2. Study Setting

This section describes the study domain, major terrain features, land use, meteorology, and regional air quality and visibility.

2.1 The Southwestern United States

Figure 2-1 shows a terrain map of the Southwestern United States. The Colorado river flows from the Northeast corner of the map, through the Grand Canyon, and into Lake Mead. Below the Hoover dam on the western edge of Lake Mead, the Colorado river flows south through the Mohave Valley and toward the Gulf of California.

MPP is located at Laughlin, NV, about 125 km south-southeast of Las Vegas, 350 km northeast of Los Angeles, and 340 km northwest of Phoenix. The MPP is a coal-fired, base loaded generating facility with a 153 m high stack. The base of the stack is at 210 m msl. It uses low sulfur (0.5 % by wt.) Arizona coal delivered by slurry pipeline. Its SO_2 emission rate is approximately 150 tons per day at full operation (Nelson, 1991) and averages 110 tons per day. MPP produces 1580 MW at peak load.

The topography in the vicinity of MPP is complex with sparse vegetation. The Mohave Valley walls are not symmetric with respect to the valley axis. Western slopes rise gradually, while eastern slopes rise slowly for the first few kilometers with steep walls further to the east. The border between Nevada and Arizona also extends along the valley axis. The bottom of the valley is about 200-300 m msl and the ridges reach 1200 m msl. Toward the west, the Mohave Valley extends into a high plateau and toward the east, into the Detrital Valley plateau (600 m msl). The Mohave valley narrows as it approaches Hoover Dam. At Lake Mead the terrain flattens. The western entrance to GCNP is at the end of the eastern arm of Lake Mead (180 m msl).

2.1.1 Land Use

Figure 2-2 is a map of the locations of major cities and roadways in the southwestern United States. The region surrounding the Grand Canyon is sparsely populated. The cities and towns closest to Grand Canyon National Park (GCNP) are Las Vegas, NV to the west, Kingman, AZ and Laughlin, NV to the southwest, Flagstaff, AZ to the south, Page, AZ to the northeast, and St. George, UT to the northwest. Los Angeles and San Diego are major population centers to the southwest with combined populations of approximately 15 million.

In addition to MPP, there are several large coal-fired electric generating facilities near the Grand Canyon National Park. NGS is a 2300 MW plant located near Page, AZ at the eastern end of the Grand Canyon. NGS is currently in the process of installing scrubbers to control its SO_2 emissions. All scrubbers will be on line in 1999. The Reid Gardner coal-fired plant north east of Las Vegas emits approximately 14 tons SO_2 per day. There are two large coal fired power plants in northwestern New Mexico. The plant in Waterflow, NM emits 100 tons SO_2 per day and the plant in Fruitland, NM emits 90 tons SO_2 per day. Emissions data for these facilities was obtained from the EPA AIRS database.

