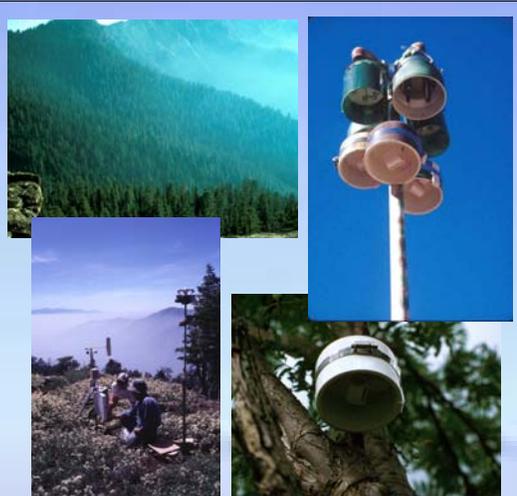


## INTRODUCTION

Tropospheric ozone is a phytotoxic gaseous air pollutant formed by photolysis from air pollution generated by large metropolitan areas, during transport over long distances to rural areas. Ozone, together with drought and bark beetles, is one of the key stressors affecting forest trees adjacent to urban areas. Recently passive samplers have been used to measure ambient ozone concentrations. Passive samplers allow O<sub>3</sub> distribution to be characterized at forest stand and landscape scales. Because they are inexpensive, easy to use and do not require electricity to operate, passive samplers are especially suited to remote areas. Large-scale evaluations have already been performed for the Sierra Nevada. In this study several sources of funding were utilized to establish an extensive network of 37 passive ozone samplers southern California mountains, foothills and desert. Samplers were changed every 2-weeks during between May and October 2005. Several active ozone monitors were installed to provide calibration of passive samplers on-site. Passive and active ozone sampler data were then used to develop spatial estimates of ozone distribution in the mountains of Southern California for the summer of 2005.



### OZONE PASSIVE SAMPLERS

Passive samplers are systems that require no power and are readily deployed directly in any forested area such as the Class 1 area in the picture above left. They can be used to cover a wide area and are much less expensive than an active monitoring program. We have tested and developed protocols for monitoring ozone, NO<sub>2</sub>, SO<sub>2</sub>, NH<sub>3</sub>, and HNO<sub>3</sub> using passive sampling systems.

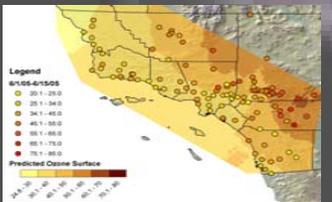
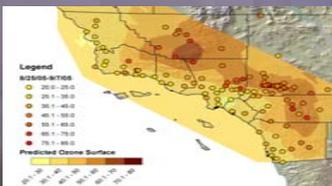
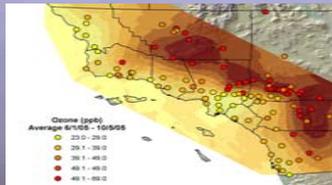
# Intensified Ozone Monitoring in Southern California

Michael Arbaugh, Andrzej Bytnerowicz, Susan Determann and Susan Schilling  
Pacific Southwest Research Station and  
Michael McCorison, Air Resource Management and James Allison, Forest Health Protection



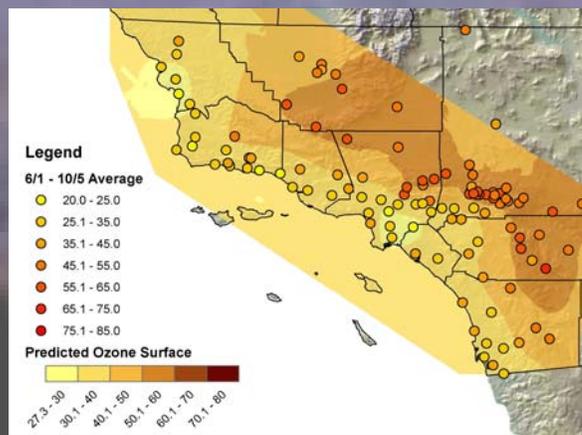
## GEOSTATISTICAL MODELING

We have developed ambient pollution concentration maps of ozone for southern California Mountains using Geostatistical Analyst Extension to ArcGIS 9.0 (Environmental Systems Research Institute). Ordinary Kriging with no trend removal was used to generate the four prediction surfaces. The model applied was spherical. The number of points used varied due to missing data. There are up to 37 FHM passive sites, 83 active CARB sites for a total possible 120. Root Mean Square Error for the summer average was 7.128 ppb, and varied between 8.0 and 12.1 ppb for individual periods. Maps are preliminary, and will be modified with elevation and temperature data in future models.



