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Research Brief 2011/01

Verification of Forecasts of Tropical Cyclone Activity over the Western North Pacific and Number of Tropical Cyclones Making Landfall in South China and the Korea and Japan region in 2010

16 February 2011

1. Introduction

Since 2000, City University of Hong Kong has been issuing real-time predictions of the annual number of tropical cyclones (TCs) affecting the western North Pacific (WNP). Verifications of the predictions have shown that the predictions are mostly correct within the error bars. We also began to predict the number of TCs making landfall in South China (SC) and the Korea and Japan region (KJ) in 2009 and 2010 respectively.

These are all statistical predictions with predictors drawn from a large group of indices that represent the atmospheric and oceanographic conditions in the previous year up to the spring of the current year. The most prominent ones include the proxies for El Niño/Southern Oscillation (ENSO), the extent of the subtropical ridge, and the intensity of the India-Burma trough. Details can be found in Chan et al. (1998, 2001).

2. Verification of the 2010 forecasts

a. Summary of the forecasts issued

1) TC activity over the WNP

Our April forecasts made on 26 April 2010 suggested "***below-normal activity for all the categories***". The June forecasts (issued on 24 June 2010) gave a similar forecast. Detailed numbers are summarized in Table 1, together with the observed numbers based on the warnings from JTWC and the Tokyo Regional Specialised Meteorological Center (RSMC).

Disagreements occurred among the warning centres on the intensity of some of the systems. Meranti was considered by JTWC as having reached typhoon intensity but not by RSMC Tokyo.

Table 1. Forecasts of TC activity in 2010 issued in April and June.

2010	*Forecast*		*Observed*		*Normal*
	April	June	JTWC	RSMC	
Entire western North Pacific					
No. of TCs	28	27	19	---	31
No. of TCs with at least tropical storm intensity	24	23	14	14	27
No. of typhoons	16	15	8	7	17
Landfall in South China					
Early Season (May to Aug)	4	---	2	---	3
Late Season (Sep to Dec)	2	---	1	---	2
Main Season (Jul to Dec)	---	3	3	---	4
Whole Season (May to Dec)	6	---	3	---	5
Landfall in the Korea and Japan region					
Main Season (Jul to Dec)	---	4	3	---	3
Whole Season (May to Dec)	6	---	3	---	4

2) South China

The forecast issued in April called for a slightly above normal number of tropical cyclones making landfall along the South China coast in the early season (May to August), a normal number in the late season

(September to December), and a slightly above normal number overall. The forecast issued in June also suggested the number of landfalling TCs to be slightly below normal for the main season (July to December). Table 1 shows a summary of these forecasts, along with the observed number in 2010 and the normal values.

3) Korea and Japan region

The April prediction called for an above normal number of TCs making landfall in the Korea and Japan region, while the prediction in June was slightly above normal. Table 1 is a summary of the predictions made.

b. Verification and discussion

1) TC activity over the WNP

The TC activity over the WNP in 2010 was exceptionally low. Based on the JTWC warnings, the number of TCs with at least tropical storm intensity is only 14, which is the lowest since the records began in 1960 (Fig. 1). It is 13 less than the normal number (the normal being 27). The typhoon activity also broke the record, with only 8 typhoons which is 9 less than the normal number (the normal being 17). Our forecasts from both April and June correctly predicted the below-normal TC activity. However, the predicted TC numbers are higher than the observed numbers, the possible reasons of which are discussed below.

Fig. 1. Annual number of tropical storms and typhoons between 1960 and 2010. The horizontal line indicates the climatological mean. Red circle and blue squares indicate the El Niño and La Niña years respectively.

