NOTES AND CORRESPONDENCE

Evolution of the Cloud Pattern during the Formation of Tropical Cyclone Twins Symmetrical with Respect to the Equator*

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ABSTRACT

The evolution of the pattern of the deep convective cloud is presented for three selected cases of tropical cyclone twins symmetrical with respect to the equator. In each case, the pattern evolution is similar and can be separated into four distinct stages.

1. Introduction

The simultaneous occurrence of tropical cyclones north and south of the equator was recognized over 100 years ago (Reid 1849). Palmer (1952) found such cyclone pairs to be most frequent in the western Pacific during November, December, April, and May. Using published tracks of named tropical cyclones, Keen (1982) recorded 22 cyclone pairs east of 100°E during the period September 1971 through January 1980. He considered two storms to be a "pair" if they had dynamically associated origins—this was established subjectively. All of Keen's "pairs" met the following criteria:

1) The initial formations for the northern and southern systems occurred within 9 days of each other.
2) The latitudinal separation of the initial systems was never more than 22 degrees.
3) The longitudinal differences of the initial disturbances ranged between +9° (northern system east of the southern) to −17°.

Some tropical cyclone pairs, which we will call tropical cyclone "twins," share the following more restrictive characteristics:

1) They form nearly simultaneously.
2) They form at low latitudes—one about 5 degrees north, the other about 5 degrees south of the equator.
3) They form along the same longitude.
4) Their wind, pressure, and cloud patterns are nearly symmetrical with respect to the equator.

The occurrence of typhoon twins symmetrical with respect to the equator was first reported by Dean (1954). Using imagery from the Japanese geostationary satellite (the data record begins in 1978), we have observed tropical cyclone twins of depression, storm, or typhoon intensity in the western Pacific and Indian oceans. Mirror-image twins of typhoon intensity occur in the western Pacific about once every two or three years. Indian Ocean twins tend to be weaker and often one of the storms slips through the official warning system—published tracks of names tropical cyclones are not the best place to gather statistics for tropical cyclone pairs or twins.

Ramage (1986) suggested that the timing of tropical cyclone twins in the equatorial western Pacific is crucial to the initiation and maintenance of ENSO. He noted that tropical cyclone twins form within troughs of low pressure symmetrical about the equator and they are generally associated with strong westerly winds along the equator. Keen (1988) noted that his cyclone pairs appear to be directly linked to the wind, SST, and cloud anomalies that occur during ENSO events.

This paper focuses on the evolution of the cloud pattern from genesis to maturity of tropical cyclone (TC) twins. Also, the association of TC twins with outbreaks of strong westerly winds along the equator (the so-called "west wind burst") is discussed. The systematic evolution of the cloud pattern of TC twins may provide insight into the mechanisms responsible for their generation.

2. Data

The cloud patterns used in this study were obtained from infrared (IR) imagery provided by the Japanese

