FINAL REPORT

Comparison of Single-Source Air Quality Assessment Techniques for Ozone, $PM_{2.5}$, other Criteria Pollutants and AQRVs

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Prepared for:

Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency
109 T.W. Alexander Drive
Mail Code: C439-1
Research Triangle Park, NC 27709

Prepared by:
ENVIRON International Corporation
773 San Marin Drive, Suite 2115
Novato, California, 94998
Under Subcontract to the University of
North Carolina at Chapel Hill

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1.0 INTRODUCTION

Dispersion models, such as the Industrial Source Complex Short Term (ISCST; EPA, 1995) or American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD; EPA, 2004; 2009c), typically assume steady, horizontally homogeneous wind fields instantaneously over the entire modeling domain and are usually limited to distances of less than 50 kilometers from a source. However, dispersion model applications of distances of hundreds of kilometers from a source require other models or modeling systems. At these distances, the transport times are sufficiently long that the mean wind fields cannot be considered steady-state or homogeneous. As part of the Prevention of Significant Deterioration (PSD) and New Source Review (NSR) programs, new sources or proposed modifications to existing sources may be required to assess the air quality and Air Quality Related Values (AQRVs) impacts at Class I and sensitive Class II areas that may be far away from the source. AQRVs include visibility and acid (sulfur and nitrogen) deposition. There are 156 federally mandated Class I areas in the U.S. that consist of National Parks, Wilderness Areas and Wildlife Refuges that are administered by Federal Land Managers (FLMs) from the National Park Service (NPS), United States Forest Service (USFS) and Fish and Wildlife Service (FWS), respectively. Thus, non-steady-state Long Range Transport (LRT) dispersion models are needed to address air quality and AQRVs issues at distances beyond 50 km from a source.

The models, modeling systems, or model application approaches discussed herein are not necessarily endorsed by US EPA as appropriate for regulatory modeling applications. This is not a guidance document for single source modeling assessments. ***This is an interim report presenting initial modeling results***. It is anticipated that subsequent reports will provide additional and where necessary updated analysis to what is presented in this report. Another important caveat is that the CALPUFF results are not post-processed using the POSTUTIL program to repartition nitrate between the aerosol and gas phases as would be recommended by Federal Land Managers for a single source air quality and air quality related values modeling assessment. Although this work was reviewed by US EPA it may not necessarily reflect official Agency policy.

1.1 BACKGROUND

The Interagency Workgroup on Air Quality Modeling (IWAQM) was formed to provide a focus for the development of technically sound recommendations regarding assessment of air pollutant source impacts on Federal Class I areas. Meetings were held with personnel from interested Federal agencies, including the Environmental Protection Agency (EPA), the USFS, NPS and FWS. The purpose of these meetings was to review respective modeling programs, to develop an organizational framework, and to formulate reasonable objectives and plans that could be presented to management for support and commitment. One objective of the IWAQM is the recommendation of LRT dispersion models for assessing air quality and AQRVs at Class I areas.

1.1.1 CALPUFF LRT Dispersion Model

One such LRT dispersion model is the CALPUFF modeling system (Scire et al., 2000a,b). The CALPUFF modeling system consists of several components:

CALMET (Scire et al., 2000a), a meteorological preprocessor that utilizes surface, upper air, and on-site meteorological data to create a three-dimensional wind field and derive boundary layer parameters based on gridded land use data. CALMET can also use as input three-dimensional output of meteorological variables from prognostic meteorological models;

CALPUFF (Scire et al., 2000b), a Lagrangian puff dispersion model that can simulate the effects of temporally and spatially varying meteorological conditions on pollutant transport, remove pollutants through dry and wet deposition processes, and includes limited ability to transform pollutant species through chemical reactions; and

CALPOST, a postprocessor that takes the hourly estimates from CALPUFF and generates *n*-hr averages as well as tables of maximum values.

In 1998, EPA published the report entitled "A Comparison of CALPUFF Modeling Results to Two Tracer Field Experiments" (EPA-454/R-98-009) (EPA, 1998a). The 1998 EPA study examined concentration estimates from the CALPUFF dispersion model that were compared to observed tracer concentrations from two short term field experiments. In 1998, IWAQM released their Phase 2 recommendations in a report "Interagency Workgroup on Air Quality Modeling (IWAQM) Phase 2 Summary Report and Recommendations for Modeling Long Range Transport Impacts" (EPA, 1998b[1]). These recommendations included a screening and refined LRT modeling approach based on the CALPUFF modeling system. The IWAQM recommendations were based in part on the 1998 EPA tracer test CALPUFF evaluation. It was IWAQM's conclusion at the time that it was not possible to prescribe all of the decisions needed in a CALPUFF/CALMET application: *"The control of the CALMET options requires expert understanding of mesoscale and microscale meteorological effects on meteorological conditions, and finesse to adjust the available processing controls within CALMET to develop the desired effects. The IWAQM does not anticipate the lessening in this required expertise in the future"* (EPA, 1998b).

On April 15, 2003, EPA issued a "Revision to the Guideline on Air Quality Models: Adoption of a Preferred Long Range Transport Model and Other Revisions" in the Federal Register (EPA, 2003[2]) that adopted the CALPUFF model as the EPA-recommended (Appendix W) model for assessing the far-field (> 50 km) air quality impacts due to chemically inert pollutants. In 2005, EPA issued another revision to the air quality modeling guidelines that recommended the AERMOD steady-state Gaussian plume model be used for near-source air quality issues. Thus, from 2005 on to present, there are two EPA-recommended models to address air quality issues due to primary pollutants: AERMOD for near-source (< 50 km) assessments; and CALPUFF for far-field (> 50 km) assessments.

In 2005, EPA formed a CALPUFF workgroup to help identify issues with the existing 1998 IWAQM guidance. In response to this, EPA initiated reevaluation of the CALPUFF system to update the 1998 IWAQM Phase 2 Recommendations. In May 2009, EPA released a draft document entitled the "Reassessment of the Interagency Workgroup on Air Quality Modeling (IWAQM) Phase 2 Summary Report: Revisions to the Phase 2 Recommendations" (EPA, 2009a).

1 http://www.epa.gov/scram001/7thconf/calpuff/phase2.pdf

2 http://www.federalregister.gov/articles/2003/04/15/03-8542/revision-to-the-guideline-on-air-quality-models-adoption-of-a-preferred-long-range-transport-model

In this document, EPA described the developmental status of the CALPUFF modeling system. CALPUFF has evolved continuously since the publication of the original 1998 IWAQM Phase 2 recommendations; however, the status of CALPUFF related guidance has not kept pace with the developmental process. The May 2009 IWAQM Phase 2 Reassessment Report noted that *"The required expertise and collective body of knowledge in mesoscale meteorological models has never fully emerged from within the dispersion modeling community to support the necessary expert judgment on selection of CALMET control options"* (EPA, 2009a). In regards to the 1998 IWAQM Phase 2 lack of prescribing recommended CALMET settings, the May 2009 IWAQM Phase 2 Reassessment Report states: *"In a regulatory context, this situation has often resulted in an 'anything goes' process, whereby model control option selection can be leveraged as an instrument to achieve a desired modeled outcome, without regard to the scientific legitimacy of the options selected"* (EPA, 2009a). The CALPUFF working group noted that when running CALMET with prognostic meteorological model (e.g., WRF and MM5) output as input, the CALMET diagnostic effects and blending of meteorological observations with the WRF/MM5 output degraded the WRF/MM5 meteorological fields. Thus, the 2009 IWAQM Phase 2 Reassessment Report recommended CALMET settings with an objective to try and "pass through" the WRF/MM5 meteorological model output as much as possible for input into CALPUFF.

However, further testing of CALMET and CALPUFF by EPA's CALPUFF workgroup found that the recommended CALMET settings in the May 2009 IWAQM Phase 2 Reassessment Report did not achieve the intended result to "pass through" the WRF/MM5 meteorological variables as CALMET still re-diagnosed some and modified other meteorological variables thereby degrading the WRF/MM5 meteorological fields. Based in part of CALMET evaluations using tracer test field study databases, EPA determined interim CALMET settings that produced the best meteorological model performance and on August 31, 2009 released a Clarification Memorandum "Clarification on EPA-FLM Recommended Settings for CALMET" (EPA, 2009b) with new recommended settings for CALMET. In the August 2009 Clarification Memorandum, EPA reiterated the desire to "pass through" meteorology from the WRF/MM5 prognostic meteorological models to CALPUFF, but the CALMET model at this time was incapable of achieving that objective.

In the meantime, EPA has developed the Mesoscale Model Interface (MMIF) software (Anderson, 2008) that where possible directly converts prognostic meteorological output data from the MM5 or WRF models to the parameters and formats required for direct input into the CALPUFF dispersion model thereby bypassing CALMET. Version 1.0 of MMIF was released in June 2009 (Emery and Brashers, 2009) and Version 2.1 was released in February 2012 (Brashers and Emery, 2012). MMIF specifically processes geophysical and meteorological output files generated by the fifth generation mesoscale model (MM5) or the Weather Research and Forecasting (WRF) model (Advanced Research WRF [ARW] core, versions 2 and 3) and reformats the MM5/WRF output for input into CALPUFF. The current beta version of MMIF (Version 2.1) not only acts as an interface MM5/WRF "pass through" tool with CALPUFF, but also allows the development of meteorological inputs for AERMOD and SCICHEM.

1.1.2 Single-Source LRT Models

The U.S. EPA is exploring different alternatives for performing single-source dispersion modeling over longer distances to address Class I and Class II area air quality and AQRV issues.

Such issues include PSD pollutant concentrations, including SO_2, NO_2 and $PM_{2.5}$ concentrations, visibility and sulfur and nitrogen deposition. Ozone is also becoming a pollutant of increasing importance. Important components of visibility and deposition are sulfate (SO_4) and nitrate (NO_3) that are secondarily formed PM species from gaseous SO_2 and NO_X emissions, respectively. Thus, the correct depiction of chemistry is an important feature of LRT dispersion models.

Although CALPUFF became the EPA-recommended LRT dispersion model in 2003 for distances beyond 50 km and chemically inert pollutants (EPA, 2003), it has several limitations and issues:

- The chemical conversion algorithm in the regulatory versions of CALPUFF (Version 5.8) is almost three decades old (developed in 1983) and has been shown to be inconsistent with our current knowledge on secondary $PM_{2.5}$ formation chemistry (Morris et al., 2003; 2005; 2006).
- The CALPUFF chemistry algorithm was recently updated in Version 6.4 (Karamchandani , Chen and Seigneur, 2008), but still does not contain photochemical reactions, which are important to simulate secondary PM formation.
    - Sulfate and nitrate formation is formed through a complex set of photochemical reactions that require the correct depiction of the radical cycle, including hydroxyl (OH) and perhydroxy (HO_2) radicals that are driven by organic and inorganic species.
- CALPUFF does not estimate ozone formation from single emissions sources.
- CALPUFF sensitivity modeling using alternative CALMET meteorological inputs found wide variations in the CALPUFF model estimates (EPA, 2012).

EPA evaluated CALPUFF and five other LRT dispersion models using data from four atmospheric tracer field experiments (EPA, 2012). The EPA tracer test comparison evaluated the transport and dispersion components of the LRT models and raised additional questions regarding the CALPUFF LRT dispersion model..

1.2 PURPOSE

The purpose of this study is to test the feasibility of using photochemical grid models (PGMs) for single-source assessments of concentration, visibility and deposition at farther downwind distances and compare the results with CALPUFF. The study also examines the CALPUFF concentrations/AQRV assessments using meteorological inputs from the CALMET diagnostic wind model (Scire et al, 2000b) and the new Mesoscale Model Interface (MMIF; Brashers and Emery, 2012) tool that where possible performs a direct “pass through” of the MM5/WRF meteorological output to generate CALPUFF meteorological inputs.

1.3 ORGANIZATION OF REPORT

Chapter 1 provides a background and purpose for the study. Chapter 2 provides an overview of the technical approach. A comparison of single-source LRT dispersion model results for example test sources and concentrations, visibility and deposition is provided in Chapter 3. References are provided in Chapter 4.

2.0 TECHNICAL APPROACH

2.1 OVERVIEW OF APPROACH

In this section we describe the technical approach for developing inputs and evaluating the CAMx and CALPUFF models for making single-source air quality and air quality related value (AQRVs) assessments at far-field downwind distances. The application methodology for CAMx is exploratory in nature and does not reflect official Agency guidance or policy.

The approach was to generally follow procedures that are used for assessing the Class I area air quality and AQRV impacts as used under the New Source Review (NSR) and Prevention of Significant Deterioration (PSD) programs or as part of an Environmental Impact Statement (EIS) or Resource Management Plan (RMP) under the National Environmental Policy Act (NEPA). The current guidance for performing such a NSR/PSD far-field assessment is to use the EPA-recommended (EPA, 2003) CALPUFF/CALMET modeling system (Scire et al., 2000a,b) following the procedures as outlined in the 2010 Federal Land Managers Air Quality Related Values Workgroup (FLAG; EPA, 2010) and the 2009 EPA Clarification Memorandum on recommended CALMET settings for regulatory modeling (EPA, 2009b). EPA recommends that Version 5.8 of CALPUFF be used for regulatory far-field air quality and AQRV assessments.

For this study, CALPUFF Version 5.8 was applied for a series of test sources using meteorological inputs generated by CALMET following EPA's recommended settings (EPA, 2009b) as well as meteorological inputs using the MMIF tool (Brashers and Emery, 2012). The air quality and AQRV impacts of the test sources were also evaluated using the CAMx photochemical grid model (PGM). The CAMx and CALPUFF modeling were conducted using two existing databases:

- The 2005 Four Corners Air Quality Task Force (FCAQTF) 12/4 km modeling database with the 4 km domain focused on the Four Corners region as shown in Figure 2-2 (Stoeckenius et al., 2009); and
- A 2006 12 km modeling database covering eastern Utah and western Colorado (UT-CO 12 km domain) shown in Figure 2-1 that was originally developed as part of the Uinta Basin Air Quality Study (UBAQS; Morris et al., 2010).

CALPUFF inputs were developed using the 2005 and 2006 MM5 data (CALMET and MMIF) and surface and upper-air meteorological observations (CALMET only). The CALMET modeling was performed following the EPA recommended procedures (EPA, 2009b; 2010) and MMIF was configured to have a similar modeling domain as CALMET (e.g., vertical layers similar to the CALMET ZFACE values).

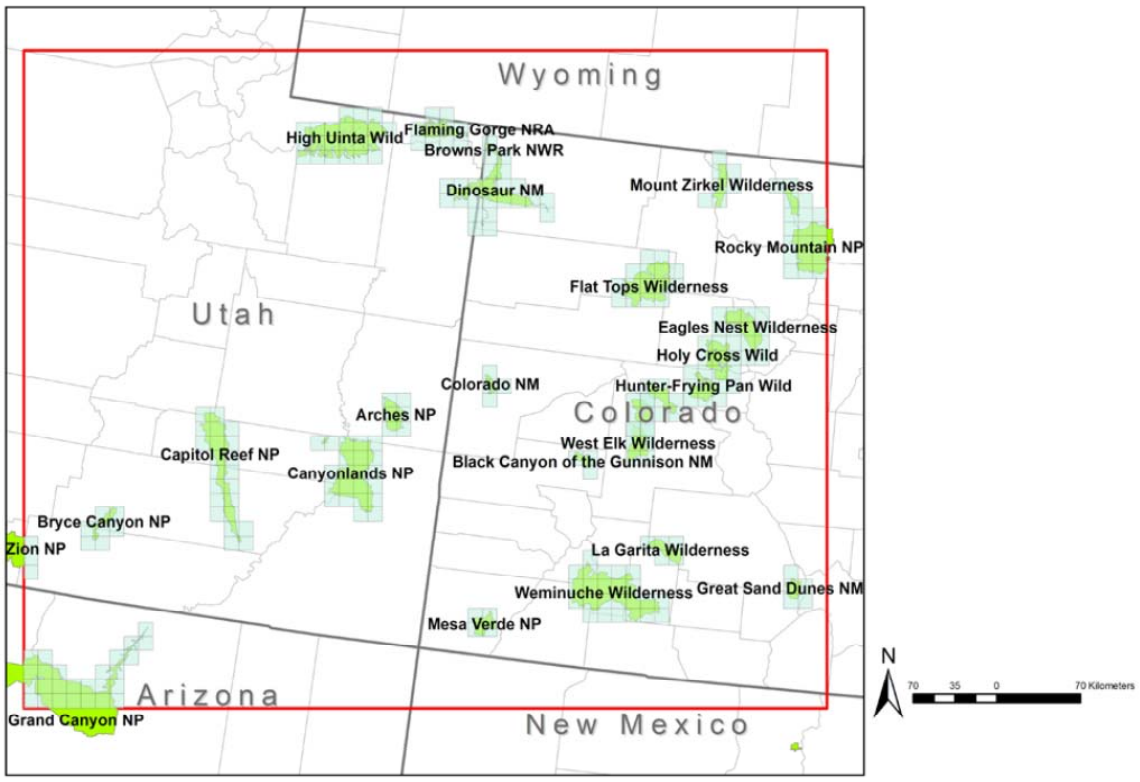


Figure 2-1. 2006 UT-CO 12-km modeling domain with locations of Class I and sensitive Class II areas showing 12 km grid cell representations of the Class I/II areas.

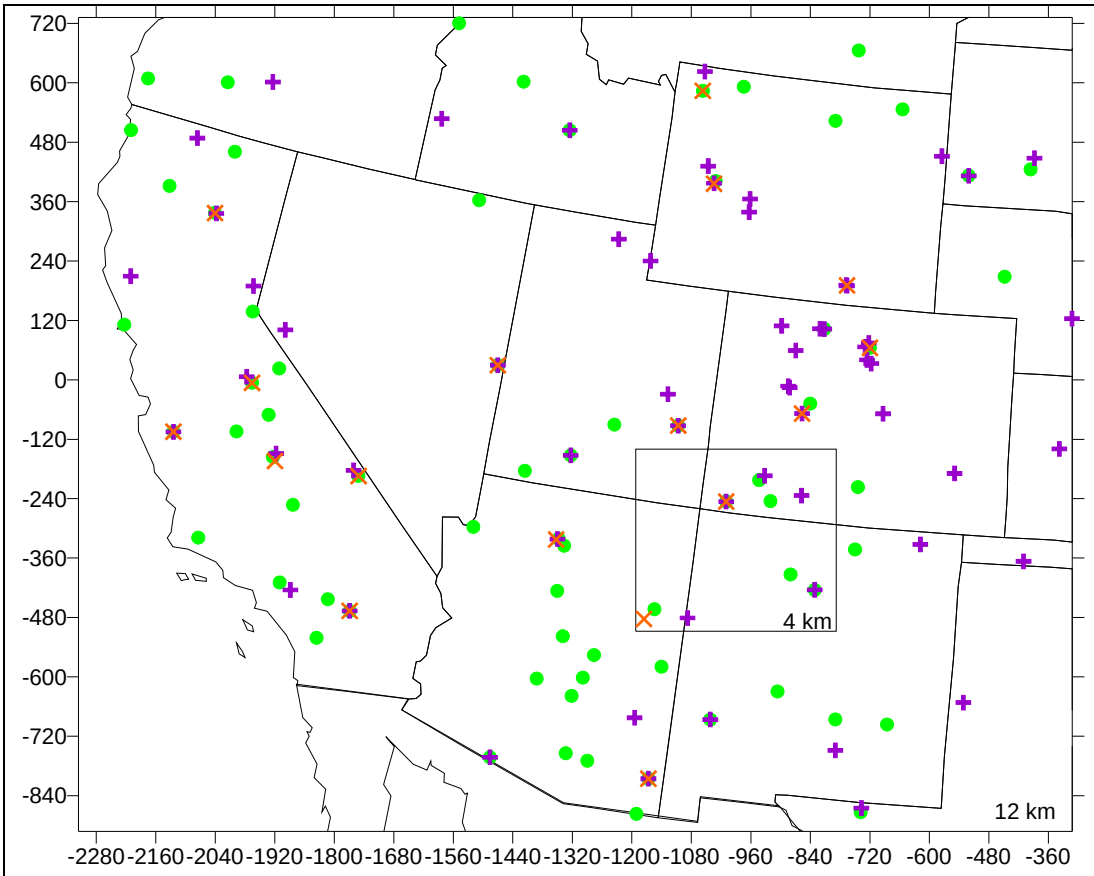


Figure 2-2. FCAQTF 2005 12/4 km modeling domains and locations of IMPROVE, CASTNet, and NADP monitoring sites.

Test sources were selected from the existing PGM modeling databases to represent the types of sources that are typically evaluated under PSD/NSR or NEPA (e.g., point sources, oil and gas development, etc.). For each of the test sources, the CAMx ozone and particulate source apportionment technology (OSAT and PSAT) was used to track the single-source contribution to air quality and AQRVs. CALPUFF V5.8 was applied for the same sources using CALMET and MMIF meteorological inputs and the results compared with CAMx and each other.

2.2 DEVELOPMENT OF CAMX EMISSION INPUTS

2.2.1 CAMx Emission Inputs for the 2006 UT-CO Database

2006 Emission inputs were developed for the 36 km continental U.S. (CONUS) and 12 km UT-CO modeling domains representative of the 2006 calendar year. The 2006 PGM emissions were originally developed for the CMAQ PGM and used three-dimensional (3-D) emission inputs. The MEGAN biogenic emissions model was employed using the 2006 36/12 km MM5 meteorological data to generate day-specific biogenic emissions for 2006. SMOKE-MOBILE6 and the 2006 MM5 meteorological data were used to develop monthly, weekday-, Saturday- and Sunday-specific on-road mobile source emission inputs for the 2006 year. The WRAP ammonia emissions model (Mansell, 2005) was used with the 2006 MM5 meteorological data to generate ammonia emissions. Detailed emission inventories for oil and gas development activities for the region were based on the WRAP Phase III oil and gas emissions. Details on the development of the 2006 CAMx-ready emission inputs for each major source category are described below.

EGU Point Source Emissions: Point source emissions were separated into Electrical Generating Unit (EGU), non-EGU and O&G production categories and were processed separately. The EGU data included annual emissions for all point sources and hourly Continuous Emissions Monitoring (CEM) data for point sources that were obtained from the EPA Clean Air Markets Division (CAMD).

Non-EGU Point Source Emissions: Point source emissions from non-EGU sectors were not based on day- or hour-specific emissions (i.e., are not included in the CAMD data). Emissions from these sources were temporally allocated to month, day, and hour using annual emissions and source category code (SCC) based allocation factors available in the WRAP SMOKE setup which incorporated any relevant data that has been developed by other RPOs.

On-Road Mobile Source Emissions: This category comprises vehicular sources that operate on roadways such as light-duty gasoline vehicles and heavy-duty diesel vehicles. The MOBILE6 module was used with SMOKE to develop the on-road mobile source emissions. The MOBILE6 parameters, vehicle fleet descriptions, and vehicle miles of travel (VMT) estimates were combined with gridded, episode specific temperature data to obtain the gridded, temporally allocated emission estimates for a weekday, a Saturday, and a Sunday for the 2006 year.

Non-Road Mobile Source Emissions: Non-road mobile sources include, for example, railroad locomotives, aircraft, commercial marine vessels, farm equipment, recreational boating, and lawn and garden equipment. The 2006 base year emissions were projected from the WRAP 2002 emission inventory. The non-road mobile source emissions were temporally and spatially allocated in the same manner as the area source emissions which are discussed below. The marine shipping emissions were held constant from WRAP 2002 inventory, which was estimated using the Waterway Network Ship Traffic, Energy and Environment Model (STEEM) to characterize ship traffic, estimate energy use and assess the environmental impacts of shipping (Corbett et al., 2006).

Area Source Emissions: Area source emissions are treated as being spread over a specific region (usually a county). Examples of stationary area sources include (but are not limited to) residential emissions, fugitive dust, and road dust. Although oil and gas exploration and production sources are often included as part of an area source inventory, they are treated as a

separate source category in this study. The 2006 year emissions were interpolated from the 2002 WRAP Plan D inventory and the 2018 WRAP Preliminary Reasonable Progress (PRP) Emission inventory. The 2018 PRP database was built from the WRAP 2002 inventory by projecting the impacts of activity growth and emission controls. The methodology for projecting emissions is described in the WRAP PRP Technical Memorandum (Fields and Wolf, 2007). Details on data collection, emission processing and quality assurance of the WRAP 2002 emission inventory can be found in Tonnesen et al. (2006).

Oil and Gas Emissions: Oil and gas sources are a critical part of the UT-CO regional emission inventory. In this section, we discuss the four O&G emissions inventories that were used across different regions in the modeling domain. These are the WRAP Phase II and Phase III oil and gas inventories, the Sage/BP inventory for Southwest Wyoming and the Four Corners Air Quality Task Force (FCAQTF) O&G inventory for the North San Juan Basin.

WRAP Phase III Emission Inventory - The WRAP Phase III emission inventory expands on the work done under WRAP Phase II and addresses the limitations of the WRAP Phase II VOC inventory. A comprehensive 2006 inventory of emissions from oil and gas sources is under development for the Denver-Julesburg Basin, Uinta Basin, San Juan Basin (North and South), Piceance Basin, Southwest Wyoming Basin (Green River Basin), Powder River Basin, Paradox Basin, Williston Basin, Wind River Basin, Big Horn Basin, North-Central Montana Basin (Great Plains Basin)

Sage/BP Emission Inventory for Southwest Wyoming - O&G sources in Southwest Wyoming for the years 2005 and 2006. Based on field data and well data from the Wyoming Oil and Gas Conservation Commission, this inventory includes emissions from drill rigs, well venting, flashing, fugitives, construction and production truck traffic, and well site production equipment such as dehydrators, heaters, and pumps.

WRAP Phase II Emission Inventory - Beginning in 2005, the Western States Regional Air Partnership initiated a series of projects to develop a regionally consistent emission inventory of oil and gas exploration and production activities for all of the western U.S. states. The first of these projects, the Phase I inventory, was completed in 2005 and represented the first regional oil and gas emissions inventory for the western U.S (Russell and Pollack, 2005). This was followed by the Phase II inventory (Bar-Ilan et al., 2007), which focused on improving emissions estimates of drilling rigs and compressors from those in the Phase I work. Both the Phase I and Phase II inventories were focused on estimating oil and gas NO_X and SO_2 emissions for regional haze modeling purposes. Final reports of the Phase I and Phase II inventories are available on the WRAP website[3,4].

FCAQTF O&G Inventory for the North San Juan Basin - The FCAQTF developed an oil and gas emission inventory for the year 2005 for the North San Juan Basin in southern Colorado. This inventory was based on the WRAP Phase II O&G inventory except within the Southern Ute Indian Tribal (SUIT) Reservation, located in Archuleta and La Plata Counties in Colorado. For the SUIT Reservation, a detailed oil and gas emissions

3 http://www.wrapair.org/forums/ssjf/documents/eictts/oilgas.html

4 http://www.wrapair2.org/emissions.aspx

inventory was developed for the year 2005 (Lee, 2005) that contains NO_X, VOC, CO and PM emissions for all major O&G source categories except drilling. Drilling emissions within SUIT lands are accounted for the in WRAP Phase II inventory.

Wind-Blown Dust Emissions: The wind-blown fugitive dust PM emission inventory was developed using the estimation methodology developed for WRAP by a team of contractors led by ENVIRON (ENVIRON, 2004) and subsequently revised by Mansell and others (Mansell, 2003a; 2003b; Mansell, et al. 2004). The methodology is based on the results of wind tunnel studies and a detailed characterization of vacant lands. The model generates estimates of PM_{10} dust emissions. The fine fraction of dust is obtained by using a nominal $PM_{2.5}$ of 0.10, as used in the implementation of the model for the WRAP. Wind-blown dust emissions are estimated hourly on a gridded modeling domain using hourly averaged wind speeds and other meteorological parameters. Estimates were developed for every hour of the 2006 year based on the MM5 meteorological fields.

Ammonia Emissions: The ammonia emissions processing was performed outside of SMOKE. Ammonia emissions from sources including livestock, fertilizer usage, domestic sources, and wild animals within WRAP states were generated from a GIS-based ammonia emissions model (Mansell, 2005) using day-specific meteorology for temporal distribution processing.

Wildfires and Prescribed Burns Emissions: Wildfire and prescribed burn emissions were handled separately from the standard area source input files. For the 2006 calendar year, ENVIRON received estimates of fire emissions from the National Center for Atmospheric Research (NCAR). These emission estimates are derived from analysis of fire locations determined by satellite-borne detectors. The MODerate-resolution Imaging Spectroradiometer (MODIS) instruments fly aboard two polarorbiting satellites, Terra, and Aqua. These two satellites orbit the Earth, traveling from pole to pole while the earth rotates beneath them; a given area of the Earth will have an overpass from Terra and Aqua approximately twice a day. MODIS instruments detect fires as thermal anomalies (i.e. hot spots seen against a cooler background) at a spatial resolution of about 1 kilometer. Fire emissions derived from the MODIS data include NO_X, CO, VOC and PM species, along with other compounds (e.g., Hg). The NCAR fire emissions inventory development is described by Wiedinmyer and co-workers (2006) and Friedli and Wiedinmyer (2008).

Biogenic Source Emissions: Biogenic emissions were modeled using the Model of Emissions of Gases and Aerosols from Nature (MEGAN) version 2.03 with modifications made by ENVIRON (Guenther et al, 2006; Guenther and Wiedinmyer, 2007; Mansell et al, 2007). MEGAN was used to prepare gridded hourly biogenic emission inventories suitable for input to CMAQ. MEGAN is the latest biogenic emissions model developed by researchers from the National Center for Atmospheric Research (NCAR) and incorporates the full range of ozone and PM precursor species. MEGAN accounts for the spatial variability of biogenic emissions through the use of high resolution estimates of vegetation type and quantity. MEGAN requires as input weather data, Leaf Area Index (LAI), plant functional type (PFT) cover and compound-specific emission factors that are based on plant species composition.

Table 2-1 summarizes the 2006 emissions within the 12 km UT-CO domain (Figure 2-1) by source category. In 2006, EGU sources were the largest contributor to NO_X emissions. Emissions from O&G and mobile sources are the next largest contributors of NO_X emissions.

For all states except Arizona, O&G sources were the largest contributor to TOG emissions during 2006, exceeding the contribution of biogenic sources. For CO, on-road sources were generally the largest contributor during 2006, except in Arizona, where fires were the largest source of CO. For PM, area and fire sources were the most important sources of emissions in the 12 km domain.

Table 2-1. Summary of emissions (tons per year) within the UT-CO 12 km modeling domain.

State	Source Category							
	Area	On-Road	Non-Road	EGU	NEGU	Oil&Gas	Biogenic	Fire
CO								
Arizona	1,052	17,235	6,006	1,131	0	1	4,063	116,490
Colorado	30,634	204,359	76,885	8,294	1,369	9,847	39,288	53,934
New Mexico	2,094	21,331	7,451	2,433	357	34,705	2,697	546
Utah	36,994	360,767	180,556	2,242	47,325	9,418	34,604	97,266
Wyoming	2,416	18,083	6,045	8	4,237	3,809	5,443	4,847
Tribes						6,324		
NO_X								
Arizona	42	2,866	1,495	34,755	0	13	158	3,297
Colorado	1,702	19,953	10,235	27,618	1,526	15,929	2,109	1,605
New Mexico	758	2,582	605	72,337	676	42,115	139	29
Utah	5,663	41,247	34,589	70,703	15,517	15,376	2,052	3,077
Wyoming	836	2,293	6,165	39	2,306	8,200	277	151
Tribes						4,704		
TOG								
Arizona	857	1,751	1,801	163	0	139	20,920	6,992
Colorado	19,823	15,496	15,635	911	2,746	1,575,502	230,593	3,186
New Mexico	4,288	2,049	852	544	1,157	517,950	14,297	26
Utah	53,998	32,445	24,130	456	9,574	273,351	171,796	5,342
Wyoming	3,180	1,430	1,128	4	4,623	251,453	26,205	281
Tribes						21,600		
PM								
Arizona	2,114	84	110	104	0	0		17,230
Colorado	11,274	507	1,084	99	0	1,066		7,765
New Mexico	5,484	76	80	672	34	114		70
Utah	13,848	1,169	2,908	184	8,602	631		13,234
Wyoming	3,093	63	294	1	1,063	276		692
Tribes						0		

2.2.2 CAMx Emission Inputs for the 2005 FCAQTF Database

The emissions used in the 2005 single-source proof-of-concept modeling were based on the CAMx modeling database developed for the Four Corners Air Quality Task Force (FCAQTF; Stoeckenius et al., 2009) study. Emission inventories were prepared for sources within the 36 km CONUS domain and the 12 and 4 km FCAQTF domains shown in Figure 2-2. The inventories contain estimates of anthropogenic PM, SO_2, NO_X, VOC, CO, NH_3 and windblown dust emissions as well as biogenic VOC and NO_X emissions and fire emissions (wildfires and prescribed burns). Primary emissions data sources used in developing the inventories included:

WRAP Regional Inventory Development and Modeling: WRAP funded development of a 2002 emissions inventory processed for use in the CMAQ and CAMx air quality models using the SMOKE emissions processing system. This inventory covers the entire continental U.S. at 36 km resolution. A similar model-ready inventory for 2018 which includes the latest available updates and is known as the PRP18 inventory was also prepared for WRAP.

WRAP Phase II Oil and Gas Emissions Updates: ENVIRON developed a region-wide oil and gas emissions inventory for the western U.S. under contract to WRAP. ENVIRON recently completed updating this inventory for the years 2002, 2005 and 2018. Emissions data for 2002 developed for the Southern Ute Indian Reservation and other areas in connection with the Northern San Juan Coal Bed Methane (CBM) EIS are included in the updated inventory.

Southern Ute 2005 Oil & Gas Emissions: An updated 2005 emissions inventory for 2005 for oil & gas sources on the Southern Ute lands compiled by the Southern Ute Indian Tribe (SUIT, 2005) was used to replace the older SUIT inventory included in the WRAP Phase II inventory.

At the time of the FCAQTF study, the inventories listed above represented the most accurate estimate of emissions in the region. A limitation in the inventories is that the WRAP Phase II Oil and Gas Inventory did not consider VOC emissions associated with production facilities. However, as part of the New Mexico Ozone Early Action Compact, ENVIRON developed a VOC inventory for the region which was used in the FCAQTF study. It should also be noted that the 2005 Southern Ute Oil and Gas Inventory is being used in the WRAP Phase III Inventory.

Model-ready (gridded, hourly) emissions for the 2005 base year for all area sources outside of the 4 km modeling domain were obtained by linearly interpolating between the WRAP 2018 (PRP18) and WRAP 2002 model-ready (gridded, hourly) emissions. Area source emissions on the portion of the 36 km grid that is overlapped by the 12 km modeling domain but outside the 4 km domain were disaggregated to 12 km resolution with emissions evenly divided over the nine 12 x 12 km grid cells within each 36 x 36 km grid cell. Model ready point source emissions for 2005 for sources outside of the 4 km modeling domain were also obtained via linear interpolation between the WRAP 2018 (PRP18) and WRAP 2002 inventories.

2005 annual emissions in the Four Corners 4 km domain are summarized by State and major source category in Tables 2-1 through 2-4. In these tables, road dust and fugitive dust emissions are included within the area source category, whereas windblown dust was included within the biogenic source category. Locomotive, aircraft and other non-road sources are included in the off-road emissions category. In the point source inventory, tribal sources were distinguished from the state sources and hence tribal point source emissions were reported separately from state emissions. For all other source categories, tribal emissions were combined with state emissions. Point sources associated with oil & gas production were separated from other point sources and reported separately in the tables below.

Table 2-2. 2005 NO_X Emissions (TPY) within the 4 km FCAQTF modeling domain by state and source category.

STATE/Tribe	Area	On-road	Off-road	Biogenic	Area Oil & Gas	Point Oil & Gas	EGU	Non EGU	Total
Arizona	97	4,661	2,407	211	13				7,389
Colorado	302	3,757	1,910	659	921	2,548		535	10,632
New Mexico	16,036	30,182	11,219	833	37,848	19,834	30,925	3,615	150,492
Utah	42	741	181	130	51	352		78	1,575
Tribes						7,264	41,743	2,770	51,777
Grand Total	16,477	39,340	15,717	1,834	38,832	29,998	72,668	6,997	221,863

Table 2-3. 2005 SO_2 Emissions (TPY) within the 4 km FCAQTF modeling domain by state and source category.

STATE/Tribe	Area	On-road	Off-road	Biogenic	Area Oil & Gas	Point Oil & Gas	EGU	Non EGU	Total
Arizona	20	52	119						191
Colorado	135	62	53		19	14		105	388
New Mexico	5,580	543	625		116	552	17,866	3,020	28,302
Utah	54	12	13		1			1,581	1,661
Tribes						35	12,653	232	12,920
Grand Total	5,789	669	809		136	602	30,518	4,938	43,461

Table 2-4. 2005 VOC Emissions (TPY) Within the FCAQTF 4 km modeling domain by state and source category.

STATE/Tribe	Area	On-road	Off-road	Biogenic	Area Oil & Gas	Point Oil & Gas	EGU	Non EGU	Total
Arizona	2,204	3,314	728	29,202	37				35,485
Colorado	3,632	2,616	4,884	84,822	891	1,257		348	98,450
New Mexico	26,675	17,079	5,690	108,515	109,480	7,857	7	1,849	277,152
Utah	479	490	388	15,931	455	77		52	17,872
Tribes						2,219	292	180	2,691
Grand Total	32,989	23,499	11,690	238,471	110,862	11,410	299	2,429	431,649

Table 2-5. 2005 PM Emissions (TPY) within the FCAQTF 4kKm modeling domain by state and source category.

STATE/Tribe	Area	On-road	Off-road	Biogenic	Area Oil & Gas	Point Oil & Gas	EGU	Non EGU	Total
Arizona	4282	131	110	21074					25,597
Colorado	2227	119	311	9766	24	34		687	13,168
New Mexico	30,324	925	772	54744		123	25	2,238	89,151
Utah	390	22	31	13057				12	13,512
Tribes						11	965	81	1,057
Grand Total	37,224	1,197	1,224	98,640	24	168	990	3,018	142,485

2.3 SELECTION OF TEST SOURCES FOR EVALUATING SINGLE-SOURCE LRT MODELS

The selection of test sources for the UT-CO 2006 and FCAQTF 2005 databases was conducted in a similar manner. For simplicity and consistency among models, we used PGM model-ready emission data and configured them for the various LRT models. Several test sources were selected as the types of sources whose far-field air quality and AQRVs are typically evaluated as part of PSD/NSR, NEPA or Best Available Retrofit Technology (BART) analysis. The test sources included Electrical Generating Units (EGU) and oil and gas (O&G) production sources. All EGU sources are point sources, while the O&G sources were modeled as a combination of area and point sources. Sources were selected to represent different locations within the interior portion of the 2005 and 2006 modeling domains and with varying emission rates (Figures 2-1 and 2-2).

For 2005 single-source model testing, five EGU source complexes were selected with locations shown in Figure 2-3 and stack parameters and emission rates shown in Table 2-6. In addition, nine O&G source groups were selected as shown in Figure 2-4 and Table 2-7. EGU1 and EGU2 are the Four Corners and San Juan coal-fired power plants that represent the two biggest sources in the region; both sources were subject to recent single-source modeling to address BART. EGU3, EGU4 and EGU5 are smaller EGUs located in the southeast portion of the 4 km domain and represent a smaller coal-fired power plant (EGU3) and two natural gas-fired power plants (EGU4 and EGU5) (Figure 2-3). For the 2005 oil and gas production test sources, we chose a 9 x 9 array of 4 km grid cells to represent an area source complex of oil and gas production sources that also includes a large O&G point source, if available. For examples, OG1 consists of only area sources and OG2 consists of a combination of point sources (Chaco Gas Plant) and area sources. Locations and amount of emissions are factors in selections. For example, OG1 represents a relatively low O&G emissions test source, whereas OG2 has relatively higher emissions. Other OG selections represent test source groups in different areas. The emission summaries of test sources are presented in Table 2-7 with locations shown in Figure 2-4.

Table 2-6. Emission summary for EGU test source complexes for 2005 FCAQTF modeling.

ID	PLANT	Latitude	Longitude	TYPE	SCC	Hs (m)	Ds (m)	Ts (C)	Vs (m/s)	NO_X (TPY)	SO2 (tons/ year)
EGU1	Four Corners Power Plant	36.701022	-108.4742	coal	10100222	115.8	8.7	147.8	24.4	41,743	12,554
EGU2	San Juan Fly Ash	36.830520	-108.4602	coal	10100221	121.9	7.6	147.8	29.3	26,809	16,569
EGU3	Escalante Station	35.415107	-108.0819	coal	10100226	137.2	6.1	147.8	15.2	3,797	1,293
EGU4	Public Service Co of New Mexico	35.427995	-106.5927	gas	10100601	36.0	3.1	166.7	19.8	151	0.4
EGU5	Delta Person Generating Station	35.0257	-106.643	gas	20100201	85.0	4.5	166.7	18.0	4	0.1

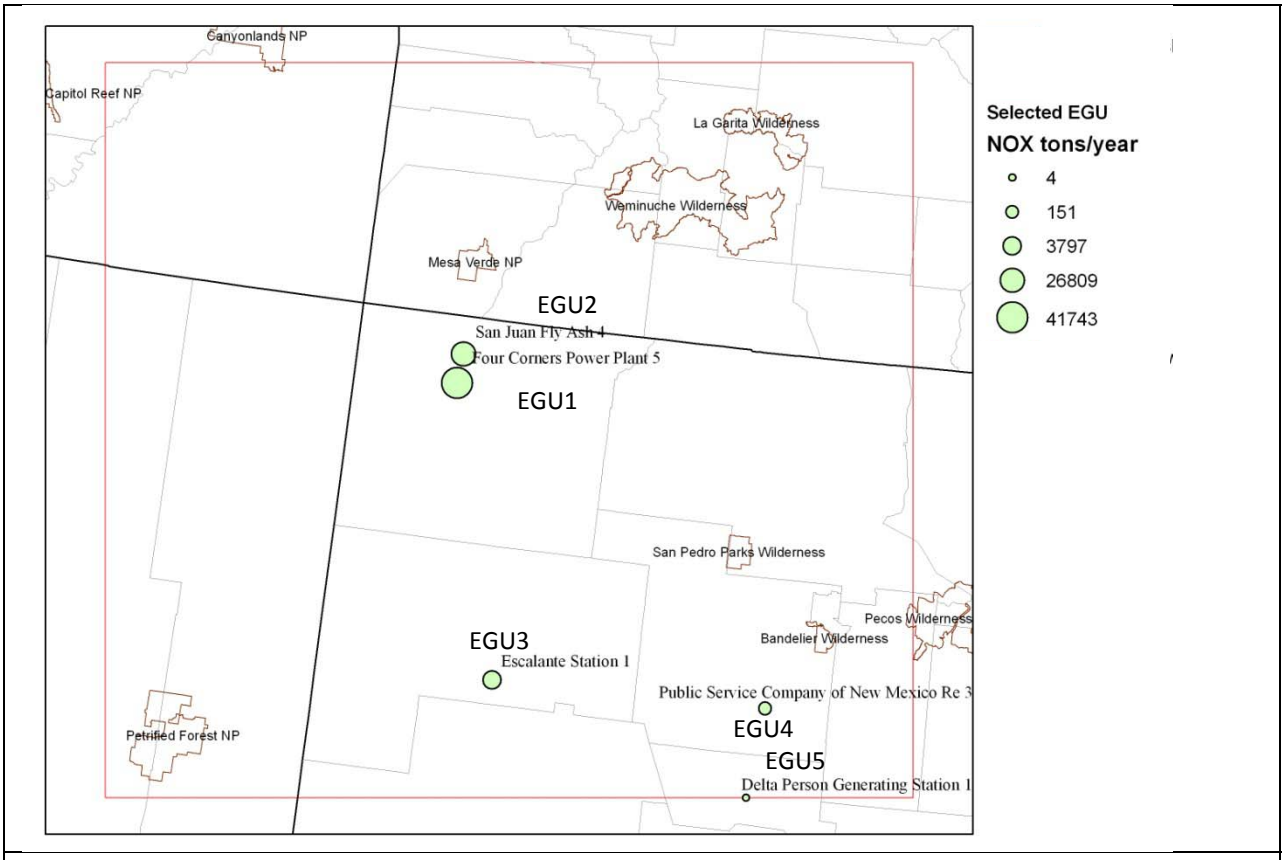


Figure 2-3. Five EGU test source complex selections in the 2005 FCAQTF 4 km domain.

Table 2-7a. Emission summary for point sources included in the oil and gas test source complexes for the 2005 FCAQTF modeling.

ID	PLANT	CO (TPY)	NH_3 (TPY)	NO_X (TPY)	PM_{10} (TPY)	$PM_{2.5}$ (TPY)	SO2 (TPY)	VOC (TPY)
OG2	Chaco Gas Plant	611.9	0.0	3024.6	1.5	1.5	2.7	68.7
OG3	Lybrook Plant	249.1	0.0	288.9	0.0	0.0	0.0	90.1
OG4	Gallup Compressor Station	274.3	0.0	1773.4	4.1	0.0	0.0	77.5
OG5	El Paso Natural Gas, Window Rock Compres	0.0	0.0	1893.9	0.0	0.0	0.0	38.2
OG6	Lisbon Natural Gas Processing Plant	180.1	4.8	327.3	0.0	1.9	0.0	51.7
OG7	QUESTAR GAS MANAGEMENT DOVE CREEK	25.1	0.0	153.4	0.3	0.0	0.0	50.7
OG8	Ignacio	46.3	0.0	217.6	0.0	0.0	0.0	19.3
OG9	Laguna Compressor Station	166.6	0.0	733.0	0.0	0.0	0.0	10.9

Table 2-7b. Emission summary for area sources included in the oil and gas test source complexes for the 2005 FCAQTF modeling.

ID	CO (tpy)	NOX (tpy)	SO2 (tpy)	VOC (tpy)
OG1	**5,119**	**9,005**	**127**	**16,199**
OG2	**231,207**	**291,808**	**878**	**668,116**
OG3	**6,888**	**11,463**	**1.98**	**24,728**
OG4	**21**	**210**	**9.38**	**3**
OG5	**18**	**175**	**7.82**	**2**
OG6	**124**	**1,515**	**0.00**	**28,780**
OG7	**59**	**248**	**9.08**	**308**

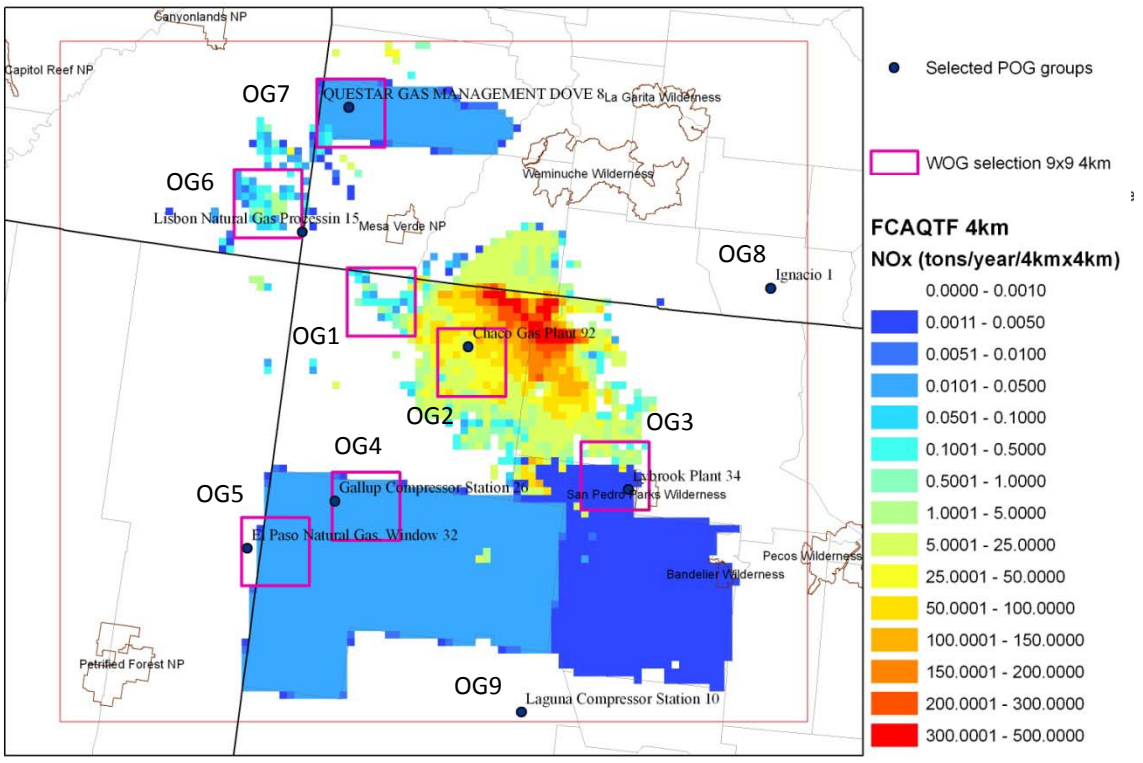


Figure 2-4. Nine Oil and Gas test source complex selections in the 2005 FCAQTF 4 km domain.

For the 2006 UT-CO modeling, 13 EGU test point sources were selected as shown in Figure 2-5 with stack parameters and emission rates given in Table 2-8. The EGU test sources include a mixture of coal and gas powered EGUs with NO_X emissions as small as 13 TPY to as large as 34,744 TPY for the Navajo Generating Station. Eleven O&G test source complexes were selected for the 2006 UT-CO modeling using a similar approach as used in the 2005 modeling. However, the difference between 2006 UT-CO and 2005 FCAQTF modeling databases is that the 2006 CAMx emissions were based on the UBAQS modeling study that used the CMAQ three-dimensional (3D) gridded format versus the 2005 CAMx database that consists of a point source file and 2-D gridded surface emissions. Each O&G test source complex covers 3 x 3 array of 12 km grid cells and all emissions, including those in the aloft layers. The emission summaries of O&G test sources in UT-CO 2006 modeling are presented in Table 2-9 with locations shown in Figure 2-6.

Table 2-8. Emission summary for EGU test source complexes for UT-CO 2006 modeling.

ID	PLANT	LATITUDE	LONGITUDE	TYPE	Hs (m)	Ds (m)	Ts (C)	Vs (m/s)	CO (TPY)	NH_3 (TPY)	NO_X (TPY)	PM_{10} (TPY)	$PM_{2.5}$ (TPY)	SO_2 (TPY)	VOC (tpy)
EGU1	HUNTER	39.1667	-111.0261	coal	182.9	7.3	147.8	20.1	555	33	18,829	45	27	7,338	67
EGU2	HUNTINGTON	39.3792	-111.0750	coal	182.9	7.3	127.8	19.5	324	19	11,130	30	19	17,395	39
EGU3	CARBON	39.7264	-110.8639	coal	52.4	3.8	162.8	23.5	121	7	3,703	11	7	6,779	14
EGU4	INTERMOUNTAIN	39.5108	-112.5792	coal	134.4	5.2	150.6	19.9	607	36	28,911	28	7	4,239	73
EGU5	CURRANT CREEK POWER PROJ	39.8223	-111.8940	gas	19.8	3.5	343.3	18.9	210	16	302	5	5	4	5
EGU6	GADSBY	40.7667	-111.9292	gas	76.2	3.4	162.8	25.3	34	4	105	1	1	1	3
EGU7	BONANZA	40.0864	-109.2844	coal	182.9	7.9	147.8	15.2	172	10	7,348	8	2	864	21
EGU8	CRAIG	40.4627	-107.5912	coal	182.9	7.6	147.8	22.3	730	44	17,081	34	9	3,586	88
EGU9	CAMEO	39.1486	-108.3189	coal	142.6	5.6	147.8	20.9	15	1	657	1	0	1,899	2
EGU10	NUCLA	38.2387	-108.5083	coal	65.5	3.7	143.3	22.6	6,881	11	1,751	47	5	1,509	19
EGU11	NAVAJO GENERATING STATION	36.9125	-111.3917	coal	145.7	5.9	145.0	21.0	1,131	68	34,744	104	68	3,843	136
EGU12	AMERICAN GYPSUM COMPANY	39.39319	-106.5724	gas	1.1	0.1	340.2	2.4	2	0	13	1	0	1	0
EGU13	AMERICAN GYPSUM COMPANY	39.38557	-106.5653	gas	12.2	1.0	537.8	2.9	36	0	86	0	0	0	0

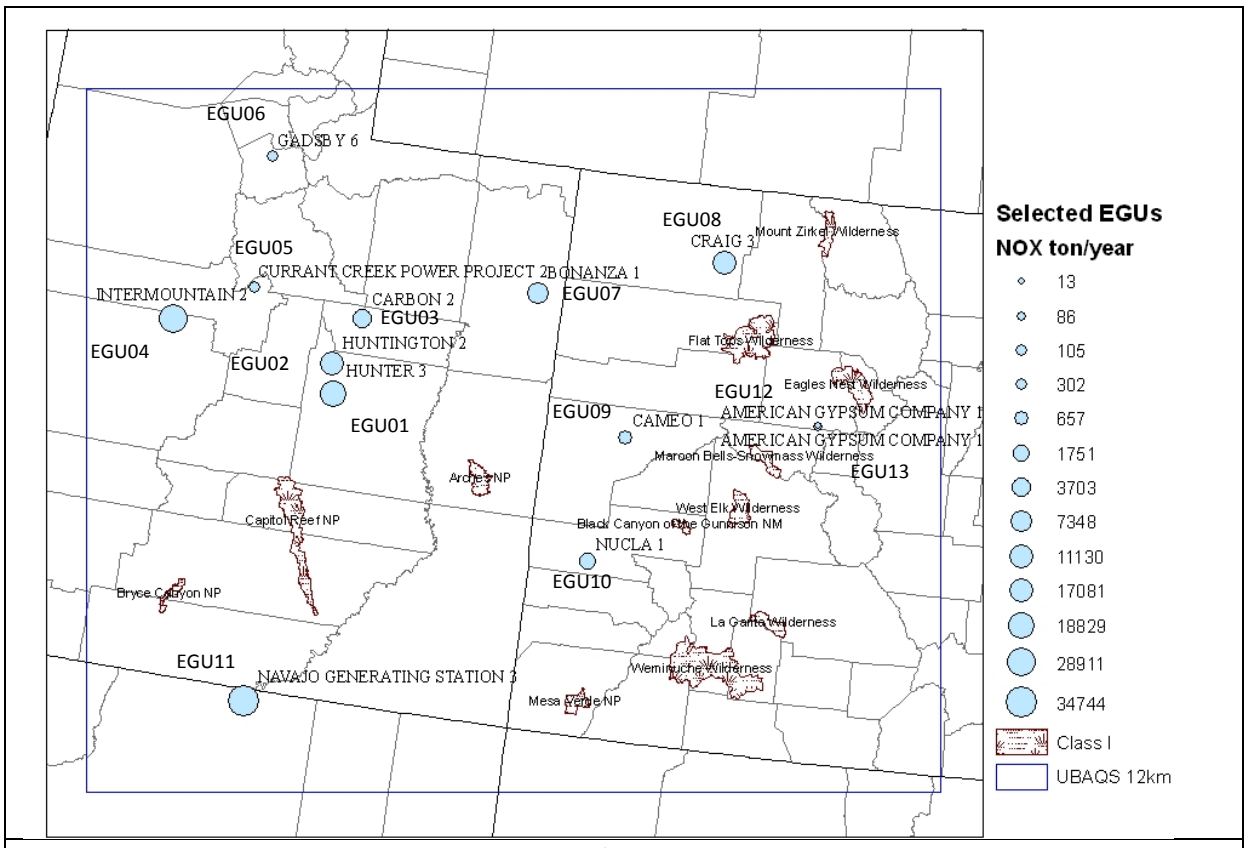


Figure 2-5. EGU test source complexes selected for the 2006 UT-CO 12 km domain.

