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TROPICAL CYCLONE ACTIVITY OVER THE WESTERN NORTH PACIFIC - FROM EL NIÑO TO LA NIÑA

Edwin S.T. Lai
The Royal Observatory, Hong Kong

ABSTRACT

A major cooling episode of the sea surface temperature (SST) occurred over the central equatorial Pacific in 1988. Time series of the SST in the vicinity of Canton Island (2.8°S, 171.7°W) revealed a dramatic fall from a peak of over 30°C in September 1987 to a low of near 26°C in February 1989. The only other known cooling event of comparable magnitude occurred in 1973. To see if such extreme SST events actually had any impact on tropical cyclone activity over the western North Pacific, monthly tropical cyclone tracks of 1972-74 and 1987-89 were studied and compared. The six tropical cyclone seasons involved were divided into three groups, i.e. seasons prior to, during, and following the cooling episode. Observational evidences were obtained in support of a SST-related migration of the ITCZ. The movement of tropical cyclones in association with these SST events could also shed some light on the prevailing environmental flow which steered the storms. The implication on interannual tropical cyclone occurrences and long-range rainfall forecast for a localized area like Hong Kong was also discussed. Despite the increasing acceptance of SST as a reliable predictor in the regression methods, the comparison of tropical cyclone activity between the 72-74 and 87-89 events aptly illustrated that the accuracy of forecasts was ultimately dependent on shorter-term events on the synoptic scale which remained outside the scope of current statistical treatment.

INTRODUCTION

The Southern Oscillation (SO) is a well known meteorological phenomenon involving the east-west see-saw fluctuations of pressure anomalies over the equatorial Pacific. Changes in the sea surface temperature (SST) along this stretch of waters are found to be intimately related to SO. The emergence of higher-than-normal SST near the west coast of South America during the Northern Hemisphere winter, affectionately known as an El Niño event, is referred to as the warm phase of SO. As an apposite, the term La Niña has come to be known as the cold phase of SO.

It is now commonly accepted that the SO is a manifestation of interactive processes between the atmosphere and the ocean (see for example Philander (1985)). Apart from obvious SO signals within the tropical region, teleconnection is also hypothesized which brings the influence of SO to mid latitudes. Although the causal relationship is still unclear, the general characteristics of a SO event have been described in various papers. Observational evidences come mainly from the compositing of major SO events, for example the comprehensive studies given in Horel and

Wallace (1981) and more recently in Ropelewski and Halpert (1987). More specifically, Kiladis and van Loon (1988) and Kiladis and Diaz (1989) attempt to compare and contrast the differences in pressure, temperature, and precipitation anomalies on a quarterly basis between the two extremes of SO - the former paper concentrates on the Indian and Pacific sector while the latter presents a more global view. The reversal in the anomaly patterns between El Niño and La Niña, the biennial tendency of SO, and a strong phase-lock with the seasonal cycle are demonstrated by the results.

The potential rewards in the study of tropical cyclone (TC) activity in relation to SO are not difficult to envisage. On one hand, TC formation is often embedded within the ITCZ and is critically dependent on warm SST. The locations of the favoured genesis areas are therefore good indicators of the SO-related shifts of the ITCZ. Furthermore, the storm tracks can reveal the prevailing synoptic systems which provide the steering flow, thereby facilitating an assessment of the likely atmospheric responses to SO forcing. On the other hand, any established correlations between SO and TC activity will in turn be useful for forecasting the interannual variability of TC. Studies along such lines have been done by Gray (1983) for the Atlantic basin, Nicholls (1984) for the Australian basin, and Chan (1985) for the western North Pacific and the South China Sea.