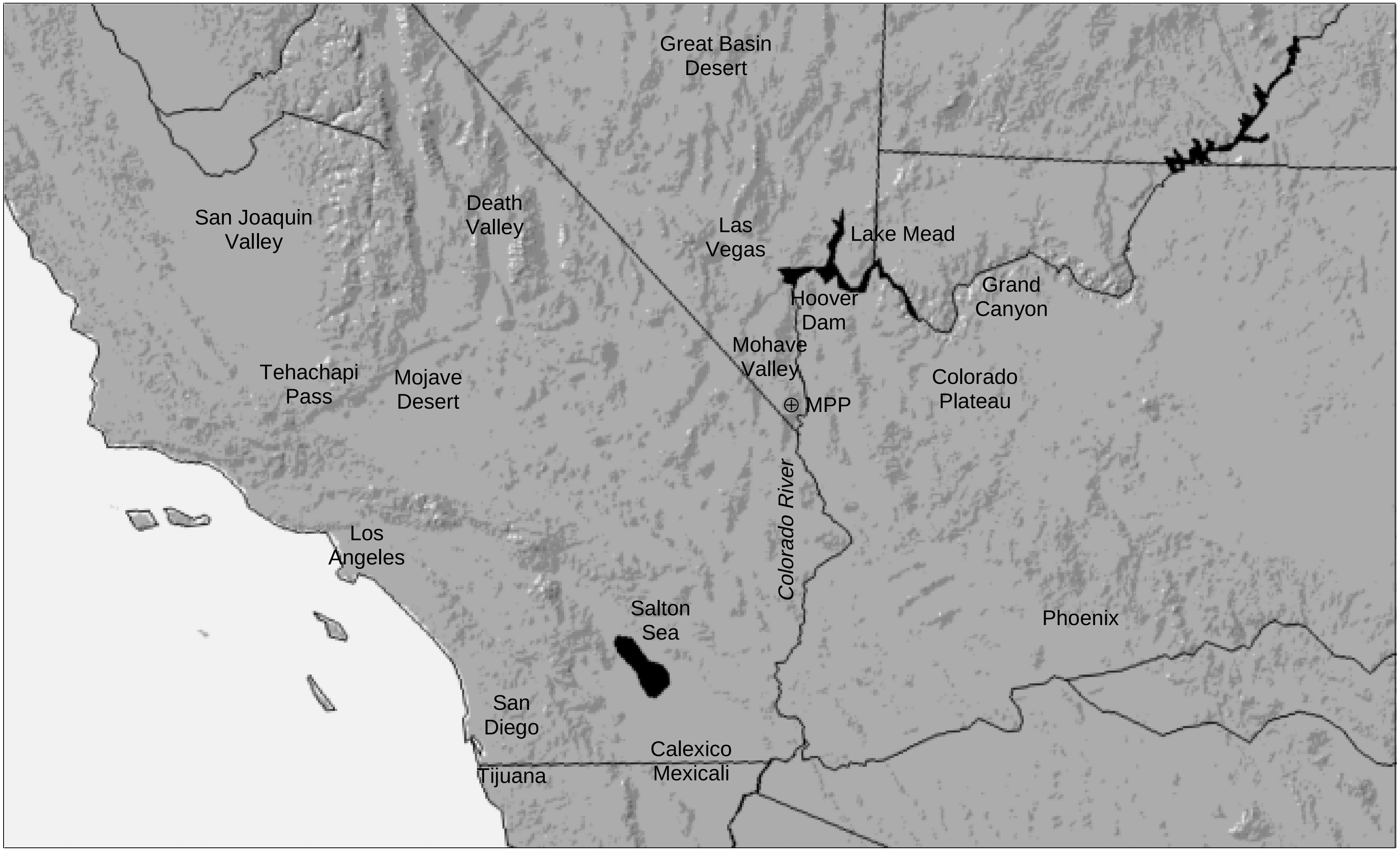

Figure 2-1 Geographic features of the Southwestern U.S.

