PICTURE OF THE MONTH

More Observations of Small Funnel Clouds and Other Tubular Clouds

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ABSTRACT

In this brief contribution, photographic documentation is provided of a variety of small, tubular-shaped clouds and of a small funnel cloud pendant from a convective cloud that appears to have been modified by flow over high-altitude mountains in northeast Colorado. These funnel clouds are contrasted with others that have been documented, including those pendant from high-based cumulus clouds in the plains of the United States. It is suggested that the mountain funnel cloud is unique in that flow over high terrain is probably responsible for its existence; other types of small funnel clouds are seen both over elevated, mountainous terrain and over flat terrain at lower elevations.

1. Introduction

Bluestein (1994) and others (e.g., Doswell 1985, p. 107; McCaul and Blanchard 1990) have documented, in the plains of the United States, small funnel clouds pendant from convective clouds whose updrafts appear to be rooted above the boundary layer. Above many of these funnel clouds, the base of the parent cloud is ragged, while the parent cloud itself has dissipating elements. Many low-precipitation (LP) supercells [see Rasmussen and Straka (1998) for a discussion of the differences among classic, LP, and high-precipitation (HP) supercells] produce these “high based” funnel clouds, especially when they dissipate (e.g., Doswell 1985, p. 104; Bluestein and Parks 1983). Other tubular-shaped clouds have been seen underneath cumulonimbus clouds (E. W. McCaul Jr. 2005, personal communication) and in the clear-air boundary layer near or within a field of cumulus humilis clouds.

Since these funnel clouds appear to be benign, they are in sharp contrast with the condensation-funnel clouds that are associated with the intense columnar vortices of many tornadoes and waterspouts. It is therefore important to understand the circumstances under which the benign funnel clouds occur so that if they are observed, severe weather warnings are not issued. Furthermore, the small funnel clouds are of interest in their own right because their dynamics are not well understood, and they have not been discussed in the literature to the much greater extent that the dynamics of tornadoes have (e.g., Davies-Jones 1986).

The purpose of this note is to provide documentation of other small funnel clouds or tubular-shaped cloud elements, including those occurring over mountainous terrain. To this extent, this note extends the discussion by Bluestein (1994). It is suggested that the dynamics of some of the vortices associated with these funnel clouds might be a result of the interaction of flow over orography with local, buoyant convection. Photographic documentation is provided in section 2. A summary and discussion are found in section 3.

2. Photographic documentation of funnel clouds

a. High-based funnel clouds pendant from ragged bases of cumuliform clouds

An example is shown of a common type of high-based funnel cloud, pendant from the bottom of a dissipating convective tower having a ragged base (Fig. 1). This ragged-based tower is in contrast to the flat bases of active convective towers nearby (to the right). A supercell was forming well to the east of this high-based
funnel cloud and was not associated with it. The parent cloud formed over the plains of northeast Colorado near a southward propagating surface boundary. Although the funnel cloud was rotating rapidly, no debris cloud was evident at the ground. The funnel cloud lasted for several minutes. This type of funnel cloud is similar to those discussed by Doswell (1985), Bluestein (1994), McCaul and Blanchard (1990), and others, especially in recent years posted on personal Web sites.

b. Upside-down “u”-shaped tubes or partial loops amongst cumulus clouds

Other tubular-shaped cloud elements have been noted in the clear-air boundary layer during the daytime (Figs. 2–4). They appear to be upside-down u-shaped (or partially looped) cloud elements that persist for several minutes in the vicinity of cumulus humilis clouds. Some storm chasers have called the tubes/loops “horseshoe vortices.” None of the funnel-like clouds, however, was attached to cumulus clouds at all or appeared to evolve from cumulus clouds.

c. The “right-side-up u-shaped tubular cloud”

A variation on the upside-down u-shaped tube is the right-side-up u-shaped tubular cloud seen only on rare occasions (Ludlum 1991, plate 207), pendant from a high cloud base in a cumulonimbus cloud (Fig. 5). Many storm chasers have called referred to this cloud structure as a “bowtie funnel.” E. W. McCaul Jr. (2005, personal communication) refers to this rare cloud structure as a “devil’s trapeze.”

d. Tubular cloud elements pendant from or near cumulus clouds over mountainous terrain

Other tubular-shaped clouds have been visible from the summits of mountains. Some were pendant from convective clouds having ragged bases (Fig. 6) near the convergence zone separating winds having an easterly component east of the Continental Divide and winds

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Fig. 1. Funnel cloud pendant from a high-based cumulus congestus cloud, viewed to the northwest, in Briggsdale, CO, on 24 Aug 2002 at 1615 mountain daylight time (MDT). (Copyright H. Bluestein.)

