PICTURE OF THE MONTH

The Merger of Two Tropical Cyclones

MARK A. LANDER

University of Guam, Mangilao, Guam

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1. Introduction

The interaction of two spatially proximate tropical cyclones is often referred to as the Fujiwhara effect after the pioneering laboratory and observational studies of Fujiwhara (1921, 1923, 1931). Fujiwhara demonstrated that the relative motion of two adjacent cyclonic vortices was composed of cyclonic orbit around their centroid, coupled with a mutual attraction. The rate of orbit steadily increases as the vortices spiral inward toward one another and eventually the two vortices coalesce into one vortex located at the centroid.

The behavior of two spatially proximate tropical cyclones differs from the classical Fujiwhara effect in several aspects; prominent among these is the fact that tropical cyclones rarely merge. On account of differences from the classical Fujiwhara effect, the interaction between two spatially proximate tropical cyclones is usually called binary interaction. Dong and Neumann (1983) studied the behavior of interacting tropical cyclones and delimited binary interaction to the occurrence of two named tropical cyclones that coexisted for at least 48 h, during which time they approached within at least 13° (1450 km) of great-circle distance and attained at least tropical storm intensity. This separation criterion was based on other studies by Brand (1970), which showed that mutual cyclonic orbit tended to dominate when storms approached within this distance. Brand further noted that mutual orbit tended to commence suddenly. Lander and Holland (1993) developed a generalized model of binary interaction (Fig. 1) and showed that the classical Fujiwhara model of converging cyclonic rotation about a centroid followed by merger is rarely followed.

In all known cases of tropical cyclone merger, one of the tropical cyclones experiences a loss of convective organization, followed by strong horizontal shearing and incorporation into the outer circulation of the other vortex. The symmetrical dissolution of two tropical cyclones as they merge into a single vortex has never been documented. Herein, the symmetrical dissolution and subsequent merger of Tropical Storm Pat and Tropical Storm Ruth is presented.

2. The symmetrical dissolution and merger of Pat and Ruth

During the last week of September 1994, the tropical atmosphere of the western North Pacific Ocean was dominated by an active monsoon trough. At the time of the satellite imagery in Fig. 2, two named tropical cyclones had formed in the monsoon cloud band—Orchid and Pat—and a tropical depression (which would later become Tropical Storm Ruth) was located between the two named storms. Over the next two days, Pat moved rapidly northwestward (Fig. 3a) and the disturbance between Pat and Orchid was upgraded to Tropical Storm Ruth. Ruth initially moved northeastward and rapidly approached Pat. Over the 22-h period, 0300 UTC September 25 (Figs.

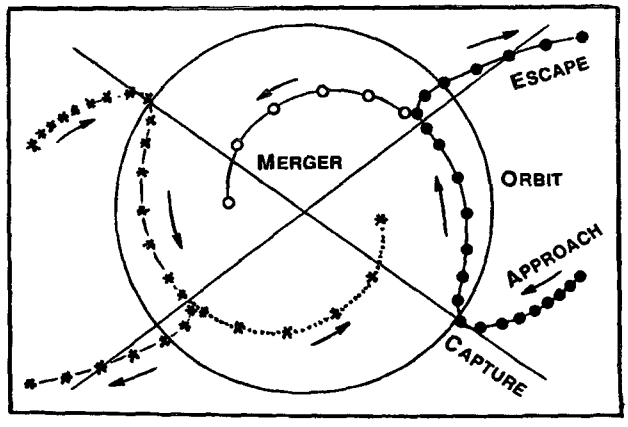

FIG. 1. Model of binary interaction of two tropical cyclones containing the major elements of approach and capture, followed by mutual orbit, then escape or merger (from Lander and Holland 1993).

Corresponding author address: Dr. Mark A. Lander, 790 N. Marine Drive, #268, Tumon 96911, Guam.

