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Subcontractor Report

Impact of Biodiesel Fuels on Air Quality and Human Health: Task 4 Report

Impacts of Biodiesel Fuel Use on PM

R.E. Morris and Y. Jia
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Novato, California

National Renewable Energy Laboratory

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EXECUTIVE SUMMARY

BACKGROUND

Biodiesel fuels have been investigated for a number of reasons, such as an extender for petroleum-based fuels derived from a domestic renewable energy source. But lately the primary interest is the potential for a more environmentally benign fuel. The potential for exhaust emission reductions and reductions in emissions toxicity have the most interest. Several studies have shown that large reductions in hydrocarbon, particulate, and carbon monoxide emissions are expected from its use either as a neat fuel or as a blend with petroleum-derived fuels.

There are several areas in the United States that are currently in nonattainment for particulate matter of 10 μm or less (PM_{10}). In addition, there is a new fine particulate matter ($PM_{2.5}$) which may result in new areas being in nonattainment for PM. Biodiesel fuel use is estimated to reduce several precursors to PM (e.g., PM, SO_2, and VOC) and increase others (NOx). Thus, the net affect of biodiesel fuel use on ambient PM levels is unclear based on analyzing changes in emissions alone, so it as assessed using air quality modeling.

APPROACH

The South Coast (Los Angeles) Air Basin (SoCAB) region of southern California was selected to assess the effects of biodiesel fuel use because it is currently a PM_{10} nonattainment area and ammonium nitrate (for which NOx is a precursor) is a major component of the PM. Thus, the SoCAB would provide a conservative (i.e., tending toward overstatement) assessment of the impacts of biodiesel fuel on PM. The CAMx photochemical grid model was applied to the SoCAB for an April 1998 through March 1999 annual modeling period to estimate the effects a 100% and 50% penetration of an 20%/80% biodiesel/diesel fuel mixture (B20) in the Heavy Duty Diesel Vehicle (HDDV) fleet would have on PM levels. The effects of biodiesel fuel use was separately assessed for particulate sulfate, nitrate, ammonium, elemental carbon (EC), organic carbon (OC), other fine particulate, coarse matter, total PM_{10} and $PM_{2.5}$ mass, and exposure to PM_{10} and $PM_{2.5}$.

RESULTS

Table ES-1 summarizes the estimated maximum increases and decreases in total PM_{10} and $PM_{2.5}$ mass and PM components due to a 100% penetration of a B20 fuel in the HDDV fleet. The results for the 50% B20 penetration are approximately half of the 100% B20 penetration scenario. The increases and decreases of the PM due to the biodiesel fuel use are extremely small and should be considered not significant. The largest effect is for particulate nitrate that exhibits both small increases and decreases due to the B20 fuel. The decreases in nitrate occur in the more populated portions of the SoCAB, whereas the increases occur east of the SoCAB in the desert. The 100% B20 biodiesel fuel scenario is estimated to reduce exposure to annual and 24-hour exceedances of the PM_{10} standard by 4% and 7%, respectively over use of a standard diesel fuel.

Table ES-1. Estimated maximum increases and decreases in PM concentrations ($\mu g/m^3$) in the SoCAB due to a 100% penetration of a B20 biodiesel fuel in the HDDV fleet.

	Annual Average		Maximum 24-Hour Average	
PM Species	**Maximum Increase**	**Maximum Decrease**	**Maximum Increase**	**Maximum Decrease**
Sulfate	0.00	-0.03	0.00	-0.07
Nitrate	+0.04	-0.09	+0.58	-1.12
Ammonium	+0.01	-0.03	+0.15	-0.34
EC	0.00	-0.06	0.00	-0.10
OC	0.00	-0.15	0.00	-0.27
Other PFIN	0.00	-0.01	0.00	-0.01
Other PCRS	0.00	-0.01	0.00	-0.01
PM_{10} Mass	+0.04	-0.31	+0.62	-1.61
$PM_{2.5}$ Mass	+0.04	-0.30	+0.62	-1.61

TABLE OF CONTENTS

TABLES

FIGURES

1. INTRODUCTION

BACKGROUND

Biodiesel fuels have been investigated for a number of reasons, such as an extender for petroleum-based fuels derived from a domestic renewable energy source. But lately the primary interest is the potential for a more environmentally benign fuel. One potential benefit of biodiesel is that it can biologically degrade, making spills and leaks less of a concern. However, the potential for exhaust emission reductions and reductions in emissions toxicity are of the most interest. Several studies have shown that large reductions in hydrocarbon, particulate, and carbon monoxide emissions are expected from its use either as a neat fuel or as a blend with petroleum-derived fuels.

There have been several studies regarding the effects of biodiesel fuels on exhaust emissions of NOx, VOC, CO, and particulate matter (PM). Almost all of these studies have examined emissions from heavy-duty diesel vehicle (HDDV) engines. However, the effects of biodiesel use on ambient air quality have not been quantified. Thus, the National Renewable Energy Laboratory (NREL) has retained ENVIRON International Corporation to estimate the air quality and resultant health effect impacts from the use of biodiesel fuels in several cities in the U.S.

Effects of Biodiesel Fuel on Particulate Matter

Currently there is a Federal health based National Ambient Air Quality Standard (NAAQS) for particulate matter with a mean geometric diameter of 10 microns or less (PM_{10}). There is also a new fine particulate standard for PM of 2.5 microns or less ($PM_{2.5}$). The Federal PM_{10} standard consists of a 24-hour standard that is basically the fourth highest value in three years with a 150 $\mu g/m^3$ threshold and an annual standard with a 50 $\mu g/m^3$ threshold. The fine particulate standard thresholds are 65 and 15 $\mu g/m^3$ for the 24-hour and annual time frames, respectively.

PM consists of many different compounds some of that are interrelated with common set of precursors and processes, others that are not. The main components of PM and their primary sources are as follows:

- SO4 Sulfate (SO4) that is formed secondarily from SO2 emissions;
- NO3 Ammonium Nitrate (NH4NO3) that is formed from NOx and ammonia emissions;
- EC Elemental Carbon primary emitted from burning (e.g., vegetative, charbroiling, etc.) and combustion (e.g., coal, gasoline, and diesel)
- OC Organic Carbon that is primary emitted from burning and combustion and formed secondarily from some VOCs;
- PM Other PM that is primary emitted that includes many compounds including crustal material, metals, sea salt, etc.

Test data indicate that biodiesel fuel use in heavy duty diesel vehicles (HDDVs) tends to increase NOx emissions but reduce emissions of volatile organic compounds (VOC), carbon monoxide (CO), particulate matter (PM, including EC and OC), and sulfur dioxide (SO2). Thus, on the one hand biodiesel fuel use will increase one PM precursors (NOx), on the other it will decrease others (VOC, primary PM, and SO2). Thus, the ultimate effect of biodiesel fuel use on ambient

PM levels cannot be determined by analyzing emissions changes alone. It must be investigated using air quality modeling of the key constituents of PM.

Purpose

This document is the Task 4 Report for the NREL "Impacts of Biodiesel Fuels on Air Quality and Human Health " study. The objective of Task 4 is to estimate the effects of the use of biodiesel fuels on PM_{10} levels and the resultant exposure to elevated levels of PM_{10}. Annual PM modeling of the South Coast (Los Angeles) Air Basin (SoCAB) region of Southern California was conducted for a standard diesel and biodiesel fuel scenarios and the effects on PM_{10} and $PM_{2.5}$ and exposure to elevated PM_{10} and $PM_{2.5}$ levels were estimated.

OVERVIEW OF APPROACH

There are currently several PM_{10} nonattainment areas in the United States that have performed PM_{10} modeling as part of their State Implementation Plan (SIP) planning. In the NREL Biodiesel Study Modeling Protocol we identified four potential PM modeling databases that could be used for the biodiesel fuel PM impact assessment (ENVIRON, 2000):

- A 1995 South Coast Air Basin (SoCAB) database used by the linear chemistry UAM/LC model to develop the PM_{10} plan in the 1997 AQMP/SIP;
- An October 1995 episode database developed for the full-science UAM-AERO model;
- A 1995 UAM/LC database for the Phoenix area; and
- A 1997/1998 annual database for the SoCAB developed as part of the Multiple Air Toxics and Exposure Study (MATES-II).

The Phoenix PM problem has a relatively smaller contribution due to secondary PM (sulfate and nitrate) compared to the SoCAB. Since biodiesel fuel is estimated to increase NOx emissions, then performing the PM assessment for the SoCAB where nitrate levels are high was believed to be a fairer assessment of its potential benefits and adverse effects on PM levels. Thus, the Phoenix database was eliminated from consideration.

Although in the past the SoCAB has violated both the 24-hour and annual PM_{10} standards, more recent measurements show the maximum 24-hour PM_{10} concentrations right at the standard, whereas the annual standard is still exceeded. Thus, the impacts of biodiesel fuel use on both, maximum 24-hour and annual PM concentrations needs to be assessing, which eliminates the episodic October 1995 UAM-AERO database from consideration. Either the 1995 or 1997/1998 PM modeling database would be adequate for assessing the effects of biodiesel use on PM concentrations in the SoCAB. Both annual periods are currently being used by the South Coast Air Quality Management District (SCAQMD) for their PM_{10} control plan being developed as part of the 2002 Air Quality Management Plan (AQMP) and SIP efforts. Ultimately the 1997/1998 MATES-II database was selected for the following reasons:

- It is more recent than the 1995 database;
- It has been set up for the CAMx model that is more up to date and current than the UAM/LC model; and
- It was used for the NREL study Task 5 biodiesel impacts on exposure and human health effects air toxics modeling.

Overview of the 1997/1998 MATES-II Annual Modeling Database

As part of the Multiple Air Toxics Exposure Study (MATES-II), the South Coast Air Quality Management District (SCAQMD) applied the UAM-Tox photochemical and air toxics grid model for a year (April 1998-March 1999). Air toxic concentration estimates were obtained across the South Coast (Los Angeles) Air Basin (SoCAB) for approximately 50 toxic compounds. The UAM-Tox used a 105 by 60 horizontal array of 2-km by 2-km grid cells to cover the SoCAB and five vertical layers up to a region top of 2-km AGL. Hourly three-dimensional meteorological inputs were generated for April 1, 1998 through March 31, 1999 using the CALMET diagnostic meteorological model and surface and upper-air meteorological observations.

As part of Task 5 of the NREL Biodiesel Study, air toxics modeling of the SoCAB was performed to assess the effects of biodiesel fuel use on human health (Morris and Jia, 2002). The Task 5 air toxics modeling built off of a study for the Coordinating Research Council (CRC) and Department of Energy (DOE) Project A-42-2 "Air Toxics Modeling" (ENVIRON, 2002). The CRC/DOE air toxics modeling study developed a new CAMx air toxics modeling system and applied it to the SoCAB for the MATES-II annual period. The same CAMx hourly meteorological fields for the April 1998 through March 1999 period as used in the CRC and NREL Task 5 air toxics modeling were used in the Task 4 PM modeling assessment of the NREL Biodiesel Fuel Impact Study. However, all new emissions were developed for PM precursors. The reader is refereed to the NREL Biodiesel Impact Study Task 5 report (Morris and Jia, 2002) or the CRC Project A-42-2 report (ENVIRON, 2002) for details on the development of the CAMx meteorological inputs. Details on the development of the PM emissions are provided in Section 2 of this report.

The MATES-II hourly CALMET meteorological inputs and UAM-Tox emission for April 1, 1998 through March 31, 1999 were acquired from the SCAQMD. The CALMET diagnostic meteorological model was run for the April 1998 – March 1999 year and a CALMET-CAMx converter program was used to convert the CALMET output to the meteorological variables and formats needed by CAMx. CAMx was configured using a 65 by 40 5-km by 5-km grid that covered the SoCAB. CAMx was set up with 6 vertical layers of spatially and temporally constant thickness up to a region top of 2,000-m AGL.

The latest emissions inventory modeling system for the SoCAB was acquired from the California Air Resources Board (ARB). These emissions were based on the EMFAC2001 mobile source emissions model and included NOx, VOC, CO, SOx, and PM for anthropogenic and biogenic sources. However, it did not include ammonia emissions. Thus, the ammonia emissions for the SoCAB were adapted from the October 1995 UAM-AERO database. Emissions consisted of hourly gridded emissions for a typical day by month accounting for seasonal variations in activity levels as well as temperature effects.

The CAMx model was run for the April 1998 – March 1999 period to generate 24-hour average and annual average PM_{10} and $PM_{2.5}$ concentration estimates.

The effects of a 100% and 50% penetration of a 20%/80% biodiesel/diesel fuel (B20) into the Heavy Duty Diesel Vehicle (HDDV) fleet on diesel NOx, SOx, VOC, CO, and PM emissions was implemented in the 1998/1999 baseline mobile source emissions. The impacts of a standard diesel and a 100% and 50% penetration of a B20 fuel in the HDDV fleet on $PM_{2.5}$ and PM_{10} concentrations were simulated.

2. EMISSION INVENTORIES FOR PM MODELING OF BIODIESEL FUEL IMPACTS

The latest Gridded Emissions Modeling (GEM) system setup for the South Coast Air basin (SoCAB) was acquired from the California Air Resources Board (ARB). GEM was set up to generate gridded hourly speciated photochemical modeling inventories for the South Coast Air Basin (SoCAB) and the August 1997 Southern California Ozone Study (SCOS) episode. On-road mobile source emissions were generated using the EMFAC2001 mobile source emissions. The ARB GEM included NOx, SOx, VOC, CO, and PM emissions. However, it did not include any ammonia emissions. Thus, the gridded hourly ammonia emissions inventory from the October 1995 UAM-AERO database was used.

TEMPORAL ALLOCATION AND SPECIATION

The August 1997 emissions were projected to 1998/1999 years and adjusted to obtain typical average emissions for each month of the April 1998 through March 1999 modeling period. These adjustments accounted for the seasonal effects on anthropogenic emissions as well as the temperature effects on biogenic emissions.

The GEM VOC species were speciated into the classes used by the Carbon Bond IV (CB4) chemical mechanism used in the CAMx Mechanism 4 PM chemical mechanism. The CB4 chemistry in Mechanism 4 is similar to the standard CB4 chemistry only biogenic terpenes are treated as a separate species (OLE2) to track the secondary organic aerosol (SOA) from terpenes.

The GEM PM emissions were speciated into the following PM components:

- Sulfate;
- Particulate Nitrate;
- Elemental Carbon (EC);
- Organic Carbon (OC);
- Other Fine (<2.5 μm) Particulate Matter (PFIN); and
- Other Coarse (2.5-10 μm) Particulate Matter (PCRS).

EMISSION SCENARIOS

Both standard diesel and biodiesel fuel scenarios were analyzed. The biodiesel fuel scenarios assumed that a 20%/80% biodiesel/diesel fuel mixture (B20) was used in just the heavy duty diesel vehicle (HDDV) fleet portion of on-road motor vehicles. The following emissions scenarios were simulated:

- Standard Diesel Fuel Base Case;
- 50% Penetration of a B20 Fuel in the HDDV Fleet; and
- 100% Penetration of a B20 Fuel in the HDDV Fleet.

The change in tailpipe emissions in the HDDV due to use of a biodiesel fuel was based on an analysis of engine test data as summarized by Lindjhem and Pollack (2000). Table 2-1 lists the net change in fleet average HDDV tail pipe emissions due to the use of a biodiesel fuel over use of a standard diesel fuel.

Table 2-1. Average change in HDDV mass emissions due to use of a biodiesel fuel over use of a standard diesel fuel.

Biodiesel Fuel	NOx	PM	CO	VOC	SO_2
B20	+2.4%	-8.9%	-13.1%	-17.9%	-20%
B100	+13.2%	-55.3%	-42.7%	-63.2%	-100%

The emissions from sources of on-road total diesel vehicles (TDV) can be controlled and adjusted by the GEM emission modeling system. The effects of the 100% and 50% B20 emission scenarios were accounted for by applying the change in emissions in Table 2-1 due to the B20 fuel accounting for the B20 penetration rate and the fraction of the on-road mobile source diesel emissions due to the HDDV fleet. For example, for the 50% B20 biodiesel fuel scenario the NOx emissions from all on-road HDDV were increased by 1.18 percent (1.18 = 2.4 x 0.50 x 0.986) to account for the 50% penetration factor of the B20 fuel and the EMFAC2001 estimate that 98.6% of the NOx emissions in the summer 1998 on-road mobile source emissions diesel inventory are due to HDDVs.

EMISSION SUMMARIES

Table 2-2 summarizes the NOx, VOC, SOx, and PM emissions in the SoCAB domain for the three diesel fuel scenarios and for the summer and winter periods. For the standard diesel base case, on-road diesel vehicles account for 22%, 0.5%, 0.4%, 7%, and 0.7% of the NOx, VOC, CO, SOx, and PM emissions in the SoCAB, respectively. The changes in the diesel vehicle emissions due to the 100% B20 emissions scenario are very close but slightly lower than the changes in HDDV emissions in Table 2-1 accounting for the small contributions of light and medium duty diesel vehicle emissions to the total on-road diesel vehicles. The change in total NOx, VOC, CO, SOx, and PM emissions in the SoCAB from the 100% B20 scenario are, respectively, +0.5%, -0.1%, -0.1%, -1.3%, and –0.1%.

Table 2-2. Summary of domain-wide total on-road diesel, area plus point sources, and total NOx, VOC, CO, SOx, and PM emissions in the SoCAB (tons per day) for the 1997 Standard Diesel Base Case and 1997 100% and 50% Penetration of a B20 Biodiesel fuel scenarios.