Table 2-9a. Emission summary for the surface layer emissions and O&G test source complexes for UT-CO 2006 modeling.

ID	CO (tpy)	NOX (tpy)	SO2 (tpy)	VOC (tpy)	PM25	PM10
OG01	1,955	3,466	85	15,801	146	148
OG02	18,261	34,806	1,296	86,919	4,396	4,527
OG03	22,059	37,388	1,362	269,813	1,897	1,934
OG04	5,500	6,168	82	6,193	195	197
OG05	17	66	3	524	0	0
OG06	660	978	12	1,202	0	3
OG07	4,934	6,269	75	1,356	25	109
OG08	29	25	0	2	0	0
OG09	3	36	0	1	0	0
OG10	467	828	25	6,133	61	62
OG11	357	562	0	284	4	4

Table 2-9b. Emission summary for the aloft emissions and O&G test source complexes for UT-CO 2006 modeling.

ID	CO (tpy)	NOX (tpy)	SO2 (tpy)	VOC (tpy)	PM25	PM10
OG1	1,461	2,069	0	262	17	17
OG2	5,768	10,227	1	12,684	13	13
OG3	0	3,635	13	2,073	62	62
OG4	93	138	2	4	15	15
OG5	0	0	0	0	0	0
OG6	801	945	0	1,368	0	4
OG7	9,259	6,924	1	2,900	0	8
OG8	59	51	0	5	0	0
OG9	5	75	0	2	0	0
OG10	873	1,398	14	6,556	30	30
OG11	900	1,091	0	17	10	10

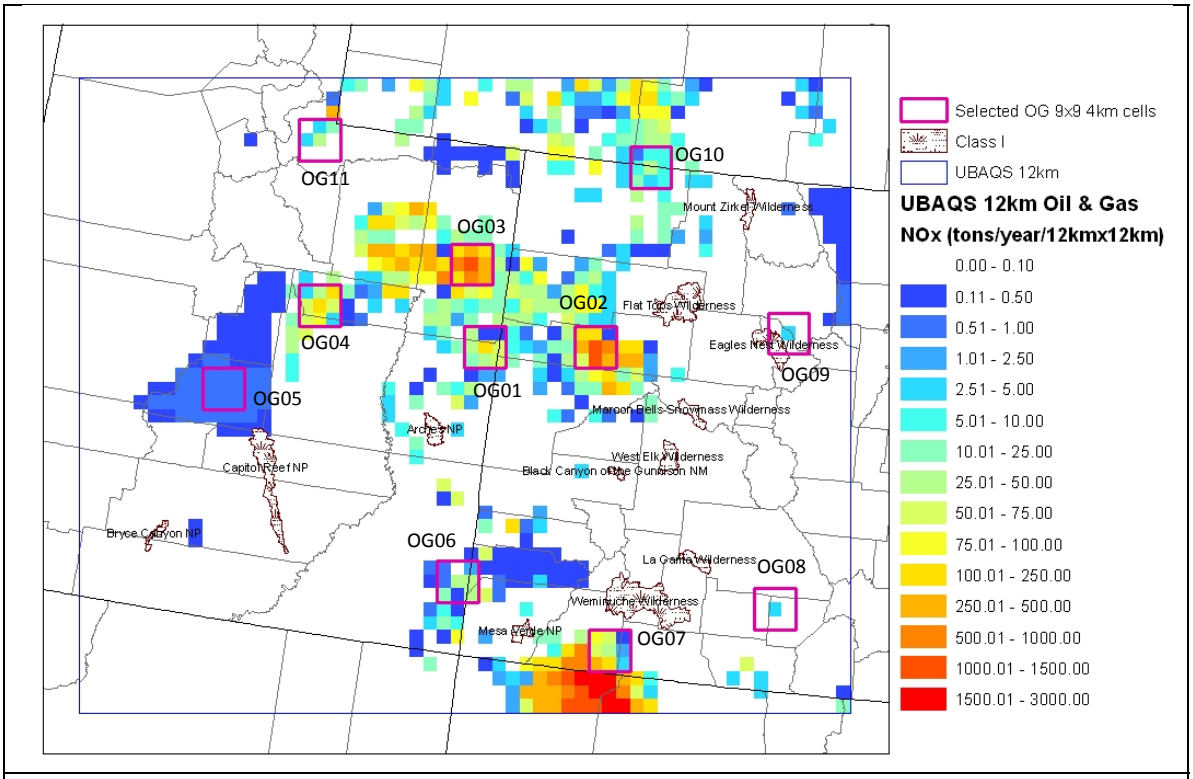


Figure 2-6. Oil and Gas test source complexes selections for the 2006 UT-CO 12 km domain.

2.4 APPROACH FOR SINGLE-SOURCE MODELING USING CAMX AND CALPUFF

The CAMx Ozone and Particulate Source Apportionment Technology (OSAT and PSAT) were used to separately calculate the contributions of each test source complex to concentrations at downwind receptor areas. The Anthropogenic Precursors Culpability Assessment (APCA) version of OSAT was used in this study to track each test source contributions to ozone and ozone precursors. To track tracers from selected test source complexes in the APCA/PSAT source apportionment probing tools requires emissions from each test source to have a unique tag in the CAMx modeling. The point source override feature was used to uniquely tag each test source complex in CAMx for the APCA/PSAT source apportionment simulations. The point source override feature allows one set of point source emissions with internal tags for different source instead of multi-point source emission datasets for CAMx source apportionment modeling. The tagging for selected point sources was performed directly as they were point source emissions. To use the point source override feature for area or 3-D gridded emissions, they were converted to point source emissions. For 2005 FCATF modeling, the area emissions are only at the surface level from the 2-D surface emission inputs. The selected emission in each grid cell is converted to a point source at the center of grid cell with low-level stack parameters as shown in the last row of Table 2-10. Therefore, there are 9 x 9 point source for each test source complex corresponding to the 9 x 9 array of 4 km grid cells. For the 2006 UT-CO modeling that was based on 12 km 3-D gridded emissions, the 3 x 3 array of 12 km emissions for each O&G test source complex were separated into surface level and aloft emissions. The surface level emissions were converted to point source emissions in the same manner as described above for the 2005 FCAQTF database modeling. The aloft emissions were

represented by 5 different O&G activities, which are flare, turbine, heater, compressor, and dehydrator. This was done to avoid concentrating the emissions within any one single plume. The conversion from aloft emissions uses the stack parameters in Table 2-10 with equally allocated emissions for a 12 km x 12 km cell size. Therefore, a column of 12 km x 12 km emissions consists of one low level point source and 5 different point sources with different stack parameters, and there are 3 x 3 sets for these point sources for each O&G test source complex using the 2006 UT-CO database. Although the emissions are input as point sources in CAMx, their emissions will be instantaneously dispersed across the 4 km by 4 km (2005) or 12 km by 12 km (2006) grid cell so will be treated like an area source.

Table 2-10. Stack parameters used in conversion from 2-D (low-level) and 3-D gridded to point source in CAMx modeling.

Category	Type	SCC	Stk Ht (m)	Stk Diam (m)	Stk Temp (K)	Stk Vel (m/s)
Gas Plant	Flares	31000205	22.89	2.77	814.00	10.55
Gas Plant	Turbine	20200201	11.61	1.04	608.40	22.86
Gas Plant	Heaters	31000404	8.72	0.49	571.00	5.55
Compressor Station	Compressor Engine - Rich burn	20200253	7.96	0.40	687.80	20.94
Compressor Station / Gas Plant	Dehydrators	31000304	6.80	0.73	416.20	13.93
Low-Level Emission (2005)			3.00	0.20	295.38	4.00

In CALPUFF modeling, there is a slight different treatment for surface level emissions while using the same point source specifications, as used in CAMx. Area emissions were treated as volume sources at the same center of lateral dimension and with the physical dimensions based on AERMOD guidance in Table 3.1 in AERMOD manual. The lateral dimension for a volume source was estimated by the lateral size of grid cell and equation 2-1 below. The vertical dimension of a volume source was estimated by half of the vertical size of surface grid cell and equation 2-2. All other point sources including actual point sources and converted point sources from aloft emissions stay the same between CALPUFF and CAMx.

$$\text{Lateral size} = \text{length of side} / 4.3 \qquad (2\text{-}1)$$

$$\text{Vertical size} = 0.5 \times \text{grid cell height} / 2.15 \qquad (2\text{-}2)$$

2.4.1 Use of CAMx Probing Tools to Perform Single-Source Modeling

The CAMx APCA ozone and PSAT particulate matter source apportionment probing tools were used to obtain the incremental concentration and deposition estimates for each of the test sources in the 2005 and 2006 modeling. APCA is an ozone source apportionment tool similar to OSAT that focuses on determining the contribution to ozone concentrations from human (i.e. controllable) activities. Below, we describe ozone source apportionment in CAMx using OSAT and then discuss how APCA differs from the standard OSAT tool.

OSAT uses multiple tracer species to track the fate of ozone precursor emissions (VOC and NO_X) and the ozone formation caused by these emissions within a simulation. The tracers operate as spectators to the normal CAMx calculations so that the underlying CAMx predicted relationships between emission groups (sources) and ozone concentrations at specific locations (receptors) are not perturbed. Tracers of this type are conventionally referred to as “passive tracers,” however it is important to realize that the tracers in the OSAT track the effects of

chemical reaction, transport, diffusion, emissions and deposition within CAMx. In recognition of this, they are described as "ozone reaction tracers." The ozone reaction tracers allow ozone formation from multiple "source groupings" to be tracked simultaneously within a single simulation. A source grouping can be defined in terms of geographical area and/or emission category. So that all sources of ozone precursors are accounted for, the CAMx boundary conditions and initial conditions are always tracked as separate source groupings. This allows an assessment of the role of transported ozone and precursors in contributing to high ozone episodes from existing and hypothetical test sources.

The methodology is designed so that all ozone and precursor concentrations are attributed among the selected source groupings at all times. Thus, for all receptor locations and times, the ozone (or ozone precursor concentrations) predicted by CAMx is attributed among the source groupings selected for OSAT. The methodology also estimates the fractions of ozone arriving at the receptor that were formed en-route under VOC- or NO_X-limited conditions. This information indicates how ozone concentrations at the receptor will respond to reductions in VOC and NOX precursor emissions, and can be useful in the event that an exploration of mitigation strategies is required.

APCA differs from the standard CAMx OSAT ozone source apportionment tool in recognizing that certain emission groups are not controllable (e.g., biogenic emissions) and that apportioning ozone production to these groups does not provide information that is relevant to development of control strategies. To address this, in situations where OSAT would attribute ozone production to non-controllable (i.e., biogenic) emissions, APCA re-allocates that ozone production to the controllable portion of precursors that participated in ozone formation with the non-controllable precursor. For example, when ozone formation is due to biogenic VOC and anthropogenic NO_X under VOC-limited conditions (a situation in which OSAT would attribute ozone production to biogenic VOC), APCA re-directs that attribution to the anthropogenic NO_X precursors present. The use of APCA instead of OSAT results in more ozone formation attributed to anthropogenic NO_X sources and less ozone formation attributed to biogenic VOC sources, but generally does not change the partitioning of ozone attributed to local sources and the transported background for a given receptor.

The PM Source Apportionment Technology (PSAT) uses reactive tracers to apportion primary PM, secondary PM and gaseous precursors to secondary PM among different source categories and source regions. The PSAT methodology is described below. PSAT was developed from the related ozone source apportionment method (OSAT) already implemented in CAMx (Dunker at al., 2002b). PSAT is designed to source apportion the following PM species modeled in CAMx:

- Sulfate (SO4)
- Particulate nitrate (NO3)
- Ammonium (NH4)
- Particulate mercury (Hg(p))
- Secondary organic aerosol (SOA)
- Six categories of primary PM
  - Elemental carbon (EC)
  - Primary organic aerosol (POA)

- Crustal fine
- Other fine
- Crustal coarse
- Other coarse

PSAT "reactive tracers" are added to the model for each source category/region. In general, a single tracer can track primary PM species whereas secondary PM species require several tracers to track the relationship between gaseous precursors and the resulting PM. For this study, we omitted SOA tracers due to the large computational requirement and minuscule SOA precursor emissions for the selected test sources.

2.4.2 CAMx Model Configuration

CAMx version 5.40 was configured for the 2006 UT-CO 12km and 2005 FCAQTF 12/4km in a similar manner. The model configuration for the 2005 and 2006 single-source modeling is summarized in Tables 2-11 and 2-12. No sub-grid plume treatment was used for these CAMx simulations.

Table 2-11. CAMx air quality model configurations for the 2006 UT-CO 12 km modeling.

Science Options	Configuration
Model Code	CAMx Version 5.40
Horizontal Grid Mesh	12 km
12 km grid	56 x 46 cells
Vertical Grid Mesh	19 Layers
Grid Interaction	One-way 12 km nested in 36 km CONUS domain
Initial Conditions	~7 days full spin-up
Boundary Conditions	Day-specific 2006 3-hourly GEOS-CHEM w/ 2002 GEOS-Chem monthly average for PM species
Chemistry	
Gas Phase Chemistry	CB05
Aerosol Chemistry	ISORROPIA
Mineral Nitrate	Yes
Secondary Organic Aerosols	SOAP
Aqueous Chemistry	RADM
Meteorological Processor	MM5CAMx
Horizontal Transport	
Eddy Diffusivity Scheme	K-theory with Kh grid size dependence
Vertical Transport	
Advection Scheme	Vertical Velocity Update
Eddy Diffusivity Scheme	CMAQ-like
Diffusivity Lower Limit	Kzmin = 0.1 to 2.0 w/ kv100
Dry Deposition Scheme	Zhang
Numerics	
Gas Phase Chemistry Solver	Euler Backward Iterative (EBI) solver
Horizontal Advection Scheme	PPM
Integration Time Step	Determined by met conditions

Table 2-12. CAMx air quality model configurations for the 2005 FCAQTF 12/4 km modeling.

Science Options	Configuration
Model Code	CAMx Version 5.40
Horizontal Grid Mesh	12/4 km
12 km grid	89 x 68 cells
4 km grid	119 x 101 cells
Vertical Grid Mesh	22 Layers
Grid Interaction	Two-Way 12/4 km
Initial Conditions	~5 days full spin-up
Boundary Conditions	Day-specific 2005 3-hourly GEOS-CHEM w/ 2002 GEOS-Chem monthly average for PM species
Chemistry	
Gas Phase Chemistry	CB05
Aerosol Chemistry	ISORROPIA
Mineral Nitrate	Yes
Secondary Organic Aerosols	SOAP
Aqueous Chemistry	RADM
Meteorological Processor	MM5CAMx
Horizontal Transport	
Eddy Diffusivity Scheme	K-theory with Kh grid size dependence
Vertical Transport	
Advection Scheme	Vertical Velocity Update
Eddy Diffusivity Scheme	CMAQ-like
Diffusivity Lower Limit	Kzmin = 0.1 to 2.0 w/ kv100
Dry Deposition Scheme	WESELY
Numerics	
Gas Phase Chemistry Solver	Euler Backward Iterative (EBI) solver
Horizontal Advection Scheme	PPM
Integration Time Step	Determined by met conditions

2.4.3 CALPUFF Model Configuration

The CALPUFF V5.8 modeling was conducted for the test sources using meteorological inputs based on both the CALMET (Scire et al., 200b) and MMIF (Brashers and Emery, 2012). The 2005 FCAQTF 4 km and 2006 UT-CO 12 km MM5 data were used as input to CALMET and MMIF. Surface upper-air meteorological observations were also used with CALMET. For the 2006 UT-CO CALPUFF V5.8 application, CALMET was run using both a 12 and 4 km grid resolution. The CALPUFF/CALMET modeling procedures used in these analyses are equivalent to those used for Class I area analyses, following the recommendations of the Interagency Agency Workgroup on Air Quality Modeling (IWAQM; EPA, 1998b) and the Federal Land Manager (FLM) Air Quality Related Values (AQRV) Workgroup (FLAG, 2010). The techniques used to construct the CALMET meteorological database followed the recent August 31, 2009 Clarification Memo from the EPA and the FLMs (EPA, 2009b).

The 2005 4 km and 2006 12 km MM5 data were processed with the MMIF tool to generate 4 km 2005 and 12 km 2006 CALPUFF meteorological inputs. The MMIF modeling domains adopted the same domains as used by CAMx (Figures 2-1 and 2-2). The CALMM5 utility was used to process the 2005 12/4 km and 2006 12 km MM5 data for use by CALMET. In all domains, each CALMET grid point is matched to a MM5 grid point. In order to match the CALPUFF/MMIF and CAMx simulations, a Lambert Conformal Conic (LCC) coordinate system was used for the CALMET modeling with an origin of 45N, 97W and standard latitudes of 33N and 45N.

Surface weather observations were extracted from the National Climatic Data Center (NCDC) Integrated Surface Hourly Observations (ISHO) dataset (TD-3505) for an area that extended 50 km beyond the study domain boundary. 121 surface stations were used in developing the meteorological grids for FCAQTF domains, while 122 surface stations were employed for the UT-CO domain. Twice daily sounding data from 11 upper air stations from the NOAA/ESRL Radiosonde (RAOBS) Database were used for all domains. Precipitation data were obtained from the NCDC's TD-3240 (COOP) dataset and processed with the CALMET utility PMERGE. Data from 198 and 188 COOP stations were used for the FCAQTF domains and UT-CO domains respectively. Sites were selected based on the criteria that the locations must be near (within 50 km) or in the model domain and there must be at least a 50 percent data recovery. The surface and upper-air meteorological data and precipitation observations were used as input into CALMET. MMIF obtains all of its meteorological data from the MM5 output. Land use and terrain data were prepared from the USGS 1:250,000 scale GTOPO30 data sets available on the internet.

CALMET (Version 5.8), the meteorological preprocessor component of the CALPUFF system, was used to combine the MM5 simulation data, surface and upper air observations, terrain elevations, and land use data into the format required by the dispersion modeling component CALPUFF (Version 5.8). In addition to specifying the three-dimensional wind field, CALMET also estimates the boundary layer parameters used to characterize diffusion and deposition by the dispersion model.

The CALPUFF/CALMET modeling system is equipped with a host of modeling options, but, as stated previously, the procedures and defaults recommended by the FLAG (2010) Phase I Report and the EPA-FLM CALMET Clarification Memo (EPA, 2009b) were used. Details on the CALPUFF model options for CALPUFF V5.8 are provided in an example CALPUFF input control files in Appendix A. The example CALPUFF input file is for the EGU2 test source and the 2006 UT-CO 12 km database. CALPUFF inputs for the other test sources will be identical with only changes to the emissions (Input Group 13) and for the 2005 FCAQTF 4 km modeling, domain definition and file names.

SO_2, SO_4, NO_X, HNO_3, NO_3, soot or elemental carbon (EC), organic carbon (OC) or organic aerosols (OA), PM fine (PMF), and PM coarse (PMC) were the 9 species modeled. The CALPUFF modeling system used the same emission rates as used for the CAMx analysis. PM_{10} emission rates were divided into six species: soot or EC, PMF, PMC, OC, SO_4, and NO_3. The PM speciation was accomplished using the same speciation profiles as used in the CAMx modeling based on EPA's SPECIATE database[5]. Sources in the database are referenced by Source Classification

[5] EPA website containing PM speciation for source categories: http://www.epa.gov/ttn/chief/emch/speciation.

Code (SCC), and the database provided information for partitioning between the coarse and fine particulate fractions as well as information for dividing the fine fraction into the species required by CALPUFF.

Receptors were placed in Class I areas of interest according to the specified locations provided by the National Park Service (NPS)[6]. Additional receptors were modeled at locations within the Clean Air Status and Trends Network (CASTNET), Interagency Monitoring of Protected Visual Environments (IMPROVE) and National Atmospheric Deposition Program (NADP) monitoring networks.

Reaction rates in the CALPUFF chemistry algorithms are influenced by background ozone concentrations. Ozone observations collected at various locations within and around the study area were obtained from the Air Quality System (AQS) monitoring network. These data were concurrent with the modeled period. CALPUFF uses a background ozone value (BCK03) for hours when *none* of the supplied ozone stations have valid data. A conservative value of 60 ppb was specified, to avoid artificially limiting chemical transformations when no observed hourly ozone data are available. However, there are no hours with all stations reporting missing values in the ozone dataset.

The CALPUFF modeling system was used to predict hourly criteria pollutant concentrations, total deposition fluxes, and light extinction coefficients attributable to test source emissions in Class I areas. These parameters were calculated from CALPUFF output files using the post-processor programs CALPOST and POSTUTIL. POSTUTIL was run without recalculating the partitioning between nitric acid and particulate nitrate (MNITRATE = 0). The CALPUFF-predicted hourly SO_2 concentrations were averaged for the 3-hour, 24-hour and annual time periods to match the form of the Class I PSD increments. Annual average NO_X and PM_{10} concentrations were calculated as were 24-hour PM_{10} concentrations. Predicted extinction coefficients and total deposition fluxes were calculated as 24-hour and annual averages, respectively. In all instances, comparisons among the models were based on the highest model-prediction of the yearlong simulation for each averaging period.

Predictions of NO_X, SO_2, and PM_{10} concentrations in the areas of interest were extracted from the CALPUFF output files using the CALPOST post-processor. PM_{10} concentration estimates include both primary and secondary aerosols and account for the molecular weights of each resulting compound. The conversion to account for molecular weight and summing of species are accomplished using the POSTUTIL processor. Total nitrogen and sulfur deposition fluxes are similarly calculated by summing and converting the various species included in the wet and dry deposition CALPUFF output files. The nitrogen deposition fluxes include the nitrogen from the background ammonia assuming that sulfate and nitrate are completely neutralized by ammonium. The deposition fluxes were converted to kilograms per hectare per year.

Visibility extinction coefficients were calculated using the 2010 revisions to the FLAG procedures. The revised procedures employ the IMPROVE extinction equation to calculate the extinction coefficient. This updated equation for extinction uses monthly relatively humidity adjustment factors with relative humidity capped at 95%. It uses annual background aerosol concentrations recommended by the FLMs for each Class I area, and assess the visibility using

6 http://www.nature.nps.gov/air/Maps/Receptors/index.cfm

the 98th percentile modeled values at each receptor. In order to use the Method 8 (2010 revised) procedure, CALPOST Version 6.221 (Level 080724) was used to post-process the CALPUFF output files.

3.0 MODELING RESULTS

The CAMx and CALPUFF models were exercised using the 2005 FCAQTF 4 km and 2006 UT-CO 12 km modeling databases to obtain the single-source incremental concentration, visibility and deposition impacts at Class I areas for the test sources defined in Section 2.3. The same types of air quality metrics were analyzed as used in a PSD/NSR far-field or NEPA EIS type analyses. These air quality and air quality related value (AQRV) metrics were extracted from the models at Class I areas and compared. The air quality and AQRV metrics were maximum SO_2, NO_2 and PM_{10} concentrations at various averaging times, maximum daily visibility impacts and maximum annual sulfur and nitrogen deposition amounts.

CALPUFF Version 5.8 was run using meteorological inputs generated by CALMET that was run following the current regulatory guidance (FLAG, 2010; EPA, 2009b) as well as using meteorological inputs generated by MMIF (Brashers and Emery, 2012). As the MMIF processor is a "pass through" tool it adopts the projection, grid resolution and layer interfaces of the MM5/WRF meteorological model, which was 4 km for the 2005 FCAQTF and 12 km for the 2006 UT-CO modeling databases. CALPUFF V5.8 was also run for the 2006 UT-CO database using meteorological inputs based on a CALMET simulation using a 4 km grid resolution. This allows for the following comparison of the maximum air quality/AQRV impacts at Class I areas:

- CAMx vs. CALPUFF V5.8/CALMET and V5.8/MMIF;
- CALPUFF V5.8/CALMET 12 km vs. 4 km CALMET grid resolution (2006 database only).

For the CALPUFF modeling, the NPS Class I area receptor files were used and concentration and deposition outputs were output for all receptors. These receptors typically have a spacing of ~1 km. For the CAMx modeling, concentrations and depositions are available in each grid cell, which is either 12 or 4 km grid cell resolution. Consequently, for each Class I area the CALPUFF model will typically contain concentration and deposition impacts for hundreds of receptors, whereas CAMx will just have output representing the Class I area just for the grid cells that intersect any part of the Class I area. One area of analysis in this study is to examine the spatial variations in AQRVs across a Class I area estimated by CALPUFF using 100s of receptors versus CAMx using 10s of grid cells.

3.1 PSD CONCENTRATION COMPARISONS

The model estimated annual average, annual maximum 24-hour average and annual maximum 3-hour average SO_2, annual average NO_2, and annual average and annual maximum 24-hour average PM_{10} concentration that occurred at any Class I area receptor (CALPUFF) or grid cell intersecting a Class I area (CAMx) were extracted from the 2005 4 km and 2006 12 km modeling results for each test source. The models were then compared by generating scatter plots of concentrations from one model configuration against another paired in time and space that are shown in Figures 3-1 through 3-12. Spatial maps of the maximum SO_2, NO_2, PM_{10}, SO_4 and NO_3 concentrations for the various model configurations, EGU1 and the 2006 UT-CO modeling database are shown in Figures 3-13 through 3-22.

3.1.1 SO_2, NO_2, and PM Concentrations

Annual SO_2: Figures 3-1 and 3-7 compare the annual SO_2 impacts at the Class I areas for the various models and the, respectively, 2005 FCAQTF and 2006 UT-CO database. The annual SO_2

contributions of EGU1 with the 2006 UT-CO database and the various models are shown in Figure 3-13. For annual SO_2 concentrations there is generally good agreement among the various models. CAMx tends to estimate slightly higher and lower annual SO_2 concentrations on average using the 2005 4 km FCAQTF and 2006 12 km UT-CO databases, respectively. V5.8/CALMET is always slightly greater than V5.8/MMIF for 2005 FCAQTF and is approximately the same on average for 2006 UT-CO database. The V5.8 simulations using 12 km and 4 km CALMET inputs produces nearly identical annual SO_2 results (Figure 3-7, middle bottom). The spatial patterns of annual SO_2 concentrations for the models are similar (Figure 3-13). V5.8/MMIF produces higher maximum annual SO_2 concentrations near the source than V5.8/CALMET, but the spatial extent of concentrations above 0.01 $\mu g/m^3$ are similar (Figure 3-13, top panels). CAMx exhibits both higher maximum annual SO_2 concentrations at the source as well as larger spatial extent of concentrations above 0.01 $\mu g/m^3$. The higher CAMx concentration near the source could be partly due to the fact that the grid cell containing the source will likely be affected on more days of the year than the gridded receptor nearest the source in the CALPUFF runs.

24-Hour SO_2: The modeling results for maximum 24-hour SO_2 concentrations are shown in Figures 3-2, 3-8 and 3-14. Surprisingly, CAMx estimates higher maximum 24-hour SO_2 concentrations at Class I areas than CALPUFF using the 4 km 2005 FCAQTF database (Figure 3-2). This is even for the EGU1 and EGU2 impacts at Mesa Verde (the two highest concentrations in Figure 3-2); sources that are in relatively close proximity (~50 km) to the receptor. This is surprising since one of the criticisms of using CAMx for single-source assessments is the numerical diffusion associated with grid cell resolution will result in underestimating the maximum concentration at a Class I area compared to using the plume model. However, using the 12 km 2006 UT-CO database, the maximum CAMx-estimated 24-hour SO_2 concentrations are lower than estimated by CALPUFF (Figure 3-8). This may be partly related to the use of a coarser grid resolution (12 km) than used in the 2005 modeling (4 km). V5.8/CALMET tends to predict higher 24-hour SO_2 concentrations than V5.8/MMIF using the 2005 FCAQTF database. Whereas with the 2006 UT-CO database base there is a lot more scatter toward higher and lower 24-hour SO_2 concentrations whether CALMET or MMIF is used to drive CALPUFF V5.8 with the regression equation indicating equal occurrences of higher/lower concentrations. The spatial distribution of 24-hour SO_2 for V5.8/CALMET is similar to V5.8/MMIF with a slightly larger footprint, whereas CAMx estimates a smaller footprint, which is consistent with the lower CAMx 24-hour SO_2 impacts at Class I areas using the 2006 UT-CO database (Figure 3-8).

3-Hour SO_2: The CAMx highest 3-hour SO_2 impacts at Class I areas are slightly (~5%) lower than CALPUFF using the 2005 FCAQTF database and much lower (about half) than CALPUFF using the 2006 UT-CO database (Figures 3-3 and 3-9). V5.8/CALMET maximum 3-hour SO_2 impacts tend to be slightly higher than V5.8/MMIF using the 2005 FCAQTF (~5% higher) and 2006 UT-CO (~10% higher) databases. Although there are some differences in the V5.8/CALMET 3-hour SO_2 concentrations when CALMET is run using a 12 km and 4 km grid resolution, the differences are not obviously systematic. The CAMx maximum 3-hour SO_2 concentrations are lower than estimated by CALPUFF, with the peak value at the source being over 3 times lower.

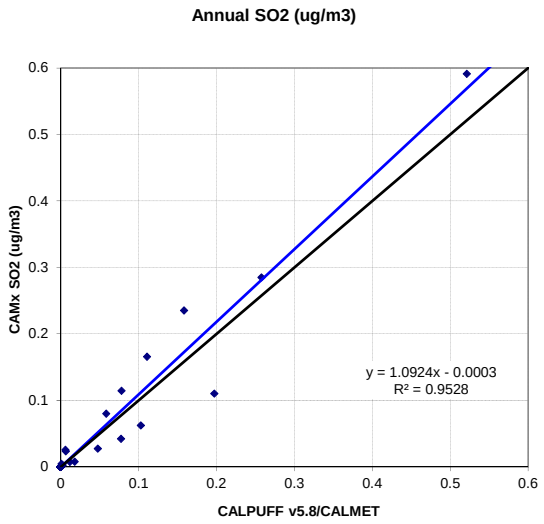
Annual NO_2: There are larger differences between the annual NO_2 concentrations among the models than seen for annual SO_2 (Figures 3-4, 3-10 and 3-16). Using the 2005 FCAQTF database, CAMx estimates slightly lower annual NO_2 concentrations compared to

V5.8/CALMET, but slightly higher values compared to V5.8/MMIF (Figure 3-4). However, using the 2006 UT-CO database, CAMx estimates lower (~25%) annual NO_2 concentrations compared to V5.8/CALMET and much lower (about half) compared to V5.8/MMIF (Figure 3-10). The use of the different meteorological drivers with CALPUFF V5.8 produces different results using the two databases with V5.8/CALMET being higher than V5.8/MMIF using the 2005 FCAQTF database but lower using the 2006 UT-CO database. Although there are differences in annual NO_2 concentrations between V5.8/CALMET using CALMET with 12 km and 4 km grid resolutions, there is no trend toward higher or lower concentrations estimates. V5.8/CALMET maximum annual NO_2 concentration (1.3 $\mu g/m^3$) is nearly double that of V5.8/MMIF (0.8 $\mu g/m^3$) with CAMx maximum value (2.7 $\mu g/m^3$) double V5.8/MMIF and approximately four times V5.8/MMIF. The spatial extent of the annual NO_2 for V5.8/MMIF is similar to V5.8/CALMET. Given that CAMx treats NO and NO_2 separately but V5.8 does not and assumes all of the NO_X is NO_2, the higher annual NO_2 concentrations by CAMx are surprising and may be partly related to the lower deposition rate of NO compared to NO_2.

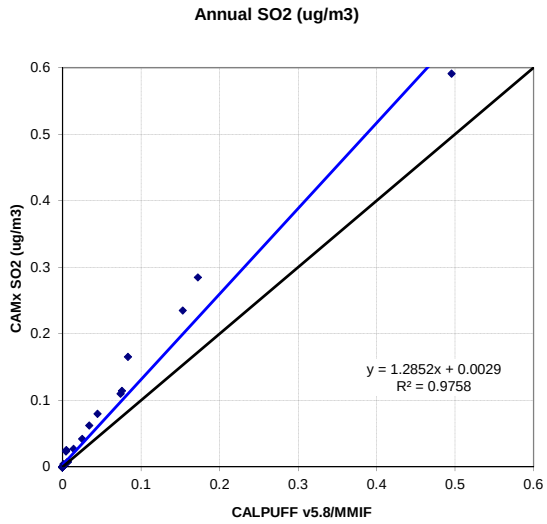
PM_{10} Concentrations at Class I Areas: The comparison of annual and 24-hour PM_{10} concentrations for the different models at Class I areas are given in Figures 3-5, 3-6, 3-11 and 3-12, which are quite different from the SO_2 and NO_2 comparisons. CALPUFF V5.8 PM_{10} concentrations are much greater than CAMx for both the 2005 and 2006 databases. Part of the reason for this is that CALPUFF does not treat ammonia/ammonium as an active transported species. The species mapping convention in CALPUFF is to assume that sulfate and nitrate are completely neutralized by ammonium and the ammonium is included in a source's PM contribution, even though the source may not have any ammonia emissions. As sulfate is not always completely neutralized and there are other anions that could neutralize sulfate and nitrate (e.g., sodium and calcium), this assumption is not always appropriate. The CAMx PSAT source apportionment tracks the PM concentrations back to the source that emitted the PM precursor, which for ammonium typically there is very little coming from most point sources. For the regulatory application of CAMx PSAT for single-source PM increments, an approach would need to be developed for the treatment of the buffering agents for sulfate and nitrate and how they would be included in single-source PM contributions. It could be as simple as the CALPUFF complete neutralizing by ammonium assumption. It should be noted that the lack of inclusion of ammonium in the CAMx PSAT PM contributions likely does not explain all of the differences between CAMx and V5.8/CALMET PM_{10} concentrations and further examination of the CAMx and CALPUFF species mappings for PM_{10} should be made. Although there is some scatter comparing V5.8/CALMET using 12 and 4 km CALMET grid resolution, on average they are very similar.

Spatial PM Comparisons: Spatial comparisons of annual and 24-hour PM_{10}, SO_4 and NO_3 concentrations due to EGU1 using the 2006 UT-CO database for the different models are given in Figures 3-17 through 3-22. The annual PM_{10} concentrations are similar among the models (Figure 3-17). There are larger differences, however, in the annual SO_4 (Figure 3-18) and NO_3 (Figure 3-19) concentrations among the model simulations.

CALPUFFV5.8/CALMET vs. CAMx



CALPUFFV5.8/MMIF vs. CAMx



CALPUFFV5.8/MMIF vs. CALPUFFV5.8/CALMET

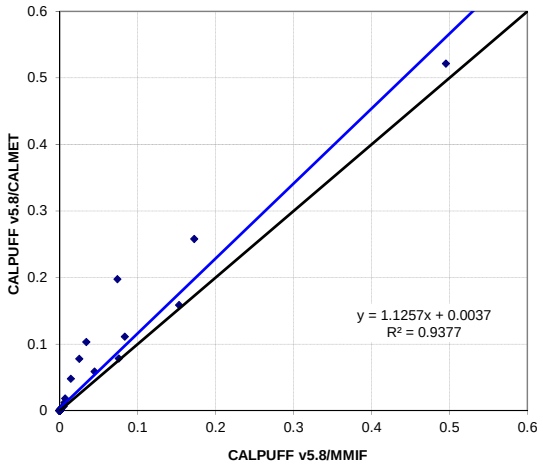
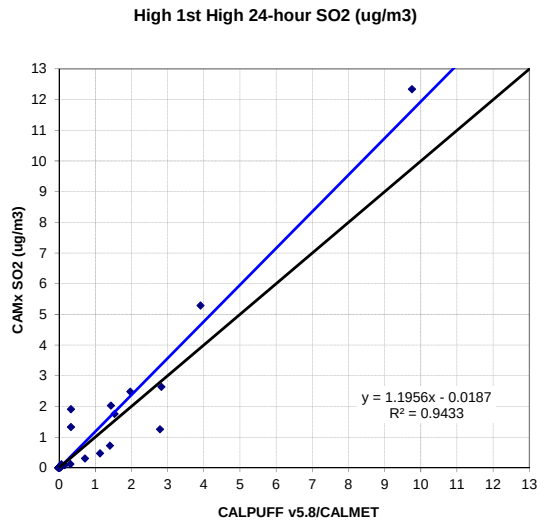
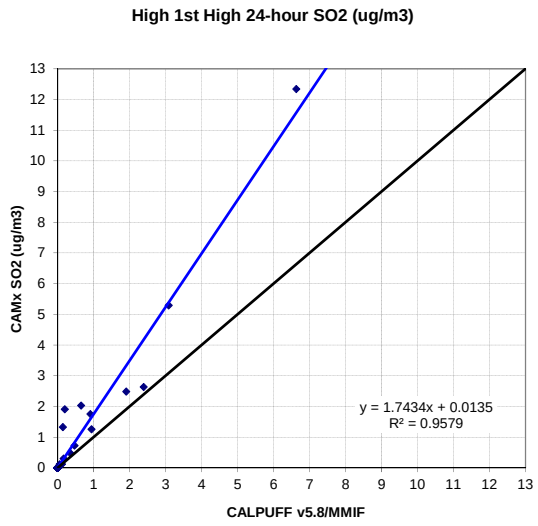


Figure 3-1. Scatter plot of test sources incremental annual SO_2 concentrations using the 2005 4 km FCAQTF database.

CALPUFFV5.8/CALMET vs. CAMx	CALPUFFV5.8/MMIF vs. CAMx
	

CALPUFFV5.8/MMIF vs. CALPUFFV5.8/CALMET

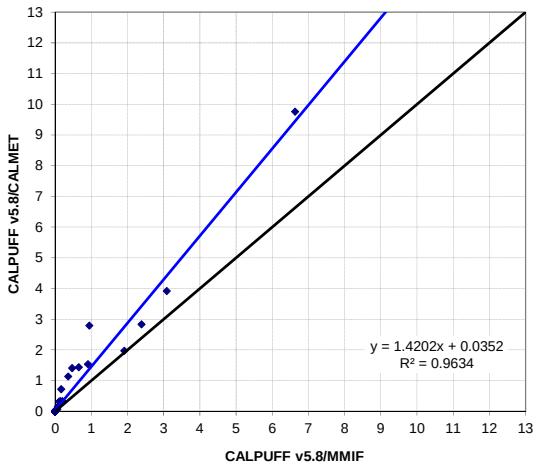


Figure 3-2. Scatter plot of test sources incremental highest 24-hour SO_2 concentrations using the 2005 4 km FCAQTF database.

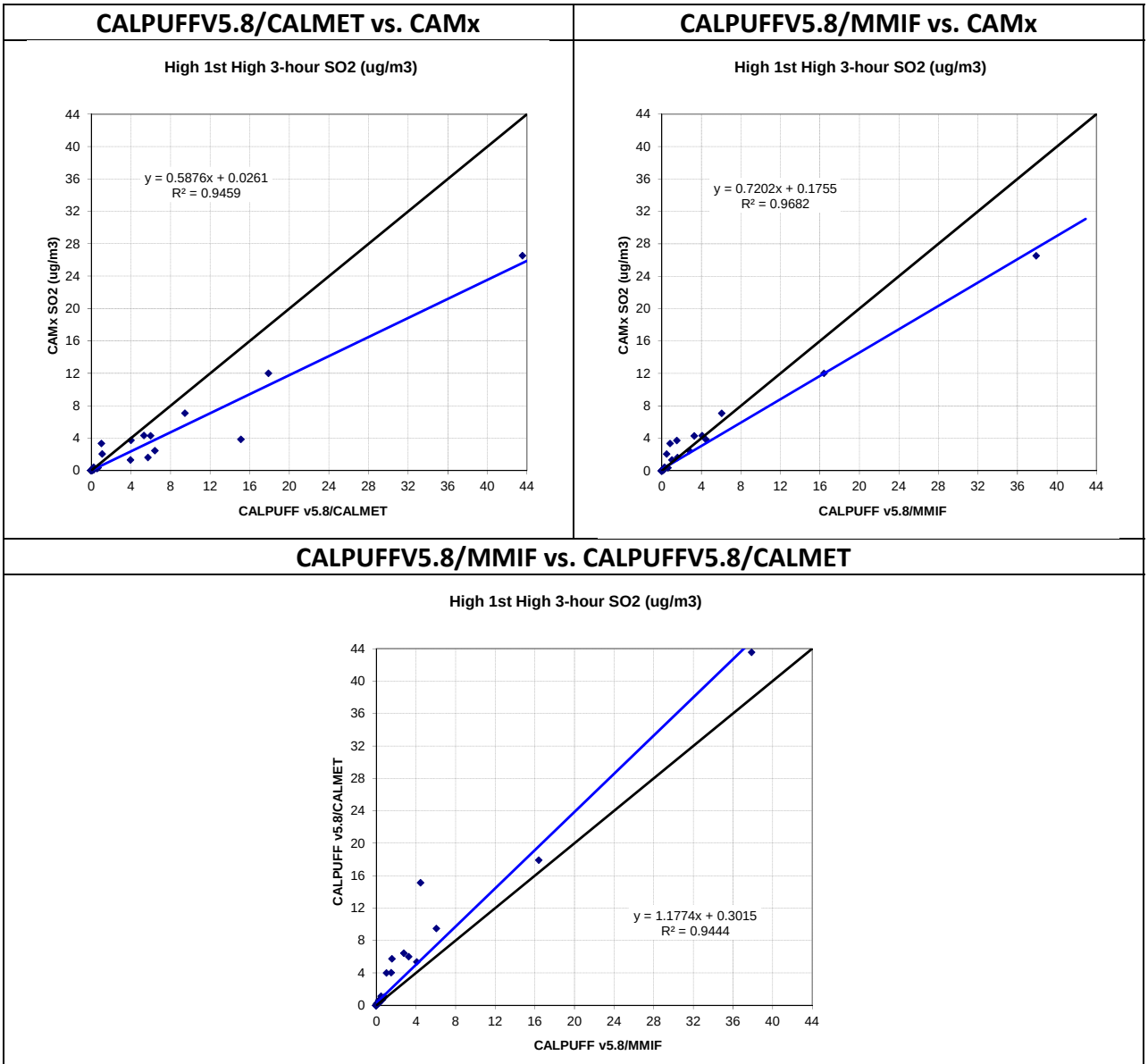
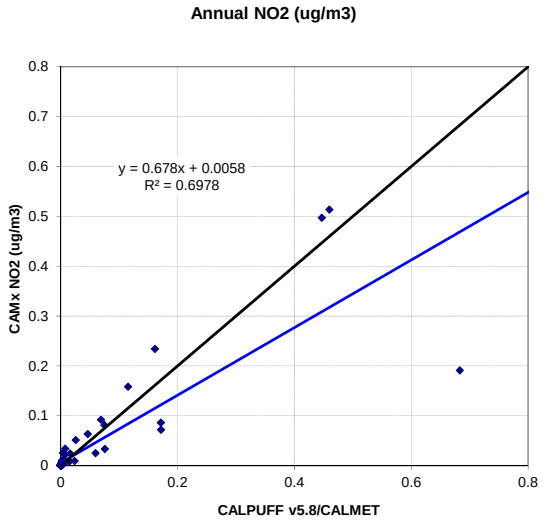
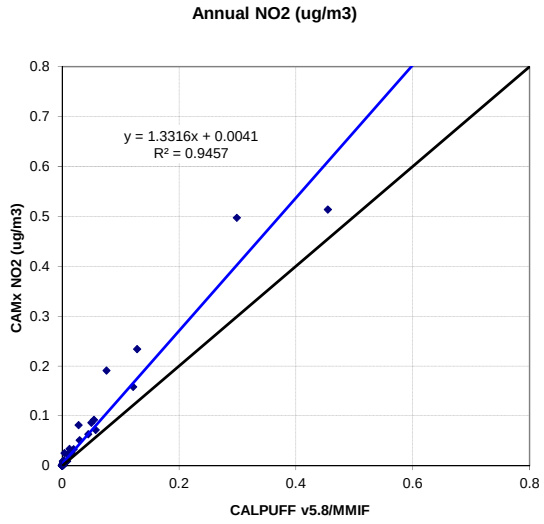


Figure 3-3. Scatter plot of test sources incremental highest 3-hour SO_2 concentrations using the 2005 4 km FCAQTF database.

CALPUFFV5.8/CALMET vs. CAMx



CALPUFFV5.8/MMIF vs. CAMx



CALPUFFV5.8/MMIF vs. CALPUFFV5.8/CALMET

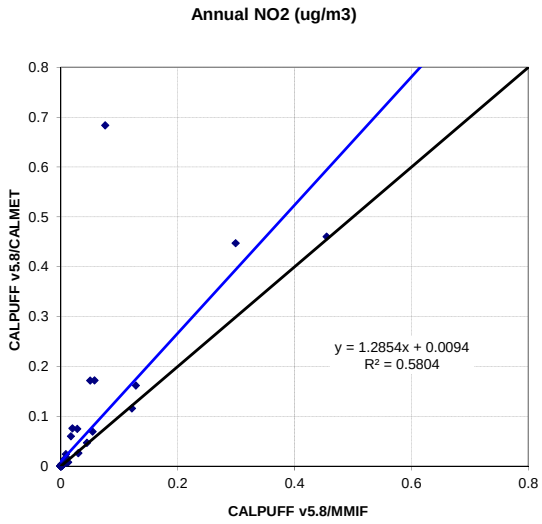
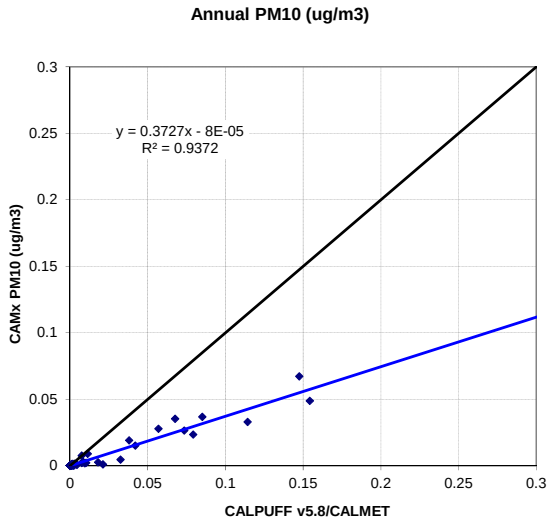
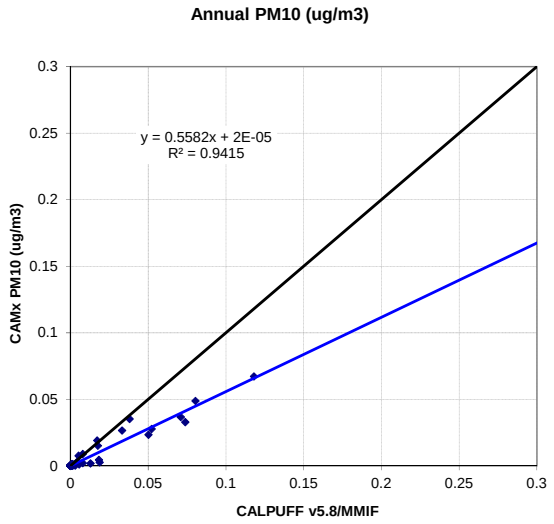


Figure 3-4. Scatter plot of test sources incremental annual NO_2 concentrations using the 2005 4 km FCAQTF database.

CALPUFFV5.8/CALMET vs. CAMx



CALPUFFV5.8/MMIF vs. CAMx



CALPUFFV5.8/MMIF vs. CALPUFFV5.8/CALMET

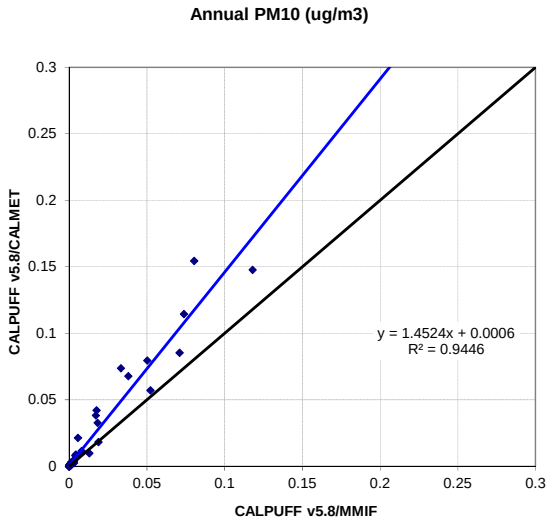


Figure 3-5. Scatter plot of test sources incremental annual PM_{10} concentrations using the 2005 4 km FCAQTF database.

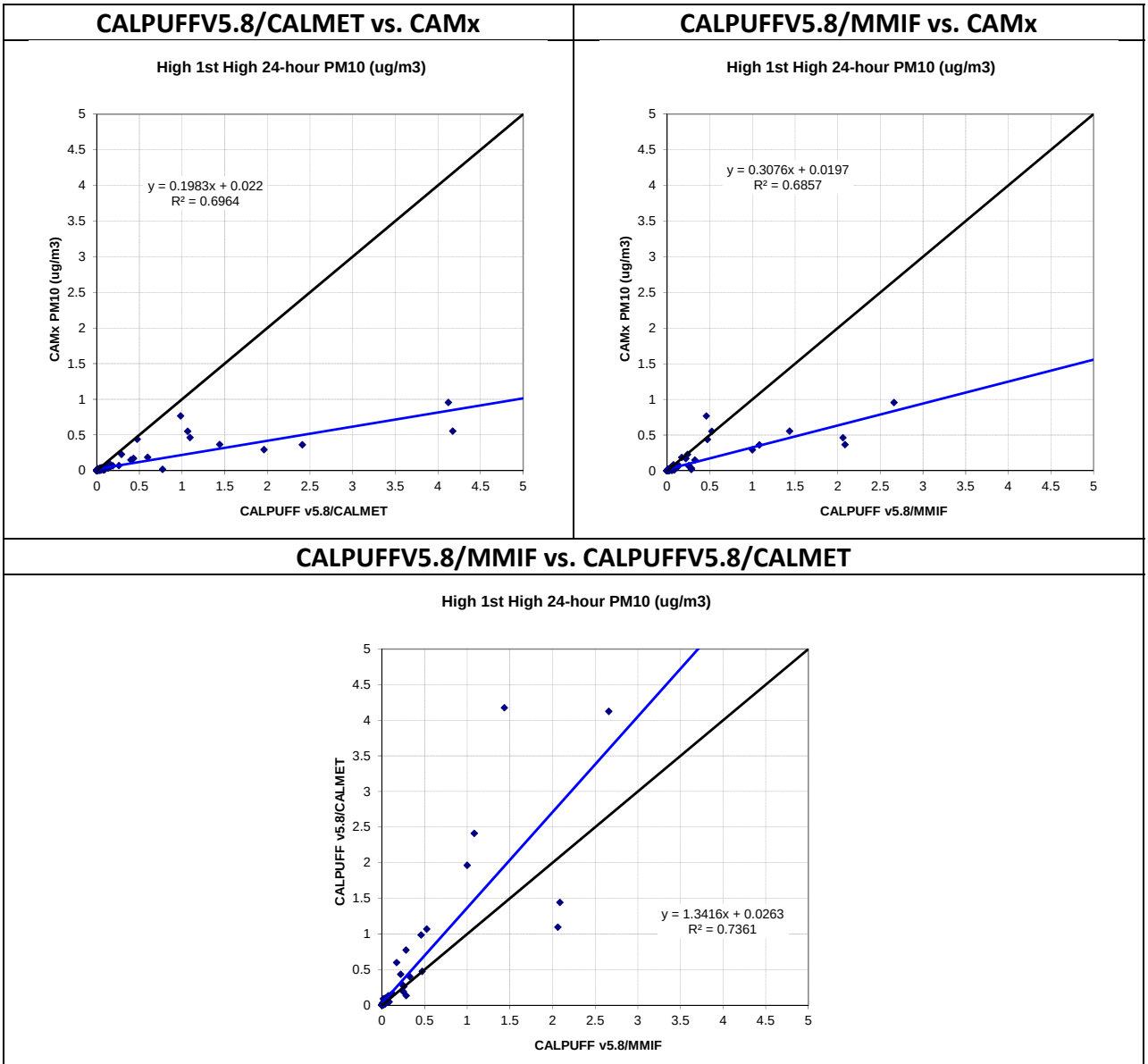


Figure 3-6. Scatter plot of test sources incremental highest 24-hour PM_{10} concentrations using the 2005 4 km FCAQTF database.

