Research Paper

POWER DISSIPATION INDEX OF TROPICAL CYCLONES IN THE EAST SEA

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ARTICLE HISTORY

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ABSTRACT

In this paper, through statistics of tropical cyclones in the East Sea from 1961 to 2017, the research team calculate Tropical Cyclone Power Dissipation (PDI), defined the maximum wind speed and the life time of tropical cyclones, compare with some other indicators that have been used by other authors such as NetTC in the East Sea to see the correlation between indicators and factors related to climate change such as sea surface temperature, Nino 3-4. Since then, the tendency of PDI increase, the correlation coefficient with Nino 3-4 is positive in the East Sea region, but this correlation is small.

Keywords: *PDI, NetTC.*

1. Introduction

The changes of tropical cyclones (TC) including storms and depressions in the East Sea are the more important consequences of climate change (Kossin et al., 2013; Doocy et al., 2013; Wu et al., 2014). The understanding of activities of TC, the characteristics of TC in the past is very important role for forecasters to grasp the rules of TC and forecast better in the future. The changes of frequency and intensity of TC affect to the economic and social activities, so the study of the nature and trend of TC changes is particularly important.

Human impact is one of the reasons affecting the number and intensity of landfalling storms, but other potential energy such as Accumulated Cyclone Energy (ACE) index is also one of the factors affecting the quantity and intensity of TC (Emanuel, 2005, 2007; Free et al., 2004; Nordhaus, 2010; Walsh et al., 2016). For the purpose of detecting climate signals, such integral measures will be preferable, owing to the much larger amount of information available for storms throughout their lifetimes compared to landfall. In this study will focus on the change of the Power Dissipation Index (PDI), defined by the author (Emanuel, 2005).

$$PDI = \int_0^{\tau} V_{max}^3 dt \qquad (1)$$

where V_{max} is the maximum surface wind at any given time in a storm, and τ is the lifetime of the event. For the purposes of this paper, the PDI is also accumulated over each year.

Annually accumulated integral metrics such as ACE and PDI show striking variations from year to year and on longer time scales (Bell et al., 2000). In the western portion of the North Pacific, ACE is significantly affected by ENSO (Camargo and Sobel, 2005). Emanuel (2005) showed that, in the Atlantic, the PDI is strongly

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correlated with SST in the later summer and early fall in the tropical Atlantic between Africa and the Caribbean, while in the western North Pacific region, the correlation, though significant, is weaker. The PDI, a measure of the total energy consumption by tropical cyclones, has been empirically related to a small set of environmental predictors selected on the basis of both theoretical and empirical considerations. The resulting index depends on ambient low-level vorticity, potential intensity, and vertical shear of the horizontal wind. The variability of all three of these factors has contributed significantly to the observed variability of the PDI over the last 25 year from 1980 to 2004, during which time they have relatively high confidence in both the tropical cyclone record and the reanalysis data. These results suggest that future changes in PDI will depend on changes not only in surface radiative flux, but in tropopause temperature, surface wind speed, low-level vorticity, and vertical wind shear, as well. These variables are among those simulated by global climate models, which can then be used, in principle, to project future changes in PDI using by:

$$PDI \sim \eta_{850}{}^{5/2} V_p{}^{7} (1+0.3S)^{-4} \qquad (2)$$

where η850 is absolute vorticity at 850 hPa, Vp is potential intensity and S is shear at 850-250 hPa. They are in the process of estimating these changes in the suite of global models being used for the 2007 Intergovernmental Panel on Climate Change (IPCC) report.

In addition to the PDI, the other authors such as Phan Van Tan (2010) also calculated the relationship between NetTC index and sea surface temperature (SST) during the TC season, in which NetTC index is calculated by:

NetTC = (%Dp + %TC8-9 + %TC10-11 + %TC12 up + %NTCDa)/5 (3)

where %Dp, %TC8-9, %TC10-11, %TC-12up, %NTCDa is the percentage of tropical depressions, storms with 8-9 force, 10-11 force, upper 12 force and number of stormy days in each year of the year compared to the average of the whole time series. The results showed a positive correlation between sea surface temperature in the regions (5^{o}N-25^{o}N, 150^{o}E-165^{o}E) and (0^{o}N-30^{o}N, 100^{o}E-180^{o}E) with NetTC index from 1981 to 2007.

