SOUSEI Program for Risk Information on Climate Change
気候変動リスク情報創生プログラム

CLIVAR WGOMD Workshop on high-resolution ocean climate modelling

Atmospheric responses to the NP mid-latitude SST induced by the WBCs represented in MIROC5 coupled with a nested regional ocean model

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Atmosphere and Ocean Research Institute
the University of Tokyo

NIES

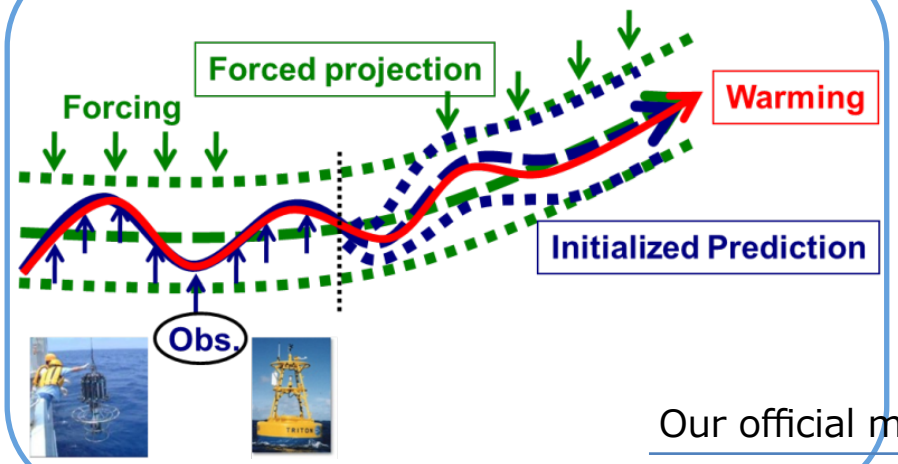
Decadal climate prediction for IPCC-AR5/CMIP5 using MIROC

System for Prediction and Assimilation using MIROC (SPAM)

MIROC

Miroku (Maitreya)

Ocean T/S assimilation



Our official models for CMIP5

	AGCM	OGCM
MIROC4h	T213L56	0.25 deg., L48
MIROC5	T85L40	1.40 deg., L50

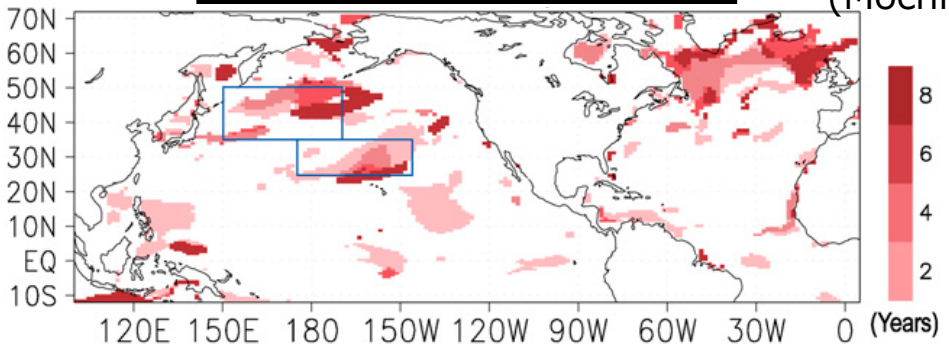
Prediction of decadal climate change

- Global warming by GHGs (externally forced mode; IPCC-AR4)
- Internal variation (e.g., IPO, AMO) ← Initialization by ocean data assimilation (T/S)

Global-scale climate predictions in MIROC

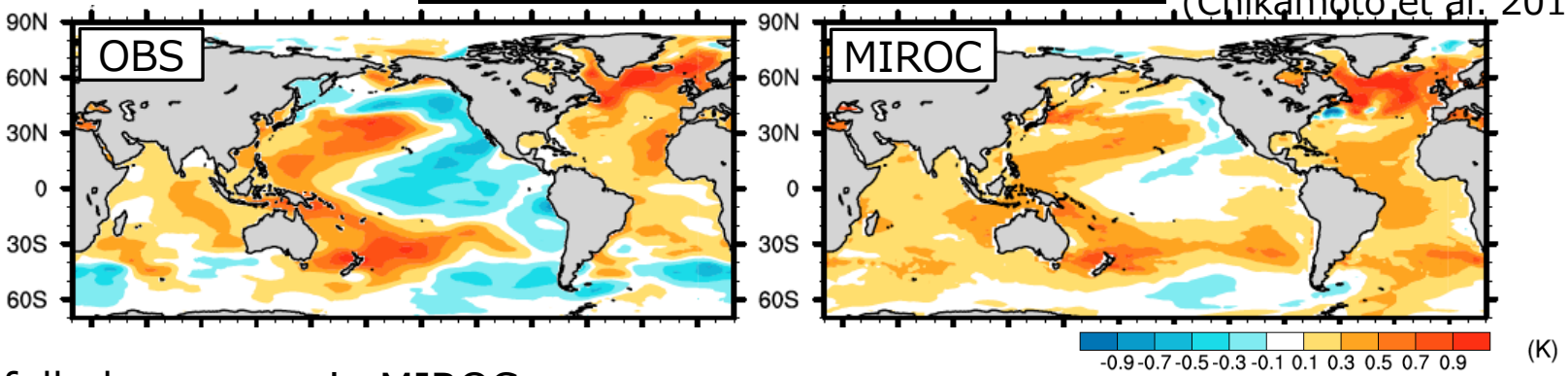
Predictive VAT300 Area

(Mochizuki et al. 2010)



SST change from 91/95 to 00/04

(Chikamoto et al. 2012)



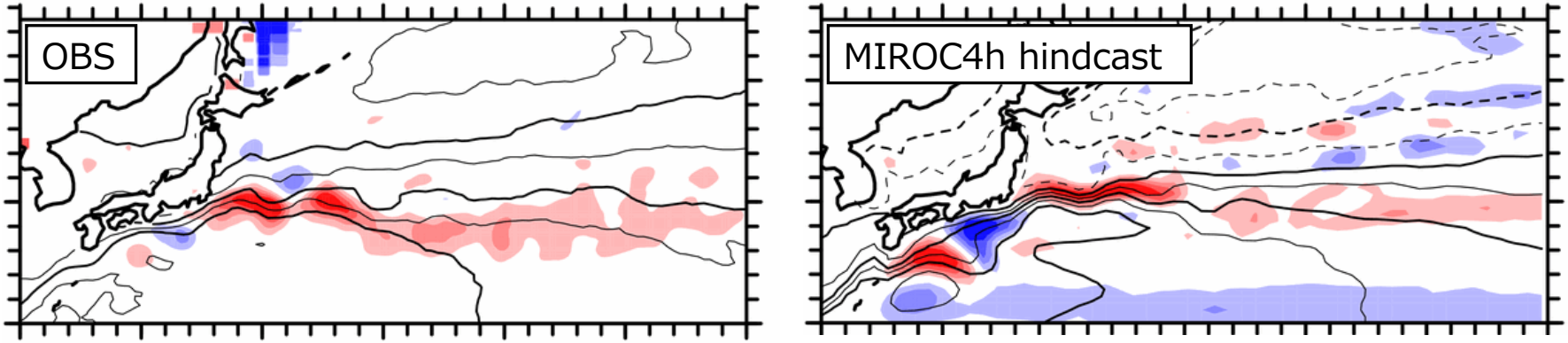
<u>Skillfull phenomena in MIROC</u>

- Mid-latitude SST and VAT300 variations associated with PDO
- Stepwise climate shift over the Pacific during the late 1990s
- Year-to-year tropical cyclone number variations in the western North Pacific (Mori et al. 2013)

