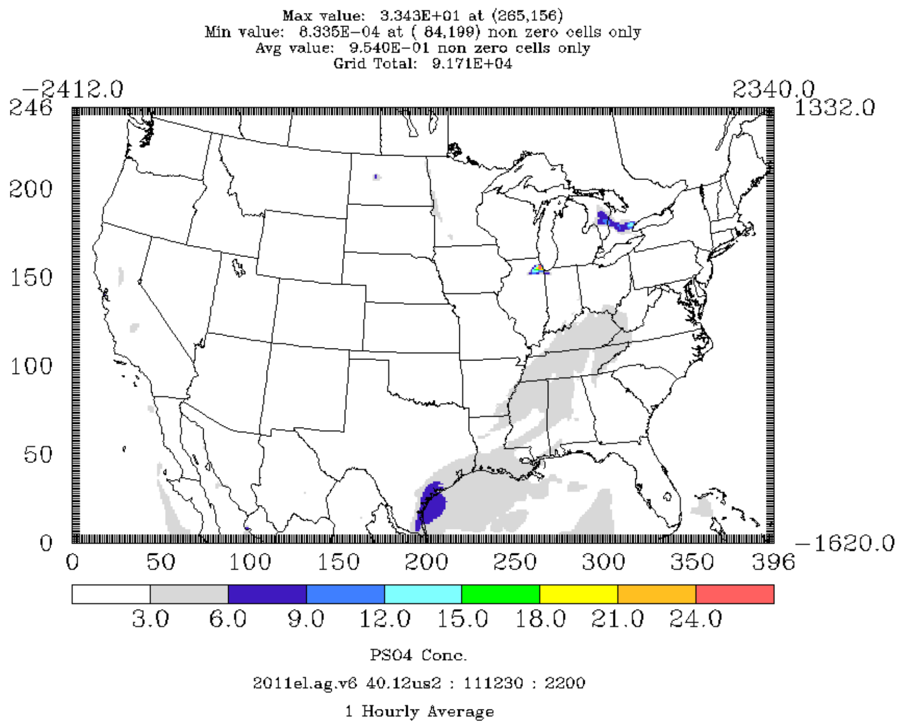


Figure 4-50: Comparison of Sulfate Concentrations (µg/m³) for CAMx 6.32 and CAMx 6.40 2011el Simulations

Eighth Highest Positive Difference: December 30 at 2200 hours

CAMx 6.40



Difference (6.32 - 6.40)

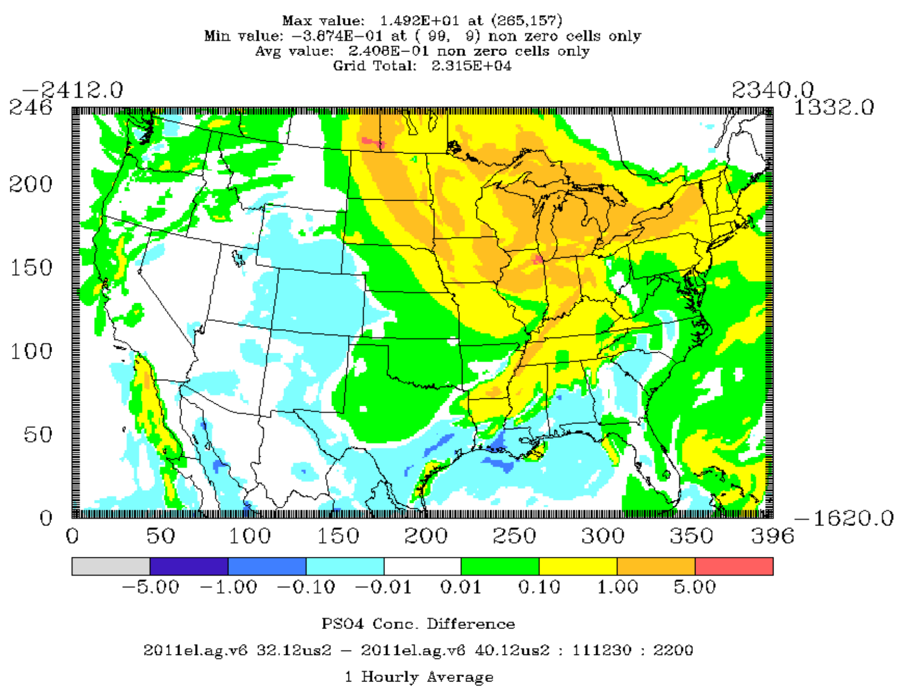
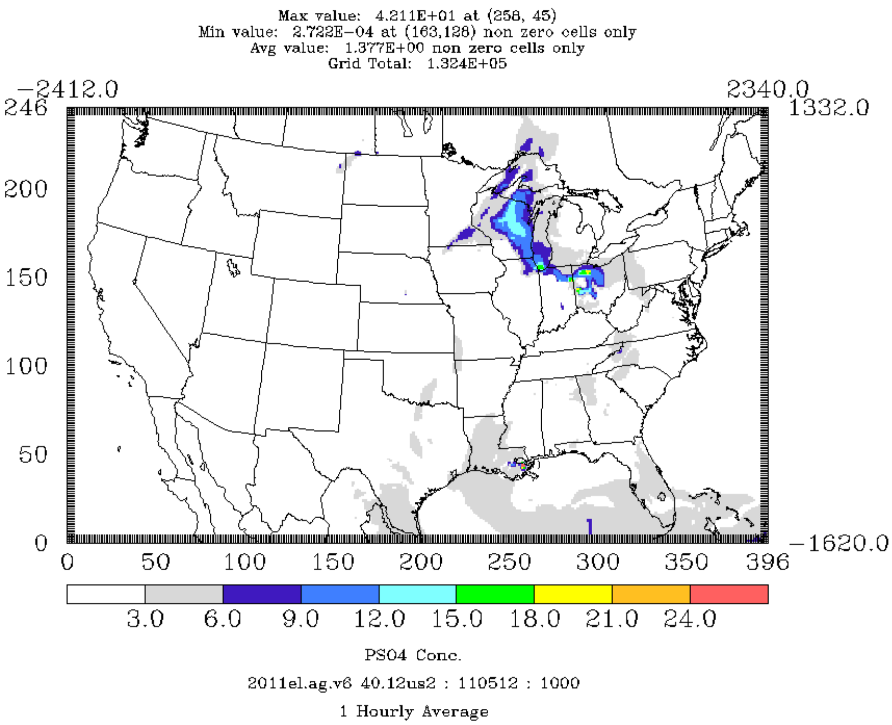


Figure 4-51: Comparison of Sulfate Concentrations (μg/m³) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Eighth Highest Positive Difference)

Ninth Highest Positive Difference: May 12 at 1000 hours

CAMx 6.40



Difference (6.32 - 6.40)

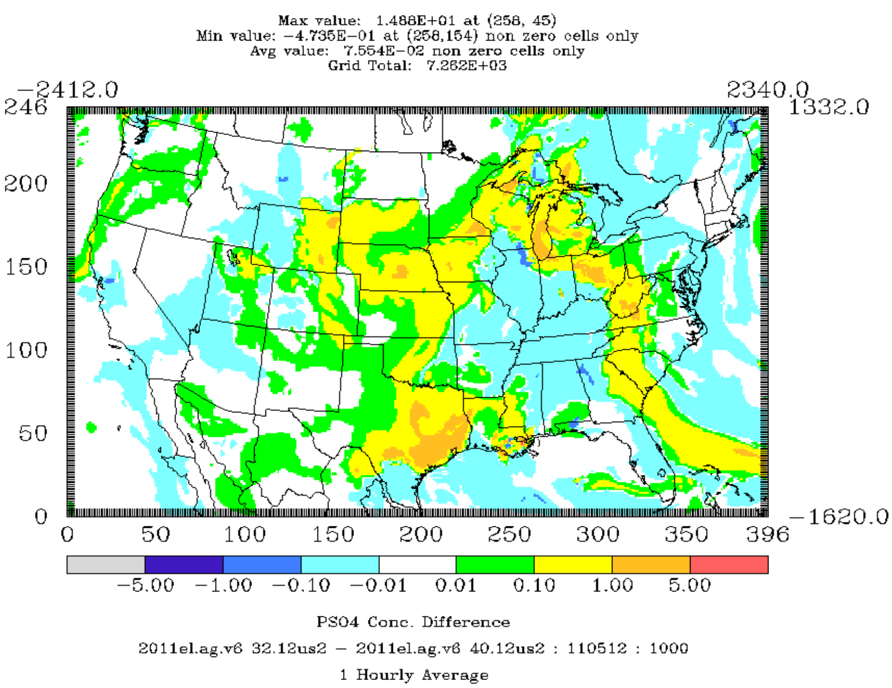
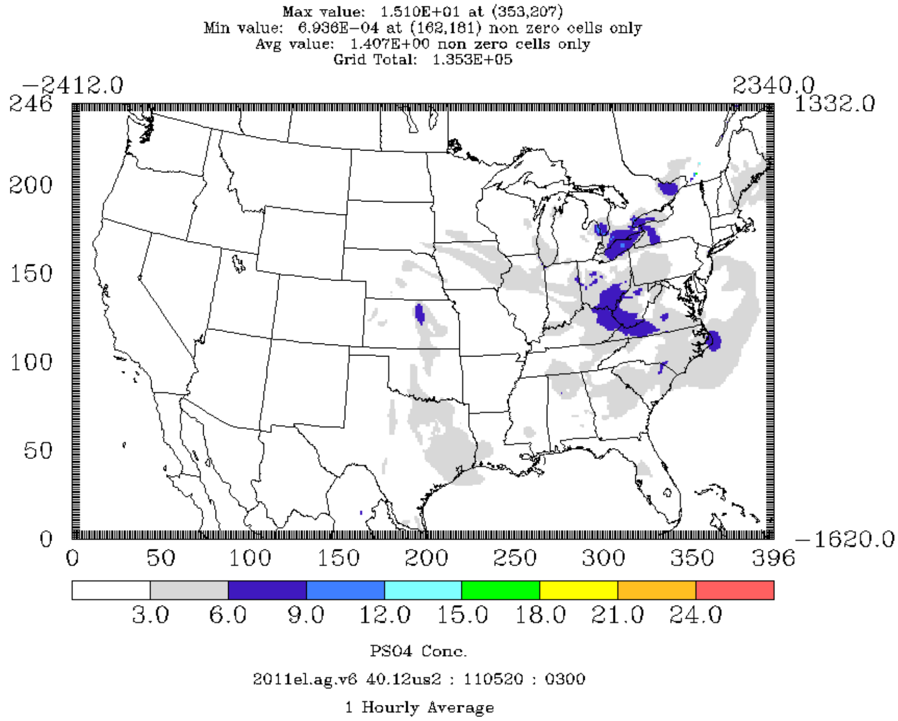


Figure 4-52: Comparison of Sulfate Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Ninth Highest Positive Difference)

Tenth Highest Positive Difference: May 20 at 300 hours

CAMx 6.40



Difference (6.32 - 6.40)

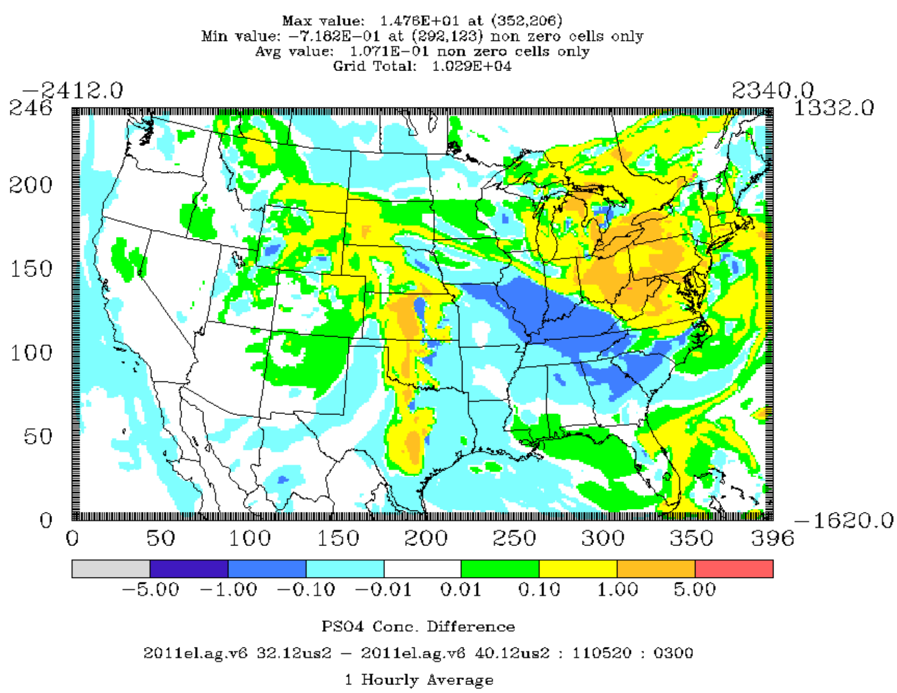
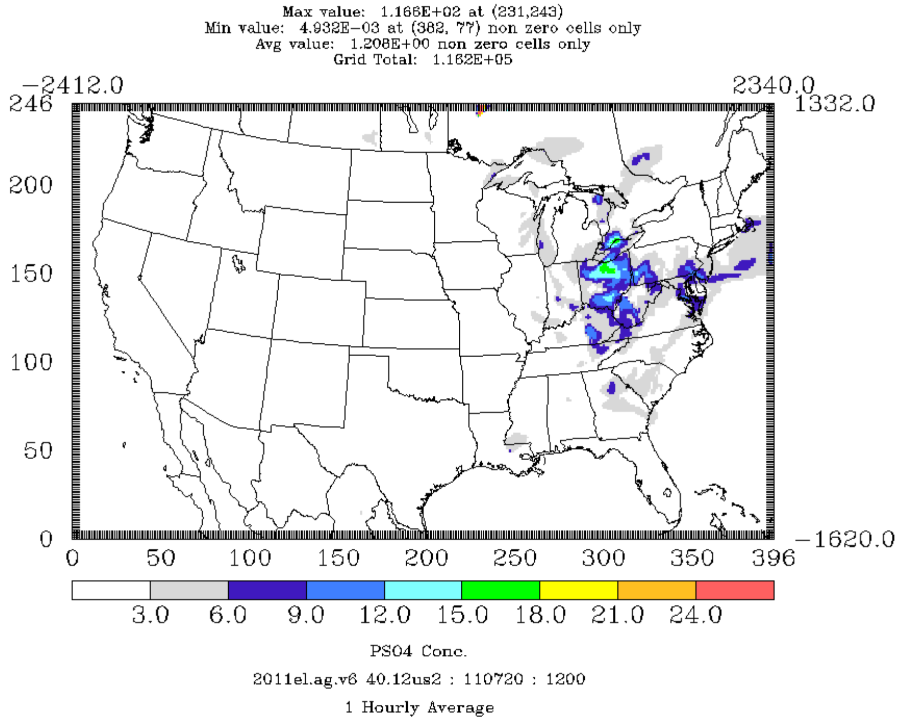


Figure 4-53: Comparison of Sulfate Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Tenth Highest Positive Difference)

Maximum Negative Difference: July 20 at 1200 hours
CAMx 6.40



Difference (6.32 - 6.40)

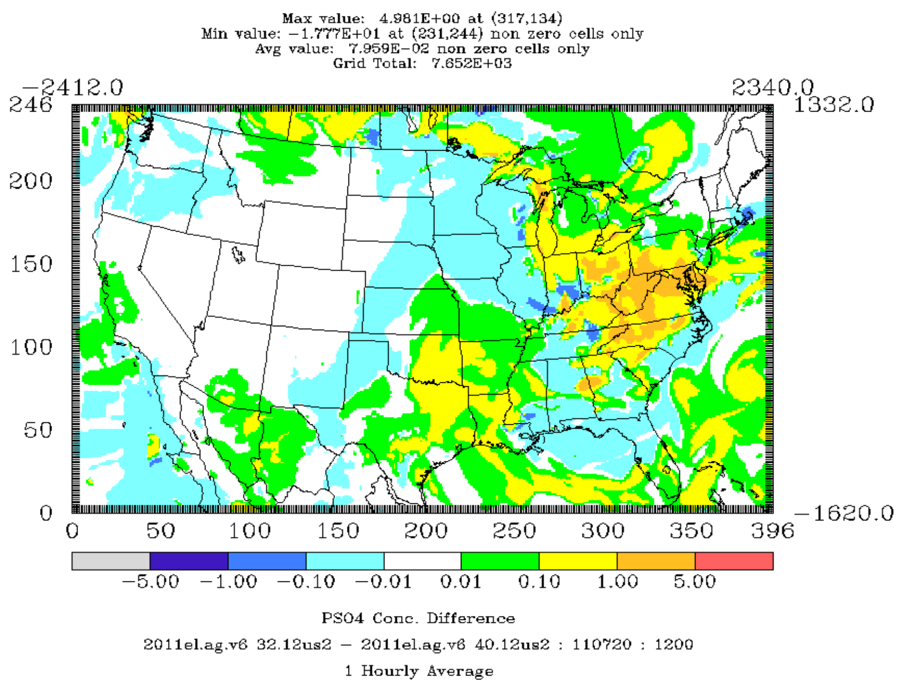
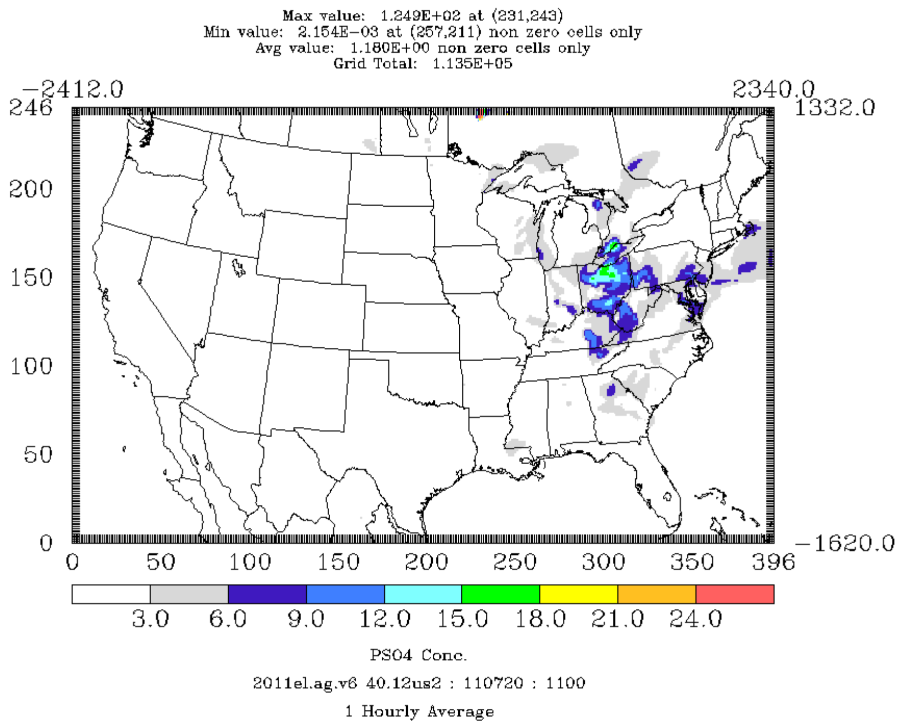


Figure 4-54: Comparison of Sulfate Concentrations (μg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Maximum Negative Difference)

Second Highest Negative Difference: July 20 at 1100 hours

CAMx 6.40



Difference (6.32 - 6.40)

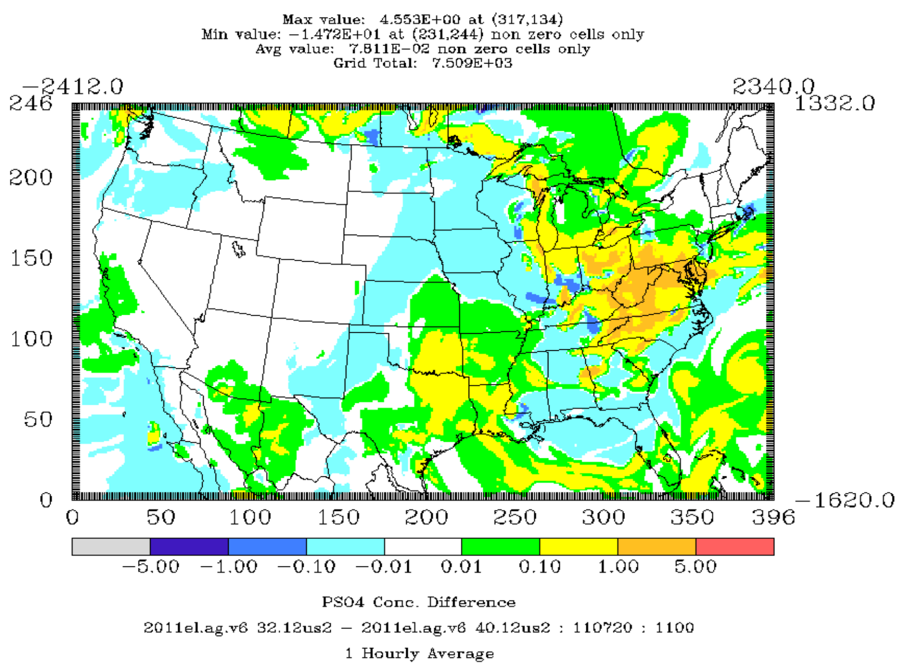
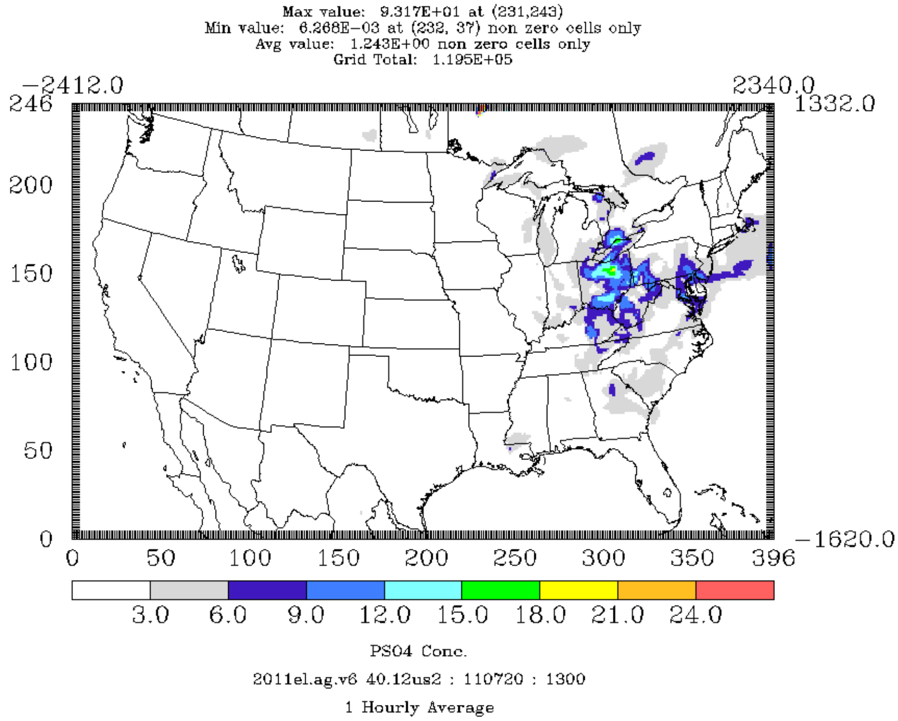


Figure 4-55: Comparison of Sulfate Concentrations (μg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Second Highest Negative Difference)

Third Highest Negative Difference: July 20 at 1300 hours

CAMx 6.40



Difference (6.32 - 6.40)

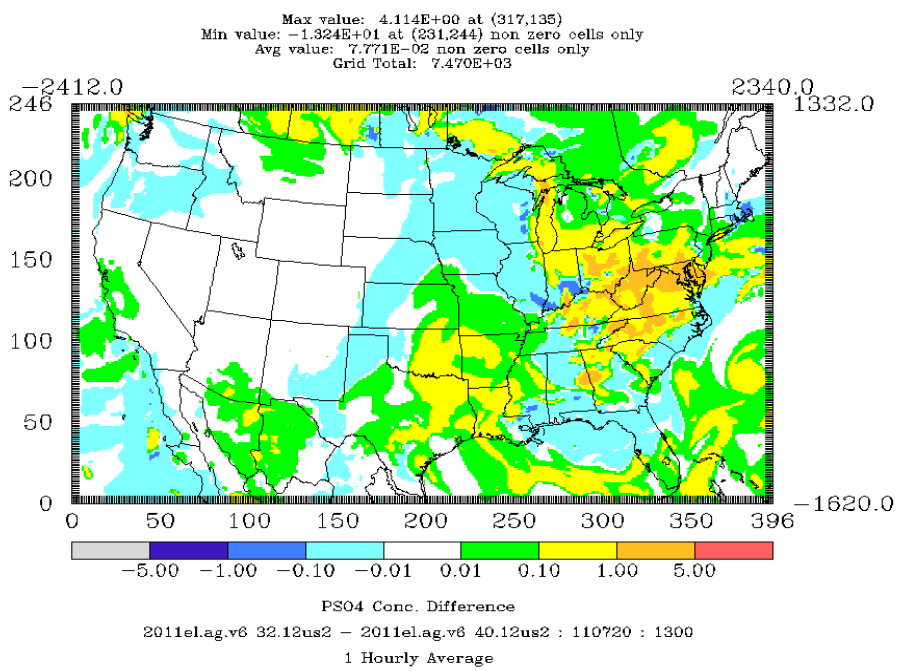


Figure 4-56: Comparison of Sulfate Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Third Highest Negative Difference)

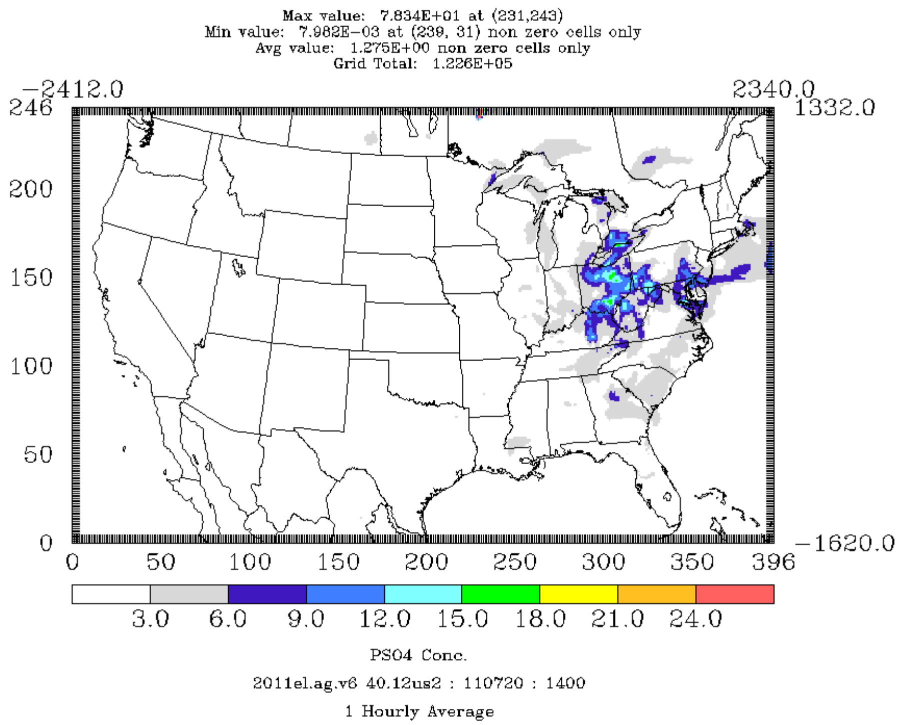
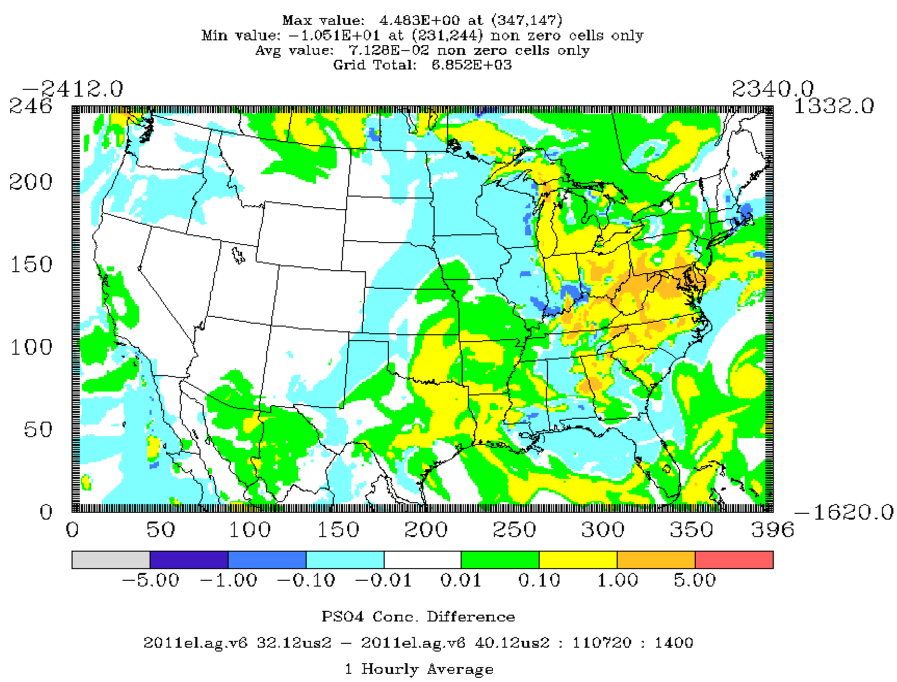
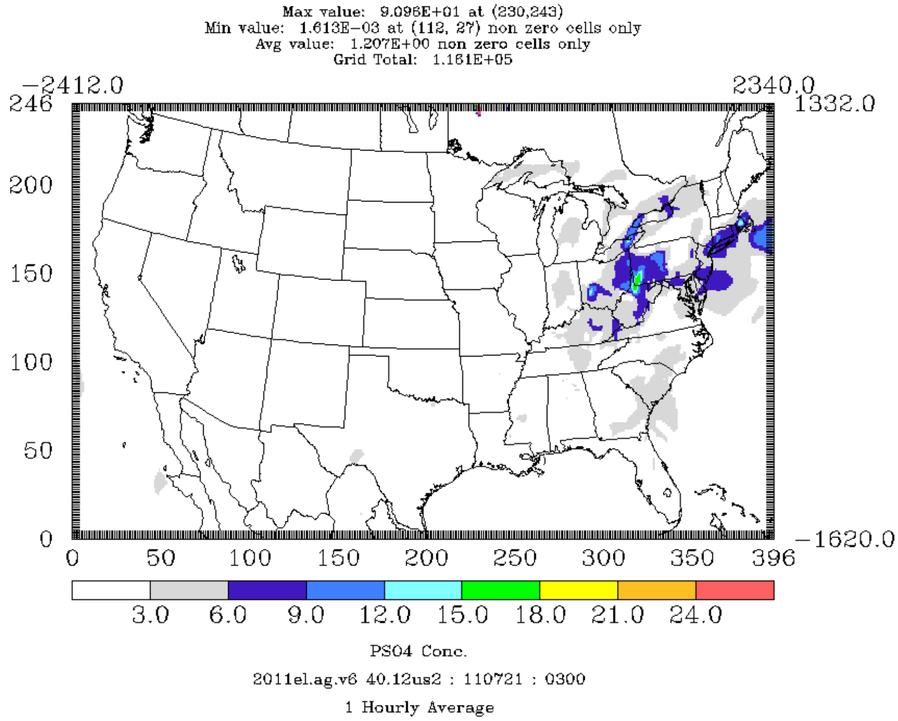
Fourth Highest Negative Difference: July 20 at 1400 hours
CAMx 6.40