From the above bases, this study will analysis and evaluate indicators with some of the factors affecting the external environment such as SST, NiNo3-4 to see variation of TC in the East Sea and the relationship between the number of tropical cyclones with environmental factors. Comparison between indicators also to find appropriate indicator that characterize the impact on variation of TC in the East Sea.

2. Data and Method

The number of tropical cyclones is collected in the East Sea from the National Center for Meteorological and Hydrological Forecasting (NCHMF) from 1961 to 2017. However, the data on maximum wind speed and lifetime in the East Sea are taken from the Joint Typhoon Warning Center (JTWC) at:

https://metoc.ndbc.noaa.gov/JTWC.

Reanalysis data of factors such as SST, Nino3-4 from Tokyo Climate Center (TCC) at: *https://extreme.kishou.go.jp/itacs5/.*

In addition to the statistical method, the PDI index is calculated according to Emanuel (2005) and NetTC index is calculated according to Phan Van Tan (2010).

3. Results and discussion

3.1. Activity of TC in the East Sea and landfalling in Viet Nam

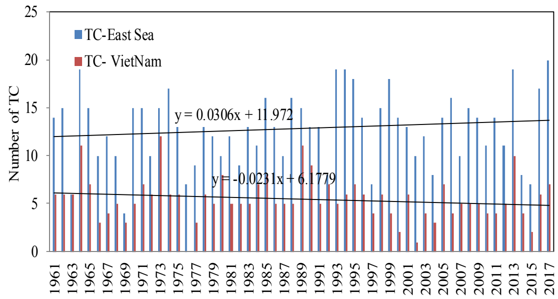

Fig. 1. Number of TC in the East Sea (blue) and landfalling in Viet Nam (red) from 1961-2017

Fig. 1 shows the number of TC in the East Sea and the number of TC that landfall Vietnam in the period from 1961 to 2017, showing a slight increase of TC in the East Sea with coefficient a = 0.03. Meanwhile, in contrast, the number of TC landfallind in Vietnam decrease in this series time.

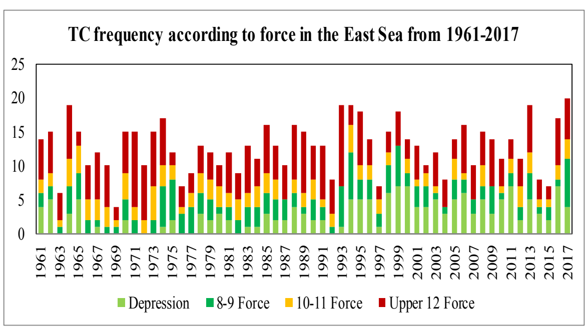

Fig. 2. TC frequency according to force in the East Sea from 1961-2017

The frequency of TC from tropical depression, TC with 8-9 force, TC with 10-11 force and sTC with upper 12 force is shown by Figure 2. It can be seen that the number of TC with upper 12 force is biggest, about 40%, following by the activity of tropical depression with 22% and the number of TC with 8-9 force and 10-11 force with 21% and 16% respectively. Frequency by 5 years, found that from 1991 to 1995, the number of TC in the East Sea is biggest with average of 15.9 times, of which the number of TC with upper 12 force is also more frequency with average of 7 times per year. However, considering this period, the number of TC effecting to Vietnam is only from 5 to 7 times, approximately with the normal.

Frequency by 10 years, the 1991-2000 decade is biggest with average of about 14.5 times per year, in which from 1993 to 1995 and 1999, there are 18 to 19 times in the East Sea. According by force, there are about 2.9 number of tropical depression, 2.7 number of TC with 8-9 force, 2.2 number of TC with 10-11 force and 5.2 number of TC with upper 12 force per year in the East Sea.