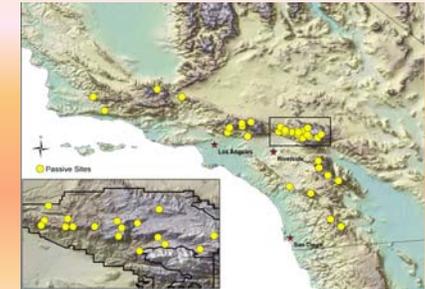
Average Ozone Concentrations from 3 Measurement Periods during 2005 Season

## Average 2005 Summer Season Ozone for Southern California



## STUDY AREA AND SITES

Ogawa passive samplers were installed near long-term ozone pine injury plots in the Cleveland, San Bernardino, Angeles and Los Padre National Forests. Sites destroyed due to fire or insect mortality were re-established at comparable nearby locations. In addition sites established as part of two other studies (in deserts and foothills) were combined with the data set to provide greater geographic extent. Ogawa passive samplers (Koutrakis et al., 1993) were used to determine of 2-week long averages of ozone concentrations. Active continuous monitors (2B Technologies) were collocated at four locations with passive samplers.



## CONTRIBUTING FACTORS TO HIGH OZONE IN MOUNTAINS AND DESERTS

### Gasoline Reformulation

Reformulated gasoline was introduced in the South Coast Air Basin in the 1990's. Reformulation changed the makeup of gasoline to reduce its rate of evaporation, reactivity, levels of air toxics such as benzene and butadiene, and increase oxygenates. One consequence of the reformulation was a geographical shift in high ozone concentration areas. Prior to reformulation high concentration areas were just east of the Los Angeles Basin in the San Gabriel and western San Bernardino Mountains. After reformulation the lower reactivity of emissions led to an eastward shift in ozone air pollution to the central San Bernardino Mountains (and Mojave Desert), which now has the distinction of recording the highest ozone concentrations in the United States almost every year.

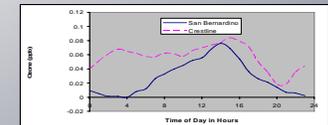
### Summer Weather Patterns

Dominant summer weather patterns lead to thermal inversion layers driven eastward by on-shore winds, as can be seen below.



### Nighttime Air Chemistry

Nitrogen dioxide (NO<sub>2</sub>) reacts in the presence of sunlight to form ozone and nitrogen oxide (NO) in the pollution source areas. In the absence of sunlight, NO reacts with ozone to form oxygen (O<sub>2</sub>) and nitrogen dioxide (NO<sub>2</sub>). However, as the nitrogen oxides and hydrocarbons are transported out of urban areas, NO is oxidized to NO<sub>2</sub> (so scavenging of O<sub>3</sub> at night does not take place) leading to different diurnal ozone patterns in urban and rural areas.



Hourly Ozone during a 24-hr period (9/3/2004)

### Population Increase in Eastern Counties

Between 1990 and 2000 the eastern counties of Riverside, San Bernardino and Imperial increased in population 20.5%, 32.0% and 32.4% respectively, resulting in over 699,000 new residents adjacent to the mountains and deserts of southern California. This population increase contributed to increased local traffic and other sources of local pollution.

## CONCLUSIONS

Ozone pollution in mountain and deserts is much higher than in urban areas. This difference is largely due to four factors: on-shore winds, gasoline reformulation, eastward population expansion and nighttime air chemistry. The result is that eastern mountain areas have higher total ambient ozone than urban areas of southern California. Geostatistical analysis indicates that the highest ozone areas occur in the Central and Eastern Transverse, and Peninsular Mountain Ranges. The analysis also indicates that eastern and northern desert areas surrounding these mountain ranges may be experiencing high ozone air pollution levels.

Well designed long-term monitoring networks are essential for understanding air pollution dispersion and effects in the complex terrain that characterizes the forest and desert wildland areas of the US.