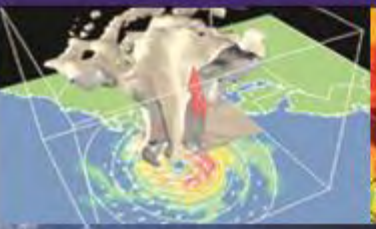
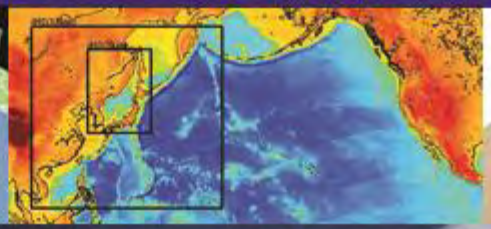
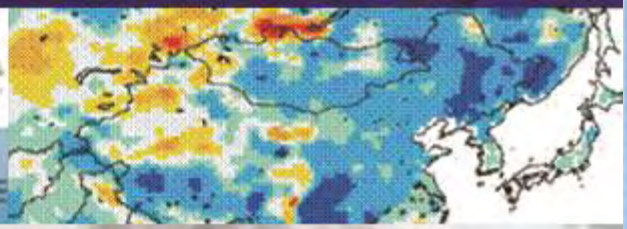
Climate change projection for the western North Pacific: Dynamical downscaling

Chan Joo Jang, Chul Min Ko, Chun Yong Jung

Korea Institute of Ocean Science & Technology

CMIP5 Modeling Groups

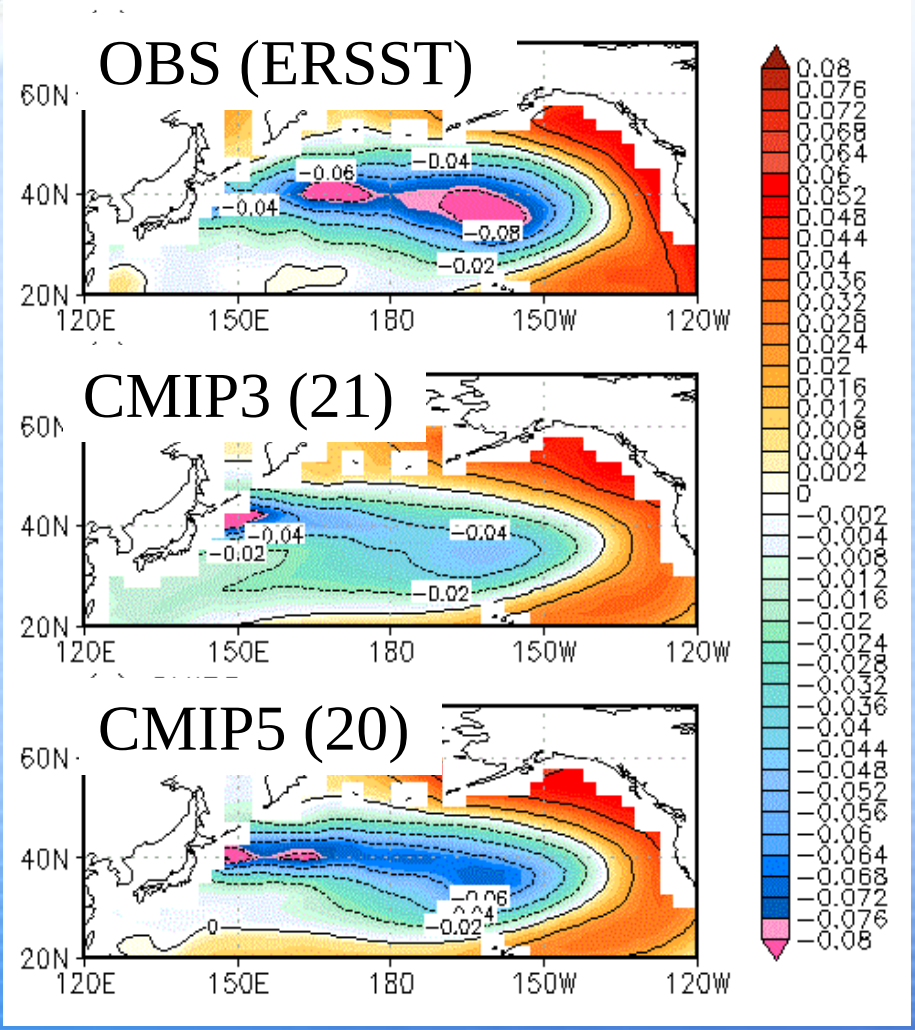
Reference: Historical Experiment

Modeling Center	Model	Institution	Country
BCC (2)	BCC-CSM1.1 BCC-CSM1.1(m)	Beijing Climate Center, China Meteorological Administration	China
CCCma (2)	CanCM4 CanESM2	Canadian Centre for Climate Modelling and Analysis	Canada
CMCC (3)	CMCC-CESM CMCC-CM CMCC-CMS	Centro Euro-Mediterraneo per I Cambiamenti Climatici	Italy
CNRM-CERFACS (2)	CNRM-CM5 CNRM-CM5-2	Centre National de Recherches Meteorologiques / Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique	France
CSIRO-BOM (2)	ACCESS1.0 ACCESS1.3	CSIRO (Commonwealth Scientific and Industrial Research Organisation, Australia), and BOM (Bureau of Meteorology, Australia)	Australia
CSIRO-QCCCE (2)	CSIRO-Mk3.6.0 CSIRO-Mk3L-1.2	Commonwealth Scientific and Industrial Research Organisation in collaboration with the Queensland Climate Change Centre of Excellence	Australia
EC-EARTH (1)	EC-EARTH	EC-EARTH consortium	Europe
FIO (1)	FIO-ESM	The First Institute of Oceanography, SOA, China	China
GCESS (1)	BNU-ESM	College of Global Change and Earth System Science, Beijing Normal University	China
INM (1)	INM-CM4	Institute for Numerical Mathematics	Russia
IPSL (3)	IPSL-CM5A-LR IPSL-CM5A-MR IPSL-CM5B-LR	Institut Pierre-Simon Laplace	France
LASG-CESS (1)	FGOALS-g2	LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences; and CESS, Tsinghua University	China
LASG-IAP (1)	FGOALS-s2	LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences	China
MIROC (2)	MIROC4h MIROC5	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology	Japan
MIROC (2)	MIROC-ESM MIROC-ESM-CHEM	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies	Japan
MOHC (additional realizations by INPE) (3)	HadCM3 HadGEM2-CC HadGEM2-ES	Met Office Hadley Centre (additional HadGEM2-ES realizations contributed by Instituto Nacional de Pesquisas Espaciais)	UK
MPI-M (3)	MPI-ESM-LR MPI-ESM-MR MPI-ESM-P	Max Planck Institute for Meteorology (MPI-M)	Germany
MRI (2)	MRI-CGCM3 MRI-ESM1	Meteorological Research Institute	Japan
NASA GISS (4)	GISS-E2-H GISS-E2-H-CC GISS-E2-R GISS-E2-R-CC	NASA Goddard Institute for Space Studies	USA
NCAR (1)	CCSM4	National Center for Atmospheric Research	USA
NCC (2)	NorESM1-M NorESM1-ME	Norwegian Climate Centre	Norway
NIMR/KMA (1)	HadGEM2-AO	National Institute of Meteorological Research/Korea Meteorological Administration	South Korea
NOAA GFDL (4)	GFDL-CM2.1 GFDL-CM3 GFDL-ESM2G GFDL-ESM2M	Geophysical Fluid Dynamics Laboratory	USA
NSF-DOE-NCAR (5)	CESM1(BGC) CESM1(CAM5) CESM1(CAM5.1, FV2) CESM1(FASTCHEM) CESM1(WACCM)	National Science Foundation, Department of Energy, National Center for Atmospheric Research	USA

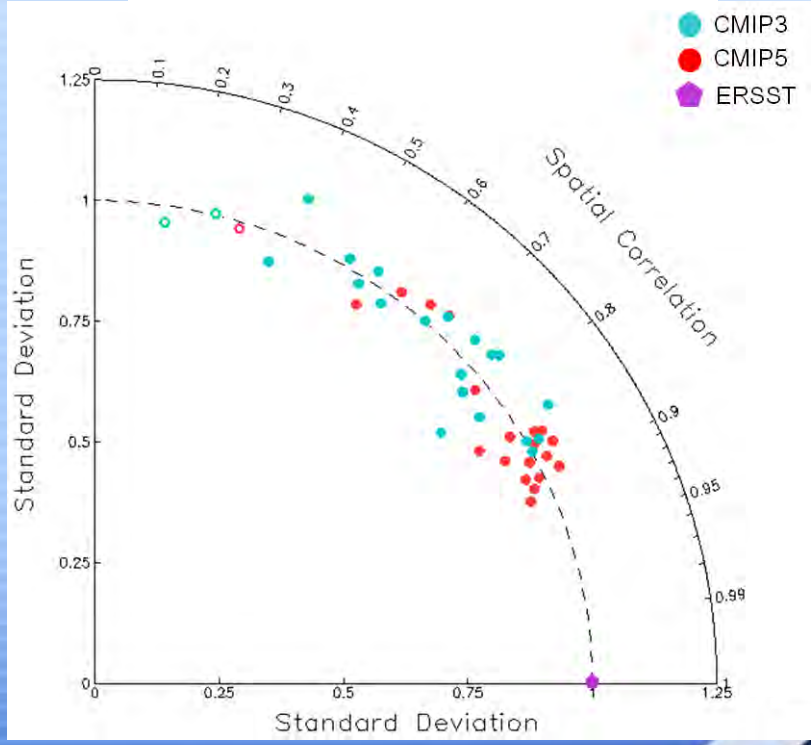
Country	Number of Models	# of center
Australia	4	2
Canada	2	1
China	6	5
Europe	1	1
France	5	2
Germany	3	1
Italy	3	1
Japan	6	3
Norway	2	1
Russia	1	1
South Korea	1	1
UK	3	1
USA	14	4
13	**51**	**24**

CMIP5 Improvement: PDO

Jo et al 2014 submitted to J. Clim.