The current study is prompted by a major cooling event in 1988, as revealed by the SST time series (Fig. 1) of Canton Island (2.8°S, 171.7°W). After a warming episode in 1987 which pushed the SST to a peak of over 30 degrees by the end of the year, a dramatic cooling episode followed in 1988 as the SST plunged to its lowest on records by early 1989. The only other cooling event of comparable magnitude occurred in 1973. It is hoped that by a selected inter-comparison between the extreme events of 1972-74 and 1987-89, some SO-related patterns which may otherwise be buried by too much filtering and averaging in the composite studies can be revealed. Such case studies can re-affirm and re-assess some commonly accepted notions concerning the ENSO phenomenon. Since the SO signals are normally quite weak for areas in the vicinity of Hong Kong, the study also aims to assess any possible enhanced impact (in terms of TC occurrence and precipitation) on the region in the face of strong and well-defined (in terms of the transition from the warm to cold phase) SO forcing. This will provide some guidance as to the future of using ENSO-related indices as predictors in seasonal and interannual forecasts.

METHODOLOGY

Best tracks of TCs for 1972-74 and 1987-89 are compiled from the archived data at the Royal Observatory, Hong Kong. The inter-event comparison is done by dividing the six TC seasons into three groups. The season prior to the cooling event is labelled as "TCS-1", i.e. the El Niño years of 1972 and 1987. The season in the middle of the cooling event is labelled as "TCS0", i.e. the La Niña years of 1973 and 1988. The season following the cooling event is labelled as "TCS+1", i.e. the post-La Niña years of 1974 and 1989 when the SST at Canton Island have recovered to near-normal values. Since a finite number of TCs is required for meaningful interpretation of results, the TC season here is confined to the months of July - October during which time climatological TC occurrences average between 4 - 6 TCs per month. TC tracks are then plotted by months for TCS-1, TCS0, and TCS+1.

For ease of comparison against a climatological background, the 500-hPa and 850-hPa vector mean winds for July - October from Chin and Lai(1974) are included in Fig. 2. The 500-hPa streamlines provide some ideas as to the probable shifts in the steering pattern in response to the seasonal behaviour of the Pacific ridge - its westward extent, the north-south migration of the ridge axis, and the location of its point of weakness. The 850-hPa streamlines are mainly intended to depict the low-level convergence zone (ITCZ) and hence the climatologically favoured areas of TC genesis.

OBSERVATIONS

The monthly TC tracks before, during, and after the cooling event are shown in Fig. 3. Despite the limited number of tracks available, some differences and contrasts that are generally consistent with the commonly accepted scenarios implied by a SO event can be readily observed. A chronological sequence on the evolution of patterns is highlight below:-

TCS-1 (when SST near central equatorial Pacific is rising)

July — **TCs form at a near-climatological latitude just north of 10°N and as far east as 170°E. Subsequent movements are generally to the west-northwest at first, becoming increasingly northward later on. Few venture into the South China Sea, suggesting that the Pacific ridge may not be as far west as it should be.**

August — The genesis area shows no signs of northward migration in contrast to the climatological trend of the ITCZ. But now, most of the storms are westward-moving, suggesting a westward extension of the Pacific ridge into China after some initial delay.

September — The genesis area remains more or less the same, departing significantly from the climatological ITCZ position. The storm tracks have a large northward component, indicating a retreat of the Pacific ridge.

October — The genesis area stayed at similar latitudes but with a tendency of more active development towards the central Pacific. As a result, most of the storms recurve before reaching Luzon.

TCS0 (when SST over central equatorial Pacific is falling)

July — Most of the storms form along 20°N north of their climatological origin and west of 140°E. Storm tracks have a large northward tendency, implying the absence of a strong Pacific ridge.

August — The genesis area is even further north, and extends as far east as 170°E. The distribution however is rather scattered, with westward-moving storms in a western pocket and northward-moving storms in an eastern pocket. The Pacific ridge is apparently not particularly dominant and also seems to be disjointed in places.

September — The pattern is generally similar to that of previous month, but the line of genesis has migrated southwards to south of 20°N.

October — The genesis area migrates further south in accordance with the seasonal cycle. However, there is a conspicuous absence of TC development east of 140°E. As a result, a large number of storms moves into the South China Sea.

TCS+1 (when SST over central equatorial Pacific has recovered)

July — The genesis area is between 15°N and 20°N and confined to waters west of 140°E. Westward-moving storms are in the majority which implies a sufficiently dominant Pacific ridge.

