REFERENCES

CHARNEY, J. G. and A. ELIASSEN, 1949 a: A Numerical method for predicting the perturbations of the middle latitude westerlies. *Tellus*, **1**. 2. pp. 38—54.

CHARNEY, J. G., 1949 b: On a physical basis for numerical prediction of large-scale motions in the atmosphere. *Journal of Met.* **6**. pp. 371—385.

CHARNEY, J. G., R. FJÖRTOFT and J. VON NEUMANN, 1950: Numerical Integration of the barotropic vorticity equation. *Tellus*, **2**. 4. pp. 237—254.

SUMNER, E. J., 1950: The significance of vertical stability in synoptic development. *Quart. J. R. Met. Soc.* **76**, pp. 384—392.

SUTCLIFFE, R. C. 1947: A contribution to the problem of development. *Quart. J. R. Met. Soc.* **73**, pp. 370—383.

SUTCLIFFE, R. C. and A. G. FORSDYKE, 1950: The theory and use of upper air thickness patterns in forecasting. *Quart. J. R. Met. Soc.* **76**, pp. 189—217.

Photographs of the "Complete Precipitation" of a Cumulus Cloud

By L. SHERMAN, Institute of Geophysics, University of California[1]

(Manuscript received 28 December 1950)

It is well known that in higher latitudes the lower parts of cumulonimbus may precipitate completely leaving only the anvil. It is also well known (KOTSCH, 1947) that in tropical latitudes precipitation occurs from clouds which have not reached the freezing level. Finally, it is known, at least to most tropical meteorologists, that quite commonly in the tropics a cumulus cloud will precipitate completely.

PALMER and ELLSAESSER (1949) describe this last phenomenon as follows: "In low latitudes the entire cloud may precipitate and disappear, and in the last stages you observe precipitation falling from a clear sky. . . . the cloud begins to show evidence of shear, and precipitation usually begins. The top part then breaks away and the bottom dissolves. In the final stage the falling precipitation from the top portion of the cloud is white and fibrous and is sometimes mistaken for cirrus (Figure 3)." I have reproduced this figure 3 as my figure 1. In a recent article CRADDOCK (1949) has presented several photographs of this phenomenon. In addition the reader may find other published examples in DEPPERMANN'S (1937) collection of cloud photographs, although Depperman does not specifically call attention to them. Both these sources, however, have portrayed clouds dissipating inland over a coastal area. In this note we present photographs of this occurring over the sea, with its horizontally uniform properties as a source of heating and of moisture.

During the summer of 1950 there occurred Operation MIDPAC—a geophysical research cruise jointly sponsored by the U.S. Navy, through its Office of Naval Research, and the University of California, through the Scripps Institute of Oceanography and the Institute of Geophysics of the University of California. The author was a member of the meteorological group aboard the Scripps' vessel *Horizon*. This group, headed by D.S. Johnson of the Department of Meteorology, UCLA, was the meteorological component of MIDPAC. It was during this cruise that the photographs, which are the reason for this note, were taken.

On 20 August 1950 at approximately 0800 local time the color photographs of figure 3, reproduced

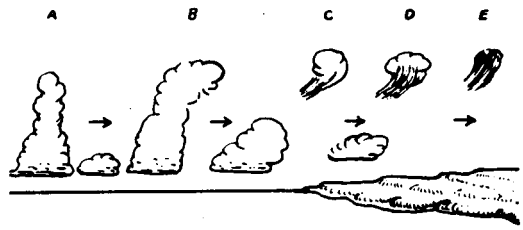


Fig. 1. The complete precipitation of cumulus (after Palmer and Ellsaesser).

[1] Publication No. 9 of the Institute of Geophysics of the University of California.

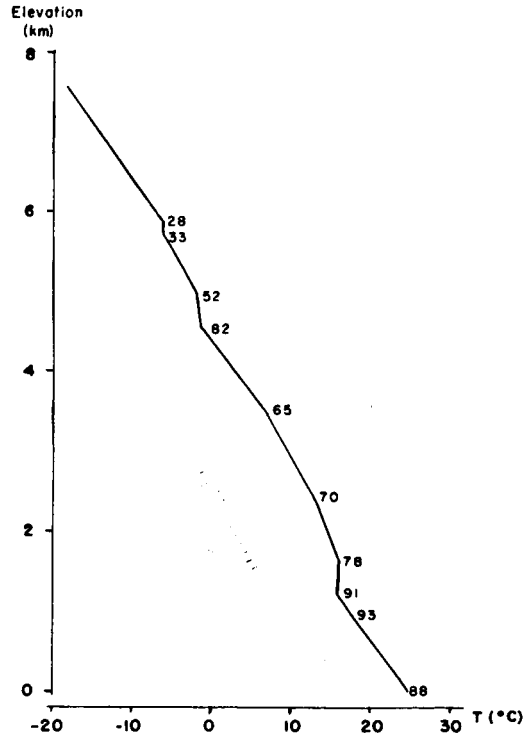


Fig. 2. A sounding released from the ship *Horizon* two hours and forty minutes prior to the time at which the photographs of figure 3 were taken. The temperature is plotted against elevation; relative humidities are entered to the right of the temperature curve. Note that the freezing level is well above 6,000 feet, which is the height just reached by the topmost tower of the clouds pictured in figure 3.