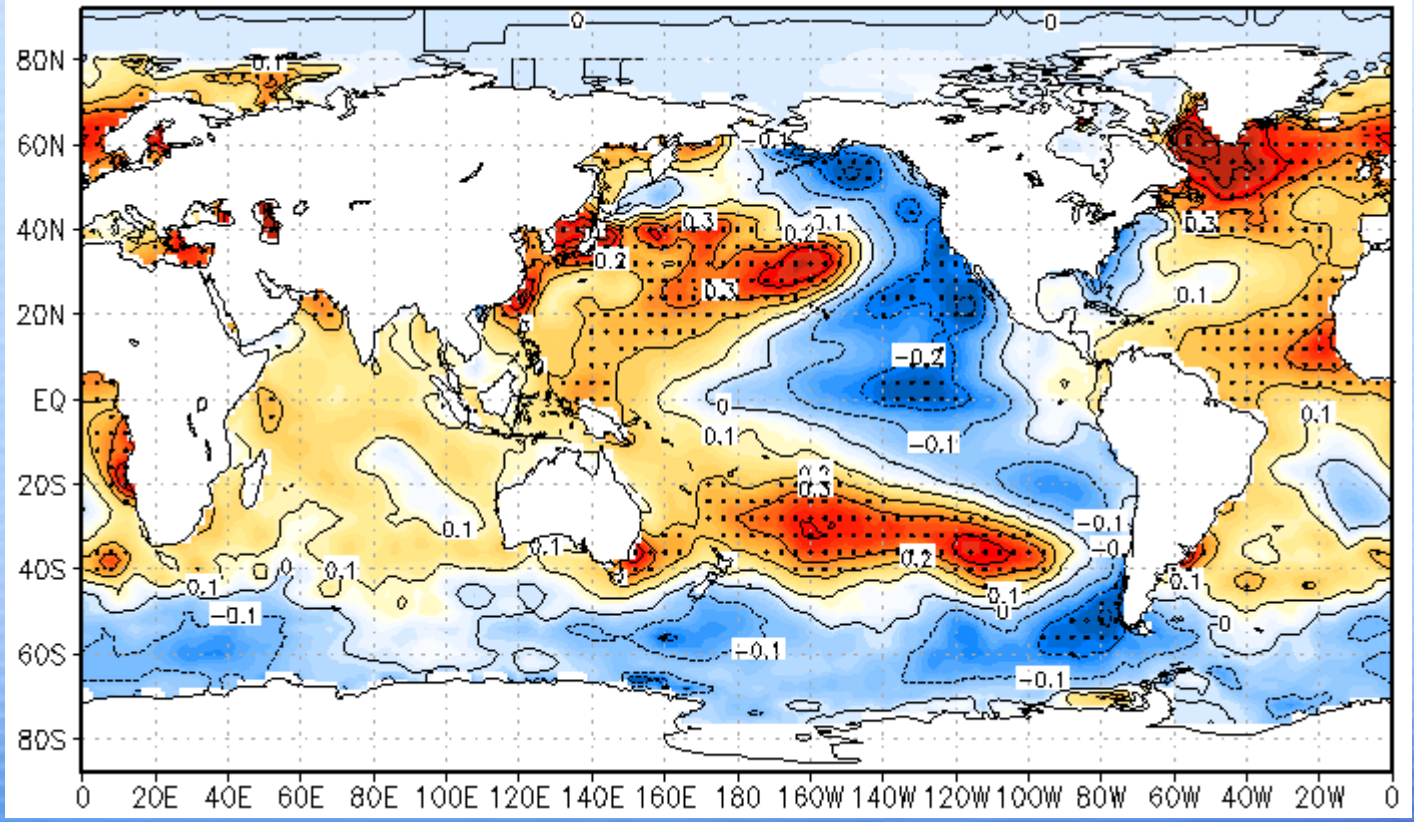


Taylor diagram for PDO spatial pattern



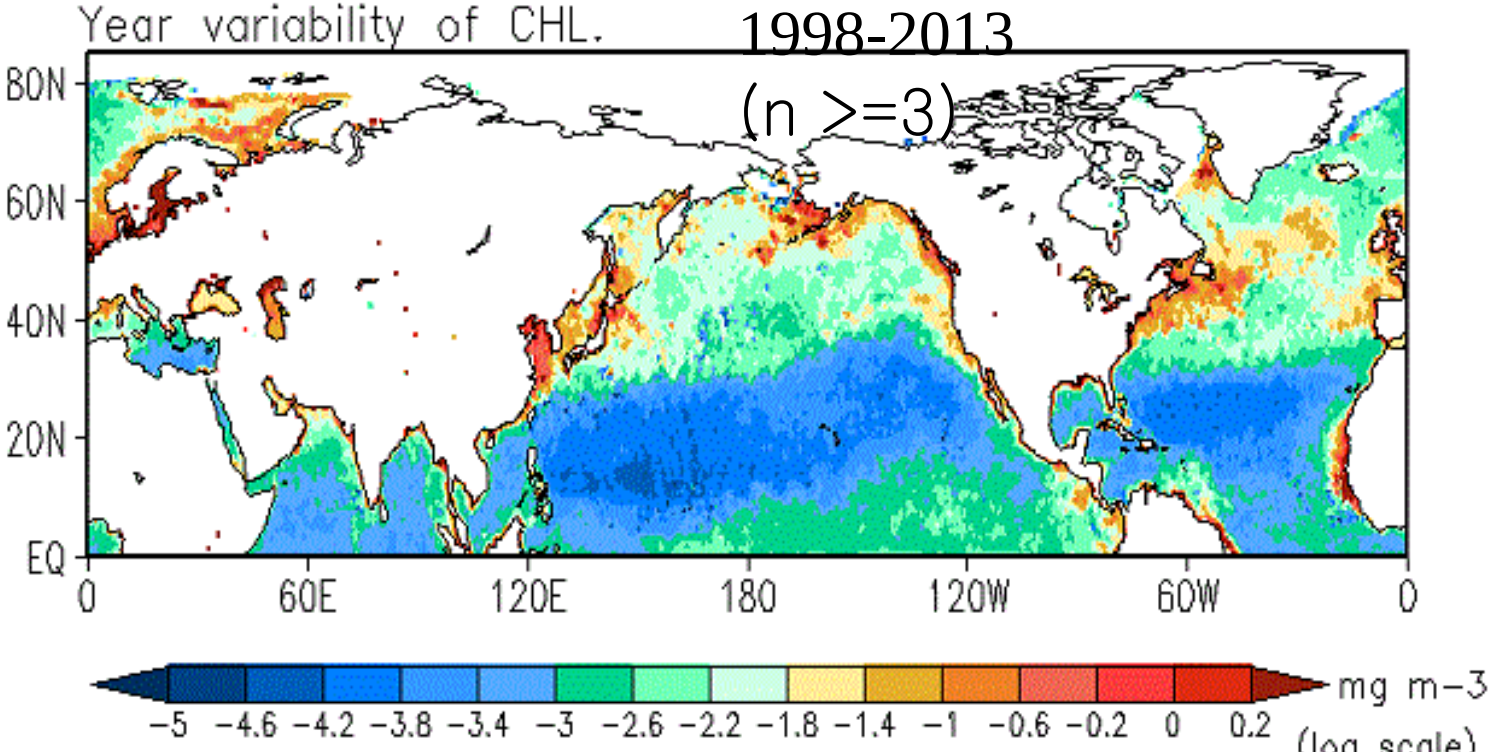
A Hot Spot of changes: Western North Pacific

Winter **SST Trend** for 1980 ~ 2010



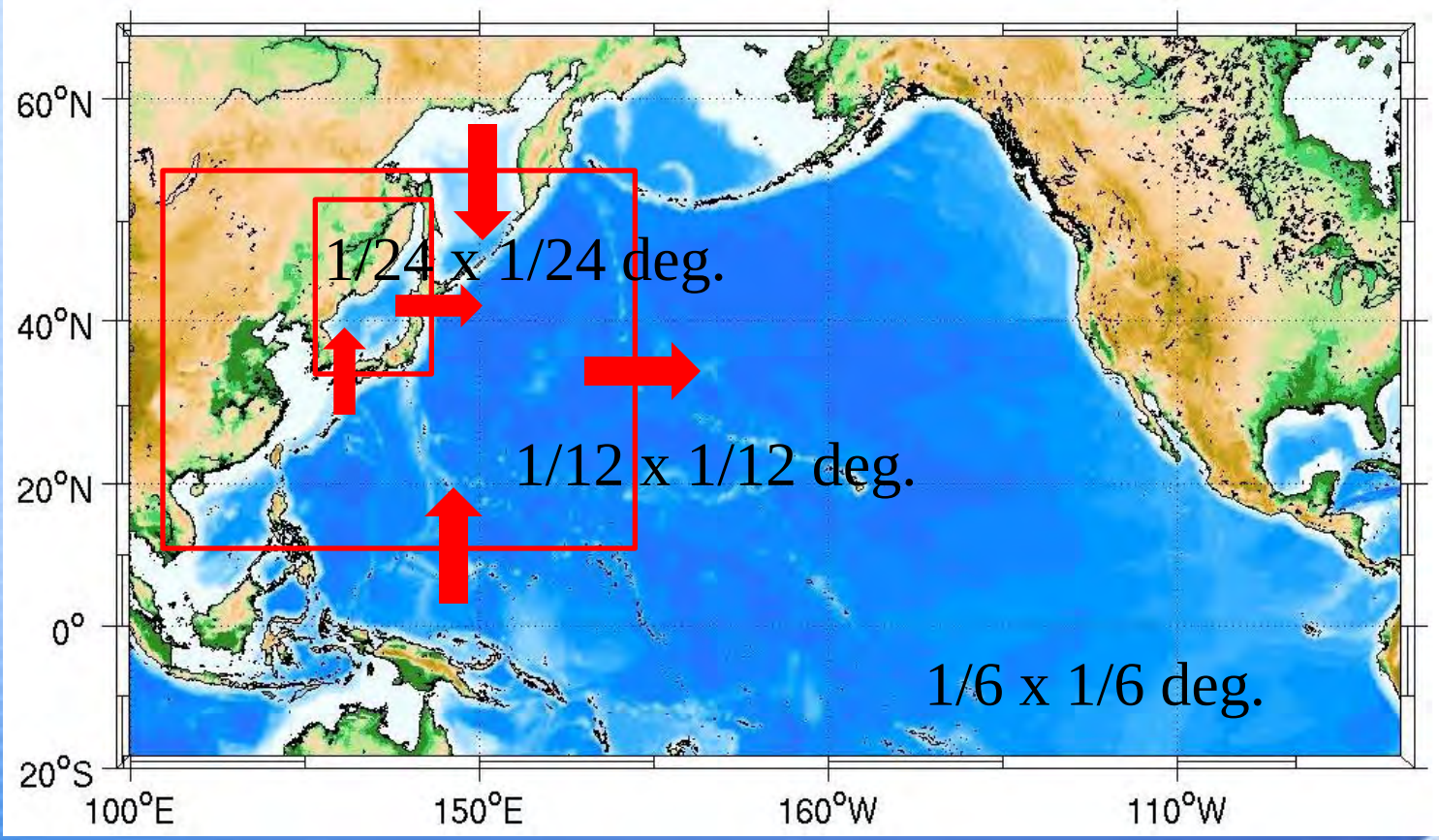
CHL year-to-year variability

Spring (April) CHL

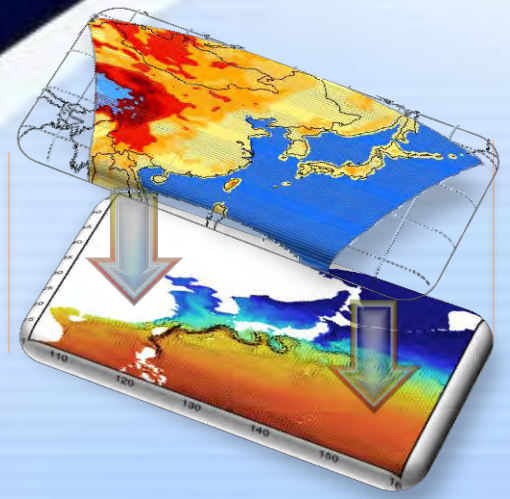


RCM nesting
focusing on Korean seas

North Pacific(Ocean only) → North West Pacific (ocean only) → East Sea (Coupled Model)



Downscaling GW Exp. Plans

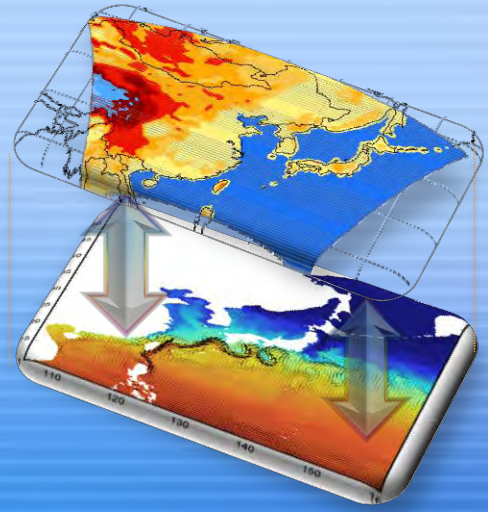


- Ocean dynamical downscaling from **one-way** coupled ocean-atmosphere modeling system (atmos ⇨ ocean)

  : Inverstigate the influence of the atmospheric model downscaling on the simulation

  ① **An experiment will be carried out using GCM's atmospheric output (no downscaling)**

  ② An experiment will be carried out using atmospheric model dynamical downscaling by WRF

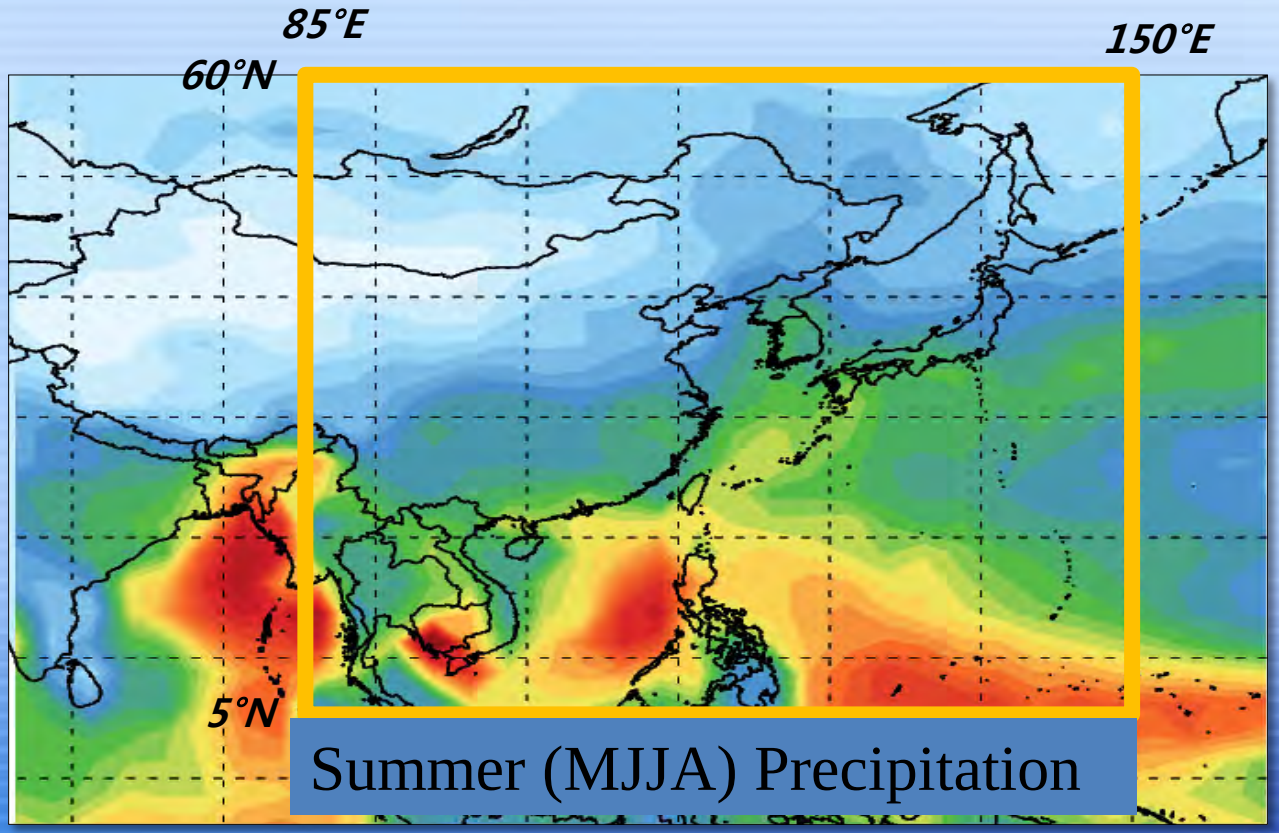


- Ocean dynamical downscaling from **fully coupled** ocean-atmosphere modeling system (atmos ⇔ ocean)