August — The genesis area extends northwards to 25°N and east of 140°E. Subsequent storm movements tend to be drawn towards the Japanese archipelago, suggesting the development of a major weakness in the Pacific ridge.

September — The genesis area has shifted slightly southwards. A ridge axis becomes apparent between 20°N and 25°N, with increased easterly steering south of the ridge for quite a number of storms.

October — The genesis area has shifted further south. Though a couple of storms develop east of 140°E and recurve later on, most form to the west and subsequently move into the South China Sea.

DISCUSSION

The observational results and implications derived from this study are summarized in this section.

(1) The behaviour of the ITCZ, as indicated by the favoured TC genesis area, is consistent with that observed in other studies (e.g. Horel and Wallace (1981)). The ITCZ tends to stay further south and fails to migrate northwards during the El Niño years. On the other hand, there is a marked northward shift of the ITCZ during the La Niña years. The latitudinal contrast is most marked in the months of August and September.

(2) The cooling event over the central equatorial Pacific severely restricts TC development east of 140°E when the seasonal positions of the ITCZ are towards lower latitudes, namely in the months of July and October. The observation is in agreement with the spectral analysis

results shown in Chan (1985). It is also worth noting that TC genesis over the waters east of 140°E and south of 20°N remains relatively subdued even during the following season when the SST over the central equatorial Pacific has largely recovered.

(3) Storms forming further east tend to recurve at an early stage. The longitudinal restriction in TC genesis in (2) implies a probable interannual variation in TC occurrences over the South China Sea in July and October, as is indeed observed. Storms from the Pacific generally fail to reach the South China Sea during the El Niño years. The contrast is most noticeable in the month of October, as has been indicated in Cheang (1984).

(4) Although definite conclusions cannot be drawn from the storm movement with regard to the synoptic environment, such as the strength and weakness of the Pacific ridge, a certain degree of self-consistency has been observed which suggests that this may be worth following up in future studies.

(5) Even though the combined display of tracks for the 1972-74 and 1987-89 episodes provides a consistent picture that can be physically related to the SO events, there is quite a large inter-event variability that makes interannual forecast for a selected sector extremely difficult. Take the example of August in 1973 and 1988 in the middle of the cooling events. Though the poleward position of the ITCZ can be anticipated, the preferred TC genesis locations along the convergence line are probably dictated by the prevailing synoptic environment. As a result of favourable conditions over or near the South China Sea in 1973, 4 TCs affected the region in contrast to a total absence of TCs in 1988.

(6) TCs are responsible for a large portion of the rain in Hong Kong. The conclusion in (5) therefore does not bode well for the annual rainfall forecast. The annual rainfall figures in Hong Kong for the years 1972-74 and 1987-89 do not reveal any trends that are consistent with the strong SO forcing. In recent years, the SST predictor at Canton Island has grown in importance in the regression methods of the forecast exercise, but this is more due to a deterioration in performance by the traditional winter monsoon indices rather than a better understanding of the SST mechanism. In any case, the study by Ropelewski and Halpert (1987) and Kiladis and van Loon (1988) indicate that the SO signal in terms of precipitation over southern China is rather weak. The current study shows that there is hardly any enhancement in the SO signal over the region even in the most extreme of events. Any definite trends in terms of TC activity and related rainfall over the South China Sea are apparently more relevant to the lower latitudes.

