# PICTURE OF THE MONTH

## An Unusual Reticular Cloud Formation

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ABSTRACT

Photographic documentation of a rare and enigmatic reticular cloud formation that occurred in conjunction with a thunderstorm outflow anvil on 4 June 1995 at 2230 UTC at Norman, Oklahoma, is presented. A National Weather Service vertical sounding, taken within 1 h of the occurrence of the formation at Norman, is also presented. Possible formation mechanisms for these unusual cloud features are discussed.

### 1. Introduction and photographic documentation

On 4 June 1995, at approximately 2230 UTC, at Norman, Oklahoma, a very unusual cloud formation was observed that was embedded within a thunderstorm anvil outflow. A series of photographs were taken over a period of about 45 min during which the cellular cloud features persisted and evolved. A particularly striking sample photo, taken near the end of the 45-min period, is shown in Fig. 1a.

At first glance, the formation may appear to resemble that of a mammatus cloud formation. However, the authors were physically present and able to observe these features visually and offer a more complete account than can be portrayed in the two-dimensional photographs presented. It was evident to the authors that the lighter areas in the center of the photo, which are surrounded by darker cloud matter, composed a netlike formation in which the lighter areas were cloud-free holes, and the darker areas were smooth, cloudy, nearly polygonal, ringed peripheries. The netlike pattern appeared to be located at a height below that of the main cirrus outflow anvil. Based on these observations, we refer to this formation as ''reticular,''[1] after Ludlam and Scorer (1953). Figure 1b shows a conceptual sketch of the assumed two-dimensional vertical structure of the reticular cloud formation.

In contrast, mammatus cloud formations [e.g., a photo from Scorer (1972), reproduced here as Fig. 2a] are defined as ''hanging protuberances, like pouches, on the under surface of a cloud'' (Huschke 1959, s.v. ''mamma''). Figure 2b shows a conceptual diagram of the vertical structure of mammatus cells. Comparison of Figs. 1 and 2 shows that the reticular case has nearly the opposite structure to the mammatus formation. That is, the regions in Fig. 2 that hang below the anvil and are composed of cloud matter (mamma cells) can be contrasted with the regions of Fig. 1 that are cloud free and appear to be holes, having some vertical extent, between the anvil deck and the underlying netlike condensation outline.

An additional difference between mammatus clouds, for which it is generally accepted that the motion at the

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[1] The term ''reticular'' is defined as an adjective meaning, ''resembling network; netted; having veins or fibers crossing like a network; intricate.'' The variation, ''reticulation,'' is a noun, which is defined as a ''web-like formation or appearance; network'' (*Webster's Collegiate Dictionary,* 4th ed., s.v. ''reticulation''). Ludlam and Scorer use this term to contrast with the case of more common convective element in which upward motion in the center is coincident with cloud material. In reticular features, the peripheries outline a netlike pattern made visible by cloud condensation and have a cloud-free center core characterized by either upward or downward vertical motion.

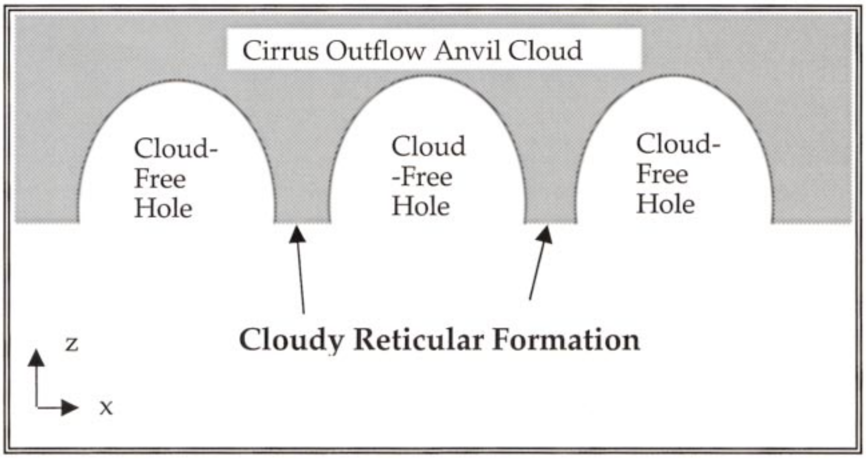


FIG. 1. (a) Photograph of reticular cloud formation observed at Norman, OK, at 2230 UTC on 4 Jun 1995. (b) Two-dimensional sketch of possible reticular vertical cloud structure.