Difference (6.32 - 6.40)


Figure 4-57: Comparison of Sulfate Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Fourth Highest Negative Difference)

Fifth Highest Negative Difference: July 21 at 300 hours
CAMx 6.40



Difference (6.32 - 6.40)

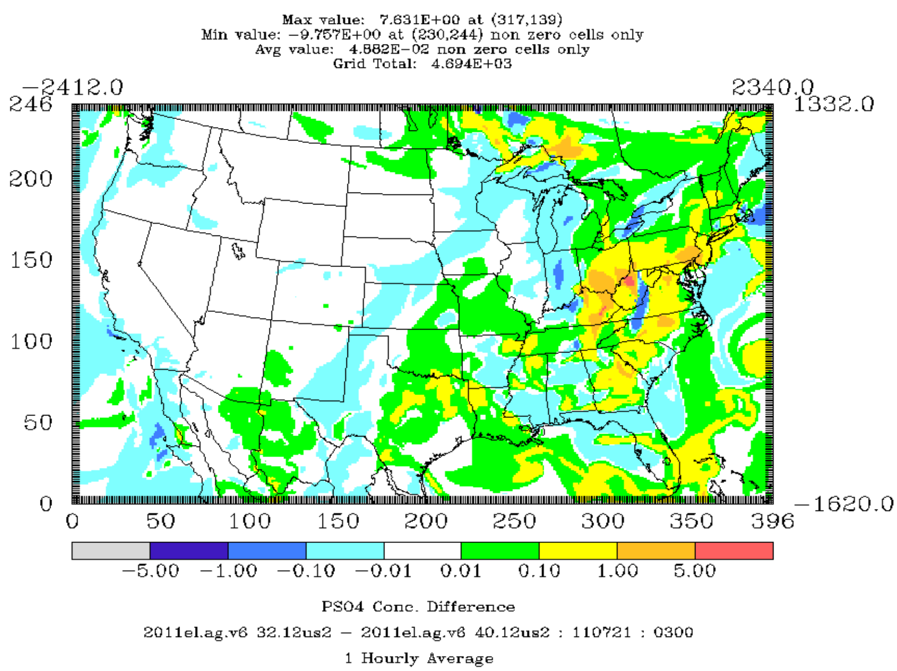
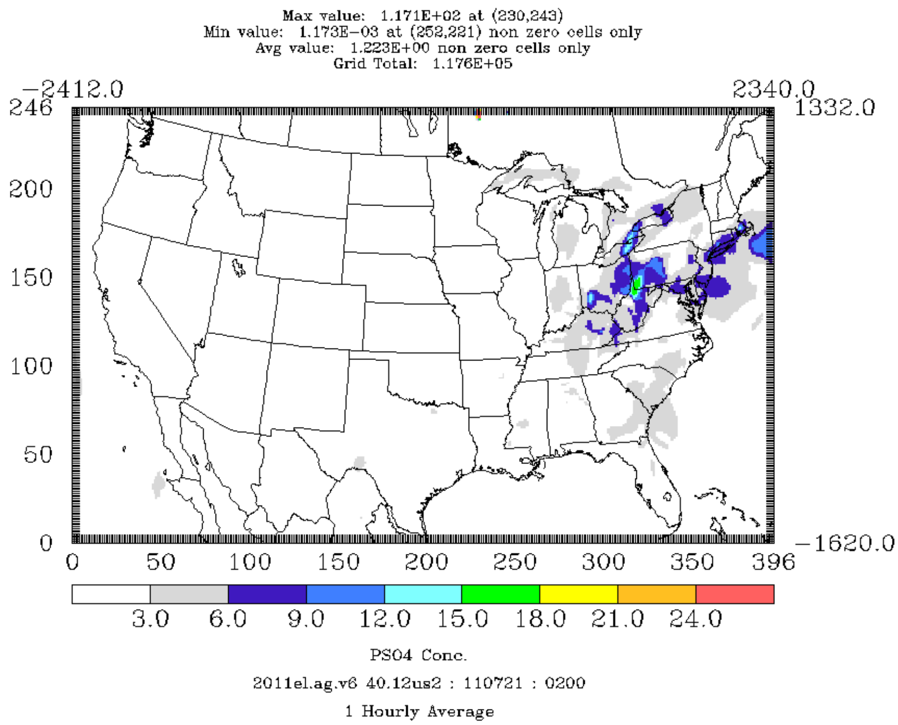


Figure 4-58: Comparison of Sulfate Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Fifth Highest Negative Difference)

Sixth Highest Negative Difference: July 21 at 200 hours
CAMx 6.40



Difference (6.32 - 6.40)

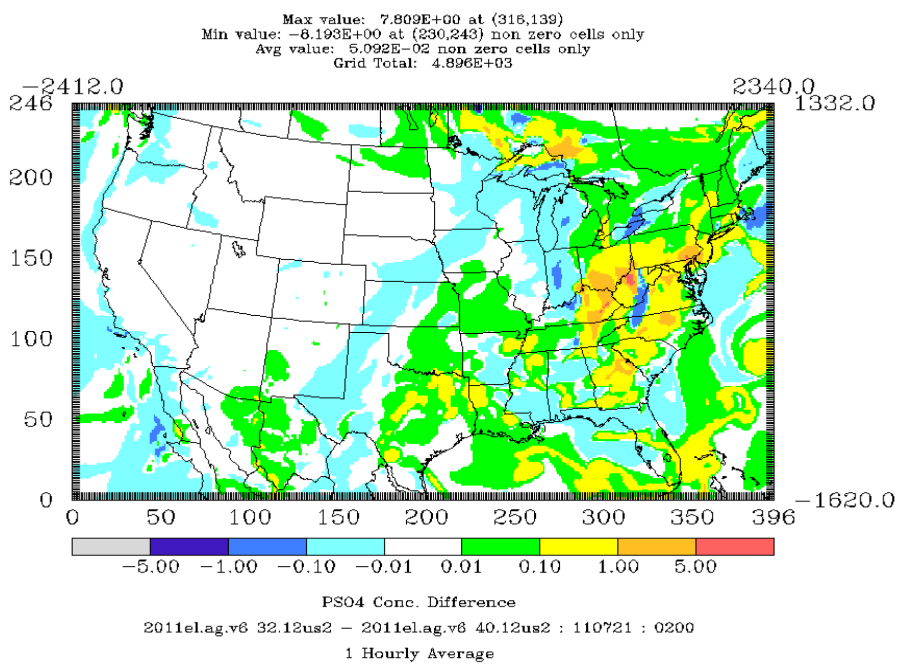
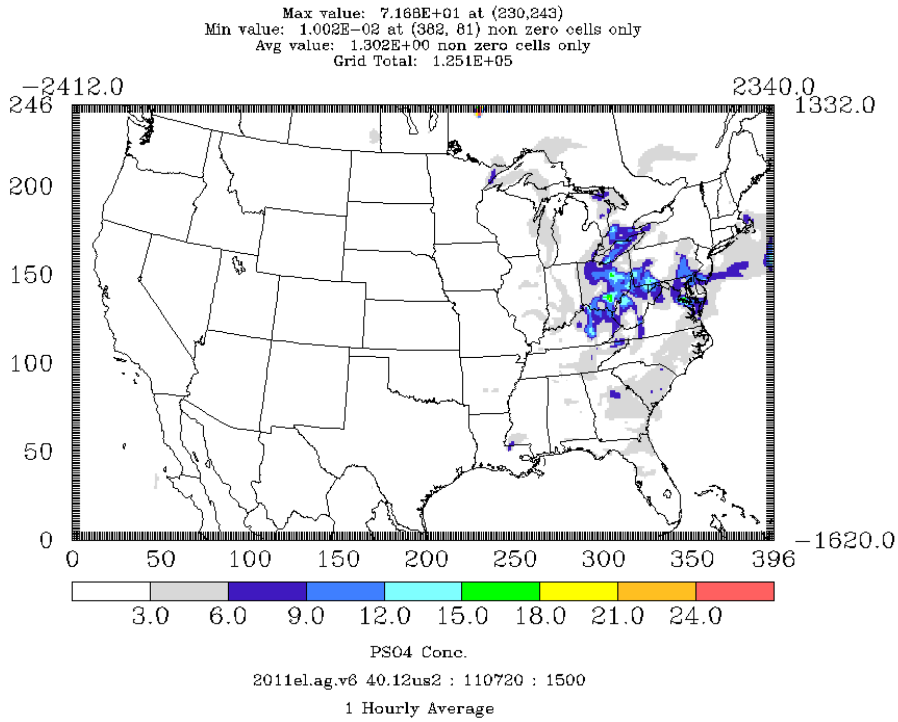


Figure 4-59: Comparison of Sulfate Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Sixth Highest Negative Difference)

Seventh Highest Negative Difference: July 20 at 1500 hours
CAMx 6.40



Difference (6.32 - 6.40)

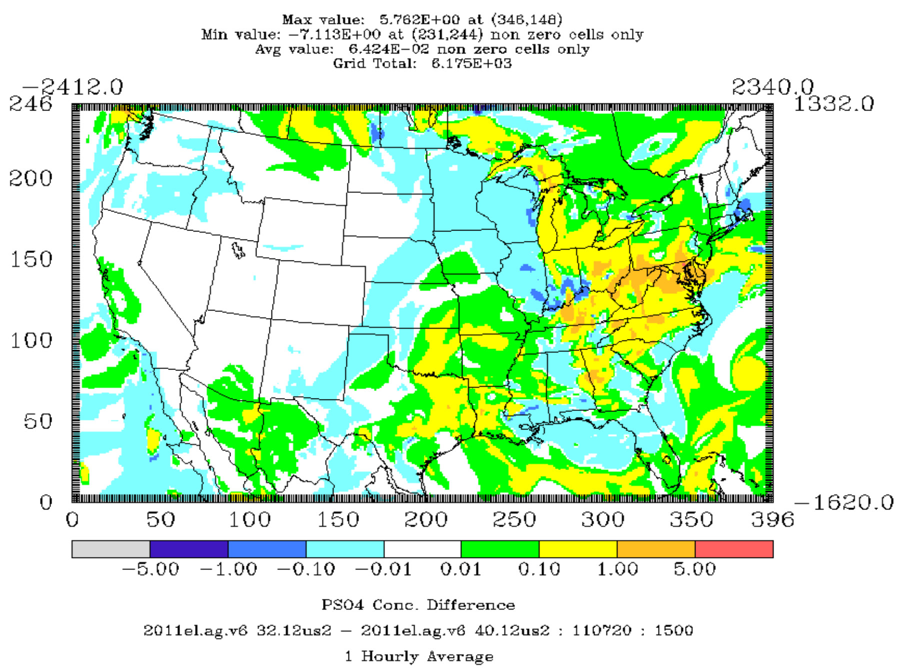


Figure 4-60: Comparison of Sulfate Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Seventh Highest Negative Difference)

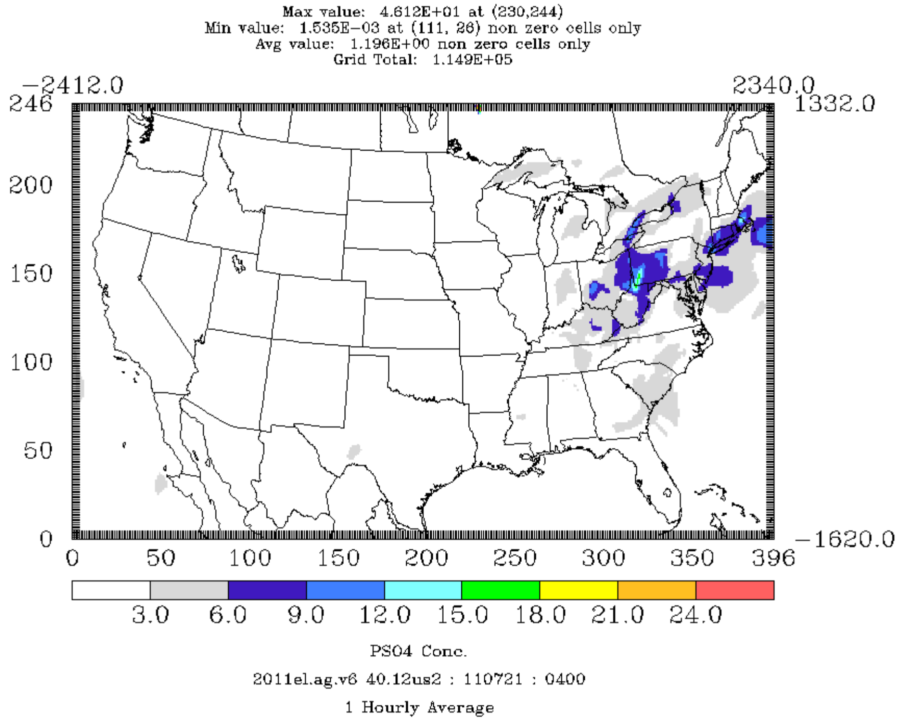
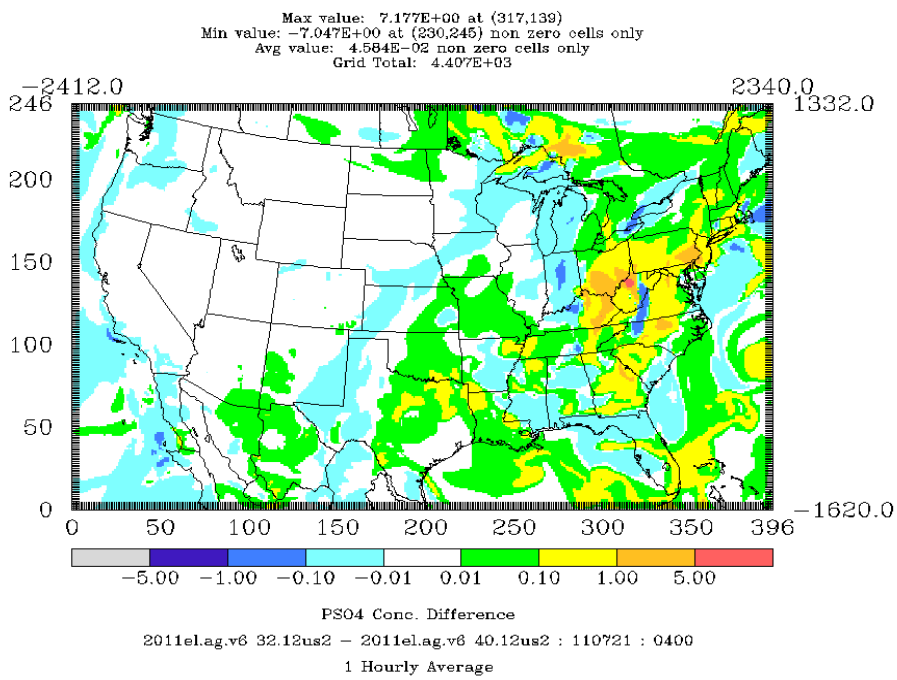
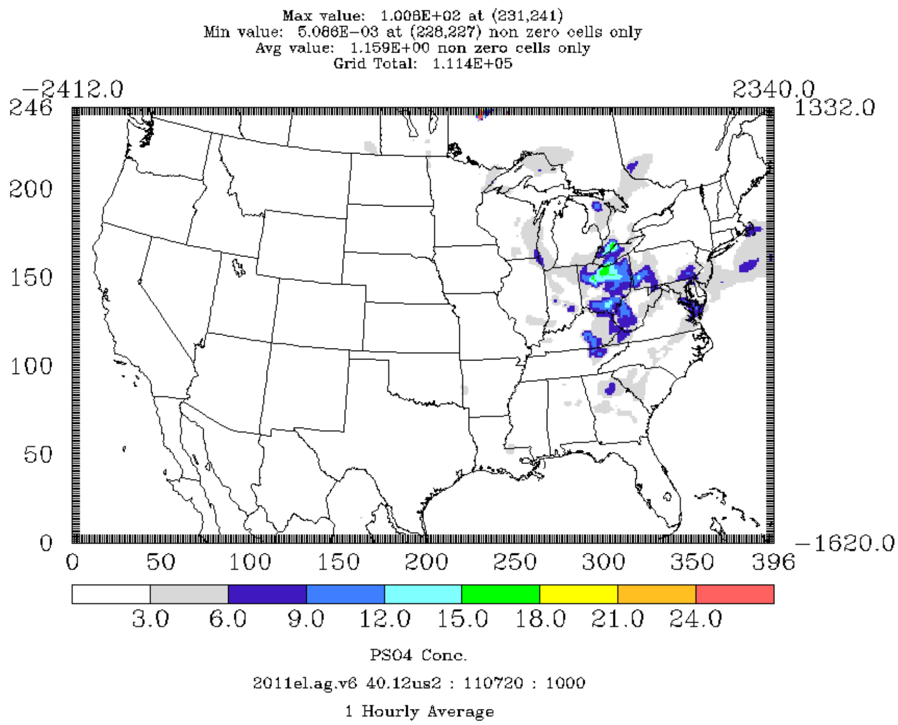
Eighth Highest Negative Difference: July 21 at 400 hours
CAMx 6.40

Difference (6.32 - 6.40)


Figure 4-61: Comparison of Sulfate Concentrations (µg/m³) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Eighth Highest Negative Difference)

Ninth Highest Negative Difference: July 20 at 1000 hours

CAMx 6.40



Difference (6.32 - 6.40)

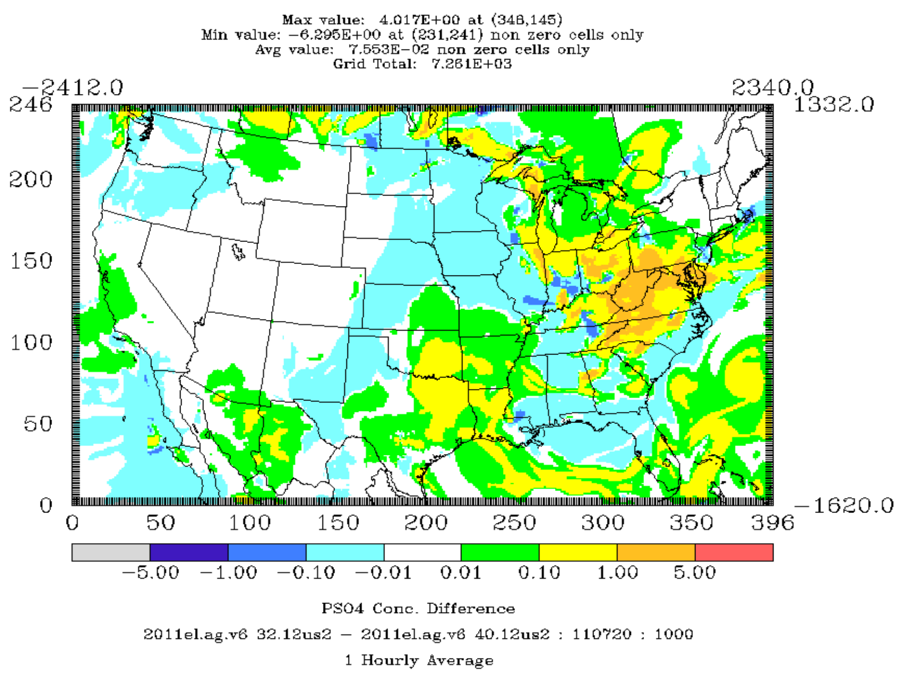
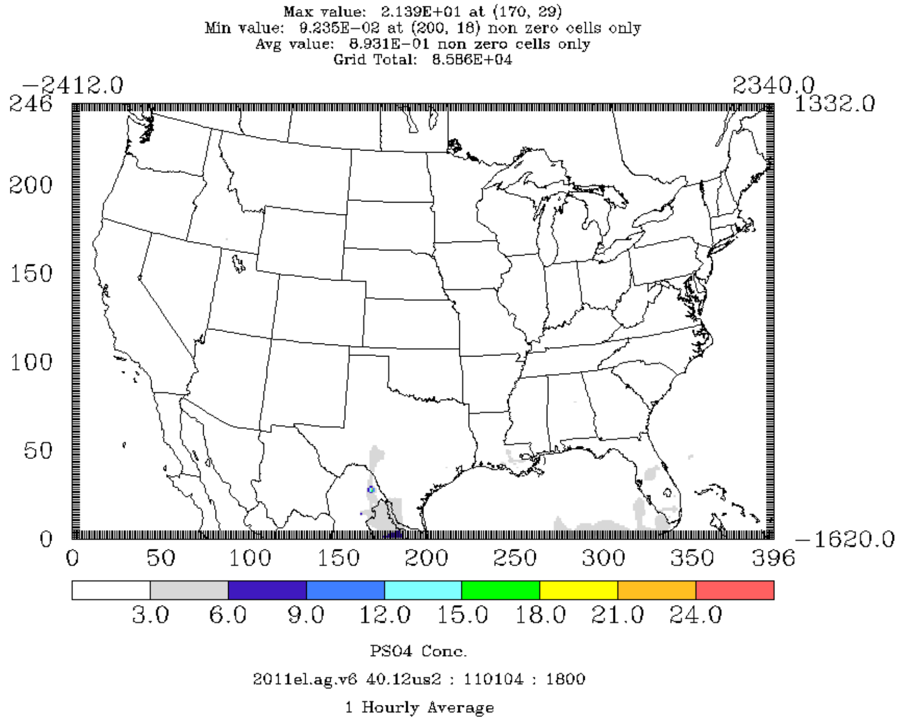


Figure 4-62: Comparison of Sulfate Concentrations (µg/m³) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Ninth Highest Negative Difference)

Tenth Highest Negative Difference: January 4 at 1800 hours

CAMx 6.40



Difference (6.32 - 6.40)

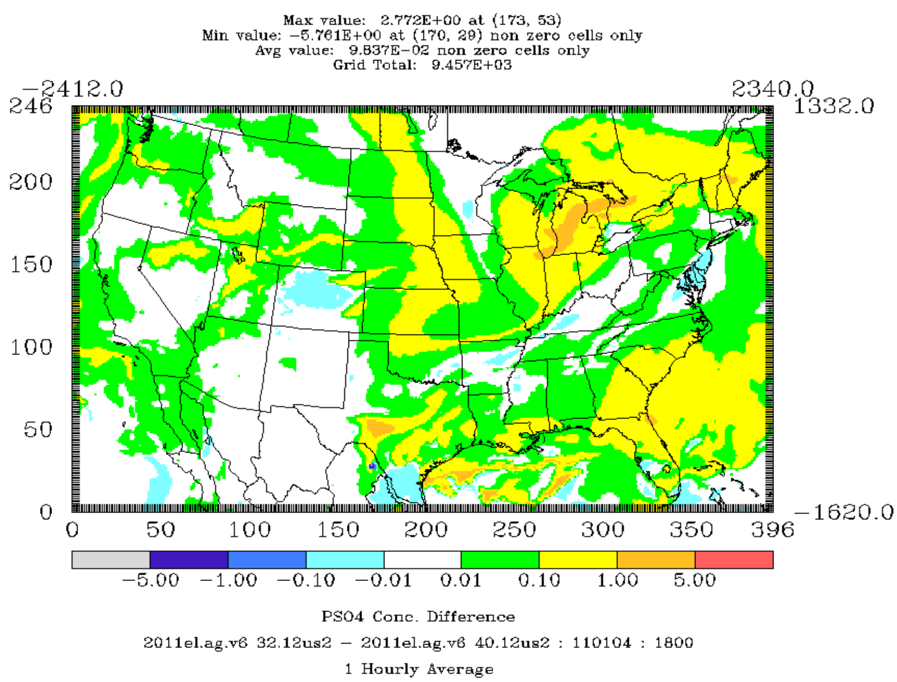


Figure 4-63: Comparison of Sulfate Concentrations (µg/m³) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Tenth Highest Negative Difference)

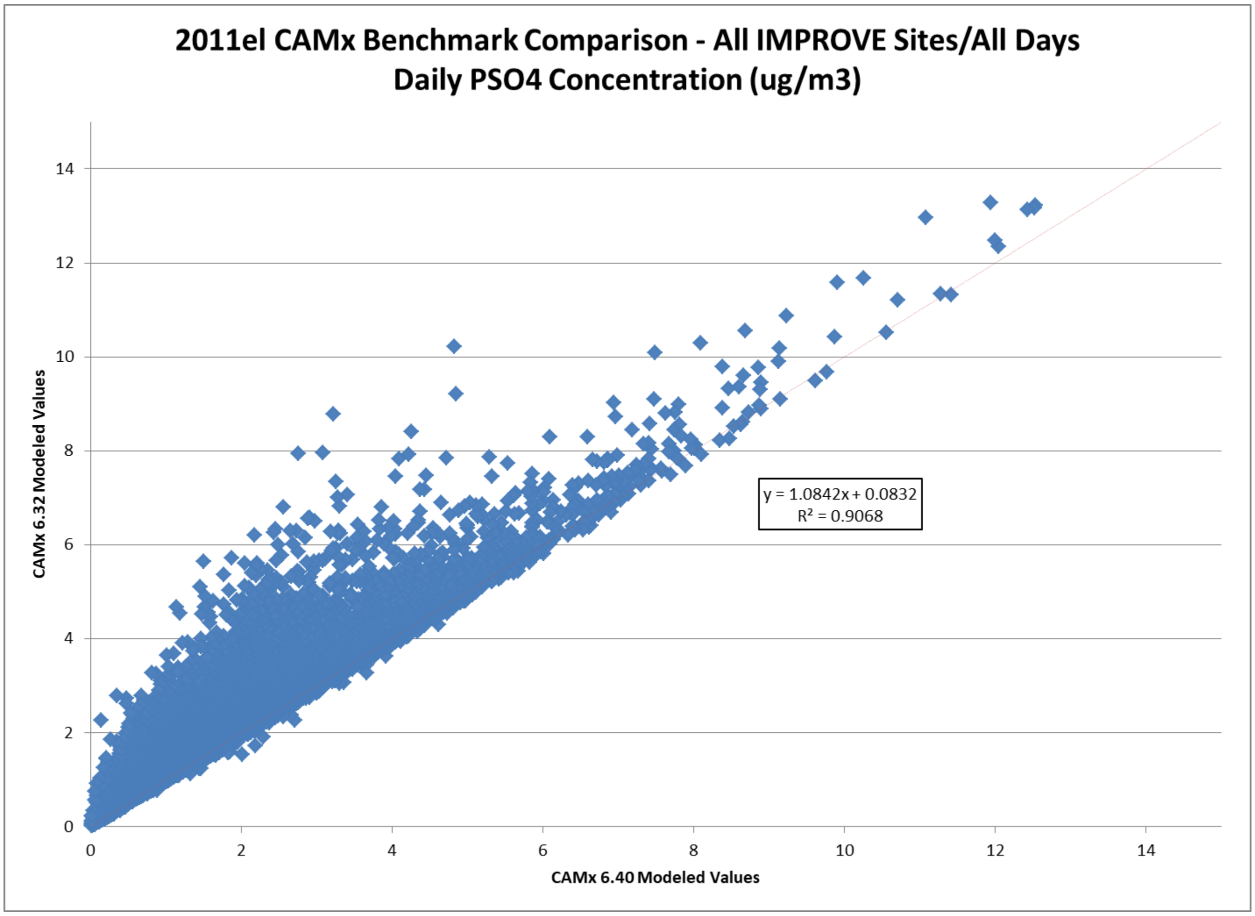


Figure 4-64: Scatterplot Comparing 24-hour Average Predicted Sulfate Concentrations (µg/m³) for All Days at all IMPROVE Monitor Locations for CAMx 6.32 and CAMx 6.40 2011el Simulations Performed by VISTAS (Alpine).

4.4 Nitrate

Nitrate results for the top 10 positive and negative hours are presented in tabular format in Table 4-4. The maximum positive difference is 28.08 μg/m^3 falling to 21.00 μg/m^3 for the 10th high. The maximum negative difference is -7.05 μg/m^3 falling to -6.16 μg/m^3 for the 10th high. The maximum positive percent difference from these days is 2512% and negative percent difference of -79.6%.

The top 10 positive difference hours are presented in Figures 4-65 through 4-74. The maximum positive difference hours all occur on either September 24th or May 14th. On September 24th the peak impacts are in Canada just north of the New York border. On May 14th the peak impacts are again in Canada, but somewhat further west, north of Lake Erie.

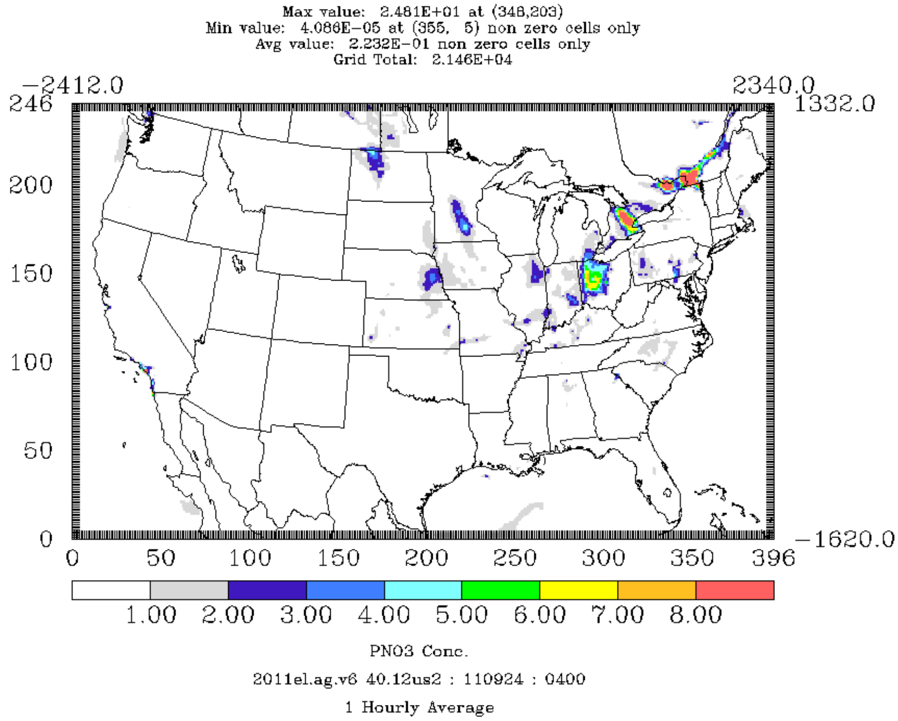
The top 10 negative difference hours are presented in Figures 4-75 through 4-84. The peak hours are either on January 25th, January 26th, or February 1. For the January days the peak impact is occurring in southern Indiana. For the February day the peak impact is in eastern Oklahoma. These are both areas for high local nitrate concentrations in CAMx 6.40.

Scatterplots of the daily average nitrate concentrations in local standard time at the IMPROVE monitors are presented in Figure 4-85. The CAMx 6.40 results are plotted on the x-axis and the CAMx 6.32 results are plotted on the y-axis. The data has considerably more scatter than the ozone or $PM_{2.5}$ results with a line of best fit with a slope of 0.9276, an intercept of 0.0013 μg/m^3 and an R^2 of 0.9635. Unlike the sulfate results which showed the CAMx 6.32 results nearly uniformly higher that CAMx 6.40, the nitrate results show more uniform scatter around the 1:1 line. Nitrate in most inland areas of the eastern U.S. appears slightly higher in v6.4 during the majority of hours. Superimposed on this slight increase there are occasional periods where when CAMx 6.40 is lower than CAMx 6.32, and other periods when CAMx 6.40 is higher than CAMx 6.32. The net results demonstrate a fairly uniform scatter around the 1:1 line.