  ① An experiment will be carried out using ROMS - WRF coupled model

  ② An experiment will be carried out using MITgcm - RegCM4 coupled model

Evaluation of the CMIP5 CGCMs for dynamical downscailing
: Climatological P annual cycle over East Asia (85E-150E, 5N-60N) for 1961 ~ 2000



CMIP5 models without offset over high terrains

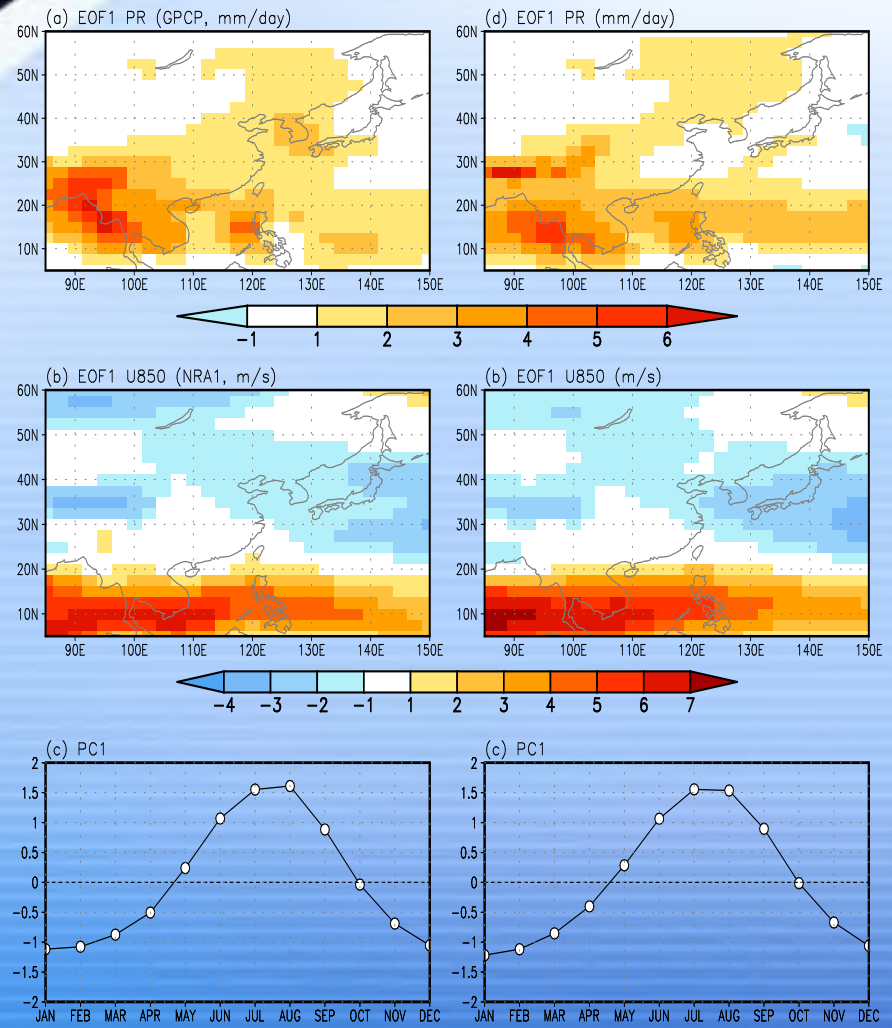
- 17 models (no shading in previous Table) provides wind data over high topography
- Among them, Multi-Variate EOF (MVEOF) was not applicable to "INMCM4".
- MVEOF was applied to climatological annual cycle obtained from **16 models.**

Designation	nz	nt	start year
1. BCC-CSM1-1	17	1956	1850
2. BCC-CSM1-1-M	17	1956	1850
3. BNU-ESM	17	1872	1850
4. CMCC-CESM	33	1872	1850
5. CMCC-CM	17	1872	1850
6. CMCC-CMS	33	1872	1850
7. CNRM-CM5	17	1872	1850
8. CanCM4	22	540	1961
9. CanESM2	22	1872	1850
10. FIO-ESM	17	1872	1850
11. HadCM3	17	1753	Dec 1859
12. MPI-ESM-LR	25	1872	1850
13. MPI-ESM-MR	25	1872	1850
14. MPI-ESM-P	25	1872	1850
15. NorESM1-M	17	1872	1850
16. NorESM1-ME	17	1872	1850

MVEOF for climatological annual cycle (1/2) : East Asia (85E-150E, 5N-60N)

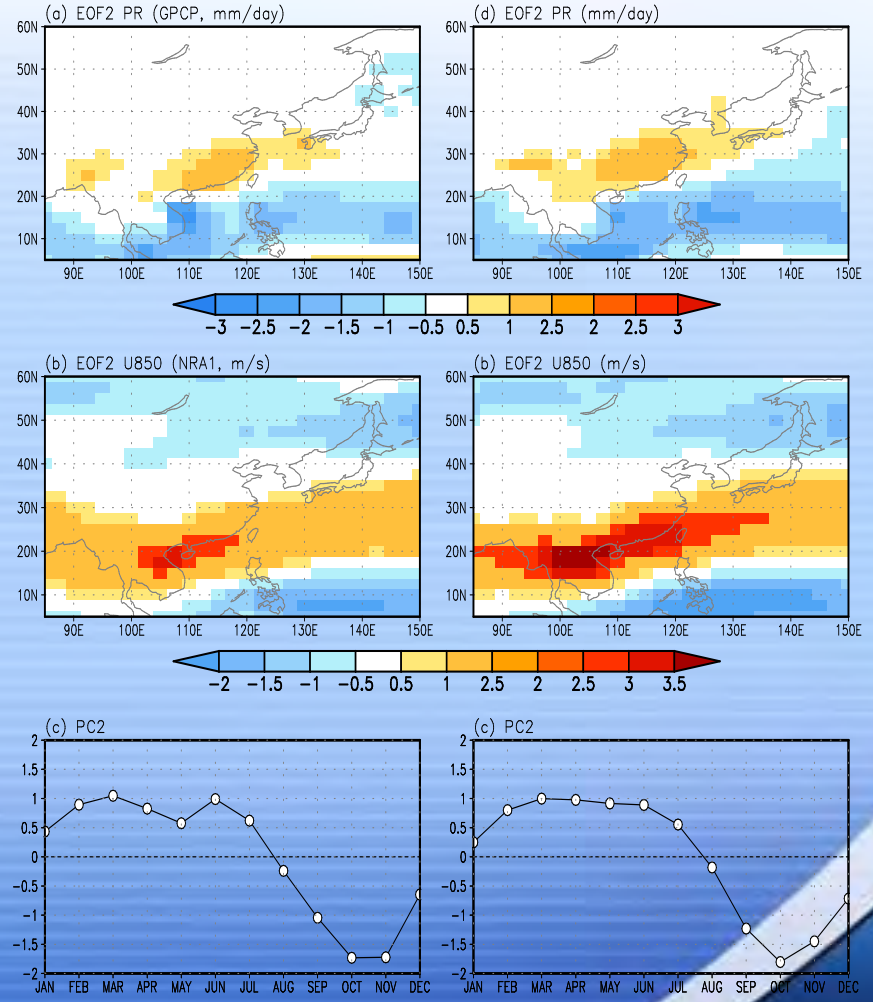
OBS MVEOF mode 1 (64%)

CMIP5 MME mean MVEOF mode 1 (61%)

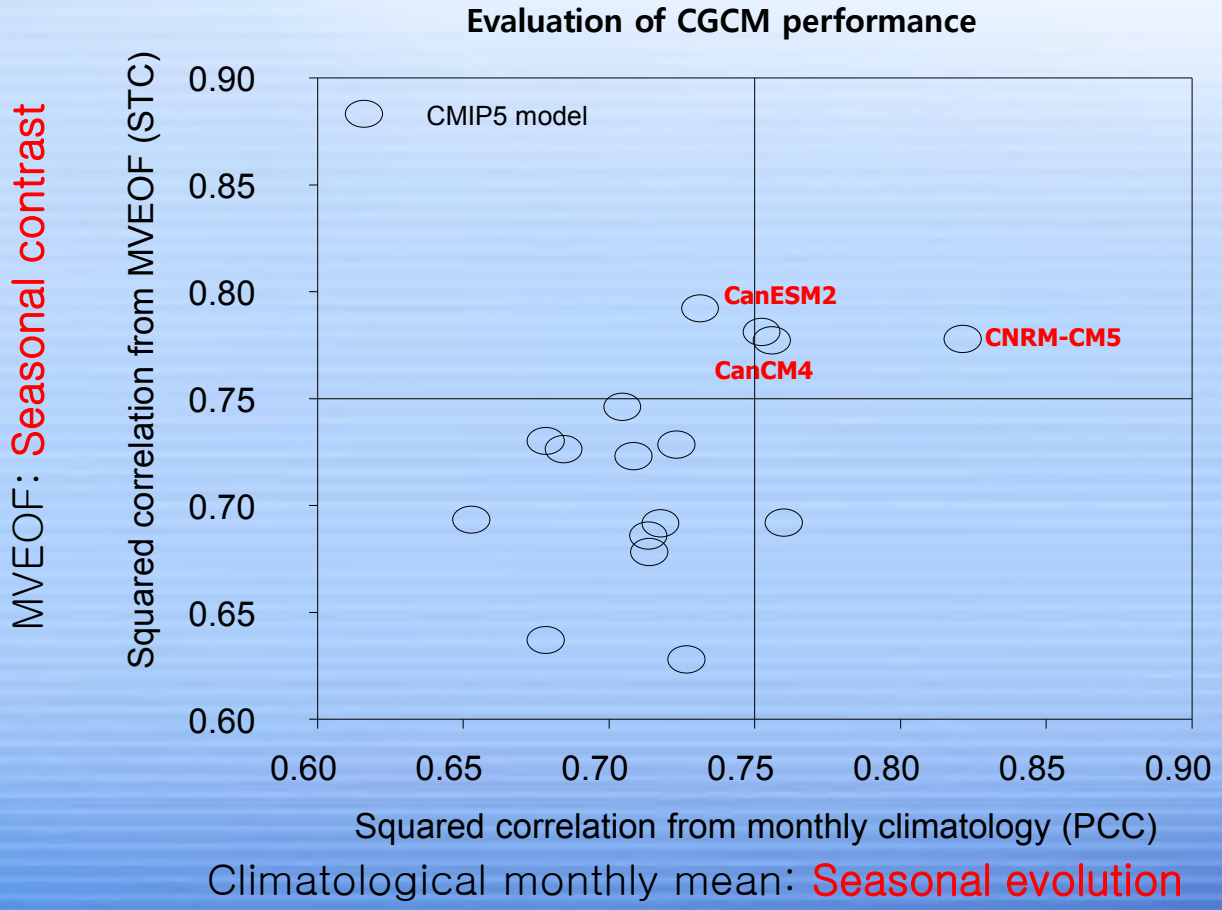


OBS MVEOF mode 2 (22%)

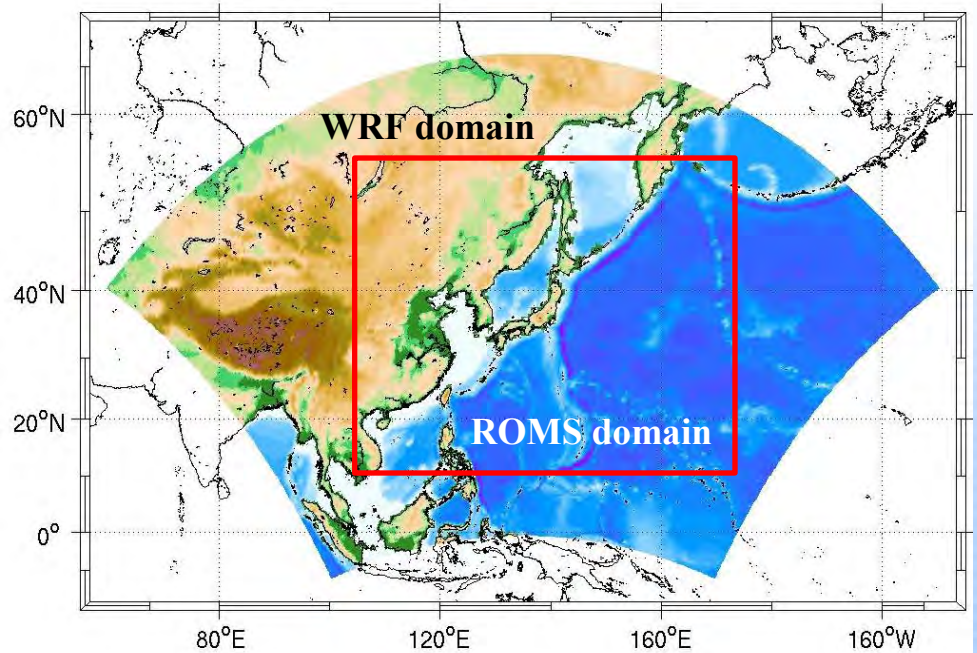
CMIP5 MME mean MVEOF mode 2 (26%)