Prediction of the ocean currents in the Kuroshio-Oyashio confluence

Hindcast experiment starting from 1996 (MIROC4h, 3 member)

SSH change between 2001/05 mean and 94/97 mean

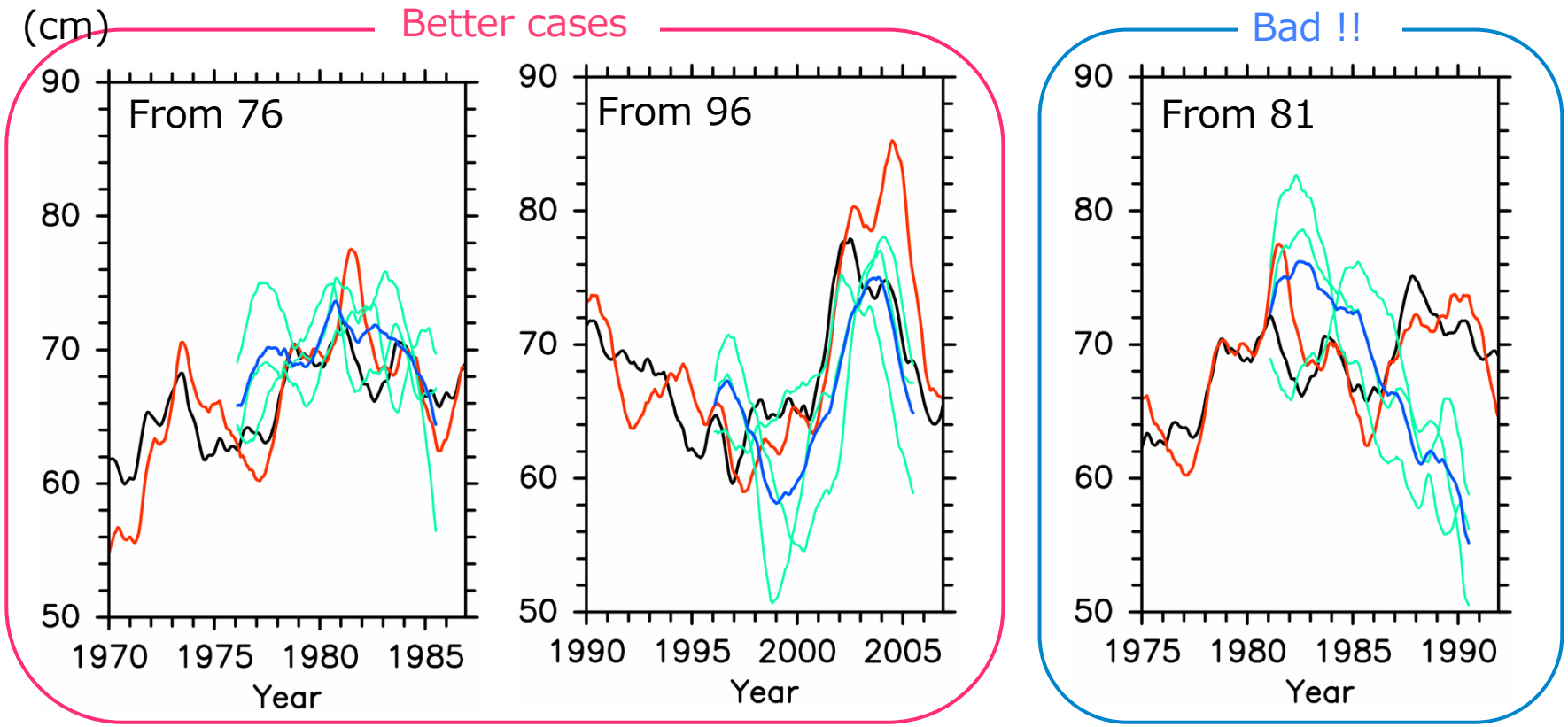


・Strengthening of the Kuroshio Extension is represented well.

Prediction of the Kuroshio Extension change

KE strength in Hindcast, Observation, Assimilation

※ KE strength : Meridional SSH difference across the KE axis



- Not enough skills of the currents changes
- Difficulty in providing useful information for adaptation

  to marine ecosystem changes in the next decade

What are needed for better climate predictions and further regional ocean ?

MIROC group

- Improvement of model climatology and variability — Update of MIROC5
- Better initialization (adequate spread, smaller errors) — LETKF initialization
- Reduction of uncertainties in climate sensitivity associated with CRF — PPE and MPE
- Physical understanding of target phenomena
- High-resolution modeling with less computational cost for large ensemble

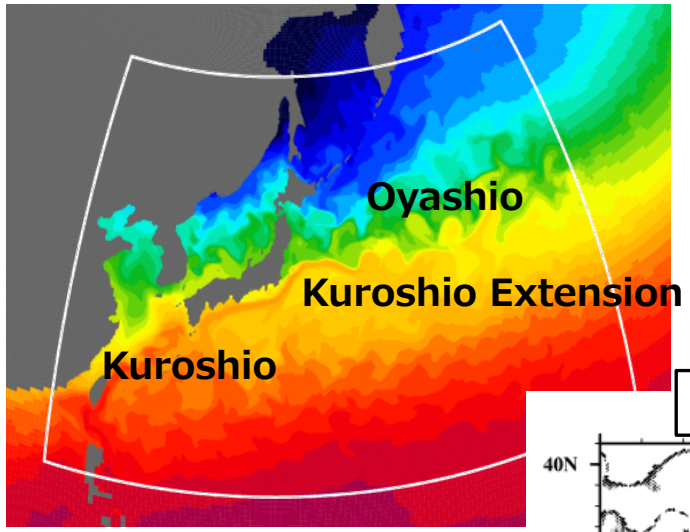
  → COCO/MIROC5 coupled with a nested regional ocean model

Today's topic

Influence of SST in the WBC region on wintertime STA and westerly jet over the NP

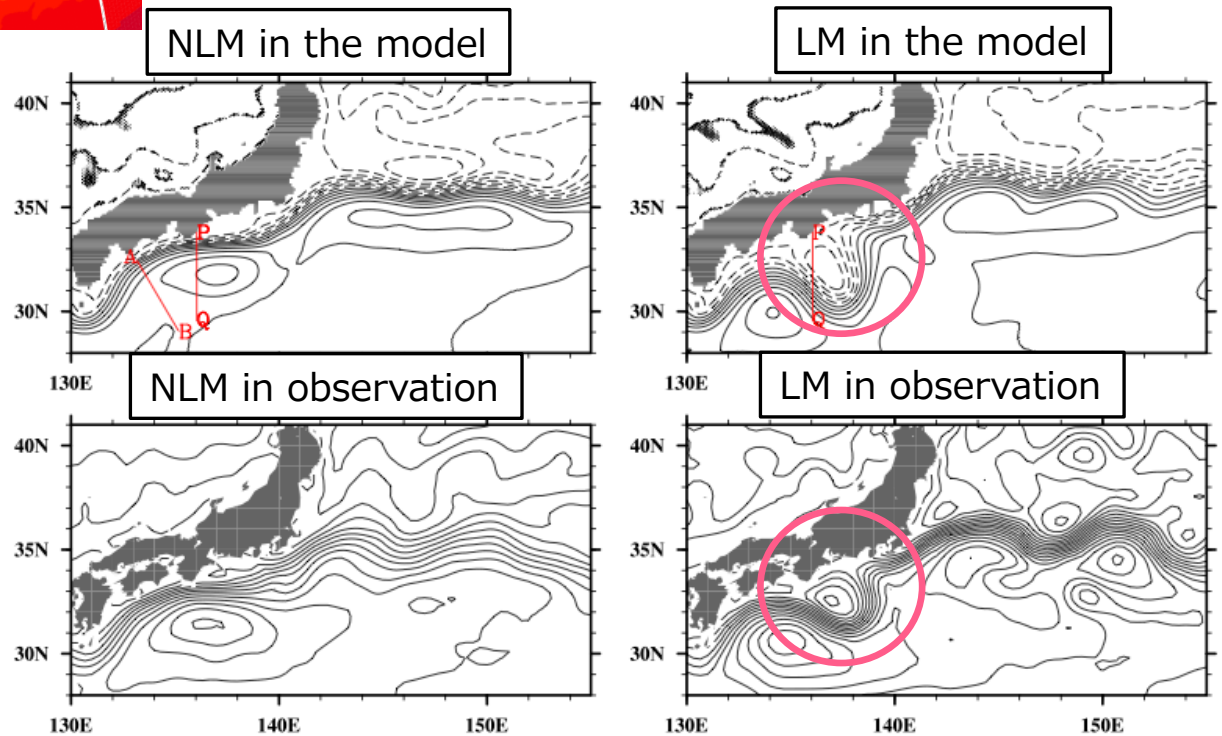
COCO coupled with a regional model embedded in the western NP