Table 4-4. Comparison of 2011el CAMx 6.32 and CAMx 6.40 Simulation of Nitrate Concentrations (µg/m³). Hours with the top 10 maximum positive and maximum negative differences are shown.

Year	Month	Day	Hour	6.32 Conc.	6.40 Conc.	Difference (µg/m³)	Percent Difference	Column	Row
Maximum Positive									
2011	9	24	4	30.90	2.82	28.08	997.3%	342	201
2011	9	24	3	32.93	5.53	27.40	495.7%	343	201
2011	5	14	13	31.25	4.39	26.86	611.1%	306	181
2011	5	14	14	27.89	1.67	26.22	1570.6%	305	182
2011	5	14	15	26.94	1.03	25.91	2512.0%	305	182
2011	9	24	5	29.33	3.63	25.70	708.6%	342	200
2011	5	14	12	33.53	8.61	24.92	289.6%	306	181
2011	5	14	16	24.38	1.67	22.71	1362.8%	305	182
2011	5	14	11	33.01	10.58	22.43	211.9%	306	180
2011	9	24	6	27.46	6.47	21.00	324.7%	341	199
Maximum Negative									
2011	1	25	22	2.57	9.62	-7.05	-73.3%	274	122
2011	1	25	21	4.19	11.19	-7.00	-62.5%	274	123
2011	1	25	23	2.75	9.67	-6.92	-71.6%	274	120
2011	1	25	20	5.50	12.17	-6.68	-54.9%	274	123
2011	1	26	0	2.61	9.27	-6.66	-71.9%	274	119
2011	2	1	6	1.68	8.23	-6.55	-79.6%	220	92
2011	2	1	5	1.56	8.08	-6.52	-80.7%	219	92
2011	1	25	19	6.37	12.59	-6.22	-49.4%	274	124
2011	1	26	3	4.80	10.99	-6.20	-56.4%	279	149
2011	2	1	4	2.68	8.84	-6.16	-69.6%	211	86

Maximum Positive Difference: September 24 at 400 hours
CAMx 6.40



Difference (6.32 - 6.40)

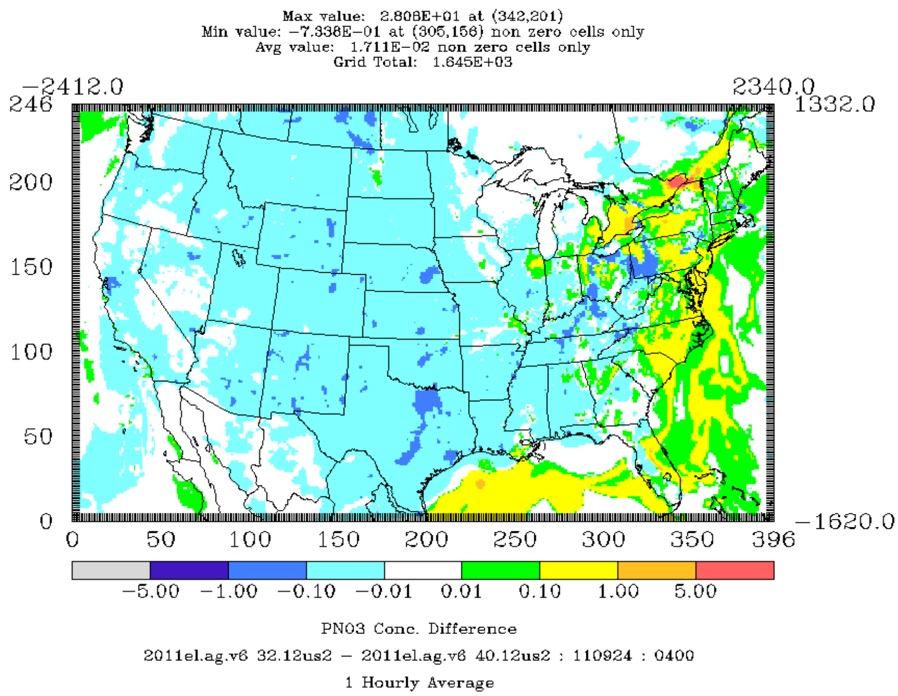
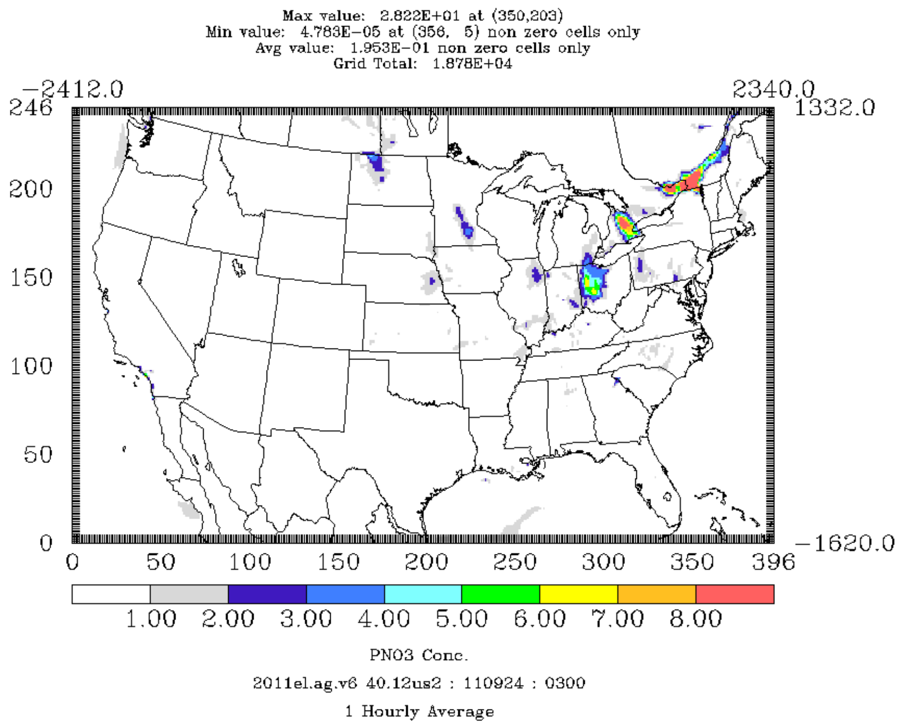


Figure 4-65: Comparison of Nitrate Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Maximum Positive Difference)

Second Highest Positive Difference: September 24 at 300 hours
CAMx 6.40



Difference (6.32 - 6.40)

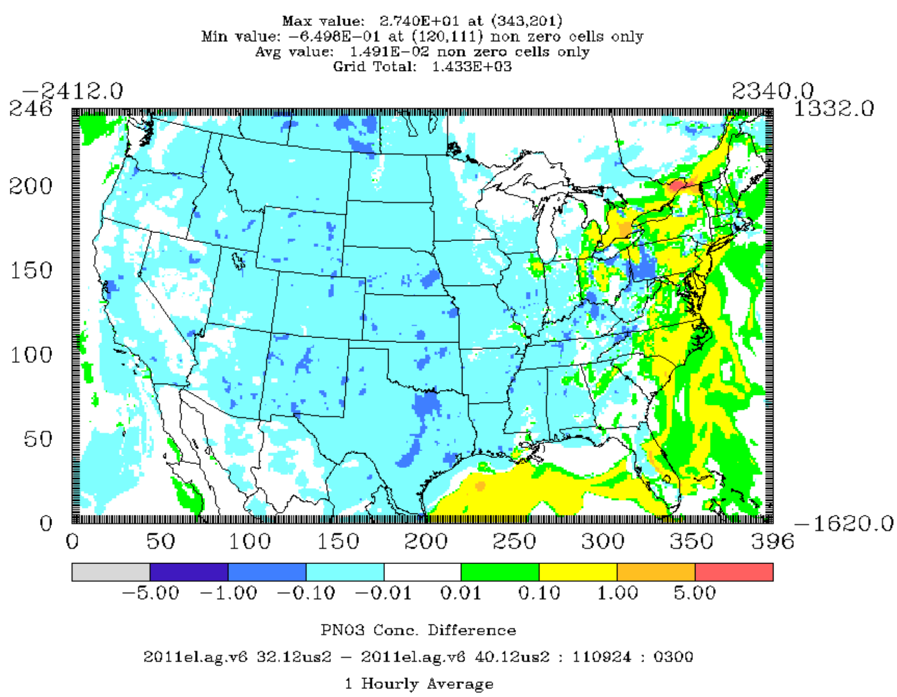
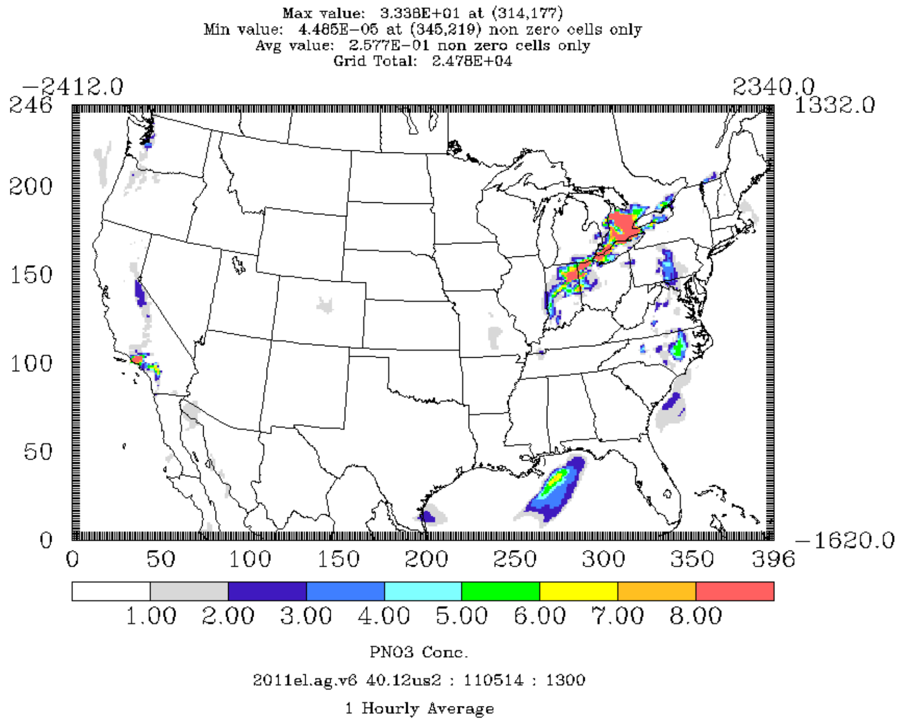


Figure 4-66: Comparison of Nitrate Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Second Highest Positive Difference)

Third Highest Positive Difference: May 14 at 1300 hours

CAMx 6.40



Difference (6.32 - 6.40)

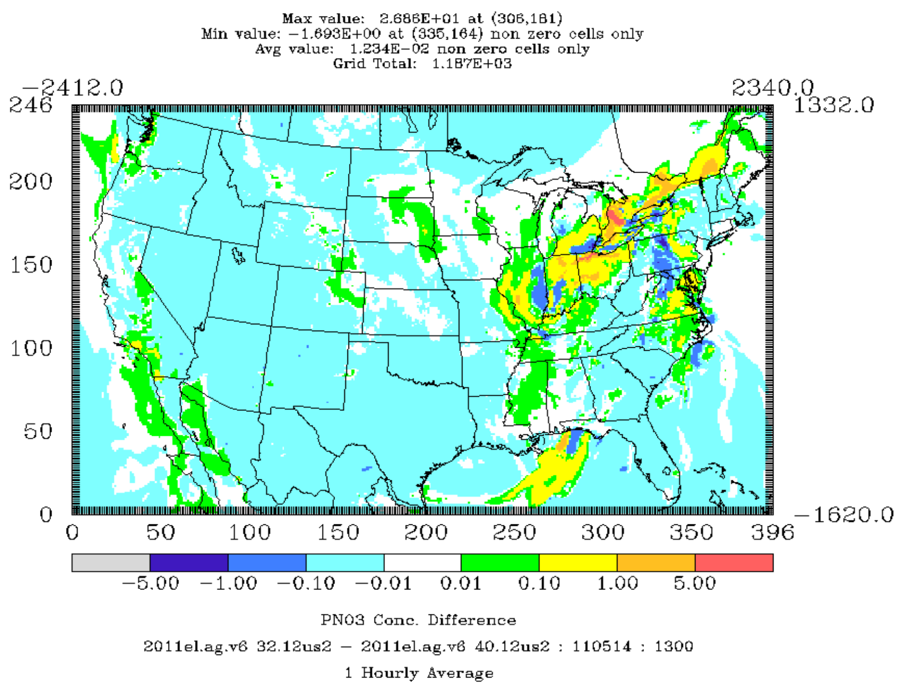
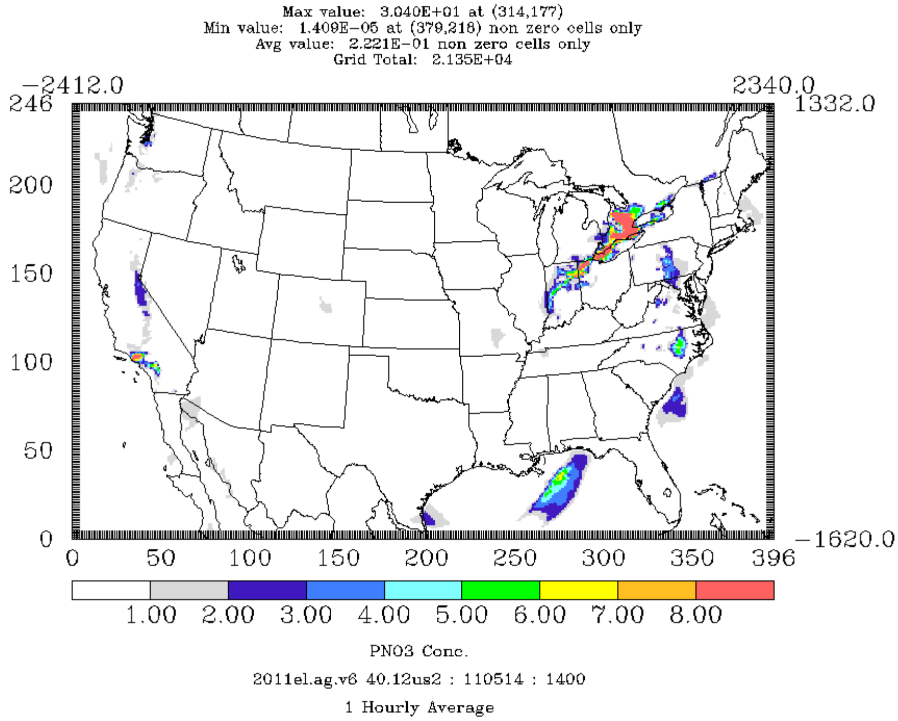


Figure 4-67: Comparison of Nitrate Concentrations (μg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Third Highest Positive Difference)

Fourth Highest Positive Difference: May 14 at 1400 hours
CAMx 6.40



Difference (6.32 - 6.40)

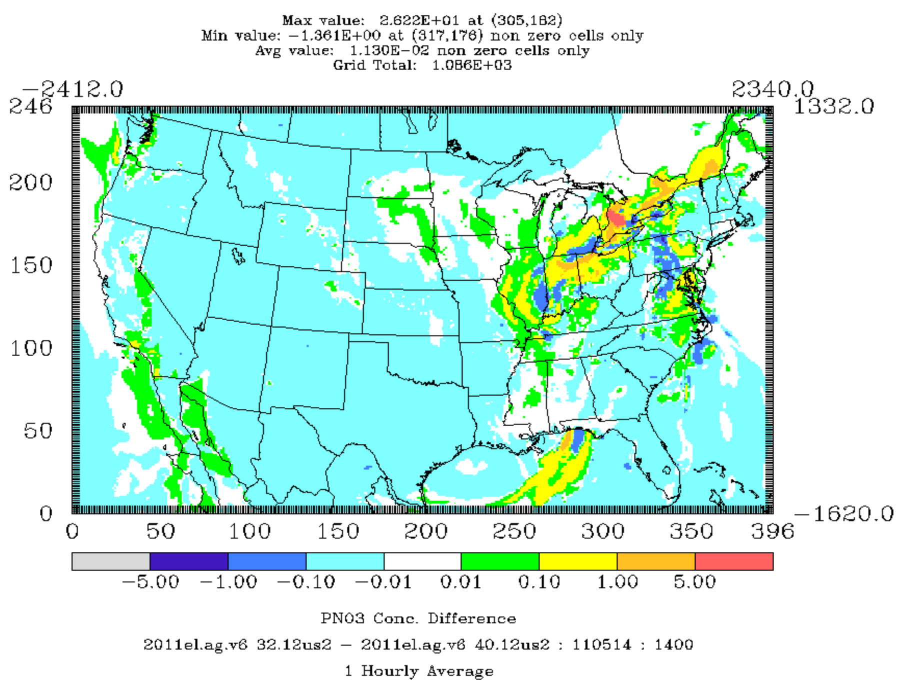
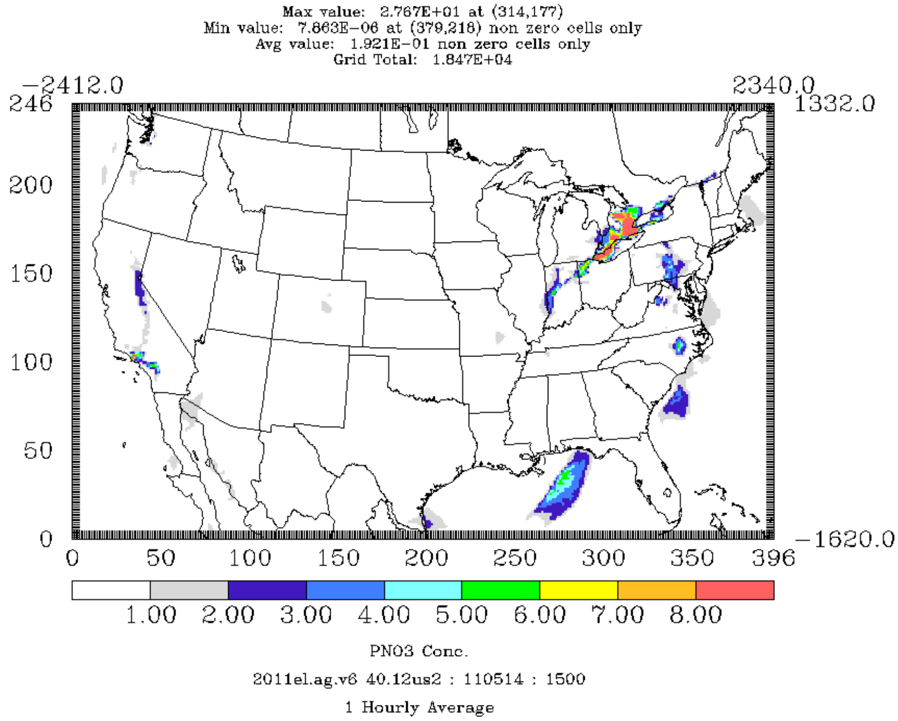


Figure 4-68: Comparison of Nitrate Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Fourth Highest Positive Difference)

Fifth Highest Positive Difference: May 14 at 1500 hours

CAMx 6.40



Difference (6.32 - 6.40)

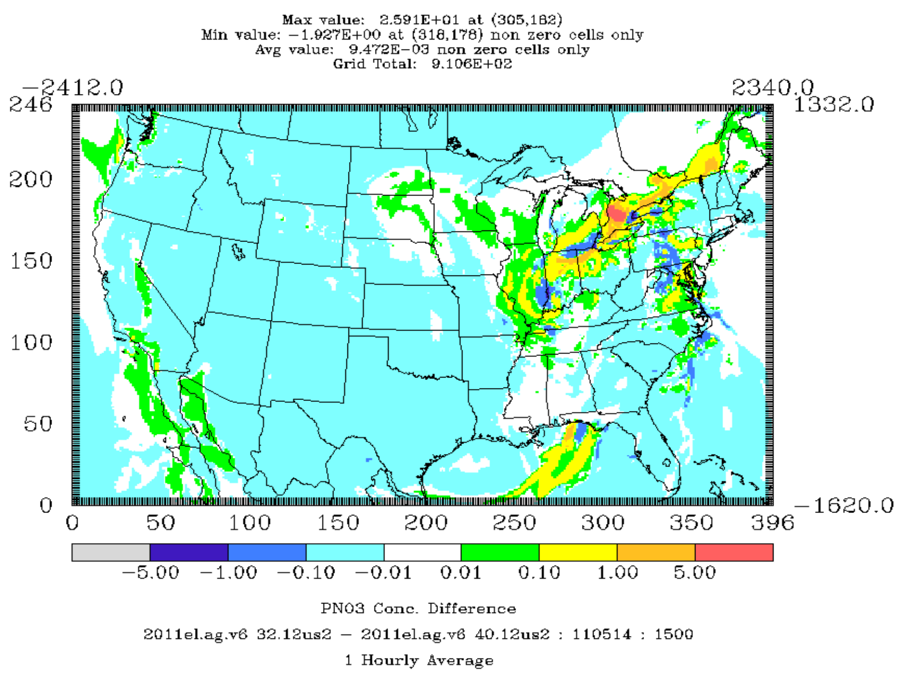
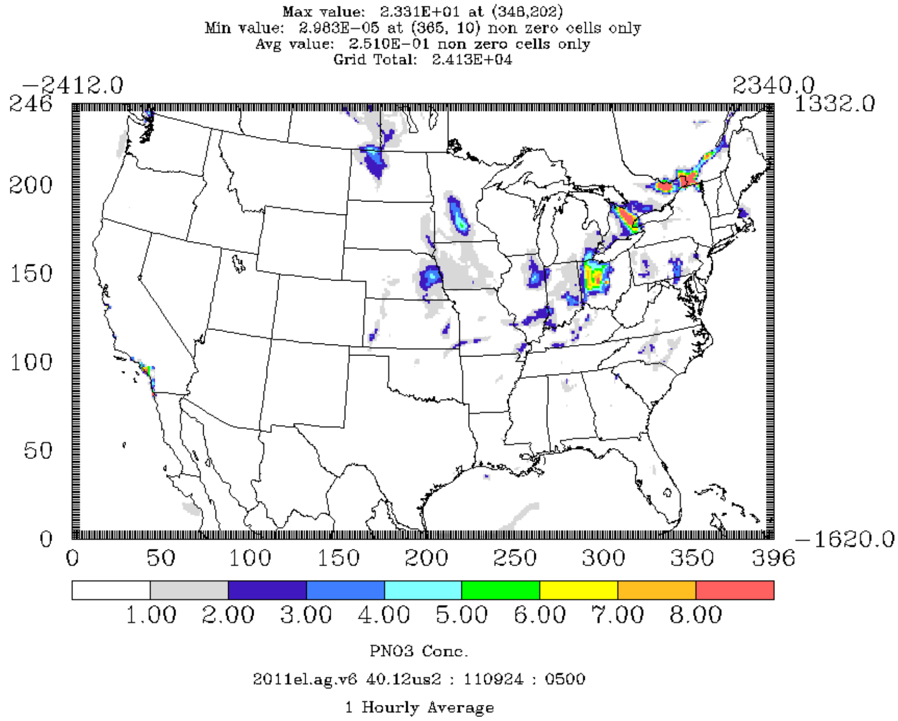


Figure 4-69: Comparison of Nitrate Concentrations (µg/m³) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Fifth Highest Positive Difference)

Sixth Highest Positive Difference: September 24 at 500 hours
CAMx 6.40



Difference (6.32 - 6.40)

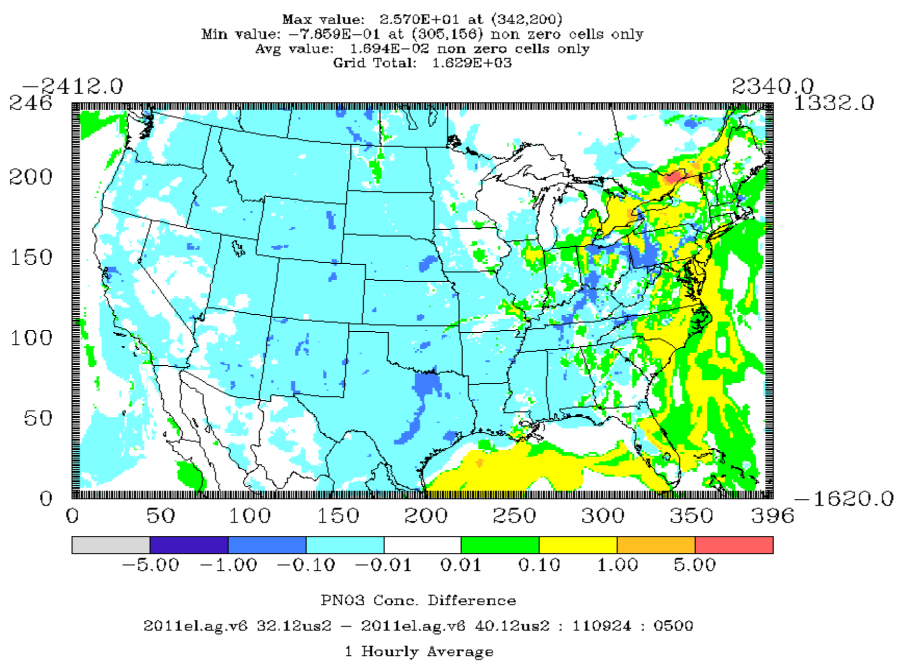
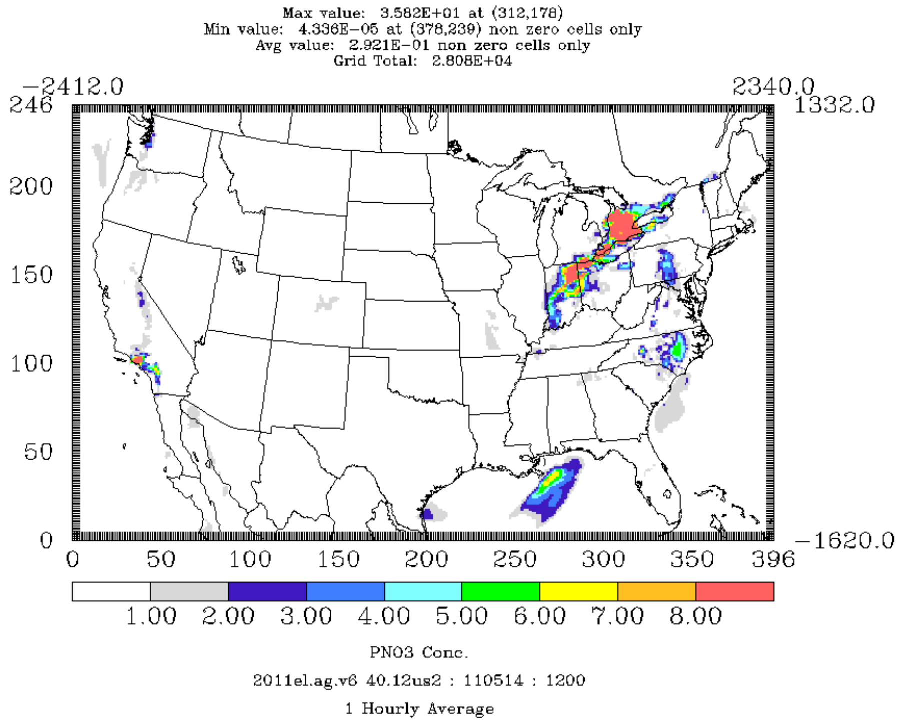


Figure 4-70: Comparison of Nitrate Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Sixth Highest Positive Difference)

Seventh Highest Positive Difference: May 14 at 1200 hours

CAMx 6.40



Difference (6.32 - 6.40)

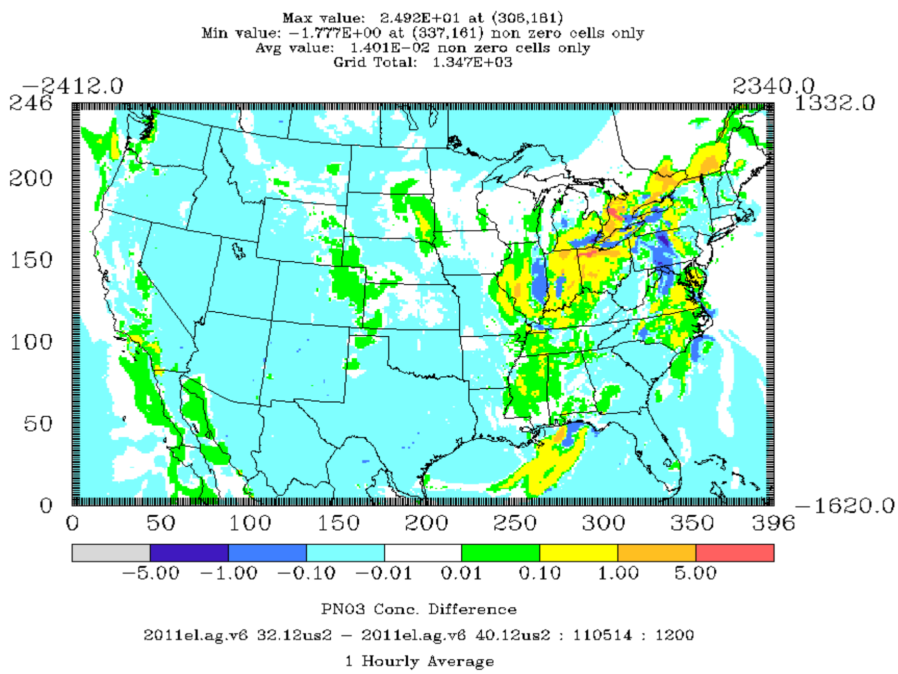
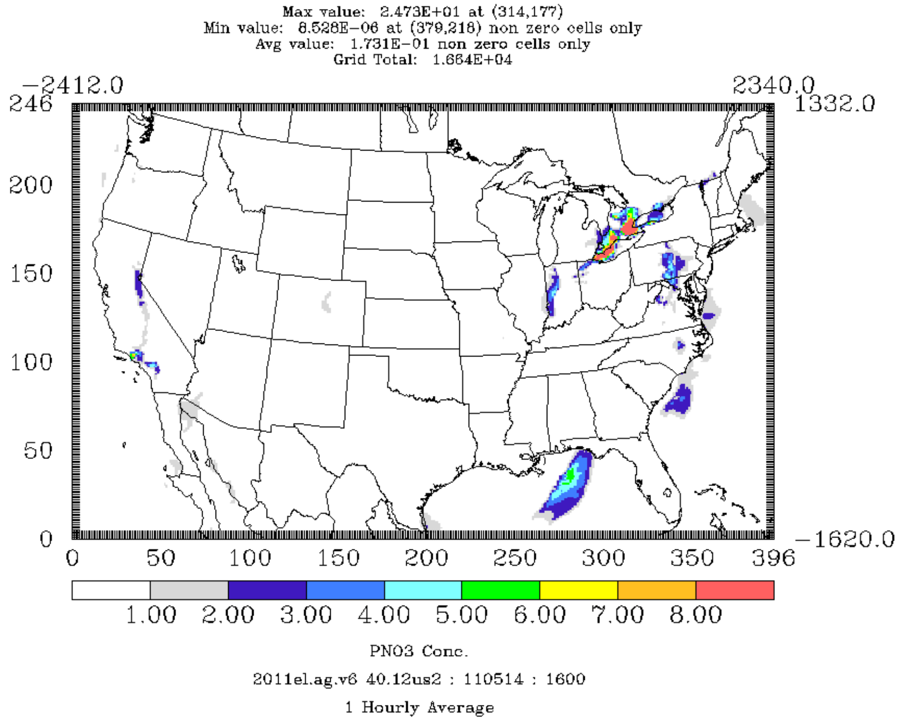


