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A Regional Climate Model for the Western North Pacific: Present and Future Climate Simulations

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- Outline -

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2. Data and Method
   I. Model description
   II. Experimental design and Pseudo Global Warming (PGW) method

3. Results
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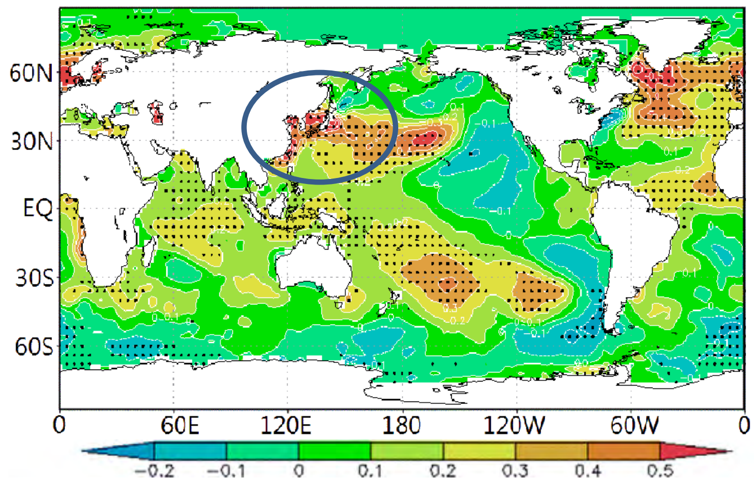
   II. Future simulation with PGW method using GCM data
   III. Future simulation with PGW method using downscaled data by WRF model

4. Summary

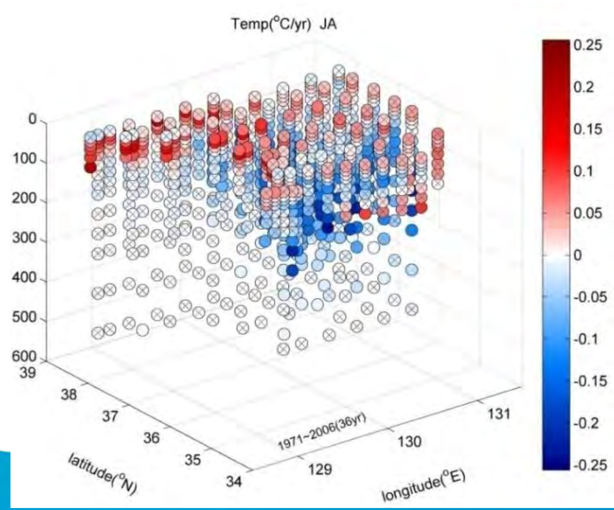
5. Future study

Motivation – historical change over the East/Japan Sea

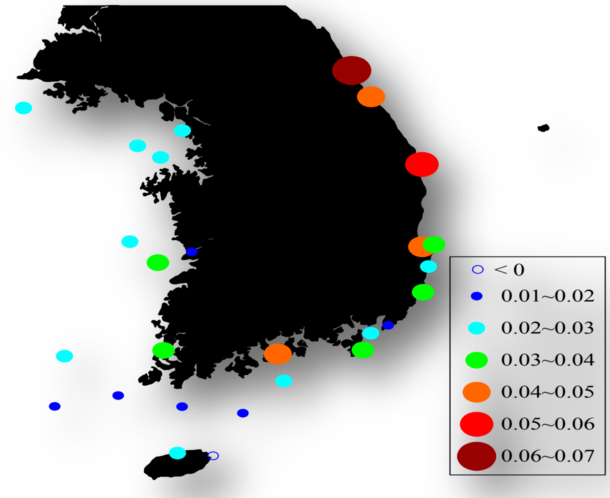
Winter SST linear trend (℃/10yr) (1981-2005)



Summer temperature linear trend (℃/yr) (1971-2006) in the East Sea



Linear trend of SSTA (℃/yr) (Min&Kim,2006)

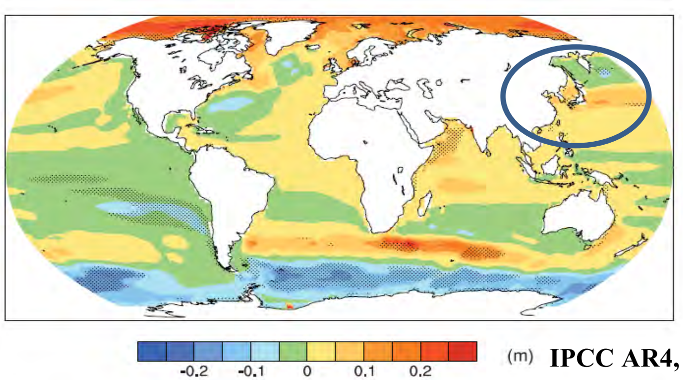


- The western North Pacific ocean is one of the rapidly changing region in temperature during wintertime.

- The East/Japan Sea has the highest trend of SST anomaly for the seas around Korea and has different trend with positive in surface and negative in subsurface.

