Fig. 1—Clouds forming at summer midday over sandy soil of Cape Cod. Cloud base at about 2500 ft., top well below icy-crystal level. Presence of active updrafts and turbulence is indicated by cloud's hard rounded edges and tops. Prevailing wind was from rear left to front right of picture (northwesterly) so as to blow clouds directly out over harbor. Fig. 2—Small, thin cloud at upper right is what remains of middle cloud in previous picture after 20 minutes of over-ocean travel. Soft, hazy appearance of cloud edges indicates that the turbulence and updrafts have disappeared and that the cloud is dying. Fig. 3—Same cloud five minutes later.

Cumulus, Thermals and Wind

By JOANNE STARR MALKUS, Ph. D.*

CUMULUS clouds have often been compared by ground-dwellers to cotton puffs floating through the sky, or to tumbleweed blown along by the wind. The sailplane pilot will recognize these descriptions as far too passive; he is aware that a cloud is not simply an aggregate of droplets drifting as a coherent body like a balloon, but rather a transient, dynamic balance between rapid growth and equally rapid destruction.

For example, it is a common observation that when an average midsummer cumulus moves out over the cooler ocean, thus leaving its energy source, the entire cloud disappears in 5-30 minutes' time. Figures 1-3 show this process occurring on a summer afternoon on Cape Cod, Massachusetts. The middle cloud in the first photograph was followed over a narrow strip of land and out over the shore. The second picture, taken from the dock 20 minutes after the first, shows the cloud in the final stages of dissipation.

An even more illuminating way to study clouds photographically is by means of a motion picture camera arranged to make exposures at the rate of about one every two or three seconds. When these so-called "time-lapse" pictures are run off on an ordinary projector at 16 frames per second, the processes appear greatly accelerated; the clouds boil and bubble along almost like steam from a railroad engine, and many important aspects of their life cycles are revealed which ordinarily occur too slowly for naked eye recognition.

Many motion picture cameras can be easily equipped for this purpose. The camera used in these studies at the Woods Hole Oceanographic Institution was a Cine-Kodak 16 mm, with an electrical shutter-triggering mechanism to expose the film once every two seconds. A red "A" filter was used with "Plus X" panchromatic film.

One of the most valuable revelations first suggested by such movies is that, in general, the speed of cumulus clouds does not correspond exactly to the speed of the wind. That often the clouds are moving through the air and not just drifting is evidenced on the film by cloud fragments seen streaming out in one direction only.

Since relative motions between cumulus clouds and the surrounding air can be shown to cause non-symmetrical patterns in the associated turbulence and vertical velocities, to modify the slopes of thermals, and to affect even the growth processes of the clouds themselves, it is necessary to verify precisely that such relative motions really do occur, and to predict their magnitude. Such experimental verifications have been made by means of radar photographs of clouds taken by the Thunderstorm Project of the United States Weather Bureau. Why these relative motions must exist, can be deduced from Newton's laws of motion, if we remember that ordinarily the wind does not remain constant with height above the ground, but increases or decreases in speed, and often changes its direction.

If a thermal chimney (the presence or absence of liquid water in the form of a cloud is unimportant insofar as the relative motion is concerned; it is merely the upward velocity which is vital) should ascend, without any frictional forces, through an environment in which

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