Developing Early 21st Century Pacific Decadal Oscillation Projections

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Objectives

The large-scale modes of variability that impact western Canada are: PDO, ENSO and NAO (AO)

1. Identify GCMs that are capable of reproducing large scale teleconnection patterns documented during the 20\textsuperscript{th} century
   • Comparing spatial/temporal patterns

2. Confirm the pre-industrial GCM control experiments (unforced experiments used to assess model stability and natural climate variability) are capturing the low frequency PDO variability (>30yr cycles) not visible with the short 20\textsuperscript{th} century runs (~110 yrs)

3. Derive early 21\textsuperscript{st} century PDO projections: A1B, A2 and B1 SRES
• Defined by EOF statistical analysis of N Pacific Ocean monthly residual SSTs for the 1900-93 using observed SSTs (HADSST2). (Mantau et al., 1997)
  • leading eigenvector - spatial pattern
  • leading principal component - time series

• Post 1993 PDO index derived by projecting the monthly residual SSTs onto the leading eigenvector of the 1900-93 SSTs

• Calculate the annual Nov-March PDO index

• Concerns with the early PDO record and missing SST data
NAO?

Controls the strength and direction of westerly winds and storm tracks across the North Atlantic (AO)

Decadal time scales

SOI?

Southern Oscillation Index (ENSO): annual, inter-annual variability in the tropical region of the Pacific Ocean—the physical basis of the phenomenon is relatively well understood and predicted months in advance.

PDO & ENSO have similar spatial and temperature patterns (+PDO/-SOI) = dry conditions
Stoner et al., (2009) and Wang and Overland (2009)
IPCC AR4: 3rd CMIP (23 GCMs available)

Reduce uncertainties of individual model formulation by conducting multi-model analysis
Table 1. List of chosen coupled atmosphere-ocean models which archived the required fields, their details, number of available 21st century runs per scenario, and length of the pre-industrial control runs (run 1 used).

<table>
<thead>
<tr>
<th></th>
<th>IPCC4 Model ID</th>
<th>Country</th>
<th>Atmosphere resolution</th>
<th>Ocean resolution</th>
<th>Number 21st century runs</th>
<th>Control run length (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CGCM3.1(T63)</td>
<td>Canada</td>
<td>2.8°x2.8° L31</td>
<td>1.4°x0.9° L29</td>
<td>1</td>
<td>1</td>
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<tr>
<td>2</td>
<td>GDFL-CM2.1</td>
<td>USA</td>
<td>2.5°x2.0° L24</td>
<td>1.0°x1.0° L50</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>MIROC3.2(medres)</td>
<td>Japan</td>
<td>2.8°x2.8° L20</td>
<td>(0.5-1.4°) x1.4° L43</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>MRI-CGCM2.3.2</td>
<td>Japan</td>
<td>2.8°x2.8° L31</td>
<td>(0.5-2.5°) x2.0° L23</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>NCAR-PCM</td>
<td>USA</td>
<td>2.8°x2.8° L18</td>
<td>(0.5-0.7°) x0.7° L32</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>UKMO-HadCM3</td>
<td>UK</td>
<td>3.75°x2.5° L15</td>
<td>1.25°x1.25° L20</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>UKMO-HadGem1</td>
<td>UK</td>
<td>1.875°x1.25° L38</td>
<td>(0.33-1.0°) x1.0° L40</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
Comparing EOF1: Observed and GCM 1900-93

Regridded each GCM to match the HADSST2 5x5° grid cells

$r > 0.7$
Compared the temporal variability of 20th century simulations to observed record to validate GCMs through MTM spectral analysis.
• Project 2000-2050 residual SST anomalies onto the leading eigenvector (EOF) from 1900-93 observed HadSST2 data.

• Presume that the same mechanism will continue to operate in the early 21st century under global warming, as it did in the 20th century during the early stage of anthropogenic forced increases in surface air temperatures and SSTs [Kaplan et al., 2000]
Seems uncertain to assume that this PDO mechanism will continue to operate as during the 20th century once the global warming trend surpasses the natural North Pacific variability ~ 2050s. Overland and Wang [2007] and Wang et al., [2010]

Table 2. 20th century observed mean Pacific Decadal Oscillation (PDO) index and multi-model mean PDO for the 20th century simulations and for the early 21st century projections under the B1, A1B and A2 emission scenarios. The observed PDO was calculated from HadSST2 data as described in the text.

<table>
<thead>
<tr>
<th>Emission scenario</th>
<th>PDO</th>
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<tbody>
<tr>
<td></td>
<td>B1</td>
</tr>
<tr>
<td>Observed mean 1900-1999</td>
<td>0.168</td>
</tr>
<tr>
<td>Multi-model 1900-1999 simulation mean*</td>
<td>-0.110</td>
</tr>
<tr>
<td>Multi-model 2000-2050 mean</td>
<td>0.104</td>
</tr>
</tbody>
</table>

*HadGEM1 had no B1 run, and CGCM3.1(T63) had no A2 run, therefore their simulation runs were dropped from the multi-model simulation mean.
HadCM3, CGCM3 (T63) and MIROC3.2 (medres) ranked as the top three models

Future multi-models simulations suggest increased number of months under positive PDO conditions

This shift towards more positive PDO-like conditions in the North Pacific Basin will be superimposed upon the general global warming trend
We thank N.J. Mantua for his help with PDO computational details.