Motivation – future climate projection for the East/Japan Sea

Sea level change projection with CMIP3 model



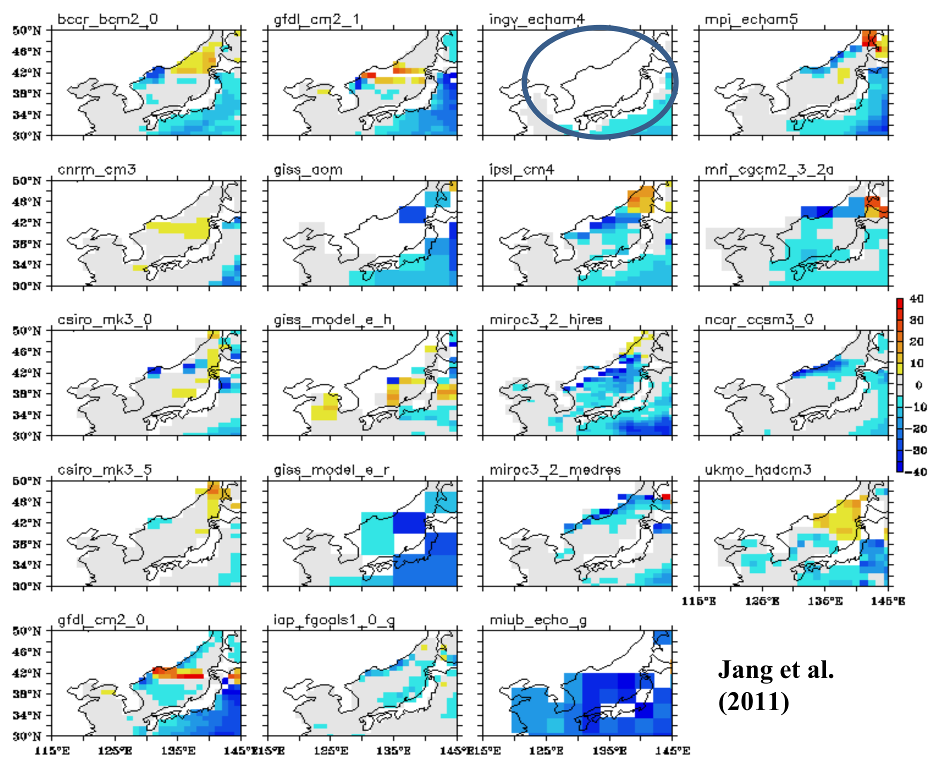
IPCC AR4, 2007

Figure 10.32. *Local sea level change (m) due to ocean density and circulation change relative to the global average (i.e., positive values indicate greater local sea level change than global) during the 21st century, calculated as the difference between averages for 2080 to 2099 and 1980 to 1999, as an ensemble mean over 16 AOGCMs forced with the SRES A1B scenario. Stippling denotes regions where the magnitude of the multi-model ensemble mean divided by the multi-model standard deviation exceeds 1.0.*

- IPCC AR4 reported sea level in the western North Pacific will get higher in the future climate, especially, in the East/Japan Sea.

- However, most of CMIP3 GCMs cannot simulate the marginal sea circulations reasonably well due to the coarse resolution.

MLD projection in the CMIP3 models



Jang et al. (2011)

Why do we need a regional climate model?

