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# "Plans for Evaluations of ROM 2.2, UAM-IV, UAM-V, and SAQM with Aerometric Data from SARMAP, LMOS and the Northest"

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# PLANS FOR EVALUATION OF ROM 2.2, UAM-IV, UAM-V, AND SAQM WITH AEROMETRIC DATA FROM SARMAP, LMOS, AND THE NORTHEAST

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## OVERVIEW

The Consortium for Regional Model Evaluation (CReME) is sponsoring the evaluation of four regional and/or urban-scale photochemical models (ROM 2.2, UAM-IV, UAM-V, and SAQM) with observations from three geographic domains, (LMOS - the Lake Michigan Oxidant Study, the Northeast U.S., and SARMAP - the San Joaquin Valley). Two multi-day ozone episode periods are being analyzed in each of the three domains.

The primary objective of the study is to determine whether models can confidently be used to develop realistic VOC and $NO_x$ emissions control strategies. ROM 2.2 and UAM-IV are included because they are presently recommended by the EPA and are being actively applied to the Northeast U.S. domain. The project will include an analysis of the uncertainties in initial and boundary conditions provided by ROM 2.2 to UAM-IV. SAQM and UAM-V are included because they are advanced state-of-the-art regional models that will be used for developing emissions control strategies in the San Joaquin Valley and in the Lake Michigan domains, respectively. The SARMAP and LMOS regional aerometric data sets are being considered because they represent higher density, multivariate measurements at the surface and aloft, and the sparser Northeast aerometric data are included because of their importance in EPA and state ROM/UAM applications.

A full spectrum of model evaluation procedures is being applied, including statistical tests as well as diagnostic/sensitivity studies. The individual model simulations will be compared with available observations in each of the domains. A comparative evaluation among the models will also be carried out in order to determine the relative performance of all the models and their implications regarding emissions control strategies. In addition, several diagnostic/sensitivity studies will be conducted in order to understand the technical reasons for model performance and to suggest possible improvements to models. To assure as fair an evaluation as possible, the model comparisons are being carried out by scientists who have not been involved in the development of the models. To remove the effects of differences in input data sets, for several types of comparisons the models are being applied using consistent input files. SAQM and UAM-V will also be run in an optimum nested manner employing the best possible initial and boundary conditions. As part of the diagnostic and sensitivity studies, alternate sets of meteorological inputs (prognostic model versus diagnostic model) and initial and boundary conditions (ROM-predicted versus observed) are being tested for some models and episodes. Model sensitivities to variations in emissions and grid resolution shall also be studied.

## MODEL APPLICATIONS TO THE LAKE MICHIGAN OZONE STUDY (LMOS) DOMAIN

The Lake Michigan Ozone Study (LMOS) is an intensive research program directed towards the development of an advanced model for use in evaluating various emissions control strategies in the region[1]. Many meteorological and air quality observations were made during the field experiment phase during the summer of 1991. Two ozone episodes (24-28 June 1991 and 15-19 July 1991) were the subject of intensive field studies, which included the use of wind profilers, aircraft, and speciated hydrocarbon observations. The LMOS program has supported the development of a comprehensive modeling system, which includes an emissions modeling system (GEMAP), a nonhydrostatic mesoscale meteorological model (CALRAMS), and a photochemical air quality model (UAM-V). The modeling has made use of a nested set of three domains and grid systems depicted in Figure 1. The original plan was that the air quality initial conditions (i.c.'s) and boundary conditions (b.c.'s) on domain A in Figure 1 would be provided by the EPA's ROM, but problems with underpredictions led to the decision to use aircraft and surface observations to set the b.c.'s. Currently the LMOS sponsors are carrying out final model runs with UAM-V.

Our project has selected the two major (24-28 June and 15-19 July) LMOS ozone episodes for application of the various models. The evaluation exercise will consider the following model base runs:

UAM-V and SAQM (optimum): Nested from domains A through C, CALRAMS meteorological model input, observed chemistry b.c.'s on domain A, emissions from GEMAP.

UAM-V and SAQM (for comparison): Single domain B with 8 km grid, diagnostic meteorological model, observed chemistry b.c.'s on domain B, emission from GEMAP.

ROM: Superdomain (eastern 2/3 of U.S.), diagnostic meteorological model, 1991 interim emissions.