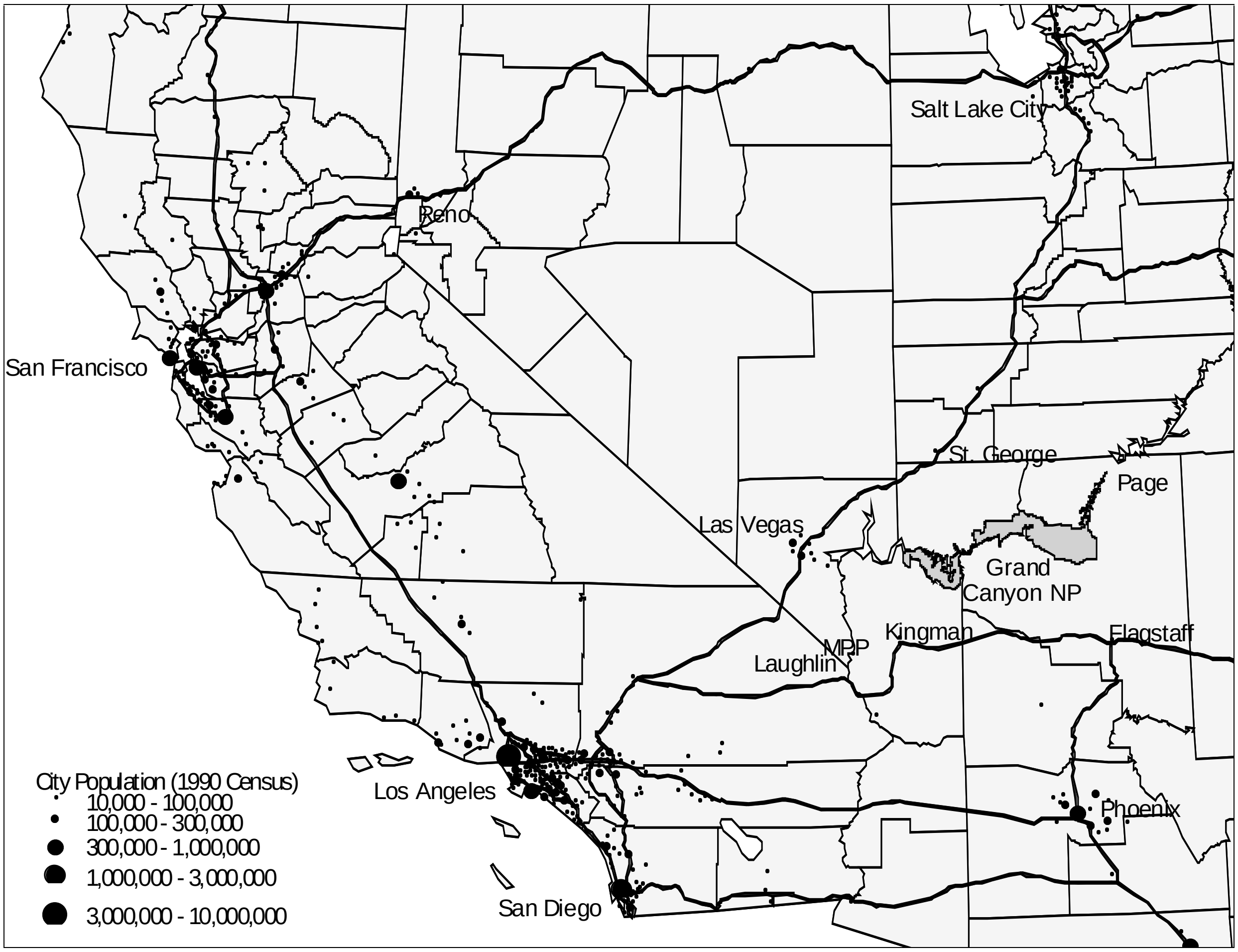

Figure 2-2 Major cities and roadways in the southwestern United States.

The soutwestern United States is the home of several Class I visibility protected areas. Figure 2-3 shows the location of these areas with respect to MPP. GCNP is the closest Class I area to MPP and its western edge is located about 130 km northeast of the facility. Joshua Tree National Monument (approximately 150 km to the southwest) is the next closest Class I area to MPP. Sycamore Canyon and Pine Mountain Wilderness Areas are approximately 200 -250 km east southeast of MPP.

2.2 Meteorology

General meteorological patterns, both synoptic-scale and mesoscale are described here. The effects of these patterns upon pollutant transport are considered in section 7.2.

Substantial differences in meteorological conditions occur across the Project MOHAVE study domain (most of Arizona and the southern parts of California, Nevada, and Utah). Major contributing factors include variations in elevation (3600 m on Mt. Charleston near Las Vegas to –85 m at Death Valley) and the relative importance of maritime versus continental effects. In the western portion of the study area, precipitation falls mostly in the winter months. The eastern portion of the study area experiences winter and summer peaks in precipitation; the summer precipitation is usually from thunderstorms associated with the southwestern or Mexican monsoon (Douglas et al., 1993). The percentage of annual average rainfall occurring from July-September ranges from less than 10% in the western portion of the study area (western Mojave Desert in California) to greater than 40% in the eastern and southeastern portions of the study area (eastern and southeastern Arizona)(Douglas et. al., 1993).