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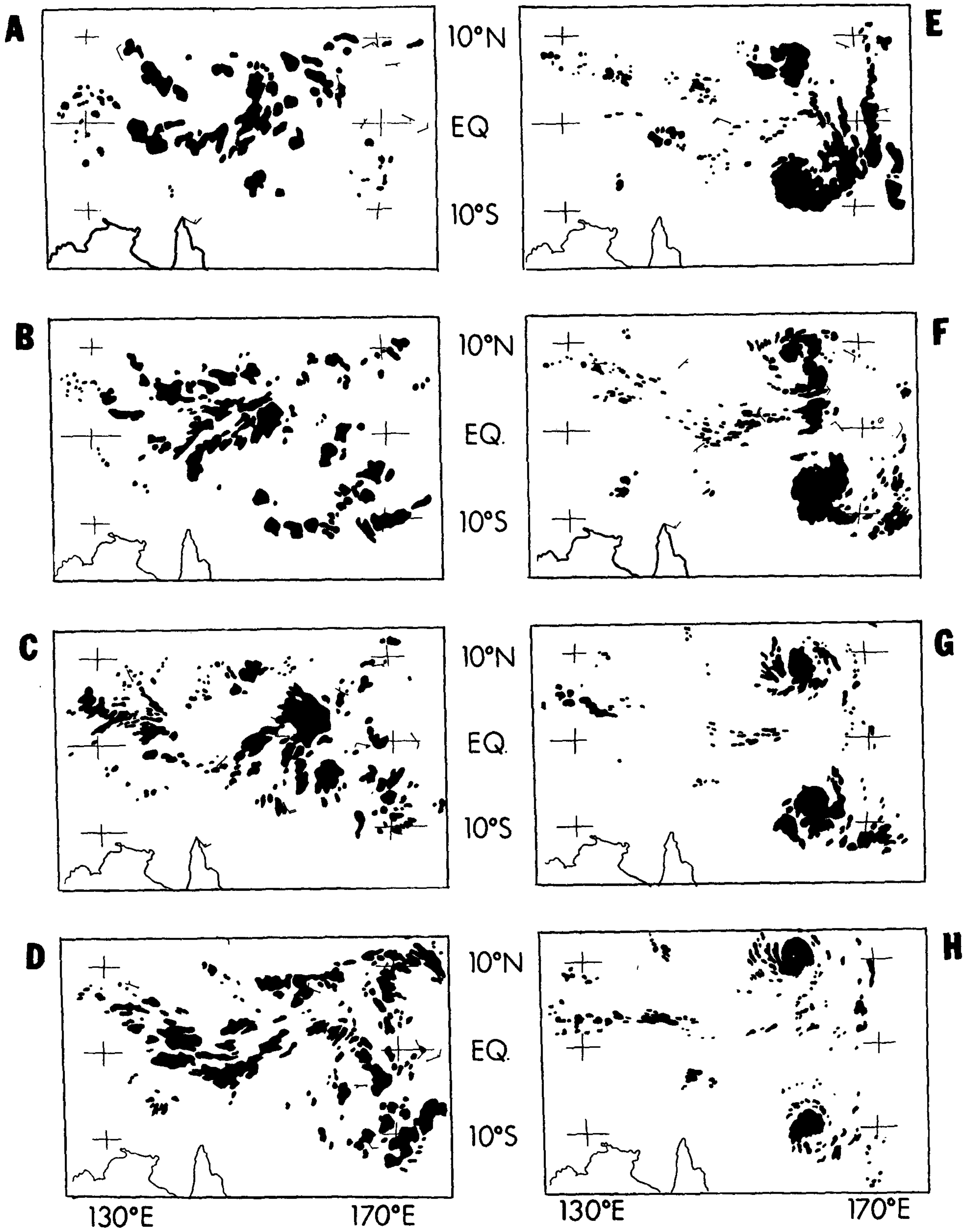

FIG. 1. Pattern of deep convective cloud associated with Supertyphoon Lola and Tropical Cyclone Namu. Panels A through H show clouds at 24-hour intervals beginning with 0000 UTC 12 May 1986.