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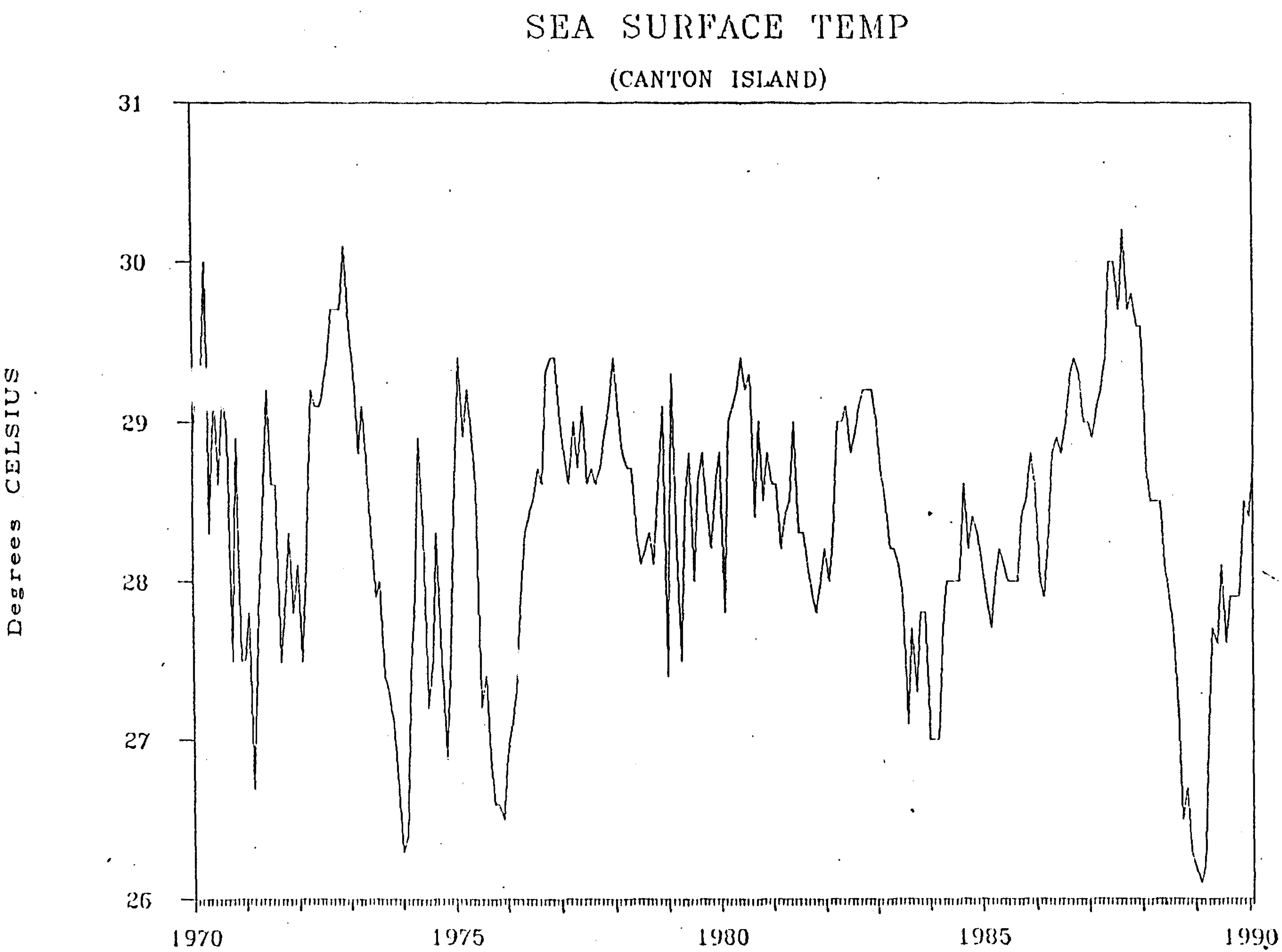

Figure 1 Time series of SST at Canton Island (2.8°S, 171.7°W).