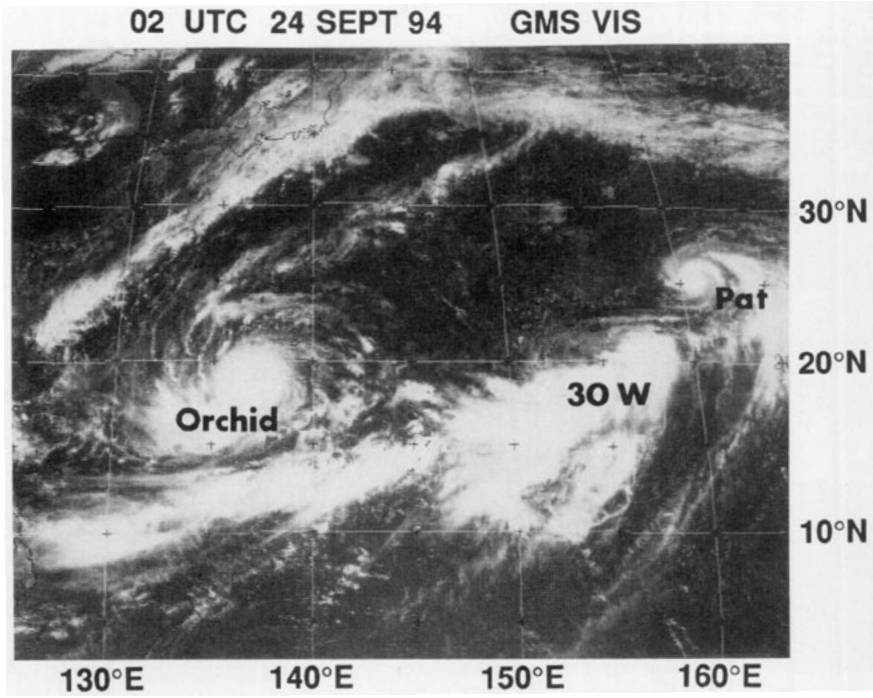

FIG. 2. Visible satellite imagery of an active monsoon trough at 0200 UTC 24 September 1991. Tropical cyclones—Typhoon Orchid, Tropical Depression 30W, and Typhoon Pat—are indicated.