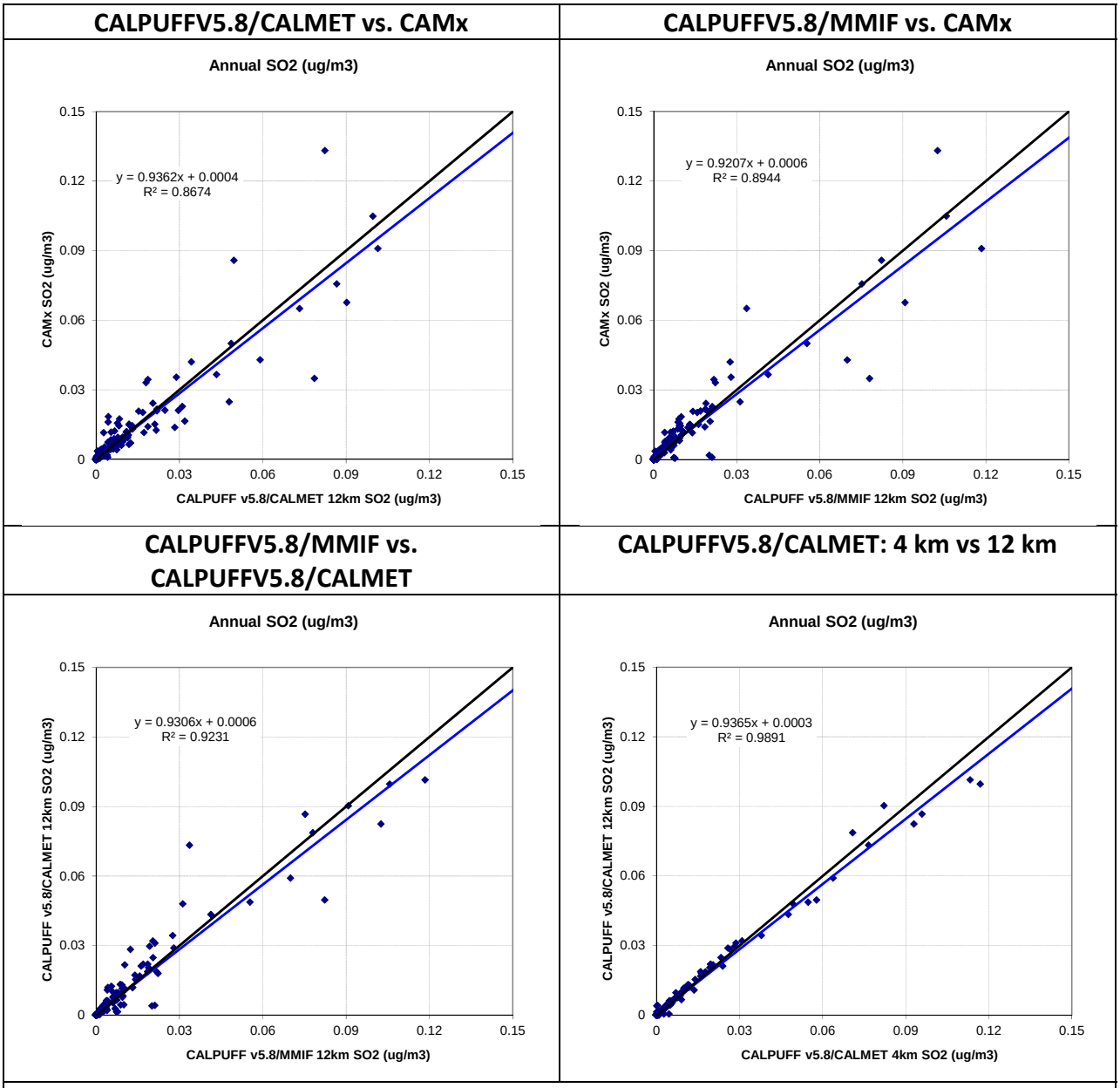


Figure 3-7. Scatter plot of test sources incremental annual SO_2 concentrations using the 2006 12 km UT-CO database.

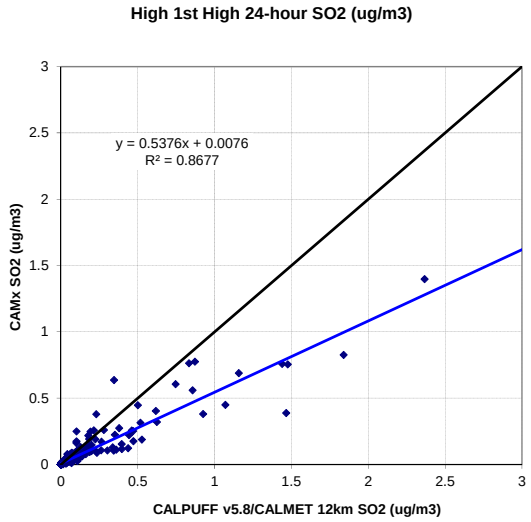
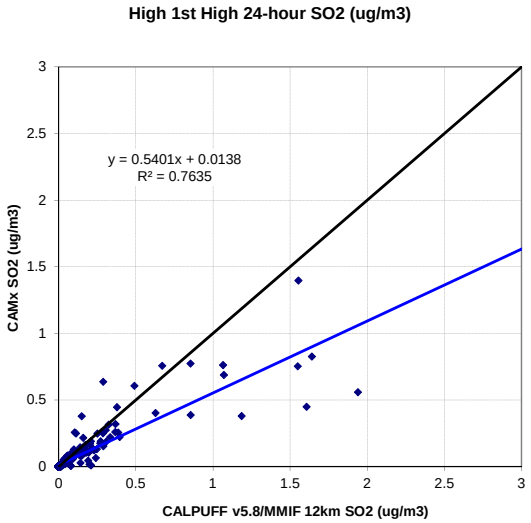
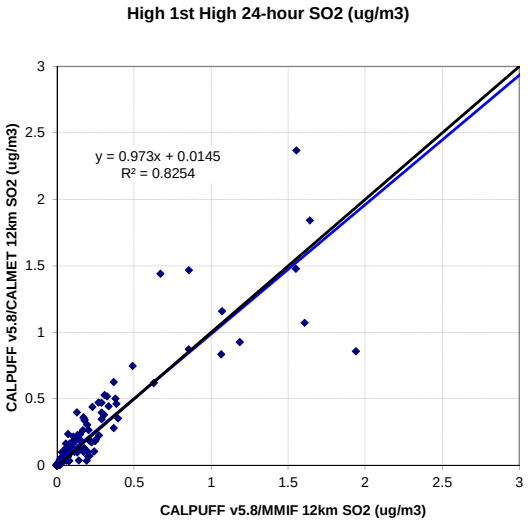
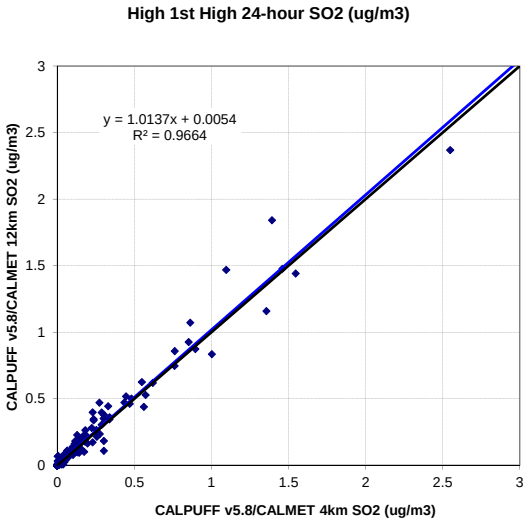
CALPUFFV5.8/CALMET vs. CAMx	CALPUFFV5.8/MMIF vs. CAMx
	
CALPUFFV5.8/MMIF vs. CALPUFFV5.8/CALMET	**CALPUFFV5.8/CALMET: 4 km vs 12 km**
	

Figure 3-8. Scatter plot of test sources incremental highest 24-hour SO_2 concentrations using the 2006 12 km UT-CO database.

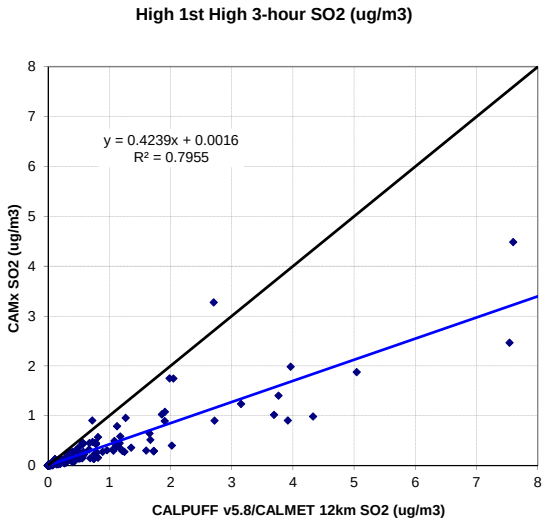
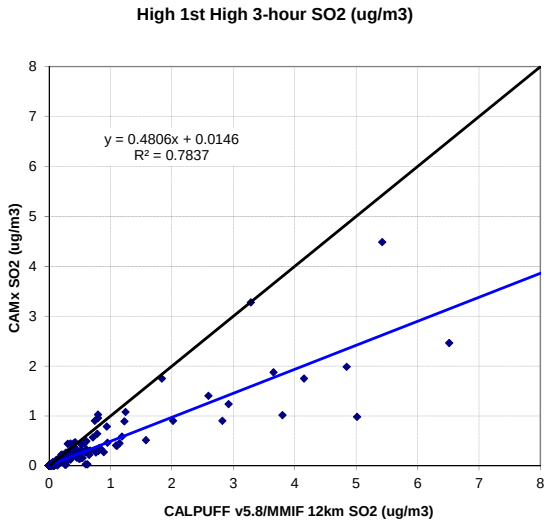
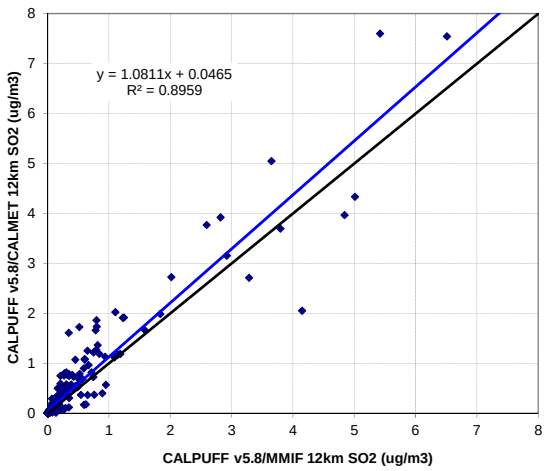
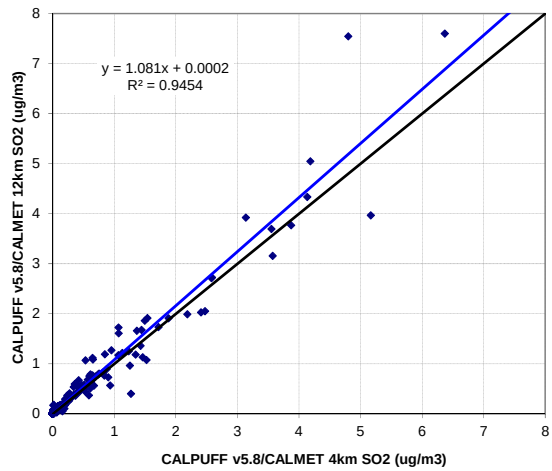
CALPUFFV5.8/CALMET vs. CAMx	CALPUFFV5.8/MMIF vs. CAMx
	
CALPUFFV5.8/MMIF vs. CALPUFFV5.8/CALMET	**CALPUFFV5.8/CALMET: 4 km vs 12 km**
	

Figure 3-9. Scatter plot of test sources incremental highest 3-hour SO_2 concentrations using the 2006 12 km UT-CO database.

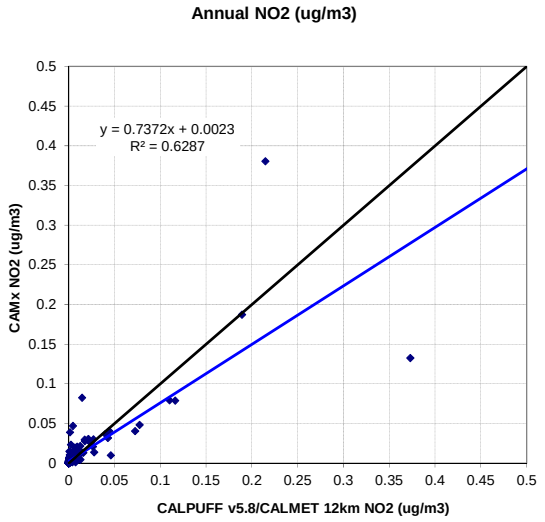
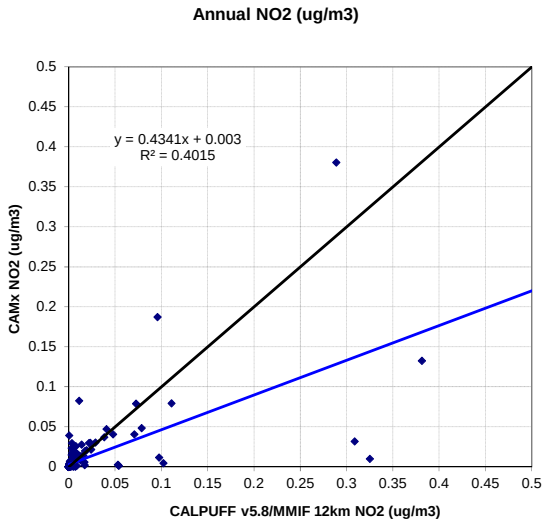
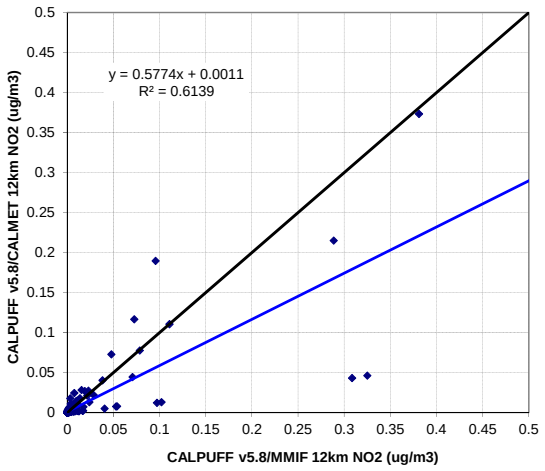
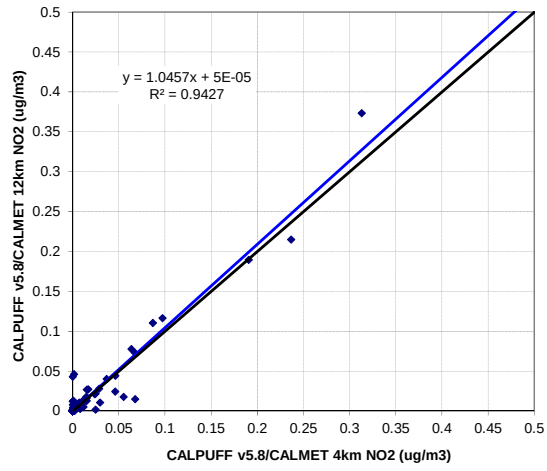
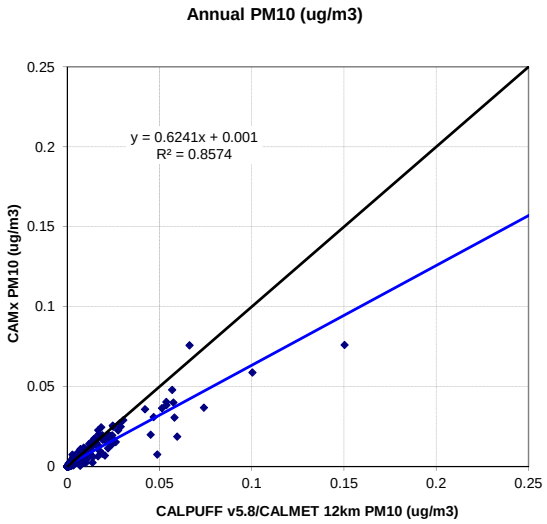
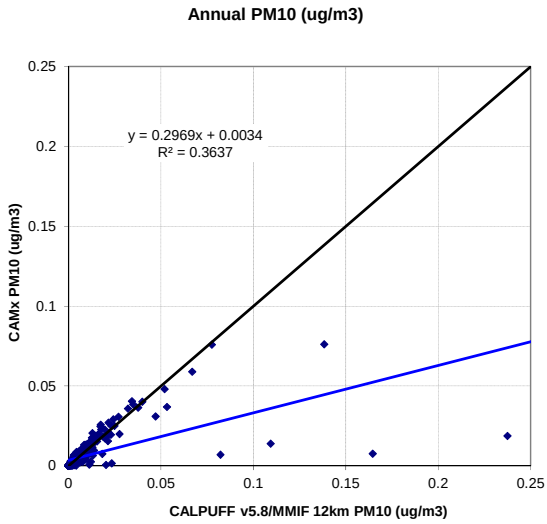
CALPUFFV5.8/CALMET vs. CAMx	CALPUFFV5.8/MMIF vs. CAMx
	
CALPUFFV5.8/MMIF vs. CALPUFFV5.8/CALMET	**CALPUFFV5.8/CALMET: 4 km vs 12 km**
	

Figure 3-10. Scatter plot of test sources incremental Annual NO_2 concentrations using the 2006 12 km UT-CO database.

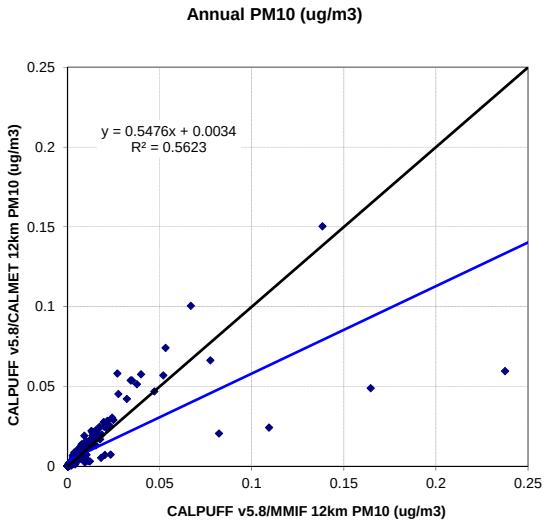
CALPUFFV5.8/CALMET vs. CAMx



CALPUFFV5.8/MMIF vs. CAMx



CALPUFFV5.8/MMIF vs. CALPUFFV5.8/CALMET



CALPUFFV5.8/CALMET: 4 km vs 12 km

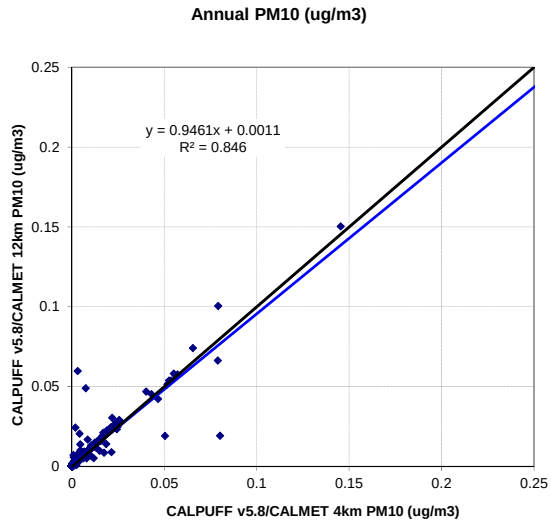


Figure 3-11. Scatter plot of test sources incremental annual PM_{10} concentrations using the 2006 12 km UT-CO database.

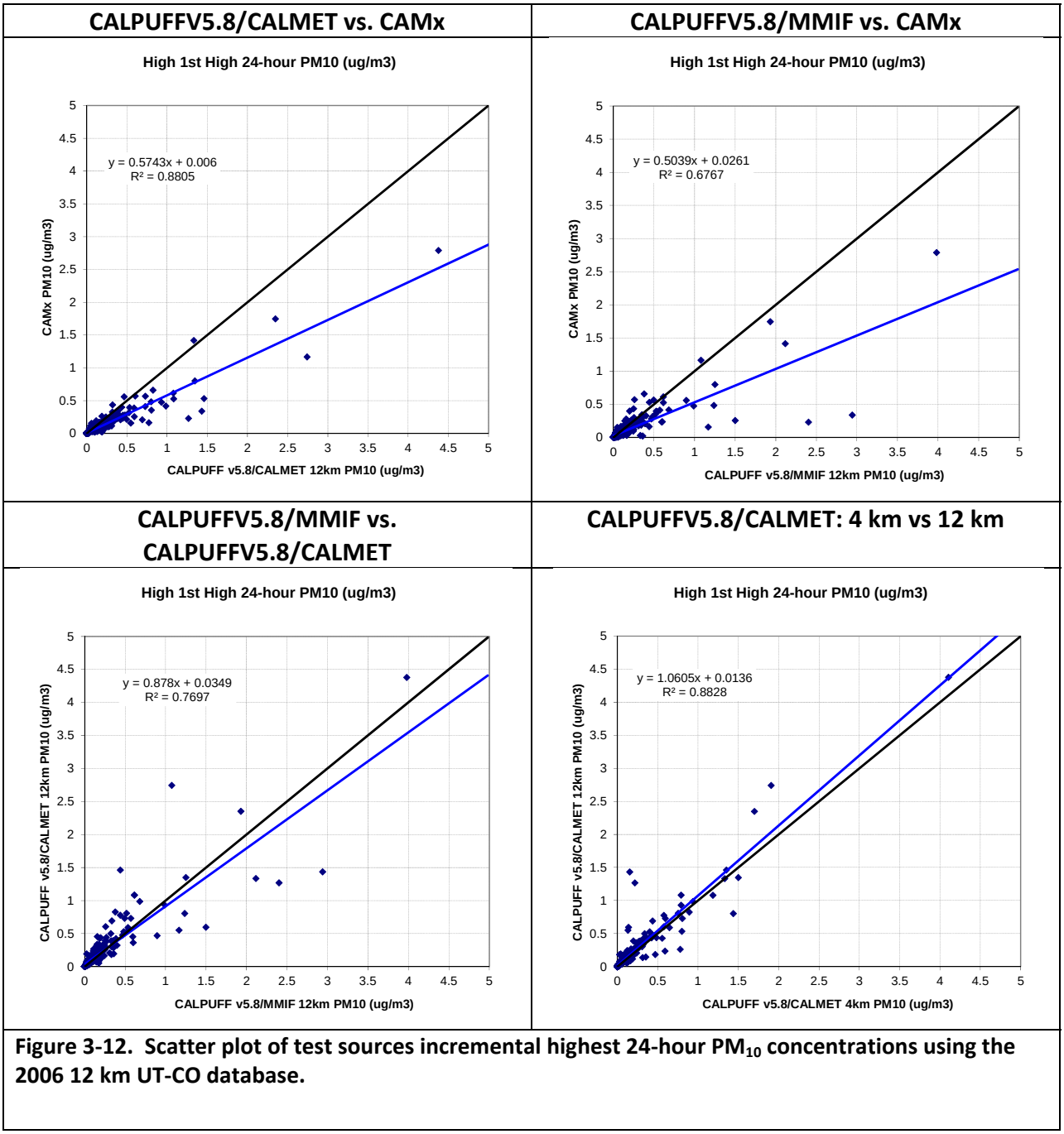


Figure 3-12. Scatter plot of test sources incremental highest 24-hour PM_{10} concentrations using the 2006 12 km UT-CO database.

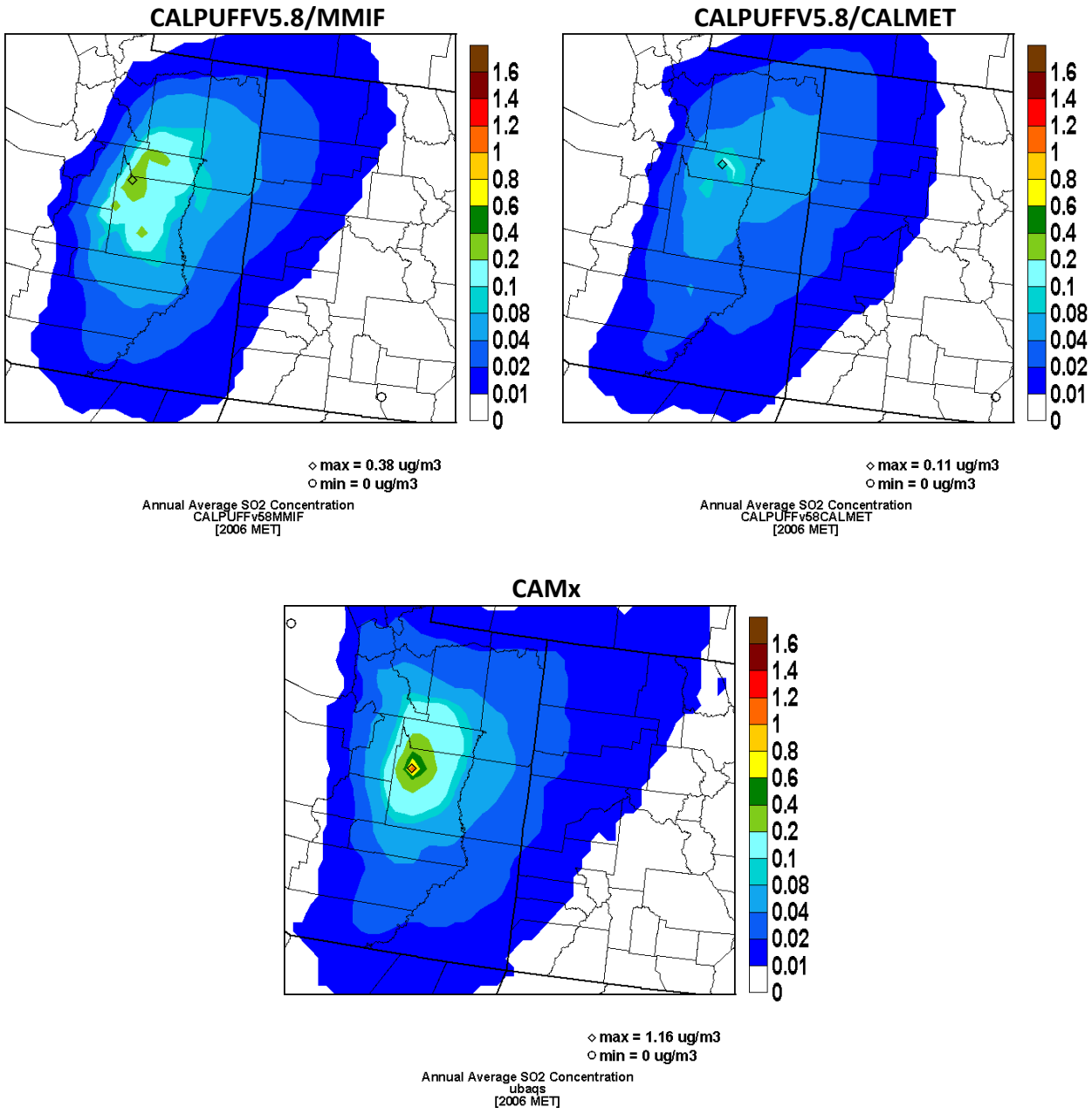


Figure 3-13. Spatial distribution of annual SO_2 concentrations for EGU1 and the 2006 12 km UT-CO modeling database.

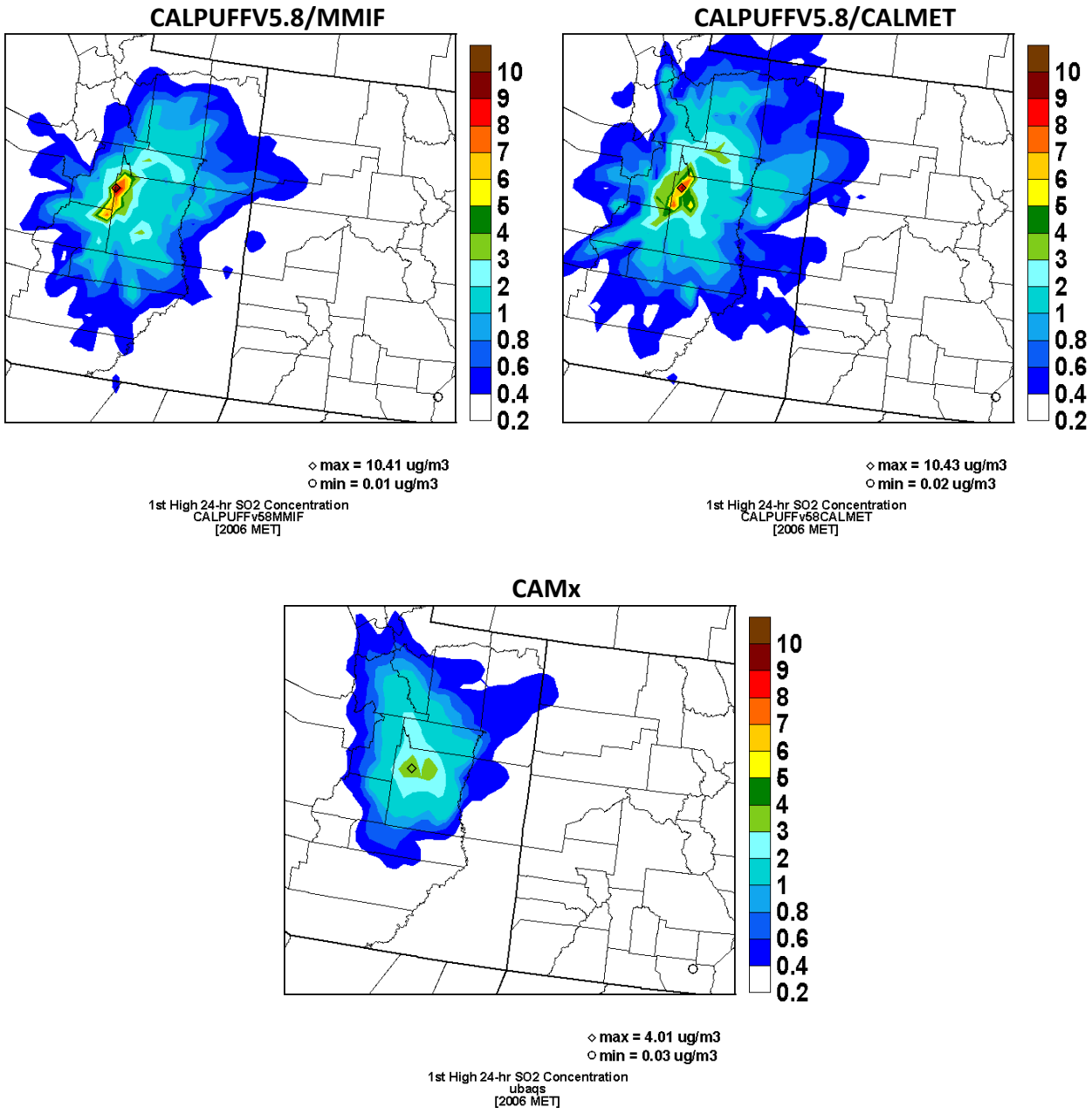


Figure 3-14. Spatial distribution of highest 24-hour SO_2 concentrations for EGU1 and the 2006 12 km UT-CO modeling database.

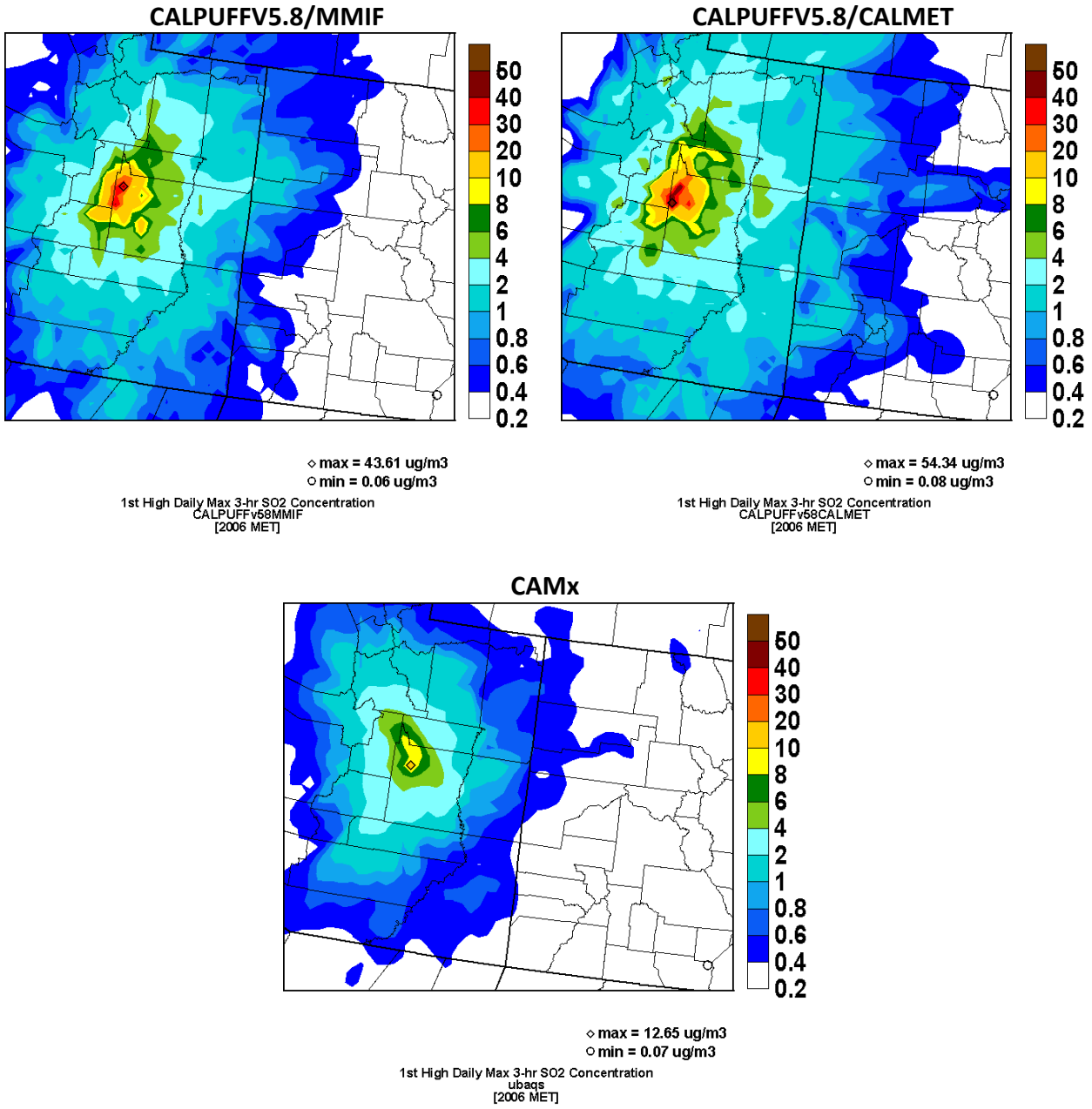


Figure 3-15. Spatial distribution of highest 3-hour SO_2 concentrations for EGU1 and the 2006 12 km UT-CO modeling database.

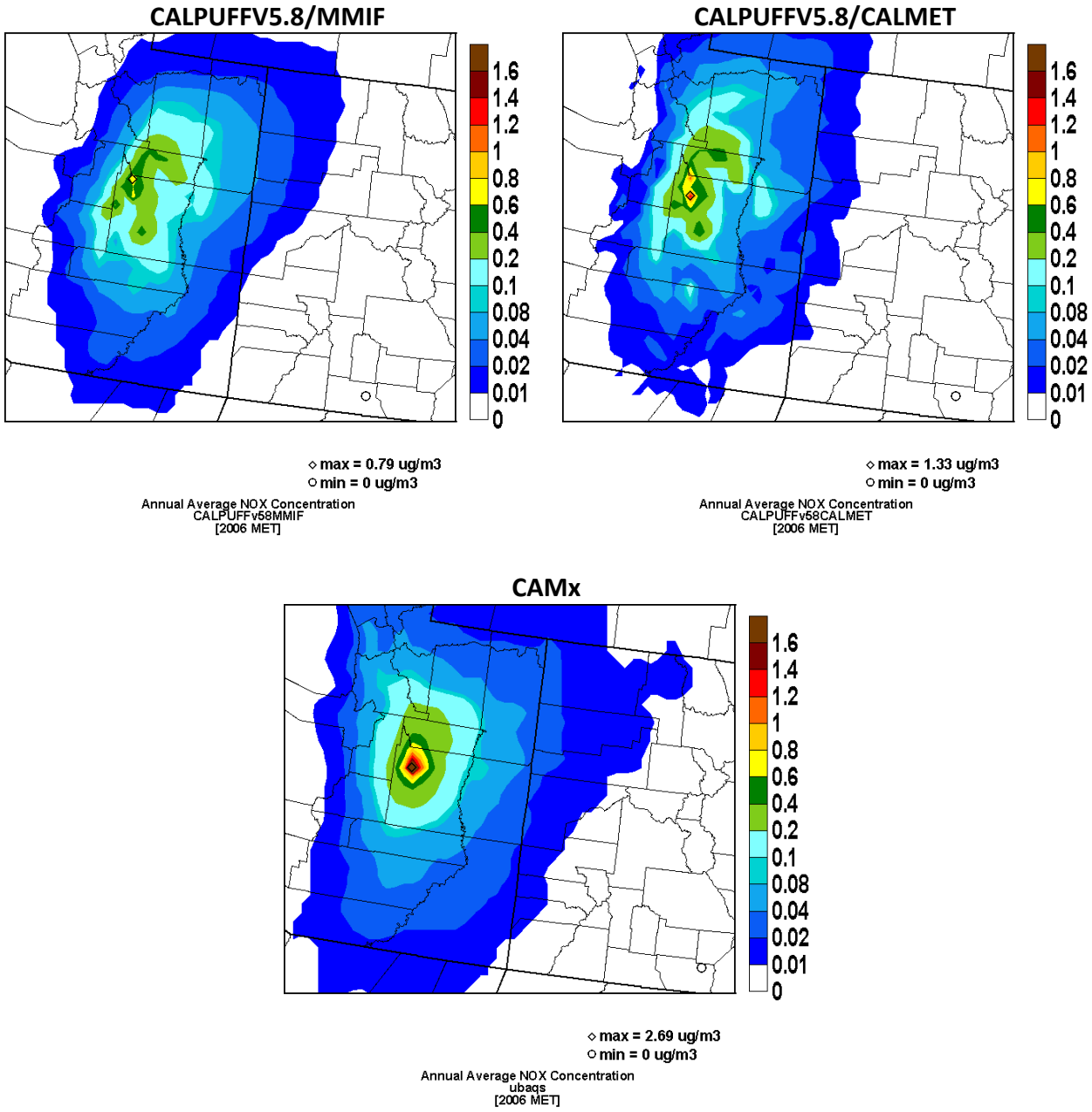


Figure 3-16. Spatial distribution of annual NO_2 concentrations for EGU1 and the 2006 12 km UT-CO modeling database.

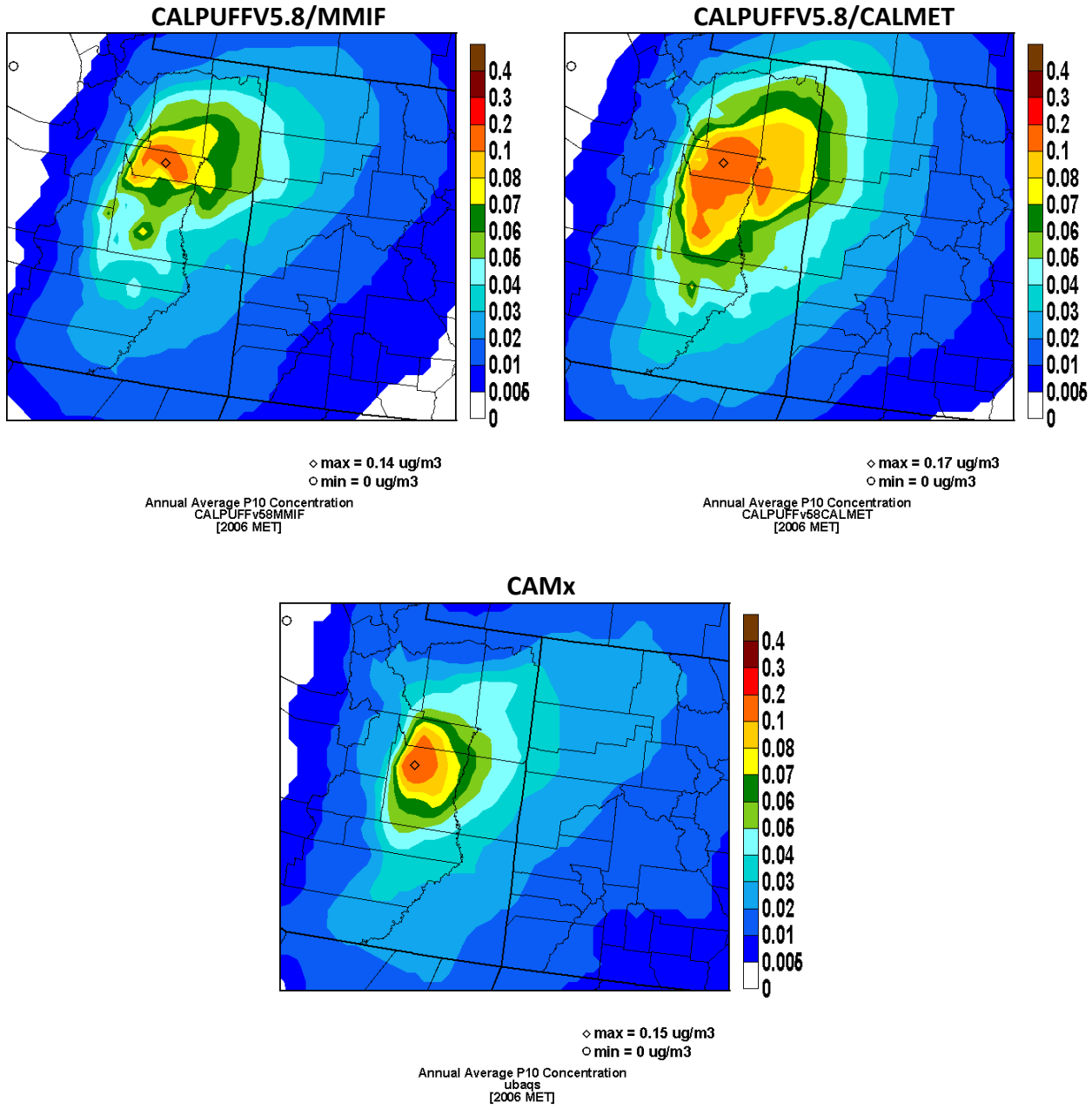


Figure 3-17. Spatial distribution of annual PM_{10} concentrations for EGU1 and the 2006 12 km UT-CO modeling database.

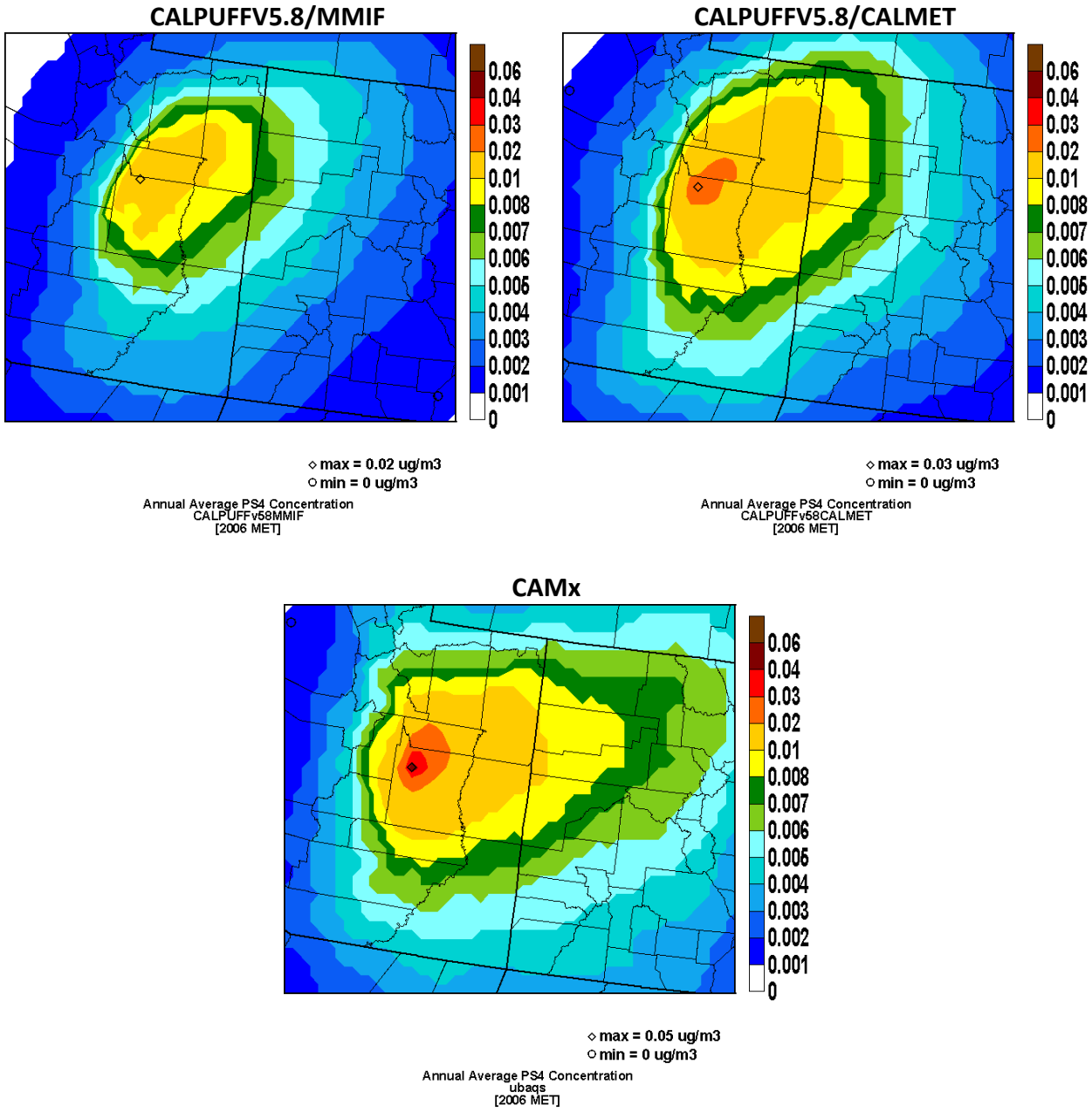


Figure 3-18. Spatial distribution of annual SO_4 concentrations for EGU1 and the 2006 12 km UT-CO modeling database.

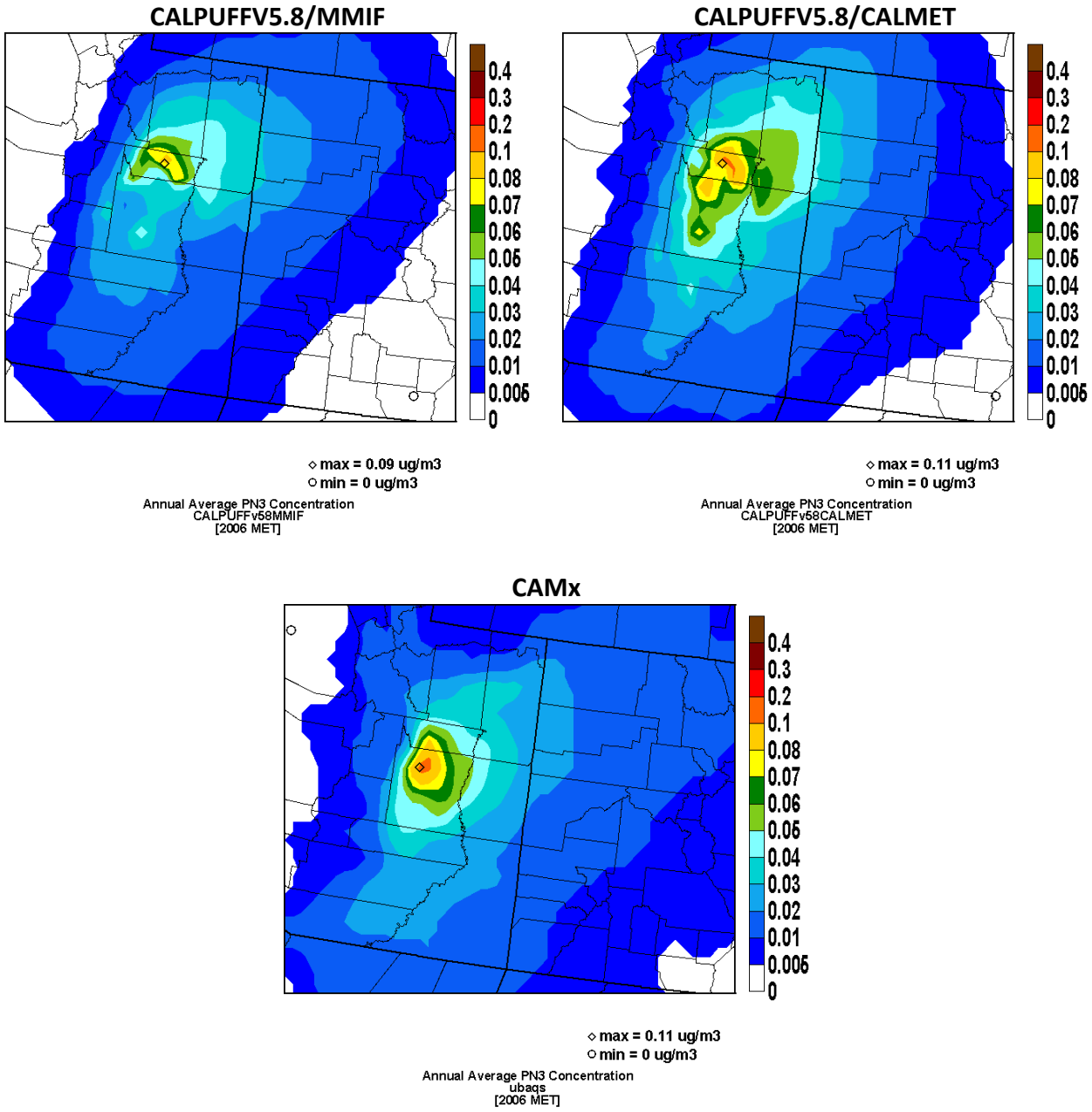


Figure 3-19. Spatial distribution of annual NO_3 concentrations for EGU1 and the 2006 12 km UT-CO modeling database.

