ATTACHMENT 1

Modeling Protocol

MODELING PROTOCOL FOR 1-HOUR OZONE MODELING IN SUPPORT OF THE SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT'S YEAR 2001 AIR QUALITY MANAGEMENT PLAN UPDATE

(DRAFT #7)

July 2, 2001

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ACRONYMS

Several acronyms are used in the modeling protocol document. For convenience, the acronyms used are listed below to aid the reader.

AAMA – American Automobile Manufacturer's Association
AGL – Above Ground Level
AQMP – Air Quality Management Plan
ARB – Air Resources Board
AUSPEX – Atmospheric Utility Signatures, Predictions, and Experiments
AVHRR – Advanced Very High Resolution Radiometer
BEIS – Biogenic Emission Inventory System
CAA – Clean Air Act of 1990
CAMx – Comprehensive Air-Quality Model with Extensions
CBM – Carbon Bond Mechanism
CCAA – California Clean Air Act
CEFS – California Emission Forecasting System
CMAQ – Community Multi-scale Air Quality (model)
CO – Carbon Monoxide
COG – Council of Governments
DARS – Data Attribute Rating System
DWM – Diagnostic Wind Model
DTIM – Direct Travel Impact Model
EIWG – Emission Inventory Working Group
EKMA – Empirical Kinetics Modeling Approach
EMFAC – Emission Factor (model)
FCM – Flexible Chemical Mechanism
FDDA – Four-Dimensional Data Assimilation
GAP – Geographical Approach to Protection of Biological Diversity
GCM – Global Climate Model
ICAPCD – Imperial County Air Pollution Control District
IOP – Intensive Operation Period
LIDAR – Light Detection and Ranging
MDAQMD – Mojave Desert Air Quality Management District
MM5 – Mesoscale Meteorological Model (5th generation)
MWG – Modeling Working Group
NAAQS – National Ambient Air Quality Standard
NDVI – Normalized Difference Vegetative Index
NOx – Nitrogen Oxides
PDT – Pacific Daylight Time
PM – Particulate Matter
RADM – Regional Acid Deposition Model

RECLAIM – Regional Clean Air Incentives Market
ROG – Reactive Organic Gases
RRF – Relative Reduction Factor
SANDAG – San Diego Association of Governments
SAPRC – State Air Pollution Research Center
SAQM – SARMAP Air Quality Model
SARMAP – SJVAQS/AUSPEX Regional Model Adaptation Project
SBCAG – Santa Barbara County Association of Governments
SBCAPCD – Santa Barbara County Air Pollution Control District
SCAB – South Coast Air Basin
SCAG – Southern California Association of Governments
SCAQMD – South Coast Air Quality Management District
SCAQS – Southern California Air Quality Study
SCE – Southern California Edison
SCOS97 – Southern California Ozone Study (1997)
SDCAPCD – San Diego County Air Pollution Control District
SIP – State Implementation Plan
SJVAQS – San Joaquin Valley Air Quality Study
SOx – Sulfur Oxides
STMPRAG – Scientific, Technical, and Modeling Peer Review Advisory Group
TOG – Total Organic Gases
UAM – Urban Airshed Model
USEPA – United States Environmental Protection Agency
UTM – Universal Transverse Mercator
VCAPCD – Ventura County Air Pollution Control District
VMT – Vehicle Miles Traveled
VOC – Volatile Organic Compound
WSPA – Western States Petroleum Association

INTRODUCTION

Under the federal Clean Air Act of 1990 (CAA), the South Coast Air Basin (Basin) is classified an "extreme" nonattainment area for ozone. Section 182(c)(2)(A) of the CAA sets November 15, 1994 as the deadline for submission of a State Implementation Plan (SIP) to demonstrate attainment of the federal ambient ozone air quality standard of 0.12 ppm by December 2010. The South Coast Air Quality Management District (District) satisfied that Act requirement with the submittal of the 1994 Air Quality Management Plan (AQMP) in September 1994, and a subsequent revision was submitted to the U.S. Environmental Protection Agency (USEPA) in February 1997. In order to take advantage of more recent information such as the 1997 Southern California Ozone Study (SCOS97) and enhancements to the emissions inventory, the District plans to revisit the recently submitted ozone attainment demonstration in a 2001 submittal.

The USEPA promulgated a new ozone ambient air quality standard in July 1997. While the SIP submittal date for the new federal ozone air quality standard is still being debated, the District committed to begin air quality analysis for the new standard. Subsequent to the release of the implementation guidance for the new ozone air quality standard, the U.S. Circuit Court ruled that USEPA could not enforce the new standard. USEPA is in the process of appealing that decision. However, the court decision may change the date for the SIP submittal for the new ozone air quality standard. A first look at the new ozone air quality standard was provided in the 1997 AQMP. However, the analysis was conducted before USEPA finalized the new ozone air quality standard.

The CAA requires the use of an USEPA-approved, photochemical grid model to perform the attainment demonstration. USEPA's "Guideline on Air Quality Models (Revised)" recommends the use of the Urban Airshed Model (UAM) for attainment demonstrations involving entire urban areas (USEPA, 1990). However, the USEPA recently revised its recommendation to no longer include a recommended air quality model for ozone. Instead, the USEPA recommends that air quality model(s) proposed for an ozone attainment demonstration, be subjected to model performance evaluations to demonstrate that they are appropriate for attainment demonstration purposes. The USEPA issued the "Guideline for Regulatory Applications of the Urban Airshed Model" to assist states in preparing the attainment demonstration

required by the CAA (USEPA, 1991 and 1996). In addition, the ARB has issued photochemical modeling guidance for use by the districts to ensure the technical validity of the modeling results (ARB 1992). Finally, the USEPA is in the process of finalizing attainment demonstration guidance for the new, federal, 8-hour ozone air quality standards. This ozone modeling protocol is based on these guideline documents.

In order to devote the maximum resources practicable to the development of the District's 2001 AQMP, the Executive Officers of the ARB and the SCAQMD have agreed to jointly develop the emissions and air quality modeling needed to determine the carrying capacity and attainment demonstration for the 1-hour ozone and PM_{10} standards. The technical staffs of both agencies are working closely together to plan and carry out the necessary work for the AQMP, and are committed to intensive and timely coordination to ensure that the AQMP is based on the soundest science possible. Both agencies agree that their staffs will collaborate on this work such that the product will be mutually acceptable modeling analyses for use in the 2001 plan.

The objective of this protocol is to define the methodology to be used for simulating ozone formation in the basin, including: the episodes to be simulated; the model(s) to be used; the modeling domain; the model input data, including meteorology, emissions, and initial and boundary conditions; and the process for model performance evaluation. In addition, the protocol outlines the attainment demonstration process, including a review of the CCAA requirements. This protocol document is intended to be dynamic, and will be updated in response to reviewer comments and to reflect the results of new information that will emerge during the process.

Background

The first Air Quality Management Plan (AQMP) for the Basin was produced in 1979 as part of a revision to California's SIP. The 1979 AQMP indicated that it would not be possible to achieve the federal ozone air quality standard of 0.12 ppm by 1982. Because the emission controls discussed in the 1979 AQMP would not be fully effective until after 1982, the ARB and the USEPA granted an extension to 1987 for achievement of the standard. As part of that extension, a revision to the AQMP was performed by the District in 1982 which included a new series of modeling analyses to address concerns regarding the original 1979 modeling analysis.

For both the 1979 and 1982 AQMP revisions, the city-specific Empirical Kinetics Modeling Approach (EKMA) was applied. The 1979 AQMP used the city-specific EKMA procedures then in existence. The 1982 AQMP revision used a more sophisticated version of the EKMA procedures and also contained sensitivity analyses (Appendix VI-A of the 1982 AQMP revision). The UAM was used in conjunction with the EKMA analyses to evaluate the effect of applying all feasible control measures by 1987 (Appendix VI-E of the 1982 AQMP revision). On the basis of those modeling studies, it was determined that hydrocarbon reductions on the order of 75 percent or greater would be required to attain the federal standard by 1987, given a forecasted 23 percent reduction in oxides of nitrogen. Forecasted emission data indicated that only a 33 percent hydrocarbon reduction could be expected by 1987. Issues raised during the 1979 and 1982 AQMP revisions highlighted the need to use a three-dimensional, photochemical model such as the UAM to better understand the complex interactions between precursor emissions, meteorology, and the formation of ozone in the Basin.

For the 1989 AQMP revision, the UAM was applied to a single, multiday, ozone episode to demonstrate attainment of the National Ambient Air Quality Standard (NAAQS) for ozone. It was determined from the modeling analysis that hydrocarbon and oxides of nitrogen emission reductions of more than 80 percent would be needed in order to attain the NAAQS by the year 2007. The 1989 AQMP revision outlined three levels of controls (identified as Tiers I, II, and III) that separated the proposed control measures by known and proven technologies from those technologies anticipated to be available within the next 20 years.

For the 1991 AQMP, the District used the UAM to further assess the effectiveness of the three tiers of control measures in reducing ambient ozone levels. To complement the single, multiday ozone episode used for the 1989 AQMP revision, two additional ozone episodes were modeled to investigate the effect of projected emission reductions on future ozone concentrations during a wider variety of meteorological conditions. Additional evaluations of model performance, including new graphical procedures and subregional performance statistics, were used to ensure adequate representation of the physical and chemical processes that influence ozone formation in the Basin.

A number of improvements were made to the modeling analysis for the 1994 AQMP. Growth factors for population and vehicle miles traveled (VMT) were revised to reflect the 1990 Census data and the economic climate of the early 1990s, and improved transportation modeling was considered. The modeling analysis benefited from a number of District, ARB, and SCAG studies that improved the area source emission inventory (Appendix III-A). On-road, mobile emission estimates were improved with the use of the latest ARB emission factors program, EMFAC7F. Five ozone episodes were simulated to evaluate control strategy effectiveness. In addition to the June 5-7, 1985, episode used in the 1989 AQMP, and the two Southern California Air Quality Study (SCAQS) episodes (August 26-28, 1987, and June 23-25, 1987) added for the 1991 AQMP analysis, two additional episodes (July 13-15, 1987, a SCAQS episode, and September 7-9, 1987) were simulated for the 1994 AQMP. In this manner, control strategy decisions were based on a range of meteorological conditions, thereby reducing uncertainty in the control strategy's effectiveness. It was determined that hydrocarbon and oxides of nitrogen emission reductions on the order of 80 and 60 percent, respectively, would be needed in order to attain the NAAQS.

Based on the District's experience with the five ozone episodes used in preparing the 1994 AQMP, the District decided to drop the June 1985 meteorological episode for the 1997 AQMP. The District believed that the 1987 meteorological episodes were satisfactorily evaluated. Since the 1985 meteorological episode was based on routine monitored data, it was believed that the 1987 SCAQS episodes provided a greater certainty level relative to their performance evaluation. In October 1998, the District provided to the USEPA a "weight of evidence" analysis that indicated that even without the June 1985 episode, a viable ozone attainment demonstration could be made.

Since the 1997 AQMP, other ozone episodes have been observed that could serve as complementary or replacement episodes:

- As a result of intense interest for aerometric databases to support *regional* ozone modeling, a large-scale field measurement program was carried out in southern California during the Summer of 1997 to collect sufficient aerometric data to allow data analysts and modelers to characterize and simulate ozone formation and fate in the region. Several agencies and others participated during the planning and operational phases of the field study, including the ARB, the USEPA, the local districts, the US Navy, the US Marines, and the marine industry. The

1997 Southern California Ozone Study, or SCOS97, occurred over a four month period from June 15 through October 15, 1997, and captured several episodic ozone days.

- A widespread and severe ozone episode occurred throughout California in July 1998, during which many districts in southern California experienced 1-hour and 8-hour ozone violations. Fortuitously, several radar wind profilers were operating in the region at the time, providing greater than normal upper air meteorological coverage.

Overview of the Ozone Modeling Analysis

The proposed modeling analysis comprises the following tasks:

- Identify potential, new ozone meteorological episodes to be used. These episodes should represent the different meteorological conditions that are conducive to ozone formation in the Basin. The new ozone episodes would complement the 1987 episodes in the 1997 AQMP.
- Evaluate at least two state-of-the-science ozone models for the attainment demonstration, for the new episodes.
- Develop model inputs. This task includes evaluation of the raw data and of the model input files developed from them. The input files will be evaluated using graphical and other techniques.
- Simulate each episode with the proposed ozone models. This task includes a separate performance evaluation for each episode and each model. Documentation of the simulation results and performance evaluations will be provided.
- Project ozone air quality with proposed control measures in effect for the years 2007, 2010, and 2020. This task includes the required attainment demonstration. Model projections for the year 2007 are necessary since that is the year that the CAA requires attainment for severe-17 areas, such as the Coachella valley and the Mojave Desert Ozone Nonattainment Area. Ozone air quality projections to 2020 will be used to demonstrate that the control strategy maintains the federal ozone air quality standard and to establish emission budgets needed for conformity purposes.

The work to do the foregoing tasks will be divided between the District and the ARB staffs, and they will fully share all analyses, model inputs and outputs, findings, and conclusions. Consensus on each component of the

analysis shall be reached before proceeding with subsequent components. In the event of technical disagreement on any of the work elements, the staffs of the District and the ARB shall attempt to reach consensus on a mutually acceptable approach. In the event that consensus cannot be reached, the disagreement will be elevated to the Executive Officers for resolution.

Schedule

Task	Due Date
1. Episode Selection	Completed
2. Air Quality and Meteorological Data Preparation	Completed
3. Emission Inventory Preparation	July 2001
4. Performance Evaluation	Late-July 2001
5. Attainment Demonstration	August 2001
6. Draft SIP Documents	August 2001
7. District Board Approval of Final SIP	November 2001
8. ARB Board Approval of Final SIP	December 2001
9. SIP Submittal to USEPA	December 2001

EPISODE SELECTION

Four ozone episodes from 1987 were simulated for the 1994 SIP and the 1997 AQMP: June 24-25, 1987; July 14-15, 1987; August 27-28, 1987; and September 8-9, 1987. To maintain continuity with recent plan submittals, the model performance for two of these episodes (June 24-25, 1987 and August 27-28, 1987) will be reevaluated using updated emission data. These two episodes have served as the controlling episodes for the 1994 and 1997 plan submittals. No new meteorological work is planned, and the updated simulations will be conducted on the SCAQS modeling domain. Because of concerns with the age of these episodes and the limited aloft data associated with them, three additional episodes from SCOS97 and 1998, as briefly described below, are proposed to supplement the SCAQS episodes.

During the four-month SCOS97 field study, the peak observed ozone concentration within the SCOS97 domain was 21 pphm. There were 13 Intensive Operation Period (IOP) days during which additional measurements were taken, such as speciated hydrocarbons and air quality aloft. The peak ozone concentration observed over all of the IOP days was 19 pphm. Because of the unique meteorological patterns during SCOS97 associated with the El Nino phenomenon, there is a concern that the peak ozone concentrations measured during SCOS97 may not represent design values for southern California. In July 1998 a severe regional ozone episode occurred in southern California which included a peak, observed, one-hour ozone concentration in the SCOS97 domain of 24 pphm. Although intensive field study data are not available for this episode, there were approximately 10 radar wind profilers operating during that period, thereby providing aloft meteorological data. These data are believed to be sufficient to support simulating an episode for this period.

Therefore, in addition to the two 1987 episodes to be simulated, three multi-day ozone episodes from SCOS97 and 1998, as discussed below, are proposed to be simulated. Synopses of the meteorology associated with each of the 1997 episodes can be found in the summary of SCOS97 field operations (ARB et. al, 1998).

1) The SCOS97 episode period of August 3-7, 1997 (Sunday–Thursday). This episode was selected because the peak, 1-hour ozone concentration of 19 pphm and the peak, 8-hour concentration of 12.5 pphm measured in

the South Coast during this period were the highest not associated with an exceptional event during SCOS97. High ozone concentrations were also observed within the Mojave Desert (1-hour peak of 14 pphm) and Ventura County (1-hour peak of 13 pphm, 8-hour peak of 11.5 pphm).

2) The SCOS97 episode period of September 26-29 (Friday–Monday) was selected because it includes the second highest, 1-hour ozone concentration measured during an IOP, and because it represents a weekend episode. The peak 1-hour (17 pphm) and 8-hour (10.7 pphm) ozone concentrations were both observed at Upland.

3) The July 13-18, 1998 (Tuesday–Saturday) episode was selected because it represents a severe, widespread high ozone event. The peak, observed, 1-hour ozone concentration in the South Coast Air Basin was 24 pphm, and the peak, 8-hour, concentration observed was 20.6 pphm. Other areas also experienced elevated ozone peaks, including San Diego (1-hour peak of 16 pphm), Ventura (1-hour peak of 17 pphm, 8-hour peak of 15 pphm), and Mojave Desert (1-hour peak of 20 pphm, 8-hour peak of 14 pphm).

Summary of Episodes to be Simulated for the Current AQMP	
Episode	Notes
• June 24-25, 1987 • August 27-28, 1987	Maintained for continuity with previous plans; updated emissions only; will utilize SCAQS modeling domain
• August 3-7, 1997	Intensive SCOS97 episode. Peak 1-hour O_3 concentration of 19 pphm; peak 8-hour O_3 concentration of 12.5 pphm in the SCAB; will utilize regional modeling domain
• September 26-29, 1997	Intensive SCOS97 weekend episode. Peak 1-hour O_3 concentration of 17 pphm; peak 8-hour O_3 concentration of 10.7 pphm in the SCAB; will utilize regional modeling domain
• July 13-18, 1998	Severe, widespread high ozone event in the region. Peak 1-hour O_3 concentration of 24 pphm; peak 8-hour O_3 concentration of 20.6 pphm in the

	SCAB; will utilize regional modeling domain

MODELING DOMAIN

As discussed previously, three new ozone episodes are planned for use in the current AQMP. These, which include two episodes captured during SCOS97 and an episode from 1998, will be simulated for a regional domain as described below. No new meteorological work is planned for the 1987 episodes, therefore they will continue to utilize the SCAQS modeling domain, which is described in previous AQMPs.

Non-SCAQS Episodes

Previous ozone modeling results in southern California, such as those in support of the 1994 State Implementation Plan (SIP), proved sensitive to boundary concentrations of air pollutants. This reflected the physical processes of recirculation of pollutants within southern California and the transport of pollutants from one air basin to another. However, because of the three-dimensional nature of transport and recirculation, it is difficult to take field study measurements that are adequate to determine boundary conditions. Thus the boundary conditions used in previous studies were uncertain and the modeling domain has been extended in an attempt to minimize their influence.

The photochemical modeling studies conducted for the 1994 SIP for the South Coast Air Basin, the San Diego Air Basin, and the South Central Coast Air Basin defined the upper domain boundary at a height of 2,000 m above ground level (AGL) or less. There were few air quality measurements above this height. However, terrain elevations in southern California often exceed 2,000 m above sea level and recirculation and transport above this height are possible. Ozonesonde measurements made during the 1997 Southern California Ozone Study (SCOS97) have shown high concentrations of ozone at heights above 3,000 m AGL.

The proposed regional modeling domain will minimize the influence of boundary conditions on simulation results and allow the effects of recirculation and interbasin transport to be better represented by meteorological and photochemical model simulations. The proposed modeling domain shown in Figure 1 will completely encompass the South Coast Air Basin and San Diego County, almost all of the South Central Coast Air Basin (excepting a small piece of San Luis Obispo County), the California-Mexico border regions, and includes most of the inland desert

areas to eliminate the need to define boundary concentrations between them. The domain will extend far enough offshore to contain wind flow patterns conducive to overwater recirculation. Specifically, the UTM Zone 11 coordinates of the domain are 150-700 km UTM East and 3580-3950 km UTM North. Vertically, the modeling domain will extend to a height of at least 5,000 m AGL for a more complete representation of atmospheric processes. This will contain observed high ozone concentrations aloft and allow three-dimensional wind flow patterns near elevated terrain features to be represented better than in previous simulations, providing more accurate representation of pollutant transport and recirculation.

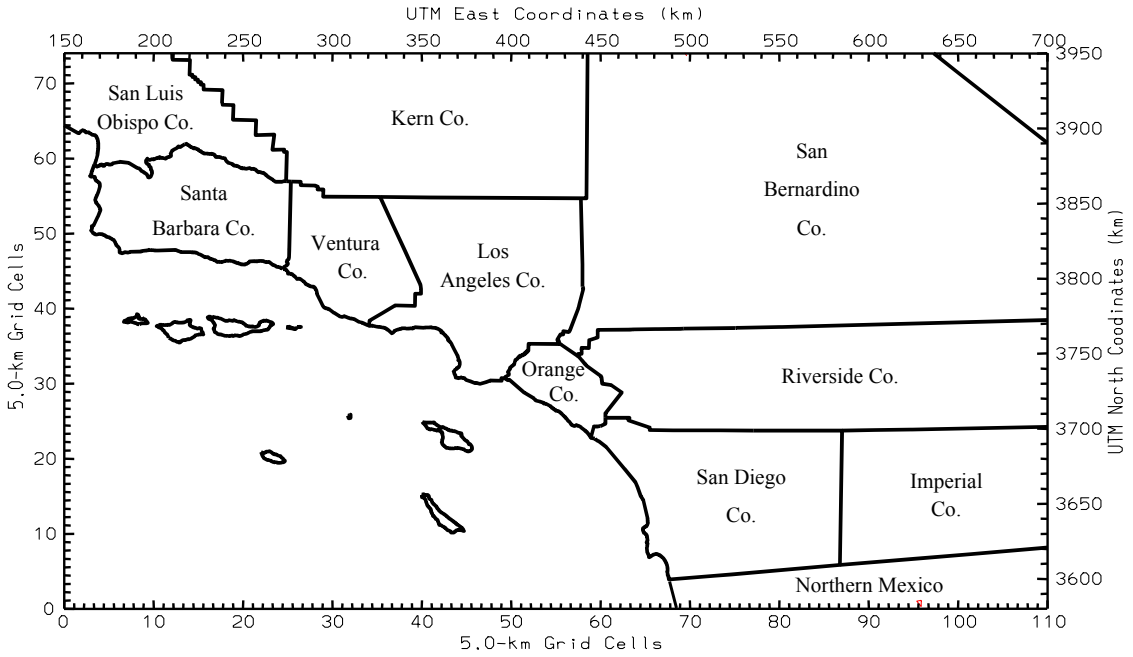


Figure 1. The regional photochemical modeling domain for the SCOS97 and the 1998 episodes.

AIR QUALITY MODEL SELECTION

The Urban Airshed Model (UAM-IV) is the only Eulerian photochemical modeling tool that has been previously approved by the USEPA for ozone modeling studies. However, the UAM-IV (USEPA 1990) is widely acknowledged to have characteristics which limit its utility when applied to large modeling domains, or to domains that are not geographically uniform. In addition, much of the science in the model is outdated, and both the USEPA and the ARB are removing that model's recommended status. A number of photochemical models have been developed over the last decade to improve upon the UAM-IV; these include:

- CALGRID (Yamartino et. al, 1989). The CALGRID model was developed for the ARB in the late 1980's. The model has been applied by various air pollution agencies around the world. It is modular to allow the user to substitute various types of wind fields and chemical mechanisms. CALGRID incorporates refined treatments of numerical advection, vertical transport and dispersion, and dry deposition. The model can be exercised with either the Carbon Bond IV (CB-IV) or SAPRC chemical mechanisms, and contains highly efficient chemical integration routines. The vertical structure of the atmosphere can be optionally defined relative to a mixing height field, similar to the UAM, or can be based on fixed layer heights and a derived mixing height.