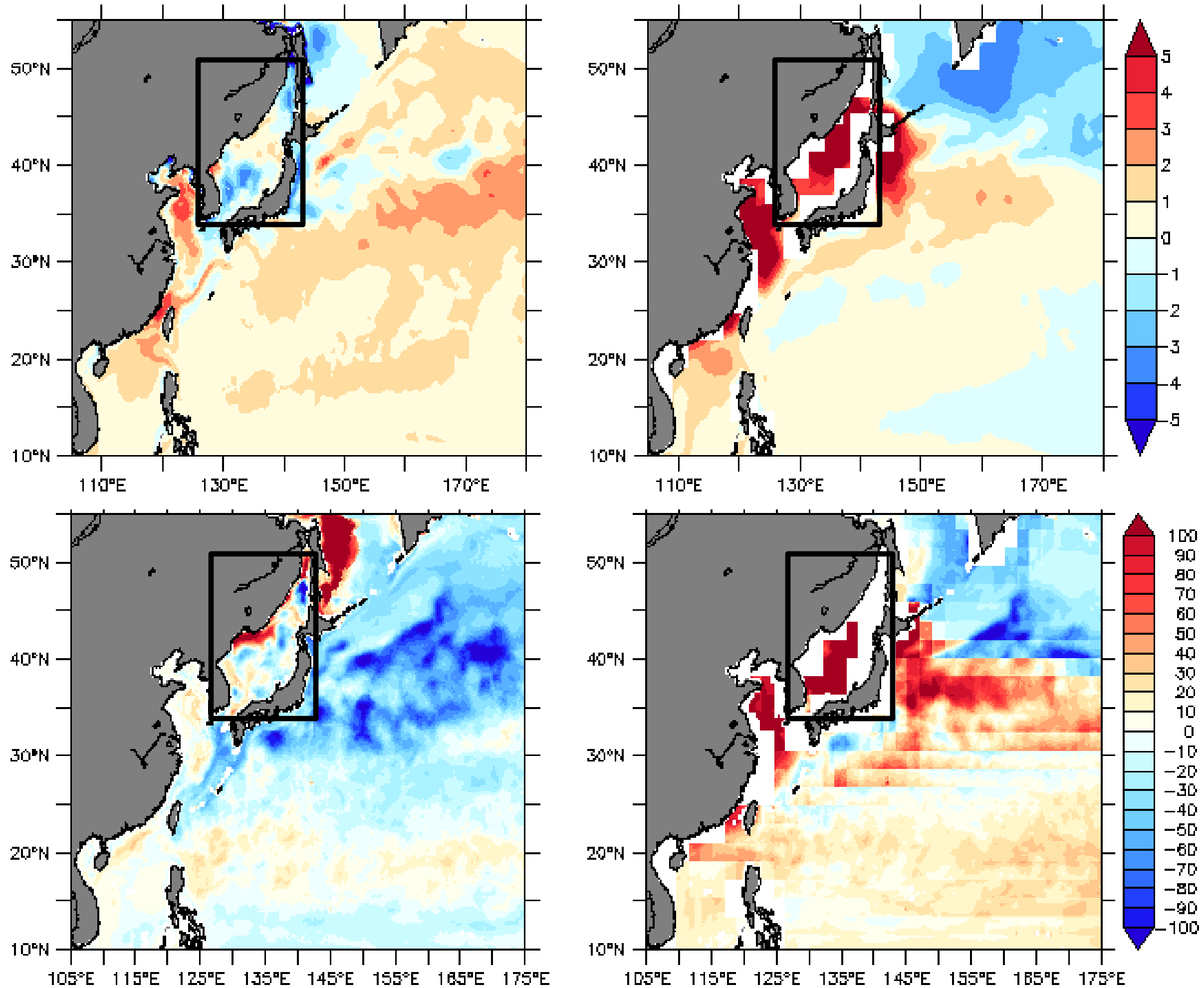
RCM **GCM**

SST bias

(Model-OISST V2)

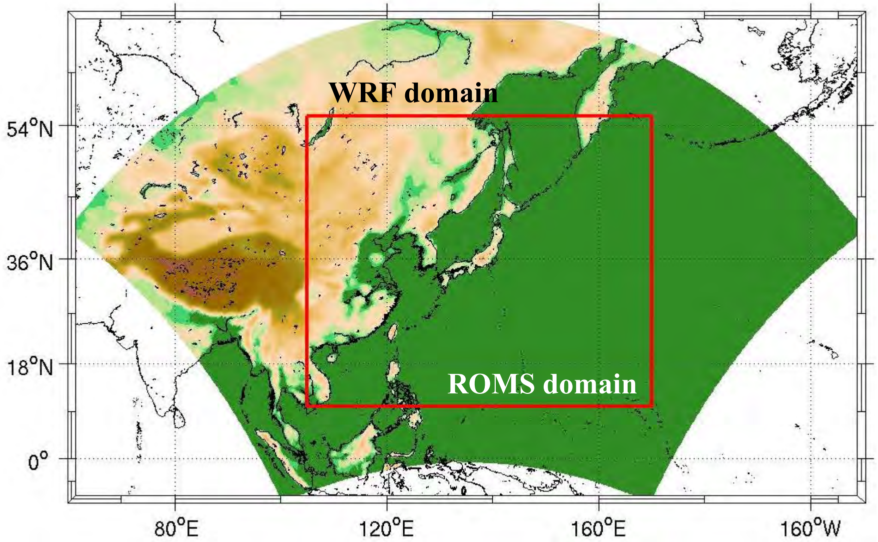
MLD bias

(Model-ECCO2)



Data and Method - Model Description

Model domain



❖ **Data for validation**

-. ECCO2 (1/4°x 1/4°, 1992-2000)

-. OISST V2 (1/4° x 1/4°, 1982-2000)

-. NCEP2 (2.5° x 2.5°, 1982-1986)

❖ **MLD definition (de Boyer Montegut et al. (2004))**

MLD_DReqDTm02 = depth where ($\sigma_0 = \sigma_{010m} + \Delta\sigma_0$)

with $\Delta\sigma_0 = \sigma_0(\theta_{10m} - 0.2°C, S_{10m}, P_0) - \sigma_0(\theta_{10m}, S_{10m}, P_0)$