(a)

(b)

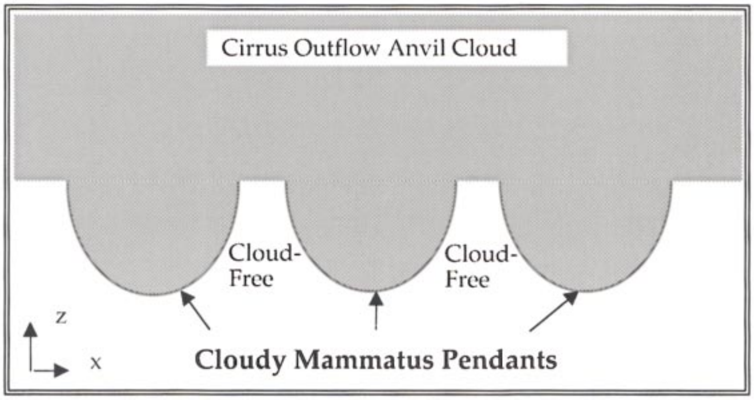


FIG. 2. (a) Mammatus cloud formation. Reprinted from Scorer (1972). (b) Two-dimensional sketch of assumed mammatus vertical cloud structure.

center of the lowered pendants is downward, and the present reticular clouds, is that the direction of vertical motion in reticular clouds is difficult to determine. In fact, Ludlam and Scorer (1953) state the following:

> though reticular (netlike) clouds do appear, it cannot be concluded from their appearance that downward motion in the middle is producing the evaporation of the clouds, for the holes may be due to the perforation of the cloud layer by a clear layer below.

Closer views of the reticular cloud pattern are shown in Figs. 3 and 4, which are taken at slightly earlier times than Fig. 1. Figure 3 shows that the cloud-free regions are not of regular size and the netlike condensation regions are extremely laminar in appearance. On the left side of the photo and in the extreme upper-right-hand corner, there is a ''ragged'' and almost banded characteristic to the darkest portions of the cloud. Figure 4 is a view with the camera pointing nearly vertically upward and taken at an earlier time than Fig. 3. The ringed formation of the netlike condensation (darker regions) pattern can be discerned from this photo. A reviewer pointed out that the fractal character of the condensation regions in Fig. 4 suggests that the reticular cloud formation is composed primarily of liquid water droplets.

Although Ludlam and Scorer (1953) state the existence of reticular clouds, to the authors' knowledge,

FIG. 3. Closer view of the cellular clouds at a slightly earlier time than Fig. 1 shows highly laminar appearance of the netlike condensation formation.

FIG. 4. Photo of reticular formation with camera pointed vertically into the clouds shows the polygonal, laminar, shape of the netlike outline.

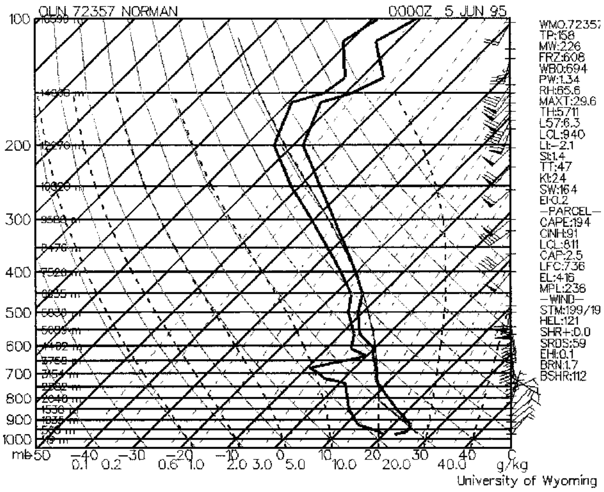


FIG. 5. Sounding plotted on a skew-*T* diagram of the temperature, dewpoint, and wind profiles at Norman at 0000 UTC 5 Jun 1995.

only one other photographic example of reticular cloud features has been previously presented in the literature. Scorer (1972, p. 61, plate 4.3.4) presented a reticular formation in cirrus clouds that is quite different in appearance than the present case. In particular, the reticular formation described by Scorer is embedded in a semitransparent cirrus deck, and the netlike cloud rings do not appear to be as laminar or continuous as the present formation. The cloud pattern documented herein is distinctive in that, to the authors' knowledge, it is the first reticular pattern to be presented that has occurred at midlevels and differs from Scorer's example in that it has a continuous, laminar, condensation outline of a clearly defined net-type pattern.

## 2. Meteorological conditions

On this date, there were widespread thunderstorms across the state of Oklahoma. Prior to 2230 UTC, there was heavy rainfall in Norman and to the southwest. At the time of the occurrence of the reticular cloud pattern, there was little or no rain falling at Norman. There was an active thunderstorm to the west-southwest, near the city of Fort Cobb, Oklahoma, and it is believed that the reticular pattern was embedded in the anvil associated with this storm. Figure 5 shows a sounding released at Norman about 45 min after the occurrence of the cloud pattern of interest. Upper-level winds are directed from the southwest and are supportive of an anvil spreading toward Norman from the Fort Cobb area. There is significant veering of the wind direction from the surface to about 608 mb. Notable speed and slight directional wind shears exist from about 700 to about 500 mb. The melting level is at 608 mb. The local temperature and dewpoint at Norman at 2230 UTC were 23° and 21°C, respectively. The local surface winds were from the ENE at about 2.25 m $s^{-1}$.

