VISIBILITY IN GEODESY

By

K. Horváth

Department of Surveying, Institute of Geodesy, Surveying and Photogrammetry,
Technical University, Budapest

(Received November 10, 1976)

Visibility is an increasing problem not only for meteorologists, but also for surveyors and specialists of aviation. Surveyors carry out measurements in the atmosphere, therefore visibility determines the range and accuracy of both traditional geodetic measurements — primarily horizontal and height goniometry — and of up-to-date electro-optical telemetry.

Determination of horizontal and slant visual range is important not only for scientific reasons, but for nearly all sections of transport: in navigation, in rail and road transport, and above all, in aviation, systematic meteorological observations are necessary of long standing for safe taking off and landing.

This problem has already been treated by us [31], here particulars of statements will be discussed.

Before examining this complicated problem, let us see the definition of visibility.

Meteorological visibility — As defined by the Meteorological World Organisation, it is the greatest distance at which a black object of suitable dimensions can be seen and recognized against the horizon sky, or, in the case of night observations, could be seen and recognized if the general illumination were raised to the normal daylight level.

Optical visibility is the greatest distance at which a given object is seen and perceived geometrically — true to form and size — under given illumination and atmospheric conditions.

Geometrical visibility is the greatest distance for a light beam from an object reaching the observer without extinction.

Theoretical and empirical formulae for determination of visibility establish relations between the physical conditions of atmosphere and visibility.

Based on research work by Koschmieder [1, 2], Middleton [3, 4, 5], Kaster [6, 7] and Möller [6, 8], certain suppositions and neglections are used in determining the theoretical visibility values, thus, Earth curvature and atmospheric refraction effect are neglected in our examinations.

Furthermore the value of the visual extinction coefficient σ is supposed to be constant along the visual ray, near the soil surface. The observing eye has a sensivity maximum in bright-field adaption circumstances at wave length $\lambda = 0.555$ mμ. The relationship

$$K_0 = \frac{B_0 - B_0'}{B_0'} \tag{1}$$

defines the contrast of the mark at the end point of the base line under investigation relative to the background. The value of K_0 is negative, when the mark of an illumination intensity B_0 is darker than the background of illumination intensity B_0'; it is positive, when the mark is brighter than the background. As only horizontal visibility near the ground is investigated, the background is substituted by the celestial horizon, brilliance of which (surface brightness) is B_H, thus:

$$K_0 = \frac{B_0 - B_H}{B_H} = \frac{B_0}{B_H} - 1\,. \tag{2}$$

Let us examine the mark at distance R. The contrast is expressed by the *Lambert-Bouguer* relationship:

$$K_R = K\ e^{-\sigma R}\,. \tag{3}$$

In this exponential expression, σ is the visual extinction coefficient valid for the entire visible range of the spectrum. In the value of σ two components are expressed: the absorption coefficient which can be neglected as a small value except in strong smoke pollution, and the scatter coefficient.

It follows from (2) and (3) that

$$K_R = \left(\frac{B_0}{B_H} - 1\right) e^{-\sigma R}. \tag{4}$$

If length R of the basis line exceeds the visual range s and the mark is still visible, then, by analogy to (1):

$$\left|\frac{B_R - B_R'}{B_R'}\right| = |K_R| > \varepsilon \quad \text{(a constant value)} \tag{5}$$

a relationship valid for $R > s$ and a relatively great angle of view.

According to the law of *Weber-Fechner*, when at the observer's place the apparent contrast between mark and background diminishes to the contrast threshold value ε of the human eye, the mark is just at the end point of visual range, i.e. just disappears against the background.

For small viewing angles δ the contrast threshold values ε cannot be considered as constant either.