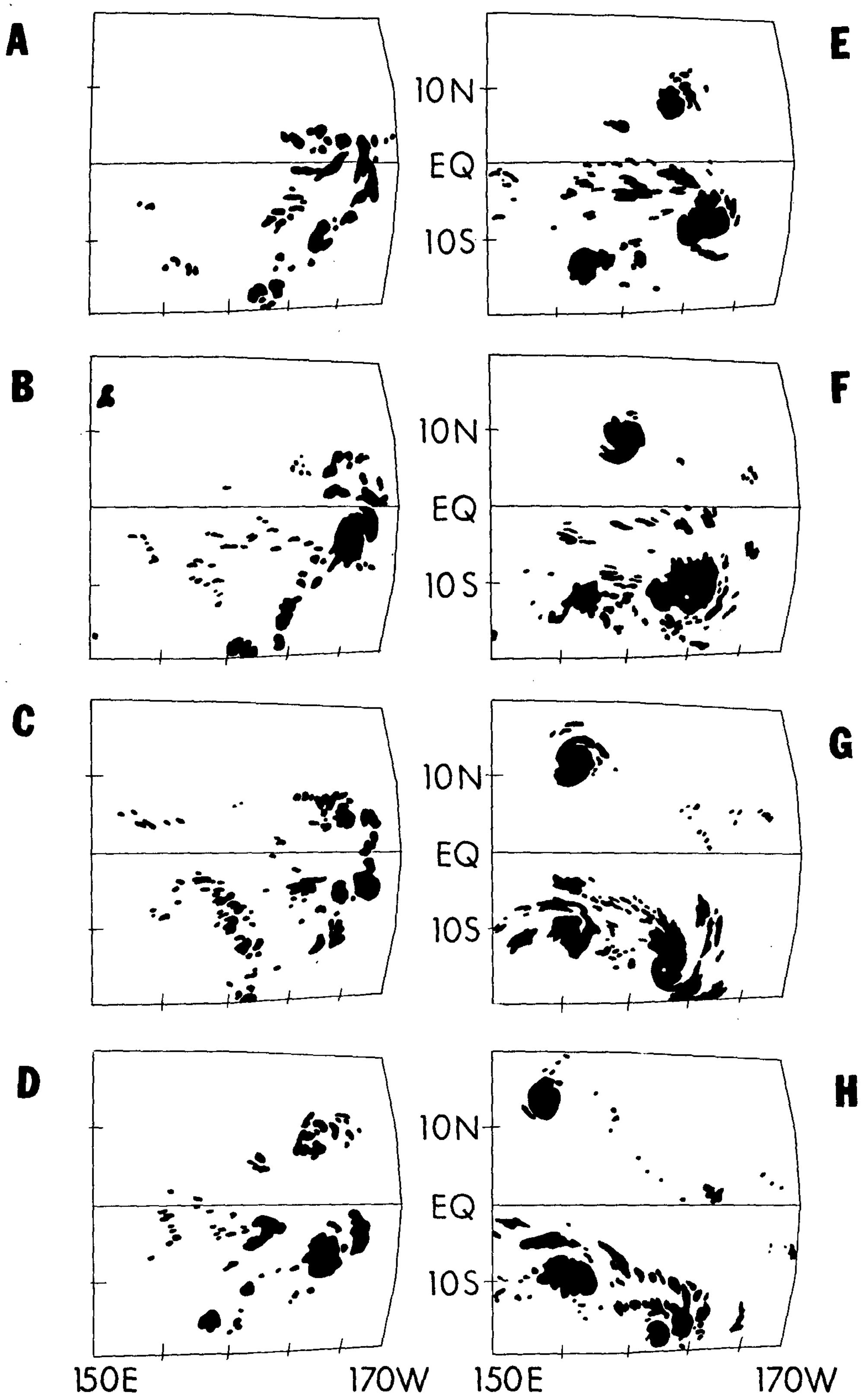

FIG. 2. Pattern of deep convective cloud associated with Typhoon Roy and Tropical Cyclone Anne. Panels A through H show clouds at 24-hour intervals beginning with 0000 UTC 5 January 1988.