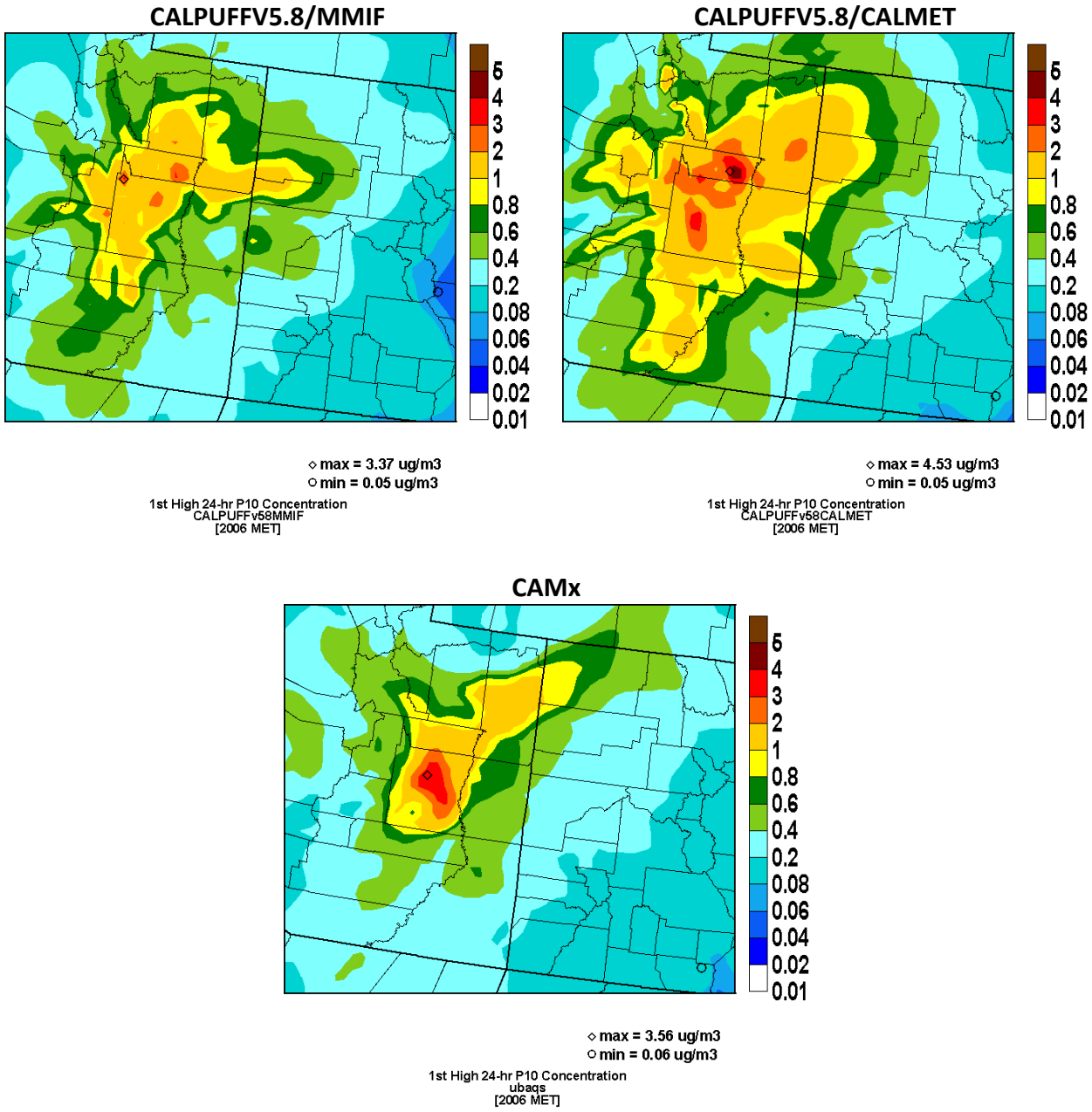


Figure 3-20. Spatial distribution of highest 24-hour PM_{10} concentrations for EGU1 and the 2006 12 km UT-CO modeling database.

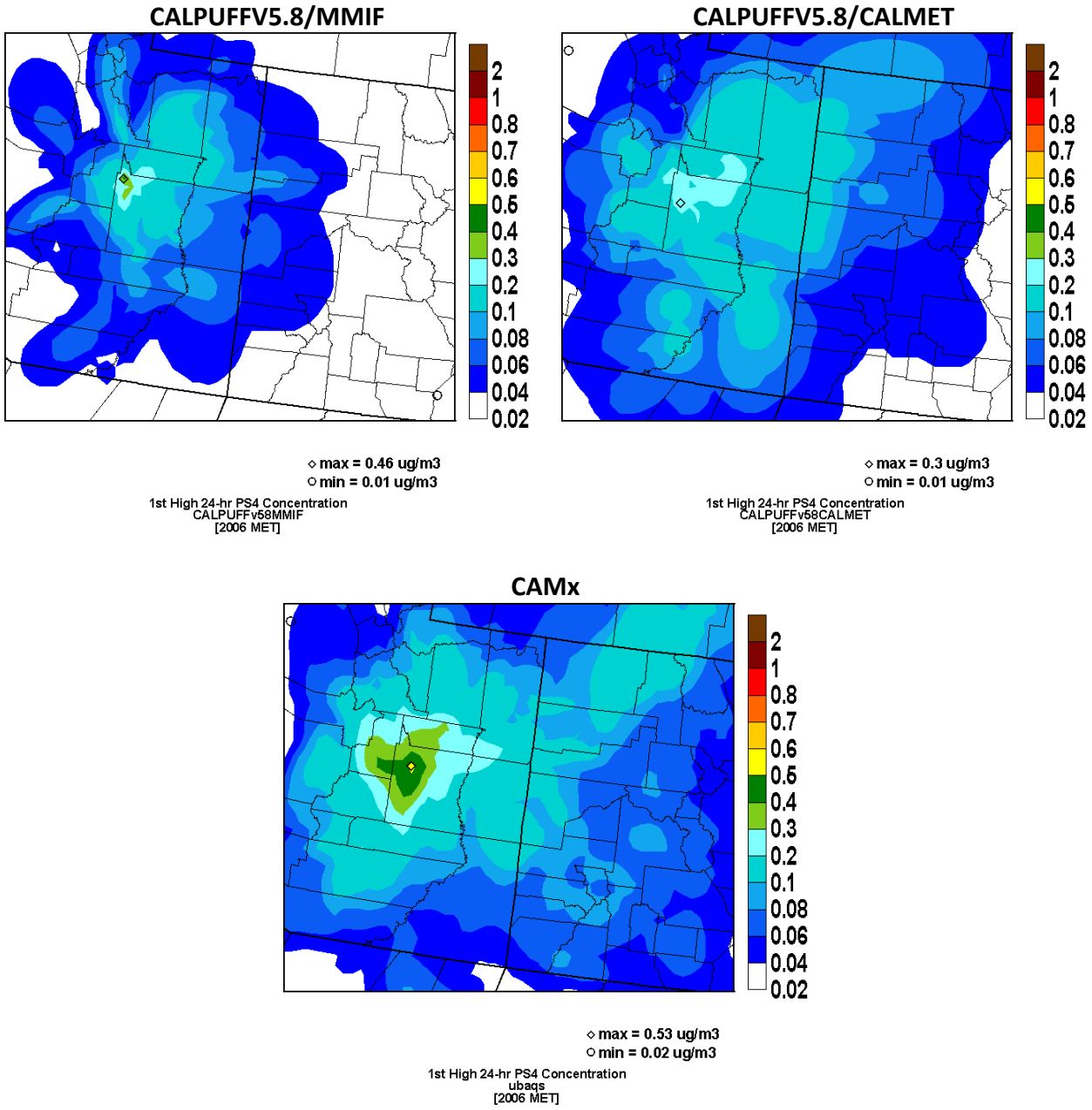


Figure 3-21. Spatial distribution of highest 24-hour SO_4 concentrations for EGU1 and the 2006 12 km UT-CO modeling database.

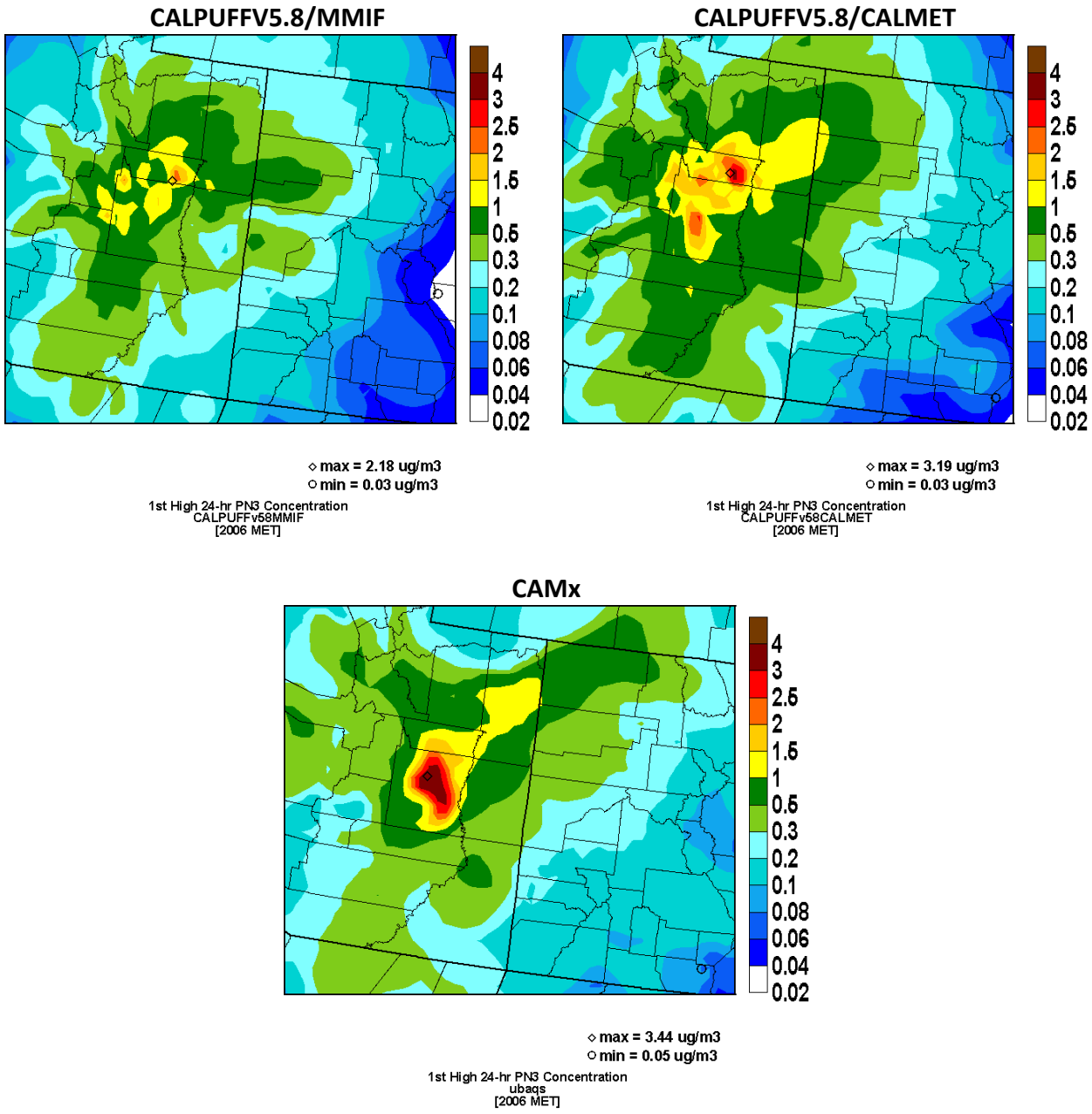


Figure 3-22. Spatial distribution of highest 24-hour NO_3 concentrations for EGU1 and the 2006 12 km UT-CO modeling database.

3.2 VISIBILITY COMPARISONS

Visibility calculations were made using the latest IMPROVE equation (FLAG, 2010) and the single-source estimates for sulfate (SO_4), nitrate (NO_3), elemental carbon (EC), organic aerosol (OA), other fine particulate ($OPM_{2.5}$), coarse mass (CM) and NO_2 concentrations. The SO_4 and NO_3 were assumed to be completely neutralized by ammonium (NH_4) and monthly relative humidity adjustment factors were used that were specific to each Class I area (FLAG, 2010). These procedures were used with all modeling systems: CALPUFF V5.8 and CAMx. Thus, unlike the PM_{10} comparisons, the same species mappings were used for the CALPUFF and CAMx visibility post-processing.

3.2.1 Comparison of Maximum 24-Hour Visibility Estimates

Figures 3-23 and 3-24 compare scatter plots of maximum 24-hour extinction (Mm^{-1}) estimated by the models due to the test sources using the, respectively, 2005 4 km FCAQTF and 2006 12 km UT-CO domains. Consistent with the concentration predictions, V5.8/CALMET estimates higher visibility extinction than CAMx or V5.8/MMIF. For example, V5.8/CALMET estimates two visibility extinction values in the 30-40 Mm^{-1} range using the 2005 4 km database with CAMx estimating values in the 5-15 Mm^{-1} range and V5.8/MMIF estimating values in the 15-25 Mm^{-1} range for the same two cases. These two cases are for the two largest NO_X and SO_2 sources examined (EGU1 and EGU2) and the Mesa Verde Class I area that is approximately 50 km away from the two sources (see Section 2.3). Using the 2005 FCAQTF database (Figure 3-23), V5.8/CALMET and V5.8/MMIF estimate much higher visibility values than CAMx. V5.8/CALMET generally estimates visibility impairment that is 40% greater than V5.8/MMIF using the 2005 FCAQTF database.

Using the 2006 UT-CO database (Figure 3-24), V5.8/CALMET visibility estimates are comparable to V5.8/MMIF and greater than CAMx. When running CALMET with 12 and 4 km grid resolution, V5.8/CALMET produces comparable visibility estimates.

3.2.2 Variation of Visibility Estimates across Class I Areas

Figures 3-25 and 3-26 display the spatial variation in the maximum 24-hour visibility impairment across a Class I area estimated by the models for the test sources using the 2005 FCAQTF and 2006 UT-CO databases, respectively. The frequency distributions of the visibility impairment across a Class I area is represented using box-and-whisker plots that display the mean (blue box symbol) and median (horizontal line), the 25^{th} and 75^{th} percentiles (the box) and the maximum and minimum values (the whiskers). The second Y axis shows the number of CAMx grid cells used to represent the Class I area (brown diamonds). Figure 3-25a displays the spatial variability of the visibility impacts for EGU1, EGU2 and EGU3 and the 2005 FCAQTF database. For EGU1 and EGU2, there is a lot of spatial variability in the visibility impacts across the Mesa Verde Class I area which is located 60 and 45 km away from the sources, respectively. There is less spatial variability exhibited by CAMx than CALPUFF for those two source-receptor relationships. This is partly due to the fact that Mesa Verde is represented in CAMx by six 4 km grid cells. As noted previously, the V5.8/CALMET and V5.8/MMIF visibility impacts are larger than CAMx. CALPUFF is estimating less spatial variability across the Class I areas for the other Class I areas than Mesa Verde, with a little variability seen for San Pedro Parks and Weminuche Wilderness Areas that are 140-170 km away from the two sources. The bottom panel in Figure

3-25a displays the spatial variability of visibility for EGU3 whose emissions are approximately a factor of 10 lower than EGU1/EGU2. It appears that there is more spatial variability across Class I areas for EGU3 than EGU1/EGU2, but that is partly because the scale of the visibility impacts is approximately a factor of 10 lower. In some cases it appears that CAMx is exhibiting more spatial variability across the Class I area than CALPUFF (e.g., EGU3 and Mesa Verde), which is surprisingly since CAMx represents a Class I area with much fewer grid cells than receptors used by CALPUFF.

It appears that after a sufficient downwind distance, the spatial variability of visibility impacts across a Class I area is reduced to a nominal range in CALPUFF. The most important factors that contribute to spatial variation in maximum daily visibility impacts across a Class I area are the distance between the source and the Class I area, the size of the Class I area (i.e., number of receptors or grid cells) and the orientation of the source-receptor relationship (e.g., if the plume from a source rarely travels to a Class I area its variation is diminished). Tables 3-1 and 3-2 display the distances between the test source and the Class I areas using in the 2005 and 2006 modeling databases, respectively.

Figure 3-25b displays the spatial results for 2005 EGU4, EGU5 and OG1. For EGU4, there is clearly variations across Bandelier Class I area that is 45 km away from the source, but very little at the other Class I areas, except maybe San Pedro Parks for V5.8/CALMET that is 75 km away. For EGU5, CAMx is showing more spatial variability than CALPUFF with noticeable variations at Bandelier (85 km), and for some models, San Pedro Peaks (120 km) and even Weminuche (300 km) for CAMx, but not CALPUFF. And OG1 shows spatial variation at Mesa Verde 40 km away, but very little at the other Class I areas including Weminuche that is 145 km from the source.

OG2 sees variations at Mesa Verde (80 km) and possibly Weminuche (130 km), whereas OG3 just sees variations at the nearby San Pedro Parks (20 km) and none at the other Class I areas including Bandelier 80 km away (Figure 3-25c). OG4 has some variations at Petrified Forest 155 km away, but little at the others. The top two panels in Figure 3-25d are for OG5 and OG7 that see variations for the two closest Class I areas (Petrified Forest 105 km and Mesa Verde 65 km) but none at the other Class I areas that 190 km or 135 km or farther away.

Using the 2006 UT-CO database, the distance where spatial variability remains in the CALPUFF estimates is sometime longer. For EGU01 and EGU02, spatial variability is seen at Arches, Canyonlands and Capitol Reef that are 110 to 160 km away from the source but not at the other Class I areas that lie further away (Figure 3-26a). EGU08 offers a clear distance cutoff for spatial variation with variability seen at Flat Tops (63 km), Mount Zirkel (84 km) and Eagles Nest (139 km), but none seen at the other Class I areas (Figure 3-26c).

In general, CALPUFF exhibits spatial variability in maximum 24-hour visibility impairment across Class I areas when the source is within 100 km of the source that sometimes extends out to 150 km of the source. In looking at the results in Figures 3-25 and 3-26 there are some exceptions to this with no spatial variability for Class I areas in the 100-150 km range and some noticeable variability with Class I areas > 150 km from the sources.

One interesting finding is that despite the fact that CAMx represents a Class I area with much less grid cells than the receptors used by CALPUFF, it frequently exhibits as much variability in visibility impacts as CALPUFF in many cases.

Table 3-1. Approximate distances (km) between the test sources and Class I areas in the 2005 FCAQTF database.

Distance (km)	Bandelier NM	La Garita Wilderness	Mesa Verde NP	Petrified Forest NP	San Pedro Parks Wilderness	Weminuche Wilderness
EGU01	220	200	60	225	160	150
EGU02	225	190	45	235	170	140
EGU03	165	305	205	165	135	255
EGU04	45	285	260	290	75	255
EGU05	85	330	295	285	120	300
OG01	235	190	40	240	175	145
OG02	180	175	80	250	120	130
OG03	80	200	175	280	20	165
OG04	195	275	150	155	145	220
OG05	240	320	190	105	200	275
OG06	315	225	70	260	255	185
OG07	315	175	65	315	255	135
OG08	155	110	200	400	130	110
OG09	130	335	265	215	130	295

Table 3-2. Approximate distances (km) between the test sources and Class I areas in the 2006 UT-CO database.

Distance (km)	Arches NP	Black Canyon of the Gunnison NP	Bryce Canyon NP	Canyon-lands NP	Capitol Reef NP	Eagles Nest WAs	Flat Tops WA	La Garita WA	Maroon Bells - Snowmass WA	Mesa Verde NP	Mount Zirkel WA	Weminuche WA	West Elk WAs
EGU01	133	293	202	139	110	410	332	388	344	308	409	367	332
EGU02	147	302	220	160	133	411	330	400	349	328	403	382	340
EGU03	156	299	263	182	173	390	306	400	336	345	372	388	332
EGU04	271	431	216	268	191	537	454	526	478	436	519	503	469
EGU05	232	384	249	243	192	478	393	483	424	412	453	467	419
EGU06	301	433	353	327	293	491	403	536	455	491	441	530	460
EGU07	153	214	373	209	266	259	172	317	221	323	233	324	232
EGU08	257	209	507	314	397	139	63	285	158	364	84	319	194
EGU09	119	82	377	169	269	185	126	185	112	212	226	193	106
EGU10	108	78	329	121	232	251	217	151	160	111	320	127	126
EGU11	255	371	102	198	141	540	490	418	452	261	589	368	418
EGU12	269	133	525	313	419	42	85	160	50	289	151	209	91
EGU13	270	133	525	314	419	43	86	160	50	289	152	209	90
OG01	85	158	330	143	220	250	174	261	189	250	259	260	187
OG02	158	111	416	212	306	154	82	205	102	256	180	225	116
OG03	148	221	361	202	255	271	185	324	232	323	246	329	241
OG04	147	296	244	168	154	395	313	396	337	333	383	381	331
OG05	187	350	139	171	85	479	404	438	409	335	484	409	392
OG06	133	167	266	101	190	342	309	208	251	70	412	162	213
OG07	245	155	408	237	334	301	308	109	219	79	403	51	175
OG08	335	182	543	348	457	229	278	80	185	222	349	115	161
OG09	320	193	578	367	470	18	98	214	109	349	114	266	150
OG10	296	267	536	354	428	187	121	344	216	419	93	377	253
OG11	271	387	371	306	295	433	344	491	402	462	378	490	411

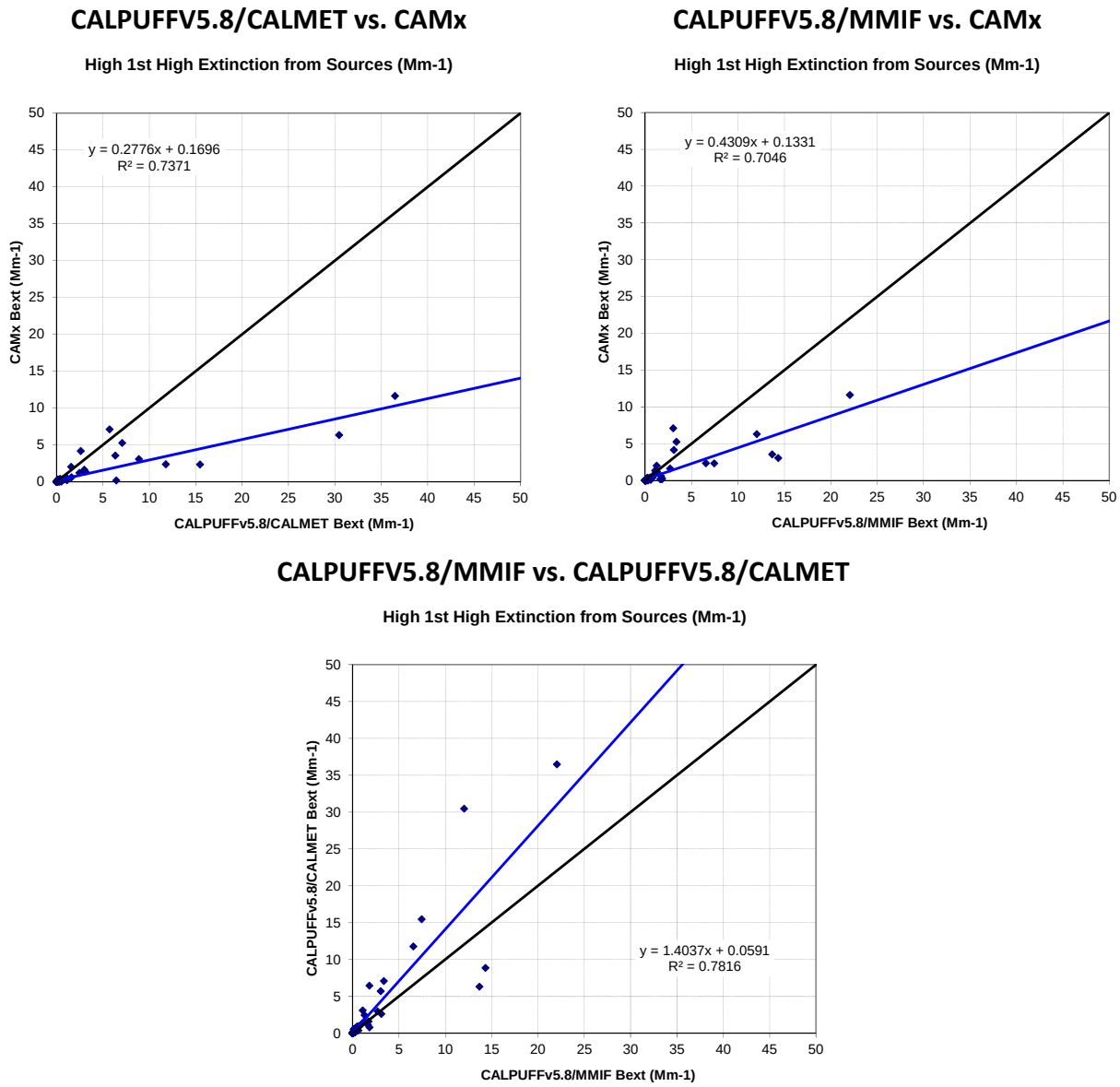


Figure 3-23. Scatter plot of test sources incremental visibility extinxtion (Mm^{-1}) using the 2005 4 km FCAQTF database.

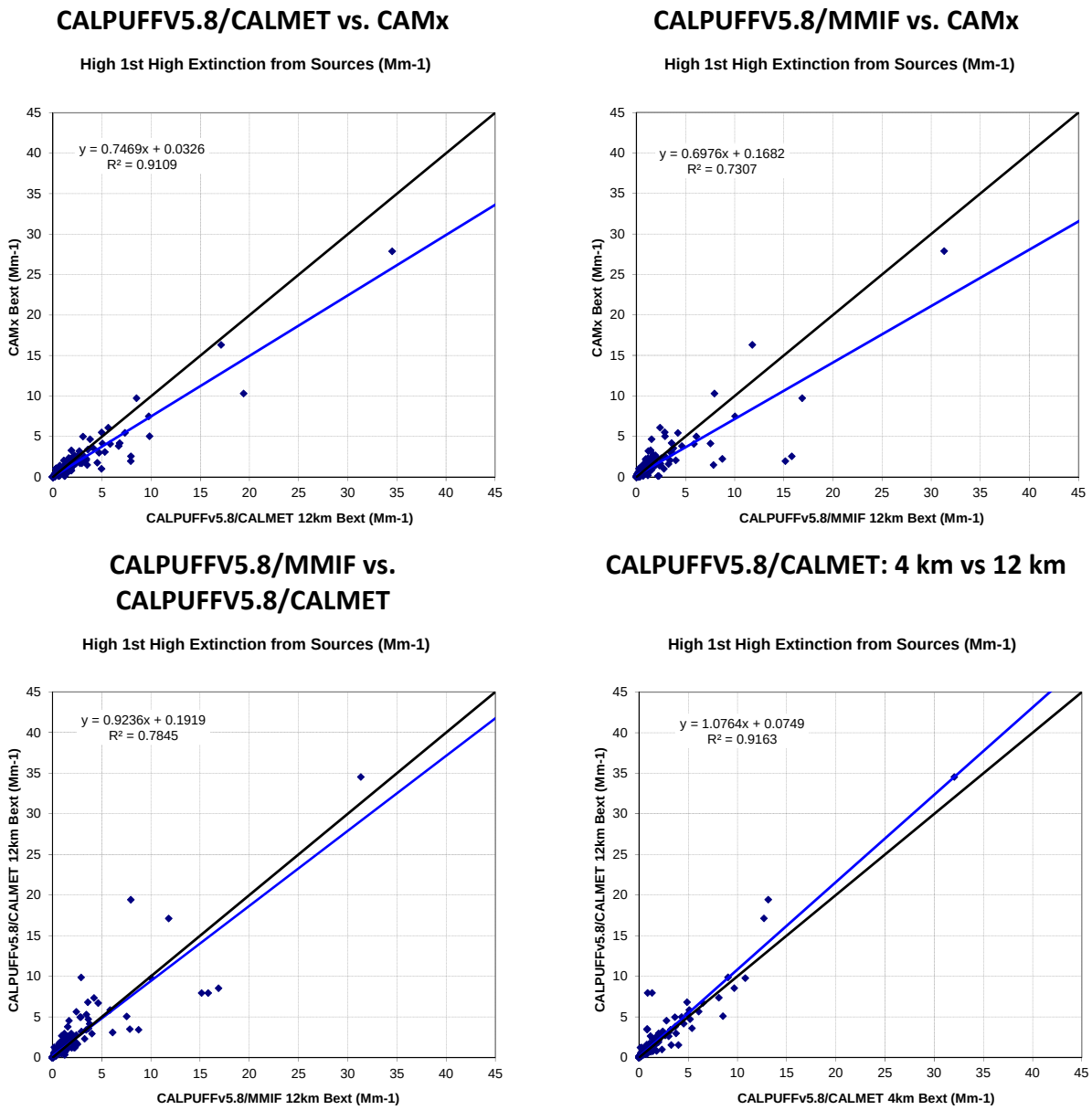


Figure 3-24. Scatter plot of test sources incremental visibility extinxtion (Mm^{-1}) using the 2006 12 km UT-CO database.

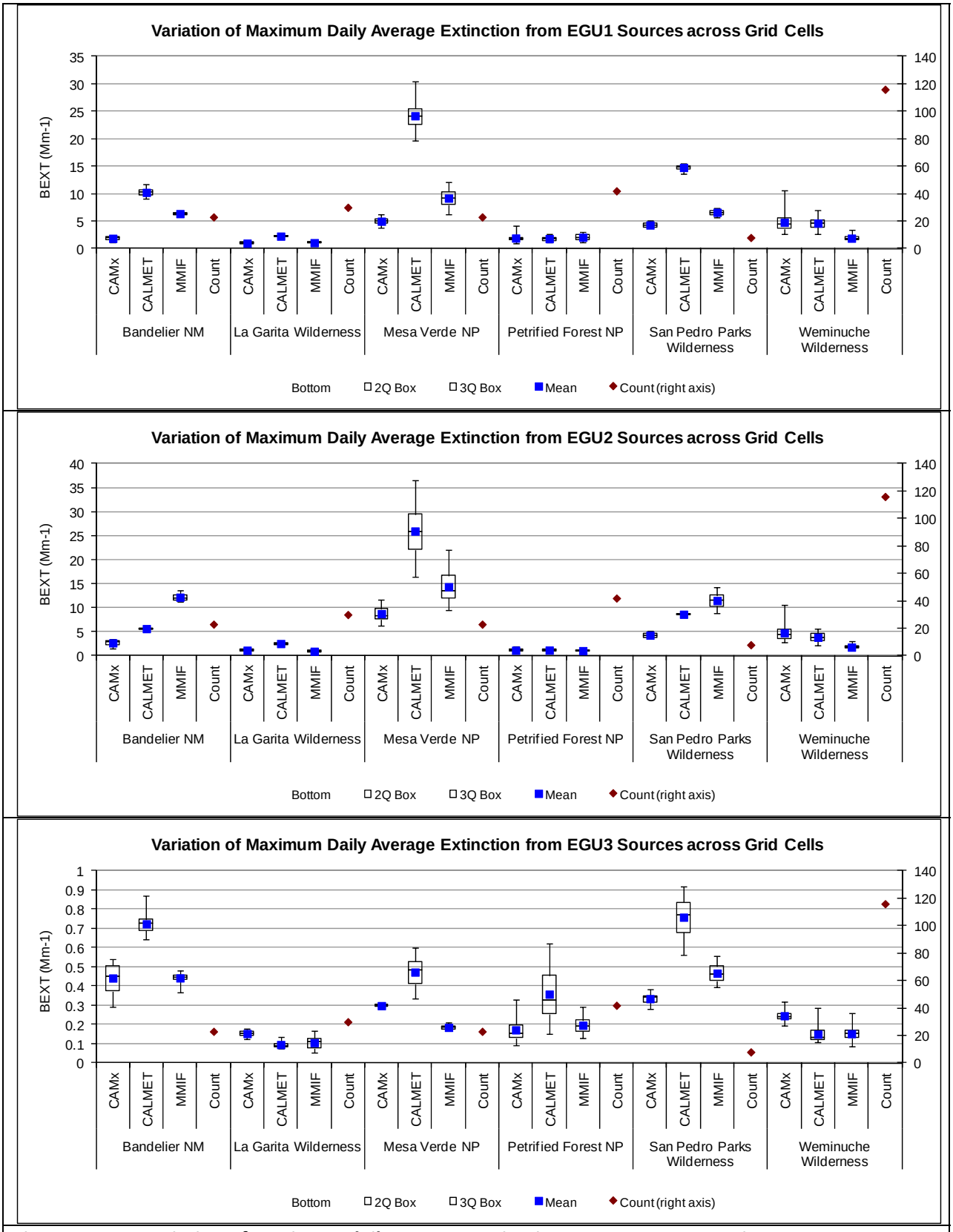


Figure 3-25a. Variation of maximum daily average extinction across receptors using CAMx, V5.8/CALMET, V5.8/MMIF for EGU1, EGU2 and EGU3 with 2005 FCAQTF database.

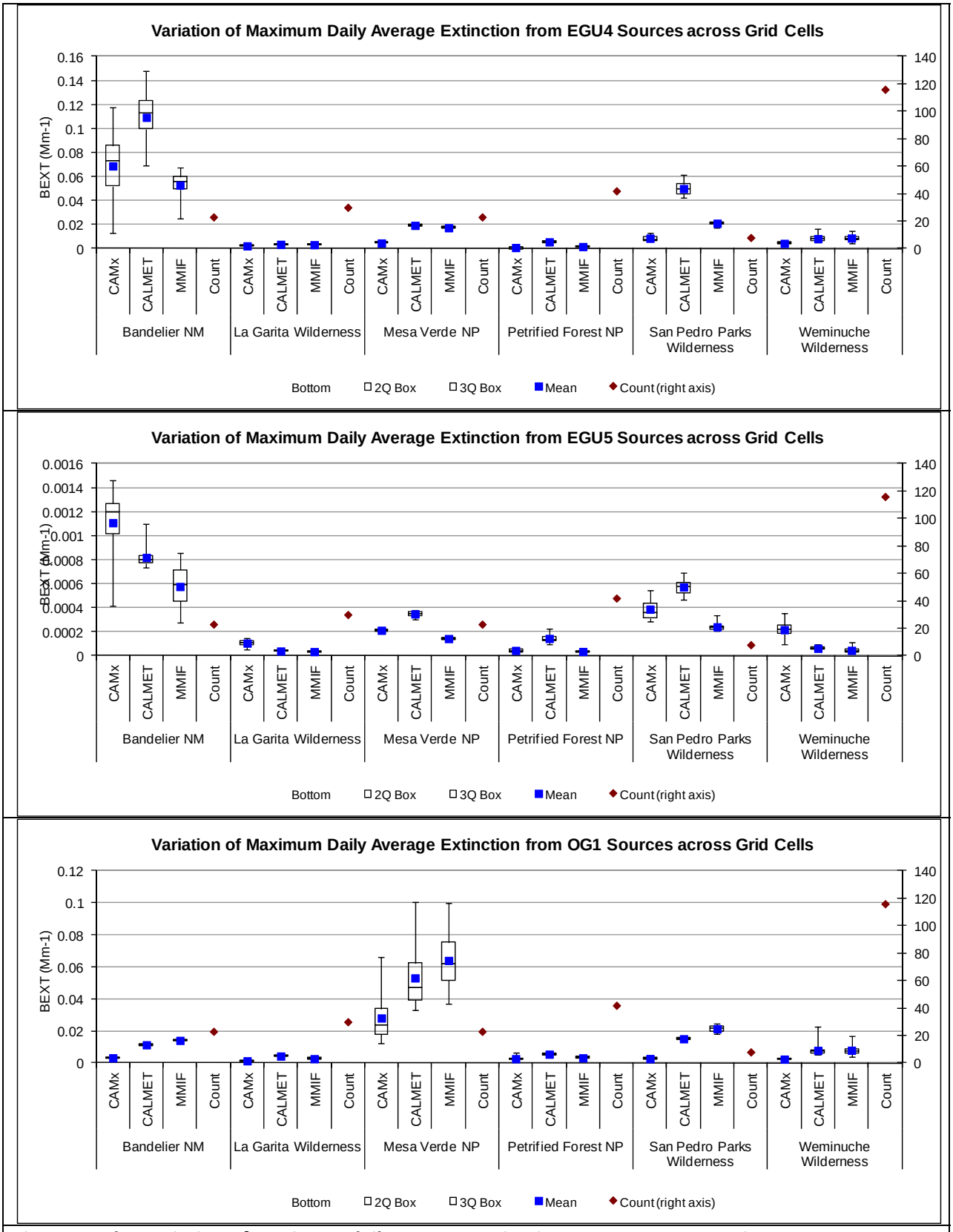


Figure 3-25b. Variation of maximum daily average extinction across receptors using CAMx, V5.8/CALMET, V5.8/MMIF for EGU4, EGU5 and OG1 with 2005 FCAQTF database.

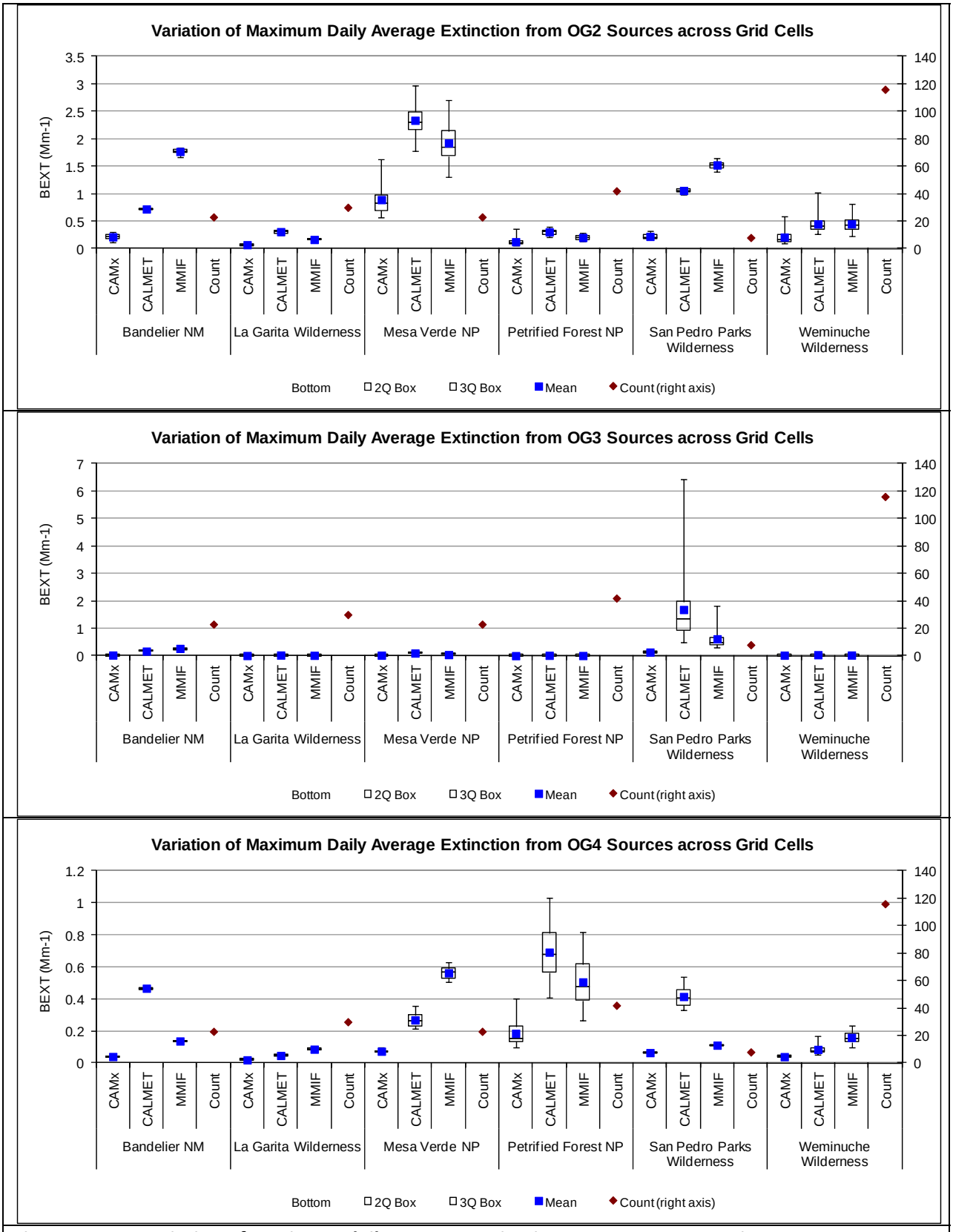


Figure 3-25c. Variation of maximum daily average extinction across receptors using CAMx, V5.8/CALMET, V5.8/MMIF for OG2, OG3 and OG4 with 2005 FCAQTF database.

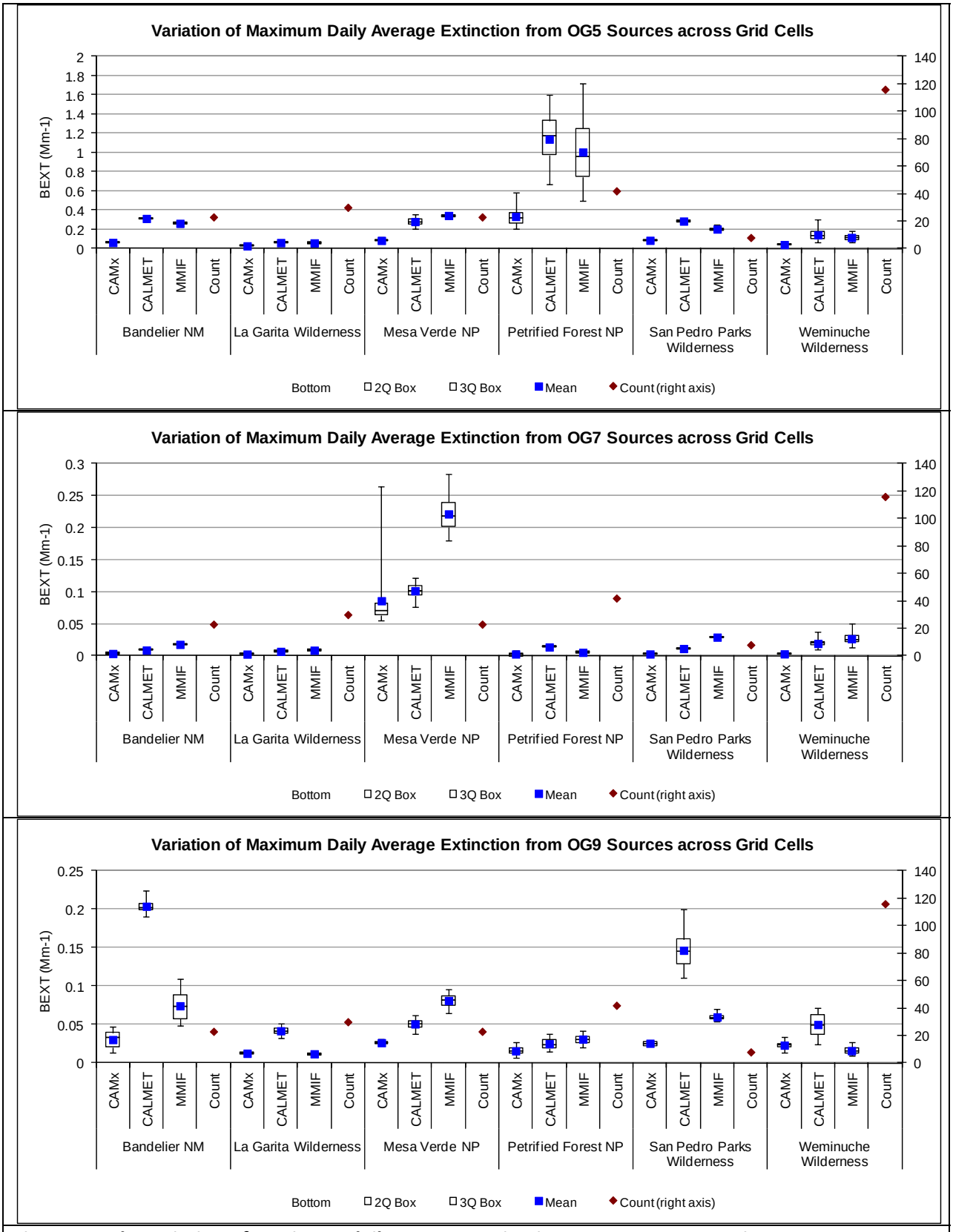


Figure 3-25d. Variation of maximum daily average extinction across receptors using CAMx, V5.8/CALMET, V5.8/MMIF for OG5, OG7 and OG9 with 2005 FCAQTF database.

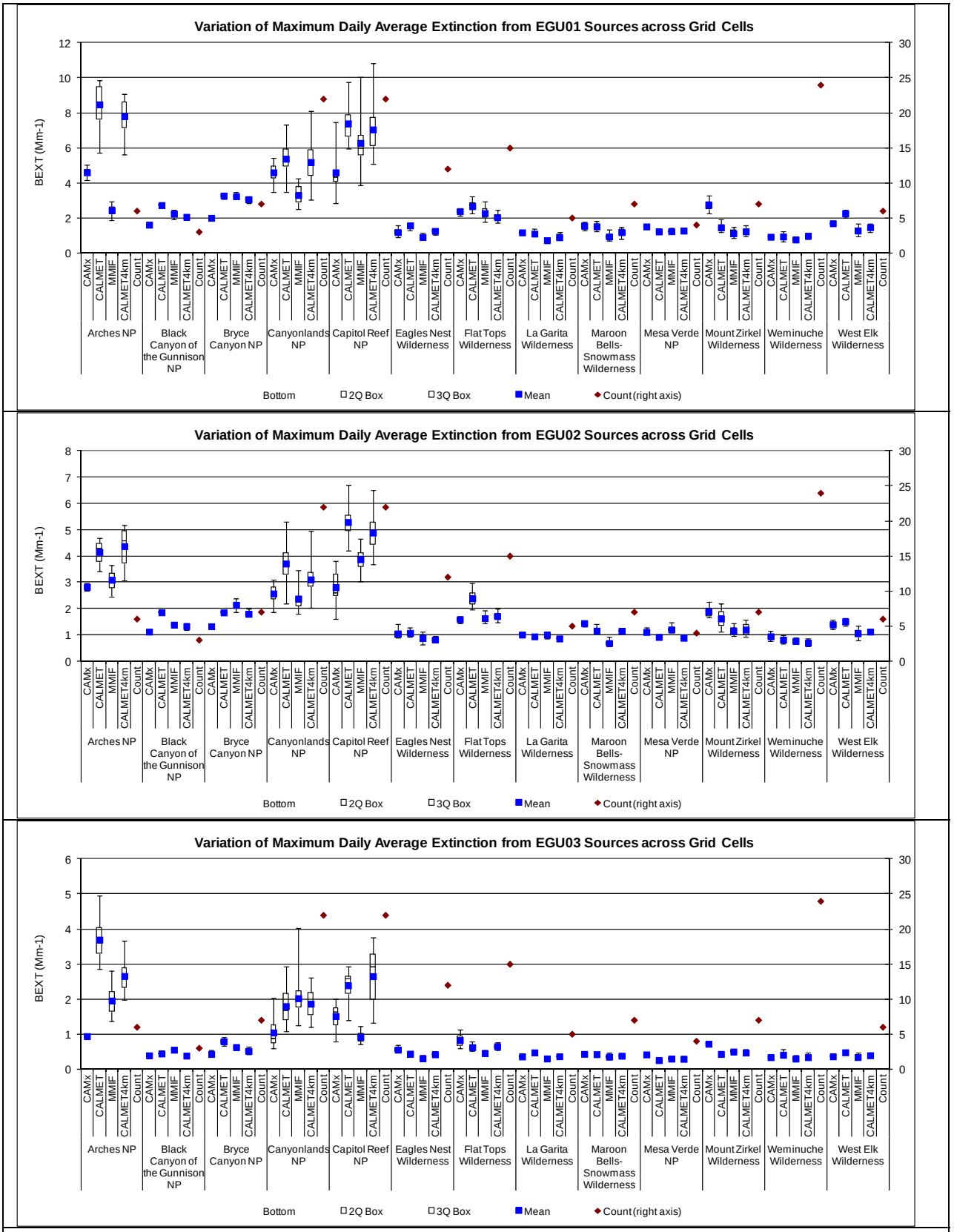


Figure 3-26a. Variation of max daily average extinction across receptors using CAMx, V5.8/CALMET, V5.8/MMIF and V5.8/CALMET-4km for EGU01-EGU03 with 2006 UT-CO database.

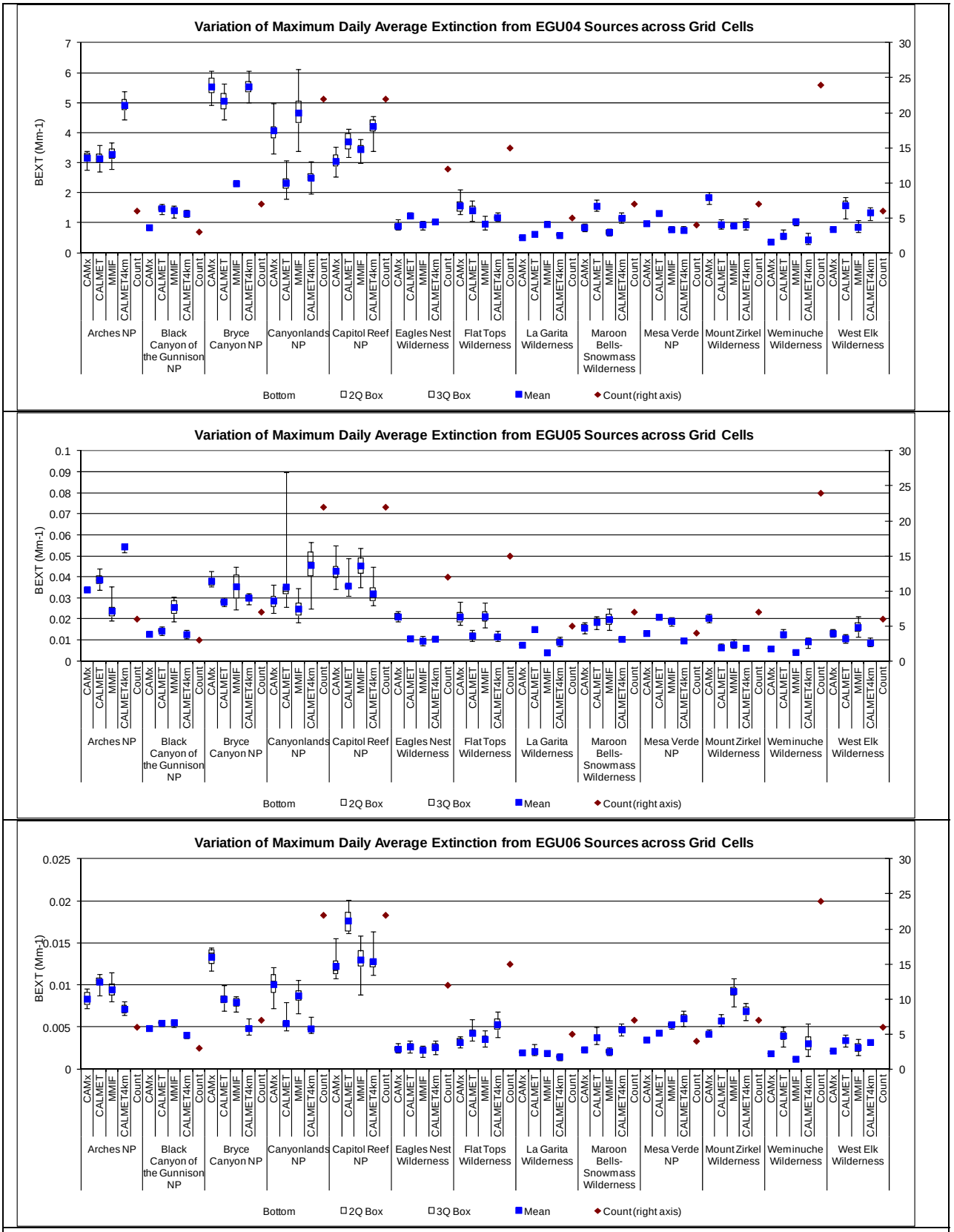


Figure 3-26b. Variation of max daily average extinction across receptors using CAMx, V5.8/CALMET, V5.8/MMIF and V5.8/CALMET-4km for EGU04-EGU06 with 2006 UT-CO database.