It follows from (4) and (5) that

$$\varepsilon = \left(\frac{B_0}{B_H} - 1\right) e^{-\sigma s}\,, \tag{6}$$

or in logarithmic form

$$\sigma s = -\ln\left|\frac{\varepsilon}{\dfrac{B_0}{B_H} - 1}\right|, \tag{7}$$

hence the visual range s:

$$s = \frac{1}{\sigma}\ln\left|\frac{1}{\varepsilon}\left(\frac{B_0}{B_H} - 1\right)\right|. \tag{8}$$

Visibility is thus function of extinction coefficient σ, of the contrast threshold value ε of the human eye, of the brightness B_0 of the investigated mark and of the brightness B_H of the horizon sky. Among the arguments the extinction coefficient can be measured with suitable instruments, also the brightness B_H of the horizon sky is relatively easy to establish, though there is some difficulty in the fact that its value is a function of the solar altitude, but the brightness of the investigated mark B_0 and the contrast threshold value ε of the human eye are somehow complexer quantities.

Eq. (8) is the most general formula of visibility. The relation simplifies by supposing the investigated mark to be absolutely black, because then $B_0 = 0$. Eq. (2) yields in this way the so-called real contrast, its value being: $K_0 = -1$. Taking this into consideration, the visibility is:

$$s = \frac{1}{\sigma}\ln\frac{1}{|\varepsilon|}\,. \tag{9}$$

The visibility of an absolutely black mark can be stated to be independent of the horizon sky brightness, hence of the solar altitude. Therefore visibility is only function of the mean value of visual extinction coefficient expressing the physical condition of the air, and of the contrast threshold value of the human eye.

Koschmieder [1] considers the contrast threshold value of the human eye with the theoretical value $\varepsilon = 0.02$, yielding a normal visibility:

$$s_N = \frac{3{,}912}{\sigma}\,. \tag{10}$$

Thus the normal visibility is inversely proportional to the extinction coefficient value.

This relationship is used in constructing instruments for determining visibility, based on determination of the extinction.

According to (10), FOITZIK [9, 10, 11, 12, 13] defines the normal visibility as the distance from which a black mark of great visual angle $\delta > 1°$ is just visible and perceptible in case of a homogeneous overcast sky, taking as relative contrast the theoretical value $\varepsilon = 0.02$ of the contrast threshold of the human eye against daylight horizon sky.

The contrast threshold value of the human eye is function of the viewing angle at which an investigated mark is seen, furthermore function of the background brightness.

BLACKWELL [14] carried out 90 000 test determinations with 19 observers during his thorough investigations. The contrast was sensed by 10 to 95% of the observers. The tests comprised round objects of various sizes (visible under 0.6 to 360 steradians) and different background brightnesses (5×10^{-4} to 4×10^2 cd/m^2). Fig. 4 in [31] shows the adjusting diagram of the test results. It is characteristic for the linear sections of the diagrams that the product of the surface by the brightness is a constant value. In this range the illuminated mark can be considered as a point light source. The contrast threshold value is nearly constant at a viewing angle of $\delta > 1°$ and daylight illumination $B_0' > 10^2$ cd/m^2. An important increase of the contrast threshold value can be reckoned with at a brightness $B_0' > 10^4$ cd/m^2, due to dazzling of the human eye.

At dusk or night illumination ($B_0' < 10^2$ cd/m^2) the value of the contrast threshold increases.

It is striking that the $B_0' =$ const. lines densify below the value 10^{-2} cd/m^2. This is due to the physiology of the human eye, namely over a surface brightness of about 10^{-2} cd/m^2 the eye is in bright adaption condition, and is the most sensitive at a light of wave length $\lambda = 0.555$ mμ. Light is then perceived by the retina cones (foveal sight). The eye is in a dark adaption below a surface brightness of 10^{-2} cd/m^2; in this condition sensivity is the highest at a wave length $\lambda = 0.515$ mμ. Here the thinner rods of the retina take part in the light perception (parafoveal sight). Adaption time for the transition from dark to bright is about 3 minutes, but for the transition from bright to dark nearly 30 minutes.

To determine the theoretical contrast threshold at different viewing angles δ, test results of BLACKWELL [14] and MIDDLETON [4] may be used.

