Multi-model projection of tropical cyclogenesis over the western North Pacific using CMIP3 archive

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Outline

1. Introduction and key question.
2. Selection of models
3. Multi-model projection by counting the TC-like disturbances
4. Discussion on reasons for the projections obtained
5. Summary
Introduction

- How would characteristics of tropical cyclone (TC) change due to the global warming?
- Most recent studies projected decrease trends in GLOBAL number of TC. (e.g. Sugi et al. 2002; McDonald et al. 2005; Oouchi et al. 2006; Bengtsson et al. 2007; Gualdi et al. 2008).
- How about REGIONAL trends?
  → Almost no consensus.
- Multi-model based approach can provide projections that are common among climate models and reduce uncertainties related to model selection.
Questions

● How would cyclogenesis frequency over the western North Pacific basin (0°–40°N, 100°E–180°) change due to the global warming?

  ➢ We perform multi-model based approach by analyzing CMIP3 archives (output of climate model experiment contributing to IPCC AR4).

  ➢ Advantage: Large number of samples (multi model, experiments, long-term simulation).

  ➢ Disadvantage: Horizontal resolution of atmospheric model is relatively coarse.

● What are mechanisms for the projected trends?

  ➢ We focus on local environmental conditions and activity of pre-TC disturbances.

  ➢ Are genesis potential indices applicable to this problem?
Definition of TC-like disturbance

(1) 850-hPa relative vorticity ($\zeta_{850}$) local maximum (=TC center) $\geq \zeta_t$.
   (cyclonic vortex)

(2) (300-hPa temperature ($T_{300}$) at the center)–(environmental $T_{300}$) $\geq T_t$.
   (warm core)

(3) Conditions 1 & 2 are satisfied at least 2 time steps.

(4) Genesis point is over the ocean.

(5) At genesis time, maximum wind speed is greater at the 850-hPa level than at the 300-hPa level.
   (exclusion of extra-tropical cyclones)

Thresholds ($\zeta_t$, $T_t$) are determined independently for each model.

➢ Try to adjust meridional distribution of annual cyclogenesis frequency.
Simulated annual cyclogenesis (20C3M)

- Five models reproduce maxima over the South China Sea and east of Philippines, and relatively low cyclogenesis east of 160E.

Unit: Number per 5°Lat. × 5°Lon. area in 10 years.
20C3M and SRES

I compare the cyclogenesis frequency between 20C3M and average of SRES experiments.

- 20C climate simulation (20C3M): 40-yr length.
- SRES A1B, A2, and B1 experiments: 80-160-yr length.

<table>
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<th>Model name</th>
<th>20C3M</th>
<th>SRESA1B</th>
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Projected trends in annual cyclogenesis frequency

**ALL 5 models project**

- increase trends over central North Pacific (CNP) (during July–November), and
- decrease trends over the South China Sea (SCS) and areas just to the east of Philippines.

Yellow (blue) tone: all 5 models project increase (decrease) trends.

Time series in (5–20°N, 150°E–180°)

GW condition

20C3M
Environmental conditions

- Environmental conditions favorable for cyclogenesis include:
  - Positive relative vorticity in the lower troposphere
  - Weak vertical shear of horizontal wind
  - High Potential Intensity (PI) [Bister and Emanuel 2002]
    - Index of SST and atmospheric stability
  - High relative humidity in the middle troposphere

\[
\text{Emanuel and Nolan (2004) Genesis Potential (GP)}
\]

\[
GP = \left| 10^5 \eta_{850} \right|^{1.5} \times \frac{1}{\left(1 + 0.1|u_{850} - u_{200}|\right)^2} \times \left(\frac{\text{PI}}{70}\right)^3 \times \left(\frac{H_{700}}{50}\right)^3
\]

where \( \eta_{850} \): 850-hPa absolute vorticity, \(|u_{850} - u_{200}|\): vertical wind shear
\( \text{PI} \): potential intensity, \( H_{700} \): 700-hPa relative humidity

GP definition was tuned with reference to the current climate.

\( \Rightarrow \) Is GP applicable to global warming problem?
Models reasonably simulate observed environment:

- monsoon trough and associated weak shear area.
- Higher PI and humidity in the tropical western North Pacific and South China Sea.

Following SST distribution

GP is largest to the east of Philippines.
Projected change in environmental fields

- Trends in dynamic conditions indicate eastward extension of the monsoon trough.
- Pattern of GP trend is completely different from that of cyclogenesis frequency.
- Vorticity, PI, and humidity would become more favorable for cyclogenesis over CNP.
  ➔ We will discuss which of the trends is more important for increase projection of cyclogenesis by analogy with the observed interannual variability.

Yellow (blue) tones: At least 4 models project that condition would become more (less) favorable for cyclogenesis.
Interannual variability of environmental condition

- Dynamic conditions (vorticity and shear) exhibit similar pattern to the projected one.
- Potential intensity and humidity do not exhibit significant correlation over CNP.
  - Since they are probably favorable for cyclogenesis every year, their slight changes due to the GW may not play a role in TC increase trend.
- Note: The pattern shown is quite similar to the ENSO-related one.
Cyclogenesis is projected to decrease. Environmental conditions would become more favorable for cyclogenesis or exhibit no significant changes.

We try to discuss the decrease projection in terms of the activity of tropical depression-type disturbances (TDDs), one of the pre-TC disturbances that can later be developed into TC.
Activity in tropical depression-type disturbances (TDDs) that reach the South China Sea (SCS)

- Active band of TDD orienting NW-SE direction is realistically simulated.
- The activity would decrease significantly over the SCS and to its southeast.
- Observed interannual variability exhibits similar pattern, implying that weakening trends of TDD activity may play a role in decrease trends in cyclogenesis over the SCS.
Summary

- We analyze output of CMIP3 climate model experiments to perform multi-model projection of tropical cyclogenesis over the western North Pacific.
- Five CMIP3 models realistically simulate horizontal distribution in cyclogenesis under the current climate.
- All of the five models project increase trends of cyclogenesis over the central North Pacific and decrease trends over the South China Sea and regions east of the Philippines.
- The former increase trends are primarily attributable to projected eastward extension and intensification of the monsoon trough.
- The later decrease trends may be associated with weakening trends in activity of tropical depression-type disturbances.
- Genesis potential proposed in previous studies would increase all over the Western North Pacific Basin south of 25°N.

Thank you for your attention.