A GIGANTIC HORIZONTAL CLOUDBOW

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We normally perceive rainbows as arcs on roughly vertical sheets of raindrops; but the same optical effects can be produced by horizontal arrays of drops. Thus dew-drops on a lawn or uncoalesced raindrops on a calm soot-covered pond can form horizontal bows of the rainbow or cloudbow type, as Minnaert (1954) points out. Clerk Maxwell described seeing such a horizontal bow produced by many droplets resting unfrozen on an *ice* surface! For all such cases, the dimensions of the luminous arc must measure only tens of *feet* at most. Here I wish to report an observation of the same phenomenon in which the luminous arc spanned many tens of *miles!*

Shortly after taking off from Honolulu *en route* to Los Angeles in a Pan American 707 jet on 19 September 1961, we attained the chosen cruising altitude of 29,000 ft. At about 10 o'clock Honolulu time, I noted from my port window that we were accompanied by a luminous arc below the aircraft. My first, wrong, impression was that I was viewing some kind of ice-crystal halo involving both reflection and refraction since it had the almost colourless luminosity characteristic of the majority of haloes. However, in a moment of further scrutiny, I noted that it seemed to originate on the cloud deck whose tops we had earlier penetrated at about 8,000 ft altitude. Its true nature was then unambiguously revealed when I noted further that here and there along its course it assumed a most vivid rainbow banding where I was looking down through breaks in the 8,000-ft deck to where the trade cumuli were raining. The near edges of the rain columns constituted for me small elements in a huge and essentially horizontal field of drops of two quite distinct size-classes: first, the tiny cloud-drops in the broken deck whose tops lay near 8,000 ft; second, the scattered patches of relatively large raindrops visible through the breaks. Having recognized its real nature, I scanned along the expected arc far to the north of our flight path, and was pleased to find that the luminosity, though very pale in the distance, constituted well over half of a full bow from my vantage point.

Subsequent check on the solar altitude for that time and place permitted assigning the numerical values indicated in Fig. 1, which is drawn in a vertical plane through sun and aircraft. The sun S at altitude very near 50° sent down rays of which the one passing near an observer in the aircraft at A strikes the top of the 8,000-ft cloud deck at C. A cone of semi-vertex angle 42° revolved about that ray SC as axis intersects the deck in the rainbow- (more precisely, in the cloudbow-) locus, whose extrema D and B are indicated. Since the top of the cloud deck lay about 21,000 ft below the aircraft, the indicated angles imply that the 'summit' of the bow at D *lay some 30 miles away*, measured from the point E directly under the aircraft. The bow is here not the *hyperbola* which must almost always be expected with dew-bows (whose occurrence can only be expected in the morning hours of low sun), but rather an *ellipse*. Further calculation shows that the minor axis running perpendicular to the plane of the figure slightly to the left of C is here about 10 mi. The geometry of the small windows in the 707 precluded my seeing the full ellipse (indeed I could barely see the weak glory at C on half-standing to peer downwards), a limitation arguing the need for glass-bottomed jet transports for meteorologically inclined passengers.

Where the bow changed from cloudbow to rainbow at a break in the underdeck near a rain area, the difference in angular spread of the two parts was easily perceived. I made rough attempts to time the passage of the cloudbow over distinctive cloud turrets, estimating 3 to 4 seconds between transit of

