The five stage life cycle of a waterspout

TECHNICALLY AN INTENSE low pressure vortex column, fair-weather waterspouts most frequently develop on the sea surface and then move skyward, rather than dropping down from parent clouds like tornadoes. Most are potentially lethal. Lasting from two to 20 minutes, they move at 10-15 knots, their intense vortices at maturity typically generating, however briefly, winds of hurricane force or greater. The funnels occur most frequently off the lee shores of continents in the tropics and sub-tropics such as Asia, Australia, and, notably, North America, particularly the Florida Keys where heated, humid air creates strong convective currents.

Conditions are best when a high temperature lapse rate (i.e. a rapid decrease of temperature with elevation) prevails at the sea surface during the warmest part of the day (usually around high noon or early afternoon) and the winds are light and variable, with an extremely weak vertical wind shear. This kind of environment thermodynamically can support strong updrafts. In the Florida Keys, due to the unique geomorphology of the region, waterspouts spawn most frequently in the late afternoon or early evening.

Research has determined that waterspouts are the end product of five interacting scales of motion (ranging from the synoptic scale to the microscale), that produce a cascade of energy. When a patch of air just above the sea surface becomes heated and rises, the resulting pressure differential causes the surrounding, slightly cooler, air to spiral inward, forming an eddy, much as a land-born dust devil. Over warm water, however, the abundant water vapor at the sea surface adds to the latent heat of condensation. And because water vapor is lighter than dry air, the steep water vapor gradient that is present helps carry the original spiraling eddy skyward. Though a parent cloud need not be directly overhead, there is always a cloud system or cloud mass nearby (usually cumulus congestus), coupled with strong convective air currents that frequently produce a funnel that moves downward.

From this point on, NOAA's Dr. Joseph Golden has distinguished five stages of waterspout formation:

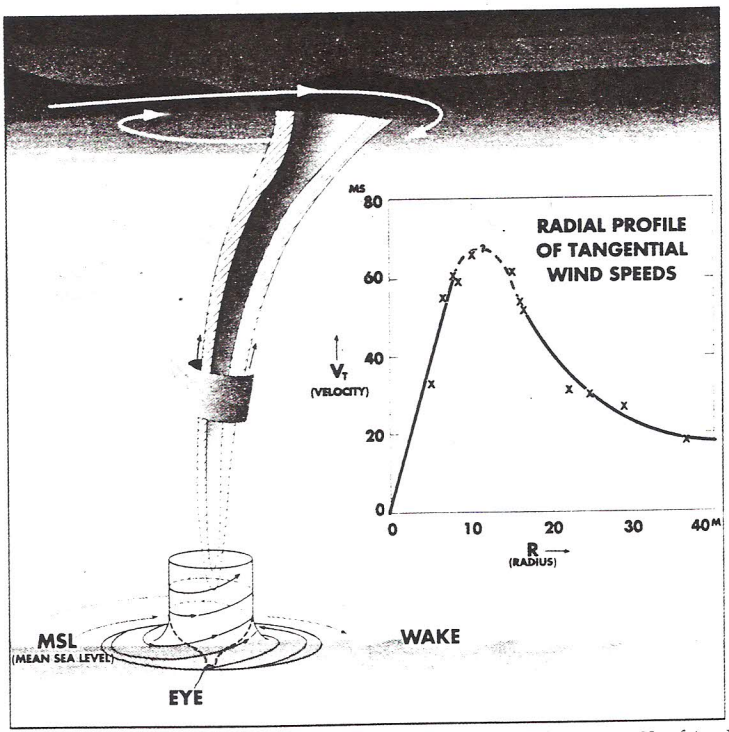
1. Dark spot A prominent circular, light-colored disk appears on the surface, surrounded by a larger dark area of indeterminate shape and with diffused edges. While not visible to the mariner at sea level, the presence of a dark spot and an associated funnel cloud overhead indicate that a complete funnel is present.

2. Spiral pattern A pattern of light and dark-colored surface bands spiraling out from the dark spot develops.

3. Spray ring A dense swirling annulus (ring) of sea spray, called a cascade, appears around the dark spot with what appears to be an eye similar to that seen in hurricanes.

4. Mature vortex The waterspout, now visible from sea surface to the overhead cloud mass, achieves maximum organization and intensity. Its funnel often appears hollow, with a surrounding shell of turbulent condensate. The spray vortex can rise to a height of several hundred feet or more and often creates a visible wake and an associated wave train as it moves.

5. Decay The funnel and spray vortex begin to dissipate as the inflow of warm air into the vortex weakens. Frequently, rain showers that develop nearby (caused by the thermal updraft) create a down draft (or leading edge gust-front) of cooler air that accelerates the waterspout's decay. Ship masters whose vessels have been hit by waterspouts during the decay phase have reported being drenched with a combination of salt water and rain water.