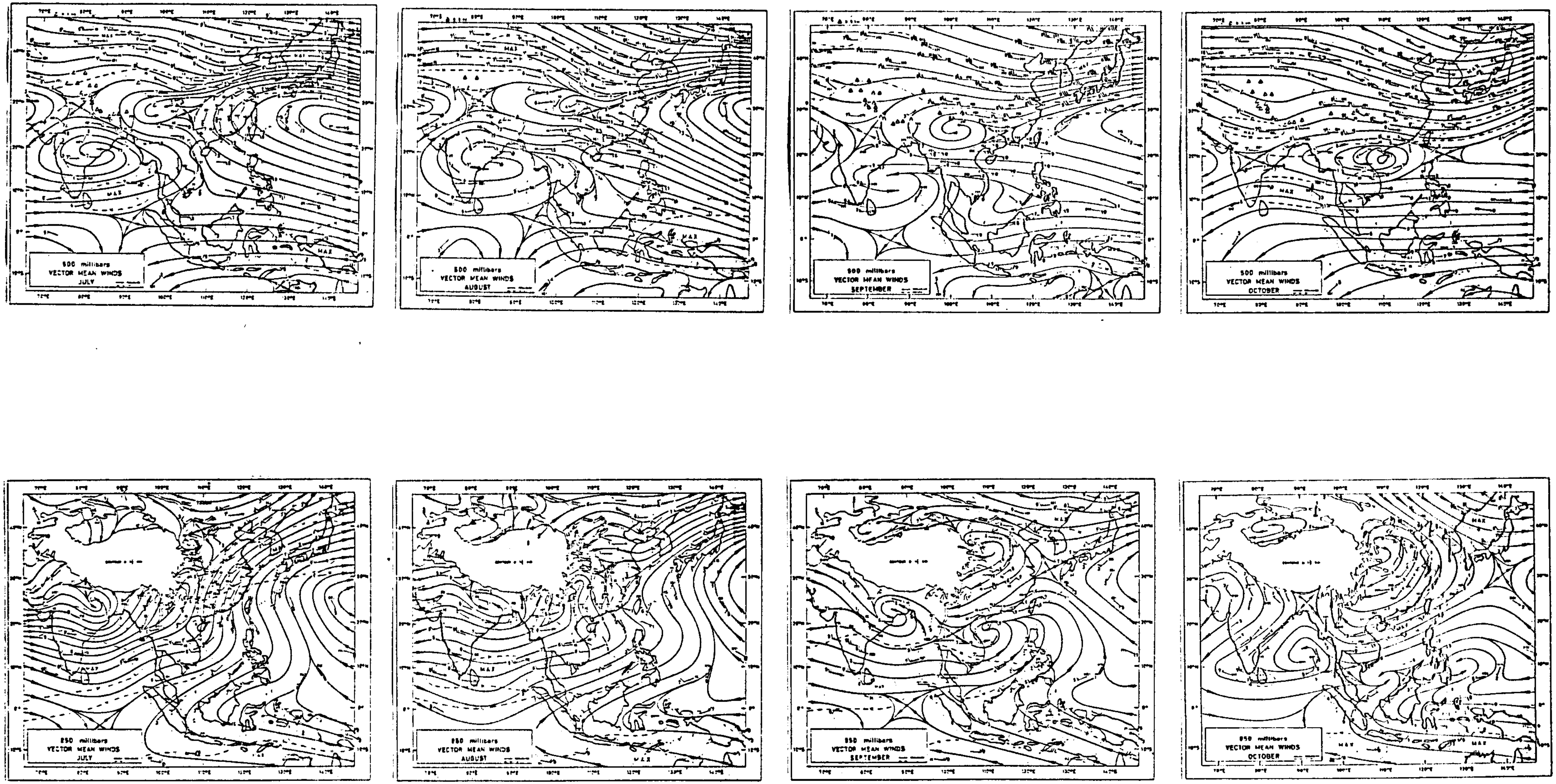

Figure 2 Vector mean winds and streamlines for 500-hPa (top row) and 850-hPa (bottom row) during the months of July - October (arranged in columns) (from Chin and Lai (1974)).