Model configuration

Model	ROMS	WRF
Domain	105˚E~175˚E, 10˚N~55˚N	60˚E~150˚W, 8˚S~65˚N
Horizontal Resolution (Vertical layers)	1/12° (30)	50km (28)
Map Projection	Mercator	Lambert
Topo	ETOPO 1'	USGS 10'
Initial/ Boundary condition	SODA monthly mean reanalysis	NCEP RA2 daily mean reanalysis
Physics Parameterization	KPP vertical turbulent mixing scheme	WSM6,RRTM/ Dudhia, M-O, Noah, YSU, KF
Surface forcing or Lower boundary condition	NCEP RA2 daily mean reanalysis with bulk formula and restoring to Levitus SSS	OISST V2 daily mean reanalysis

Data and method – Experimental design

Experimental Design

<table>
<tr><th>Experiments number</th><th>Experiments name</th><th>Boundary condition</th><th>Time period (year)</th></tr>
<tr><td>1</td><td>Present simulation (Control Run)</td><td>Reanalysis</td><td>1981-2000</td></tr>
<tr><td>2</td><td rowspan="2">Future simulation</td><td>Reanalysis and GCM difference</td><td>2081-2100</td></tr>
<tr><td>3</td><td>Downscaled data by WRF</td><td>2082-2086</td></tr>
</table>

Pseudo Global Warming (PGW) method

Future climate change		Present climate
(RCP4.5 – historical)	+	Reanalysis

❖ **The advantage of the PGW method**

- to estimate the global warming effects on the specific past year.
- to estimate climate difference between present and future climate without ensemble of numerous number of simulations.

