An improvement of Pacific Decadal Oscillation pattern simulation in Climate models (CMIP5)

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Background of study

Motivation and Objectives

Data and Method

Result
  ✓ PDO pattern simulation
  ✓ ENSO-PDO teleconnection pattern simulation

Discussion

Conclusion and Summary
Pacific Decadal Oscillation (PDO): A dominant SST variability on a decadal timescales in the North Pacific
Mantua and Hare 2002

Impacts of PDO on North Pacific
1) Marine ecosystems
2) Oceanic/Atmospheric variability

Reproducibility of Natural variability in climate models is important to evaluate and improve model performance.
Oshima and Tanimoto 2009

"we examine how well patterns of the PDO match between the observations and simulations by calculating a metric of the patterns with CMIP3 models"

→ the models with the high PDO metric reproduce the linkage between the central North Pacific and the tropical Pacific.

Bellenger et al. 2013

How are the PDO simulations from CMIP3 to CMIP5?
To investigate factors affecting the PDO simulation in CGCM, following questions should be answered.

Q.1: Do CGCMs can simulate tropical convection with the precipitation responding sensitively to tropical SST?

Q.2: Do CGCMs can correctly simulate ENSO?

Q.3: Do CGCMs can simulate appropriate ENSO-PDO teleconnection?
   - planetary waves from tropics to extratropics: $\Phi_{500}$, $U_{wnd_{850}}$

Objectives

1) To evaluate PDO pattern simulations in CMIP3 and CMIP5 CGCMs: Is it improved in CMIP5?

2) To study the relationship of pattern simulation performance between PDO and ENSO-PDO teleconnection in CGCM
Data and Method

- **Data**
  - CMIP3 20C3M exp. (21 models)
  - CMIP5 Historical exp. (20 models)

- **Assessment Method**
  - Taylor diagram and Regression analysis with data re-gridded on 2.5° x 2.5°

<table>
<thead>
<tr>
<th>Simulation</th>
<th>Variable</th>
<th>Period</th>
<th>Observational data</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDO and ENSO</td>
<td>SST</td>
<td>1900~1999 (DJF)</td>
<td>ERSST</td>
</tr>
<tr>
<td>Precipitation</td>
<td>Precipitation</td>
<td>1979~1999 (DJF)</td>
<td>GPCP</td>
</tr>
<tr>
<td>sensitivity to SST</td>
<td>SST</td>
<td></td>
<td></td>
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<tr>
<td>(NINO3.4)</td>
<td></td>
<td></td>
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<tr>
<td>Φ₅₀₀ composite for ENSO</td>
<td>Geopotential height</td>
<td>1948~1999 (DJF)</td>
<td>NCEP &amp; NCAR</td>
</tr>
<tr>
<td>U₈₅₀ composite for ENSO</td>
<td>Zonal wind</td>
<td>1949~1999 (DJF)</td>
<td>NCEP &amp; NCAR</td>
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</table>
Part 1. PDO pattern

Part 2. ENSO-PDO teleconnection

Alexander et al. 2002
PDO patterns in CMIP3 and CMIP5

Rs : Spatial correlation coefficient
RMS : Root Mean Square
σ : Amplitude of variability

<table>
<thead>
<tr>
<th>RMS</th>
<th>Rs</th>
<th>Pattern correlation ave.</th>
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<tbody>
<tr>
<td>CMIP3</td>
<td>0.66</td>
<td>0.66 → 0.83</td>
</tr>
<tr>
<td>CMIP5</td>
<td>0.83</td>
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MME : Multi-model ensemble mean

MME PDO pattern
Result

Part 1. PDO pattern

Part 2. ENSO-PDO teleconnection

Precipitation sensitivity to tropical SST

Alexander et al. 2002
Q.1: Is the precipitation sensitivity to tropical SST improved? **Yes**

- **Observation**
  - Equation: \( y = 2.36x - 60.5 \)
  - Correlation coefficient: 0.84

- **CMIP3**
  - Equation: \( y = 0.75x - 17 \)
  - Correlation coefficient: 0.55

- **CMIP5**
  - Equation: \( y = 1.41x - 34.5 \)
  - Correlation coefficient: 0.79

\( \diamond \) Precipitation sensitivity to tropical SST
Part 1. PDO pattern

Part 2. ENSO-PDO teleconnection

<Simulated ENSO pattern>
ENSO pattern simulation in CMIP3 and CMIP5

Q.2: Is simulated ENSO pattern improved? Yes

Pattern correlation ave.

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<tr>
<td></td>
<td>0.82</td>
<td>0.87</td>
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MME ENSO pattern

- **Obs**
- **CMIP3**
- **CMIP5**

**Spatial Correlation**

- Standard Deviation
- **CMIP3**
- **CMIP5**
- ERSST

Graph showing observed and simulated ENSO patterns with correlation values.
Part 1. PDO pattern

Part 2. ENSO-PDO teleconnection

<Simulated planetary waves>
Q.3: Is simulated pattern of ENSO-PDO teleconnection improved? Yes

 Composite ENSO-PDO teleconnections pattern simulation in CMIP3 and CMIP5

**Φ₅₀₀ Comp. for El Nino years**

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**Uwnd₈₅₀ Comp. for El Nino years**

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<td>0.47</td>
<td>0.67</td>
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<td>0.21</td>
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## Discussion

Is there relationship of model performances between PDO and ENSO-PDO teleconnections in Climate models?

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Correlation (CMIP3) = 0.63 (without outliers, 0.68)

Correlation (CMIP5) = 0.64 (without outliers, 0.74)

Correlation (CMIP3+CMIP5) = 0.64

Correlation (CMIP3+CMIP5) = 0.59

Correlation CMIP5 = 0.63 (without outliers, 0.65)
Improvement of PDO pattern simulation has been found from CMIP3 to CMIP5.

It is considered that this improvement of PDO pattern simulations in CMIP5 is deeply related to the enhanced pattern simulation of ENSO-PDO teleconnections.

- More appropriate locations and formation of planetary waves and stronger westerly wind related to cooling SST (positive PDO) by in North Pacific in CMIP5.
- Enhanced amplitude and spatial patterns of ENSO in CMIP5.
- More realistic linear relationship between SST and precipitation in CMIP5 (improved processes of convection/precipitation).

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Thank you : D