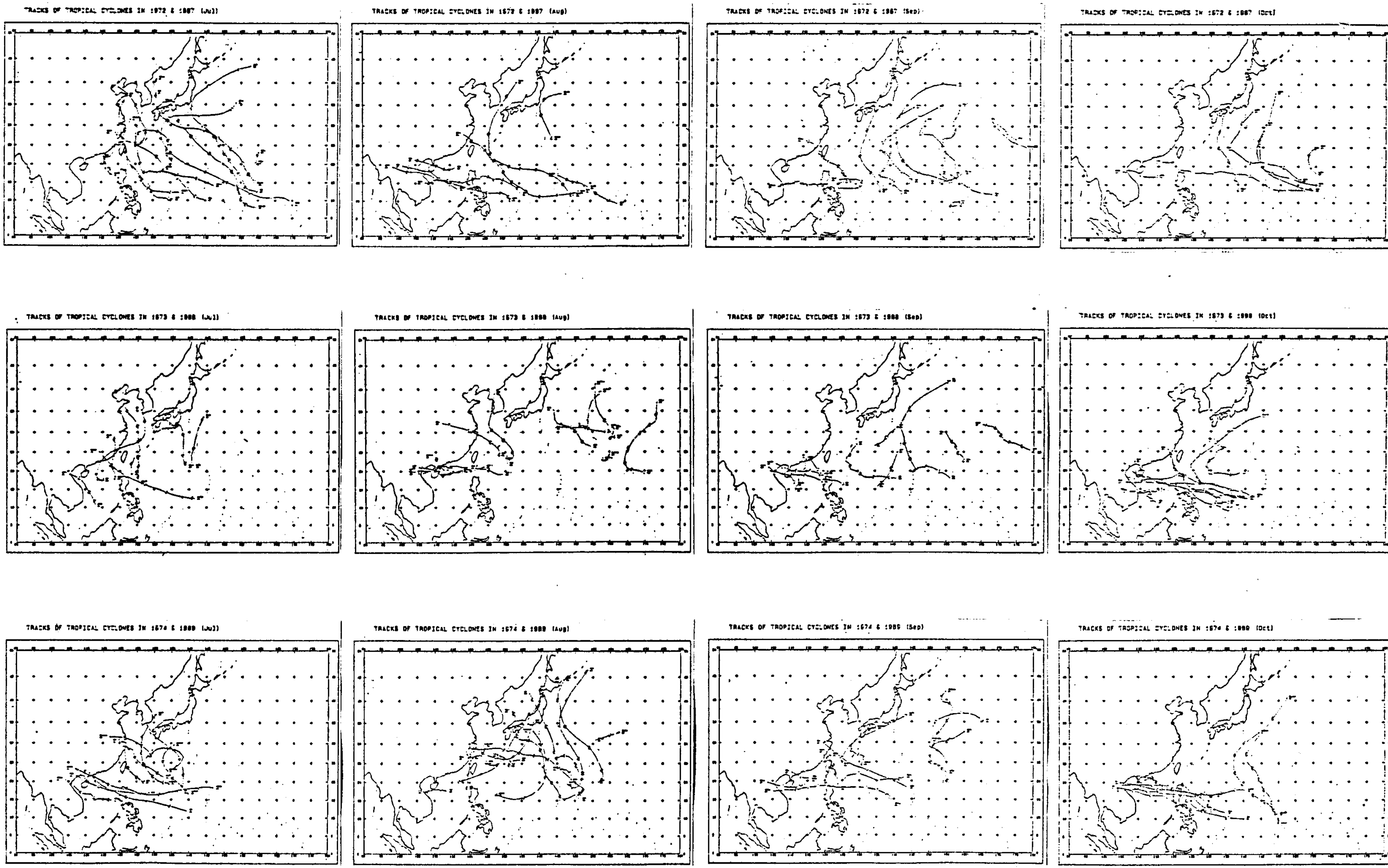

Figure 3 Tropical cyclone activity over the western North Pacific and the South China Sea in the months of July - October (arranged in columns) for TCS-1 (top row), TCS0 (middle row), and TCS-1 (bottom row).

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Extended Abstract

A major cooling episode of the sea surface temperature (SST) over the central equatorial Pacific occurred in 1988. The SST in the vicinity of Canton Island (2.8°S, 171.7°W) revealed a dramatic fall from a peak of over 30°C in September 1987 to a low of near 26°C in February 1989. The only other known cooling event of comparable magnitude occurred after the famous El Niño year of 1972.