- The Comprehensive Air-Quality Model with Extensions (Environ, 1997). CAMx contains a number of advanced features, including grid nesting, sub-grid-scale plume-in grid simulation, alternative numerical advection solvers, and the ability to use alternative chemical mechanisms. In addition it has the ability to tag emissions so that at the end of the simulation one can determine the sources of emissions impacting a particular receptor. Since CAMx is a relatively new model, there is a relatively short history of experience applying the model.

- Models-3 (USEPA, 1998a). Models-3 is a flexible software system designed for applications ranging from regulatory and policy analysis to understanding the complex interactions of atmospheric chemistry and physics. The Models-3 system is a framework that allows the user to go from developing model inputs to visualizing results all in one package. At the heart of the current version of Models-3 is the Community Multi-

scale Air Quality (CMAQ) model. Its capabilities include urban to regional scale air quality simulation of ozone, acid deposition, visibility, and fine particles. CMAQ is a modular system capable of using output from the MM5 prognostic meteorological model, along with the CBIV, RADM-2, or SAPRC-99 chemical mechanism. The CMAQ model also includes a plume-in-grid module, vertical and horizontal growth due to turbulence and shear, a choice of advection schemes, and a cloud-module to simulate precipitating and non-precipitating clouds. A forthcoming aerosol module will allow simulation of $PM_{2.5}$ and PM_{10}. Since the Models-3 system is new, some implementation and application problems are likely.

- SARMAP Air Quality Model (J.S. Chang et. al, 1997). SAQM is a three-dimensional non-hydrostatic model based upon the Regional Acid Deposition Model (Chang et. al 1987, 1990). However, SAQM includes a number of improvements over RADM, including: a fixed vertical coordinate system that is compatible with MM5; a horizontal coordinate system defined in a Lambert-Conformal projection that accounts for curvature of the Earth; a mass conservation module for compatibility with non-hydrostatic meteorological inputs; the Bott advection scheme (Bott 1989a, 1989b) to reduce numerical diffusion and increase numerical accuracy; two-way nesting, and the capability to use either the CB-IV or SAPRC chemical mechanisms. A version of SAQM with plume-in-grid treatment is also available.

- Urban Airshed Model-Flexible Chemical Mechanism (Kumar et. al, 1995). The UAM-FCM is an alternate version of the UAM-IV that has been enhanced to allow the flexibility to incorporate any Carbon Bond- or SAPRC-type chemical mechanism. The FCM allows incorporation of reaction-specific photolysis rates. In addition, the UAM-FCM has a generalized methodology to solve the set of differential equations that is mechanism independent. However, the meteorological dispersion algorithms are the same as in UAM-IV.

- Urban Airshed Model-Variable (SAI, 1996). The UAM-V is an updated version of the Urban Airshed Model (UAM-IV) which incorporates many state-of-the-art enhancements in chemical mechanisms, meteorological models, and representation of emissions. Perhaps the most significant additions are: an updated CB-IV mechanism to include aqueous phase chemistry; plume-in-grid capabilities; an improved dry deposition

algorithm; and an improved plume rise algorithm. Other enhancements over UAM-IV include allowing the user a fixed vertical structure as opposed to one that is relative to the diffusion break, the ability to use three dimensional inputs from prognostic models, and two-way grid nesting. However, the present non-public domain status of UAM-V may preclude regulatory usage. The model developers have indicated that the model could be made available for any party to review if the party agrees that the use of the model would be solely for the review of the AQMP.

The ozone meteorological episodes to be simulated for the current AQMP include two from 1987 for continuity with previous AQMPs. It is planned to simulate those episodes using the UAM-IV or the UAM-FCM, with updated emissions only. For the SCOS97 and later episodes, the staffs of the ARB and the SCAQMD have agreed to test at least two of the available models: CAMx and CMAQ. CAMx will be run using both diagnostic and prognostic windfields.

The models will be run using the Carbon Bond IV (Gery et. al, 1989) and SAPRC (Carter1990; Carter et. al, 1993; Carter 1995; Carter et. al, 1996; Carter et. al, 1997) chemical mechanisms. The SAPRC chemical mechanism is the basis for chemical reactivity scales.

At its meeting on October 8, 1999, the ARB's Reactivity Scientific Advisory Committee (chaired by Dr. John Seinfeld, with participation by other members Dr. Roger Atkinson, Dr. Jack Calvert, Dr. Harvey Jeffries, Dr. Jana Milford, and Dr. Armistead Russell) discussed a peer review of the SAPRC-99 mechanism conducted by Dr. William Stockwell. Members of the committee agreed that the peer review was excellent, that SAPRC-99 was a state-of-the-art chemical mechanism, and they approved the peer review. The Committee then unanimously recommended that SAPRC-99, as the most up-to-date mechanism available, be used for SIP modeling.

HORIZONTAL AND VERTICAL GRID RESOLUTION

The horizontal and vertical grid resolution for the 1987 SCAQS episodes will be unchanged; the details are provided in previous AQMPs. The remainder of this section describes the resolution for the SCOS97 and later episodes.

Horizontal Grid Resolution

Over the past decade, photochemical models have been applied in California with horizontal grid resolutions in the range from 2 x 2 km to 8 x 8 km. The specific grid resolution chosen was primarily dependent on the size of the modeling domain, computer resources available, and the time and money available to carry out the simulations. In effect the final resolution was a compromise between the accuracy desired and the cost. However, the current generation of high-speed computers have minimized cost and resource constraints.

The horizontal grid resolution plays an important role in the modeling process. Large grid resolution tends to smooth emission gradients and meteorological inputs, which in turn leads to a smoothing of the resulting concentration fields. In general, the resolution should be sufficiently small to pick up emission gradients in urban areas and be consistent with the major terrain features which may affect the air flow.

- **Air Quality Modeling**

For the year 2001 AQMP revision, a horizontal grid resolution of 5 km is proposed to be used for the air quality modeling. No grid nesting is anticipated. This resolution is consistent with the grid resolution used in earlier photochemical modeling studies for the South Coast Air Basin (e.g., SCAQMD, 1994) and for San Diego. In addition, this will reduce resources needed to create gridded emissions for the SCAQS episodes which are based on 5 km grid cells. For the proposed modeling domain, use of a 5 km resolution results in a modeling grid with 110 cells in the east-west direction, and 74 cells in the north-south direction. The CMAQ model will be based on a Lambert-Conformal map projection system, as will CAMx when used with MM5-based meteorological fields; these models will use a slightly

different domain. All other air quality models will use a UTM-based horizontal coordinate system.

- **Meteorological Modeling**

Meteorological inputs to the air quality model will be provided for the same horizontal grid resolution and coordinate system (i.e., UTM or Lambert Conformal). More details of the meteorological modeling can be found in the section "METEOROLOGICAL INPUTS."

- **Emission Inventory**

The emission inventory is based on a UTM coordinate system, with a horizontal resolution of 2 km. For CMAQ, the emissions will be mapped from UTM into a Lambert Conformal coordinate system. More information on the inventory can be found in the section entitled "EMISSION INVENTORY."

Vertical Resolution

As with the selection of the horizontal grid resolution, the vertical resolution defined for photochemical modeling domains has been limited by computational resources. In addition, available aloft meteorological and air quality databases were not sufficient to characterize conditions aloft. As a result, simulation results have been limited by the relatively few number of vertical layers within the surface mixed layer, resulting in poor representation of the stratification of the atmosphere.

As enhanced aerometric databases have become available—such as the 1990 San Joaquin Valley Air Quality Study and 1997 SCOS97—more has been learned about the vertical structure of the atmosphere. The ability to better simulate the vertical structure of the atmosphere is emerging due to the availability of measurements aloft, the emergence of higher-speed computers, and our increased experience with diagnostic and prognostic meteorological models.

- **Air Quality Modeling**

To improve the vertical representation of the atmosphere, the number of vertical layers below 500 m (the nominal height of the afternoon mixing height within the Los Angeles coastal plain) will be increased from previous studies, and the modeling domain top will be set to a height of at least 5,000 m.

CAMx/MM5 – The vertical structure is shown in Table 1.

CAMx/CALMET - The fixed height vertical layers are the same as those from CALMET, and are shown in Table 2.

UAM/FCM – As for the UAM, the vertical atmosphere is defined in two zones: that above the mixing height and that below. A total of 5-8 vertical layers are proposed for the SCOS97 simulations.

CMAQ – The vertical structure is shown in Table 1.

Table 1
Proposed vertical layer heights for CMAQ and CAMx/MM5

Layer #	Height (m)*	Layer #	Height (m)*	Layer #	Height (m)*
1	58	7	737	12	1,767
2	146	8	879	13	2,094
3	250	9	1,022	14	2,942
4	369	10	1,234	15	3,962
5	490	11	1,450	16	4,986
6	613				

* *These height estimates are based on sigma-level calculations at sea level using standard conditions. Height increments will decrease as terrain elevation increases.*

- **Meteorological Modeling**

For the terrain-following CALMET model, the proposed vertical layer definition is shown below.

Table 2
Proposed vertical layer heights for CALMET/CALGRID

Layer #	Height (m)*	Layer #	Height (m)*	Layer #	Height (m)*

1.....20.0 2.....60.0 3.....100.0 4.....300.0 5.....400.0 6.....500.0	7 ..... 600.0 8 ..... 800.0 9 ..... 1,000.0 10 ..... 1,500.0 11 ..... 2,000.0	12 ..... 2,500.0 13 ..... 3,000.0 14 ..... 3,500.0 15 ..... 4,000.0 16 ..... 5,000.0
* *Heights are for a constant-height, terrain-following coordinate system*		

For the MM5 prognostic model, the following vertical structure is proposed.

Table 3
Proposed vertical structure for MM5

Level	Height (m)*	Level	Height (m)*	Level	Height (m)*
30	61	20	1528	10	7270
29	154	19	1862	9	7981
28	263	18	2207	8	8773
27	389	17	2714	7	9624
26	516	16	3228	6	10499
25	646	15	3837	5	11371
24	776	14	4452	4	12230
23	926	13	5083	3	13227
22	1077	12	5816	2	14334
21	1300	11	6551	1	15635

** The vertical coordinate system for MM5 is based on a normalized pressure scale. The above layer heights were calculated from sea level using standard conditions. Layer heights are lower relative to ground level as terrain height increases.*

METEOROLOGICAL INPUTS

Air quality models require three-dimensional, meteorological inputs. The key parameters are winds, mixing heights, temperature, and insolation. The windfields describe the transport and dispersion of pollutants. Mixing heights define the vertical extent of pollutant mixing near the surface. Temperature and insolation fields influence emission rates and the rates of chemical transformation. Because meteorological measurements can be made only at discrete locations, meteorological models are required to develop the 3-dimensional fields required by models.

The meteorological models used to generate these three-dimensional fields are generally of three types: objective, diagnostic or prognostic.

Objective models are the least sophisticated meteorological models. These models rely on interpolation of observations. Obtaining a reasonable field requires sufficient observations to accurately represent the atmosphere. This is especially true for windfields. In areas with complex terrain and bodies of water, such as the proposed modeling domain, the meteorology can be quite complex, and a successful objective analysis would require an extremely large number of observations.

Diagnostic models rely both on observations and constraints based on physical concepts such as the conservation of mass. A diagnostic wind model can simulate thermally induced circulations and the effects of surface friction. One example of this type of model is the Diagnostic Wind Model (DWM) which is distributed by the USEPA. For the DWM, the user first defines an initial guess mean wind field that can be representative of synoptic scale patterns. The domain mean wind is then adjusted for the effects of terrain. Available observations are then used to develop meteorological fields using objective analysis. The initial guess and the objective analysis are then combined using a weighting function based on distance from observations. A criticism of diagnostic models is that the fields produced are not consistent from one hour to the next. Since the processes which create the wind, temperature, and mixing height fields are relatively independent, the model is criticized for not being thermodynamically consistent between the meteorological parameter fields.

Prognostic models are the most sophisticated of the meteorological models. They are based on principles of atmospheric physics, i.e., conservation of mass, momentum, energy and moisture. As a result, they are computationally intensive. The use of four dimensional data assimilation (FDDA) or observational nudging–where observations are introduced to the model as an additional forcing term–is typically used in areas of complex meteorology to improve the accuracy of the outputs. Another approach is objective combination, in which observations are introduced after the model has estimated a value. Prognostic models are capable of explicitly incorporating many of the physical flow processes important in the domain. However, prognostic models have historically had problems estimating fine-scale flow features due to the limited resolution of datasets used for describing geographic features

As indicated previously, no new meteorological work is planned for the 1987 episodes, which will be re-simulated with new emissions only for continuity with prior plans. The remainder of this section focuses on the preparation and review of meteorological inputs for the SCOS97 and later episodes.

Previous Applications

In the past, the ARB and the SCAQMD have utilized prognostic, diagnostic, and objective models to generate meteorological inputs for modeling. The National Center for Atmospheric Research's prognostic, non-hydrostatic Mesoscale Model (MM5) was applied for modeling in support of attainment planning in the San Joaquin Valley. The SCAQMD also has experience with the SAIMM prognostic model. Diagnostic models (WIND2D, WIND3D, DWM) have been applied in the Sacramento area and in southern California to prepare meteorological input fields for the application of photochemical models in those areas. The ARB and the SCAQMD have also begun a review of CALMET, which may be viewed as an improved version of the DWM and which is being distributed through the USEPA for air quality modeling applications. The CALMET model has an added feature that allows a hybrid meteorological field to be developed by merging the results from a prognostic model, such as MM5, with an objective or diagnostic analysis characteristic of the CALMET model. This hybrid approach has the potential to take advantage of the prognostic capabilities of MM5 in areas of the domain where meteorological measurements are few, and utilizing measurements in an objective analysis where there are many.

Proposed Approaches

The SCOS97 field study generated a dataset with a relatively high spatial density of meteorological observations. While this dataset suggests that an objective/diagnostic model could be adequate to develop the meteorological parameter fields required for air quality modeling, there are large portions of the modeling domain—such as over the ocean or the inland desert—where there are few observations. Therefore, three approaches are proposed to develop the necessary meteorological fields. After the fields have been developed using each approach, they will be evaluated to determine which is the most suitable for air quality modeling. This evaluation is described below.

- **Diagnostic Modeling**

The first approach will be to use the diagnostic meteorological model CALMET. As described previously, CALMET uses a fixed-height, terrain-following coordinate system. For the AQMP modeling, 16 vertical layers will be used to a height of 5,000 m above the ground (see Table 2).

- **Prognostic Modeling**

The second approach will be to use the MM5 prognostic model. The meteorological boundary conditions for MM5 are generated using the output from a Global Climate Model (GCM) with a relatively coarse grid scale of 45 km. Nested domains of 15 km and 5 km are then defined within MM5 to simulate meteorological fields for the fine grid scale of the modeling domain. The modeling domain for MM5 is defined in a Lambert-Conformal projection with two parallels to account for curvature of the Earth within the modeling domain over such a large region. Figure 2 shows the nested MM5 domains. Figure 3 shows the finest scale (interior) MM5 domain.

The vertical structure of MM5 is defined in a terrain-following, "sigma" coordinate system based upon a normalized pressure index. The 30 vertical layers defined for MM5 (see Table 3) can be transformed to fit the requirements of any air quality model.

- **Hybrid Approach**

The third approach for developing meteorological parameter fields will be to combine the results of the CALMET and MM5 models into a hybrid meteorological field. In this approach, the parameter fields will be overlaid using a weighting scheme that is based on the proximity to meteorological observations. The resultant fields benefit from the capabilities of the prognostic model in those areas of the modeling domain with few observations (such as offshore, in complex terrain, and in the desert areas), and benefit from the objective analysis component of the diagnostic model to force the fields to agree with observations. To develop the hybrid fields, the fields developed using CALMET and MM5 will need to be mapped into common horizontal and vertical coordinate domains. The CALMET model code is structured to facilitate this mapping.

Meteorological Input Validation and Technical Review

The meteorological inputs have a profound influence on the spatial and temporal resolution of ozone and other pollutant concentrations estimated by the air quality model. It is therefore essential that the products of meteorological models undergo a rigorous evaluation. By evaluating both offshore and onshore flow characteristics of the windfield and other key meteorological parameters the uncertainty in the air quality simulations can be minimized.

This process includes an evaluation of the gross circulation features in the modeling region to determine if the model is replicating those essential features (Mulberg, 1995, Lolk and Douglas, 1996). These features include areas of convergence and divergence, eddy circulations, land/sea breezes, slope flows, and transport corridors. Since the modeling domain includes large overwater areas it is also necessary to evaluate offshore flows as well.

Key features of the windfield are areas of convergence and divergence. These features result in vertical velocities which can transport pollutants upward (in the case of convergence) or bring pollutants from aloft down to the surface (with divergence). The evaluation should include a review of the convergence and divergence zones in the simulated windfield to determine if they agree with measurements or conceptual models in terms of location, timing, and extent. The impact on vertical velocities should also be evaluated.

Converging flows can sometimes result in an eddy circulation. In the SCOS97 domain two key eddy features are prevalent: the Catalina eddy (centered near Catalina Island), and the Gaviota Eddy in the Santa Barbara Channel (Smith, et. al., 1984). Both eddy circulations are important transport mechanisms; they are capable of transporting precursors and aged ozone concentrations onshore. Exceedances of the ozone standards are often observed with the presence of an eddy circulation. The timing of the onset of eddy circulation, its persistence, and spatial extent should be considered as part of the windfield validation.

Land/sea breeze circulations are another important flow feature. The sea breeze is one method whereby pollutants generated in the Los Angeles Basin are transported eastward. That is, the strength of the sea breeze will determine how far precursors and ozone generated near the coast will be

transported inland. Errors in the timing of the sea breeze can cause precursor emissions to be transported to the wrong locations instead of inland where peak concentrations are observed. It is thus essential that the onset of the sea and land breezes simulated by the model be compared to observations for reasonableness.

The onshore portion of the SCOS97 domain includes areas of complex terrain. Slope flows are important as a recirculation mechanism that may influence ozone concentrations. Slope flows are probably the most challenging feature for prognostic meteorological models, due to the sparse observational data in complex terrain. A proposed qualitative approach is to determine if wind speeds estimated by the model appear to be reasonable in areas of complex terrain.

As a qualitative and quantitative evaluation of the windfields, wind speeds are proposed to be statistically summarized and plotted by site and globally throughout the SCOS97 domain (Seaman et. al., 1995, Bigler-Engler et. al., 1996). Temporal plots for key sites will be examined to determine agreement with observations. Quantitative techniques will make use of statistical measures such as the mean gross error and mean bias to compare modeled and measured wind speeds (Mulberg, 1995).

The proposed approaches for generating meteorological inputs incorporate observations, thus it should be expected that good agreement near those observation sites where data was used as input to the model. In order to diagnose the impact that incorporation of the observations has on the meteorological models, it may be useful to consider withholding some observations when executing the models to have an independent set of observations for comparison. The sites withheld should have some relation to the sites used to provide some assurance in the results from the comparison. This diagnostic evaluation is proposed to be conducted once acceptable meteorological fields have been prepared.

Temperature fields will also be examined. At the surface, qualitative analyses will include an examination of the temporal and spatial variation of estimated and observed temperatures. The interface at the coastline will also be examined. Mean bias and mean gross error statistics will also be calculated to provide quantitative measures of performance.

In addition, the vertical temperature profiles generated by the models will be compared to those observed at rawinsonde sites and wind profiler locations. The vertical temperature profile influences the stability characteristics of the modeling domain. One of the most notable affects is on mixing heights. The evaluation will include temporal and spatial evaluations of simulated mixing heights as compared to those estimated from observed soundings and profiler data. The timing of the onset and breakup of the inversion will also be evaluated, as this phenomenon has a profound effect on estimated ozone concentrations.

The staffs of the District and the ARB will consider the above procedures in judging the meteorological fields and in reaching consensus on the appropriateness of those fields for use in the AQMP.

Figure 2
Nested MM5 Domains

The horizontal grid resolution of the outermost domain is 45 km, for the middle domain is 15 km, and for the fine scale domain is 5 km.