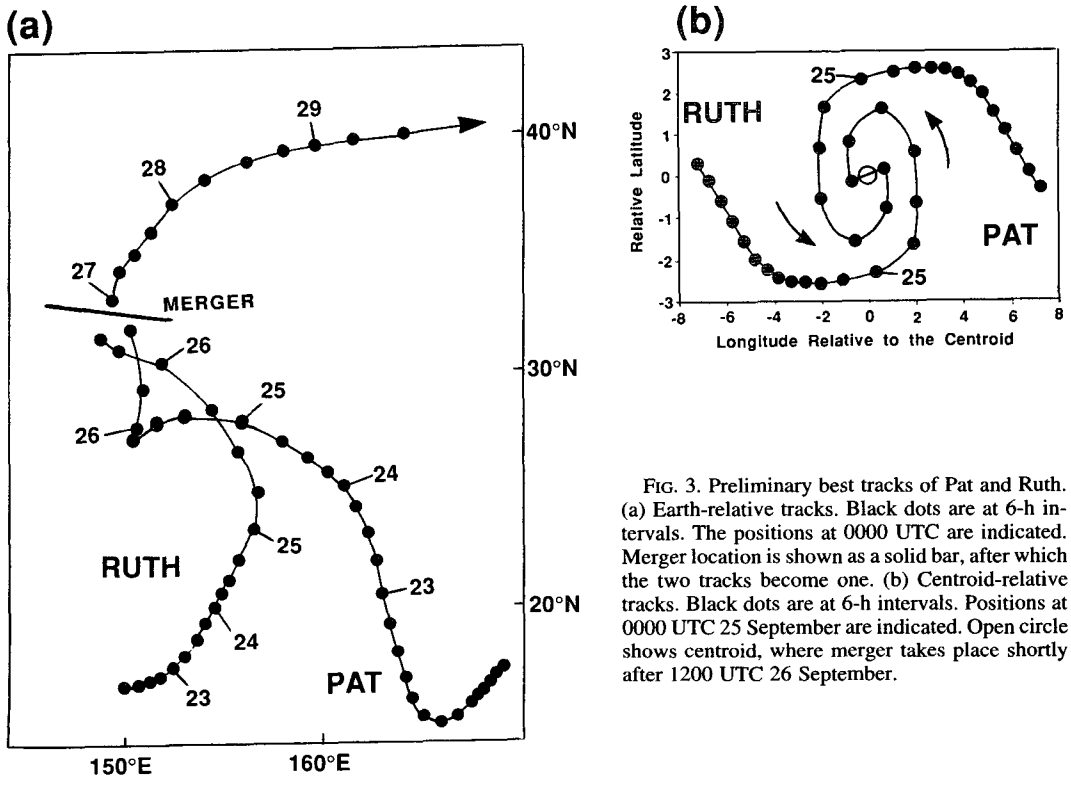

FIG. 3. Preliminary best tracks of Pat and Ruth. (a) Earth-relative tracks. Black dots are at 6-h intervals. The positions at 0000 UTC are indicated. Merger location is shown as a solid bar, after which the two tracks become one. (b) Centroid-relative tracks. Black dots are at 6-h intervals. Positions at 0000 UTC 25 September are indicated. Open circle shows centroid, where merger takes place shortly after 1200 UTC 26 September.