The potential rewards in the study of tropical cyclone activity in relation to ENSO are not difficult to envisage. On one hand, tropical cyclone formation is critically dependent on warm SST and the locations of genesis are good indicators of the ENSO-related shifts of the ITCZ. Furthermore, the storm tracks can reveal the prevailing synoptic systems which provide the steering flow, thereby facilitating an assessment of the likely atmospheric responses to ENSO forcing. On the other hand, any established correlations between ENSO and tropical cyclone activity will in turn be useful for forecasting the interannual variability of storm occurrences.

To see if such extreme SST events actually had any impact on tropical cyclone activity over the western North Pacific, monthly tropical cyclone tracks from July to October of 1972-74 and 1987-89 were studied and compared. The tropical cyclone seasons of 1972 and 1987, i.e. the El Niño years, were labelled "TCS-1". The seasons of 1973 and 1988 when the cooling events were taking place were labelled "TCS0". The seasons of 1974 and 1989, referred to as "TCS+1", were when the cooling events had peaked and the SST had largely recovered.

From this categorization, a consistent picture began to emerge (see Fig. 1). The favoured genesis areas of tropical cyclones showed a systematic shift as the SST went from one extreme to another, with the most interesting contrasts occurring in the months of August and September. It provided further observational evidences in support of a SST-related migration of the ITCZ.

For the month of August, genesis areas during TCS-1 were mainly located at lower latitudes south of 15°N. The genesis areas then jumped to latitudes north of 20°N during TCS0 before shifting back gently southwards to latitudes between 15°N and 20°N in TCS+1. For southern China and the adjacent seas, this implied the proximity of a semi-permanent low-level trough and therefore more persistent showery weather in August before and after La Niña. But the actual occurrences of tropical

cyclones could be very different. For example, there were four tropical cyclones affecting the South China Sea in 1973 but none in 1988; three in 1974 and again none in 1989. Another intriguing observation here was that whereas storms affecting the South China Sea mostly originated from the Pacific, all the seven storms (including one re-generated storm) in August 1973 and 1974 developed in or near over the South China Sea . Subsequent analysis indicated that the upper-air conditions over the northern part of the South China Sea were probably not conducive to tropical cyclone development in August 1988 and 1989. It went to show even if the SST variation could pre-determine the general position of the breeding grounds, whether tropical cyclones would actually form at a certain location remained largely a matter of synoptic consideration.

For the months of July and October, the contrast was in the longitudinal sense. During TCS-1, genesis areas extended east of 140°E. But during TCS0, they were confined to the west of 140°E before becoming more spread out towards the east in TCS+1. This, perhaps, was not unexpected since genesis potential during a major La Niña event would decrease towards the central Pacific where the SST was relatively low. However, it was found that the suppressive effect was quite persistent and carried over to the following season (i.e. TCS+1) even when the SST over the central equatorial Pacific had largely recovered.

The meridional distribution of tropical cyclone activity was especially relevant in terms of the interannual variability of storm occurrences over the South China Sea. Storms forming west of 140°E stood a better chance of making their ways into the South China Sea while those forming further east tended to recurve at an early stage. This suggested there should be years during and following a La Niña event when tropical cyclone activity over the South China Sea would be enhanced, as were indeed the cases in 1973-74 and 1988-89.

Apart from the genesis areas, it was hoped that the movement of tropical cyclones during such dramatic SST events could shed some light on the prevailing environmental flow which steered the storms. This would provide useful observational guidances on probable teleconnection patterns associated with extreme ENSO events that could be pursued further in future studies.

In the light of this study, the implication on long-range rainfall forecast for a localized area like Hong Kong was also discussed. Despite the increasing acceptance of SST as a reliable predictor in the regression methods, the comparison of tropical cyclone activity between the 1972-74 and 1987-89 events aptly illustrated that the accuracy of forecasts was ultimately dependent on shorter-term events on the synoptic scale which remained outside the scope of current statistical treatment.