Snapshot of SST in the nested region



Large Meander
Non-Large Meander

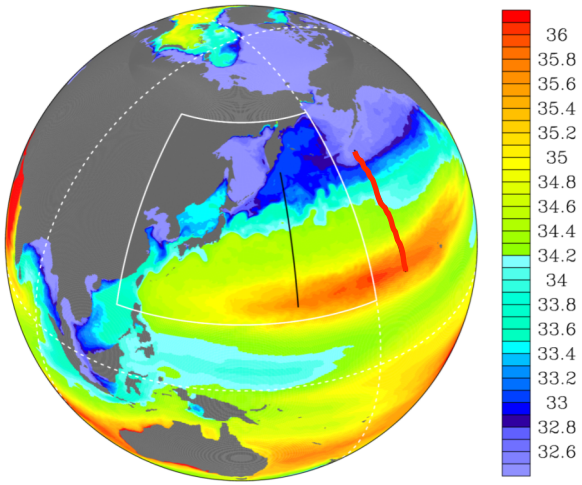
Bimodal path of the Kuroshio south of Japan

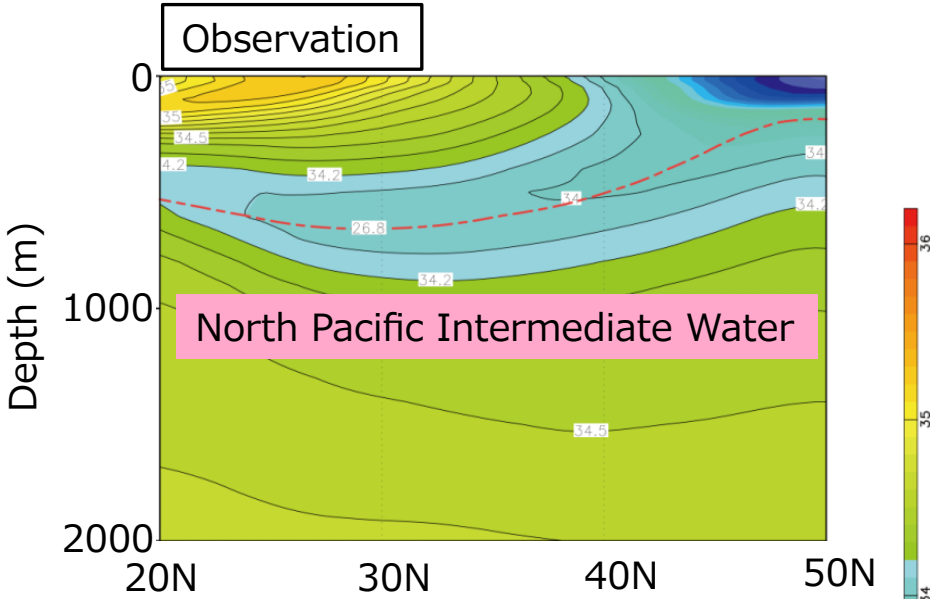


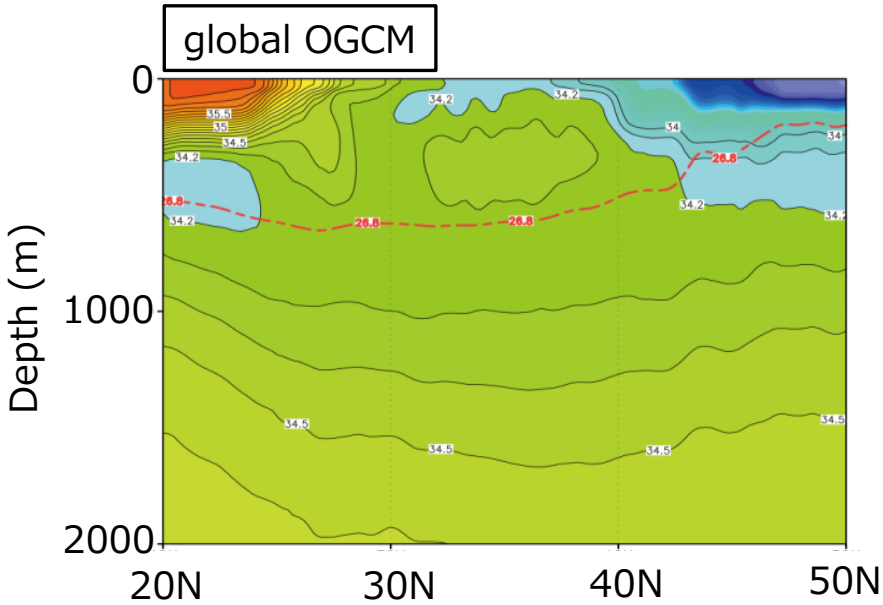
(Kurogi et al. 2013, JGR)

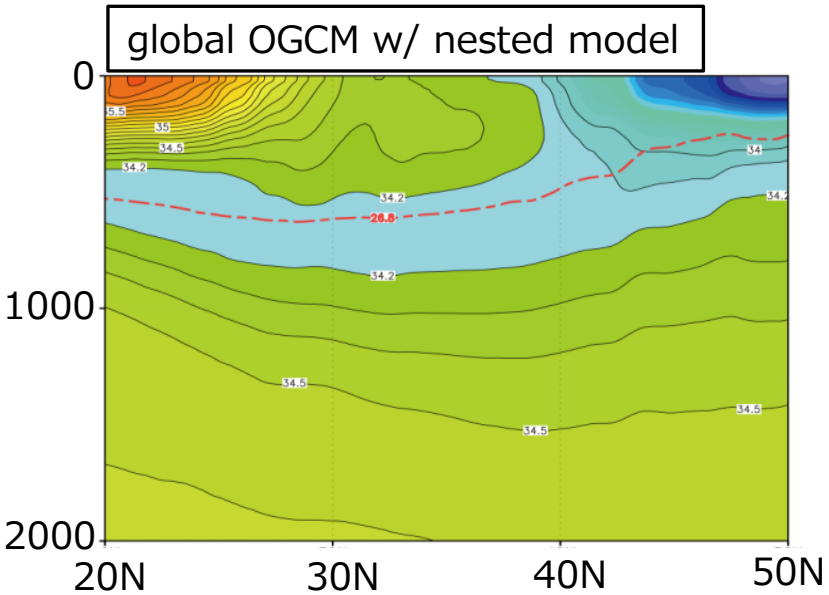
COCO coupled with a regional model embedded in the western NP