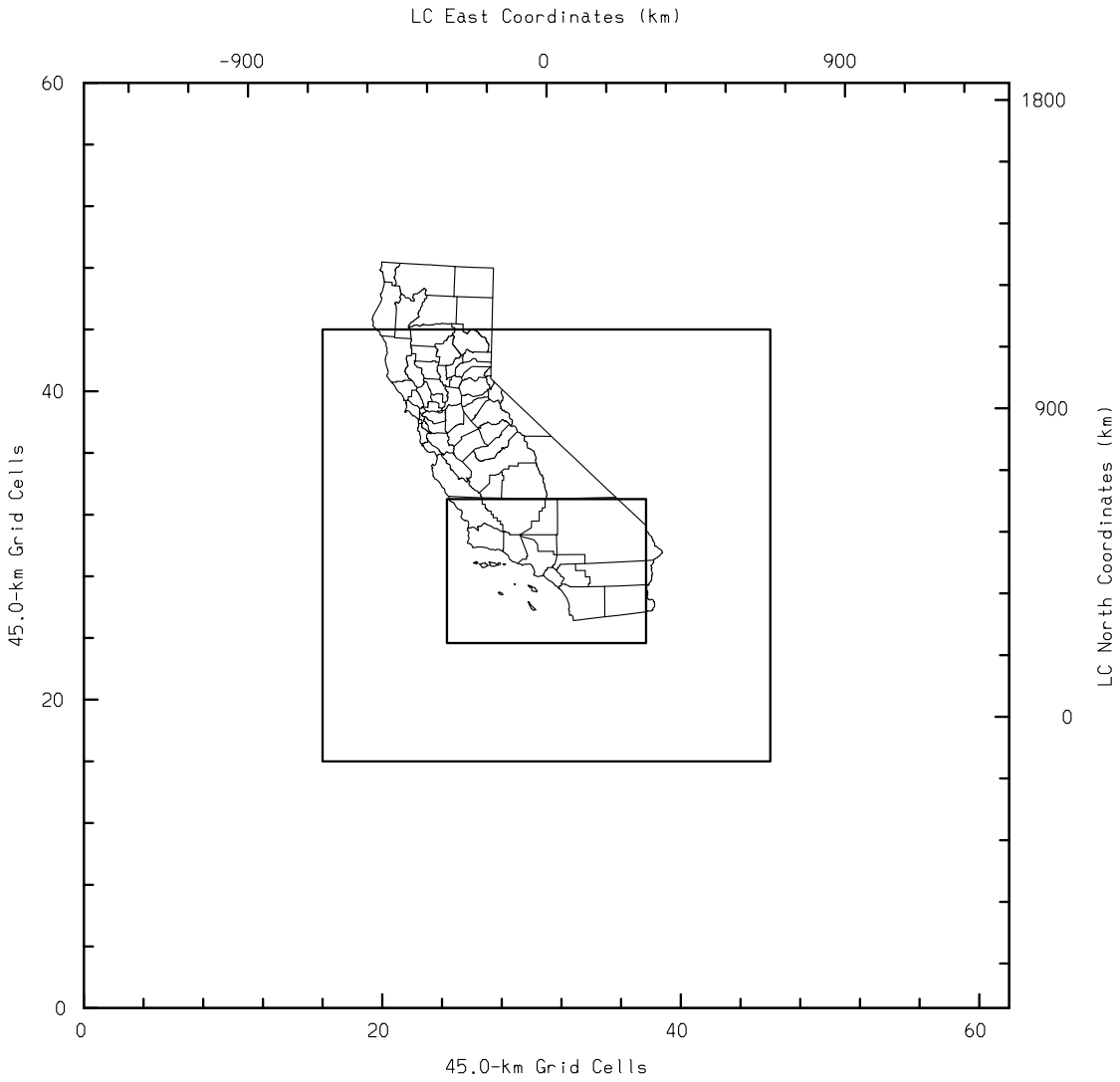
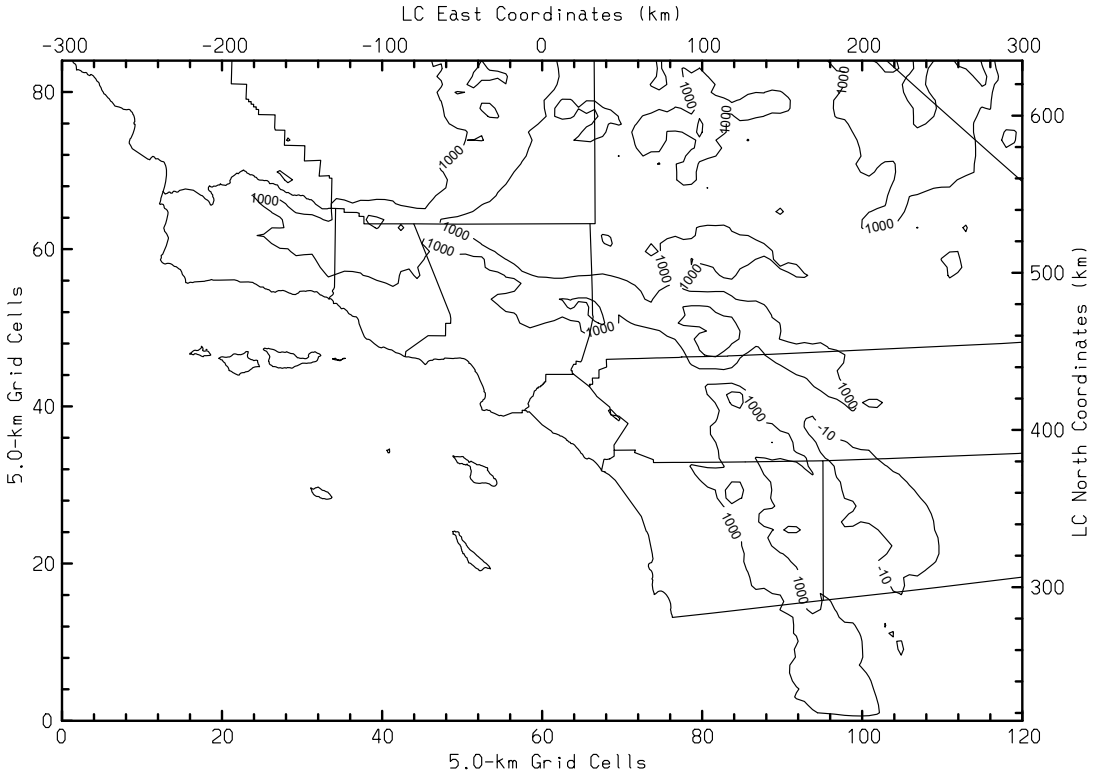

LC East Coordinates (km)
-900
0
900
60
40
20
0
1800
900
0
45.0-km Grid Cells
LC North Coordinates (km)
0
20
40
60
45.0-km Grid Cells

Figure 3
The Fine-Scale (5 km) MM5 Domain.



EMISSION INVENTORY

Ozone episodes occurring in 1987, 1997, and 1998 will be simulated for the AQMP. Base year inventories for those years for CO, NOx, SOx, and TOG are needed for photochemical ozone modeling. PM is also included in the inventory in order to support inputs needed for aerosol modeling. Photochemical air quality models require gridded, hourly emissions. The information needed to complete the emission inventory for the modeling region is obtained from local air pollution control districts, transportation planning agencies, and the California Air Resources Board. In addition, contracts have been established with universities and the private sector to provide important inventory components.

1997 (SCOS97) and 1998 Episodes

The 1997 (SCOS97) and 1998 episodes will be simulated using the larger, regional modeling domain. To develop a regional emission inventory for these episodes, a SCOS97 Emission Inventory Working Group (EIWG) was formed. The EIWG is comprised of members from the ARB, SCAQMD, SDCAPCD, VCAPCD, ICAPCD, MDAQMD, SBCAPCD, and US Navy (ARB 1997a). The products of that effort, which is described below, will directly benefit the AQMP process.

Anthropogenic Emissions

- *Point Sources*

Point sources are the responsibility of the districts. Emission inventories for point sources (including RECLAIM facilities) are compiled by local districts and reported to the ARB. If annual emissions for a facility fall below 10 tons/year (this cutoff varies with district) the source is included in the area source inventory. Point sources are allocated to grid cells using the location that is stored as part of the point source emission database. Temporal codes which describe hours of operation are also included in the emission database. Factors are also stored to convert annual average emissions to a specific month and day of week.

Point sources have been inventoried for 1997. The SCAQMD's point source inventory for 1997 includes an update to locations (UTM coordinates) and

stack parameters. Point source emissions for 1998 will be estimated using the ARB's California Emission Forecast System (Johnson, 1997).

- *Area Sources*

Area sources are comprised of emission source types that are difficult to inventory individually. Examples are architectural coatings, residential water heating, gasoline stations, and off-road mobile sources not included in the ARB OFFROAD model. Districts and the ARB share responsibility for estimating area source emissions according to a long-standing division of categories. Methodologies used to estimate emissions from area sources are described in several documents (ARB 1997b). Factors are also included that allow estimates of specific month and day of week emissions from annual average emissions. Temporal codes which describe hours of operation are also included in the area source emission database.

Area source categories have been inventoried for 1997. Emissions for 1998 will be grown using ARB's emission forecasting system.

- *On-Road Mobile Sources*

On-road mobile source inventories are prepared using vehicle activity data from transportation planning agencies. The majority of travel is reflected in transportation plans developed by:

- Southern California Association of Governments (SCAG);
- San Diego Association of Governments (SANDAG);
- Santa Barbara County Association of Governments (SBCAG); and
- Kern Council of Governments (Kern COG).

Travel for areas not covered by the transportation planning agencies is extracted from the California Statewide Planning Model maintained by the California Department of Transportation.

Emission factors for on-road mobile sources will be estimated using the ARB's EMFAC2000 (EMFAC2K) emission factor model. DTIM4 will use both the emission factors and travel activity data to produce hourly gridded emission estimates for the SCOS97 region.

The ARB has an extramural contract to acquire all travel data needed for this modeling study. The contractor will ensure that the digitized highways are consistent at the boundaries of the various planning areas. The network and travel activity data provided by transportation planning agencies is

developed for peak and off-peak time periods, which will be processed into 24 hourly data sets. As discussed below, day-specific traffic count data will be used to calibrate DTIM4 inputs for development of day-specific on-road mobile source emissions.

ARB staff will use the network and travel activity data to produce gridded DTIM4 inventories for episode days not run by the contractor. One of the contractor's tasks is to provide training in processing inputs and executing the DTIM4 code.

- *Other Mobile Sources*

Area source emissions from most categories of off-road mobile sources will be estimated using ARB's off-road mobile source emission model (OFFROAD). OFFROAD covers more than 12 off-road categories, including lawn and garden equipment, small utility and construction equipment, as well as farm equipment. Categories not estimated by OFFROAD will be covered under "area sources". However, specific emissions for aircraft, marine vessels, and locomotives will be provided through separate special studies. OFFROAD will produce countywide emission inventories for each calendar year desired. The OFFROAD model will have the capability to estimate exhaust, starting, and evaporative emissions for differing spatial and temporal conditions.

- *Day-Specific Emissions*

Emissions from many sources vary from day to day. Evaporative emissions from vehicles and vegetation increase with ambient temperature. Exhaust emissions are also a function of ambient temperature. Increased air conditioning demands on hot days also lead to increased emissions from electrical generation. Hourly surface temperatures for episode days are interpolated to each grid cell and are used in estimating emissions from vegetation and on-road mobile sources.

Criteria pollutant emissions from approximately 80 major point sources will also be estimated hourly for each specific episode day. Each district has acquired data from major point sources for 1997 episode days and has already finished or is developing day-specific point source inventories for that year. Day-specific data for the July 1998 episode have been solicited

from the districts. Districts also collected information on variances, temporary breakdowns, and shutdowns.

The results from a University of California, Davis project (that is nearing completion) to incorporate traffic count data from episode days will be used to calibrate DTIM4 inputs. The contractor will run the DTIM4 program to develop mobile source inventories for several episode days, including weekend days.

Wildfire emissions occurring on 1997 and 1998 episode days have been compiled by ARB staff, and hourly emissions have been estimated for each wildfire. The type of information collected will allow development of temporally and spatially resolved emission estimates.

A computer model to estimate emissions from large ships for the SCOS97 episodes is being developed by ARB staff. Ship activity data (for commercial vessels) from shipping ports, ship-specific engine characteristics data, and the latest emission factors will be used to estimate emissions for transit in the shipping lanes and at the ports.

The ARB has purchased aircraft activity data for the SCOS97 and July 1998 episode days. This data has one minute radar-derived locations for all aircraft in the SCOS97 region. Hourly landing, takeoff, approach, climbout, and cruise emissions can be determined from these data for each episode day. This database will be used to construct a three dimensional commercial jet emissions array that can be input to photochemical models.

In addition to the ARB efforts, the District is sponsoring special studies to collect aircraft and marine vessel activity data that will complement the ARB database.

An analysis of air quality-related special events (such as air shows, sporting events, and unusual traffic problems) has turned up an absence of such events.

Natural Emissions

- *Biogenics*

The derivation of a gridded biogenic emission inventory requires data sets describing the spatial distributions of plant species, biomass, and emission factors that define rates of hydrocarbon emissions for each plant species. The Biogenic Emission Inventory System (BEIS 2.3) (USEPA, 1995) model, distributed by the USEPA for this purpose, is one source of these data sets for areas throughout the United States. However, the BEIS model has been shown to have limited use in California because of poor spatial resolution within the referenced data sets and a simplified scheme for assigning emission factors (e.g., Jackson, et al., 1996). The development of a gridded biogenic emission inventory for the SCOS97 domain will benefit from research conducted within California that describes the needed data sets in more detail than is defined within the BEIS model (Benjamin et. al., 1998).

ARB staff in consultation with researchers at UCLA has developed a methodology to complete a gridded biogenics inventory for the SCOS97 region. The following paragraphs describe this approach.

Gridded Plant Species Maps

The distribution of plant species within the SCOS97 modeling domain will be determined using a composite of a number of data sets. Plant species as a function of urban land-use classifications were described by SCAQMD (1990) for the Los Angeles basin and updated by Benjamin et. al. (1996) and Arey et. al. (1995). These land-use classifications were extrapolated to other urban areas within the modeling domain. For the SCOS97 modeling domain, plant species distributions were taken from the GAP data base (Davis et. al., 1995), an inventory of biomass diversity for the United States.

Biomass Distribution

Plant biomass is difficult to measure and there are few descriptive data sets of biomass distribution for areas within the SCOS97 modeling domain. Therefore, estimates of biomass distribution were determined using published correlations between biomass and Normalized Difference Vegetative Index (NDVI). The NDVI is an index of relative "greeness" calculated from Advanced Very High Resolution Radiometer (AVHRR) data. Spatial distribution of NDVI from satellite remote sensing data sets were acquired from the United States Geological Survey EROS Data Center.

Emission Factors

The chemical species and rates of hydrocarbon emissions vary by plant species. Emission factors have been measured for only a relatively small subset of the more than 6,000 plant species known in California, and for only a few general categories of chemical species. However, research has shown that emission factors for various plant species can be correlated using taxonomic relationships between the plant species (Benjamin et. al., 1996). Using this "taxonomic model", emission factors were assigned for all plant species known to exist within the SCOS97 modeling domain. However, because of the limited research results available, biogenic emission factors are available for only three classes of hydrocarbons: isoprene, monoterpenes, and methyl butenol.

Gridded Biogenic Inventory

The gridded plant species, biomass distribution, and emission factor databases will be combined with episode-specific ambient temperature and photosynthetically active radiation data using a Geographic Information System to produce gridded hourly emissions of isoprene, monoterpenes, and methylbutenol.

- *Soil NOx Emissions*

Soil emissions of NOx to the air have been associated with the use of nitrogen containing fertilizers. Emissions have been estimated from fertilizer usage in the San Joaquin Valley. The soil NOx emissions were seen to have insignificant impacts on ozone concentrations. As a result, a soil NOx inventory has not been planned for this study.

- *Oil and Gas Seeps*

There are substantial emissions from oil and gas seeps near the coast in the area of Santa Barbara county. Estimates for these sources are provided to the ARB by the SBCAPCD.

Organic Gas Speciation

Organic gas speciation profiles are applied to all categories of TOG emissions to obtain estimates for each organic gas species emitted in the

modeling region. ARB maintains a database of current profiles that are routinely updated to reflect recent information. The most recent updates were for gasoline exhaust and evaporation, diesel exhaust and jet engine exhaust. These recent updates were presented by the ARB at the September 10, 1998, VOC Speciation Workshop held in Sacramento. The ARB publication "Identification of VOC Species Profiles" (ARB 1991) documents the organic gas profiles; an update is planned by summer 1999 to reflect the recent workshop.

Gridding Surrogates

Area and OFFROAD emissions are estimated and stored in the emission inventory database at the county level. There are many types of data (with highly resolved spatial resolution) that can be used as surrogates for one or more emission categories. For example, census tract population can be used to allocate consumer product emissions to grid cells. Housing units, also available for census tracts, can be used to spatially allocate residential lawn and garden equipment emissions.

Maps are used to digitize and spatially allocate emissions for several categories of watercraft, locomotives, and airports.

The ARB contractor working on the DTIM4 runs will also provide gridded surrogates for all area and off-road mobile source emission categories. The contractor will seek inputs from the districts and ARB on the appropriate gridding surrogates to use for each emission category for the SCOS97 region.

SCOS97 surrogates are being resolved to a 2 kilometer grid scale to allow high spatial resolution if needed. The 2 kilometer inventory can easily be aggregated to larger grid cells.

Northern Mexico Inventory

A portion of northern Mexico is included in the SCOS97 modeling region. A gridded inventory for this region was developed as part of a study to develop a 1990 gridded inventory for the region (SAI, 1997). The ARB contractor will also review and recommend updates to the gridded inventory for Northern Mexico. Organic gas emissions will be speciated using the most appropriate species profiles used for California emission categories.

Quality Assurance Procedures

ARB provided specific guidelines to assist state and local agencies in implementing uniform and systematic approaches for collecting, compiling, and reporting emission inventory data. A comprehensive quality control and quality assurance plan was prepared to ensure good quality practices during development of the 1997, and future year emission inventories. These procedures include: quality control checks for collecting non-emission data, updating activity data, and using appropriate emission factors for calculating emissions; emission calculation methodology; quality assurance evaluation using the Data Attribute Rating System (DARS); and quality review of the entire inventory. The DARS program, originally developed by the USEPA, will be used as an additional quality assurance tool to quantify the relative accuracy of the annual emission inventories. ARB has also provided the districts with a variety of quality assurance reports to aid in the review of inventory data important for modeling. These reports were intended to provide checks on the accuracy of the emission calculations, stack data, facility location data, temporal data, devices data, process data, etc.

Emission Projections

Future year emissions form the basis for an air quality emission reduction target. Future year emissions for area and point sources are projected by accounting for growth and control, generally using growth and control factors applied to the base year (1997) emissions. Control factors are derived based on adopted measures. Growth factors are derived from socioeconomic and demographic data provided by districts and local agencies, and ARB-sponsored research factors elsewhere. Area source and offroad emissions are gridded using the appropriate surrogates as used for 1997. The ARB contractor is also preparing gridded future year surrogates for the entire SCOS97 region for 2005, 2010, and 2020. Surrogates for other years can be interpolated as needed.

Future year traffic activity and network data are also prepared by local planning agencies. EMFAC2K will give estimates of future year emission factors. DTIM4 uses future year emission factors and network travel data to obtain gridded future year on-road mobile emissions. DTIM4 inputs for future years are being compiled and prepared (for DTIM4 input) under

contract to the ARB. Ambient temperatures that occurred during 1997 are also used in calculating future year emissions for each episode day.

Biogenic emissions will not change for future years. Even though there may be a shift in farm or landscaping plans and species, the capability does not exist to incorporate any potential changes into the inventory. Seep emissions will also remain constant in future year inventories.

1987 (SCAQS) episodes

The 1987 (SCAQS) episodes will be simulated for continuity with the 1994 SIP and the 1997 AQMP, using the SCAQS modeling domain. Emissions for these episodes will be updated to reflect the following:

- a 1987 inventory re-created from a 1997 base year;
- improved VOC speciation profiles;
- ARB's EMFAC2K on-road mobile source emission factor model;
- the latest version of the Direct Travel Impact Model (DTIM4); and
- the ARB's OFFROAD (off-road) mobile source emission factor model.

In addition, work is currently underway to review stack parameter data within the SCAQMD, and the results of that effort will be incorporated when available.

INITIAL AND BOUNDARY CONDITIONS

Initial and boundary conditions for the 1987 episodes have been developed previously; no new work is planned for those episodes.

Initial Conditions

Initial conditions define the spatial distribution of chemical species concentrations throughout the 3-dimensional modeling domain at the time at which the air quality model simulation begins. There are two limitations inherent in defining initial conditions. The first is that chemical species concentrations are only measured at discrete locations and, for some species, for discrete time periods. Therefore, observed concentrations must be extrapolated to estimate concentrations throughout the modeling domain. The second limitation is that observed chemical species concentrations may not represent chemical equilibrium, especially since not all important chemical species are measured explicitly.

To minimize the importance of initial conditions on air quality model simulation results, the simulation is frequently started at some time interval before the period of interest. Historically, this "spinup" time interval has ranged between 8 and 72 hours. For the 1997 and 1998 episodes, the spinup period will begin at between 0000 PDT and 0500 PDT of the day before the first day of interest (the difference in the begin time reflects the difference in time-base – GMT vs. local time – for some meteorological models). This spinup period will allow a full diurnal cycle of sunlight, prior to the period of interest, to enable the air quality model to reach chemical equilibrium.

Initial conditions will be determined by interpolation/extrapolation of the chemical species concentration measurements available from the SCOS97 field study archive or other episode-specific data. For the large areas of the study domain in which there are few such measurements, initial-conditions will be assigned "background" values based on the minimum concentrations measured from monitoring sites where measurements are available.

Boundary Concentrations

Boundary concentrations are chemical species concentrations on the study domain boundaries and represent the concentrations for the air mass moving

into the domain. Unlike initial conditions which need to be defined only for the beginning of the simulation, boundary conditions must be defined for each hour of an air quality model simulation on the 2-dimensional, vertical planes on each of the horizontal boundaries of the domain, and at the top of the modeling domain.

Ideally, modeling domain boundaries are placed so remotely that simulation results are insensitive to boundary conditions. For the SCOS97 study domain, the influence of boundary conditions on the simulation results from an air quality model is problematic. Beyond the northern SCOS97 boundary, emissions from central California could have an impact on the domain. To the south, emissions from Mexico could have an impact. The western boundary is over the Pacific Ocean, where recirculation may be an issue. Boundary conditions will be determined from measured chemical species concentrations where they are available from the SCOS97 field study. Where measurements are not available, background chemical species concentrations will be assigned based on the lowest concentrations from sites where concentrations were measured. A part of the air quality model evaluation process will be to assess the influence of boundary and initial concentrations on simulation results.

MODEL PERFORMANCE EVALUATION

It is a well established tenet of the modeling community that for an air quality modeling simulation to give reliable results, it must be capable of giving the right answers *for the right reasons*. That is, not only must the model be capable of reproducing observed ozone measurements with a reasonable level of accuracy, but it must also pass a series of prescribed tests designed to ensure that the apparently accurate results are not produced by a combination of compensating errors. As discussed below, several tests on the modeling simulations, both at the surface and aloft–for precursor and secondary species in addition to ozone–as part of the model performance process are proposed to be conducted. The statistical tests will be performed for the domain, by district, and for several subregions to ensure that the domainwide statistics do not mask subregional problems. This information should allow a determination that the model is working properly. Much of the following information is taken from the ARB's photochemical modeling guidance (ARB 1992).

Statistical and Graphical Analyses

The evaluation will include both graphical and statistical analyses. Graphical analyses compare simulated pollutant concentrations with measured values. These will include time series plots showing temporal variations, contour plots showing spatial variations, scatter plots showing tendencies for over- or underestimation, and residual plots showing the distribution of the differences between observed and predicted concentrations. The statistical analyses will examine the accuracy of peak estimates (both paired and unpaired in time and space), mean normalized bias, mean absolute gross error, and mean absolute normalized gross error. The statistical performance criteria outlined in the ARB's guidance document for Class B or better ozone performance will be used to guide the determination of acceptable model performance. These statistical criteria will be used as a criterion for acceptable model performance. However, other analyses (graphical, multi-species, aloft comparisons, and the diagnostic simulations) will also be used to determine acceptable model performance, and ultimately a conclusion that the model is working properly must be made considering all of the analyses.

- **SUBREGIONAL PERFORMANCE**

Since the South Coast Air Basin is very large, six subregions are proposed to be evaluated for model performance: San Fernando Valley, west (or coastal) basin, mid-basin, San Gabriel Valley, east basin, and the Coachella Valley area.

The same statistical acceptance criteria for the subregions as for the entire domain will be used.

Multi-Species Evaluations

To be useful for planning or other purposes, an air quality model must be able to replicate measured ozone concentrations with reasonable accuracy. However, it is also important to compare estimated and measured concentrations of ozone precursors and secondary species, to establish confidence that the chemistry processes are being simulated properly. The important precursors are NO, NO_x, HONO, and organic gas species; important secondary species are HNO_3 and PAN. Organic gas concentrations will be lumped according to the scheme employed by each model's chemical mechanism. Comparisons will be made for each of the estimated precursor species and lumped organic gas species, for each monitoring location. In addition, comparisons will also be made for NO_x, and total ROG.