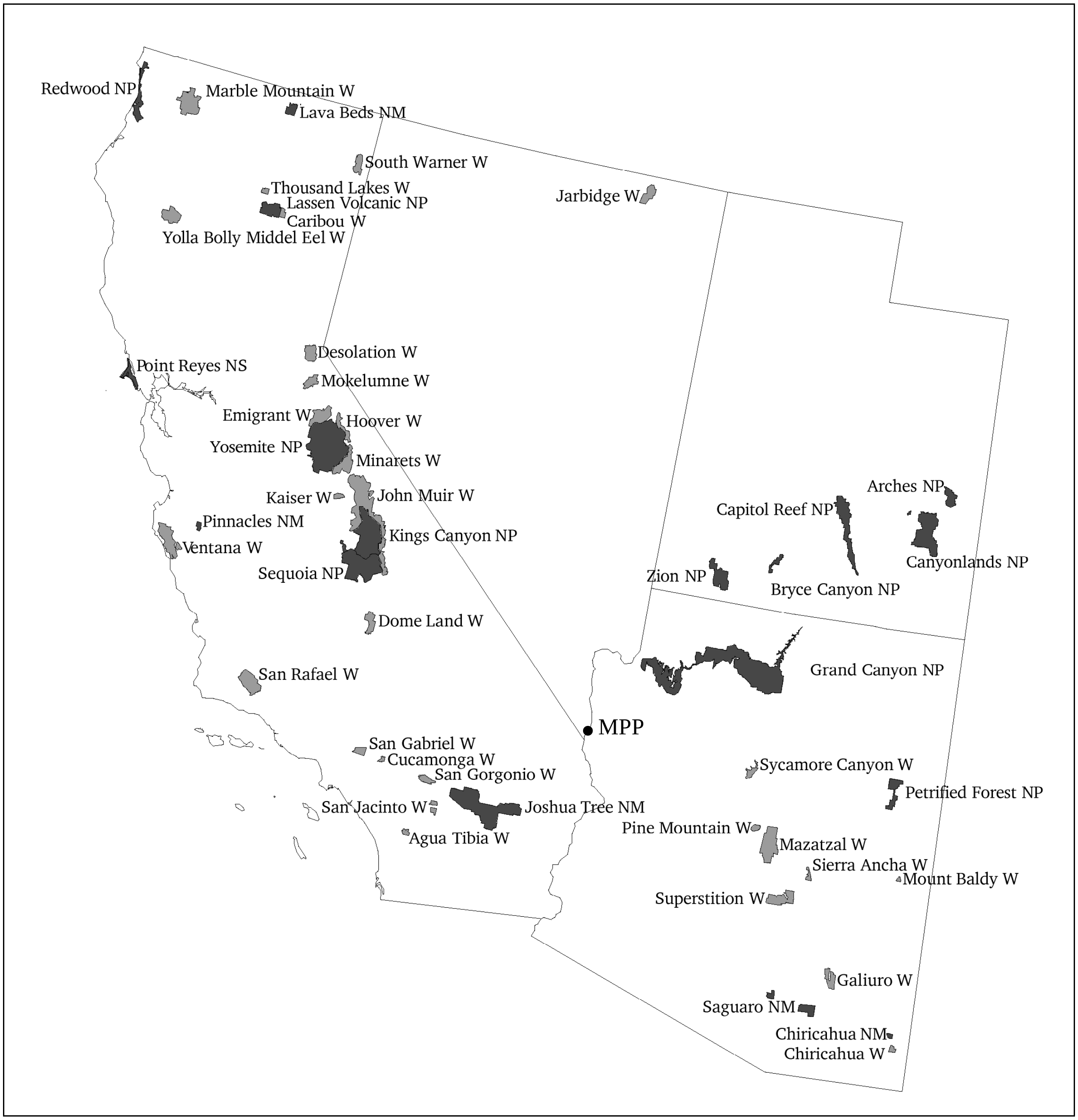

Figure 2-3 Class I areas in California, Nevada, Utah, and Arizona.

