WATER BOWS: WHITE BOWS AND RED BOWS

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WHEN one hears the expression 'all the colours of the rainbow' one is inclined to expect all the known colours in some degree. But in some rainbows and similar atmospheric optical phenomena such a generous display of many colours is not necessarily present. Some of these 'monochromatic' and 'achromatic' phenomena have a beauty of their own, rivalling that of their more normally-coloured cousins.

I noted one such effect, a white rainbow or fog bow, on two successive mornings in early August 1971. The observation point was on a nunatak on the east side of the middle Taku Glacier of south-east Alaska, about 100 m above the surface of the ice immediately below. Shortly after sunrise on both mornings a thin layer of fog formed on the glacier surface below the nunatak. Light turbulent mixing lifted the fog to roughly the level of the observation point. As the fog rose above the shadow of the nunatak, a glory appeared around the shadow of my head. At the same time, segments of the fog bow appeared to the left and right of the glory; as the fog lifted, the two arcs extended upward until the bow was complete. Generally, at any given elevation angle, the bow became visible just before the fog became apparent. As the fog changed density, so the bow changed brightness, being brighter for the denser fog patches. The distant peaks often

Fig. 1. White fog bow, middle Taku Glacier, Alaska, about 60 km north of Juneau. Elevation 1200 m. Taken on 10 August 1971 about 0600 solar time, with a 24-mm lens on 35-mm film (picture angle about 80°)

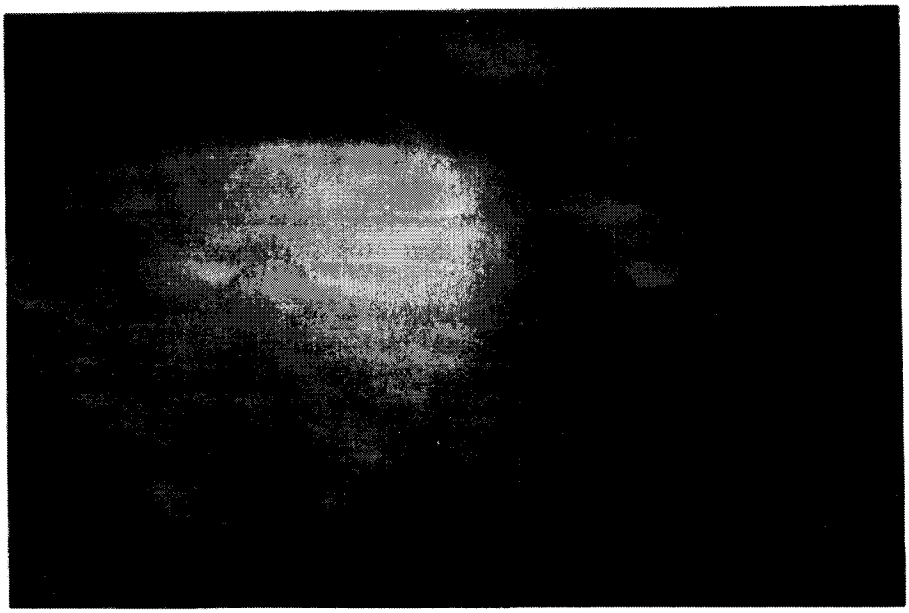

Fig. 2. A red rainbow, photographed at Polson, Montana, 18 August 1972 about 1945 local solar time

were visible through the fog. Many of these features are illustrated in Fig. 1, taken with a lens of 24 mm focal length (picture angle about 80°) at a setting of 1/250 sec, f 11 on Ektachrome film.

These white bows are well known (Minnaert 1954; Tricker 1970). They are observed occasionally at low sun angles in almost any area where hills extend above low fog banks. Minnaert suggests that for the fog or mist bow the reflecting drops have a diameter less than 0·05 mm. The diffraction phenomena depend on the size of the drops. Tricker suggests that in theory the white bow should be present frequently against any cloud lighted by the bright sun and in the proper position relative to the sun and the observer. In practice, however, such broad white bows are seldom detected, even when looked for, because of the dazzling brightness of the cloud resulting from the multiple scatterings of light by the cloud droplets. The white bow described above, however, was quite evident against the white snow of the glacier surface. Perhaps this was because of the relatively low angle of the sun; the snow surface away from the direction of the low sun certainly does not have the dazzling brightness of that surface in the direction of the sun.

Another occasion offered a brilliant red rainbow. The location was Polson, Montana; the time was 18 August 1972 just at sunset and a few minutes after. The edge of a thunderstorm cell or cells was perhaps a kilometer or two to the east, while the anvil spread overhead and to the west, but without obscuring the horizon. The rays of the setting sun, with the blues scattered out due to the long path length, tinted the underside of the anvil with brilliant oranges and reds, offering one of the most vivid sunsets I have seen. At the same time, rain falling from the anvil reflected the rays, forming a complete bow, but one with a brilliant red or red-orange as the dominant colour, and with no sign of the blues and violets characteristic of most rainbows. A secondary bow was occasionally barely visible, though the characteristic darkening between the two bows was more evident than I had previously seen. As the sun dropped below the horizon, the lower limbs of the bow disappeared and the upper part became a very dark red arc appearing unusually high in the sky, as indeed its highest point was about 42° above the horizon. Many of these features are illustrated in Fig. 2, exposed a minute or so after the sun dropped below the western horizon.

These phenomena are rare and seen only under special circumstances, but are by no means unknown. Minnaert, for example, mentions many of them.

Unusually-coloured halo phenomena may also be produced in a similar fashion. I have seen brilliant red and dark red haloes, parhelia and sun pillars near sunrise or sunset on a few occasions in connection with the upper surface of a layer of ice fog and an immediately superjacent layer of ice crystals over and near Fairbanks in interior Alaska. T. Ohtake of the University of Alaska has some remarkable photographs of these and related phenomena; see for example the article by Ohtake and Jayaweera (1972). The original colour transparency of Fig. 3(b) of that article shows these halo features as quite red, though, as Ohtake has pointed out (personal communication), their picture may be underexposed. The refraction effects can be very red as the sun rises or sets. I mention these

effects to point out that one should look not only away from the sun but also toward the sun to seek the opportunity to view these anomalous and beautiful features of our atmosphere.

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