Interannual and Interdecadal Variations of Tropical Cyclone Activity in the South China Sea

Andy Zung-Ching GOH and Johnny C. L. CHAN

Guy Carpenter Asia-Pacific Climate Impact Centre

City University of Hong Kong

December 15, 2008
Introduction

• Tropical Cyclones (TCs)
  – Storms with wind speeds > 40 km/h
  – Typical occurrences: May to October
  – Areas of interest:
    • Western North Pacific (WNP) (West of 180°)
    • South China Sea (SCS) (0° to 25° N, 100° to 120° E)

• TCs in WNP
  – Occurrences affected by El-Niño Southern Oscillation (ENSO)
  – Interdecadal and interannual variations observed
Introduction

• Factors Affecting Cyclogenesis (Gray 1979)*
  – 850mb Vorticity
  – Vertical Shear of Horizontal Wind
  – Sea Surface Temperature
  – Coriolis Parameter
  – Mid-level Moisture
  – Low- to Mid-level Moist Instability

Introduction

• Factors Affecting Movement
  – 500mb Height Gradient
  – 500mb Wind

• TCs inside SCS
  – Formed in SCS
    • Depends on the conditions in SCS?
  – Entered SCS
    • Formed in the WNP and then moved in?
Objectives

• To study the variations in number of TCs inside the SCS;
• To determine the factors leading to changes in the frequency of TC occurrences in the SCS;
• To decide if and how large-scale atmospheric phenomena can have an effect on the factors affecting TC behaviour
TC Data

• Hong Kong Observatory TC data from 1946 to 2005 (60 years)
• Only those after 1965 used (41 years)
• Only those with at least tropical storm strength (max winds >65 km/h) used
• Season divided into 2 halves
  – 1st: May to August
  – 2nd: September to December
• TCs can enter SCS from WNP (ENT) or formed inside SCS (FORM)
Flow Pattern Data

- NCEP Reanalysis data starting from 1965
- Parameters studied:
  - 850-hPa vorticity
  - 850-hPa height
  - 200-hPa – 850-hPa wind shear
  - 200-hPa divergence
  - 500-hPa height
  - Moist static energy
  - 500-hPa u-wind
- May to December, divided into 2 seasons
- Anomalies, EOF calculated
### Wavelet Analysis

<table>
<thead>
<tr>
<th>ENT</th>
<th>EARLY</th>
<th>LATE</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Early Wavelet Analysis" /></td>
<td><img src="image2.png" alt="Late Wavelet Analysis" /></td>
<td></td>
</tr>
<tr>
<td>FORM</td>
<td><img src="image3.png" alt="Early Wavelet Analysis" /></td>
<td><img src="image4.png" alt="Late Wavelet Analysis" /></td>
</tr>
</tbody>
</table>
TC Trends (per 100 years)

**TC Trends (per 100 years)**

<table>
<thead>
<tr>
<th>WHOLE</th>
<th>EARLY</th>
<th>LATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOT</td>
<td>-5.7  (95%)</td>
<td>-2.4 (95%)</td>
</tr>
<tr>
<td>ENT</td>
<td>-5.2  (95%)</td>
<td>-2.6 (95%)</td>
</tr>
<tr>
<td>FORM</td>
<td>-0.2  (not sig)</td>
<td>+0.2 (not sig)</td>
</tr>
</tbody>
</table>
### Effect of ENSO

<table>
<thead>
<tr>
<th>Above/Below</th>
<th>EN (12 events)</th>
<th>LN (10 events)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Whole</td>
<td>Early</td>
</tr>
<tr>
<td>TOT</td>
<td>1/5</td>
<td>2/1</td>
</tr>
<tr>
<td>ENT</td>
<td>3/6</td>
<td>3/4</td>
</tr>
<tr>
<td>FORM</td>
<td>5/4</td>
<td>5/3</td>
</tr>
</tbody>
</table>

- Effect more prominent in late season
  - Due to ENSO peaking in winter
- Effect on ENT apparently more significant than on FORM
## Effect of PDO

<table>
<thead>
<tr>
<th>Above/Below</th>
<th>PDO+ (16 events)</th>
<th>PDO- (13 events)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Whole</td>
<td>Early</td>
</tr>
<tr>
<td>TOT</td>
<td>4/7</td>
<td>3/4</td>
</tr>
<tr>
<td>ENT</td>
<td>4/5</td>
<td>6/4</td>
</tr>
<tr>
<td>FORM</td>
<td>4/6</td>
<td>3/6</td>
</tr>
</tbody>
</table>

- Effect more prominent in late season
  - Due to PDO peaking in winter
- Effect of PDO similar to that of ENSO
  - Due to possible forcing of PDO by ENSO forcing?
## Stepwise Linear Regression