Evaluation of CMIP5 models (summer precipitation)



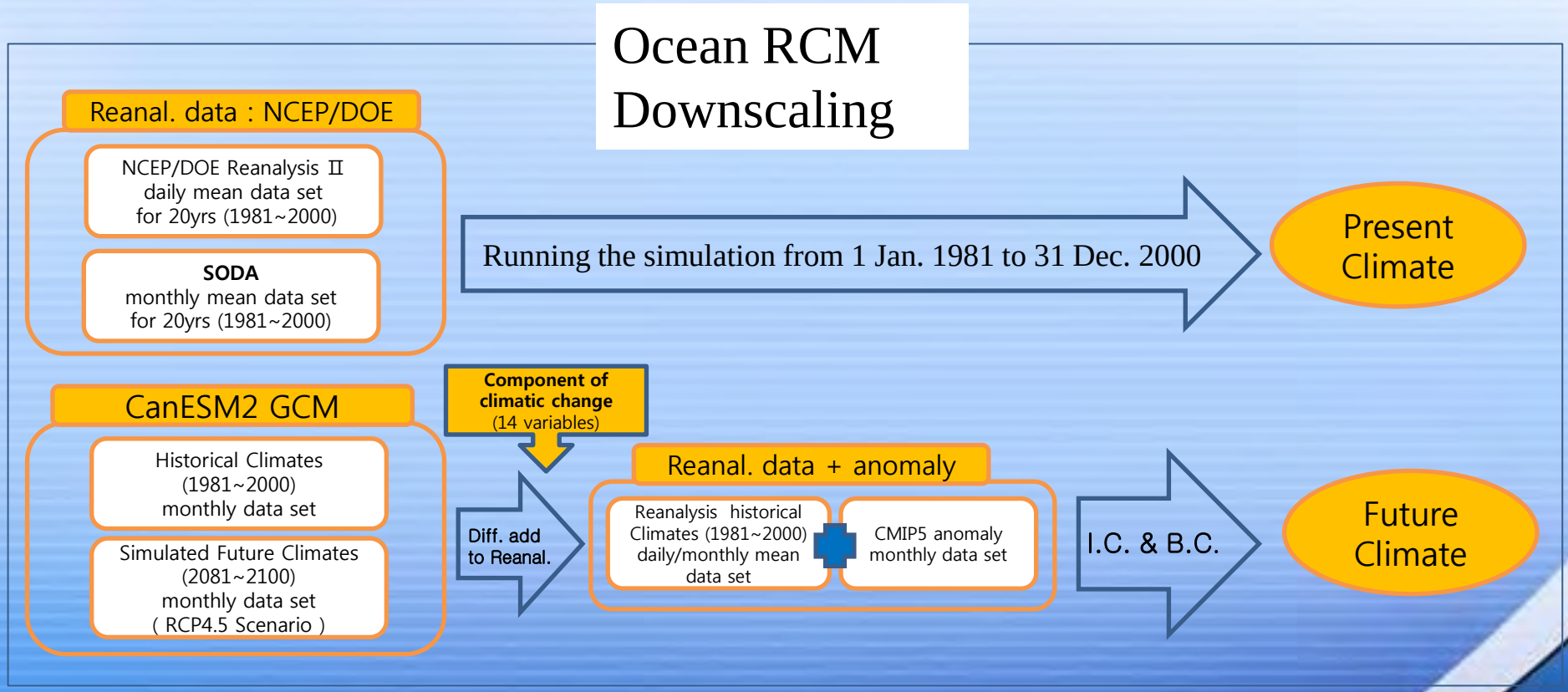
RCM with GCM forcing



ROMS V3.2	
Domain	105°E~175°E, 10°N~55°N
Horizontal resolution	1/12°(≒10km)
Vertical layers	30 layers
I.C & B.C	SODA V2.2.4 monthly mean reanalysis data (u, v, temp. salt. ssh)
	NCEP RA2 daily mean reanalysis with bulk formula and PGW method
Vertical mixing scheme	KPP

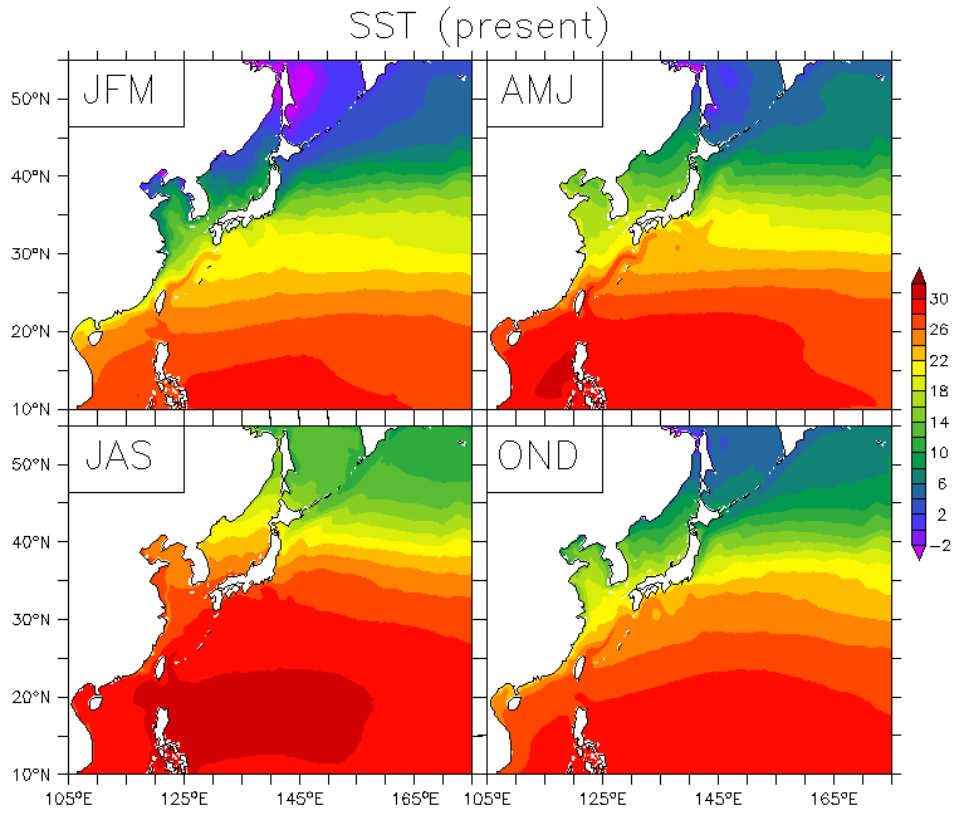
RCM Downscaling PGW

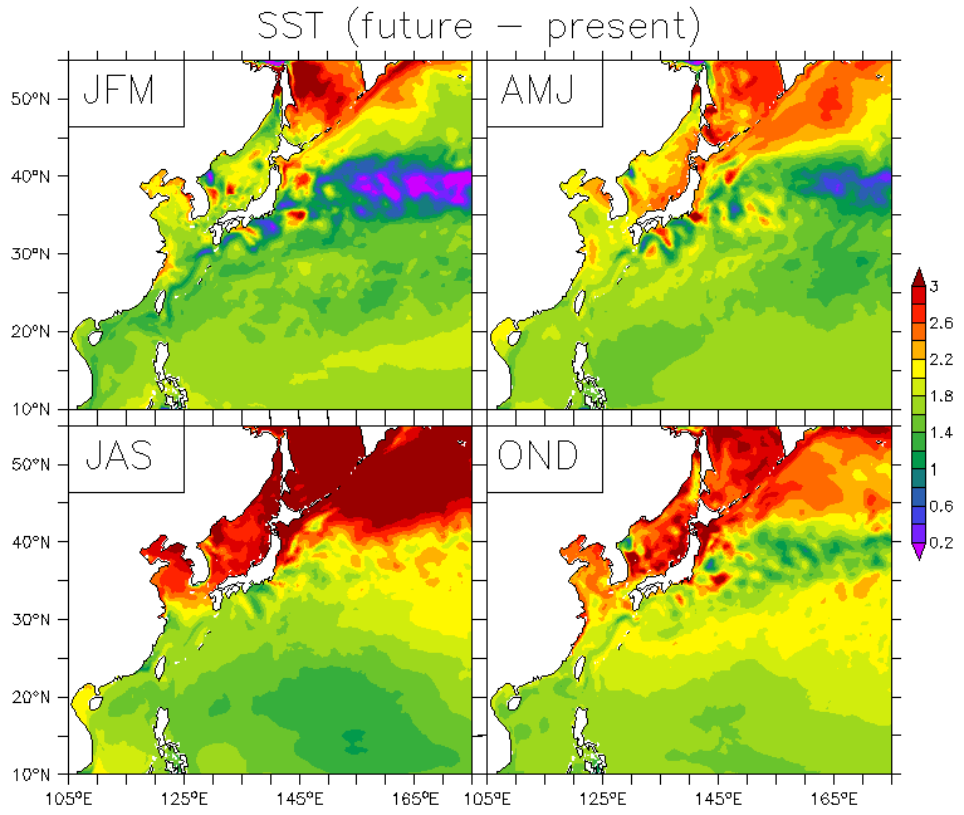
Present: 1981-2000, Future: 2081-2100



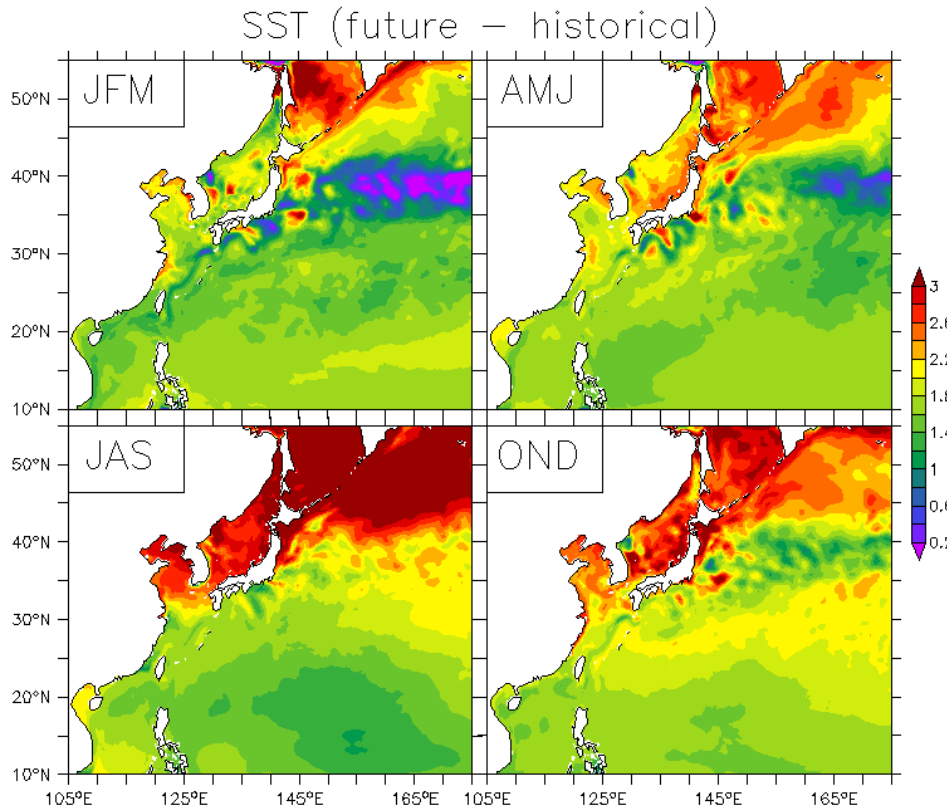
RCM Projected Changes: Preliminary Results

