PICTURE OF THE MONTH

Observations of “Steam Devils” over a Lake during a Cold-Air Outbreak

HOWARD B. BLUESTEIN

School of Meteorology, University of Oklahoma, Norman, Oklahoma

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1. Introduction

Lyons and Pease (1972) coined the term “steam devil” to describe columns of rotating steam fog they observed over the upwind side of Lake Michigan during a cold-air outbreak. They suggested that the steam devils are “subcloud convective plumes rising out of surface superadiabatic layers”; the latter have been discussed by Warner and Telford (1967). Kaimal and Businger (1970), however, have discussed wind and temperature data recorded in a dust devil and in a convective plume; they found that the plume did not have much rotation, while the dust devil did. Raman and Riordan (1988) and Grossman and Betts (1990) have described steam devils, steam plumes, and waterspouts near the Gulf Stream during a cold-air outbreak. Reinking (1978) and Holle (1982) have documented steam devils over hot bodies of water which did not appear to be connected to any cumulus clouds above. Steam devils look like dust devils (Sinclair 1969) over water. Ash devils (Blanchard 1986) and fire whirls (Hannes and Hannes 1984) are similar-looking phenomena which have also been documented.

The purpose of this note is to document the steam-devil phenomenon over a small lake in Oklahoma during the winter, and to compare our observations to those made by others elsewhere.

2. Synoptic and mesoscale environment

Record cold temperatures associated with an arctic high-pressure area at the surface were reported over much of the eastern half of the U.S. during the third and fourth weeks of December 1989. On 22 December, morning temperatures were near or below −20°C over much of Oklahoma. These cold temperatures, in conjunction with northerly winds of 5–8 m s⁻¹, were responsible for bitter wind chills. A high-pressure ridge at the surface lay across eastern Oklahoma. The next morning temperatures were even colder, but warmed up more rapidly as the ridge moved off to the east.

Winds over central Oklahoma were calm early, and increased to several m s⁻¹ by mid-morning as a lee trough developed in the wake of the arctic high.

The morning sounding at Norman was not available on 22 December. The morning sounding on 23 December showed a shallow radiation inversion, above which there was a nearly isothermal layer up to 600 mb (Fig. 1); the arctic air mass was therefore relatively deep.

Lake Thunderbird is a small body of water approximately 15 km east of downtown Norman (Fig. 2). Measurements of surface lake temperature are made about once a month (Dr. Ken Crawford, Oklahoma Climatological Survey, personal communication). Measurements of 4.4°C and 7.8°C were made on 5 December 1989 and 9 January 1990, respectively. It is likely that the actual lake temperature on 22–23 December was colder, yet above 0°C; most of the lake was not frozen. The lake was 18.3 m deep at the location where the temperature was measured. It is therefore likely (cf. Fig. 1) that there was a superadiabatic temperature profile above the lake.

![Fig. 1. Skew-T log-p diagram for Norman, Oklahoma, 1200 UTC, 23 December 1989. Temperature (thick solid line) and dew point (thick dashed line). Skewed abscissa (temperature in °C); ordinate (pressure in mb).](image-url)
abatic layer just above the surface of the lake, with the lake surface at least 20°C warmer than the air.

3. Visual observations

a. 22 December 1989

On the morning of 22 December I drove to the lake with the intention of taking photographs of steam fog (arctic sea smoke). When I arrived there indeed was steam fog. The wind had blown steam fog onto the leeward shores of the lake, producing a coating of rime ice on the northern side of trees. The depth of the steam fog increased from only a meter or so to as much as 10 m when the wind gusted. The additional stirring caused by the stronger wind gusts probably had mixed upward slightly warmer sub-surface water.

Sometime between 1600 and 1700 UTC, steam devils began to form (see Fig. 2 for locations). Viewing conditions were ideal, owing to the deep blue sky above. The use of a polarizing filter helped increase the contrast of the steam devils against the sky. The steam devils had characteristics similar to those reported elsewhere. They each lasted on the order of 10 seconds to several minutes. I estimate that most were no more than several meters in width; some extended as high as 20–30 m. Cumulus clouds were not visible above any of the steam devils.

Representative photos of relatively wide ones (Fig. 3) and narrow ones (Fig. 4) are seen extending upward.

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Fig. 2. Map of Lake Thunderbird showing observation points and approximate locations of steam devils: A and B are observing points on 22 and 23 December, respectively. C and D are the corresponding steam-devil locations. The water temperature and depth are measured near the location marked E.

Fig. 3. Photograph of steam devil on 22 December 1989 near location C in Fig. 2.
from the layer of steam fog which hugged the surface of the lake. The steam devils all appeared to move along with the wind (from left to right).

The narrow steam devil shown in Fig. 5 was unusual in that the top portion of the condensation funnel broke away from the vortex in the steam fog below. It resem-

FIG. 4. As in Fig. 3.

FIG. 5. As in Fig. 3.
bled the condensation funnel of a tornado documented by Bluestein et al. (1988), in which the condensation funnel also fractured into several parts.
I was not able to estimate the sense of rotation in any of these steam-devil vortices.

b. 23 December 1989

I returned to the lake the following morning and observed more steam devils. Again, cumulus clouds were not visible above the steam devils. Since the wind was much weaker than it had been the previous day, it appears that wind speed is not a critical factor in determining whether or not steam devils form.

On this morning I brought along a video camera and recorded some of the larger-scale air motions just above the lake surface. The motion of the steam fog was an excellent means of visualizing the flow. My observing location was situated approximately 3 m above the lake surface, so I could look down upon the steam fog. The steam devils that formed within approximately 75 m of me were preceded by cycloonic vortices of tens of meters in scale. The environmental flow associated with steam devils farther away was not discernible. Unfortunately, I did not have my tripod and consequently could not shoot steady pictures. The bitter cold temperatures also made it difficult to adjust the camera; there was no record at what focal length the zoom lens had been set. In addition, I was looking into bright sunlight reflected off the steam fog and therefore had some contrast problems. It was not possible to analyze the videotape photogrammetrically.

Two other observations are noteworthy: Some of the steam devils had multiple vortices rotating around each other. I don’t believe this has been reported before. In addition, some of the steam devils had hollow cores, with rapid upward motion visible along the outer edge.

My observations were all serendipitous. I hope to record some higher-quality video of steam devils in the future, which will allow one to do quantitative photogrammetric analysis.

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REFERENCES