	1998 Summer Baseline					1998 Summer 100% B20 Biodiesel					1998 Summer 50% B20 Biodiesel				
	NOX	**TOG**	**CO**	**SOX**	**PM**	**NOX**	**TOG**	**CO**	**SOX**	**PM**	**NOX**	**TOG**	**CO**	**SOX**	**PM**
TOTAL DIESEL	336.5	13.5	35.3	7.7	8.0	344.5	11.3	30.9	6.2	7.3	340.5	12.4	33.1	6.9	7.6
On-Road Mobile	932.9	860.5	6912.3	38.1	23.7	940.9	858.2	6907.8	36.6	23.1	936.9	859.4	6910.1	37.4	23.4
Area+Point	571.1	1489.3	1466.9	73.3	1076.0	571.1	1489.3	1466.9	73.3	1076.0	571.1	1489.3	1466.9	73.3	1076.0
Total	1504.0	2349.8	8379.2	111.4	1099.7	1512.0	2347.5	8374.8	110.0	1099.1	1508.0	2348.6	8377.0	110.7	1099.4
						% Change					**% Change**				
TOTAL DIESEL						2.38	-16.57	-12.55	-19.30	-8.30	1.19	-8.28	-6.29	-9.65	-4.16
Total						0.53	-0.10	-0.05	-1.33	-0.06	0.27	-0.05	-0.03	-0.66	-0.03
	1999 Winter Baseline					**1999 Winter 100% B20 Biodiesel**					**1999 Winter 50% B20 Biodiesel**				
TOTAL DIESEL	364.1	14.8	31.7	5.4	7.9	372.7	12.4	27.7	4.3	7.3	368.4	13.6	29.7	4.9	7.6
On-Road Mobile	1009.4	944.5	6204.4	26.7	23.6	1018.0	942.0	6200.4	25.7	23.0	1013.7	943.3	6202.4	26.2	23.3
Area+Point	503.7	1484.3	1528.4	72.1	1070.7	503.7	1484.3	1528.4	72.1	1070.7	503.7	1484.3	1528.4	72.1	1070.7
Total	1513.1	2428.8	7732.8	98.8	1094.3	1521.7	2426.3	7728.8	97.8	1093.7	1517.4	2427.5	7730.8	98.3	1094.0
						% Change					**% Change**				
TOTAL DIESEL						2.36	-16.58	-12.53	-19.31	-8.30	1.18	-8.29	-6.25	-9.66	-4.15
Total						0.57	-0.10	-0.05	-1.05	-0.06	0.28	-0.05	-0.03	-0.53	-0.03

SPATIAL DISTRIBUTION OF EMISSIONS

Figures 2-1 through 2-4 display the spatial distribution of the, respectively, NOx, VOC, CO, and PM emissions for the standard diesel Base Case and differences in the emissions between the Base Case and 100% penetration of a B20 biodiesel fuel emission scenarios for a typical summer day. The differences between the Base Case and 50% B20 fuel scenario are similar with differences half of those for the 100% B20 fuel scenario.

The highest NOx emissions occur in the areas with the most roadways and population (Figure 2-1, top). The maximum NOx emissions of 15 tons per day (TPD) occurs in downtown Los Angeles where congestion and the confluence of the 5, 10, 60, and 110 freeways produces high mobile source NOx emissions. Elevated NOx emissions occur in downtown Los Angeles stretching north into the San Fernando Valley, west toward Santa Monica and down the coast, south toward Anaheim, and east following freeway 10 and 60 to San Bernardino and Riverside. The effects of a 100% penetration of a B20 biodiesel fuel are to increase NOx emissions mainly along the major freeways in the SoCAB (Figure 2-1, bottom). All of the major freeways are clearly visible in the NOx emissions difference plot. The maximum NOx increase due to the 100% B20 scenario (0.11 TPD) occurs in downtown Los Angeles.

The spatial distribution of the daily total summer VOC emissions is similar to the NOx emissions only it appears to be more rooted to population centers rather than major roadways (Figure 2-2, top). The reductions in VOC emissions for the 100% B20 scenario (Figure 2-2, bottom) are not as great as the NOx increases with a maximum reduction of 0.03 TPD occurring in downtown Los Angeles. Similar results are seen for the spatial distribution of the CO emissions (Figure 2-3).

The distribution of the PM emissions is a little different than the other three pollutants (Figure 2-4). Although downtown Los Angeles still produces the highest primary PM emissions (8 TPD), there are several other "hot spot" PM emissions locations:

- downtown Los Angeles;
- downtown Anaheim in Orange;
- Ontario in Western San Bernardino County;
- Corona south of Ontario in Riverside County;
- San Bernardino;
- Victorville north of Ontario in San Bernardino County; and
- Lancaster/Palmdale north of Los Angeles in Los Angeles County.

Although the downtown Los Angeles and Anaheim PM hot spots are likely dominated by mobile sources, the rest likely have major contributors from other source categories (especially the more rural Victorville and Lancaster locations to the north of the SoCAB).

As seen for the other pollutants, the reductions in PM emissions between the 1997 Base Case and 100% B20 scenario follow the major roadways in the SoCAB. The maximum reduction in PM due to the 100% B20 fuel use is 0.01 TPD in downtown Los Angeles.

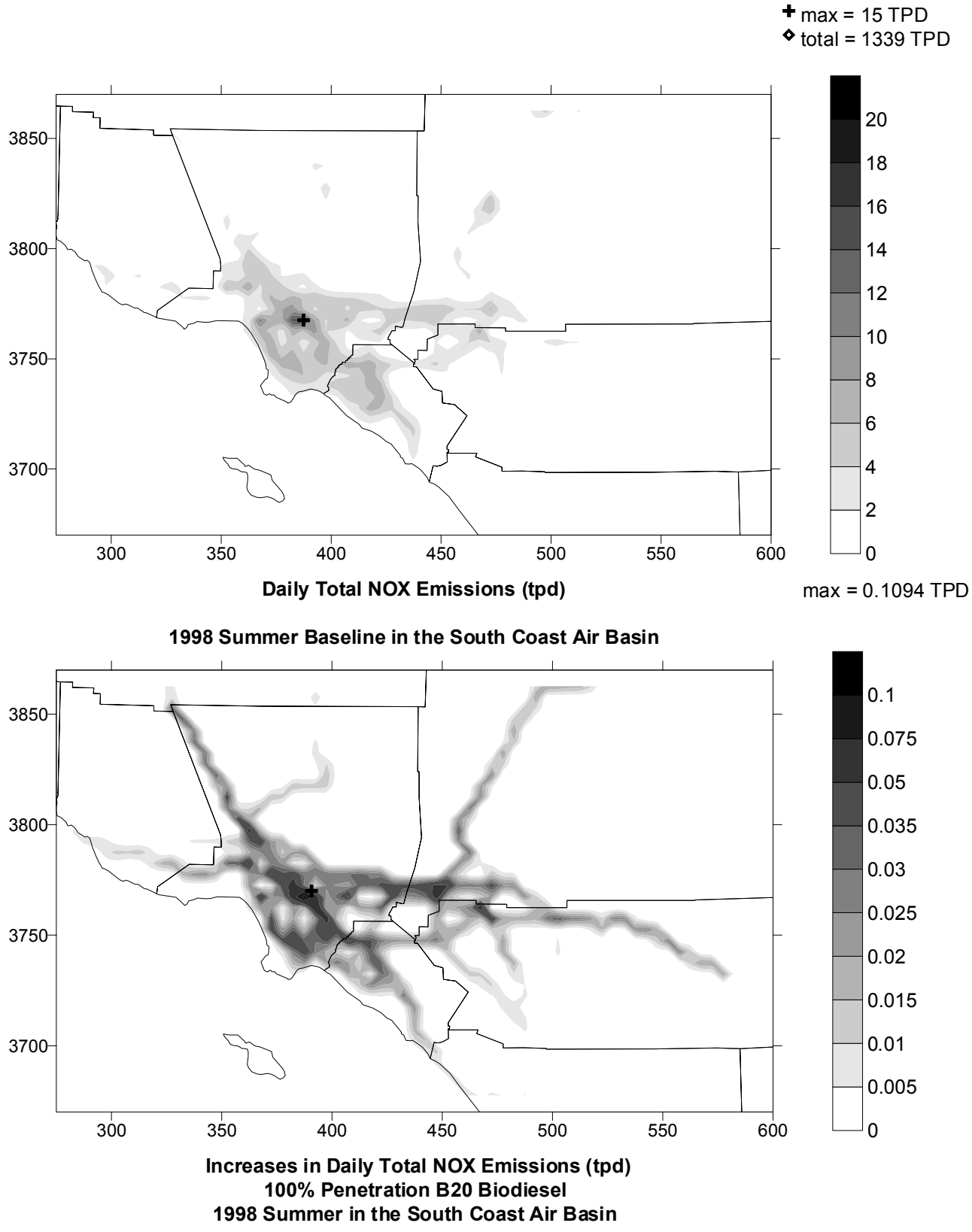


Figure 2-1. Total NOx emissions (tons per day) and change in NOx emissions due to the 100% B20 biodiesel fuel scenario for a typical 1998 summer day in the SoCAB.

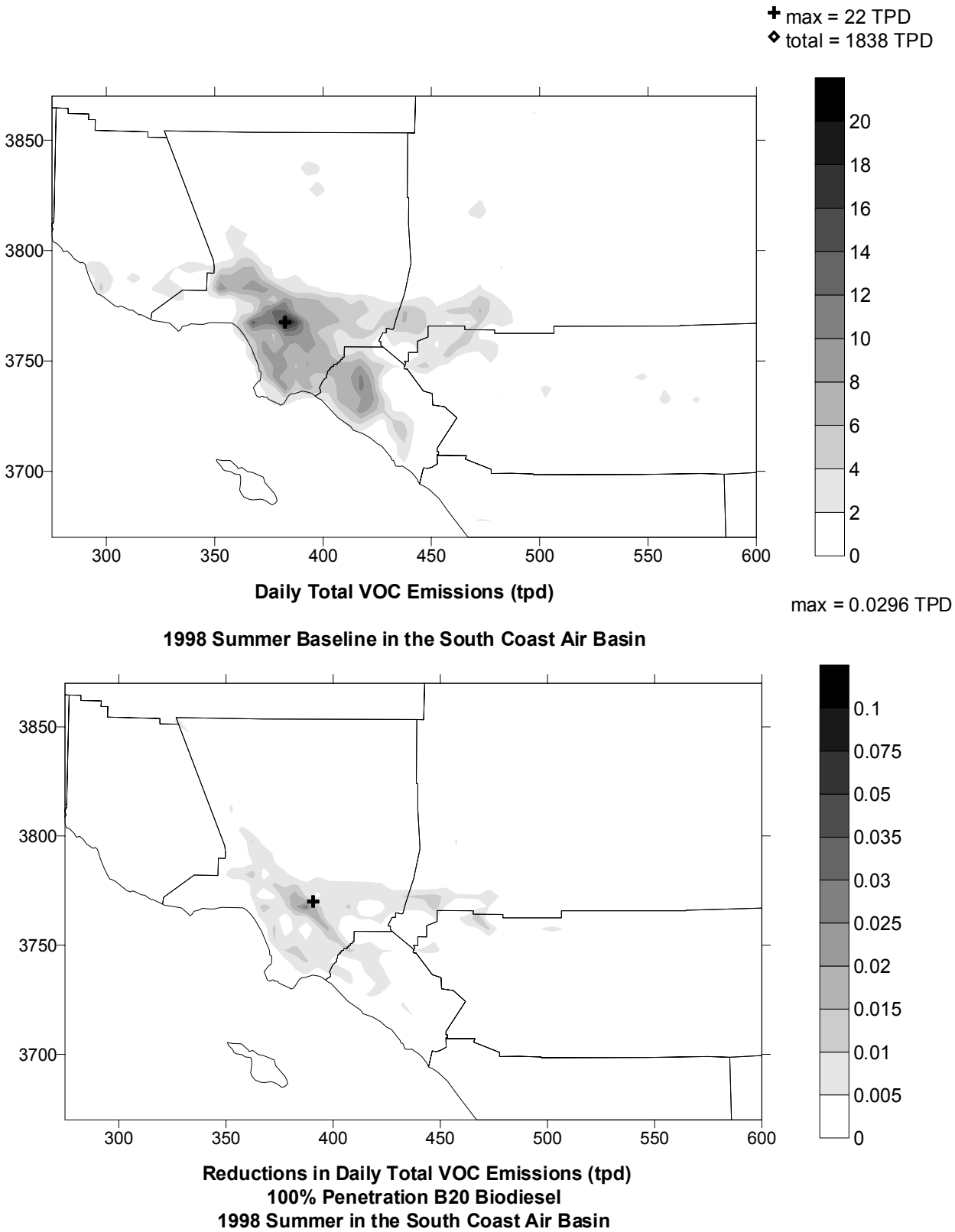


Figure 2-2. Total VOC emissions (tons per day) and change in VOC emissions due to the 100% B20 biodiesel fuel scenario for a typical 1998 summer day in the SoCAB

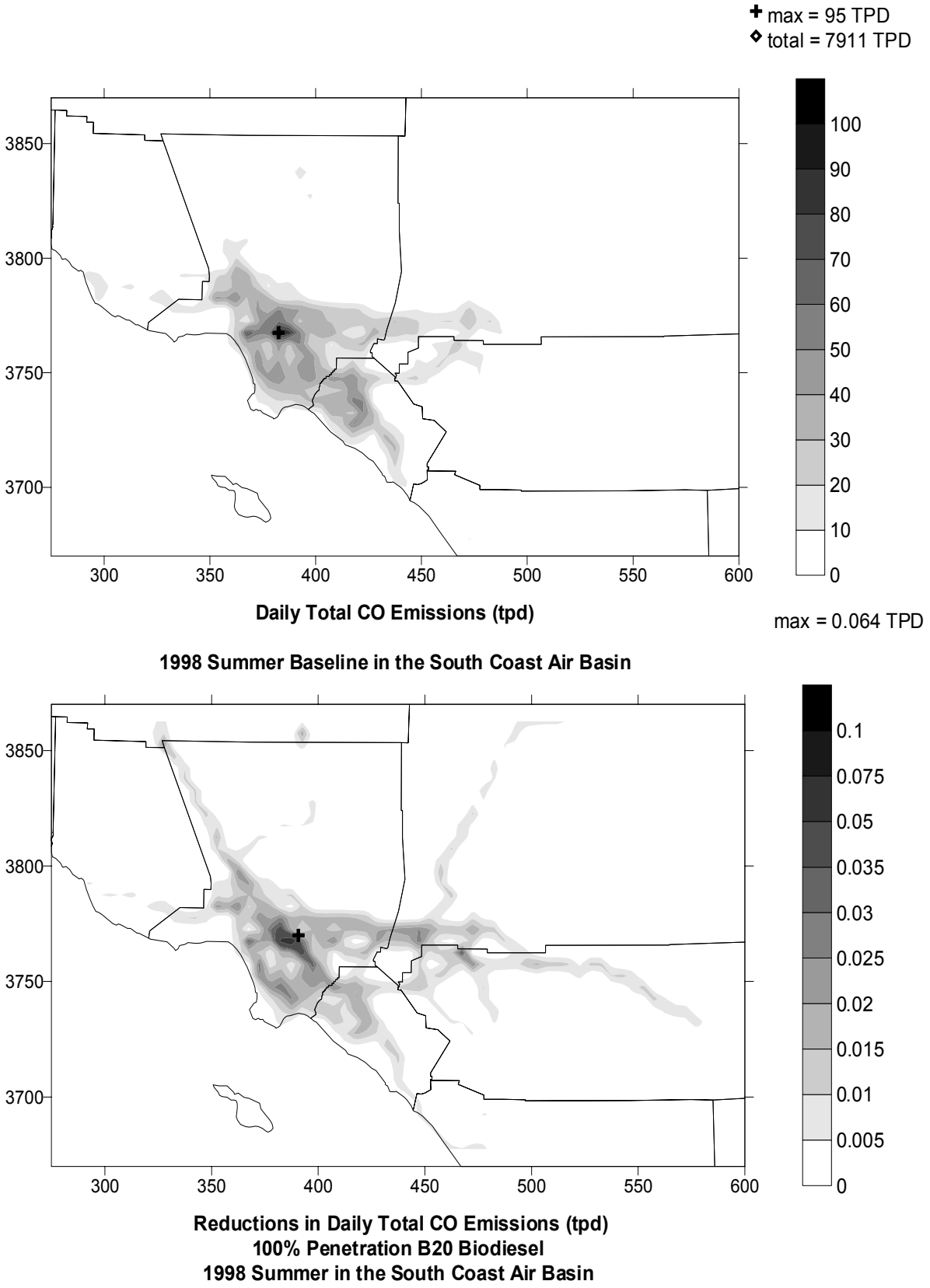


Figure 2-3. Total CO emissions (tons per day) and change in CO emissions due to the 100% B20 biodiesel fuel scenario for a typical 1998 summer day in the SoCAB

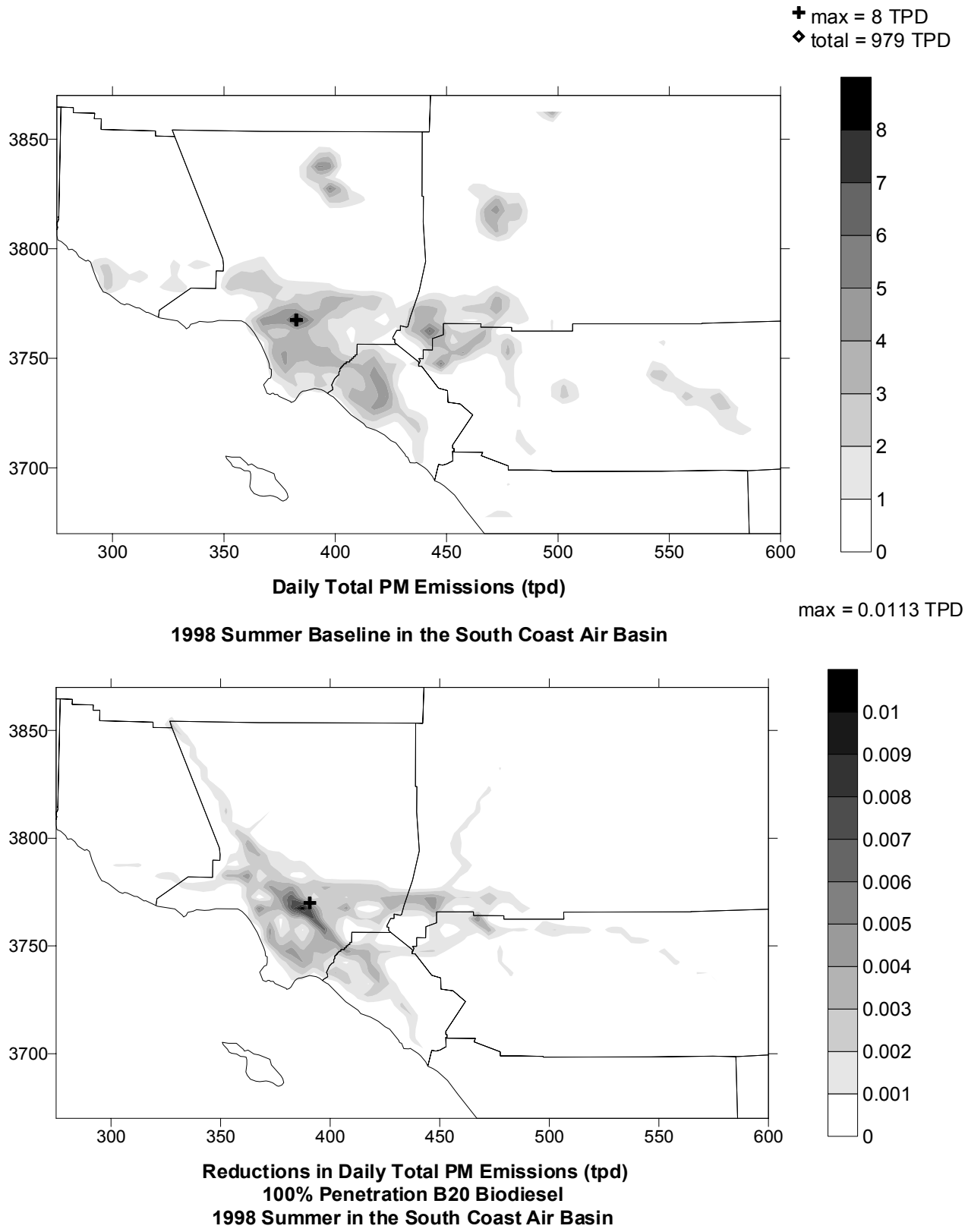


Figure 2-4. Total PM emissions (tons per day) and change in PM emissions due to the 100% B20 biodiesel fuel scenario for a typical 1998 summer day in the SoCAB

3. PM CONCENTRATION MODELING RESULTS

In this section we present the particulate matter (PM) modeling results of the annual simulations of the April 1998 through March 1999 period for the biodiesel fuel emission scenarios and compare them with the standard diesel base case simulation. There are currently 24-hour and annual Federal standards for PM of 10 μm or less (PM_{10}) with threshold concentrations of 150 and 50 $\mu g/m^3$, respectively. In 1997, EPA promulgated a new fine particulate ($PM_{2.5}$) standard with 24-hour and annual thresholds of 65 and 15 $\mu g/m^3$, respectively. The new fine particulate standard was challenged and was vacated by the Court. On appeal, the new fine particulate standard was reinstated, but has not fully been implemented and attainment designations are not expected until 2005. Thus, in this study we assess the effects of biodiesel fuel use on both PM_{10} and $PM_{2.5}$.

