J2.4 AIR QUALITY NOWCASTING FOR THE ISSUANCE OF HEALTH ADVISORIES IN THE SACRAMENTO, CALIFORNIA, METROPOLITAN REGION

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1. INTRODUCTION

The Sacramento, California, metropolitan region (SMR) is designated by the U. S. Environmental Protection Agency (EPA) as a severe non-attainment area for ground-level ozone (Figure 1). On average, over the past ten years, the region exceeded the federal 1-hr ozone standard of 0.12 parts per million (ppm) 8 days per year, exposing thousands of people in the region to unhealthy air each summer. Factors such as geography, meteorology, population, and traffic patterns contribute to the region's serious ozone problem.

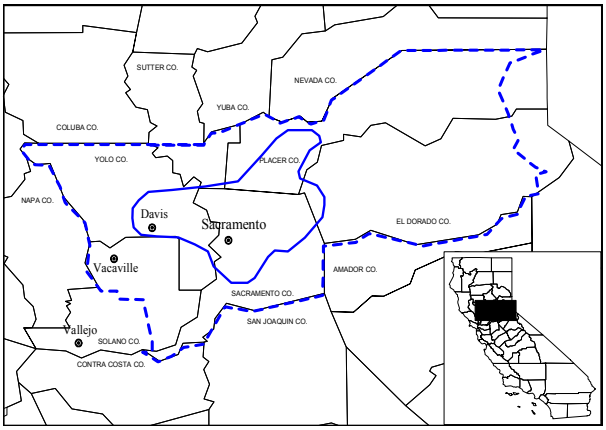

Figure 1. The Sacramento Metropolitan Air Quality Management District (solid line) and the SMR ozone non-attainment region (dashed line).

Located in the Central Valley of California, the region is bounded by the Coastal Range to the west and the Sierra Nevada Range to the east and joins the San Francisco Bay Area to the southwest through the Carquinez Strait. Occasionally during the summertime, the typical onshore marine flow from the Golden Gate into the Sacramento and San Joaquin Valleys is disrupted, producing conditions conducive to high ozone formation. This disruption usually occurs when an aloft ridge of high pressure moves over California. The ridge of high pressure causes the Pacific surface high to move east over Oregon, Idaho, and Nevada. This pattern shift creates a synoptic-scale offshore pressure gradient that counteracts the typical onshore flow, causing light winds in Sacramento. The stagnant wind conditions in the Sacramento Valley minimize the horizontal dispersion of ozone and its precursors. In addition, the ridge causes air to sink and adiabatically warm, forming a temperature inversion between 1500 and 3000 ft. The inversion and stable atmosphere reduce the amount of vertical dispersion and "trap" ozone and its precursors near the surface (Dye et al., 2000). These favorable ozone-producing conditions, combined with vehicular and other emissions in the SMR, which has a population of 2 million people, often cause ozone concentrations to reach unhealthy levels.

Because of the harmful impacts of these unhealthy ground-level ozone concentrations, the Sacramento Metropolitan Air Quality Management District (SMAQMD) started the Spare The Air (STA) program in 1995 to protect public health. This is a voluntary driving reduction and air quality notification program that uses a specific daily ozone forecast as a criterion to initiate an STA day.

Daily ozone forecasts are issued at 1100 PDT from May 1 to October 31 for the current- and next-day peak 8-hr and 1-hr ozone concentrations for three major air districts within the SMR. An STA day is issued when 8-hr peak ozone concentrations are forecast to be 95 parts per billion (ppb) or higher. Advisories and notifications are sent to the media, public, an employer network, and schools through e-mails, faxes, pagers, cell phones, and personal digital assistants (PDAs), and published on the Internet at www.sparetheair.com. In addition, based on the forecasts, the SMAQMD purchases television and radio time to broadcast public service announcements that advise people to reduce or avoid exposure to harmful ozone concentrations during the day as well as encourage the public to reduce emissions-producing activities such as driving and using gas-powered yard tools.

An important component of the STA program is the issuance of a Healthy Advisory (HA). California state law mandates air districts to alert the news media, public safety officials, health care providers, and school officials with an advisory when 1-hr ozone concentrations are expected to reach or have reached 145 ppb. By "nowcasting" HAs, the public has one to two hours advance warning to avoid or reduce exposure to unhealthy air. On average, in the past ten years, the SMR has experienced two to three HA days per year (Figure 2).