Winter storms arrive in the study area from the eastern Pacific Ocean. The winter precipitation falls mainly as snow, sometimes heavy, in the higher elevations and light rain at the lower elevations. In-between the winter storms are periods with clear skies and often light winds from the north or north-east associated with flow of cold air off the Colorado plateau. The frequency of occurrence of different meteorological patterns varies substantially from month-to-month and year-to-year.

Summer-time patterns are dominated by either dry, southwesterly flow or moist south-southeasterly monsoonal flow. The monsoonal flow is most common during mid-July through early September, while the dry southwesterly flow occurs throughout the warm months, and occurs most regularly in May, June , and September (Green et al., 1992). Low pressure systems over the southwestern U.S. occasionaly pass through the area during summer, most commonly in early (May-June) or late summer (September) (Green et al., 1992; Farber et al. 1997).

Local wind patterns are strongly influenced by terrain features, with channeling within mainly north-south valleys and flows above influenced by synoptic-scale pressure gradients (Green et al., 1998; Farber et al., 1997; and Gaynor and Ping, 1992a). A radar wind profiler was operated at the Mohave Power Project during the Project MOHAVE field study (see section 3.5 for a description of the meteorological monitoring network). During the winter , northerly winds predominated below 1 km AGL (the depth of the Colorado River canyon at MPP), often with a strong jet of 10-15 m s^{-1}. Above about 2 km AGL, winds were in balance with the synoptic scale pressure gradient (Gaynor and Ping, 1992b). The within-canyon jet was especially strong during periods with a high pressure system centered over the Great Basin. For the Great Basin high pattern, rawinsonde measurements near MPP at 5 AM and 5 PM MST showed light winds at the surface in the morning (2 m s^{-1}) with a steady increase to 12-14 m s^{-1} at 800 m AGL and quickly subsiding above this level (Gaynor et. al. 1993). During the afternoon sounding, surface wind speed were higher (6 m s^{-1}) and the peak wind speeds of 10 ms^{-1} occurred over a thicker and lower vertical layer, from about 200-600 m AGL.

Figure 2-4 and Figure 2-5 show the frequency of wind direction as a function of height at MPP and Cottonwood Cove (in the lower Colorado River valley about 40 km north of MPP) during the summer intensive study. Figure 2-4 shows a gradual broadening of the wind direction histogram with height at MPP. Only the last panel shows data for heights above the surrounding mountains. In Figure 2-5, the data are grouped for all heights below 1 km AGL and 1-4 km AGL for morning and afternoon rawinsonde releases; this essentially stratifies the data into within the Colorado River canyon and above the canyon. Within the canyon about 75% of the observations are from the southeast, which corresponds to the local orientation of the valley (wind blowing up-river). Above the canyon, winds are much more variable, with southwesterly winds being the most frequent.

2.3 Air Quality and Visibility

The Project MOHAVE Study area includes some of the best and worst remote area visibility conditions in the western U.S. as measured by the IMPROVE network (Sisler et al., 1996). Emissions from the urban/industrial sources in Southern California and from northwestern Mexico are the cause of a major southwest to northeastern gradient in particulate matter concentrations and visibility across the study area. Table 2-1 below shows the annual, winter and summer average concentrations of PM_{10}, $PM_{2.5}$, coarse mass (PM_{10} - $PM_{2.5}$), and major fine particle components for San Gorgonio (an IMPROVE monitoring site in the mountains that separates the Los Angeles urban area from the Mojave Desert) and for the average of six sites on the Colorado Plateau (Bandelier, Bryce Canyon, Canyonlands, Grand Canyon, Mesa Verde, and

Petrified Forest National Parks). The annual and summer gradient across the study area is apparent for both fine and coarse particle size-ranges. However, the gradient across the study area is much less pronounced in the winter season.