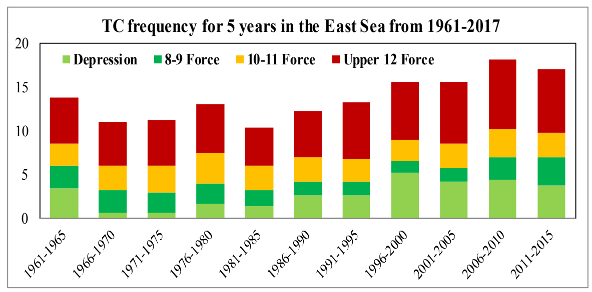

Fig. 3. TC frequency by 5 years in the East Sea from 1961 to 2017

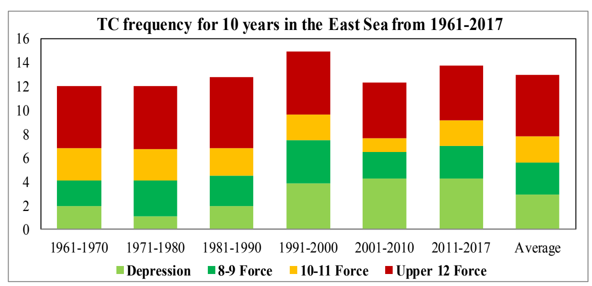

Fig. 4. TC frequency by 10 years in the East Sea from 1961 to 2017

3.2. Power dissipation index and NetTC

PDI in the East Sea tends to increase slightly in the series time with coefficient a = 0.0032 (Fig. 5), similar to that, Nino 3-4 index also tends to increase slightly in this series time from the year 1961 to 2017 with coefficient a = 0.0038 (Fig. 6). Considering the correlation coefficients between these two series of data, the positive correlation is 0.2 (Fig. 7).

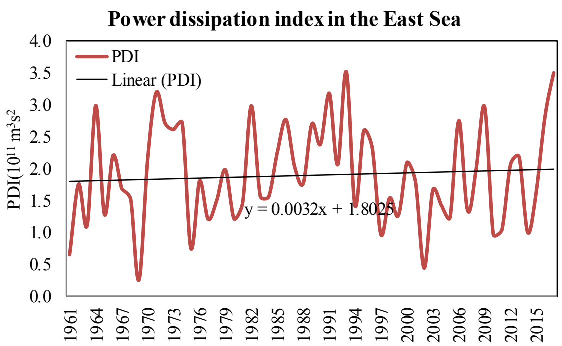

Fig. 5. Power dissipation index (PDI) tin the East Sea

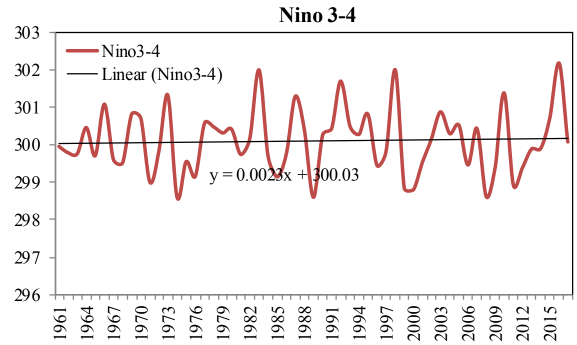

Fig. 6. Nino 3-4 index from 1961 to 2017

Table 1. Average number of TC by 10 years according to force

Year	Dpression	8-9 Force	10-11 Force	Upper 12 Force
1961-1965	3.4	2.6	2.6	5.2
1966-1970	0.6	2.6	2.8	5
1971-1975	0.6	2.4	3	5.2
1976-1980	1.6	2.4	3.4	5.6
1981-1985	1.4	1.8	2.8	4.4
1986-1990	2.6	1.6	2.8	5.2
1991-1995	2.6	1.6	2.6	6.4
1996-2000	5.2	1.4	2.4	6.6
2001-2005	4.2	1.6	2.8	7
2006-2010	4.4	2.6	3.2	8
2011-2015	3.8	3.2	2.8	7.2