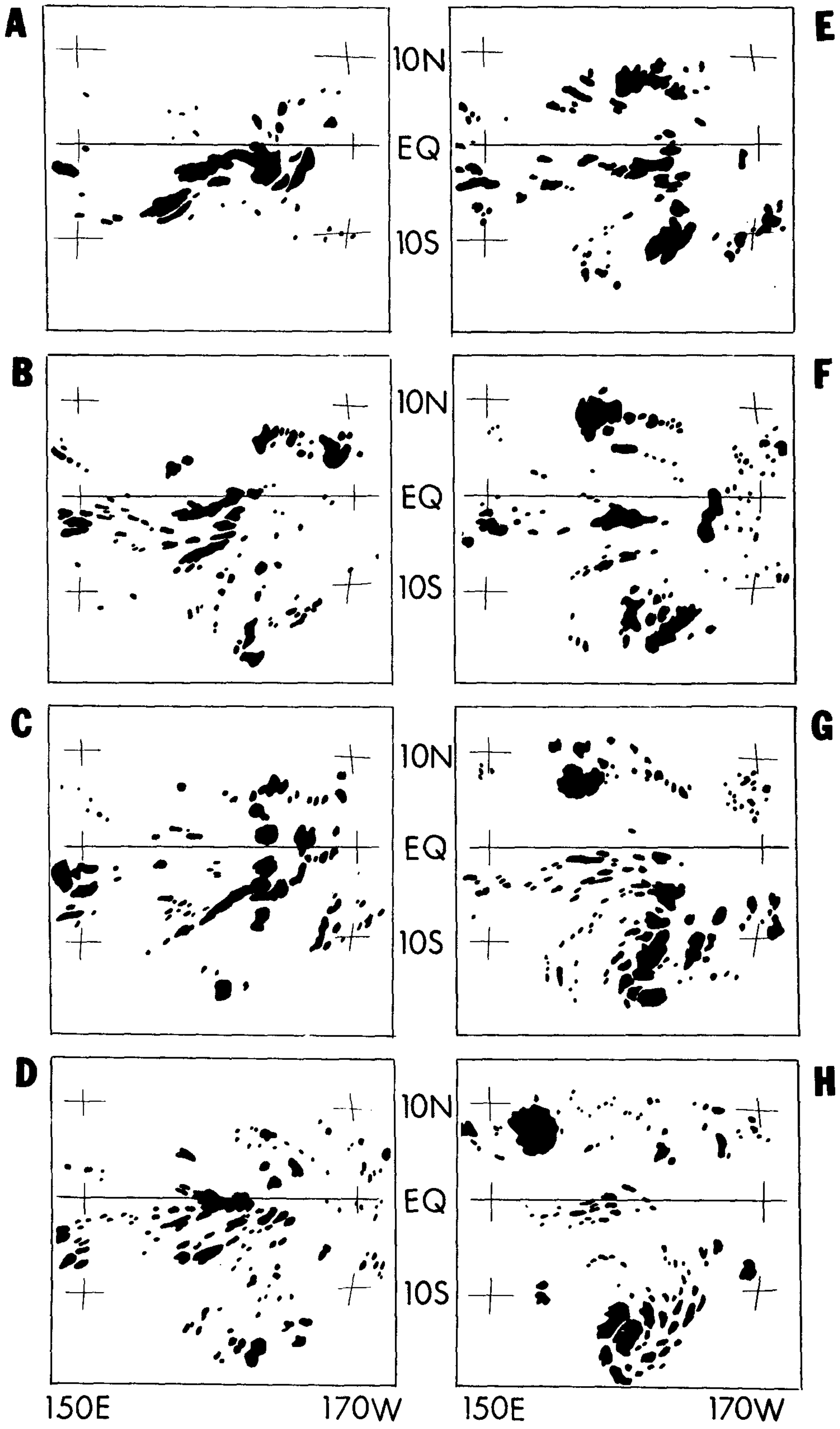

FIG. 3. Pattern of deep convective cloud associated with Typhoon Lex and Tropical Cyclone Patsy. Panels A through H show clouds at 24-hour intervals beginning with 0000 UTC 8 December 1986.

geostationary meteorological satellite. The IR imagery was subjectively analyzed to extract the pattern of active deep convective cloud. The very cold cloud masses (on the scale of individual thunderstorms to mesoscale complexes of cumulonimbus clouds) were differentiated from cirrus and other warmer, more diffuse regions of layered cirrus and/or middle cloud. Kilonsky and Ramage (1976) and Garcia (1985) used a similar subjective procedure to extract the brightest cloud masses from visual imagery. Our nephanalyses are high contrast: black for deep cold cloud and white for all other conditions (see Figs. 1, 2, and 3).

Surface wind reports during twin-cyclone events in the western Pacific were extracted from hand-plotted charts prepared by forecasters at the National Weather Service Forecast Office in Honolulu, Hawaii. Several island stations are ideally situated to record the near-equatorial wind flow: Nauru (0.5°S, 167°E), Ocean Island (1°S, 169°E), Kapingamarangi (1°N, 155°E), Nukuoro (4°N, 155°E), Tarawa (1°N, 173°E), Beru (1°S, 176°E), Arorae (3°S, 177°E), and Momote (2°S, 147°E). In addition, a major north–south shipping lane crosses the equator at 155°E.

3. Cloud pattern evolution during twin formation

The evolution of the cloud pattern during the formation of TC twins follows a sequence that is consistent among all such events that we have observed. Three cyclone-twin events that occurred in the western Pacific are presented in this paper:

1) Typhoon Lola and Tropical Cyclone Namu; 15–20 May 1986 (Fig. 1).
2) Typhoon Roy and Tropical Cyclone Anne; 4–10 January 1988 (Fig. 2).
3) Typhoon Lex and Tropical Cyclone Patsy; 10–15 December 1986 (Fig. 3).

