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THE VISUAL IDENTIFICATION OF LIGHTNING-PRODUCING THUNDERSTORM CLOUDS

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***Abstract*—Lightning safety involves recognizing when a thunderstorm is ready to produce a flash, where is a safe location, and how long to stay there. While outdoors, visual recognition of lightning-bearing clouds is often possible. However, intervening clouds and distracting features may be present. This paper will identify cloud types that help identify the presence of lightning. A description of cloud formation will include the names and definitions of relevant cloud types, as well as examples using cumulus photographs from a variety of locations, climatic regions, and seasons. Additional discussion will focus on the existence of dark clouds that may or may not be lightning indicators. Most critical for lightning safety purposes is the common situation where only segments of the critical cloud segments that indicate lightning potential may be evident.**

Keywords-lightning safety; lightning cloud formations; lightning identification from clouds.

I. CONCEPTS OF CUMULUS FORMATION

The goal of this paper is to describe the types of clouds that are most likely to produce lightning. The situation being considered is one of being outside and viewing the sky for the possibility of the lightning threat; quality lightning network detection data will clearly locate the lightning once the situation has been identified as holding a potential for lightning in the vicinity [Walsh et al., 2013].

There is a substantial literature on the classification of clouds that is based on both appearance and formation processes. The standard definitions are given in the *International Cloud Atlas* of the World Meteorological Organization [1987]. The American Meteorological Society also has published cloud type definitions in the online Glossary of Meteorology at the following address: http://glossary.ametsoc.org/wiki/Main_Page.

Cumulus clouds are necessary for lightning to form. In fact, cumulus clouds range from the barely perceptible small cloud to the huge cumulonimbus and a complex of many cumulonimbi adjacent to each other. An underlying process is the spherical vortex in the presence of vertical instability resulting in upward buoyancy, such as Turner [1964]. An example of an undiluted single cumulus cloud tower is shown in Fig. 1 [Holle, 1984].

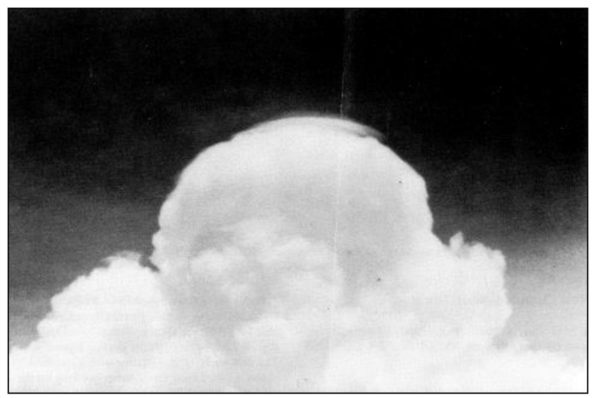

Fig. 1. Photograph of rounded-top spherical vortex at the top of a cumulonimbus cloud over the Florida Everglades (Holle 1984). All photos by author except as noted.

II. NON-RAINING CUMULUS HUMILIS

The first stage of cumulus cloud formation is humilis. Figure 2 illustrates two fields of cumulus humilis clouds in varying environments. There are many details with respect to the formation and shape in publications such as the *WMO Atlas*. For the context here of identifying the lightning threat, cumulus humilis has a rather flat base and only a slightly rounded top. In particular, they are shallow in depth. That is, their vertical depth is typically less than their width. These features are invariant whether the cumulus humilis clouds are in the humid tropical environment of Barbados (top Fig. 2) or the dry high-altitude climate of Arizona (bottom Fig. 2). No rain falls from this shallow cloud. Somewhat deeper cumulus humilis clouds are termed cumulus mediocris, a transition stage into more significant cumulus clouds.

III. CUMULUS CONGESTUS

The next stage of cumulus development is cumulus congestus, often called towering cumulus. At this stage, the cumulus cloud has become taller than it is wide. This stage may end the cumulus life cycle, or be a transition stage from humilis to larger clouds. Congestus clouds often have a sharp outline and can exist in groups. Fig. 3 shows groups or lines of congestus without rain falling. Figure 4 shows congestus with rain falling from cloud base, although it may not reach the ground in dry sub-cloud environments.