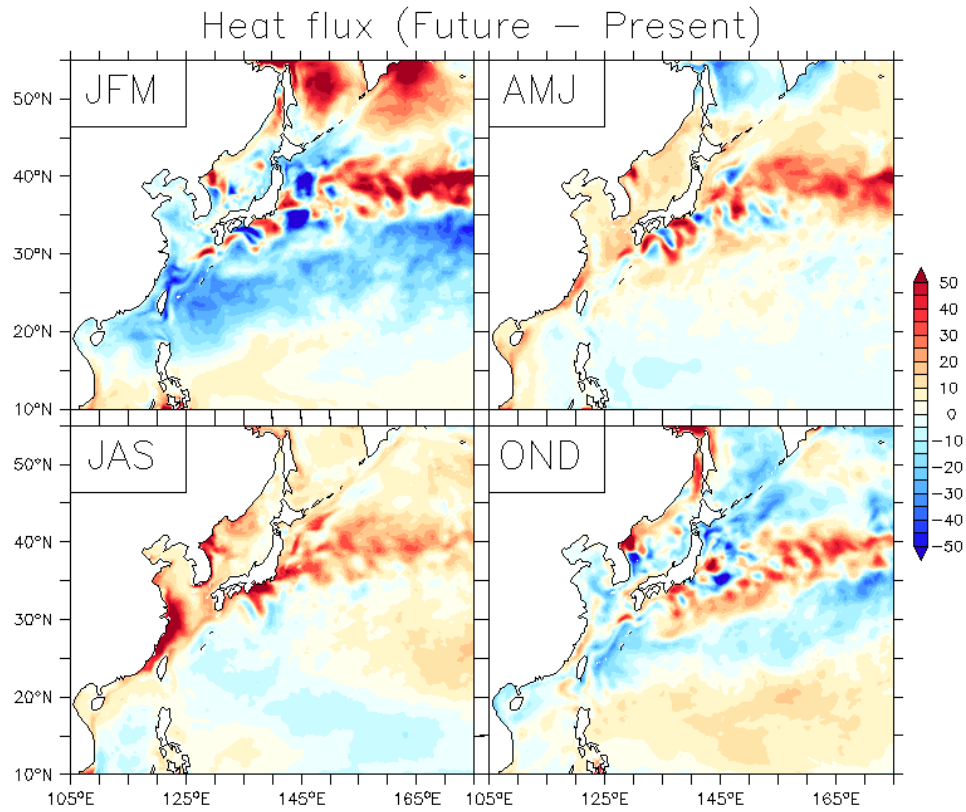
Projected SST change





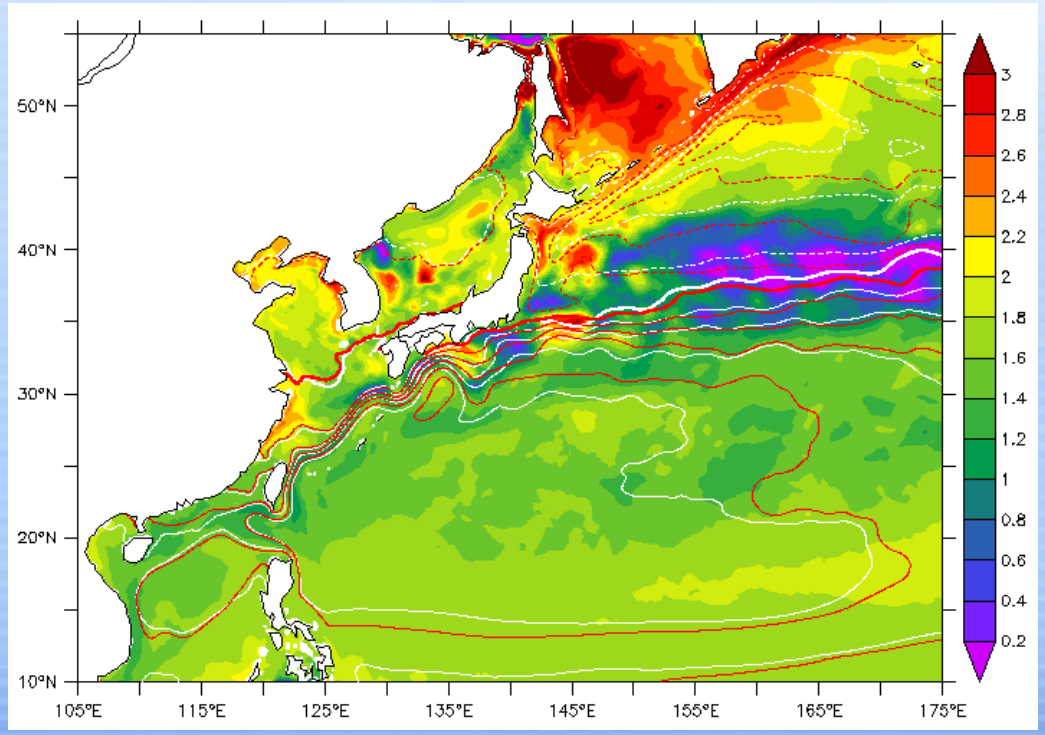
Changes: SST vs. Heat flux





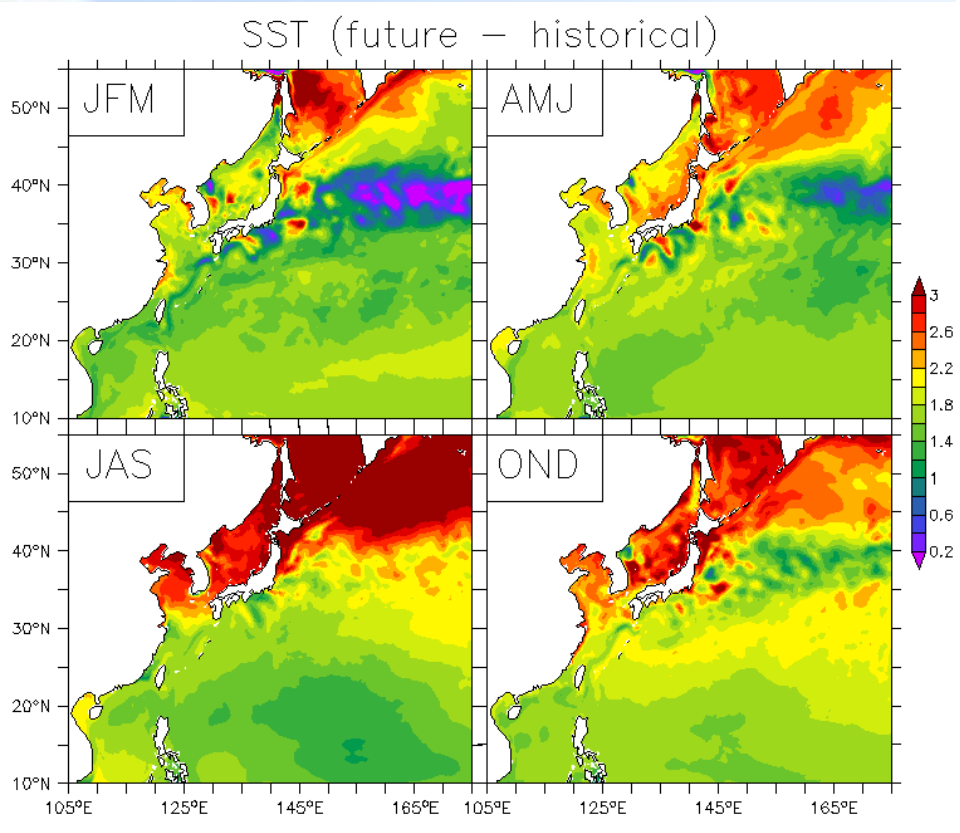
SSH change (winter)

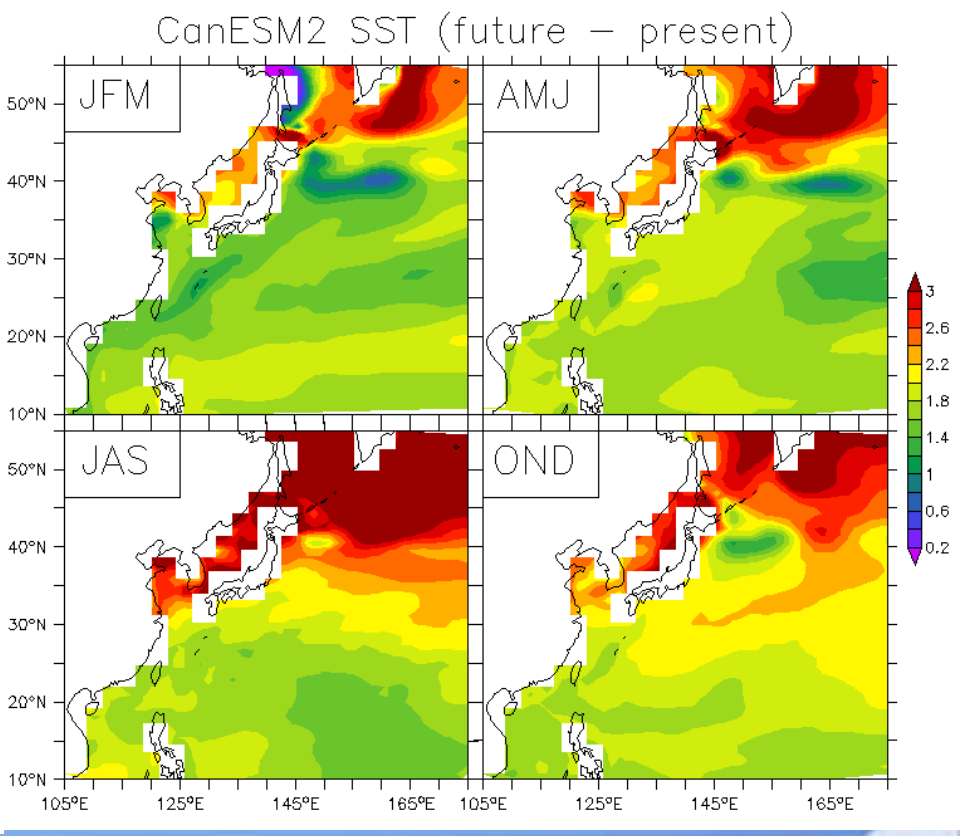
White contours: Present, Red : Future



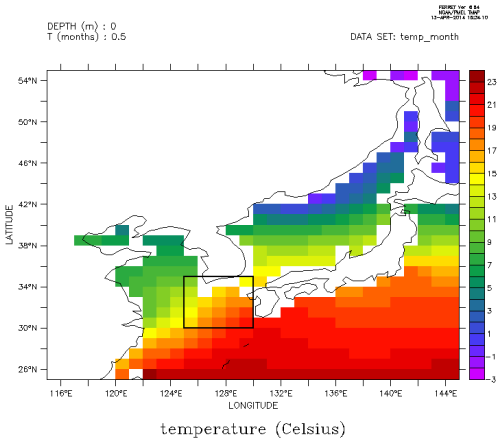
Color shading: SST change

Projected SST changes (RCM vs. CanESM2)