Because issuing an HA has many financial and societal impacts, much effort has been made to improve the accuracy of forecasting HA ozone levels. This effort includes improved understanding of conditions associated with HA ozone levels, better forecasting

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tools, and more streamlined forecasting procedures. This paper discusses components of HA forecasting and evaluates the performance of the HA forecasts, shows a case study of an HA forecast, and discusses the ongoing development of ozone forecasting methods.

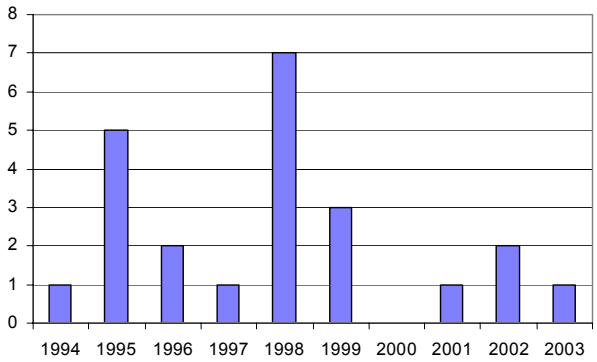


Figure 2. Number of days with ozone concentrations reaching the Health Advisory level from 1994 to 2003 in the Sacramento Metropolitan Region.

2. HEALTH ADVISORIES

The majority of high ozone days reaching the HA criterion in the SMR occurs during the height of the ozone season from June through September (Figure 3). However, a few such high ozone days occurred in April and May during the early 1980s and 1990s. Over the past ten years, 1994-2003, hourly ozone values have reached as high as 163 ppb. Advisory-level ozone concentrations occur most frequently (80%) during the mid-afternoon hours from 1500 to 1600 PDT lasting for one to two hours. Typically, one or two monitoring sites in the SMR register the HA level during each episode.

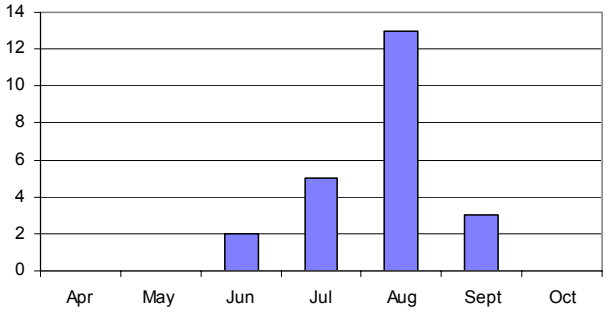


Figure 3. Monthly distribution of the number of days with ozone concentrations reaching the Health Advisory level from 1994 to 2003 in the Sacramento Metropolitan Region.

The area impacted by HA ozone levels varies greatly and depends on wind direction and strength. On days with light northerly winds (1-3 m/s), the highest values are more likely to occur at monitors such as Bruceville and Sloughhouse in the southern part of Sacramento County (Figure 4). When very light and variable winds (<1 m/s) are observed, HA ozone levels occur at Del Paso Manor, Roseville, and other monitors near downtown Sacramento. During days with light delta breezes or southwesterly winds, HA levels occur at monitoring sites in eastern Sacramento County and the foothills, for example, at Folsom, Cool, Colfax, and Auburn. This statistical analysis of past HAs has helped guide HA forecasting.

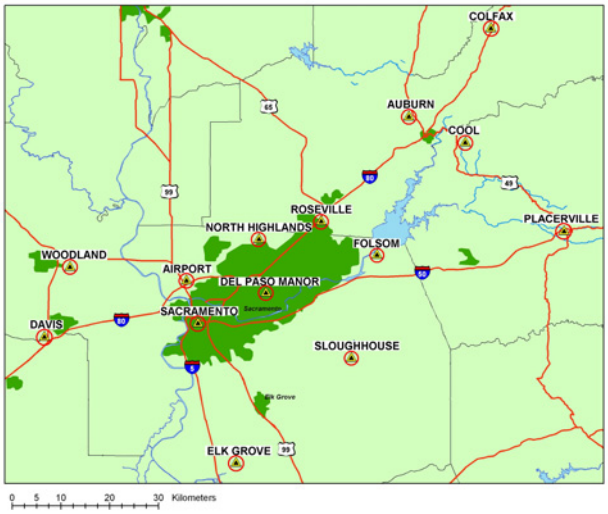


Figure 4. Ground-level ozone monitoring sites in the Sacramento Metropolitan Region.

