Toward reliable projection and assessment of future ocean changes

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Related Research Projects

Scale interaction and large-scale variation of the ocean circulation
- JST/CREST “High Performance Computing for Multi-scale and Multi-physics Phenomena”
- FY2006-2011

Improvement of future climate change projection by developing a high-performance ocean model
- MEXT “Innovative Program of Climate Change Projection for the 21st century”
- FY2007-2011

JST: Japan Science and Technology Agency
CREST: Core Research for Evolitional Science and Technology
MEXT: Ministry of Education, Culture, Sports, Science and Technology
# Current Status of Ocean-Climate Modeling

MIROC (Model for Interdisciplinary Research On Climate) version 3.2

<table>
<thead>
<tr>
<th>Component</th>
<th>High</th>
<th>Medium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmosphere: CCSR/NIES/FRCGC AGCM 5.7</td>
<td>T106 (~1.1°) 56 levels</td>
<td>T42 (~2.8°) 20 levels</td>
</tr>
<tr>
<td>Ocean: CCSR Ocean Component Model 3.4</td>
<td>~0.28°x0.19° 47 levels</td>
<td>~1.4°x0.5°-1.4° 43 levels</td>
</tr>
<tr>
<td>Land: MATSIRO</td>
<td>~0.56°</td>
<td>~2.8°</td>
</tr>
<tr>
<td>River: TRIP</td>
<td>0.5°</td>
<td>~2.8°</td>
</tr>
<tr>
<td>Sea ice: dynamic (EVP)-thermodynamic (0-layer)</td>
<td>same as ocean</td>
<td>same as ocean</td>
</tr>
</tbody>
</table>
Current Status of Ocean-Climate Modeling

Ocean model resolution for IPCC AR4:
- CCSR/NIES/FRCGC MIROC-hires horizontal grid-size: ~20 km (highest)
  - Typical horizontal grid-size: ~100 km

Fundamental difference between ~20 km and ~100 km horizontal grid-size due to representation of meso-scale processes
- Western boundary currents (e.g., Kuroshio)
- Deep water formation
Current Status of Ocean-Climate Modeling

Kuroshio (North Pacific western boundary current)

20 km grid

100 km grid

Realistic path and separation

20 km grid enables...
- realistic representation of surface currents
- reliable projection of their changes under global warming

Unrealistic
Current Status of Ocean-Climate Modeling

Deep water formation sites

20 km grid

100 km grid

100 km grid leads to...
- shifted
- too broad

deep water formation

Observed
Current Status of Ocean-Climate Modeling

20 km grid is still insufficient for...
Current Status of Ocean-Climate Modeling

20 km grid is still insufficient for... behavior of western boundary currents
Current Status of Ocean-Climate Modeling

20 km grid is still insufficient for subduction (eddy-driven water formation process).

SSH variability

Subduction velocity

AAIW (30W salinity)

1/6°

1/12°
Current Status of Ocean-Climate Modeling

20 km grid is still insufficient for... coastal upwelling (eastern boundary processes) affects global-scale ocean and climate (such as ENSO) via coupling with the atmosphere
Future Perspective of Ocean-Climate Modeling

Western boundary currents, subduction, coastal upwelling, ...
  localized (< 10 km) oceanic processes/currents/structures heavily affects global-scale climate and its changes

3 km-grid global ocean model climate-timescale calculation is very difficult (or unfeasible) even with next-generation computing resource (10-PFLOPS-class supercomputer is planned in Japan)
Future Perspective of Ocean-Climate Modeling

Assessment of coastal environment changes under global climate changes...

global ocean modeling with ~0.1 km grid is unthinkable even with next-generation super computing resource
Future Perspective of Ocean-Climate Modeling

Process-oriented study on the link between water mass formation and global-scale circulation

Water mass (especially of deep and mid-depth) formation: micro spatial scale (~0.1 km) and short (~1 day) time scale nonhydrostatic process

Too large spatial/temporal scale-gap with global-scale circulation (e.g., compared with the case of atmosphere)

...Global nonhydrostatic modeling is too unrealistic (or just a waste of time and resource) for the case of ocean
Future Perspective of Ocean-Climate Modeling

- Water mass: 0.1~1 km-grid marginal-sea-scale
- Global circulation: ~10 km-grid global-scale
- Local currents: ~1 km-grid local-scale
- Coastal environment: ~0.1 km-grid coastal-scale

Hierarchical modeling with respect to spatial scale
- High-resolution modeling for each scale to specify and quantify important processes for climate study (parameterized? resolved?)
- Develop a method to link different scales (e.g., nested-grid modeling)
Multi-scale Modeling

Intermediate water formation in the Southern Ocean (basin-scale modeling)

SSH variability
Subduction velocity

AAIW (30W salinity)

1/6°

1/12°
Multi-scale Modeling

Inter-basin water exchange

Warm water route (pathway of Indian-origin water)

Cold water route (pathway of Pacific-origin water)
Multi-scale Modeling

Marginal sea-scale modeling for deep/intermediate water formation

Labrador Sea

Sea of Okhotsk

Winter sea ice production

Surface current
Multi-scale Modeling

Dense water formation and modification
(Non-hydrostatic modeling)

Down-sloping flow and its entrainment
Nested-grid Modeling

Nest a ~3 km-grid Kuroshio-region model into a ~20 km-grid global model in a CGCM
To assess the impact of (possibly) better representation of Kuroshio/Oyashio current system on future climate change projection (feasibility study)
Nested-grid Modeling

Study on Kuroshio variability

Inner model

Outer model