Fig. 2. Photographs of nearly flat cumulus humilis clouds over Barbados (top) and Arizona (bottom). Lower photo by Shirley M. Holle.

Cumulus congestus are not directly associated with lightning at this stage of cumulus growth, although rain may be falling. The tops are somewhat to very distinct, and there is no flattening of the top into an anvil shape that indicates a cumulonimbus. Small puffs may separate from the main updraft, and the tops may become somewhat diffuse at top, as in Fig. 3.

IV. TRANSITION TO CUMULONIMBUS

From the point of view of the lightning threat, the transition from congestus to cumulonimbus is very important. The distinctive features that indicate the potential for lightning are the loss of a hard outline of the upper part of the cumulus tower, and the development of an anvil. The term anvil is the common colloquial term used more often than incus, capillatus, or calvus that is also identified for cumulonimbus in the WMO Atlas [1984] and AMS Glossary [2000]. The term anvil refers to an object, more commonly known in past years, that consisted of a heavy steel or iron block with a flat top on which metal was hammered and shaped.

Fig. 3. Photographs of cumulus congestus over Arizona (top) and the Florida Keys (bottom).

As the cumulus congestus clouds become taller and deeper, rain can fall, sometimes at heavy rates. Fig. 4 shows a row of congestus with rain falling from several of them with distinct somewhat rounded tops.

Fig. 4. Photograph of a row of cumulus congestus over Oklahoma.

In the atmosphere, an anvil indicates an updraft that has reached a buoyancy level which is not likely to be exceeded. That is, the cloud top will mostly remain below that altitude, although an isolated updraft may emerge through the top of the anvil for a few minutes. The anvil top then becomes more smooth and diffuse. Such an appearance indicates the presence of ice crystals, one of the key ingredients in lightning formation. Typical views of anvils are shown in Fig. 5, where the flat spreading tops and smooth fibrous appearance at the top are readily apparent.

At this point, it is instructive to show simultaneous views of all types of cumulus clouds in various stages of development. Fig. 6 includes aerial views of cumulus humilis and tall congestus in the center of the view, and anvil-topped cumulonimbus on the right and left in Arizona and Florida.

Fig. 5. Photographs of cumulonimbus clouds with anvil tops in Arizona (top) and Florida (bottom).

Fig. 6. Photographs of a range of cumulus cloud stages over Arizona (top) and Florida (below) as viewed from aircraft at altitudes between ~ 18,000 and 25,000 feet (~5.5 and 7.6 km).

V. CUMULONIMBUS

A. Single cumulonimbus cloud

A cumulonimbus cloud can have a variety of visual appearances (Fig. 7). In this figure, there are samples of mainly single cumulonimbus clouds that range from an isolated updraft in the top panel, to a somewhat larger group of them at the bottom. Note the flattening and fibrous appearance at the cloud top that typically spreads sideways for a short distance, or sometimes a long distance away from the main updraft tower. In each of these photos, a portion of an updraft is visible as it penetrates in a rounded shape above the flattened smooth anvil. This rounded shape was shown in isolation in Fig. 1.

Fig. 7. Photographs of single cumulonimbus clouds over Arizona (top two panels), and a small group of cumulonimbus over Florida (bottom).

B. Multiple cumulonimbus clouds

Cumulonimbus clouds often are organized into groups, rows, or clusters. Fig. 8 shows views of such clouds in three perspectives. The top photo shows three separate but similarly-shaped cumulonimbus complexes with separate anvils. The lower view has several anvils emerging from separate cumulonimbus updrafts with less organization.

Fig. 8. Photographs of multiple cumulonimbus clouds in complexes over Colorado (top panel), and Arizona (bottom).