<table>
<thead>
<tr>
<th>Factor</th>
<th>% Var</th>
<th>Coeff</th>
<th>Factor</th>
<th>% Var</th>
<th>Coeff</th>
</tr>
</thead>
<tbody>
<tr>
<td>500U1</td>
<td>26.72</td>
<td>+1.422</td>
<td>MSE2</td>
<td>13.04</td>
<td>+0.366</td>
</tr>
<tr>
<td>500H1</td>
<td>55.09</td>
<td>+1.333</td>
<td>500U1</td>
<td>26.72</td>
<td>+0.315</td>
</tr>
<tr>
<td>MSE3</td>
<td>10.37</td>
<td>+0.349</td>
<td>MSE1</td>
<td>35.18</td>
<td>+0.193</td>
</tr>
<tr>
<td>VOR2</td>
<td>13.98</td>
<td>+0.301</td>
<td>DIV1</td>
<td>32.17</td>
<td>-0.047</td>
</tr>
<tr>
<td>DIV3</td>
<td>11.03</td>
<td>+0.179</td>
<td>SHR3</td>
<td>13.16</td>
<td>-0.130</td>
</tr>
<tr>
<td>500H3</td>
<td>9.65</td>
<td>-0.448</td>
<td>DIV2</td>
<td>17.74</td>
<td>-0.188</td>
</tr>
<tr>
<td>500H2</td>
<td>19.22</td>
<td>-0.539</td>
<td>DIV3</td>
<td>11.03</td>
<td>-0.287</td>
</tr>
<tr>
<td>VOR1</td>
<td>17.08</td>
<td>-0.575</td>
<td>500U2</td>
<td>19.76</td>
<td>-0.387</td>
</tr>
</tbody>
</table>

- 500U: 500-hPa zonal wind, DIV: 200-hPa divergence, 500H: 500-hPa geopotential height, 850H: 850-hPa geopotential height, MSE: moist static energy, SHR: 200-850-hPa shear, and VOR: 850-hPa vorticity. The last number indicates the EOF, 1 for the first EOF, 2 for the second etc.
### FORM in late season

<table>
<thead>
<tr>
<th>FORM</th>
<th>EN (12 events)</th>
<th>LN (10 events)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late</td>
<td>Above: 2, Below: 1</td>
<td>Above: 5, Below: 1</td>
</tr>
</tbody>
</table>

**EN Composites**

- **500U1 (ms⁻¹)**

**LN Composites**

- **DIV3 (×10⁻⁶ s⁻¹)**
FORM in late season

EN Composites

LN Composites

MSE1 \( (\times 10^6 \text{ Wm}^{-2}) \)

SHR3 (ms\(^{-1}\))
# FORM in late season

<table>
<thead>
<tr>
<th></th>
<th>PDO+ (16 events)</th>
<th>PDO- (13 events)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late</td>
<td>Above: 2, Below: 3</td>
<td>Above: 4, Below: 0</td>
</tr>
</tbody>
</table>

**PDO+ Composites**

500U1 (ms\(^{-1}\))

**PDO- Composites**

DIV2 (\(x10^{-6} \text{ s}^{-1}\))
FORM in late season

PDO+ Composites

PDO- Composites

MSE1 ($\times 10^6$ Wm$^{-2}$)

MSE2 ($\times 10^6$ Wm$^{-2}$)
FORM in late season

PDO+ Composites

PDO- Composites

SHR3 (ms⁻¹)
ENT in late season

<table>
<thead>
<tr>
<th>ENT</th>
<th>EN (12 events)</th>
<th>LN (10 events)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late</td>
<td>Above: 2, Below: 8</td>
<td>Above: 5, Below: 1</td>
</tr>
</tbody>
</table>

**EN Composites**

- **500U1 (ms⁻¹)**

**LN Composites**

- **500H1 (gpm)**
ENT in late season

EN Composites

LN Composites

500H2 (gpm)

500H3 (gpm)
ENT in late season

DIV3 ($\times 10^{-6}$ s$^{-1}$)

MSE3 ($\times 10^6$ Wm$^{-2}$)

EN Composites

LN Composites
ENT in late season

VOR2 ($10^{-6}$ s$^{-1}$)
**ENT in late season**

<table>
<thead>
<tr>
<th>ENT</th>
<th>PDO+ (16 events)</th>
<th>PDO- (13 events)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late</td>
<td>Above: 5, Below: 10</td>
<td>Above: 5, Below: 1</td>
</tr>
</tbody>
</table>

**PDO+ Composites**

500U1 (ms⁻¹)

500H2 (gpm)

**PDO- Composites**

500U1 (ms⁻¹)

500H2 (gpm)
ENT in late season

PDO+ Composites

PDO- Composites

500H3 (gpm)

MSE3 ($\times 10^6$ Wm$^{-2}$)
ENT in late season

PDO+ Composites

PDO- Composites

VOR1 \(\times 10^{-6} \text{ s}^{-1}\)

VOR2 \(\times 10^{-6} \text{ s}^{-1}\)
Summary

• SCS TCs show interannual and interdecadal variations
• ENT: Decreasing trend, FORM: no trend
• ENT:
  – EN, PDO+: Below-normal
    • WNP formation inhibited, TCs recurve
  – LN, PDO-: Above-normal
    • WNP formation, easterly flow prevail
Summary

• FORM:
  – **EN** vs **LN**:
    • Below-normal vs Above-normal
    • SCS formation inhibited vs preferred
    • Location & strength of monsoon trough
      → North-South discrepancy
  – **PDO+** vs **PDO-**:
    • Below-normal vs Above-normal
    • Difference more due to dynamical factors
    • Monsoon trough virtually constant
      → No North-South discrepancy
Conclusion

ENSO and PDO

Variations in factors affecting TC activities

Interannual and interdecadal variations in SCS TCs
THANK YOU