Fig. 2. Two upside-down u-shaped tubular cloud structures in the clear-air boundary layer, alongside cumulus humilis clouds, south of Leadville, CO, on 26 Sep 1986. (Copyright H. Bluestein.)
having a westerly component west of the Continental Divide. These funnel clouds are probably similar to those seen underneath dissipating, high-based cumuliform clouds over the plains (Fig. 1). Inferences about the winds were made based on visual observations of cloud motion. It is thought that the easterly winds were part of the diurnal mountain–valley wind, while the westerly winds were associated with the ambient flow above mountaintop level. In Fig. 7 a horizontally oriented funnel cloud that lasted for several minutes is seen. It seems to be similar to that shown in Figs. 6 and 1.
Other tubular-shaped clouds (e.g., Fig. 8) were visible as cloud fragments separated completely from their parent cloud, which had earlier evaporated completely. These funnel clouds also persisted for several minutes or longer.

e. Funnel cloud pendant from a cumulus fractus cloud over mountainous terrain

An example of what might be yet another variety of funnel cloud is shown in Fig. 9. The parent cloud of this funnel cloud was a ragged, broken, roiling convective cloud mass composed of many elements, which formed over high mountain peaks in Colorado (Fig. 9a). The cloud elements were rapidly rotating and thereby easily caught my attention. The parent cloud then developed vertically oriented tendril-like features underneath it (Fig. 9b); the cloud looked like a jellyfish. Soon one of the tendrils developed into a laminar funnel cloud almost overhead. The laminar funnel cloud, which was connected to its parent cloud, became turbulent looking above (Fig. 9c). Such a structure is reminiscent of the transition to vortex breakdown sometimes seen in tornadoes near the ground (Pauley and Snow 1988). The funnel cloud persisted for several minutes, but did not produce any visible surface debris cloud. After the funnel cloud had dissipated, an upside-down u-shaped fragmented cloud mass remained (Fig. 9d) as the cloud drifted to the northeast.
3. Summary and discussion

A number of tubular-shaped cloud elements or small funnel clouds have been photographically documented both over the plains and over mountainous terrain. The feature common to all the hitherto noted funnel clouds is their proximity to small cumuliform clouds having ragged bases. Some were connected to cumulus clouds, while others were detached from them. None was associated with deep, convective storms. It is likely then that turbulent, shallow convection played a role in their development.

In the case of the detached cloud loops appearing near a field of cumulus humilis clouds, it is speculated that the vorticity associated with them probably originates in boundary layer shear (horizontal vorticity) that is tilted by the internal eddies associated with clear-air convection in the manner described by Prandtl (Scorer 1972). It is also possible that tilted Kelvin–Helmholtz rolls may be associated with these loop clouds.

In the case of the funnel clouds pendant from ragged bases, the source of vorticity is simply not known (Bluestein 1994). That the funnel clouds sometimes persist longer than their parent clouds is very enigmatic, though the stabilizing role of rotation may be important. However, since they may appear both vertically and horizontally oriented, it is suggested that tilting of ambient vorticity associated with environmental
Fig. 9. The development of a funnel cloud over Long’s Peak and Mt. Meeker, in northeastern Colorado, on 30 Sep 2002, around 1200–1300 MDT, as viewed to the west from the summit of Twin Sisters. (a) A roiling, cumulus fractus; (b) the cumulus fractus assumes an upside-down u shape with tendrils; (c) a funnel cloud appears in the southernmost vertical column, making up the u-shaped cloud; (d) after the funnel cloud had dissipated, an upside-down u-shaped cloud mass is left behind. (Copyright H. Bluestein.)
vertical shear or vorticity produced baroclinically at cloud edges may be important.

In the case of the cumulus fractus cloud over the mountains discussed last, it is speculated that a horizontal roll associated with an orographic wave aligned along the mountain range was distorted into a u shape by the convective eddy associated with the cumulus fractus cloud as a whole. It is thought that horizontal, orographically induced rolls are quite common over Front Range of the Rocky Mountains (Bedard 1978) when there is a component of wind normal to it. One side of the vortex tube may have been stretched sufficiently as a result of a local, convective updraft, to lower the pressure enough to produce a smooth condensation funnel. Shapiro and Markowski (1999) have demonstrated how such a funnel cloud might build downward from a parent vortex aloft.

The small-scale, short-lived, and relatively rare funnel clouds discussed in this paper present a particularly difficult challenge for direct observations and/or remote sensing. It is suggested that they might best be studied using moist, large-eddy simulation (LES) models.

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REFERENCES