Salinity along 170°W









MIROC coupled with a nested regional ocean model

Two-way nested regional ocean model by Kurogi et al. (2013, JGR)

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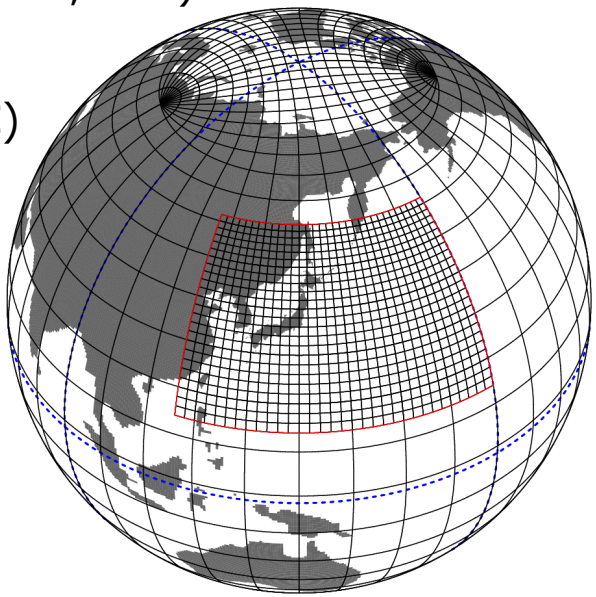
Climate model MIROC5 (Watanabe et al. 2010, JC)



MIROC5 with a nested regional OGCM (MIROC5n)

ATM	global	T85L40 (TOA 3hPa)
OCN	global	0.5° x 0.5°cosθ, L50, tripole
	regional	0.1° x 0.1°cosθ, L50, lat-lon

MIROC5n is integrated for 70 years.

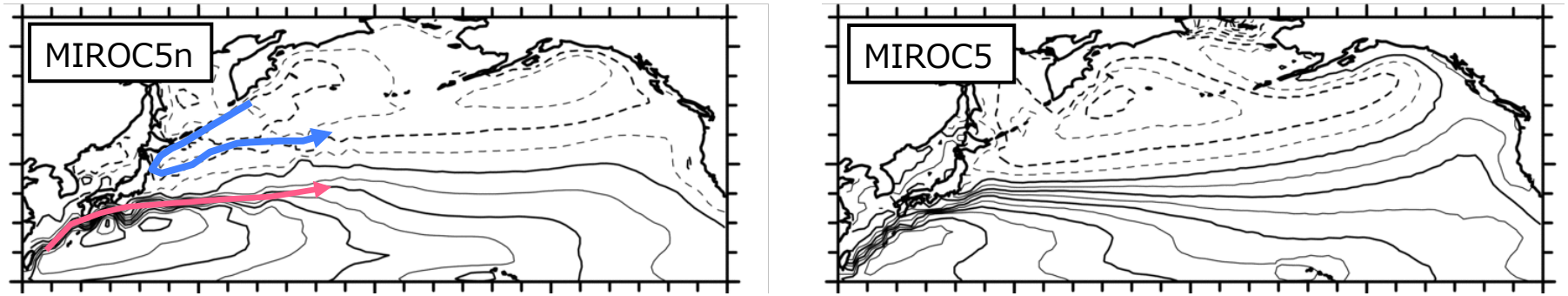
Using the last 30-yr-long data, climatological differences between MIROC5n and MIROC

- SST, current structure
- wintertime storms activity and its feedback to Aleutian Low

are examined.

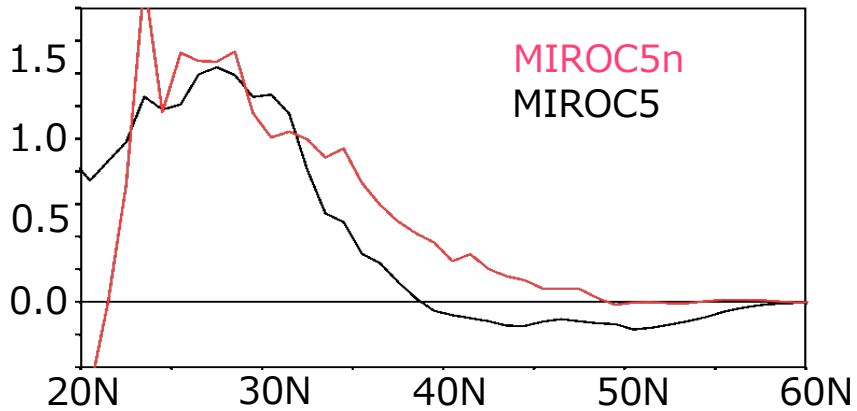
Ocean currents to the east of Japan

Annual-mean sea surface height



・Realistic currents in MIROC5n (clear fronts, location of the Oyashio front)

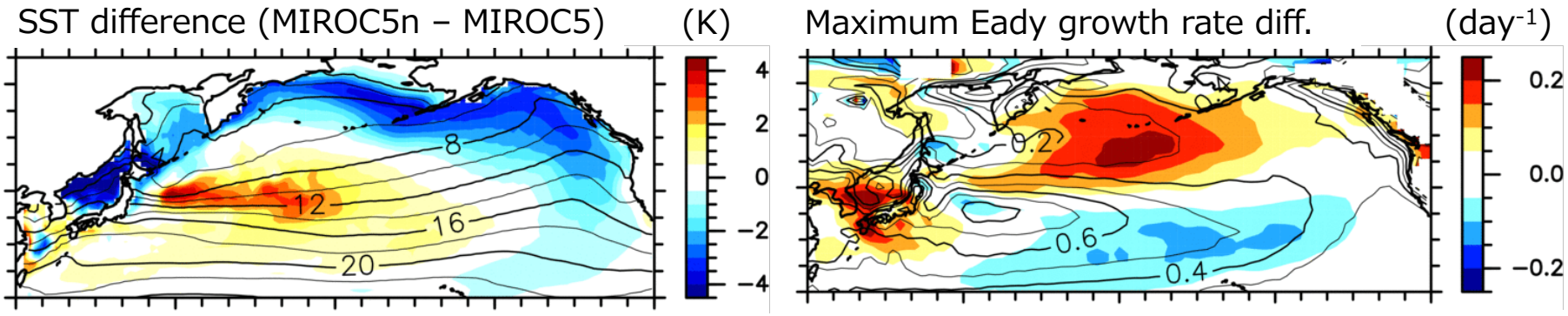
Meridional heat transport (140°E-180°)



・Warm (cold) water transport by the Kuroshio (Oyashio) is increased (decreased).

