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Research Article

Identifying of the start date of the active tropical cyclone season in the western North Pacific and East Sea

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Abstract: This paper presents the way of identifying the start date of an active storm season in the western North Pacific (WNP) and East Sea (ES). The start (end) date for an active TC season in a year is identified at 5th (95th) percentile of data. Normal and empirical distributions are used to estimate climatological thresholds for the early and late start of the active TC season. Climatological early (late) start is under (over) the date at 33% (67%) of cumulative probability function. Climatological early start is 24 April (20 May) while climatological late start is 28 May (20 June) for the WNP (ES). In the WNP, the start date of storm season tends to be in early and normal (normal and late) phase in post–La Niña (post–El Niño) years. The relationship is not really clear in ES.

Keywords: Start of TC season; Climatological start date of TC season.

1. Introduction

The western North Pacific (WNP) is the most active tropical cyclone basin in the world [1]. Normally, there are about 25 to 30 storms annually. TCs activating in the WNP tend to attack many countries in East Asia (Japan, Korea, China) and Southeast Asia (the Philippines, Vietnam), causing significant damage to people and properties. Being a part of the WNP, East Sea (ES) has about 10–12 TCs each year, which accounts for roughly one third of the total number of TCs in the WNP; about 5–7 of them either making landfall or having direct impact on Vietnam. The damage caused by TCs in ES may be very serious due to its shorter warning time before landfall. For instance, the Haiyan typhoon directly affected the Philippines, Vietnam and China in November 2013, causing $ 4.55 billion in damage and 6300 deaths [2,3]. Thus, it is essential to identify and forecast the start of storm season in WNP and ES.

Many studies have mentioned different characteristics of TC activity, such as, genesis, intensity, landfall and track as well [1,4,5]. Especially, TC features in relation to ENSO, intra–seasonal oscillation (ISO), Pacific Decadal Oscillation (PDO), Indian Ocean Dipole (IOD) were intensively understood by meteorologists over the world. For instance, ENSO modulates monsoon trough in WNP. Consequently, in El Niño (La Niña) years, TC genesis location expands southeastward (retreats northwestward). Li and Zhou (2013a,b) [4,5] demonstrated effects of ISO on genesis, intensity and track of TC in WNP. In particular, increase (decrease) of genesis in active (non–active) phases of ISO is associated with strengthening (weakening) of monsoon trough. Kubota and Chan (2009) [6] found that, during low PDO phase, TC landfall in Philippines decreases (increases) significantly in El Niño (La Niña) years. During high PDO phase, difference in TC landfall between ENSO phases is u nclear. However, inter–annual variation of start date of TC receives less attention by scientists. A few studies mentioned this issue. Kim et al. (2017) [7] and Zhao et al. (2019) [8] illustrated relationship between ENSO and inter–annual variation of start date of TC season in WNP. Although start date of TC season in ES has not understood well yet. More studies relating to this issue should be conducted to enhance our understanding. For purpose of operational forecast, National Center for Hydro–Meteorological Forecasting, Vietnam (NCHMF) is responsible for providing information of start date of TC season for community in seasonal forecast bulletins. Meanwhile, currently, NCHMF has no objective criteria to evaluate start date of TC season in both WNP and ES. Thus, goal of this paper is to document the way of identifying. Hopefully, this paper will provide useful information for operational forecast. In this paper, Section 2 describes data, methodology. Section 3 presents results and discussions. Section 4 is the conclusion.

2. Methodology

Climatology of tropical cyclone

In this study, Japan Meteorology Agency (JMA) TC data is used. After 1980s, data quality was more reliable due to contribution of satellite measures. Thus, the analysis is performed in period 1980 – 2019. Only TCs having maximum wind speed is above 17.2 m s^{-1} retained to analyze. Figure 1 shows the monthly climatology of TC numbers in twelve months in the WNP and ES. February has the lowest TC numbers, while the most active period of TC over WNP and ES is from July to November. A similar trend of TC numbers is also exhibited in the ES, but, the number of TC is lower than that in WNP. Thus, the concept of “TC year” in the WNP and ES is defined as starting on 1 February and ending on 31 January of the coming year.