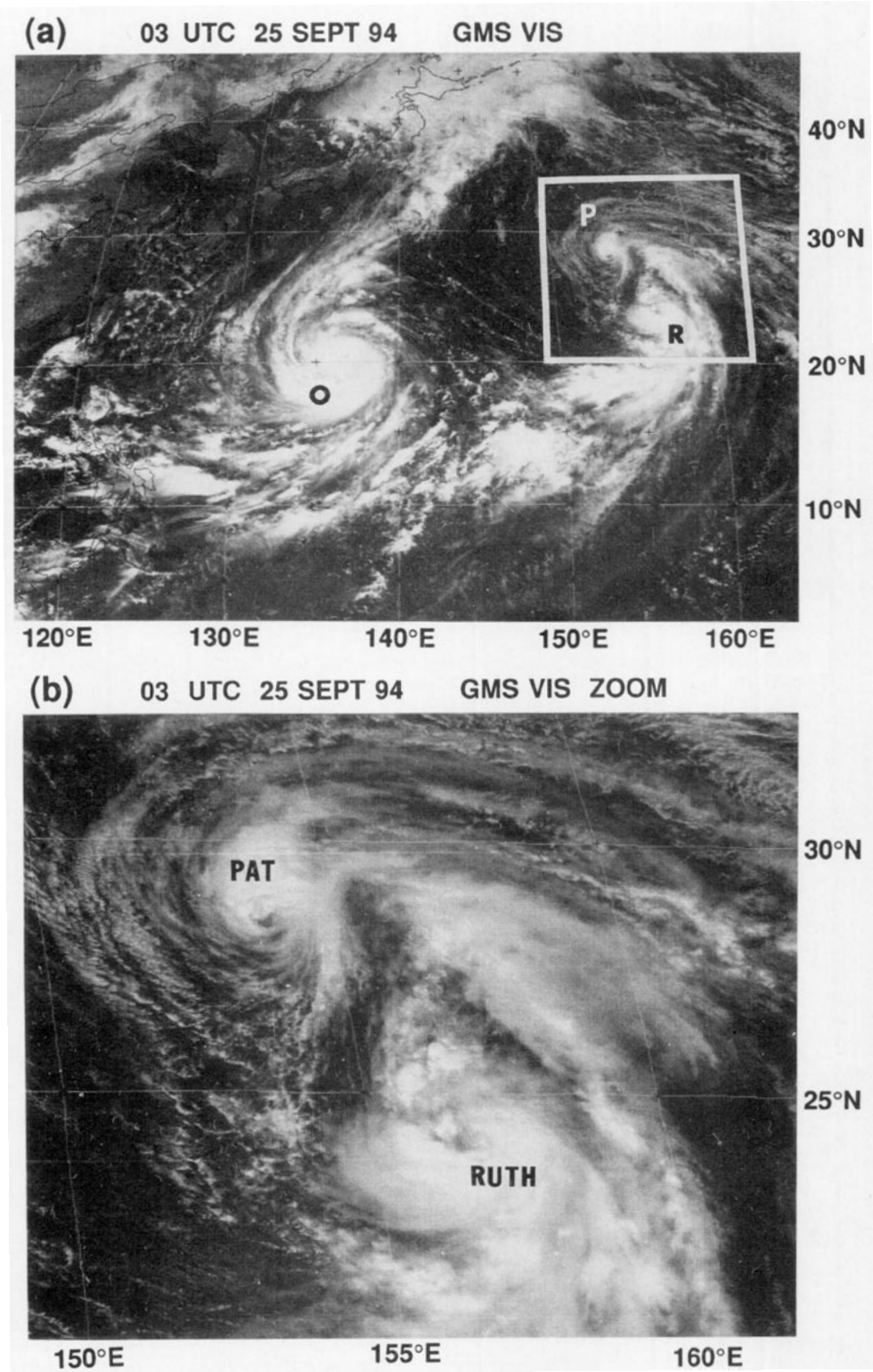

FIG. 4. Visible satellite imagery of Pat and Ruth as they rapidly orbit. (a) Large-scale view of Orchid (O), Pat (P), and Ruth (R) at 0300 UTC 25 September 1994. Boxed area indicates region on zoomed image; (b) close-up zoom of Pat and Ruth locked in close orbit; (c) large-scale view of Orchid (O), Pat (P), and Ruth (R) at 0100 UTC 26 September 1994; (d) close-up zoom of Pat and Ruth locked in close orbit. Note that Pat and Ruth have completed nearly 180° of mutual cyclonic orbit in the 22 h elapsed since the images in (a) and (b).