[Diagram by Bruce Krefting]

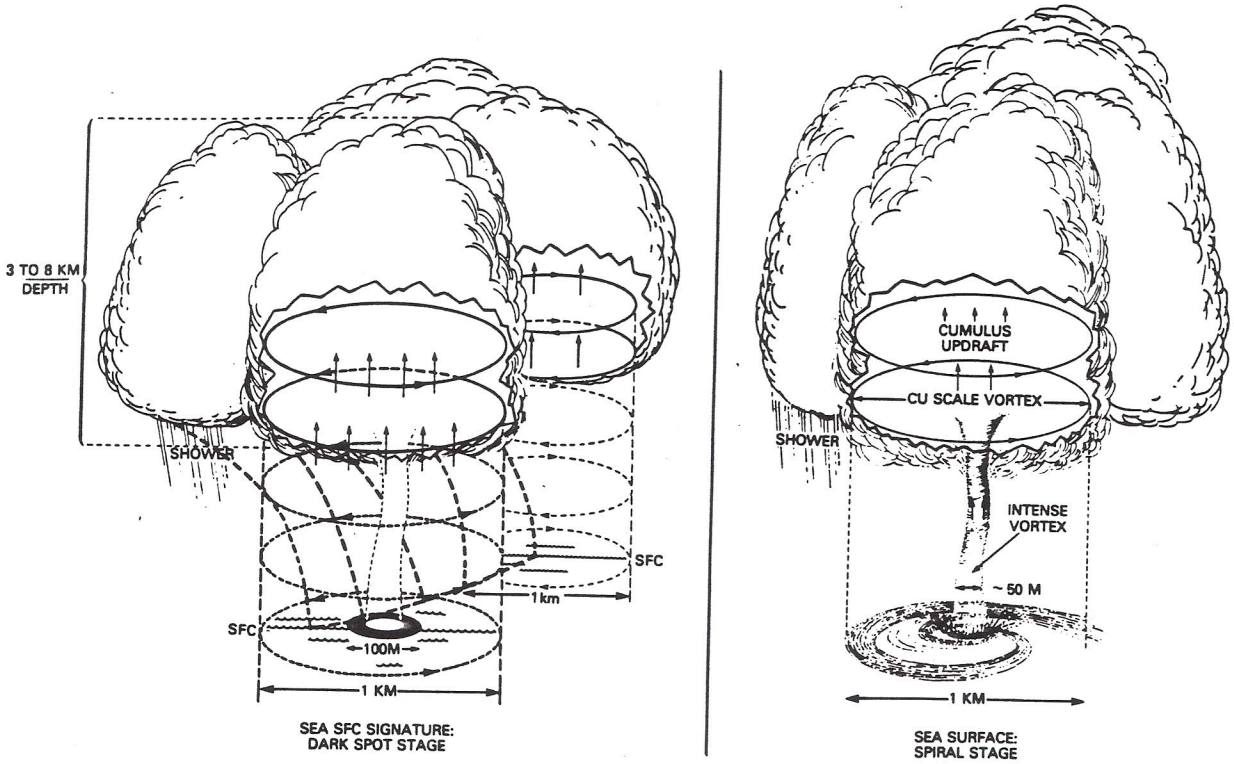


FIG. 1. Schematic illustration of early prefunnel (left) and intermediate (right) stages of waterspout development from interaction of cumulus processes. The different horizontal sizes of the parent vortices (solid circles in cloud, dashed when shown below, as on left), surface dark spot, and condensation funnel are illustrated. The heavy dashed curves on the left picture denote cold downdraft air which terminates at the surface as a gust front; its postulated role is discussed in section 7 of the text. For simplicity, the cold downdraft, the anticyclonic member of the parent vortex pair, and the subcloud extension of the parent vortices are omitted in the right picture. On the right, the high wind, low pressure center of the vortex is made visible by a condensation funnel. The dark sea-spray ring at funnel base suggests tangential winds exceed 22 m s^{-1}.

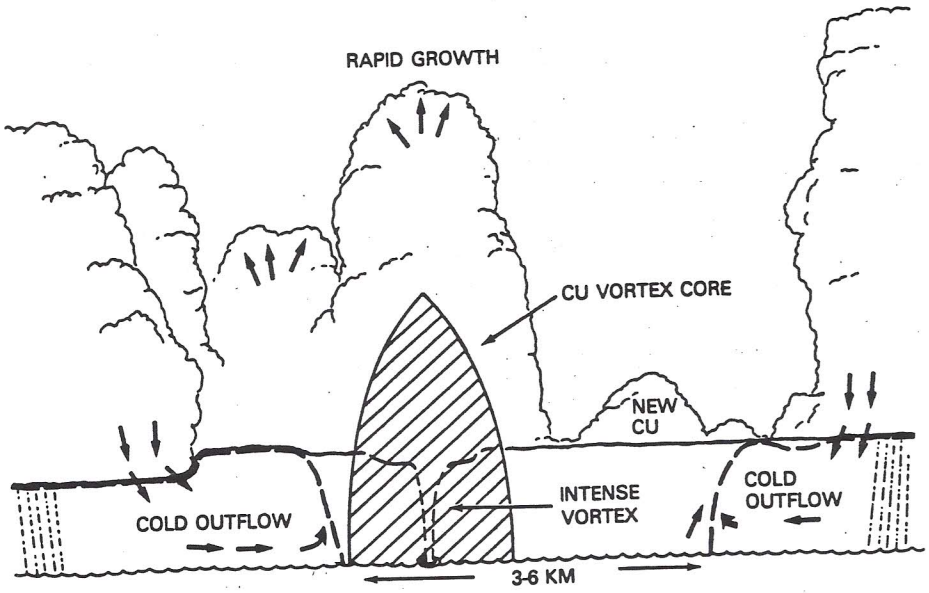


FIG. 19. Schematic illustration (not to scale) of cumulus-outflow interactions in relation to invigorated cumulus overhead of parent vortex development. The shaded region approximately outlines the vortex core of one of the vortex pair organized by the model cloud F on day 186. The circle at the surface within the core is the sea surface dark spot; the dashed vertical lines show where the condensation funnel will appear as the central pressure drops. The gust front within and beneath cloud F (Fig. 18) is not shown on this diagram.