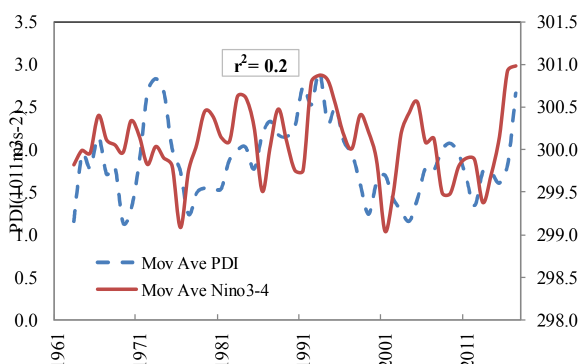

Fig. 7. PDI (blue) and Nino 3-4 index (red) in the East Sea. The time series have been smoothed using moving average with 3 year to reduce effect of interannual variability and fluctuation on time scales

In general, there is a similarity between the PDI and Nino 3-4 from 1961 to 1970 and from 2011 to 2017 (Fig. 8). However, from 1981 to 1990, the correlation is bigger but it is negative, as the year of strong ElNino like 1983, 1988, 1998, PDI index in the East Sea is smaller than the normal, with $1.6*10^{11}m^3.s^{-2}$, $1.8*10^{11}m^3.s^{-2}$, $1.5*10^{11}m^3.s^{-2}$, respectively. In these years, the number of TC are bigger than the normal with 13 to 16 times and effecting to Vietnam with 5 to 7 times. With strong Lanina like 1989, 2000 and 2011, the PDI is $2.7*10^{11}m^3.s^{-2}$, $2.1*10^{11}m^3.s^{-2}$ and $2.1*10^{11}m^3.s^{-2}$, bigger than the normal, the number of TC are also bigger than the normal, from 14 to 15 times; however, landfalling in Vietnam has not been uniform, there were 11 TC in 1989 but there were only from 2 to 4 number of TC in 2000 and 2001. In general, PDI depends on three factors: maximum wind speed, lifetime of TC. PDI correlates with the Nino3-4 index, but this correlation is small.

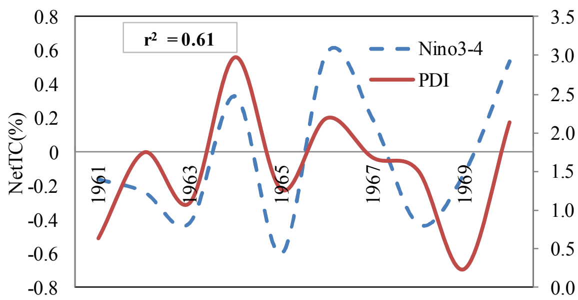

Fig. 8. Correlation between PDI (blue) and Nino 3-4 (red) from 1961 to 1970

We also calculate the NetTC index, finding that this index also tends to increase in the series time from 1961 to 2017 with coefficient a = 0.28 (Fig. 9). The correlation between the NetTC index and SST in the region (0-30°N; 100-180°E) has a positive correlation (Fig. 10, Fig. 11). In general, there is a similar between the NetTC index and SST in this area, especially from 1981 to 2003, this correlation is stronger that means SST in the region (0 - 30°N; 100 - 180°E) increasing related to the increasing of NetTC index in the East Sea (Fig. 12). Considering the two hottest years of 2016 and 2017 with SST in the East Sea, it is approximately 28.9°C, the NetTC index is 126.3 and 170.6% respectively, the number of TC in the East Sea is bigger than the normal, from 17 to 20 number of TC per year. Meanwhile, in the three coldest years, 1972, 1976 and 1992, SST in the East Sea is approximately 28.1°C, NetTC index is smaller, 74.7%, 63 % and 64.2%, respectively. The number of TC in the East Sea in these years is also smaller than the normal, about 7 to 10 number of TC per year.

