CORRESPONDENCE

Comments on "Downdrafts in cumulus clouds"

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We should like to submit some observational data on downdrafts around a growing cumulus cloud which may be pertinent to the exchange of correspondence among Drs. Vonnegut, Malkus, Byers and Braham.[3]

On the evening of 16 July 1952, a large polyethylene balloon was launched from Minneapolis by our group at General Mills. The inflated diameter of the balloon was 22 m, and a total load of more than 450 kg was carried on the lifting gas. A free lift of about 40 kg was used, causing the balloon to rise at 2.8 m/sec. The balloon shown in fig. 1 was launched just ahead of a thunderstorm, which was approximately 4 km away at the time of the launching and was advancing from the northwest. The balloon climbed through the air ahead of the storm until it reached an altitude of 8.25 km. At approximately this time, the storm was directly overhead, but no rain at the ground was noted then or subsequently. After reaching the altitude of 8.25 km, however, the balloon descended at 1.7 m/sec until it leveled off near 2.1 km above sea level. The balloon then apparently passed under the storm, oscillating up and then down, and then continued its climb on the back side of the storm. Initially, the new rate of ascent was approximately 3.4 m/sec to an altitude of 5.2 km, and thereafter the balloon climbed more slowly to the maximum altitude of approximately 18 km, where it remained for some time. The time-altitude curve for this flight is shown in fig. 2.

The observations recorded at the time are quoted as follows: "The balloon was launched just ahead of a thunderstorm, where it was caught in a downdraft, passed under the storm and climbed behind the storm to its maximum altitude."

Our previous experience has been that such heavily loaded plastic balloons do not survive when caught

[1] Mr. Moore's present affiliation: Arthur D. Little, Inc.
[2] Mr. Smith's present affiliation: Free Europe Press.
[3] B. Vonnegut, J. S. Malkus, H. Byers, and R. R. Braham, Correspondence on "Downdrafts in cumulus clouds," *J. Meteor.*, 12, 508–510, 1955.

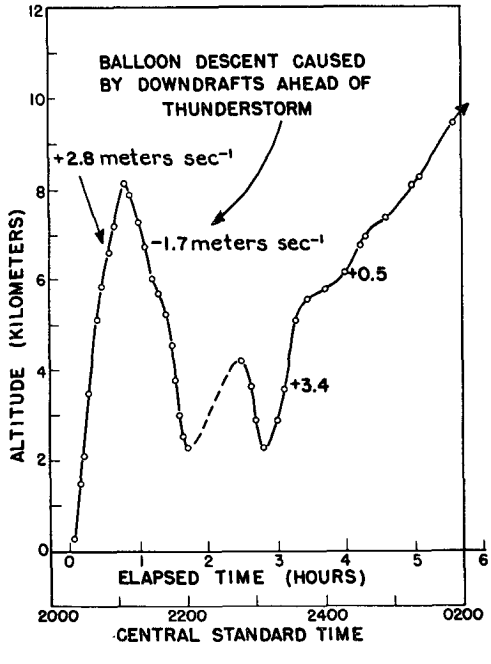

FIG. 1. Large polyethylene balloon just after launching at 0218 GCT 10 July 1952. Approaching thunderstorm is in background.

FIG. 2. Time-altitude curve for balloon ascent, showing effect of downdrafts ahead of thunderstorm.

inside a Midwestern thunderstorm. The survival of this balloon probably indicates that it did not enter the turbulent areas of the storm nor acquire a "load" of rainwater, as would have been the case had the downdraft been caused by falling rain. From the descent, it also appears that the velocity of the downdraft ahead of the storm may have been in excess of 4.5 m/sec from 8.25 km down to the altitude of 2.4 km.

