Site Selection Criteria for the Optical Atmospheric Visibility Monitoring Telescopes

K. Cowles
Communications Systems Research Section

A description of each of the criteria used to decide where to locate the Atmospheric Visibility Monitoring (AVM) telescope systems is given, along with a weighting factor for each of them. These criteria include low probability of clouds, fog, smog, haze, low scattering, low turbulence, availability of security and maintenance, and suitability of a site for a potential optical reception station. They will be used to determine which three of several sites under consideration will be used for monitoring visibility through the atmosphere as it applies to an optical ground-based receiving network as may be used in NASA space missions in decades to come.

I. Introduction

The Atmospheric Visibility Monitoring (AVM) program is designed to set up three optical telescope systems on mountains in the southwestern United States to observe atmospheric transmission at possible laser communication wavelengths and monitor cloud cover correlation between the three different locations. A goal is to find three sites which experience a low correlation of weather patterns such that at least one of the sites is clear at any given time. A previous study has determined that with three such sites there is a joint probability of visibility of 94 percent [1]. Since this project will only use three telescope systems, to attempt to determine the actual amount of time in which at least one site is operational it is crucial to carefully consider the characteristics of each candidate observatory site.

II. Criteria

The criteria being considered for selection of AVM telescope sites are low probability of clouds, fog, smog, and haze; low particle scattering; low turbulence; availability of security and maintenance; and suitability of the site for a potential deep-space optical reception station. Also, the sites must exist in locations which exhibit low correlation of weather patterns. Each site being considered already has available roads, power, and telephone lines.

Each site will be rated on a 1–10 basis in each category. This rating will be multiplied by a weighted percentage (each weight based on the relative importance of that criteria to the project), and all the weighted ratings will be summed. Each site will then be judged based on this weighted comparison of conditions.

A. Low Probability of Cloud Cover, Fog, Smog, and Haze

Many factors go into the evaluation of the rating of each site for a particular characteristic. Sites are judged for their low probability of cloud cover, fog, smog, and haze based on a history of annual percentage of sunshine, orographic effects, the height of the temperature inversion, and low correlation with other sites in question.

In [2] is a study of annual percentage of sunshine for the continental United States, however, it is unclear how exact the estimates are in some areas because the amounts of annual sunshine can differ by several hundred hours in a distance of fifty miles (see Fig. 1). A minimum number of sunshine hours has been set at 3,200 hours, and the corresponding areas are shown in the figure. The number of sunshine hours does not take into consideration orographic effects, i.e., clouds "clinging" to some mountains. These effects vary with the altitude of the mountain. Generally, mountains and ridges above 9,000 feet will exhibit more of this behavior, although if the peak is above 12,000 feet, it may rise above the cloud line, as is the case with Mauna Kea. Another consideration is the height of the temperature inversion in relation to the elevation of the observatory. Fog and smog tend to stay below the inversion, so if the site is a few hundred feet above the inversion layer it should not generally be affected. The fourth item considered is the low correlation of weather patterns with other possible sites. The sites have already been broken down into three different areas, but some areas in Arizona, California, New Mexico, and Texas suffer from the same weather patterns, possibly to a smaller degree. For example, northern Arizona falls prey to some of the winter storms from California as well as some of the summer storms that are known to attack southern Arizona. New Mexico experiences the same summer storms as southern Arizona, but sometimes there is a time delay between sites if the storm is not too large. Several such relationships exist.

Lack of cloud cover is the most important criterion because the basis of this study is to find clear skies in at least one of three places as often as possible. Some astronomical observers look for other characteristics which are also considered here, but they are usually trying to find the best "seeing," even if it only happens for a small fraction of the time. "Seeing" refers to image quality, which is enhanced when atmospheric turbulence is low. Since the goal here is counting photons, not imaging, clear skies are needed as often as possible and atmospheric turbulence is a lesser consideration.

B. Low Particle Scattering

Low scattering is important to atmospheric visibility because as many photons as possible need to be detected. Future missions may require detection of extremely weak signals, thus locating a receiving station away from areas exhibiting large amounts of aerosols and larger particles (i.e., sand blowing from a desert area) would be desirable. Aerosol content diminishes with elevation, improving visibility with higher elevation. A shorter path through the atmosphere will decrease scattering making it possible to receive weaker signals since the amount of atmospheric attenuation will be lower. Vegetated areas tend to decrease the amount of dust by holding down the soil. Desert areas would cause problems with even the slightest wind. A small amount of wind is usually beneficial for turbulence effects, but larger amounts will cause scattering. Sites should therefore be located away from sources of aerosols and dust, and at elevations above 5,000 feet.