VI. DARK CLOUDS OVERHEAD

It is frequently assumed that the presence of lightning should be accompanied by dark, mainly low clouds as viewed from a specific location. There are two possibilities for dark clouds in this context. One is the presence of dark but irrelevant clouds. The other is the presence of dark cumulus clouds that are not indicative of the occurrence of lightning in a more complicated situation with regard to the path of sunlight.

Dark clouds may be occurring overhead, or nearby, for reasons that are not related to lightning. In the most basic sense, the presence of a dark cloud means there is an absence of light.

The top panel of Fig. 9 shows dark late afternoon clouds that hold no potential for lightning, since the cumulus humilis clouds are wider than tall. Lower Fig. 9 shows cumulus and cumulonimbus clouds in the distance, and an overhead anvil that is shading nearby low clouds that have no lightning potential, although the anvil may be a source of occasional lightning.

Fig. 9. Photographs of dark cumulus clouds at twilight in Michigan (top panel) and shaded by an anvil over Florida (bottom).

VII. FRAGMENTARY VIEWS

A more difficult situation occurs when only fragments of a cumulonimbus are visible. In this scenario, any portion of a cumulonimbus cloud visible at any distance indicates that the atmosphere in this region is capable of producing lightning. That is, a nearby cumulonimbus also represents a lightning threat. Fig. 10 shows an overhead anvil cloud that is a lightning threat, since lightning occasionally comes downward from an active anvil. In this case, the updraft on the right is close to the anvil spreading outward toward the left and is nearly overhead, so a lightning threat exists.

Often only a part of the anvil shape is evident. Fig. 11 shows a spreading anvil in a triangular shape in the upper center of the view. This anvil is indeed attached to a cumulonimbus producing lightning on the left side, where it is evident that there is a penetrating rounded updraft near the top of the photo to the left of center.

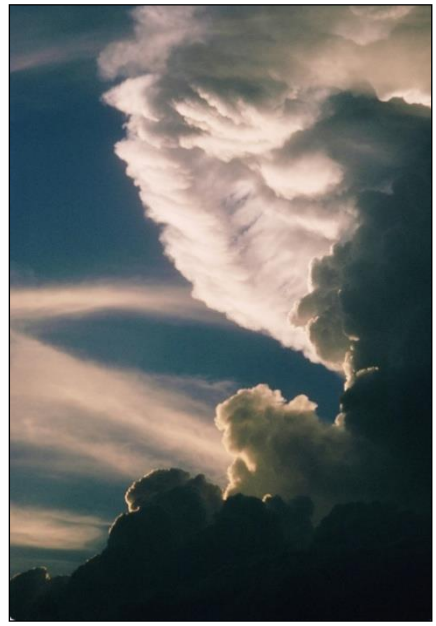

Fig. 10. Photograph of an overhead Oklahoma anvil near sunset.

Although too far away to be a direct threat at the location of the photo in Fig. 11, the anvil's presence indicates that cumulus clouds in the region have the potential to become a cumulonimbus cloud that could result in lightning. The appearance of any anvil fragment anywhere in the sky is cause for a raised level of alertness. Then, if a somewhat distant cumulus seems to be growing quickly, a nearby cumulus may be capable of developing an anvil at nearly the same time, or in the near future.

Fig. 11. Photograph of a portion of a Florida anvil in the distance.

Both an anvil fragment and dark skies are present in the near-sunset photograph of Fig. 12. This view shortly before sunset shows a significant amount of dark skies from shading by other clouds. But there is a white anvil shape almost hidden in the center of the view. That cloud is white because it is tall enough to continue to be in the bright sunlight that is not hiding it, as is the case for the lower clouds. Seeing this shape raises awareness of the lightning threat, not necessarily from that somewhat distant cloud, but from other thunderstorms that may grow nearby during the next hour or two under the same environmental conditions as the one farther away.