Because PM is composed of many different constituents it is difficult to understand the changes in PM concentrations when multiple PM precursor emissions are changed, some with increases and others with decreases, as with the biodiesel fuel impacts. Thus to better understand the effects of the biodiesel fuel we not only examine its impacts on total PM_{10} and $PM_{2.5}$ mass, but also its impacts on each of the major pm components. In this section we analyze the annual average and maximum 24-hour average concentrations and impacts of biodiesel fuel for the following species:

- Sulfate
- Particulate Nitrate
- Ammonium;
- Elemental Carbon;
- Organic Carbon;
- Other Fine PM;
- Coarse PM;
- Total PM_{10} mass; and
- Total $PM_{2.5}$ mass;

PM SPECIES IMPACTS

The spatial distribution of the annual average and yearly maximum 24-hour average concentrations for each of the PM_{10} components is examined below. Because the biodiesel fuel scenarios have a small effect on the total emissions in the SoCAB (see Table 2-2), the spatial distribution of PM estimates for the 1998/1999 Base Case and 1998/1999 biodiesel fuel scenarios are almost identical. Thus, we present absolute modeling results of the spatial distribution of annual and maximum 24-hour average PM concentrations for only the 1998/1999 Base Case. We also present the spatial distribution of the differences in concentrations between the 1998/1999 Base Case and the 1998/1999 100% B20 biodiesel fuel scenario. The difference in the estimated PM concentrations between the 50% B20 scenario and the base case have a very similar pattern and approximately half the magnitude of the differences in the 100% B20 scenario, so are not presented.

Sulfate Concentrations

Figure 3-1 presents the spatial distribution of the estimated annual average sulfate concentrations for the 1998/1999 standard diesel Base Case scenario (top) and the differences in the annual average sulfate concentrations between the Base Case and the 100% B20 emissions scenario (bottom). Similar plots for the maximum 24-hour average sulfate concentrations are displayed in Figure 3-2. The highest estimated annual average sulfate concentration is 8.2 $\mu g/m^3$ and occurs in the Port of Los Angeles and Port of Long Beach area on the coast just west of Long Beach. This is also where the highest SO_2 emissions occur due primarily to marine vessel emissions and port operations. Away from the port area, the annual average sulfate concentrations are much lower, typically less than 3 $\mu g/m^3$. The use of a 100% B20 biodiesel fuel is estimated to result in extremely small reductions in annual average sulfate concentrations across the SoCAB (Figure 3-1, bottom). The maximum sulfate reduction due to 100% B20 use is 0.025 $\mu g/m^3$ and occurs in downtown Los Angeles. Unlike annual average sulfate concentrations that are centered on the port area, the reductions in sulfate due to biodiesel fuel use are highest over the densest urban areas (Los Angeles to Anaheim) and then fall off and follow the major roadways in the more rural areas (e.g., freeways 5, 15, and 60).

The maximum 24-hour average sulfate concentrations in the 1998/1999 Base Case simulation is 16.3 $\mu g/m^3$ and occurs at the port area west of Long Beach (Figure 3-2). Elevated yearly maximum 24-hour average estimated sulfate concentrations in excess of 8 $\mu g/m^3$ stretch from the port area up to downtown Los Angeles. The peak reduction in annual maximum 24-hour sulfate concentrations due to the 100% B20 fuel scenario is 0.074 $\mu g/m^3$ and occurs in downtown Los Angeles. The use of the biodiesel fuels results in small reductions (< 0.1 $\mu g/m^3$) in maximum 24-hour sulfate concentrations across the SoCAB with no areas of sulfate increases.

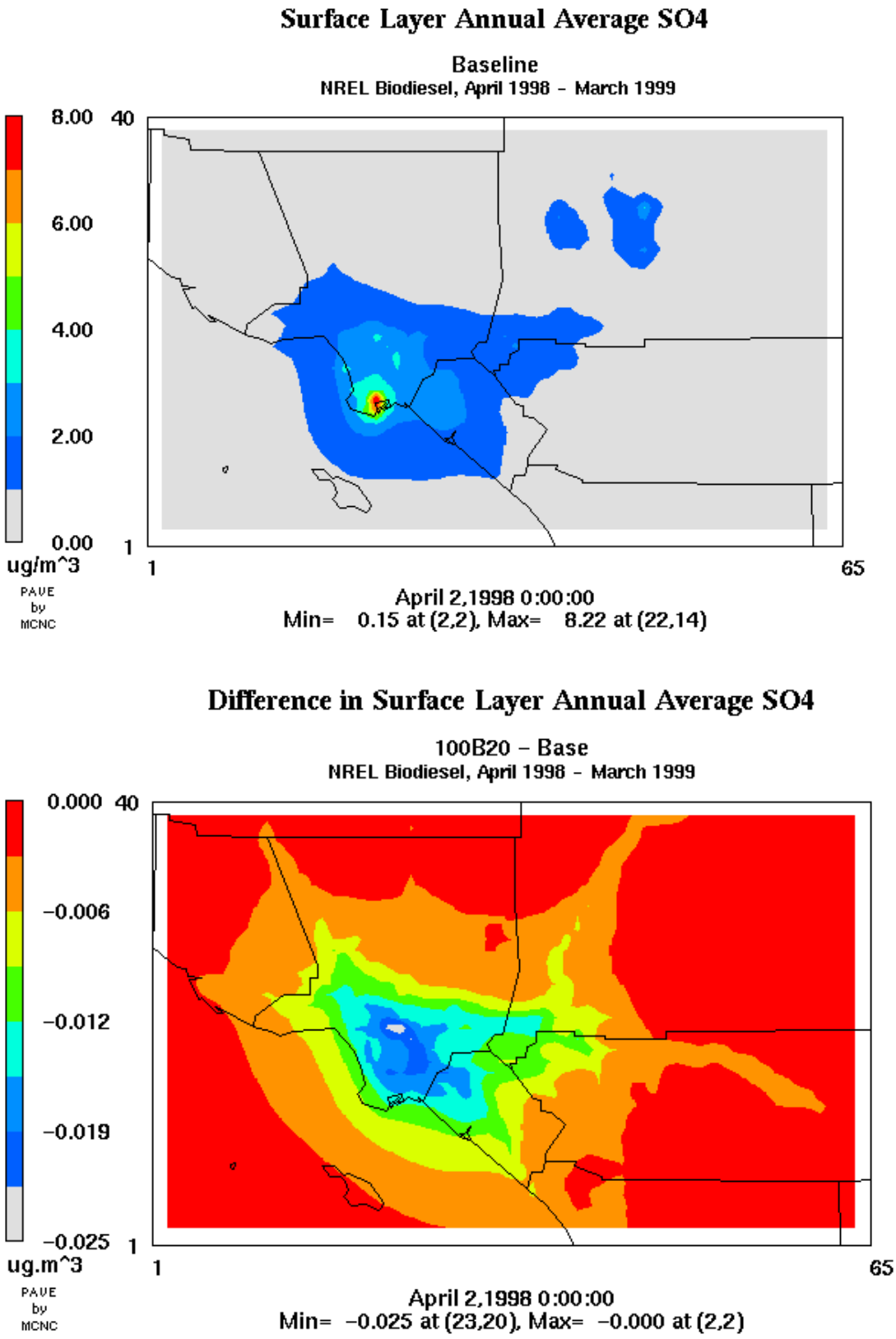


Figure 3-1. Estimated annual average sulfate concentrations ($\mu g/m^3$) for the 1998/1999 standard diesel base case simulations (top) and differences in annual average sulfate concentrations between the Base Case and 100% B20 biodiesel emissions scenarios (100% B20-Base Case).

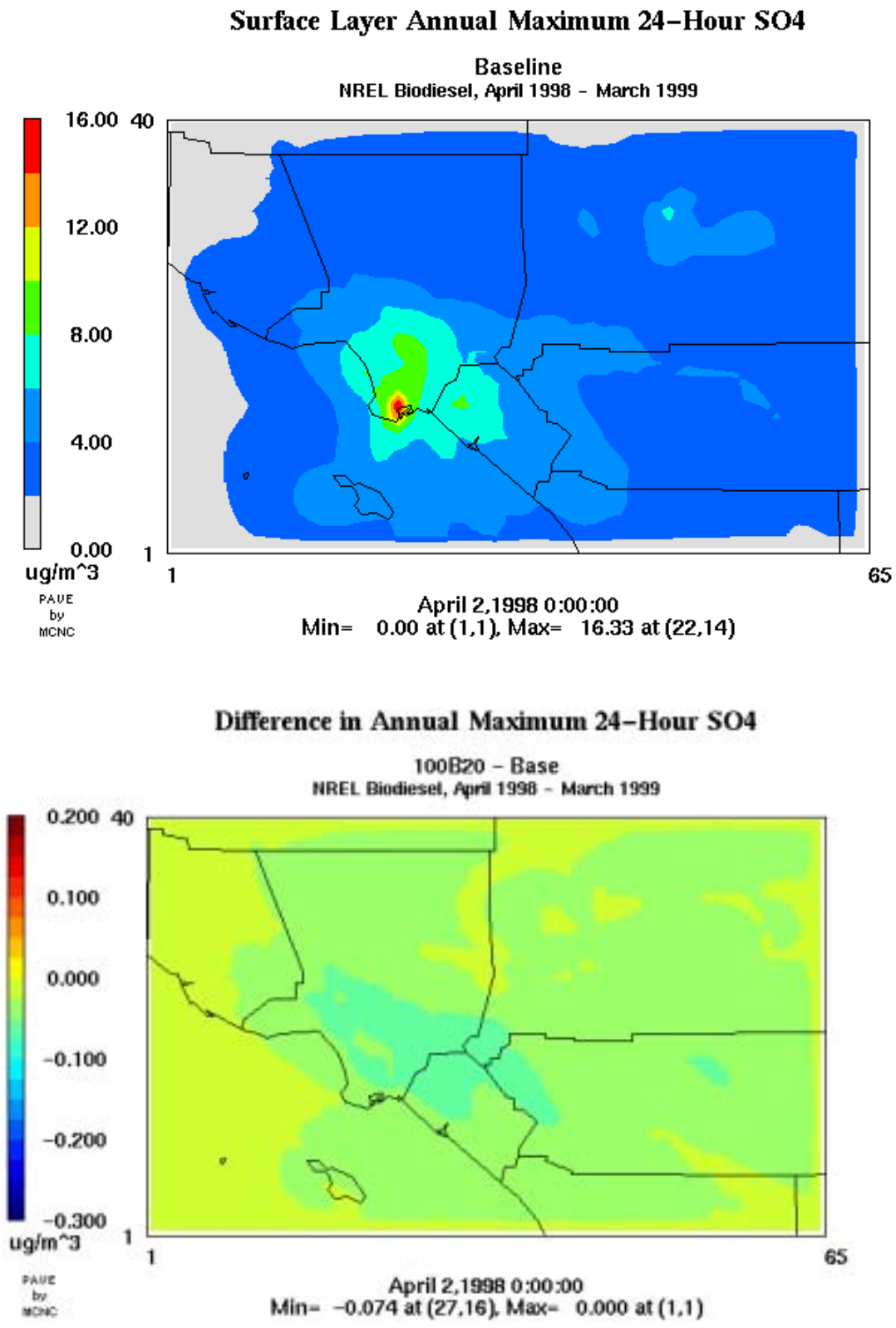


Figure 3-2. Estimated maximum 24-hour average sulfate concentrations ($\mu g/m^3$) for the 1998/1999 standard diesel base case simulations (top) and differences in maximum 24-hour average sulfate concentrations between the Base Case and 100% B20 biodiesel emissions scenarios (100% B20-Base Case).

Particulate Nitrate Concentrations

Figures 3-3 and 3-4 display the, respectively, annual average and annual maximum 24-hour average particulate nitrate concentrations for the standard diesel Base Case and the differences in particulate nitrate concentrations between the Base Case and 100% B20 emissions scenario. The peak annual average particulate nitrate concentration is 22 $\mu g/m^3$ and occurs in Orange County. Elevated annual average particulate nitrate concentrations exceeding 20 $\mu g/m^3$ occur in Orange County and in the Ontario area and vicinity. Annual average particulate nitrate concentrations in excess of 18 $\mu g/m^3$ occur over the major urban areas in Los Angeles, Orange, and western Riverside and San Bernardino Counties. The effects of the 100% B20 fuel are to cause annual average particulate nitrate concentration increases and decreases (Figure 3-3, bottom). The maximum annual average particulate nitrate increase and decrease due to the 100% B20 fuel are +0.04 $\mu g/m^3$ in the Coachella Valley in Riverside County and – 0.09 $\mu g/m^3$ around Santa Ana in Orange County. The reductions in annual average particulate nitrate occur in the populated areas of Los Angeles, Orange, Riverside, and San Bernardino Counties and are higher in magnitude than the increases that tend to occur to the east and northwest of the population centers of the SoCAB. However, both the particulate nitrate increases and decreases are extremely small and should be considered insignificant.

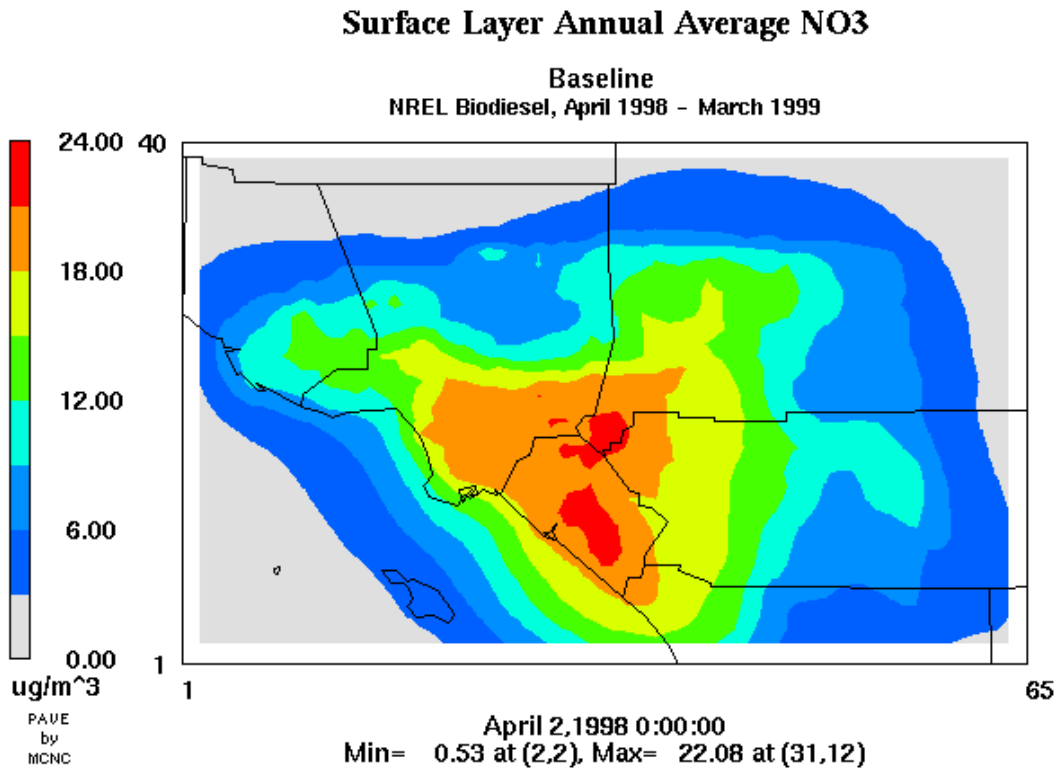
The maximum 24-hour average particulate nitrate concentrations during the modeling year occur in the eastern part of the SoCAB in the Riverside area, which is also where the maximum 24-hour observed nitrate concentrations tend to occur. The peak estimated 24-hour particulate nitrate concentrations is 121 $\mu g/m^3$ near Riverside, which is a little bit higher than the maximum values typically observed at Riverside (typically around 100 $\mu g/m^3$) but not unreasonable given the sparseness of the PM monitoring network and 1:6 day usual sampling frequency. The effects of the 100% B20 scenario on the maximum 24-hour average particulate nitrate concentrations are to have areas of concentration increases and decreases. The particulate nitrate decreases due to the 100% B20 fuel tend to occur in the more populated areas of the SoCAB with maximum decreases in excess of 1 $\mu g/m^3$ occurring in western Riverside County stretching from Corona to Lake Elsinore. The largest increase in maximum 24-hour average particulate nitrate due to the 100% B20 fuel is 0.6 $\mu g/m^3$ and occurs near Palm Springs. There are pockets of particulate nitrate increases of 0.2 $\mu g/m^3$ or greater near Palm Springs, Hemet, and in the Coachella Valley. The areas of particulate nitrate decreases of –0.2 $\mu g/m^3$ or more include most of Orange County, pockets in Los Angeles County, and in western San Bernardino and Riverside Counties. Over the remainder of the domain the changes in particulate nitrate due to the 100% B20 fuel are < $\pm$0.2 $\mu g/m^3$. The increases (maximum of 0.6 $\mu g/m^3$) and decreases (maximum of –1.1 $\mu g/m^3$) of particulate nitrate due to the 100% B20 fuel are very small and should be considered not significant.

