Variations of Western North Pacific Tropical Cyclone Activity on Decadal Time Scales and Longer

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Outline

- Number variations
- Intensity variations
- Track variations
- Landfall variations
- Summary
Annual No. of TS & TY in the western North Pacific

Annual number of tropical storms and typhoons

- El Niño
- La Niña

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Annual No. of TC & TY in the western North Pacific

Yumoto and Matsuura (2001)
Relative vorticity and vertical wind shear

Yumoto and Matsuura (2001)
SST Difference

\[(L7385 - H6172)\]

Yumoto and Matsuura (2001)
OLR Difference

Yumoto and Matsuura (2001)
Possible mechanism

Matsuura et al. (2003)
Annual no. of tropical storms and typhoons in the western North Pacific

- El Niño
- La Niña
Correlation between TC number and the 850-200-hPa vertical shear of zonal wind
Difference in TC number between weak and strong vertical wind shear years
Time series of the vertical wind shear index

- El Niño
- La Niña

Active

Inactive

Active

Inactive
Mean Jun-Oct vertical shear of zonal wind

1960-74, active

1975-88, inactive

1998-97, active

1998-2011, inactive
Correlation map between TC number and 500-hPa geopotential height

H500 vs no. of tropical storms
Difference in number of TC formations between the weak and strong subtropical high years
Time series of the subtropical high area index

El Niño

La Niña

Inactive

Active

Inactive

Mean Jun-Oct 5880 gpm lines at 500 hPa

Jun-Oct 500-hPa Geopotential height

1960-74
1975-88
1998-2011
1989-97
Correlation between 850-hPa zonal wind and subtropical high index

850-hPa zonal wind (Jun-Oct) vs SHAI

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Correlation between 850-hPa relative vorticity and subtropical high index

850-hPa relative vorticity (Jun-Oct) vs SHAI
Possible mechanism

Matsuura et al. (2003)
Annual No. of Cat45 in the western North Pacific

The chart shows the annual number of Category 4-5 hurricanes (Cat45) in the western North Pacific from 1960 to 2010. The line graph compares the number of hurricanes to the background climate (mean) and includes data for El Nino and La Nina years, as well as tropical storms (TS) and typhoons (TY) combined (TOTAL). The data highlights periods of higher hurricane activity, particularly from the late 1980s to 2000.
Annual No. of Cat45 in the western North Pacific

- 2-7 year
- 16-32 year
Annual No. of Cat45 in the western North Pacific

- ENSO 2-7 year
- ENSO 16-32 year

NCat45
2-7 year
16-32 year
Annual No. of Cat45 in the western North Pacific

ENSO 16-32 year

NCat45

16-32 year
Wavelet Analysis of Intense Typhoon Occurrence Frequency

- 2-7 yr
- 16-32 yr

Period A1
Period B
Period A2

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Sea-surface Temperature Anomalies
Reconstructed Moist Static Energy (EOF2)

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Vertical Gradient of Saturated Moist Static Energy

(1000 minus 600 hPa)
Precipitation Rate Anomalies
Lower Tropospheric Streamfunction Anomalies
200-hPa minus 850-hPa Zonal Wind Shear

Period A1 minus Period B

May–Nov 200–850 hPa zonal wind shear
(1960–70) − (1971–86)

Period A2 minus Period B

May–Nov 200–850 hPa zonal wind shear
Frequency of occurrence of intense Typhoons

Period A1

Period A2

Period B

Frequency of Occurrence of Intense Typhoons
Difference in the Frequency of Occurrence of Intense Typhoons

Period A1 minus Period B

Frequency of occurrence of intense Ty (x10) (1960–70) minus (1971–86)

Period A2 minus Period B

Frequency of occurrence of intense Ty (x10) (1987–97) minus (1971–86)

Blue shading: 95%  Green shading: 90%
Difference in Typhoon Passage Frequency (JJAS)

1980-2001 minus 1951-1979 (%)

Ho et al. (2004, J Climate)
JJAS 500-hPa Height Anomaly (20-25°N, 125-140°E)

Ho et al. (2004, J Climate)
Difference in Typhoon Passage Frequency (JJASO) 1965-83 minus 1984-2003

Wu and Wang (2005, GRL)
EOF1 of 10-year-filtered TC occurrence
EOF2 of 10-year-filtered TC occurrence

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 EOF3 of 10-year-filtered TC occurrence

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Time series of EOFs of 10-year-filtered TC occurrence

EOF1 (25.8%)

EOF2 (18.0%)

EOF3 (15.2%)
Time series of EOFs of 10-year-filtered 500-hPa Heights and Zonal Winds

EOF1 of 500-hPa zonal winds ($r = 0.80$)

EOF2 of 500-hPa heights ($r = 0.58$)

Pattern 1
1977-88 Pattern 1

EOF2 of 500-hPa Heights

EOF1 of 500-hPa zonal winds
Time Series of EOFs of Track Patterns & PDO

The graph shows the time series ofEOFs of track patterns and PDO from 1964 to 1999. The x-axis represents the years, and the y-axis represents the TS occurrence pattern and PDO. The graph includes plots for different EOFs, with PC1, PC2, and PC3 represented by different line styles. The PDO is also plotted on the right y-axis. The shading indicates periods of significant PDO events.
No. of surface pressure observations/month

ICOADS 1910–1940
Typhoon numbers of the target area over the Western North Pacific
Tropical Cyclone Variations and Trends
Variations of Landfall in Each Area at Various Oscillation Periods

**South Asia**

**East China**

**Japan/Korea**
No. of Landfalling TCs in the Philippines

1902–2005 TS Philippines landfall
No. of Landfalling TCs in South China

![Graph showing the number of landfalling tropical cyclones in South China over time from 1500 to 1900. The graph displays a trend with fluctuations and increases in the number of landfalling cyclones over the years.](image-url)
No. of Landfalling TCs in East China
### No. of Landfalling TCs in East China

<table>
<thead>
<tr>
<th>PDO status</th>
<th>Number of years</th>
<th>Mean number of typhoons</th>
<th>Standard deviation</th>
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<tr>
<td>EN</td>
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<td></td>
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<tr>
<td>PDO+</td>
<td>34</td>
<td>3.41</td>
<td>1.62</td>
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<tr>
<td>PDO−</td>
<td>55</td>
<td>3.18</td>
<td>1.47</td>
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<td>$t = 0.68$ (not significant)</td>
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<tr>
<td>LN</td>
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<tr>
<td>PDO+</td>
<td>16</td>
<td>2.38</td>
<td>1.46</td>
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<tr>
<td>PDO−</td>
<td>31</td>
<td>3.36</td>
<td>1.02</td>
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<tr>
<td></td>
<td>$t = 2.41$ (significant at 99%)</td>
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</table>
Summary

- Variations of TC activity on decadal time scales or longer in the western North Pacific are large.

- Dynamic factors (horizontal and vertical shear), which can be forced by remote SST variations, such as ENSO and PDO, are mainly responsible for the observed TC variability in these regions.