Weather Note

THE FIRST WATERSPOUT DISCOVERED ON SATELLITE PHOTOGRAPHS

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On September 13, 1961 a Project Mercury satellite carried a 70-mm. time-lapse camera. The camera axis was nearly normal to the flight trajectory; consequently, adjacent pictures comprised stereo pairs, one of which is shown in figure 1. The stereo base for this pair is about 25 n. mi., the altitude 75 n. mi., and the view is approximately toward the south from 29.5° N., 77° W., at 1407 GMT. At 25° N. (approximately the center of the field of view) and at the satellite longitude, the elevation of the sun was 42° and its azimuth 110°.

The unusual feature of this pair is the "one in a million" view of a waterspout existing as its parent cloud was dissipating. The vortex top is easily seen as a dark spot at the cloud top and the doughnut clouds surrounding this spot merge with the overhang (toward the camera) of the evaporating tower behind it. The vortex tube curves downward to the left and away from the camera into the lower part of the cloud that remains.

Figure 2 is a larger field of view of the same area with labels marking some of the interesting features. The waterspout vortex is marked "a". The cumulus tower which contained the top of the waterspout reached a height of 54,000 ft., ±2,500 ft. The cumulus tower marked "b" was at approximately the same height. The top of the cloud patch, "c", was at 34,700 ft., ±1,400 ft., and that marked "d" at 45,000 ft., ±4,000 ft. The uncertainty figures represent a semi-objective estimate of the measurement errors; the larger error in the last item reflects the fact that the edge of that cloud patch shadow is more difficult to identify on the ocean surface.

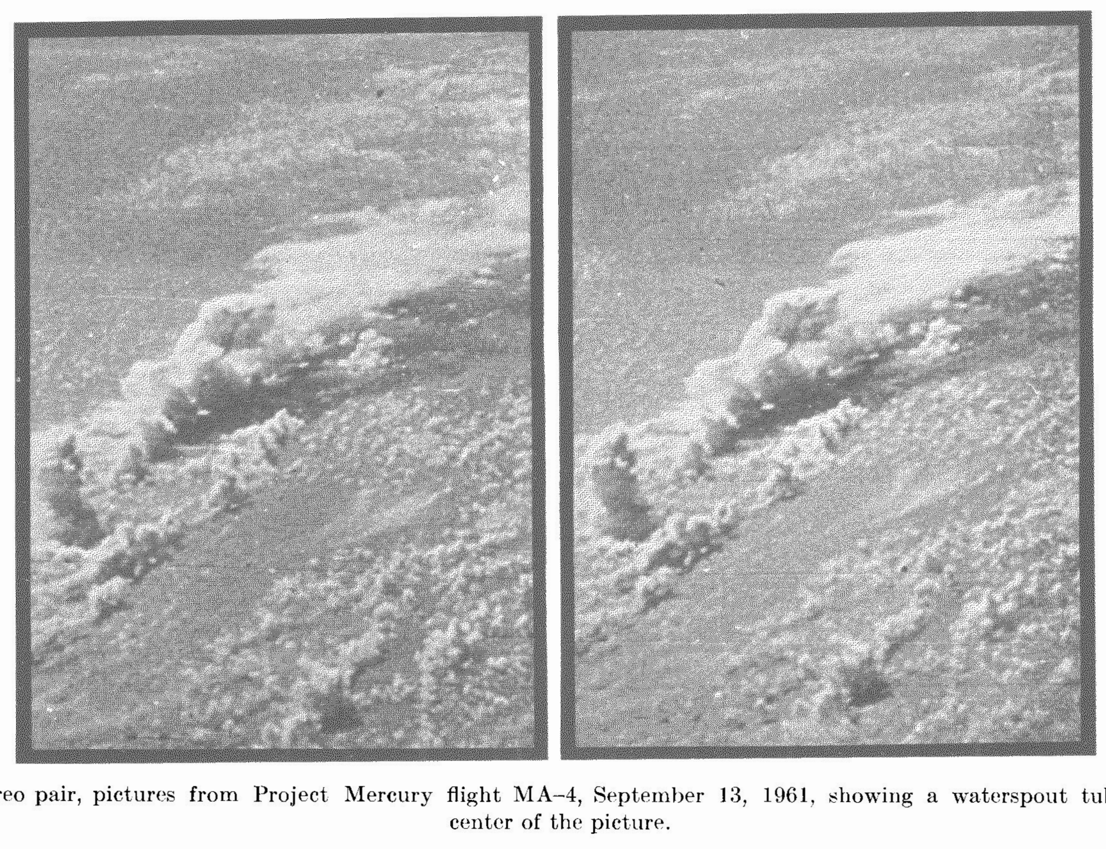

FIGURE 1.—Stereo pair, pictures from Project Mercury flight MA-4, September 13, 1961, showing a waterspout tube at about the center of the picture.