These comparisons may reveal problems not associated with those for ozone concentrations. Many of the precursor species have a secondary component as well. Concentrations of primary pollutants tend to have higher gradients than do secondary species. This makes it more difficult to assume that a measured concentration of a primary pollutant represents a grid cell average. For these reasons it is probably unreasonable to expect the same accuracy in replicating precursor concentrations as for ozone concentrations. Thus use of a specific statistical error or bias criterion is not recommended. These comparisons should be viewed as qualitative, to uncover potential problems in precursor and secondary performance.

Aloft Comparisons

During the SCOS97 field study, concentrations of selected air pollutants were measured above the ground using aircraft, balloons, and LIDAR. The primary component of these measurements was oxidant concentrations

measured with ozonesondes to a height of 5,000 m AGL. Ozonesondes were flown at seven sites, at 6-hour intervals, for selected episode days. Also, four aircraft were flown up to three times per day and an ozone LIDAR was operated continuously on selected episode days.

The performance of air quality model simulations above the ground will be determined by comparing simulated oxidant and ozone concentrations with measurements, for the same times and locations. Measured concentration profiles will be averaged for the vertical layer increments corresponding to those of the air quality model. Because of the vertical spacing required for the air quality models, the vertical resolution of this comparison will be relatively poor. Therefore, initially this comparison will be of a qualitative nature only.

In addition to measuring ozone, three of the aircraft measured oxides of nitrogen and collected samples for later hydrocarbon analysis. Comparisons between these precursor data and concentrations simulated using the air quality models will also be made. However, there are relatively few samples and because an aircraft is not in one grid cell for an hour, comparisons may not be consistent with modeled concentrations. Comparisons to see if any large discrepancies exist between modeled and measured concentrations aloft will be made.

Diagnostic Simulations

Several diagnostic, or investigative, simulations are proposed to further determine the fidelity of the model results. These are anticipated to include the following:

- *Zero emissions* – all anthropogenic and biogenic emissions will be set to zero to test the model's sensitivity to emissions and to ensure that the base case results are influenced appropriately by the emission inputs.
- *Double anthropogenic emissions* – all anthropogenic emissions will be doubled to test the model's sensitivity to increased man-made emissions. In addition, as separate tests of anthropogenic emissions affects, only mobile source emissions will be doubled and only stationary source emissions will be doubled.
- *Zero biogenics* – biogenic emissions will be set to zero to test the model's sensitivity to biogenic emissions.

- *Zero and clean air boundary and initial conditions* – the initial (interior) and boundary (at the top and sides of the modeling domain) conditions will be set to zero and USEPA recommended clean air values to determine model sensitivity to these inputs.
- *Zero surface deposition* – deposition will be turned off for all species to examine the effects of dry deposition on ozone estimations.
- *Reduced wind speeds* – reducing the wind speeds by 50% is proposed to test the model's sensitivity to that parameter. However, the feasibility of doing so in the event that a dynamically consistent, prognostic model is used, has not yet been investigated.

Acceptable Model Performance

While it is expected that acceptable model performance can be achieved for the new (SCOS97) and updated (SCAQS) ozone meteorological episodes, it is not always possible given the regulatory deadlines for plan submittals. Should the model performance of any of the new episodes not meet acceptable performance goals, that episode will not be used for carrying capacity and attainment demonstration purposes. The episode(s) will continue to be analyzed to improve on model performance for possible use in future plan revisions and SIP submittals.

USE OF THE MODELING RESULTS

We anticipate that the model results will be used for carrying capacity estimation and attainment demonstration. Use of the model results for these goals is contingent upon acceptable base case model performance for the episodes simulated. That is, only episodes for which the model is judged to be operating properly and which meet the model performance acceptance criteria will be used.

Historically, the District developed the carrying capacity and attainment demonstration for ozone based on a set of specific control measures that was projected to achieve the national 1-hour ozone air quality standard for all modeled episodes. For the 2001 AQMP revision, the ozone carrying capacity and attainment demonstration will again be based on a specific set of control measures such that the ozone concentrations predicted by the air quality model will be at or below 0.124 ppm (in order to be a viable attainment demonstration). However, we also propose to consider the use of adjustment factors (described below) to account for model bias and to use the model to address the ozone design value.

The USEPA's draft 8-hour ozone guidance (USEPA, 1998b) proposes the use of relative reduction factors (RRFs) as part of the attainment demonstration process for the 8-hour ozone standard, assuming that satisfactory base year model performance is established. The RRF approach incorporates design period monitoring data directly into the attainment test along with the ratio of future to current year model predictions. This allows the model to be used in a relative, rather than absolute, sense to reduce uncertainty in the predictions. The use of RRFs also potentially address two problems in model applications that tend to result in underestimation of emission reductions needed to attain standards. The first problem is that modeled episodes usually have ozone concentrations lower than the design value. The second problem is that simulation results have historically exhibited a tendency towards underestimation of observed concentrations. By utilizing monitored data along with model estimations, RRFs address both problems.

However, there may be some limitations in using RRFs for the one-hour standard. Examples of such situations include:

- Measured ozone concentrations at some sites and for some episodes may differ substantially from design values for those sites. That is, each available ozone episode will not be representative of design value conditions at all sites. In such instances it is unreasonable to include the non-representative sites in the RRF analysis.
- Model performance typically varies considerably between sites and episodes in a domain. The reported ozone performance measures (such as peak prediction accuracy, bias, and gross error) do not capture this variation. It may be unreasonable to include sites which have poor model performance for a given episode.

The potential use of RRFs, and details of application, will be considered after model performance evaluations are completed and analyzed. If model-estimated peaks are near design values for some episodes then RRF-type adjustments will probably not be necessary.

Carrying Capacity Estimation

A traditional use of models for planning has been the estimation of carrying capacities for ozone precursors. This is typically achieved by exercising the model with a series of across-the-board precursor emission reductions from the future year baseline, from which an ozone isopleth ("EKMA") diagram is constructed. The metric used for the isopleth diagram can be one of several, such as peak 1-hour or 8-hour ozone concentrations within the modeling domain (or subregion), number of grid cells above the standard, or one of many population exposure metrics. *Since the carrying capacity for each precursor is based on across-the-board emission changes, rather than source- and location-specific controls as would be specified in a plan, it should be viewed as an initial estimate only.*

For the AQMP process, ozone isopleth diagrams by episode for the following air quality metrics will be constructed:

- Peak 1-hour ozone concentration for the domain.
- Population exposure for 1-hour ozone concentrations.
- Peak 8-hour ozone concentration for the domain. This information will serve as an indicator of the need for potential additional precursor emission reductions to meet the 8-hour ozone NAAQS.

The resulting isopleth diagrams will be used as an initial guide for determining the emission reductions necessary for attainment.

Attainment Demonstration

The attainment strategy will be developed as in the past. All proposed control measures (the control strategy) will be modeled with the future year (2010) emission inventory to predict if the control strategy achieves the ozone standard for the episode(s) simulated. When predicted ozone concentrations in all grid cells are 124 ppb or less for each episode this step is completed.

Depending on the results from model performance evaluations, the use of RRFs will be considered, to account for differences between the episodes simulated and the ozone design values.

TECHNICAL OVERSIGHT

The District has established a technical oversight committee to review the technical aspects of the ongoing modeling analyses. During the adoption of the 1989 AQMP revision, the District's Governing Board passed a resolution to form such a group to provide oversight and to enhance technical consensus on AQMP modeling issues. The District has budgeted for the formation of a Modeling Working Group (MWG) comprised of individuals with photochemical and aerosol modeling expertise.

In 1997, the District Governing Board reconstituted the MWG and formed the Scientific, Technical, and Modeling Peer Review Advisory Group (STMPRAG). The STMPRAG role expands upon that of the MWG and includes experts in socioeconomic assessment and human health.

The STMPRAG assists the District in resolving technical issues related to air quality modeling by providing ongoing technical review of procedures and analyses. The objectives of the STMPRAG are as follows:

1. Suggest methods to gather and process meteorological, aerometric, and emission data with a specific focus on air quality modeling.

2. Provide technical guidance to the District's air quality modeling efforts, with an emphasis on ozone and PM_{10}. Areas of technical guidance include:

    - Formulation of modeling approaches;
    - Selection and development of appropriate modeling techniques; and
    - Identification of model performance evaluation methods.

3. Review and provide comments on the District's modeling procedures and analysis.
4. Make recommendations on future resource requirements (i.e., staffing and computational needs).
5. Recommend methods for interpretation of modeling results.

The MWG consists of representatives from the District, ARB, USEPA, American Automobile Manufacturers Association (AAMA), Southern

California Association of Governments (SCAG), Southern California Edison (SCE), Western States Petroleum Association (WSPA), and special technical consultants.

In addition to the STMPRAG, many of the technical work elements are being separately reviewed by a series of technical working groups established as part of the SCOS97 regional modeling effort. An Emission Inventory Working Group has already been established, and has met several times to discuss inventory-related issues and coordinate inventory preparation activities. A Meteorological Modeling Working Group has been convened with the goal of reviewing the preparation of regional meteorological inputs. Other working groups are planned, such as for air quality modeling. The participation of these groups will provide a valuable additional source of technical review to that of the STMPRAG.

Finally, as progress is made and products are available, interim results will be shared with the interested public at appropriate times and locations.

REFERENCES

Arey, J., D.E. Crowley, M. Crowley, M. Resketo, and J. Lester: 1995. "Hydrocarbon emissions from natural vegetation in California's South Coast Air Basin." Atmos. Environ. 21: 2977-2988.

Benjamin, M.T., M. Sudol, L. Bloch, and A.M. Winer. 1996. "Low-emitting urban forests: A Taxonomic methodology for assigning isoprene and monoterpene emission rates." Atmos. Environ. 30: 1437-1452.

Benjamin, M.T., A.M. Winer, J. Karlik, S. Campbell, B. Jackson, and A. Lashgari. 1998. "Assembling a biogenic hydrocarbon emissions inventory for the SCOS97-NARSTO modeling domain." Proceedings of the A&WMA 91st annual Meeting. Paper No. 98-WP75.08. A&WMA. Pittsburg, PA 15222.

Bigler-Engler, V., H. Brown, and K. Wagner, 1996. "A Hybrid Modeling Technique to Address Coastal Meteorology and Complex Terrain in the San Diego Photochemical Modeling Domain." Proceedings Ninth Joint Conference on Applications of Air Pollution Meteorology with A&WMA, Atlanta.

Bott, A. 1989a. "A Positive Definite Advection Scheme Obtained by Non-Linear Renormalization of the Advective Fluxes." Mon. Wea. Rev., 117:1006-1015.

Bott, A. 1989b. "Reply." Mon. Wea. Rev., 117:2633-2636.

California Air Resources Board. 1991. Identification of Volatile Organic Compound Species Profiles. August 1991.

California Air Resources Board: 1992. TECHNICAL GUIDANCE DOCUMENT: Photochemical Modeling. April, 1992.

California Air Resources Board. 1997a. The 1997 Southern California Ozone Study–NARSTO: Preparation of the 1997 Gridded Emission Inventory. A&WMA June 1998 Presentation.

California Air Resources Board. 1997b. Emission Inventory Procedures Manual: Methods for Assessing Area Source Emissions, Volume III. October 1997.

California Air Resources Board, and the SCOS97-NARSTO Technical Committee. 1998. SCOS97-NARSTO 1997 Southern California Ozone Study and Aerosol Study, Volume III: Summary of Field Operations. April 1998.

Carter, W.P.L. 1990. "A Detailed Mechanism for the Gas-Phase Atmospheric Reactions of Organic Compounds." Atmos. Environ. 24A:481-518.

Carter, W.P.L., D. Luo, I.L. Malkina, and J.A. Pierce. 1993. An Experimental and Modeling Study of the Photochemical Ozone Reactivity of Acetone. Final Report to the Chemical Manufacturers Association. Contract No. KET-ACE-CRC 2.0. December 10, 1993.

Carter, W.P.L. 1995. "Computer Modeling of Environmental Chamber Studies of Maximum Incremental Reactivities of Volatile Organic Compounds." Atmos. Environ., 29:2513-2527.

Carter, W.P.L., D. Luo, and I.L. Malkina. 1996. Environmental Chamber Studies for Development of An Updated Photochemical Mechanism for VOC Reactivity Assessment. December, 1996. Prepared by the University of California, Riverside for the California Air Resources Board.

Carter, W.P.L., D. Luo, and I.L. Malkina. 1997. Environmental Chamber Studies for Development of An Updated Photochemical Mechanism for VOC Reactivity Assessment. Final Report to the California Air resources Board, Coordinating Research Council, and National Renewable Energy Laboratory. November 26.

Chang, J.S., R.A. Brost, I.S.A. Isaksen, S. Madronich, P. Middleton, W.R. Stockwell, and C.J. Walcek. 1987. "A Three-Dimensional Eulerian Acid Deposition Model. Physical Concepts and Formulation." J. Geophys. Res., 92:14681-14700.

Chang, J.S., P. Middleton, W.R. Stockwell, C.J. Walcek, J.E. Pleim, and H.H. Lansford. 1990. The Regional Acid Deposition Model and Engineering Model. Final Assessment Reports of the National Acid Precipitation Assessment Program. V. 4. Government Printing Office, Washington, D.C.

Chang, J.S., S. Jin, Y. Li, M. Beauharnois, C.L. Lu, and H. Huang. 1997. The SARMAP Air Quality Model. April, 1997. Prepared by the Atmospheric Sciences Research Center, State University of New York.

Davis, F.W., P.A. Stine, D.M. Stoms, M. I. Borchert, and A. D. Hollander. 1995. "GAP analysis of the actual vegetation of California 1. The southwestern region." Madrono. 42: 40-78.

ENVIRON. 1997. User's Guide to the Comprehensive Air Quality Model with Extensions. April, 1997.

Gery, M.W., G.Z. Whitten, J.P. Killus, and M.C. Dodge. 1989. "A Photochemical Kinetics Mechanism for Urban and Regional Scale Computer Modeling." J. of Geophys. Res. 94: 12,925-12,956.

Jackson, B.S., E. Mulberg, and N. Wheeler. 1996. "The application of biogenic emission inventory estimates to photochemical modeling in California." Proceedings of the 9th Joint Conference of the American Meteorological Society and A&WMA. January, 1996. Pages 575-579. American Meteorological Society. Boston, MA. 02108.

Johnson, M. 1997. Redesign of California's Emission Forecasting System (CEFS). California Air Resources Board. A&WMA Presentation October 1997 presentation.

Kumar, N., F.W. Lurmann, and W.P.L. Carter. 1995. Development of the Flexible Chemical Mechanism Version of the Urban Airshed Model. August, 1995. Prepared by Sonoma Technology, Inc. for the California Air Resources Board.

Lolk, N.K. and S.G. Douglas. 1996. "Evaluation of Meteorological Fields Generated by a Prognostic Mesoscale Model Using Data Collected During the 1993 GMAQS/Coast Field Study." Proceedings Ninth Joint

Conference on Applications of Air Pollution Meteorology with A&WMA, Atlanta.

Mulberg, E. 1995. "A Comparison of Three Wind Models for the Broader Sacramento Area." Proceedings Regional Photochemical Measurement and Modeling Studies, A&WMA, San Diego.

SCAQMD. 1990. "Inventory of Leaf Biomass and Emission Factors for Vegetation in the South Coast Bain Basin." Technical Report III-C. Draft Air Quality Managenent Plan. South Coast Air Quality Management District. Diamond Bar, CA. 91765.

SCAQMD. 1994. "Ozone Modeling - Performance Evaluation." Technical Report V-B. Air Quality Managenent Plan. South Coast Air Quality Management District. Diamond Bar, CA. 91765.

Seaman, N.L., D.R. Stauffer, and A.M. Lario. 1995. "A Multi-Scale Four Dimensional Data Assimilation System Applied in the San Joaquin Valley During SARMAP. Part 1: Modeling Design and Basic Performance Characteristics." Journal of Applied Meteorology, 34:1739-1776.

Sonoma Technology, Inc. 1996. "Development of a Gridded Leaf Biomass Inventory for use in Estimating Biogenic Emissions for Urban Airshed Modeling". Final Report STI-996086-1599-R. Ventura County APCD. Ventura, CA. 93003-5401. August 28, 1996.

Smith, T.B., W.D. Saunders, and D.M. Takeuchi. 1984. Application of Climatological Analysis to Minimize Air Pollution Impacts in California. Prepared for the California Air Resources Board, Sacramento. Report A2-119-32.

Systems Applications, Intl. 1996. User's Guide to the Variable-Grid Urban Airshed Model (UAM-V). October 1996. SYSAPP-96-95/27r.

Systems Applications, Intl. 1997. Preparation of a Draft 1990 Gridded Emission Inventory for Southern California. March 1997. Prepared for the California Air Resources Board. SYSAPP-97/08.

United States Environmental Protection Agency. 1990. User's Guide for the Urban Airshed Model, Volume I: User's Manual for UAM (CB-IV). Office of Air Quality Planning and Standards. EPA-450/4-90-007A.

United States Environmental Protection Agency. 1991. Guideline For Regulatory Application of the Urban Airshed Model. EPA Publication No. EPA-450/4-91-013. U.S. Environmental Protection Agency, Research Triangle Park, NC.

United States Environmental Protection Agency. 1995. Urban Airshed Model (UAM) Biogenic Emission Inventory System Version 2. (BEIS2) User's Guide. Final Report. EPA Contract No. 68-D3-0034. Work Assignment No. 1-9. EC/R Project No. AQM-108. United States Enviromental Protection Agency. Air Quality Modeling Group. RTP, NC 27711.

United States Environmental Protection Agency. 1998a. EPA Third-Generation Air Quality Modeling System: Models-3 Volume 9b User Manual. June 1998. Office of Research and Development. EPA-600/R-98/069(b).

United States Environmental Protection Agency. 1998b. Use of Models and Other Analyses in Attainment Demonstrations for the 8-Hour Ozone NAAQS (Draft). October, 1998.

Yamartino, R.J., J.S. Scire, S.R. Hanna, G.R. Carmichael, and Y.S. Chang. 1989. CALGRID: A Mesoscale Photochemical Grid Model, Volume I: Model Formulation Document. June, 1989. Prepared for the California Air Resources Board by Sigma Research Corp.

ATTACHMENT 2

Expert Panel Modeling Critiques

Review of Operational Evaluation for South Coast Air Quality Management District 2003 Air Quality Management Plan

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January 18, 2003

Introduction

The South Coast Air Quality Management District (SCAQMD) is conducting air quality modeling for ozone (O_3) and PM_{10} in support of its 2003 Air Quality Management Plan. The UAM (Ver 6.21), CALGRID, and CAMx air quality models were applied to 1997 base-year emissions and one field study episode (August 4-6, 1997) to estimate O_3 in southern California for an operational evaluation. The models were configured to be as similar as possible in terms of grid size, boundary conditions, initial conditions, and deposition. The CB-IV chemical mechanism was used in UAM and both the CB-IV and SAPRC99f mechanisms were used in CALGRID and CAMx. The MM5 meteorological model generated prognostic wind fields that drove each of the models. The number and depths of vertical layers differed among the different models.

Operational evaluations compare model outputs to measured concentrations of O_3 and intermediate chemical components. The objective of this operational evaluation is to justify the selection of one of these modeling systems for evaluating effects of planned emission reductions in the South Coast Air Basin (SoCAB). Several comparison statistics and plots were created for O_3, NO_x, and CO model estimates and observations as part of this evaluation.

The review evaluates these performance measures and comments on how these might be used to justify the model selection.

Operational Evaluation Statistics for Ozone

An initial examination of the plots and statistics for the UAM, CALGRID and CAMx models using CB-IV and/or SAPRC99 shows that the SAPRC mechanism yields much better agreement between model-estimated and measured O_3. Given that all other inputs to CALGRID and CAMx are the same, and that the improvement it performance measures is consistent across the two models, it appears that the SAPRC99 mechanism better represents the ozone-forming chemistry in the modeled region, at least on an operational basis. Normalized bias, normalized error, and correlation statistics were tabulated for each sub-region and each of the five model applications. It was clear from this tabulation (not shown here) that biases

and errors were smaller and correlations were higher (especially for r>0.6) for most of the sub-regions when the SAPRC99 mechanism was used.

Table 1 summarizes the ranges of performance measures for O_3 classified by the ten sub-regions. Entries in Table 1 are those that were closest to the U.S. EPA (1991) performance objectives of 0.8 t 1.2 for the unpaired peak ratio, ±15% for average normalized bias, and <35% for average normalized gross error. For the models with both mechanisms, the SAPRC99 mechanism better attained these objectives than the CB-IV. However, the UAM with CB-IV was equivalent to or slightly better than the other models for sub-regions 1. N. Central Coast, 3. San Fernando Valley, and 5. LA. It would be useful to determine the extent to which performance measures would improve if the UAM was capable of using both chemical mechanisms as are the CALGRID and CAMx.

All of the models tend to underestimate peak hourly O_3 more often than they overestimate these concentrations. CALGRID-S appears to have the smallest bias most of the time. It usually underestimates O_3 by ~10% to 20% for all sub-regions except at the boundaries, where O_3 is underestimated by ~30%. UAM-C appears to have performed best in the Los Angeles sub-region 5, and comparably with CALGRID-S in the N. Central Coast (2) and San Fernando Valley (3) sub-regions. The CALGRID-S August 6 statistics for the Los Angeles sub-region show a very large bias that contrast with good agreement between calculated and measured values on the previous two days. Valid O_3 measurements were available at only the Pasadena and Palos Verdes monitors in this region, and this may be a partial cause of this and other biases.

The ranges in Table 1 must be qualified by the fact that different numbers of modeled/measured comparisons are included in the comparison statistics. CALGRID-S and CAMx-S comparisons include three more sites (Tijuana, Trona, & Pt. Mugu) than were included for the CALGRID-C and CAMx-C comparison for sub-region 0. It is unclear why the Tijuana site is included in the background category. Pt. Mugu was included in sub-region 2 for the CB-IV comparisons. The Phelan-Beekley site was in sub-region 4 for the CB-IV comparisons and in sub-region 8 for the SAPRC99 comparisons. The sub-region 7 LA N. Main and SJVUCD sites used for SAPRC99 comparisons were omitted for CB-IV comparisons. Documentation of the reasons for including different monitors in each sub-region for CB-IV and SAPRC99 runs is needed. It's not clear why the sub-regions are defined as they are.

Plots of residuals were available only for the CB-IV results. These show that all models tend to overestimate NO at low concentrations and especially at night. They tend to underestimate NO at high concentrations. Residuals appear to be largest for the UAM-C comparisons. NO_2 concentrations biases are smaller than those for NO and shift from overestimation to underestimation at 70 to 80 ppb.

Time series comparisons of calculated and measured O_3 for CALGRID-S and CAMx-S show a tendency to underestimate the peak concentrations. Overestimation is more prevalent at outlying sites (sub-regions 1, 2, 7, 8, and 9). At low concentrations both CALGRID-S and CAMx-S show peaks and valleys that are not similar to those observed in the measurements.