Be the brightness of the horizon for completely overcast celestial background:

$$10^2 \text{ cd/m}^2 \leqq B_H \leqq 10^3 \text{ cd/m}^2$$

and

$$B_H = B_0' . \tag{11}$$

At the contrast threshold $|\varepsilon_{50}|$ the perception probability of the investigated mark is 50%, then, according to [14]:

$$\log|\varepsilon_{50}| = -\frac{1}{0{,}197\dfrac{1}{\log\delta} + 0{,}0489\log\delta} - 0.849(\log\delta - 2)^2 + 2.540. \tag{12}$$

The symbol of absolute value refers to the possibility of either a positive sign (a mark lighter than the background) or a negative sign (a mark darker than the background) for ε.

Eq. (12) can be transformed for the 100% contrast threshold value:

$$\log|\varepsilon_{100}| = \log|2\varepsilon_{50}| = \log|\varepsilon_{50}| + \log 2 \tag{13}$$

that is:

$$\log|\varepsilon_{100}| = -\frac{1}{0{,}197\dfrac{1}{\log\delta} + 0{,}0489\log\delta} - 0.849(\log\delta - 2)^2 + 2.239. \tag{14}$$

The contrast threshold value ε determined by Eqs (12) and (14) can be substituted into Eqs (8) and (9) for determining the visibility.

A somewhat simpler relationship is obtained by dividing the curve $B_H = B'_0 = 10^3$ cd/m^2 into linear ($\log\delta < 0.8$) and hyperbolic ($\log\delta > 0.8$) lengths

$$\log|\varepsilon_{50}| = -\frac{1}{0{,}197\dfrac{1}{\log\delta} + 0{,}0489\log\delta + 0{,}191} \tag{15}$$

and taking (13) into consideration

$$\log|\varepsilon_{100}| = -\frac{1}{0{,}197\dfrac{1}{\log\delta} + 0{,}0489\log\delta + 0{,}191} - 0{,}301\,. \tag{16}$$

In case of smaller viewing angles ($\delta < 10^{0.8'} = 6.31'$) the Kasten and Möller linear equation is used:

$$\log|\varepsilon_{50}| = -1.767\log\delta - 0.671 \tag{17}$$

and

$$\log|\varepsilon_{100}| = -1.767\log\delta - 0.972. \tag{18}$$

Based on further simplification by Kasten and Möller, the viewing angle δ is substituted by a simple trigonometric relationship:

$$\mathrm{tg}\,\frac{\delta}{2} = \frac{D/2}{s} \tag{19}$$

where D is the diameter of the circular mark, and s the visibility. In case of small viewing angles it can be written, with an error of about 1%:

$$\delta = \frac{D}{s} \tag{20}$$

for $\delta < 1.835 \times 10^{-3}$; expressing the value δ in radians leads to the following relationship:

$$\log|\varepsilon| = \log|K| = \log\left|\frac{B_0}{B_H} - 1\right| = - 1.767 \log \delta - 6.620 + 0.434\, \sigma\, s. \tag{21}$$

In case of an ideally black mark, the left side of the equation is zero.

In his extensive tests with 10 observers, Middleton obtained contrast threshold limit values

$$0.01 < \varepsilon < 0.15\ ;$$

taking all the observations into account, he obtained the mean value

$$\varepsilon = 0.031\ .$$

According to BRICHAMBAUT [15] the contrast threshold ε is in the range:

$\varepsilon = 0.02$ for a trained observer;

$\varepsilon = 0.06$ under unfavourable observation circumstances;

$\varepsilon = 0.03$ generally accepted mean value.

In aviation meteorology under unfavourable conditions the value $\varepsilon = +0.05$ is recommended. The extreme values of the threshold value show about 15% relative deviation even for one and the same observer.

From the aspect of geodetic measurements it is noteworthy that the same regularity is observed for surveying by theodolite. However, the contrast reduction due to the optic system has to be taken into consideration. The contrast threshold variation as a function of the brightness of the theodolite field of view is shown in Fig. 1.