A generalized sequence of the evolution of the cloud pattern during TC twin formation (Fig. 4) was derived from these three events and several others that are not shown. A general description of the cloud pattern and associated wind and pressure fields at each stage is as follows:

Stage 1: Deep convection increases along and near (5°N–5°S) the equator associated with the establishment and gradual strengthening of surface westerlies along the equator. Low-pressure troughs form at about 5°–7° N and S. The low-pressure troughs are relatively cloud free.

Stage 2: A large area of deep convection erupts explosively along the equator in association with the intensification to near-gale strength of the equatorial westerly surface winds. The winds are westerly under and to the west of the large equatorial cloud complex. Low-pressure minima and associated vortical wind circulations form in the pressure troughs near the longitude of the equatorial cloud complex (Fig. 5). The wind pattern at this stage is accurately portrayed by the theoretical response of the low-level wind to an equatorial heat source (Gill 1980) (see Fig. 6). Orga-

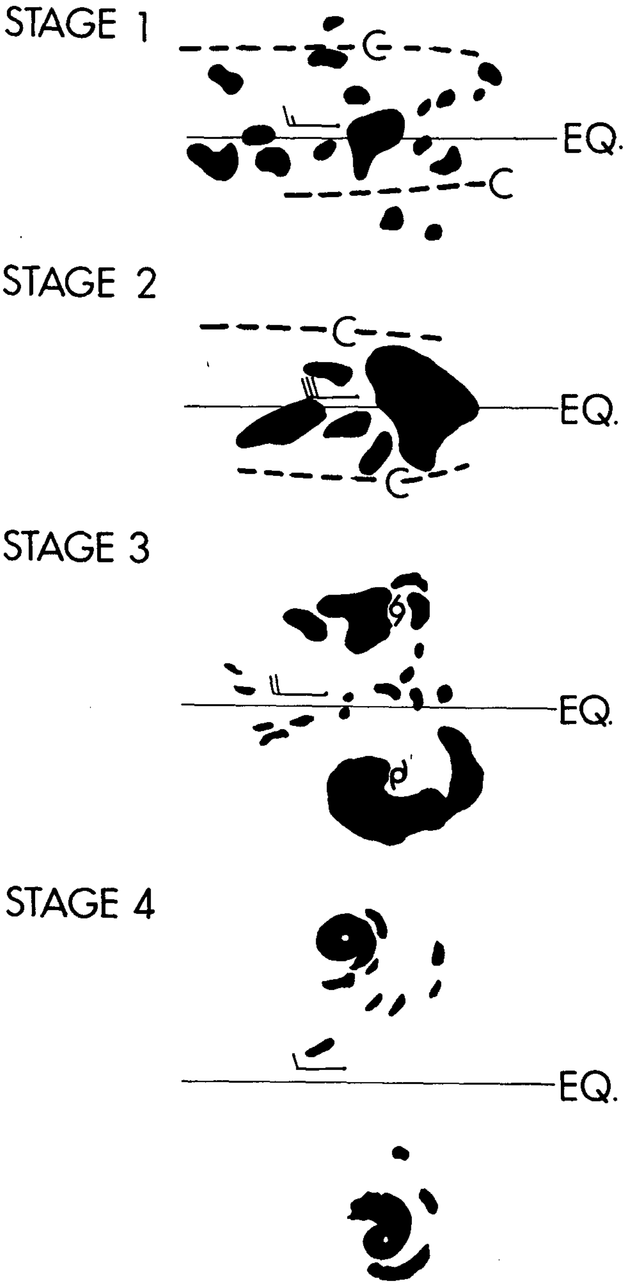

FIG. 4. Schematic illustration of the evolution of the deep convective cloud during the development of typhoon twins. Dashed lines show pressure troughs and a "C" indicates locations of subdepression strength vortices. Wind barbs indicate equatorial wind flow at each stage: one full barb equals 10 kt (5 m s^{-1}).