Scattering will be a larger problem during the daytime because signals will already be very weak compared to the background. Solar observatories are very concerned with scattering and daytime conditions, so choosing sites near solar observatories will prove beneficial for daytime studies.

C. Low Turbulence

Turbulence is caused by microthermal fluctuations in the atmosphere. It can cause effects such as scintillation, beam broadening, loss of spatial coherence, and phase distortions [3]. Astronomers characterize turbulence by rms image motion, a characteristic which has been measured at most of the observatories under consideration. Turbulence will degrade an optical communications signal by creating a larger blur circle at the receiver detector. Complete signal detection (capture) can still be accomplished in operational systems by opening up the detector field-of-view, although with an increase in system background noise susceptibility. Although cost considerations will not permit monitoring of the atmospheric turbulence at this time with the AVM project, published values of turbulence will be included in the site evaluation criteria. Because of its secondary impact on future possible operational systems, the turbulence criterion will be given a reduced weighting factor.

D. Availability of Security and Maintenance

The automated telescopes are designed to operate remotely, so there will be no operator present at the telescope to keep an eye on the equipment or to fix any problems that may arise. It is therefore important to locate the telescopes at a present observatory site, where someone familiar with the system could periodically check up on it for a small fee. If anything went wrong he or she could fix it, or at least make sure the roof was closed in inclement weather until JPL personnel could arrive and make repairs.

Some observatories are open to the public. People can walk around and look at the different telescopes and viewing galleries. In such a case a fence may have to be built around the telescope enclosure to make sure no one interferes with its operation or gets injured by a moving roof or telescope.

E. Suitability of a Site for a Potential Optical Reception Station

The results of the AVM research will provide knowledge of transmission, daytime conditions, and weather conditions at three different locations. If a ground-based optical receiver is developed in the future, it would be a great advantage to locate it at one of these sites providing the site proved to be favorable. Therefore, the feasibility of this potential future need is being taken into consideration. Any site under consideration for the AVM study should also be able to accommodate a larger transceiver station. The people who manage the land where the receiver would be located need to accept this idea and be willing to have a large facility operating there. Also, there needs to be enough space on the mountain to expand to a larger facility. Security and safety become an added issue for a large photon bucket and an earth-to-space laser system. Weighting for this criterion applies to how *well suited* a site would be for a potential station; however, for a site to be considered in the first place, it must be possible to locate a potential station at the site.

III. Rating

After consideration of all of the factors, it has been decided to weight the criteria in the following manner, as a percentage according to what is most important to the project:

	Percent
Low probability of cloud cover, fog, smog, haze	30
Low particle scattering	20
Suitability of the site for a potential optical reception station	20
Low turbulence	15
Availability of security and maintenance	15
	100

Each location will be rated on a 1 – 10 basis for each criterion. Then each criterion value will be multiplied by its corresponding percentage, and the weighted ratings will be summed. Site selection is a very inexact science, so the percentages and ratings chosen are loosely defined. However, they are the best estimates that can be given at this time. The benefits need to be weighted individually, while still producing a result which has some general meaning. Site selections for other telescopes have faced similar difficulties in determining what is important as the problem becomes more complex with logistical, financial, and technical factors [4].

These weighting factors are being used to rate sites which have not been already eliminated by other factors. Examples include Mt. Graham, where environmentalist opposition has limited new construction, or Kitt Peak, where there is no space to put another telescope.

Sites still under consideration include Mt. Hamilton, Table Mountain Observatory (TMO), Mt. Wilson, and Mt. Laguna in California; Mt. Hopkins, Mt. Lemmon, and the Hualapai Indian Reservation in Arizona; South Baldy and Sacamento Peak in New Mexico; and Mt. Locke in Texas. Data is presently being gathered which will allow the rating system to be applied to these sites.

IV. Conclusions

In weighting the criteria for the site selection, it has been determined that the most important factor is a low probability of cloud cover, fog, smog, and haze. If a site does not have clear skies to allow communications, none of the other factors matter. The criteria take into account the needs of the visibility monitoring telescopes as well as general considerations for a ground-based optical receiving station. A full list of criteria for a possible future optical transceiver is not known at this time, although a minimal set of criteria has been determined. These future needs are also given a fairly large weighting in the present criterion list.

References

[1] K. Shaik, "A Preliminary Weather Model for Optical Communications Through the Atmosphere," *TDA Progress Report 42-95*, vol. July–September, Jet Propulsion Laboratory, Pasadena, California, pp. 212–218, November 15, 1988.