## 3. Discussion

The available observational data are not complete enough to make definitive conclusions about the origins of this reticular cloud formation. Therefore, only speculative descriptions of some possible mechanisms that may explain their existence are offered.

The explanation for the reticular cirrus cloud case presented by Scorer (1972) involves the fallout of ice crystals due to subsidence of a newly glaciated cirrus cloud deck. Crystals that fall from the cirrus deck into the dry layer of air below could induce local downdrafts, which may cool and moisten the ambient air through which they fall by sublimation. Scorer states that the paths of these downdrafts become preferred routes for subsequent falling crystals. Thus, crystals fall along the paths of the downdrafts and not the updrafts between them. Furthermore, Scorer adds that updrafts can also create clear holes in a cloud deck. These two processes acting together could result in a netlike pattern of cirrus crystals below the original cirrus deck and clear holes that penetrate into, and above, the base of the original cirrus deck cloud.

The current reticular formation is different from that of Scorer (1972) in that it is embedded in a thunderstorm anvil outflow and is likely composed of liquid water droplets rather than ice crystals. Because the reticular formation is associated with the thunderstorm outflow anvil, the dynamics of the anvil cloud may be important to its formation. In particular, anvil outflows (and the adjacent clear air below them) tend to subside and the cloud becomes thinner in vertical extent as it spreads out downwind of the thunderstorm updraft (e.g., Lilly 1988). Thus, a steepening of the local lapse rate and an impetus for vertical motions can result. [This concept was also hypothesized by Ludlam and Scorer (1953) as a possible mechanism for mammatus formations. Schaefer and Day (1981) further suggested that the bottom of an anvil may even exhibit a Benard-type cellular convective pattern.]

A few specific things can be noted from Fig. 5. The nearly saturated layers at, and above 562 mb, are assumed to represent the thunderstorm outflow anvil cloud deck. The dry-adiabatic layer from 608 to 562 mb suggests that subsidence may have occurred in that region. However, the wind speeds and directions in this layer are contradictory to this contention. In particular, if there was subsidence in that layer, it would be expected that momentum from above would have mixed down as well. Instead, there is a notable speed maximum and directional change in the winds in this layer. The winds are from the south at about 26 m $s^{-1}$ at this level, while above this they are from the southwest. The wind speeds increase from about 17.5 m $s^{-1}$ at 608 mb to 29 m $s^{-1}$ at 500 mb. This significant wind shear could be responsible for substantial mixing (and associated vertical motions) at these heights. Such vertical motions might have been bounded on the top by the stable stratification from 562 to 450 mb and inhibited on the bottom by the moist-adiabatic stratification from 734 to 608 mb (i.e., dry downward parcel displacements would be warmer than the environment below 608 mb and thus stable to dry downward displacements). Therefore, one possible explanation for the formation of the cellular reticular cloud pattern might be that vertical wind shears may have generated vertical motions at or near the level of 608–562 mb that may have been limited in vertical extent on the top and bottom by the ambient environmental stratification.

Alternatively, subsidence could have resulted in the dry-adiabatic layer from 608 to 562 mb and could have led to a steepening of the local lapse rate (despite the wind profiles). In this case, weak downdrafts could bring dry air downward and create clear holes in the moist layer at 623 mb. A further alternative explanation is that proposed by Scorer (1972): that lifting of a dry layer from below (perhaps the layer from 734 to 634 mb) could have perforated the cloud layer (perhaps the layer from 634 to 562 mb) and resulted in the cloud-free holes.

Future work may include numerical investigations with explicitly represented microphysical processes of thunderstorm anvil outflow dynamics that may permit the exploration of the differences between mammatus and reticular formations.

## 4. Summary

We present photographic documentation of a rare reticular cloud formation that occurred in conjunction with a thunderstorm outflow anvil on 4 June 1995 at 2230 UTC at Norman, Oklahoma. Although there has been mention in the literature of reticular clouds, they are apparently extremely rare and even less often documented and, therefore, this interesting case is presented as a Picture of the Month. Based on limited meteorological data, speculative explanations as to the origins of their existence are offered. It is hoped that the documentation of these features may call more attention to them and result in the presentation of additional observations by other investigators that will further the understanding of these very unique and intriguing cloud formations.

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