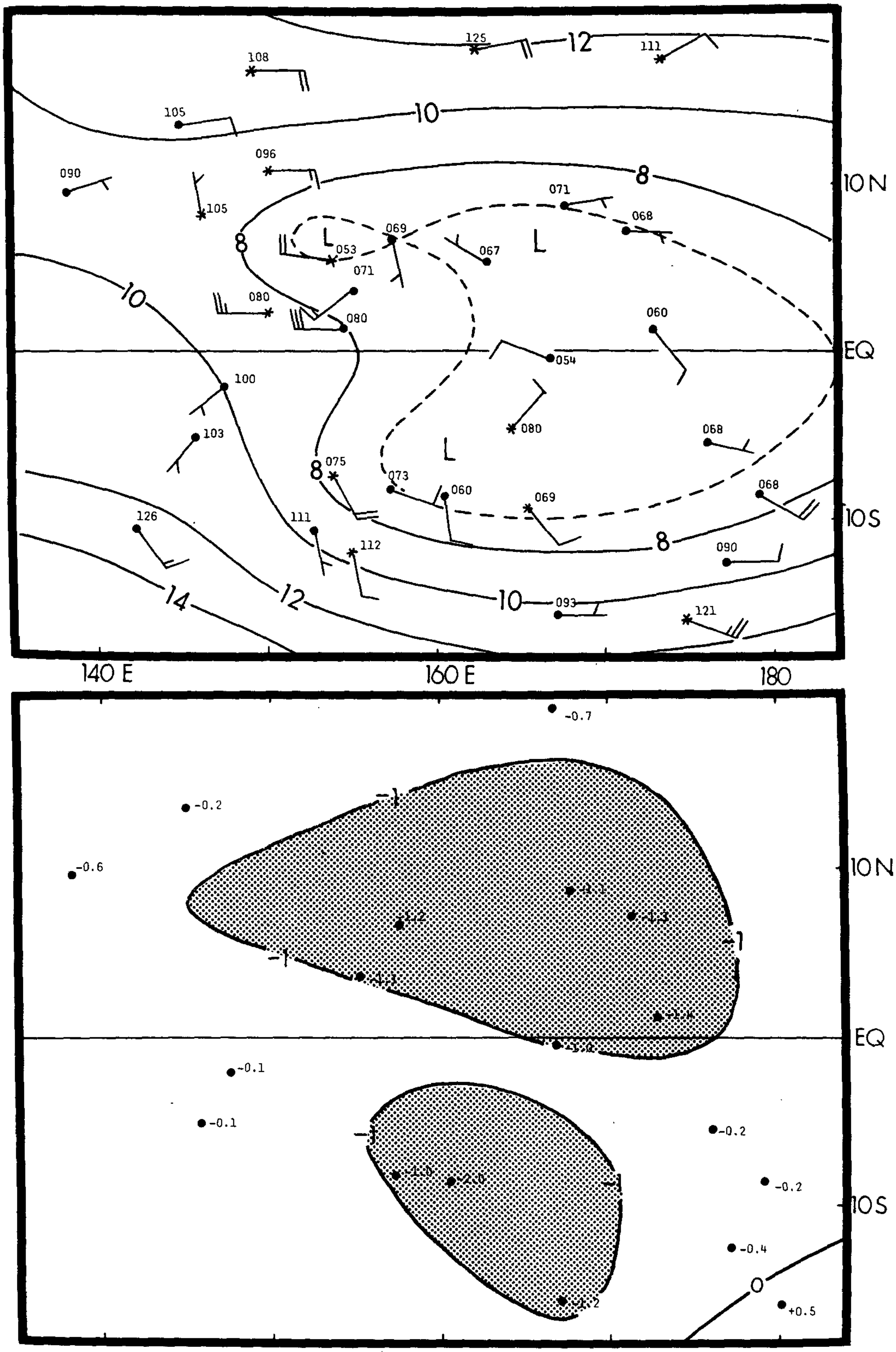

FIG. 5. Surface pressure analysis 0000 UTC 14 May 1986 in the equatorial western Pacific (top panel). Dots (●) are island stations, stars (*) are ship reports. Pressure changes in the equatorial western Pacific for the 24-hour period ending 0000 UTC 14 May 1986 (bottom panel). Within shaded regions the surface pressure fell by at least 1 hPa.