[2] R. Lynds and J. Goad, "Observatory Site Reconnaissance," *Publications of the Astronomical Society of the Pacific*, vol. 96, pp. 750-766, September 1984.

[3] K. Shaik, "Atmosphere Propagation Effects Relevant to Optical Communications," *TDA Progress Report 42-94*, vol. April–June, Jet Propulsion Laboratory, Pasadena, California, pp. 180–200, August 15, 1988.

[4] N. J. Woolf, "Out of Site-Out of Mind, the Common Sense of Site Selection," in *Identification, Optimization and Protection of Optical Telescope Sites*, Flagstaff, Arizona: Lowell Observatory, p. 119, 1987.

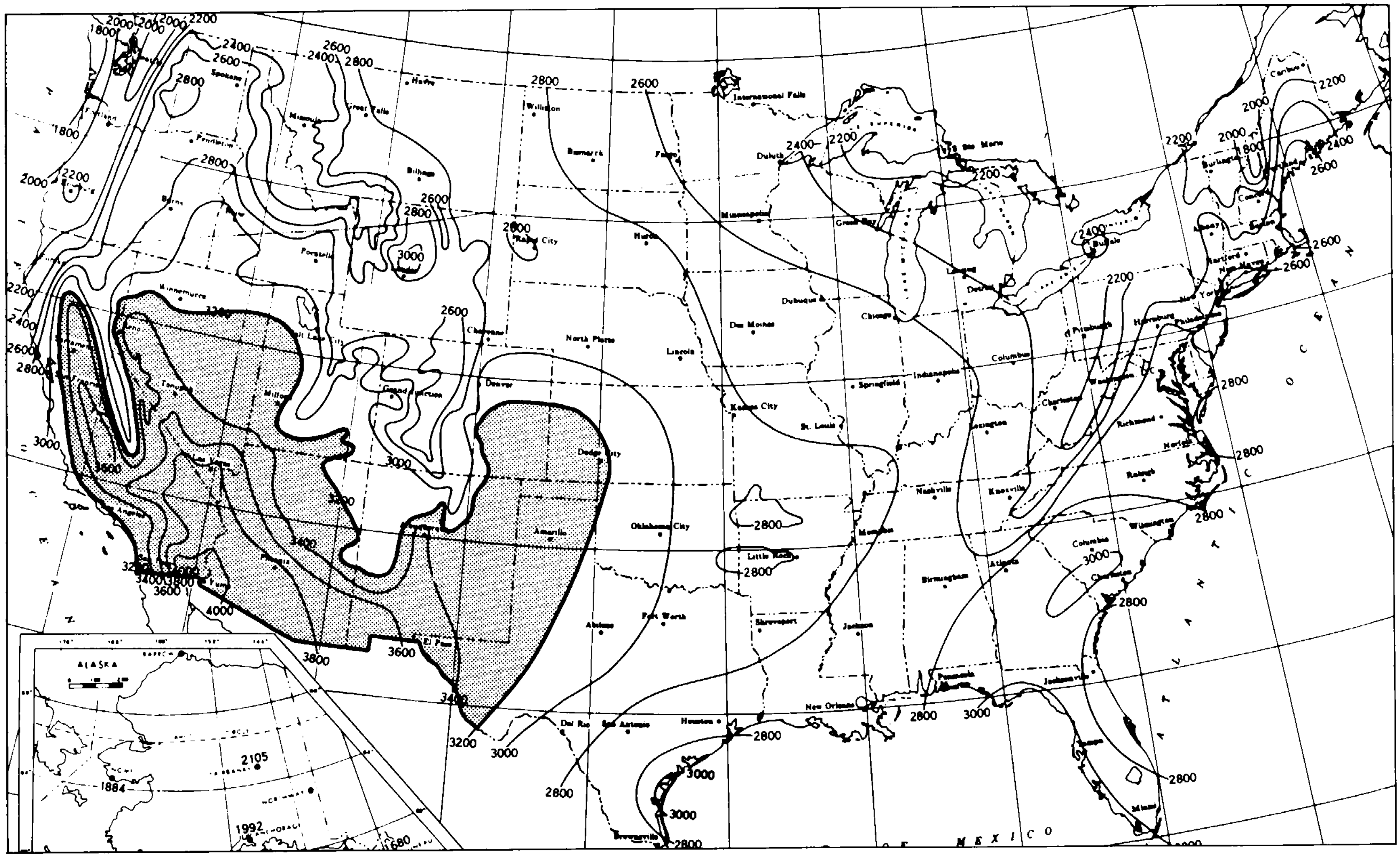

Fig. 1. Annual mean total hours of sunshine ≥ 3200; from [2].