7. Optical Monitoring

Overview

The optical monitoring plan for project MOHAVE consists of two fundamental aspects:

1) View Monitoring

View monitoring documents the visual impairment of specific unique vistas under various air quality conditions. View monitoring is primarily accomplished with 35mm color slide photography and 8mm color time-lapse photography. Color slides provide high resolution documentation of the visible effects of uniform and layered hazes on the vista. Digitization of the slides can be done to yield relative radiance fields that can be used to calculate color contrast, average landscape contrast, visual range, modulation depth, equivalent contrast, and just noticeable change. In addition, slides of extremely clean days can be used as the basic input to present visual air quality scenarios. 8mm time-lapse photography captures the important spatial and temporal patterns of visibility events that allow for a more in-depth understanding of visual air quality.

2) Electro-Optical Monitoring

Electro-optical monitoring measures the basic electro-optical properties of the ambient atmosphere and aerosols, independent of specific vista characteristics. Monitoring will include measurements of the ambient atmospheric extinction coefficient (b_{ext}), and its scattering (b_{scat}) and absorption (b_{abs}) components. Primary operational monitoring techniques include the transmissometer (b_{ext}), nephelometer (b_{scat}), and filter absorption (b_{abs}). Temperature and relative humidity measurements, taken simultaneously with electro-optical measurements, are mandatory to infer visibility effects associated with chemical and physical interactions between water vapor, liquid water, and aerosols.

Project MOHAVE will incorporate current state-of-the-art monitoring instrumentation, operating and quality assurance procedures, and data collection, reduction, editing, and reporting protocols that have been developed for the IMPROVE monitoring program (ARS, 1990a; ARS 1990b).

View Monitoring

Equipment

Automatic 35mm and 8mm camera systems will be an integral part of the optical monitoring for project MOHAVE. The spatial and temporal variations in visual air quality captured by these systems will be used to:

- Document how vistas appear under varied conditions;
- Qualitatively record the frequency that various conditions occur; e.g. incidence of uniform haze, layered haze, plumes, and meteorology;
- Provide a quality assurance reference for collocated electro-optical measurements;
- Serve as a backup method to estimate the electro-optical properties of the atmosphere (if appropriate teleradiometric targets are in view);
- Support the calculation of advanced visibility indices;
- Support computer imaging studies;
- Provide quality media for visually presenting program goals, objectives, and results to study participants, decision makers, and the public.

Systems based on the following cameras will be used:

- 35 mm cameras: Olympus OM series
Contax 136 and 167
Cannon EOS series
- 8mm time-lapse: Minolta 601 series

Standard operating procedures developed for the IMPROVE monitoring program will be followed (ARS, 1990a).

Monitoring Locations and Sampling Frequency

The 35mm camera systems will be located at all receptor sites and other Class I Area sites. The 8mm time-lapse systems will be located at Meadview and various scenic view points along the south rim of the Grand Canyon. During non-intensive periods, only 35mm cameras will operate, taking three exposures daily at 0900, 1200, and 1500 hrs.

During intensive monitoring periods, 35mm cameras at the receptor sites and at GCNP will take nine exposures daily from 0800-1600 hrs. Time-lapse photography will take 1 frame per minute from 0800-1600 hrs daily. Additional view monitoring locations will be added as the study progresses.

Electro-optical Monitoring

Extinction Measurements

The Optec, Inc. LPV-2 long path transmissometer will be the primary instrument used to measure b_{ext} for project MOHAVE. The transmissometer incorporates a light detector (receiver) at one end of a specific atmospheric sight path. The receiver directly measures the illuminance of a constant output light source (transmitter) located at the opposite end of the path. Calibration of the transmissometer accurately determines the inherent output of the transmitter. The transmission of the sight path can then be calculated:

$$T = \frac{I_r}{I_{cal}}$$

where

T = transmission of sight path r
I_r = illuminance measured by receiver at distance r
I_{cal} = calibration illuminance of transmitter

By measuring the exact length of the sight path the average atmospheric extinction coefficient of the path can be calculated:

$$B_{ext} = \frac{-\ln(T)}{r}$$

where

b_{ext} = average extinction coefficient of sight path r
T = transmission of sight path r
r = length of sight path r

During the past ten years, transmissometers have been developed, tested, and deployed in the IMPROVE monitoring network, National Park Service IMPROVE protocol sites, and various other monitoring programs. They have become the accepted method for reliably making continuous precise, accurate, b_{ext} measurements. Standard operating and data reporting procedures developed for the IMPROVE program will be followed (ARS, 1990b).

