

THE CLOUD CONTRAST BOW AS SEEN FROM HIGH FLYING AIRCRAFT

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THE commercial jet traveller typically spends much of his flight over layers of altocumulus clouds. Under such conditions, and assuming a window on the shady side, some semblance of the glory is invariably seen about the anti-solar point. The strength of the glory varies enormously from a just detectable patch of brightness to the full blown display of concentric colour rings. But even in the worst case the experienced observer can usually spot it, aided no doubt by the plane's motion relative to the clouds. If he now directs his attention approximately 40° away from the glory another phenomenon is seen, which I have been calling a 'cloud-contrast bow'. At an angle of about 37° about the anti-solar point there exists a band inside which clouds display a textured fine structure distinctly different from outside this band.

In common with the glory the cloud contrast-bow is highly variable, but almost always present. Because the projection of a 37° angle onto a plane is an ellipse or hyperbola of large extent, the contrast-bow can be seen even more frequently than the glory which often may be hidden by the aircraft wings or other obstructions.

The contrast-bow is normally about 5° wide. At times the area of contrast enhancement extends inward almost to the glory itself but the outer boundary is invariably approximately 40° from the anti-solar point. Motion of the observer causes clouds to cross this angular band rapidly, and the eye readily detects contrast enhancement peculiar to this area. Away from the contrast-bow the cloud structure is softer, more amorphous. Fig. 1 is a snapshot of the phenomenon but because still photographs cannot readily convey the sense of change accompanying motion the effect is hardly noticeable.

A qualitative explanation of the contrast-bow may be offered as follows. Fig. 2 shows the intensity of the scattered light from the surface of a cumulus water cloud as a function of viewing angle, according to Deirmendjian (1964). Forward scatter near 0° corresponds to the intense aureole, while the rise at 180° is related to the glory. The region of interest here is the broad feature centred at 143° usually identified with the fogbow or white rainbow. Cloud structure, or contrast, arises mainly from the difference between the shadows and the sunlit surfaces. While the intensity of the shadows is independent of phase angle the sunlit surface scattering follows the function in Fig. 2. Thus, near 143° , the fine detail contrast between cloud and shadow is greater than elsewhere. This is the case even though the intensification representing the fogbow may be invisible because it is a broad, smooth feature and is easily lost in the other large-scale patterns of the cloud deck. The fact that the scatter intensity remains high for $137^\circ < \theta < 180^\circ$ accounts for an extension of the contrast zone up to the glory. We note that certain of the experimental scatter functions of Pritchard and Elliott (1960) show a monotonic intensity increase for $\theta > 140^\circ$. Of course in the vicinity of the glory the contrast falls to near zero because all shadows disappear there.

The observation is without question peculiar to an age of jet travel. Although it seems unlikely to have escaped general notice, the writer has been

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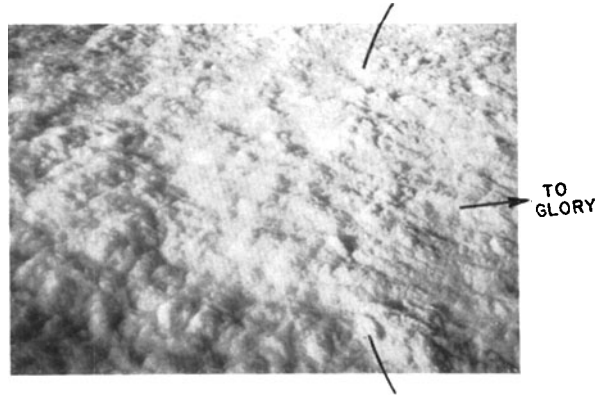


Fig. 1. An attempt to record photographically the contrast-bow effect on a bank of alto-cumulus clouds as seen from a jet aircraft window. Cloud structure to left of the fiducials is softer than to the right

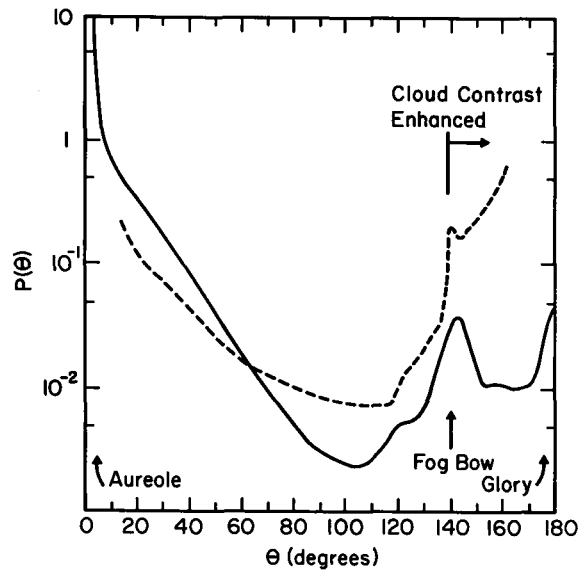


Fig. 2. Cumulus phase function according to the model of Deirmendjian (solid line). Nephelometer observations of Pritchard and Elliott generally confirm the model calculations, except in one case the intensity remains high for $\theta > 140^\circ$ (dashed line), which could explain the extension of contrast enhancement to near the glory

unable to find previous descriptions of the cloud contrast phenomenon in the literature. I am grateful to Drs David Lynch and Lloyd Wallace for helpful discussions.

REFERENCES

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| DEIRMENDJIAN, D. | 1964 | Scattering and polarization properties of water clouds and hazes in the visible and infrared. <i>Appl. Optics.</i> , 3 , pp. 187-196 |
| PRITCHARD, B. S. and ELLIOTT, W. G. | 1960 | Two instruments for atmospheric optics measurements. <i>J. Optical Soc. Amer.</i> , 50 , pp. 191-202 |



Fig. 1. View of the halo display at Saskatoon, at about 1230 MST on 9 December 1976, showing the 22° halo and parhelia, the 46° halo, part of the parhelic circle, the circumzenithal arc and the upper tangent arc to the 22° halo. The photograph was taken using a 15 mm fisheye lens



Fig. 2. As Fig. 1 except taken using a 35 mm lens, showing only the 22° halo and parhelia, and the upper tangent arc