Wintertime difference of SST and surface baroclinicity

$$0.31\frac{f}{N}\frac{\partial U}{\partial z}$$



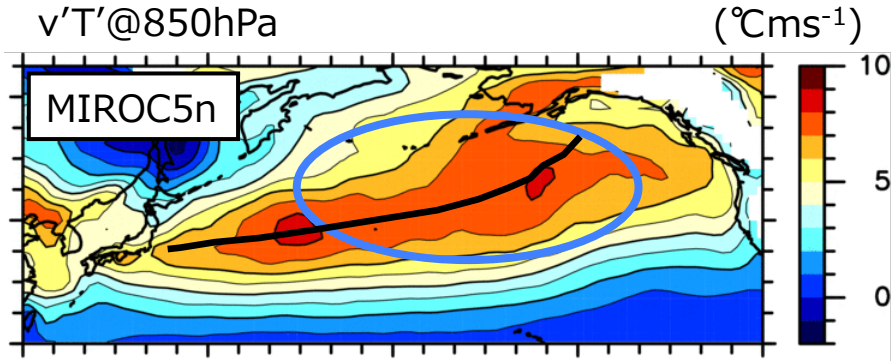
In MIROC5n,

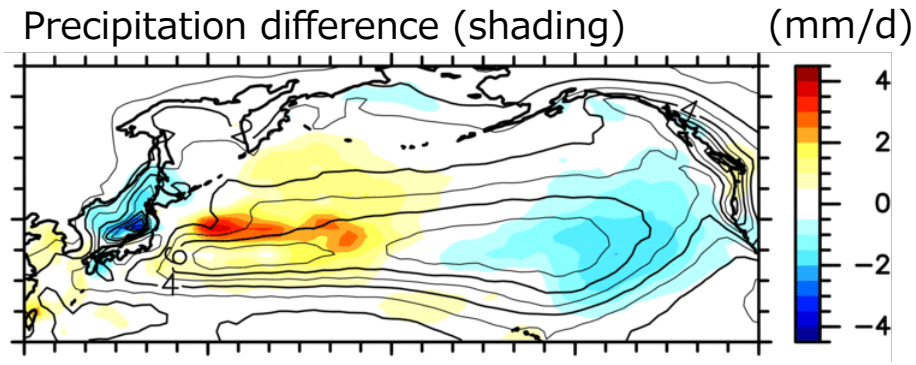
- Warmer SST to the east of Japan
- Colder SST along the west coast of North America (discussed later)

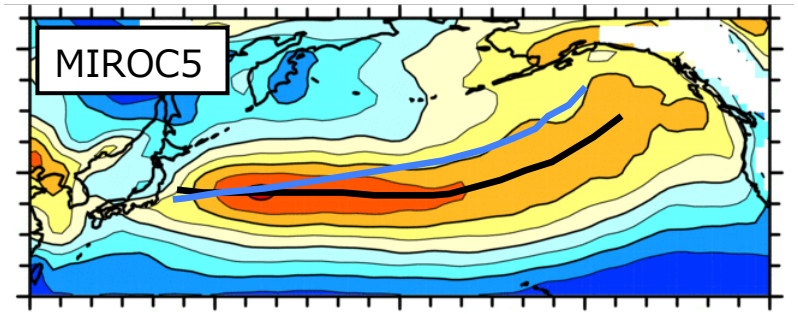
→ Meridional SST gradient in the subarctic North Pacific is larger in MIROC5n.

Eady growth rate becomes larger through thermal wind relation.

Difference of wintertime storm track activity and precipitation







8day highpass filter is used to extract synoptic scale disturbances.

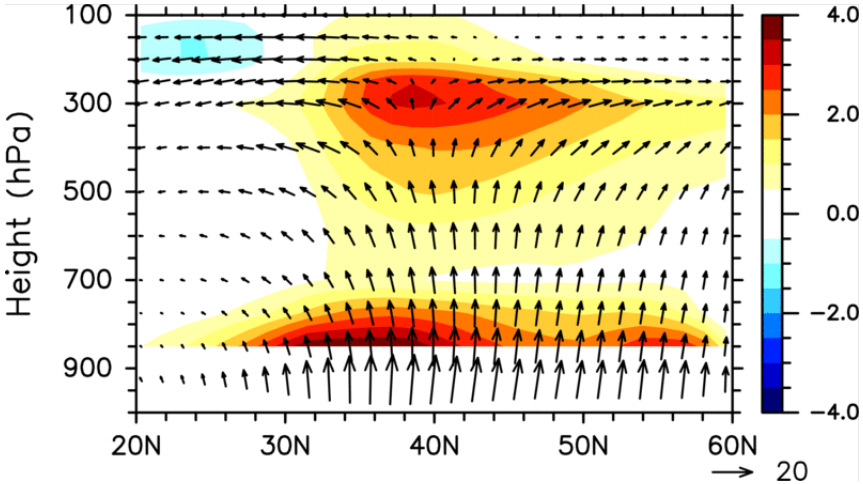
In MIROC5n,

- Wintertime STA becomes larger and its maximum shifts/extends northward.
- Precipitation is increased in the KO zone.

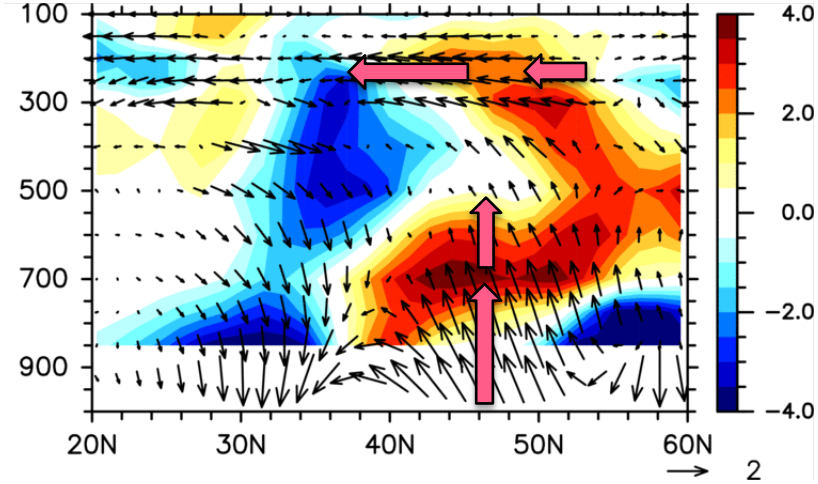
Zonal-mean E-vector (Hoskins et al. 1983;140°E and 120°W)

$$\left(\overline{v'-u'}, -\overline{u'v'}, f\frac{\overline{v'T'}}{T_p}\right)$$