3. FORECASTING HEALTH ADVISORIES

Much like forecasting infrequent weather events such as severe weather and tornadoes, forecasting HAs relies greatly upon "nowcasting" or short-term forecasting using the most recent observational data, insights into the causes of the phenomena, and general guidance from daily ozone forecasts.

Forecasting health advisories is part of a daily operational ozone forecasting routine. Meteorologists with experience in air quality forecasting utilize several tools to create an ozone forecast for the current and next days by 1100 PDT. One such tool is the Criteria method which uses specific threshold values (criteria) of meteorological or air quality variables to forecast ozone concentrations. For example, hot temperatures are often associated with high ozone concentrations; thus, high ozone concentrations can be expected when hot temperatures are predicted. Several criteria, or "rules of thumb", have been developed to forecast high (120 to 160 ppb) 1-hr ozone concentrations in the SMR:

1. 500-mb heights in Sacramento greater than 582 dm in May and June and greater than 588 dm in July through September.
2. Winds at 5-8 m/s at Travis Air Force Base, California (located near the Carquinez Strait) in the morning.
3. A predicted diurnal temperature range of 35-40^{o}F.
4. A 900-mb temperature greater than 25^{o}C in San Francisco.
5. One-hour peak ozone concentrations of 100 ppb or higher observed during the previous day.

These rules of thumb provide a good indication of whether conditions are favorable for producing high ozone concentrations that may eventually lead to HA issuance later in the day.

Another useful tool is statistical methodology. For ozone forecasting, regression equations were developed to describe the relationship between ozone concentrations and other predictor variables (for example, temperatures and wind speeds). Generally, increasing or decreasing trends of ozone levels are predicted fairly well by regression equations. However, exceptionally high episodes are often underpredicted. For example, the 1-hr ozone equation for the SMR predicted 129 ppb for July 18, 2003, when the observed value was 145 ppb (HA level). Nonetheless, this tool gives forecasters an objective baseline for formulating an ozone prediction.

Other air quality forecasting techniques include Classification and Regression Tree (CART), Intuition, and climatology (Dye et al., 2000).

After daily ozone forecasts are issued, meteorologists monitor surface temperatures, wind directions and speed, and near real-time hourly and sub-hourly ozone observations in the SMR and use guidelines to aid the process of nowcasting HAs. These guidelines were developed by analyzing historic ozone and meteorological data from 1991-1998 to determine if there are any variables or combinations of variables that differentiate high 1-hr ozone concentrations (120 to 144 ppb) from extreme 1-hr ozone concentrations (≥145 ppb, the HA level). The analysis showed that while there were only subtle differences in meteorological conditions on HA days, subjective analysis of meteorological conditions coupled with same-day air quality observations were found to be useful in forecasting HAs a few hours before they occur, providing the public adequate time to reduce or avoid exposure to harmful ozone concentrations. The following is a list of guidelines used by meteorologists for issuing an HA by 1400 PDT:

1. Ozone concentrations at North Highlands or Del Paso Manor are greater than 100 ppb by 1300 PDT.
2. A thermal low located over the western Sacramento Valley (Fairfield) in the afternoon.
3. Prevailing light surface winds throughout the early afternoon.
4. Afternoon 850-mb temperature >25°C.

Once a meteorologist decides to issue an HA, the forecast is evaluated by a second meteorologist. If they concur on the HA forecast, they then determine the affected region, peak concentrations, and duration of unhealthy air.

After the decision is made and approved by the SMAQMD to issue an HA for the SMR, the advisory is disseminated to the public, news media, public safety officials, health care providers, school officials, and other air agencies via faxes, e-mails, pagers, cell phones, and PDAs (Figure 5). The turn-around from the time meteorologists issue the advisory to its dissemination is less than 15 minutes.

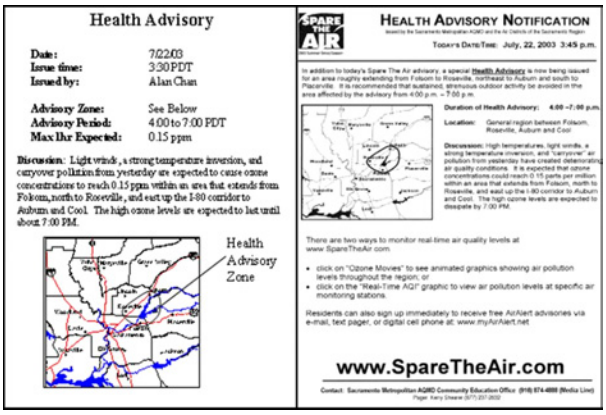


Figure 5. A Health Advisory forecast form prepared by meteorologists (left) and a notification sent out by SMAQMD (right).