RCP 4.5 r

Historical

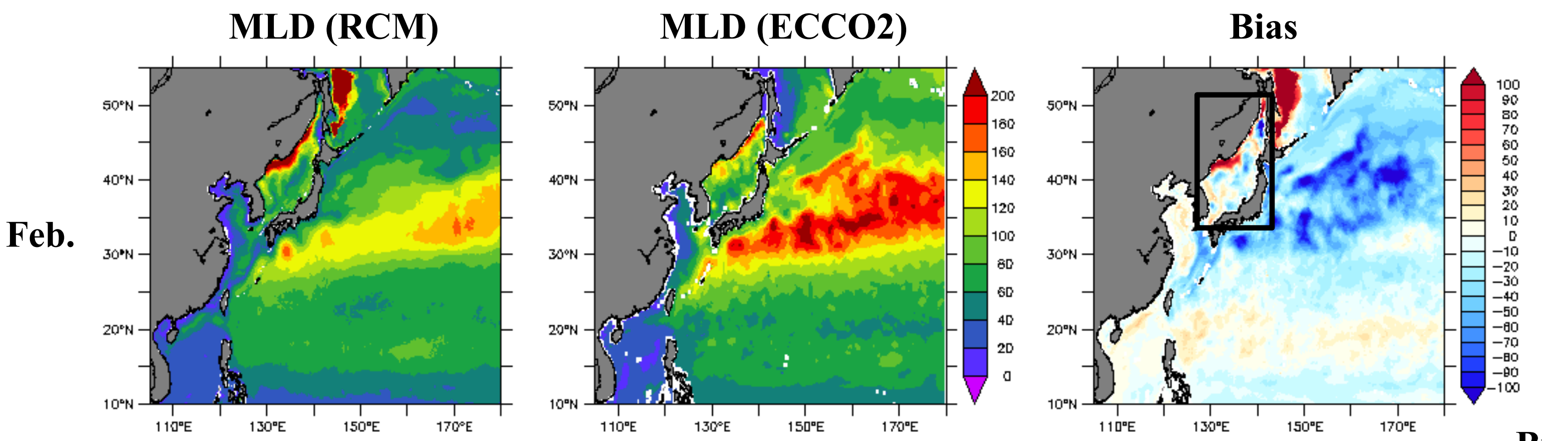
Future climate projection

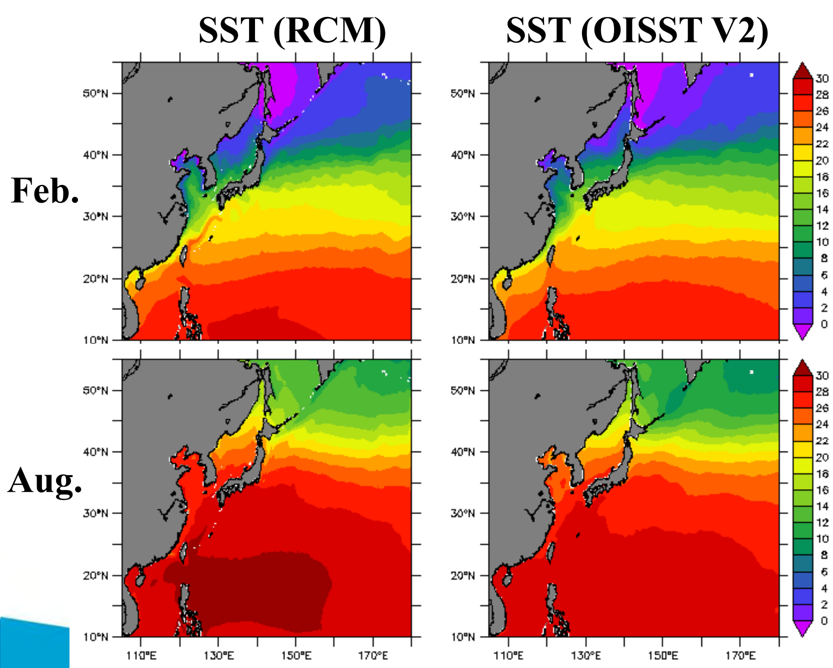
Data and Method – CanESM2 variables

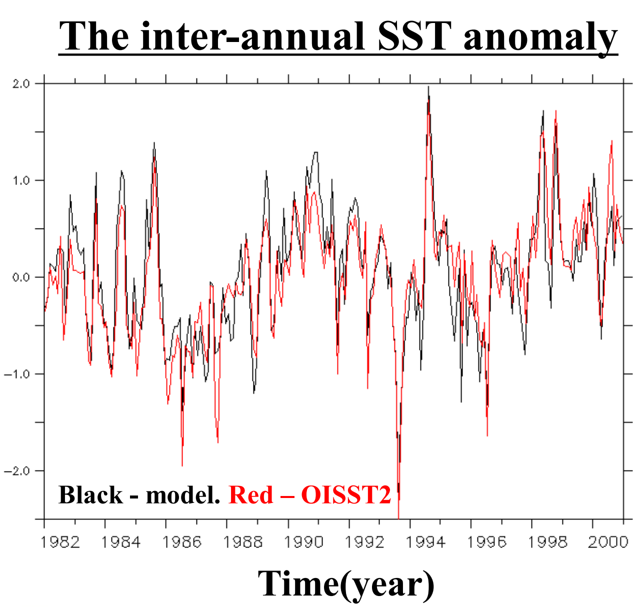
3-dimensional variables	2-dimensional variables	
U (ua) V (va) Air temprature (ta) Relative humidity (hur) Geopotential hight (zg)	T at 2m (tas) RH at 2m (hurs) U at 10m (uas) V at 10m (vas) Sea level pressure (psl) Surface pressure (ps)	Daily
Sea Water Potential Temperature (thetao) Sea Water Salinity (so) Sea Water X velocity (uo) Sea Water Y velocity (vo)	Ground temperature (ts) SST (tos) Soil moisture (mrsos) Soil temperature (tsl) Sea Surface Height Above Geoid (zos)	Monthly

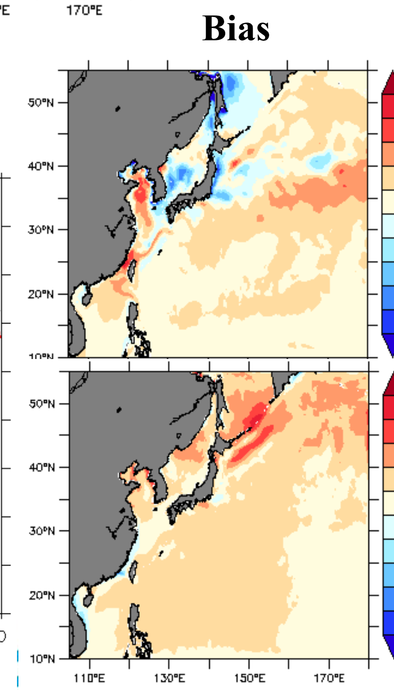
(Ocean and atmosphere)

