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Author
Boileau, Almerian R

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Visibility Laboratory
University of California
Scripps Institution of Oceanography
San Diego 52, California

OPTICAL CONTRAST REDUCTION FACTORS FOR DOWNWARD LOOKING CASES

Almerian R. Boileau

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Approved:

Seibert Q. Duntley, Director
Visibility Laboratory

Approved for Distribution:

Roger Revelle, Director
Scripps Institution of Oceanography

Optical Contrast Reduction Factors for Downward Looking Cases*

Almerian R. Boileau

Scripps Institution of Oceanography, University of California
La Jolla, California

INTRODUCTION AND SUMMARY

The Visibility Laboratory of the University of California, La Jolla Campus, is engaged in an on-going research program studying image transmission through the atmosphere. The paper "Image Transmission by the Troposphere I"[1] published in the Journal of the Optical Society of America, discusses this program. In that paper the reduction of optical contrast due to atmospheric attenuation of the optical signal and the veiling effect of the scattered light along the path of sight is discussed.

This report tabulates some real contrast reduction factors computed from measured atmospheric optical quantities. These contrast reduction factors range from .067 to .175.

* This paper represents results of research which has been supported by the Bureau of Ships, U.S. Navy, and the Geophysics Research Directorate, Air Force Cambridge Research Center, Bedford, Massachusetts.

NOTATION

The symbols and equations in the reference are completely general. While the symbols and equations in the reference are given in radiometric quantities they apply equally well to the special case of photometric quantities.

In this report the following quantities are used:

$_bB_o(0,180^\circ,0)$ - Inherent background luminance as seen by an observer looking vertically downward from an altitude of zero feet.

$_bB_r(20^*,180^\circ,0)$ - Apparent background luminance as seen by an observer looking vertically downward from an altitude of 20000 feet.

$T_r(20,180^\circ,0)$ - Transmittance of the image forming rays along a path of length r. In this case the path r is the vertical line of sight between altitudes of 20000 feet and zero feet.

$C_o(0,180^\circ,0)$ - Inherent contrast of target at zero feet altitude as seen against the background having an inherent luminance $_bB_o(0,180^\circ,0)$ by an observer looking vertically downward from zero feet altitude.

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* Altitude is indicated in thousands of feet.

$C_r(20,180^\circ,0)$ - Apparent contrast of target at zero feet altitude as seen against the background having apparent luminance ${}_bB_r(20,180^\circ,0)$ by an observer looking vertically downward from 20000 feet.

$\dfrac{C_r(20,180^\circ,0)}{C_o(0,180^\circ,0)}$ - Contrast transmittance or contrast reduction factor. To prevent possible confusion between transmittance $T_r(20,180^\circ,0)$ and contrast transmittance $\dfrac{C_r(20,180^\circ,0)}{C_o(0,180^\circ,0)}$, the term "contrast reduction factor" will be used in this report.

For the general case the contrast reduction factor is given by Equation (7) of reference as follows:

$$\frac{C_r(z,\theta,\phi)}{C_o(z_t,\theta,\phi} = \frac{{}_bN_o(z_t,\theta,\phi)}{{}_bN_r(z,\theta,\phi)} \quad x \quad T_r(z,\theta,\phi)$$

For the specific case in this report the contrast reduction factor is given by the following equation:

$$\frac{C_r(20,180^\circ,0)}{C_o(0,180^\circ,0)} = \frac{{}_bB_o(0,180^\circ,0)}{{}_bB_r(20,180^\circ,0)} \quad x \quad T_r(20,180^\circ,0)$$

EXPERIMENTAL DATA

The data from five selected flights are presented in Table 1.

TABLE 1

Flight	100	101	107	109	112
Date	3-21-57	3-22-57	4-27-57	5-6-57	5-16-57
Place	Patrick AFB	Patrick AFB	Grand Bahama Is.	Patrick AFB	Cape San Blas, Fla.
Sun's Approx. Zenith Angle	30°	65°	20°	40°	15°
${}_bB_o(0,180^\circ,0)$	200	40	2800	300	300
${}_bB_r(20,180^\circ,0)$	700	300	2800	1400	1100
Luminance Ratio	.286	.133	1.000	.214	.273
$T_r(20,180^\circ,0)$	.613	.914	.067	.586	.432
$\frac{C_r(0,180^\circ,0)}{C_o(0,180^\circ,0)}$	.175	.122	.067	.126	.118

Note: Luminance values are foot-lamberts.

An examination of the data in Table 1 shows that the contrast reduction factor is dependent on both the transmittance and the luminance ratio and that both of these are important. A comparison of Flights 100 and 101 show this.

Flights 100 and 101 were both made east of Patrick Air Force Base, Florida, over relatively deep ocean water. Flight 100 was made during the middle of the day with the sun approximately 30° from the zenith and with an atmospheric transmittance of .613 for the vertical path of 20 000 feet. Flight 101 was made the next day, an exceptionally clear day, when the sun was approximately 65° from the zenith, with an atmospheric transmittance of .914 for the vertical path of 20 000 feet. The luminance ratios, however, are .286 and .133 for Flights 100 and 101, respectively, and the contrast reduction factors, that is, the products of luminance ratios and transmittances for the two flights show that the loss of contrast during Flight 100 was less than the loss of contrast for Flight 101 even though the atmospheric transmittance for Flight 101 was one and a half times greater.

Flight 107 was made near Grand Bahama Island over relatively shallow water and a light sandy ocean floor. The day was murky. During this flight the luminance as seen by looking vertically downward was constant without regard to change of altitude. This indicates that the measured luminance was the equilibrium luminance.[1] The luminance ratio therefore is unity and the contrast reduction factor is the same as the atmospheric transmittance.

Flights 109 and 112 were made during "clear" days, Flight 109 east of Patrick Air Force Base, Flight 112 southwest of Cape San Blas, Florida, both over relatively deep water. In this comparison the luminance ratio for Flight 112 is the larger by 25%, but the atmospheric transmittance for Flight 109 is the greater by 35% and therefore the contrast reduction factor for Flight 109 is the larger.

SUMMARY

1. The contrast reduction factor consists of two factors, viz., luminance ratio and atmospheric transmittance, both of which must be considered.

2. In the case of the "clear" days in which measurements were made the luminance ratio was in the order of 25% thereby causing the contrast reduction factor to be approximately 25% of the atmospheric transmittance.

3. In the case of the "murky" day the measured luminance was the equilibrium luminance so that the luminance ratio was unity, but the atmospheric transmittance was low so that the contrast reduction factor was small.

4. The maximum contrast reduction factor for the vertical line of sight, looking downward from 20 000 feet, was .175, while the minimum was .067.

REFERENCE

1. Duntley, S. Q., A. R. Boileau, and R. W. Preisendorfer, "Image Transmission by the Troposphere I," <u>Journal of the Optical Society of America</u>, <u>47</u>, pp. 499-506, (1957).