Perceptibility of survey beacons under field conditions also influences the visibility value, which is a function of sharpness of sight and of other psychological factors.

In connection with the contrast threshold value of the observer it must be noted that its value in geodetic measurements depends — like that of the pilot in aviation meteorology — on the physiological condition of the observer, therefore visibility determined from the mean contrast threshold value must be considered only as a representative value.

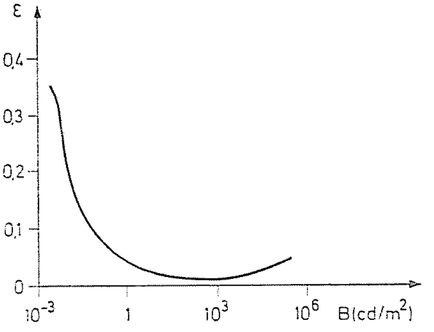

Fig. 1. Effect of light intensity of the theodolite field of sight on the contrast threshold value of human eye at a visual angle greater than 1°

The value of the visual extinction coefficient σ depends on the concentration of particles larger than the absorbed gas molecules, the colloids and aerosols present in the atmosphere. These particles weaken the light arriving through the atmosphere:

- partly in consequence of diffuse scattering on particles of radii r smaller than, or equal to the wave length λ of light;
- partly because of reflection, for particle radii greater than the wave length of light.

The value of the diffusion coefficient depends on:

a) the Rayleigh coefficient; in case of colloids and concentration nuclei with radii $r < 0.5 \cdot 10^{-5}$ cm;

b) the absorption coefficient of haze — according to the theories by Mie [16] and Stratton [17], for particle radii r of 10^{-5} to 10^{-3} cm;

c) the water vapour absorption coefficient.

Based on the theories by Rayleigh, Mie, Stratton, and the experiments of Gaertner [18, 19], floating particles with radii $r = (0.2$ to $0.8)\ 10^{-4}$ cm can be stated to cause greater diffusion in the short wave than in the long wave range of the electromagnetic spectrum. On the other hand, fog particles of $r > 10^{-4}$ cm result in greater diffusion in the long wave range; presence of particles of $r > 2 \cdot 10^{-4}$ cm causes a decrease of the diffusion in the wave range $\lambda > 5$ m.

Aqueous solutions of hygroscopic materials present in the atmosphere, the so-called nuclei (10^{-6} cm $\leq r \leq 10^{-1}$ cm) in form of veil, mist, haze and fog, have a darkening effect. The size of the hygroscopic nuclei grows with increase of the relative humidity by causing more and more water to condense. Up to $r = 5 \times 10^{-5}$ cm they cause selective diffusion of the light, this is the veil of bluish hue in reflection. With further growth of size, selectivity is off, and a practically colourless fog is formed. Mie determined the light intensity of an investigated direction by means of the electromagnetic wave theory. The value of light intensity depends on the ratio of the particle circumference to the wave length $2\,\pi r/\lambda$ and on the refractive index of the particles (for water $n = 1.33$). From the spherical integral of the light intensity function, the entire quantity of diffuse light can be determined. It is noteworthy that in general it is greater than that which actually hits the drop. This is explained by diffraction. For larger drops of the fog the geometrical diffusion theory of BRICARD [20] can be used.

The size of fog particles, determined by several researchers, is of a distribution that can be expressed by a unimodal function between particle sizes $r = 4 \cdot 10^{-4}$ cm to $10 \cdot 10^{-4}$ cm.

Interference of the aerosols present in the atmosphere may greatly reduce visibility. Relation between fog and visibility is shown in Table 1.

Distribution in time and space of visibility less than 1000 m is decisively influenced by wind, atmospheric pollution, temperature distribution (vertical and horizontal lapse rate) and humidity of the air.

