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ON THE ORIGIN OF DOWNDRAUGHTS IN A THUNDERSTORM.

Meteorologists are generally unanimous in the view that before a CuNb cloud can culminate into a thunderstorm, it is essential that a local concentrated cooling must develop at a high altitude inside the cloud. According to the present idea such conditions are produced in an airmass CuNb cloud as a result of the falling of cold rain or hail and rain, and the consequent cooling of the air mainly by evaporation and to a little extent by conduction. If, however, such a process is taken to be the primary cause for initiating the downdraught in the cloud, it is difficult to explain the following observed facts :—

(*i*) All airmass CuNb clouds do not culminate into thunderstorms although in the life history of all CuNb clouds a stage must develop when the vertical currents are either absent or too feeble to support the hails or raindrops against gravity ;

(*ii*) Downdraughts do not result in all cases where rainfalls from thick NS clouds ;

(*iii*) All CuNb clouds from which rain is falling are not associated with downdraughts and squalls ;

(*iv*) Cloud looking like an inverted crater was observed during a thunderstorm at Kano, the peculiar structure being obviously due to evaporation of cloud in the zone ot downdraught, although it goes against the assumption that the presence of raindrops or hail and raindrops is essential for the maintenance of the downdraughts.

Moreover, an air parcel carrying waterdrops and moving downwards through clouds should be neither accelerated nor decelarted as it will have the same temperature as its cloud environment while moving down at the saturated adiabatic rate. It can be accelerated to cause a downdraught below the cloud base only if the air below the cloud base is less humid than the air parcel itself. But contrary to the above expectation, thunderstorms with squalls have actually been observed with downdraughts having lower mositure contents than the environment.

From the observed facts stated above, it appears that the existing idea about the physical process for initiating the downdraughts in CuNb clouds requires modification as it is unable to stand all its usual tests. A physical process for the development of conditions initiating downdraughts is suggested below, which provides suitable explanation for all the facts observed in this connection.

It is well known that although Cumulonimbus clouds above the freezing level in some cases consist of ice crystals, yet in the majority of cases they consist of supercooled water drops. Bergeron has, further inferred that in an adiabatically ascending airmass in which the droplets would be expected to be considerably disturbed and to have a large size, the region of supercooled water drops would not extend above the level of -10°C or -20°C. Or in other words the Cumulonimbus clouds would consist of ice crystals only above the level of -10°C or -20°C.

If for some reason, such a layer of supercooled waterdrops gets suddenly disturbed and stirred up, the sudden congelation of these supercooled water drops would result and as a consequence heat would be liberated raising the temperature of that layer. On account of this heating the layer of air aloft will now be potentially colder than the layer below which initially contained supercooled drops, resulting in a turbulent motion similar to the one observed in an unstable layer of fluid. As this occurs very near the freezing level, the turbulence will carry some of the ice crystals to levels where the temperature is higher than 0°C. These ice crystals will melt consuming the heat from the environment and thus cool it suddenly. Such a cooling will be local, concentrated and decided.

It is evident that the degree of cooling will depend upon the amount of ice crystals. But since the lowest temperature to which any layer at a temperature higher than 0°C can be cooled by the melting of ice is 0°C, the possible amount of cooling will be greater, as the ice crystals are carried further below 0°C level. This will depend upon the degree of turbulence—the greater the turbulence the greater will be the descent of ice crystals. Both the amount of ice crystals and the intensity of turbulence will be maximum if the zone of supercooled water drops is also the level of accumulation. The cooling so produced will act as a trigger for the downdraught. This descending air will follow a saturated adiabat on account of the water drops it carries and will thus be cooler than the surrounding column of air at all levels right upto the base of the cloud, for the lapse rate in cloud air has been found to be greater than saturated adiabatic. As the down rushing air is moving in an energy producing medium, it will get accelerated in its descent from the 0°C level right up to the cloud base. If below the cloud the vapour pressure of the environment is less than the vapour pressure of the downrushing air, further cooling of the downdraught on account of the evaporation of water drops into the environment will take place and this will further increase the acceleration of the downrushing air. If, however, the vapour pressure of the environment below the cloud base is not less than the vapour pressure of the downrushing air, further cooling of the downdraught due to evaporation will not occur but still the downcurrent will continue due to the acceleration already acquired.

On the basis of the process outlined above one would expect the following :—

(*i*) CuNb clouds with ice crystals above the freezing level will not culminate into a thunderstorm.

(*ii*) In Nimbostratus clouds probably the water accumulation in the supercooled zone is not greater than in the layer above and hence no downdraught results.

(*iii*) CuNb clouds with supercooled water drops above the freezing level will culminate into a thunderstorm only if the level of accumulation of water in liquid and solid phase coincides with the levels of supercooling so that the amounts of liquid water (per Kg. of dry air) contained in supercooled layers is greater than the amount in the layers above having only the solid phase.

(*iv*) As the presence of raindrops or hail are not essential either for the initiation or maintenance of downdraught, the thunderstorm cloud may develop a crater in the zone of downdraught, if the amount of water content in the downdraught is not enough to keep the humidity 100% and a hole may develop at the base of the cloud which will look like an inverted crater like the one observed at Kano.

(*v*) As the process outlined above is independent of the evaporation cooling, it is possible to have a squall associated with a thunderstorm in which the environment has higher water content than the downdraught itself.

The process for initiating downdraughts in thunderstorms and the resulting circulation will be discussed in detail in a subsequent paper to be published shortly.

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