Figure 4-71: Comparison of Nitrate Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Seventh Highest Positive Difference)

Eighth Highest Positive Difference: May 14 at 1600 hours
CAMx 6.40



Difference (6.32 - 6.40)

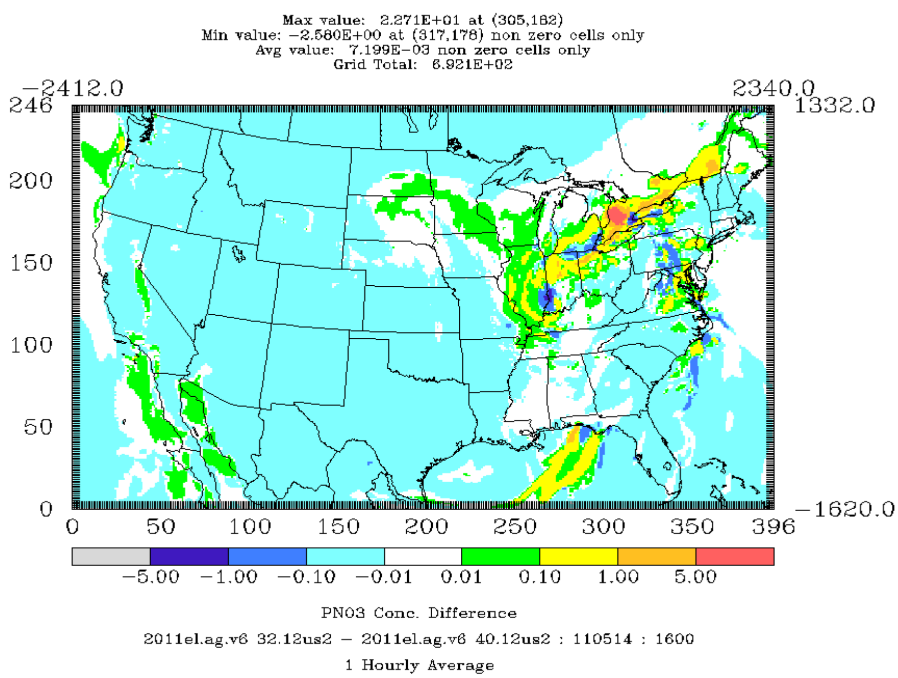
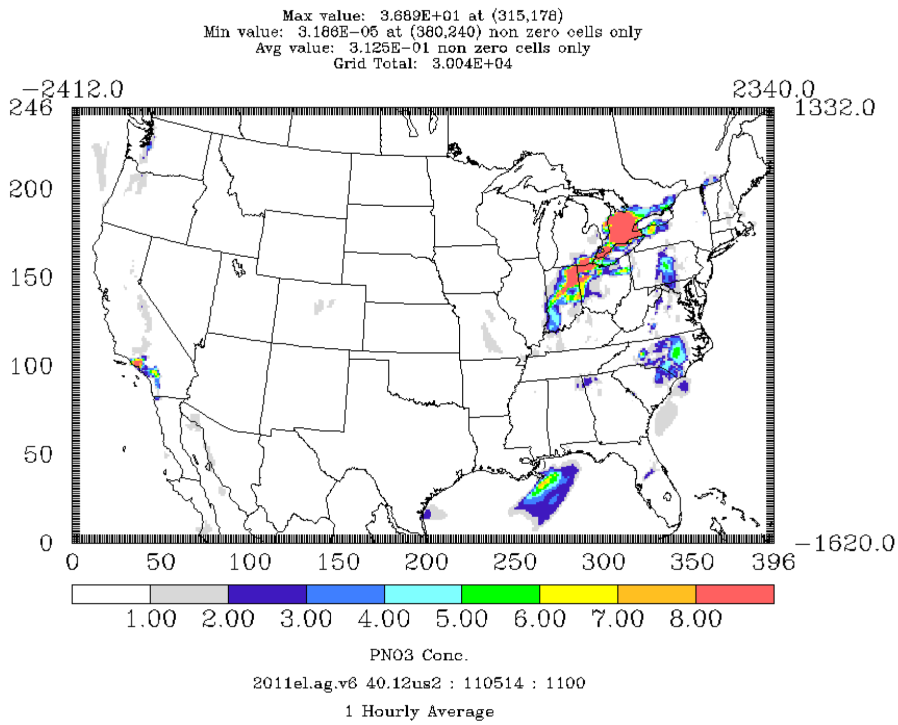


Figure 4-72: Comparison of Nitrate Concentrations (μg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Eighth Highest Positive Difference)

Ninth Highest Positive Difference: May 14 at 1100 hours
CAMx 6.40



Difference (6.32 - 6.40)

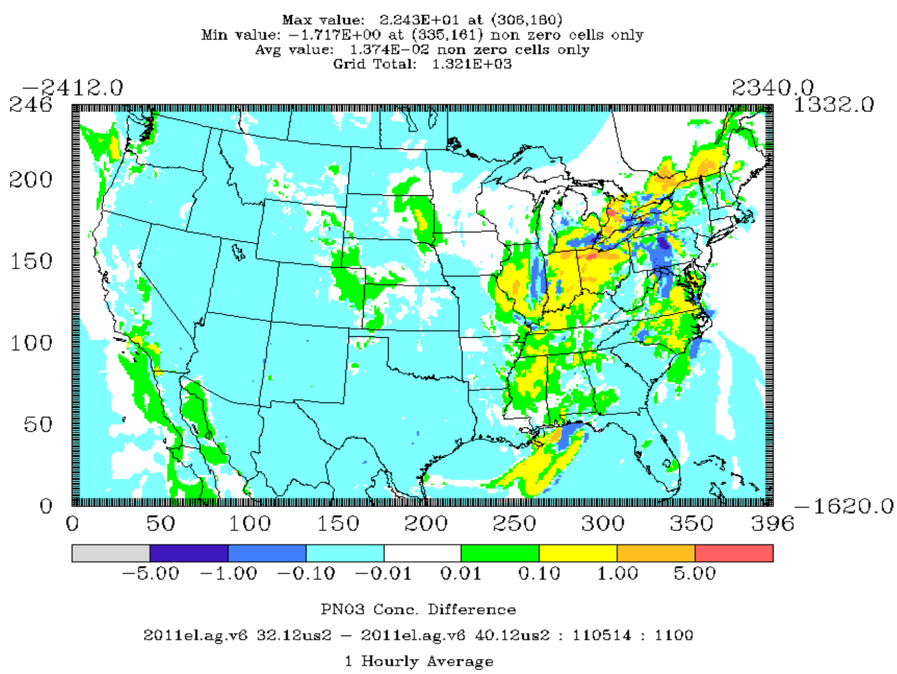


Figure 4-73: Comparison of Nitrate Concentrations (µg/m³) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Ninth Highest Positive Difference)

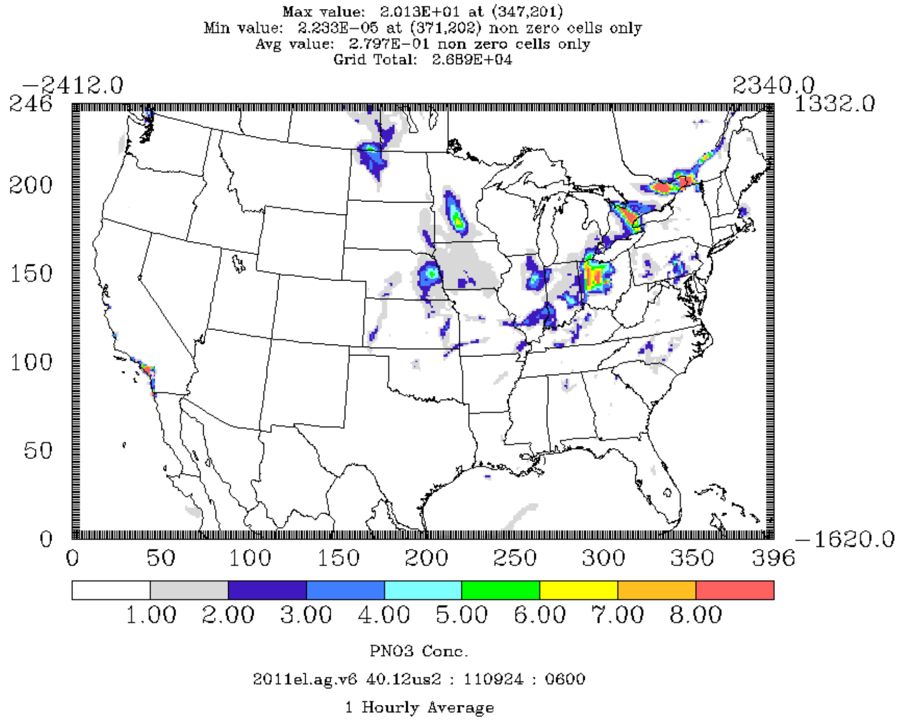
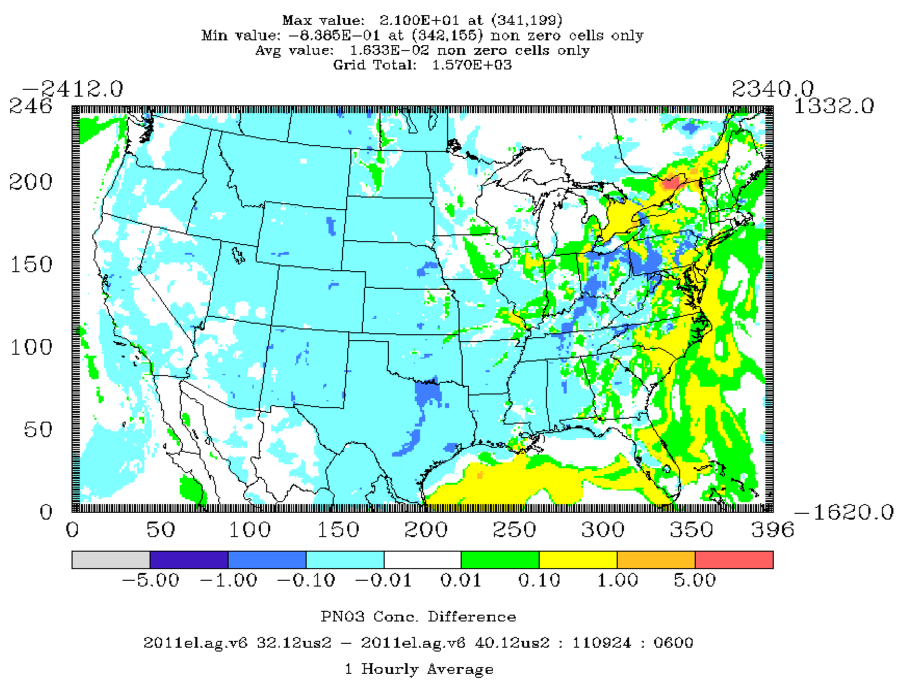
Tenth Highest Positive Difference: September 24 at 600 hours
CAMx 6.40

Difference (6.32 - 6.40)


Figure 4-74: Comparison of Nitrate Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Tenth Highest Positive Difference)

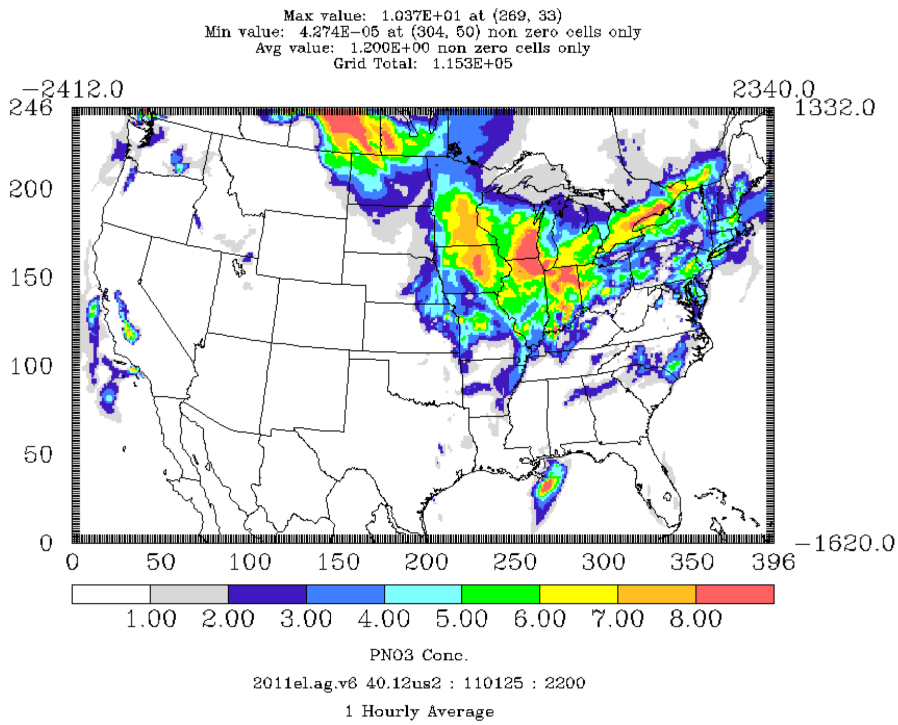
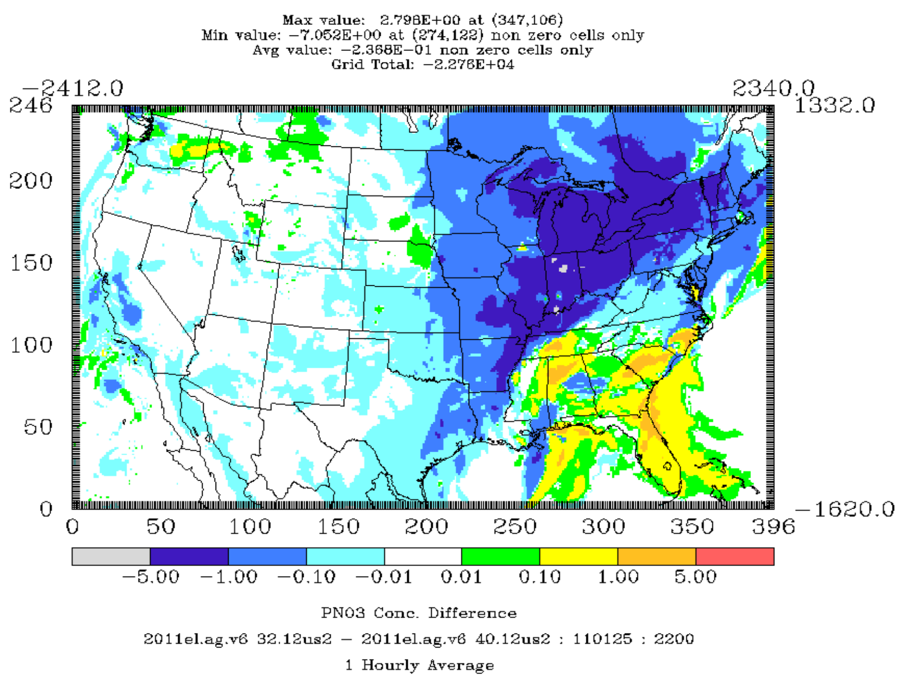
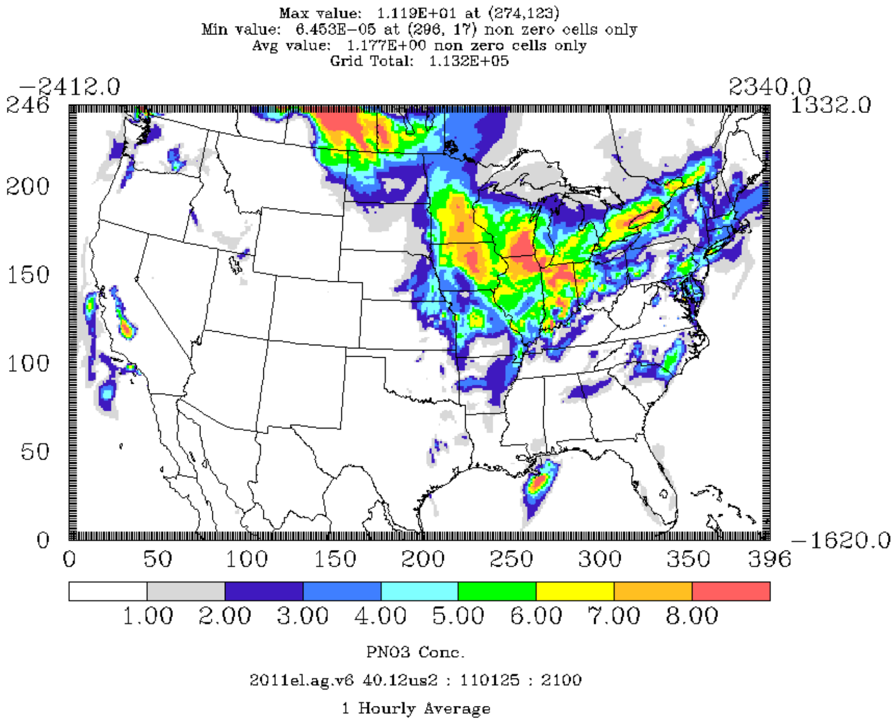
Maximum Negative Difference: January 25 at 2200 hours
CAMx 6.40

Difference (6.32 - 6.40)


Figure 4-75: Comparison of Nitrate Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Maximum Negative Difference)

Second Highest Negative Difference: January 25 at 2100 hours

CAMx 6.40



Difference (6.32 - 6.40)

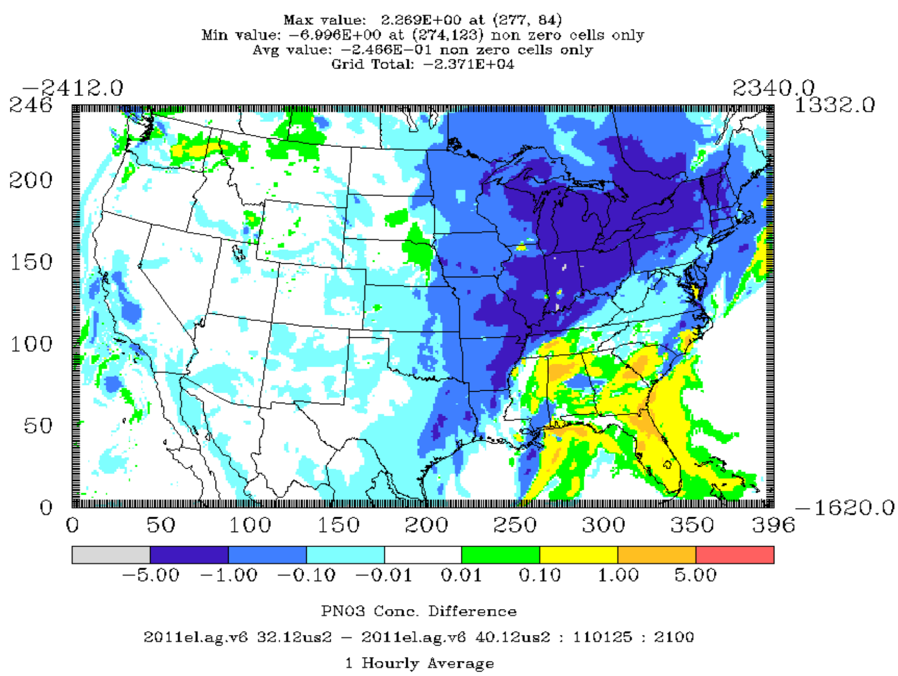
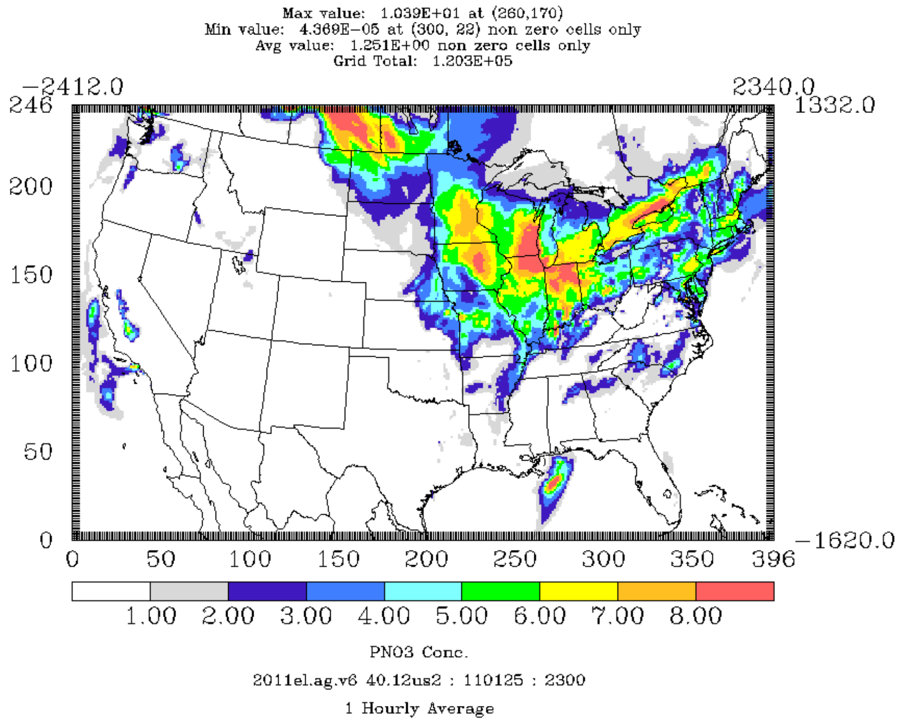


Figure 4-76: Comparison of Nitrate Concentrations (μg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Second Highest Negative Difference)

Third Highest Negative Difference: January 25 at 2300 hours

CAMx 6.40



Difference (6.32 - 6.40)

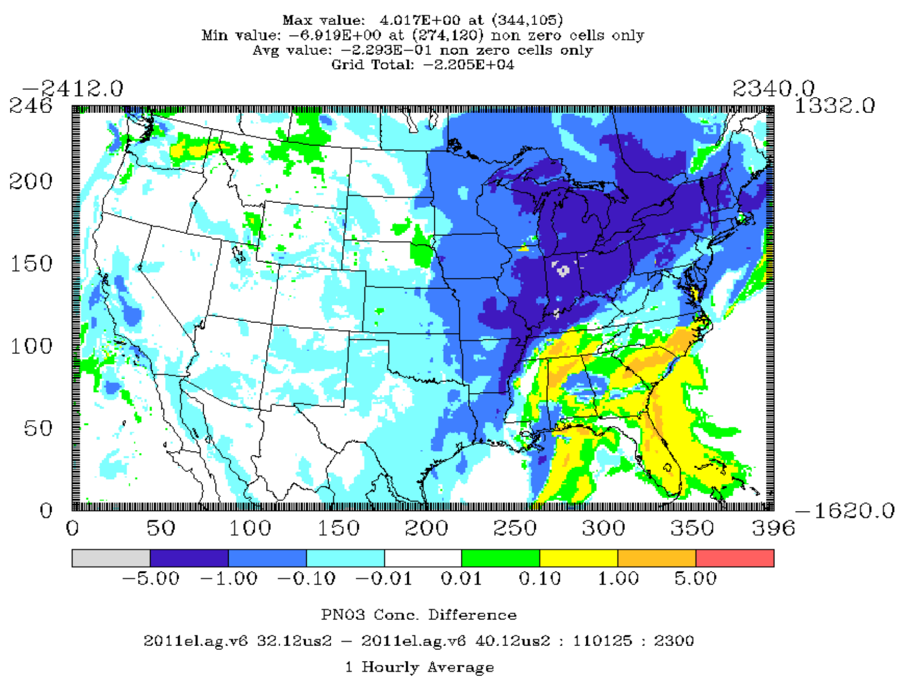
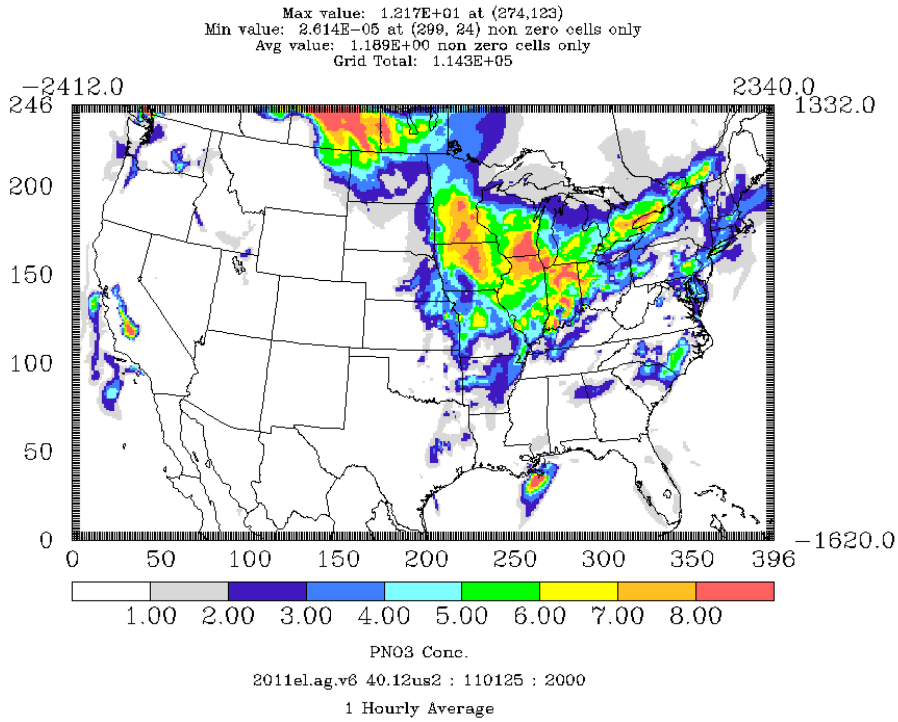


Figure 4-77: Comparison of Nitrate Concentrations (μg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Third Highest Negative Difference)

Fourth Highest Negative Difference: January 25 at 2000 hours
CAMx 6.40



Difference (6.32 - 6.40)

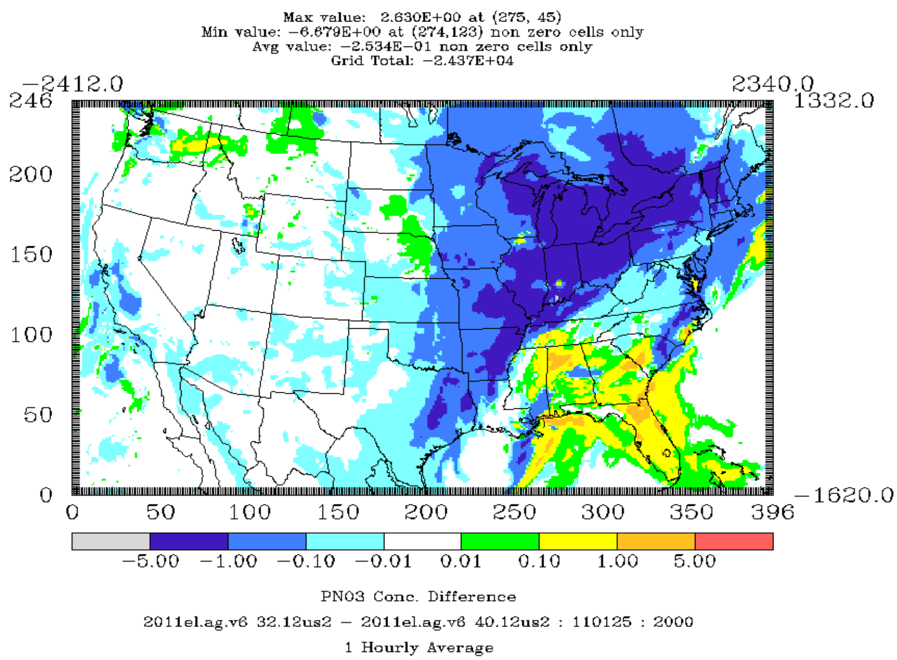
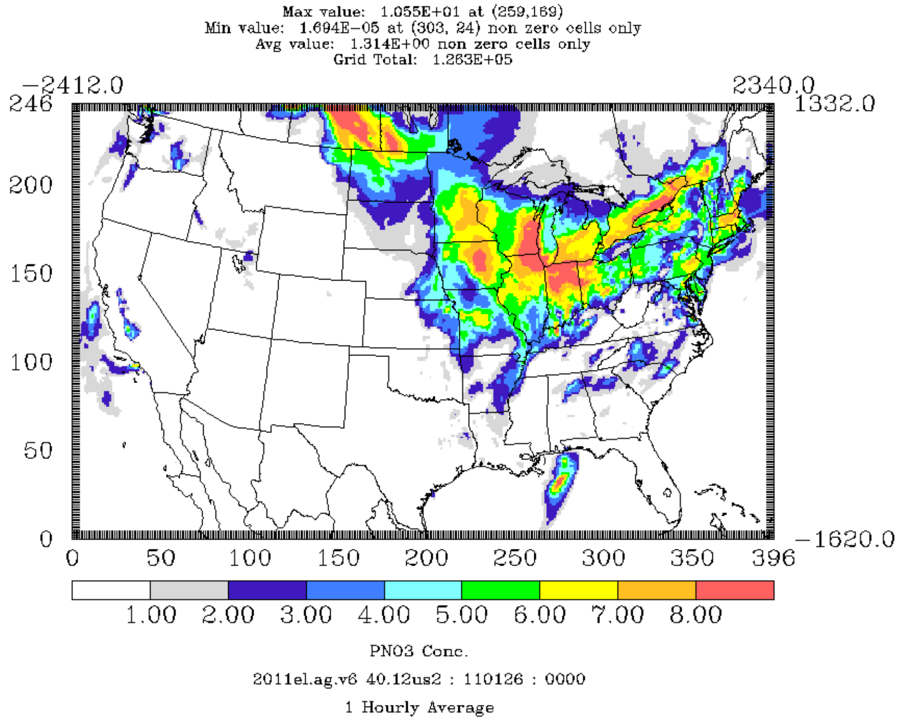


Figure 4-78: Comparison of Nitrate Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Fourth Highest Negative Difference)

Fifth Highest Negative Difference: January 26 at 0000 hours

CAMx 6.40



Difference (6.32 - 6.40)