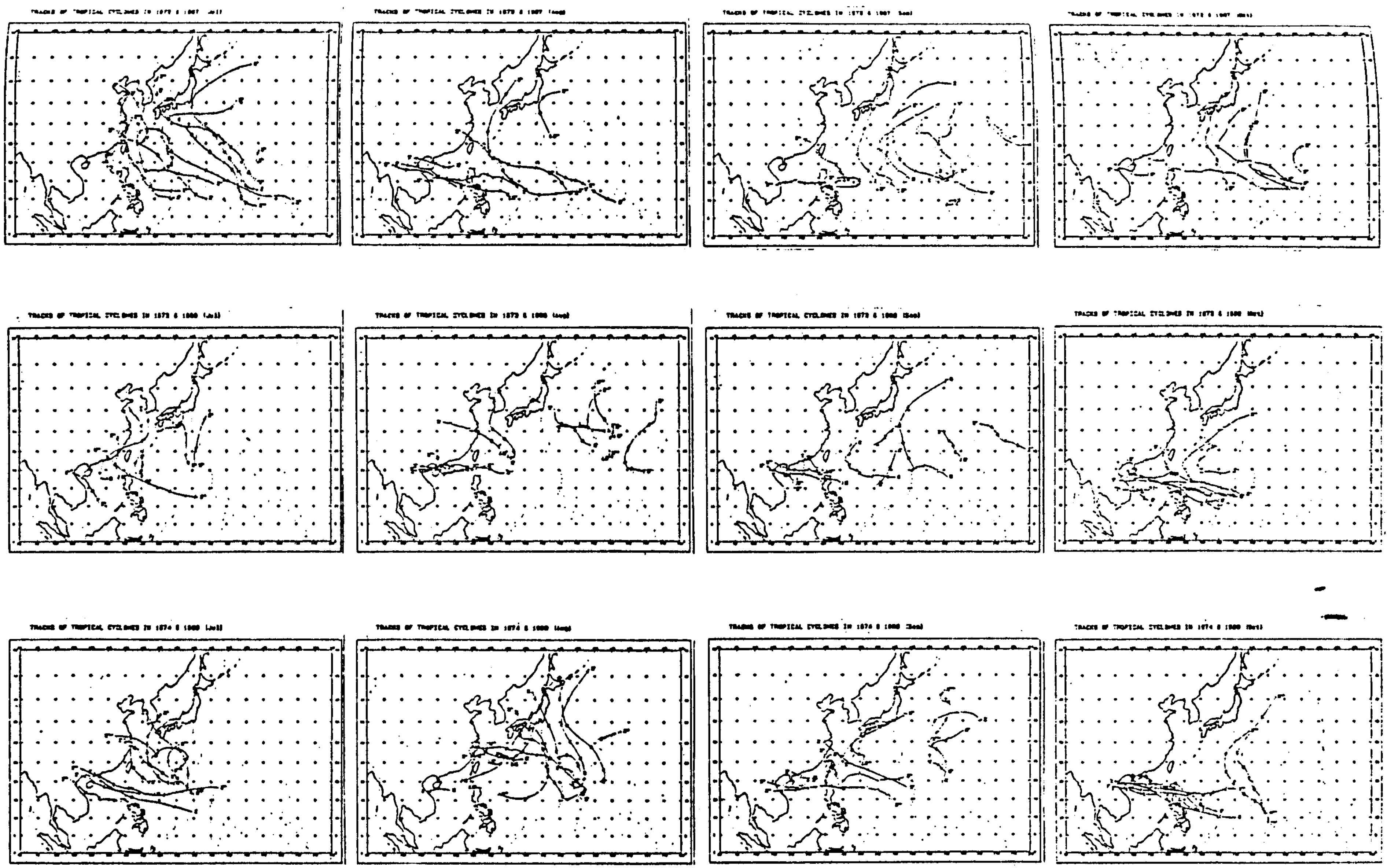

Figure 1 Tropical cyclone activity over the western North Pacific and the South China Sea in the months of July - October (arranged in columns) for TCS-1 (top row), TCS0 (middle row), and TCS+1 (bottom row).