UAM-IV: Domain B with 8 km grid, diagnostic meteorological model, emissions from GEMAP.

a) Coupled with ROM for i.c.'s and b.c.'s.
b) Stand-alone using observed b.c.'s.

The predictions of UAM-V, SAQM, ROM, and UAM-IV for the base runs described above will be compared with each other and with observations, including ozone, $NO_y$, and VOC's, at the surface and aloft. For example, we have already completed the UAM-IV "stand-alone" base runs, and have generated contour maps and time series for comparison with the UAM-V output. This analysis will permit a preliminary assessment of whether the models are faithfully representing ozone processes, and should allow specification of possible diagnostic and sensitivity runs (four or five additional runs are planned per model for each episode) that look at the following major issues:

- Horizontal Grid Size - There is a question whether use of a 4 km grid size would yield improved predictions on domain B. Some previous sensitivity runs suggest that this may be true, at least near the Chicago-Milwaukee source regions. Possible diagnostic runs would involve use of a 4 km grid size with UAM-IV and SAQM on domain B. These runs would make use of the 4 km resolution in the emissions and CALRAMS predictions on that domain.

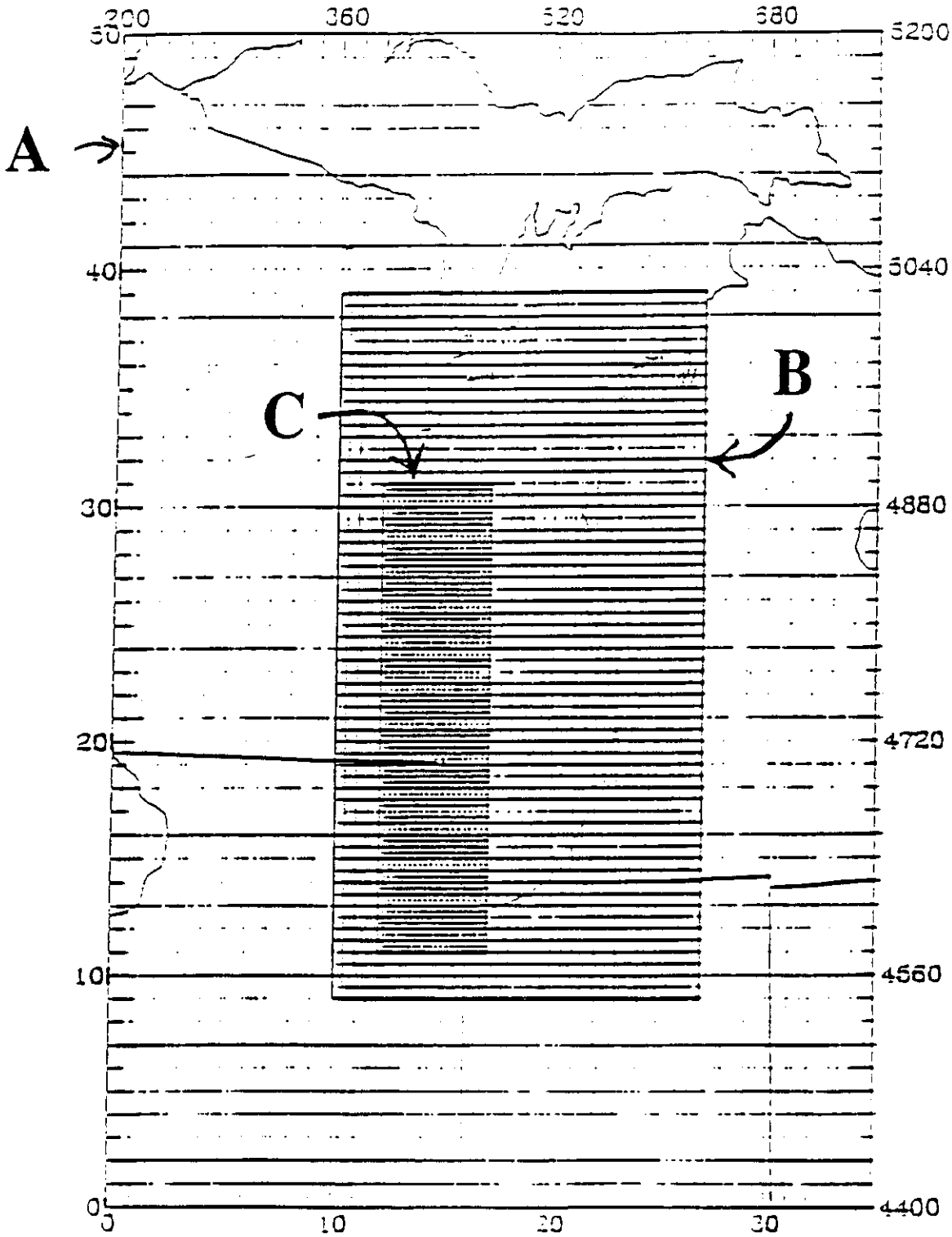


Figure 1. UAM-V nested modeling grid for the 1991 LMOS photochemical modeling efforts. Horizontal grid spacing are 16, 8, and 4 km for areas A, B, and C.

- Vertical Grid Resolution - Diagnostic/sensitivity runs can investigate whether model performance degrades in SAQM, UAM-IV, and UAM-V as vertical resolution degrades. Currently, both the SAQM and UAM-V modelers are recognizing that more vertical resolution is needed (1) during stable conditions near the ground, and (2) during periods when elevated layers of high ozone are present at heights of 200-600 m. Consequently, one set of possible sensitivity runs could involve a variation in the number of vertical grid points.

- Plume-In-Grid - UAM-V is the only one of the four models being tested that employs an explicit Plume-In-Grid algorithm to treat the diffusion and chemical reactions in individual plumes from large point sources such as power plants. There is a question whether the use of this algorithm improves the simulations. A diagnostic run could be made in which the Plume-In-Grid algorithm is turned off in UAM-V.