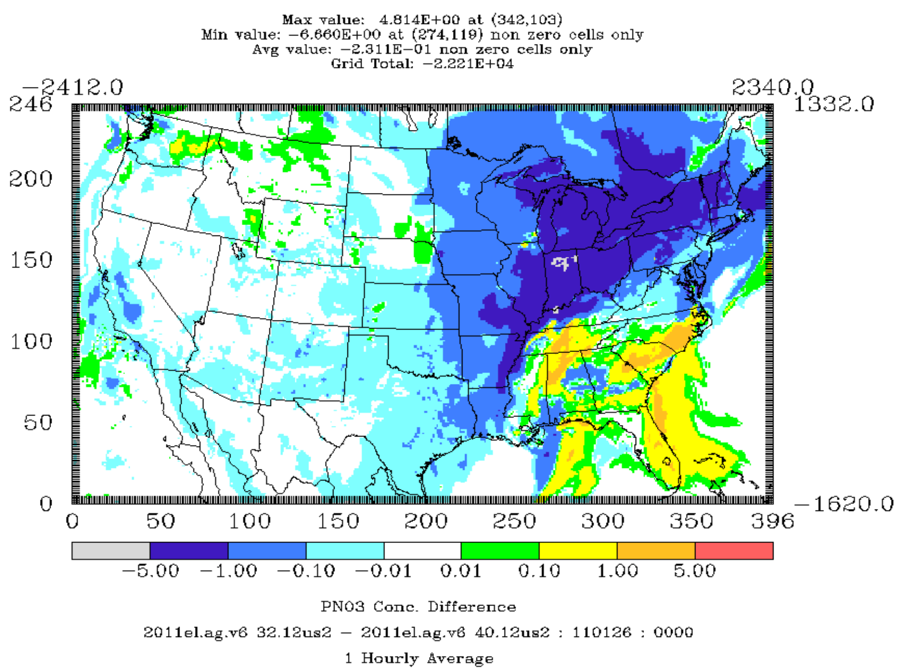
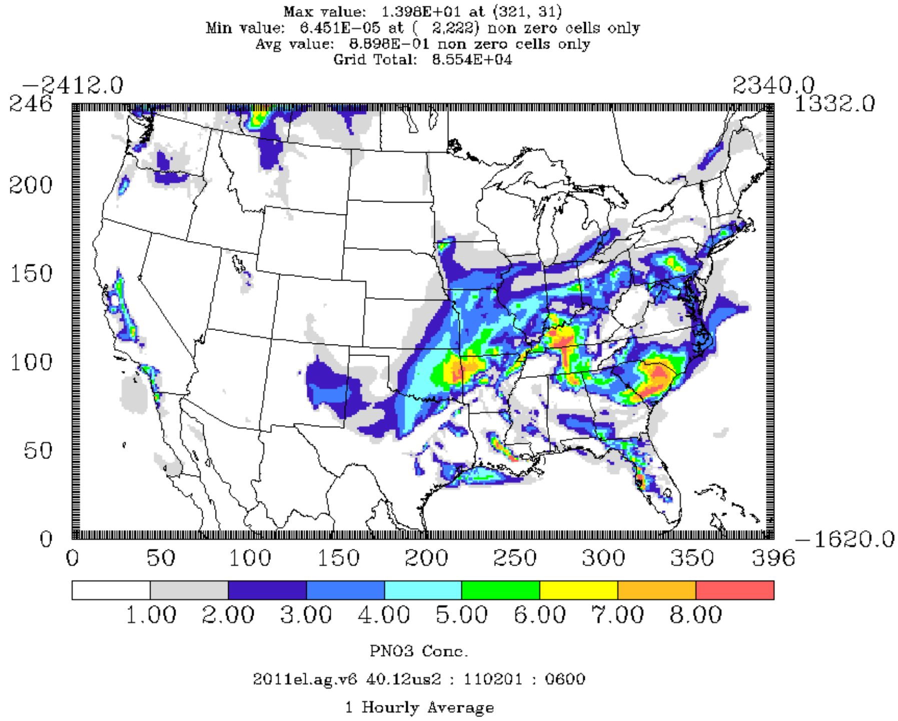


Figure 4-79: Comparison of Nitrate Concentrations (μg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Fifth Highest Negative Difference)

Sixth Highest Negative Difference: February 1 at 600 hours
CAMx 6.40



Difference (6.32 - 6.40)

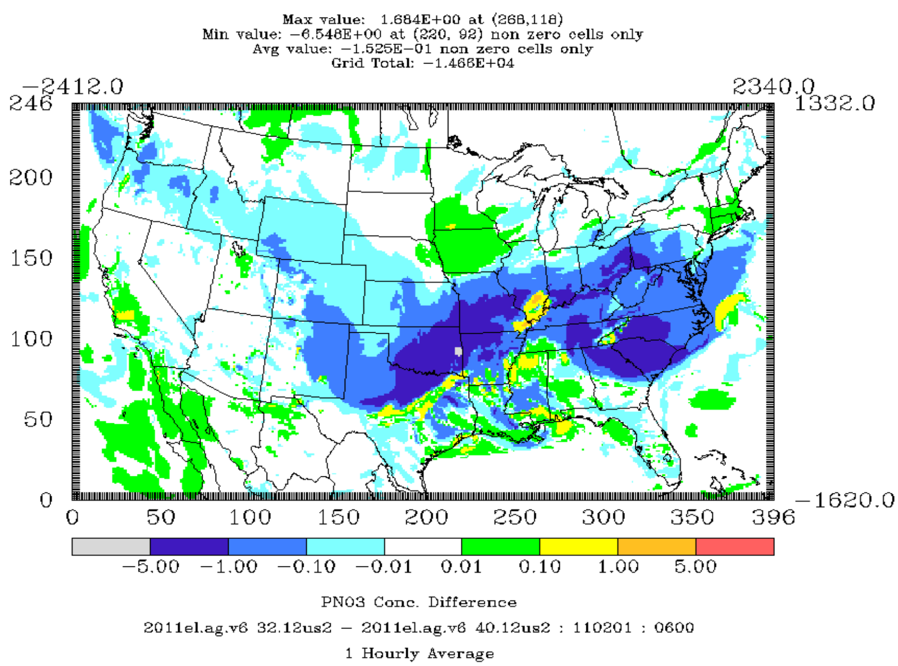
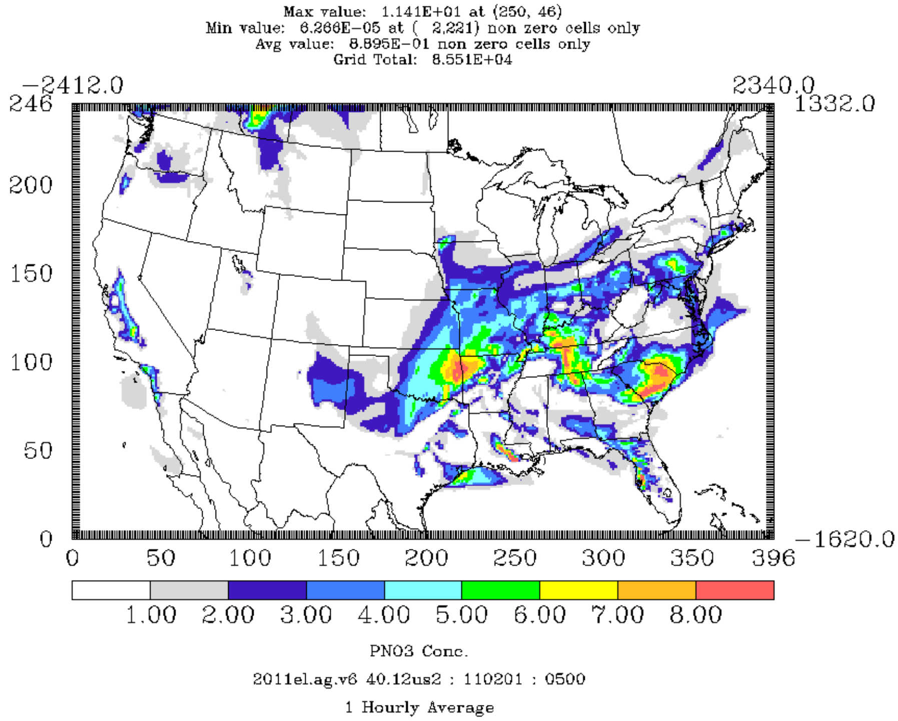


Figure 4-80: Comparison of Nitrate Concentrations (μg/m³) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Sixth Highest Negative Difference)

Seventh Highest Negative Difference: February 1 at 500 hours

CAMx 6.40



Difference (6.32 - 6.40)

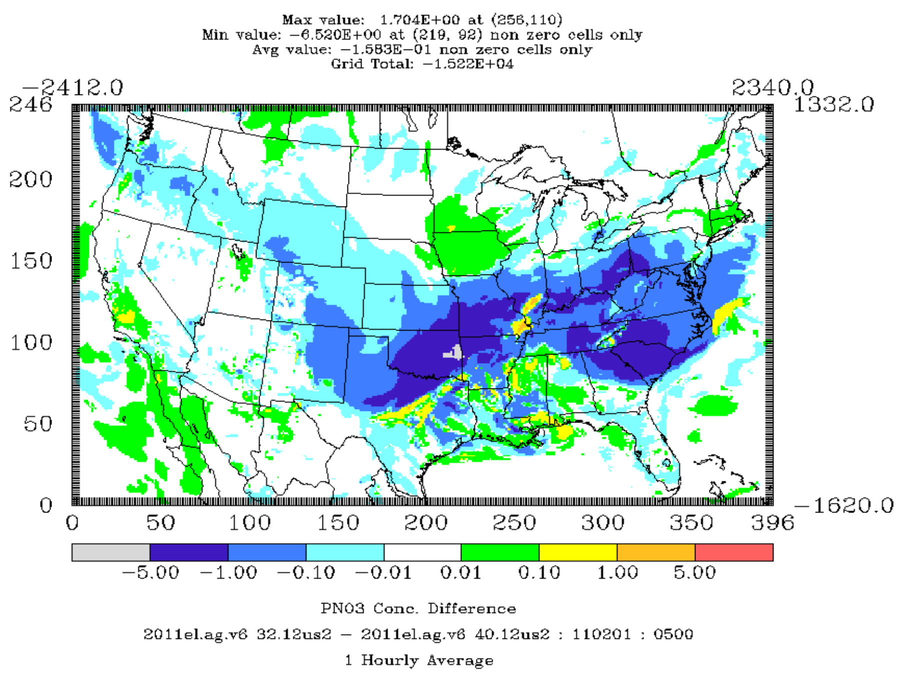
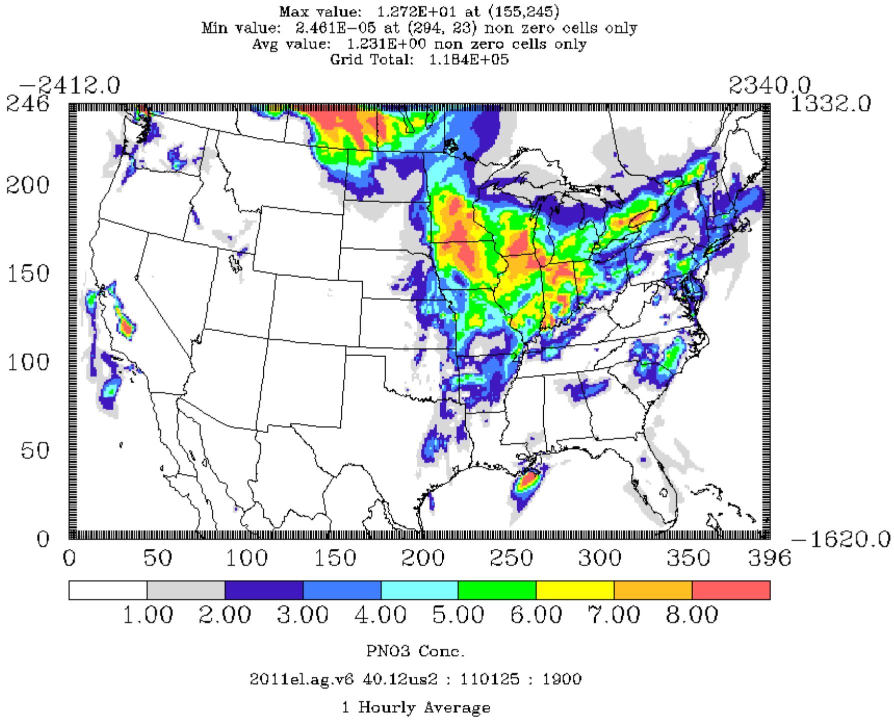


Figure 4-81: Comparison of Nitrate Concentrations (µg/m³) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Seventh Highest Negative Difference)

Eighth Highest Negative Difference: January 25 at 1900 hours
CAMx 6.40



Difference (6.32 - 6.40)

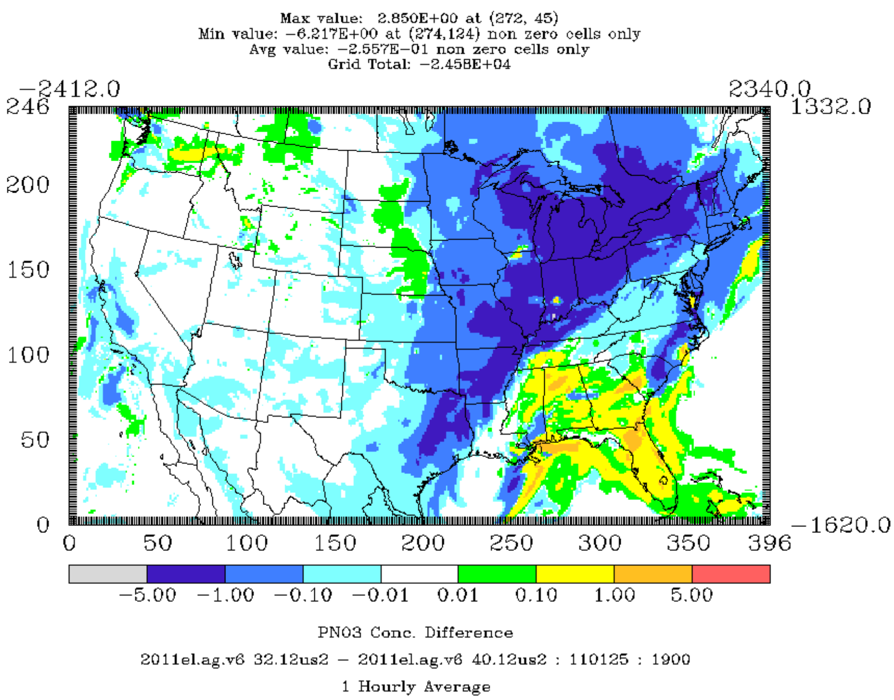
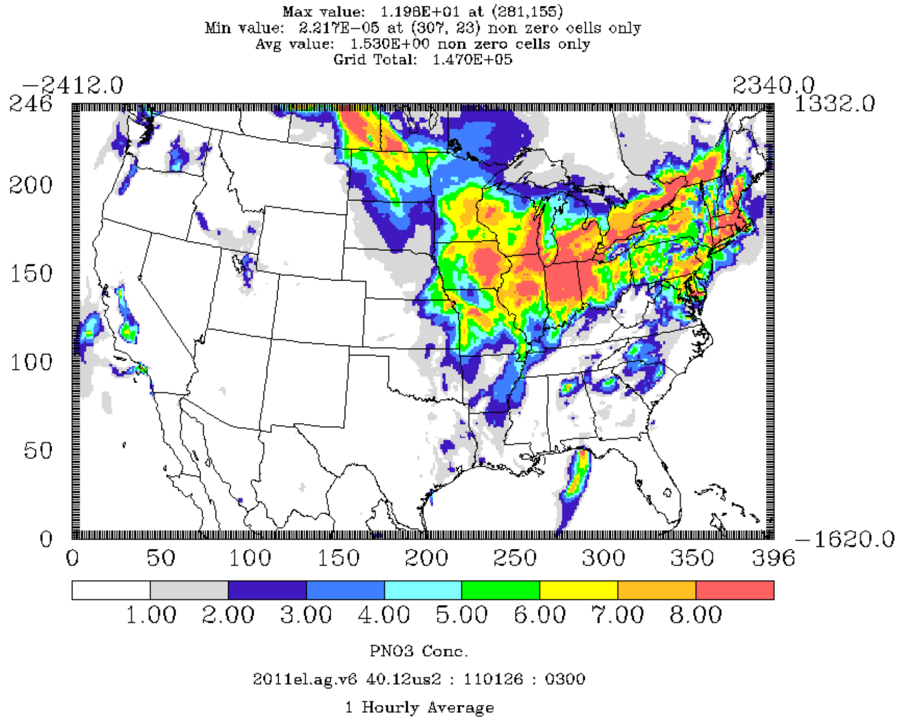


Figure 4-82: Comparison of Nitrate Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Eighth Highest Negative Difference)

Ninth Highest Negative Difference: January 26 at 300 hours

CAMx 6.40



Difference (6.32 - 6.40)

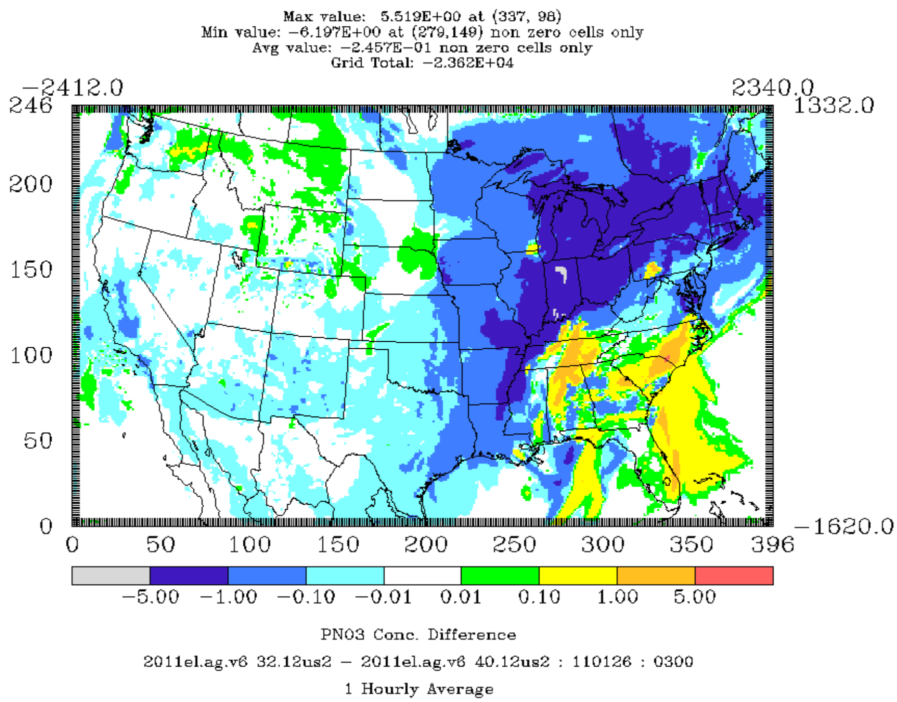
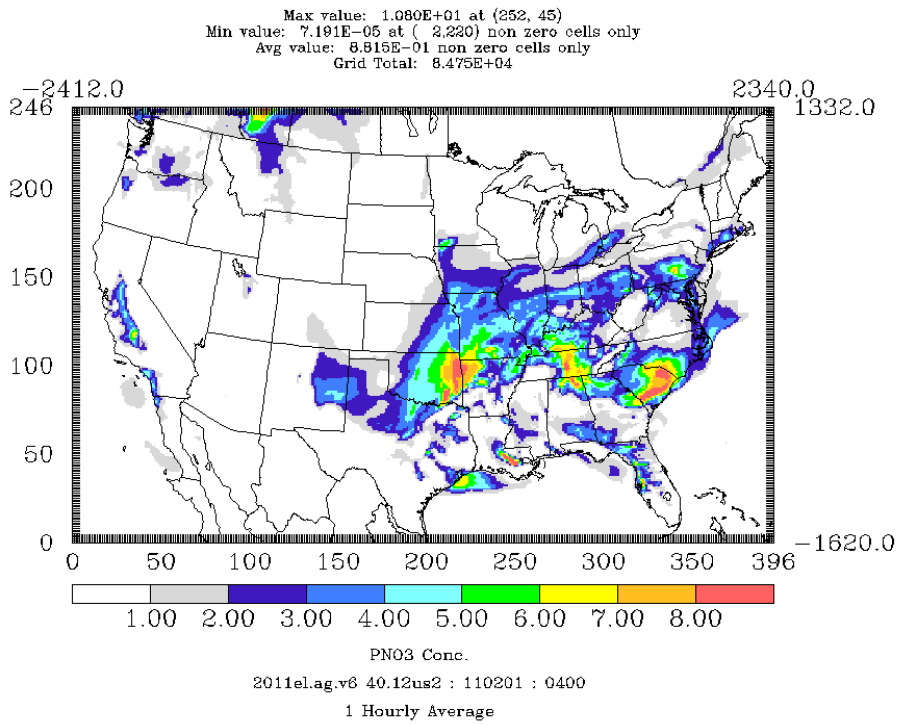


Figure 4-83: Comparison of Nitrate Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Ninth Highest Negative Difference)

Tenth Highest Negative Difference: February 1 at 400 hours

CAMx 6.40



Difference (6.32 - 6.40)

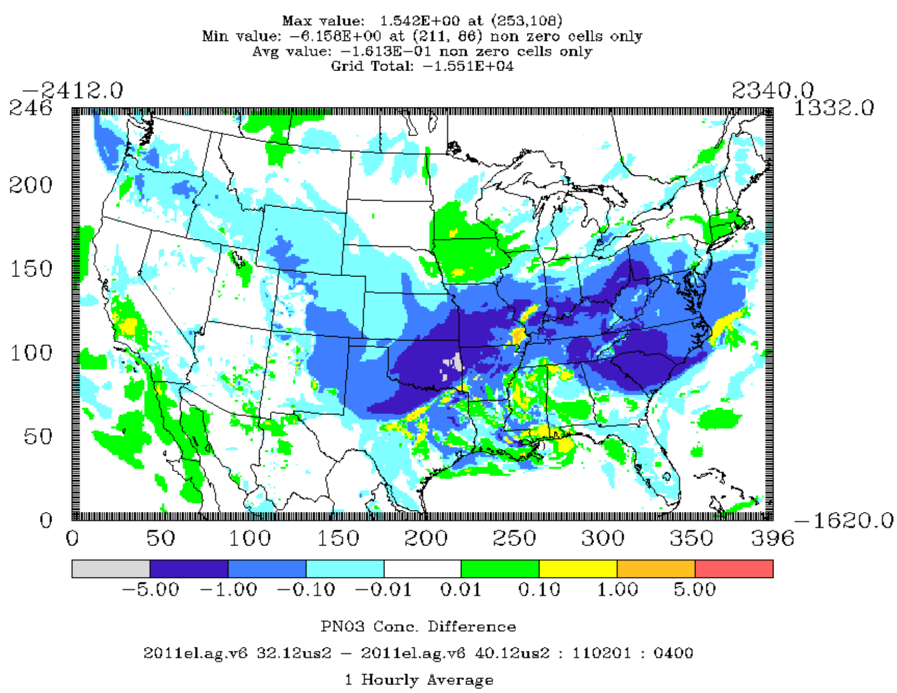


Figure 4-84: Comparison of Nitrate Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Tenth Highest Negative Difference)

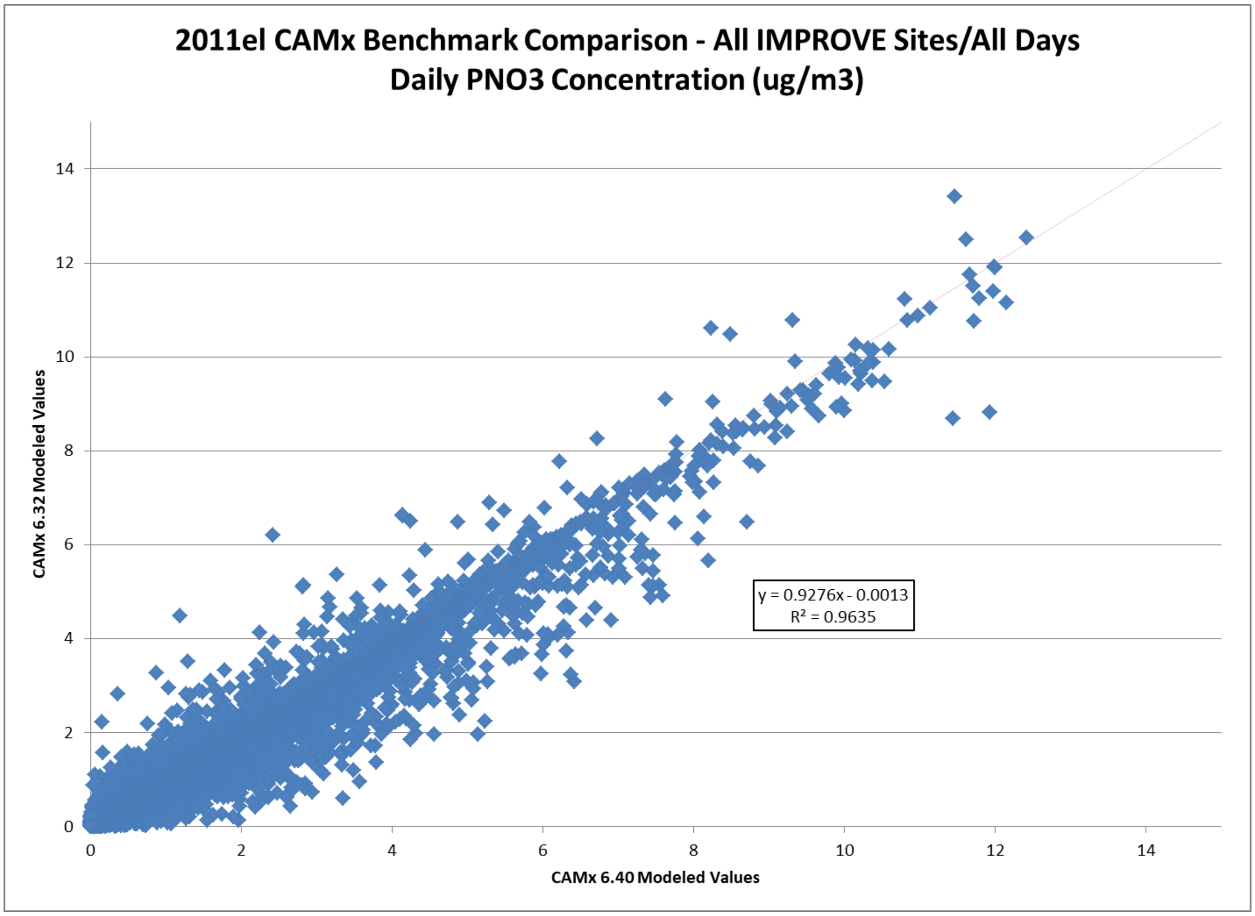


Figure 4-85: Scatterplot Comparing 24-hour Average Predicted Nitrate Concentrations ($\mu g/m^3$) for All Days at all IMPROVE Monitor Locations for CAMx 6.32 and CAMx 6.40 2011el Simulations Performed by VISTAS (Alpine).

4.5 Organic Matter (OM)

Organic Matter (OM) results for the top 10 positive and negative hours are presented in tabular format in Table 4-5. The maximum positive difference is 30.29 µg/m^3 falling to 25.25 µg/m^3 for the 10th high. The maximum negative difference is -28.67 µg/m^3 falling to -16.60 µg/m^3 for the 10th high. The maximum positive percent difference from these days is 801% and negative percent difference of -80%.

The top 10 positive difference hours are presented in Figures 4-86 through 4-95. The differences on the two highest days are in the Pacific Northwest. On other days the peaks are scattered across Southern Canada, north of New York and the south eastern U.S.

The top 10 negative impact hours are presented in Figures 4-96 through 4-105. Five of the top ten hours occur on July 20th. On this day the location of the peak is along the northern border of the U.S., north of Minnesota. This is an area where CAMx simulations are showing very high OM concentrations and an area heavily influenced by boundary conditions. As was discussed in Section 2, the SOA species definitions changed between CAMx 6.32 and 6.40, but the mapping of the boundary conditions was not updated between model versions to reflect this change. This difference in boundary condition species mapping is likely the reason for the concentration deltas. On July 3, the peak difference is over Lake Michigan; on August 19 the peak is in eastern Texas.

Scatterplots of the daily average organic matter concentrations in local standard time at the IMPROVE monitors are presented in Figures 4-106 and 4-107. The CAMx 6.40 results are plotted on the x-axis and the CAMx 6.32 results are plotted on the y-axis. The data has a high degree of correlation with a line of best fit with a slope of 1.0122, an intercept of 0.2973 ppb and an R^2 of 0.983.

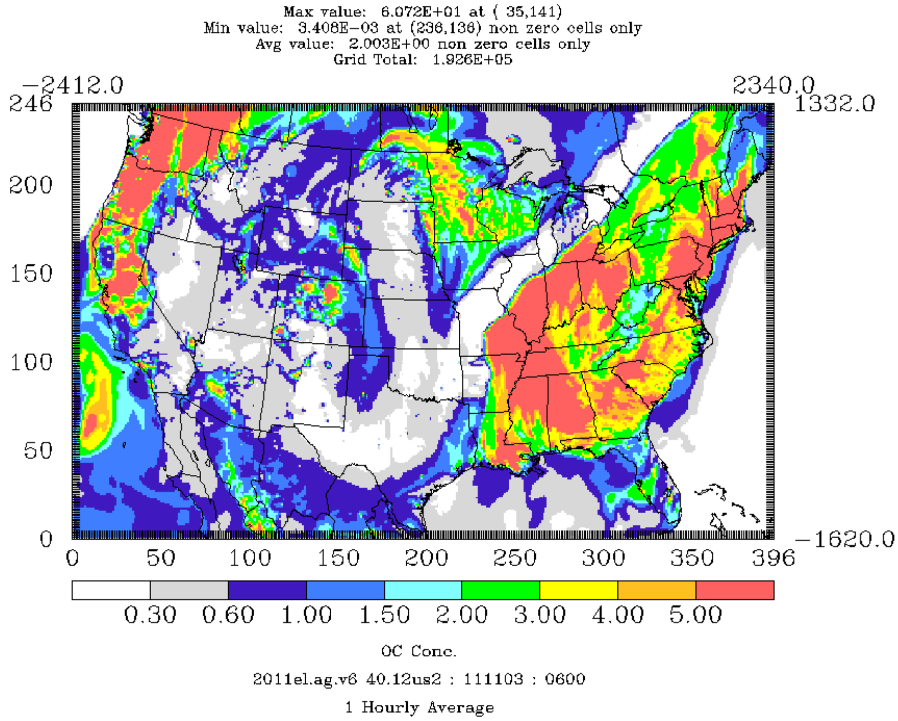
Examination of the animations reveals that away from frontal boundaries and low pressure areas, OM in CAMx 6.40 is generally slightly lower compared to CAMx 6.32. While near frontal boundaries and low pressure areas the opposite is true. These positive and negative difference seem to balance give a high degree of correlation between the model versions.

Table 4-5. Comparison of 2011el CAMx 6.32 and CAMx 6.40 Simulation of Organic Matter Concentrations (µg/m³). Hours with the top 10 maximum positive and maximum negative differences are shown.