Model Selection for OZONE Control Strategy Simulations

Operational evaluation is only one part of a comprehensive model evaluation effort. Seigneur et al. (2000) recommend: 1) operational testing that demonstrates an ability to estimate O_3 and its intermediate chemical components; 2) diagnostic testing that examines the degree to which precursor and intermediate concentrations are reproduced; 3) mechanistic testing that determines the effects of emission and meteorological changes on estimated concentrations; and 4) probabilistic testing that quantifies uncertainties in model results. The operational comparison statistics indicate that the SAPRC99 mechanism probably performs better than the CB-IV. It is not clear that other differences between the models improve or degrade performance, although the CALGRID-S seems to meet the EPA criteria for most of the sub-regions. In many cases, CAMx-S produced comparable results. The use of more than one model over several episodes would facilitate understanding of the uncertainties related to proposed emission reduction strategies.

PM_{10} Modeling

PM_{10} modeling is not as well documented or evaluated as O_3 modeling. Information given consisted of: 1) tables of a linear rollback calculation, 2) tables of annual average concentrations estimated by UAM-AEROLT and compared with sulfate, nitrate, organic carbon, elemental carbon, ammonium, and "other" concentrations at five sites, and 3) time series plots of calculated and measured concentrations. Ambient measurements are from the 1995 PM_{10} Technical Enhancement Program (PTEP) that partially represent sub-regions 4 and 5 from Table 1.

Comparison statistics show 7% to 34% differences in annual averages between calculated and measured concentrations for the different chemical components. For quarterly averages, the model overestimates measured PM_{10} by 40% to 50% for the first quarter and underestimates PM_{10} by 20% to 50% during the fourth quarter. Part of this might be due to the use of calendar quarters than seasonal quarters (e.g., Dec, Jan, and Feb for winter). Nitrate at Rubidoux is underestimated by 13%, but this includes a 35% overestimate during the first quarter and a 39% underestimate during the fourth quarter. The annual average differences masks more serious differences over shorter time periods. Comparisons of intermediate species concentrations such as ammonia and nitric acid is needed to evaluate the extent to which the model gives the right answers for the right reasons.

There needs to be a greater unity between O_3 and PM_{10} modeling, as NO_x and VOC strategies for O_3 may also affect the ammonium nitrate in PM_{10}. This is another argument in favor of using the SAPRC99 mechanism for ozone, as the CB-IV mechanism cannot be adapted to secondary organic aerosol formation (Stockwell, 2002). It appears that the UAM-AEROLT underestimates secondary organic carbon by factors of 2 to 3 compared to CMB (STMPR presentation, Aug 3, 2001). Several recent studies have used CAMx and CMAQS models for air quality forecasting (e.g., Cai et al., 2002, Stockwell et al., 2002) and for regional modeling in New England and Southern Nevada. Unifying assessment and forecasting capabilities for both O_3 and PM_{10} would be a worthwhile goal that could provide continuous performance evaluation and continued improvement in the modeling/measurement system within the SoCAB.

References

Cai.,C., Hogrefe,C. Biswas, J. Rao,S.T., Seaman, N. Gibbs,A. Kallos, G., Katsfados,P. Walcek, C., Chang J., and Demerjian,K.L. (2002). An experimental air quality forecast modeling system (AWFMS) for the northeast United States: A demonstration study. Presented at the Fourth Conference on Atmospheric Chemisty, Orlando FL, American Meteorological Society.

Seigneur,C., Pun,B.K., Pai,P., Louis,J., Solomon,P., Emery,C., Morris,R., Zahniser,M., Worsnop,D., Koutrakis,P., White,W.H., and Tombach,I.H. (2000). Guidance for the performance evaluation of three-dimensional air quality modeling systems for particulate matter and visibility. *JAWMA* **50,** 588-599.

Stockwell, W.R., Artz, RS., Meagher, J.F., Petersen, R.A., Shere,K.L., Grell, G.A., Peckham,S.E., Stein A.F., Piercde, R.V., O'Sullivan, J.M., Whung, P.Y. (2002). The scientific basis of NOAA's air quality forecasting program. *EM* **8**, 20-27.
Stockwell, W.R. (2002). Brief overview of gas-phase atmospheric chemistry mechanisms for air quality models. Internal NOAA report, National Oceanic and Atmospheric Administration, Silver Springs, MD.

U.S. EPA (1991). Guideline for regulatory application of the Urban Airshed Model. EPA-450/4-91-013, U.S. Environmental Protection Agency, Research Triangle Park, NC.

Table 1. Ranges of the best performance statistics for ozone modeling systems by modeling sub-region for the August 4-6, 1997 episode. (More than one modeling system is tabulated when statistics are comparable. Based on reports from Simulation ID arb97b for UAM-C, CALGRID-C, and CAMx-C, p85 for CALGRID-S and p800s for CAMx-S. CALGRID-C and CAMx-C comparisons were examined but they consistently yielded poorer performance statistics than other models.)

Sub-Region[a]	**Model**[b]	**Unpaired Ratio (range)**[c]	**Percent Normalized Bias (range)**[d]	**Percent Normalized Gross Error (range)**[e]
0. Boundary	CALGRID-S	0.67 to 0.75	-42 to -38	38 to 43
1. N. Central Coast	CALGRID-S	0.89 to 0.95	-14 to 0	8 to 20
	UAM-C	0.8 to 1.02	-19 to -12	16 to 24
2. Ventura County	CALGRID-S	0.82 to 1.24	-4 to 20	11 to 37
	CAMx-S	0.75 to 1.01	-28 to -4	13 to 29
3. San Fernando Valley	CALGRID-S	0.91 to 1.1	-3 to 14	15 to 31
	UAM-C	0.8 to 1.1	-20 to -6	25 to 32
4. Eastern SoCAB	CALGRID-S	0.82 to 0.99	-5 to 16	24 to 34
5. Los Angeles	UAM-C	0.72 to 1.09	3 to 8	22 to 40
Aug 4&5	CALGRID-S	0.81 to 1.0	-10 to -5	12 to 25
Aug 6	CALGRID-S	1.52	-10	60
6. SanDiego/Baja	CAMx-S	0.94 to 0.97	-29 to-26	34 to 38
	CALGRID-S	1.09 to 1.27	-16 to 2	33 to 42
7. S. San Joaquin	CALGRID-	0.82 to	-28 to -14	20 to 42

Valley	S	0.86		
8. Antelope Valley	CAMx-S	0.73 to 1.07	-27 to -8	20 to 28
	CALGRID-S	1.02 to 1.36	3 to 8	22 to 40
9. Imperial Valley	CAMx-S	0.75 to 1.02	-40 to -33	41 to 44
	CALGRID-S	1.13 to 1.60	-3 to 3	26 to 52

[a]Groups of monitoring sites used for model/measurement comparisons.
[b]S designates the SAPRC99 mechanism and C designates the CB-IV mechanism.
[c]Ratio of highest modeled to highest measured O_3 within the sub-region for each modeled day, regardless of hour or location. Range is for the 3-day episodes. Measured O_3 concentrations below 60 ppb are excluded.
[d]Average of differences between modeled and measured O_3 divided by measured O_3 for each day. Measured O_3 concentrations below 60 ppb are excluded. Range is for the 3-day episode.
[e]Average of absolute differences between modeled and measured O3 divided by measured O_3 for each day. Measured O_3 concentrations below 60 ppb are excluded. Range is for the 3-day episode.

Review, Critique and Recommendations Concerning Modeling of Ozone and Particulate Matter in the South Coast Air Quality Management District

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Prepared in partial fulfillment of AQMD Contract Number 03223

January 27, 2003

Acknowledgment of Support and Disclaimer

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1.0 Introduction

This review is based on materials provided by the South Coast Air Quality Management District (AQMD) as well as discussions with the AQMD and other reviewers in a meeting on January 10, 2003. Prior to the January 10 meeting, I was provided with the following information:

1. an initial modeling protocol;
2. peer review comments on the initial protocol;
3. a series of presentations by the technical staff of AQMD and/or California Air Resources Board (CARB) to stakeholders;
4. a draft appendix describing current and future inventories, as well as methods used to make these estimates;
5. a brief discussion addressing model selection;
6. results of performance tests for ozone and precursors using CALGRID, CAMx and UAM6.21, all with the carbon bond 4 (CB4) chemical mechanism;
7. results of performance tests performed for 6 components of particles less than or equal to 10 micrometers aerodynamic diameter (PM10) and particles less than or equal to 2.5 micrometers aerodynamic diameter (PM2.5) using the UAM-LT air quality model, and
8. projected estimates in 2006 and 2010 for PM10 and PM2.5 and their components.

Subsequent to the January 10 meeting, I was also provided with the results of performance tests for ozone, N0x and CO obtained using the CALGRID and CAMx models with the SAPRC99f chemical mechanism (rather than the CB4 mechanism).

Much of the AQMD's concern is focused on whether the modeling approaches examined are adequate to support the 2003 State implementation plan (SIP) revision. In particular, they wish to know which, if any, of the 5 modeling approaches considered for ozone (UAM/CB4, CALGRID/CB4, CAMx/CB4, CALGRID/SAPRC99f, CAMx/SAPRC99f) is likely to be the most reliable approach. The AQMD has asked reviewers to respond to 8 questions regarding each of the 5 ozone modeling approaches under consideration. AQMD also poses three additional, general modeling questions for us to respond to. In Section 2.0, I describe results of my review of ozone model performance and make a recommendation regarding choice of a modeling approach for the 2003 SIP revision. Section 3.0 addresses questions posed by the AQMD. Section 4.0 discusses information presented about PM10 and PM2.5. Section 5.0 makes recommendations concerning future analyses and model performance evaluations. Section 6.0 summarizes material presented in the preceding sections.

2.0 Performance Evaluation for Ozone and Precursors

Model performance information I review covers a 3-day period (August 4-6, 1997). This period corresponds to an intensive monitoring study (SCOS97) and is one of the episodes modeled for the 2003 SIP revision. The performance evaluations for ozone include several aggregate statistical measures: ratios of unpaired global predicted to observed peak concentrations, ratios of spatially paired peaks, normalized bias, gross error and time series correlations between observations and predictions. All such comparisons are compartmentalized into 9 zones within a large, regional modeling domain. Demarcation of the zones is somewhat subjective. It is based on location of primary sources of precursors, as well as locations of high observed ozone. Other considerations, like assurance of a sufficient number of air quality monitors in each zone and some correspondence with neighboring air quality basins, which in the past have been modeled separately, also appear to apply.

Graphical displays constitute the other major means for evaluating model performance. The displays include diurnal comparisons of predicted and observed ozone concentrations at monitoring sites. Diurnal curves are available for ozone for all five modeling approaches. For the 3 approaches featuring the CB4 mechanism, diurnal curves are also available for NO, NO2 and CO. Stratified curves, examining dependencies between model performance and level of observations are also available.
For the two approaches featuring the SAPRC99f mechanism, all that is available are diurnal curves for N0x, CO and ozone.

My review proceeds by first considering how modeling results have usually been interpreted by the U.S. EPA to determine whether attainment of the national ambient air quality standard (NAAQS) for ozone will be achieved by a required date. Based on this, I emphasize several performance measures for ozone, which, in my opinion, appear closely related to the predictions likely to receive greatest attention in the attainment demonstration. I then combine these performance measures in such a way to develop a numerical rating for each of the 5 modeling approaches. This procedure produces an initial choice. Next, I compare the initially chosen model's ability to replicate observed precursor concentrations against that for alternative approaches. Markedly worse performance would be cause for reexamining the initial choice.

2.1 Model Performance Predicting Ozone

I used six criteria to evaluate performance and weighted each as shown.

1. Normalized bias (all sites in each zone) $\leq \pm 15\%$. (BIAS) (1 point)

2. Gross error (all sites in each zone) $\leq 30\%$. (ERROR) (1 point)

3. Most sites, including the site with the highest observed peak have predicted and observed peaks within $\pm$ 20%. (SITE PEAK) (1 point)

4. Within a zone, the predicted global peak is at least as high as the observed global peak, but not more than 20% higher than the observed global peak. (GLOBAL PEAK) (2 points)

5. Within a zone, the time of the predicted global peak is within 2 hours of the observed global peak and the same is true for most site-specific peaks. (TIMING) (1 point)

6. Within a zone, predicted exceedances of 124 ppb coincide with observed exceedances (EXCEEDANCES)
   (a) at all sites with an observed or predicted exceedance (2 points)
   or
   (b) at most sites with an observed or predicted exceedance. (1 point)

For any given zone, a model could have a score as high as 8 points on each of the modeled days, or 24 points for the 3-day episode. In a zone where there are no observed or predicted exceedances at any site, the maximum daily score is 6 points, or 18 points for the episode.

Criteria 1 and 2 are similar to ones suggested by the U.S. EPA (U.S.EPA, 1991, 1996). They address, all predicted/observed pairs, not just cases where predictions and/or observations are high. This provides some assurance that the model is working well under variety of conditions. The second criterion puts a limit on the size of residual error between predictions and observations, while the first criterion ensures that there is a balance between over- and underpredictions.

Criterion 3 emphasizes performance in predicting peak hourly ozone concentration at each site with observations. Peak predicted ozone usually receives great emphasis in attainment demonstrations.

The fourth criterion also emphasizes ability to predict peak hourly ozone concentrations accurately. Predicted global maximum is often the key factor in an attainment demonstration. For attainment to be shown, it needs to be $\leq$ 124 ppb or to be explained and discounted through a weight of evidence determination. Because there are many more surface grid cells than monitoring sites, the criterion requires predicted global maxima to be at least as high as observed global maxima. Since the South Coast Air Basin has a dense array of monitors, an upper bound has been added for the predicted global maximum ozone concentration to suggest adequate performance. Because the predicted global maximum is such an important factor in an attainment demonstration, satisfactory performance according to this criterion is awarded 2 points.

Criterion 5 addresses the timing of predicted vs. observed peak ozone concentrations. Poor timing could be due either to inadequate meteorological characterization or to some flaw in the modeled chemistry. If a chemical problem exists, large delays in predicted peaks could overstate the benefits of VOC control. In contrast, if predicted peaks occur well before the observed ones, benefits of N0x control might be overstated. If the poor timing is attributable to meteorological problems, incorrect combinations of sources could be mixing at inappropriate times, leading to a potential error in the predicted effectiveness of controls.

Criterion 6 addresses how well each of the models performs in predicting concentrations that approach the level of the NAAQS. This is likely to be a critical issue in the "post-control" state, with relatively small differences resulting in potentially large differences in the cost of control efforts. Thus, consistently accurate performance in meeting this criterion is given 2 points. If the model gets this measure right most of the time, 1 point is awarded. Note that a very small difference (e.g., 125 ppb predicted vs. 124 ppb observed) precludes a model from getting the full 2 points.

Tables 2.1 – 2.5 show performance results for each of the five modeling approaches. I summarize the results from Tables 2.1 – 2.5 in two ways. The first considers results from all 9 zones. However, in several of the zones monitoring sites are spread out over large areas. Further, these zones may experience lower ozone concentrations and are probably not as critical for determining whether the South Coast Air Quality Management District will attain the NAAQS. Thus, model performance is also summarized for zones 2-5. The summary is shown in Table 2-6. Numbers in the body of the table depict the average daily score per zone for each group of zones.

Table 2.6. Summary of Model Performance Predicting Ozone

Model	Zones 1 – 9	Zones 2 – 5
UAM/CB4	2.36	2.73
CALGRID/CB4	2.40	3.45
CAMx/CB4	2.44	3.09
CALGRID/SAPRC99f	3.24	4.45
CAMx/SAPRC99f	2.76	3.82

It is apparent from Table 2.6 that there is little to choose among the modeling approaches when the CB4 mechanism is used and all 9 zones are considered. Focusing only on zones 2-5 with CB4, CALGRID begins to emerge as having the best performance. Substituting SAPRC99f for CB4, substantially improves the performance of CALGRID. Performance of CAMx is also considerably improved. Although a version of UAM exists which permits substituting a different chemical mechanism, this version was not used by AQMD. Thus, it is not possible to note the effects using SAPRC99f has on the UAM's predictions. Table 2.6 indicates that CALGRID/SAPRC99f is the best performing model for predicting observed ozone on the three days tested.

Table 2.1. Performance of UAM/CB4 Predicting Observed Ozone

Zone	August 4, 1997	August 5, 1997	August 6, 1997
1	Sample too small	Bias-1 pt. Error-1 pt. Site peak-1 pt.	Bias-1 pt. Error-1 pt. Site peak-1 pt.
2	Error-1 pt. Site peak-1 pt. Global peak-2 pts.	Error-1 pt. Global peak-2 pts.	Bias-1 pt. Site peak-1 pt. Exceedances-1 pt.
3	Bias-1 pt. Error-1 pt. Timing-1 pt.	0 pts.	Bias-1 pt. Site peak-1 pt.
4	Bias-1 pt. Error-1 pt. Site peak-1 pt. Timing-1 pt.	Bias-1 pt. Error-1 pt. Timing-1 pt.	Bias-1 pt. Global peak-2 pts. Exceedances-1 pt.
5	Bias-1 pt. Error-1 pt. Timing-1 pt.	Site peak-1 pt.	Sample too small
6	Site peak-1 pt. Timing-1 pt.	Bias-1 pt. Error-1 pt.	Bias-1 pt. Timing-1 pt.
7	Error-1 pt. Global peak-2 pts.	Site peak-1 pt.	0 pts.
8	Error-1 pt. Timing-1 pt.	Error-1 pt. Global peak-2 pts.	Bias-1 pt. Error-1 pt. Timing-1 pt. Exceedances-2 pts.
9	Bias-1 pt.	Bias-1 pt. Site peak-1 pt.	0 pts.

Total = 59 points.

Table 2.2. Performance of CALGRID/CB4 Predicting Ozone

Zone	August 4, 1997	August 5, 1997	August 6, 1997
1	Sample too small	Error-1 pt. Timing-1 pt.	0 pts.
2	Error-1 pt. Site peak-1 pt. Global peak-2 pts. Timing-1 pt.	Timing-1 pt.	Bias-1 pt.
3	Bias-1 pt. Error-1 pt. Site peak-1 pt. Global peak-2 pts. Timing-1 pt.	Bias-1 pt. Error-1 pt. Timing-1 pt.	Bias-1 pt. Error-1 pt. Site peak-1 pt. Timing-1 pt.
4	Bias-1 pt. Error-1 pt. Site peak-1 pt Global peak-2 pts. Timing-1 pt.	Bias-1 pt. Error-1 pt. Timing-1 pt.	Bias-1 pt. Timing-1 pt.
5	Bias-1 pt. Error-1 pt. Timing-1 pt. Global peak-2 pts.	Site peak-1 pt. Timing-1 pt. Global peak-2 pts.	Sample too small
6	Bias-1 pt. Timing-1 pt.	Timing-1 pt. Site peak-1 pt.	Site peak-1 pt. Global peak-2 pts.
7	Error-1 pt. Timing-1 pt.	Timing-1 pt.	Timing-1 pt.
8	Bias-1 pt. Timing-1 pt.	Global peak-2 pts.	Timing-1 pt. Exceedances-1 pt.
9	0 pts.	0 pts.	Site peak-1 pt.

Total = 60 pts.

Table 2.3. Performance of CAMx/CB4 Predicting Ozone

Zone	August 4, 1997	August 5, 1997	August 6, 1997
1	Sample too small	Timing-1 pt.	0 pts.
2	Error-1 pt. Site peak-1 pt. Global peak-2 pts. Timing-1 pt.	0 pts.	Bias-1 pt. Site peak-1 pt.
3	Bias-1 pt. Error-1 pt. Timing-1 pt.	Bias-1 pt. Error-1 pt. Timing-1 pt.	Bias-1 pt. Error-1 pt. Site peak-1 pt. Exceedances-2 pts.
4	Timing-1 pt.	Bias-1 pt. Error-1 pt. Timing-1 pt. Exceedances-1 pt.	Bias-1 pt. Error-1 pt. Site peak-1 pt. Timing-1 pt.
5	Bias-1 pt. Timing-1 pt.	Bias-1 pt. Error-1 pt. Timing-1 pt. Global peak-2 pts.	Sample too small
6	Global peak-2 pts.	Error-1 pt. Global peak-2 pts.	Error-1 pt. Site peak-1 pt. Timing-1 pt.
7	Timing-1 pt.	Timing-1 pt.	Timing- 1 pt.
8	Bias-1 pt. Error-1 pt. Timing-1 pt.	Global peak-2 pts.	Bias-1 pt. Error-1 pt. Global peak-1 pt. Timing-1 pt.
9	0 pts.	Global peak-2 pts.	Global peak-2 pts. Timing-1 pt.

Total = 61 pts.

Table 2.4. Performance of CALGRID/SAPRAC99f Predicting Ozone

Zone	**August 4, 1997**	**August 5, 1997**	**August 6, 1997**
1	**Sample too small**	**Bias-1 pt.** **Error-1 pt.** **Timing-1 pt.**	**Bias-1 pt.** **Error-1 pt.** **Site peak-1 pt.** **Timing-1 pt.**
2	**Bias-1 pt.** **Error-1 pt.** **Site peak-1 pt.** **Global peak-2 pts.**	**Bias-1 pt.** **Error-1 pt.** **Site peak-1 pt.** **Global peak-2 pts.** **Timing-1 pt.**	**Timing-1 pt.** **Exceedances-1 pt.**
3	**Bias-1 pt.** **Error-1 pt.** **Site peak-1 pt.** **Global peak- 2 pts.** **Timing-1 pt.**	**Bias-1 pt.** **Site peak-1 pt.** **Global peak-2 pts.** **Exceedances-1 pt.**	**Bias-1 pt.** **Error-1 pt.** **Site peak-1 pt.** **Timing-1 pt.** **Exceedances-1 pt.**
4	**Bias-1 pt.** **Error-1 pt.** **Site peak-1 pt.** **Global peak-2 pts.** **Timing-1 pt.** **Exceedances-1 pt.**	**Site peak-1 pt.** **Exceedances-1 pt.**	**Bias-1 pt.** **Site peak-1 pt.** **Timing-1 pt.** **Exceedances-1 pt.**
5	**Bias-1 pt.** **Error-1 pt.** **Site peak-1 pt.** **Timing-1 pt.**	**Bias-1 pt.** **Error-1 pt.** **Site peak-1 pt.**	**Sample too small**
6	**Bias-1 pt.** **Site peak-1 pt.** **Timing-1 pt.**	**Bias-1 pt.**	**Bias-1 pt.** **Site peak-1 pt.**
7	**Bias-1 pt.** **Error-1 pt.** **Site peak-1 pt.**	**Error-1 pt.** **Site peak-1 pt.** **Timing-1 pt.**	**Error-1 pt.** **Timing-1 pt.**
8	**Bias-1 pt.** **Error-1 pt.** **Timing-1 pt.**	**Bias-1 pt.**	**Bias-1 pt.** **Error-1 pt.** **Timing-1 pt.**
9	**Bias-1 pt.**	**Bias-1 pt.** **Error-2 pts.**	**Bias-1 pt.**

Total = 81 pts.