Table I

Scale number	Daylight visibility	Fog, mist or haze
0	Less than 50 m	Dense
1	50— 200 m	Thick
2	200— 500 m	Medium
3	500—1000 m	Moderate
4	1—2 km	Mist
5	2—4 km	Slight mist or haze
6	4—10 km	Slight mist or haze
7	10—20 km	—
8	20—50 km	—
9	Above 50 km	—

In case of calm, air pollution — primarily by traditional energy carriers — is very high. The free energy of the haze depends on the relative atmospheric humidity. This free energy determines the degree of interactions between the haze, the hygroscopic, soluble and insoluble macro-particles. Smoke particles are condensation nuclei, increasing the stability of fog drops. In the environment of cities, quickly forming and slowly dissolving fogs are frequent and visibility persists below 100 m (in London, visibilities below 10 m occur). Materials such as sulphur (sulphuric acid) from exhaust products of motor cars modify the relative humidity balance and at the same time its effect on light diffusion.

Fett related air pollution and visibility as:

$$M = \frac{1{,}8 \cdot 10^6}{s} \; [\mu \, g/m^3] \tag{22}$$

where M is the mass concentration in $\mu g/m^3$, s is visibility in m.

CHARLSON [22] deduced a similar relationship by using an integrating nephelometer for atmospheric aerosol measurements:

$$M = 3.8 \cdot 10^5 \cdot \sigma_{0,5\mu} \; [\mu g/m^3] \tag{23}$$

where $\sigma_{0,5\mu}$ is the diffusion factor for a wave length $\lambda = 0.5$ mμ, M is the mass concentration.

Comparing relationships for visibility and mass loads, GRIGGS [23] established that these yielded essentially similar results and expressed the actual situation.

Investigations conducted on different continents and in different seasons proved that the visibility values of meteorological stations — especially in the environment of cities — yielded conclusions about the long-range trend of air pollution, and data valuable also for environment protection.

Investigation of visibility changes during rain and snowfall

Visibility decreases not only in fog but also because of rain and snowfall.

From examination of the microstructure of rain POLIAKOVA [24] established a relationship between rain intensity and visibility:

$$s = 14 \; \mathrm{I}^{-0,74} \tag{24}$$

where s = visibility in km, I = rain intensity in mm/h.

The relationship between snowfall and visibility, according to POLIAKOVA and TRETIAKOV [25] is:

$$s = 0.94 \; \mathrm{I}^{-0,91} \tag{25}$$

or, in approximative form:

$$s = \frac{1}{\mathrm{I}} \tag{26}$$

1 mm/h is the rain equivalent of snowfall intensity.

According to these relationships upon medium rain intensity of 4 mm/h, visibility decreases to 5 km, whereas in a medium snowfall of 4 cm/h, visibility is 260 m (1 cm snow corresponds to 1 mm rain).

Richards [26] determined visibility as a function of snowfall intensity per hour from his observations carried out in the winter months for 12 years at *Malton* (Canada) Airport. From the mean value of increasing snowfall, he constructed the probable visibility curve, which shows good agreement with the diagram computed from the relationship of Poliakova and Tretiakov (Fig. 2).

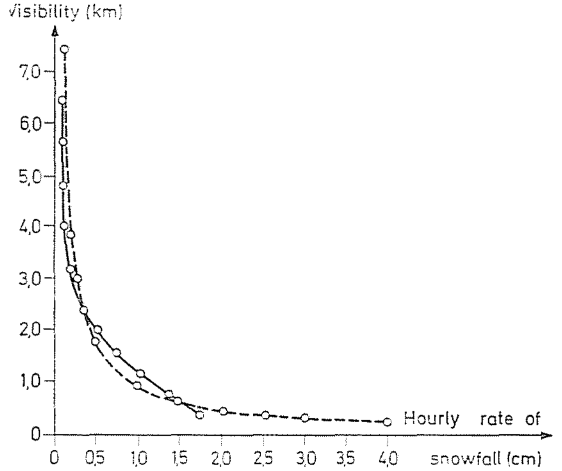

Fig. 2. Expected visibility curves calculated from the mean value of snowfall intensity according to Richards (smooth line), Poliakova—Tretiakov (dotted line)