Validation of present climate simulation by the RCM





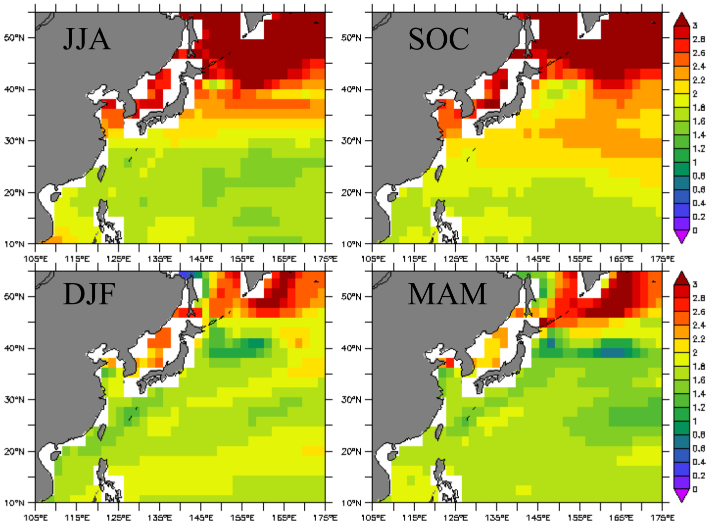




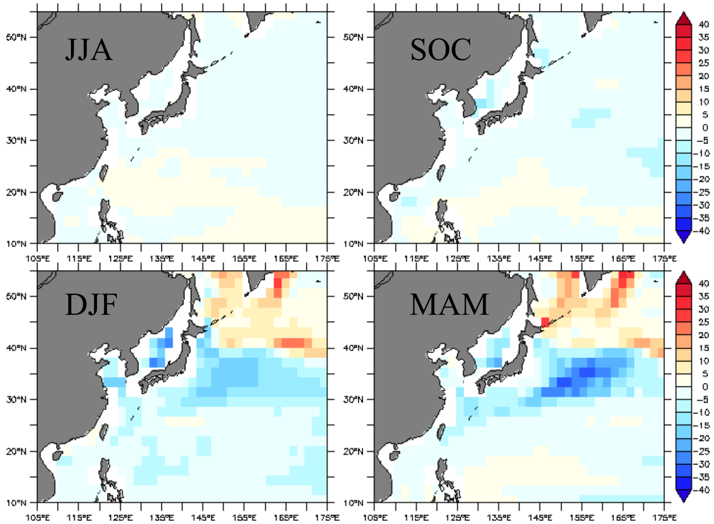
Seasonal difference (CanESM2 RCP4.5 - historical)

KIOST 한국해양과학기술원

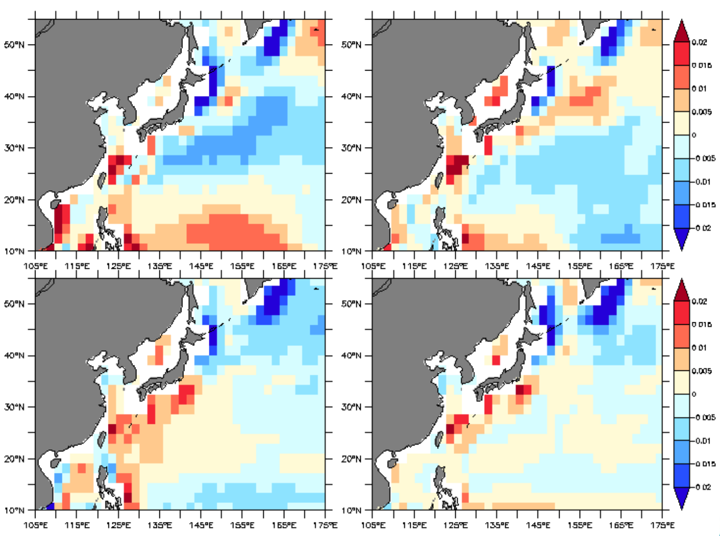
SST (°C)



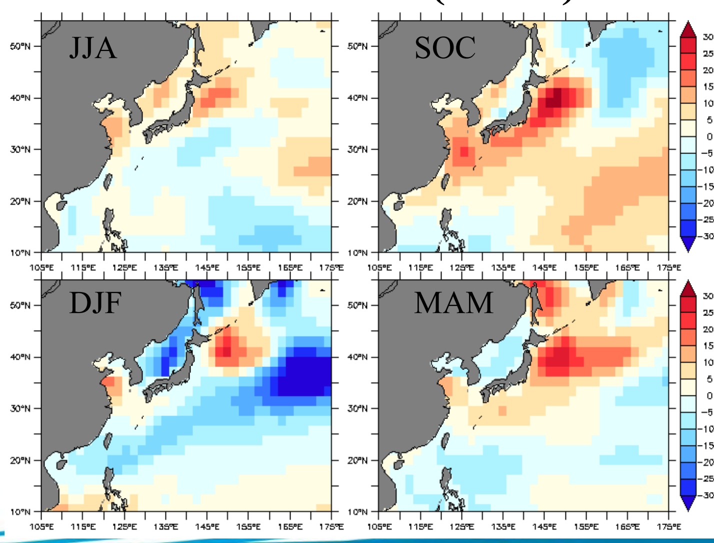
Mixed Layer Depth (m)