Table 2.5. Performance of CAMx/SAPRC99f Predicting Ozone

Zone	August 4, 1997	August 5, 1997	August 6, 1997
1	Sample too small	Timing-1 pt.	Error-1 pt.
2	Bias-1 pt. Error-1 pt. Site peak-1 pt. Timing-1 pt.	Error-1 pt. Timing-1-pt.	Bias-1 pt. Error-1 pt. Site peak-1 pt. Exceedances-1 pt.
3	Bias-1 pt. Error-1 pt. Site peak-1 pt. Global peak-2 pts. Timing-1 pt.	0 pts.	Bias-1 pt. Error-1 pt. Site peak-1 pt. Timing-1 pt. Exceedances-1 pt.
4	Bias-1 pt. Error-1 pt. Site peak-1 pt. Global peak-2 pts. Timing-1 pt. Exceedances-1 pt.	Bias-1 pt. Error-1 pt. Exceedances-1 pt.	Bias-1 pt. Error-1 pt. Site peak-1 pt.
5	Error-1 pt. Global peak-2 pts. Timing-1 pt.	Error-1 pt. Global peak-2 pts. Timing-1 pt.	Sample too small
6	Site peak-1 pt. Global peak-2 pts.	Global peak-2 pts. Timing-1 pt.	Site peak-1 pt. Global peak-2 pts. Timing-1 pt.
7	Timing-1 pt.	Timing-1 pt.	Timing-1 pt.
8	Bias-1 pt. Error-1 pt. Site peak-1 pt. Timing-1 pt.	Error-1 pt.	Error-1 pt. Global peak-2 pts. Timing-1 pt.
9	0 pts.	Global peak-2 pts.	Site peak-1 pt.

Total = 69 pts.

2.2 Model Performance Predicting Precursors and Other Considerations

Agreement between predicted and observed primary precursors (NO and CO) is poor for all three models which use the CB4 mechanism. Only N0x prediction/observation comparisons are provided for CALGRID/SAPRC99f and CAMx/SAPRC99f. However, observed data, as well as data with the 3 models using CB4, indicate NO peaks occur in the early morning, usually about 6 – 9 am local time. NO2 peaks, when they occur, usually happen about 11 am – noon local time. Thus, it is possible to infer whether it is NO or NO2 which influences predicted N0x concentrations at various times of day. Generally, like the other 3 models, those which use SAPRC99f do not reproduce observed concentrations of NO very well.

Based on composite sets of predicted/observed NO comparisons presented for each of the three models using CB4, the CALGRID and CAMx models tend to underpredict highest observed NO and overpredict the lowest observed concentrations. This tendency is a little more pronounced for the CALGRID model than it is for CAMx. There is much scatter between observations and predictions within the range of observations. In my opinion, it is likely that the poor performance of the CALGRID and CAMx models predicting NO (and CO) is attributable to the incommensurability problem. That is, sources of NO and CO are not uniformly distributed, and monitored data are likely to vary more than predictions, because they are subject to small scale meteorological and emissions variations which are not reflected by the uniform model inputs and outputs spread over 5 km grid cells of various depths.

In contrast to the CALGRID/CB4 and CAMx/CB4 models, UAM/CB4 almost uniformly overpredicts observed NO, sometimes by considerable amounts. Since NO peaks tend to be observed in the early morning (before much chemistry has happened), I believe the contrast among the three models is most likely a reflection of the first few vertical layers assumed in the three approaches. Perhaps in the early morning, the first layer is deeper in the UAM approach, allowing for more uniform mixing of NO, which is seldom reflected by the monitored data.

Performance improves for all three models when paired comparisons of predicted and observed concentrations of NO2 are considered. There is a tendency for each of the models to underestimate highest observed concentrations of NO2 (say above 5 pphm). This tendency is a little more pronounced for CALGRID/CB4 than it is with the other two models. Performance of CAMx/CB4 and UAM/CB4 in predicting NO2 appears about the same.

All we are able to consider with CAMx/SAPRC99f and CALGRID/SAPRC99f are N0x, rather than NO and NO2 data. I examine zone 5 (a source-intensive area) and zone 4 (an area where highest peak ozone concentrations are often observed). Numerical performance statistics for the ability of these two models to predict observed N0x in the two zones are not particularly meaningful, since the predictions and observations reflect a mixture of NO and NO2. Timing of predicted peaks (probably largely attributable to NO) is better for CAMx/SAPRC99f than for CALGRID/SAPRC99f. Although the time series correlation coefficients between observations and predictions are not especially good, they are systematically higher for CAMx/SAPRC99f than for CALGRID/SAPRC99f.

Because the numerical comparisons between observed and predicted N0x are misleading (due to N0x being a mixture of NO and NO2), I rely primarily on graphical data to assess performance of the models in replicating observed concentrations of NO and NO2. Thus, my assessment of performance is more subjective than it is for ozone.

I compare performance of CALGRID/SAPRC99f with that of CAMx/SAPRC99f and UAM/CB4 at 8 sites in zone 5: Anaheim, Hawthorne, Los Angeles, La Habra, Lynwood, Long Beach, Pasadena and Pico Rivera. These sites are in source intensive areas, and monitored observations may be higher (and perhaps more reliable) than elsewhere. I consider factors such as ability of predicted peaks to track observed patterns at each of these sites, as well as the extent to which levels of observed peak N0x concentrations are captured. In the case of the UAM/CB4, I have to "eyeball" a sum of NO and NO2 observations. Often, the differences between models are either small, or there are compensating features (e.g., one model predicts diurnal patterns better, while another captures an observed peak concentration more accurately).

Table 2.7. Selected Comparisons of N0x Performance

Location	CALGRID/SAPRC99f vs. UAM/CB4	CALGRID/SAPRC99f vs. CAMx/SAPRC99f
Anaheim	CALGRID	CAMx
Hawthorne	CALGRID	Even
Los Angeles	CALGRID	CAMx
La Habra	Even	CALGRID
Lynwood	UAM	Even
Long Beach	Even	CAMx
Pasadena	CALGRID	Even
Pico Rivera	Even	CAMx

One might infer from Table 2.7 that adding the SAPRC99f mechanism to CALGRID improved its performance vis a vis UAM. However, the conclusions in the table may simply reflect the finding that UAM appears to do a much worse job predicting NO and a slightly better job predicting NO2. Results of the comparison between CALGRID/SAPRC99f and CAMx/SAPRC99f are consistent with the earlier finding that CAMx/CB4 does slightly better than CALGRID/CB4 replicating observed concentrations of NO and NO2. It appears as though predicted N0x disappears more slowly with CAMx/SAPRC99f than it does with CALGRID/SAPRC99f.

2.3 Recommendations

CALGRID/SAPRC99f does the best job predicting observed ozone. On the other hand, CAMx/SAPRC99f does a somewhat better job predicting observed NO and NO2. Both models that use SAPRC99f do a better job predicting ozone than any of the three models using CB4.

I recommend that AQMD use CALGRID/SAPRC99f as its primary model to support the 2003 SIP revision. This recommendation is based on the following:

- the difference in reproducing key ozone observations is more pronounced than the differences in reproducing observed NO and NO2;

- I have more confidence in the representativeness and validity of the observed ozone data than I do in the NO and NO2 data, and the method I use to compare performance vis a vis NO, NO2 and N0x is

more subjective than that used to assess performance replicating observed ozone;

- past peer reviewers have strongly recommended using the SAPRC99f mechanism over CB4 on the basis of scientific merit, and it appears feasible for the AQMD to do so;

- staff of the California Air Resources Board has had considerably more experience using CALGRID than CAMx;

- I think it will be essential to use a diagnostic wind model (CALMET) to augment coarse scale MM5 meteorological inputs. I have concerns about the feasibility of using fine scale MM5 predictions alone, or even with FDDA in a complex area like the AQMD. It is probably easier to interface CALMET with CALGRID than it is with CAMx.

3.0 Questions Posed by the South Coast Air Quality Management District

The AQMD has asked each reviewer to address 8 questions to each of the five models that they are considering for use.

1. Is the modeling protocol adequate for the proposed attainment demonstration? Does it require revisions to satisfy EPA modeling guidance?

Most current (draft) EPA guidance (U.S. EPA, 1999) for ozone modeling identifies 15 topics that should be addressed in the protocol. Many of these, are in fact, addressed. Those which are not include (1) identifying the stakeholders involved with reviewing results and the procedure followed in revising the initial protocol as the analysis proceeds; (2) types of analyses used in weight of evidence (WOE) determinations, if WOE is used; (3) procedures used to archive, document and report results; (4) identification of specific deliverables and schedule for delivery to U.S. EPA Region IX.

The preceding omissions notwithstanding, I think the AQMD developed a good initial protocol, which provided an adequate basis to proceed with the analysis. Further, evidence is presented to show that there were

numerous briefings in which subsequent results were discussed and proposed changes to initial ideas were pursued. The main concern I have about the protocol is that it is no longer clear what was *actually done* to produce the results whose performance we reviewed. The procedures that were finally followed need to be documented. It would also be helpful to mention how these differ from what was originally proposed. For example, I was uncertain about what was finally assumed regarding vertical structure of the atmosphere in CALGRID vs. CAMx vs. UAM. This makes it difficult to come up with explanations about why predicted and observed precursor concentrations sometimes disagree.

2. Is the science embodied in the model and mechanism adequate for use in the AQMP? If not, why not?

The science in the UAM is older than that in CALGRID and, especially, CAMx. However, if UAM/CB4 had outperformed the other 4 approaches or it had not been feasible to implement any of the newer approaches, I would not have hesitated to recommend its use. After all, it has been used in many other applications. In the same vein, the CB4 mechanism is older than SAPRC99f, and I believe a consensus of prominent scientists has stated that SAPRC99f is the most current chemical mechanism available. CB4 has advantages in that it is less resource intensive to use and is consistent with many existing emissions databases. I would not have hesitated to recommend it if practical considerations had precluded use of SAPRC99f in concert with a grid model. All of the models being considered have to make a series of assumptions. It is the *combination* of these assumptions which produces predicted air quality values. Although some features of a particular model may reflect a more current scientific understanding, it does not necessarily follow that all of its assumptions are correct. Indeed, it is possible for performance to deteriorate if a less appropriate *combination* of assumptions results.

3. Are the meteorological models, pre- and post processors adequate for using this model/mechanism in the AQMP?

At the January 10 meeting, we were assured by CARB and AQMD technical staffs that it was feasible to use any of the 5 models within the timeframe required for preparing the 2003 SIP revision. Although I am not sure what post-processors the question is alluding to, I assume that

since any of the 5 approaches can be used to produce results within the required time frame, they are adequate. One reservation I have is with the time and resources to run MM5 on a fine (<~8-10 km) scale with many vertical layers, as well as how realistic such predictions are likely to be in a complex terrain area like the south coast. This is one of the factors I considered in making the recommendation I did in Section 2.3.

4. Was the model applied (e.g., initial and boundary conditions, modeling domain, number layers, etc.) in a manner that would make it adequate for use in the AQMP?

I think the initial protocol and subsequent technical presentations gave evidence that these issues were addressed thoughtfully. The initial assumptions, as described in the protocol, seem plausible to me. I am reasonably confident that these issues were considered in a technically competent manner and that changes which were made were warranted technically. As I noted in response to question 1 however, it is not clear *how* the models were finally applied, given the various changes that became adviseable in the evolving analyses.

5. Is the sub-regional zone definition used to group model performance adequate to characterize model performance for ozone and precursors?

Dividing the domain into zones is a very good idea and is, incidentally, consistent with a recommendation in the most current U.S. EPA ozone modeling guidance (U.S. EPA, 1999). It has not been done too often, because most locations do not have a sufficient number of monitors to permit robust comparisons. With its large network, complex topography and geographic distribution of precursor emissions and observed high ozone, the AQMD is well advised to divide the area into zones. The zones are appropriate in that they appear to be based on past ozone observations, distribution of emissions, topography and distinctive air basins which heretofore have been considered separately.

6. Are the graphical ozone model performance presentations consistent with the statistical evaluation?

I don't believe I could have done a meaningful evaluation without the statistical *and* the graphical presentations. The graphical presentations are helpful for trying to understand what is happening to cause the

numbers generated by the numerical procedures. I used both to evaluate model performance predicting ozone. I relied primarily on graphical data assess model performance predicting observed precursor concentrations. The several procedures utilized appear to lead to consistent conclusions.

7. Does the model/mechanism meet U.S. EPA and ARB model performance acceptance criteria?

With respect to ozone, all of the models meet these criteria (gross error, normalized bias, peak ratios) in most of the zones most of the time. I found however, that these criteria were among the easiest to meet of those that I used to assess performance. Based on a more complete analysis, I believe the CALGRID/SAPRC99f model performs the best in predicting ozone. There are no criteria for assessing performance predicting NO or NO2. Based primarily on a review of graphical material, CAMx/SAPRC99f appears to perform a little better than CALGRID/SAPRC99f predicting these precursors.

8. Considering all of the factors above, is this model/mechanism significantly better than the others?

As a result of my performance review, past scientific critiques and practical considerations, I believe the CALGRID/SAPRC99f model should be the preferred approach to support the 2003 SIP revision.

Three additional general questions have been asked by the AQMD.

9. Using the existing tools and information, is there anything that could be done to provide greater confidence in the modeling used in the AQMP?

Yes. I believe a data base exists or can be created relatively easily which would enable the AQMD to compare the *response* of predicted and observed ozone to changes in emissions and/or changes in emissions + meteorology. Such an analysis should be done. Ideally, performance of model response could be evaluated by reconstructing 1987 emissions using updated estimation procedures. Observations and predictions could then be noted for the 1987 episodes. Next, 1997 emissions and episodes could be run. Changes in predictions vs. changes in observations could then be compared. These changes would be

attributable to differences both in emissions and meteorology. Another, more subjective, approach might be used to assess the accuracy of a model's response to primarily to changes in emissions. If 1997 episodes "similar" to the 1987 episodes could be selected, it would be possible to assess accuracy of a model's response that is due, primarily, to changes in emissions. Evaluations of this sort would help circumvent the concern expressed by some about "getting the right answers for the wrong reasons". The reason some feel this concern is valid, is that when model performance is evaluated solely on the ability to replicate one or more past episodes, one is not asking the question which is of paramount concern: how accurately does a model predict *changes* in air quality? If one asks this key question directly in the performance evaluation, getting the right answer provides greater confidence than asking a related, but less relevant question for SIP purposes. I would like to see this test applied for both the CALGRID/SAPRC99f and CAMx/SAPRC99f models.

10. Many of the model runs exhibit underestimation of observed peaks to some degree. Is there sufficient understanding of the reason(s) for the underestimation to warrant making an adjustment?

I do not believe there is, at least for this SIP revision. The process analysis technique, which I believe can be utilized with the CAMx model, might provide some useful subsequent insights about appropriate changes. I also think it would be useful to apply the CALGRID/SAPRC99f, CAMx/SAPRC99f and UAM/CB4 approaches and then use the relative reduction approach with the appropriate ozone design values for several of the zones. This would likely provide some insight into the potential significance of using absolute predictions of ozone in an attainment demonstration with a model that systematically underpredicts observed peak hourly concentrations of ozone.

11. Is model performance acceptance biased by the underestimation of the peak concentrations?

Ability to predict peak observed ozone concentrations is a very important consideration. Ratio of peak predicted to peak observed concentrations is one of three U.S. EPA ozone performance measures for which a criterion exists. Predicted future peak concentrations are generally compared to the level specified in the ozone NAAQS to judge whether a SIP is

adequate. As I noted in Section 2.0, I try to consider how model results are typically used in a demonstration in order to judge how to evaluate performance of the 5 models under consideration. Thus, several measures related to the ability to predict the magnitude of peaks are included in my assessment. There are other measures, such as timing, ability to predict exceedances, normalized bias and gross error that are also considered.

One should remember that no matter how scientifically current certain components of a model are, what is also critical is how these components interact to produce an air quality prediction. Regardless of how sophisticated a model is, assumptions have to be made about how to consider emissions, parameterize meteorological and chemical phenomena, etc., etc. The best combination of assumptions is not intuitively obvious. This is why the ability to produce an answer that appears to coincide with observations is a very important consideration in choosing a model for use in a SIP.

In short, I believe it is appropriate to give heavy consideration to a model's ability to predict a measure that is a key one in accepting an attainment demonstration. I would not characterize this as "bias".

4.0 Conclusions About PM10 and PM2.5

4.1 UAM-LT Predictions and Observations of PM10

Annual and quarterly mean predictions and observations are provided for the following components of PM: ammonium (NH4), nitrate (NO3), sulfate (SO4), organic carbon (OC), elemental carbon (EC) and "Other". Comparisons are an aggregate of days when 24-hour mean observations are taken, typically once in 6 or once in 3 days. AQMD has defined acceptable model performance for each component as agreement between prediction/observation spatially averaged pairs to within $\pm$ 30%. The basis for this criterion is unclear, but I have nothing better to offer.

Looking at comparisons between spatially averaged observations and predictions for annual means of each component, the performance criterion is satisfied for NH4, NO3 and OC components, or about 86% of the reported mass (i.e., the sum of the 6 components). Measurements are made at 5 sites. Acceptable performance for spatially averaged annual concentrations, as well as agreement within $\pm$ 30% at individual sites, is as follows:

Anaheim---NH4, NO3, OC, EC
Diamond Bar---NH4, NO3, OC
Fontana---NH4, NO3, SO4, Other
LA---NH4, NO3, OC
Rubidoux---NH4, NO3, SO4, OC, EC, Other
Spatial Average---NH4, NO3, OC

However, due to seasonal variations in emissions and meteorology, it is good practice to evaluate performance (as well as perform strategy simulations) separately for each quarter of the year. Upon doing this, one finds generally poor performance for UAM-LT during the first quarter. The model typically overpredicts observations during this quarter. Indeed, agreement within $\pm$ 30% is limited to the following during quarter 1:

Anaheim---EC
Diamond Bar---SO4, OC, EC
Fontana---NH4, NO3, OC, Other
LA---SO4, EC
Rubidoux---none.
Spatial Average---EC (~7% of the observed spatially averaged mass of PM10 is predicted "correctly")

Of the 4 quarters, observed mean PM10 concentrations are generally lowest during the first quarter.

Performance improves for the second quarter. Agreement within $\pm$ 30% is noted below.

Anaheim---NH4, NO3, OC, EC, Other
Diamond Bar---OC, EC, Other
Fontana---NH4, NO3, OC, Other
LA---NH4, NO3, OC, EC, Other
Rubidoux---OC, EC, Other
Spatial Average---NH4, NO3, OC, EC, Other (~90% of the observed spatially averaged mass of PM10 is predicted "correctly")

Observed quarterly means for the second quarter are generally not as high as those observed in the third and fourth quarters.

Agreement within $\pm$ 30% during the third quarter is as follows:

Anaheim: NH4, NO3, OC, EC
Diamond Bar---NH4, NO3
Fontana---SO4, Other
LA---NH4, NO3, OC
Rubidoux---NH4, NO3, Other
Spatial Average---NH4, NO3, Other (~64% of the observed spatially averaged mass of PM10 is predicted "correctly")

Observations during the fourth quarter are generally 50-60% higher than those seen during the next highest (i.e., the third) quarter. Agreement within $\pm$ 30% during the 4^{th} quarter occurs as follows:

Anaheim---NH4, NO3, OC
Diamond Bar---NO3, OC
Fontana---SO4, Other
LA---NO3, OC
Rubidoux---SO4, OC, Other
Spatial Average---NO3, OC (~49% of the observed spatially averaged mass of PM10 is predicted "correctly")

Looking at projections to 2006 and 2010, it appears the annual NAAQS will not be met at only 3 of 57 sites. Further, the projected violations are within about 10% of the concentration level specified in the NAAQS. As noted below, it is projected to be much more difficult to meet the annual NAAQS for PM2.5. Thus, once a SIP is developed for PM2.5, attainment of the PM10 NAAQS should "follow along" from efforts to meet the PM2.5 NAAQS. Further, if efforts to meet the PM10 NAAQS focus on reducing the "Other" (primary?) component, they will have little impact on reducing PM2.5.

4.2 UAM-LT Predictions and Observations of Annual/Quarterly PM2.5

Although AQMD is not yet required to submit a SIP revision addressing PM2.5, a modeling analysis has been performed in anticipation of a future requirement to do so. The same performance criteria are applied to the same components noted in the discussion of PM10. The extent to which mean quarterly or annual predictions agree with corresponding observations within $\pm$ 30 % is noted below.

Annual Concentrations

Anaheim---NH4, NO3, OC
Diamond Bar---NH4, NO3
Fontana---NH4, NO3
LA---NH4, NO3, OC
Rubidoux---SO4, OC, EC
Spatial Average---NH4, NO3, OC (~73% of the observed PM2.5 is predicted "correctly")

Note that for the spatial average, it is 73% of the *measured* mass has associated acceptable model performance.

Quarter 1

Anaheim---SO4, EC
Diamond Bar---NH4, NO3, SO4, EC
Fontana---NH4, NO3, EC
LA---NH4, SO4, OC
Rubidoux---None
Spatial Average---EC (~11% of the observed PM2.5 is predicted "correctly")

Quarter 2

Anaheim---NH4, OC, EC
Diamond Bar---NH4, OC
Fontana---NH4, NO3
LA---NH4, OC
Rubidoux---OC, EC
Spatial Average---NH4, NO3, OC, EC (~72% of the observed PM2.5 is predicted "correctly")

Quarter 3

Anaheim---NH4
Diamond Bar---NH4
Fontana---NH4
LA---NH4
Rubidoux---NH4, NO3
Spatial Average---NH4 (~14% of the observed PM2.5 is predicted "correctly")

Quarter 4

Anaheim---NO3, OC
Diamond Bar---NO3, OC
Fontana---SO4, OC
LA---OC
Rubidoux---SO4, OC
Spatial Average---OC (~18% of the observed PM2.5 is predicted "correctly")

The seasonal pattern for observed PM2.5 is similar to that for PM10, only more pronounced. Quarterly average values during the 4th quarter are about double that of the next highest quarter. This is mostly attributable to large increases in nitrate and ammonium.

One major difference between model performance for PM2.5 and PM10 is the very poor performance predicting the "Other" component for PM2.5. The model drastically overpredicts this component (by factors ranging from "3" to "61"). Although the "Other" component is the least important component according to the observations, it is the second (to nitrates) most important component according to the model's predictions. Thus, the potential exists for misleading results when simulating strategies. Generally poor performance in predicting PM2.5 as well as the relative importance of components of PM2.5 argues for using a "relative reduction factor" (RRF) type of approach for PM2.5 strategy simulations. Note also that the comparisons emphasize the need to consider each quarter separately. Looking simply at the annual averages implies better performance than is actually the case.

As with PM10, it appears that sulfates and all, or nearly all, of the nitrates are likely to be ammonium salts.