The reason why the 100% B20 fuel results in increases and decreases in particulate nitrate concentrations when NOx emissions are increased has to do on the competing effects of the increases in the particulate nitrate precursor emissions (i.e., NOx emission increases) and reductions in atmospheric reactivity due to the reductions in the VOC and CO and increases in the NOx. The competing effects are summarized as follows:

- The biodiesel fuel results in small increases in NOx emissions so if nitrate formation rates remained the same would produce more total nitrate (combined nitric acid and particulate nitrate) and potentially more particulate nitrate if ammonia is available to neutralize the gaseous nitric acid and form particulate ammonium nitrate;

- The lower SO_2 emissions of the biodiesel fuel reduces sulfate thereby releasing ammonium that was bound to the sulfate that is now available to convert gaseous nitric acid to particulate ammonium nitrate thereby increasing particulate nitrate concentrations (note that the sulfate reductions are small so this is a very small effect, see Figures 3-1 and 3-2);
- The lower VOC and CO emissions and higher NOx emissions of the biodiesel fuel reduces photochemical activity (atmospheric reactivity) reducing the oxidation rate of NOx to total nitrate thereby reducing the particulate nitrate concentrations.

The western to central part of the SoCAB (from the coast to about San Bernardino/Riverside) is where the NOx inhibition effect on photochemistry occurs. That is, it is where reductions in NOx emissions tends to speed up photochemistry so forms more ozone and vice versa. This is also the area where ozone formation is more VOC-limited; that is in the City of Los Angeles area, VOC emission reductions are more effective at reducing photochemical reactivity and ozone formation than NOx controls. Thus, the biodiesel fuel increase in NOx and reductions in VOC emissions further reduces photochemical reaction rates in this area resulting in less nitrate formed. However, further east of about San Bernardino/Riverside or so, ozone formation is more NOx-limited so the increases in NOx emissions of the biodiesel increases photochemistry and nitrate precursors resulting in higher particulate nitrate concentrations.



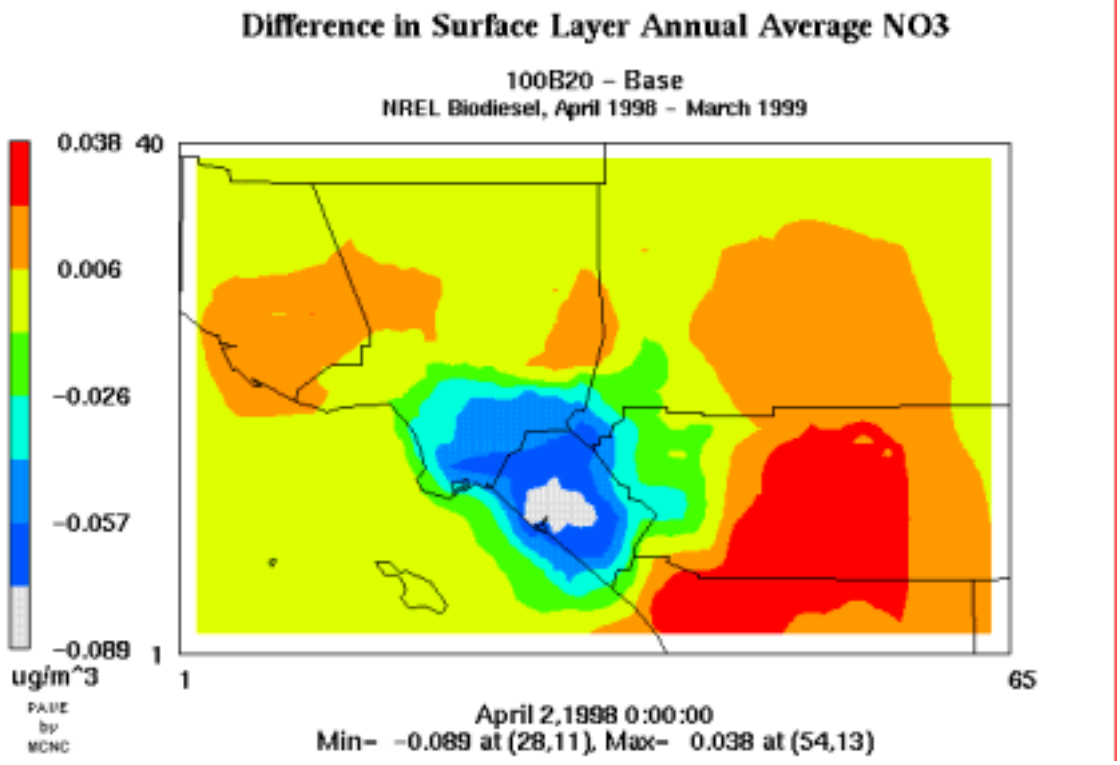
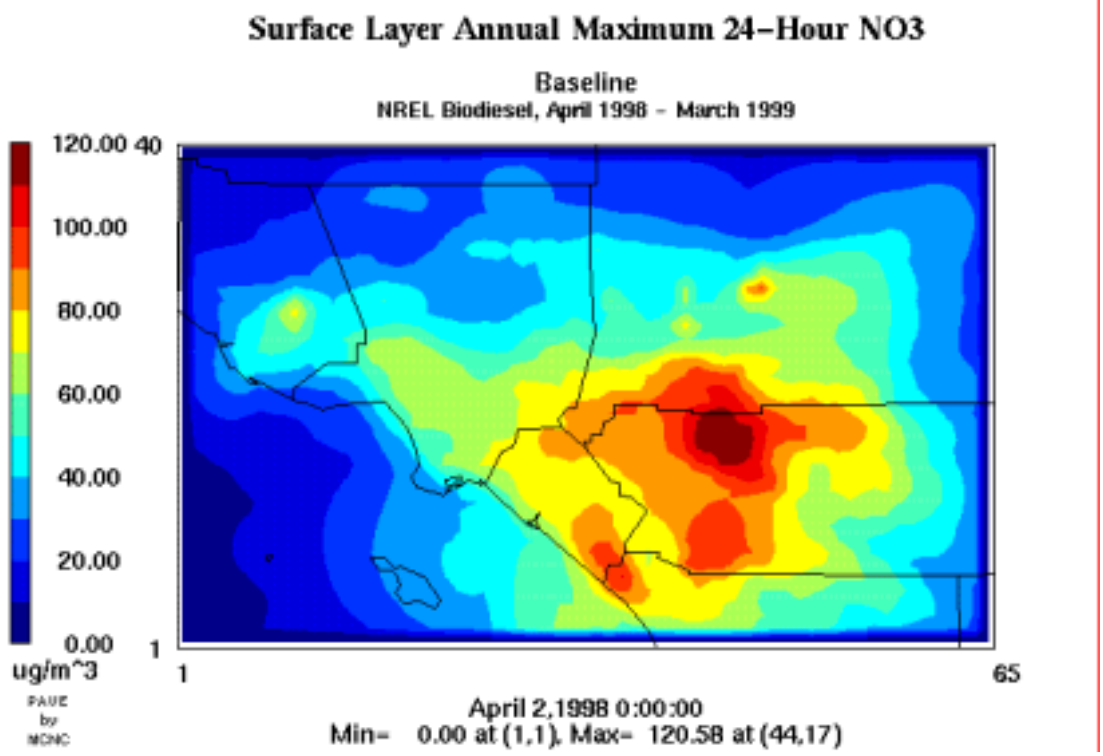


Figure 3-3. Estimated annual average particulate nitrate concentrations ($\mu g/m^3$) for the 1998/1999 standard diesel base case simulations (top) and differences in annual average particulate nitrate concentrations between the Base Case and 100% B20 biodiesel emissions scenarios (100% B20-Base Case).



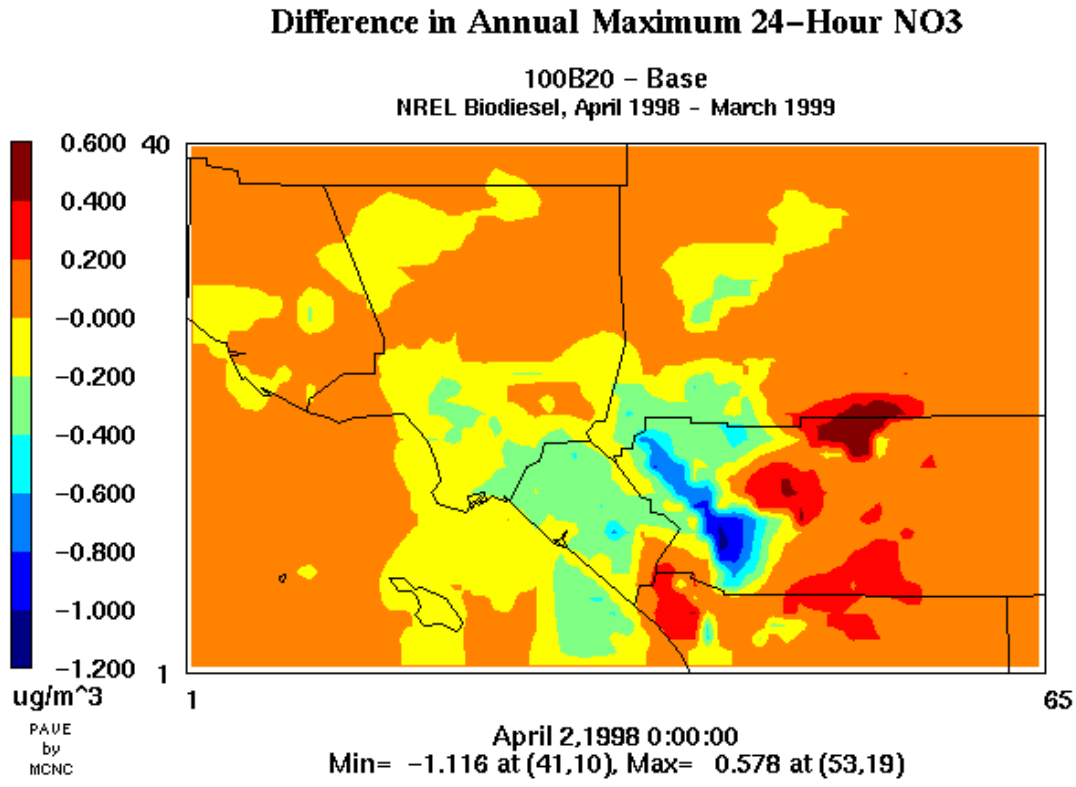
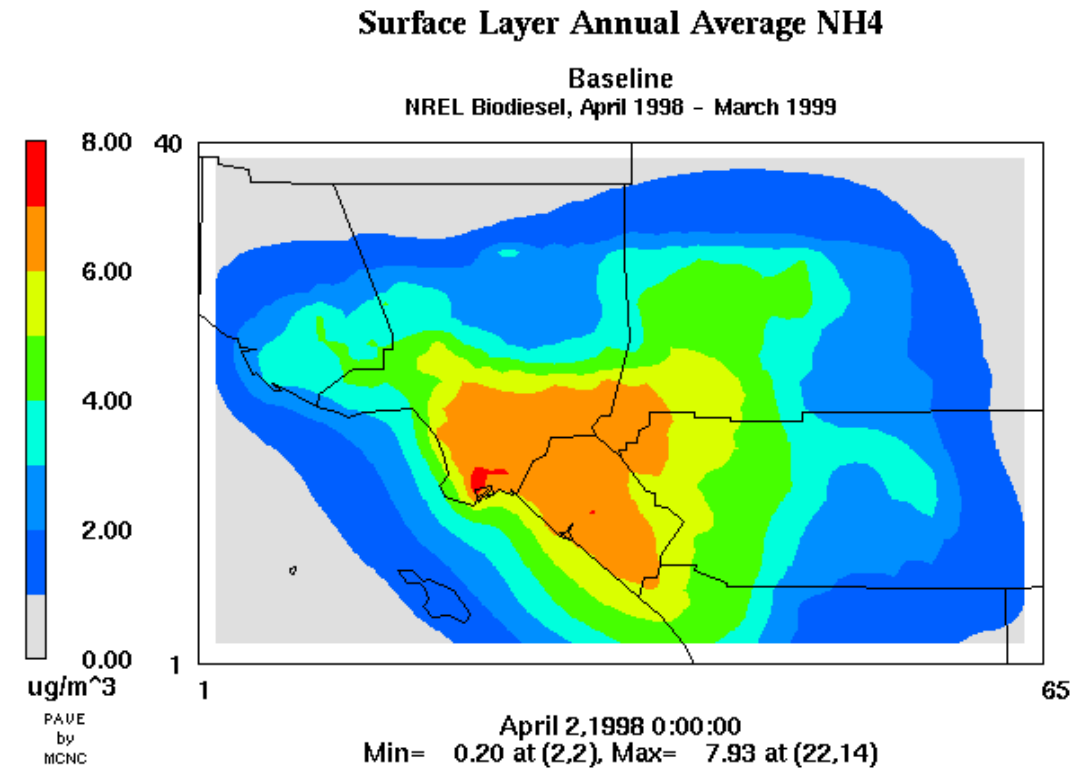


Figure 3-4. Estimated maximum 24-hour average particulate nitrate concentrations ($\mu g/m^3$) for the 1998/1999 standard diesel base case simulations (top) and differences in maximum 24-hour average particulate nitrate concentrations between the Base Case and 100% B20 biodiesel emissions scenarios (100% B20-Base Case).

Ammonium Concentrations

The spatial distribution of the 1998/199 Base Case annual average ammonium concentrations (Figure 3-5) is a combination of the spatial distribution of the annual average sulfate (Figure 3-1) and nitrate (Figure 3-3) concentrations reflecting the fact that the particulate ammonium is associated with the particulate sulfate and nitrate concentrations. The highest annual average ammonium estimate is at the port area, which is the sulfate hot spot, whereas the remainder of the annual average ammonium distribution follows the particulate nitrate distribution reflecting the higher particulate nitrate than sulfur concentrations in the SoCAB away from the port area. The spatial distribution of the difference in annual average ammonium concentrations between the Base Case and 100% B20 scenario (Figure 3-5, bottom) is an identical pattern as the differences for particulate nitrate (Figure 3-3, bottom) and approximately 30% of the magnitude reflecting the difference in the ammonium (18 g/mole) and nitrate (62 g/mole) molecular weights (18/62=0.29). Like the particulate nitrate, the areas of annual average ammonium reductions occur over the population centers in the SoCAB, with a maximum reduction of –0.03 in Orange County, and areas of annual ammonium increases occur mainly east of the SoCAB in the desert regions with a maximum increase of +0.01 $\mu g/m^3$.

The spatial distribution of the maximum 24-hour average ammonium concentrations (Figure 3-6) follow the distribution of the maximum 24-hour average nitrate concentrations (Figure 3-4) with about a third of the magnitude. The effects of the ammonium associated with the sulfate concentrations is not as apparent in the 24-hour average ammonium concentrations as was seen in the annual average values because the maximum 24-hour ammonium concentrations are associated with the maximum nitrate days, not the maximum sulfate days. Because of the difference in molecular weights, the amount of ammonium associated with the 16 $\mu g/m^3$ peak 24-hour sulfate concentration in the Port area (Figure 3-2) is 3 $\mu g/m^3$, which is a barely noticeable amount in the maximum 24-hour average ammonium plot (Figure 3-6). As for maximum 24-hour particulate nitrate, the reductions in ammonium due to the 100% B20 fuel occur in the populated areas of the SoCAB and the pockets of ammonium increases occur mainly in the Palm Springs and Coachella Valley areas east of the SoCAB.



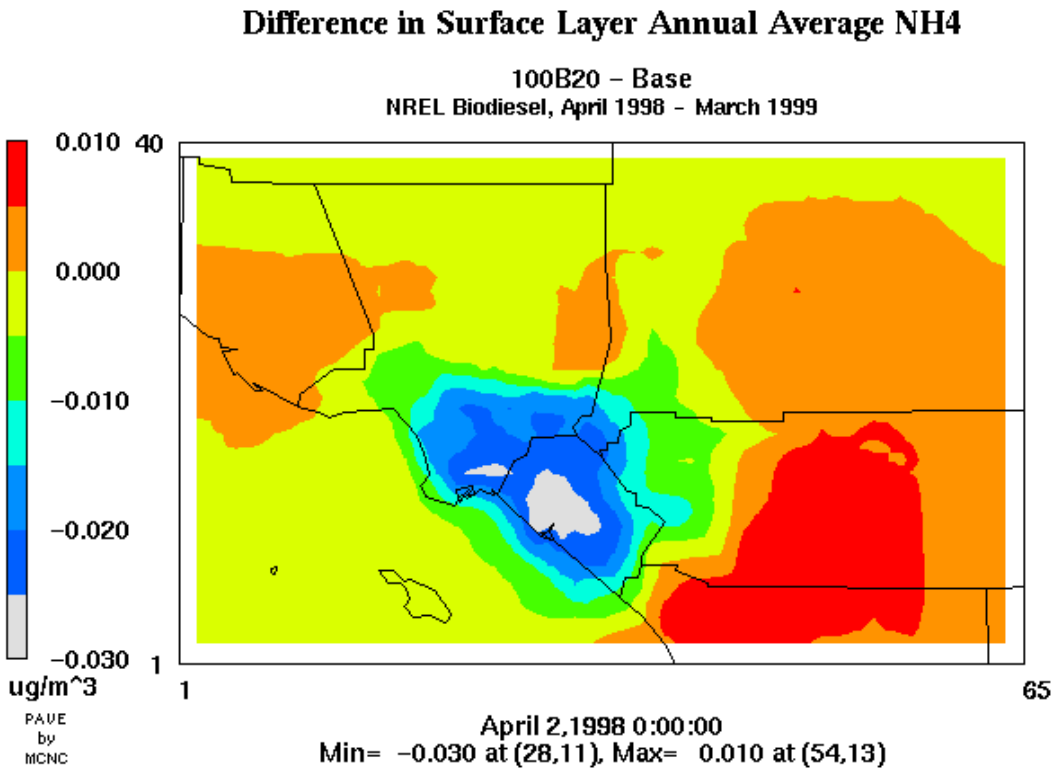


Figure 3-5. Estimated annual average ammonium concentrations (µg/m^3) for the 1998/1999 standard diesel base case simulations (top) and differences in annual average ammonium concentrations between the Base Case and 100% B20 biodiesel emissions scenarios (100% B20-Base Case).

