Astronomy and Air Pollution

In May 1972, astronomer Charles G. Abbot of the Smithsonian Institution celebrated his 100th birthday in Washington, D.C. Several weeks before this event, astronomers gathered following a meeting of the American Astronomical Society in Seattle, Washington, to discuss progress in a field for which Abbot laid the foundation. The University of Washington sponsored a 1-day seminar entitled "The Use of Astronomical Techniques for the Study of Atmospheric Deterioration," at which the utilization of astronomical measurements to determine properties of the atmosphere and to monitor air pollution was discussed (*1*). Two topics were considered: the use of photometry to study the extinction of light by small particles in the atmosphere, and the use of spectroscopic techniques for determining the concentrations of molecular contaminants.

A comprehensive study of the aerosol content of the atmosphere in North America, South America, and Africa was provided by the efforts of C. G. Abbot and his co-workers, who determined the atmospheric extinction in connection with the Smithsonian's study of the solar constant from 1902 to 1950. Abbot was exceedingly careful to determine the transparency of the atmosphere accurately and frequently during the many years of the solar constant program. The extinction over the spectral range from 3500 Å to 1.6 μm showed that the atmospheric aerosol content is lowest in the winter and highest in the summer, an effect also noted by others. A further correlation was found between the atmospheric transparency at all wavelengths and the humidity, in the sense that under circumstances of high humidity, the transparency is low. Scientists from the National Aeronautics and Space Administration (NASA) and the San Diego State College, analyzing Abbot's data, found a connection on a worldwide scale between the atmospheric extinction and volcanic activity. This connection was also noted by workers at Lowell Observatory in Arizona. In the latter case, however, the extinction measurements were carried out at night by utilizing photometry of the outer planets instead of direct photometry of the sun. At Lowell Observatory, at least, the average extinction for 1972 is not significantly different from the lowest value observed during the 1950's, which suggests that extinction variations in northern Arizona, until now, have been mainly affected by volcanic rather than human activity.

A large number of observatories around the world have submitted extinction data for possible atmospheric use to Project ASTRA (Astronomical and Space Techniques for Research on the Atmosphere) at the University of Washington. They have been examined sufficiently to show the presence of seasonal variations of extinction similar to those reported by NASA. There is also a definite decrease of extinction with altitude, which indicates an aerosol scale height of about 2 km. It is interesting to compare the data from two observatories in India, one in Hyderabad and one 56 km away from the city. The latter shows very large extinction values that are virtually indistinguishable from those obtained at the observatory in the city itself, which suggests a widespread uniformity of aerosol. Data collected from astronomers who have used Mt. Wilson have shown a steady deterioration over the last 60 years that can only be due to the increased pollution of the atmosphere in the Los Angeles valley. It was noted at the meeting that Mt. Wilson was abandoned by the Smithsonian as early as 1920 because of atmospheric pollution. Abbot had written (*2*), "Mount Wilson atmospheric conditions had proved unsuitable, and seemed steadily deteriorating for these exacting purposes as Los Angeles and neighboring towns expanded."

Among the surprising results obtained in the studies of atmospheric extinction was the discovery by several astronomers of what appeared to be an anomalous wavelength dependence. The extinction due to aerosol is greater in the red than in the blue. This seems to be an effect that occurs frequently only in sites where the aerosol content is extremely low. However, on the rare occasions when this anomalous wavelength dependence is in effect during periods of high aerosol content, a remarkable result occurs: Objects are blued instead of reddened, and a true "blue moon" can occur. Calculations by Project ASTRA scientists using the Mie equations suggest that for this to happen there must be a dominance of particles of radius near 0.5 μm, the geometric standard deviations must be small, and the imaginary part of the refractive index cannot be larger than about 0.01. Thus, the anomalous extinction characteristic itself may be a property of atmosphere aerosol that is subject to pollution effects by increases in light absorption by soot and similar particles.

Comparisons of nephelometric data with astronomical extinction measurements have provided new possibilities for the interpretation of each type of measurement in terms of the characteristics of particles and their atmospheric distribution. Reviews of problems in the interpretation of aerosol densities as determined by collections on filters, by lidar backscattering measurements, and by other techniques related the astronomical measurements more closely to traditional determinations of the nature and amount of atmospheric contaminants.

High-resolution spectroscopy has long been an important tool for investigating stellar and planetary atmospheres, and many of its techniques have been applied to the study of the minor constituents of the earth's atmosphere. The application of spectroscopic techniques in monitoring these constituents and their concentrations was discussed. In particular, it was suggested that certain spectral lines of CH_4 might be used to monitor its terrestrial abundance and to serve as an atmospheric thermometer through its rotational temperature.