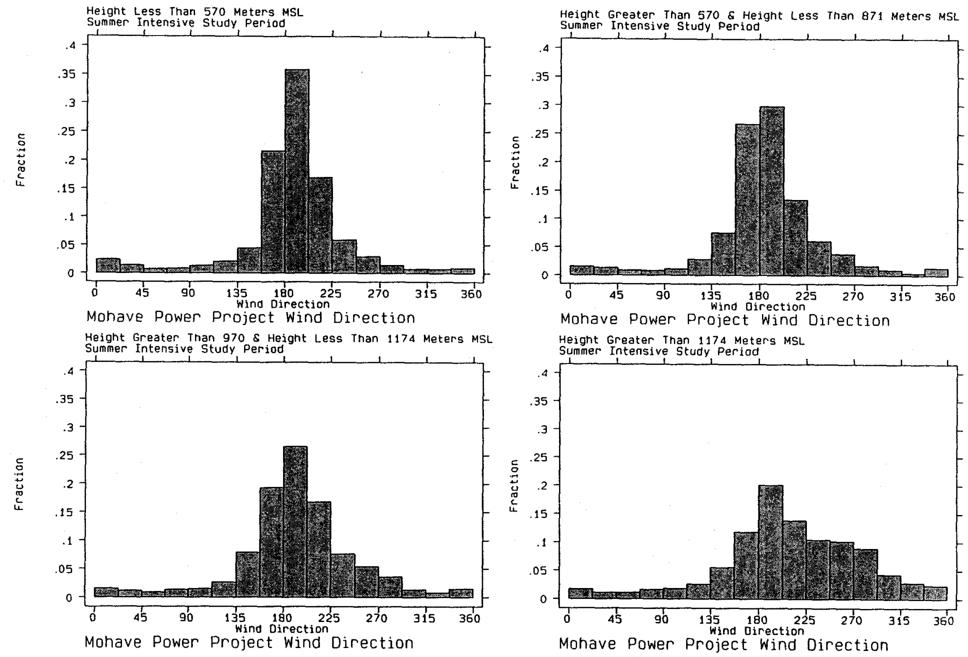

Figure 2-4 Radar wind profiler summary for the summer intensive period at Mohave Power Plant. Data are for all 24 hours of the day.

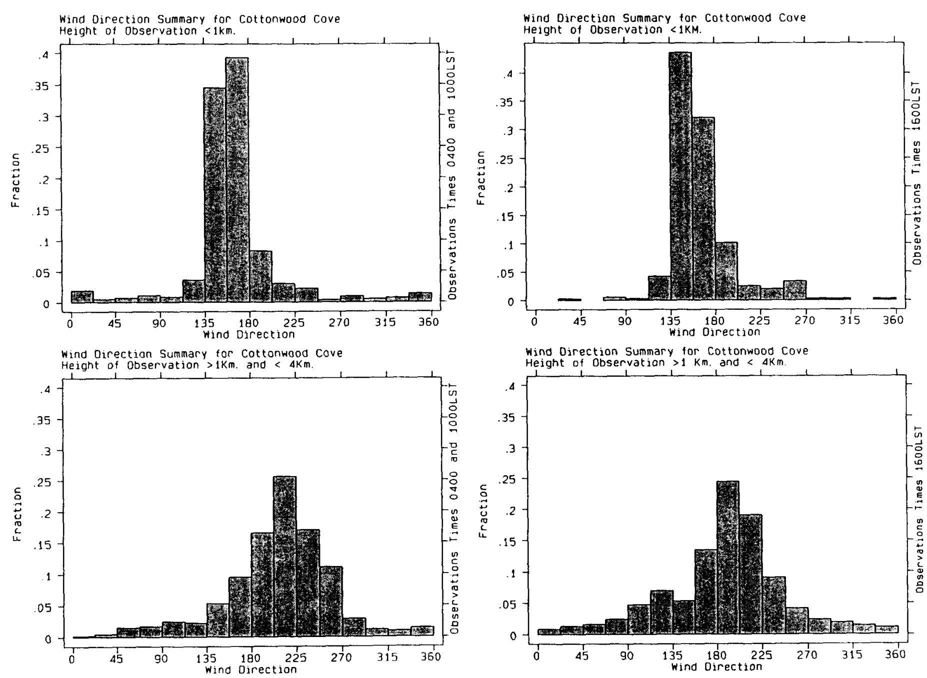

Figure 2-5 Rawinsonde summary for the summer intensive period at Cottonwood Cove. Data are for all 24 hours of the day.