Scattering Measurements

Integrating nephelometers will be used to measure b_{scat}. The integrating nephelometer measures b_{scat} by directly measuring the light scattered by aerosols and gases in an enclosed sample volume. The scattered radiation is integrated over a large range of scattering angles. Since the total light scattered out of a sight path is the same as the reduction of light along the sight path due to scattering, a properly calibrated integrating nephelometer gives a direct measurement of b_{scat}.

Nephelometer measurements are involved in considerable controversy because of the modification of the ambient aerosol as it passes through the sampling train and optical chamber. The instrument heats the air thus lowering the relative humidity environment of the aerosols. This leads to an underestimation of ambient b_{scat}. Extreme efforts have been made to operate nephelometers as close to ambient temperatures as possible. The best results have been a heating of approximately 1.5° C. This is approximately a 10% change in relative humidity, which can lead to underestimation of ambient b_{scat} measurement. In addition, nephelometers underestimate the scattering by coarse particles (> 2.5μm in diameter). As with the transmissometers, standard protocols developed for the IMPROVE program will be followed (ARS, 1990b).

Absorption Measurements

Where collocated transmissometers and nephelometers are collecting data, b_{abs} will be estimated by subtracting b_{scat} from b_{ext}. The term, b_{abs}, will also be estimated by absorption measurements from channel A filters collected by the aerosol monitoring network. These b_{abs} measurements will be average values for the collection period of each filter. Data from these measurements will be available only for periods when aerosols measurements are taken.

Temperature and Relative Humidity Measurements

Accurate air temperature and relative humidity data are critical to establish the relationship between ambient aerosols and visibility effects. Small changes in relative humidity, especially above 70%, can dramatically affect aerosol size and optical characteristics. Rotronic Instrument Corporation Model MP-100F sensors will be used in Project MOHAVE. The MP-100F combines a 100 ohm platinum temperature sensor with an enhanced hygroscopic polymer film humidity sensor to provide an integrated air temperature/relative humidity device that will maintain a 2% relative humidity measurement accuracy over the range of 0-100% relative humidity. These sensors will be operated with every transmissometer and nephelometer in the Project MOHAVE network.

Monitoring Locations and Sampling Frequency

Transmissometers and nephelometers will operate continuously through the year of Project MOHAVE at various locations. Data from instruments specifically installed for Project MOHAVE as well as data from other existing networks will be collected for inclusion in the Project MOHAVE data base. Measurements from the following sites, with sponsoring networks, are listed in the table below. Data will be collected and archived as hourly averaged values for the entire monitoring year.

Transmissometer and Nephelometer Monitoring Locations in the Southwest

Site	Sponsoring Network	Transmissometer	Nephelomet
Bandelier NM	NPS	✓	
Big Bend NP	IMPROVE	✓	
Bryce Canyon NP	SRP		✓
Canyonlands NP	IMPROVE	✓	
Chirichahua NM	NPS	✓	
Grand Canyon NP			
south rim	IMPROVE/SRP	✓	✓
in-canyon	NPS	✓	
Long Mesa	SCE		✓
Meadview	MOHAVE/SCE	✓	✓
Mesa Verde NP	IMPROVE	✓	
Page, Arizona	SRP		✓
Petrified Forest NP	NPS	✓	
San Gorgonio W	IMPROVE	✓	
Spirit Mt., Nevada	SCE	✓	✓
Tonto NM	IMPROVE	✓	
Guadalupe Mts. NP	NPS	✓	
Total		13	