Year	Month	Day	Hour	6.32 Conc.	6.40 Conc.	Difference (µg/m³)	Percent Difference	Column	Row
Maximum Positive									
2011	11	3	6	70.40	40.11	30.29	75.5%	38	213
2011	11	3	5	70.91	41.19	29.72	72.2%	39	214
2011	12	6	2	57.66	29.11	28.55	98.1%	354	207
2011	5	21	11	33.46	5.75	27.71	481.9%	226	47
2011	12	6	1	62.13	34.78	27.35	78.6%	353	209
2011	1	26	15	57.93	30.97	26.96	87.1%	314	125
2011	12	6	3	39.21	12.97	26.24	202.3%	355	207
2011	1	26	16	63.39	37.28	26.11	70.0%	314	125
2011	5	21	12	28.46	3.16	25.30	801.3%	225	48
2011	5	21	10	33.98	8.73	25.25	289.4%	226	47
Maximum Negative									
2011	7	20	15	3,944.01	3,972.68	-28.67	-0.7%	230	243
2011	7	20	14	3,589.46	3,616.33	-26.88	-0.7%	231	244
2011	7	20	16	3,261.57	3,285.59	-24.02	-0.7%	230	243
2011	7	3	21	4.58	23.21	-18.63	-80.3%	269	156
2011	8	19	5	72.72	91.27	-18.55	-20.3%	216	52
2011	7	3	22	4.62	23.11	-18.50	-80.0%	269	156
2011	7	20	17	1,657.89	1,675.83	-17.94	-1.1%	229	244
2011	7	20	13	2,382.39	2,399.65	-17.26	-0.7%	231	245
2011	7	3	20	4.43	21.62	-17.18	-79.5%	269	156
2011	8	19	6	70.62	87.22	-16.60	-19.0%	216	52

Maximum Positive Difference: November 3 at 600 hours

CAMx 6.40



Difference (6.32 - 6.40)

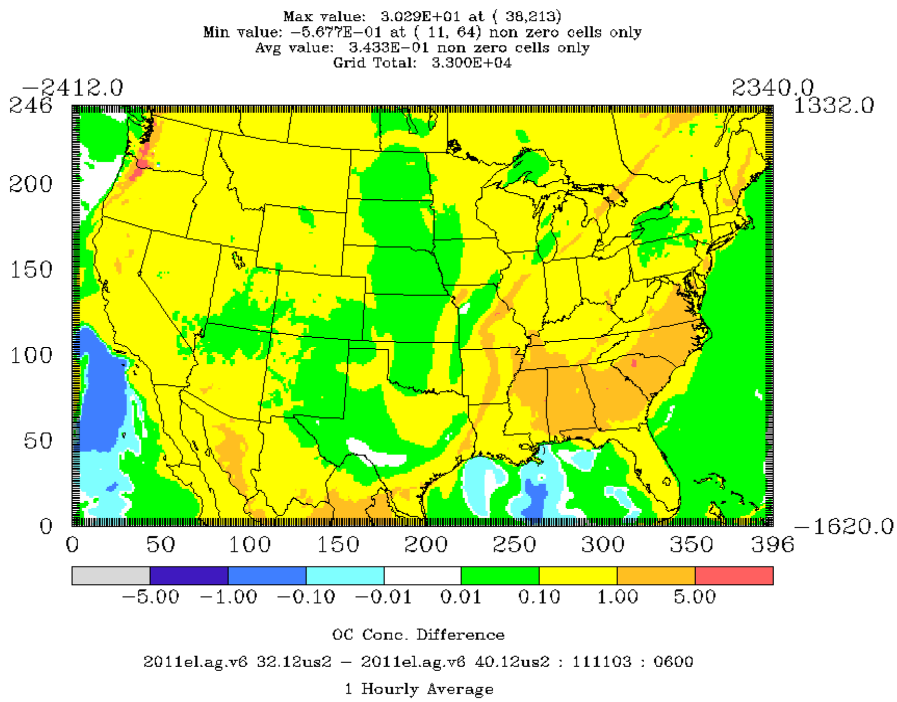
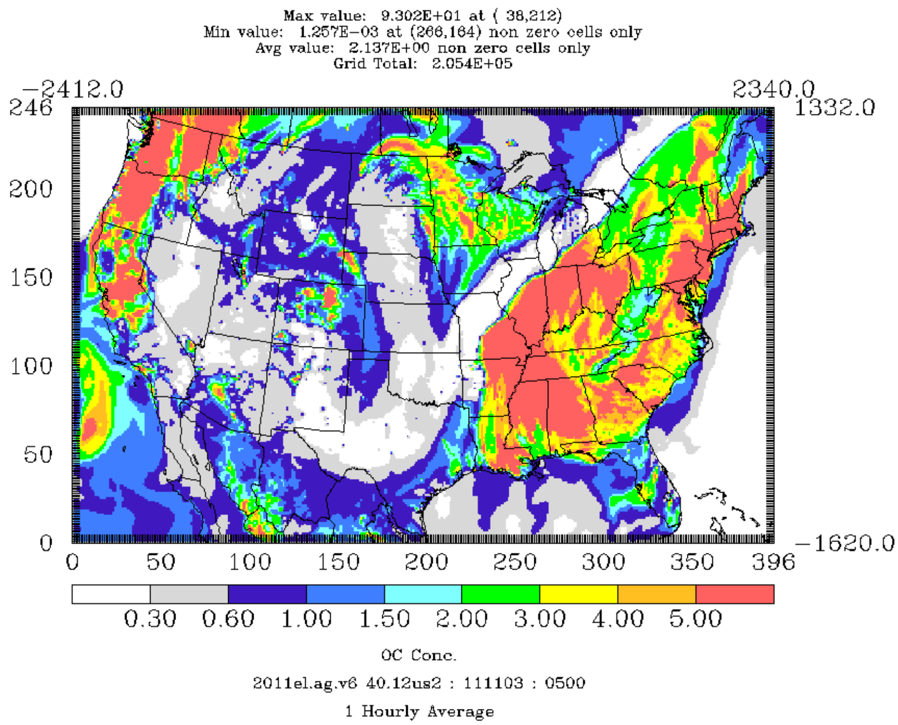


Figure 4-86: Comparison of Organic Matter Concentrations (μg/m³) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Maximum Positive Difference)

Second Highest Positive Difference: November 3 at 500 hours
CAMx 6.40



Difference (6.32 - 6.40)

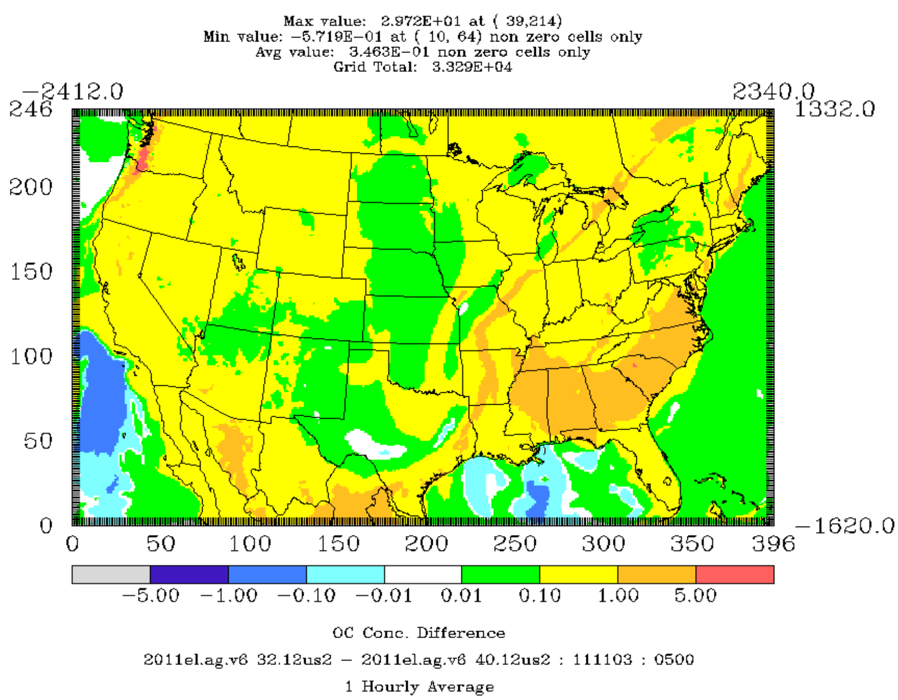
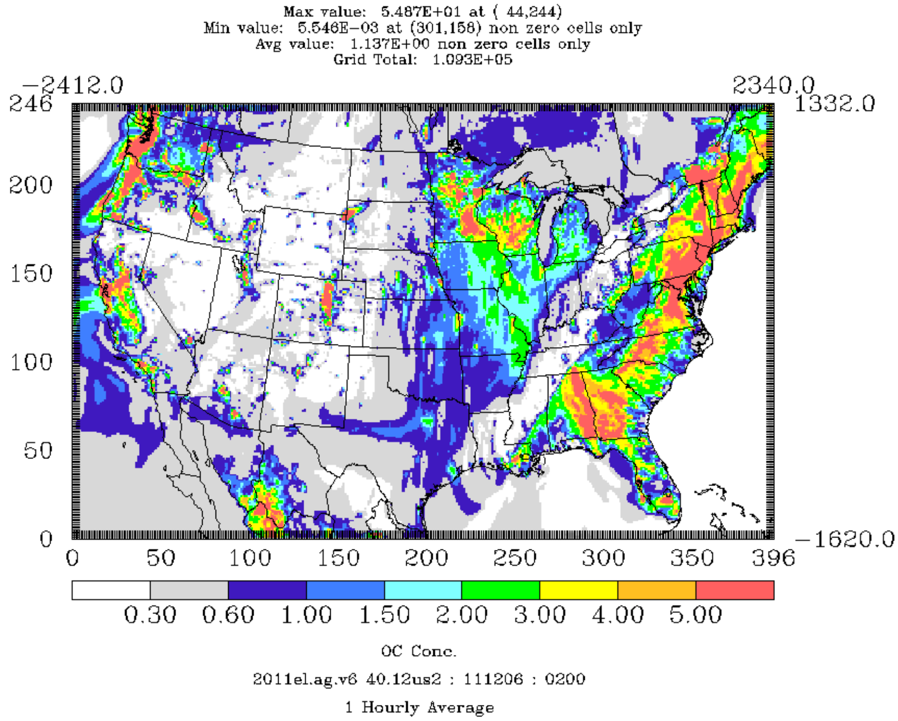


Figure 4-87: Comparison of Organic Matter Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Second Highest Positive Difference)

Third Highest Positive Difference: December 6 at 200 hours

CAMx 6.40



Difference (6.32 - 6.40)

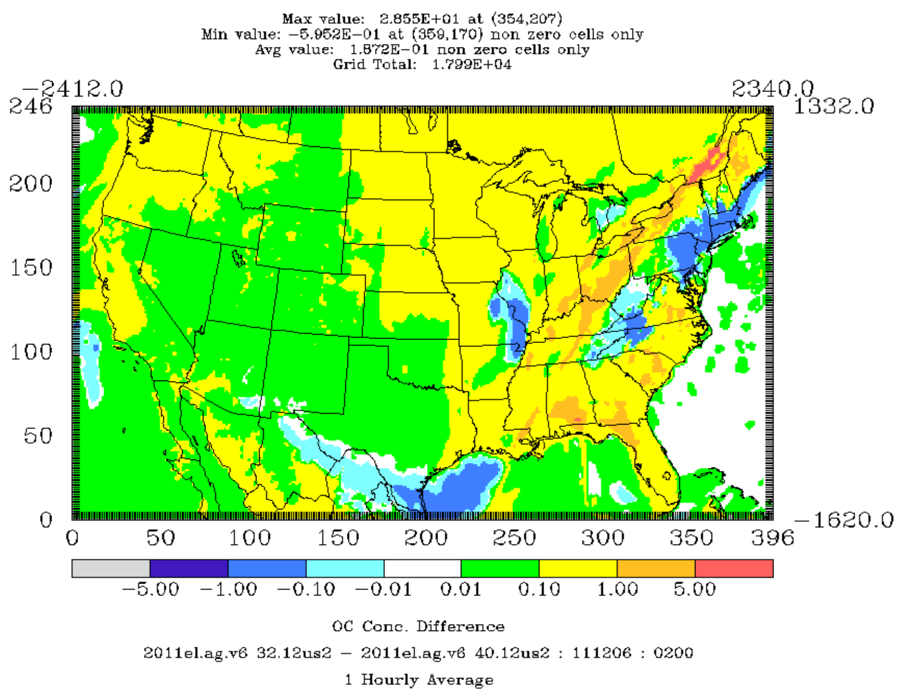
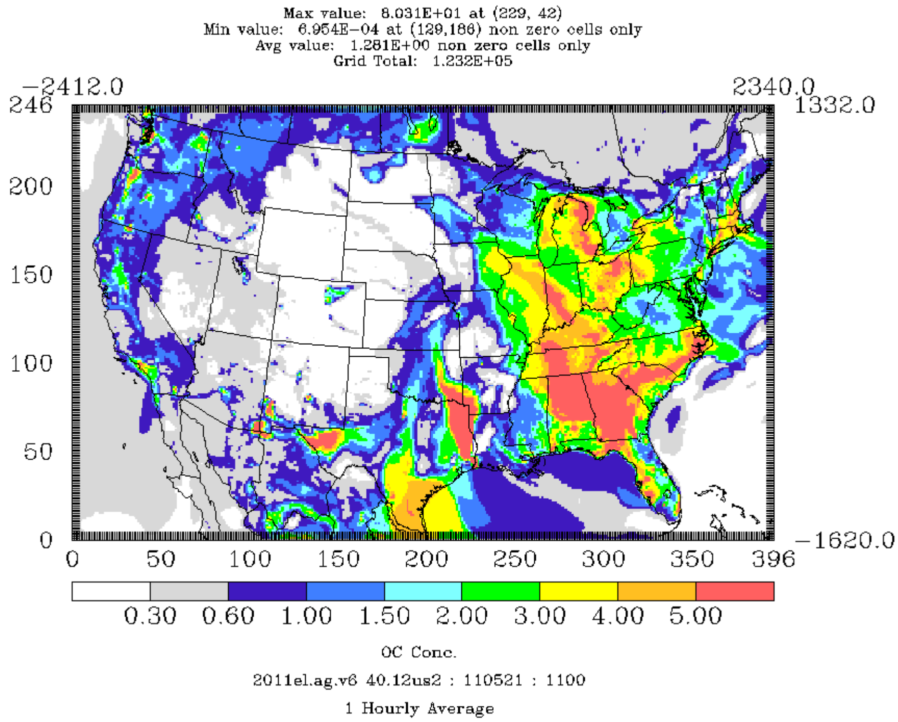


Figure 4-88: Comparison of Organic Matter Concentrations (μg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Third Highest Positive Difference)

Fourth Highest Positive Difference: May 21 at 1100 hours

CAMx 6.40



Difference (6.32 - 6.40)

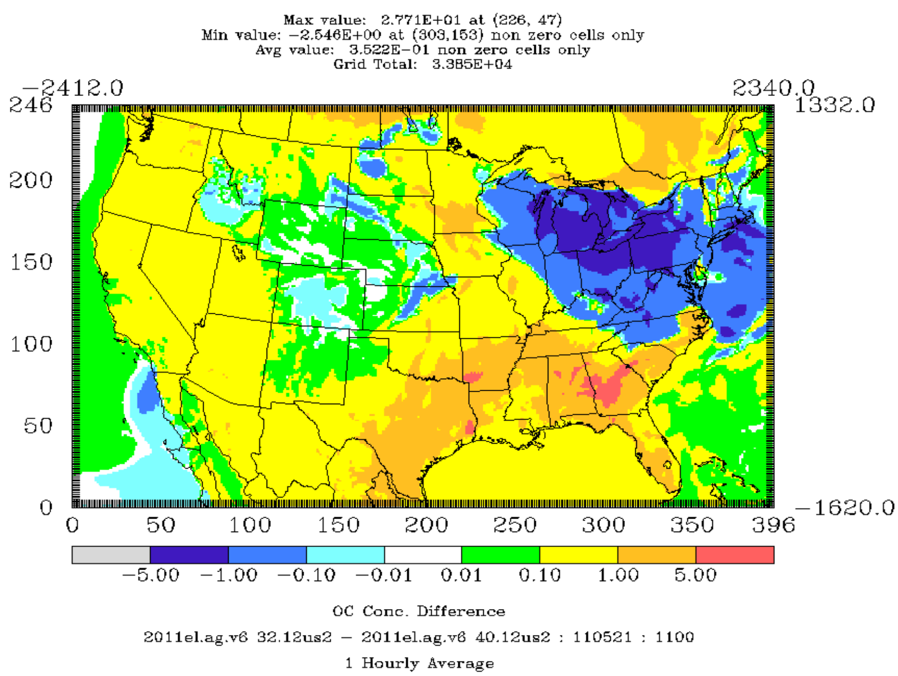
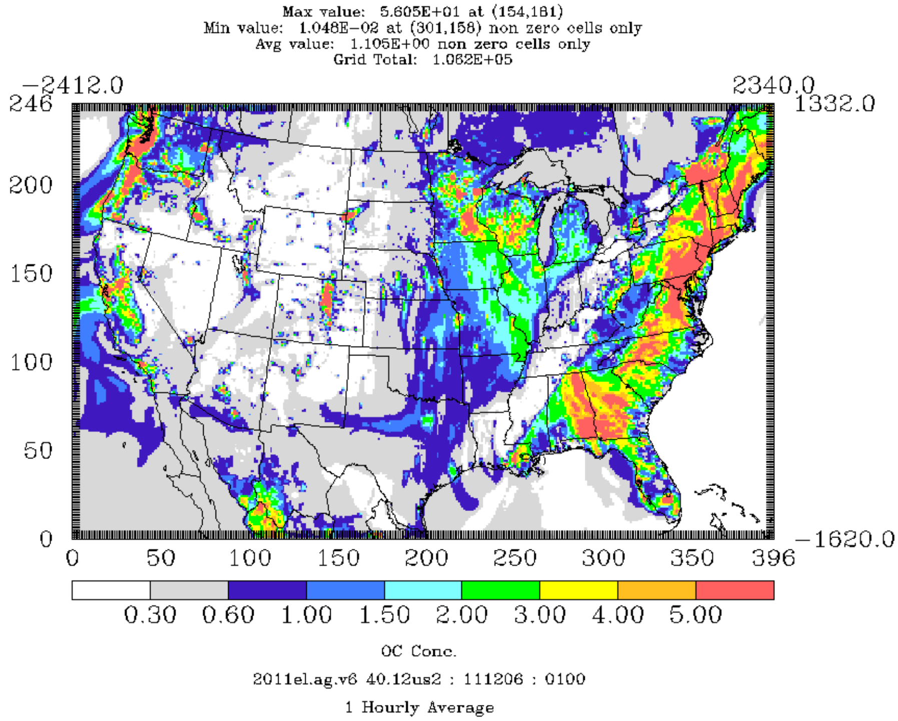


Figure 4-89: Comparison of Organic Matter Concentrations (μg/m³) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Fourth Highest Positive Difference)

Fifth Highest Positive Difference: December 6 at 100 hours

CAMx 6.40



Difference (6.32 - 6.40)

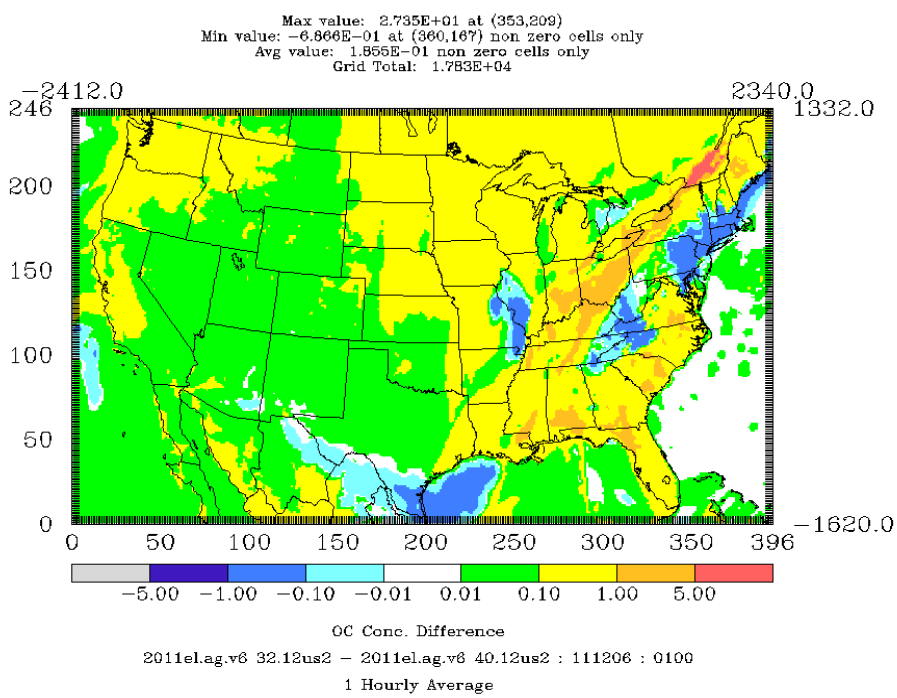


Figure 4-90: Comparison of Organic Matter Concentrations (μg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Fifth Highest Positive Difference)

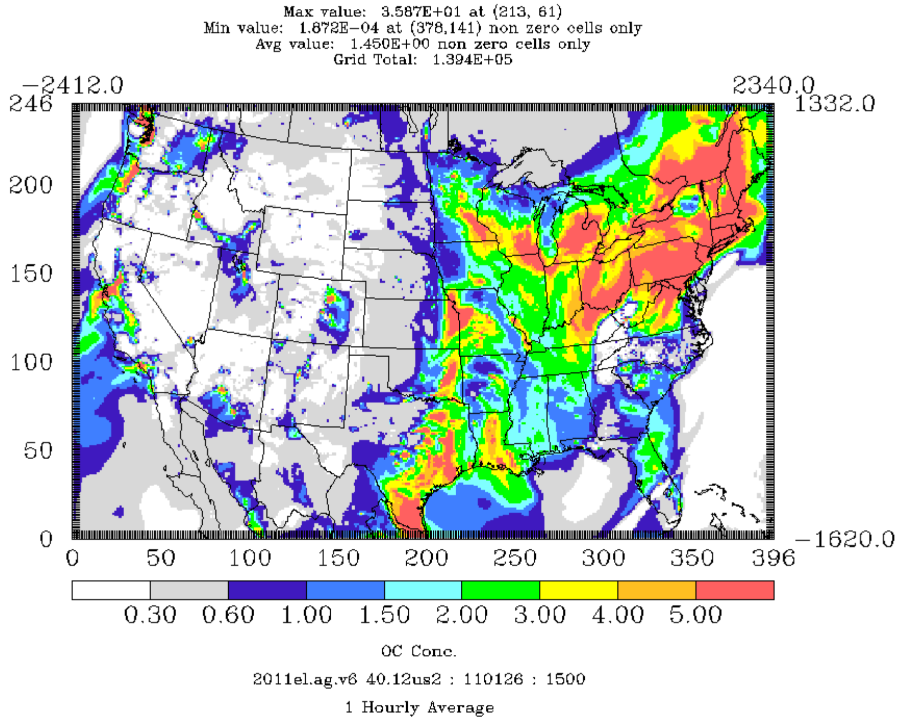
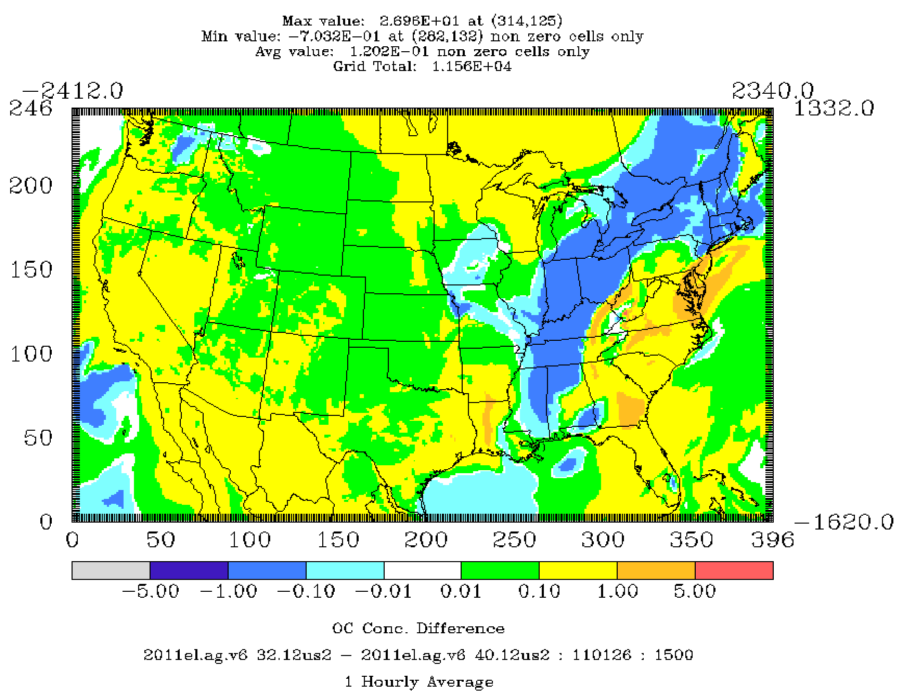
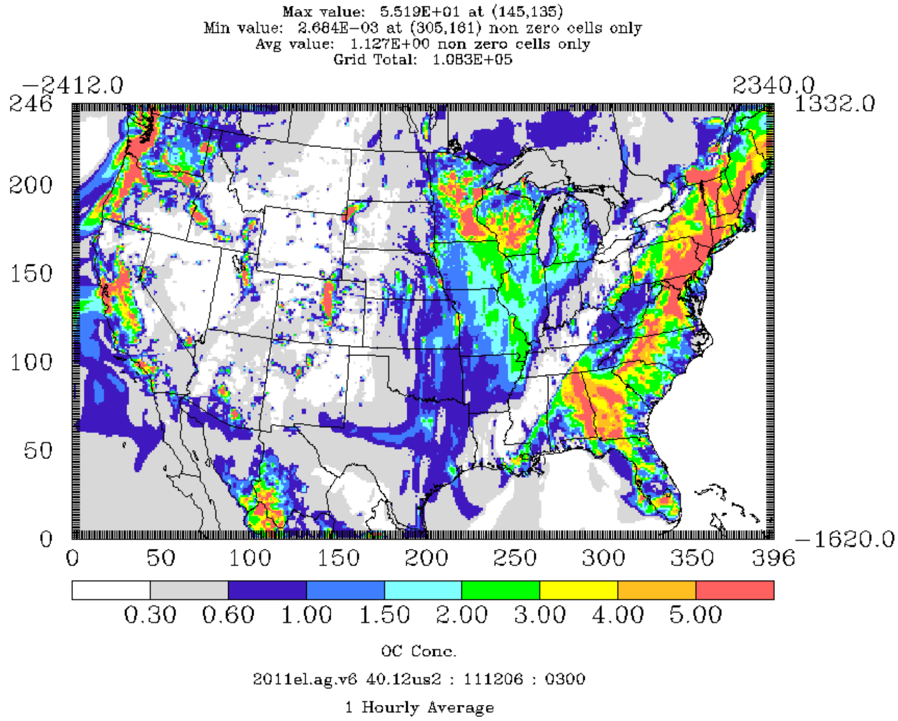
Sixth Highest Positive Difference: January 26 at 1500 hours
CAMx 6.40

Difference (6.32 - 6.40)


Figure 4-91: Comparison of Organic Matter Concentrations (μg/m³) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Sixth Highest Positive Difference)

Seventh Highest Positive Difference: December 6 at 300 hours
CAMx 6.40



Difference (6.32 - 6.40)

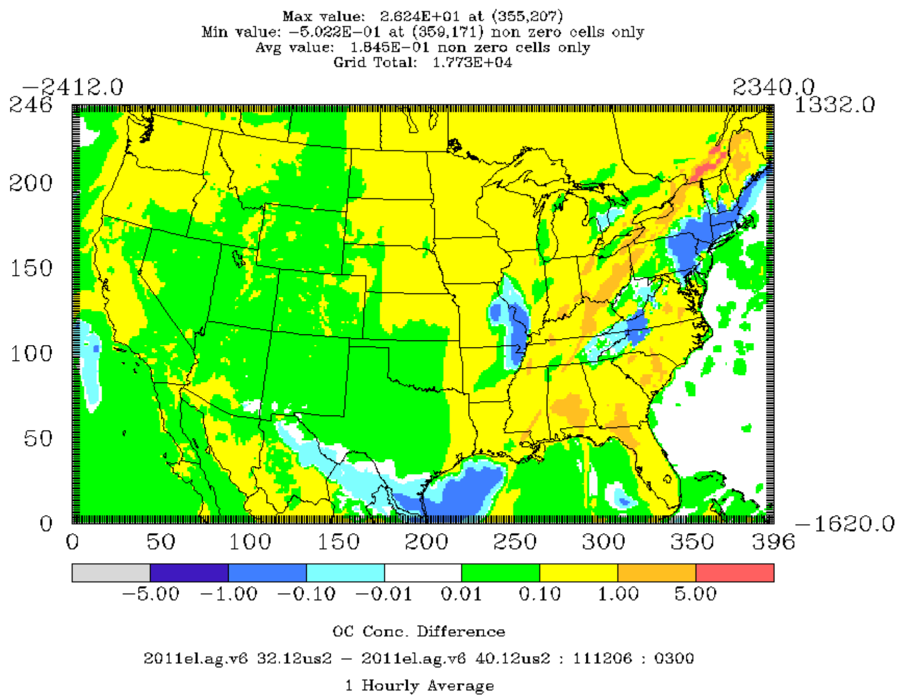
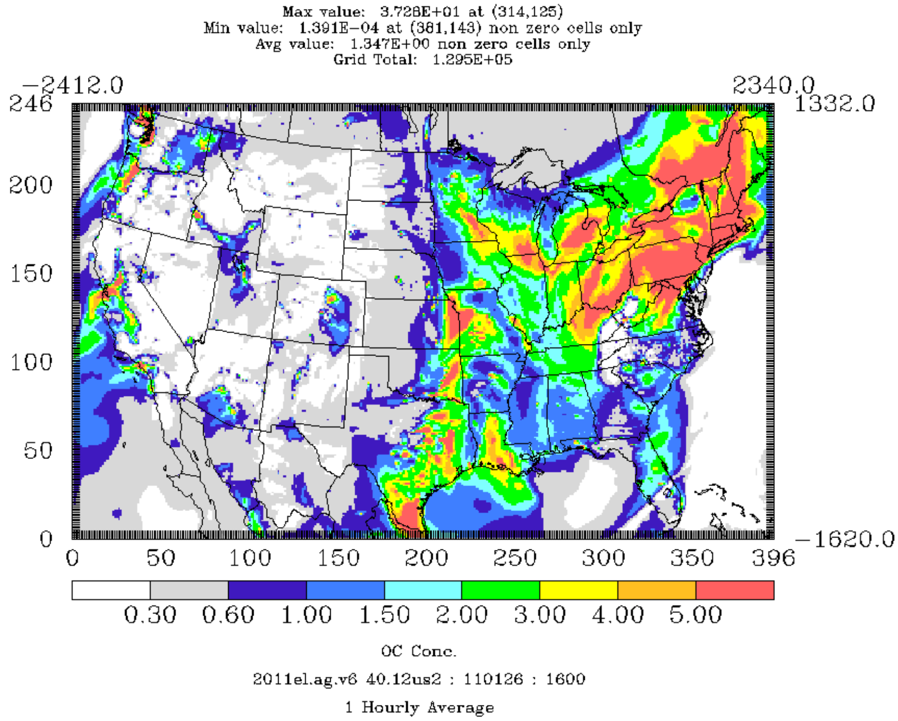


Figure 4-92: Comparison of Organic Matter Concentrations (μg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Seventh Highest Positive Difference)

Eighth Highest Positive Difference: January 26 at 1600 hours

CAMx 6.40



Difference (6.32 - 6.40)