Some lightning occurs from storms occurring near or after sunset, so only outlines of the significant cloud may be apparent [Holle, 2014]. Fig. 13 shows a line of thunderstorms in a squall line to the west. The strong updrafts penetrating above the line in the form of large towers indicates the possibility of lightning-producing clouds beneath them. While it is not certain that lightning is present in this situation, it is very apparent that the line to the west should be monitored carefully.

Fig. 12. Photograph of an Arizona anvil segment near sunset hidden by dark lower clouds.

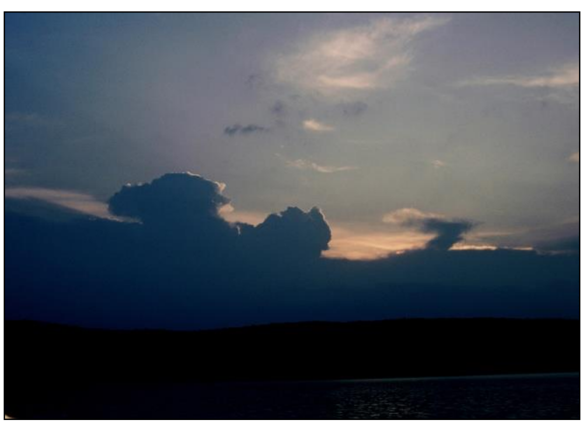

Fig. 13. Photograph of a Michigan squall line with penetrating towers near sunset.

VIII. SKY NEAR TIME OF LIGHTNING

Blue sky at and near the time of lightning is often reported. This is not especially unusual. Consider a vertical cumulonimbus cloud nearby in the middle to late afternoon, when lightning is most frequent in many locations. A cumulonimbus is taller than wide, and can be isolated, as shown in previous figures. Consider such a cloud nearly overhead or to the east, with the sun shining from the west. There may well be blue sky in the western half of the sky at the same time as a lightning threat exists overhead and to the east. Such a case is clearly shown in the late-afternoon case of Fig. 10.

Depending on a wide variety of factors, there may be blue sky somewhere in the sky at the same time as an isolated cumulonimbus or small group of such clouds. Examples in Fig. 14 show clouds within one minute of lightning very close by, and accompanying thunder. Note that such photos are from the western United States, where the cloud layer near the ground is relatively dry, yet there is enough moisture aloft for thunderstorm formation. Also in those photos, note the presence of virga, rain falling from the cloud aloft without reaching the ground to any significant extent. In these cases, it is essential to have observed the cloud during its growth stage. At some point during its life cycle, a small anvil with a flattened and/or wispy top occurred, although it may have been difficult to observe. An additional visual observation is to determine whether other clouds in the area reached the cumulonimbus stage with a fibrous and/or flattened top.

IX. TREES

The ultimate hindrance in many locations is the presence of trees. There are several choices in this situation, but all are challenging:

- Find a clearing in order to see the sky, such as a lake or a road.
- Listen for thunder and go immediately to a safe place since its distance and direction may be impossible to determine with vision alone, although quality lightning network detection data will locate the lightning.
- There is some value in looking for dark skies, but that may or may not be indicative of lightning.

X. CONCLUSIONS

A summary of visual indication of clouds associated with lightning has been presented. Horizontal cumulus humilis clouds that are wider than tall present no lightning threat. But cumulus congestus clouds are a concern when they are quickly growing vertically. When cumulus cloud tops become flat, spread horizontally, and/or fibrous, then the cumulonimbus stage has been reached when lightning is likely. These well-known indicators are first shown for isolated thunderstorms or small clusters of cumulonimbus.

Fig. 14. Photographs of sky within one minute of nearby lightning in Colorado (top panel) and Arizona (lower three panels).

Not all of these features are typically visible at the same time due to rainfall, intervening clouds, trees, and other local structures. Examples are shown of these cloud features that can be identified when only portions of the cumulonimbus cloud can be seen. It is emphasized that if a storm in the area is undergoing such a development, then a nearby congestus cloud may also become a lightning threat as it grows to the cumulonimbus stage.

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