Simulations projected to 2006 and 2010 suggest that meeting the annual NAAQS for PM2.5 will be a challenge in the AQMD. 36 of 57 sites have projections exceeding the annual NAAQS. Assuming PM2.5 is the sum of the 6 components which are reported, levels exceed that of the annual NAAQS by anywhere from 0.1 to 12.1 micrograms/cubic meter.

4.3 Some Concerns with the Analysis

Details of the modeling analysis for particulate matter (and for that matter about the model which was used) are sketchy. Thus, it is not possible to comment at length about what was done. However, based on the material reviewed, I have at least two concerns.

First, it appears that an assumption has been made that the spatially averaged composition observed at 5 monitoring sites is representative of the entire modeling domain. Predicted differences in each of the components were then most likely weighted according to their importance to derive future concentrations of PM10 and PM2.5 at 50-60 monitoring sites. If this was what was done, a great deal more effort is needed to explain the procedure and to justify the use of just 5 locations to draw inferences about the entire domain.

The second concern is related to the first. It has to do with using spatially averaged predicted and observed concentrations to evaluate model performance. Due to the incommensurability problem, I think use of spatial averages may be a legitimate way to assess a grid model's performance predicting concentrations of primary pollutants. However, it seems to me that the evaluation should be preceded by some effort to document why it is appropriate to group information from certain sites, be it proximity, presence of nearby, similar sources, or whatever.

Since the PM10 problem in the AQMD appears to be a relatively minor one, a great deal more in the way of a modeling effort may not be warranted. However, PM2.5 looks to be a major future problem. Draft U.S. EPA guidance for modeling PM2.5 (U.S. EPA, 2001) closely parallels the Agency's draft guidance for applying models to address the 8-hour NAAQS for ozone. Both sets of guidance require developing a modeling protocol and addressing many of the same problems which the AQMD faced in applying models to address the 1-hour NAAQS for ozone. The guidance recommends using models in a relative sense to develop relative reduction factors that are applied to observed air quality.

5.0 Recommendations for Additional Work

1. AQMD should document what modeling assumptions, modeling preprocessors and/or components were *actually used* to produce the estimates that underlie the strategy reflected in the 2003 SIP revision. It is clear that the approach originally outlined in the modeling protocol has been changed in response to subsequent findings and discussions.

2. As another peer reviewer has suggested, AQMD needs to put a great deal of effort into producing a relatively brief (e.g., 15-20 page) narrative summarizing what analyses were done and how they lead to the conclusion that the SIP revision will meet its intended goals. This narrative should be aimed at managers and the lay public. More detailed descriptions (e.g., for CARB and U.S. EPA technical staffs) should be in appendices.

3. I strongly recommend that model performance in predicting secondary pollutants like ozone, NO2 and particulate mass associated with nitrates, sulfates and ammonium ion focus on how accurately the model is able to replicate the observed *response* to changes in emissions, meteorology and both. In the near future, this can likely only be done for ozone and its precursors. I recommend that AQMD revise 1987 emissions (using the current, state of the art methodologies), rerun the 1987 episodes with the revised emissions and compare changes in predicted ozone and NO2 between the 1987 and 1997 episodes with the observed changes between the 1987 and 1997 episodes. Adding this approach to the others for model performance evaluation, addresses a key concern about model performance: how well does the model replicate the *response* of secondary pollutants to changes in precursor emissions and/or changes in meteorology. Contrasting changes in predictions vs. observations for weekends and weekdays is another potential way to evaluate a model's response. However, I am less sure whether the differences in emissions on weekends vs. weekdays are sufficient to send a signal strong enough to be discerned over "noise" attributable to uncertainties in weekend vs. weekday inventories.

4. AQMD should retain and archive all files that are needed to perform simulations in the future that contrast predicted vs. observed changes in ozone over time. These files should also be made available to the research community to test whether incremental changes (reflecting more current scientific findings) improve the performance of grid models.

5. Some additional suggestions about model performance evaluation for predicting ozone and its precursors follow.

> (a) Site by site comparisons in which predictions within a surface grid cell are matched with observations occurring within the cell at the same time may present a test that is needlessly restrictive. For example, the EPA Guidance for the 1-hr ozone NAAQS (pp.10-11) (U.S. EPA, 1996) suggests looking at a 3x3 array of 5-km cells centered on the monitor and using the highest prediction within this array in what that guidance defines as "the statistical attainment test".
>
> U.S. EPA monitoring regulations suggest that ozone monitors should represent an "urban scale". This is a rather wide range, but the modeling guidance has selected a value (15 km) near the lower end of the range. The recommendation to consider an array of cells was also made in recognition that, in many cases, it may be nearly impossible to get the exact time and location correctly and that, in any event, small discrepancies may not be important. Likewise, it may often be legitimate to compare the highest nearby prediction within $\pm$ 1-2 hours to each site's peak observation when evaluating model performance, to see whether a seemingly poor result is simply a reflection of a bunch of "near misses".
>
> (b) The time series correlations for predicted vs. observed ozone presented by AQMD are almost uniformly bad. However, this may reflect the relatively narrow range of observations available at most sites on the days selected for modeling. Excluding all hours with ozone observations <.06 ppm from the analysis exacerbates this problem. Often, the range of observations is only .06 – about .13 ppm. If these low correlations are a concern, AQMD should repeat the analysis including all observations and predictions to increase the range.
>
> (c) Comparisons may yield worse than expected results due to the apparently different rounding conventions used for the monitoring data (to the nearest whole pphm for everything but CO) and modeled data, reported to the nearest 0.1 pphm (for everything but CO). Differing conventions for reported monitoring and modeled data may be even more of a problem for CO, as it appears measured values of this pollutant are rounded to the nearest 0.5 ppm. Much of the diurnal data presented for CO show little hour-to-hour variability, in part perhaps, due to this convention. If it

is possible to access more precise observed data from the archives, AQMD should see whether using identical levels of precision in the predicted and observed data improves performance.

(d) I urge AQMD to make greater use of special air quality measurements that may have been taken during the SCOS97 field program to help evaluate model performance. More specifically, observed and predicted "indicator ratios" of pollutants should be looked at when the measurements permit. Accurate prediction of observed indicator ratios may suggest that a model's ozone predictions will respond correctly to changes in precursor emissions. Identity and use of indicator ratios are described in Sillman (1995), Sillman (1998) and Blanchard, *et al.* (2000), as well as elsewhere.

6. Not surprisingly, agreement between predicted and observed primary pollutants (NO and CO) is poor. In my opinion, this likely reflects an incompatibility between assuming a uniform concentration of these pollutants within a 5-km grid cell and effects of smaller scale phenomena on the monitored observations. It may be preferable to average modeled and monitored data of these pollutants over several sites when making comparisons. Perhaps this might help random, small-scale fluctuations in the observations to balance. Another potentially useful approach may be to compare observed and predicted *ratios* of primary pollutants.

If spatial averaging is used, there should be an accompanying rationale for combining the data from several locations. This was lacking in the UAM-LT performance evaluation comparing observed and predicted components of PM10 and PM2.5.

7. I believe its underlying science is sufficient and it performed sufficiently well for the recommended primary model for ozone (CALGRID/SAPRC99f) to be used to support the 2003 SIP revision for ozone.

Nevertheless, performance of CALGRID/SAPRC99f is not outstanding. Further, my assessment is based on only 3 modeled days. It is also troubling that CAMx/SAPRC99f and UAM/CB4 appear to better replicate observed concentrations of NO2. Therefore, I believe AQMD should make plans to perform a "mid-course review" in accordance with U.S. EPA guidance (U.S. EPA, 2002), as well as perform a weight of evidence (WOE) analysis. More specifically, AQMD should archive modeling files used to create predictions for the 1997 episodes. Project emssions to a future "mid-course" date (e.g., 2006) and to the attainment date (e.g., 2010) and apply the model to obtain corresponding estimates. When 2006 comes, derive ambient trend information and normalize this for meteorological differences. Compare the apparent relative progress toward the NAAQS from the normalized trend data against the relative progress projected for 2006 by the model. By "relative progress", I mean the percentage of the way between 1997 predicted (or observed) air quality and the air quality goal (e.g., 124 ppb) that is predicted (or observed) in 2006. If the relative change in the air quality observations is less than that predicted, a SIP adjustment or reexamination of the model may be needed.

The weight of evidence analysis could include looking at changes predicted between 1997, 2006 and 2010 with the most current model in 2006 that exhibits adequate performance. Whether a new SIP revision is deemed necessary may depend on whether the normalized trend in observed ozone leads to a relative changes in high ozone which is less than that predicted with the updated model.

8. Because it appears likely that the PM10 NAAQS will be close to being attained and subsequent efforts to meet the NAAQS for PM2.5 will likely lead to improvement in PM10 as well, I do not believe that a major additional effort to model PM10 is necessary. AQMD should instead focus its efforts on performing modeling to support a SIP to meet the NAAQS for PM2.5. As outlined in draft U.S. EPA modeling guidance related to the PM2.5 NAAQS (U.S. EPA, 2001), this will require a major effort, comparable to the ones needed to support the 1-hour and 8-hour NAAQS for ozone.

6.0 Summary

In this review, I first examine the ability of 5 modeling approaches to replicate observed ozone concentrations during a 3-day episode in 1997. In Section 2.1, I use six measures to evaluate the models'

performance in each of 9 geographical zones identified by the AQMD. Choice of measures is influenced by my familiarity with how modeling results are used by regulatory agencies to determine whether a SIP is likely to lead to attainment of the NAAQS for ozone. Using these measures, CALGRID/SAPRC99f performs substantially better than the other models. CAMx/SAPRC99f performs second best. UAM/CB4, CALGRID/CB4 and CAMx/CB4 perform comparably.

In Section 2.2, I review performance of CALGRID/SAPRC99f, CAMx/SAPRC99f and UAM/CB4 in predicting observed concentrations of NO, CO and NO2. Evaluation of this performance is based on graphical presentations and is more subjective than the evaluation for ozone. For understandable reasons, no model does very well predicting NO or CO. CAMx/SAPRC99f and UAM/CB4 do better than CALGRID/SAPRC99f in replicating observed concentrations of NO2. The latter model's predictions of NO2 are lower than those of the former two on some days at some sites.

Despite the outcome of the NO2 comparisons, in Section 2.3 I recommend that AQMD use CALGRID/SAPRC99f as the primary modeling approach to support the 2003 SIP revisions for ozone. This recommendation reflects greater confidence in the observed ozone data, larger differences among the models than was true for NO2, as well as some practical considerations.

In Section 3.0, I address a series of questions posed by the AQMD. In general, these questions concern (a) whether the five ozone models considered for use by the AQMD are sufficiently well grounded scientifically; (b) whether the methodologies used by the AQMD in applying the models are adequate, and (c) whether the procedures followed are consistent with regulatory guidance issued by the CARB and the U.S. EPA. My sense is that all of the models are adequate provided those applying them prepare a detailed protocol which is discussed in the local scientific community, model performance is assessed and found adequate and diagnostic tests are applied to see how sensitive conclusions might be to assumptions which need to be made in the modeling.
In general, the assumptions that were made by the AQMD and CARB in applying the models seem plausible. Finally, I did not detect major inconsistencies with U.S. EPA guidance nor problems relative to the guidance that cannot be easily addressed.

In Section 4.0, I summarize some of the findings regarding application of the UAM-LT model to estimate annual and quarterly mean concentrations of PM10, PM2.5 and 6 components of these mixtures. In general, model performance is pretty good for PM10. Typically, components which comprise well over 50% of the measured mass of PM10 are predicted accurately according to the criterion of $\pm$ 30% agreement established by the AQMD. The exception occurs in the winter, when performance is poor, but observed concentrations are low. Usually, the relative amounts that each component comprises of predicted spatially averaged PM10 agree reasonably well with spatially averaged observations.

Performance predicting PM2.5 is not good. Usually, less than 50% of the measured mass is accurately predicted. As with PM10, performance is worst during the winter months. More significantly, performance is not good during the 3rd and 4th quarters, when observations are the highest. More significantly still, the model substantially overestimates the relative importance of primary particulate matter. This latter shortcoming could lead to selection of ineffective control strategies, unless models are applied in a relative sense using relative reduction factors.

The documentation for the PM10 modeling is poor and should be improved. However, I do not believe substantial additional resources need to be spent on PM10 modeling. I recommend modeling of particulate matter focus on PM2.5 and that results should be used in a relative sense using relative reduction factors.

Section 5.0 contains a series of recommendations concerning documentation, performance evaluation, data archiving, mid-course reviews and use of weight of evidence in subsequent analyses. Key recommendations follow.

-A major effort should be made to summarize for managers and the lay public the modeling used to justify the strategy reflected in the SIP revision.

-More emphasis should be placed on efforts to evaluate how well the model responds to *changes* in emissions and meteorological conditions.

-Although the available models provide an adequate basis for selecting SIP control strategies, there are uncertainties associated with the predictions. There should be ongoing efforts to perform a mid-course review which includes comparing the response of the chosen modeling approach to changes in emissions and meteorology to that obtained with the most current, viable model (e.g., in 2006) and with observed air quality trends normalized for meteorological fluctuations.

-Care should be taken to archive modeling files to facilitate future mid-course reviews, performance evaluations and model improvements.

7.0 Cited References

Blanchard, C.L., P.M. Roth, S.J. Tanenbaum, S.D. Ziman and J.H. Seinfeld, (2000), "The Use of Ambient Measurements to Identify Which Precursor Species Limit Aerosol Nitrate Formation", Accepted for publication in *J.Air & Waste Management Association*.

Sillman, S., (1995), "The Use of N0y, H2O2 and HNO3 as Indicators for O3-N0x-ROG Sensitivity in Urban Locations", *J.Geophys. Res. 100,* pp.14175-14188.

Sillman, S., (1998), *Evaluating the Relation Between Ozone, N0x and Hydrocarbons: The Method of Photochemical Indicators*, EPA/600R-98/022.

U.S. EPA, (1991), *Guideline for Regulatory Application of the Urban Airshed Model*, EPA-450/4-91-013.

U.S. EPA, (1996), *Guidance on Use of Modeled Results to Demonstrate Attainment of the Ozone NAAQS*, EPA-454/B-95-007.

U.S. EPA, (1999), *Draft Guidance on the Use of Models and Other Analyses in Attainment Demonstrations for the 8-Hour Ozone NAAQS*, EPA-454/R-99-004.

U.S. EPA, (2001), *Guidance for Demonstrating Attainment of Air Quality Goals for PM2.5 and Regional Haze (draft 2.1)*, January 2, 2001, available on www.epa.gov/ttn/scram.

U.S. EPA, (2002), *Recommended Approach for Performing Mid-course Review of SIP's to Meet the 1-hour NAAQS for Ozone*, January 2001, available on www.epa.gov/ttn/scram.

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TO: Barry Wallerstein
Joe Cassmassi

FROM: John Seinfeld

DATE: January 21, 2003

SUBJECT: Initial Critique of AQMP Models and Results

Five models have been used to simulate the August 4-6, 1997 episode, for which the peak 1-hour ozone level is 187 ppb, which occurred on August 5 at Riverside. The ΔVOC is that needed to reduce the 1-hour peak ozone from 187 to 120 ppb, a ΔO_3 of 67 ppb. If a model exactly predicts the 187 ppb peak concentration for August 5, 1997, then one needs only to vary VOC emissions until the peak is reduced to 120 ppb. The level of VOC emissions August 4-6, 1997 for the meteorological conditions of required to lower the peak to 120 ppb then becomes the so-called "VOC carrying capacity" of the Basin. The actual ΔVOC that would be required in 2010 is the different between the estimated base VOC emissions in 2010 (about 600 tons/day) and the calculated VOC carrying capacity.

If a model does not reproduce the peak 187 ppb on August 5, the ΔO_3 required to reach 120 ppb is different from 67 ppb. Those models that do not predict 187 ppb all happen to underpredict the peak value. A typical peak prediction might be 160 ppb. Then the ΔO_3 required from that predicted peak is only 40 ppb, rather than the actual 67 ppb. Consequently, the VOC carrying capacity that results from that model will reflect an ozone reduction of only 40 ppb and cannot be expected to accurately reflect the ΔVOC needed if starting from a 187 ppb peak O_3. So, if a model is used that underpredicts the peak O_3 concentration on the design day, one issue that must be dealt with is how to correct the VOC carrying capacity to reflect the effect of that underprediction.

The elements of a model simulation include:

- emissions
- meteorology (velocity and temperature field, mixing depth)
- chemistry
- boundary conditions
- dry deposition
- vertical and horizontal diffusion
- numerical analysis of advection, diffusion, and chemical reaction
- grid system

Each of these elements is complicated in its own right. Ideally, when comparing performance of several models, one would like to have identical emissions meteorological fields, and boundary conditions, so that differences in prediction reflect

differences in chemical mechanisms, dry deposition treatments, diffusion treatments, and numerical methods used to solve the governing equations. Even so, interactions among these submodels are nonlinear so that behavior of one submodel can compensate for inaccuracies in another submodel to produce a simulation that matches actual data. The difficulty with this situation is that when emissions are reduced these factors that compensate each other in the base case may not do so in the reduced emission case.

In principal, one should employ the model that most accurately reflects the underlying physics and chemistry. Of the five models, UAM, and especially CB4, is known to be the most out of date. UAM also has a notoriously inaccurate advection solver (Smolarkewicz) that strongly smears out concentration distributions. Yet, the UAM CB4 simulation of the August 4-6, 1997 episode produces the closest match to the observed peak O_3 of the five models. Enhanced photochemical production of O_3 is, most likely, compensating for the artificial spreading induced by the Smolarkewicz advection algorithm. SAPRC-99 is the preferred chemical mechanism, and indeed would be considered as state-of-the-science. Both CALGRID and CAMx represent improvements over UAM in scientific treatments; however, both of these models underpredict peak O_3 on August 5, 1997 with both SAPRC 99 and CB4. If CB4 is "hot" chemically, as suggested above, one might expect O_3 predictions to be higher with both CALGRID and CAMx using CB4; this is not the case.

I have not been associated with this AQMP modeling process long enough to be able to diagnose why UAM is matching the design day peak O_3 and why the other models are underpredicting. The AQMD staff should continue to attempt to determine the underlying explanations for the behavior of the models through diagnostic simulations, and I will assist with designing these as much as possible. In summary, however, it is not apparent why each of the models is performing as they are. As discussed at the meeting at the AQMD, based on overprediction of NO_x levels in the western portion of the Basin, it appears that there may be some problem with CAMx.

While the AQMD staff should continue to identify the reasons for underprediction of the peak O_3 by each of the four models, the AQMD must decide on a strategy for determining the VOC carrying capacity of the Basin in 2010 based on the meteorology of the August 4-6, 1997 episode in the event that it is not possible to improve the simulations before the AQMP must be submitted. The following potential strategies exist:

1. Because it is close to the actual observed peak O_3, use the UAM CB4 simulation as the basis for determining the VOC carrying capacity.
2. Use either the CALGRID or CAMx simulations as the basis for determining the VOC carrying capacity with no adjustment for underpredicted peak O_3.
3. Artificially increase the CALGRID or CAMx predicted peak O_3, perhaps by enhancing photolysis rates, to match the measured O_3 and use that simulation as the base case.
4. Determine the percentage underprediction of peak O_3 in the base case simulation and reduce the target concentration of 120 ppb by the same percentage.
5. Starting from the simulated peak O_3, determine the VOC reduction required for a reduction of $\Delta O_3 = 67$ ppb.

None of these is ideal. In the absence of more information, I would recommend option #4. By reducing the target concentration (120 ppb) by the percentage by which the peak O_3 is underpredicted, one obtains a more realistic ΔO_3 from which to determine the VOC carrying capacity. Hopefully, it will be possible to continue to evaluate the model simulations over the next couple of months.

MEMORANDUM

DATE: January 13, 2003

TO: Joe Cassmassi

FROM: Mel Zeldin

SUBJECT: Ozone Modeling Evaluation and Suggestions

This memo is in response to your request for written input regarding the ozone modeling evaluation as an outcome of the meeting held last Friday. As I stated in the meeting, it is my belief that the UAM model has been the historical workhorse for ozone attainment modeling purposes for the last decade, and in order for another model to be used, either of two conditions would need to occur: (1) the UAM model would have to be shown to be deficient in the validation process; or (2) either the CALGRID or CAMx models would have to be shown to be definitively superior to the UAM.

In my opinion, neither of these conditions is evident in the validation statistics. While there are advantages and disadvantages shown for each model, there is clearly nothing to show that any one model is superior to the others. Therefore, I would suggest that the UAM continue to be the model used for the ozone attainment process. I believe that other members of the Review Panel shared that opinion. I further believe that changing to another model, without clear superiority of that model, could be considered “gaming” or “model shopping” to a desired result.

In my advisory capacity to the Staff, however, I do have some suggestions:

1) The AQMP (Plan) should be based on the UAM results at this time.

2) It should be noted in the Plan, however, that the science experts believe that, in theory, at least, the CALGRID and CAMx models utilize newer techniques that should be better than the older UAM. It should be further noted that the ARB believes the CALGRID model to be the preferred model.

3) It should further be noted that due to the number of model runs involved, and the short time frame in which to produce the attainment demonstration to avoid conformity lapse, one episode is deemed to be insufficient to determine if either CALGRID or CAMx are superior to the UAM.

4) The District should commit to perform additional model evaluations of other episodes to determine if indeed CALGRID or CAMx show superior performance to the UAM, and these evaluations would be completed within a two-year time frame.

5) Since the UAM has the lowest VOC carrying capacity, and it is presumed that the additional tonnages to be reduced would be placed in the "black box," the District would commit not only to the larger "black box," but also to proceed with studies, in parallel during the same two-year period, to explore and evaluate advanced technologies for additional VOC reductions. Any rulemaking activity to gain the extra VOC tonnages would be deferred until 2005 – when the model evaluation would be completed.

6) As part of the current Plan and SIP submittal, the District should state that, at the end of the two-year period, the results of the model evaluations will be presented. If the results do not show any superiority from either CALGRID or CAMx, then the District would proceed to move forward with identifying measures in the "black box" to get to the UAM VOC carrying capacity. If, on the other hand, the additional model evaluations show that either the CALGRID or CAMx models are superior to the UAM, then the extra tonnages assigned to the "black box" would be removed. This would likely involve a SIP amendment.

7) In taking this course of action, the District should state that there is too much uncertainty in the model evaluations at this time, and is therefore erring on the side of public health interests until a more complete evaluation is completed. In stating this, the District should make clear at this time, that any changes to the carrying capacity, at the end of the two-year period, are reflecting better science in evaluating future year attainment, and removing "black box" tonnages are not to be considered "backsliding," since attainment would be demonstrated with a (presumably) higher VOC carrying capacity. If either CALGRID or CAMx were shown to be the superior model, the only thing "lost" by the District would be the parallel effort for identifying new VOC control technologies, and I don't think such an effort could ever be deemed "wasted" in the sense that such methods may ultimately be needed for 8-hr attainment in the future.