E-vector and its divergence in MIROC5



Difference in E-vector and its divergence



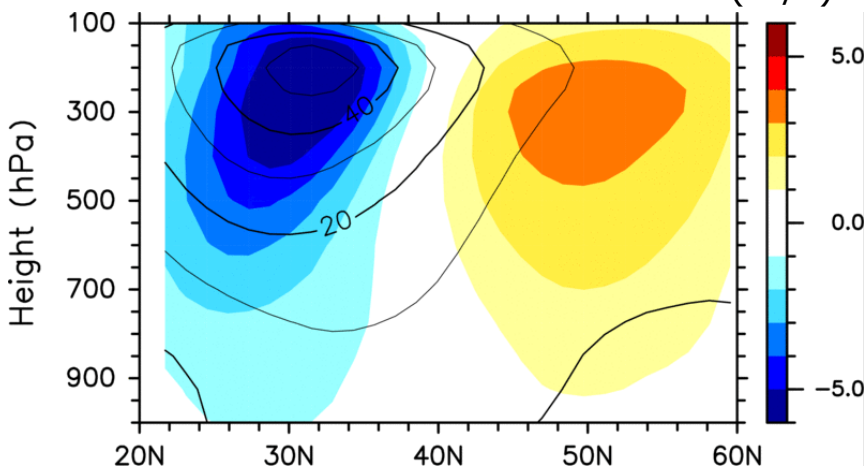
In MIROC5n,

- Increased eddy poleward momentum flux
- Increased eddy upward temperature flux

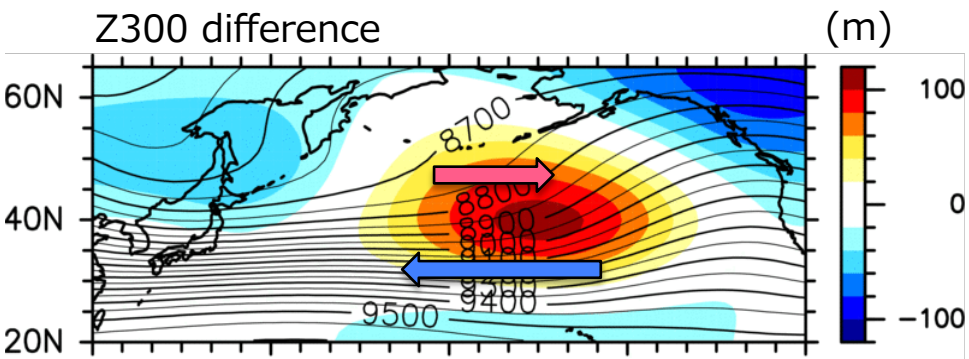
To the north of 40°N : mean-flow acceleration

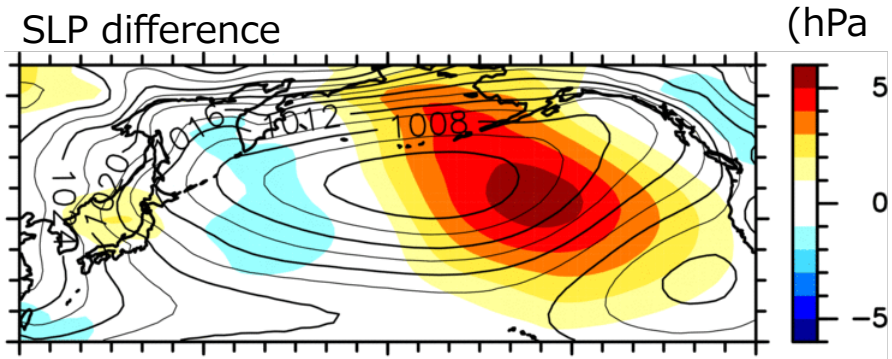
To the south of 40°N : mean-flow deceleration

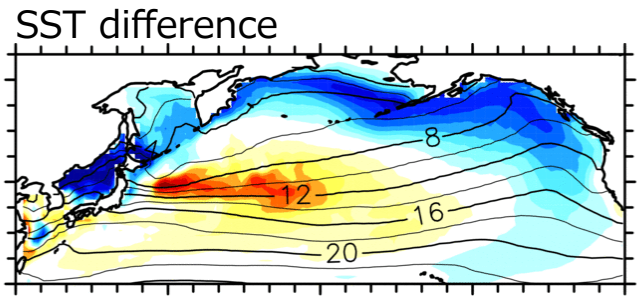
Zonal wind difference (m/s)



Basin-scale changes of atmospheric circulation over the NP







- Weaker Core speed of the westerly jet
- Broader meridional width of the jet

Anomalous pressure looks like the negative PDO pattern

→ Anomalous Ekman transport amplifies the pre-existing warmer SST

and it also makes negative SST anomaly along North America.

Positive feedback loop among the ocean currents, STA and the westerly jet

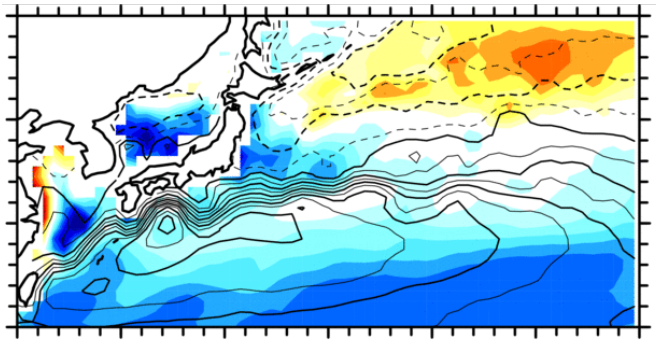
Summary

Using MIROC5 coupled with the regional ocean model embedded in the western NP, we have examined influences of the SST on the atmosphere.

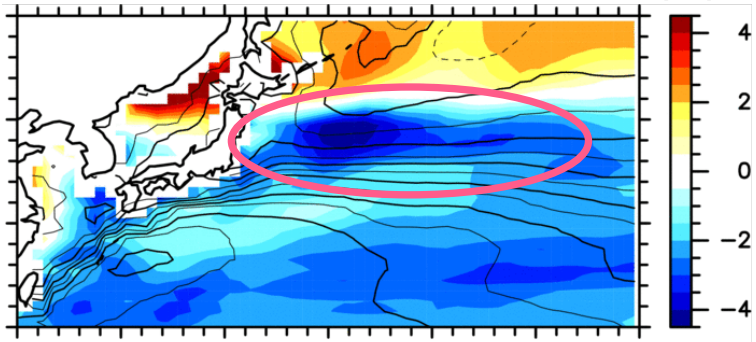
- Warmer SST to the east of Japan by the WBCs
- Enhanced surface baroclinicity and wintertime STA
- Weaker and northward shift of the westerly jet due to eddy-mean flow interactions
- Anomalous surface Ekman transport

What about the model climatology ? Improved ?

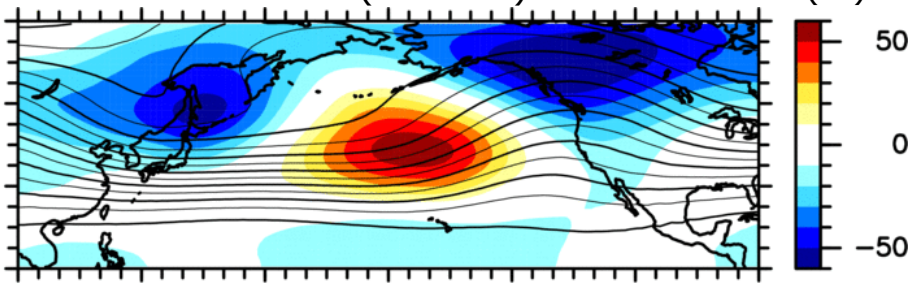
SST bias in MIROC5n



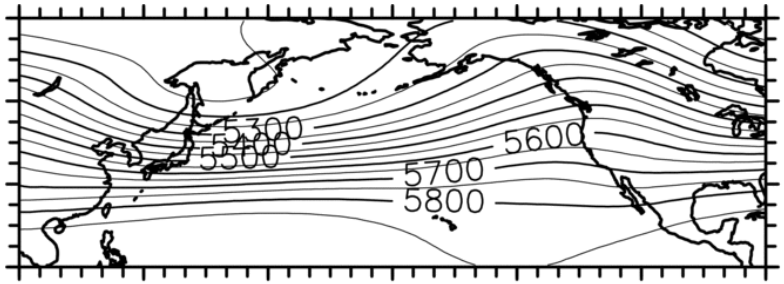
SST bias in MIROC5 (℃)



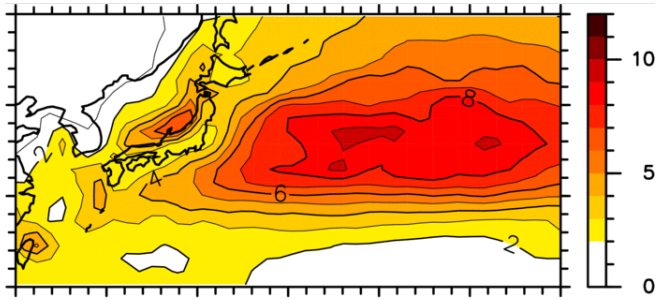
Z500 in MIROC5n (contour) (m)