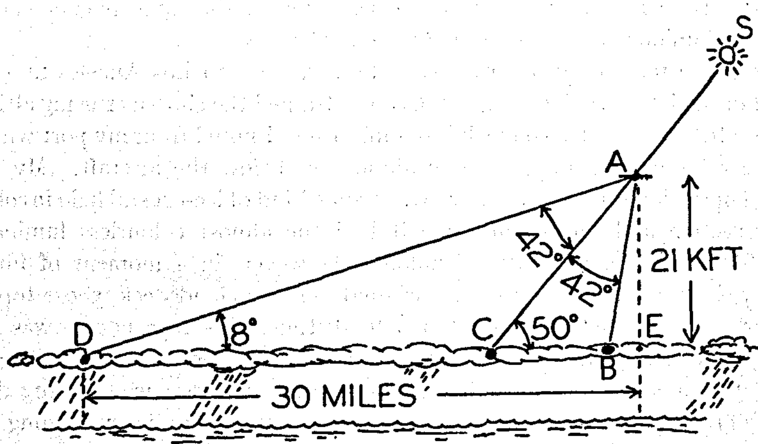

Fig. 1. Formation of mixed rainbow-cloudbow

leading and trailing edge of the bow where the latter lay normal to our flight path. Assuming a ground speed of 600 mph, this gave an actual width of the cloudbow luminosity of somewhat under a half-mile, implying an angular width of about 3 to 4°. The angular width of a typical rainbow is about 1·7°, so the cloudbow was about twice as wide as a rainbow, in good enough agreement with theory (Minnaert).

This phenomenon seems noteworthy on a number of grounds: here was a bow spanning a space of 10 by 30 miles, large beyond all ordinary circumstances; its locus of luminosity was *elliptical* rather than hyperbolic; and, finally, it was actually a *mixed rainbow-cloudbow*, chiefly the latter. Searching correspondence in *Weather* over the past dozen years disclosed no similar observation. With the rising volume of jet traffic, surely many opportunities to see similar gigantic cloudbows should arise. A little thought will reveal that the most favourable circumstances will be with maximum flight-altitude and minimum underdeck-altitude, for then the 'graininess' of the cloud deck is favourably suppressed, giving a bow a better chance to become perceptible. Also, I noted that the cloudbow was most readily perceived where the deck was thinnest (within limits). An optically thick underdeck will send back so much multiply-scattered light *not* satisfying cloudbow geometry that the cloudbow luminosity will be washed out. Perhaps the same kind of trade cumulus situation as that here described will prove nearly optimal for seeing such cloudbows. Surely it is optimal for the added treat of intermittently visible rainbow patches.

REFERENCE

MINNAERT, M. 1954 *The Nature of Light and Color in the Open Air.* Dover, New York, pp. 183–186

ROYAL METEOROLOGICAL SOCIETY MEETINGS

4 April: IN THE SOCIETY'S ROOMS

SYMONS MEMORIAL LECTURE

After welcoming Professor K. R. Ramanathan and Dr. A. Ångström among distinguished visitors, the President introduced the Symons lecturer, Professor G. D. Rochester, F.R.S. In his view the science of meteorology included any phenomenon which starts, spends part of its time, or finishes in the atmosphere. Cosmic rays were therefore clearly pure meteorology.

Professor Rochester began by making a broad division of the subject under two headings—the study of the particles themselves and their interaction, and the information they can give about planetary or intergalactic space. In this lecture he would speak first about the time variation of cosmic rays, in which meteorology plays a large part, and then go on to discuss the possibilities of using the isotopes produced by cosmic rays in the study of the atmospheric circulation.

The stream of cosmic rays arriving at the fringe of the earth's atmosphere has many components of different origin; we are mainly concerned with those whose energies range from 10^9 to 10^{19} eV and whose composition is 85% protons, 14% helium nuclei and 1% nuclei of heavy elements. Solar flare particles are also important. These are protons and electrons trapped in the earth's magnetic field; their energies slope down steeply to a cut-off at 10^{10} eV.

The primary particles interact with atoms in the atmosphere, to give mainly π-mesons (of mass 273 times the electron mass) together with high and low energy protons and neutrons and a whole family of unstable particles. The neutral π-mesons produce γ-rays whose energy is absorbed by production of pairs of positive and negative electrons. This gives the soft component of cosmic rays which has its maximum at about 14 km. The charged π-mesons decay to μ-mesons, which interact very weakly with matter and therefore penetrate deep underground.

In passing through the atmosphere the neutron component suffers a strictly exponential absorption, amounting to about 9% per mb. It is thus relatively easy to correct for the effects of atmospheric absorption. The μ-mesons, however, do not follow an exponential law, since their energy loss is a complicated function of their energy. Correction for atmospheric absorption requires allowance for variations both in the effective height of production and also in the mean temperature of the main absorbing region. No satis-