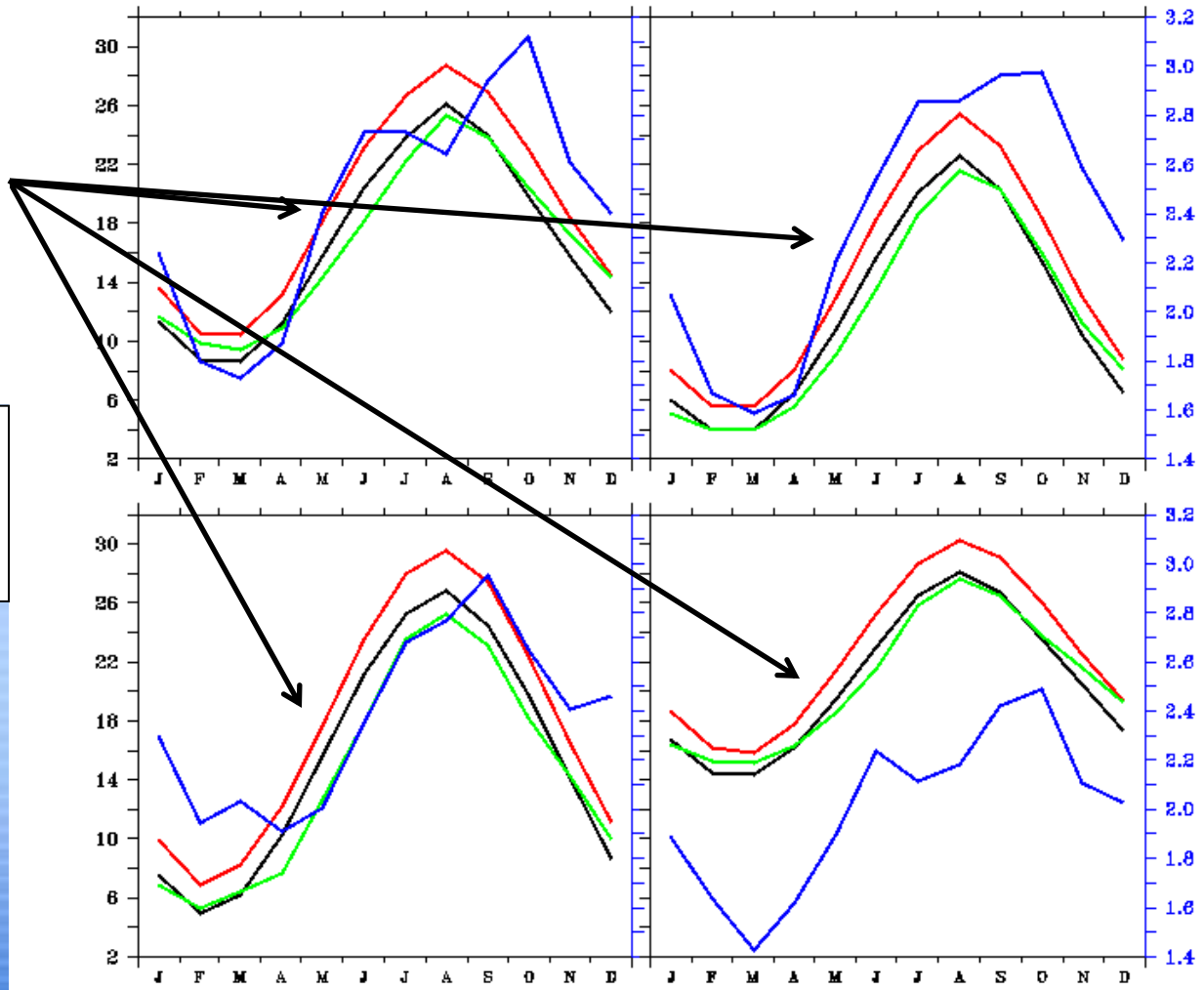




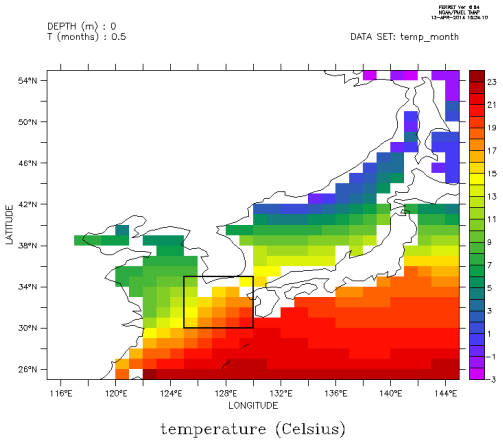
SST change



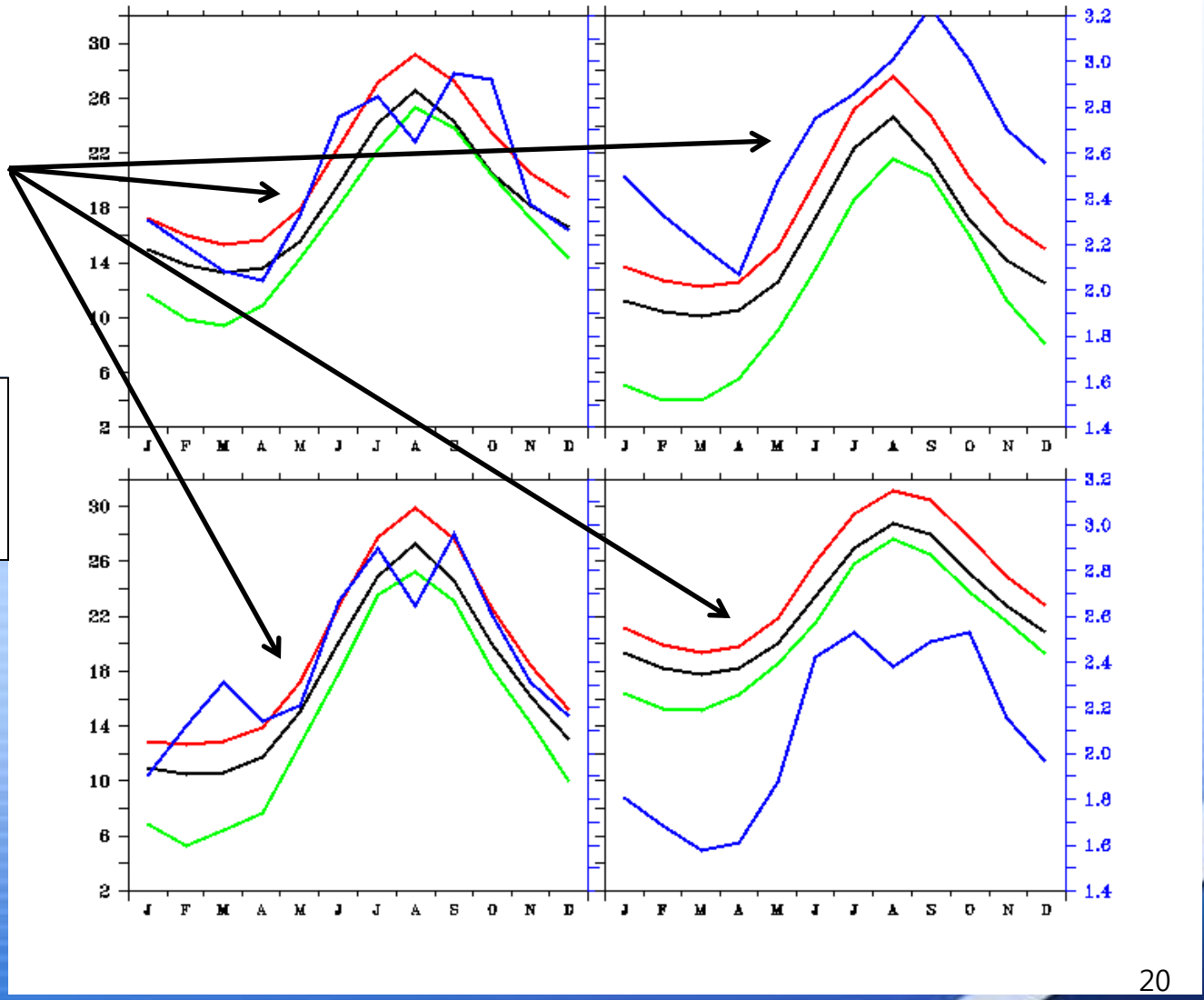
Red : Future
Black : Present
Green : Levitus
Blue : Difference



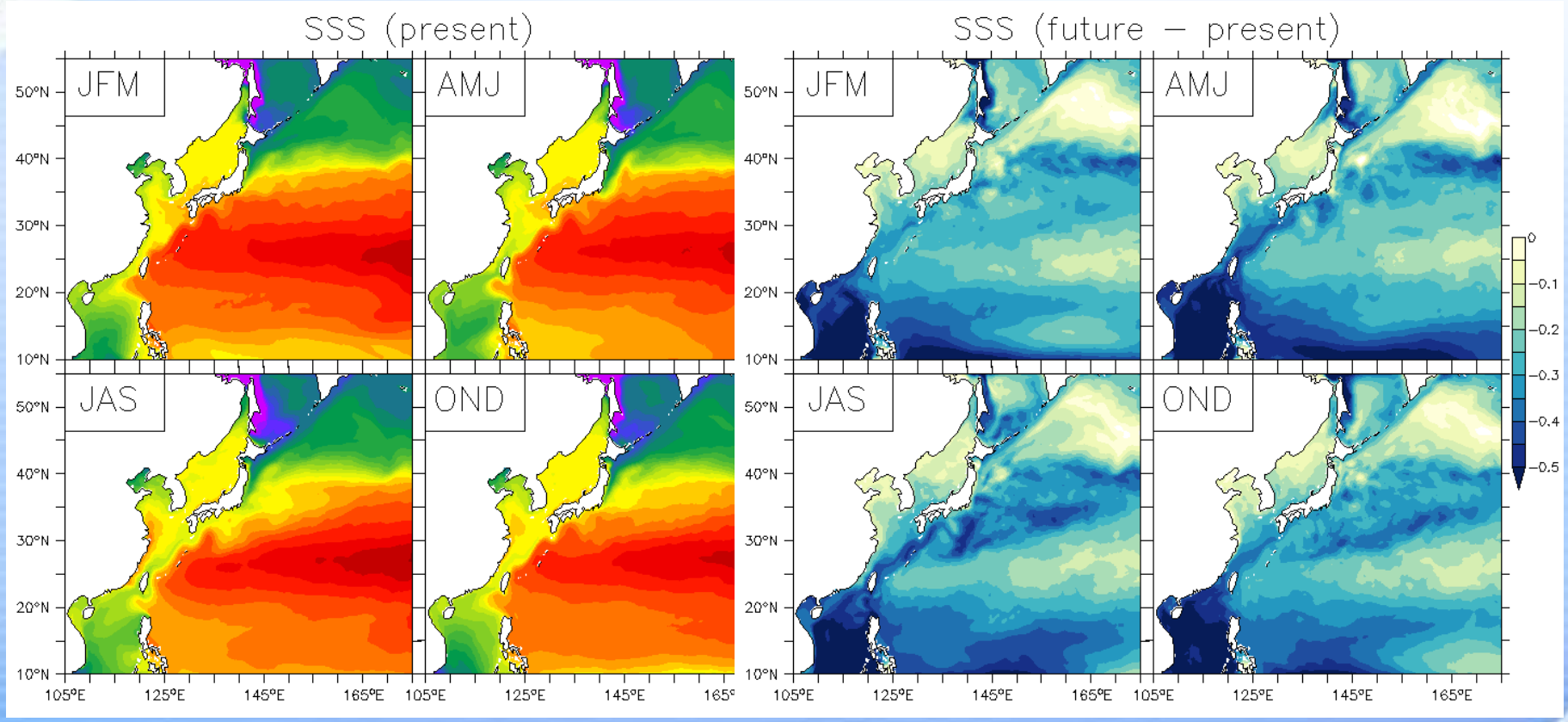
CanESM2 SST change



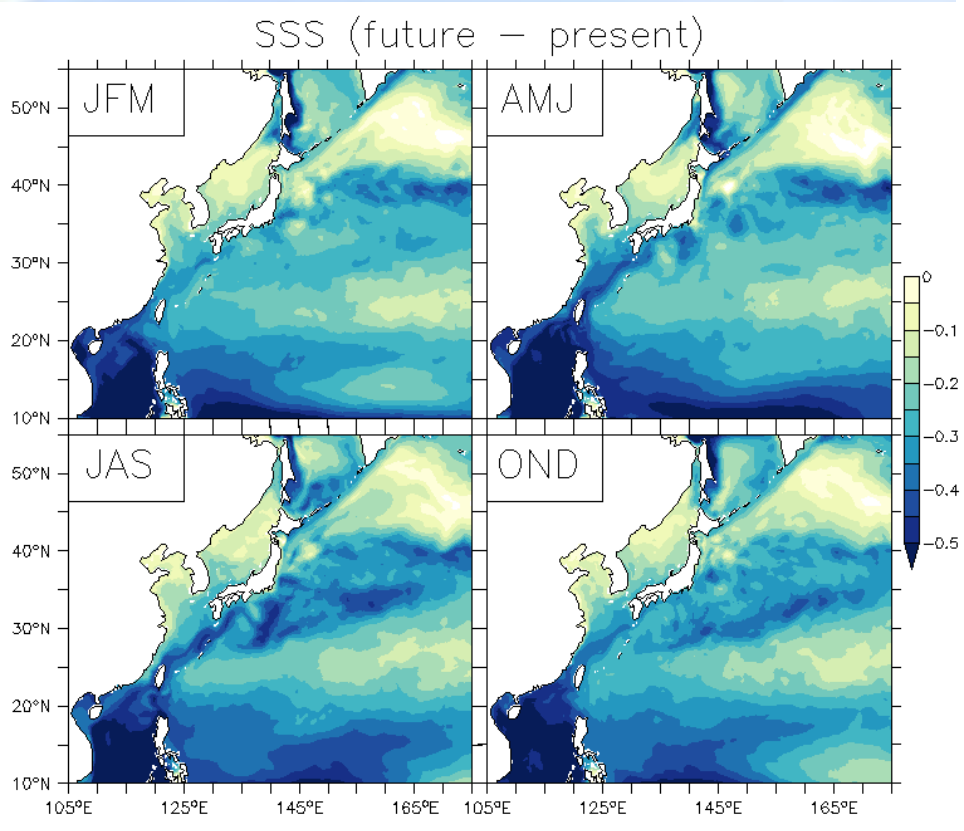
Red : Future
Black : Present
Green : Levitus
Blue : Difference