- Optimum Input Meteorology - There are two types of questions related to input meteorology--(1) does the prognostic model (CALRAMS) provide improved input meteorology to the air quality models, and (2) are the diagnostic meteorological models improved if additional specialized LMOS observations are incorporated? The first question can be addressed by analyzing UAM-IV, UAM-V, and SAQM results for both prognostic and diagnostic input meteorology. The second question can be addressed by making diagnostic runs in which the additional LMOS observations are included in the diagnostic meteorological model.

- Emissions Control Options - Sensitivity runs are planned where the responses of all models to a certain reduction in emissions (e.g., a 25% reduction in $NO_x$ and VOC) are investigated. The results (e.g., surface and aloft patterns in $O_3$, $NO_y$ and VOC's) will be compared across all models in order to identify areas of agreement and disagreement and to develop scientific hypotheses for model differences that could be investigated in further diagnostic/sensitivity runs.

- Boundary Conditions - There is concern over whether it is best to use observed or model-predicted boundary conditions (b.c.'s) in the LMOS domain. For example, the sponsors decided not to use ROM 2.2 boundary conditions because the predicted ozone concentrations were 30 or 40 ppb low and now use a combination of surface and aircraft observations. They plan to carry out operational runs using observed b.c.'s on domain B. Consequently, another set of candidate diagnostic runs can investigate the use of alternate b.c.'s for UAM-IV, UAM-V, and SAQM, recognizing that the aircraft observations are available on the boundaries of domain B.

## MODEL APPLICATIONS TO THE NORTHEAST DOMAIN

Several ozone episodes have been observed in the urban/industrial corridor running from Richmond to Boston. The EPA's ROM was originally developed for application to the Northeast U.S.[2], and UAM-IV has been applied to parts of the Northeast by many consultants and state and federal agencies[3,4,5]. ROM is run on an 18.5 km horizontal grid on the "superdomain" which includes the eastern 2/3 of the U.S. UAM-IV is run on a 5 km grid on a rectangular domain with dimensions of 100 to 200 km, as illustrated in Figure 2.

