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COOL INFLOW AS A WEAKENING INFLUENCE ON EASTERN
PACIFIC TROPICAL CYCLONES

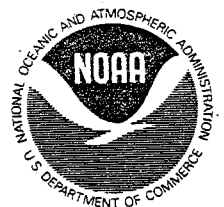
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COOL INFLOW AS A WEAKENING INFLUENCE ON
EASTERN PACIFIC TROPICAL CYCLONES

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ABSTRACT. Relevant research reports are reviewed briefly. They are the basis for concluding that the possibility of cool inflow should be considered regularly in making Eastern Pacific hurricane intensity forecasts. Greater inflow into the right side of a moving storm has special significance for Eastern Pacific hurricane intensity changes. The areal extent of the storm's circulation is another important factor in determining the amount of cool inflow. Satellite pictures reveal much about the volume of air rising in a hurricane's central chimney and, therefore, of the cyclone's intensity. Further application of satellite information and a computer program could be the way to improved intensity forecasts.

I. THESIS

Forecasters dealing with Eastern Pacific hurricanes have long been faced with an apparent difference of opinion as to the importance of inflow of cool air as a dissipating influence. At the National Weather Service (NWS) Eastern Pacific Hurricane Center, the problem has traditionally been dealt with in a qualitative way using trajectory techniques to anticipate weakening and satellite pictures or other indications of current intensity for confirmation and comparison. This approach was first questioned on the record by Sadler (1963), who concluded, incidental to a Television Infrared Observation Satellite (TIROS) study of 1962 hurricanes, that the outer storm circulation usually acts as a barrier keeping cold air to the north from entering directly into the inner storm circulation.

Sadler's conclusion was discounted by forecasters as contrary to the equations of motion, which require friction-induced cross-isobar flow with streamlines toward lower pressure in the inflow layer. Also, later high-resolution satellite pictures seemed to explain Sadler's observation as having originated from a breaking up of trade-wind stratocumulus when approached by the hurricane. This breakup was a result of turbulence from stronger low-level winds, heating from below and vertical stretching of the cool layer as this air moved along a cyclonic trajectory into the hurricane circulation.

Operational application of the weakening effect due to cool air inflow continued into the 1970s (Denney 1969, 1971, 1972), with seeming support from indications of satellite pictures and from data received from air-reconnaissance flights. However, Hansen (1972)

disputed claims as to the importance of cool inflow. He stated that dissipation from the effects of cold water would be limited to contact of the cyclone's circulation (radius about 100 n.m.) with water as cold as 77.5° F. (25.3° C.). Hansen's paper is self-contradictory, however, in that it later says in listing evidences of dissipation: "Cyclonic deformation of the stratocumulus cloud bank north of the storm indicates incorporation of cooler air from below the inversion level north of the cyclone into the peripheral cyclone circulation". Hansen's principal objection to the importance of cool inflow was that the response of the atmosphere to a warmer sea is quite rapid, so one would expect air that had traveled more than 200 miles south of the 80° F. isotherm to be capable of sustaining any ongoing intensity of a hurricane, whatever initial properties of the air may have been, or however direct to the center the trajectory might be.

It is theoretically possible to formulate an equation giving the modification of air along a trajectory into a hurricane; unfortunately, no such equation or other objective approach to the problem is available to the forecaster just now. There is substantial expert opinion supporting the concept of cool inflow as a hurricane dissipating influence (Riehl 1954, p. 339), (Simpson 1971). Also it has been shown that equivalent potential temperature (θ_E) determines the minimum pressure possible in the rain area of a tropical cyclone. No lower than 1000 mb seems possible from normal tropical air (θ_E about 350° A) which reaches the base of the eye wall (Malkus and Riehl 1959). From the same hydrostatic considerations, for each degree the inflow air is warmer or cooler than normal, a 2.5 mb lower or higher possible pressure results.