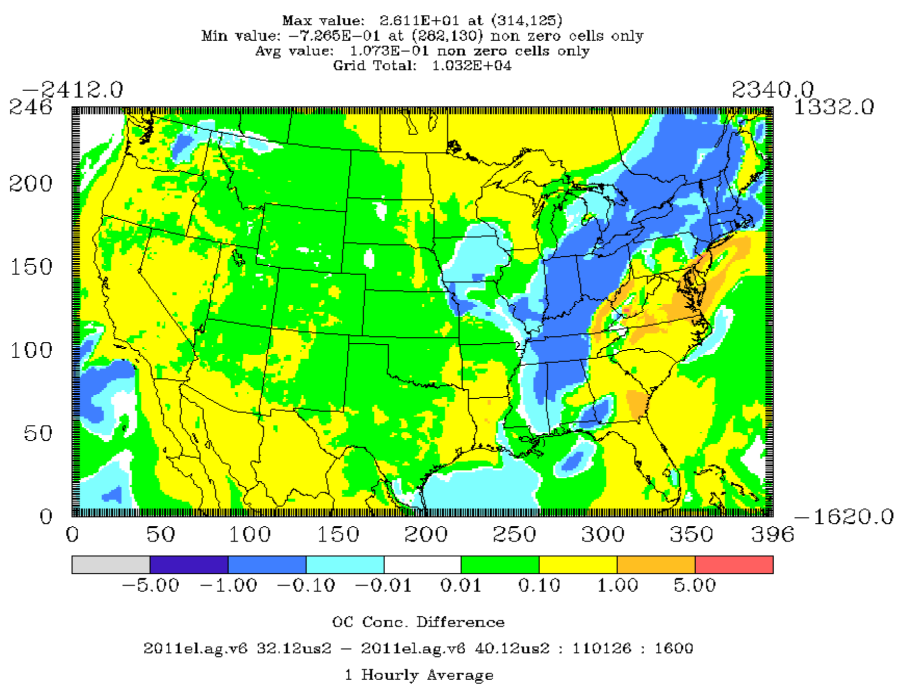
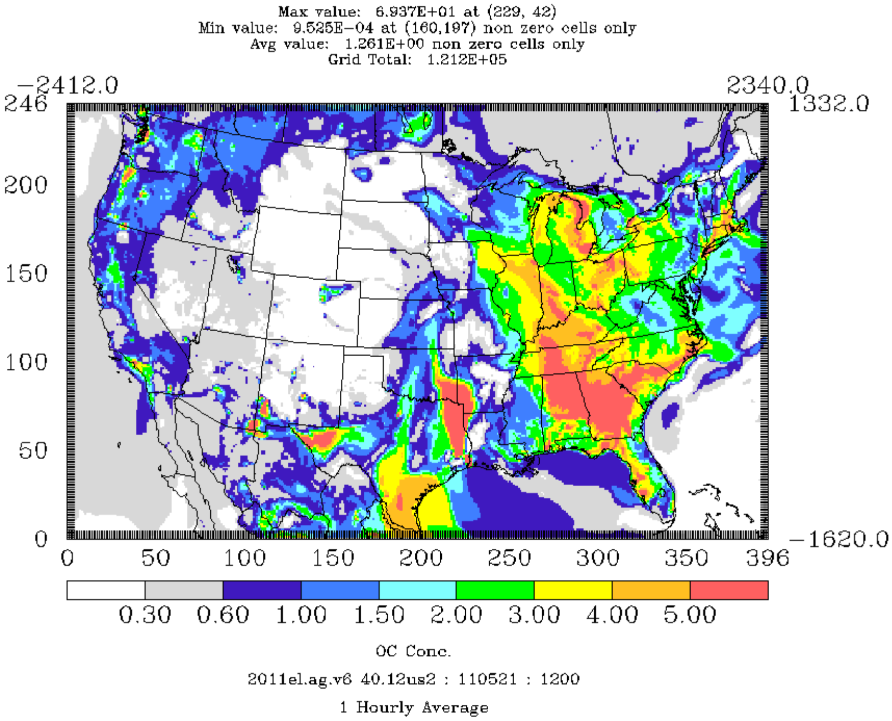


Figure 4-93: Comparison of Organic Matter Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Eighth Highest Positive Difference)

Ninth Highest Positive Difference: May 21 at 1200 hours
CAMx 6.40



Difference (6.32 - 6.40)

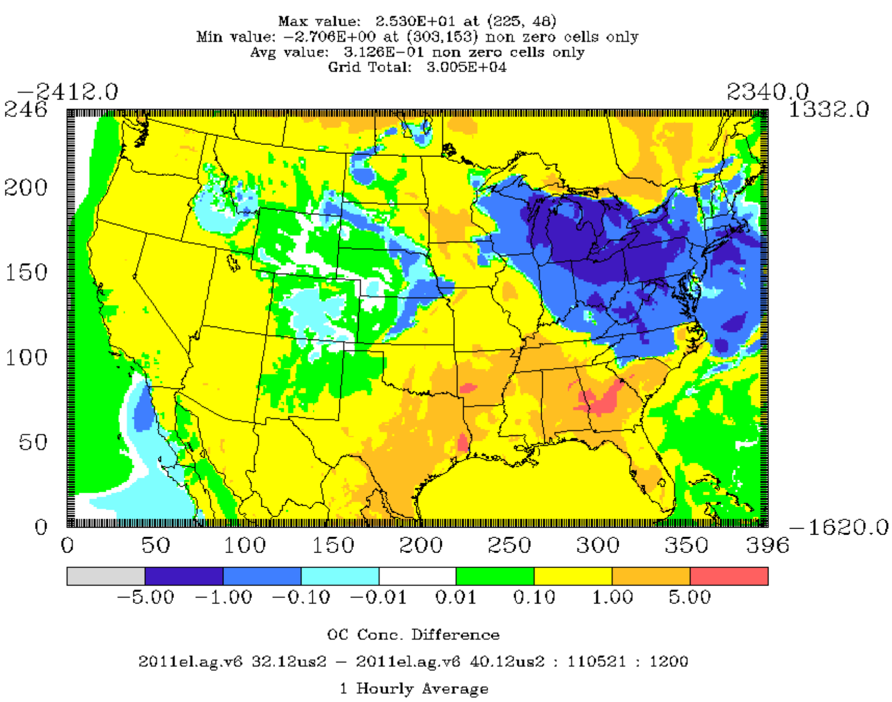
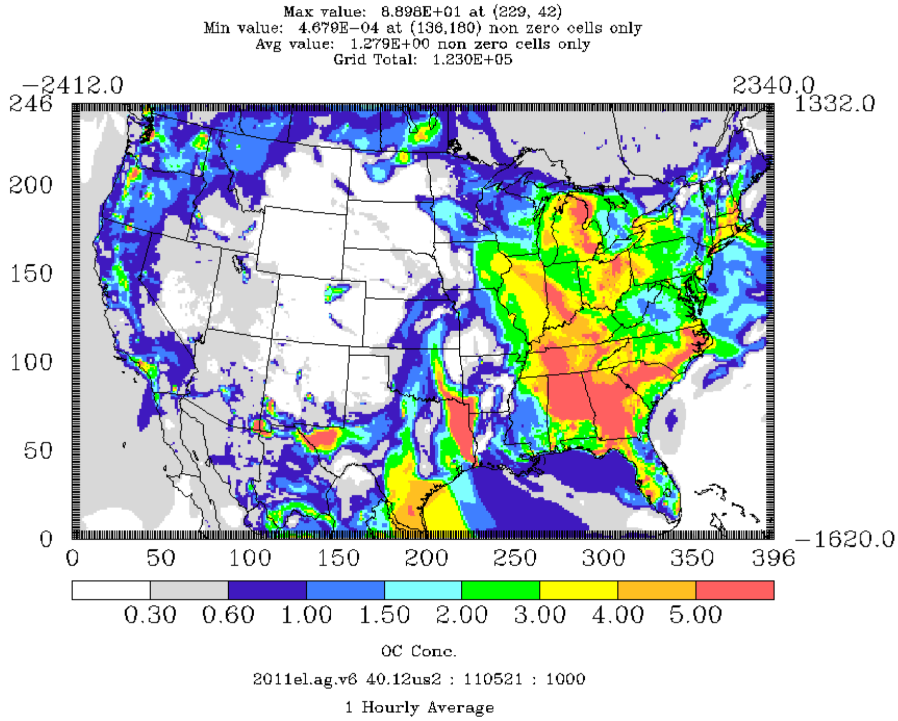


Figure 4-94: Comparison of Organic Matter Concentrations (μg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Ninth Highest Positive Difference)

Tenth Highest Positive Difference: May 21 at 1000 hours

CAMx 6.40



Difference (6.32 - 6.40)

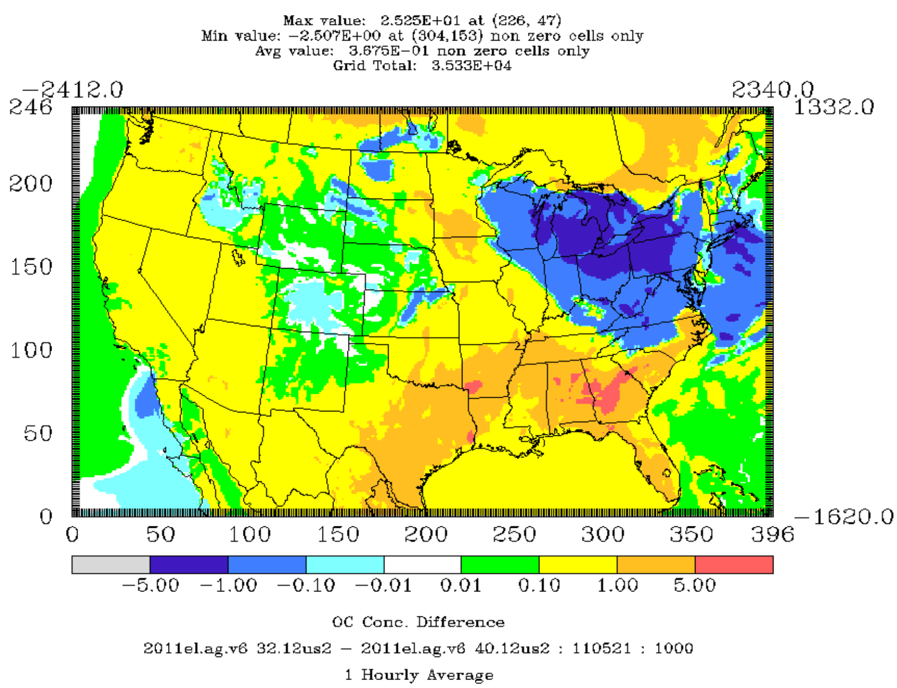
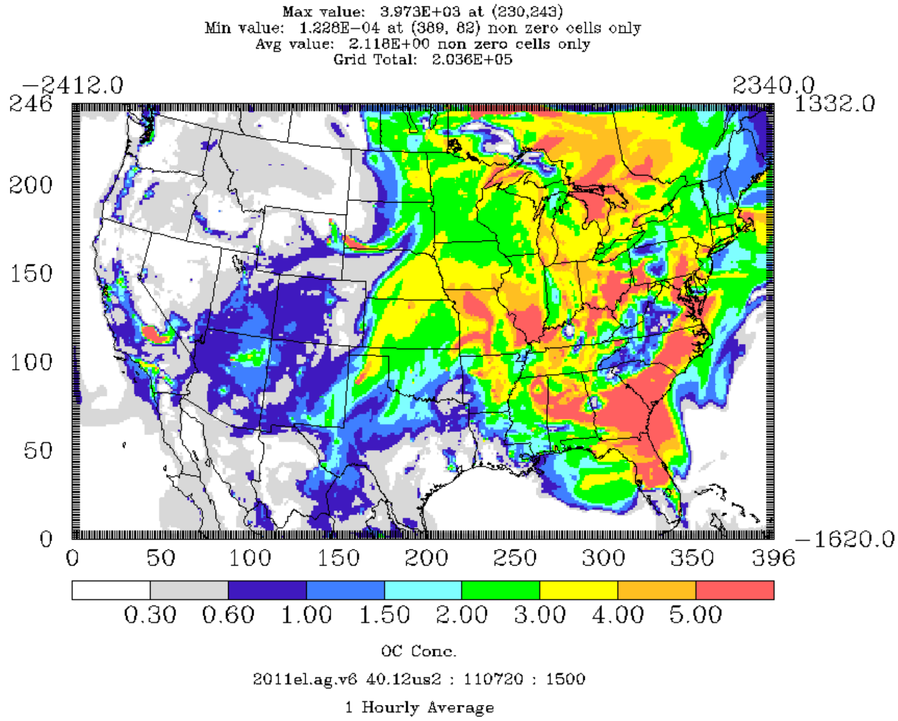


Figure 4-95: Comparison of Organic Matter Concentrations (μg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Tenth Highest Positive Difference)

Maximum Negative Difference: July 20 at 1500 hours
CAMx 6.40



Difference (6.32 - 6.40)

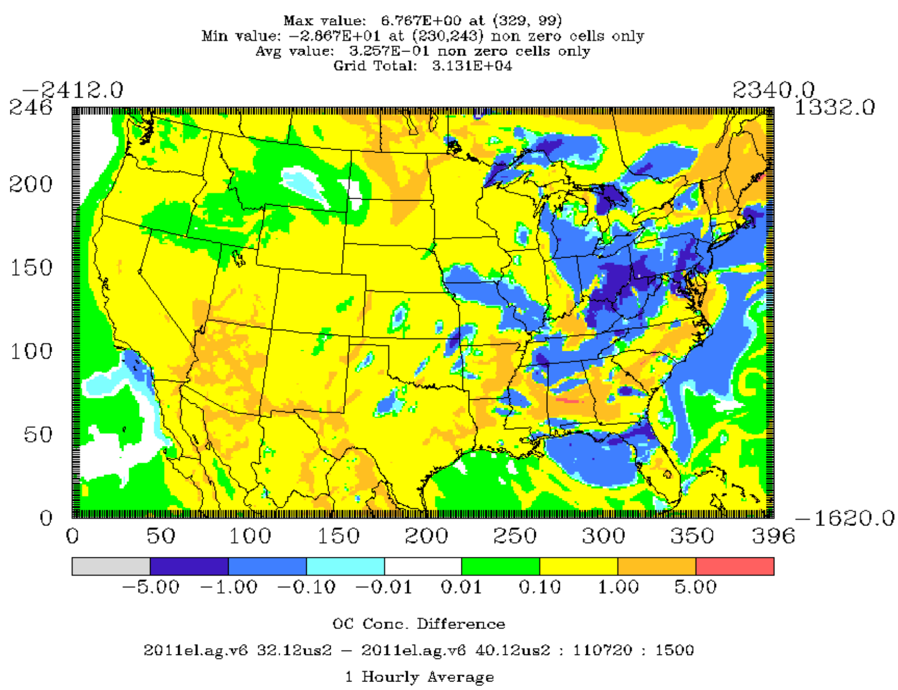
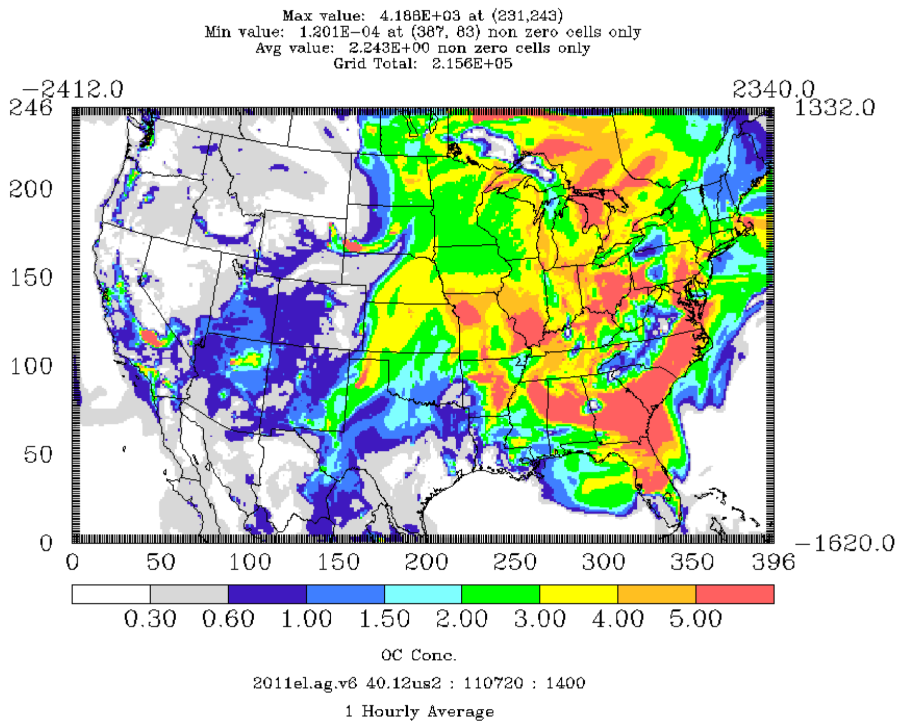


Figure 4-96: Comparison of Organic Matter Concentrations (μg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Maximum Negative Difference)

Second Highest Negative Difference: July 20 at 1400 hours

CAMx 6.40



Difference (6.32 - 6.40)

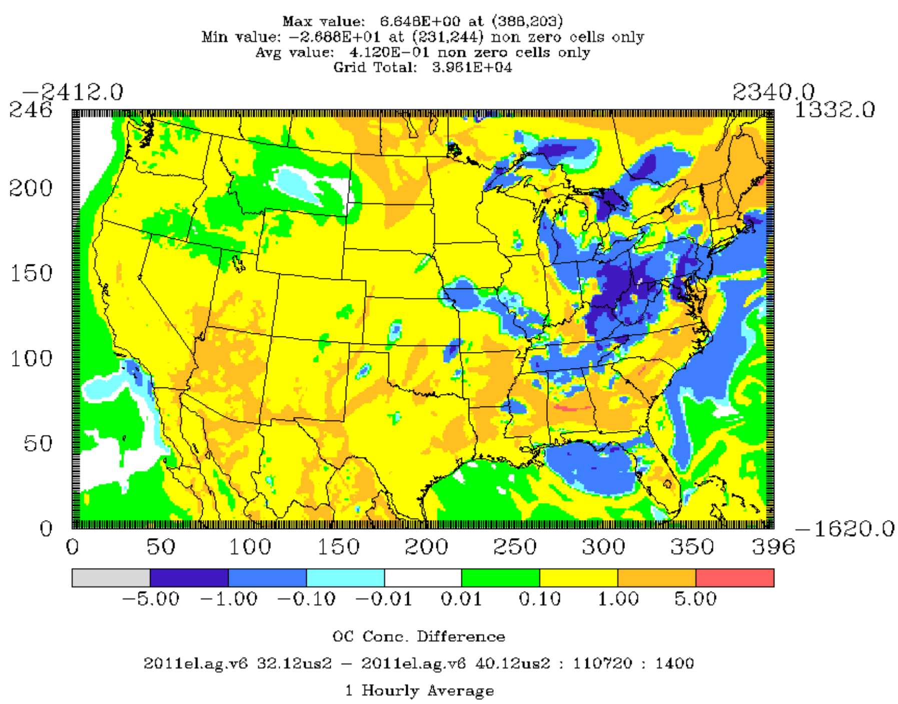


Figure 4-97: Comparison of Organic Matter Concentrations (μg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Second Highest Negative Difference)

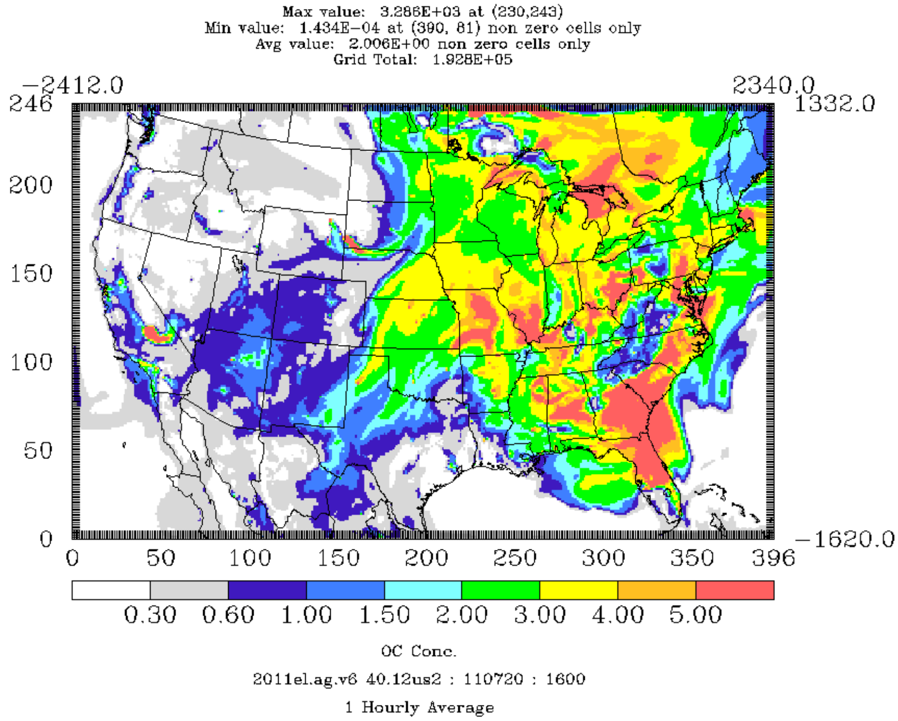
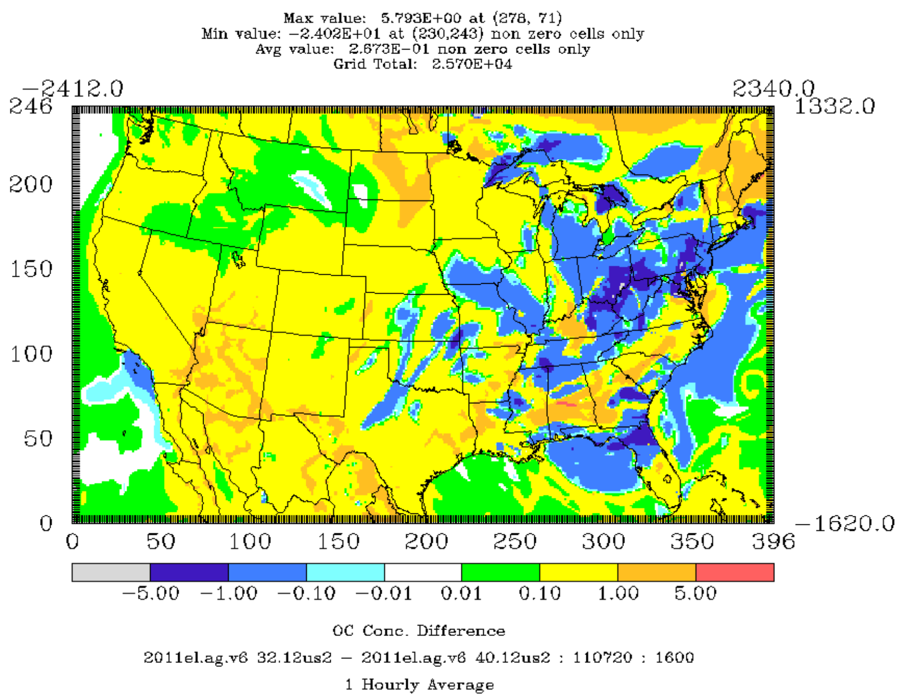
Third Highest Negative Difference: July 20 at 1600 hours
CAMx 6.40

Difference (6.32 - 6.40)


Figure 4-98: Comparison of Organic Matter Concentrations (μg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Third Highest Negative Difference)

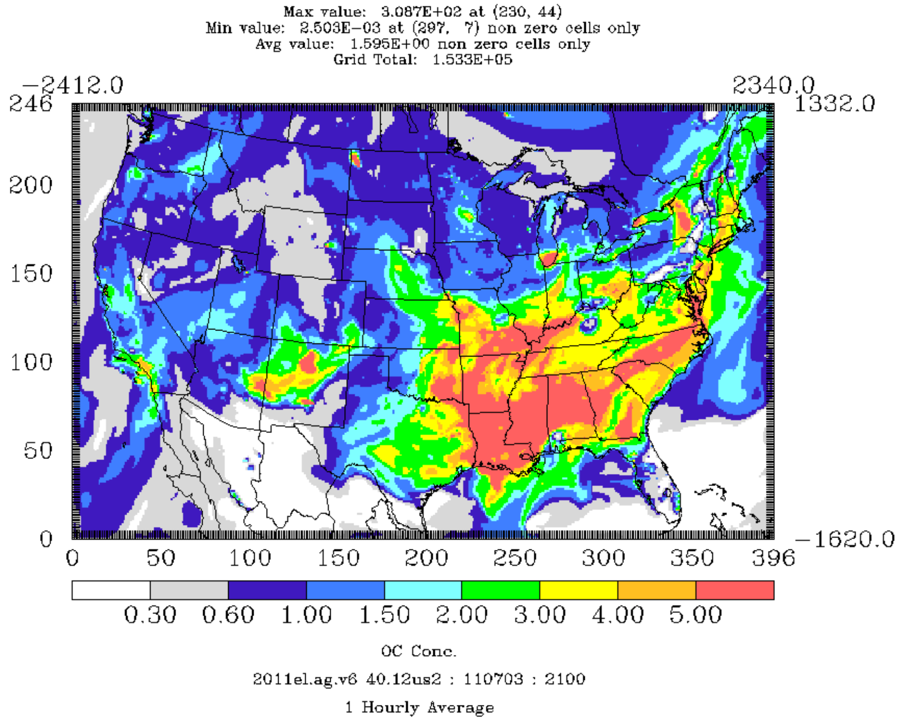
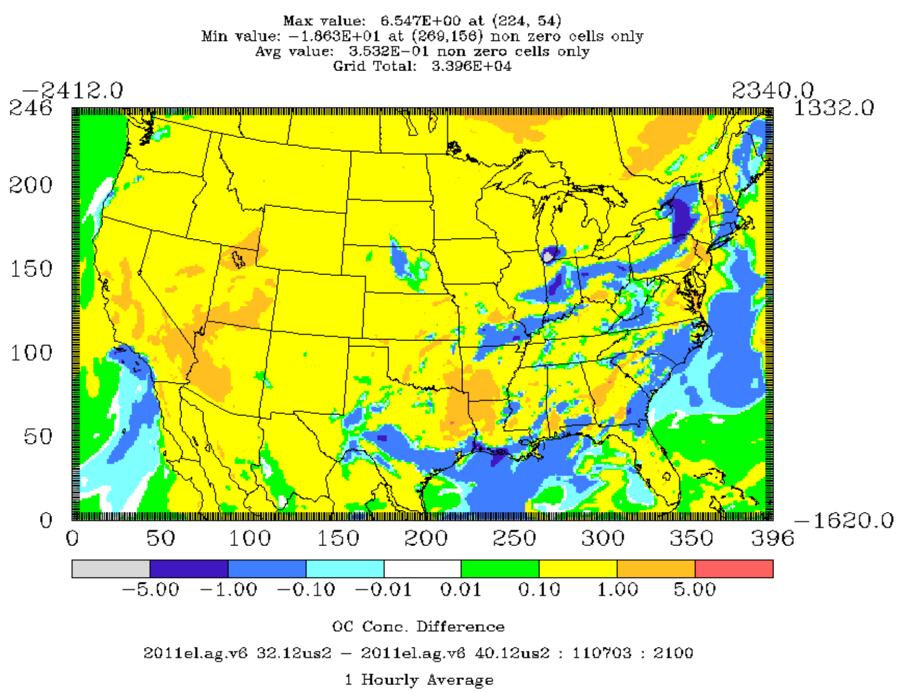
Fourth Highest Negative Difference: July 3 at 2100 hours
CAMx 6.40

Difference (6.32 - 6.40)


Figure 4-99: Comparison of Organic Matter Concentrations (μg/m³) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Fourth Highest Negative Difference)

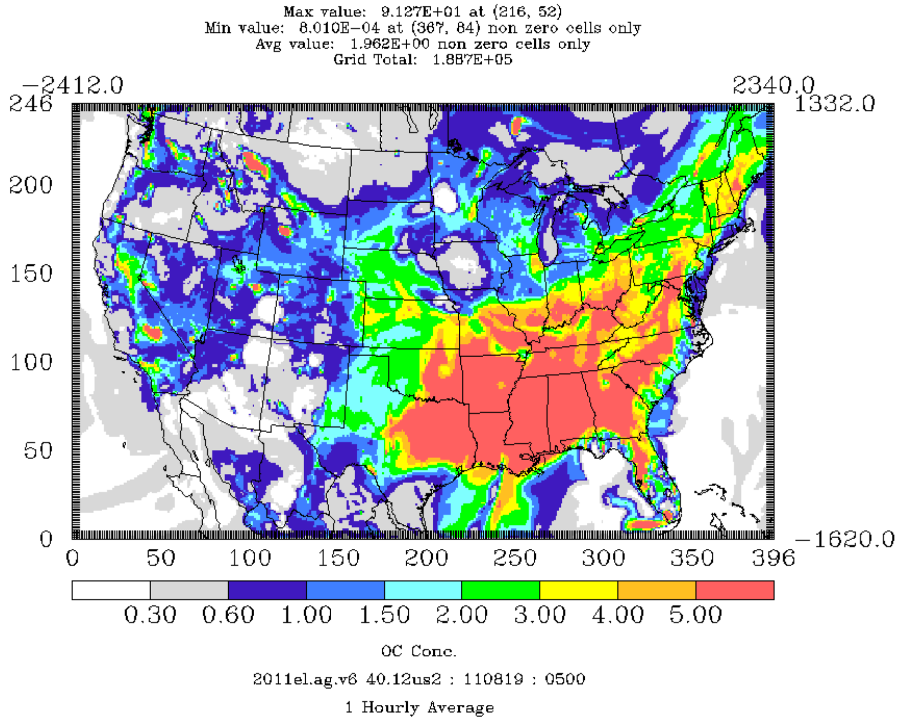
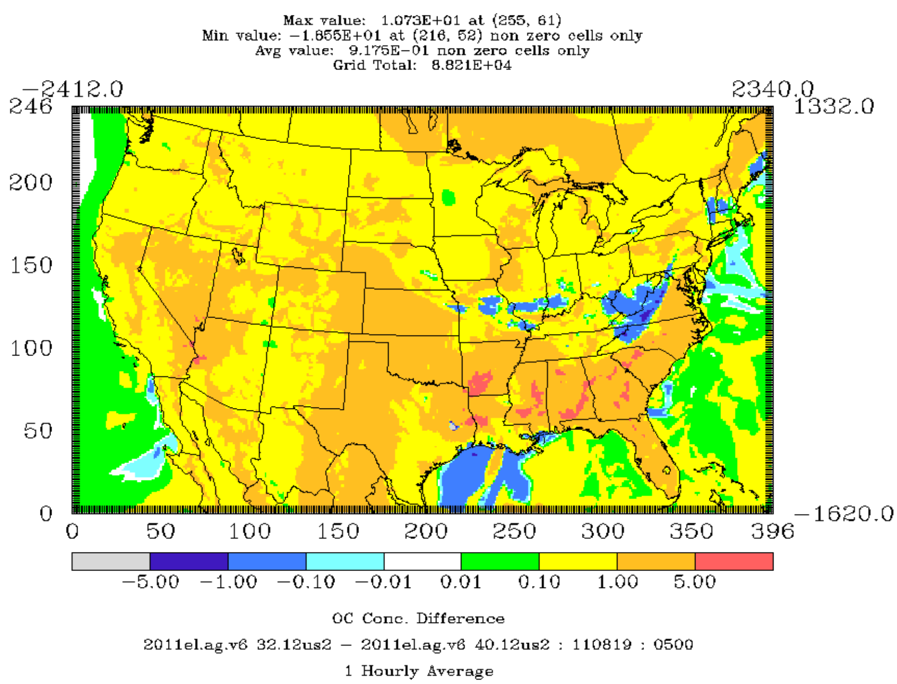
Fifth Highest Negative Difference: August 19 at 500 hours
CAMx 6.40