Jefferson [27] established from the observation data of meteorological stations in the Atlantic region that heavy showers diminished visibility less than continuous rains of similar intensity. Namely — because of its smaller spatial (horizontal) extension — the shower obscures only part of the distance between the observing station and the investigated point, whereas continuous rain blurs the entire distance. Furthermore it has to be taken into consideration that showers over the sea occur generally in the presence of cold air masses, and the fog-free condition, characteristic for this atmosphere, improves also visibility conditions. For mean values of visibility in dry weather, the effect of haze or fog, generally present over the sea, is of importance. It is noteworthy that in case of weak showers, good visibility is relatively more frequent than in dry weather. This can be attributed to northwest winds of high or medium intensity, usual concomitants of showers, dissipating the fog over the water surface.

Practical determination of visibility

Until recently, visibility, the meteorological visual range where the background contrast of a given object is just identical with the contrast threshold of the observer, has been determined by setting out marks for visual estimation. This method is still in use at most meteorological observatories as well as at airports with no busy traffic. In aviation meteorology, however, visibility along the runway in take-off and landing direction is the greatest distance at which definite lights of the runway are still visible above the centre line of the runway from a height corresponding to the eye level of the air men at touch down. From this definition the difficulties are immediately apparent: to place the observer above the centre line of the runway at eye level of the air man seems to be nearly impossible. Moreover observations have to be continuous and the data of visibility changing with time and space along the runway have to be transferred each 15 sec. to the control tower. The observer can be replaced by a television camera, making this way the observations semi-automatic, but even in this case at least one camera per runway has to be handled continuously, thus operators are indispensable.

These difficulties necessitated the development of automatic measuring and recording instruments for the determination of visibility. Instruments in actual use belong to either of two groups:

1. Transmissometers measuring the optical transmittance of the tested atmosphere. Taking into consideration different parameters, continuous values of visibility can be determined from the optic transmittance. This instrument has been developed taking requirements for the measuring range and lifetime of automatic and distant signalling meteorological stations, e.g., meteorological satellites, into consideration.

2. Instruments measuring the extinction coefficient, i.e. light beam losses after passing through the tested atmosphere. Disadvantage of these instruments is to yield reliable results only in case of nuclei consisting of drops of water, whereas for frost fog, snow and industrial pollution no reliable values can be expected.

Effect of visibility on geodetic measurements

1. In traditional — horizontal and altitude angle — measurements the chief requirement is the reciprocal visibility (and sighting). Namely, the sighted survey beacon has to be seen definitely for the sake of sighting with $\pm 0.5''$ to $\pm 2''$ accuracy depending on the performance of the instrument in actual use. When working with strongly magnifying theodolites ($M = 30$ to 50 times) the marked loss of contrast due to the instrument has to be reckoned with.

With regard to all this, it can be stated that the sighting distance should not exceed about one half of the visual range.

2. In the use of up-to-date electro-optical distance measuring, mutual vision between the measuring instruments and the reflecting surface is a paramount requirement. Telemeters namely work with a sharp measuring beam. In poor visibility conditions the most difficult operation is the sighting of the reflecting surface. Sighting is easier using a cylindrical lens, in spite of a great reduction of light intensity. When measuring over greater distances, because of poor visibility, reflected light cannot be sighted and received even by a searching theodolite.

In a weather free of fog and heavier haze, electro-optical telemetric instruments now in use generally permit 5 km of visibility, under Hungarian conditions. For greater distances a minimum requirement is recognizability of at least the outlines in the environment of the other end point. Namely, if the sharp measuring beam misses the reflecting instrument, because of inaccurate sighting or of some minute displacement due to handling of the instrument, the measuring program fails.