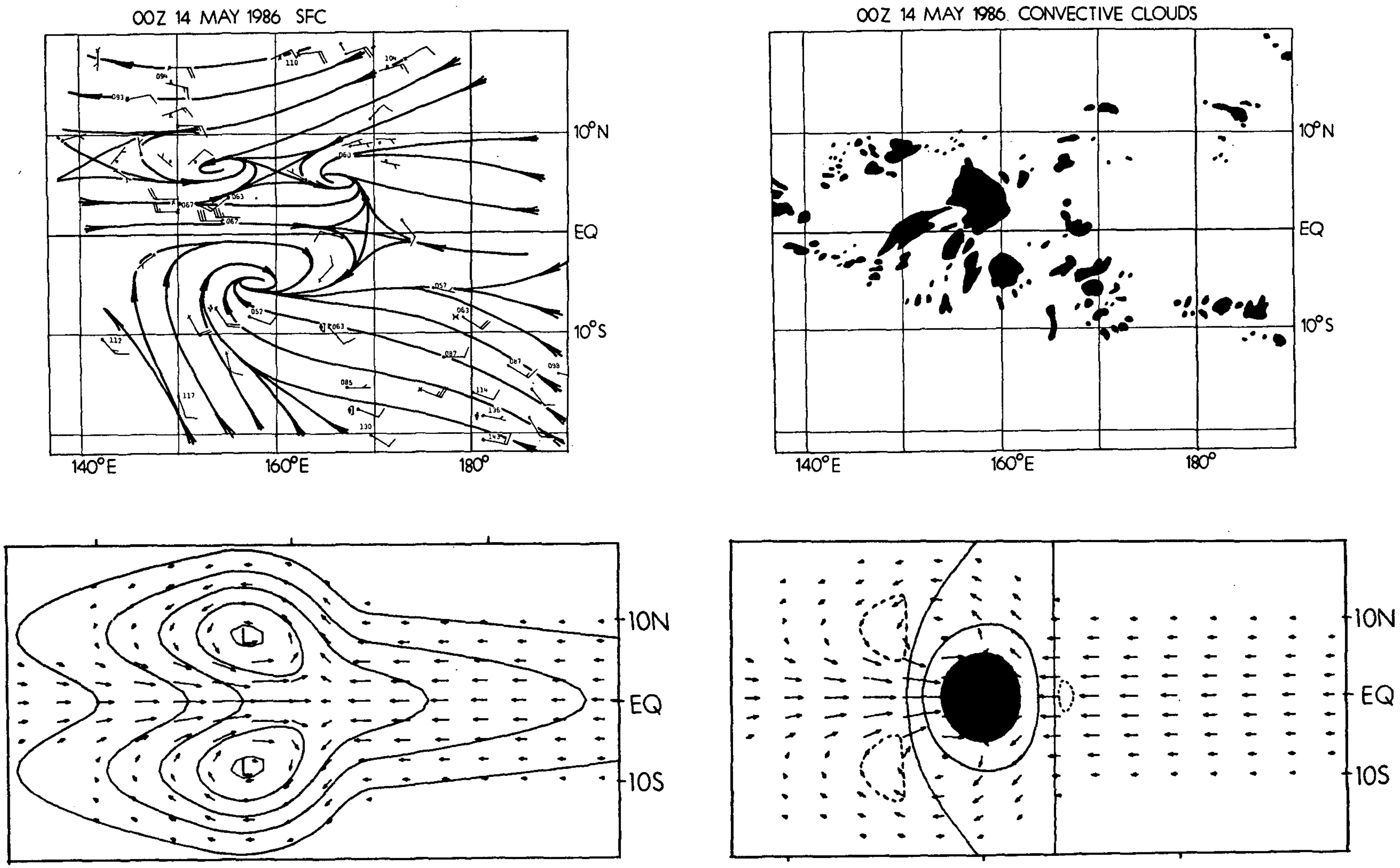

FIG. 6. Comparison of the theoretical tropical surface wind and pressure response (bottom panels) to a specified equatorial heat source (after Gill 1980) which is maximum in the dark-shaded region of the bottom right panel. Contours in bottom left panel are arbitrary pressure units and are approximately spaced at one hectopascal intervals for a realistic 30 kt (15 m s^{-1}) west wind burst. Top panels show actual wind and cloud pattern at the peak of a west burst (14 May 1986).

nized convective cloud bands begin to develop in the circulations associated with the deepening low-pressure centers.