Difference (6.32 - 6.40)


Figure 4-100: Comparison of Organic Matter Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Fifth Highest Negative Difference)

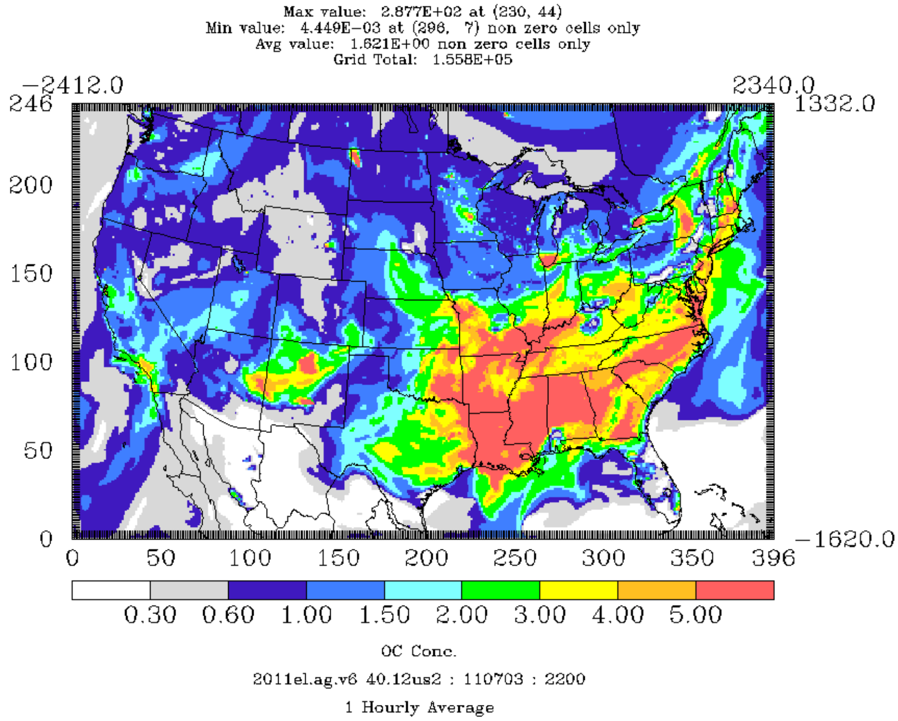
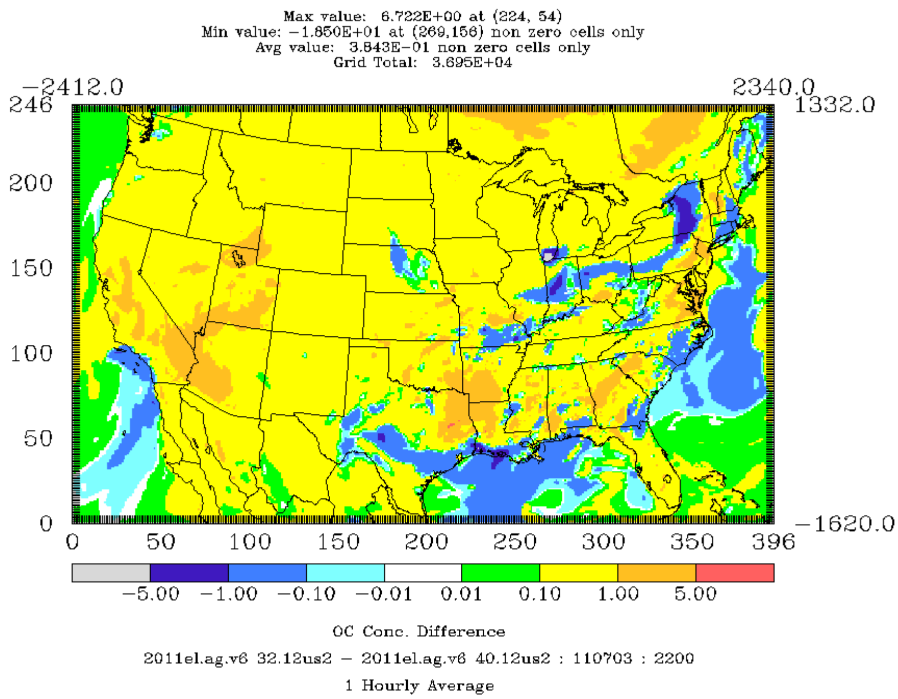
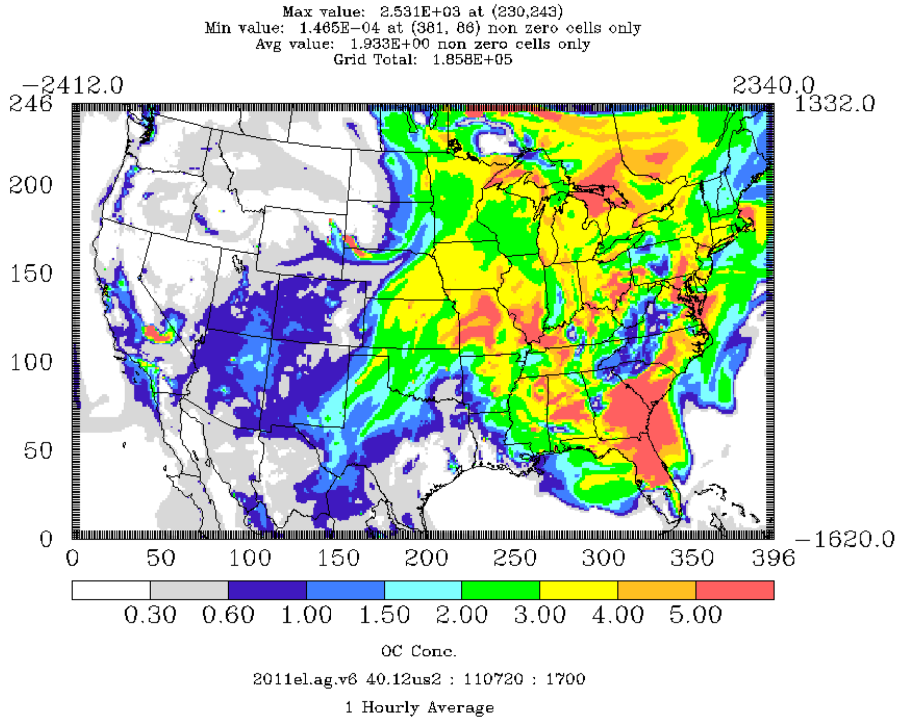
Sixth Highest Negative Difference: July 3 at 2200 hours
CAMx 6.40

Difference (6.32 - 6.40)


Figure 4-101: Comparison of Organic Matter Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Sixth Highest Negative Difference)

Seventh Highest Negative Difference: July 20 at 1700 hours

CAMx 6.40



Difference (6.32 - 6.40)

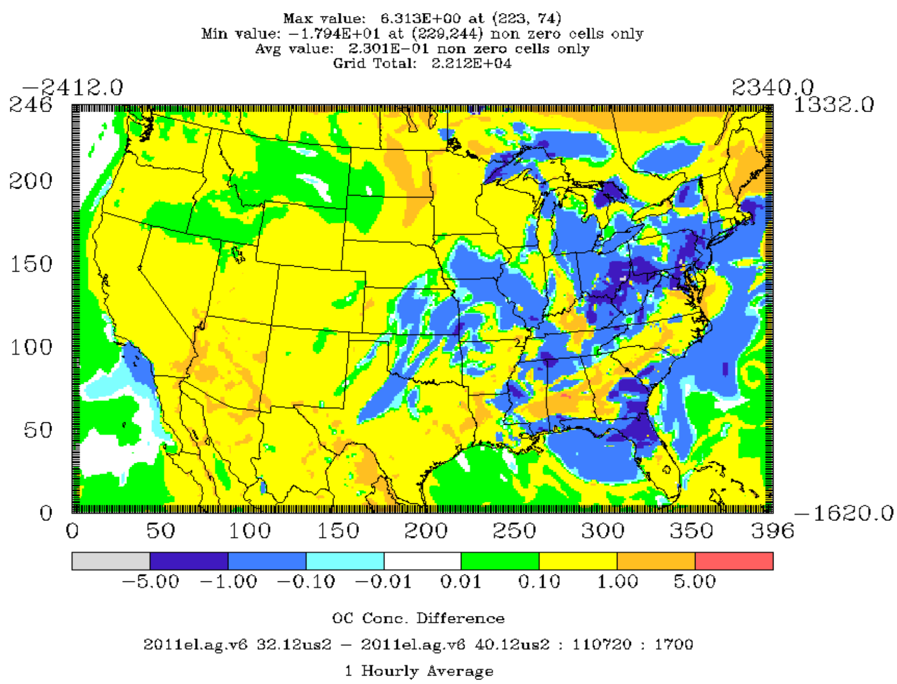
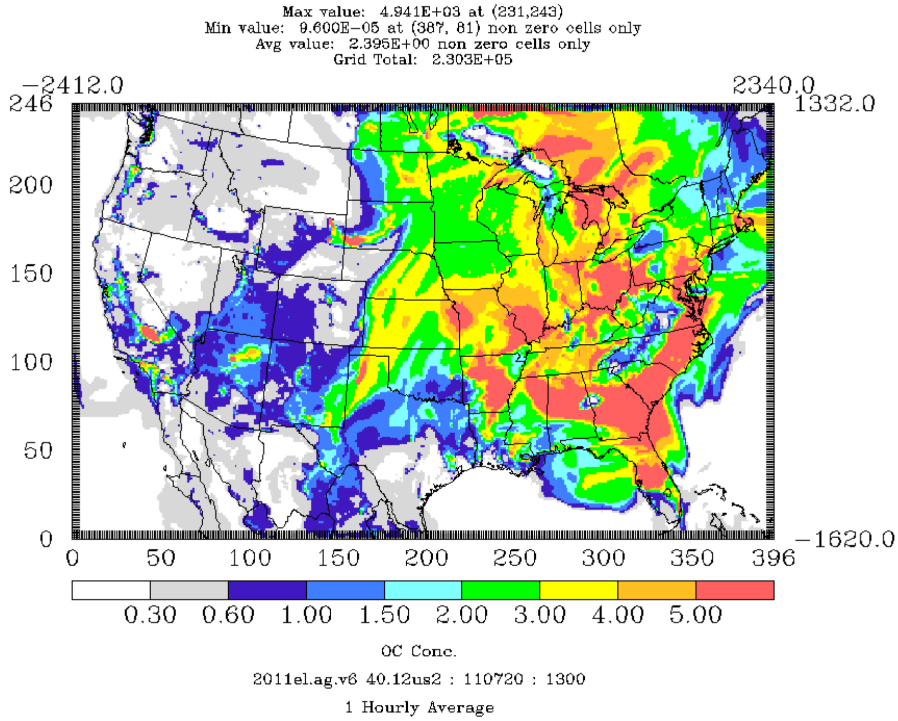


Figure 4-102: Comparison of Organic Matter Concentrations (μg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Seventh Highest Negative Difference)

Eighth Highest Negative Difference: July 20 at 1300 hours
CAMx 6.40



Difference (6.32 - 6.40)

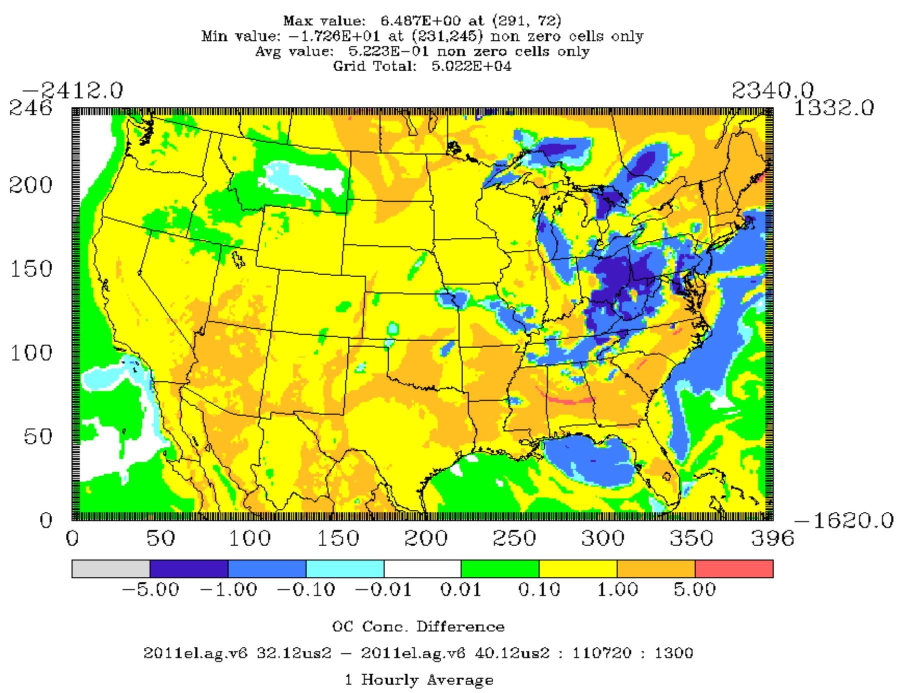


Figure 4-103: Comparison of Organic Matter Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Eighth Highest Negative Difference)

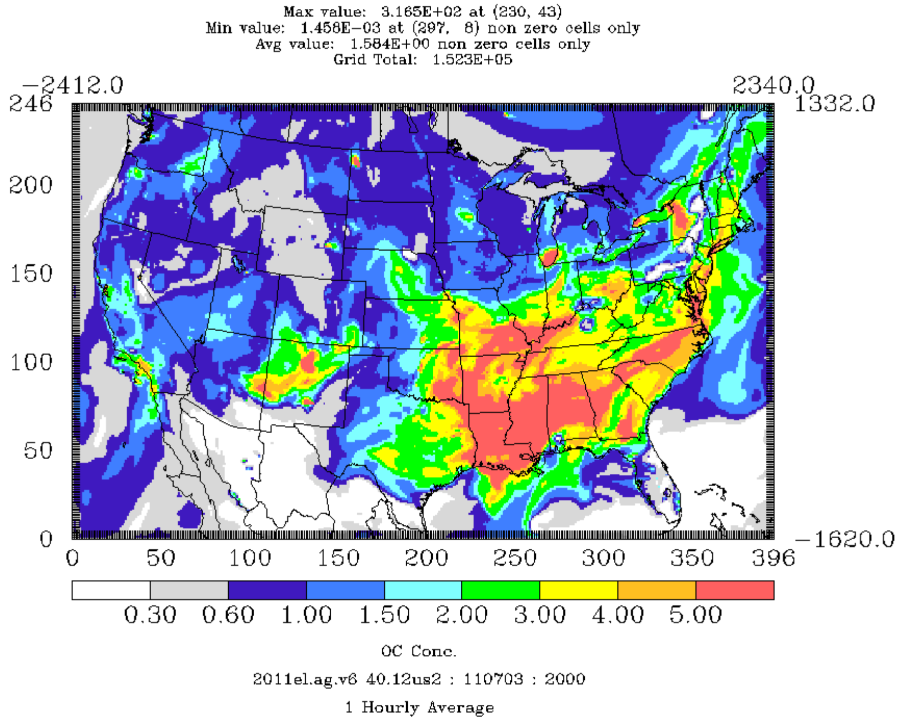
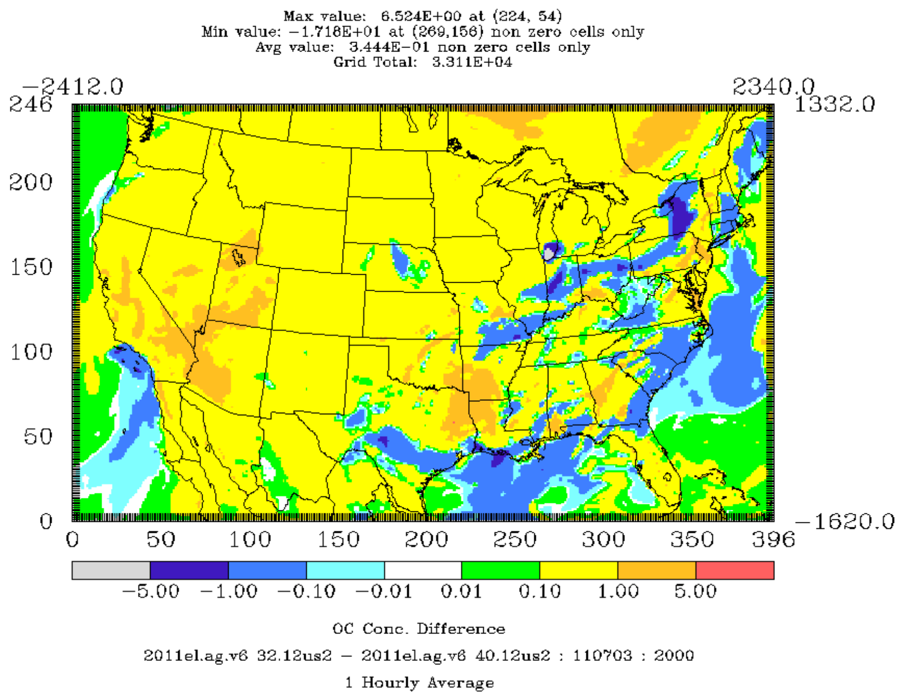
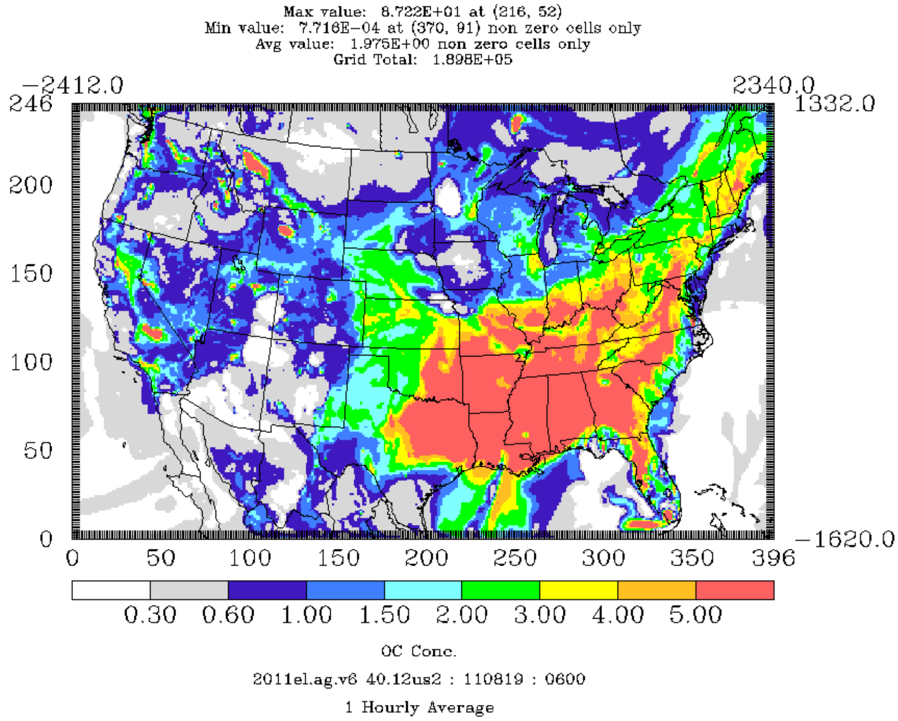
Ninth Highest Negative Difference: July 3 at 2000 hours
CAMx 6.40

Difference (6.32 - 6.40)


Figure 4-104: Comparison of Organic Matter Concentrations (μg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Ninth Highest Negative Difference)

Tenth Highest Negative Difference: August 19 at 600 hours

CAMx 6.40



Difference (6.32 - 6.40)

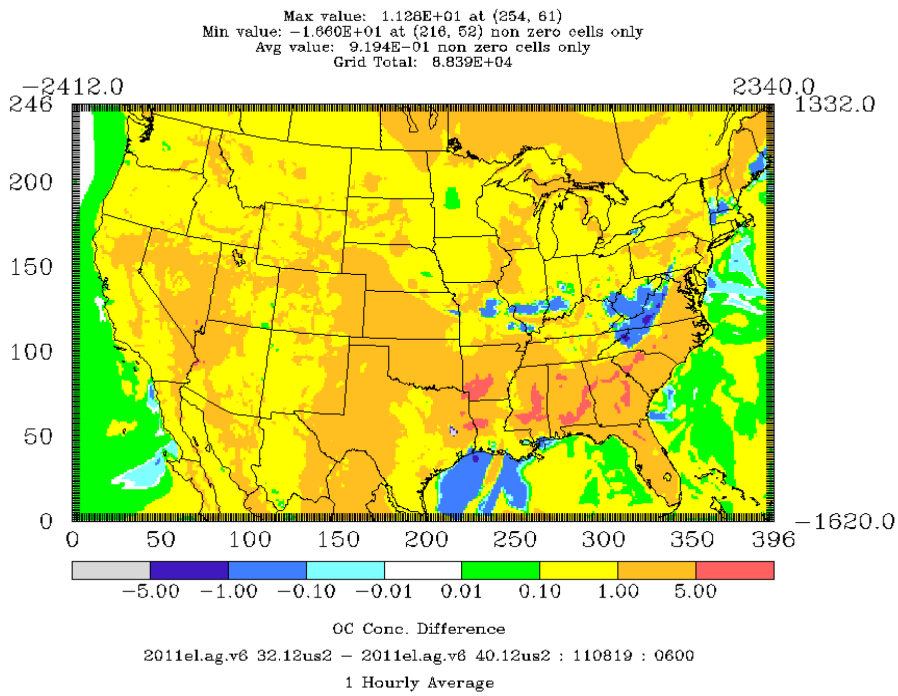


Figure 4-105: Comparison of Organic Matter Concentrations (µg/m^3) for CAMx 6.32 and CAMx 6.40 2011el Simulations (Tenth Highest Negative Difference)

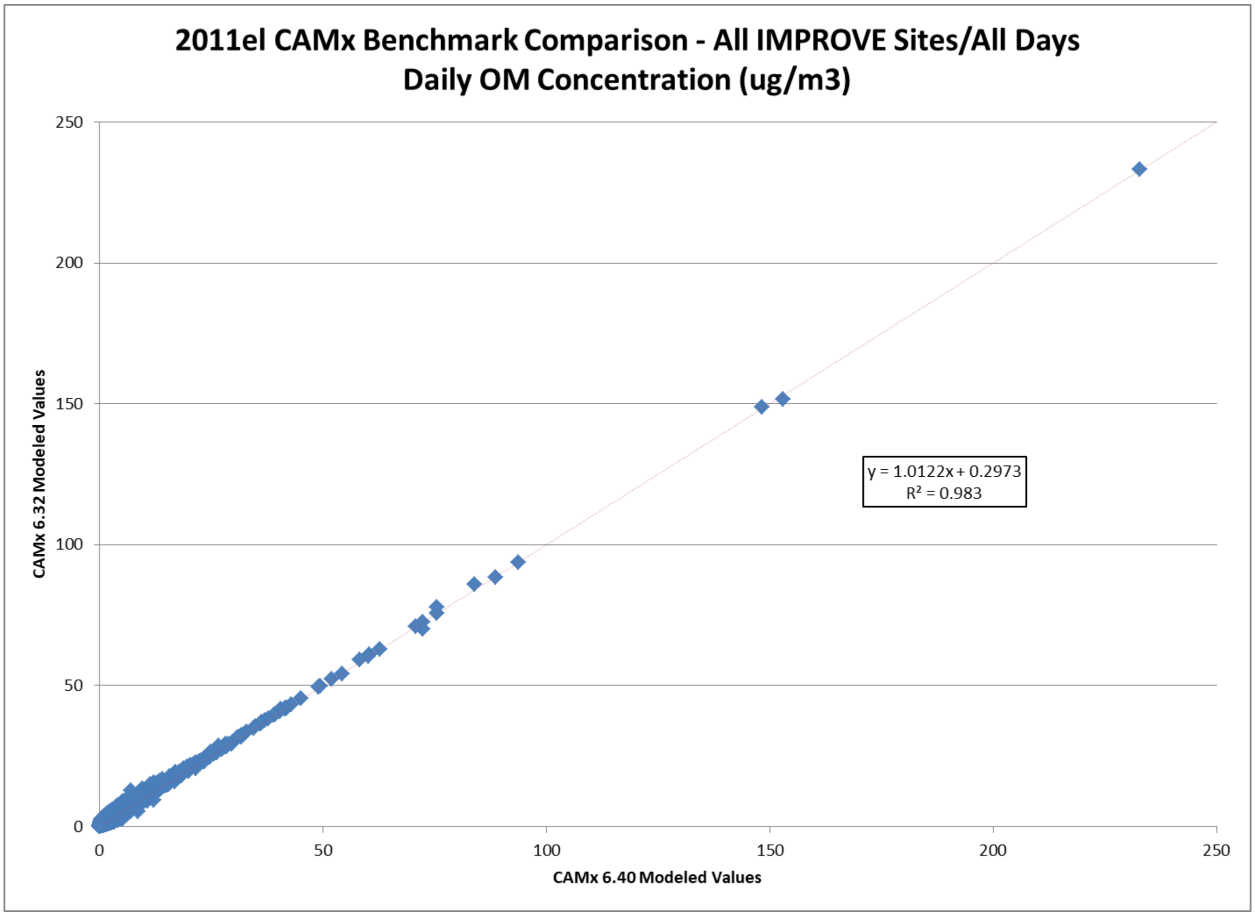


Figure 4-106: Scatterplot Comparing 24-hour Average Predicted Organic Matter Concentrations (µg/m^3) for All Days at all IMPROVE Monitor Locations for CAMx 6.32 and CAMx 6.40 2011el Simulations Performed by VISTAS (Alpine).

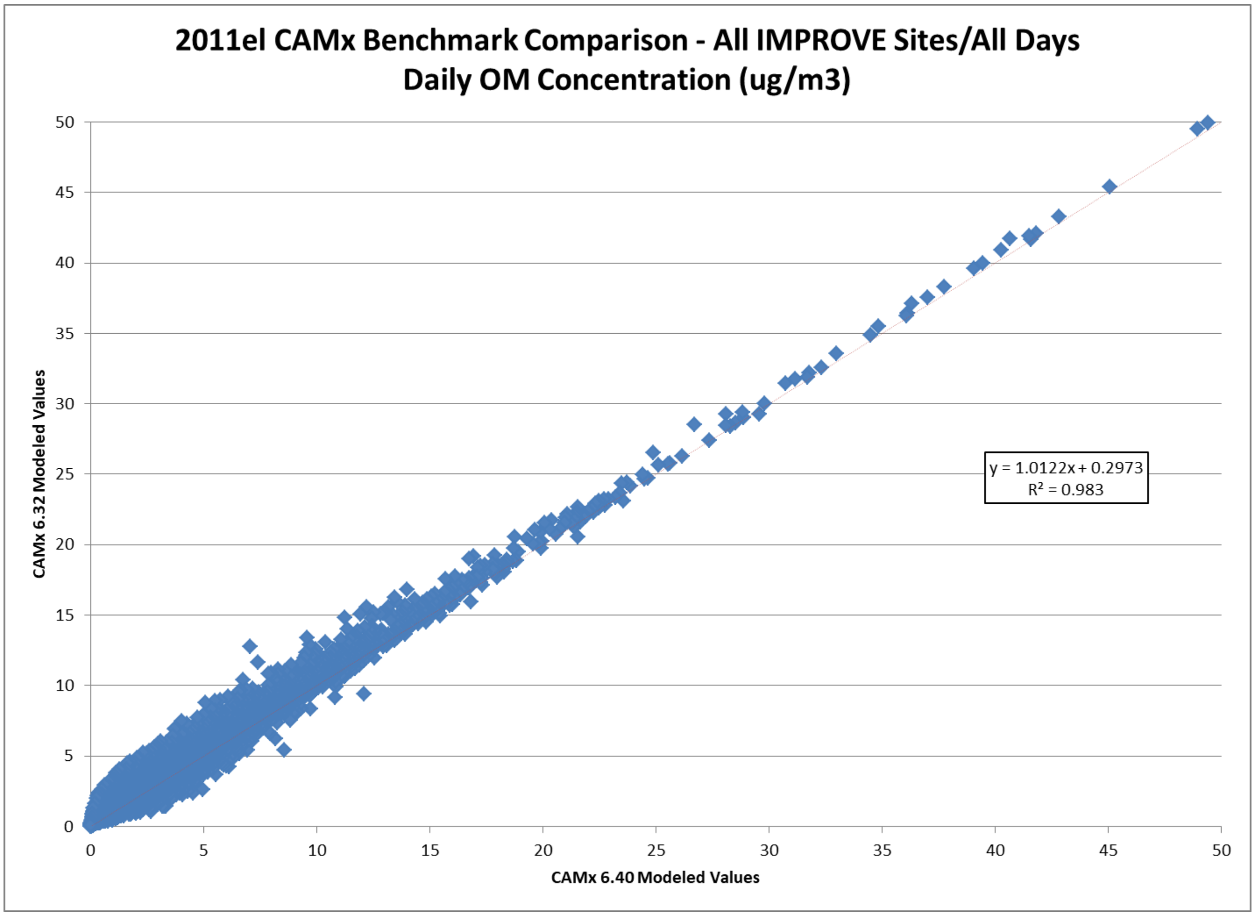


Figure 4-107: Scatterplot Comparing 24-hour Average Predicted Organic Matter Concentrations (μg/m^3) for All Days at all IMPROVE Monitor Locations for CAMx 6.32 and CAMx 6.40 2011el Simulations Performed by VISTAS (Alpine); Modified Scale.

5.0 CONCLUSIONS

A comparison has been made between CAMx 6.32 and CAMx 6.40 simulations using EPA's 2011el modeling platform as performed on the Alpine Geophysics computer system for the VISTAS project. The comparison was conducted for ozone, $PM_{2.5}$, sulfate, nitrate and organic carbon and included an examination both of hourly gridded concentrations, and at daily average concentrations at the IMPROVE monitors.

The hourly gridded comparison showed areas of differences across the domain that varied hour to hour with the maximum hourly differences varying greatly.

A comparison of the daily average concentrations at the IMPROVE monitors showed fairly small differences for ozone and OM. For sulfate, the CAMx 6.40 results were generally lower than CAMx 6.32. For nitrate, the CAMx 6.32 and CAMx 6.40 results differed, with neither version of the model consistently higher than the other. There appears to be a trend where CAMx 6.40 is generally slightly higher that CAMx 6.32 during dry periods, but CAMx 6.32 is generally slightly higher during wet periods. The $PM_{2.5}$ results generally showed higher CAMx 6.32 concentrations compared to CAMx 6.40 at lower concentration levels, with consistent results at higher concentrations.

The comparison of CAMx 6.32 and 6.40 showed differences in model concentration estimates. This is to be expected given the changes to the model from the inclusion of new science into CAMx 6.40 over that which was included in CAMx 6.32. Alpine does not see any features in the modeling that would preclude the use of the better science in CAMx 6.40 for use in the VISTAS air quality planning.