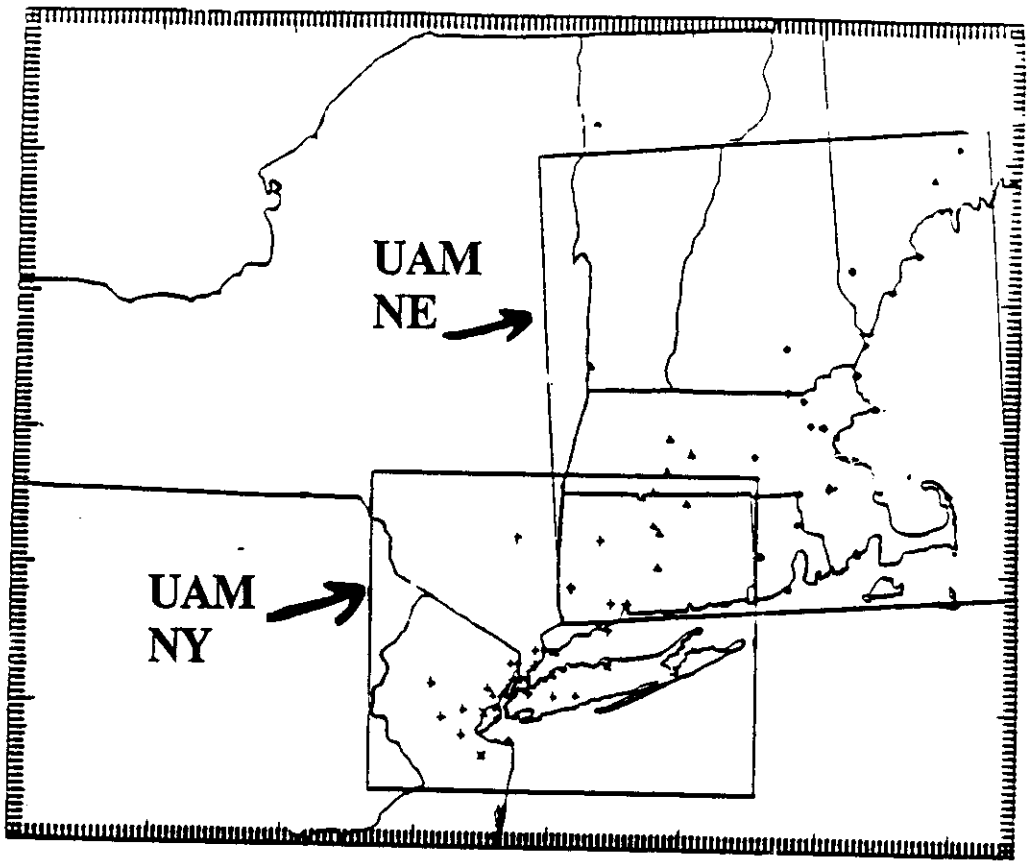


Figure 2. Map of part of Northeast domain showing the New York and New England UAM-IV domains, and a few of the $O_3$ monitoring sites.

Regional photochemical models can be used in the Northeast to answer important questions regarding emissions control strategies. For example, what is the relative influence of local emissions sources versus distance sources? What are the benefits of controlling VOC emissions versus $NO_x$ emissions? However the overriding question is "How reliable is the air quality management guidance these models provide?".

The Northeast has not yet been the subject of an intensive regional photochemical field experiment similar to the experiments recently carried out in the Lake Michigan area, in central and southern California, in the Southeast, and in the Gulf of Mexico. There was an intensive regional acid rain field experiment (EMEFS[6]) in the Northeast in 1988 and 1990, but photochemical pollutant observations were only incidental and emphasis was not on locations near the urban/industrial corridor. Consequently the model evaluation exercise is hampered by a lack of detailed observations at the surface and aloft for use in setting i.c.'s and b.c.'s and in evaluations of photochemical models.

Two ozone episodes have been proposed for analysis in the Northeast--1-15 July 1988 and 30 August - 4 September, 1988. The first episode is under extreme scrutiny by all local agencies because ozone NAAQS exceedances occurred over a broad region (1000 km in diameter) for several days. ROM, UAM-IV, and UAM-V runs have already been made or are planned for the 1-15 July episode by these agencies. The second episode is chosen because there are some detailed EMEFS data (e.g., aircraft profiles and speciated VOC observations) available, even though ozone concentrations barely exceeded the NAAQS.

The base model runs planned for the Northeast domain are summarized below:

UAM-V and SAQM: The UAM-V runs are being carried out by a separate contractor but will be available for our analysis. We will carry out all the SAQM runs ourselves. The two models will be run on three nested domains (the largest size is the ROM superdomain with a grid size of 20 km for UAM-V and 36 km for SAQM, the intermediate size is the Northeast region from about Ohio to Maine with a grid size of 10 or 12 km, and the smallest size is approximately the UAM domain shown in Figure 2, with a grid size of 4 or 5 km). A diagnostic meteorological model will be used. Observed i.c.'s and b.c.'s are to be used on the outer domain, and so-called 1988 interim emissions (prepared by the EPA) will be used. As an option, plans are underway to run the MM5 prognostic meteorological model for these episodes, since that model is able to dynamically simulate important local flows such as sea-land breezes and orographic effects.