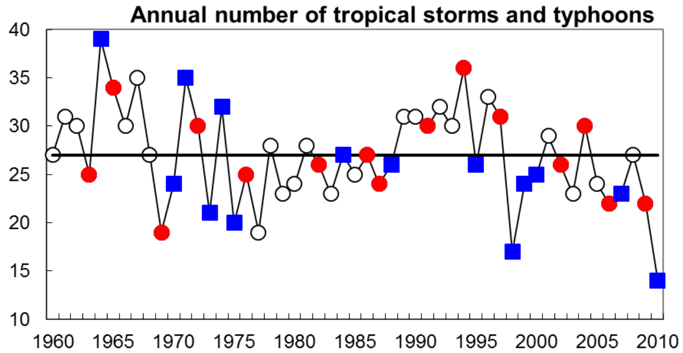
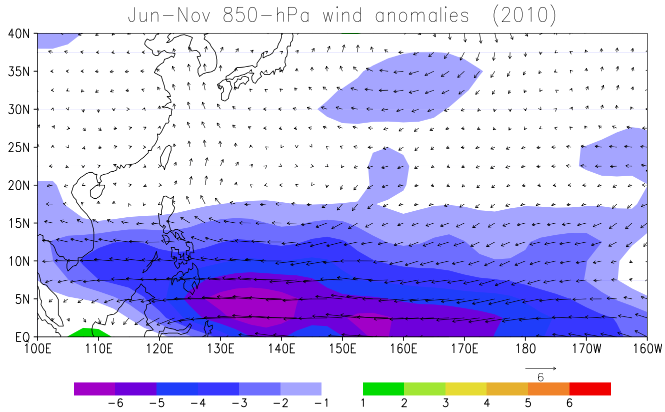


Fig. 2. 850-hPa wind anomalies (vector) between June and November in 2010. Contour indicates the zonal wind speed (interval = 1.0 m s^{-1}).

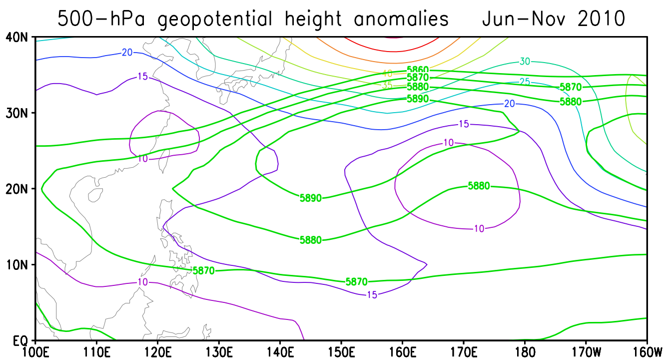


A strong La Niña event developed in the summer of 2010 and the mean Jun-Nov Niño3.4 index is -1.21. The changes in atmospheric circulation associated with the La Niña event should be the dominant factor affecting the TC activity. Previous studies suggest that in a La Niña year, easterly anomalies are generally found over the tropical WNP, resulting in the weakening of the monsoon trough and hence a lower TC activity (Wang and Chan 2002) (Table 2). This is a main reason for our forecast of the below-normal TC activity. In the 2010 TC season, strong easterly anomalies are found over the entire tropical WNP, with the maximum amplitude between 130^{o}E and 160^{o}E (Fig. 2). It should be noted that the anomalies are even stronger than those found in previous La Niña years. As a result, the monsoon trough is much weaker than normal and the atmospheric conditions are therefore not favourable for TC genesis and development. The mean genesis location shifted westward and only one TC formed over the tropical WNP east of 150^{o}E, which is the typical pattern associated with a La Niña event. At the same time, the June-November 500-hPa geopotential height shows positive anomalies over the subtropical WNP, indicating the stronger than normal subtropical high (Fig. 3). Thus, all atmospheric conditions are not favourable for TC genesis, which is likely the reason for the record-breaking low TC activity. Our statistical model is not capable of predicting the extreme TC numbers.

Table 2. Number of tropical storms and typhoons and number of typhoons in a La Niña year. Red and blue shadings indicate the above-normal and below-normal TC activity respectively.

	La Niña Year	Number of tropical storms and typhoons	Number of typhoons
Active period	1964	39	26
	1970	24	12
	1971	35	24
	1973	21	12
	1974	32	15
	1975	20	14
	1995	26	15
Inactive period	1984	27	16
	1988	26	14
	1998	17	9
	1999	24	12
	2000	25	15
	2007	23	15
	2010	14	8

Fig. 3. 500-hPa geopotential height anomalies between June and November in 2010. Thick contour indicates the geopotential height (contour interval = 10 m) ≥ 5860 m.