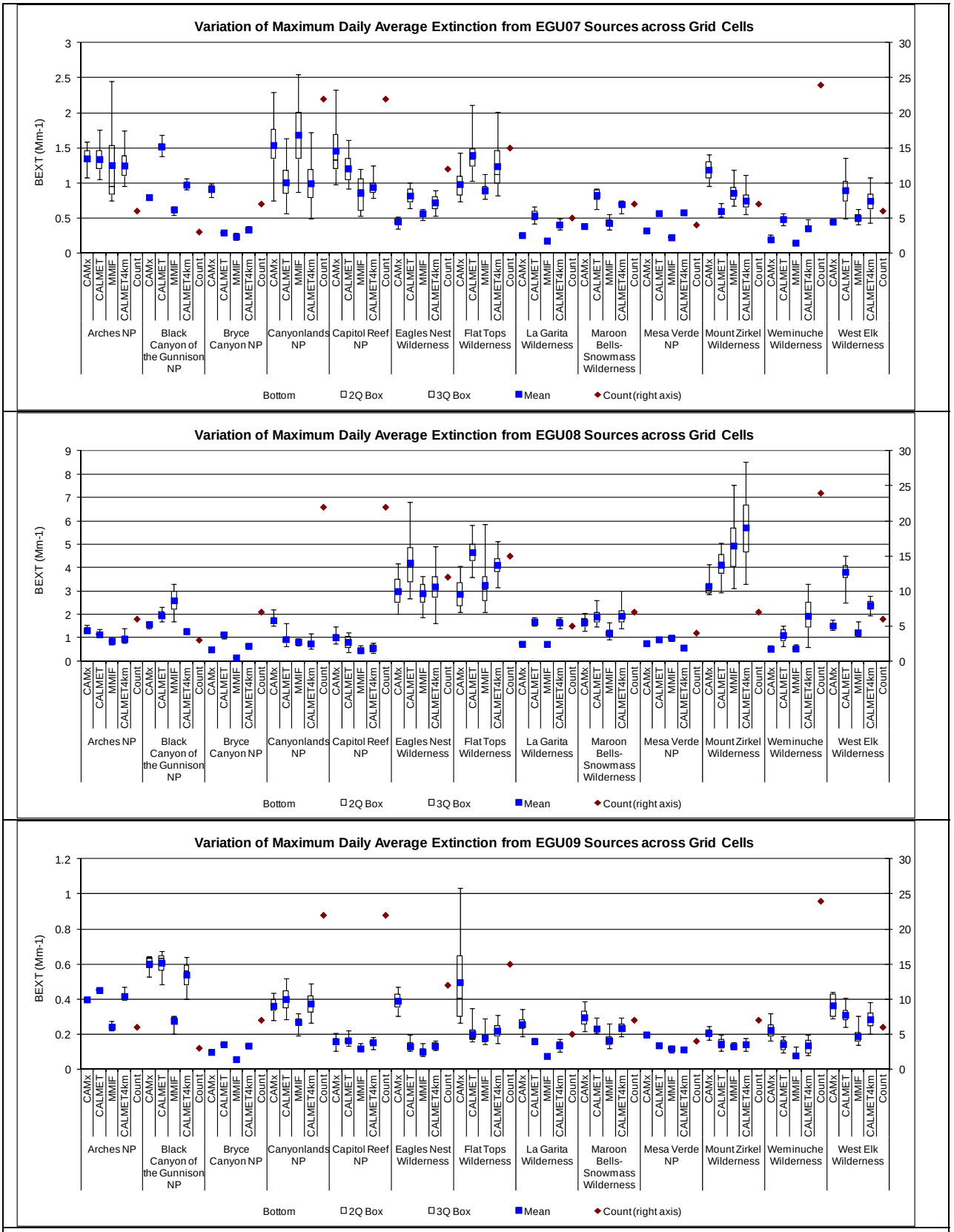


Figure 3-26c. Variation of max daily average extinction across receptors using CAMx, V5.8/CALMET, V5.8/MMIF and V5.8/CALMET-4km for EGU07-EGU09 with 2006 UT-CO database.

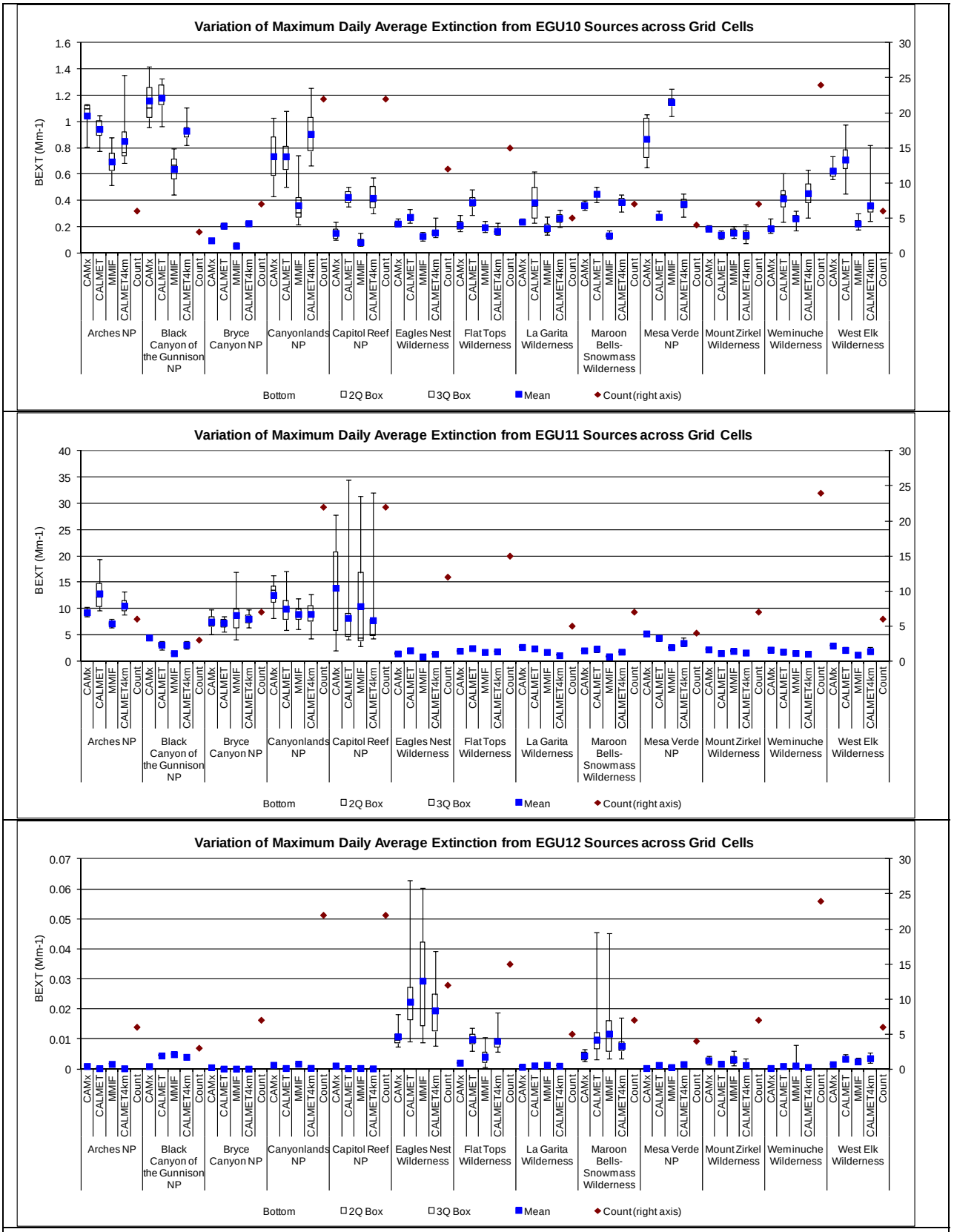


Figure 3-26d. Variation of max daily average extinction across receptors using CAMx, V5.8/CALMET, V5.8/MMIF and V5.8/CALMET-4km for EGU10-EGU12 with 2006 UT-CO database.

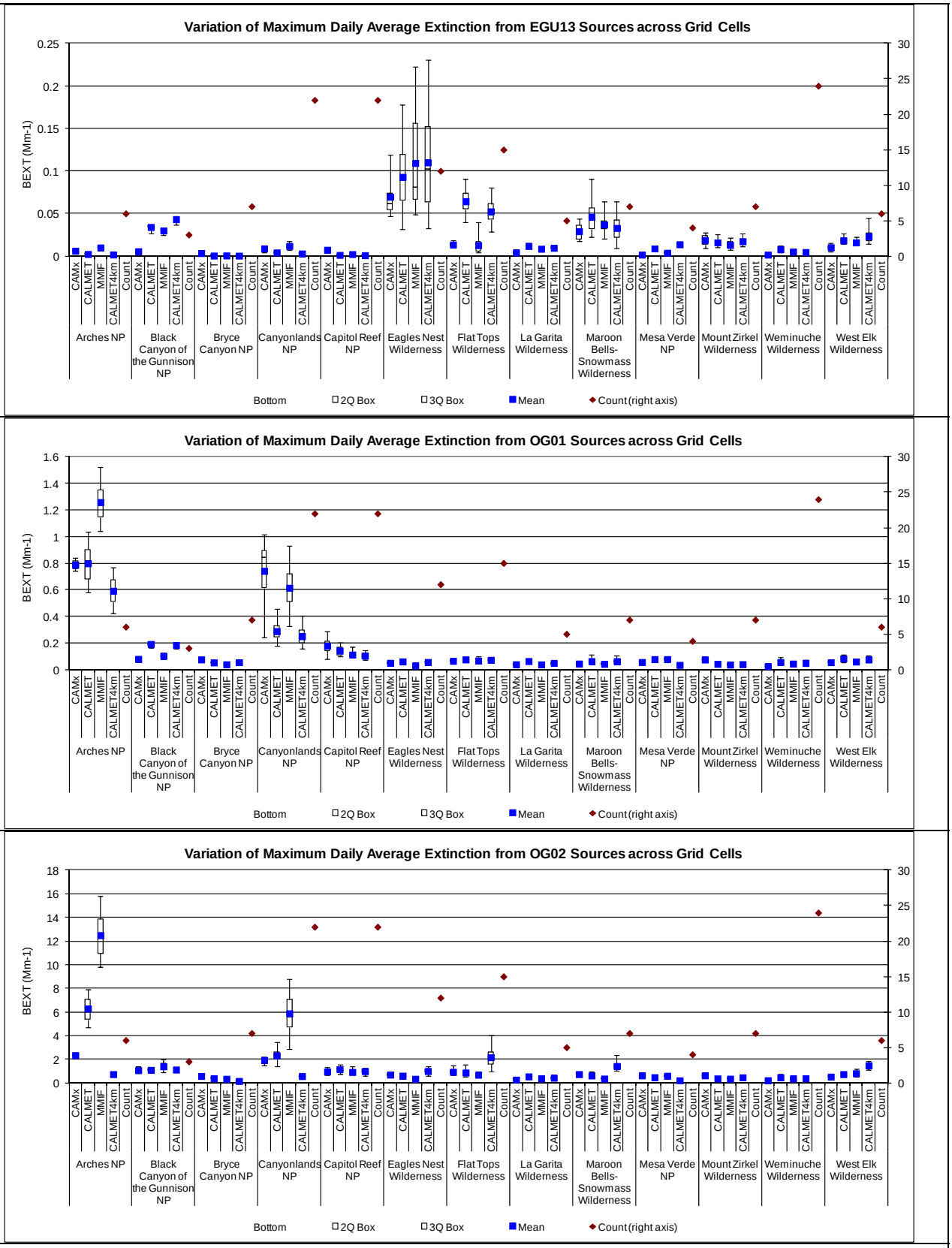


Figure 3-26e. Variation of max daily average extinction across receptors using CAMx, V5.8/CALMET, V5.8/MMIF and V5.8/CALMET-4km for EGU10-EGU12 with 2006 UT-CO database.

3.3 DEPOSITION IMPACTS

Figures 3-27 through 3-30 compare the model estimated annual total sulfur and nitrogen deposition due to the test sources at Class I areas for the 2005 4 km and 2006 12 km modeling results. The total deposition is obtained by combining the wet and dry deposition summing up all the sulfur and nitrogen species converting them to sulfur or nitrogen and expressing them as kg/ha/yr. The maximum annual total sulfur or nitrogen deposition at any Class I area receptor (CALPUFF) or grid cell (CAMx) that intersects a Class I area is used to represent the deposition for that Class I area.

For CAMx, the deposition for a source is taken from the PSAT source apportionment deposition output that for nitrogen includes reactive nitrogen species (RGN = $NO+NO_2+N_2O_5+NO_3$-), gaseous peroxyl acetyl nitrate (PAN) plus proxy nitric acid (PNA) (TPN = PAN + PNA), organic nitrates (NTR = RNO_3), gaseous nitric acid (HN3 = HNO_3), particulate nitrate (PN3), ammonia (NH3) and particulate ammonium (PN4) that are associated with each test source's emissions. CALPUFF V5.8 has three deposited nitrogen species of NO_X ($NO+NO_2$), nitrate and nitric acid. The convention in CALPUFF is to also add two nitrogen atoms for every sulfate and one nitrogen atom for every nitrate deposited to account for ammonium assuming sulfate and nitrate are fully neutralized even if the source has no ammonia emissions. In CAMx PSAT, the ammonium will be attributed to the source only if it comes from the source's ammonia emissions. Thus, there is an inconsistency between the CALPUFF and CAMx nitrogen deposition estimates. For sulfur deposition, almost all of the sulfur in CAMx are in SO_2 and SO_4, which are also the two species carried by CALPUFF so sulfur deposition is consistent between the two models.

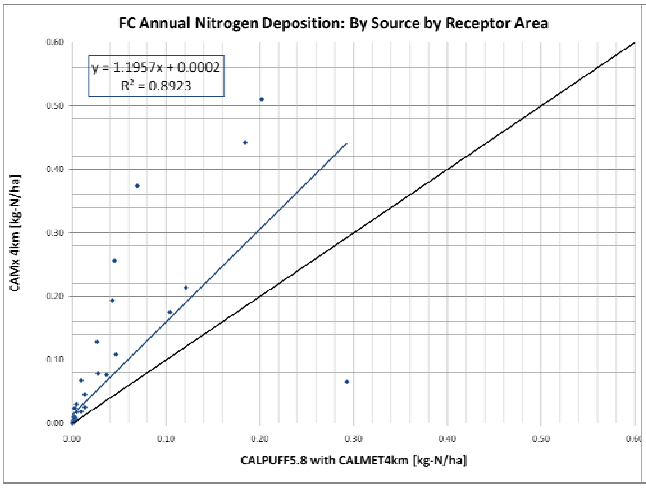
Figure 3-27 compare scatter plots of total nitrogen deposition due to the test sources at the six Class I areas in the 2005 4 km modeling domain for all the model configurations. CAMx has higher nitrogen deposition compared to V5.8/CALMET and V5.8/MMIF with a linear regression slopes of 1.2 and 2.1, respectively, and near zero intercept. V5.8/CALMET always has lower N deposition than CAMx except for one case of OG3 impacts at San Pedro Parks Class I area where V5.8/CALMET has a 0.3 kg-N/ha/yr impact compared to 0.07 and 0.03 kg-N/ha/yr for CAMx and V5.8/MMIF, respectively. OG3 is in close proximity to this Class I area. In general, the CAMx nitrogen deposition values tend to be twice that of V5.8/CALMET. V5.8/MMIF has slightly more nitrogen deposition than V5.8/CALMET. The nitrogen deposition data points in the V5.8/MMIF versus CAMx scatter plot lie right along the regression equation that indicates CAMx value are always twice those of V5.8/MMIF, which is likely due to similar MM5 defined transport patterns in CAMx and V5.8/MMIF. The reason why CAMx has twice as much nitrogen deposition as CALPUFF is unclear. Although CAMx treats more nitrogen species, the additional nitrogen species tend to have lower mass and one would expect the additional ammonium deposition assumed in the CALPUFF species mapping convention would make up for that. Figure 3-28 compares the total sulfur deposition among the models for the 2005 4 km domain modeling. There is better agreement in sulfur deposition among the models than seen for nitrogen deposition. Both CAMx and V5.8/MMIF estimate higher annual sulfur depositions than V5.8/CALMET. Surprisingly, CAMx matches the V5.8/CALMET sulfur deposition better than V5.8/MMIF with a linear regression slope of 1.2 and near zero intercept. For the 2006 12 km modeling, CAMx also estimates approximately twice as much nitrogen deposition as CALPUFF V5.8 (Figure 3-29). V5.8/MMIF estimates slightly more nitrogen deposition than

V5.8/CALMET using the 2006 12 km modeling. The nitrogen depositions estimated by V5.8/CALMET using 12 km and 4 km CALMET inputs are nearly identical. The sulfur deposition results using the 2006 UT-CO modeling database are shown in Figure 3-30. Although there is a fair amount of scatter in the sulfur deposition estimates, CAMx tends to estimate slightly higher deposition than V5.8/CALMET and approximately the same to a little less than V5.8/MMIF. Use of the MMIF meteorological driver tends to produce higher CALPUFF deposition compared to CALMET, which may be due to higher precipitation in the MM5 fields than in the observations. Figure 3-31 compares bar charts of annual total nitrogen deposition by Class I area for test sources from the 2005 FCAQTF database. For most scenarios, CAMx, whether the 4 or 12 km modeling results, estimates the highest nitrogen deposition followed byV5.8/MMIF and V5.8/CALMET. In some cases, the CAMx nitrogen deposition can be many times greater than CALPUFF (e.g., EGU5 at Bandelier in Figure 3-31b). For CAMx and the 2006 UT-CO database, the nitrogen deposition was processed two ways:(1) sum up all of the CAMx PSAT nitrogen species as described previously; and (2) use just the same species mappings as included in CALPUFF (i.e., NO, NO_2, HNO_3 and particulate NO_3) and add on ammonium to the CAMx nitrogen depositions assuming nitrate and sulfate are complete neutralized as is done in CALPUFF (camx-with_calpuff_N). In most cases the two ways of presenting the CAMx nitrogen deposition produces similar results with the CALPUFF deposition approach producing slightly higher values. However, in some cases the CALPUFF nitrogen deposition approach can be double what is obtained by summing up the CAMx/PSAT native nitrogen species and there are even cases when the CALPUFF approach is slightly less. The CAMx and CALPUFF V5.8 sulfur deposition estimates are generally similar(Figure 3-34).

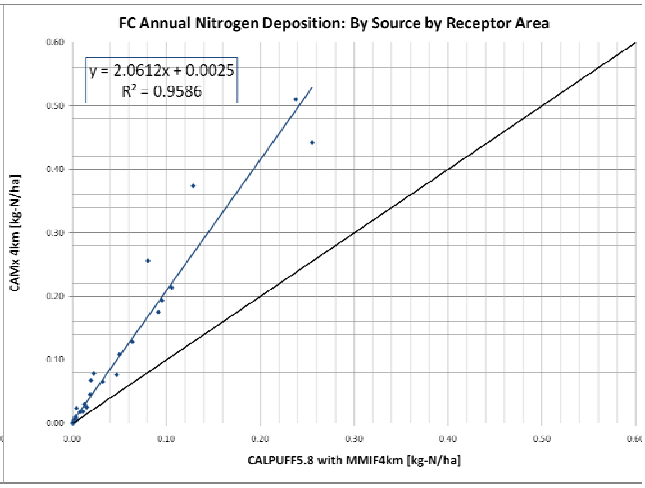
The reasons why CAMx estimates approximately twice as much nitrogen deposition and slightly more sulfur deposition than CALPUFF V5.8 is unclear. One contributor is the difference species mappings used in CAMx and CALPUFF. However, the 2006 UT-CO modeling results where the CAMx nitrogen deposition output was processed using the CALPUFF convention generally resulted in increases of CAMx nitrogen deposition amounts for larger NO_X sources.

Figure 3-35 displays the composition of the CAMx nitrogen deposition for EGU1 and the 2006 UT-CO modeling database. Most of the nitrogen deposition in CAMx is due to dry deposition of nitric acid with the nitrogen species not treated by CALPUFF (i.e., TPN and portion of RGN) not accounting for a large component of the CAMx nitrogen deposition. Whether reacted NO_X is in the particle (NO_3) or gas-phase mode (HNO_3) depends on in part the availability of a buffering cation. For the CALPUFF modeling, only one background ammonia input is specified across the region for the entire run where a 1 ppb value was assumed. However, in the CAMx runs the predicted ammonia background was usually much lower varying spatially and temporally according to the locations of the ammonia sources and atmospheric conditions. Thus, the main reason for the higher nitrogen deposition in CAMx is likely due to the fact that it carried more of the reacted nitrogen as nitric acid that has a higher dry deposition rate than particulate nitrate.

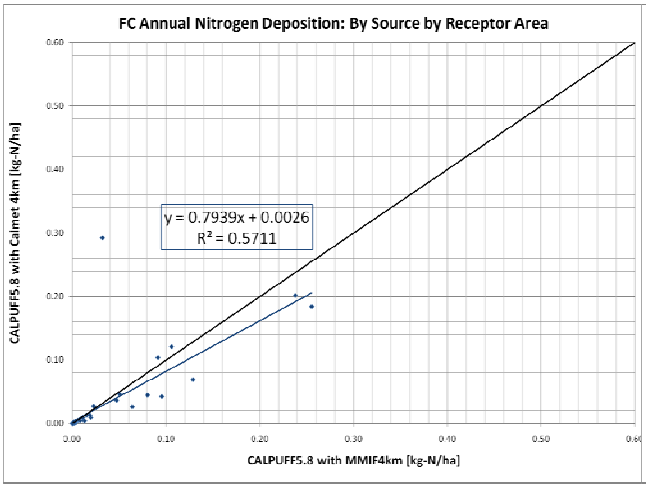
CALPUFFV5.8/CALMET vs. CAMx



CALPUFFV5.8/MMIF vs. CAMx



CALPUFFV5.8/MMIF vs. CALPUFFV5.8/CALMET



CAMx 12 km vs. CAMx 4 km

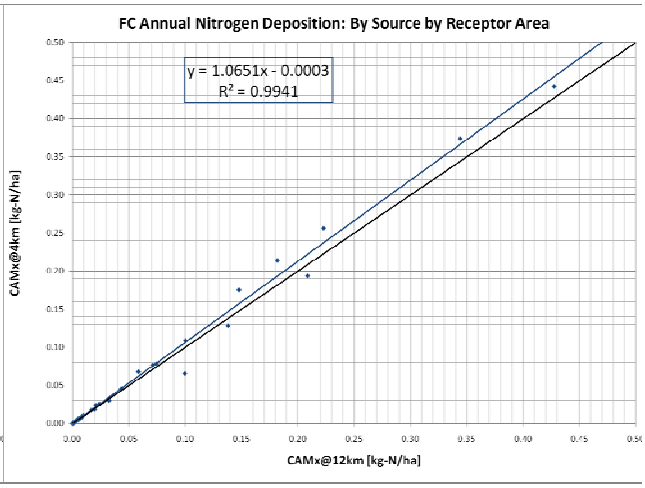
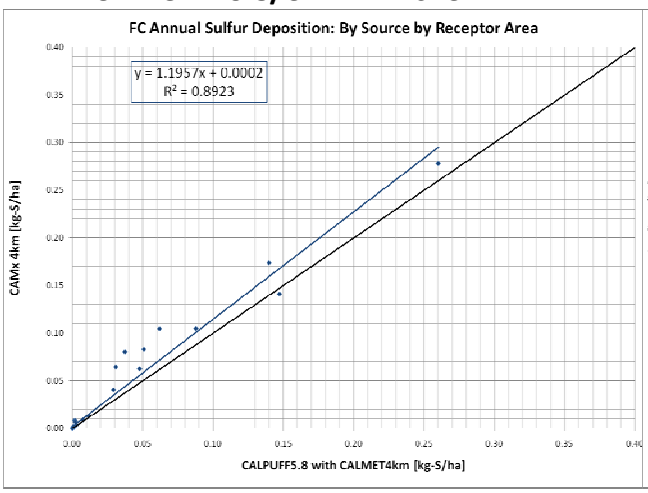
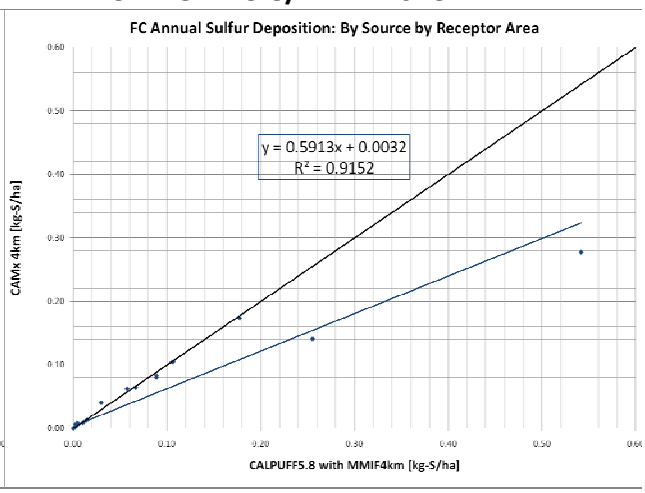


Figure 3-27. Comparison of annual nitrogen deposition (kg-N/ha/yr) at Class I areas using the 2005 4 km FCAQTF database.

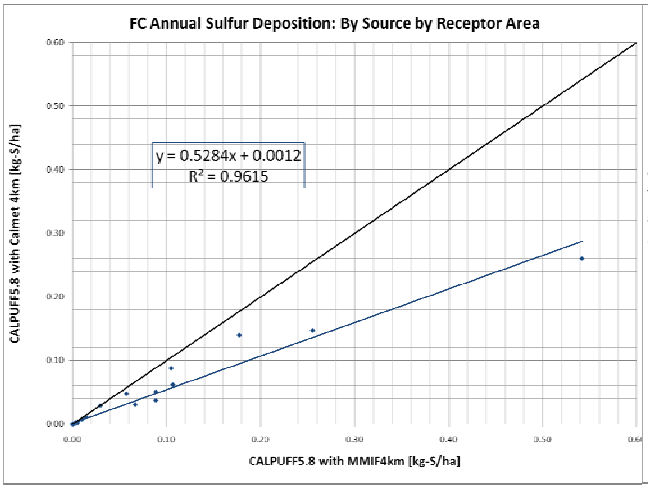
CALPUFFV5.8/CALMET vs. CAMx



CALPUFFV5.8/MMIF vs. CAMx



CALPUFFV5.8/MMIF vs. CALPUFFV5.8/CALMET



CAMx 12 km vs. CAMx 4 km

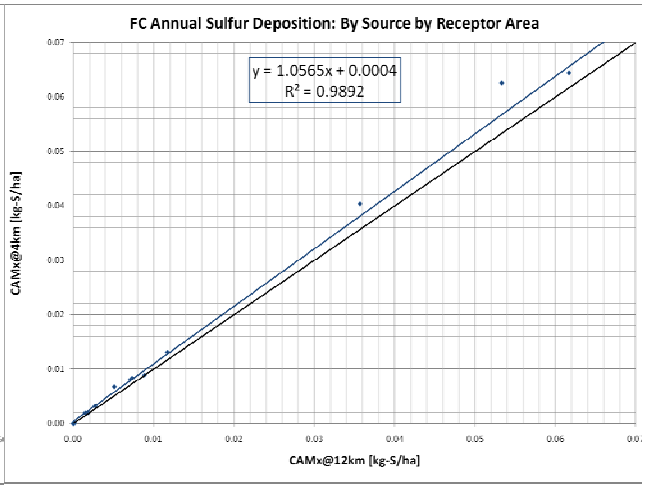
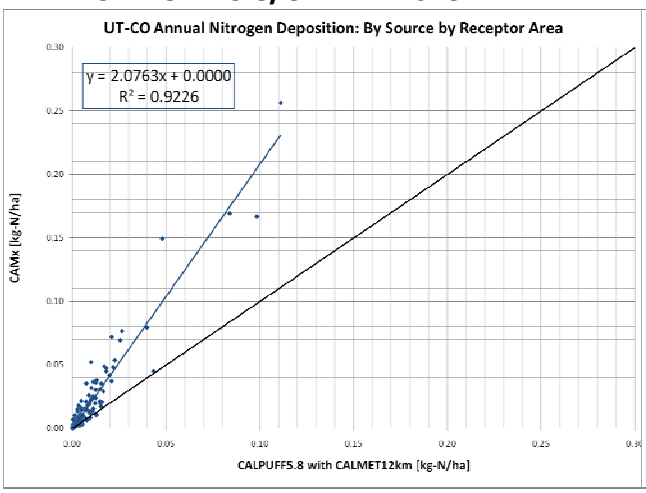
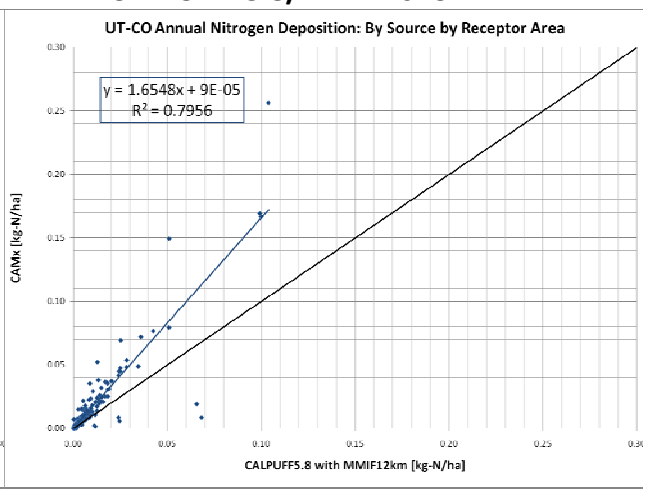


Figure 3-28. Comparison of annual sulfur deposition (kg-S/ha/yr) at Class I areas using the 2005 4 km FCAQTF database.

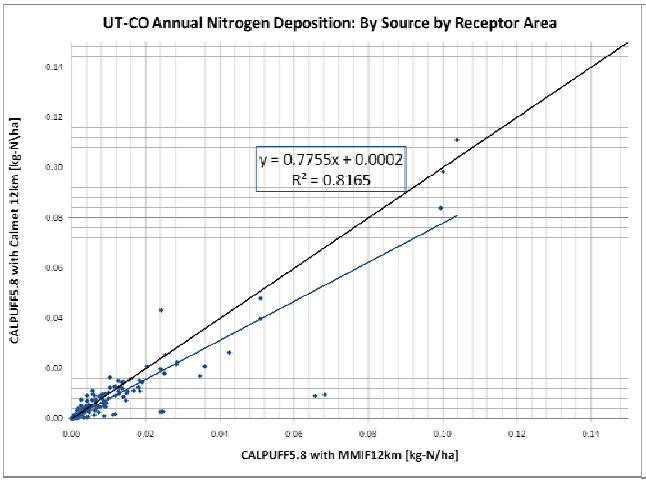
CALPUFFV5.8/CALMET vs. CAMx



CALPUFFV5.8/MMIF vs. CAMx



CALPUFFV5.8/MMIF vs. CALPUFFV5.8/CALMET



CALPUFFV5.8/CALMET 4 km vs. 12 km

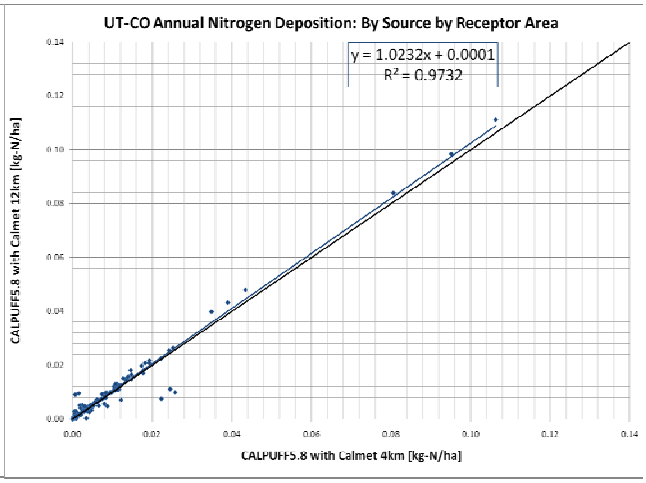
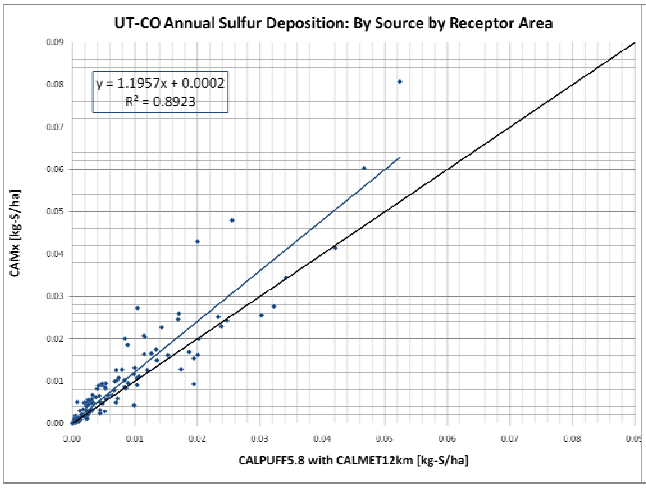
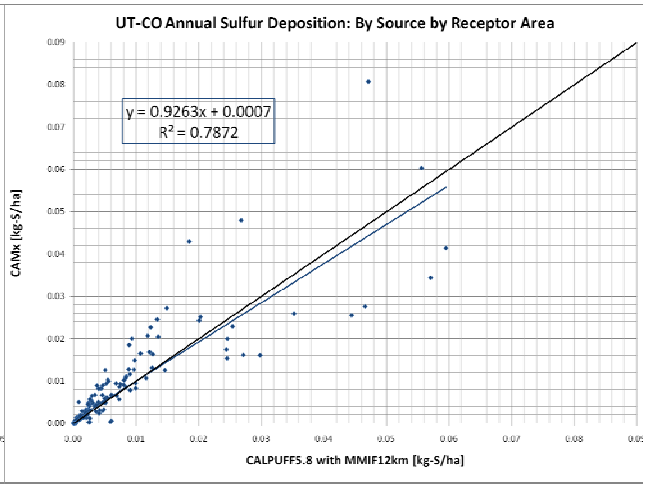


Figure 3-29. Comparison of annual nitrogen deposition (kg-N/ha/yr) at Class I areas using the 2006 12 km UT-CO database.

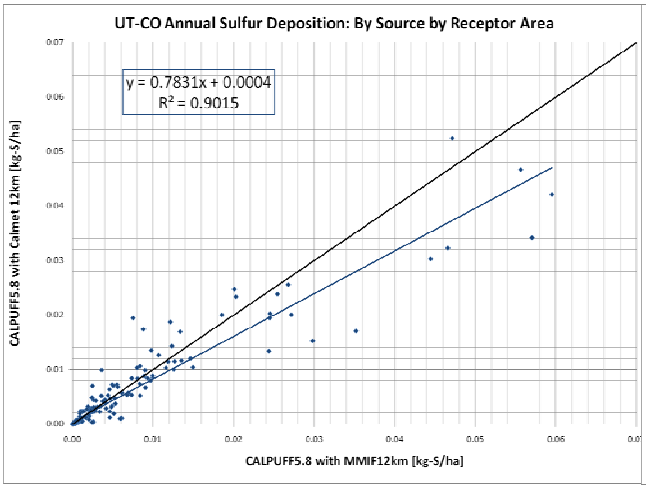
CALPUFFV5.8/CALMET vs. CAMx



CALPUFFV5.8/MMIF vs. CAMx



CALPUFFV5.8/MMIF vs. CALPUFFV5.8/CALMET



CALPUFFV5.8/CALMET 4 km vs. 12 km

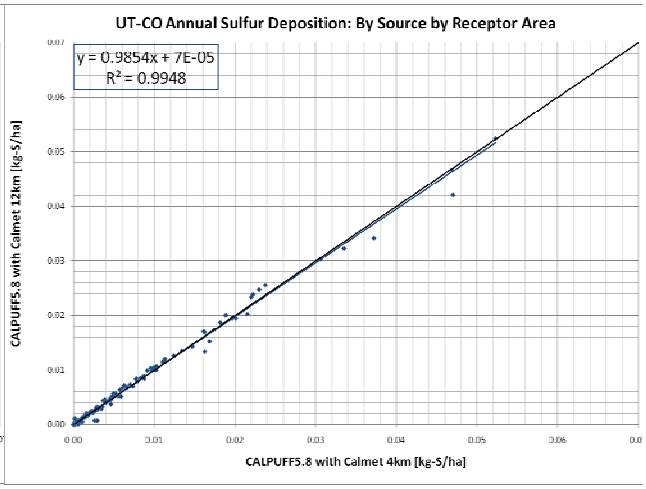


Figure 3-30. Comparison of annual sulfur deposition (kg-S/ha/yr) at Class I areas using the 2006 12 km UT-CO database.

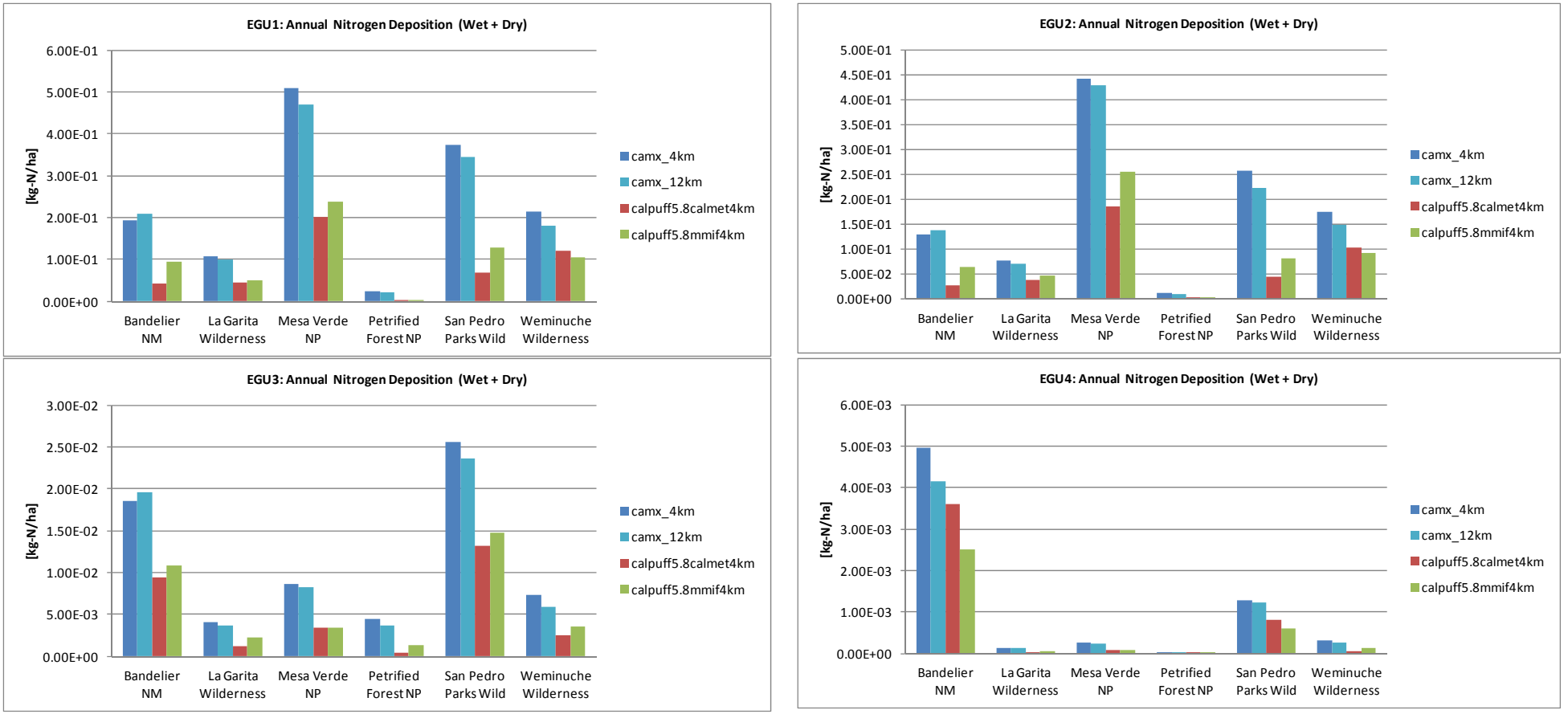
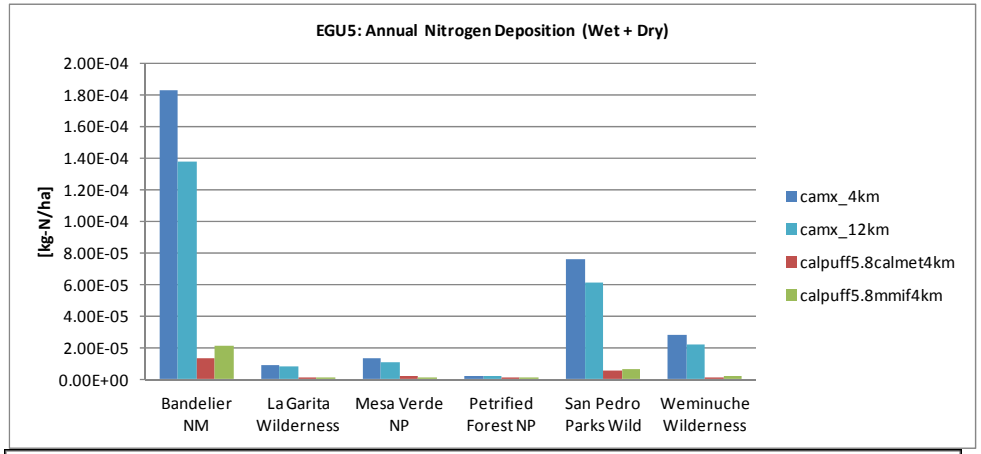
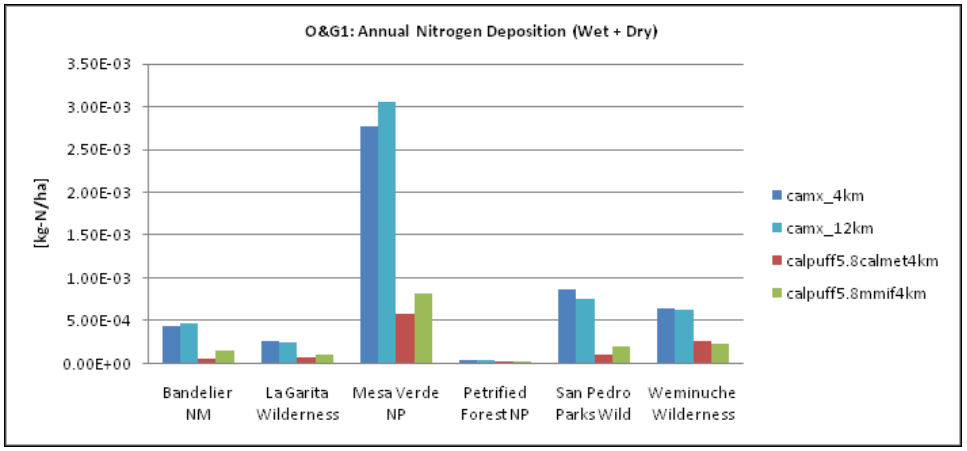
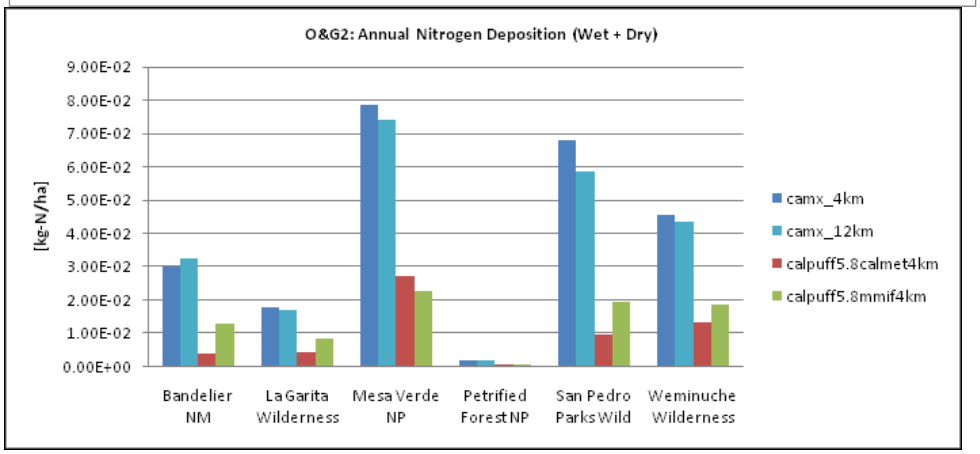


Figure 3-31a. Annual nitrogen deposition (kg-N/ha/yr) at Class I areas using the 2005 4 km FCAQTF database.







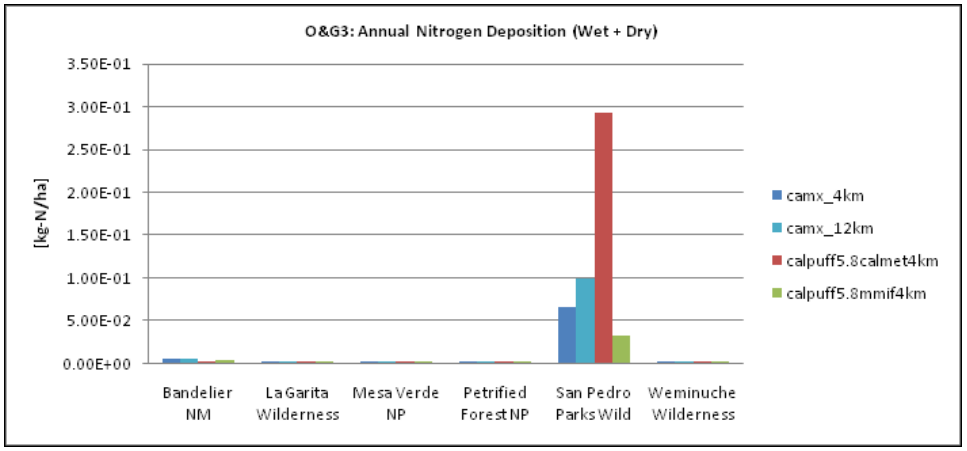
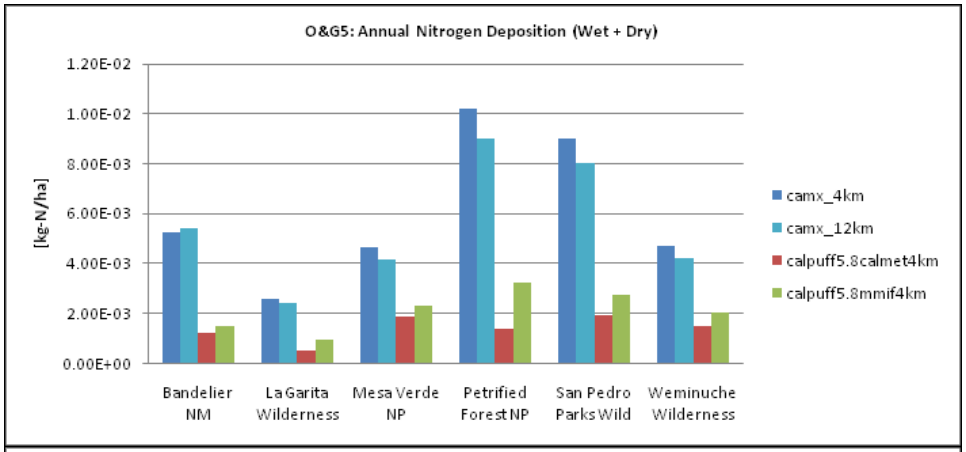
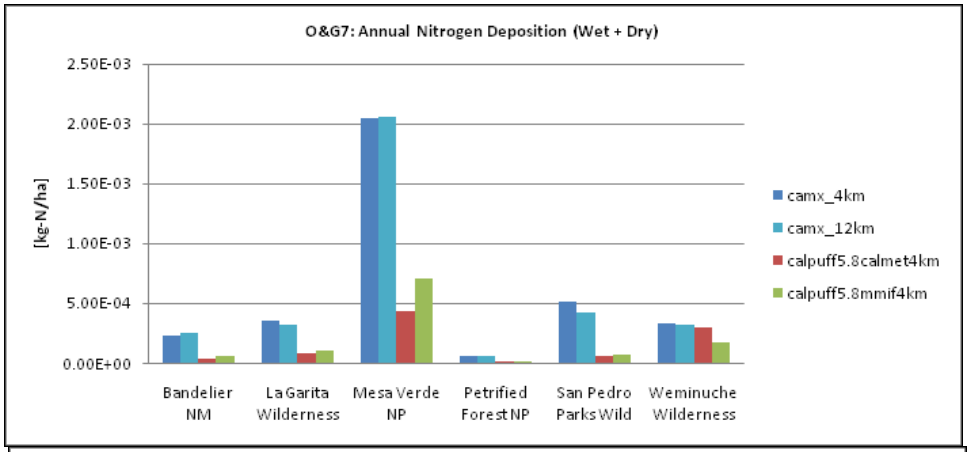
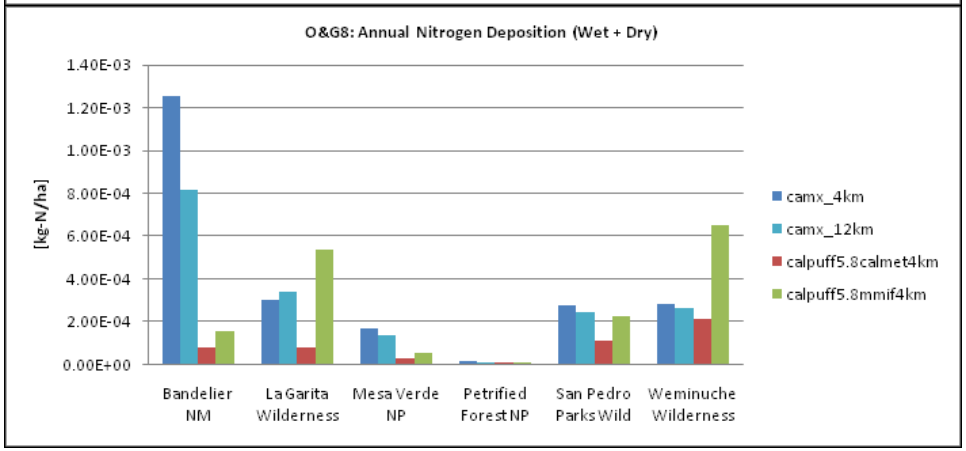


Figure 3-31b. Annual nitrogen deposition (kg-N/ha/yr) at Class I areas using the 2005 4 km FCAQTF database.







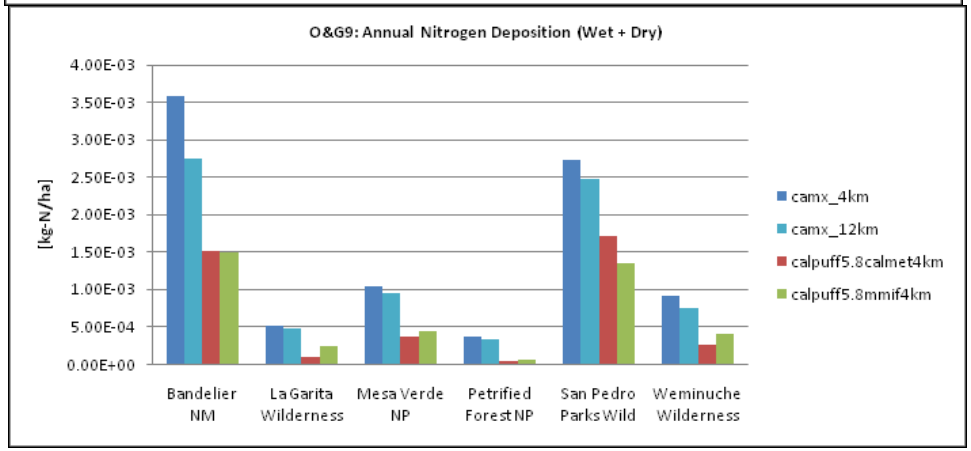


Figure 3-31c. Annual nitrogen deposition (kg-N/ha/yr) at Class I areas using the 2005 4 km FCAQTF database.