ROM 2.2: The EPA is providing the ROM 2.2 base runs for the 1-15 July episode. We will make the ROM base runs for the second episode on the superdomain using input from the diagnostic meteorological model.

UAM-IV: The model will be run on the New York and New England domains (see Figure 2). The diagnostic meteorological model will be applied, and 1988 interim emissions will be used. The i.c.'s and b.c.'s will be obtained a) from ROM and b) from observations.

Following initial analyses and evaluations, several diagnostic and sensitivity runs will be carried out that will be related to those described previously under the LMOS section heading.

## MODEL APPLICATIONS TO THE SAN JOAQUIN VALLEY (SARMAP) DOMAIN

Central California was the subject of an intense regional photochemistry field study in the summer of 1990. The level of funding for that experiment was higher than for any other similar experiments (e.g., LMOS or the 1992 SOS intensive campaigns). The study called the San Joaquin Valley Air Quality Study/Atmospheric Utilities Signatures: Predictions and Experiments (SJV AQS/AUSPEX), has resulted in the availability of detailed high-quality three-dimensional observations of meteorology and air quality that are of great use for setting i.c.'s and b.c.'s and for evaluating regional models[7]. The subsequent data analysis and modeling phases are termed the SJVAQS/AUSPEX Regional Model Adaptation Project (SARMAP). The data have been used in the development of a comprehensive modeling system consisting of the GEMAP emissions modeling system, the MM5 meteorological model, and the SARMAP Air Quality Model (SAQM). However, ROM 2.2 and UAM-V have not been tested in the SARMAP domain, although UAM-IV is being evaluated by the California Air Resources Board on a domain similar to that of the SARMAP. The goal of our study is to evaluate these four air quality models with the SARMAP data and determine if the models are likely to lead to the correct decision regarding emissions control strategies.

Intensive field studies involving the use of aircraft and remote sounders took place during ozone episodes on 27-29 July 1990 and 3-6 August 1990. These two multi-day episodes will be the subject of our model evaluation exercise.

The modeling plans for the SARMAP domain are tentative. SAQM itself is still under revision on that domain and final results are not expected for many months. We expect to do the evaluations on the LMOS and Northeast domains first, and then use those experiences to improve the design of the SARMAP evaluations. Figure 3 presents the domains proposed for the ROM and UAM-IV runs. The following base model runs are planned:

SAQM and UAM-V: Since SAQM is being developed for the SARMAP domain, several base runs will be already available from that project. UAM-V will be run in nested mode using as close a representation as possible to the SAQM domain sizes and grid lengths. The MM5 model will be used for meteorological inputs. GEMAP will be used for emissions, and observed i.c.'s and b.c.'s will be used.

ROM 2.2: EPA's ROM 2.2 has been applied only to geographic domains east of the Rocky Mountains. It is being applied to the SARMAP domain as a research exercise in order to gain insights into why it responds as it does to the more challenging topography and air flow of central California. The ROM domain shown in Figure 3 is similar to the domain being used for SAQM; however ROM is limited to its 18.5 km grid size and to three vertical layers. Observations will be used for i.c.'s and b.c.'s, and GEMAP will be used for emissions. ROM will be run with both MM5 prognostic meteorological input (which is already available) and with its own diagnostic meteorological model.

UAM-IV: The proposed UAM-IV domain shown in Figure 3 is the Fresno domain being modeled by the state agency. As was the case in the LMOS and Northeast studies, UAM-IV will be applied in two modes: a) coupled with ROM, and b) stand-alone.

The results from the above base runs will be evaluated and used to select a set of diagnostic and sensitivity runs from various options similar to those listed under the LMOS domain section.