Knowledge of the interaction between visibility and the range of the measuring instruments as well as of the probable meteorological vision, contributes to planning more reliably the measuring program. In Fig. 5 of [31] visibility is shown according to experiments made by RICHTER and WENDT [28, 29]. In this way the range is up to 3 km about one third, up to 7 km approximately one fifth of visibility. For the relation between visibility and range there exist empirical equations. The relatively small range is due to losses of the focussed measuring light beam depending on the extinction coefficient, because the measuring beam passes twice the distance between the instrument and the reflecting surface, while the sighting point has still to be kept clearly evaluable. Decrease of the visual range is of great importance both for accuracy and economy in choosing adequate periods of measurements, therefore the expected values of the visual range have to be known. To increase practical efficiency of electro-optical telemeters, the theory of interaction between visibility and range still awaits development. For the possibility to fulfill this task, an extensive measuring program seems necessary to determine the value of the measuring light loss by an instrument measuring the exact extinction coefficient.

From the interaction of meteorology and geodesy, the development of instruments suitable to a precise and rapid determination of the light loss value is expected to comply with practical requirements. The practical use of the developed instruments would permit an exacter prediction of visual range and accuracy of electro-optical telemetry and also the measuring program could be planned more accurately.

Definitions of photometric quantities used in the study:

1. Unit of light intensity or brightness:
   1 cd (Candela) = 0,981 I.C. (International candle) = 1,107 HC (Hefner candle).
2. Light intensity E; Lambert-value, brightness of the evenly lighted dull surface receiving 1 lumen of light on every cm^2.

$$\text{Phot} = \frac{\text{Lumen}}{\text{cm}^2}; \quad \text{Lux} = \frac{\text{Lumen}}{\text{m}^2}$$

3. Light intensity B, unit

$$\text{Stilb} = \frac{\text{cd}}{\text{cm}^2}; \quad \text{Apostilb} = \frac{\text{cd}}{\text{m}^2}.$$

4. Extinction coefficient σ expresses the weakening of light while passing the atmospher e:

$$\sigma = -\ln \tau$$

where τ is the transfer coefficient, reciprocal of the ratio of the entering to the leaving fluxus:

$$\tau = \frac{F}{F_0}.$$

5. Contrast K is the difference of light intensities (or brightnesses) between two surfaces:

$$K = \frac{B_1 - B_2}{B_2}$$

for $B_1 > B_2$, K has a positive value.

Summary

Knowledge of visual range and reckoning with its variation is a fundamental requirement both in geodetic measurements and in transport. In aviation meteorology, systematic observation of visibility is a long-standing requirement for safe taking off and landing.

Accuracy requirements have already exceeded reliability of visual estimation, therefore different instruments have been developed for an exacter determination of visibility. Manysided requirements are for the most part fulfilled by instruments measuring extinction coefficient.

Knowledge of visibility is important both in scientific and in practical geodesy. Fundamental condition of traditional geodetic measurement is the definite visibility and sighting of the sighted point. Decrease in visibility reduces accuracy and range of the measurements.

A similar problem arises in electro-optical telemetry, where mutual sight between the instrument and the reflecting surface is required. Visibility influences decisively the range and the accuracy. Visibility might change definitely as a function of space and time, also because of changes occurring in physical characteristics of the fog. Small changes in wind velocity and direction might cause a relatively rapid change of visibility.

Thus, requirements of geodetic measurements are not met by knowing the statistical probability of visibility; it is indispensable to take atmospheric factors influencing the representative value into consideration. Interaction between meteorology and geodesy lets expect the development of instruments suitable for accurate and rapid determination of the light loss value.

References

1. Koschmieder, H.: Theorie der horizontalen Sichtweite. Beitr. Phys. frei Atmos. 1924.
2. Koschmieder, H.: Luftlicht und Sichtweite. Naturwiss. 26. 1938.
3. Middleton, W. E.: Note on the Visual Range of White and Grey Objects. Quart. J. Roy. Meteor. Soc. 1947.