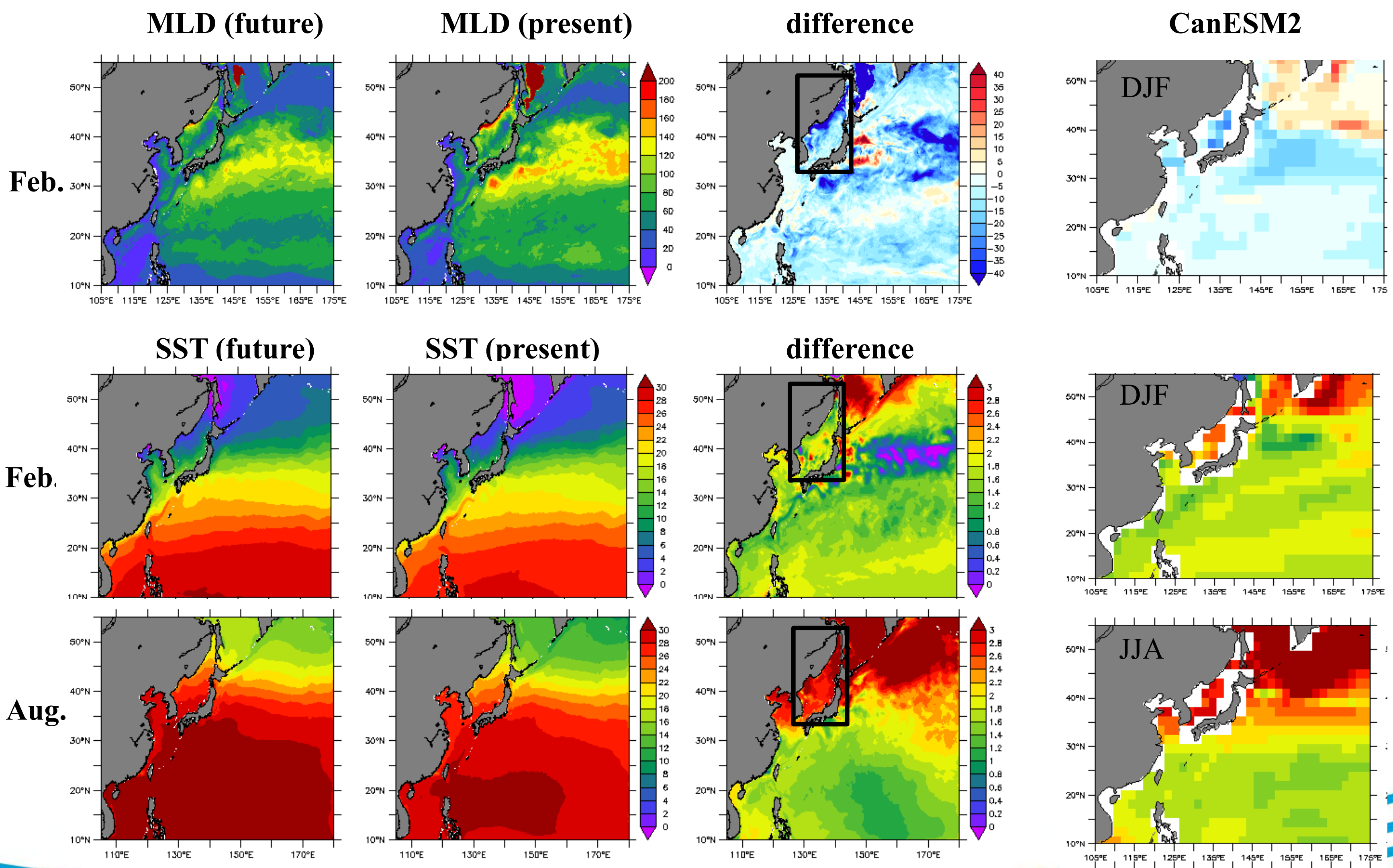
Meridional ocean current (m/s)



Net Heat Flux (W/m²)