In the vicinity of the waterspout most of the cumuli towers did not penetrate the 500-mb. level, no doubt because of the presence of a dry and/or stable layer in the mid-troposphere. The dryness is suggested by the evaporation at middle levels of the towers that did penetrate to high levels. Both the cloud containing the waterspout and the cloud marked "b" probably reached at least to the tropopause. The latter cloud had just commenced evaporating in middle levels giving it a pinched-in waist, and the waterspout cloud had completely evaporated in the dry middle layer. The patches of anvil cloud at two elevations, "c" and "d", are further evidence of at least two levels of stability in the high troposphere.

Radiosonde observations were made at Bonefish Bay (index number 089) and Goldrock Creek (063) in the Bahama Islands. Only minor stability layers are evident from the transmitted data to explain the stratification shown by the pictures, but large moisture decreases occurred between 1200 GMT, September 13 and 0000 GMT, September 14, in the layer 400 mb. to 500 mb., supporting the suggestion of a dry middle layer.

A vortex tube reaching all the way to the tropopause may be quite unusual[1] but is quite possible from a theoretical standpoint. Although there is no direct evidence for it, this waterspout may have reached to the ocean surface, or it may have terminated at a low-level inversion. Theory shows that a vortex cannot terminate interior to a fluid—it must terminate at boundary surfaces or close upon itself. This condition is also satisfied if a vortex

[1] Another possible occurrence may have been seen in 1950. See H. T. Harrison, "Tornado Funnel Observed at 35,000 ft.," *Bulletin of the American Meteorological Society*, vol. 33, No. 8, Oct. 1952, pp. 350–351.

FIGURE 2.—Large field of view in region of stereo pair of figure 1. Letter "a" indicates waterspout vortex; "b", a cumulus tower; "c" and "d", patches of anvil cloud.

terminates at one boundary while the other end terminates at a mass sink, for example, water draining from a bathtub. This condition (upside down) must also exist during the formation of a waterspout in a cloud. Convection within the cloud must produce a mass divergence from the top of an air column so that a converging column of air concentrates its angular momentum to form a vortex tube. The effective level of this mass sink is usually inside the cumulus tower well below the tropopause. In the case pictured here, however, it is suggested that the vertical motion existed for a time throughout the height of a cumulus tower which reached to, and perhaps somewhat above, the tropopause and that the divergence (mass sink) took place in a thin layer near the top, thereby producing a vortex to the tropopause. Once formed, theoretical conditions were satisfied for a vortex tube that could maintain itself with no further driving mechanism. Indeed the existence of a vortex tube from a low-level inversion to the tropopause is the situation most favorable for its persistence after the mass sink disappeared. Viscosity must eventually have destroyed the vortex, but its existence after the parent cloud had dissipated as shown here indicates the vortex must have existed quite a few minutes after the formation mechanism (convection within the clouds) had disappeared.

Several other interesting features are shown in figure 2. Strong winds from the east in the upper troposphere are shown by the sheared-off anvils over much of the picture. From the upper right portion down to the center of the picture are many cumulus and cumulus congestus lines which indicate southwest flow in at least the lowest 10,000 ft., marking the circulation about the vortex which developed into the "sneak storm"[2] that moved up the coast causing some damage in New England a few days later. The actual vortex of this storm is out of view, but the cirrus generated by it lies across the foreground of figure 2 and the lower right of the picture is the southeastern periphery of the storm.

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[2] This storm developed and moved so quickly that it was not given a name and was not included in the original list of tropical cyclones of the 1961 season. See Richard Fay, "Northbound Tropical Cyclone—A Case History," and G. E. Dunn, "Note on Tropical Cyclones of 1961," *Monthly Weather Review*, vol. 90, No. 8, Aug. 1962, pp. 351–361 and 362.