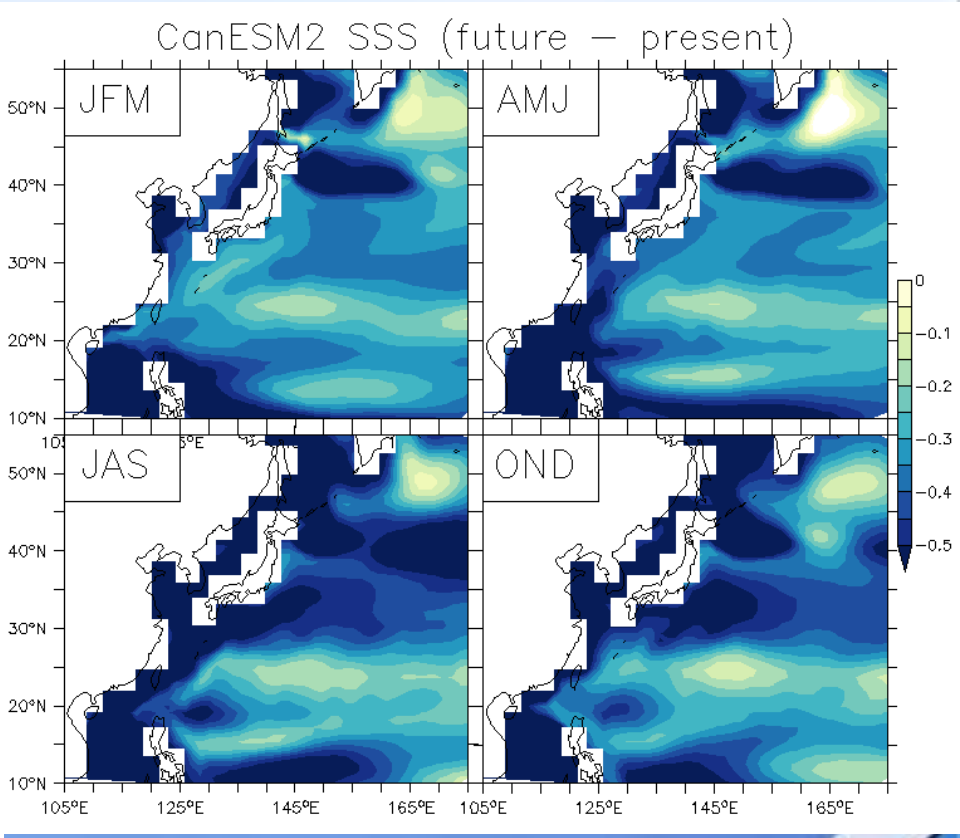


Seasonal SSS change RCM



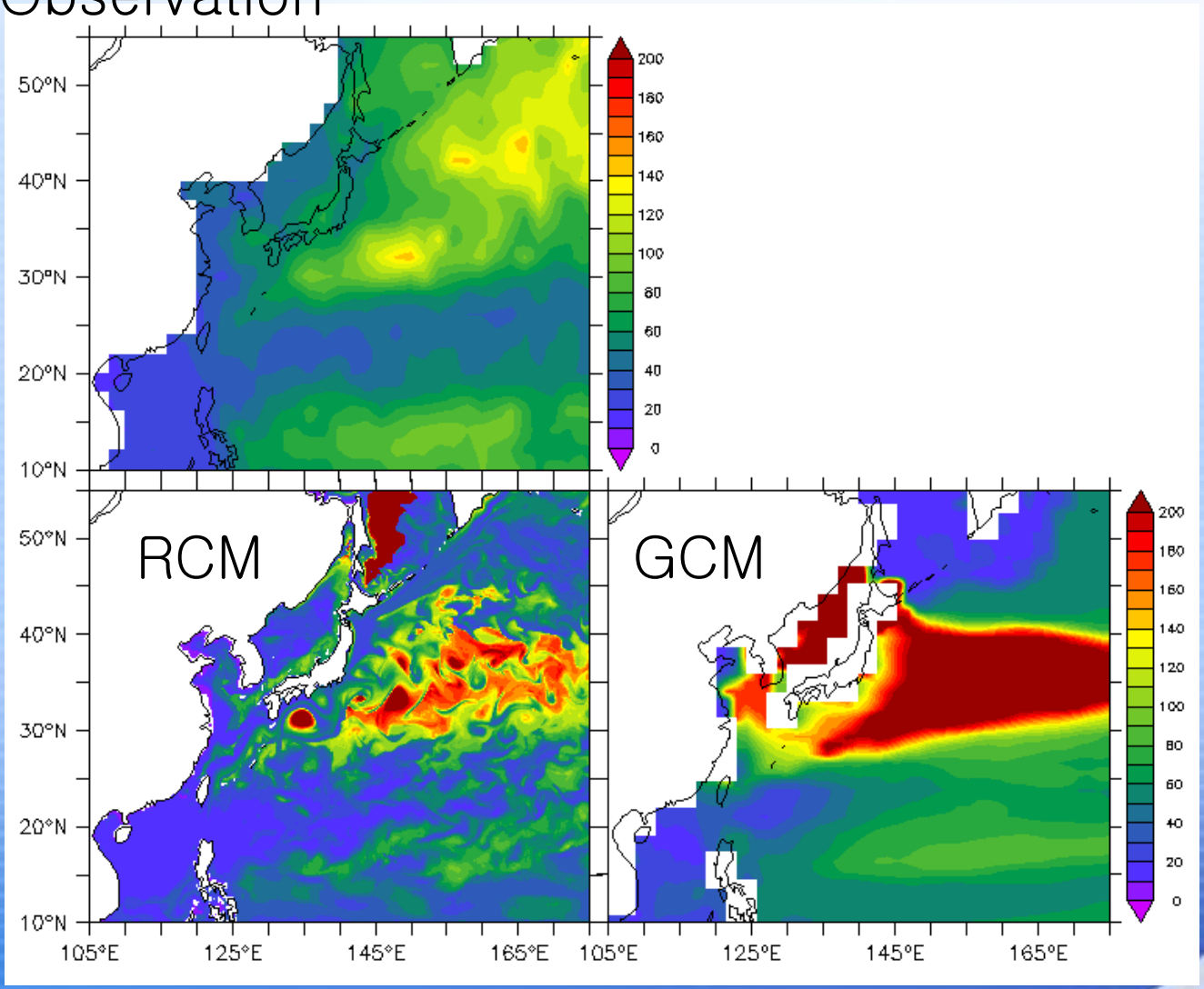
SSS change: RCM vs. GCM



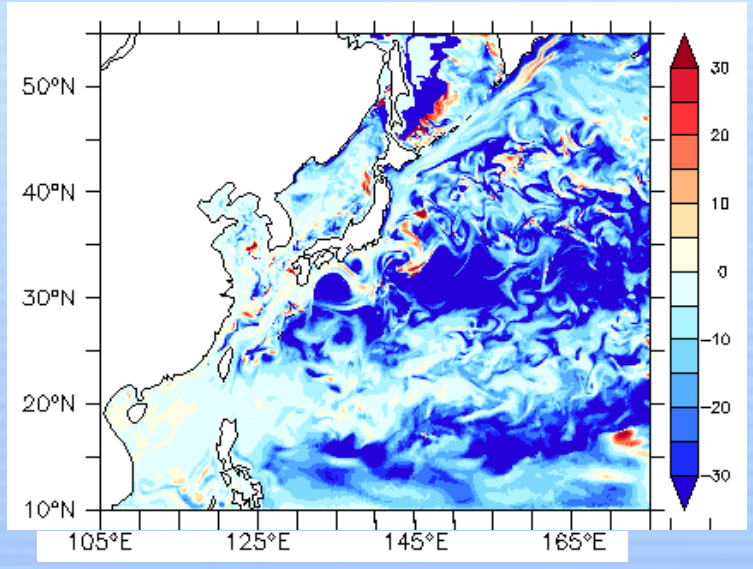


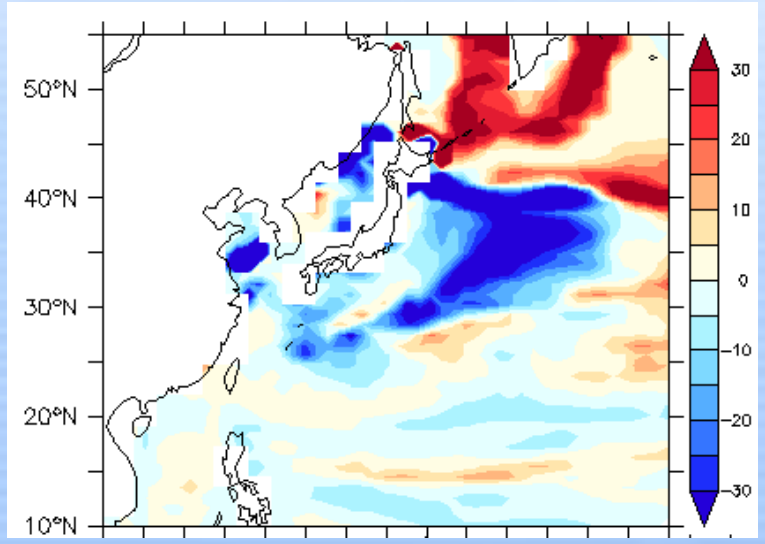
Present MLD (March)

Observation



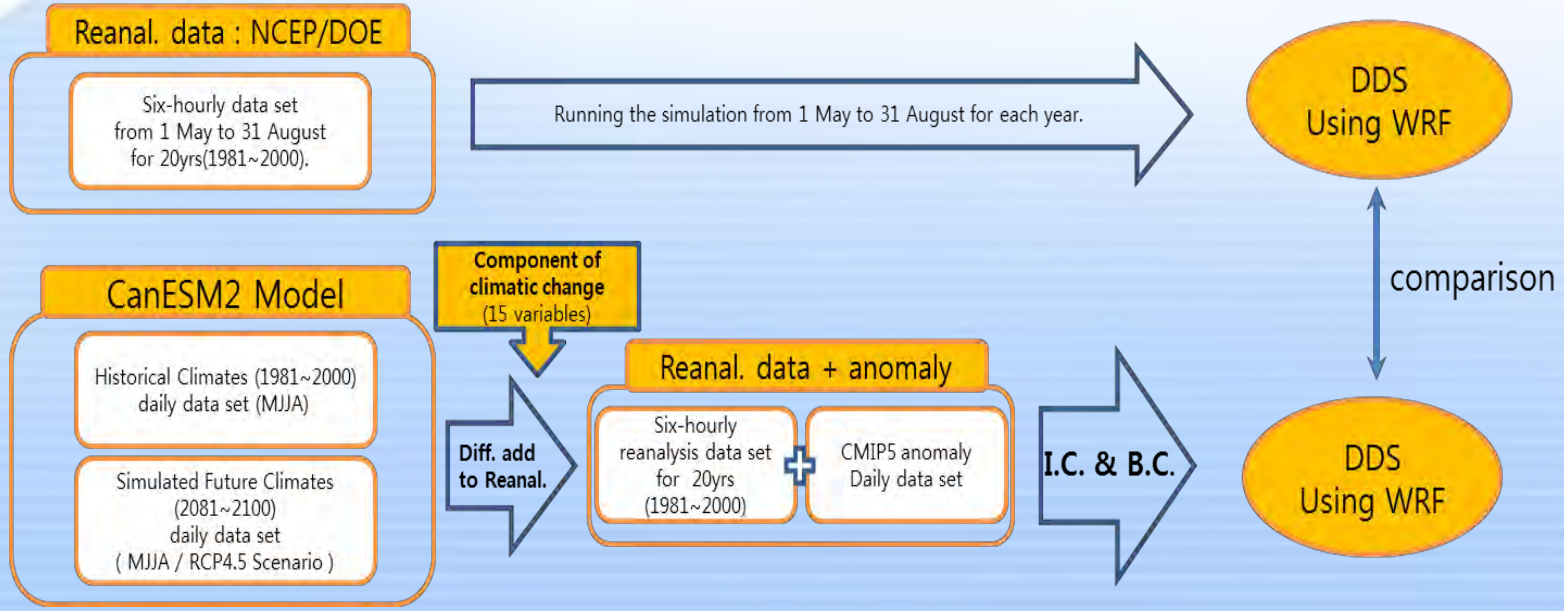
MLD change (March)
RCM vs. GCM





Downscaling for atmosphere

- Pseudo Global Warming Downscaling (PGWDS)

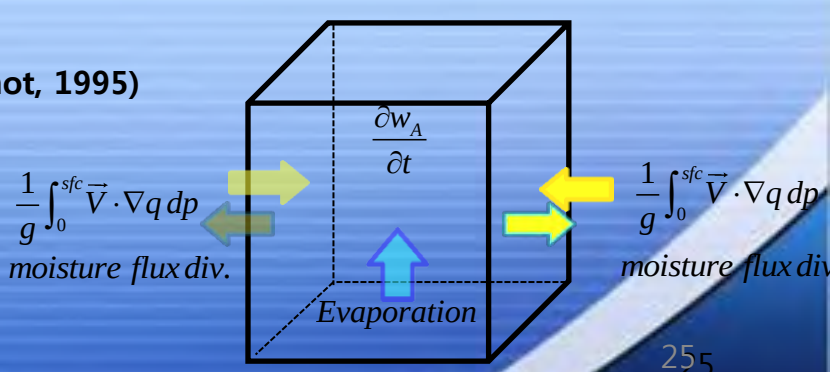


- A column-integrated moisture budget

$$\frac{\partial w_A}{\partial t} + \nabla \cdot \frac{1}{g}\int_0^{sfc} q\vec{V}\, dp = E - P$$ **(Trenberth and Guillemot, 1995)**

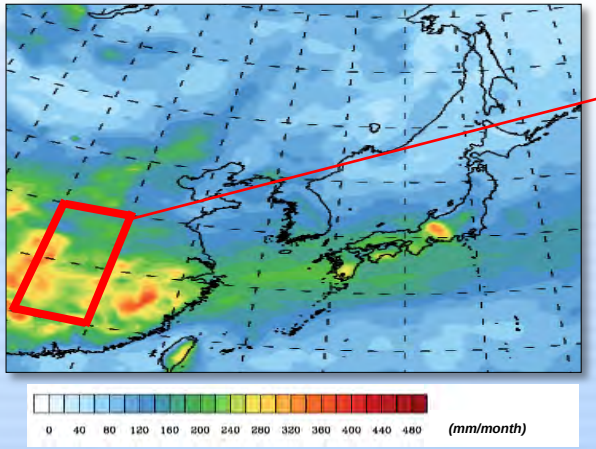
Where, $w_A = \frac{1}{g}\int_0^{p_s} q\, dp$ **Let,** $< > = \frac{1}{g}\int_0^{sfc} dp$