8) In making additional model evaluations, I would suggest using the other episodes mentioned in the model protocol: September 26-29, 1997 and July 13-18, 1998. While only the August 1997 episode is used for attainment demonstration purposes, I see no reason why the other episodes can't be used for model evaluation purposes only. Since some effort has been made to identify these episodes already, presumably these events will be easiest to develop the model inputs. Also, I would recommend that the August 1997 episode be "backcasted" to 1987 for an additional evaluation when emissions were considerably different than the 1997 period. An evaluation of an episode in 1987, which is meteorologically similar to the 1997 episode, could be used for approximated validation data, or, as you suggested, a mean value for that meteorological classification could be used. This will at least demonstrate if any of the new models "blow up" with a 1987 inventory, or are able to reasonably simulate those conditions.

9) I like the idea suggested by another panel member for some kind of scoring system for evaluating model performance, other than just the performance statistics. This could be something that evaluates: the pattern representativeness (i.e, the modeled ozone spatial pattern replicates the observed pattern); the peak ozone representativeness; the temporal representativeness (i.e., the timing of the peaks at sites across the Basin match the observed time of the peaks); and similar evaluations for other pollutants, such as NO and NOx. It would be advisable to establish a scoring system prior to undertaking the additional model evaluations.

I hope these comments are helpful. Please call me if you have any questions or would like to discuss further.

ATTACHMENT 3

Mid-Course Modeling Reviews

ATTACHMENT 4

CEPA Source Level Emissions Reduction Summary for 2006: Annual Average Inventory

Year 2006 Emission Reductions Excluding Natural Sources by Control Measure

in the South Coast Air Basin (Annual Average Inventory - Tons/Day)

(A) Reductions Without Overlapping/Double-Counting With Other Control Measures (1)

		(Reductions - Tons/Day)					
Measure	Name	VOC	NOx	CO	SOx	PM10	PM2.5
BA-2202	Baseline adjustment for R2202	2.67	2.79	29.47	0.02	0.08	0.05
BA-POWER	Power Plants Adjustments	0.00	0.29	0.00	0.00	0.00	0.00
BA-FVR	ARB-Petroleum Marketing - Bas. Adj.	-1.20	0.00	0.00	0.00	0.00	0.00
BA-GSE	ARB-Airport Ground Support Equip - Bas. Adj.	0.03	0.78	0.00	0.00	0.00	0.00
BA-SMOG	ARB-Smog Check II - Bas. Adj.	2.50	3.98	0.00	0.00	0.00	0.00
CTS-07	FER Architectural Ctg (R1113 Phase 3) (VOC)	3.27	0.00	0.00	0.00	0.00	0.00
CTS-10	Misc. Industrial Coating&Solvent Opr. (VOC)	0.86	0.00	0.00	0.00	0.00	0.00
FUG-05	ER from fugitive Emission Sources (VOC)	1.68	0.00	0.00	0.00	0.00	0.00
CMB-09	Petroleum FCCU (PM10,PM2.5,NH3)	0.00	0.00	0.00	0.00	0.10	0.08
BCM-7	FER from Fugitive Dust Sources (PM10)	0.00	0.00	0.00	0.00	0.00	0.00
BCM-08	Aggregate Operation (PM10)	0.00	0.00	0.00	0.00	0.62	0.33
PRC-03	COE fr Restaurant Operations (PM10)	0.00	0.00	0.00	0.00	0.33	0.33
PRC-07	Industrial Process Operations (VOC)	0.81	0.00	0.00	0.00	0.00	0.00
WST-01	Ems Reduction fr Livestock Waste (VOC,NH3)	4.81	0.00	0.00	0.00	0.00	0.00
WST-02	COE fr Composting (PR1133) (VOC,NH3,PM10)	0.40	0.00	0.00	0.00	0.00	0.00
CMB-07	Refinery Flares (VOC,NOX,SOX,CO,PM)	0.17	0.17	0.99	2.16	0.03	0.03
MSC-05	Truckstop Electrification (ALL)	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total (Net)		16.00	8.01	30.47	2.18	1.16	0.81

EMISSION SUMMARY FOR
(POINT, AREA, MOBILE SOURCE, AND OFF-ROAD MV)

Baseline Emissions	VOC	NOx	CO	SOx	PM10	PM2.5
Point source	67.62	14.50	45.27	6.11	12.97	11.58
Area source	224.53	46.24	165.36	0.95	239.62	69.90
RECLAIM	0.00	34.20	0.00	12.03	0.00	0.00
Total Stationary	292.15	94.94	210.63	19.09	252.59	81.48
On-road	257.65	555.89	2513.55	4.84	19.27	13.09
Off-road	134.06	264.82	1109.53	34.62	20.21	17.69
Aircraft	5.33	27.01	50.16	0.95	0.62	0.62
TOTAL	689.20	942.66	3883.87	59.50	292.69	112.88
EMISSION REDUCTIONS						
Point source	2.15	0.45	0.99	2.16	0.41	0.27
Area source	8.64	0.00	0.00	0.00	0.67	0.49
Total Stationary	10.79	0.45	0.99	2.16	1.08	0.76
On-road	5.17	6.77	29.47	0.02	0.08	0.05
Off-road	0.03	0.78	0.00	0.00	0.00	0.00
Aircraft	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	16.00	8.01	30.47	2.18	1.16	0.81
REMAINING EMISSIONS						
Point source	65.47	14.04	44.28	3.95	12.56	11.31
Area source	215.89	46.24	165.36	0.95	238.95	69.41
RECLAIM	0.00	34.20	0.00	12.03	0.00	0.00
Total Stationary	281.36	94.48	209.64	16.92	251.52	80.72
On-road	252.48	549.12	2484.08	4.82	19.19	13.04
Off-road	134.03	264.04	1109.53	34.62	20.21	17.69
Aircraft	5.33	27.01	50.16	0.95	0.62	0.62
TOTAL	673.20	934.66	3853.41	57.31	291.53	112.07
NSR/Set-Aside	0.00	0.00	0.00	0.00	0.00	0.00
GRAND TOTAL (T/D)(2)	673.20	934.66	3853.41	57.31	291.53	112.07
SCAG's RTP/TCMs (3)	8.49	6.98	88.80	0.08	0.64	0.47

(1) Emission reductions for individual measures were estimated based on the sequence of listing contained here. When the sequence changes, reductions from each measure could be affected, but the net total remain the same. The purpose of this table is to estimate total emission reductions without overlapping or double-counting between measures.
(2) Total remaining emissions are slightly different from figures in 2003 AQMP main document due to rounding.
(3) Reflects SCAG's 2001 Regional Transportation Plan (including transportation control measures).

ATTACHMENT 5

CEPA Source Level Emissions Reduction Summary for 2010: Annual Average Inventory

Year 2010 Emission Reductions Excluding Natural Sources by Control Measure

in the South Coast Air Basin (Annual Average Inventory - Tons/Day)

(A) Reductions Without Overlapping/Double-Counting With Other Control Measures (1)

		(Reductions - Tons/Day)					
Measure	Name	VOC	NOx	CO	SOx	PM10	PM2.5
BA-2202	Baseline adjustment for R2202	1.81	1.88	20.34	0.02	0.09	0.05
BA-POWER	Power Plants Adjustments	0.00	0.33	0.00	0.00	0.00	0.00
BA-FVR	ARB-Petroleum Marketing - Bas. Adj.	-1.20	0.00	0.00	0.00	0.00	0.00
BA-GSE	ARB-Airport Ground Support Equip - Bas. Adj.	0.16	0.81	0.00	0.00	0.00	0.00
BA-SMOG	ARB-Smog Check II - Bas. Adj.	1.85	3.66	0.00	0.00	0.00	0.00
CTS-07	FER Architectural Ctg (R1113 Phase 3) (VOC)	7.22	0.00	0.00	0.00	0.00	0.00
CTS-10	Misc. Industrial Coating&Solvent Opr. (VOC)	2.79	0.00	0.00	0.00	0.00	0.00
FUG-05	ER from fugitive Emission Sources (VOC)	1.99	0.00	0.00	0.00	0.00	0.00
CMB-09	Petroleum FCCU (PM10,PM2.5,NH3)	0.00	0.00	0.00	0.00	0.30	0.24
BCM-7	FER from Fugitive Dust Sources (PM10)	0.00	0.00	0.00	0.00	0.00	0.00
BCM-08	Aggregate Operation (PM10)	0.00	0.00	0.00	0.00	0.67	0.36
PRC-03	COE fr Restaurant Operations (PM10)	0.00	0.00	0.00	0.00	0.99	0.98
PRC-07	Industrial Process Operations (VOC)	1.74	0.00	0.00	0.00	0.00	0.00
WST-01	Ems Reduction fr Livestock Waste (VOC,NH3)	4.81	0.00	0.00	0.00	0.00	0.00
WST-02	COE fr Composting (PR1133) (VOC,NH3,PM10)	1.20	0.00	0.00	0.00	0.00	0.00
CMB-07	Refinery Flares (VOC,NOX,SOX,CO,PM)	0.16	0.17	0.99	2.16	0.03	0.03
CMB-10	Further RECLAIM Reductions	0.00	2.85	0.00	0.00	0.00	0.00
MSC-05	Truckstop Electrification (ALL)	0.09	1.69	0.55	0.00	0.02	0.02
CONS-1	ARB-Consumer Products Limits for 2006 (2)	2.27	0.00	0.00	0.00	0.00	0.00
CONS-2	ARB-Consumer Products Limits to 2010 (2)	14.69	0.00	0.00	0.00	0.00	0.00
FVR-1	ARB-Vapor from Aboveground Storage Tanks (2)	0.08	0.00	0.00	0.00	0.00	0.00
FVR-2	ARB-Vapor from Gasoline Dispensing at (2)	0.08	0.00	0.00	0.00	0.00	0.00
FVR-3	ARB-Gasoline Dispenser Hoses (2)	0.60	0.00	0.00	0.00	0.00	0.00
LMD-1	ARB-Passenger Cars + Light Duty Trucks (2)	19.21	19.17	160.39	0.00	0.00	0.00
LMD-2	ARB-Smog Check Improvements (2)	5.80	9.02	58.73	0.00	0.00	0.00
ONHD-1	ARB-Truck and Bus Highway Inspections (2)	0.08	0.00	0.00	0.00	0.08	0.07
ONHD-2	ARB-Vapor from Gasoline Cargo Tanks (2)	4.94	0.00	0.00	0.00	0.00	0.00
ONHD-3	ARB-Clean-up Existing Truck/Bus Fleet (2)	4.52	11.61	19.97	0.00	1.51	1.39
OFCI-1	ARB-Clean-up Existing IC Engines (Diesel) (2)	7.89	0.00	0.00	0.00	2.05	1.89
OFCI-2	ARB-Off Road Equipment Inspection Program (2)	0.00	0.10	0.00	0.00	0.00	0.00
OFLSI-1	ARB-Off-Road New Standards (Gasoline + Nat. (2)	0.00	0.76	8.01	0.00	0.00	0.00
OFLSI-2	ARB-Clean-up Existing Off-Road (2)	1.29	3.33	0.00	0.00	0.00	0.00
OFLSI-3	ARB-Electrified New Forklifts (Gasoline + Nat. (2)	0.54	2.67	24.07	0.00	0.05	0.04
SMOF-1	ARB-Handheld Lawn & Garden Equipment (2)	1.81	0.13	0.00	0.00	0.00	0.00
SMOF-2	ARB-Non-Handheld Lawn & Garden Equipment (2)	7.28	1.71	0.00	0.00	0.00	0.00
MARINE-1	ARB-Clean-up Existing Harbor Craft (2)	0.10	2.70	0.00	0.00	0.05	0.05
EPA-01	EPA-Clean-up Existing Truck/Bus Fleet (3)	1.11	2.75	4.62	0.00	0.33	0.30
EPA-02	EPA-Harbor Craft and Ocean-Going Ship Stds. (3)	0.39	2.92	0.00	0.00	0.30	0.28
EPA-03	EPA-Clean-up Existing Ocean-Going Ships (3)	1.47	16.62	0.00	0.00	1.21	1.12
EPA-04	EPA-Reductions from Jet Aircraft (3)	0.56	1.80	0.00	0.00	0.00	0.00
LT1-DIST	Mid-Term District Measures (VOC)	10.23	0.00	0.00	0.00	0.00	0.00
LT1	Long Term Measure 1	42.45	147.43	0.00	0.00	0.00	0.00
LT2	Long Term Measure 2	174.89	0.00	0.00	0.00	0.00	0.00
Grand Total (Net)		324.88	234.08	297.67	2.18	7.68	6.81

EMISSION SUMMARY FOR
(POINT, AREA, MOBILE SOURCE, AND OFF-ROAD MV)

Baseline Emissions	VOC	NOx	CO	SOx	PM10	PM2.5
Point source	71.32	12.68	48.41	6.22	13.79	12.29
Area source	224.17	42.09	168.47	0.99	247.22	71.85
RECLAIM	0.00	34.20	0.00	12.03	0.00	0.00
Total Stationary	295.50	88.97	216.87	19.24	261.01	84.14
On-road	196.68	425.76	1882.82	1.99	19.07	12.65
Off-road	117.48	225.14	1041.66	37.79	18.96	16.56
Aircraft	5.01	31.08	51.77	1.05	0.51	0.51
TOTAL	614.67	770.95	3193.11	60.07	299.55	113.86
EMISSION REDUCTIONS						
Point source	18.70	0.49	0.99	2.16	0.64	0.45
Area source	110.41	0.00	0.00	0.00	1.36	1.16
RECLAIM	0.00	2.85	0.00	0.00	0.00	0.00
Total Stationary	129.11	3.34	0.99	2.16	1.99	1.61
On-road	130.55	157.46	264.05	0.02	2.01	1.82
Off-road	64.65	65.13	32.63	0.00	3.68	3.39
Aircraft	0.56	8.15	0.00	0.00	0.00	0.00
TOTAL	324.88	234.08	297.67	2.18	7.68	6.81
REMAINING EMISSIONS						
Point source	52.62	12.18	47.42	4.06	13.15	11.85
Area source	113.77	42.09	168.47	0.99	245.86	70.68
RECLAIM	0.00	31.35	0.00	12.03	0.00	0.00
Total Stationary	166.39	85.62	215.88	17.08	259.02	82.53
On-road	66.13	268.30	1618.76	1.97	17.06	10.83
Off-road	52.83	160.01	1009.03	37.79	15.28	13.17
Aircraft	4.45	22.93	51.77	1.05	0.51	0.51
TOTAL	289.79	536.87	2895.44	57.89	291.87	107.04
NSR/Set-Aside	5.00	3.00	0.50	1.00	0.85	0.85
GRAND TOTAL (T/D) (4)	294.79	539.87	2895.94	58.89	292.72	107.89
SCAG's RTP/TCMs (5)	15.65	8.73	165.24	0.17	1.69	1.24

(1) Emission reductions for individual measures were estimated based on the sequence of listing contained here. When the sequence changes, reductions from each measure could be affected, but the net total remain the same. The purpose of this table is to estimate total emission reductions without overlapping or double-counting between measures.
(2) The higher end of emission reduction range is included for these CARB's short-term control measure. However CARB is only committing to the mid point of the reduction range for these measures with the balance to be achieved under the long-term strategy.
(3) Emission reductions for these control measures affecting federal sources are considered under long-term strategy. These measures which were originally contained in CARB's draft State and Federal Element (Jan 2003) are re-numbered to avoid confusion with CARB's revised control measure numbers.
(4) Total remaining emissions are slightly different from figures in 2003 AQMP main document due to rounding.
(5) Reflects SCAG's 2001 Regional Transportation Plan (including transportation control measures).

ATTACHMENT 6

CEPA Source Level Emissions Reduction Summary for 2006: Planning Inventory

Year 2010 Emission Reductions Excluding Natural Sources by Control Measure in the South Coast Air Basin (Planning Inventory - Tons/Day)

(A) Reductions Without Overlapping/Double-Counting With Other Control Measures (1)

Measure	Name	(Reductions - Tons/Day) VOC	NOx	CO	NO2
BA-2202	Baseline adjustment for R2202	1.71	1.74	20.00	2.05
BA-POWER	Power Plants Adjustments	0.00	0.33	0.00	0.33
BA-FVR	ARB-Petroleum Marketing - Bas. Adj.	-1.20	0.00	0.00	0.00
BA-GSE	ARB-Airport Ground Support Equip - Bas. Adj.	0.16	0.81	0.00	0.82
BA-SMOG	ARB-Smog Check II - Bas. Adj.	1.84	3.38	0.00	3.99
CTS-07	FER Architectural Ctg (R1113 Phase 3) (VOC)	8.52	0.00	0.00	0.00
CTS-10	Misc. Industrial Coating&Solvent Opr. (VOC)	3.00	0.00	0.00	0.00
FUG-05	ER from fugitive Emission Sources (VOC)	2.01	0.00	0.00	0.00
CMB-09	Petroleum FCCU (PM10,PM2.5,NH3)	0.00	0.00	0.00	0.00
BCM-7	FER from Fugitive Dust Sources (PM10)	0.00	0.00	0.00	0.00
BCM-08	Aggregate Operation (PM10)	0.00	0.00	0.00	0.00
PRC-03	COE fr Restaurant Operations (PM10)	0.00	0.00	0.00	0.00
PRC-07	Industrial Process Operations (VOC)	1.95	0.00	0.00	0.00
WST-01	Ems Reduction fr Livestock Waste (VOC,NH3)	4.81	0.00	0.00	0.00
WST-02	COE fr Composting (PR1133) (VOC,NH3,PM10)	1.20	0.00	0.00	0.00
CMB-07	Refinery Flares (VOC,NOX,SOX,CO,PM)	0.16	0.17	0.99	0.17
CMB-10	Further RECLAIM Reductions	0.00	3.00	0.00	3.00
MSC-05	Truckstop Electrification (ALL)	0.11	2.07	0.43	1.31
CONS-1	ARB-Consumer Products Limits for 2006 (2)	2.27	0.00	0.00	0.00
CONS-2	ARB-Consumer Products Limits to 2010 (2)	14.69	0.00	0.00	0.00
FVR-1	ARB-Vapor from Aboveground Storage Tanks (2)	0.08	0.00	0.00	0.00
FVR-2	ARB-Vapor from Gasoline Dispensing at Marinas (2)	0.08	0.00	0.00	0.00
FVR-3	ARB-Gasoline Dispenser Hoses (2)	0.60	0.00	0.00	0.00
LMD-1	ARB-Passenger Cars + Light Duty Trucks (2)	19.10	17.71	157.71	20.91
LMD-2	ARB-Smog Check Improvements (2)	5.73	8.35	57.80	9.81
ONHD-1	ARB-Truck and Bus Highway Inspections (2)	0.08	0.00	0.00	0.00
ONHD-2	ARB-Vapor from Gasoline Cargo Tanks (2)	4.94	0.00	0.00	0.00
ONHD-3	ARB-Clean-up Existing Truck/Bus Fleet (2)	4.52	11.32	19.97	12.32
OFCI-1	ARB-Clean-up Existing IC Engines (Diesel) (2)	7.92	0.00	0.00	0.00
OFCI-2	ARB-Off Road Equipment Inspection Program (2)	0.00	0.10	0.00	0.10
OFLSI-1	ARB-Off-Road New Standards (Gasoline + Nat.(2)	0.00	0.80	7.36	0.72
OFLSI-2	ARB-Clean-up Existing Off-Road (2)	1.40	3.51	0.00	3.16
OFLSI-3	ARB-Electrified New Forklifts (Gasoline + Nat.(2)	0.59	2.82	21.97	2.53
SMOF-1	ARB-Handheld Lawn & Garden Equipment (2)	1.92	0.15	0.00	0.12
SMOF-2	ARB-Non-Handheld Lawn & Garden Equipment (2)	7.72	1.90	0.00	1.52
MARINE-1	ARB-Clean-up Existing Harbor Craft (2)	0.10	2.70	0.00	2.70
EPA-01	EPA-Clean-up Existing Truck/Bus Fleet (3)	1.11	2.68	4.62	2.91
EPA-02	EPA-Harbor Craft and Ocean-Going Ship Stds. (3)	0.39	2.92	0.00	2.92
EPA-03	EPA-Clean-up Existing Ocean-Going Ships (3)	1.47	16.62	0.00	16.62
EPA-04	EPA-Reductions from Jet Aircraft (3)	0.57	1.84	0.00	1.76
LT1-DIST	Mid-Term District Measures (VOC)	10.99	0.00	0.00	0.00
LT1	Long Term Measure 1	44.66	144.78	0.00	153.07
LT2	Long Term Measure 2	183.44	0.00	0.00	0.00
Grand Total (Net)		338.62	229.67	290.85	242.82

EMISSION SUMMARY FOR
(POINT, AREA, MOBILE SOURCE, AND OFF-ROAD MV)

BASELINE EMISSIONS

	VOC	NOx	CO	NO2
Point source	84.31	14.86	51.93	14.86
Area source	226.06	33.10	332.05	55.00
RECLAIM	0.00	35.67	0.00	35.67
Total Stationary	310.36	83.63	383.97	105.53
On-road	193.95	406.03	1856.71	456.70
Off-road	134.25	234.40	861.54	216.06
Aircraft	5.09	31.91	50.20	30.47
TOTAL	643.65	755.97	3152.42	808.76

EMISSION REDUCTIONS

Point source	22.22	0.49	0.99	0.49
Area source	112.85	0.00	0.00	0.00
RECLAIM	0.00	3.00	0.00	3.00
Total Stationary	135.07	3.49	0.99	3.49
On-road	128.81	149.61	260.11	169.26
Off-road	74.17	68.20	29.76	62.08
Aircraft	0.57	8.37	0.00	7.99
TOTAL	338.62	229.67	290.85	242.82

REMAINING EMISSIONS

Point source	62.09	14.37	50.93	14.37
Area source	113.20	33.10	332.05	55.00
RECLAIM	0.00	32.67	0.00	32.67
Total Stationary	175.29	80.14	382.98	102.04
On-road	65.14	256.42	1596.60	287.44
Off-road	60.08	166.20	831.78	153.98
Aircraft	4.52	23.54	50.20	22.48
TOTAL	305.03	526.30	2861.57	565.94
NSR/Set-Aside	5.00	3.00	0.50	3.00
GRAND TOTAL (T/D)(4)	310.03	529.30	2862.07	568.94
SCAG's RTP/TCMs (5)	15.68	7.86	161.76	9.62

(1) Emission reductions for individual measures were estimated based on the sequence of listing contained here. When the sequence changes, reductions from each measure could be affected, but the net total remain the same. The purpose of this table is to estimate total emission reductions without overlapping or double-counting between measures.
(2) The higher end of emission reduction range is included for these CARB's short-term control measure. However CARB is only committing to the mid point of the reduction range for these measures with the balance to be achieved under the long-term strategy.
(3) Emission reductions for these control measures affecting federal sources are considered under long-term strategy. These measures which were originally contained in CARB's draft State and Federal Element (Jan 2003) are re-numbered to avoid confusion with CARB's revised control measure numbers.
(4) Total remaining emissions are slightly different from figures in 2003 AQMP main document due to rounding.
(5) Reflects SCAG's 2001 Regional Transportation Plan (including transportation control measures).