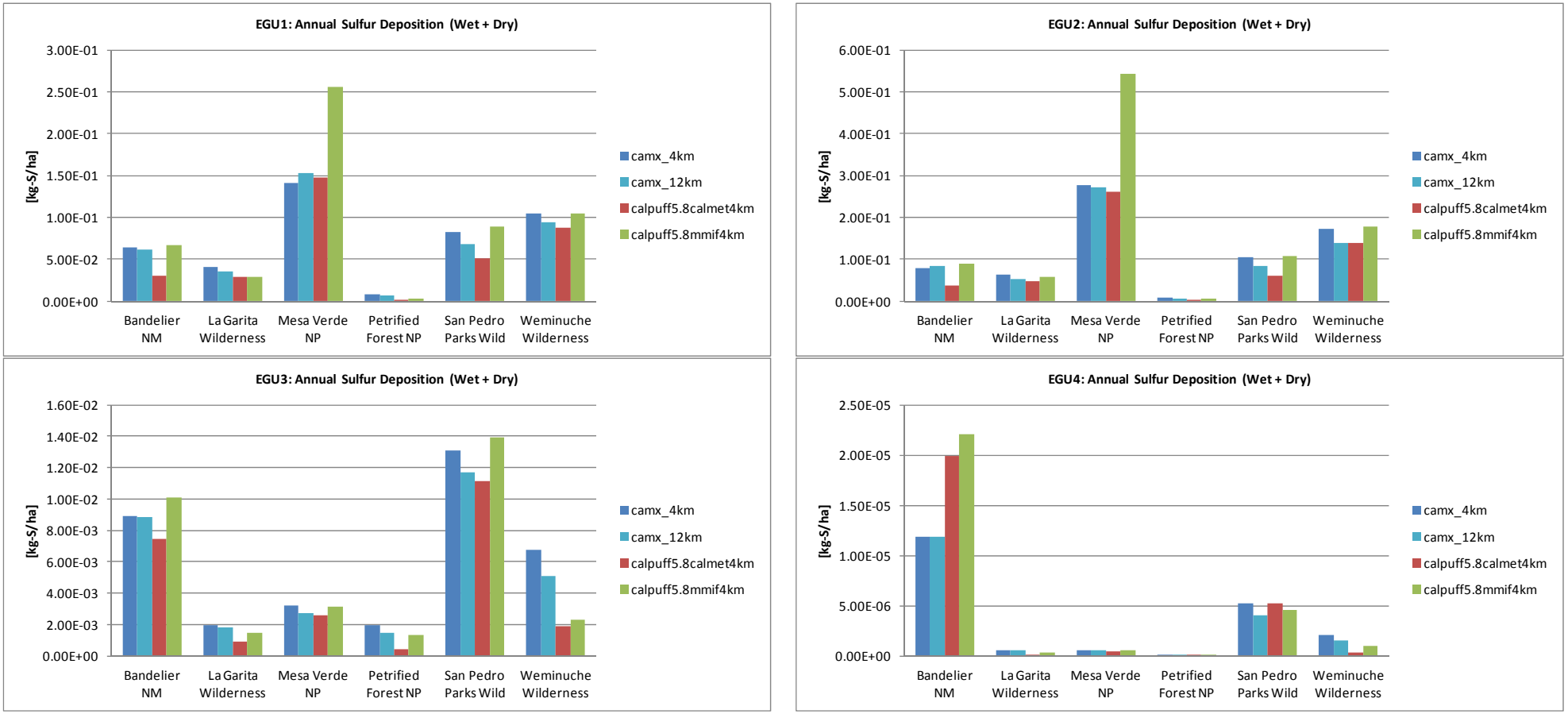


Figure 3-32a. Annual sulfur deposition (kg-S/ha/yr) at Class I areas using the 2005 4 km FCAQTF database.

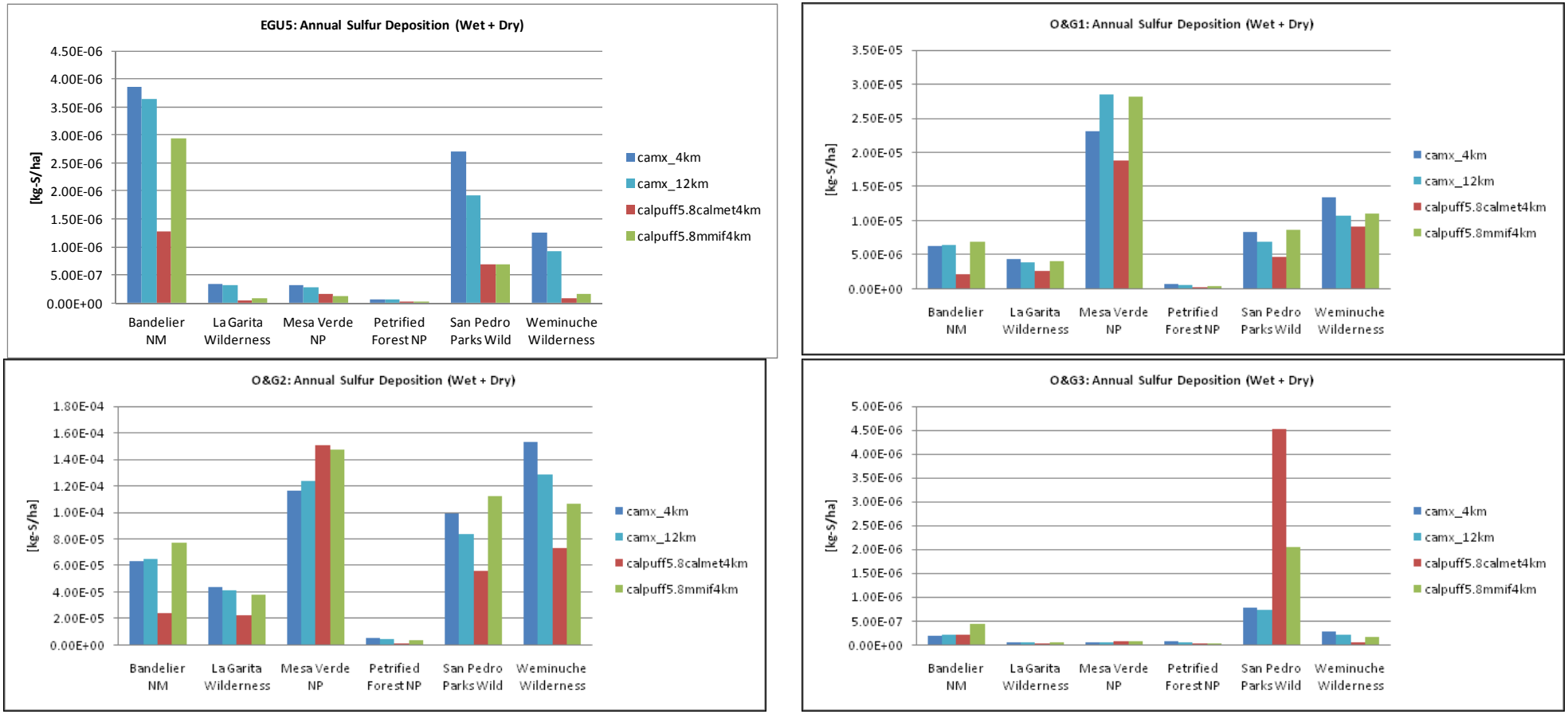


Figure 3-32b. Annual sulfur deposition (kg-S/ha/yr) at Class I areas using the 2005 4 km FCAQTF database.

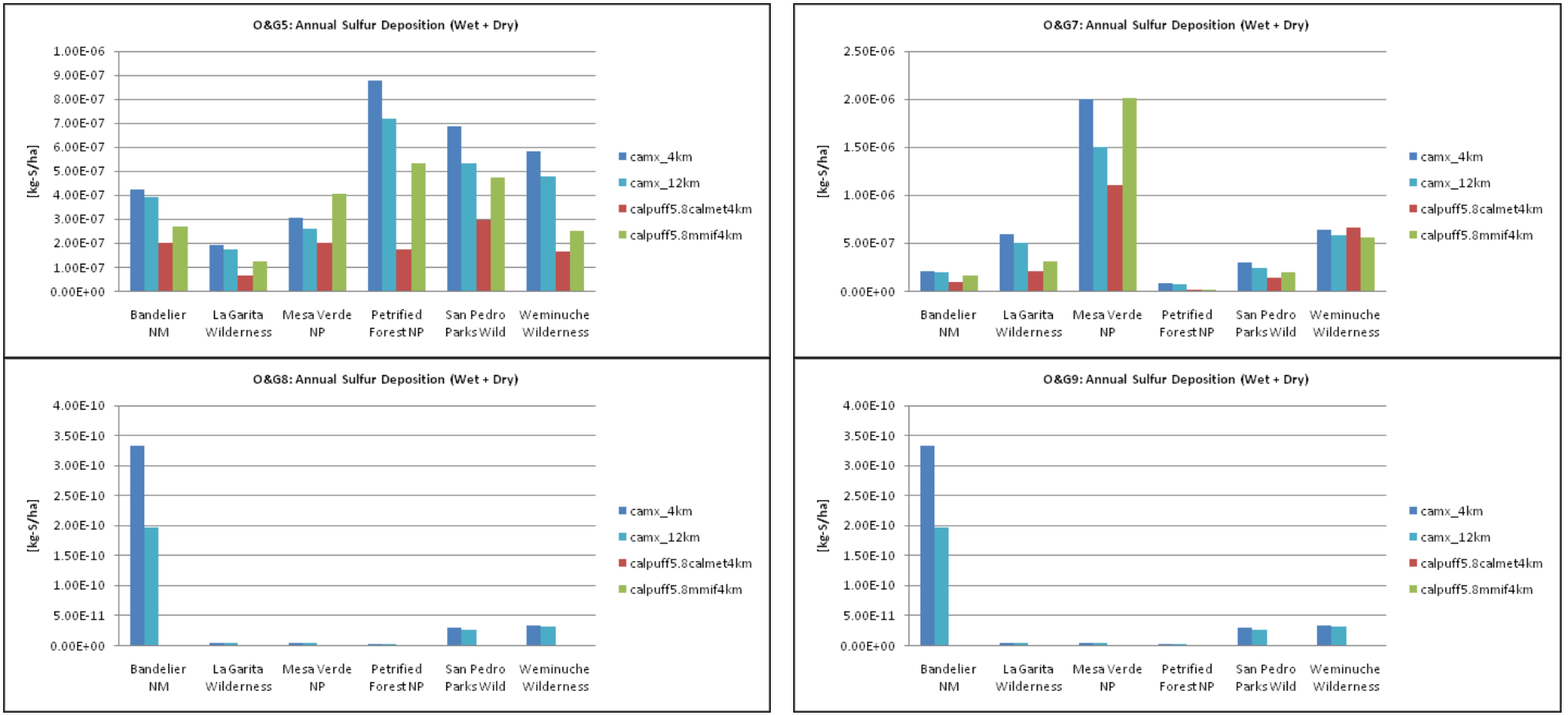


Figure 3-32c. Annual sulfur deposition (kg-S/ha/yr) at Class I areas using the 2005 4 km FCAQTF database.

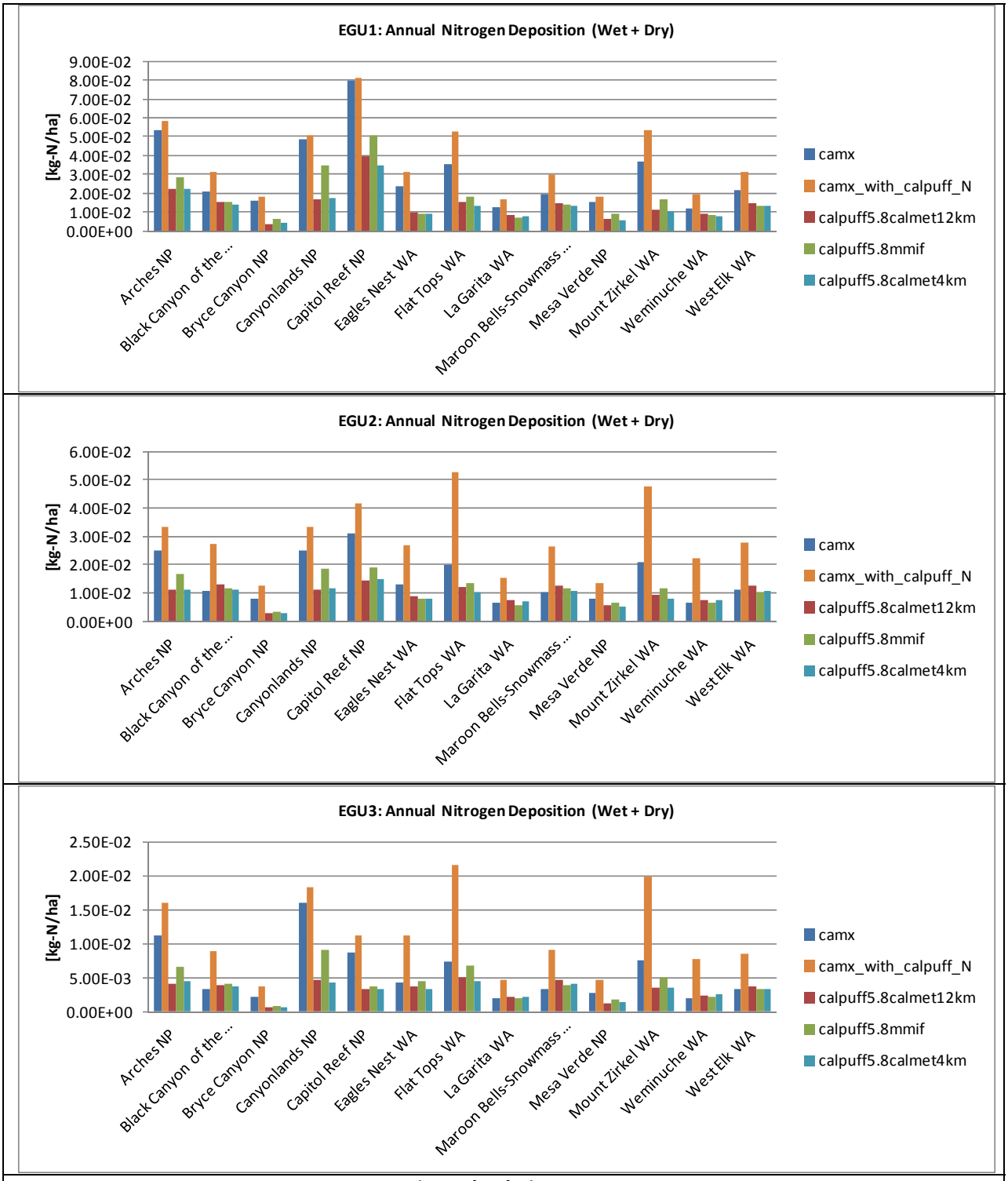


Figure 3-33a. Annual nitrogen deposition (kg-N/ha/yr) at Class I areas using the 2006 12 km UT-CO database.

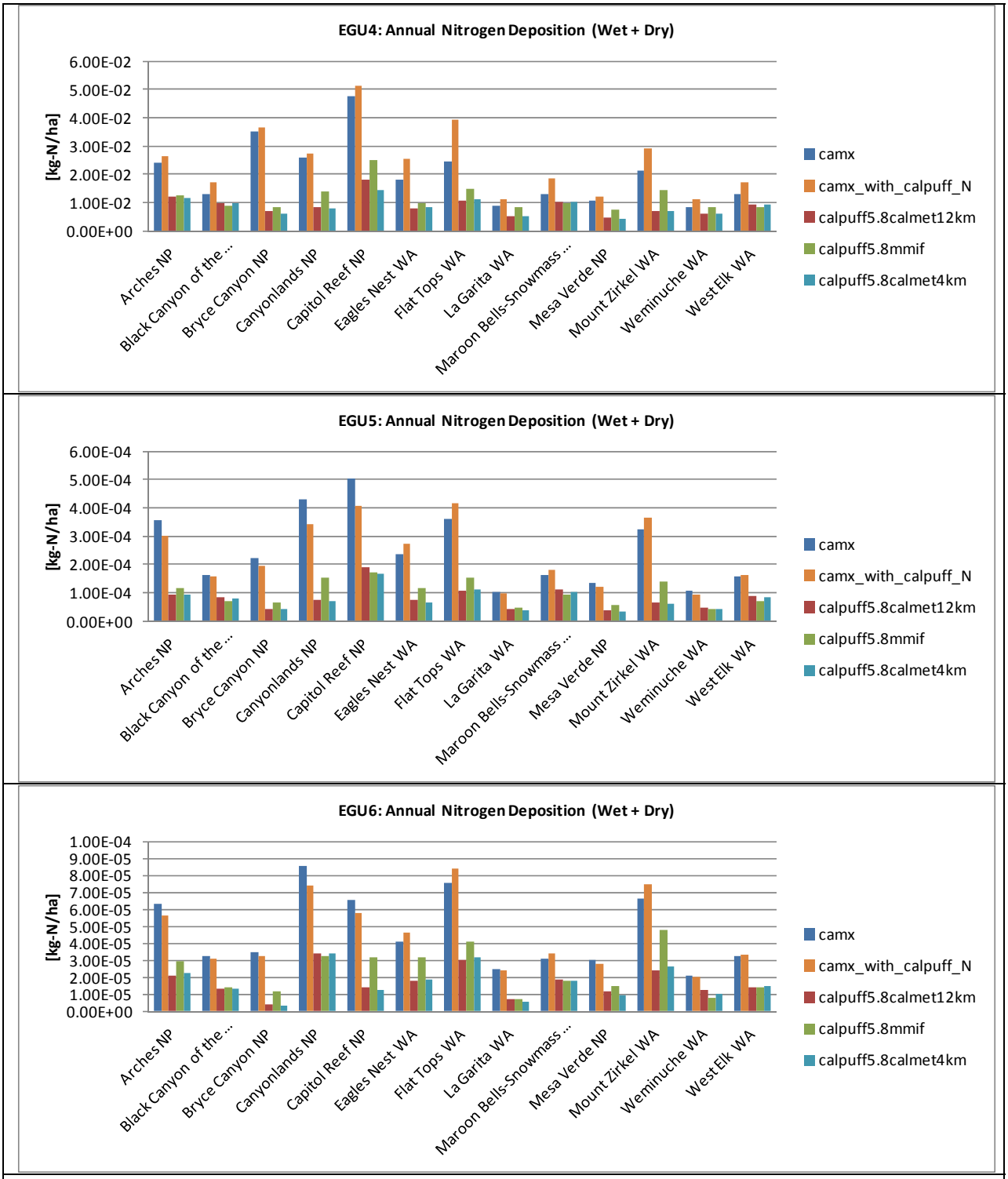


Figure 3-33b. Annual nitrogen deposition (kg-N/ha/yr) at Class I areas using the 2006 12 km UT-CO database.

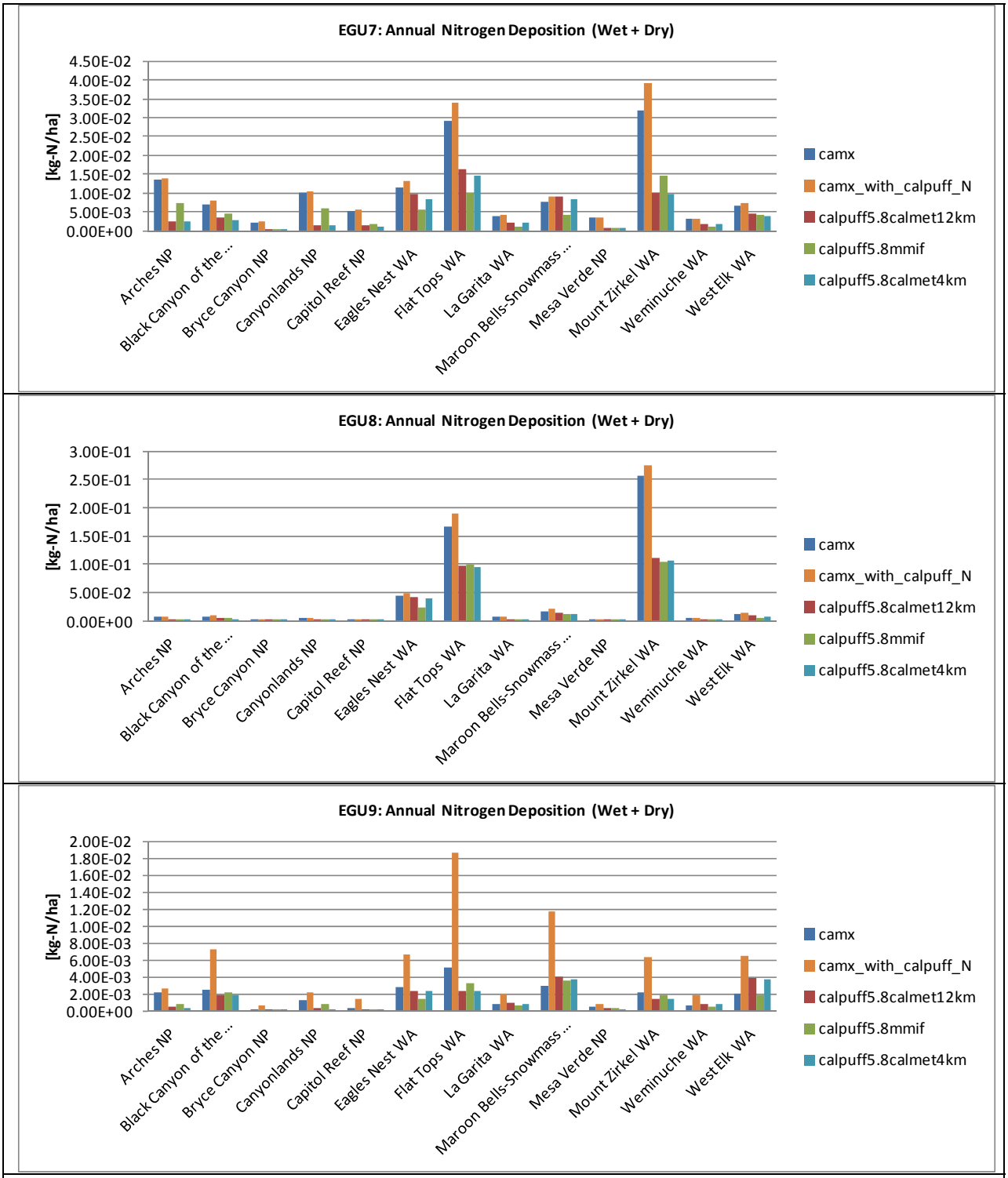


Figure 3-33c. Annual nitrogen deposition (kg-N/ha/yr) at Class I areas using the 2006 12 km UT-CO database.

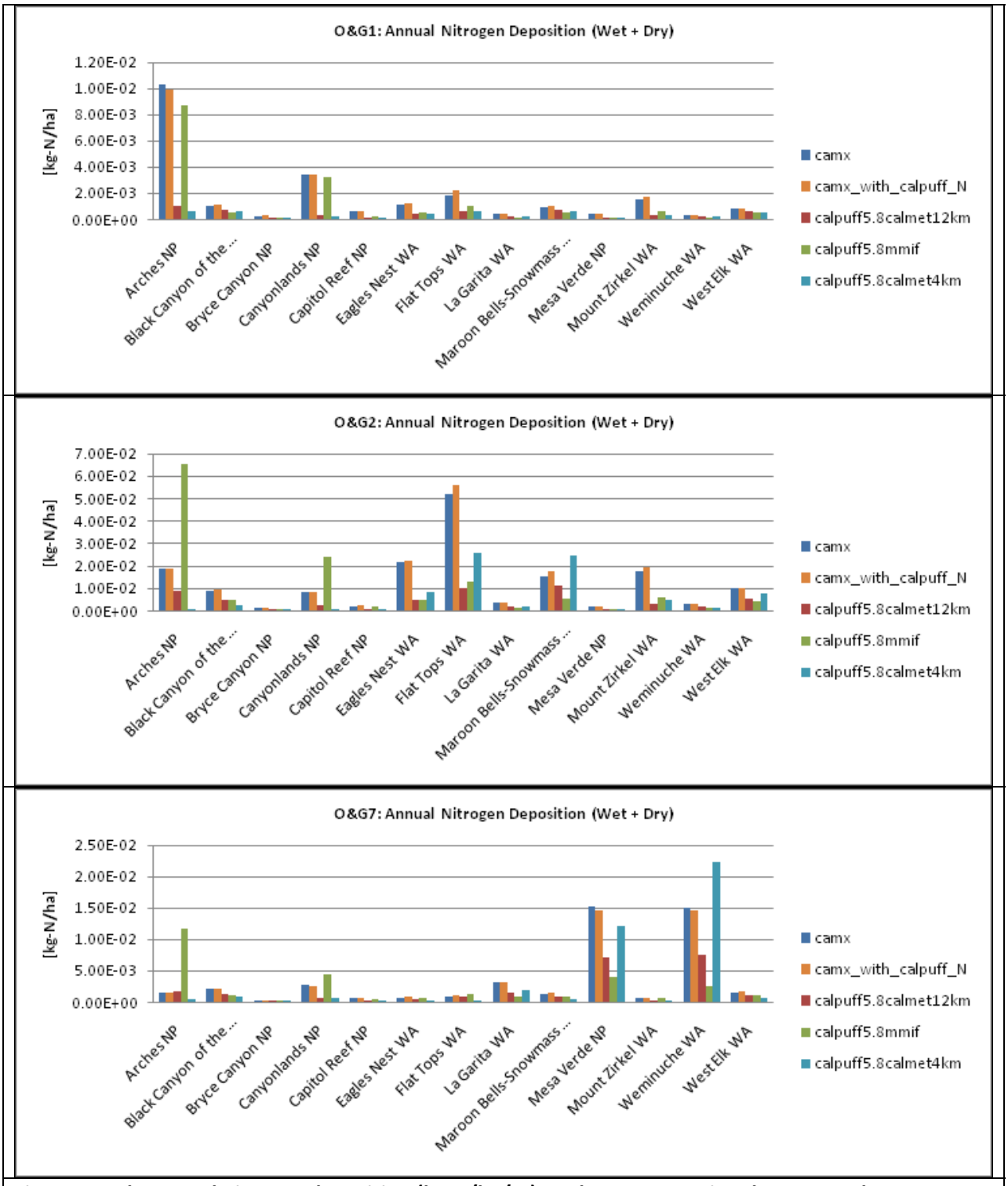


Figure 3-33d. Annual nitrogen deposition (kg-N/ha/yr) at Class I areas using the 2006 12 km UT-CO database.

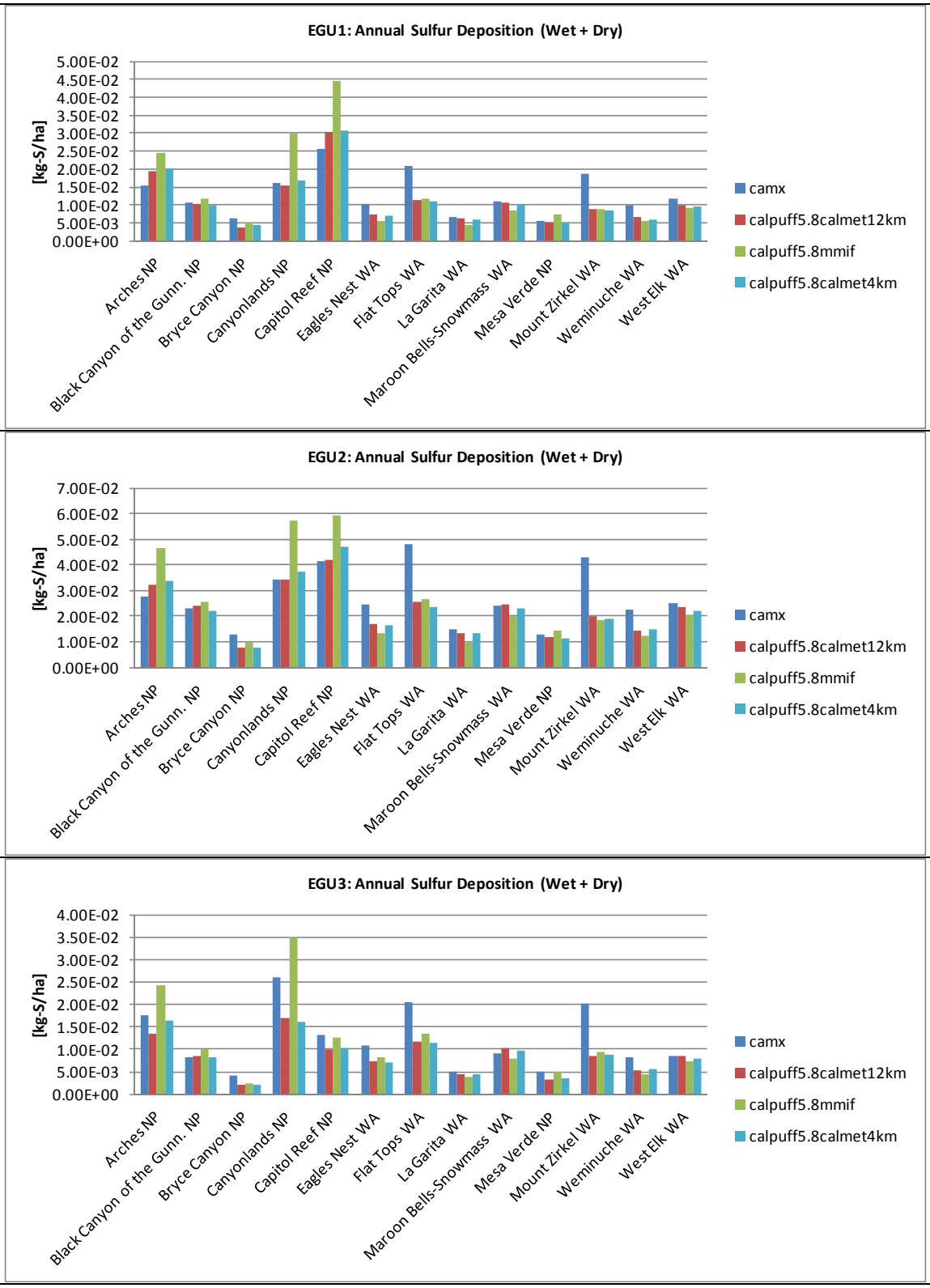


Figure 3-34a. Annual sulfur deposition (kg-S/ha/yr) at Class I areas using the 2006 12 km UT-CO database.

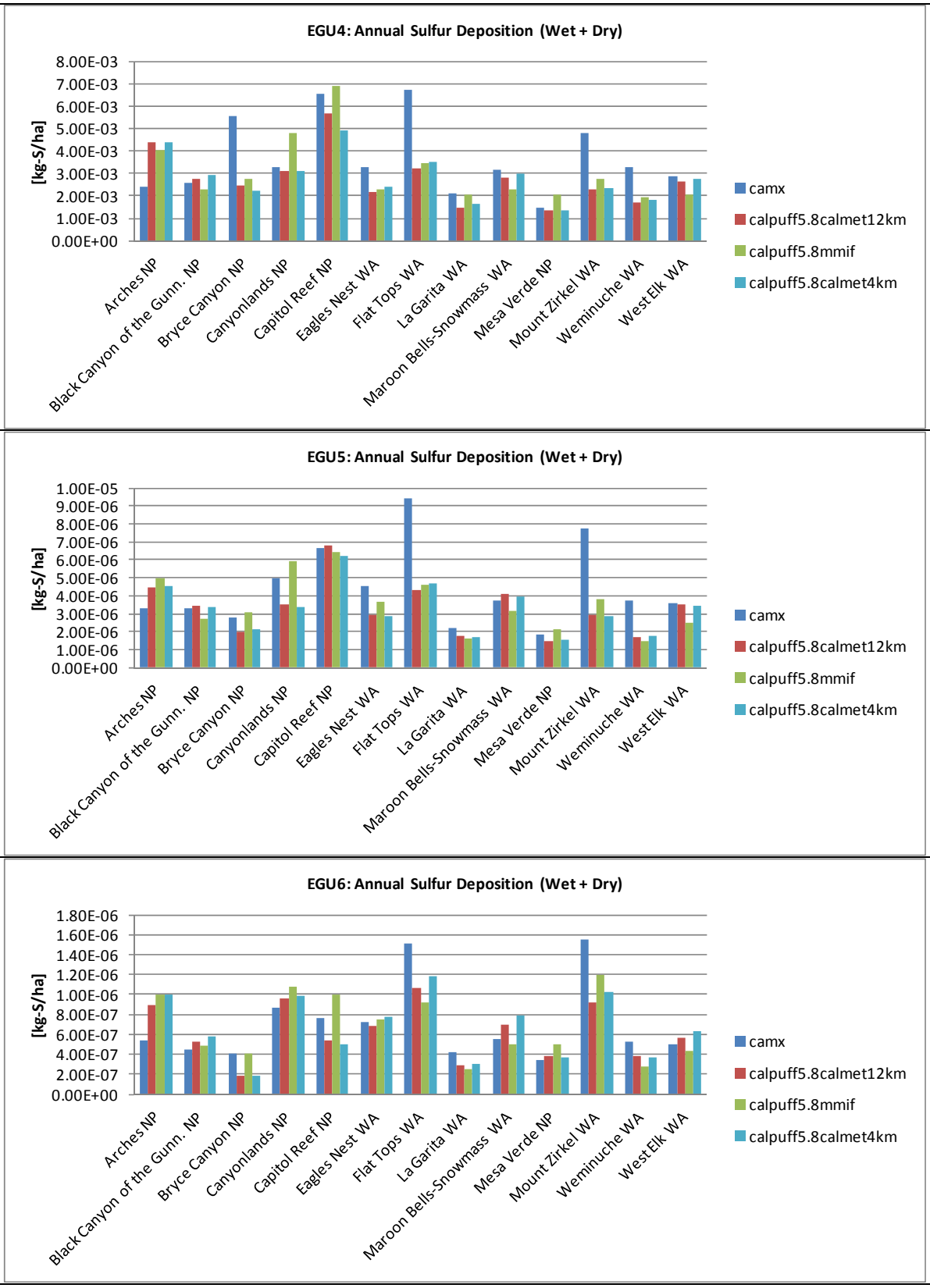


Figure 3-34b. Annual sulfur deposition (kg-S/ha/yr) at Class I areas using the 2006 12 km UT-CO database.

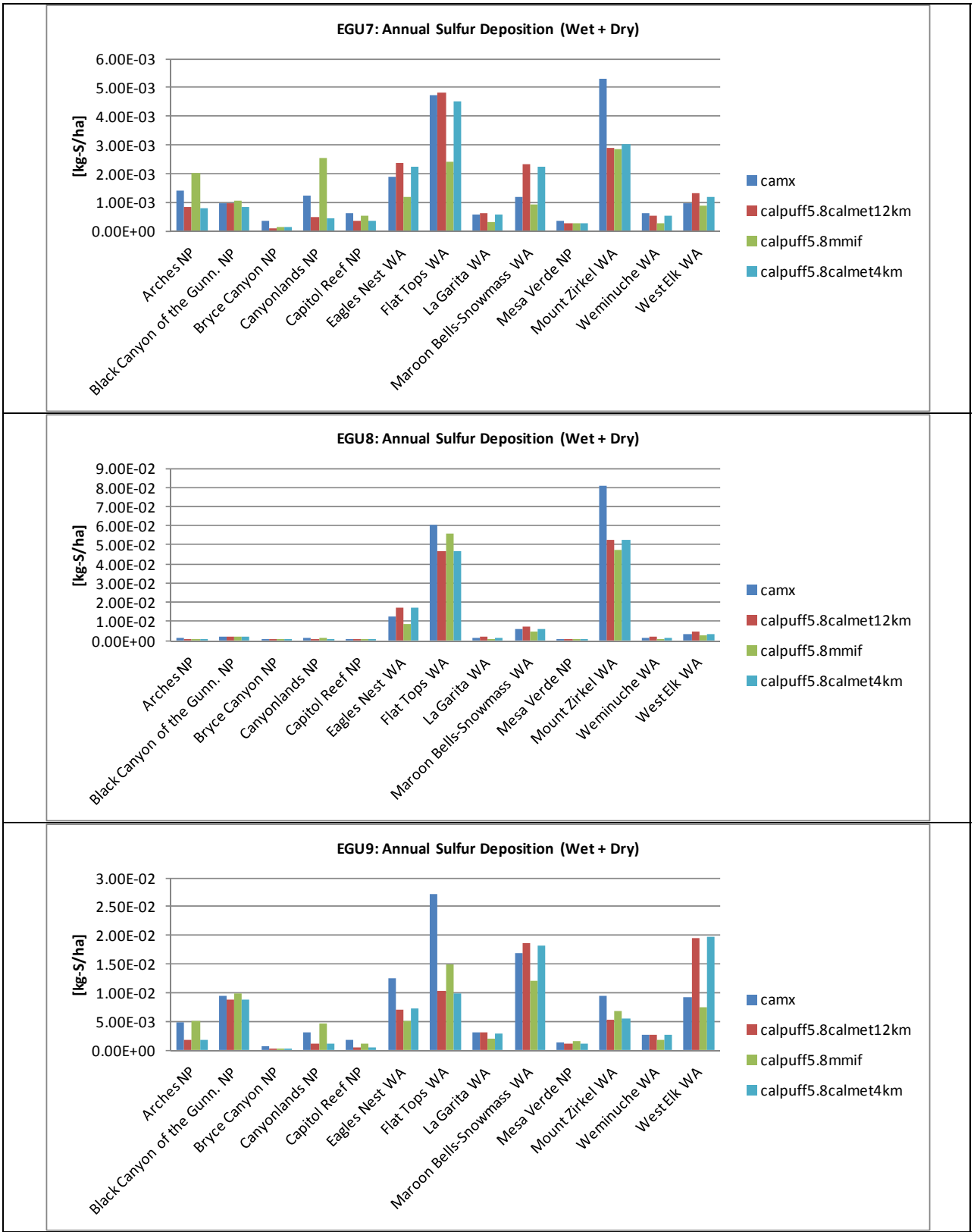


Figure 3-34c. Annual sulfur deposition (kg-S/ha/yr) at Class I areas using the 2006 12 km UT-CO database.

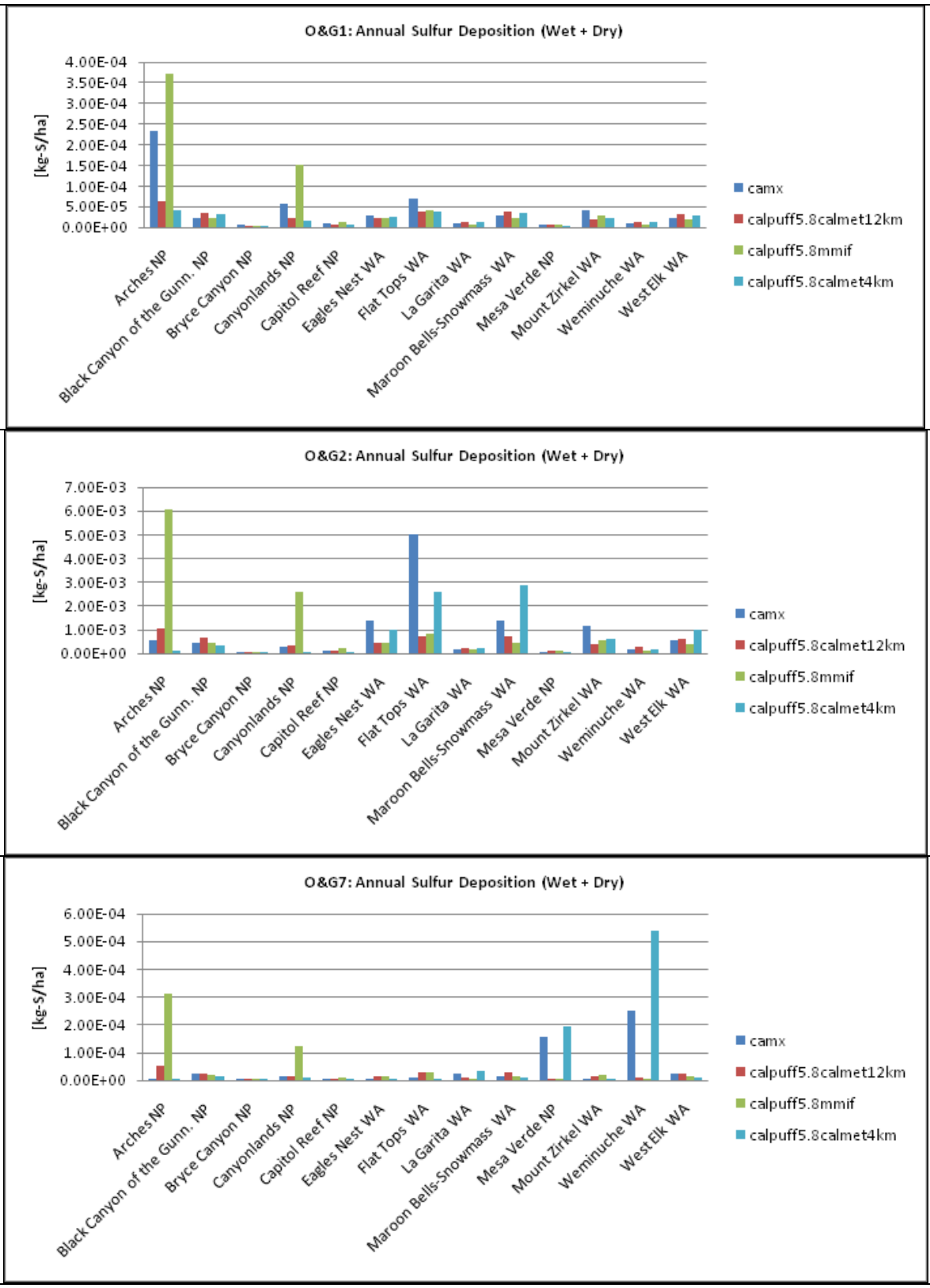


Figure 3-34d. Annual sulfur deposition (kg-S/ha/yr) at Class I areas using the 2006 12 km UT-CO database.

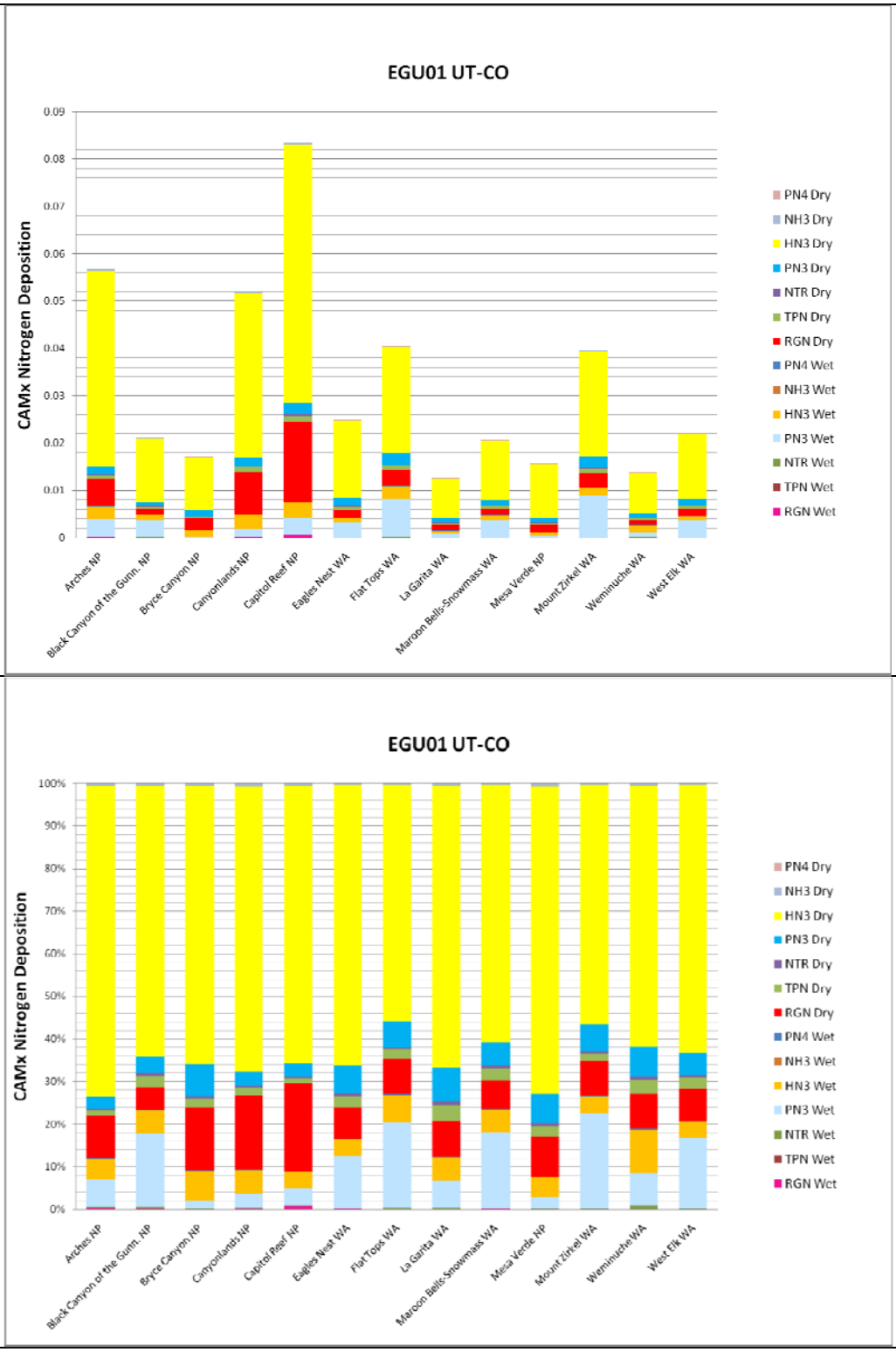


Figure 3-35. Total nitrogen deposition (as kg-N/ha/yr top panel and as percent bottom panel) estimated by CAMx by nitrogen species.

3.4 OZONE MODELING RESULTS

Ozone modeling results were only available for CAMx since CALPUFF does not treat ozone concentrations. Currently, there are no incremental ozone concentration thresholds for Class I areas. The incremental ozone concentrations for each of the test sources calculated by CAMx APCA ozone source apportionment approach were processed to obtain the highest incremental daily maximum 8-hour ozone concentrations produced by test source emissions during the year that were then displayed using spatial plots (note this is in contrast to the incremental ozone contribution that occurs at the same time as the maximum 8-hour ozone concentration during the year).

Figure 3-36 and 3-37 display the maximum incremental daily maximum 8-hour ozone concentration produced by each test sources for the, respectively, 2005 4 km FCAQTF and 2006 12 km UT-CO modeling. The top right panel in Figure 3-36a displays the maximum ozone due to all of the test sources, whereas the top left panel displays the contributions of all other sources in the region (i.e., none of the test sources) for the 2005 4 km modeling. The remaining panels in Figure 3-26 displays the ozone contributions of the individual test sources. The maximum ozone due to all of the test sources in the 2005 4 km modeling is 19 ppb. The maximum 8-hour ozone concentrations attributed to EGU1-EGU5 in the 2005 4 km modeling are 13, 10, 6, 1 and 0 ppb respectively. These maximum ozone concentrations follow the strength of the EGU NO_X emissions well (see Table 2-6), which would not necessarily be a similar result in other regions with different meteorology and mixes of pollutants. Similarly, for the OG test sources, OG2 has the highest NO_X and VOC emissions of any 2005 4 km OG test sources and has the highest ozone contributions as well (7 ppb).

The maximum 8-hour ozone contributions due to the test EGUs for the 2006 12 km UT-CO modeling ranged from 0 to 17 ppb (Figure 3-37) with the level of the ozone contributions following the level of the NO_X emissions of the EGUs (see Table 2-8). The maximum ozone contributions due to all of the test sources in the 2006 12 km modeling is 20 ppb (Figure 3-37a, top right). The OG test sources in the 2006 12 km modeling tend to have smaller ozone contributions than the EGUs with maximum values of 0 to 7 ppb. It is important to note that these results are not necessarily reflective of a single source ozone PSD impact assessment and the impacts from these sources (and their emissions) are not necessarily transferable to other regions that have different mixes of pollutants and different meteorology.

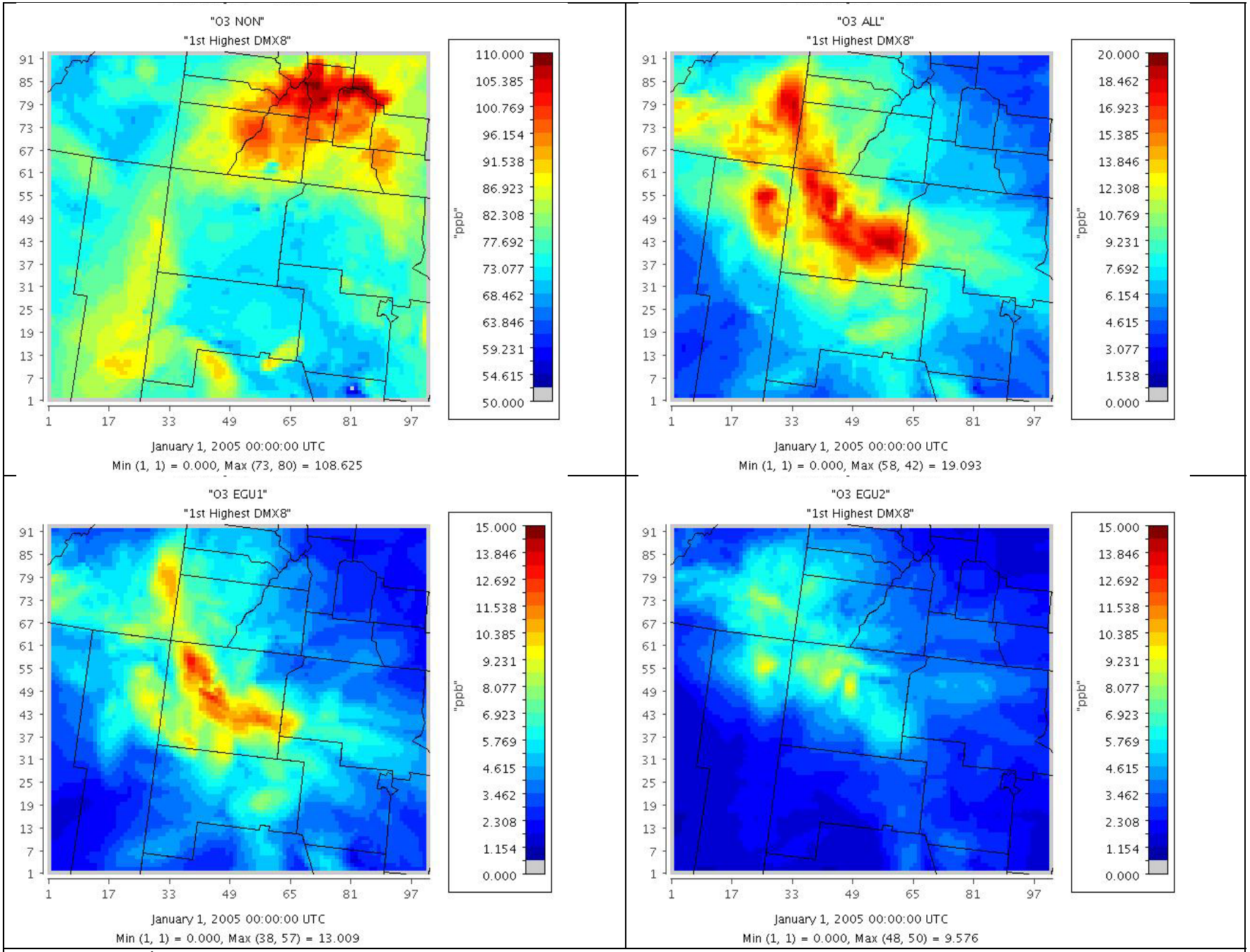


Figure 3-36a. 1st high daily maximum 8-hour ozone of none test sources (top left), all test sources (top right), EGU1 (bottom left), and EGU2 (bottom right) in FCAQTF 4 km domain.

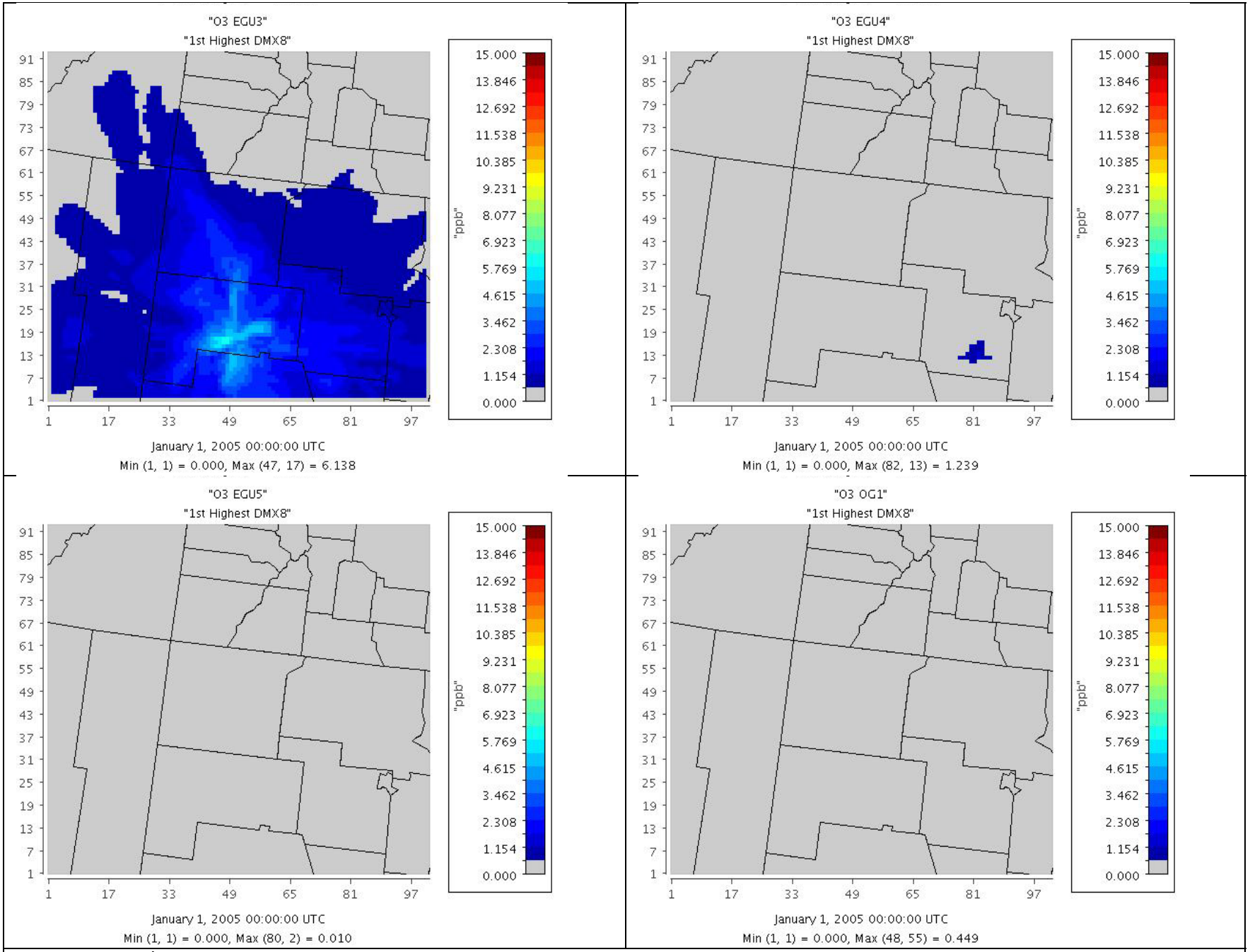


Figure 3-36b. 1st high daily maximum 8-hour ozone of EGU3 (top left), EGU4 (top right), EGU5 (bottom left), and OG1 (bottom right) in FCAQTF 4 km domain.