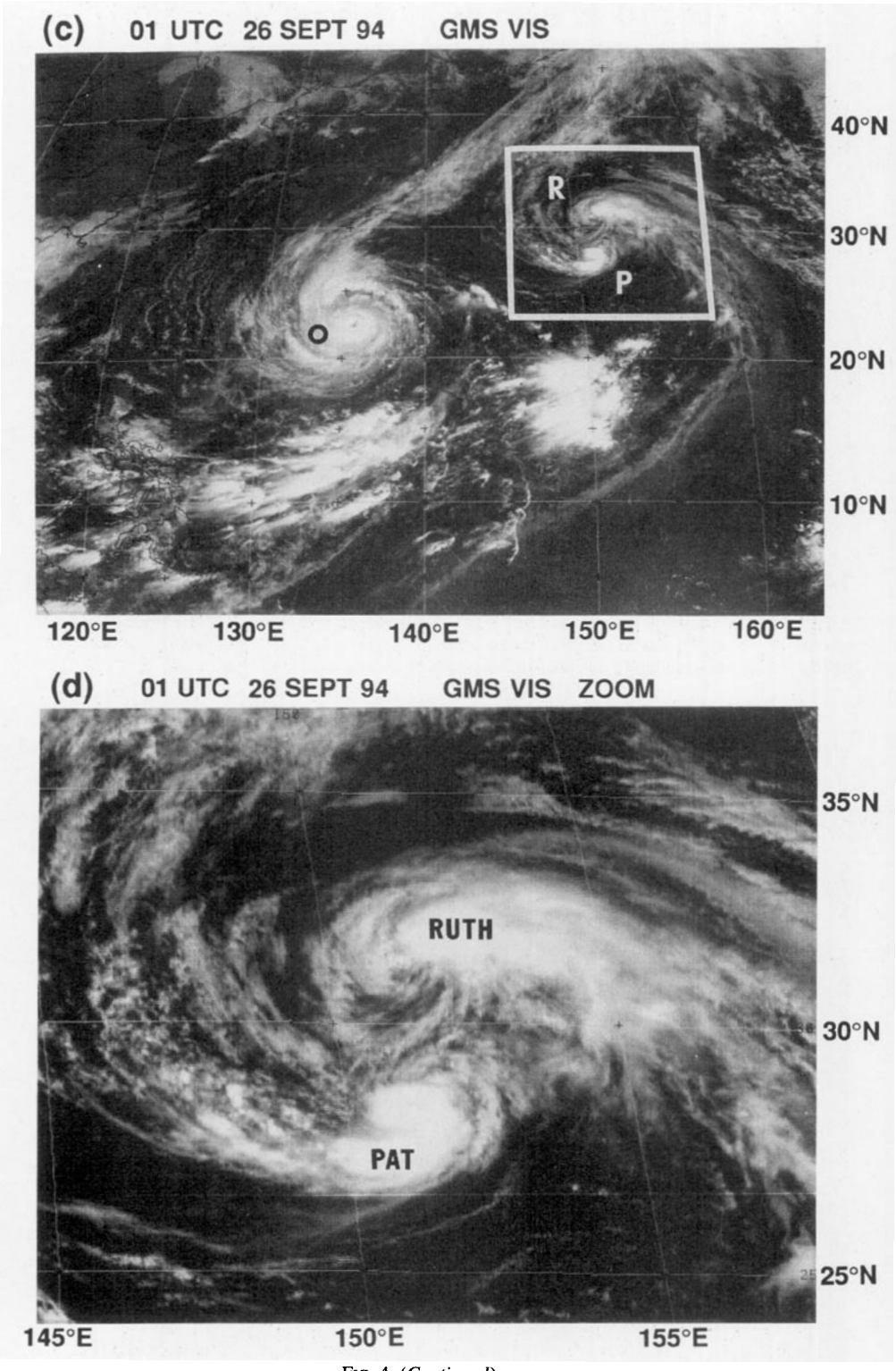

FIG. 4. (*Continued*)

4a,b) to 0100 UTC September 26 (Figs. 4c,d), Pat and Ruth approached to within 200 n mi; (370 km) and had undergone about 180° of cyclonic orbit relative to their centroid (Fig. 3b). The orbit continued during the local night (0600 UTC 26 September–1800 UTC September 26), and sometime during this