4. MIDDLETON, W. E.: Visibility in Meteorology. Compend. Meteor. Boston, 1951.
5. MIDDLETON, W. E.: Vision through the Atmosphere. Toronto, 1952.
6. KASTEN, F.—MÖLLER, F.: Theoretical Investigation of the Visibility under Special Atmospheric Conditions. Universität Mainz. Meteor. Geophys. Inst. Final Report. 1959.
7. KASTEN, F.: Sichtweite und Albedo insbesondere im Polargebiet. Beitr. Phys. Atm. 1961.
8. MÖLLER, F.: Über die Farbsicht und die Himmelsfarbe am Tage. Arch. Meteor. Geophys. Klimatol. 1953.
9. FOITZIK, L.: Zur Optik von Dunst und Nebel. Z. Meteor. 1950.
10. FOITZIK, L.: Sichtbeobachtungen, Sichtmessungen. Z. Meteor, 1951.
11. FOITZIK, L.: Sichtmeßgeräte. Ann. Meteor, 1952.
12. FOITZIK, L.: Die meteorologische Sichtweite, ihre Messung und Registrierung. Akad. d. Wiss. Ann. 1953.
13. FOITZIK, L.: Aufgaben und Ergebnisse der Sichtforschung. Z. Meteor, 1958.
14. BLACKWELL, H. R.: Contrast Thresholds of the Human Eye. Journ. Opt. Soc. Amer. 1946.
15. BRICHAMBAUT, C. P.: Problems in the Measurement of Runway Visual Range and Slant Visual Range. World Met. Org. London, 1968.
16. MIE, G.: Beiträge zur Optik trüber Medien, speziell kolloidaler Metallösungen. Ann. Phys. Leipzig, 1908.
17. STRATTON, J. A.: Electromagnetic Theory. New York, 1941.
18. GAERTNER, H.: Die Durchlässigkeit der getrübten Atmosphäre für ultrarote Strahlen. VDI Zeitschr. 1951.
19. GAERTNER, H.: Die Durchlässigkeit der getrübten Atmosphäre im Ultra-Rot-Gebiet. Verm. Rundschau, 1950.
20. BRICARD, J.: Réflexion, réfraction, diffraction de la lumière par une goutte d'eau sphérique. Ann. Géophys. 1946.
21. CHANDLER, T. J.: The Climate of London. 1965.
22. CHARLSON, R. J.: Atmospheric Visibility Related to Aerosol Mass Concentration. A Review. Environmental Science and Technology Vol. 3. Washington, 1969.
23. GRIGGS, M.: Relationship of Optical Observations to Aerosol Mass Loading. Japca. Vol. 22. 1972.
24. POLIAKOVA, E. A.: Visibility in Rain. Glav. Geof. Obs. T. Leningrad, 1960.
25. POLIAKOVA, E. A.—TRETIAKOV, V. D.: Visibility in Falling Snow. Glav. Geof. Obs. T. Leningrad, 1960.
26. RICHARDS, T. L.: An Approach to Forecasting Snowfall Amounts. Circ. Met. Div. Dep. Transp. Toronto, 1954.
27. JEFFERSON, G. I.: Visibility in Precipitation. The Meteor. Mag. 1961.
28. RICHTER, H.: Die Sichtweite und die Reichweite elektrooptischer Streckenmeßgeräte. Vermess. Techn. 1970.
29. RICHTER, H.—WENDT, H.: Das neue elektrooptische Streckenmeßgerät EOK 2000 aus Jena. Allg. Verm. Nachr. 1969.
30. RICHTER, H.—WENDT, H.: Elektrooptisches Streckenmeßgerät EOK 2000. Jenaer Rundschau, 1969.
31. HORVÁTH, K.: The Effect of Atmospheric Anomalies on Geodetic Measurements. Per. Pol. Civ. Eng. Vol. 19 (1975) No. 1—2.

Ass. Prof. Dr. Kálmán HORVÁTH, H-1521 Budapest