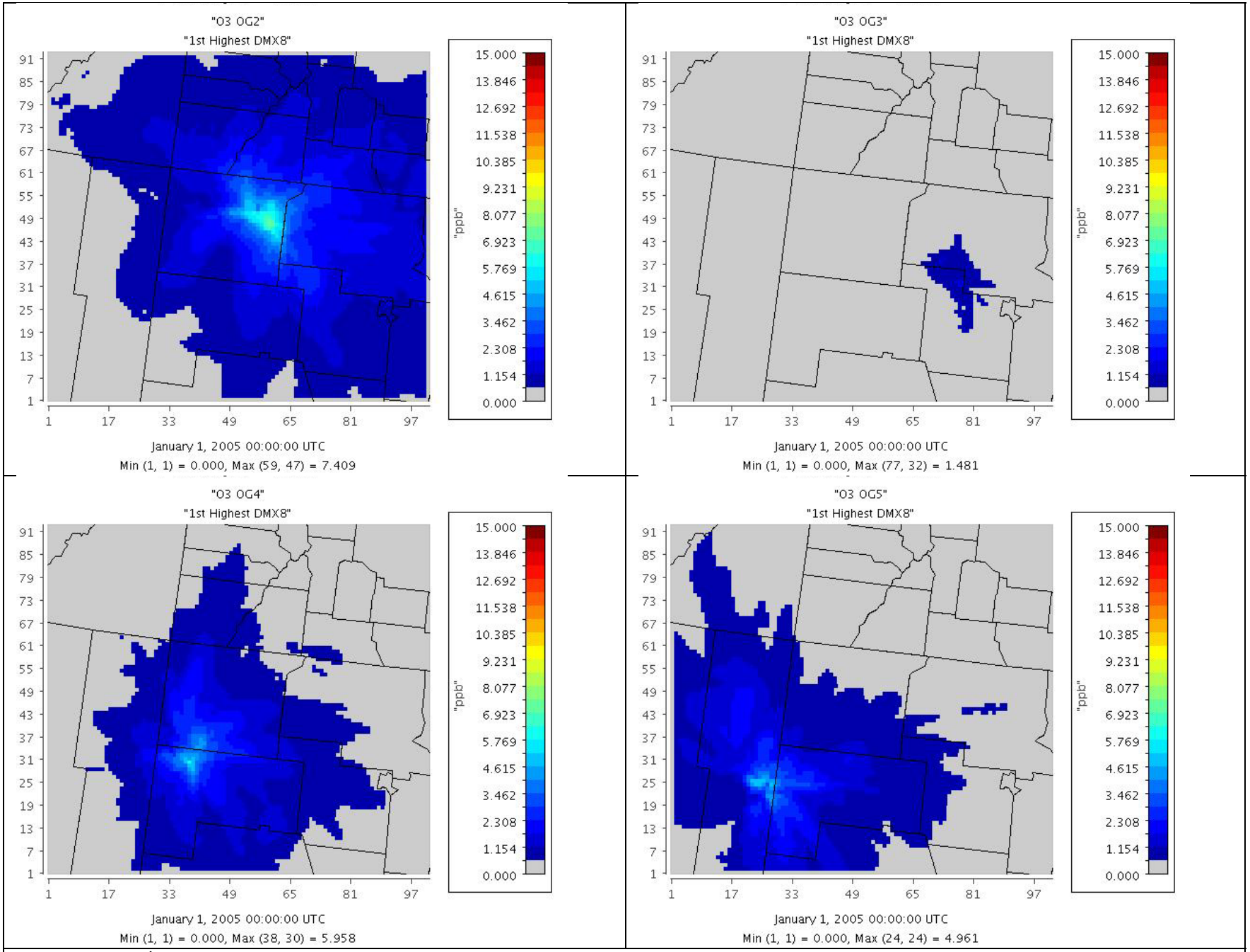


Figure 3-36c. 1st high daily maximum 8-hour ozone of OG2 (top left), OG3 (top right), OG4 (bottom left), and OG5 (bottom right) in FCAQTF 4 km domain.

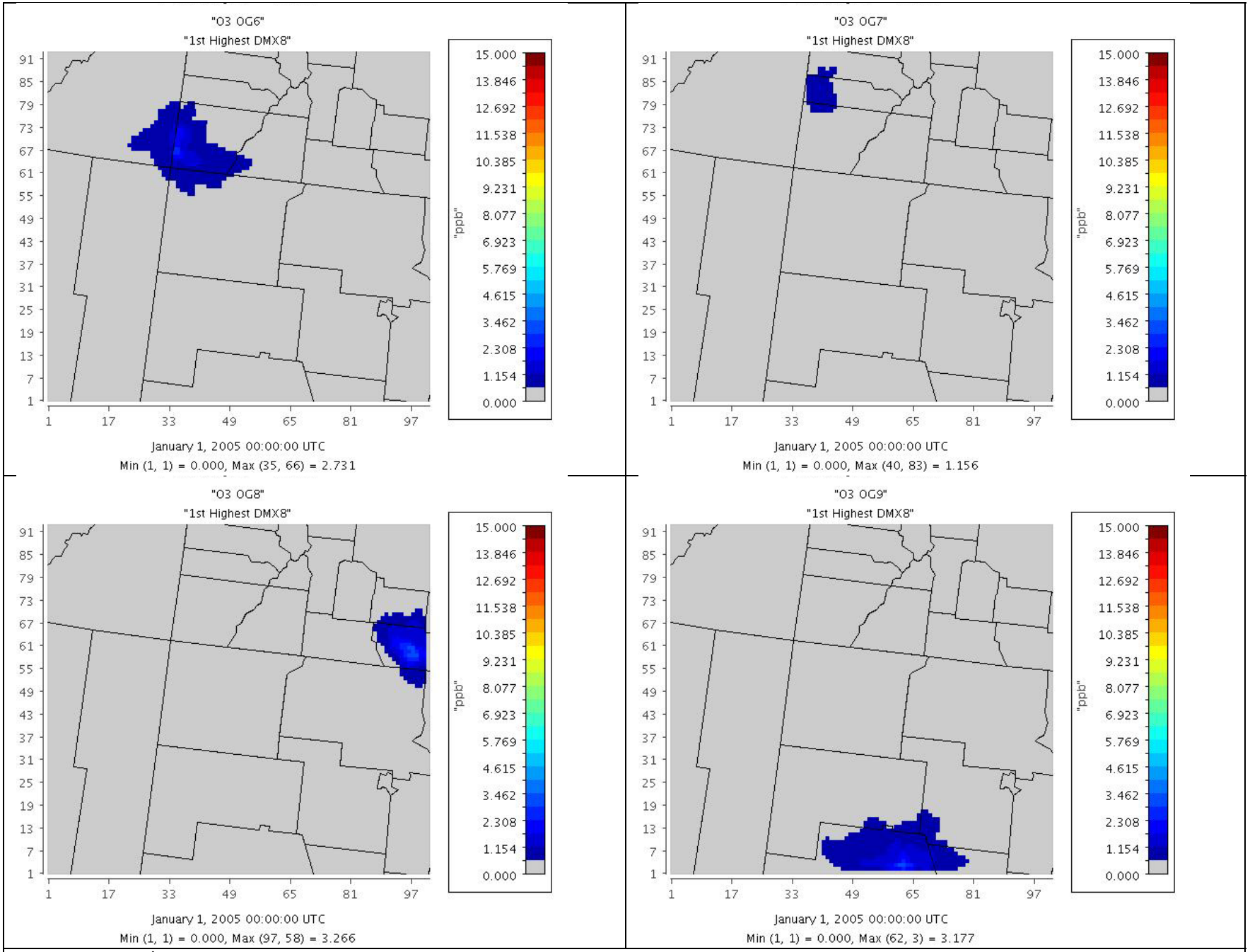


Figure 3-36d. 1st high daily maximum 8-hour ozone of OG6 (top left), OG7 (top right), OG8 (bottom left), and OG09 (bottom right) in FCAQTF 4 km domain.

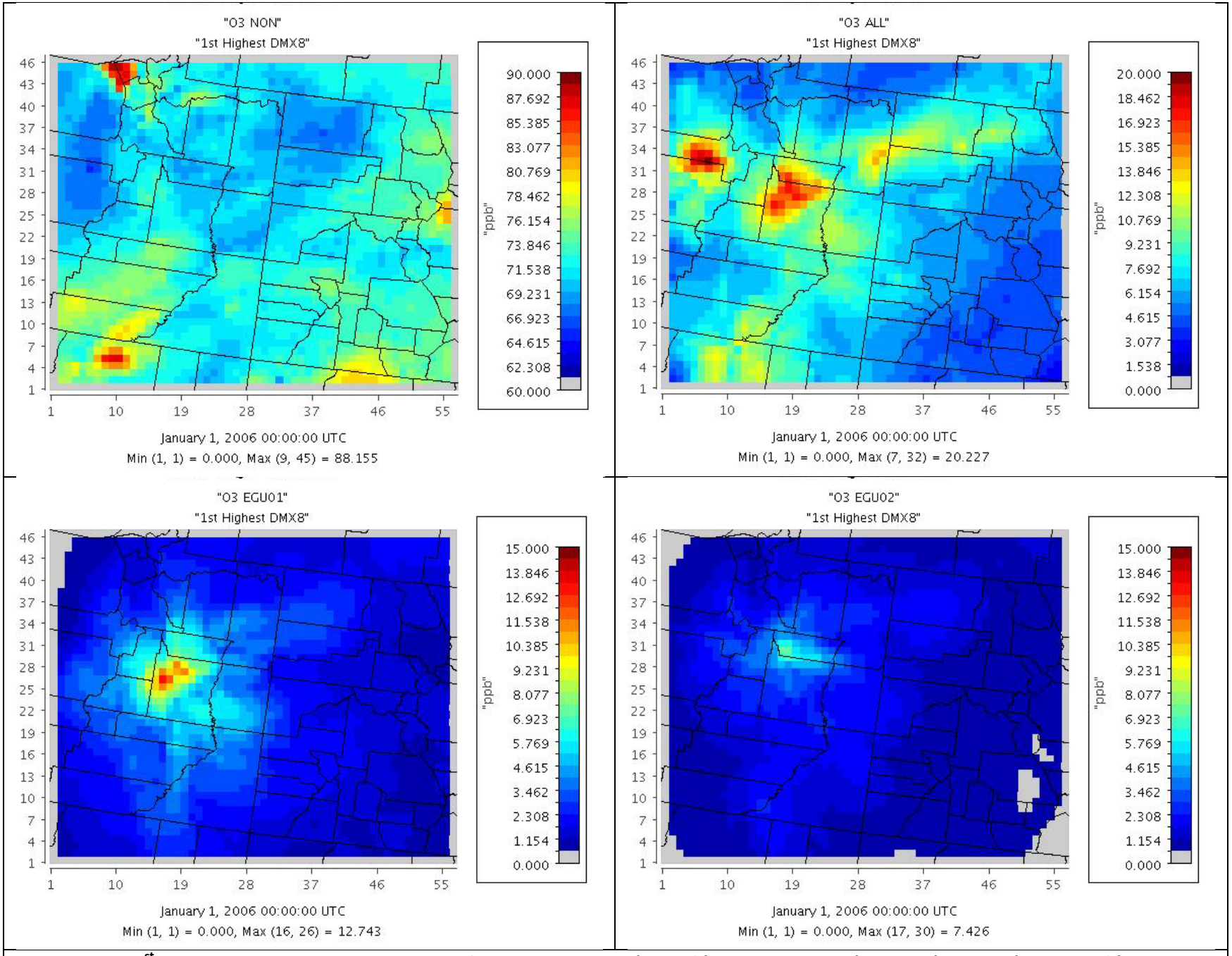


Figure 3-37a. 1st high daily maximum 8-hour ozone of none test sources (top left), all test sources (top right), EGU01 (bottom left), and EGU02 (bottom right) in UT-CO 12 km domain.

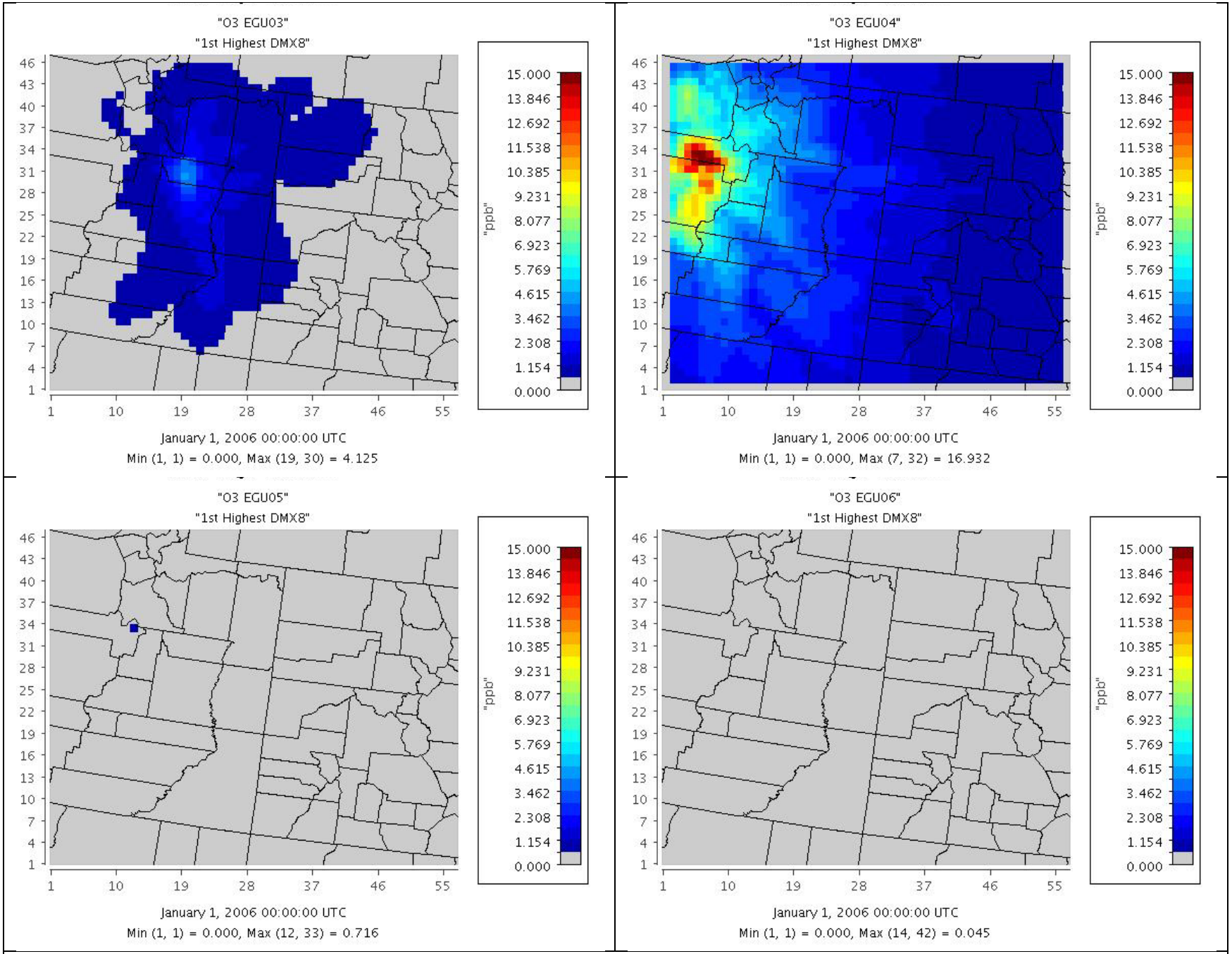


Figure 3-37b. 1st high daily maximum 8-hour ozone of EGU03 (top left), EGU04 (top right), EGU05 (bottom left), and EGU06 (bottom right) in UT-CO 12 km domain.

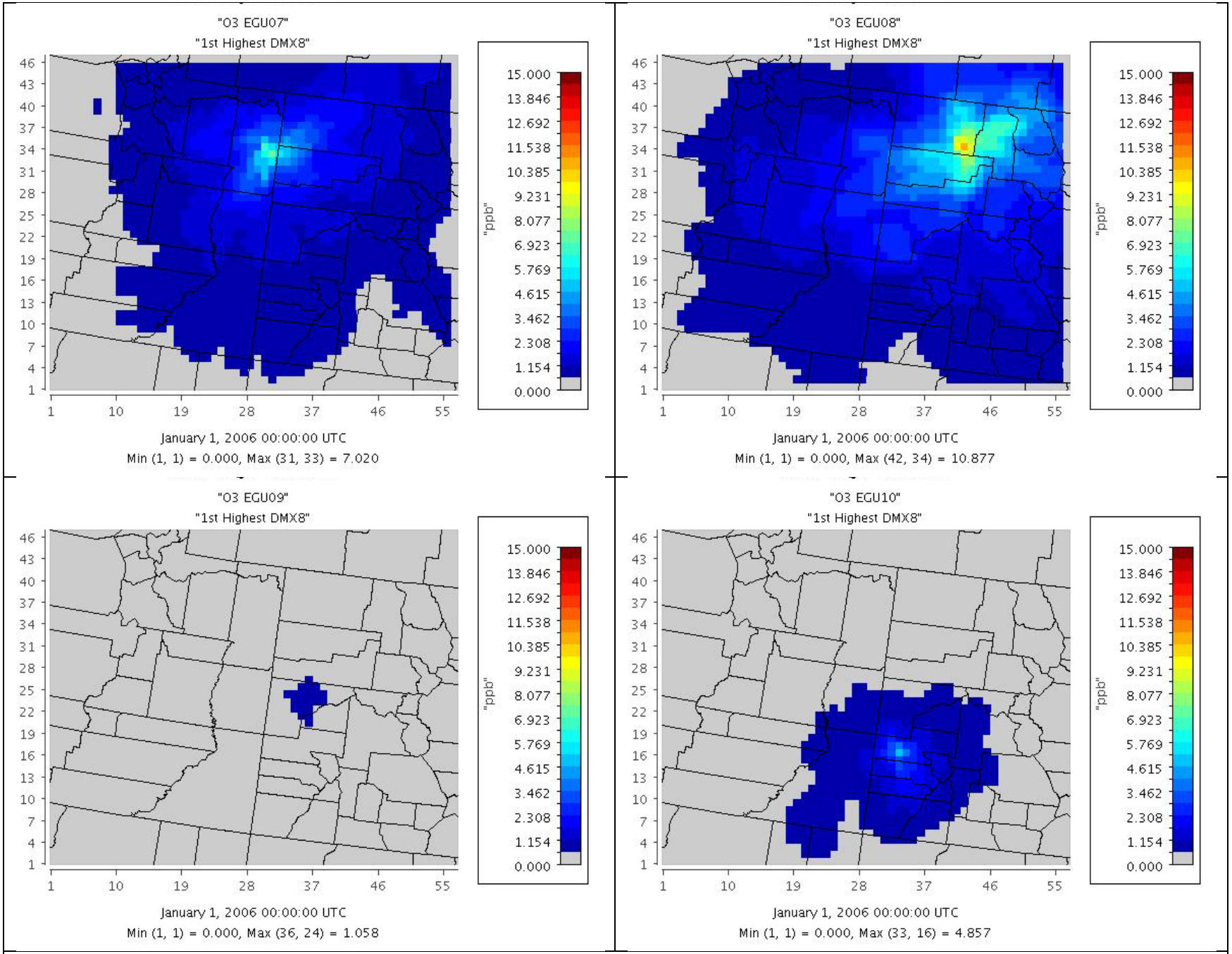


Figure 3-37c. 1st high daily maximum 8-hour ozone of EGU07 (top left), EGU08 (top right), EGU09 (bottom left), and EGU10 (bottom right) in UT-CO 12 km domain.

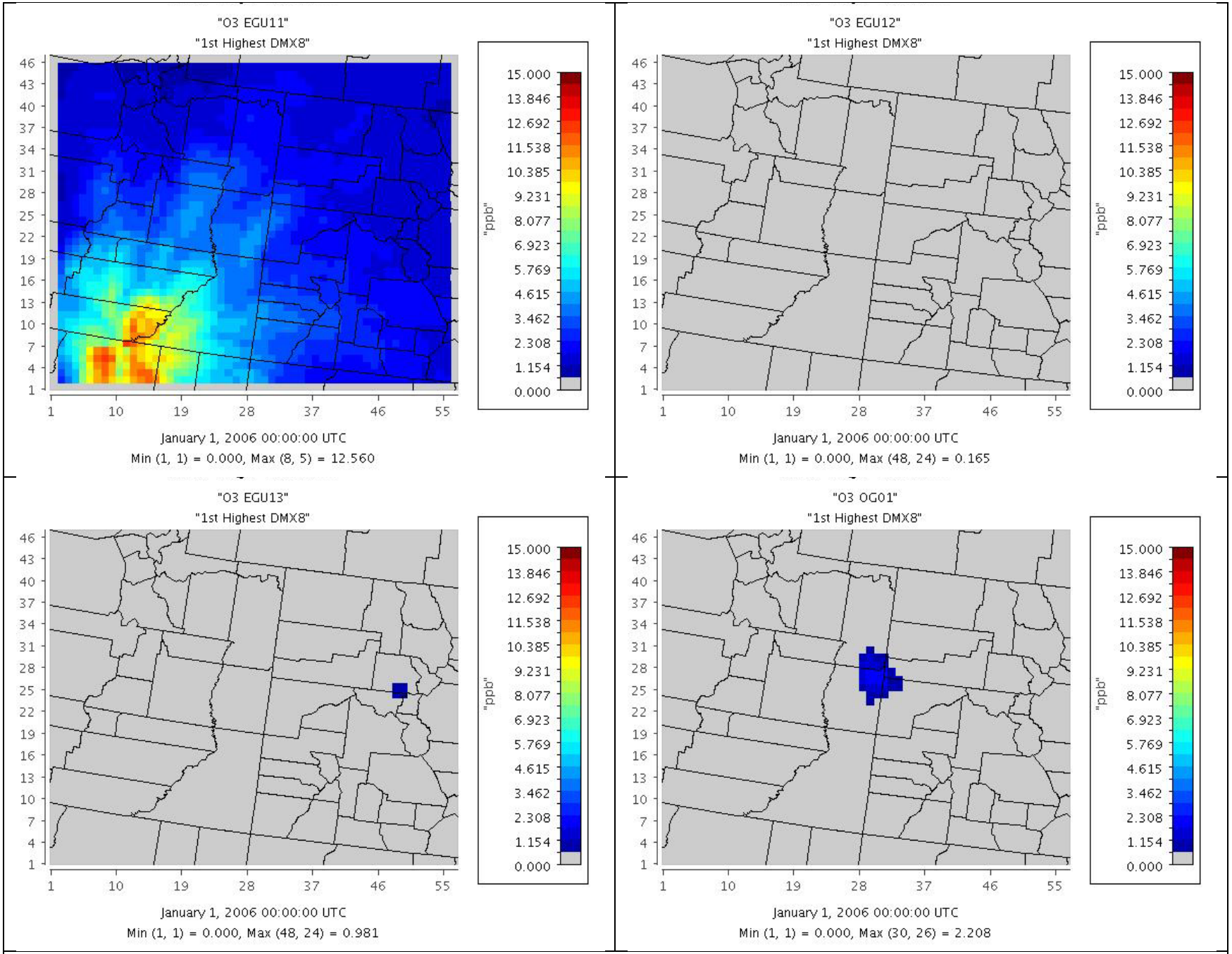


Figure 3-37d. 1st high daily maximum 8-hour ozone of EGU11 (top left), EGU12 (top right), EGU13 (bottom left), and OG01 (bottom right) in UT-CO 12 km domain.

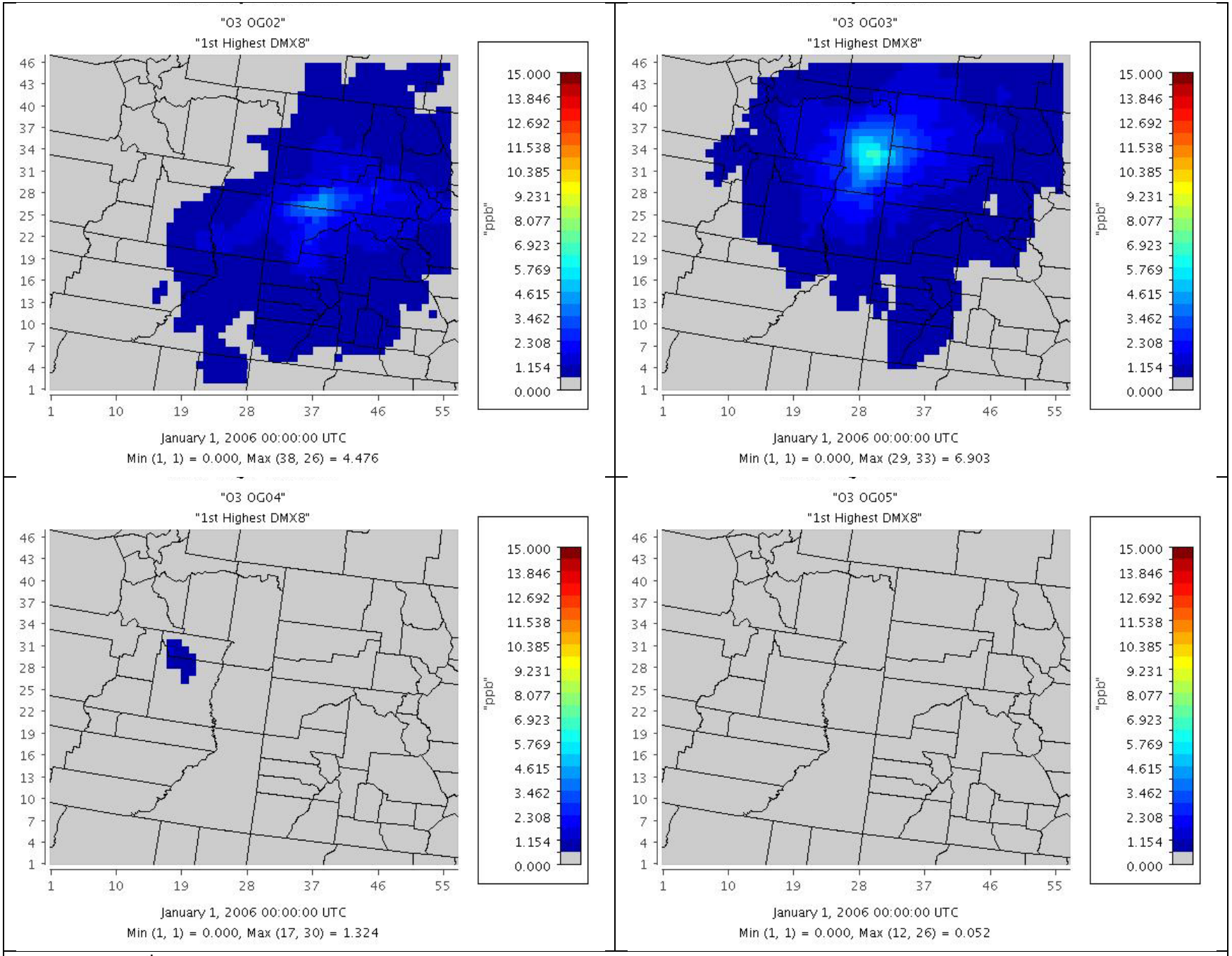


Figure 3-37e. 1st high daily maximum 8-hour ozone of OG02 (top left), OG03 (top right), OG04 (bottom left), and OG05 (bottom right) in UT-CO 12 km domain.

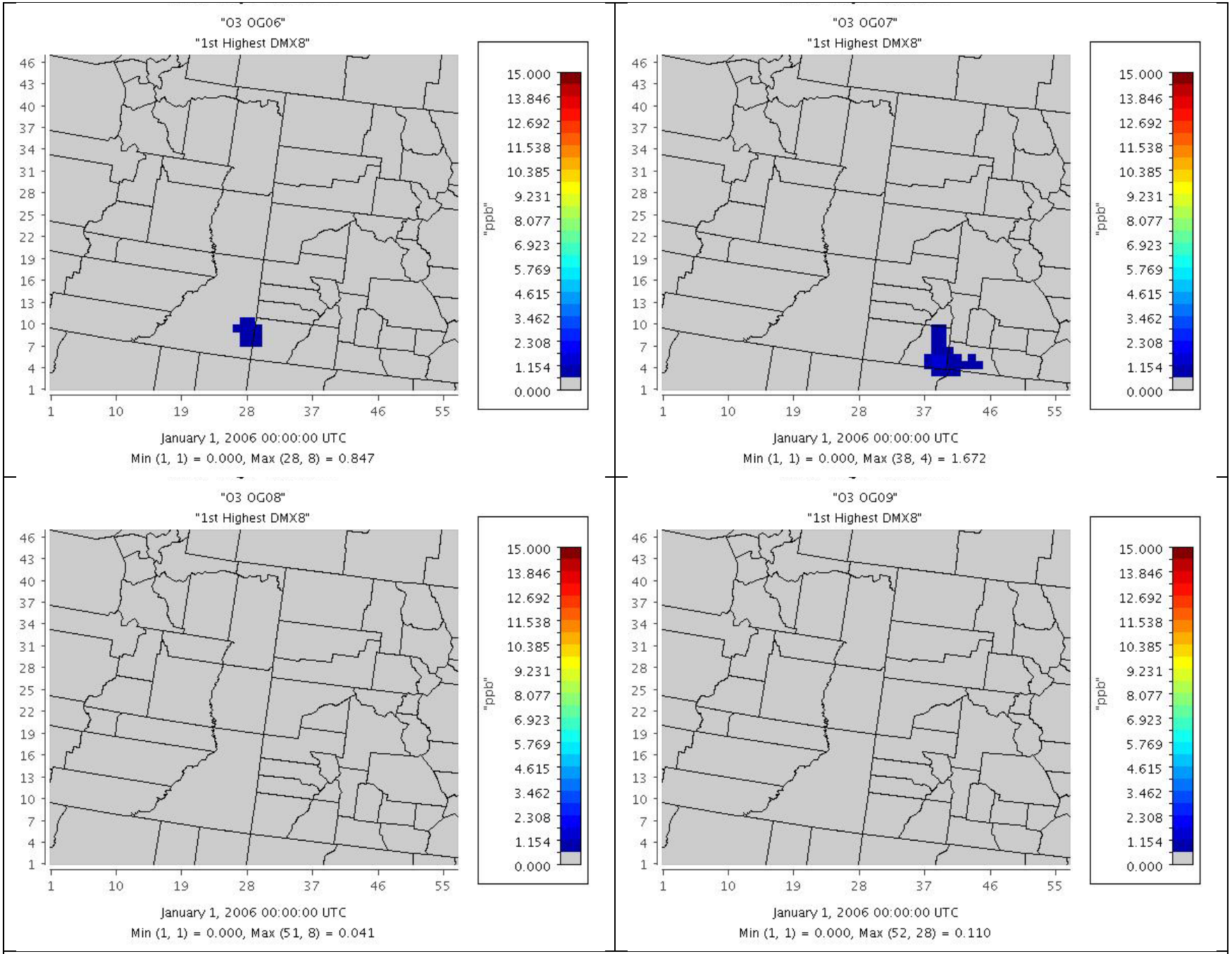


Figure 3-37f. 1st high daily maximum 8-hour ozone of OG06 (top left), OG07 (top right), OG08 (bottom left), and OG09 (bottom right) in UT-CO 12 km domain.

3.5 DISCUSSION OF RESULTS

Given that CAMx and CALPUFF V5.8/MMIF use the same "pass through" MM5 meteorological fields, whereas CALPUFF V5.8/CALMET processes the MM5 data using CALMET with observations, it was surprising that the CAMx and V5.8/CALMET annual NO_2 and SO_2 2005 4 km results agreed very well with each other and were both about 50% higher than V5.8/MMIF. The reasons for this are unclear. However, the same result for annual NO_2 and SO_2 concentrations was not seen for the 2006 12 km modeling with CAMx values being much lower than the CALPUFF values (using either CALMET or MMIF). This may be due in part to use of a coarser 12 km grid resolution in CAMx 2006 modeling that dilutes the primary emitted NO_2 and SO_2 concentrations more than the 4 km grid resolution database used for the 2005 modeling. CALPUFF V5.8/CALMET consistently estimated higher concentrations than V5.8/MMIF, but lower deposition amounts. The higher concentrations in V5.8/CALMET may be related to the tendency of CALMET to reduce the MM5 wind speeds, which is not done when MMIF is used. The higher deposition by V5.8/MMIF may be due to the higher precipitation amounts produced by MM5 compared to the observed values used by CALMET, the MM5 precipitation amounts are passed through to CALPUFF in the V5.8/MMIF simulations. This is especially true over high terrain where MM5 can account for the enhanced precipitation due to orographic effects that is typically not captured in the measurements that tend to be located down in the valleys (e.g., at airports).

CALPUFF estimates higher visibility impairment than CAMx, with V5.8/CALMET also estimating slightly higher visibility impairment than V5.8/MMIF, which is consistent with the concentration differences. The CALPUFF background ammonia value assumed in these simulations was 1 ppb. CAMx simulates ammonia as an active species and in previous analysis of CAMx results in a UT-CO domain found values that were much less than 1 ppb in the elevated terrain of the Rocky Mountains. Thus, CALPUFF will be carrying much more of the reacted NO_X emissions as particle nitrate, whereas CAMx will be carrying it more as gaseous nitric acid. Thus, not only will CALPUFF have higher visibility extinction due to the higher nitrate concentrations, but since the dry deposition rate of nitric acid is much faster than nitrate, CAMx will have lost more of the reacted NO_X emissions on the way to the Class I area and will have higher nitrogen deposition. Since POSTUTIL adjusts the phase of nitrate between gas and particle after the CALPUFF simulation is complete the repartioning done in this step would not make particulate nitrate concentrations and deposition more comparable to CAMx since important chemical and physical processes (such as dry deposition of nitric acid) can not be changed after the fact.

Although CALPUFF frequently estimated more spatial variation in maximum visibility impairment across the 100s of receptors used to cover a Class I area versus the 10s of grid cells used by CAMx, for most Class I areas the spatial variation in visibility across the Class I area was similar between CALPUFF and CAMx. When CALPUFF tended to exhibit much more spatial variability in visibility than CAMx it occurred at Class I areas close to the source (e.g., Four Corners and San Juan power plants impacts at Mesa Verde that is ~50 km away). Typically, CALPUFF always exhibited spatial variability in visibility impacts across Class I areas within ~100 km of the source and there was much less variability beyond ~150 km from the source. In some cases, CAMx exhibited more spatial variability across a Class I area than CALPUFF.

CAMx estimated approximately twice as much nitrogen deposition as CALPUFF. At first we thought this might be due to different species mappings used in CAMx and CALPUFF and the

fact that CAMx carries many more nitrogen species than CALPUFF. However, extracting the CAMx results using nitrogen species mappings as close to possible to match the CALPUFF approach did not change this finding. An examination of the deposition output found CAMx has much higher nitric acid deposition than CALPUFF, which is due to CALPUFF having much higher background ammonia (default of 1 ppb) than simulated by CAMx (spatially and temporally varying and typically < 1 ppb) resulting in higher nitric acid concentrations and nitrogen deposition in CAMx. This finding emphasizes the importance for modeling nitrogen deposition of carrying the reacted NO_X in the model correctly as either particulate NO3 or gaseous HNO3. CALPUFF uses a background ammonia value and simulates the partitioning of total nitrate to NO3 and HNO3 separately for each puff so when puffs overlap it "double counts" the background ammonia and overstates the puff NO3 and understates the puff HNO3 concentrations thereby understating nitrogen deposition given that HNO3 has a higher dry deposition rate than NO3. For PM concentrations and visibility at receptors CALPUFF has a fix for this ammonia double counting where the CALPUFF POSTUTIL post-processor can use the Ammonia Limiting Method (ALM) to repartition the NO3/HNO3 accounting for puff overlap. But the application of ALM to the concentrations does not fix the CALPUFF nitrogen deposition estimates.