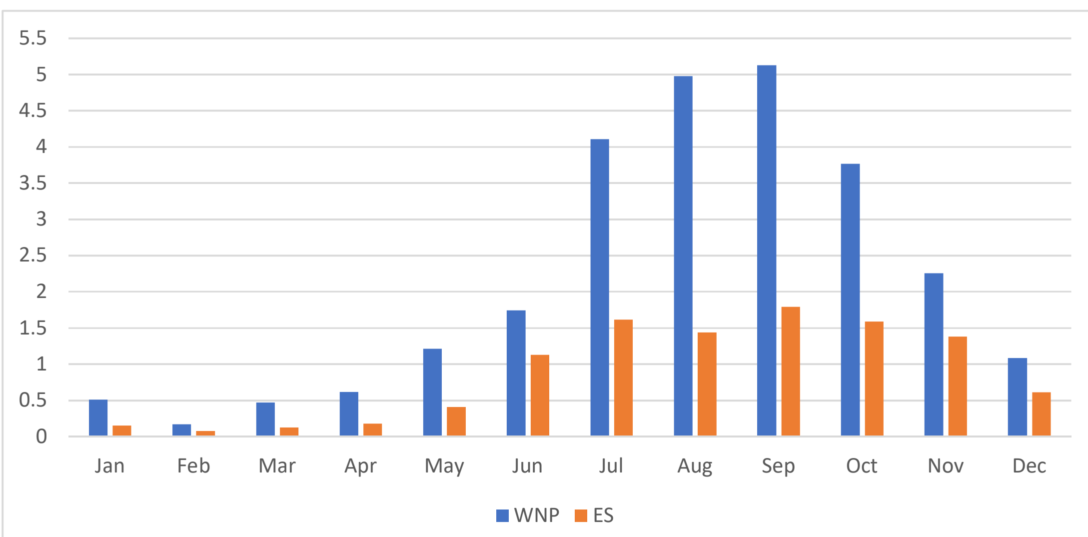

Figure 1. Monthly mean TC numbers in the WNP during 1980–2019.

Identification of the start of storm season

In this study, start dates were identified by percentile which is a common concept in statistical science. Normal distribution with two parameters: mean (μ) and standard deviation (σ) were used to estimate climatological early and late starts. The general form of its probability density function as below:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} \quad (1)$$

Kernel (empirical) distribution was also employed. It is a non–parametric function and is estimated from a sample of data. While normal distribution function is built from two parameters of mean and standard deviation. Thus, it is useful if data estimated by normal distribution is compared with that estimated by empirical distribution. The goal is to identify whether normal distribution is appropriate to apply or not. More detail of the methods can be found in Wilks (2011) [9].

We define the TC season in the WNP (ES) as the period from the 5th percentile to the 95th percentile of TC formation dates in each TC year. This definition, based on the percentiles, thus, the TC season occupies 90% of total TC numbers of TC year. Based on this definition, the start date of the active TC season is identified for each year from 1980–2019. Then, the empirical distribution functions of the start date for the WNP and ES are built (Figure 2) and are compared with the normal distributions. The figure 2 shows that the empirical distributions of start date in the WNP which have similar shapes with the normal distributions. Thus, the normal distribution can be applied to estimate the start date of the active TC season. Meanwhile, in ES, empirical distribution of start date skews to right side of normal distribution. It implies that normal distribution should not be utilized. More specifically, Table 1 shows terciles of start dates (early, normal, and late) identified by normal and empirical distributions. In WNP, for normal distribution, the point of 24 Apr (28 May) representing 33% (67%) data of cumulative distribution function separates early and normal (normal and late) stages of start dates. The results received from normal and empirical are relatively same for WNP. But, they are much different for ES (Table 1). It suggests that, for ES, empirical distribution should be used to estimate early, normal and late stages of start date instead of normal distribution. The results in Figure 3 illustrate that the climatological start date in ES is later than that in WNP, which is consistent with distribution of start dates in Figure 2. The median of start date in ES (WNP) is nearly 160 (nearly 140). First and third quartiles of whisker–box–plot in ES are also later than those in WNP. The results will be discussed in more details in next Section (Figure 4 and Table 2).