During the past five decades, the TC activity exhibited a significant interdecadal variation, with the active periods of 1960-76 and 1989-97 and the inactive periods of 1977-1988 and 1998-2009. The inactive TC period 1998–2009 appeared to continue into 2010. The number of tropical storms and typhoons is below the climatological mean in the 2010 TC season, which is the 11th out of the last 13 years since 1998 with a below-normal TC activity (Fig. 1).

2) South China

The observed number of TCs making landfall along the coast of South China was 2 in the early season, 1 in the late season, 3 in the main season, and 3 in the whole season. Apart from the prediction for the main season, which was perfect, the predictions for the number of landfalling TCs in the early and late seasons were overestimated, which also led to an overestimation of the predicted value for the whole season.

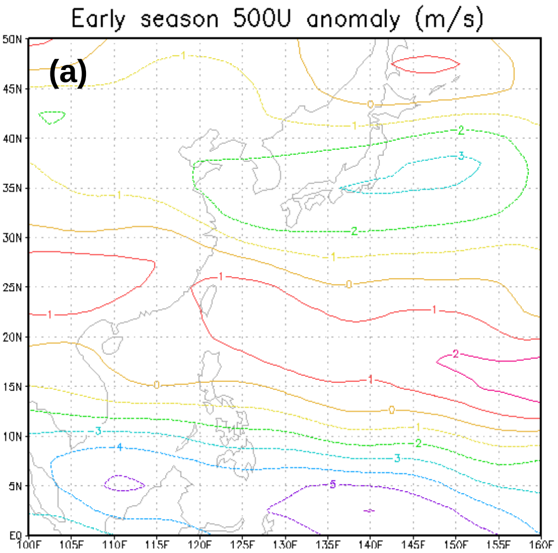
Table 3. Comparison of TCs making landfall along the South China coast and the Korea and Japan region during the early and late seasons in EN+1 years. Years marked with an asterisk (*) are LN years. Green and blue shadings indicate above-normal and below-normal TC activity years respectively.

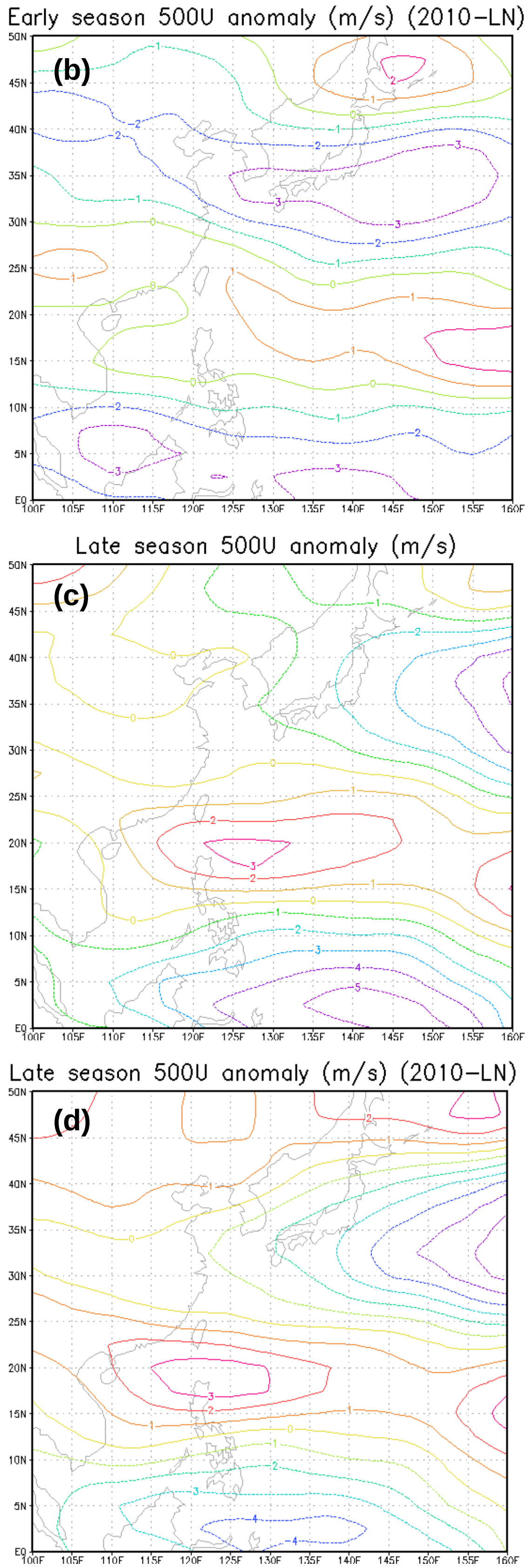
	South China coast		Korea and Japan region	
	Early season	Late season	Whole season	Main season
1966	4	0	7	7
1969	2	0	2	2
1973*	6	3	3	1
1977	2	1	1	1
1978	3	1	5	4
1983*	2	2	4	4
1987	1	0	3	3
1988*	1	5	0	0
1992	5	0	3	3
1995*	5	3	2	2
1998*	0	1	5	6
2003	4	0	4	2
2005*	2	1	3	3
2007*	2	0	4	4