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APPENDIX A: Example CALPUFF Control Input Filed for CALPUFF V5.8 (EGU2 using the 2006 UT-CO 12 km Database)

```
UBAQS 12km CALPUFF run, 56x46x12km mesh, 2006 12km MM5.
CALMET following 2009-08-31 guidance.
Class I, NADP, CASTNET, & IMPROVE receptors

---------------- Run title (3 lines) ------------------------------------------

                    CALPUFF MODEL CONTROL FILE
                    --------------------------

------------------------------------------------------------------------------

INPUT GROUP: 0 -- Input and Output File Names

--------------
Default Name  Type          File Name
------------  ----          ---------
CALMET.DAT    input    * METDAT =             *
    or
ISCALMET.DAT    input    * ISCDAT =             *
    or
PLMMET.DAT    input    * PLMDAT =             *
    or
PROFILE.DAT   input    * PRFDAT =             *
SURFACE.DAT   input    * SFCDAT =             *
RESTARTB.DAT  input    * RSTARTB=             *
------------------------------------------------------------------------------
CALPUFF.LST   output   ! PUFLST = group02.2006.out  !
CONC.DAT      output   ! CONDAT = group02.2006.con  !
DFLX.DAT      output   ! DFDAT  = group02.2006.dry  !
WFLX.DAT      output   ! WFDAT  = group02.2006.wet  !

VISB.DAT      output   ! VISDAT = group02.2006.vis  !
TK2D.DAT      output   * T2DDAT =             *
RHO2D.DAT     output   * RHODAT =             *
RESTARTE.DAT  output   * RSTARTE=             *
------------------------------------------------------------------------------
Emission Files
--------------
PTEMARB.DAT   input    * PTDAT  =             *
VOLEMARB.DAT  input    * VOLDAT =             *
BAEMARB.DAT   input    * ARDAT  =             *
LNEMARB.DAT   input    * LNDAT  =             *
------------------------------------------------------------------------------
Other Files
-----------
OZONE.DAT     input    ! OZDAT  = ../../all.ozone/ozone_ubaqs.dat !
VD.DAT        input    * VDDAT  =             *
CHEM.DAT      input    * CHEMDAT=             *
H2O2.DAT      input    * H2O2DAT=             *
HILL.DAT      input    * HILDAT=              *
HILLRCT.DAT   input    * RCTDAT=              *
COASTLN.DAT   input    * CSTDAT=              *
FLUXBDY.DAT   input    * BDYDAT=              *
BCON.DAT      input    * BCNDAT=              *
DEBUG.DAT     output   * DEBUG =              *
MASSFLX.DAT   output   * FLXDAT=              *
MASSBAL.DAT   output   ! BALDAT= group02.2006.bal !
FOG.DAT       output   * FOGDAT=              *
------------------------------------------------------------------------------
All file names will be converted to lower case if LCFILES = T
Otherwise, if LCFILES = F, file names will be converted to UPPER CASE
         T = lower case      ! LCFILES = T !
         F = UPPER CASE
NOTE: (1) file/path names can be up to 70 characters in length


Provision for multiple input files
----------------------------------

     Number of CALMET.DAT files for run (NMETDAT)
                                    Default: 1       ! NMETDAT = 12  !

     Number of PTEMARB.DAT files for run (NPTDAT)
```

```
                                    Default: 0       ! NPTDAT =  0  !

     Number of BAEMARB.DAT files for run (NARDAT)
                                    Default: 0       ! NARDAT =  0  !

     Number of VOLEMARB.DAT files for run (NVOLDAT)
                                    Default: 0       ! NVOLDAT =  0  !

!END!

-------------
Subgroup (0a)
-------------

  The following CALMET.DAT filenames are processed in sequence if NMETDAT>1

Default Name  Type     File Name
------------  ----     ---------
CALMET.DAT    input    ! METDAT =../../calmet/calmet.2006.01.met ! !END!
CALMET.DAT    input    ! METDAT =../../calmet/calmet.2006.02.met ! !END!
CALMET.DAT    input    ! METDAT =../../calmet/calmet.2006.03.met ! !END!
CALMET.DAT    input    ! METDAT =../../calmet/calmet.2006.04.met ! !END!
CALMET.DAT    input    ! METDAT =../../calmet/calmet.2006.05.met ! !END!
CALMET.DAT    input    ! METDAT =../../calmet/calmet.2006.06.met ! !END!
CALMET.DAT    input    ! METDAT =../../calmet/calmet.2006.07.met ! !END!
CALMET.DAT    input    ! METDAT =../../calmet/calmet.2006.08.met ! !END!
CALMET.DAT    input    ! METDAT =../../calmet/calmet.2006.09.met ! !END!
CALMET.DAT    input    ! METDAT =../../calmet/calmet.2006.10.met ! !END!
CALMET.DAT    input    ! METDAT =../../calmet/calmet.2006.11.met ! !END!
CALMET.DAT    input    ! METDAT =../../calmet/calmet.2006.12.met ! !END!

------------------------------------------------------------------------------

INPUT GROUP: 1 -- General run control parameters
--------------

    Option to run all periods found
    in the met. file     (METRUN)   Default: 0       ! METRUN =   0  !

         METRUN = 0 - Run period explicitly defined below
         METRUN = 1 - Run all periods in met. file

     Starting date:   Year (IBYR) -- No default       ! IBYR =  2006 !
     (used only if   Month (IBMO) -- No default       ! IBMO =  01   !
      METRUN = 0)      Day (IBDY) -- No default       ! IBDY =  01   !
                      Hour (IBHR) -- No default       ! IBHR =  01   !

     Base time zone        (XBTZ) -- No default       ! XBTZ = 7.0   !
        PST = 8., MST = 7.
        CST = 6., EST = 5.

     Length of run (hours) (IRLG) -- No default       ! IRLG =  8760 !

     Number of chemical species (NSPEC)
                                    Default: 5       ! NSPEC =  9   !

     Number of chemical species
     to be emitted  (NSE)           Default: 3       ! NSE   =  9   !

     Flag to stop run after
     SETUP phase (ITEST)            Default: 2       ! ITEST =  2   !
     (Used to allow checking
     of the model inputs, files, etc.)
           ITEST = 1 - STOPS program after SETUP phase
           ITEST = 2 - Continues with execution of program
                       after SETUP

     Restart Configuration:

        Control flag (MRESTART)     Default: 0       ! MRESTART =  0   !

           0 = Do not read or write a restart file
           1 = Read a restart file at the beginning of
```

```
            the run
         2 = Write a restart file during run
         3 = Read a restart file at beginning of run
             and write a restart file during run

      Number of periods in Restart
      output cycle (NRESPD)        Default: 0       ! NRESPD =  0   !

         0 = File written only at last period
        >0 = File updated every NRESPD periods

   Meteorological Data Format (METFM)
                                   Default: 1       ! METFM =  1   !

         METFM = 1 - CALMET binary file (CALMET.MET)
         METFM = 2 - ISC ASCII file (ISCALMET.MET)
         METFM = 3 - AUSPLUME ASCII file (PLMMET.MET)
         METFM = 4 - CTDM plus tower file (PROFILE.DAT) and
                     surface parameters file (SURFACE.DAT)
         METFM = 5 - AERMET tower file (PROFILE.DAT) and
                     surface parameters file (SURFACE.DAT)

   Meteorological Profile Data Format (MPRFFM)
          (used only for METFM = 1, 2, 3)
                                   Default: 1       ! MPRFFM =  1   !

         MPRFFM = 1 - CTDM plus tower file (PROFILE.DAT)
         MPRFFM = 2 - AERMET tower file (PROFILE.DAT)


   PG sigma-y is adjusted by the factor (AVET/PGTIME)**0.2
   Averaging Time (minutes) (AVET)
                                   Default: 60.0    ! AVET = 60. !
   PG Averaging Time (minutes) (PGTIME)
                                   Default: 60.0    ! PGTIME = 60. !


!END!


--------------------------------------------------------------------------------

INPUT GROUP: 2 -- Technical options
--------------


   Vertical distribution used in the
   near field (MGAUSS)                  Default: 1     ! MGAUSS =  1   !
      0 = uniform
      1 = Gaussian

   Terrain adjustment method
   (MCTADJ)                             Default: 3     ! MCTADJ =  3   !
      0 = no adjustment
      1 = ISC-type of terrain adjustment
      2 = simple, CALPUFF-type of terrain
          adjustment
      3 = partial plume path adjustment

   Subgrid-scale complex terrain
   flag (MCTSG)                         Default: 0     ! MCTSG =  0   !
      0 = not modeled
      1 = modeled

   Near-field puffs modeled as
   elongated 0 (MSLUG)                  Default: 0     ! MSLUG =  0   !
      0 = no
      1 = yes (slug model used)

   Transitional plume rise modeled ?
   (MTRANS)                             Default: 1     ! MTRANS =  1   !
      0 = no  (i.e., final rise only)
      1 = yes (i.e., transitional rise computed)
```

```
Stack tip downwash? (MTIP)           Default: 1     ! MTIP =  1  !
   0 = no  (i.e., no stack tip downwash)
   1 = yes (i.e., use stack tip downwash)

Method used to simulate building
downwash? (MBDW)                     Default: 1     ! MBDW =  1   !
   1 = ISC method
   2 = PRIME method

Vertical wind shear modeled above
stack top? (MSHEAR)                  Default: 0     ! MSHEAR =  0  !
   0 = no  (i.e., vertical wind shear not modeled)
   1 = yes (i.e., vertical wind shear modeled)

Puff splitting allowed? (MSPLIT)     Default: 0     ! MSPLIT =  0  !
   0 = no (i.e., puffs not split)
   1 = yes (i.e., puffs are split)

Chemical mechanism flag (MCHEM)      Default: 1     ! MCHEM =  1   !
   0 = chemical transformation not modeled
   1 = transformation rates computed internally (MESOPUFF II scheme)
   2 = user-specified transformation rates used
   3 = transformation rates computed internally (RIVAD/ARM3 scheme)
   4 = secondary organic aerosol formation computed (MESOPUFF II scheme for OH)

Aqueous phase transformation flag (MAQCHEM)
(Used only if MCHEM = 1, or 3)       Default: 0     ! MAQCHEM =  0   !
   0 = aqueous phase transformation not modeled
   1 = transformation rates adjusted for aqueous phase reactions

Wet removal modeled ? (MWET)         Default: 1     ! MWET =  1   !
   0 = no
   1 = yes

Dry deposition modeled ? (MDRY)      Default: 1     ! MDRY =  1   !
   0 = no
   1 = yes
   (dry deposition method specified for each species in Input Group 3)

Gravitational settling (plume tilt)
modeled ? (MTILT)                    Default: 0     ! MTILT =  0   !
   0 = no
   1 = yes
   (puff center falls at the gravitational
    settling velocity for 1 particle species)

    Restrictions:
    - MDRY  = 1
    - NSPEC = 1  (must be particle species as well)
    - sg    = 0  GEOMETRIC STANDARD DEVIATION in Group 8 is
                 set to zero for a single particle diameter

Method used to compute dispersion
coefficients (MDISP)                 Default: 3     ! MDISP =  3   !

   1 = dispersion coefficients computed from measured values
       of turbulence, sigma v, sigma w
   2 = dispersion coefficients from internally calculated
       sigma v, sigma w using micrometeorological variables
       (u*, w*, L, etc.)
   3 = PG dispersion coefficients for RURAL areas (computed using
       the ISCST multi-segment approximation) and MP coefficients in
       urban areas
   4 = same as 3 except PG coefficients computed using
       the MESOPUFF II eqns.
   5 = CTDM sigmas used for stable and neutral conditions.
       For unstable conditions, sigmas are computed as in
       MDISP = 3, described above.  MDISP = 5 assumes that
       measured values are read

Sigma-v/sigma-theta, sigma-w measurements used? (MTURBVW)
(Used only if MDISP = 1 or 5)        Default: 3     ! MTURBVW =  3  !
```

```
   1 = use sigma-v or sigma-theta measurements
       from PROFILE.DAT to compute sigma-y
       (valid for METFM = 1, 2, 3, 4, 5)
   2 = use sigma-w measurements
       from PROFILE.DAT to compute sigma-z
       (valid for METFM = 1, 2, 3, 4, 5)
   3 = use both sigma-(v/theta) and sigma-w
       from PROFILE.DAT to compute sigma-y and sigma-z
       (valid for METFM = 1, 2, 3, 4, 5)
   4 = use sigma-theta measurements
       from PLMMET.DAT to compute sigma-y
       (valid only if METFM = 3)

Back-up method used to compute dispersion
when measured turbulence data are
missing (MDISP2)                    Default: 3     ! MDISP2 =  3  !
(used only if MDISP = 1 or 5)
   2 = dispersion coefficients from internally calculated
       sigma v, sigma w using micrometeorological variables
       (u*, w*, L, etc.)
   3 = PG dispersion coefficients for RURAL areas (computed using
       the ISCST multi-segment approximation) and MP coefficients in
       urban areas
   4 = same as 3 except PG coefficients computed using
       the MESOPUFF II eqns.

[DIAGNOSTIC FEATURE]
Method used for Lagrangian timescale for Sigma-y
(used only if MDISP=1,2 or MDISP2=1,2)
(MTAULY)                            Default: 0     ! MTAULY =  0   !
   0 = Draxler default 617.284 (s)
   1 = Computed as Lag. Length / (.75 q) -- after SCIPUFF
  10 < Direct user input (s)             -- e.g., 306.9


[DIAGNOSTIC FEATURE]
Method used for Advective-Decay timescale for Turbulence
(used only if MDISP=2 or MDISP2=2)
(MTAUADV)                           Default: 0     ! MTAUADV =  0   !
   0 = No turbulence advection
   1 = Computed (OPTION NOT IMPLEMENTED)
  10 < Direct user input (s)   -- e.g., 800


Method used to compute turbulence sigma-v &
sigma-w using micrometeorological variables
(Used only if MDISP = 2 or MDISP2 = 2)
(MCTURB)                            Default: 1     ! MCTURB =  1   !
   1 = Standard CALPUFF subroutines
   2 = AERMOD subroutines

PG sigma-y,z adj. for roughness?    Default: 0     ! MROUGH =  0  !
(MROUGH)
   0 = no
   1 = yes

Partial plume penetration of        Default: 1     ! MPARTL =  1  !
elevated inversion?
(MPARTL)
   0 = no
   1 = yes

Strength of temperature inversion   Default: 0     ! MTINV =  0  !
provided in PROFILE.DAT extended records?
(MTINV)
   0 = no (computed from measured/default gradients)
   1 = yes

PDF used for dispersion under convective conditions?
                                    Default: 0     ! MPDF =  0  !
(MPDF)
   0 = no
   1 = yes
```

```
Sub-Grid TIBL module used for shore line?
                                        Default: 0     ! MSGTIBL = 0  !
(MSGTIBL)
   0 = no
   1 = yes

Boundary conditions (concentration) modeled?
                                        Default: 0     ! MBCON = 0  !
(MBCON)
   0 = no
   1 = yes, using formatted BCON.DAT file
   2 = yes, using unformatted CONC.DAT file

Note:  MBCON > 0 requires that the last species modeled
       be 'BCON'.  Mass is placed in species BCON when
       generating boundary condition puffs so that clean
       air entering the modeling domain can be simulated
       in the same way as polluted air.  Specify zero
       emission of species BCON for all regular sources.


Individual source contributions saved?
                                        Default: 0     ! MSOURCE = 0  !
(MSOURCE)
   0 = no
   1 = yes


Analyses of fogging and icing impacts due to emissions from
arrays of mechanically-forced cooling towers can be performed
using CALPUFF in conjunction with a cooling tower emissions
processor (CTEMISS) and its associated postprocessors.  Hourly
emissions of water vapor and temperature from each cooling tower
cell are computed for the current cell configuration and ambient
conditions by CTEMISS. CALPUFF models the dispersion of these
emissions and provides cloud information in a specialized format
for further analysis. Output to FOG.DAT is provided in either
'plume mode' or 'receptor mode' format.

Configure for FOG Model output?
                                        Default: 0     ! MFOG =  0   !
(MFOG)
   0 = no
   1 = yes  - report results in PLUME Mode format
   2 = yes  - report results in RECEPTOR Mode format


Test options specified to see if
they conform to regulatory
values? (MREG)                          Default: 1     ! MREG =  1   !

   0 = NO checks are made
   1 = Technical options must conform to USEPA
       Long Range Transport (LRT) guidance
                  METFM    1 or 2
                  AVET     60. (min)
                  PGTIME   60. (min)
                  MGAUSS   1
                  MCTADJ   3
                  MTRANS   1
                  MTIP     1
                  MCHEM    1 or 3 (if modeling SOx, NOx)
                  MWET     1
                  MDRY     1
                  MDISP    2 or 3
                  MPDF     0 if MDISP=3
                           1 if MDISP=2
                  MROUGH   0
                  MPARTL   1
                  SYTDEP   550. (m)
                  MHFTSZ   0
                  SVMIN    0.5 (m/s)
```

```
!END!


------------------------------------------------------------------------------

INPUT GROUP: 3a, 3b -- Species list
-------------------

------------
Subgroup (3a)
------------

  The following species are modeled:

! CSPEC =          SO2 !         !END!
! CSPEC =          SO4 !         !END!
! CSPEC =          NOX !         !END!
! CSPEC =         HNO3 !         !END!
! CSPEC =          NO3 !         !END!
! CSPEC =           EC !         !END!
! CSPEC =          SOA !         !END!
! CSPEC =          PMF !         !END!
! CSPEC =          PMC !         !END!

                                                    Dry                OUTPUT GROUP
    SPECIES          MODELED          EMITTED      DEPOSITED             NUMBER
     NAME         (0=NO, 1=YES)    (0=NO, 1=YES)   (0=NO,               (0=NONE,
   (Limit: 12                                       1=COMPUTED-GAS       1=1st CGRUP,
    Characters                                      2=COMPUTED-PARTICLE  2=2nd CGRUP,
    in length)                                      3=USER-SPECIFIED)    3= etc.)

!          SO2  =         1,              1,          1,                 0  !
!          SO4  =         1,              1,          2,                 0  !
!          NOX  =         1,              1,          1,                 0  !
!         HNO3  =         1,              1,          1,                 0  !
!          NO3  =         1,              1,          2,                 0  !
!           EC  =         1,              1,          2,                 0  !
!          SOA  =         1,              1,          2,                 0  !
!          PMF  =         1,              1,          2,                 0  !
!          PMC  =         1,              1,          2,                 0  !

!END!

  Note:  The last species in (3a) must be 'BCON' when using the
         boundary condition option (MBCON > 0).  Species BCON should
         typically be modeled as inert (no chem transformation or
         removal).


-------------
Subgroup (3b)
-------------
  The following names are used for Species-Groups in which results
  for certain species are combined (added) prior to output.  The
  CGRUP name will be used as the species name in output files.
  Use this feature to model specific particle-size distributions
  by treating each size-range as a separate species.
  Order must be consistent with 3(a) above.



------------------------------------------------------------------------------


INPUT GROUP: 4 -- Map Projection and Grid control parameters
--------------

     Projection for all (X,Y):
     -------------------------

     Map projection
```

```
(PMAP)                    Default: UTM    ! PMAP = LCC  !

    UTM :  Universal Transverse Mercator
    TTM :  Tangential Transverse Mercator
    LCC :  Lambert Conformal Conic
     PS :  Polar Stereographic
     EM :  Equatorial Mercator
   LAZA :  Lambert Azimuthal Equal Area

False Easting and Northing (km) at the projection origin
(Used only if PMAP= TTM, LCC, or LAZA)
(FEAST)                   Default=0.0     ! FEAST  = 0.000  !
(FNORTH)                  Default=0.0     ! FNORTH = 0.000  !

UTM zone (1 to 60)
(Used only if PMAP=UTM)
(IUTMZN)                  No Default      ! IUTMZN =   0   !

Hemisphere for UTM projection?
(Used only if PMAP=UTM)
(UTMHEM)                  Default: N      ! UTMHEM = N  !
    N   :  Northern hemisphere projection
    S   :  Southern hemisphere projection

Latitude and Longitude (decimal degrees) of projection origin
(Used only if PMAP= TTM, LCC, PS, EM, or LAZA)
(RLAT0)                   No Default      ! RLAT0 = 40.0N !
(RLON0)                   No Default      ! RLON0 = 97.0W !

    TTM :  RLON0 identifies central (true N/S) meridian of projection
           RLAT0 selected for convenience
    LCC :  RLON0 identifies central (true N/S) meridian of projection
           RLAT0 selected for convenience
    PS  :  RLON0 identifies central (grid N/S) meridian of projection
           RLAT0 selected for convenience
    EM  :  RLON0 identifies central meridian of projection
           RLAT0 is REPLACED by 0.0N (Equator)
    LAZA:  RLON0 identifies longitude of tangent-point of mapping plane
           RLAT0 identifies latitude of tangent-point of mapping plane

Matching parallel(s) of latitude (decimal degrees) for projection
(Used only if PMAP= LCC or PS)
(XLAT1)                   No Default      ! XLAT1 = 33.0N !
(XLAT2)                   No Default      ! XLAT2 = 45.0N !

    LCC :  Projection cone slices through Earth's surface at XLAT1 and XLAT2
    PS  :  Projection plane slices through Earth at XLAT1
           (XLAT2 is not used)

----------
Note:  Latitudes and longitudes should be positive, and include a
       letter N,S,E, or W indicating north or south latitude, and
       east or west longitude.  For example,
       35.9  N Latitude  =  35.9N
       118.7 E Longitude = 118.7E


Datum-region
------------

The Datum-Region for the coordinates is identified by a character
string.  Many mapping products currently available use the model of the
Earth known as the World Geodetic System 1984 (WGS-84).  Other local
models may be in use, and their selection in CALMET will make its output
consistent with local mapping products.  The list of Datum-Regions with
official transformation parameters is provided by the National Imagery and
Mapping Agency (NIMA).

NIMA Datum - Regions(Examples)
------------------------------------------------------------------------------
WGS-84    WGS-84 Reference Ellipsoid and Geoid, Global coverage (WGS84)
NAS-C     NORTH AMERICAN 1927 Clarke 1866 Spheroid, MEAN FOR CONUS (NAD27)
NAR-C     NORTH AMERICAN 1983 GRS 80 Spheroid, MEAN FOR CONUS (NAD83)
```

```
     NWS-84    NWS 6370KM Radius, Sphere
     ESR-S     ESRI REFERENCE 6371KM Radius, Sphere

     Datum-region for output coordinates
     (DATUM)                    Default: WGS-G     ! DATUM = NWS-84  !
                                                 *** Same as MM5 ***


METEOROLOGICAL Grid:

     Rectangular grid defined for projection PMAP,
     with X the Easting and Y the Northing coordinate

           No. X grid cells (NX)      No default     ! NX = 56  !
           No. Y grid cells (NY)      No default     ! NY = 46  !
       No. vertical layers (NZ)       No default     ! NZ =   10  !

         Grid spacing (DGRIDKM)       No default     ! DGRIDKM = 12 !
                                      Units: km

              Cell face heights
                  (ZFACE(nz+1))       No defaults
                                      Units: m
          ! ZFACE =0.,20.,40.,80.,160.,320.,640.,1200.,2000.,3000.,4000. !

           Reference Coordinates
          of SOUTHWEST corner of
                grid cell(1, 1):

           X coordinate (XORIGKM)     No default     ! XORIGKM = -1392 !
           Y coordinate (YORIGKM)     No default     ! YORIGKM = -312 !
                                      Units: km


COMPUTATIONAL Grid:

     The computational grid is identical to or a subset of the MET. grid.
     The lower left (LL) corner of the computational grid is at grid point
     (IBCOMP, JBCOMP) of the MET. grid.  The upper right (UR) corner of the
     computational grid is at grid point (IECOMP, JECOMP) of the MET. grid.
     The grid spacing of the computational grid is the same as the MET. grid.

        X index of LL corner (IBCOMP)      No default     ! IBCOMP =  1  !
                  (1 <= IBCOMP <= NX)

        Y index of LL corner (JBCOMP)      No default     ! JBCOMP =  1  !
                  (1 <= JBCOMP <= NY)


        X index of UR corner (IECOMP)      No default     ! IECOMP = 56 !
                  (1 <= IECOMP <= NX)

        Y index of UR corner (JECOMP)      No default     ! JECOMP = 46 !
                  (1 <= JECOMP <= NY)



SAMPLING Grid (GRIDDED RECEPTORS):

     The lower left (LL) corner of the sampling grid is at grid point
     (IBSAMP, JBSAMP) of the MET. grid.  The upper right (UR) corner of the
     sampling grid is at grid point (IESAMP, JESAMP) of the MET. grid.
     The sampling grid must be identical to or a subset of the computational
     grid.  It may be a nested grid inside the computational grid.
     The grid spacing of the sampling grid is DGRIDKM/MESHDN.

        Logical flag indicating if gridded
        receptors are used (LSAMP)         Default: T     ! LSAMP = F !
        (T=yes, F=no)

        X index of LL corner (IBSAMP)      No default     ! IBSAMP =  1 !
         (IBCOMP <= IBSAMP <= IECOMP)
```

```
        Y index of LL corner (JBSAMP)      No default     ! JBSAMP =  1 !
         (JBCOMP <= JBSAMP <= JECOMP)


        X index of UR corner (IESAMP)      No default     ! IESAMP = 56 !
         (IBCOMP <= IESAMP <= IECOMP)

        Y index of UR corner (JESAMP)      No default     ! JESAMP = 46 !
         (JBCOMP <= JESAMP <= JECOMP)


       Nesting factor of the sampling
        grid (MESHDN)                      Default: 1     ! MESHDN =  1  !
        (MESHDN is an integer >= 1)

!END!


-------------------------------------------------------------------------------


INPUT GROUP: 5 -- Output Options
--------------
                                          *                          *
     FILE                        DEFAULT VALUE             VALUE THIS RUN
     ----                        -------------             --------------

   Concentrations (ICON)              1                   !  ICON =  1   !
   Dry Fluxes (IDRY)                  1                   !  IDRY =  1   !
   Wet Fluxes (IWET)                  1                   !  IWET =  1   !
   2D Temperature (IT2D)              0                   !  IT2D =  0   !
   2D Density (IRHO)                  0                   !  IRHO =  0   !
   Relative Humidity (IVIS)           1                   !  IVIS =  1   !
    (RH file is required for
     VISIBILITY analyses)
   Use data compression option in output file?
   (LCOMPRS)                            Default: T        ! LCOMPRS = T !

   *
    0 = Do not create file, 1 = create file



    QA PLOT FILE OUTPUT OPTION:

       Create a standard series of output files (e.g.
       locations of sources, receptors, grids ...)
       suitable for plotting?
       (IQAPLOT)                        Default: 1        ! IQAPLOT =  1  !
         0 = no
         1 = yes


    DIAGNOSTIC MASS FLUX OUTPUT OPTIONS:

       Mass flux across specified boundaries
       for selected species reported hourly?
       (IMFLX)                          Default: 0        ! IMFLX =  0  !
         0 = no
         1 = yes (FLUXBDY.DAT and MASSFLX.DAT filenames
                  are specified in Input Group 0)

       Mass balance for each species
       reported hourly?
       (IMBAL)                          Default: 0        ! IMBAL =  1  !
         0 = no
         1 = yes (MASSBAL.DAT filename is
              specified in Input Group 0)


    LINE PRINTER OUTPUT OPTIONS:

       Print concentrations (ICPRT)     Default: 0        ! ICPRT =  0   !
```

```
       Print dry fluxes (IDPRT)        Default: 0         ! IDPRT =  0   !
       Print wet fluxes (IWPRT)        Default: 0         ! IWPRT =  0   !
       (0 = Do not print, 1 = Print)

       Concentration print interval
       (ICFRQ) in hours                Default: 1         ! ICFRQ =  24   !
       Dry flux print interval
       (IDFRQ) in hours                Default: 1         ! IDFRQ =  1   !
       Wet flux print interval
       (IWFRQ) in hours                Default: 1         ! IWFRQ =  1   !

       Units for Line Printer Output
       (IPRTU)                         Default: 1         ! IPRTU =  1   !
                    for              for
                Concentration    Deposition
           1 =       g/m**3         g/m**2/s
           2 =      mg/m**3        mg/m**2/s
           3 =      ug/m**3        ug/m**2/s
           4 =      ng/m**3        ng/m**2/s
           5 =     Odour Units

       Messages tracking progress of run
       written to the screen ?
       (IMESG)                         Default: 2         ! IMESG =  2   !
         0 = no
         1 = yes (advection step, puff ID)
         2 = yes (2006JJJHH, # old puffs, # emitted puffs)


     SPECIES (or GROUP for combined species) LIST FOR OUTPUT OPTIONS

             ---- CONCENTRATIONS ---- ------ DRY FLUXES ------ ------ WET FLUXES ------ -- MASS
FLUX --
   SPECIES
   /GROUP    PRINTED?  SAVED ON DISK? PRINTED?  SAVED ON DISK? PRINTED?  SAVED ON DISK? SAVED ON
DISK?
   -------   ----------------------- ----------------------- ----------------------- ---------
------
!    SO2 =     0,           1,           0,           1,           0,           1,           0  !
!    NOX =     0,           1,           0,           1,           0,           1,           0  !
!   HNO3 =     0,           1,           0,           1,           0,           1,           0  !
!    SO4 =     0,           1,           0,           1,           0,           1,           0  !
!    NO3 =     0,           1,           0,           1,           0,           1,           0  !
!     EC =     0,           1,           0,           1,           0,           1,           0  !
!    SOA =     0,           1,           0,           1,           0,           1,           0  !
!    PMC =     0,           1,           0,           1,           0,           1,           0  !
!    PMF =     0,           1,           0,           1,           0,           1,           0  !

  Note:  Species BCON (for MBCON > 0) does not need to be saved on disk.


     OPTIONS FOR PRINTING "DEBUG" QUANTITIES (much output)

       Logical for debug output
       (LDEBUG)                                Default: F     ! LDEBUG = F !

       First puff to track
       (IPFDEB)                                Default: 1     ! IPFDEB =  1  !

       Number of puffs to track
       (NPFDEB)                                Default: 1     ! NPFDEB =  1  !

       Met. period to start output
       (NN1)                                   Default: 1     ! NN1 =  1   !

       Met. period to end output
       (NN2)                                   Default: 10    ! NN2 =  10  !

!END!


------------------------------------------------------------------------------
```

```
INPUT GROUP: 6a, 6b, & 6c -- Subgrid scale complex terrain inputs
-------------------------

---------------
Subgroup (6a)
---------------
       Number of terrain features (NHILL)       Default: 0     ! NHILL =  0   !

       Number of special complex terrain
       receptors  (NCTREC)                      Default: 0     ! NCTREC =  0   !

       Terrain and CTSG Receptor data for
       CTSG hills input in CTDM format ?
       (MHILL)                                  No Default     ! MHILL =  2   !
       1 = Hill and Receptor data created
           by CTDM processors & read from
           HILL.DAT and HILLRCT.DAT files
       2 = Hill data created by OPTHILL &
           input below in Subgroup (6b);
           Receptor data in Subgroup (6c)

       Factor to convert horizontal dimensions  Default: 1.0   ! XHILL2M = 0. !
       to meters (MHILL=1)

       Factor to convert vertical dimensions    Default: 1.0   ! ZHILL2M = 0. !
       to meters (MHILL=1)

       X-origin of CTDM system relative to      No Default     ! XCTDMKM = 0.0E00 !
       CALPUFF coordinate system, in Kilometers (MHILL=1)

       Y-origin of CTDM system relative to      No Default     ! YCTDMKM = 0.0E00 !
       CALPUFF coordinate system, in Kilometers (MHILL=1)

! END !

---------------
Subgroup (6b)
---------------

                      1 **
     HILL information


HILL           XC        YC       THETAH  ZGRID  RELIEF    EXPO 1    EXPO 2   SCALE 1    SCALE 2
AMAX1     AMAX2
 NO.          (km)      (km)      (deg.)   (m)     (m)      (m)       (m)       (m)        (m)
(m)       (m)
----          ----      ----      ------  -----  ------    ------    ------   -------    -------
-----     -----

---------------
Subgroup (6c)
---------------

    COMPLEX TERRAIN RECEPTOR INFORMATION

                      XRCT         YRCT        ZRCT          XHH
                      (km)         (km)         (m)
                     ------       -----      ------         ----


-------------------
1
     Description of Complex Terrain Variables:
          XC, YC  = Coordinates of center of hill
          THETAH  = Orientation of major axis of hill (clockwise from
                    North)
          ZGRID   = Height of the  0  of the grid above mean sea
                    level
          RELIEF  = Height of the crest of the hill above the grid elevation
          EXPO 1  = Hill-shape exponent for the major axis
```

```
          EXPO 2  = Hill-shape exponent for the major axis
          SCALE 1 = Horizontal length scale along the major axis
          SCALE 2 = Horizontal length scale along the minor axis
          AMAX    = Maximum allowed axis length for the major axis
          BMAX    = Maximum allowed axis length for the major axis

          XRCT, YRCT = Coordinates of the complex terrain receptors
          ZRCT    = Height of the ground (MSL) at the complex terrain
                    Receptor
          XHH     = Hill number associated with each complex terrain receptor
                    (NOTE: MUST BE ENTERED AS A REAL NUMBER)

   **
     NOTE: DATA for each hill and CTSG receptor are treated as a separate
           input subgroup and therefore must end with an input group terminator.

-------------------------------------------------------------------------------


INPUT GROUP: 7 -- Chemical parameters for dry deposition of gases
--------------

      SPECIES     DIFFUSIVITY      ALPHA STAR      REACTIVITY    MESOPHYLL RESISTANCE     HENRY'S
LAW COEFFICIENT
       NAME        (cm**2/s)                                          (s/cm)
(dimensionless)
      -------     -----------      ----------      ----------    --------------------     -------
----------------

!          SO2 =     0.1509,         1000.,            8.,            0.,     0.04 !
!          NOX =     0.1656,            1.,            8.,            5.,      3.5 !
!         HNO3 =     0.1628,            1.,           18.,            0.,   0.00000008 !

!END!


-------------------------------------------------------------------------------


INPUT GROUP: 8 -- Size parameters for dry deposition of particles
--------------

     For SINGLE SPECIES, the mean and standard deviation are used to
     compute a deposition velocity for NINT (see group 9) size-ranges,
     and these are then averaged to obtain a mean deposition velocity.

     For GROUPED SPECIES, the size distribution should be explicitly
     specified (by the 'species' in the group), and the standard deviation
     for each should be entered as 0.  The model will then use the
     deposition velocity for the stated mean diameter.

      SPECIES      GEOMETRIC MASS MEAN        GEOMETRIC STANDARD
       NAME             DIAMETER                 DEVIATION
                        (microns)                (microns)
      -------      -------------------        ------------------
!          SO4 =         0.48,                     2.0  !
!          NO3 =         0.48,                     2.0  !
!           EC =         0.48,                     2.0  !
!          SOA =         0.48,                     2.0  !
!          PMC =          5.0,                     1.5  !
!          PMF =         0.48,                     2.0  !

!END!


-------------------------------------------------------------------------------


INPUT GROUP: 9 -- Miscellaneous dry deposition parameters
--------------

     Reference cuticle resistance (s/cm)
     (RCUTR)                          Default: 30    !  RCUTR = 30.0 !
```

```
     Reference ground resistance  (s/cm)
     (RGR)                          Default: 10    !    RGR = 10.0 !
     Reference pollutant reactivity
     (REACTR)                       Default: 8     ! REACTR = 8.0 !

     Number of particle-size intervals used to
     evaluate effective particle deposition velocity
     (NINT)                         Default: 9     !   NINT =  9  !

     Vegetation state in unirrigated areas
     (IVEG)                         Default: 1     !   IVEG =  1   !
        IVEG=1 for active and unstressed vegetation
        IVEG=2 for active and stressed vegetation
        IVEG=3 for inactive vegetation

!END!


-------------------------------------------------------------------------------


INPUT GROUP: 10 -- Wet Deposition Parameters
---------------

                      Scavenging Coefficient -- Units: (sec)**(-1)

       Pollutant      Liquid Precip.       Frozen Precip.
       ---------      --------------       --------------
!          SO2 =         3.0E-05,             0.0E00 !
!          SO4 =         1.0E-04,            3.0E-05 !
!          NOX =          0.0E00,             0.0E00 !
!         HNO3 =         6.0E-05,             0.0E00 !
!          NO3 =         1.0E-04,            3.0E-05 !
!           EC =         1.0E-04,            3.0E-05 !
!          SOA =         1.0E-04,            3.0E-05 !
!          PMC =         1.0E-04,            3.0E-05 !
!          PMF =         1.0E-04,            3.0E-05 !

!END!


-------------------------------------------------------------------------------


INPUT GROUP: 11 -- Chemistry Parameters
---------------

     Ozone data input option (MOZ)     Default: 1           ! MOZ =  1  !
     (Used only if MCHEM = 1, 3, or 4)
        0 = use a monthly background ozone value
        1 = read hourly ozone concentrations from
            the OZONE.DAT data file

     Monthly ozone concentrations
     (Used only if MCHEM = 1, 3, or 4 and
      MOZ = 0 or MOZ = 1 and all hourly O3 data missing)
     (BCKO3) in ppb                    Default: 12*80.      !  BCKO3 = 12*60. !

     Monthly ammonia concentrations
     (Used only if MCHEM = 1, or 3)
     (BCKNH3) in ppb                   Default: 12*10.      !  BCKNH3 = 12*1.0 !

     Nighttime SO2 loss rate (RNITE1)
     in percent/hour                   Default: 0.2         ! RNITE1 = .2 !

     Nighttime NOx loss rate (RNITE2)
     in percent/hour                   Default: 2.0         ! RNITE2 = 2.0 !

     Nighttime HNO3 formation rate (RNITE3)
     in percent/hour                   Default: 2.0         ! RNITE3 = 2.0 !

     H2O2 data input option (MH2O2)    Default: 1           ! MH2O2 =  0   !
```

```
     (Used only if MAQCHEM = 1)
        0 = use a monthly background H2O2 value
        1 = read hourly H2O2 concentrations from
            the H2O2.DAT data file

     Monthly H2O2 concentrations
     (Used only if MQACHEM = 1 and
      MH2O2 = 0 or MH2O2 = 1 and all hourly H2O2 data missing)
     (BCKH2O2) in ppb                  Default: 12*1.        !  BCKH2O2 = 12*1.0 !


 --- Data for SECONDARY ORGANIC AEROSOL (SOA) Option
     (used only if MCHEM = 4)

     The SOA module uses monthly values of:
          Fine particulate concentration in ug/m^3 (BCKPMF)
          Organic fraction of fine particulate     (OFRAC)
          VOC / NOX ratio (after reaction)         (VCNX)
     to characterize the air mass when computing
     the formation of SOA from VOC emissions.
     Typical values for several distinct air mass types are:

        Month    1    2    3    4    5    6    7    8    9   10   11   12
                Jan  Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec

     Clean Continental
        BCKPMF   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
        OFRAC  .15  .15  .20  .20  .20  .20  .20  .20  .20  .20  .20  .15
        VCNX    50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.

     Clean Marine (surface)
        BCKPMF  .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5
        OFRAC  .25  .25  .30  .30  .30  .30  .30  .30  .30  .30  .30  .25
        VCNX    50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.

     Urban - low biogenic (controls present)
        BCKPMF  30.  30.  30.  30.  30.  30.  30.  30.  30.  30.  30.  30.
        OFRAC  .20  .20  .25  .25  .25  .25  .25  .25  .20  .20  .20  .20
        VCNX     4.   4.   4.   4.   4.   4.   4.   4.   4.   4.   4.   4.

     Urban - high biogenic (controls present)
        BCKPMF  60.  60.  60.  60.  60.  60.  60.  60.  60.  60.  60.  60.
        OFRAC  .25  .25  .30  .30  .30  .55  .55  .55  .35  .35  .35  .25
        VCNX    15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.

     Regional Plume
        BCKPMF  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
        OFRAC  .20  .20  .25  .35  .25  .40  .40  .40  .30  .30  .30  .20
        VCNX    15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.

     Urban - no controls present
        BCKPMF 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100.
        OFRAC  .30  .30  .35  .35  .35  .55  .55  .55  .35  .35  .35  .30
        VCNX     2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.

     Default: Clean Continental
     !  BCKPMF = 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00 !
     !  OFRAC  = 0.15, 0.15, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.15 !
     !  VCNX   = 50.0, 50.0, 50.0, 50.0, 50.0, 50.0, 50.0, 50.0, 50.0, 50.0, 50.0, 50.0 !


!END!


-------------------------------------------------------------------------------


INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters
---------------

     Horizontal size of puff (m) beyond which
     time-dependent dispersion equations (Heffter)
     are used to determine sigma-y and
```

```
sigma-z (SYTDEP)                          Default: 550.   ! SYTDEP = 550.0 !

Switch for using Heffter equation for sigma z
as above (0 = Not use Heffter; 1 = use Heffter
(MHFTSZ)                                  Default: 0      ! MHFTSZ =  0 !

Stability class used to determine plume
growth rates for puffs above the boundary
layer (JSUP)                              Default: 5      ! JSUP =  5   !

Vertical dispersion constant for stable
conditions (k1 in Eqn. 2.7-3)  (CONK1)    Default: 0.01   ! CONK1 = .01 !

Vertical dispersion constant for neutral/
unstable conditions (k2 in Eqn. 2.7-4)
(CONK2)                                   Default: 0.1    ! CONK2 = .1 !

Factor for determining Transition-point from
Schulman-Scire to Huber-Snyder Building Downwash
scheme (SS used for Hs < Hb + TBD * HL)
(TBD)                                     Default: 0.5    ! TBD = .5 !
   TBD < 0   ==> always use Huber-Snyder
   TBD = 1.5 ==> always use Schulman-Scire
   TBD = 0.5 ==> ISC Transition-point

Range of land use categories for which
urban dispersion is assumed
(IURB1, IURB2)                            Default: 10     ! IURB1 =  10  !
                                                   19     ! IURB2 =  19  !

Site characterization parameters for single-point Met data files ---------
(needed for METFM = 2,3,4,5)

   Land use category for modeling domain
   (ILANDUIN)                             Default: 20     ! ILANDUIN =  20  !

   Roughness length (m) for modeling domain
   (Z0IN)                                 Default: 0.25   ! Z0IN = .25 !

   Leaf area index for modeling domain
   (XLAIIN)                               Default: 3.0    ! XLAIIN = 3.0 !

   Elevation above sea level (m)
   (ELEVIN)                               Default: 0.0    ! ELEVIN = .0 !

   Latitude (degrees) for met location
   (XLATIN)                               Default: -999.  ! XLATIN = -999.0 !

   Longitude (degrees) for met location
   (XLONIN)                               Default: -999.  ! XLONIN = -999.0 !

Specialized information for interpreting single-point Met data files -----

   Anemometer height (m) (Used only if METFM = 2,3)
   (ANEMHT)                               Default: 10.    ! ANEMHT = 10.0 !

   Form of lateral turbulance data in PROFILE.DAT file
   (Used only if METFM = 4,5 or MTURBVW = 1 or 3)
   (ISIGMAV)                              Default: 1      ! ISIGMAV =  1  !
       0 = read sigma-theta
       1 = read sigma-v

   Choice of mixing heights (Used only if METFM = 4)
   (IMIXCTDM)                             Default: 0      ! IMIXCTDM =  0  !
       0 = read PREDICTED mixing heights
       1 = read OBSERVED mixing heights

Maximum length of a slug (met. grid units)
(XMXLEN)                                  Default: 1.0    ! XMXLEN = 1.0 !

Maximum travel distance of a puff/slug (in
grid units) during one sampling step
(XSAMLEN)                                 Default: 1.0    ! XSAMLEN = 1.0 !
```

```
     Maximum Number of slugs/puffs release from
     one source during one time step
     (MXNEW)                                  Default: 99     ! MXNEW =  99   !

     Maximum Number of sampling steps for
     one puff/slug during one time step
     (MXSAM)                                  Default: 99     ! MXSAM =  99  !

     Number of iterations used when computing
     the transport wind for a sampling step
     that includes gradual rise (for CALMET
     and PROFILE winds)
     (NCOUNT)                                 Default: 2      ! NCOUNT =  2   !

     Minimum sigma y for a new puff/slug (m)
     (SYMIN)                                  Default: 1.0    ! SYMIN = 1.0  !

     Minimum sigma z for a new puff/slug (m)
     (SZMIN)                                  Default: 1.0    ! SZMIN = 1.0  !

     Default minimum turbulence velocities sigma-v and sigma-w
     for each stability class over land and over water (m/s)
     (SVMIN(12) and SWMIN(12))

                    ----------  LAND  ----------       ---------  WATER  ----------
        Stab Class :  A    B    C    D    E    F         A    B    C    D    E    F
                      ---  ---  ---  ---  ---  ---       ---  ---  ---  ---  ---  ---
     Default SVMIN : .50, .50, .50, .50, .50, .50,      .37, .37, .37, .37, .37, .37
     Default SWMIN : .20, .12, .08, .06, .03, .016,     .20, .12, .08, .06, .03, .016

          * SVMIN = 0.500, 0.500, 0.500, 0.500, 0.500, 0.500,  0.370, 0.370, 0.370, 0.370,
0.370, 0.370 *
          ! SVMIN = 12* 0.5 ! MREG = 1 requirement

          ! SWMIN = 0.200, 0.120, 0.080, 0.060, 0.030, 0.016,  0.200, 0.120, 0.080, 0.060,
0.030, 0.016!

     Divergence criterion for dw/dz across puff
     used to initiate adjustment for horizontal
     convergence (1/s)
     Partial adjustment starts at CDIV(1), and
     full adjustment is reached at CDIV(2)
     (CDIV(2))                                Default: 0.0,0.0  ! CDIV = 0.0, 0.0 !

     Minimum wind speed (m/s) allowed for
     non-calm conditions. Also used as minimum
     speed returned when using power-law
     extrapolation toward surface
     (WSCALM)                                 Default: 0.5    ! WSCALM = .5 !

     Maximum mixing height (m)
     (XMAXZI)                                 Default: 3000.  ! XMAXZI = 3000.0 !

     Minimum mixing height (m)
     (XMINZI)                                 Default: 50.    ! XMINZI = 50.0 !

     Default wind speed classes --
     5 upper bounds (m/s) are entered;
     the 6th class has no upper limit
     (WSCAT(5))                     Default   :
                                    ISC RURAL : 1.54, 3.09, 5.14, 8.23, 10.8 (10.8+)

                               Wind Speed Class :  1     2     3     4     5
                                                  ---   ---   ---   ---   ---
                                      ! WSCAT = 1.54, 3.09, 5.14, 8.23, 10.80 !

     Default wind speed profile power-law
     exponents for stabilities 1-6
     (PLX0(6))                      Default   : ISC RURAL values
                                    ISC RURAL : .07, .07, .10, .15, .35, .55
                                    ISC URBAN : .15, .15, .20, .25, .30, .30
```

```
                          Stability Class :  A     B     C     D     E     F
                                            ---   ---   ---   ---   ---   ---
                                   ! PLX0 = 0.07, 0.07, 0.10, 0.15, 0.35, 0.55 !

Default potential temperature gradient
for stable classes E, F (degK/m)
(PTG0(2))                       Default: 0.020, 0.035
                                   ! PTG0 = 0.020,   0.035 !

Default plume path coefficients for
each stability class (used when option
for partial plume height terrain adjustment
is selected -- MCTADJ=3)
(PPC(6))                  Stability Class :  A     B     C     D     E     F
                             Default  PPC : .50,  .50,  .50,  .50,  .35,  .35
                                            ---   ---   ---   ---   ---   ---
                                   !  PPC = 0.50, 0.50, 0.50, 0.50, 0.35, 0.35 !

Slug-to-puff transition criterion factor
equal to sigma-y/length of slug
(SL2PF)                              Default: 10.        ! SL2PF = 10.0!

Puff-splitting control variables ------------------------

  VERTICAL SPLIT
  --------------

  Number of puffs that result every time a puff
  is split - nsplit=2 means that 1 puff splits
  into 2
  (NSPLIT)                           Default:   3        ! NSPLIT =  3  !

  Time(s) of a day when split puffs are eligible to
  be split once again; this is typically set once
  per day, around sunset before nocturnal shear develops.
  24 values: 0 is midnight (00:00) and 23 is 11 PM (23:00)
  0=do not re-split    1=eligible for re-split
  (IRESPLIT(24))                     Default:  Hour 17 = 1
  !  IRESPLIT = 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0 !

  Split is allowed only if last hour's mixing
  height (m) exceeds a minimum value
  (ZISPLIT)                          Default: 100.       ! ZISPLIT = 100.0 !

  Split is allowed only if ratio of last hour's
  mixing ht to the maximum mixing ht experienced
  by the puff is less than a maximum value (this
  postpones a split until a nocturnal layer develops)
  (ROLDMAX)                          Default: 0.25       ! ROLDMAX = 0.25 !


  HORIZONTAL SPLIT
  ----------------

  Number of puffs that result every time a puff
  is split - nsplith=5 means that 1 puff splits
  into 5
  (NSPLITH)                          Default:   5        ! NSPLITH =  5  !

  Minimum sigma-y (Grid Cells Units) of puff
  before it may be split
  (SYSPLITH)                         Default:  1.0       ! SYSPLITH = 1.0 !

  Minimum puff elongation rate (SYSPLITH/hr) due to
  wind shear, before it may be split
  (SHSPLITH)                         Default:  2.        ! SHSPLITH = 2.0 !

  Minimum concentration (g/m^3) of each
  species in puff before it may be split
  Enter array of NSPEC values; if a single value is
  entered, it will be used for ALL species
  (CNSPLITH)                         Default:  1.0E-07   ! CNSPLITH = 1.0E-07 !
```

```
     Integration control variables ------------------------

       Fractional convergence criterion for numerical SLUG
       sampling integration
       (EPSSLUG)                          Default:   1.0e-04  ! EPSSLUG = 1.0E-04 !

       Fractional convergence criterion for numerical AREA
       source integration
       (EPSAREA)                          Default:   1.0e-06  ! EPSAREA = 1.0E-06 !

       Trajectory step-length (m) used for numerical rise
       integration
       (DSRISE)                           Default:   1.0      ! DSRISE = 1.0 !

     Boundary Condition (BC) Puff control variables ------------------------

       Minimum height (m) to which BC puffs are mixed as they are emitted
       (MBCON=2 ONLY).  Actual height is reset to the current mixing height
       at the release point if greater than this minimum.
       (HTMINBC)                          Default:   500.     ! HTMINBC = 500. !

       Search radius (km) about a receptor for sampling nearest BC puff.
       BC puffs are typically emitted with a spacing of one grid cell
       length, so the search radius should be greater than DGRIDKM.
       (RSAMPBC)                          Default:   10.      ! RSAMPBC = 10 !

       Near-Surface depletion adjustment to concentration profile used when
       sampling BC puffs?
       (MDEPBC)                           Default:   1        ! MDEPBC = 1  !
          0 = Concentration is NOT adjusted for depletion
          1 = Adjust Concentration for depletion

!END!


--------------------------------------------------------------------------------


INPUT GROUPS: 13a, 13b, 13c, 13d -- Point source parameters
--------------------------------

---------------
Subgroup (13a)
---------------

     Number of point sources with
     parameters provided below      (NPT1)  No default  !  NPT1 = 1 !

     Units used for point source
     emissions below                (IPTU)  Default: 1  !  IPTU =   1 !
           1 =        g/s
           2 =       kg/hr
           3 =       lb/hr
           4 =     tons/yr
           5 =     Odour Unit * m**3/s  (vol. flux of odour compound)
           6 =     Odour Unit * m**3/min
           7 =     metric tons/yr

     Number of source-species
     combinations with variable
     emissions scaling factors
     provided below in (13d)        (NSPT1) Default: 0  !  NSPT1 =  0  !

     Number of point sources with
     variable emission parameters
     provided in external file      (NPT2)  No default  !  NPT2 =  0  !

     (If NPT2 > 0, these point
     source emissions are read from
     the file: PTEMARB.DAT)

!END!
```

```
---------------
Subgroup (13b)
---------------
                                    a
          POINT SOURCE: CONSTANT DATA
          ----------------------------
                                                                                b          c
  Source      X UTM     Y UTM     Stack   Base     Stack    Exit  Exit    Bldg.  Emission
   No.     Coordinate Coordinate Height Elevation Diameter  Vel.  Temp.   Dwash   Rates
              (km)      (km)       (m)      (m)       (m)  (m/s) (deg. K)
  ------   ---------- ---------- ------  ------   -------- ----- -------- ----- --------
*** Max short-term  emission rates ***
      X       Y         Ht Elev Diam Vel   Temp  DW SO2      SO4      NOX   HNO3 NO3      EC
SOA    PMF PMC
! SRCNAM = G02_EGU !
! X = -1198.132,24.325,182.88,2275.416,7.312152,19.5072,400.9277778,0,
500.4041816,0,320.1831343,0,0,0.011629394,0.006765176,0.540710912,0.298193426 !
! END !
--------

    a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.

     SRCNAM  is a 12-character name for a source
             (No default)
     X       is an array holding the source data listed by the column headings
             (No default)
     SIGYZI  is an array holding the initial sigma-y and sigma-z (m)
             (Default: 0.,0.)
     FMFAC   is a vertical momentum flux factor (0. or 1.0) used to represent
             the effect of rain-caps or other physical configurations that
             reduce momentum rise associated with the actual exit velocity.
             (Default: 1.0  -- full momentum used)
     ZPLTFM  is the platform height (m) for sources influenced by an isolated
             structure that has a significant open area between the surface
             and the bulk of the structure, such as an offshore oil platform.
             The Base Elevation is that of the surface (ground or ocean),
             and the Stack Height is the release height above the Base (not
             above the platform).  Building heights entered in Subgroup 13c
             must be those of the buildings on the platform, measured from
             the platform deck.  ZPLTFM is used only with MBDW=1 (ISC
             downwash method) for sources with building downwash.
             (Default: 0.0)

    b
     0. = No building downwash modeled
     1. = Downwash modeled for buildings resting on the surface
     2. = Downwash modeled for buildings raised above the surface (ZPLTFM > 0.)
     NOTE: must be entered as a REAL number (i.e., with decimal point)

    c
     An emission rate must be entered for every pollutant modeled.
     Enter emission rate of zero for secondary pollutants that are
     modeled, but not emitted.  Units are specified by IPTU
     (e.g. 1 for g/s).

---------------
Subgroup (13c)
---------------

           BUILDING DIMENSION DATA FOR SOURCES SUBJECT TO DOWNWASH
           ------------------------------------------------------
Source                                                                    a
 No.       Effective building height, width, length and X/Y offset (in meters)
           every 10 degrees.  LENGTH, XBADJ, and YBADJ are only needed for
           MBDW=2 (PRIME downwash option)
------     ---------------------------------------------------------------


--------

    a
```

```
     Building height, width, length, and X/Y offset from the source are treated
     as a separate input subgroup for each source and therefore must end with
     an input group terminator.

---------------
Subgroup (13d)
---------------
                                          a
          POINT SOURCE: VARIABLE EMISSIONS DATA
          -------------------------------------

     Use this subgroup to describe temporal variations in the emission
     rates given in 13b.  Factors entered multiply the rates in 13b.
     Skip sources here that have constant emissions.  For more elaborate
     variation in source parameters, use PTEMARB.DAT and NPT2 > 0.

     IVARY determines the type of variation, and is source-specific:
     (IVARY)                              Default: 0
           0 =       Constant
           1 =       Diurnal cycle (24 scaling factors: hours 1-24)
           2 =       Monthly cycle (12 scaling factors: months 1-12)
           3 =       Hour & Season (4 groups of 24 hourly scaling factors,
                                    where first group is DEC-JAN-FEB)
           4 =       Speed & Stab. (6 groups of 6 scaling factors, where
                                    first group is Stability Class A,
                                    and the speed classes have upper
                                    bounds (m/s) defined in Group 12
           5 =       Temperature   (12 scaling factors, where temperature
                                    classes have upper bounds (C) of:
                                    0, 5, 10, 15, 20, 25, 30, 35, 40,
                                    45, 50, 50+)



--------
    a
     Data for each species are treated as a separate input subgroup
     and therefore must end with an input group terminator.


--------------------------------------------------------------------------------


INPUT GROUPS: 14a, 14b, 14c, 14d -- Area source parameters
---------------------------------

---------------
Subgroup (14a)
---------------

     Number of polygon area sources with
     parameters specified below (NAR1)       No default  !  NAR1 =  0   !

     Units used for area source
     emissions below            (IARU)       Default: 1  !  IARU =   1  !
           1 =        g/m**2/s
           2 =       kg/m**2/hr
           3 =       lb/m**2/hr
           4 =     tons/m**2/yr
           5 =     Odour Unit * m/s  (vol. flux/m**2 of odour compound)
           6 =     Odour Unit * m/min
           7 =     metric tons/m**2/yr

     Number of source-species
     combinations with variable
     emissions scaling factors
     provided below in (14d)        (NSAR1) Default: 0  !  NSAR1 =  0  !

     Number of buoyant polygon area sources
     with variable location and emission
     parameters (NAR2)                      No default  !  NAR2 =  0   !
     (If NAR2 > 0, ALL parameter data for
     these sources are read from the file: BAEMARB.DAT)
```

```
!END!

---------------
Subgroup (14b)
---------------
                                  a
          AREA SOURCE: CONSTANT DATA
          --------------------------
                                                          b
Source           Effect.    Base      Initial    Emission
 No.             Height   Elevation   Sigma z     Rates
                   (m)       (m)        (m)
-------          ------    ------     --------   ---------


--------
    a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.
    b
     An emission rate must be entered for every pollutant modeled.
     Enter emission rate of zero for secondary pollutants that are
     modeled, but not emitted.  Units are specified by IARU
     (e.g. 1 for g/m**2/s).

---------------
Subgroup (14c)
---------------

           COORDINATES (UTM-km) FOR EACH VERTEX(4) OF EACH POLYGON
           -------------------------------------------------------
Source                                                          a
 No.       Ordered list of X followed by list of Y, grouped by source
------     ------------------------------------------------------------


--------
    a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.


---------------
Subgroup (14d)
---------------
                                        a
          AREA SOURCE: VARIABLE EMISSIONS DATA
          ------------------------------------

     Use this subgroup to describe temporal variations in the emission
     rates given in 14b.  Factors entered multiply the rates in 14b.
     Skip sources here that have constant emissions.  For more elaborate
     variation in source parameters, use BAEMARB.DAT and NAR2 > 0.

     IVARY determines the type of variation, and is source-specific:
     (IVARY)                              Default: 0
           0 =       Constant
           1 =       Diurnal cycle (24 scaling factors: hours 1-24)
           2 =       Monthly cycle (12 scaling factors: months 1-12)
           3 =       Hour & Season (4 groups of 24 hourly scaling factors,
                                    where first group is DEC-JAN-FEB)
           4 =       Speed & Stab. (6 groups of 6 scaling factors, where
                                    first group is Stability Class A,
                                    and the speed classes have upper
                                    bounds (m/s) defined in Group 12
           5 =       Temperature   (12 scaling factors, where temperature
                                    classes have upper bounds (C) of:
                                    0, 5, 10, 15, 20, 25, 30, 35, 40,
                                    45, 50, 50+)
```

```
--------
    a
     Data for each species are treated as a separate input subgroup
     and therefore must end with an input group terminator.


------------------------------------------------------------------------------

INPUT GROUPS: 15a, 15b, 15c -- Line source parameters
---------------------------

---------------
Subgroup (15a)
---------------

     Number of buoyant line sources
     with variable location and emission
     parameters (NLN2)                          No default  !  NLN2 =  0   !

     (If NLN2 > 0, ALL parameter data for
      these sources are read from the file: LNEMARB.DAT)

     Number of buoyant line sources (NLINES)    No default   ! NLINES =  0  !

     Units used for line source
     emissions below              (ILNU)        Default: 1  !  ILNU =   1  !
           1 =        g/s
           2 =       kg/hr
           3 =       lb/hr
           4 =     tons/yr
           5 =     Odour Unit * m**3/s  (vol. flux of odour compound)
           6 =     Odour Unit * m**3/min
           7 =     metric tons/yr

     Number of source-species
     combinations with variable
     emissions scaling factors
     provided below in (15c)      (NSLN1) Default: 0  !  NSLN1 =  0  !

     Maximum number of segments used to model
     each line (MXNSEG)                         Default: 7   ! MXNSEG =  7  !

     The following variables are required only if NLINES > 0.  They are
     used in the buoyant line source plume rise calculations.

        Number of distances at which            Default: 6   ! NLRISE =  6  !
        transitional rise is computed

        Average building length (XL)            No default   ! XL = .0 !
                                                (in meters)

        Average building height (HBL)           No default   ! HBL = .0 !
                                                (in meters)

        Average building width (WBL)            No default   ! WBL = .0 !
                                                (in meters)

        Average line source width (WML)         No default   ! WML = .0 !
                                                (in meters)

        Average separation between buildings (DXL)  No default   ! DXL = .0 !
                                                (in meters)

        Average buoyancy parameter (FPRIMEL)    No default   ! FPRIMEL = .0 !
                                                (in m**4/s**3)

!END!

---------------
Subgroup (15b)
---------------

          BUOYANT LINE SOURCE: CONSTANT DATA
```

```
          ---------------------------------
                                                                                 a
Source     Beg. X      Beg. Y      End. X    End. Y     Release    Base        Emission
 No.     Coordinate  Coordinate  Coordinate Coordinate  Height    Elevation     Rates
            (km)        (km)        (km)       (km)       (m)       (m)
------   ----------  ----------  ---------  ----------  -------   ---------    ---------

--------

    a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.

    b
     An emission rate must be entered for every pollutant modeled.
     Enter emission rate of zero for secondary pollutants that are
     modeled, but not emitted.  Units are specified by ILNTU
     (e.g. 1 for g/s).

---------------
Subgroup (15c)
---------------
                                                    a
          BUOYANT LINE SOURCE: VARIABLE EMISSIONS DATA
          --------------------------------------------

     Use this subgroup to describe temporal variations in the emission
     rates given in 15b.  Factors entered multiply the rates in 15b.
     Skip sources here that have constant emissions.

     IVARY determines the type of variation, and is source-specific:
     (IVARY)                                Default: 0
           0 =       Constant
           1 =       Diurnal cycle (24 scaling factors: hours 1-24)
           2 =       Monthly cycle (12 scaling factors: months 1-12)
           3 =       Hour & Season (4 groups of 24 hourly scaling factors,
                                    where first group is DEC-JAN-FEB)
           4 =       Speed & Stab. (6 groups of 6 scaling factors, where
                                    first group is Stability Class A,
                                    and the speed classes have upper
                                    bounds (m/s) defined in Group 12
           5 =       Temperature   (12 scaling factors, where temperature
                                    classes have upper bounds (C) of:
                                    0, 5, 10, 15, 20, 25, 30, 35, 40,
                                    45, 50, 50+)



--------
    a
     Data for each species are treated as a separate input subgroup
     and therefore must end with an input group terminator.


-------------------------------------------------------------------------------


INPUT GROUPS: 16a, 16b, 16c -- Volume source parameters
---------------------------

---------------
Subgroup (16a)
---------------

     Number of volume sources with
     parameters provided in 16b,c (NVL1)     No default  !  NVL1 = 0   !

     Units used for volume source
     emissions below in 16b       (IVLU)     Default: 1  !  IVLU =   1  !
           1 =        g/s
           2 =       kg/hr
           3 =       lb/hr
           4 =     tons/yr
```

```
           5 =     Odour Unit * m**3/s  (vol. flux of odour compound)
           6 =     Odour Unit * m**3/min
           7 =     metric tons/yr

     Number of source-species
     combinations with variable
     emissions scaling factors
     provided below in (16c)      (NSVL1)    Default: 0  !  NSVL1 =  0  !

     Number of volume sources with
     variable location and emission
     parameters                   (NVL2)     No default  !  NVL2 =   0   !

     (If NVL2 > 0, ALL parameter data for
      these sources are read from the VOLEMARB.DAT file(s) )

!END!

---------------
Subgroup (16b)
---------------
                                      a
           VOLUME SOURCE: CONSTANT DATA
           ----------------------------
                                                                          b
        X UTM      Y UTM      Effect.    Base     Initial    Initial    Emission
     Coordinate  Coordinate   Height   Elevation  Sigma y    Sigma z     Rates
        (km)       (km)         (m)       (m)       (m)       (m)
     ----------  ----------   ------    ------    --------   --------   --------
*** Max short-term  emission rates ***
      Xutm    Yutm      Hgt   Elev
insert-block-16a-here

--------
    a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.

    b
     An emission rate must be entered for every pollutant modeled.
     Enter emission rate of zero for secondary pollutants that are
     modeled, but not emitted.  Units are specified by IVLU
     (e.g. 1 for g/s).

---------------
Subgroup (16c)
---------------
                                              a
          VOLUME SOURCE: VARIABLE EMISSIONS DATA
          --------------------------------------

     Use this subgroup to describe temporal variations in the emission
     rates given in 16b.  Factors entered multiply the rates in 16b.
     Skip sources here that have constant emissions.  For more elaborate
     variation in source parameters, use VOLEMARB.DAT and NVL2 > 0.

     IVARY determines the type of variation, and is source-specific:
     (IVARY)                              Default: 0
           0 =       Constant
           1 =       Diurnal cycle (24 scaling factors: hours 1-24)
           2 =       Monthly cycle (12 scaling factors: months 1-12)
           3 =       Hour & Season (4 groups of 24 hourly scaling factors,
                                    where first group is DEC-JAN-FEB)
           4 =       Speed & Stab. (6 groups of 6 scaling factors, where
                                    first group is Stability Class A,
                                    and the speed classes have upper
                                    bounds (m/s) defined in Group 12
           5 =       Temperature   (12 scaling factors, where temperature
                                    classes have upper bounds (C) of:
                                    0, 5, 10, 15, 20, 25, 30, 35, 40,
                                    45, 50, 50+)
```

```
--------
    a
     Data for each species are treated as a separate input subgroup
     and therefore must end with an input group terminator.


------------------------------------------------------------------------------

INPUT GROUPS: 17a & 17b -- Non-gridded (discrete) receptor information
-----------------------

---------------
Subgroup (17a)
---------------

     Number of non-gridded receptors (NREC)  No default  !  NREC = 4239 !

!END!

---------------
Subgroup (17b)
---------------
                                                a
           NON-GRIDDED (DISCRETE) RECEPTOR DATA
           ------------------------------------

                  X UTM       Y UTM        Ground        Height   b
Receptor       Coordinate   Coordinate    Elevation   Above Ground
  No.             (km)        (km)          (m)           (m)
--------       ----------   ----------    ---------   ------------
 00001 ! X =   -777.581,   -244.881,     2287.8,    0 ! !END! 3network_receptors-0001
 00002 ! X =   -725.936,     40.380,     3252.4,    0 ! !END! 3network_receptors-0002
 00003 ! X =   -881.980,    -15.812,     2568.7,    0 ! !END! 3network_receptors-0003
 00004 ! X =   -856.879,    -68.300,     3238.0,    0 ! !END! 3network_receptors-0004
 00005 ! X =   -897.926,    109.083,     1997.9,    0 ! !END! 3network_receptors-0005
 00006 ! X =   -722.029,     74.357,     2835.7,    0 ! !END! 3network_receptors-0006
 00007 ! X =   -729.693,     66.632,     3194.2,    0 ! !END! 3network_receptors-0007
 00008 ! X =   -722.322,     38.039,     2975.0,    0 ! !END! 3network_receptors-0008
 00009 ! X =   -857.551,   -233.698,     3128.2,    0 ! !END! 3network_receptors-0009
 00010 ! X =   -884.608,    -12.851,     2496.6,    0 ! !END! 3network_receptors-0010

                ONLY THE FIRST AND LAST 10 RECEPTORS ARE SHOWN FOR BREVITY

 04230 ! X =   -916.370,   -194.394,     3605.3,    0 ! !END! wemi2-0735
 04231 ! X =   -906.237,   -195.564,     3463.1,    0 ! !END! wemi2-0736
 04232 ! X =   -904.789,   -195.730,     3430.4,    0 ! !END! wemi2-0737
 04233 ! X =   -903.341,   -195.896,     3396.2,    0 ! !END! wemi2-0738
 04234 ! X =   -887.414,   -197.702,     3095.3,    0 ! !END! wemi2-0739
 04235 ! X =   -885.966,   -197.864,     3075.5,    0 ! !END! wemi2-0740
 04236 ! X =   -884.518,   -198.027,     3056.6,    0 ! !END! wemi2-0741
 04237 ! X =   -883.070,   -198.189,     3044.2,    0 ! !END! wemi2-0742
 04238 ! X =   -920.499,   -192.057,     3574.9,    0 ! !END! wemi2-0743
 04239 ! X =   -919.052,   -192.226,     3601.3,    0 ! !END! wemi2-0744
-------------
    a
     Data for each receptor are treated as a separate input subgroup
     and therefore must end with an input group terminator.

    b
     Receptor height above ground is optional.  If no value is entered,
     the receptor is placed on the ground.
```