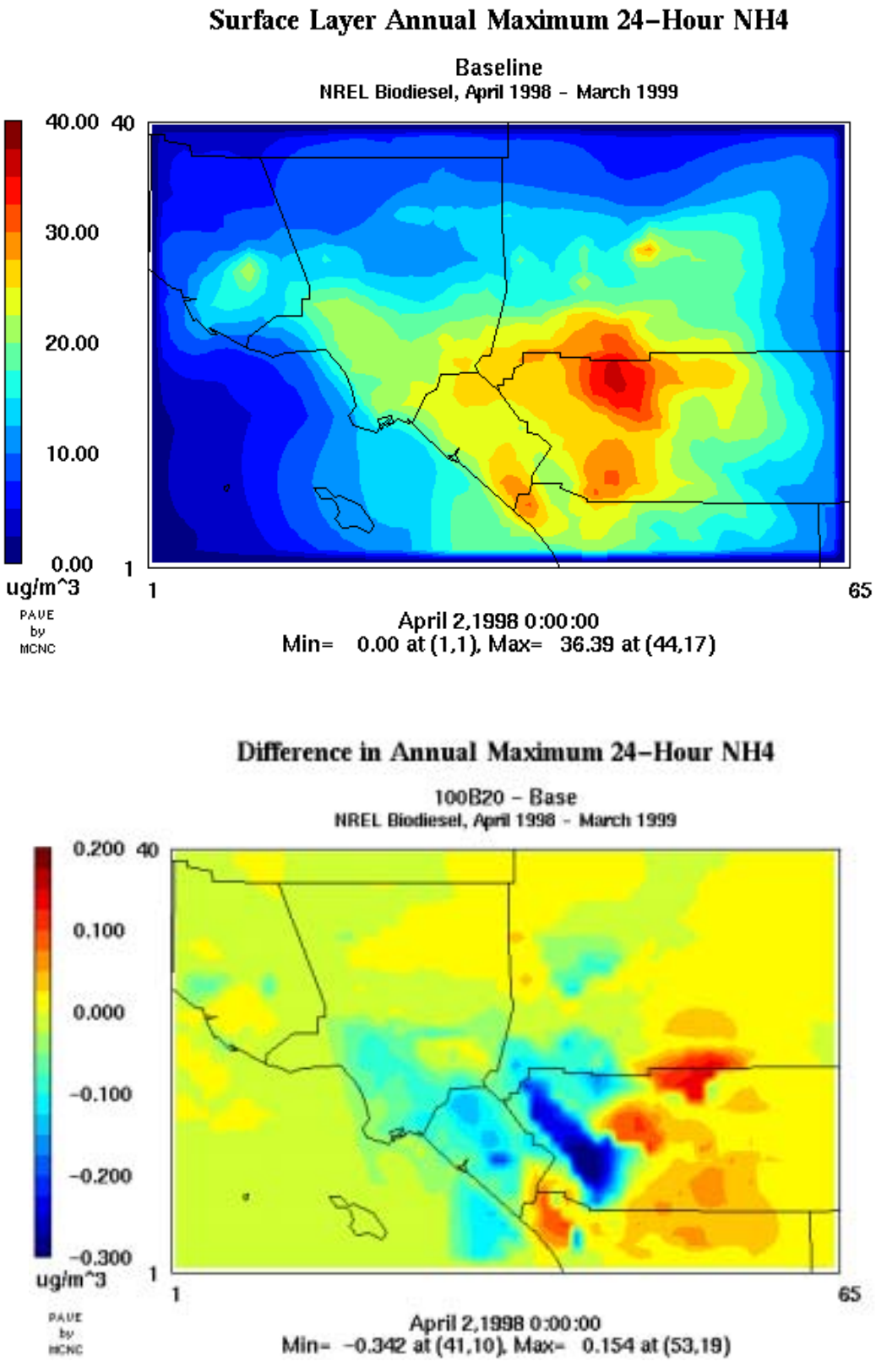


Figure 3-6. Estimated maximum 24-hour average ammonium concentrations (µg/m^3) for the 1998/1999 standard diesel base case simulations (top) and differences in maximum 24-hour average ammonium concentrations between the Base Case and 100% B20 biodiesel emissions scenarios (100% B20-Base Case).

Elemental Carbon (EC) Concentrations

There are three "hot spots" (> 2 μg/m^3) of annual average elemental carbon (EC) concentrations in the 1998/1999 Base Case simulation (Figure 3-7): (1) downtown Los Angeles, where the region-wide maximum annual EC concentration of 2.8 μg/m^3 occurs; (2) the port area where the high EC concentrations are likely due to the marine diesel engines; and (3) around Corona/Norco in western Riverside County. The source of this third hot spot is not known. The effects of the biodiesel fuel are to reduce EC concentrations throughout the SoCAB. The maximum annual EC reduction due to the 100% B20 fuel is –0.06 μg/m^3 and occurs in downtown Los Angeles. This reduction is not significant. The highest annual average EC reductions occur in the populated areas and along the major roadways in the SoCAB. The peak maximum 24-hour EC concentration for the 1998/1999 Base Case simulation is 5.4 μg/m^3 and occurs in downtown Los Angeles (Figure 3-8). Elevated maximum 24-hour concentrations stretch from downtown Los Angeles to the port and Anaheim areas and in the Corona/Norco and Ontario areas. With the exception of the port area, the effects of the 100% B20 biodiesel fuel are to reduce maximum 24-hour EC concentrations where the higher EC concentrations reside. The largest reduction is -0.10 μg/m^3 that occurs in downtown Los Angeles. These reductions in EC due to the biodiesel fuel are not measurable so are not significant.

Organic Carbon (OC) Concentrations

The maximum annual average primary organic carbon (OC) concentrations estimated in the Base Case simulation is 5.4 μg/m^3 and occurs in downtown Los Angeles (Figure 3-9). Elevated annual average OC concentrations are estimated in the population centers of the SoCAB. Unlike for EC, there is no OC hot spot in the port area. The effects of the 100% B20 fuel are to reduce annual OC concentrations across the SoCAB, with a maximum reduction of –0.15 μg/m^3 (an insignificant amount) occurring in downtown Los Angeles. The highest annual OC reductions due to the 100% B20 fuel occur in areas with the highest population and along the major roadways. The highest maximum 24-hour average OC concentrations occur in an area stretching from Los Angeles to Anaheim and in Ontario. The peak 24-hour OC concentration is 11.1 μg/m^3 and occurs over downtown Los Angeles (Figure 3-10). The effects of the 100% B20 fuel are to reduce the maximum 24-hour OC concentrations with the maximum reduction (-0.27 μg/m^3) occurring at the same place as where the highest estimated maximum 24-hour average OC concentration occurs. Again, the reductions in OC due to the biodiesel fuel are below the level that is typically reported from monitoring so are not significant.

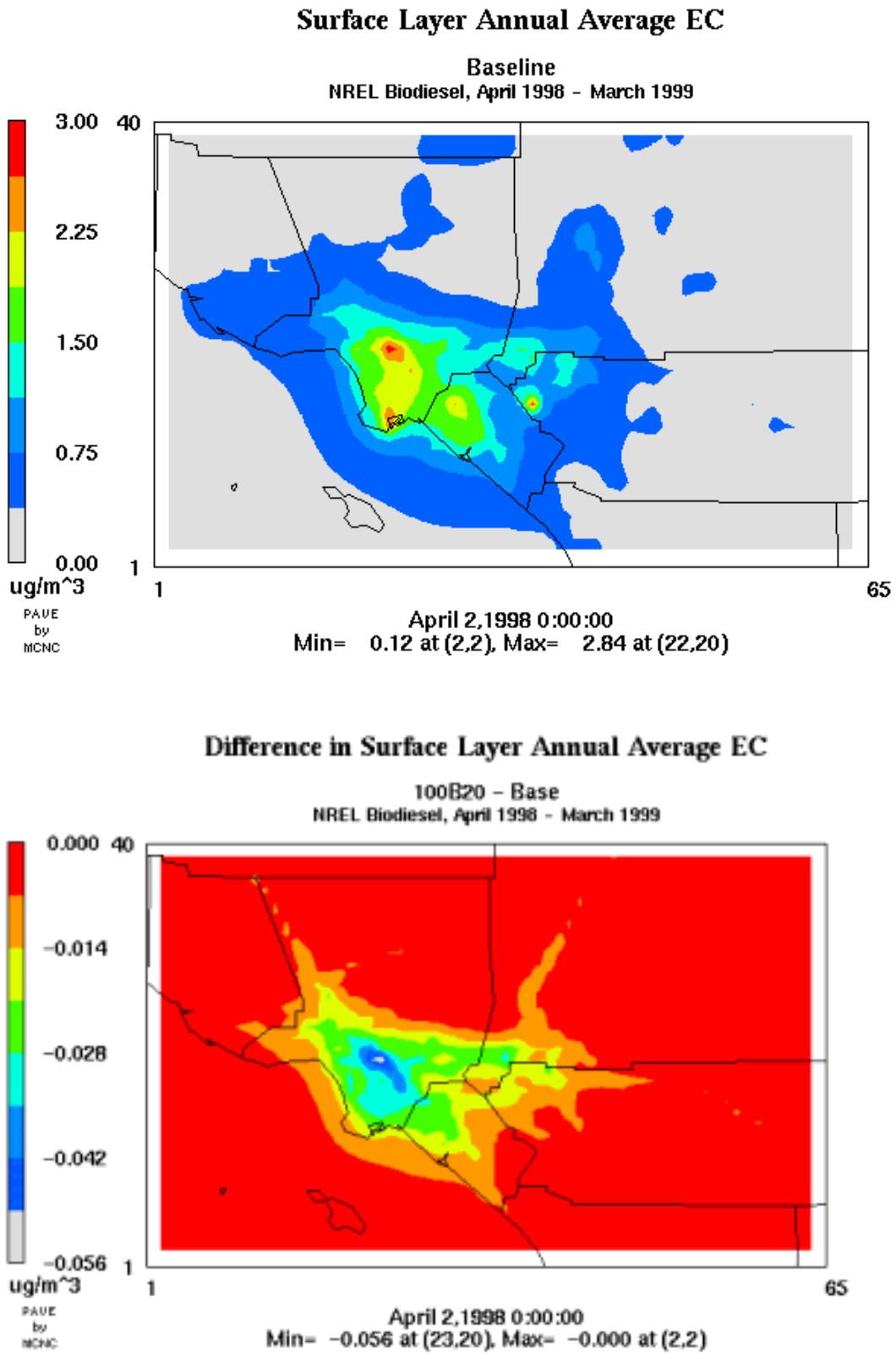


Figure 3-7. Estimated annual average Elemental Carbon (EC) concentrations ($\mu g/m^3$) for the 1998/1999 standard diesel base case simulations (top) and differences in annual average Elemental Carbon (EC) concentrations between the Base Case and 100% B20 biodiesel emissions scenarios (100% B20-Base Case).

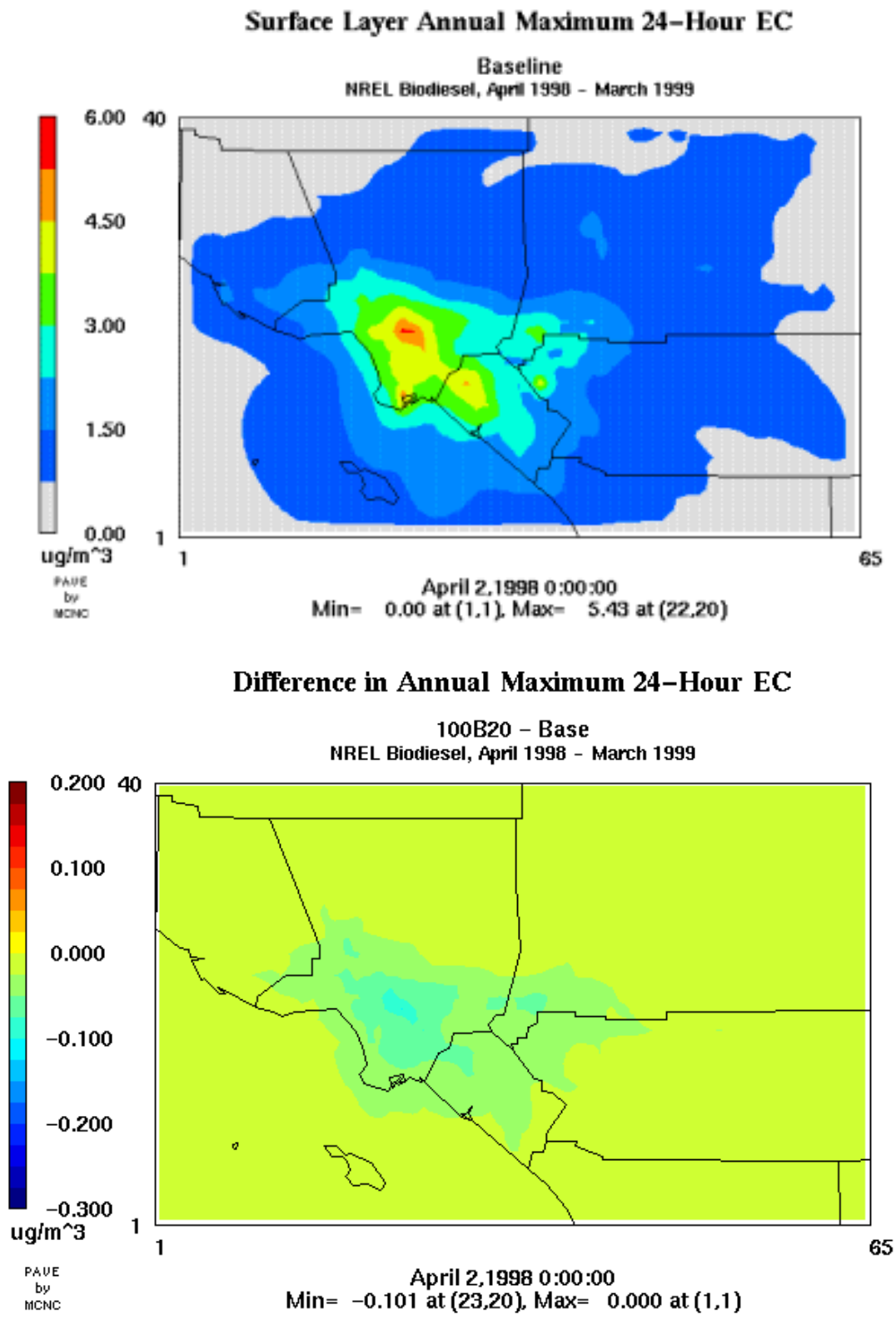


Figure 3-8. Estimated maximum 24-hour average Elemental Carbon (EC) concentrations ($\mu g/m^3$) for the 1998/1999 standard diesel base case simulations (top) and differences in maximum 24-hour average Elemental Carbon (EC) concentrations between the Base Case and 100% B20 biodiesel emissions scenarios (100% B20-Base Case).

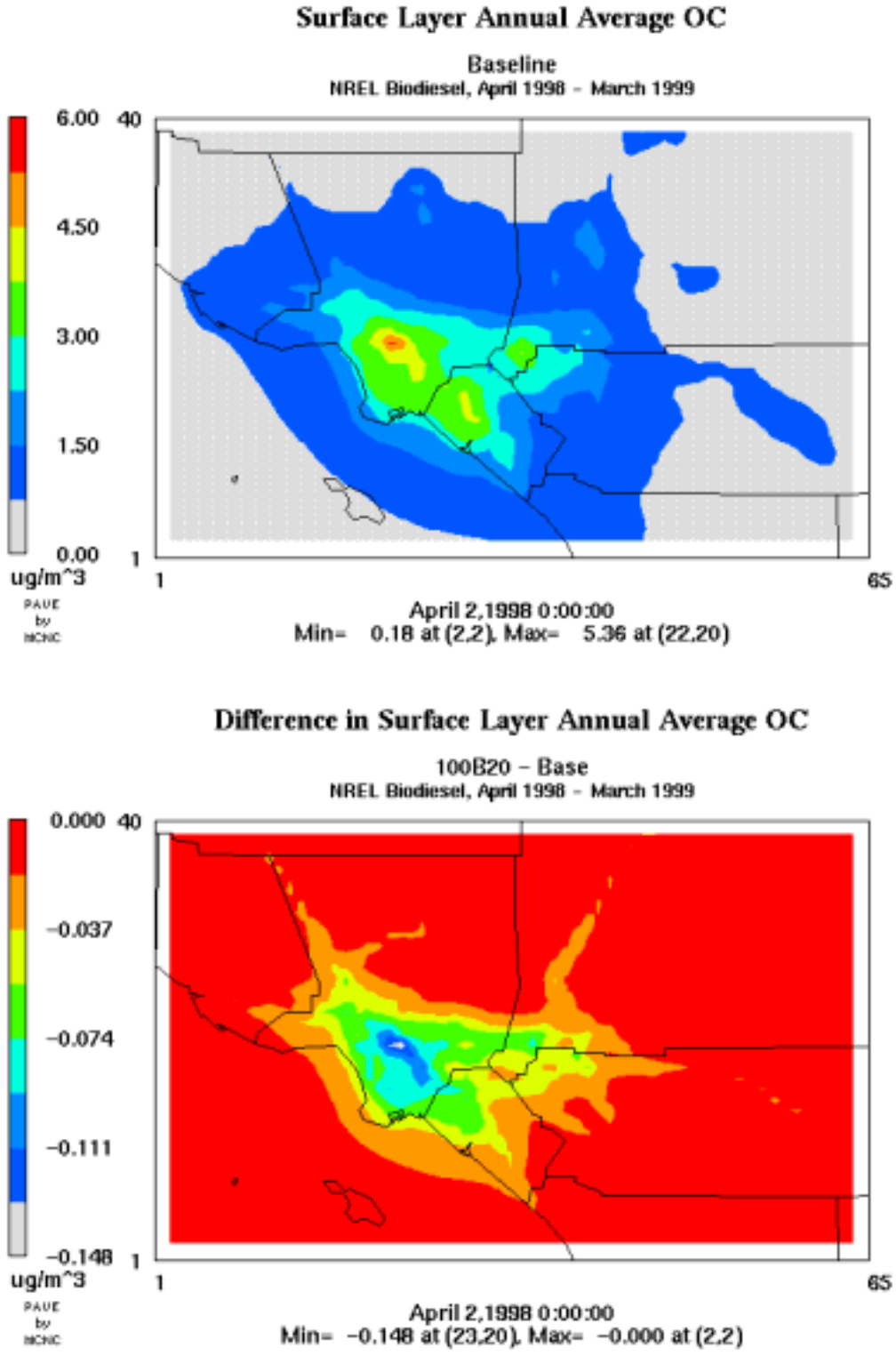


Figure 3-9. Estimated annual average Organic Carbon (OC) concentrations ($\mu g/m^3$) for the 1998/1999 standard diesel base case simulations (top) and differences in annual average Organic Carbon (OC) concentrations between the Base Case and 100% B20 biodiesel emissions scenarios (100% B20-Base Case).