Casual examination of *Meteorological abstracts and bibliography* shows a number of references to downdrafts being observed in the clear air outside of cumuliform clouds. For example, Eldridge[4] reported a tail-balloon observation with which downdrafts of 2.5 m/sec were measured for 3 min between 1.8- and 1.2-km altitude. Jones[5] reported up and down currents of 6 m/sec or more inside a cloud, while outside the cloud, down currents exceeded 3 m/sec with no up currents being observed. Samson[6] reported a descending air current at Nairobi with 1-min average velocities of 5 m/sec observed by radar-tracked radiosonde balloon between 12,000 and 15,000 ft. In addition, Humphreys[7] states that ". . . down flow of air over the evaporating, hence cooling, surface of a cumulus cloud is well known to aviators. . . ." Radok,[8] in Australia, made some glider measurements inside a well developed and presumably precipitating thunderstorm. He found downdrafts of speed greater than 40 m/sec at 2-km elevation and pointed out that this was considerably greater than any extremes of downdraft-velocity measurements reported for Florida thunderstorms by the Thunderstorm Project.

In view of the great divergence of views regarding the motion of cumulus circulation, it seems desirable to obtain longer duration, more direct measurements by a slower-moving probe than powered aircraft.

Under consideration for this purpose is the use of a controlled, neutrally stable, plastic balloon which would be towed into a growing cumulus cloud, then released there to follow the cloud motions. The altitude changes would be recorded and telemetered. A radar target, or beacon, might provide information as to the balloon's location within the cloud echo. From such a low-velocity platform, periodic photomicrographs could be taken automatically of the cloud and precipitation particles. In addition, the measurement of the cloud conductivity, and of horizontal components of the electric field, is of considerable interest in examining the genesis of charge accumulation in growing clouds.

In conclusion, we should like to acknowledge that the Minneapolis observation of a thunderstorm downdraft was part of some research supported by the Department of Defense at General Mills, Inc. The use of a neutrally stable balloon is part of a study supported at Arthur D. Little, Inc., by the Geophysics Branch of the Office of Naval Research, under Contract Nonr-1684(00).

[4] R. H. Eldridge, "Pilot balloon ascent near a cumulonimbus cloud," *Meteor. Mag.*, 79, 327–328, 1950.

[5] R. F. Jones, "Five flights through a thunderstorm belt," *Quart. J. r. meteor. Soc.*, 80, 377–387, 1954.

[6] H. W. Sampson and J. Gross, "Strong descending air current at Nairobi," *Weather*, 8, 282, 1950.

[7] W. J. Humphreys, *Physics of the air* (3rd ed.), New York, McGraw-Hill, 317, 1940.

[8] U. Radok, "A remarkable thunderstorm flight record," *Austral. J. sci. Res.*, A, 2, 550–563, 1949.

Reply

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The data supplied by Messrs. Moore, Smith and Church is a most welcome contribution on the subject of downdrafts in and near large cumulus clouds, in particular since the downdrafts experienced by their balloons appeared not to be in the main turbulent or rain area within cloud.

The question concerning at which stage of the cloud's life the downdraft formed, or whether such are present in or near all large cumuli is, of course, still not resolved. Continued analysis at this Institution of cumulus data obtained by PBY aircraft in the trades shows, however, downdrafts of the same order of magnitude as the main updrafts within or just adjacent to all cumulus clouds studied so far. The system of measurement and data reduction have been placed on a footing far firmer than previously reported, and there is no possibility that these downdrafts are fictitious recordings. The largest cloud studied so far is a precipitating cumulonimbus about 6 km across, so that very large thunderstorm clouds have not been included by us.

There also seems to be some theoretical evidence accumulating that the formation of a downdraft is a necessary concomitant of the formation of an updraft in unstable surroundings. I believe this should be true also for saturated air in conditionally unstable surroundings. If so, a downdraft would almost inevitably form on the downshear side of a rising cloud tower, but might on occasion penetrate very little distance downward if the liquid-water content were rapidly consumed by evaporation.

The dynamics of cumulus downdrafts and especially their role in the cloud's life cycle, precipitation and electrification is still, in my opinion, not fully understood, and much further observational and theoretical evidence is extremely desirable.