4. CASE STUDY

During the third week of August 2002, the SMR was in the midst of one of the worst ozone episodes in over a decade. Ozone concentrations exceeded the 1-hr federal standard for six consecutive days. An HA was issued the afternoon of August 14.

A 500-mb high pressure system extended from the northeastern Pacific Coast toward Central California (Figure 6a). The morning temperature sounding indicated a strong inversion over the SMR (Figure 6b). Additionally, the 900-mb temperature at San Francisco was forecast to be 29°C. After reviewing the meteorological conditions, statistical tools, and rules of thumb, meteorologists issued a general forecast based on 8-hr ozone concentrations of 110 ppb (or "Unhealthy" on the Air Quality Index) at 1100 PDT. The regression equation for predicting 1-hr ozone concentrations indicated the possibility of an HA later in the day.

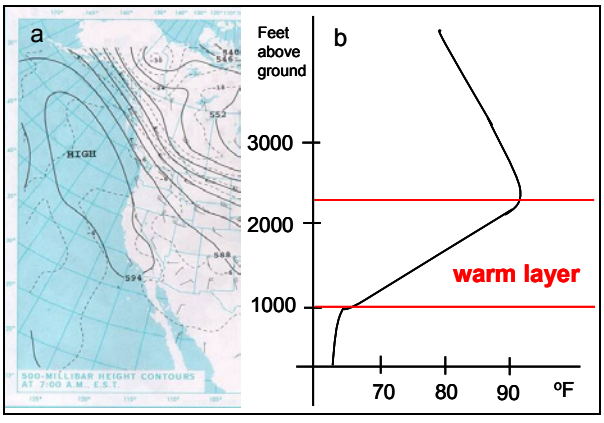
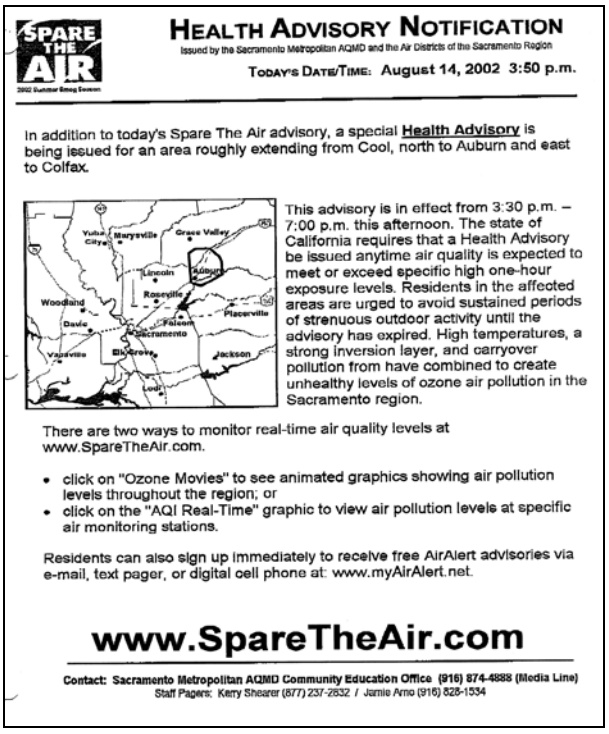


Figure 6. (a) 500mb height pattern over California and (b) California Air Resources Board vertical temperature profile over Sacramento on the morning of August 14, 2002.

Throughout the day, meteorologists monitored air quality and meteorological conditions closely. Winds had been light (1-2 m/s) since early morning, and varying wind directions implied recirculation of polluted air in the region from the past few days. Moreover, surface temperatures peaked at about 100°F which would not break the inversion. Sub-hourly (5-minute intervals) and hourly ozone concentrations recorded at Auburn, Colfax, and Cool at 1300 PDT were well above 100 ppb. However, the HA criterion for Del Paso Manor and North Highlands was not met.

At 1400 PDT, after carefully reviewing the latest wind and air quality data and comparing them against historic high ozone episodes, meteorologists decided to issue an HA for the foothills effective from 1530 PDT until 1900 PDT. Maximum ozone concentrations were expected to exceed 150 ppb. The SMAQMD was notified and the advisory was sent to the public and various agencies shortly after 1430 PDT (Figure 7).