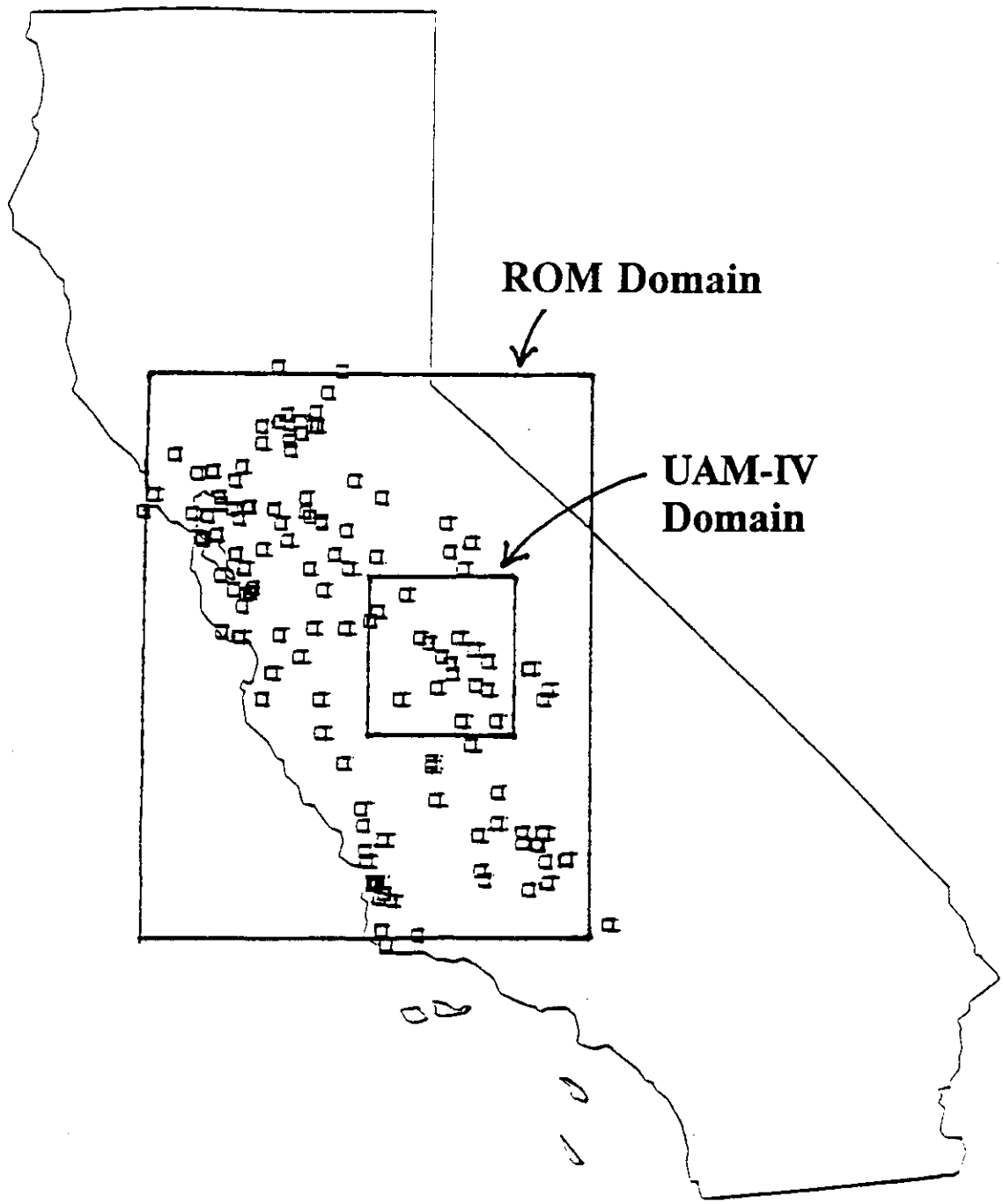


Figure 3. Locations of surface air quality stations used in the SARMAP field study. The proposed ROM domain is the large box and the proposed UAM-IV domain is the small box.

## MODEL EVALUATION PROCEDURES

The model evaluation procedures are directed towards understanding whether the models are able to give the correct guidance regarding $NO_x$ and VOC emission control strategies in order to reduce ozone concentrations below prescribed levels. Although standard statistical tests will be applied to the model predictions and observations and 95% confidence intervals will be calculated for the performance measures, it is recognized that it is possible for models to give the right answers for the wrong reasons. Consequently diagnostic and mechanistic evaluations will also be carried out where individual model components are tested with specialized field observations. Also, the responses of the various models to perturbations in input conditions such as i.c.'s and b.c.'s VOC and $NO_x$ emissions, and changes in model resolution will be compared. More details are given in the project workplan[6].

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