One of the reasons for this discrepancy could be due to the early arrival of La Niña (LN) conditions during the season. Earlier in the season, most prediction agencies predicted that 2010 would be ENSO-neutral, whereas in reality LN conditions set in during mid-year, making 2010 an EN+1 (year after an El Niño) year that was also a LN year. As shown in Table 3, in the previous 14 EN+1 years, 8 and 6 have below-normal number of TCs in the early and late season respectively. Specifically, of the 7 EN+1 years that were also LN years, 5 of them had below-normal TC activity in the early season, and 4 saw normal or below-normal activity in the late season.

Further, a study of the 500-hPa zonal wind pattern in 2010 reveals the presence of anomalous westerlies between 15°N and 25°N during the early season (Fig. 4a), which served to steer TCs away from the South China coast. This westerly anomaly is similar to, and much stronger than, what is seen in the early season of a typical LN year (Fig. 4b), thus explaining the below-normal number of TCs making landfall over the South China coast during this period. On the other hand, similar situation can be seen in the late season, as anomalous westerlies dominated the area between 15°N and 25°N (Fig. 4c), again at a stronger strength than in typical LN situation (Fig. 4d). Therefore, it seems the below-normal landfalling activity in 2010 can be accounted for by the occurrence of LN during the season.

Fig. 4. 500-hPa zonal wind anomaly from (a) the mean and (b) LN years, during the early season of 2010. (c) and (d). Same as (a) and (b) except for late season.





3) Korea and Japan region

The observed number of TCs making landfall in the Korea and Japan region was 3 in both the whole and main seasons, both of which are less than the number predicted.

The difference between the predicted and the observed values could again be attributed to the occurrence of LN during the season. Similar to the situation in the South China Sea, the number of landfalling TCs in KJ in the whole and main seasons tends to be below normal in EN+1 years (8 and 6 out of the past 14 respectively), and in those 7 EN+1 years that were also LN years, 4 and 3 years had below-normal number of landfalling TCs respectively in the whole and main seasons (Table 3).

A study of the 500-hPa steering flow of the peak season (July to September) of 2010 (Fig. 5a) shows easterly anomalies to the southeast of Japan, which should be favourable for TCs to be steered into the region. However, the 850-hPa geopotential height pattern reveals a positive anomaly, again stronger than the typical LN year, over much of the WNP, a condition unfavourable for TC formation (Fig. 5b). Therefore, the below average number of TCs making landfall in KJ could be due to a below average number of TCs being formed over the WNP.

References

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Fig. 5. Peak season anomalies from LN years of (a) 500-hPa zonal wind (m s^{-1}) and 850-hPa geopotential height (m).