Table 2-1 Annual, winter and summer particulate matter concentrations and fractional contributions of $PM_{2.5}$ for the San Gorgonio and Colorado Plateau IMPROVE monitoring location sites for March 1992 to February 1995.

	Mass Concentration (μg/m³)			Major $PM_{2.5}$ Components (μg/m³)				
Location Season	PM_{10}	$PM_{2.5}$	$PM_{10-2.5}$	Ammonium Sulfate	Ammonium Nitrate	Organic Mass	Elemental Carbon	Crustal Species
San Gorgonio A	16.8	8.3	8.5	1.5	3.7	2.6	0.4	0.7
CO Plateau A	7.4	3.5	3.9	1.1	0.2	1.3	0.2	0.6
San Gorgonio W	6.7	4.1	2.6	0.6	1.3	1.1	0.2	0.2
CO Plateau W	5.4	2.4	3.0	0.8	0.2	1.1	0.2	0.2
San Gorgonio S	22.4	10.4	12..0	2.4	4.2	4.0	0.6	0.7
CO Plateau S	9.2	4.3	4.9	1.3	0.2	1.5	0.2	0.7

The component $PM_{2.5}$ masses do not always sum to the gavimetric $PM_{2.5}$ mass. Differences may be due to the analytical uncertainties of the component and gravimetric measurements. When the sum of components is less than the measured mass, additional material on the filter such as water or seasalt may have been present.

The major components most responsible for the gradient are nitrate and organic carbon, with sulfate and elemental carbon also contributing to the difference between the two regions. Project MOHAVE and other studies have shown the nitrate gradient to be very sharp with much lower concentrations measured at sites only a few tens of kilometers to the east in the Mojave Desert. Notice that during the winter season the Colorado Plateau experiences the same component concentrations as at the San Gorgonio monitoring site with the exception of the nitrate which is considerably higher near Los Angeles and sulfate which is modestly higher on the plateau.

Corresponding visibility levels expressed as calculated light extinction coefficient values are shown in Table 2-2. In this case, light extinction was calculated from chemical measurements with the method used in the IMPROVE report (Sisler et al., 1996). These data reflect a similar seasonal pattern and spatial gradient as seen in the particulate matter concentrations. Fine particle scattering calculated from chemical speciation measurements is responsible for most of the difference between sites with a smaller contribution to the differences from aerosol absorption which is assumed to be caused solely by elemental carbon. Gas molecules that make up the air (e.g. N_2 & O_2) cause the Rayleigh scattering component of the total light extinction, and except for variations caused by air density differences (e.g. altitude changes) is a constant. As a result the relative contribution of Rayleigh scattering to total extinction which is a measure of its importance to visibility is much higher at the Colorado Plateau sites (about 1/3) than at San Gorgonio (about 1/7).

Table 2-2 Annual, winter and summer averages of total calculated extinction and its major components in units of inverse megameters (Mm^{-1}) for San Gorgonio and the Colorado Plateau IMPROVE network sites.

Location	Season	Calculated Total Extinction	Fine Scattering	Coarse Scattering	Aerosol Absorption	Rayleigh Scattering
San Gorgonio	Annual	69.7	43.8	5.8	10.2	10.0
CO Plateau	Annual	31.4	13.4	3.0	4.9	10.0
San Gorgonio	Winter	35.6	19.8	1.9	3.9	10.0
CO Plateau	Winter	29.3	13.5	2.0	3.8	10.0
San Gorgonio	Summer	80.3	47.9	7.4	15.0	10.0
CO Plateau	Summer	33.6	13.8	3.9	5.9	10.0