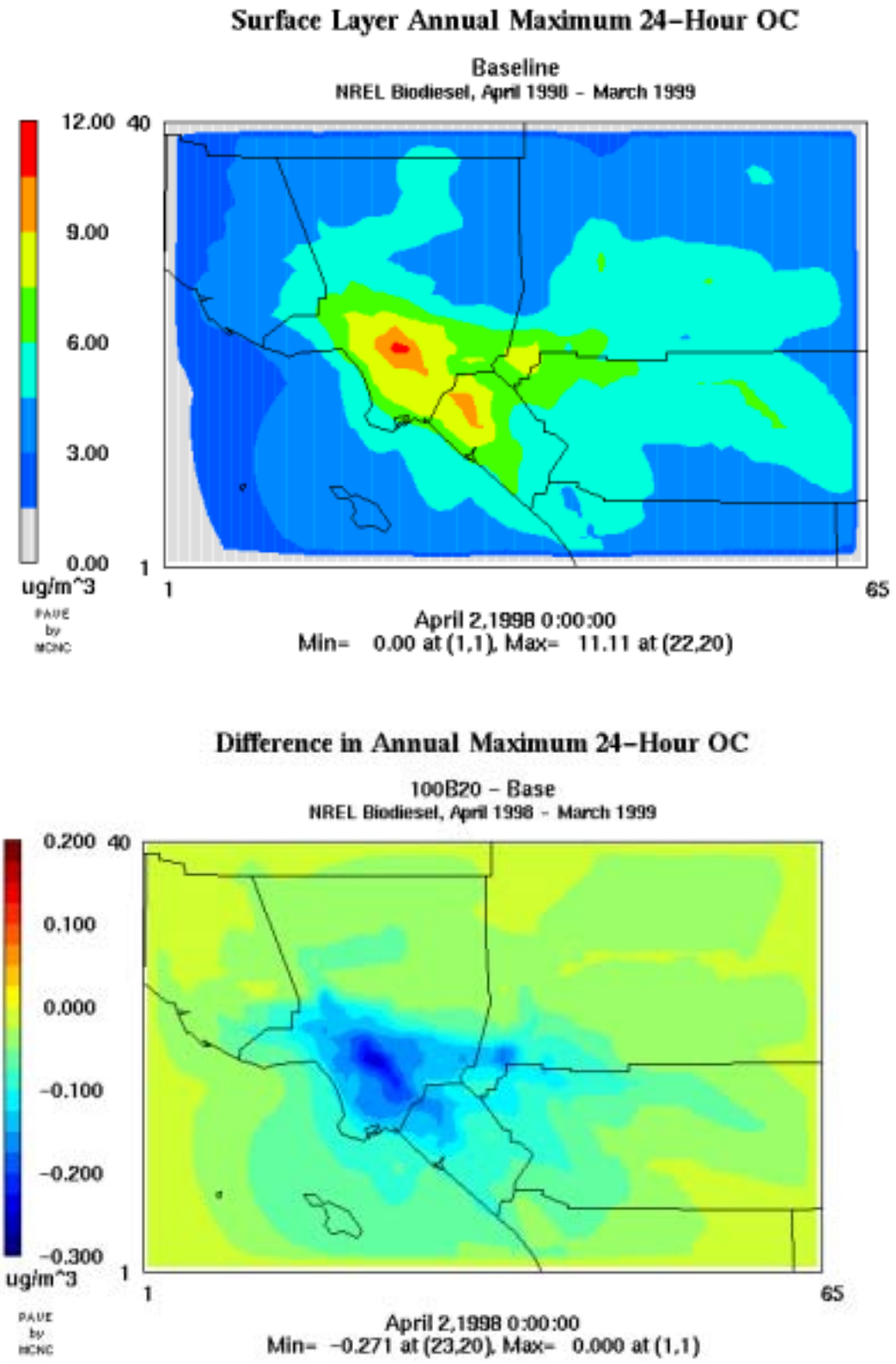


Figure 3-10. Estimated maximum 24-hour average Organic Carbon (OC) concentrations ($\mu g/m^3$) for the 1998/1999 standard diesel base case simulations (top) and differences in maximum 24-hour average Organic Carbon (OC) concentrations between the Base Case and 100% B20 biodiesel emissions scenarios (100% B20-Base Case).

Other Fine Particulate Matter ($PM_{2.5}$)

Figure 3-11 displays the annual average of the other fine particulate (PFIN) concentrations (i.e., PM2.5 that is not EC, OC, sulfate, or nitrate). There are several "hot spot" locations of elevated (> 10 $\mu g/m^3$) PFIN concentrations that occur over downtown Los Angeles, in the Corona/Norco area, up near Victorville, and two side-by-side hot spots near Lancaster/Palmdale. The peak annual average PFIN concentration of 16.1 $\mu g/m^3$ occurs near Victorville in San Bernardino County. The effect of the 100% B20 biodiesel fuel scenario is to have extremely small reductions in the PFIN concentrations with a maximum annual reduction of only –0.005 $\mu g/m^3$ that occurs in downtown Los Angeles. The maximum 24-hour PFIN concentrations have a similar distribution to the annual values (Figure 3-12). Again, the effects of the 100% B20 fuel on maximum 24-hour PFIN concentrations are very small with the maximum reduction being -0.01 $\mu g/m^3$ that occurs in Los Angeles. These reductions are not significant.

Coarse Particulate Matter ($PM_{2.5-10}$)

Figures 3-13 and 3-14 display plots of annual and maximum 24-hour concentrations for coarse PM with a mean diameter between 2.5 μm and 10 μm (PCRS). There are five main locations of elevated PCRS concentrations: downtown Los Angeles and Anaheim, Ontario, Victorville, and Lancaster/Palmdale. The peak annual average coarse PM concentration is 31 $\mu g/m^3$ and occurs in Ontario. The peak 24-hour PCRS concentration is 57 $\mu g/m^3$ and also occurs in Ontario. The effect of the 100% B20 biodiesel emissions scenario is to have extremely small reductions in the coarse PM. The maximum annual and 24-hour average reduction in PCRS due to the 100% B20 fuel are, respectively, -0.008 and –0.012 $\mu g/m^3$ (insignificant changes).

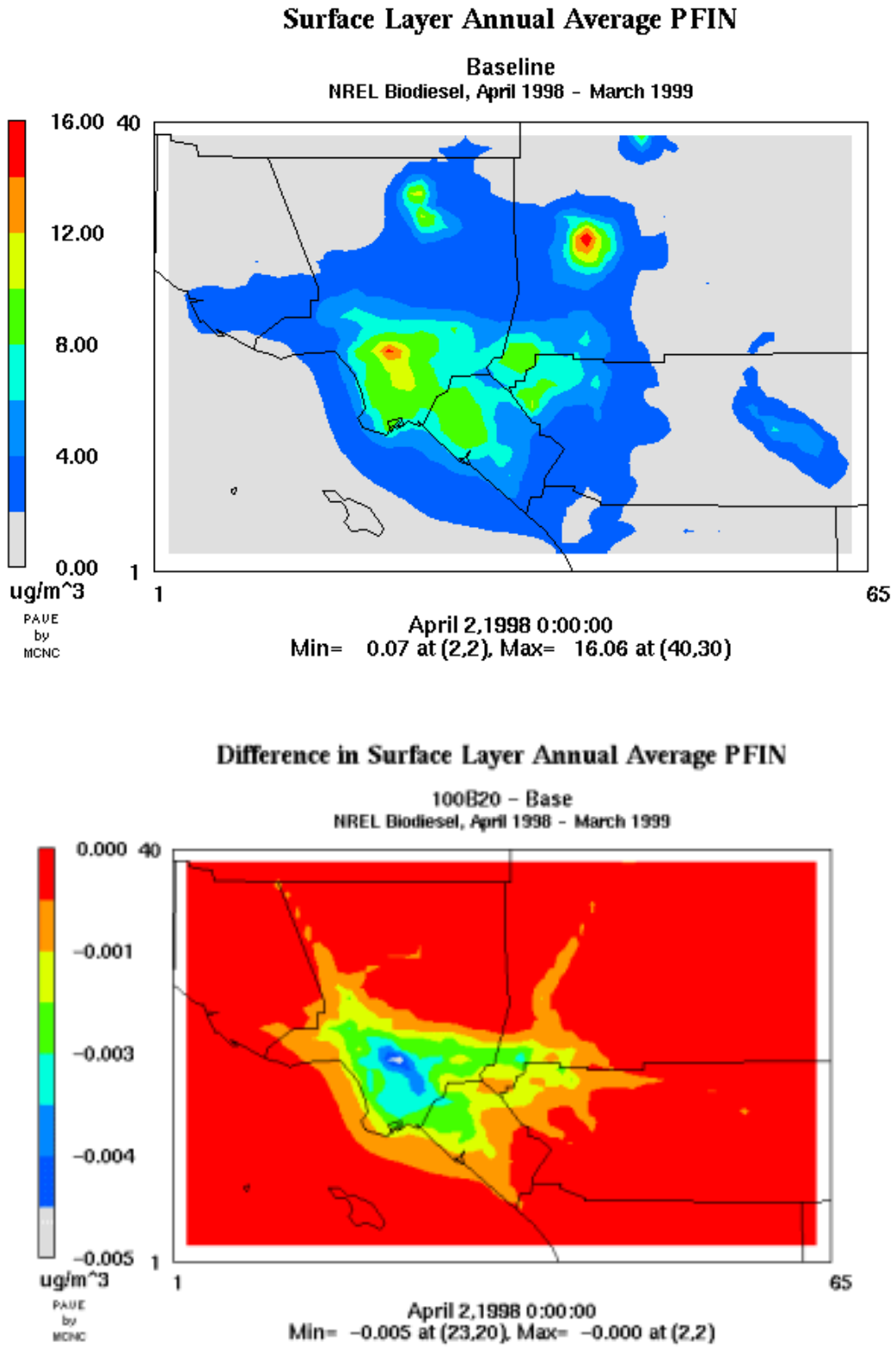


Figure 3-11. Estimated annual average other fine particulate concentrations ($\mu g/m^3$) for the 1998/1999 standard diesel base case simulations (top) and differences in annual average other fine particulate concentrations between the Base Case and 100% B20 biodiesel emissions scenarios (100% B20-Base Case).

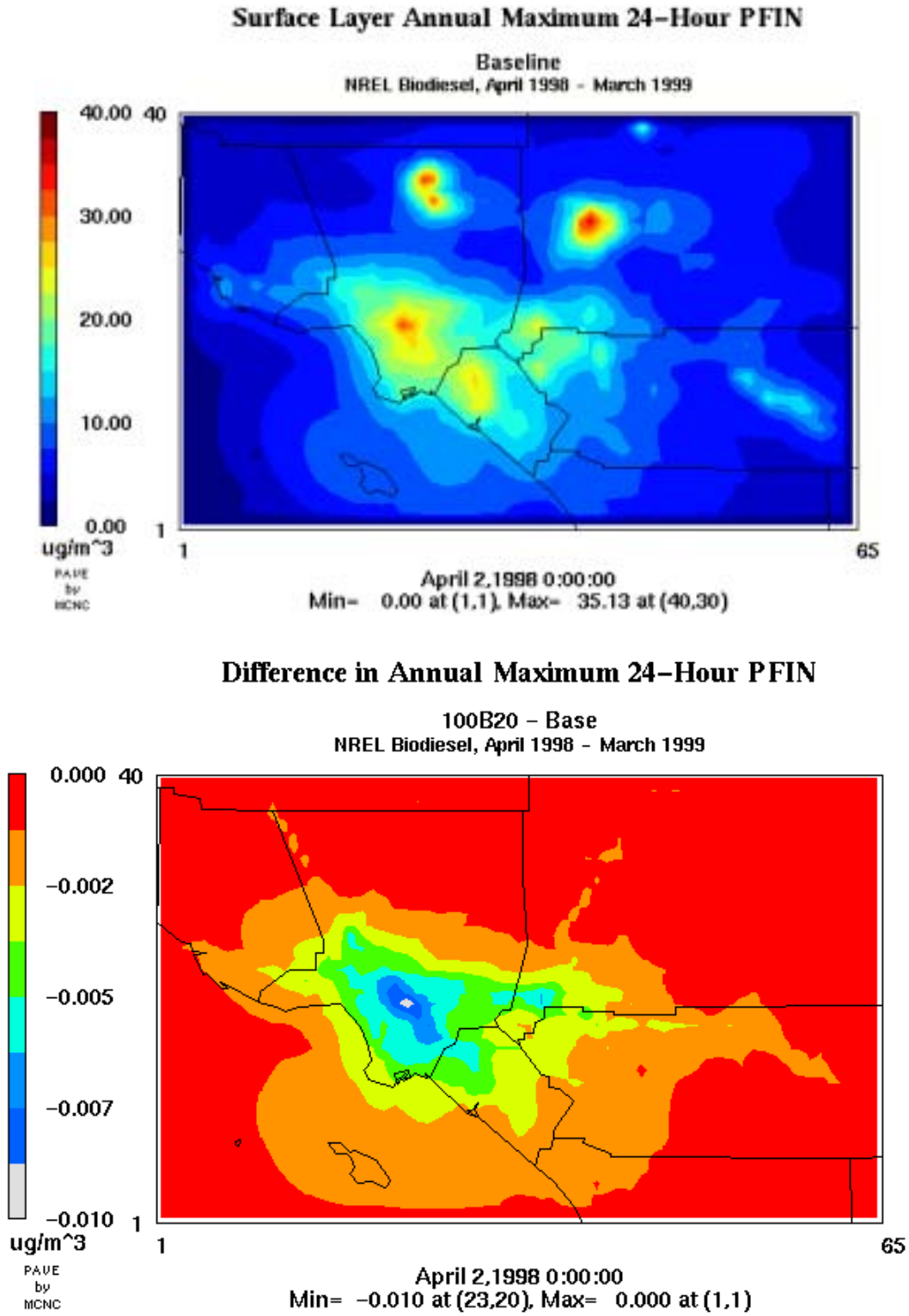
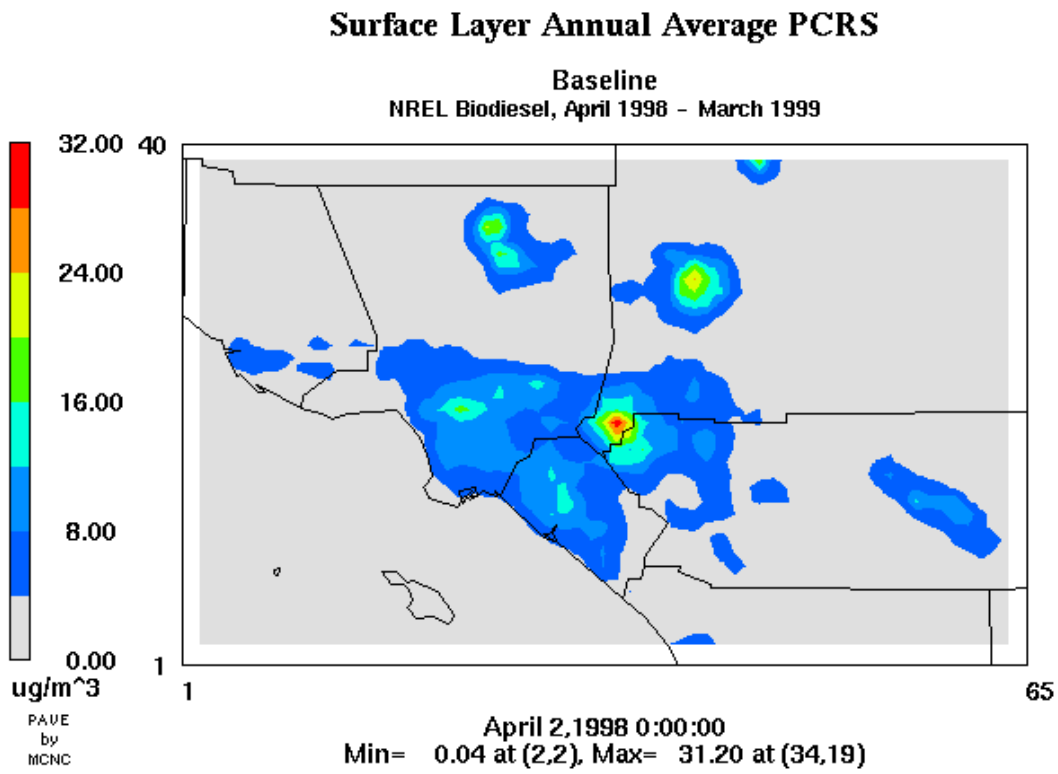


Figure 3-12. Estimated maximum 24-hour average other fine particulate concentrations (μg/m^3) for the 1998/1999 standard diesel base case simulations (top) and differences in maximum 24-hour average other fine particulate concentrations between the Base Case and 100% B20 biodiesel emissions scenarios (100% B20-Base Case).



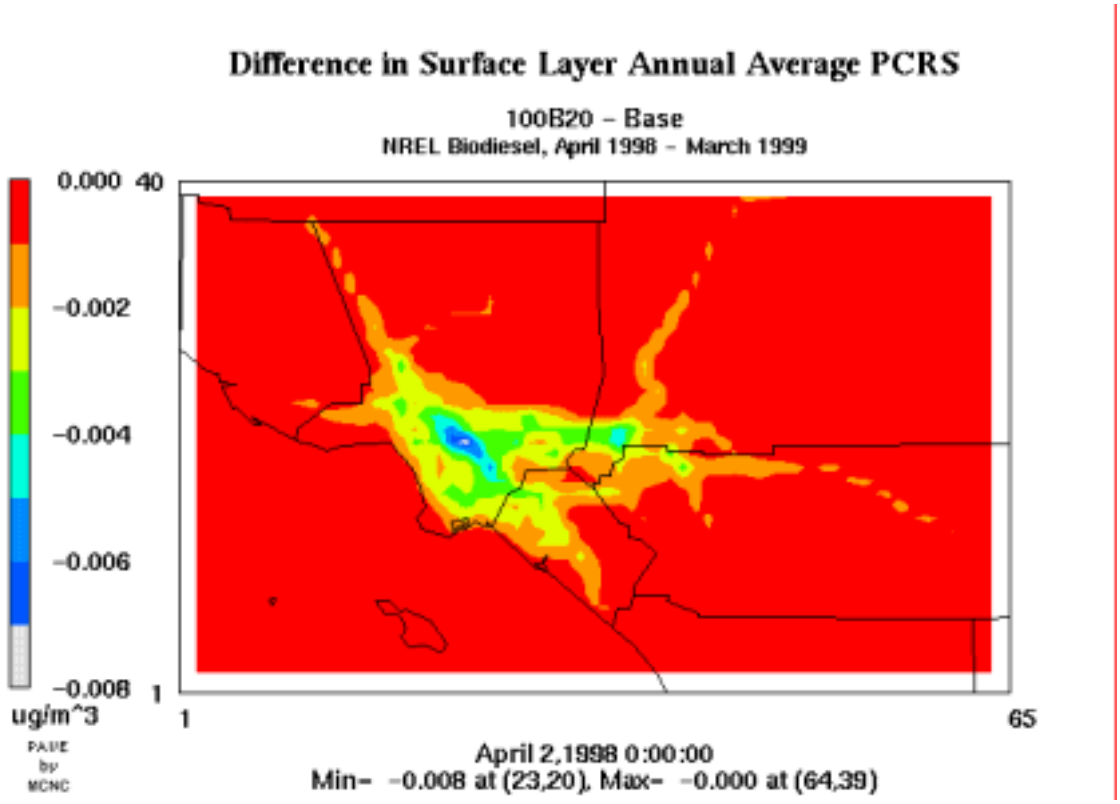


Figure 3-13. Estimated annual average coarse particulate matter concentrations ($\mu g/m^3$) for the 1998/1999 standard diesel base case simulations (top) and differences in annual average coarse particulate matter concentrations between the Base Case and 100% B20 biodiesel emissions scenarios (100% B20-Base Case).