Stage 3: The equatorial convection collapses and the convection in the developing tropical cyclones increases. The strengthening of the circulation of the tropical cyclones is accompanied by a gradual weakening of the equatorial westerlies.

Stage 4: The tropical cyclones reach storm or typhoon intensity as they migrate westward and poleward. The equatorial convection almost disappears and the equatorial westerlies become light.

4. West wind bursts and tropical cyclone twins

Luther et al. (1983) found that the zonal wind at each of three equatorial western Pacific island stations [Ocean Island (1°S, 169°E), Tarawa (1°N, 173°E), and Canton Island (3°S, 172°W)] is sometimes (depending on season and ENSO) punctuated by short pulses (days to weeks) of strong westerly winds—the so-called "west wind bursts." Numerical studies have attempted to explain the organized large-scale wind patterns associated with west wind bursts in the equatorial western Pacific. In a single layer model, Matsuno (1966) demonstrated that equatorial quasi-geostrophic atmospheric Rossby waves take the form of symmetric lows on either side of the equator with strong westerlies on the equator between the lows. This pattern, which resembles the double-trough condition described by Ramage (1986) and Keen (1988), is also reproduced as the steady-state solution of a reduced-gravity shallow-water model forced by a localized patch of diabatic heating symmetric about the equator (Gill 1980) (see Fig. 6). Although the models accurately reproduce the wind and pressure patterns associated with west wind bursts, they cannot explain their evolution or their intermittent recurrence. Lastly, the relationships of tropical cyclones to west wind bursts has not been adequately modeled or closely examined from a purely observational perspective.

In our study of tropical cyclone twins, the data are adequate to provide a preliminary answer to the following two questions:

1) In what portion of the cyclone development sequence are the equatorial westerlies strongest?

2) Do tropical cyclones act to strengthen the equatorial westerlies?

Twin cyclones associated with a west wind burst form (i.e., that reach tropical-storm intensity) about a day after the equatorial westerlies reach their peak strength (Lander and Morrissey 1988) (see Fig. 7). As the tropical cyclones intensify, the equatorial westerlies decay. The hypothesis that the tropical cyclones are a byproduct of the west wind burst is supported by the observed evolution of wind and cloud during a twin-cyclone event.

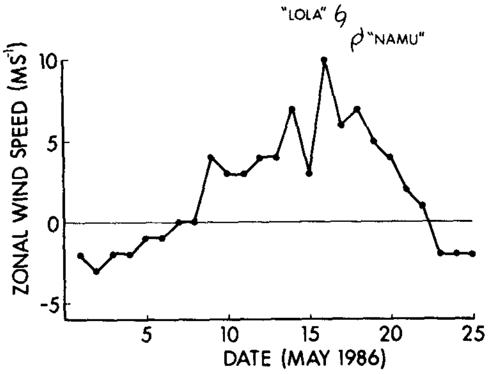

FIG. 7. Daily averaged zonal wind speed at Kapingamarangi (1°N, 155°E) during May 1986. Tropical cyclone symbols indicate times when Lola and Namu first reached tropical storm intensity.

5. Conclusions

Tropical cyclone twins symmetric with respect to the equator exhibit a characteristic evolution of their cloud pattern that features an initial clustering of deep convective cloud along the equator which then collapses as deep convection increases and becomes organized around the centers of the developing cyclones. The initial outbreak of convection along the equator is associated with a burst of westerly wind along the equator. When the equatorial convection collapses, the equatorial surface wind flow becomes light while the wind speed near the centers of the tropical cyclones increases. In some cases, only one storm survives during the cyclogenesis stage (stage 3).

In general, a major outbreak of convection along the equator accompanied by a burst of westerly surface wind may be a useful predictor of cyclogenesis. Also, a careful diagnosis of twin-cyclone events may improve our understanding of tropical cyclogenesis.

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