Researchers at the University of Tennessee, Kitt Peak National Observatory, the University of Hawaii, Pomona College, and the University of Washington have been studying several particularly noxious gases, such as SO_2 and NO_2, in the laboratory and in the atmosphere, as well as theoretically. One novel approach involves a photometric system for matching the absorption minima and maxima of the spectrum of a pollutant in a restricted wavelength region with Fabry-Perot filters. The technique is suitable for use on small telescopes, and would thus allow scientists to measure the temporal variations of the contaminants in areas of moderate to heavy pollution by using either fixed urban telescopes or portable telescopes. It was suggested that it might even be possible to measure the movement of clouds of smog over the telescope. This technique has the advantage, too, that the spectrum of the star used as a source is not critical, as long as it is not variable and there are not too many deep absorption lines in the band under study.

Viewed by the meteorologist, the

Seattle meeting confirmed an opinion that is held by certain astronomers that their data are a useful adjunct to routine air pollution monitoring activities. While there are limitations in astronomical data, these are usually smaller and better known than the errors in other types of data. Astronomers can provide (i) nighttime extinction data, (ii) a new set of remote locations as well as some new urban ones, (iii) a lengthy data record (beginning in 1902 in the case of Abbot's data), and (iv) a variety of new measuring techniques.

Some conclusions reached through astronomical research that are of special interest to atmospheric scientists are as follows:

1) No global trends in extinction that can be ascribed to human causes have been detected at remote locations so far.

2) Both volcanic activity and some apparently natural cycling of the biosphere affect astronomical extinction; the latter effect produces an annual pattern.

3) The transparency of the atmosphere near cities continues to deteriorate in most cases.

4) The anomalous wavelength dependence of extinction suggests a unique aerosol size distribution in background locations.

Also from the meteorological viewpoint, a number of gaps became apparent in available knowledge. Perhaps the most obvious one is the need for coordinating extinction measurements with local and synoptic meteorological data. Certain biases exist because of the lack of extinction data for cloudy periods. Also, effects have been discovered that are due to dust derived from upslope winds on mountaintops. Since regional effects of human activity will certainly be apparent before global effects, studies of the transport of air masses to and from observing sites may be possible.

Finally, another kind of pollution is of less concern to meteorologists but of vital concern to astronomers. Light pollution, caused by the rapid expansion of outdoor lighting in cities and even in open western countryside, has been of great concern in many observatories recently. Greater public awareness of the problem, research on more efficient lamps (from the point of view of increased ground illumination and reduced light loss to the sky), and political action through the introduction of city ordinances are among the goals of astronomers in various research centers of the Southwest.

At the Seattle meeting astronomers emphasized their concern about the deterioration of the atmosphere, through which most of the information about the universe must pass. Progress in the application of certain kinds of astronomical data to research on atmospheric deterioration has begun. Much more must be done to understand fully the implications of the data and even more, of course, to turn the tide. Charles Abbot may not have expected that his data and methods would be used for these purposes, but his are the best optical data available over such a long time base and they have come to us only because of his painstaking care in gathering and recording all available information in his experiments.

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References

1. N. Laulainen and P. W. Hodge, Eds., *Project ASTRA Publication 15* (Univ. of Washington, Seattle, 1972).
2. C. G. Abbot, *The Sun and the Welfare of Man* (Smithsonian Institution, New York, 1929), p. 68.

Forthcoming Events

January

9–12. American **Astronomical** Soc., Las Cruces, N.M. (H. M. Gurin, AAS, 211 FitzRandolph Rd., Princeton, N.J. 08540)

9–13. National Soc. of **Professional Engineers**, Salt Lake City, Utah. (P. H. Robbins, NSPE, 2029 K St., NW, Washington, D.C. 20006)

14–19. **Protein Phosphorylation in Control Mechanisms**, Miami, Fla. (W. J. Whelan, Dept. of Biochemistry, School of Medicine, Univ. of Miami, P.O. Box 875, Biscayne Annex, Miami 33152)

15–16. **Regional Environmental Management** Conf., San Diego, Calif. [L. E. Coate, REMC, County of San Diego, Environmental Development Agency, Integrated Regional Environmental Management (IREM) Project, 1600 Pacific Hwy., San Diego 92101]

15–17. **Lunar Dynamics and Observational Coordinate Systems**, Houston, Tex. (J. D. Mulholland, Lunar Science Inst., 3303 NASA Rd. 1, Houston 77058)

15–18. American **Crystallographic** Assoc., Gainesville, Fla. (Mrs. E. E. Snider, ACA, 335 E. 45 St., New York 10017)

15–19. **Geophysics of the Earth and the Oceans**, 2nd intern. conf., Australian Inst. of Physics and Australian Soc. of Exploration Geophysicists, Sydney. (B. D.