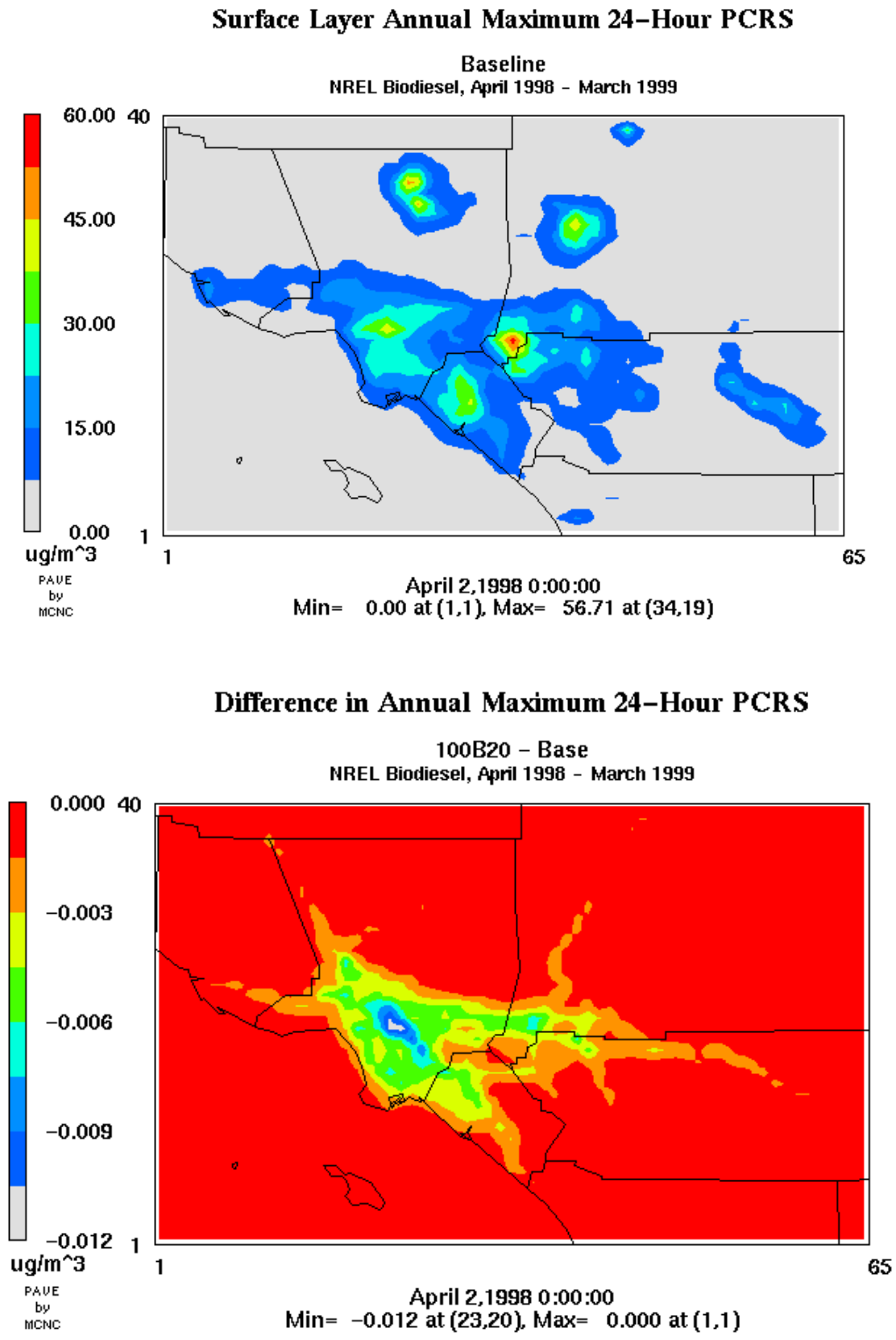


Figure 3-14. Estimated maximum 24-hour average coarse particulate matter concentrations ($\mu g/m^3$) for the 1998/1999 standard diesel base case simulations (top) and differences in maximum 24-hour average coarse particulate matter concentrations between the Base Case and 100% B20 biodiesel emissions scenarios (100% B20-Base Case).

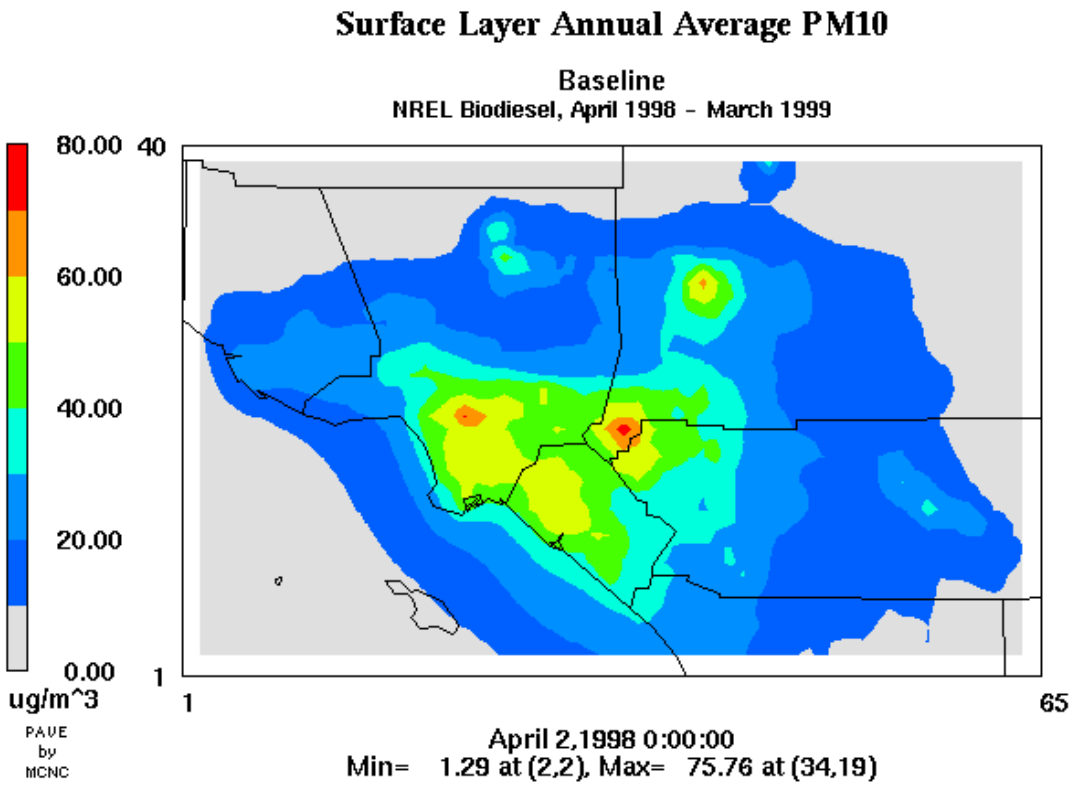
PM_{10} Mass Concentrations

The spatial distribution of the annual average estimated total PM_{10} mass concentrations for the 1998/1999 Base Case is shown in Figure 3-15, along with the differences in annual average PM_{10} concentrations between the 100% B20 scenario and the Base Case. The maximum estimated annual average PM_{10} concentration (76 $\mu g/m^3$) is approximately 50% higher than the Federal annual standard (50 $\mu g/m^3$) and a little bit (20%) higher than the maximum observed value that occurred during this period (63 $\mu g/m^3$). The location of the estimate PM_{10} peak (Ontario) is also where the peak coarse PM (PCRS) annual average of 31 $\mu g/m^3$ occurred so that approximately 40% of the PM_{10} peak is due to coarse PM, which is not typical for the SoCAB. Clearly there is a coarse PM emissions artifact in the Ontario area that is driving this peak value. Ignoring the Ontario hot spot, estimated maximum annual PM_{10} concentrations are in the 50-65 $\mu g/m^3$ range stretching from downtown Los Angeles to Anaheim and in western San Bernardino and Riverside Counties.

The changes in annual PM_{10} concentrations due to the use of the 100% B20 fuel exhibit mostly decreases across the SoCAB with a maximum decrease of 0.31 $\mu g/m^3$. In the far eastern portion of the domain, slight increases in PM_{10} are estimated from the use of the 100% B20 fuel with a maximum increase of 0.04 $\mu g/m^3$. The PM_{10} reduction benefits of the biodiesel fuel are larger in magnitude and cover the population regions of the SoCAB, whereas the disbenefits are smaller and cover areas that are mostly desert. However, both the PM_{10} mass increases and decreases due to the 100% B20 biodiesel fuel use are extremely small and are probably not significant.

The estimated maximum 24-hour average PM_{10} concentrations in the SoCAB during the 1998/1999 year are shown in Figure 3-16. The peak 24-hour estimated PM_{10} concentration (186 $\mu g/m^3$) is 24% higher than the Federal standard (150 $\mu g/m^3$) and approximately 20% higher than the maximum value observed in the SoCAB during this period (153 $\mu g/m^3$ in 1999), but lower to the maximum value observed in the recent past (219 $\mu g/m^3$ in 1995). Elevated maximum 24-hour PM_{10} concentrations in excess of 180 $\mu g/m^3$ are estimated to occur in the Riverside area, which is where the observed highest 24-hour PM_{10} concentrations typically occur. Elevated PM_{10} concentrations in excess of 160 are estimated to occur in the Riverside/San Bernardino, Ontario, and Anaheim areas.

The effect of the 100% B20 emissions scenario results in both increases and decreases in maximum 24-hour total PM_{10} mass in the modeling domain. PM_{10} reductions are estimated in the populated areas of the SoCAB with a maximum reduction of -1.0 $\mu g/m^3$ estimated to occur around Lake Elsinore in southwestern Riverside County. East of the SoCAB in the mainly desert regions there are slight increases in PM_{10} due to the 100% B20 fuel use with the highest increase in maximum 24-hour PM_{10} concentrations of +0.6 $\mu g/m^3$.



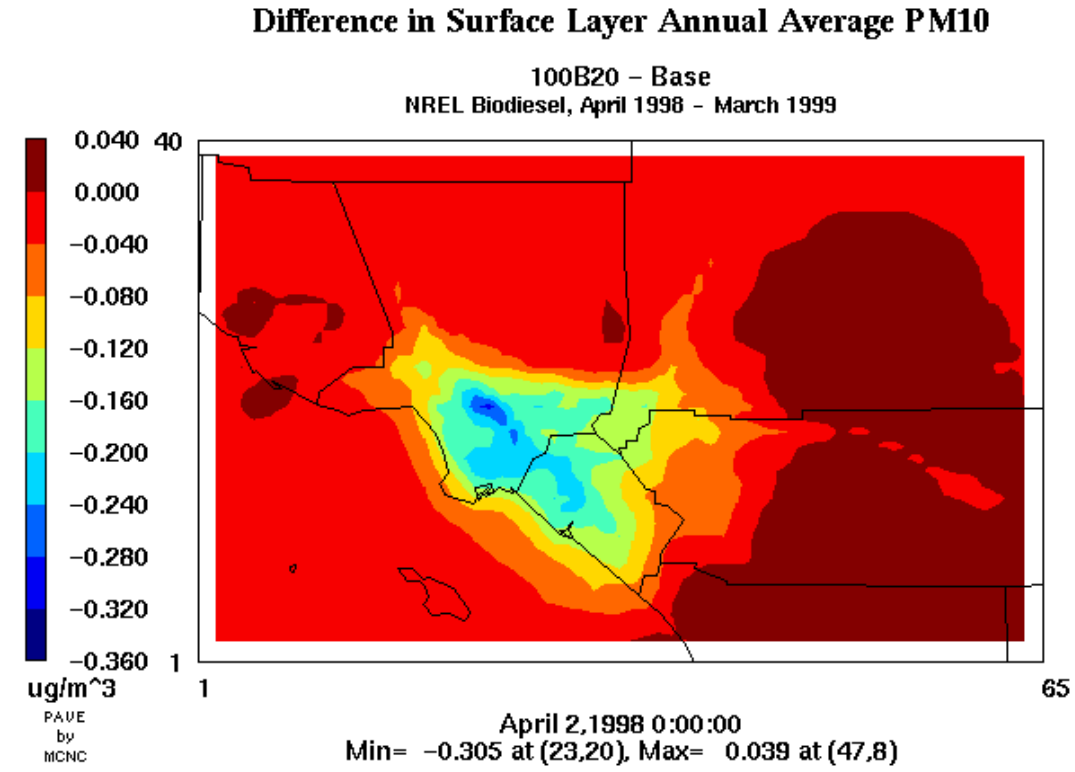
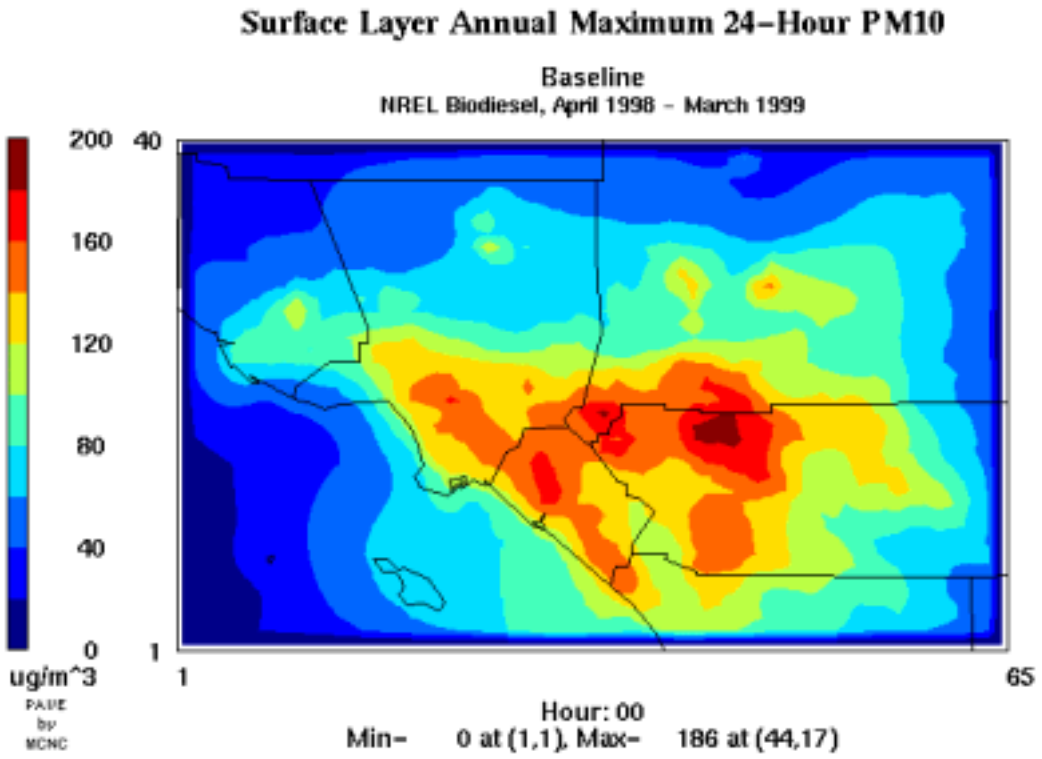


Figure 3-15. Estimated annual average PM_{10} concentrations ($\mu g/m^3$) for the 1998/1999 standard diesel base case simulations (top) and differences in annual average PM_{10} concentrations between the Base Case and 100% B20 biodiesel emissions scenarios (100% B20-Base Case).