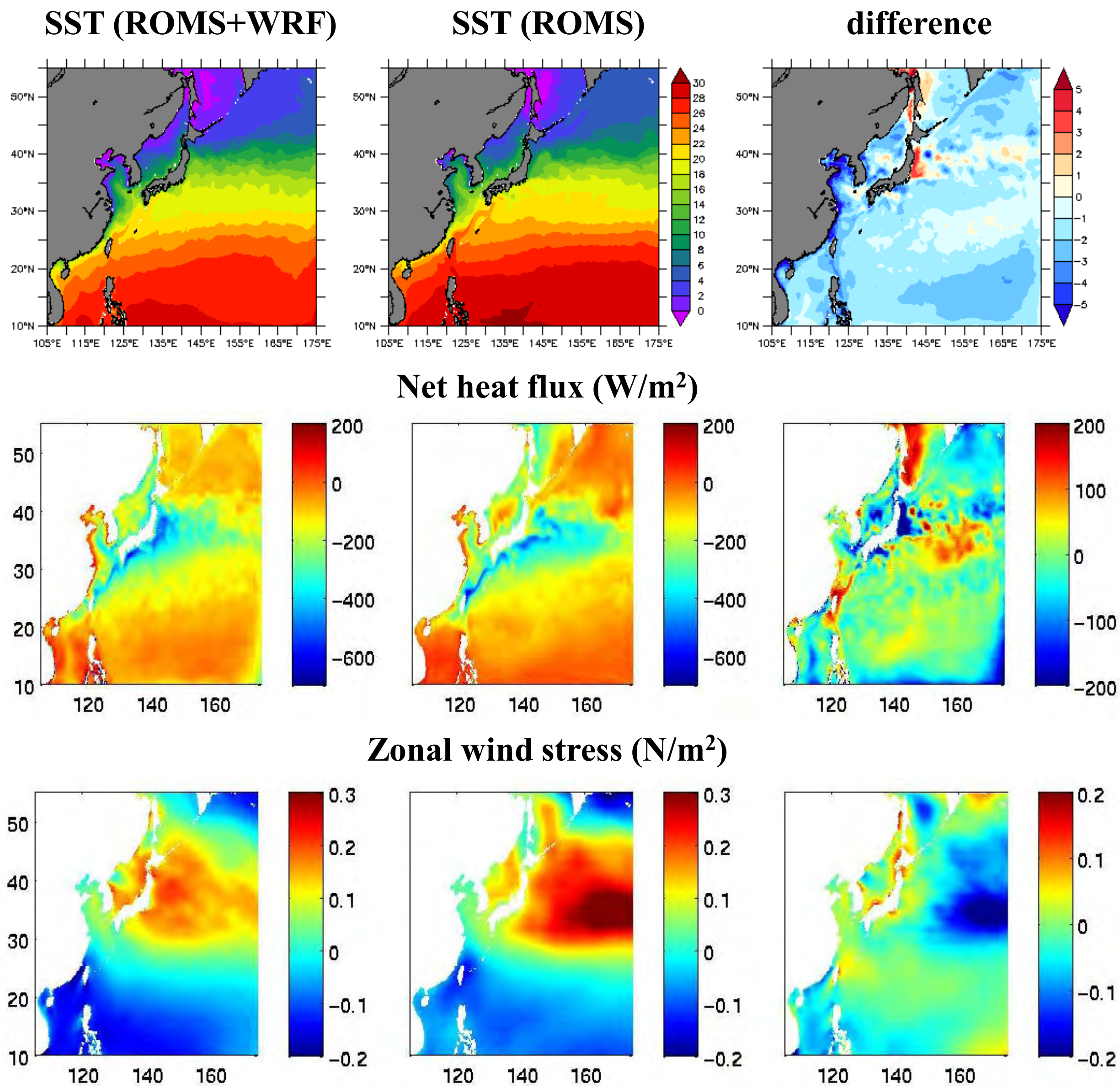


Future ocean climate change using the RCM



Preliminary result (Future simulation with WRF model)

Feb.



4. Summary

1. We developed a regional climate model for the western North Pacific marginal seas and conducted three experiments with Pseudo Global Warming method using WRF model to investigate the high-resolution atmospheric forcing effects.

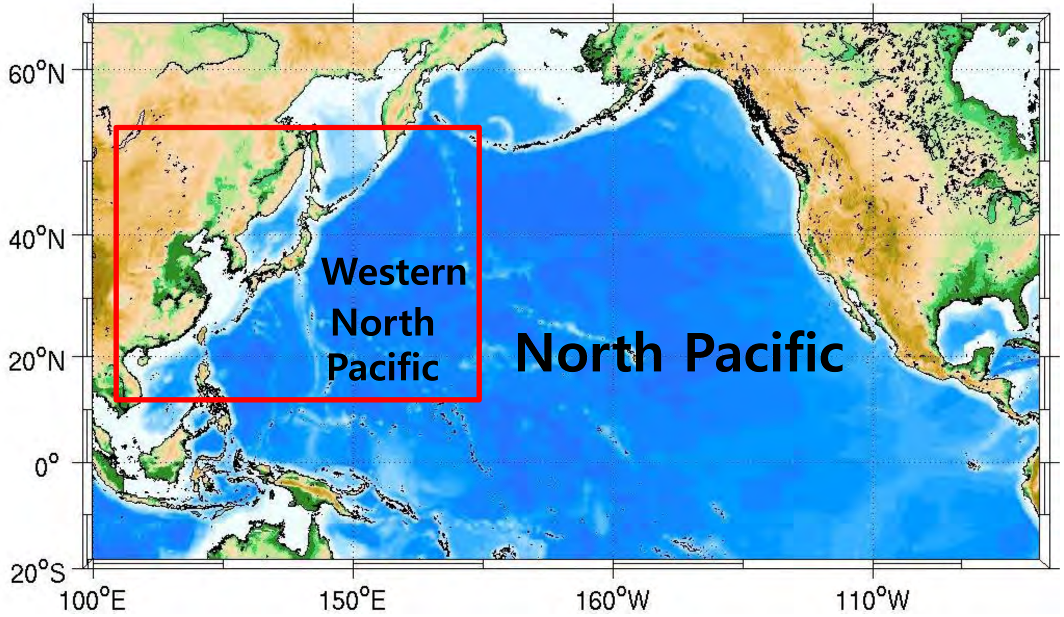
2. The model simulated the observed SST and MLD climatology over the western North Pacific and inter-annual variability averaged in the East/Japan Sea with detailed pattern of coastal areas.

3. The simulated MLD is projected to get shallower and the SST increase in the future over the western North Pacific. Reduced warming in the East/Japan Sea was simulated by the RCM in winter due to the cold bias of the RCM.

4. The future projection with downscaled data by WRF model shows the cold bias of SST due to model systematic error. But detailed spatial pattern of wind stress is shown in coastal regions.

5. Future study

- Connecting North Pacific model with 2-way nesting method
  - To improve boundary problem in RCM



- Ensemble experiment using other CMIP5 models
  - Selecting models showing better performance with statistical method

5. Future study

- 2-way coupling effect with WRF model
  - Future typhoon intensity
  - Erosion changes in coastal region

- Application study
  - Ecosystem and fishery changes for the seas around Korea using the coupled physical and biological model

Thank you.