THE Ω SHAPE OF THE LOW SUN

By C. Floor

Fysisch Laboratorium, Utrecht State University, the Netherlands

When the sun is rising over a calm sea its reflection can be seen as a bright horizontal streak along the horizon (Figs 1, 2). When the reflection merges with the sun's disc the shape resembles that of a capital omega (Ω). The low sun can also be observed to be omega shaped if the sea water is warmer than the air above (Fig. 3) (O'Connell 1961), when the lower part of the sun's disc is reflected in a layer of warm air just above the sea's surface. The purpose of this article is to help an observer ascertain whether this omega shape is due to a reflection from the sea surface or in a thin layer of warm air. The phenomena described in this article apply equally well to the setting sun, but the sequence is of course reversed.

REFLECTION IN A SHALLOW LAYER OF WARM AIR

When the sun is reflected in a layer of warm air the reflection is always seen above the horizon and can be understood in terms of the Ω shape being an 'inferior' mirage which has a 'limiting line' and a 'vanishing line' (Minnaert 1954). Fig. 3 shows successive forms of the rising sun over a warm water surface as observed on 22 May 1980 from Schiermonnikoog in the Netherlands. The sun does not appear right at the horizon but a few minutes of arc above it; the horizontal line at which the sun appears is the 'vanishing line' and is marked as v in Fig. 3. This line passes through the broadest part of the 'first' segment (Fig. 3a, b) and through the neck (the narrowest part) of the omega (Fig. 3e, f). Between the vanishing line and the horizon is an inverted image of the part of the sky (or sun) that is just above the vanishing line. This is why the rising sun appears first at the vanishing line and is then seen to grow upwards and downwards (Fig. 3a, b). The line known as the 'limiting line', marked as l in Fig. 3, is the imaginary horizontal line connecting the highest points of the sky (or sun) that are reflected. On either side of the reflection of the sun's disc there is a reflection of the bright sky which cannot be distinguished from the sky itself. Consequently the whole of the reflection is seen above the horizon.

REFLECTION FROM THE SEA SURFACE

The reflection of the sun in the sea surface is generally seen below the horizon (Fig. 1) but occasionally looks as if it is above (Fig. 2). In the latter case the brightness of the sun's disc is almost equal to that of the surrounding sky and so the brightness of the reflection of the sun's disc in the sea's surface will be roughly equal to that of the reflection of the surrounding sky. Under these conditions it is almost impossible to distinguish

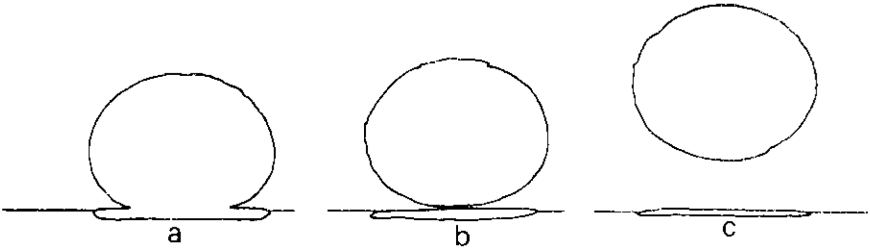

Fig. 1. Sunrise over the Waddenzee observed from Schiermonnikoog (Dutch North Sea Islands), 29 March 1977. The reflection of the sun in the sea's surface is below the horizon

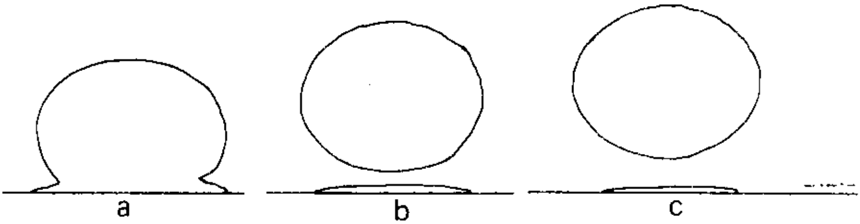

Fig. 2. Sunrise over the Waddenzee observed from Schiermonnikoog, 30 March 1977. The reflection of the sun in the sea's surface looks as if it is above the horizon. In the original slide a very faint horizon was just visible at the level indicated by the dotted line