HEALTH ADVISORY NOTIFICATION

Issued by the Sacramento Metropolitan AQMD and the Air Districts of the Sacramento Region

TODAY'S DATE/TIME: August 14, 2002 3:50 p.m.

In addition to today's Spare The Air advisory, a special **Health Advisory** is being issued for an area roughly extending from Cool, north to Auburn and east to Colfax.

This advisory is in effect from 3:30 p.m. – 7:00 p.m. this afternoon. The state of California requires that a Health Advisory be issued anytime air quality is expected to meet or exceed specific high one-hour exposure levels. Residents in the affected areas are urged to avoid sustained periods of strenuous outdoor activity until the advisory has expired. High temperatures, a strong inversion layer, and carryover pollution from have combined to create unhealthy levels of ozone air pollution in the Sacramento region.

There are two ways to monitor real-time air quality levels at www.SpareTheAir.com.

- click on "Ozone Movies" to see animated graphics showing air pollution levels throughout the region; or
- click on the "AQI Real-Time" graphic to view air pollution levels at specific air monitoring stations.

Residents can also sign up immediately to receive free AirAlert advisories via e-mail, text pager, or digital cell phone at: www.myAirAlert.net.

www.SpareTheAir.com

Contact: Sacramento Metropolitan AQMD Community Education Office (916) 874-4888 (Media Line)
Staff Pagers: Kerry Shearer (877) 237-2632 / Jamie Arno (916) 828-1534

Figure 7. HA notification sent by the SMAQMD on August 14, 2002.

For the remainder of the day, meteorologists closely monitored meteorological and air quality observations. Table 1 shows that the maximum 1-hr ozone concentrations at Cool reached 156 ppb on August 14 which was above the HA threshold.

5. ACCURACY

On average, 60% of HAs accurately predict an actual occurrence of hourly ozone concentrations reaching 145 ppb or greater. In the past six years (1998-2003), a total of 12 days reached the HA level. Using the methods discussed in this paper, meteorologists correctly predicted 9 of these days for a probability of detection of 75%. On the 3 days when air quality reached the HA level, an advisory was not issued. In addition, four HAs were issued on days that did not reach the advisory level, resulting in a false alarm rate of 31%.

Monitoring Sites	Concentrations (ppb)
Cool	156
Rockland*	130
Auburn	129
Roseville	128
North Highlands	123
Colfax	117
Del Paso Manor	116
Folsom	109
Placerville	105
Sloughouse	103

* Decommissioned May 2003

Table 1. Peak 1-hr average ozone concentrations of selected sites in the SMR on August 14, 2003.

It is important to realize that issuing an HA involves several factors in addition to meteorological and air quality observations. For example, depending on the magnitude of the episode and the exact location of the plume, existing monitors may fail to record hourly ozone concentrations over the advisory level. Additionally, sub-hourly ozone concentrations may vary greatly for individual monitors under light to moderate wind conditions which can cause hourly averages to remain under the HA threshold. While HA false alarms or overpredictions are not desirable, they serve to alert the public to potentially harmful air during exceptionally high ozone episodes.

6. CONCLUSION

HAs allow the public to avoid or reduce exposure to unhealthy air. Air quality nowcasting plays a crucial role in providing the public with advance notice. Several forecasting methods were developed to aid meteorologists in predicting the location, magnitude, and duration of an HA. These methods are constantly revised to account for changes in emission pattern. Ongoing analyses reveal a better understanding of air quality and meteorology in the SMR. Ultimately, accurate ozone forecasts will protect the public health and achieve the goal of the STA program.

7. REFERENCES

Dye T.S., MacDonald C.P., and Anderson C.B. Air quality forecasting for the Spare The Air Program in Sacramento, California: Summary of four years of ozone forecasting. In preprints of the *Second Conference on Environmental Applications during the 80th Annual Meeting of the American Meteorological Society, January 9-14, 2000, Long*

Beach, CA; American Meteorological Society: Boston, MA.

8. ACKNOWLEDGEMENTS

The authors thank the sponsors of the ozone forecasting program: the Sacramento Metropolitan Air Quality Management District (SMAQMD). We especially thank Mr. Kerry Shearer, Ms. Lori Kobza-Lee, and Ms. Jamie Brown-Arno of the SMAQMD who manage the Spare The Air program and are responsible for the program's great success.