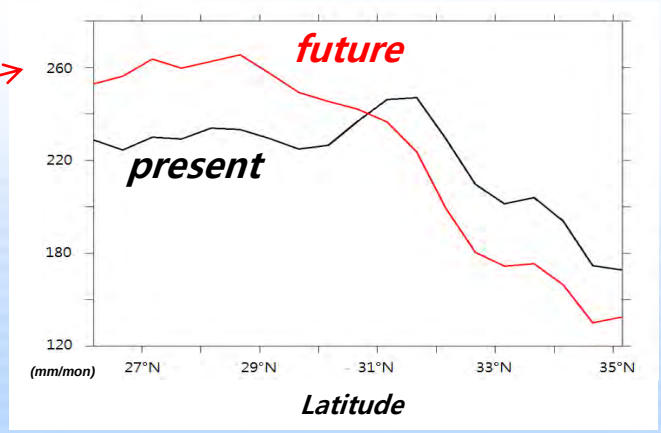
$$precip = -< q\nabla \cdot \vec{V} > - < \vec{V} \cdot \nabla q > + E - \frac{\partial w_A}{\partial t}$$



Projected precipitation changes and analysis

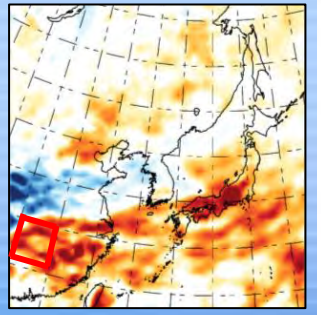
Summer (MJJA) mean precipitation

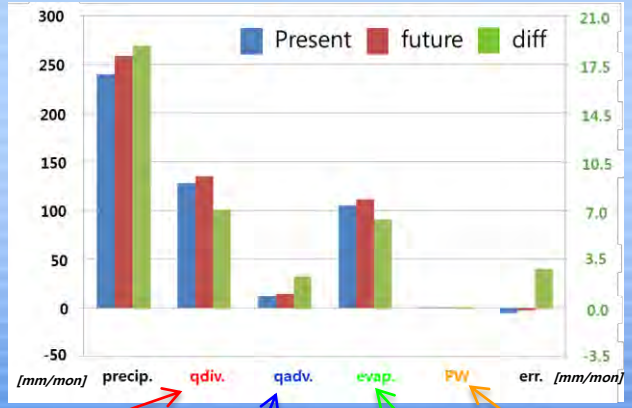




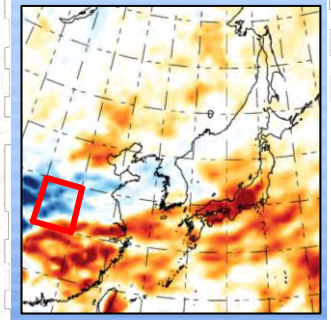
- Moisture diagnoses of precipitation change

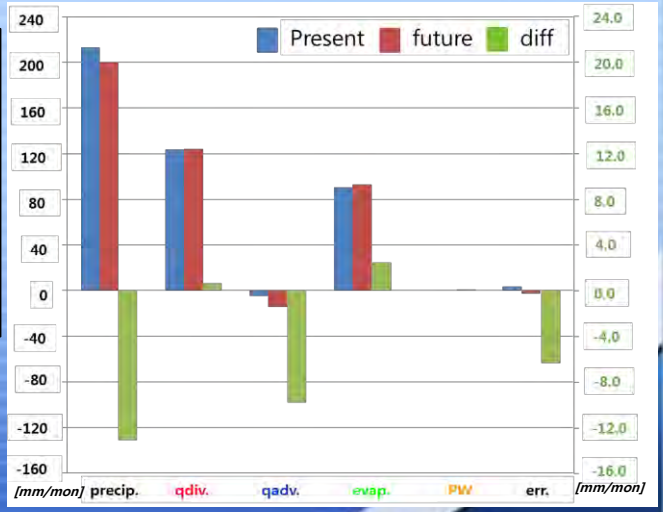
Area averaged precip. (26N~30N, 110E~115E)





Area averaged precip. (30N~35N, 110E~115E)



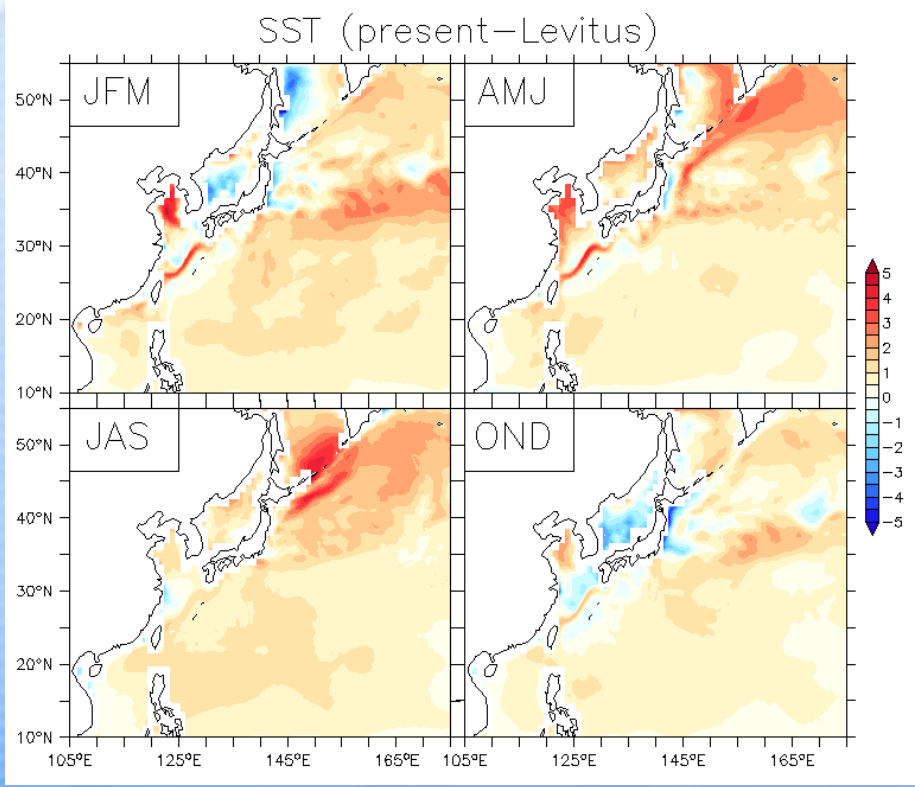


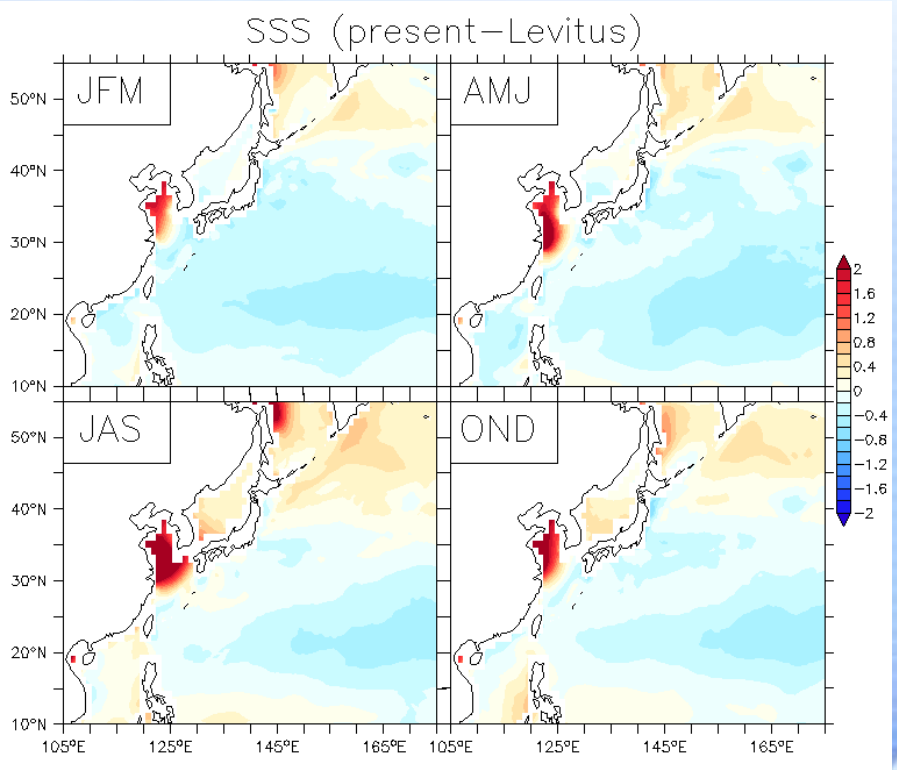
$$precip = \underbrace{-<q\nabla\cdot\vec{V}>}_{\text{qadv.}} \underbrace{-<\vec{V}\cdot\nabla q>}_{\text{qdiv.}} + \underbrace{E}_{\text{evap.}} - \underbrace{\frac{\partial w_A}{\partial t}}_{\text{precipitable water}}$$

Future works

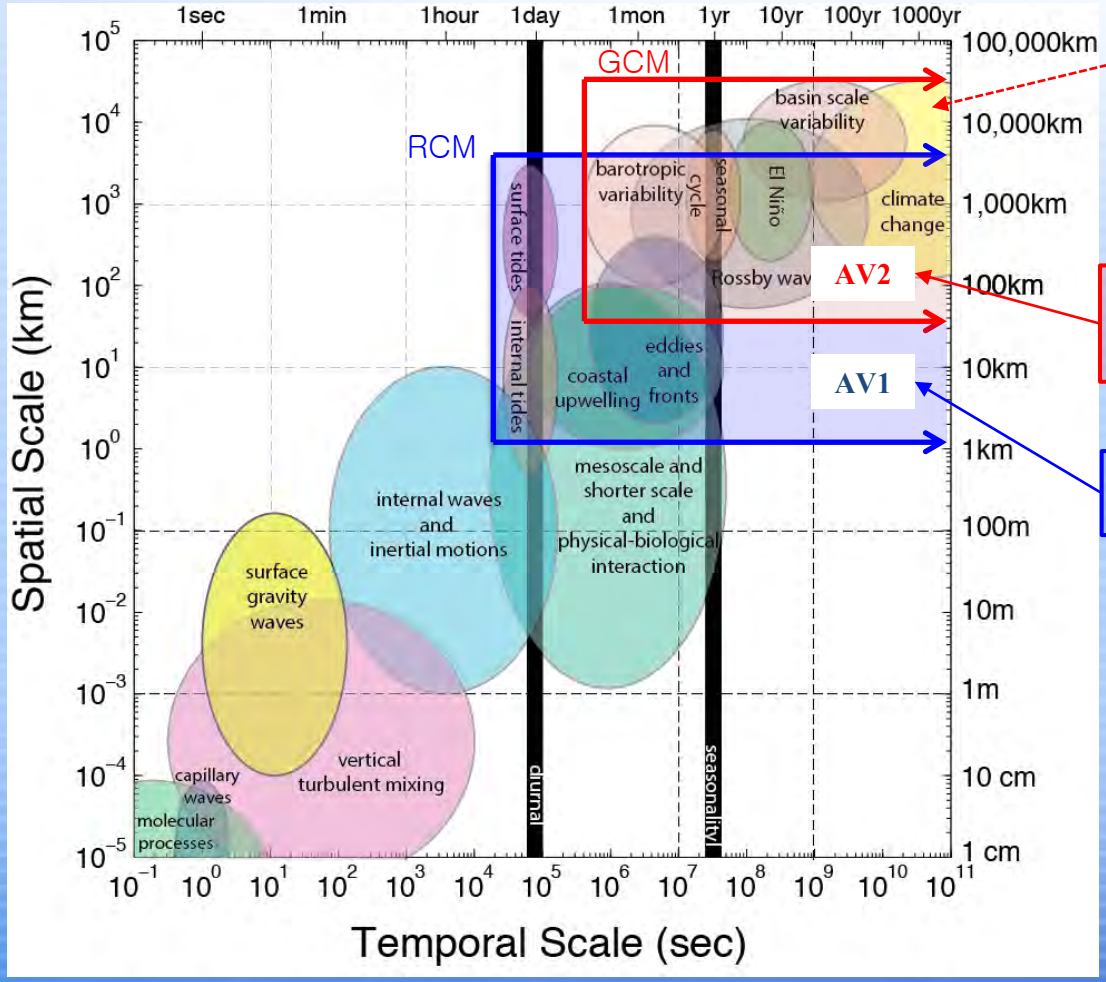
- RCM evaluation & improvement
- Comparison with existing downscaling projection (mostly AR4)
- Ocean downscaling with downscaled atmosphere for global warming projection
- Identify some added value by the RCM projection
- Ensemble experiments
  - Multi-scenarios
  - Multiple warming exp. Approaches

RCM biases (present - Levitus)





Added Value by ORCMs



RCM cannot provide scale larger than domain size and integration period

AV2

Improvement of commonly represented processes in both GCM and RCM

AV1

Small-scale processes such as Extremes only resolved in RCMs

Based on Chelton (2001) & Luca et al (2012)

Thank you