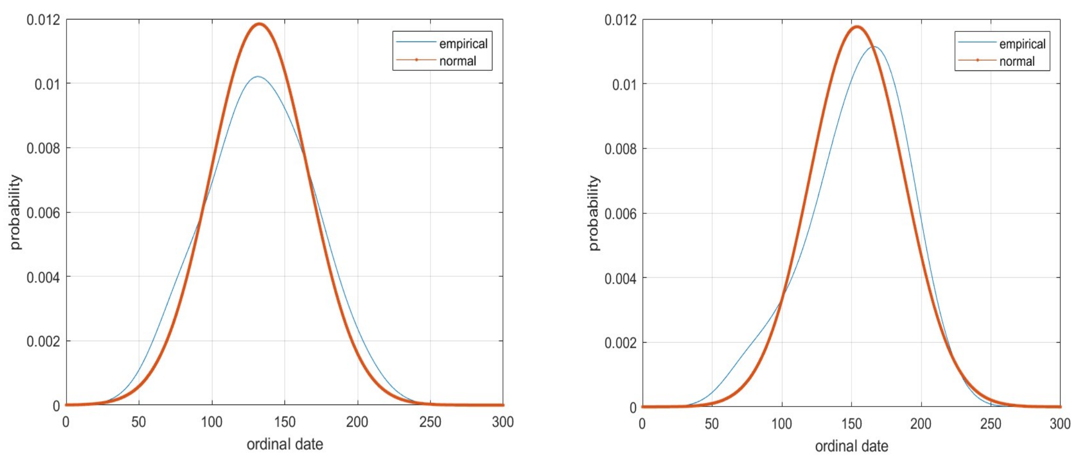

Figure 2. Empirical and normal distributions of the start date of the TC season during 1980 – 2019 for WNP (left) and ES (right).

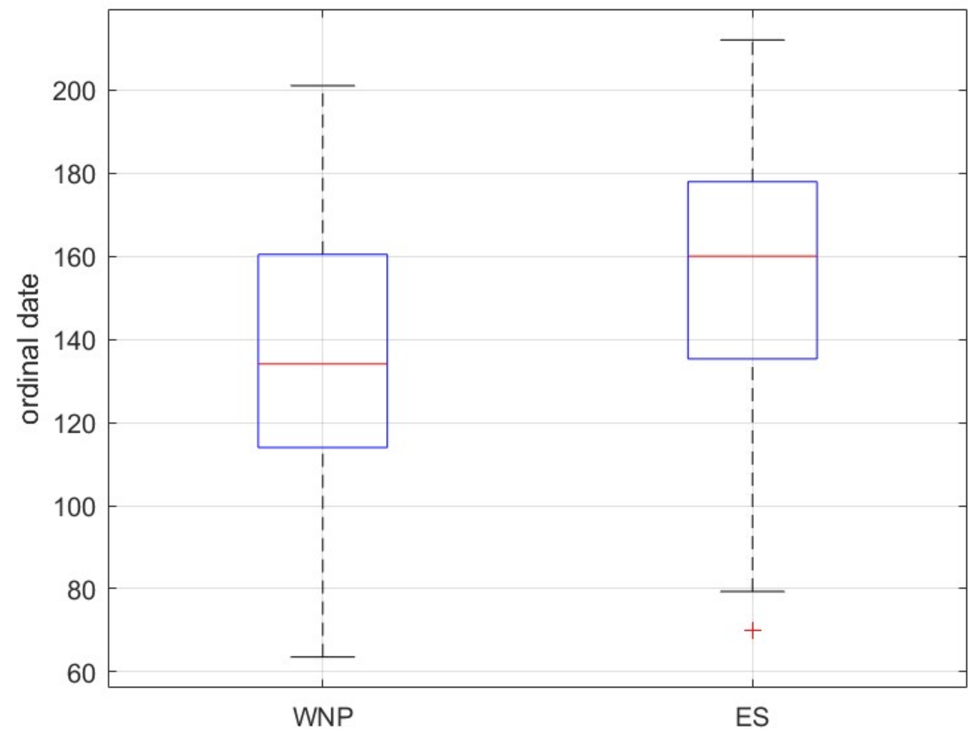

Figure 3. Box plots of start dates during 1980–2019 for the ES and WNP. Vertical axis is ordinal start dates. Red lines in center of boxes are median. Red cross in ES is outlier.

Table 1. Definition of early, normal, and late start date of storm season

Early	Normal	Late
For the WNP (Normal)		
date < 24 Apr	24 Apr =< date =< 28 May	date > 28 May
For the WNP (Empirical)		
date < 28 Apr	28 Apr =< date =< 24 May	date > 24 May
For the ES (Normal)		
date < 16 May	16 May =< date =< 18 June	date > 18 June
For the ES (Empirical)		
date < 20 May	20 May =< date =< 20 June	date > 20 June