Two statistical studies of the components of motion in hurricanes (Hughes 1952 and Miller 1959) revealed the radial component of low-level motion toward the center much greater on the right side than on the left. Those results were not related to the speed of the cyclone. Malkin and Myers (1961) did relate the imbalance of inflow to the speed of the cyclone center through wind fields simulated by a trajectory technique and found a direct relationship. Their simulated hurricane moving 30 mph had radial motion inward at 75 mph from the right rear quadrant 25 miles out, while on the left front quadrant at the same distance there was outflow at 25 mph.

Snellman (1962) applied low-level (2000-ft) trajectories in relating the speed of hurricanes Diane of 1955 and Carol of 1954 to weakening produced by entry of relatively cool air from the U. S. land mass to the left of their tracks. Diane's relatively slow movement allowed penetration of the cool air and dissipation followed. Carol moved rapidly north-northeast to Long Island and New England as a disastrous hurricane, with the rapid movement precluding entry of cool air into the hurricane's circulation.

II. CONCLUSIONS

The possibility of cool inflow should be considered regularly when making forecasts of intensity of tropical cyclones in the Eastern Pacific. Evaluation of the problem will be difficult in many instances

because the forecaster will have much less than full knowledge of the distribution of sea-surface temperatures and of distribution of atmospheric winds, moisture, and temperature. Also, the complex relationships involved in modification of the inflow moving over progressively warmer water, with downward mixing of dry air a factor in some cases, could be handled by a computer program.

Lack of information or a technique for direct application of the cool inflow concept does not preclude use of the idea. An attempt should be made to recognize onset of cool inflow possibilities at any stage of the 72-hour period regularly covered in the forecasts, and to take account of them in the forecast intensities. Ship routing is usually done on the basis of the 48- and 72-hour forecast positions and intensities; thus if forecast winds are routinely too high in certain areas, the forecasts will come to be disregarded.

The greater flow from the right side to the center in a cyclone circulation is one reason why, on a climatological basis, westward-moving Eastern Pacific tropical cyclones tend to weaken shortly after they pass the longitude of Cape San Lucas, Baja California (110°W.), since cooler sea-surface temperatures exist to the right of the storm. It is also a reason why recurring cyclones in the same area are less likely to weaken as they move rapidly northeast toward Mexico since, climatologically, warmer sea-surface temperatures exist to the right of the storm center. Further, west-northwestward moving cyclones are typically impinging on the periphery of a subtropical high-pressure cell to the north with its low-level cool outflow at the same time that increasing distance from the ITCZ is reducing equatorial inflow.

Size of a tropical cyclone is a factor affecting inflow. The large cyclone draws in low-level air from great distances, and thereby can take in cool air from areas that a smaller one could not reach. Thus, the normal growth with maturity is a self-limiting feature for many Eastern Pacific cyclones, leading to their weakening and dissipation. It contributes to the average smaller size of cyclones in the area (Hansen 1972), although all factors that reduce average cyclone life span also contribute.

Satellite pictures are a means of indirect analysis of properties of inflow to a hurricane, and can be even more useful than a direct analysis. For example, the cessation of cirrus production by the central chimney of a hurricane as revealed by satellite pictures may be a clear indication that the equivalent potential temperature of inflow air reaching the base of the eye-wall is so low that the inflow will no longer rise to the cirrus level despite continuing low-level convergence. In such a situation eye-wall conversion of latent heat to kinetic energy has been almost totally disrupted, and low-level convergence is building a surface stable layer of increasing depth under the central area of the cyclone. Obviously, central pressure is increasing rapidly, and eye-wall winds have already decreased considerably because of loss of the source of kinetic energy together with accumulation of relatively dense low-level air under the eye-wall. Rapid dissipation normally continues. Other less-dramatic information is regularly apparent and should be put to full use. For example, techniques for determining cloud temperatures and movements could be given wider application, as could lapse rates determined through satellite sensors such as VTPR.

All forecasters dealing with Eastern Pacific tropical cyclones would benefit from careful study of each item of literature cited, developing insights into processes of energy exchange and knowledge of typical cyclone behavior. Such insights and knowledge might be a basis for more accurate analyses and forecasts of tropical cyclones.

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