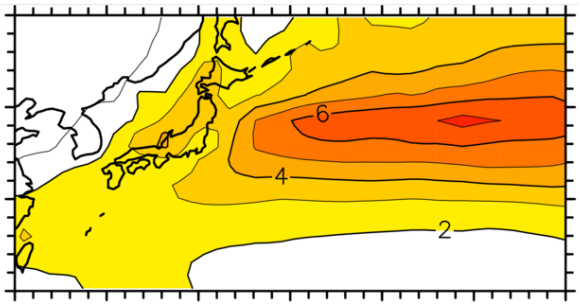
ERA-I



Precipitation in MIROC5n (mm/d)



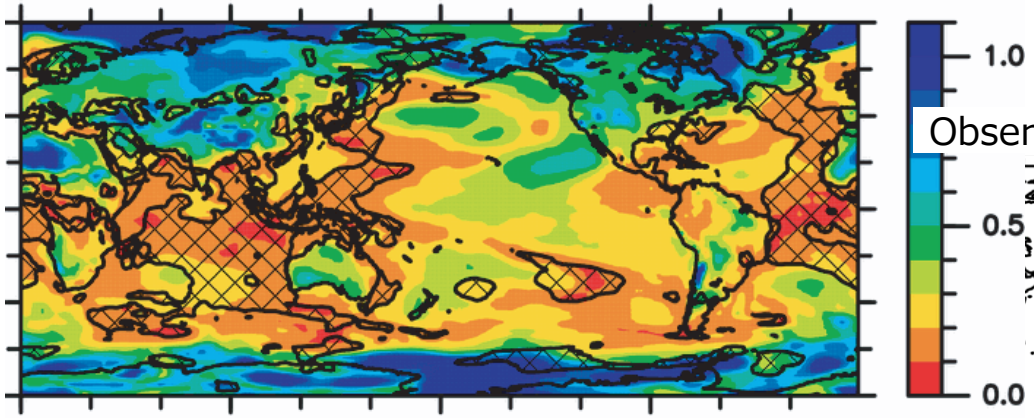
Precipitation (GPCP)



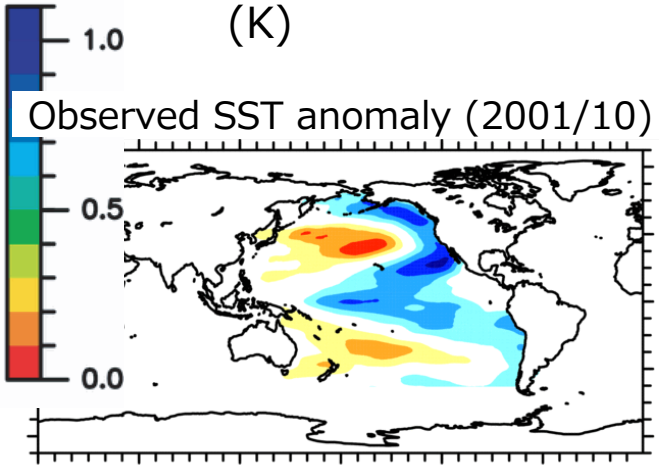
Appendix

RMS Errors in SAT : Hindcast (first 5 years)

RMS error of SAT during the first 5 hindcast years of MIROC



Hatched: RMSE < internal variability

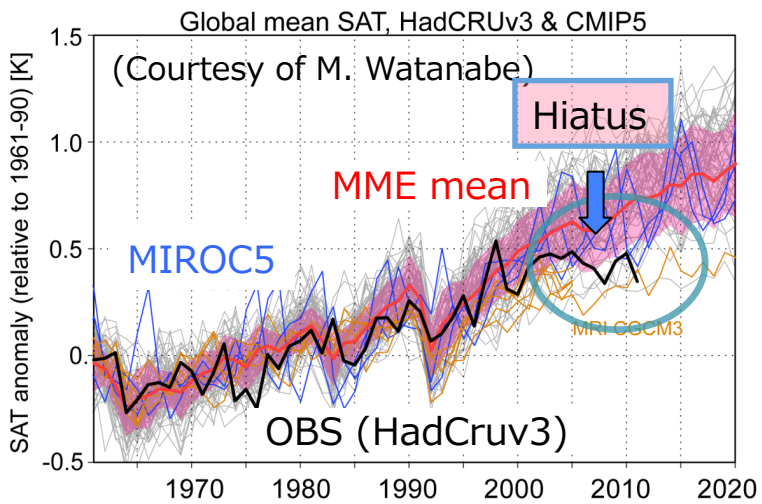


- Remarkable RMS errors in the tropics and North Pacific mid-latitudes
- e.g., Difficulty in predicting the recent "Hiatus" associated with negative IPO

