'GREENHOUSE EFFECT' AND OTHER REFLECTIONS ON SATELLITE IMAGERY

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A visible-light picture from a weather satellite contains nothing but sunlight reflected by clouds or by the earth's surface. Nevertheless, anomalously-strong reflections of sunlight from the earth's surface can sometimes easily be mistaken for normal clouds on satellite imagery. In such cases it is possible to distinguish between clouds and reflections only by comparison with infrared pictures taken at the same time. Further, anomalously strong reflections from clouds can cause an erroneous estimation of cloud type. The reflections occur when the line of sight of the sensor lies in the plane of the incident and reflected solar beams and the elevation of the satellite is equal to the solar elevation. The situation is then conducive to a mirror-like reflection, if there is a high reflective substance between the sun and the satellite at a location called the specular point. More details on finding the sun's specular point are given by Tsui and Fett (1980).

The most common of these reflections seen in satellite imagery is 'sun glint', a bright area over a sea or ocean caused by reflection from the water surface. (Anderson and Veltishchev 1973, Fett 1979). Fig. 1 gives an example of sun glint in the Gulf of Gdansk, as seen by NOAA 8 on 23 June 1983, 0751 GMT. Four other, more rare

Fig. 1 NOAA 8, pass 1232, 23 June 1983, 0751 GMT visible-light picture with sunglint in the Gulf of Gdansk and reflections in lakes and rivers

reflections are seen in Figs. 1 and 2. The vertical streak of light in Fig. 1 extending southward over Poland from the coast of the Gulf of Gdansk is caused by reflections of sunlight from the many rivers and lakes in that area. The exact brightness and shape of the sun glint is affected by the state (waviness) of the water surface.

In order to be able to distinguish between reflections and clouds, the infrared (IR) picture that corresponds with Fig. 2 is given as Fig. 3. Both were made by NOAA 8 on 7 June 1983, 0839. The most striking difference in suggested cloud cover is associated with a bright spot on Fig. 2 extending from the south edge of the Ijsselmeer in the direction of Antwerp. As a cloud deck of the same size and shape cannot be seen on the IR picture, one could be inclined to interpret the bright spot as thick low clouds whose temperature is about the same as that of the surface below. However, the synoptic reports of the stations within the bright spot region (06265, 06260 and 06350)

Photograph courtesy University of Dundee

Fig. 2 NOAA 8, pass 1006, 7 June 1983, 0839 GMT visible-light picture with subsun over the Netherlands, reflections on sand bars and the 'greenhouse-effect'

Photograph courtesy University of Dundee

Fig. 3 IR picture (Channel 4) corresponding with Fig. 2

do not mention any low clouds; these stations only report high cirrus at 0800 and 0900. This is in accordance with the IR picture, which shows a band of cirrus, directed from north-west to south-east, over the middle and the south sections of the Netherlands. In fact, the bright cloud-like area over the Netherlands is caused by a reflection in the ice-crystals of cirrus clouds. The reflection occurs mainly in flat plate crystals – thin hexagonal ice-crystals that tend to fall with the flat hexagonal bases oriented nearly horizontally. The reflection is anomalously bright, because in this sun-satellite configuration the horizontal faces of the ice-crystals act as common mirrors. This reflection, known as a subsun, is often seen from airplanes (Minnaert 1954, Tricker 1979, Greenler 1980); its appearance on satellite imagery was discussed by Können and Zwart (1975). Since the bright spot on the visible-light picture is larger than the area where cirrus can be expected from what is seen on the IR picture, at least a part of the cirrus that reflects the sunlight must be so thin that it can not be detected with the help of this IR picture.

Another area of anomalous reflection is over the Waddenzee, between the Dutch North Sea Islands and the main part of the country and the Ijsselmeer. The shapes of these fictitious 'clouds' are very much like the shapes of the sand bars in this area (Balgzand, Griend, Friese Wad and others). At low tide these sand bars become exposed above the water level. The reflectivity of these exposed sand bars, when near to the sun's specular point, proves to be very high, and the reflection of Fig. 2 results.

A third small-scale cloud-like feature on Fig. 2 is found over land near the Dutch North Sea coast, just north of the 'Nieuwe Waterweg' channel, somewhat left of the middle of the subsun. Here the bright area is also caused by a reflection, which we will call the 'greenhouse-effect', for the reflection occurs in a region of abundant greenhouses (Westland) and is caused by their glass roofs.

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