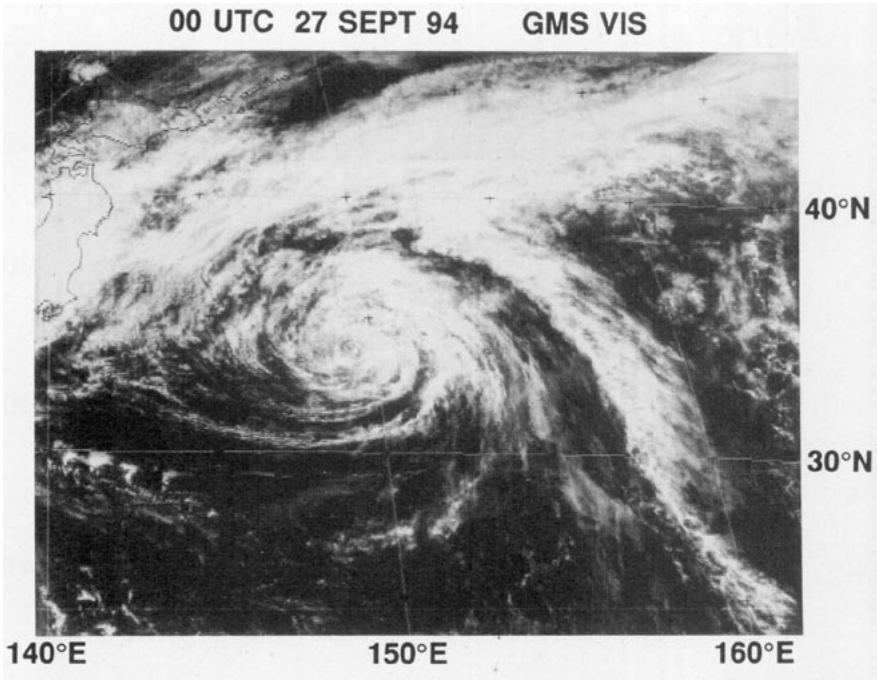

FIG. 5. Visible satellite imagery at 0000 UTC 27 September of the single vortex that is the product of the merger of Pat and Ruth. Deep central convection is absent, but ship reports and tightly wound low-cloud lines indicate surface winds of tropical storm intensity.

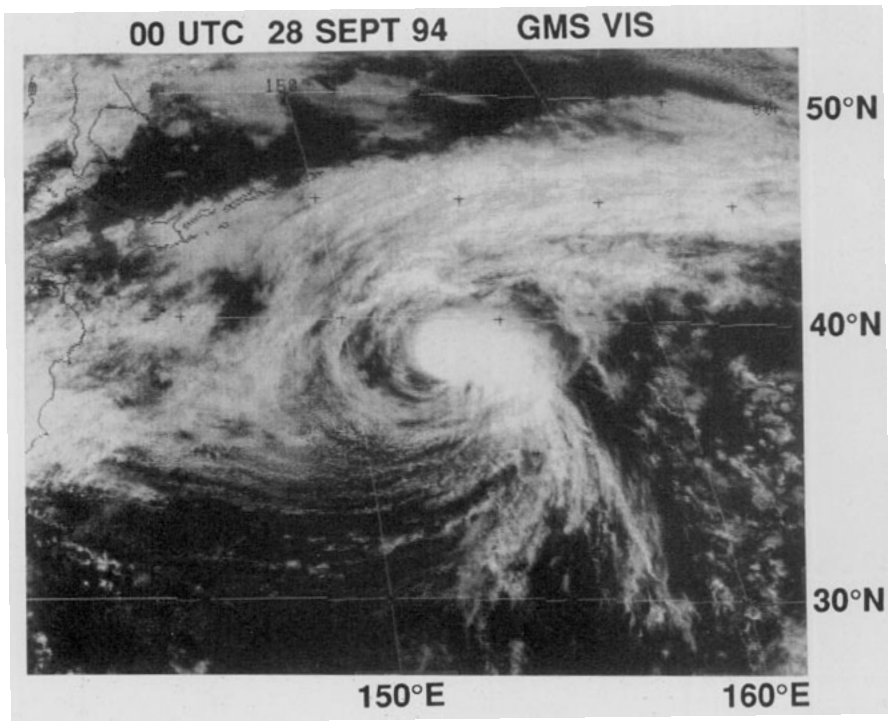

FIG. 6. Visible satellite imagery of Tropical Storm Ruth (i.e., the merged Ruth and Pat) at 0000 UTC 28 September 1991. Deep central convection has been reestablished as the system recurves into midlatitudes.

time the two vortices both lost their central convection and merged to become one vortex. By the next local morning (0000 UTC September 26), only one vortex could be located in the satellite imagery (Fig. 5), where previously there had been two separate tropical cyclones in close proximity.

At first the merged vortex lacked significant central convection, but it still possessed tropical-storm-intensity wind, and the Joint Typhoon Warning Center on Guam arbitrarily chose to name it Ruth. The merged vortex regained central convection and reintensified within 24 h following the merger (Fig. 6). Later Ruth (i.e., the merged Pat and Ruth) recurved into midlatitudes and decayed.

The symmetrical dissolution of Pat and Ruth and their subsequent merger into a single tropical cyclone is believed to be the first documented example of such a phenomenon.

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