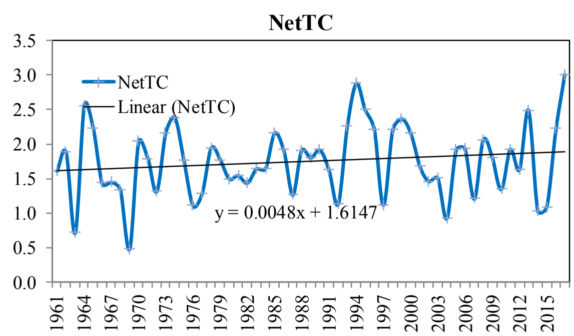

Fig. 9. The NetTC index (blue) and linear (black) in the East Sea from 1961 to 2017

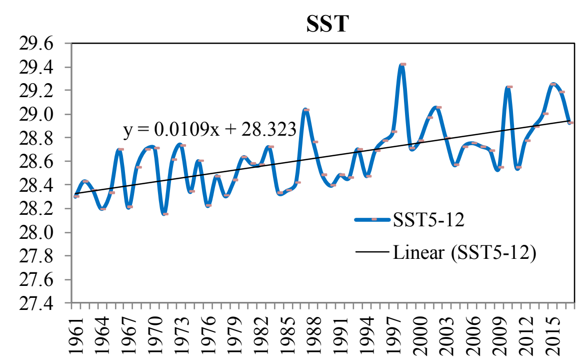

Fig. 10. The SST (red) and linear (black) in the East Sea from 1961 to 2017

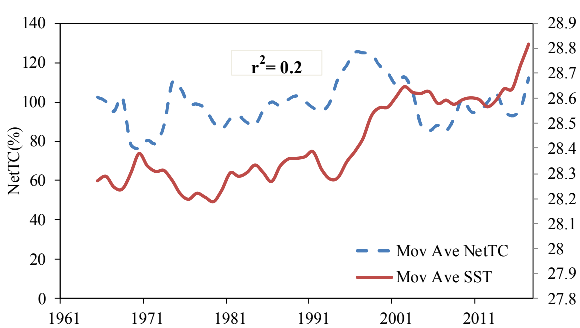

Fig. 11. NetTC index (blue) and SST (red) in the East Sea. The time series have been smoothed using moving average with 3 year to reduce effect of interannual variability and fluctuation on time scales

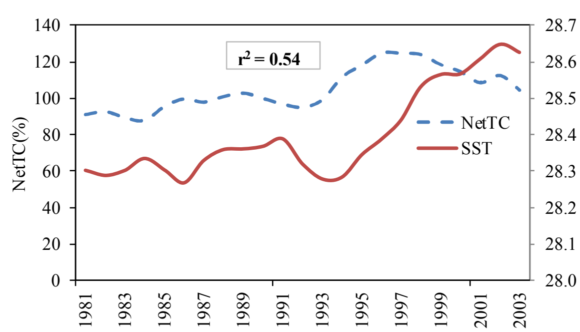

Fig. 12. Correlation between NetTC (blue) and SST (red) from 1981 to 2003

4. Conclusion

In the series time from 1961 to 2017, TC in the East Sea tends to increase slightly. Meanwhile, in contrast, the number of TC landfalling in Vietnam tends to decrease. The number of TC with upper 12 force is biggest, about 40%, following by the activity of tropical depression with 22% and the number of TC with 8-9 force and 10-11 force with 21% and 16% respectively. Frequency by 10 years, the 1991-2000 decade is biggest with average number of TC about 14.5 times per year.

The indicator of PDI depends on three factors: maximum wind speed, lifetime and number of TC. PDI correlates with the Nino3-4 index, but this correlation is weak. Similarly, the correlation beween the NetTC index and SST is positive. In general, indicators related to the changes of TC in the East Sea have correlation with factors related to climate change, but this correlation is not strong and it only shows clearly in extreme years such as in the strong ENSO phase or hottest years.

Acknowledgements

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