3. Results and discussions

Figure 4 shows interannual variation of start dates for both WNP and ES. The correlation between two timeseries is 0.17. It implies that, although ES is a part of WNP, interannual variation of start date in ES is not completely dependent on that in WNP. In particular, in some years (e.g., 1982–1985, 1998, 1999, 2016), the start dates come early/late in WNP, they are also similar in ES. Inversely, start dates are not coincident in some other years (e.g., 1997, 2002, 2005, 2010, 2012, 2013, 2014, 2015). In fact, WNP is much larger than ES. If active storm area is in eastern part of WNP far away from ES and Philippines Sea, the start date in ES might not be related to that in WNP. Table 2 shows the start dates of both WNP and ES in relation to post–ENSO years. In WNP, in post–El Niño (post–La Niña) years, the start dates tend to come later (earlier). The start dates are between June and July in post–El Niño years, while they stay around April and May in post–La Niña years. This trend also occurs in ES, but, it is not really clear as in WNP. The results for WNP, in this study, is consistent with the finding of Kim et al. (2017) [7]. Kim et al. (2017) documented that a strong El Niño in the previous winter can cause the late TC season in the coming year. It can be speculated that, ES is among interaction of monsoon systems, physical mechanism of TC formation can be more complicated and affect relationship of start date and ENSO. The results from this study suggest that it is feasible to use ENSO as a potential predictor to predict start date in WNP and ES. More studies need to be conducted to provide useful seasonal forecast.

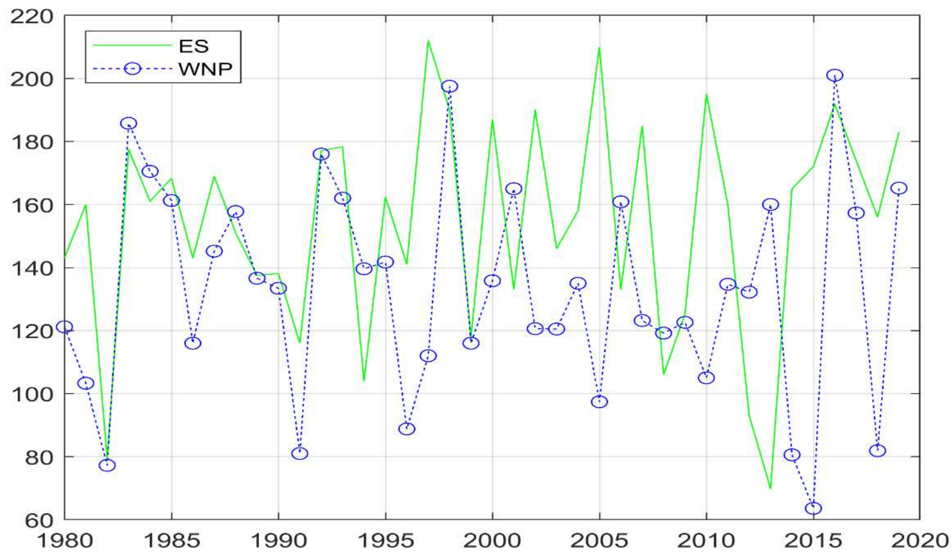

Figure 4. Interannual variation of start dates in WNP and ES during 1980–2019.

Table 2. The start date of the active TC season in post–ENSO years.

post–El Niño	**1983**	**1988**	**1998**	**2003**	**2016**
WNP	3–Jul	5–Jun	15–Jul	29–Apr	19–Jul
ES	25–Jun	3–May	8–Jul	25–May	9–Jul
post-La Niña	**1989**	**1999**	**2000**	**2008**	**2011**
WNP	15–May	25–Apr	14–May	28–Apr	13–May
ES	16–May	27–Apr	5–Jul	15–Apr	8–Jun

4. Conclusions

This paper examined inter–annual variation of start date in WNP and ES by using normal and empirical distributions. In WNP, the start dates built by normal and empirical distributions have the almost similar shapes. It suggests that it is feasible to apply normal distribution. Meanwhile, in ES, normal distribution is not really appropriate. Empirical should be used stead. The results found that, in WNP, if start date of a year comes among 24 April and 28 May (by normal distribution), it will be in normal class. In ES, normal class is identified as among 20 May and 20 June (empirical distribution). Thus, climatologically, active storm season seems to be later in ES than in WNP. In WNP, interannual variation of start date has relationship with ENSO (mentioned by Kim et al., 2017 [7]). However, it might be not really clear in ES. The relationship between ENSO and start date in ES needs to be deepened in coming studies. The information from this paper can provide the useful way and criterion to identify start date of active storm season in WNP and ES for operational seasonal forecast.

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Conflicts of Interest: There is no conflicts.

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