Present and future of the North Pacific simulated by a high resolution coupled atmosphere-ocean model

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- National Institute for Environmental Studies (NIES)
- Frontier Research Center for Global Change (FRCGC)

for global warming projections by using a high resolution atmosphere-ocean model, under the government-funded “Project for Sustainable Coexistence of Human, Nature and the Earth.”
## Coupled GCM

**MIROC (Model for Interdisciplinary Research On Climate) version 3.2**

<table>
<thead>
<tr>
<th>Component</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmosphere</td>
<td>CCSR/NIES/FRCGC AGCM 5.7</td>
</tr>
<tr>
<td>Ocean</td>
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## Coupled GCM

**MIROC (Model for Interdisciplinary Research On Climate) version 3.2**

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<tr>
<th>Component</th>
<th>Resolution</th>
</tr>
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<tbody>
<tr>
<td><strong>Atmosphere:</strong> CCSR/NIES/FRCGC AGCM 5.7</td>
<td>T106 (~1.1°) 50 levels</td>
</tr>
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<td><strong>Ocean:</strong> CCSR Ocean Component Model 3.4</td>
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</tr>
<tr>
<td><strong>Land:</strong> MATSIRO</td>
<td>~0.56°</td>
</tr>
<tr>
<td><strong>River:</strong> TRIP</td>
<td>0.5°</td>
</tr>
<tr>
<td><strong>Sea ice:</strong> dynamic (EVP)-thermodynamic (0-layer)</td>
<td>same as ocean</td>
</tr>
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</table>
Coupled GCM

Resolution dependence of Kuroshio separation
(sea surface height snapshot)

1x1 deg

1/3x1/3 deg

1/4x1/6 deg
**Coupled GCM**

**MIROC (Model for Interdisciplinary Research On Climate) version 3.2**

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<th>High</th>
<th>Medium</th>
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<tbody>
<tr>
<td><strong>Atmosphere:</strong></td>
<td>T106 (~1.1°) 50 levels</td>
<td>T42 (~2.8°) 20 levels</td>
</tr>
<tr>
<td><strong>Ocean:</strong></td>
<td>~0.28°x0.19° 47 levels</td>
<td>~1.4°x0.5°-1.4° 43 levels</td>
</tr>
<tr>
<td><strong>Land:</strong></td>
<td>~0.56°</td>
<td>~2.8°</td>
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Experiments

Runs for IPCC AR4 and CMIP Coordinated Ex.

1% / yr CO₂ Incr. (Coupled)

CO₂ Increase 1% / year

Spin-up

Control

20th Century

Scenario Runs (Coupled)

A2

A1B

B1

Year 2000 Fix

2100

Year 2100 Fix

B1 Year 2100 Fix

A1B Year 2100 Fix

4xCO₂ Fix

2xCO₂ Fix

High and Medium

Medium only

1850/1900

2000

2100

2200

2300

0 70 100 140 150 220 290

1%/yr CO₂ Incr. (Coupled)
Overall performance of the model

Biases in annual-mean SST of the control run

Hi-CGCM - Obs.

Medium-res.

Mid-CGCM - Obs.

High-res.
Overall performance of the model

Annual mean SSS

High-res. CONTROL

WOA01

Medium-res. CONTROL
Overall performance of the model

Salinity along 180E (NPIW)

High-res.

Medium-res.
Overall performance of the model

Equatorial thermocline

High-res.

Observed

Medium-res.
Surface Currents for the Present Climate

Surface currents in the North Pacific

Tomczak and Godfrey (2002)
Surface Currents for the Present Climate

Kuroshio and Oyashio: High-res. 100m velocity
Surface Currents for the Present Climate

Kuroshio and Oyashio: Medium-res. 100m velocity

Annual-mean surface currents: Medium-res. CONTROL
Surface Currents for the Present Climate

Hawaiian Lee Counter Current

SST and surface currents

Hawaii

SST anomaly from 5°-width meridional average and surface currents

Sakamoto et al. (2004)
Surface Currents for the Present Climate

Hawaiian Lee Counter Current

Local dipole wind-curl in the Hawaiian lee
→ Thermocline shoaling to the north
→ Westward propagation of the thermocline slope by Rossby waves

Xie et al. (2001)
Surface Currents for the Present Climate

Hawaiian Lee Counter Current

Local dipole wind-curl due to an orographic effect of the Hawaiian lee under the trades → Thermocline shoals to the north → Westward propagation of the thermocline slope by Rossby waves (Xie et al., 2001)
Surface Currents for the Present Climate

Hawaiian Lee Counter Current

with Hawaii

SST anomaly and winds

without Hawaii

Ocean surface currents

(a) SST and wind vectors

(b) Current vectors (34-m depth)
Surface Currents for the Present Climate

Equatorial currents and Mindanao Dome

North Equatorial Current
North Equatorial Counter Current
New Guinea Coastal Current

Mindanao Current

Suzuki et al. (2005)
Surface Currents for the Present Climate

Equatorial currents and Mindanao Dome
Surface Currents for the Present Climate

Seasonal cycle of the Mindanao Dome

Jan-Feb-Mar  Apr-May-Jun

Jul-Aug-Sep  Oct-Nov-Dec
Surface Currents for the Present Climate

Seasonal cycle of the Mindanao Dome
- Wintertime generation by local winds (Asian winter monsoon)
- Decay by westward propagation of downwelling Rossby waves excited by the northeasterly trade winds farther east (~160E) in winter
- The downwelling Rossby waves are associated with wind stress curl changes accompanied by meridional migration of the ITCZ

(Masumoto and Yamagata, 1991; Tozuka et al., 2002)
Surface Currents for the Present Climate

Sea surface height variability (standard dev.)
Global Warming Climate

Global-mean surface air temperature change

![Graph showing 20C3M & SRES runs and CCSR/NIES/FRCGC data with thick curves for Hi-CGCM and thin curves for Mid-CGCM, with SRES A2, SRES A1B, and SRES B1 paths. The graph includes the 1961-1990 mean and the Commit level.]
Global Warming Climate

Surface air temperature change for A1B scenario
Global Warming Climate

Pacific SST change for A1B scenario
Global Warming Climate

Kuroshio: 100 yr average of the control case
Global Warming Climate

Kuroshio: (2071-2100 of A1B) - (1971-2000)

Sakamoto et al. (2005)

+30 cm/s
Global Warming Climate

Surface currents: (2071-2100 of A1B) - (1971-2000)

Sakamoto et al. (2005)
Global Warming Climate

Sverdrup transport

1971-2000

2071-2100
**Global Warming Climate**

**Curl $\tau$ change: (2071-2100 of A1B) - (1971-2000)**

- Acceleration of the Kuroshio accounted for by Sverdrup transport $\sim 5$ Sv
- Actual acceleration $\sim 30$ Sv

Sakamoto et al. (2005)
Global Warming Climate

Wind change: (2071-2100 of A1B) - (1971-2000)

- Weakened trades
- Intensified Aleutian Low
... El Nino-like response

Sakamoto et al. (2005)
Global Warming Climate

Change of sea surface height variability

Suzuki et al. (2005)
Global Warming Climate

Sea level rise: Medium-res.

Suzuki et al. (2005)
Global Warming Climate

Sea level rise: High-res.

Suzuki et al. (2005)
Global Warming Climate

Global mean sea level rise

Suzuki et al. (2005)
Summary

- Western boundary currents and other swift surface currents have a large impact on the climate, so their proper representation in climate models is very important for studies of climate and its changes, especially of basin and regional scales.
- Our high resolution model results are encouraging in this regard, though there still are many things to be done.