NOT ENOUGH SKILLS for the next decade

Water resources, Ecosystem, Extremes

→ Political decision making for adaptation and natural disaster prevention



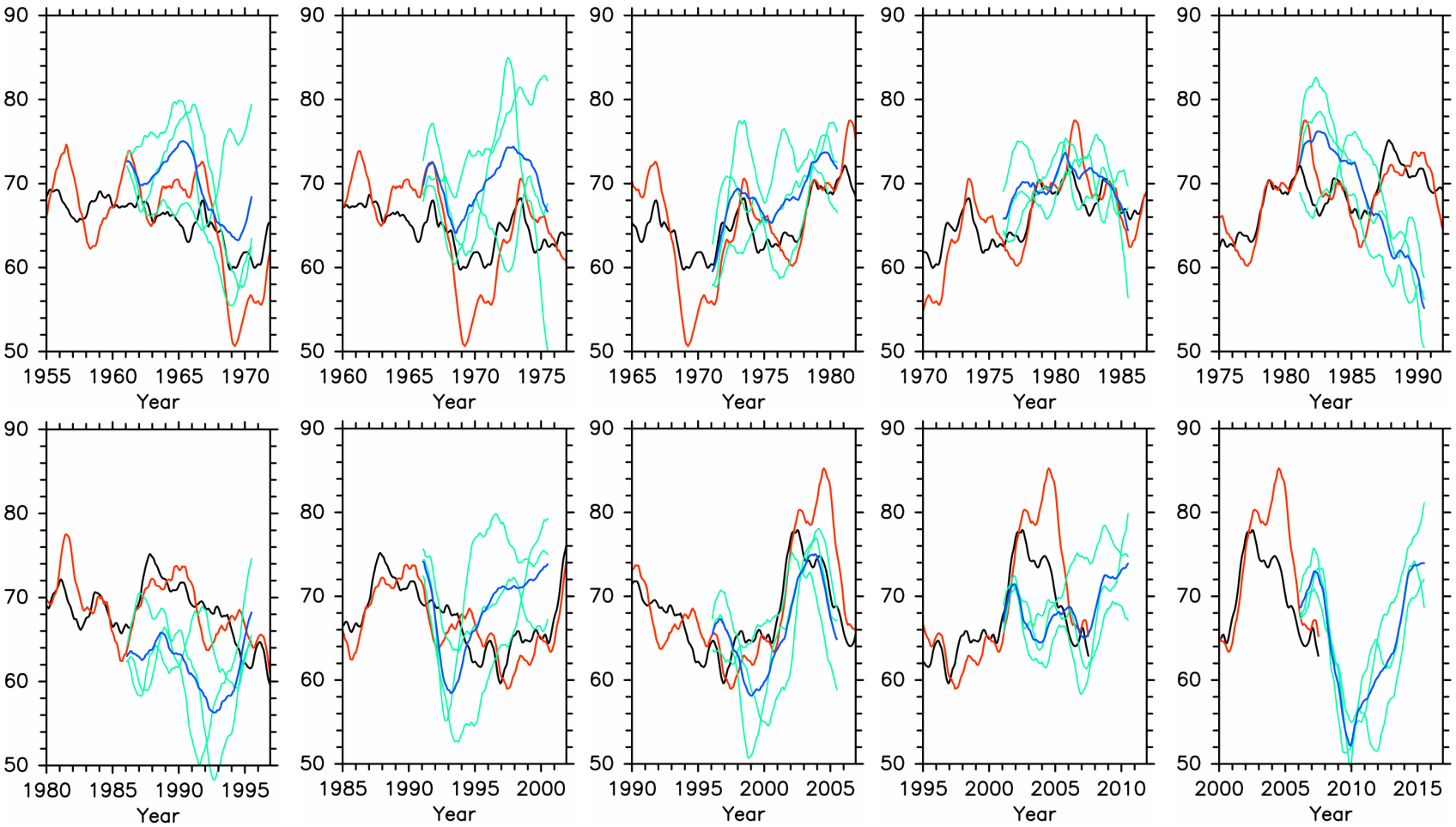
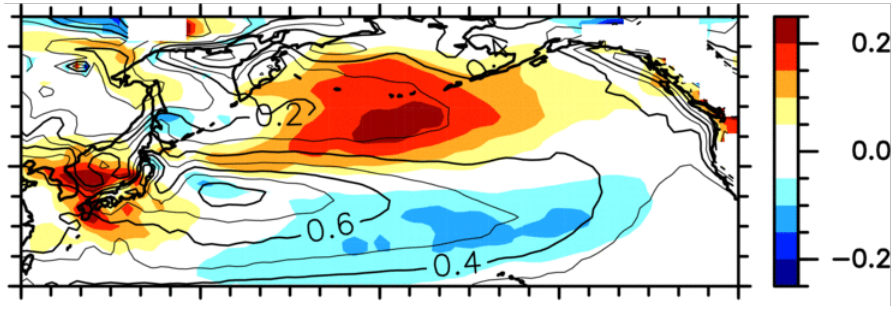


Fig. 1. Time-series of the Kuroshio Extension strength with 1 yr running-mean filter. In each panel, black line denotes the observation, red line the assimilation, blue line the ensemble-mean of the 3 member hindcasts, and light blue line each member of the hindcast, respectively. The unit is cm. See details for the definition of the strength. The number in each panel is the correlation coefficient between the observations and the ensemble-mean of the 3 member hindcasts with a 5-yr running-mean filter

Maximum Eady growth rate below 850 hPa

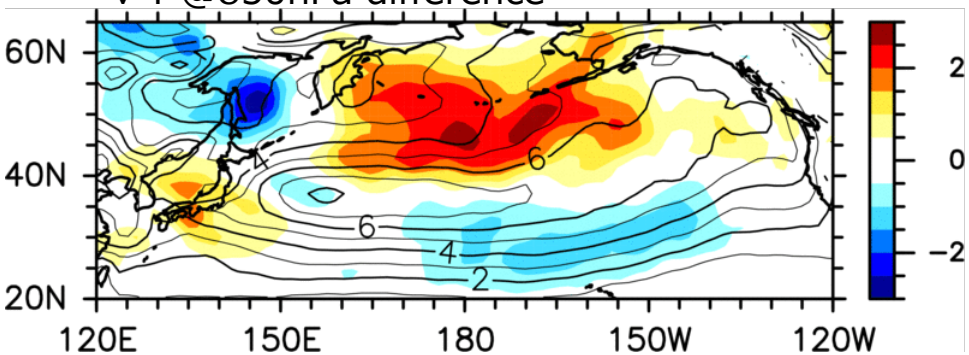
Difference (MIROC5n – MIROC5) (day^{-1})



Climatological mean Wintertime Storm Track Activity

STA: Wintertime mean v'T'@850hPa, 8 day high-pass filter

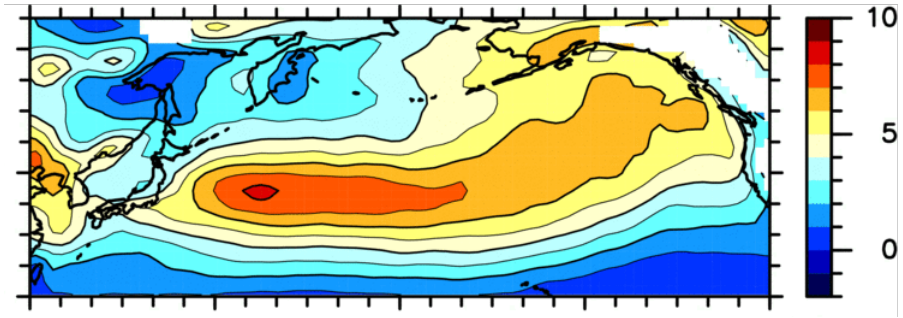
v'T'@850hPa difference



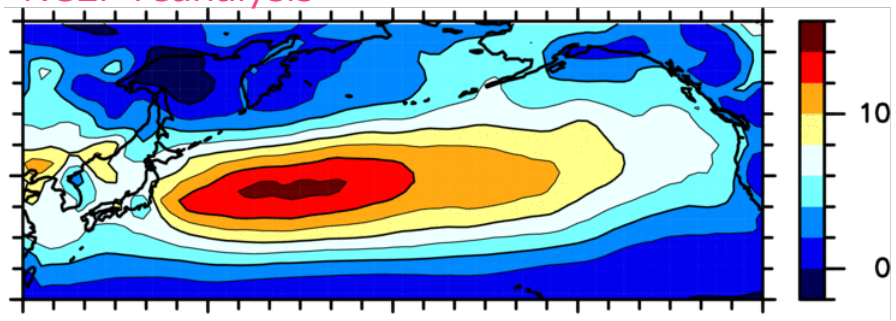
Climatological mean Wintertime Storm Track Activity

STA: v'T'@850hPa, 8 day high-pass filter

MIROC5

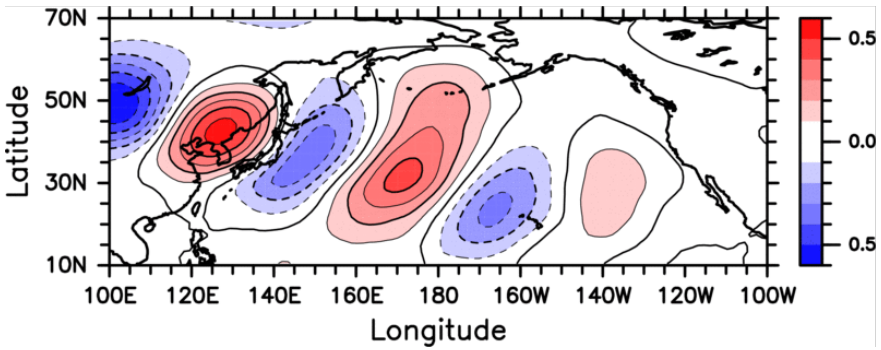


NCEP reanalysis



One-point lagged correlation coefficient of Z300 (47N, 105E)

MIROC5n



MIROC5