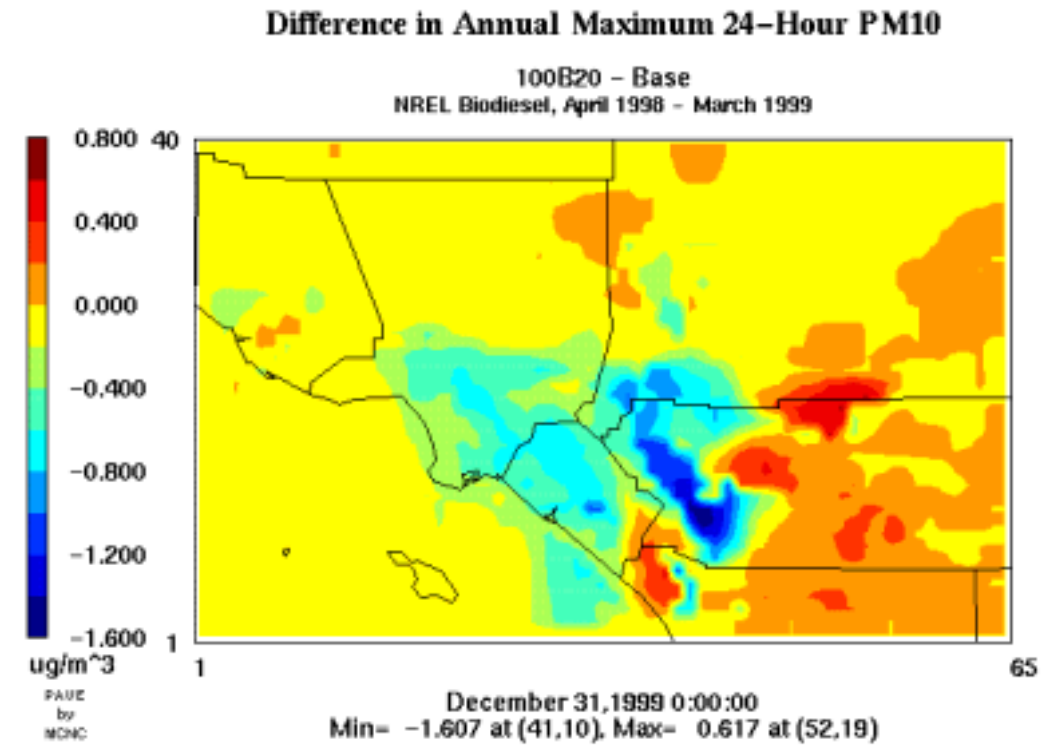
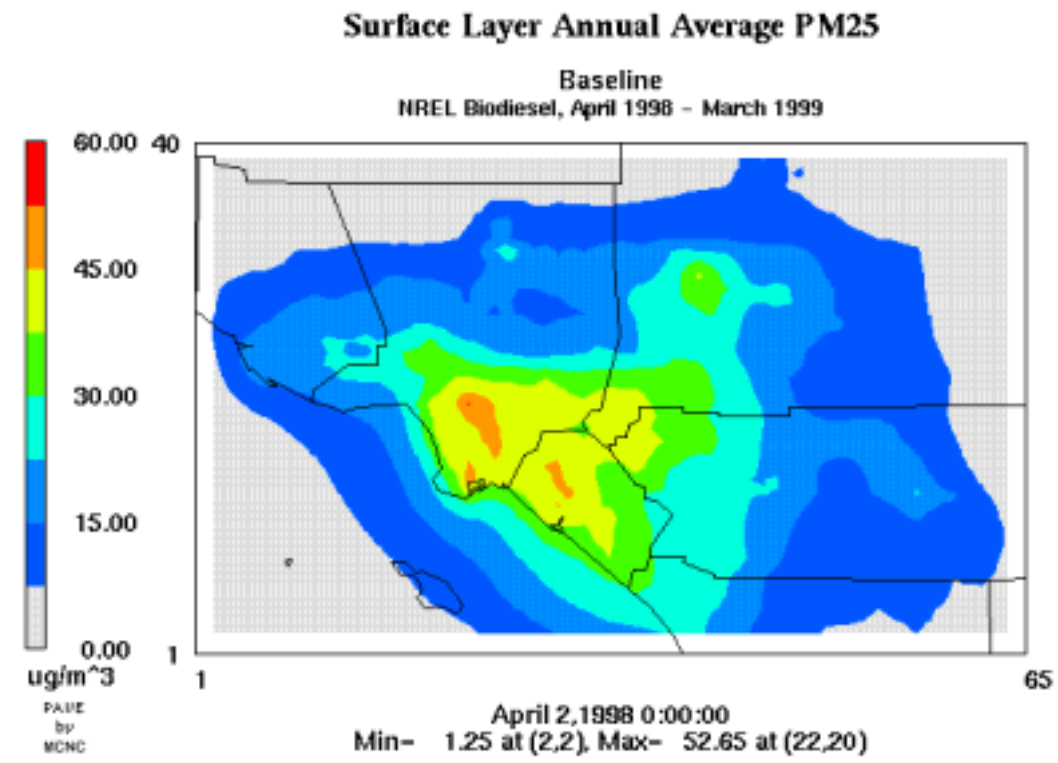


Figure 3-16. Estimated maximum 24-hour average PM_{10} concentrations ($\mu g/m^3$) for the 1998/1999 standard diesel base case simulations (top) and differences in maximum 24-hour average PM_{10} concentrations between the Base Case and 100% B20 biodiesel emissions scenarios (100% B20-Base Case).

$PM_{2.5}$ Mass Concentrations

The maximum estimated annual average fine particulate ($PM_{2.5}$) concentration for the standard diesel Base Case simulation is 53 $\mu g/m^3$ in Los Angeles, approximately 350% above the new annual $PM_{2.5}$ standard of 15 $\mu g/m^3$ (Figure 3-17). Annual average $PM_{2.5}$ concentrations more than double the Federal Standard are estimated to occur over most of the populated areas of the SoCAB. The use of a 100% B20 biodiesel fuel is estimated to cause small reductions in $PM_{2.5}$ concentrations in the more populated areas of the SoCAB with a maximum reduction of –0.3 $\mu g/m^3$ estimated to occur in Los Angeles. The 100% B20 fuel is estimated to cause very small increases in $PM_{2.5}$ concentrations in the eastern desert portions of the domain with a maximum increase of + 0.04 $\mu g/m^3$.

The peak maximum 24-hour $PM_{2.5}$ concentration is 178 $\mu g/m^3$, approximately 275% above the Federal Standard of 65 $\mu g/m^3$, and occurs in the Riverside area (Figure 3-18). The 100% B20 biodiesel fuel is estimated to result in areas of $PM_{2.5}$ increases and decreases. The decreases occur in the more populated areas of the SoCAB, whereas the increases occur in the desert area east of San Bernardino/Riverside. The highest decrease in maximum 24-hour average $PM_{2.5}$ concentrations is –1.6 $\mu g/m^3$ and occurs near Lake Elsinor. Whereas the maximum increase of +0.6 $\mu g/m^3$ occurs near Palm Springs.



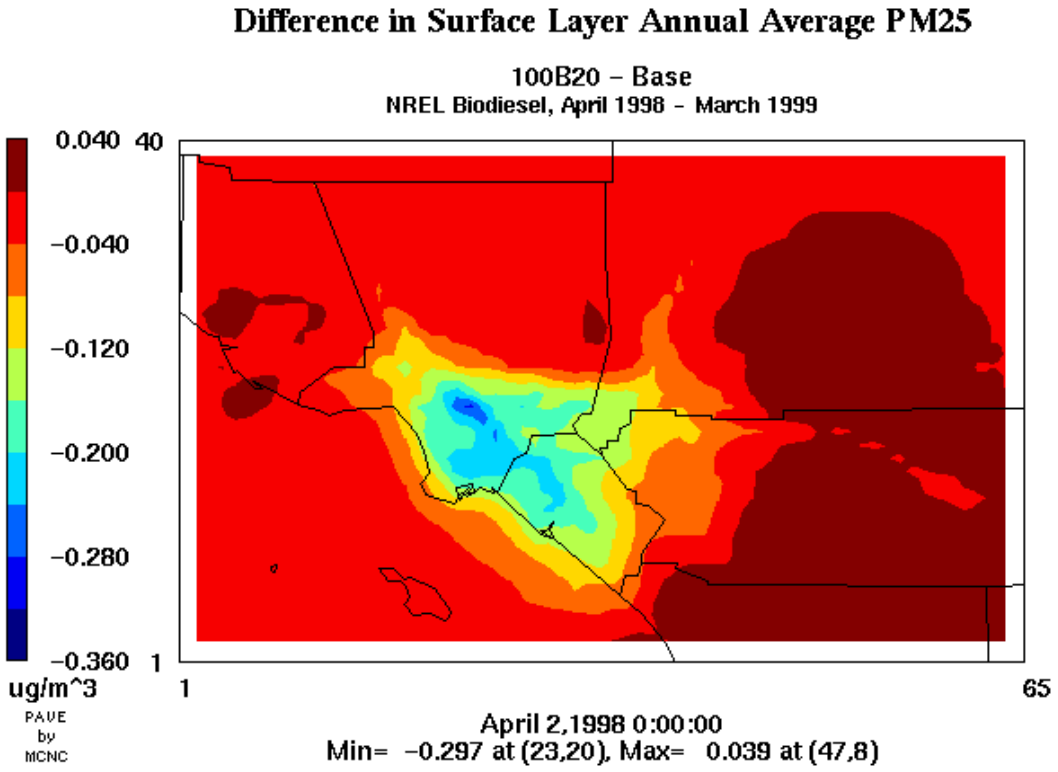


Figure 3-17. Estimated annual average fine particulate ($PM_{2.5}$) concentrations ($\mu g/m^3$) for the 1998/1999 standard diesel base case simulations (top) and differences in annual average fine particulate ($PM_{2.5}$) concentrations between the Base Case and 100% B20 biodiesel emissions scenarios (100% B20-Base Case).

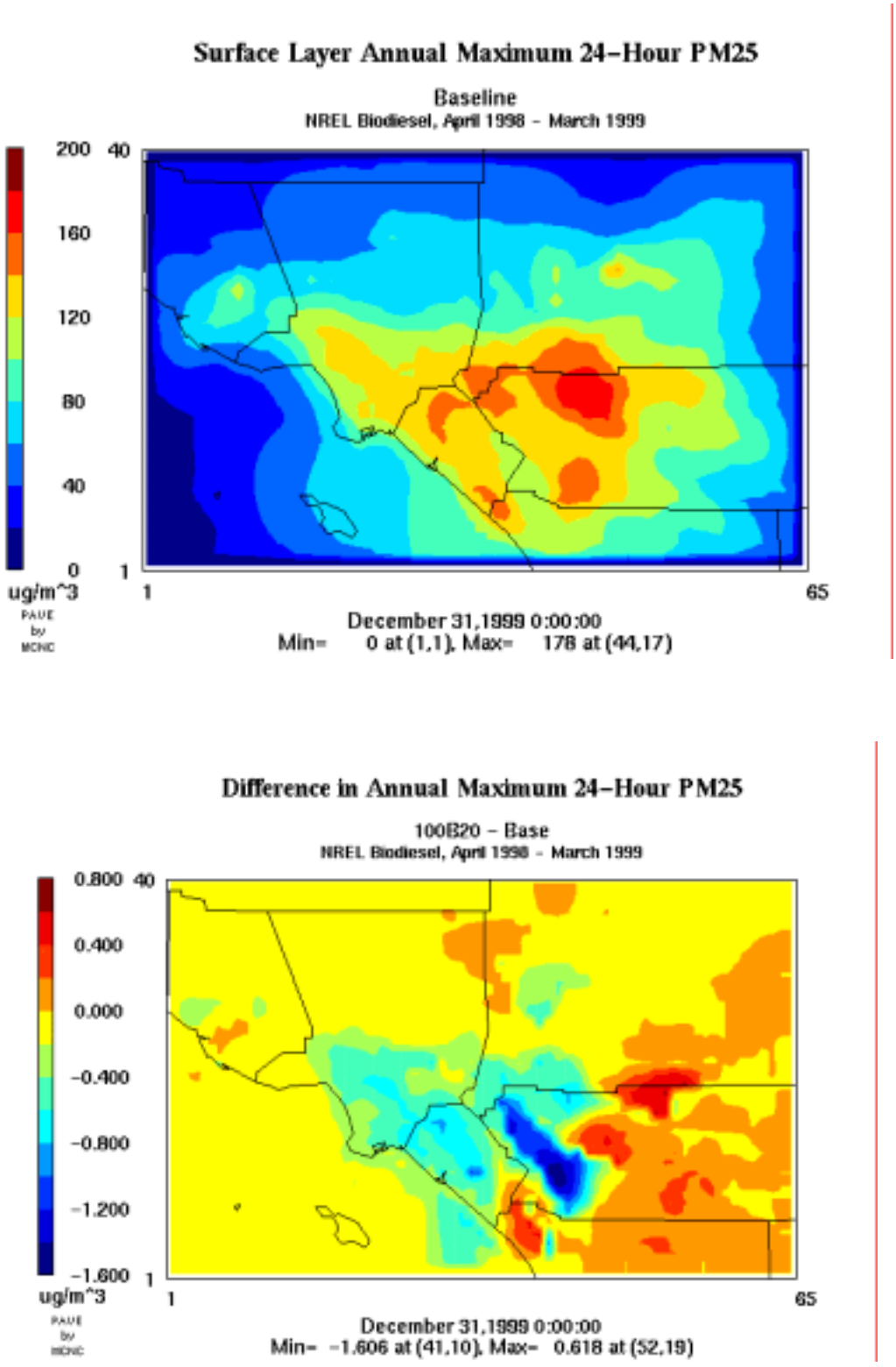


Figure 3-18. Estimated maximum 24-hour average fine particulate matter ($PM_{2.5}$) concentrations ($\mu g/m^3$) for the 1998/1999 standard diesel base case simulations (top) and differences in maximum 24-hour average fine particulate matter ($PM_{2.5}$) concentrations between the Base Case and 100% B20 biodiesel emissions scenarios (100% B20-Base Case).

4. SUMMARY AND CONCLUSIONS

The effects of biodiesel fuel on ambient particulate matter (PM) concentrations in the South Coast Air Basin (SoCAB) were estimated using the Comprehensive Air-quality Model with extensions and an April 1998 through March 1998 annual modeling database. The effects of the biodiesel fuel on both total PM_{10} and $PM_{2.5}$ mass concentrations as well as each of the major PM compounds were analyzed:

- Sulfate
- Particulate Nitrate
- Ammonium
- Elemental Carbon (EC)
- Organic Carbon (OC)
- Other fine particulate matter (PFIN)
- Other coarse particulate matter (PCRS)

BIODIESEL FUEL IMPACTS ON PM CONCENTRATIONS

The air quality effects of a 20%/80% biodiesel/diesel (B20) fuel used in the Heavy Duty Diesel Vehicle (HDDV) fleet was assessed and compared against a standard diesel fuel scenario. Both a 100% and 50% penetration of B20 into the HDDV fleet was modeled. The HDDV NOx emission increases and decreases in VOC, CO, and PM emissions due to the B20 fuel use were accounted for.

The spatial distributions of the impacts of the B20 fuel were analyzed. The impacts of the B20 fuel tended to be greatest where major roadways and population centers existed. Table 4-1 summarizes the maximum increase and maximum decrease for each of the major PM components as well as PM_{10} and PM_{10} total mass for the 100% B20 scenario. The impact of the 50% B20 scenario was approximately half of the 100% B20 scenario.

As seen in Table 3-1, the increases and decreases in PM concentrations due to the biodiesel fuel use are extremely small and should probably be considered not significant. The biodiesel fuel use has the biggest impacts on the ammonium nitrate, EC, and OC PM species. The biodiesel fuel use is estimated to have areas of increases and decreases in ammonium nitrate and total PM_{10} and $PM_{2.5}$ mass and only areas of decreases for sulfate, EC, OC, PFIN, and PCRS. It is interesting to note that the areas of decreases in ammonium nitrate and total PM_{10} and $PM_{2.5}$ mass occurs in the populated areas of the SoCAB, whereas the areas of increases correspond to areas east of the SoCAB in the desert.

Table 4-1. Estimated maximum increases and decreases in PM concentrations ($\mu g/m^3$) in the SoCAB due to a 100% penetration of a B20 biodiesel fuel in the HDDV fleet.

	Annual Average		Maximum 24-Hour Average	
PM Species	Maximum Increase	Maximum Decrease	Maximum Increase	Maximum Decrease
Sulfate	0.00	-0.03	0.00	-0.07
Nitrate	+0.04	-0.09	+0.58	-1.12
Ammonium	+0.01	-0.03	+0.15	-0.34
EC	0.00	-0.06	0.00	-0.10
OC	0.00	-0.15	0.00	-0.27
Other PFIN	0.00	-0.01	0.00	-0.01
Other PCRS	0.00	-0.01	0.00	-0.01
PM_{10} Mass	+0.04	-0.31	+0.62	-1.61
$PM_{2.5}$ Mass	+0.04	-0.30	+0.62	-1.61

BIODIESEL FUEL IMPACTS ON PM EXPOSURE AND DOSAGE

The impacts of the 100% B20 and 50% B20 biodiesel fuel scenarios on exposure to elevated PM_{10} and $PM_{2.5}$ concentrations was calculated using two integrated exposure metrics:

> Exposure: Number of grid cells the annual and number of grid cell-days the 24-hour PM_{10} and $PM_{2.5}$ concentration exceeded the PM_{10} and $PM_{2.5}$ NAAQS, respectively.
>
> Dosage: Similar to Exposure only multiplied by the concentrations in the grid cell exceeding the NAAQS.

The biodiesel fuel scenarios are estimated to reduce PM_{10} exposure (number of grid cells exceeding the annual PM_{10} standard) by approximately 1 and 3 percent for the 50% and 100% B20 scenarios, respectively with a reduction in dosage being slightly greater (2 and 4 percent). The areal extent of the exposure to exceedances of the 24-hour PM_{10} standard is reduced even more, approximately 5 and 9 percent for the 50% and 100% B20 scenarios, respectively. Slightly lower reductions are seen for the 24-hour PM_{10} dosage reduction due to the 50% and 100% B20 fuel scenarios (4 and 7 percent).

Smaller percent reductions in exposure and dosage to elevated $PM_{2.5}$ concentrations are seen because there are so many more occurrences of exceedance of the standard than seen for the PM_{10} standard. The biodiesel fuels are estimated to have no effect in exposure to exceedances of the annual average $PM_{2.5}$ concentrations exceeding the annual standard and small reductions in dosage (0.2 and 0.5 percent). For the 24-hour $PM_{2.5}$ concentrations, the 100% and 50% B20 biodiesel fuel are estimated to have small reductions in both exposure (0.3 and 0.6 percent) and dosage (0.6 and 1.1 percent).

The changes in PM_{10} and $PM_{2.5}$ exposure and dosage due to the use of the biodiesel fuel are small and like the changes in concentrations may not be significant. However, it is encouraging that directionally the biodiesel fuels do exhibit a net reduction in exposure and dosage to annual average and 24-hour average coarse and fine particulate matter concentrations in excess of the NAAQS.

Table 4-2. Summary of integrated exposure metrics for annual and 24-hour PM_{10} and $PM_{2.5}$ concentrations ($\mu g/m^3$) exceeding the NAAQS.

	Std Diesel	50% B20 Biodiesel		100% B20 Biodiesel	
Exposure Metric	**$\mu g/m^3$**	**$\mu g/m^3$**	**%**	**$\mu g/m^3$**	**%**
Annual Average PM10 Exposure Metrics					
Exposure	92	91	-1.1%	89	-3.3%
Dosage	441	433	-1.9%	425	-3.7%
24-Hour PM10 Exposure Metrics					
Exposure	285	274	-3.9%	264	-7.4%
Dosage	2327	2246	-3.5%	2184	-6.1%
Annual Average PM2.5 Exposure Metrics					
Exposure	1014	1014	0.0%	1014	0.0%
Dosage	11114	11088	-0.2%	11063	-0.5%
24-Hour PM2.5 Exposure Metrics					
Exposure	31380	31285	-0.3%	31192	-0.6%
Dosage	588109	584638	-0.6%	581487	-1.1%

CONCLUSIONS

The two biodiesel fuel scenarios analyzed have nearly identical impacts on PM_{10} and $PM_{2.5}$ as the standard diesel fuel scenario. The changes in PM concentrations, exposure, and dosage are sufficiently small that they may be considered insignificant by some. Both PM_{10} and $PM_{2.5}$ concentration increases and decreases are estimated due to the use of biodiesel fuels, it is encouraging that the reductions in PM_{10} and $PM_{2.5}$ due to biodiesel fuels are greater in magnitude and extent than the increases and occur in the more populated locations of the SoCAB as compared to the increases that are smaller and occur in the desert east of the SoCAB.

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