in black and white, were taken at intervals of less than a minute. At that time the approximate position of the *Horizon* was 16.2N, 152. 8W. Earlier that morning, at 0520 local time, a radiosonde had been released; this sounding is shown in figure 2. From the surface weather log of the expedition we find that the 0800 surface observation included: 1/10 cumulus humilis, bases 2,000 feet; 1/10 swelling cumulus, bases 2,000 feet; 2/10 stratocumulus, bases 4,000 feet; light showers in sight (from the swelling cumulus), surface wind 050 degress 20 knots. The cloud heights were estimates.

In the three photographs we see almost exactly the sequence shown in figure 1, save that the lower portion of the original cumulus does not disappear. Initially a cumulus cloud, with base about 2000 feet and capped by a narrow tower reaching to 6000 feet or less was observed to the southwest of the ship. The tower showed evidence of shearing, and a rainbow was observed between two and four thousand feet. At this juncture a mad dash to obtain the camera ensued. Then the pictures of figure 3 (a, b, and c), which show the tower shearing and breaking away from the cloud, were taken. During all the time that the tower was tilting and drifting away, it was also precipitating. Ultimately it disappeared entirely. The last photograph is taken obliquely through the rain falling from a clear sky (not evident in the photo) with the remaining lower portion of the original cumulus in the background. It strikingly bears out the statement of Palmer and Ellsaesser that this precipitation might be mistaken for cirrus. Were it not for the evidence of its low elevation given by the cumulus cloud in the background, the photograph of this rain could easily be identified as a photograph of cirrus.

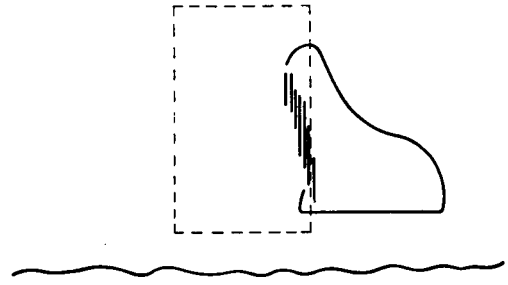
REFERENCES

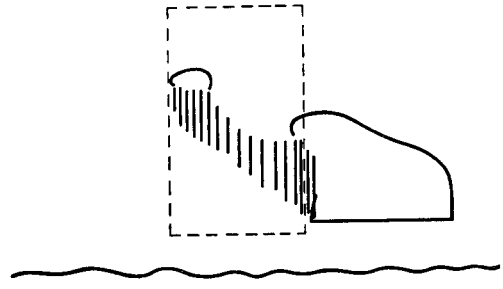
CRADDOCK, J. M., 1949: The Development of Cumulus Cloud; Results of Observations Made in Malaya. *Q. Jour. Roy. Met. Soc.*, **75**, 324, pp. 147—153.

DEPPERMAN, C. E., 1937: *The Weather and Clouds of Manila.* Manila Bureau of Printing.

KOTSCH, W. S., 1947: An Example of Colloidal Instability of Clouds in Tropical Latitudes. *Bull. A.M.S.*, **28**, 2, pp. 87—89.

PALMER, C. E. and ELLSAESSER, H. W., 1949: Notes on Tropical Meteorology. *Tech. Bull. of 2143d Air Weather Wing*, **1**, 2, pp. 1—49.





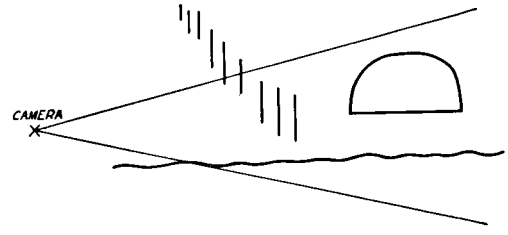


Fig. 3. A sequence of 3 photographs of the "complete precipitation" of cumulus. Taken 0800 local time on 20 August 1950 at 16° N, 153° W. The camera was pointed approximately toward 245° (SW). To the right of each picture is given a diagrammatic sketch of what was occurring together with an indication of the extent of the photograph.