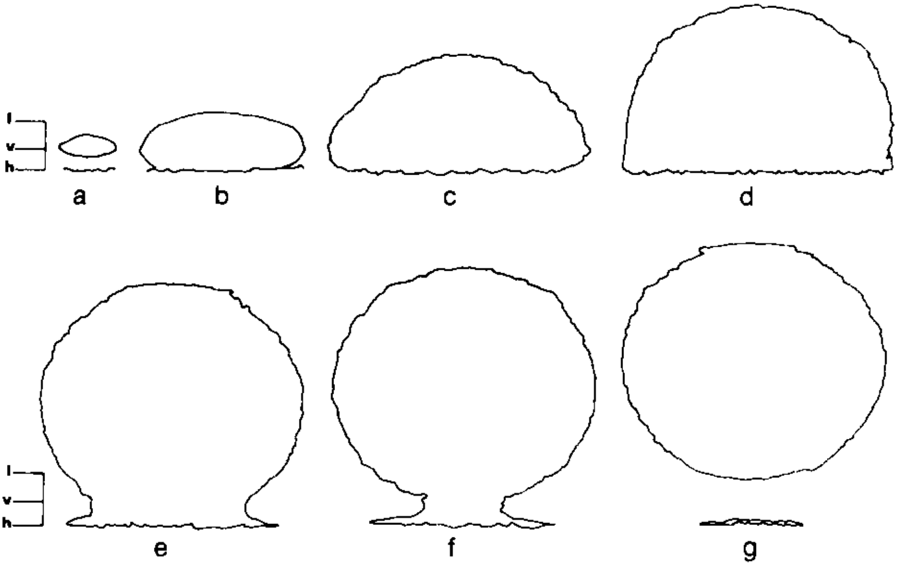

Fig. 3. Sunrise over the North Sea from Schiermonnikoog, 22 May 1980. Between the undulating horizon (h) and the vanishing line (v) one sees an inverted image of the part of the sky (or sun) between the limiting line (l) and the vanishing line (v). The sun first appears at the vanishing line (a). The 'first' segment of the sun's disc is seen to have upturned corners (a, b, c.)

the reflection of the sky from the sky itself; an observer is likely to assume (wrongly) that the horizon is at the lower side of the reflection and will perceive the whole of the omega to be above this false horizon. The original slides on which Fig. 2 is based show the real horizon very faintly.

The observation of a reflection above the horizon is therefore not sufficient to reveal the cause of the Ω shape, necessitating further discussion of some characteristic features which act to distinguish the source of the reflection.

(i) Atmospheric refraction causes far-off sea waves to stand out against the horizon (Minnaert 1954). In this case the horizon will be an undulating line (Fig. 3) instead of a straight one (Figs 1, 2) so that if an omega shape is seen together with an undulating horizon it is related to reflection in a warm layer of air.

(ii) When the sun is low its image as formed by the atmosphere is flattened so that its height is on average 87 per cent of its width. There is less flattening of the image when the air temperature over the surface is relatively high. In Figs 1 and 2 (reflection in water) the height of the image of the solar disc is only 78 per cent and 75 per cent of its width respectively; in Fig. 3 (reflection in a layer of warm air) it is 92 per cent. Thus when the flattening of the sun's image is only slight, the reflection is more likely due to a layer of warm air.

(iii) The distance between the vanishing line and the horizon is a measure of the difference between the sea and air temperatures and is unlikely to change during the few minutes that the sun takes to rise. For this reason the distance between the vanishing line and the horizon should remain more or less constant during this period (as in Fig. 3). When there is a space between the reflection and the solar disc the vanishing line is about half way between the lower rim of the disc and the top of the reflection (Fig. 3g).

If the shapes seen in Figs 1 and 2 were due to reflection in a layer of warm air then the vanishing lines would be roughly half way between the lower rim of the sun's disc and the top of the reflection. It can be seen by comparing the distances between these (imaginary) vanishing lines and the horizon that they are not constant. The Ω shape in Figs 1 and 2 is thus more likely to be due to a reflection in water.

(iv) The reflection of the rising sun's disc in a layer of warm air gradually drops down from the vanishing line to the horizon (see Fig. 3). If the reflection is in water it varies only very slightly with the sun's height (Figs 1 and 2).

(v) When sea water is warmer than the air above, the lower edge of the 'first' segment of the sun's disc is not straight but bent upwards at the corners (Minnaert 1954). If this phenomenon appears just before the omega shape does, it must be attributed to reflection in a layer of warm air (Fig. 3b, c).

(vi) The presence of higher sea than air temperature can be deduced from the presence of 'inferior' mirages (such as 'floating' coastlines, 'floating' ships, etc) around the time of sunrise or sunset. For instance, just after the rising sun in Fig. 3 was observed, the coastlines of Groningen and Friesland were seen to 'float' above the water of the Waddenzee. In other words mirage conditions were present and the reflection was due to a layer of warm air.

(vii) If representative observations of air and sea temperature are available they will help to determine the cause of the Ω shape of the low sun.

If the sea temperature is the higher, the Ω shape is more likely to be due to a reflection in a layer of warm air.

CONCLUSIONS

When the Ω shape of the low sun is due to reflection in a warm layer of air one can usually observe some of the other phenomena which are linked with warm sea water and which have been described above. When the sun's disc is reflected in the surface of a calm sea these warm water phenomena are absent, although the reflection sometimes can be thought to be above the horizon. If we want to ascertain whether an Ω shape is due to reflection in a layer of warm air or in water, we need to verify whether the phenomena linked with warm sea water are present or absent.

ACKNOWLEDGMENT

The advice of Miss S. M. McNab in the preparation of this manuscript is gratefully acknowledged.

REFERENCES

Minnaert, M. (1954) *The Nature of Light and Color in the Open Air*. Dover, New York

O'Connell, D. J. K. (1961) The green flash and kindred phenomena, *Endeavour*, **20,** pp. 131–137